

# Seasonal and Interannual Variability of the Nordic Seas Circulation

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## 1. INTRODUCTION

The Nordic Seas are major exchange regions between the Arctic and Atlantic oceans. The main surface circulation consists of the East Greenland Current (EGC) transporting cold and fresh water from the Arctic to the North Atlantic, and the continuation of the North Atlantic Current transporting warm and saline water masses northward along the Norwegian coast and to the west of Spitsbergen through the Fram Strait, towards the Arctic. In general the upper layers of the Nordic seas consist of warm and salty Atlantic water in the east and fresh and cold polar waters in the west. Furthermore, there are two major cyclonic gyres in the Greenland and Norwegian Seas located between the two main currents. The surface circulation in the Nordic seas is shown below.

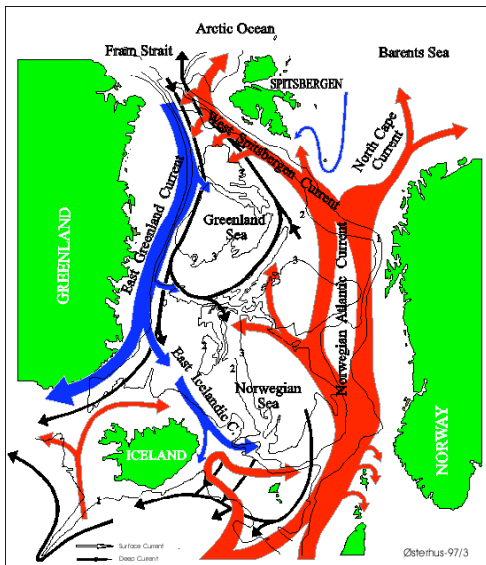


Fig. 1. Surface circulation in the Nordic Seas. Warm and saline Atlantic water is marked in red. Cold and fresh water transported from the Arctic by the East Greenland Current is marked in blue. (Source: Eliassen et al. (2000), *The Current Conditions at Ormen Lange-Storegga*, <http://www.uib.no/People/nmaic/ormen/notat/ol/img26.gif>)

The circulation in the Nordic Seas is known only during the summer because of the unavailability of in situ data from sea-ice regions during the winter. It is known that the surface circulation exhibits seasonal variability in relation to a wind stress and heat exchanges between ocean and the atmosphere. Recently it became possible to use satellite radar altimeter data to obtain sea surface height measurements also in the ice-covered seas (Peacock and Laxon, 2004). This research uses this novel technique in order to describe seasonal and interannual circulation variability in the Nordic Seas.

## 2. METHODS

Sea surface height anomaly (ssha) was measured by the radar altimeter (RA-2) on board Envisat satellite. The data was corrected by applying a set of relevant geophysical corrections: atmospheric, inverse barometer and tides. The processing of ssha in sea-ice regions was performed by Seymour Laxon, Centre for Polar Observation and Modelling, using a method described in Peacock and Laxon (2004). The data analysed here consists of two data sets: open ocean and sea-ice region. In total fifty three months of data are available, starting from October 2002.

It was found that the altimeter measurements had a lot of single spikes that were much higher than the expected values of ssha (from -1m to 1m). Therefore, data was filtered by removing the ssha greater (or less) than three standard deviations from the monthly mean from each data set. The two data sets (ice and ocean) were processed separately because of the possible offset between them. Afterwards, data was gridded into square boxes and the currents were calculated using the geostrophic equations:

$$\begin{aligned} x) \quad V &= g/f \partial ssha / \partial x \\ y) \quad U &= -g/f \partial ssha / \partial y \end{aligned}$$

where  $V, U$  are the velocity components,  $g$  is a gravitational acceleration of the Earth ( $9.81 \text{ m/s}^2$ ),  $f$  is the Coriolis parameter and depends on latitude,  $x$ -longitude,  $y$ -latitude. The velocity components were averaged into three months means to describe seasonal variability of the circulation.

## 3. PRELIMINARY RESULTS

The variation of the sea level can be caused by changes in atmospheric pressure, wind and the expansion/contraction of the water column above the thermocline due to heating/cooling (steric effect). Furthermore, the convergence, created by the wind stress, generates heat and salt changes in the mixed layer. Additionally, the Ekman pumping acts to displace the seasonal thermocline. Previous research of seasonal variability in the region (Gill and Niller, 1973) showed that the local heat flux is mainly responsible for seasonal changes in SSH. The seasonal steric height can explain 1.4cm - 4cm (up to 40% of SSHA) of the SSH variation but the associated changes in the surface currents are very small- few mm/s (Mork and Skagseth, 2005).

