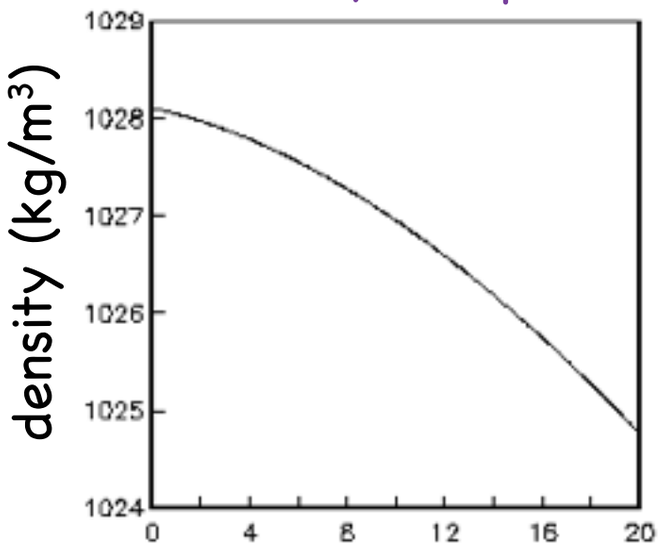
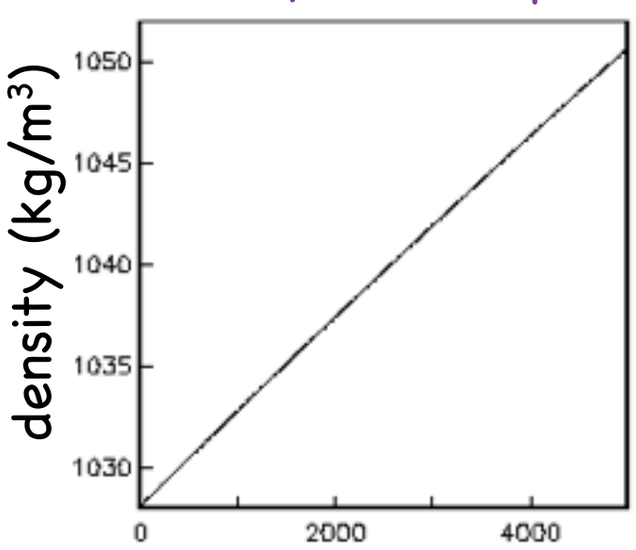
Physical properties of Seawater

Lecture 3

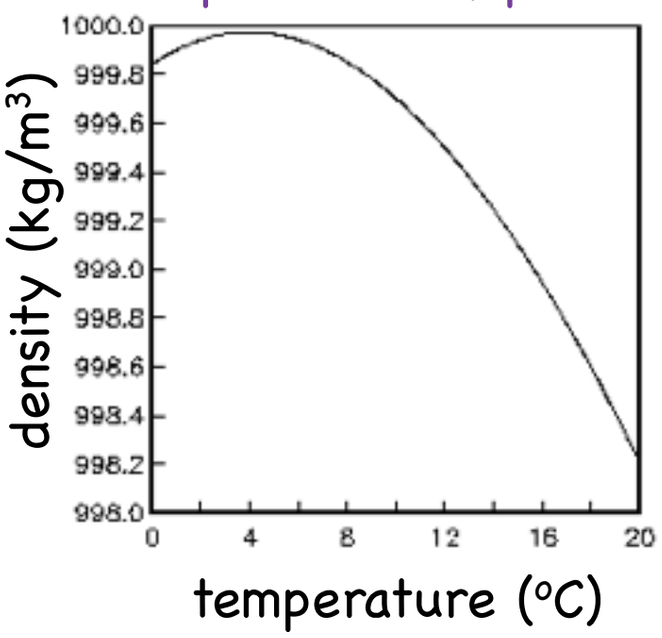
salinity=35, p=0



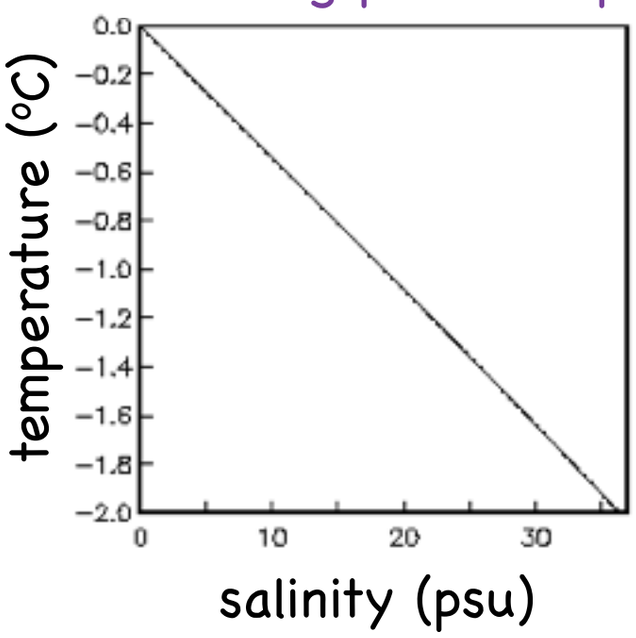
salinity=35, temp=0



pure water, p=0



freezing point temp



- pure water densest at 4°C, freezes at 0°C
- salt water densest at freezing point, -2°C
- as salt water freezes, salt is expelled (brine rejection) and ice crystals expand
- sea ice floats

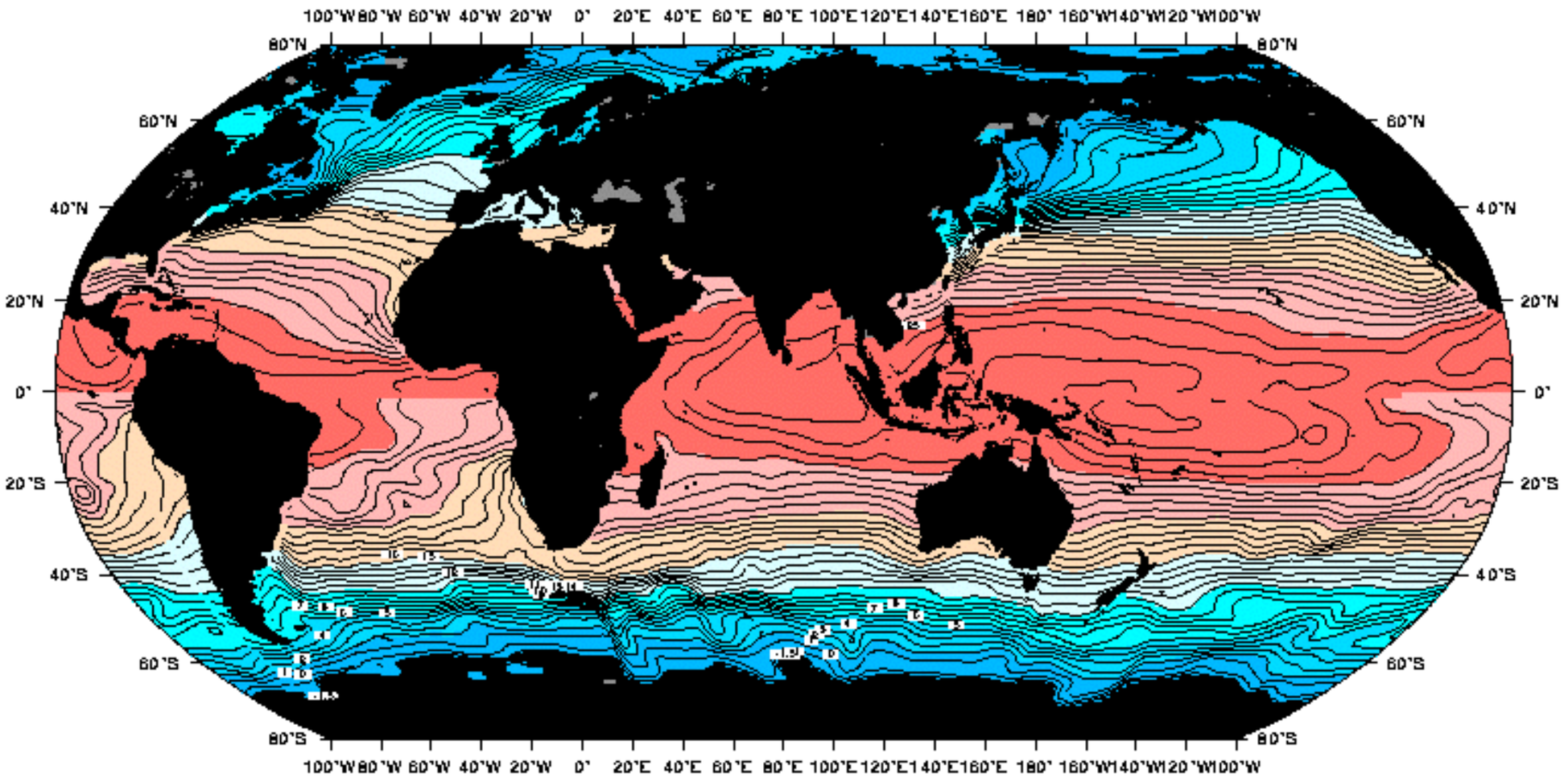
What affects the temperature and salinity of sea water at the surface of the ocean?

