Iceland Sea Planning Meeting Report

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Background

The conventional view regarding the source of Denmark Strait Overflow Water, which is the largest contributor to the deep limb of the AMOC, is that it is supplied by the East Greenland Current. The water mass transformation process in the Nordic Seas that leads to this overflow is believed to occur primarily in the region's boundary currents (the Norwegian Atlantic Current and East Greenland Current) where water is densified through air-sea interaction (Figure 1). The recent discovery of the North Icelandic Jet (NIJ), a southward flowing oceanic current transporting dense water into Denmark Strait, has called this conventional paradigm into question. It appears that the NIJ contains convected water whose source region is the interior Iceland Sea (Figure 1). The Iceland Sea Project (ISP) has been proposed as a coupled atmosphere-ocean observational program aimed at understanding the processes that result in open ocean convection in the Iceland Sea and how the NIJ subsequently supplies this dense water to the deep limb of the AMOC.

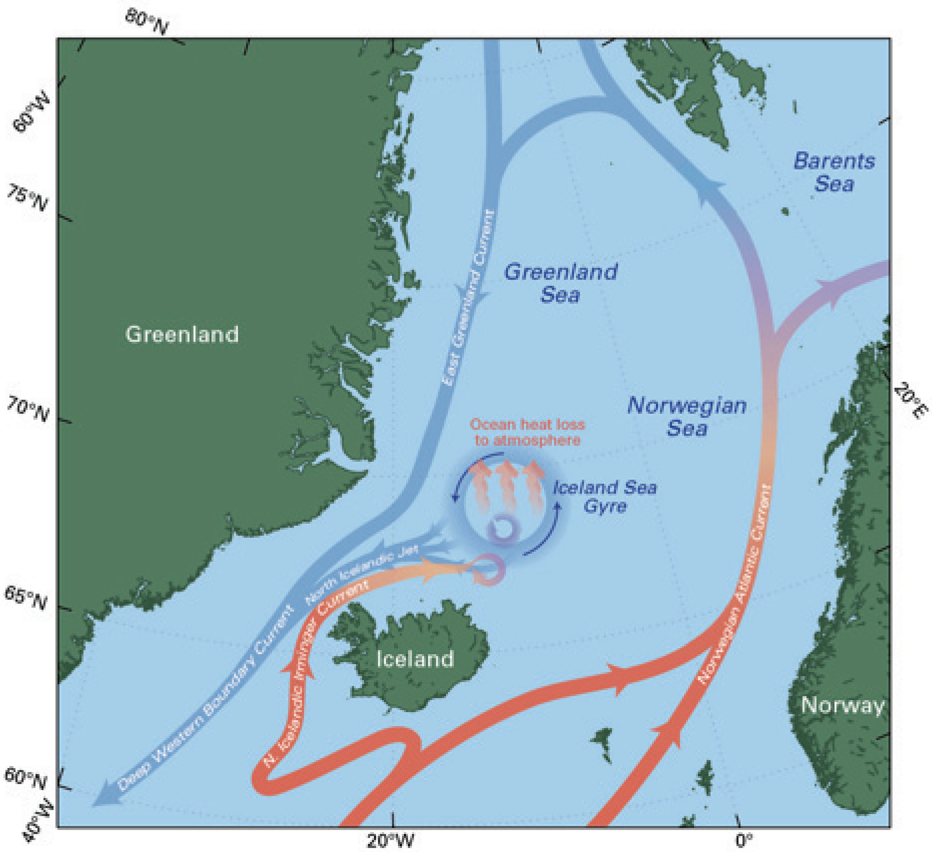

Figure 1: Schematic of the circulation and water mass transformation that supplies dense water to the Deep Western Boundary Current (DWBC). The traditional view suggests that water flows directly from the Norwegian Atlantic Current into the East Greenland Current (with a contribution from the Arctic) and then into the DWBC. Recent evidence suggests that the North Icelandic Jet, emanating from the Iceland Sea gyre, supplies roughly half of the dense water through Denmark Strait.

