Numerical investigation of the Nordic water overflow in the Faroe-Shetland Channel

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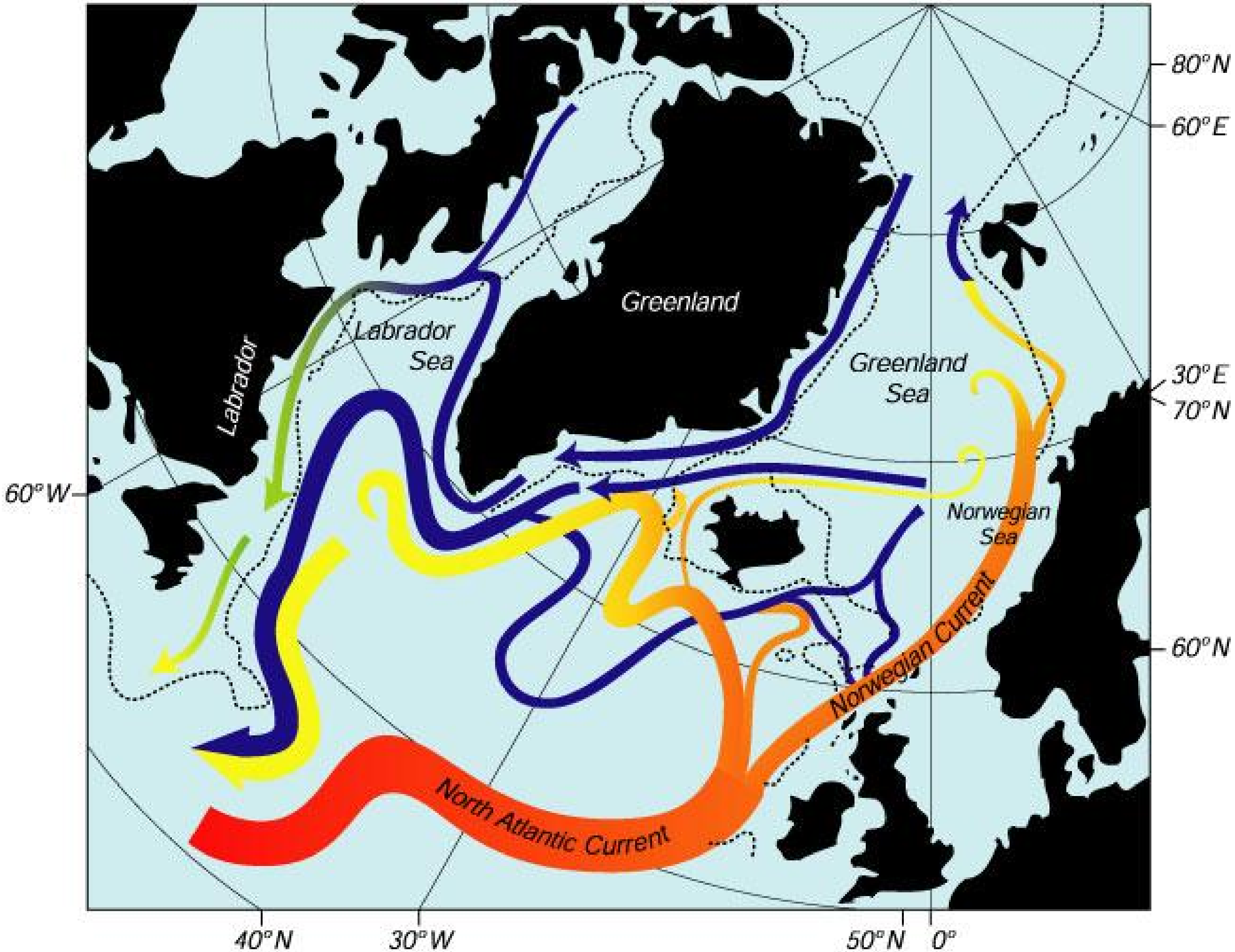
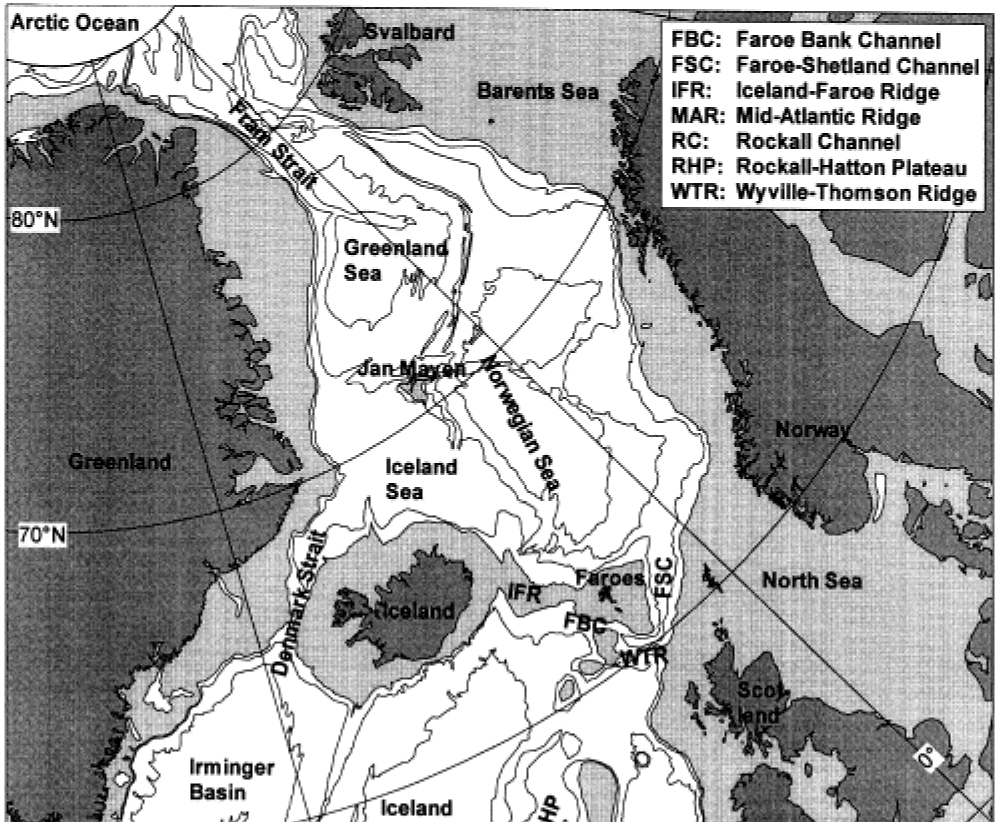


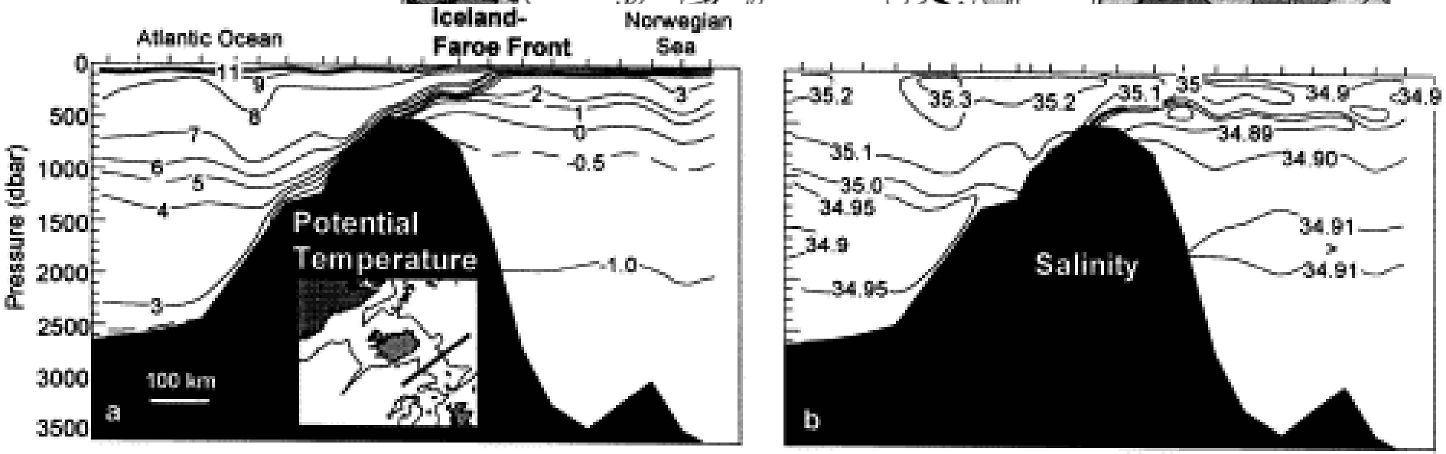
Real configurations: North Atlantic

The surface (red, orange, yellow) and deep (violet, blue, green) currents in the North Atlantic. The North Atlantic Current brings warm water northward where it cools. Some sinks and returns southward as a cold, deep, western-boundary current.
Some returns southward at the surface (from Stewart, 2005).

