Chapter 8: Air Masses, Fronts, and Middle-Latitude Cyclones

1. Air Mass: body of air with very little horizontal variation in temperature or humidity at any given altitude
2. Source region, ideal source region characteristics
3. Air Mass classification: know general characteristics, typical associated weather and primary source regions for North America for each type, cP, cA, mP, mT, cT
4. Lake effect Snow: conditions and locations
5. Front: transition zone between air masses of different density (temperature and usually dew point)
6. How the different fronts are shown on a map
7. Stationary front, surface winds and typical weather
8. Cold front
   a. surface winds; typical weather sequence, Table 8.2, p. 224
   b. “structure” of a cold front
   c. average speed (15–25 knots) and slope (1:50)
9. Warm front
   a. surface winds; typical weather sequence, Table 8.3, p. 226
   b. “structure” of a warm front, overrunning, frontal inversion
   c. average speed (10 knots) and slope (1:200)
10. Occluded front
    a. typical weather sequences, Table 8.4, p. 229
    b. “structure” of both cold-type (coldest air behind the front) and warm-type (coldest air ahead of the front) occlusions
11. Polar front theory (or Norwegian Front Theory)
    a. process from frontal wave to occluded cyclone – Figure 8.25, p. 230
    b. open wave, warm sector
12. regions of cyclogenesis, lee-side lows – Figure 8.28, p. 232
13. vertical structure – Figure 8.30, p. 234 and 8.32, p. 236
    a. stable and unstable waves, upper-wind flow controls stable vs. unstable
    b. convergence; divergence
    c. ideally upper-level low located west of surface low
    d. upper-level divergence > surface convergence then low strengthens (decreased surface pressure)
    e. upper-level divergence < surface convergence then low weakens (increased surface pressure)
    f. upper-level convergence > surface divergence then high strengthens (increased surface pressure)
    g. upper-level convergence < surface divergence then high weakens (decreased surface pressure)
    h. cyclone velocity: 16 knots in summer, 27 knots in winter
14. upper-level waves
    a. longwaves, planetary waves, Rossby waves: 3-6 around globe, travel < 8 knots
(even retrograde)
b. shortwaves
   i. move like the wind at the 700-mb level, shorter shortwaves move faster
c. cold advection: transport cold air from a cold region to a warmer region
d. warm advection: transport warm air from a warm region to a cooler region

15. polar lows and arctic fronts

Chapter 9: Weather Forecasting

1. Mission of National Weather Service
   a. Generation of Watches, Warnings, and Advisories
   b. Protection of life, avoid property damage

2. Acquisition of Weather Information
   a. surface stations, radiosonde data, ASOS data
   b. data reported to World Meteorological Centers
   c. transferred to National Center for Environmental Prediction - compile weather maps and charts (global and national)
   d. data received by the National Weather Service
      i. generate regional forecasts
      ii. generate **watches** (conditions favorable to hazardous weather are occurring)
      iii. generate **warnings** (hazardous weather is occurring or is imminent)
   e. local stations may modify forecasts for local conditions

3. Forecasting Methods
   a. problems with computer models
      i. assumptions about how the atmosphere works and what is important
      ii. boundary problems
      iii. sparse observations
      iv. grid spacing too large
      v. inadequate treatment of surface features
      vi. chaos
   b. ‘basic’ forecasting methods
      i. **persistence forecast**
      ii. steady-state or trend forecast
      iii. analogue method, pattern recognition, or weather types
      iv. ensemble forecast
      v. climatological forecast
   c. the interpretation of a percentage or probability forecast
   d. **accuracy** (correctness of the forecast) and **skill** (better than a persistence or a climatological forecast) in forecasting

Chapter 10: Thunderstorms and Tornadoes

1. Thunderstorm triggers
   a. random, turbulent eddies that lift small bubbles of air
   b. unequal heating at the surface
   c. the effect of terrain (such as small hills) or the lifting of air along shallow boundaries of converging surface winds
   d. diverging upper-level winds, coupled with converging surface winds and rising air
e. large-scale uplift along mountain barriers or gently rising terrain
f. warm air rising along a frontal zone

