Fixed Ghost Particles Boundary Conditions in DualSPHysics

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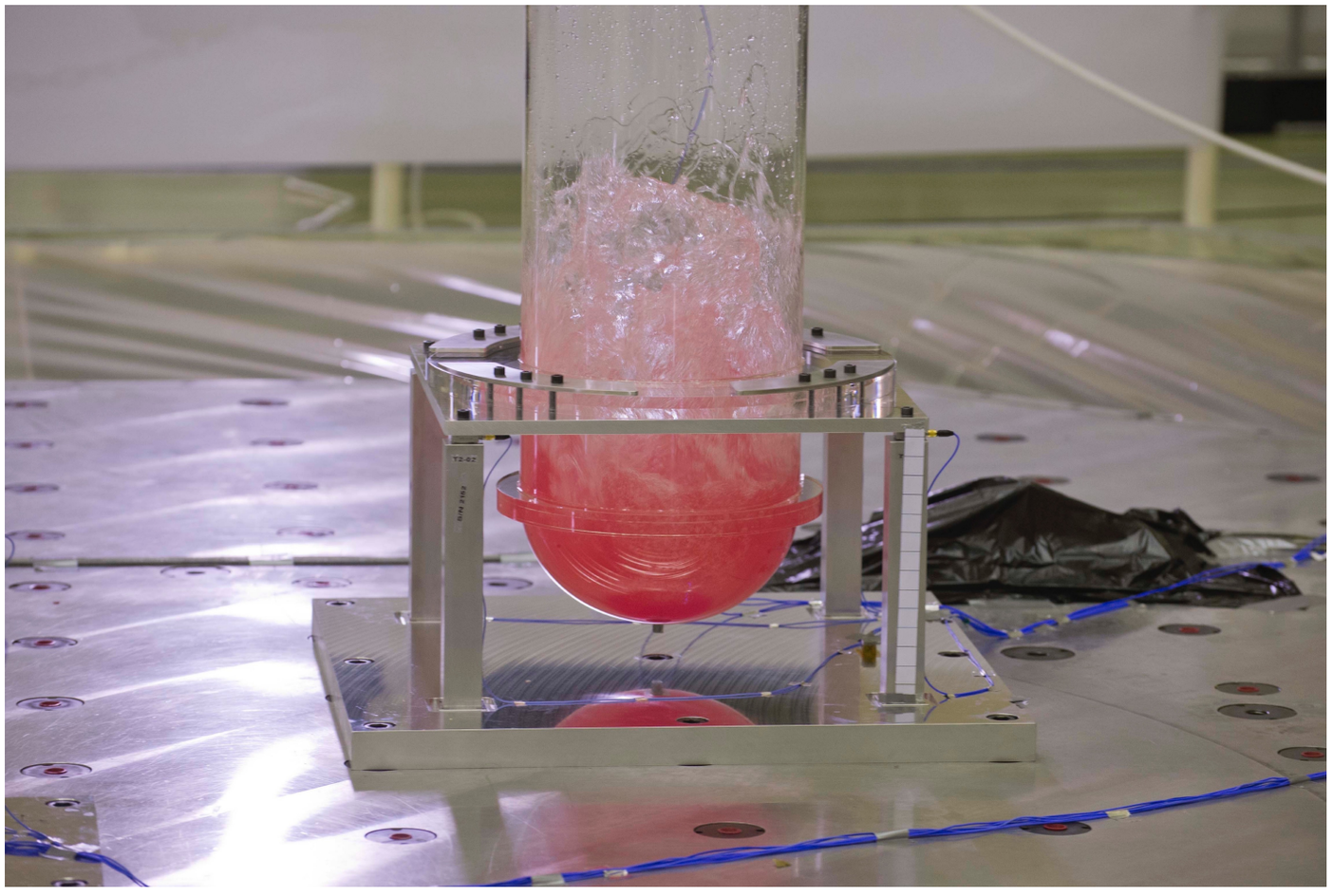
DualSPHysics User Workshop

