Large Eddy Simulations of flow around underwater gliders and the impact on sensor measurements

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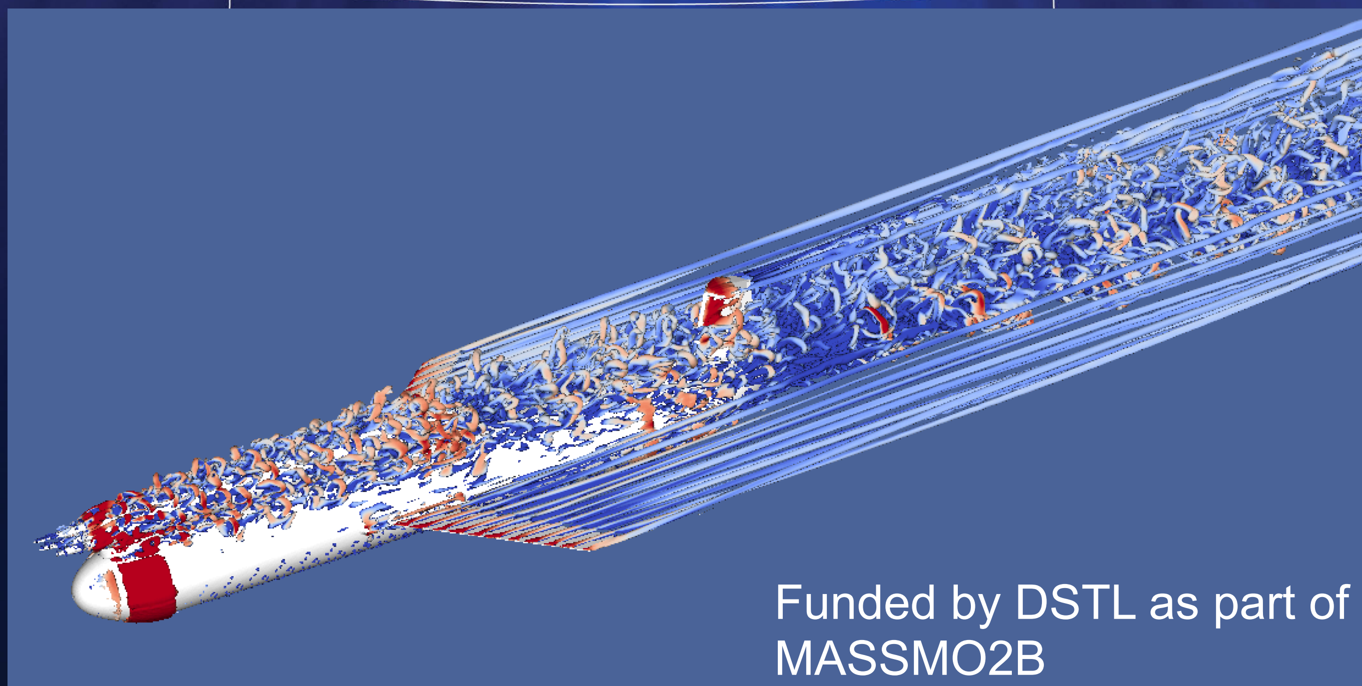

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@benmoat1

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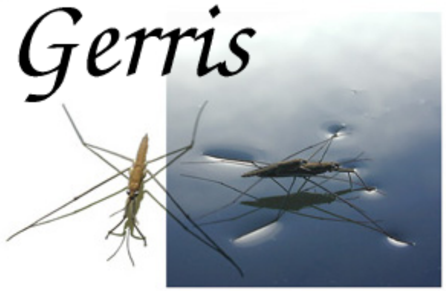
Motivation

- How are sensor measurements affected by flow distortion around the glider body?
- What is the best place to mount sensors on a glider?
- How are the flight characteristics changed by the adding extra sensors?
- How large is the turbulent wake?

Large Eddy Simulation (LES) modelling: GERRIS

- Solves the time-dependent incompressible variable-density Euler, Stokes or **Navier-Stokes equations**
- Solves the linear and non-linear shallow-water equations
- **Adaptive mesh refinement**: the resolution is adapted dynamically to the features of the flow.
- **Entirely automatic mesh generation** in complex geometries
- Second-order in space and time
- Unlimited number of advected/diffused passive tracers
- Flexible specification of additional source terms
- No Subgrid Scale model (SGS) model. **MILES** approach
- Volume of Fluid advection scheme for interfacial flows
- Accurate surface tension model
- Portable **parallel** support using the MPI library, **dynamic load-balai** parallel offline visualisation

