# TP08: A physical model of the Gibraltar Strait

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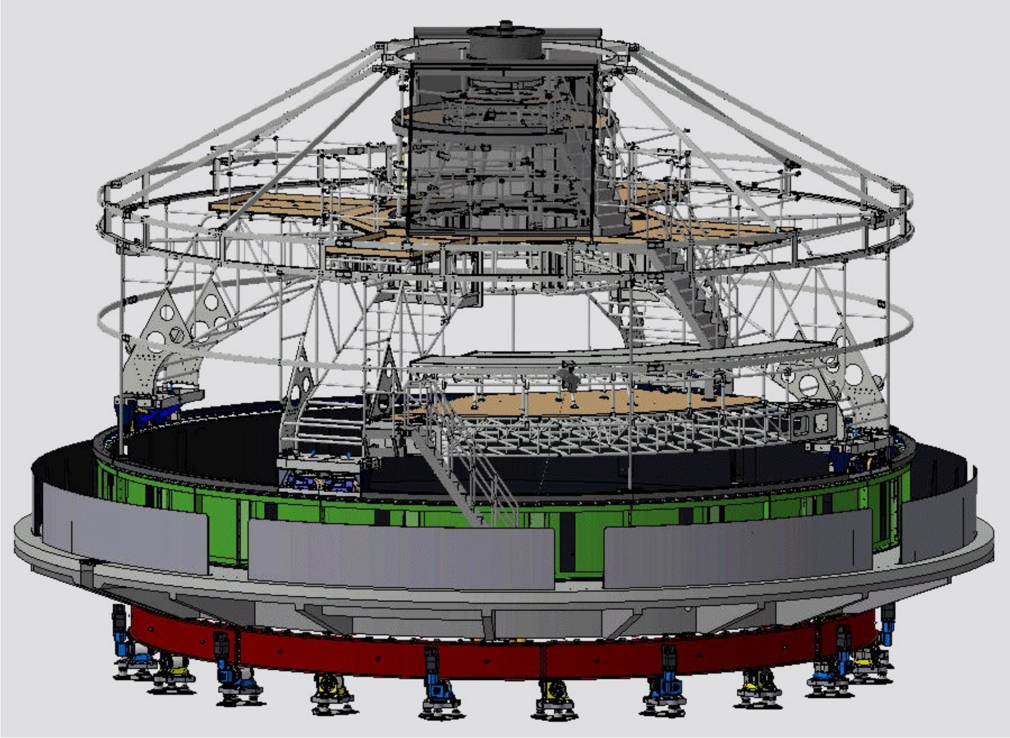
cnrs

# The Coriolis Platform

The Coriolis Rotating Platform is the largest Rotating Platform in the world, with its 13m diameter. It permits to study geophysical and environmental fluid mechanics problems taking into account the Earth's rotation, the stratification and the topography, approching the dynamical similarity of real flows.



Tecnical management

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Scientific coordination

Eletta Negretti
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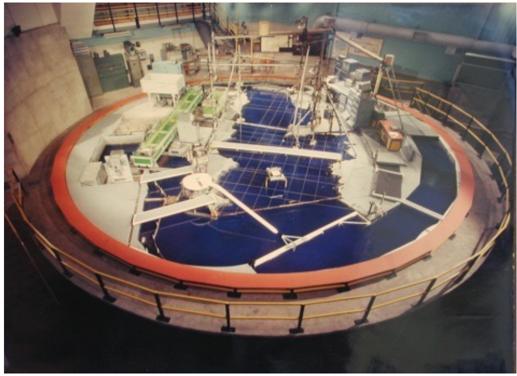
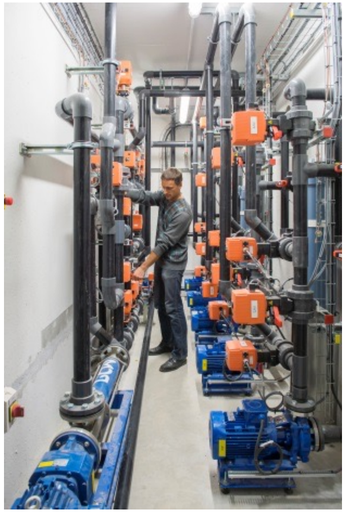
Joël Sommeria
(DR CNRS)

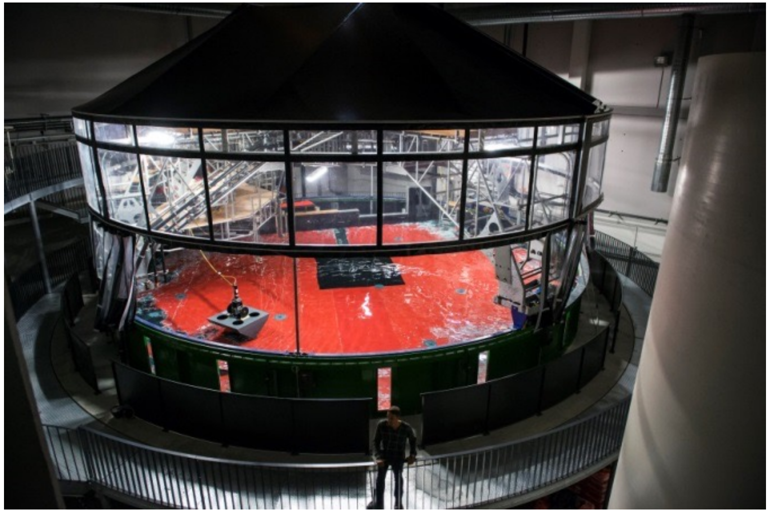
# The Coriolis Platform

## A brief history



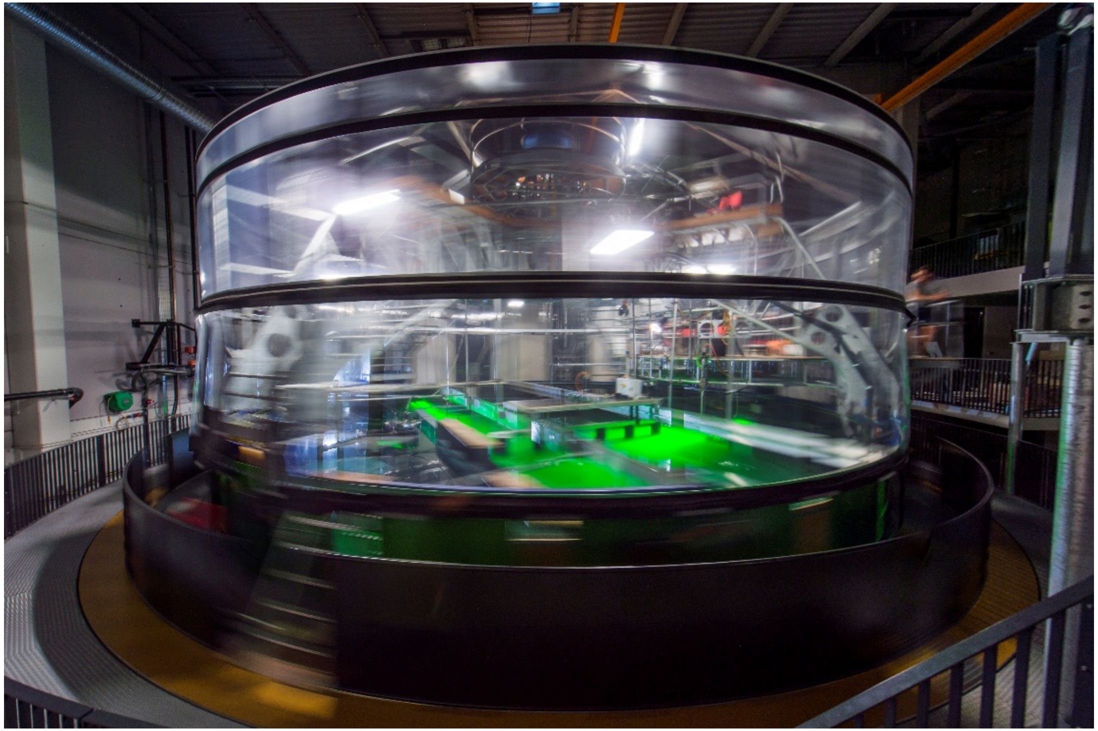
In 1960 the French national electricity company (EdF) asked for the construction of a model of the English channel for the simulation of tidal motions, aimed at the construction of a tidal power plant. In 1985, the Platform has been took in charge by the University and the CNRS, who financed the construction of the experimental tank and the in site portique. In 2011 it has been destroyed and reconstructed at LEGI.





