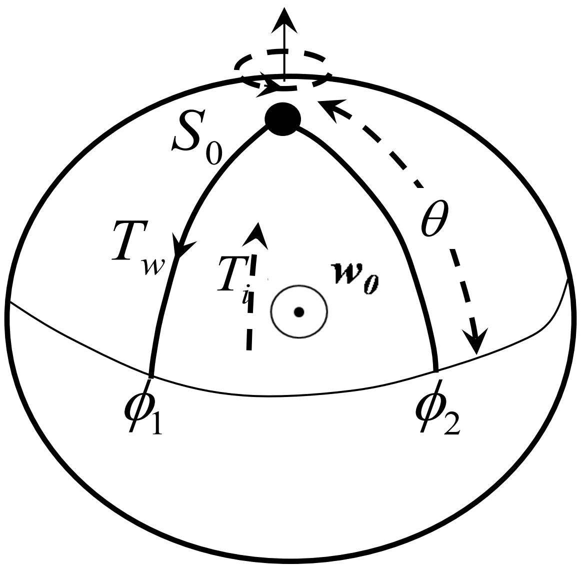
Δημιουργία πυκνών νερών και η θερμοαλατική κυκλοφορία



7. Deep convection and the thermohaline circulation

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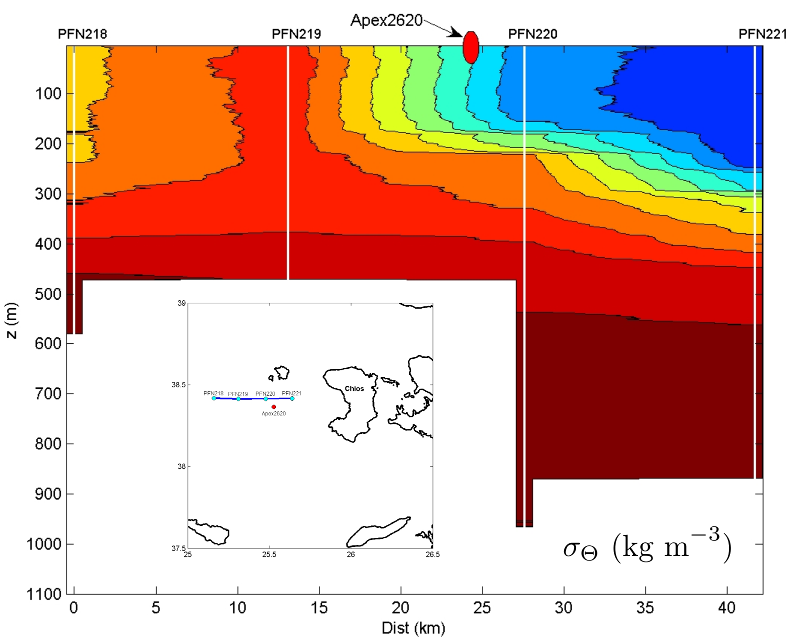
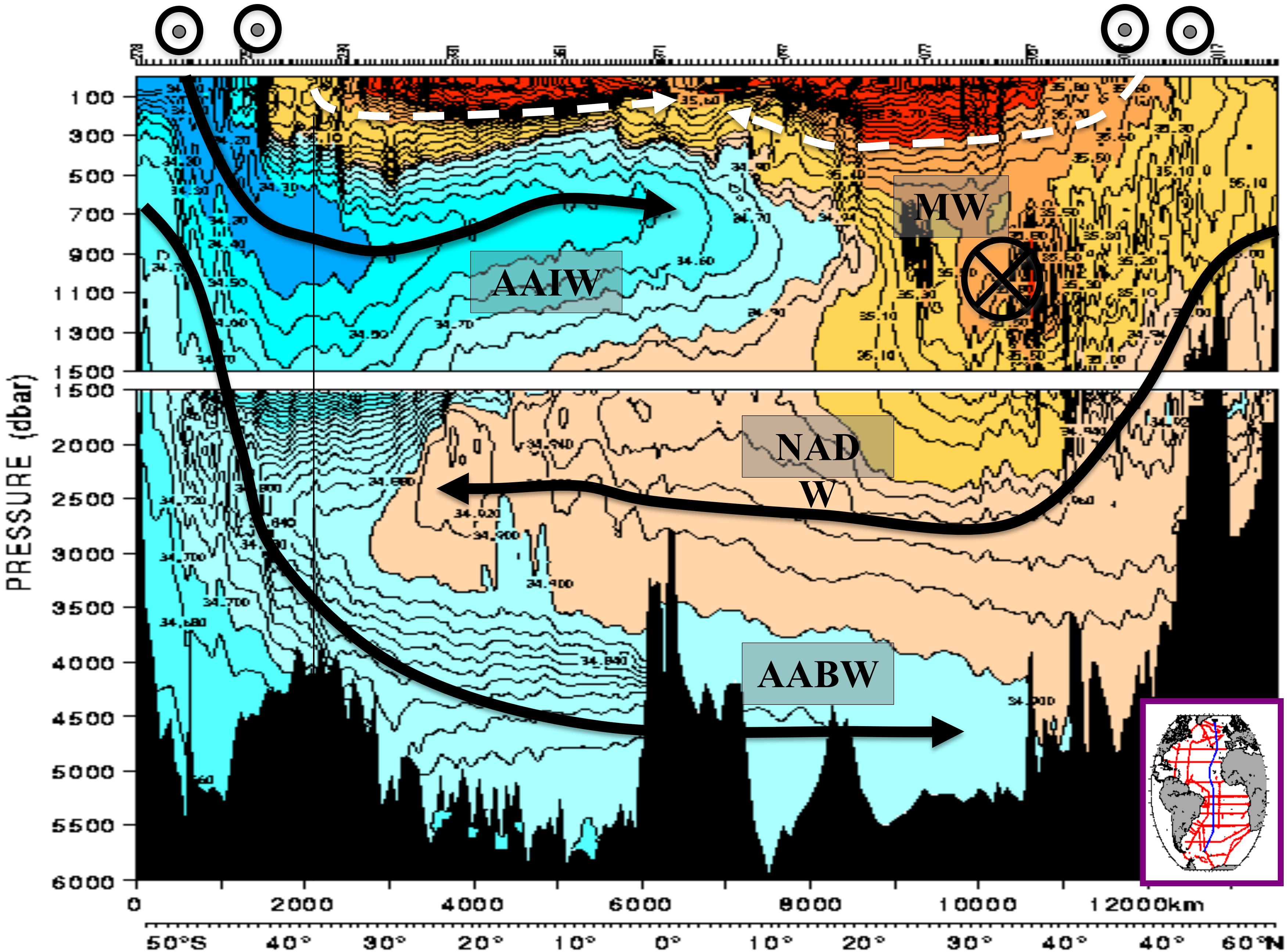
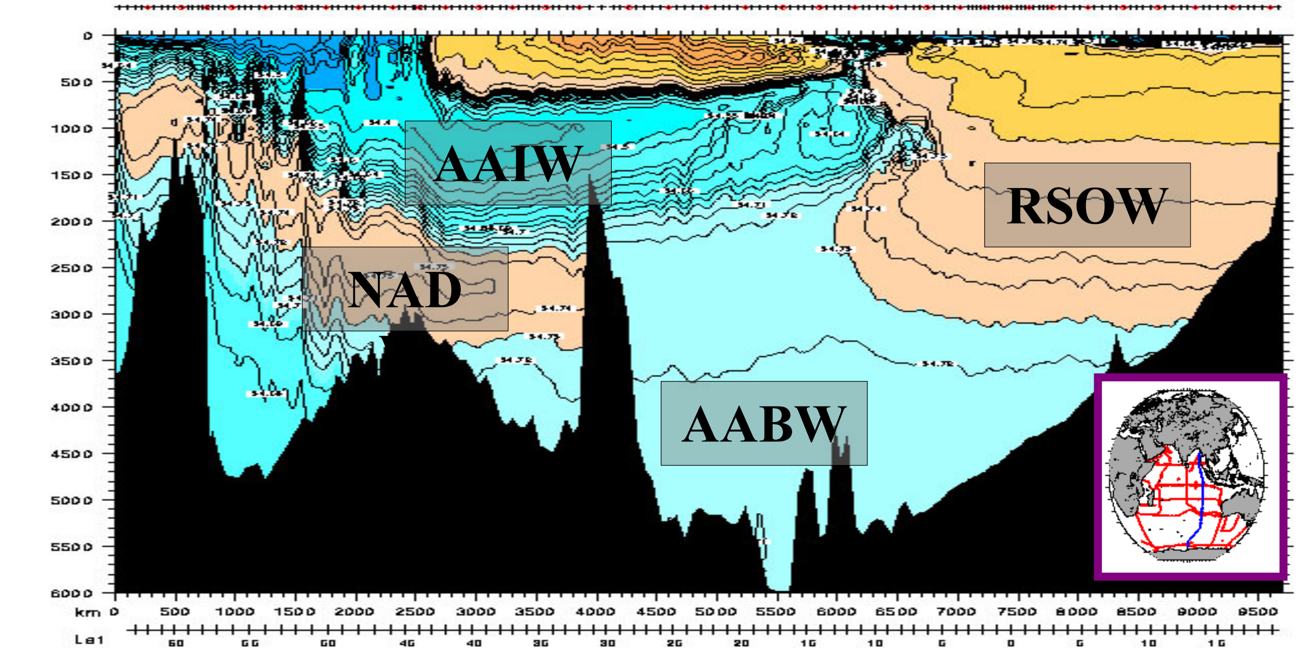


