

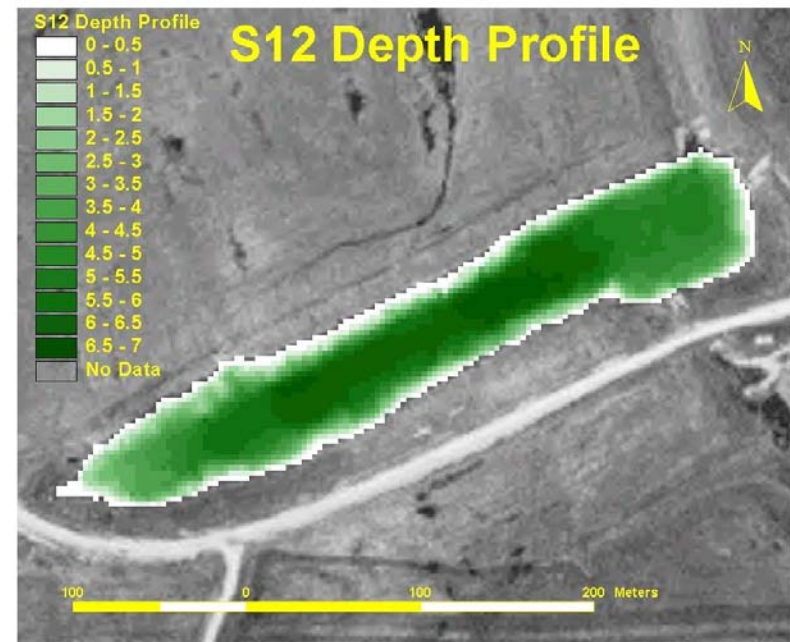
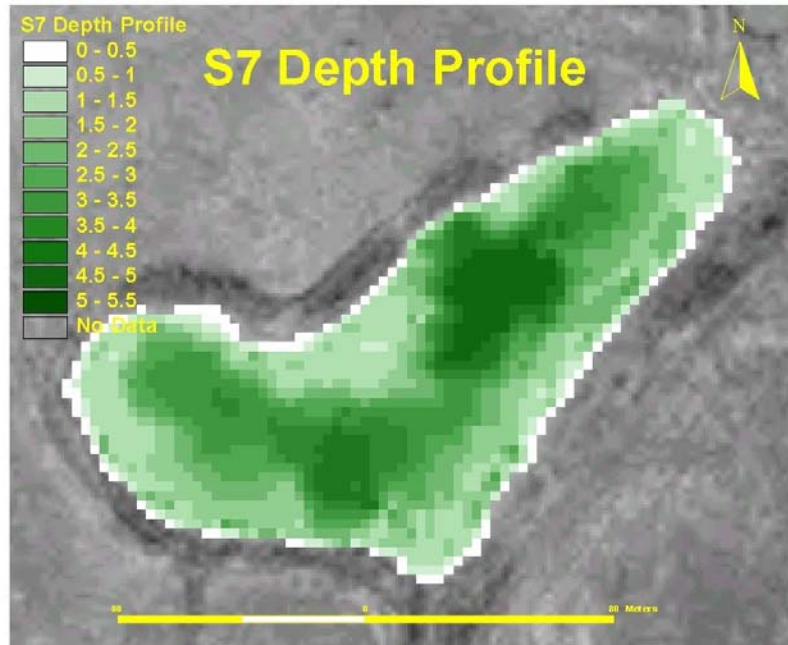
Lake Morphometry

- Shape and size of lake influences
 - Heat (important, given uniqueness of water)
 - Thermal stability
 - Light transmission
 - Plants, fish, insects, plankton
 - Chemical masses (movement of salts, nutrients, etc.)

