LECTURE 2

Scientific Method

1.) *Observe and Measure*
2.) *Form and Test a Hypothesis*
3.) *Develop a Theory*

Nomothetic Approach
Generalizes and comes up with theories that generally work

Idiographic Approach
Explains a single event, does not consider the entire system

Inductivism
Uses empirical data to generalize a theory
Use observations and should not contradict other theories
Presents a theory, waits for data to prove wrong

Falsification
Deduction from other theories
Uses experiments to prove other theories wrong
Uses for explanation until fitter theories are proven

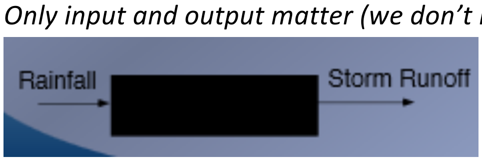
System Approach
A set of variables and their relationship, distinct from relationships outside the system

Why? Because it stresses relationships between variables
It assists in developing theories

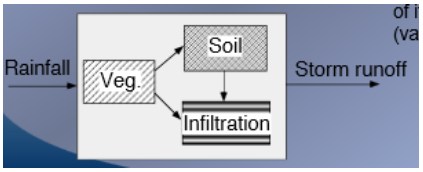
Open System
Inputs and Outputs (global energy entering and exiting the Earth's system)

Closed System
No input or output from the system (only internal) like the hydrological cycle of the Earth…water never leaves the Earth

Black Box System
Only input and output matter (we don't know what goes on internally)



Grey Box
Partial understanding



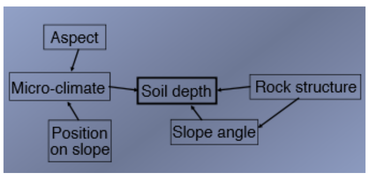
White Box

Comprehensive understanding of the internal system

Morphologic System

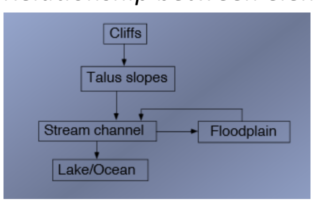
Vague relationships between elements

We do not understand the transfer of energy or matter between elements



Cascading

Relationship between elements understood through flux of matter



Process/response

Combination of morphologic and cascading

GEYSER

Control

Process response modified by human activity

FLOOD CHANNEL

Ecosystem

Process-response with physical, chemical, biological interactions

Positive Feedback

Small disturbance causes large change

A produces more B which in turn produces more A

Warmer atmosphere melts ice which changes the albedo and further warms the atmosphere

Negative Feedback

Disturbance reduces changes

Stable, self-regulating systems

Lake level increases, runoff increases, lake level gets back to normal

LECTURE 4

Black Body
Idealized body that emits radiation solely based on temperature, and irrelevant of shape or size

Laws of Thermodynamics:
- *Energy can be transformed but not destroyed*
- *Heat can never pass spontaneously from a colder to hotter body*
- *Isolated system will reach equilibrium (Entropy)*

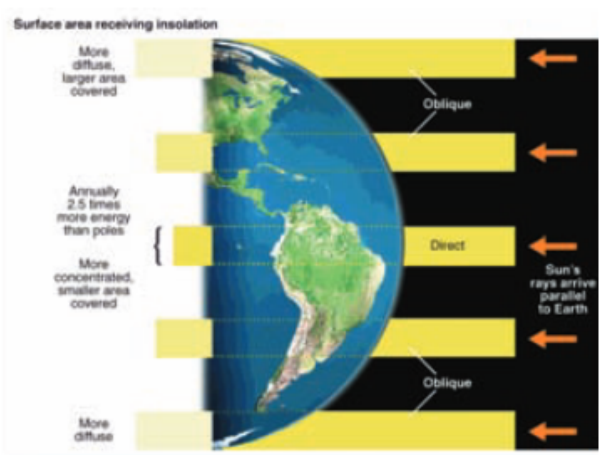
Stefan Boltzmann Law
How much energy is emitted?
Measures intensity of radiation emitted from a body based on temperature

Wien's Displacement Law
What kind of energy is emitted?
Calculates the wavelength of emission from temperature of body

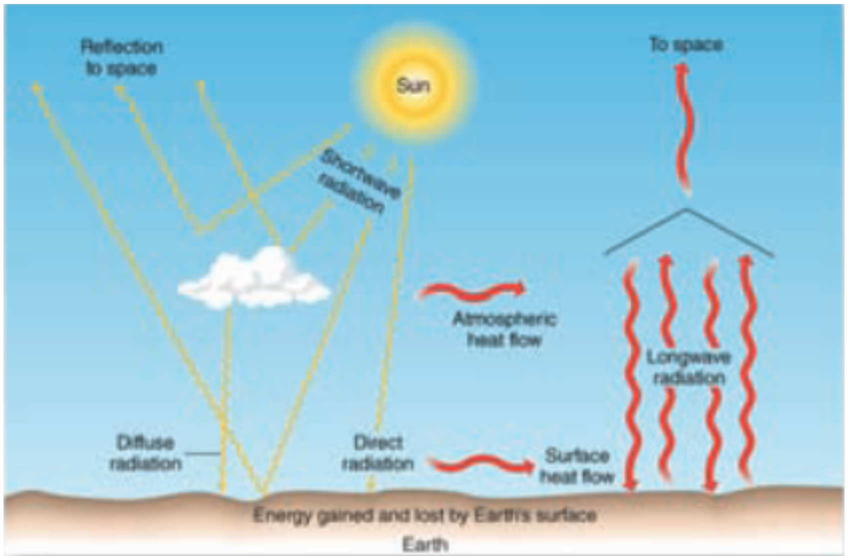
Inverse Square Law
Intensity decreases with distance
Intensity = $1/d^2$

