Proposition détaillée de la thèse

The turbulent life of rotating downslope gravity currents

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Predicting the response to natural and anthropogenic forcing of Earth's climate is one of today's greatest challenges. It crucially depends on our understanding of the ocean dynamics over a large variety of interacting scales in time and space. The abyssal waters are mainly fed by oceanic overflows, which are bottom-trapped dense gravity currents (GC) originating in semi-enclosed basins or on continental shelves (Marshall & Schott 1999). Their descent on the continental slope involve boundary layers (BLs), high shears and density gradients, instabilities, breaking internal waves and the generation of sub-mesoscale vortices at [*km*] scale and smaller. The resulting mixing influences the final stabilisation depth of the water mass, its density and transport, which controls the whole convection process. As discussed by Wells et al. (2010), the process of shear-driven entrainment associated with GCs is one of the key processes determining diapycnal transport in the world's oceans (Ferrari & Wunsch (2009), Ferrari et al. (2016), McDougall & Ferrari (2017)). On a smaller scale, GC's related processes can produce interannual-to-decadal ocean variability, e.g. the (BIOS) in the Ionian Sea (Rubino el al 2019).

Water mass mixing is the main mechanism that drives energy dissipation in the ocean and is related to turbulent sub-mesoscale processes, such as those produced by GC, but they are still poorly understood. **The main goal of TUBE is to identify and quantify the relevant processes, such as turbulence production, induced by intruding rotating gravity currents.**

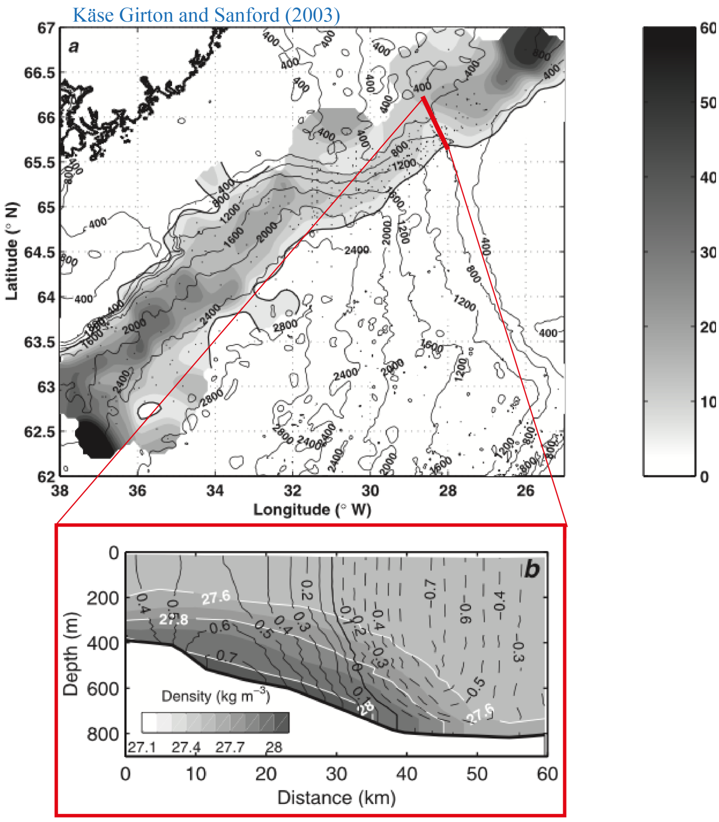

Figure 1 : Measurements of the overflow generated in the Denmark Strait from Käse et al (2003).

The main goal of the PhD is to study the extended life of GCs, which includes the following objectives :

(O1) to characterize the transition from a downslope GC to a quasi-horizontal current under the effect of the Coriolis force: this is a form of geostrophic adjustment that leads to a horizontal current, where the downslope gravity force is balanced by the upslope Coriolis force, as long as friction is neglected (Wirth 2009, Smith 1975);

(O2): To investigate the mechanism of injection of vorticity into the ocean interior through boundary layer (BL) detachment of rotating gravity currents. At the bottom boundary or at the upper sheared interface of gravity currents thin layers of high vorticity are created. The vorticity is then advected towards the interior when they interleave at the level of neutral buoyancy by BL detachment.

