GEOLOGY 10 Extended Notes #6

The Atmosphere (LT Chapter 11)

Weather vs. **climate?**

Composition of Air

Major Gases — **Mostly N and O** (Fig. 11.2 on p. 283).

"Additives"

Water vapor — the source of clouds and precipitation

Aerosols — tiny liquid and solid particles of dust, pollen, ash, sea salt, etc.

Ozone (O_3) — a form of oxygen

Origin of Air

Structure of the Atmosphere

The pressure and temperature of air are used to divide the atmosphere into four layers.

Air **pressure**, or the weight of overlying atmosphere; decreases upward (Fig. 11.5 p. 285).

Air **temperature** changes are complex (Fig. 11.7 p. 287).

Troposphere: The lowest level, where humans live and where almost all weather happens. Temperature drops roughly 3.5°F for each 1000' of elevation gain. Thus when it's 30°F and snowing on Mt. Hamilton (elevation >4000'), it's only about 44°F and miserably drizzling in downtown San José (elevation near sea level). [also see LT Fig. 11.6 p. 286]

Stratosphere: Home of the ozone layer, which absorbs ultraviolet radiation.

Mesosphere and Thermosphere: Almost no air is left here, because the pressure is so low.

The Ozone Problem (LT p. 284-285)
Ozone (O_3), a form of oxygen, forms naturally in the stratosphere between 10 and 50 km above Earth's surface. [Ultraviolet radiation breaks down an oxygen molecule (O_2) into individual oxygen atoms, and then each of these O atoms combines with another O_2 molecule to form O_3.]

Stratospheric ozone prevents much of the Sun's ultraviolet radiation from penetrating to Earth's surface. This "ozone layer" or "ozone shield" absorbs or reflects ~ 99% of incoming UV radiation. Without the ozone layer, Earth's surface would be sterilized of most life forms.

Impact of Humans
Atmospheric pollution due to human activities has significantly damaged the ozone layer. Ozone depletion initially was observed over the poles, where "ozone holes" have developed (LT Fig. 11.4), but the layer has thinned worldwide, including over North America.

The chief culprits are chlorofluorocarbons (CFCs), widely used as propellants in aerosol cans, as coolants in air-conditioning units and refrigerators, and in insulation and packaging foams.

Effects on Humans
Thinning of the ozone layer causes severe, widespread trouble.

* Higher rates of skin cancer and cataracts; weakened immune systems.

* Substantial crop damage (UV destroys chlorophyll).

* Damage to plankton—the base of the ocean food chain (esp. abundant near Antarctica).

Ozone in the *troposphere* is almost entirely due to humans (burning fossil fuels), where it contributes to smog and acts as a greenhouse gas.

Unfortunately, ozone in the troposphere can't be magically funneled to the stratosphere. Thus, we're losing ozone where we need it, and have too much where we don't want it.

<u>Earth-Sun relationships</u>

Rotation: Earth spinning on its axis **Revolution**: Earth orbiting the Sun

The Reasons for the Seasons (see links on course Web site)
Why is it colder in the winter than in the summer?
Angle of Sun's rays is the key reason (LT Figs. 11.9).

Why do we have seasons like winter and summer?
Because Earth's rotational axis is inclined to its plane of revolution (LT Figs. 11.10-11).

<u>How Does Heat Move</u>? (Fig. 11.14, LT p. 292)
Conduction: Heat (energy) is transferred from warmer to cooler materials by direct molecular contact (e.g., hand burned by a pot handle).

Convection: Heat moves with a substance from one place to another.

Radiation: Heat moves from a source through a material or a vacuum such as space (light and sound are also radiated forms of energy). Heat is emitted throughout the **electromagnetic spectrum** (Fig. 11.15 p. 293) at the speed of light (whether or not we can see it).

