G476/576 Overview of Precipitation Meteorology

I. HUMIDITY, CONDENSATION, AND PRECIPITATION

A. Terminology

1. Humidity- amount of water vapor in air
2. Vapor Pressure- total atmospheric pressure that can be attributed to water vapor content
3. Vapor Saturation- maximum amount of water vapor the air can hold,
   a. rate of evaporation = rate of condenstation
   b. "Vapor Capacity"- measure of amount water vapor air can hold
   c. Temperature dependent
      (1) >T, air can hold more moisture (>expansion of volume, > motion of molecules)
      (2) <T, air can hold less moisture (< expansion of volume)

Temp. C	Vapor Capacity (gm/kg)
-40	0.1
-20	0.75
0	3.5
10	7
20	14
30	26.5
40	47

      (3) Thus by taking an unsaturated system to lower temperature, system can become saturated

4. Specific Humidity- amount of water vapor contained in unit of air (expressed as wt. of vapor/mass of air = gm/kg)
   a. not affeted by changes in pressure or temperature

5. Relative Humidity- ratio of airs water vapor content to its water vapor capacity at a given temperature

for given temp.

$$R.H. = \frac{\text{water vapor}}{\text{vapor capacity}} \times 100\%$$

E.g. referring to table above, given a temp of 20 C, vapor capacity of air is 14 gm/kg. Assume a specific humidity of 7 gm/kg, relative humidity = 7/14 x 100% = 50%

   a. Temperature influence on relative humidity

Relative humidity changes with temperature according to vapor capacity of air. In example above at 20 C, vapor capacity is 14 gm/kg, assuming a specific humidity of 7 gm/kg, relative humidity = 7/14 x 100% = 50%.

By decreasing the temperature to 10 C, vapor capacity of air is now 7 gm/kg, assuming the same specific humidity of 7 gm/kg, the relative humidity = 7/7 x 100% = 100% humidity.

Vapor capacity must be exceeded to oversaturation for condensation/precipitation to occur

(1) In sum: a decrease in air temperature will result in an increase in relative humidity, and an increase in air temperature will result in decrease in relative humidity

(2) <T, > R.H.; >T, < R.H.

(3) In terms of absolute air moisture...

(a) cold air contains less specific humidity than warm air, although cold air relative humidity and warm air relative humidities may be identical (e.g. 85%), the vapor capacities are different, and the warm air will have much more moisture than cold air at same relative humidity

6. Dew Point Temperature

a. Temperature at which air would have to be cooled in order to reach saturation

(1) at temperatures colder than dew point, air vapor capacity is exceeded and condensation would occur

7.Atmospheric Precipitation – condensation of atmospheric moisture below dew point

a.condensating nuclei in atmosphere (dust)

b.aggradation of microscopic cloud droplets into rain drops

c.measurement – rain gage collection device at point locations

i.measured in inches or mm of precip as collected in gage

II. Evaporation

A.Defined – addition of heat energy to water surface, transformation from liquid to vapor phase

1.Heat of Vaporization = 590 cal / gram to transform from liquid to vapor
2. Evaporation of water at surface-air interface (lakes, rivers, etc)
3. evaporation driven by solar radiation

B.Evaporation = portion of outflow from drainage basin

C. Measurement of Evaporation

1.Pan Evaporation – water placed in shallow pans, measure volume of evap.

a. varies according to temperature and wind speed

III. FORCEFUL LIFTING (A Mechanism for Lifting and Cooling Air)

A. Air may be forced upward regardless of stability of air mass or adiabatic processes

B. Methods of Forceful lifting of air

1. Convergence- flowing of air masses together, occupies less space, air column forced to rise vertically
a. air forced to rise upward
b. enhances instability
c. E.g. Florida: on warm summer days
(1) Atlantic air flow westward over land
(2) Gulf air flow eastward over land
(a) convergence + vertical uplift + intense solar heating = high rate of thunderstorm occurrence (greatest occurrence in U.S.)

2. Orographic Lifting- sloping terrain/mountain slopes act as barriers to air flow, forces air to ascend
a. Rain fall on windward side, rising moist air masses, <Temp during ascent, >saturation point.... rain
(1) e.g. Mt. Waialeale Hawaii: 38 Ft rain/yr
b. Lee sides: dry air descends... orographic deserts
(1) Rain shadow deserts
(2) e.g. Columbia Basin of Wash, Mojave of Calif.

