2016-06-12

Geometric parameters for a 2D-Numerical Wave Tank

Musiedlak, Pierre-Henri

http://hdl.handle.net/10026.1/10829

INORE 10th European Symposium 12-18 June 2016 Nantes, France

Geometric parameters for a 2D-Numerical Wave

Pierre-Henri Musiedlak // pierre-henri.musiedlak@plymouth.ac.uk // Plymouth University, UK

Deborah Greaves, Ben Child (DNV-GL) Gregorio Iglesias, Martyn Hann, Edward Ransley

Aim

This poster aims to be a storyboard on the realisation of a 2D-Numerical Wave Tank (2D-NWT), simulating numerically a wave-tank and its experiments.

Context

In the atmosphere of after the COP21 and its 2°C agreement, ORE shows even more its potential. But, engineering design and survivability of devices are still critical, and consist of a key point to insure the sector development.

Tools

- **OpenFOAM**, an open-source software made of a set of C++ libraries written on text files, allowing customization
- **Waves2FOAM**, a library allowing generation and absorption of waves.

Physics and equations

- **Physics:** two incompressible viscous fluids
- **Mathematical model:** Navier-Stokes for incompressible fluids

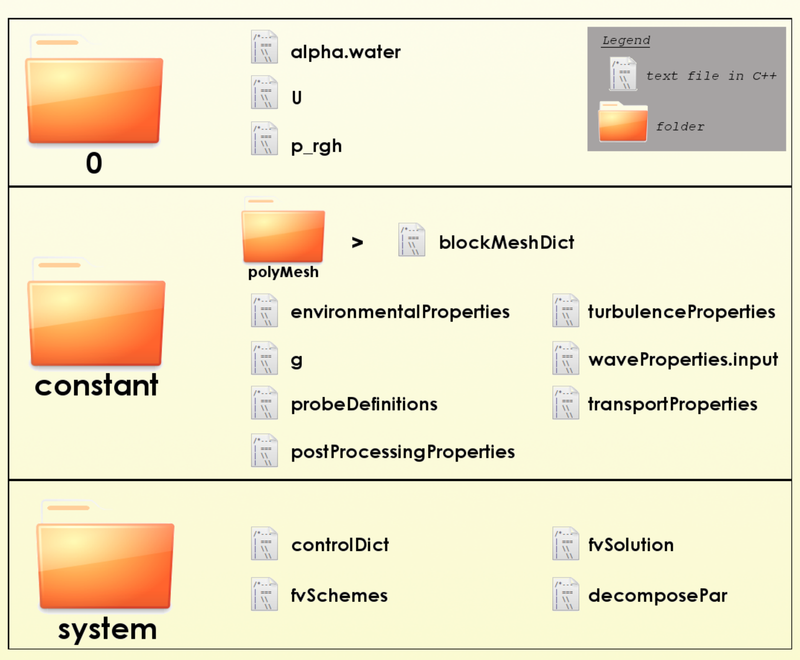
Continuity equation $\nabla \cdot \mathbf{U} = 0$

Mass conservation

$$\frac{\partial \rho \mathbf{U}}{\partial t} + \nabla \cdot (\rho \mathbf{U}\mathbf{U}) - \nabla \cdot (\mu_{eff} \nabla \mathbf{U})$$
$$= -\nabla p^* - g * X \nabla \rho + \nabla \mathbf{U} \cdot \nabla \mu_{eff} + \sigma \kappa \nabla \alpha$$

- **Numerical method:** Finite Volume Method for space and time discretisation
- **Interface air/water:** Volume of Fluid (VoF) Method - a fraction $\alpha \in [0,1]$ at at each cell (0 is pure air, 1 is pure water)
- **Unknowns:**
  `U` (velocity)
  `p` (pressure - is `p/rho*g*h` in OpenFOAM)
  `alpha.water` (water proportion)

OpenFOAM architecture



Case directory

OpenFOAM is set up with lots of different classes - *C++ special names* - use to define different parameters

