I. Axial Tilt and Orbit around Sun—
   A. Earth tilts 23.5^{o} 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

II. Heating
   A. Greater heating capability with higher Sun angle
      1. latitude controls on Sun energy
      2. seasonal controls on Sun energy
   B. Low latitudes have high Sun angle year round
   C. Incoming Solar Radiation
      1. Temperature Variation greater in areas closer to poles
      2. Temperature Distribution—affected by land-water relation as well as latitude

III. Heat—
   A. Thermal energy, transferred from warm substances to cooler ones
   B. Methods of heat transfer
      1. conduction—
         a. through matter by molecular activity
         b. air is poor conductor of heat energy
      2. 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
      3. radiation—through empty space
         a. Solar radiation is source of energy for weather and climate
            1) Electromagnetic radiation from radio waves to gamma waves
            2) Visible light small segment between infra-red and ultraviolet
               a) Infrared is heat
               b) Ultraviolet causes sunburn, etc.
            3) microwaves and x rays bracket ir and uv
         b. all objects emit radiant energy
            1) hotter object emit more, and at shorter wavelengths
            2) the better absorber of radiation, the better ability to emit energy
               a) Earth is excellent absorber and emitter
               b) Atmospheric gases selective absorbers of longer wave radiation

IV. Incoming solar radiation
- A. Absorbed, transmitted, redirected (reflected or scattered)
- B. Distribution
  1. about 50% is transmitted to surface and absorbed by Earth
  2. about 30% is reflected back to space
  3. about 20% absorbed by atmospheric gases and clouds
- C. reflection and scattering
  1. reflection—
     a. changing direction of light without reducing intensity
     b. Albedo—fraction of radiation reflected by a surface
        1) Affected by length of travel through atmosphere
        2) Affected by angle of incidence upon water
  2. scattering—
     a. disperses light into many weaker rays in many directions
     b. accomplished by dust, gas molecules
     c. diffuses light to make shadows have light
- D. absorption
  1. nitrogen poor absorber of radiation
  2. oxygen and ozone absorb most of uv radiation high in atmosphere
  3. most atmospheric gases do not absorb visible wavelengths—transmit

V. Atmosphere is mixture of gases, with varying proportions with respect to location and timing
- A. Nitrogen and Oxygen make up 99% of clean, dry air up to 80 km
- B. Minor components include argon (0.93%), and carbon dioxide (0.037%)
- C. Variable components affect weather and climate
  1. water vapor
     a. varies from almost none to up to 4% of atmosphere
     b. source of all clouds and precipitation
     c. absorbs heat from Earth and Sun
     d. change of water's phase captures or releases 'latent heat'
  2. aerosols and dust
     a. remain suspended for extended period of time
     b. sources include sea salt, blown soil, fires, pollen, volcanic eruptions
     c. act as surfaces for water vapor to begin condensation
     d. reflect and scatter incoming solar energy
  3. ozone
     a. molecular oxygen with three atoms has properties distinct from O_2
        1) damages tissue of organisms
        2) can be created near surface by reactions in smog
     b. concentrated 10 to 50 km above surface in stratosphere
        1) Sun's radiation breaks O_2 into O and O in stratosphere
        2) O collides with O_2 and forms O_3 at this altitude
        3) Lightning makes O_3 in troposphere
     c. Ozone important absorber of UV radiation

VI. Height and structure of atmosphere
- A. Pressure is weight of overlying air
  1. about 1000 millibars, 1 kg/cm^2, 14.7 lbs./in^2
  2. half of all atmosphere is below 5.6 km from surface (Mt. McKinley~6.2)
  3. beyond 16 km, less than 10% of atmosphere remains
  4. traces exist above 100 km, less than one millionth of it
- B. temperature variation with height
  1. troposphere—mixed zone includes most weather phenomenon
     a. temperature decreases with height in troposphere
     b. average temperature change is 6.5^o C/km
        1) normal 'environmental lapse rate'
        2) not constant, monitored by weather equipment
     c. average height of tropopause: 12 km
        1) height varies with location and temperature
        2) end of troposphere called 'tropopause'
     d. temperature and humidity can be transferred in troposphere by turbulence and mixing
  2. Stratosphere
     a. Stratosphere lacks mixing of troposphere
     b. Constant temperature to about 20 km
     c. Gradually increases to about 50 km, at the 'stratopause'
        1) Ozone concentrated in stratosphere absorbs UV energy
        2) This absorbed energy creates the increased temperatures
  3. Mesosphere
     a. Temperatures in mesosphere decrease with height to ~80 km
     b. Decreases to about -90^o C at 'mesopause'
  4. Thermosphere beyond mesopause
     a. Tiny fraction of atmosphere
     b. Subject to direct radiation from Sun
     c. Temperature increases to "1000^o C", but described by speed of molecules, not feeling of warmth, due to extremely low density

