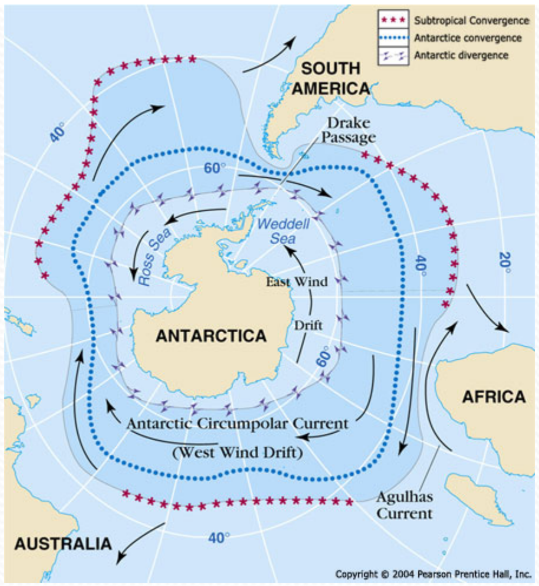
Laboratory modelling of momentum transport by internal gravity waves and eddies in the Antarctic circumpolar current

J. Sommeria, A. O. Ajayi , K. J. Raja, C. Staquet, S. Viboud, B. Voisin

LEGI

Routes to energy dissipation for geostrophic flows in the Southern Ocean *Nature Geoscience 2012*

Maxim Nikurashin*†, Geoffrey K. Vallis and Alistair Adcroft



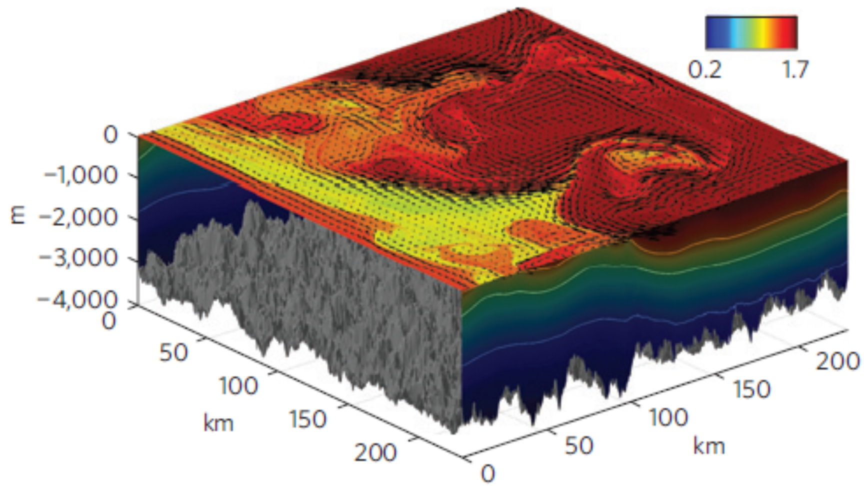
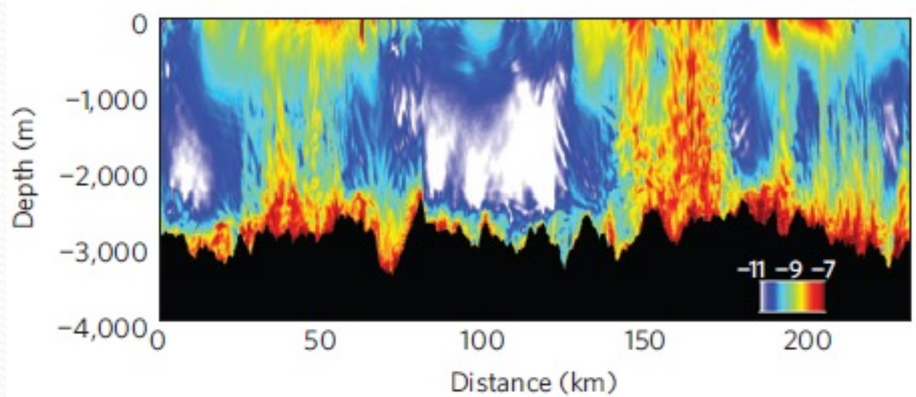


Figure 1 | A snapshot of temperature in (°C), surface currents and bottom topography after 40 days of simulations. The interior temperature isolines of 0.5, 0.9 and 1.3 °C are shown in light blue, green and orange colours, respectively.

Rate of kinetic energy dissipation $\log_{10}(\mathrm{W\,kg^{-1}})$



Processes of vertical momentum transport

Lee wave emission -> resonant interaction -> inertial waves (2D topography)

-Nikurashin and Ferrari, 2010 .

-Labreuche, LeSommer Staquet, submitted.

Vortex wakes behind 3D topography + baroclinic instability

-Nikurachin et al. 2012

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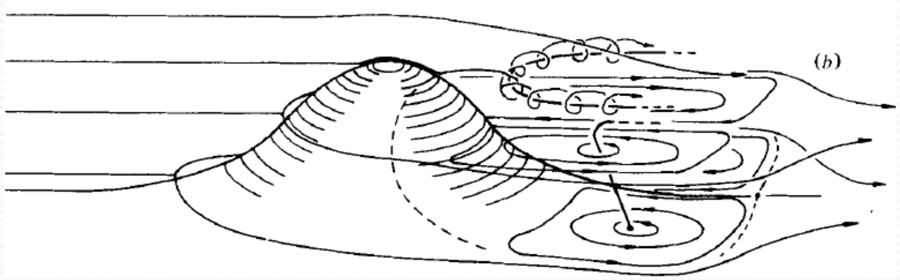
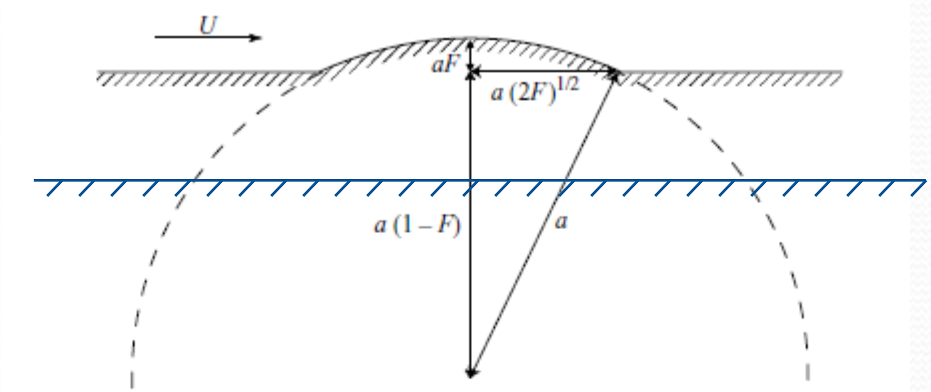
Wave-eddy splitting



