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G2TRC | GAS TURBINE AND TRANSMISSIONS RESEARCH CENTRE

Stratified Flow in a Horizontal Channel

Gerris/Basilisk Meeting, 18 June 2019, Paris

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The University of Nottingham

Introduction & Motivation
CFD work in the group

LUBRICATION + COOLING FOR VARIOUS INDUSTRIAL APPLICATIONS

- Large scale
- With high Reynolds numbers
- Multiphase

- Large-scale applications use URANS (Unsteady Reynolds-Averaged Navier-Stokes) for modelling turbulence in industrial applications

Introduction & Motivation

- Widely used CFD turbulence models (URANS) do not model interfacial turbulence well!
- Currently: CFD uses a semi-empirical method of **turbulence damping** (TD), which is inaccurate for wavy films.
- This impacts our modelling of bearing chambers and gearboxes – the models are very sensitive to the choice of empirical constants.

Turbulence Damping

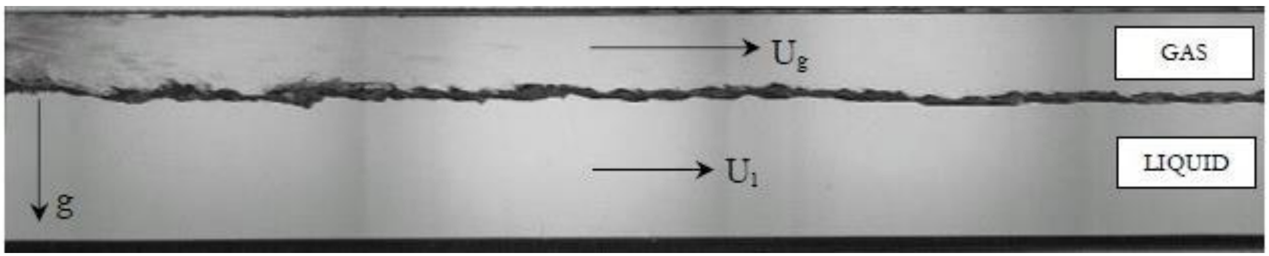
- In CFD models of stratified flow, using a method such as VOF, **sharp discontinuities** in the velocity field at the interface often result in **over-prediction** of turbulent kinetic energy at the interface by isotropic turbulence models
- This has an **impact** on the overall mass, momentum and energy transfer across the interface
- For **smooth interface** (non-wavy) stratified flows, Egorov [1] proposed a **correction** to the specific turbulence dissipation – Eqn (1) – which has been shown to reproduce wall-like damping at the liquid-gas interface and provide more accurate prediction

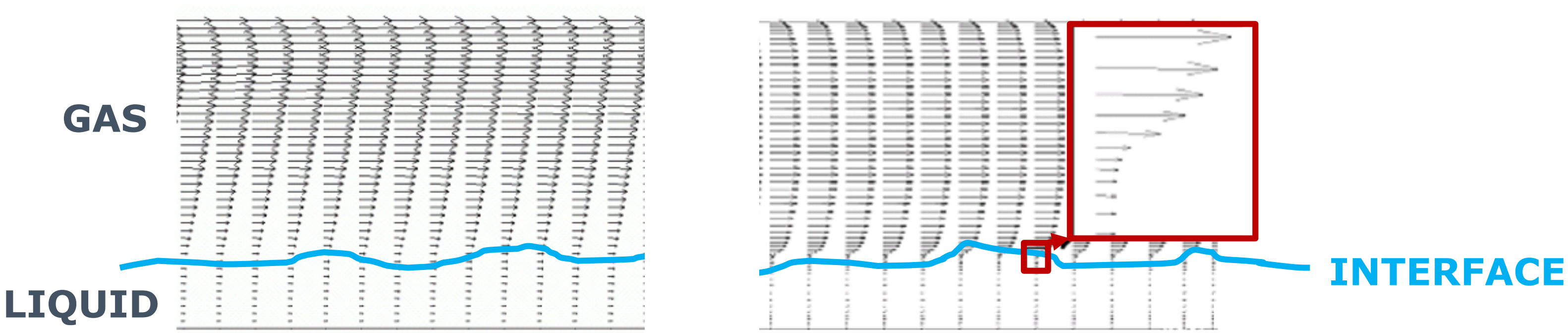
$$S_{\omega} = A\Delta n\beta\rho_i\left(B\frac{-6\mu_i}{\beta\rho_i\Delta n^2}\right)^2, \tag{1}$$

where variable A is used to activate this source term only at the free surface and B is the damping coefficient which should be at least 10 [1].

