Modelling the overflow of brine-enriched shelf water from Storfjorden by Bjørn Ádlandsvik and Ilker Fer

Introduction

Storfjorden is a well documented area with production of brine-enriched dense water. This shelf-produced water overflows a sill (marked by arrows below), forms southwesternly in Storfjorden, flows northward along the continental slope, and when its density excess permits, sinks down into the Nordic Seas. Its mixing, particularly along the steepest continental slope, determines its ultimate water mass properties and depth. In 1986, the Storfjorden overflow was observed at several stations (circles below) in the Deep Fram Strait (Quaidafill et al., 1988). Predicted path of the overflow (solid line) using Killworth's constant-density pure model (Killworth, 1981) approximates the core of the plume both in the Fram Strait and in Storfjorden (squares show the observed core of the plume in June 2005, Fer et al. 2005). A hydrostatic, reduced-gravity plume model was previously applied to the overflow (Jungclaus et al., 1995) and the mixing and spreading of the overflow was most recently studied by Fer et al. (2004).

Volumetric analysis

Initially, there is 43 km$^3$ of water with density, $\rho = 28.2$ in Storfjorden. The total production of dense water with $\rho > 24.95$ over a 150-day period is 77 km$^3$.

Volume flux

The figure shows time evolution of the volume flux of brine enriched water (defined by $\rho > 28.1$) through various sections shown in a preceding figure. Also shown is the forcing given by production of brine water. To filter out the mesoscale fluctuations, the modelled flux series has been smoothed by a 15 day moving average.

Concluding remarks

- The path of the model-generated plume agrees with observations
- The hydrography is too much idealized for easy comparison with observations, but the mixing and entrainment seems realistic.
- The overflow is pausing, with periods of 4–10 days.
- The area with converging isobaths west of Sørkapp limits the volume and density in the plume before it reaches the west Spitzbergen slope.

References

B. Skogsholm, I. Fer, and P.M. Haugan. Dense-water production and overflow from an Arctic coastal polynya in Storfjorden. In Climate Variability of the Nordic Seas, Geophysical Monograph Series. AGU, 2004. in press.

The Regional Ocean Model System

The Regional Ocean Model System (ROMS) is a community ocean circulation model developed by Roman Arango at Rutgers University and Alexander Skougsholm at UCLAr. More documentation is found on the website http://www.mywiki.uio.no/go/tid.php?mode=roma. The ROMS model is based on the primitive Boussinesq equations. The model uses a terrain-following coordinate system in the vertical direction called “e-coordinate”. In the horizontal, general orthogonal curvilinear coordinates are used. The model uses relatively high order explicit finite differences methods with a time splitting between the fast 2D barotropic mode and the slower baroclinic 3D mode.

Model domain

Model domain covering Storfjorden and the continental slope west of Spitzbergen. The horizontal resolution is approximately 2 km.

Model set-up

The model is used in an experimental setup. The initial density structure is uniform horizontally, following vertical profiles adapted from Jungclaus et al. (1995), see below. Storfjorden north of the sill is filled up to sill depth with dense water of $\Theta = 34.9$ and $T = 0.7^\circ$C (derived from observations in October, see Fer et al. 2004) to illustrate remaining brine-enriched water from the previous season. The only forcing is brine production. This is parameterized by the river mechanism in ROMS. Dense water with salinity 35.5 and temperature $-1.8^\circ$C is introduced at bottom 10 land/sea interface locations north of the sill. The time evolution of the brine supply starts with 0.1 Sv the first month and decreases to zero at day 150, corresponding to typical average brine-water production reported for freezing periods of 1948–1982 (Skogsholm et al., 2004). The simulation continues for another 150 days without any external forcing.

Outflow from Storfjorden (28.1) through various sections shown in a preceding figure. Also shown is the forcing given by production of brine water. To filter out the mesoscale fluctuations, the modelled flux series has been smoothed by a 15 day moving average.

Model and Observations

The ambient density structure adopted from Jungclaus et al. (1995) in a virtual profile that ensures that at each depth the overflow encounters the proper water mass. However, in reality, the depth and the average properties of the water masses vary during the simulation period, in particular in Storfjorden e.g. Atlantic water. As a result, direct model–observation comparisons using temperature-salinity values are not successful. Below we attempt to compute the density anomaly (delta $\rho$, difference between the plume density and the ambient density) at two representative sections. For the model results, ambient density is the initial profile whereas for observations it is the average within 50m above the plume. For reference, if C isotherms are also shown (thick black line), Model results at Section 3, day 110, are compared to observations in August 2002 (section C of Fer et al. 2004). The section worked in June 2005 is approximately 25 km west of Section 4 (section D of Fer et al. 2003). Typical cut-off of the plume and its density anomaly are comparable to the observations, with the core lying above comparable isobaths. Across section 4, the Atlantic water is observed to have two cores with a cyclonic circulation, which lacks in our simulations. This circulation is downwelling favorable and can explain the observed downwelling of the isopycnals (see Fer et al. 2005, Fig. 8).

Downstream section

The figure shows the salinity and the 28.1 isopycnal along the downstream section at simulation day 150.

Temperature at station B

The colour palette shows the temperature development at the bottom 100 meter at station B. The contour line indicates the 28.1 isopycnal.

Here, we use a 3D shell circulation model, in an idealized setup, to study the pathway of this water mass and its evolving water mass properties due to mixing with the surrounding water masses.

The overflow is pulsating, with periods of 4–10 days.

The path of the model-generated plume agrees with observations

The area with converging isobaths west of Sørkapp limits the volume and density in the plume before it reaches the west Spitzbergen slope.

The only forcing is brine production. This is parameterized by the river mechanism in ROMS. Dense water with salinity 35.5 and temperature $-1.8^\circ$C is introduced at bottom 10 land/sea interface locations north of the sill. The time evolution of the brine supply starts with 0.1 Sv the first month and decreases to zero at day 150, corresponding to typical average brine-water production reported for freezing periods of 1948–1982 (Skogsholm et al., 2004). The simulation continues for another 150 days without any external forcing.