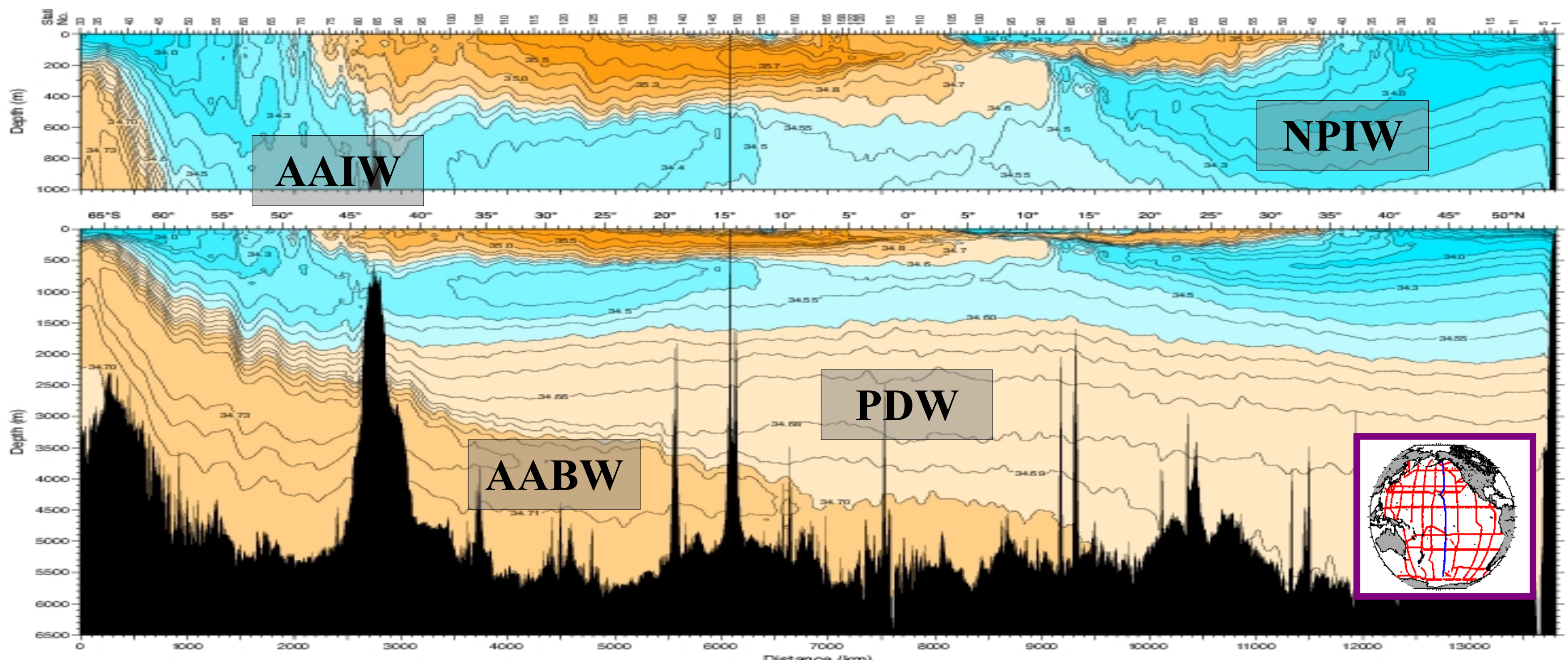
- **Deep water masses**
- **Deep convection**
- **Thermohaline circulation and the "conveyor belt"**

Atlantic Main Water Masses (on salinity section)

