Optimizing monitoring of volume, heat, and salt transport across the Greenland-Scotland Ridge towards the Arctic

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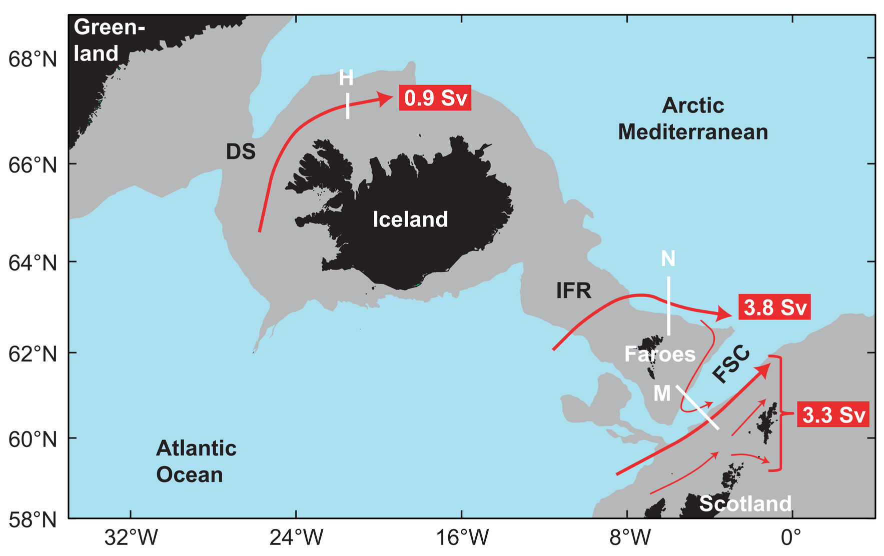
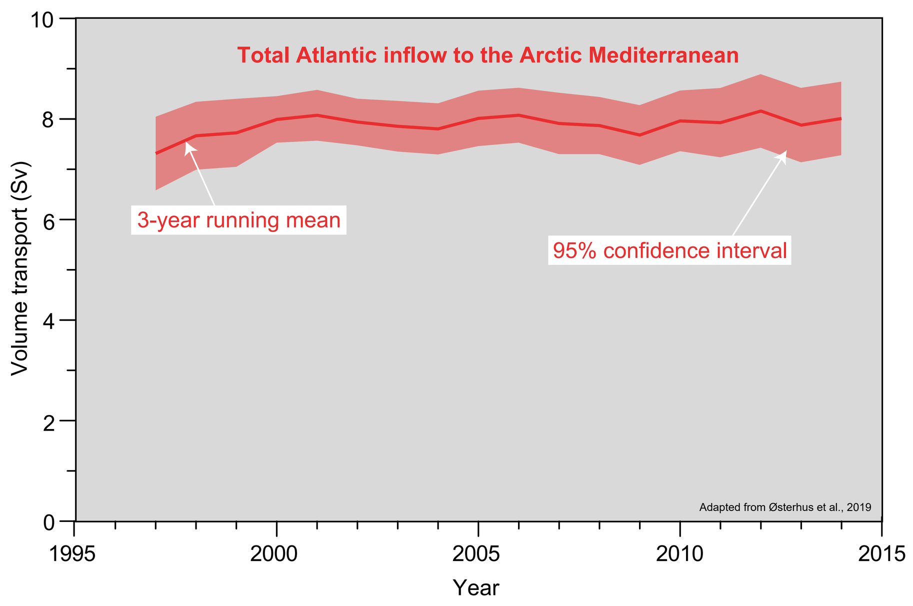
Rationale

The inflow of warm and saline water of Atlantic origin across the Greenland-Scotland Ridge into the Arctic Mediterranean (Arctic Ocean + Nordic Seas) has a large impact on the climate and sea-ice in the Arctic. This flow is a main component of the AMOC, which is projected to weaken due to climate change and the knowledge of its variability and possible trend is therefore of huge importance in predicting Arctic climate change. The inflow has been monitored since the late 1990s with moored instrumentation combined with regular hydrographic cruises and data from satellite altimetry, but deploying moorings in the heavily fished region close to the Greenland-Scotland Ridge is highly demanding in terms of manpower and funding. Efforts have therefore been made to optimize the monitoring systems. These efforts have been focused and intensified within the H2020 Blue-Action project.

