Climate of the Ocean

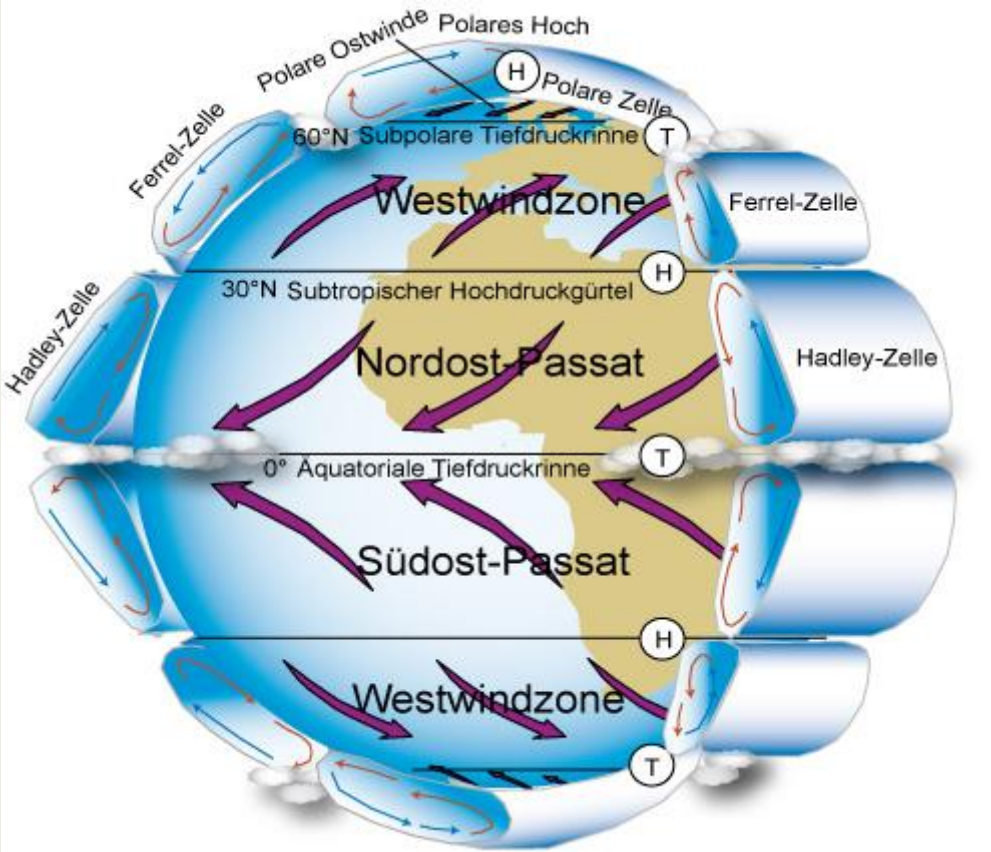
Lecture 2: Large-scale atmosphere and ocean circulation

Prof. Dr. Markus Meier

Leibniz Institute for Baltic Sea Research Warnemünde (IOW)

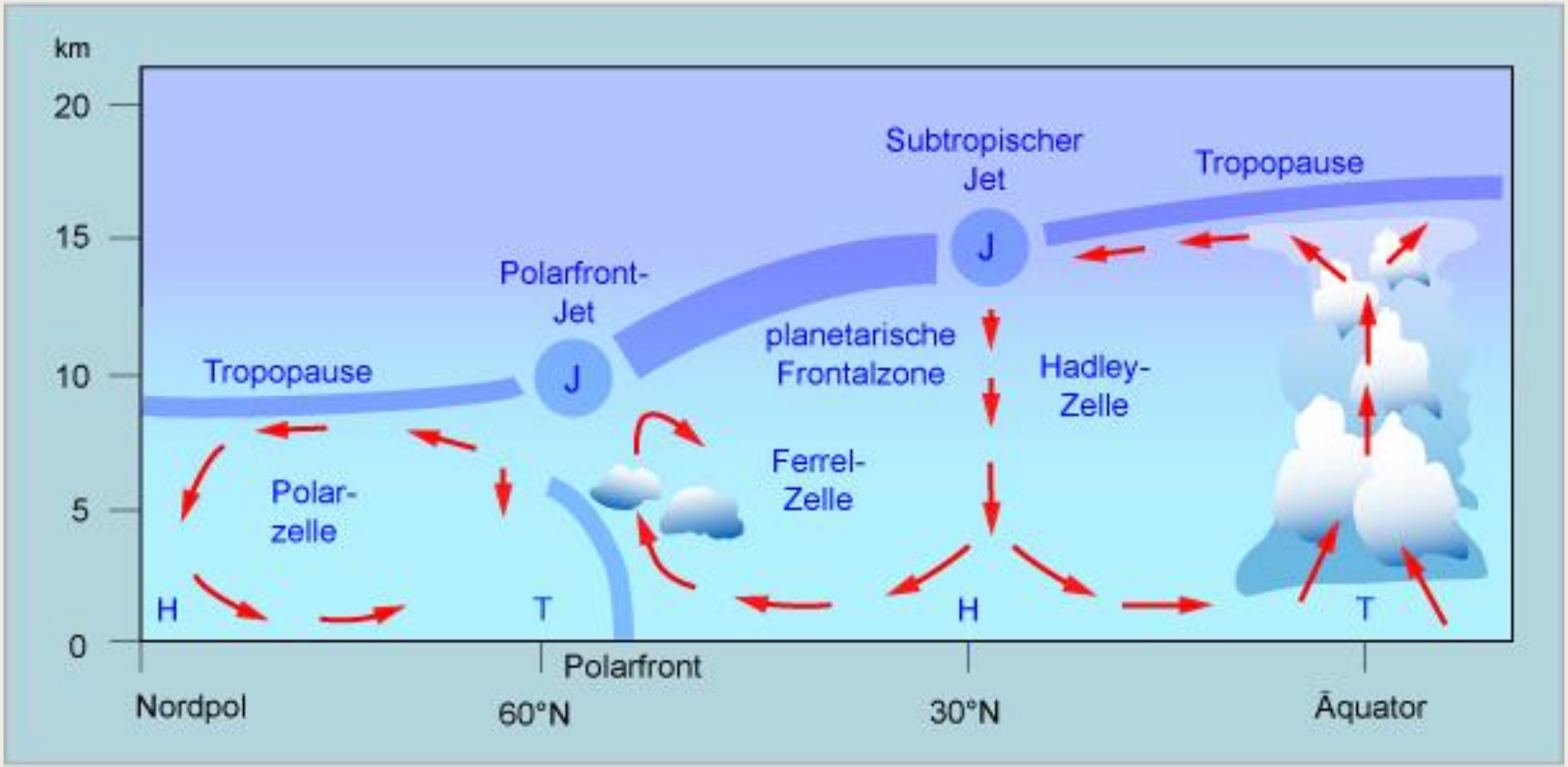
markus.meier@io-warnemuende.de

Zellen und Windsysteme der atmosphärischen Zirkulation



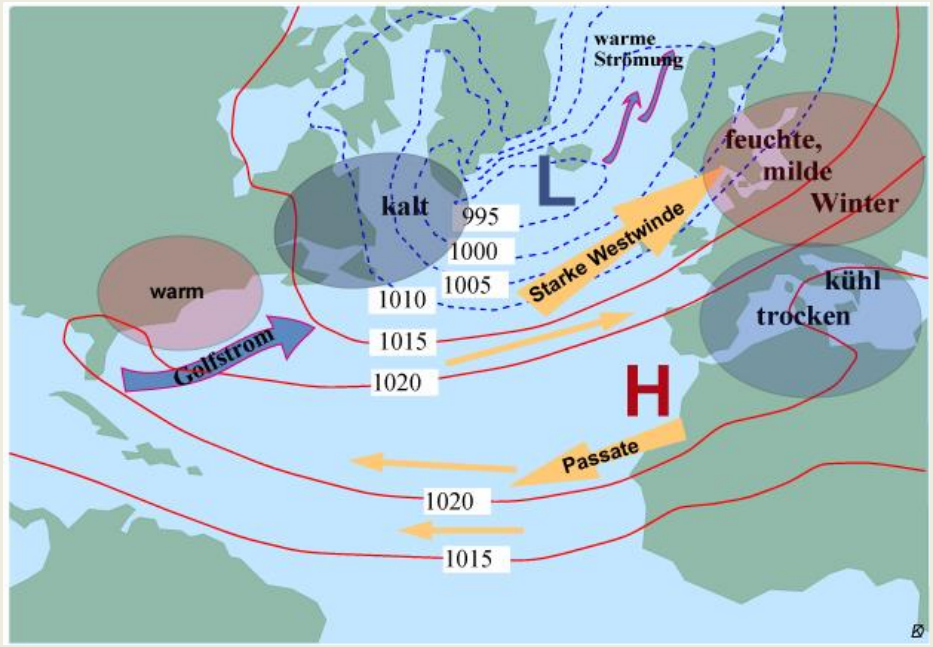
(Quelle: Hamburger Bildungsserver)

