AOS 103

Week 2 Discussion

Internal Energy

1) Write down and explain the terms in the internal energy equation

2) What variables can change the internal energy?

3) What physical processes in the ocean/atmosphere will change the internal energy

Internal Energy

- Energy depends on mass, specific heat capacity and temperature

$$E = mC_pT$$

- Temperature and mass (which implies a volume or density change) can change internal energy

$$\Delta\left(E = mC_pT\right)$$

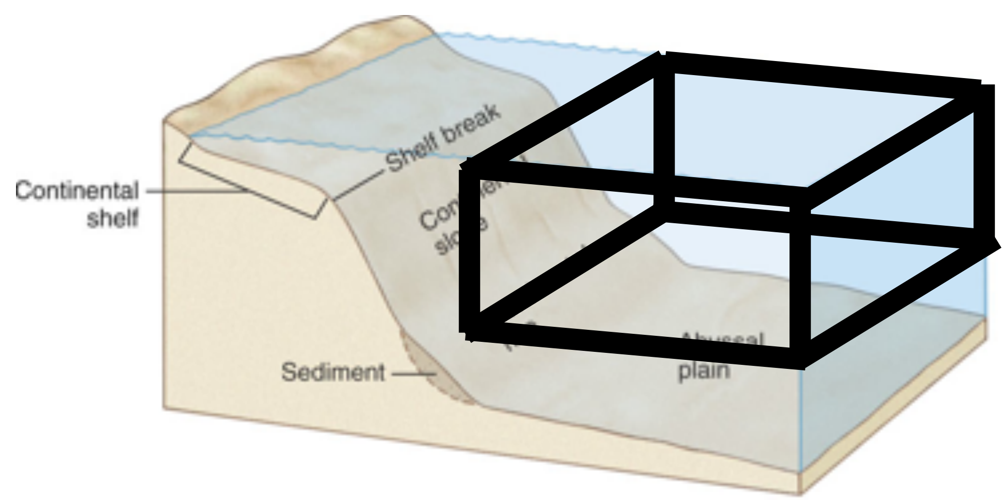
$$\Delta E = \Delta m C_p \Delta T$$

-Any source of heat flux into the ocean that change the temperature can change the internal energy
-Mass change can occur through compression of water parcels by pressure which changes the volume (a change in mass will change the internal energy)

(Heat) Fluxes

1) **Define a flux (give a real world example that elaborates on your definition)**

2) **Image in a box in the middle of the ocean (near the continental shelf) that is flush with the surface. Describe how temperature would change in this box (with an equation and words)**



3) Consider an ocean column with a surface area of 1m^2 and a depth of 2500m. The column experiences a surface input F_top = 100W/m^2 from solar radiation. How long would it take this radiation to raise the water temperature by 1C (use density=1000 kg/m^3 and C_p = 4000J/kg/K)