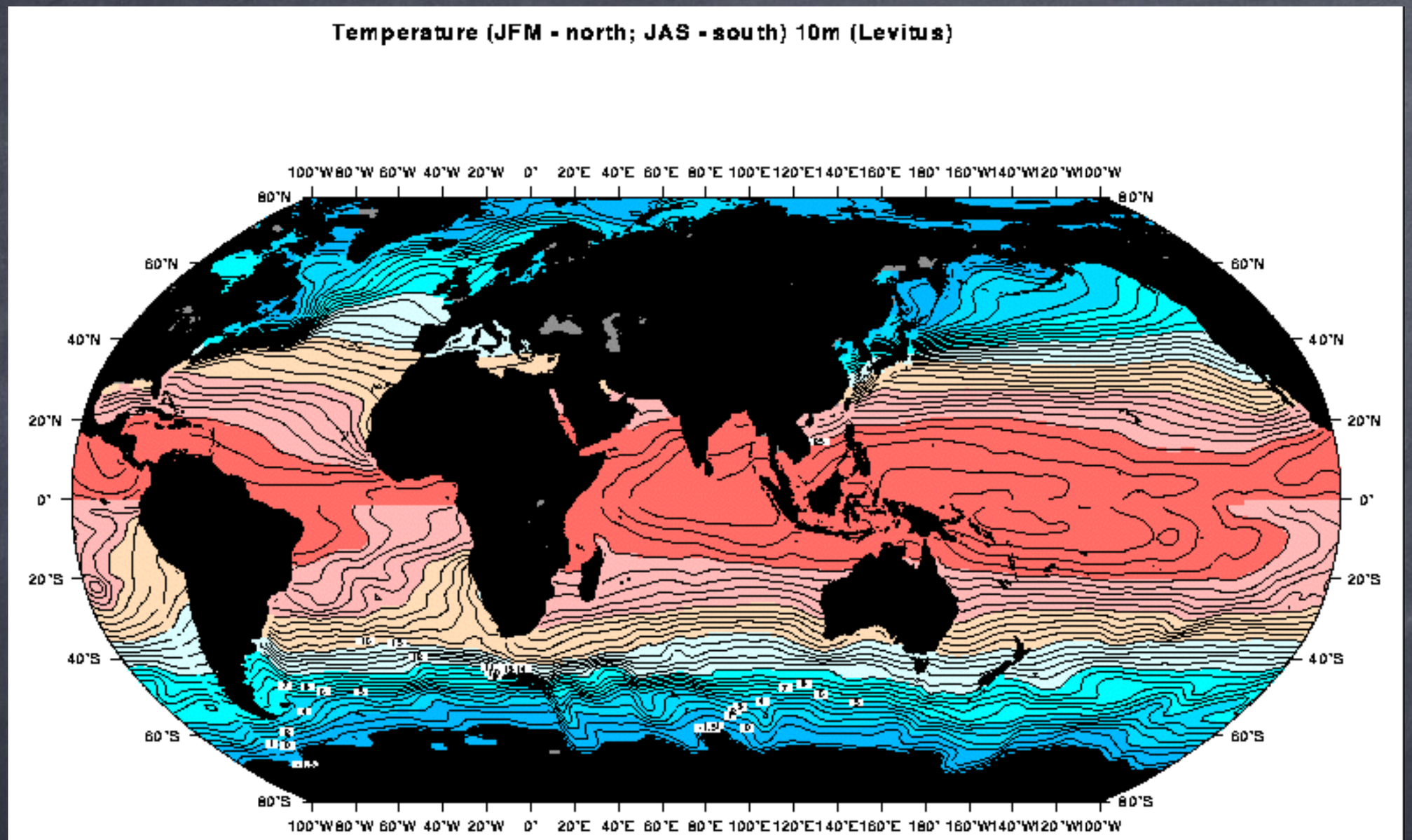
- surface heat fluxes (e.g. incoming solar, outgoing longwave, sensible and latent heat)
- evaporation/precipitation
- river inflow
- freezing/melting of sea ice
- buoyancy-driven convection
- wind-driven mixing

Why are temperature and salinity important in the ocean?

- Changes in T and S lead to changes in density: water may convect or subduct away from the surface and into the deeper ocean.
- Once water sinks away from the ocean surface it retains its distinctive T/S relationship for large time scales.
- These T/S properties enable the tracking of "water masses" as they flow away from their source and have revealed the global-scale thermohaline/overturning circulation.
- Gradients in density are directly related to ocean currents.

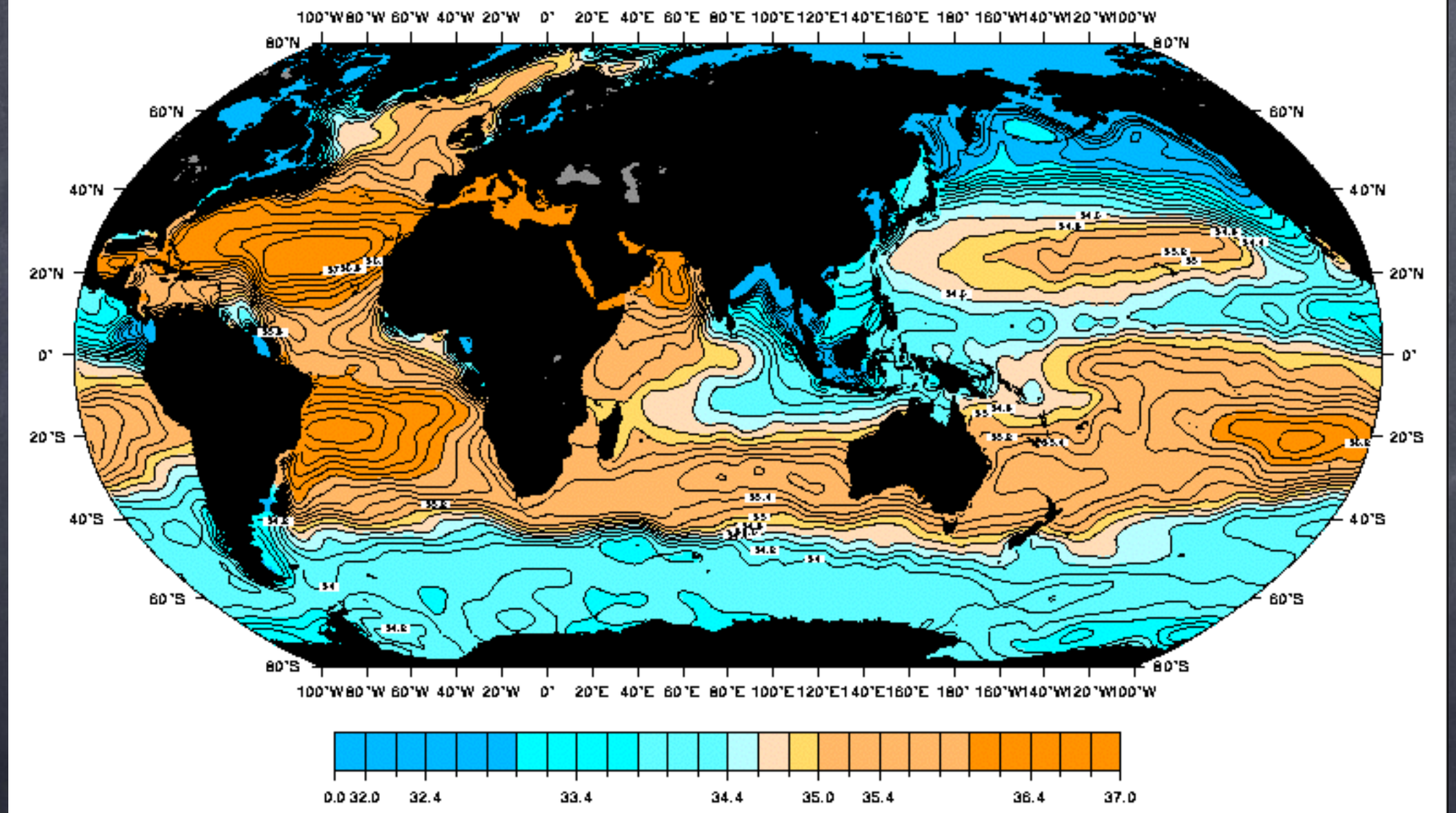
Temperature (JFM - north; JAS - south) 10m (Levitus)

