FACULTY OF ENGINEERING AND ARCHITECTURE

Application Of Open Boundaries Within A Coupled DualSPHysics-OceanWave3D Model

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INTRODUCTION

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Open Boundaries

Open Boundaries

Potential Flow Solver

Smoothed Particle Hydrodynamics

Potential Flow Solver

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WAVE PROPAGATION MODEL

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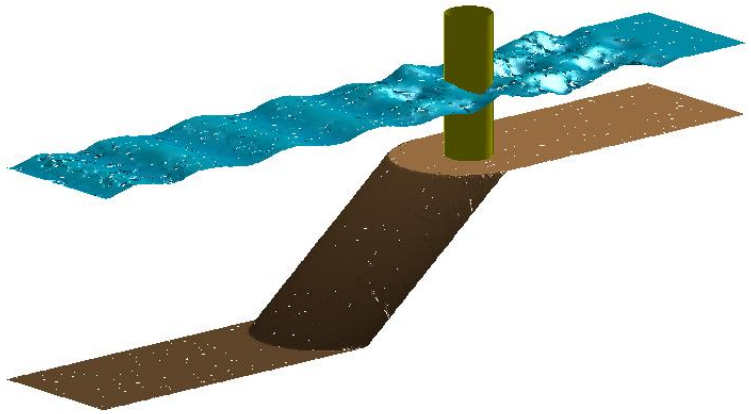
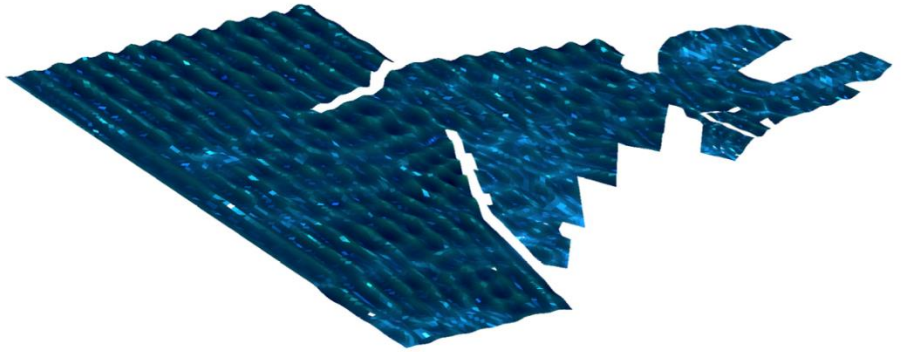


OceanWave3D



- Fully non-linear potential flow solver
- Flexible-order finite difference
- Fourth-order Runge-Kutta method
- Sigma layers in Z-direction
- Fast calculations

SPH MODEL

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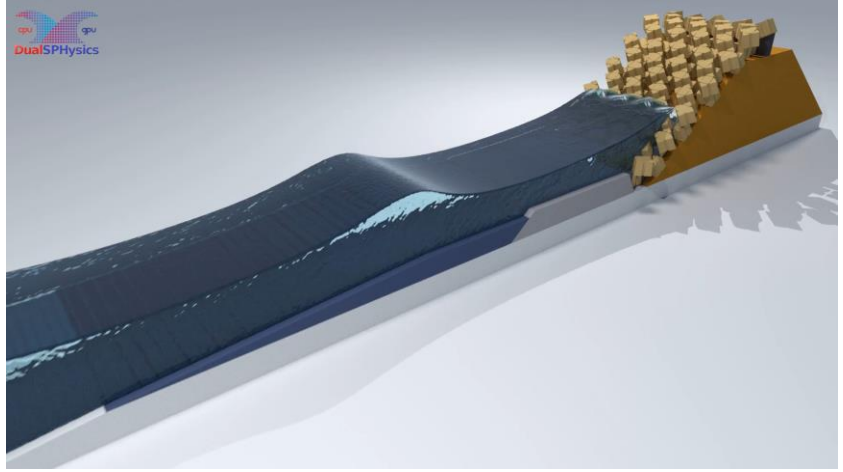
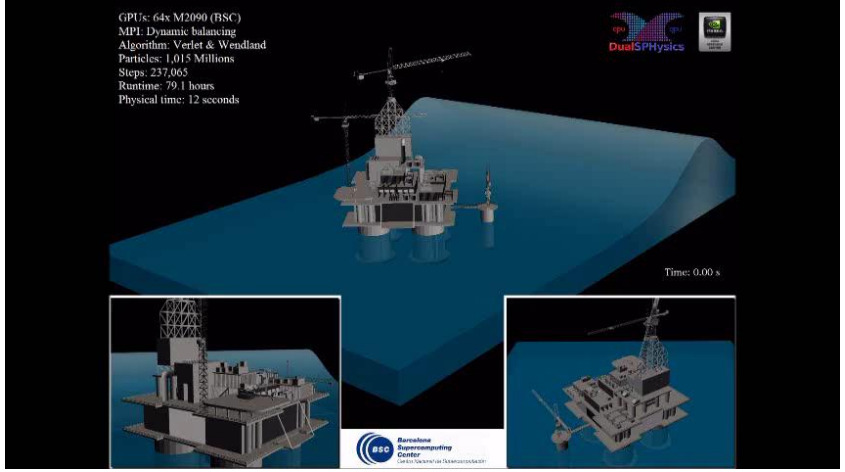
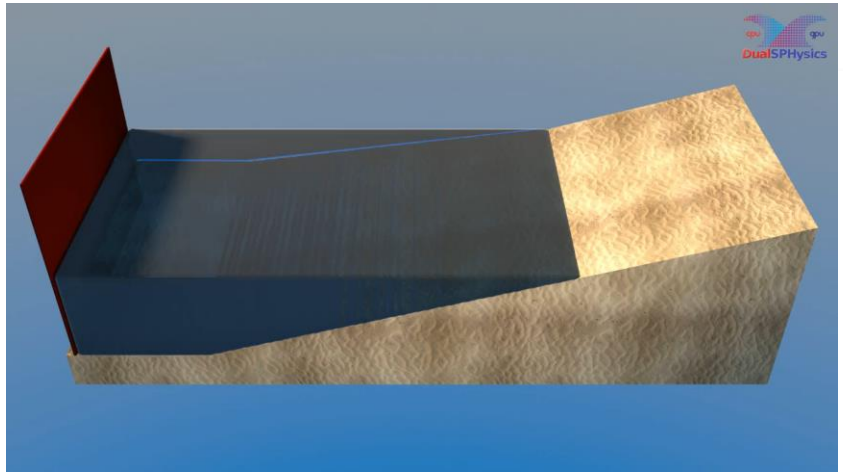




cpu gpu
DualSPHysics



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- Lagrangian particle method
- Weakly-Compressible SPH
- δ-SPH value of 0.1 (Antuono et al. 2012)
- Particle shifting (Lind et al. 2012)
- Explicit second-order symplectic scheme
- Open Boundaries (Tafuni et al. 2016)

