Physical Geography – Midterm 2/27/2011 7:51:00 PM

4 means of energy transfer? Which transfers all energy into and out of Earth's climate? Possible sketches?

- Conduction: molecules bump into each other and transfer energy
  - Closely packed = more likely to bump
    - High energy with several "circles" surrounding ⇒low energy receives " circles" (not as large)
- Convection: energy transfer by internal mixing of a medium
  - As things heat up, molecules vibrate more ⇒more energy between them ⇒need more space ⇒become less dense ⇒ rise(warm)
    - Pan: red water molecules at bottom rises to top, blue water molecules at top more densely packed sink
- Advection: horizontal movement from one environment to another
  - Boiling water in cold freezer to defrost
- Radiation: energy transfer by electrical and magnetic fields
  - Warm molecules vibrate ⇒nucleus vibrates towards
    - electrons ⇒electrons move away = generates electrical
      - magnetic radiation
    - **Nucleus in middle, electrons on outside move side to side**

What controls the quantity and type of energy the Earth System receives?

Stefan-Bolzman:

- D (constant) x T (surface temperature) [^4] *4 because hot objects emit a disproportionately larger quantity of energy
- Hotter objects ⇒more vibration ⇒more electromagnetic radiation

Wein:

What type according to electromagnetic radiation spectrum (longest to shortest):

Radio
Radar
Microwaves
Infrared
Visible light
UV
Xrays, Gamma Rays

Planck's Law: there is a range of wavelengths emitted by an object

- Different amounts of energy released
- Earth emits much less energy than sun
- Earth: RECEIVES most energy at SHORT wavelengths and LOSES it at LONGER wavelengths

<u>What is the solar constant?</u>
Quantity of energy falling on outside of Earth's atmosphere (1360, 345)

<u>^ 11 year cycle?</u>
Increased UV light is produced 1-2% more or less each year = increased solar constant
Heat leaves sun and comes back cooler creating sunspots (arcs)

<u>Zenith angle:</u>
Proportion of solar constant that you're getting
90° at sunrise and sunset
Sun is directly overhead = falls perfectly on 1 square meter of ground
Bigger zenith angle ⇒covers more ground ⇒less direct heat (distributed more)

Relationship between latitude and zenith angle at noon on:
March 21 AND September 21: everywhere on Earth gets 12 hours of daylight ⇒zenith angle = latitude
NOON = ZENITH ANGLE CLOSE TO ZERO
The proportion of solar constant intercepted is determined by:

- Q [quantity of insolation] = Cos (Z) [zenith angle] *S [solar constant]

<u>Perihelion and Aphelion</u>
Perihelion: closer to the sun on January 4 ⇒91.5
Aphelion: farther away from the sun on July 3 ⇒95.5
Formula: average/actual distance (solar constant)
6% change in solar radiation

More latitude and zenith angle:
Summer (June in N, December in S) = latitude – 23.5°
Winter (December in N, June in S) = latitude + 23.5°
At equator, all places receive 12 hours of daylight and 12 hours of darkness, no matter what day it is
On 3/21 and 9/21 ⇒all places get 12 hours of daylight and 12 hours of darkness, no matter what latitude
On 12/21 ⇒north of Arctic Circle (N) = 1 day of total darkness and 1 day of total daylight south of Antarctic Circle (S) REVERSE on 6/21
Farther from equator and closer to poles ⇒0 hours of daylight on 12/21 and more sunlight in June

Explain the significance of the Equator, Tropics, and Arctic/Antarctic circles in terms of patterns of insolation:
Greater variation in seasons as you move further from the Equator

<u>Atmosphere:</u>
78% Nitrogen, 20% Oxygen, .9% Argon, .03% others

- (Carbon Dioxide, Methane, Nitrous Oxide, Ozone, and Water Vapor)

Atmospheric pressure = height of column x density of gases
Closer to Earth's surface = less space for molecules ⇒densely packet at bottom = strong gravitational attraction
Charles' Law vs. Boyle's Law
Charles' Law
PRESSURE is held constant
Temperature and volume is DIRECTLY proportional
Freeze water ⇒molecules vibrating DECREASES, take up less space, volumes also DECREASES
Boyle's Law
TEMPERATURE is held constant
Pressure and volume are INVERSELY proportional
Brick on balloon ⇒INCREASE in pressure causes molecules to use less space so volume DECREASES
More molecules can fit if under pressure
How the two are related (CONNECTED BECAUSE OF VOLUME)

