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Communicating Air: Alternative Pathways to Environmental Knowing through Computational Ecomedia

Polli, Andrea

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University of Plymouth

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**Communicating Air:
Alternative Pathways to Environmental Knowing through
Computational Ecomedia**

by

Andrea Polli

BA (Johns Hopkins University) 1989

MFA (The School of the Art Institute of Chicago) 1992

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Committee in Charge:

First Supervisor: Dr Jill Scott, Zurich University of the Arts

and the University of Plymouth

Secondary Supervisor: Dr Angelika Hilbeck, ETHZ, Zurich

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Abstract

This dissertation, *Communicating Air: Alternative Pathways to Environmental Knowing through Computational Ecomedia*, is the culmination of an art practice-led investigation into ways in which the production of ecomedia may open alternative pathways to environmental knowing in a time of urgent climate crisis. This thesis traces the author's artistic, personal and political development across the period of study and presents an extended argument for greater public engagement with weather and climate science, greater public and private support for long-term collaborations between media art and climate science, and increased public open access to global weather and climate monitoring and computationally modelled data.

While this dissertation addresses weather and climate from a social, political, scientific, and theoretical perspective, it also presents an analysis of a series of projects by the author and others in relation to what human-computer interaction expert Paul Dourish calls “environmental knowing” (2006, p. 304). Since the author's projects connect art and science primarily through a computational approach, computing is the shared practice that connects scientific understanding to place and content-based creation.

A less common term used extensively in this thesis is *ecomedia*. In media theory, Sean Cubitt (2005) has used the term *ecomedia* to describe popular film and television works that address environmental concerns. In this thesis, the author employs a narrower definition of the term, that is media made with the emerging technologies, tools, and information structures that describe and model environmental systems. The author proposes that the sphere of monitoring and modelling data is where a transformation is taking place and new forms are emerging.

The bulk of this argument has been formed through the collection and interpretation of relevant literature across disciplines, extensive interviews with scientists, other experts and audience members internationally, and the author's direct experiences creating and presenting location-based ecomedia art projects around the world.

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Samples of work referred to in this dissertation:

Sonic Antarctica Audio CD

Ground Truth, Hello, Weather! and *Particle Falls* videos on DVD

Prologue

The primary question to be explored through this doctoral thesis is:

How can the production of geosonification and other ecomedia open alternative pathways to environmental knowing in a time of urgent climate crisis?

A series of practice-based projects led this doctoral thesis. With each project analysed in this dissertation, the author strived to explore and generate a different kind of data and to shift the structure of the work in the context of this data. In order to focus on location, projects have been created in and about distinct geographic areas, some addressing global environmental concerns and others more local issues. Although the author's art projects in and about dense urban areas like New York City and Taipei have been analysed, the bulk of this thesis has focused on results from the author's seven-week residency in Antarctica and four-week residency in the Arctic working in collaboration with and alongside weather and climate scientists.

This thesis documents a trajectory of transformation of both the author's artistic practice and her personal politics. According to the Intergovernmental Panel on Climate Change, global climate change is the greatest crisis humanity has ever faced. Warming of the climate system, including sea level rise and habitat loss, is unequivocal, is very likely due to anthropogenic greenhouse gas concentrations, and will continue for centuries even if greenhouse gas concentrations are stabilized (IPCC 2007). However, because this crisis is emerging from a complex system, the uncertainties that are inherent in the science have played a role in the public's perception. This thesis, *Communicating Air: Alternative Pathways to Environmental Knowing through Computational Ecomedia*, presents some ways in which art might be a catalyst for increased environmental knowing. Through extensive research including several interviews with IPCC scientists, the author has determined that a widening cultural gap has become a battlefield with environmental science the target of widespread controversy. The goal of this thesis is not to elucidate the science but to explore the gaps between scientific and public culture through computational and participatory media and therefore help to build a bridge to broaden communication. Although a wide range of ecosystems are affected by climate change, the scope of this work lies within a specific compartment of the ecosystem where uncertainties are pervasive: air, climate, weather, pollutants and other atmospheric phenomena.

Table 0.1: Sampling of Projects Completed as Part of the Author's Doctoral Research

	Project 1 Airlight	Project 2 Sonic Antarctica	Project 3 Ground Truth	Project 4 Hello, Weather!	Project 5 90 Degrees South	Project 6 Particle Falls
Research aims	Sonifying & presenting near real-time air quality data	Documenting & presenting Antarctic soundscape & sonifications of data	Exploring qualitative aspects of weather and climate data gathering and analysis	Exploring various interpretations of real time and archived weather data on site	Mapping subjective experiences in Antarctica using community mapping tools	Visualizing near real-time air quality data in public space
Resulting work	Real-time sound and visual installation in galleries	Sound and video performance, audio CD	Video documentary online and DVD	Temporary public artwork in community and art centers	Website (blog, flickr, youtube) and Google Earth	Temporary outdoor public artwork, documentation on DVD
Data used	Hourly observed air quality data	Ice + weather/climate measured data, soundscape interviews, seismology audification	Video interviews, soundscape recordings and sonifications	Real time weather data from author-run stations in New York City, Los Angeles, New Delhi, Zurich and Brighton	Maps and gps data, audio and video interviews, photographs,	Real time measured particulate pollution data from author-run station in San Jose California
Location of data	Taipei, Southern California, Colorado, New York (narrow)	Various sites in Antarctica (wide)	Three main sites in Antarctica (wide)	New York, Los Angeles, New Delhi, Zurich and Brighton (narrow)	Various sites in Antarctica (wide area)	San Jose California (narrow area)
Scientific collaborators and participants	Taipei EPA, US and local agencies (Colorado, New York California EPA, private data firm)	Weather and climate scientists in Antarctica, New Zealand, Switzerland and the US	Weather and climate scientists and science teams in Antarctica	Academic meteorologist, students and media technologists	Weather and climate scientists and science teams in Antarctica, New Zealand, Switzerland and the US	US and local agencies (California EPA, private data firm)
Analysis methods	Video and photography, observation, collaborator & participant interviews	Video and photography observation, recorded interviews	Video and photography, observational notes, recorded interviews	Video and photography, observational notes, recorded interviews	Video and photography, observational notes, online feedback	Video and photography, observation collaborator & audience interviews
Audience and mode of presentation	Gallery and public art	Audio CD, Performance sound installation, and radio broadcast	Screening and video installation	Public art	Online and interactive installation	Public art
Location of production	Residencies in multiple locations	Residency on location, continued work off-site	Residency on location, continued work off-site	Residencies in multiple locations	Residency on location, continued work off-site	Commission on location, continued work off-site

Introduction: Scaling the Temporal Terrain

Technological mediation supports and conditions the emergence of new cultural practices, not by creating a distinct sphere of practice but by opening up new forms of practice within the everyday world, reflecting and conditioning the emergence of new forms of environmental knowing. (Dourish 2006, p. 304)

Computational Representation, Risk, and Denaturalisation

In *Re-Thinking Science*, Helga Nowotny described the rise of scientific uncertainty in the public consciousness as creating a “risk society”, and explored how living in a perpetual state of risk has transformed societies historically (Nowotny & Gibbons 2001). The representation of the risks humanity faces from anthropogenic climate change presents a unique challenge because while human behaviour plays a pivotal role in the magnitude of change, the representation itself can influence this behaviour. Hess has identified technology as playing a significant role in what he calls “denaturalised” environments in which the anthropogenic impact is greater than any other. As he stated: “society creates its environment as much as it adapts to it, and that technology has changed the environment into an increasingly synthetic product of human activity. Perhaps there is no better example of ‘denaturalization’ [quotes added] than the looming uncertainty regarding the effects of human activity on the global climate” (Hess 2007, p. 9).

Over the last thirty years, the idea of computational representation has become increasingly significant from an environmental point of view. Many contemporary environmentalists now look to technology as a way to build models for authentic natural experiences without the danger of human impact. This is a radical departure from the philosophy of the traditional naturalist. The environmentalist movement born in the late nineteenth century stressed the importance of a direct, sensual, and unmediated encounter with nature. Henry David Thoreau (1854) and the transcendentalists suggested that an indirect, mediated experience of nature robs humanity of a fundamental and universal human truth. However, a direct, human experience of nature, mediated or unmediated, can also transform nature. Today, humanity faces an urgent climate crisis. What impact has the ubiquitous potential of computers and computational representation of the environment had on public and scientific understanding in light of this crisis? What are the social and cultural effects of defining both the natural and man-made environment as a new “information space?”

The theoretical challenge of this thesis can be expressed by the following quote by Mark Weiser from his 1991 essay, “The Computer for the 21st Century”: “There is more information available at our fingertips during a walk in the woods than in any computer system” (p. 94). By comparing a walk in the woods with an information-rich computer system, he was both disparaging and elevating the social power of a computer system. On the one hand, he was highlighting the shortcomings of computer systems. As a screen-based, primarily visual medium, without touch, taste, or smell, the information presented through a computer system lacks the multidimensionality and perceptual embodiment of a physical space. On the other hand, by merely showing that it is possible to make such a comparison, Weiser was elevating the computerised way of understanding as something that might approach real-world understanding through “information”. This represented a major shift in thinking as the woods are identified as an “information-rich” environment, analogous to a computer-based environment.

Through his essay, Weiser was challenging software designers and engineers to design computer-mediated experience that is as aesthetically and emotionally powerful as a walk in the woods. Weiser’s work in 1991 was at the forefront of the ubiquitous computing movement, when futurists merely imagined computers embedded into every aspect of society. Ubiquitous computing is a now condition that is a part of everyday life and has changed how the world is seen. As Paul Dourish confirmed: “the world becomes a site of computation and an object of informational representation. We start to understand and model the world in information terms” (Dourish & Bell 2005, p. 32).

Terminology in the Context of this Dissertation

The premise of this dissertation contains several terms that have been very precisely defined by the author. This section on terminology contains background to help clarify the premise of this dissertation.

The author has created the term *geosonification* for this thesis in order to describe location-inspired sonification. According to the Sonification Report prepared for the National Science Foundation by members of the International Community for Auditory Display, sonification is the use of nonspeech audio to convey information. As a method for exploration of data and scientific modelling, sonification is an auditory complement to visualization. A related term that has also been used in this thesis is *audification*. Audification is a subset of sonification

that involves a direct signal-to-sound conversion, and has been used to compare projects made by artists and Antarctic seismologists.

Specifically, what the author will refer to as geosonification is the sonification of geospatial scientific data using the real-world soundscape as a model. This geospatial scientific data includes data that is previously recorded, modelled, or monitored in real time. These geographical areas are either point based (very small) or vast, and they may be static or moving. As a kind of media, geosonification can be produced and presented using traditional media or it can be designed as a networked, locative media practice. The term *geosonification* was created not only to emphasise the origin of the data but also to reference two of the aims of this research: to build art and environmental science collaborations and to raise awareness about emerging environmental science issues.

In this thesis, geosonification will be compared to soundscape. Composer R. Murray Schafer defined the term *soundscape* to refer to the “acoustic environment . . . the total field of sounds wherever we are. It is a word derived from landscape, however it is not strictly limited to the outdoors” (1977 [1994]). The author has utilized the term *soundscape* not only to indicate the physical vibrations of sound but also to indicate the ways in which a sound environment might be interpreted by composers and listeners. She has emphasised the phenomenon of a listener within a soundscape as “part of a dynamic system of information exchange” (Truax 2000) and playing a role in its structure. Soundscape is the acoustic manifestation of place; sounds give inhabitants a sense of place and in turn the place’s acoustic quality is shaped by the inhabitants’ activities and behaviour. Meanings of place are created through the interaction between a soundscape and listeners as a kind of improvisation. The term *soundscape composition* refers to an electroacoustic recording or a performance of sounds that creates the sensation of experiencing a particular sound environment, either exclusively or in conjunction with other sounds. Therefore, some of the case studies by the author can be defined as soundscape compositions. However, these cases have also been defined under the broader term of *ecomedia*.

In 2005 media theorist Sean Cubitt used the term *ecomedia* to describe popular film and television works that address environmental concerns, and this term has since been used by various commercial media production houses internationally in marketing environmentally conscious video and Web sites (Cubitt 2005). While the use of existing media, including the Web, for dissemination of environmental information may be extremely important; this thesis has focused on a more narrow definition. For the author *ecomedia* is media made with the

emerging technologies, tools, and information structures that describe and model environmental systems. The author will propose that this is an area where a transformation is taking place and new forms are emerging. This definition of *ecomedia* encompasses media projects that use environmental data, such as geography, weather conditions, and air quality, but it could also encompass information about the human ecosystem, such as census data, urban development, and even social interaction. Ecomedia can also include work using environmental data that are not tied to a static location, for example, the patterns of various global systems like weather. Because the data sets for geographic systems can be very large, ecomedia projects often involve some kind of data mapping, translation, or interpretation. These translations and interpretations can serve to open alternative pathways to understanding the encoded information.

“Alternative pathways” could be considered the most important term in this premise. As Human Computer Interaction expert C. Lenay wrote in 1997: “Technical artefacts should not merely be understood as means that allow human beings to achieve certain pre-set goals. On the contrary, the process of their development and integration by individuals and societies transforms, or invents, the very goals of human activities” (Lenay & Vilon 1997, p. 1). In science, the term *alternative pathway* is a biochemical term that means a course followed by a process, a chain of nerve fibres along which impulses normally travel, or a sequence of enzymatic reactions by which one material is converted to another. From this perspective, this term implies energy flow, entropy, and connections with biological systems. When used as a term to describe nerve impulses, it also connotes the flow of information. When the term refers both to movement along a trajectory and a transformative process, and as a biological term, it favours rather than denies complexity.

In this thesis, alternative pathways will be explored within a social and cultural context rather than a biological one. Artworks will be analysed as alternative media for social movement and/or activism and as social actions that can lead to the development of new social interactions and structures. Pathways that will be explored include: technology-oriented movements, including new technologies and uses and misuses of existing technology; public participation; access and new audiences; alternative readings and viewpoints; new pathways of communication; and creative, critical, theoretical, and methodological intervention. Through the mechanism of alternative pathways, the author will attempt to decode the complex relationships among people, nature, and technology with regards to technological art and environmental issues. How can ecomedia artworks suggest alternative possibilities or critical perspectives? How

can such artworks contribute to a change in cultural practices? How can these artworks function as a driver or catalyst for social change? Because environmental issues directly affect the lives of individuals and structures of societies, it is crucial that these issues be addressed in the social realm through art and culture.

The use of the term *alternative pathways* was inspired by social theorist and activist David Hess's book, *Alternative Pathways in Science and Industry* (2007). As Hess suggests, these pathways are those provided by social environmental activism and innovation based in local and global industries. This thesis will also address activism and innovation, but more precisely from the perspective of the intersection of art, science, and technology. While Hess examined emerging social structures of environmental science in government, industry, and culture, this thesis has examined the role that creativity and aesthetics plays in the emergence of alternative pathways. The historical and theoretical basis for the investigation of alternative pathways of reception partially lies in the aesthetic ideas of Herbert Marcuse (1979, p. 7), who analysed the role of art in reshaping and reordering the dominant paradigm and in the idea of creating new understandings through "negation", a concept once suggested by Guy Debord and the situationists (1967). The kinds of knowledge and understanding that can be gained through alternative pathways will be a major investigation of this thesis.

What is meant by "environmental knowing" in the premise? While there are many different kinds of knowing, both quantitative and qualitative, this final thesis will focus on qualitative, experiential, and situated knowing as the domain of the artistic process and practice. In the following quote, environmental scientist Dr Sharon Collinge observed that the idea of socially constructed knowledge can sometimes conflict with scientific training: "We've been trained as scientists to . . . not extrapolate beyond our data . . . There are the data, and the data are the truth, and that should guide everything, right? We know the truth so let's just act according to the truth. We know the climate is changing, what's the problem? Why are we hesitating? Well, that's not the only truth. There are many truths" (Collinge 2008).

Inside the community, or constructivist, approach, "knowledge" has been defined as a socially constructed paradigm, and this definition in practice exists in opposition to the commodity view in which "knowledge" is defined as absolute or universal truth. By exploring environmental philosophies and the psychology of perception, this thesis will attempt to situate a philosophically deeper, nonverbal knowing that goes beyond simply the raising of awareness. The thesis will specifically draw upon the models of situated and embodied action outlined by

Paul Dourish (2001) in the context of the geosonification of data, and the theoretical work of Brian Massumi (2002) and others. Because a geosonification is a nonverbal expression, the “knowing” described in this thesis is tacit as opposed to explicit.

One of the most difficult aspects of collaboration between art and science is the clarity of communication between disciplines. The definitions of four terms in the premise of the proposed thesis: *geosonification*, *ecomedia*, *alternative pathways*, and *environmental knowing* have been outlined in detail in this section because the meanings of these terms differ in various disciplines or philosophical perspectives; or, in the case of *geosonification*, the term itself has been created to describe a specific artistic practice undertaken by the author. The ways in which these terms may be applied to the practice and process of art and environmental science collaboration in relation to climate change will be a part of the analysis and contextualization of artworks in this thesis.

Methods and Methodologies

The analysis in this dissertation will include three qualitative methods: analysing relevant literature across the disciplines of art, technology, cultural theory, and environmental science, interviewing environmental scientists and researchers, artists, technologists, and the general public, and developing geosonification and ecomedia art projects that serve as demonstrable products of the research and generate primary research data that are analysed through interviews and observation.

A thorough examination of the intersection of information technology art and environmental science has been undertaken across the relevant disciplines. In addition to a substantial survey of the history of climate, weather, and art (see timeline in appendix), the author has examined literature pertaining to the history of climate modelling, weather and climate monitoring, biometeorology, bioclimatology, and the social aspects of climate change. Many of her interview subjects (see interview list in appendix and references) have published articles on their research, and the author reviewed much of this literature pre- and post-interview in order to contextualize the interview responses. Information technology literature pertaining to embodiment and affect comprise a major portion of the theory of technology literature, and a large number of artworks have been examined through catalogue essays, documentation, and direct communications with the artists, including interviews. In addition, in order to address the idea of “alternative pathways”, theories of social activism, art, and science have been reviewed at

length. Although art and climate is a fast-developing area of investigation with many new artworks being created, the author found limited literature pertaining specifically to the intersection of the four areas of social activism, information technology, art, and climate science. In fact, the sparse existing analysis of this developing practice speaks to the need for this research by the author.

Twenty-seven in-depth interviews with scientists, artists, research assistants, graduate students, and support staff have been conducted. Eleven of these interviews were conducted in Antarctica, four were conducted in the Arctic, and the remaining twelve were conducted in various locations internationally. These in-depth histories of scientists, artists, and researchers and short interviews with audience members of artworks have been conducted and analysed. The in-depth interviews have run between thirty minutes to one hour, recorded on either audio MP3 or videotape. The question format was used only loosely. Since the focus was to learn about important aspects of the research and to find directions for future discourse, the author found a flexible, conversational style to be the most effective toward this aim. In order to ensure the most accurate information, each in-depth interview was transcribed, and interview subjects were invited to listen to and read the transcripts and add changes or suggest extra additions.

In asking scientists and researchers about their work and histories, the author focussed on a few major areas of interest depending on the interview subject's field of research. Therefore, the interviews can be divided into four areas: climate modelling, climate and weather monitoring and observation, sound experiences, and the creation of media and technology artworks. Firstly, several of the interview subjects had been involved in some aspects of computer climate modelling work, and interviews with these subjects focused on an in-depth discussion of how climate models are created, used, and evaluated. Because climate change has become a mainstream topic, and the development of climate models is evolving so quickly (involving complex methods and tools), this area became a central subject of debate among the scientific community. Secondly, a large number of the interview subjects, including those involved with modelling, were engaged in some kind of climate and weather data collection (from analysis of remote sensing from satellites to weather balloon launching to physical observations). In one case, a paleoclimatologist spoke about the analysis of geological evidence of past climate. A major area of research developed from these interviews was the term *ground truth*. This term, used by several interview subjects, is employed to indicate data gathered by a human as opposed to a machine. The author was surprised to learn that a majority of weather monitoring conducted

in Antarctica by the United States is not made by monitoring devices, but by human observations. These weather observers, who are often trained in meteorology, have become a subset of interview subjects. In particular, interviews with subjects who had experience in weather observation focussed on teasing out the reason for human observations, especially in the harsh living environment of Antarctica. The very question of human presence in such a fragile environment became the basis for the author's video essay, *Ground Truth*. Thirdly, a small number of interview subjects had had unique sound interests, including hands-on experiences with the audification of scientific data, and this became a topic of further discussion, and finally, three of the in-depth interviews were conducted with artists or artists' teams who discussed their processes and the results of their aesthetic investigations. In addition to this directed area of questioning, all interview subjects were asked the following questions: What aspects of your research are most difficult for the general public to understand? What is the role of scientists in the greater community? Short, informal interviews with audiences of and participants in the author's artworks have also been made for this thesis. Various international locations internationally and a wide range of participants have been included. Throughout this process, the responses from audience members have not only influenced new projects but also the presentations of existing projects.

Since entering the Z-Node program in April 2007, theoretical and practical research has led the author to focus on location-based sonification and ecomedia works related to climate and weather. This practice of geosonification in the author's own creative work has evolved into a unique methodology and strategy for further research. The art projects have provided the central role (or practice base) for the theoretical research. Manifestations of these projects have consisted of: media installations, live performances, video screenings, public workshops, printed material, published papers, curated exhibitions, Web sites including rich media content on sharing sites, the creation of new interactive media tools, audio CDs and radio broadcasts. In addition to being an artefact or demonstrable product of the research, these exploratory art projects produced for and analysed in this dissertation will serve to generate a set of primary research data by developing and generating new methods for analysis, creating a novel approach to the use of numerical and quantitative data (sonifications and interviews for example), and raising new questions for future researchers. As these projects connect art and science primarily through a computational approach, computing is the shared practice that connects scientific understanding and content-based creation. Each project strives to explore and generate a

different kind of environmental data and to shift the structure of collaboration. The projects not only provide live situations for developing appropriate research methodologies for others, but in addition interpret various kinds of data, build mechanisms for generating new data, and include interviews and documentation. The projects themselves also serve as documentation for further analysis. Findings from each project can enable identification of further relevant issues and research questions. Specifically, these projects have been designed to link sonic energy with the subjective experience of weather, climate, and environment, to find metaphors that connect environmental science concepts with real-world experience (particularly soundscape experience), and to link the geosonification of an environment with the science (deep structure) of that same environment

In this thesis, the art projects will serve as proof that the tools and ideas of environmental science can intersect with the media arts in order to create alternative pathways towards a deeper understanding of weather and climate. Each project has a unique physical structure, uses dissimilar primary data or technology, and has been presented in a different way and/or uses an alternate process of creation. In order to focus on geography, projects have been created in and about distinct geographic areas, some focusing on the global and others on the local.

Audiences and participants for these projects have included gallery, museum, and science centre attendees; people interested in weather/climate issues; weather/climate and other environmental scientists and engineers; students; policymakers; and the general public. Differences between project structures and outcomes and various audience and participant responses has been the primary data for comparative analysis in this thesis. Research findings will be substantiated by gathering corresponding evidence between projects, relevant literature across disciplines, and by analysing the interviews with experts and audience members.

In the Z-Node program, the author produced six major creative projects that explore various research topics. In the following section, the aims and structure of each project is described in greater detail.

Three of four versions of the *Airlight* series have been developed since entering the Z-Node program. The *Airlight* series presented a real-time sonification and visualization of air quality data in three urban centres internationally. Each version of *Airlight* automatically downloaded and translated daily amounts of O₃ (ozone), NO₂ (nitrogen dioxide), CO (carbon monoxide), PM (particulate matter), and/or other pollutants in the atmosphere as data and transformed them into a changing, rhythmic soundscape and visualization. Live, local traffic webcam images were presented in real time and were visibly transformed based on pollutant levels.

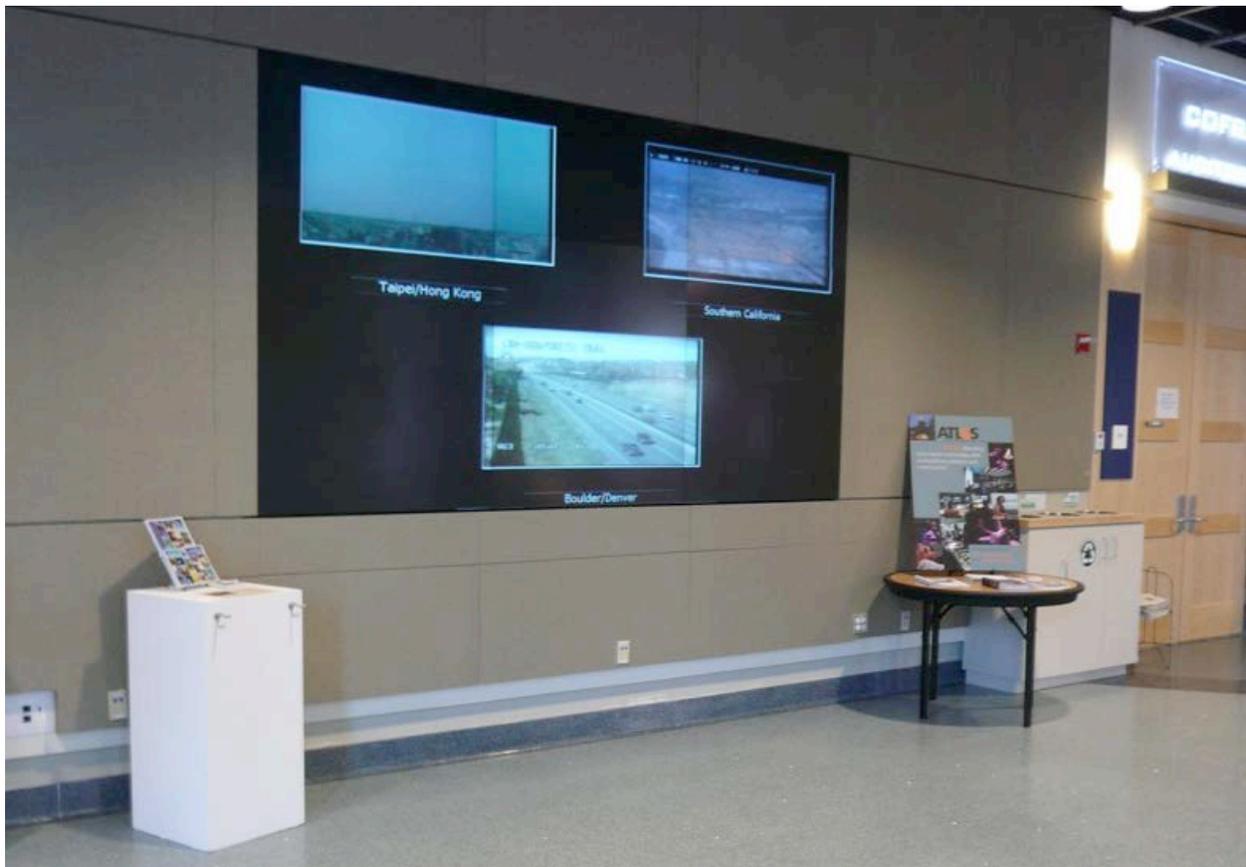


Figure 1. AIRLIGHT installation at the University of Colorado, Boulder, Andrea Polli (2007)



Figure 2. AIRLIGHT NYC installation, Cooper Union, New York, Andrea Polli (2010)

The *Sonic Antarctica* project consisted of a radio broadcast, live performance, soundscape, and multichannel visual installation featuring recordings of the Antarctic soundscape. Early *Sonic Antarctica* performances also featured natural and industrial field recordings, scientific sonifications, audifications, and soundscape compositions by members of the Antarctic community. This included the author, other artists, scientists, and support staff. The author developed her own recordings and geosonifications into a full-length audio CD that was published on the record label *Gruenrekorder* in order to gather audience feedback and raise awareness on a more public level.

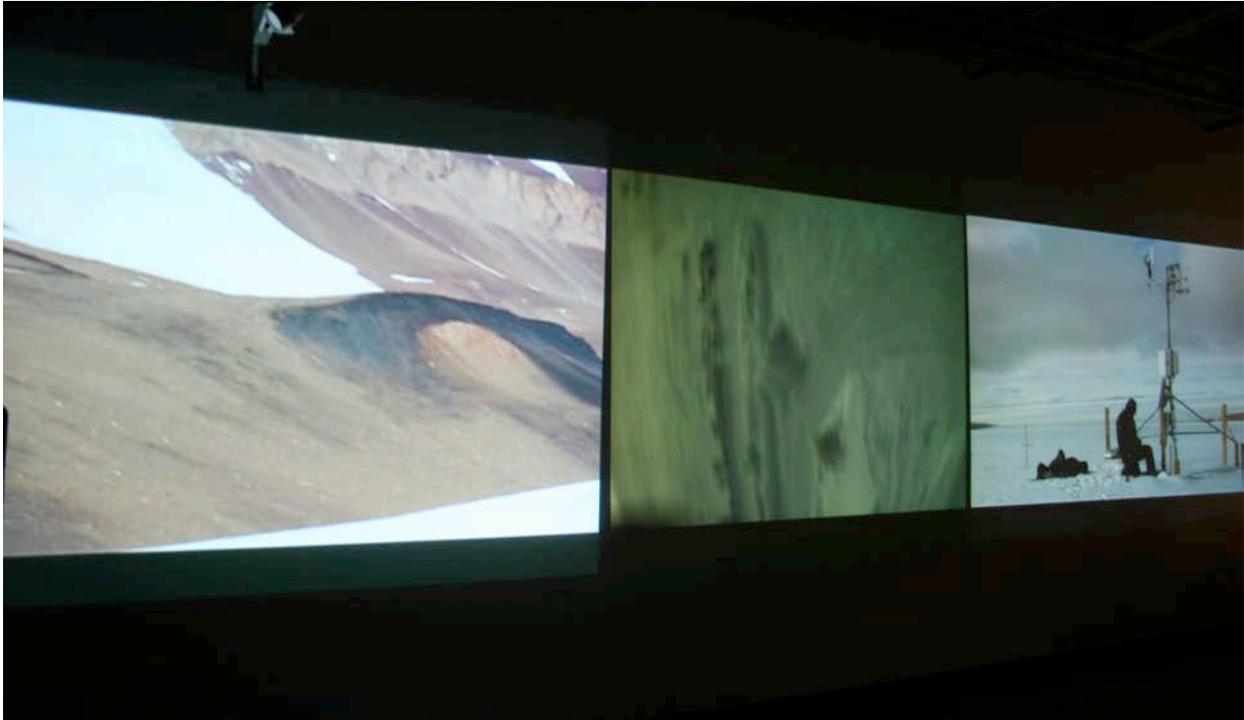


Figure 3. SONIC ANTARCTICA video installation Colgate University, New York, Andrea Polli (2008)

A video essay entitled *Ground Truth* presented weather and climate observation at the South Pole, McMurdo Station, and field sites in the Dry Valleys of Antarctica. The author asked weather experts why they go to remote, uncomfortable, and often-hazardous locations, conducting what is known as “ground truthing”. *Ground Truth* presented interpretations of weather data, interviews, and documentation of observers and scientists as they discussed, maintained, and gathered this data from remote sites. In interviews with scientists about this subject, many of the scientists spoke about the importance of nonquantitative knowledge and the visceral experience of a specific site. For example, in the recording of an interview with Dr Andrew Fountain, the head of the Dry Valleys Long Term Ecological Research Group, Fountain said: “Just because you have the data doesn’t mean you understand the system. It’s important to come down and view the landscape and in our case view the glaciers, and see how the glaciers are reacting to these changing environments. And that feeds into our understanding and our nonquantitative knowledge” (Fountain 2008).

90 Degrees South was an online interactive mapping project using rich media in Google Earth, YouTube, and Flickr to present interviews, sound, video, and other media related to Antarctic weather and climate. This content and analysis was compiled by the author using material from her residency in Antarctica. The project aimed to communicate both the aesthetic

beauty and the scientific importance of Antarctica to the global environment in a novel way (see www.90degreessouth.org).

Hello, Weather! is a network of temporary and permanent public installations of modified weather stations and a series of public workshops and lectures related to micrometeorology and local and global weather and climate. The first aim of this project was to develop informed strategies for art and environmental science collaboration through art practice around the process of weather monitoring. The second aim of this project was to create a catalyst to educate the public about the science of weather and climate. *Hello, Weather!* stations are currently in operation in New York City, Los Angeles, Zurich, New Delhi, and Brighton.



Figure 4. Weather Station installation at the University of Colorado, Boulder, Andrea Polli (2008)



Figure 5. PARTICLE FALLS public artwork, San Jose, California, Andrea Polli (2010)

Particle Falls was a temporary, large-scale public art project that visualized real time particulate pollution as a projected waterfall on the side of the AT&T building in San Jose, California. The project was part of the San Fernando Corridor public art project sponsored by the City of San Jose. Santa Clara County, which contains San Jose, received a failing grade for air quality in the American Lung Association's 2009 State of the Air Report and currently surpasses unhealthy short-term pollution particles a yearly average of eleven days, the twenty-fourth highest level in the United States. The number of people that airborne particulate pollution kills each year has tripled in California (American Lung Association 2009). Despite the invisibility of air, modern sensors can detect tiny particulate pollution levels in real time. Particle Falls focused on the smallest particle, particulate matter PM 2.5, since the global monitoring of it is one of the most recent developments in aeronomy. The project involved installing a particulate monitor and contributing the data to the AirNOW data aggregator. Since this was the first time an independent citizen had contributed data to this national system; Particle Falls may serve as a model for future projects by the author and others.

As an additional part of her research, the author curated an online exhibition for the Green Museum called *AER* (see <http://www.greenmuseum.org/c/aer/>) that included an exhibition essay titled "AER: The Vehicle of the Soul", as well as an online survey of opinions about air quality and artworks. Air pollution is a silent killer, and artists in the exhibition were chosen because their work gave a voice to the body's dependence on clean air. Most of the *AER* projects blurred the line between art and activism, and all the artists in the exhibition hoped to change public understanding of air. By questioning accepted norms of ownership of and responsibility for the air we must breathe to live, the project aimed to raise public awareness about the connection between social and environmental issues. The results of all this practice-based research has been analysed and contextualized in this dissertation.

Chapter Outline

The accelerating crisis in climate change and the realization that humans are the primary cause of this change has raised questions about ownership and responsibility. Who 'owns' the climate change crisis and who is responsible for mitigating and reversing it if possible? The overwhelming response to these questions by governments on an international level has been to propose a market solution, in essence, to sell the atmosphere.

In chapter one, *Who Owns the Air? Public Participation in Climate Issues*, the author has explored the idea of air for sale from an economic, political, and cultural perspective. It includes a history of public participation in air and climate issues and an analysis of contemporary public forums for weather and climate, including weatherunderground.com and climateprediction.net. Contemporary art projects that attempt to address the politics of air have been discussed in the context of the author's experiences while curating the online *Aer* exhibition for the Green Museum in California.

In chapter two, *Soundscape, Sonification, and Sound Activism*, three areas of sound research are examined: soundscape composition, in particular those compositions developed through the practice of soundwalking, sonification and audification, or the process of translating inaudible signals into sound, and sound activism, specifically that designed to raise awareness of the sound environment and to change social and cultural practices. In bringing these distinct areas together, a theory of environmentally aware audification and sonification practice has been created that is grounded in the natural and man-made soundscape. An argument that the act of listening through public soundwalks and other formal and informal exercises can build environmental and social awareness and promote changes in social and cultural practices has been built by examining the act of listening as an alternative pathway and comparing the research, writings, and creative work of leaders of the acoustic ecology movement (e.g., R. Murray Schafer and Hildegard Westerkamp). For purposes of comparison, projects that explored the sonification and audification of inaudible signals have been examined, including the work of sound artists Christina Kubisch and Mark Bain. The process of audification and sonification of these signals has been examined in comparison to soundscape experiences in order to develop a theory of data sonification based on the soundscape.

In order to build a community around the urban soundscape, in 2003 the author cofounded the ongoing New York Society of Acoustic Ecology (NYSAE). Through this endeavour, she co-created the NYSoundmap and Sound Seeker projects, which were further developed by the author over the past four years in order to provide practical research for this chapter. Thus by comparing and contrasting theoretical writings with practical experiences leading listening exercises, public soundwalks, soundscape-related brainstorming sessions, and presenting field recordings in various settings, new methodologies have been documented.

According to Nigel Thrift's nonrepresentational theory (2008), the most salient characteristics of embodied existence are sensation, affect, and movement. In the next chapter,

the author has discussed and compared nonrepresentational theory with other theories of cognitive science and cultural geography in order to examine the role of affect in environmental understanding. The claim is that immersive experiences of soundscapes or geosonifications can constitute a kind of “witnessing space” (Dewsbury 2003).

In chapter three, *Witnessing Space [Focus: Taipei]*, the author has provided a background to contemporary air quality science that included excerpts from interviews with two aeronomists in the USA, former National Center for Atmospheric Research aeronomist, Paulette Middleton, and Desert Research Center aeronomist, David DuBois. Previous projects by the author using real-time and modelled weather information (*Atmospherics/Weather Works* and *N.*) have then been compared with these opinions and immersive experiences. *Airlight*, a series of real-time, ambient geosonifications of air quality data from various government and private sources has been presented as a case study, and using these findings, theories of affect have been examined. The following questions have been explored: Are there correlations between the idea of continual emergence as described in Thrift’s nonrepresentational theory and the ambient sonic experience of real-time, real-world data? Can geosonification be identified as an affective medium? Has widespread public access to real-time, real-world environmental data changed the public’s experience of ‘being in the world’ and therefore altered the immersive affect?

In chapter four, *Airspace [Focus: McMurdo Station, Antarctica]*, the author has examined affect and real-time data transmission by investigating the impacts of independent and mass media on science and scientists working in Antarctica. Several art and science transmission-based projects related to Antarctica have been used as case studies. As outlined in this introduction, weather and climate research has a certain amount of unavoidable uncertainty. Through interviews with Antarctic climate scientists (Peter Doran, Andrew Fountain, and others), this chapter has shown how this uncertainty has been used by the mass media to discredit Antarctic science. Uncertainty has also been exploited to support various political agendas. How have scientists responded to the misuse of their data in the mass media? What alternative pathways have been developed to respond to this problem of misrepresentation?

Like independent news agencies, transmission-based projects, including radio and Internet broadcasts, by independent artists’ and scientists’ groups can provide a direct alternative to the mass media. Specifically in Antarctica, how have such transmission-based projects developed, and how do these works use interdisciplinarity and systems thinking to create alternative pathways in order to better understand environmental issues? Art often presents a

personal interpretation of information, and how does this personal expression intersect with the uncertainties of weather and climate science? Does this intersection help or hinder public understanding of science? With this element of uncertainty, what are ways that robust science can be presented? The author created *Sonic Antarctica* from a personal experience of being in an extreme environment. The work combined soundscape recordings and sonifications by members of the Antarctic community with audio interview excerpts, and these combinations have been examined in the context of the other transmission science and art works in this chapter.

In chapter five, *Ground Truth [Focus: The Antarctic Dry Valleys]*, the author has argued that affective experience plays an important role in the gathering of rational and analytic information about weather and climate. The physiological and cognitive effects of the experience of weather and climate from biometeorology and bioclimatology activities have been compared and contrasted with the physiological and cognitive effects of experiencing sound. Information from scientists has been compared with the work of performance artists who have pushed the body to physical extremes (Sarah Jane Pell).

In addition to the author's own experiences in Antarctica in 2007/2008, interviews with weather and climate observers have provided a new approach. For example, in interviews with members of the Long Term Ecological Research group monitoring long-term climate in the Dry Valleys, the author found evidence of the role of physical experience in information gathering. Utilizing the results from the *Ground Truth* series, a video essay and temporary public artwork that have compared the collection of data through automatic weather stations with the human experience of weather, the subject of embodiment has been addressed.

How are weather and climate currently measured and modelled and how are information technologies integrated into this process? What are some of the current cultural understandings of weather and climate and how have physical and computational models affected these understandings? Are there structural aspects of computing (especially networked computing) that inform weather and climate understandings? The author has attempted to answer these questions in chapter six, *Breathtaking: Measuring and Modelling Weather and Climate [Focus: Local Communities]* through a series of cases. Here light has been shed on cultural aspects of weather and climate measuring and modelling, from simple instrumentation and physical models to satellite remote sensing, sophisticated computer models, and countermapping in order to provide a historical basis for further research into environmental knowing.

Research has included two major phases in the history of weather and climate monitoring and how the public has participated in that monitoring. The author has argued that the effect of technology on the study of complexity has transformed the core analysis of weather and climate, in particular in the area of uncertainty. Additionally, original research gathered from interviews with weather and climate measuring and modelling experts has been compared and contrasted. The experts include IPCC lead author Andreas Fischlin from the Eidgenössische Technische Hochschule (ETH) in Zurich; glaciologist Wolfgang Rack from Christchurch, New Zealand; and climate modeller Larry McDaniel from the National Centre for Atmospheric Research in Boulder, Colorado. Finally, the author has analysed the most recent results of the ongoing *Hello, Weather!* project, a small international network of volunteer weather stations she has installed at art and community centres in the context of creating alternative pathways to public understanding of the local and global environment.

Through analysis of her working experiences in art residencies at scientific field stations in the Arctic and Antarctic, in chapter seven, *Scary Stories: Risk and Art and Science Collaborations in Extreme Environments [Focus: The Arctic and Antarctic]*, the author has explored ways in which collaborations between artists and scientists at field sites in extreme environments can create alternative pathways to foster environmental understanding. What has been the role of environmental activism at these sites and in the resulting projects? Using evidence from the author's projects, interviews with scientists, and working experiences, the author has argued that ecomedia artworks resulting from field-based collaboration have the potential to create a kind of situated knowing in relation to environment, and can extend the fieldwork to allow both specialist and nonspecialist audiences to experience geographic and temporal scales that cannot be understood through the physical experience of the environment (i.e., large geographical areas and long periods of time).

This chapter has included the author's collective analysis of travelling to the South Pole and to the Finnish Arctic where she created ecomedia artworks and conducted extensive interviews with scientists. The author's interactive mapping project, *90 Degrees South*, created with the aim of increasing public awareness and understanding of Antarctic weather and climate science has been presented as a case study.

The conclusion is a comprehensive chapter in which the author has drawn a summary related to the premise, aims, structure, and main topics of this thesis. In this chapter, the number of different strategies employed by the author is summarized in regard to why art can be a

catalyst to environmental knowing. In this conclusion, the author has synthesized evidence from the theoretical discourse, and projects in geosonification, and ecomedia and has demonstrated that these works can open alternative pathways to environmental knowing in our time of urgent climate crisis.

This final dissertation makes a contribution to new knowledge by having developed a synthetic conceptual framework for understanding the complex interactions between media art, technology, and environmental science. It has developed conceptual categories to assist in the study of new media and technology artworks that addressed weather and climate, in particular those that relate to climate change. The perspective presented in this thesis is unique in that it combines ecomedia art and environmental science collaboration with soundscape and geosonification studies. It is also unique in that it examines how this work can address emerging issues of global climate change by attempting to develop alternative pathways to environmental knowing.

The original research developed in this thesis has included:

1. Developing state of the art ecomedia artworks that explore alternative pathways to environmental knowing
2. Conducting comparative interviews with leading contemporary environmental scientists in relation to emerging issues of weather, climate, and public perception
3. Extending the evaluation and analysis of primary sources in relation to soundscapes and geosonification
4. Extending the evaluation and analysis of artwork in its potential to shift knowledge, specifically ecomedia and geosonification artworks
5. Developing artworks using new and emerging technologies and analysing empirical tests of these works with participants
6. Expanding environmental understanding through transdisciplinary collaboration

Part I. Background to Research—Environmental Crisis and Ecomedia

Chapter 1. Who Owns the Air? Public Participation in Climate Issues

Introduction

The accelerating crisis in climate change and the realization that humans are the primary cause of this change has raised questions about ownership and responsibility. Who “owns” the climate change crisis and who is responsible for mitigating and reversing it if possible? The overwhelming response to these questions by governments on an international level has been to propose a market solution, in essence, to sell the atmosphere.

This chapter explores the idea of air for sale from an economic, political, and cultural perspective. It includes a history of public participation in air and climate issues and an analysis of contemporary public forums for weather and climate, including weatherunderground.com and climateprediction.net. Contemporary art projects that attempt to address the politics of air will be discussed in the context of the author’s experiences while curating the online *Aer* exhibition for the Green Museum in California.

In 1661, public servant John Evelyn made a humble yet persuasive proposal to King Charles II. *Fumifugium or The Inconvenience of the Aer and Smoke of London Dissipated* was intended to alert the king and parliament to the dangerous levels of polluted air in pre-Victorian London and to urge swift action to stop the poisoning of citizens. Although he was writing over three hundred years ago, Evelyn remarkably outlined many of the presently known health effects of poor air quality: persistent cough and bronchial ailments, low birth weights, and premature deaths, for example. He also addressed currently known effects of air pollution on crops and long-distance visibility. With consummate charm, Evelyn entreated Charles II, “his illustrious presence that is the joy of his people's hearts,” who serves as “the very breath of the nostrils” of Londoners, to respond to this crisis by moving the offending industries, primarily those burning coal, out of the city and away from the majority of the population (Evelyn 1661).

Sadly, although Charles II did improve the situation briefly, London’s problems with “pea soup”, the lethal combination of smoke and fog that would later be known as smog, were to become much worse. By the end of the nineteenth century, the city had a noxious reputation, and in 1873, over one thousand Londoners died in a smog incident, the beginning of a series of similar incidents that occurred again in 1880, 1882, 1891, and 1892. Around that time, Claude

Monet spent many weeks in London painstakingly rendering views of parliament from his apartment window. His documentation of the light and sky is so detailed that contemporary aerologists have looked to the paintings as evidence of the chemical composition of the air on a historical level (Glassie 2006). Although Monet must have known about the deadly smog incidents in London, like many artists of the industrial revolution he chose to focus on documenting the air from a politically neutral position, and some say he even celebrated the effects of smog on the air (Glassie 2006). Later, artists like those of the Futurist movement outwardly celebrated deadly air, saying that humans should evolve lungs to breathe the poisonous fumes and embrace even this aspect of the industrial revolution. This they saw as a necessary part of human progress, ignoring the disastrous consequences of increased pollution (Marinetti 1911–15).

London's most horrible air pollution tragedy took place over four days in December 1952 and was known as the Great Smog. It is now believed to have cost the lives of almost twelve thousand Londoners. After that tragic event the city sent out a fleet of Civil Defence 'smog detectives' to measure the acidity, sulphur dioxide (SO₂), hydrogen sulfide, and carbon monoxide in the air and implemented a Clean Air Act. Despite those and other efforts worldwide, London and other cities continue to face air crises (Greater London Authority 2002).

