Chapter 4: Humidity, Condensation, and Clouds

1. Evaporation and Condensation
2. Saturation (Equilibrium)
   a. rate at which water evaporates from the liquid (ice) surface is the same as the rate at which water vapor is condensing out of the air onto the liquid (ice) surface
3. Condensation nuclei, hygroscopic vs. hydrophobic
4. Measures of humidity
   a. Mixing ratio: mass of vapor/mass of dry air (g/kg) (also remains constant as long as the water vapor content does not change)
   b. Relative humidity: water vapor content/water vapor capacity or actual vapor pressure/saturation vapor pressure (%), most common reported value (changes with temperature and slightly with pressure)
      i. Actual vapor pressure: (partial) pressure exerted by the water vapor in the air (varies with atmospheric pressure)
      ii. Saturation vapor pressure: (partial) pressure exerted by the water vapor if the air were saturated (varies with atmospheric pressure and temperature)
      iii. Supersaturated
c. Dew point, frost point
d. Be able to use the graph in Figure 4.5 (p. 83) or Table B.1 in Appendix B (p. 467) to find the relative humidity given the dew point and current air temperatures or to find the dew point given the current air temperature and relative humidity. (The graph or table would be provided.)
5. Relative humidity in the home - summer vs. winter
6. Dew, frozen dew, frost, freeze, black frost - conditions for formation of each
7. Haze
8. Fog - conditions for formation and characteristics
   a. Radiation fog, ground fog, valley fog
   b. Advection fog
   c. Upslope fog
d. Evaporation fog, mixing fog, steam fog, frontal fog
9. Economic aspects of fog - both positive and negative
10. Cloud classifications
    a. Level (mid-latitude): high (> 16,000 ft), middle (6,500 to 23,000 ft), low (< 6,500 ft), vertical development
    b. Appearance: cirrus, stratus, cumulus, nimbus
11. Each cloud type, description, and characteristics (including associated weather)
    a. Cirrus, cirrocumulus, cirrostratus
    b. Altostratus, altocumulus (including castellanus)
    c. Stratus, stratocumulus, nimbostratus (including stratus fractus or scud)
    d. Cumulus (including humilus, fractus, and congestus), cumulonimbus
12. Special clouds - lenticular, banner, pileus, mammatus, contrail, nacreous, noctilucent
13. Describing sky conditions
Chapter 5: Cloud Development and Precipitation

1. Stable, unstable, and neutral equilibrium
2. Adiabatic process (definition)
3. Dry adiabatic rate (10°C/1000 m or 5.5°F/1000 ft)
4. Moist adiabatic rate, including range and factors affecting value
   a. Range: 3.0—9.5°C/1000 m or 1.6—9.5°F/1000 ft
   b. Why the moist adiabatic rate is always less than the dry adiabatic rate
5. Rising parcel of air expands and cools; Sinking parcel is compressed and warms
6. Environmental lapse rate, average environmental lapse rate (6.5°C/1000 m, 3.6°F/1000 ft)
7. Absolutely stable air: conditions (ELR<MAR)
   a. subsidence inversion
8. Neutrally stable air: conditions (ELR=MAR for saturated air, ELR=DAR for unsaturated air)
9. Absolutely unstable air: conditions (ELR>DAR)
10. Conditionally unstable air: conditions (MAR<ELR<DAR)
11. Causes of instability
   a. wind bringing in cold air aloft (cold advection)
   b. radiational cooling of clouds or air
   c. solar heating of the surface
   d. wind bringing in warm surface air (warm advection)
   e. cool surface air moving over a warm surface
12. Atmospheric stability changes during the day
13. Most clouds form as air rises and cools
14. Mechanisms of cloud development
   a. surface heating and free convection
   b. topography
   c. widespread ascent due to convergence of surface air
   d. uplift along weather fronts
15. “Thermal”
16. Orographic uplift, orographic clouds
   a. Rain shadow
17. Lenticular clouds, wave clouds, rotor clouds
18. Equilibrium vapor pressure over water or ice
19. Condensation nuclei
20. Cloud droplet size vs. raindrop size (number of cloud droplets per raindrop = about 1 million)
21. Warm cloud, warm rain
22. Collision-coalescence process (top of clouds warmer than −15°C or 5°F)
   a. Terminal velocity: qualitative variation with droplet diameter
   b. Factors in raindrop production: cloud liquid water content, range of droplet sizes, cloud thickness, updrafts in the cloud (presence or absence), electrical charge of the droplets
23. Cold cloud
24. Ice-crystal or Bergeron process (mix of ice crystals and cloud droplets)
   a. Temperatures for water only, mixed ice and water (mixed clouds) and ice only
b. Supercooled water
c. Ice nuclei - temperature at which a particle becomes an ice nucleus varies with particle composition
d. Saturation vapor pressure - variation between above water vs. above ice
e. Ice crystals grow larger at the expense of the surrounding water droplets
f. Accretion, graupel
g. Aggregation
h. Ideal ratio of ice crystals to water droplets (1:100,000 to 1:1,000,000)