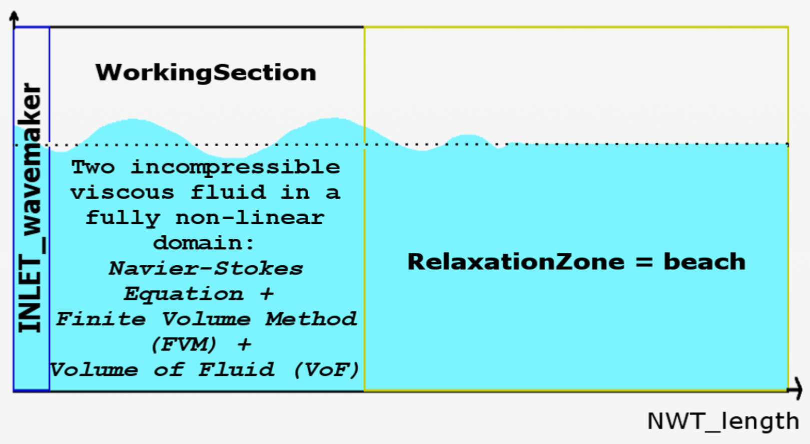
Using the terminal in the case directory:

- `blockMesh` : generate the mesh according to blockMeshDict
- `waveGaugesNProbes` : generate wave-gauges
- `setWaveParameters`: set wave input
- `setWaveFields`: set wave and fields (alpha.water, U, p_rgh)
- `waveFoam` : run solver
- `paraFoam`: visualise results

Setup

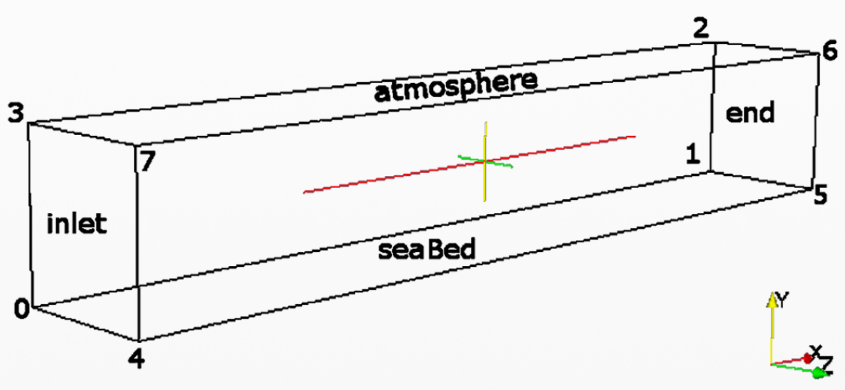
Like a Physical Wave Tank (PWT), the 2D-NWT is composed of three parts:

- **INLET_wavemaker**
  non-physically-realistic area where waves2Foam allows different wave types to be generated (regular, irregular, combined) through a `relaxationZone`.
- **WorkingSection**
  where simulation matches experiment
- **BEACH**
  non-physically-realistic area where waves2Foam absorbs the incoming wave and prevents from reflection.



Boundaries

2D-NWT = 3D-NWT with one-cell thickness in the third direction, plus two boundaries type `empty` for both left and right sides.



Using classes, each boundary is then defined

	Geometry		Boundaries		
Name	points	*blockMesh*	*alpha.water*	*U*	$p_r gh$
inlet	{0,4,7,3}	patch	waveAlpha	waveVelocity	zeroGradient
seaBed	{0,1,5,4}	wall	zeroGradient	fixedValue (0,0,0)	zeroGradient
end	{1,5,6,2}	patch	zeroGradient	fixedValue (0,0,0)	zeroGradient
atmosphere	{3,7,6,2}	patch	inletOutlet	pressureInletOutletVelocity	totalPressure
left	{0,1,2,3}	empty	empty	empty	empty
right	{4,5,6,7}	empty	empty	empty	empty