From Hunt and Snyder (1980)

Froude number $F=U/(aN)$

Low Froude number <1:
initial wake 2D horizontal below $\eta=aF$ from the top, such that $U/(\eta N)=1$ (Drazin 1961, Voisin 2007)



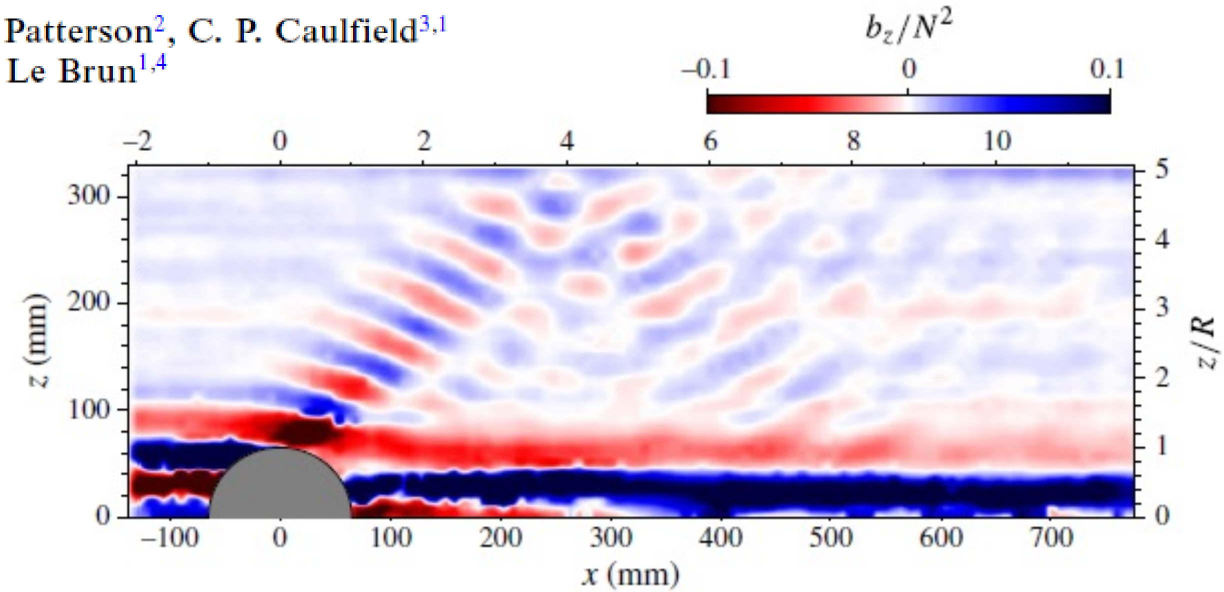
J. Fluid Mech. (2011), *vol.* 689, *pp.* 3–31.

doi:10.1017/jfm.2011.384

The structure of low-Froude-number lee waves over an isolated obstacle

Stuart B. Dalziel[1]†, Michael D. Patterson[2], C. P. Caulfield[3,1] and Stéphane Le Brun[1,4]

F=0.13
(based on
sphere radius)



Moderate Re=Ua/ν=1300
Lateral confinement (a=6.5 cm, flume width 40 cm)
No background rotation

Experiments in Fluids 11, 255–261 (1991)

Internal waves generated by a moving sphere and its wake in a stratified fluid

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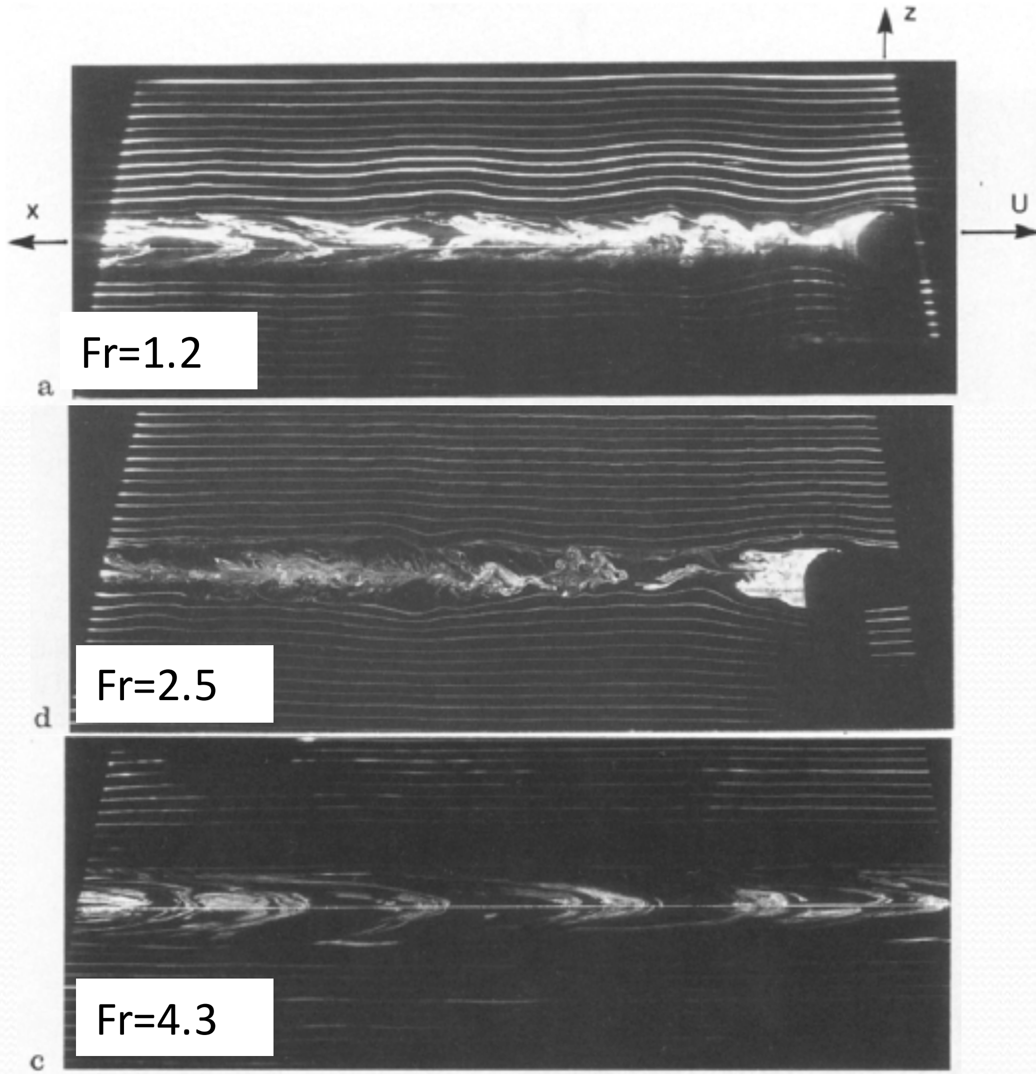
J.-M. Chomaz and **P. Bonneton**

Abstract. The internal gravity waves and the turbulent wake of a sphere moving through stratified fluid were studied by the fluorescent dye technique. The Reynolds number $Re = U \cdot 2\,a/\nu$ was kept nearly constant at about $3 \cdot 10^3$ and the Froude number $F = U/a\,N$ ranged from 0.5 to 12.5. It is observed that waves generated by the body are dominant only when $F < 4$ and are replaced by waves generated by the large scale coherent structures of the wake when $F > 4$.



