ES 106 2007 May 7-11 Sun and Earth Relations, Atmosphere

I. Axial Tilt and Orbit around Sun—
   A. Earth tilts 23.5° to orbit around Sun
   B. Latitudes of Sun incidence
      1. polar circles—Arctic, Antarctic
      2. tropical circles—Cancer, Capricorn
      3. equator
   C. Days corresponding to Sun incidence
      1. solstice—overhead Sun at tropical circle—June 22, December 22
      2. equinox—overhead Sun at equator—March 22, September 22
   D. Day length varies with latitude and season, due to circle of illumination
      1. longest/shortest at solstice, at high latitudes
      2. equinox—equal day and night all over the world
   E. Heating
      1. Greater heating capability with higher Sun angle
         a. latitude controls on Sun energy
         b. seasonal controls on Sun energy
      2. Low latitudes have high Sun angle year round
   F. Incoming Solar Radiation
      1. Temperature Variation greater in areas closer to poles
      2. Temperature Distribution—affected by land-water relation as well as latitude
II. Weather and climate
   A. Controlled by two predominant factors
      1. latitude
      2. land-water relations
   B. creates patterns of
      1. temperature
      2. humidity
      3. cloudiness
      4. precipitation
      5. pressure and wind patterns
III. Composition of atmosphere
   A. mixture of gases
      1. lower atmosphere is evenly mixed: troposphere
         a. nitrogen: 78%
         b. oxygen: 21%
         c. Argon nearly 1%
         d. Water vapor variable up to 4%
            1) Dust and aerosols provide surfaces for condensation
            2) Condensation of water vapor into clouds releases latent heat
         e. Carbon dioxide 0.037%--increasingly released from geologic storage
      2. stratosphere above troposphere, marked by different temperature
         a. major gases about the same as troposphere

        b. contains most of ozone in atmosphere 20-30 km from surface
            1) ozone form of oxygen with three atoms, not two
            2) different properties:
                a) absorbs UV light from Sun: our natural sunscreen: highly ‘greenhouse’ property
                b) damaging to organism tissues
    3. outside the stratosphere, gases divided by molecular weight

IV. Structure of atmosphere
- A. Pressure diminishes with altitude
    1. Half of molecules are below 5.6 km
    2. Few are further than 16 km (10%)
- B. Temperature changes more complicated
    1. troposphere—turning over part
        a. heated from below, by reradiation from Earth
        b. lower density with altitude accounts for some of cooler temperature—fewer molecules to run into one another
        c. changes on average 6.5^{o} C per 1000 m—environmental lapse rate
        d. abrupt break where temperature stops decreasing--zone above troposphere is tropopause
    2. stratosphere—layer above troposphere: about 10 km
        a. temperature stable, then increases gradually
        b. most ozone is here: absorbs UV—causes the heating
    3. outer temperature zones
        a. mesosphere decreases again—no ozone
        b. thermosphere increase—direct radiation from Sun

V. Atmospheric heating
- A. Heat transfer
    1. radiation
    2. conduction
        a. through matter by molecular activity
        b. air is poor conductor of heat energy
    3. convection—heat rises
        a. transfer of heat by circulation within fluid
        b. caused by expansion of heated fluid reduces density
        c. lower atmosphere heated by Earth’s surface
- B. radiation
    1. electromagnetic spectrum
        a. gamma rays (short) to radio waves (long)
        b. visible light small short range
        c. ultraviolet shorter: sunburn rays
        d. infrared longer: heat waves
    2. all bodies emit radiant energy
        a. hotter bodies shorter
        b. cooler bodies longer
    3. emit at their temperature wavelength

        a. Sun emits short—UV and visible
        b. Earth emits longer—heat: energy absorbed from incoming solar radiation
  C. Gases of atmosphere selectively absorb or transmit radiation, depending on wavelength
    1. mostly transparent to visible
    2. absorbs much UV and shorter wavelengths in outer atmosphere: oxygen and ozone
    3. infrared absorbed by carbon dioxide and water vapor
        a. infrared from emission of energy absorbed from Sun
        b. heats atmosphere from below by radiation and conduction
  D. about ½ of incoming solar radiation absorbed by Earth's surface
    1. Albedo: reflection from clouds, snow, water—30%
    2. Scattering splits rays into numerous weaker rays: some to space
    3. Absorption by atmospheric gases
        a. Greenhouse effect
            1) glass does not transmit heat, but also rely on lack of mixing with outside air to keep them warm
            2) greenhouse effect of atmosphere makes life on Earth possible
            3) Water vapor and carbon dioxide instrumental greenhouse effect gases
        b. Oxygen and ozone absorb most of incoming UV wavelengths
  E. Mostly between Tropical circles, where direct rays fall
    1. seasonal variations in Sun energy from constant axial tilt toward Polaris
        a. solstice when direct rays most poleward—June 21 and December 21
        b. equinox when direct rays at equator—March 21 and September 21
        c. day length varies between extremes at solstices, equal on equinox
    2. additional causes of local temperature other than day length and Sun angle