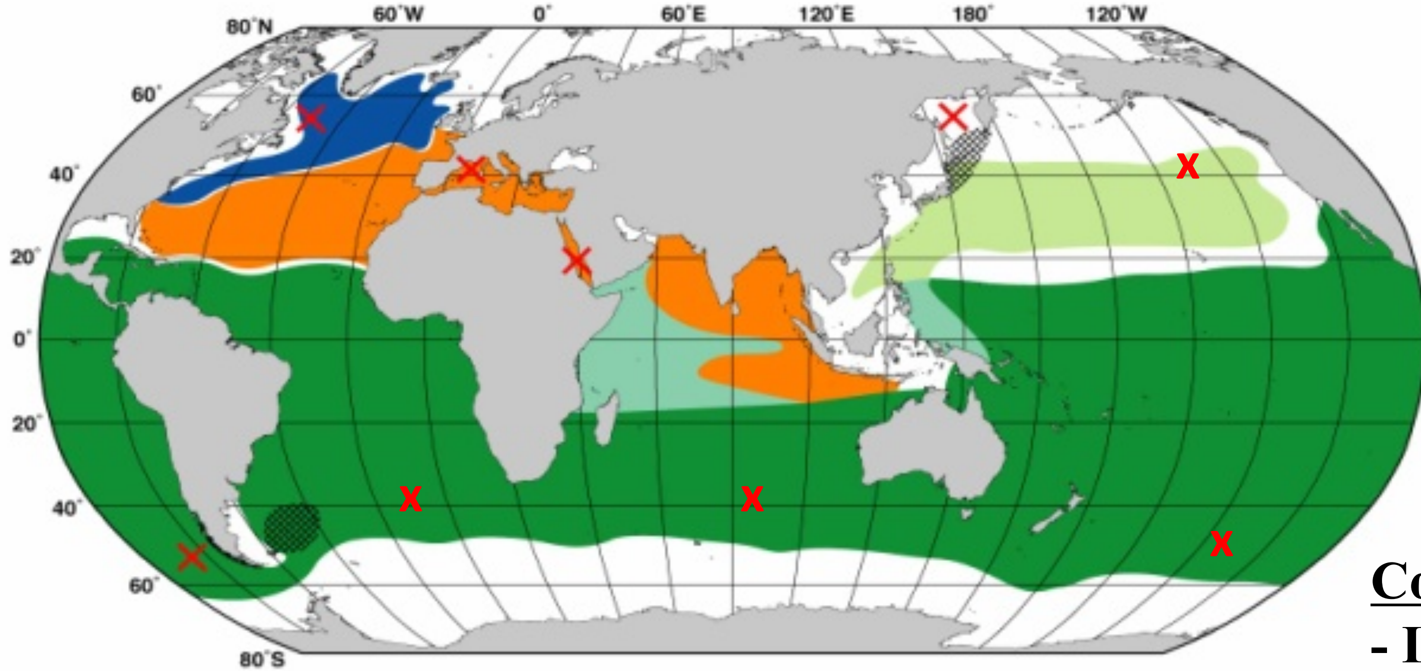


Indian and Pacific Main Water Masses

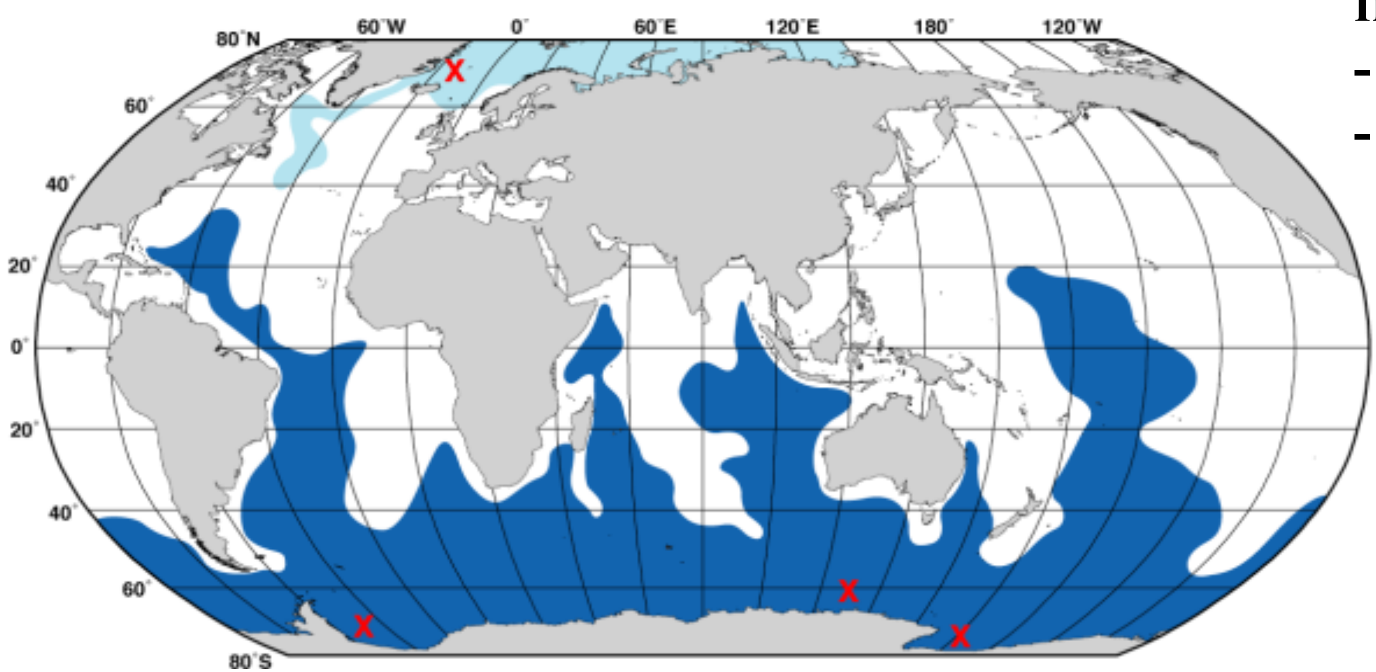




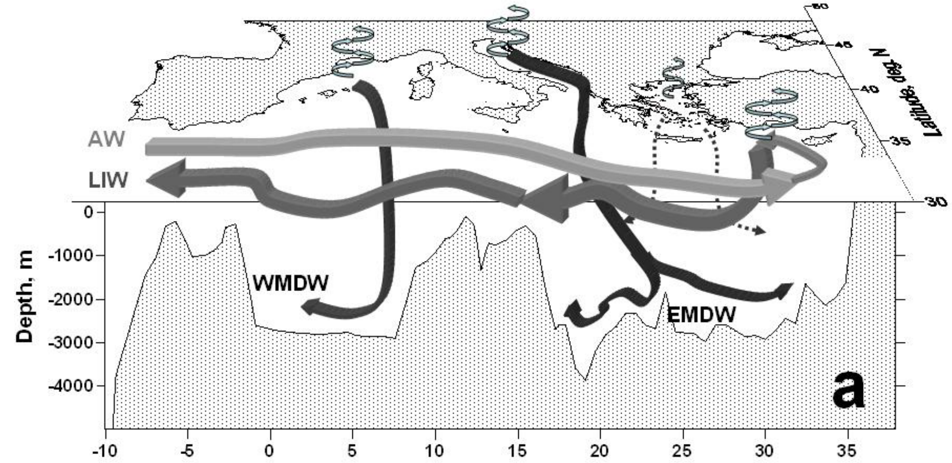
Water mass formation areas



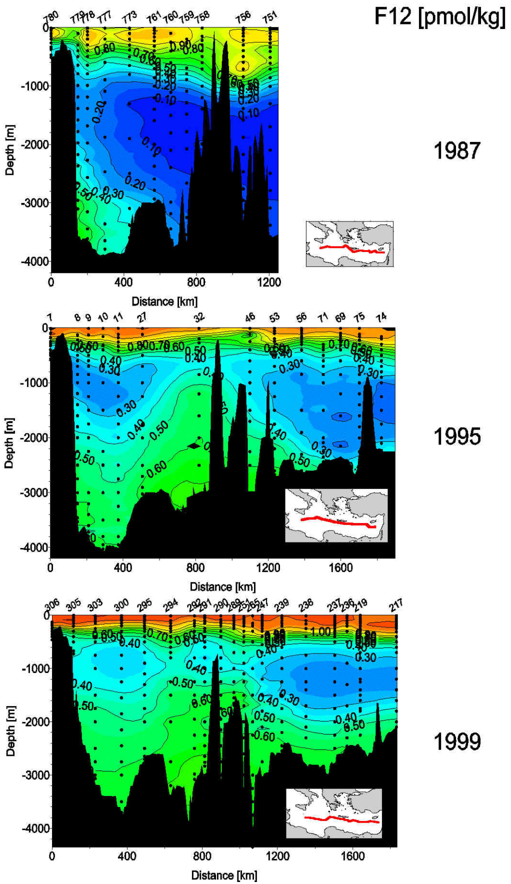
Conditions:
- Intense heat and/or freshwater loss
- Weak stratification
- Trapping

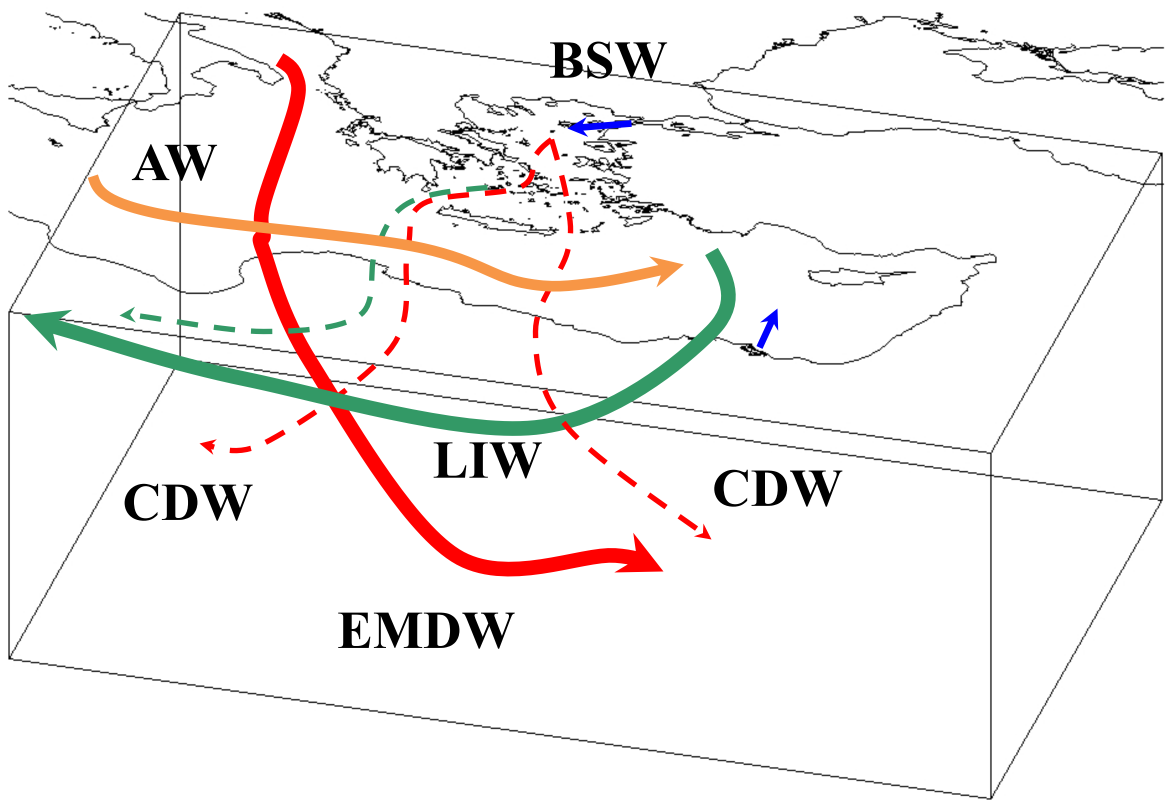


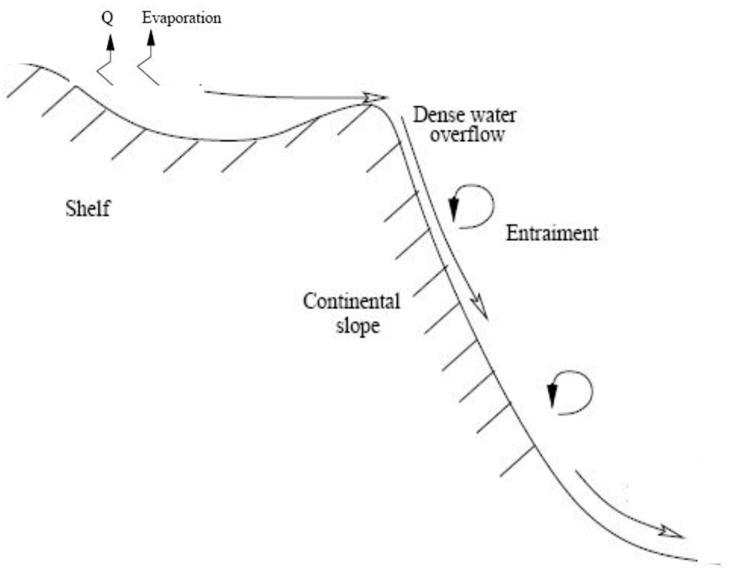
Areas:
- Arctic regions
- Semi-enclosed seas
- Continental shelf
- Cyclonic features

