Experimental turbulence in rotating & stratified geophysical flows

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Beginning: Due to funding constraints, the PhD must start by the end of 2024.

CONTEXT: Geophysical flows generally result from the interplay between various forcings, such as planetary rotation, buoyancy forces, turbulence, and topography. This is the case in the Earth's atmosphere or oceans (thin layers), but also in deeper fluid layers (thick layers) like the Earth's liquid outer core. These generic ingredients could be key to explain certain geodetic observations (e.g. variations of the Earth's rotation axis [1]), or the generation magnetic field of the Early Earth [2] or Moon [3]. However, many characteristics of such geophysical flows remain badly constrained to date. For instance, the most advanced numerical models (e.g. atmospheric and oceanic GCMs, or for the geodynamo [4]) cannot resolve the small and meso (i.e. intermediate) scales of such flows. Moreover, the flow dynamics near the boundary and the associated stress (see fig. 1*a*) are largely unknown whereas they are key for coupling geophysical flows with topography [5,6].

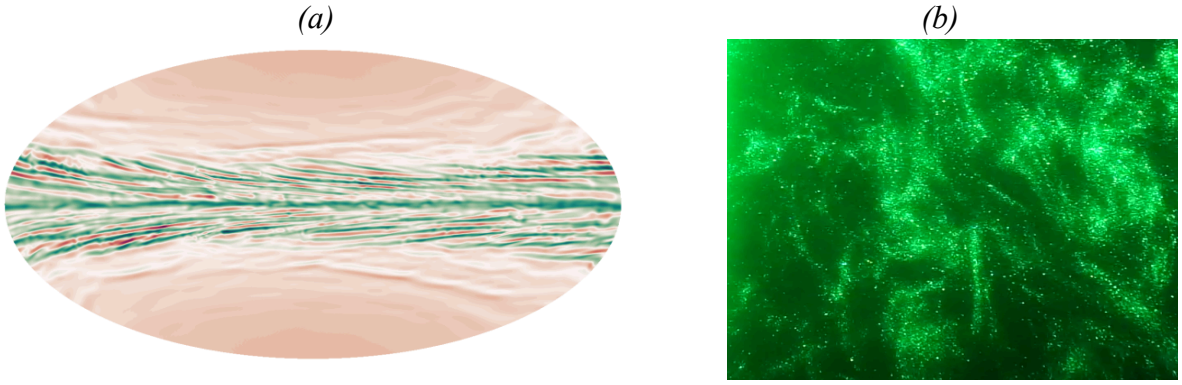

Figure 1. Our ongoing studies of boundary-driven turbulent flows. ***(a)*** XSHELLS simulations of rotating turbulent flows below a spherical boundary. Courtesy of N. Schaeffer & A. Meresse. ***(b)*** Experimental visualisation of turbulent flows in a rotating cylinder (eccentric Taylor-Couette flow).

PHD PROJECT: As modelling such turbulent flows remains challenging using simulations, laboratory experiments will be employed (fig. 1*b*). To do so, the candidate will have access to an equipped experimental room with several laboratory experiments (see details below). We will progressively increase the complexity of the experiments, starting with the study of

- pattern-formation on a dynamic topography with rotation and oscillating flows,
- buoyancy effects on the dynamics of rotating fluids (e.g. Rayleigh-Taylor instability),
- the fluid-solid stress due to rotating (stratified) turbulence above topography.

Particular attention will be dedicated to linking the experimental observations to theoretical predictions, notably in the linear and (when possible) weakly nonlinear regimes. One of the long-term goals is the validation of parameterised models that are currently investigated in the community [6,7].

(a) *(b)*

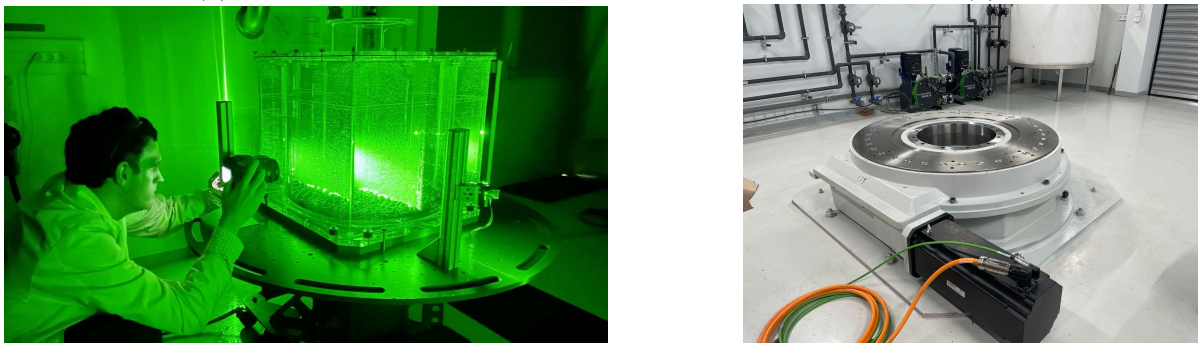

Figure 2. Experimental setups. ***(a)*** Ongoing rotating experiment with a bottom 3D-printed topography. ***(b)*** THEIA rotating platform, on which a one-metre cylinder will be mounted by 2025.

EXPERIMENTAL SETUPS: ISTerre built in 2024 a new experimental facility, currently hosting several experiments designed by a in-house CNRS engineer to investigate geophysical flows. A 50-cm experiment is already operational (fig. 2*a*), which is well suited to investigate rapid rotation rates (< 100 rpm), thermal plumes, and oscillating flows. To study rotating stratified fluids with minimal effect of centrifugal forces, a larger one-metre tank will be delivered before the beginning of the PhD and mounted on the large THEIA platform (fig. 2*b*) rotating at < 10 rpm. Finally, a large two-metre diameter experiment (currently under design) may be used by the end of the PhD to investigate topography-driven turbulence with a high aspect-ratio tank (suited for the study of thick fluid layers).

CANDIDATE PROFILE: The candidate should have an M.Sc. in physical sciences, preferentially (but not necessarily) in fluid mechanics, experimental physics, or geophysical fluid dynamics (GFD). A strong desire for laboratory experimentation is also required. A good level of French would be an advantage, notably to deal with manufacturers.

The PhD student will develop interdisciplinary skills in both theoretical (e.g. stability analysis) and experimental fluid mechanics (e.g. PIV measurements). Depending on the student's interests, complementary numerical simulations may also be performed (e.g. using numerical codes of the community). The PhD thesis will allow the candidate to either continue in academia or to apply for R&D positions in companies.

COLLABORATION(S): This research topic is currently of great interest for the GFD community. Other collaborations may thus be considered (e.g. within the Grenoble team, or with our colleagues from Lyon or in Switzerland).

BIBLIOGRAPHY:

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[7] Cébron et al., *GJI*, 2019, 219(Supplement_1):S34-57.