hydralab+ Adaptation for Climate Change

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LABORATORY MODELING OF GAP-LEAPING AND INTRUDING WESTERN BOUNDARY CURRENTS UNDER DIFFERENT CLIMATE CHANGE SCENARIOS

Stefano Pierini [1], Paola de Ruggiero [1], Henk A. Dijkstra [2], Ilana Schiller-Weiss [2], Julia Weiffenbach [2], **Eletta Negretti** [3] & Joël Sommeria [3]

(1) Department of Science and Technology, Parthenope University of Naples, Italy
(2) Department of Physics and Astronomy, Utrecht University, The Netherlands
(3) LEGI-CNRS, Grenoble, France

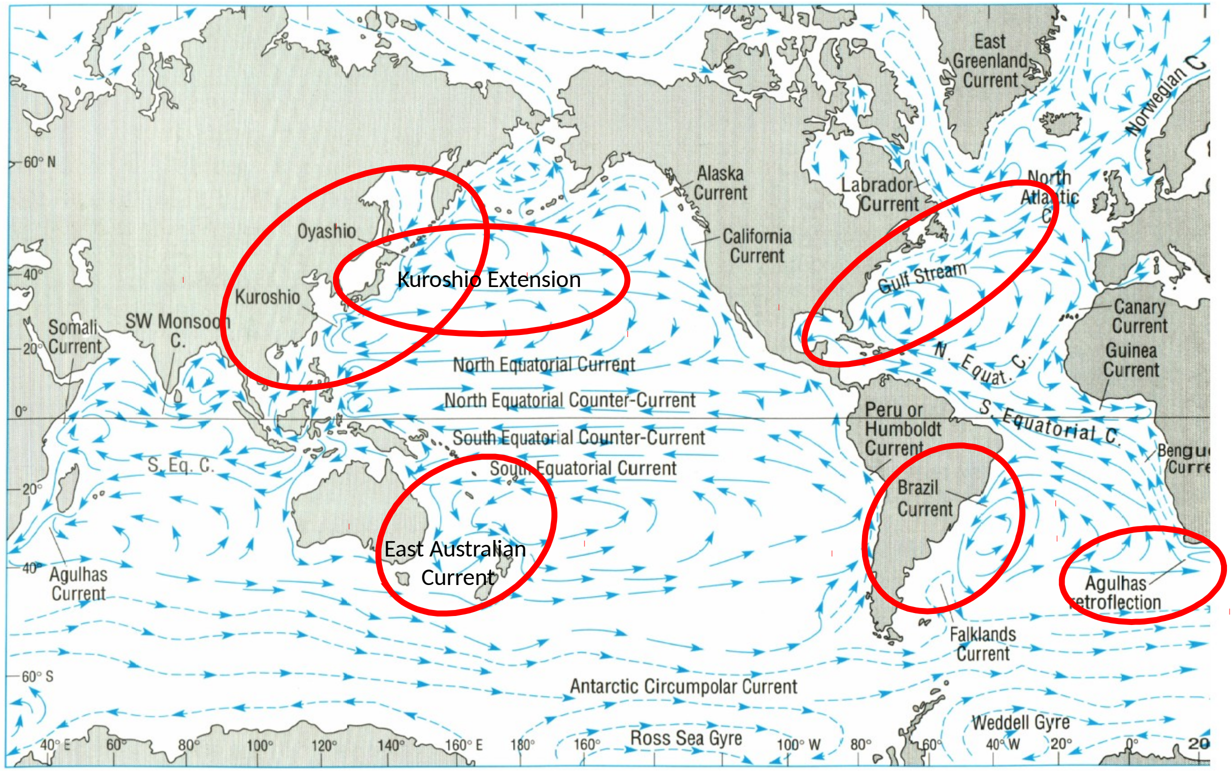
The experiments of the **Hydralab+ 19GAPWEBS project** referred to in this presentation will be carried out with the 13-m diameter Coriolis rotating tank at LEGI-CNRS in Grenoble in **June-July 2019**. Here the proposed project will be presented

- Introduction
- Experimental setup
- Dynamic similarity and dimensionless parameters

Western boundary currents (WBCs)

- very intense currents flowing along the western boundaries of the oceans induced by a gradient of the Coriolis parameter .

- WBCs important for **climate** because of their huge heat transports, corresponding air–sea interactions and the role they play in sustaining the global conveyor belt.