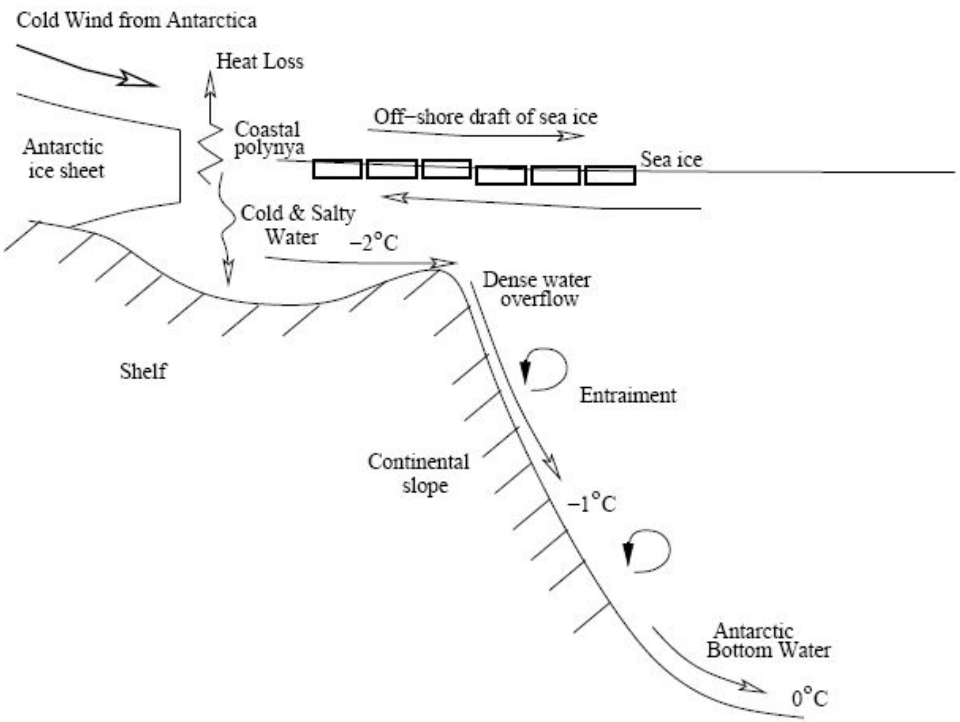


The Mediterranean Sea water masses









Shelf water mass formation

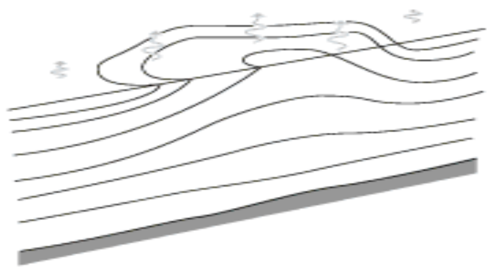
- Strong heat loss and/or evaporative rates over the relatively shallow water column on the continental shelf can lead to formation of very dense waters.
- Entrainment on the continental slope changes dramatically the new water mass temperature and salinity properties and gives the water mass its final characteristics.

Arctic/Antarctic shelf water mass formation

- Winds blowing offshore open the ice sheet, forming a polynya.
- Salt addition to the water column, related to ice formation increases the water salinity.
- Large heat fluxes (~1000 W m-2) from the exposed ocean drives bottom water formation.
- Entrainment changes the water mass properties.

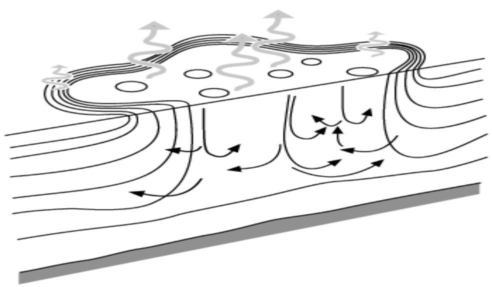
Open ocean convection

1. Pre-conditioning (order of 100 km)

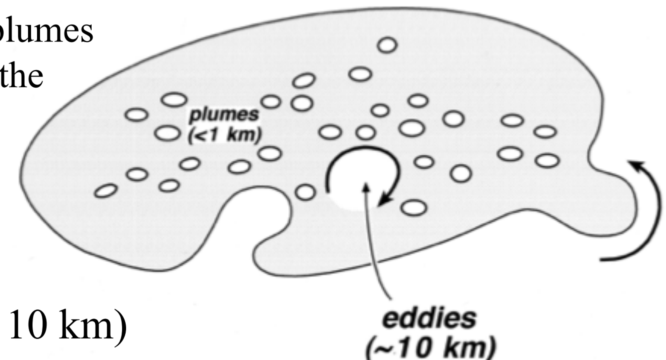


During preconditioning the gyre-scale cyclonic circulation with its “doming” isopycnals, brings weakly stratified waters of the interior close to the surface. Buoyancy loss is preconditioning the “trapped” water.

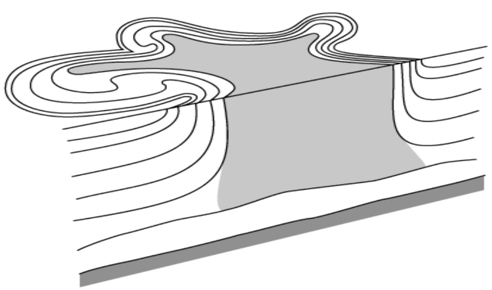
2. Deep convection (order of 1 km)



Subsequent cooling events may then initiate deep convection in which a substantial part of the fluid column overturns in numerous plumes that distribute the dense surface water in the vertical.

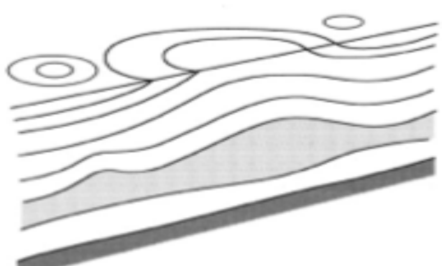


3. Lateral exchange (order of 10 km)



With the cessation of strong forcing, or if the cooling continues for many days, the predominantly vertical heat transfer on the convective scale gives way to horizontal transfer associated with eddying on geostrophic scales as the mixed patch laterally exchanges fluid with its surroundings.

4. Re-stratification

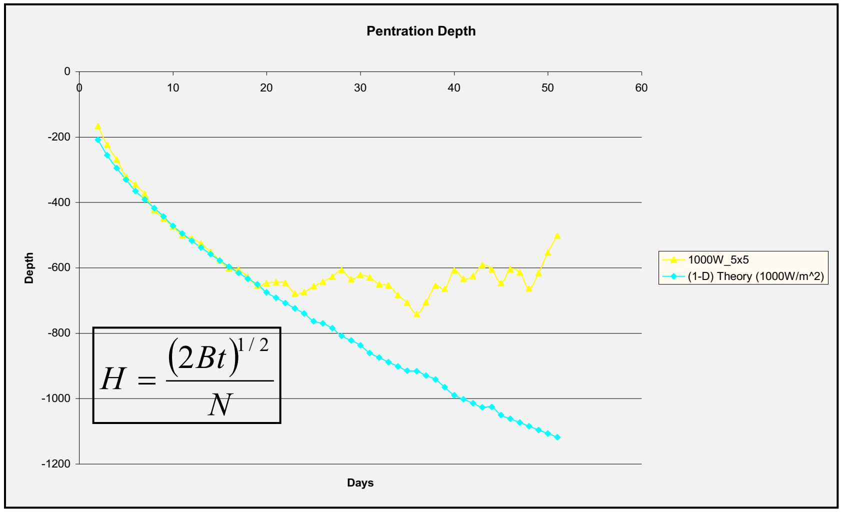


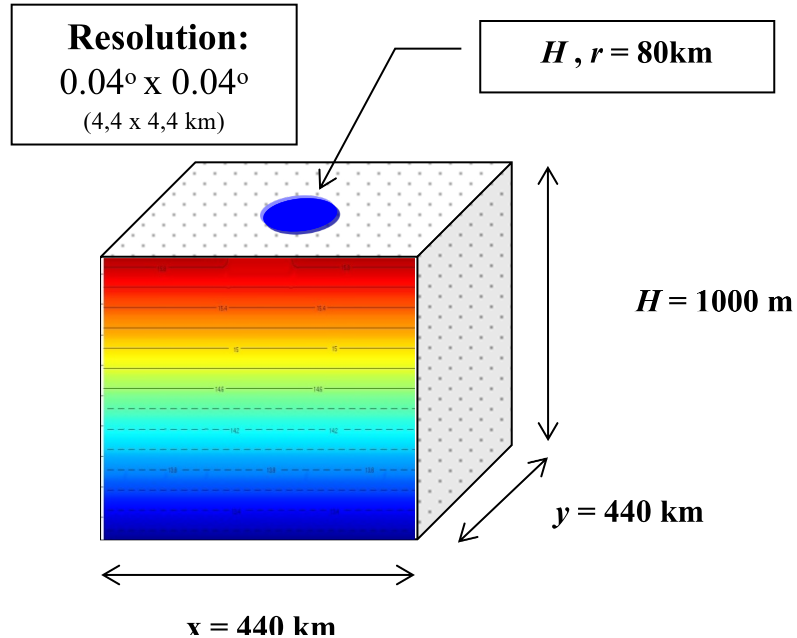
The mixed fluid disperses under the influence of gravity and rotation, spreading out at its neutrally buoyant level and leading, on a timescale of weeks to months, to the disintegration of the mixed patch and reoccupation of the convection site by the stratified fluid of the periphery.