# The Coriolis Platform

## Technical aspects

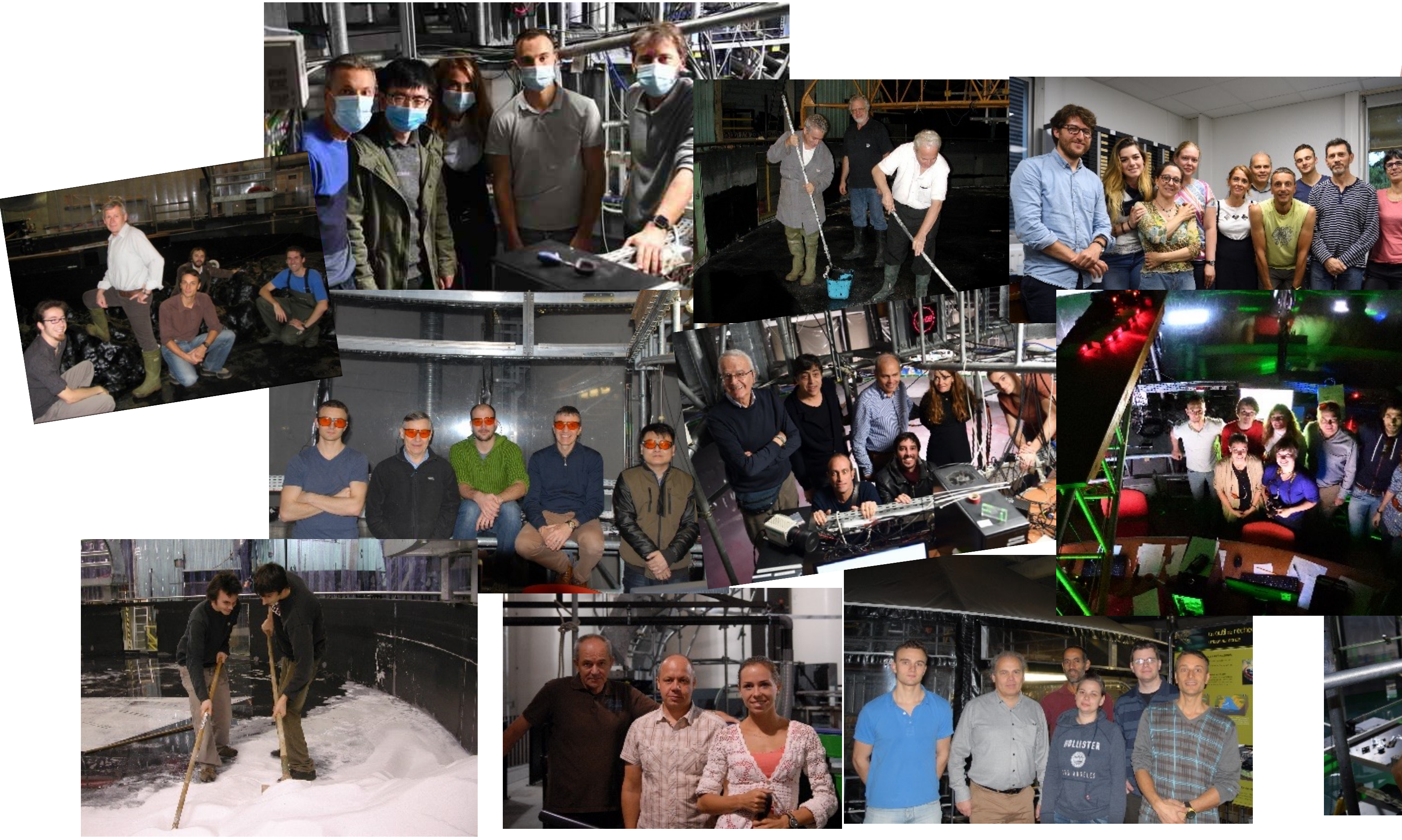


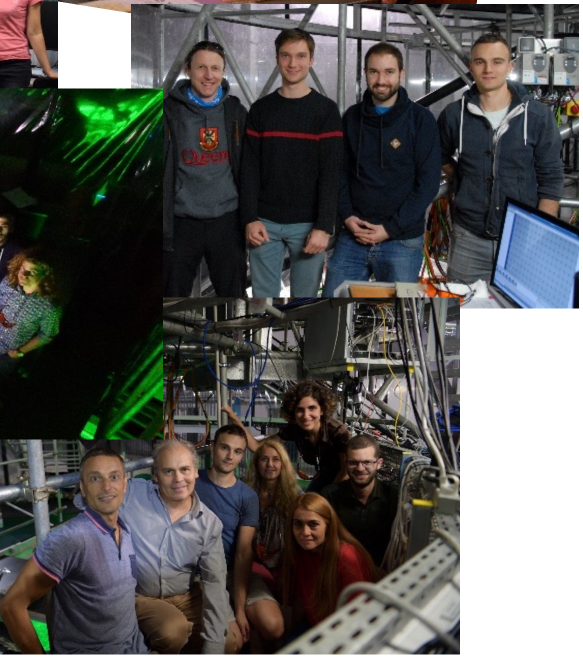
### Caracteristics :

- 13 m de diameter
- 350 Tons fully charged
- Maximum speed: 6 Tr/ min
- Maximum water depth: 1 m
- Global Cost: 6,5 M€

# International research groups

98 research projects in 22 years, 35 since 2014

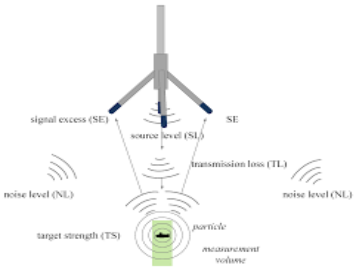




# Laboratory measurement techniques

Experimental techniques permit to measure the velocity fields (2D-3D, 2-3 velocity components) and the density fields, along with their fluctuations with high temporal and spatial resolution. These are the most important quantities on the base of which mean flow and turbulent characteristics can be determined. Experimental techniques are substantially based on

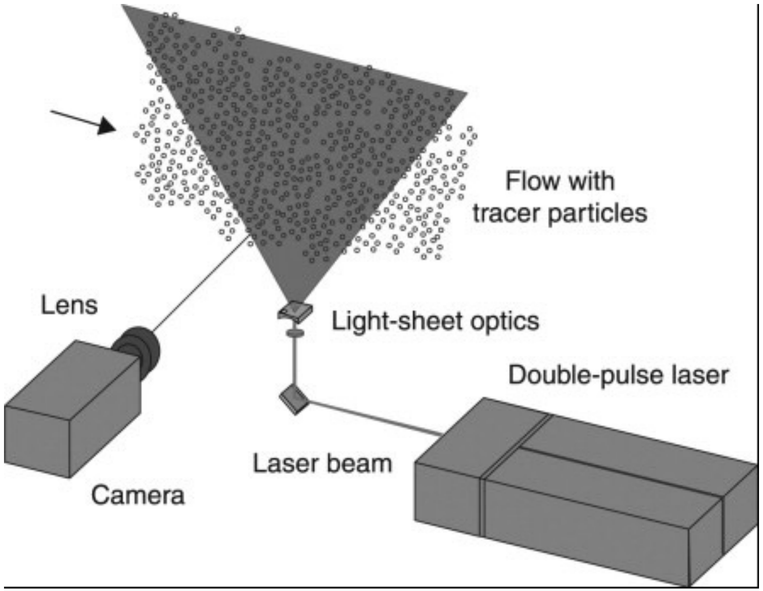
- Intrusive (point-wise, profiler): Acoustic doppler Velocimetry (ADV, for 3C velocities), Conductivity probes (measure of salinity and temperature for density)

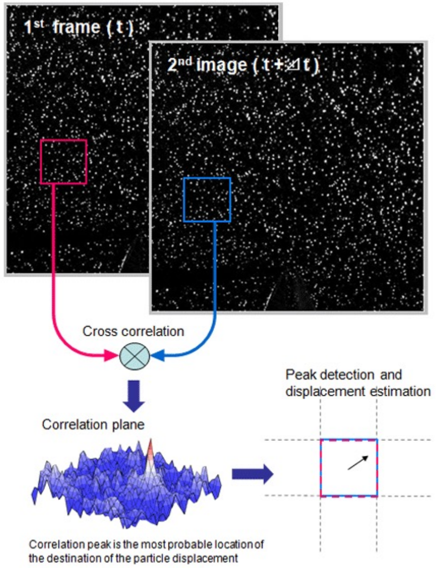



- Optical, non intrusive:
  - Particle Image Velocimetry (PIV), for 2D-2C velocities
  - Laser Induced Fluorescence (LIF)

# Particle Image Velocimetry

Used to obtain instantaneous velocity measurements and related properties in fluids. The fluid is **seeded with tracer particles** which, for sufficiently small particles, are assumed to faithfully follow the flow dynamics. The fluid with entrained particles is **illuminated with a laser** so that particles are visible. Images are captured using **scientific cameras** at a given frequency, **synchronized** with the laser. The motion of the seeding particles is used to calculate speed and direction, i.e. velocity field of the flow, via (auto/cross-) correlations between sub-areas of two successive images.



# TP08: The Coriolis platform experiment
# 03/10/2023

# The Mediterranean Sea

# The Mediterranean Sea

## Why is the Mediterranean important?

The Mediterranean influences the global thermohaline circulation. In fact, the maximum salinity in the middle layer (1000-1500 m) of the North Atlantic is determined by the input through Gibraltar of intermediate Levantine water (LIW), which forms in the Mediterranean in the eastern basin and, passing through the Strait of Gibraltar, becomes a tongue that spreads into the North and East Atlantic.

The Mediterranean can be regarded as a laboratory (a miniature ocean) for a series of processes that also occur on a global scale.