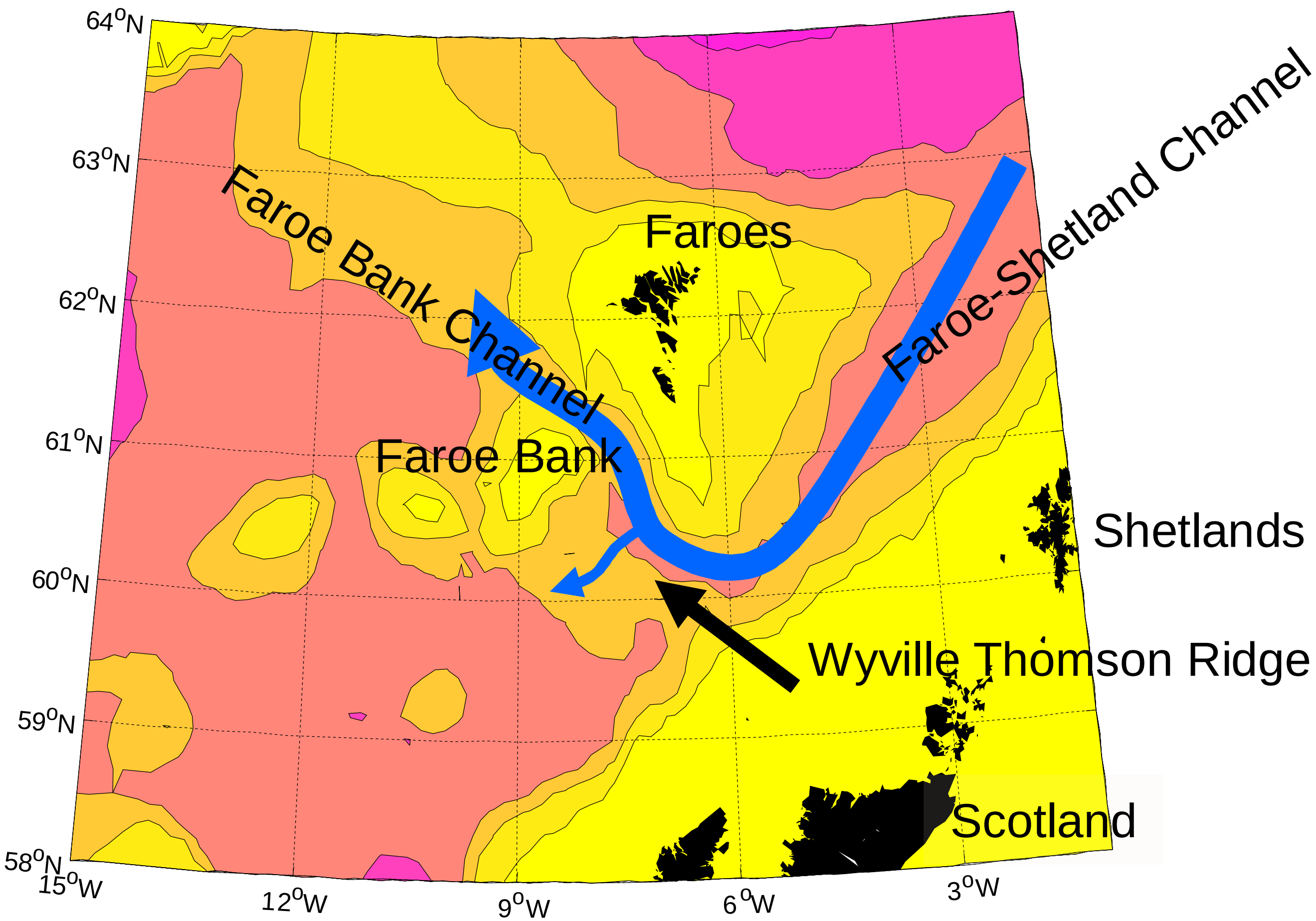
The Greenland-Scotland Ridge extends from East Greenland to Scotland and below a depth of 840 m it forms a continuous barrier between the North Atlantic and the ocean regions north of the ridge**.**

The Greenland-Scotland Ridge separates the Atlantic Ocean with high temperature and salinity (T>5ºC, S>35.0) water down to 1000 m or more and Arctic Mediterranean with cold (T<0ºC), low-salinity (S~34.9) water from about sill-level down to bottom.



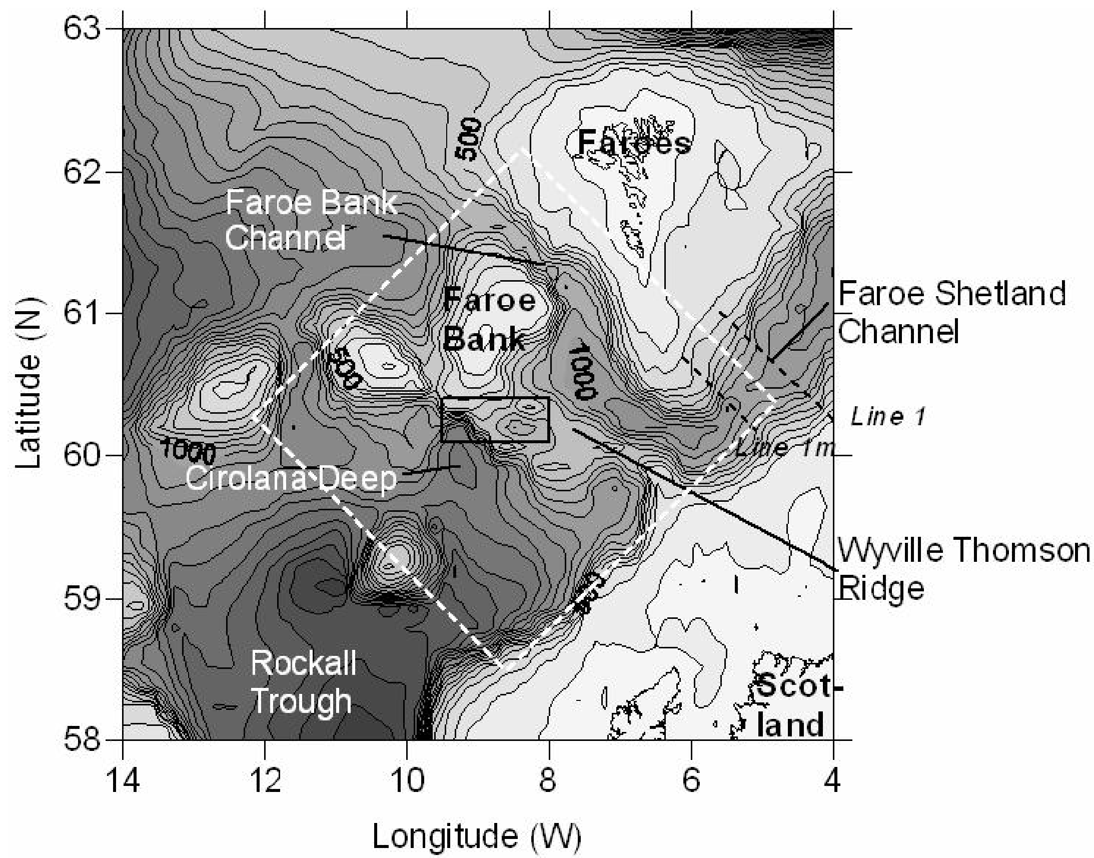


Between the Faroes and Scotland the bottom topography is more complex. The relatively broad, deep Faroe-Shetland Channel is blocked at its south-western end by the Wyville-Thomson Ridge with sill depth around 600 m.



The Wyville-Thompson Ridge joins the Scottish shelf at its southern end and at the northern end joins the Faroe Bank rather than the Faroe Plateau and these two are separated by the narrow, deep Faroe Bank Channel with sill depth around 840 m.

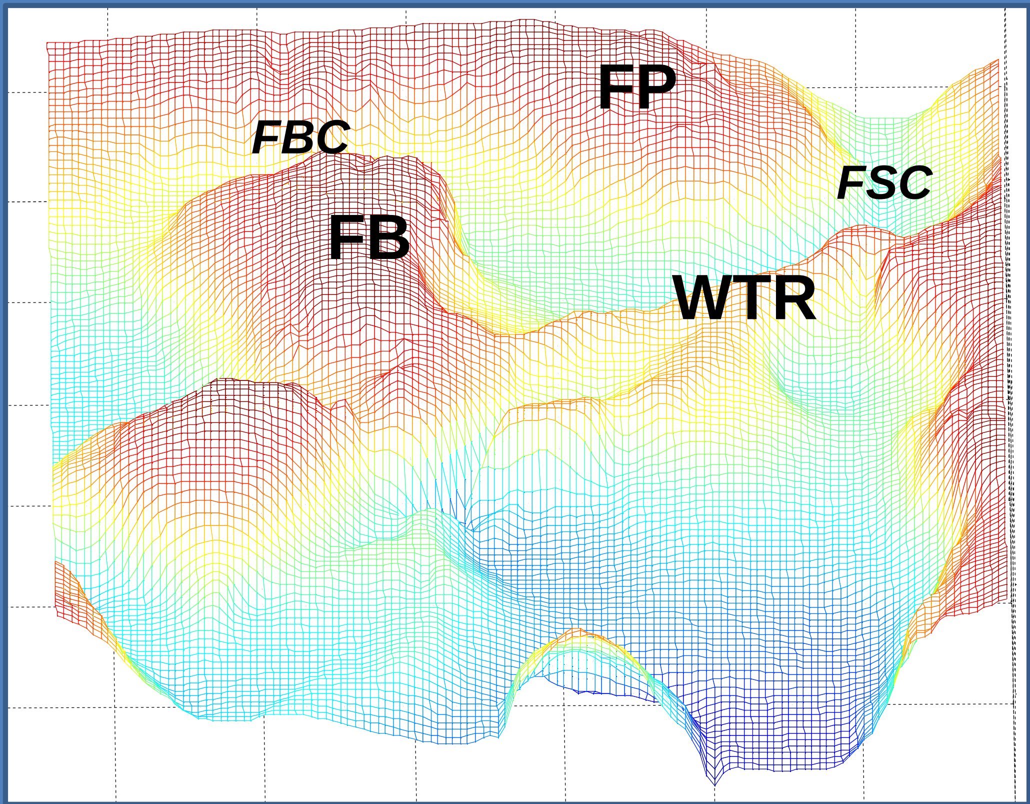
The Wyville Thomson Ridge forms the northern most limit of the Rockall Trough and is though to limit the deep overflow from the Faroe Shetland Channel towards the Rockall Channel. The ridge is fairly flat with water depths between 500-600 m along its total extent from the Faroe Bank to the Hebridean Slope, except for a depression in the middle where the maximum sill depth of about 600 m. To our knowledge the Wyville Thomson Ridge overflow was first documented in 1972 by Ellett and Roberts (1973). More recent observations of the overflow through the WTR was reported by Sherwin and Turrell (2005).At the same time no comprehensive model investigations of the water dynamics in the area of the WTR and appropriate conditions required for the water overflow have not been conducted so far.