Die wichtisten Zirkulationszellen der atmosphärischen Zirkulation

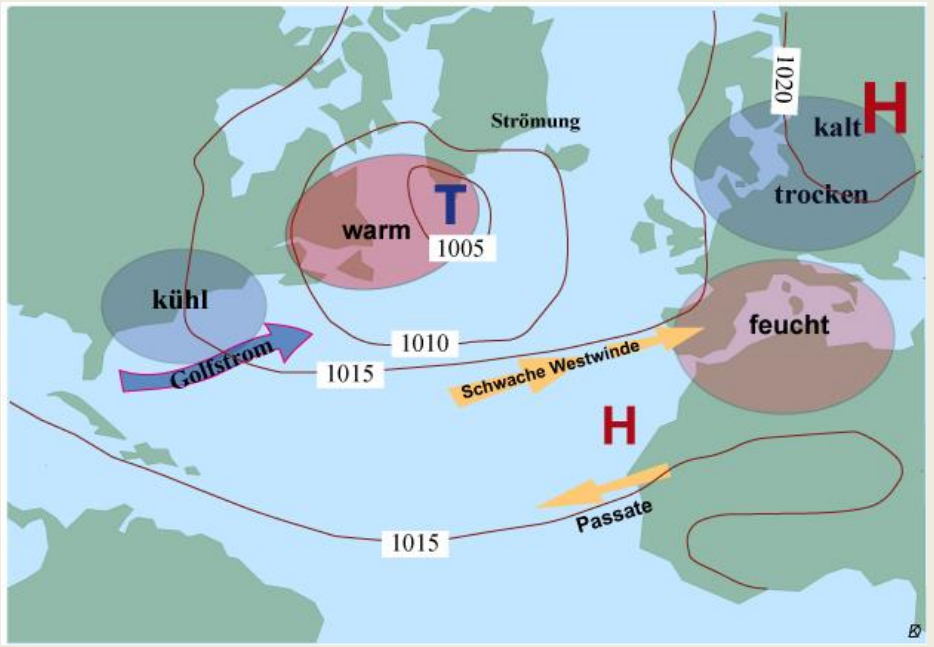


(Quelle: Hamburger Bildungsserver)

Große zeitliche Variabilität: Nordatlantische Zirkulation



NAO positiv



NAO negativ

(Quelle: Hamburger Bildungsserver)

Mehr zur atmosphärischen Zirkulation am 2. und 23. November

Oceans

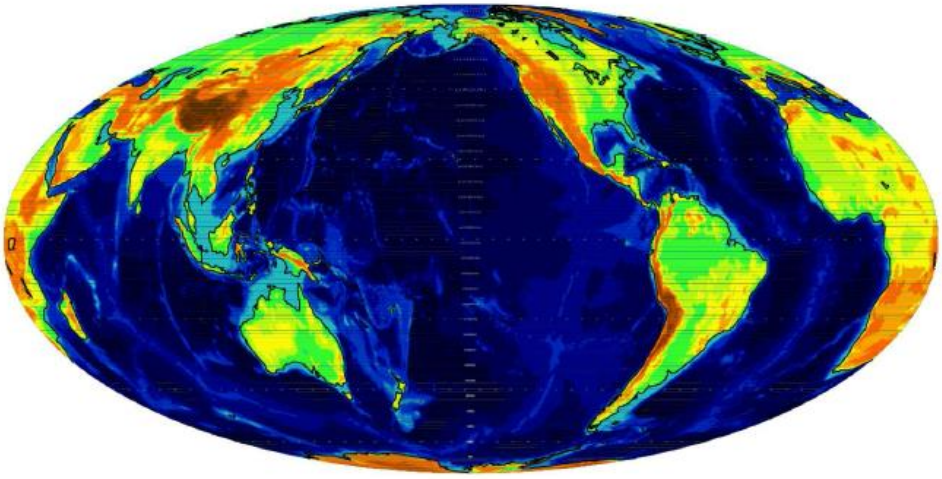


Figure 3.43: 2/3 of the globe is oceans

- Large heat storage
- Main source of atmospheric water vapor (greenhouse gas, rain)

(Source: D. Dommenget)

Differences between the atmosphere and oceans

- Incompressible liquid (density does not much depend on pressure) – ideal gas
- Water is 1000 times denser than air
- Water has a 4-times larger specific heat capacity than air
- Oceans are forced from the top, atmosphere from below (implications for mixing)
- Ocean currents are mostly forced by atmospheric winds, atmospheric winds are initiated by temperature contrast

(Source: D. Dommenget)

Differences between the atmosphere and oceans

- The oceans have lateral boundaries with small gateways between the 3 major basins (e.g. Indonesian through flow, Drake passage)
- The oceans do not have latent heating by water phase transitions (e.g. liquid to water vapour and vice versa). Latent heating drives the atmospheric circulation to some part
- Salinity in the oceans affects density
- The oceans have floating sea ice affecting air-sea exchange of heat, water vapour and momentum

(Source: D. Dommenget)

