PHYSICAL LIMNOLOGY OF LAKES

(Disclaimer: these are lecture outlines with some figures; these are not lecture notes)

MORPHOMETRY OF LAKES

What is required for a lake to form on a landscape?

Some lake types:

GLACIAL

-moraine dams - e.g. Finger lakes

-kettle lakes

TECTONIC

-rift - e.g. Lake Baikal , Lake Tanganyika (part of the Dead Sea Rift Valley)

-volcanism - collapsed craters, filled blowholes, lava dams

-earthquakes and landslide - Lake Reelfoot, TN

SOLUTION - sinkhole (solution) lakes, collaspsed saltdomes

WIND - playas, carolina bays?

RIVER - oxbows

ANIMAL - beaver, humans ...

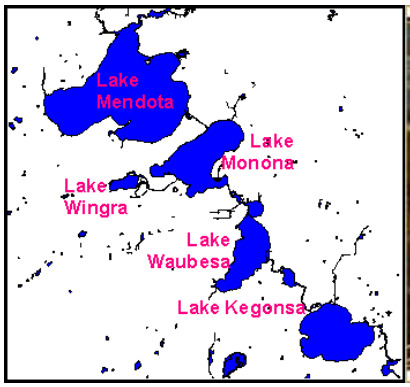
Are lakes permanent features of the landscape?

Natural Lakes versus Artificial Reservoirs

How might RESERVOIRS (impoundments) and LAKES *differ based on:*

- *Drainage basin area to lake surface area*
- *Flushing rate*

- *Sedimentation, turbidity*
- *Water level*



What are some uses of lakes, what are the impacts of those uses, and what should one measure to assess these impacts?

MATTER IN WATER

Includes:

* dissolved gases (*such as ….?*)

* inorganic ions (*such as ….?*)

* free organic molecules (*such as ….?*)

* inorganic particles (*such as ….?*)

* detritus

* living cells and multicellular organisms

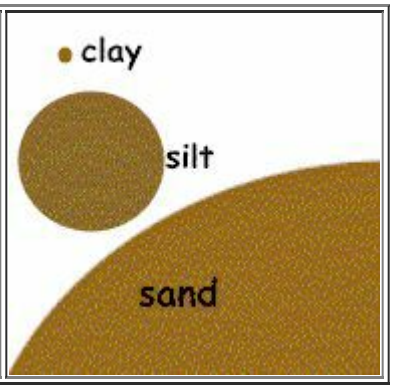
Can everything in water be measured easily as separate entities? Do substances tend to have single source and single impacts?
What can be estimated more easily?

Measurements used to characterize matter in water:

Total solids

- **Total dissovled** (filtrable) **solids** - solids that pass through a GFC filter (pore size 0.8 µm)
- **Total suspended** (nonfiltrable) **solids** - solids that are retained on a GFC filter

In still water:

Clay <2 µm 14 days to sink 5 cm water Silt 2-20 µm 3.5 days Sand 20-2000 µm 1.5 second	

In aquatic systems, how does the rate of settling depend on the mechanical energy of the water (water movement)?
In a reservoir like Lake Allatoona, would you expect a gradient in suspended solids from the incoming streams to the dam?

Both dissolved and suspended solids can be measured **gravimetrically**
Which is likely to weigh more in an typical surface freshwater sample?
Which is more likely to interfere with light transmission through water?

Estimating dissolved solids:

Much of the fraction that is dissolved, can be estimated by **conductivity (specific conductance)** - the capacity of a solution to conduct electrical current. Estimates total dissolved ions. *Why?*

Estimating suspended solids:

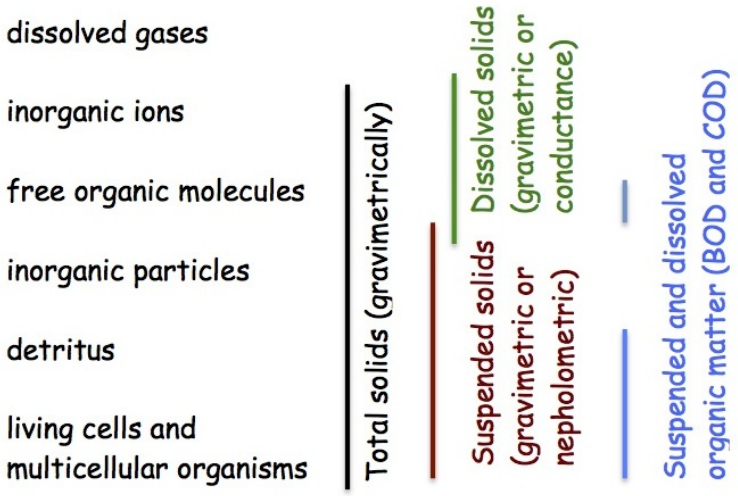
What will happen to the transmission of light as more solids are suspended in water?
How then could to amount of suspended substances be estimated indirectly?
Given this, will suspended solids affect temperature in natural waters? How?