Three main inflow branches



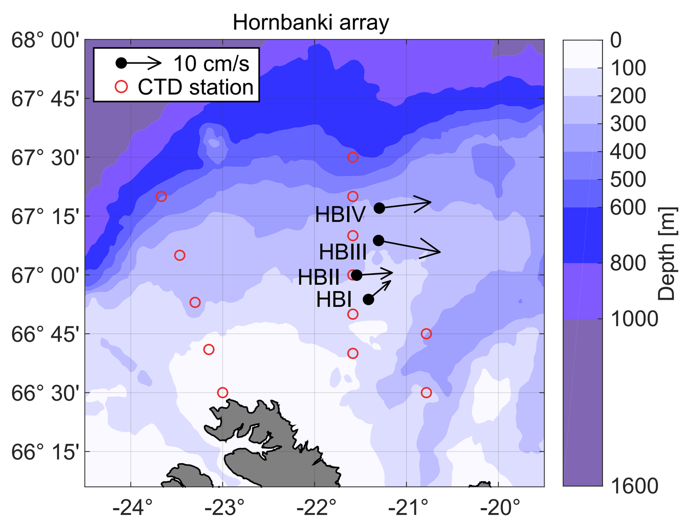
The Greenland-Scotland Ridge (grey areas are shallower than 750 m) is split by three gaps (DS = Denmark Strait, IFR = Iceland-Faroe Ridge, FSC = Faroe-Shetland Channel). Warm Atlantic water crosses the Ridge through all of these gaps (red arrows) with a total average volume transport around 8 Sv (1 Sv = 10^6 m^3 s^{-1}). Monitoring of volume transport, temperature, and salinity has been focused on three sections crossing the flows (white lines labeled H, N, and M). (Østerhus et al., 2019).

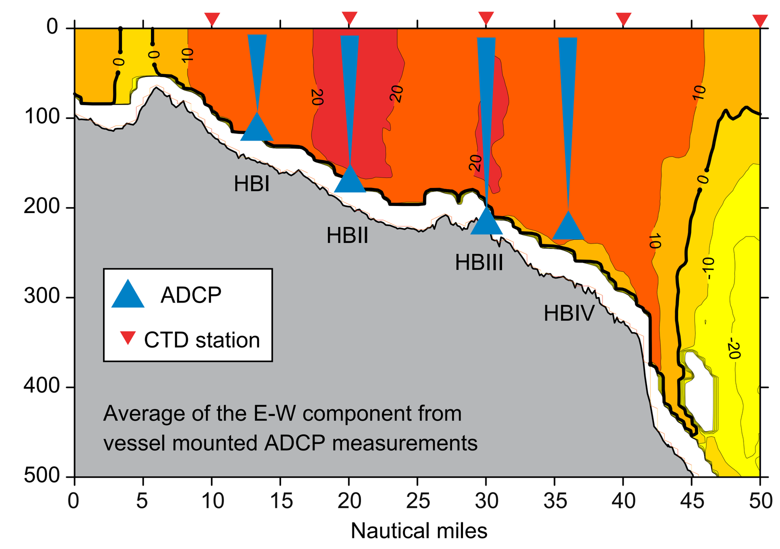


Although some of the individual time series have gaps, they may be combined to allow estimates of long-term variations of the total volume transport, which has exhibited a high degree of stability. Transports of heat and salt then depend primarily on the variations of temperature and salinity. The overarching question for future monitoring is:

Will the Atlantic inflow to the Arctic Mediterranean remain stable?