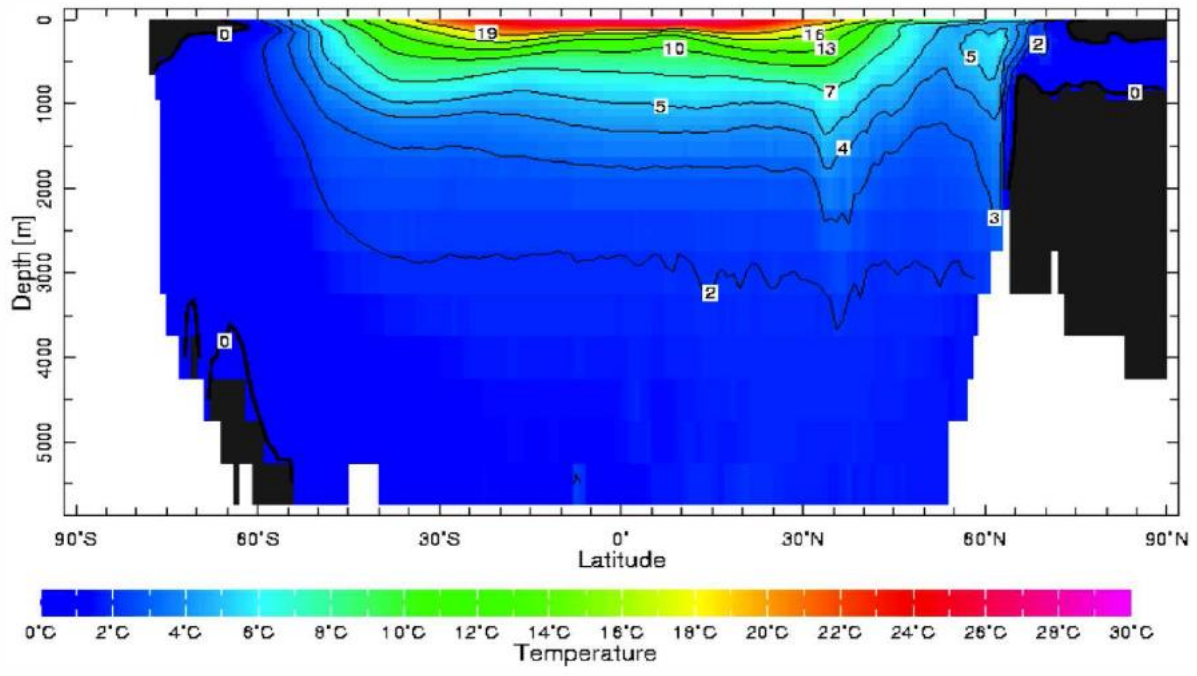
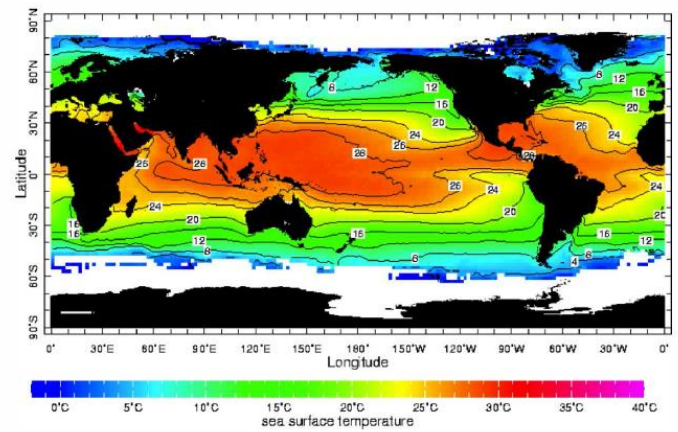
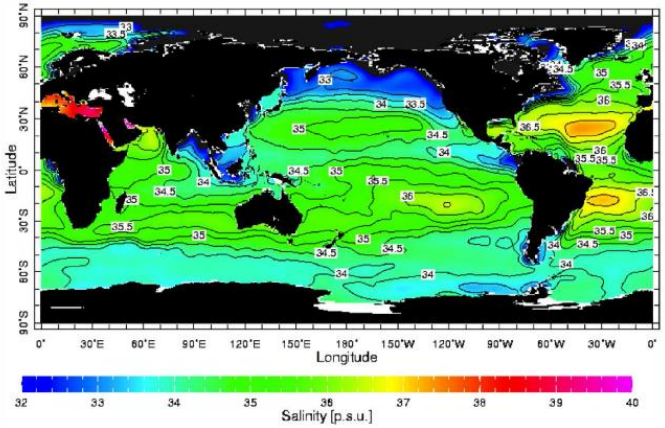


Figure 3.45: Annual-mean cross-section of zonal-average temperature [°C] in the world's oceans - the whole water column. Data from the Levitus World Ocean Atlas 1994.

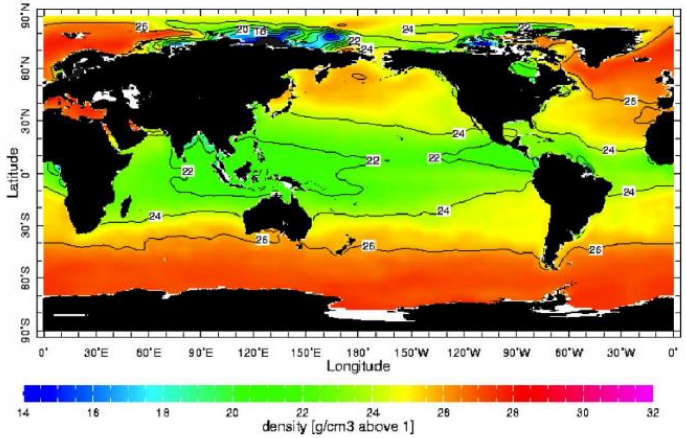
(Source: D. Dommenget)