MITgcm was applied on a fine-resolution grid.

T, S, u, tracer

Open boundary conditions



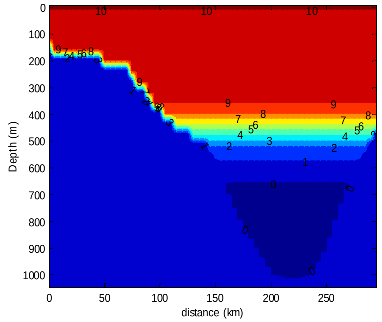
Open boundary conditions

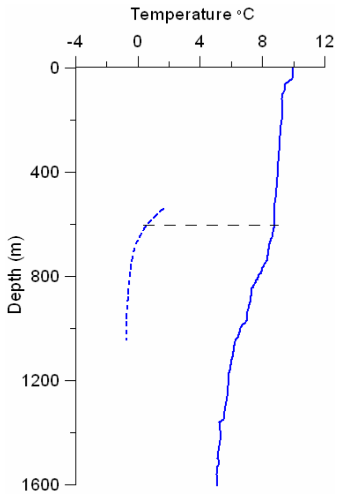
Open boundary conditions

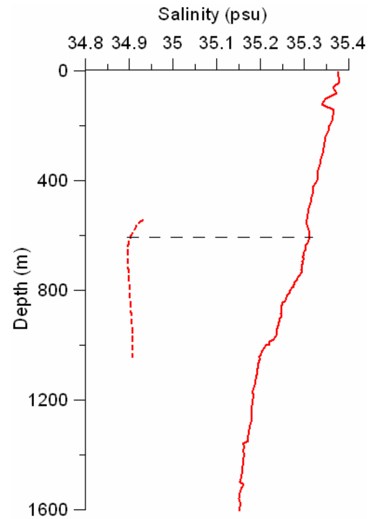
$\phi_t + c\phi_x = 0, \phi$ is any variable,

c is the phase velocity of waves

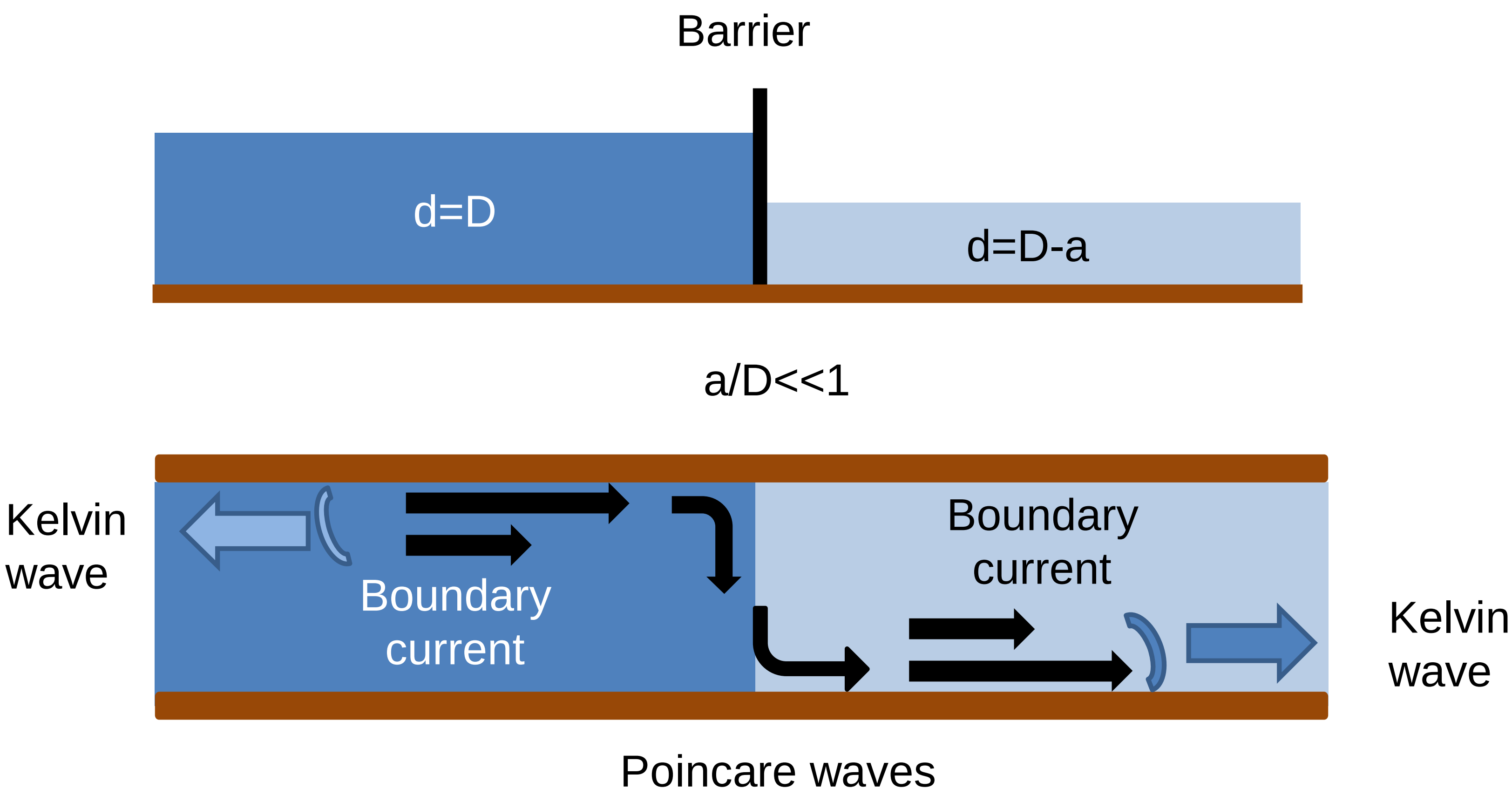
$\Delta x = \Delta y = 500$ m, $\Delta z = 10$ m , below 600m $\Delta z = 5$ m





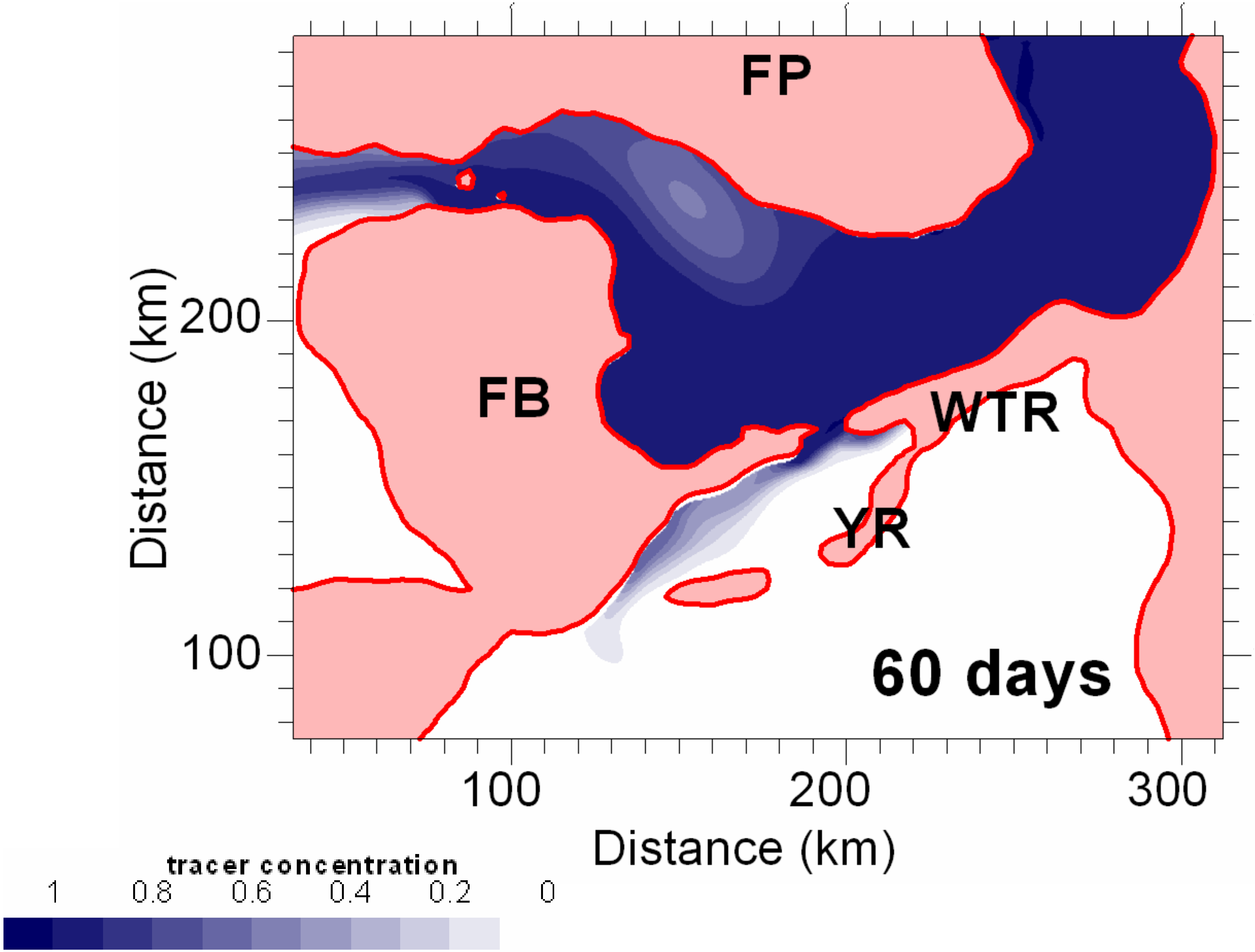


Rossby adjustment in a rotating channel Gill (1976)