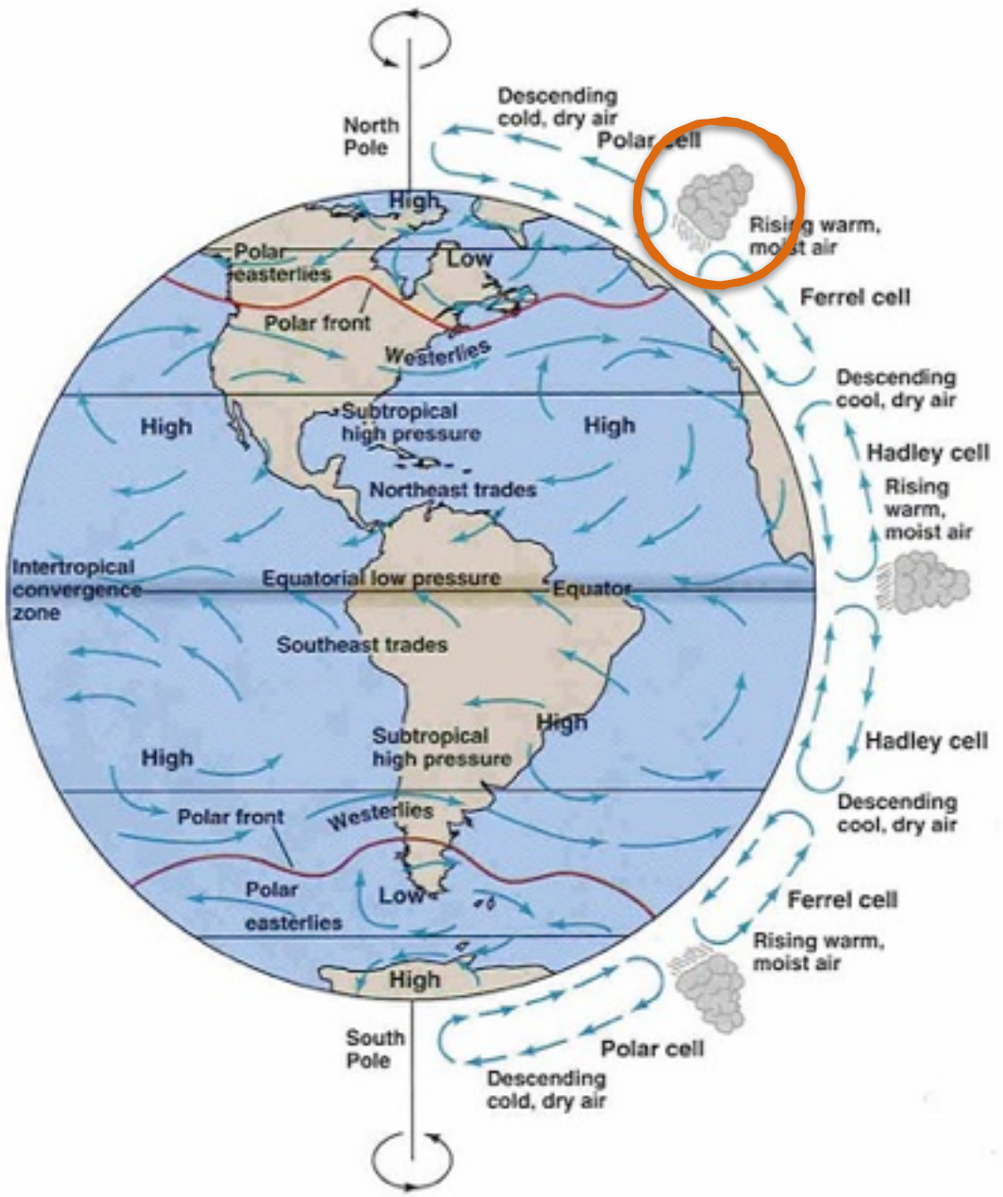


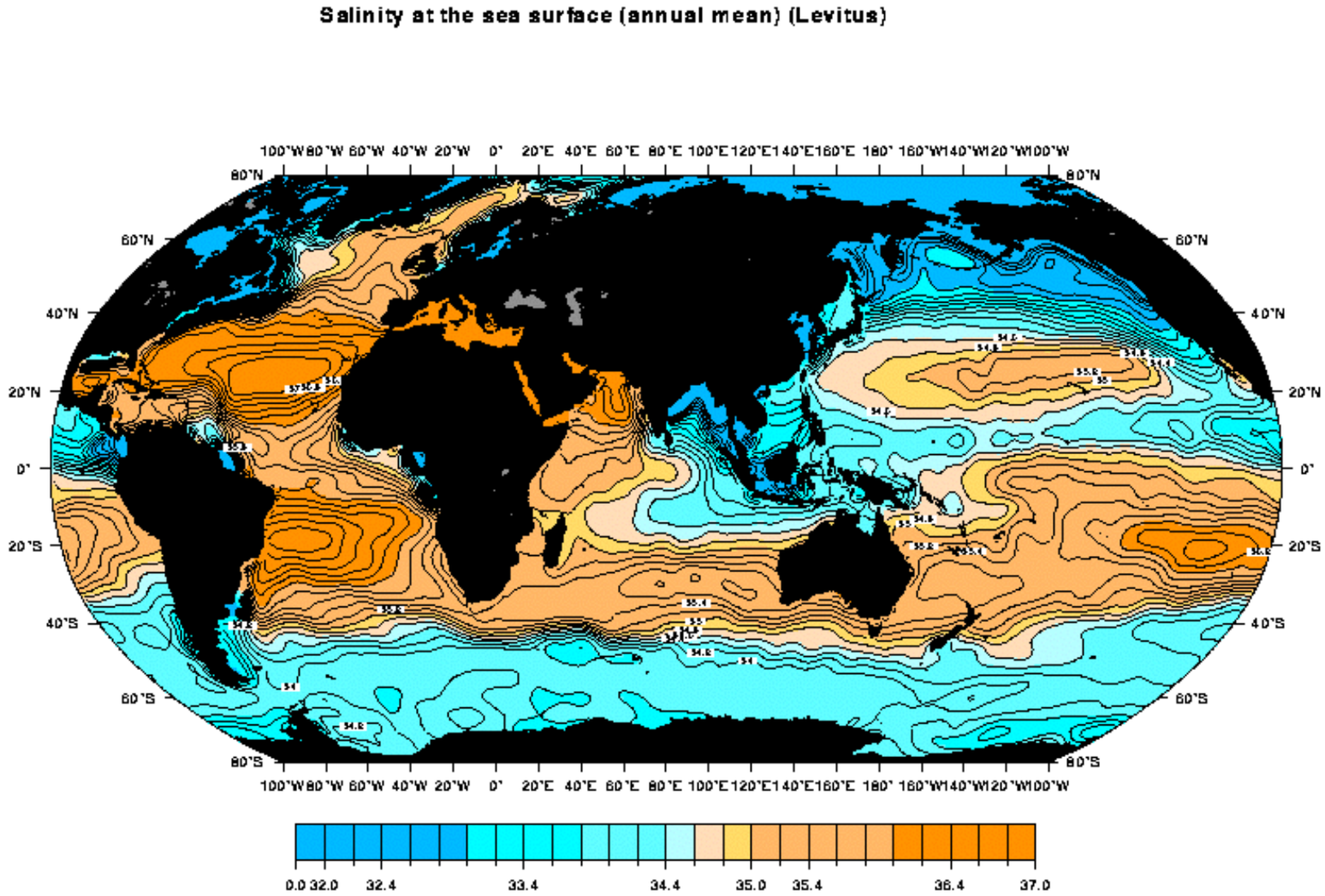


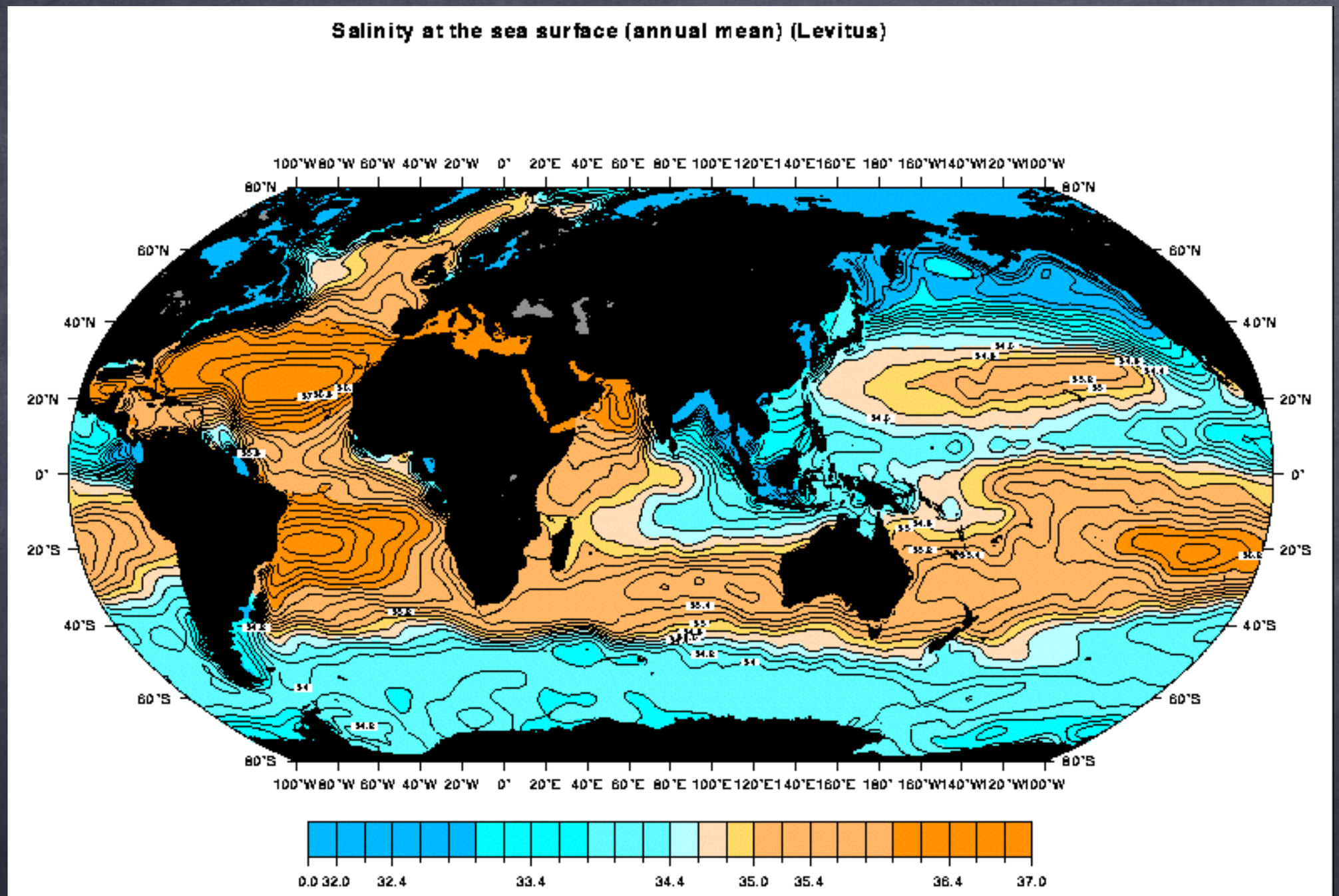
Surface temperature is dominated by net heating in the tropics and cooling at higher latitudes. The total range of temperature is from the seawater freezing point (-2ºC) up to about 30ºC.

Salinity at the sea surface (annual mean) (Levitus)




North Pole
Descending cold, dry air
Polar cell
Rising warm, moist air
Ferrel cell
Descending cool, dry air
Hadley cell
Rising warm, moist air
High
Polar easterlies
Low
Polar front
Westerlies
High
Subtropical high pressure
High
Northeast trades
Intertropical convergence zone
Equatorial low pressure
Equator
Southeast trades
High
Subtropical high pressure
High
Hadley cell
Descending cool, dry air
Polar front
Westerlies
Polar easterlies
Low
Ferrel cell
Rising warm, moist air
High
South Pole
Polar cell
Descending cold, dry air

