

Surface and Deep Ocean Circulation



Take away ideas

Ocean Temperatures and Salinity

Deep ocean properties

Wind driven surface ocean circulation

Wind fields and Geostrophic flow

Thermohaline deep ocean circulation

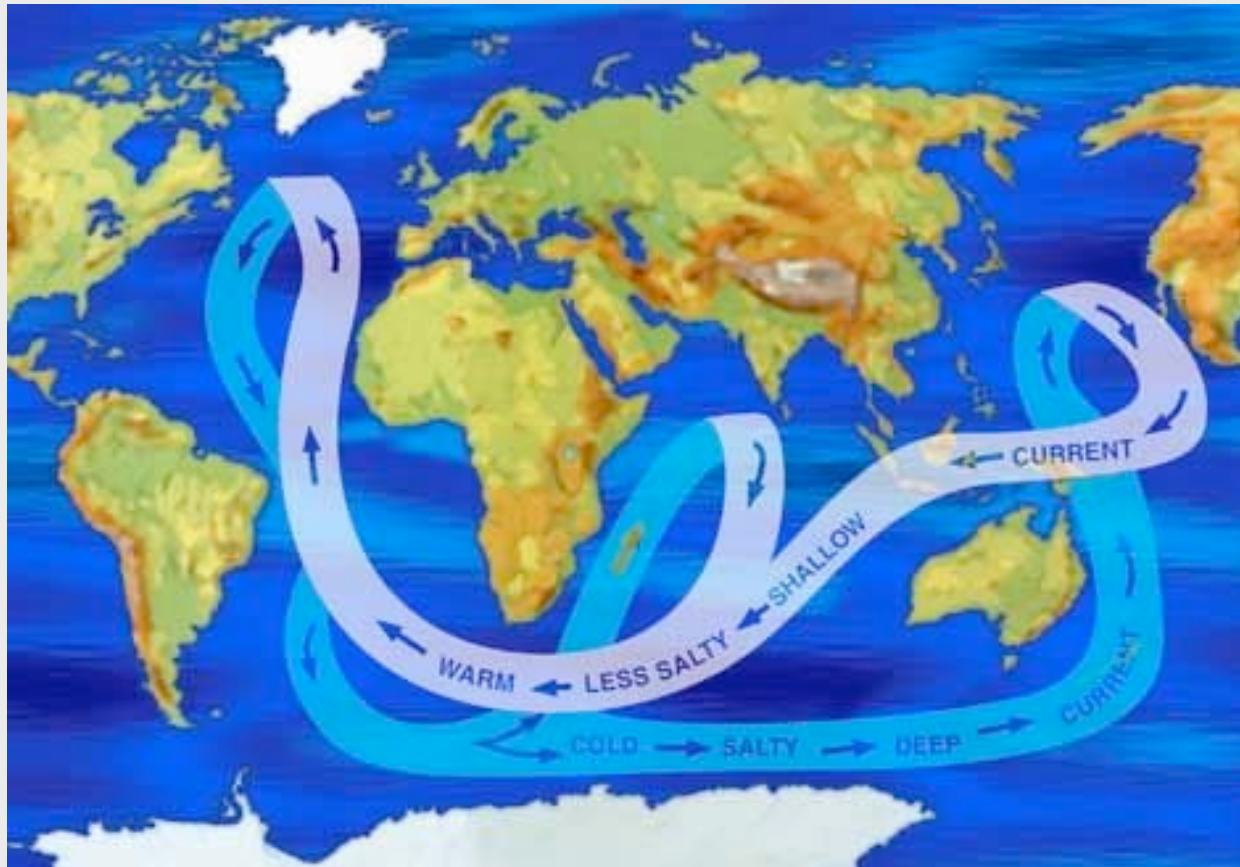
Why and where deep waters form

Two forces drive ocean circulation:

1. Wind stress acting on the ocean surface
2. Buoyancy [heat & freshwater] flux between ocean and atmosphere

Wind-driven is more vigorous than buoyancy [or thermohaline] driven circulation, but wind-driven is mostly upper km, thermohaline is full depth and involves ocean overturning, in which the deep ocean waters can contact and interact directly with the 'climate'