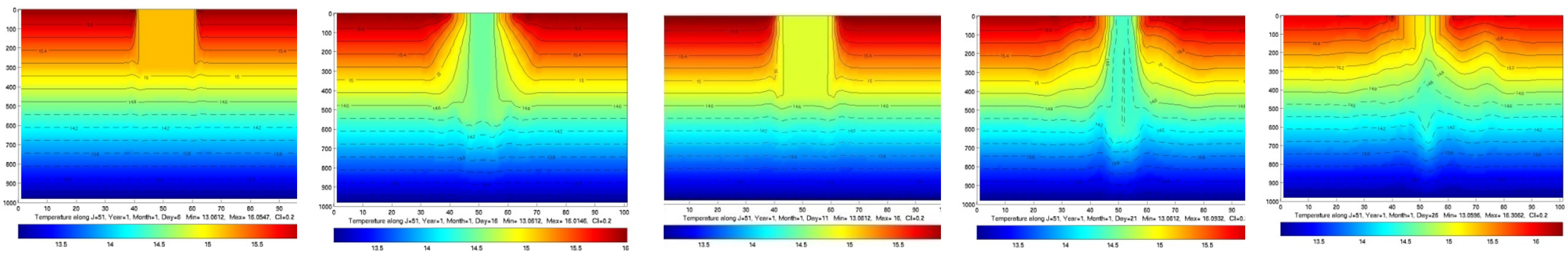
For details: Marshall, J., and F. Schott, Open-ocean convection: Observations, theory, and models, Rev. Geophys., 37, 1–64, 1999.

An example:

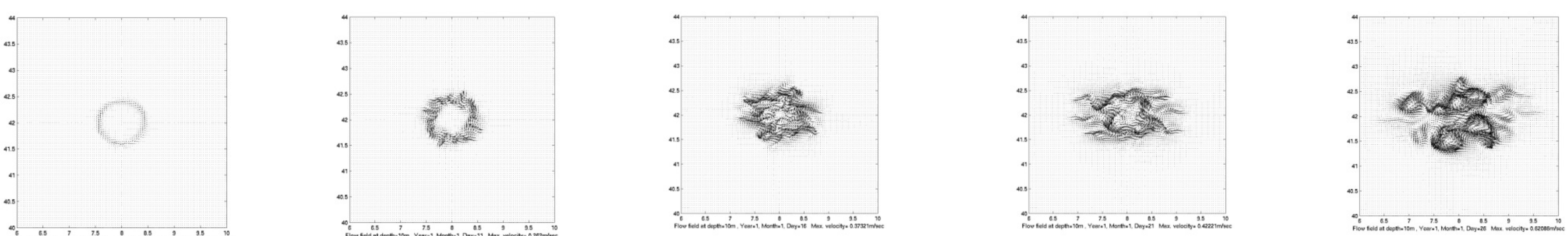
Compare 1-D approach with 3-D results







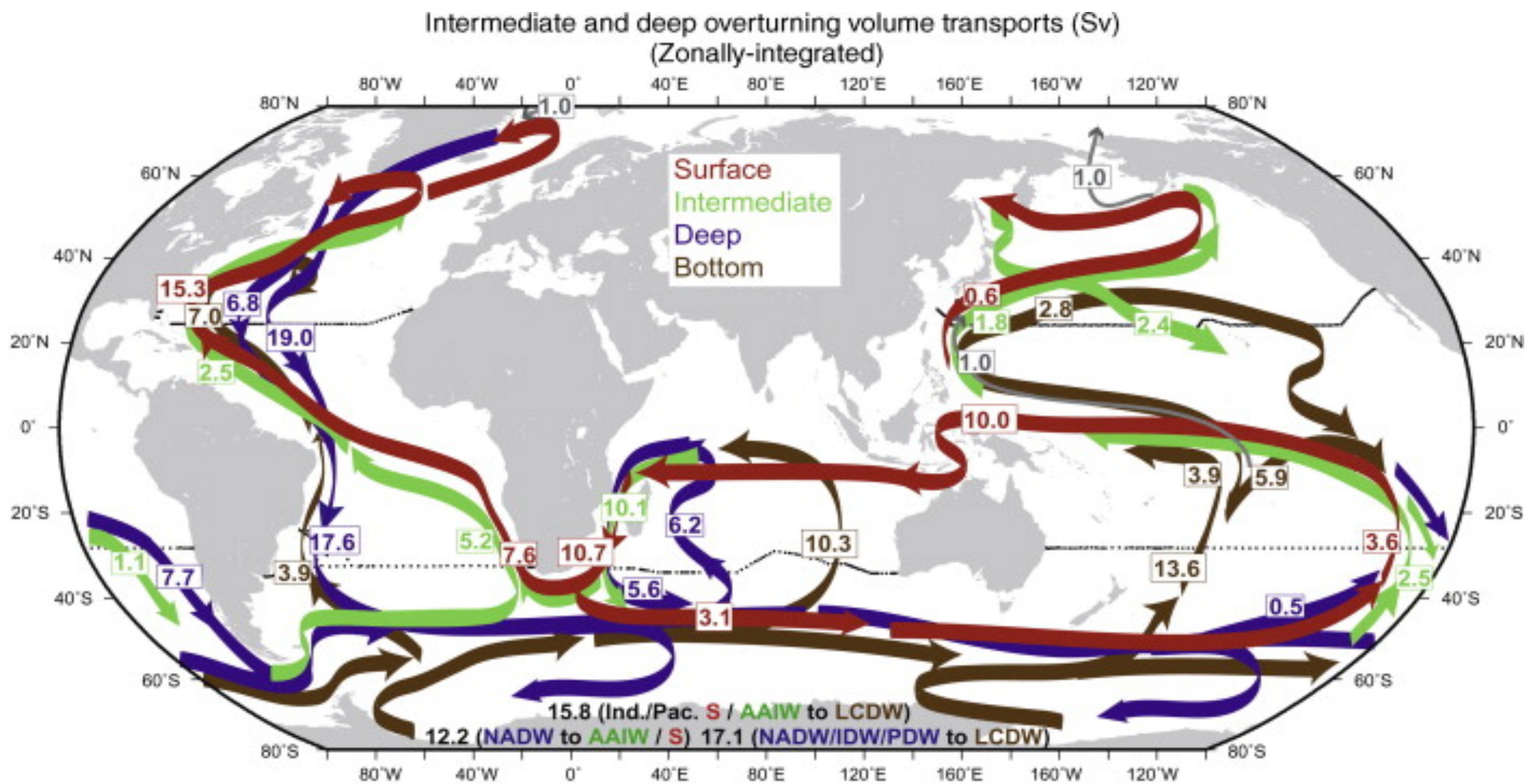
5days → **10 days** → **15 days** → **20 days** → **25 days**



