Pathways of Nordic Overflows From Climate Model Scale and Eddy Resolving Simulations

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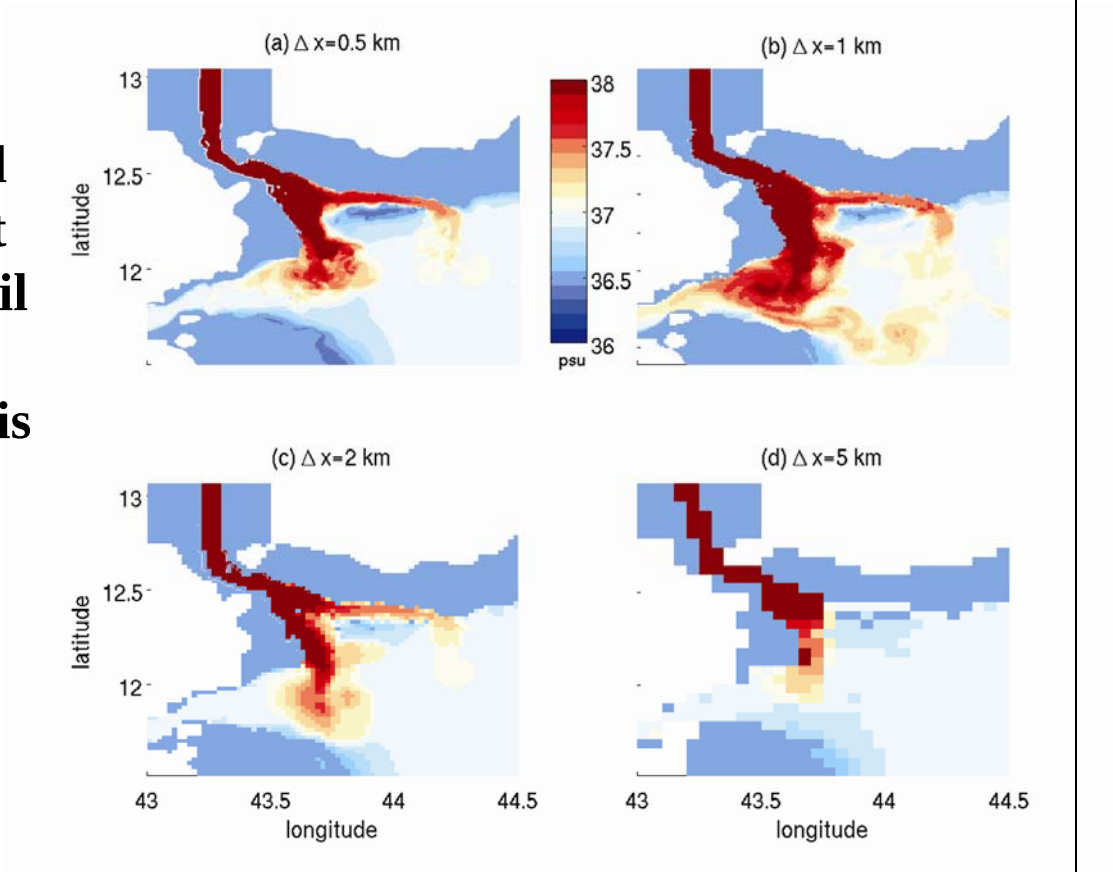
Motivation

We previously conducted numerical experiments for the sensitivity of the horizontal resolution on overflow models.

The pattern and pathways of the Red Sea Overflow do not become realistic until the details of the bottom topography is resolved.

(Published in JPO, 2008: Chang, Özgökmen, Peters, Xu)



Objectives

To investigate the effect of the model resolution on numerically simulated Nordic Overflows and other aspects of the North Atlantic circulation.

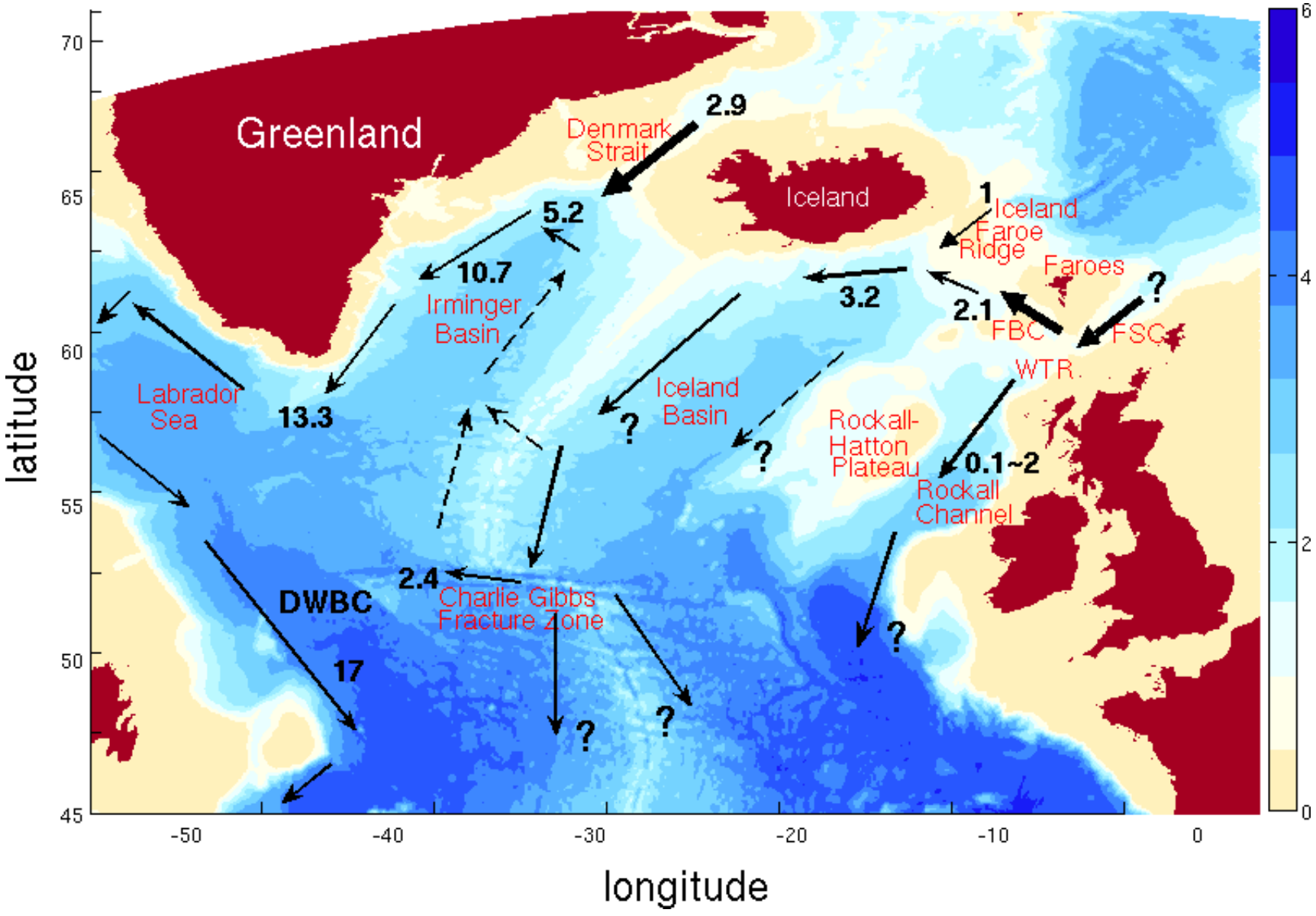
Related questions

- Can we obtain realistic Nordic overflows and deep transport pathways using ocean general circulation models, in which the overflows are explicitly simulated ?
- If so, at which model horizontal resolution is this achieved ?