How can either of the two parameters above be estimated more directly?

Estimating organic matter:

The **amount of organic matter in water** can be estimated as biochemical oxygen demand (BOD) or chemical oxygen demand (COD). *What will happen to the level of oxygen in water as more organic carbon is added?*

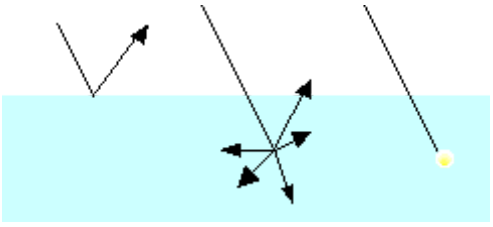
Summary of matter in water:



LIGHT

Why might light be important to measures in aquatic systems?

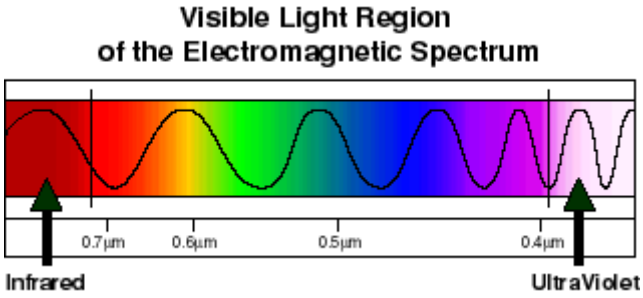
<u>Fate of light in aquatic systems:</u>

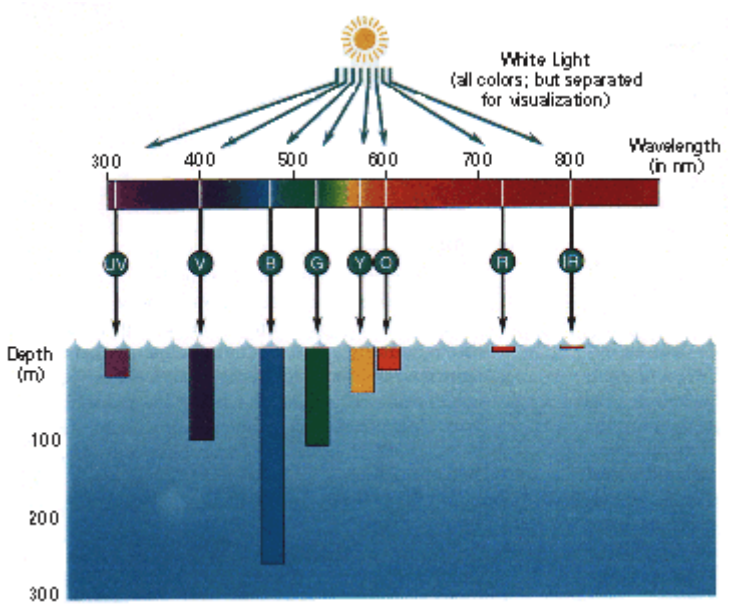


* **Reflection** - prevented from entering water by air-water surface interface
    - Angle of incidence
    - Cloud conditions
    - Surface waves
    - Ice

* **Scattering** - suspended particles reflect light at a massive array of angles

* **Absorption** - diminution of light by transformation. What is light energy typically transformed into upon being absorbed (or is the energy simply destroyed)?





Light entering pure water:

* longer visable light (reds) absorbed shallower

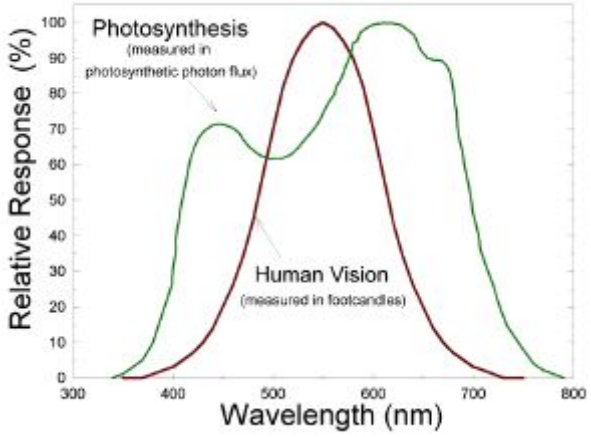
* shorter wavelengths (blues) tend to scatter

Light entering lake water with other matter:

* organic compounds - often absorb blues and greens

* silts and clays - reds and oranges more likely to be scattered - *How do color and clarity differ from water with high concentrations of organic compounds?*

* phytoplankton chlorophyll - *What color is not absorbed by chlorophyll a?*



Measuring light properties in water (usefulness depends on question asked):

Turbidity (nephlometric) - an expression of the optical properties that cause light to be scattered and absorbed rather than transmitted in a straight line.