What John Evelyn called 'a magnificent inconvenience' has grown dramatically in scale and complexity since the publication of *Fumifugium*. Evelyn's solution of moving polluting industries away from population centres is no longer an option. Population and industrial growth has been so large that there is no longer anywhere to move industry without creating an environmental and humanitarian disaster. With rising levels of CO₂ in the atmosphere, this 'inconvenience', referenced by Al Gore in the film *An Inconvenient Truth* (2006) (directed by Davis Guggenheim), has risen to global proportions, the effects of which will resonate for decades if not longer. The problem of rising levels of CO₂ is now one of the most pressing global crises of the twenty-first century.

The Philosophy of the Common Good

The ethical and philosophical discussion of natural resources as part of the 'commons' has a long theoretical history. Aristotle used the term 'common good' in regard to ethics and the distribution of material benefit, advantage, and interest (Jowett 1885). Thomas Hobbes (1651) talked about the Right of Nature and the 'Common-wealth', but also acknowledged that

humankind's need for self-worth required some amount of private property. David Hume, Jean Jacques Rousseau, and Karl Marx all based a large part of their ethical philosophies on the economics and politics of the 'common good' (Selznick 1994).

In 1949, Aldo Leopold published *A Sand County Almanac* (1966) and defined a 'land ethic' that many contemporary environmental groups ascribe to today. He calls for the land (and by extension, flora, fauna, water, and atmosphere) to be considered a part of community with the same kinds of rights as citizens. He describes the land and ecosystems as part of a global energy circuit that needs to remain open (in other words, unpolluted) for the survival of mankind.

In the modern era, one of the most influential and controversial works of environmental ethics is Garrett Hardin's 1968 essay in the journal *Science* titled 'The Tragedy of the Commons'. In his essay, Hardin uses a central metaphor of herders sharing a common parcel of land on which they all allow their cows to graze. He argues that a system of open sharing created an incentive for each individual herder to act against the common good by overgrazing the finite resource of land. He then extrapolates from this model and applies it to other finite resources like the rivers, fish stocks, national parks, and even the atmosphere and oceans. Hardin addresses possible management solutions about the tragedy of the commons, like privatization and regulation, and advocates for clearly defined property rights. Despite the fact that Hardin's essay has been used to promote the privatization of the commons, he advocated regulation of the commons, stating that the U.S. concept of private property actually favours pollution (Hardin 1968, p. 1245). Privatization, often called 'trading', is now a popular method used by governments to address problems of resource sharing.

For example, a system used in some global fisheries is known as 'catch quotas'. In most U.S. fisheries, the government has a regulatory system to control catch amounts by limiting the number of days fishermen operate and how much they collect each trip. However, in Alaska a market system called 'dedicated access privileges' has been in place since 1995; this system grants shares of each fishery to individual fishermen, who can then buy and sell their shares. Since 2005 there has been a move to expand this program throughout the United States, which has angered many environmentalists who see this as a move to give private property rights to a public resource (Eilperin 2005, p. A21). Creating a market system seems to be the automatic political answer for every environmental problem, but is this the most effective solution?

Property rights to air, or rights to pollute the air, have been rising in popularity as a way to control emissions. What follows are several examples of contemporary emissions and air-related trading systems with various goals and structures.

The Buying and Selling of Greenhouse Gasses

“Economic super-powers have been as successful today in their disproportionate occupation of the atmosphere with carbon emissions as they were in their military occupation of the terrestrial world in colonial times.”

—Andrew Simms, The New Economist Foundation (2006)

The Kyoto Protocol was born in 1997. It required thirty-five industrialized countries and the European Union (EU) to reduce greenhouse gas emissions by an average of 5 percent below 1990 levels by 2012. Despite, or perhaps because of, being the world’s biggest emitter of greenhouse gasses, the United States is not a part of the protocol. In the Kyoto Protocol, the main ‘basket’ of greenhouse gases to be reduced contains carbon dioxide (CO₂), methane, nitrous oxide, hydrofluorocarbons, perfluorocarbons, and sulphur hexafluoride. In addition, the protocol identifies ‘annex’ gases (or indirect greenhouse gases) that must also be monitored. These are carbon monoxide, nitrogen oxides, non-methane volatile organic compounds, and sulphur oxides (United Nations Framework Convention on Climate Change 2007).

The Kyoto Protocol includes a global greenhouse gas emissions trading system that has now been in place in Europe for almost three years. This emissions trading system could also be called a ‘cap-and-trade’ system. In the first year, credits are generous and the total amount of emissions for each company is determined. Each company has to achieve no more than that amount. Then, each subsequent year, the amount of credits allotted to each company is reduced, allowing companies to slowly lower emissions.

The most recent model of an emissions trading system is the Chicago Climate Exchange (CCX). This is a voluntary global trading system that covers six greenhouse gases that was launched in 2003 by economist Dr Richard L. Sandor. CCX emitting members make a voluntary but legally binding commitment to meet annual reduction targets. Companies committed to reduce their baseline greenhouse gas emissions by 6 percent between 2007 and 2010. The CCX currently has nearly one hundred full members, including industries from aerospace to coal to food and manufacturing, local and state governments, and universities. The CCX traded over 1

million tons of CO₂ in its first six months of carbon trading (Chicago Climate Exchange 2007). However, this voluntary system is nowhere near the scale needed to make the necessary reductions to slow or halt global warming.

In 1990 the United States launched a cap-and-trade program in sulphur dioxide as an amendment to the Clean Air Act. An initial objective of the program was to reduce sulphur dioxide emissions from utilities by 8.5 million tons below 1980 levels. To accomplish this, electric utility plants larger than a certain size were given an initial allocation of emissions allowances based on historical patterns. The act included stiff penalties for excess emissions, at a value more than ten times that of reduction costs. The program achieved a very high degree of compliance and the U.S. Congress considers the program a success. The current European greenhouse gas trading system is modelled after this system, but can it work in every situation? (U.S. Congress 1997).

Another model is the Montreal Protocol on Substances That Deplete the Ozone Layer, an international treaty that entered into force on January 1, 1989 designed to protect the ozone layer by phasing out the production of a number of substances believed to be responsible for ozone depletion, in particular chlorofluorocarbons (CFCs) and halons. This Montreal Protocol created a system for the international trading of allowances. In the protocol, trading is combined with a tax to offset any large profits from allowances that might discourage the reduction of CFCs. Since the Montreal Protocol came into effect, the atmospheric concentrations of the most important CFCs and related chlorinated hydrocarbons have either levelled off or decreased. Kofi Annan, former secretary general of the United Nations, calls the protocol “perhaps the single most successful international agreement to date” (Natural Science 1997).

However, by 1997 smuggling of CFCs from developing nations, where they were still permitted, into the United States and other developed nations had become big business. In Miami in 1997 smuggling of CFCs was believed to be second only to cocaine. The problem with smuggling still has not ended. Although the protocol’s goal was to completely phase out these gases by 2000, as recently as 2005 several companies in eastern China were found to be involved in illegal international trading of CFCs (China Development Brief 2005). A market solution can be very susceptible to this kind of exploitation.

The difference between a CO₂ market and both the CFC and sulphur dioxide markets is that technology exists to clean up CFC and SO₂ emissions and applies only to a relatively small number of companies with outdated technology, while the CO₂ system applies to thousands of

companies, and despite optimistic talk of ‘clean coal’ there is presently no existing technology to make coal burn more cleanly or sequester carbon emissions more safely on a large scale.

Another model for distributing air rights that can be examined is the right of the airwaves, or broadcasting rights. The U.S. Federal Communications Commission (FCC), which was created out of the Communications Act of 1934, regulates all nongovernment wire and wireless communications. The act specified only that broadcasting be in the hands of American citizens, and left it up to the FCC to decide how to license broadcast rights. In the past, applicants were required to describe plans for programming to be judged on general usefulness to the public and on its practicality. In practice, this resulted in a combination of private and governmental control.

However, in 1993 Congress gave the FCC authority to use competitive bidding, and since 1994 the FCC has conducted auctions of licenses for the electromagnetic spectrum, open to any eligible company or individual that submits an application and an upfront payment. According to the FCC, the auctions more effectively assign licenses than previously used hearings or lotteries and have reduced the time from initial application to license grant substantially. In 1997 Congress passed legislation that required the FCC to use auctions for all licensing unless exemptions apply, for example, public safety, and educational and public broadcasting. For a commercial broadcaster, purchasing through auction became the only way to gain rights to the airwaves (Federal Communications Commission 2007). This system created a broadcasting sphere widely dominated by the large commercial interests with the resources required to win this bidding war for the airwaves.

In 1996 the system was changed to favour large corporate media even more. The FCC relaxed the rules that restricted broadcasters from owning several radio or television stations in one market, allowing broadcasters, for example, to own an unlimited number of radio stations. This move has created an increase in advertising prices and has caused an unexpected outcry from communities who have found that the consolidation of the media within the hands of a few large corporations has resulted in a loss of quality local programming, with corporations instead polluting the airwaves with homogenized, computer-controlled broadcasts. The lesson to be learned here that might also apply to a market in greenhouse gasses is that the deregulation of the market, allowing the unrestricted purchasing of air rights, be it polluting or broadcasting, could well result in a disastrous reduction of the quality of air and the airwaves.

The New York City noise code can also be looked at as a model for emissions control on a local level. Like air pollution, loud noise poses health risks. The Environmental Protection

Agency warns against exposure to sound higher than 75 decibels, while most New York City traffic is already at 85 decibels, an ambulance siren is 120, and the subway is 95. Hearing loss is not the only health problem that can be caused by constant exposure to noise; the resulting stress has been shown to increase the risk of heart attacks (CBS News 2005).

In 1972, New York was the first city in the United States to adopt a noise code, and on July 1, 2007, the first update to the noise code in thirty-five years went into effect. Police are equipped with noise meters, and the code limits loud air conditioners, fans, car alarms, music, construction, and barking dogs. Policing the noise code is difficult because like air pollution, noise can be elusive, honking horns or loud car stereos are often gone by the time police arrive. It is difficult to pinpoint the source of noise, and individual sound sources can add up to loud noises, for example, in the case of groups of air conditioners, each individual one might not exceed noise regulations, but the combination is deafening. The right to produce noise is not traded on a market, but like the emissions markets, the biggest producers of noise get special allowances. Therefore, airplanes and trains are exempt from the New York noise code.

In conclusion, a fundamental aspect of the greenhouse gas emissions trading system is the granting of property rights to the air. The idea of ecological economics as illustrated in Hardin's essay, 'The Tragedy of the Commons', came from the understanding that environmental resources are finite, and since these resources can be destroyed, there should be incentives for protecting them. The question of how these incentives should be created, however, whether through a trading system or through regulations or some other means, is a topic of great controversy. What follows are some of these conflicting viewpoints.

Air as Property

Ecological economics provides both a mechanism for the valuation of environmental resources and an incentive for keeping within an established environmental 'budget'. In 1997 the U.S. Congress described ecological economics in this way:

From an economic perspective, pollution problems are caused by a lack of clearly defined and enforced property rights. Smokestack emissions, for example, are deposited into the air because the air is often treated as a common good, available for all to use as they please, even as a disposal site. Not surprisingly, this apparently free good is overused. A primary and appropriate role for government

in supporting the market economy is the definition and enforcement of property rights. Defining rights for use of the atmosphere, lakes, and rivers is critical to prevent their overuse. Once legal entitlement has been established, markets can be employed to exchange these rights as a means of improving economic efficiency (U.S. Congress, 1997).

Emissions trading systems have been criticized for a long time. At the 1992 Earth Summit in Rio de Janeiro, the NGO Global Forum emphasised avoiding pollution trading schemes that “perpetuate or worsen inequities hidden behind the problem or have a negative impact” (United Nations 1992). Later, arguments escalated, trade in greenhouse gases was called a new form of colonialism. Arguments for and against this system range from concern about flaws and possible abuses of the system to criticism of its fundamental assumptions about ownership.

The biggest beneficiaries of a greenhouse gas emissions trading scheme can be found in the banking industry (in the United States this industry is currently lobbying heavily for the implementation of a carbon cap and trade system) and the nuclear power industry, which stands to gain a loosening of restrictions on the production of new power plants.

However, despite the support of banks, not all economic experts support the use of such a system. Many would rather see a carbon tax in place. In practice, a carbon tax functions very much like a trading system because polluting companies either pay a tax or pay for carbon credits for their emissions. Both systems will also raise consumer prices on fossil fuels. Yet critics of the tax system say that it does not provide the incentive or ‘race for the pot of gold’ that the carbon trading system instils by financially rewarding companies that can substantially cut emissions (Solomon 2007).

There are critics of the trading system on both the political right and left. From the right, Nicole Gelinas, a journalist with the *Wall Street Journal*, argues against a trading system in the United States by stating that the global competition created by the system will hurt U.S.-based corporations. If U.S. energy companies cannot limit emissions, the international cap-and-trade system would require them to buy emissions credits from other countries. Interested in protecting the financial interests of these U.S. corporations, she calls the trading system a “direct subsidy to developing nations by paying for their power-plant upgrades” (Gelinas 2007). Gelinas argues that a federal carbon tax, an alternative to the international carbon cap-and-trade system, would provide revenue to the U.S. government that could then be used to subsidize U.S. power plant

upgrades, while an international cap-and-trade system could put this revenue in the hands of other countries, particularly those that already have reduced emissions. Gelinas's views seem to be in line with those of the U.S. government. In fact, one of the reasons the United States has stated that it is against the Kyoto Protocol is that it provides exceptions for developing countries, the countries that stand to benefit most from the protocol and lose the most from the consequences of global warming.

In *The Weather Makers*, Tim Flannery debates this position, stating that although developing nations were not bound by the Montreal Protocol, it was very successful. Flannery has mixed feelings about the subject of carbon trading. On the one hand, he observes that emissions trading is cost effective, and as a tool to reduce pollution, it has been successful in the past (for example, in the case of sulphur dioxide trading). On the other hand, he talks about the case of Eastern European countries whose economies have suffered ruin since the 1990s and therefore are producing approx 25 percent less CO₂ than they were in 1990. Since the Kyoto trading system requires emissions only 8 percent less than 1990 levels, without doing anything to actively lower emissions, these countries end up with a surplus of carbon credits, known as 'hot air' to critics of the protocol. Flannery (2005, p. 225) posits that creating a new global currency is too risky, since the foundation of any currency is based on trust—in this case trust that the seller will lower emissions, and so far he has not seen any guarantee that this will happen.

Arguing from the political left in 'Carbon Trading', Larry Lohman quotes Flannery's work when outlining the potential effects of climate change, but he is much more pessimistic than Flannery, particularly in regard to the commercial markets. He focuses on the seriousness of the problem and predicts that many markets will eventually collapse. He uses the example of the insurance business, providing quotes from insurance specialists who estimate that chaotic climate change could increase insurance rates several times higher than that of world economic growth, creating a situation where the world economy will not be able to sustain the losses and will collapse (Lohman 2006).

Lohman is critical of the hopeful attitude held by many industrialized countries about technological developments, which would allow continued use of fossil fuels such as carbon sequestration as the solution. He devotes a chapter on analysing how these technological solutions are nothing but a smoke screen used to distract public attention away from the government's lack of necessary action. He calls this distraction the "second strategy". He calls the first strategy 'the public denial of the existence of anthropogenic climate change'.

The first strategy works to reshape or suppress understanding of the climate problem so that public reaction to it will present less of a political threat to corporations. The second strategy appeals to technological fixes as a way of bypassing the debate over fossil fuels while helping to spur innovations that can serve as new sources of profit. The third strategy appeals to a ‘market fix’ that secures that property rights of heavy Northern fossil fuel users over the world’s carbon-absorbing capacity while creating new opportunities for corporate profit through trade (Lohman 2006, p. 54).

In *Earth in the Balance*, Al Gore embraces in part what Lohman critically calls the “second strategy”, proposing an SEI (Strategic Environment Initiative), which like the existing U.S. SDI (Strategic Defense Initiative), would require a major national effort, but with a focus on the environment rather than the military. Although he does emphasise that any new technologies should be evaluated, his focus is primarily on developing new technologies to combat climate change (Gore 2006).

Finally, Lohman is very critical of what he calls the third strategy, the “market fix”, primarily because of the property rights issue, the privatization of the air. Like Flannery, he is concerned that if a “top down” creation of a greenhouse gas emissions market were created without public debate, it would result in a market filled with distrust, including a lack of faith in both the structure and the implementation of the market (Lohman 2006).

The bottom line according to Lohman is that the current emissions trading structure allocates the most allowances to the biggest emitters, effectively giving a handout of billions of dollars to the most egregious polluters and providing incentives to them to keep polluting.

In ‘The Great Emissions Rights Give-Away’ (2006), Andrew Simms, policy director of the New Economics Foundation (NEF) and Feasta (The Foundation for the Economics of Stability), proposes an alternative structure for EU carbon trading. In his structure, the EU’s emissions allowances would be divided into an equal per capita basis and distributed to every EU resident. Residents would then be able to sell these allowances to companies or keep them off the market, thus actually promoting cleaner air.

Simms compares this approach to some other alternative approaches. For example, David Fleming’s proposed Tradable Energy Quotas (TEQs) allows governments to provide each citizen

with a portion of carbon units equal to the amount of the general public's fossil fuel use. Each citizen can use these units to purchase energy and fuel, or sell unused units on an open market (Fleming et al. 2011). Carbon units used by industry are sold at an auction similar to the FCC broadcast rights auction. The proposals of both Fleming and Simms are based on the fundamental principle that the atmosphere belongs to all people equally and not to any governments or corporations (Simms 2006). Artist Amy Balkin has created an artwork critiquing the greenhouse gas trading system. Her work will be examined later in this chapter.

One might think that the idea of 'air for sale' is absurd; however, it is in place in the abstract arena of the market. After all, no one would *actually* pay for the air they breathe. Culturally, this may no longer be the case, as evidenced by the rising popularity of something called the oxygen bar and portable canned air.

In both the cases, oxygen is touted as a cleansing medical 'therapy'. Advertisements focus on the healing power of air, using aromatherapy or 'oxygen therapy'. Advertisers promote the air as energizing for exercise, effective in combating cigarette smoke and curing a hangover. They sell air based on the idea of it being pure, fresh, and clean, and many promote it as an escape from the smog of city life. In the case of the 'oxygen bar', customers pay for a five-minute session or so in which they are able to relax and breathe clean, sometimes scented air. The oxygen bar started as a trend in the 1990s in Japan, Mexico, and South America and quickly spread to nightclubs, spas, casinos, and malls in Europe and the United States. In 2003 the oxygen bar at Olio!, a restaurant at the MGM Grand Hotel in Las Vegas, boasted two hundred to four hundred customers per day (Rimbach 2003). Portable canned air is becoming just as popular and widespread. In Japan, a recent large-scale commercial venture is O2supli, a portable can of oxygen.

The idea behind the product is to allow buyers to replenish their oxygen levels anytime they feel a lack of it due to stress, fatigue, or other factors. . . . Each can contains enough oxygen for 35 two-second inhalations, meaning each can lasts for roughly a week if it is used five or six times a day. At first the canned oxygen will be sold in Tokyo . . . then at all 11,000 of Seven-Eleven Japan's nationwide stores (*Mainichi Daily News* 2006).

How could our global culture have gotten to a point where the absurd notion of buying and selling the air is acceptable on any level, corporate or individual? Perhaps the arts, specifically conceptual artworks, have played a role in making buying air a culturally acceptable activity.

Air for Sale in Contemporary Art

“When art becomes idea, idea becomes commodity.” (Alberro & Buchman 2006)

As creative works, art and architecture have value in society, not just cultural value (although they have that too), but monetary value. In the 1950s and 1960s, Yves Klein’s concept of *Air Architecture* challenged the definitions of art and architecture by building with ephemeral materials, but on a wider scale it may have contributed to the idea of commodifying the public resource of air. Klein was interested in the ways that humans can use science and technology to conquer the ephemeral, to the point of turning even air and fire into building materials. Klein saw science and technology as the saviour of architecture, because they promoted new forms and structures made from sculpting the air and other ‘immaterial-materials’. He believed that *Air Architecture* would actually improve the environment, positing, “*Air Architecture* must be adapted to the natural conditions and situations, to the mountains, valleys, monsoons, etc., if possible without requiring the use of great artificial modifications” (Noever 2004). By creating *Air Architecture*, Klein radically redefined the limits of architecture, asking why solid materials like stone, wood, and brick should be the only materials in an architect’s palette. By developing technologies for using (or, some may say, misusing) ephemeral materials for building, Klein created an alternative pathway for the architectural imagination.

In the late 1960s, a group of artists, including Robert Barry, became associated with dealer Seth Siegelaub and started producing work that questioned the limits of art. Barry’s series of works, known as ‘invisible’ art, included *Inert Gas Series* (1969), in which a specific amount of gases (neon, xenon, and helium) were released “from measured volume to indefinite expansion” in the Mojave Desert (Wood 2002, pp. 35–36).

Lucy Lippard observed in *Six Years: The Dematerialization of the Art Object* that “novelty is the fuel of the art market”, and at the time of Robert Barry’s *Inert Gas Series*, this “fuel” was being burned at a rapid pace, constantly stretching the boundaries of the definition of art. By using the term “dematerialization”, Lippard attempts to remove art from its status as commodity by creating such ephemeral “objects” of art like those including the natural

expansion of gas, a substance that would be absurd to commodify. Artists like Barry were reacting against and attempting to create an alternative to the art market. However, over time, this work has not been removed from the art market. The ephemeral art movement was actually embraced by commercial galleries and dealers. As Lippard suggests, this market needed the fuel of these increasingly novel ideas (Lippard 1973, p. 31).

A connection to the market may have been necessary for the creation of the art and the survival of the artist; nonetheless, it created a paradoxical situation in which the immaterial was moved into the object realm. The critical stance of the artist on the art market was compromised through the positioning of the work within the art market.

In 2005, Tue Greenfort made *Bonaqua Condensation Cube* as homage to Hans Haacke's *Condensation Cube* from 1963. *Bonaqua*, a popular brand of bottled water, as the water of condensation was meant to directly address the issue of ownership of both the natural resource of water and of an ephemeral artwork. Water was considered in 1963 to be a public resource. However, by the early twenty-first century, it had become a commercial product. Like the earlier work, the piece was positioned in a gallery as an artwork that could be attributed with a monetary value. Like the earlier work from Haacke, *Bonaqua Condensation Cube* was a satire about the absurdity of the art market, but unfortunately by being exhibited in a gallery, both works remained a problematic part of that commercial system.

A recent public work related to air was *Hays Woods/Oxygen Bar* (2005) by Laurie Palmer. This project highlighted the natural processes that create air, and air as a public resource. Palmer used the format of the oxygen bar, but she subverted the commercial concept of the bar by giving away the air for free. Customers at the *Hays Woods/Oxygen Bar* learned that the oxygen was actually coming from the same plants that surrounded them in the woods and realized the value of that green space. In her statement for the work, she used the language of advertising:

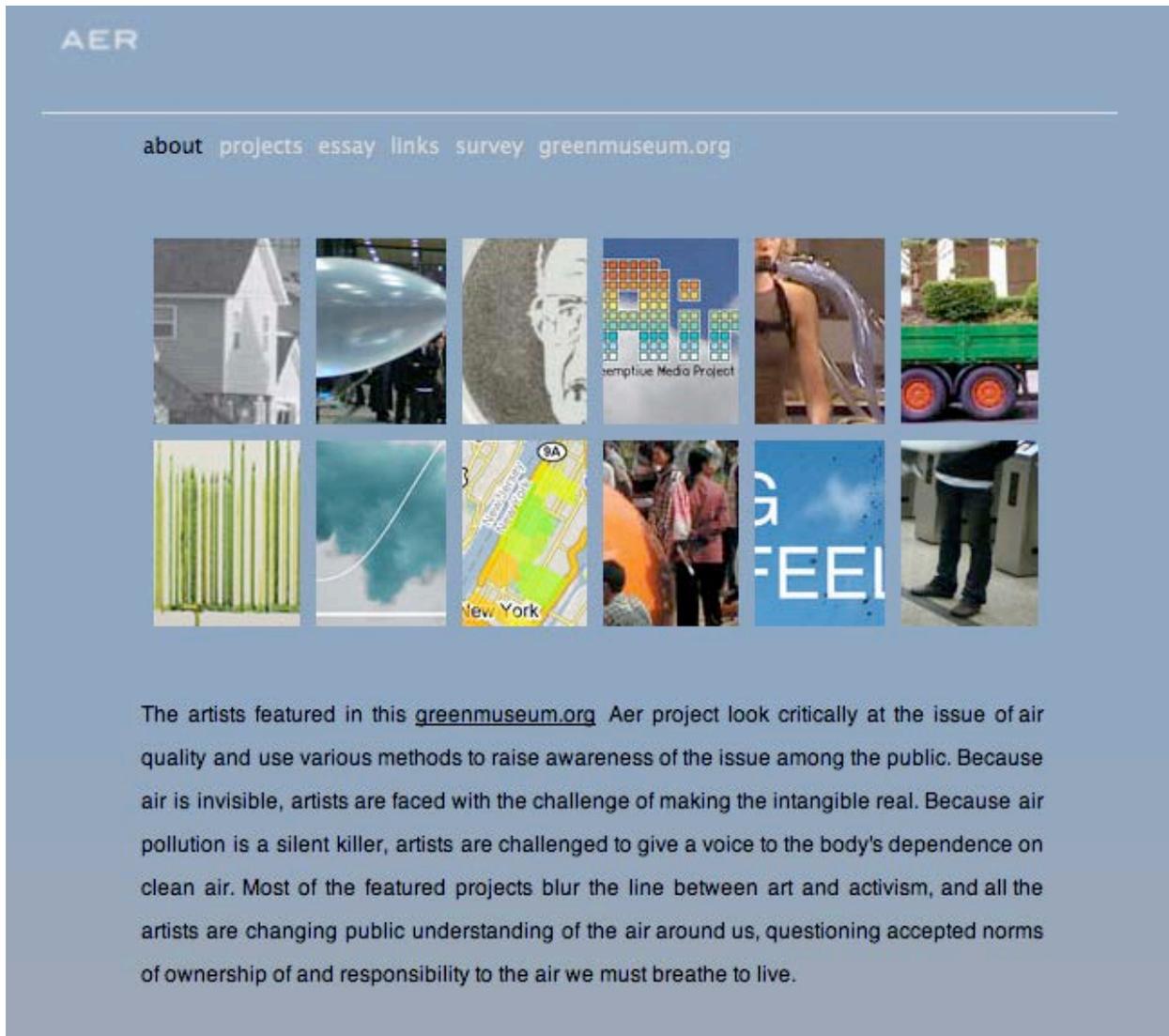
Want to breathe some pure oxygen courtesy of plants from Hays Woods? Try the Oxygen Bar, a project of artist A. Laurie Palmer. The oxygen bar is a mobile breathing machine, offering free hits of 'natural' oxygen on a first-come, first-serve basis. This oxygen is produced by the photosynthetic work of green plants (from Hays Woods) and is offered as a public service. It reproduces in miniature the beneficial cleansing and refreshing effects of city green spaces on the air we breathe. The oxygen bar anticipates the imminent loss of public resources that

filter Pittsburgh's dirty air and replenish it with oxygen, in particular, Hays Woods. At the same time, the oxygen bar anticipates the active participation of citizens of Allegheny County in land use decisions affecting our public health (Palmer 2005).

As evidenced in this quote, Palmer had a specific political goal in the presentation of this work. She wanted to encourage active participation of citizens in land use decisions. Palmer's work used the metaphor of an established commercial product (oxygen) and the language of advertising related to health and well-being in an attempt to convince her audience to appreciate the value of the natural setting of the woods and promote preservation. This work creates an alternative pathway in order to advocate for public action. It is a creative and critical intervention that reaches new audiences with an alternative viewpoint.

The *Aer* Exhibition

Today there are a growing number of contemporary art and social media projects conceived from a multidisciplinary perspective that represent the beginning of an effort to give a voice to each one of us affected by poor air quality, to highlight the flaws in the current system, and to empower individuals to preserve and protect our fragile atmosphere.



The artists featured in this greenmuseum.org AER project look critically at the issue of air quality and use various methods to raise awareness of the issue among the public. Because air is invisible, artists are faced with the challenge of making the intangible real. Because air pollution is a silent killer, artists are challenged to give a voice to the body's dependence on clean air. Most of the featured projects blur the line between art and activism, and all the artists are changing public understanding of the air around us, questioning accepted norms of ownership of and responsibility to the air we must breathe to live.

Figure 6. AER EXHIBITION WEBSITE, Andrea Polli, Greenmuseum.org (2008)

The *Aer* exhibition was curated by the author as part of her research, and the featured artists were far from neutral about the issue of air and air quality (Polli 2008a). The artists in *Aer* all look critically at air issues and use various methods to raise awareness among the public. Some also take an active role by directly affecting the air quality and therefore human lives. Because air is invisible, artists are faced with the challenge of making the intangible real. Air pollution is a silent killer, and it is challenging to give a voice to the body's dependence on clean air. Most of the featured projects blur the line between art and activism, and all the projects aim to change public understanding of air as well as question accepted norms of ownership and responsibility.

The Los Angeles based artist, Kim Abeles, created her *Smog Collectors* series in order to make the invisible visible by literally using the air as an almost photographic medium, placing

material surfaces on her rooftop and allowing particulate matter to collect on those surfaces over time. The resulting images look like beautiful photograms, but they present the shocking effects of particulate pollution. The *Presidential Commemorative Smog Plates* were also made as part of this series. She exposed each plate to actual smog for amounts of time that corresponded to the environmental record of each U.S. president. This process caused the resulting images on the plates to darken with each successive president, and strongly illustrates the tragic decline in U.S. air quality with each new presidential administration. *The Smog Collectors* series captured the attention of mainstream media and was covered by *Newsweek* (Howard & Zeman 1991, p. 6) and Dan Rather (CBS Evening News 1992). Abeles used a playful method of illustration as an alternative pathway for informing the public of the relationship of governmental policies to air quality.

Another project that uses the visualization of the air to make a powerful statement is *Pollstream*, a series by Hehe (Helen Evans and Heiko Hansen). Using interactive media and sophisticated visualization of the composition of air and smoke, these works inform and alert the public to real-time, local air quality. As mentioned earlier in this chapter, Monet found the skies of European cities awash with unusual colours caused by human-made pollution. In a similar way, Hehe's *Champs D'Ozone* overlays a real-time image of Paris skies with colours representing the unseen pollutants contained within. On the one level, Hehe's *Pollstream* projects pay homage to Monet's nineteenth-century works by aestheticising the air and smoke. On another level, unlike viewers of Monet's paintings, *Champs D'Ozone* viewers can directly link the colours to actual levels of pollutants. Hehe's work forces viewers to pay critical attention to what the colours represent: a deteriorating quality of air.

Another elegant example of local air visualization is Sabrina Raaf's *Translator II: Grower*. In this project, a tiny robotic rover drew a simple green line at the bottom of a white wall perpendicular to the floor. This line indicated the level of CO₂ in the room—the taller the line, the more CO₂. The rover moved around the room creating a horizon of tall and short grasses, a history of the changing airscape around us. This interactive work responds directly to the number of people in a room, since we all exhale CO₂.

Australian performance artist Sarah Jane Pell has also highlighted the body's transfer of air and our dependence on air as living, breathing beings. Her works explored the physical and emotional limits of the body. For example, *Interdepend* creates a closed-circuit life support system between Pell and artist Martyn Coutis, and *Undercurrent* presents a single performer

contained within a sealed transparent dome with a finite amount of breathable air. These works were physically demanding for the performers and created an overwhelming emotional intensity for the public. In *Fumifugium*, Evelyn refers to the air as the soul or spirit of man, and Pell's works seem to give that soul or spirit a physical manifestation. This can be witnessed either through human interdependence or through a single womb-like containment that without breathable air would become a tomb. Like Raaf's work, Pell's works seem to hold a vision of the future. For example, in *Translator II: Grower*, Raaf presents a robot that methodically records the human imprint on air. This rover, which can continue to perform its duties even when the air becomes toxic to humans, questions our future on the planet if we continue to poison the air. In Pell's case, this vision is apocalyptic, one in which the very air we breathe is a limited commodity. In the future, will the earth's fragile atmosphere continue to sustain us, or will we be forced to remain contained in controlled environments while our machines roam freely, reporting to us the world outside? By suggesting an alternative future of limited air, these works by Raaf and Pell created a pathway that forced audiences to consider the important reciprocal relationship between humans and the earth's atmosphere.

In *Fumifugium*, Evelyn called air "the vehicle of the soul", and the author concluded that the term 'vehicle' was appropriate for defining air in the context of the *Aer* exhibition. Many of the various definitions of 'vehicle' fit not only the specific artworks in *Aer* but also many contemporary artworks. For example, a vehicle can be a means of transmission and a medium of communication, a means of accomplishing a purpose, and also an idea to which the subject of a metaphor is compared. The 'vehicle' can be a means by which the idea is transmitted, through some kind of tangible art medium like a painting or sculpture, yet in our current artistic climate (the age of the dematerialism of the art object) air has become a viable art medium. Although air is as fleeting as an idea, and perhaps even because of this, it can also be the vehicle through which an idea is expressed, as has been shown through the work of Yves Klein and Robert Barry.

A series of artworks featured in the *AER* exhibition that functioned as both vehicles of wireless communication and literally floating vehicles using the transportation medium of air were Jed Berk's inflatable *ALAVs 2.0* (Autonomous Light Air Vessels). These human-size floating vessels communicated with the audience using mobile devices, and the works seem to anthropomorphize the invisible wireless networks that activate the air itself. Berk's project also created a very tangible alternative model for networked communication, a model in which

information flows freely between people, objects, and even space. This created a participatory networked environment, one in which every being and object occupied a space and a voice. It was impossible to view the *ALAVs* without seeing some kind of floating body or without projecting a kind of sentient life on these simulated creatures. They seemed to represent how our consciousness could be freed from gravity, lighter than air, giving us a way to directly communicate with air itself. By developing technologies for new social interactions and structures, Berk has envisioned an alternative pathway for public communication.



Figure 7. SUPERGAS/USER/UTA, SUPERFLEX, Cambodia (2001)

While Berk created the inflatable *ALAVs* using contained gas in order to shape a space, the artist's team called Superflex have created a project that contained gas for the purpose of influencing social change. Superflex worked in collaboration with Danish and African engineers on *Supergas*, which aims to provide a modest and efficient portable biogas system for families in Africa. Superflex identifies their artworks as tools, shaped by a social and economic commitment. The tool *Supergas* has helped individual families to become independent producers of energy with minimal time investment and without making dramatic changes to their culture.

This trans-disciplinary process of development involved the community on a deep level. Also, the design process didn't end with implementation; the tool itself was originally designed for flexible use, a kind of open-ended platform. *Supergas* captures organic materials that are an ordinary artefact of farming in order to promote individual energy empowerment and to protect the air from more polluting forms of energy production. The thought process that can take a polluting compound and with minimal costs turn it into an energy resource can be a contagious activity, in turn promoting similar independent and innovative cross-disciplinary and cross-cultural cooperation in the future.

In the 1960s, the United States first implemented air quality monitoring and advisory systems to alert the public about dangerous levels of pollution. During days of poor air quality, public notification came bundled with the weather report, and people were told to avoid going outside. While this 'one too many' kind of information exchange may work effectively for these kinds of warnings, other models in a networked environment could be exploited with respect to air quality. In an open platform, *Area's Immediate Reading (AIR)* by Pre-Emptive Media (Beatriz da Costa, Jamie Schulte, and Brooke Singer), the artists turned individual citizens into volunteer 'smog detectives' using a network of wireless pollution-monitoring devices. This open platform allowed real-time sharing of location and time-based information about pollution, health, and the environment. Media was used as a strategy to open public dialogue. This wireless network created for the *AIR* project functioned like another definition of 'the vehicle': a medium in which medicine is administered. In this case, the illness represented is a complacent society, blind to the dangerous effects of air pollution, and the metaphorical 'medicine' is increased public participation in monitoring.



Figure 8. PUBLIC SMOG OFFSETS TOMORROW TODAY, Amy Balkin, Douala, Cameroon (2009)

Amy Balkin's *Public Smog* (2007) projects address the commodification of clean air from the perspective of the market. Balkin is an artist whose works create metaphoric shifts, question social and political assumptions, and take an activist stance. Her work often involves intensive legal, financial, and political research. *Public Smog* is a public park located in the atmosphere, of changing size and floating in an unfixed location. At first it seems like a fantasy! How can anything exist in such an ephemeral location? The premise of Amy Balkin's work references the economic system of emissions trading. Through her project, the 'global public' can purchase as many emissions allowances as possible on the emissions market. These carbon offsets are then retired, in other words they are taken off the market, making them unavailable to polluting corporations. By openly embracing the free market for the public good, Balkin presents a sharp critique of the system the project must operate within. Therefore she sees her 'public space' as the emissions trading market.

Balkin's work clearly questions the market, and the solution she proposes is meant to be absurd. However, in the context of contemporary culture, the solution seems like a viable one. In fact, it is very similar to the structure proposed by Feasta, whereby individuals buy and sell emissions credits on the market, and a certain amount of emissions credits are distributed to citizens for free. A group called TheCompensators* proposes the exact same solution as Balkin, claiming to have retired over 1,500 EU emissions allowances (TheCompensators* 2007). These solutions create potential problems grounded in the very idea of the market. Healthy markets may grow, but if people decide to buy emissions credits or clean air, the market may issue more emissions credits to balance the market and meet the demand. This process would force the public to pay ever-higher prices for clean air.

The difference between Balkin's *Public Smog* and TheCompensators* projects lies in the fact that one identifies itself as an art project and the other as an environmental project, but the underlying metaphors are similar. By using the metaphor of a public park, Balkin's work allows viewers and participants to look at the system of emissions trading through a familiar lens. Most viewers understand the difference between public and private property in the context of land use. The privatization of air as if it were a public park is a metaphor Balkin uses to influence a greater understanding of the problems that may emerge from an emissions trading system. Balkin invites public participation through the purchase of emissions allowances and offers an alternative reading of the carbon trading system, and therefore creates an alternative pathway for examining this market.

The message of *Public Smog* becomes even clearer when seen in relation to one of Balkin's earlier works, entitled *This Is the Public Domain*. In 2003, Balkin purchased a 2.5-acre parcel of land located in Tehachapi, California, intended as a permanent, international commons, free to everyone, held in perpetuity. Since there was no precedent in the creation of such a commons in the current legal system, Balkin's project involved a complicated legal process that explored solutions in both real property law and copyright law. Through this process, Balkin questioned the foundations of the existing laws and highlighted the disappearance of public space. Balkin has identified the project as an art project, and this classification is essential to her legal approach, one that explores the land as a creative work of art. Through this project, she joins a movement of people who move fluidly between the roles of artists, environmentalists, and activists.

On December 11, 1997, the Kyoto Protocol was adopted by the United States and 121 other nations, but was not ratified by the U.S. Congress. American industry forced the rejection, predicting ‘disaster’ if CO₂ reductions were enforced. In March of 2001, the United States again pulled out of Kyoto, saying that complying would destroy the economy. Many U.S. citizens disagree with their government’s actions and are concerned about rapid increases in global temperatures, ice melting, and the sea level rising, changes that the 2007 UN intergovernmental report on climate change states is ‘unequivocal’. In another example, Ben Engebret provides individuals in various U.S. cities the chance to personally comply with the Kyoto Protocol. Engebret does not identify himself purely as an artist or call his latest project, *Personal Kyoto*, an art project, and his projects often operate outside of the art market on the Internet. *Personal Kyoto* analyses electric usage information and calculates an energy reduction goal of what the Kyoto Protocol might require for an individual. *Personal Kyoto* allowed individuals to monitor electric use on a daily basis with the goal of reducing their personal consumption of greenhouse gases. Like Balkin’s *Public Smog*, *Personal Kyoto* works within an existing system to empower public action and benefit. While *Public Smog* takes on the publicly traded carbon offset system with collective action using a public space model, *Personal Kyoto* looks to individual responsibility and accountability as a means to encourage global change.

Projects that focus on personal responsibility embrace the philosophy of ‘voluntary’ emissions reduction and can be compared with the Chicago Climate Exchange on an individual scale. While these projects may help raise awareness of the problem of CO₂ emissions among the general public and as such may have an impact on total emissions, their focus on personal choice may detract from the urgent need to curb emissions now. Can the American individualist ideal (the ideals behind the problematic proposal made by the United States to the EU, which recently promoted volunteer emissions reduction) promote the changes needed? Voluntary emissions reductions may be a great idea on an individual level, but can they work on a corporate scale?

The paradoxical problems and metaphors that have been raised by these artworks are part of the system in which the works exist. They are either in the art world, with its gallery economy based on the buying and selling of works, or in the public art world, in which works can be supported by government or private interests; some works also operate in the semi-public forums of the market or the Internet. These works bring up larger questions about the potential of art in a time of global environmental crisis, and more specifically the potential of art and science

collaboration in creating alternative pathways to understanding and responding to climate change.

If air is the ‘vehicle of the soul’ it is ironic that today most of the poison in our air is caused by gas-powered devices that are also known as ‘vehicles’. Eve Andrée Laramée turned this contradiction on its head with her project called *Parks on Trucks* for the city of Aachen, Germany. By planting gardens inside of truck beds, Laramée created a carbon-neutral fleet of three Mercedes Benz trucks. Along with biogeographer Dane Griffin, she calculated the amount the trucks would drive so that their emissions would match the amount of air cleaned by the flatbed gardens. How far could these trucks travel so that they created no harm? In one case, she concluded it was no more than one-third kilometre per month! Andrée Laramée’s work created an alternative pathway for addressing the problem of automobile emissions by presenting a potential solution. However, by showing that this solution was impractical, she emphasised the magnitude of the problem.

In the seventeenth century, John Evelyn proposed moving polluters away from densely populated cities as a solution to London’s air pollution crisis. This was a local solution, but climate change is a global problem that requires international cooperation. In the author’s interviews with meteorologists and climatologists on projects interpreting weather and climate data, she has learned that scientists have taken a very practical approach, that of the mitigation of inevitable climate change. In part, this practical approach is related to the damage already affecting the atmosphere. Even if CO₂ emissions were to stop tomorrow, several scientists interviewed predict that climate change will continue for at least the next one hundred years. Perhaps another part of the focus on mitigation might eventuate from an understanding that at the present time there is a lack of political will to do what is necessary on a global level to reduce greenhouse gas emissions.

The projects in the *Aer* exhibition navigate the economic and personal politics of air and air quality. As these politics can be complex and controversial, Platform London, a group whose work crosses disciplinary lines to achieve social and ecological justice, attempts to blur the boundaries between art and activism. Their projects involve rigorous research, advocacy, public art and education, or various combinations of each. The global price of oil is set at London’s International Petroleum Exchange, and Platform London’s artwork aptly entitled *Unravelling the Carbon Web* looks closely at two major players in the oil industry that have headquarters in London: BP and Shell. The project focuses on their activities in Iraq, the former Soviet Union,

and Nigeria. The project included the oil industry in Nigeria and the policy of Shell. A component of the project, *Remember Ken Saro-Wiwa*, was a tribute to the Nigerian writer and activist who led a nonviolent campaign against the environmental damage associated with the operations of Shell and other multinational oil companies in the Niger Delta. Ken Saro-Wiwa's execution by the Nigerian military in 1995 provoked international outrage. Platform London then coordinated a coalition of organizations and individuals to contribute a series of living memorials to Saro-Wiwa, these included a book of poetry and a stainless steel bus made by Nigerian-born artist Sokari Douglas Camp. This growing project, *Unravelling the Carbon Web*, contains an archive of related news, historical documents, and analysis, including fables that try to reach the conscience of the global oil industry.

Conclusion

The work of the artists in the author's curated exhibition, *Aer*, and the related art and activist projects discussed in this chapter represent the beginnings of an effort to address the issue of air pollution from a multidisciplinary perspective. In the 1960s, Yves Klein, Robert Barry, Hans Haacke, and others developed artworks from ephemeral materials. By making artworks from air and water, these artists pushed boundaries and expanded the definition of art. At the time that Klein, Haacke, and Barry were creating the ephemeral works discussed in this chapter, water and air were seen as public resources. However, by the early 1990s bottled water had become a popular item in stores, and air pollution trading systems in sulphur dioxide and CFCs had already been implemented. Because artworks generally operate within various economies, whether they are gallery works or works of public art, the position of ephemeral artworks as private property may have unintentionally softened the public to the idea of selling bottled water and to the buying and selling of air. The context in which an artwork is presented, for example, as a high-priced product in a gallery or in a public space, affects the extent of its message and the effectiveness of the work in responding to a global crisis like climate change.

Therefore, recent contemporary artists using ephemeral materials, for example, Laurie Palmer (*Hays Woods/Oxygen Bar*) and Tue Greenfort (*Bonaqua Condensation Cube*), have responded to the idea of selling air and water by offering an alternative reading to the mainstream commercial messages that encourage marketing these resources. By presenting the *Hays Woods/Oxygen Bar* as a public artwork in which clean air is distributed for free, Palmer

developed an alternative mechanism to access new audiences for art and to encourage social activism in support of preserving the woods.

Contemporary artists presented in this chapter have used dramatic visuals in order to offer alternative viewpoints. Both Kim Abeles (*Smog Collectors*) and Hehe (*Pollstream* and *Champs D'Ozone*) developed innovative ways to visualize air quality. Their works dramatically make the invisible tangible to art audiences in dramatic ways. Other artists presented in this chapter have used technology as a means of creative and critical intervention. Sabrina Raaf (*Translator II: Grower*) and Sarah Jane Pell (*Interdepend* and *Undercurrent*) have designed works that highlight the human body's impact and dependence upon air. Their works suggested the implications of an alternative future in which air is a limited resource.

Like Raaf and Pell, Jed Berk (*ALAVs 2.0*) used the communications potential of technology as a means of intervention by placing audiences in direct conversation with anthropomorphized floating vehicles. Berk's project drew attention to a different kind of human interaction with the air, highlighting air as a pathway of communication and transportation. Eve Andrée Laramée (*Parks on Trucks*) also used a vehicle to illustrate the potential of air, but unlike Berk's *ALAVs*, the vehicle Laramée used was severely handicapped by the constraint that it have no negative impact on the air quality. Through this work, Laramée illustrated the magnitude of emissions coming from each individual automobile compared to its physical footprint.