VI. Temperature
  A. Measure
    1. daily minimum and maximum are recorded
    2. these used to calculate all other statistics
        a. Daily range: difference between high and low
        b. Daily average: mean of the two values
        c. Monthly average: mean of the daily averages for the month
        d. Annual Mean: mean of the monthly averages
        e. Annual range: difference between highest monthly average and lowest monthly averages
    3. maps of temperature plot 'isotherms'
        a. lines of equal temperature

            1) close—large differences across area
            2) far—small difference across area
        b. useful for comparing areas, or comparing different seasons
            1) seasonal shifts of high temperature
            2) land water contrasts notable
            3) ocean currents can affect temperature

B. Controls of temperature
    1. latitude
        a. Sun angle
            1) High: more energy per unit area
            2) Low: less energy per unit area
        b. Day length—greater variance at high latitude
        c. Amount of atmosphere to penetrate—greater amount at high latitude
    2. land and water
        a. water properties significant to heating differences
            1) water has high specific heat—can absorb much more energy with minimal change in temperature compared to land
            2) water is transparent—more than just surface is heated
            3) water is mobile—mixes cooler water with warmer
            4) water evaporates—
                a) heat of vaporization 540 calories per gram!
                b) Heat energy goes with the evaporated molecules
                c) Released upon condensation of the water
        b. Water moderates the temperature of areas
            1) Lower high temperatures
            2) Higher low temperatures
    3. Altitude
        a. Lapse rate 6.5^{o} C less per 1000 meters up
        b. Some reradation minimizes this lapse rate
    4. geographic position
        a. leeward or windward coast
            1) get weather from sea—milder
            2) get weather from land—harsher
        b. barriers—mountains block moisture
    5. cloud cover
        a. clouds reflect incoming radiation—albedo in day
        b. clouds absorb heat—greenhouse effect at night

VII. World temperature distribution

A. All of the above affect distribution—latitude most pronounced
    1. sun angle
    2. day length

B. Land-water contrast contributes to annual range
    1. coldest and hottest far from water
    2. most mild in -coastal tropical areas

C. oceanic currents transport heat from equatorial area toward poles

D. Maps are ‘adjusted’ for elevation (by lapse rate calculations)
   1. useful for comparing different times of year
   2. useful for noting anomalies, leading to investigations

VIII. Atmospheric moisture

A. Water changes phase from solid to liquid to vapor with transfer of heat between environment and water molecules
   1. this transfer of heat in evaporation/condensation moves heat as ‘latent heat’—hidden as energy is moved by water vapor
      a. latent heat of vaporization cools environment as it evaporates
      b. latent heat of condensation warms environment when droplets form
   2. sublimation and deposition are the change between solid and vapor
      a. ice cubes can evaporate by sublimation
      b. frost can form from vapor in the air

B. saturation with water—humidity
   1. amount of water the air can hold
      a. ways to measure
         1) mixing ratio—grams of water per kilogram of air
         2) relative humidity—percent of water compared to how much it could hold: more commonly reported, easier to measure
      b. changing relative humidity
         1) adding moisture
            a) above water bodies, especially hot springs
            b) plants, animals also contribute
         2) warm air can hold more moisture
            a) constant mixing ratio, increasing temperature will result in decrease of relative humidity
            b) cooling temperature, constant mixing ratio results in increase of relative humidity
               i. cools until air is saturated—100% relative humidity
               ii. condensation begins
                  a. latent heat is released to environment
                  b. temperature stops decreasing
               iii. this is the DEW POINT TEMPERATURE
         3) relative humidity changes throughout the day due to temperature change, with little change in mixing ratio
   2. measuring relative humidity
      a. comparing air temperature to depression created by evaporation the air can accomplish with its moisture content
      b. noting temperature at which condensation of water in a container that is gradually cooled