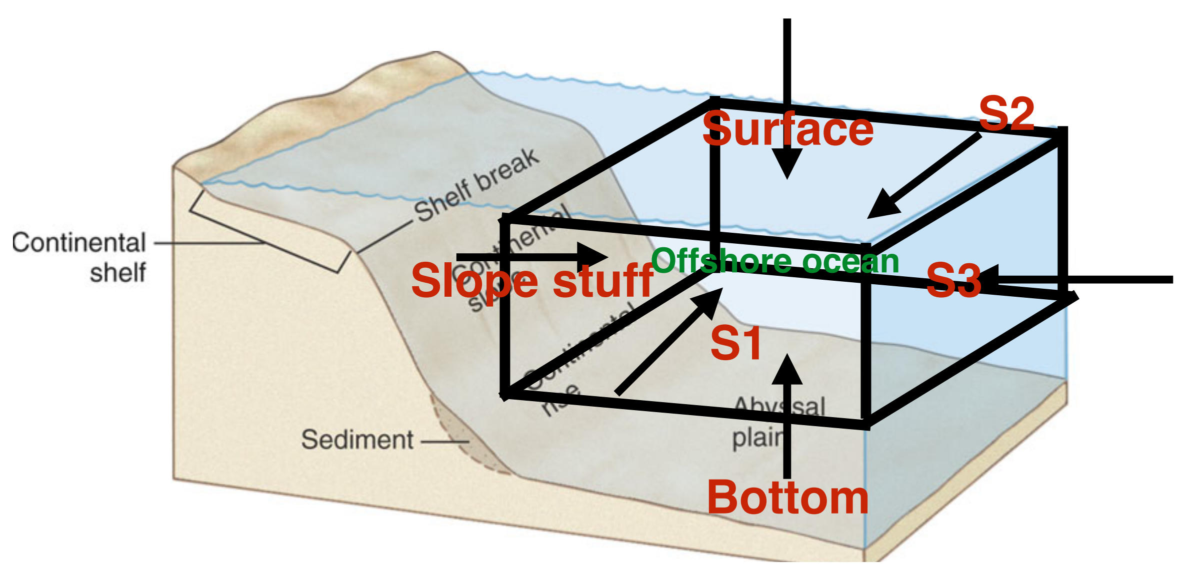
(Heat) Fluxes

-A flux is the rate of transfer of some property (heat, water, mass, salt, etc.) from one place to another

- **A simple example is a water flowing out of a hose…water is fluxing out of the hose**
- **The general units of a flux are:**

$$\left[\frac{\frac{\text{property}}{\text{time}}}{\text{area}}\right]$$

-Temperature could change due to any heat flux (sensible, latent, radiative, advective) passing through one of the faces