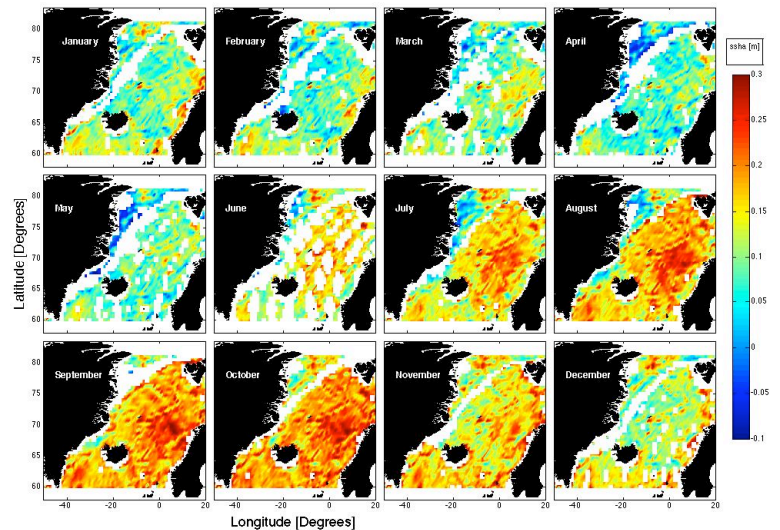


Fig. 2. Sea surface height anomalies [m] averaged over 4 years (2002-2006). Data was gridded into 0.5 (latitude) x 1 (longitude) degree boxes.

Hovmoller diagrams show seasonal variability as rises and falls of ssha with the period of six months. The propagation of Rossby or other waves was not observed.

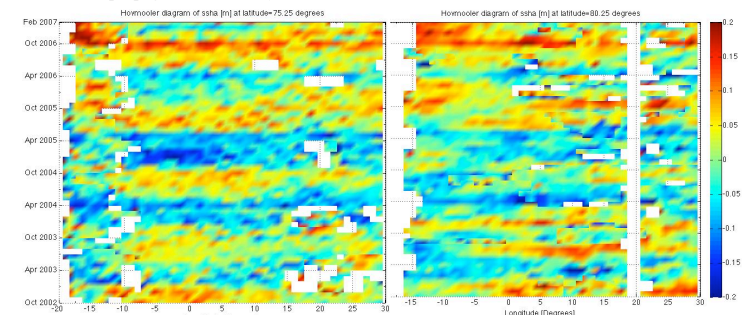


Fig. 3. Hovmoller diagrams showing time series of sea surface height anomalies [m] at 75.25°N and 80.25°N.

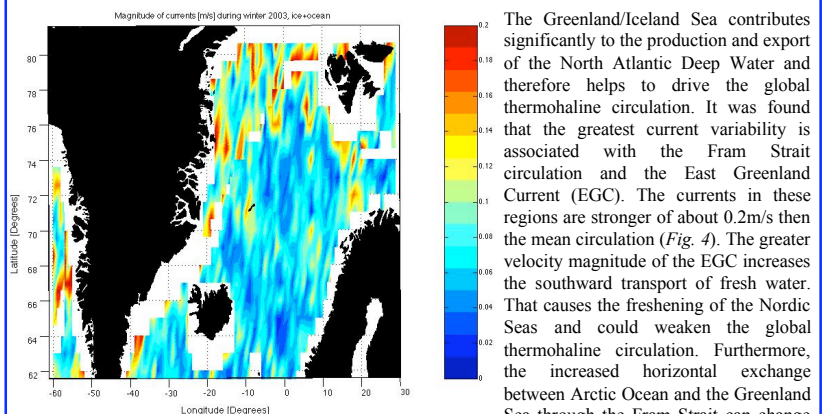


Fig. 4. Magnitude of current velocity anomaly [m/s] in winter 2003.

## REFERENCES

- Gill A.E., Niller P.P. (1973), The theory of seasonal variability in the ocean, *Deep-Sea Research*, 20, pp. 141-177.  
 Mork K.A., Skagseth O. (2005), Annual Sea Surface Height Variability in the Nordic Seas, *The Nordic Seas: An Integrated Perspective*, AGU, pp. 51-64.  
 Peacock N.R., Laxon S.W. (2004), Sea surface determination in the Arctic Ocean from ERS Altimetry, *J. Geophys. Res.*, 109, C07001.

The Greenland/Iceland Sea contributes significantly to the production and export of the North Atlantic Deep Water and therefore helps to drive the global thermohaline circulation. It was found that the greatest current variability is associated with the Fram Strait circulation and the East Greenland Current (EGC). The currents in these regions are stronger of about 0.2m/s than the mean circulation (Fig. 4). The greater velocity magnitude of the EGC increases the southward transport of fresh water. That causes the freshening of the Nordic Seas and could weaken the global thermohaline circulation. Furthermore, the increased horizontal exchange between Arctic Ocean and the Greenland Sea through the Fram Strait can change the properties of the Greenland Deep water and therefore could generate changes in the North Atlantic Deep water formation.