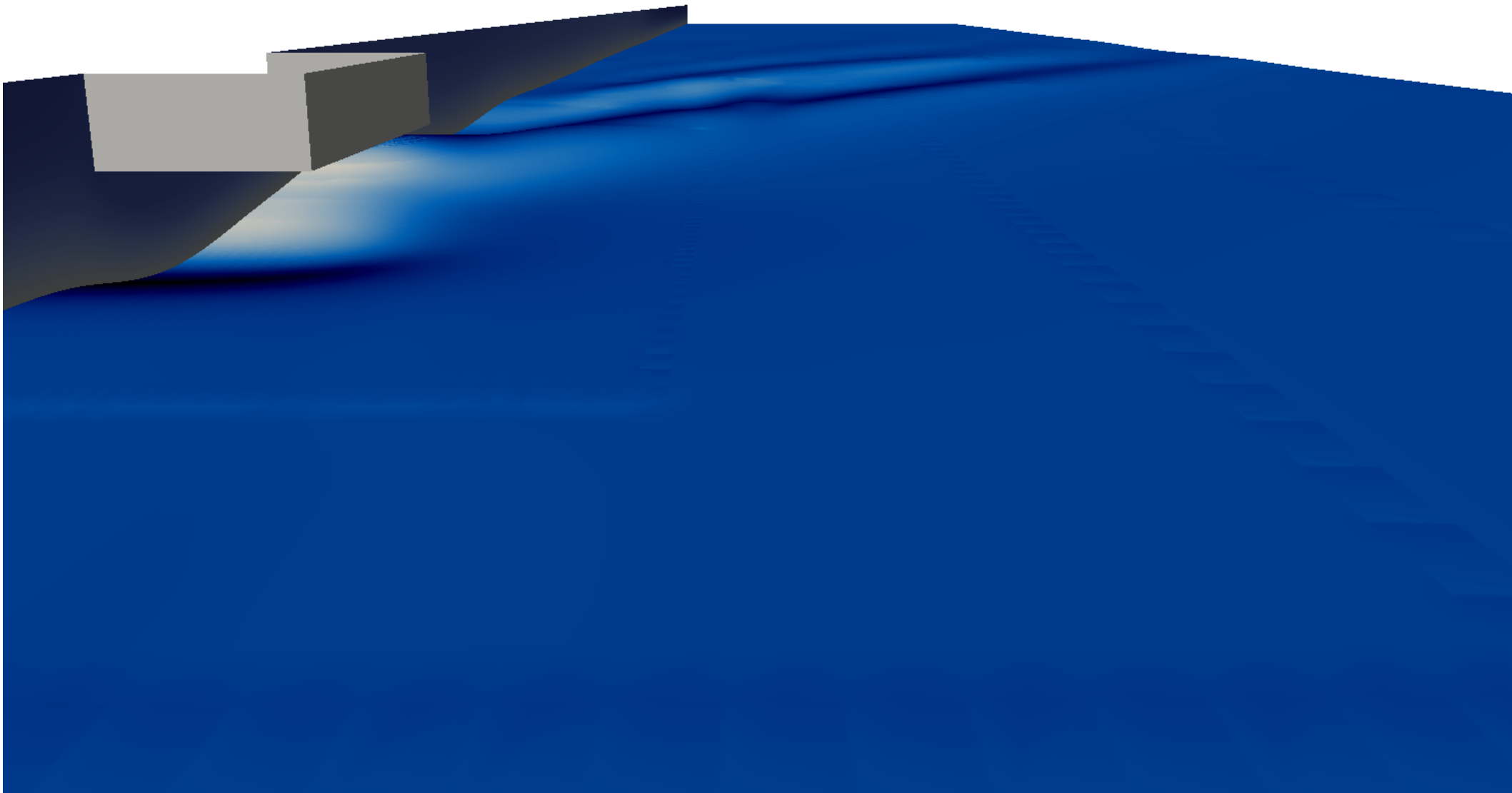


A study of dead water resistance

Reynolds Averaged Navier Stokes simulations of
a barge moving in stratified water