CFD work

Stratified gas-liquid flow in a horizontal channel



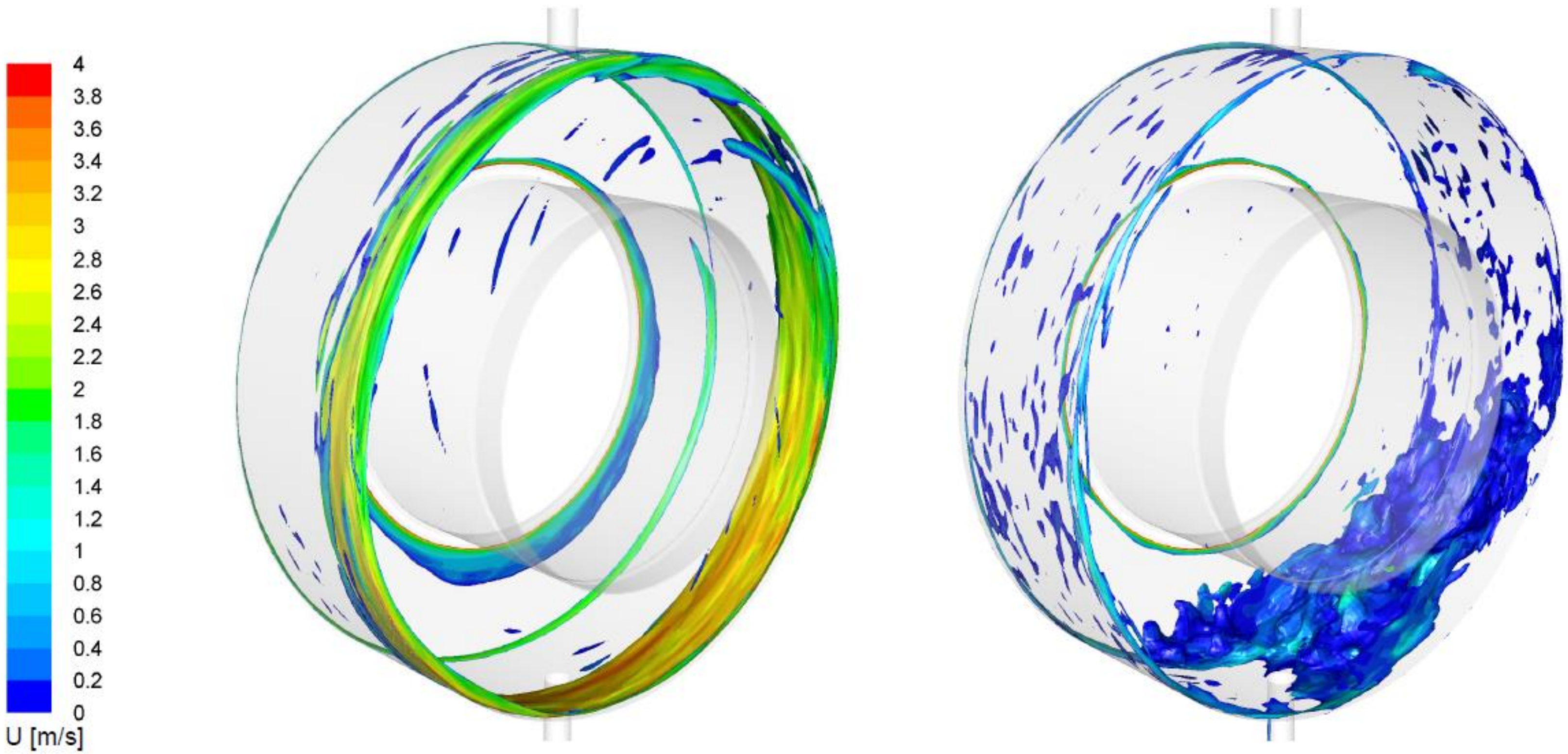


Without TD **With TD**

Effect of interface turbulence damping on the velocity profiles of a stratified gas-liquid flow in a rectangular channel [1]

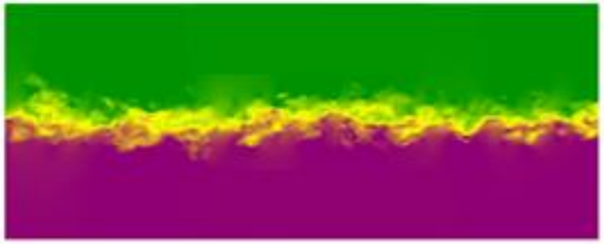
Effect of Turbulence Damping

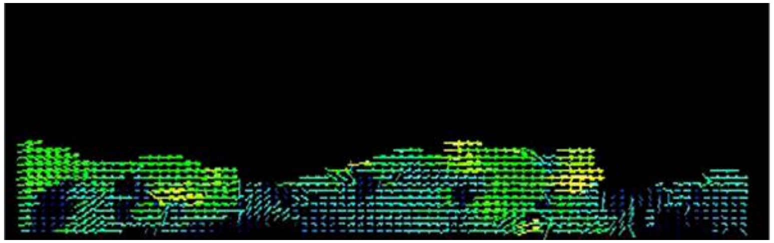
Bearing chamber test [2]



TDF=100

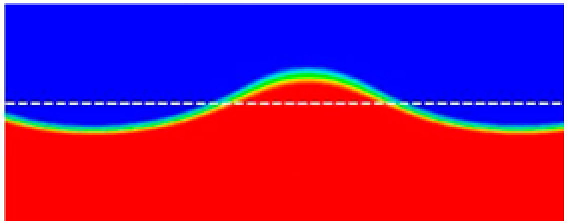
TDF=10





DNS/LES (scale-resolving methods)

Cornerstone



PIV

Improved URANS!