Oceanography

The wintertime conditions in the Iceland Sea, including the circulation and water mass transformation, are presently not well understood. Limited historical hydrographic data, and more recent Argo float data, suggest that there is a cyclonic gyre in the Iceland Sea (Figure 1) with concomitant isopynical doming and weak surface stratification. Typical winter mixed layer depths appear to be less than 200 m, although there is evidence from Argo data of convection between 300m-400m in center of the sea. There is also evidence of water dense enough in the region to contribute to the Denmark Strait Overflow Water. Sea ice is present in the northwest region of the Iceland Sea with the suggestion of recent retreat of wintertime maximum extent. Oceanographic fieldwork investigating the structure and dynamics of the NIJ are ongoing. The proposed ISP fieldwork would be aimed at understanding the source of the water supplying the NIJ, thereby shedding light on its sensitivity to climate change.

Meteorology

The meteorology of the Iceland Sea is largely unknown. The Greenland Flow Distortion Experiment was focused on the region south of the Denmark Strait, although one mesoscale cyclone flight was made over the Iceland Sea. There was an Icelandic Met Buoy deployed in the region (68.5^{o}N, 9.40^{o}W) from Nov 2007-Aug 2009. Some analysis of the data has been done but perhaps most importantly, the buoy survived two winters in this region.

The Iceland Sea lies near a saddle point in the sea-level pressure field that exists between the Icelandic Low and Lofoten Low (Figure 2). Depending on the relative strength of these two synoptic-scale low pressure systems, one can either have northerly or southerly flow over the region. In the mean, this results in low wind speeds over the Iceland Sea, although the distribution is bipolar.