OPEN BOUNDARIES

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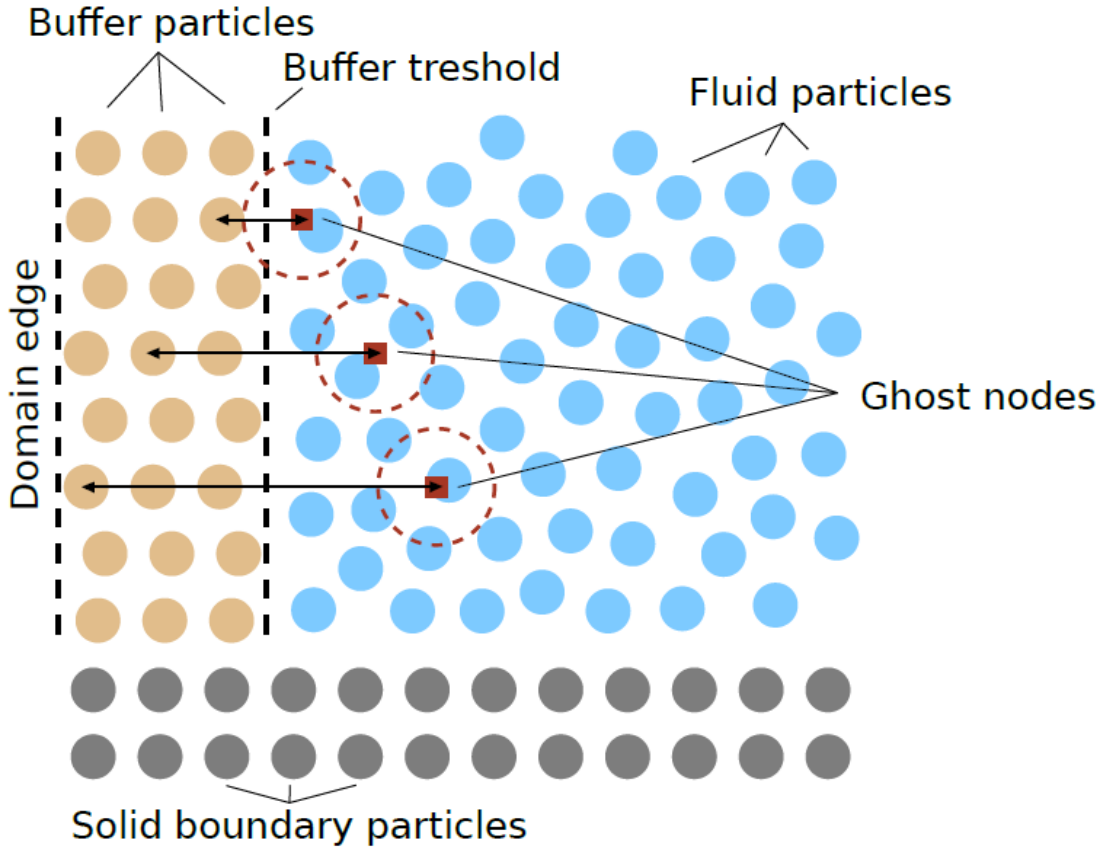
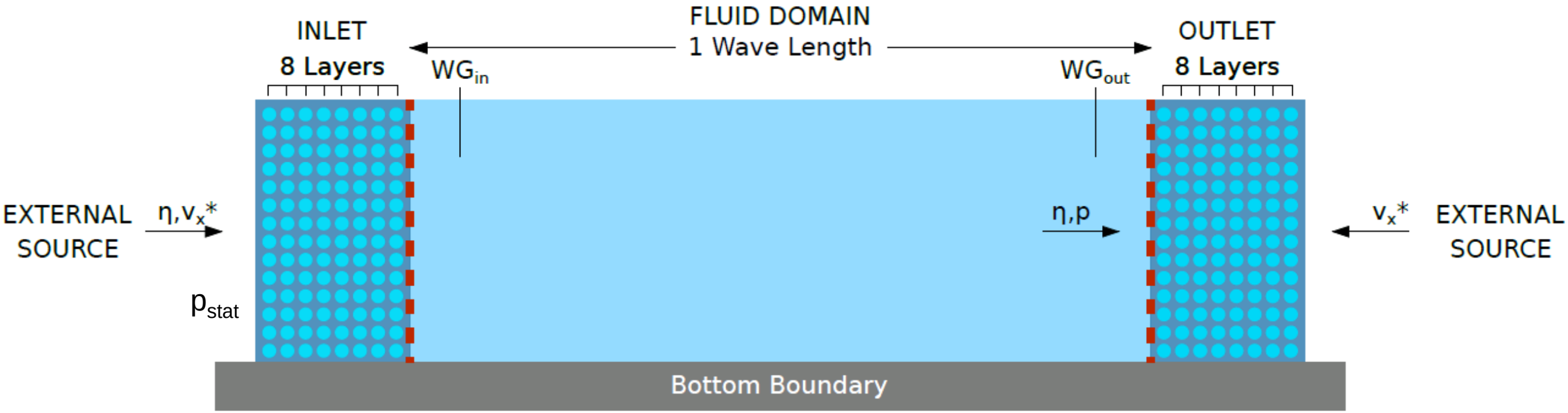
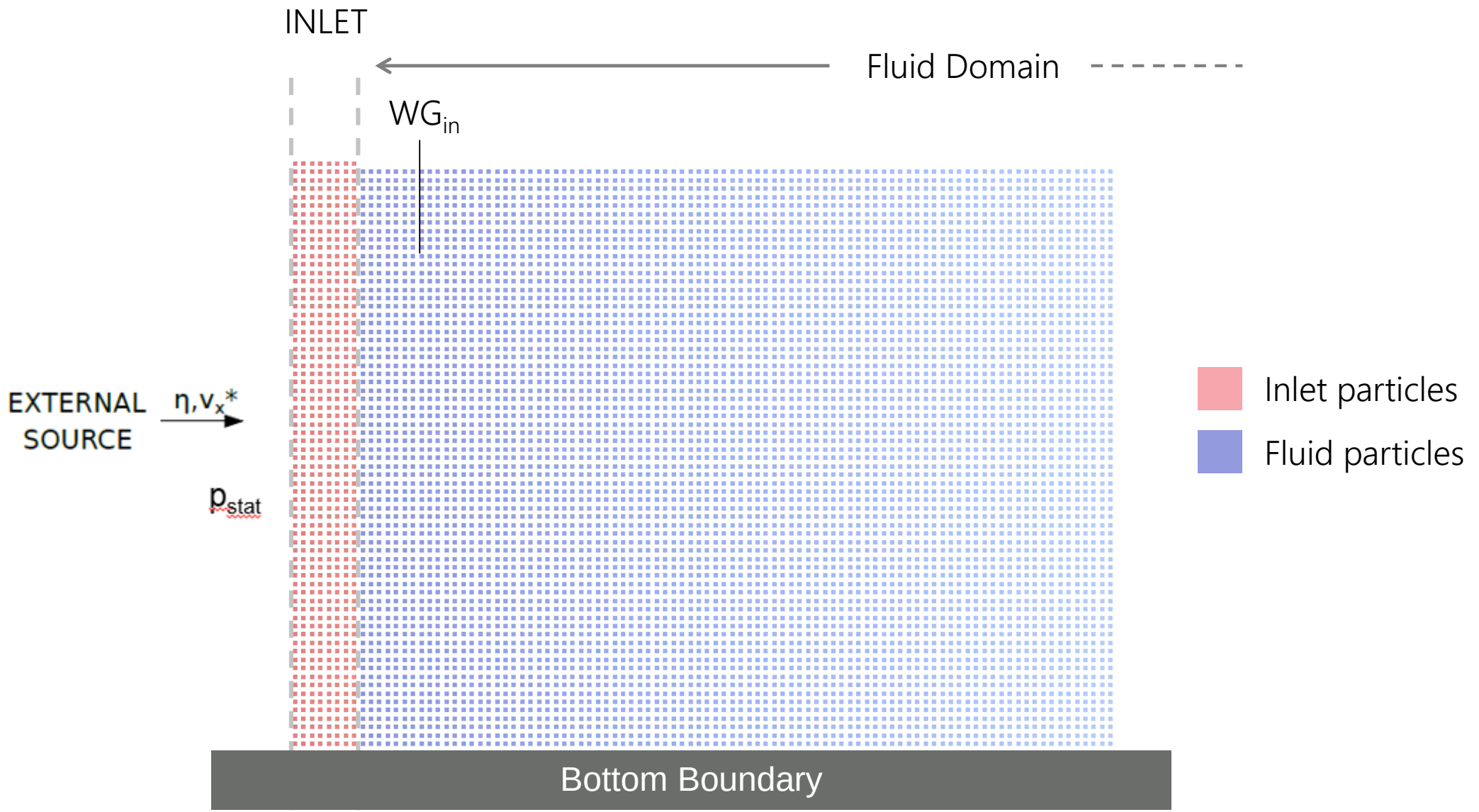
- Impose physical quantities
- Extrapolate from fluid domain using ghost nodes