VII. Sun energy heats atmosphere
- A. Mostly between Tropical circles, where direct rays fall
  1. solstice when direct rays most poleward—June 21 and December 21
  2. equinox when direct rays at equator—March 21 and September 21
  3. day length varies between extremes at solstices, equal on equinox
- B. seasonal variations in Sun energy from constant axial tilt toward Polaris
- C. additional causes of local temperature other than day length and Sun angle
- D. Distribution of temperatures
  1. Cooler in polar areas
  2. Warmest at tropics in continental areas
  3. Warmness follows the direct rays of Sun: as it travels from tropic to tropic throughout year
  4. Oceanic currents warm western side of ocean basins, and the continents adjacent to them
  5. Oceanic currents cool eastern side of ocean basins and the continents adjacent to them.
- E. Heating of Atmosphere—greenhouse effect
  1. Atmosphere transmits about 50% of energy received to Earth's surface
  2. Absorbed energy by Earth's surface re-emitted as longer wavelength
  3. This longer wavelength is readily absorbed by atmosphere, not transmitted
     a. Result is lower atmosphere heated from Earth's surface
     b. WHY temperature decrease with distance from surface in troposphere
  4. Greenhouse effect
     a. Incoming light is absorbed by Earth
     b. Reradiated heat is trapped by carbon dioxide, water, methane
     c. glass does not transmit heat, but also rely on lack of mixing with outside air to keep them warm
     d. greenhouse effect of atmosphere makes life on Earth possible
     e. carbon dioxide instrumental greenhouse effect gas

VIII. Temperature of Earth locations
- A. Recording of temperature
  1. needs to be done without direct heating of Sun in sheltered places
  2. daily range is maximum minus minimum
  3. daily minimum and maximum temperatures averaged to 'daily mean T'
     a. monthly mean temperature is average of each daily mean Ts
     b. annual mean temperature is average of monthly mean temps
     c. these means used to compare one area to another, or compare one time to another within a certain area
  4. Isotherms are maps of temperatures
     a. Each isotherm connects the same temperature
     b. Intervals between isotherms constant
     c. Closeness of isotherms show the change in temperature over distance—called temperature gradient

IX. Controls of temperature
    1. mostly latitude
        a. variation of day length,
        b. angle of incoming Sun rays
        c. atmospheric thickness
    2. Land water relationship,
        1) Distribution of heat due to mobility and transparency of water
        2) Land has lower heat capacity than water,
            a) water heats more slowly than land, stores lots of heat
            b) land loses heat more rapidly and can become very cold
        3) evaporation is a cooling process
        4) Proximity to water moderates temperature
        5) Northern Hemisphere has greater range of temperature than Southern Hemisphere
    3. Altitude
        1) troposphere is heated from below, from reradiation of incoming Sun energy
        2) change in temperature
        3) called the 'lapse rate'
        4) 6.5^{o}C/1000 m from one altitude to another
    4. Geographic position, due to prevailing circulation of atmosphere and ocean currents
        a. with respect to sea and elevation
        b. also with respect to prevailing wind, topographic barriers and influence of ocean currents
            1) leeward coasts more continental in character, where windward coast more influenced by ocean (Eureka vs. NYC)
            2) mountain barriers block ocean effect (Seattle vs. Spokane)
    5. cloud cover affects albedo
        a. clouds reflect much solar radiation, keeping daytime temperatures lower than without clouds
        b. clouds absorb infrared radiation from surface and reradiate it back to surface, keeping nighttime temperatures higher
        c. snow and ice also reflect energy, rather than allowing it to be absorbed, acting to keep temperatures low

X. World Distribution of Temperature
    A. Commonly shown on maps of January and July
        1. maps corrected for elevation by adding environmental lapse rate
        2. show effects of latitude, distribution of land and water, ocean currents
    B. patterns
        1. decrease in temperatures from equator toward poles—
            a. latitude control is extremely important
            b. seasonal shift of warmer temperatures toward 'Sun' hemisphere
        2. extreme temperatures have additional controls of land and water
            a. hottest temperatures within tropics, but in continental areas
            b. coldest temperatures in continental northern areas
        3. oceanic currents can warm or cool an area
            a. notice summer isotherms where cold currents exist at eastern edge of Pacific Ocean
            b. Gulf Stream elevates temperatures in western Europe winter
    C. Distance from equator, and distance from ocean increase annual temperature range