B. Deep ocean circulation: Buoyancy (Δ salt & Δ temperature)



Thermohaline Circulation

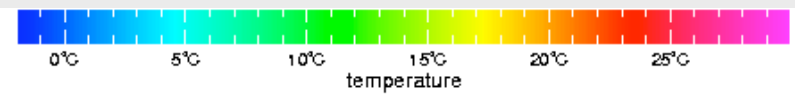
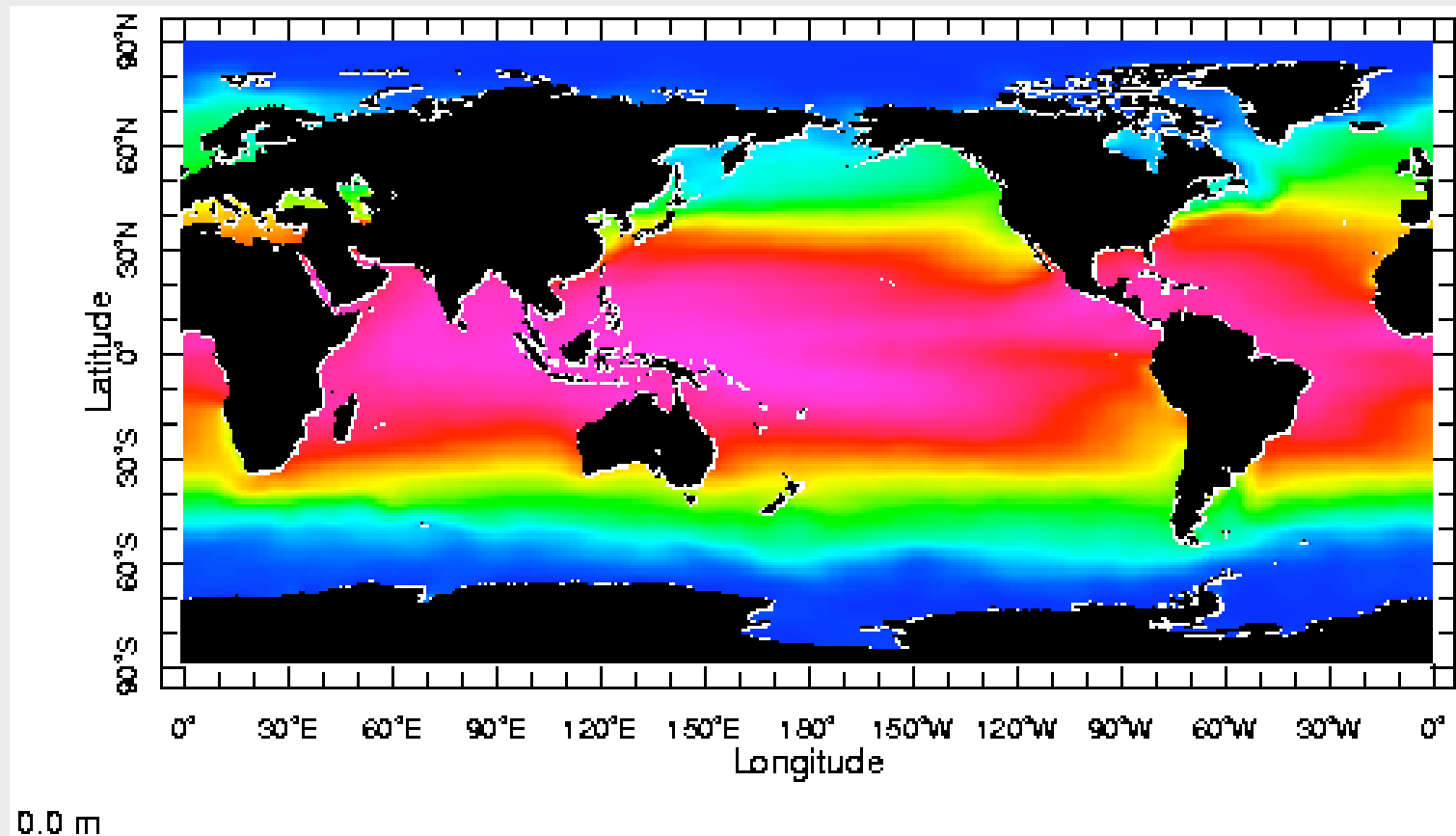
Ocean heat & salt gradients = density gradients.

More dense water sinks below less dense water.

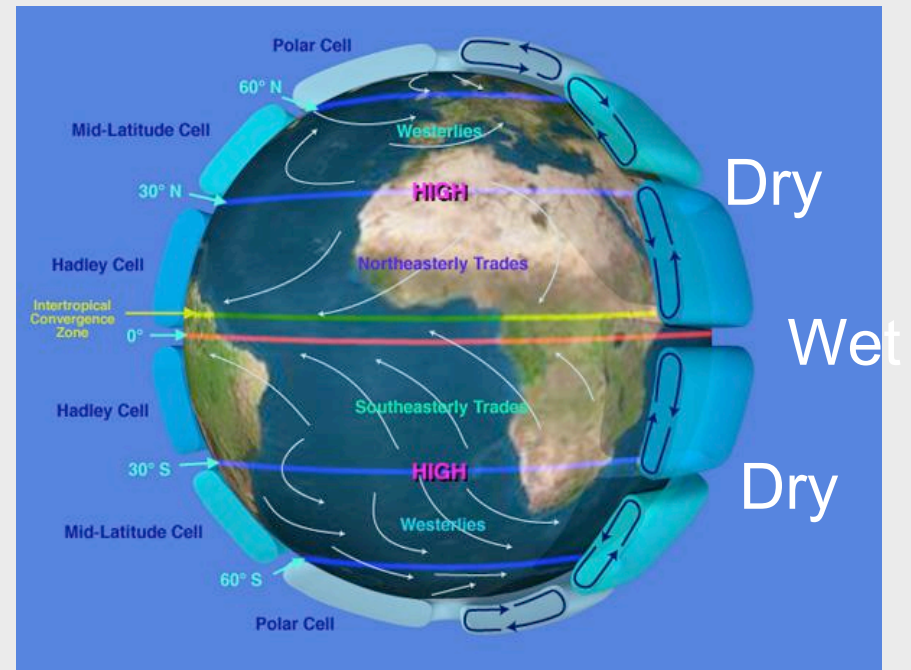
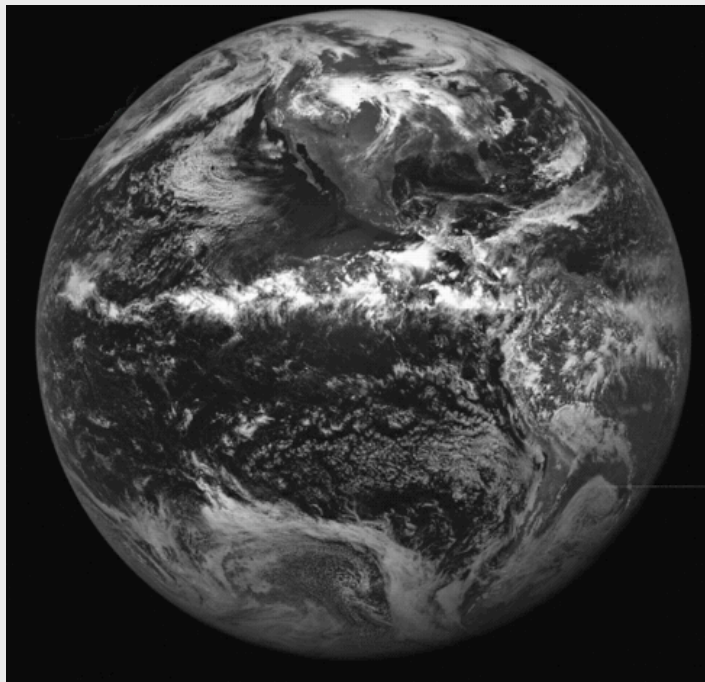
By continuity, the flow has to be closed =
“overturning circulation cells”.

