I. Air Masses
   A. Defined: large body of air, 1600 km or more across, with similar temperature and moisture at similar altitudes
      1. Brings these characteristics with it as it moves to different areas
      2. example
         a. Canadian continental air mass goes to Mexico
         b. Air mass temperature changes, but brings its cold characteristics
      3. Boundary between air masses called ‘front’
   B. Source regions indicated by simple code—tells you what air mass is like
      1. Polar vs. Tropical:
         a. Designation of temperature
         b. capital P and capital T after the little letter
            1) P: cold—polar, from high latitudes
            2) T: warm—tropical, from low latitudes
      2. maritime vs. continental:
         a. designation of moisture content
         b. little m and little c at beginning of symbol
            1) m: moist—maritime: from sea
            2) c: dry—continental: from land
   C. Weather due to movement of air masses
      1. Lake Effect snow due to movement of continental polar air mass
         a. cold air moves over Great Lakes
         b. acquires warmth and moisture from water of lakes
         c. moves over cold land, and snow result of cooling of moist air
      2. Maritime tropical air from Gulf of Mexico, Caribbean Sea, Equatorial Atlantic Ocean
         a. Warm, moist, unstable air moves onto North America in summer
         b. High temperature, humidity, most of rainfall of eastern 2/3 of continent
      3. few continental tropical air masses affect North America
      4. maritime polar air masses
         a. often originate as Siberian continental polar air masses
            1) gain moisture on travel across Pacific Ocean
            2) orographic uplift results in precipitation in intermountain west
         b. Nor’easters are also maritime polar air masses
II. Fronts—the ‘not-mixing’ of air masses
   A. narrow bands between contrasts of temperature and moisture
   B. slope at low angle, with warmer air above cooler air
   C. named for type of air that is displacing the type present: idealized descriptions follow, actual weather associated with a front may vary
      1. warm fronts bring warm air
         a. warm air rides over cold air in place
            1) ground friction inhibits movement of cold air in place
            2) difficult to move out of the way
         b. gently sloping wedge of cold air carries warm air aloft
            1) 1:200 common—1 km up for 200 km ground distance
            2) adiabatic cooling creates clouds and precipitation
               a) sequence of clouds associated with approaching warm front
               b) cirrus to cirrostratus to alto stratus to nimbostratus
               c) light to moderate precipitation common with warm fronts
         c. shift in wind direction commonly indicates passage of front
         d. designated with red lines and half-circles on advancing side

2. cold fronts force warm air present to ascend
    a. steeper angle of front created by pushing warm air up—1:100
    b. cold fronts advance faster than warm fronts
    c. more active weather associated with cold fronts
        1) heavy downpours
        2) strong winds, gusty
    d. designated with blue line and triangles on advancing side
3. occluded fronts
    a. when cold front catches warm front
    b. result is sudden uplift of all of the warm air present
    c. dissipates due to lack of more warm air to lift

III. Mid-latitude Cyclone—30^{O} to 60^{O} latitude

A. Large centers of low pressure moving in the westerly wind belt
1. circulation inward around low pressure
2. generally contain a cold front and a warm front, extending from the center of the low pressure, toward the outward edge
3. convergence toward center of low, and frontal lifting create weather associated with mid-latitude cyclones

B. Life cycle generally lasts a week or two
1. development well predicted by air mass interaction model
2. initial clash of unlike air masses,
    a. traveling in opposite direction along front
    b. wave develops along front due to irregularities present
3. wave changes surface air flow, pressure patterns
    a. Low pressure situated at the apex of the wave
    b. result in nearly circular isobars—cyclonic flow!
    c. Uplift and precipitation created by
        1) Convergence toward low pressure
        2) Frontal development along unlike air masses
4. cold front moves faster than warm front—catches it!
    a. Occlusion begins as this starts to occur, from low pressure outward
    b. Intensifies storm as this step is initiated
    c. Forcing all warm air aloft ends mid-latitude cyclone

C. Passage of a mid-latitude cyclone—see figure in book
1. point A
    a. cirrus clouds when front is 1000 km away, pressure falling
    b. 12-24 hours later, light rain begins, temperature rises, wind shifts
2. point C and D
    a. starts with warm southwesterly breezes
    b. replaced by cooler gusty west or northwest winds
    c. precipitation along cold front—wind shift as it passes
3. point F and G
    a. greatest intensity of storm
    b. temperatures remain cold at surface
    c. passage of warm air aloft results in storminess

D. Airflow aloft relation to cyclone-anticyclone systems
1. maintains the persistence of the cyclones and anticyclones
2. divergence aloft keeps cyclone from filling and dissipating
3. surface air from anticyclone feeds cyclone
4. convergence aloft maintains anticyclone

IV. Cyclone
   A. Circulating storm system
   B. Alternative meanings
      1. hurricane (Most cyclones are not hurricanes)
         a. Hurricane: defined by wind speed, area of origination
         b. Smaller than mid-latitude cyclones (typically 600 km across)
         c. Often have greater pressure differences from center to edge
      2. tornado
         a. small (1/4 km), extremely violent cyclones
         b. extreme pressure gradient creates incredible wind speeds