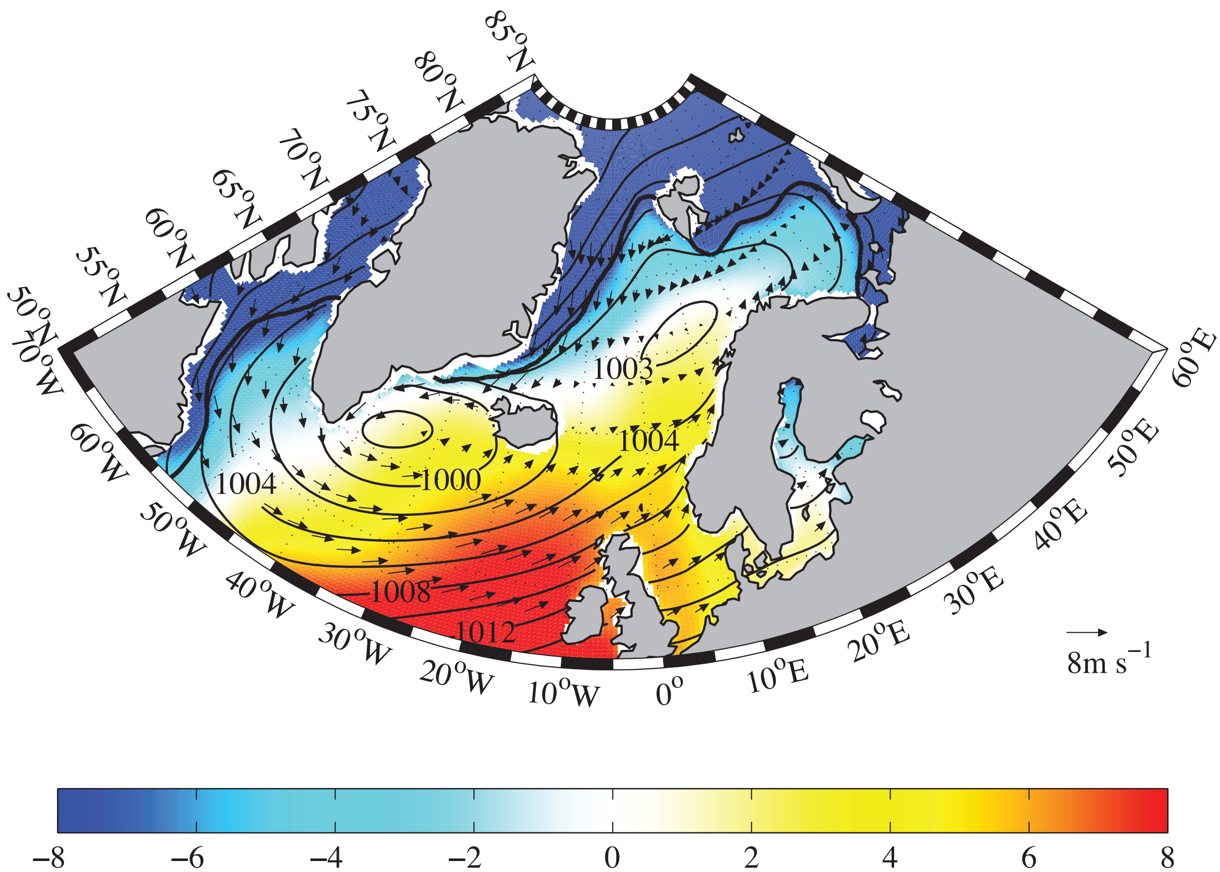

Figure 2) Winter mean (DJFM) climatology of the sea-level pressure (mb-contours); the 10m wind (m/s-vectors) and the 2m air temperature (^{o}C-shading) from the ERAI 1979-2012. The thick black line represents the 25% winter mean ice concentration isocontour.

Despite the presumed importance of Iceland Sea convection in forming much of the Denmark Strait Overflow Water, a new high resolution climatology of the air-sea heat fluxes over the Nordic Seas indicates that there is a local minimum in both the sensible and latent heat fluxes over the Iceland Sea (Figure 3). This minimum is the result of relatively cold SSTs associated with the East Icelandic Current emanating from the Greenland slope as well as low wind speeds associated with the saddle point in the sea-level pressure field. However, the meteorology of the region appears to be quite subtle with the possibility of either cold air outbreaks during northerly flow or warm air advection during southerly flow. Northerly flow in the region has the potential to access the cold air over the sea ice along the northeast coast of Greenland (Figure 2). During a typical winter month, there are approximately 3-4 cold air outbreaks over the region. This is modulated by the phase of the sea-level seesaw between the Icelandic and Lofoten Lows.