As was shown through the controversies surrounding the creation of global markets that trade in air and through artists' critical responses to this controversy, there can be new mechanisms for communicating problems related to the environment in general and climate change in particular. From a top down perspective, carbon trading systems may put the atmosphere under the control of a small number of large corporations rather than in the hands of the citizens that need to breathe air to survive. However, there may be another kind of trading system that artists can play a role in developing, one that facilitates a grassroots exchange of ideas in opposition to corporate control.

Towards that aim, *Supergas* not only operated outside of the traditional art market but also operated outside of the global energy market. *Supergas* functioned as a catalyst for social change by turning consumers into producers. Ben Engebretth (*Personal Kyoto*) drew attention to global efforts to reduce greenhouse gases and also redirected the power of that reduction to individual citizens. Preemptive Media (*AIR*) also placed tools in the hands of citizens by empowering the public to record and monitor local air quality, and Amy Balkin (*Public Smog*)

critically questioned the carbon trading system by suggesting a way for individuals to collectively subvert the system and return the air to the public domain.

Each human being is affected by poor air quality and climate change, and the response of governments to privatize the air may not solve the problem but rather might create more difficulties. Several of the artists discussed in this chapter have created alternative pathways to highlight the flaws in the carbon trading system and to empower individuals to preserve and protect the fragile atmosphere. As has been shown in this chapter, artworks can serve as an alternative medium for promoting social movement and activism and as a social action that can lead to the development of new social interactions and structures.

Chapter 2. Soundscape, Sonification, and Sound Activism

Introduction

In this chapter the author will attempt to unite three areas of sound research:

1. Soundscape composition, in particular those compositions developed through the practice of soundwalking
2. Sonification and audification, or the process of translating inaudible signals into sounds
3. Sound activism, specifically designed to raise awareness of the sound environment and change social and cultural practices

In bringing these distinct areas together, she will attempt to create a theory of environmentally aware audification and sonification practice that is grounded in the natural and man-made soundscape. She will argue that the act of listening through public soundwalks and other formal and informal exercises can build environmental and social awareness and promote changes in social and cultural practices. By examining the act of listening as an alternative pathway and comparing the research, writings, and creative work of leaders of the acoustic ecology movement (e.g., R. Murray Schafer, Hildegard Westerkamp, and Bernie Krause), the author hopes to shed light on these potentials. For purposes of comparison, projects that explore the sonification and audification of inaudible signals will be examined, including the work of Christina Kubisch. The process of audification and sonification of these signals will be examined in comparison to soundscape experiences in order to develop a theory of data sonification based on the soundscape.

In order to build a community around the urban soundscape, in 2003 the author cofounded the ongoing New York Society of Acoustic Ecology (NYSAE). Through this endeavour, she co-created the NYSoundmap and Sound Seeker projects, which have been developed over the past four years in order to provide practical research for this chapter. Thus, by comparing and contrasting theoretical writings with practical experiences leading listening exercises, public soundwalks, soundscape-related brainstorming sessions, and presenting field recordings in various settings, new methodologies will be documented.

The Politics of Soundwalking

“In the soundscape composition . . . it is precisely the environmental context that is preserved, enhanced and exploited by the composer. The listener’s past experience, associations, and patterns of soundscape perception are . . . integrated within the compositional strategy.” (Truax 1996, pp. 47–63)

‘Soundscape’ is a widely used term coined by Canadian composer R. Murray Schafer as an analogue to ‘landscape’ to define the collection of sounds in an environment. In Schafer's seminal 1977 publication, *The Tuning of the World*, the natural and man-made soundscape was characterized with geography as the foundation. Schafer defined natural ‘keynotes’ as sounds that arise from the overall geography of a specific area. ‘Sound signals’ were defined as alarms and other sounds that carry information, and ‘soundmarks’, like landmarks, were defined as elements of the soundscape that identify place in time as important historical markers that demand public protection. In addition to defining the field of acoustic ecology, *The Tuning of the World* was also a call to action, as it alerted readers to the widespread global disappearance of soundscapes and the urgent need for their preservation. For example, Schafer identified ‘hi-fi’ and ‘lo-fi’ soundscapes. He valued the endangered hi-fi, relatively quiet soundscapes with a wide amplitude range where it is possible to hear a large amount of detail, over lo-fi, loud and noisy environments created from large amounts of machinery where sonic detail is masked by the industrial sounds of modernity (Schafer 1977 [1994]). Schafer was part of a global movement called the World Soundscape Project (WSP) founded over thirty years ago by an international interdisciplinary community of artists, scientists, activists, and engineers that included Barry Truax, Howard Bloomfield, Peter Huse, Bruce Davis, and Hildegard Westerkamp. The contemporary global movement represented by the World Forum for Acoustic Ecology (WFAE) was born out of the WSP.²

According to Schafer, a soundscape cannot and should not be separated from its geographical location. In *Tuning the World*, he used the term ‘schizophonia’, evoking schizophrenia or mental dislocation, to describe the separation of sound from its location to

² The World Forum for Acoustic Ecology (WFAE), founded in 1993, is an international association of affiliated organizations and individuals who share a common concern with the state of the world’s soundscapes. See <http://interact.uoregon.edu/medialit/wfae/home/> for a detailed history, the journal *Soundscape*, and links to international affiliates.

argue against the prevailing practice of electro-acoustic musicians inspired by composer Pierre Schaeffer's idea of the 'sound object', i.e., creating compositions made of recorded sound disconnected to its source. In contrast to Schaeffer, Schafer promoted the reestablishment of the ecological connection of sound to its environment (Schaeffer 1966).

Analogous to colours, every sound has a frequency 'spectrum', which is the combination of frequencies present in the sound. Noisy sounds like white noise or the sound of water have a wide frequency spectrum and clear tones have a narrow spectrum. Composer and acoustic researcher Bernie Krause expanded upon Schafer's ideas about hi-fi and lo-fi soundscapes to create an analysis of the frequency spectrums of ecosystem soundscapes. He found that in a healthy ecosystem, for example an old growth forest, living creatures fill every possible frequency band in the sound spectrum, while the frequency spectrums of more recently developed ecosystems, like forests regrown after extensive logging and clear-cutting, have prominent gaps in the spectrum (Krause 1998).

Composer Hildegard Westerkamp initiated another major development called 'soundwalking'. One of Schafer's collaborators on the WSP, she defined soundwalking as an embodied method of personally connecting with the soundscape through focused listening while physically moving through space. The main purpose of a soundwalk is to deeply listen to an environment. This can be any environment, from pristine natural settings to a busy city street, the mall, or the subway. A soundwalk can be accomplished alone or shared with others, with recording equipment or without, and Westerkamp and those inspired by her have created thousands of recorded electro-acoustic soundscape compositions for performance, publication, and broadcast (1974, pp. 18–19).

This movement towards recorded soundwalks (also known as field recording or phonography) and the subsequent mixing and broadcasting of these recordings seems opposed to the original aims of Schafer, which emphasised the soundscape's inextricable connection to place. Westerkamp has addressed this incongruity in her writings, emphasising that the recording, manipulation, and broadcast of soundwalks can actually bring listeners closer to the environment through immersion. She says that composers can "make use of the schizophonic medium to awaken our curiosity and to create a desire for deeper knowledge and information about our own as well as other places and cultures" (Westerkamp 1974, p. 2). She argues that listening to a soundscape composition does not disorient the listener, but rather "creates a clearer sense of place and belonging for both composer and listener" through the artistic transmission of

meanings about place, time, environment, and listening, and that “a soundscape composition is *always* rooted in themes of the sound environment.” Finally, she concludes that a soundscape composition is “meaningful precisely because of its schizophonic nature and its use of environmental sound sources” (1974, p. 2). Westerkamp argued that the immersive nature of a soundscape composition, in other words its ability to transport the listener into another place and time, could enhance a listener’s understanding of a particular place.

A specific technical area of soundscape recording that Westerkamp emphasised is the ability of recording equipment to amplify barely audible environmental sounds. As she stated: “position the microphone very close to the tiny, quiet and complex sounds of nature, then amplify and highlight them . . . [so that] they can be understood as occupying an important place in the soundscape and warrant respect” (1974, p. 19). While the use of recording equipment as a technical prosthesis does allow listeners to hear outside the range of normal human hearing and is an element in some soundwalk compositions, the value of listening on a human scale is the focus in the soundwalk recordings of Westerkamp and others. This technique emphasises the embodied nature of listening. Canadian soundscape composer and scholar Andra McCartney has also written extensively about embodiment in soundwalk recordings. She explains: “Soundwalk work is far from detached. The recordist’s perspective is written into the recording . . . a recording soundwalker is simultaneously an intensely engaged listener, connected by a phonic umbilicus to the surrounding world” (McCartney 2009).

Therefore, the practice of soundwalking allows for an active engagement with the soundscape, but the practice could also be seen as closely tied to political actions. As if engaged in a political demonstration, soundwalkers can move through space in a silent protest of both the visual dominance in contemporary culture and the constant industrial and electro-acoustic noise assaulting our sonic environment. Composer and scholar David Dunn has described this visual primacy of modern culture, adding the observation that this primacy has a direct affect on environmental awareness: “Our modern 20th-century culture—but by no means all human cultures whether extant or extinct—tends to privilege our understanding of reality through our sense of sight. . . . Aural experience is largely pushed further into a background perception, and we pay for this diminishment with a loss of sensitivity and awareness towards certain aspects of our environment” (Dunn 2008). Dunn observed that bringing the auditory nature of an environment into conscious attention inevitably serves to define the historical and ongoing social relationship of humans to that environment. He and Schafer have discussed the disintegrating

social impacts and psycho-physiological destructive aspects of both the loss of traditional knowledge conveyed through sound and the increase in industrial noise.

Beyond environmental acoustics, McCartney also argued that just walking through the landscape can be a political act, and she presented a multifaceted analysis of soundwalks in which “soundwalks can provide a good basis for audience conversations that have epistemological, aesthetic and ethical dimensions” (2009). In agreement, English sound artist Viv Corringham’s ‘shadow walk’ works have drawn attention to the history of rural walking as a public right of way in England by cutting across private lands (2008). Therefore, soundwalking and soundscape composition can serve as both a philosophical and political practice, and these interdisciplinary practices can create alternative pathways for increasing environmental knowing from a personal, environmental, and political perspective.

By design, soundscape-oriented activities focus on the personal, embodied experience of sound. Therefore, the environmental knowing afforded by this practice is limited to the portion of the wave spectrum that is audible to the human ear and to the scale of human movement and temporal experience. In the 1970s, German conceptual artist Joseph Beuys questioned the communication potentials of art by creating the term ‘social sculpture’ to define a process in which the art is the process of thought, speech, and discussion that could be a political and environmental action and could embrace many disciplines. He attempted to open participation in art-making and free art from its materiality in order to create an active space of potential (Beuys & Tisdall 1979). Using these criteria, the over-thirty-year history of the interdisciplinary exploration of the soundscape and the practice of soundwalking is a fine example of an investigation of social sculpture. However, the author believes that audification and sonification projects inspired by soundwalking might also serve to increase awareness of aspects of the environment that are outside of the range of human hearing. An analysis of the similarities and differences in the attitude of listening to a soundscape, or a sonification or audification, could be compared to the listening of music and may shed light on how the content is received.

Listening Attitudes: Soundscape versus Music

The following analysis of listening attitudes of soundscape versus music is not intended to create a dichotomy between music and soundscape composition. As composer Barry Truax (2010) has confirmed, contemporary musical structures and techniques, especially computer music, encourage a variety of listening attitudes, and therefore there may be no difference between

contemporary music and soundscape or soundscape composition. Soundscape can be listened to as music and music can function as a soundscape. However, to understand how sonic information might be received, it may be useful to examine the usual kind of attention paid by the listener to a soundscape versus that given to a traditional musical performance or recording. The following table outlines some of the strengths and weaknesses of each, which will be described in more detail in this chapter.

Table 2.1: Listening Attitudes in Traditional Music as Compared to Soundscape

Traditional Music	Soundscape
I. How the sound is usually presented	
Orchestral analogy	Architectural analogy
Directional	Immersive/Spatial
Stationary	Moving
II. How the sound is usually notated/recorded	
Pitch-based	Timbre-based
Quantitative	Qualitative
Notation	Modelling
Repeatable/Discrete	Non-repeatable/Authentic/Continuous
III. How the sound is usually received and interpreted as content	
Consciously	Unconsciously
Foreground	Background
Eurocentric	Non-Eurocentric
Inspiring power/control	Inspiring empathy

Here the author suggests that the strengths and weaknesses of traditional music versus soundscape can be divided into three subsections: how the sound is presented, how the sound is notated and recorded, and how the sound is received and interpreted. The first subsection, how the sound is presented, encompasses the first three items of the table, beginning with the orchestral analogy versus the architectural analogy. Therefore, traditional music is most often presented using the orchestral analogy, with the listener facing a stage of performers or a pair of directional speakers, while a soundscape is most often experienced as surrounding the listener. This analogy is also transferable to recorded soundscape compositions, which, as Westerkamp

emphasises, are often thought to transport the listener into a different environment. Soundscape compositions are often designed to be experienced through headphones and can employ holophonic techniques to virtually position sounds in various places around the listener. Finally, the orchestral model presents the sound source as stationary, while in soundscape listening, both the sources of the sound (cars, people, animals) and the listeners (as in the case of soundwalking) are often in motion. Soundscape compositions are generally designed with a particular environment in mind, and the way the sound is presented attempts to emphasise environmental knowing.

The way in which sound is notated and recorded is also critical to how traditional music and soundscapes function in constructing a worldview. Traditional musical forms are based much more on pitch than on timbre, while soundscape compositions depend almost entirely on timbre, actually expanding the definition of timbre to the extreme. The focus on pitch in traditional music emphasises the quantitative aspects of sound, with the listener able to mentally calculate the distances between notes of the scale and between the octaves. In contrast, soundscape compositions may contain a variety of pitches, but the listener's mental focus is usually on the source and quality of the sound rather than on pitch. However, one very important quantitative aspect of soundscape listening is the volume of a sound. The practice of acoustic ecology includes the work of environmental activists who measure the decibel levels of soundscapes in order to promote noise reduction. Even in these cases the quality of the sound must be taken into account. For example, the sounds of laughing children may reach the same decibel level as the sounds of traffic, but the former is usually considered more acceptable in a healthy urban sound environment than the latter.

The quantitative versus the qualitative modes of listening are further informed by the ways in which music and soundscape compositions are notated or otherwise recorded. Of course, in the case of traditional music, there is a formal structure of notation, while soundscape composition usually depends on specific field recordings. In addition, although soundscape compositions are usually fixed on some recording medium, there is a general understanding that a soundscape itself is so complex that it cannot be notated and experienced exactly the same way twice. It could be argued that a musical performance is never exactly the same due to the physical nature of performer, instrument, and setting. Although variation must be present, the exact nature of musical notation reinforces a listener's belief that identical performances are possible. The expectation of identical performances is reinforced by the existence of improvised

music, which intentionally challenges the repeatability of a score in favour of an authentic, unique experience. In this way, listening to improvised music could be compared with listening to a soundscape in the field, and indeed, this analogy is often made by soundwalk leaders who encourage participants to move their bodies in such a way to ‘compose’ the sound (Polli et al. 2010). Listeners use their bodies in an improvisatory way in concert with the randomness of the terrain and the sound environment.

Those composing and analysing soundscapes have come to depend on representations of sound waves in computerized sound editing and mixing applications, for example, Bernie Krause’s ‘niche hypothesis’ (1998), according to which nature’s audio spectrum is finely divided between species in any given habitat, might not have been possible without visual representations of the sound spectrum. The ability to view and manipulate the shape of the sound wave itself has spawned the field of instrument modelling, where computer music programmers virtually create the exact sounds that would come from specific instrument shapes, materials, and performance situations. This fascination with controlling the timbre is an area where, as Truax has observed, computer music and soundscape composition have collided (Truax 2010). However, computer instrument modelling, and even computer music in general, remain outside what is considered to be traditional music by the general public.

Finally, how the sound of traditional music versus soundscape is most often received and interpreted is crucial to understanding the differences between the two listening attitudes. Primarily, traditional music is listened to intentionally, that is, consciously in the foreground. Alternatively, some kind of soundscape is always present and therefore by necessity must be attended to unconsciously, in the background of listening. Practices like soundwalking purposely bring listening to the soundscape out of the unconscious realm to the foreground, but even the most dedicated soundwalking devotee cannot continuously operate in this mode. Music can also function in the background by design, as ‘furniture music’ (Satie 1997), or as ambient music (Eno 1978), however, except in these less-common cases, music is traditionally composed with the intention of being in the foreground.

‘Music’ as a general term is a Eurocentric idea not present in every culture prior to the nineteenth century. For example, there was no word for ‘music’ in the Japanese language before western influence. Instead, historical Japanese used words for specific functions of music, for example, for the Noh theatre or in the court. Yet listening to the soundscape has been a tradition in Japan for much longer than the past thirty years in the West. For example, for thousands of

years in the autumn Japanese people have travelled to specific places for the purpose of ‘listening to the leaves fall’ (Torigoe 2010). Other non-Eurocentric forms of music such as that in India or Mali will be performed differently depending on the weather or time of day. This directly connects the listener with the environment.

Although some Eurocentric traditional music is composed with the intention of connecting the listener to the natural world, this kind of composition is rare. Compositions designed to inspire a feeling of power and control over nature are much more common, as can be seen with the popular music of pageantry and nationalism. The organizing power of musical notation naturally conforms to the function of organizing the chaos of nature. Except in the most experimental of musical compositions, sounds from the natural world are commonly experienced as a negative intrusion, or ‘noise’, in a composition or recording. In contrast, listening to a soundscape is an activity designed specifically to connect human ears with the environment. By immersing him- or herself in the immediate soundscape, a local awareness is developed that builds empathy for and communion with the inhabitants of the sounding sphere, both human and nonhuman. Therefore, the meaning of traditional music leans towards the celebration of human shaping and manipulation of the environment through sound, while if it would be possible to assign meaning to listening to a soundscape, it would be closer to celebrating human connection and subordination to the complexity of the environment. In this way, listening to a soundscape or soundscape composition can be an alternative pathway to environmental knowing.

The listening attitudes reinforced when experiencing traditional music versus soundscape can be divided into the following areas: how the sound is presented, notated and recorded, and how it is received and interpreted. The immersive nature of the soundscape reinforces the feeling of being inside of a vast soundscape, experiencing only one part of a larger whole, while traditional Eurocentric music is usually presented facing the listener from a single direction. Traditional musical notation not only distils sound to a series of quantifiable measurements, it also invokes the possibility that a score could be repeated. In contrast, a soundscape can function more like a unique, improvised experience made of complex sound qualities. Finally, the mode of listening to the soundscape in the background as opposed to the foreground afforded by traditional music reinforces the idea of the constant presence of the soundscape, for example, when one experiences a soundwalk, it is as if one was simply ‘dropping in’ to an ongoing composition. The idea that a soundscape is present before and after a listener experiences it implies a continuity of the natural world existing before and after human life. Each of these

listening attitudes contributes to the construction of the meaning of the soundscape that is one of environmental empathy and communion with nature. But how can subjectivity in soundscape listening and its levels of subjectivity be examined in relation to the audification and sonification of environmental data?

Geosonification, Audification, and Soundscape Composition

Audification, the process of taking a vibrational signal outside the range of normal human hearing and shifting it into the audible range, is closely related to soundscape or field recording. For example, they both involve the technological mediation of signals in an environment. However, unlike field recording, signals that must be audified are not consciously perceived by the body without supplemental technology, but like soundwalking and other soundscape hearing, listening to an audification of an environment can provide an opportunity to re-establish an ecological link with the source of information. For example, the audification of electromagnetic activity can be described as a kind of environmental soundscape. In such cases, audification can provide an alternative pathway for understanding a specific environment.

International sound artist Christina Kubisch has used the soundwalking process combined with real-time audification to explore the inaudible electromagnetic spectrum. In 2003 she began a series of 'Electrical Walk' installations in which participants wore custom-made wireless headphones to hear aboveground and underground electromagnetic fields. These fields were amplified and made audible as the listeners walked along a city street. Kubisch found that although the palette of electromagnetic material varies from site to site, the vibrations themselves are ubiquitous, present even where one might not expect them. As she explains: "Light systems, wireless communication systems, radar systems, anti-theft security devices, surveillance cameras, cell phones, computers, streetcar cables, antennae, navigation systems, automated teller machines, wireless internet, neon advertising, public transportation networks, etc. create electrical fields that are as if hidden under cloaks of invisibility, but of incredible presence" (Kubisch 2009). Kubisch's Electrical Walk series allowed participants to listen to this world with new ears and emphasised the electromagnetic spectrum that is a part of any environment. The electrical fields that Kubisch made audible were not presented as 'natural' sounds, but rather as man-made sounds, and the inaudibility of these vibrations cloaked them in a kind of subterfuge.

Although revealing inaudible-yet-present signals seems like a very different process from that of a soundwalk in which participants listen to sounds that are present and obvious in an

environment, in practice they are very similar. In many of the conventional soundwalks the author herself has led and observed, participants have often expressed their surprise about the sounds they have been able to hear. Despite the fact that sounds are clearly present, without the context of the soundwalk to focus the ears of the participants on the sounds, these sounds often go unnoticed even though they are unconsciously heard. Westerkamp herself emphasises the importance of amplifying this range of barely audible sounds in her soundscape compositions. When custom systems detect and record sounds outside the normal range of hearing, listeners are allowed to hear new sound universes that were previously undetectable. Technologically mediated listening could be perceived as more objective, with technology serving as a tool to remove the subjectivity of the human observer. Mediation of an environment, enabling a closer connection to that environment, is a form of ecomedia. However, the addition of a technological interface is in fact a highly subjective practice in which the choice and development of the technology contributes to the perspective of the work.

Data sonification, specifically the process of translating numerical data into sound, demands the interpretation and simplification of the observed phenomenon. *Geosonification*, a term created by the author to describe the sonification of data from the natural world inspired by the soundscape, also suffers from this translation process. Unlike audification, where a vibrational signal is monitored and recorded directly with minimal human intervention, numerical data used in geosonification is itself a simplification. This is because it is impossible to collect discrete data on every process that happens in a continuous environment. Yet the human and instrumental intervention inherent in geosonification can be seen as an extension of human and instrument intervention in soundwalks and audifications, since human presence is highly apparent in soundwalk recordings and audification also requires the intervention of an instrument to transpose the signal. All three—soundscape recording, audification, and geosonification—require practitioners to make high-level choices about when, where, and what to record, from microphone placement to post processing. For the purposes of comparison and analysis, the author created the following chart to propose some of the structural aspects of soundscape recording, audification of the environment, and geosonification.

Table 2.2: Technology and Subjectivity in Soundscape, Audification and Geosonification

Soundscape Composition	Audification	Geosonification
Technological		
Some technological mediation	More technological mediation	Most technological mediation
Re-organizing sounds	Shifting and reshaping	Reshaping numerical data
Subjective		
Continuous/analogue data	Continuous/analogue data	Discrete/numerical data
Re-arrangement/Transposition	Transposition	Mapping
Human scale	Can be human scale or not	Can be human scale or not

Audification and geosonification both involve reshaping information. This process of translating data into an unfamiliar form for an aesthetic purpose can be compared to what media scholar Herbert Brün called ‘anticommunication’. At a seminal meeting at UNESCO in 1970, Brün presented ‘anticommunication’ as a new language development and the offspring of communication, an attempt to say something through new modes and an active way of redefining or recreating our language (Brün 2004). Within the conceptual universe of Joseph Beuys, media art could not only reshape and reorder information but also could reshape the communication and distribution of media. Beuys called for a reshaping of the unbalanced worldview in the West by constructing his 1974 *Energy Plan for Western Man*, which radically changed the definition (and distribution) of art with the label of “social sculpture” (Beuys & Tisdall 1979). Although the radical nature of the process of audification and data sonification may seem to transport the listener out of his or her environment, this process of reshaping and reordering information may actually bring him or her closer to the natural world. By closely examining soundscape, audification, and sonification in relation to the Acoustic Ecology movement, it may be possible to re-establish a link between data, communication, and the environment and to show that geosonification could possibly increase environmental awareness.

To establish this link the comparison of the sonification of data describing various environments to soundscape recording and composition might be necessary, and the author proposes to limit this comparison to only sonifications that have been inspired by the soundscape, or geosonifications. Both soundscape and data sonification use sound to understand

the environment, but many data sonifications are modelled on music and are therefore not relevant to this argument. Thus, in contrast to the author's process of geosonification, which involves taking numerical data and translating it to sound using computer-based systems, the process of field recording can be quite direct, most simply holding a microphone to a source and recording its sound. In comparison, when creating a geosonification the author has had to translate the data to sound and undergo a series of preliminary steps, from creating a detailed model of the environment in collaboration with scientists to designing a system for mapping this numerical data to sounds.

As previously suggested, both phonographers and creators of audifications and geosonifications have to address subjectivity. Field recording is conducted on a human scale, with a certain amount of selection criteria on the part of the phonographer, for example, what kind of microphone to use, where to direct it, and such. Although some phonographers attempt to take a neutral stance as if to suggest that an objective field recording is possible, Chris DeLaurenti, a phonographer who primarily works in the urban sound environment, has made the subjectivity of his recordings very evident (DeLaurenti 2006).

The author's own geosonification work has attempted to highlight subjectivity. Selecting the scientists with whom to collaborate, the variables, geographical locations, and time scale, and then ultimately by choosing how to map the numerical variables onto the parameters of sound can create an extremely subjective sonification of any phenomena. This describes the way collaborators struggle with how the data should be structured, output, and translated, and even when to start and end the data modelling. For example, in 1999 the author began working on a series of storm sonifications that required a series of decisions to determine when the selected storms started and ended. Even the idea that a storm could be considered to be an 'object' to be sonified was examined. It was determined that the very idea of a storm is a human construction unrelated to the phenomena it describes.³ Finally, the choice of beginning and ending the composition was somewhat arbitrarily determined by extracting twenty-four hours of the greatest intensity of the storm. Another choice made was the duration of the sonifications; in this case the twenty-four hours of data modelled were compacted into a series of approximately four-minute compositions. All these decisions contributed to a very subjective interpretation, even before any

³ Hurricanes, for example, are anthropomorphized. They are even given human names; for a while hurricanes were given only female names but currently the names alternate between male and female.

sound was generated. Therefore, subjectivity can be highly present in both phonography and in geosonification.

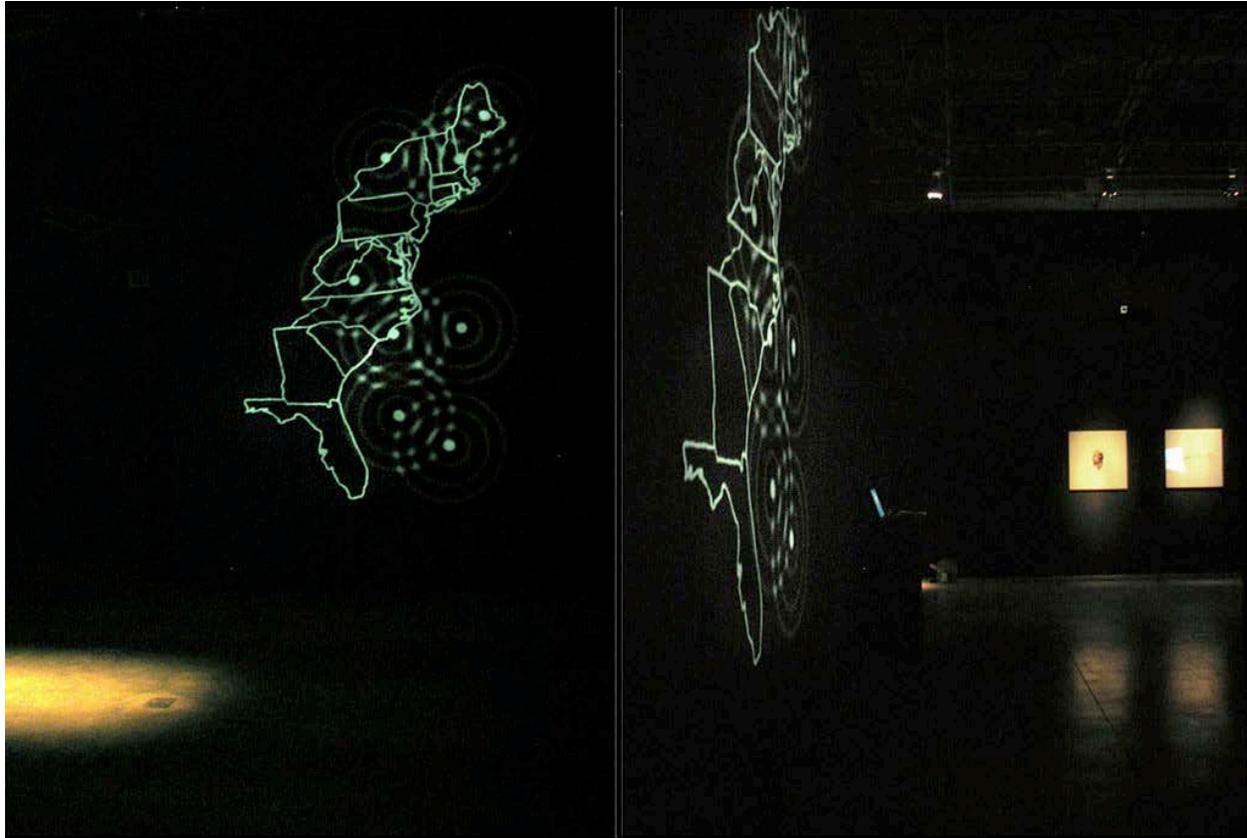


Figure 9. ATMOSPHERICS/WEATHER WORKS, Andrea Polli, Irvine, California (2007)

However, a listener's experience of this subjectivity as analogous to his or her own experience presents a challenge in geosonification. One important difference between the author's geosonification work and phonography is the issue of scale. Phonographers by design work on a human scale, using the ears as a starting point and combining listening with human locomotion. Even Kubisch's audification works using sounds outside of the human hearing range involved physical human presence in the field to capture the information. Sonification is by necessity a different process. The data might involve physical measurements (model data are usually coupled with observed data from the field), but the scale of the data set ultimately sonified may be far outside of possible human experience. For example, vast geographical distances might have to shrink to the size of a room or long time periods might need to be compressed into a few minutes. Thus, combining sonifications with soundwalking and soundscape compositions or using a soundscape as a model for the design of a sonification may

serve to humanize the results by bringing the data into the human scale and thereby may allow audiences to relate to the sonification in an embodied way. This might serve to increase environmental knowing by allowing listeners to experience data through their bodies.

Christina Kubisch shifted the pitch of vibrational signals, and her audification process revealed existing features with an objectivity similar to that provided by soundwalking. While both soundwalking and creating audifications can involve decisions about what to focus on, the underlying process is one of revealing something that is already present in an environment. However, the author claims that soundscape-inspired sonification of environmental data, or geosonification, can be much more subjective than field recording or audification. From her previous experience creating multi-channel geosonifications, the author can confirm that the selection process for the creation of a geosonification is full of technical precision, from choosing the phenomena to sonify, to the kind and format of numerical data to be output, to all the possible parameters of sound itself, from rate of play to pitch, timbre, rhythm, and duration.⁴ However, the geosonification process offers a potential expansion of the shifts in scale inherent in audification. While audification can allow the amplification of very small signals, the acceleration of very slow signals, and the deceleration of very fast signals, sonification can allow the composer far greater control of speed and scale. Geosonification allows the selection of very specific parameters and the examination of these parameters under very controlled conditions.

⁴ Ten years before the author created her first geosonification with weather and climate data, she created systems for the generation of algorithmic improvisational music. She experimented with sound compositions using the Lorenz attractor, a simplified model of the movement of air particles in a vacuum and very early weather model. Her first geosonification collaboration with a scientist was the 2001 *Atmospherics/Weather Works* project, translating detailed data from two historic storms that passed through the centre of New York City. In 2004 the author began to pursue a climate sonification project with Dr Cynthia Rosenzweig, the leader of the climate research group of NASA Goddard Institute. The resulting climate sonification project, called *Heat and the Heartbeat of the City* had a very different sonic character than the previous storm sonifications due to the data sonified, since an extreme weather event is highly chaotic and dramatic, and climate undergoes a constant repetitive cycle. The ambient sound resulting from the climate sonification inspired the author's later work in ambient real-time sonification. The process of creating these two atmospheric data sonification projects, *Atmospherics/Weather Works* and *Heat and the Heartbeat of the City*, also led the author to consider the soundscape as a model for the creation of sonifications. Inspired by the phenomenon of wind harmonics, the author developed a reductive technique for creating sonifications that resulted in complex individual sound characters more related to soundscape composition than to music. The addition of a multichannel environment in which the sounds coming from each speaker represented data at a particular geographic location furthered this soundscape analogy.

Geosonification research, therefore, can focus on precise aspects of the human perception of sound for the most effective and efficient delivery of information. One focus of this research should incorporate soundscape studies, especially in the area of environmental data analysis, because the soundscape is an essential part of how humans understand an environment. The soundscape model of sonification also can offer listeners an immersive and spatial experience of environmental data that can allude to an ongoing phenomenon and can inspire empathy in the listener by placing him or her inside the environment. But what are the challenges when examining the soundscape of a large city, filled with various subjective experiences, both positive and negative?

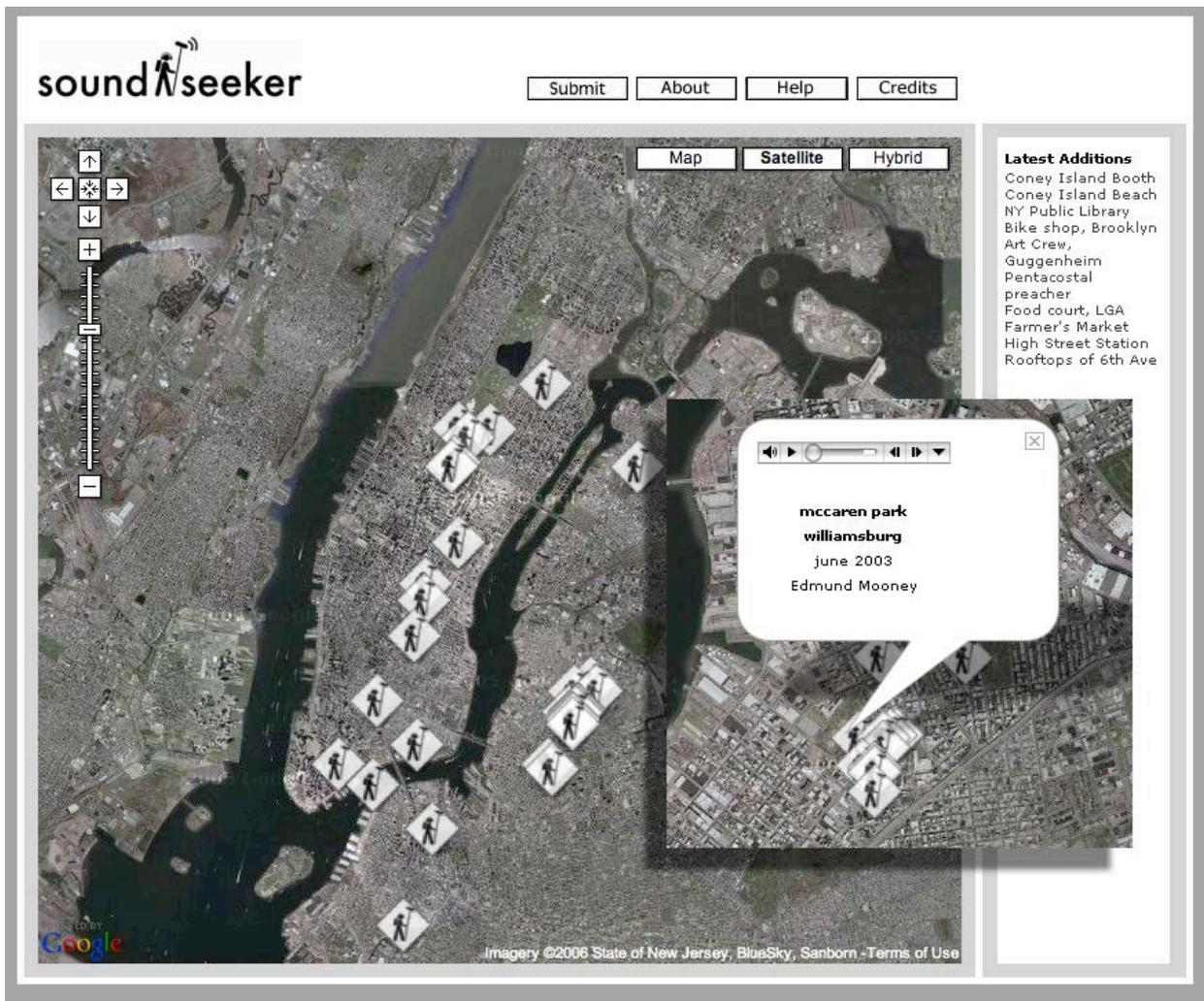


Figure 10. Screenshot SOUNDSEEKER.ORG, Andrea Polli, New York (2004-Present)

The New York Society for Acoustic Ecology and the NYSoundmap

As a major metropolitan centre with over 9 million inhabitants, New York City is subject to many of the pressures that affect similar large cities around the world. One of these pressures is noise. In New York City, by far the majority of complaints registered to the city pertain to noise, with over 3 million calls per year (Bronzaft 2006). Noise researcher and head of the New York City mayor's commission on noise, Arline Bronzaft has conducted a series of research studies related to the effects of noise on New Yorkers and has found that urban planning projects in the city rarely take sound design into consideration. In the plans for the Ground Zero memorial, for example, a 'contemplative space' was originally positioned near a busy highway with no noise ablation (Bronzaft 2006). Another noise specialist, architect and phonographer Geoff Dugan (2004), has observed that the qualifying architectural licensing exam in New York City, a comprehensive exam lasting several days, contains only three questions related to the soundscape and architectural sound design. How can public awareness of the city's soundscape be improved? As evidenced by the city's complaint log, sound is important to quality of life, despite being ignored by city planners and architects.

Instead of organizing in groups to combat increasing noise levels, city dwellers are more likely to spend personal money to buy an iPod to try to cut off their sound experience. While this action may provide a solution, it may lead to a disconnection between individuals and their environment. It supports a value system where silence is a commodity to be purchased. Perhaps those without the means to buy silence would then be subjected to a constant barrage of advertising, machine, traffic, and construction noise. However, in New York City the most coveted living spaces are in the most central and congested areas, therefore this city offers an interesting contrast to other American cities. For example, in Los Angeles, those with the financial means can choose to live in relatively isolated locations with very low noise levels, but wealthy New York residents choose central locations for their convenience. Some of the most expensive city real estate is located in the neighbourhoods with the most polluted air, water, and soundscape. This economic geography has the potential to influence widespread environmental improvements since wealthier residents can wield considerable political power with their complaints about environmental pollution.



Figure 11. SOUNDSEEKER.ORG, Andrea Polli, The Kitchen, New York (2010)

In order to explore the potential for increasing awareness of the New York City soundscape, the author created a chapter of the American Society for Acoustic Ecology (ASAE) called The New York Society for Acoustic Ecology (NYSAE) with soundscape artist Michelle Nagai. The original members of NYSAE came from a wide range of backgrounds, with a common interest in field recording, soundscape composition, soundscape preservation, and the problem of noise in the city. Immediately after forming, the group began developing public projects like the NYSoundmap (www.nysoundmap.org). This project was designed as a container for questions, research, and projects related to the soundscape. Like countermapping, the project sought to examine the concept of a new kind of map, in this case one that privileges the ear over the eye.

Visual soundmaps had already been used by municipal governments working on noise abatement, for example, noise pollution maps of London and the Noisetube project. These used colour to indicate decibel levels at various times of day (London Sound Survey, Noisetube 2010). NYSAE held an ongoing series of public soundwalks, and archives of soundwalk

recordings and participant reactions were placed online. Participant reactions were solicited in a formal way through the establishment of a yearly town-hall meeting-style event designed by the author called Citizen Sound. Citizen Sound encouraged participants to imagine the future of the New York soundscape after participating in a soundwalk. Soundwalk recordings also became a part of the collaborative documentary project Sound Seeker, one of the first sound-oriented Google map interfaces (www.soundseeker.org). Public soundwalk recordings were placed on the map and submissions were invited from the general public through an online form. Sound Seeker is still growing and has collected recordings from all over the city of New York and has influenced the development of similar projects in several cities worldwide.

NYSAE found that there was also a need to present submitted works that couldn't be placed on a city map, either because they were recorded in another location or consisted of combined recordings from various locations. To address this problem, NYSAE created Giant Ear))), a monthly Web radio program. The combination of these four elements—soundwalks, town-hall meetings, online sound map, and Web radio program—has proven to sustain the NYSoundmap project, now in its sixth year of operation, with hundreds of Sound Seeker recordings and over thirty original Giant Ear))) programs.

During the course of her PhD research, the author designed and hosted three of the Citizen Sound town-hall meeting events, two in New York City for the Ear to the Earth Festivals 2007 and 2008 and one in Chicago for the 2010 ASAE conference retreat. The first meeting was held immediately after three public soundwalks around Greenwich Village, New York, and had approximately forty attendees, mostly members of the general public. The second was held prior to a phonography concert in the same Greenwich Village area and had approximately thirty attendees. The third was held in downtown Chicago as the opening event of a three-day symposium and had approximately forty attendees. While the two New York Citizen Sound events seemed to energize the participants to take action, the event lacked any structured follow-up beyond presenting ideas and recordings in the context of the NYSoundmap project. Although participants did connect with one another and pursue projects on their own, the momentum generated during the event was not sustained over time. Art historian and scholar Sophie Hope has looked critically at how participatory art practice does or does not encourage the politicization and activation of the participant. She suggested that social practices in art “could even lead to further de-politicization if conceived as a mirage of social inclusion rather than the real thing” (Hope 2009). The ideal situation, in Hope's view, was that consumers would be

turned into producers, and in the case of the soundwalk and online soundmap participants, this transformation from consumer to producer did occur. However, in the case of Citizen Sound, the danger of the creation of a mirage of political action rather than actual action or transformation has been evident. This may have been due to the fact that the Citizen Sound forums have had the structure of traditional town-hall-style meetings rather than a more innovative format.

In an attempt to inspire different expectations from the participants, the Chicago Citizen Sound was designed not as a town-hall meeting but as a playful social mixer, with activities like ‘soundscape speed dating’. This format, and the placing of the event at the beginning of a weekend symposium, helped to build momentum that carried over three days of events. However, the Chicago mixer was combined with two keynote presentations and a soundscape concert on the same evening, and although these complementary events provided constant entertainment to the audience, it may have forced participants to change focus too quickly from active collaboration to passive listening. An important part of the author’s research has been expanding these structures to cities beyond New York. For example, in addition to hosting the three Citizen Sound events, the author has hosted a series of public soundwalks during the course of her doctoral research: in New York, Holland, California, and Antarctica. After each public forum and soundwalk, participants have been invited to submit their recordings to the Sound Seeker map (if New York City–based) or to Giant Ear))), and these recordings have been featured several times in both venues.

The four main collaborative processes used in the creation of the NYSoundmap can be analysed in terms of social sculpture and networked media. Each container—the public soundwalks, the town-hall meetings or social mixers Citizen Sound, the online interactive collaborative soundmap Sound Seeker, and the Web radio program Giant Ear)))—was designed to take shape out of the intersection of projects, participants, and the city. The public soundwalks may have provided a novel way to engage participants with their surroundings. Soundwalk experiences could be discussed and recorded in town-hall meetings, and recordings from the soundwalks could be selected and placed on the online collaborative map or extended to compositions and distributed to listeners worldwide via Web radio. Without taking an overt political stance, these activities became a centre of activist thought and action, addressing members’ concerns about large-scale city initiatives like the 9/11 memorial or the Brooklyn Atlantic Yard development. The four containers of the NYSoundmap are ongoing, and although the author no longer resides in New York City, she continues to organize soundwalks and other

related projects there. The alternative pathways to environmental understanding established by the NYSoundmap project created a channel for collaboration and social action. But can these processes combined with geosonification lead to greater art and science collaboration and social action in response to climate change?

Ambient Geosonification

Although the global soundscape holds an endless amount of information and provides clues to ecological and social processes, with the exception of Krause's work and some scattered initiatives in analysing the urban sound environment for noise control, there has been a greater scientific interest in research related to the potentials of sonification. For example, the International Community for Auditory Display (www.icad.org) holds a yearly conference to present contemporary scientific and aesthetic work in sonification and publishes papers from the conference on its Web site. In the 1990s the group was commissioned to write an important position paper on the role of sonification in scientific research for the U.S. National Science Foundation (Kramer et al. 1997). Perhaps this scientific interest is tied to the necessary simplification evident in the sonification process. In other words, scientific data are necessarily simplified in order to focus on a specific feature or series of features in the environment. The choices made in creating a sonification of this data can also be considered control variables, allowing every parameter of a sonification to be strictly designed. In contrast, soundscapes are filled with complexity, and it is not possible to tightly control each variable. Therefore, sonifications are potentially easier to use as a scientific tool. For example, there are many ways in which the practical implementation of real-time data sonification has been studied to enhance engineering efficiency and productivity (Kramer et al. 1997). Scientific studies of sonification have examined what kind of information can be more effectively gathered through the ears versus the eyes or other senses (Kramer et al. 1997). There is promise in the area of real-time ambient monitoring using sonification because listening can be done by a human observer focused on other, visual tasks. The ears collect information from all directions at once constantly, and repetitive sound can be tuned out. However, a significant change in a repetitive sound signal can alert a human listener very quickly. Spatial location is also interpreted well by the human hearing system, specifically on the horizontal plane (Kramer et al. 1997). Pattern recognition is another area in which sonification has been investigated, since patterns in music are easily recognized, even when transposed into a different key. Human sound pattern memory is also

very developed, as evidenced by the human ability to remember pop songs for many decades. Would a long-term adoption of data sonification allow listeners to use long-term sound memory to make connections between sound patterns heard twenty years or more apart, gaining new knowledge in the process? Human sound memories could be filled with knowledge of the natural world in the form of sonifications.