# The Mediterranean Sea

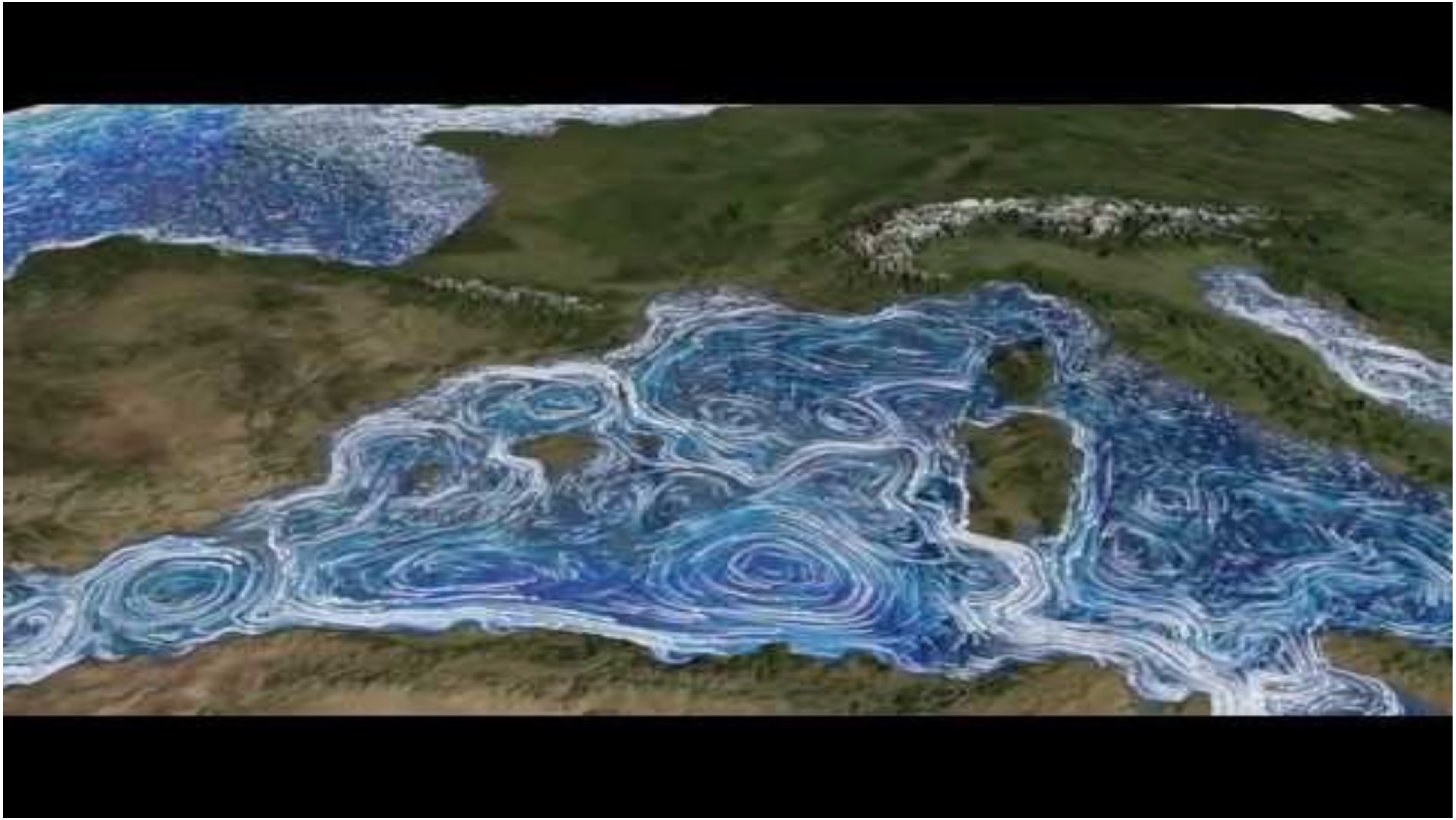
The Mediterranean is a semi-enclosed sea characterised by high salinity, temperature and density. E > P

The 3D circulation is characterised by a thermohaline cell composed of the surface layer that communicates directly with the Atlantic Ocean, and two deep 'sub-cells', one for each of the two main basins (eastern and western)

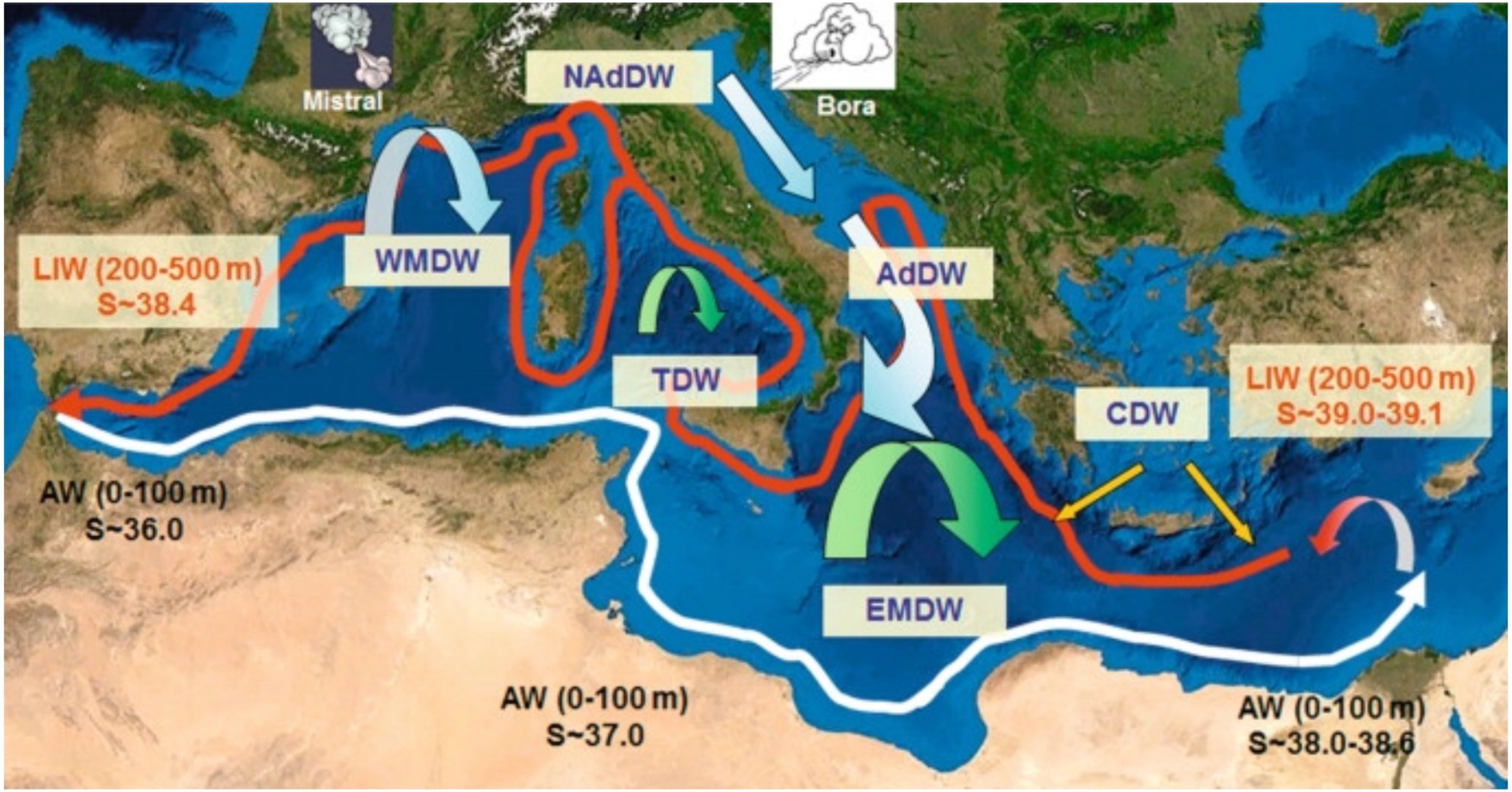
The Mediterranean basin includes densely populated areas and is therefore sensitive to anthropogenic impacts.

Very significant changes in oceanographic and biogeochemical parameters have been observed in the recent past, underlining the need to better monitor and understand changing conditions and forcings.