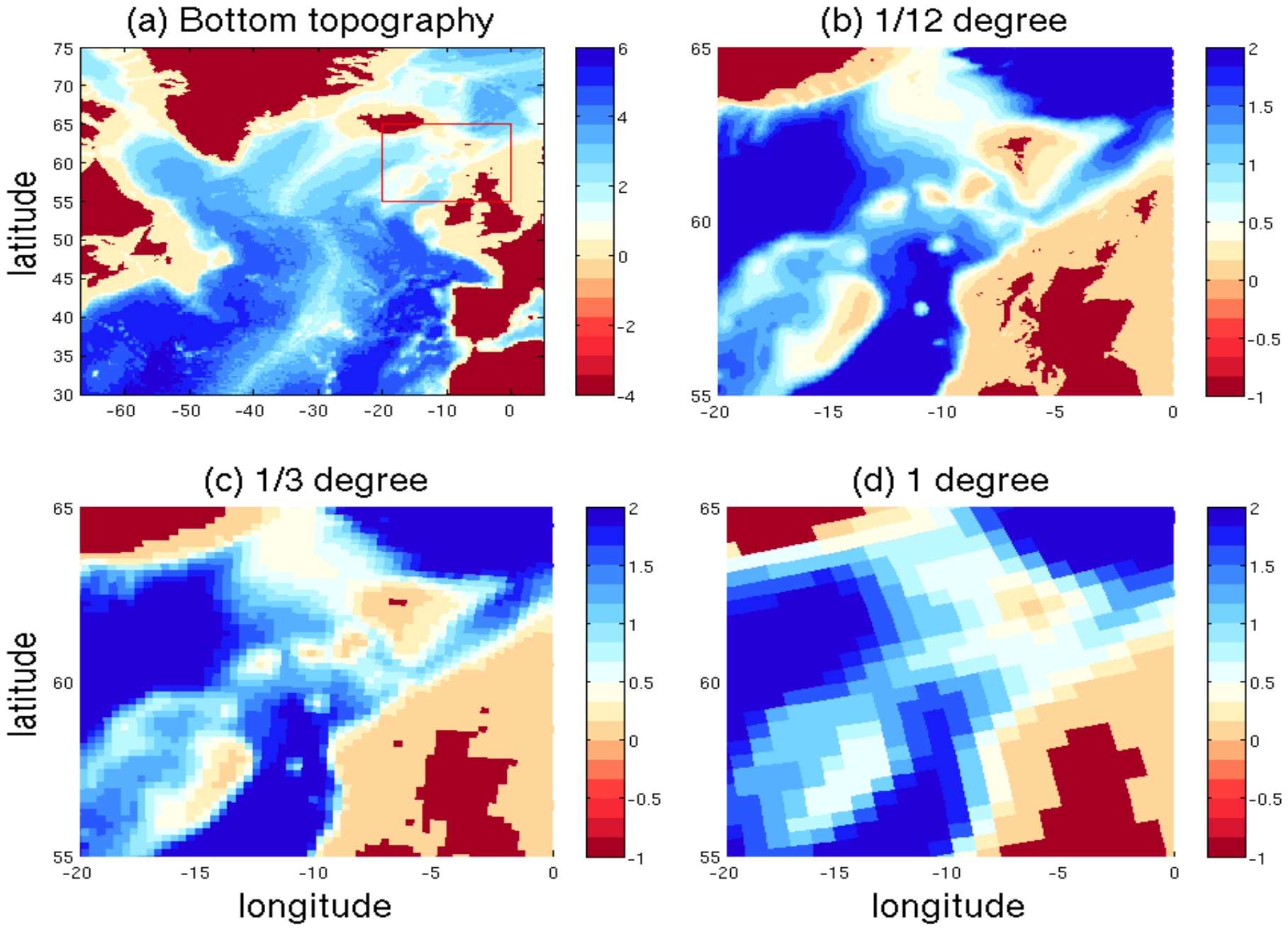
Experimental Configuration

- North Atlantic simulations with HYCOM by gradually increasing horizontal resolutions starting from 1 º (typical ocean model resolution for climate studies) to the finest 1/12 º (most important topographic features as well as meso-scale eddies are resolved), and a intermediate 1/3 º North Atlantic.
- Model domains are extended northward to (20 º S ~ 77, 80ºN) so that the Norwegian Sea is covered by the model.
- Other initial and boundary conditions remain similar between the cases so that no serious difference can be caused by these conditions.