Inflow between Greenland and Iceland



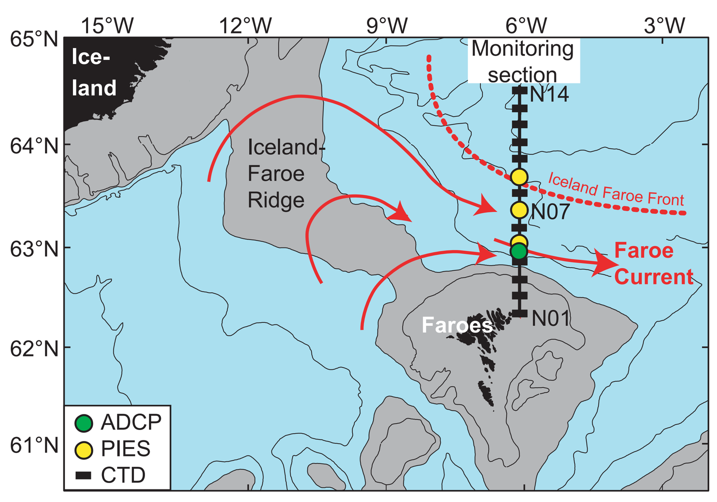


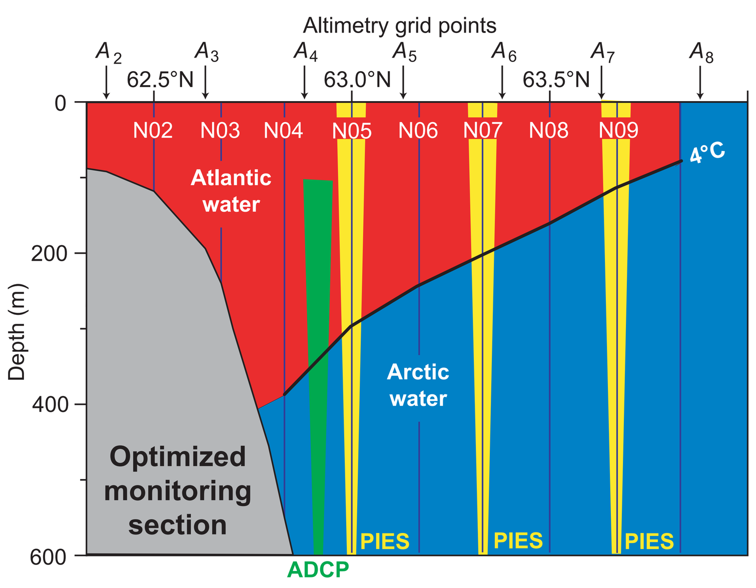
The North Icelandic Irminger Current (NIIC) carries Atlantic water through Denmark Strait into the Iceland Sea. The Atlantic water inflow is highly variable due to mixing with Polar water and wind stress. In addition to five CTD stations taken 4x per year, the Atlantic water inflow has been monitored at Hornbanki by moored current meters since 1994, and ADCPs since 2009. The volume flux is determined by integration of the velocity measurements, and the mixing ratio of Atlantic and Polar water by applying a mixing scheme to the T/S data provided by Microcats on the moorings (Jónsson and Valdimarsson, 2012).

Between one and four moorings (HBI to HBIV) have been deployed. Altimetry was not used for optimization, as Hornbanki is north of the Topex/Poseidon turning latitude, and close to coast and sea ice, making altimetry less reliable. Instead, it has been investigated how much difference it makes if fewer moorings are used, revealing that a reasonable estimate of the transport can be obtained with HB III (and HB II) alone. These turned also out to be the safest positions, while at HB I and HB IV moorings were lost due to fishing or icebergs.

– ***The optimized monitoring system for this inflow branch will therefore combine observations from one or two ADCPs and Microcats as well as four annual CTD surveys to track long-term water mass variations.***