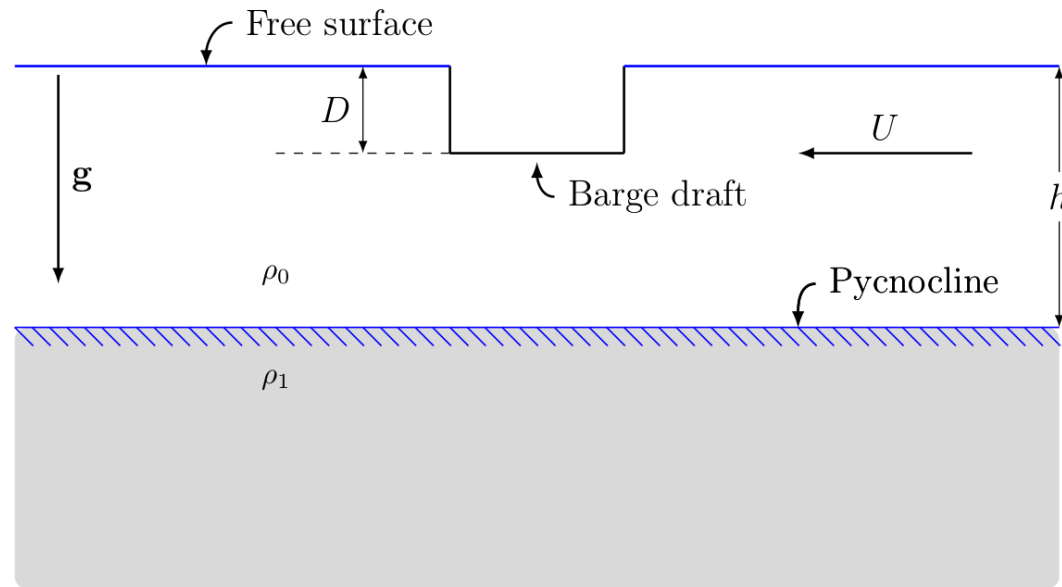
Project description

- The objective of this project is to get qualitative understanding of the dead water phenomenon. Comparison of two RANS turbulence models is also conducted to find the most suitable model.
- To study the dead water phenomenon, a multiphase OpenFOAM solver has been used to calculate drag on a barge moving in stratified water.

Numerical models

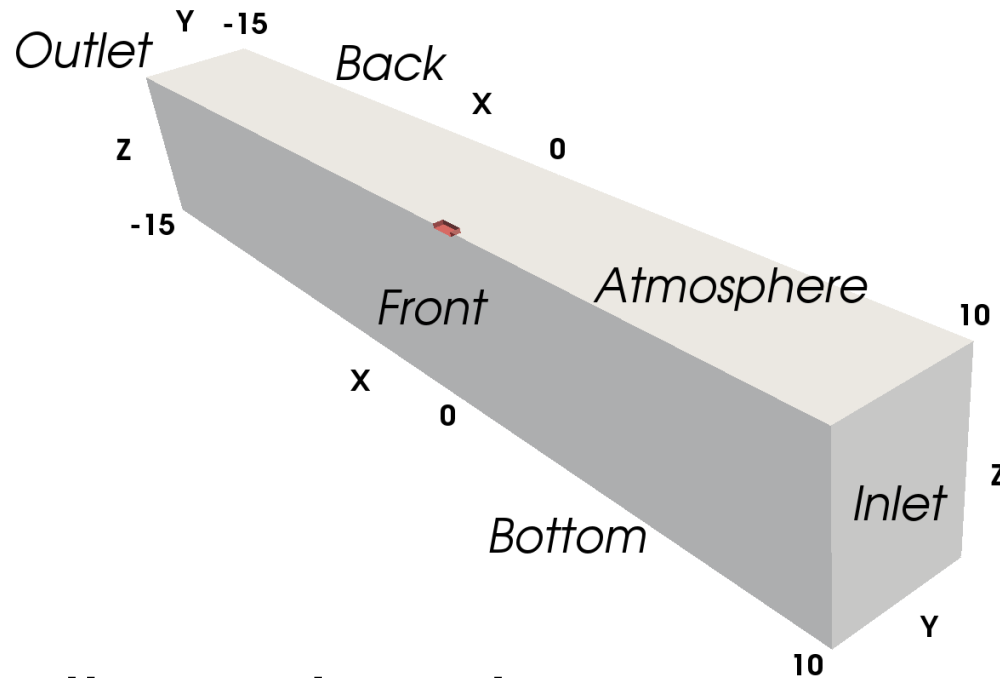
- The multiphase solver TwoLiquidMixingFoam
- The RANS turbulence models used for comparison is the k-Omega SST and the k-epsilon.
 - k-omega SST is known for good performance calculating drag
 - k-epsilon has good performance in multiphase fluid flow

Simulation set up



- Constant draft
- Speed varies from $0.06 \leq U \leq 0.22$
- Three pycnocline depths $\frac{D}{h} = 0.5, 1.0 \text{ and } 1.5$
- $0.35 \leq Fr_h \leq 1.35$
- $26815 \leq Re \leq 73743$

Simulation geometry

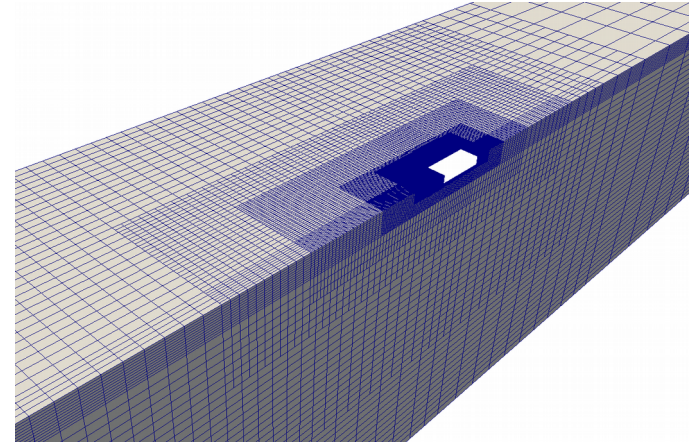
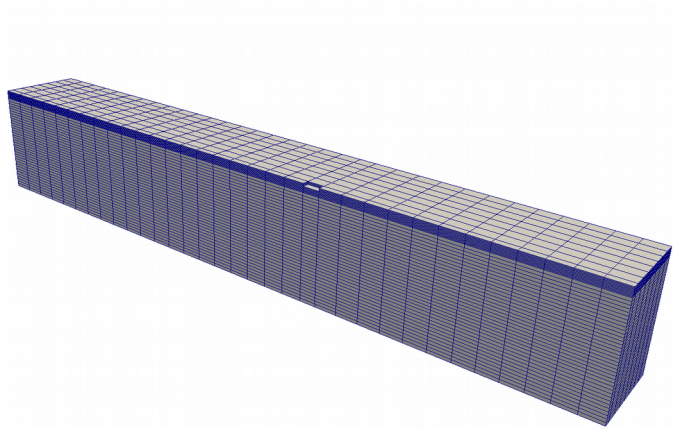