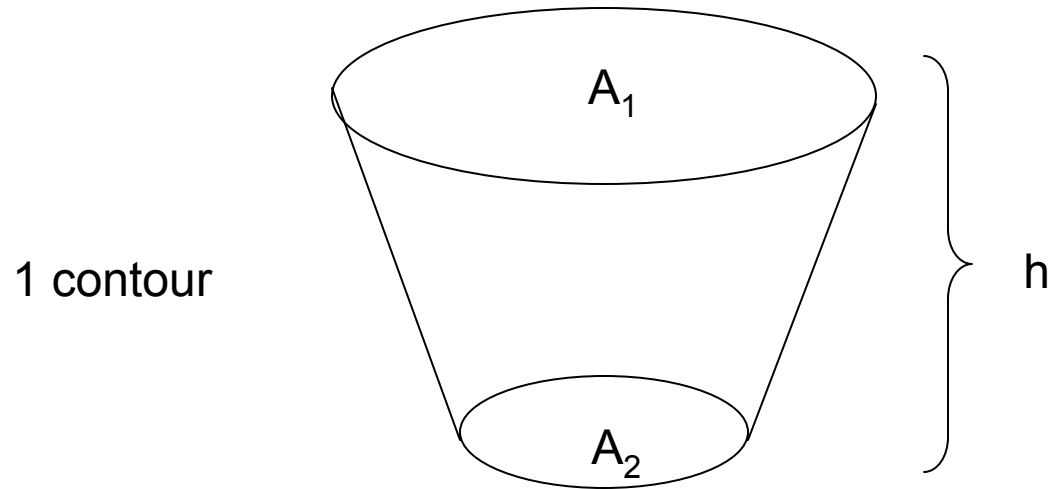
Lake Morphometry

- Lots of different characteristics
- Maximum length (l ; m)
 - Also called the fetch (wind interacts with this)
 - Greatest distance between shoreline points
- Area (A_o ; m^2)
 - Lake surface area
- Volume (V ; m^3)
 - Bathymetric map provides insight (depends on resolution)

Lake Morphometry

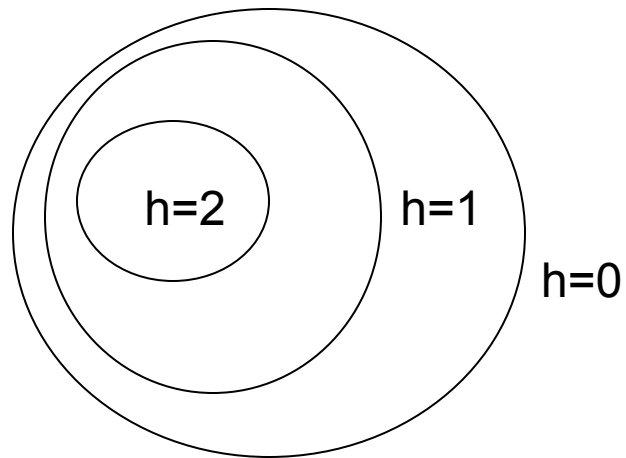


Volume



$$V = (h/3) * (A_1 + A_2 + \text{square root } (A_1 * A_2))$$

Sum volumes across all contours.



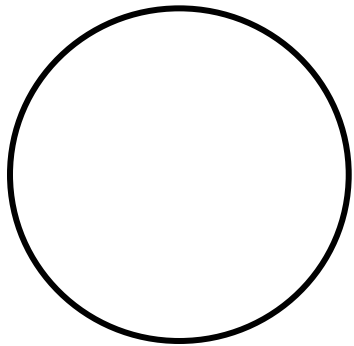
Lake Morphometry

- Maximum depth (Z_{\max}) – deepest point
- Mean depth (\bar{Z}) = $V/A_o = \text{m}^3/\text{m}^2 = \text{m}$
- $\bar{Z}:Z_{\max}$ = measure of shape of the lake
 - Cylinder Ratio = 1
 - Cone Ratio = 0.33
- Shoreline length (L) = total linear distance shoreline

Lake Morphometry

- Shoreline development

$$D_L = \frac{L}{2\sqrt{\pi A}}$$



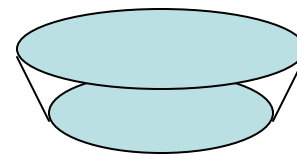
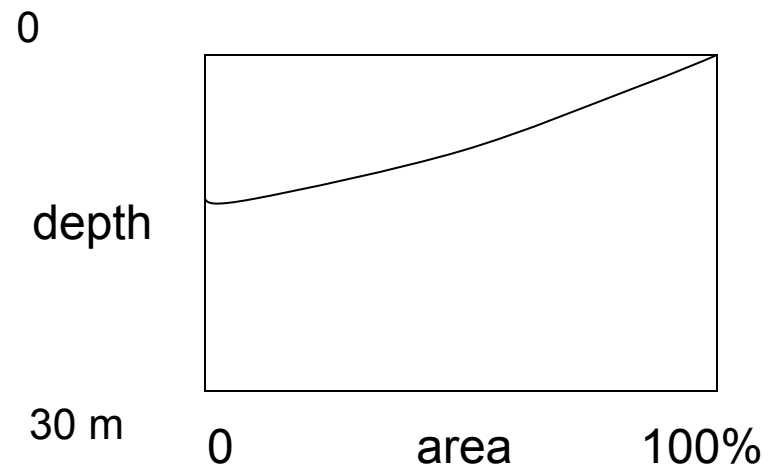
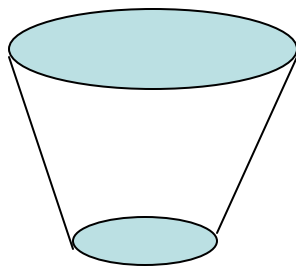
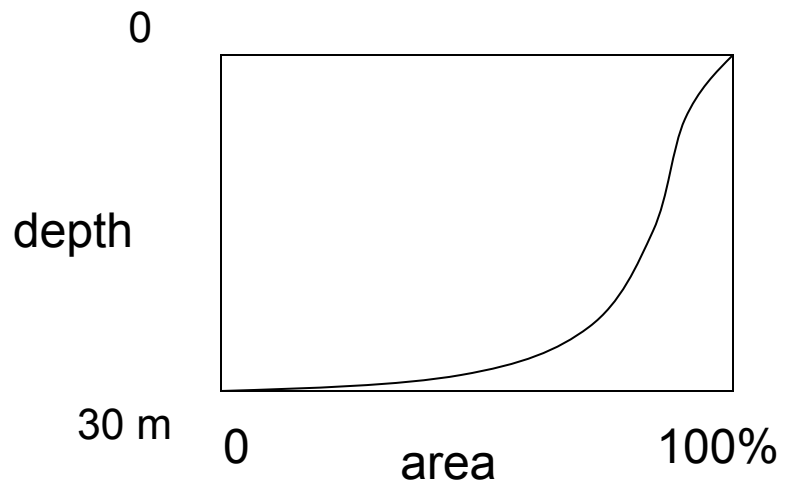
$$D_L = 1$$