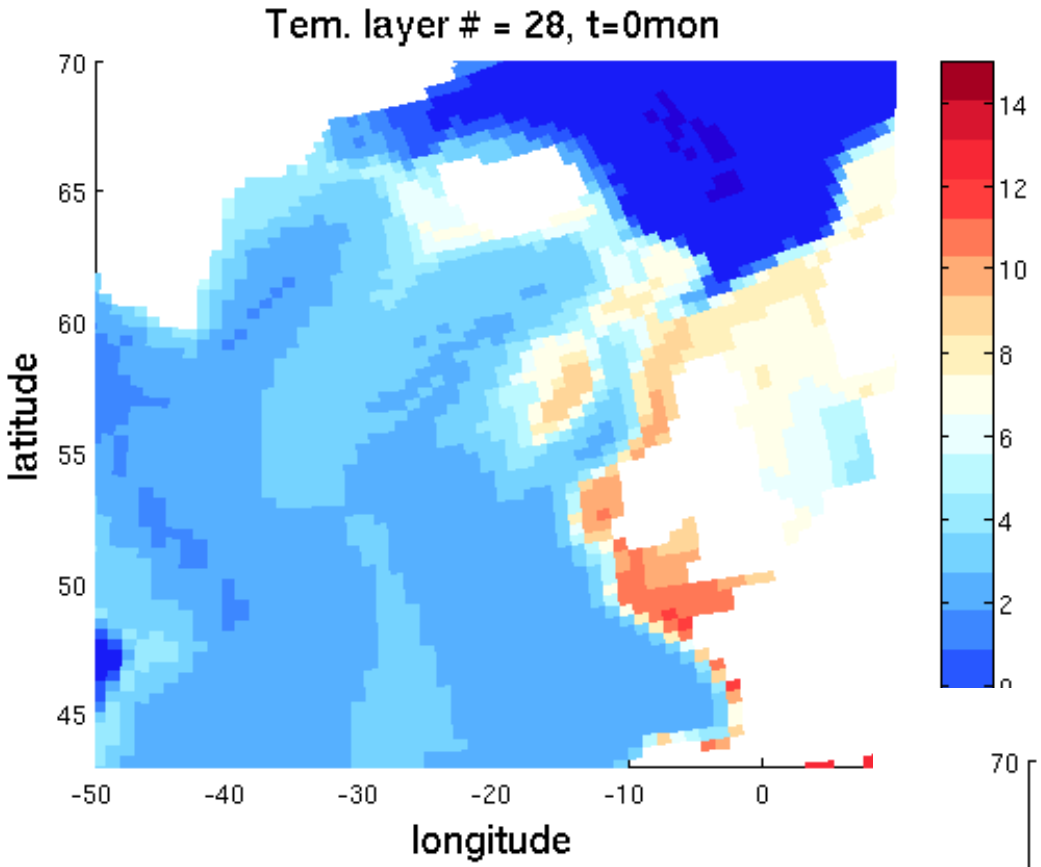
Review of overflows in North Atlantic



Topography of computational domain

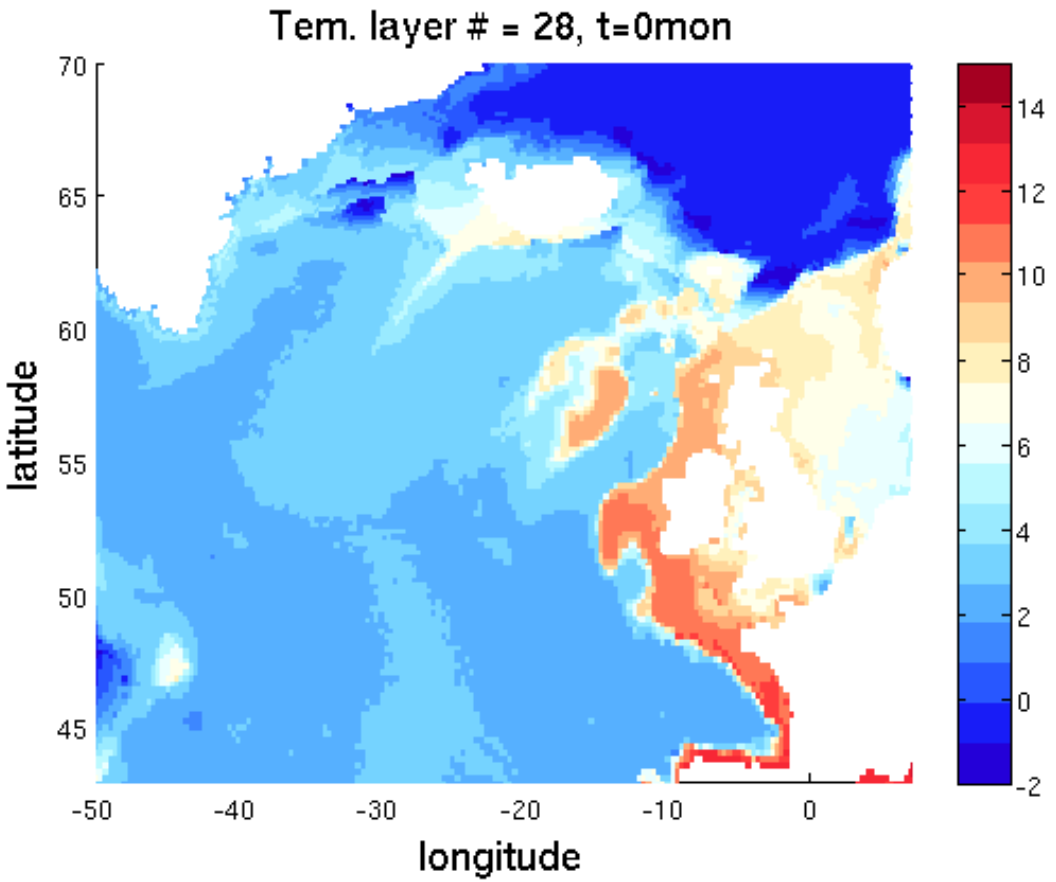


Overflow propagation

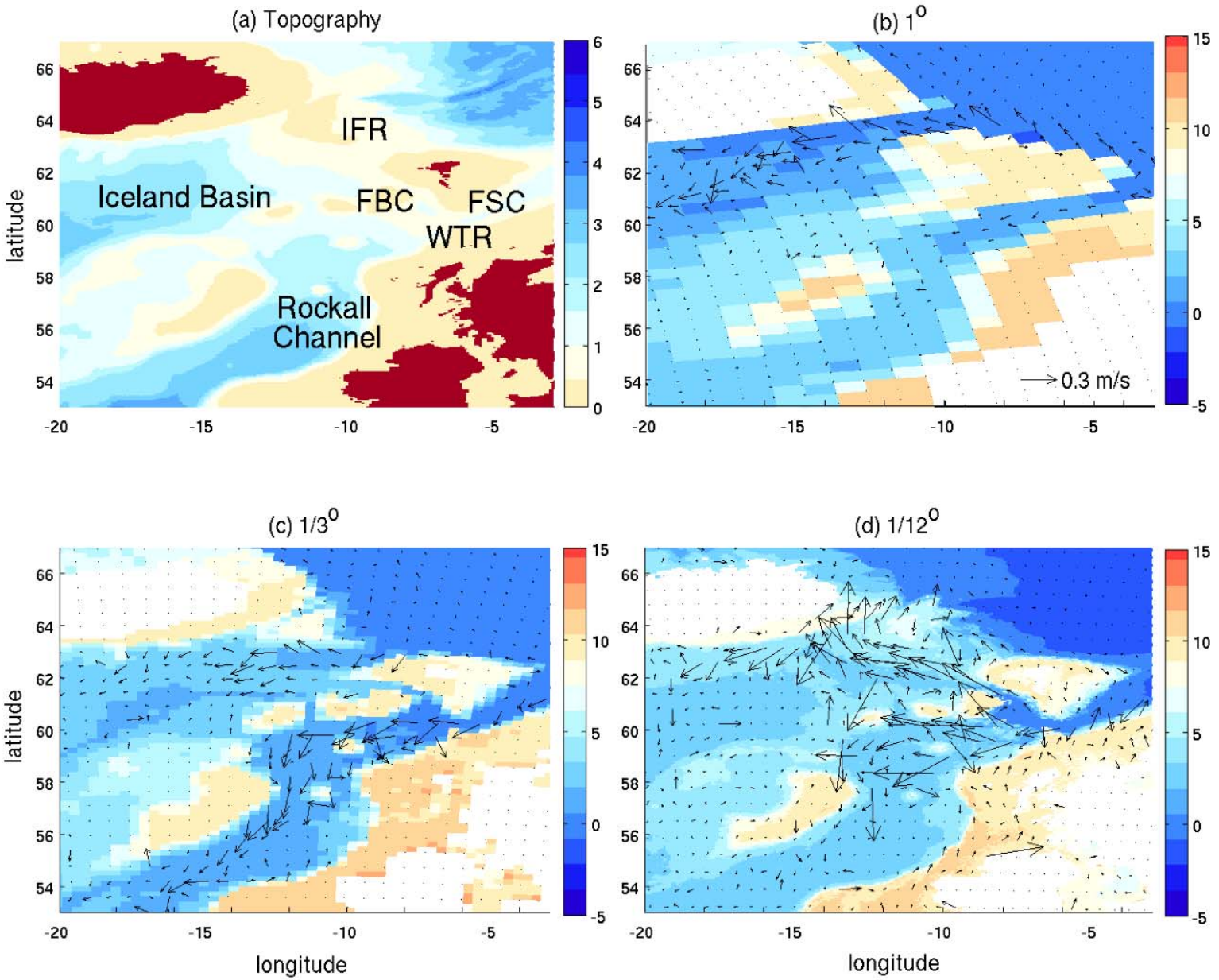


1 degree

1/3 degree

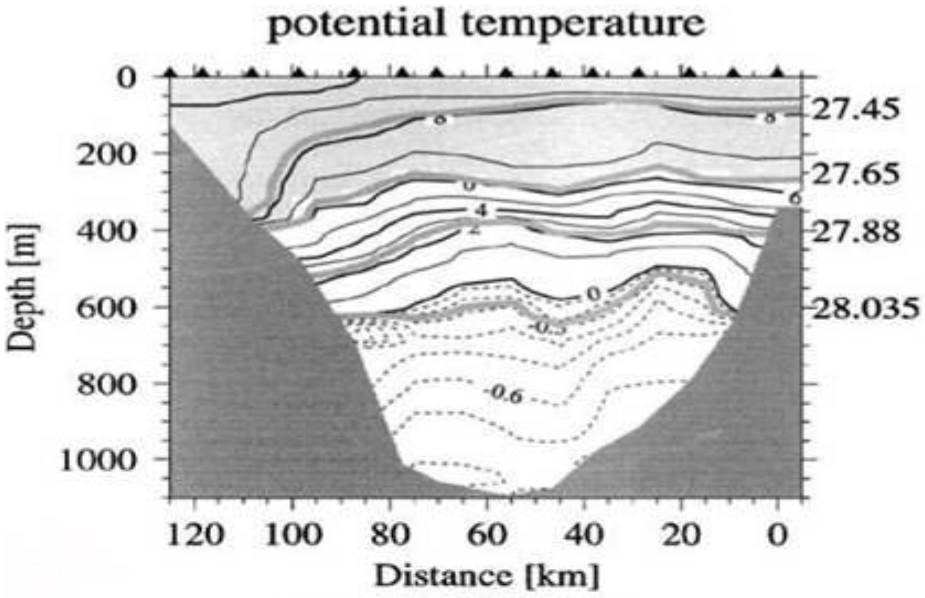


Overflow vel. vectors : Faroese Channels

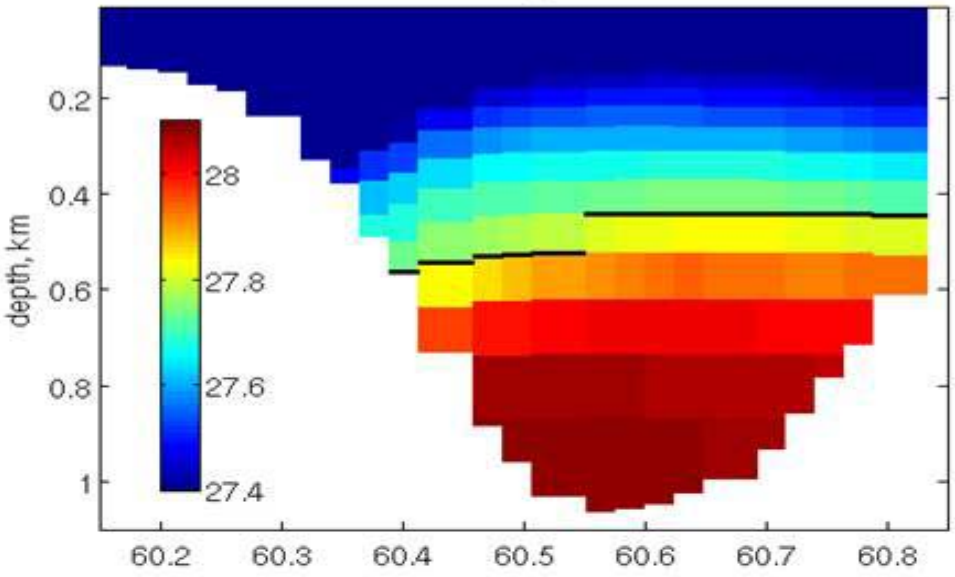


Cross-section: Faroe Shetland (Mauritzen et al. , 2005)