Vertical diffusion of the far wake of a sphere moving in a stratified fluid

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Phys. Fluids A **5** (11), November 1993

J. Fluid Mech. (1993), *vol.* 254, *pp.* 1–21

The structure of the near wake of a sphere moving horizontally in a stratified fluid

By J. M. CHOMAZ[1,2], P. BONNETON[1] AND E. J. HOPFINGER[3]

J. Fluid Mech. (1993), *vol.* 254, *pp.* 23–40

Internal waves produced by the turbulent wake of a sphere moving horizontally in a stratified fluid

By P. BONNETON[1], J. M. CHOMAZ[1,2] AND E. J. HOPFINGER[3]

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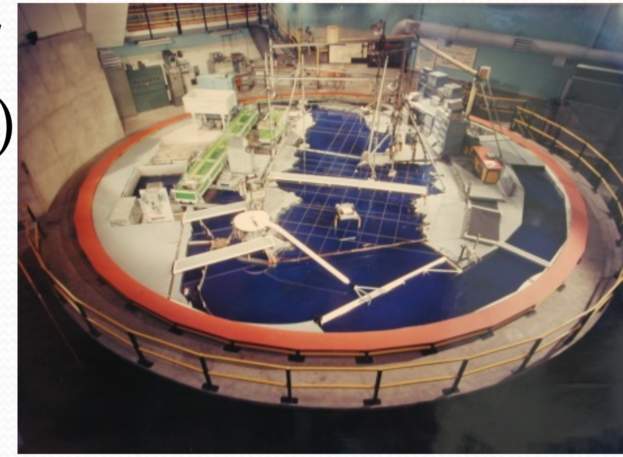
2016

Coriolis platform

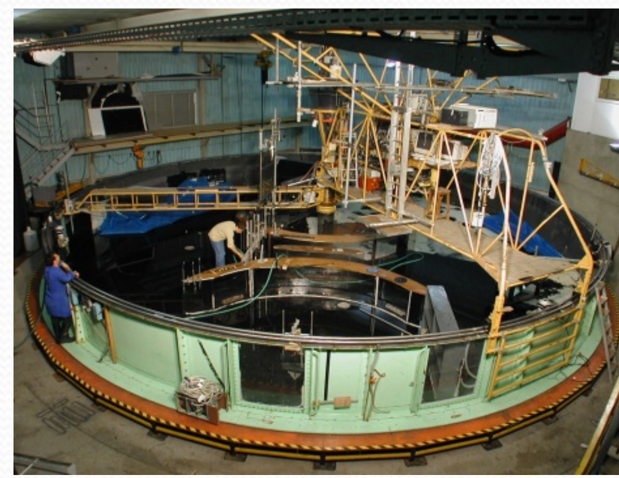
- 1960 Construction as a physical model of the English channel (tidal energy project)



Gabriel Chabert d'Hières

1er ISSF à Novosibirsk, 1972

- 1985 Rénovation as a rotating tank



Coriolis platform

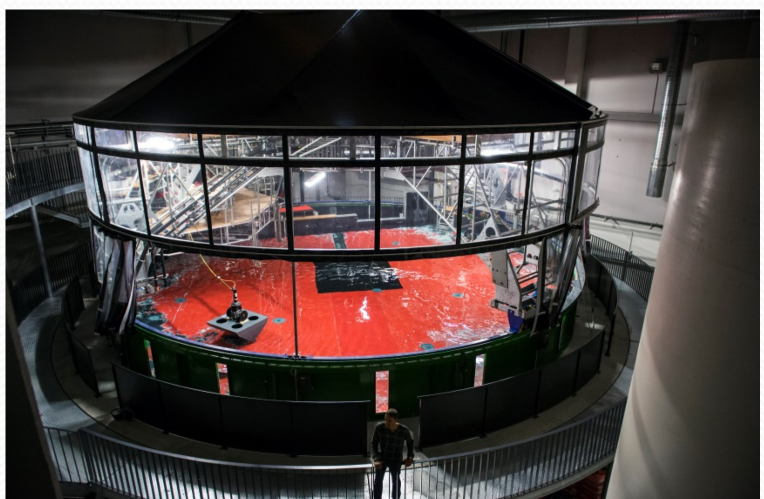
1996: Adam Fincham hired, development of PIV, turbulence.

1999: my arrival, Emil director of LEGI.