$$\frac{dE}{dT} = Q_1 + ... + Q_6$$

$$mC_p\frac{dT}{dt} = Q_1 + ... + Q_6$$

$$\frac{dT}{dt} = \frac{Q_1 + ... + Q_6}{mC_p}$$

(Heat) Fluxes

Only process that is changing the temperature is the heat flux at the top…

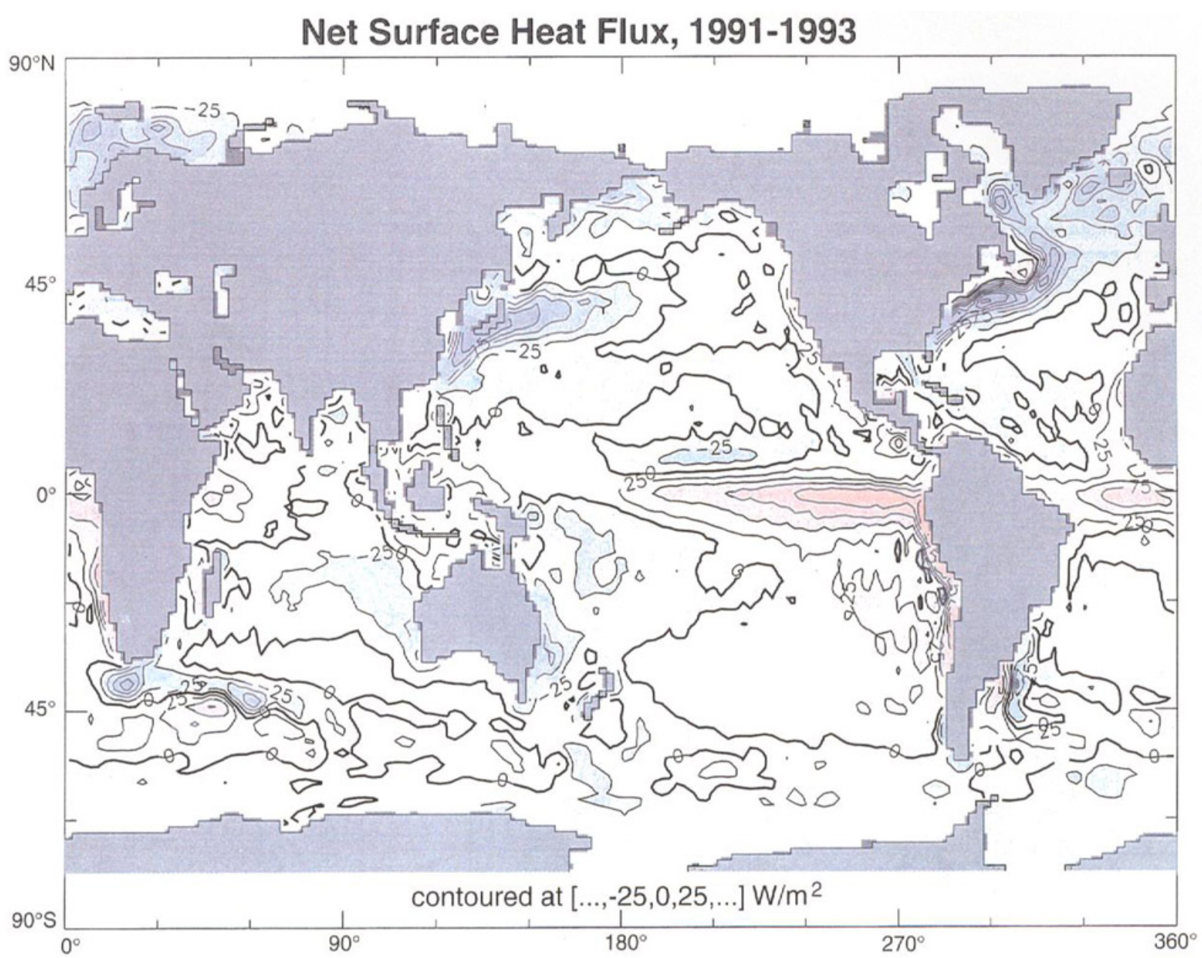
$$Q_{top} = F_{top} A$$

$$\frac{\Delta E}{\Delta t} = Q_{top}$$

$$\Delta t = \frac{\Delta E}{Q_{top}} = \frac{\rho V C_p \Delta T}{Q_{top}}$$

We know the dimensions of the column (surface area, and depth), so we know the volume

Surface Heat Fluxes



Global distribution of the 1991–93 average net heat flux, <*in>, after 16.4 W m^{-2} has been subtracted everywhere to make the global average zero. The contour interval is 25 W m^{-2} and positive (red) values indicate ocean heating.

For the <u>Gulf Stream</u> and eastern <u>equatorial Pacific regions:</u>

1) **What are the net surface heat fluxes for these regions and what do they mean for the ocean?**
2) **What physical processes drive this and what types of heat flux are associated with these physical processes?**

Surface Heat Fluxes

Sensible Heat Flux $T_w - T_a$

Latent Heat Flux $H_w - H_a$

Gulf Stream: **The net surface heat flux is negative (blue), according to the legend (text on the side) of the figure this indicates that the ocean is LOSING heat. In this region this can occur through sensible heat flux b/c the ocean is warmer than the air ($T_w - T_a > 0$). This is due to an advective heat flux via the Gulf Stream flow which brings up relatively warm water from the south. This sensible heat flux is shown on the sensible heat flux map from Lecture 2 (red in that map indicates a flux "upward" = outward from the ocean). There is also a latent heat flux indicative of the ocean losing heat in this region that is caused by the specific humidity of the ocean being greater than that of the overlying atmosphere ($H_w - H_a > 0$). Finally, there are radiative fluxes (short and longwave) with shortwave warming the ocean and long wave cooling the ocean. Howeve, the reason this area has such a striking surface heat flux (relative to the rest of the map) is due to the latent and sensible heat fluxes. If shortwave radiation were the only story, then the net surface heat flux at any latitude would look the same around the globe.**

Equatorial Pacific: **The net surface heat flux is positive, indicative of the ocean gaining heat. Again, there are general radiative fluxes here (shortwave heating, longwave cooling), but the main story is in the sensible, latent and advective heat fluxes. Upwelling along the coast of South America brings up cold water from depth. This cold water is colder than the overlying atmosphere when it reaches the surface. This causes a sensible heat flux with $T_w-T_a < 0$ and thus the ocean gains heat from the atmosphere. There is a small, positive latent heat flux indicative of the ocean being more humid than the ocean, but it is negligible compared to the sensible heat flux (look at surface maps from lecture 2 and pay attention to magnitudes/ signs in those maps).**