3. Frontal Wedging- cool air acts as a barrier over which warm, less dense air rises
a. Responsible for rainfall patterns over much of continental U.S.
(1) Cold Fronts moving in from w-nw, forcing warm continental air above
(a) Arctic/Canandian cold fronts moving into US

(2) Warm Fronts moving in from w-nw, riding over cold

IV. FACTORS AFFECTING WIND

A. General
1. Wind = horizontal movement of air (advective motion)
2. Wind and Pressure
a. basic gas law: air of higher pressure moves towards air of lower pressure
b. wind = drive toward equilbrium of air pressure
3. Pressure Differences on Earth's Surface
a. Caused by unequal heating of atmosphere by sun
b. Variable solar insolation due to tilt of earth, orbital path, latitudinal changes

B. Factors Influencing Air Motion
1. General : if earth did not rotate and there were no friction of air motion, wind would be simply controlled by air motion from high pressure to low pressure

2. Influencing factors
a. Pressure Gradient Force- degree of pressure changes per unit distance
b. Coriolis Effect- motion on rotating objects/centrifugal force
c. air friction- resistance to flow

C. Pressure Gradient Force

1. Pressure variation = wind
   a. > press. diff, > wind speed
2. Mapping air pressure
   a. pressure contour maps
   b. isobars = lines on constant air pressure

3. Pressure Gradient = $\frac{\text{change in pressure}}{\text{unit distance}}$
   a. gradient to hill
      (1) steeper the hill (pressure gradient)
         (a) > press. gradient, > wind acceleration
         (b) > close spacing of isobars

      (2) gentler the hill slope (pressure gradient)
         (a) < press. gradient, < wind acceleration
         (b) widely spaced isobars

4. Coriolis Effect
   a. Coriolis = apparent shift due to rotation and velocity variation by latitude
      (1) Earth rotating in counterclockwise direction as viewed from north pole
      (2) Net result:
         (a) Northern Hemisphere: air deflected to right in the direction of travel
         (b) Southern Hemisphere: air deflected to left in direction of travel
   b. View from north pole
      (1) counter clockwise rotation
      (2) air deflection to right, due to coriolis
   c. View from south pole
      (1) clockwise rotation
      (2) air deflection to left, due to coriolis

   d. Coriolis relationships
      (1) deflection always directed at right angles to direction of airflow
      (2) deflection affects only wind direction, not wind speed
      (3) deflection affected by wind speed
         (a) > speed, > deflection

5. Friction
   a. friction of air motion with earth's surface/topography
   b. acts to slow wind velocity
      (1) tends to deflect wind via "refraction"
      (2) friction effects prominent to 2000 Ft altitude
   c. rough mountainous landscape: > friction
   d. smooth ocean surface: < friction

6. Air motion and Isobars

   a. in frictionless, non-rotating environment, air motion perpendicular to isobars

b. Coriolis + friction effects ------

(1) Upper level (high altitude) airflow parallel to isobars

(a) Jet stream: "rivers of air" flowing at 75-150 mph at upper altitudes (reduced friction > speed)

(2) near-surface air flow winds cross isobars at an acute angle

V. CYCLONES AND ANTICYCLONES

A. General

1. Cyclones: low pressure center

2. Anticyclones: high pressure center

B. Cyclonic and Anticyclonic Winds

1. Cyclones

a. Northern Hemisphere

(1) low pressure center (influenced by coriolis and friction)

(2) winds blow inward and counterclockwise around the low

b. Southern Hemisphere

(1) winds blow inward and clockwise

2. anticyclones

a. Northern Hemisphere

(1) high pressure center

(2) winds blow outward and clockwise around the high

b. Southern Hemisphere

(1) winds blow outward and counterclockwise

C. Weather Generalizations about Highs and Lows

1. Rising air: associated with clouds/precipitations

2. subsiding air: adiabatic heating and clearing conditions

3. Cyclone: low pressure system

a. inward flow of air

b. winds converge to center

(1) air pile up

(2) pushes air upward

(3) > pressure due to rising column of coverged air (a paradox, low pressure results in > pressure)

(4) rising air cools adiabatically---- clouds/condensation---precipitation associated with low pressure system

4. Anticyclone: high pressure system
    a. outward flow of air
    b. winds diverge from center
        (1) air descends and thins
        (2) pushes air downward
        (3) descending air is compressed and warmed
        (4) air moisture vaporizes and clears
5. Short range weather predictions
    a. barometric tendency
        (1) rising barometeter: high pressure system approaching, clearing weather
        (2) falling barometer: low pressure system approaching, clouds and rain
    b. Cyclones---- rain
    c. Anticyclones---- clear

I. AIR MASSES

A. General

1. Air Mass - immense body of air, characterized by homogeneity of temperature and moisture at any given altitude
    a. 1000 miles or more in breadth
    b. Passes through area over the course of days
        (1) e.g. Summer: heat wave, high temps, high humidities
            (a) ends with series of thunderstorms and few days of cooler weather
        (2) e.g. Winter: frigid clear, subzero cold spell
            (a) ends with thick stratus clouds, rising temps. and snowfall.