Future Work

Test Chamber

Representative Chamber

Large-scale goal: provide input for improvements of URANS models from scale-resolving methods

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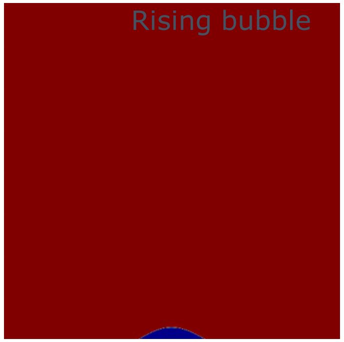
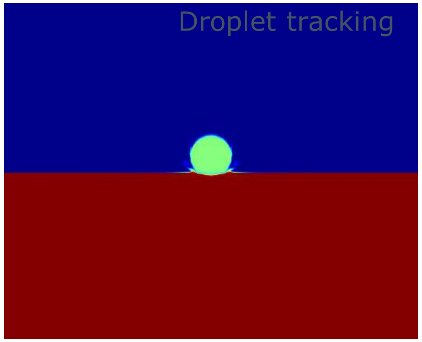
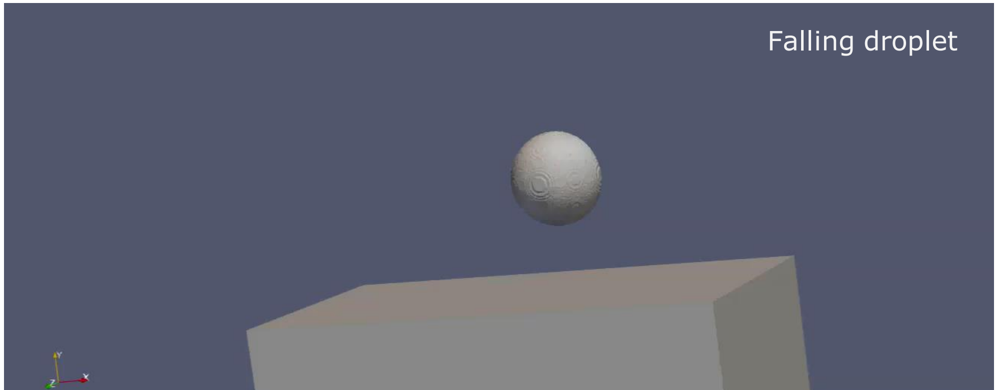
Number of tests with varied CFD software

Reasons for choosing Gerris:

- Open-source free software
- Aims at Direct Numerical Simulations
- Efficient quadtree/octree grid structure
- Adaptive grid
- Multiple criteria for adaptive grid
- Modifiable
- Possibility to run in parallel
- Periodicity
- Unexplored in our group

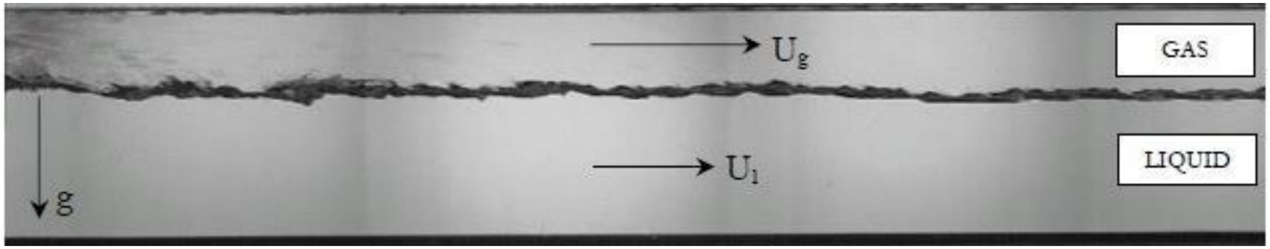






Experiments are planned for the near future

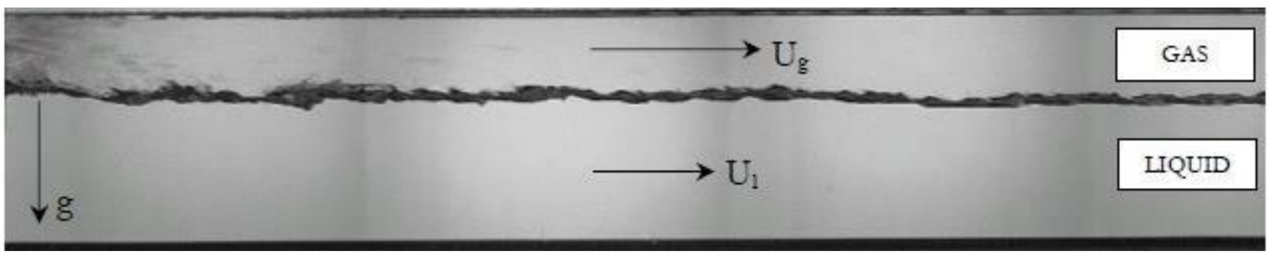
Experimental case by Fabre et al. (1987)