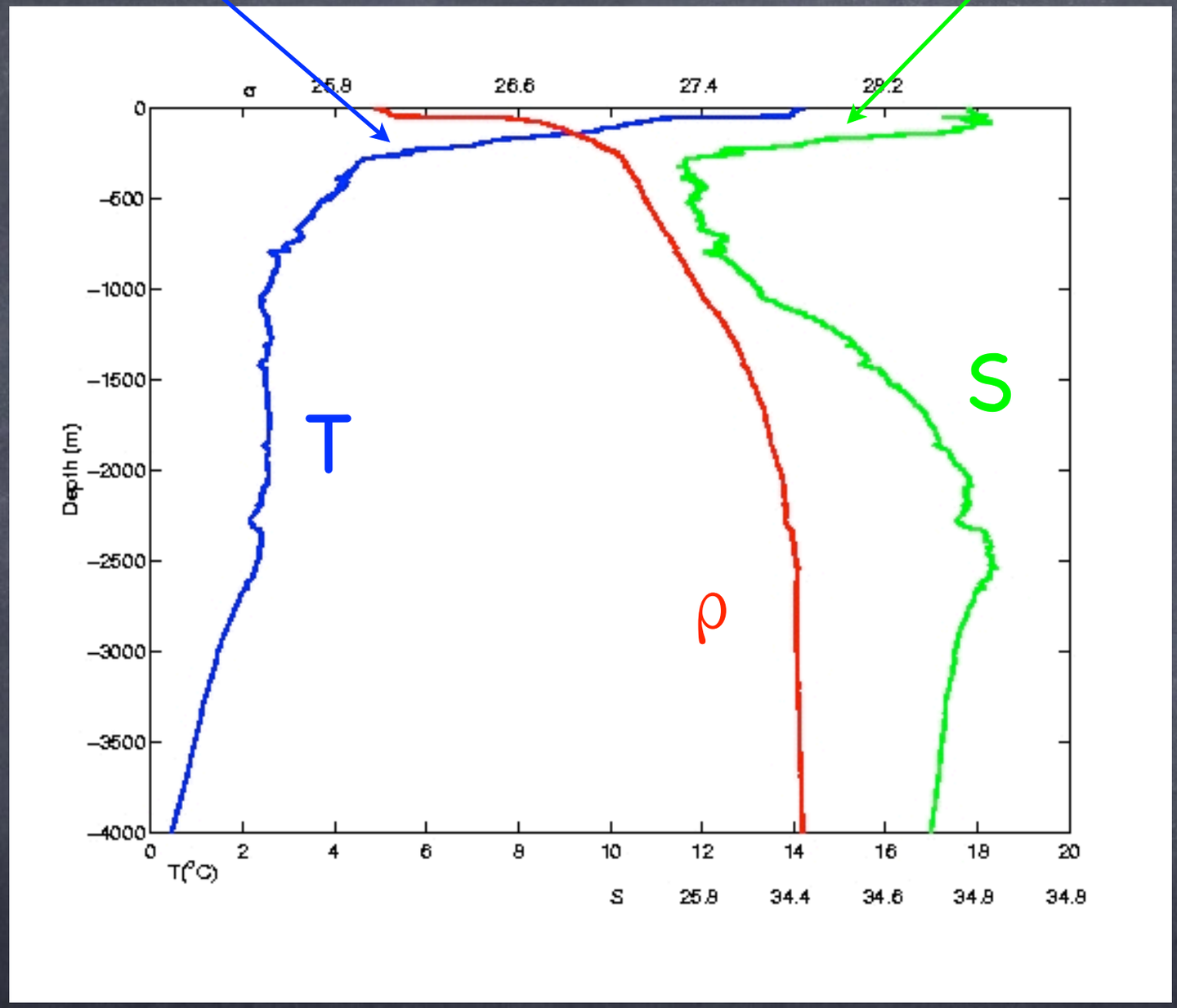

Salinity at the sea surface (annual mean) (Levitus)
100°W 80°W 60°W 40°W 20°W 0° 20°E 40°E 60°E 80°E 100°E 120°E 140°E 160°E 180° 160°W 140°W 120°W 100°W
80°N
60°N
40°N
20°N
0°
20°S
40°S
60°S
80°S
0.0 32.0 32.4 33.4 34.4 35.0 35.4 36.4 37.0



Surface salinity is dominated by net evaporation in the subtropical regions, and net precipitation/runoff at higher latitudes and in the tropics. Range in open ocean is 31 to 38.

