Near-bottom temperature and salinity evolution around Iceland, 1975-2007

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Motivation and Data set

The near-bottom water masses in the deep basins of the northern North Atlantic and the Nordic Seas hold major temperature differences due to the barrier formed by the Greenland-Scotland-Ridge (GSR). Deep water exchanges across the ridge are prohibited, and only limited water mass exchange in intermediate layers is possible through deep channels (the Nordic Overflows).

The shallow surface layers exhibit warm and saline Atlantic water flowing north-eastward across most of the ridge, only at the western GSR cold and fresh water is transported south-westward within the East Greenland Current.

The GSR and its environmental conditions shape the species distribution and composition of particular benthic groups in this region. Species distribution models (SDMs), which use spatial environmental variables, can lead to a better understanding of species distributions within the marine environment.

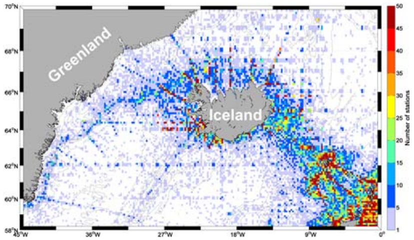

Fig. 1: Gridded data distribution in the area of investigation. The overall maximum number of measurements for a few grid cells is exceeding 300 and is thus out of scale, which was adjusted to the range of the most common numbers of measurements in the cells. The bottom depth is taken from ETOPO2 bathymetry and contours illustrate the [5000 4000 3000 2000 1500 1000 500 300 100] m depth levels.

Here we use near-bottom measurements of about 88,000 CTD (conductivity-temperature-depth) and bottle profiles, collected in the period 1975-2007 (Fig. 1 and 2). The data is quality and depth-checked against the ETOPO2 topography and then gridded into regular boxes of about 11 km size. We apply an interpolation scheme following isobaths (*Davis, 1998*) and derive average spatial temperature and salinity distributions in the region around Iceland, showing the influence of the GSR on the near-bottom properties. These spatial property distributions can provide the basis for SDM modelling.

Furthermore we present an analysis of the seasonal and interannual variability of properties around Iceland and the Faroes for boxes where the data coverage is sufficient.

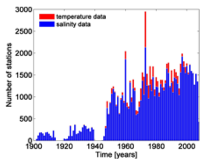

Fig. 2: Number of annual stations from 1900 to 2008. Blue: temperature and salinity data; red: temperature data only. In total 88,046 temperature and 79,856 salinity measurements were used for the analysis, covering the period 1975-2007.

Average near-bottom temperature and salinity distribution

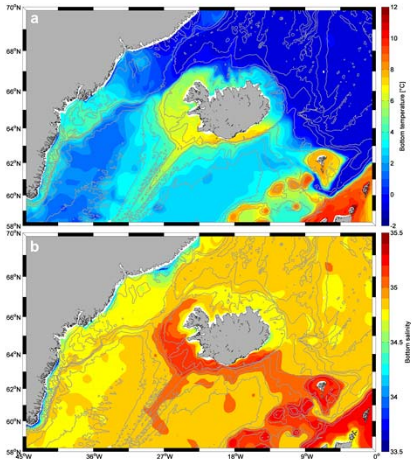

Fig. 3: Interpolated gridded mean bottom properties. a: temperature; b: salinity. An interpolation scheme following isobaths (f/H contours) was applied. The bottom depth contours illustrate the [3000 2000 1500 1000 500 250] m depth levels.

The variability of the hydrographic properties in the considered region is largest at shallow depths and confined to a distinct T/S space at depths > 500 m, which is illustrated in the temperature-salinity diagram in Figure 4. The coldest and densest water masses are found in the deep basins north of the ridge (purple circle in Fig. 4). The warmest and saltiest waters are associated with the North Atlantic Current branches at the southern GSR at shallow and intermediate depth levels (yellow circle in Fig. 4).

As seen in the near-bottom distribution of the hydrographic properties (Fig. 3), the GSR clearly separates warm Atlantic waters in the south from cold waters in the north for depth levels >1000 m.

The shallow East Greenland Current and the Denmark Strait overflow flow southwestward along the Greenlandic coast and shelf break. The overflow is seen as the narrow band of low bottom temperatures connecting the basins north and south of Denmark Strait. South of Denmark Strait East Greenland Current Waters mix with Atlantic Waters in the Irminger Current, which leads to warmer waters on the Greenlandic shelf. Salinity close to the Greenlandic shore is fairly low due to local ice and glacial melt compared to all other regions of the whole research area.

The water temperatures on the coastal region around the Faroe Islands and on the Faroe Plateau show the highest temperatures within the whole considered area. Cold overflowing waters are recognized through the Faroe Bank Channel southeast of Iceland between the Faroe Bank and the Faroe Plateau. Entrainment into the overflow is indicated by the subsequent warming of the bottom temperatures along the channel.

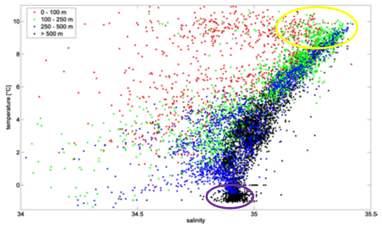

Fig. 4: Temperature-salinity diagram of the gridded data, colored in depth classes (see figure legend and Figure 5). The purple and yellow circles mark the water masses of the northern basins and the shallow shelf regions south of the ridge, respectively.