# The Mediterranean Sea: surface circulation

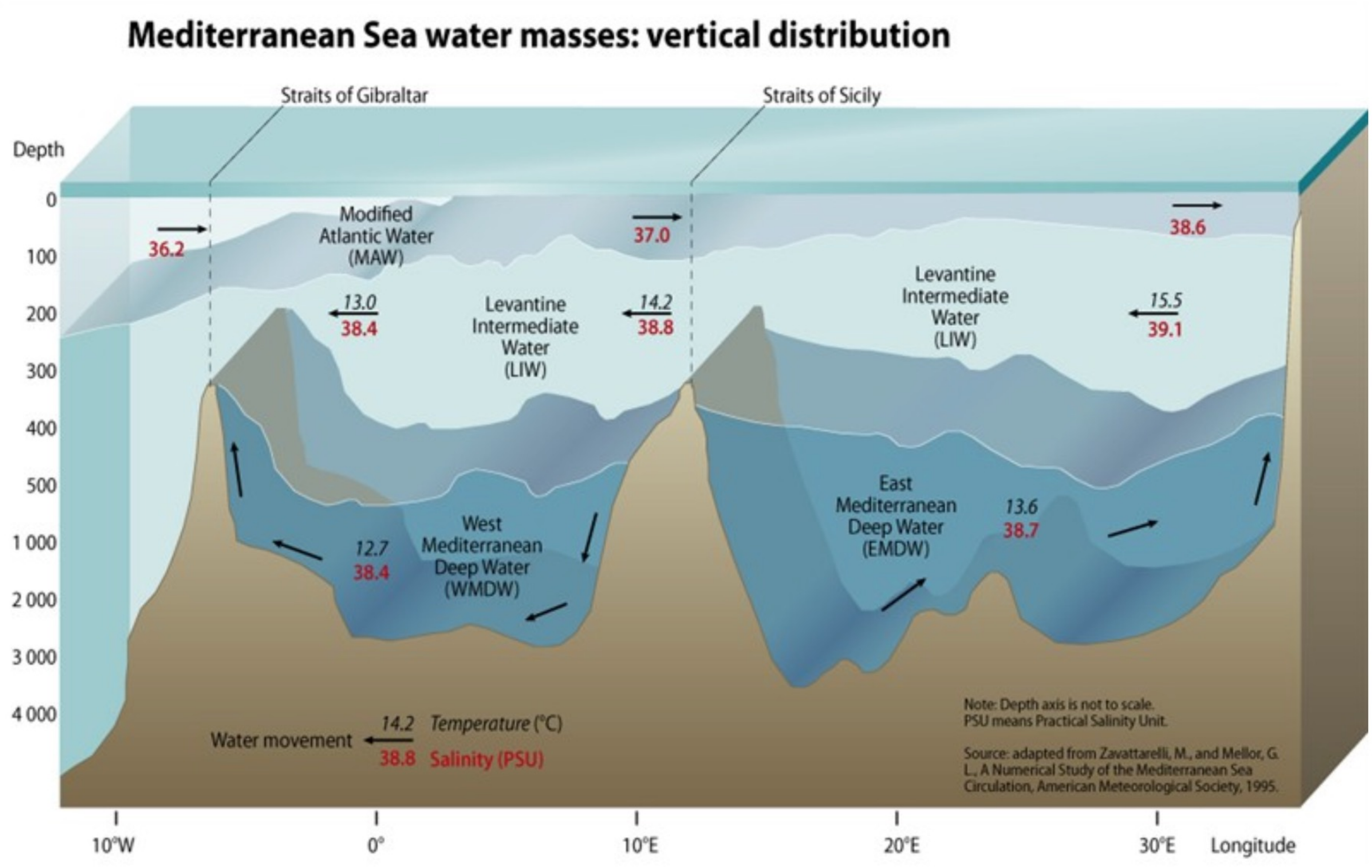


# The Mediterranean Sea



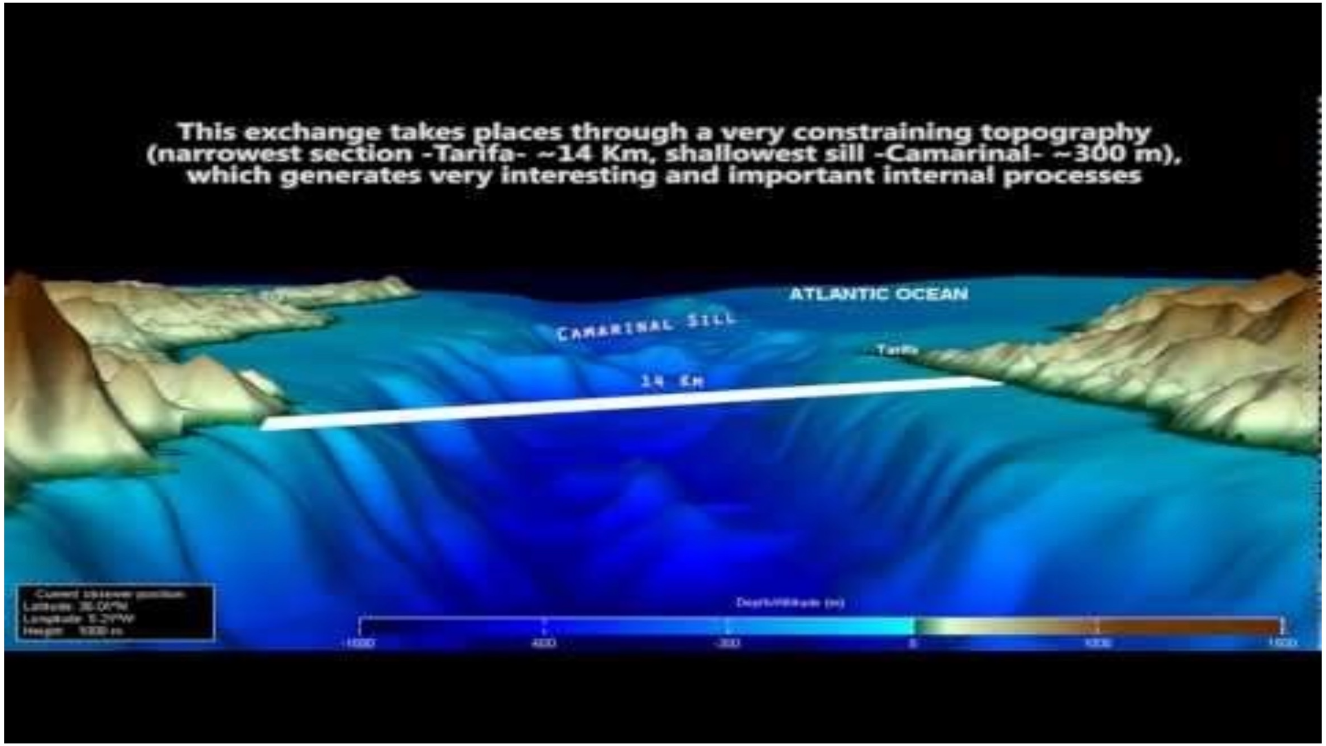

Thermohaline circulation and deep water formation

# The Mediterranean Sea

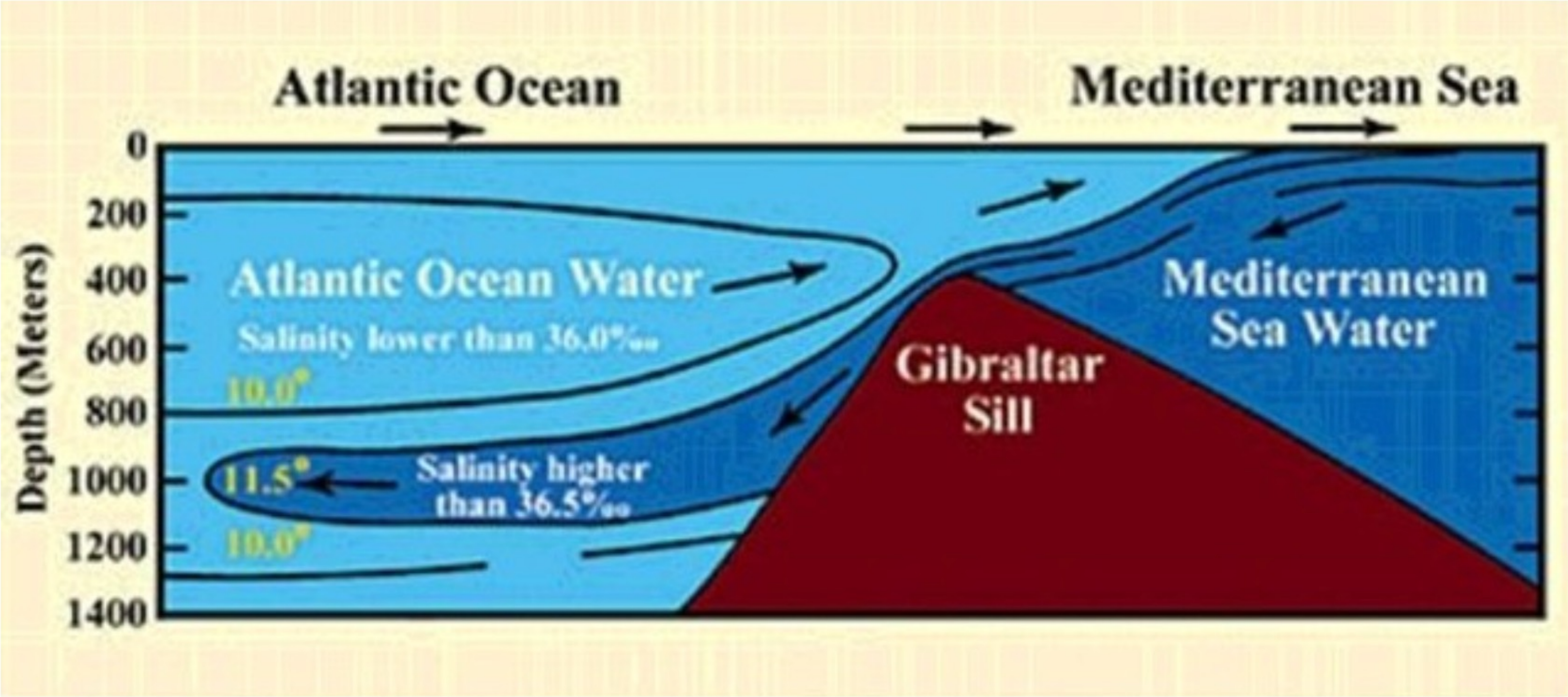


# The Gibraltar Strait

Narrow passage: the minimum width of the Strait of Gibraltar is 14 km (Tarifa) and shallowest point Camarinal Sill, 175m deep.
1 million m3/s flow passes through the strait in each direction!

