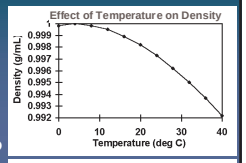
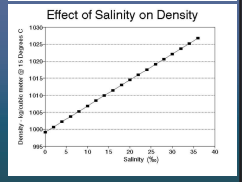
# Density and Stratification

the major players of the ocean's layers

## Density of water

- density = mass/volume
  - units: g/cm$^3$ (= g/ml = kg/L)
  - density of water - @ 4$^o$C and 1 atm pressure
    - fresh: 1.000 g/cm$^3$ *(by definition!)*
    - sea: 1.027 g/cm$^3$ *(on average)*
- what determines water density?
  - temperature – inverse relationship
    - lower temp = higher density
    - higher temp = lower density
  - salinity – direct relationship
    - lower sal = lower density
    - higher sal = higher density
  - pressure
    - water is essentially (but not exactly) incompressible
    - but at very high pressures (deep depths) – pressure increases density
    - sea level would be ~30-50 m higher without pressure effect




## Ocean surface temperature

- often called sea surface temperature or *SST*
- strongly correlates with latitude because *insolation* (amount of sunlight striking Earth's surface) is high at low latitudes & low at high latitudes
- surface ocean *isotherms* (lines of equal temperature)
  - generally trend east-west
  - except where deflected toward poles or equator by *currents*
    - warm water carried poleward on western side of ocean basins
      - Gulf Stream, Kuroshio Current – Northern Hemisphere
      - Brazil Current, East Australia Current – Southern Hemisphere
    - cooler water carried equatorward on eastern side of ocean basins
      - Canary Current, California Current – Northern Hemisphere
      - Benguela Current, Peru Current – Southern Hemisphere
- SST overall pattern
  - highest in the tropics (~25-29$^o$C) where insolation is highest
  - decreases poleward with decreasing insolation
  - negative temperatures in Arctic Ocean & around Antarctica

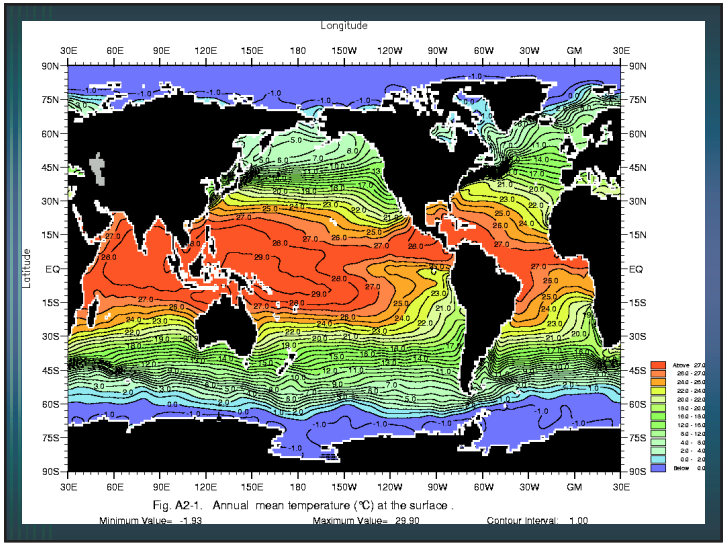
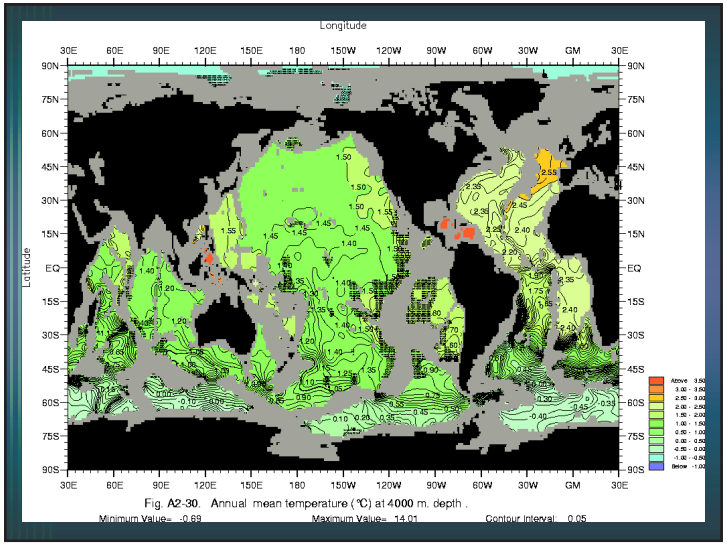



Fig. A2-1. Annual mean temperature (°C) at the surface.