“The global ocean conveyor”

Sea-surface temperatures

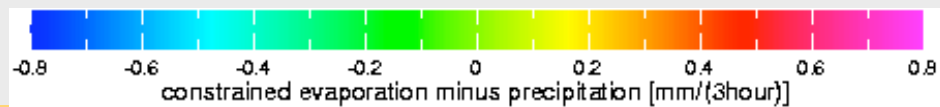
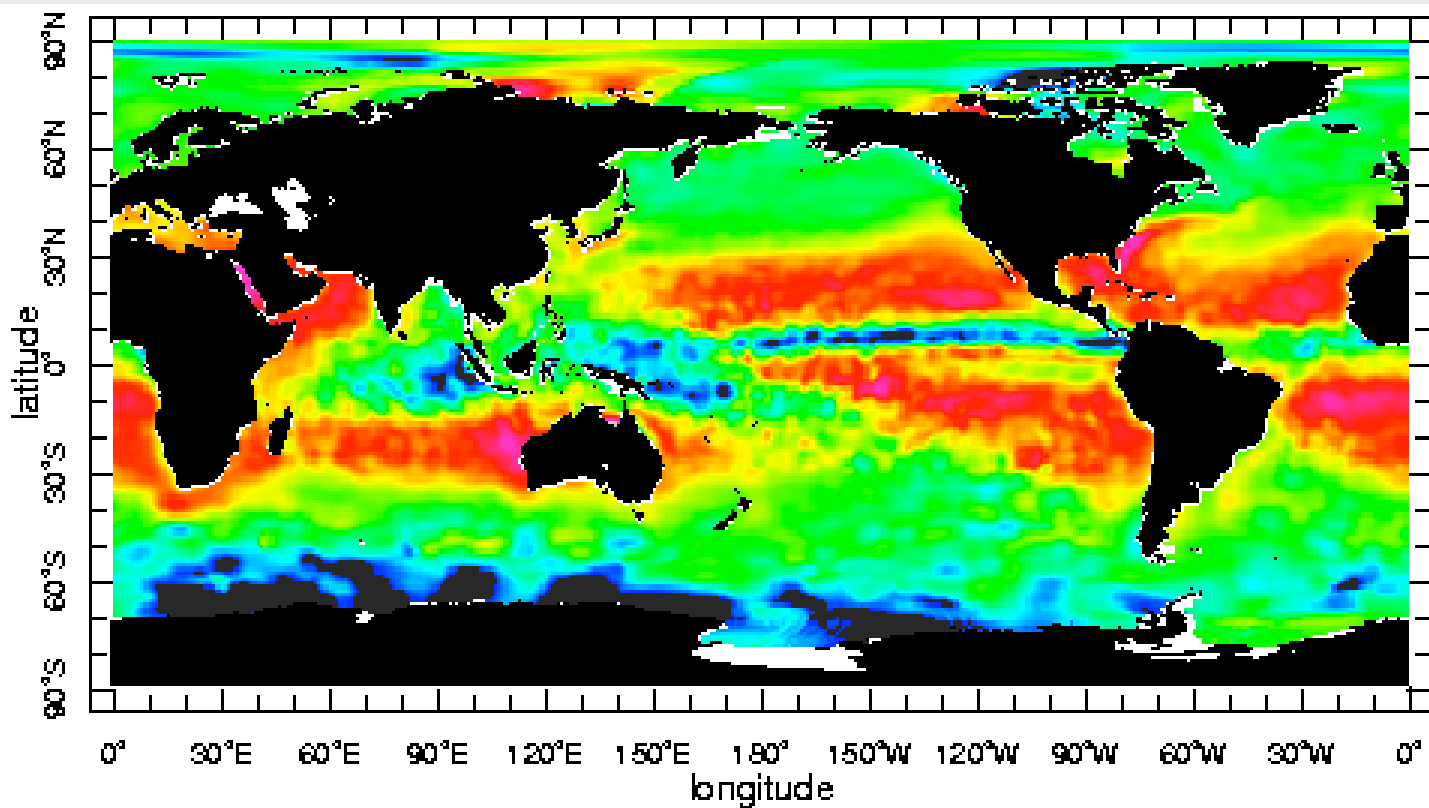


