SMS 204: Integrated marine sciences II

- Instructors: E. Boss and L. Karp-Boss.

- Units in homework – in upcoming homework AND exam.

Heat and temperature

Temperature- proportional to microscopic kinetic energy of matter.

If two objects (systems) have the same temperature they will stay the same upon contact (1st law of thermodynamics).

If they have different temperatures heat (energy) will be transferred (hot→cold).

(Average) Kinetic Energy of a Molecule

$$\frac{m\,u^2}{2} = \frac{3\,k_B\,T}{2}$$

Molecules move fast, but in liquids they are so densely packed that collisions are very frequent, and it is impractical to measure the molecular velocity. The velocity is the same, however, in air or water if the temperature is the same.

k_B = Boltzmann's constant = $1.3806503 \times 10^{-23}$ m^2 kg s^{-2} K^{-1}

For room temperature, 20 °C, 293.15 K

Mass of a single atom of water = 2.99×10^{-26} kg

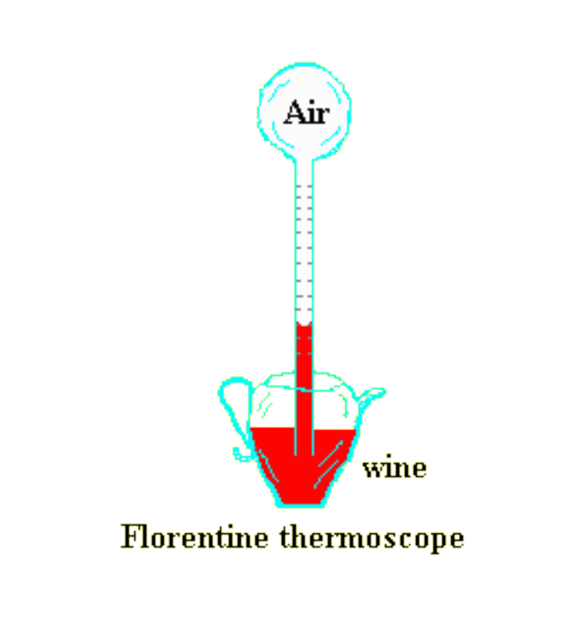
Therefore mean u = 637 m s^{-1}

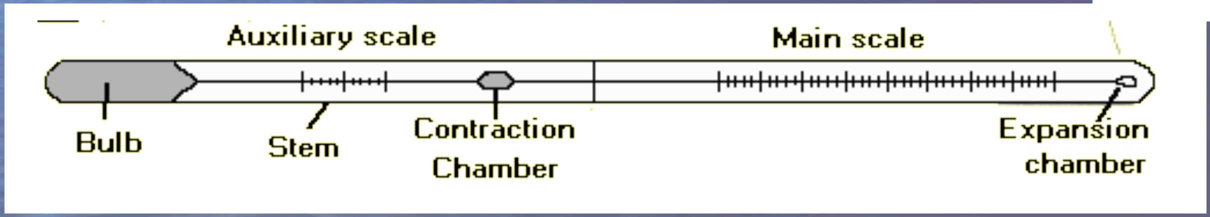
Measuring temperature

Find materials whose physical properties you measure (X, e.g. volume) varies linearly with temperature (T):