Minimum Value= -1.93 Maximum Value= 29.90 Contour Interval= 1.00

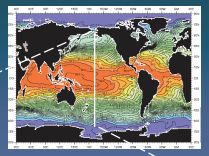
# Ocean abyssal temperature

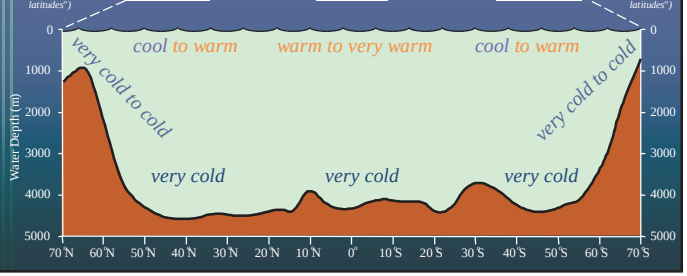
- cold and dense
  - colder than 4°C (remember *Challenger* expedition)
  - colder = more dense
    - remember temperature-density relationship for seawater
    - temperature of maximum density is right at freezing point (~ -1.91°C)
- smaller temperature range than SST
  - <1°C – 2.5°C @ 4000 m depth
  - overall, from ~1000 m and below, most temperatures are 2° – 4°C
- more uniform distribution than SST
  - isolation from insolation *(read that twice!)*
  - still, some patterns can be discerned
    - colder near Antarctica
    - warmer in North Atlantic
    - warmest in isolated basins (due to diffusion of heat over time)
      - Caribbean Sea basin
      - Philippine Sea basin




# Predict-a-profile

*kinda like whack-a-mole except you don't actually hit anything*

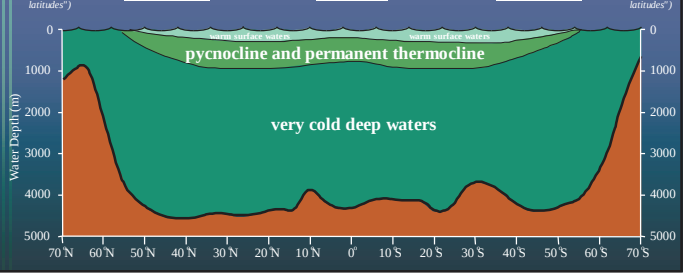





# Produce-a-profile

*How did we do?*

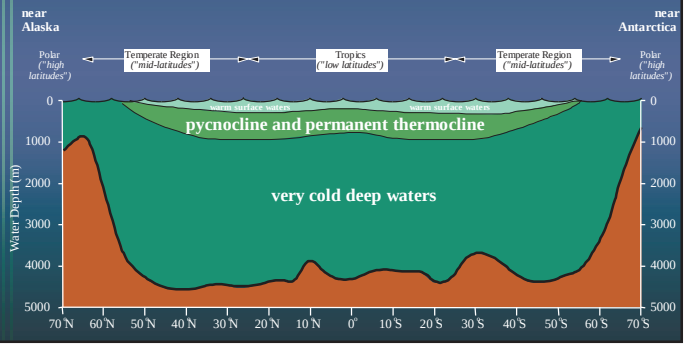
- warm surface waters ≈ 2% of ocean volume
- thermocline waters ≈ 18% of ocean volume
- deep waters ≈ 80% of ocean volume



# Explain-a-profile

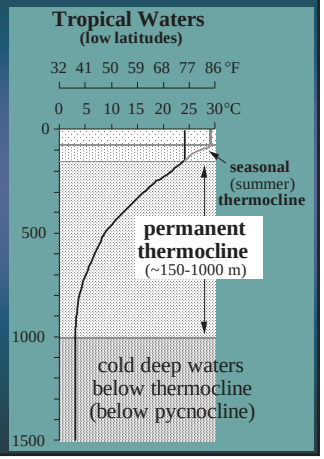
*What does this mean?*

- warm, less dense surface layer over very cold and dense deep waters
- the *permanent thermocline* is the interval through which temperature decreases rapidly with increasing water depth