- Domain dimensions is:
 - 4 m in z-direction
 - 3 m in y-direction
 - 25 m in x-direction

Boundary conditions

[illegible]

Mesh generation



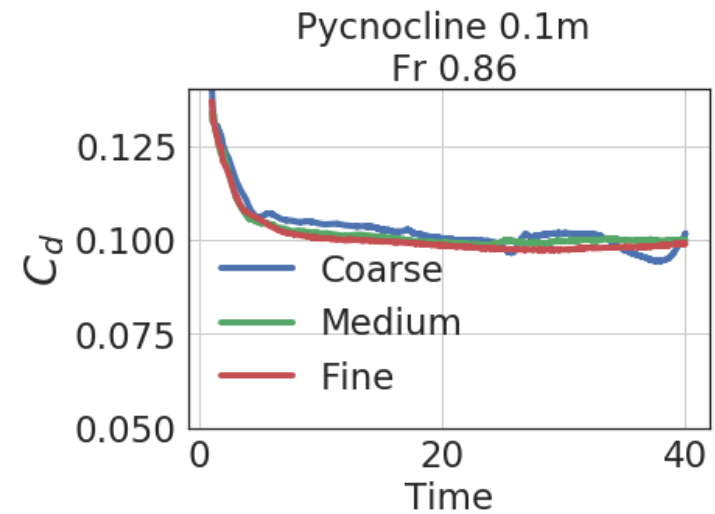
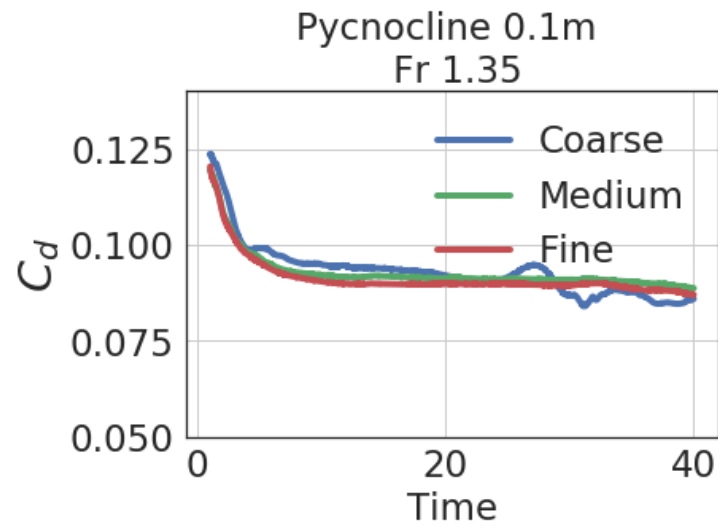
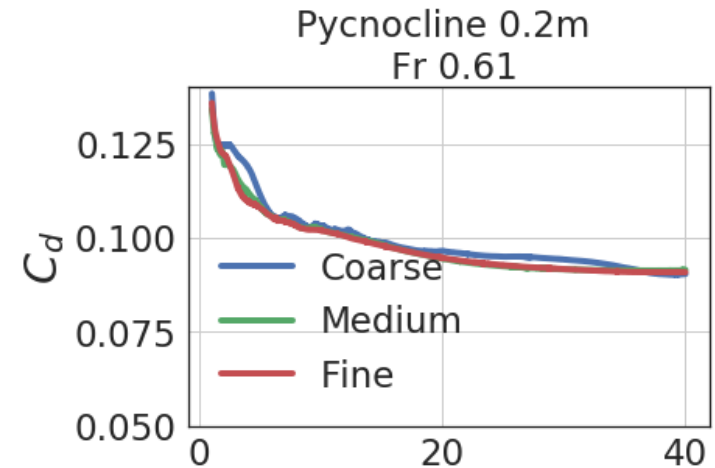
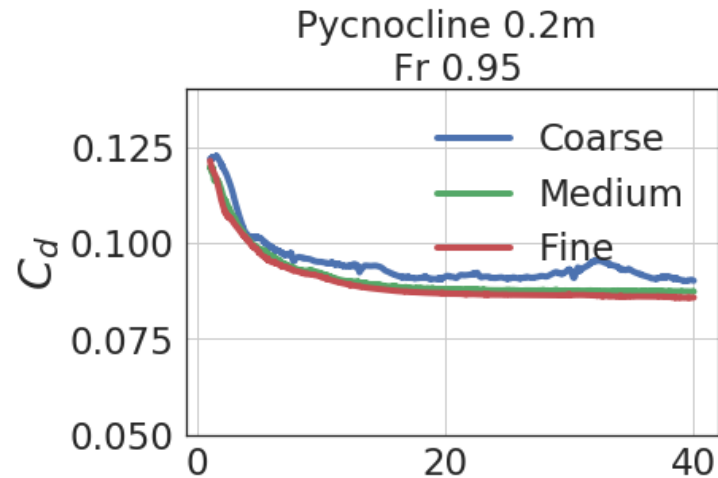
- Using a base mesh with 12668 cells.
- Using topoSetDicts in order to refine mesh around barge and pycnocline locations.