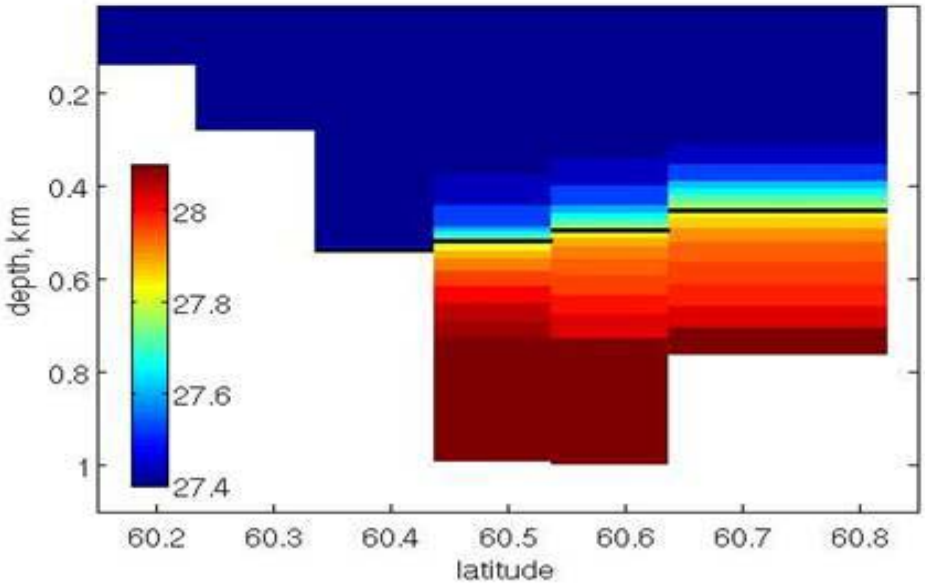
(a) Potential temp. distribution at FSC (Mauritzen et al.,2005).



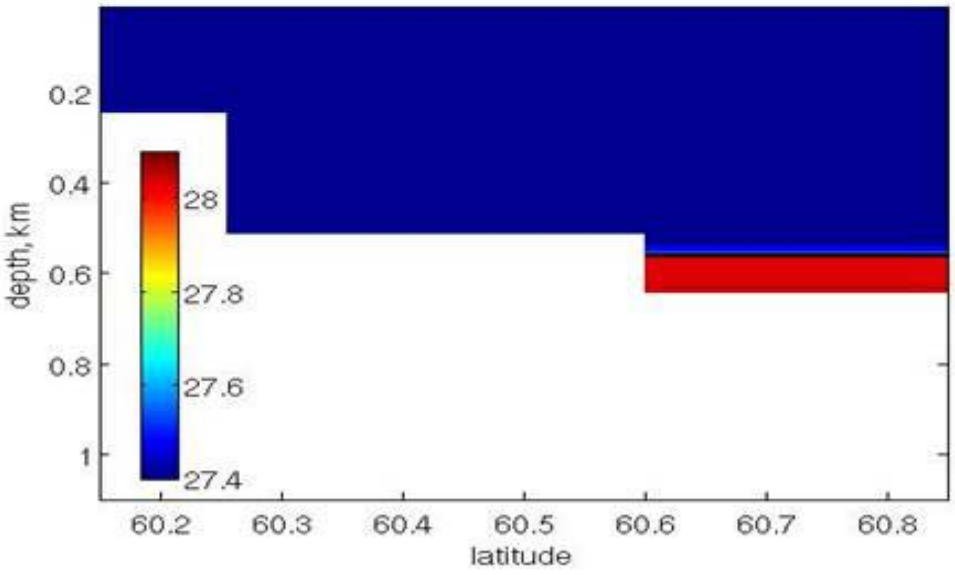
(b) Density (σ_θ), 1/12 deg.



(c) Density (σ_θ), 1/3 deg.

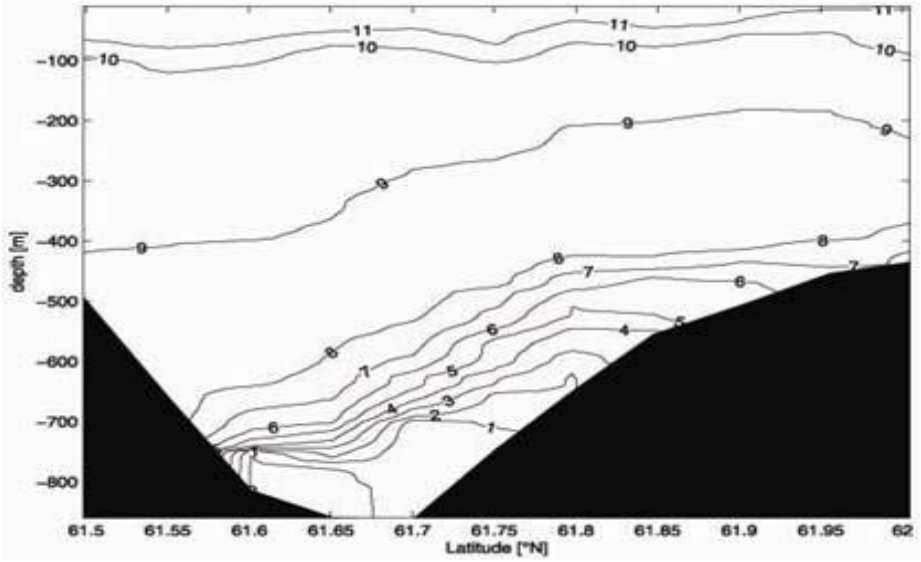


(d) Density (σ_θ), 1.0 deg.

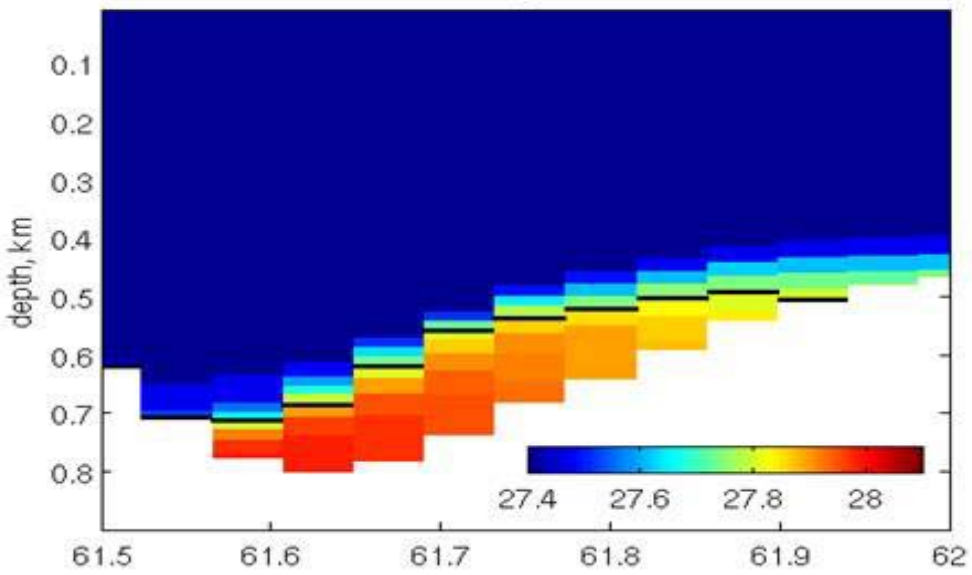


Cross-section: Faroe Bank Channel (Geyer et al. , 2006)

(a) Observed temp. distribution at FBC exit (Geyer et al. ,2006).



(b) Density (σ_θ), 1/12 deg.