Solar Constant
Average amount of radiation received at the top of the atmosphere at right angles to solar beams
Caculated by the Stefan Boltzmann Law

Insolation
Amount of solar radiation received on a surface area



LECTURE 5



Scattering

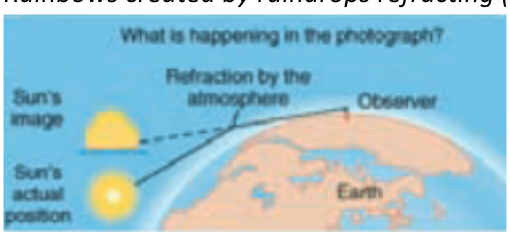
Light changes direction without altering wave length

Hits molecules in the atmosphere

Refraction

Change in speed and direction of light

Rainbows created by raindrops refracting (change wavelength making colours)



Albedo

Percentage of incoming shortwave radiation that is reflected

High Albedo -→ most radiation is reflected (Fresh snow)

Low Albedo → Absorbs a lot of shortwave radiation (wet ground)

Fresh Snow	*90%*
Dirt Snow	*40%*
Desert	*25%*
Meadows	*15%*
Water	*5%*

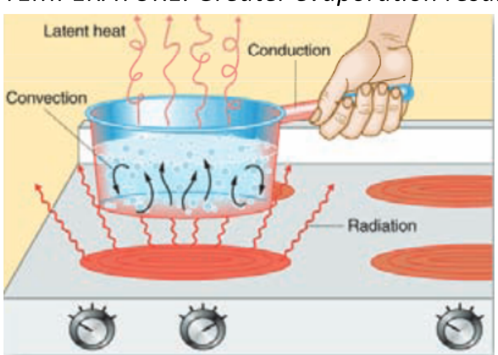
Gasses
Selectively absorb radiation
As a result, some wavelengths pass through the atmosphere while some are absorbed by gasses

Atmospheric Window
8 to 14 µm
Infrared wavelength that is emitted from earth and aloud to pass through the atmosphere into space without being absorbed

Conduction
Molecule transfer

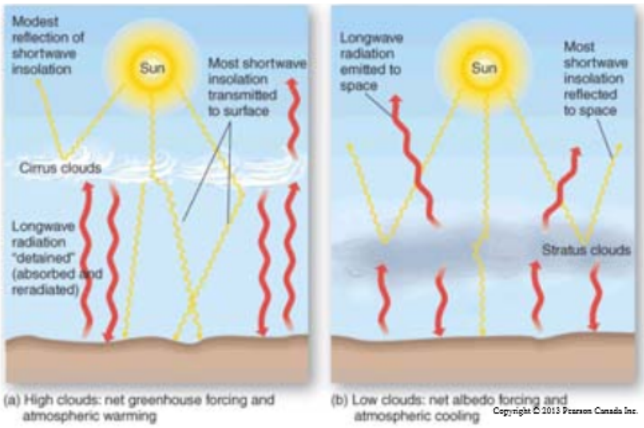
Convection
Fluid movement energy transfer
High density to low density
High pressure to low pressure

Latent Heat
Energy transferred during phase changes (not measurable)
When water evaporates in an ocean, latent heat is absorbed by water vapour resulting in LOWER AIR TEMPERATURE. Greater evaporation results in greater latent heat LOSS → Colder air



Sensible Heat
Heat than can be measured by a change in temperature

Greenhouse Effect
Short wave radiation passes through clouds, absorbed by Earth; long wave radiation emitted from Earth, reflected or absorbed by clouds back to Earth



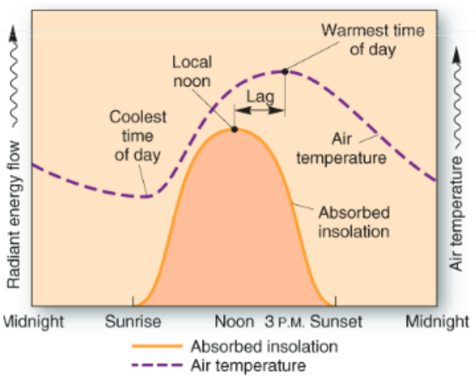
(a) High clouds: net greenhouse forcing and atmospheric warming
(b) Low clouds: net albedo forcing and atmospheric cooling

Radiation Balance Equation

Q = K(1-albedo) + L↓ - L↑

Daily Radiation Patterns

The lag is because the sun is still being absorbed but it takes a bit of time for the long wave radiation to be released by the surface. So we have a bit of lag because it is hotter when long wave radiation is released



Why do we have seasons?

