ES 106 Clouds, Precipitation

I. Condensation and cloud formation
   A. Condensation nuclei necessary for clouds to form
      1. dust, pollen, salt, smoke
      2. at sub-freezing temperature, form by deposition of water vapor onto ice
   B. cloud types—all clouds are three basic shapes or combinations/modifications
      1. three predominant shapes
         a. cirrus—curl of hair
         b. cumulus—puffy masses
         c. stratus—layer or sheet
      2. three predominant levels
         a. high clouds—above 6000 m: often ice crystals
         b. middle clouds—from 2000 to 6000 m
         c. low clouds—less than 2000 m above ground level
      3. clouds of vertical development extend from low level to towering heights
II. Fog—cloud at the ground: Created by cooling other than lifting
   A. Advection fog from movement of warm, moist air over cooler surface (CA current)
   B. Radiation fog when ground cools on clear night—air cooled by conduction
   C. Upslope fog forms when humid air moves up topographic high ground
   D. Evaporation fogs
      1. steam fog—cool air moves over warm water
         a. warm water can evaporate, because molecules have high energy
         b. fog formed because cool air causes immediate condensation of vapor
      2. frontal fog or precipitation fog
         a. warm air lifted by frontal lifting results in rain
         b. rain falls through cold air below, condensation of vapor into fog in cold air

III. Precipitation

A. droplets formed on condensation nuclei or ice crystals too small to fall
   1. average size about 20 microns (0.02 mm)
   2. needs to be about 2 mm to fall (100 times as large)
   3. growth of droplets by Bergeron Process or collision-coalescence

B. Bergeron Process—mid latitudes and high latitudes
   1. ice forms in supercooled cloud upon impact with objects: at —10 ^{O} C
   2. ice crystal preferentially attracts water vapor over attraction of liquid droplets
   3. becomes too large to be supported, falls, melts into raindrops, or not

C. Collision-coalescence—low latitudes (Tropics)
   1. some large droplets begin to fall
   2. run into 20 micron droplets, etc., and become larger, fall faster
   3. coalescence may be function of electrical charge of droplets too

D. forms of precipitation
   1. rain—liquid droplets at least ½ mm in diameter
      a. from nimbostratus or cumulonimbus clouds
      b. drops larger than 4 mm break up into smaller drops
      c. less than ½ mm is drizzle, or mist
   2. snow—aggregates of ice crystals: fluffy or clumps depends on temperature
   3. freezing rain—sleet or glaze created when rain falls into colder air or onto subfreezing surfaces and freeze upon contact
   4. hail—ice balls from ½ cm to 5 cm (usually)
      a. created by updrafts in cumulonimbus clouds lifting ice balls
      b. successive trips allow numerous layer of ice to form
   5. rime, hoarfrost, pogonip—deposition from vapor onto surface

E. measuring precipitation
   1. standard rain gauge funnels water into narrow tube
      a. calibrated to area differences, to magnify the water height
      b. errors usually from high wind not allowing water to enter funnel
   2. snowfall measurements complicated by drifting
   3. annual precipitation maps show colored bands for annual rainfall
      a. drawn from data of many stations
      b. ALL classes between an area of low rainfall and high rainfall are shown, without leaving out those in between
      c. 40-60 is NOT next to 140 to 180, the 60 to 80, 80 to 100 and 100 to 140 are shown in between.
      d. Be sure you do this in lab next week!!
   4. weather radar shows water density of clouds, but inaccurate for snow

Air Pressure and Wind

I. Pressure
    A. 14.7 lab./in^2, exerted in all directions: up, down, sideways
    B. Measuring air pressure with barometer
        1. millibars—standard sea-level pressure: 1013.2 mb
        2. inches of mercury:
            a. rises in evacuated tube from pressure on open dish
            b. standard sea-level pressure: 29.92 inches
        3. aneroid barometer uses partly evacuated metal chamber
            a. high~fair
            b. low~storm
            c. overgeneralization
        4. barograph records pressure continuously

II. Wind
    A. Horizontal movement of air (advection)
        1. flows due to pressure differences: Pressure Gradient Force
            a. from high to low
            b. created by unequal heating of Earth's surface
        2. affected by surface friction
        3. affected by Coriolis Effect
    B. pressure gradient force
        1. maps drawn of pressure shown with isobars—equal pressure lines
        2. spacing of isobars shows the pressure gradient
        3. wind blows more strongly with larger pressure gradients
        4. initial direction from high pressure toward low pressure…but…
    C. Coriolis Effect begins to affect direction
        1. general mechanism
            a. deflected to right of their path in Northern Hemisphere
            b. deflected to left of their path in Southern Hemisphere
            c. regardless of direction of travel
            d. not affected at equator
        2. affect on wind flow
            a. changes direction at 90^O angle to wind flow
            b. does not affect wind speed
            c. wind speeds affect amount of Coriolis Effect
                1) greater speeds: more deflection
                2) slower speeds: less deflection
    D. friction of Earth's surface affects wind flow
        1. upper levels of atmosphere not affected by friction
            a. wind flow follows isobars:
            b. geostrophic winds
        2. slows wind speeds at lower levels of atmosphere
            a. reduces amount of Coriolis Effect—pressure gradient prevails
            b. surface winds directed toward low pressure at angle across isobars
            c. surface roughness affects amount of surface friction