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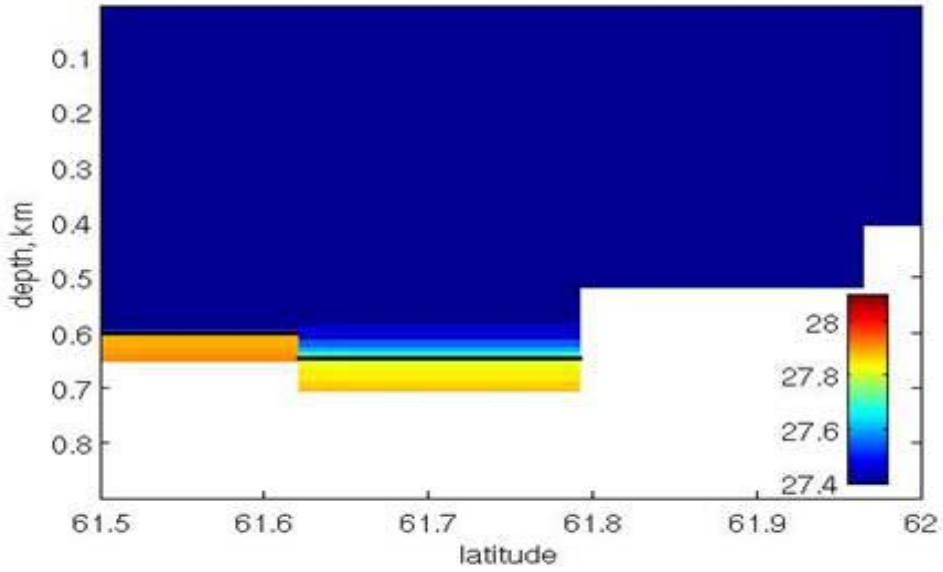

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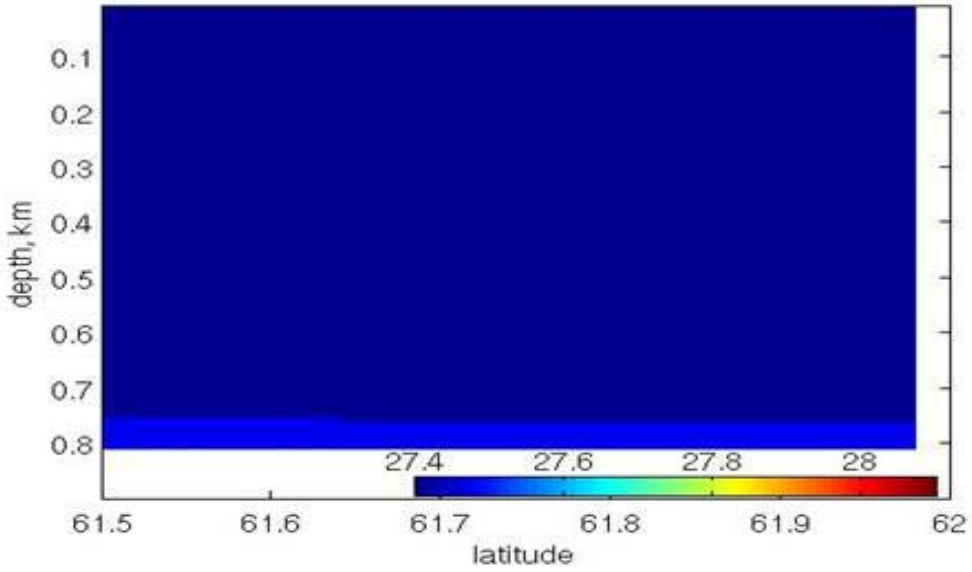
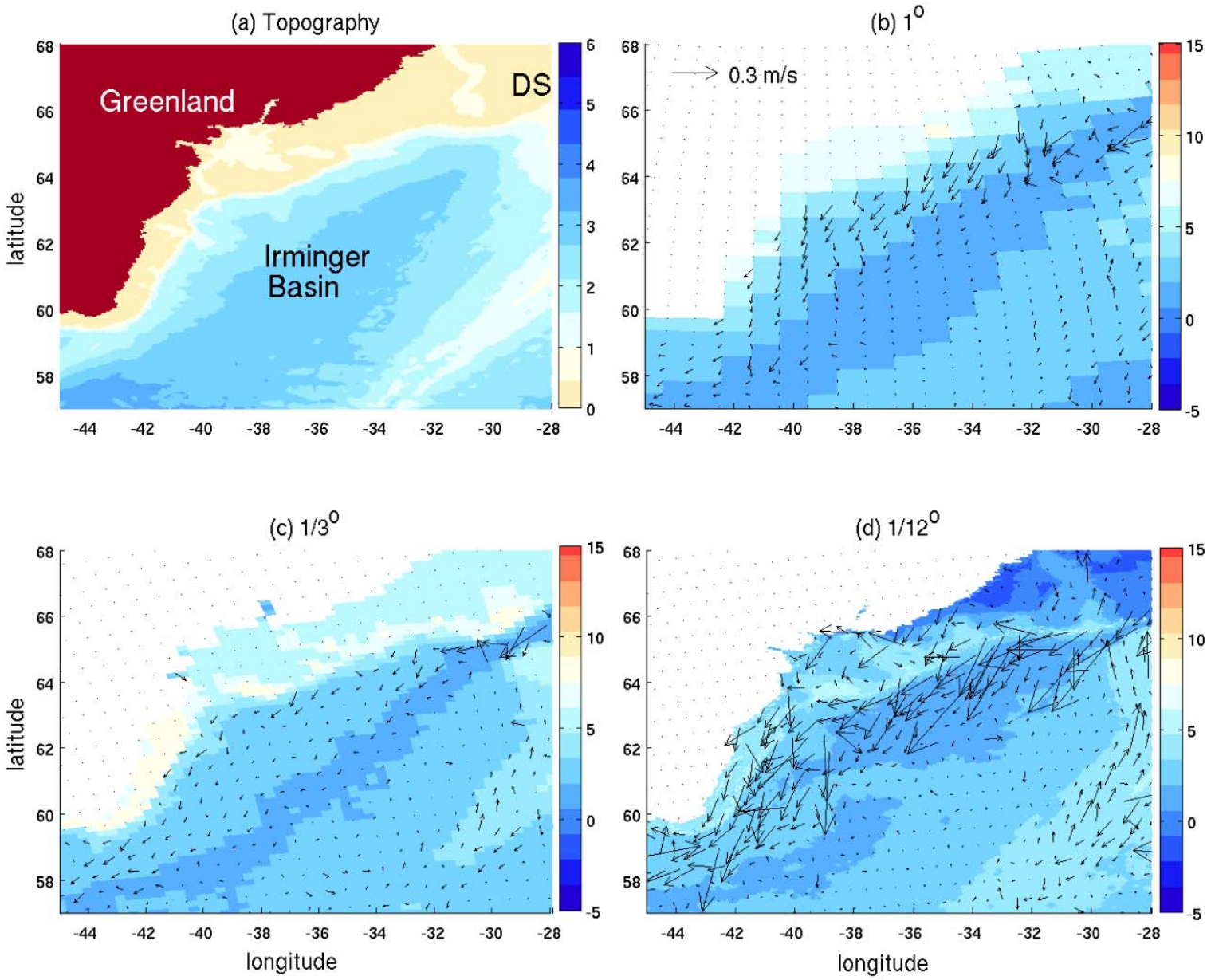
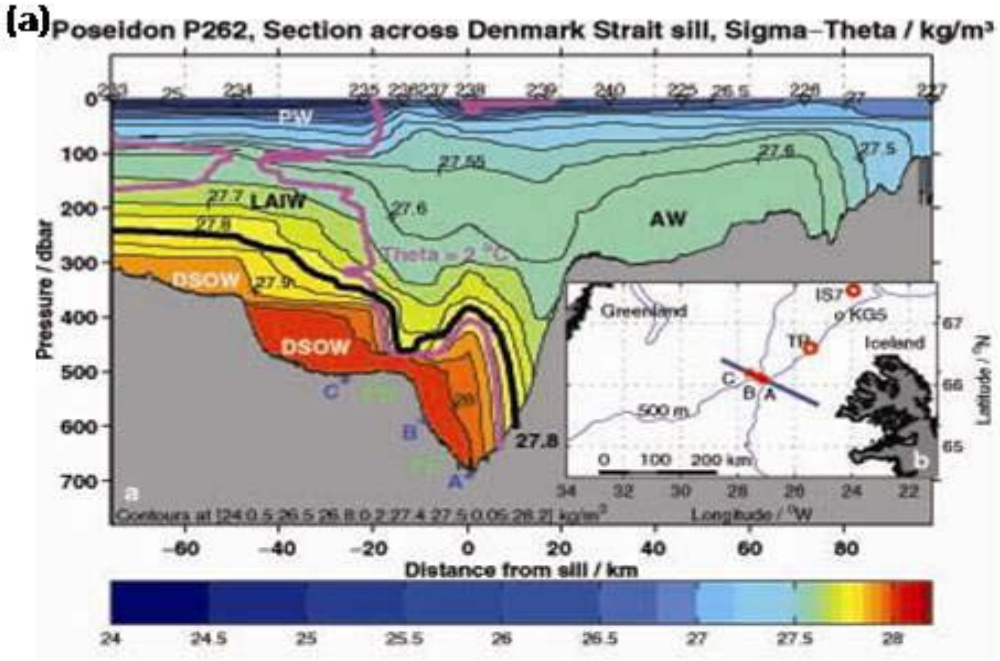
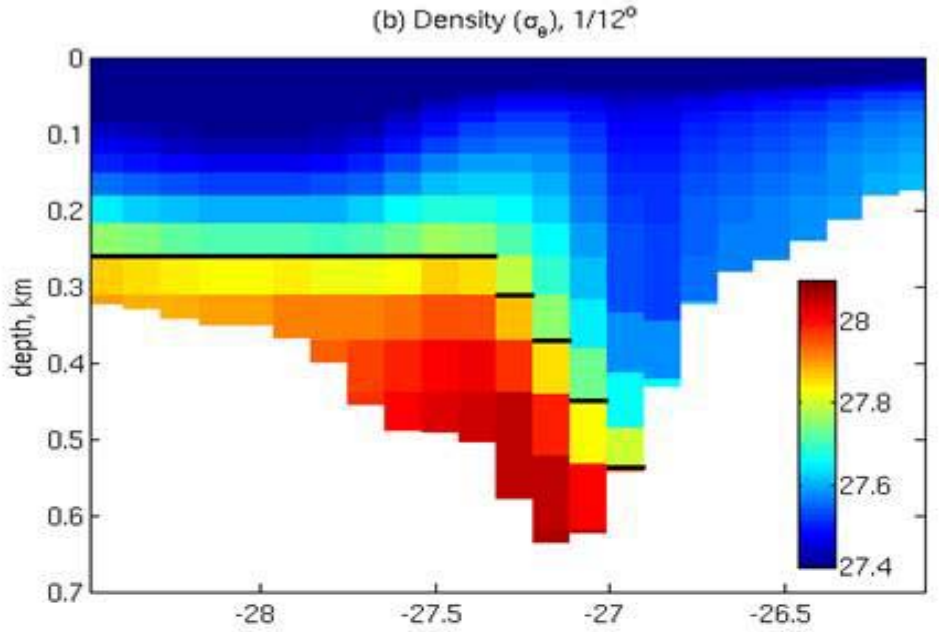