Turbidity is primarily caused by total suspended solids but a direct relationship varies from system to system. *Why?*

Turbidometers (nephlometer) measures intensity of light scattered at 90°. Units are Nepholometic Turbidity Units (NTU's).

Vertical illumination (light penetration) - illumination at some depth as measured by underwater photometer.

Light is absorbed exponentially with depth (a constant percentage of light available is extinguished at each meter)

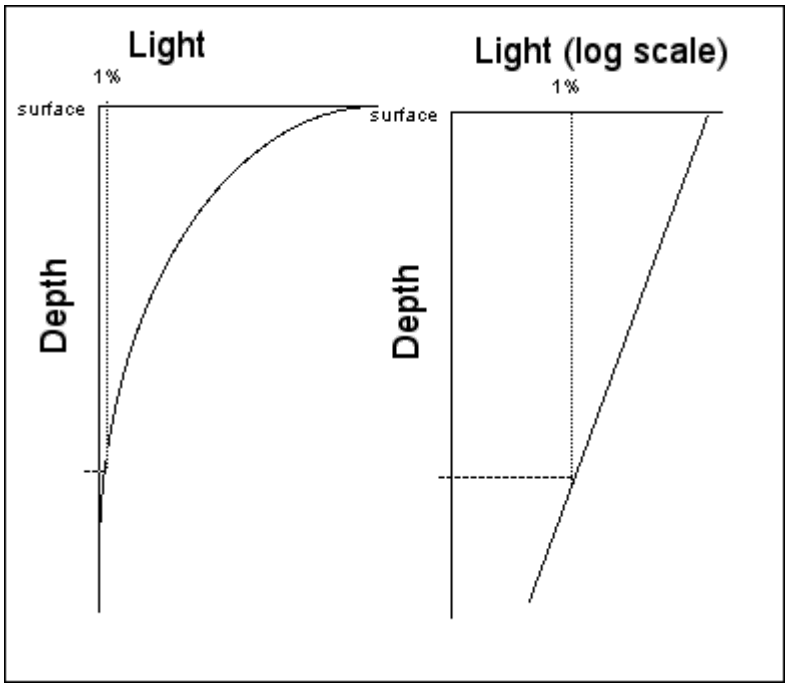
$$I_z = I_o e^{-kz}$$

where:

I_o = intensity of light at surface

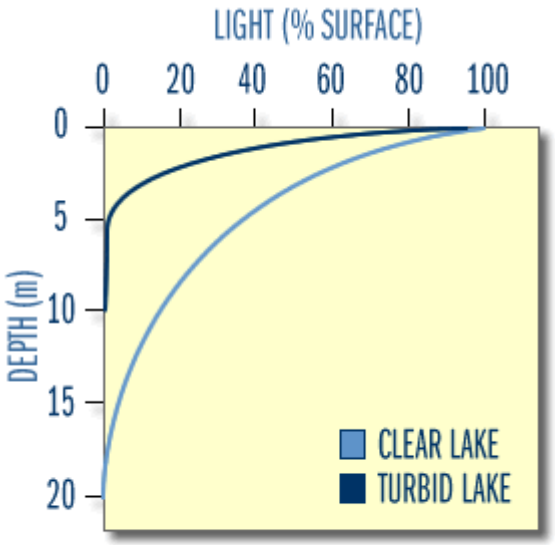
I_z = intensity of light at depth z in meters

k = vertical absorption coefficient



When plotted as depth vs log % incidence of light, line is straight in a homogeneous solution.

How are vertical illumination and turbidity related?



LIGHT VERSUS DEPTH PROFILES FOR A CLEAR LAKE ($k=0.2\ M^{-1}$) AND A TURBID LAKE ($k=0.9\ M^{-1}$).

What would a deflection in the line indicate?

Why might it be important to measure vertical illumination?

Compensation depth - Respiration exceeds photosynthesis within a cell at about 1% of incident surface light (the **photic zone** is the region from the surface to where 99% of light has disappeared).

Visibility - measure of the depth at which one can see into the water. Measured using a **secchi disc**.

What factors affect this measurement?

Visibility can be used to estimate photic depth and trophic state
What factors affect these estimate?

http://dipin.kent.edu/secchi.htm http://www.hao.ucar.edu/public/education/sp/images/secchi.html

In the above three methodologies, where is the light source and light sensor in each?
Why not use just one?
Which provides more information, secchi depth or a vertical profile from photometer measurements? Which is less expensive?

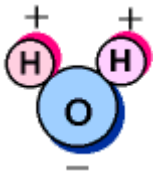
TWO SUMMARY POINTS:

- Light penetration is limited (be extinguished exponentially)
- Matter affects penetration

TEMPERATURE

What happens to the energy when light is absorbed?