Temperature



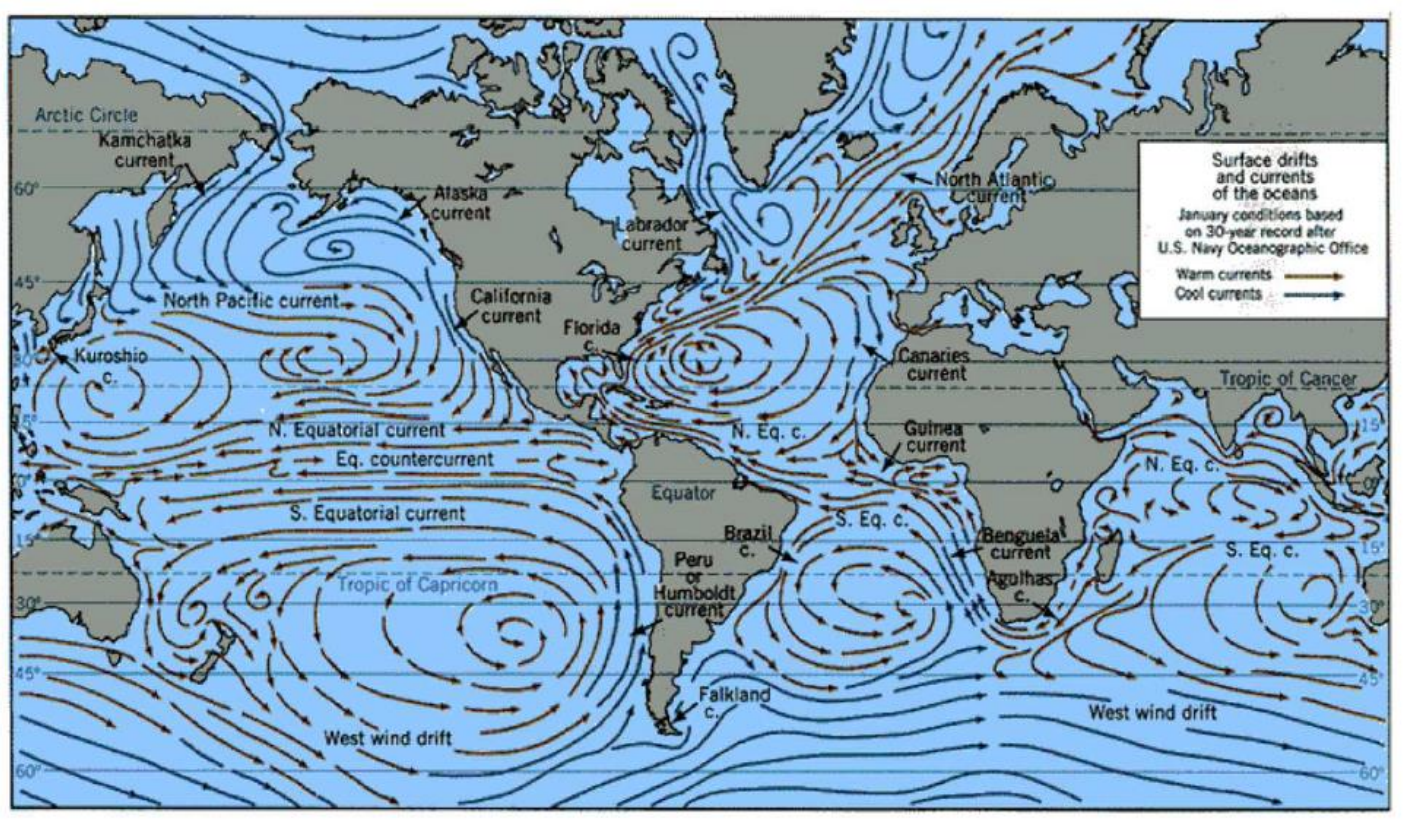
Salinity



Density

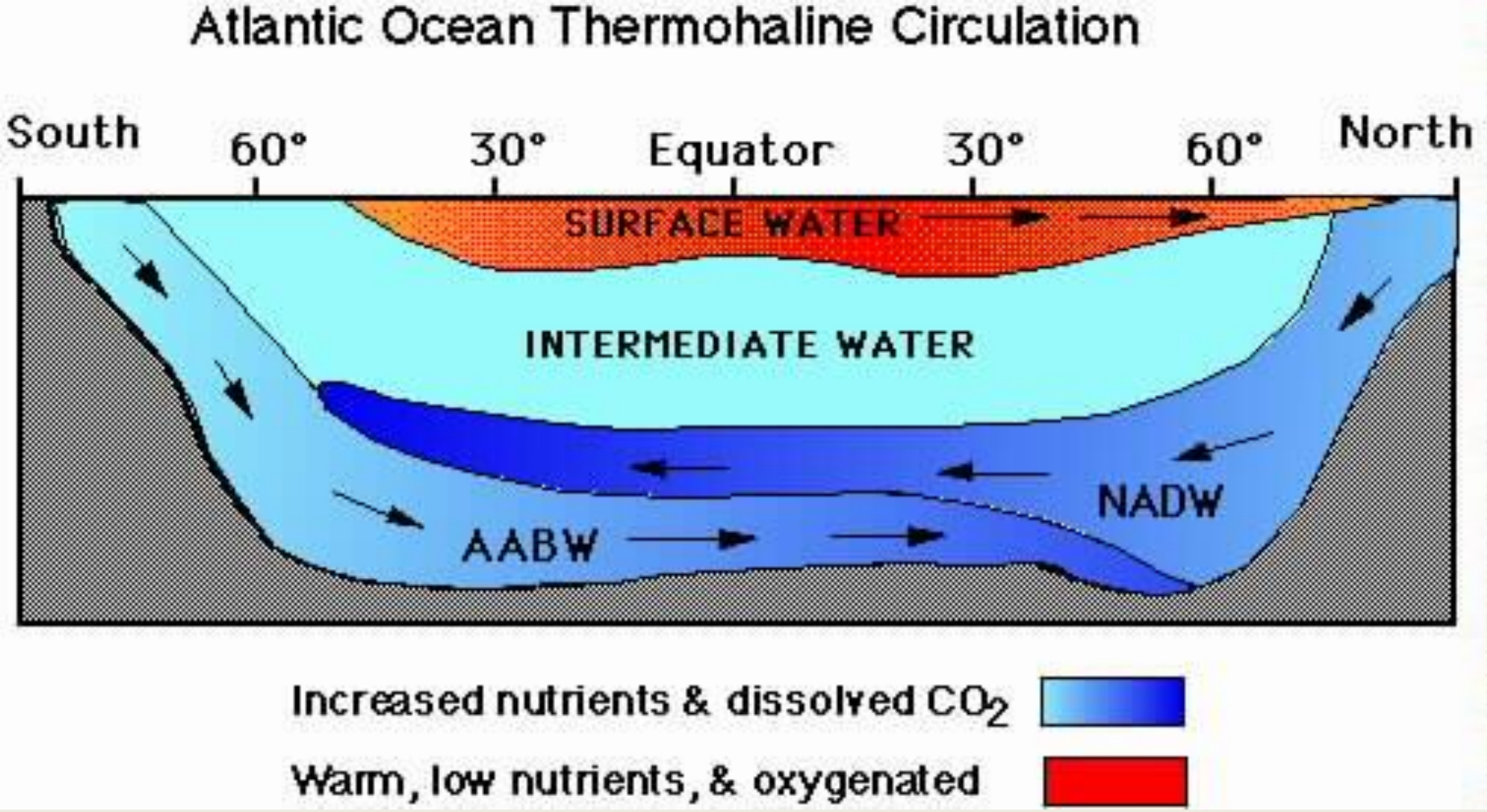
(Source: D. Dommenget)

Wind driven (surface) circulation



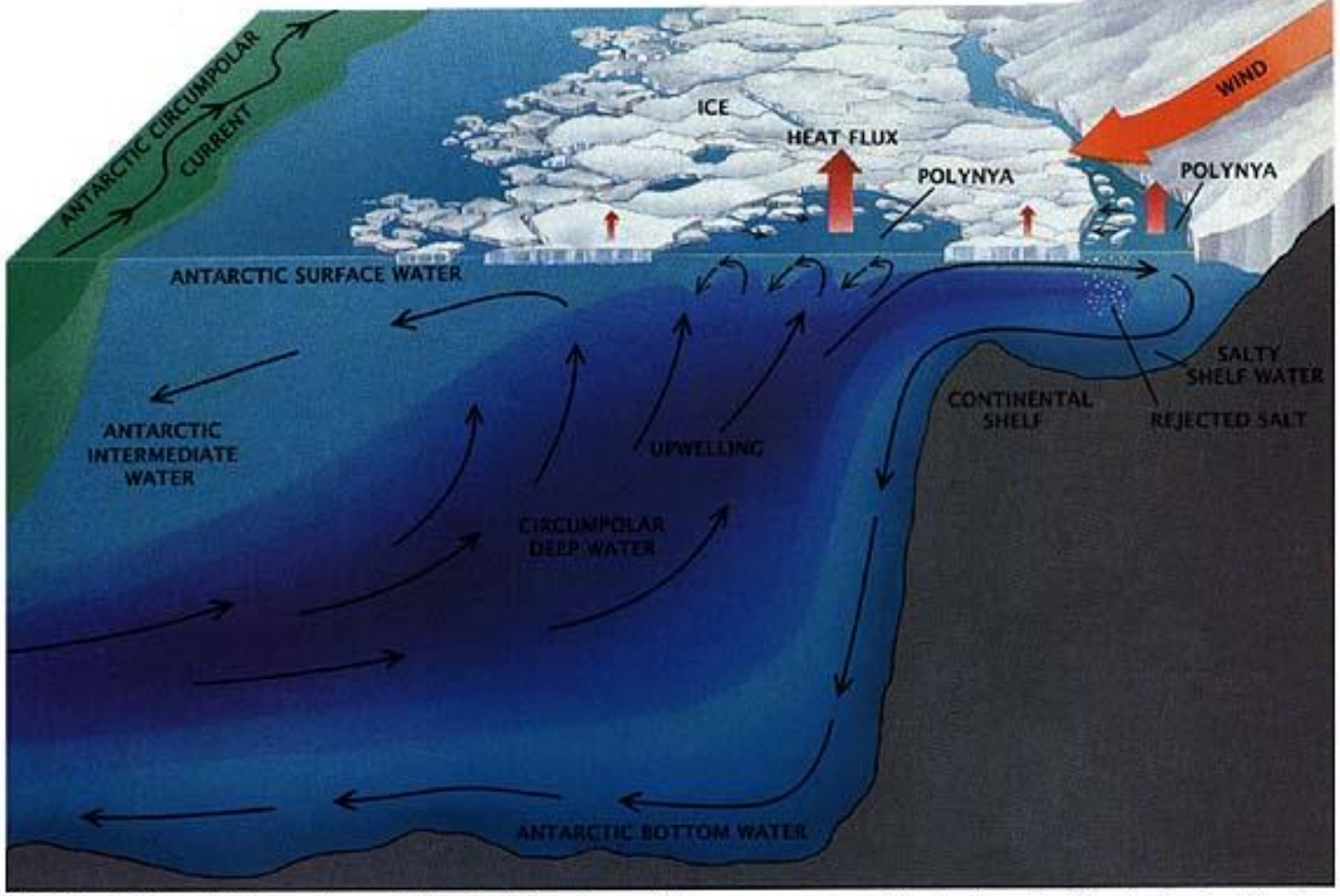
(Source: D. Dommenget)