$$D_L \gg \gg \gg 1$$

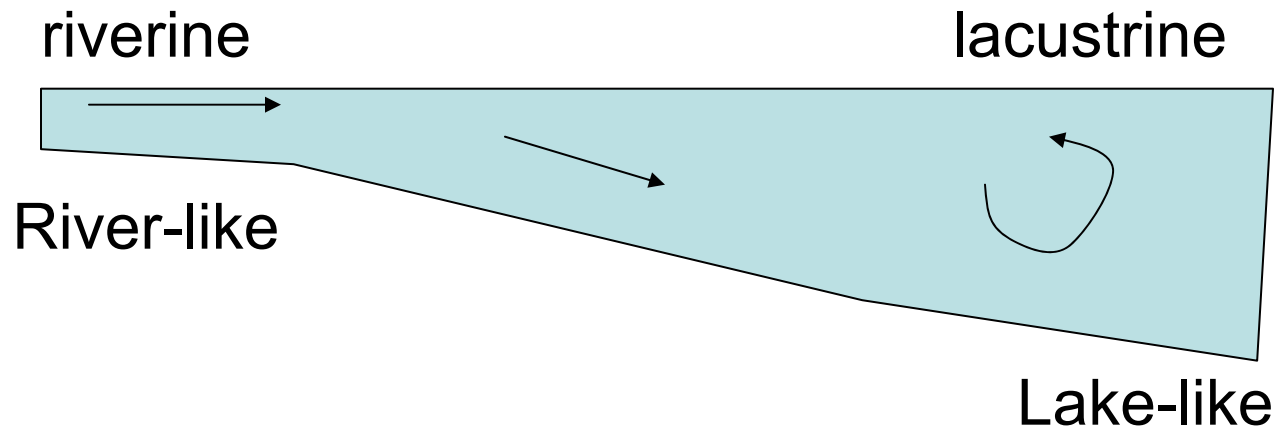
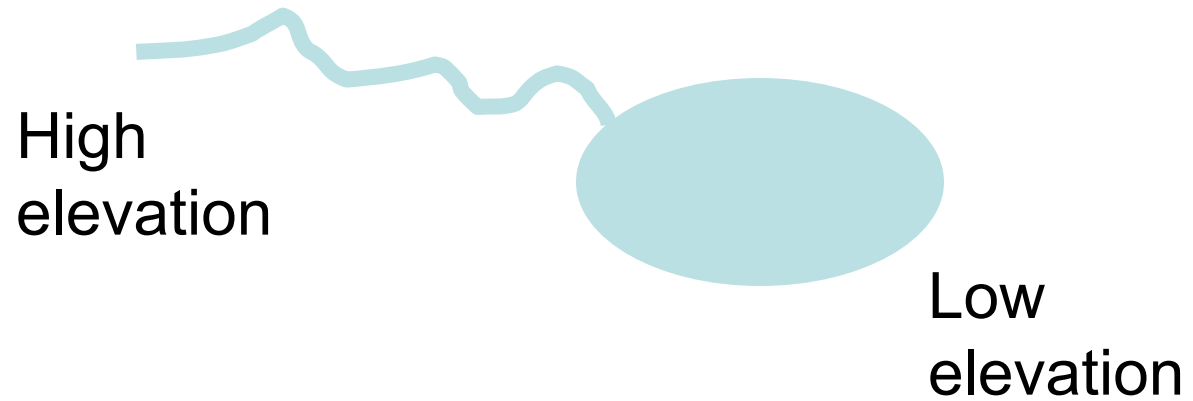
Lake Morphometry