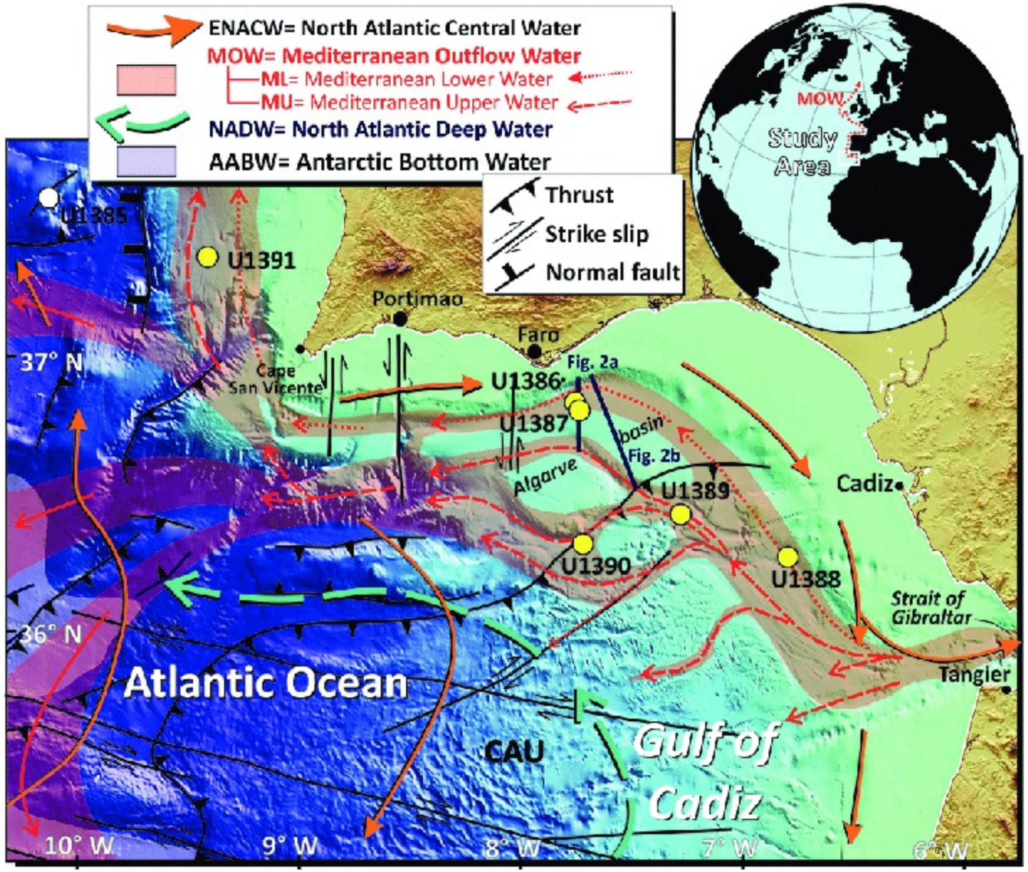


# The Gibraltar Strait




The salinity maximum (36.5) in the middle layer (1000-1500 m) of the North Atlantic is determined by the input through Gibraltar of intermediate Levantine water (LIW), which is formed in the Mediterranean in the eastern basin and passes through the Strait of Gibraltar to become a tongue that spreads into the North and East Atlantic.

# Following the Mediterranean waters in the Gulf of Cadiz




The Mediterranean waters at the exit of the Strait are deviated by the Coriolis force to the right. Part of the salt waters follow the spanish coast and part is transported through canyons. The Mediterranean waters stabilize at 1000-1500m in the Atlantic Ocean.

# The Gibraltar Strait

**Why is the Strait of Gibraltar so important?**

The Strait of Gibraltar is the only connection that the Mediterranean sea has with the open ocean. It is crucial for

1. The global Mediterranean circulation and hence climat and primary productivity

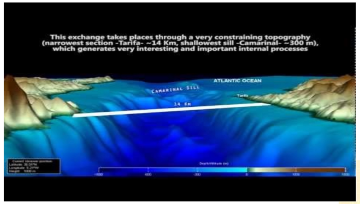
2. One of the hugest marine traffic areas

3. Contributes to the intermediate waters formation in the North Atlantic

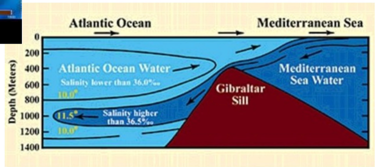
# Forcings at the Gibraltar Strait

Includes:

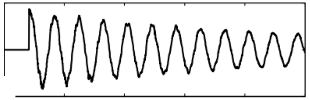
1. Topography




2. Baroclinic exchange flow




3. Barotropic flow (tides)



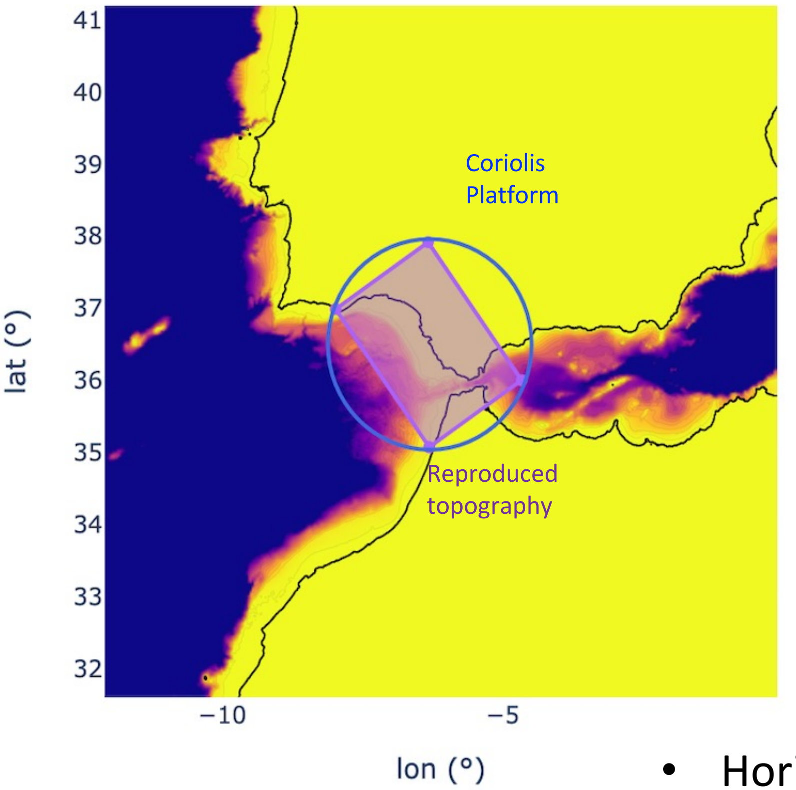
4. Earth's rotation

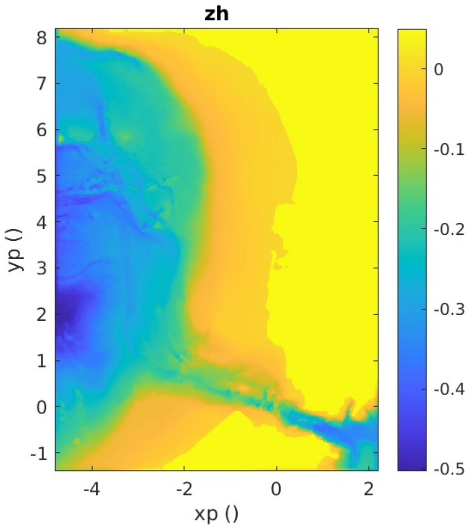
5. Surface wind forcing

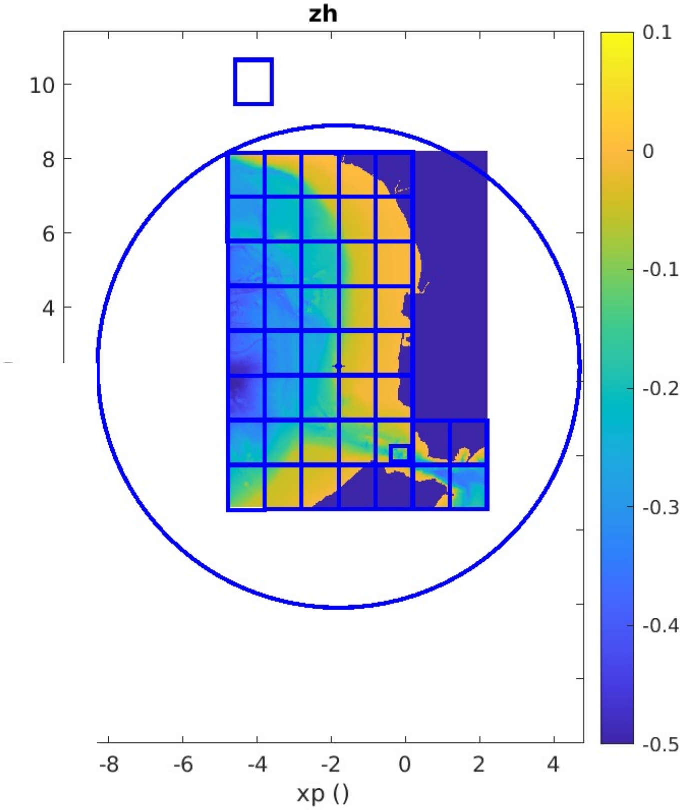
Physical model is a engineering challenge