Mainly because of the tilt of the Earth (decreases the intensity of solar beams)
Partly because on non-circular orbit

Electromagnetic Spectrum

Radio, Microwave, Infrared, Visible, UV, X-ray, Gamma

Atmospheric Layers

Thermosphere

Ionosphere (absorbs xrays, gamma rays, SOME UV rays)

Mesosphere

Stratosphere → bottom contains ozonosphere (reradiates longwave energy)

Troposphere

Effect of Clouds
Day → Cooler because they reflect radiation
Night → Warmer because they reflect longwave radiation from the Earth back to the Earth

Factors Influencing Temperature Variation

Latitude	*Insolation*
Altitude	*Pressure?*
Cloud Cover	*Absorption*
Land-water heat difference	*Ability to become heated and release heat*
Marine and continental effect	

Equinox
Twice per year (late September and March)
Tilt of the Earth's axis is inclined neither away nor towards the Sun

Solstice
Twice per year (late June and December)
Tilt of the Earth's axis is inclined at maximums, (tropics receive maximal direct sunlight)

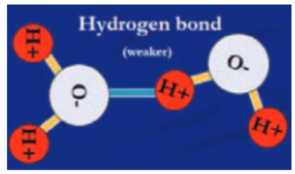
Air Circulation of Atmospheric Heat
High pressure to low pressure

Ocean Currents
Cold currents poles to tropics
Warm currents from topics to poles

LECTURE 8

Covalent Bond
Strong bonds (H20)

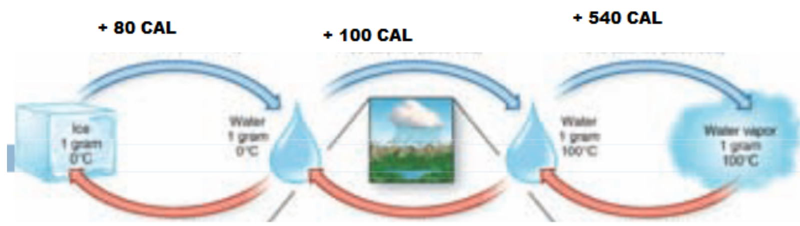
Hydrogen Bond
Weak bond
Allow water to be liquid and solid
If we didn't have, water would only be a gas



Density
Maximum density at 4 degree Celsius
Solid ice is less dense than liquid water (crystalline structure)

Phase Change
Function of temperature and air pressure
Triple point → At LOW pressure, and just above zero degrees, water is all phases at once

Specific Heat
Amount of energy required to increase the temperature by one degree



Latent Heat of Fusion
To melt ice → 80 cal

Latent Heat of Vaporization
To evaporate water → 540 cal

Absolute Humidity (e_a)
Varies with temperature

$$\frac{Number\ of\ water\ molecules\ in\ air}{total\ mass\ of\ air}$$

Vapour Pressure
The pressure that water vapor exerts on air

Saturation Vapour Pressure (e_s)
MAXIMUM absolute humidity
Air is holding all the water it can (for that temperature)

Relative Humidity (R_H)

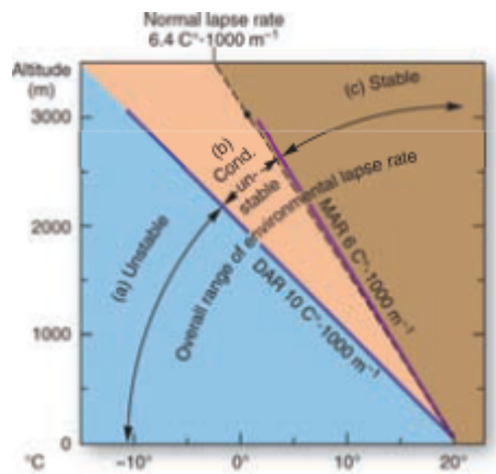
$$R_H = \frac{e_a}{e_s}$$

Dewpoint Temperature

Temperature at which the air would be saturated for the current water content

Methods of Measuring Humidity

1.) *Hair hygrometer → Change in tension of hair due to humidity (moves like a seismogram)*
2.) *Psychrometers → Dry vs. wet bulb temp (evaporate wet bulb and compare the temp change)*
3.) *Capacitive humidity sensors → (low accuracy) measures effect of humidity on metal oxide*

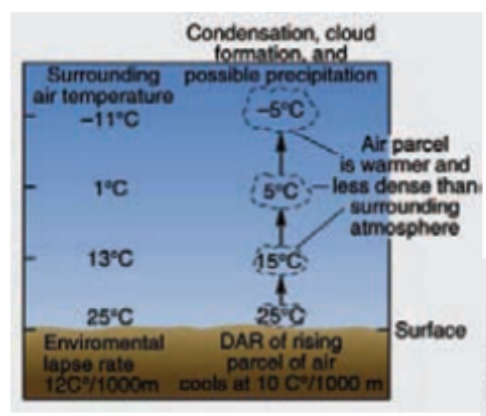


Temperature Decrease in the Troposphere

Troposphere does not absorb solar energy, so temperature in the troposphere is only reflected from the ground