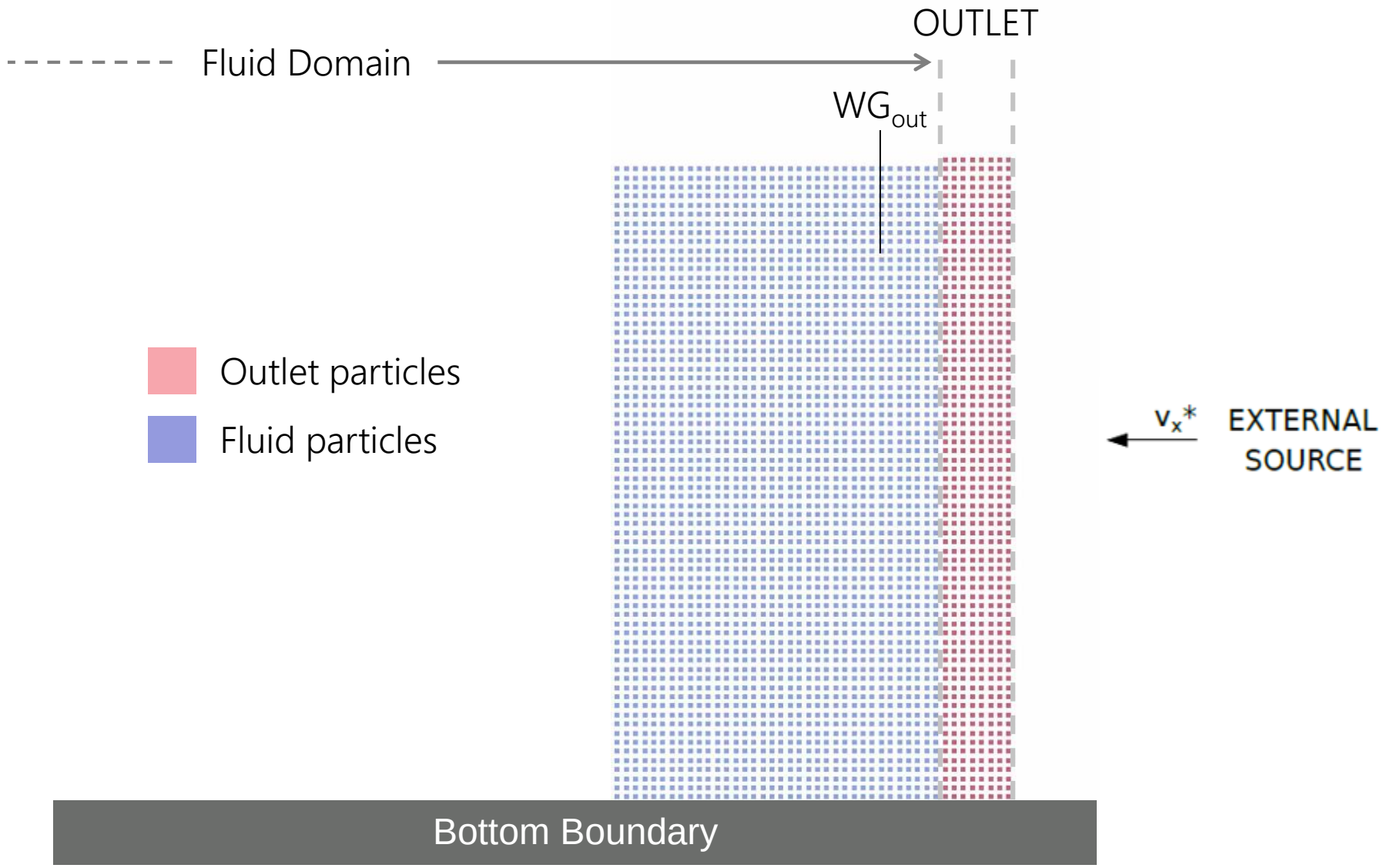


Tafuni, A., Domínguez, J. M., Vacondio, R., & Crespo, A. J. C. (2018). A versatile algorithm for the treatment of open boundary conditions in Smoothed particle hydrodynamics GPU models. Computer Methods in Applied Mechanics and Engineering, 342, 604-624.



Quantity	X-Velocity	Z-Velocity	Surface Elevation	Pressure
INLET	Imposed	/	Imposed	Hydrostatic
OUTLET	Imposed	/	Extrapolated	Extrapolated


INLET
Fluid Domain
WG_{in}
EXTERNAL SOURCE
η, v_x^*
p_{stat}
Bottom Boundary
Inlet particles
Fluid particles


OUTLET
Fluid Domain
WG_{out}
Outlet particles
Fluid particles
v_x* EXTERNAL SOURCE
Bottom Boundary

Inlet Correction:

$$v_{x,in}(z,t) = v_{x,theory}(z,t) - [\eta_{WG,in} - \eta_{theory}] \cdot \sqrt{\frac{g}{d}}$$

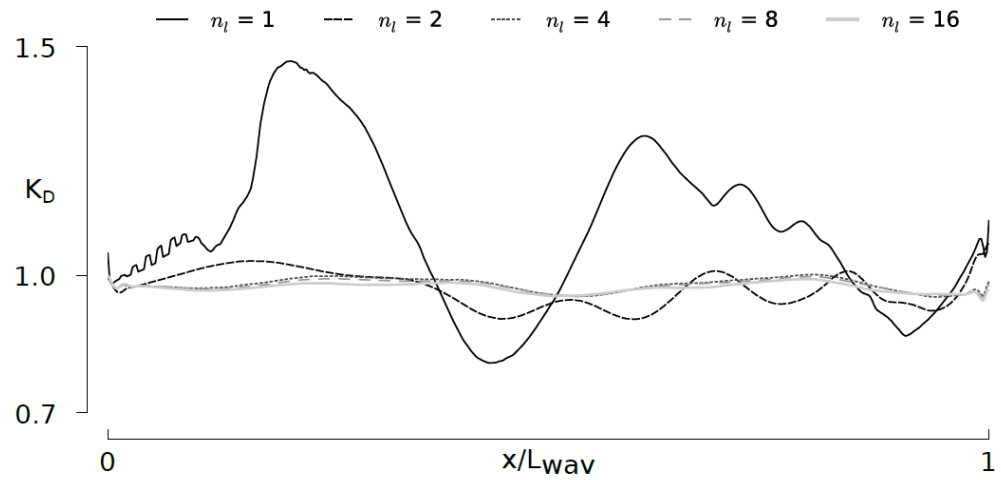
Outlet Correction:

$$v_{x,out}(z,t) = v_{x,theory}(z,t) - [\eta_{theory} - \eta_{WG,out}] \cdot \sqrt{\frac{g}{d}}$$

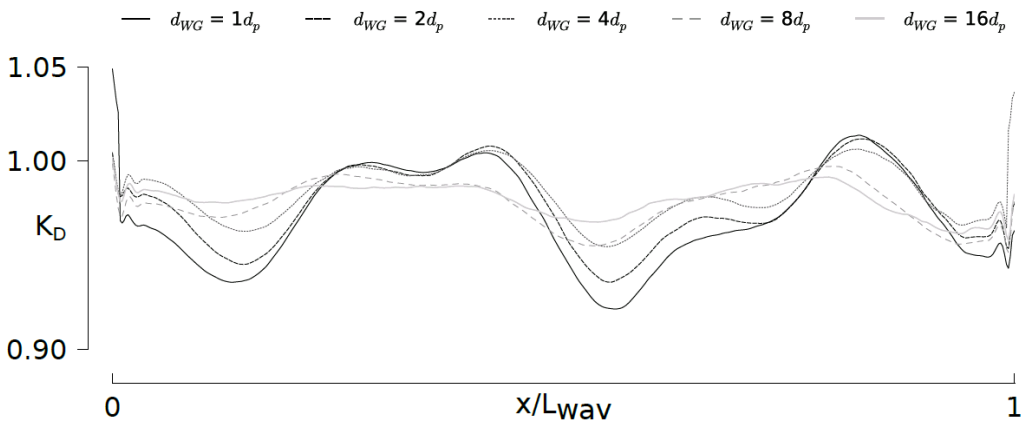
= Active wave absorption based on shallow water approximation

Altomare, C., Domínguez, J. M., Crespo, A. J. C., González-Cao, J., Suzuki, T., Gómez-Gesteira, M., & Troch, P. (2017). Long-crested wave generation and absorption for SPH-based DualSPHysics model. COASTAL ENGINEERING, 127, 37–54.