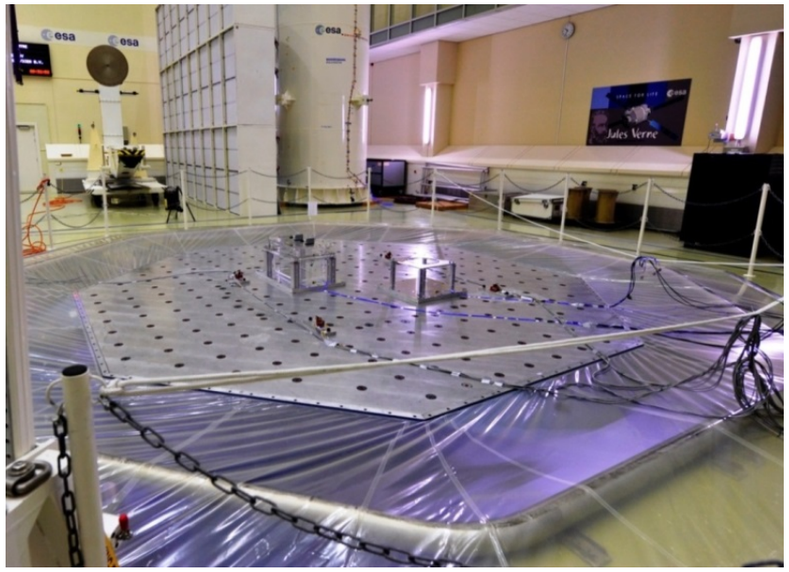
Imperial College London

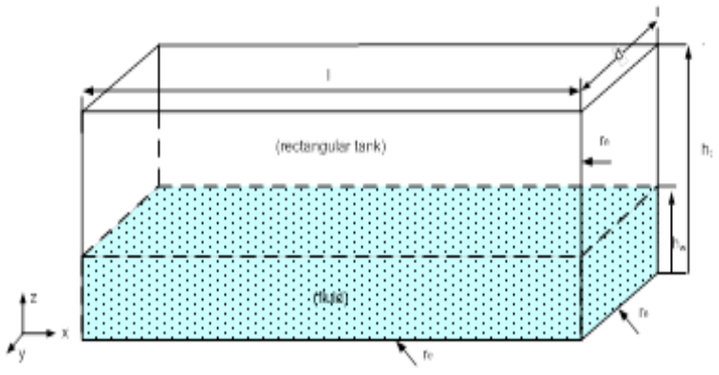
Motivation

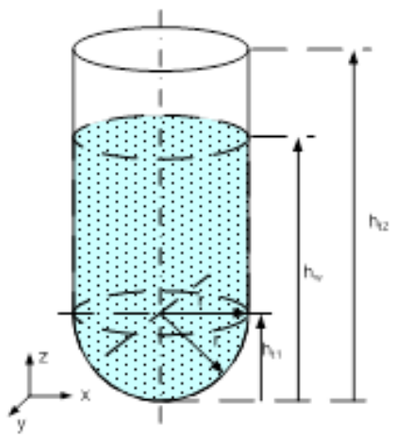
To investigate the capability of the current state-of-the-art SPH software tools for simulating sloshing motions in propellant fuel tanks.

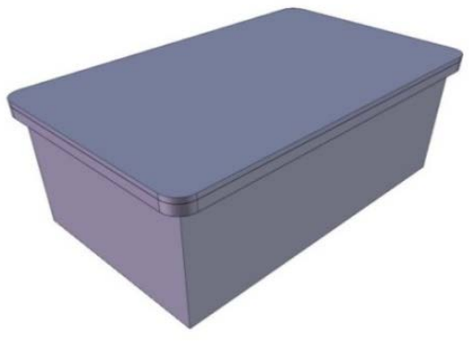


Experiment: Sloshing in rectangular and pill-shaped tanks









Rectangular

Specification	value	dimension
tank height h_t	0.25	m
tank length l	0.59	m
tank depth d	0.335	m
maximum liquid height h_w	0.03	m
approximated mass (water)	8	kg

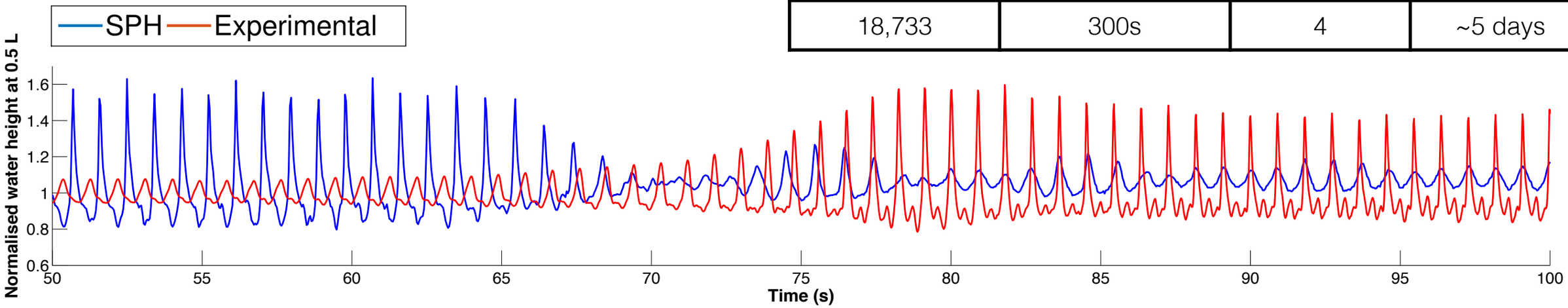
Pill-shape

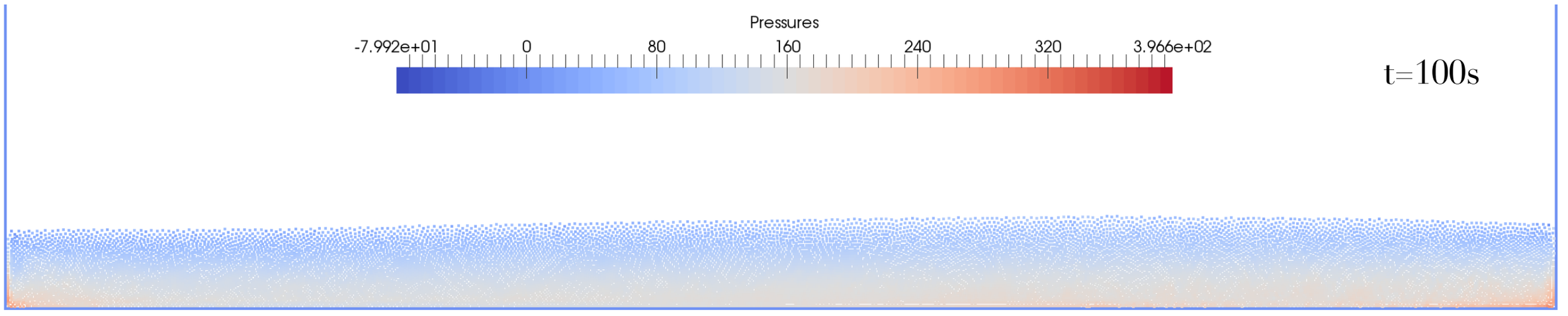
Specification	value	dimension
spherical cap $h_{t1}=r$	0.144	m
cylindrical part $h_c=(h_{t2}-h_{t1})$	0.6	m
maximum water height h_{wmax}	0.5	m
minimum water height	0.2	m
approximate maximum mass	68	kg

First Attempts: SPHysics

- DualSPHysics (v2) proved unstable.
- SPHysics - wave heights agree in some cases, but a lot of problems.