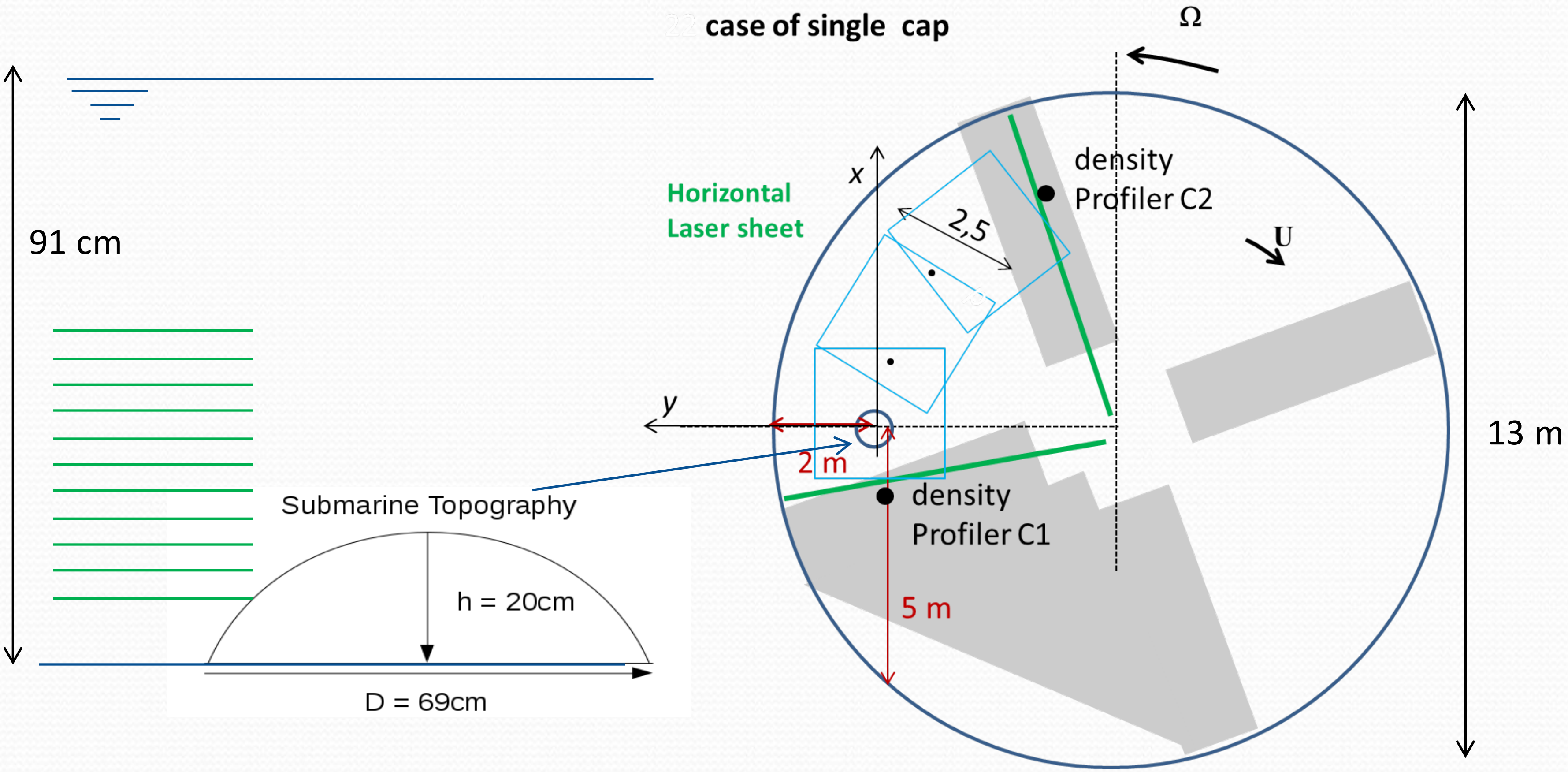
2003: new instrumentation carriage

2011: démolition

2012-14: construction Coriolis II

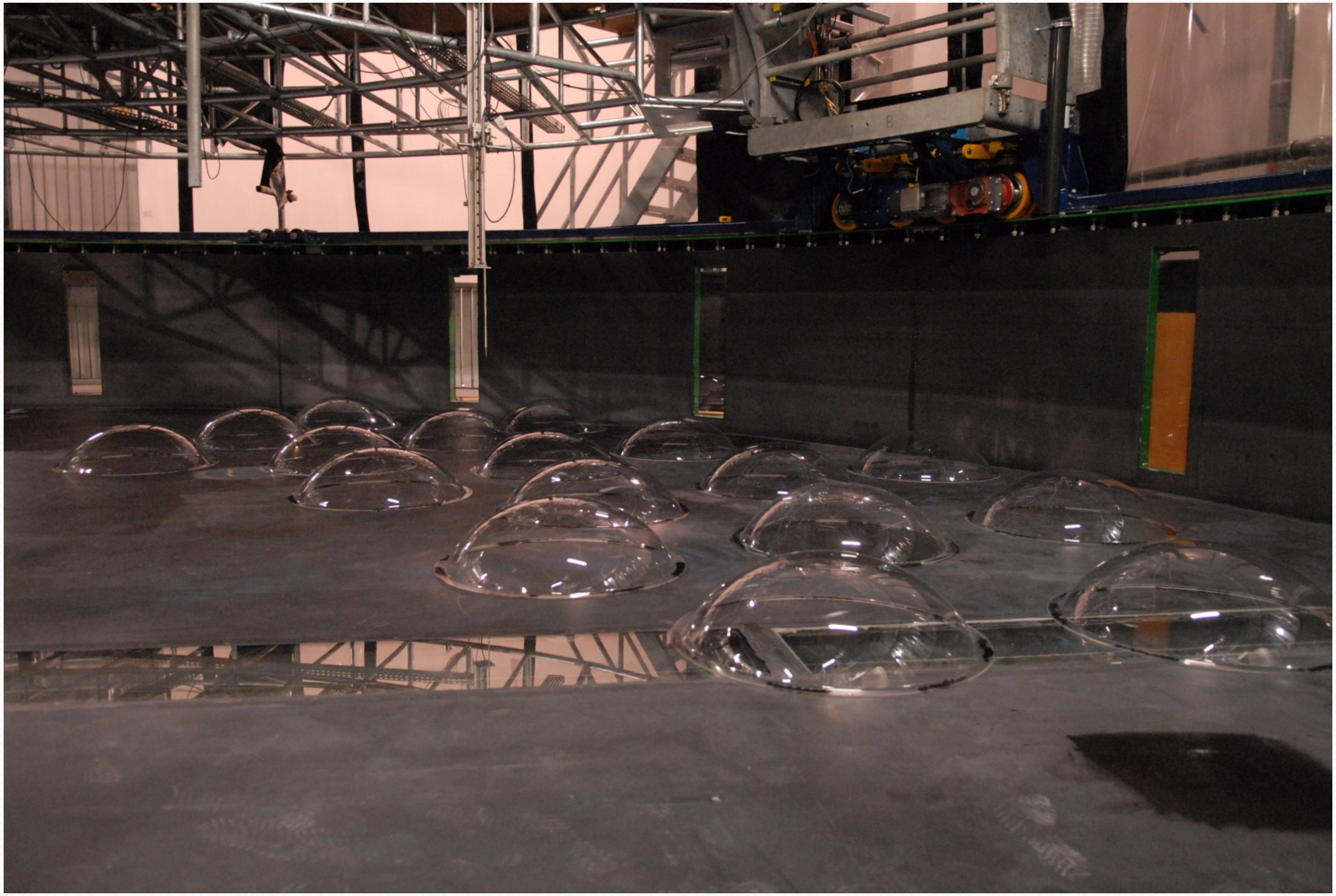


Experimental device: one mountain wake



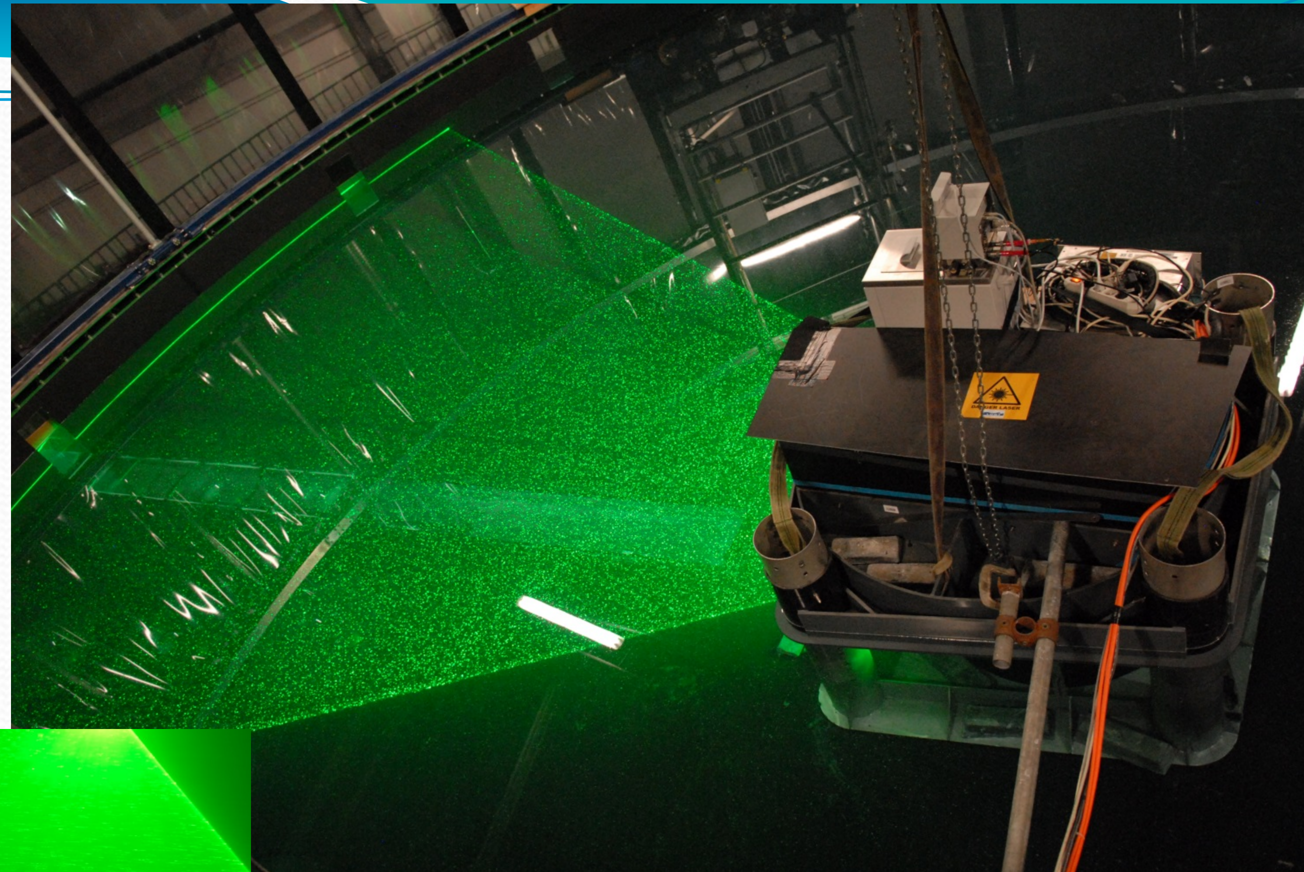