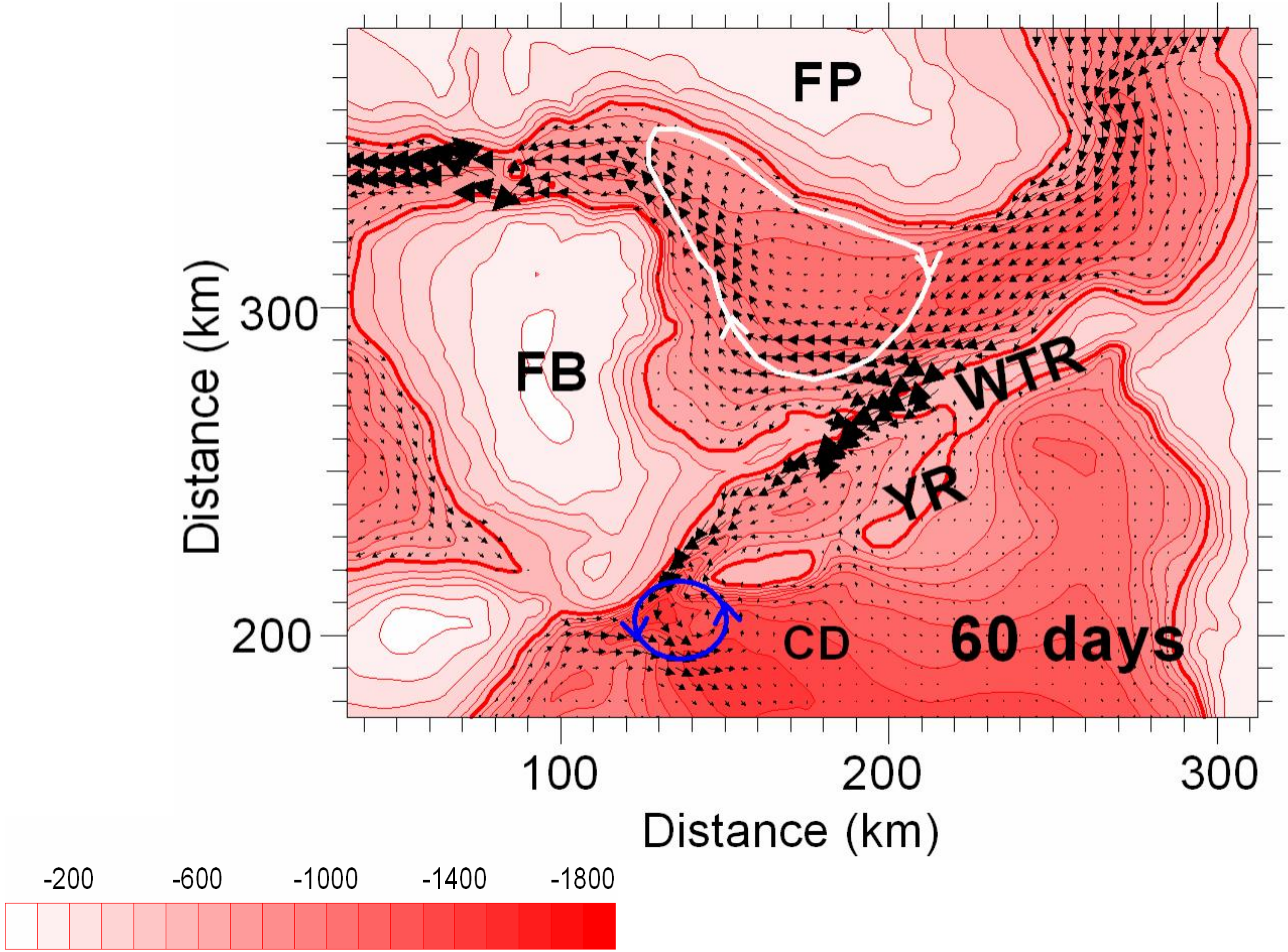


The numerical study was arranged as a series of lock-exchange experiments.
The motion in FSC starts when the barrier separating two water masses with different characteristics (temperature and salinity) is released.
At the initial stage this removal results in generation of Kelvin wave

Evolution of a tracer concentration at the depth of 600 m.



Horizontal velocity at the depth of 600 m.



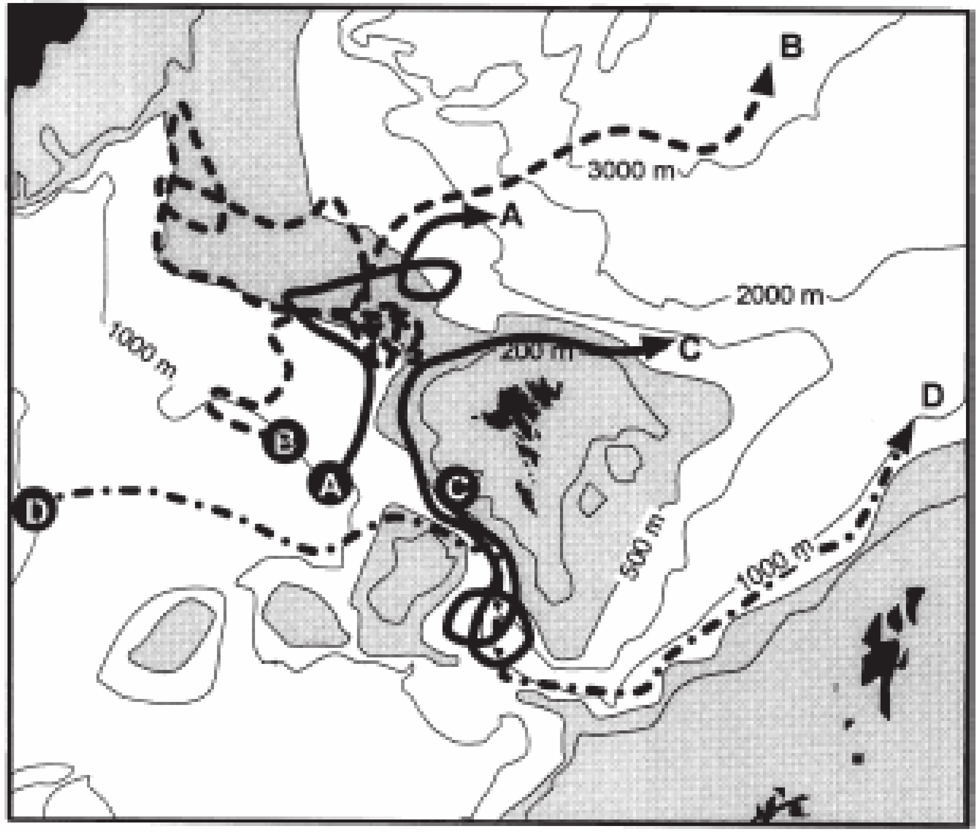
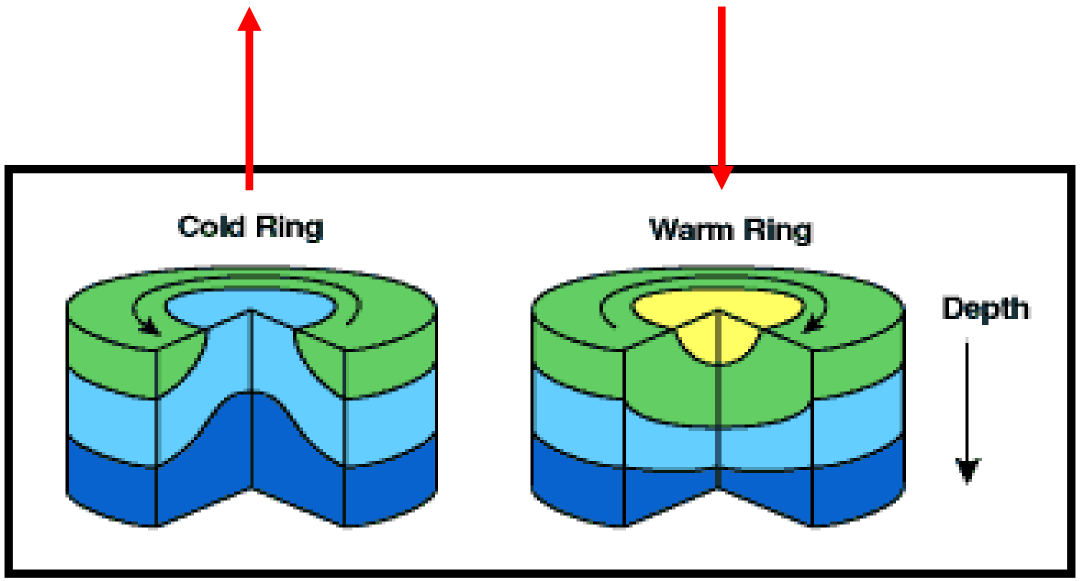


Fig. 18. Simplified tracks of four drifters crossing the Iceland–Scotland Gap. Based on Hansen et al. (1998b) and Krauss (1995).