$X=aT+b$

Demo: water thermometer

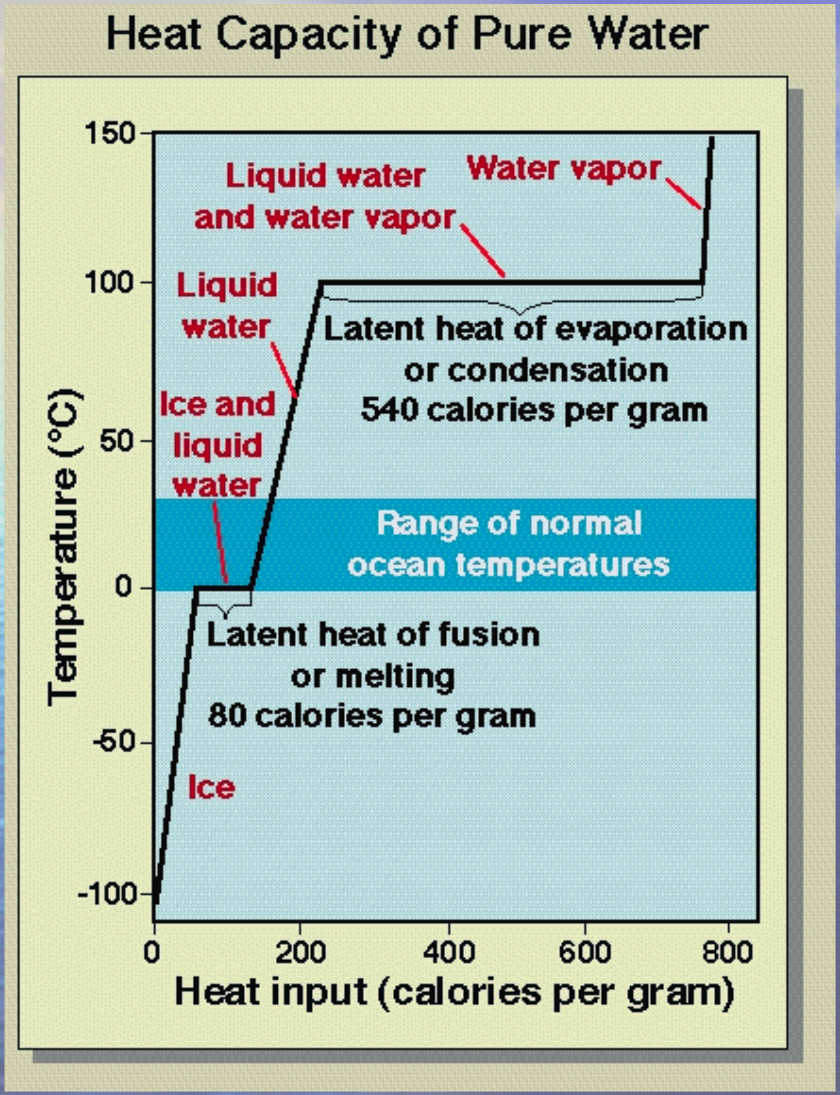




Latent and sensible heat

- Sensible heat: changes temperature but not state.
- Latent heat: chages state but not temperature.

Heat and temperature



Heat- microscopic kinetic + potential energy of matter. When we change the state of a material we need to provide heat.

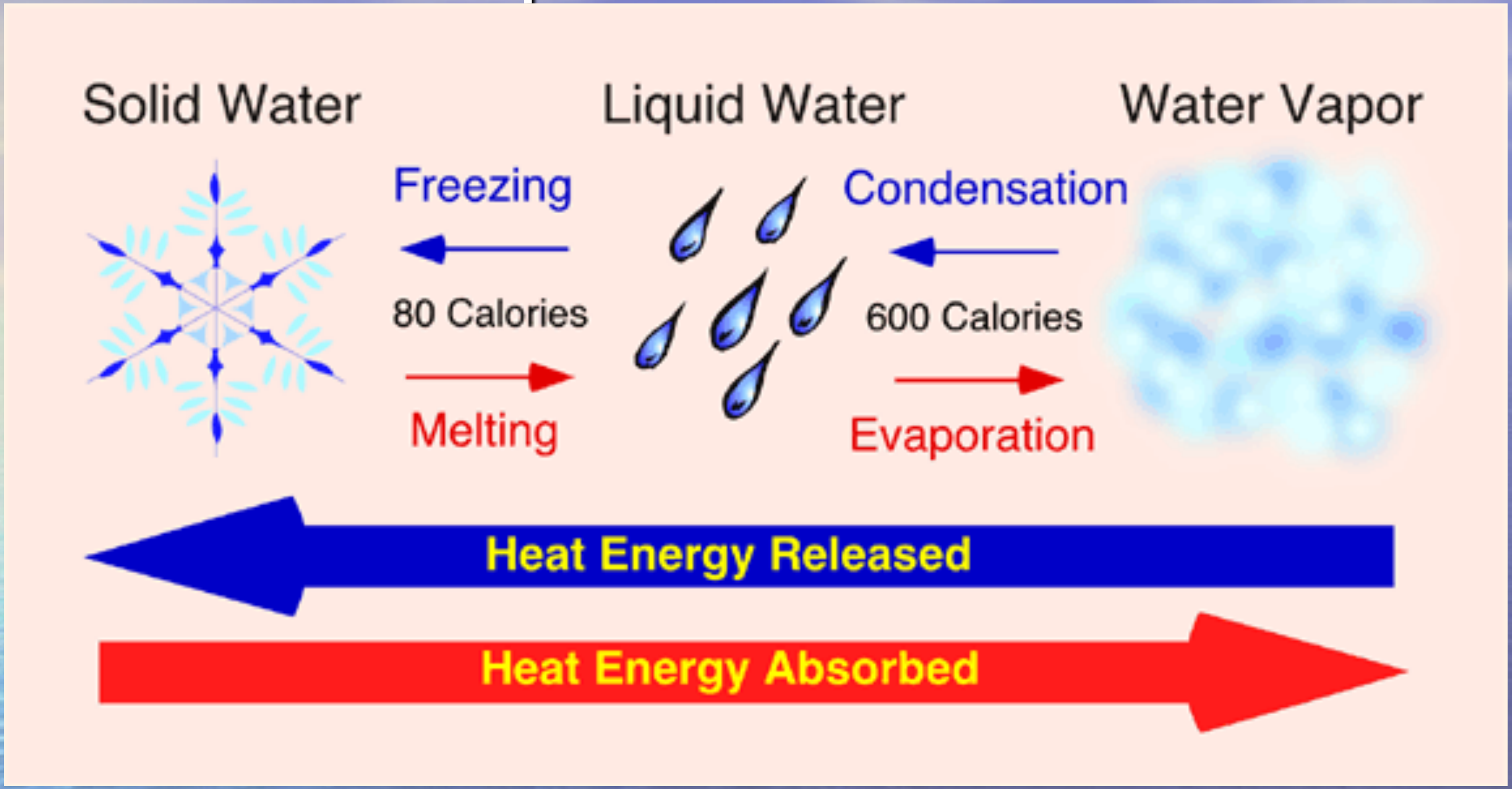
To warm a mass of material by ΔT we need to supply it with heat (energy):