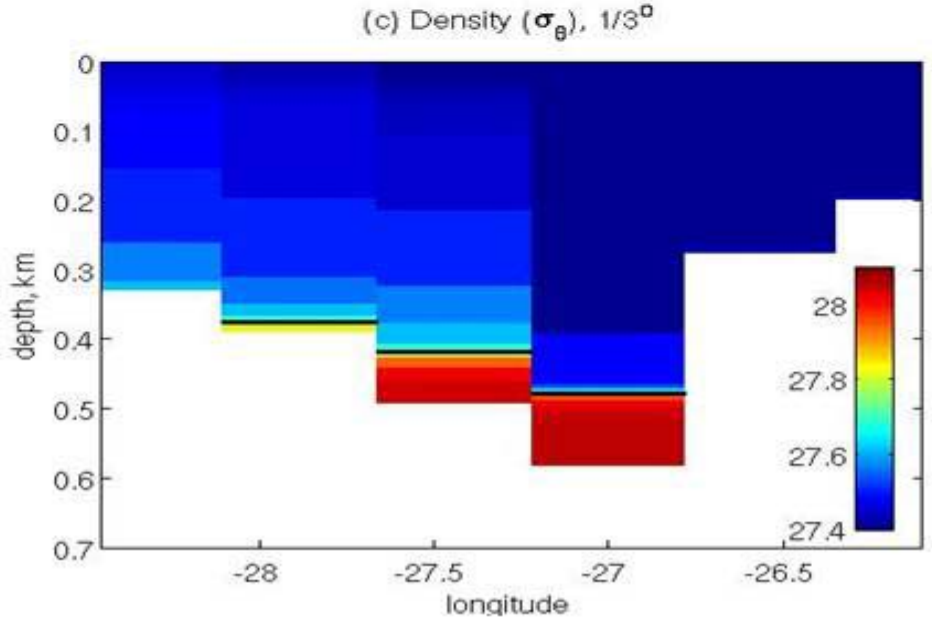
Overflow vel. vectors : Denmark Strait

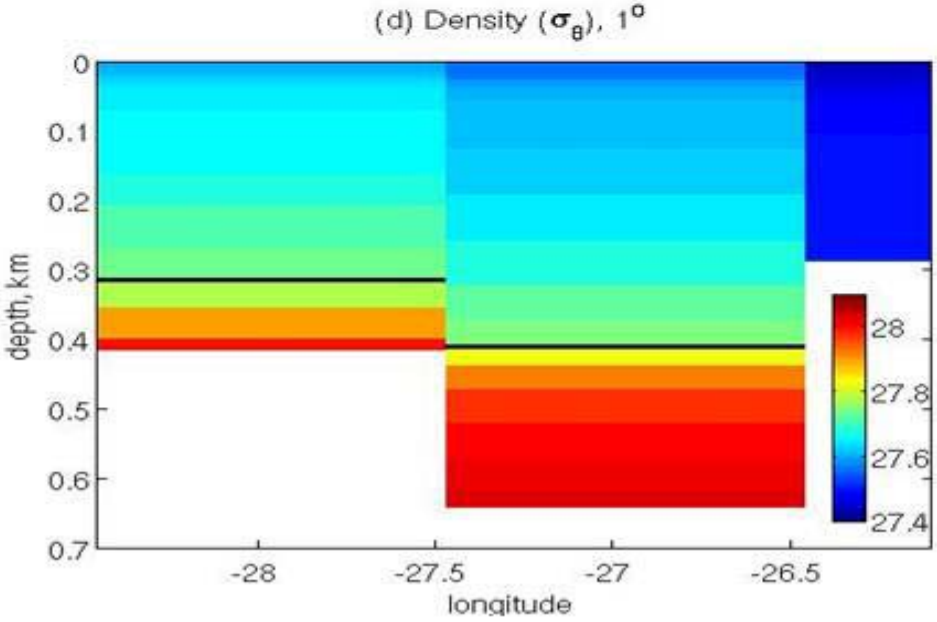


Cross-section: Denmark Strait (Macrander et al. 2007)