Deep water formation and the conveyor belt circulation



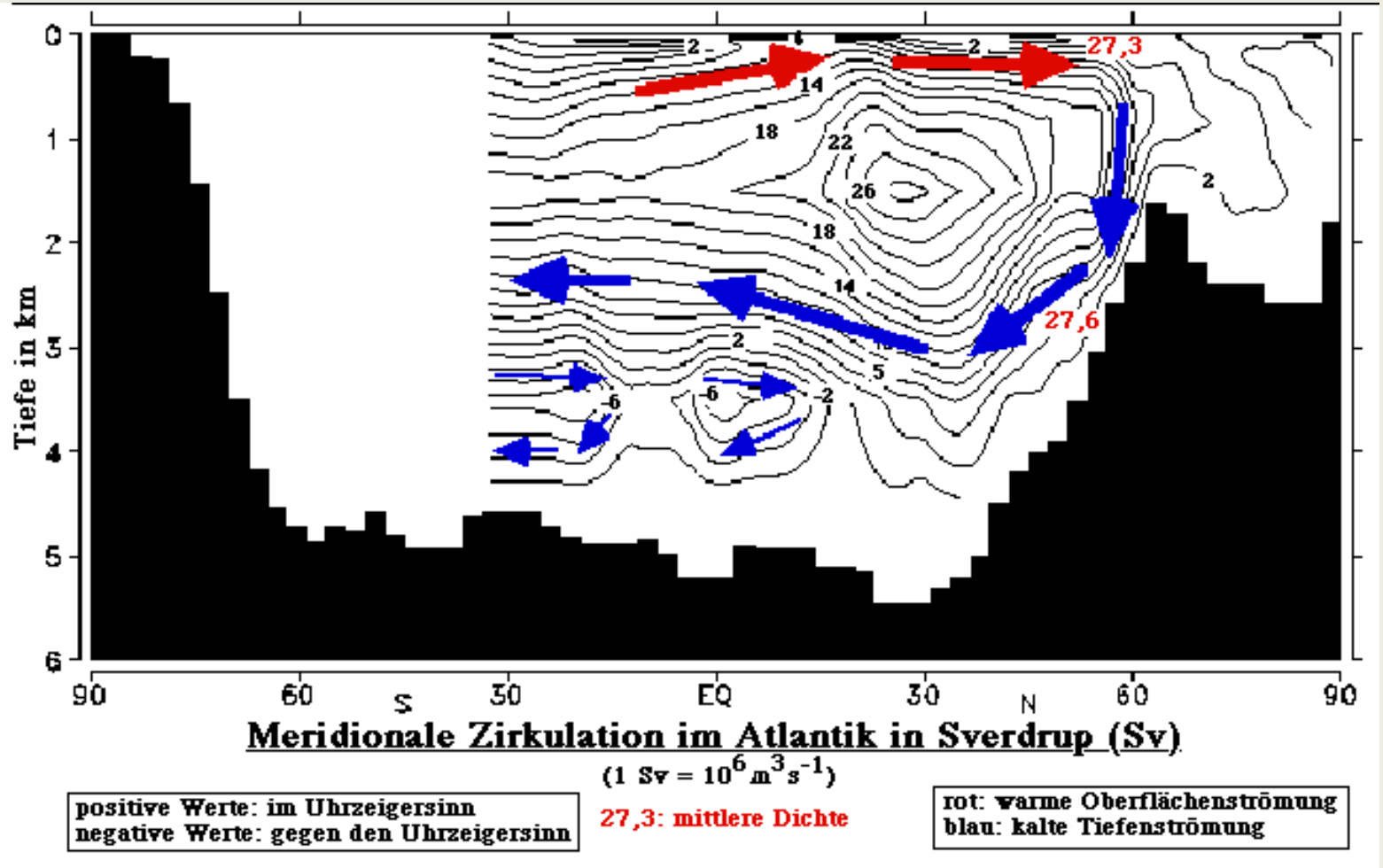
(Source: U. Cubasch)

Source: Gordon, Arnold L. and Josefino, C. Comiso (1988) "Polynyas in the Southern Ocean." *Scientific American*, June 1988, Vol. 256, No. 6, p. 92.

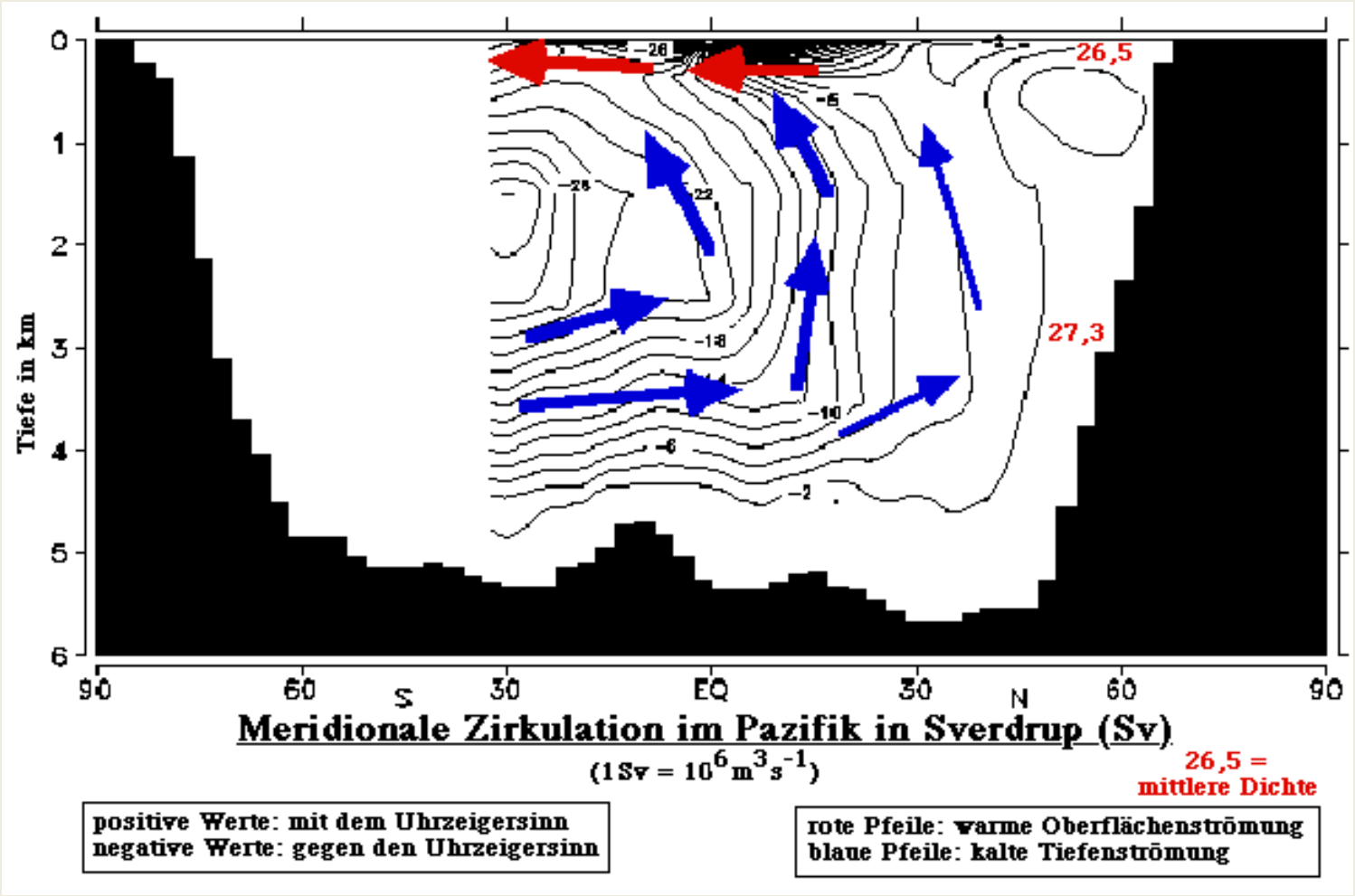


Meridional circulation pattern of the Southern Ocean (the ocean surrounding Antarctica) is dominated by the upwelling of a warm, salty water mass called the Circumpolar Deep Water and its transformation into Antarctic Surface Water, which ultimately sinks to become Antarctic Intermediate Water and Antarctic Bottom Water. The circulation is driven by wind and the exchange of heat and fresh water between the ocean and the atmosphere.