Environmental Lapse Rate

Rate of temperature change in troposphere due to adiabatic process



Atmospheric Stability

ELR < DAR or MAR

Rising air parcel is cooler (denser) than surrounding air

Air parcel cools faster than the air cools

It will remain at same height

Clear skies

Atmospheric Instability

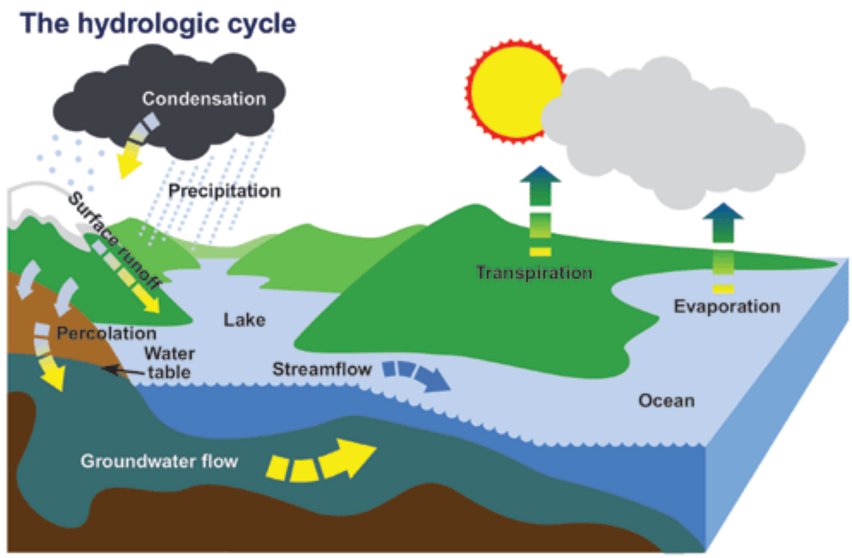
ELR > DAR or MAR

Rising air parcel is warmer (less dense) than surrounding air

Air parcel cools slower than the lapse rate

Formation of clouds, condensation

Hydrologic Cycle



Evaporation

- *Open water evaporation*
- *Interception loss (vegetation steals water and evaporates it)*
- *Transpiration (from leaves)*
- *Soil evaporation*

Occurs when….

1.) *Water is available*
2.) *Energy is available*
3.) e_s *at the surface is less than* e_a *above the surface*

Cloud Formation

Cooling air increases its relative humidity close to 100%

Unstable conditions

Condensation

Vapour to liquid

Condensation Nuclei

Small particles that water vapour condensates onto

Dust, sea salt, sulfur, nitrogen oxide

Sea salt, sulfur (hygroscopic)

Soot, organic carbon (non-hygroscopic)

Cloud Types

- *Stratus → Layer-like*
- *Cirrus → Thin, wispy, consist of ice particles*

- *Cumulus* → *Thick puffy clouds*

Fog Types

- *Advection Fog*
- *Valley Fog*
- *Ice Crystal Fog*

LECTURE 9

Formation of Precipitation

- *Cool air to almost 100% relative humidity*
- *Need condensation nuclei*
- *Cooling via rising air particles*

Coalescence Process

Large water droplets collide and combine until their gravity force outweighs their buoyant and drag force

Ice-Crystal Process (Snow)

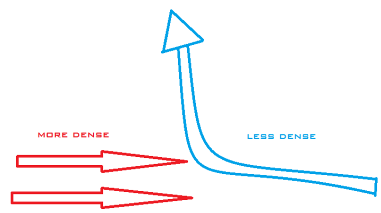
When a cloud contains both water droplets and ice particles

Water droplets evaporate and sublimate onto ice particles

1.) Convergent Lifting

Opposing air masses force the less dense mass to rise

Horizontal movement



2.) Convective Lifting

Convective heating of the lower atmosphere causes vertical lifting

Unstable atmosphere

Vertical movement

➔ *Thunderstorms are convective precipitation*

➔ *Moist air rises and condensates (latent heat is released)*

3.) Orographic Lifting

Air masses are forced to lift due to physical barriers (mountains)

Wet windward / dry leeward

4.) Frontal (Cyclonic) Lifting

Warm front → *Light warm air overrides cool dense air*
→ *Small gradient boundary*
→ *Light precipitation (slow cooling)*
→ *Stratus clouds*

Cold front → *Cold dense air pushes warm air upwards by slipping under it*
→ *Steep boundary*
→ *Intense rainfall (quick cooling)*
→ *Cumulus clouds*

Water Balance Equation

$P = Q + E + \Delta S$

Lecture 10

Climate

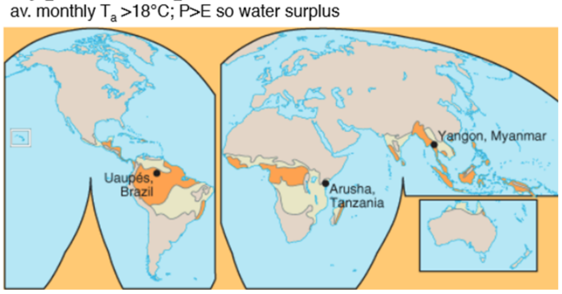
Average values of weather components over a 30-year period