Mesh sensitivity

- Three meshes has been systematically refined for convergence tests
- A grid refinement ratio of 2 has been used on the base mesh
- The resulting course, medium and fine mesh has 4.2×10^5 , 7.4×10^5 and 1.3×10^6 cells respectively.

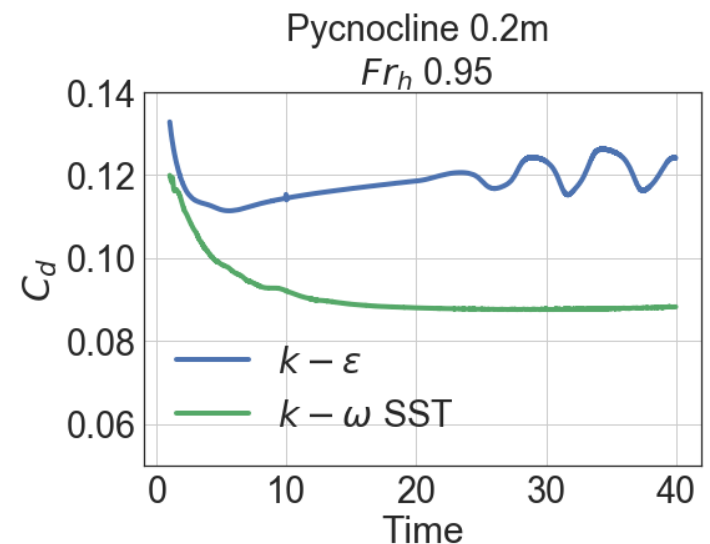
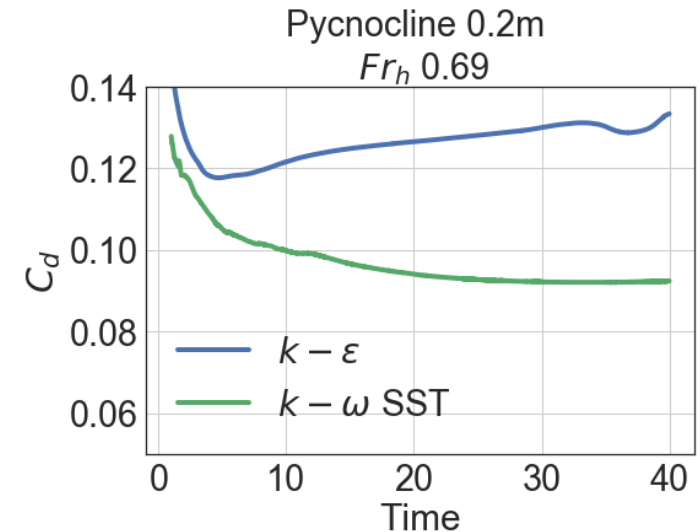
Mesh \ Fr_h	0.86	1.35
Coarse	11.14	13.10
Medium	8.39	11.33
Fine	6.8	8.95