III. High pressure and low pressure
   A. Low pressure called a ‘cyclone’
      1. northern hemisphere cyclones turn counterclockwise as winds blow inward toward low pressure and are deflected to right by Coriolis effect
      2. southern hemisphere cyclones turn clockwise by same effect
      3. flow inward results in surface convergence,
         a. creating uplift and storminess: due to expansion and cooling
         b. consequent divergence aloft—may become stronger than surface convergence and intensify cyclone
   B. High pressure called ‘anticyclone’ (the opposite of cyclone)
      1. winds flow outward
      2. surface divergence at center,
         a. convergence aloft where air drawn into area of divergence
         b. subsiding air precludes rainfall because it is compressed and warms
   C. these effects are the basis for ‘fair’ and ‘stormy’ indications on barometer
   D. isobar maps show high pressure ridges, and low pressure troughs
IV. General circulation of the atmosphere
   A. Greatest heating in tropics creates uplift of rising air
      1. flow from poles to equator would occur without Coriolis Effect or friction
      2. these break single circulation into smaller cells, with surface directions
   B. Idealized global circulation
      1. equatorial low created by Sun heating
         a. abundant precipitation
         b. 20-30^{O} N and S of equator
         c. Cooling aloft, and poleward flow at tropopause
      2. descending air about 30^{O} N and S of equator
         a. subtropical high pressure
         b. descending air does not rain—desert belts across Earth
      3. wind flow between equatorial low and subtropical high
         a. affected by Coriolis—turns wind: east to west flow
         b. creates **Trade Winds**
      4. poleward flow at surface from subtropical high deflected into Westerlies
      5. cold dense air from Polar High converges with Westerlies to create subpolar low
         a. Polar easteries occur here
         b. Polar front is interaction of cold polar air and warmer midlatitudes air
      6. Jet Streams are geostrophic winds created at the interaction of global circulation patterns
         a. Polar front jet stream at the polar front—Rossby waves
         b. Subtropical jet stream between tropical and midlatitudes air

7. continents interfere with idealized global circulation
    a. result is closed, semi-permanent pressure cells
    b. high pressure
        1) Pacific High—persistent
        2) Azores high—seasonal winter
        3) Siberian High—seasonal winter
            a) Results in offshore winds from Asia to Indian Ocean—dry
            b) Summer heating draws air off Indian Ocean—wet "Monsoon!"
        4) Bermuda High—seasonal summer
    c. Low pressure—seasonal winter: source of storms
        1) Aleutian low
        2) Icelandic low
8. Westerlies
    a. Coriolis Effect creates wind from west to east
    b. Interrupted by migrating cyclonic systems bringing weather
        1) Cyclones driven by upper level wind flow
        2) Upper level flow migrates seasonally
            a) Winter months allow storms further toward equator
            b) Summer month storms generally further poleward

V. Local wind systems created by local temperature and pressure differences
  A. Land and Sea Breezes
    1. heating land in daytime causes rising air
    2. air drawn in off sea is a 'sea breeze'
    3. nighttime cooling of land leaves sea warmer
    4. air drawn toward sea from land is 'land breeze'
  B. Mountain and Valley Breezes
    1. similar to Land and Sea Breezes, due to temperature changes
    2. daytime heating of slopes results in a 'valley breeze', more predominant in summer
    3. nighttime cooling of upper areas can chill air to descent slopes as 'mountain breezes', most predominant in winter
  C. downslope, strong, drying, warm winds have local names: Chinook, Santa'na, Mistral

VI. Measuring wind
  A. Winds named for the direction from which they come
  B. Prevailing wind describes the usual direction of wind
    1. sometimes indicated by slant of tree trunks, or branch density
    2. US has generally west winds: we are in the Westerly Wind Belt
    3. interference of migrating cyclonic systems
  C. anemometer measures wind speed
  D. some areas have very reliable predominant winds:
    1. knowledge of persistent pressure patterns helps predict these
    2. Trade Winds are example

VII. El Nino and La Nina
  A. Interruption of Trade winds and equatorial oceanic current
  B. Consequent see-saw of pressure centers in southern hemisphere