2. Ordinary Thunderstorms
   a. life cycle: cumulus stage, mature stage, dissipating stage, lasts about 1 hour
   b. entainment, updraft, downdraft, cell, overshooting, multicell storms

3. Severe Thunderstorms
   a. definition: hail ≥ 3/4 inch, surface wind gusts ≥ 50 knots, produce tornadoes (any one or more)
   b. gust front, mesohigh, downburst, microburst, macroburst, wind shear
   c. Supercell storm
      i. structured to be self-sustaining
      ii. very high updrafts, large hail, tornadoes, high surface winds, sometimes corkscrew shape (LP supercell)
      iii. high precipitation supercell, low precipitation supercell
   d. squall line, pre-frontal squall line thunderstorms, ordinary squall lines
   e. flash floods
   f. mesoscale convective complex: organized thunderstorms lasting up to 12 hours
   g. motion of thunderstorm

4. Distribution of thunderstorms: maximum in Florida, minimum along Pacific Coast, small bump in Colorado

5. Distribution of hail: peak in Colorado, Wyoming, Nebraska, Kansas

6. Lightning and Thunder
   a. ~20% of strokes are cloud-to-ground
   b. current typically 18,000 amps, temperature up to about 30,000°C
   c. what causes thunder?
   d. speed of sound (330 m/sec, 1100 ft/sec), 3 sec/km, 5 sec/mi
   e. thunder heard when lightning is 100 m to 5 km away
   f. electrification of clouds
      i. probably from falling hail or graupel colliding with rising ice crystals or supercooled water
      ii. top positive, middle negative, bottom mostly negative with positive regions
   g. lightning stroke (cloud-to-ground)
      i. induced charge below the cloud
      ii. step leader usually starts at negative end (base of cloud), advances about 50 m/step
      iii. return stroke goes the opposite direction - most of the current
      iv. dart leader for successive strokes
      v. forked lightning, ribbon lightning, ball lightning, sheet lightning, heat lightning, corona discharge, St. Elmo’s fire, sprites, ELVES, jets
   h. lightning detection
   i. lightning safety
   j. first aid for lightning strikes: most important is CPR; burns are usually on the surface
7. Tornadoes
   a. “rapidly rotating winds that blow around a small area of intense low pressure”
   b. funnel cloud
   c. typical characteristics: direction or rotation, size, motion, duration
      i. most rotate counterclockwise, rare to have clockwise rotation (about 2%)
      ii. typically 100-600 m wide, up to 1600 m
      iii. generally move toward northeast at 20-40 knots, up to 70 knots
      iv. average life of a few minutes, 7 km path, up to 7 hours and 470 km
   d. life cycle: dust-whirl stage, organizing stage, mature stage, shrinking stage, decay stage
   e. tornado families and tornado outbreaks (6 or more in the same storm)
   f. occurrence: where, when (U.S. has the most of any country)
   g. winds
      i. typically 125 knots, up to 280 knots, 75% ¡ 100 knots
      ii. wind speed - usually highest on the tornado’s right due to addition of rotation
         and translation speeds
      iii. multi-vortex tornado and suction vortices (about 10 m diameter)
      iv. Enhanced Fujita scale - based on damage, not on measured wind speeds
      v. be acquainted with which is considered weak, strong, or violent, and have a
         rough idea of relative wind speeds (exact values are not necessary)
      vi. about one EF5/year, a few percent are over EF3
   h. formation
      i. understand the “typical” conditions for formation
      ii. typical vertical temperature profile - weak inversion stops small thunderstorms; only strong storms will develop
      iii. convective instability
      iv. vertical wind shear necessary to develop the rotation; mesocyclone forms (5-10 km across) in the middle of the cloud and descends; mesocyclone stretches vertically and shrinks horizontally, turns into tornado cyclone (2-4 km across) which may descend from the cloud
      v. waterspouts; “rotating column of air over a body of water”
      vi. gustnadoes form at the gust front
      vii. landspouts and fair weather waterspouts are weak tornadoes that form without a mesocyclone
      viii. supercell thunderstorms are the most likely to produce tornadoes
   i. safety and observing tornadoes
      i. tornado watch - conditions are likely for tornado formation within the next few hours, typically 6-8 hours; covers area of about 65,000 square km
      ii. tornado warning - a tornado has been detected; covers several counties for about 30-60 minutes
      iii. take shelter!
      iv. tornado preceded by rotating clouds in the base of the storm and a wall cloud extending below the base
      v. funnel cloud may not be visible
      vi. Doppler Radar can detect wind shear but not sufficient resolution to see
an individual tornado; **Doppler Lidar** can see an individual tornado (experimental)