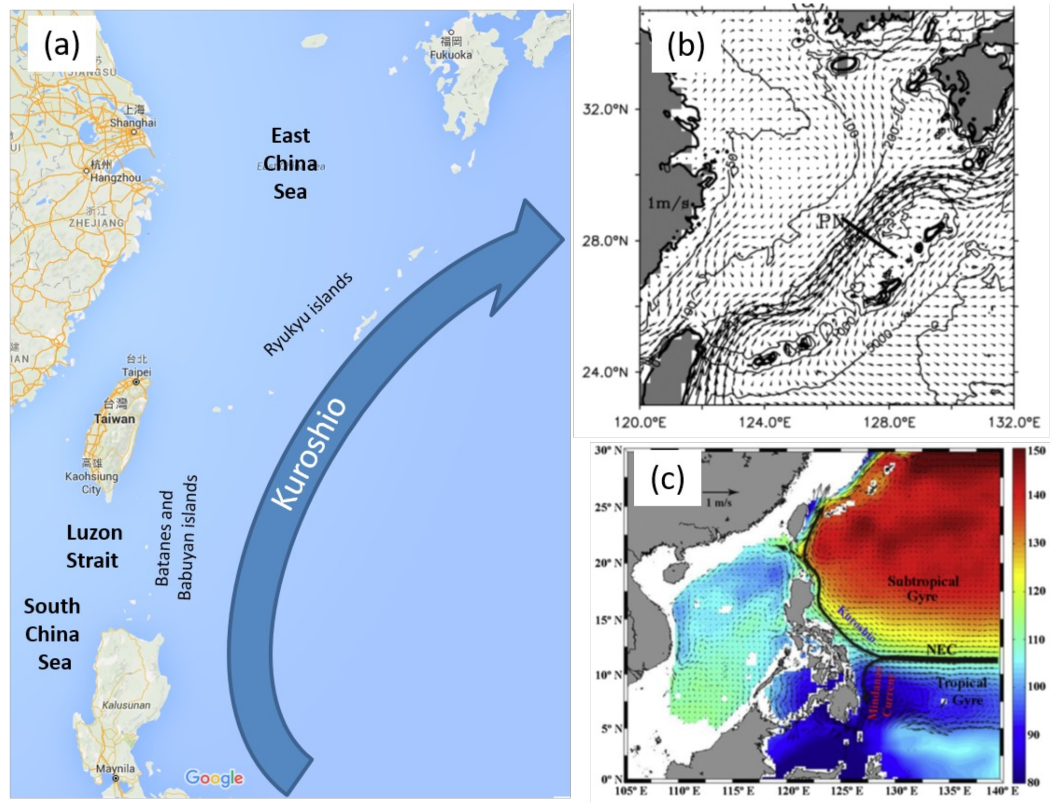


(from "Ocean Circulation", The Open University Oceanography Course Team, 2001)

One of the most interesting and intriguing WBC phenomena of climate relevance is the **interaction of the jet with a gap located along the western coast**

Examples include the Gulf Stream leaping from the Yucatan to Florida, and the Kuroshio leaping, and partly penetrating through the South and East China Seas (SCS and ECS, panel a).

The Kuroshio carrying the northwestern Pacific water intrudes partially into the SCS through the Luzon Strait (panel c), significantly affecting the hydrology, circulation and mixing in the SCS (e.g., Nan et al., 2015).



A similar phenomenon occurs through the wider gap separating Taiwan to Japan (panel b, e.g., Liu et al., 2014).

Previous laboatory experiments

- WITHOUT GAPS (Pierini et al., Coriolis I 2002, Trondheim 2008; 2011).

- WITH GAPS (Sheremet & Kuehl (2007) and Kuehl & Sheremet (2009)): in smaller rotating table (1m diameter) → extent and resolution of the WBC much smaller.

The great relevance of the problem calls for **larger scale simulations** and, in turn, a larger rotating tank facility.