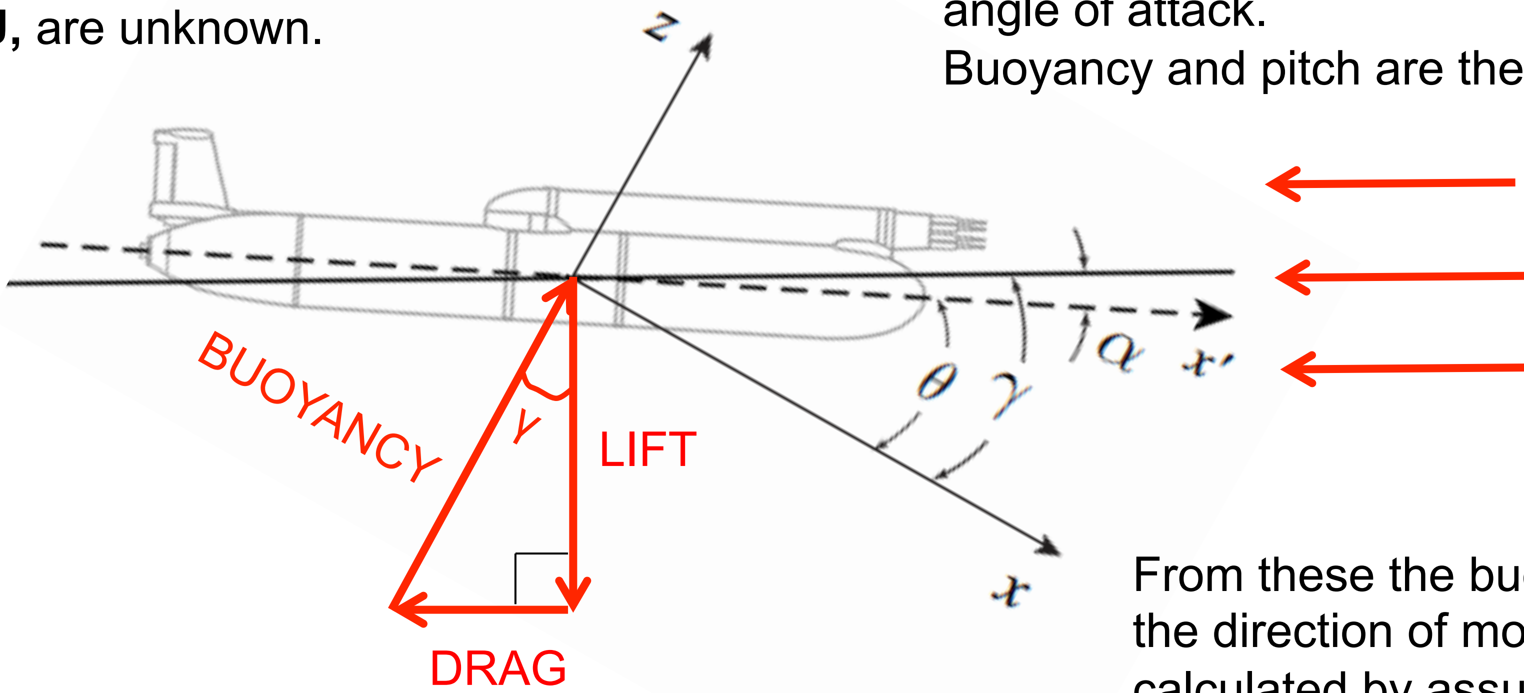
http://gfs.sourceforge.net



Model setup (1)

For a real glider: the pilot usually controls the net buoyancy and the pitch θ. A priori the angle of **attack, α**, and **speed, U,** are unknown.

Our model glider: does not move. Set **U** the upstream flow speed and **α** angle of attack.
Buoyancy and pitch are then calculated



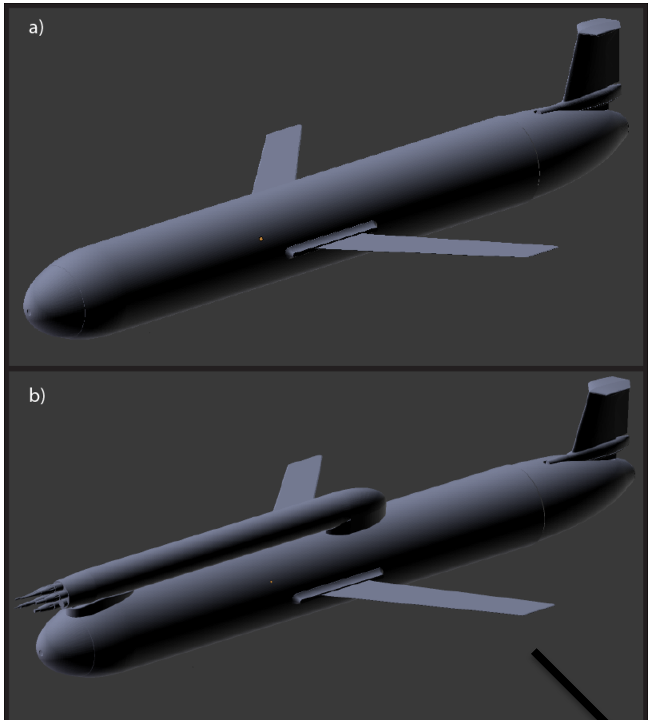
U = speed of upstream flow

From these the buoyancy and the direction of motion are then calculated by assuming the static balance of buoyancy, drag and lift.

Thus by interpolating between the results of a number of different simulations the pitch (θ) can be estimated for any given buoyancy and attitude.

$$\theta = (\gamma - \alpha)$$, (Glide angle – angle of attack)

Model setup (2)