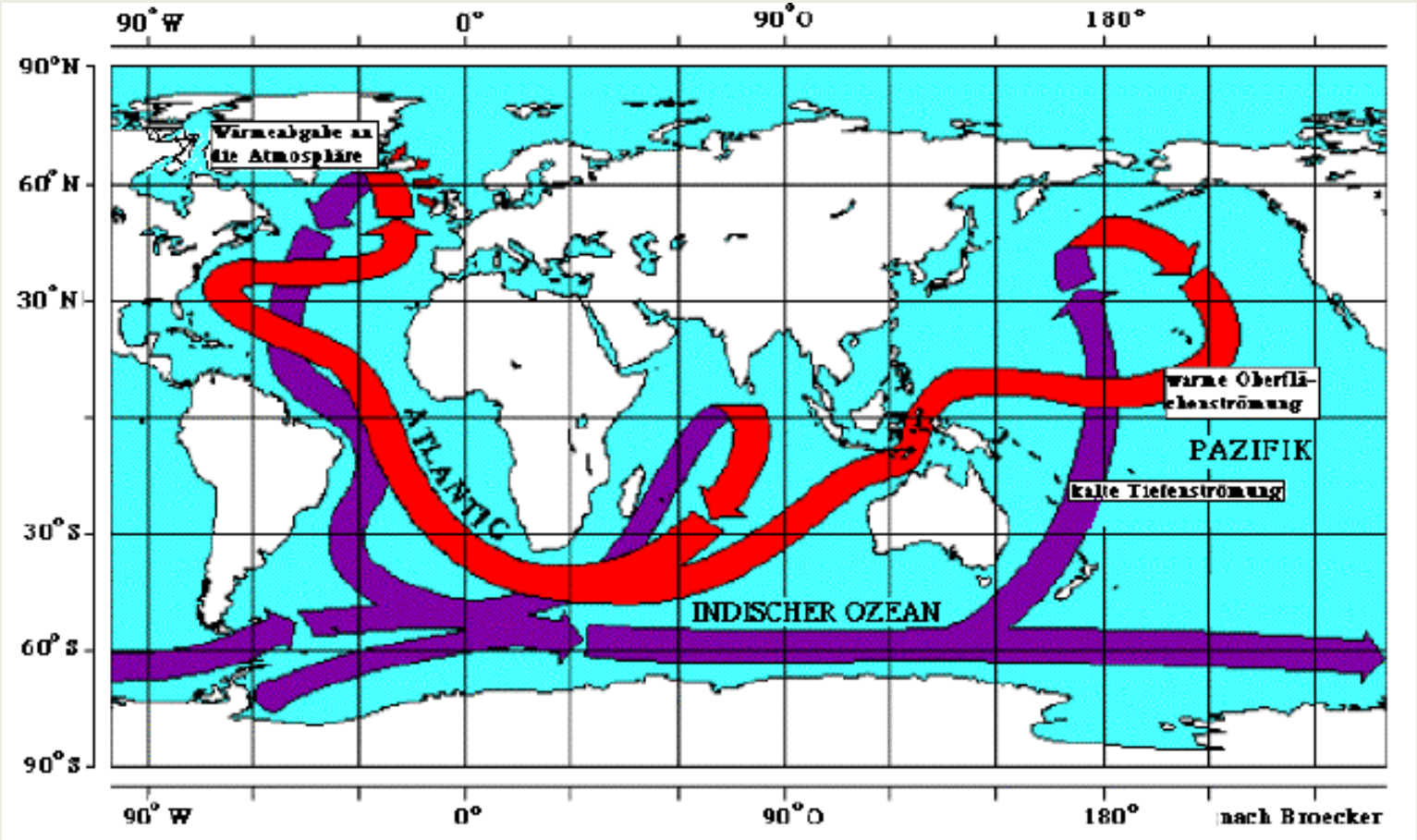
(Source: U. Cubasch)



www.hamburger-bildungsserver.de



www.hamburger-bildungsserver.de



Das große marine Förderband

www.hamburger-bildungsserver.de

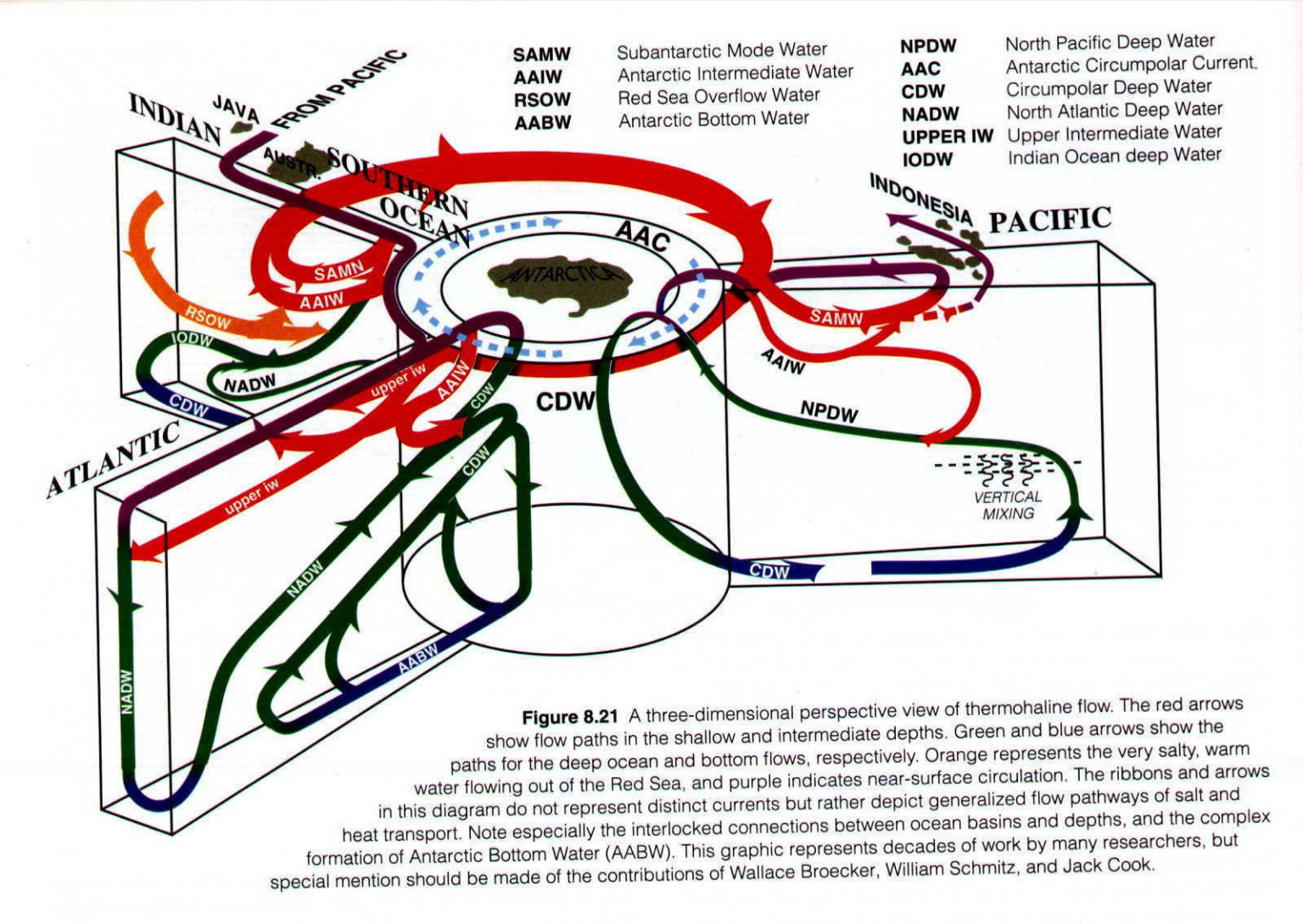


Figure 8.21 A three-dimensional perspective view of thermohaline flow. The red arrows show flow paths in the shallow and intermediate depths. Green and blue arrows show the paths for the deep ocean and bottom flows, respectively. Orange represents the very salty, warm water flowing out of the Red Sea, and purple indicates near-surface circulation. The ribbons and arrows in this diagram do not represent distinct currents but rather depict generalized flow pathways of salt and heat transport. Note especially the interlocked connections between ocean basins and depths, and the complex formation of Antarctic Bottom Water (AABW). This graphic represents decades of work by many researchers, but special mention should be made of the contributions of Wallace Broecker, William Schmitz, and Jack Cook.