Table 1: Geometry and Boundaries definition

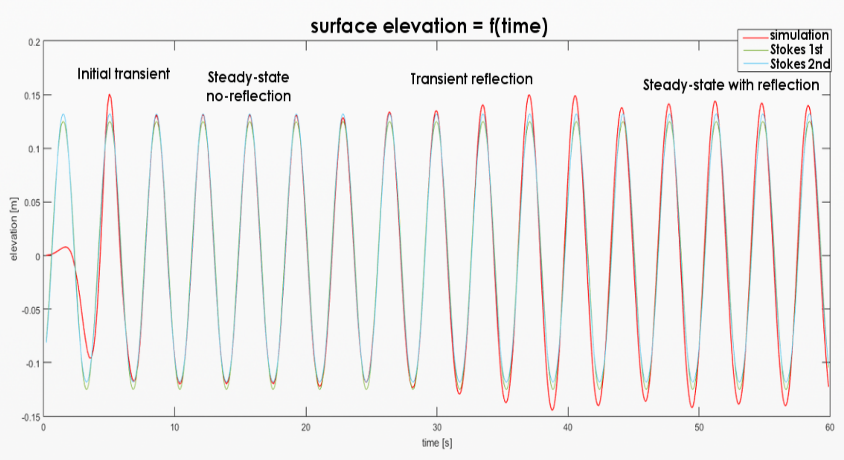
waves2Foam defines the INLET_wavemaker by the keywords: `waveAlpha` and `waveVelocity` allowing wave generation.

Reflection issue

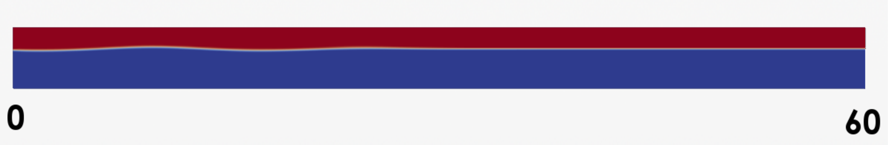
Even in NWT and whatever the length of the beach, some reflections will happen!

A simulation in a 60m long non-optimised NWT shows four distinct behaviours:

- Initial transient
- Steady-state no-reflection
- Transient reflection
- Steady-state with reflection



Simulation in a non-optimsed 60m NWT



- In this NWT, simulations with differents beach length show that the reflection phenomenon always takes place at the same time (21s). So the reflection occurs at the end of the NWT.
- But it goes faster - (2*60-6)/21=5.4m/s - for a 4.3m/s input waves.

Process

The depth is fixed to 2.8m according to Plymouth University Ocean Basin, and the three parameters left to define are:

- NWT length
- Beach length
- Cell-size

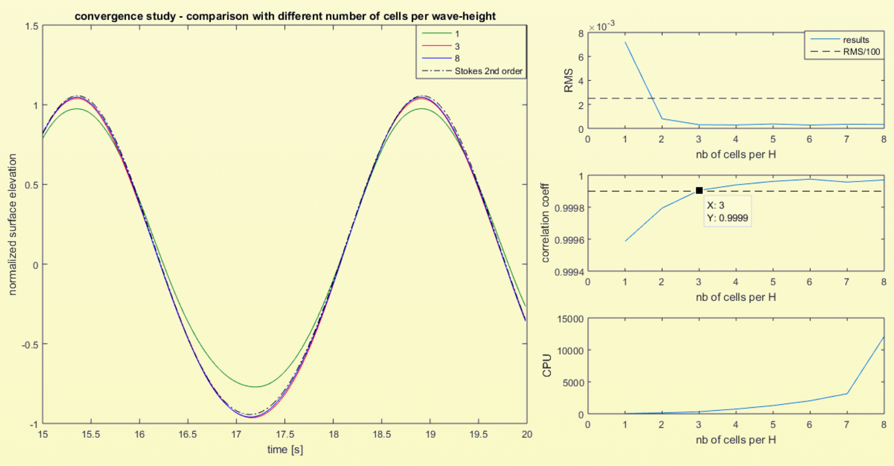
First, the cell-size, as it has miror influence on both other parameters.

INLET is fixed to 1m according to previous work - [3] and [4].

WorkingSection is here fixed to 6m, for the future experiments.