- Hypsographic Curve

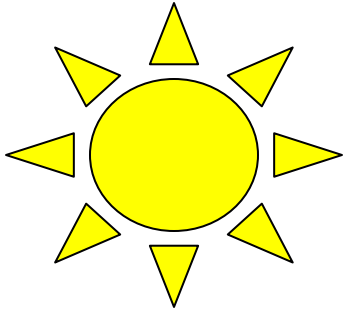


Lake Morphometry

Catchment



Light

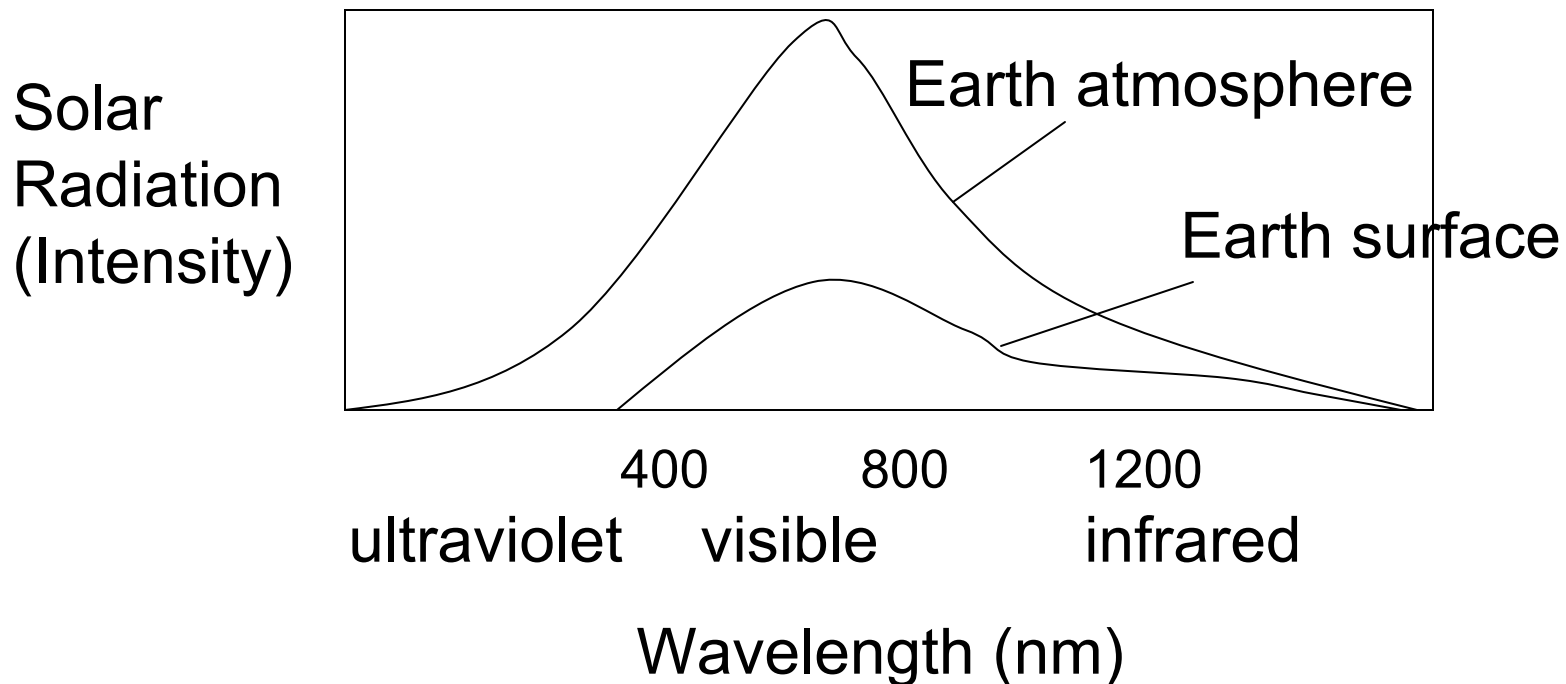


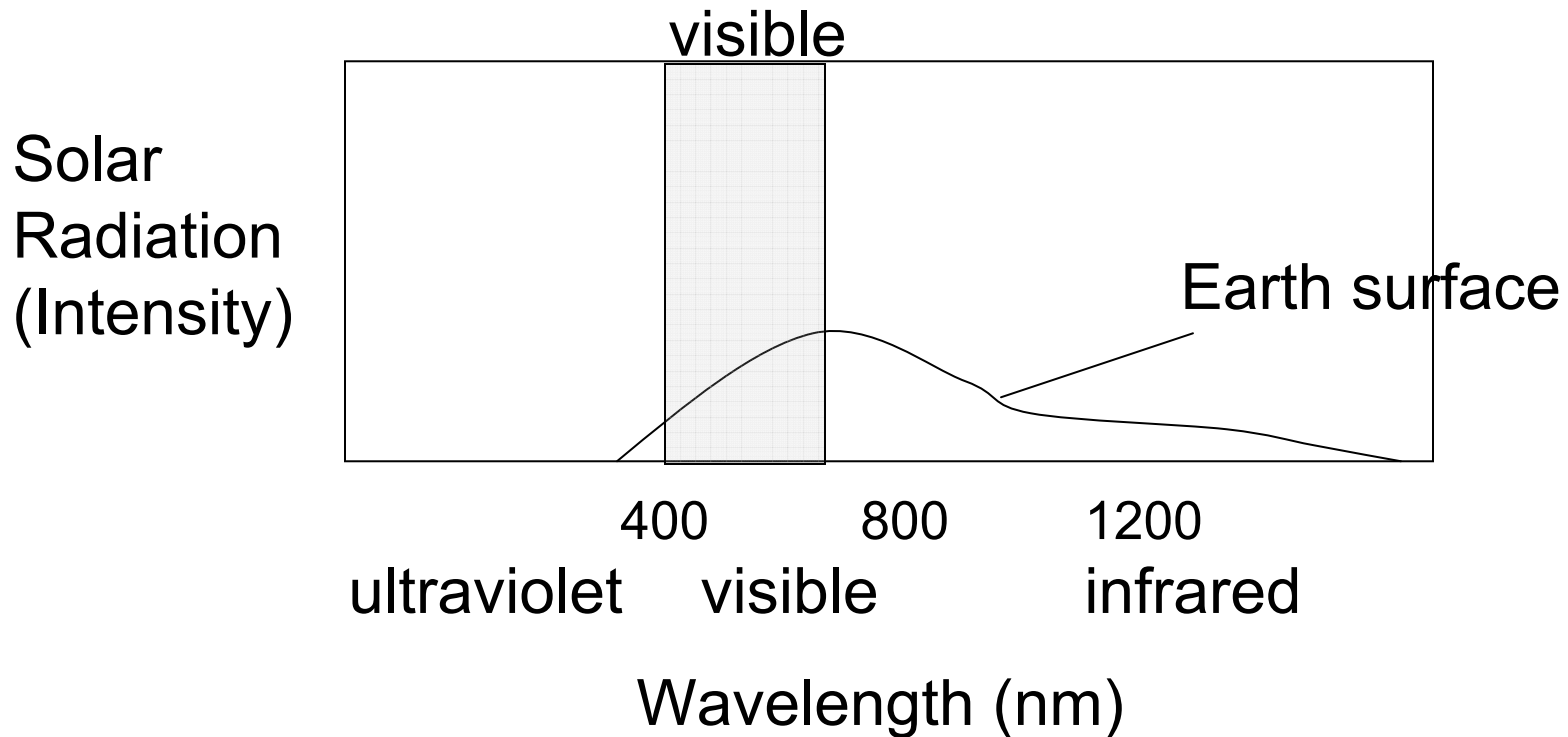
1. Light is source of heat energy
2. Drives most thermal dynamics
3. Stratifies water masses
4. Circulates water masses
5. Drives photosynthesis
6. Affects biological behavior

Typically the sun, although radiation from moon and thermal vents important occasionally

Light

- Important characteristics
 - Intensity (how bright, quantity)
 - Wavelength (energy, color)





Of visible light, only 400-700 nm is PAR
(photosynthetically active radiation)

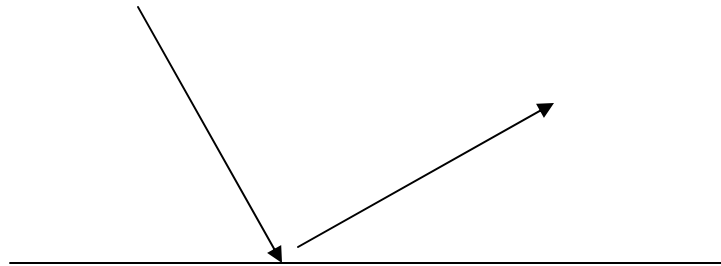
Chlorophyll a (major photosynthetic pigment) 445-660 nm

absorbance peaks at about 650 nm (red)

Light

How does light interact with water?