Location determines temperature ⇒temperature and volume change together ⇒focus on volume and ignore temperature ⇒amount of space molecules take up (volume) DETERMINED BY the pressure
Hot ⇒large volume ⇒low pressure
Cold ⇒smaller volume ⇒high pressure
Ideal gas law: (what we would like every gas to act like – NOT REAL)
P (pressure) = R (gas constant) x p (density of gas) x T (temperature of gas)
Density = mass/volume
(Charles) to keep pressure constant [get the same #] = If temperature increases ⇒must increase temperature of gas
(Boyle's) to keep pressure constant = pressure increases ⇒volume decreases

From Online Book
Insolation and the atmosphere
69% energy = earth ⇒20% absorbed in atmosphere and 49% reaches Earth's surface
RETURNED TO SPACE AS LONGWAVE RADIATION
Molecules in atmosphere are very large in order to interfere with very long wavelengths (blue visible light) ⇒energy is not absorbed and is scattered, strips out large proportion of blue, leaves them bouncing in atmosphere = SCATTERING
Proportion of reflectivity = ALBEDO ⇒31% for planet, 20% for clouds
Albedo:
Greatest at the poles (colder = snow), least in tropical and equatorial regions
Greater in Southern Polar regions than Northern polar regions
N. pole = mostly oceans, S. pole = more continents and loses heat faster ⇒ higher albedo
Slightly higher albedo in equatorial regions, 0-10° than at 10-20°
0-10 = equator ⇒global deserts, high reflectivity because nothing is blocking the sun from hitting the sand
10-20 = rain forests, canopy of trees that prevents sunlight from passing through, not as strong

Oceans: moderately high, but a lot of variability because it covers a different amount of surface when sun is overhead vs. setting

Where is energy stored?
Ground heat flux: changes temperature of SURFACE (oceans and continents) of PLANET
Sensible heat flux: changes temperature of ATMOSPHERE
Latent heat flux: energy changes state of WATER with NO CHANGE to the TEMPERATURE
Moderates climate by changing the state of physical spacing of molecules
Adding energy increases temperature of molecules
Low energy state = ice and snow
To change from low to high, ADD latent heat
Solid ⇒liquid = melting (FUSION = 80 calories per gram), liquid ⇒gas = evaporation (VAPORIZATION = 540 calories)
High energy state = water vapor
To change from high to low, latent heat RELEASED to environment
Gas ⇒liquid = condensation, liquid ⇒solid = freezing (FUSION)
Increased temperatures ⇒more vibration ⇒short elastic must be replaced by a longer one [represent a change of state]

How does energy escape the Earth system?
Global longwave radiation budget: (from total of 69%)
Remaining 19% of surface energy stored as ground heat flux ⇒surface loses this amount to space (longwave) = 12% escape directly to space, 7% intercepted by greenhouse gases
7% joins other 50% and combine to warm atmosphere ⇒stored as sensible heat
SENSBILE HEAT CANNOT BE TRANSMITTED DIRECTLY, so
1/3 of 57% actually returned to space, remaining 2/3 continues to warm surface ⇒surface temperatures much warmer than expected ⇒longwave radiation leaves much larger
Repeated until 69% returns to space as longwave radiation

ATMOSPHERE WARMS from BOTTOM ⇒WATER VAPOR INCREASE, COOLS to create CONDENSATION

How does insolation vary spatially?
Highest and most uniform values = tropics and equatorial regions
Declining gradient in midlatitudes
Low values in Arctic and Antarctic ⇒large zenith angle = total day of darkness
Irregularity of continents and slowly changing patterns of oceans
NORTH OF EQUATIOR ⇒low insolation, high albedo

How does outgoing longwave radiation (OLR) vary spatially?
Temperatures and longwave radiation related to latitude
Range of values for OLR < insolation
CONTINENTAL Antarctic = COOLER than OCEANIC Arctic
Water vapor around greenhouse gases prevents energy from escaping, which alters rule for high OLR around equator in areas: Africa, South America, maritime Asia
Highest OLR ⇒20° and 30° (deserts)…absence of water = OLR escapes

How does balance between incoming and outgoing radiation change spatially?
Tropics: insolation > outgoing radiation
Polar regions/midlatitudes: insolation declines more rapidly than outgoing radiaton
Energy balance becomes increasingly negative toward Poles
35°: insolation = OLR