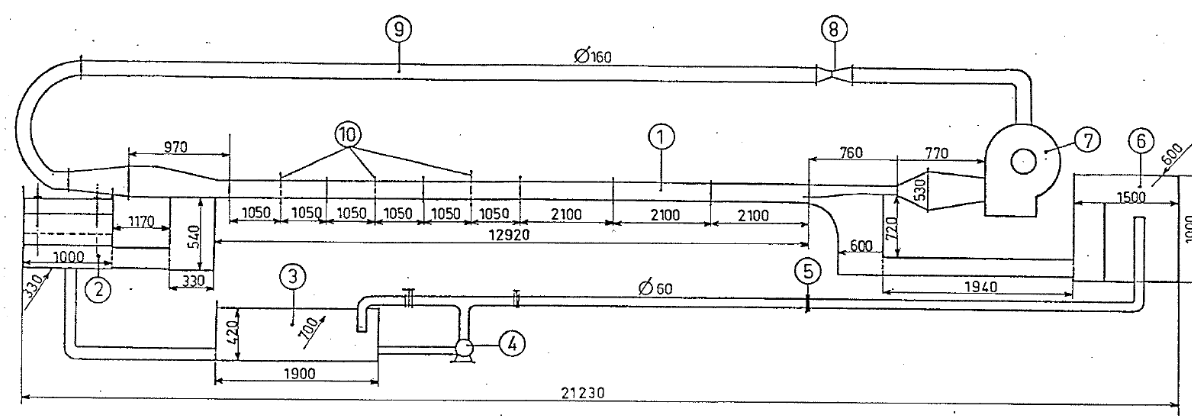


In the meantime the simulations are set up for a similar case where **data** is already **available**

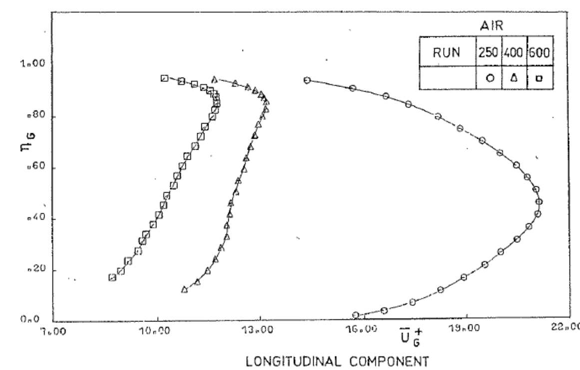
Experimental case by Fabre et al. (1987)

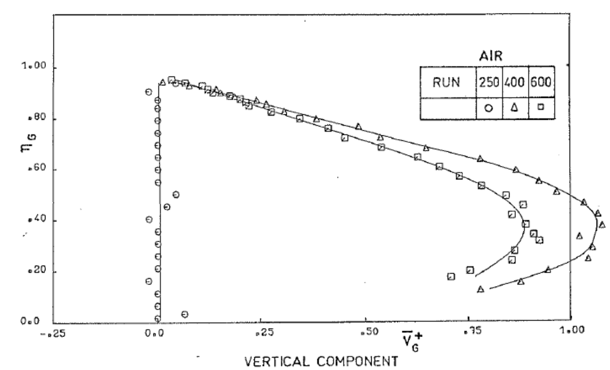
Stratified flow in a channel





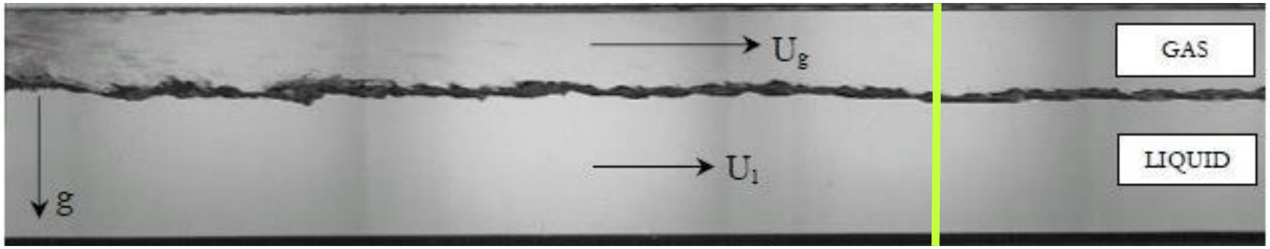
1 Rectangular channel 240 × 140 mm²
2 Constant level tank
3 Water tank
4 Centrifugal pump
5 Orifice meter
6 Tranquilization tank
7 Centrifugal fan
8 Venturi meter
9 Air loop
10 Measuring test section