# thermocline in tropics

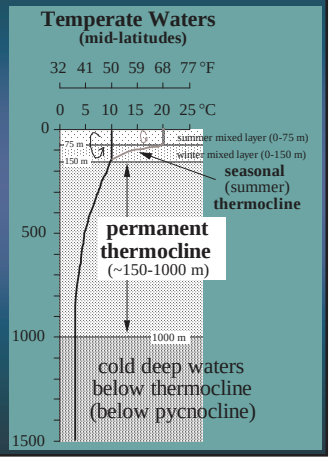
- The permanent thermocline extends from the base of the surface *mixed layer* (~75-150 m) to ~1000 m water depth.
- The depth of the mixed layer is a function of mixing (homogenization) of the warmed surface waters downward by day-to-day winds and storms, waves and surface currents.




# thermocline in mid-latitudes

- Winter storms tend to be bigger/stronger than summer storms.
- Therefore the mixed layer tends to be deeper during winter months.
- Summer heating causes the creation of a seasonal thermocline (a steeper temperature gradient than during the winter).

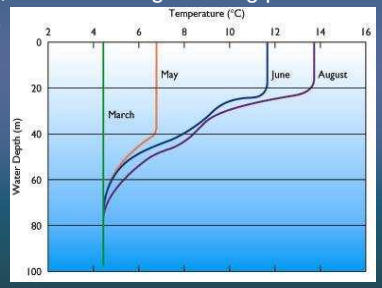
***pronounced seasonality is the hallmark of the mid-latitudes***




# Growth of Seasonal Thermocline

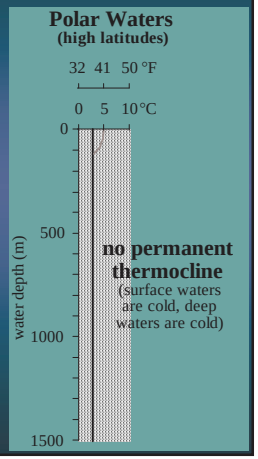
***NOTE: applies to mid-latitude temperate regions only***

- March – winter cooling of surface waters has destroyed seasonal thermocline, vertical mixing is taking place
- May – surface waters begin to warm, weak thermocline forms
- June – surface layer increasingly shallow and isolated from deeper waters; thermocline strengthens
- August – thermocline reaches maximum
- *Decay of thermocline* occurs August – January, as surface waters increasingly cool and mix with deeper waters



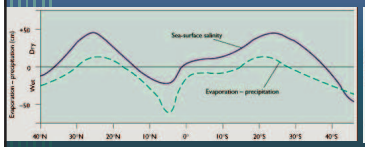
## thermocline in polar regions

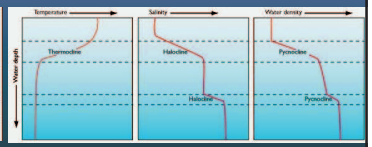
- A permanent thermocline is absent in polar regions because surface waters are very cold and deep waters are very cold.
- Therefore, there is little temperature contrast (or gradient) between polar surface and deep waters.
- A small seasonal (summer) thermocline forms but vertical mixing occurs basically year-round.




## Salinity and the halocline

- Salinity changes with latitude due to variations in precipitation and evaporation with latitude.
- Highest ocean salinity is between 20-30º north and south of the equator, because evaporation exceeds precipitation there.
- Low salinity at the equator and poleward of 30º results from evaporation being less than precipitation.
- In some areas of the ocean, surface water and deep water are separated by a *halocline*, a zone of rapid change of salinity with water depth.
- The thermocline and halocline combine to form the *pycnocline* (which is mighty fine).
- Water *stratification* (layering) within the ocean is most pronounced at the latitudes between 40ºN and 40ºS.




temperature = "thermo" | salinity = "halo" | density = "pycno"

## Fun with dots on plots