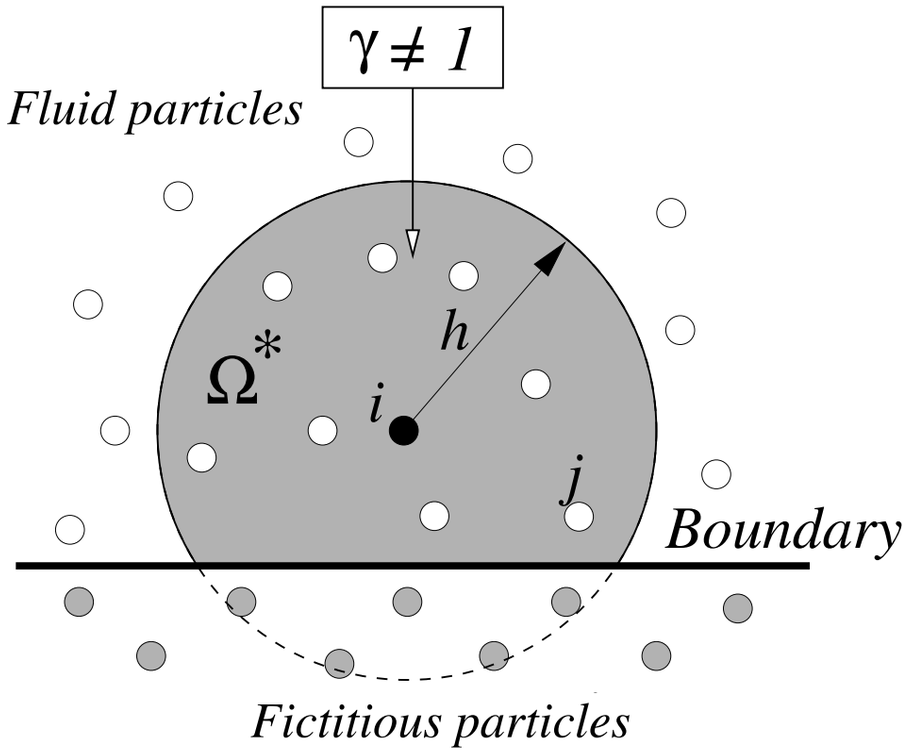
No. of Particles	Simulation Time	No of Procs	Run Time
18,733	300s	1	~9 days
18,733	300s	4	~5 days





Solutions?

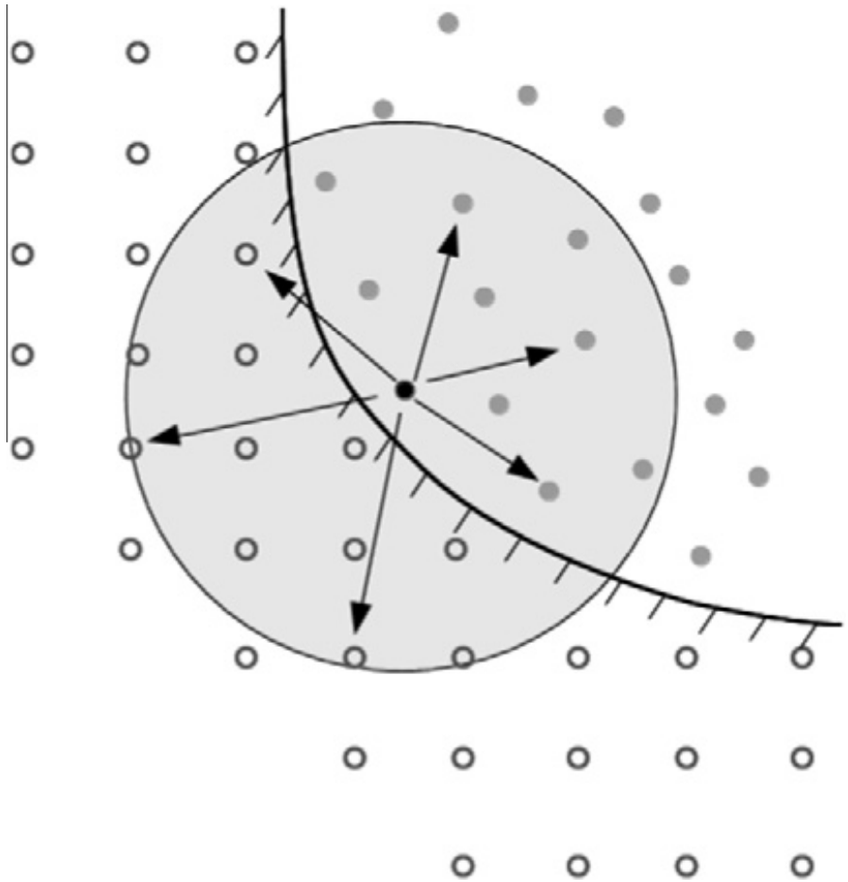
1. Identify a more suitable boundary condition.
2. Identify means to reduce pressure noise.
3. Identify cause of water elevation.



	kernel support	physical behaviour	improved pressure	simple
Repulsive	No	No	No	Yes
Dynamic	No	No	No	Very
Semi-analytic	YES truncated	Yes	Yes	No
Ghost particles	YES with particles	Yes	Yes	Yes

Boundary Condition

Fixed ghost particle boundary condition by Adami et. al. 2010



Force balance at the wall interface:

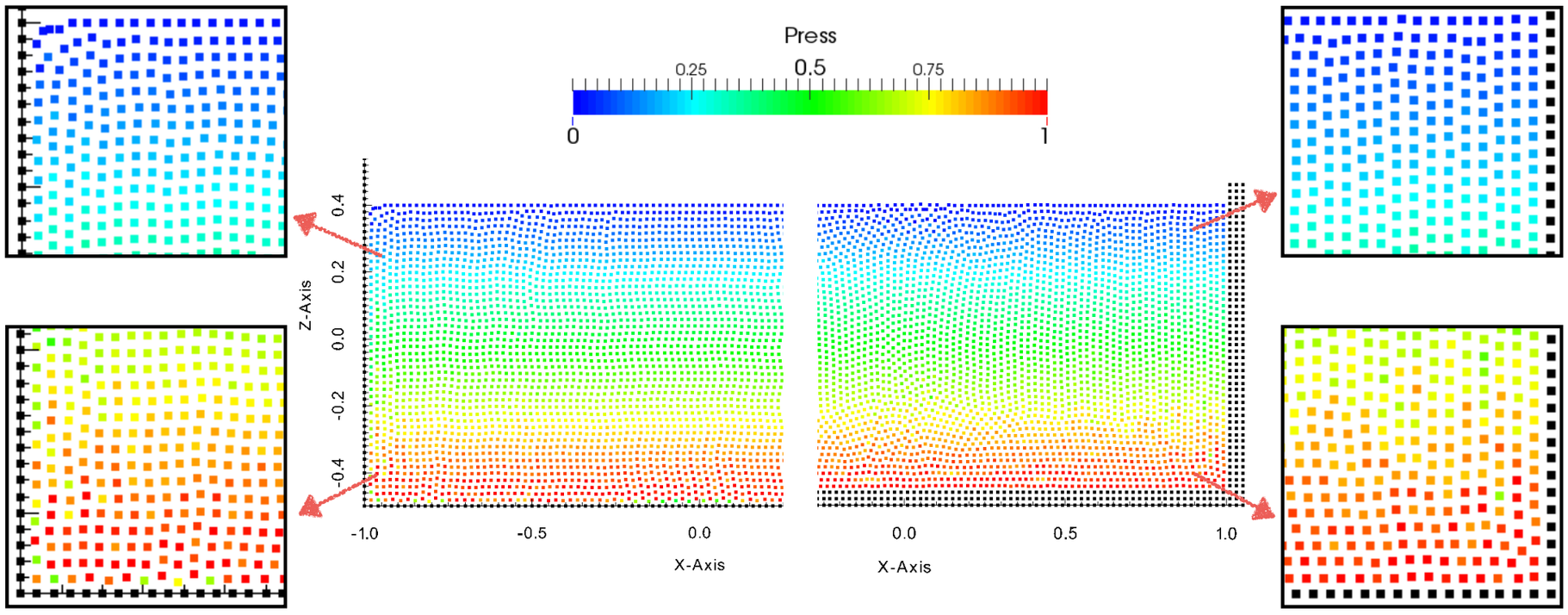
$$p_w = \frac{\sum_f p_f W_{wf} + (\mathbf{g} - \mathbf{a_w}) \cdot \sum_f \rho_f \mathbf{r_{wf}} W_{wf}}{\sum_f W_{wf}}$$

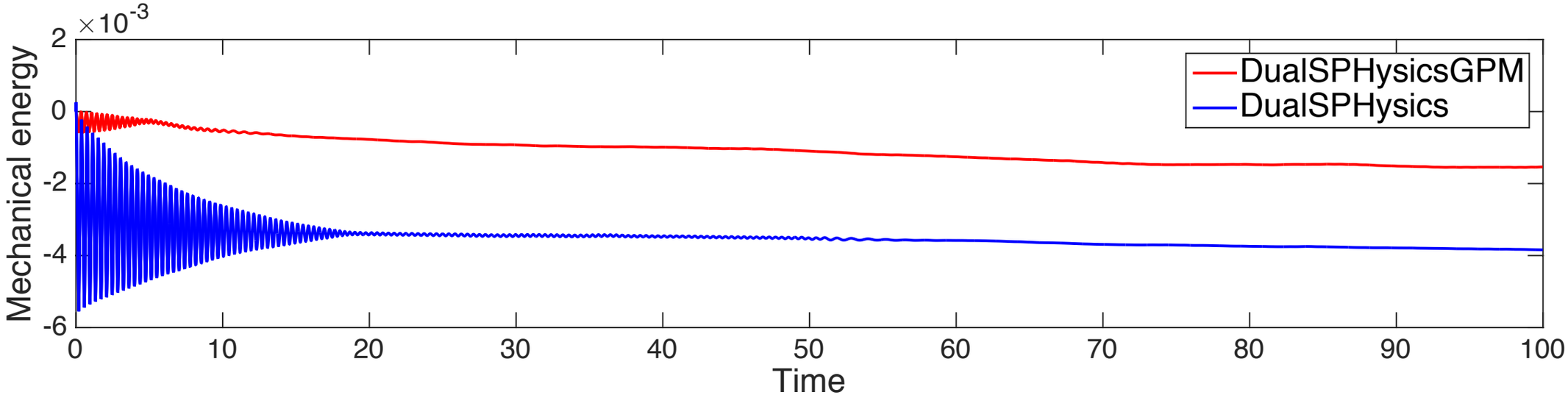
$$\rho_w = \rho_{0,b} \left(\frac{p_w - \chi}{p_{0,b}} + 1 \right)^{\frac{1}{\gamma}}$$

Implementation Experience

- Modular code base - easy to make changes to specific functions without affecting others.
- Steep learning curve from serial CPU to GPU code.
- Long chains of function calls - takes time to get around, but essential for modularity of the code.
- Highly hardware optimised - some function's purposes are not trivial to understand.
- Version 3 (and 4) offer HUGE improvements in developer friendliness over version 2. In particular, assigning arrays to the GPU is much simpler and streamlined.

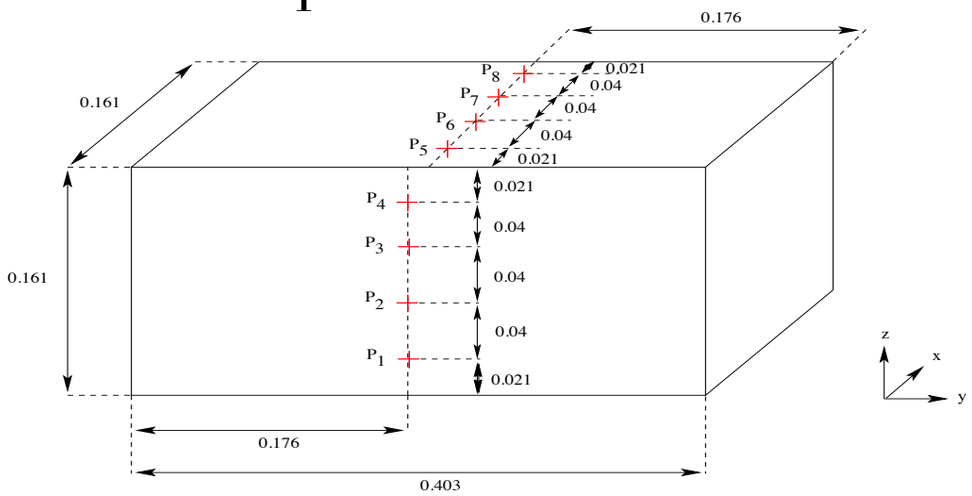
Still Water Boundary Conditions Verification