Evaporation and Precipitation

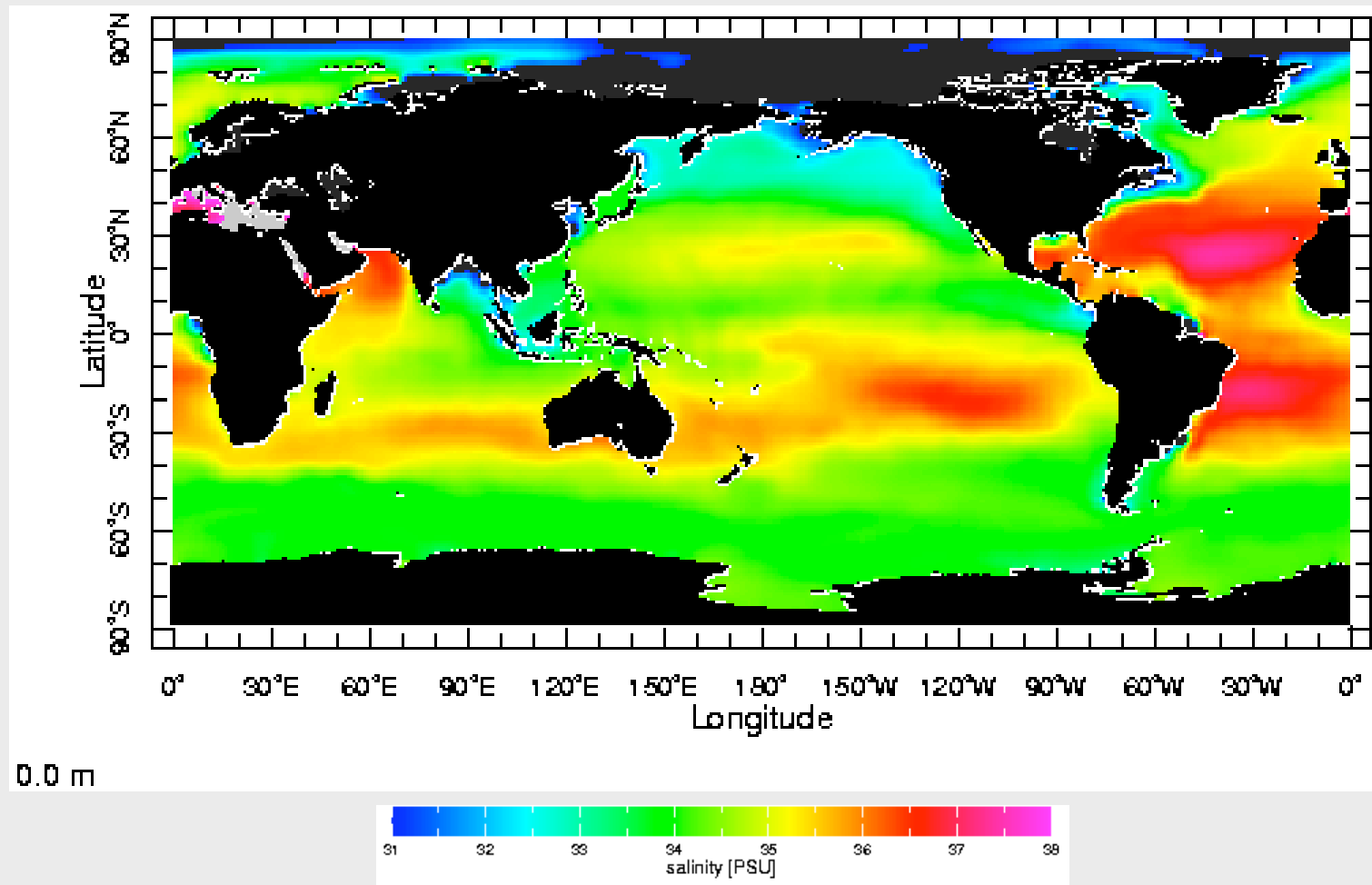


General atmospheric circulation defines E-P zones

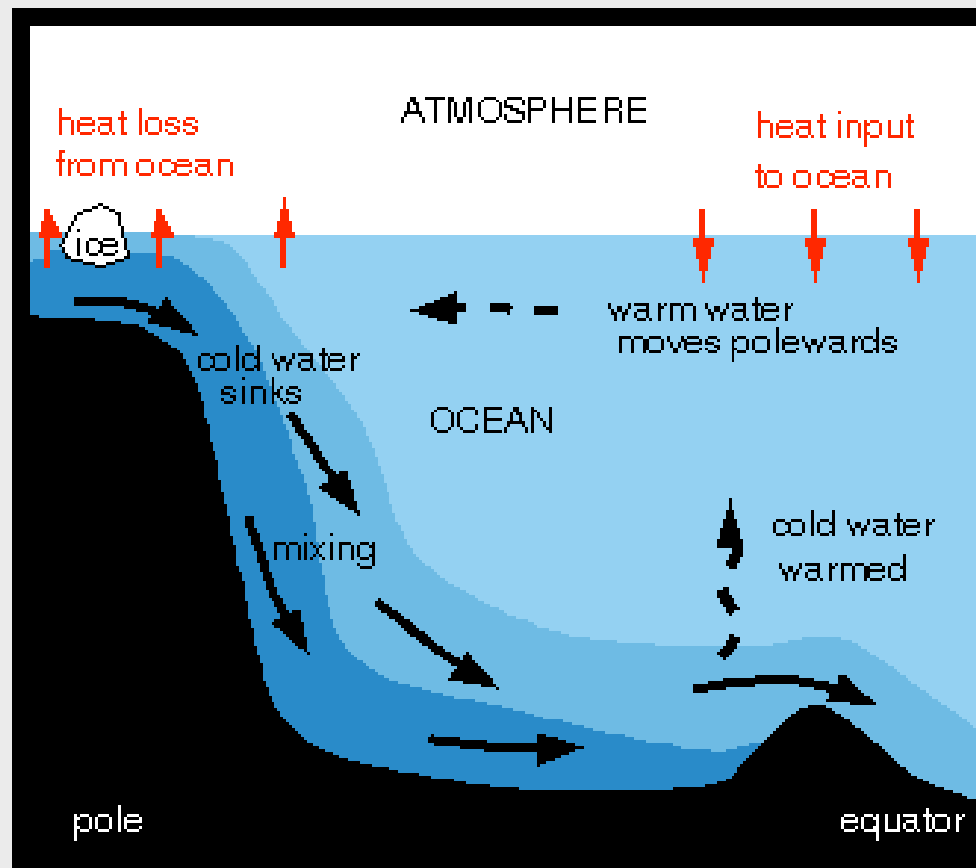
Why subtropical waters are salty: *Evaporation minus Precipitation*