Mesh sensitivity 2

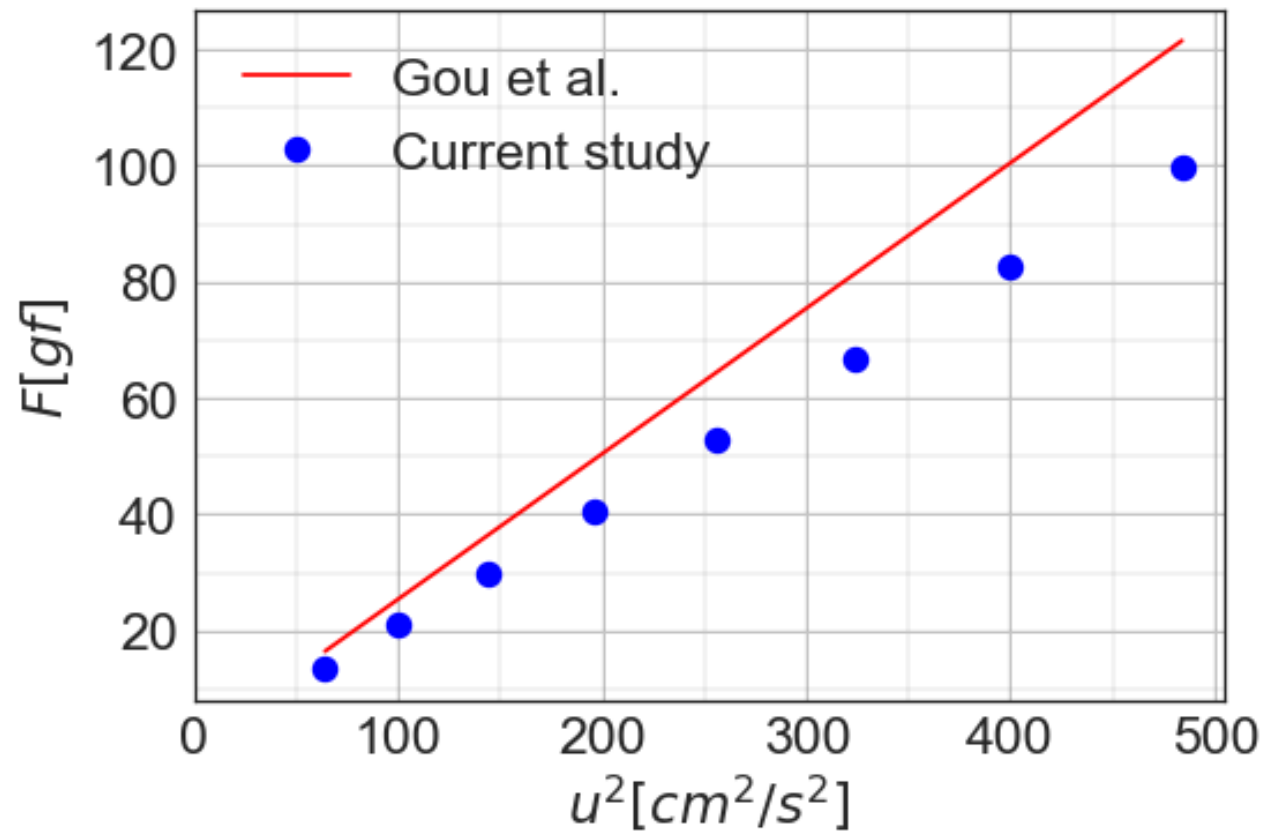


Comparison of turbulence models

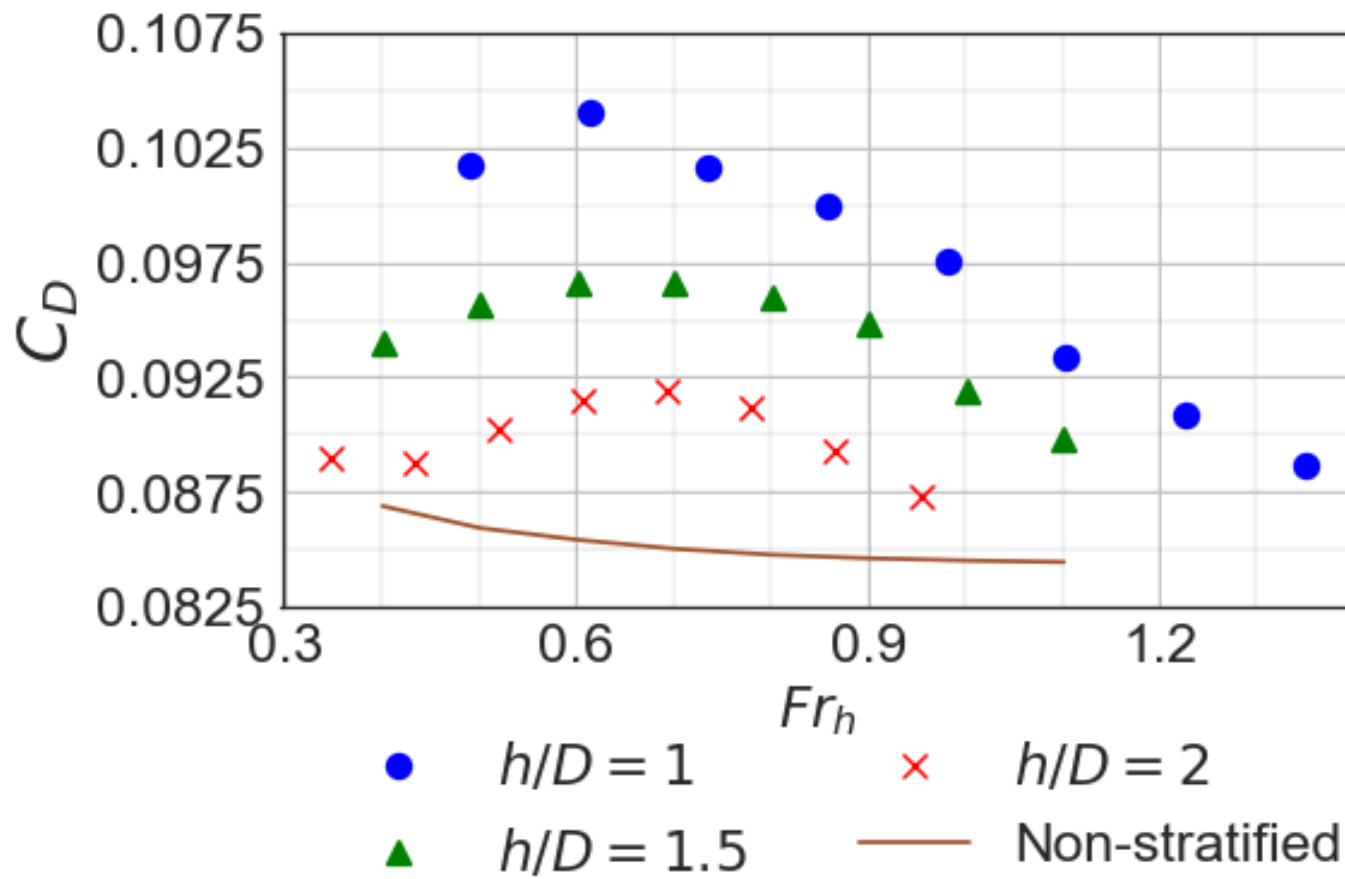
- Comparison of turbulence models done at densimetric Froude number close to peak drag and close to critical densimetric Froude number



