Density and Stratification
the major players of the ocean’s layers

Density of water

- density = mass/volume
- units: g/cm³ (= g/ml = kg/L)
- density of water - @ 4°C and 1 atm pressure
  - fresh: 1.000 g/cm³ (by definition)
  - sea: 1.027 g/cm³ (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°C) where insolation is highest
  - decreases poleward with decreasing insolation
  - negative temperatures in Arctic Ocean & around Antarctica
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 (~ -1.9°C)
- smaller temperature range than SST
  - <1°C – 2.5°C @ 4000 m depth
  - overall, from ~1000 m and below, most temperatures are 2°C – 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

pynocline and permanent thermocline
- very cold deep waters
**Explain a profile**

*What does this mean?*

- A 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).

**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.
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 20-30° north and south of the equator, because evaporation exceeds precipitation there. Low salinity at the equator and poleward of 30° 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 40°N and 40°S.

Fun with dots on plots

Temperature vs. density and temperature vs. water depth graphs are shown with dots indicating the presence of thermocline and pycnocline.