2016

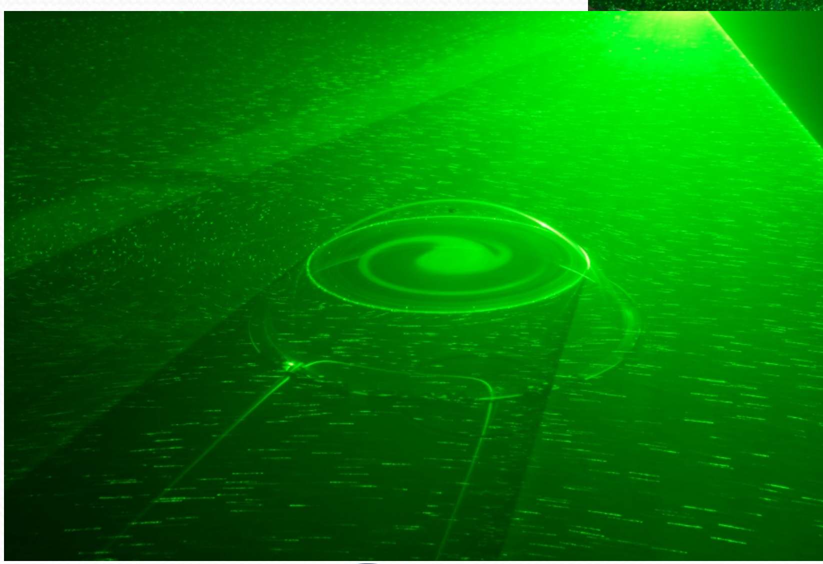
Experimental set-up with 18 mountains



2016

Laser sheet with vertical scan



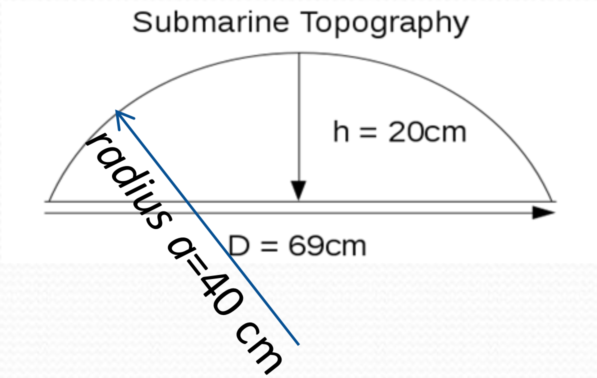


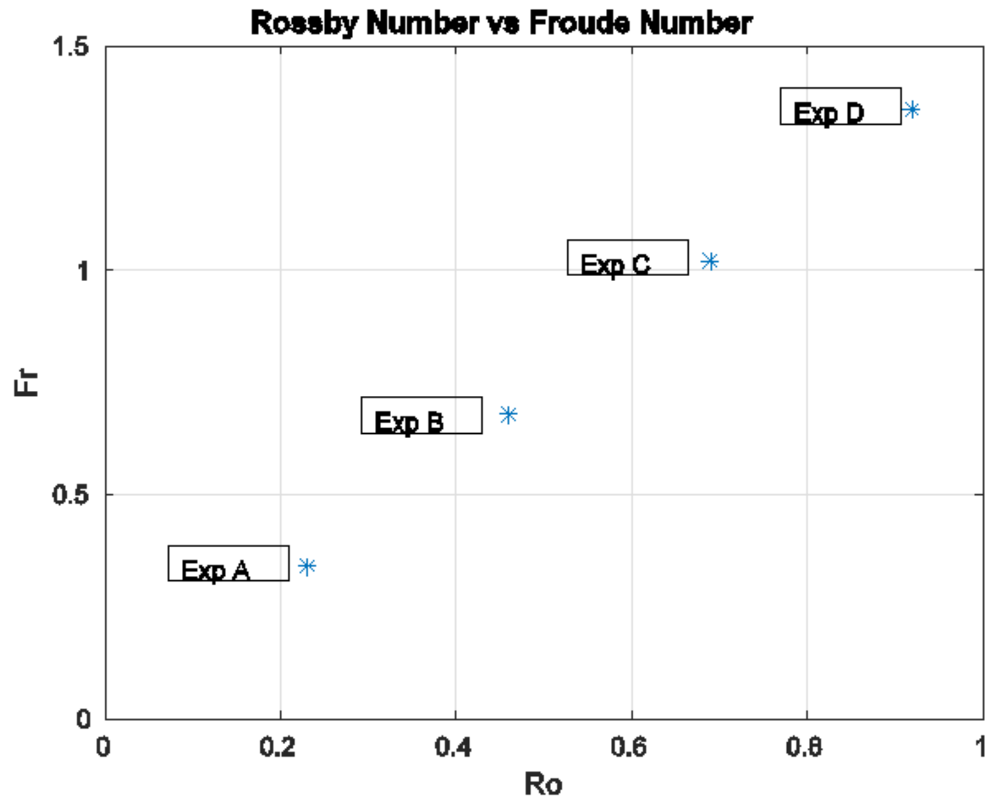
Non-dimensional numbers