Sea-surface salinity



Thermohaline Circulation



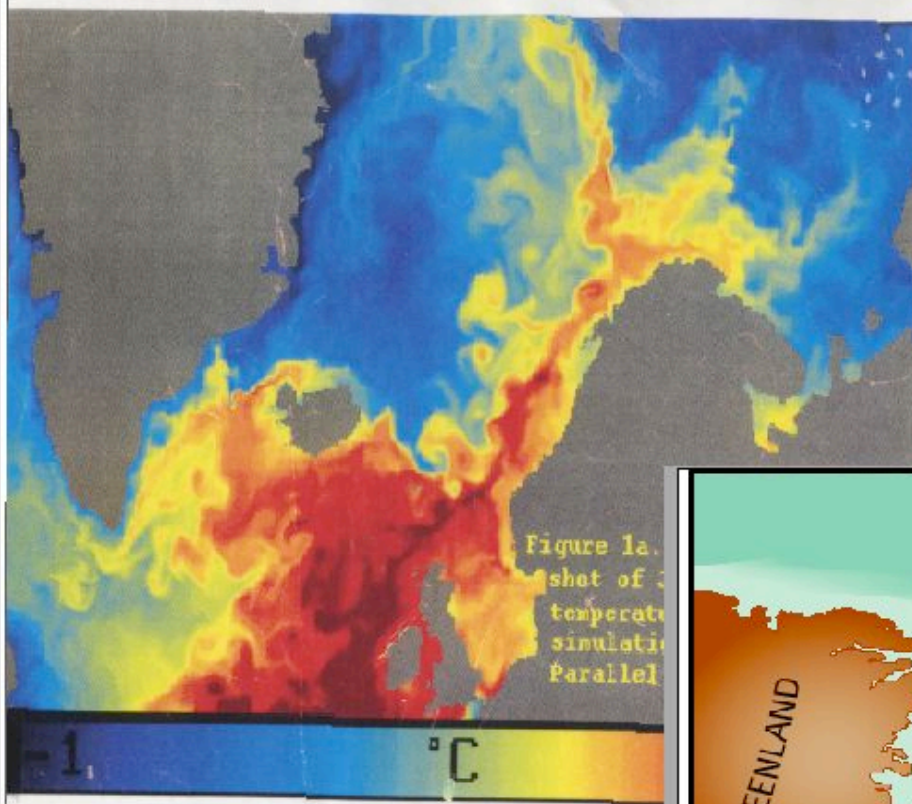
