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The THOR Project

THOR stands for ***Thermo-Haline Overturning – At Risk?*** and during 4 years (2008-2012), the project investigated the dynamics of the Atlantic Ocean's circulation and its impact on European climate. THOR's scientists cut across all disciplines of ocean science: from scientists observing the ocean, to those creating reconstructions of the past (based on marine fossil records) and those developing climate models, allowing researchers to look at the present state of Atlantic circulation, its natural variability and predicting its future development.

The project's key findings were:

- We need a good knowledge of the state of the North Atlantic circulation as a pre-requisite for reliable decadal climate forecasts.
- Circulation in the Atlantic has been stable in the past decades, but there is evidence that it can react to external changes over short time periods (just decades).
- Although there is a risk that something might happen to the Atlantic circulation in future, we can be quite sure that a collapse of the thermohaline circulation will not happen within the next ten years.
- We need to continue to observe the circulation, in order to develop an early-warning system and to allow society time to develop adaptation strategies.

Marine Scotland's work in the Faroe Shetland Channel contributed to the THOR Observational Programme (*see* "Our latest results" box).

What next? - NACLIM

The work of THOR will be continued until 2017 in a new EU FP7 Collaborative Project: North Atlantic Climate (NACLIM). The main focus of the project is to work towards more reliable seasonal to decadal forecasts, but as knowledge of the North Atlantic Circulation is key to achieving this, the observational efforts established under THOR will be continued. The ability to generate forecasts decades in to the future will help in many ways: from being better prepared for extreme events such as flooding or heat waves, to ensuring that we manage our use of the marine environment sustainably.

One focus of NACLIM is to explore the predictability of the marine ecosystem on these longer time scales. This is a tremendous challenge: our understanding of the linkages between physical and biological variability is still basic compared to our understanding of the drivers of the variability in the North Atlantic basin and its impact on our climate. Climate change will have far reaching effects, and we are now starting to explore the predictability of biological variability and how we will manage our marine ecosystem under these new conditions.

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SEVENTH FRAMEWORK PROGRAMME

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TOPIC SHEET NUMBER 123 V1

Scottish Government
Riaghaltas na h-Alba
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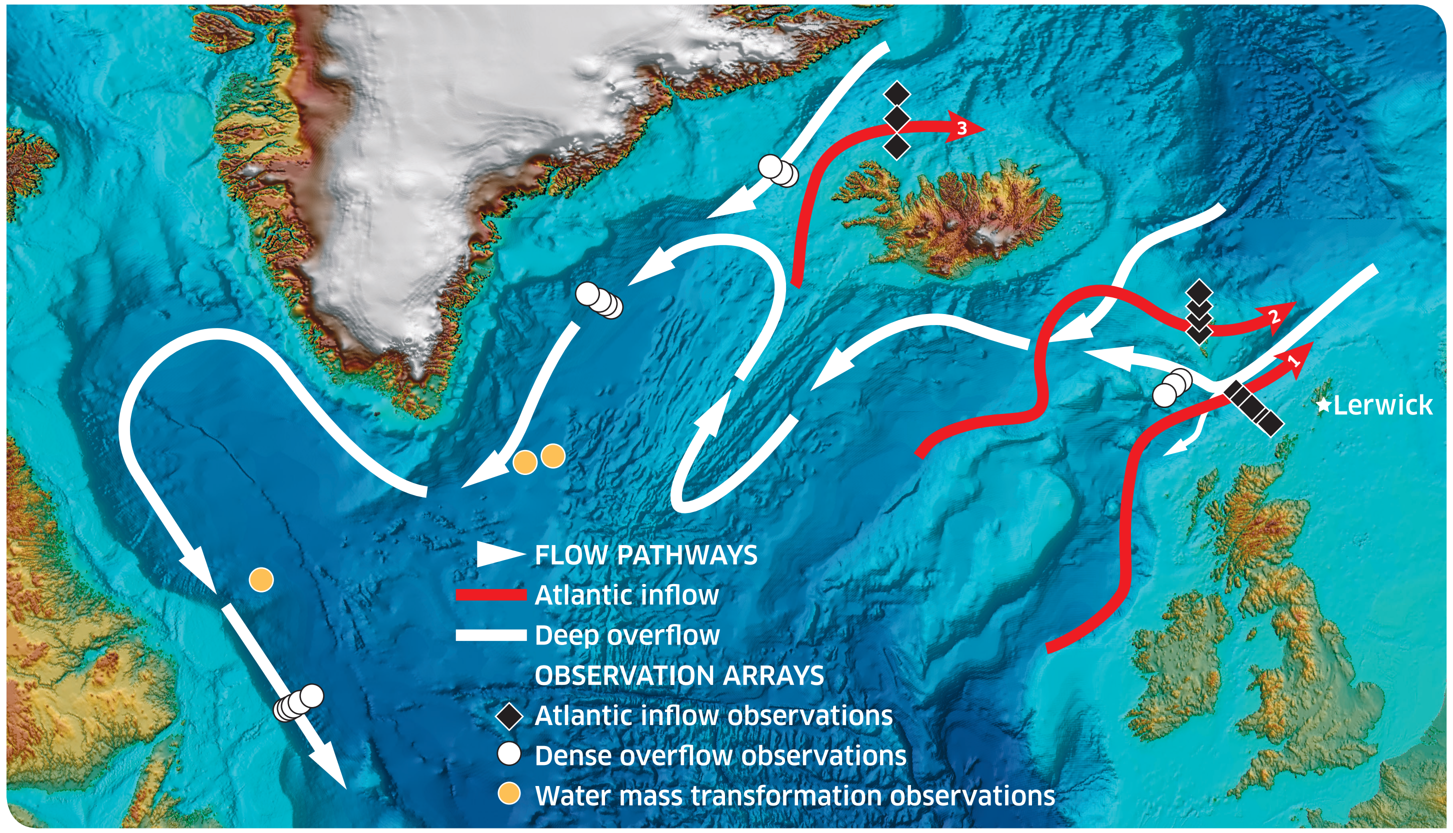
OCEAN CIRCULATION IN THE NORTH ATLANTIC: WHY IT IS IMPORTANT FOR SCOTLAND