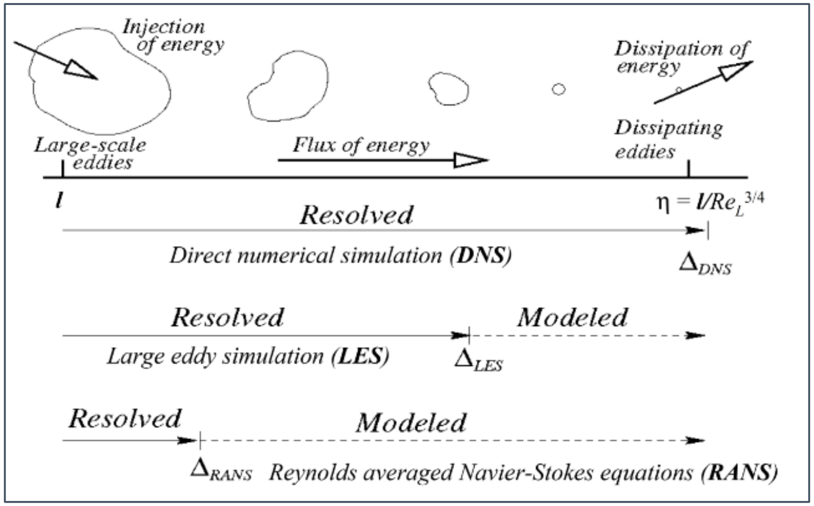


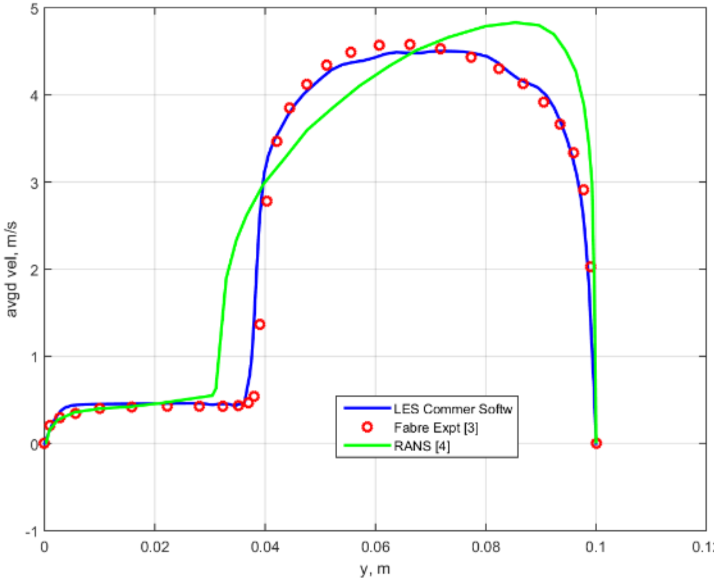


RANS vs LES

X-velocity along a vertical line in a cross-section



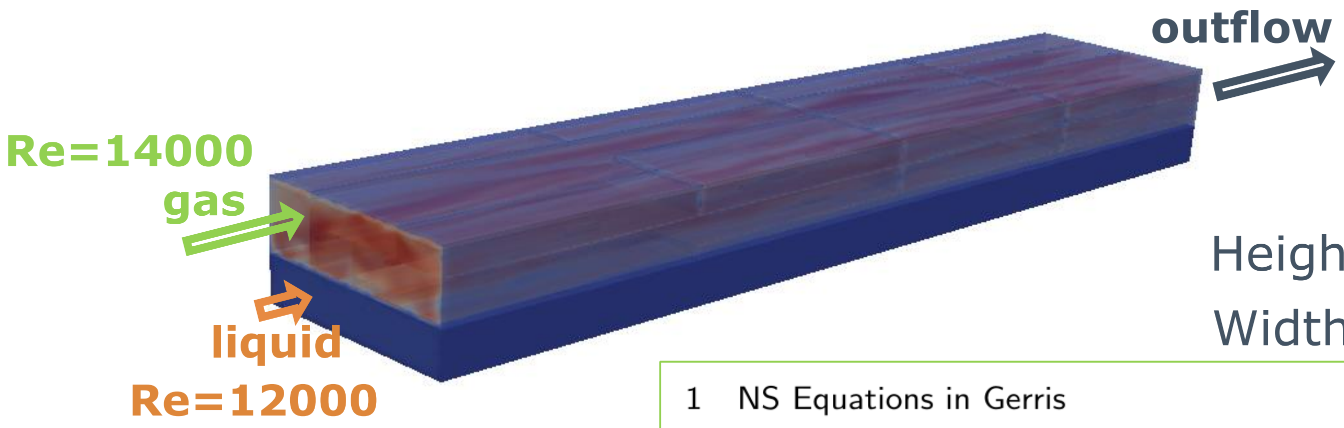




Simulations Setup

Case 1: 3m long (problems near outlet)

Case 2: Periodic (inlet-outlet), 1m long



Height=0.1m

Width=0.2m

1 NS Equations in Gerris

$$\frac{d\vec{u}}{dt} = \alpha\{-\vec{\nabla}p + \vec{\nabla}\cdot(\mu(\vec{\nabla}\vec{u} + \nabla\vec{u}^T)) + \sigma\kappa\delta_s\vec{n}\} + \texttt{Source}(\vec{u})$$