Circulation of various oceans

(Source: U. Cubasch)

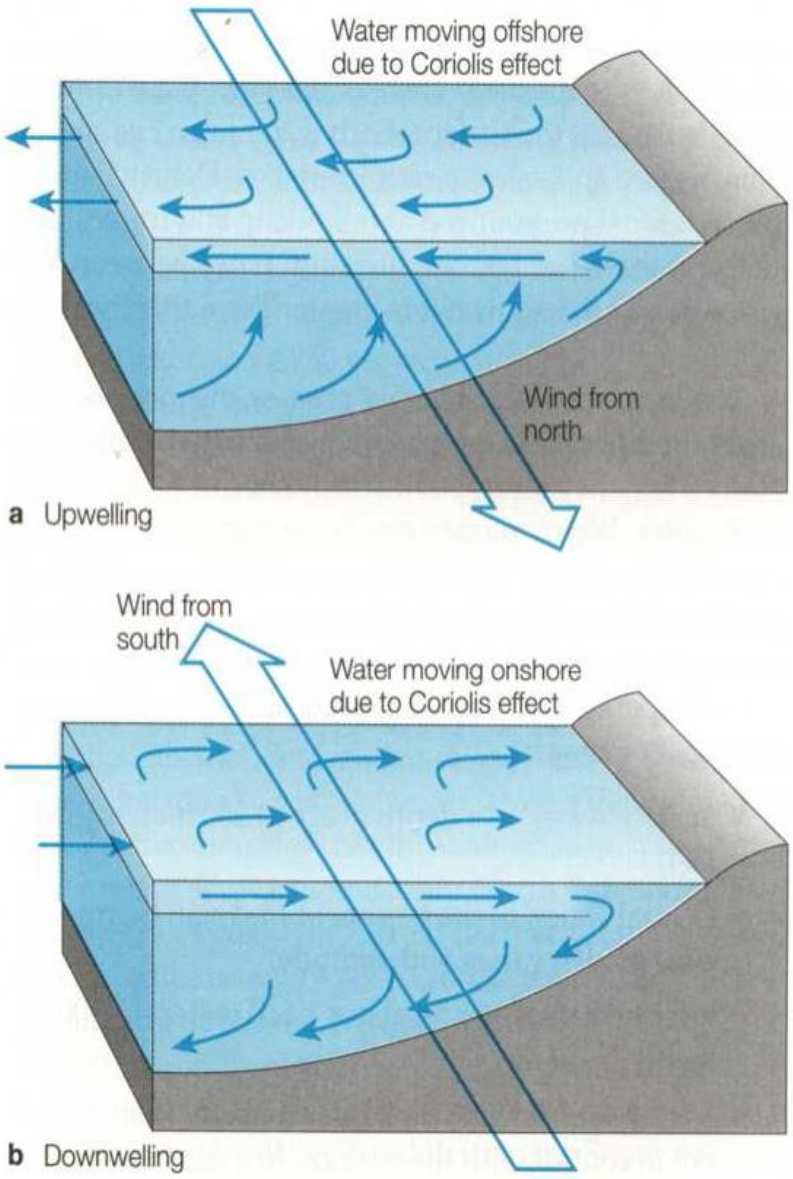


Figure 3.52: Upwelling in NH

(Source: D. Dommenget)

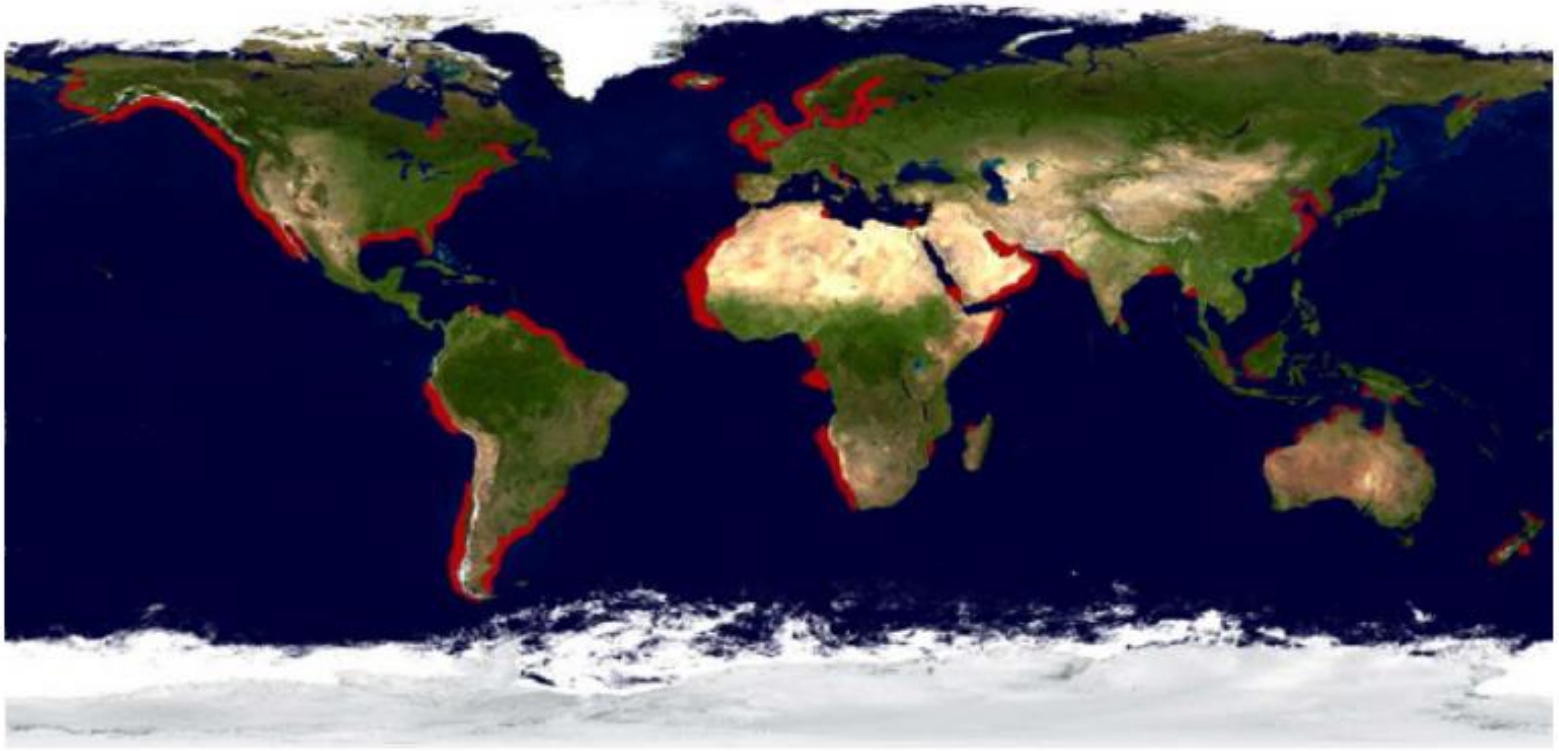


Figure 3.55: Coastal upwelling regions through out the global oceans.