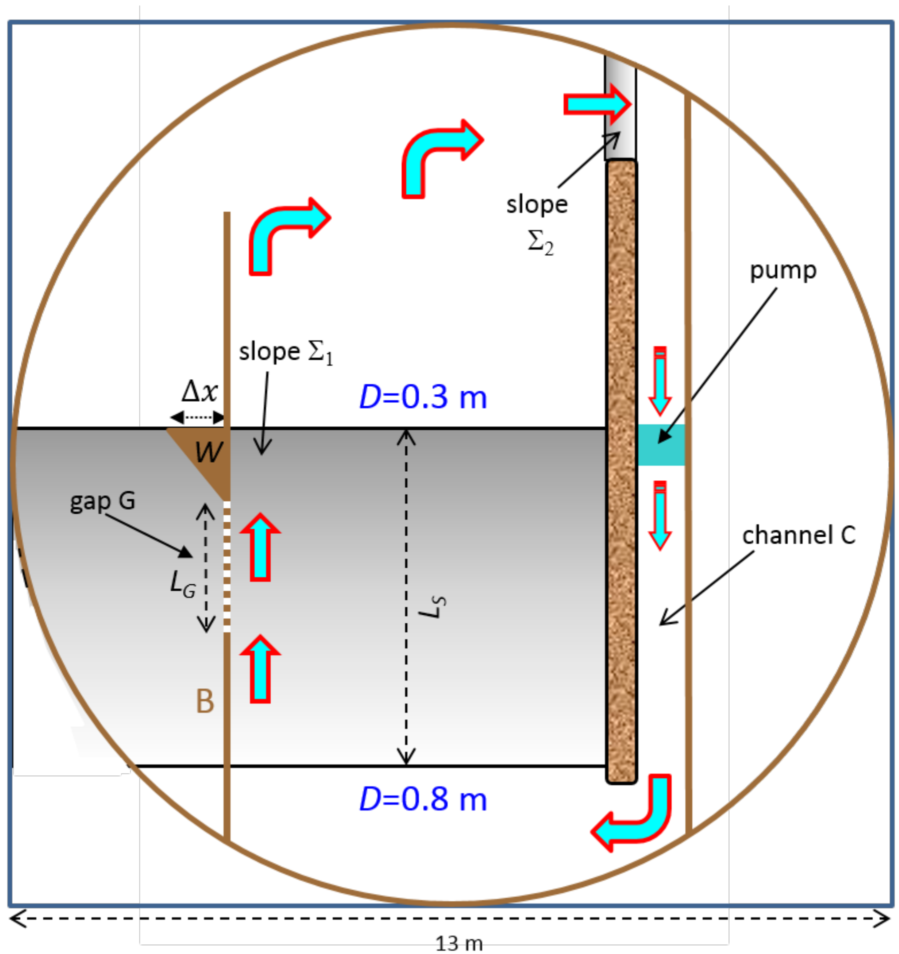
A pumping system located in channel *C* produces a current of speed u_p that, following the lateral boundaries, generates a virtually **unsheared flow at the entrance of the slope Σ_1**. This provides the **topographic beta-effect** necessary for the intensification.