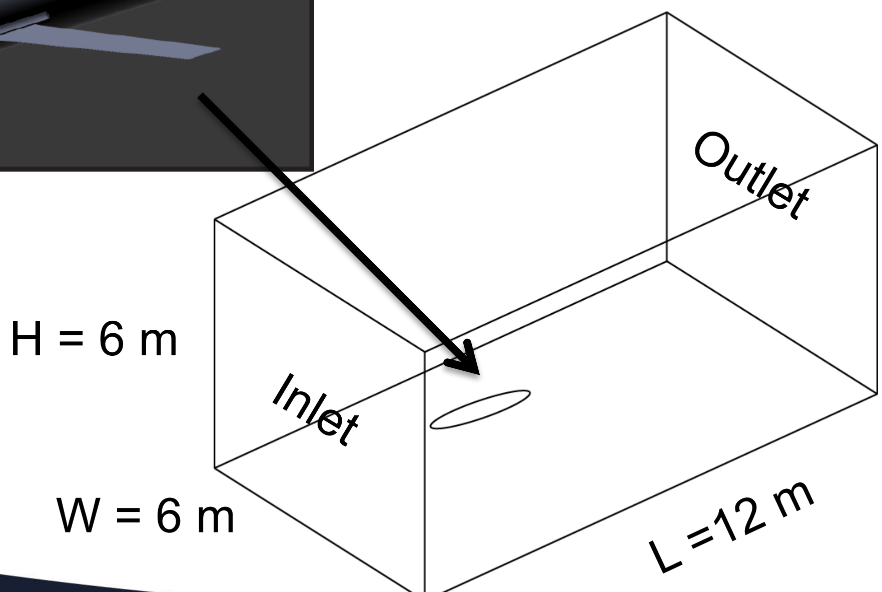


SOLVE: Time-dependent incompressible **Navier-Stokes equations**

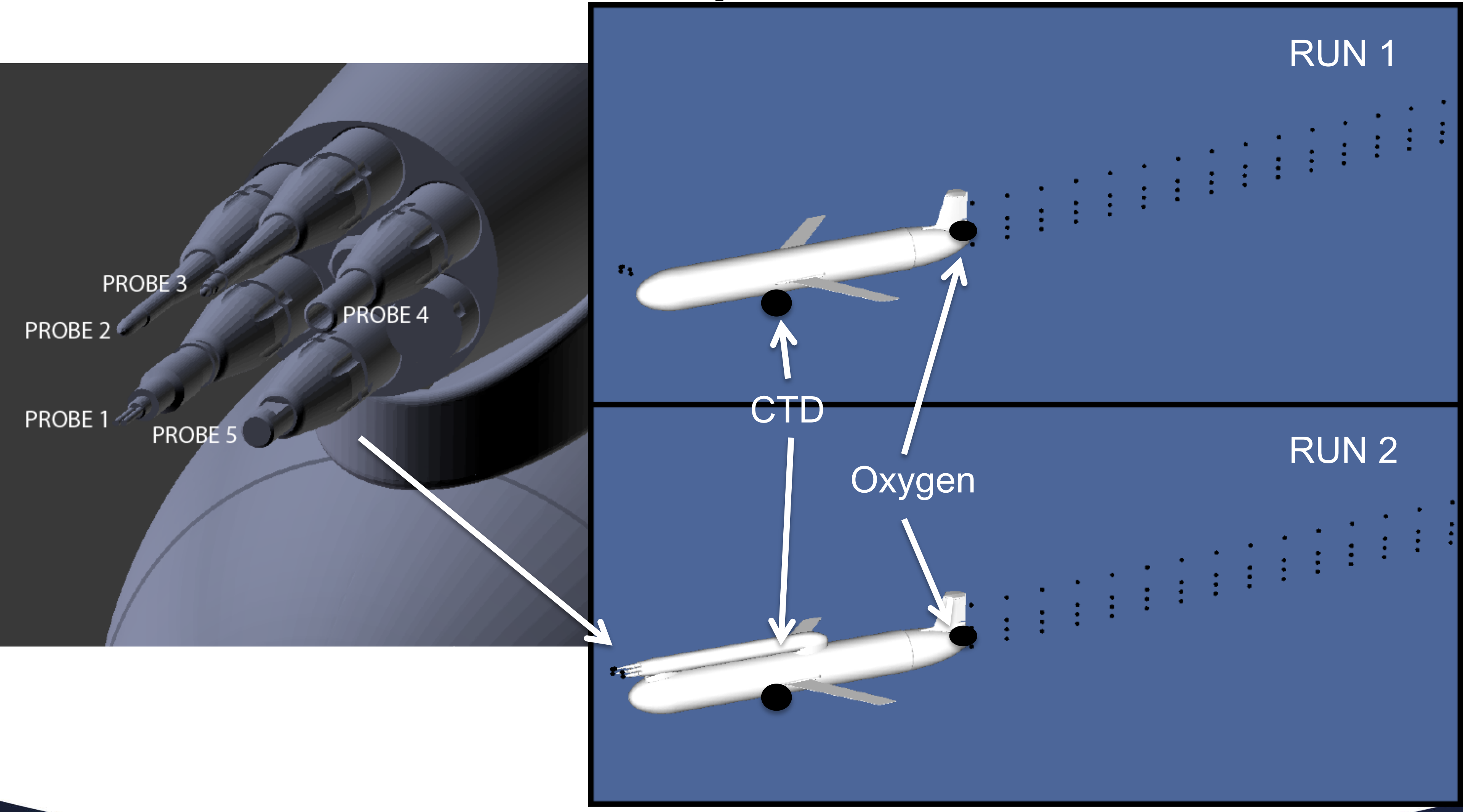
2 simulations: Slochum glider with and without MicroRider package attached

α = 2.5° (water speed = **0.33 m/s**)

Viscosity : 1.05×10^{-6} m^2 s^{-1}
(sea water at 20 °C)
Reynolds number = 5.78×10^5