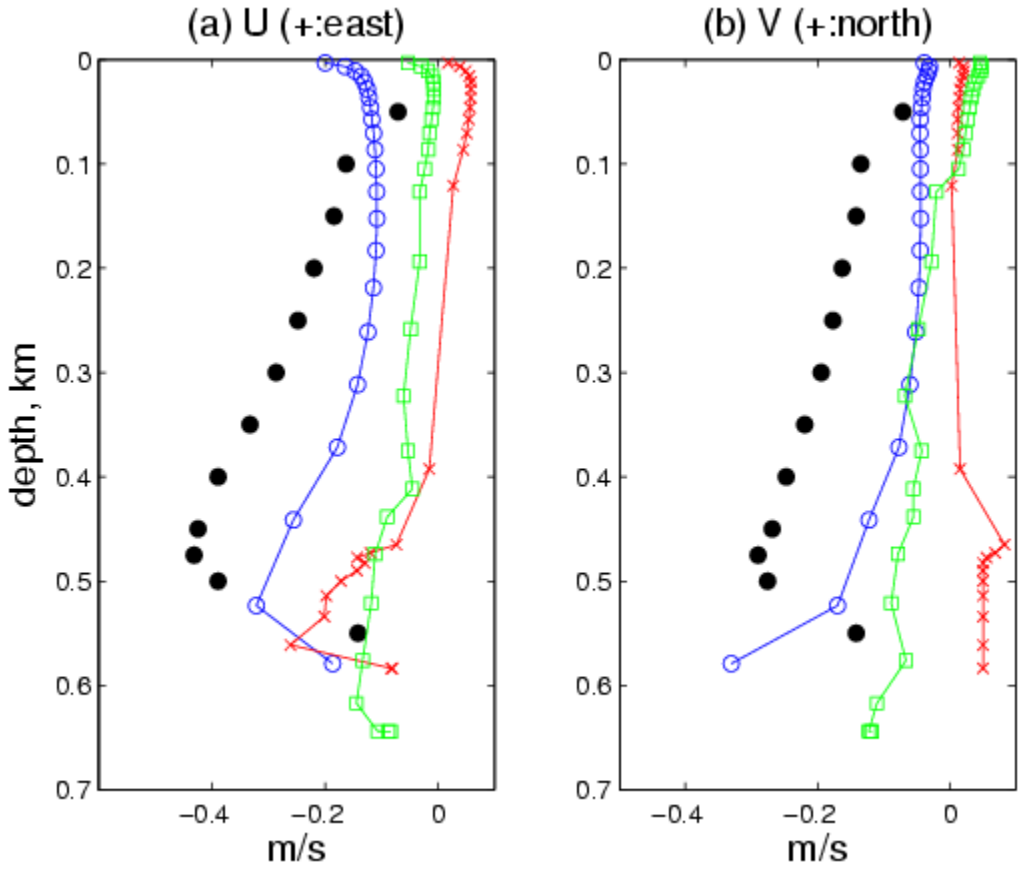




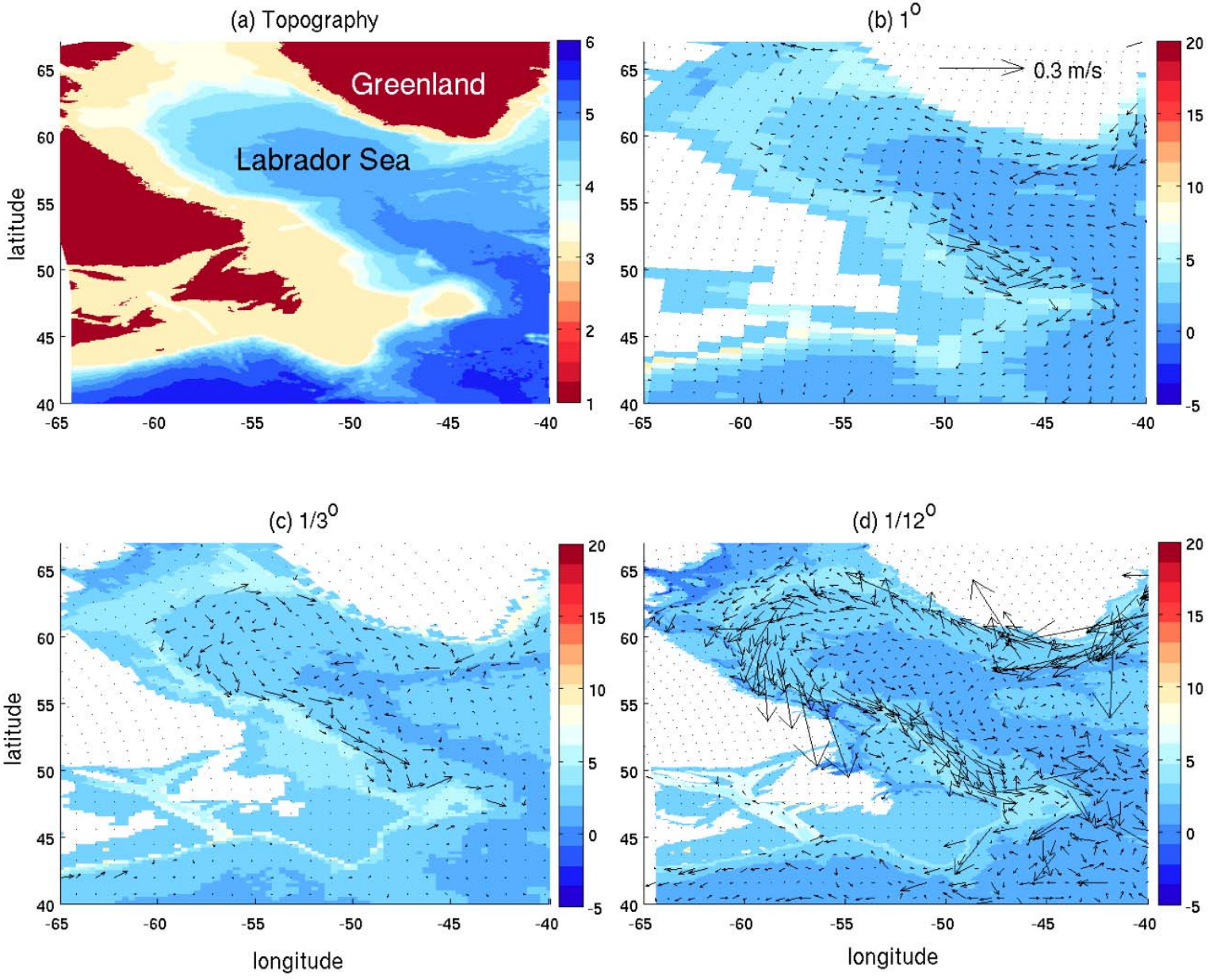




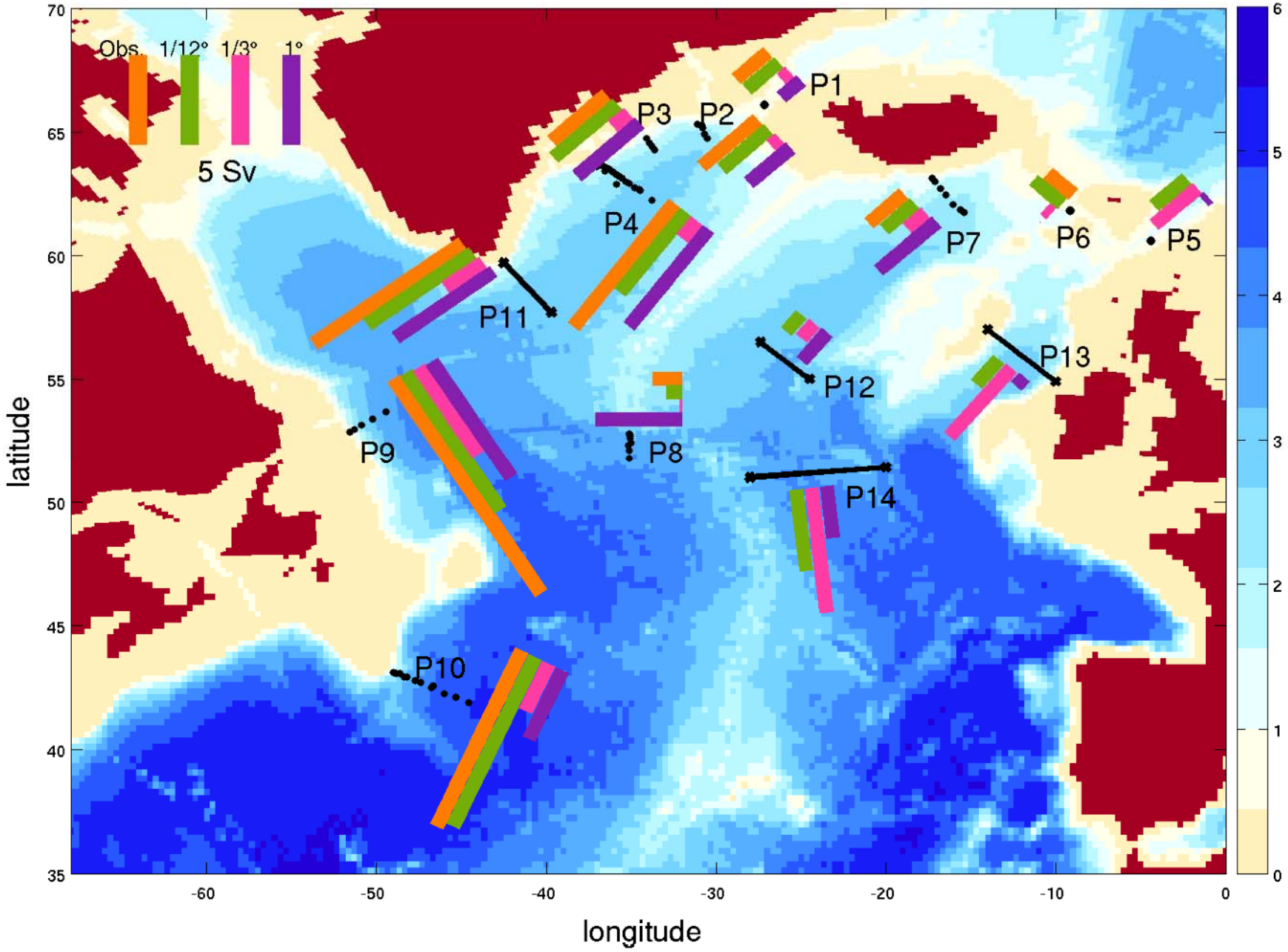
Velocity profiles at the Denmark Strait sill
(blue: 1/12 º, red: 1/3 º, green: 1º , black: observation)