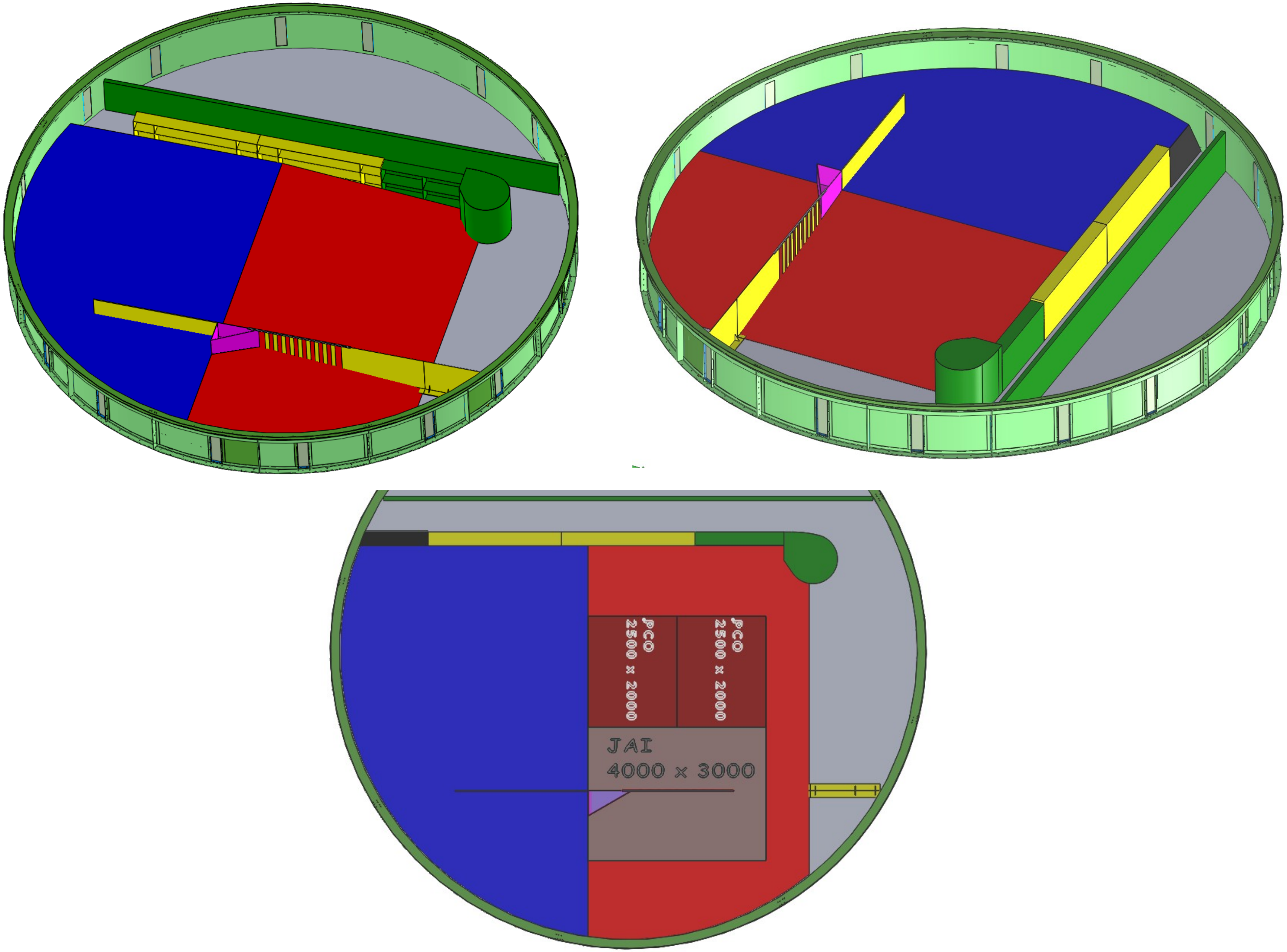
beta=f/H $dh_s(y)/dy$

Variation parameters:

- the rotation period *T*;
- u_p (and so the intensity of the WBCs) by taking into account both the various dynamical ranges and the climate change scenarios;
- the gap length L_G;
- the number and width of the islands inside the gap *G*;
- the width Δ*x* of the obstacle W.

The measuring technique will be the Particle Imaging Velocimetry (PIV).




PCO
2500 x 2000
PCO
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To study the dynamic similarity between the proposed experiments and the full-scale phenomenon one can rely on the evolution equation of potential vorticity in the quasigeostrophic approximation (valid because the Rossby number ε_R is $\varepsilon_R \approx 0.05 \ll 1$) in its steady and dimensionless form:

$$\varepsilon(uv_{xx} - vu_{xx}) + v = Ev_{xxx} - Bv_x$$

Here, (x,y) and (u,v) are the dimensionless zonal and meridional coordinates and velocity components, respectively, and the dimensionless parameters

$$\varepsilon = \frac{U}{\beta \ell^2} = \left(\frac{\delta_I}{\ell}\right)^2 ; \; E = \frac{A_H}{\beta \ell^3} = \left(\frac{\delta_M}{\ell}\right)^3 ; \; B = \frac{r}{\beta \ell} = \frac{\delta_s}{\ell}$$

measure the importance of nonlinearities and lateral and bottom friction, respectively. ***U*** and ***ℓ*** are typical zonal velocity and length scales, ***β*** is the meridional gradient of the Coriolis parameter ***f*** (in our experiments it is given by β^*), ***A_H*** is either a constant lateral eddy viscosity coefficient in a full-scale schematization of WBCs or the molecular viscosity of water in our experiments, ***r*** is the inverse of the spin-down time due to bottom friction, and ***δ_I***, ***δ_M***, and ***δ_s*** represent the boundary layer length scales for **purely inertial and purely viscous Munk and Stommel flows**, respectively.

Conclusions

The conclusions will be drawn after performing the experiments

(these will be carried out next June-July)

Thank you

The interplay between experimental research and mathematical/numerical modeling is quite a subtle issue.

Experimental and numerical hydraulic researches were often seen as competitors; in the ‘90s experimental research was rather seen as supporting process research for the improvement of mathematical models, but the latter could in turn assist the experimental facility.

In a more challenging approach, the integrated use of physical models, numerical models, theoretical analysis and field experiments can provide the best advancements in our understanding of the hydraulic processes under investigation. The real challenge is to **achieve a two-way cooperation between experimental research and mathematical modeling so as to migrate from competition to synergy**.

According to this view, numerical modeling based on primitive equations/shallow water models will be carried out in synergy with the laboratory experiments.

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