Sensor positions



Mean flow speed

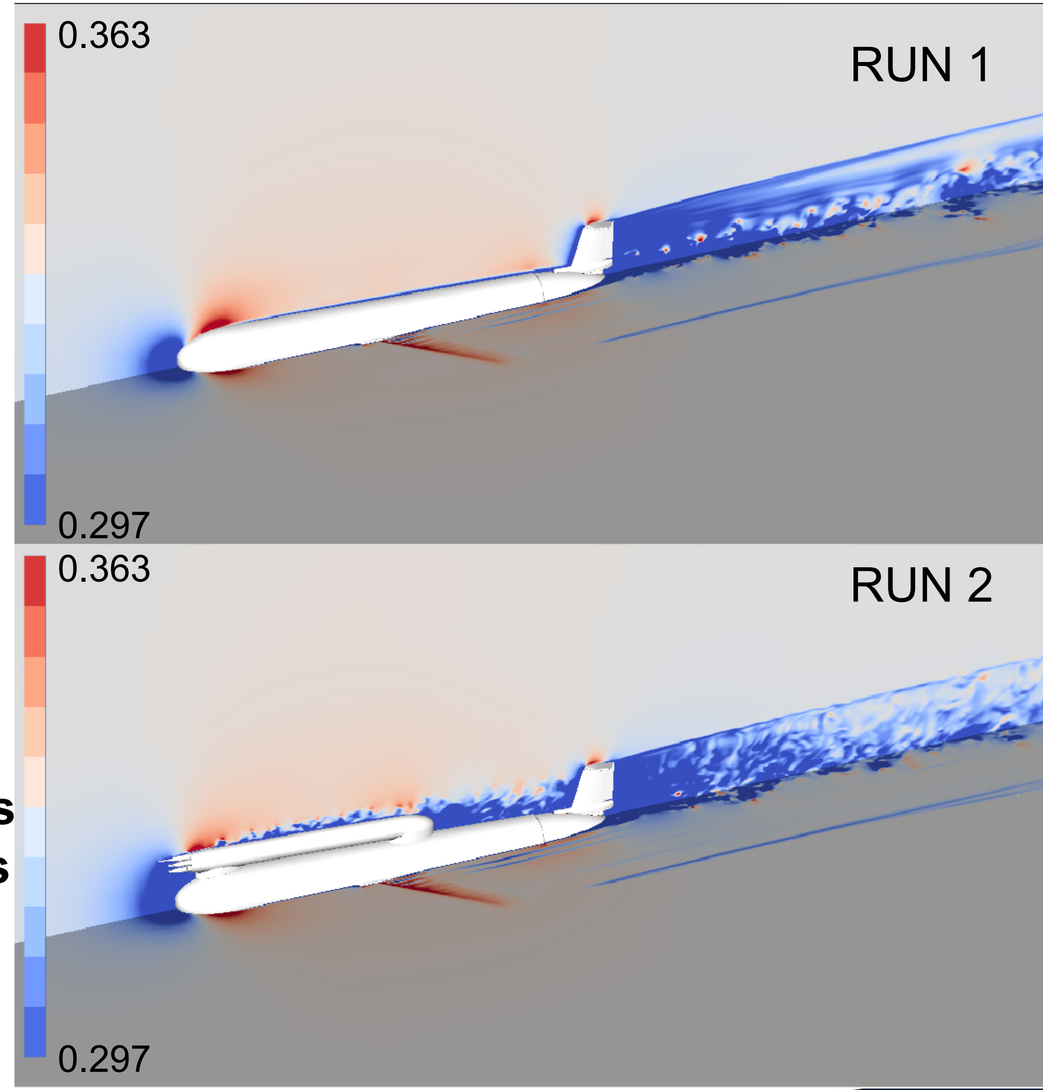
Time = 25 seconds
U = 0.33 m/s, α = 2.5

Cell size on the body is: **2.93 mm**
Cell size on the wings is: **1.46 mm**
Flow field mesh adapted to: **2.93 mm**

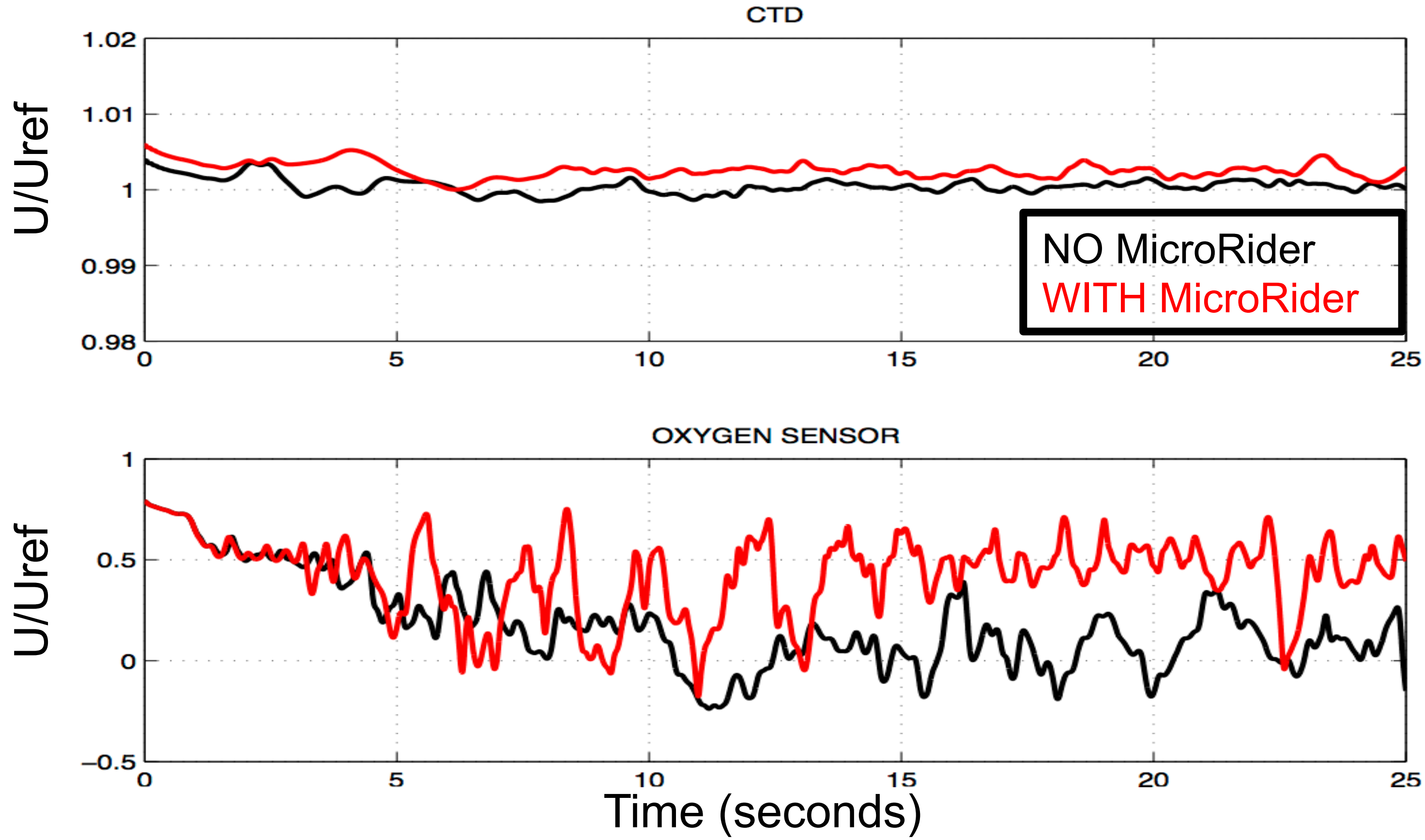
Total number of cells at 25 seconds:
No probe : **18,509,183**
With probe : **22,340,709**

Run times to 25 seconds:
No probe : **4.7 days** using **128cores**
With probe : **5.7 days** using **128cores**

Without grid adaption = 10^{12} cells !!