Froude number $Fr = U_0/(hN) = 2U_0/(aN)$

Rossby number $Ro = U_0/(Df)$

Reynolds number $Re = U_0 h/\nu = 6\,000\text{–}24\,000$





U_0=3 cm/s

U_0=6 cm/s

U_0=9 cm/s

U_0=12 cm/s

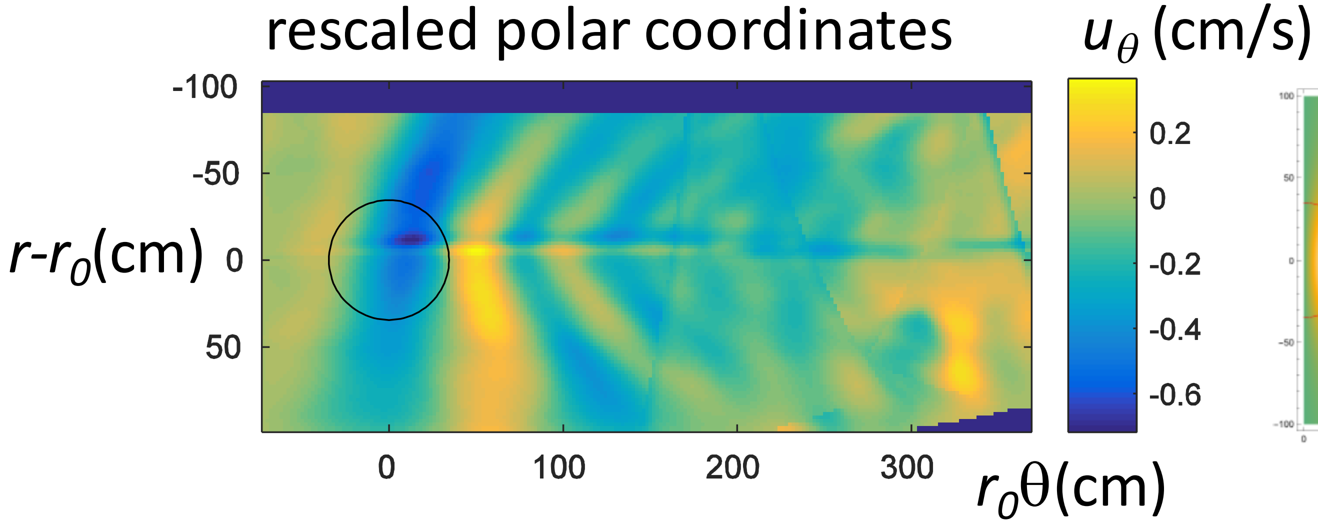
$Ro=\infty$
(no rotation)