In the media arts, real-time interactivity is often valued over the quality and complexity of the information. For example, prior to beginning the sonification process for the author's Atmospherics/Weather Works project, the author's scientist collaborator, Dr Glenn Van Knowe, spent weeks tying up several high-end computers at his lab modelling the meteorological data for the project. The art curators of the project were very interested in the idea of real-time interactivity, and for this reason the author and her scientist collaborator had to explain that the weather models they were using were too large to be generated in real time. The complexity of the model seemed to be less interesting to the curators than the concept of presenting everything in real time, although ultimately the curators were very pleased with the final result. This interest in real-time interactivity by the art gallery could be interpreted as a lack of understanding of complex weather and climate models, but this focus could also be viewed as an interest in 'art as experience' as highlighted in the psychogeography movement and the related practice of soundwalking (DeBord 1958). Could a real-time sonification of environmental data inspired by the soundscape be an appropriate analogue to the soundwalking process?

Interest in both the scientific and artistic uses of real-time interactivity led the author to create a real-time, ambient geosonification project, called *N.*, with the help of artist Joe Gilmore and meteorologist Dr Patrick Market of the University of Missouri (Polli 2004b). For the project the author created a system that downloaded data from a weather model centred on the North Pole and live webcam images in order to present a 4-channel sonification and visualization of the weather at the pole (Polli 2004a). This real-time ambient sonification was presented in a gallery and allowed listeners access to only a small chunk of data that are continuous over time. Listeners have only had access to this work during gallery hours for the duration of an exhibition. A future goal might be to design a way for listeners to experience an ambient geosonification over an extremely long period of time, for example, decades. Over many years, listeners might gain insight into the nature of the phenomenon presented.

Although computing challenges exist that prevent the presentation of complex atmospheric model data in real time, there may be benefits to further exploration of real-time,

ambient geosonification. Such projects can highlight the continuous and immersive aspects of an environment by creating listening attitudes similar to those employed while listening to a soundscape. Unconscious, ambient geosonifications that listeners live with over long periods of time might provide new insights into patterns and structures of data.

Conclusion

This chapter has attempted to compare soundwalking and phonography to audification and geosonification in the realms of listening attitudes, subjectivity, social action, and art/science collaboration. The practices of acoustic ecology generally, and soundwalking and phonography specifically, provide alternative pathways for understanding the natural and man-made environment. Soundwalking by its nature is a subjective experience, and soundwalking compositions often emphasise this subjectivity. The creation of sonifications of environmental data extracted from models or field research is also a subjective process, and modelling the design of sonifications on the real world soundscape can provide opportunities for addressing this subjectivity. Soundwalking and field recording can be activist practices that address pollution and preservation through the organization of groups of people undertaking subversive activities, through the uncovering of unheard sounds and vibrational signals, and through collective documentary action, as demonstrated in the author's NYSoundmap project.

Sonifications modelled on the soundscape also have the potential to convey environmental information more effectively than those modelled on music. Although music is present in the contemporary soundscape, the soundscape of the world is primarily constructed of nonmusical sounds. Sonification offers an opportunity for scientists and the public to experience data in new ways. In the author's experience, atmospheric scientists have been receptive to the sonification of data. Atmospheric scientists working today have seen a radical transformation of the field in their lifetimes due to visualization, so much so that it would be almost impossible for an atmospheric scientist to work successfully without visualization (Wang 2006). Scientific sonification offers many benefits and may become just as important to atmospheric research in the future. A sustainable process of recording and analysing soundscape over time has been demonstrated to be possible by the over-thirty-year history of the World Soundscape Project and the subsequent World Forum for Acoustic Ecology. Therefore, sonification modelled on the soundscape may also have the potential to augment the natural and man-made soundscape if experienced over long time scales.

The development of geosonification works interpreting environmental data and modelled after the natural and man-made soundscape may have the potential to open alternative pathways to environmental understanding. Any soundscape holds a vast amount of information that listeners engage with constantly. A more conscious engagement with the soundscape through soundwalking, field recording and phonography, and soundscape composition, may have a dramatic effect on environmental awareness and may promote direct action and interdisciplinary research. Audification can bring inaudible sounds to the foreground and change a listener's experience and understanding of a place. Geosonifications, similarly, have the potential to engage listeners with information about an environment. Such information could exist on very long time scales or very large geographical scales, requiring sonification of the data to fit into normal listening patterns. When modelled after the soundscape, geosonification may open alternative pathways to connecting art and science and offer opportunities to enhance a listener's knowledge of an environment.

Part II. Body of Evidence—Ecomedia as a Catalyst for Environmental Knowing

Chapter 3. Witnessing Space [Focus: Taipei]

Introduction

According to Nigel Thrift's nonrepresentational theory (2008), the most salient characteristics of embodied existence are sensation, affect, and movement. The author will discuss and compare nonrepresentational with other theories of cognitive science and cultural geography in order to examine the role of affect in environmental understanding. The claim is that immersive experiences of soundscapes or geosonifications can constitute a kind of "witnessing space" (Dewsbury 2003).

First, the author will provide a background to contemporary air quality science that will include excerpts from interviews with two aeronomists in the USA, former National Center for Atmospheric Research aeronomist Paulette Middleton and Desert Research Center aeronomist David DuBois. Previous projects by the author using real-time and modelled weather information (*Atmospherics/Weather Works* and *N.*) will then be compared with these opinions and immersive experiences. *Airlight*, a series of real-time, ambient, animated geosonifications of air quality data from various government and private sources will be presented as a case study using these findings. The first manifestation of that project, *Airlight Taipei*, will be the primary reference, and theories of affect will be examined in this context. The following questions will be explored: Are there correlations between the idea of continual emergence as described in Thrift's nonrepresentational theory and the ambient sonic experience of real-time, real-world data? Can geosonification be identified as an affective medium? Has widespread public access to real-time, real-world environmental data changed the public's experience of "being in the world" and therefore altered the immersive affect?

Poor air quality has had a dramatic impact on human lives. The World Health Organization reports that 3 million people worldwide now die each year from the effects of air pollution (WHO 2002), and research suggests that each year in Europe, air pollution is responsible for 310,000 premature deaths (House of Commons 2010). With the institution of global trading in sulphates and other air pollutants, breathable air has become a commodity. Air is not only a part of the system that sustains life but has also become part of the international economy. Therefore, both this air economy and the lives of all breathing beings on Earth depend

on the extent, accuracy, and interpretation of air quality monitoring networks. Despite the importance of the problem, air quality sensor networks have only been in use on an international level for just over twenty years. These networks are usually funded by national governments. For example, in the United States, air monitoring networks are supported by the Environmental Protection Agency (EPA), the Forest Service, the Fish and Wildlife Service, the Park Service, and the Inter-Agency Monitoring for Protected and Visual Environments (IMPROVE). As an example to illustrate the scope of these networks, the IMPROVE system oversees approximately two hundred sites in the United States. In addition to these ground-based sensor networks, there are a number of remote-sensing satellites in operation that examine levels of ozone, sulphates, nitrogen oxide, and other air pollutants. Compared to the thirty-year scientific standard for measuring atmospheric trends, this twenty-year air monitoring record can now only begin to provide somewhat reliable trend analysis. In addition, worldwide small (2.5 micron) particulate collection is only just over ten years old, placing scientists at the cusp of interpreting and understanding this large body of international data (DuBois 2009).

This new, wide-ranging collection is beginning to have a cultural impact. It is transforming public understanding of the air because a vast majority of this monitoring data, both from ground-based sensors and remote satellites, is available to the public online, and large, ad hoc international networks of amateurs have emerged that look at and analyse this data (DuBois 2009). Theorist Nigel Thrift suggests that this expansion of public access to earth-sensing data will have a transformative effect on human spatial awareness and therefore will shift what it means to be human. He defines a human's 'qualcalculative' sense as a kind of intuitive interaction with information because it cumulates from continuous access to a constantly transforming data space, or 'ambient information' (Thrift 2008). Counter to Thrift's theoretical ideas about human transformation due to exposure to ubiquitous data space, air is invisible and moves in complex ways, and it is challenging for nonscientists to understand and interpret air quality data (DuBois 2009). In the realm of public policy, poor air quality is often described through sensations, like the negative effects of pollution on visibility. In Denver, Colorado, scientists, including Paulette Middleton, and environmental activists have mobilized public concern about the visibility of distant mountain ranges to transform the way air quality science could be conducted. The interdisciplinary work performed by Middleton and her associates was actually able to change public consciousness by connecting the aesthetic aspects of visibility with the health problems caused by air pollution. The aesthetic experience of an environment

was used to increase public scientific environmental knowledge and affect change (Middleton 2008).

Therefore, the author will examine Thrift's theories of qualcalculation in the context of air quality data monitoring and interpretation, analyse Middleton's assessment of the Denver study, and attempt to demonstrate that ecomedia artworks that visualize and sonify invisible air pollution can also have an impact on how people understand local and global air quality. To begin, how were aesthetic experiences of environmental beauty in Denver, Colorado, integrated into scientific aeronomy research, and did an interdisciplinary effort to create policy changes improve air quality in the region?

Seeing Is Believing

Poor long-range visibility is caused by what scientists call 'regional haze'. Regional haze is caused by aerosols, which are chemicals or particulate matter (PM) combined with tiny liquid droplets suspended in a gas, for example, smoke, dust, or sulphate combined with water. The most commonly measured particulates are based on size, PM 10, or particles of approximately 10 microns in size, or the smaller 2.5-micron size (PM 2.5) (United States National Institute for Occupational Safety and Health 2010). These fine particulates scatter incoming sunlight to create *airlight*, a visible white smog caused by the illumination of fine dust particles in the air. The term *airlight* is often used by meteorologists in Los Angeles, where fumes from car exhaust create what author Lawrence Weschler describes as 'a billion tiny suns' (Weschler 2004). On the American East Coast, high levels of humidity make poor long-range visibility the norm, so, for example, a good day in New Jersey might have a visibility of 15 to 25 kilometres. In contrast, in the American west, where dry conditions are common, visibility can regularly be as much as 200 kilometres (DuBois 2009). In a region dominated by scenic mountain vistas and some of the largest and most beautiful national parks in the world, a distorted or blocked view can be easily understood by the public as an air quality problem. Scientist and activist Paulette Middleton describes this phenomenon in an interview with the author: "People love to see the mountains here in Denver just like they love to see beautiful vistas in national parks and wilderness areas all over the country. When there's a lot of air pollution in the air sometimes you can't even see the vistas, or they're discoloured, or you get borders or all kinds of disturbances. . . . And of course the fact that you have that in the air is a good indication that the air is not good for you to be breathing, either" (Middleton 2008).

In scenic areas poor visibility can be a catalyst to promote public interest in air quality issues and to boost public action to reduce air pollution. In Denver, visibility problems have actually changed the way aeronomy has been conducted, and because the issue of visibility became such a major factor in air quality legislation, scientists in the Denver study focused on correlating physical and chemical properties of the air with changes in visibility. As Middleton explained: “The idea [of the scientific research] was to get a very clear understanding of where people were judging the air quality to be really bad, in other words, [where] the vistas didn’t look very good . . . and how that related to the standard things you can measure in the air, the physical and chemical properties. You’d have an instrument measuring things like light scattering and light absorption, so that way you could have those instruments out there all the time and when they hit certain levels you could say ‘that’s a visual air quality violation’” (Middleton 2008). Middleton and her colleagues created an extensive program, and the result was that the state of Colorado was one of the first states in the USA to actually set a visibility regulation. Visibility measurements are now standard in U.S. national parks and wilderness areas.

However, in Denver there was more at stake than purely aesthetics. Aesthetic degradation could actually be directly connected to negative economic impacts in the region. Because Colorado straddles the Rocky Mountains, a large part of the state’s economy is tied to tourism, with people from all over the world visiting the state to ski, hike, mountain climb, and enjoy the majestic national parks. When Middleton first began her work, something she and others called a ‘brown cloud’ caused by industrial and automobile pollution had formed over the entire Denver metropolitan area. As she states, this factor was causing economic decline: “There were other studies pointing to the fact that Denver, because of its brown cloud, was suffering economically. Industries did not necessarily want to move into the area” (Middleton 2008). The economic problems provided a governmental incentive to support studies of the brown cloud and to try to develop policies that would reduce its visibility. This change to the research promoted by the city of Denver certainly required a more interdisciplinary approach, so Middleton’s aeronomy group worked closely with scientists from other disciplines, government agencies, and the public. She described how the interdisciplinary approach was employed from the very beginning of the research: “Part of [the science] was not just working together with psychologists who had to set up the [experiments] to measure the impacts, but we actually made a connection and had a long-term relationship with the Colorado Department of Health and the people. They knew what was going on, they were part of the whole process, and then by the time the results started coming out

they were co-authors on papers and they could just take the [results] and start moving through the official policy channels” (Middleton 2008).

Middleton believes that the reduction of air pollution in Colorado was successful in part because it was easy for the public to relate to the idea of bad air in the context of its visibility. In contrast to public understanding of more complex issues like climate change, she said, “air pollution is not a hard thing to grab on to. People see the air and it looks bad, they smell stuff from the air and they know something is bad. That doesn’t seem to be much of a problem, talking about air quality” (Middleton 2008).

It is obvious that an encounter with a beautiful vista from a far distance is a pleasurable experience, provoking a series of positive emotions, and of course people pay large amounts of money to have these views from their home or from a resort. When the bottom of the Grand Canyon is shrouded in smog during a few short days of a family vacation, clearly strong negative emotions are produced. The emotional power of the landscape in Colorado played a strong role in mobilizing the public around the air quality issue and changed the process of scientific research by promoting a direction that correlated visibility with chemistry. This interdisciplinary approach can create positive policy changes, but questions remain: what is the role of affect in the experience of both physical space and data space, and can affect in data space cause similar shifts in public awareness? In order to investigate the similarities and differences of the affect of physical space versus data space, the author analysed several theoretical perspectives that serve to elucidate the concept of environmental knowing.

Affect and Data Space

Affect from a cognitive science perspective is generally defined in two ways: firstly as mood, in other words, pleasant or unpleasant feelings, and secondly as intensity. For example, in the research of psychologists Gerald Clore and Maya Tamir on the impact of emotions on decision-making, affect is defined as mood. Clore and Tamir argue that moods are evaluative, and that most decisions, whether intuitive or deliberative, involve appraisals of positive or negative feelings. For example, in their research they confirmed that a positive or negative mood affects risk judgements, with subjects experiencing feelings in a particular situation as information about the level of risk in that situation (Clore and Tamir 2002). Although the complexity of mood and emotion was reduced to only positive or negative, this research opens up the possibility that affect can alter judgement and therefore understanding. Conversely, in ‘The Autonomy of

Affect', cultural theorist Brian Massumi defines affect as a level of intensity. He describes intensity as a point of possibility, a disembodied state "autonomous to the degree to which it escapes confinement in the particular body" (Massumi 1995). Geographer Nigel Thrift seems to expand upon Massumi's ideas from the perspective of ubiquitous information technology in his discussion of the concept of qualcalculation. Using the term 'intuition' rather than 'affect', Thrift describes contemporary society as an ordered universe of calculation "in which potentially every thing and every location . . . could become the subject of calculation" (Thrift 2004, p. 590). Like Massumi's description of the 'point of possibility', Thrift defined the intuitive universe as a point of calculation. Thrift describes this universe as a qualcalculative space that shifts what is understood to be 'human' and what is understood as an 'environment' based on the actual feelings experienced while interacting with an artificial environment (for example, a GIS database). However, Thrift combined both intensity and mood in his extensive functional definition of qualcalculation, because for him a 'qualcalculative sense' is analogous to mood and this sense informs decision-making. Thrift calls this level of intuition 'rapid reasoning'. In another article he addresses affect in the data space by referring to the experience as housed in 'suggestible environments', wherein subjects are able to "catch and amplify mood . . . allowing (them) to bathe in an affective ether of signs and thus produce an intensified everyday [experience]" (Thrift 2009, p. 119). Thus in this way physical reality can be augmented by a representation of a data space that can intensify the experience of space and therefore increase its affect on the subject. Such suggestible environments can use media to trigger an emotional response. For example, real space can be augmented with advertising, where images or video can evoke the hopes and desires of consumers.

A major part of Thrift's definition of the qualcalculative sense describes the degree of memory afforded by the data space itself. Thrift further explored this idea by defining how the representation and experience of memory in data space can increase affect. This aspect of the qualcalculative sense has analogies in Clore and Tamir's descriptions of the affective experience of physical space. For example, in Clore and Tamir's analysis of affective judgement, emotions are described as equivalent to memory. In other words, the evaluation of a situation as a positive or negative experience is tied to the emotional intensity of similar situations in the past. Taking this idea into the future, Thrift says that the stability of symbolic memory afforded by computational media has caused a radical change in the consciousness of the general public. He further suggests that the existence of a persistent recording of life promotes a "mania for

remembering forwards', even to the point of placing the subject in the position of a clairvoyant (Thrift 2004, p. 592). This dreaming state of the qualcalculative sense as defined by Thrift can perhaps become clearer in the context of environmental modelling. For example, a vast amount of energy and resources in atmospheric science are currently given to the creation and maintenance of computer-based models. These models are primarily used to understand complex environmental interactions, to re-create situations of the past, and most importantly to help us to 'remember forward' by creating predictions of the future that are as accurate as possible. In fact, one of the main drivers of the increase in computer processing power over the past thirty years has been to allow scientists to build more accurate weather and climate models for military operations.

Thrift speculated that constant access to ambient information could make interaction with environmental modelling systems like those of weather and climate much more intuitive. Rather than accessing an entire dataset or global model, most users access only local data in response to particular parameters. In other words, similar to real-world experience, calculations are accessed from a specific location, point of view, and context (Thrift 2004, p. 593). According to Thrift the predictive sense afforded by a data space is already a 'remembering forward', and applications of prediction are not unique to the computerized study of weather and climate. Before data space, humans have been looking at, listening to, feeling, and smelling the environment with the goal of prediction since the beginning of history.

As will be shown in the upcoming chapter, *Ground Truth*, memory and affect can also play a key role in the prediction of weather conditions, and experienced weather observers in the field can often provide the most accurate predictions. In a majority of cases examined by the author, these weather observers often make risk assessment predictions. If, as Clore and Tamir have attempted to show, memory and emotion are symbiotic, and as they have further suggested, emotion plays a major role in risk assessment, then perhaps emotion and weather prediction can be correlated. Qualities of air, wind, light, and humidity can obviously have emotional effects on people immersed in atmospheric events. The Santa Ana (USA) and Foehn (Switzerland) winds, for example, have been known to increase the intensity of anxieties and depressions to the point where significant increases in police reports and emergency room visits have been reported (Giannini et al. 1983). Other studies have shown that people living in different climates have reported different frequencies of high, low, or uneven moods, with a higher frequency of positive moods corresponding to sunny climates and more pessimistic moods often occurring in dark or

damp climes. Although this research simplifies the complexity of human emotion, significant design practice has been influenced by these studies, with some gardens and architectural spaces designed specifically to amplify mood (Thrift 2009). Could sound based on environmental data play a role in affecting the emotions of those experiencing the atmosphere of an environment? Thrift examined ways in which qualcalculation can be made known in the sensorium, or in other words how data space can be embodied (Thrift 2004, pp. 596–97). One way this qualcalculative background might be felt is through the ambient soundscape.

While affect has been described as both mood and intensity, the operational function of each appears to be similar. Clore and Tamir explored ways in which affect (mood) can influence decision making, and despite the duality of positive versus negative moods that overlooks the complexity of human emotions, their research indicates the possibility that affect can impact understanding. Massumi and Thrift acknowledged the complexity of the human emotional spectrum and defined affect in terms of intensity. Both authors examined affect in relation to data spaces and speculated that immersion in data space could create a feeling of disembodiment. However, Thrift's analysis was grounded in physical space, and he preferred to discuss the impact of intensity in the experience of data space in conjunction with physical space. He described a sixth sense, the 'qualcalculative sense', that is the affective and intuitive dimension afforded to a subject by interaction with data space. Although he regarded memory in data space as an important influence on affect, Thrift identified the phenomenon of clairvoyance or prediction within data space, what he called 'remembering forwards'. An example of this phenomenon might be interaction with a predictive weather or climate model. However, the prediction of future weather through embodied affective experience existed long before the creation of atmospheric computer models. Therefore, weather prediction provides an example of how interaction with the data space and interaction with physical space can provoke a similar intuitive response. However, unlike physical space, data space provides opportunities to reveal the imperceptible, allowing the possibility for an affective experience to undergo expansion into the unknown. The author, alongside other contemporary artists, has used ambient audifications, electro-acoustic composition, and sonifications of environmental data to affect listeners' moods and to convey imperceptible information about various aspects of space and place. What design and compositional elements impact the listener's experience of these sounding spaces?

Ambient Sound and Mood

The emotional quality of music has been heavily researched, from studies that ask subjects to identify the emotions they experienced while listening to various kinds of music to measuring real-time physiological responses like heart and breathing rate, blood flow, and skin conductance (Savan 1999). Changes in tempo, consonance as well as dissonance, and pitch and dynamics have been identified as the primary indicators of emotional meaning in music, and studies have found that behaviour is affected by changes in these parameters (Deutsch 1999; Juslin & Sloboda 2001; McElrea & Standing 1992). The sound of the spoken word also contains emotional information that can strongly affect listeners (Liscombe et al. 2003; Burkhardt & Sendlmeier 2000). However, the emotional analysis of the ambient soundscape is sadly lacking even though acoustic ecologists like Bernard Krause (1998) have found parallels between human-composed music and the sounds of the natural world, including whale and bird songs. Despite this lack of research, artists who use ambient audification and sonification often describe their work as bringing an emotional quality to the information.

For example, the self-identified ‘vibration artist’ Mark Bain has created sonic works in relation to location through architectural space. He claims that he is “interested in sound as material and the certain tactility of it, the rawness . . . [because] it is heavy, distinct, infested, and most importantly, alive!” (Altstatt 2003). Bain amplified and audified the inner workings of large architectural structures, translating this vibrational information into the audible range for listeners. As he described: “The action of bringing something that is unheard and unfelt to the realm of the ‘hearable’ and the ‘feelable’ as what is interesting. I try to reveal these hidden agents, unearthing the spectra for human reception” (Altstatt 2003). Thus his use of the qualities of pitch and loudness provoked physiological reactions in listeners and sometimes even shook the buildings themselves. For example, regarding an exhibition in The Hague in The Netherlands, he stated: “I would ramp up the system till you could feel the crack both in your gut and in the structure. It’s not so comfortable for the body but nice to test the potentials” (Altstatt 2003). In the past, Bain studied and employed sound vibrations called infrasonics that can affect very specific parts of the body, from resonating the entire body to pinpointing the inner ear in order to create a sense of vertigo in the listener or to cause sensations of nausea or anxiety (c 2005).

IMAGE FROM TUNEDCITY.NET

Figure 12. Promotional image for *STARTENDTIME*, Mark Bain (2005)

StartEndTime, a seventy-four-minute audio work broadcast on London's art radio station Resonance 104.4 FM, was one of Bain's most emotionally charged works. This experimental sound composition directly translated seismic earth vibration records from Columbia University, the nearest monitoring station to the World Trade Center on September 11, 2001, into sound (Oliver 2004). Bain audified this vibrational data without speeding up or slowing down the pace, so listeners experienced the Earth's reactions to the catastrophic events unfolding at the exact same pace they actually happened. The empty time between the cataclysmic events of the two planes hitting the buildings and their subsequent collapse seem to contain very little dramatic content, yet the gap is fraught with anticipation for each listener. In a similar manner, musicologist Leonard Meyer describes music as "the perception of and response to attributes such as tension and repose, instability and stability, and ambiguity and clarity" (1967, p. 43). Bain's *StartEndTime* experimental sound art work functioned emotionally like a piece of music. Meyer explained that tension experienced by the listener depends on his or her expectations and memories. Bain's listeners may have been affected by the fact that they were listening to a tragic historical event unfold at the exact speed at which it occurred; however, audified or sonified historical data may not have to be presented at the same speed it was recorded in order to provoke an emotional reaction. The audification or sonification of data might provide an alternative pathway to environmental knowing at various time and spatial scales. For example, during presentations of the author's 16-channel sonification of meteorological models of historical storms called *Atmospherics/Weather Works*, a strong emotional reaction from some audience members who had experienced the storms was evident despite the fact that the audience was experiencing twenty-four hours of data compressed down into a four-minute composition (Polli 2001). In this case, the tension was increased by actually speeding up the event. In both Bain's *StartEndTime* and the author's *Atmospherics/Weather Works*, a listener's memories of past events played a role in his or her emotional response to the work and invoked a transfer of space and time. Environmental understanding was enhanced through the intensity conveyed by these sound works.

Although Bain has not always translated scientific environmental data into sound, his work has often exhibited a sensibility similar to geosonification in that he has investigated spatial

texture and has been interested in revealing the imperceptible in space. For example, Bain's work has often communicated the qualities of materials and objects. He is referred to as an 'anti-architect' for his work audifying various architectural structures. However, in many instances the qualities of the material were imperceptible, and without the artist's manipulation of the signal (for example, pitch-shifting seismic vibrations into the audible range) would not be possible. Bain called his manipulation process 'magnification'. Using the analogy of a microscope, Bain described his aims: "If you ring a bell, you know the materiality of that bell; your action defines the certain molecular construct. If you zoom in to a supposedly static object by a few orders of magnitude, you find at the atomic level there is certainly an active system at play, of vibrating electrons and circulating orbits" (Altstatt 2003). When Bain was at MIT he worked with a friend with access to a scanning electron microscope (SEM), one of the most powerful electron microscopes in the world, with the ability to magnify the atomic level and to allow the viewer to observe the stacked electron shells. Viewing the world at this nano-level was revelatory for Bain and became the basis of his sonic experiments. He made the following statement about his experience: "What I found was this oscillatory buzzing of the shells, shifting from dark to light and resonating with a peculiar sense of energy" (Altstatt 2003). Bain found the audification of spatial vibrations to be one of the most effective ways to communicate this oscillatory energy to his audiences.

Radical sound artist Maryanne Amacher has also worked with the interactions between sound and architecture, but while Bain used sound to vibrate and magnify architectural structures, Amacher used architectural space to create acoustic illusions. In an interview with Eliot Handelman, Amacher described a performance she gave in Tokushima, Japan, in which she manipulated the acoustical properties in two different rooms: "I discovered something there I'd never heard before. In the stone curved room this whole enhancement shapes, the interaural and melodic shapes and patterns we perceive in this interaural imaging—this was completely enhanced. It was like an actual image that you could almost see and touch. I've never known that to happen before. The space was enhancing something in the sound that further intensified the 'neural shaping' that we give to these melodies, but it was like the perfect shape" (Handelman 1991). Amacher emphasised the tactile nature of sound by creating perceptible shapes in space through the exploitation of the reflection of sound waves in real architectural spaces. She chose these architectural spaces for their acoustical properties, carefully composed sound combinations, and positioned speakers facing walls or floors in order to enhance the spatial

effect of what she called “structure borne sound” (Watrous 1988). Amacher invited audiences to walk around and experience the sound, which emanated from a multichannel array of speakers, and experience how their position affected the resulting sound. By manipulating the expectations of the listener in these situations, and by emitting sudden, loud sounds from speakers as audience members came near, she created a sense of fear and anticipation (Margasek 2009).

Finally, Amacher worked with the physiological phenomenon of otoacoustic emission, in which the ears themselves act as sound-emitting devices by utilizing loud, high pitches to vibrate the bones of the inner ear and cause the stimulation of clear tones actually generated by the listener’s ears. As she explained: “We hear tones other than the given acoustic tones taking their shape inside our ears, as the membrane vibrates in response to the given acoustic tones. In music as we know it, such tone responses have been repressed. . . . We’re not aware that they exist, or that we’re actually creating them as listeners. The experience of our own processing isn’t available to us. I want to release this music, bring it out of subliminal existence” (Handelman 1991). Amacher used otoacoustic emission as an alternative pathway to enhance the listener’s understanding of his or her own body. A sense of geography can also be derived from Amacher’s statement. Although GIS or environmental data was not employed, she described her work as ‘perceptual geography’ and her process as ‘mapping’ (Handelman 1991). Simply, her desire was to locate sounds in space and create a sense of presence. As such, her work represented a radical arm of ambient soundscape composition in which electronically generated sound is used to highlight natural phenomenon as it occurs.

Her work also shared qualities with soundscape composers. Amacher was fascinated by virtual reality and cross-modal perception and wanted to fully immerse her audiences in her sound compositions. Furthermore, the way she described the aim of her immersive sound experience is similar to an extreme weather event, analogous to standing in a field during a storm: “Will certain sounds be locatable, seem miles away, feel close, pulsate vertically above our head, vibrate an elbow, suddenly appear in the space, dramatically disappear as though without a sound? Do we perceive the sound in the room, in our head, a great distance away: do we experience all three dimensions clearly at the same time? In the room, does the sound drift, float, fall like rain? Does it make such a clear shape in the air we seem to ‘see it’ in front of our eyes?” (Amacher 1999). Through the use of ambient sound composition, Amacher was attempting to communicate spatial and environmental knowledge to her audiences.

The author's 16-channel geosonification past experiment *Atmospherics/Weather Works* was an attempt to merge some of these same perceptual properties of sound addressed by Bain and Amacher with the sonification of scientific data, specifically data from highly detailed weather models of two historic storms (Polli 2001). While Bain used the model of the electron microscope and Amacher the phenomenon of otoacoustics, the author explored an architectural acoustic phenomenon for the design of one aspect of the overall data-mapping scheme, that of wind harmonics. When air is travelling through a building or courtyard of a specific shape, it can, depending on the speed of the air, be filtered to resonate a clear tone. In turn these wind harmonics inspired a mapping scheme in which some of the model data were used to control the parameters of acoustic filters, and these were used to filter the original sound sources that contained a wide frequency spectrum. For example, the sound of white or pink noise, radio static, or running water could be filtered into a single pure tone. The resultant sound became a clear tone that emerged from a noisy background, as if a solid shape had emerged out of murky water. Memories were invoked by the choice of a set of historic storms, and in one case, an audience member started to cry while listening to the work because it brought back a flood of memories about her own near-death experience during the storm (Polli 2001). In addition, like Bain the author utilized infrasonic sound by mapping the atmospheric pressure measurements during the storm into near subaural frequencies that are felt by the body rather than heard.

In another of the author's prior experiments, produced in collaboration with UK-based artist and programmer Joe Gilmore and called *N.*, modelled weather data from the North Pole were sonified into a four-channel real-time ambient soundscape. The data was modelled in the form of a sounding, as if it were data received from a weather balloon as it travelled vertically from sea level to the top of the atmosphere. Weather balloon data is commonly used by atmospheric scientists to gain information about the changing layers of air in the troposphere, and the author's subtractive filtering technique, again inspired by wind harmonics, was combined with an additive technique (designed by Gilmore) in which simple sound waves were made more complex based on the actual data. Also as in the author's previous work, wind speed and direction were mapped onto the loudness of specific speakers in order to create the sensation of wind spiralling upwards. In *N.*, a system was created in order to capture model data in real time as it was being generated, and therefore audiences were able to hear the weather conditions at the pole at nearly that exact moment. This was similar to a 'remote viewing exercise' in that listeners were experiencing a remote location in real time through the sonification. The technical and the

conceptual influences of this work has continued to have a strong influence on the research of the author, as the real-time geosonification process allows for the creation of changing ambient soundscapes based on actual atmospheric conditions. Another important area of investigation has been the emotional response of the audience and how this response could be directed towards greater environmental understanding.

Thus, as evidenced by their descriptions, the works of Mark Bain, Maryanne Amacher, and the author discussed in this section have attempted to provoke an emotional reaction in the listener. Firstly, they attempted to create emotions of fear and anticipation by building tension. In the case of *StartEndTime* and *Atmospherics/Weather Works*, this tension was built on the listener's knowledge of past events (9/11, historical hurricanes). While in Amacher's work the unexpected, loud sounds were used to unsettle the audience as they walked around spaces full of speakers. Secondly, specific frequencies and amplitudes were chosen because of their physiological effects on listeners. For example, Bain and the author primarily used infrasonic frequencies, while Amacher added otoacoustic frequencies. All these works were designed to emphasise the tactility of sound by using sound to vibrate structures, including buildings, bridges, and even the listener's eardrums. Unlike Bain and Amacher, the author created these effects using the geosonification of modelled atmospheric data, therefore attempting to engage the qualcalculative sense (Thrift 2009). These works represent ways in which experimental sound composition inspired by the soundscape attempt to engage the listener's affect and therefore increase awareness of spatial and environmental phenomena. Another area lacking in analysis is the affective potential of the geosonification of ambient information. What could be the affect of visualizing and sonifying air quality information on a range of expert and nonexpert listeners?

Airlight Case Studies

In order to shed light on this question, as a part of her doctoral work the author has conducted a case study. This practical study, the *Airlight* series of ambient ecomedia artworks, began with a month-long residency at the Taipei Artist Village during which the author created *Airlight Taipei* (2006). Versions of *Airlight* have since been created for Irvine, California, as *Airlight SoCal* (2007) and for Boulder, Colorado, as *Airlight Boulder/SoCal/Taipei* (2007). The most recent version of the *Airlight* series to date was *Airlight NYC*, exhibited at Cooper Union in New York City (2009).

The goals of the *Airlight* project were to collaborate with local air quality agencies to make real-time monitoring information more accessible to the public and to work with local air quality scientists to develop ways to effectively communicate this monitoring information to the public by employing the following aims:

1. To present a real-time ambient sonification and visualization expressing local air quality information to the public
2. To design a sonification of real-time data in the form of an ambient soundscape so listeners are able to ‘feel’ a different rhythmic pattern on various days, representing the daily variation
3. To make an analogy between air and noise pollution
4. To give a kind of ‘life’ to the air quality data being collected, creating the illusion of breathing through an alarming ‘screaming’ sound and image blur that increases in intensity as the levels of pollutants increase

The author’s four-year research study was undertaken in Taiwan and three locations in the United States: Southern California, Colorado, and New York. The study began during a typical summer in Taipei: the unbearably hot and humid air forced residents to stay in air-conditioned buildings during most of the daytime. At the time, this crowded city was home to over 6 million people, and although public transportation was excellent, several elevated highways seemed to cut through the city like contrails cutting through dense air. Taipei’s geography also worked against its air quality. Geographically, Taipei is located at the base of a bowl shape, surrounded on all sides by small mountains with only one narrow outlet for the stagnant air that often stays trapped for days. Additionally, Taipei is located downwind of southern China, where the energy demands of recent modernization have promoted the development of an increased number of coal-burning power plants. Thus, the wind flowing from west to east puts a large amount of the pollution from China’s coal industry into the Taipei air. All these elements combine to create very poor air quality for Taipei’s residents. The effects of poor air quality are visible in the faces of Taipei’s citizens, or rather, visible over the faces of citizens, as dust masks have become a fashion item, colour coordinated with clothing and motorbike helmets. The presence of poor air quality and the public awareness of this problem made Taipei an appropriate location choice for a practical exploration of the impact of the real-time geosonification of air pollution.



Figure 13. Promotional image AIRLIGHT TAIPEI, Andrea Polli, Taipei (2006)



Figure 14. Screenshots AIRLIGHT SOCAL, Andrea Polli, Irvine, CA (2007)

Similarly, Los Angeles's smog levels have been notorious from the very early twentieth century, and over the years the dramatically poor air quality in Southern California has inspired many local and national air quality regulations. This noxious brew is caused by a combination of geography, lack of wind, industry, vehicle exhaust, and high levels of solar radiation, which increase photochemical reactions in the atmosphere that in turn increase some forms of pollution like low-level ozone (California Environmental Protection Agency, 2010). Although ozone levels have been consistently improving in Los Angeles over the past ten years, in 2009 the city was again host to the highest levels in the country, and an estimated 6,500 people in the city die prematurely each year as a result of this pollution (American Lung Association 2009).



Figure 15. AIRLIGHT BOULDER, SOCAL AND TAIPEI, Andrea Polli, Boulder, CO (2007)

Although the air quality in Boulder, Colorado, is not as dangerous as that in Taipei or Los Angeles overall, since it is less than thirty miles from Denver, the city has also been victimized by the previously mentioned brown cloud that threatened both the physical and economic health of the area. Like Los Angeles and Taipei, part of the problem in Denver and Boulder is geography. Since mountains surround it, Denver's stagnant air becomes trapped in the bottom of the bowl shape. Located at a slightly higher elevation than Denver and with a much smaller population, Boulder experiences less air pollution.



Figure 16. Installation AIRLIGHT NYC, Andrea Polli, New York, NY (2009)

New York City's air pollution is not as severe as Los Angeles's, however, the city still rates as one of the worst for air quality in the USA (American Lung Association 2009). Manhattan has the worst street-level concentrations of particulate pollution in the city, with the wealthy Upper East Side neighbourhood faring the worst of the borough. Overall, vehicular emissions contribute more than 91 percent of the total cancer risk from hazardous air pollutants in the city, and living within 500 feet of major roads can dramatically increase the health risks of air pollution. In New York City, over a million people live within that distance (NYC Health, 2009). In each of these situations, the author worked with local scientists and air quality agencies to create a real-time, ambient geosonification and visualization of air quality monitoring data, including particulate matter PM 2.5 and PM 10, sulphur dioxide, nitrogen dioxide, and ozone.

While in residence in the Taipei Artist Village, the author contacted and collaborated with Chung-Ming Liu, the director of the Global Change Research Center and professor in the Department of Atmospheric Sciences at National Taiwan University. Liu gathered and formatted real-time Taipei air quality data for approximately twenty sites throughout the city and made this raw data accessible online for the project. Liu's work allowed the author to write a computer program to automatically download these hourly measurements of particulates, ozone, and other pollutants in the atmosphere and translate this information in real time into a changing rhythmic visual and soundscape, translating the 'noise' of the pollutants into a kind of rhythmic 'noise'. Although data for all the sites was available, the measuring station closest to the Taipei Artist Village gallery where the work would be presented was chosen. This site happened to be the Taipei Main Station. Since it was the standard way air quality data was collected, Liu and the author agreed to format the data as a time series, with each hourly measurement or a specific pollutant in a twenty-four-hour period placed in a row and each column containing measurements of a different pollutant. Thus, listeners to the sonification could hear change occurring over twenty-four hours, and the author could choose various pollutants to sonify. Therefore, at the end of one day, each data file contained a total of twenty-four rows and the number of columns corresponding to the number of pollutants measured, from one to eight depending on the equipment installed at a particular site, for example, particulate matter PM 2.5 and PM 10, sulphur dioxide, nitrogen dioxide, and ozone. Each column of data would then be read into the sonification system, row by row, with a new row added each hour from midnight to midnight.

In order to reinforce the pattern created by the pollution levels changing over time, an ambient visualization of the data was also integrated into the project. The author discovered that the traffic engineering office of Taipei city offers a large number of public traffic cams online, so she wrote a computer program to automatically download traffic-cam images near the air monitoring sites in order to synchronize the sound of the air quality with the live traffic images. In this automated system, the numerical value representing the various pollutant levels was used to break the images apart into pixels, causing traffic scenes to appear and disappear with rising and lowering pollutant levels.

The idea of 'noise' was central to the structure of both the sound and image in this work. In constructing the sonification system, the author generated an initial sound source with a wide frequency spectrum, in other words, a very 'noisy' sound. She then used the numerical values representing levels of pollutants to amplify and filter frequencies of this noisy sound. She programmed the system to pick out certain frequencies to represent levels of pollutants, and therefore created the effect of high-pitched screeches, like automobile brakes, when high pollutant levels were read. The imagery was also structured around the idea of noise. The original image was an unaltered traffic-cam image designed to pixellate based on the levels of pollutants in the air. This had the effect of a blurring and focusing of the image in a rhythmical way in sync with the sound.

With the aim of understanding a variety of different environmental and social situations and by using similar methodology, the author also created similar projects in three other locations: Southern California; Boulder, Colorado; and New York City. The first project, *Airlight SoCal*, integrated images from live webcams from the California Department of Transportation (DOT) and daily amounts of ozone (O₃) and nitrogen dioxide (NO₂) for various locations in Southern California updated hourly and provided to the project by the South Coast Air Quality Management District (AQMD) with the help of monitoring technology specialist Kevin Durkee.

For *Airlight Boulder/SoCal/Taipei* presented in Boulder, Colorado, three visualizations and sonifications were presented simultaneously, representing the Boulder/Denver area, Southern California, and Taipei. The AQI and VSI Air Quality Reporting Systems of the Colorado Department of Public Health and Environment provided hourly air quality data for Boulder and Denver and traffic-cam images were obtained from the Colorado Department of Transportation (DOT).

Finally, for *Airlight NYC*, the author used data from the three sites operated by the EPA to measure continuous levels of PM 2.5 in Manhattan and presented the visualizations on video screens placed in relative locations on a simplified, painted map of the city. The national organization AIRNow gathered and formatted the data for the project, and real-time traffic-cam images were obtained from the NYC Department of Transportation (DOT).

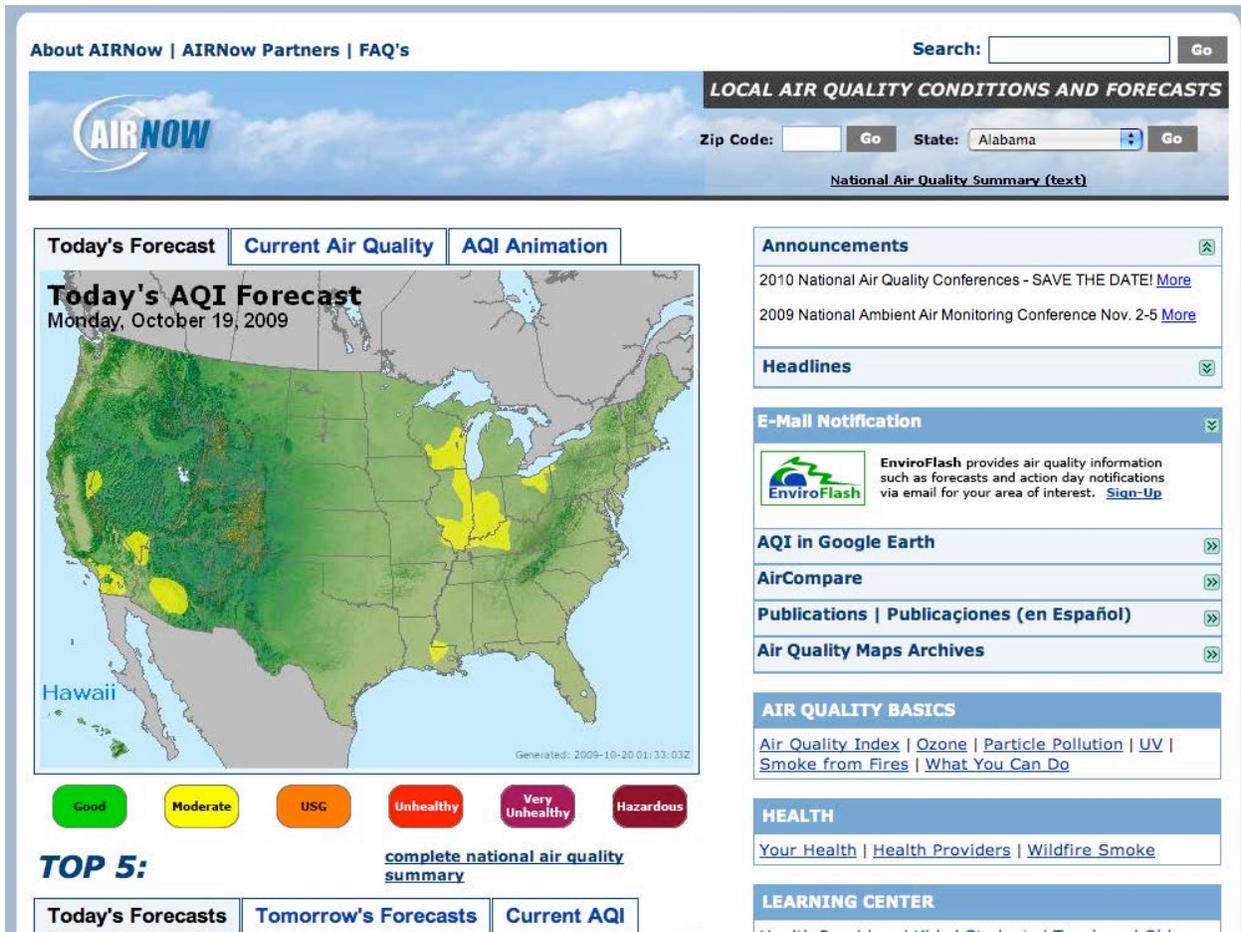


Figure 17. AIRNow WEBSITE, Sonoma Technologies (2010)

Successes/Failures

Air quality data is most often provided to the public through preformatted Web pages that include charts, graphs, and colour-coded alerts rather than raw data. This oversimplification makes it difficult for the general public to understand the complexity of the information and also presents a problem for developers wanting to design creative ways to interpret the data. For programming the *Airlight* series, it was necessary to have access to the raw data, and each organization the author worked with was able to provide this raw data in a different way on an

individual basis. As aeronomist DuBois observed earlier in this chapter, there is a growing community of amateur enthusiasts who follow air quality data online, including data from monitoring stations (DuBois 2009). Unfortunately, in the United States and other countries the author has investigated including Taiwan and China, the real-time, raw data are not made available to the public online. Instead, this real-time information is filtered into a graphic representation of the ‘threat level’ using a colour-coded system of green for low levels of air pollution and red for dangerous levels. Although this system is simple and easy to understand, it does not interpret the subtleties of the data, something that artists and designers with access to the raw data could possibly provide. Data interpretations that allow for complexity of developing information could add an emotional layer that could bring audiences to a more visceral understanding of air and atmosphere. This alternative pathway to interpretation and reception could play on the affective response of audiences.

The author discovered that one reason raw data is not made public is that the scientists and engineers involved have concerns about publicizing data that has not been verified by human eyes. Automatic sensor systems can often malfunction and provide bad data. For example, in the case of the Taipei data, a malfunctioning monitor would output the number “99.9999”, a value that was determined to be impossible, to indicate a problem with the equipment. Knowing this, the author was able to write her sonification and visualization program to ignore values of 99.9999. However, other malfunctions may output values that seem correct, but are not, and therefore could foil a real-time system into presenting an inaccurate interpretation. This concern could easily be addressed by including a simple disclaimer with a real-time presentation of the data. By the third time this project was presented, the project’s data providers had carefully considered this idea, and AIRNow provided text for a disclaimer to the author to use when publicizing *Airlight New York*. Due in part to this project, the AIRNow organizers determined that presenting real-time air quality data to the public was valuable enough to take the time to create this disclaimer rather than to restrict access.