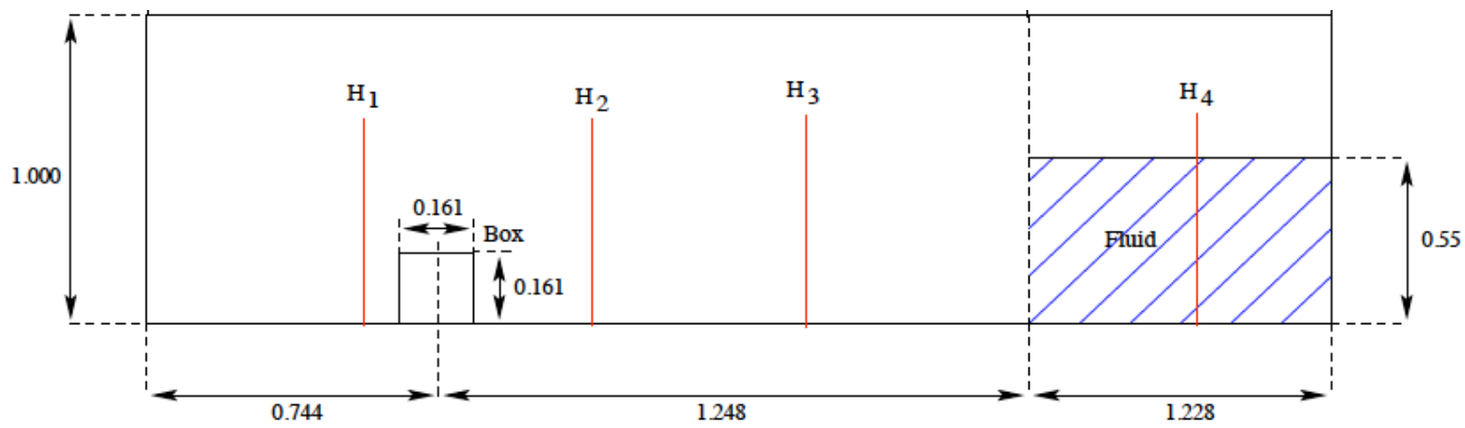


Dam Break Validation

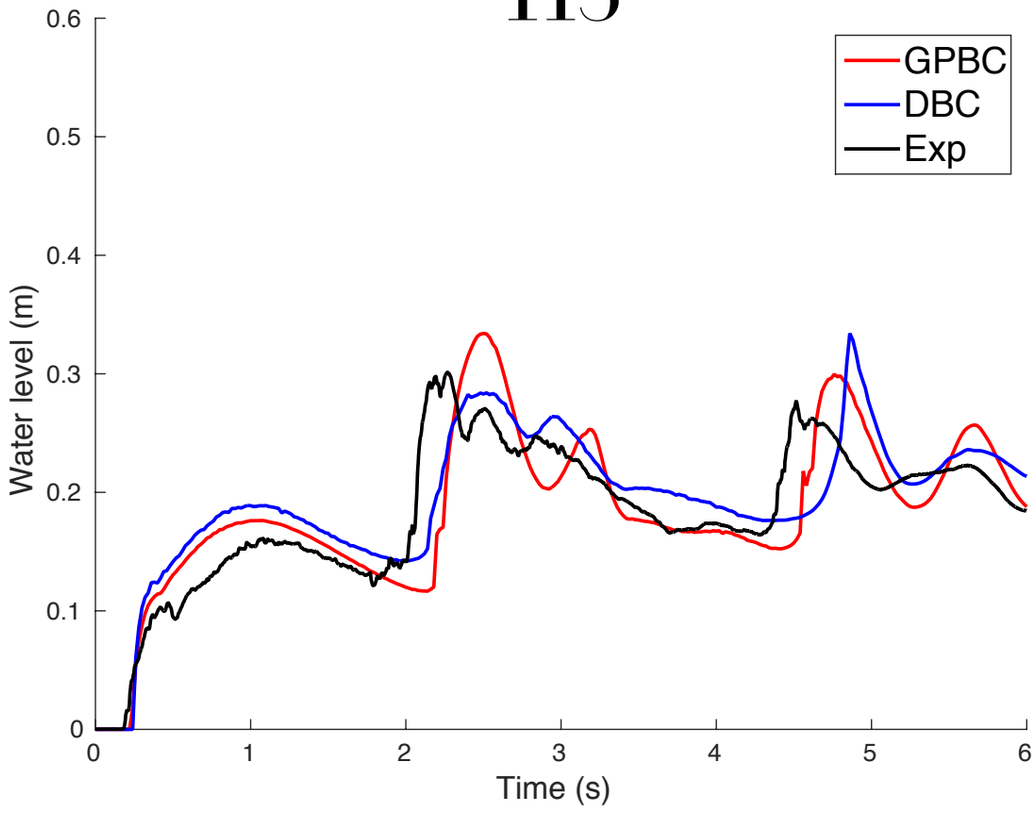
Pressure tap locations



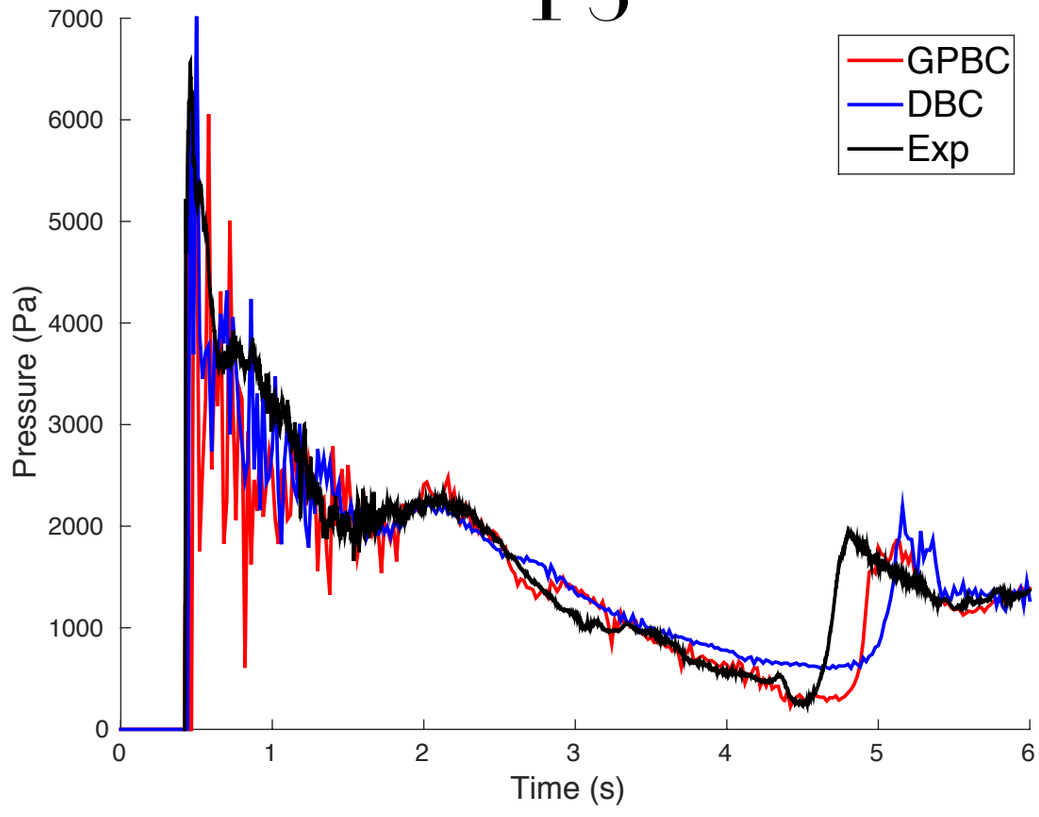
Wave height probe locations



H3