Earth rotation is very important for understanding eddies. Mesoscale eddies occur when there is a balance of two major forces -- one is a horizontal pressure gradient force arising from differences in water density and the other is an "apparent" force associated with the Earth's rotation.

In northern hemisphere:

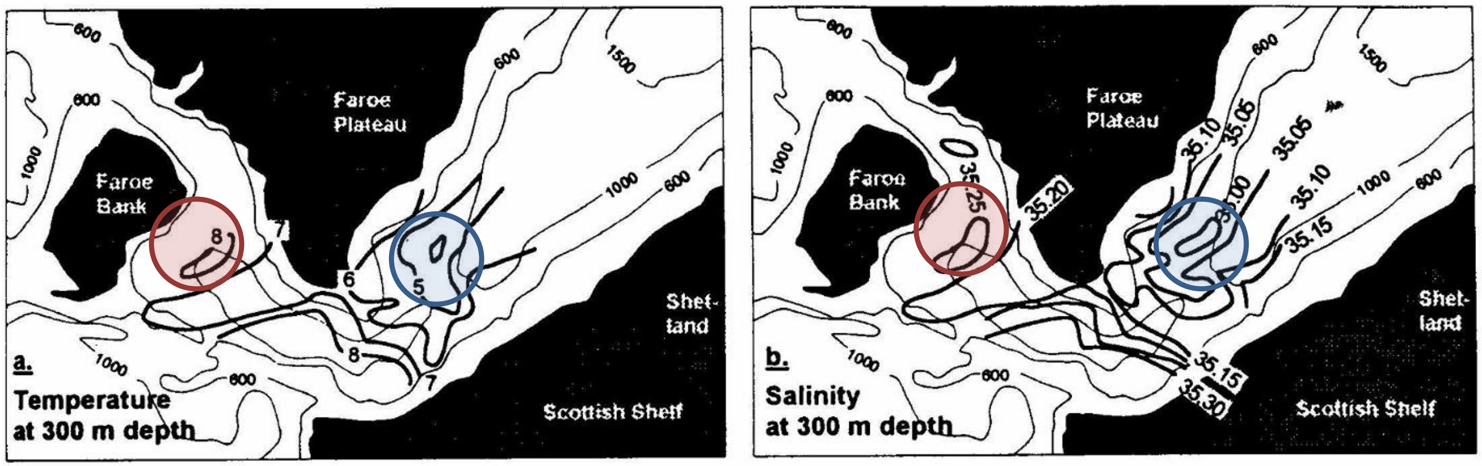
Upwelling Downwelling



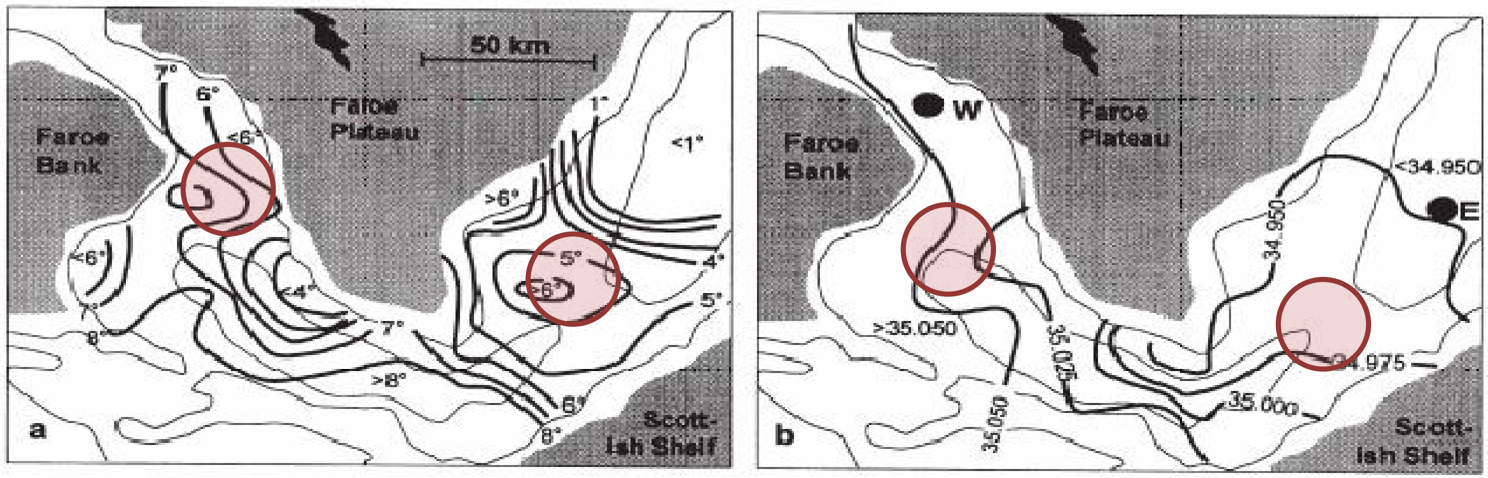
Cyclonic eddy Anti-cyclonic eddy

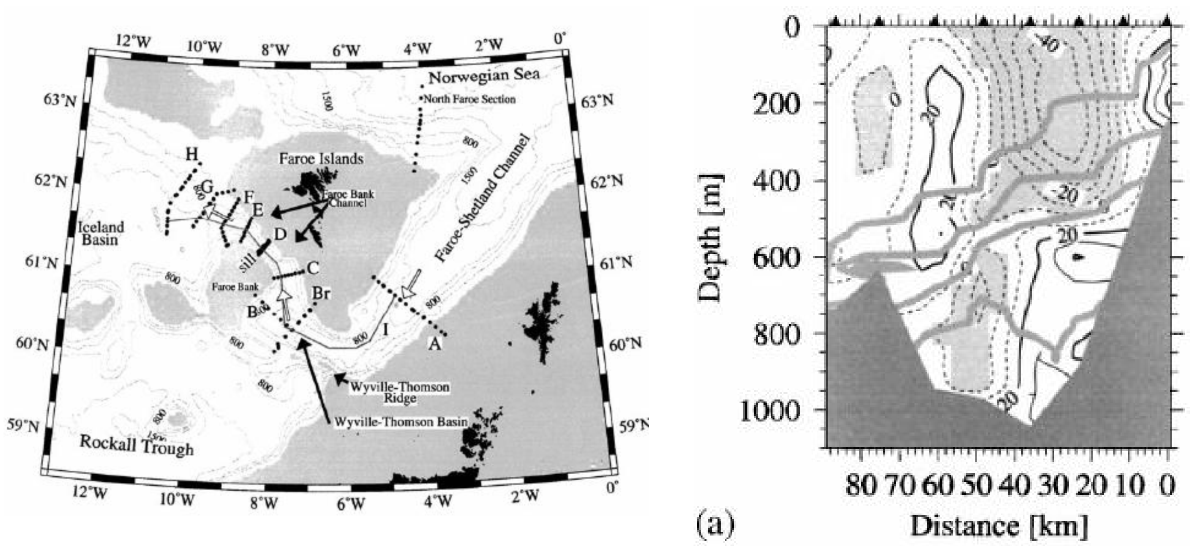
Horizontal distribution of properties in April-May based on CTD measurements of vessel *Magnus Heinason*. a: Temperature at 300 m depth. b: Salinity at 300 m depth.

in April-May 1987 (Becker and Hansen(1998))