25. Cloud seeding: crushed dry ice, silver iodide crystals, ice crystals from overlying cirri-form clouds, pollution, bacteria

26. Precipitation and related clouds
27. Rain, drizzle, virga, rainshower, cloudburst
28. Snow, fallstreaks (sublimation in dry air)
29. Flurries, snow squall, thundersnow, blowing snow, ground blizzard, blizzard, drifting snow

30. Snowfall intensity (heavy = visibility ≤ 1/4 mile; moderate = visibility ≤ 1/2 mile, > 1/4 mile; light = visibility > 1/2 mile)

31. Growth of ice crystals and snowflakes
   a. Why are snowflakes most common (difference between saturation vapor pressure over ice and saturation vapor pressure over water is maximum at the same temperature where dendrites are most likely to form)
   b. Large, soggy flakes vs. small, powdery (dry) flakes

32. Benefits of snowfall
33. Sleet, freezing rain (glaze), freezing drizzle, rime, black ice, ice storm, snow grains, snow pellets, graupel (Fig. 5.38 on p. 138)
34. Hail: conditions of formation, appearance, economics of hail

Chapter 6: Air Pressure and Winds

1. Air pressure
   a. Cold air is more dense, warm air is less dense
   b. Atmospheric pressure changes faster with altitude in cold air
   c. Warm air aloft ⇒ high atmospheric pressure aloft; cold air aloft ⇒ low atmospheric pressure aloft
   d. Hot surface air ⇒ low surface atmospheric pressure; cold surface air ⇒ high surface atmospheric pressure

2. Pressure measurements
   a. Standard atmospheric pressure (meaning and value)
   b. Station pressure - local pressure corrected only for temperature, gravity, and instrument errors
   c. Sea level pressure - station pressure corrected for altitude (10 mb/100 m to correct for altitude - remember that the pressure always increases as you move from a high altitude to a lower altitude)

3. Charts
   a. Surface chart (constant height chart)
      i. Isobars - sea level pressure, why are they smoothed?
ii. \( H = \) high pressure, anticyclone; \( L = \) low pressure, cyclone

iii. flags indicate direction wind is from

b. isobaric chart (constant pressure chart)
   i. constant height contours (of the constant pressure surface)
   ii. winds aloft blow parallel to the constant height contours
   iii. high heights \( \Rightarrow \) high atmospheric pressure; low heights \( \Rightarrow \) low atmospheric pressure
   iv. high heights \( \Rightarrow \) warm air \textit{aloft}; low heights \( \Rightarrow \) cold air \textit{aloft}
   v. ridge/trough

4. Newton’s Laws of Motion

5. Pressure Gradient force
   a. due to horizontal differences in pressure; proportional to \( \frac{(\text{pressure change})}{\text{(distance)}} \)
   b. directed high pressure to low pressure at right angles to isobars
   c. this is the cause of all wind