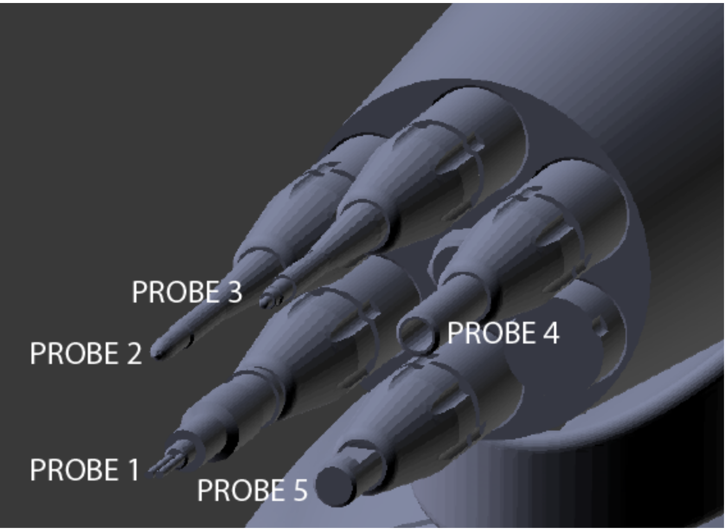
CTD and OXYGEN

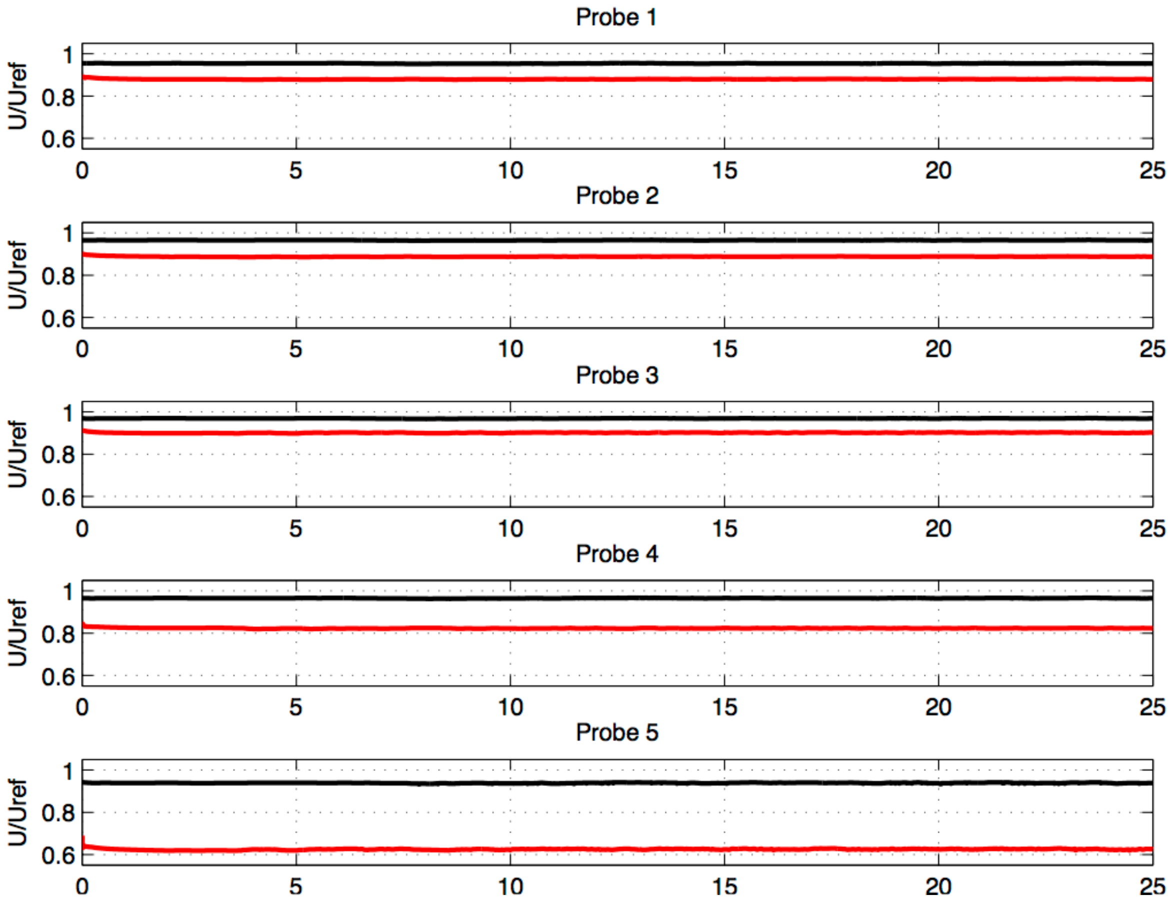


CTD: mean speed is HARDLY AFFECTED (<1% of the inflow speed)

OXYGEN SENSOR: mean speed is **BADLY AFFECTED** (stagnation to 50 % of the inflow speed)

MicroRider





Time (seconds)

NO MicroRider
WITH MicroRider

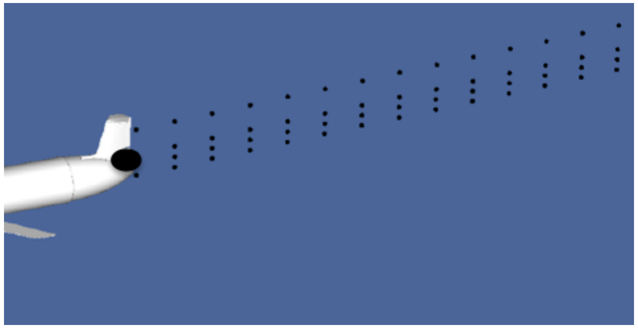
Decelerated in all cases.