1. Reflected



- angle of incidence (morning, shallow angle, high reflectance)
- smooth versus turbulent surface

Light

(light penetrating the water is incident light or I_0)

2. Scattering

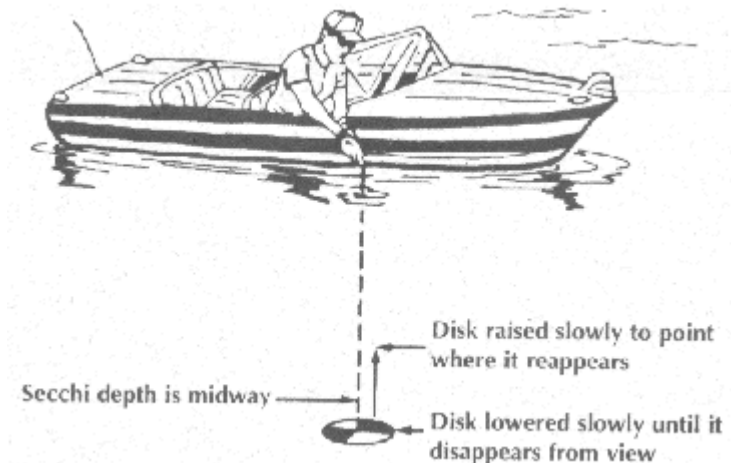
- particles (biological and abiotic)
- dissolved substances (tannins)

3. Absorption

- Light is weird stuff – wave-like behavior but also particulate called photons
- Absorbed photon releases energy as heat
- Most heat generated in upper 1 meter

Ways to measure light in water

- Spectroradiometer-
has slit; measures
light wavelengths
separately
- Photometer
(measures a range of
wavelengths) ours
PAR
- Secchi disk



Light

- Measuring

Photometer measures quantity of photons hitting the sensor

Recall, mol is a unit of molecular mass

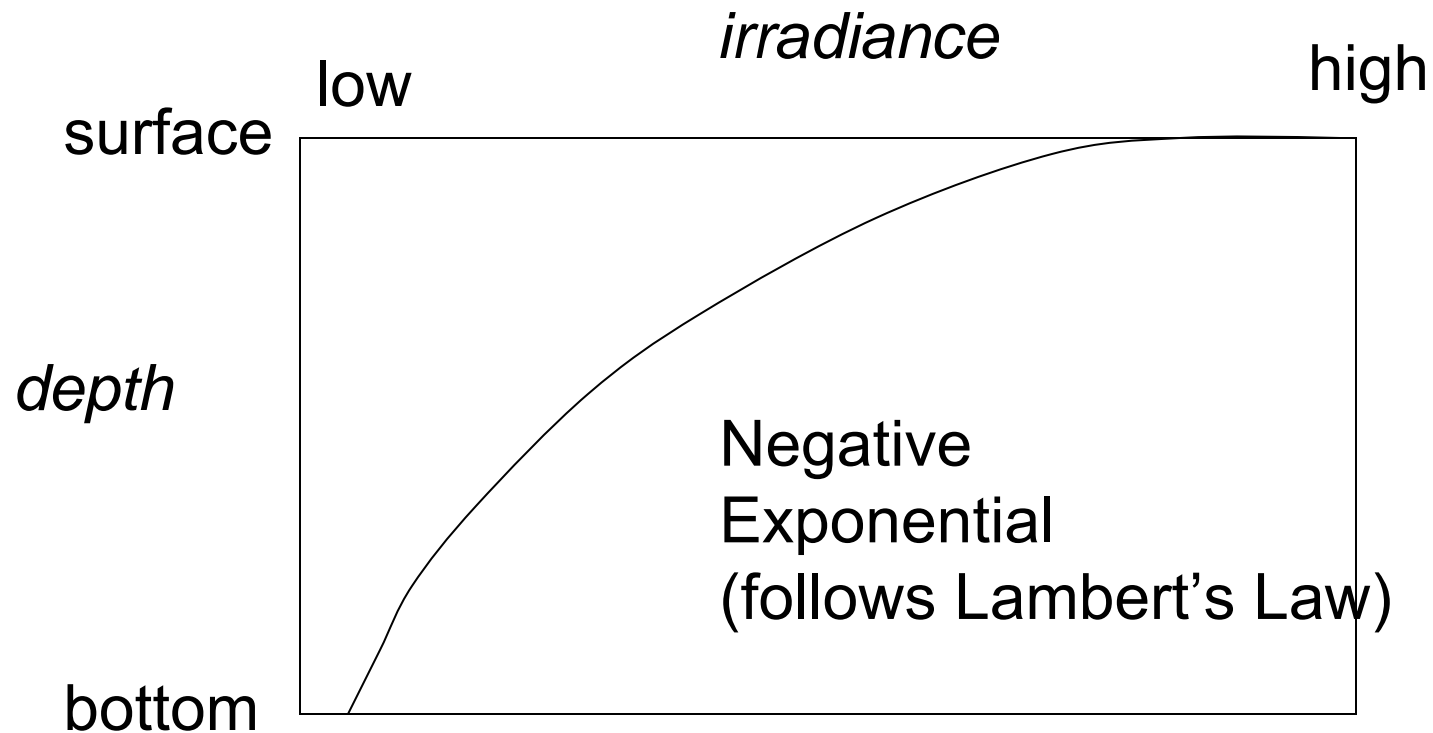
$$\mu\text{mol}/\text{sec}/\text{m}^2 = \mu\text{Einstein} = \mu\text{E}$$

or...the photons of light exerted per second per unit area

Called **IRRADIANCE**

Incident Light Entering Water

- Begins to attenuate as it is scattered and absorbed



Lambert's Law

Use photometer & quantify light at intervals from surface to bottom

$$I_Z = I_0 e^{-\eta Z}$$

I_Z = Irradiance at depth Z (m)