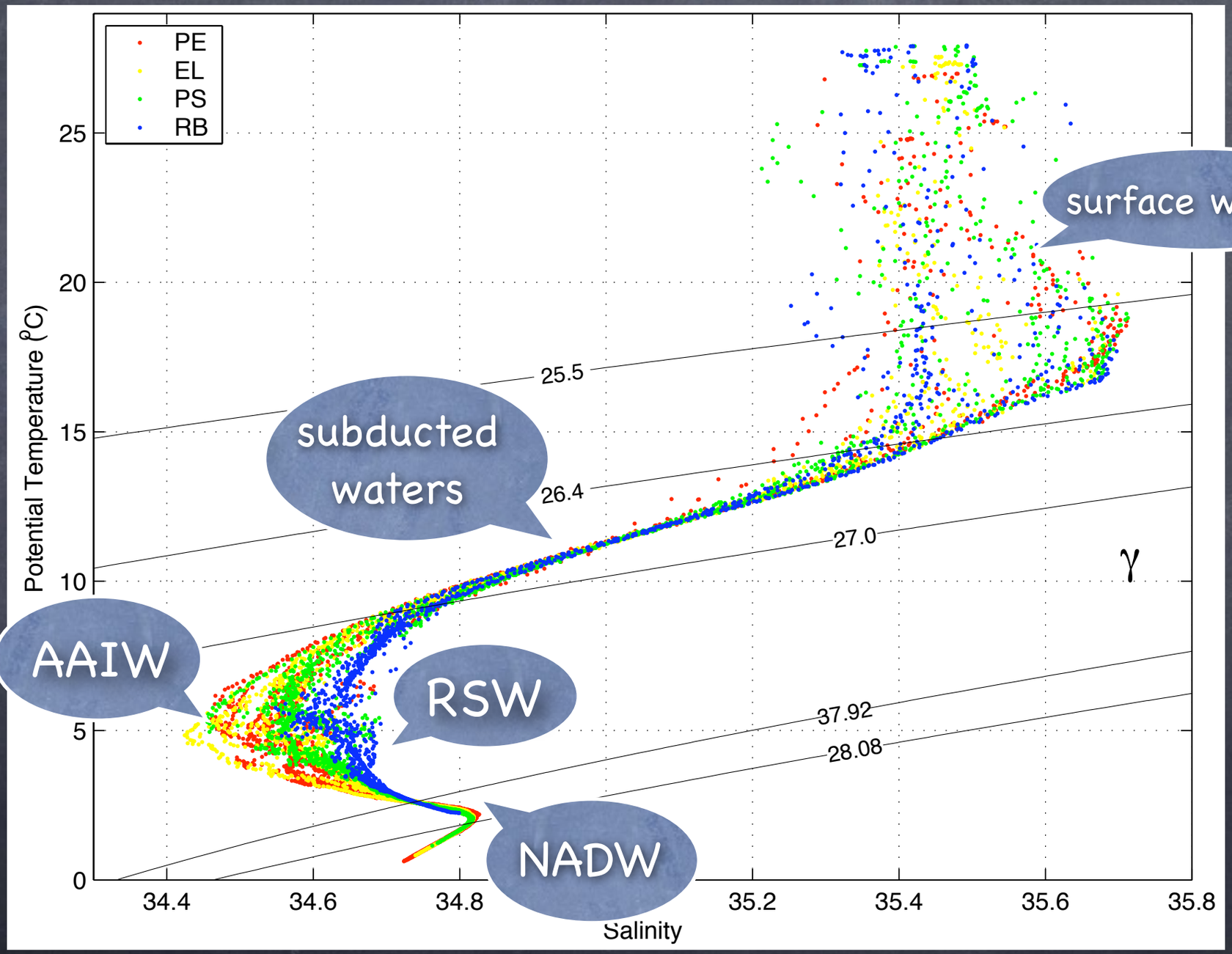
thermocline

halocline



typical in subtropics / mid-latitudes

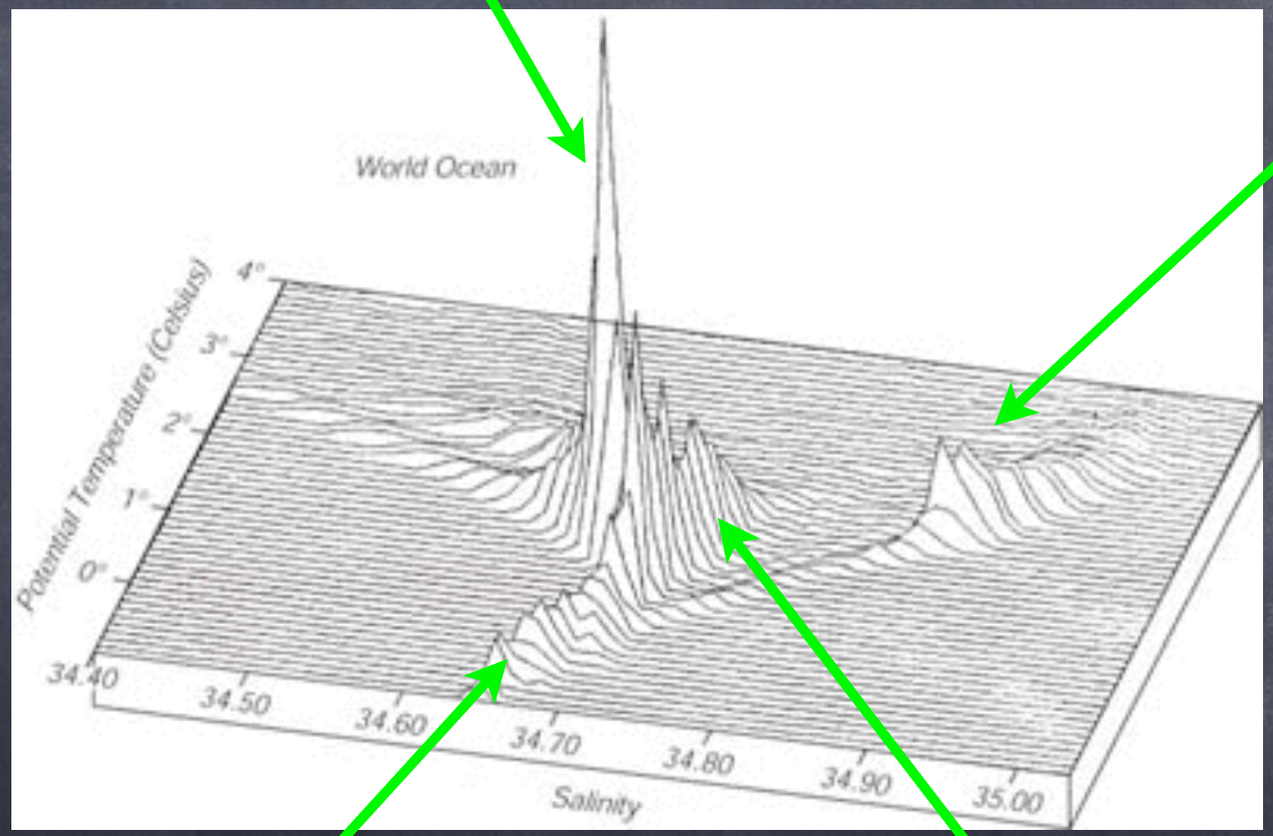
Example of a T/S (or T-S) diagram



γ = neutral density surfaces

"Mount Worthington" - global distribution of deep waters in T-S space

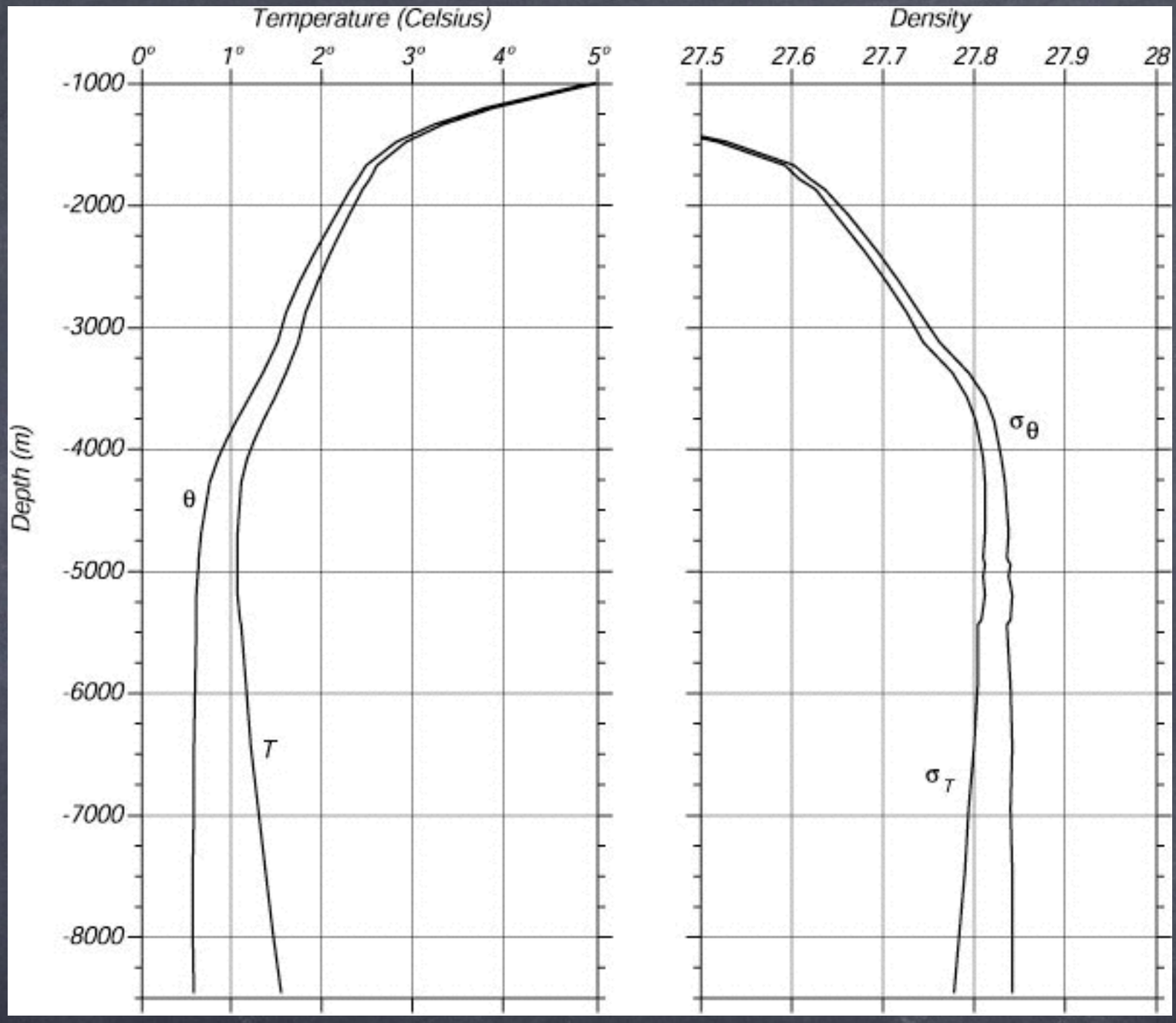
Pacific