6. Coriolis Force
   a. \textit{apparent} force from being on a rotating surface
   b. causes wind (and water) to deflect to the right in the north and the left in the south
   c. What affects the strength of this force? [mass, velocity, latitude]
   d. generally requires long distances to act (very weak)

7. Geostrophic Winds - \textit{earth turning} winds
   a. straight-line flow – parallel to straight isobars
   b. force balance in geostrophic winds (pressure gradient force balanced by Coriolis force)

8. cyclonic, anticyclonic flow

9. centripetal force \( \Rightarrow \) centripetal acceleration \( \Rightarrow \) circular path – centripetal force due to imbalance between pressure gradient and Coriolis forces

10. force balance around cyclone or anticyclone

11. zonal vs. meridional flow

12. Surface Winds, friction slows winds \( \Rightarrow \) reduced Coriolis force; friction layer about 1000 m thick

13. Buys-Ballot’s law for both upper-level winds and surface winds (Northern Hemisphere)
   a. Stand with your back to the wind (either aloft from cloud movements or at the surface)
   b. For winds aloft, the low pressure will be to your left, high pressure to your right
   c. For surface winds, rotate clockwise between 15° and 30°, the low pressure will be to your left and the high pressure to your right

14. Winds and vertical air motions

15. Specifying wind direction
   a. standard specification (direction it’s coming \textit{from})
   b. exceptions: upslope, downslope; onshore, offshore
   c. prevailing wind

Chapter 7: Atmospheric Circulations

1. Wind Scales, microscale, mesoscale, synoptic scale, global scale
2. Size, type of wind, duration of wind
3. Eddies, size, causes
4. Rotors, mountain wave eddy
5. Wind shear, clear air turbulence, waves
6. Thermal circulation, thermal high, thermal low
7. Sea breeze, land breeze
8. Valley breeze, mountain breeze
9. Katabatic winds
10. Chinook wind
11. Santa Ana wind
12. Dust storms, sandstorms, Haboob
13. Dust devils
14. Monsoon winds
   a. Asian monsoon
   b. Southwestern U.S.
15. General circulation of the atmosphere = average flow of the atmosphere
16. Three-cell model (see Figure 7.25 on pg. 190 of the text)
   a. Hadley cell: rough latitude limits, winds, doldrums, trade winds, ITCZ
   b. Ferrell cell: rough latitude limits, winds, subtropical high, horse latitudes, westerlies
   c. Polar cell: rough latitude limits, winds, polar front, subpolar low, polar easterlies
17. Semipermanent highs and lows - when and where
   a. Bermuda high, Pacific high, Icelandic low, Aleutian low (all move north in the summer and south in the winter; Aleutian low generally disappears in the summer)
   b. Siberian high (from intense winter cooling–source region for mP air mass in western US)
18. Average circulation, summer vs. winter, qualitative differences
19. Jet stream or tropopause jets
   a. Fast - 100-200 knots; located at 200-300 mb level
   b. Subtropical jet over subtropical high, polar jet over polar front
   c. Driving forces for jet stream: steep pressure (temperature) gradient, conservation of angular momentum – result in high speeds in polar jet compared to the subtropical jet
20. Wind-ocean interaction
   a. Currents roughly follow wind circulation
   b. Major north Atlantic currents: Gulf Stream, Labrador Current, North Atlantic Drift
   c. Major north Pacific currents: North Pacific Drift, California Current
   d. Ekman spiral: caused by Coriolis force on moving water, average water motion perpendicular to wind motion
   e. Upwelling: where, causes, and effects
   f. Water moves a lot of energy!
21. ENSO - El Niño/Southern Oscillation
   a. El Niño
      i. Pacific Ocean condition (ocean temperature patterns, trade winds, precipita-
b. La Niña
   i. Pacific Ocean condition (ocean temperature patterns, trade winds, precipitation patterns)
   ii. cause

22. Pacific Decadal Oscillation
23. North Atlantic Oscillation
24. Arctic Oscillation