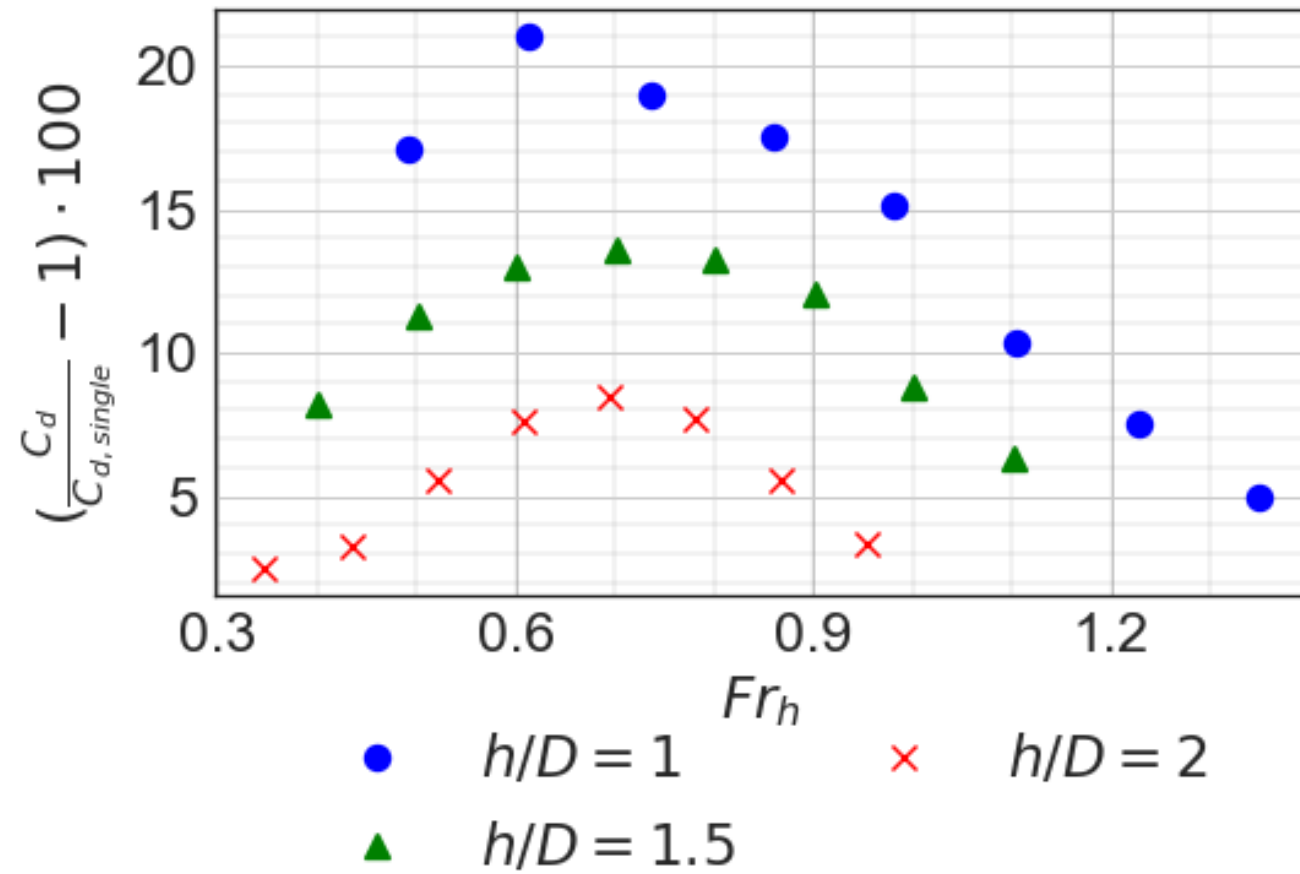
Drag



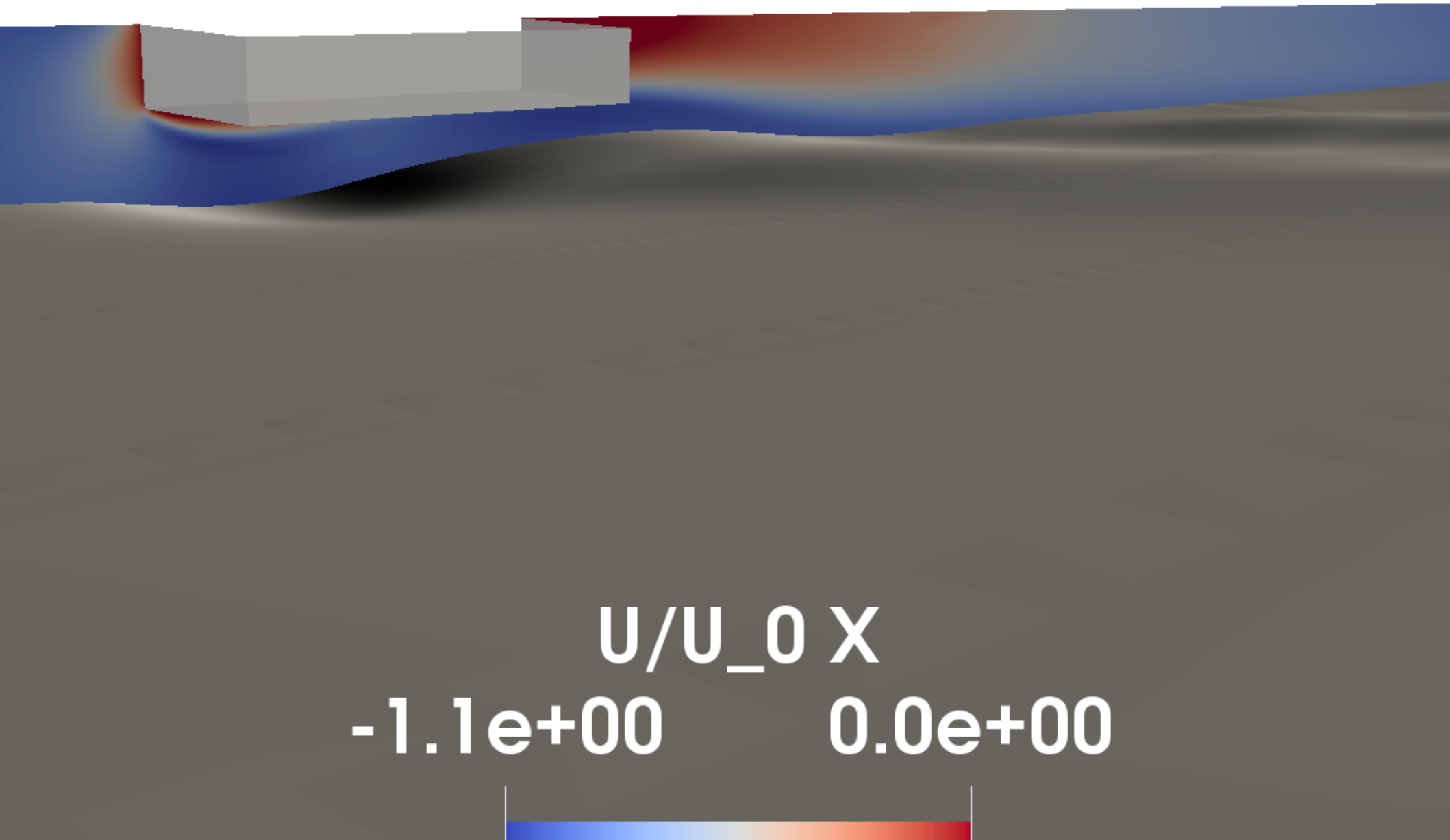
Drag 2