# of Layers



WG distance



COUPLING METHODOLOGY

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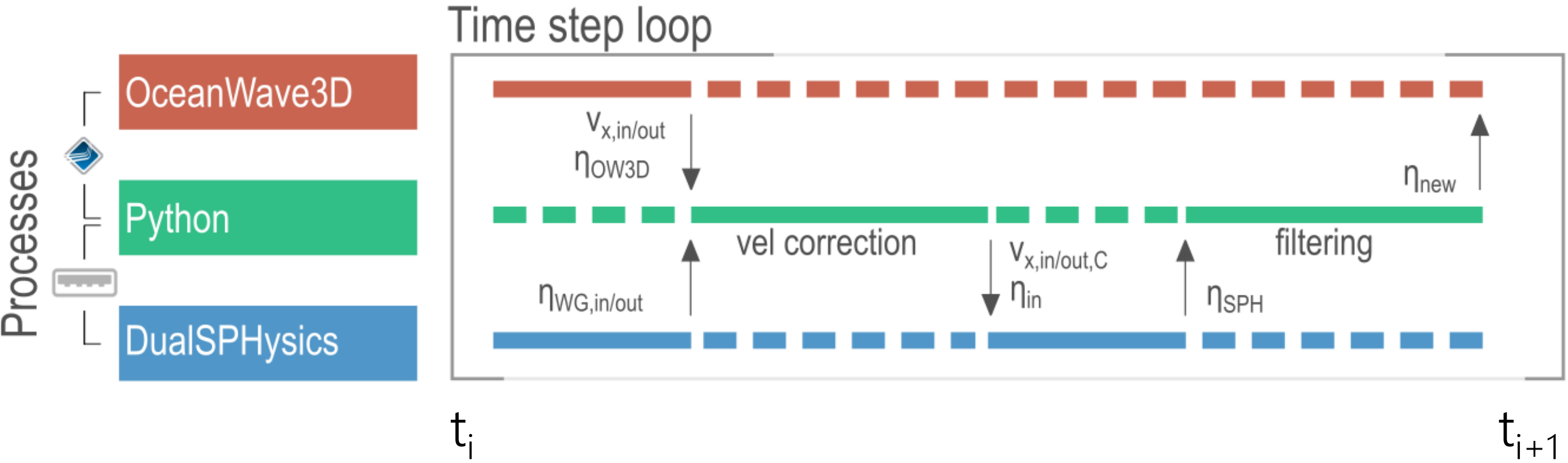
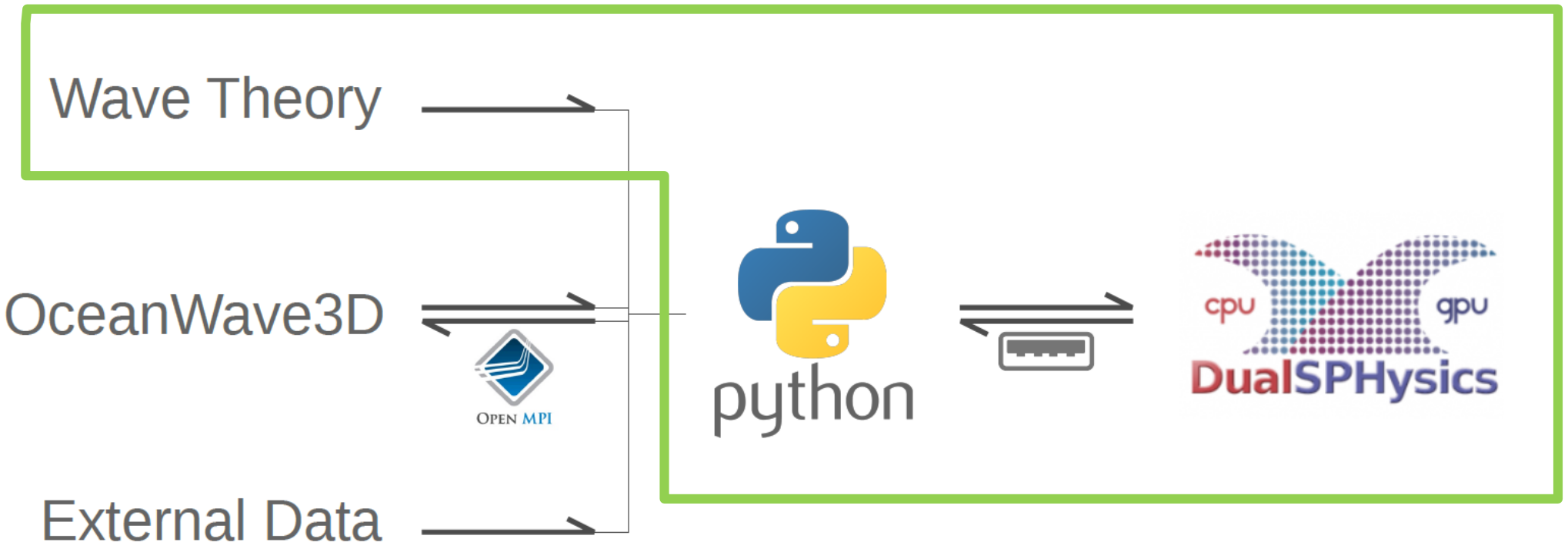
Wave Theory
OceanWave3D
External Data
Open MPI
python
cpu
gpu
DualSPHysics
Open MPI
Socket
Client-Server

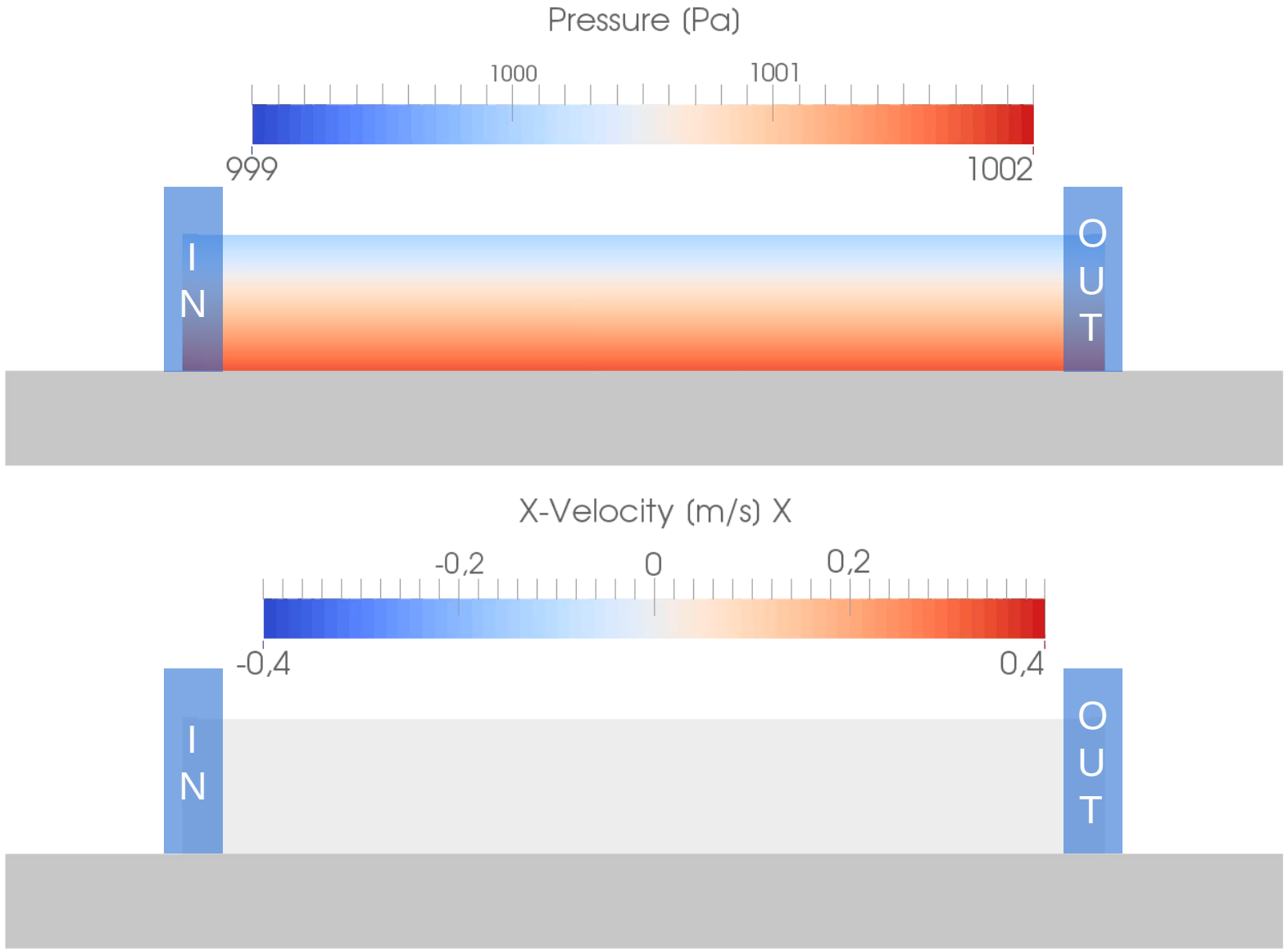

Processes
OceanWave3D
Python
DualSPHysics
Time step loop
$v_{x,in/out}$
η_{OW3D}
η_{new}
vel correction
filtering
$v_{x,in/out,C}$
η_{in}
$\eta_{WG,in/out}$
η_{SPH}
t_i
t_{i+1}

VALIDATION



Open MPI

Socket
Client-Server



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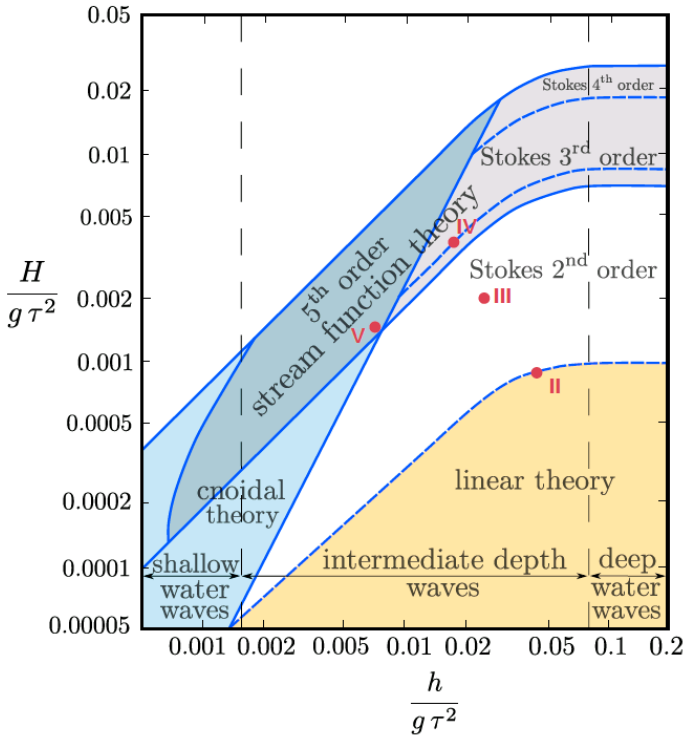

Test Number	Wave Theory	Wave Height $H_{(s)}$ [m]	Wave Period $T_{(m)}$ [s]	Water Depth d [m]	Wave Length L [m]	Particle Size d_p [m]
I	Standing	0.15	2.0	0.7	4.62	0.020
II	Linear	0.02	1.5	1.0	3.35	0.0020
III	Stokes 2^{nd}	0.08	2.0	1.0	5.22	0.010
IV	Stokes 3^{rd}	0.15	2.0	0.7	4.62	0.010
V	Stream Function	0.06	2.0	0.3	3.26	0.005
VI	Irregular Wave	0.15	2.0	1.0	/	0.01