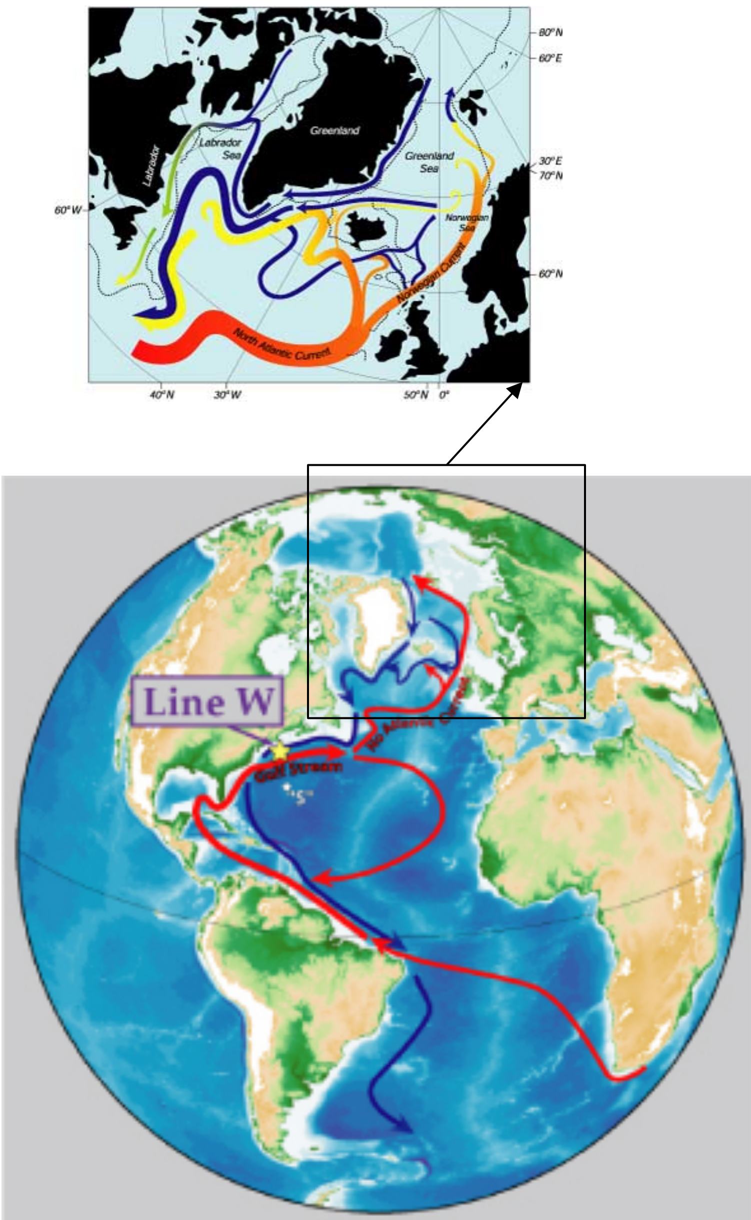
Krokos, MSc Thesis, Univ.

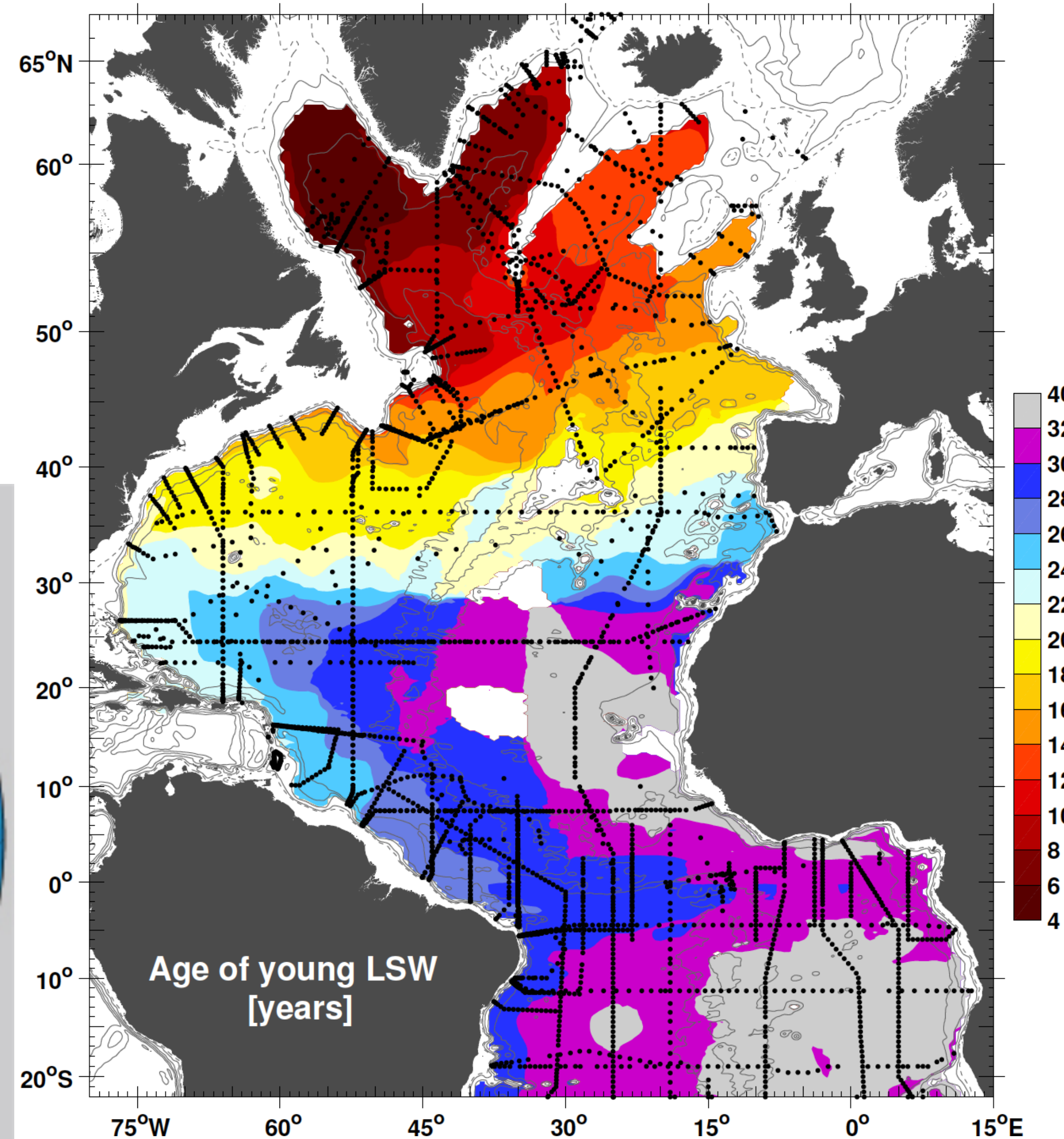
The fate of the formed water masses:

The "conveyor belt"
The "overturning circulation"

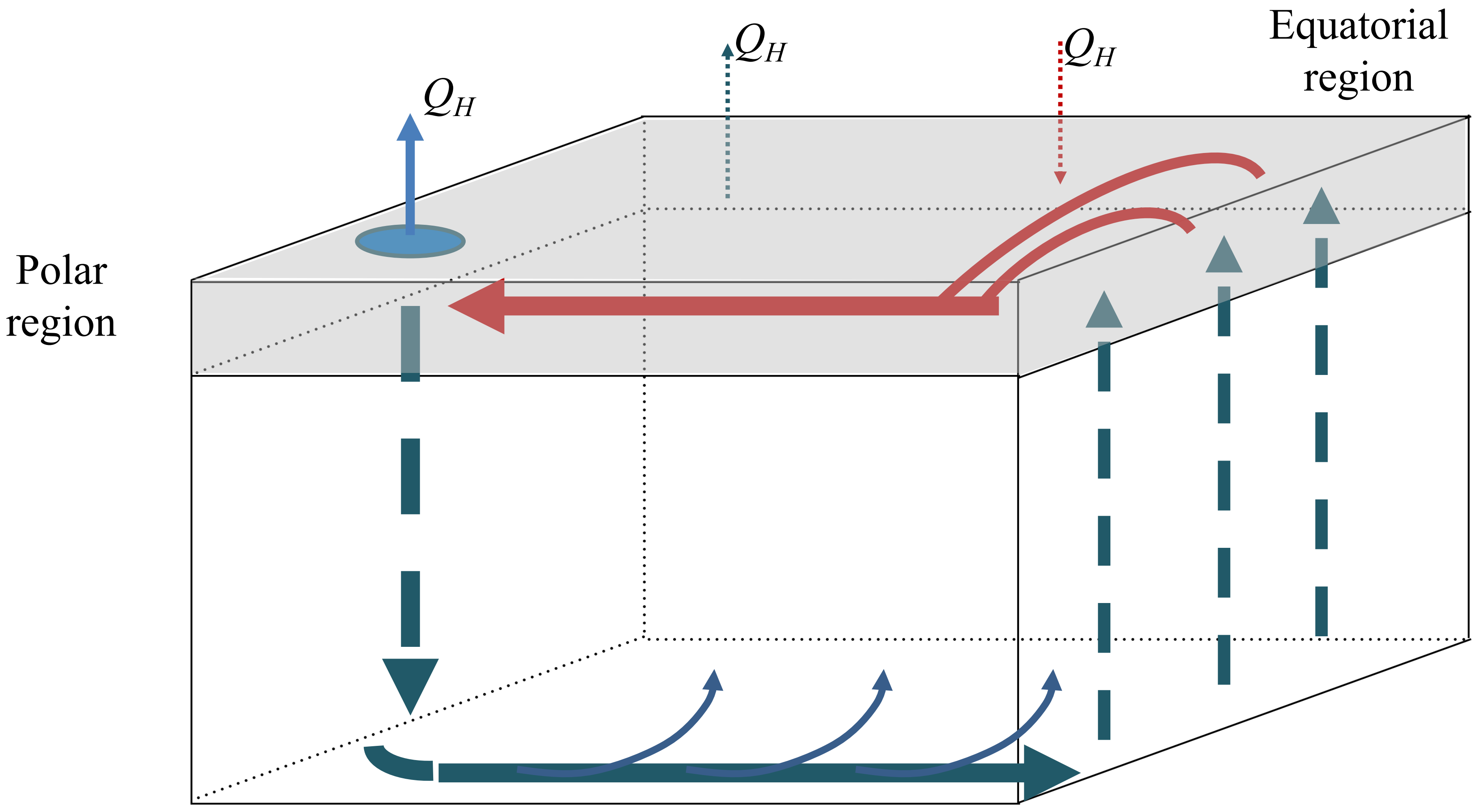


The pathways of deep waters





The overturning circulation



Abyssal Circulation (Stommel-Arons Theory)