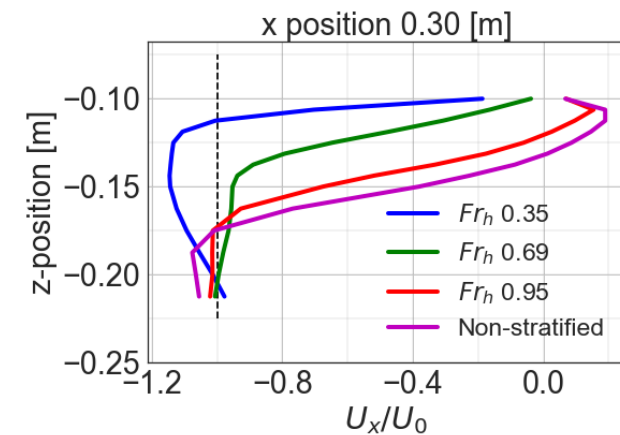
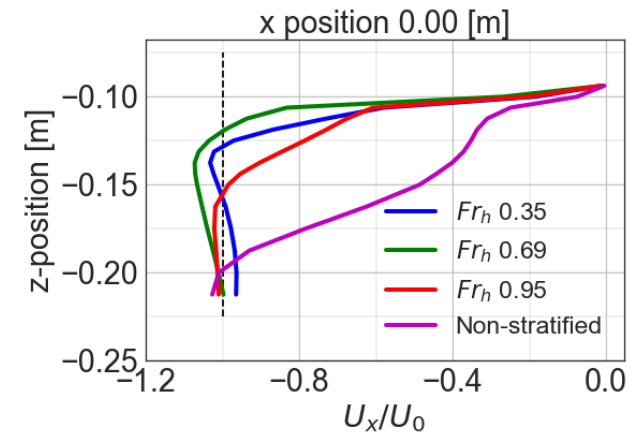
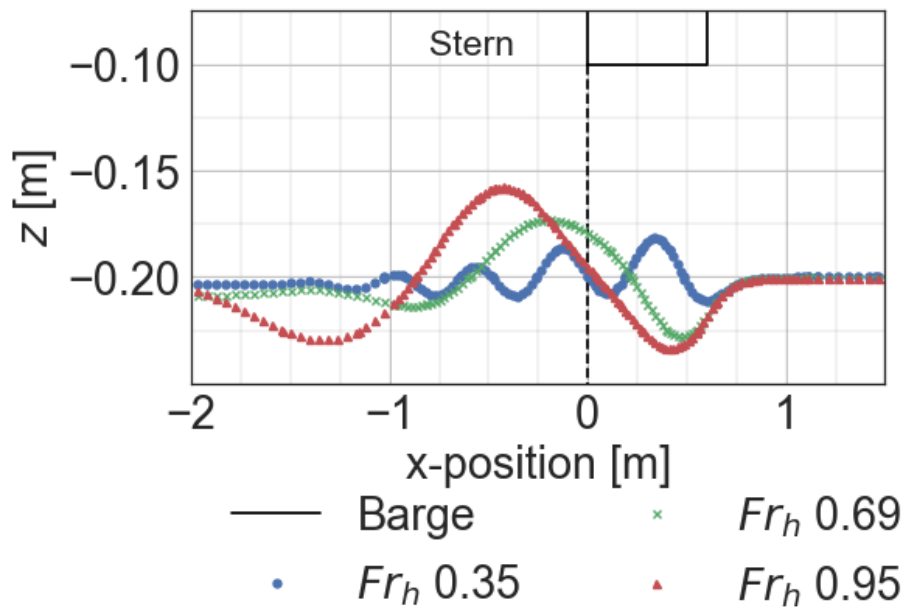
Drag 3