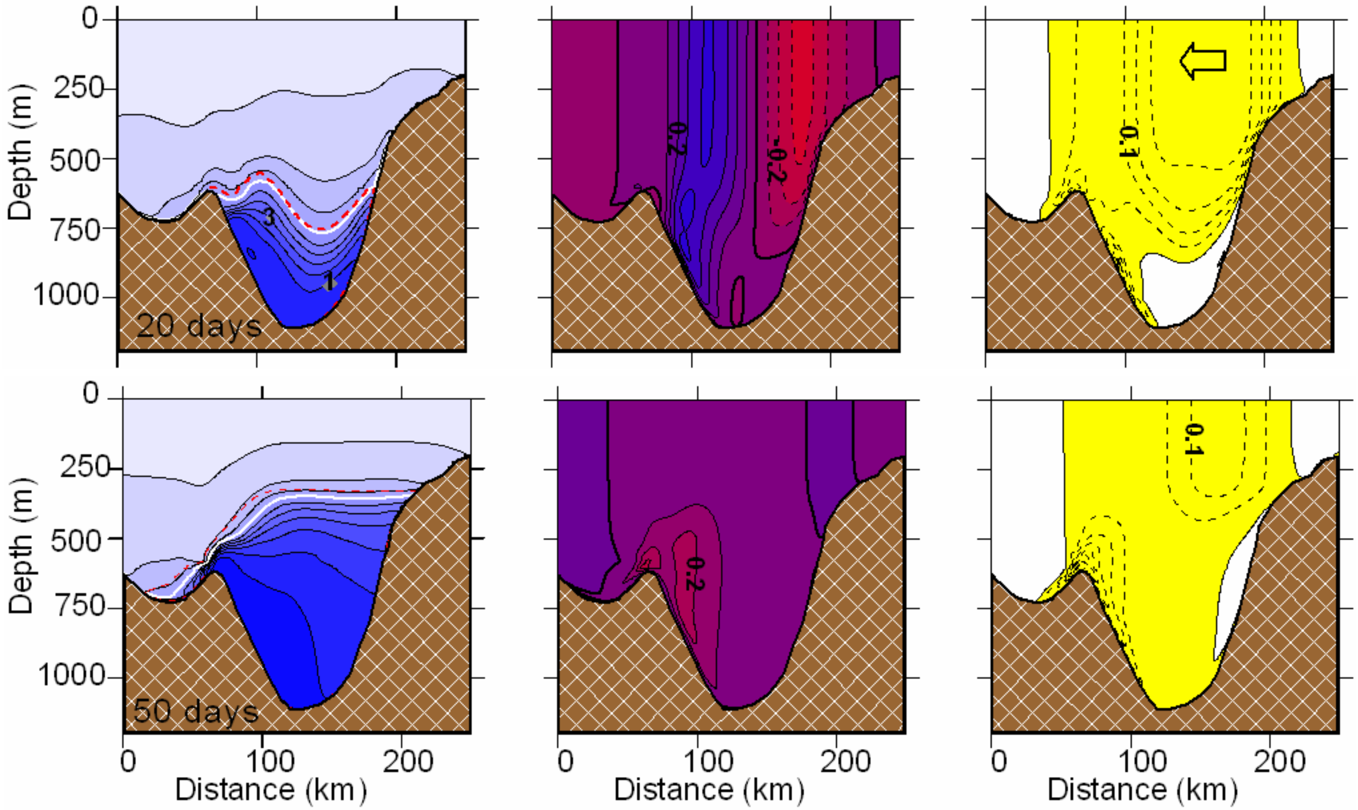


in April-May 1989 (Hansen and Osterhus (2000))



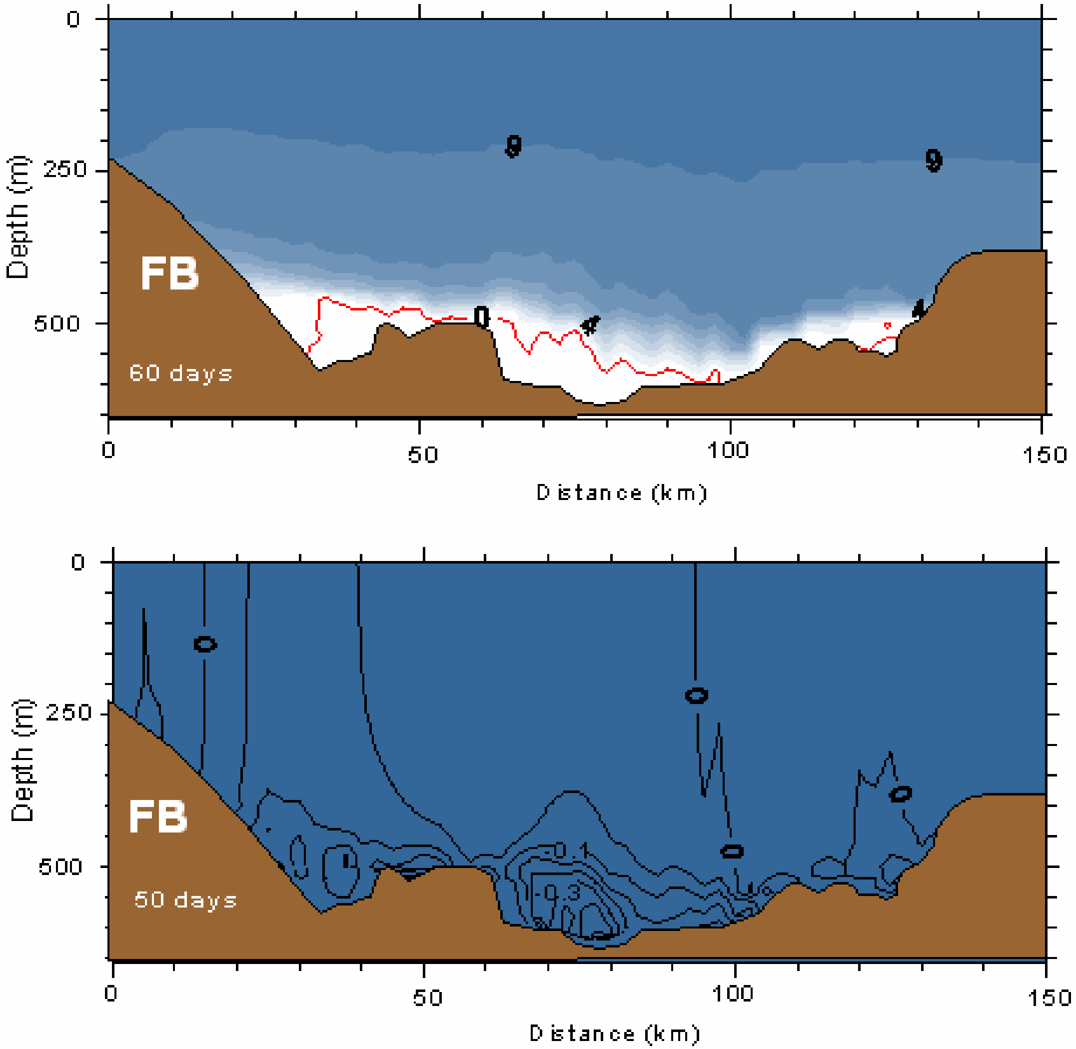


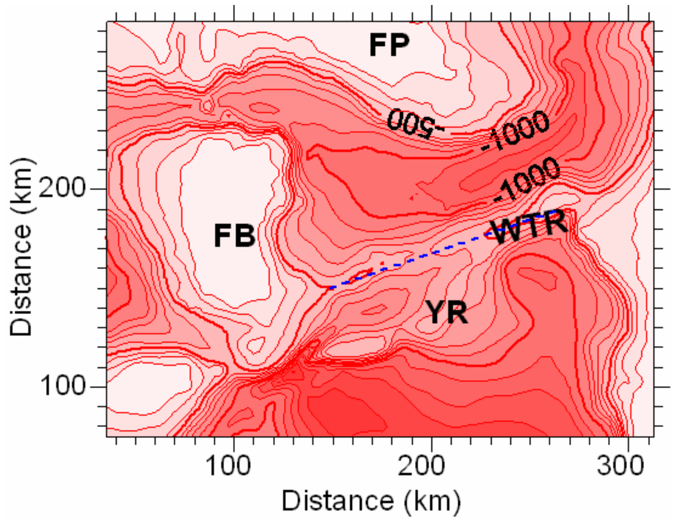
Cross-sections velocities and density for Br section. (Mauritzen et al. 2005)



Temperature , along and cross-section velocities after 20 and 50 days of numerical runs.

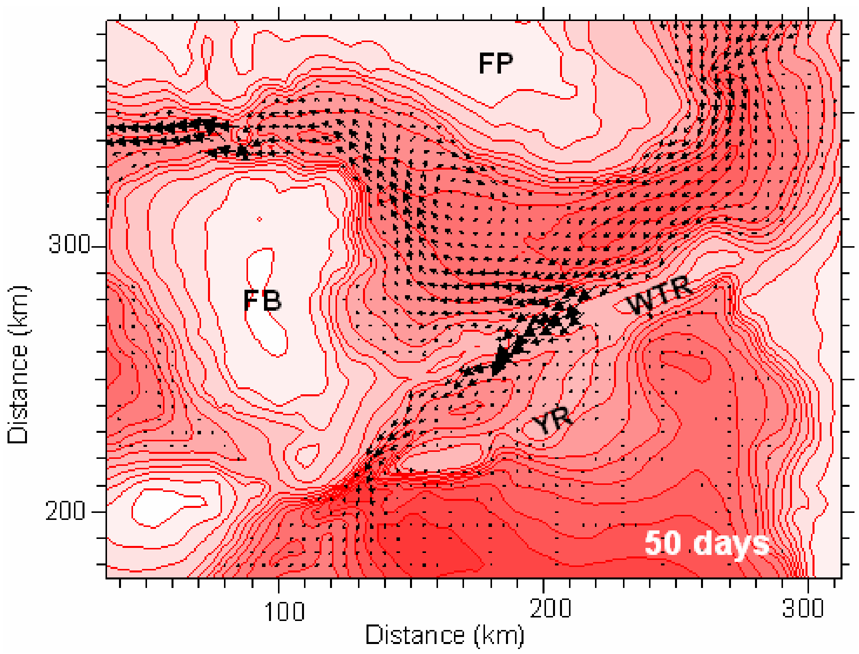
Distribution of the temperature and velocity across the WTR after 60 days of evolution.