2. Front: boundary between two adjoining air masses having contrasting characteristics
    a. passage of a front marks a change in weather

B. Source Regions

1. Source Region: area of earth's surface over which air masses assume their distinguishing characteristics
2. Types of Air Masses
    a. Classified According to Latitude and Temperature
        (1) Polar (P) air masses
            (a) originate in high latitudes
            (b) cold air mass temps.
        (2) Tropical (T) air masses
            (a) originate in low latitudes
            (b) warm air mass temps
    b. Classified According to Geographic Source and moisture
        (1) Continental (C) designates land source
            (a) On the dry side
        (2) Maritime (M) designates ocean/water source
            (a) On the wet side

c. Four Basic Types of Air Masses
(1) Continental Polar
(a) On dry and cold side
(2) Continental Tropical
(a) On dry and warm side
(3) Maritime Polar
(a) On wet and cold side
(4) Maritime Tropical
(a) On wet and warm side

II. FRONTS

A. General
1. Fronts- boundaries that separate air masses of different densities
a. one warmer and often higher in moisture
b. avg. 15-200 km wide, narrow compared to breadth of air mass
2. Vertical Configuration
a. Warm air: less dense
(1) warm air over cold air (more dense)
(2) warm air/cold air interface often sloping/wedge shaped at low angle
b. Fronts often collisional in nature
c. Always warm air forced aloft, with colder bottom air acting as a wedge

B. Warm Fronts
1. warm air moves over wedge of cold air
a. map symbol: line with semi-circles extending into cold air
2. Average slope of warm front: 1:200 (V:H)
3. Ascending Warm Air
a. cooling by adiabatic expansion
b. often clouds and precipitation
(1) several hours of gentle precipitation over large region
(a) gentle slope of front does not encourage convective activity
c. Increase in temperature

C. Cold Fronts
1. cold air moves into region of warm air
a. map symbol: line with triangular barbs extending into warm air
2. Average slope of cold front: 1:100 (V:H)
a. steeper than that of warm front
b. cold fronts in general advance more rapidly than warm fronts

3. Actively forces warm air aloft
a. cold fronts produce more violent weather
(1) sudden downpours
(2) wind gusts
(3) >intensity, < duration compared to warm front

4. Behind Front

a. cold air mass, subsiding air
b. Often clear and cold behind the front

D. Occluded Fronts
1. Cold front over takes a warm front
2. Wedging of warm air aloft between two cold air masses
3. Complex weather patterns/ heavy or light rain possible

III. MIDDLE LATITUDE WAVE CYCLONES (LOW PRESSURE SYSTEMS)
A. General
1. At Middle Latitudes (Like U.S.)
a. Cold and Warm Front Activity Commonly Associated with Low Pressure Systems
(1) Cyclone = low pressure system, counterclockwise rotation
(a) Common Harbringer of Rainfall to Central and Eastern U.S.
(2) "Wave" Cyclone- refers to a low pressure system comprised of cold and warm air, with the front commonly bending into a swirling low pressure system

B. Role of Upper Level Jetstream in Maintaining Low Pressure System
1. Cyclone: low pressure system with converging air drawn inward
a. with inward flow, if there were no mechanism for air escape, the low pressure area would eventually "fill up" with converging air and cease to exist

(1) However, we know that low pressure systems can exist for low periods of time, migrating across U.S.

2. Upper level air flow
a. With converging air into low pressure system, air is piped to higher altitudes aloft, where it escapes the low pressure zone into the upper jetstream
(1) "piping" of air through the low to the jet stream allows low pressures to be maintained in the cell over longer periods of time
(a) otherwise the cell would "fill up" and the pressure would rise

b. Air flow aloft also helps direct and mobilize cyclonic systems through shear flow

3. Moral of the story: air flow aloft, is important in maintaining and influencing lower level weather patterns

IV. HURRICANES
A. Hurricanes- whirling tropical cyclones with wind speeds up to 185 mph
1. highly destructive because of high winds in coastal areas
2. may form 50 "storm surge" waves

B. Character

1. Form in tropical waters between 5 and 20 Latitude
    a. Atlantic = "Hurricanes"
        (1) U.S. avg. = 5/yr
    b. Pacific = "typhoons"
        (1) N. Pacific highest no. of occurrence =20/yr
    c. Indian = "Cyclones"
2. Characteristics
    a. wind speed = > 74 mi/hr
    b. rotary counterclockwise circulation
    c. Dimensions
        (1) D=375 mi
        (2) Height = up to 40,000 Ft altitude
    d. Low pressure centers
        (1) outside press. - inside press. = 60 millibars
        (2) steep pressure gradient
        (3) inward, converging, spiraling winds
    e. Upper level air flow
        (1) divergent and outward, maintaining the low pressure center of the storm
3. Morphology
    a. Eye of Hurricane
        (1) low pressure center of cyclone
            (a) avg. 12 mile in Diameter
            (b) zone of calm and scattered clould cover
            (c) warm zone
    b. swirling rotation of storm function of coriolis effect

4. Process
    a. Hurricane = heat energy built up and liberated by release of water vapor
    b. hurricanes form over oceans in late summer, with abundant warm moist air plentiful
        (1) water temps to 80 F, warm moist overlying air
        (2) can not form in cool water temps, hence limited latitudinally
    c. Storm Progression
        (1) Tropical depression- cyclone with wind speed < 38 mi/hr
        (2) Tropical Storm- cyclone with wind speed 38-74 mi/hr
        (3) Hurricane - cyclone with wind speed > 74 mi/hr
        (4) Land docked hurricane
            (a) loses moisture source
            (b) frictional effect of land slows winds
            (c) pressure gradient dissipated

C. Identification
1. weather satellit imagery
2. storm tracking and prediction
3. emergency management and contingency in coastal areas