CIRCULATION OF THE NORTH ATLANTIC SHOWING LONG-TERM OBSERVATION EFFORTS (ADAPTED FROM THE THOR PROJECT).

North Atlantic Circulation

Have you ever noticed that Lerwick-residents enjoy quite a mild climate despite being at a similar distance from the equator as Anchorage (Alaska) and Magadan (Siberia) (*see* graph over page)? It's because Lerwick sits on the edge of the North Atlantic basin.

The North Atlantic Basin

In the North Atlantic, warm salty water flows northwards at the sea surface and the transfer of heat by the ocean and the atmosphere provides Northern Europe with a milder climate than similar latitudes of other ocean basins.

The water from the North Atlantic enters the Norwegian and Greenland Seas (Nordic Seas) through three pathways (*see* above):

1. an inflow of Atlantic water through the Faroe-Shetland Channel (between Faroes and Shetland);
2. the Faroe Current crosses the Iceland-Faroe Ridge (east of Iceland); and
3. the North Iceland Irminger Current flows polewards in the eastern Denmark Strait (west of Iceland).

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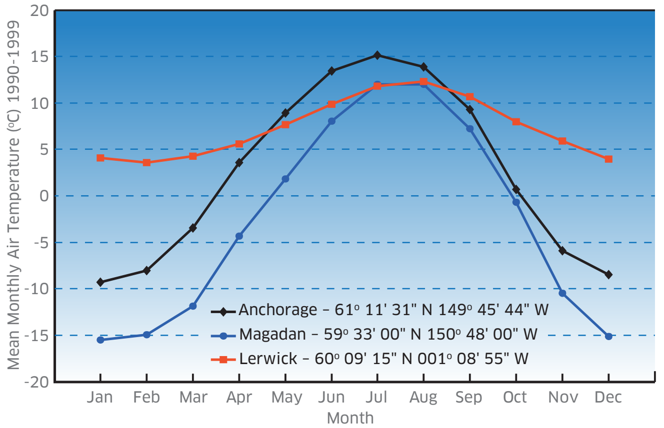


MONTHLY MEAN AIR TEMPERATURE, IN °C, IN THE 1990S AS OBSERVED IN ANCHORAGE (ALASKA), MAGADAN (SIBERIA) AND LERWICK (SHETLAND).

Within the Greenland Sea, the relatively saline Atlantic waters lose their heat to the atmosphere and cool. This makes them sufficiently dense (heavy) to sink to the deep, filling the deepest parts of the Greenland and Norwegian Seas. This formation of deep water in turn draws more Atlantic water northwards into the Nordic Seas across the underwater Greenland–Scotland Ridge and the deep cold water masses flow towards the equator, channelled through narrow gaps in the underwater ridge.

This circulation is called the *Atlantic Meridional Overturning Circulation (AMOC) and forms part of the 'great ocean conveyor belt'*. Also, it is of global significance in the Earth's climate system.

Why is it important?

In 2005, some observations suggested that the AMOC was slowing down, raising concerns that a breakdown of this circulation would have significant impact on the oceanic heat supply to Europe's climate. Since then, more measurements and computer simulations have been made to help better understand the changes that were observed, to understand what drives the AMOC and how and why it varies naturally.

Observing ocean circulation

Since the mid-1990s, scientists have observed the overturning circulation in the North Atlantic at key locations on the Greenland-Scotland Ridge, using state-of-the-art techniques that complement the more traditional measurements carried out since the end of the 19th century. They deploy temperature and salinity sensors and profiling current meters, allowing them to better estimate the volume of water leaving the Nordic Seas in the deep cold overflows, and the amount of surface Atlantic water flowing poleward at the sea surface.

In 2004, a British-American collaboration saw the start of a monitoring array further south across the North Atlantic at 26°N.