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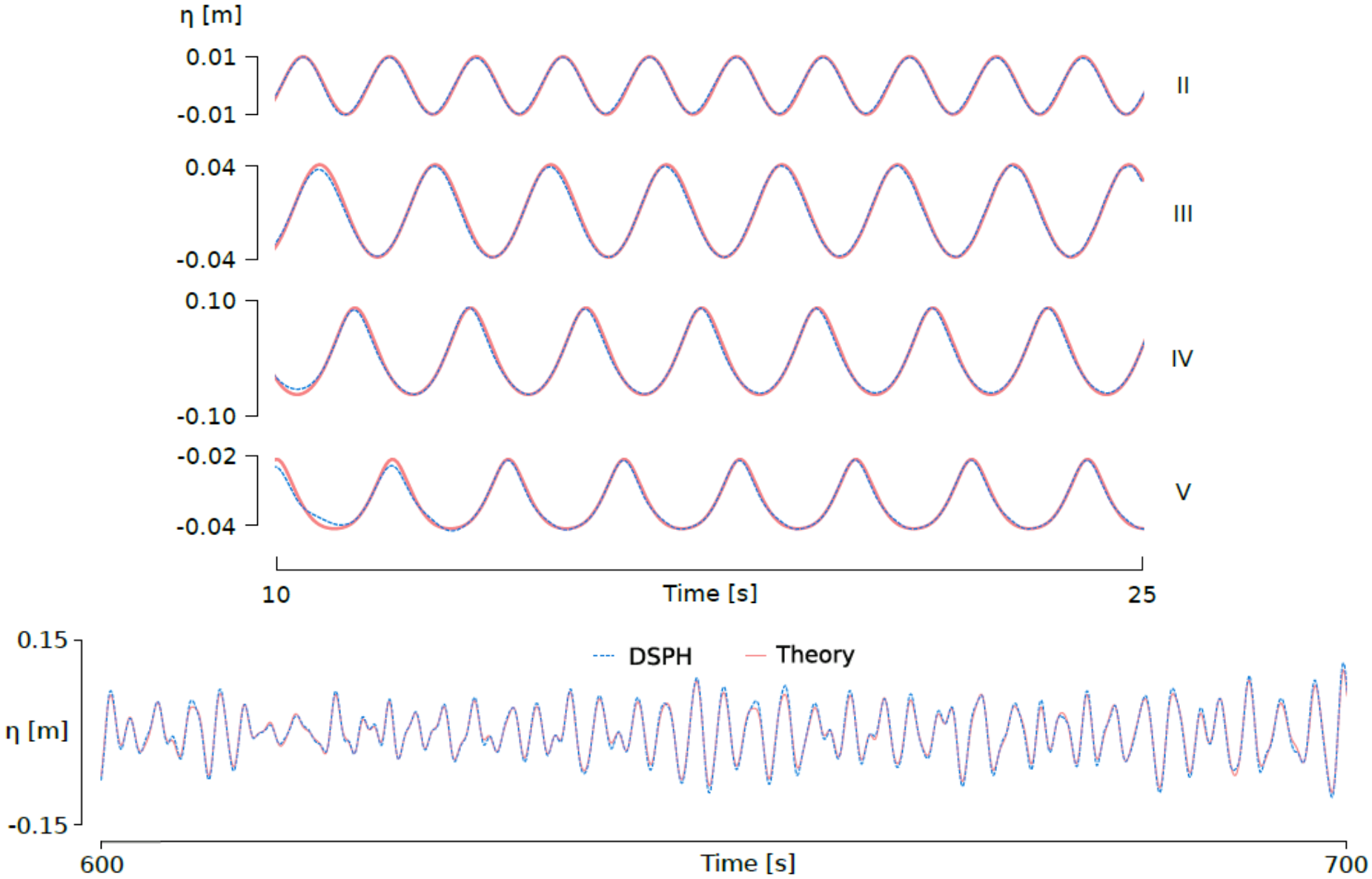

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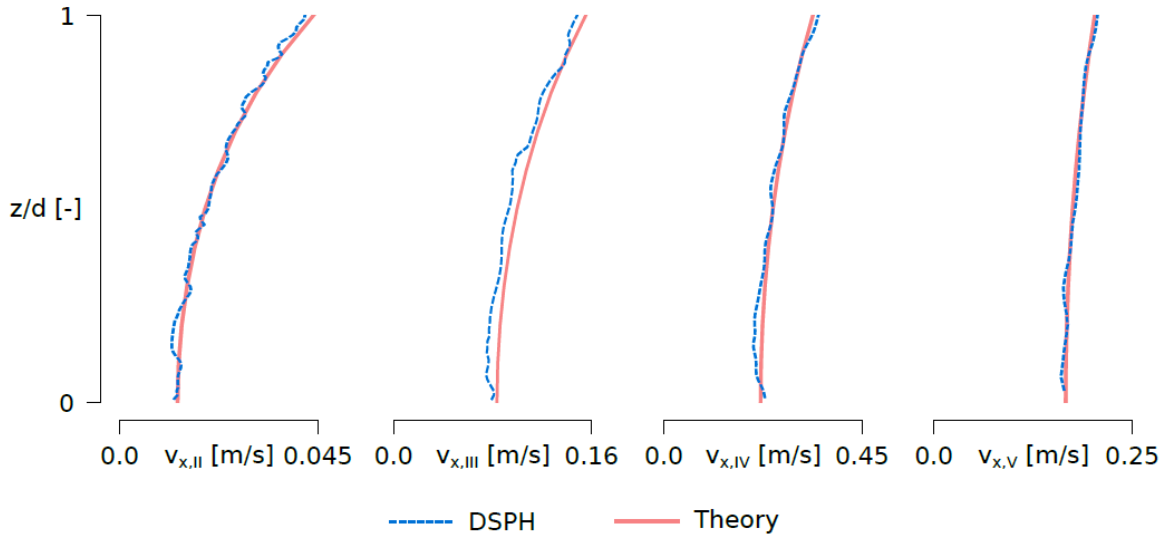
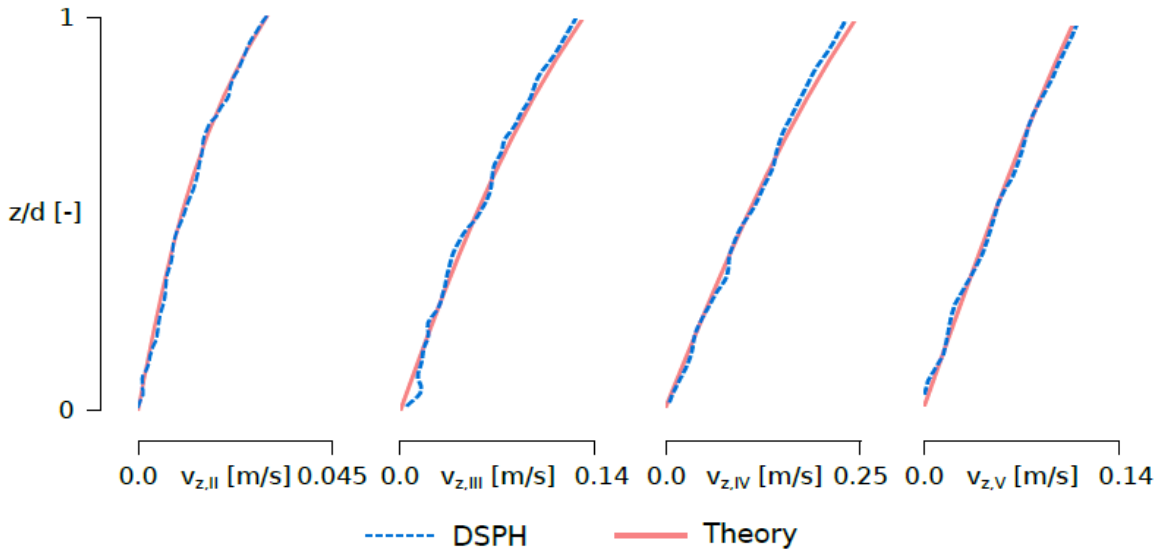
Validation