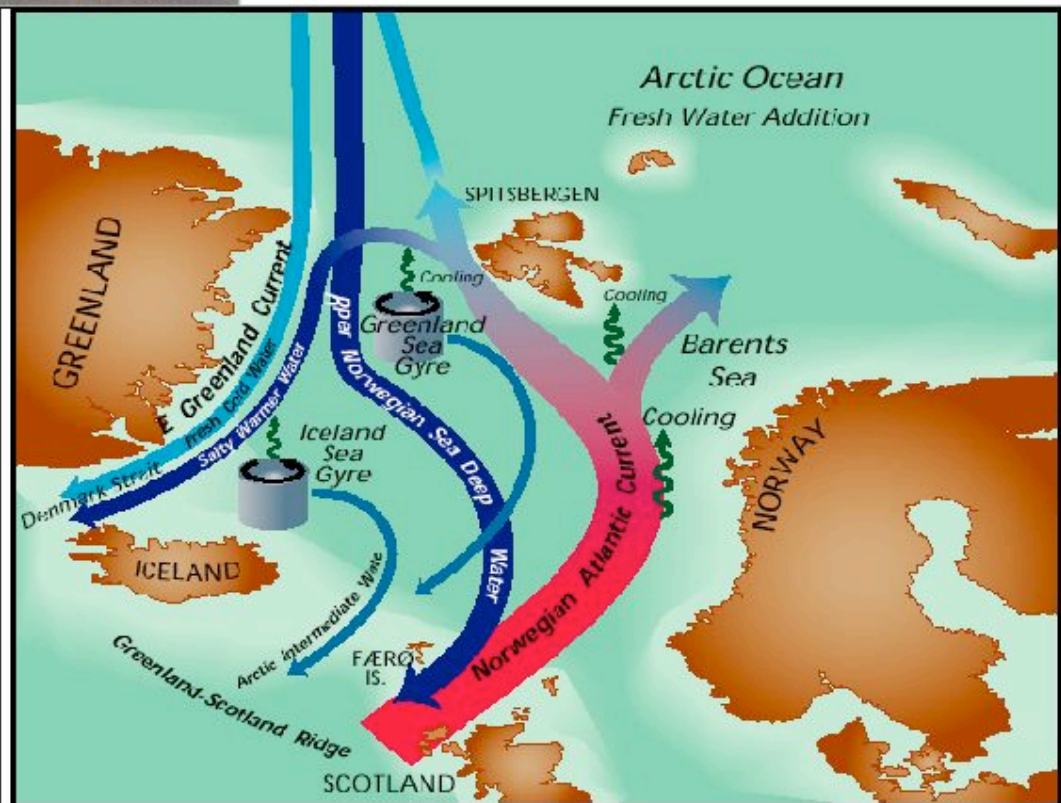
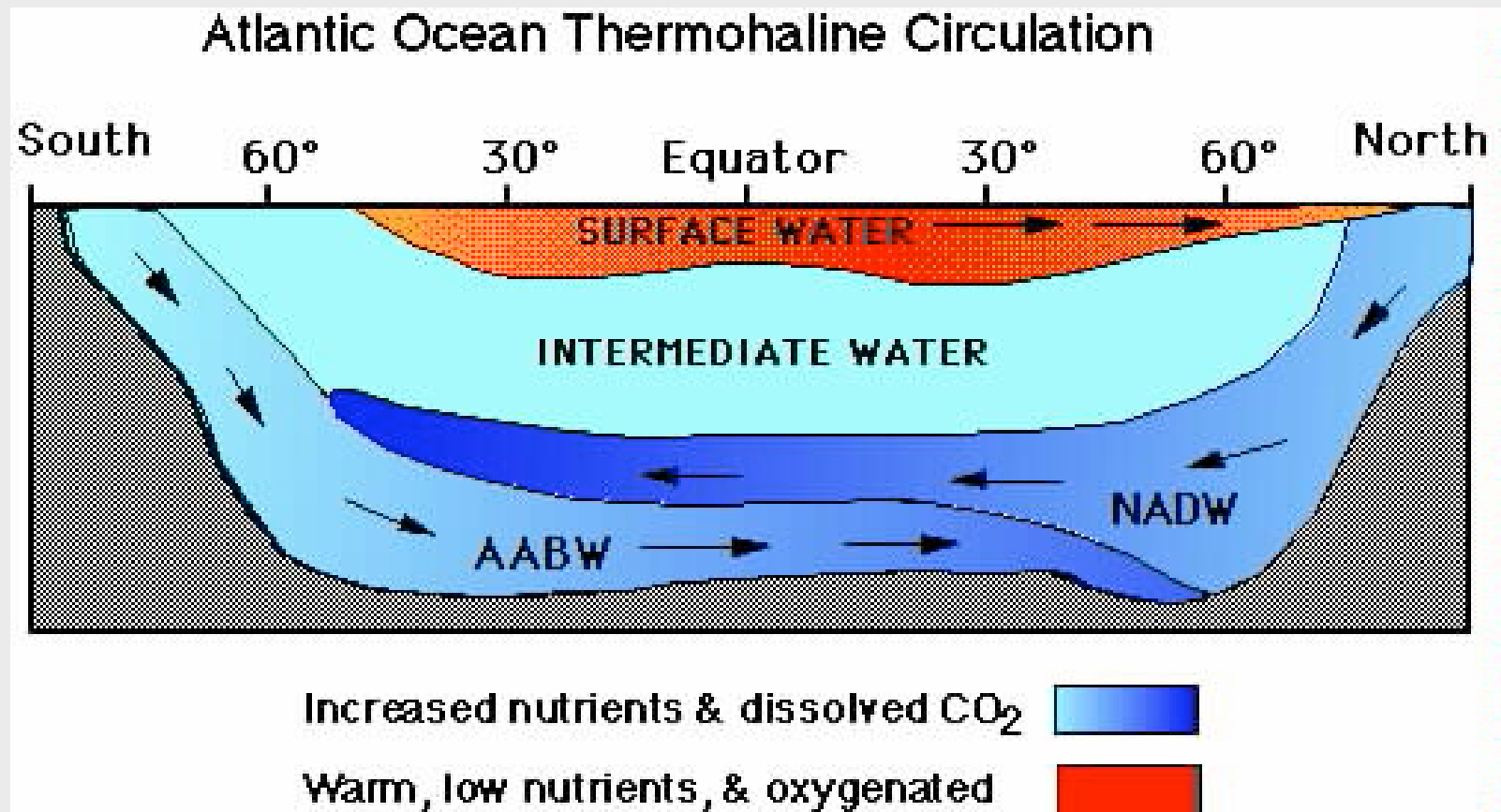