Atlantic

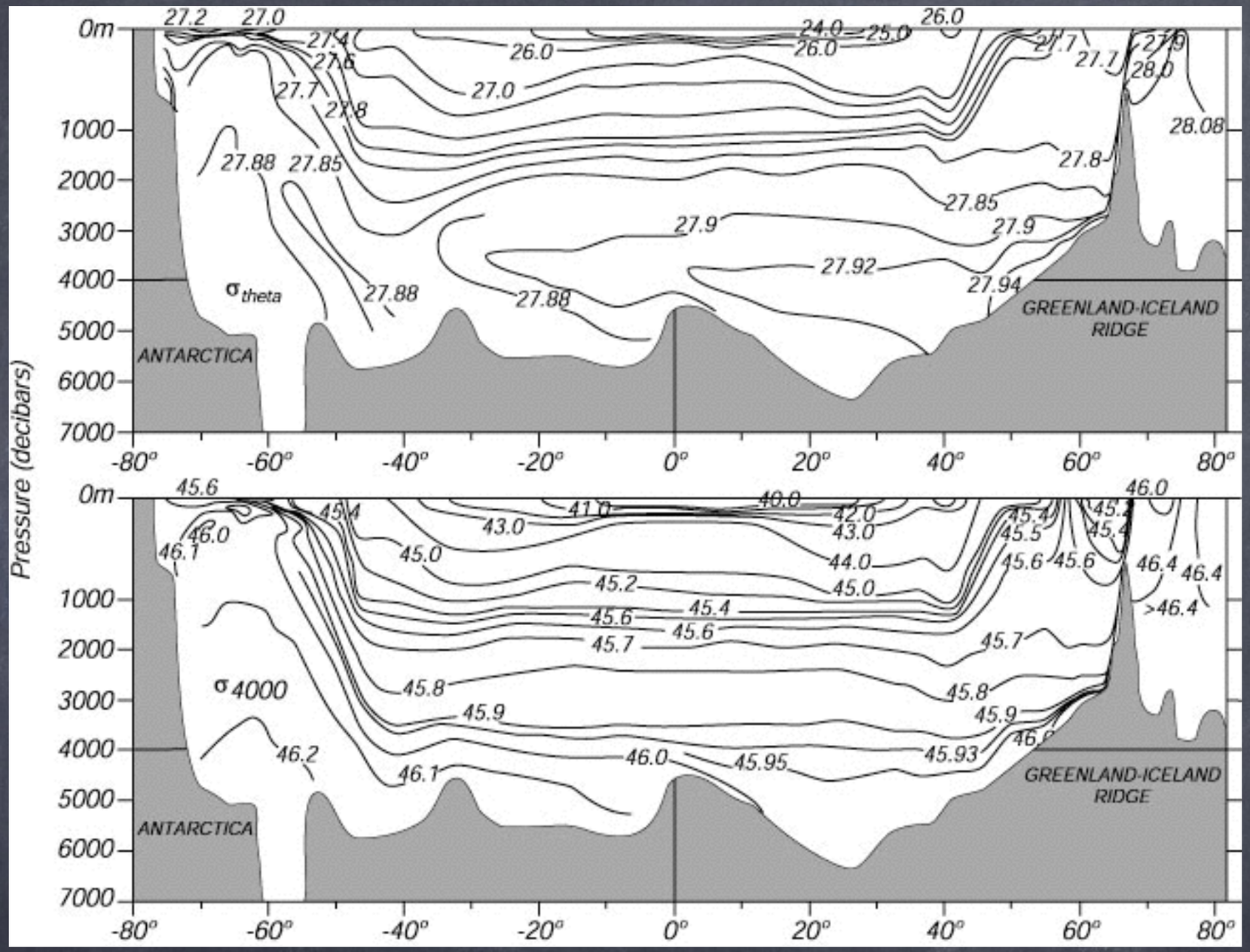
Antarctic

Indian



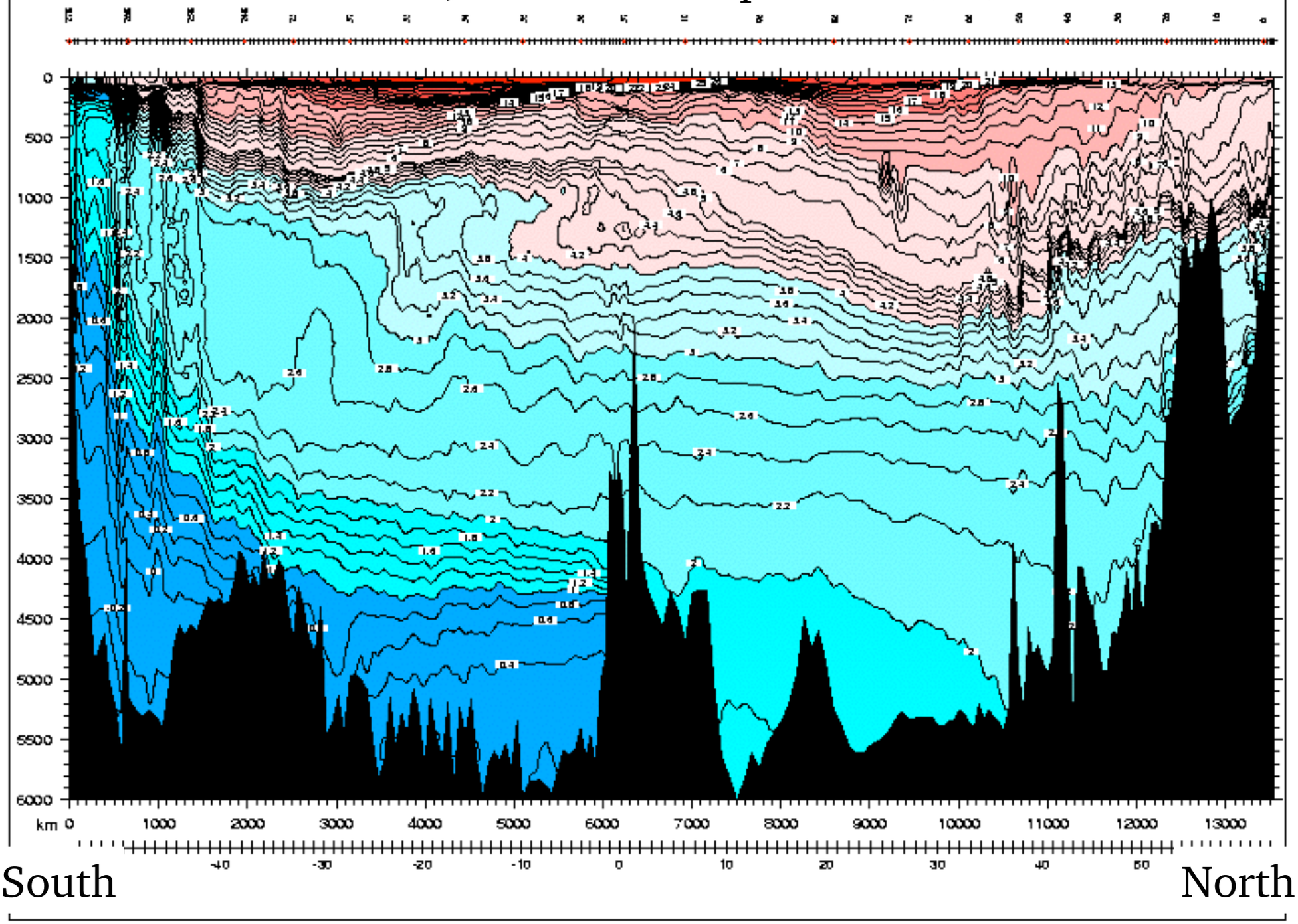
Temperature and potential temperature

Density and potential density



Stewart Figure 6.10: Vertical sections of density in the western Atlantic. Note that the depth scale changes at 1000 m depth. Upper: $\sigma\theta$, showing