Eddy overturning across a shelf edge front.

V. Tverberg and O. A. Nøst
Norwegian Polar Institute, Tromsø, Norway

F. Cottier, Scottish Association for Marine Research, Oban, UK.
F. Nilsen, University Centre in Svalbard, Longyearbyen, Norway

Abstract

Eddy overturning across a shelf edge front has been investigated in a simplified model setup comprising an along-slope uniform shelf and slope with a slope current, and is initiated with temperature and salinity data collected off Kongsfjorden at Spitsbergen. The model results illustrate how eddy overturning act towards flattening cross-frontal density gradients. Clockwise eddy overturning combined with atmospheric cooling may have lead to an efficient cooling of the West Spitsbergen Current during the late winter seasons of 2007 and 2008.

Observations

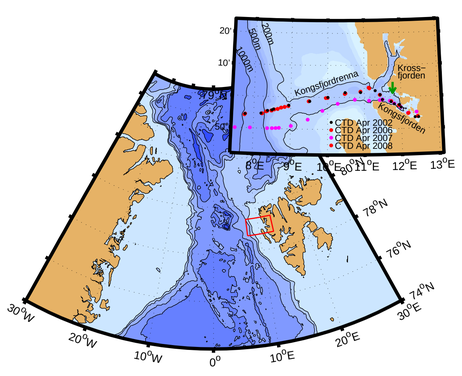


FIGURE 1: Bathymetry of the study area, based on the IBCAO data set. Warm and saline Atlantic Water (AW) is flowing along the continental shelf slope in the West Spitsbergen Current (WSC).

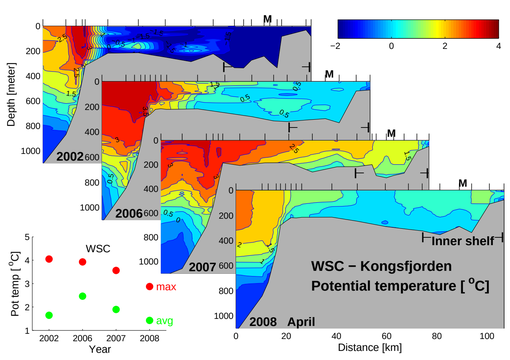


FIGURE 2: Four April sections of potential temperature at transect in Figure 1.

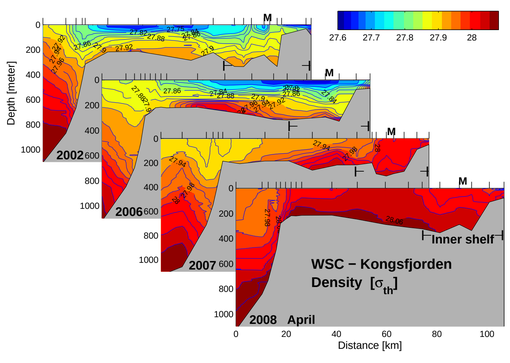


FIGURE 3: Four April sections of σ_{th} at transect in Figure 1.

In April 2007 and 2008 there is clearly a surface bound on-shelf flow of warm Atlantic Water (AW). In April 2002 and 2006 some remnants of AW are seen at deeper levels on the shelf. The two situations coinside with a positive surface density gradient in 2007 and 2008, and a negative gradient in 2002 and 2006.

Idealized model set up

The numerical domain consists of a shelf and shelf slope that is uniform in the north-south direction. A cyclic boundary condition is applied in the north (the outflow in the north enters the domain through the southern boundary). The initial density fronts are based on hydrographic data from the standard transect outside Kongsfjorden, shown in Figure 1 [TN09]. MITgcm was used for the numerical simulations, which were run on the HPC-cluster - Snowstorm at the University of Tromsø.

Run A: April 2002 **Run B:** April 2007 **Run C:** September 2000.

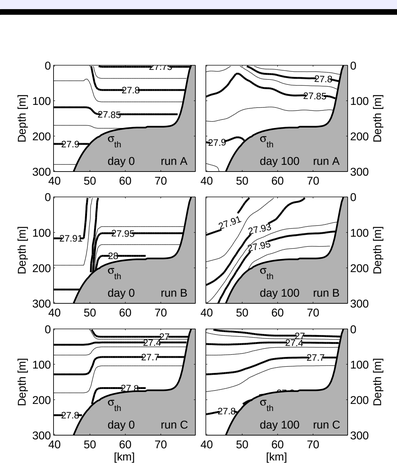


FIGURE 4: Modeled along-slope mean density fronts; initial and after 100 days model run.

Over the southern 5km of the model domain, the hydrography and current is nudged towards the sharp initial front.