However, even if access to international raw air quality monitor data was free and available to the public online, there is no standard monitoring equipment suite in use. Technicians in the four regions the author selected for this project all were collecting different kinds of data in various formats. Some, like those in Taipei, had standard equipment installed at many sites in the city collecting the same series of variables, while those in Boulder had only two sites in the entire city, and each one was collecting a single different variable, with one site

gathering particulate matter and another observing ozone levels. Southern California had many more sites in operation, but each site was measuring different combinations of variables with no standardization. This lack of standards made the comparison of ambient sonifications, which the author hoped to enable by presenting Boulder/Denver, Southern California, and Taipei simultaneously in the Boulder exhibition, impossible. Even more problematic for the sonification system was that the local air quality monitoring agencies in Colorado and California each formatted data in a slightly different way. This meant that the sonification system had to be modified for each data format, again affecting comparison.

Despite these barriers, it is possible to make some comparisons. In all cases, the public reaction was that of curiosity, especially after learning that what was being presented was real-time air pollution information. The New York City version presenting only one variable, PM 2.5, from three different locations, proved to be the easiest for audiences to understand, and more audience members viewing the New York City version spoke about their personal experiences with air pollution. Audience members at the other presentations in Boulder, Southern California, and Taipei expressed more curiosity about the system interpreting the data than about their air quality. However, the most meaningful comparisons have been of the systems used to provide the data and the processes needed to gain access.

As a newly developed aggregator of EPA air quality data for the entire USA, the AIRNow program created by Sonomatech has helped to solve many of the author's problems with standards and formatting. In the creation of *Airlight NYC*, the author first directly contacted local Manhattan monitoring sites for data access, but her initial request was rejected. These local sites automatically send their data to the AIRNow system, so the author contacted the AIRNow staff directly. AIRNow already knew about the *Airlight* project from the Boulder and SoCal versions, and the author was granted not only data access but also standardized formatting and technical support. However, despite the author's constant encouragement to do so, AIRNow has not yet made their raw data feeds free and easily available to the public, it is still necessary to request special permission for specific data sets. This is due to both the challenge of making sure the public understands that no real-time data from automatic monitors can ever be verified and the challenge of convincing scientists, technicians, and bureaucrats that public access to raw data can have value. Open availability of the raw data would encourage more amateur or 'citizen' scientists to become involved in evaluating the mass of air quality data. This public participation is becoming more important for several reasons. Firstly, the amount of air quality data being

collected has seen a massive increase over the past twenty years, with increases accelerating over the past ten years with the installation of PM 2.5 monitoring (DuBois 2009). Secondly, the increasing adoption of air trading systems (for example, sulphate and CO2 markets) has tied the public's confidence in accurate monitoring to the economy. Thirdly, rapid climate change has a dramatic effect on air quality forecasts. Aeronomist Paulette Middleton and others pointed out that despite the fact that most air quality models assume no climate change, in reality a lot of places are getting warmer and their precipitation patterns are changing, and this has a direct impact on air quality because temperature and relative humidity changes can exacerbate pollution (DuBois 2009).

What Scientists Learned

The first and closest scientist collaborator on this project, Chung-Ming Liu, was very interested in how the sonification of air quality data might express the 'daily variation' of air quality in the city. By this he meant how each twenty-four-hour period might express a different kind of pattern, and how that pattern could be understood scientifically. His interest in the daily variation directly influenced the design of the sonification system, which built upon itself with each additional hourly data value and then reset after twenty-four hours. The sonic result of the *Airlight* system was a simple, repeating rhythmic pattern that became more complex through the course of the day. Unfortunately, the gallery presentation of the artwork available to the author did not provide constant exposure to the sonification for the scientists. Therefore, although the project served as a prototype to prove it was possible to create the sonifications in real time, the presentation conditions did not allow it to be formally evaluated by the scientists. Liu was also very interested in how the sonification could express a quality of the data not available in visual charts and graphs. However, according to Liu, the project did prove that it was possible to express the data in a visceral way. After experiencing the work for the first time, Liu said, "this project allows you to really feel the data, not just see it" (Liu 2006).

What Agencies Learned

Through the Boulder project, the author came in contact with the AIRNow Data Management Center, which collects and distributes air quality data from over 2,000 sites in the United States. The AIRNow staff hoped that the *Airlight* project could become a model for ways in which the data being collected can be made available to artists and designers developing ways in which the

information can be communicated to the public more effectively. The author communicated extensively with AIRNow staff about the kind of data formatting she needed for the project, and since that time staff members have used the *Airlight* project as a model for implementing raw data access to artists and developers around the world. Presently, developers need to contact AIRNow for the specific Web site addresses to access the raw data, but as the public realizes the importance of air quality monitoring, AIRNow staff has indicated that they are creating plans for a more open platform in the future. Consequently, the *Airlight* project has served as a model for implementing a way for government environmental protection agencies to provide raw data access to artists and developers around the world. Through the development of an art project creating a sonic and visual interpretation of air quality, which could also be called an alternative pathway to the common ‘threat level’ visualizations of air quality available to the public, this project has helped to change the culture of closed data access to a more open model. Since the data is real time and raw, by definition it has not been verified by the agency and therefore disclaimers must be used by artists and developers who are using the data. This is a simple process of protection: a disclaimer like the one implemented for the *Airlight NYC* project can help make it easier for agencies to get information out to the public in timely and engaging ways, helping to publicize the work of the agency and encourage more public education and involvement.

What the Author Learned

Despite the noise that was built into the structure of the computer program, the author found that the resulting sonification was surprisingly pleasant to listen to due to its repetition. The repetitive short loop, transforming slightly each hour when a new pollutant measurement was taken, created a rhythmic, ambient sound that functioned very much like background noise. The distortion of the image created a rhythmic blurring and focusing and resulted in an effect of quivering or breathing, referring to a kind of living being. In discussing ephemeral and process-based art, Steven Connor says that “in much recent art, air has become the marker, not of the difference between art and life, but of the aspiration of art to trespass beyond its assigned precincts, to approach and merge into the condition of ‘life’” (Connor 2007). As this was the first sonification and visualization project the author had created using repetition, the *Airlight* project did highlight potentials of that technique to raise public awareness of varying levels of pollution over time.

For example, the security guard at the *Airlight, NYC* exhibition at Cooper Union became very disturbed, asking the author if the distorted image was what the pollution actually looked like. The author explained that particulate pollution of 2.5 microns is generally invisible, although it sometimes can be seen as a bright fog in the distance, and that the visualization presented what it might look like if the pollution were made visible from a closer range. The guard then recounted her experiences living with poor air quality in the Bronx, including her son's asthma. The guard's memories of the problems she had encountered in the past due to poor air quality became a part of her experience of the artwork. This demonstrates that there may be a potential benefit of audience members to experience ambient geosonification and visualization works like the *Airlight* project continuously over time.

Conclusion

Sonification and visualization of real-time environmental monitoring data is an alternative pathway that may have the potential to increase environmental knowing. Air quality monitoring offers a unique opportunity for sonification and visualization because it is generally thought to be invisible. However, although at close range air is invisible, poor air quality can impact long-range visibility and this phenomenon can provide a metaphor for the development of visualizations and sonifications. This can also bring emotional qualities into the interpretations of such work. As was shown by Dr Paulette Middleton's discussion of the prominence of the visibility issue in public air quality decisions in Colorado, the aesthetics of distant vistas can play an important role in influencing scientific studies and political legislation. The natural beauty of a clear landscape can have a positive impact on local economies through promoting real estate sales and tourism. As evidenced by the author's interview with aeronomist Middleton, tying visibility to the composition of air can critically transform aeronomic science to favour a more interdisciplinary approach. Art can play a role in this interdisciplinarity by serving to open alternative pathways to experiencing and understanding environmental data.

Aesthetic experiences can change mood, and these emotions in turn can impact decision making. For example, mood can change the estimation of risk, with a positive emotion influencing more risk-taking actions. However, as Middleton observed: "Scientists have been called upon as long as I can remember, historically, to bring some intelligence to decision making" (Middleton 2008), and since emotions are tied to decision making, it is important for scientists in all fields to be aware of the various ways in which moods can be changed. Data

space through monitoring and modelling plays such a critical role in the area of climate and other atmospheric sciences that an analysis of the emotional impact of data space is essential to the public communication of the science. Nigel Thrift has extensively analysed the emotional impact of data space, identifying the ‘qualcalculative’ sense as the affect obtained through interaction with the virtual. This sense is tied to melding of memory and the process of ‘remembering forward’, or future visioning. Imagining the future is a major goal of computerized atmospheric science models, and the predictive capabilities of these models has penetrated mainstream society through the ubiquity of weather and climate change information.

While music has been shown to affect the emotional state of the listener, less research has investigated the affect of pure sound or sound art. Artists like Mark Bain and Maryanne Amacher have used physical information such as that from architecture, seismic vibrations, or the listeners’ bodies themselves to provoke both a physical and emotional reaction. The author used the ambient sonification and visualization of real-time air quality data in her project *Airlight* in an attempt to create an emotional connection between the listener and the invisible molecules in the atmosphere. Through the use of noise and repetition, she attempted to convey the daily variation of changing air quality situations. Through working with the EPAs of Taiwan and the United States, the author’s work can serve as a model for artists and developers interested in interpreting data to collaborate with government agencies collecting real-time data.

The *Airlight* series opened a pathway for the author to collaborate with local air quality scientists and agencies to make real-time monitoring information accessible to the public. By working with the local Taiwanese air quality scientist Chung-Ming Liu, the author was able to develop a real-time ambient sonification and visualization, viscerally expressing local air quality information to the public. The resulting ambient soundscape allowed listeners to ‘feel’ a different rhythmic pattern on various days, representing the daily variation of pollutant levels. This geosonification and visualisation made an analogy between air and noise pollution and gave a kind of ‘life’ to the air quality data being collected, creating the illusion of breathing through an alarming ‘screaming’ sound and image blur that increases in intensity as the levels of pollutants increase. Since real-time air quality information is most commonly presented to the public using a simple colour-coded system, the *Airlight* project created an alternative pathway to experience up-to-date pollution data based on the real visibility effects of this pollution and using noise as a metaphor for increased pollution.

The *Airlight* project brought up a series of problems with data access and control. Although the scientists and engineers the author interacted with wanted to provide open data access to the public, their abilities were limited by the bureaucratic structures of their agencies. The next logical step in the author's investigation, therefore, was to explore ways to gather data from independent environmental monitoring equipment and to find alternative pathways to share this data. Researching open data networks and undergoing the process of gathering and sharing data, will promote a more complete understanding of the issues inherent in these systems and provide a better sense of how to build environmental knowing in communities. The author's *Hello, Weather!* project, discussed in the chapters "Ground Truth" and "Breathtaking", provided an opportunity for analysis of the author's experiences in the creation of an international weather station network installed at art and community centres.

In addition, audiences experiencing the *Airlight* ambient sonifications found the sound to be intriguing but were unclear on the meaning of the abstract soundscape, which was reminiscent of electronic music. Since raising awareness of climate change was of central importance to the author, her next steps to address this issue were to explore how sound can more effectively address an environmental issue. Soon after her first experiments with *Airlight*, she had an opportunity to work in a unique environment, that of the Antarctic continent. This artist's residency provided a perfect research base and experimental testing ground to examine how a soundscape can define place and express environmental issues related to place. In the next chapter, "Airspace", the author will analyse aspects of this unique soundscape in relation to media as experienced by various listeners and her own attempts to engage communities and the general public with this unique environment.

Chapter 4. Airspace [Focus: McMurdo Station, Antarctica]

Introduction

This chapter will examine affect and real time data transmission by investigating both the effect of media on science and scientists working in Antarctica. Several art and science transmission-based projects related to Antarctica will be used as case studies. Through interviews with Antarctic climate scientists (Dr Peter Doran, Dr Andrew Fountain, and others), this chapter will show how the uncertainties that are a part of weather and climate science have been used by the media to discredit Antarctic science. These uncertainties have also been exploited to support various political agendas. How have scientists responded to the misuse of their data in the mass media? What alternative pathways have been developed to respond to this problem of misrepresentation?

Like independent news agencies, transmission-based projects including radio and Internet broadcasts by independent artists' and scientists' groups can provide a direct alternative to the mass media. Specifically in Antarctica, how have such transmission-based projects developed, and how do these works use interdisciplinarity and systems thinking to create alternative pathways in order to better understand environmental issues? Art often presents a personal interpretation of information, and how does this personal expression intersect with the uncertainties of weather and climate science? Does this intersection help or hinder public understanding of science? With this element of uncertainty, what are ways that robust science can be presented? The author has created *Sonic Antarctica* from a personal experience of being in an environment. The work combines soundscape recordings and sonifications by members of the Antarctic community with audio interview excerpts, and these combinations will be examined in the context of the other transmission science and art works.

The poles are on the front lines of climate change. Known as the planet's refrigerators (Doran 2008), they circulate cold air that drives many of the weather systems in the Northern and Southern hemispheres. The Arctic has experienced unequivocal warming, leading to accelerated melting over the past ten years. In contrast, Antarctica had become a focus in the politicized mainstream media global warming debate because by 2002 the research showed that overall the continent was cooling (Doran 2008). Lacking an understanding of the science and looking for proof against global warming for political purposes, some members of the mass media began to use the findings of Antarctic climate scientists to support a claim that global warming was false.

Through a series of interviews with climate scientists in Antarctica, the author discovered that the politicization of the global warming issue combined with the difficulty of communicating the complexity of climate science to the general public has created public confusion about the reality of climate change. Several scientists interviewed by the author expressed the need for a greater understanding of climate change among the general public. For example, climate scientist Dr Peter Doran of the Earth and Environmental Sciences Department at the University of Illinois at Chicago spoke with the author at length about the difficulties that nonscientists, particularly journalists, have in understanding the complexities of climate science. He said, “in Chicago I get called up by the local media sometimes, when it’s cold, and they say ‘Oh, well, I thought global warming was happening’. The point I make in response is that we don’t say one day is global warming and the next day isn’t, it’s all sort of a mixture. Some stuff is anthropogenic, some stuff is human-caused and some stuff is natural, and you can’t tease them out” (Doran 2008). According to Doran, his research and that of other scientists was intentionally misrepresented by members of the media as evidence against anthropogenic global warming. He experienced firsthand the misleading reports in the mass media distorting the findings of climate scientists. He said, “We wrote an article in 2002 for *Nature* and it was immediately misused by some of the spokespeople of the Republican Right like Rush Limbaugh and Ann Coulter” (Doran 2008). Doran was disappointed but not surprised at this misuse of his data. He said that he expected political pundits to do this, but he became very upset when the mainstream media misreported his findings. He continued: “Then it got picked up and there was this broken telephone effect and it become sort of the poster child of ‘Look, this proves that global warming isn’t happening’, but it was all from misinterpretation from the beginning, and no one went back to look at the original paper” (Doran 2008).

With all the checks and balances that have to occur before a scientific paper hits the mainstream press, how could such a drastic misinterpretation have happened to Doran’s research? Doran stated that part of the problem in the media was limited resources to support the expertise needed to translate this science to the public. He clarified: “There is some great scientific reporting out there—the *New York Times*, the *San Francisco Chronicle*, and others, but other, smaller papers don’t have science reporters on staff and they don’t have the tools to be able to translate from the science to the public . . . so we’ve got this language barrier” (Doran 2008). One thing Doran found that was helping to help break down this language barrier was an emerging trend of scientists contacting the media directly with their findings. Although Doran

admitted that scientists talking directly to the media creates controversy within the scientific community, he said that the political pressures on scientists, especially those involved in climate science, have made them much more willing to speak out despite the disapproval of their peers. He explained: “I think that ten years ago scientists were reticent to come out and speak about their science, but I think more and more the message is getting through that there’s war going on, essentially. Especially in the last about eight years or so . . . and we’ve become less trusted. So we’ve had to take to the street to get our message out there” (Doran 2008).

Doran himself became a model for other scientists by publishing a groundbreaking editorial about the misuse of his research on the opinion pages of the *New York Times* (Doran 2006). He was one of the first climate scientists in recent history to make such a prominent public stand. Although he initially struggled with a fear of being identified as a science ‘populariser’, a label that within some circles of the scientific community is interpreted to mean one is not doing serious science, he felt compelled to write the editorial. “I thought that it was time to set the record straight, and you can’t do that in the scientific literature, people don’t read science papers, so you have to go out to the public and straighten this out,” he noted (Doran 2008). Responses to Doran’s article came mostly in the form of e-mails, and he said that although he received some negative e-mails, the vast majority of responses to his article thanked him for making this important statement of clarification in the public forum.

Members of the mainstream media have also misinterpreted the research of Dr Andrew Fountain, lead scientist of the Antarctic Long Term Ecological Research (LTER) project. The author also interviewed Fountain at length. In this interview, like Doran, Fountain advocated for scientists to speak directly to the media. He explained how, in his experience over the years, the attitudes within the scientific culture had changed, and he defended his and Doran’s activist approach: “Oh, yes—this changed completely, because when I started out in science it was ‘keep your head low, stay out of newspapers’. You know, if newspapers come to you, fine. You don’t go seeking publicity, that’s a bad thing. . . . Now, with climate change, this whole edict in a sense has changed” (Fountain 2008). Fountain continued to explain the reasons for this change: “Because in a sense science is really separated from public understanding . . . [but] now the funding agencies want to bring that back into the public arena, to at least make our results known and appreciated by the public . . . it’s gone from ‘this [going to the media] is something I should do’ to ‘this is my duty, to be involved and to get the word out’” (Fountain 2008).

As Fountain illustrates, the complexity of climate science makes climate change difficult for the layman to understand. The politicization of the climate change issue has caused a cascade of misinterpretations of scientific findings, and the translation of scientific language to general language has become an increasing problem within the mainstream media due to lack of reporter resources and expertise. In the public climate-change debate, the voices of scientists directly involved in climate research are essential to help to break down the language barrier between science and the public. Technologies such as the Web have made it possible for scientists to not only communicate with media professionals but also to directly communicate with the public and get an immediate response. The next section will investigate the ways in which the structure and use of a specific form of media—radio—has influenced public perceptions of the Arctic and Antarctic.

Radio and Public Perception of the Arctic and Antarctic

Since the first successful transatlantic radio communication by Guglielmo Marconi and his assistant, George Kemp, in 1901, radio has contributed greatly to the public imagination of the poles. For example, within the subculture of the ham, or amateur, radio enthusiast, the poles are the cause of both enhancement and disruption of long-range radio transmissions, and contacting the poles is a coveted goal of a long-distance ham radio operator⁵. The following scenario based on the story of an actual long-distance amateur radio operator, known as a DXer, provides a snapshot of life within this active subculture:

John Manna sat in his radio room, or 'shack' as he called it, surrounded by various radios and desk microphones. He used to build all his own equipment, but by the 1980s everything was store-bought. He had modified some of it, though. He couldn't resist experimenting with the electronics. He glanced over at the telegraph he used for Morse code,

⁵ There are several conflicting stories as to the origin of the term 'ham' used to refer to amateur radio operators. The term first appeared in print around 1909, and one story identifies three early operators whose first initials spell out 'HAM', another states that it is a usage of the slang term for 'incompetent' (as in 'ham' actor). The National Association for Amateur Radio, history page, viewed September 21, 2010, <<http://www.arrl.org/ham-radio-history>>. L. C. Hall, "Telegraph talk and talkers: human character and emotions, an old telegrapher reads on the wire", *McClure's Magazine*, January 1902, pp. 227-231, viewed September 21, 2010, <<http://earlyradiohistory.us/1902slng.htm>>.

wondering how long it had been since he had his last ‘CW’ (Continuous Wave) communication. It had been years since he used anything but voice or ‘sideband’ contacts.

He fiddled with the telegraph keys, remembering how he used to understand CW ‘copy’ at over forty-five words per minute. He would listen to the musical tone of the Morse code at such a speed that he couldn’t make out the letters at all. Instead he would hear whole words, forming in his head at the speed of conversational speech. When he was really rolling, it felt like a kind of telepathy.

John had been surrounded by electronics his entire life. He was an engineer for the Diebold Company and holds a patent on a device that turns off a car’s turn signal when it’s been left on too long. He had been a fire captain, quartermaster for the VFW, radio officer for the Office of Emergency Management, and is now a board member at the new local senior centre. His radio club, the Valley Radio Club, has been in operation for over eighty years. As a ham, or amateur radio operator, like other hams throughout the world, John routinely spent seven to eight hours a day listening.

He glanced up at the No. 1 DXCC Honor Roll Award hanging on the plywood wall. The award identified John by his call sign, WA2F. To a ham, this recognition by the American Radio Relay League (ARRL), confirming contacts with every country in the world, is the pinnacle of amateur radio success. John earned it about five years ago, when he confirmed communications with the Philippines (O’Brien 2008).

The DX in John’s DXCC award stands for ‘distance’, and hams listening for faraway communications often call themselves ‘DXers’. For amateur DX contests, an operator proves contact with a particular country by presenting a kind of postcard, called a QSL card, sent to him or her from that country affirming the contact. John displays his cards proudly, including his prized QSL from a North Pole explorer (Gerard 2009).

In order to receive radio beyond the limits of the line of sight, a distance DXers call the ‘far field’, the Earth’s ionosphere must refract the radio beam. Although radio signals pass through the lower atmosphere undistorted, signals directed through the ionosphere may be distorted, totally reflected or absorbed. If the signal is reflected, it can be heard at locations hundreds of miles away from the broadcasting station. However, solar winds can cause the ionosphere to behave highly erratically, particularly at high latitudes near the poles. Uncertain like weather, the ionosphere’s unpredictability near the poles can create both great advantages

and disadvantages in transmission and reception to the DXer. This practical experience with the ionosphere near the poles through radio information exchange gives DXers a unique sense of the volatility and significance of these remote locations.

The paradigm of radio for a DXer is very different from the paradigm for the average broadcast listener. A DXer actively searches, bouncing around the ionosphere looking for an unusual signal, while a broadcast listener is a passive receiver. The DXer is goal-oriented, aiming for some kind of exchange. One goal, for example, is obtaining coveted QSL cards, documents that confirm a conversation and verify that a signal has been sent and received from both sides. Through personal exchange, the DXer sees the radio sphere as a distributed medium, while the broadcast radio listener envisions a single shining radio tower sending a message to many ears. Unlike the DXer who has an intimate knowledge of the potential of radio transmission, the broadcast listener has only a vague sense of what is possible through the magic of the ionosphere, if he or she has any sense of it at all.

Similar to the difficulties the public has in understanding the complexity of climate science, the technical complexity of global radio transmission and lack of public experience with the nature of this transmission opens the door to outlandish claims by the media that amplifies misunderstandings. Outlandish media claims in relation to polar exploration can be traced as far back as 1926 when the Mexican radio station El Buen Tono, operated by Mexico's largest tobacco company, published an advertisement suggesting that Norwegian Arctic and Antarctic explorer, Roald Amundsen, the first man to reach the South Pole, had not only smoked El Buen Tono cigarettes on his famous zeppelin expedition to the North Pole that same year, but also by some strange fluke of radio transmission had actually heard the El Buen Tono radio broadcast at the precise moment of floating over the pole. However unlikely this occurrence was, it became one of the radio station's greatest points of pride and turned Amundsen's journey into a great fascination throughout Mexico. Mexican historian, Ruben Gallo, analysed this myth as a wish-fulfilment fantasy of a post revolution Mexican population longing to become part of a community of modern nations. As he states: "During a time marked by great expectations, the company's radiophonic fantasy propelled Mexico, a poor country recovering from a devastating civil war, from the margins to the 'top of the world'" (Gallo 2006). The post-war Mexican population was responding to the idea that they could be a part of what the philosopher Gernot Böhme calls the "acoustic atmosphere" of the pole. According to Böhme's essay, *Acoustic Atmospheres. A Contribution to Ecologic Aesthetics*, musical space is expanded corporeal space,

a modification of space as experienced by the body forming and informing the listener's sense of self. The Mexican citizens inferred that by listening to Mexican radio, Amundsen was becoming a part of Mexico, and by extension Mexico was making a connection to the world. As Böhme explains, through the radiophonic model, "listening has grown from an instrumental experience—I hear something—to a mode through which one participates in the world" (Böhme 2004, p. 17).

These examples clearly show that the public perception of the poles has been affected by the medium of radio. Members of the subculture of ham radio operators, in particular long-distance hams, have a working knowledge of the volatility of the ionosphere near the poles and the effect of this uncertainty on radio transmission. The general public, in contrast, has little to no practical experience with ionospheric transmission and therefore is susceptible to elaborate hoaxes like that perpetrated by El Buen Tono radio in the 1920s. These myths take advantage of the public's limited knowledge of how radio transmission works in conjunction with the ionosphere while at the same time capitalizing on a nation's collective fantasy of connecting to the most remote place in the world. In the next section, based on the author's personal experiences in Antarctica, the author will discuss how the everyday use of radio in Antarctica differs from both the DXers functional experience of radio and the general public's broadcast model of radio.

The Practical Use of Radio in Antarctica

The previous analysis indicates that the general public can interpret the content of radio at the poles as a symbol of internationalism. According to Gallo, the Mexican people saw their fantastic radiophonic connection to the Arctic explorer Amundsen as a symbol of an emerging global Mexico. The Antarctic and Arctic International Treaties and the long history of International Polar Years (IPY, 1882/83, 1932/33, 1957/58, 2007/08) have also contributed to another myth of the poles as utopian science-villages of global cooperation and collaboration. Potentially, radio could make a contribution to collaboration at the poles, but in the author's experience living in two U.S. bases in Antarctica, radio is highly regulated, without widespread use beyond logistics and survival.

McMurdo Station is an Antarctic base founded by the United States government in 1956 that in 2007/08 was operated by the global defence contractor, Raytheon, through the U.S. National Science Foundation (NSF). Built on top of volcanic rock on the southern tip of Ross

Island on the shore of McMurdo Sound, this science facility holds the largest community in Antarctica, up to 1,258 residents in what appear to be very temporary buildings. McMurdo also serves as a logistics base for half the continent (Pacheco 2009).

Although a limited amount of broadcast radio for news and entertainment is available to residents at McMurdo, the travel demands of the science and the unpredictable extremes of the weather make distributed radio communication much more prominent than broadcast radio. Every researcher is issued a personal two-way radio and is trained in local radio communication and in contacting one of several main radio dispatch locations around Ross Island. Residents also receive training in larger field radio systems with long-range capability. During a training session, the author's first experience with these systems was to use one of these radios to contact the communications office at the South Pole from a site near Williams Field on Ross Island, a distance of over eight hundred miles. Although awkward at first, the author became familiar with the necessary radio protocol, saying 'over' when finished speaking and waiting for a reply and 'over and out' when signing off.



Figure 18. Historical field radio kit on display at Scott Base, Antarctica, Andrea Polli (2007)

Any significant travel, even on foot, without a radio is forbidden at McMurdo, and all other U.S.-operated bases, including the South Pole. Researchers are expected to check in on a regular basis, and if the radio check is not received by the home base within an allotted time, a search party is immediately deployed. McMurdo residents hold radios in the front pocket of a vest, a kind of ‘technical prosthesis’, as electro-acoustic music pioneer, Pierre Schaeffer, calls radio in *Traite des objets musicaux* (Schaeffer 1966). Schaeffer defines radio as the electro-acoustic chain that connects a human being to the environment. However, at McMurdo the importance of the electro-acoustic chain between radio and human beings is not in how it connects residents to the environment, but in how the radio protects residents by connecting them to people who could save their lives in an emergency.



Figure 19. Antarctic researchers raising a radio antenna to contact the South Pole station, Andrea Polli (2007)

While in Antarctica the author visited and made recordings at several communications sites and reviewed triangulation maps of the paths a radio signal could take in various situations. For example, if interference was high in one area, or if a mountain was blocking transmission, the

signal might be routed through transmitters on various outlying islands. These meaningless blank white places on the map gained significance through their role in relaying life-saving messages.



Figure 20. Radio antennae at McMurdo, Andrea Polli (2007)

Despite the many successful examples of international scientific cooperation with regard to the poles, extreme systemic resistance to any form of international communication was highly prominent during the author's time in Antarctica. The communications specialists she interviewed at McMurdo were well aware of the ham radio DXers and found their listening relatively benign. However, during radio training given by employees of Raytheon, the author was cautioned about outsiders 'snooping' and was told not to use the conventional radios for anything other than routine contact to maintain privacy and control the public's perception of the Antarctic research. For example, in an emergency, residents were advised to use the satellite Iridium phone to communicate details.

Reframing Radio in the Antarctic Context

The following atmospheric scenario taken from the experience of the author illustrates other barriers to communication on the continent:

While I was in McMurdo, I heard stories of many of the other bases: the German base that is a complicated system of underground tunnels allowing residents to work in summer or winter under nearly the same conditions; the Russian base, Vostok, located at what is known as the 'Pole of Inaccessibility' and the most remote and harsh environment on the whole of the continent; the Italian base rumoured to have the best food and most beautifully designed architecture; and, of course, the South African base where the previous summer the Polar Radio project had first set ground. I became fascinated with these stories, which seemed almost mythological to me, and I innocently asked how I might get a chance to visit these bases, at the very least the Italian base, which was closer to McMurdo than the South Pole where I had recently visited. I learned that travel between bases operated by different countries was highly restricted and that only scientists working collaboratively on an approved project were allowed to make such travel. In fact, it was usually easier for a scientist from one country to travel to another country's Antarctic base from that host country than to travel between bases on the continent.

The tightly controlled nature of interaction in Antarctica became shockingly apparent to me while at the South Pole station. The weather at the South Pole on the summer day I spent there was to me almost unbearably cold. I had hoped to do a lot of filming outside, but the cold kept me behind the glass of the newly inaugurated station. I fixed my camera on the circle of flags that represent the thirteen countries of the Antarctic treaty and began to film. At the corner of the frame I noticed a small orange tent with some people standing around it less than 500 yards from the entrance of the giant, state-of-the-art main station. I asked a nearby researcher what was happening, thinking that this might be an experiment in the human body's response to cold weather over an extended time period. Instead, I learned that the people in the tent were a group of adventurer-athletes who as a result of their training had received support to ski from the edge of Antarctica to the South Pole. This gruelling task takes several weeks through a completely featureless white landscape. I thought that the residents of the South Pole station, a quite small number of a few hundred compared to over a thousand at McMurdo, would welcome the adventurers into the station for a meal and human contact, but instead I was told that in order to preserve resources, as a policy no unauthorized person was allowed into the base.

While I watched, a small Basler aircraft landed near the tent and these unknown adventurers boarded the plane, having never interacted with anyone on the American base.



Figure 21. Antarctic explorers and tent at the South Pole station visible on far left Andrea Polli (2008)

The absurd situation outlined in this scenario was created by the will of political leaders who know very little about what it is like to live in Antarctica. The international politics of reframing the broadcast radio paradigm in the Antarctic context is the subject of the *Polar Radio* project by Radioqualia and I-TASC (the Interpolar Transnational Art Science Constellation). The project's Web site identifies *Polar Radio* as Antarctica's first ever artist-run radio station. Their first station began FM broadcasts of new music, sound art, documentaries, and live shows in December of 2006 in the Dronning Maud Land sector of Antarctica, the site of the South African base, SANAE IV, with plans to eventually broadcast in between several Antarctic bases. While *Polar Radio* was inspired by the history of amateur radio broadcasting at the poles for both science and global communication, its intention is to create an international radio network that is a platform for creative work. *Polar Radio* aims to promote discussion and collaboration amongst

the researchers living in Antarctica, enable researchers to share information about their respective bases, make it possible for the many artists-in-residence and others at the bases to communicate their creative work to the wider population of Antarctica, and broadcast creative work produced both in and outside Antarctica through a continental radio network and through the Internet (MediaShed 2009). The *Polar Radio* project is one example how sound transmission can be used to work against the restricted and confined uses and promote greater collaboration between nations and disciplines.

The author proposed an open radio project connecting *Polar Radio* to the McMurdo administration, but the idea was immediately dismissed as completely out of the scope of what was permitted. In casual conversation about the idea within the McMurdo community, it was revealed that a pirate radio station had been in operation in McMurdo intermittently over the past fifteen years. The Raytheon staff clearly considered this pirate station a serious violation of the policies, suggesting that this station clogged important channels of communication and put residents in danger. Long-term McMurdo residents the author spoke with took a different view, applauding the efforts of the pirate radio station and the operator's ability to evade detection. These residents did not believe that the station posed a threat to their safety, citing the essential communications channels are not those used by the pirate station. Despite Raytheon's best efforts, the operator of the pirate station had not been found by the time the author left Antarctica, but if he or she had been, there would have been serious consequences.

Interdisciplinary Exchange through Listening to McMurdo

In order to bring McMurdo residents from various backgrounds and disciplines together around the topic of sound, the author held an open field-recording workshop called a 'sound walkabout'. The author's goals for conducting the workshop included sharing an enthusiasm for listening to soundscapes and learning about the Antarctic soundscape from various people who had spent a significant amount of time living there. The workshop attracted a diverse interdisciplinary audience of about fifteen participants, from carpenters and physicists to architects and boiler technicians. Each participant brought a unique perspective and identified a special place they wanted to record. Although a variety of microphones and recording devices were provided for participants to use, some brought their own equipment, including handmade devices. The following scenario, written from the perspective of one of the actual participants of the workshop, helps to illustrate the experience:

Dr John W. Mitchell is an astrophysicist in the High Energy Cosmic Ray Group, Astrophysics Science Division of NASA/GSFC in Greenbelt, Maryland. Since 1985 he has been designing instruments for measuring cosmic rays using long-duration balloons (LDBs) and satellites. In 2007/2008, Dr Mitchell was in Antarctica as the principal investigator for the BESS-Polar (Balloon-Borne Experiment with a Superconducting Spectrometer—Polar) LDB. This large-scale project used a cosmic ray spectrometer to measure cosmic-ray particles with a focus on searching for exotic sources of cosmic antiprotons (Goddard Space Flight Center 2010). The work is gruelling, physically and mentally taxing, not only when the project is underway, but also during the long periods of waiting for the perfect weather conditions under which to launch the football-field sized balloon and waiting for the data to come in once the balloon is launched. December 2007 was the second LDB launch of John's project, the first being three years earlier in 2004.

His second time directing this project in Antarctica, John had become accustomed to the routine and began looking around McMurdo Station for something to occupy his downtime. He noticed a flyer with a hand-drawn cartoon penguin on it in the mess hall. The penguin was facing into a large funnel, and upon closer inspection he realized that the cartoon was a parody of the famous RCA advertisement known as 'His Master's Voice', where a dog is listening to an old Victrola. The flyer announced a 'sound walkabout' and invited interested people to meet at the entrance of the mess hall after dinner that evening. The large entrance area was commonly used for meetings and displays, in fact the previous evening he had watched a presentation of a new design for the Mars Rovers by a team of engineers from MIT. John decided to take a peek to see what the sound walkabout was all about.

A group of about fifteen people gathered in the entranceway at 7:30 PM; two members of the group had an array of microphones and recording instruments lined up along the stairwell. The walkabout leader, a resident artist and a communications specialist described the microphones and the idea of a 'soundwalk' to the group. As far as John could gather, the group was going to walk around the base listening for sounds unique to Antarctica that could be used to define the base's 'soundscape'. Just a few weeks earlier, John had been thinking about the unusual soundscape he had been experiencing at McMurdo. He spent almost a day on the ice runway for the launch of the LDB that held his research payload. The ice runway is in the centre of a vast ice field surrounded by large mountains, including the famous volcano, Mount Erebus.

The isolation, cold, flat ice, and surrounding mountains created a strange sonic experience for John on the runway, as the sounds were sharply reflected. When the giant balloon was filled with helium using tanks the size of large semi trucks, the vast expanse was filled with a deafening screech. Then, once filled, the balloon launched in an almost ethereal silence. John was still thinking about that contrast as he teamed up with a young man next to him and grabbed a recorder, a set of headphones, and a boom microphone to set off on the soundwalk.

Despite the late hour, McMurdo was brightly lit by what would be considered an afternoon sun someplace nearer to the equator. During the austral summer, the light at McMurdo never went away and dorm room windows were covered with heavy curtains to create the illusion of a real night and day. For John, this phenomenon was just another advantage to doing his work in Antarctica, for he could scan the sky to see the progress of his balloon payload at any time of day or night, and the light gave him the energy to work longer hours designing and calculating current and future projects.

John's partner for the soundwalk was Jason Seehafer. Jason had worked in the carpentry shop at McMurdo every summer season for the past eight years, and John discovered that he had designed and built some of the trusses that protected his project's multi-million-dollar payload. Jason was also a sculptor and wilderness guide who had hiked the entire Pacific Coast Trail. The unlikely pair set off listening for sounds around the base and was surprised at the variety and subtlety they found. The base was dominated by the sounds of its human inhabitants, but these human-made sounds seemed different from those you might hear in an urban area. The sounds of life support, the heating systems that the group discovered with the help of a participant who worked as a boiler technician, the wastewater treatment plant, and the water and gasoline travelling through the pipes overwhelmed even the sounds of transportation, the giant vehicles that would travel over the uneven surfaces of rock and ice with chains and treads. John and his partner thought about the various categories of soundscape discussed in the introduction to the soundwalk, listening for the 'keynote' of the base, 'soundmarks' that could be heard at McMurdo and nowhere else, and the very prominent 'sound signals' that guided overworked scientists around the treacherous construction areas on base that seemed to be constantly growing and changing.

John switched microphones and recorders a few times during the walk, using the in-ear binaurals that captured a back-up sound signal from a delivery truck coming from the ice runway. Focusing on the base in this way allowed John some time to escape from his research

and gain a new perspective on his surroundings. He thought that this process was similar to what he did looking for evidence of cosmic rays from the distant universe. At best he could find trace evidence of these rays, examining them in a very indirect way, like his examination of sound during the soundwalk. Like sounds, the traces of cosmic rays would appear and disappear, and he would have to use the traces to determine where the rays originated and where they were going. As the group listened to the motors of the NASA satellite receiver on top of a nearby hill, John imagined the sounds that his payload might hear travelling through the upper atmosphere around the Antarctic continent.



Figure 22. Dr John Mitchell and Jason Seehafer recording at McMurdo, Andrea Polli (2007)

Soundwalking is a well-established interdisciplinary practice that was first described by acoustic ecologist Hildegard Westerkamp (1974), and many of the terms used in soundscape analysis, like

keynote and *sound signal*, were coined by R. Murray Schafer (1977 [1994]) who advocated for an extremely interdisciplinary field of soundscape studies. Focused listening builds knowledge. As sound scholar Brandon LaBelle states: “Without listening there is no communication, no exchange, and no understanding. It is a prerequisite for participation, intervention, and interactivity that one’s input responds appropriately to the aesthetic-communicative intention of the media-defined setting, fulfils it, and completes it. Even in the age of networked media architectures, the practice and discipline of listening remain the origin of creative and intellectual sovereignty” (LaBelle & Jensen 2007, p. 69).

Participants in the author’s sound walkabout workshop were representative of the highly interdisciplinary community at McMurdo and were given a chance to communicate with one another in an alternative way, through experiencing and sharing the sound environment of Antarctica. In informal interviews after the experience, participants spoke about being inspired not only by observing and interacting with the Antarctic soundscape but also by the rare opportunity to interact with people outside their field. Many of the climate scientists interviewed by the author also highly value interdisciplinary interaction.



Figure 23. Participants in the sound walkabout workshop, Andrea Polli (2008)

For example, Andrew Fountain spoke of the importance of interdisciplinary interaction in advancing climate science: “To really understand the system you can’t rely on just atmospheric science because there’s interactions with the ocean, the land, the ice sheets—the biology in the oceans and on the lands . . . this whole interdisciplinary world is critical for us to understand how the system is working. Until you really find that integration, you don’t really understand the system. You understand a part of one component” (Fountain 2008).

The sound walkabout workshop sought to expand the interdisciplinary experience beyond interdisciplinary scientific collaboration by creating focused data-gathering interaction among people from many different disciplines and backgrounds. After the sound walkabout workshop, the group decided to share their listening experiences with the larger community of McMurdo by hosting a soundscape listening party at the local coffee shop. This concert was highly attended and was standing room only. The author also shared the listening experience with audiences outside of Antarctica by regularly posting soundscape recordings on the blog at the

90degreessouth.org Web site and later by publishing the audio CD, *Sonic Antarctica that* includes her own soundscape recordings of the continent.

If continued work is possible in Antarctica for the author in the future, the soundwalking experience and the subsequent creation of soundscape compositions could be expanded to a longer workshop, with group meetings every week for a one- or two-month period, and to the development of a radio series created by residents about the Antarctic soundscape featuring completed works that combine interviews with field recordings. Soundscape recording is a kind of environmental data gathering, and the climate science view that data becomes more valuable the longer it is collected applies to these soundscape recordings (Fountain 2008). A longer-term establishment of in-depth workshops at McMurdo Station on creative radio production, in combination with the efforts of the *Polar Radio* project, might also serve to begin to change the culture of tightly controlled uses of radio in Antarctica to a more open paradigm that encourages collaboration using radio as a medium. A cultural shift towards collaboration using sound could have a positive effect on the scientific work being done at the poles. In the context of the LTER, Fountain spoke of the need for interdisciplinary collaboration to occur over long time periods: “It actually takes a while, to learn what the other disciplines are, and to get used to each other’s working style, such that we’re comfortable working together. Really it was only after our first six-year [LTER project] that I think we really started to do interdisciplinary work. . . . For me, it’s really broadened my view of what’s happening in the [dry] valleys. . . . Now I have a much wider perspective of how glaciers are part of the whole system” (Fountain 2008).

The soundscape is another part of the whole system of an environment, and the interdisciplinary practice of soundwalking provides an alternative pathway for understanding that system. The next section will provide examples of ways in which the author discovered another kind of sound transmission, data sonification and audification, being used by scientists for Antarctic research.

Data Sonification and Audification by Scientists at McMurdo

While at McMurdo, the author had the opportunity to interview and work alongside two Antarctic scientists who were making seismic audifications and sonifications. Dr Rick Aster was co-principal investigator for the Mt. Erebus volcano observatory project with his colleague Dr Phil Kyle (Johnson et. al. 2005). Part of their project involved recording motions of the Earth’s surface on the volcano at various points and using that information to understand how the

seismic waves, the solid-earth equivalent of sound waves, bounced around inside the volcano and how they were generated by volcanic eruptions. Aster was transforming signals from Mt. Erebus with a lowest harmonic frequency of around 1 hertz. When he decided to speed up the signals 100 times to move the information into the audible band and listened, he discovered musical sounds like horns and whales. He and his collaborators, Dr Douglas MacAyeal at the University of Chicago and Dr Emile Okal at Northwestern University, discovered that these musical sounds came from iceberg tremor signals (Martin et al. 2010). In an interview with the author, Aster outlined what he found significant about these audifications: “I’m a guitarist so I was very interested in the harmonic structure of this [seismic information]. . . . So this of course is also one way for me to think about the science when I hear these sounds because we all have a spectrum analyser in our heads, especially those of us who have played music for a while, and it’s kind of fascinating to think about the analogous ways that nature makes sound and human beings make sound with musical instruments . . . when you hear a sound in nature it usually has some analogy in the orchestra” (Aster 2007).

Despite the technological pitch-shifting process required to bring the seismic vibrations into the audible range, as evidenced in this quote, Dr Aster clearly believed the sounds of the seismic audifications to be a part of the natural soundscape. Throughout the interview he spoke about instrument analogues and how listening to the sound of the signal could tell scientists about the seismic structure: “The signals I’ve been studying from Erebus that are particularly musical are the iceberg tremor signals . . . they sound like horns and whales and swooshes and all kind of interesting, wind noise, all kinds of interesting sounds . . . as these icebergs grind against each other, they basically produce a sequence of tens of thousands of tiny ice quakes . . . it’s sort of like the macroscopic version of the squeaks you might get from a hinge or from pushing a heavy piece of furniture across a polished floor, . . . or the squealing of tires, because those are just a sequence of thousands and thousands of little stick-slip events” (Aster 2007). Aster and MacAyeal’s listening to the audifications influenced the scientific outcomes because the unusual sounds they discovered inspired them to place seismic instruments on the iceberg, which allowed them to gather more detailed information about the structure of its movement.

Another Antarctic seismologist, Dr Robert Smalley, was interested in listening to seismic signals, but in this case not by audification or pitch-shifting the vibrational information, but rather by transforming the data into the amplitude and pitch of simple sine waves. Unlike Aster, who was interested in the scientific potential of interpreting the resulting seismic sounds,

Smalley was interested in the public communication of the seismic data. He was interested in designing sonifications of seismic events that unfolded at the same speed as the actual event, for example, he presented twenty minutes of the greatest intensity of an earthquake in a twenty-minute minimalist style sonification. He worked closely with the author while developing his sonifications and presented his experiments to the public alongside audifications by Aster and MacAyeal and the soundscape recordings by the sound walkabout participants at the McMurdo coffeehouse concert organized by the author.

The combining of sonification and audification works by scientists with soundscape recordings by scientists and other members of the McMurdo community have great potential to serve both scientific research and scientific communication and is a rich area for further research. Several audience members of the coffeehouse concert expressed surprise at the sonifications and audifications, finding the sonifications extremely musical and the audifications very similar to some of the Antarctic wildlife recordings also presented at the concert. Other audience members talked about the feeling of being physically transported to the location where the soundscape was recorded. A small amount of scientific information was available to the audience, but a more focused approach to public presentation could provide audiences with greater detail about both the science and geography of the works presented, perhaps through a combination of text and maps. Like soundscape field recording, data audification and sonification in Antarctica presents a rich area for blurring the disciplinary boundaries between art and science. The next section discusses artists' sonifications and audifications of Antarctic data.

Sonic Antarctica Case Study

While in Antarctica, the author collected a large amount of numerical data from climate and weather scientists and later created a series of sonifications of this data. The data consisted of ice movement data from various sites, weather balloon data from the South Pole and McMurdo, and data from climate monitoring weather stations in the Dry Valleys. The author combined these sonifications with excerpts from the audio interviews she conducted with scientists and soundscape recordings she made in Antarctica on the aforementioned audio CD, *Sonic Antarctica*.

Other artists have explored ways in which Antarctic data may be translated into sound. In 2007, the artists' collective, Mongrel, produced the *Antarctic Data Jam* in conjunction with MediaShed and I-TASC using data collected by weather monitoring equipment sent to the

Antarctic by SoSLUG. The group held workshops during which participants created sonifications from the data using open source tools and produced an audio CD with the resulting compositions. The *Antarctic Data Jam* producers invited electronic musicians and artists, programmers, students, and the general public to make songs, images, videos, or noise with the raw Antarctic weather data they provided. Guidelines for the project were very open, and although they provided a piece of software people could use to translate the data to sound, participants were also invited to collect their own Antarctic sounds via the Web. The only requirement was that the resulting pieces have some or all Antarctic sound or data content (MediaShed 2008).

