Master 2 Internship in Physics / Physical Oceanography

Oceanic Vortex Generation at a Sea-Ice Edge in a Rotating Tank

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Scientific context

Mesoscale oceanic vortices are major components of ocean circulation and play an important role in the transport and redistribution of heat, momentum, and tracers [1,2,3]. Their dynamics are especially important at high latitudes, such as the Arctic and Southern Oceans, where they can influence sea-ice melt. In turn, sea-ice melt can also contribute to the generation of vortical structures, see Fig. a [4,5,6].

Observational studies and high-resolution numerical simulations provide increasingly detailed information on oceanic vortices in polar and subpolar regions. However, the physical mechanisms governing vortex generation and their interaction with sea ice are difficult to isolate in the ocean [7,8]. Laboratory experiments offer a complementary approach by allowing these processes to be studied under controlled and reproducible conditions.

A rotating tank is being developed at the Laboratoire d'Océanographie Physique et Spatiale (LOPS) to investigate these processes experimentally, see Fig b. The system allows the generation of controlled rotating geophysical flows and can be operated at rotation rates of up to 10 rpm, and enables the introduction of an ice sheet to simulate a sea-ice edge. Velocity and vorticity fields can be measured using Particle Image Velocimetry (PIV, see Figs. c-e), while a high-resolution infrared camera provides surface temperature measurements.

Objectives and expected outcomes

The objective of this internship is to investigate experimentally the generation and evolution of oceanic vortices at a sea-ice edge using a rotating-tank laboratory setup. The intern will use the existing experimental system and contribute to its further development and characterization. A series of controlled experiments will be conducted by varying the main physical parameters governing the system, including the rotation rate, fluid properties and stratification, as well as the properties and configuration of the sea-ice sheet.

The resulting velocity, vorticity and temperature fields will be analyzed using Python notebooks in order to determine how the presence of a sea-ice edge promotes the generation of vortical structures. This work will provide the first systematic experimental characterization of vortex generation at a sea-ice edge using a rotating-tank facility. The expected outcomes include the establishment of a reproducible experimental protocol, the characterization of the relevant parameter space, and quantitative measurements of velocity, vorticity and surface temperature fields. The internship will also lead to the identification and characterization of vortical structures generated near the sea-ice edge, as well as the physical mechanisms controlling their generation and evolution trough theoretical analysis of the instability mechanism. In addition, it will contribute to the development of a framework for comparing laboratory experiments with numerical simulations and observations.

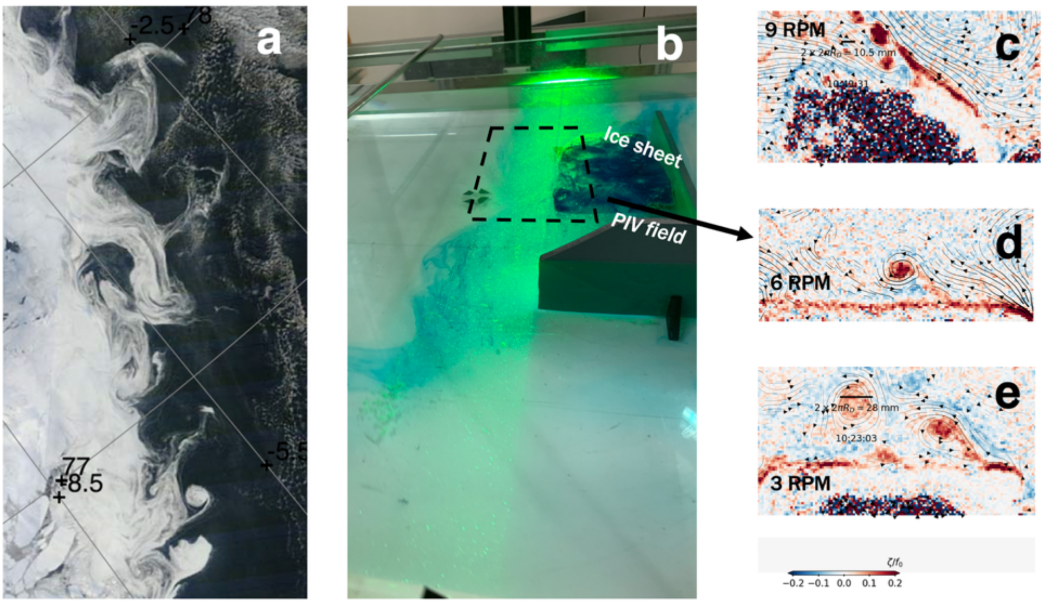
Beyond these scientific results, the internship will support the development of a new experimental research capability at LOPS dedicated to high-latitude ocean dynamics and ice–ocean interactions.

<u>Profile</u>

This internship is intended for a Master 2 student in Physics, Physical Oceanography, Fluid Mechanics, or a closely related discipline, with a strong interest in experimental fluid dynamics and geophysical flows. The candidate should have a strong background in fluid mechanics and/or physical oceanography, and good programming skills, particularly in Python. Experience with image processing, PIV, laboratory experiments, or rotating flows would be an advantage.

The internship will involve a combination of experimental work, data analysis, programming and physical interpretation, providing broad training in experimental geophysical fluid dynamics.

The internship will take place at the Laboratoire d'Océanographie Physique et Spatiale (LOPS) in Brest, within a dynamic research environment dedicated to ocean science. The intern will benefit from the proximity of the Technopôle Brest-Iroise, which brings together major institutions and research organizations in oceanography and marine science, including Ifremer, providing opportunities for interaction with a broad scientific community and exposure to complementary expertise in ocean research.



a. Eddies at the sea ice edge observed by satellite [7]; b. "Test" experiment in the LOPS rotating tank; c–e. Relative vorticity obtained from PIV measurements in the LOPS rotating tank.

References

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[2] Zhang, Z., Wang, W., and Qiu, B.: Oceanic mass transport by mesoscale eddies, Science, 345, 322–324, 2014.

[3] Dong, C., McWilliams, J. C., Liu, Y., and Chen, D.: Global heat and salt transports by eddy movement, Nature Communications, 5, 2014.

[4] Jennifer A Kosty, Ken X Zhao, Andrew L Stewart, Daniel E McCoy, Daniele Bianchi,and Georgy E Manucharyan. Marine mammal-based observations of subsurface intensified eddies in the seasonally sea ice-covered southern ocean. Journal of Geophysical Research: Oceans, 130(4):e2024JC021781, 2025.270

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