A numerical and experimental study of thermally-driven flows in subglacial lakes

Start date: Fall 2026 – Applications open until the position is filled (or July 1st, 2026)

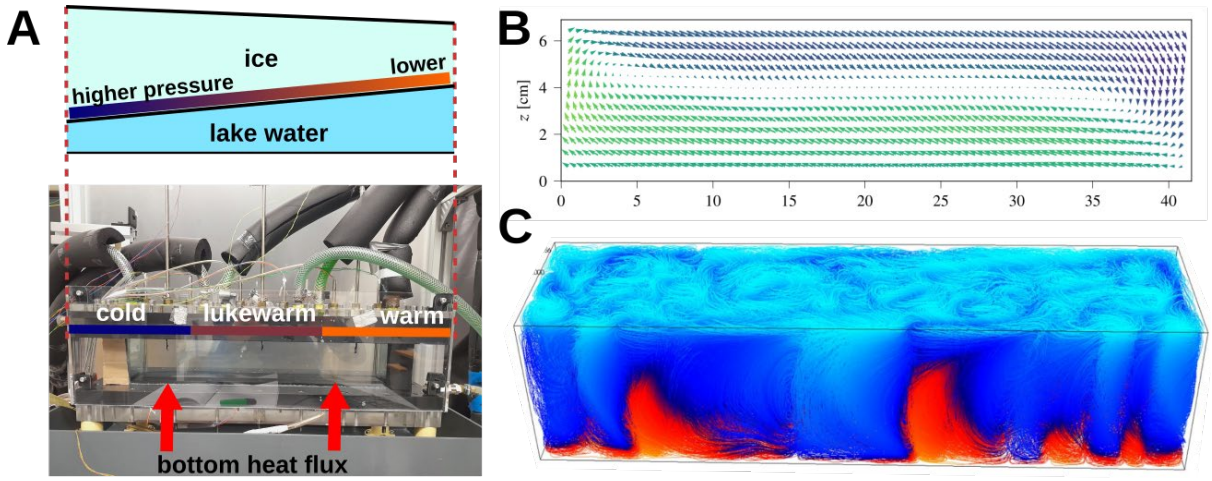


Figure 1: A. Schematic (top) of subglacial lakes and existing laboratory experiment of subglacial lakes in Lyon (bottom). The colormap from blue to orange shows how the freezing temperature goes from low to high as the ice thickness decreases. This heterogeneous surface temperature forcing is reproduced in the laboratory using 3 independent temperature-controlled plates [Rab25]. B. Example of velocity field reconstruction from feature-tracking on shadowgraph images. C. Preliminary high-resolution Direct Numerical Simulations of lake circulation taking into account planetary rotation.

Practical Information

- Supervisors: Louis-Alexandre Couston, Julien Salort, Francesca Chillá (Laboratoire de Physique, ENSL, Lyon), Catherine Vreugdenhil (U Melbourne, Australia)
- Contact: louis.couston@ens-lyon.fr, julien.salort@ens-lyon.fr
- Fully funded position for a 3-year PhD (source: CNRS-Melbourne Graduate Research Projects Scheme, PIs: Catherine Vreugdenhil & Louis-Alexandre Couston)
- Work Placement (*please note that the final year will be based in Melbourne!*) :
    - Year 1, Year 2 : Laboratoire de Physique, ENS de Lyon, Lyon, France
    - Year 3 : University of Melbourne, Department of Mechanical Engineering, Melbourne, Australia
- Relevant Academic Background and Training: Fluid mechanics, Turbulence, Thermodynamics, Physical oceanography and/or limnology, Lab work, Statistical analysis, Numerical modeling
- A research internship in spring/summer 2026 is not required but can be considered

Context

This PhD opening is part of the Graduate Research Project:

"Temperature-induced regime changes in the Earth's hydrosphere: insights from models of the oceans and subglacial lakes"

between CNRS and the University of Melbourne, which has financial support for two PhD projects. The advertised PhD project will be primarily based in Lyon and combine laboratory experiments and numerical simulations to characterize the dynamics of subglacial lakes (Lyon PhD). Subglacial lakes populate the base of the Antarctic and Greenland ice sheets and are of interest to fluid dynamics, glaciology, paleoclimatology and

astrobiology. The other PhD project will be primarily based at the University of Melbourne and focus on idealized models of the large-scale ocean circulation using numerical models (Melbourne PhD). An exchange program is planned between the two institutes. The PhD candidate in Lyon will spend the final year (year 3) in Melbourne to benefit from Dr. Vreugdenhil's expertise in running high-resolution large-eddy simulations of thermally-driven flows. Regular discussions between the two teams will motivate the exchange of ideas and results on related topics.

Scientific abstract for the two PhD projects

The Earth's hydrosphere, in particular the large-scale circulations of oceans and subglacial lakes, is shaped by temperature conditions and heat fluxes. For instance, the difference in surface ocean temperatures between the equator and poles helps drive the Atlantic Meridional Overturning Circulation (AMOC), while variable ice sheet thicknesses can drive similar large-scale flows in subglacial lakes. Ocean and subglacial lake circulations can change abruptly when forcing conditions evolve, such as surface air temperatures rising due to climate change. Here, our aims are to characterize the different dynamical regimes of key components of the Earth's hydrosphere, identify thresholds for regime changes in parameter space, and investigate the nature of transitions. To make progress, we will investigate idealized models of oceans and subglacial lakes, which include the physical processes key to surface and subglacial environments. Expected outcomes include new knowledge of ocean and subglacial lake circulation, the impact of climate change on abruptly altering these systems, and insights into how well the temperature-induced processes are represented in climate models.