I_0 = Irradiance at surface

η = extinction coefficient (0.2 clear versus 4-10 stained)

Lambert's Law

$$I_Z = I_0 e^{-\eta Z} \quad \text{Can be shown as}$$

$$\ln I_Z = -\eta Z + \ln I_0$$

So,

$$\eta = (\ln I_0 - \ln I_Z) / Z$$

At surface, $I_0 = 1000 \mu\text{mol/s/m}^2$ & at bottom, $I_7 = 9 \mu\text{mol/s/m}^2$

Extinction coefficient = $\eta = (\ln(1000) - \ln(9))/7 = (6.91 - 2.2)/7 = 0.681$

Predicted light at 4 m:

$$\ln I_z = -\eta Z + \ln I_0$$

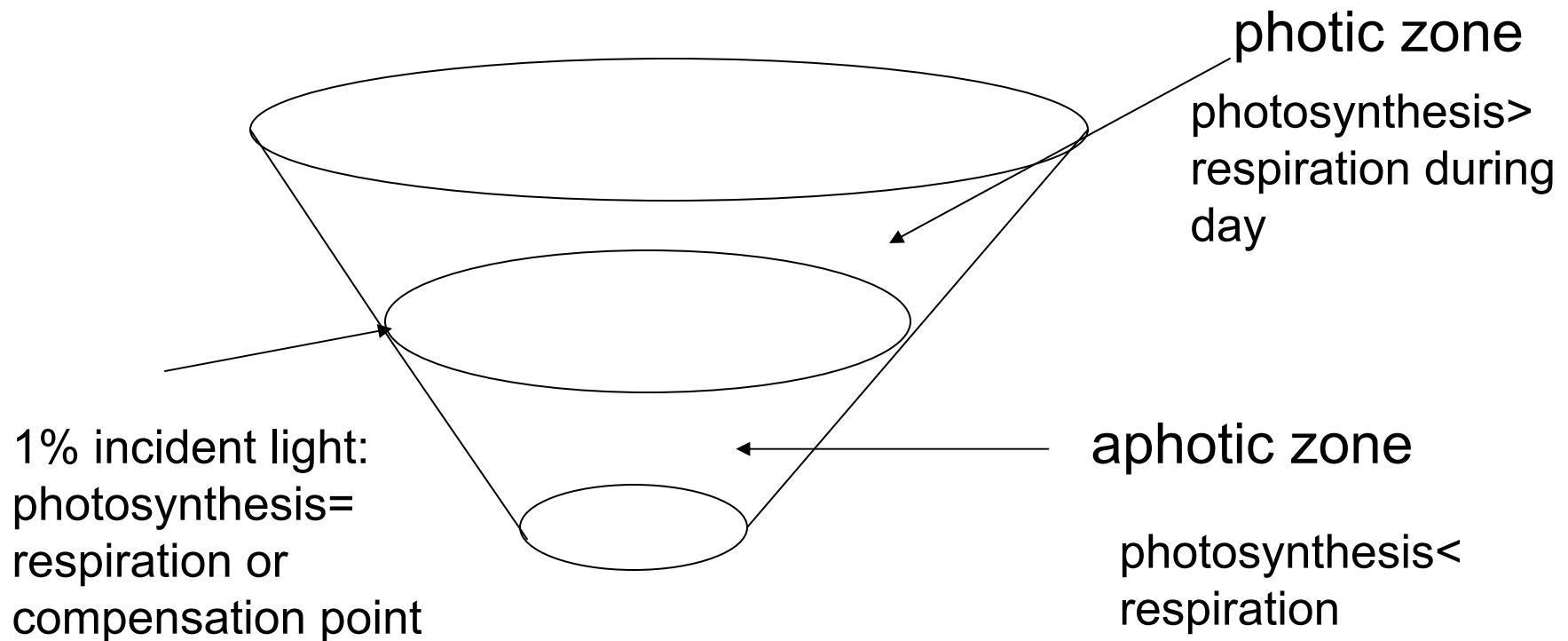
$$\ln I_4 = - (0.681)4 + \ln (1000)$$

$$\ln I_4 = - 2.72 + 6.91 = 4.186 \quad e^x \text{ both sides}$$

$$I_4 = 65.8 \mu\text{mol/s/m}^2$$

Why this math?