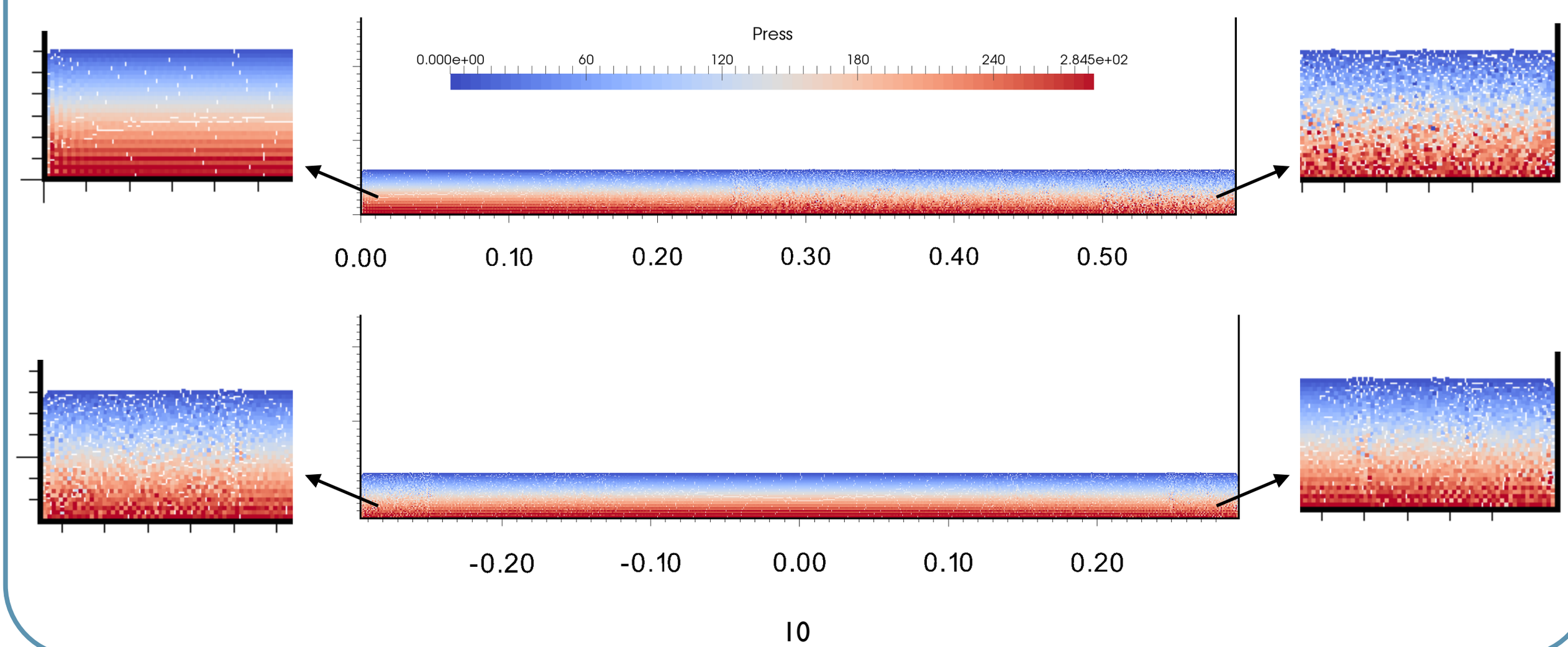
P3



More Problems: Precision

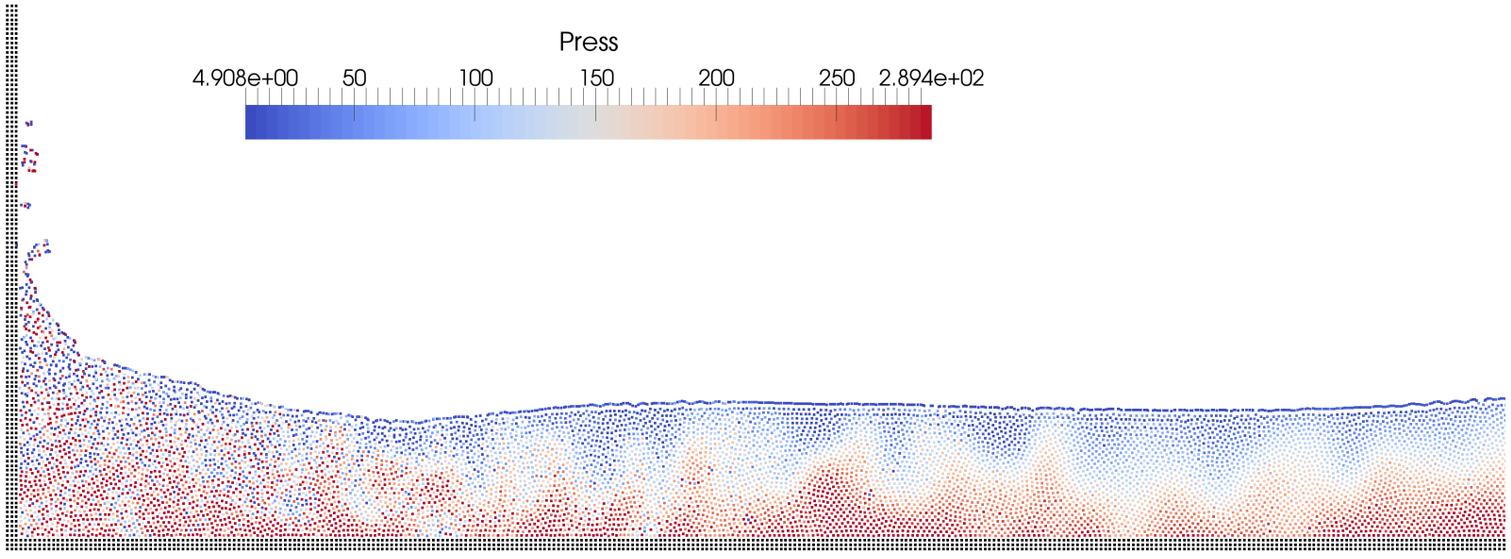
DualSPHysics (version 3) supports only single precision.

For our very stretched domain, shifting the origin generates errors in different regions.

