Tipping thresholds and bistability of Antarctic continental shelf regimes

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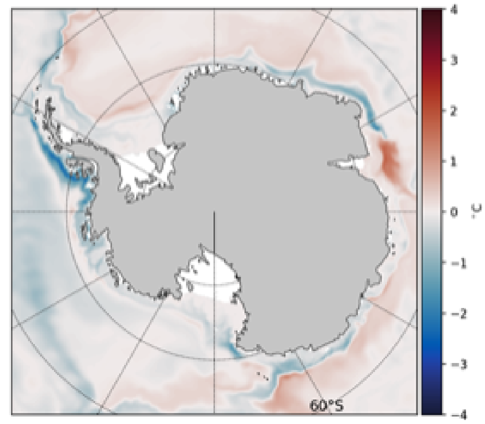
A funded PhD project starting in fall 2027 or earlier. The initial part of the proposal should take part as a Master 2 internship, ideally taking place in the spring of 2027.



Projected subsurface temperature change around Antarctica by 2100, as induced by interactive ice-shelf melting.

Project context and objective

The Antarctic ice sheet flows from the continent into the ocean and forms floating ice shelves, which then melt at their basal boundary, freshening and cooling the world's ocean. The amount of ocean heat that is delivered into each ice-shelf cavity and made available for melting is determined by the type of ocean water masses present at the respective portion of the Antarctic continental shelf. Different oceanographic regimes have been identified around the continent[1] and they are largely set by the combination of local sea-ice formation, proximity of deeper warm waters to the continental shelf break, and winds – all of which are ultimately set by the atmosphere. As greenhouse gas concentrations continue to rise, the associated changes in wind patterns and air temperatures around Antarctica have the potential to cause rapid shifts between different oceanographic regimes neighboring ice-shelf cavities, which can ultimately lead to large and sudden increase in freshwater input into the ocean[2], rising sea level, and modifying the global climate[3]. While a number of works have investigated such regime change, the focus has been primarily on regional and global domains, which has made it difficult to identify the relevance of individual physical process in the tipping thresholds and there is a number of contradicting results that exist regarding the existence of bistability in ice-shelf cavity regimes[4–6].

The goal of the project is to investigate mechanisms and physical processes on the Antarctic continental shelf and inside the ice-shelf cavities and to assess their relevance for regime change tipping points and bistability.

Proposed work

Building on earlier work in the laboratory that used a simple box model[7], the candidate will conduct 3D ocean simulations (using the NEMO ocean model) in idealized domains of increasing complexity designed to retain the realism of the physical problem, while isolating the role of different processes.

The project will begin by investigating the relevance of melt rate feedbacks in an ice-shelf cavity for regime change on the neighboring continental shelf and their effect on bistability in an existing model setup. Next, the candidate will formulate the coupling of atmospheric-driven dynamical changes – changes in sea-ice formation and thermocline depth – and investigate how different formulations affect the dynamics of the continental shelf regime transition and bistability. The ultimate goal of this part of the project is to reconcile differing results regarding bistability in existing studies and to assess which dynamics are expected under projected climate change – information that will be obtained from existing climate model outputs.

Depending on the outcomes of the first part of the project, there will be flexibility to direct the second portion of the PhD in different directions, such as:

1) Study the role of climate variability on continental shelf regime tipping points using a global climate model.

2) Study interactions between neighboring ice shelves around Antarctica in an idealized setup. As a regime change next to one ice shelf can result in large increase in freshwater input into the ocean, advection of this freshwater can cause regime change at ice-shelves located further downstream[8]. The goal of this project would be to study the conditions under which the change is propagated efficiently to the next ice shelf, and whether it accelerates or delays its tipping – conceptual mechanisms for both have been proposed but they have not been investigated in a set of controlled numerical simulations.

Supervision and Collaboration

The PhD candidate will work with Irena Vaňková and Corentin Herbert. Irena is a polar oceanographer with experience in ocean observations and both idealized and global scale climate numerical modeling. Corentin is an expert in geophysical fluid dynamics, tipping points, and rare events in climate. The student will be part of the Climate Physics group within the physics laboratory at ENS de Lyon.

Prerequisites

Background in physics, applied mathematics, computing, or physical sciences is required. Proficiency in English is strictly required.

Application: If interested, please email your CV (in English) and all available university grades to both supervisors.

References

1. Thompson, A. F., Stewart, A. L., Spence, P. & Heywood, K. J. The Antarctic Slope Current in a Changing Climate. *Rev. Geophys.* **56**, 741–770 (2018).
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3. Bronselaer, B. *et al.* Change in future climate due to Antarctic meltwater. *Nature* **564**, 53–58 (2018).
4. Hellmer, H. H., Kauker, F., Timmermann, R. & Hattermann, T. The Fate of the Southern Weddell Sea Continental Shelf in a Warming Climate. *J. Clim.* **30**, 4337–4350 (2017).
5. Hazel, J. E. & Stewart, A. L. Bistability of the Filchner-Ronne Ice Shelf Cavity Circulation and Basal Melt. *J. Geophys. Res. Oceans* **125**, e2019JC015848 (2020).
6. Reese, R., De Rydt, J. & Naughten, K. A. Ice-Sheet–Ocean Interactions and the Reversibility of a Regime Shift Beneath Filchner-Ronne Ice Shelf. *J. Geophys. Res. Oceans* **131**, e2025JC023952 (2026).
7. Saddier, L., Herbert, C., Bull, C. Y. S. & Couston, L.-A. Irreversible Transitions of the Ocean Circulation in Antarctic Ice-Shelf Cavities. *Geophys. Res. Lett.* **53**, e2025GL118278 (2026).
8. Hoffman, M. J. *et al.* Ice-shelf freshwater triggers for the Filchner–Ronne Ice Shelf melt tipping point in a global ocean–sea-ice model. *The Cryosphere* **18**, 2917–2937 (2024).