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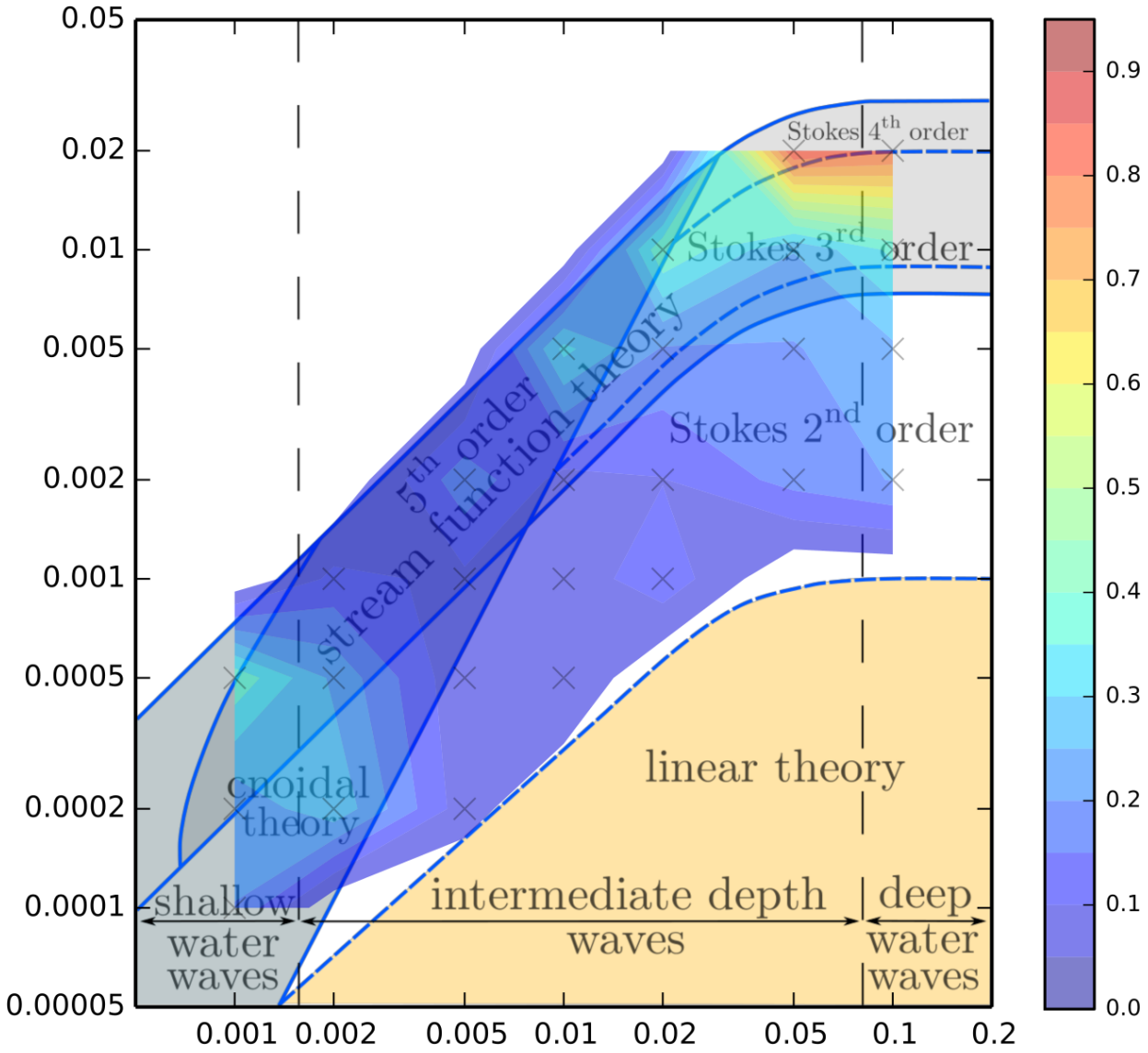

RMSE error
Normalized with smoothing length

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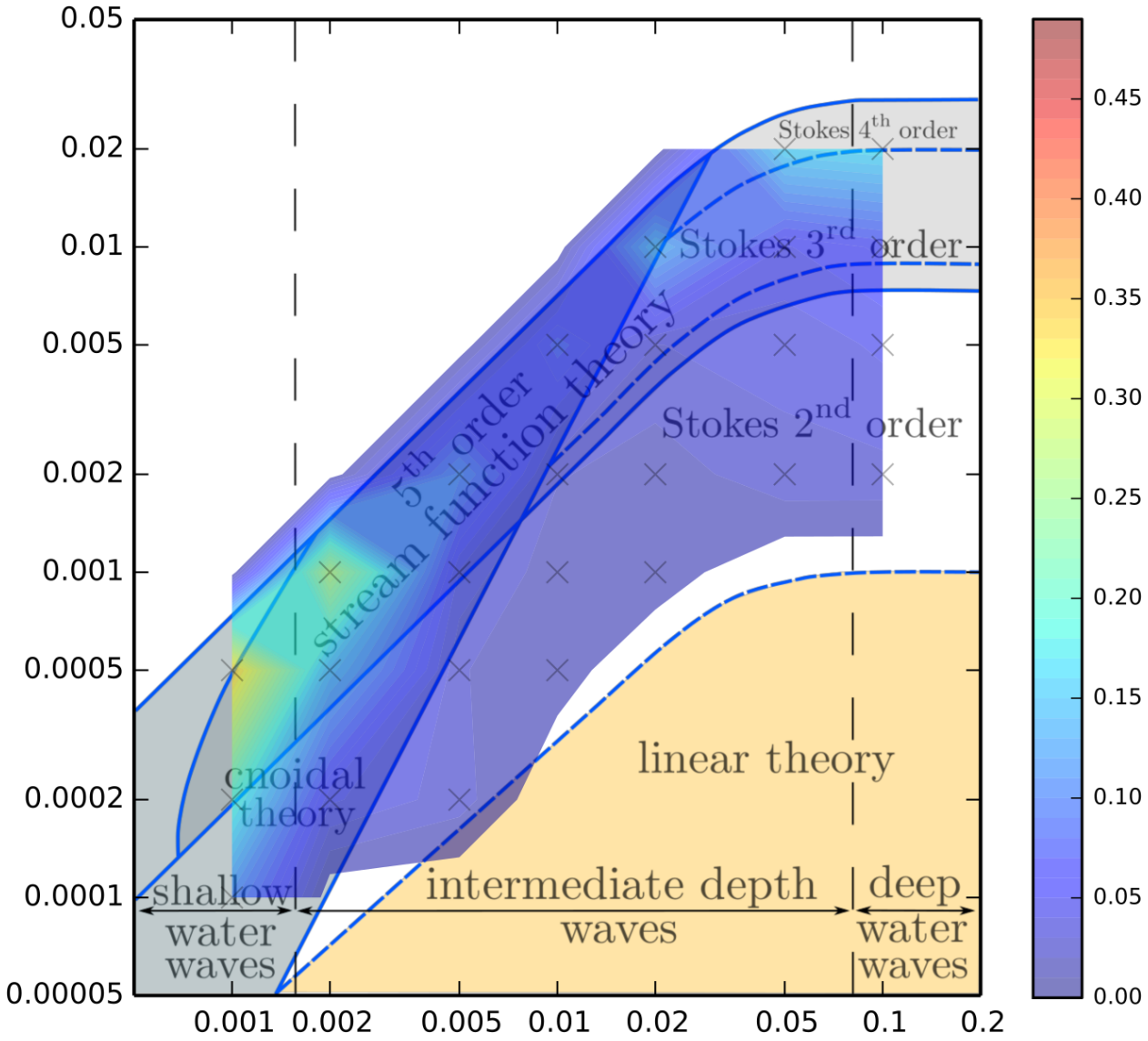