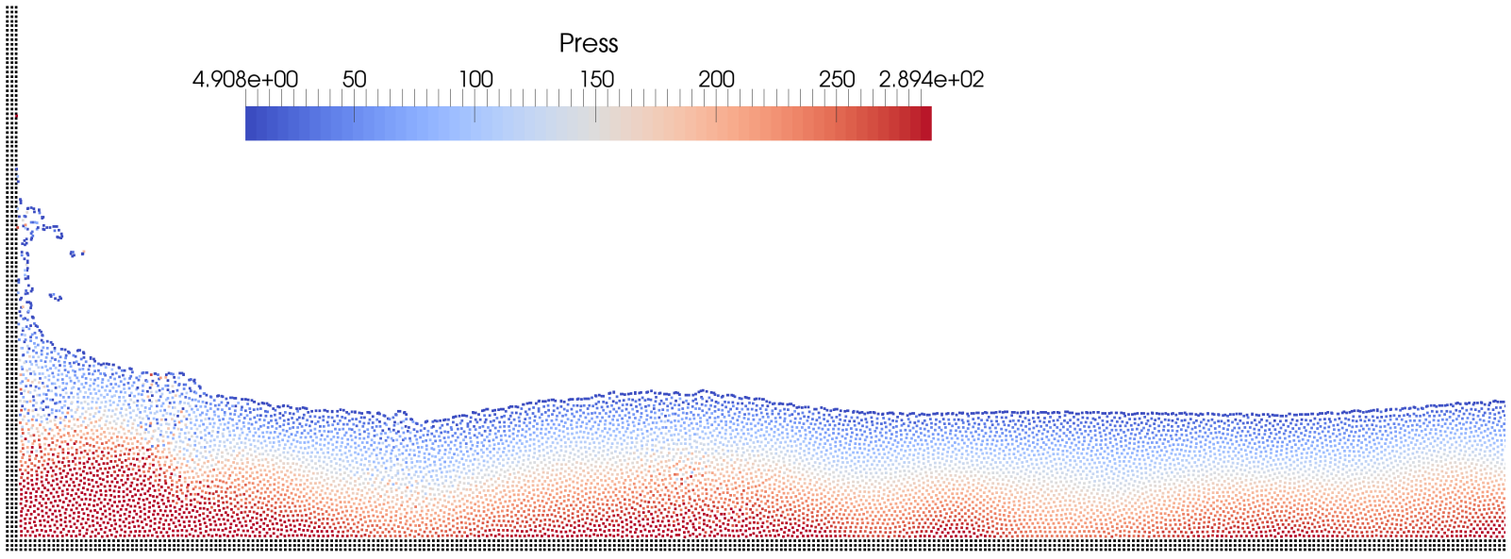


DualSPHysics 4!

1. Double precision.
2. Ghost particles boundary conditions - Adami et. al. 2012
3. Corrected delta-SPH scheme - Antuono et. al. 2010