# TP: The Coriolis platform experiment
03/10/2023

# 1. Topography model: Strait of Gibraltar and Gulf of Cadiz

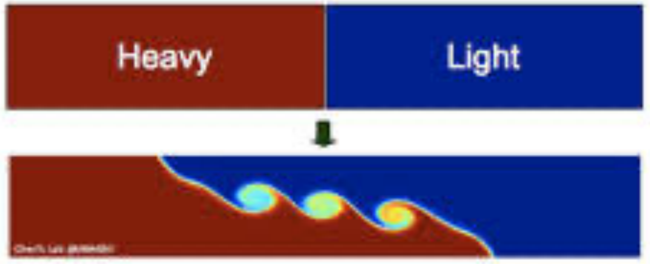


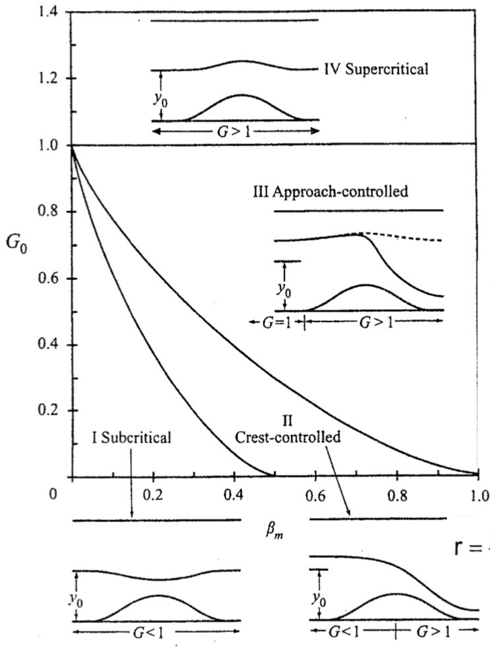

- Horizontal area to be represented: 250km x 150km => 9.6m x 7m
- SHOM Bathymetry has been used (resolution of 100m)

# 2. Baroclinic flow: Exchange at SoG




1. **Initial condition**: ‘Lock exchange’ configuration

**2. Internal hydraulics** (Armi, Lawrence…): consider maximal exchange regime only (minimum duration: 20min)



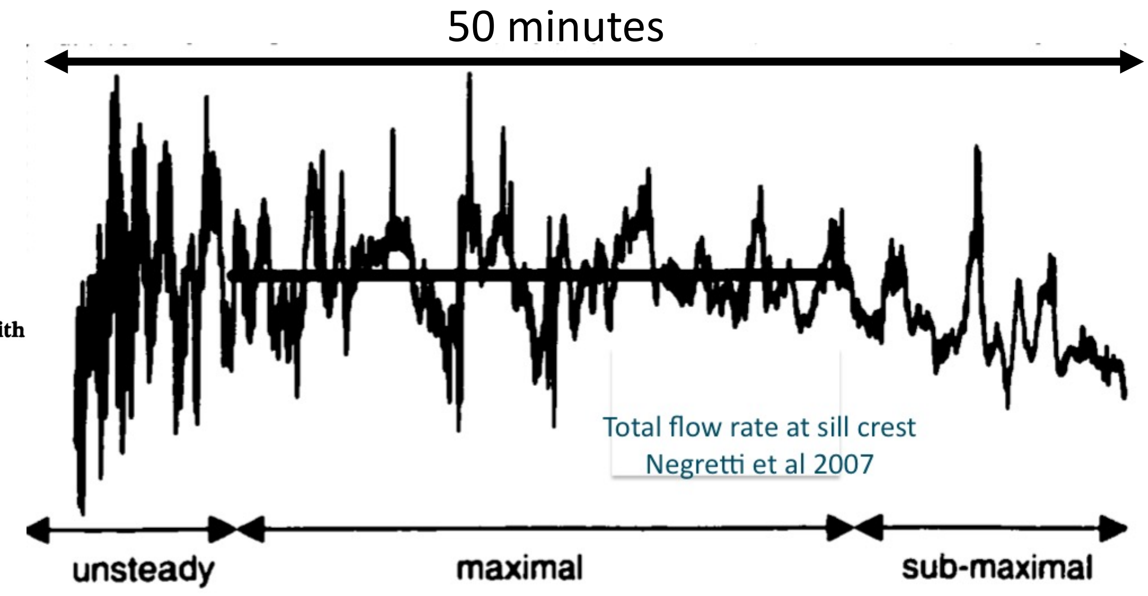

*J. Fluid Mech.* (1986), *vol.* 163, *pp.* 27–58
*Printed in Great Britain*

**The hydraulics of two flowing layers with different densities**

By LAURENCE ARMI
Scripps Institution of Oceanography, La Jolla, California 92093

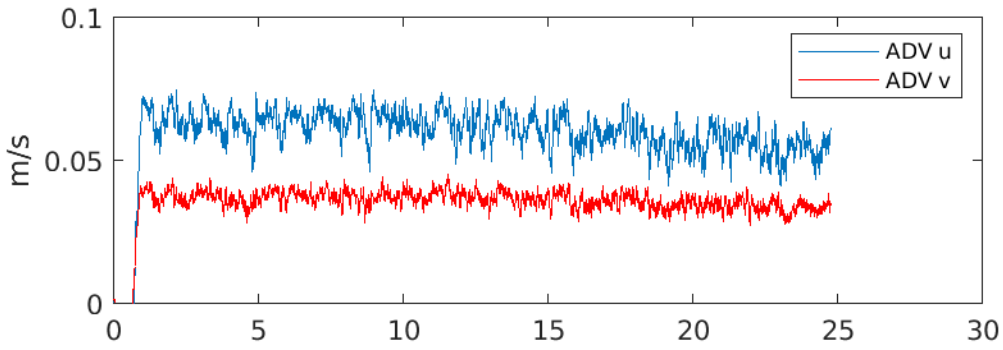
(Received 24 August 1984 and in revised form 11 April 1985)

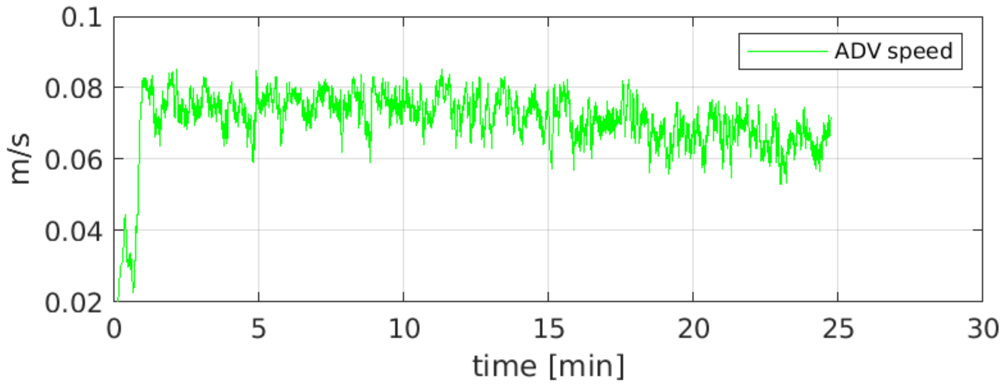
$$r = \frac{q_2}{q}, \quad \beta_m = \frac{z_m}{h}, \quad G_o = \frac{q}{\sqrt{g' r (1-r) h^3}}, \quad \frac{\Delta\rho}{\rho}$$

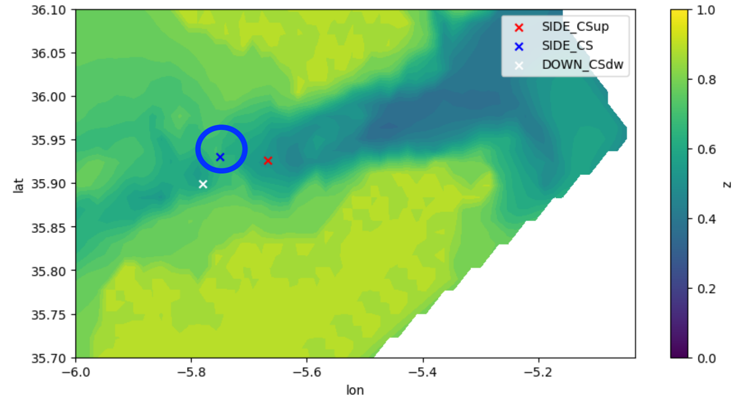


# Purely baroclinic forcing

1) g'=0.19m/s2 7.5 cm/s @ CS (190m/220m)