an apparent density inversion below 3,000 m. Lower: $\sigma 4$ showing continuous increase in density with depth. From Lynn and Reid (1968).

Atlantic, Potential Temperature (°C)



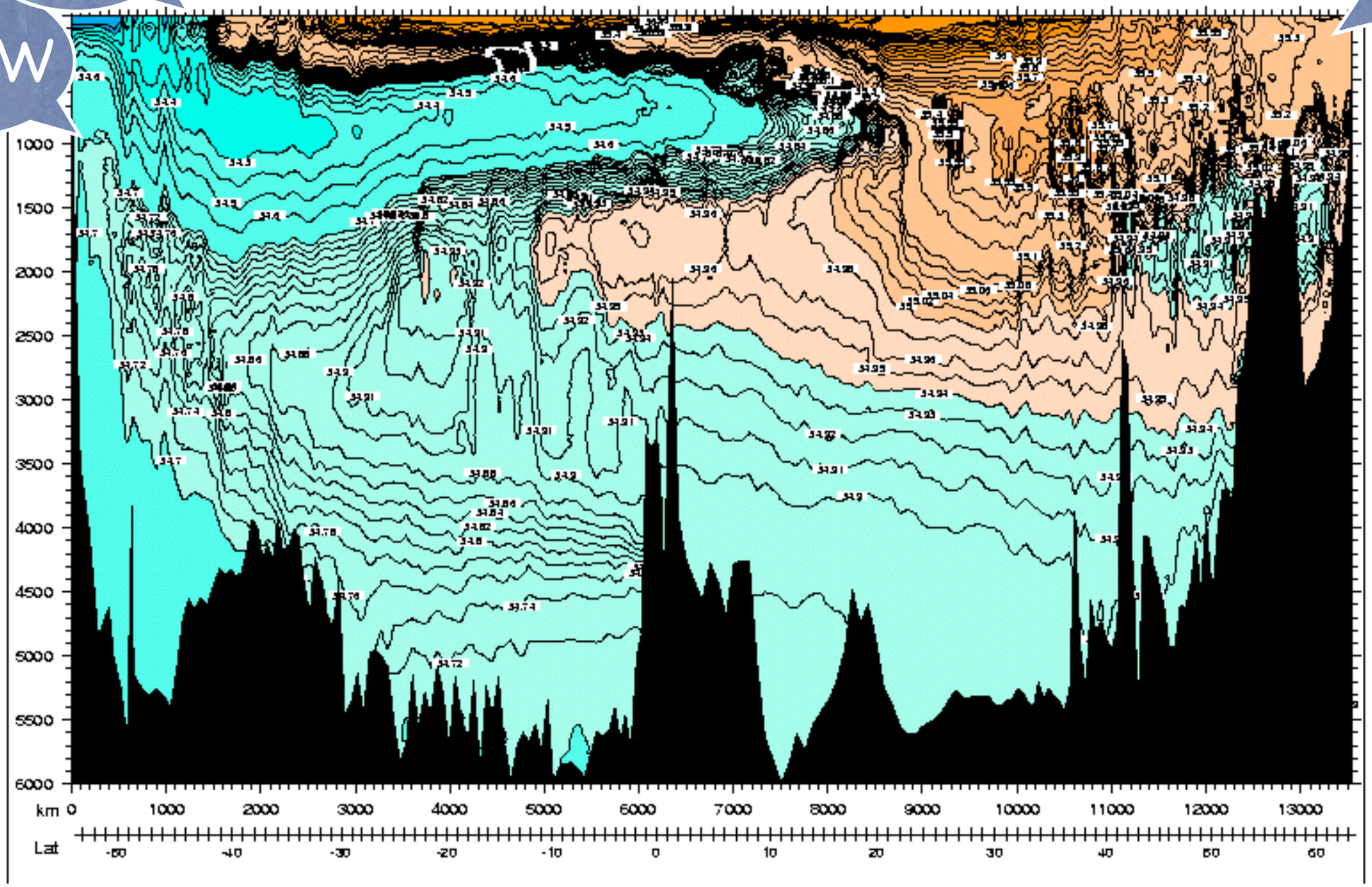
Notice: (1) upward T gradient towards poles (2) downwelling at subtropical gyre centers, (3) upwelling at equator