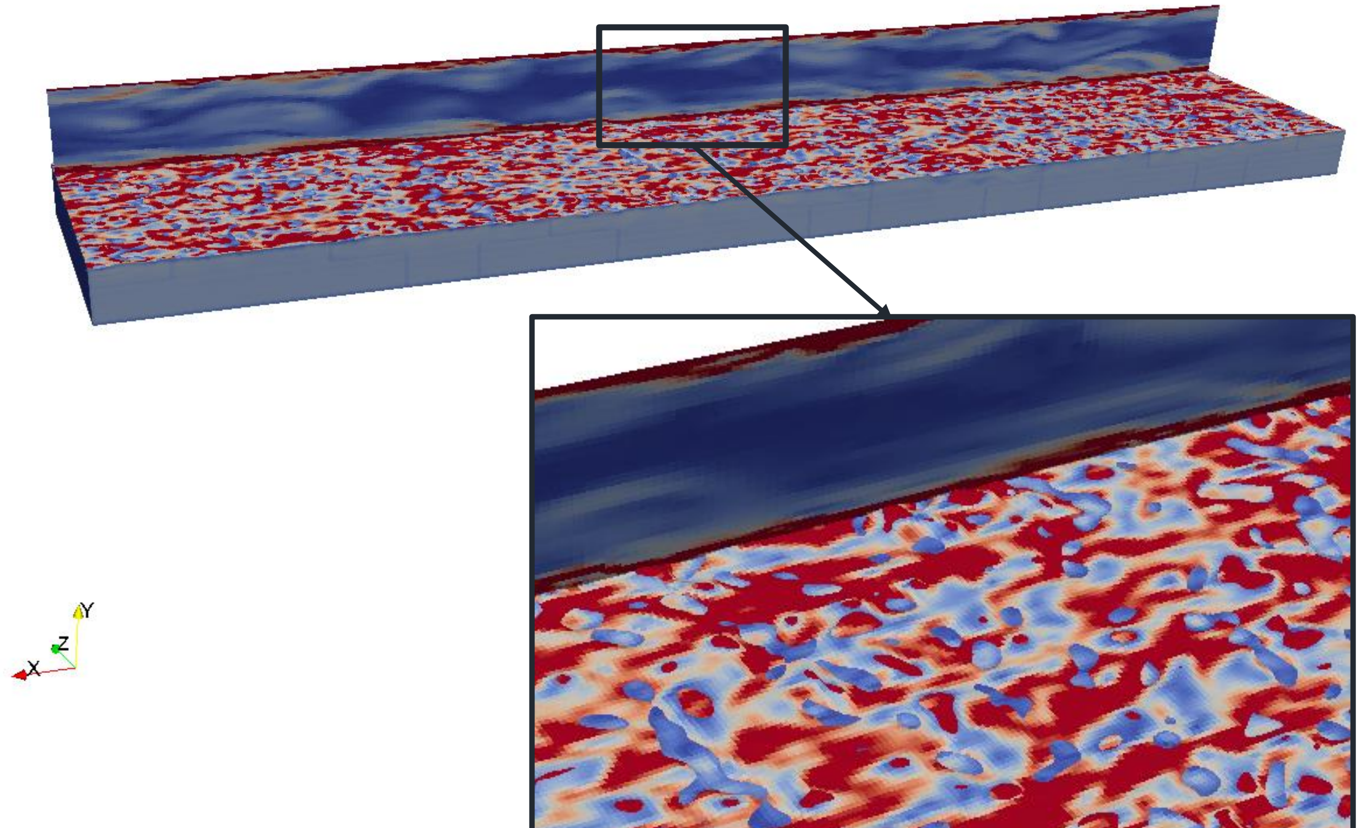
- No-slip walls
- Two phases: water at the bottom (0.04m); air at the top (0.06m)
- Refinement: near walls, near the interface + adapted vorticity

Preliminary Results

Vorticity plot (range: 0..500 1/s)