For large scale motions ($R_o << 1$)

Starting from:

$$\frac{d}{dt}(f+\zeta) = -(f+\zeta)\left(\frac{\partial u}{\partial x} + \frac{\partial \upsilon}{\partial y}\right)$$

and using the continuity equation $\frac{\partial u}{\partial x} + \frac{\partial \upsilon}{\partial y} = -\frac{\partial w}{\partial z}$

$$\frac{d}{dt}(f+\zeta) = -(f+\zeta)\left(-\frac{\partial w}{\partial z}\right)$$

Scaling

$$\zeta = \frac{\partial \upsilon}{\partial x} - \frac{\partial u}{\partial y} = O\left(\frac{U}{L}\right)$$

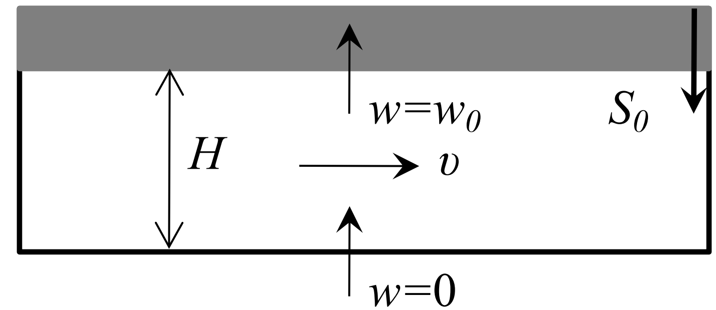
$$\frac{\zeta}{f} = O\left(\frac{U}{f_0 L}\right) = O(R_o) << 1$$

$$f = O(f_0)$$

ignoring ζ

$$\frac{df}{dt} = \frac{\partial f}{\partial t} + u\frac{\partial f}{\partial x} + \upsilon\frac{\partial f}{\partial y} + w\frac{\partial f}{\partial z} = \beta\upsilon$$

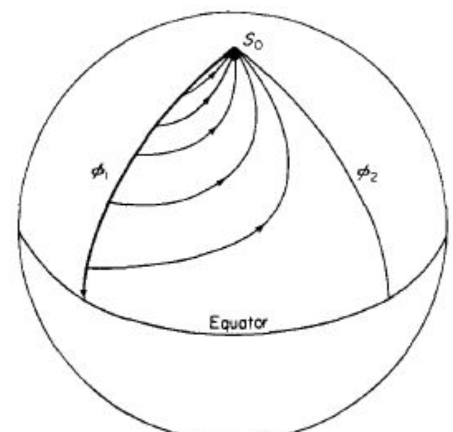
$$\Rightarrow \beta\upsilon = f\frac{\partial w}{\partial z}$$



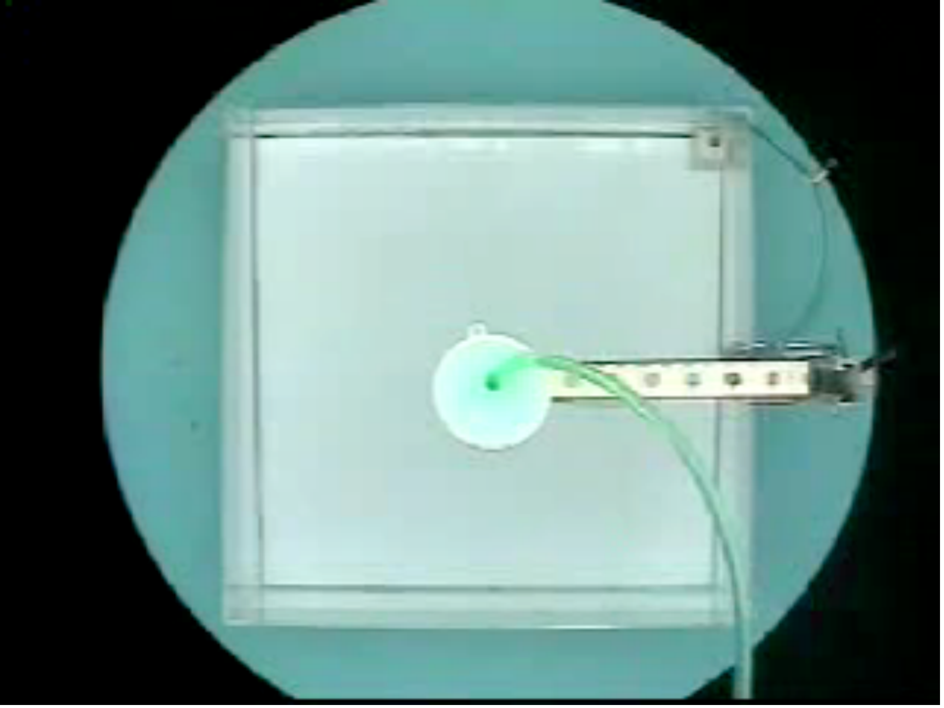
$$\beta\upsilon = f\frac{\partial w}{\partial z}$$