Internal waves

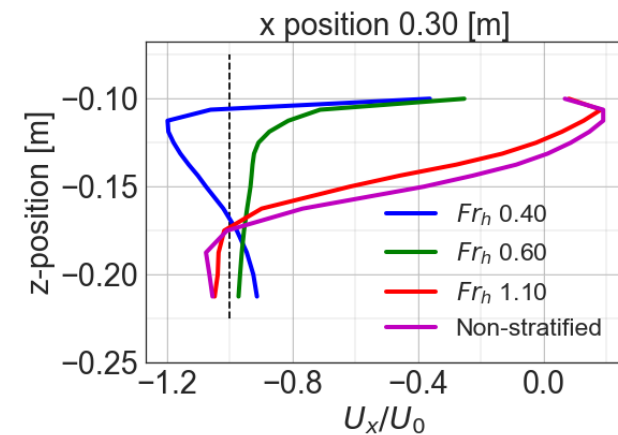
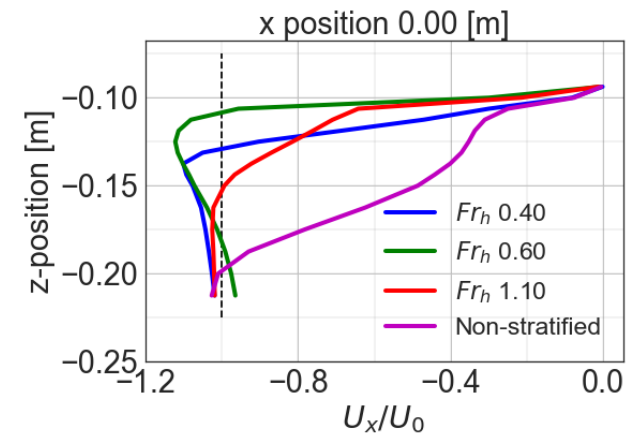
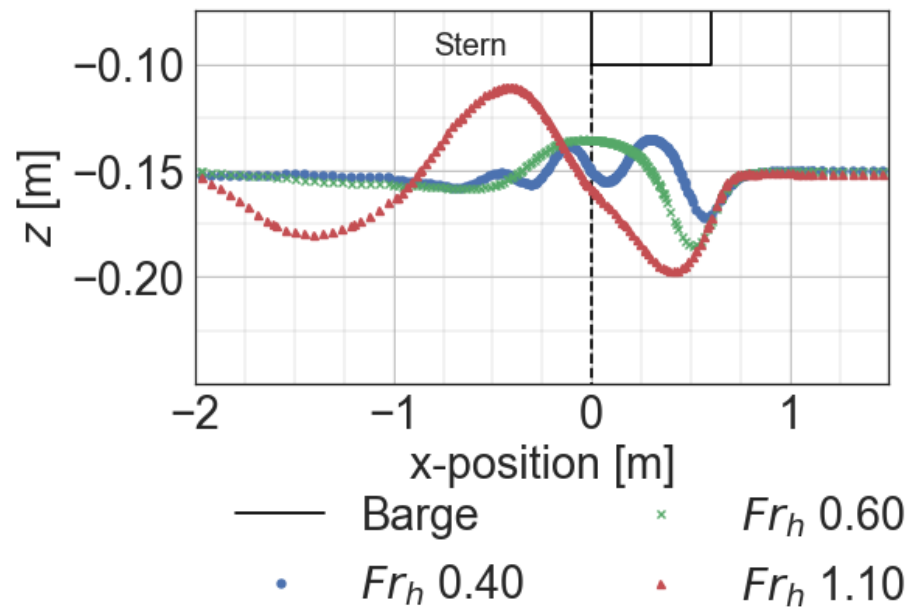


Internal waves and effect on velocity



Internal waves and effect on velocity

2



Conclusions

- K-Omega SST gave better results than k-epsilon.
- Similar results as Gou et.al simulating non-stratified water
- Able to catch the dead water phenomenon
- Under estimation of the increase in drag