RMSE error
Normalized with dimensionless amplitude

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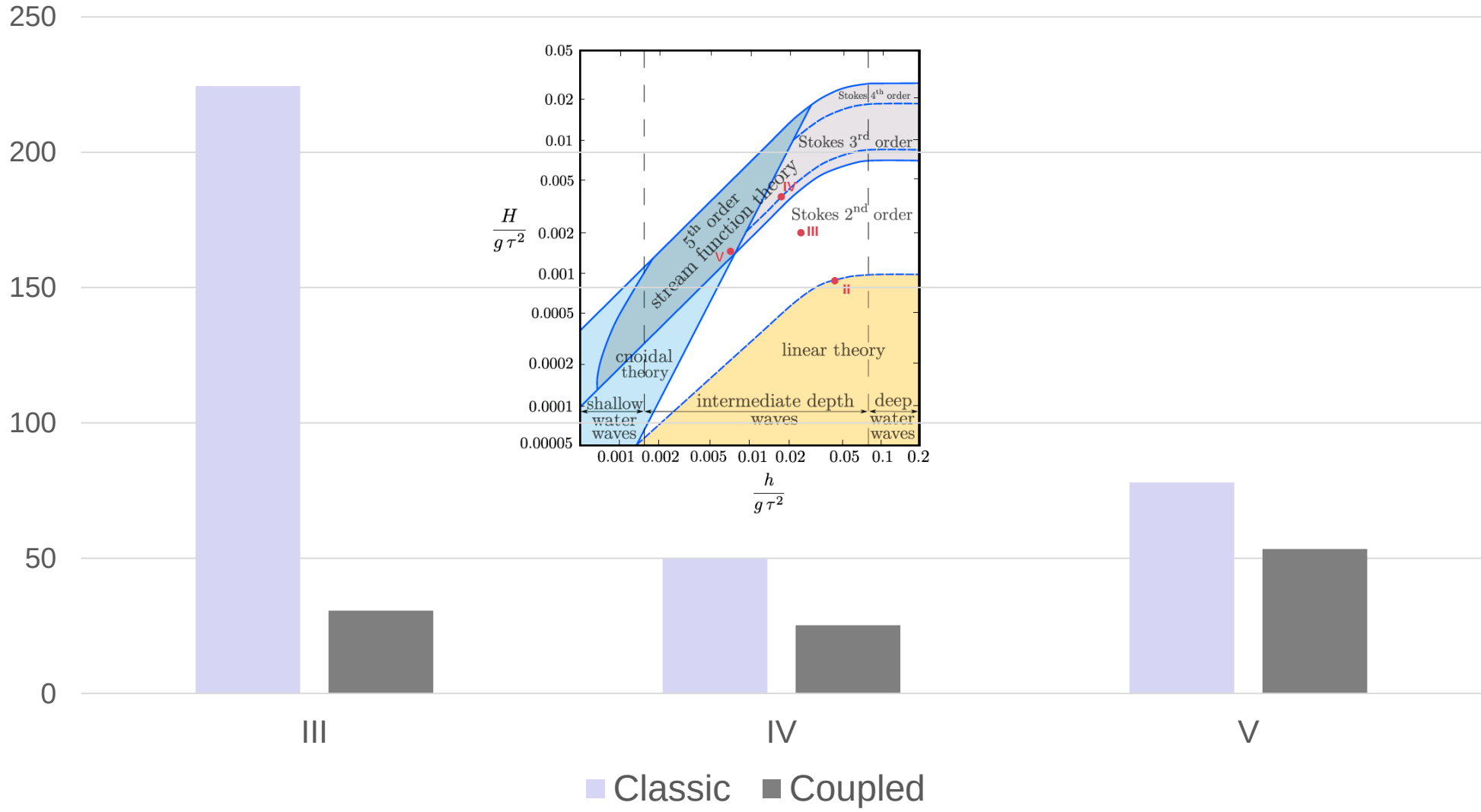
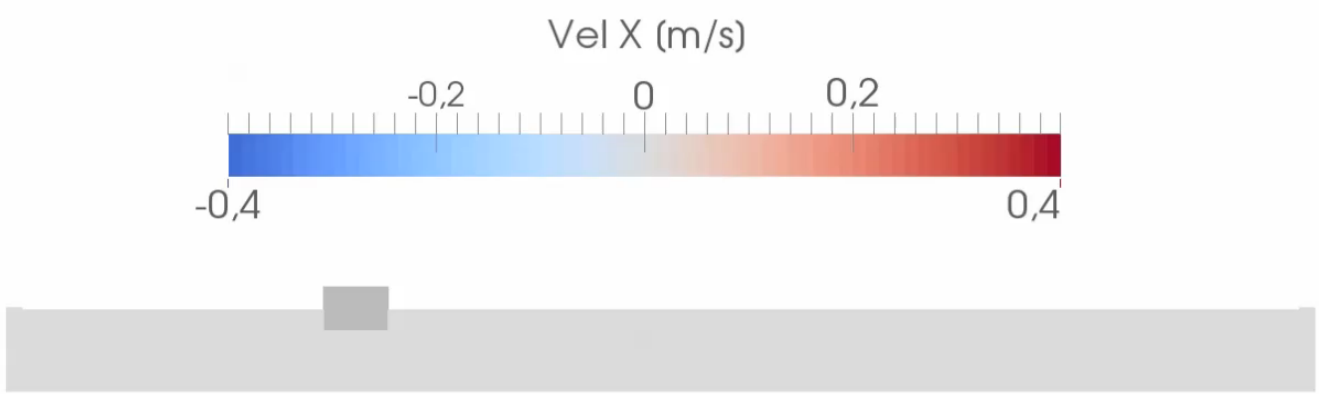
Simulation Time in Minutes