Objectives and work program specific to the Lyon PhD project

The primary task for the Lyon PhD project (Task 1) is to characterize the large-scale circulation of subglacial lakes, which is driven by variable temperature conditions on the lake boundaries, and understand its sensitivity to lake geometry.

Subglacial lakes (SL) are pockets of high-pressure cold-temperature water trapped between the polar ice sheets and continental bedrocks. They are buried under several kilometers of ice (about 2 km on average) and can be as large as Lake Michigan in the United States. To date, almost 700 subglacial lakes have been detected in Antarctica and 64 have been found in Greenland.Subglacial lakes have dynamics which depend on forcing mechanisms that can be implemented in a meter-scale laboratory experiment. The Lyon team has worldwide expertise in laboratory experiments of thermal convection, which can typically reach more extreme control parameter values than Direct Numerical Simulations [Mét22]. Thus, Task 1 will be primarily based on laboratory experiments and build upon a recent apparatus that we constructed and instrumented to report the first laboratory study of subglacial lake dynamics (Fig. 1A) [Rab25]. Planetary rotation, which is challenging to reproduce in a laboratory setting, has recently been suggested to be unimportant in the context of subglacial lakes [Cou21a]. However, rotation is key to a broad range of water environments (such as the oceans) and hence its impact on subglacial lake dynamics will be thoroughly investigated using simulations.

The planned activities for the Lyon PhD project are:
Task 1.1: Non-rotating laboratory experiments with freshwater (ENS de Lyon; Year 1)
Task 1.2: Non-rotating laboratory experiments with thermasolv (ENS de Lyon; Year 2)
Task 1.3: Simulations of freshwater with rotation (University of Melbourne; Year 3)

Tasks 1.1-1.2 will unlock the exploration of a broad range of parameter values using a larger tank than in [Rab25]. Notably, Task 1.2 will expand the range of turbulence intensity values and test the sensitivity of the dynamics to fluid properties by replacing freshwater used in Task 1.1 with thermasolv (which has lower viscosity [Mét22]). Tasks 1.1 and 1.2 will also enable well-converged statistical descriptions of regime

transitions as laboratory experiments can be run for long times. Finally, Task 1.3 will test the robustness of the laboratory results to rotation and provide more insights into the dynamics for a set of control parameters identified based on the results of Tasks 1.1 and 1.2. Together, the three sub tasks will provide detailed information on the large-scale circulation in subglacial lakes, thus guiding their future exploration.

Training

The successful candidate will receive training in simulation codes, the use of temperature and conductivity sensors, dataloggers, Particle Induced Velocimetry and shadowgraphs, as well as stratified turbulence analysis, dynamical system theory and regime transitions. They will benefit from stimulating discussions with other group members (both in Lyon and Melbourne) leveraging machine learning and high-performance simulations to address outstanding questions in physical oceanography and polar science. The project offers excellent opportunities for travel, laboratory placements with worldwide collaborators and to present findings at international scientific meetings.

How to apply

All applications must be sent via email to louis.couston@ens-lyon.fr & julien.salort@ens-lyon.fr and include a short motivation letter (<1 page), CV, under/graduate (L3/M1/M2) transcripts and the names and email addresses of 2 to 3 referees. Do not hesitate to send us an email if you have questions before applying, or to reach out to PhD students in our group (cf. team page at https://climatephysics-ensl.fr/).

Research group

The successful candidate will join the Climate Physics team at ENS de Lyon (https://climatephysics-ensl.fr/), which currently consists of 5 permanent researchers, 7 PhD students and 2 postdoctoral researcher. We combine laboratory experiments, numerical simulations, artificial intelligence and field observations to address outstanding questions in physical oceanography, atmospheric sciences, physical limnology (focusing on polar and alpine environments) and geophysical fluid dynamics. We collaborate with several colleagues from the Laboratoire de Physique, who are experts in hydrodynamics/climate research (about 15 PIs) and/or machine learning (about 10 PIs). The Laboratoire de Physique is about 180-member strong and conducts world-leading research on a broad range of topics, including quantum technology, statistical physics, biophysics and climate physics. Roughly 30 new doctoral students and postdoctoral researchers join the Laboratoire de Physique every year.

Fair and inclusive environment.

We know diversity fosters creativity and innovation. We are committed to equality of opportunity, to being fair and inclusive, and to being a place where all belong. We therefore encourage applications from all candidates, including those who are likely to be underrepresented at the Laboratoire de Physique.

References

[Cou21a] (Lyon PI) **Couston, L.-A.**, & Siegert, M. (2021). Dynamic flows create potentially habitable conditions in Antarctic subglacial lakes. *Science Advances*, 7(8), eabc3972.

[Mét22] (Lyon collaborators) Méthivier, L., Braun, R., **Chillà, F., & Salort, J.** (2022). Turbulent transition in rayleigh-bénard convection with fluorocarbon (a). *Europhysics Letters*, *136*(1), 10003.

[Rab25] (Lyon PI and collaborators) Rabaux, V., Bu, Y.-Z., **Couston, L.-A., Chillá, F., & Salort, J.** (2026). Rayleigh-Bénard Convection, Horizontal Convection, and Internal Gravity Waves in an experimental model of subglacial lakes. preprint / in revision for *Journal of Fluid Mechanics.*