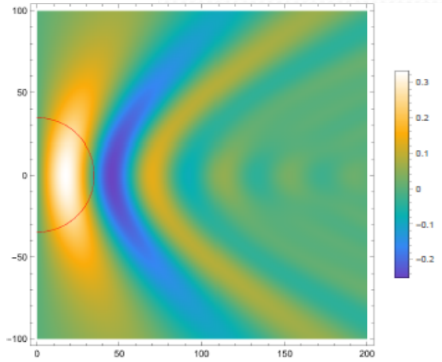
Buoyancy frequency: $N=0.48\ s^{-1}$

Coriolis parameter $f=2\Omega=0.188\ s^{-1}$

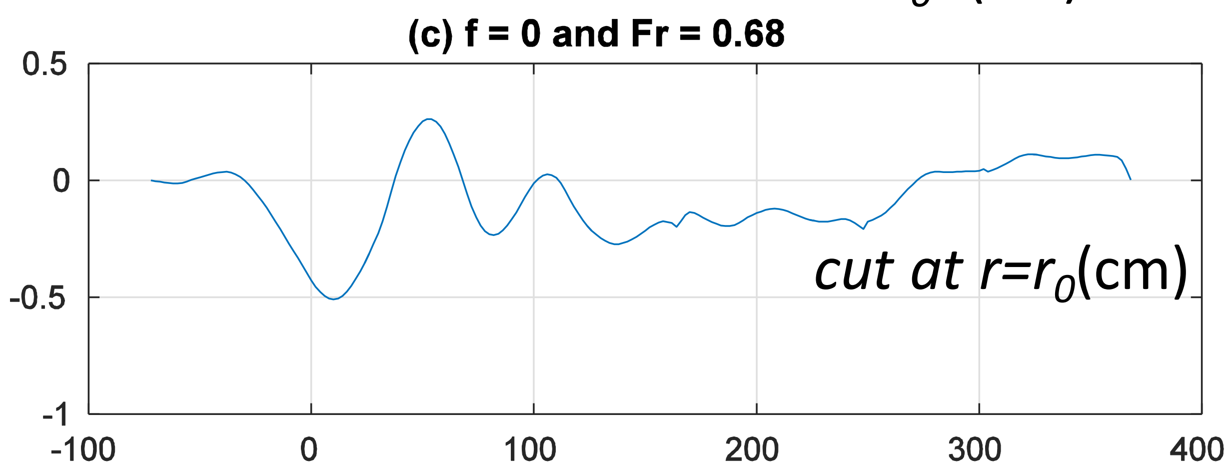
$N/f=2.5$

Waves: streamwise velocity fluctuations, z=60 cm

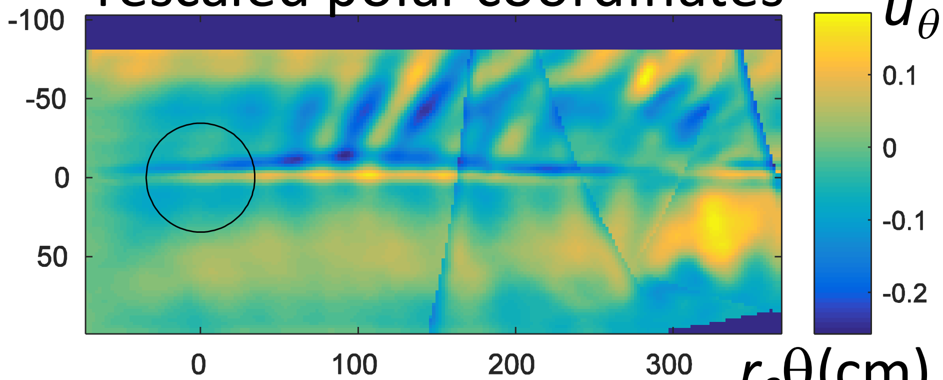




Linear theory (adapted from Voisin 2007)



Waves with Ro=0.5: streamwise velocity fluctuations, z=60 cm



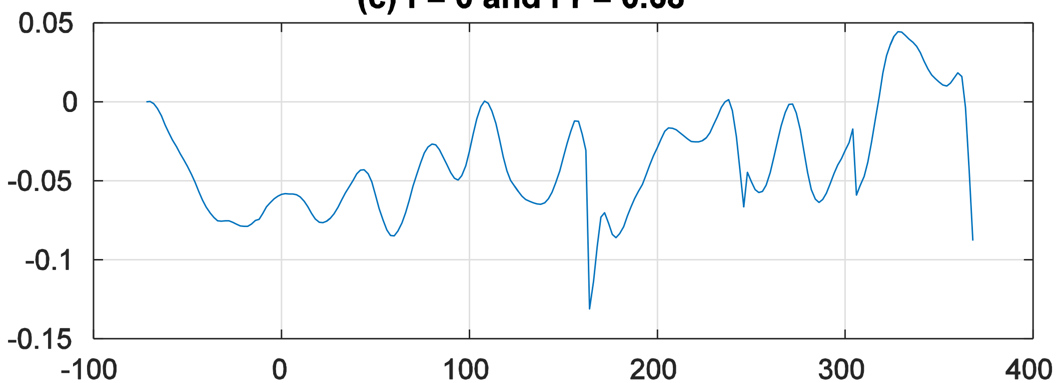
u_θ (cm/s)

r-r_0(cm)

$r_0\theta$(cm)

anticyclonic side

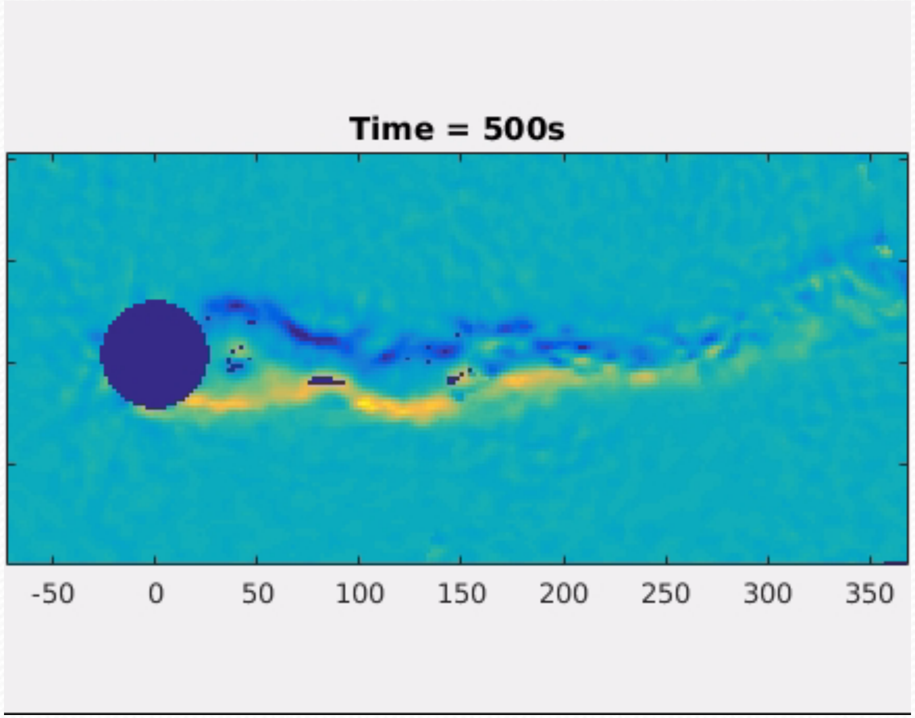
cyclonic side



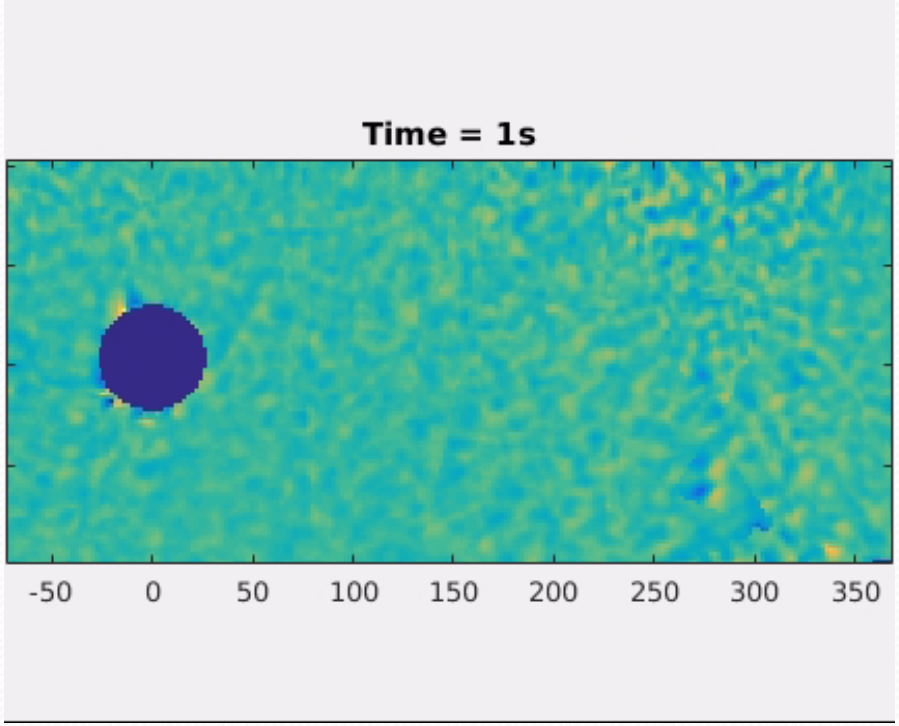
cut at $r=r_0$(cm)