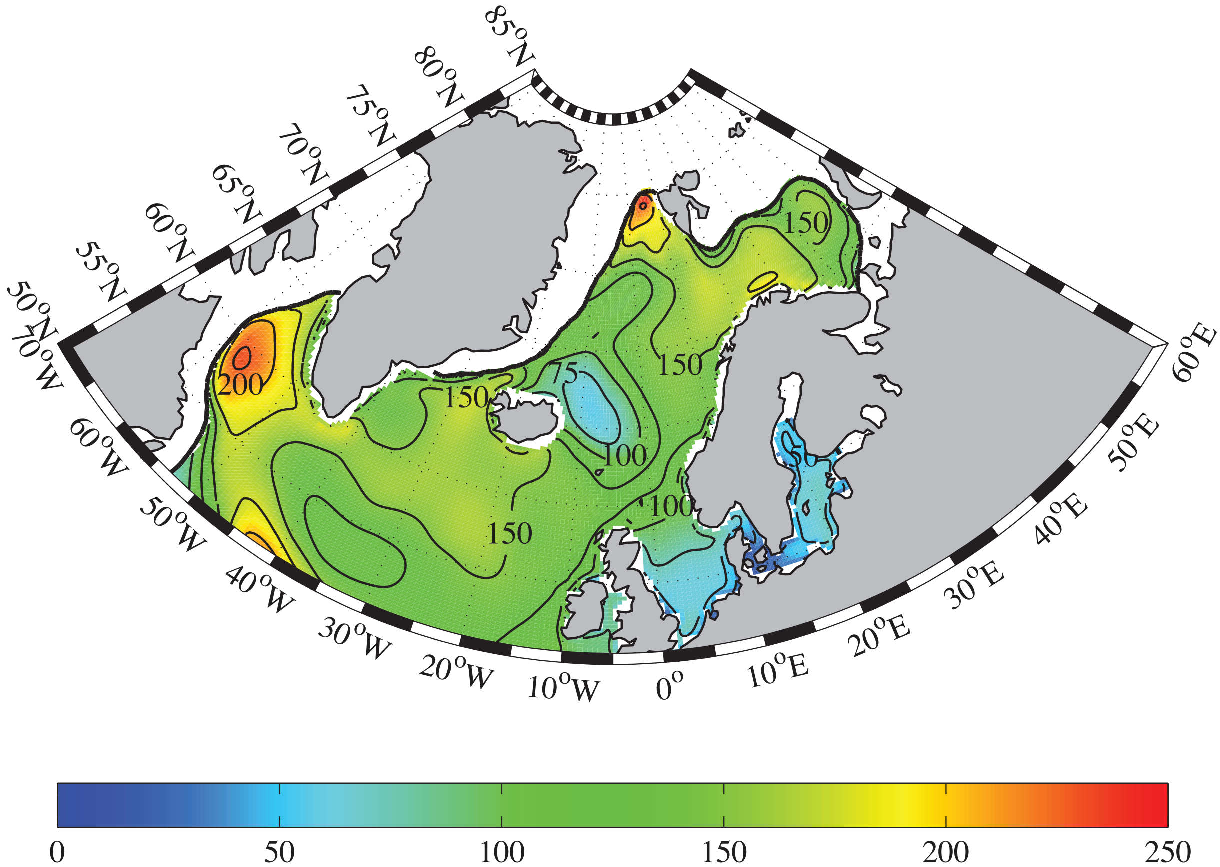

Figure 3) Winter mean (DJFM) climatology of the total turbulent heat flux (W/m²- contours and shading) from the ERAI 1979-2012. The thick black line represents the 25% winter mean ice concentration isocontour.

The recent retreat of sea ice along the east coast of Greenland and the warming trend in surface air temperature over the Nordic Seas implies that there is a trend towards weaker air-sea interaction over the Iceland Sea. There is also evidence of barrier flow along the northeast coast of Greenland that plays a role in cold air outbreaks over the Iceland Sea. Flow distortion over Jan Mayen, including the formation of von Karman vortex streets, is a common occurrence during cold air outbreaks (Figure 4). Overall, it is not obvious how the complex meteorology in the region of the Iceland Sea, and its link to the far-field atmospheric conditions, results in convection and water mass transformation in the Iceland Sea Gyre that in turn feeds the NIJ. This forms the primary motivation for the ISP.

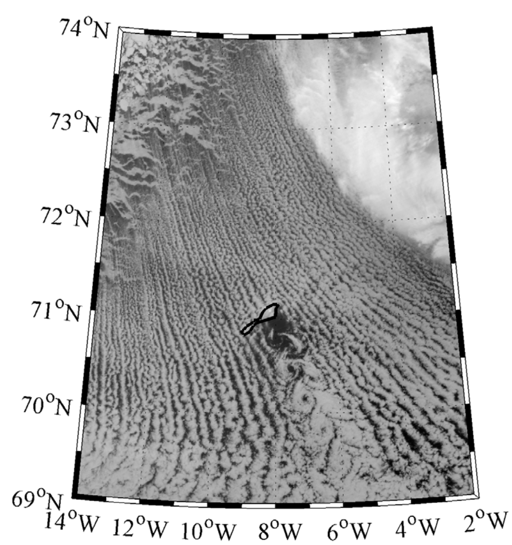

Figure 4) MODIS IR satellite image from 12Z Feb 24 2009 showing a cold-air outbreak over the Greenland and Iceland Seas. Flow distortion near Jan Mayen (center of the image) has resulted in the formation of a von Karman vortex street downstream of the island.