Vertical Profiles of Temperature

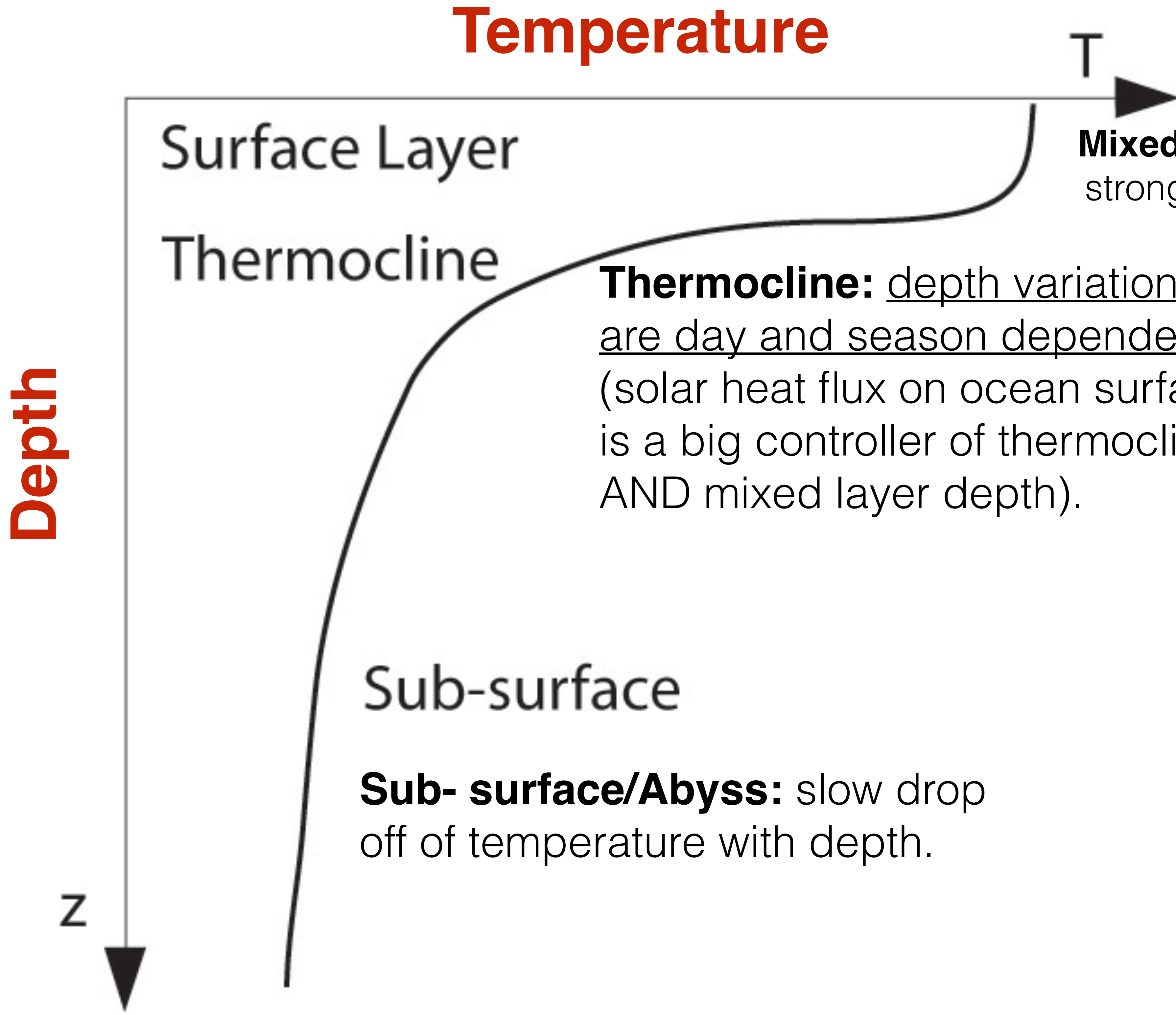
1) Draw a typical T(z) profile and label the layers in the water column

2)What physical processes can set the depth of the bottom of the mixed layer

3) At what time do you expect the mixed layer to be the deepest (explain by drawing a curve showing solar heat flux and a resulting curve showing ML depth with time)

4) Draw T(z) plots night/day and summer/winter and explain what processes lead to similarities/differences in each plot