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Greenhouse gases/effect
Greenhouse gases and their reaction with the electromagnetic spectrum:
Methane: decaying material
Increase in world population ⇒increase in animal usage ⇒increase in the gas

Nitrous Oxide (N_2O): production of fertilizers
More agriculture ⇒more chemical fertilizers ⇒increase in the gas
Carbon dioxide:
Increased through burning of fossil fuels and deforestation
Water vapor and ozone:
Ozone intercepts UV light
Water vapor prevents thermal infrared energy from escaping to space and decreases risk of damaging cold temperatures
Benefit of Greenhouse gases:
Keeps Earth about 59° warmer ⇒habitable temperatures and water in liquid state

Surplus and deficit:
35°N latitude
Half the world is in energy surplus and half is in energy deficit
Incoming radiation equal to outgoing
Max amount of energy
Surplus: more energy coming in
Ideally move energy to Poles ⇒wants to maintain balance

How is energy moved? (Cells)
At the equator [1], hotter = air is less dense ⇒area north of the equator [2] is cooler
In order to ensure that products are equal (pressure), increase temperature of [1] and decrease of [2]
Warm less dense air rises until it hits the tropopause BUT it cannot exceed that area ⇒proceeds into the stratosphere because the temperature of the air is not hot enough for the stratosphere SO it is pushed sideways towards the poles and continues to cool ⇒repeats
Hadley cell = between 30°N and 30°S
Air rises and either keeps going on turns and comes to surface ⇒repeats
Similar to process for tropopause but in a more confined area (30-30)
If air keeps on rising, it enters the Ferrell cell, 30°-45°
Planetary front, 45°-66.5°

Polar cells are from 66.5°-90°
BASICALLY ⇒warm air rises from equator + cold air sinking from Poles = meet in planetary front and repeat

…continued ⇒pressure and winds
30° = high pressure because it is intercepting cold air from planetary front, meaning molecules are tightly packed
45° = warmer because the warm air rises over the cold air, meaning molecules spread out more and there is lower pressure

Coriolis effect
Angular velocity: rotates 360°/24 hours no matter what latitude, BUT
Linear velocity: changes depending on location
Latitude increases, smaller circumference, linear velocity decreases
CE = ACCELERATION
Higher the linear velocity ⇒greater the acceleration (has to go around faster because it covers a greater area, i.e. equator)
GREATER THE LATITUDE = LOWER THE VELOCITY (smaller circumference)
CE: WIND DEFLECTION AND LINEAR VELOCITY
Ferrell's law:
All objects are deflected by the CE
N Hemisphere = right, S Hemisphere = left
Pressures move from high to low
HIGHER LATITUDES (Poles) = SMALLER LINEAR VELOCITY (less distance to travel around [imagine looking from above])
Equator = minimal CE, Poles = maximum CE
Quantitative expression:
-2omega(angular velocity)* x V(linear velocity of moving object) x sin of phi(latitude)

- *doesn't change = 360°/24

Example: latitude is 0 (equator), plug into ^ sin(0) = 0, meaning

- NO CE AT THE EQUATOR

Global surface winds
0-30 S ⇒winds want to move upward BUT deflected to left = South Easterlies
0-30 N ⇒winds want to move downward BUT deflected to right = Northeast Trade winds
30-45 S ⇒winds wants to move downward BUT because there is more ocean than land in this area, there is nothing to absorb the CE SO they are deflected all the way to the left = Westerlies
30-45 N ⇒winds wants to move upward BUT deflected to right = South Westerlies
Poles (N or S) ⇒winds want to deflect only halfway BUT end up having full deflection = Easterlies (both)

Cyclones
N Hemisphere ⇒low pressure, rotates counterclockwise, deflected to right
S Hemisphere ⇒low pressure, rotates clockwise, deflected to left

Anticyclones
N Hemisphere ⇒high pressure, rotates clockwise, deflected to right
S Hemisphere ⇒high pressure, rotates counterclockwise, deflected to left

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Differences in thermal properties of oceans and continents
CONTINENTS HEAT UP MORE QUICKLY THAN OCEANS
Specific heat: [1 and 2 ⇒specific #s you have to remember]
Same amount of solar radiation comes down,
Water cools down/heats up by about 1 degree
Land cools down/heats up by about 2 degrees (larger increment of increase or decrease either way)
Latent heat:
Changing the state of WATER without changing the temperature
Oceans ⇒more water to change the state of, so the proportion of latent heat flux is HIGHER…no change in temperature!