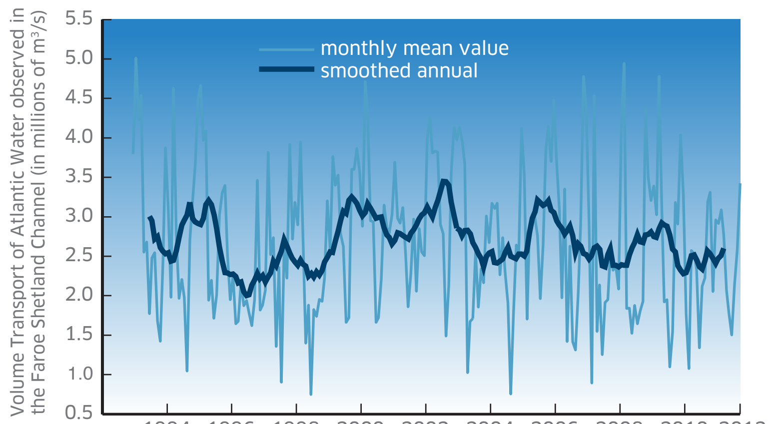
What is the role of Marine Scotland in observing circulation in the North Atlantic?

The Marine Laboratory in Aberdeen has a long history of making observations in one of the three important gaps in the Greenland-Scotland Ridge - the Faroe Shetland Channel. This region is also key for commercial fisheries and oil exploration. Since the late 19th century, researchers from Aberdeen have made regular observations of the vertical temperature and salinity structure in the Channel. In collaboration with scientists from the Faroe Islands (Faroe Marine Research Institute) and Norway (University of Bergen), Marine Scotland also started monitoring the velocity of the surface water flowing through the Faroe Shetland Channel, by deploying vertically profiling current meters which are moored near the sea bed, measuring towards the surface. Together with temperature and salinity observations made during regular ship surveys, these data can be used to calculate the amount of Atlantic water entering the Nordic Seas through the Faroe Shetland Channel and the amount of heat and salt it carries polewards.

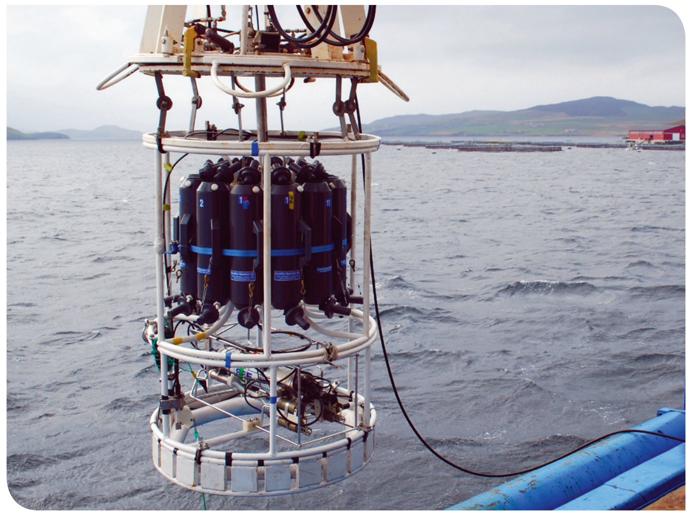
Our latest results

The latest results from the observations made by Marine Scotland in the Faroe Shetland Channel (FSC) are:

- On average, every second approximately 1,100 Olympic-sized swimming pools of Atlantic Water (i.e. 2.7 x 10^6 m^3) flow northwards into the Nordic Seas through the Faroe Shetland Channel. When combined with the Atlantic Water transported East of Iceland and across the Iceland-Faroe Ridge: 2,800 swimming pools (i.e. 7.0 x 10^6 m^3) enter the Nordic Seas every second across the Greenland-Scotland Ridge.
- The estimated transport (amount of water and energy) is not constant. Instead, complex variations in the currents mean patches of energy travel through the region from the Atlantic (also called meso-scale eddies) introducing variability.
- The deployment of only four current meters across the FSC is insufficient to capture all the dynamics of the Atlantic water transport, but we can combine the observations with satellite based altimetry (sea surface height) measurements to obtain an almost 20-year time series.
- So far, there is no significant long term change in the amount of Atlantic water flowing into the Nordic seas, but the temperature and salinity of the Atlantic water have increased since the early 1990s.
- Our observations are a small but essential contribution to large EU research projects on climate variability and its impacts on society.



OBSERVATIONS OF THE QUANTITY OF ATLANTIC WATER FLOWING POLEWARDS THROUGH THE FAROE SHETLAND CHANNEL: THE LARGE VARIATIONS FROM MONTH-TO-MONTH AND BETWEEN YEARS HIGHLIGHT THE ENERGETIC CIRCULATION OF THE NORTH ATLANTIC.



THE WATER SAMPLER AND INSTRUMENTATION READY TO COLLECT A PROFILE OF THE WATER COLUMN PROPERTIES, SUCH AS TEMPERATURE AND SALINITY.

PROFILING CURRENT METERS READY FOR DEPLOYMENT IN THE FAROE SHETLAND CHANNEL.