Vertical Profiles of Temperature



Mixed Layer: will get deeper with stronger winds or surface cooling

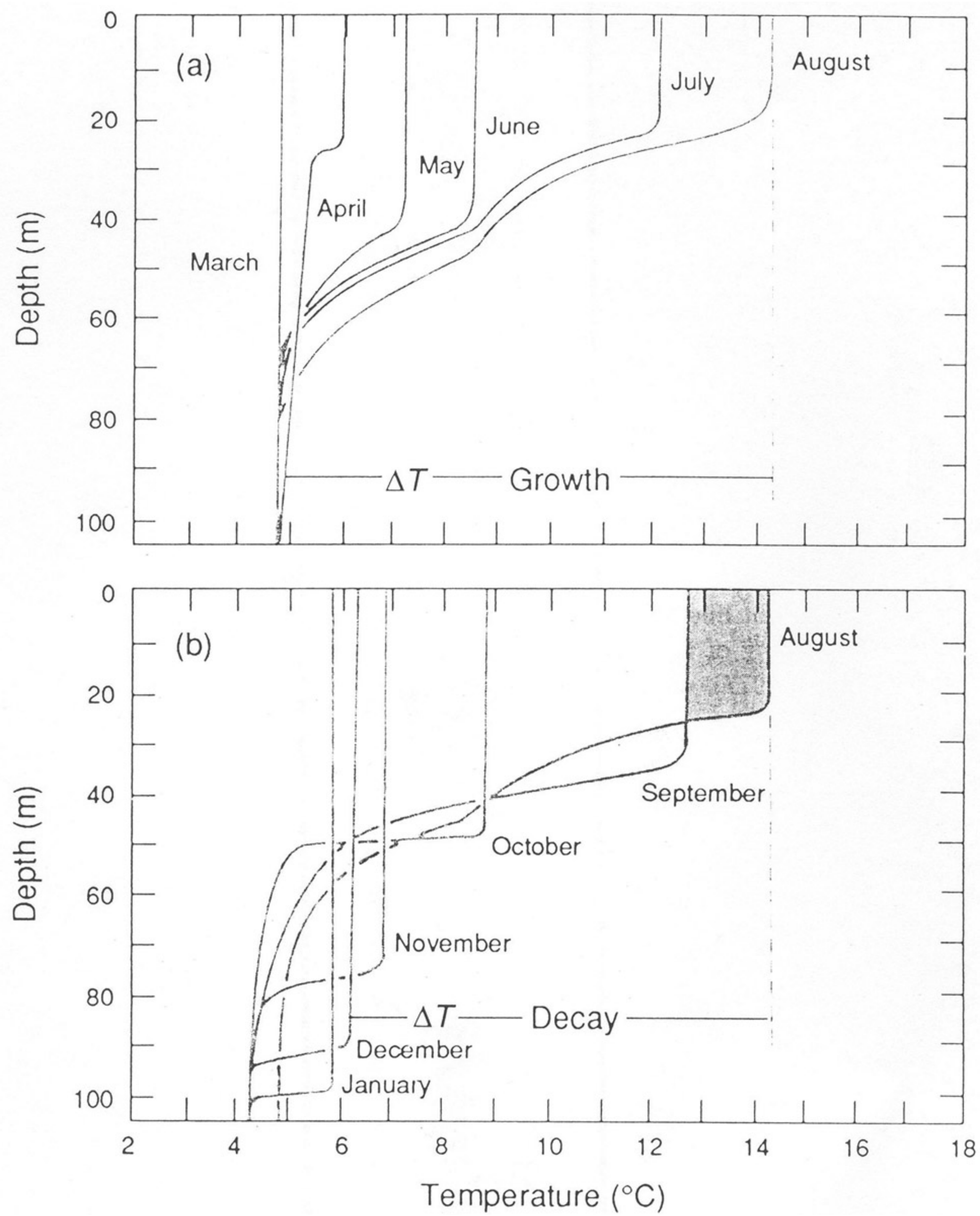
Thermocline: <u>depth variations are day and season dependent</u> (solar heat flux on ocean surface is a big controller of thermocline AND mixed layer depth).

Sub- surface/Abyss: slow drop off of temperature with depth.

- The depth of the mixed layer (and thus thermocline) is set by the extent of vertical mixing. Think of vertical mixing as the turbulent process that “mixes” the water column into an apparently uniform temperature (and salinity). In the above plot the mixed layer is indicated by the vertical line (i.e., $dT/dz = 0$). A “mixing” analogy is cream in coffee: when you place the cream in the coffee you can see the difference between the two (mainly by their color). But if you stir (mix) it with a spoon, the result will be a uniform looking fluid of a single color.

- Wind at the surface, solar heat flux (positive and negative), and vertical shear of surface currents control how much vertical mixing is occurring the surface layer and thus control the depth of the mixed layer and thermocline

-The mixed layer will generally be the deepest around 6AM if solar heat flux is the main control on vertical mixing: the nighttime cooling will result in the deepest mixed layers just before sunlight



-Night/day is generally analogous to winter/summer. Deeper mixed layers (and thermoclines) will occur at night(winter) and vice versa. This is mainly due to less solar heating which will lead to a decrease in stratification. In the winter the deeper mixed layers could be due to more storm activity (winds) and thus more vertical mixing of the water column