Figure 1a.
 A snapshot of a
 temperature
 simulation
 Parallel

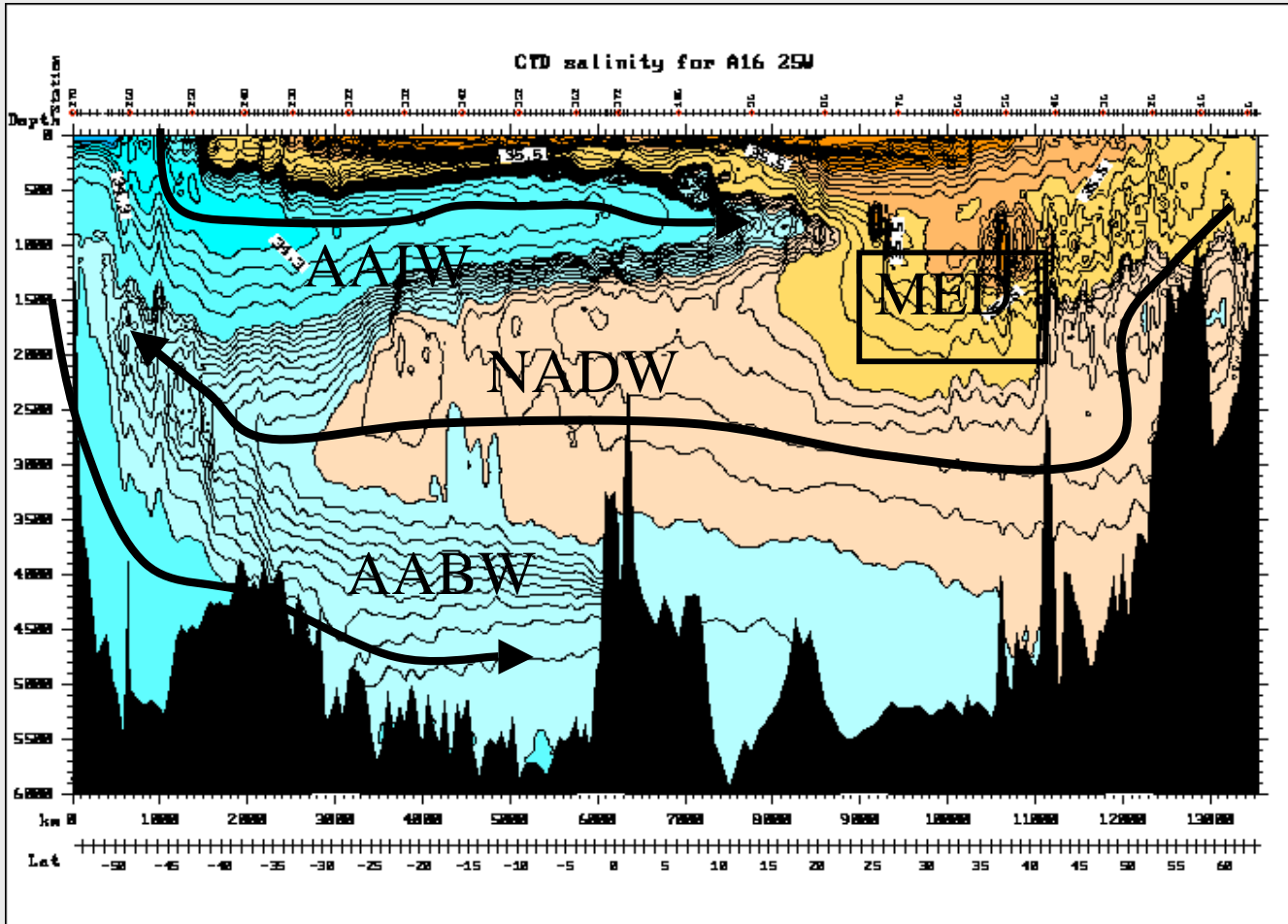
Warm, salty surface waters cool.
 They become more dense and sink.
 Flow southward at ~2-4 km depth.



