



# INTERNATIONAL OCEAN DRILLING PROGRAMME

## PROPOSAL 1119-PRE

**DENGATE: Reconstructing flow through Denmark Strait oceanic gateway – A crucial missing element in the Atlantic Meridional Overturning Circulation**

# IODP<sup>3</sup> Proposal Cover Sheet

## Proposal Title:

DENGATE: Reconstructing flow through Denmark Strait oceanic gateway – A crucial missing element in the Atlantic Meridional Overturning Circulation

## Broad Geographic Area of the Proposal

Denmark Strait, between Greenland and Iceland

## Project Abstract

Denmark Strait is a crucial but under-studied gateway within the Atlantic Meridional Overturning Circulation (AMOC) system of oceanic currents. The AMOC plays a central role in Earth's climate system as a major tipping element for interhemispheric heat redistribution and atmospheric carbon uptake. DENGATE targets a core-based reconstruction of Denmark Strait Overflow Water (DSOW), the deep, dense AMOC component that flows from the Arctic to the Atlantic through the Denmark Strait gateway in the Greenland-Scotland Ridge (GSR). At present, DSOW is the principal contributor to the mean strength of the AMOC, and its most southerly penetrating Arctic component, making DSOW critical for global ocean ventilation and climate. Past fluctuations in Arctic-to-Atlantic (cross-GSR) flow are hypothesized by modelling studies to be associated with changes to global climate, over timeframes from centuries to millions of years, throughout the period when the northern hemisphere ice sheets expanded and glacial-interglacial cycles were established. We cannot fully test these models for the dynamics of the AMOC-climate system because the past behaviour of DSOW, currently the major component of Arctic-to-Atlantic flow, is unknown for most of a history that exceeds 10 million years. This data gap has arisen because the existence of a suitable sedimentary contourite drift archive specific to DSOW was previously unknown. The proponent team have now identified such an archive: Freydis Drift is predicted to contain a continuous Miocene-Recent succession up to c.1500 m thick, with sedimentation rates that can provide sub-millennial resolution. Coring Freydis Drift is the only means to reconstruct the entire history of DSOW, e.g. through time series of current flow, temperature, and chemical fingerprint. Integration with existing and forthcoming sediment drift-based records will then allow the first detailed temporal reconstruction of the relative contributions to AMOC of deep water produced north and south of the GSR, which will transform our understanding of the dynamics of the AMOC-climate system. We propose a two-stage IODP3 programme. Initially, a shore-based IODP3 science party would analyse a suite of cores of up to 200 m (spanning approximately 2 million years) from Freydis Drift, obtained with predominantly external funding. Ground-breaking science results that address three IODP3 Strategic Objectives and the Flagship Initiative "Groundtruthing Future Climate Change" would then justify investment in a second stage of IODP3 deep drilling to obtain the complete DSOW record. Geophysical and shallow coring site surveys to initiate this programme are scheduled for 2027.

## Scientific Objectives

The overarching aim of DENGATE is to transform our understanding of the AMOC-climate system by making the first specific reconstruction of the entire past behaviour of Denmark Strait Overflow Water (DSOW) from Neogene to Quaternary.

- O1. To understand the upstream processes that caused variation in DSOW over millennial, orbital and million-year timeframes, including changing contributions of deep-water sourced in the Arctic Ocean and Greenland Sea, influence of fresh water from the Greenland ice sheet, and the role of stratification in the Nordic Seas.
- O2. To understand the tectonic processes that have caused variation on DSOW on timescales over 100 ky by changing the cross-sectional area of the Greenland-Scotland Ridge (GSR). As well as providing a case study for how oceanic gateway tectonics controls global climate, tectonic effects should be accounted for when considering past DSOW as a future analogue.
- O3. To reconstruct the relative roles of DSOW and Iceland-Scotland Overflow Water in Arctic-to-Atlantic oceanic exchange across the GSR, and test models for AMOC dynamics that predict similar, independent or compensatory behaviour on different timescales.
- O4. To determine the age of DSOW onset, to give a step-change improvement in GSR subsidence models, which provide important boundary conditions for ocean circulation and climate models but which disagree by over 30 million years in predicted DSOW onset.
- O5. To determine the down-stream influence of DSOW on deep-water formation in the Irminger Basin.
- O6. To assess how changes in strength and composition of DSOW have controlled the AMOC on millennial, orbital and million-year timescales.

## Science Communication Plain Language Summary

The Atlantic Meridional Overturning Circulation (AMOC) system of oceanic currents plays a central role in Earth's climate system. The AMOC faces an unquantified risk of a collapse in strength that severely threatens global

climate and society, related to climate warming and melting of the Greenland ice sheet. Climate models used for future AMOC predictions disagree on the likelihood and consequences of such a collapse, and direct ocean sensor measurements of the AMOC are too short to disentangle its long-term climate response from its substantial short-term variability. This proposal addresses a key cause of our inadequate AMOC forecasts: we lack a long-term observational record of the deep and dense Denmark Strait Overflow Water (DSOW) component that most strongly influences the AMOC. We propose scientific drilling of a sedimentary deposit called Freydis Drift that we have recently discovered beneath Denmark Strait. The sediment and rock cores we retrieve will allow the project team and the wider scientific community to make the first complete reconstruction of the strength, temperature and chemical fingerprint of DSOW, from the initial opening of the Denmark Strait oceanic gateway up to the present. During this period of over 10 million years, the Earth cooled, northern hemisphere ice sheets expanded, and glacial-interglacial cycles were established. Some of these changes occurred over millions of years, and others occurred on timeframes as short as decades that may be particularly relevant to possible future AMOC collapse scenarios. Different potential explanations for the various ice-climate interactions are associated with different changes to DSOW relative to other components of the AMOC. These ideas can be tested by comparing our new reconstruction of past DSOW with results of previous scientific drilling that reconstructed the other AMOC components. In this way we will improve understanding of the AMOC-ice-climate system, and provide the new constraints needed for next-generation climate models, which will ultimately transform our ability to predict the future AMOC.