Sensible heat = C_p × Mass × ΔT
$[M\ L^2\ T^{-2}] = [L^2\ T^{-2}\ K^{-1}] \times [M] \times [K]$

C_p-specific heat capacity

For water 1calorie (=4.184 joules) heats 1gr of water one degree at STP. For air ~1 joule.

- Heat and temperature



Why do we sweat? Why do dogs have a wet nose? Do we feel a different temperature on a humid day (Heat index, wind chill)?

Ocean vs. atmosphere, which gets cooled which gets heated in different parts of the hydrologic cycle?

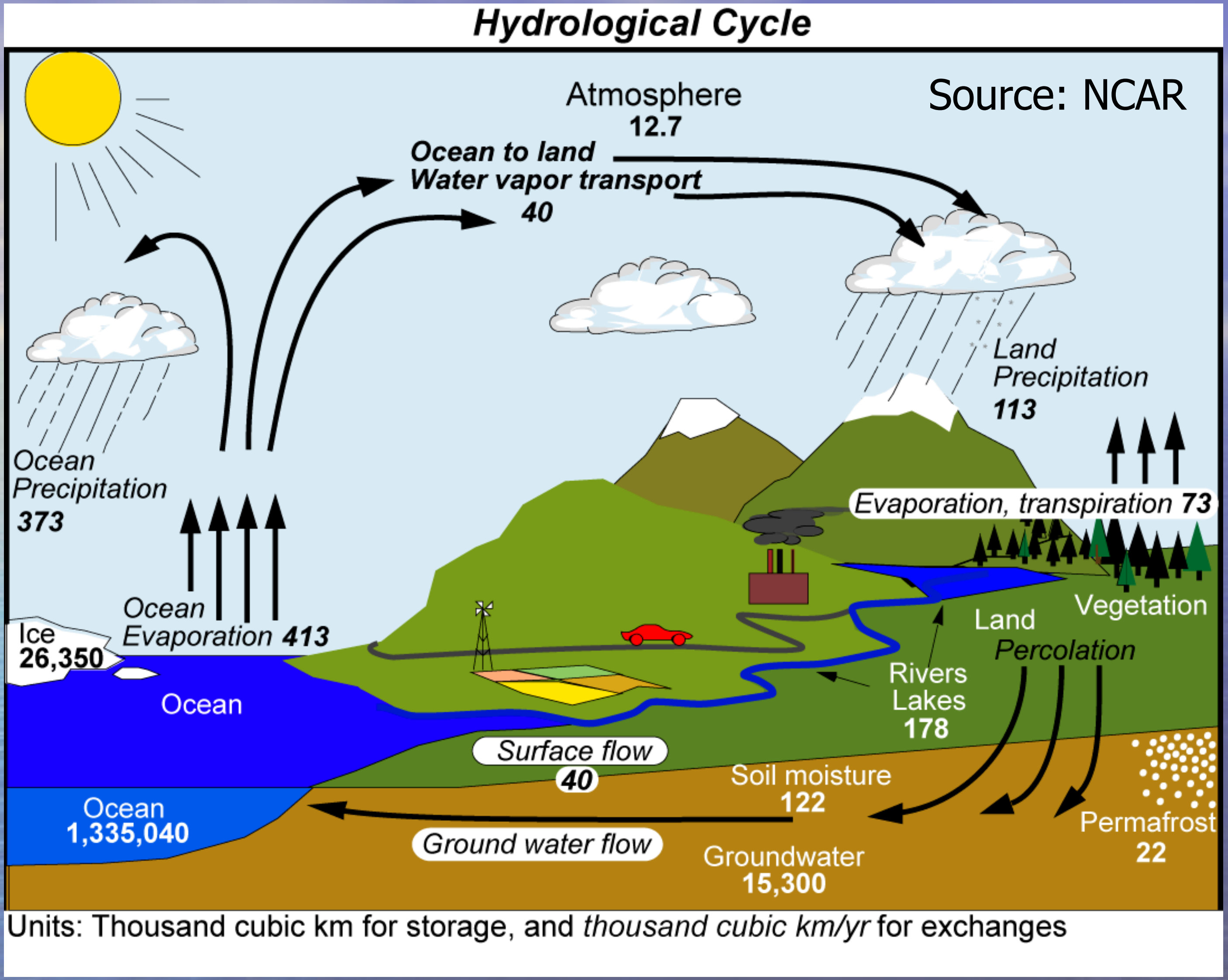
Energy, heat content in food:

1 Calorie = 1000 calories= 4184J, energy to heat ~1 liter by 1°C, evaporate ~2gr of water at 100°C or melt ~50gr of water at 0°C.

Q: does evaporation only occur at 100°C ?

A Hershey kiss (26 Calories) could provide the energy to lift an SUV 2m off the ground. ← extra credit

Food webs are not very efficient. Only a small percentage of the energy available in the food is effectively transferred into biomass.



Ocean vs. atmosphere, which gets cooled which gets heated in different parts of the hydrological cycle?

Principal modes of heat *transfer*:

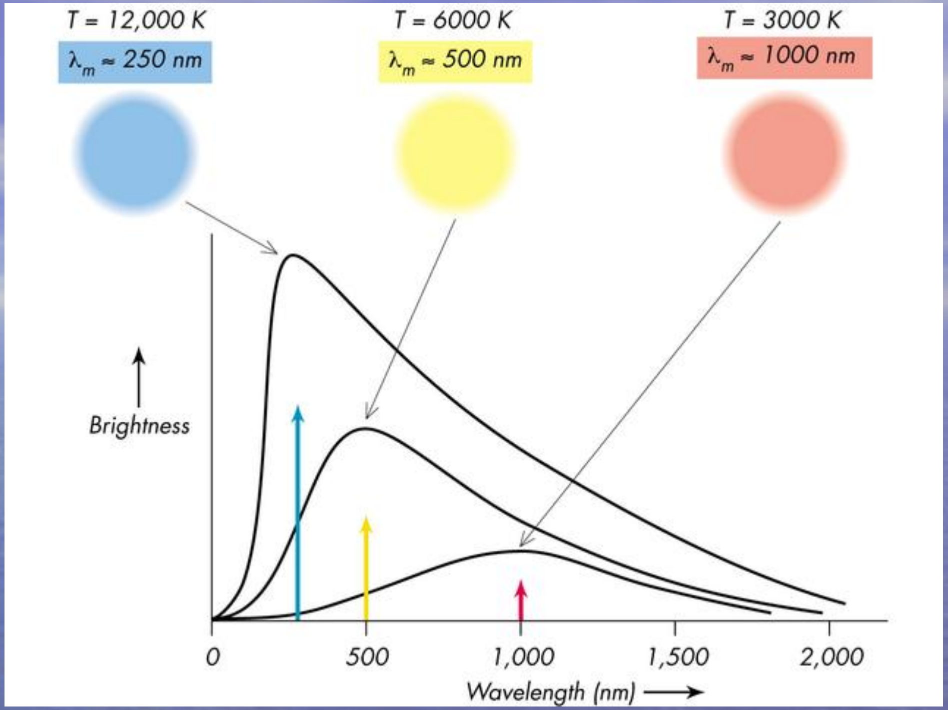
1. Radiation (E/M radiation travel through space absorbed).