Function of:
- → *Latitude (influences solar intensity)*
- → *Altitude (environmental lapse rate, temperature)*
- → *Location of global high and low-pressure zones (influences winds)*
- → *Heat exchange from ocean currents (influences air temperature and evaporation)*
- → *Prevailing winds (if winds flow over water, will have maritime climate)*
- → *Land/Sea ratio (land heats and cools faster than water, continental have large seasonal temperature range)*
- → *Topography (orographic precipitation)*

Köppen-Geiger Climate Classification

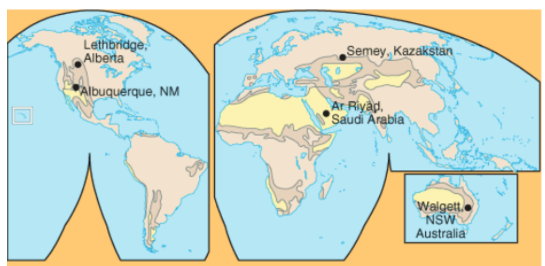
Type A: Tropical Climates

av. monthly T_a >18°C; P>E so water surplus



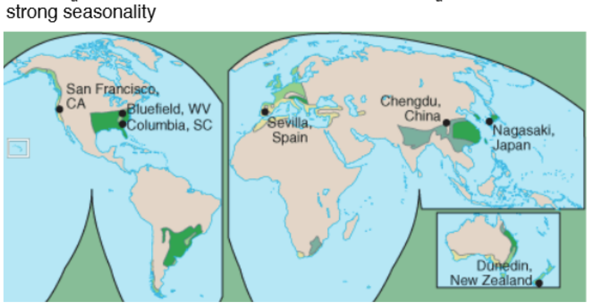
Type B: Dry Climates

PE>E so net water deficit



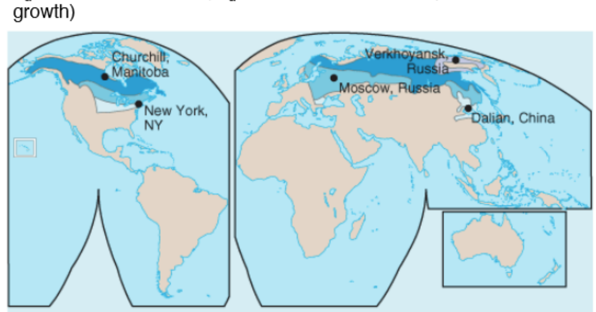
Type C: Mesothermal Climates

-3°C< T_a coldest month <18°C; at least one month T_a >10°C; strong seasonality



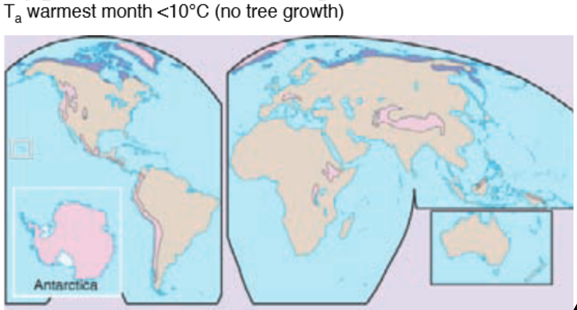
Type D: Microthermal Climates

T_a coldest month <-3°C; T_a warmest month >10°C (allows tree growth)



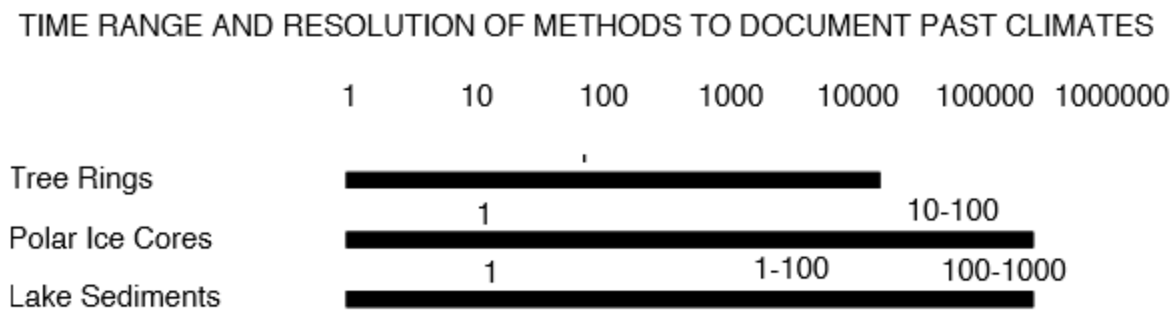
Type E: Polar and Highland Climates

T_a warmest month <10°C (no tree growth)



And TYPE H – highlands

Methods of Documenting Past Climate



Tree rings: → *Ring width and density shows growth in a season (temperature and precipitation)*
Lake cores: → *Vegetation existence, moisture, show temperature precipitation*
Glacial cores: → *Warmer summers show more melt, colder winters show dense compaction*
→ *Very expensive*
→ *At lower depths, the pressure becomes very large*

Temperature Variation Since Pliocene (5.5 million years ago)

5.5 million years ago → *High frequency, low amplitude*
→ *Often had warmer and colder periods, but not severe change*
1.5 million years ago → *Low frequency, high amplitude*
→ *Doesn't change often, but when it does it's a fucking iceage*
NOW → *Same as 1.5 million years ago*
→ *Getting worse*