$$\frac{\partial w}{\partial z} > 0 \Rightarrow \beta\upsilon > 0$$

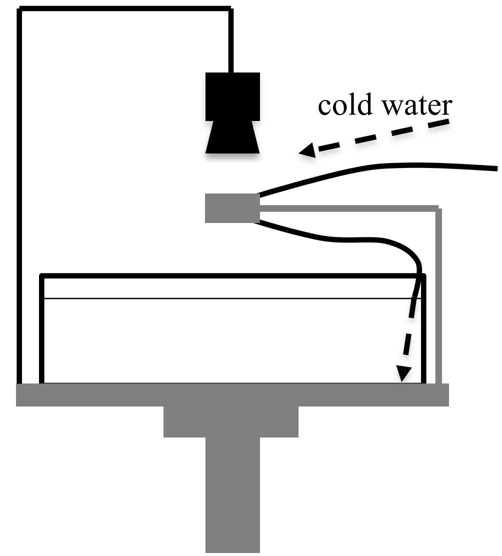
generation of βU
"Sverdrupian" dynamics

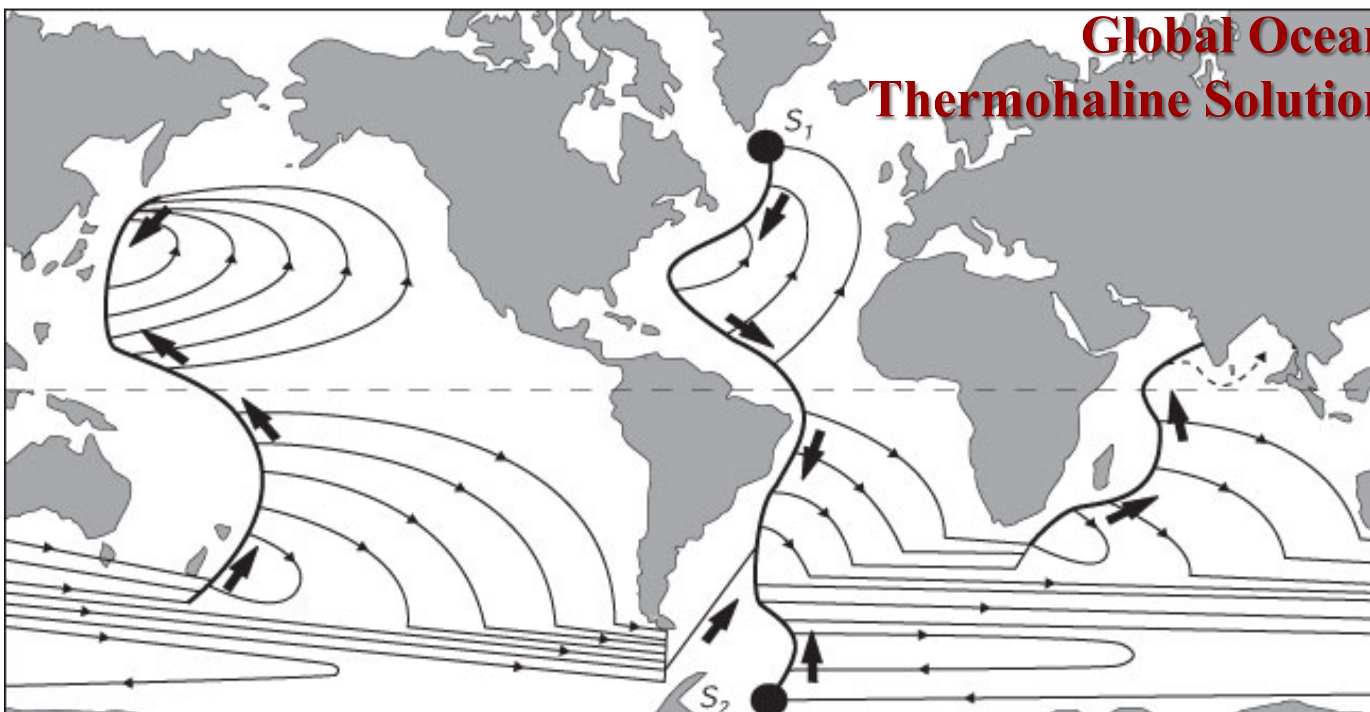


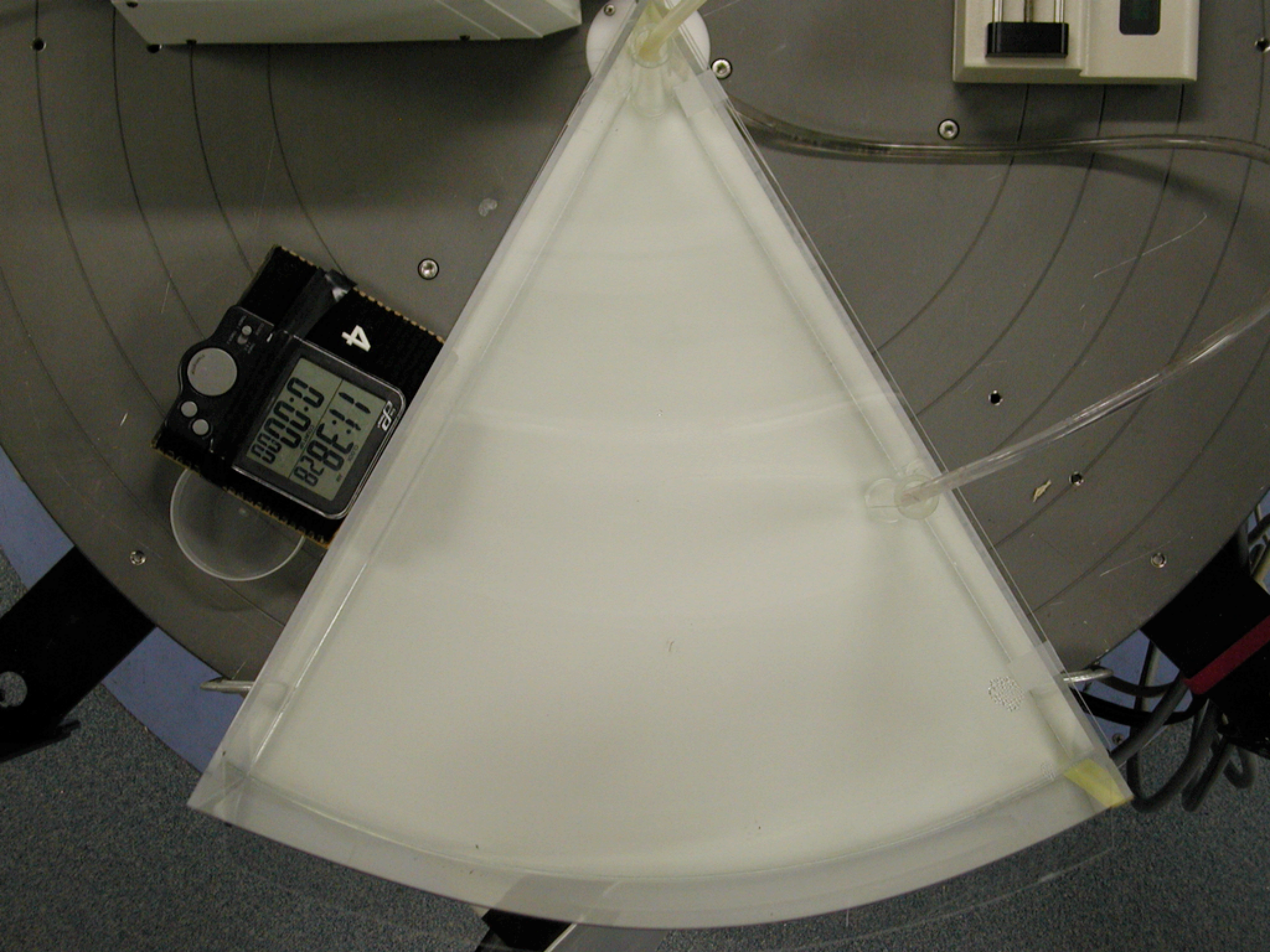
Stommel et al.; Stommel & Arons (1958, 1960)



"Whole" basin solution



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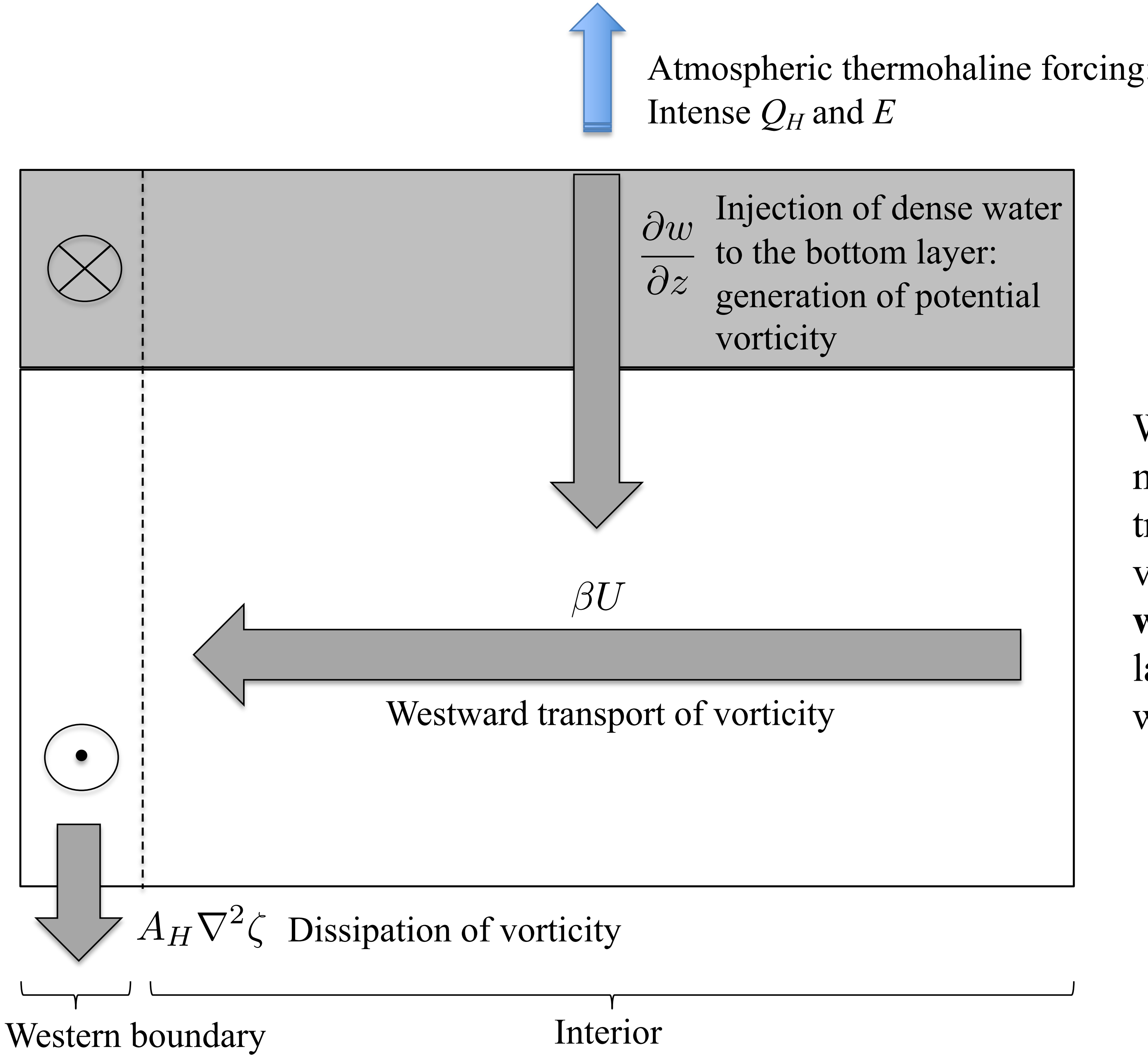

Which mechanism is tranposrting vorticity/energy **westwards**? (see large-scale waves)