2. Conduction (objects touch).

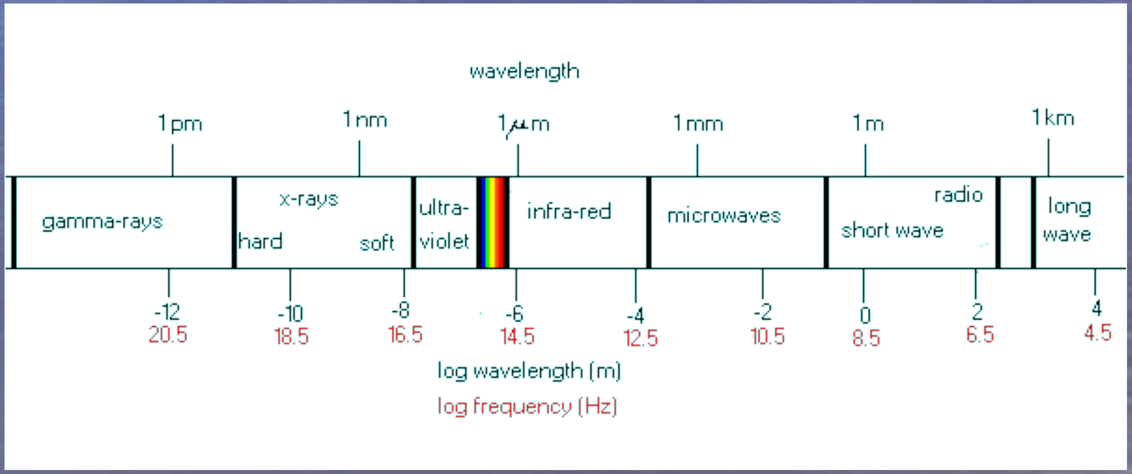
3. Convection/advection (fluid motion transfers heat).

Radiative heat flux:

Bodies radiates energy according to their temperature (humans, 311K, radiation at 10μm, Radiates about 2,000Kcal day^{-1}).



Demo - radiation



Earth/oceans:

Short wave heat flux

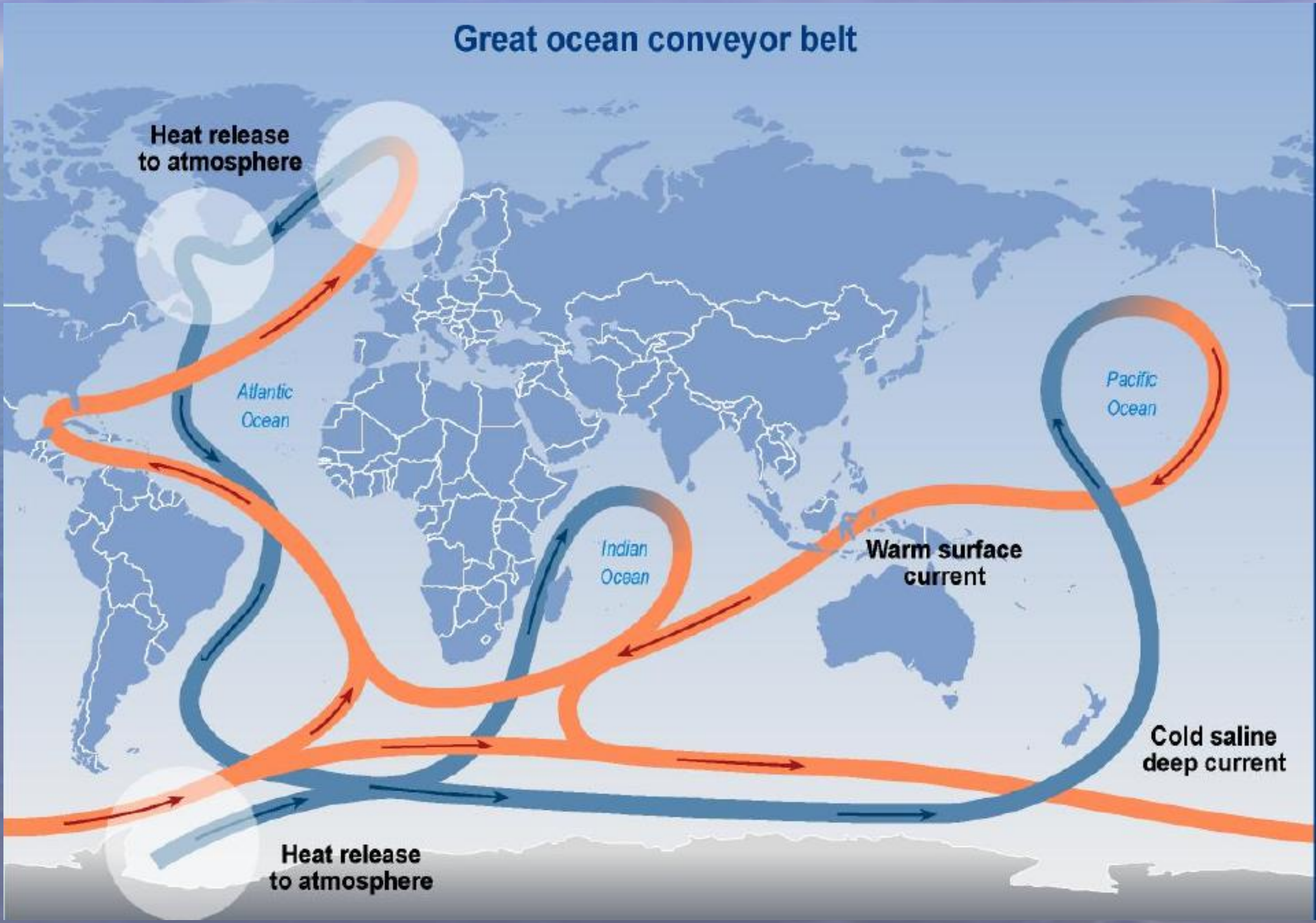
Long wave heat flux

Convective heat flux:

The fluid density is temperature dependent.