V. Thunderstorms
   A. Occurrence
      1. clouds of vertical development created by absolute or conditional instability
         a. single cumulonimbus cloud, or clusters over large area
         b. within tropical maritime air masses that have moved into continent, lifted by daytime heating, often shortlived
         c. orographic or frontal lifting of warm moist air makes larger set
      2. characteristics
         a. must have thunder and lightning
         b. commonly has gusty winds, intense rainfall, hail
         c. may also have microburst or tornado development
      3. statistics
         a. 2000 thunderstorms in progress at any time
         b. there are 6000 lightning strikes/min. worldwide
         c. Florida has most thunderstorms per year in US
   B. Development—need uplift of warm, moist air
      1. latent heat released with condensation creates unstable conditions
      2. cumulus stage commonly produced by daytime heating
      3. mature stage reached with unstable conditions leading to cooling
         a. adiabatic expansion cools air
         b. reaches dew-point temperature, but continues to rise
         c. requires there to be condensation for continued cooling
         d. downdrafts associated with consequent rainfall
      4. dissipation stage reached when downdrafts dominate, surface is cooled by rainfall/hail
   C. Lightning safety considerations
      1. fully enclosed vehicles with windows closed conduct electricity around them—rubber tires not significant insulation from ground
      2. get away from high or exposed places
         a. open fields, peaks, lakes isolated trees
         b. towers, metal fences, flagpoles, open vehicles
      3. do not use electrical or plumbing fixtures inside during lighting storms
         a. telephone, light switches, cable TV connections
         b. faucets, shower
      4. If you can hear it or see it, take action!—
         a. don’t’ wait for rainfall
         b. don’t go out too soon—it can get you after it passes

VI. Tornadoes—local storm of short duration associated with thunderstorms
   A. Characteristics
      1. large pressure drop (to 10%) over short distance (250 m) results in extreme pressure gradient
      2. creates extreme wind speeds (can be over 450 km/hr!!)
      3. wind spirals inward, convergent lifting into parent thunderstorm
      4. many have multiple suction vortices circulating around central core
   B. Occurrence
      1. most thunderstorms do not produce tornadoes
         a. tornado development favored if thunderstorm complex becomes a 'mesocyclone'—vertical cylinder of rotation 3-10 km across
         b. tornadoes associated with hurricanes, strong cold fronts
      2. atmospheric conditions
         a. commonly at cold front of a mid-latitude cyclone
         b. contrasting air masses in central US in springtime
            1) continental polar air meets maritime tropical air
            2) few topographic barriers to keep them apart
      3. climatology
         a. average 1200/year in US
         b. most occur from April to June, but can happen in any month
   C. Development
      1. characteristics
         a. wind speeds within tornado estimated up to 500 km/hr
         b. 150 to 600 m across
         c. Travels at average 45 km/hr across landscape—
            1) Ahead of cold front so
            2) usually from SW toward NE
         d. Cuts path of about 10 km long for 'documented' tornadoes
            1) Most are weak, shortlived
            2) Occasional ones cause devastation in 1 km path for 150 km
      2. destruction
         a. Fujita intensity scale determined by damage of strong winds
         b. Winds cause damage, flying debris causes injuries
      3. forecasting
         a. important because of potential destruction and injury
            1) difficult because of minute size in large weather system
            2) forecast of severe thunderstorms can be up to a day ahead
         b. watches and warnings
            1) 'watch' alerts people to possibility
            2) 'warning' issued when tornado has been sighted, or is indicated on radar, indicates direction and speed of tornado
         c. Doppler radar can detect motion of mesocyclone—its circulation!
            1) Sharp gradients of wind speeds can be seen
            2) Crescent shape in wind speed plot indicates likely tornado

VII. Hurricanes—tropical cyclones, typhoons

A. Characteristics

1. form between 5 and 20^{O} of equator, most in Pacific, north of equator
2. wind speed greater than 119 km/hr
3. average 600 km across, 12 km high into atmosphere (base of stratosphere)
4. pressure drop from edge to center commonly 50 millibars (1.5 in Hg)
    a. pressure gradient results in high wind speeds
    b. convergence creates uplift
5. components
    a. eye wall of cumulonimbus towering clouds
        1) greatest wind speeds at eye wall
        2) heaviest rainfall from towering cumulonimbus there
    b. circular shaped eye in center
        1) nearly windless
        2) weakly subsiding air not strong enough to be cloudless
    c. trailing bands of cumulonimbus around eye wall

B. Development

1. high water temperatures in tropical ocean fuels formation
    a. uplift creates inflow, Coriolis effect creates circulation
    b. Cannot form within 5^{O} of equator, because Coriolis is too weak
2. tropical disturbances organize with rotation
    a. release of latent heat warms storm system, enhances uplift
    b. pressure drop at center creates pressure gradient
        1) increases wind speeds
        2) brings ‘fuel’: warm moist air that will lift
    c. divergence at top of storm enhances inflow at surface
3. wind speed determines what the disturbance is
    a. tropical depression: less than 61 km/hr
    b. +61 km/hr=tropical storm—get a name at this point
    c. +119 km/hr—designated hurricane
4. movement of storm causes it to gain or lose strength
    a. over land or cooler water—loses energy source: diminishes
    b. over warm water—intensifies

C. Destruction

1. loss of life has been minimized by excellent forecasting
2. property damage has been rising: greater development in coastal areas
3. causes of destruction
    a. storm surge 2-3 m above tide level
        1) most common cause of property damage and death
        2) created by intense low pressure, and wind push of water
        3) greater impact if storm has landfall at high tide
    b. wind damage
        1) greater area affected than storm surge
        2) poorly built structures, flying debris
        3) some tornadoes imbedded in hurricanes
    c. inland flooding—100s of km from storm center
        1) several inches of rain even after winds subside
        2) outlying areas actually may benefit from rainfall