Objectives

Based on the results presented at the meeting, we propose the following major objectives:

1) Oceanographic

- To document the seasonal cycle of convection and restratification in the central Iceland Sea, including the mixed-layer development, in light of the air-sea buoyancy forcing.

- To determine the lateral extent of the convection and the volume and water mass characteristics of the transformed water.

- To characterize the broad-scale circulation in which the convection occurs and verify the link between the interior transformation process and exit pathway of the North Icelandic Jet.

2) Meteorological

- To characterize and quantify the air-sea buoyancy fluxes in the Iceland Sea including its seasonality and the evolution during high impact weather events.

- To characterize the spatial and temporal evolution of the atmospheric boundary layer during cold air outbreaks over the Greenland and Iceland Seas.

- To characterize the far-field atmospheric conditions, including flow distortion along the northeast coast of Greenland and in the vicinity of Jan Mayen Island, that influence and promote the cold-air outbreaks.

Observing Platforms

The beginnings of a synergistic atmospheric-oceanographic field program emerged from the meeting that will enable the above objectives to be achieved. The program builds upon a strong research partnership between the participating meteorologists and oceanographers extending back over 15 years. We discussed in turn the potential contributions from each of the international partners, and the timing of the program.

1) Oceanographic

WHOI is aiming to carry out a dedicated winter cruise to the Iceland Sea to undertake hydrographic (CTD, water sampling) , velocity (VMADCP), and surface and upper-air observations. An oceanographic profiling mooring (WHOI) and a meteorological surface buoy (IMO) will also be deployed in the center of the gyre to provide longer-term time series of the atmospheric forcing and the oceanographic response. At least two gliders will be deployed by UIB that will traverse the Iceland Sea. Available ARGO float data from the region will be accessed, and UIB aims to deploy additional ARGO floats during the program. Finally, moorings will be maintained at different locations in the NIJ by MRI. The moorings (both in the center of the gyre and in the NIJ), glider transects, and met buoy will be operational for the complete calendar year bracketing the winter cruise and the aircraft work.

2) Atmospheric

A bid will be made for instrumented aircraft time on the FAAM's BAE 146 (UEA, UT). This medium-range well-instrumented and reasonably flexible research aircraft will be available to undertake observations over the Iceland Sea, based out of Iceland. The project team has a good track record arising from the success of GFDex. There is the possibility of additional flight hours being made available to EU partners (e.g. Norway and Iceland) to provide supplementary flight hours, but only if the EUFAR trans-national programme restarts in time or additional outside funding is obtained. The FAAM's station time over the Iceland Sea would be similar to that during GFDex and would be sufficient to sample both the surface meteorology and upper-air structure. However, it is limited in its abililty to operate north of Jan Mayen. This would curtail sampling of the upwind air mass modification that occurs close to the ice edge during cold air outbreaks. The availability of an additional long-range aircraft asset such as the NCAR C-130 or a NOAA P-3 would therefore be an advantage.

There are a number of radiosonde stations in the region, including Jan Mayen, that would be of benefit to the experiment.

In situ observations of the atmosphere will also be made during the wintertime cruise. A radiosonde programme will be undertaken, e.g. with UK equipment (as was done for October 2008 cruise). Additionally, an unmanned aircraft sampling programme is planned with the SUMO aircraft (UIB, IMO). It would also be an asset to involve an experienced team to measure eddy covariance air-sea fluxes, e.g. the ETL team, during the cruise.

In addition to products from major national and international meteorological services, specialized real-time forecasting support for the experiment has been pledged by StormGeo, a Norwegian weather services company with extensive experience in offshore weather forecasting.

Timing

The winter of 2014-15 is the target winter, with cruise and aircraft operations during the period from Jan – Mar 2015. Every attempt will be made to coordinate the submission of proposals and facilitate interaction between the cognizant program managers, in order to maximize the synergy of the atmospheric and oceanographic components of the project.