Subpolar North Atlantic fresh water dynamics

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Key words:	Ocean circulation, Atlantic, overturning, ice melt, fluid dynamics
Research theme(s):	• Oceanography, Climate and Palaeoenvironment
Eligible courses for this project:	• DPhil in Earth Sciences • ILESLA (NERC and BBSRC DTP) • Intelligent Earth (UKRI CDT)

This project would best suit a student with a background in Physics, Maths, Earth Science or Computer Science who is interested in ocean circulation, climate, numerical modelling and interdisciplinary aspects of the changing Earth system.

Overview

In the subpolar North Atlantic warm and salty water flowing north in the upper kilometre loses heat to the atmosphere, becoming dense and eventually flowing south again at greater depths. This region, at the headwaters of the Atlantic overturning circulation, is critical to maintaining the ocean's northward heat transport and to transferring carbon from the atmosphere into the deep ocean.

As a consequence of climate change, the discharge of fresh water from Greenland melt and the Arctic Ocean is increasing, with the potential to radically change ocean circulation and properties in the subpolar region and beyond. Appreciation of the importance of freshwater in North Atlantic circulation is not new – we have long worried about the implications of increased freshwater export from the Arctic for deep water formation, overturning and hence climate. What is new is our growing appreciation that the role of freshwater in determining circulation, sea surface temperatures and atmospheric impacts is not limited to its ability to disrupt deep ocean convection in the Labrador Sea. Flooding the subpolar North Atlantic with fresh water would have immediate and significant effects on the atmosphere and ecosystems through dramatically reducing mixed layer depths and insulating the warm Atlantic Water from the atmosphere.

Ocean and climate models differ widely in their representation of salinity in the subpolar North Atlantic; at the resolution currently used for climate prediction, models cannot faithfully represent the pathways and fate of fresh water leaving the Arctic and Greenland, and we do not know how big a problem this is for their ability to accurately capture the response to anthropogenic change.

This project will investigate fresh water pathways in the subpolar North Atlantic, what determines them, their representation in models and their likely changes in a warming climate. The exact focus of the project will depend in part on the student's interests and skills. We will use observations and models to determine, for example, where and how fresh water leaves the subpolar boundary currents and enters the basin interior. What pathways does it follow, how do these depend on atmospheric forcing, and what governs whether the fresh water stays at the surface where it can have a direct effect on heat loss to the atmosphere? We may explore the impacts of fresh water distribution and variability on oxygenation and ecosystems. Another angle might be to test, using a hierarchy of model resolutions, whether climate models' inability to faithfully represent freshwater pathways really does hinder their ability to predict the things we care about (e.g. weather, ecosystems). It is thought that changes in fresh water input could potentially lead to an abrupt change in subpolar gyre mixed layer depths and/or in the overturning circulation – a "tipping point" from which the system may struggle to recover; the student could explore the mechanisms and feedbacks involved in models which exhibit such behaviour. Finally, we may bring Machine Learning approaches to bear on statistical analysis of the links between fresh water, ocean stratification and regional weather patterns.

The role that fresh water plays in overturning and climate is subtle, poorly represented in the models we rely on for prediction, and likely to change in a warming climate. This project will take a deep dive into the fresh water dynamics of the subpolar North Atlantic with the long term goal of improving our predictions and confidence in future circulation and surface properties in the region.

Methodology

The focus of the project and specific tools used will depend in part on the interests and skills of the successful applicant, and will be determined in consultation with the project supervisors. We will use recent observations made in the subpolar North Atlantic (e.g. by Argo and by the OSNAP observing array https://www.o-snap.org/) together with the output from ocean and climate model simulations at a range of resolutions. The student may design and run their own ocean model sensitivity experiments in a regional high-resolution ocean model to test specific hypotheses, work with remote sensing data to estimate eddy fluxes of fresh water between the boundary current and interior, use Lagrangian trajectory analysis to study where freshwater originates from, and/or use an adjoint model approach to look at the sensitivity of key subpolar metrics to fresh water input. Where possible, the student will develop simple theory to capture the essential dynamical relationships involved and will assess whether smart, machine-learning approaches might help make progress.

Timeline

Year 1: core training programme in research skills, quantitative methods and ocean modelling techniques; literature review; initial data analysis.

Years 2 and 3: exploration of freshwater pathways in models and/or observations, and writing of research publications for international journals.

Year 4: further analysis and paper writing, presentation of research at an international conference, thesis completion.

Training & Skills

You will receive training and guidance on how to interpret and synthesize model and observational data, how to present scientific results and how to write scientific papers for publication. You will acquire a solid grounding in ocean dynamics and a range of numerical modelling tools. There may be opportunities to expand your skill set further by participating in an ocean research cruise if you desire.

References & Further Reading

Haine, T. W. N., A. H. Siddiqui and W. Jiang (2023) Arctic freshwater impact on the Atlantic Meridional Overturning Circulation: status and prospects. *Philosophical Transactions of the Royal Society A: Mathematical, Physical and Engineering Sciences*, **381**. https://doi.org/10.1098/rsta.2022.0185

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Further Information

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