Glacial Periods
Last 100 000 years, 10 000 in-between

Milankovitch Theory

Eccentricity of Orbit → *100 000 year cycle*
→ *Circular = no seasons*
→ *Elliptical = larger seasonality in one hemisphere, less seasonal in other*

Tilt of Axis → *41 000 year cycle*
→ *22 to 24.4 degrees (going towards 22)*
→ *Greater tilt = greater seasonality*

Wobble → *22 000 year cycle*
→ *Changes equinoxes (dates of perihelion and aphelion change)*

→ *Affects seasonality in different hemispheres (more in one, less in the other)*

Infiltration Capacity

Maximum rate at which a soil can absorb water

Lecture 11

Relative Time

Older rocks at the bottom, younger layers on top

Absolute Time

Radioactive dating

Core

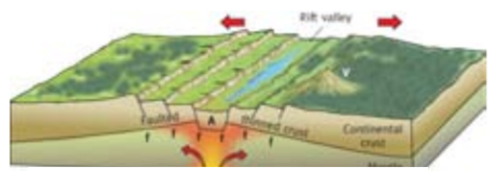
Inner core is solid iron

Outer core is liquid iron that changes the magnetic field of the Earth

Mantle

Lower mantle, Fe Mg Si…

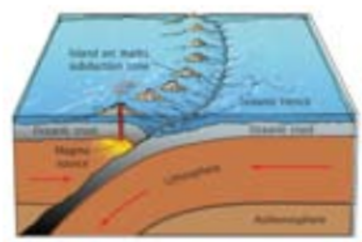
Upper mantle :
- *Solid upper mantle*
- *Plastic asthenosphere*
- *Solid lithosphere*



Tectonics:

Divergence

- *Mid-oceanic ridges*
- *Plates spread out and magma comes out*

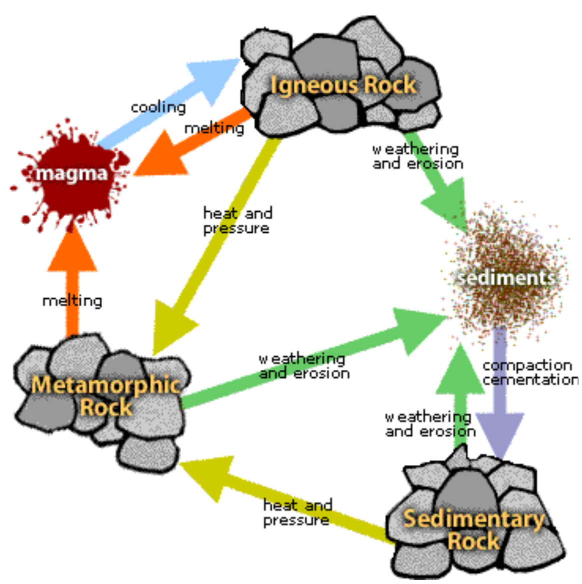


Subduction

- *Denser plate wedges under lighter one*
- *Lots of earthquakes and volcanoes*
- *Creates mountains and oceanic trenches*

Types of Rocks:

- *Igneous (magma cools and becomes a rock)*
  - *Basalt*
- *Metamorphic (change from heat / pressure)*
  - *Gneiss*
  - *Marble*
- *Sedimentary (from sedimentation)*
  - *Limestone*
  - *Shale*



Rock Cycle:

Weathering:

- ***Physical***
  - *Dilitation (Spalling from stress in rocks)*
  - *Thermal stress (expansion/contraction)*
  - *Congelifraction (rocks break because of freezing water in pores)*
  - *Salt weathering (salt brought to pores by water, and expands during heat)*
- ***Chemical***
  - *Depends on the rock composition and water content*
  - *Acid in water dissolves rocks (chemical reaction)*
  - *(stalactites in caves)*
- ***Biological***
  - *Small bacterium can eat away the rock*

- *More weathering in lower latitudes with high heat, rainfall, humidity*

Weathering Zone

Area weathered above the underlying undamaged bedrock
Shallow in hot and cold regions
Deep in wet and humid regions

Weathering Front

Zone that the bedrock and weathered rock meet

Erosion

Once the particle is broken off from weathering, erosion moves the particles and removes it from the area

- *Glacial Erosion*
- *Fluvial Erosion*
- *Karst Erosion (Sinkholes, Canyons)*
- *Coastal Erosion*

1.) ***Detachment*** *(rocks particles detached)*
   a. *Weathering*
   b. *Glacation (ice glaciers freeze rock, cause water to expand, rock cracks)*
   c. *Abrasion (suspended rocks hit the rock)*
   d. *Raindrop impact*
2.) ***Entrainment*** *(velocity of water is large enough to cause motion of the particle)*
   - *Small particles need high velocity because they have cohesion to the original rock*
   - *Large particles are heavy and require high entrainment*
3.) ***Transport***
   a. *Suspension*

b. Saltation (bouncing)
c. Traction (dragging)
d. Solution (dissolved)

4.) ***Deposition***

- *Happens when the velocity of the flow slows*

Landform

Single unit (one mountain, a sinkhole, a sand dune)