The role of the rotation in water leakage through the WTR

f≠0



f=0

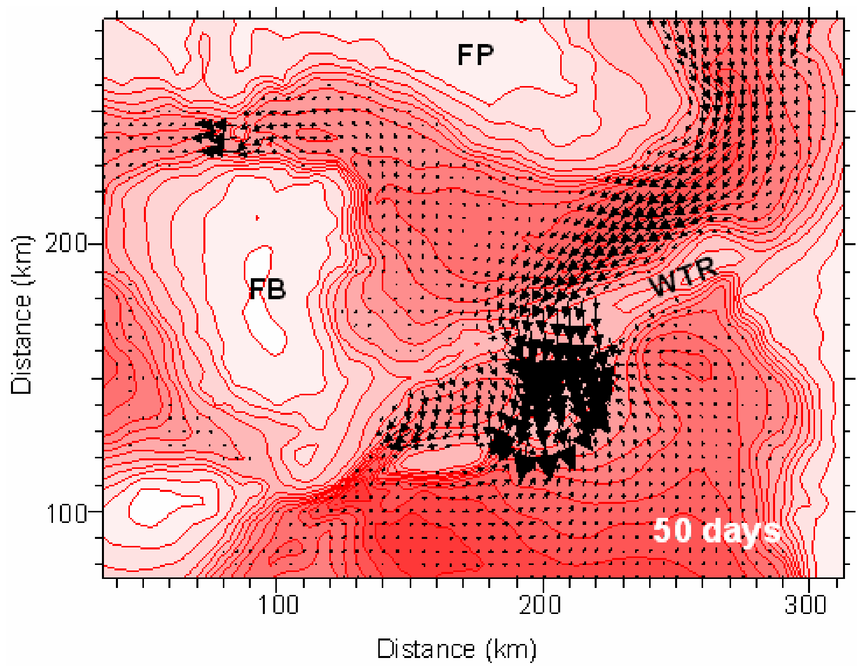
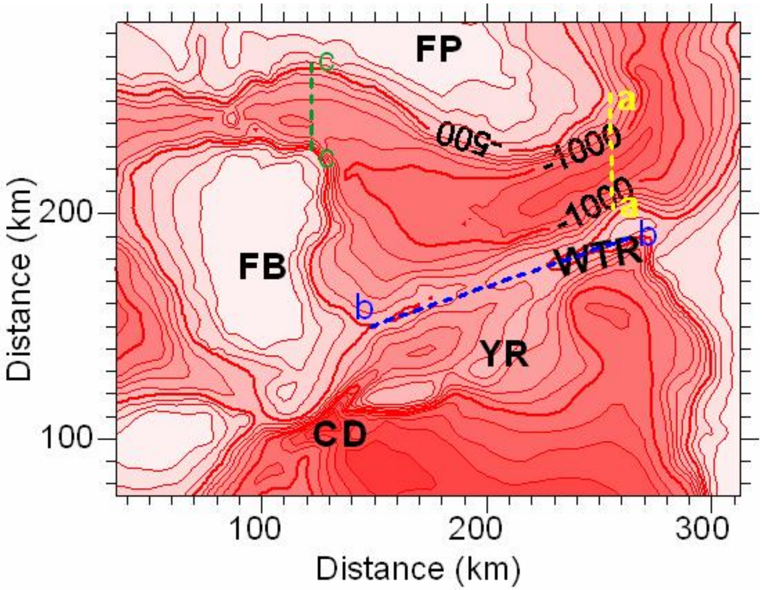
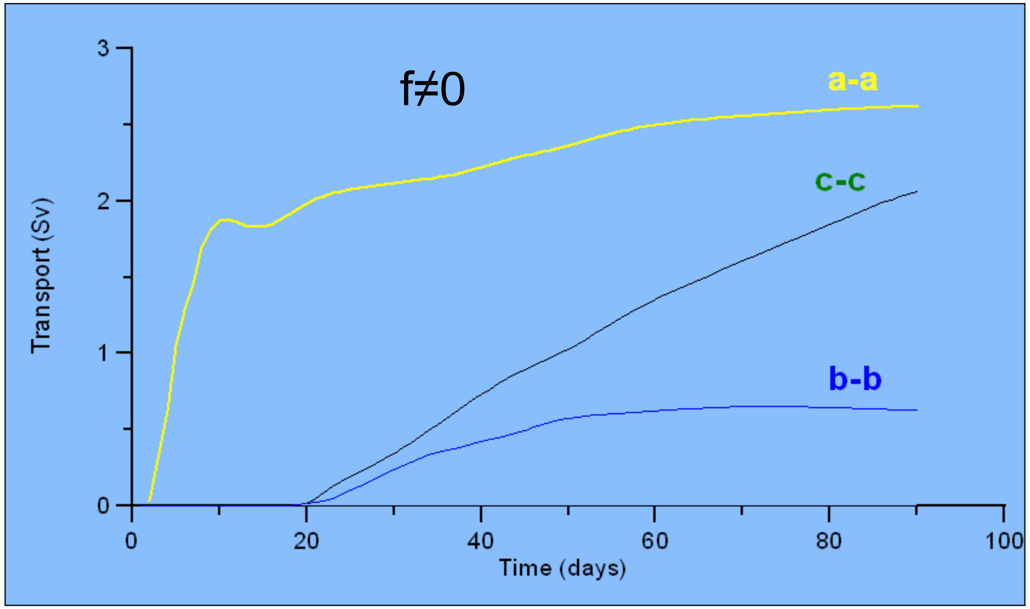


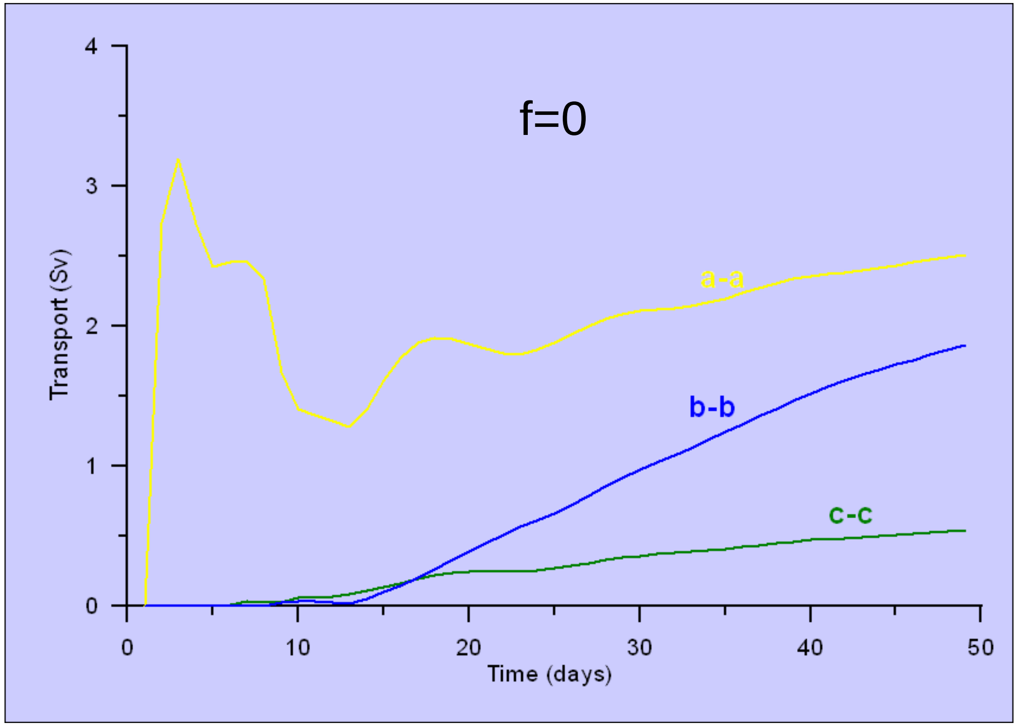
Figure shows that the current between the FP and Shetland Plato (Herbidies) curves around FP and detaches from it as a jet stream which then impinges the WTR. Here the jet splits into two parts: one them overflows through the ridge, but the other one turns to the right. This stream current hits the Faroe Bank once again and splits into two branches. The right branch enters the Faroe Bank Channel, but the left one moves in opposite direction completing formation of an anti-cyclonic eddy. Such a behaviour of the bottom currents takes place due to the rotation and complex bottom topography.

Figure a shows the velocity vectors at the depth of 600 m after 50 days after the start of the experiment. Comparison of Figures shows that a much wider stream jet overflows the WTR in non-rotating model domain. At the same time the current entering the Faroe Bank Channel becomes slower. It seems that the leakage of water become predominant through the WTR than the amount of water directed to the FBC in the case without rotation. The estimation of the water discharge through several section of the model domain confirms this conclusion.

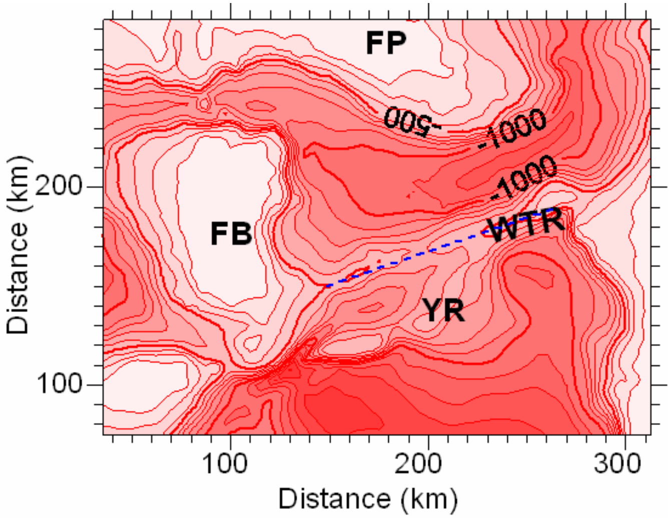
Evolution of transport through the sections a-a, b-b and c-c