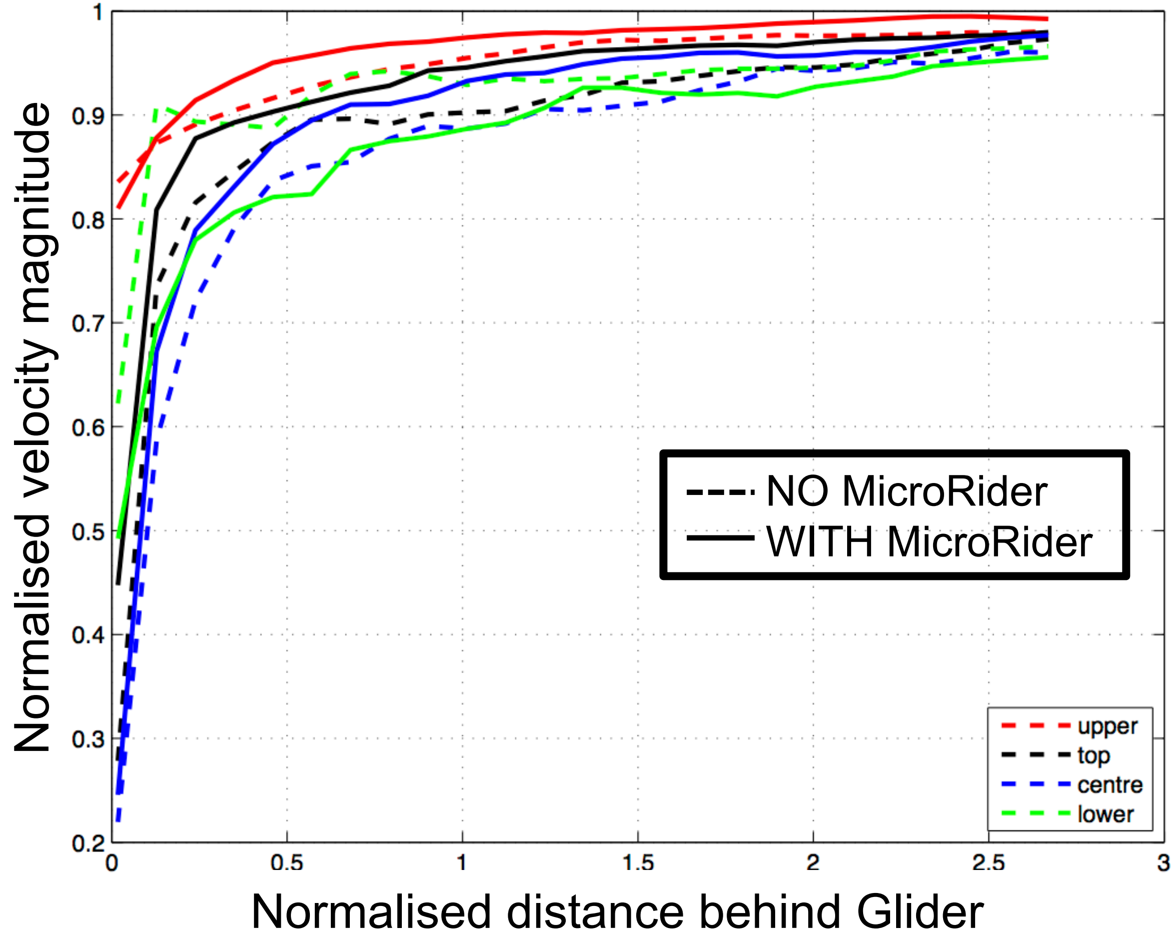
No MicroRider: -3% to -6%

With MicroRider: -10% (1 to 3)
-18% (4)
-38% (5)

May result in a slight underestimation of the turbulence levels

WAKE REGION





10% of the inflow speed at 1 glider length.

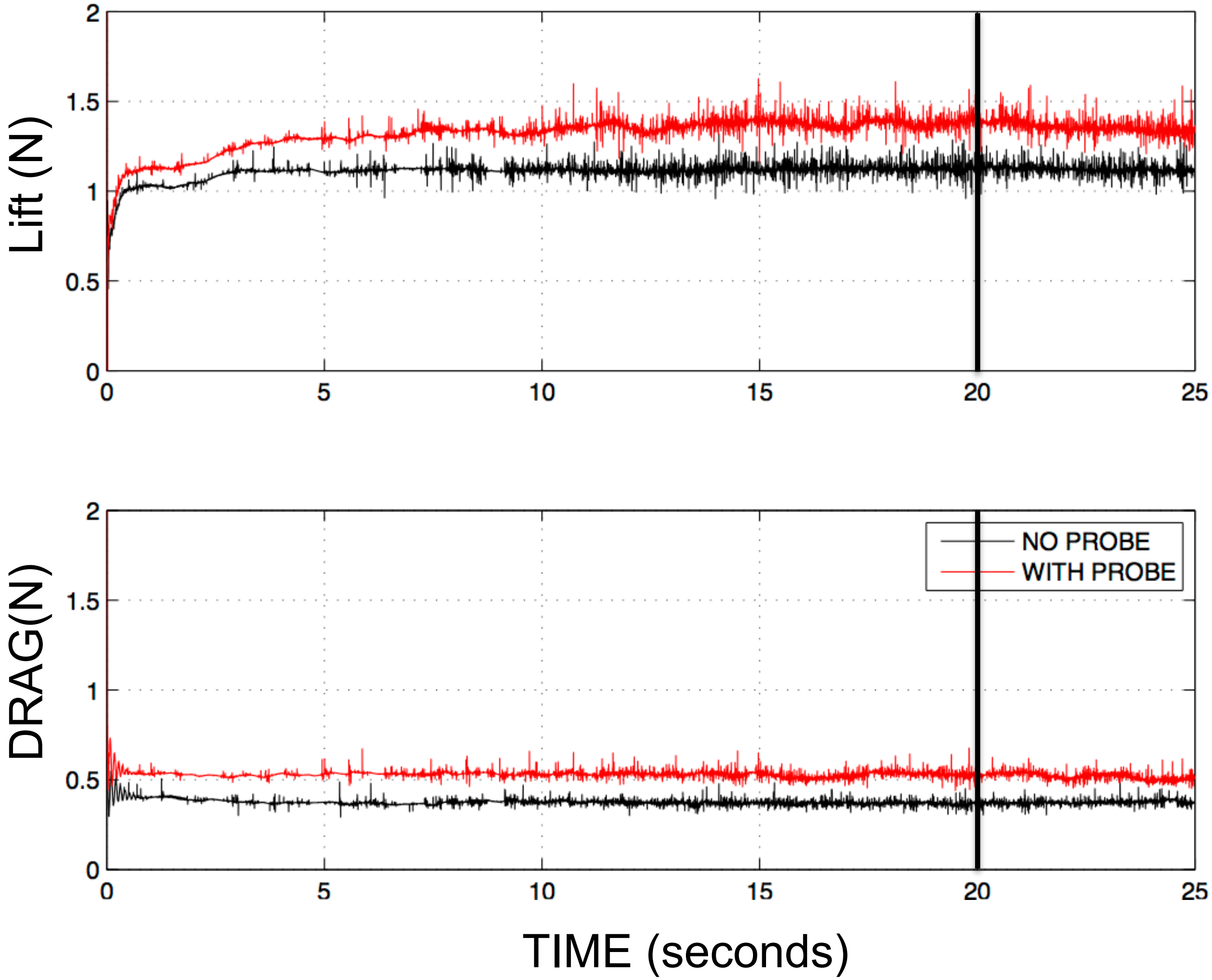
5% of the inflow speed At 2 glider lengths.