- Where does light become extinct?



Wavelengths of light with depth

- red (long wavelengths) are absorbed first (chlorophyll *a* “eats” this)
- blue (short wavelengths) light backscatters and reflects as blue
- as descend, lose most color except blue wavelengths (penetrates deep water)

Light heats water

Specific heat capacity of water = 4.2 joules per gram

Amount of energy necessary to raise 1 g water
by 1 degree Celsius

Compare to other substances:

Mercury = 0.14 j/g

Grain alcohol = 2.3 j/g

Water is very high compared to most

Light varies seasonally

- Density of water changes with temperature
 - density is mass per volume
 - most dense at 4°C; density declines as temperature increases
- Water masses can stratify (warm floats on top of cold)
- Related to photic zone (warms faster than aphotic and causes temperature stratification)

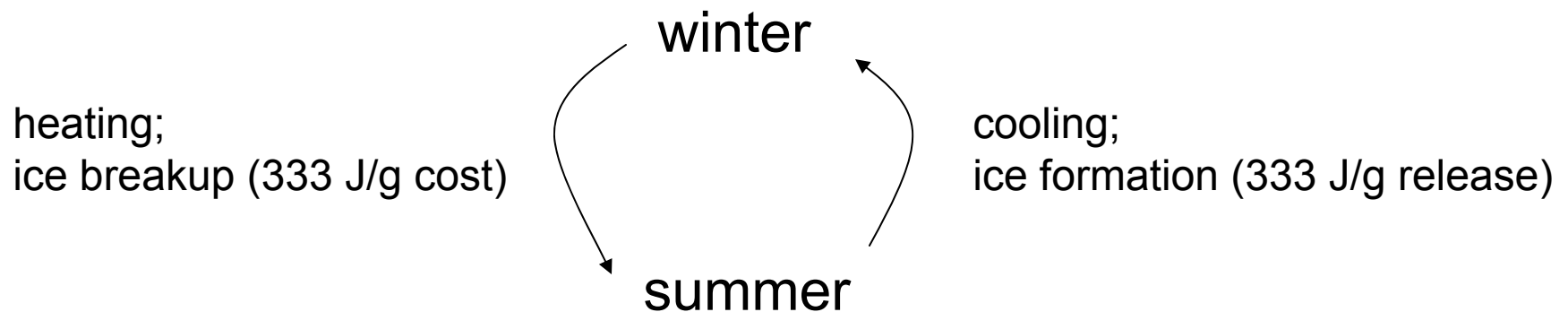
Light attenuation

- Varies with trophic status
 - Oligotrophic – photic zone 20-25 m (or deeper)
 - Mesotrophic – photic zone 5-15 m
 - Eutrophic – photic zone 0-5 m (algal blooms block light) ... strong stratification possible

Heat budgets

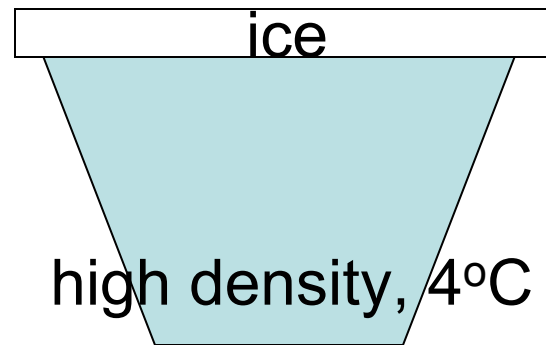
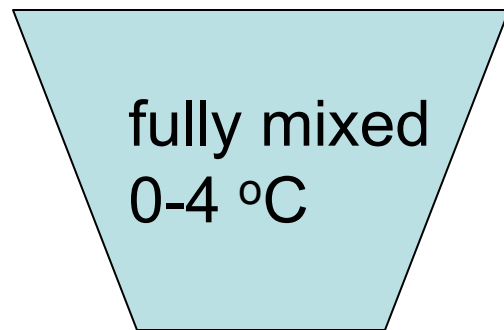
- Heat Input = Heat output
- Temperature is easy to measure

heat budget increases with lake volume (hold more heat)



Thermal Regimes

1. Amictic - permanently sealed by ice
2. Cold monomictic lake (maximum air temperature $\leq 4^{\circ}\text{C}$)...winter stratified
 - vertically circulate once per year
 - 4°C sinks to bottom when ice cover



low density, $\leq 0^{\circ}\text{C}$

Thermal Regimes

3. Dimictic Lake

- circulates twice a year (need ice cover)

4. Warm monomictic lake

- circulates once a year (no ice cover)
- summer stratified

5. Oligomictic – stay stratified for long times (occasionally circulates)

6. Polymictic – shallow, mixes often