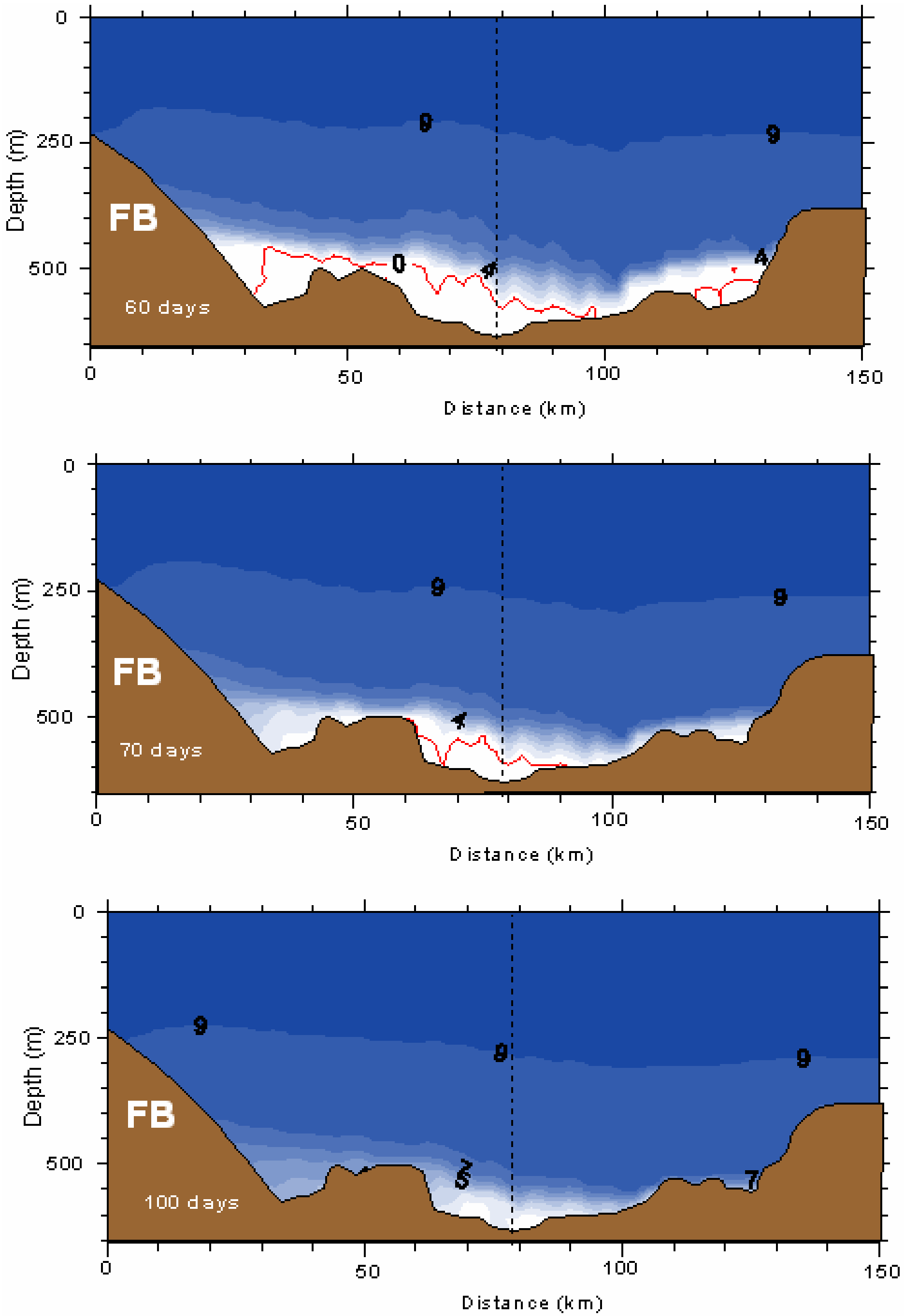






Distribution of the temperature and velocity across the WTR after 60 days of evolution.



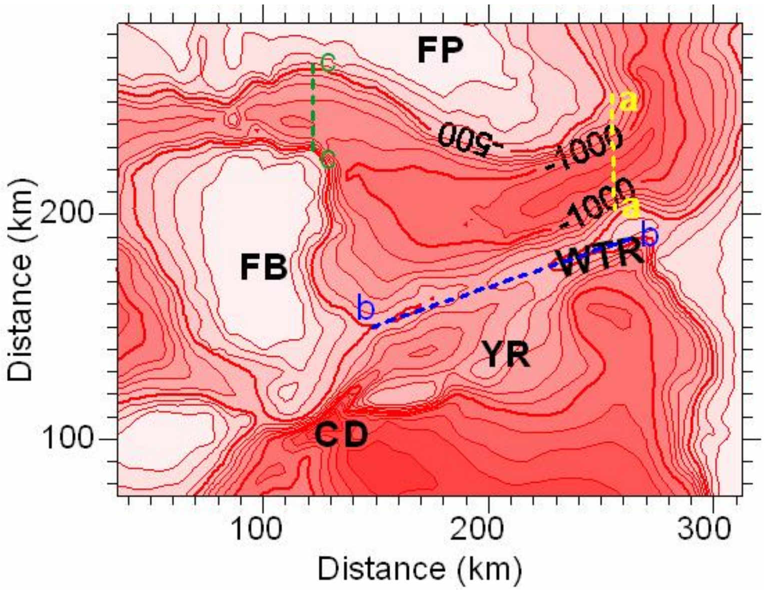


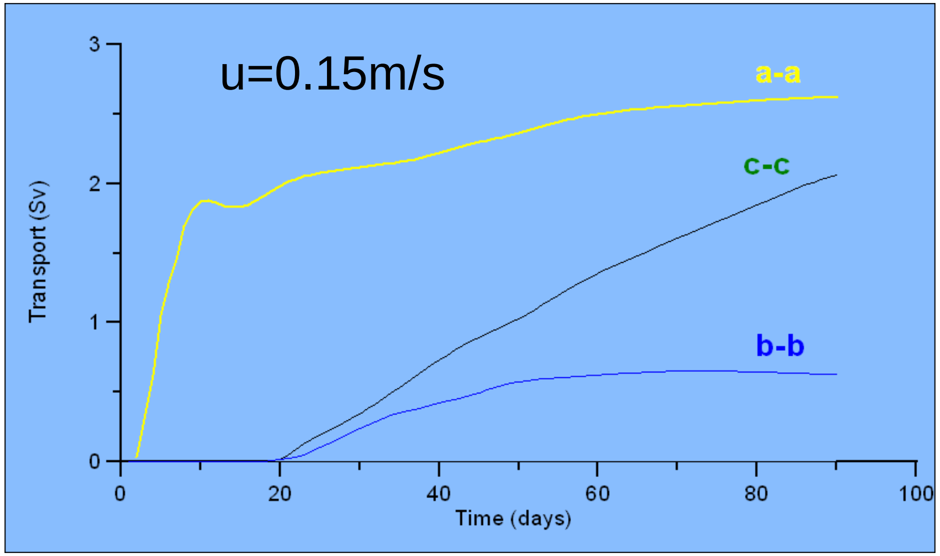
u=0.15m/s

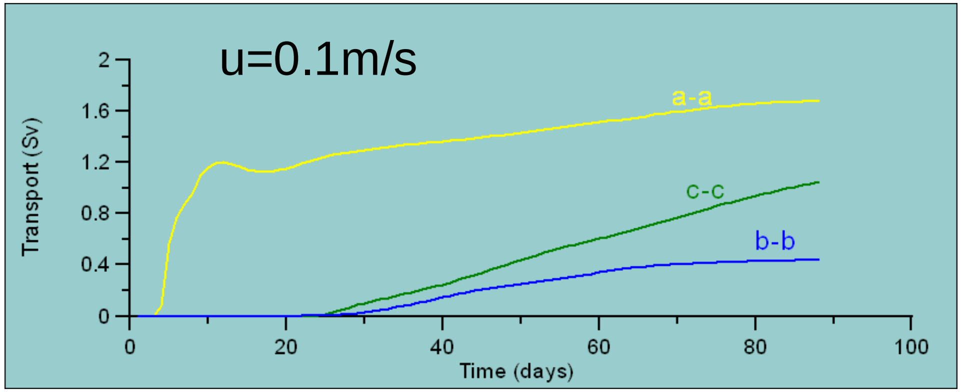
u=0.1m/s

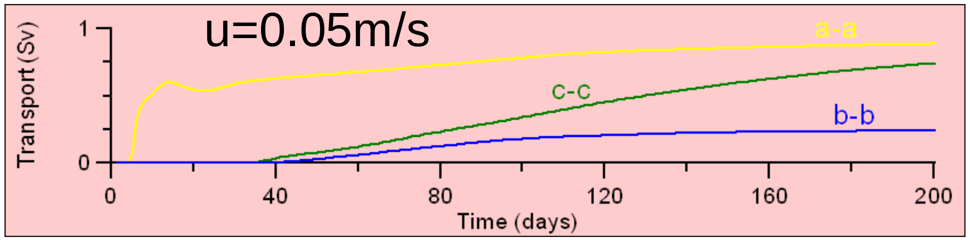
u=0.05m/s

Water transport through the sections a-a, b-b and c-c









Conclusions

- Our numerical experiments revealed that the majority of the Faroe Shetland Channel bottom water propagates in the direction of the Faroe Bank Channel. However, a fairly steady flow escapes from the major current and overflows through the central depression of the WTR.

- The major part of the overflow over the Wyville-Thomson Ridge is located on its western part. Guided by topography and the earth rotation, the cold waters spilling over the section funnel in the Ymer Trough and concentrate southeast of the Faroe Bank in a narrow boundary current.

- The model predicts cold water currents (temperature below 0ºC) overflowing with velocities up to 0.4 m /s over the WTR, which represents a great influence of cold water from the Faroe Shetland Channel bottom water.