The *Antarctic Data Jam* was a project that took advantage of and lived in the digital sound environment. Data and sounds were transmitted extensively via the Internet, and the works were primarily digitally produced. While traditional radio is technically a ‘push’ medium, sending signals out to receivers whether under the communications or the broadcast model, the digital environment, whether experienced on an Internet terminal or on a wireless device, operates on the ‘pull’ principle, sending information only if the receiver requests it. Through the digital, the paradigm of radio as broadcast is structurally and functionally transformed into radio as multiuser interactive space. By emphasising the input of community, projects like *Sonic Antarctica* and *Antarctic Data Jam* use this model as a basis for the work.

The soundscape of the Arctic and the Antarctic has also been transmitted via the Internet, and recently there have been distributed listening projects that transmit sonic information related to ice, climate change, and arctic ecosystems in real time using mobile phone technology. In 2007 two art projects allowed the general public to call and listen to glaciers in real time. In March, Kalle Laar placed a weather-resistant microphone at the gauging station run by the Commission for Glaciology of the Bavarian Academy of Sciences and Humanities at the Vernagtferner Glacier in the Oetztal Valley in Austria and transmitted the sound of the glacier using a mobile phone modem. Laar’s work (2007) was presented in June at the Venice Biennale as part of the *Mobile Journey* exhibition on the Island of San Servolo. Also in June 2007, as part of her thesis exhibition at the Slade Gallery in London, artist Katie Paterson launched *A Graveyard of Glaciers* that included the ability to call Iceland’s Vatnajökull, the largest glacier in Europe, on a mobile phone number. Paterson (2008) submerged underwater microphones and gained the support of Virgin Mobile for the phone link. *The Guardian* suggested that people call Vatnajökull and “listen to its death throes, live, through a microphone submerged deep in the

bitterly cold lagoon which relays the splashes, creaks and groans as great masses of melting ice sheer off and crash into the water” (Kennedy 2007).

Real-time Antarctic listening projects have been presented online in a scientific context. In 2008, the Alfred Wegener Institute’s (AWI) PerenniAL Acoustic Observatory in the Antarctic Ocean observatory (PALAOA, Hawaiian for whale) began providing an online live streaming feed of sound collected by hydrophones beneath the ice of the Antarctic ocean near Neumayer Station and the Ekström ice shelf (AWI 2008). The German scientists involved in this project aim to record this underwater soundscape that is relatively free of anthropogenic disturbances for as long as possible and at a minimum several years in order to study the bioacoustics of whales and seals and to examine the effects of climate change and sporadic shipping traffic on the behaviour of these marine mammals. PALAOA states that it has made the live audio stream and webcam images available to the general public in order to satisfy the Berlin declaration of “Open Access to Knowledge in the Science and Humanities” required by AWI policies. While listening to the stream can be a relaxing experience, PALAOA’s site warns listeners of sudden extremely loud iceberg calving. Although the ice shelf is very thick, the scientists have also prepared for the possibility of parts of the shelf breaking off. They have equipped the wireless hydrophone systems with advanced GPS to follow them if they eventually float out to sea on an iceberg (Madrigal 2008).

Through digital production and transmission, the MediaShed’s *Antarctic Data Jam* and the author’s sound walkabout and *Sonic Antarctica* projects emphasise the digital paradigm of many to many, encouraging open resource sharing and collaboration. This paradigm is unlike either the communications or the broadcast model of radio. However, like radio, both of the art and science real-time online listening projects discussed in this section created the illusion of transporting a listener to a remote location. The medium through which listeners experienced this remote location had a strong effect on the illusion. In the author’s experience, listening to both the glacier phone calling artists’ projects and the online scientists’ project provoked an intense feeling of presence in another geographical space. Although the real-time aspect of this listening added an intensity to the experiences of both projects not often present when listening to field recordings, the medium of the telephone, held closely up to the listener’s ear without the distraction of visual maps or charts, made the glacier phone calls a much more profoundly intimate experience than listening to the PALAOA sounds over the Internet. The telephone created a feeling of urgency, as if one was receiving an emergency 911 call. As a listener, the

author felt a strong desire to reach out through the telephone lines to help the melting glaciers. The next section will discuss how the author's *Sonic Antarctica* recordings were an attempt to create a kind of intimacy while providing real information about the complexity of climate change to listeners.

The author's *Sonic Antarctica* CD combines field recordings of the human and natural Antarctic soundscape, sonifications of weather and climate data, including data from weather stations, weather balloons, and ice movement. The structure of each composition loosely follows that of a radio documentary, as described by Aurelio Cianciotta: "Polli alludes to the radio-broadcast format but develops a new audio-based art with a genuinely scientific basis and an aesthetically dense style" (Cianciotta 2009).

In the work, humorous dialogue is combined with more serious discussion of climate change. Henry Lauer finds this humour to be something that draws him into the subject as he writes: "Thus I loved, for example, a geologist's tongue in cheek explanation about how geology is the true prince of the sciences. . . . It's pretty hilarious to know that scientists, especially ones so devoted to their work, can make fun of themselves. In general society science is seen as such a serious, straight-laced, stodgy and boring business. This CD humanises these folk quite beautifully and I really enjoyed the contrast between the warmth of the interviewees and the frigid realm in which they work" (Lauer 2009). For Lauer, understanding the humanity of the scientists gave him a feeling of empathy for the politicization of their work: "But the real power comes toward the end of the CD, when researchers talk about politics and the science of climate change. They express their dismay that all their hard work, their determination, sincerity and rigour, can be attacked, trivialised and dismissed in the political arena so easily and with so little concern for truth or consequence. This is the telling point of this release: that here, in perhaps the coldest place on earth, researchers still feel the political heat for revealing the inconvenient truth of global warming. It is really powerful to hear their personal perspectives on this issue because these are perhaps the only people on the planet who have a full appreciation of the problem" (Lauer 2009).

The interview excerpts in and research represented by *Sonic Antarctica* merely scratch the surface of the vast amount of scientific research being done at the poles, but the interviews and research show that scientists and other field workers in Antarctica have an interest in recording and listening to the soundscape and to audifications and sonifications of scientific data, and that the combination of field recordings, sonifications, and interviews with scientists can

help members of the general public understand and empathize with the work of these polar dwellers.

Conclusion

Making contact with the Arctic or Antarctic can be the proudest achievement of a dedicated amateur radio enthusiast. These places not only represent the farthest geographical points on the globe, but their relationship to the ionosphere also makes these locations an important centrepiece of long-range radio transmission and reception. As shown by the El Buen Tono example, broadcast radio can create an entertaining and inspiring fantasy image of these areas to the general public. However, due to the extreme climate of the Arctic and the Antarctic and the related fact that these places have a relatively low amount of human presence, the function of radio is very different there than in more populous areas of the Earth. In Antarctica, radio is primarily a communications tool used for logistical operations with a small amount of communications with DXers and broadcast news radio for residents. This relatively blank slate provides an opportunity for media projects like *Polar Radio* to reframe the paradigm of broadcast radio in the field.

Seismologists Rick Aster and Robert Smalley found audification and sonification useful to their scientific research as well as beneficial to raising public awareness, and Andrew Fountain and Peter Doran observed the need for longer-term interdisciplinary collaboration for understanding climate complexity. Projects like *Polar Radio* and *Sonic Antarctica* provide alternative pathways to help scientists forge interdisciplinary collaborations and communicate their research to the wider world. Once these pathways are open, they need to be extended in time. A multiyear soundscape recording and radio production series of workshops and concerts that include sonification could serve to enhance interdisciplinary collaboration and advance science in Antarctica.

The Internet has also changed the paradigm of broadcast radio to a more distributed model, and media projects that use the Internet to stream sound live from melting glaciers and the Antarctic have been made in both an artistic and scientific context. Douglas Kahn (2009) has said that the annihilation of space and time is the goal of radio, but while these transmission projects transcend a seemingly insurmountable distance in near real time, in content they are firmly grounded in the present time and the political and geographic dimensions of the Earth. *Polar Radio* focuses on possibilities for international collaboration in a place where strict

boundary lines are drawn, while *Sonic Antarctica* draws connections between scientific and artistic disciplines through combining interviews, recordings of the Antarctic soundscape, and sonifications of climate data. The two live ice listening projects discussed in this chapter draw attention to the rapidly changing climate of the Arctic, an anthropogenic phenomenon that is an emblem of our present era. Structurally, metaphorically, and aesthetically, all the projects discussed in this chapter reframe transmission from a polar perspective, giving a voice to both the people living in these remote locations and the rapid melting occurring there due to anthropogenic climate change.

In conclusion, because of the complexity of the information and the misinformation in mainstream media, there is a need for more direct public communication of weather and climate science. Sound offers a way for scientists to bring their messages directly to the public, through recordings and radio transmissions and by the audification and sonification of scientific data. Listeners often respond to sound with emotion and empathy for the scientists' messages. Interdisciplinary collaboration is essential to the work of climate scientists in Antarctica, and sound transmission allows for communication and possibly collaboration across vast distances, especially near the poles. For these reasons, these geographical areas can offer an opportunity for innovative uses of sound transmission, and this sound can contribute to the public understanding of climate change within the context of the Arctic and Antarctic.

While radio transmission may play a role, it is not the only way in which scientists in Antarctica understand their environment. In addition to using advanced monitoring equipment, these scientists and researchers have made use of embodied knowledge extensively. In the next chapter, *Ground Truth*, the author will analyse in detail the ways in which atmospheric scientists and researchers in Antarctica gathered data and used their bodies to transform this data into environmental knowing.

Chapter 5. Ground Truth [Focus: The Antarctic Dry Valleys]

Introduction

In this chapter, the author will argue that affective experience plays an important role in the gathering of scientific information about weather and climate. The physiological and cognitive effects of the bodily experience of weather and climate will be compared and contrasted with the physiological and cognitive effects of experiencing sound through soundwalks, electro-acoustic soundscape compositions, and geosonification works. Information from interviews with weather and climate scientists in Antarctica will be compared with the work of performance artists who have pushed the body to physical extremes.

In addition to the author's own experiences in Antarctica, interviews with weather and climate observers have provided a new approach. For example, in interviews with members of the Long Term Ecological Research (LTER) group monitoring shifts in climate over time inside the Dry Valleys, the author found evidence about the role of physical experience in information gathering. The subject of embodiment will be addressed through the results from the author's video essay titled *Ground Truth*, which compares the collection of data through automatic weather stations with the human body's actual experience of extreme weather. *Hello Weather!*, a temporary public artwork by the author, will further examine the experience of weather and real-time weather monitoring data and aim to demonstrate the potentials to bring this experience to the public.

The main questions of this chapter are:

1. What role does affective experience play in the gathering of scientific information about weather and climate in extreme environments like Antarctica?
2. How can ecomedia, soundscape, and geosonification artworks about the human experience of extreme environments construct alternative pathways to understanding weather and climate?

Human Weather Observers in Antarctica

Human beings are already endowed with a sophisticated set of weather sensors: rain, heat, and cold are felt on the surface of the skin; clouds, fog, and lightning are seen with the eyes; heavy winds and thunder are heard by the ears; and changes in atmospheric pressure are experienced in the body. A database of these sensory responses is not only stored in human memory, but in any situation the brain can also call up these memories and evaluate the sum of

sensory experiences in order to make future predictions. Thus the body is a weather station combined with the predictive and interpretive capabilities of a weather database and models. However, although extremely effective in gathering qualitative information, the human brain lacks the quantitative abilities of computerized weather instrumentation.

When humans spend time in extreme environments like those of the Antarctic, the accuracy of weather information is necessary for safety and survival. It is also very important to precisely track weather in the Antarctic because melting and other events have the potential to transform global weather patterns that can cause disastrous changes across the globe in areas including temperature, sea level rise, and wind circulation (Cassano 2008; DeRosa 2008). In this chapter the author will discuss how humans gather and transmit qualitative information about weather and climate in Antarctica, and how this sensory experience may be interpreted and expressed via geosonification and ecomedia works by artists.

Human weather observers have been stationed in Antarctica for over fifty years. Despite the isolated location, their work plays an important part in the generation of weather and climate forecasts throughout the world.



Figure 24. Professional weather observers Katie Koster and Victoria Sankovic and NOAA Researcher Andy Clarke, January, Andrea Polli, The South Pole Station Antarctica (2008)



Figure 25. Long Term Ecological Research Group (LTER) automated weather station December, Andrea Polli, The Dry Valleys Antarctica (2007)

For example, during the 2006–07 season, there were fewer than one hundred automated weather stations collecting data within the over 14 million square kilometres (5.4 million square miles) that form the Antarctic continent. Human observers supplement this limited weather station coverage. Of course, unlike weather stations, human weather observers are also able to assist in day-to-day camp operations. Remote camps such as the West Antarctic Ice Sheet (WAIS) Divide and Siple Dome usually have one or two trained meteorological technicians (known as MetTechs), who in addition to collecting meteorological data may conduct radio operations, shovel snow, fuel vehicles, and help cook meals (Australian Government Australian Antarctic Division 2009).

Human weather observers play several other roles in Antarctica: they verify data from instruments, provide contextual geographical information, contribute overview information (for example, cloud heights and visibility), conduct real-time analyses, and give users confidence in the data (for example, they send real-time radio updates to pilots and air passengers). Because human observers can quickly assess weather conditions with limited equipment available at a remote field, MetTechs provide baseline information for aviation forecasts and atmospheric science research. A substantial amount of training of MetTechs focuses on determining cloud ceiling heights for aviation. Whether a cloud is at 900 metres or 200 metres (3,000 feet or 700 feet) can literally be a matter of life or death for a pilot, and automated weather stations cannot provide this kind of overview information with any reliable accuracy (Carmody 2008). According to several weather and climate researchers interviewed by the author in Antarctica, it is unlikely that pilots and passengers would trust their lives to the data from a machine without real-time human verification, even if the automatic stations were able to provide the same overview information (Cassano 2008; DeRosa 2008).

The author witnessed firsthand the powerful authority of a weather observer at the South Pole. During an interview with South Pole weather observer Victoria Sankovic, a C-130 flight came within range of the station. Sankovic had the sole authority to determine whether or not this plane, containing about twenty researchers and much-needed supplies, would be allowed to land. While the plane was approaching, the weather observations that she had been taking hourly necessarily increased in frequency until she found herself out in the -27 degree Celsius air every five minutes trying to determine whether the visibility was adequate for a safe landing. She kept the plane in the air circling for almost three hours waiting for a window of visibility and nearly directed the plane to turn back. A decision to make a C-130 military aircraft turn around, a

situation called a ‘boomerang’, is taken very seriously in Antarctica. The wasted fuel of a boomerang can cost over \$50,000 in addition to lost research time, but the safety of the passengers and crew must take priority (National Center for Atmospheric Research 2009). At last, Sankovic spotted a clear window and the plane was able to land. At the South Pole and other Antarctic sites, weather observers can undergo this agonizing process as much as twice daily during the busy air traffic in the austral summer season.

As this episode indicates, despite the expense of keeping the human body alive in a dangerous environment like Antarctica, human weather observers are not only prominent, they are also essential to field operations. Human weather observers must sense weather conditions with their bodies and respond rapidly to changing conditions. In matters of life and death in the field, the sensing capabilities of the human body are trusted more than the state of the art instruments. How does the body gather this essential information about weather and climate in contrast to automated weather stations?

Automated Stations Compared to Human Observers

The author interviewed several scientists in Antarctica who stressed the importance of human weather observers. Jeffrey DeRosa and others reaffirmed that stations are unable to provide accurate information about precipitation and cloud cover (DeRosa 2008). Human observers can conduct continuous observations, while weather stations can only gather discrete measurements of data. Human observers have the ability to refer to memories of experiences to make a real-time analysis of a situation, while an automated station is able to store information but cannot analyse in real time.

A basic automatic weather station in Antarctica has a suite of sensors that measure the temperature, pressure, relative humidity, wind speed, and wind direction. Some stations have additional sensors to measure variables such as snow temperature, water temperature, and perhaps even a range of vertical temperature from the top of the station tower to the bottom. If the station is connected to a network, the data are directly transmitted to a weather satellite. If not, a human technician must download the data (National Center for Atmospheric Research 2009).

Unlike humans, stations can stay in one spot in extreme environments for long periods of time; however, like humans, stations are susceptible to wear and tear. Matthew Lazzara, a meteorologist in the Antarctic Meteorological Research Center at the University of Wisconsin–

Madison who is the Principal Investigator on the Antarctic Automatic Weather Station project, explained some of the problems with maintaining the stations over time: “Some of the biggest challenges in getting weather observations in the Antarctic are being able to keep the stations that we have running. Some stations are susceptible to those high wind conditions that the Antarctic experiences and don’t survive a whole year. Some stations are in marine environments, and they are either corroded away or succumb to the icing conditions that they may experience . . . after a few years, those weather stations do eventually become buried [in snow]. So we do have to routinely revisit them on some regular schedule, unbury the instruments, and add new sections of mast or tower to our stations and then reapply the instruments to the tower to keep those sites running” (National Center for Atmospheric Research 2009).

Besides the human maintenance of instruments, some scientists discussed the value of nonquantitative information gathered by human observers to scientific research (Basagic 2008; Cassano 2008; DeRosa 2008; Fountain 2008; Sankovic 2008). Dr Andrew Fountain, principal investigator of the Antarctic Long Term Ecological Research (LTER) project explained: “For us, there are two ways to look at it, and one is just the maintenance of the instruments. Because, for example, measuring the sunlight with a sensor—well, if a windstorm comes along that bends the sensor we wouldn’t necessarily know that. We would just say ‘oh, it’s getting a lot cloudier’ or something. So just the basic visits to the stations really help. But also, just because you have the data doesn’t mean you understand the system. It’s important to come down and view the landscape and in our case view the glaciers, and [see] how the glaciers are reacting to these changing environments, and that kind of feeds into our understanding and our nonquantitative knowledge” (Fountain 2008). Other scientists also spoke about the value of this nonquantitative knowledge. Dr John Cassano, Antarctic climate modeller and Assistant Professor at the University of Colorado, spoke about how experiencing weather helps him to build better climate models: “I think experiencing the weather that you’re trying to study provides you with . . . a lot of clues and a lot of bits to think about that you miss from just having a weather observation that just tells you the temperature is this and the wind speed is this. If you’re standing outside and you feel the gustiness of the wind or you see the way the clouds are moving across the sky, these are intangible things that are providing clues. . . being on the ground and seeing what a place is like and seeing what the weather is like there gives you an intangible sense of the location there and improves your interpretation and your understanding of what your computer model is telling you or what the weather data is telling you” (Cassano 2008).



Figure 26. LTER Researcher Hassan Basagic performing yearly maintenance on automated weather stations in the Dry Valleys Antarctica, December, Andrea Polli (2007)

Although most nonscientists would refer to the bodily experience of weather as ‘tangible’ rather than ‘intangible’, as a climate modeller, Cassano was not alone in describing sensory experiences as intangible and the numerical data as tangible (Fountain 2008; Voigt 2007). To a weather and climate modeller, numerical data is necessary to create representations of both current and future scenarios. Information gained from a physical experience of weather cannot currently be quantified in the same manner that information from weather sensors can be, and therefore bodily experience cannot play a major role in computerized models. Computer-based representations of weather and climate are what most meteorologists interact with on a daily basis; they rarely have the opportunity to be present in extreme weather situations like Antarctica. The actual, physical experience of a location is primarily something that is imagined by a modeller while he or she is exploring a screen-based representation. Therefore, to a climate and weather modeller, the representation is the tangible and the lived experience is the intangible.

Despite their prominence, even the most advanced weather and climate models are simplified versions of reality. This simplification is necessary for a useful model (Fischlin 2007). However, scientists often spoke in depth about how bodily experience of the real world detail that weather and climate models lack can help a scientist’s understanding of his or her model. As Cassano explained: “I know that my computer simulations will never fully capture what is being observed there because I’m not resolving all of the details of the small rocky island, and the position of that weather station relative to the geography of the area. And so I think it gives you that sense of how much to expect what you model to match what is actually being observed, because what you’re modelling is different than what’s being observed in reality” (Cassano 2008).

Several scientists affirmed that a keen sense of the limitations of computer models is essential in understanding weather and climate. Cassano also pointed out the limitations of the weather instruments themselves. He stressed the value of human observers on the ground in Antarctica to verify the data from instruments: “Things always go wrong. You get problems, your rain gauge has become blocked with blowing snow, or . . . all kinds of things can happen that a human observer going in day in and day out making measurements would see and an unmanned, untended weather station sitting out there—you have no idea. You might get clues looking at the data that something has gone wrong. I think there’s a real value to human observers” (Cassano 2008).



Figure 27. Dr John Cassano measuring yearly snowfall at an automated weather station site at Windless Bight Antarctica, January, Andrea Polli (2008)

Rolf Hennig, a weather forecaster employed by Scientific Research Corporation, a private company that provides meteorological support for the United States Antarctic Program, also emphasised the importance of experience in human weather observing, specifically in the area of pattern recognition: “The experience level of our forecasters helps immensely with our forecasts. . . . These forecasters that we currently have employed with us have been to the ice (Antarctica) a minimum of four or five continuous operating seasons, so they have had the benefit of having seen every year recurring patterns and are now adept at pattern recognition on satellite imagery. We are at the point now where the experience is so beneficial that if we were to lose these forecasters and hire forecasters that have never been to the ice before, then that learning curve needs to be re-established again with them, and then that learning curve becomes rather steep” (National Center for Atmospheric Research 2009). Despite all the advantages of human observers, Cassano made it clear that one problem with human observers is that they lack the consistency of instruments: “That said, human observers introduce bias, every personal look, some state of the atmosphere and it’s a little bit different to them. They might report a slightly different cloud cover or measure a slightly different cloud base, and so there’s this inconsistency between the observations that a purely automated observation doesn’t have. You know what accuracy your instruments have” (Cassano 2008). What Cassano calls the ‘personal bias’, or the implications of embodied weather perception, will be examined further in the next section.

Human weather observers clearly have some advantages over automated stations. Humans can verify data coming from a station by observing inconsistencies between data and actual conditions and by watching for instrument problems like snow cover and damage. Humans can provide overview information, assessing general conditions much more quickly than machines. The human skill of pattern recognition makes a seasoned weather observer extremely valuable for his or her ability to analyse trends in real time. Despite these benefits, each individual human weather observer’s experiences introduce a personal bias that is far more complex and difficult to correct than errors introduced by automatic stations. However, physical conditions such as snow cover and wind damage can cause stations to sense incorrectly. These inconsistencies, present in data collected by both humans and machines, require that humans work with machines to obtain the most accurate results. The next section will examine the statements of the Antarctic scientists and weather observers through a dual lens of the philosophies of embodiment and social geography.

Embodiment and Ground Truth

In *Where the Action Is: The Foundations of Embodied Interaction*, computing pioneer Paul Dourish examines the philosophical basis of embodiment in human-computer interaction. He outlines two definitions of embodiment. First, he defines it simply as possessing and acting through a physical manifestation in the world. He then rejects this description as too restricted to the physical foundation in favour of a category that encompasses phenomena that unfold in space over time, like conversations and mutually engaged actions. This new definition describes embodied phenomena as those that by their very nature occur in real time and real space, combining the physical interactions with the symbolic (2001, p. 100). This definition of embodiment allows Dourish to include embodied interaction as a part of networked computing. One of his theories of embodied interaction—tangible interaction—includes many of the skills of human weather observers. For example, the skills of “exploring, sensing, assessing, manipulating, and navigating” are essential human skills that Dourish suggests tangible interfaces should exploit (2001, p. 206). While Dourish gives equal weight to these five skills of human beings, the Antarctic weather and climate scientists interviewed by the author focused on the two skills of assessing and manipulating as those human skills most valuable to the task of weather observation (Basagic 2008; Cassano 2008; DeRosa 2008; Fountain 2008; Sankovic 2008). Dourish separates the skills in his analysis, but according to Rolf Hennig, any experienced human weather observer will comment that the skills of sensing and assessing are inextricable.

Throughout his analysis, Dourish criticizes the traditional core of computational media, symbolic representation, but he does not embrace Nigel Thrift’s ideas of ‘non-representation’ (Dourish 2001, p. 206). As a radical embodiment theorist, Thrift’s definition of embodiment includes “tripping, falling over, and a whole host of other mistakes. It includes vulnerability, passivity, suffering, even simple hunger. It includes episodes of insomnia, weariness and exhaustion, a sense of insignificance and even sheer indifference to the world. In other words, ‘bodies can and do become overwhelmed’” (Thrift 2008, p. 10). Thrift’s qualities of embodiment are extremely relevant in environments like Antarctica where the freezing cold can cause bodies to shut down completely, overwhelmed by hypothermia. Thus, Thrift’s nonrepresentational theory posits that “there is no stable ‘human’ experience because the human sensorium is constantly being re-invented as the body continually adds parts in to itself; therefore how and what is experienced as experience is itself variable” (Thrift 2008, p. 2).

Thrift's viewpoint reinforces Cassano's statements about the inconsistency of human observations but confirms that spatial technologies may decrease embodiment. For example, social geographers argue that spatial technologies like GIS can increase the psychological distance between an individual and his or her environment, leading to a marked decline in knowledge of and familiarity with the world (Pickles 1995, pp. 101, 102). Social geography examines the social implications of knowledge of the world, in particular that knowledge gained from geographic information systems (GIS), and since both Dourish and Thrift discuss social and spatial practices, their work has informed this growing field. Dourish, Thrift, and the social geographers agree that while machines are clearly useful, the data they provide are most often static, unable to represent interactions, uncertain phenomena, and to determine the quality of relationships (Pickles 1995, pp. 40, 99). These critiques express much of the same frustrations the Antarctic weather and climate scientists expressed to the author about the weather stations: their inability to provide data for more than one static location, lack of pattern recognition, and inability to provide relational and qualitative data.

Social geographers and the scientists interviewed by the author in Antarctica described 'ground truth' as the antidote to this psychological distance (Pickles 1995). The term *ground truth* was used by the scientists to describe one of the most essential jobs of field researchers, that is, gathering information with the human body, in contrast to the remote sensing of satellites or even the automatic gathering of ground-based data. Seismic researcher Don Voigt described the role of researchers in a typical field operation in Antarctica: "Part of what we were doing was sort of 'ground truthing' where we were getting very detailed information about the ice so that when we fly the radar we know what the radar is looking at because you can get features in the radar data that unless you've been on the ground and looked, you don't know what those features represent" (Voigt 2007). However, 'ground truth' as understood by the researchers seems to derive primarily from visual observations, whereas the work of Dourish and Thrift includes all the senses.

Physical presence in extreme environments has been described as necessary to weather and climate research by Antarctic specialists because human observers can provide timely information, describe detailed features of an environment that may affect the weather and climate, and use past experience to analyse conditions. The relationship between human observers and automated sensors in Antarctica is one of checks and balances, with human observers validating machine data and machines verifying human observations through precise

measurements. Paul Dourish and Nigel Thrift define embodiment in the context of machine-human interaction from the perspective of machine interface design. Dourish provides a basic analysis, outlining five human skills related to embodiment. These skills are clearly valued by Antarctic weather and climate researchers, but Dourish's analysis does not consider how these skills might be affected when the observer is in an extreme environment. Thrift's nonrepresentational theory of embodiment takes the effects of exhaustion, illness, and other causes of weakness into account. These issues are of much concern in Antarctica, for example, the unpredictable margin of error of a human observer as described by Cassano makes machine sensors invaluable in such conditions. Thus, understanding qualitative human experience in relation to machines in weather and climate research is an important issue to scientists in Antarctica. Can art, in particular technology art, in and about these extreme conditions help to further define these relationships and perhaps even build new perspectives? In the next section, the author will discuss the triad of spatial practices, representation of space, and representational space in the context of contemporary technological artworks.

Sociologist Henri Lefebvre analysed the social production of space through three moments: spatial practices, representation of space, and representational space. The term *spatial practice* describes the organization of actions in space: daily routines, transport networks, urban hierarchies, and divisions of public and private space. For example, while *representations of space* are symbolic constructs that describe space, *representational spaces* describe nonverbal symbols and images, the works of artists, photographers, and filmmakers, in other words, the space lived through images and symbols. In Lefebvre's analysis (1974), these three productions of space form a triad where spatial agents move through each part of the three elements seamlessly.

Lefebvre was mostly looking at urban spaces and the influence of capitalism, but it is possible to apply his triad to the working lives of the researchers in Antarctica. To an Antarctic field researcher, spatial practices might include reviewing fixed wing and helicopter flight patterns and schedules, performing radio checks, and making weather observations. To an Antarctic weather and climate scientist, Lefebvre's representations of space would be defined as a combination of GIS, images and data from remote sensing satellites, and weather and climate models. Based on the author's interviews, widespread representational spaces created by Antarctic weather and climate scientists seem to be in flux. For example, after returning from fieldwork on the Taylor Glacier in the Dry Valleys, the author spent several hours with a group

of glaciologists discussing a visualization they had created of changing temperatures inside the glacier. Slight changes to the parameters of this visualization created dramatic perceptual changes in the meaning of this image. Yet at the same time the algorithms and assumptions used to create the visualization were highly controversial. These researchers' experiences of symbolic representational spaces were much more active than Lefebvre's more passive definition.

The author has produced a short documentary, *Ground Truth*, in which Antarctic researchers attempt to express how nonquantitative, experiential information is integrated into the mental models of weather and climate science. In this video essay, the scientists describe the importance of 'ground truthing' and how this information is used to develop and verify models. In a linked Web site, 90degreesouth.org, a full set of these audio and video interviews allows audiences to gain more detailed information about the subject. By asking the scientists to speak directly to audiences about their experiences rather than presenting these ideas filtered through a nonscientist interpreter, the author attempted to create an alternative pathway for understanding the process of weather and climate data gathering and analysis. In these interviews one can find two distinct worldviews. One group of scientists stated that human observers will only be necessary until instruments become advanced and reliable enough to collect the same level of information a human can gather; a second group explained that machines will never be able to collect the same quality of information as humans, and that the human researchers will never accept the validity of information without the 'ground truth'. Therefore, one group imagines the results of computational and sensing machinery to be absolute, while the other accepts a biological mode of sensing and analysis that has intrinsic value, either actual or perceived. Both views accept a current symbiotic relationship between human and machine that is based on embodiment in the space. The experiences of the weather observers are clearly time based and process oriented, thus the level of spatial experience that both Dourish and Thrift make central to their philosophical analyses can be applied to these researchers and their environment. However, the phenomena experienced by the weather observers is often invisible, atmospheric phenomena, and while both Dourish and Thrift discuss invisible social networks between people, interaction between humans and atmospheric phenomenon at this advanced level is not explored in detail by either theorist. This is unfortunate because the experience of invisible atmospheric phenomena is a basic part of human interaction with the spatial environment, and therefore a detailed analysis could provide inspiration to the design of effective social networks. This is a rich area for further research. An important yet invisible aspect of human atmospheric experience is the soundscape.

The next section will examine the extreme sounds of Antarctica and how this soundscape can affect scientific research.



Figure 28. Cover of GROUND TRUTH video essay, showing meteorologist Jonathan Tham at an automated weather station at Windless Bight Antarctica, January, Andrea Polli (2008)

Soundscape, Geosonification, and Ground Truth

The scientists interviewed for the *Ground Truth* video essay commented on three qualities of embodiment: the importance of quantitative knowledge, the visceral experience of a specific field site, and being immersed in a particular place (Polli 2008). As has been described, an important part of the experience of any place is its soundscape. The human experience of sound is inherently immersive, and as R. Murray Schafer and others have described in detail, the elements of a soundscape can give listeners an enhanced sense of place (Schafer 1977 [1994]). Musician and scholar Bernie Krause and others have even used soundscape analysis to determine the health of an ecosystem (Krause 1998). In Antarctic seismic research, sound can be used to augment understanding. Antarctic seismologists Dr Rick Aster and Dr Douglas McAyeal employed audification of ice movement data to help in their analysis of natural phenomena (Aster 2008). Active seismic research (the process of expelling small explosive charges in the ice and recording the echoes of the blast using geophones in order to determine the shape of the surface beneath the ice) is also used in Antarctica. Antarctic researcher Don Voigt was a field researcher in the Pole Net project, a five-year project to map the Transantarctic Mountain Range through passive seismology. Voigt described in detail how his work on the ground with both passive and active seismology has been affected by weather, and in particular he talked about the difficulty of differentiating signal and noise. For example, in relation to an active seismic project in Greenland, he explained: “The wind in particular produces a lot of white noise at the surface. You can’t really correlate it between locations, you can’t really subtract it out, and if the wind starts blowing to the point where the snow is moving we have to stop our work because it just hammers the geophones. They are so sensitive that it will swamp the geophones. Even though these are very sensitive and we have a fairly large explosion, some of the recordings are very small, so just the noise of the snow moving across the surface would swamp the kinds of reflections” (Voigt 2007).

While seismic researchers on the ground listen in real time and make judgements about where and what to record, Voigt was careful to point out that while this makes it possible to analyse data in the field, researchers must limit the amount of analysis to a quality-control level only. Because the field operation in an extreme environment is so costly, it is necessary for researchers to limit their analysis to favour constant moving and making measurements. Voigt described an experience he had in Greenland that applied to his fieldwork in Antarctica as well: “There is information you get, we call it just QC, quality control, information about the records.

If your signal to noise ratio is bad in the field you may want to stack. You can see that. You may want to do closer interval shots so you can get more records to add up the signal and reduce the noise. . . . In Greenland, the signal, the bed, everything was coming out so clearly in the field that it was really quite remarkable, and it was at times slowing us down because everybody was trying to do science when we needed to be collecting data” (Voigt 2007).

Voigt also revealed the unusual nature of the soundscape in the deep Antarctic. He and others confirmed that the Antarctic soundscape was one of extremes, from the very quiet to the oppressively loud: “Some of the quiet times down here are really some of the most interesting, the times when the wind drops and you have no reflectors around you at all. Especially in the West Antarctic it’s flat, and when you have no reflectors you have no sound coming back that you’re generating. It actually can get still enough that you hear your heart beat, and that’s pretty interesting. Especially when the wind is completely still” (Voigt 2007). To be in a place so quiet you can hear the processes of your own body is a profound experience. While recording in the Dry Valleys, the author continuously heard a high-pitched sound she attributed to the wind. However, when she reviewed the recordings in the lab, the high-pitched sound was not on the recording. After trying to record the sound twice, she realized that in the field she was most likely hearing the sound of her own nervous system.

While the soundscape of the Antarctic can be one of the most quiet in the world, it can also be extremely loud, as Voigt describes: “Then the other extreme would be when the wind is really screaming, and you’re in a tent and everything is just sort of vibrating. You get poles humming and bamboo sometimes will crack and the whole thing will whistle as the wind travels past it. So, that’s always interesting. The tent will vibrate and set up harmonics, it gets pretty intense when the wind is really screaming” (Voigt 2007).

The experience of these sonic extremes was one of the author’s motivations to travel to Antarctica. In an attempt to reproduce the immersive nature of the Antarctic soundscape, the author recorded sound while wearing in-ear binaural microphones (microphones that are placed inside the ears while recording in order to create a stereo image). These recordings were used as inspiration for geosonifications made by the author with Antarctic weather and climate data collected by the researchers. Both the soundscape recordings and the geosonifications serve as the soundtrack of the *Ground Truth* video essay. Through the soundscape recordings, audiences can become immersed in these environments. Through the geosonifications, the scientists and scientific instruments ‘speak’ directly to audiences through their data sets. In this way the video

essay integrates a combination of geosonification and soundscape in order to bring audiences closer to a visceral understanding of weather and climate and the Antarctic continent. As has been demonstrated in the previous sections, the real-time experience of atmospheric conditions, including the soundscape, is an element of scientific research. The next section looks at contemporary artworks that use real-time atmospheric monitoring technologies to convey information and create novel experiences.

Ecomedia Experiencing and Monitoring Atmospheres

In 2008, the author's curated exhibition for the online Greenmuseum called *Aer* included two works by Australian performance artist Sarah Jane Pell (Polli 2008). Both of these artworks place the human body in an extreme environment and highlight our dependence on air as living, breathing beings. *Interdepend*, a closed-circuit life support system created by Pell and artist Martyn Coutis, placed the artists in mutual dependence for the very breath of life, and *Undercurrent* presented a single performer contained within a sealed transparent dome containing a finite amount of breathable air. Presenting these works is very physically demanding for the performer. Pell is a professional scuba diver, and her works are inspired by her experiences in this extreme environment. In Antarctica, researchers also depend on each other for life support in the extreme cold; they must work against time as there is a limited amount of time a human body can be continuously exposed to extreme cold environments. For example, in frigid water, hypothermia can begin to occur within ten minutes (Ballantyne 2009). At the South Pole, where temperatures of -27 Celsius are considered warm in the summer, weather observers often limit the time of outdoor observations to just a few minutes. Often they must take a partner on the observation for both verification of the observation and for safety. Pell's apparent apocalyptic vision of the future as evidenced in *Interdepend* and *Undercurrent* is one in which the very air we breathe is a limited commodity. In the future, will breathable air be so scarce that humans will have to be contained in controlled environments while our machines report on the world outside? Will every environment require special technologies for survival? By addressing a future of limited air, Pell's work creates an alternative pathway that forces audiences to consider the important reciprocal relationship between our bodies and the Earth's atmosphere.

The author's experiences with weather and climate scientists in Antarctic led her to create the art and science project titled *Hello, Weather!* that is analysed in depth in the chapter

“Breathtaking”. This series of professional weather stations installed in art and community centres throughout the world attempts to demystify the collection and interpretation of weather and climate data. Artists, technologists, ecologists, and environmentalists have been brought together around a growing number of these public weather stations. By using sophisticated weather technology in an accessible way, *Hello, Weather!* attempts to create an alternative pathway for audiences to access and compare information about weather and climate.⁶ At these sites, the station itself ‘becomes’ a public artwork in context, giving it a presence beyond that of a merely functional station. All stations are wireless and solar powered and transmit data to a receiver that logs and uploads the data to an on-site computer. Data is saved locally for archiving and use in projects, and several stations currently provide data to three international volunteer weather observer projects: Weather Underground, Anything Weather, and the Cooperative Weather Observer Program (CWOP). The data are extensively reused in government and commercial forecasts and scientific research. In addition, the stations provide updated, online custom-formatted data. For example, various combinations of data are available in ascii text format and xml. The station also serves as a context for workshops, presentations, and other activities related to weather and climate.⁷ For example, in 2009 at Outpost Contemporary Art in Los Angeles, the author hosted a workshop on the theme of ‘we are all weather stations’ in which visitors learned about weather stations and shared stories of their most pleasant and unpleasant affective weather experiences both verbally and in writing on a large weather map in the gallery space. Also in 2009 at Springs Preserve in Las Vegas, the author hosted a workshop that combined a scientific talk by the air quality scientist from the Desert Research Institute, Dr David Dubois, with a ‘we are all weather stations’ creative writing workshop. Visitors to the *Hello, Weather!* Web site are invited to contribute stories of extreme weather experiences, and

⁶ After an initial trial at the Atlas Centre for Art and Technology at the University of Colorado, Boulder, the first official *Hello, Weather!* station was installed at Eyebeam Center for Art and Technology in New York City (2008) and remains in operation at the time of this writing. Stations have been installed at various locations internationally and a total of five are now permanently installed in New York, Los Angeles, Brighton, New Delhi and Zurich (see chapter 6).

⁷ The first workshops hosted by *Hello, Weather!* were a series of group discussions bringing weather and climate scientists and artists together at Eyebeam in the summer and fall of 2008. Scientists presenting their work included Tim Dye of AirNow and the Environmental Protection Agency; Ken Mankoff of the Columbia University NASA Goddard Institute Climate Research Group; and Sarah Williams, Director of the Spatial Information Design Lab, Columbia University, Graduate School of Architecture Planning and Preservation.

the site includes several audio conversations between the author and interview subjects from all over the world; they are talking about personal experiences of climate change. Through these workshops, the author attempts to bring the affective experience of weather and climate into public consciousness and to connect personal stories to the process of weather data monitoring and analysis. By sharing their experiences, workshop participants become aware of the importance of weather and climate to their personal life history and of the subjectivity of individual weather interpretation. This awareness, coupled with learning about the science of weather and climate monitoring, will hopefully lead to a greater understanding and appreciation of the work of atmospheric scientists.

Conclusion

Through examples from the author's own experiences in Antarctica in 2007/08 and interviews with Antarctic weather and climate researchers, the author has shown in this chapter that affective experience plays an important role in the gathering of scientific information about weather and climate. The capabilities and roles of human weather observers have been compared to the functions of automated weather stations, and the physiological and cognitive effects of the experience of weather and climate has been examined. The immersive experience of weather has been compared and contrasted with the immersive experience of sound, specifically soundscape and geosonification. The work of performance artist Sarah Jane Pell, who has pushed the body to physical extremes, and the author's ecomedia artworks *Ground Truth* and *Hello, Weather!* were examined for their connection to the theories of embodiment of Paul Dourish and Nigel Thrift, among others.

Through the video essay *Ground Truth*, the author examined the role of embodied experience in the science of weather and climate from a documentary perspective, while through the ongoing public art project *Hello, Weather!* she explores ways to engage the general public with weather monitoring in the context of weather stations. These works approach the creation of alternative pathways to environmental understanding in two ways: *Ground Truth* brings the rarely heard voices of scientists and geosonifications of their data to the public, while *Hello, Weather!* brings microclimate monitoring and unfamiliar scientific instrumentation to public awareness and allows the public to share personal experiences and perspectives on weather and climate. The theme of 'we are all weather stations' used in two *Hello, Weather!* workshops allow participants to relate to weather monitoring in a personal way. *Ground Truth* highlights the

importance of human affect and experience in monitoring the environment and provides the general public with an alternative pathway to connect to remote and inaccessible scientific work, since everyone has a personal experience of the weather. In the opposite way, *Hello, Weather!* brings scientific instrumentation and processes to the public, providing a different alternative pathway to understanding the functions of some of the complex machines used by the scientific community.

Chapter 6. Breathtaking: Measuring and Modelling Weather and Climate

[Focus: Local Communities]

Introduction

How are weather and climate currently measured and modelled and how are information technologies integrated into this process? What are some of the current cultural understandings of weather and climate and how have physical and computational models affected these understandings? Are there structural aspects of computing (especially networked computing) that inform weather and climate understandings? The author will attempt to answer these questions through a series of cases. Here the author will shed light on cultural aspects of weather and climate measuring and modelling, from simple instrumentation and physical models to satellite remote sensing, sophisticated computer models, and countermapping in order to provide a historical basis for further research into environmental knowing.

Research will include two major phases in the history of weather and climate monitoring and how the public has participated in that monitoring. The author will argue that the effect of technology on the study of complexity has transformed the core analysis of weather and climate, in particular in the area of uncertainty. Additionally, original research gathered from interviews with weather and climate measuring and modelling experts will be compared and contrasted. The experts include IPCC lead author Andreas Fischlin from the ETH in Zurich; glaciologist Wolfgang Rack from Christchurch, New Zealand; and climate modeller Larry McDaniel from the National Center for Atmospheric Research in Boulder, Colorado.

Finally, the author will analyse the most recent results of the ongoing *Hello, Weather!* project, a small international network of volunteer weather stations she has installed at art and community centres in the context of public participation creating alternative pathways to understanding the local and global environment.

The Public Good and the Cooperative Weather Station Network

“The Good particular Men may do separately . . . is small, compared with what they may do collectively, or by a joint Endeavour and Interest.” (Franklin 1791)

Like independent news agencies, public environmental measuring and monitoring projects can provide a direct alternative to information available through official government and mass media

sources. Such projects have created alternative pathways to understanding environmental issues. Some of these projects, to be detailed in this chapter, have also acted as a driver or catalyst for changes in cultural or social practices. As a case study in this section, the author will examine the history of volunteer weather observers in the United States and how these nonspecialist, independent individuals working collectively using publicly available technology have had a dramatic impact on the social production of science.

The first systematic weather observations in the American colonies were taken by Lutheran Minister John Campanius Holm in 1644, and by the time of the American Revolution, serious weather observation was a widespread practice of the elite, including the major political figures George Washington, Thomas Jefferson, and Benjamin Franklin. The first U.S. president, George Washington, took his last weather observation just days before he died, and between 1776 and 1816 Thomas Jefferson maintained an almost unbroken record of weather observations. Not coincidentally (since accurate weather observations have been essential to military operations throughout history), in the same year as the United States declared its independence, Thomas Jefferson began to recruit volunteer weather observers throughout Virginia. Volunteer weather observation proved to be popular among the new U.S. citizenry, and by 1800 there were volunteers in six states (Helms 2008).

Ben Franklin was the first political leader to publicly connect volunteer weather observation with the developing political and social theories of the new republic and with the growing myth of the American entrepreneurial spirit. A strong advocate of the common good, Franklin formed the first public library, fire department, and non-sectarian university in the colonies. As an entrepreneur, Franklin set up printing and newspaper franchises throughout the colonies. Yearly, from 1732 to 1758, he published *Poor Richard's Almanack*, an unprecedented success that, in addition to providing folk wisdom and poetry designed for the common people, publicized seasonal and local weather information (Laughter 2007). He blatantly connected his political philosophy of the common good with the publication of atmospheric data and in so doing paved the way for future developments in information sharing.

The weather observation network Jefferson started during the American Revolution expanded and grew across the United States through the early and mid 1800s. Telegraph technology was largely responsible for this advancement. With the telegraph, weather observations from distant points could be rapidly collected, plotted, and analysed at one location. In 1849, in order to establish a more extensive weather observation network, the Smithsonian

Institution began working directly with the telegraph industry by supplying instruments to companies. One hundred and fifty volunteer observers at the end of 1849 grew to five hundred by 1860, providing daily telegraphic weather reports to the *Washington Evening Star*. As the volunteer network grew, other weather observation networks were gradually absorbed, including several official government-run state weather services. By 1891 the network of voluntary weather observers across the country had grown to 2,000 and was known as the Cooperative Weather Observer Program (CWOP) (Helms 2008).

In 1933 the U.S. secretary of agriculture, Henry Wallace, informed the newly elected president, Franklin Delano Roosevelt, that the CWOP was one of the most extraordinary programs ever developed and that through the extensive network of unpaid volunteers it had more value per dollar expended than any other government service in the world (Helms 2008).⁸ The value of a vast network of weather observers became even more evident when advances in chaos theory began to show that a greater number of initial data points could aid weather prediction. In other words, more observers meant more accurate prediction. In 1953, Director Helmut Landsberg of the Weather Bureau established a plan to evenly blanket the nation with volunteer weather observers. He conducted a study with Iowa State University to establish a method of filling in the open spaces of the volunteer or cooperative observer network, determining, for example, that one weather station every twenty-five miles could allow for an estimation of rainfall within an accuracy tolerance of 10 percent. By 1990 the CWOP network had expanded to 10,000 sites and most recent statistics estimate about 12,000 cooperative observers in the United States. Only about a third of these observers are paid, and those that do get paid receive a very small amount (NOAA 2009a).