Inflow between Iceland and Faroes



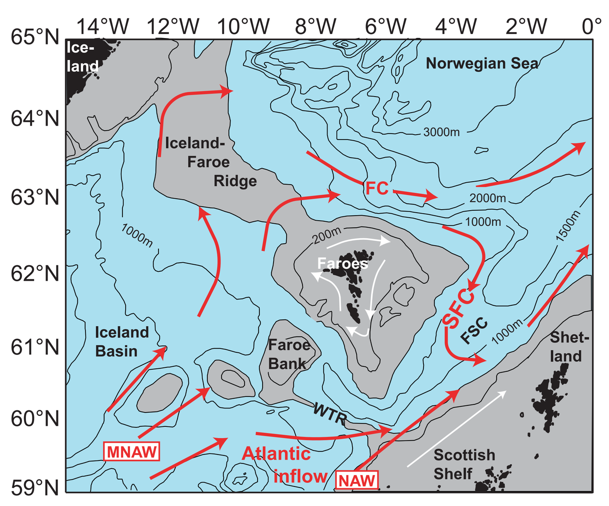


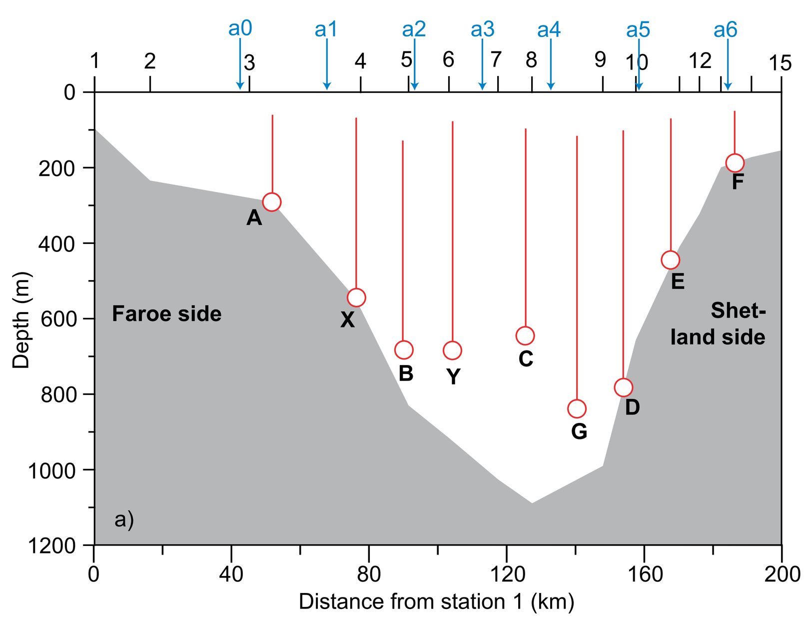
Atlantic water crosses the Iceland-Faroe Ridge over most of its width (red arrows on left panel), but east of the ridge it gets focused into a boundary current, the Faroe Current, which is narrower and more easily monitored on a section crossing the flow (section N). Since the late 1980s, CTD profiles have been regularly obtained at 14 standard stations along this section. To establish transport monitoring, ADCP arrays were deployed on the section from 1997 to 2015, but analysis of the data has shown that satellite altimetry may provide a better representation of the velocity field on the section than even a dense ADCP array, once the altimetry has been calibrated by the ADCP data (Hansen et al., 2015; Hansen et al., 2019a). The future monitoring system will therefore maintain only one ADCP at a long-term deployment site to complement altimetry for monitoring the velocity field.

To monitor transport of Atlantic inflow, the Atlantic water on the section has to be distinguished from other water masses of Arctic origin and the 4°C isotherm has been found to represent the deep boundary of the Atlantic water. This isotherm may be accurately mapped by CTD surveys, but they are demanding in manpower and ship-time and therefore infrequent. To test a system for continuous isotherm monitoring, two PIES (Pressure Inverted Echo Sounders) were deployed on the section 2017-2019 in a cooperation between the Faroe Marine Research Institute and the University of Hamburg. The results from this experiment have been analyzed within the Blue-Action project and the FARMON projects funded by the Danish government. They were very successful (Hansen et al., 2019b).

– ***The optimized monitoring system for this inflow branch will therefore combine satellite altimetry with observations from one ADCP and three PIES in addition to three annual CTD surveys to track long-term water mass variations.***

Inflow between Faroes and Scotland





The Atlantic waters between the Faroe Islands and the Scottish continental shelf originate from a few different regions: (1) along the Scottish shelf edge, the European continental slope current transports Atlantic waters northeastward, (2) water masses from the Rockall Trough and Hatton Rockall Basin flow across the Wyville Thomson Ridge, and (3) close to the Faroe Islands, Atlantic water from the Faroe Current (FC) flows southwestward close to the Faroe shelf (SFC), before re-circulating (red arrows on left panel, adapted from Hansen et al., 2017). Monitoring of temperature and salinity on two hydrographic sections across the Faroe-Shetland Channel (FSC) dates back to the 1890s, but regular data collection with CTD profilers was established only in the 1980s. Since 1995, ADCP moorings have collected direct observations of the strength of the Atlantic circulation in this region. Using a calibration of satellite sea surface height observations, the Atlantic inflow time series has been generated for the whole altimetry period starting in 1993 (Berx et al., 2013).

Work is still underway to further optimize the monitoring of Atlantic inflow in the Faroe-Shetland Channel. Up to 6 ship-based surveys, in combination with satellite altimetry will hopefully allow for a time series of heat and salt transport to accompany the already established volume transport time series. Some Atlantic water also flows on the Scottish continental shelf, and currently a data collection and numerical modelling effort is underway to help quantify the contribution of this shallow transport branch, which has previously not been monitored.

– ***The optimized monitoring system for this inflow branch will combine satellite altimetry with ship-based surveys and a small number of moored instruments.***

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References: Berx et al., 2013 (doi: 10.5194/os-9-639-2013); Hansen et al., 2015 (doi:10.5194/os-11-743-2015); Hansen et al., 2017 (doi:10.5194/os-13-873-2017); Hansen et al., 2019a (http://www.hav.fo/PDF/Ritgerdir/2019/TechRep1901.pdf); Hansen et al., 2019b (http://www.hav.fo/PDF/Ritgerdir/2019/TechRep1902.pdf); Jónsson and Valdimarsson, 2012 (doi.org/10.1093/icesjms/fss024); Østerhus et al., 2019 (doi:10.5194/os-15-379-2019).

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BLUE ACTION
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