Overflow vel. vectors : Labrador Sea

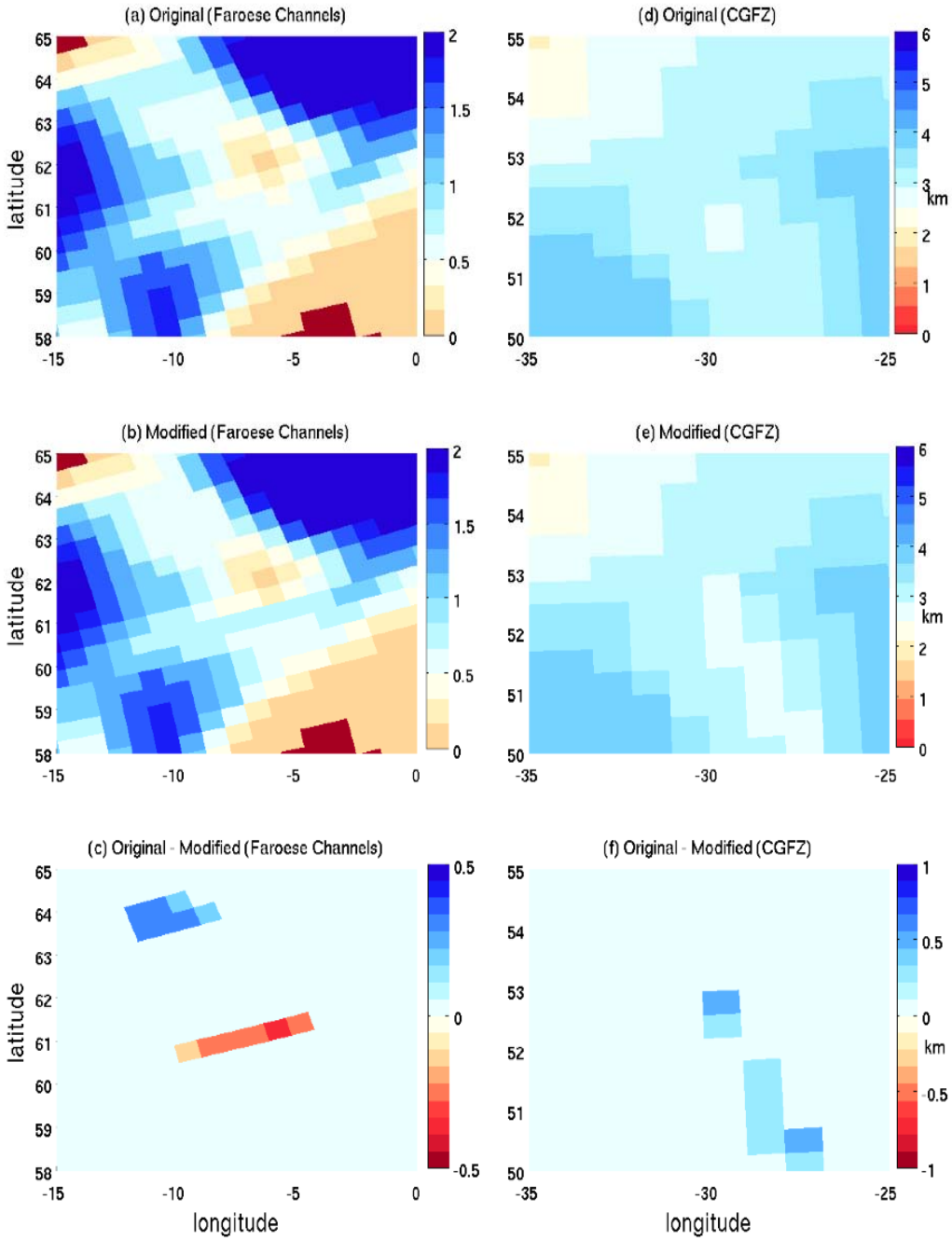


Transport map : Comparison with observations

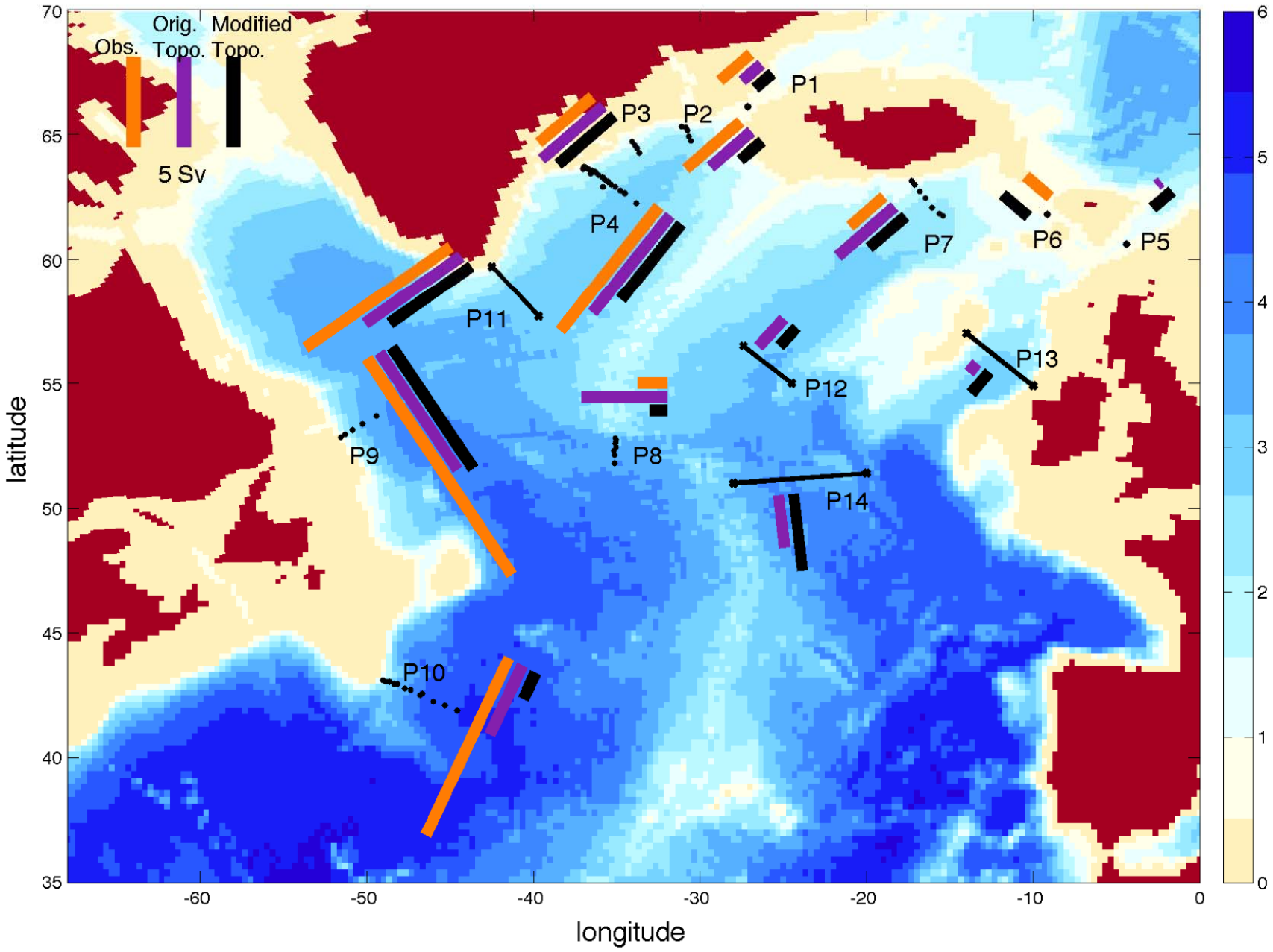


Simulation with Hand-Tuned Topography

1. **The incorrect overflow pathways in coarse resolutions are due to large errors in critical deep channels.**
2. **Additional experiment was conducted for the 1º resolution with a manually modified bathymetry in an attempt to rectify the pathways.**
3. **New experiment is only with 1º since it contains less degrees of freedom than 1/3º regarding the grid points to be modified.**
4. **The hand tuning is focused on FBC(P6), IFR(P7), and CGFZ(P8) that show largest errors in 1º.**



Transport map with the modified topography, 1º



Conclusions

1. **The structure of the overflows are simulated at 1/12º only. Lower resolutions fail quantitatively or even qualitatively.**
2. **Increase of resolution from 1º to 1/3º lead no significant imrovement in the model performance, which implies that under-resolved topography sets a threshold as to prohibit the usual gradual improvement in model performance until dynamically important channels are adequately represented in the domain.**
3. **In order to produce fairly realistic overflow and AMOC, the resolution need to be an order of magnitude larger than the typical 1º of current climate models.**
4. **Manual corrections to IFR, FBC, CGFZ in 1º show significant reductions in errors near these regions, but simultaneously creation of higher errors in other parts of the basin as well.**
5. **Great care needs to be taken in generating model seafloor topographies, especially at lower resolutions.**

Y. Chang, Z. Garraffo, H. Peters, T. Özgökmen, 2009: Ocean Modelling 29(1), pp66-84