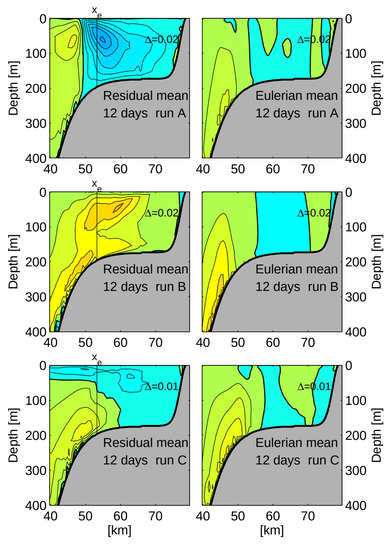
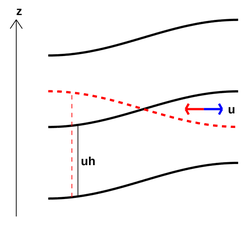


FIGURE 5:
Left panels: Residual mean stream function. Averaging made within density layers.
Right panels: Eulerian mean stream function. Averaging made at constant z-levels.

The stream functions are based on ensemble means of 12 along-slope mean cross-slope volume transports.

Theory on residual-mean overturning



Residual mean (averaged within density layers) equals Eulerian mean (averaged in z-layers) pluss eddy Stokes drift arizing from divergence in isopycnal eddy density flux [MM96].

$$\frac{\overline{uh}}{\bar{h}} = \bar{u} - \left(\frac{\overline{u'\rho'}}{\bar{\rho}_z}\right)_z + O(\alpha^2) = \bar{u} + u^*.$$

The residual mean flow determines the advection of density (buoyancy) in the transformed density equation in the plane perpendicular to the mean geostrophic current (the overturning plane) [PF05]:

$$\bar{\rho}_t + (\bar{u} + u^*)\,\bar{\rho}_x + (\bar{w} + w^*)\,\bar{\rho}_z = -\nabla_y \cdot \left(\overline{\mathbf{v}'\rho'}\right)_{diap} + S.$$

Comparison data - model

The model runs are initiated with two source profiles taken from real data. Comparisons between the modeled fronts and original data are done via a consept we call Atlantic Water fraction F_{AW}.

Atlantic Water fraction: Fraction between source profile of Atlantic Water and Shelf Water, assuming mixing occur along isopycnals.

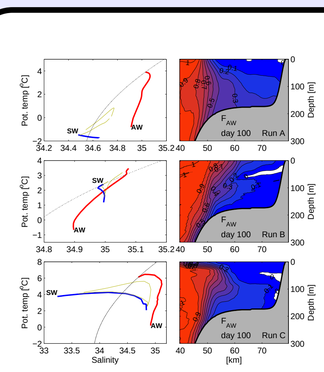


FIGURE 6:
MODELED:
Left panels: TS-relations of source profiles for calculating Atlantic Water fraction.
Right panels: Distribution of Atlantic Water fraction after 100 days model runs.

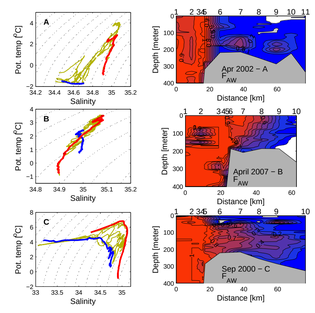


FIGURE 7:
OBSERVATIONS:
Left panels: TS-relations of observed source profiles for calculating Atlantic Water fraction.
Right panels: Distribution of observed Atlantic Water fraction.

On-shelf heat flux

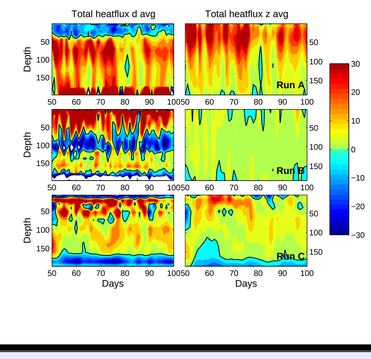


FIGURE 8:
MODELED:
Left panels: Time series of distributed total on-shelf heat flux, averaged within density layers.
Right panels: Time series of distributed total on-shelf heat flux, averaged within z-layers.

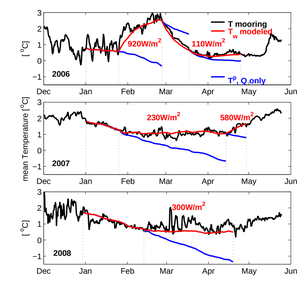


FIGURE 9:
BOX MODEL and OBSERVATIONS:
A simple heat budget calculation of Atlantic Water on-shelf heatflux, compared with time series of observed mean temperature at the inner shelf.

References

[MM96] P. C. McIntosh and T. J. McDougall. Isopycnal averaging and the residual mean circulation. *J. Phys. Oceanogr.*, 26:1655–1660, 1996.

[PF05] R. A. Plumb and R. Ferrari. Transformed Eulerian-Mean Theory. Part I: Nonquasigeostrophic theory for eddies on a zonal-mean flow. *J. Phys. Oceanogr.*, 35:165–174, 2005.

[TN09] V. Tverberg and O. A. Nøst. Eddy overturning across a shelf edge front. West-Spitsbergen - Kongsfjorden. *J. Geoph. Res.*, 2009. doi:10.1029/2008JC005106, in press.