If weather observers have not received payment, what has been their motivation for participation over all these years? Perhaps participants get a greater sense of “ownership” and therefore gain knowledge of nature through participation. Benefits to cooperative weather observers are primarily intangible; these include receiving local and national recognition for service, providing help to others in emergency situations, and the gaining pleasure in tinkering with do it yourself (DIY) monitoring equipment and information technologies. The National Weather Center provides awards to long-time weather observers and recognizes important observations, like recording the coldest temperatures of the year or decade regionally and/or

⁸ According to CWOP, that statement is still valid today. CWOP human hours total over a million a year.

nationally. All cooperative weather observers are recognized for their important contribution to public service on May 4, National Weather Observer's Day. Many volunteer observers are also amateur (also known as ham) radio operators, and in that role provide the public service of emergency communications, which can save lives in natural disasters such as hurricanes or floods. Since very early on in the CWOP program, the network also benefited from popular interest in technology and science. For example, CWOP grew in popularity by showing ham radio enthusiasts that it would be possible to send weather data through the airwaves. This capability initiated the technological development of packet radio, which since the 1970s has employed Internet protocols such as TCP/IP (Helms 2008).

However, weather observers have also taken risks for their hobby. From its origins in the early 1900s, ham radio has been at the centre of legal controversies related to communications technology development. In the United States, the Radio Act of 1912 limited ham radio transmission, but by 1914 an organized relay system called the American Radio Relay League (ARRL) was created, allowing operators to increase their range. Nearly every four or five years since then, amateur radio has faced a series of dismantling attempts by governments and media corporations citing concerns about interfering broadcasts followed by counter legal action to save private radio use or technological developments that make the regulations obsolete (Lewis 1991). However, a thin veil of licensing rules (different in each country) continues to separate legal amateur radio operation from illegal 'pirate' radio. Legal radio transmission may, for example, become illegal once it is received, or due to the content of the information or if someone experiences interference with a commercial broadcast. Free radio is a subset of pirate radio whose operators intentionally defy licensing laws because they believe they are designed to favour large corporate interests rather than the common good. Free radio can be considered an alternative pathway for communicating ideas, and the content of free radio is tied to independent artistic production, often combining progressive political reporting with experimental music (Yoder 1990). These stations provide an alternative outlet to mass-market radio for artists to speak to audiences.

For various reasons, pirate and free radio remains in widespread use, including a recent resurgence in conjunction with developing laws related to digital and wireless technologies. The rise of the Internet, led by ham radio operators, has since provided many new opportunities for the global dissemination of independently gathered information. Weather station data distribution was one of the first applications to use the TCP/IP protocol. Since radio technology

has a limited range, the Automatic Position Reporting System (APRS) and later the APRS Internet Service (APRS-IS) were developed to provide a way for weather station operators to distribute weather data much farther than their transmitter range.⁹ The success of this organized cooperative network has served to promote open access to geographic and geophysical information on the Internet. Information from CWOP is in the public domain by U.S. law, and the data collected by these volunteer observers is actually used by the National Weather Service (NWS), the National Climatic Data Center (NCDC), other government agencies, universities, and private companies.¹⁰ Since the development of the Internet, private weather aggregator startups have been created using CWOP as a model. One of the most popular, the Weather Underground (WU), named after the 1960s radical anarchist group, is a personal weather station network and a commercial weather service that provides real-time weather information via the Internet. In addition to using CWOP data through the NWS, Weather Underground also provides an independent outlet for volunteers with personal weather stations not on the CWOP network, creating yet another alternative pathway for sharing data.¹¹

⁹ APRS was originally created to provide position information, but actually can transmit all kinds of digital data. The original packet radio concept now includes the APRS Internet Service (APRS-IS) for weather data transmitted from CWOP stations. APRS-IS communicates this data to FindU servers, a set of privately operated Internet servers currently run by ham Steve Dimse, callsign k4hg. FindU weather observer data are organized and made available to the Meteorological Assimilation Data Ingest System (MADIS) Quality Control and Monitoring System (QCMS) operated by the National Oceanic and Atmospheric Administration, which checks data quality.

<<http://aprs.org/APRS-docs/APRS.TXT>>

¹⁰ The National Weather Service (NWS) uses coop data as the foundation of the nation's surface weather observing systems and the National Climatic Data Center (NCDC) uses coop data for climate research. The U.S. Department of Agriculture (USDA) uses the coop network for monitoring the agricultural community, and the U.S. Army Corps of Engineers uses coop data for its flood control network. The Federal Emergency Management Agency (FEMA) uses coop data to gauge the relative severity of weather-related disasters and to respond appropriately, and the Environmental Protection Agency (EPA) includes coop data as an important element in the calculation and prediction of environmental problems and in determining how to mitigate them. The U.S. Department of Transportation (DOT) uses coop data in the design and construction of new and upgraded highways and state governments use coop data in design of facilities, the enforcement of regulations, and the design of highway, water, and agricultural systems. Future of the National Weather Service Cooperative Observer Network (1998). Commission on Engineering and Technical Systems (CETS),

<http://books.nap.edu/openbook.php?record_id=6197&page=42>.

¹¹ Weather Underground was founded in 1995 as an offshoot of the University of Michigan's Internet weather database. The name is a reference to the 1960s radical student group of the same name, which also originated at the

Throughout its history, U.S. politics has been polarized, and currently it is highly divided between the conservative right and the progressive left. The tremendous success and longevity of the Cooperative Weather Observation Program in the United States can be attributed in part to the fact that over the years it has appealed to both the left and right wings. This crossover appeal can be evidenced by the sustaining myth of one of the founding members of the cooperative network, Benjamin Franklin. As contemporary political artist Sam Gould of the red76 Revolutionary Spirit project suggested: “What’s interesting to me with regard to Franklin’s writings is not his ideas as an individual, but how much he is revered in the US today. He is revered by conservatives as a successful entrepreneur and for his ideas about individual liberty and by progressives for his ideas of the common good” (Gould 2007). Franklin’s ideas are also revered by contemporary technologists, most highly by proponents of the open source movement. Journalist Amy Anselm of *Redhat* magazine claims that Ben Franklin was the “first [open source] American”. She explained how Franklin’s philosophies were similar to the ideals of the open source community: “All of Ben Franklin’s ideas, actions, and contributions can be linked back to his own ideals. An appreciation of community. A love of truth. His belief in an inherent responsibility to his fellow man. Franklin was truly ahead of his time. He wasn’t just the first American, he was the first open source American. Freedom. Transparency. Collaboration. Accountability. Sound familiar? This was how he lived his life and impacted society” (Anselm 2008). Franklin is revered among technologists not only because of his advocacy of collective action, but also because he supported such action in the context of technology. As an inventor and information technology (printing press) entrepreneur, he understood the value of shared innovation. For example, the following statement by Franklin has been referenced in arguments by open source activists against extending patent expirations: “as we enjoy great advantages from the inventions of others, we should be glad of an opportunity to serve others by any invention of ours; and this we should do freely and generously” (Franklin 1791). Since Franklin’s *Almanack* included weather data and he himself operated weather stations over time,

University of Michigan. In 1991, Jeff Masters wrote a menu-based telnet interface that displayed real-time weather information around the world. By 1992 Weather Underground was purported to be the most popular service on the Internet. In 1995 Weather Underground, Inc., evolved as an independent commercial entity, and by 2005 had become the weather provider for the Associated Press. Weather Underground, Inc., The First Internet Weather Service, viewed April 5, 2008. Weather Underground, Inc., Dr Jeff Masters’ WunderBlog, viewed April 5, 2008. WEATHER UNDERGROUND for the Associated Press. The Nation’s Weather, viewed on April 5, 2008

weather data was most certainly a part of what he believed should be freely and generously shared.

The cooperative weather station networks of CWOP, Weather Underground, and others serve as an example of how individuals working collectively using information technology can provide an important public service, and therefore the author claims this to be an effective argument against the privatization of all media and information technology. Not only can individuals and groups who operate stations help to increase awareness of local weather monitoring, but also as an organized network they can help to increase mainstream understanding of the complexity of climate science. For example, they monitor the difference between natural and local variability of weather and climate change. In an interview with the author, Antarctic research scientist and cryosphere specialist Wolfgang Rack described the problem of the narrow focus on individual weather events within the mainstream media:

. . . the most important thing to keep in mind is that we have very good observational tools and that we can observe a high complexity and a high variability, and to understand that many observations might look controversial but because of the complexity of the system, if you look at it closer, they actually fit together. So, I would say it's important to . . . filter out that noise in the press releases and in the reports in newspapers, and to keep the big picture in mind (Rack 2007).

In addition, the work of CWOP members can actually improve climate science. In the interview, Rack highlighted this fact by discussing the importance of long-term monitoring to the advancement of climate science. He clarified the scientific reason that station operators who have kept records for long periods of time receive special accolades in the CWOP community: “Year to year weather may be highly variable and that is also what nowadays perhaps makes it complicated to decide between natural variability in weather phenomenon and climate change. . . . In the case of climate observation that means measuring climate, temperature for example, for decades, and that is what makes it so difficult, we need long time series” (Rack 2007). Thus the long-time series afforded by CWOP and other monitoring networks have proven to be extremely valuable to climate science.

The cooperative weather-observing program presents a successful model of an alternative economy based on volunteers working together. Today, weather station operators worldwide use the Internet to combine DIY technology with organized forums for collecting and analysing data. The cooperative observation network combines the work of individuals, governments, and companies, with participants receiving a variety of rewards from personal satisfaction and recognition to government salaries to commercial profits as in the case of Weather Underground. Although this democratization of weather monitoring is not widely discussed in the mainstream media, a vast majority of Americans depend on this cooperative weather observation network. They depend on network observations whenever they fly in a plane or look at weather forecasts online, on television, or in a newspaper. CWOP is also the backbone of the United States' climate records because it provides the longest record for climate research (some stations have had an unbroken chain of records for over 150 years). Furthermore, scientists regularly use this data to study trends and predict future climate conditions. The system serves as a model and a microcosm of alternatives to currently dominant economic and social norms, proving through its over two-hundred-year history that the open source model for software development and distribution and, in fact, many open culture initiatives, could be sustainable and profitable.

In the current era of rapid climate change and disappearing natural resources, the general public will need to become more directly engaged with local information. For example, microclimate data from local weather stations are essential to estimate the energy potential that can be derived from alternative energy systems like wind and solar and can even determine optimum conditions for farms and gardens. As a case study, the author's *Hello, Weather!* research has attempted to play a role in the demystification of weather and climate monitoring as well as bring the instrumentation and technology of weather monitoring to a wider public.¹²

¹² As of this writing, five Professional Davis Vantage Pro II Weather stations mounted on 12'–25' Avenger professional light stands or custom mounting hardware have been placed in operation as part of the *Hello, Weather!* project. Two are in New York City, one at the Eyebeam Art and Technology Center in Chelsea, and one at the Ecoartspace in Soho. One is in Los Angeles at the Deb's Park Audubon Center, one is currently at the author's residence in Albuquerque, New Mexico, and one is at the Media Campus of the HDK in Zurich, Switzerland. All stations are wireless, solar powered stations that transmit data to an indoor receiver that logs the data and uploads it to the WXsolution application on a Windows PC. Data from all stations is saved locally for archiving and for use in projects. The stations send weather data to one or more of three online sites that aggregate volunteer weather observer data and make it available to the public: Weather Underground, Anything Weather, and The Cooperative Weather Observer Program (CWOP). In addition, each station provides updated online, custom-formatted data.

Public Access to Satellite and Remote Sensing

Since the 1960s, satellite and remote sensing technology has had a tremendous impact on both the scientific and the public understanding of weather and climate. The world's first weather satellite was also the first satellite to transmit a televised image of the Earth, the Television Infrared Observation Satellite (TIROS-1) launched in April 1960 (NOAA 2009b). Since then, hundreds of global weather monitoring satellites have been launched by various government agencies in the United States, Japan, and Europe. Many of these real-time and archived images from satellites have been available to the public for over thirty years. Additionally, radar images have been available for the past fifteen years (Fischlin 2007). International law states that no individual, corporation, or nation may own outer space, but there seems to be no limit to the commercial opportunities for satellites orbiting the Earth (United Nations 1967). Commercial firms have also launched hundreds of satellites for communications, generally making their imagery available to anyone who can pay a fee. However, in recent years, the U.S. government has exercised what is known as 'shutter control' over what may be imaged by various American companies. For example, in 1998, despite the needs of weather and climate scientists to analyse images of the entire Earth, the U.S. Department of State prevented satellite companies from imaging certain portions of the Middle East for political reasons (Dubno 1999). The Iraq war, 9/11, and the commercial success of online mapping tools like Google Maps has provoked discussion about whether or not satellite imagery should be made public at all. Indian spatial technologies experts Mukund Rao and K. R. Sridhara Murthi summarized the issues in the debate about access: "How far satellite images can still be considered a 'public good', conflicts between commercial and national interests is becoming a major issue, especially where security is concerned, sovereignty and the rights of sensed states, shutter control vs. transparency. . . . At the same time, the societal and public good of GI (Geographic Information) is well accepted with

CWOP provides a series of pages for each station with several comma-delimited tables, rss feeds, and graphical representations of the station data at various time scales: daily, weekly, and monthly. CWOP also locates the station on a variety of different maps, including acme mapper, aprs, findu.com, googlemaps, pdb, teraserver, topographic, and topozone; evaluates the data quality; and provides detailed recommendations for most effective station siting and other aspects of station operation. Weather Underground provides data tables and some graphical representation and also provides an xml and comma-delimited file of data. Custom formatted data is available in a variety of ascii plain text, tab delimited files.

innumerable national and international examples. It is clear that societies would greatly benefit from the proper use of GI” (Rao & Sridhara Murthi 2006). Several scientists interviewed by the author emphasised the importance of public access to satellite data, for example, aeronomist and state climatologist of New Mexico, David DuBois, expressed support for open access and advocated for global public involvement with remote monitoring in the realm of air quality control. He described the successes of public access to environmental data: “A high schooler can download the file and look at it, and if you’re a little bit savvy in programming, you can look at the same data I’m looking at. It’s all available on public ftp and Web sites. That’s the big thing, I think, managing the data, understanding it, and knowing what to do with the data. . . . People use little slices here and there and over time . . . terabytes of information . . . if this trend continues, how do you actually use all this data? Is it going to waste? How do we better ourselves with all this data?” (DuBois 2009). In this quote, DuBois strongly links broad public access to environmental data to increased scientific understanding.

The communications technologies and social forces that have developed to support public access to ham radio, the federal and private cooperative weather monitoring networks that formed out of these technologies, and similar data-sharing initiatives like air quality monitoring have fostered a culture of transparency in satellite monitoring data. Updated, high-resolution satellite data is widely available on the Internet through both commercial and public channels. The increasing demands of globalization after the fall of the Berlin wall has inspired many governments to enact freedom of information legislation, including access to remote sensing data (Perkins & Dodge 2009). This democratization of access to this data has inspired a ‘countermapping’ movement in which communities, NGOs, and individuals have “challenged power relations by highlighting social inequalities” in geographic space (Perkins & Dodge 2009, p. 4), creating alternative mappings that serve to expose corporate and governmental violations against the environment and humanity. The Internet allows these and other kinds of alternative mappings to connect with mass audiences, thereby helping to globalize local resistance (Perkins & Dodge 2009).

Contemporary artists like Trevor Paglen and Marko Peljhan have attempted to push this growing culture of transparency even further. In Paglen’s artwork, *The Other Night Sky* (2007), he used spy-satellite data compiled by renowned amateur astronomer Ted Molczan, a computer-controlled telescope, and a high-resolution camera to track and photograph secret ‘moons’ (classified satellites) in Earth orbit.

IMAGE FROM PAGLEN.COM

Figure 29. THE OTHER NIGHT SKY, Trevor Paglen (2007)

Paglen's project took advantage of information gathered by a member of another international cooperative community, the community of amateur astronomers who calculate the trajectories of satellites in order to pinpoint their exact location in the night sky and attempt to spot them with their amateur telescopes or even with the naked eye. While Paglen's artwork exposed the hidden actions of governmental agencies, it also aestheticized and commodified this information through the creation of breathtaking high-resolution photographic prints presented in gallery and museum settings. The cool beauty of his images was sharply contrasted by the shocking implications of his subject matter.

Marko Peljhan's *Projekt Atol* aims to construct and launch two of what he calls 'nano-satellites' with medium resolution, multispectral remote sensing capability (Birringer 1996). *Projekt Atol* espouses some of the same aims of the nearly fifty-year-old amateur satellite community that grew out of the ham radio movement. For example, AMSAT, an international organization, designs, builds, arranges launches for, and operates satellites carrying amateur radio payloads (Baker 1994). Peljhan has argued that independent operation and control of communication and information technology is an essential part of a more sustainable social and economic system. As he explained: "The global dynamics of change are very powerful and the knowledge distribution is uneven, in both economic and geographic terms. This needs to change, and communication technology is one of the possible vehicles for this change, but only if we will be able to liberate it from the grasp of the blind, solely capital-based use. The electromagnetic spectrum is an immaterial field with very material consequences, and unfortunately it has become a serious commodity. We have to liberate at least part of it, with all the democratic and technological means possible" (Smite & Auzina 2004). In this statement, Peljhan presented art, information technology, and democracy as forces that could operate in opposition to global capitalism, providing an alternative pathway to environmental understanding. While Peljhan's goals of information liberation through an independent artist's satellite may have merit, British technology artist Susan Collins has created artwork that questions the wisdom of launching any more satellites. Collins brought the idea of artists in orbit to the public by placing a virtual 'Tate Satellite' with a webcam in orbit. The project also brought architects and artists together to

imagine an extension of the Tate Modern into space by the addition of a new ‘wing’ attached to the International Space Station (ISS) (Collins 2002). Unlike Peljhan’s attempt to separate his art projects from the corporate structure, Collins accepted that the Tate Modern is itself a corporation and used the fictional Tate in Space project as a kind of ‘rebranding’ of the art museum. In a discussion about the project in 2004, she talked about ‘cultural colonization’ and brought up questions about whether or not artists should be putting objects in space for any reason. She observed: “There was quite a serious element which was that space so far has been really explored by governments and it’s so far been quite militaristic in it’s uses . . . and that there was a very serious imperative for culture to be in there and colonise that space as well. . . . I had a list of questions that I thought was quite useful to put out as a series of provocative statements that were to do with the nature of cultural ambition and to question it” (Collins 2004). She continued, wondering whether a Tate satellite could be seen as Space Art or space pollution: “I think there are probably many camps, some people are very excited about putting this kind of stuff out there and other people who question whether we should be messing up beyond our own planet” (Collins 2004).

Remote sensing data of the Earth’s environment is essential to weather and climate science, providing vast amounts of information that (as a fifteen-to-thirty-year record) has only started to prove its usefulness to climate trend analysis.¹³ Since the 1960s public access to government satellite images has been generally available, and private data has been available for a fee. However, the widespread use of satellite imagery has opened up debates about the level of access, questioning whether public safety and privacy can be effectively maintained. At certain times, governments have enacted ‘shutter control’ to keep information out of the public eye. Artists like Trevor Paglen and Marko Peljhan have used information from shared astronomy networks in an attempt to push the limits of transparency and increase public awareness of the environment. Paglen practiced countermapping by compiling orbital information and photographs from ‘secret’ government satellites; Peljhan has since pursued the launch of an independent satellite; and artist Susan Collins has used Web-based media to create a fictional Tate satellite, opening discussions about access, social inclusion, and power in the art world (Bonaventura 2002).

¹³ A thirty-year record is generally thought to be minimum for establishing trends in climate science (DuBois 2009).

As the amount of public access to remote sensing satellite data of the Earth continues to grow, organized communities of volunteers have formed to try to make sense of this mass by analysing and highlighting aspects of the data. Although much smaller in participation than the established volunteer weather station networks, cooperative satellite networks have formed to launch independent Earth monitoring systems as an alternative to government and commercial sensing. Some artists have responded to these technological and social breakthroughs through direct action, joining the networks and bringing their information and analysis to a broader public, and proposing projects like the launching of independent satellites and the imagining of the counter scenarios that such satellites might create in an art context. Both the cooperative networks and the independent artworks serve as alternative pathways to building the body of knowledge, understanding and interpreting remote sensing data, alternatives that scientists like Dr DuBois believe are essential to advancing climate science.

In order to be useful for weather and climate prediction, satellite, instrument monitor, and weather observation data must be combined with computerized models. Data from monitoring stations and satellites are used to provide initial conditions for predictive models and geographic conditions for historical reconstructions. Monitor data is used to verify, and if necessary correct, model algorithms. In the next section, in order to shed light on the link between monitoring and modelling, the author will explore the historical influences on the development of computerized weather and climate models.

Modelling, Prediction, and Public Participation

Visual representations of weather and climate through paintings and drawings were the first attempts to understand the changing structures of the atmosphere, and as such, artists were central to advancing this understanding. These early visual representations not only illustrated the movement of air but also held philosophical and spiritual meanings for viewers. For example, eighth-century paintings of cloud vortices in China may not only have helped viewers understand the rapidly changing weather conditions in South Asia, but may also have contributed to Chinese philosophies of change and movement (Gedzelman 2003). Working in the sixteenth century, artist Leonardo Da Vinci was an accomplished and innovative meteorologist who contributed to the future development of atmospheric science. He created detailed drawings of the movement of air that in modern times have been praised for presenting a sophisticated understanding of the fluid dynamics of air. Da Vinci not only spent time observing the movement of clouds in the

natural environment, but he also conducted experiments with dyed water or sawdust in water to observe flow patterns, which he extrapolated into air movement. Da Vinci created these physical models in order to recreate the patterns of atmospheric movement in a controlled setting. Many hundreds of years before computers, these simple physical objects were the first models for weather and climate (Gedzelman 2003).

In 1939, Swedish American meteorologist Carl-Gustaf Rossby performed an influential experiment to model the global circulation of the Earth's atmosphere and oceans using a simple physical model. By heating the sides of a turning circular tank of water mixed with coloured dye, designed to represent the Earth while it turns on its axis and the effect of sun's energy, Rossby was able to demonstrate what are now known as 'Rossby waves'. Also known as planetary waves, these emergent behaviours in the atmosphere have a significant influence on global weather (NOAA 2009). These kinds of simple physical models are still in use in laboratories today, but of course they are used in conjunction with high-speed imaging technologies (Coriolis 2009). Rossby's research was important not only because he designed physical experiments and observed the movement of fluids in tanks, but also because he translated the behaviours evident in these physical models into mathematical equations of thermodynamics. The original formulae written by Rossby and other meteorologists working in atmospheric dynamics in the early twentieth century became the basis for future global computer models of weather and climate.

Space exploration may have inadvertently created useful physical models of Earth weather and climate by providing data on planets and moons with similar properties to Earth, like Mars, Venus, and Europa. While scientists were comparing and contrasting transmitted information from these heavenly bodies to Earth as quickly as it was gathered, and continue to do so, the idea of other planets as physical models was first popularized by Carl Sagan (1985). These alternative planets with their unbearably cold or hot deserts devoid of life (but, as in the case of Mars, with clues that might indicate a verdant past) presented a picture of a possible doomsday scenario for the Earth. While space exploration is still gathering data useful to weather and climate science, and physical models like Rossby's are still used in labs, by far the most widely used models of air in the atmosphere in the present day are computational Global Climate Models (GCMs).

Initially called the General Circulation Model, the GCM grew out of the numerical approaches developed in fluid dynamics by Rossby and others. In 1950 the first weather simulation was run on the ENIAC computer, starting with real weather data for a particular day

and covering the entire United States with a grid of only 270 data points. Although the initial models were regional, by the 1970s, GCM had become the central tool of global climate science (AIP 2009). There are currently three major GCM modelling houses in the United States: GISS, the Goddard Institute of Space Studies in New York City; NCAR, the National Center for Atmospheric Research in Boulder, Colorado; and GFDL, the Geophysical Fluid Dynamics Laboratory in Princeton, New Jersey. In addition, there are major modelling houses in the United Kingdom, Australia, and Europe. All of these projects are government-scale, with large numbers of people in labs distributed throughout the world logging in to shared supercomputing resources. The models are highly detailed and were developed through interdisciplinary collaboration, including contributions from fields as diverse as plant biology, chemistry, oceanography and physics (McDaniel 2008). Despite their detail, by design contemporary climate models are nowhere near as detailed or complex as the systems they represent; however, they are essential to the scientific understanding of climate. In an interview with the author, ETH climate scientist, IPCC coordinating author, and Nobel Prize winner Andreas Fischlin explained: “A model is only a caricature or a cartoon of reality, and it will never match reality, and it actually wouldn’t make sense to match reality, then we don’t need a model, we can as well study it directly. Sometimes that is actually a pitfall, people build models that are too complex and then have to struggle with them. In that case it would be better to do fieldwork, but you see we need to use models to see what future impacts could have on our environment” (Fischlin 2007). This is the essential problem to which climate modellers continually refer: how to determine what details are important to the behaviour of any environmental system and what details can be left out. As Fischlin continued: “However, it’s not that bad, even a cartoon usually has some truth to it. Even if it’s distorting certain aspects and exaggerating ones and neglecting others, it is still only a good cartoon if it matches some reality, if it resonates something in you when you look at it. . . . We have to build models that have a relationship to reality” (Fischlin 2007). These crucial properties need to come not only from the model’s calculations but also from the observational data that are available. As was discussed in the case of the volunteer weather network, again in this context a larger set of data collected from the real world is described as more valuable. Rack discussed the issue: “We never will have a complete set of observations. . . . We have to find out what are the most important things to measure and what are the most important places to measure . . . to decide what are the important things we would like to know, the most important things to include in the models” (Rack 2007).

The problem of discovering what is important to measure is more complex than this interview excerpt might indicate, because there are different models for different purposes. For example, data sets of observations that are not useful in cryospheric research might become essential in biospheric research, or a model designed to study global climate change has different properties than a model to study nutrients in forests or plantations (Fischlin 2007). Another major problem in the public understanding of climate modelling is the uncertainty inherent in any model. As in an interview with the author, atmospheric scientist Peter Doran of the Antarctic Long Term Ecological Research project reveals: “I think that everyone would admit it’s difficult to make a model where you can say ‘Yes, I’m 100% sure this is the way it’s going to happen.’ The way that it works is they run a whole bunch of different models with different parameters, and they don’t draw a line of what the temperature’s going to be, they draw an envelope. They say ‘this is what the range of the temperature is going to be’” (Doran 2008). Public understanding of how climate models and predictions work, including their inherent uncertainty, is essential because anthropogenic effects on climate are increasing. According to the scientists interviewed by the author, the human impact on climate is not only the fastest growing influence on climate change, it is also the most uncertain. Rack clarified by saying: “There are many uncertainties, not only from a modelling point of view, but there are many uncertainties from a human point of view” (Rack 2007). How human behaviour can be introduced into climate models is one of the most radical, but to many of the climate scientists interviewed by the author, one of the most important questions in computer-based modelling.

The author spent a semester completing a research fellowship at the University of Colorado, Boulder, in order to meet with climate scientists at the National Center for Atmospheric Research (NCAR). One of her interview subjects, Larry McDaniel, an NCAR climate modeller and visualization specialist, discussed the activities of his group, called the Institute for the Study of Society and the Environment. This group was focused on the study of climate but included specialists in fields outside the traditional climate science areas, like economics and sociology. The project looked at demographics, cities and many aspects of health, growth, and transportation, and was designed to work on a feedback loop, with governments and individuals making decisions that affected the models and with simulation results allowing societies to make more informed decisions (McDaniel 2008). McDaniel explained: “We’re there to bring the information to the public so they can not only understand it but use it in their decision-making. So that the decisions they make are going to be based on realistic expectations

of the climate in the region they're in" (McDaniel 2008). While NCAR, the IPCC, the Institute for the Study of Society and the Environment, and other groups like them consist of a select group of experts providing recommendations to the public, other initiatives aim to directly bring the tools of the GCMs themselves to the public.

One example of a project providing general access to GCMs is the EdGCM, the Educational Global Climate Model. Ken Mankoff is a software developer whose main project at the Goddard Institute for Space Studies (GISS) is EdGCM, a project that attempts to democratize climate science by bringing climate models and the science behind them to the public. Until the past few years, climate models were only available to people with access to supercomputing power, but the increase in the speed of modern laptop or desktop computers has made them equivalent in terms of processor power to a decade-old supercomputer. In this light, the EdGCM project has repurposed a real climate model from ten years ago to run on home Mac and Windows machines. This project allows individuals to learn about the capabilities and limitations of climate models by running simulations themselves. EdGCM users could, for example, see what might happen after ten or even after one hundred years if the Kyoto protocol was met internationally (Mankoff 2007). This project could also help the public understand difficult concepts like local and regional variability versus climate change.

With similar aims, the distributed computing GCM project called climateprediction.net in the United Kingdom gives the public access to a slightly simpler model that can also run on personal computers. They deliver the software to thousands of different computer users who run models locally and then ship the results back to the project's organizers, who collect hundreds of thousands of simulation results. This kind of distributed computing project allows scientific researchers to take advantage of the computing power of millions of desktop and laptop machines. Both the author and Mankoff believe that this kind of networked structure could be more widely used and has great potential for the future of climate science. Mankoff discussed, for example, the potential of using the downtime of networked high-speed game engines like Playstation to process large amounts of data (Mankoff 2007). By involving large numbers of public participants, projects like EdGCM and climateprediction.net are beginning to address problems like the vast amounts of available air quality data outlined by aeronomist DuBois earlier in this chapter. Formerly only available to those with access to supercomputing resources, with increases in desktop and laptop speed, Global Climate Models can now be used by members of the general public, certainly projects like EdGCM and climateprediction.net serve to

democratize climate science by bringing its tools to nonspecialists. These projects also use technology to create alternative pathways to the understanding of the science, and these pathways are potentially more powerful and convincing than interpretations of the science in the mass media or even than the work of the scientists themselves, which are often complex technical papers that are inaccessible to the general public. Furthermore, the public participation afforded in projects like climateprediction.net can advance the science. Climate change is the largest challenge that humanity has ever faced, and since human behaviour is the fastest growing influence on global climate change, humanity must engage with the study of local and global weather and climate from both a scientific and a social perspective in order to determine the most effective participatory behaviours. These include both personal engagement and political advocacy. As Fischlin stressed: “We have a climate crisis and that calls for everybody, whoever they are, whatever they do, might they be artists, journalists, whatever, scientists, we have to do our part in this and consider options. . . . We are all part of the problem. We are all part of the solution as well” (Fischlin 2007).

Another part of the problem might be public discomfort with weather and climate scientific instrumentation and data and scientists’ discomfort with the public use of such equipment and data. Could an art project that builds a network of weather stations at community and art centres around the world serve as an alternative pathway to increase environmental awareness and understanding among the general public and promote greater cooperation between art and science?

Hello, Weather! Case Studies

In order to shed light on the question of public participation in data gathering the author has conducted a case study. The *Hello, Weather!* growing network of community weather station artworks began with a demonstration in Boulder, Colorado. Since that initial temporary station installation, stations have been installed in New York City; Los Angeles, California; Death Valley and Las Vegas, Nevada; Santa Fe and Albuquerque, New Mexico; Zurich, Switzerland; New Delhi, India; and Brighton, United Kingdom. Long-term stations are presently in New York, Los Angeles, New Delhi, Zurich, and Brighton.



Figure 30. Sketch for HELLO, WEATHER! using station image from Taylor Glacier, Antarctica, Andrea Polli (2008)

The goals of the *Hello, Weather!* project were:

1. To collaborate with local arts and community organizations to make real time weather and climate data accessible to the public
2. To work with national and international weather station networks to effectively communicate this monitoring information to the public and to contribute this data to local and global weather and climate models
3. To give workshops and presentations bringing art and science together in the context of a professional weather station
4. To build weather and climate monitoring and data literacy among the general public
5. To raise awareness of weather and climate monitoring and increase the general public's comfort with weather and climate monitoring equipment

This analysis will focus on the *Hello, Weather!* project's five sites of long-term weather monitoring: The Eyebeam Center for Art and Technology in New York City, The Debs Park Audubon Center in Los Angeles, The HDK Mediacampus in Zurich, Blast Theory Studios in Brighton, and Khoj Studios in New Delhi. The following table presents specifics about each of the five long-term stations currently in operation as part of the *Hello, Weather!* project. This table is followed by a more detailed analysis of each site.

Table 1: Hello, Weather! Community Sites

	Eyebeam	Debs Park	HDK	Blast Theory	Khoj
Operation	Art and Technology Center hosting events and artists' residencies	Public park run by the Audubon Society	Media Art Program at art college	Artists' Collective developing projects and hosting artists' residencies	Community Art Center hosting events and artists' residencies
Organization	Independent international artists, designers, and engineers invited for project-based residencies	Private foundation operating public programs, primarily for children	Art college with degrees specific to film and media arts	Collaborating artists' team hosting independent international artists and designers	Independent international artists invited for thematic projects
Physical site	Single building with offices, labs, exhibition and presentation space	Several buildings with offices and classrooms	Several buildings with offices and classrooms	Single building with offices and studios	Single building with offices, labs, studios and exhibition space
Personnel	15–20 people in residence	3–5 staff members,	20+ faculty and staff, 200+ students	5–10 people in residence	15–20 people in residence
Audience	500+ people of all ages, openings and events on and off site	100+ people of all ages, events on site	Serves university students	Events always off site serve participants of all ages	100+ people of all ages, openings and events on and off site
Staff	One staff member in charge of station	Director and one staff member in charge of station	One staff member in charge of station	One staff member in charge of station	One staff member in charge of station
Station and receiver site	Station on rooftop, receiver in kitchen	Station on rooftop, receiver in public area	Station on patio, receiver in wiring closet	Station on street level, receiver in studio	Station on rooftop, receiver in computer lab
Station online presence	Link to data on organization Web site	Data on main page of organization Web site	No link or data on organization Web site	No link or data on organization Web site	Data on organization Web site

The first station the author installed was at the Atlas Center for Art and Technology in Boulder, Colorado. This was a one-week-long installation during which the station data was visualized and sonified in real time on screens inside and outside of the centre.



Figure 31. Projected visualizations of real time weather data in Boulder Colorado, Andrea Polli (2008)



Figure 32. Real time weather visualizations with quotes from Richard Byrd's diaries, Andrea Polli (2008)

She then proposed a long-term station as part of a residency at the Eyebeam Centre for Art and Technology in New York City. During a three-month residency, she developed a Web site for the project that included real-time data in various formats and data contributions to CWOP and Weather Underground and hosted a series of workshops.



Figure 33. HELLO, WEATHER! station on site at Eyebeam, NYC, Andrea Polli (2008)

Temporary stations in Santa Fe, New Mexico; at the Goldwell Art Museum near Death Valley, Nevada; Soho and Queens, New York; and in Los Angeles, California followed this station. Each of these installations included visualizations, sonifications, and/or workshops and presentations by the author.



Figure 34. HELLO, WEATHER! temporary station at the Outpost Centre for Contemporary Art, Los Angeles, Andrea Polli (2009)

The temporary station at the Outpost Center for Contemporary Art led to a long-term station installation at the nearby Debs Park Audubon Center. Through the author's doctoral research, she was able to install a long-term station at the HDK Mediacampus in Zurich. Finally, she has installed long-term stations at the Khoj Centre for Contemporary Art in New Delhi and Blast Theory in Brighton through artists' residencies at each.

Successes/Failures

Each of the long-term station sites has presented individual challenges and opportunities. While the station itself and the station receiver have required no maintenance, the computer uploading the real time data to the Internet has presented difficulties. Each site has required this computer to be restarted every two or three months. Because the data is regularly uploaded and archived, the author has been able to monitor this data upload and to contact staff at the sites when maintenance is required. The most successful site in terms of this maintenance has been the Debs Park site. The director of this site, Jeffrey Chapman, was very motivated to have a station and placed the current data on the homepage of the park's Web site. Therefore, every day park staff and patrons are notified of the station status, and staff can provide maintenance if necessary.



Figure 35. Installing HELLO, WEATHER! station at the Khoj Centre for Contemporary Art, New Delhi India, Andrea Polli (2010)



Figure 36. HELLO, WEATHER! station control area at Khoj, Andrea Polli (2010)

The least successful site in this regard has been Khoj. While Khoj also placed the current data on their Web site, they placed it several layers down on a page devoted to an exhibition. In addition, in order to save money, Khoj staff members have had to turn off their electricity every night. Therefore the Internet, station receiver, and uploading computer do not function for half of every day. This daily power outage has created problems for the equipment, which has had to be reset on a regular basis, coupled with the challenges of long distance communication, including time zone differences and language barriers.

However successful in terms of data consistency, the Debs Park site has been one of the least successful in terms of workshops and public outreach, having not scheduled any public programs related to the project to date.



Figure 37. HELLO, WEATHER! station and LED sign with real-time weather readout at Khoj, Andrea Polli (2010)

In contrast, Khoj was very focused on connecting the station to the public and not only hosted workshops on the station and climate and weather issues, but the authors was able to install an LED sign next to the station facing the street that presented scrolling weather updates. The Eyebeam Centre for Art and Technology has been another successful site for public workshops, having hosted five public events related to the station during its first year.¹⁴

In an attempt to reconcile the local and global functions of the stations, the author has created two projects that provide automatic station updates via the text messaging system, Twitter. These two projects: freefarmfeed.org and atmosfeed.org, were inspired by the Internet of things, specifically the Twitter feed from London's Tower Bridge, which sends a text message

¹⁴ The author hosted a series of *Hello, Weather!* workshops at Eyebeam during her residency the summer of 2008, including monthly meetings of the Eyebeam Sustainability Research Group focused on climate and weather discussions between artists and scientists, a weather balloon launch, and an all-ages workshop building extreme weather snow globes.

whenever the bridge raises and lowers, including details about ships passing (Towerbridge 2010). Freefarmfeed.org and atmosfeed.org were initially designed to tweet only from the five long-term stations; however, the author soon realized that the thousands of stations on the Weather Underground network could be accessed, allowing users to subscribe to a station in a particular area of interest. The projects currently allow users to register for up to five stations using a city name or postal code anywhere in the United States and Europe. The development challenge to the freefarmfeed.org and atmosfeed.org projects has been getting users to subscribe and provide feedback on the project. While the author has presented the project in public talks and has invited subscribers, it seems that most people have not been Twitter users and are sceptical about subscribing to an unfamiliar social network. This project is currently in the very early stages, and much more work is needed to create messages that are more varied, personal, and engaging and to improve functionality by allowing users to call for messages on demand and to send messages to other subscribers. In keeping with the goals of the open source movement at the heart of *Hello, Weather!*, the project code has been released as open source under the Creative Commons GPL license.

Hosts of long-term stations for the *Hello, Weather!* project have both been able to engage with the online data and to use the physical station as a context for workshops and events related to weather and climate. Most hosts have focused on one or the other of these two station benefits depending on the interests and expertise of the organization and its constituents.

What the Author Learned

The author was not prepared for the challenges of a long-term, ongoing project. Each site has required regular contact and troubleshooting, and although the author was aware of this need prior to installing the stations, the reality of the demands of these ongoing relationships was not fully understood. In order to be useful to the communities over this longer time frame, the *Hello, Weather!* project has had to be customized for each particular site. The author has also undertaken ‘maintenance visits’, even when a station is working fine, in order to try to encourage the host organization to become more involved with the station.

Even members of the more technically minded organizations like Eyebeam have not yet engaged with the raw data as the author had hoped. While the author had shied away from presenting specific examples of how the raw data might be used in order to avoid influencing the kind of projects created, in the future more examples, including step-by-step instructions, could

help community members who are interested in trying to use the raw data to create applications to get started. The author has offered hands-on workshops on the use of the data, but the organizations have rejected these technical workshops in favour of multilevel workshops in which no technical skill is required. For a beginner, using the raw data in projects would require a week or more of intensive training, and it seems that more advanced artists have been interested in either creating or finding other data. This might be due to the question of ‘ownership’ of the data. Although the author has made the project information and data from the stations freely available, the station network has been identified as an art project created by the author. Therefore, other artists might be reluctant to use what might be considered someone else’s art. A future direction might be to develop methods for projects that can eliminate this concern.

One possible way to achieve this might be to act as a ‘curator’ of station projects and provide support and promotion of other artists through the Web site or other means. Eyebeam fellow, artist, and activist Steve Lambert’s *Ad Art* project (2010) is an example of how an online framework might be made useful to other artists. *Ad Art* is a grease monkey plug-in that replaces Web page advertisements with artwork from a growing database. Lambert created the plug-in and invited other artists to submit ‘exhibitions’ of their artwork. This project provides both an easy entry point, as most artists have digital images of their work, and benefits the artists by letting their work be seen by potentially large audiences. The New York-based *SP Weather Station* project initiated by Natalie Campbell and Heidi Neilson in 2007, with whom the author collaborated for two Queens station installations, is a weather-related example of this kind of curatorial process. The *SP Weather Station* project collects monthly data and invites artists to create new works with the month’s data of their choosing. These works are produced as multiples and given to *SP Weather Station* project subscribers for a fee. Since the author would like to encourage projects using the real-time data and is interested in sound-based works, she might try curating a series of music and sound performances in which artists devise ways to use the real-time data. Ideas like this and others highlight the benefits of a long-term project with many possible outcomes.

Difficulties supporting a long-term project are not unusual, even in the sciences. The U.S. National Science Foundation (NSF), which has supported climate research for decades, needed to be encouraged to support projects longer than three years. After many years of making requests, the Long Term Ecological Research Project finally convinced the NSF to fund some of

their research on a six-year basis, and this time frame is not even half of the widely accepted fifteen-year timeline for establishing climate trends (Doran 2008; DuBois 2009). This limited timeline is clearly tied to the two- and four-year election cycles in the United States (Fischlin 2007). Like the Santa Fe Center for Contemporary Art that briefly hosted a *Hello, Weather!* station until its administrative structure changed, democratic governments are subject to radical restructuring every few years, making long-term studies difficult. This observation can make the success of the CWOP volunteer weather station network even more amazing since it has weathered multiple generations and has amassed data that becomes more valuable every year.

What the Organizations Learned

Like the author herself, the majority of the host sites did not understand the reality of a long-term, ongoing project, and it has forced them to function slightly differently. As arts organizations, most of the sites have had extensive experience hosting short-term exhibitions and events. Therefore, despite their generally sophisticated understanding of the value of long-term weather data in climate research, most organization staff members expressed confusion about a visible, multiyear project. To date, the longest-running station is Eyebeam, which has been installed for over two years, and time will tell how long any of the sites will sustain interest and involvement. Community organizations often lack stability. For example, a long-term *Hello, Weather!* station attempted at the Center for Contemporary Art in Santa Fe, New Mexico, was taken down within a few months because the executive director who had originally invited the author to install the project left the organization and the new director asked that the station be removed. Inevitably, this might happen at every site, since a multiyear project works against the fluid structure of these organizations.

Clearly, a place like Debs Park has seen more value from the station because they provide outdoor recreation and therefore the weather has been an important selling point to their audience. Because the park is completely off the grid and obtains energy through solar collectors on a roof near the *Hello, Weather!* station, the staff has been able to use the station's solar radiation data to predict their available energy. The other *Hello, Weather!* sites offer primarily indoor activities, although Eyebeam has sponsored a series of street and rooftop art projects and has expressed interest in installing alternative energy on site. Considering the relationship between the inside and the outside has been a challenge for even the most ecologically focused organizations. For these organizations, their building has offered a refuge from both dangerous

city streets and unpleasant weather, making a connection to the outside not only challenging but also possibly undesirable. However, many of these organizations would like to have more outdoor activities and to use alternative energy, and over time they might be able to see that their station data can provide valuable information for project planning and for creating engineering feasibility studies for wind and solar installations.

Conclusion

One great challenge to effective public decision-making about climate change is that the inherently complex nature of weather and climate demands a deep understanding of the science. This calls for media artists and technologists to develop situations, scenarios, and tools that provide public entry points to the methods of weather and climate science, including monitoring, measuring, sensing, and modelling. In the United States, a cooperative network of weather observers has been in place for over two hundred years, but is relatively unknown to the general public. Any individual or group with minimal resources could install a station and join the cooperative network, providing an additional data point and therefore improving the predictive capabilities of the entire system. The success of the cooperative weather observation network provides a powerful, non-commercial alternative model for public participation in data gathering and analysis. The author's experiments through the *Hello, Weather!* project aim to demystify the process of weather and climate monitoring and thus widen the network. Participation in cooperative environmental data gathering brings focus to an alternative social and economic system in which a volunteer public takes a greater responsibility for preserving the Earth and its environment.

Remote satellite sensing of the Earth has provided compelling images of the fragility of our atmosphere and ecosystems. Despite the controversy about technology in the sky, widespread public access to updated satellite imagery is the norm and has inspired a wave of alternative 'countermapping' projects that attempt to bring a humanistic perspective to overview information that presents structure and movement but not motivation (Perkins & Dodge 2009). Some artists have taken a direct role in this alternative mapping strategy, what is sometimes called 'countermapping', but have also imagined alternative scenarios in which the control and motivation of remote Earth sensing is in the hands of private individuals and artists for the good of humanity rather than in the hands corporations and governments for militaristic purposes.

Scientists have strongly advocated for public access to data, information, and scientific results, some citing this access as the purpose of science itself. As Fischlin expressed in an interview with the author: “As scientists we have an obligation to inform the public who is generally also funding us, and I’m glad it’s funding us because it gives us independence and we are neutral in our statements and we can remain that way” (Fischlin 2007). He went on to explain that the wider perspective afforded by global monitoring networks and remote sensing highlights the need for public engagement with climate science: “Having broadened my perspective I have to admit I was shocked. I was shocked to find out how sensitive many ecosystems are and how much they could be impacted by climate change in the future. So I felt as a citizen and an individual as a human being, an obligation to tell other people who are interested, who are willing to listen, and I believe everybody should be, it’s their life” (Fischlin 2007).