Continents ⇒a lot less water to change state, so more of solar radiation is going to go to sensible heat (atmosphere) and ground heat (surface) MEANING THERE WILL BE A CHANGE IN TEMPERATURE BECAUSE THERE'S NO WATER
Penetration and radiation: how far something will go and how it will be dispersed
Ocean: greater depth of light to penetrate, goes farther down (deep) but not as far across the surface = cooler
Land: cannot go through solid surface as easily ⇒does not penetrate much but does spread out across the surface more = warmer

Mixing
Ability of a substance to take the energy that has been delivered and redistribute it
Water: as you go farther down into the water, it follows the pattern: warm ⇒ cooler ⇒coolest, because the sunlight can only reach so far
Calm: stable profile, not much mixing, cool ⇒cooler ⇒coolest (least dense to most dense)
Rough: wave energy promotes surface mixing, waters are going to be a little cooler after mixing because of turbulence
Salty: still follows "cool ⇒cooler ⇒coolest" pattern, but adding salt makes each more dense ⇒vertical mixing = convection because of the differences in density
Cold (icecaps and glaciers melting): colder water = more dense, also promotes vertical mixing

Putting it all together!
In a zone of surplus energy (30 degrees) ⇒oceans warm up slower than continents (oceans cooler) = really high pressure
In a zone of deficit energy ⇒oceans cool down slower than continents (continents cooler) [ocean is warmer]
0-35 N and S is SURPLUS
Reminder about pressure:
Equator = low pressure
30° N and S: air from Poles is cold, molecules tightly packed = high pressure

45-60: warm subtropical air moves up and rises over cool polar air = low pressure (planetary front)
Air from the Poles is cold, comes down, but stops before equator at 30° and then goes back around to Poles (high) ⇒repeat
Highs and lows over continents:
Equator ⇒surplus ⇒low pressure ⇒warm
Low pressures (warm air) are bigger over continents than oceans because the oceans are cooler ⇒high pressure
High pressure all around, but higher over the oceans
Strength of energy is lower over continents because they lose energy faster ⇒cooler (low pressure)
Poles
Cold air, deficit, high pressure ⇒continents in zone of deficit are cooler than the oceans, so the pressure is really high over continents
N and S subtropical anticyclones = very high pressure
In ocean ⇒extend pressure more on land ⇒deflected winds also blow more on land
Winds and currents
Equator: warm water moved by winds to the Poles ⇒current makes water warmer at surface = warm surface ocean current, positive ground heat flux
Poles: cooler warm transferred to equator ⇒cold surface ocean current, negative ground heat flux
Latitudes:
20-40 E: warm currents
20-40 W: cold currents
50-70 E: cold
50-70 W: warm
Transfers energy from zone of surplus ⇒zone of deficit
Horizontally mixing (advection) of winds from currents

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FINAL:
June 21, summer ⇒N Hemisphere [everything moves up]
Equator usually is the position of maximum heat, but because of the EARTH'S TILT, the belt of low pressure is moved upward to vicinity of Tropic of Cancer:

BUT moved more upward on land but stays closer to equator over the ocean
Occurs because in zones of surplus, oceans take longer to respond to changes in temperature
Band of high pressure at 30° expands ⇒causes winds at 30° to be stronger, so winds are pushing upwards (South Westerlies)
High pressure at the poles, winds are coming from NE, band of high pressure is not as strong ⇒so when these winds meet, pushes band at 45 upwards
Cross equatorial winds: since band of low pressure moved up, band of high pressure at 30 S has a farther distance to travel, and so do the winds ⇒ deflected to left, but once they pass the equator, they deflected to the right (now in N Hemisphere)
December 21, winter ⇒N Hemisphere [everything moves down]
Equator: band of low pressure, position of maximum heat moves southward towards the Tropic of Capricorn (ToC)
Zone of surplus energy ⇒oceans take longer to respond to a change in temperature, so it gets closer to ToC on land than in water
Poles: bands of high pressure over land are REALLY strong because it freezing ⇒band of high pressure at 30 isn't very strong (because the oceans are staying a lot warmer) SO, Poles cold air is strong, when cold air meets warmer air, band at 45 is pushed down
Cross equatorial winds: both pressure bands moved down, winds from 30 N at high pressure flow downward to right of intended path, BUT since belt moved down they have a longer distance to travel ⇒winds deflected to right, but once they pass the equator, they deflected to the left (now in S Hemisphere)