Cross-section of the Atlantic Basin



Deep water is formed at southern and northern ends



Surface

6 km

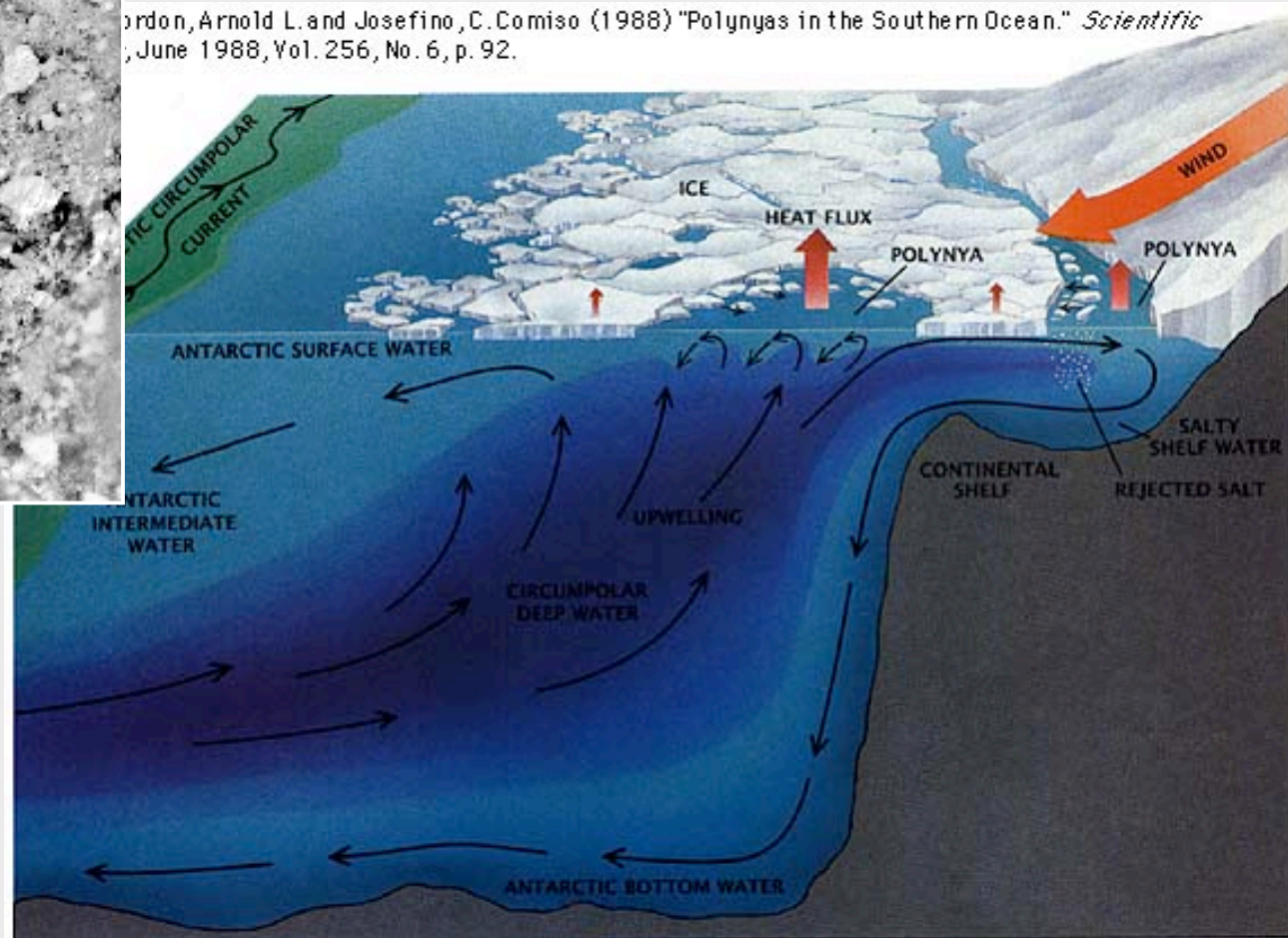
South

North

Antarctic Deep water formation

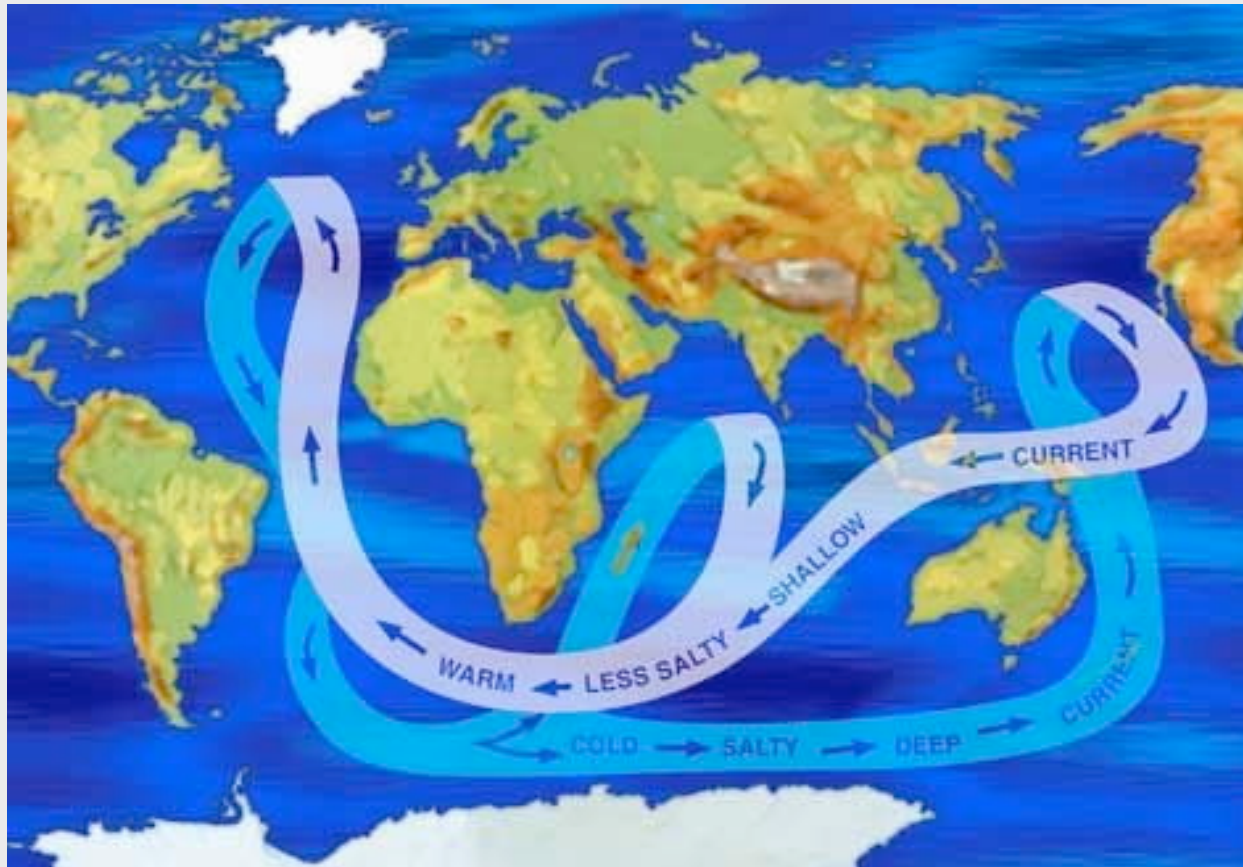


Gordon, Arnold L. and Josefino, C. Comiso (1988) "Polynyas in the Southern Ocean." *Scientific*, June 1988, Vol. 256, No. 6, p. 92.



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.

The Global Ocean Conveyor



The Global Ocean Conveyor



Summary (deep circulation)

Deep ocean circulation (>1 km) results from changes in ocean density (buoyancy).

Warm salty waters cool release heat to atmosphere as they move north.

Cooling of salty waters makes denser water, eventually sinks to bottom and flows south.

The Global Ocean Conveyor: “Wind-driven surface circulation” and “Thermohaline deep circulation”