Lift and Drag

NO PROBE:
LIFT/DRAG RATIO 3.0

WITH PROBE:
LIFT/DRAG RATIO 2.6

Including the MicroRider increases both the Lift and drag.



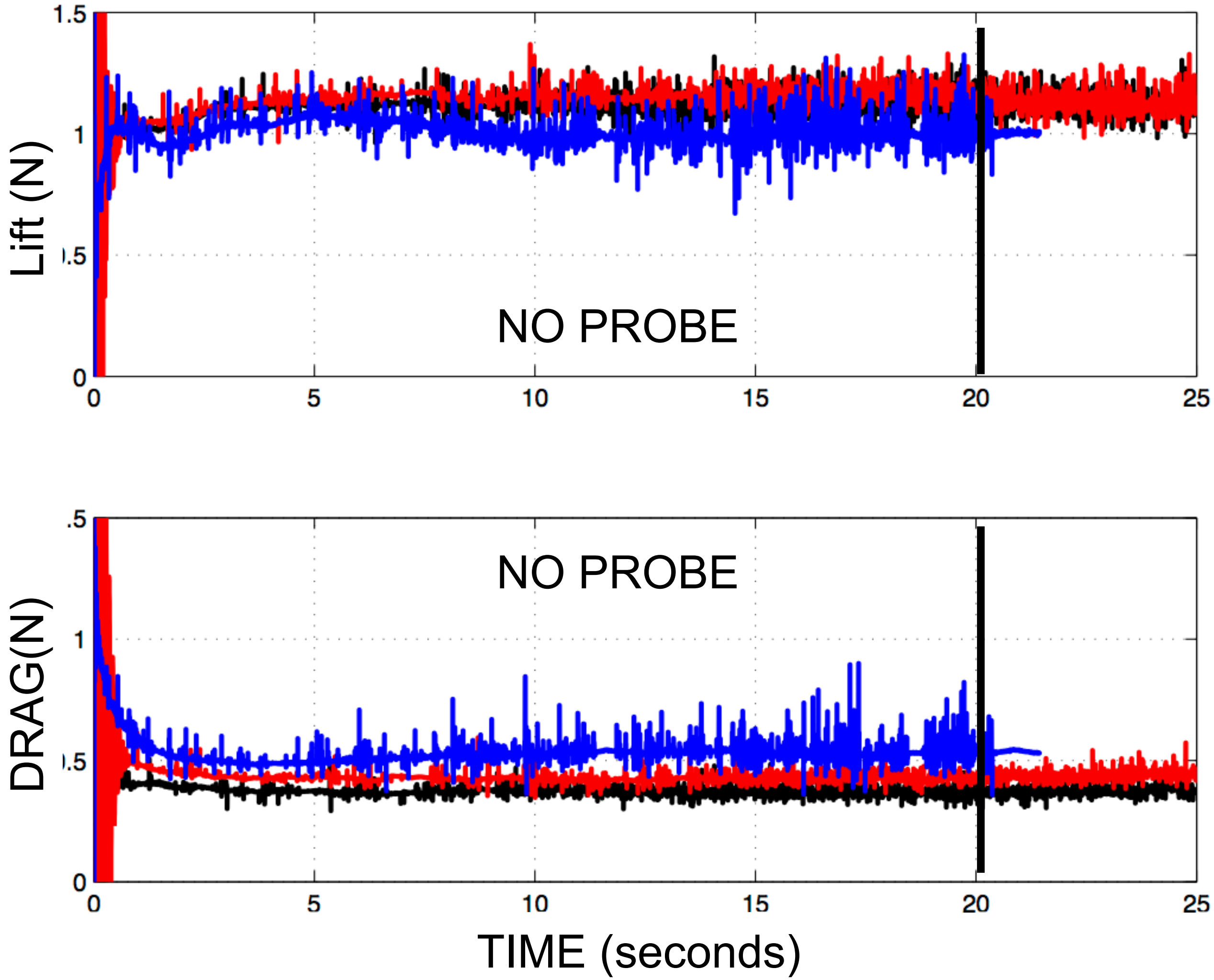
Grid resolution tests

Body: 2.93 mm
Wings: 1.46 mm
LIFT/DRAG RATIO: 3.0
Glide angle = 18.4°

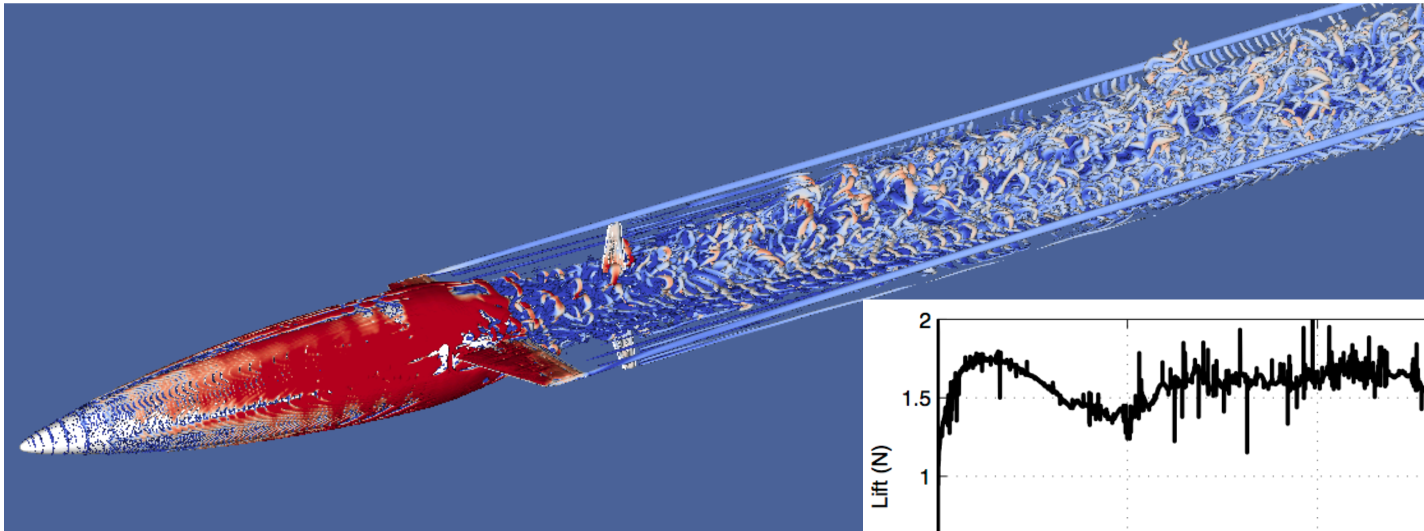
Body: 1.46 mm
Wings: 1.46 mm
LIFT/DRAG RATIO: 2.5
Glide angle = 21.2°

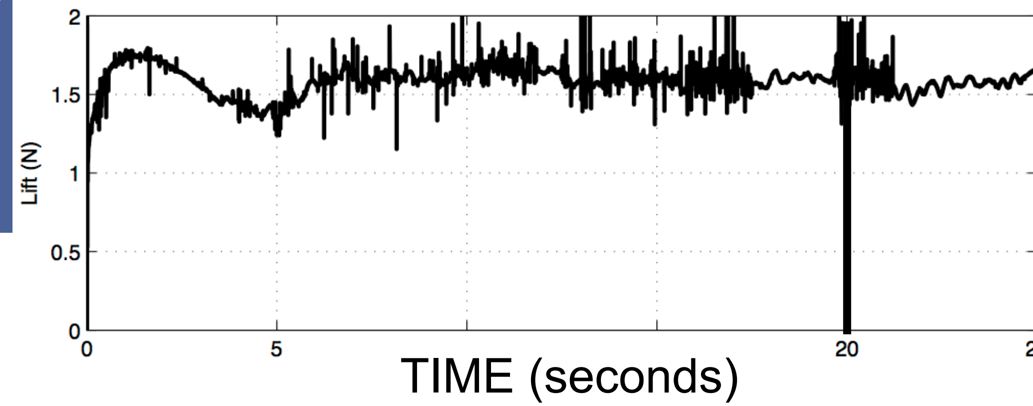
Body: 0.73 mm
Wings: 0.73 mm
LIFT/DRAG RATIO: 1.9
Glide angle = 28.1°

Merckelbach et al. (2010)
Predict lift/drag : 2.52
Glide angle: 21.6°

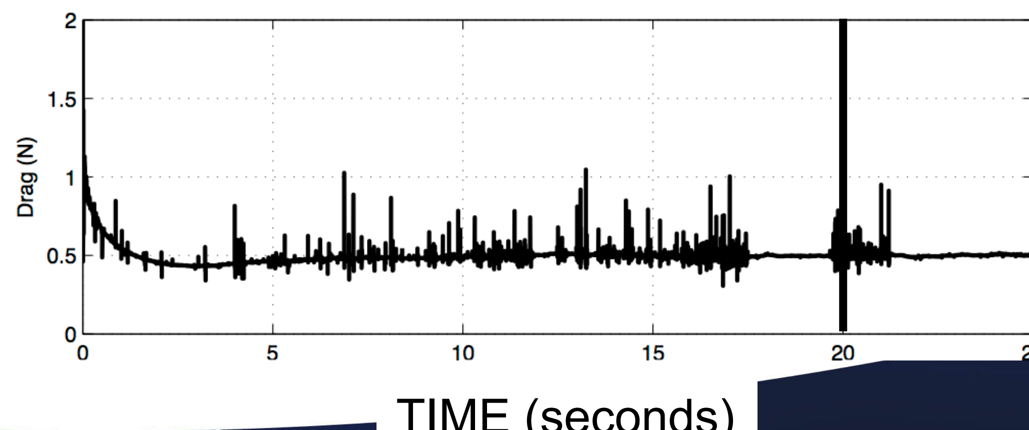


SEAGLIDER





U=0.33 m/s
Angle of attack: 2.5°
Glide angle: 17.7°
Body and wings : 0.73 mm
Lift/drag ratio : **3.13**
0.9 seconds in 24hrs
(on128 cores)



SUMMARY

Oxygen sensor may not positioned in a well exposed location
(stagnation to 50 % of the mean inflow speed)

CTD sensor is well placed. (<1 % of the mean inflow speed)

MicoRider probes: decelerated in all cases.
slight underestimation of turbulence levels
(10% to 38% of the mean inflow speed)

FUTURE

Tank testing to validate/verify the model results.
Run various angles of attack and speeds.

Thanks to TeledyneWebb, Rockland Scientific and University of Washington.

NEXUSS PhD project

A coupled CFD and observational approach to improve measurements of ocean turbulence from gliders.

Matthew Palmer (NOC), Ben Moat (NOC), Rob Hall (UEA) and Rolf Lueck (Rockland Scientific)