Properties of water:



* density-temperature relationship
* high specific heat
* high specific gravity

Why is there a temperature difference between lake inputs and output?

Sources of heat:

* direct absorption of solar radiation - DOMINANT
* transfer of heat from air
* inflows

Sinks of heat:

* conduction of heat to air
* evaporation
* outflow

How should heat energy be distributed vertically within a lake (what should a temperature-depth profile look like)?

Consider:

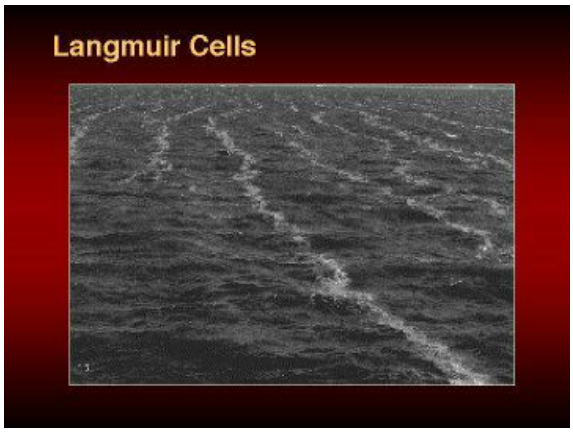
- exponential decline in light
- change in density with temperature
- water movement
- …

Major sources of water movement in lakes:

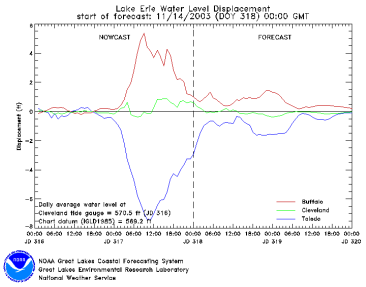
* **wind-generated waves** **(animation)** *What determines wave height?*

* **currents**

* **langmuir spirals**

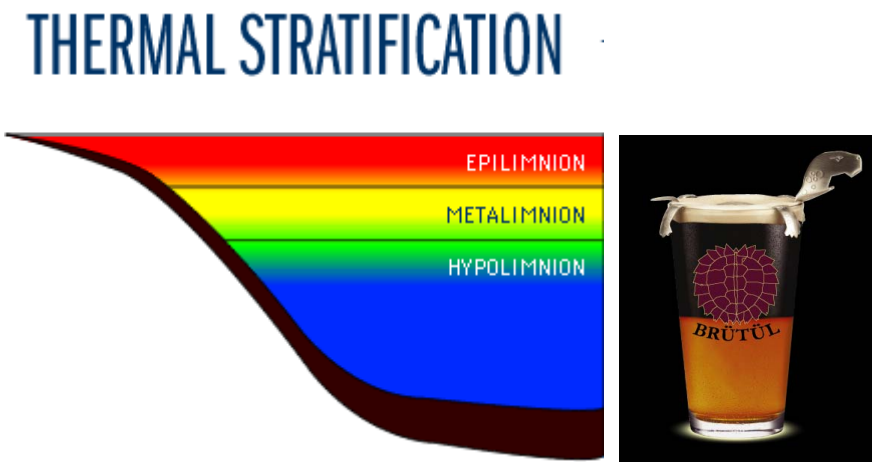


* **seiches**



* internal waves

Thermal stratification is a function of water movement and heat distribution



http://wow.nrri.umn.edu/wow/under/primer/page5.html

Three layers identified in thermal stratification:

- **Epilimnion**
- **Metalimnion (thermocline) - usually the layer that has the greatest temperature change by depth**
- **Hypolimnion**

Why is the warmest water shallowest?

What factors affect intensity (depth) of thermal structure?

Which would take more wind energy to mix, a lake with a shallow thermocline or a deep one?

Is reverse thermal stratification possible?

What will happen to **thermal stratification** *as air temperatures cool in the fall?*

Lake types based on mixing vs. stratification:

Holomictic
- Monomictic
- Dimictic
- Polymictic

Meromictic

Amictic

How will thermal stratification change as a lake becomes more eutrophic?

Quantifying the intensity of thermal stratification - **Relative Thermal Resistance to Mixing (RTRM)**

$$RTRM = \frac{\text{Density of Upper Layer - Density of Lower Layer}}{\text{Density at 5°C - Density at 4°C}}$$

RTRM is a relative, non-dimensional value used to:

- Identify the depth of the thermocline and assess the relative strength of stratification. A "strongly stratified lake" typically has an RTRM max > 80 (when calculated in 1 meter depth increments).
- RTRM can be summed to calculate Σ RTRM, an estimate of total stratification intensity.

So depth of light penetration is important in determining depth of thermal stratification. *How can we test this idea in Lake Allatoona?*

What are the ecological consequences of thermal stratifcation?