Along path, horizontal advective heat flux may be important.

Demo - convection

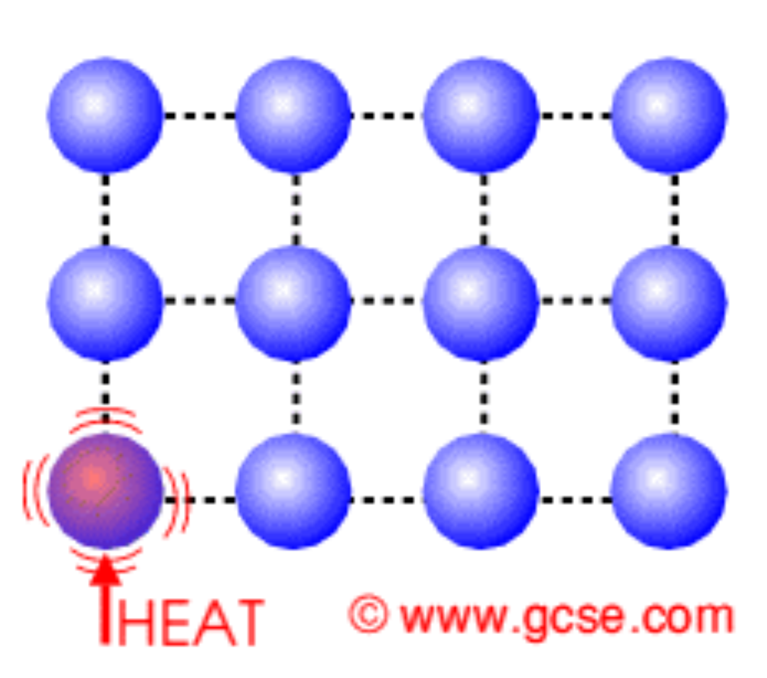


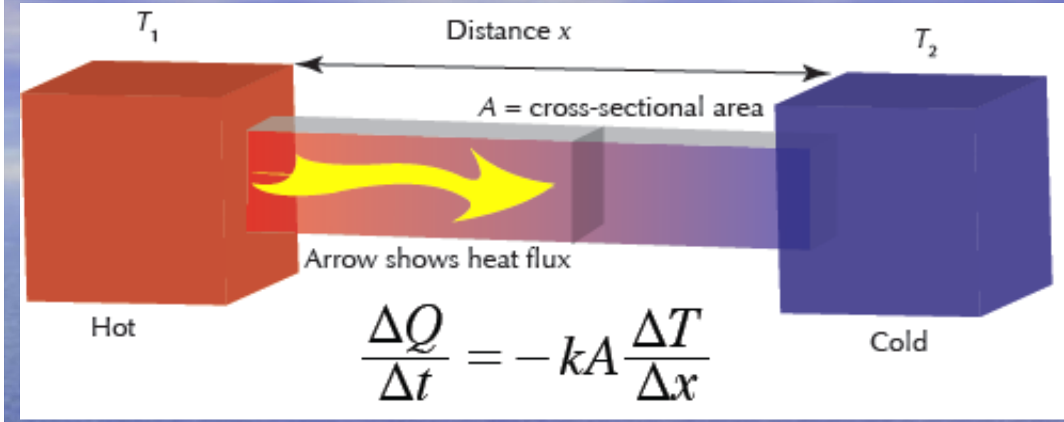
Convection and advection

Confusing terminology

- Thermal convection: fluid density decreases with increasing temperature; unstable stratification produces overturn.
- Engineers sometimes make a distinction between thermal convection and forced convection (e.g., by a fan rather than by density-driven overturn)
- What engineers call convection, oceanographers more generally call advection, except in the case of density-driven overturn, when convection is commonly used by oceanographers as well.
- The point is that lots of heat can be moved by currents, whether it is vertically or horizontally.