Vorticity field z=10 cm

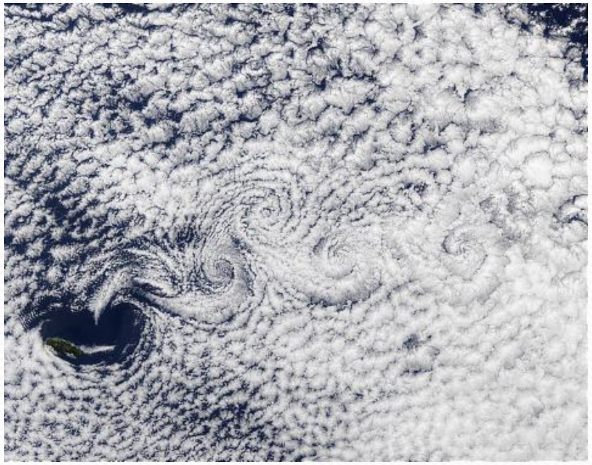
No rotation



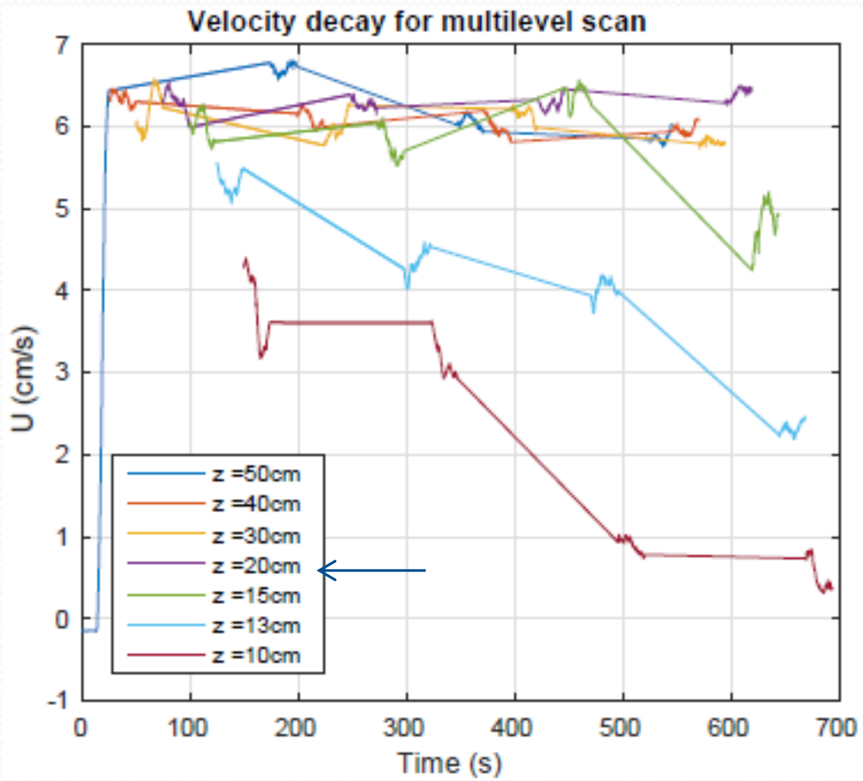
Ro=0.68



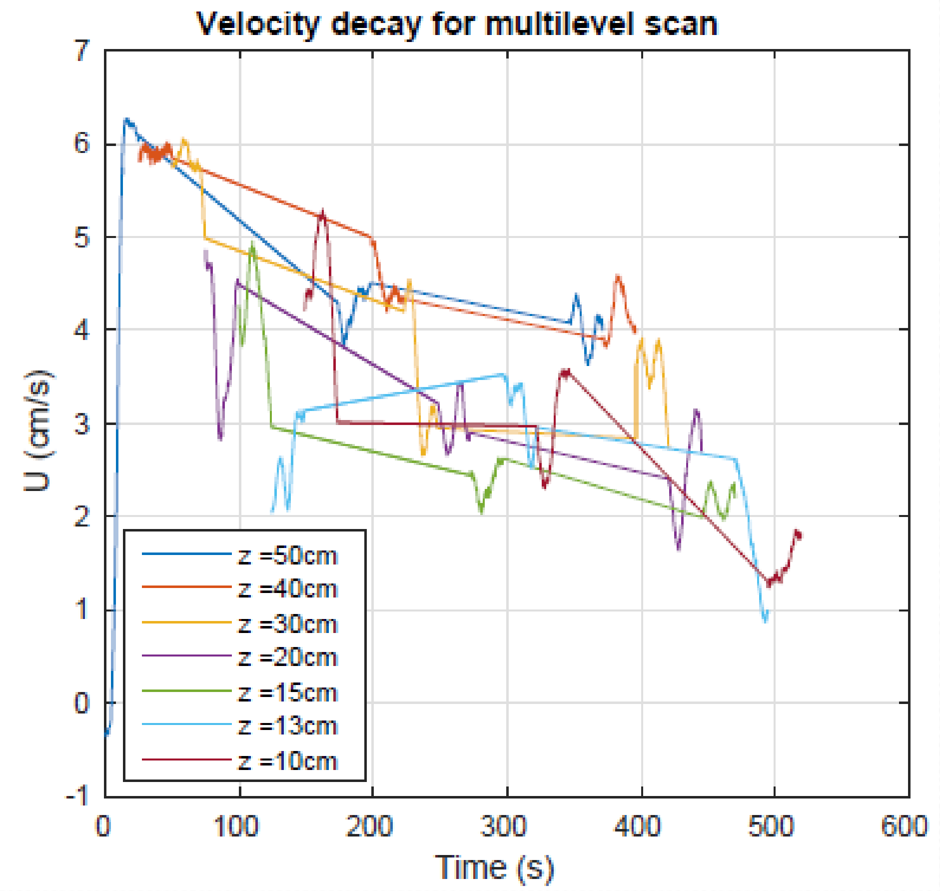
Atmosphere:
Madeira Island



Mean velocity decay 18 mountains: no rotation



Mean velocity decay 18 mountains: with rotation



Conclusions

- Wave-vortex splitting confirmed (agreement with linear theory of Voisin 2007)
- Shorter waves and transverse asymmetry observed with rotation (theory?)
- Periodic vortex shedding observed only with rotation
- Topographic drag remains localised to the lower layers in the absence of rotation
- Vertical transmission with rotation, no hint of inertial oscillations: theory of turbulent transport need for $Fr \simeq 1$ and $Ro \simeq 1$