Perhaps the most complex aspects of climate science and the most difficult for the public to understand are global climate models. While physical models of fluid dynamics using water and ink-filled tanks can be beautiful, their usefulness to science is only relative to the mathematical formulae that describe the movement and therefore can be used to determine behaviour in a real-world context. So far, these mathematical formulae have been generally inaccessible to the untrained public. However, space exploration has brought vivid alternative climate scenarios to public consciousness, presenting images of a possible doomsday: our cold, dead planet! However, because of the difficulty of studying them in detail, the usefulness of other heavenly bodies as models for the Earth’s climate is limited. Computerized models are most commonly used in climate science, but have been inaccessible to those lacking supercomputing power until recent projects like EdGCM and climateprediction.net. These projects gave the public access to run their own climate models on home computers or to be engaged with other aspects of computerized models and therefore allowed individuals to gain a firsthand understanding of modelling issues like local and regional climate variability and how climate science addresses uncertainty. With distributed computing projects like climateprediction.net, the public actually donates their computer time and processing power to advancing the science.

Public access to networked information technology has created opportunities for individuals working independently and collectively to participate in climate science through operating measuring and monitoring instruments and contributing data to cooperative networks, viewing and analysing remote sensing data, and more recently running computerized climate

models and contributing those results to global analysis. Thus climate science projects as discussed in this chapter do have the potential to transform the culture of science and society because they open up alternative pathways to public participation. They serve to decentralize and democratize the process of data collection, distribution, and analysis. This data sharing is particularly important in light of our current situation in which the actions of human individuals and groups is having the fastest growing impact on climate change than any other factor.

The author's *Hello, Weather!* project has been an investigation into how local nodes of an international community weather station network might function over time. In addition to providing valuable data for climate and weather research, experiences with each site might shed light on the challenges and opportunities provided by environmental data sharing. It is the author's hope that through projects like *Hello, Weather!*, communities will become more comfortable with the tools and technologies of weather and climate monitoring and will gain a greater understanding of their role in supporting global climate models. A more challenging goal has been to try to move the thinking of arts and community organizations from the inside to the outside, not only by connecting the organization with constituents in the community, which is already a focus of each organization, but also by connecting the organization with the air outside their building walls. Beyond this, perhaps the most challenging goal of the *Hello, Weather!* project has been to convince community organizations to embrace a long-term project that gains value over time. Despite the best intentions, these organizations are often subject to radical staff restructuring for political and economic reasons.

Connecting to monitoring tools, global networks, local conditions, and long-term records is an important part of environmental knowing. Volunteer networks like CWOP and Weather Underground and artists' projects like *Hello, Weather!* may provide alternative pathways to government or privately run data collection and analysis and this public participation may increase general environmental understanding. Through these kinds of citizen (or 'community') science, the public might become more aware of the scientific process and more able to grasp difficult scientific topics like the complexity of the air and atmosphere.

Chapter 7. Scary Stories: Risk and Art and Science Collaborations in Extreme Environments [Focus: The Arctic and Antarctic]

Introduction

Through analysis of her experiences at art residencies at scientific field stations in the Arctic and Antarctic, in this chapter the author will explore ways in which collaborations between artists and scientists at field sites in extreme environments can create alternative pathways to foster environmental understanding. What has been the role of environmental activism at these sites and in the resulting projects? Using evidence from the author's ecomedia projects, interviews with scientists, and working experiences, the author will argue that ecomedia works resulting from field-based collaboration have the potential to create a kind of situated knowing in relation to environment, and can extend the fieldwork to allow both specialist and nonspecialist audiences to experience geographic and temporal scales that cannot be understood through the physical experience of the environment (i.e., large geographical areas and long periods of time).

This chapter will include the author's collective analysis of travelling to the South Pole and to the Finnish Arctic where she created ecomedia artworks and conducted extensive interviews with scientists. The author's interactive mapping project, 90 Degrees South, created with the aim of increasing public awareness and understanding of Antarctic weather and climate science, and a public art extension of the *Ground Truth* project created at the Kilpisjärvi research station in Northern Finland will be presented as case studies.

Art, Science, and Activism at Field Stations in the Arctic and Antarctic

To be present in the Arctic or the Antarctic is to be keenly aware of one's global geography. These are two rare places on the Earth where latitude and longitude are part of the geographical consciousness of most residents. Signs and markers throughout the Arctic indicate significant destinations like the Arctic Circle or the North Pole, and latitude and longitude values are placed on the doors of pubs and restaurants. Perhaps more significant but not marked by humans are boundaries in the Arctic such as the observable tree line or the yearly snow cover marked by dark lichen on the trunks of birch trees. The grazing paths of reindeer in the Arctic are also important indicators of conditions. In Finland these paths are affected both by the natural movements of the herds and by border restrictions with Norway and Sweden.



Figure 39. Sign marking arrival to the Kilpisjärvi Biological Station near bus stop, Andrea Polli (2010)



Figure 40. C-17 arriving at the South Pole, Antarctica, Andrea Polli (2008)

What opportunities does this geographical location provide artists working with geospatial information? How do the extreme weather and climate and the resulting simplified ecosystems of these areas affect and inform ecomedia projects? What is the significance of global geographical awareness at these remote sites? During the author's PhD research, she completed one residency in the Antarctic and another in the Arctic and worked at field sites in extreme environments during both. She was a 2007/08 artist-in-residence sponsored by the U.S. National Science Foundation (NSF) and spent two months in Antarctica travelling to McMurdo Station, the Dry Valleys and the South Pole Station. In 2010 she spent one month as an artist-in-residence at the Kilpisjärvi Biological Station operated by the University of Helsinki and sponsored by the independent Finnish Bioart Society.

The two residency sites had several similarities and differences as can be seen in the following table:

Table 7.1: Structure of the Author's Residencies in the Arctic and Antarctic

Kilpisjärvi Station, Finland	McMurdo, Dry Valleys, and South Pole
Scientists and artists in residence working alongside each other	Scientists and artists in residence working alongside each other
Scientists, research assistants, students, staff	Scientists, research assistants, students, staff
<50 people total at any time	>2,000 people total combined McMurdo and South Pole
Diverse local communities with varying histories in the area from >500 years to <100 years	No local community except science support staff living there on a temporary basis, with a one year maximum stay
Most scientists come for short 2–6 week stays	Most scientists stay for 2–4 months
Travel, food, and other resources relatively easy and available commercially as well as on station	Travel and food requires major resources to bring in via fixed wing aircraft or ship, and operated only through the station
Tourism prominent, lots of interaction between research and tourism	Tourism minimally present, no interaction between tourists and research
Languages of researchers mixed Finnish, English, and German with local signage in Finnish, Swedish, and English	Primary language English with a small percentage of international researchers
Station run by Helsinki University	Station run by U.S. military contractor Raytheon and government agency NSF
Research funded by private and public sources	Research funded by NSF (U.S. government)
Artist residencies supported by a combination of private and public sources	Artist residencies supported by NSF (government)
Artists using primarily new media	Artists primarily from traditional disciplines, including journalists and writers

The differences between the two operations are apparent upon arrival, with the mode of transport revealing the scale of the effort. Antarctic field sites are approached by military transport, either by large military cargo plane as in the case of McMurdo or by icebreaker as in the case of the other main U.S. base in the Antarctic, Palmer Station. McMurdo is the starting point for most travel within U.S.-operated sites in Antarctica, including the Dry Valleys, which are reached via helicopter from McMurdo, and the South Pole, which is also reached from McMurdo, but via fixed-wing military cargo aircraft. In contrast, the author arrived at Kilpisjärvi Station on a public bus and travelled to field sites by private car or on foot, revealing that U.S. Antarctic scientific research is clearly a much larger-scale operation than that at Kilpisjärvi. However, once the author became familiar with the scientific work being done in the field, the similarities became apparent. For example, in both the Arctic and the Antarctic, scientists go out to field sites and have ongoing, long-term experiments. However, in all the cases the author observed in Kilpisjärvi, field research involved a day trip, whereas in Antarctica a majority of fieldwork involved a several weeks' stay in the field. The nature of the work, however, was similar, with scientists undergoing basic research in both the Arctic and the Antarctic. In both cases, scientists spoke of the advantages of the simplified ecosystem, in other words limited flora and fauna in these areas, which allowed for controlled experiments in the field. That and other unique aspects of the site, for example abundance or lack of certain minerals in the rocks, were essential for the research being done.

The process of undergoing the science was slightly different in the two locations. For example, in the Antarctic scientists spoke of limiting their analysis while in the field, and “in the field” in Antarctica generally included the laboratories and outdoor field sites. Therefore, scientists would limit their two or three months in Antarctica to gathering data that they would then spend the remainder of the year analysing in their home university's laboratories. In contrast, at Kilpisjärvi, due to the relative ease at which one could travel, scientists referred to “the field” as outdoor sites only and treated the laboratory as any other, undergoing both data gathering and analysis there and in the field. In addition, in Kilpisjärvi the social implications of the research seemed to concern the scientists much more due to the fact that the station is situated in the middle of a complex community of people including traditional native communities (the Saami), tourists, and entrepreneurs. The Antarctic scientists the author spoke with were certainly aware of the social implications of their work, but the isolated setting

provided an oasis that many scientists lauded for providing time away from social concerns and for permitting interaction within a purely scientific community.

The goals of the artists-in-residence programs in each location were similar, with artists intended to work alongside scientists on related but separate projects. However, the way in which artists were received in each site differed greatly. The NSF Antarctic Artists and Writers in Residence Program is well-established, and by 2007/08 had been operated for fifteen years by the same government agency that runs the science research. The artists selected are primarily U.S. based, although the German filmmaker Werner Herzog had been an artist-in-residence the year before the author. In contrast, the residency at the Kilpisjärvi Station was a new program run by an independent entity. Although as of this writing there haven't been enough artists-in-residence at Kilpisjärvi to analyse their backgrounds (the author herself was one of the first residents), it was apparent that one of the goals of the organizers is to invite primarily international and Finnish artists.

The author investigated the role of activism in both the U.S. Antarctic program and Kilpisjärvi. In the case of the Antarctic, she found that although scientists were very concerned with and knowledgeable about the political controversy surrounding climate change, particularly with regard to the U.S. government and media as discussed in the previous chapter 'Ground Truth', only one of the scientists she spoke with had acted on this concern by publishing in the mainstream media. Several scientists in Antarctica said that it was beneficial to have artists involved in the work there because artists had the freedom to make political statements that the scientists felt they did not.



Figure 41. Flag showing the Kilpisjärvi Station mascots, two Arctic lemmings, Andrea Polli (2010)

In contrast, the scientists in Kilpisjärvi in the Arctic were politically active, and the station itself had taken controversial positions with regard to the local community. For example, the station director, Antero Järvinen, had taken a public position about overgrazing of reindeer by the local Saami herders that was met with some opposition. Surprisingly, this opposition did not come from the Saami people themselves, as Järvinen states: “visiting cultural scientists or . . . students come to the station, [and] they have a very romantic belief of Saami and Saami culture, and when they come here they want to do good things to these people because they are minority. . . . For instance, when they try to criticize me when I criticize Saami reindeer men that they have too many reindeer here—that if they are trying to find a sustainable system, they have to cut their animal numbers. And these romantic people that come from Helsinki and other southern regions . . . they do not like it that Saami people are criticized. They are more Saami than the Saami themselves!” (Järvinen 2010). Clearly the position of the people that Järvinen labels ‘romantic’ in this quote is based on a wider set of concerns beyond whether or not overgrazing is having a

negative effect on the Arctic ecosystem, for example, the historical mistreatment of the Saami. Järvinen, however, believed that this political position should be based on the scientific facts, which created conflict between the station and the community.

This concern with scientific fact extended to how Järvinen described potential difficulties with the artist-in-residence program. Järvinen's scientific research in the area over the past thirty years had been on Arctic bird populations, and in that time he had found no evidence of a change in the avian life due to anthropogenic climate change. Because of this he often stated that the facts do not unequivocally support global warming and expressed concern that artists might come to Kilpisjärvi with the goal of expressing the 'scary stories' of climate change. He said: "I think artists are dramatic . . . maybe they can artistically describe dramatic things better than less dramatic things. But I've told them that . . . they can find other, in my opinion, very interesting things in Northern Arctic nature" (Järvinen 2010). Järvinen believed that the artists' works were not subject to the same rigor as that of scientists. Unlike the scientists in Antarctica, who celebrated the artists' freedom as providing a potential outlet for ideas the scientists themselves did not have the freedom to express, as discussed in the chapter 'Ground Truth', Järvinen was concerned about potential conflicts between art and science. As he stated: "Artists are allowed more freedom, and it doesn't matter if they go wrong. But if a scientist goes wrong, it does matter. And he may be ridiculed or lose a job if he gets very deeply involved in such programs which are not very clearly cited" (Järvinen 2010).

Like the Antarctic scientists, Järvinen did believe that artists could bring scientific understanding to the public, and that they could play a role in helping the public to understand uncertainty in environmental science. However, unlike the U.S. Antarctic scientists who were very concerned about the public's understanding of science, speaking as a Finnish scientist, Järvinen said that the average citizen in his country had a relatively good understanding of the scientific process. The U.S. scientists on the whole believed that the public had a great misunderstanding of science and blamed this primarily on the mainstream media, which they believed (except in isolated cases) was ill equipped to handle science journalism (Doran 2008).



Figure 42. Kilpisjärvi science researcher posing with Arctic lemming killed by dog, Andrea Polli (2010)

In the author's experience, some of the Arctic researchers were not as comfortable with being interviewed and documented while working as the majority of the scientists in the Antarctic. This hesitation was most likely due to the fact that in the Antarctic, artists and journalists were part of the same residency, therefore artists were seen in the same light as journalists. In fact, in the Antarctic scientists were eager to be interviewed, and on more than one occasion a scientist would jokingly ask the author if she was going to make him or her famous. In contrast, when the author wrote what she believed to be a favourable blog entry about the work of one Kilpisjärvi science researcher, the researcher was upset that she had not approved the blog entry in advance, despite the fact that the author spent an entire day photographing and recording the researcher for the purposes of the blog. The controversial content of this particular blog entry was documentation of the researcher's dog, which was brought along on the field expedition and who in the course of the day killed an arctic lemming, an animal considered to be the 'mascot' of the biological station. The documentation of the dog and the lemming, including the researcher holding the dead lemming for the author to photograph, was in conflict with the researcher's reputation as an environmental activist in the town of Kilpisjärvi, since the dog's destructive act would be seen as having a negative impact on the remote environment. In essence, the researcher believed that the only 'content' to be of interest on the outing was the scientific research activity,

while in contrast as an artist, the author was looking for an engaging narrative to write about in the blog. The actions of the dog were clearly the most ‘dramatic’ events of the day to the author, while the researcher didn’t even seem aware that this occurrence might be documented and presented to the public.

Scientists in both field stations were very interested in talking with the author about philosophical issues related to science. The context of an artist’s presence seemed to provide an opportunity for these philosophical discussions to occur that might not have otherwise, and some scientists expressed appreciation for this opportunity that they found inspiring to their work. Järvinen presented philosophy as a grounding for his concerns about the rush to consensus on climate change. He said: “Of course, there are no absolute truths in science. And that is also why we cannot say there is a consensus on global warming. Because consensus steals science” (Järvinen 2010). Austrian biologist Martin Kainz, also at Kilpisjärvi, spoke about the importance of synergy in climate science: “You need to understand different systems in the same climate environment, like the subarctic, or the arctic, or the temperate areas, or even the tropic areas” (Polli 2010b). Kainz had observed changes in Arctic water fleas and other lake creatures and was critical of a narrow focus in science, as he continued: “Here in northern Finland, there is data from ornithologists from other ecologists, terrestrial ecologists . . . and they argue that there is no change. . . . We do, however, understand that there’s a higher UV radiation in a northern environment, and that has an impact on those organisms that can’t hide themselves” (Kainz 2010). Kainz’s work focuses on the food chain, and he argued that if a single variable like UV radiation can have an affect on one organism, this could have an impact on the entire food chain.

Like Järvinen, Kainz extended his ideas about the scientific process to his philosophies of knowledge. He said: “The creation of knowledge means that human beings have the opportunity to work on themselves, to develop themselves, and to perhaps be able to tackle certain problems because they have been agonizing over problems. And the moment you agonize over a problem, you change your brain” (Kainz 2010). In this way he was identifying the creation of knowledge as a kind of ecosystem stressor, or a factor that creates a physiological change. He stressed that the way one most effectively agonizes over a problem is through collaboration, and he extended this collaboration to interdisciplinary work. As he stated: “We need to listen to each other. If we listen to each other carefully, then it will change us as well. That’s the wonderful trade of the human being. If we think that we need to solve a problem in arts or in science, or in economy, then we can do that” (Kainz 2010). In this statement Kainz emphasised the transformative

potential of interdisciplinary collaboration not only to solve problems but also to change the people involved in the collaboration.

Antarctic paleoclimatologist Adam Lewis used a geographical metaphor when discussing the importance of interdisciplinarity. He said: “At some point there are no boundaries, because a physicist who worries about the planet—that physicist is essentially working as a geologist. And geologists have to understand physics because of things like heat flow, so it’d be hard to draw boundaries” (Lewis 2007). Like Kainz’s previous statement about problem solving, Lewis’ statement privileges the problem over the disciplinary boundary. As has been documented throughout this thesis, the problem of climate change is one that is strongly affected by human behaviour and therefore extends beyond the scientific domain into the social and must be addressed by artists, scientists, and others. The first step of problem solving as observed by Kainz is the creation of knowledge, and, as he states, one way that knowledge is created is through listening to a range of ideas across disciplines.

A common difficulty experienced by the organizers of the artists’ residencies in both the Arctic and the Antarctic was how to justify the artists’ use of resources. In both cases, resources were scarce and the artists did not have outside funds to contribute to the endeavour, so the perspective was very one-sided. As Järvinen observed: “At the moment it’s mainly those artists that benefit more from scientists when they come here to the station and learn the facts of nature; and the scientists try to help them as much as they can, but there is a lot of work to do” (Järvinen 2010). Despite this view of artists as consumers rather than producers, Järvinen felt that there was great value to the interdisciplinary exchange and that as a scientific leader in the residency program, it was his challenge to try to get scientists involved more closely and to get them to see the benefits of the interactions between artists and scientists. He said: “Of course, ideally, scientists could see the world in other ways when they discuss their research subjects with artists; and they may find some new perspectives in their work. That is at least one possibility, which may . . . be the result of this cooperation” (Järvinen 2010). Both in the Arctic and the Antarctic, the two primary benefits of the art and science interaction that were discussed were the possibility of publicity for the scientific endeavours and the expansion of interdisciplinary thinking. However, the scientific research always took priority over the art and science interaction. In the Antarctic, the difficulties of travel actually had a positive impact on interdisciplinary work. Bad weather would often delay flights, leaving scientists with time on their hands while waiting for the weather to clear. The author found these to be ideal times to

discuss ideas and projects, to conduct interviews, and to collaborate with the scientists. Since travel was usually on foot or by land vehicle around the Kilpisjärvi area, interactions between artists and scientists needed to be carved into the busy schedule of the scientists, usually occurring after a communal dinner. However, the Finnish Bioart Society had worked to create an atmosphere in which artists-in-residence could have open access to the science labs, and unlike in the Antarctic where an artist needed to have an invitation to enter one of the science labs, artists at Kilpisjärvi could freely enter the science labs and use microscopes and other equipment.

One motivation for the residency in Finland was to develop university programs in art and science. When asked how the success of the artist-in-residence program would be evaluated, Järvinen said that the development of new interdisciplinary programs in Finnish universities would be a major indicator of the success of the program. He cited successful programs in bioart in other countries such as Australia and the importance of Finland's universities remaining relevant in the international community. In Antarctica success was primarily gauged by the number of presentations to the public given by the artists after the residency.

The two artist-in-residence programs experienced by the author—one operated by the U.S. National Science Foundation in the Antarctic and the other hosted by the Kilpisjärvi Station and Finnish Bioart Society in the Arctic—can offer a contrasting perspective on how art and science collaborations can occur in extreme environments. Although the structures of the two residencies were very different, cultural conflicts between the practice and purpose of art versus science were evident. In both residencies, the benefits of interdisciplinary interactions and communicating research from remote parts of the world to the general public were stressed. The presence of a local population in the Arctic created political pressures that made the scientists much more likely to take on an activist role in the community, for example, advocating for particular policy changes that would limit the amount of reindeer grazing. In contrast, in the Antarctic the climate scientists were well aware of the politics surrounding their work but were less willing to openly take a political position. Because of this the scientists in the Arctic were more critical of the political positions taken by the artists, while scientists in the Antarctic welcomed the opportunity to express their political ideas in a nonscientific forum. In both cases, the resources allotted to artists were tightly controlled to ensure that the art and science experiment did not detract from the scientific research. One concern evident in Kilpisjärvi was that the artists' work could potentially be seen as representing the views of the station. Surprisingly, despite being a large bureaucracy, the content of the artists' work was not as much

of a concern of the U.S. NSF Antarctic sponsoring agency. This might be due to the fact that the NSF had a long history of artists' residencies and was familiar with the kind of work produced by artists, or it may have been that the operation in the Antarctic was so large that any individual artist's statement could not possibly be seen as representing the whole of the Antarctic project. Or, it may have been due to the fact that an artist's proposal for acceptance into the program had to be extremely detailed, leaving little room for dramatic changes in form or content.

A technique of ecomedia that has offered a connection point between the author's artwork and the practices of environmental scientists at extreme field sites has been the use of GPS and other geospatial technologies. This developing technology offers cultural and scientific crossovers, for example, opportunities for GPS drawing and cultural and emotional mappings. In the next section, the author will compare and contrast the works of several artists and social geographers using geospatial tools and the potentials for increasing environmental knowing and social activism with these technologies.

Cultural Geospatial Computing Practices and Situated Knowing

“Language is like a road, it cannot be perceived all at once because it unfolds in time, whether heard or read. This narrative or temporal element has made writing and walking resemble each other.”

—Rebecca Solnit, *Wanderlust: A History of Walking*

Communications scholar Marco Quaggiotto (2010) has defined a map as having three possible functions: as a narration, as a communicative device, and as a tool. Several contemporary artists and artists' groups working with locative media have exploited the idea that maps can tell stories, communicate, and create space for interaction and collaboration. Artists Jeremy Wood, Christian Nold, Robin Hewlett and Ben Kinsley, and Blast Theory have created dramatic narratives rooted in theatre and performance art using mapping technologies. In all four cases, the works unfold as the participant explores physical or virtual space. The artists have created structures that encourage participants to add their personal experiences to the overall narrative, and therefore make the mapping experience highly collaborative. According to Quaggiotto's definition, therefore, these interactive mapping systems functioned in all three possible ways: as a narration in that participants experienced a story unfolding through physical space, as a communicative device since the artists and participants 'tagged' space or otherwise shared ideas with one

another, and as a tool because participants used the systems to both navigate through space and to collaborate.

London-based artist Jeremy Wood has worked with Global Positioning System (GPS) drawing and mapping projects in an art context since 2000. Using GPS satellite technology as a tool for making a mark over land, on water, and in the air, he has both built a personal cartography of map drawings and has conducted numerous GPS drawing and mapping seminars and workshops with schools, museums, and galleries (Wood 2010). While the most prominent aspects of a GPS drawing are the resulting shapes, often consisting of words or simple geographic shapes distorted by the topology of the landscape, the drawings also include numerical values for distance, speed of travel, date, and spatial coordinates. In addition to referring to his works as drawings, Wood also has used the term ‘cartographic journals’ and has written about the memories of space and time contained in the data. He has stated that individuals can both be defined and transformed through this technological mapping process, using the data to expand self-awareness (Lauriault 2009).

Similarly, artist Christian Nold’s projects, which he has called ‘emotional cartography’, include both personal work and public workshops. Nold’s most widely known project is the Bio Mapping device, a combination of a simple biometric sensor measuring Galvanic Skin Response and a GPS system. Wearers of the Bio Mapping device could travel through space while recording their level of ‘emotional intensity’ through perspiration on their fingertips. Nold’s workshop process involves not only recording the data, however. Because it is impossible to automatically determine the nature of the emotional intensity recorded using Galvanic Skin Response alone, during workshops, Nold has talked with participants after their walks and has asked them to describe their personal interpretations of the data as it is displayed on the map. For example, a spike in emotional intensity might be caused by a pleasant encounter with friends or by a fearful traffic crossing. Like Wood, Nold has described the travels of his project participants as narratives, although he has also given some agency to the Bio Mapping system by observing that participants are co-storytelling with the technology. He has determined that travelling through a familiar space can be a trigger for powerful memories that evoke emotional responses, and that a personal narrative can be constructed by observing these responses on a map. As Wood has observed, this process can expand a participant’s self-understanding.

Both Wood and Nold have been inspired to create projects in the Greenwich area of London. Wood was interested in the area historically as a place where mathematical models of

space and time intersected through the 1847 establishment of Greenwich mean time (GMT). Using a chronometer on GMT, travellers by sea or land could calculate their longitude from the Greenwich meridian, therefore using the position of the sun to calculate their geographical location. Although GPS uses a different technology, the 1984 World Geodetic System (WGS84) based on atomic time, GMT was the first coordinated universal time in history and therefore was a significant step towards the development of GPS. In Wood's project, *Meridians*, he undertakes a 458.6 mile performance where he writes the following quote from Herman Melville's *Moby-Dick* along the Greenwich and the WGS84 meridians: "It is not down on any map; true places never are" (Wood 2010). Through his choice of location between the close but still conflicting meridians, his irregular letters and his choice of text, Wood highlighted the glitches of GPS, the imperfections that draw attention to the physical limits of the technology, and the magnitude of the problem of mapping.

Nold's emotional mapping projects also consider the global. He describes the Bio Mapping tool as "a unique device linking together the personal and intimate with the outer space of satellites orbiting the Earth" (Nold 2009). However, Nold's Greenwich Emotion Map project created in 2005/06 examined the relationship between emotions and physical space through resident workshops. While Nold kept the possibility open that participants might discuss their position in relation to the Earth when interpreting their resulting emotion maps, discussions of the local event space predominated. As Nold described: "the Greenwich Emotion Map suggests an experience of the city as a series of distinct 'events', by which we mean moments of distinct attention. The actual nature of these 'events' varies from meeting people, taking a photo, crossing roads, to being annoyed by one's surroundings. . . . It suggests an embodied being within the environment actively interacting with people, objects and places" (Nold 2009). Through this and other mapping projects, Nold and Wood have challenged the typical notion of the map as a static, objective document and have defined an alternative pathway to understanding geography through the people who inhabit and create a place.

The idea of defining geospatial technologies as events rather than objects is not only the purview of alternative mapping or locative media art projects, it is also prominent in the field of social geography. Social scientist Adrian Mackenzie analyses human interaction with technology in terms of 'technicity' and 'transduction'. He has stated that technicity "refers to the extent to which technologies mediate, supplement, and augment collective life; the extent to which technologies are fundamental to the constitution and grounding of human endeavour"

(Mackenzie 2003). According to Mackenzie, technicity occurs through a process of transduction in which a person undergoes individuation over time through various interactions with technology. Mackenzie uses the example of a person travelling through a city, making choices about direction based on goals, avoiding obstacles and traffic, and having social interactions. The introduction of technologies such as GPS, goals like Wood's GPS drawings, or additional technologies like Nold's Bio Mapping system intervenes in the transduction process by bringing in alternative goals and affordances. This shift in technicity and therefore in the meaning of space can enhance environmental understanding by providing a new perspective on environment, experience, and technology.

The ubiquity of GPS technology in cell phones and cameras and the popularity of Google Maps and other online mapping systems have made geospatial technologies a part of everyday experience. The mass-market implementation of GPS has caused large-scale creative locative media projects to emerge. For example, a game in which participants use geographic coordinates to find a hidden 'treasure' (usually a log book) has emerged called 'geocaching', and there are now over one million geocaches in countries all over the world, including Antarctica (Geocaching 2010). Geocaching was invented in 2000 when 'selective ability', or the intentional overlay of random errors in navigation coordinates, was removed from public GPS receivers (Grewal et al. 2001). Despite this increased accuracy, as can be seen expressed in Jeremy Wood's GPS drawings, the system still contains glitches, which can add to the excitement of the geocaching. Geotagging, another popular mass-market activity, is the process of automatically adding location-based information to photographs and other media so that they can be placed appropriately in digital mapping programs. However, public access to these technologies has also created controversies.

As has been discussed in earlier chapters, the rise in popularity of and the detail in Google Maps have provoked concerns about privacy, particularly Google Maps streetview, which has published views into the windows of private residences. In 2008, artists Robin Hewlett and Ben Kinsley worked with Google to create the intervention 'Street with a View', surrealistic tableaux of Pittsburgh's Northside neighbourhood viewable only in Google Maps. While searching for an address along Samsonia way, for example, users might encounter a series of costumed characters, a parade complete with marching band and cheering fans, a marathon, a mad scientist's laboratory, garage band, a sword fight, and two firemen rescuing a cat from a tree (Hewlett 2008). 'Street with a View' subverts the power relationship established by Google

Maps, one in which Google has the ability to invade the privacy of citizens by virtue of its control of online mapping data, to one of citizen empowerment where the artists and their team of merry neighbourhood pranksters have created the city of their dreams. In this way, Hewlett and Kinsley have created an alternative pathway that demonstrates the value of Google Maps streetview as a potential narrative medium.

Locative media practitioners Blast Theory work with the dramatization of personal experience, exploring how the experience of a body in an environment could be made theatrical by placing the participant into a mixed-reality narrative. The artists in the group have struggled with the definition of narrative in the context of mobile media and have created projects with strongly authored narratives as well as open-ended projects in which the participants create the narrative content and structure. Often these projects are described as ‘games’, although they have admitted that a part of their project is to stretch the definition of the term ‘game’. In many of their works, the audience provides the content based on a structure developed by the artists. In their 2007 mixed-reality work, ‘Rider Spoke’, participants rode through a city on a bike equipped with a custom GPS system. This system directed the rider to find spaces that satisfied certain criteria, for example: “find a place where you can hide” or “find a building that your father would like.” The GPS system recorded both the location of each of these destinations and the voice of the rider talking about these places. Participants could also visit the places found by other riders and listen to their comments on the system. In this case, the places are defined by the thoughts and feelings of the riders as expressed through their own words.

Blast Theory believes that their work could have an influence on personal activism in regard to climate change. They have recently started to develop work addressing global climate change and personal activism based on the English traditions of Springwatch and Autumnwatch, festivals during which the public tries to spot the first appearance of a species of a season. Springwatch and Autumnwatch have also become popular seasonal programs on the BBC, and the challenge for Blast Theory has been how to effectively dramatize this aspect of the environment in the context of mobile media while still providing accurate and interesting scientific information (Tandavanitj & Adams 2010).

In all the projects discussed in this section, the user gains agency by moving through geographical space. He or she can create traces of movement through GPS drawing, record personal emotional states through Bio Mapping, share experiences on maps through geotagging, find a hidden treasure through geocaching, create a fantasy narrative as in the ‘Street with a

View' project, or be a part of an unfolding narrative as in Blast Theory's works. All these projects support an alternative definition of a map, one in which the map is in a constant state of becoming, brought into being by embodied practice. These countermapping strategies may increase environmental knowing by tying emotion, memory, and embodied experience to an experience of place. In the next section, the author will examine geospatial practices as they relate to scientific environmental information in the Arctic and Antarctic.

Mapping and Time in the Polar Regions

During the austral summer when the sun never sets, mapmaking is a constant process in the U.S. Antarctic bases around McMurdo Sound and the South Pole. Maps are generated for each of hundreds of field expeditions to explain and monitor the radio signal transmission networks, to analyse the weather conditions in order to determine safe air travel, or simply to plan a recreational excursion. Mapmaking is central to many of the research projects, whether it is a map of the extent of a glacier over time, a document describing seismic activity, or a track of the movements of the Weddell seal or Adélie penguin colonies. Flat file cabinets at McMurdo are overflowing with large-format printed maps with features named after long-time Antarctic researchers and staff who are often still present in the field. This activity creates a strange sense of geographical flux in a place where the lack of substantial flora and fauna and restrictions to human intervention in the environment has kept the landscape shockingly static.

For example, in the Dry Valleys there is relatively little ice cover, so the barren landscape looks like a desert. Occasionally, a seal or penguin will wander into the valleys from McMurdo Sound, become lost, and die. Since there are very few microorganisms present in the air and soil, the bodies of these animals decompose extremely slowly, and visitors might encounter bodies that are thousands of years old that appear to have arrived only recently. Researchers have determined that much of Antarctica froze between 14.1 and 13.9 million years ago, including the Dry Valleys, and they have found no evidence that a threshold to warmer conditions has been crossed since (Lewis 2007). Dry Valleys' paleoclimatologist Dr Adam Lewis's research team had found freeze-dried leaves, twigs, and roots that were over 15 million years old. Thus Antarctic researchers have an expanded sense of time and can be critical of those who do not. Lewis explained:

Most people's understanding of time is so pathetically thin and insignificant. Human life scales . . . people talking about a forest fire, for example, will say "You know, we shouldn't let these forest fires burn because it takes a hundred years to come back". Which is just pathetically stupid. In the life of a forest, a forest fire is a second compared to your life. The point is, you may see that as devastation and your grandchildren may see that as devastation, and their grandchildren may see that as devastation, but the trees would come back on their own timescale, not your timescale. So human beings in general have this horrible understanding of how old the Earth is, of how slowly some processes work (Lewis 2007).

In addition to experiencing a landscape that has not undergone significant change in millions of years of geologic time as in the Dry Valleys, the space-time connection that comes from the position of the sun and that was exploited by a chronometer on GMT is not possible in either the Arctic or Antarctic polar regions. In these places, the sun sits in the same place hour after hour, depending on the time of year rather than time of day, again emphasising slow time. From 2001 to 2005, the artist-team of Bruce Gilchrist and Jo Joelson, known as London Fieldworks, performed a series of experiments in the northern polar regions of Greenland and Norway under the name of Polaria (Verbeke Foundation 2010). Gilchrist and Joelson's work focused primarily on the impact of constant natural daylight on the human body. As in the author's video essay "Ground Truth", the Polaria project stressed the importance of embodied experience in an extreme environment. The London Fieldworks team adopted a scientific-like methodology in order to work with the idea of science as metaphor and were interested in exploring technicity in connection with the abstractions of science. For example, they measured solar radiation in conjunction with a variety of their own physiological data. Like Christian Nold, London Fieldworks took measurements of the human body in relation to geographical space. However, the Fieldworks team examined more than the geographical location, they collected data about one aspect of the atmospheric conditions that reached their bodies in that location. The radical act of connecting physical and personal data with environmental data can be a powerful way to create alternative pathways to understanding the world. As they have observed: "If aesthetics is the study of new ways of seeing and of perceiving the world, then the Polar

Regions are exceptional loci for the quest for multiple ways of interpreting what it feels like to be human in the natural world” (Verbeke Foundation 2010).

Technicity, or technology in conjunction with the body, was very prominent in Polaria, as it was in the author’s experience in Antarctica. For example, during Gilchrist and Joelson’s trip to Greenland, in addition to constantly monitoring their physical conditions and those of their surroundings, they were dependent on two 12V solar panels for power, and as the sun changed position over the time they were there, they had to conserve more and more power in order to maintain necessary radio contact. In Antarctica, the author was burdened by the technical prosthesis of the two-way radio, her mobility was limited by weather monitors and forecasts, and as a focus of her project she visited remote weather and climate monitoring instruments. Perhaps the aesthetic opportunities that the polar regions can afford is not only a new way to interpret what it feels like to be human in the world, but also to add to the understanding of human technicity by examining an environment that is far outside that for which the human body has evolved, and therefore humans must depend on technology for mere survival. London Fieldworks’ project, Polaria, attempted to communicate the physiological experience of the extreme environment of Greenland to the public through coloured light and electrical current. They also mapped this coloured light and current to the physiological responses of the viewers, creating a technological feedback loop that was mitigated by the participant. In this way the participants were provided with a similar experience to the process that London Fieldworks had subjected themselves to in the field, in that they observed their embodied response to external stimuli (London Fieldworks 2010).

The unique geographical position of the poles and their resulting extreme conditions promote a unique relationship between humans and the environment. The position of the sun throughout the year requires a different sense of time and space than what has been established by standards like GMT. The constant sunlight (or lack of) affects the body accustomed to daily cycles. Survival for humans in the extreme weather conditions of the polar regions requires a technological dependence of a greater magnitude than in more temperate climes. Unlike places with more significant flora and fauna that transform the landscape seasonally, the poles have a relatively stable physical environment, with material that decays much more slowly and remains in one place for thousands of years or more. Understanding this kind of place requires scientists to mentally compress time and space in order to understand very slow ecological processes. In the next section, the author will outline the challenges and opportunities she encountered through

creating an online mapping system of a personal journey combined with social media containing soundscape recordings, images, and interviews with Antarctic scientists. This kind of art, science, and ecomedia ‘mash-up’ might provide an alternative pathway to understanding art and science in these extreme locations.

90 Degrees South Case Study

The author created 90 Degrees South as a personal journey in Antarctica told through Google Earth (Polli 2009). Like the author’s video essay, “Ground Truth”, this Google Earth journey was designed as an ecomedia work to communicate some of the concepts explored in the author’s research, but unlike the video essay, the Google Earth project was designed to be map-based, allowing the user to choose locations and directions for the narrative. The project, currently active, includes approximately fifty video clips linked from the 90 Degrees South YouTube channel, links to over 1,500 images on the author’s flickr site, and approximately thirty sound excerpts including soundscape recordings and extended interviews with scientists. The project is available for download and viewable online with a Google Earth plug-in and has been presented to the public as a large tabletop and floor projection with a touch-screen interface.¹⁵

The author confronted several challenges with the creation of this kind of interface. Initially, she wanted to use Google Maps since that format allows online accessibility without an additional plug-in, but the flat map projection used by Google Maps meant that the continent of Antarctica was highly distorted, and any detail up to the latitude of 90 degrees south was not available. In response to this, the author created a custom Google Map using a flat projections map of Antarctica, but this map did not allow users to see the relation between Antarctica and the rest of the Earth. Thus the spherical projection of Google Earth was determined to be the most effective solution. Although Google Earth was significantly more useful, the limited resolution afforded by the default system near the poles required overlays of satellite and aerial images. However, the spherical mapping of images over the globe in Google Earth meant that an image overlay directly on top of the South Pole would be distorted 360 degrees around polar coordinates, making it completely illegible. Despite this restriction, the 90 Degrees South on

¹⁵ “90 Degrees South: Interactive Experience of Antarctica” was created by the author with the production assistance of Sha Sha Feng and Michael Medina and has been presented to the public at the Atlas Center for Art and Technology at the University of Colorado, Boulder, at the Eyebeam Center for Art and Technology, and at the Kitchen in New York City. More information is available at <http://www.90degreessouth.org>.

Google Earth helped the author to emphasise the unique position of Antarctica on a globe, while flat maps privileged the more populated areas of the Earth.

Another challenge was the scale of the Antarctic versus the concentration and restriction of the author's of activities to only the U.S. and New Zealand bases. This meant that large swaths of area would not contain material and that users would need to zoom in to areas to view the narrative. While emptiness might emphasise the feeling of vast blank white spaces on that continent, the author felt that it was important to also emphasise the large distances that are normally travelled by the researchers there, so she added colour-coded travel paths based on mode of travel, for example, fixed-wing aircrafts like C-130 or C-9, piston bully, helicopter, or terrabus. These paths cut through the map both on the continent and across the globe to indicate how the author arrived in Antarctica from her home in the United States.

The intention of the map was to be a companion to the "Ground Truth" video essay and the Sonic Antarctica audio CD and multichannel video installation by giving users the ability to browse the raw source material used for each of these projects in relation to the place the material was gathered. The 90 Degrees South map has served as a hub for material online at social networking and file sharing sites, and this consequently can allow for expansion of the project, potentially with additions by other researchers and artists, and to the Arctic polar regions. The project helps to illustrate the potential for virtual globe-based interactive documentary storytelling.

Conclusion

Formal art and science collaborations in extreme environments like the Arctic and the Antarctic have the potential to expand environmental knowledge across domains. These collaborations can explore complex interactions between natural and social phenomena. Understanding these contexts extends beyond the skills typically associated with science to those inscribed by the arts and humanities. However, these collaborations pose challenges inherent in the differing goals and working styles of artists and scientists, especially in relation to communicating the stories of climate change. While scientists participating in long-standing art and science collaborations like the U.S. National Science Foundation's Antarctic Artists and Writers program appreciate the freedom that artists have to express politically controversial ideas, some scientists in less-established programs like Kilpisjärvi have concerns that artists' preconceived notions about climate change may blind them to other, perhaps more important, issues. In these extreme

environments, the use of resources plays a substantial role, with the artists' use of resources at the bottom of the priority list in all cases. Educational programs in art and science may offer an opportunity for building resources, as can be seen in the Aalto University initiatives of Kilpisjärvi. Such programs may serve to extend what counts as valid knowledge in scientific and public contexts.

Places like the Arctic and the Antarctic hold particular significance on the globe and may be a particularly interesting area of the development of geospatial mapping art projects. For example, Christian Nold's projects have explored the intersections of emotions and geospatial location. Jeremy Wood's projects have examined how one might engage with the land while aware of a global dimension, and Blast Theory's works have built narratives through the intersection of individuals and an environment. These projects also explore aspects of the technicities that have transformed people's lives since the introduction of GPS and the development of mobile technologies for mapping. These technicities are prominent in extreme environments such as the poles in order to combat the difficulty in sustaining human life there. Therefore, art and science collaborations using such technologies in and about the Arctic and Antarctic may have the potential to expand knowledge of these environments.

One area in the Arctic and Antarctic that could gain from an art/science perspective is the unusual experience of time. Time in polar environments is experienced in dramatically different ways than on the rest of the globe. For example, in the Antarctic, the landscape has remained relatively undisturbed for millions of years, and therefore one encounters the distant past everywhere. Coupled with this, the constant daylight or night-time is counter to human experience, and living in such light over long periods of time may promote a physiological transformation. Artists such as London Fieldworks have used scientific methodologies in the context of polar field sites to examine the connections among humans, technology, and geography in the situation of constant light, and the author's works in geosonification of weather and climate as discussed in previous chapters have compressed time and space to a human scale.

While the representation of virtual map-based narratives related to the poles using social networking has potential to build public knowledge, there are challenges that come from the nature of the media. For example, the mapping of a flat image over a sphere using polar coordinates by the publicly available mapping system Google Earth makes it impossible to overlay an image directly on the poles, while the flat map projection afforded by Google Maps doesn't even extend to 90 degrees south. The vast empty spaces of Antarctica create clusters of

concentrated activities that are unlike other map projections, but indicating the long distances travelled, as in the author's 90 Degrees South Google Earth project, may add a dimension that can help to illustrate the Antarctic experience. The author's conceptual, theoretical, and practical explorations of the extreme environments of the Arctic and Antarctic and her experience and analysis of art and science residencies in these locations may help to identify the challenges and opportunities that exist at the far corners of the world for creating new knowledge about the local and global environment.

Conclusion: Remembering Forward

This dissertation has traced the author's artistic, scholarly and political trajectory towards a position of advocacy for increased public access to geospatial environmental data and information. This position evolved through the process of creating and distributing a series of ecomedia artworks using modelled and real-time atmospheric data from various parts of the world.

Through this dissertation, the author has:

1. Provided a theoretical framework for the creation and analysis of ecomedia and geosonification artworks, with ecomedia defined as media using geospatial and environmental monitoring and model data and geosonification defined as sonification modeled after the real-world soundscape rather than after musical structures.
2. Through 27 original interviews with scientists, artists, and practitioners, gathered and shared alternative information that presents questions and problems related to rapid climate change that would not have been available through the theoretical research alone.
3. Through ecomedia and geosonification artworks that present direct and immediate translation of local and global environmental data, found an alternative way to encourage a public discussion about environmental issues.
4. Developed a series of recommended methods, methodologies and strategies for other researchers and students to follow.

In examining the primary question of this doctoral thesis, **How can the production of geosonification and other ecomedia open alternative pathways to environmental knowing in a time of urgent climate crisis?** the author has come to the following conclusions: because of the complexity of scientific information related to the atmosphere and the misinformation in mainstream media, it could be asserted that there is a need for more direct public communication of weather and climate science, and that geosonification and other ecomedia artworks may serve as an alternative medium for promoting social action around environmental issues by leading to the development of new interactions and structures. The development of geosonification and other ecomedia works interpreting environmental data may have the potential to open alternative pathways to increased environmental understanding through geospatial and computational knowing. Sound can offer a way for scientists to bring their messages to the public, through recordings, radio transmissions and the audification and sonification of scientific data; and the

affective experience of geosonifications modelled after the soundscape may play a role in the public reception of scientific information about weather and climate.

Connecting media art to scientific monitoring tools and global networks of environmental data, including local conditions and long-term records can be an important part of environmental knowing. Ecomedia works using networked environmental data can help to make this data more accessible to the public. Volunteer networks like CWOP and Weather Underground and artists' projects like *Hello, Weather!* may help to provide public alternatives to private data collection and analysis. Formal art and science collaborations in extreme environments like the Arctic and the Antarctic also have the potential to expand environmental knowledge across domains. The author's conceptual, theoretical, and practical explorations of the extreme weather and climate of the Arctic and Antarctic and her experience and analysis of art and science residencies in these locations may help to identify the challenges and opportunities that exist at the far corners of the world for creating new knowledge about local and global conditions.

Questions for Further Research

In this thesis the uncertainties and risks in relation to anthropogenic climate change have been examined with the risks associated with living and working in extreme environments and the risks of public action. The representation of the risks humanity faces from anthropogenic climate change presents a unique challenge because while human behaviour plays a pivotal role in the magnitude of change, a representation itself can influence this behaviour. It has been demonstrated that geosonification and ecomedia may promote social change through the cultural practice of sharing environmental data, specifically real-time weather and climate data. By drawing on models of situated and embodied action, it has been shown that geosonification and ecomedia artworks may be used to promote changes in public access to such data and that greater public access to raw environmental data may serve as a driver or catalyst for increased environmental knowledge.

As a way of 'remembering forward' based on Thrift's definition discussed in the chapter *Witnessing Space*, the author has concluded this thesis by predicting a number of general questions for future analysis that might be investigated by the author and shared with other researchers:

1. As carbon-trading markets become more mature and the idea of 'air for sale' becomes more widespread, how can artists, scientists, and technologists collaborate to develop alternative strategies for improving air quality?
2. What will be the long-term impact of art and science residency programs in remote science field stations, especially in the Arctic and Antarctic after the expiration of treaties protecting these areas?
3. What strategies can be employed for collaboration between artists, scientists, and government agencies towards safely increasing public data access? How can the public understand and use this data more effectively?
4. As environmental data monitoring and public access to this data expands, how will art, culture, and society be affected? How will this data be integrated into individual, embodied experience?

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