Landscape

Aggregation of landforms (Rocky Mountains, a whole desert)

Degradational Process

Forces that work to flatten the landscape

- *Avalanches, mudslides, landslides*

Aggradational Process

Land height is levelled out or increased

- *Sedimentation*

Factors Affecting Landscape

- *Running water (erosion)*
- *Glaciers (erosion)*
- *Wind (erosion)*
- *Coastal waves (how much land there will be)*
- *Chemical dissolution (weathering, karstic landscape)*

Lecture 12

Soil Components:

- *Minerals (45%)*
- *Voids (25%)*
- *Water (25%)*
- *Organic matter (5%)*
  - *Humus (broken down organic matter)*

Water in Soil

- *Surface water*
- *Gravitational water (drains to GWT)*
- *Capillary water*
- *Hygroscopic water (held to the surface of particles from tension)*
- *Chemically bonded water*

Factors for Soil Formation:

Parent Material
Residual soils (minerals from underlying rock)
Transported soils
Coversands (sands transported by winds)

Climate
Soil moisture

Organisms
Micro-organisms eat and create organic content
Macro-organisms
Worms create trails that allow water and air to flow, and their shit creates bacteria
Termites remove all vegetation for their nests, accelerate organic decay

Topography
Amount of precipitation
Amount of erosion (thickness of soil)
Infiltration volumes

Time
Takes time for shit to happen

Describing Soil

Soil Colour

Grain Size Distribution

Soil Structure

Soil Porosity

Soil Permeability

Field Capacity

Soil Processes

Addition

Gains made by the soil when sun, water, organic matter is added

Transformation

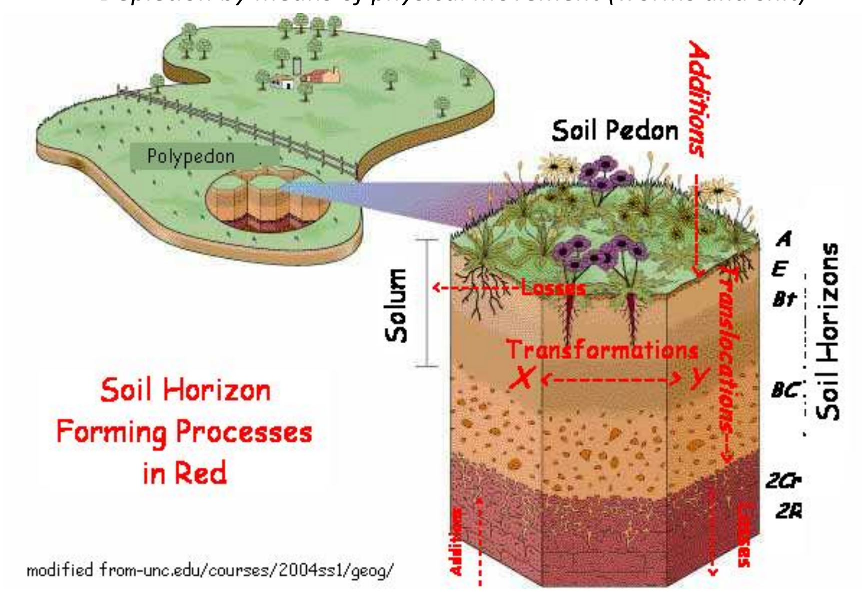
Rock weathering and decomposition of organic material

Depletion (losses)

Water percolates downwards and brings particles with it from upper layers

Translocation

Depletion by means of physical movement (worms and shit)



Soil Structure

Platy

Little cinnamon toast crunches

Prismatic

Vertical strength

Angular

Considerable strength

Spherical

Porous, weak

Lecture 13

Interception

Water falls onto vegetation and evaporates before reaching the soil

Infiltration

Water seeping into the soil

Runoff

Occurs when there is precipitation and the soil is fully saturated

Factors affecting infiltration capacity

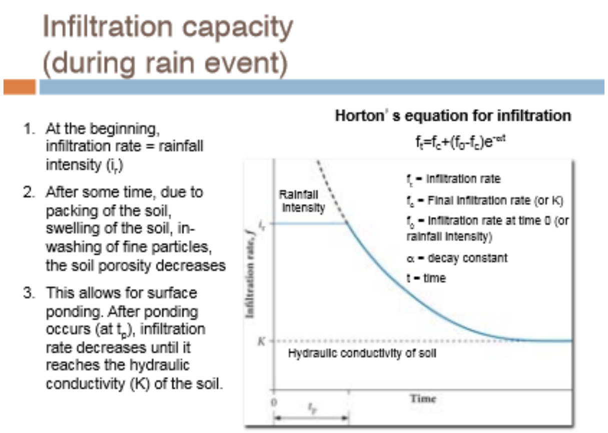
Soil type (porosity, water content)

Vegetation (amount of cover)

Land Use

Weather prior to rainfall (if ground is saturated)