Heat conduction:





Examples:
Ice, Fur, Blubber

Heat flux = $-K\Delta T/\Delta x$

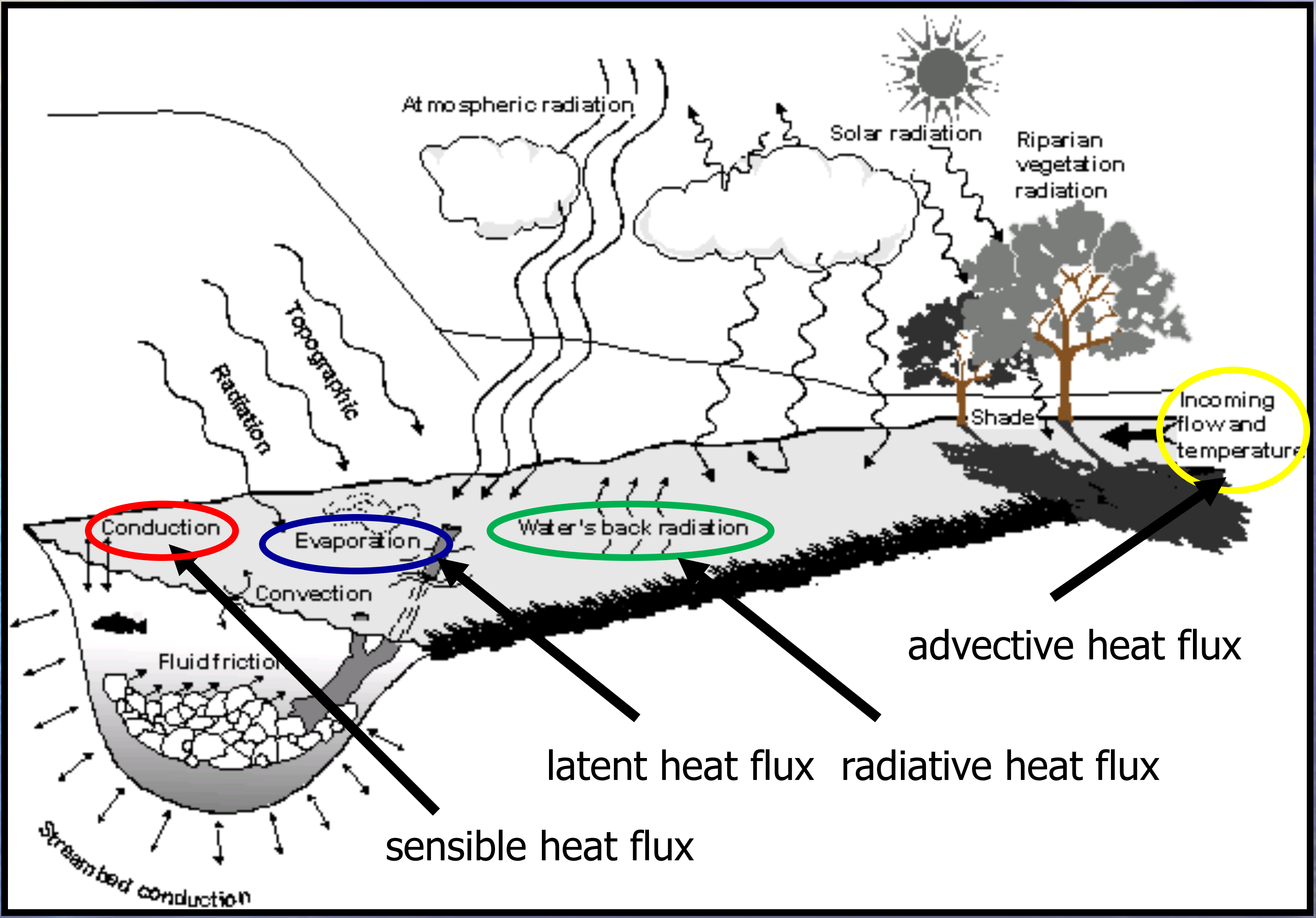
K-heat diffusion coefficient

Material	k (W m^{-1} K^{-1})
Air	0.025
Water	0.6

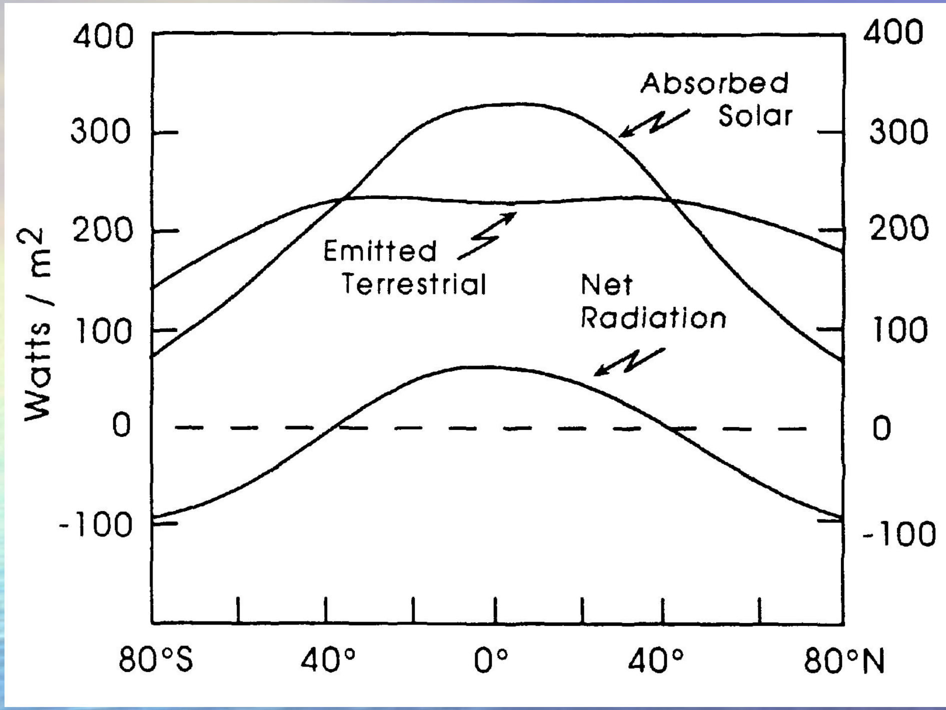
Where is conduction important in fluids?

- Where convection (flow) is weak
- Because of the no-slip condition, conduction dominates over convection in a thin layer of water next to solid boundaries (*e.g.*, a whale or the seabed over which water is flowing).
- This layer where conduction dominates over convection is typically < 1 cm thick.
- Conduction is also important where friction restricts fluid motion, *e.g.*, in pore fluids of marine sediments.

Heat flux, recap:



- The heat balance of the Earth:



Water vs. air

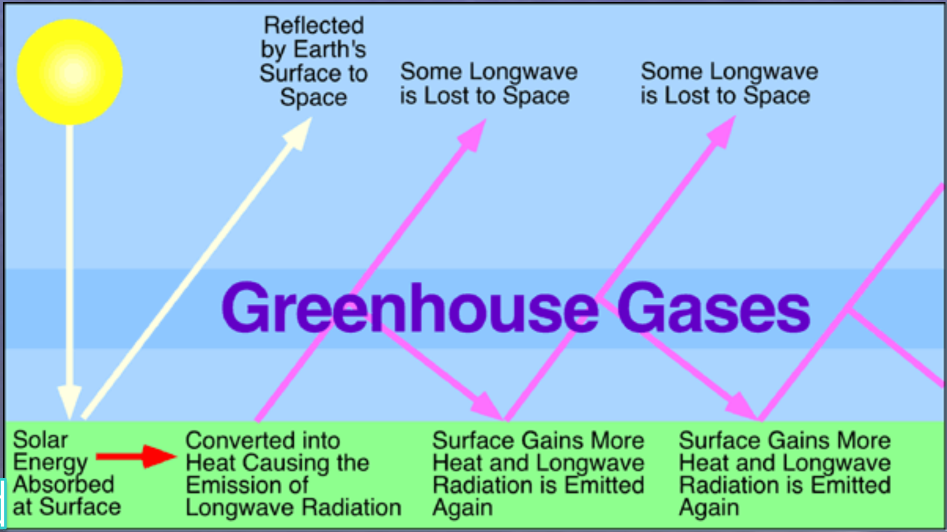
Density: 1.2 vs. 1000 kg m^{-3}

C_p: 1 $Jg^{-1}K^{-1}$ vs. 4.2 $Jg^{-1}K^{-1}$

Heat content:

Atmosphere ~ 2.5m of ocean

The 'greenhouse' effect:



Water vs. land

Density: 2500 vs. 1000 kg m^{-3}

C_p: 1 $Jg^{-1}K^{-1}$ vs. 4.2 $Jg^{-1}K^{-1}$

Difference in how heat is acquired

1. When are the longest/shortest day of the year?

2. When are the hottest/coldest days of the year?

3. How is ocean heating/cooling different from land?

Temperature profiles in lakes and the ocean.

1. What should we expect?
2. Where is warming occurring? Cooling?
3. How is heat transferred in the interior?

How does T affect biology?

- How do organisms lose/gain heat?
- Cold/warm blooded organisms
- Enzymatic reactions as f(T)
- Swimming & brain performance
- Heat and size (area/volume ratio)
- Wind chill?
- Hypothermia
- Viscosity as f(T)