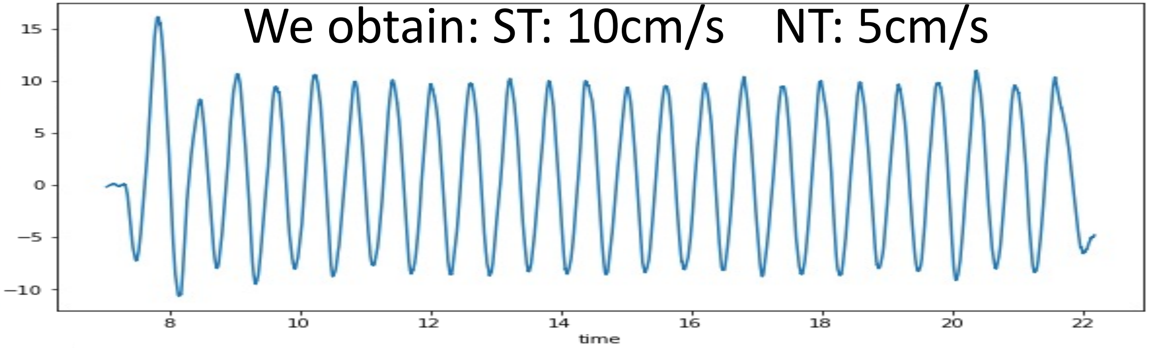




| parameter (primary) | parameter (derived) | ocean | experiments | ratio |
|---|---|---|---|---|
| $L$ | | 100 km | 4 m | 25 000 |
| $H$ | | 1000 m | 0.4 m | 2 500 |
| $H_s$(sill) | | 100 m | 0.04 m | 2 500 |
| $g'$ | | 0.05 ms$^{-2}$ | 0.312 ms$^{-2}$ | 1/6.25 |
| | $U_g = (g'H_s)^{1/2}$ | 1.5 m/s | 11 cm/s | 20 |
| | $\mathrm{Fr} = U_g(g'H_s)^{-1/2}$ | **1** | **1** | **1** |
| | $T = L/U_g$ | 66.6 $10^3 s$ | 53 s | 1 250 |
| $f$ | | 0.8 $10^{-4}$s$^{-1}$ | 0.1 s$^{-1}$($T = 125s$) | 1/1 250 |
| | $\mathrm{Ro} = U_g/(fL)$ | **0.275** | **0.275** | **1** |
| | $R_D = (g'H_s)^{1/2}/f$ | 27.5 km | 1.1 m | 25 000 |
| $T_{\mathrm{tide}}$ | | 44 712 s | 35.8 s | 1 250 |
| $U_b$ | | 1 m/s | 5 cm/s | 20 |
| | $\mathrm{Re} = U_g H_s/\nu$ | 2.2 $10^8$ | 4.4 $10^3$ | 5 $10^4$ |
| | $\mathrm{Bu} = (R_D/L)^2$ | 0.075 | 0.075 | **1** |

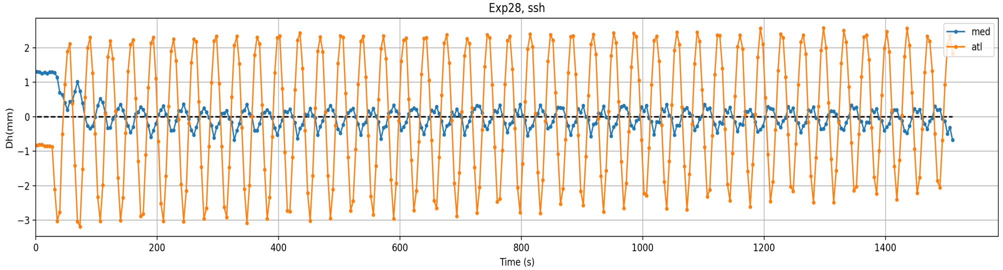
# Purely barotropic forcing

1) M2 : ST (50+50), NT (50)

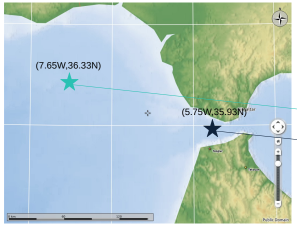
U (cm/s)

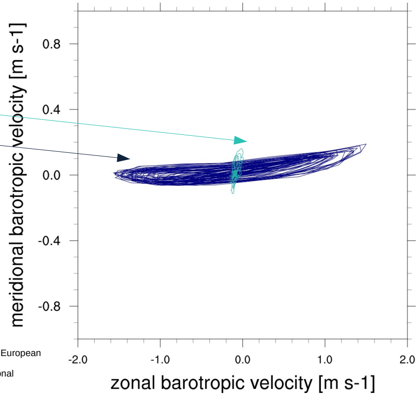



SSH




Barotropic currents in the Southern Spain



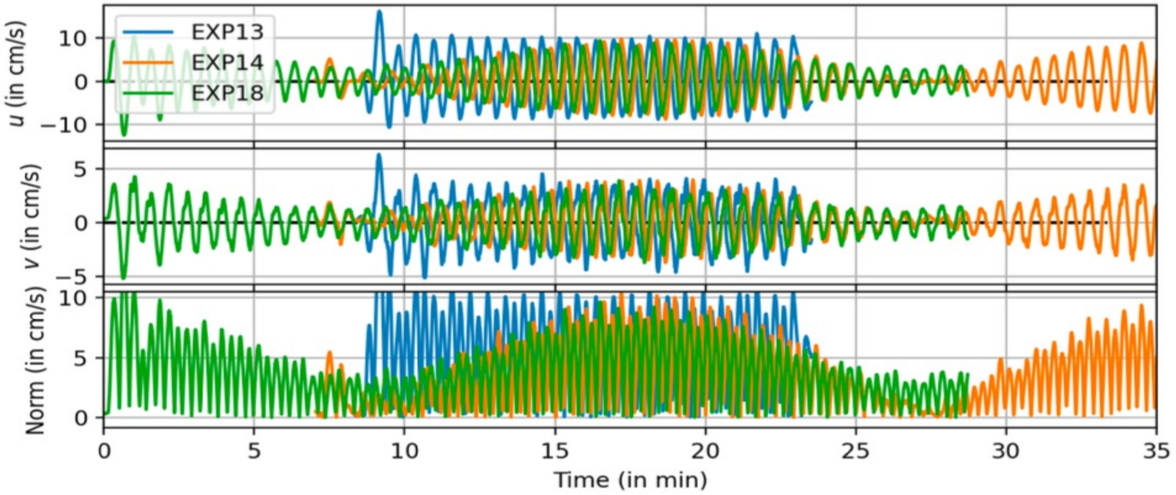




Hourly barotropic currents from September, 24th to October, 24th,
Source : IBI_ANALYSISFORECAST_PHY_005_001 product, delivered by European Marine Service CMEMS
Courtesy : Gepeto project, funded by LEFE and Mercator Ocean International

# Purely barotropic forcing

## 1) M2+S2: transition ST-NT-ST

(a)




(b)

Figure 9: (a) One of the plunger use to reproduce the tidal forcing. (b) The resulting barotropic speed on the east flank of Camarinal Sill for two plungers with $A = 50\,\mathrm{mm}$ and the same frequency M2 (EXP13), with $A = 50\,\mathrm{mm}$ and frequencies M2 and S2 (EXP14) and with $A_1 = 60\,\mathrm{mm}$, $A_2 = 30\,\mathrm{mm}$ and frequencies M2 and S2 (EXP18).

# Experiments

- ✓ Purely baroclinic
- ✓ purely barotropic flow (NT, ST, ST/NT)

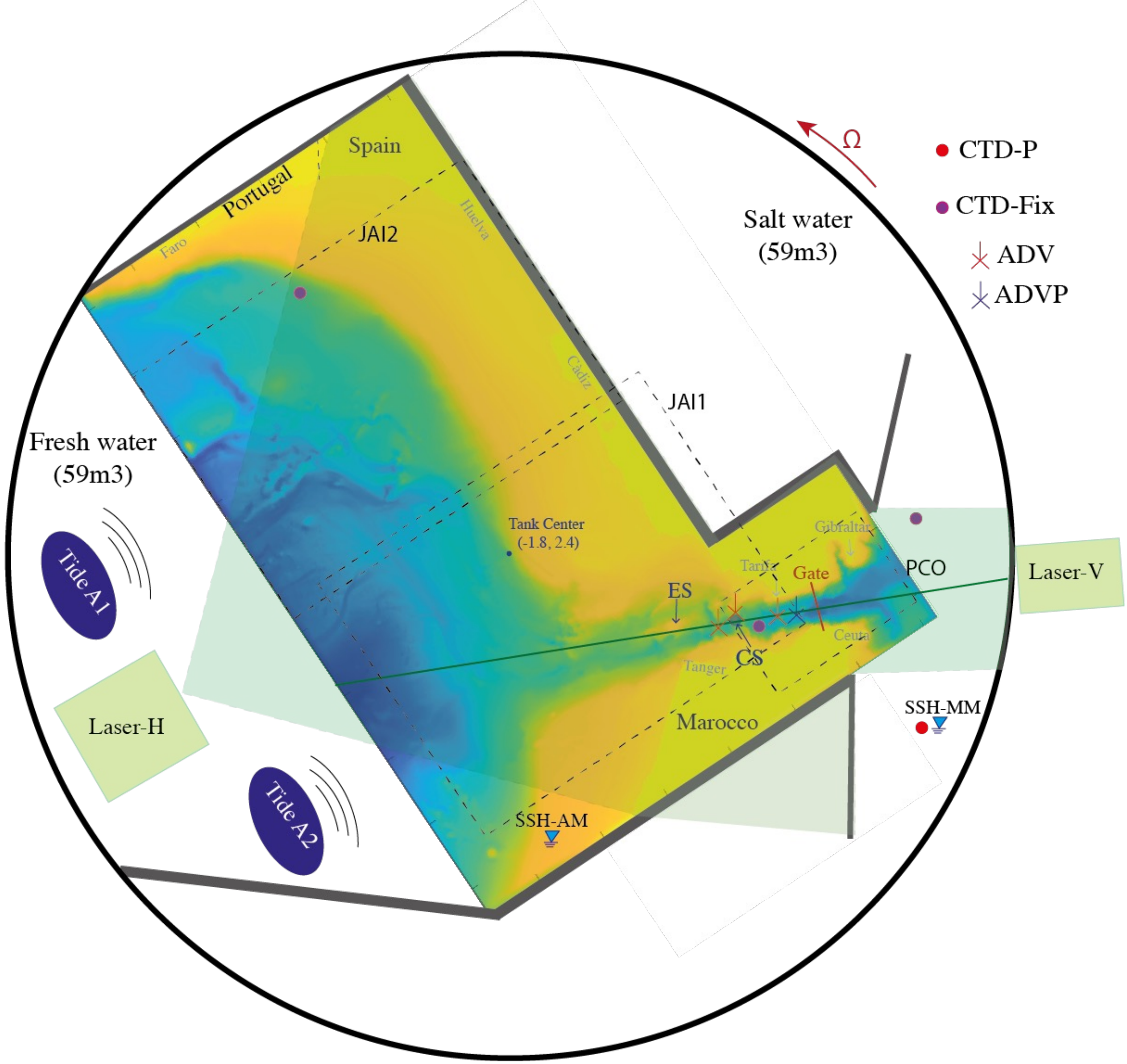
1. Horizontal PIV in GC + SG (multilevel) + CTD, ADV, (only intrusive devices)
   Sept-Oct