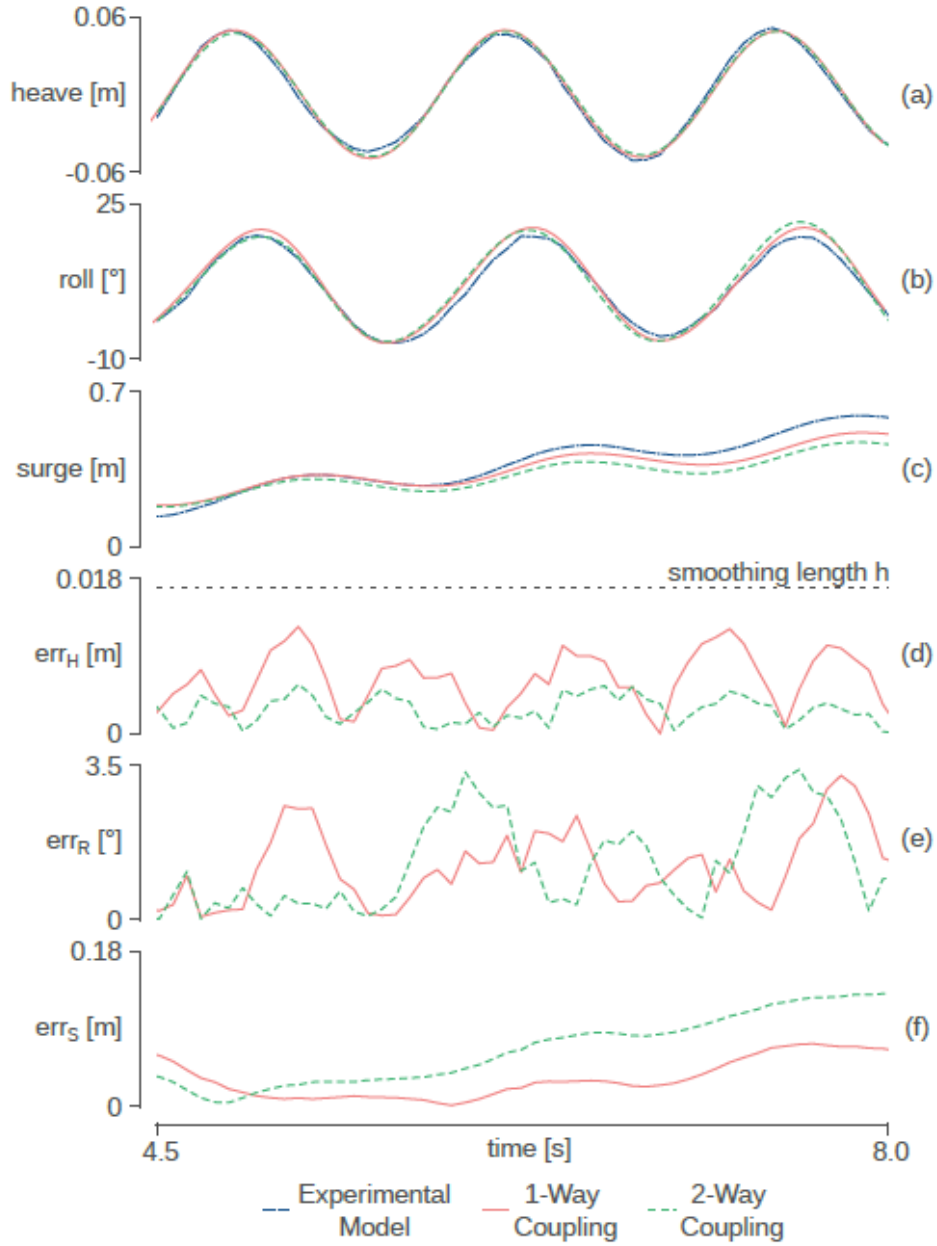


Open MPI

Socket
Client-Server

2D Validation of floating box





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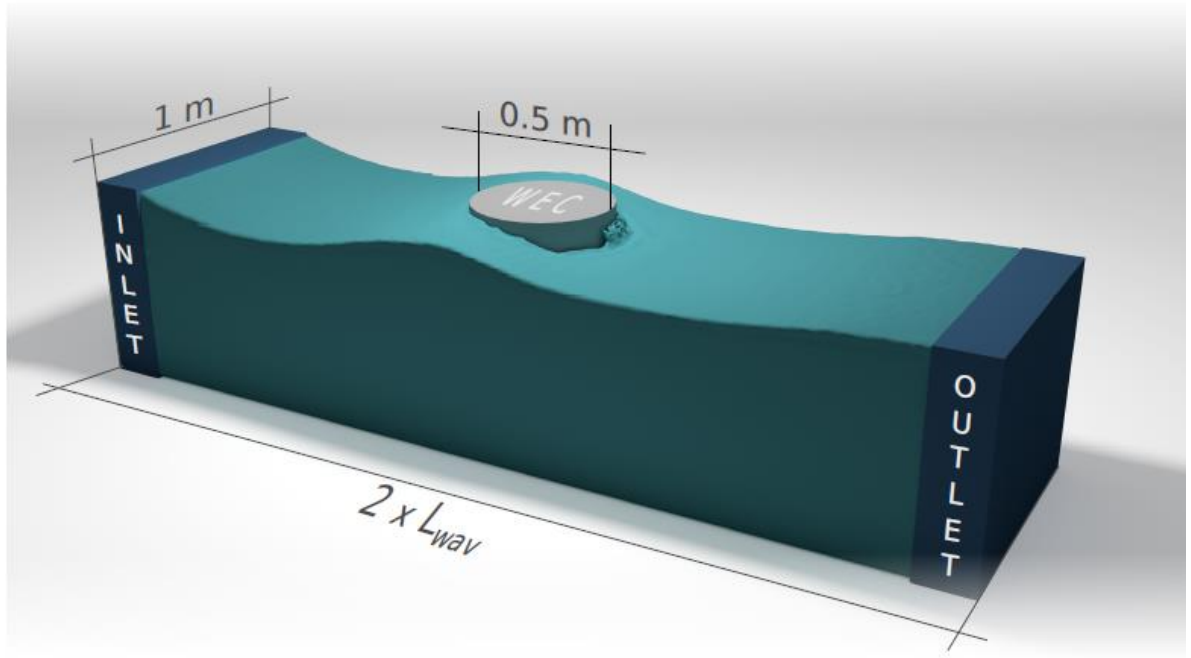
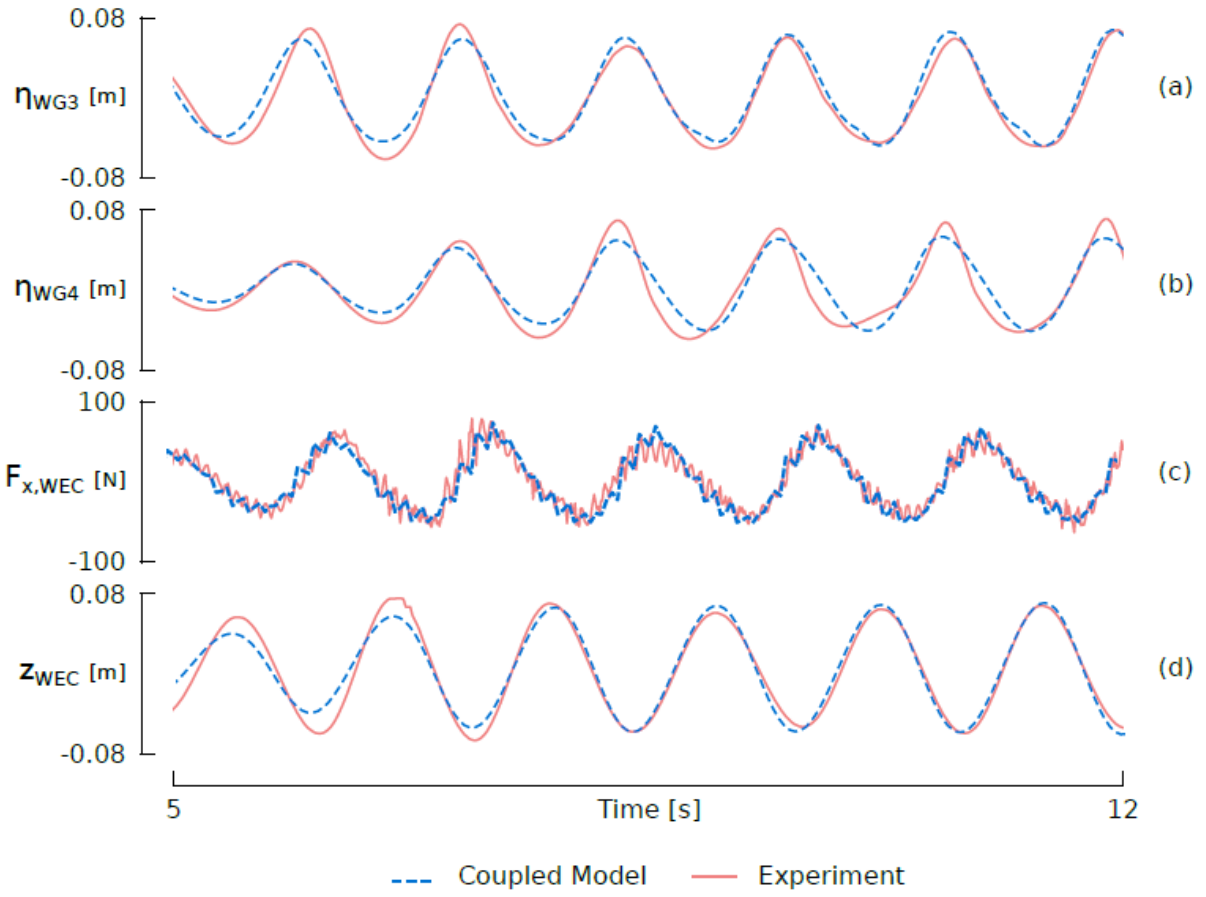
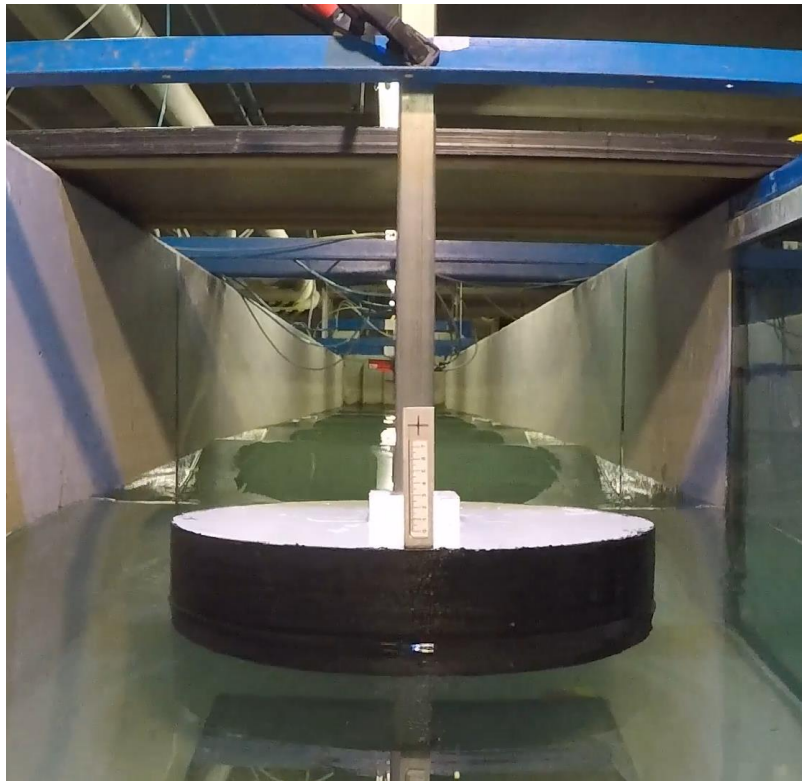
Validation

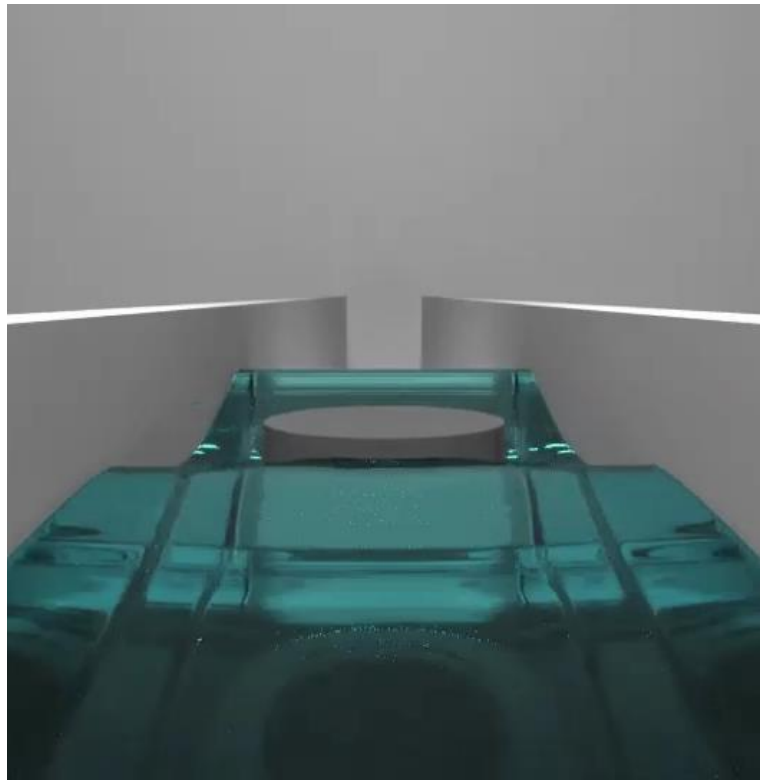
3D Validation of Heaving Cylinder with overtopping





3D Validation of Heaving Cylinder with overtopping





CONCLUSIONS

- Open boundaries are ideal for accurate wave generation/propagation/absorption
- 2-way coupling is applied to calculate velocity corrections
- 2-way coupling with fast wave propagation models is possible
- Both socket client-server protocol as well as MPI protocol can be used for communication