AAIW

AABW

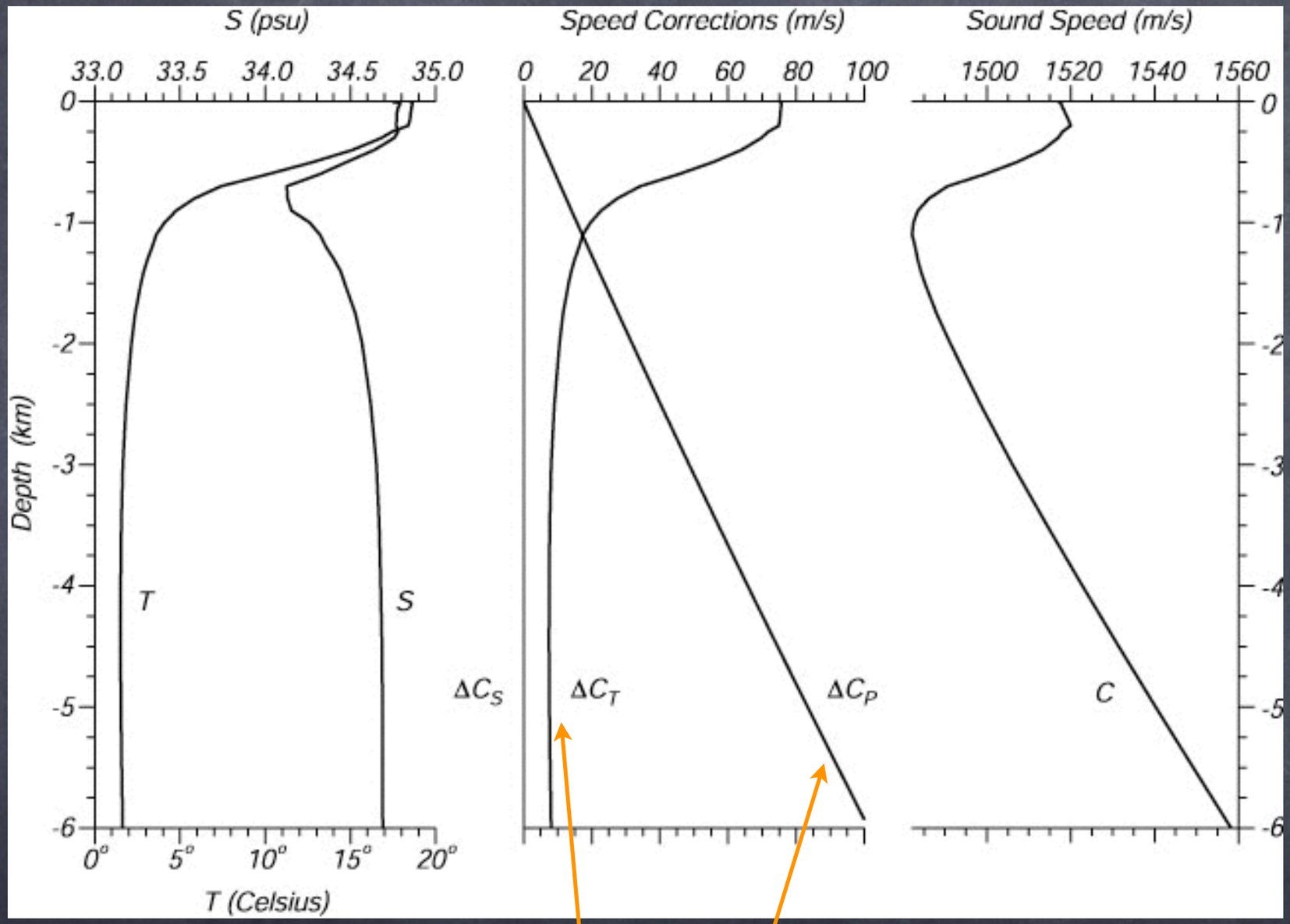
NADW

Atlantic, Salinity (psu)



South — North

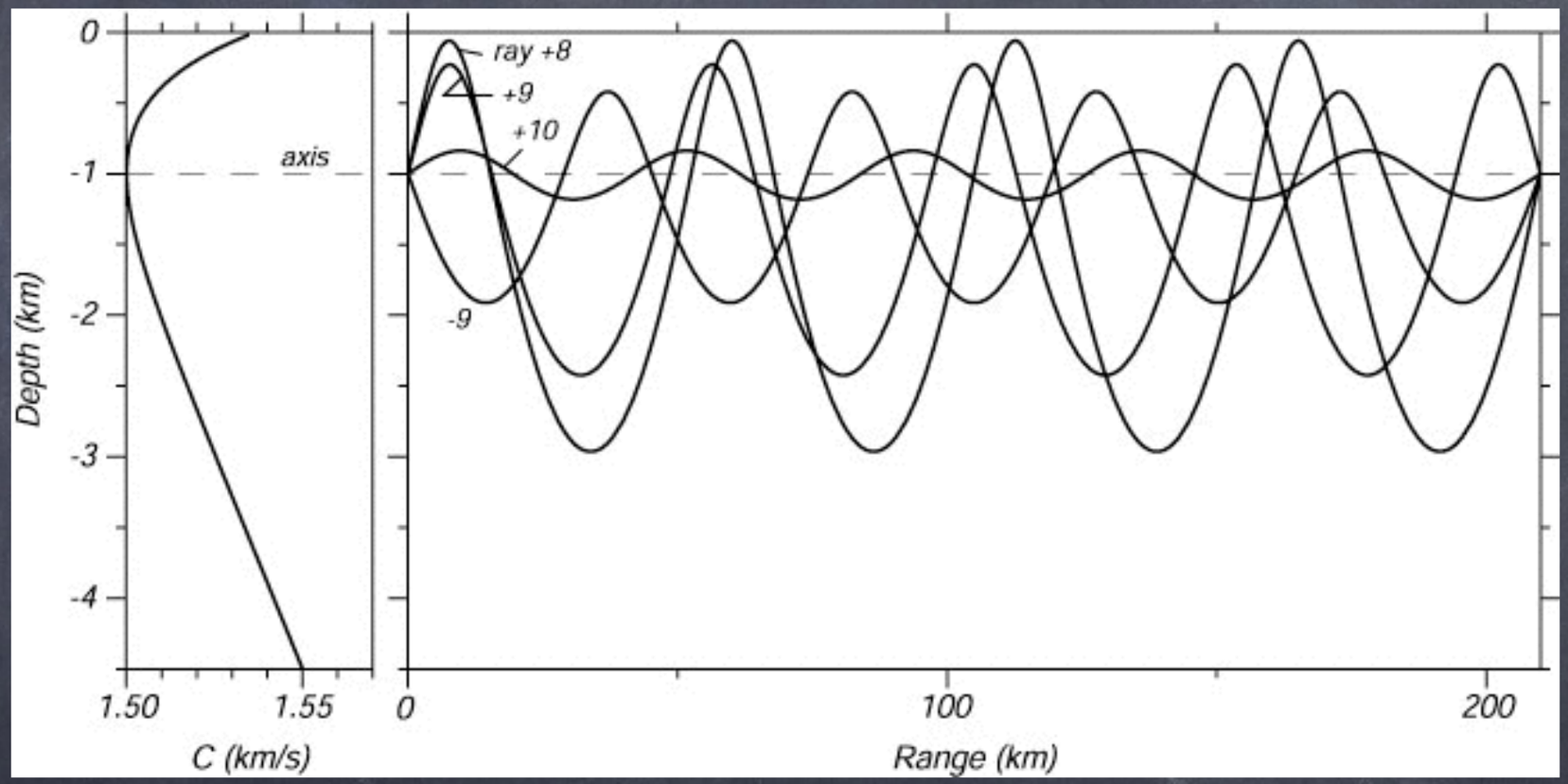
Effect of p,T, and S on sound speed.



effect of temperature on sound speed

effect of pressure (depth) on sound speed

Ray paths of sound in the ocean for a source near the axis of the sound channel. Munk et al. (1995).



Rays are bent (or attracted) towards sound speed minimum - SOFAR channel