Chapter 11: Hurricanes

1. Tropical weather
   a. **non-squall cluster**, **tropical squall cluster**, **squall line**
   b. wind **streamlines** generally used rather than isobars on tropical weather maps
   c. **tropical wave** or **easterly wave**

2. Anatomy of a Hurricane
   a. an organized mass of thunderstorms with sustained winds exceeding 64 knots, **eye**, **eye wall**, **spiral rain bands**

3. Formation and Dissipation
   a. generally form between 5° and 20° latitude - have to have sufficient Coriolis force for rotation
   b. conditions for formation: warm water (≥ 26.5°C) to a depth of about 200 m (or less), deep region of high humidity, converging surface winds, light to moderate diverging upper-level winds, no subsidence inversion (**trade wind inversion** associated with the subtropical high)
   c. El Niño and La Niña - their effect on hurricane formation
      i. El Niño: warmer water in eastern Pacific and increased upper-level winds in Caribbean and Atlantic
      ii. La Niña: cooler water in eastern Pacific and decreased upper-level winds in Caribbean and Atlantic
   d. Stages of development: **tropical disturbance** or **tropical wave**, **tropical depression** - winds of 20-34 knots and several closed isobars, **tropical storm** - winds of 35-64 knots and closely packed isobars, **hurricane** - winds over 64 knots
   e. typical hurricane movement
      i. travel westward or northwestward in the tropical easterlies at about 10 knots
      ii. move north into the westerlies
      iii. travel northeastward to northward at up to 50 knots
      iv. path is *very* hard to predict
      v. generally dissipate rapidly over land or cooler water
   f. differences between a hurricane and a mid-latitude cyclone

4. Destruction
   a. **hurricane watch** issued when storm poses a direct threat within 24-48 hours
   b. **hurricane warning** issued when storm is almost certain to arrive within less than 24 hours
   c. also issue tropical storm wind watches and warnings to indicate where tropical storm strength winds are possible or likely
   d. when watch or warning is issued, make necessary preparations and evacuate when advisable
   e. usually **overwarn** by about 3 times the damage swath of the hurricane
   f. high winds inflict considerable damage
   g. flooding, huge waves, and high seas produce most of the damage
   h. **storm surge** caused by **Ekman transport** pushing water ahead of the storm, large waves (10-15 m) due to high winds, and up 1/2 meter sea level rise due to
the low air pressure
i. embedded tornadoes: in about 1/4 of hurricanes; usually in right front quadrant
j. spin-up vortices or mini-whirls: very high winds due to the horizontal shrinking of the vortex; typically 30-100 m in diameter; rotation speeds up to 70 knots
k. translation speed, rotation speed, and speed of any embedded tornadoes or spin-up vortices add (and subtract) just as they do in a tornado
l. Saffir-Simpson scale: ranking and roughly what peak continuous wind speeds are present and pressure depression in the eye

5. Naming
   a. all tropical storms are named - alphabetically with alternating male and female names
   b. if you can remember which years start with male names and which with female names you have a better memory than I do