2. Vertical PIV(+LIF) at Gibraltar (CS, Espartell), FOV (1m x depth)

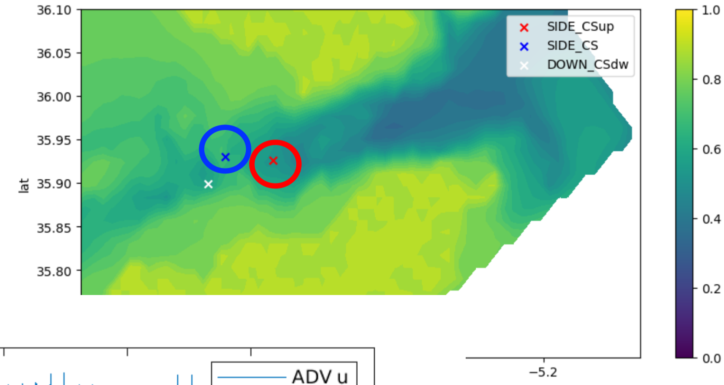
+CTD, ADV, SSH

3. Pycnocline PIV for ISW in SG-Alboran +CTD, ADV, SSH

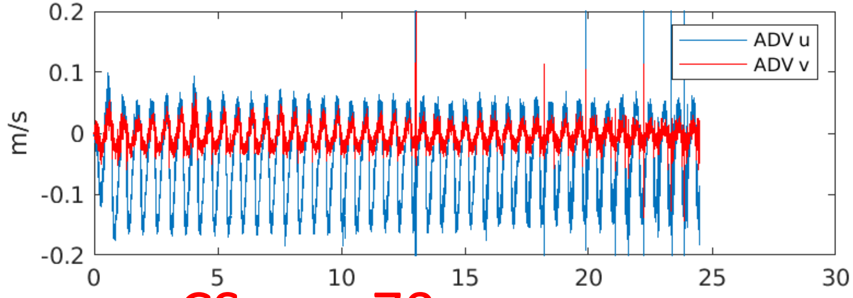
nov-dec

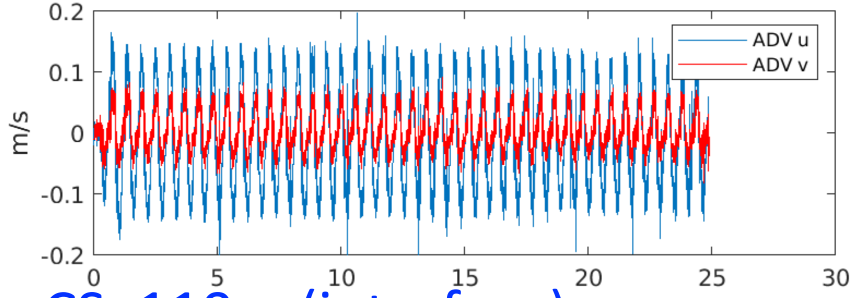


# Baroclinic + barotropic forcing



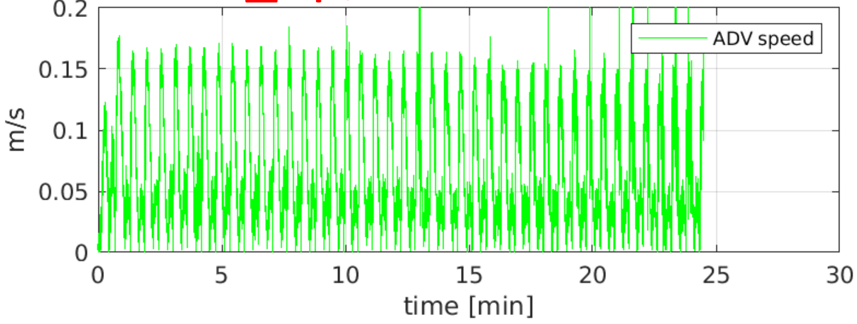

g'=0.29m/s2, **Flow reversal @CS**

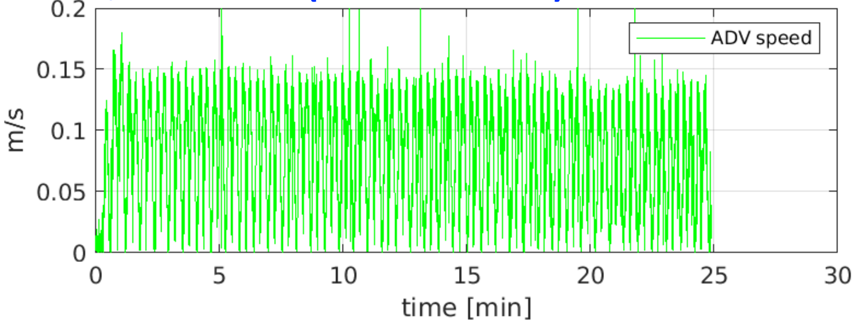


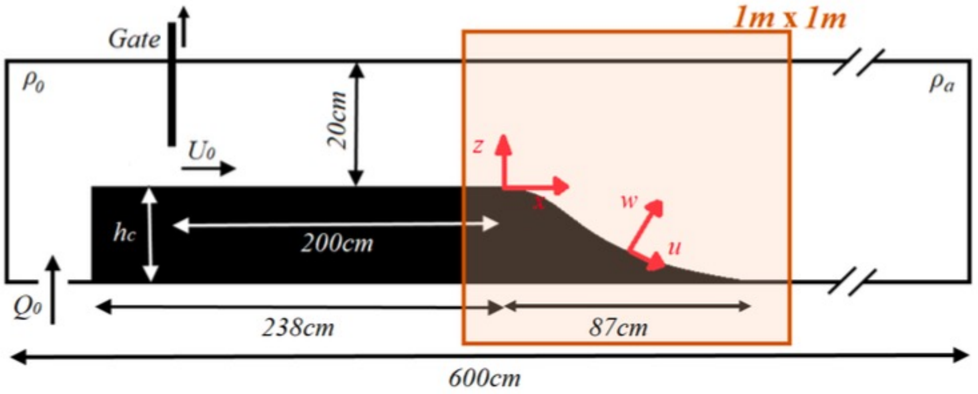

CS_up, 70m

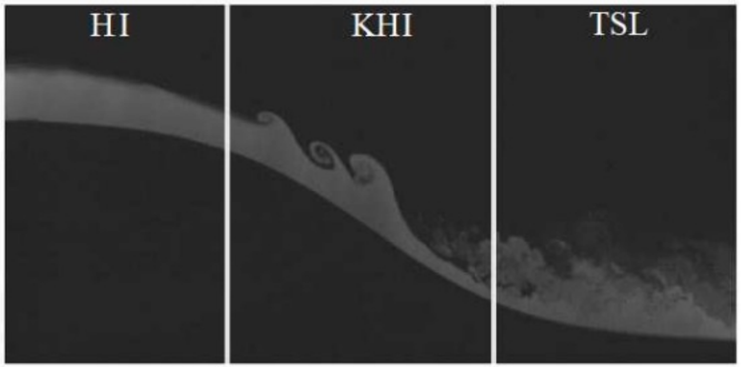
CS, 110m (interface)



# Data Analysis TP08: Slope Stratified




Ex: Q12g5.nc(nx,ny,nt): file contains temporal series of 2D spatial fields

| Run | $q_0(\mathrm{cm^2 s^{-1}})$ | $g'_0(\mathrm{cm\ s^{-2}})$ | $Re_0$ | $B_0(\mathrm{cm^3 s^{-3}})$ | $h_{0i}(\mathrm{cm})$ |
|---|---|---|---|---|---|
| $R5_1$ | 32.28 | 5 | 3200 | 160 | 6 |
| $R5_2$ | 45.76 | 5 | 4600 | 225 | 6.7 |
| $R5_3$ | 57.24 | 5 | 5700 | 280 | 7.5 |
| $R10_1$ | 32.28 | 10 | 3200 | 320 | 5.8 |
| $R10_2$ | 45.76 | 10 | 4600 | 460 | 6.3 |
| $R10_3$ | 57.24 | 10 | 5700 | 570 | 7 |
| $R15_1$ | 32.28 | 15 | 3200 | 485 | 5.7 |
| $R15_2$ | 45.76 | 15 | 4600 | 685 | 6 |
| $R15_3$ | 57.24 | 15 | 5700 | 860 | 6.4 |
| $D5_1$ | 32.28 | 5 | 3200 | 160 | 6 |
| $D5_2$ | 45.76 | 5 | 4600 | 225 | 6.7 |
| $D5_3$ | 57.24 | 5 | 5700 | 280 | 7.5 |