Cell-size & Mesh

- Full square cells mesh: better physical representation in both directions
- No reflection effect: 60m NWT with a 53m long beach, and only the 20s will be considered (before reflexion occurs).
- Stokes 2nd order, T = 3.56s H=0.25m (for a bigger wave)



Comparison of simulations using an increasing number of cells per wave-height

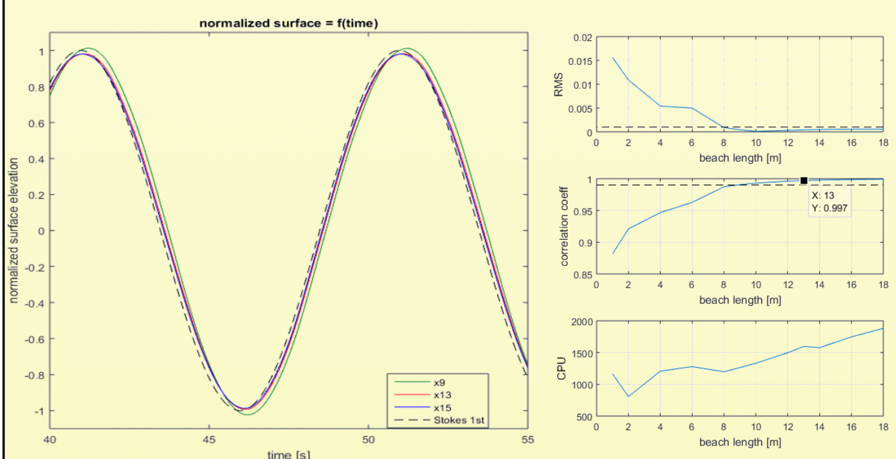
$$RMS < \frac{H}{100} \;\&\; corrcoeff > 0.9999$$

Cell-size = 3 cells per wave-height

Beach

The longer the input wave-length, the longer the beach should be. Plymouth University Ocean Basin generates waves from 0.1Hz to 2Hz

- **Most restrictive**: 10s period wave.
- **Process:** Increase NWT_length with beach_length, to reach compromise

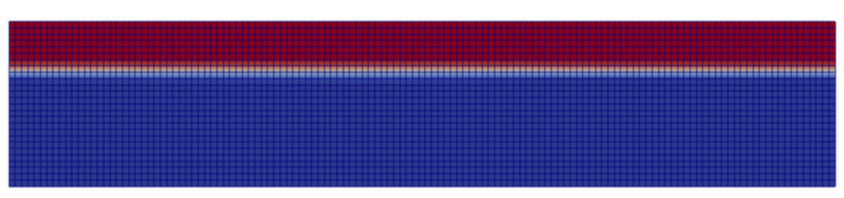


Comparison of simulations using an increasing beach length

$$RMS < \frac{H}{100} \;\&\; corrcoeff > 0.999 \;\&\; \frac{d(corrcoeff)}{d(x)} < 0.001$$

Beach_length = 13m

Final NWT



INLET [m]	Working Section [m]	Beach [m]	cells per wave-height
1	7	13	3

Table 2: NWT characteristics

This poster is tagged with augmented content

To access additional content on your mobile device:

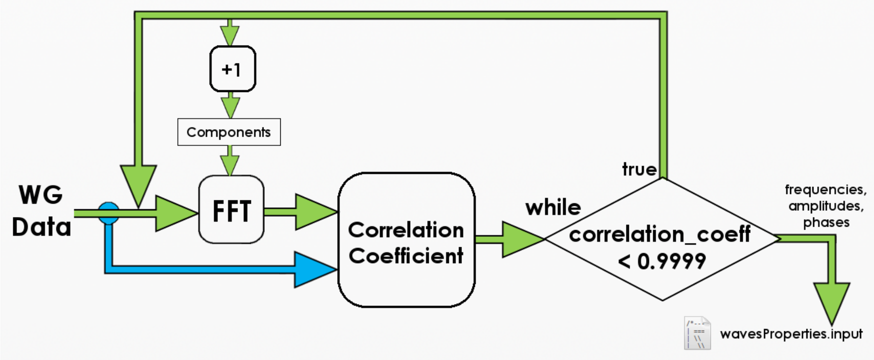
- ensure you have a strong internet connection (Wi-Fi).
*- download the **Aurasma**© app onto your mobile device.*
- Skip making an account.
*- Press the **A** at the bottom centre.*
*- search for **pmusi** using the*
*- follow **pmusi's Public Auras***
- Return to the viewfinder by pressing the
- frame images tagged with Aurasma's logo in the app viewfinder.