2.8 M cells

Refnm Lvl 7



Preliminary Results

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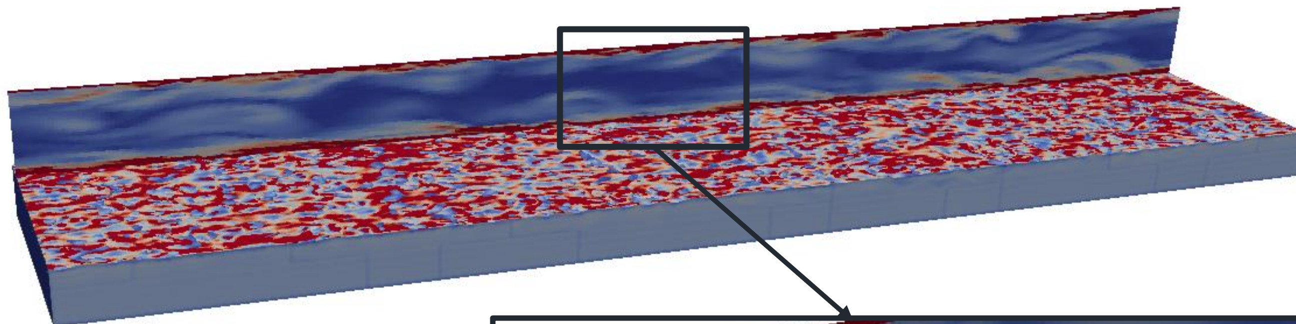
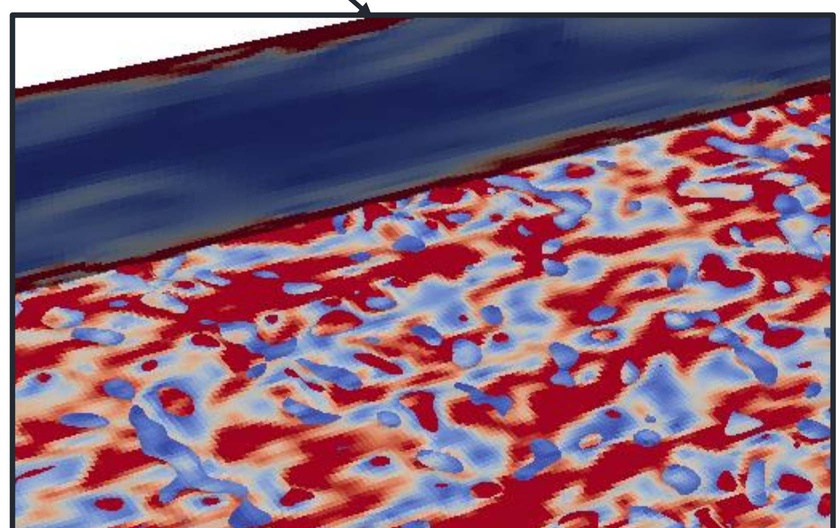
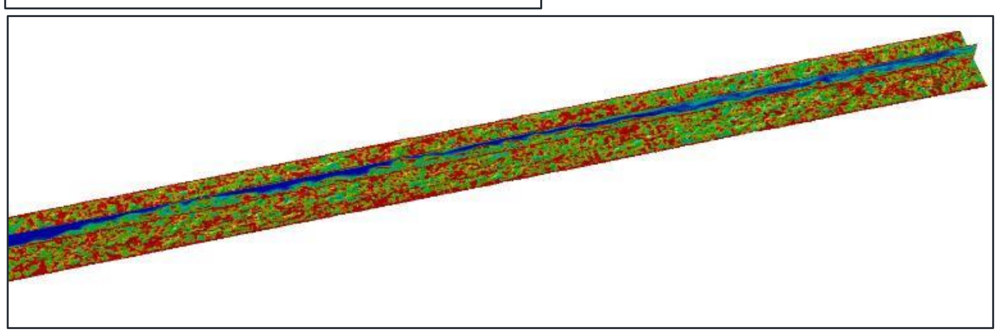