Acknowledgments

The hydrographic data were provided by: The Marine Research Institute, Iceland; Institute of Marine Research, Norway; the Faroese Fisheries Laboratory; the Arctic and Antarctic Research Institute, Russia, and Geophysical Institute, University of Bergen, Norway, through the NISE project (*Nilsen et al., 2008*).

ETOPO2v2 is a global gridded 2-minute database, provided by the National Geophysical Data Center, National Oceanic and Atmospheric Administration, U.S. Dept. of Commerce on http://www.ngdc.noaa.gov/mgg/global/etopo2.html.

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Seasonal and interannual variability

Only grid cells containing more than 100 data points were considered for time series analysis, as sufficient data resolution is needed to obtain robust results. The 102 selected grid cells were sorted into depth classes according to the average bottom depth within each cell (Fig. 5).

For each of the selected cells the average seasonal cycle was determined by a harmonic analysis. The average seasonal amplitude, as well as the long-term trends obtained from the de-seasoned hydrographic measurements are summarized in Table 1 for each depth class.

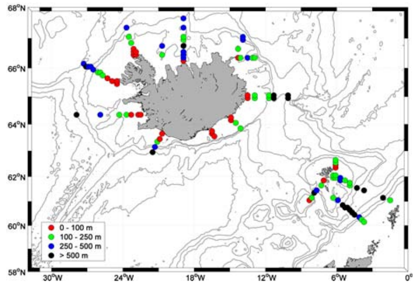

Fig. 5: Grid cells with more than 100 data points, which were selected for further analysis. The cells were ordered into classes according to the average depth in each cell. Red: 0-100 m; green: 100-250 m; blue: 250-500 m; black: deeper than 500 m. Bottom depth contours as in Fig. 3.

Temperature

depth class	number of boxes	av. seasonal amplitude	av. decadal trend
1	27	4.3°C	0.33°C/10 years
2	36	2.2°C	0.31°C/10 years
3	21	0.9°C	0.13°C/10 years
4	18	0.3°C	0.05°C/10 years

Salinity

depth class	number of boxes	av. seasonal amplitude	av. decadal trend
1	26	0.11	0.03/10 years
2	34	0.07	0.03/10 years
3	18	0.03	0.01/10 years
4	18	0.01	0.00/10 years

Table 1: Results of the time series analysis for temperature and salinity. Depth class: depth class of grid cell as shown in Fig. 5; number of boxes: quantity of grid boxes for the given depth class; av. seasonal amplitude: averaged amplitude of the seasonal variability in the given depth class; av. decadal trend: averaged decadal trend in the given depth class.

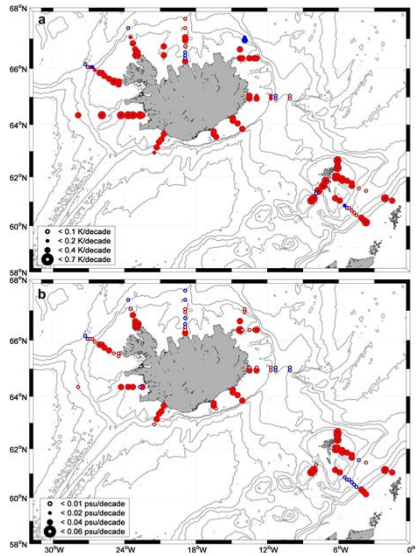

Fig. 6: Temperature (a) and salinity (b) trends in relation to a 10 year period for grid boxes with more than 100 data points. Blue colors denote negative trends, red colors mark positive trends. The size of the circle gives the magnitude of the trend (see figure legend). Bottom depth contours as in Fig. 3.

The spatial distribution of the obtained trends is illustrated in Figure 6. Warming is most pronounced on the shallow shelf around the Faroes, the northern Shetlands and northwest Iceland. These regions correspond to the position of the Atlantic inflow branches into the Nordic Seas. Warming decreases with depth and in some deep or overflow areas even negative trends were found.

In salinity, the trends show a similar distribution: salinification on the shallow shelf and no or small trends in the deep areas, where even freshening was found (e.g. the Faroe Shetland Channel).

Our results indicate a warming and salinification of the Atlanitc inflow water when entering the Nordic Seas, which is in agreement with other recent studies (e.g. Yashayaev and Seidov, 2015).

References

Davis, R. (1998), Preliminary results from directly measuring mid-depth circulation in the tropical and South Pacific, Journal of Geophysical Research, 103, doi:10.1029/98jc01,913.

Nilsen, J., H. Hatun, K. Mork, and H. Valdimarsson (2008), The NISE Dataset, Tech. rep., Faroese Fisheries Laboratory, Box 3051, Torshavn, Faroe Islands.

Yashayaev, I., and D. Seidov (2015), The role of the Atlantic Water in multidecadal ocean variability in the Nordic and Barents Seas, Progress in Oceanography, in press, http://dx.doi.org/10.1016/j.pocean.2014.11.009.

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