Duration and intensity of pcp



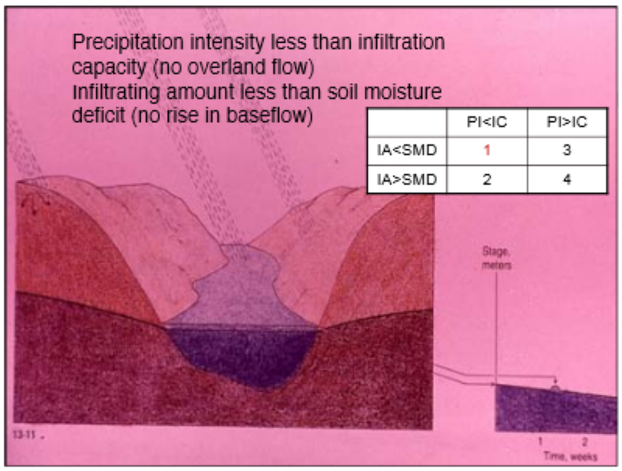
Horton's Theory

Applies to semi-arid areas with low vegetation cover (low infiltration capacity) and high intensity storms

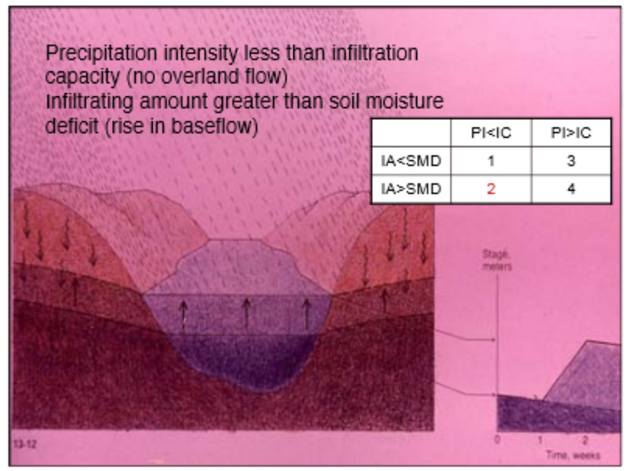
Surface Runoff (SR) *controlled by* ***Precipitation Intensity (PI)*** *vs.* ***Infiltration Capacity (IC)***

Baseflow *controlled by* ***Infiltrating Amount (IA)*** *vs.* ***Soil Moisture Deficit (SMD)***

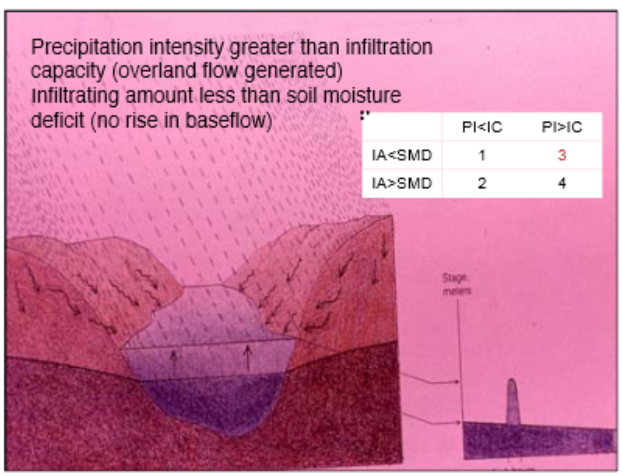
	PI < IC	***PI > IC***
IA < SMD	*1*	*3*
IA > SMD	*2*	*4*



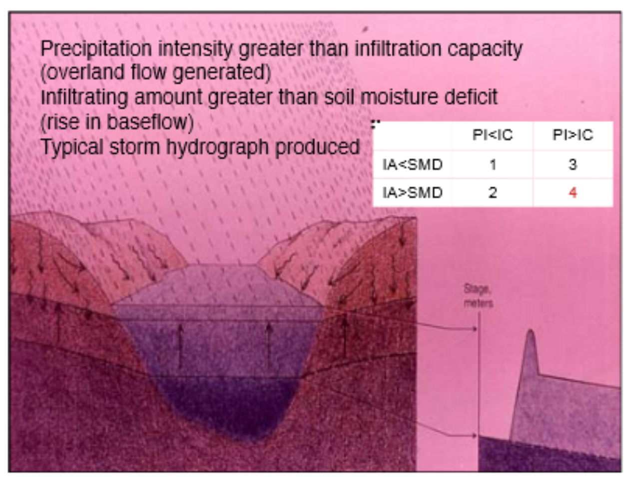
Hortonian type 1



Hortonian type 2



Hortonian type 3



Hortonian type 4

Formation of Lakes

Glacial Activity
Tectonic Processes (faulting of crust)
Volcanic Activity (crater lakes)

Meteorites
Solution lakes (sinkholes)
Organic (beavers)
Human (dams)
Etc..

Thermal Stratification of Lakes

Epilimnion
Surface layer that is warm and less dense from the Sun
Thermocline
Transition layer that has large thermal gradient
Hypolimnion
Bottom of lake, cool dense water

Holomictic Lake
Entire lake is involved in the mixing
Seasonal mix

Meromictic Lake
Could be centuries before the lake mixes
Pink Lake

Oligotrophic Lake
Clear, lack nutrients

Mesotrophic Lake
Clear, average nutrients

Eutrophic Lake
A lot of nutrients
Algae bloom

Hypertrophic Lakes
Too much nutrients
Turbid
Shit-tonne of algae bloom, and low DO