(Source: D. Dommenget)

Deep convection

Main causes of upwelling:
Coastal winds
Coriolis force
Continuity

Main causes of deep convection:
Buoyancy
Cooling
Sea ice formation

(Source: D. Dommenget)

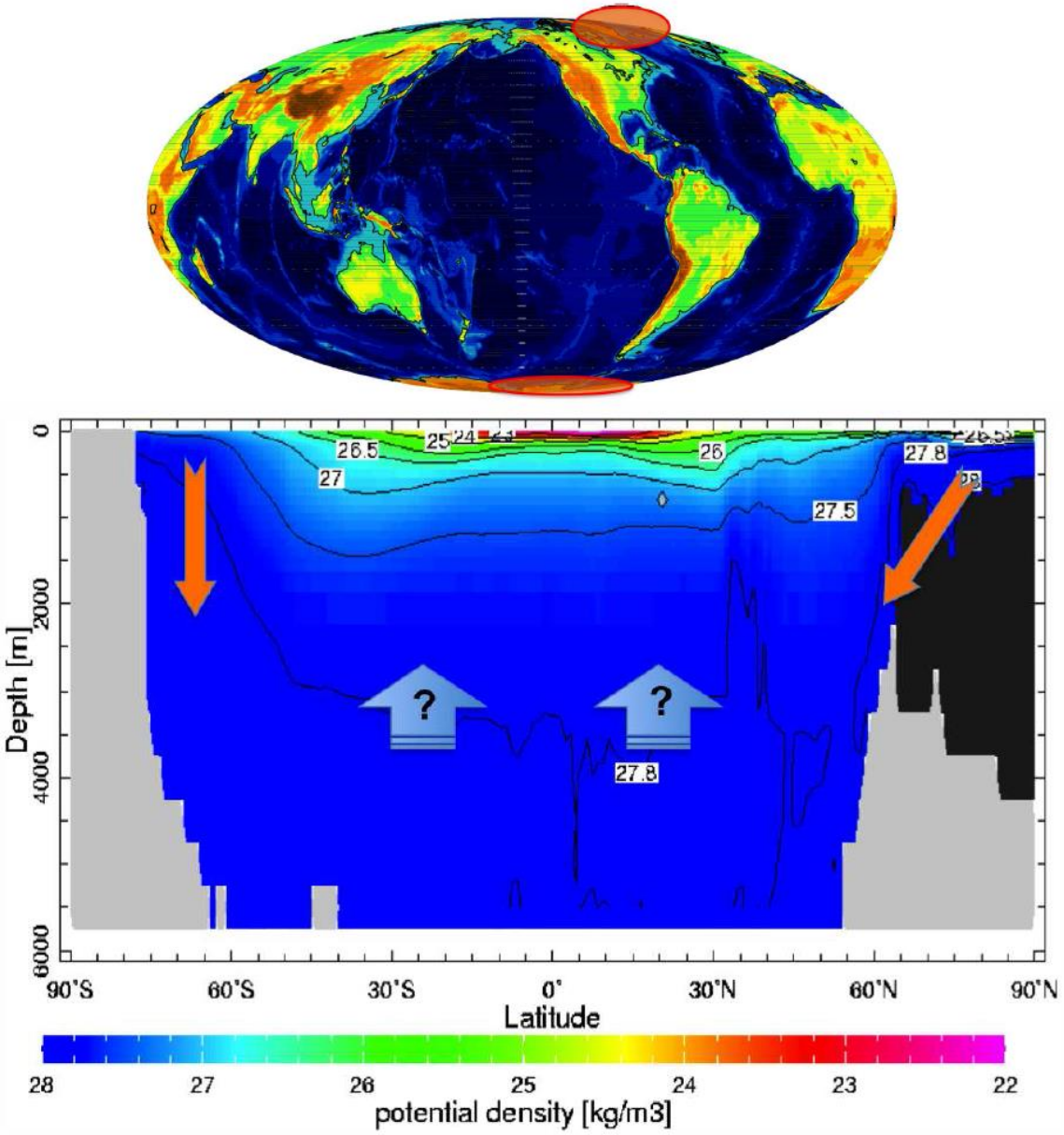
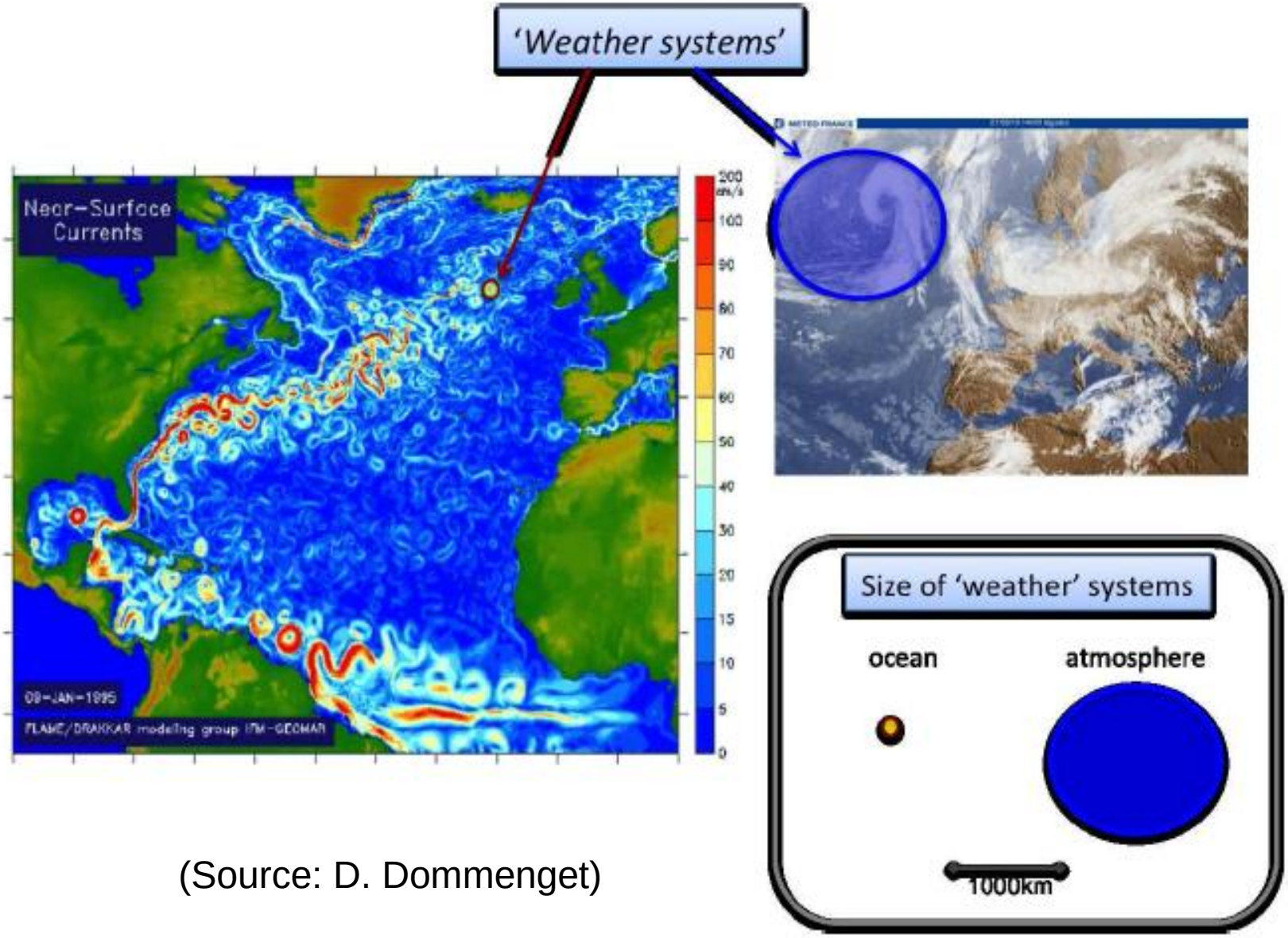


Figure 3.59: Deep ocean convection regions:



(Source: D. Dommenget)

Thank you very much for your attention!