LES (comm. soft.),

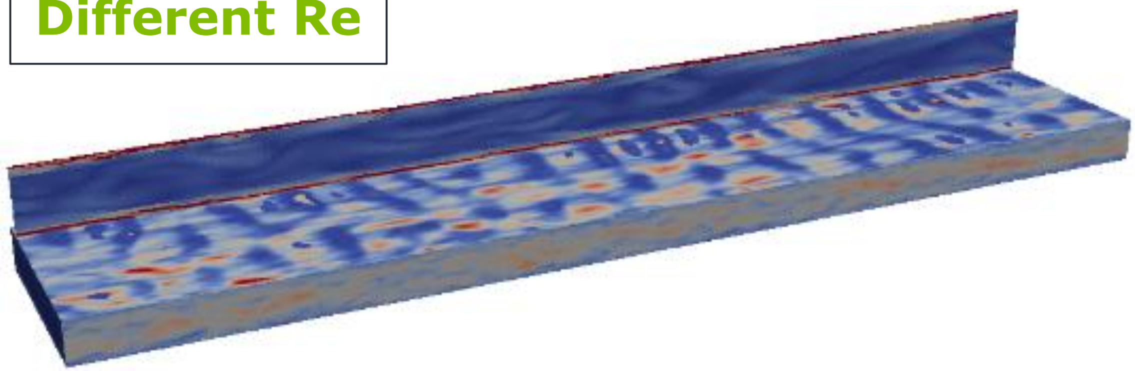
>14M cells

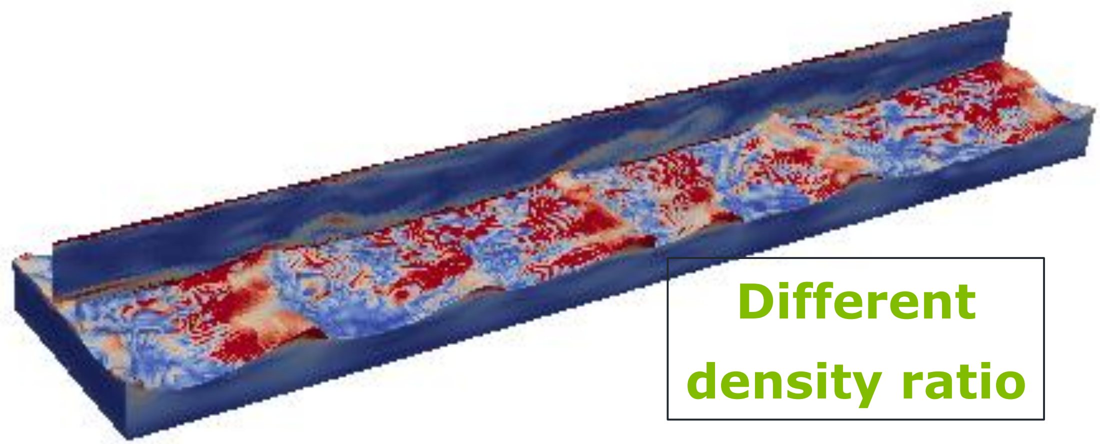


Preliminary results

Testing different Re and density ratio

Different Re





Different density ratio

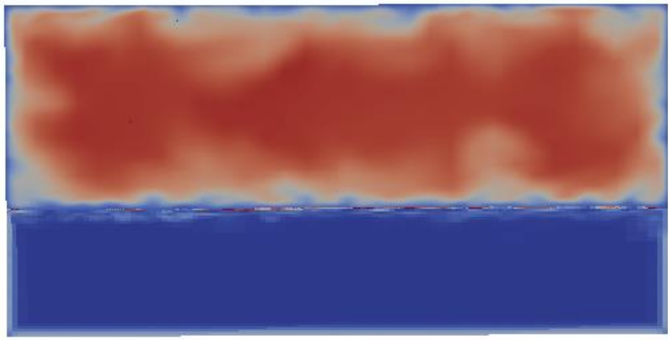
Preliminary Results

Velocities U

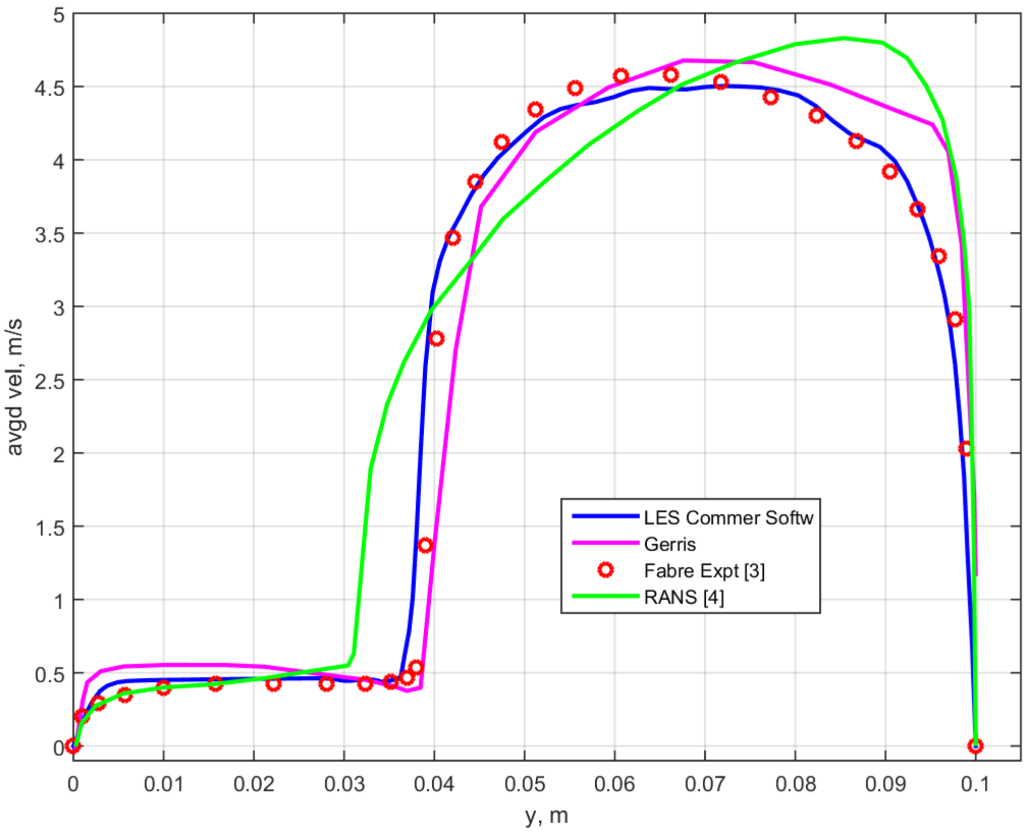
Smaller case (shorter domain):

0.6 M cells, Refnm Lvl 7

U-velocities plot (cross section)



U-velocities along a vertical line



Future plans

- **Robust methodology** for the planned test cases
- **New simulations** that would represent experimental cases
- **Comparison** of data with experimental data
- **Conclusions** with regard to turbulence damping
- Potential **changes** of the models where TD is used and publications

Thank you

References:

- [1] Egorov, Y., 2004, "Validation of CFD codes with PTS-relevant test cases," Report EVOL-ECORA-D07, ECORA.
- [2] Bristot, A., 2017, "Application of the Volume of Fluid Method with Heat Transfer to a Two-Shaft Aero-Engine Bearing Chamber", PhD Thesis, University of Nottingham.
- [3] Fabre J. et al, 1987, "Stratified Flow: Part 1", International Workshop on Two-Phase Flow Fundamentals.
- [4] Tkaczuk P. & Morvan H., 2012, "Methodology for Modelling Two-Phase Flow in Bearing Chambers using CFD (Volume of Fluid)", Internal Report.

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