Application

Plymouth University Ocean Basin data:

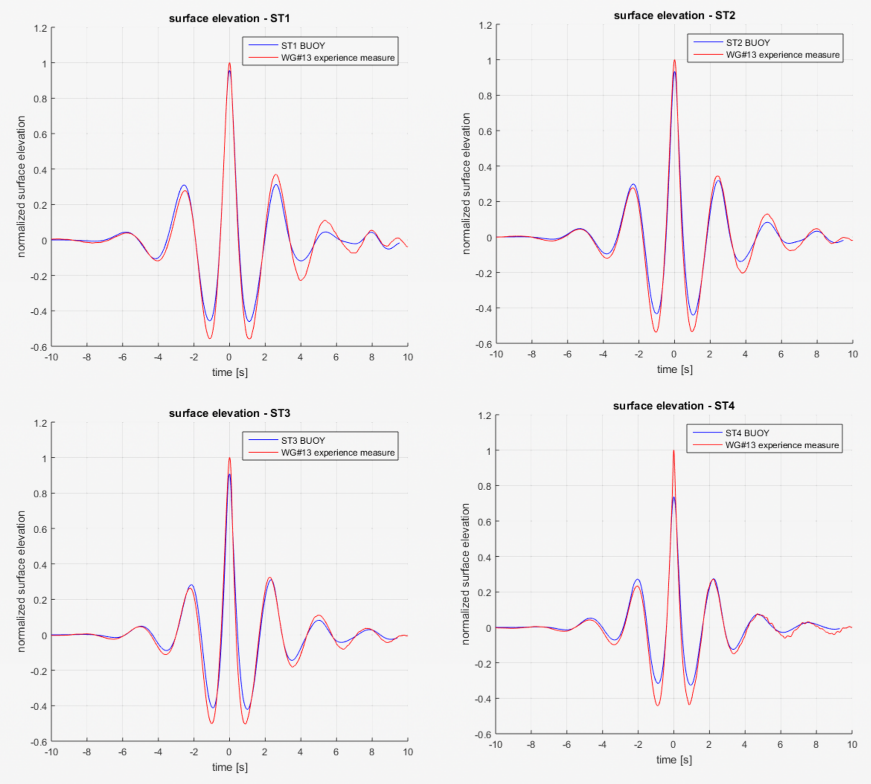
- Time-series of surface-elevation at different position
- Extreme events (NewWave)
- Time-series of loads
- Time-series of model movement
- Several models or without

4 cases with increasing steepness and non-linearity were simulated using a wave-gauge (WG) time-series.



From raw experimental data to readable input for INLET_waveMaker (`combinedWave`)

`combinedWave` in `wavesProperties.input` allows a linear addition of Stokes 1st order.



Surface elevation with increasing steepness time-series

The NWT proves its ability to generate any experiment using the surface-elevation time-series as input.

Future development

This NWT is indeed a solid basis for future development:

- Go 3D
- Fixed structure
- Single taunt moored buoy
- Multi-body

And as part of WaveDyn development:

- Comparison with WaveDyn
- Coupling with WaveDyn

OpenFOAM community and its development will be very helpful: a moored buoy, a multi-body floating device, a water-turbine...

http://www.ccp-wsi.ac.uk/

References

[1] N. G. Jacobsen, D. R. Fuhrman and J. Fredsøe, A wave generation toolbox for the open-source CFD library: OpenFoam®, Int. J. Numer. Meth. Fluids, 2012; 70:1073–1088.

[3] T. Vyzikas, E. Ransley, M. Hann, D. Magagna, D. Simmonds, V. Magar, and D. Conley. Integrated Numerical Modelling System for Extreme Wave Events at the Wave Hub Site, in Proceedings of Institue of Civil Engineering (ICE): Coasts, Marine structures and Breakwaters, 18-20 September 2013: Edinburgh, UK.

[4] E. Ransley, Survivability of Wave Energy Converter and Mooring Coupled System using CFD. Phd Thesis, September 2012: Plymouth University, UK.

[5] M. Hann, D. Greaves, and A. Raby. Snatch loading of a single taut moored floating wave energy converter due to focussed wave groups, Ocean Engineering, 2015; 96:258–271.

Acronyms

RMS : Root Mean Square difference between results and theory
corrcoeff : correlation coefficient - MATLAB script
NWT: Numerical Wave Tank
PWT: Physical Wave Tank