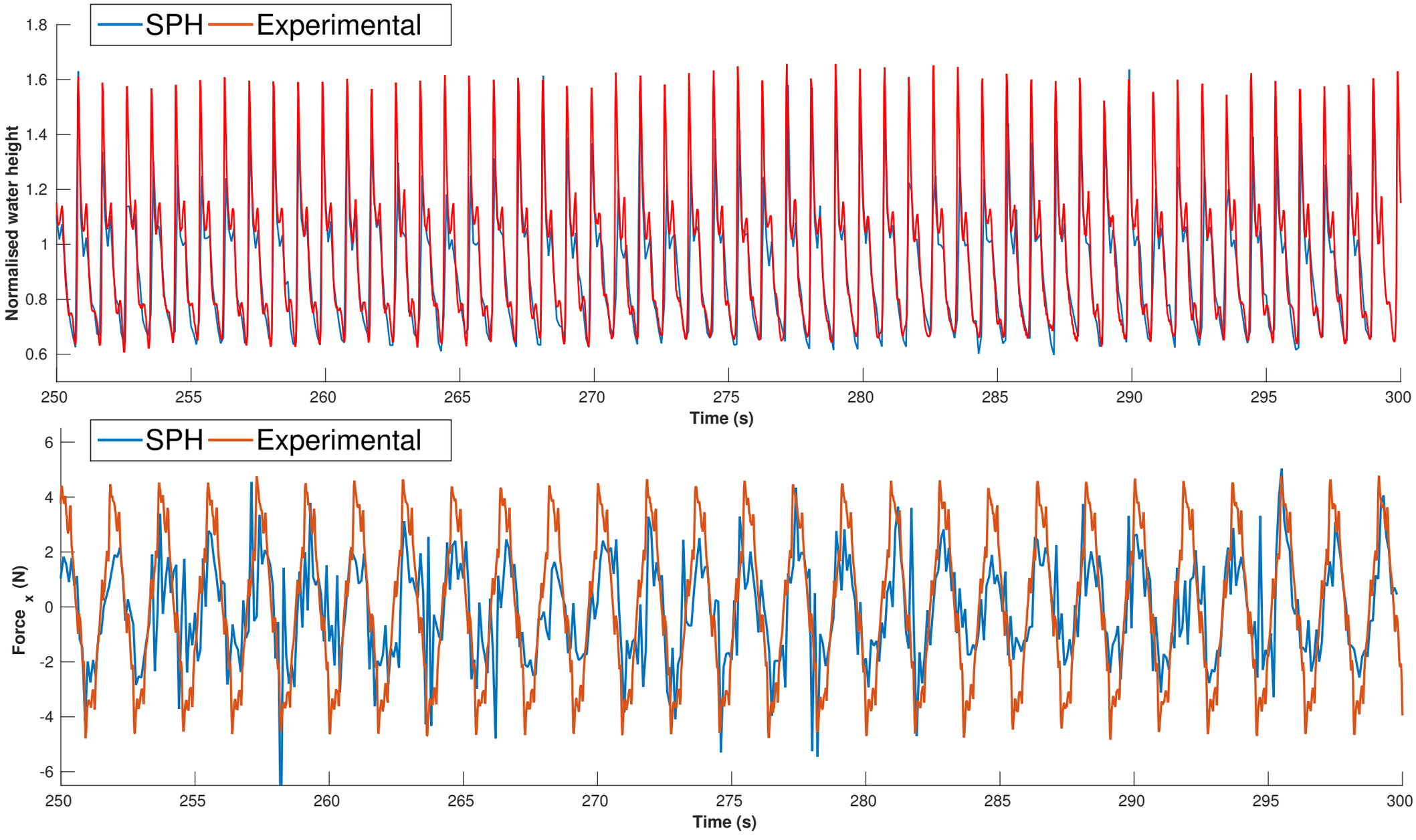


without delta-SPH



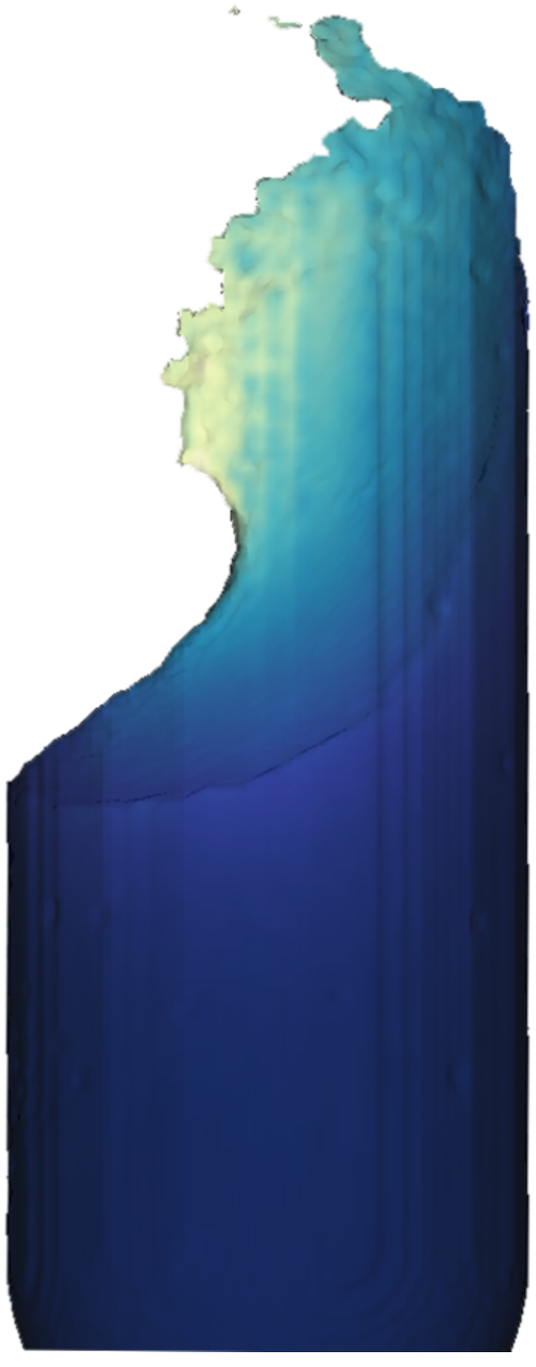
with delta-SPH

Results (finally!)



No. of Particles	Simulation Time	GPU	Delta	Run Time
~20,000	300s	K40 (2880 sm)	Antuono	< 48 hours
~20,000	300s	Quadro 4000 (256 sm)	None	< 30 hours

Results (3D)



Conclusions and Future Work

We have confirmed the applicability of the fixed ghost particle boundary condition and demonstrated the improvements over the current boundary condition offered in DualSPHysics (version 3).

Our future work consists of:

- Higher resolution and 3D simulations of the sloshing experiments.
- Implementation of multi-fluids and surface tension.
- Simulations in micro-gravity environments.

Tank you for your attention!