(O3): To study the energy transfer processes in the resulting turbulent environment within the ocean interior and its route to dissipation. In the interior, the mutual advection of vorticity constitutes the turbulent dynamics and is finally dissipated at smaller scales by dissipative processes; mixing processes produced at the sheared interface contribute to modify the Potential Vorticity (PV) distribution, which is not conserved in these circumstances, and may generate vortices, dipoles and vortex filaments (Vic et al. (2015)); on sloping boundaries, the planetary vorticity in the fluid column above the current is stretched and therewith amplifies the effect of the Earth's rotation.

Methods : The topic may include experimental and/or numerical work.

Laboratory experiments will be realized using saline solutions injected at 32 points equispaced on the Coriolis platform's circonference at the top of an inclined boundary, shaped as an inversed cone with circular cross section. This configuration with axisymmetric injection will provide a long experimental duration of several hours (~300 rotation days) which is fundamental to the evolution of the created turbulent environment. The ambient reservoir will be discrete-layered or linearly stratified. The velocity fields will be measured by PIV technique and concentration fields using a Laser Induced Fluorescence (PLIF). Further, conductivity probes and ADV will help resolving the boundary layer. The data will be processed with MATLAB/Python.

Numerical simulations will follow closely the laboratory experiments and allow to cover further parameter ranges difficult to reach experimentally giving a robust benchmark between the laboratory/numerical experiments. This will serve to test existing parameterizations of unresolved processes and determine the resolution necessary to resolve the important dynamical features. The numerical experiments on the configuration will be performed using the CROCO model. The comparison between the experimental and numerical data will finally permit to test and validate the CROCO code in non-hydrotatic regimes.

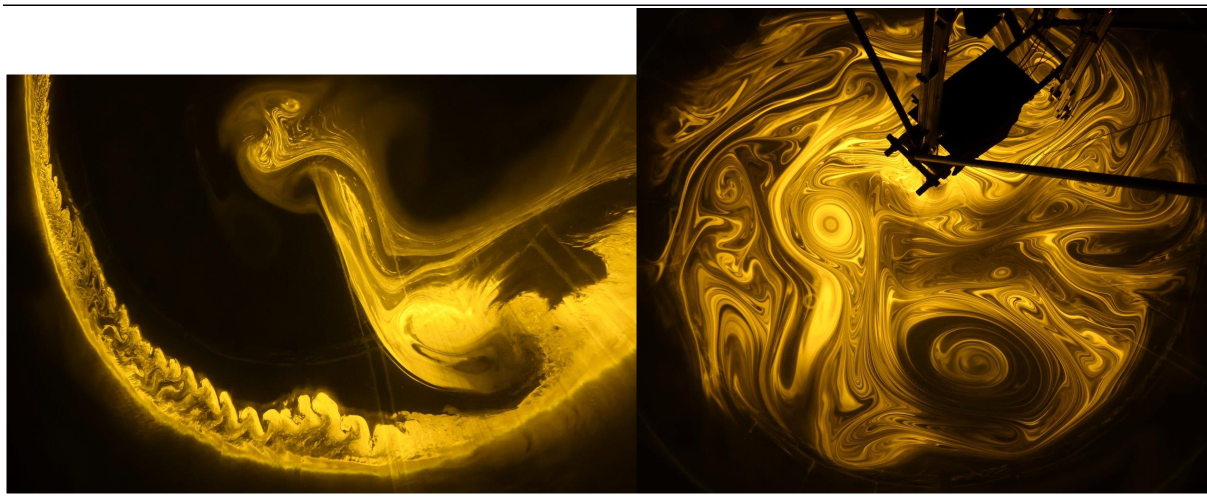

Figure 2 : Top view of the pycnocline layer of preliminary experiments at the Coriolis Rotating Platform using fluorescent dye injections. (a) After 40 days dipole ejection and the detaching frictional boundary layer into the quiescent ambient are evident and (b) after 120 days the environment has become fully turbulent with formation of coherent vortices.

Support. All the technical material to realize the experiments and/or numerical simulations are available at LEGI/Coriolis. For data analysis, a PC equipped with classic scientific software licences (MATLAB, MATEMATICA, PYTHON) are available at LEGI/Coriolis.

Encadrement. Eletta Negretti is researcher CR1 CNRS at LEGI since 2011. She cosupervised two PhDs (T Caudwell 2015, MC De Falco, 2020), and one at present (J Dagaut 11/2017-11/2020), along with a post-doc (A Martin, 2017-2020). She directed 15 MII thesis. During the PhD she engages to pass the habilitation (HDR) at ED TUE (proposal of admission under evaluation). The PhD will bec o-supervised by Achim Wirth, who has the HDR at the ED TUE.