<u>How Is Earth's Surface Heated</u>?
Solar Input
The radiation emitted by the Sun (mostly at visible wavelengths) is enough to heat Earth's surface to a temperature of 0°F (-18°C)—too cold for life to thrive. In fact, Earth's average surface T is about 60°F (15°C). Why? What causes the additional heating?

The "Greenhouse Effect" (LT Fig. 11.17, 11.19)
About 50% of incoming solar radiation ultimately is absorbed by Earth's surface.

Most of the energy is radiated back into the atmosphere, but at *infrared (IR)* wavelengths.

Some gas molecules in Earth's atmosphere absorb this infrared radiation.

These molecules eventually radiate away their own energy; some is lost to space, but some is absorbed by Earth's surface, thereby heating it.

Thus, the Earth's surface is heated both by direct radiation from the Sun, and by radiation from the atmosphere. The atmospheric heating often is called the "greenhouse effect," but real greenhouses work for a different reason (they prevent cooler outside air from mixing with the warmer air inside the greenhouse).

[**Global Warming** will be distributed and discussed later.]

<u>What Controls Air Temperature?</u>

Latitude — Different amounts of incoming solar radiation (least at poles, greater in tropics). Isotherms are generally about E-W in Fig. 11.28, 11.29.

Season — For astronomical reasons discussed earlier.
Compare Fig. 11.28 (January) and Fig. 11.29 (July).

Proximity to Water — Water heats and cools more slowly than land, and doesn't experience the extreme highs and lows that land can experience (several reasons on p. 298; not on exam).

Compare Vancouver and Winnipeg (Fig. 11.23 p. 301) or Bay Area and St. Louis.

Compare areas of maximum and minimum temperature on Figs. 11.28 and 11.29.

Effect of Mountains — Block interior areas from moderating coastal effects.
Compare Bay Area with Modesto or Sacramento, only 60 miles apart.

Altitude — Due to 3.5°F/1000' drop in tropospheric temperature.
Compare central San José with Mt. Hamilton or Sierra Nevada (all at same latitude); also, see LT comparison of cities in Ecuador (Fig. 11.24 p. 301).

Cloud Cover (Fig. 11.27) — Clouds reflect incoming radiation, so cloudy days are cooler than clear ones. Clouds reflect outgoing IR radiation back to Earth, so cloudy nights are warmer than clear ones.

Clouds, Wind, and Weather (LT Chapters 12, 13, and 14)

Introductory Stuff

(1) Chapters 12-14 focus on the U.S. east of the Rockies; not all applicable to California.

(2) Water vapor—an odorless, colorless gas—is the most important gas for understanding these topics (remember: it's a greenhouse gas that absorbs heat).

(3) Water easily changes state (solid, liquid, gas) at Earth's surface conditions (Fig. 12.1). Heat is absorbed or released by each of the six processes below:

Melting	**freezing**
Evaporation (cooling effect)	**condensation** (clouds)
sublimation (ice-cube shrivel)	deposition (freezer frost)

Clouds & Precipitation

Humidity

Relative humidity: Ratio of actual to possible water-vapor content (at a given temperature), i.e., how close air is to being saturated w/water vapor (max 100%); see Fig. 12.3.

Warm air (e.g., in a jungle or summer in the U.S. midwest) can hold more water vapor than cold air can (e.g., in the mountains) (see Fig. 12.4).

Figure 12.5 shows typical daily variations in humidity and temperature (this only applies if the amount of water vapor in the air stays constant).

Dew point: Temperature to which air must be cooled to become saturated. If air is cooled below that temperature, water vapor will condense to form water in the form of dew, fog, or clouds (Fig. 12.4C).

Why Clouds Form

As air rises, it expands and cools off.

The air cools only because the volume of air changes, not because of a loss or gain of heat (e.g., inflating a bike tire or spraying an aerosol can). This process is called *adiabatic* cooling.

If air rises high enough, it will cool down to its dew point, and condensation will start to form clouds **(Fig. 12.7)**. [wet vs. dry adiabatic rates are NOT ON THE EXAM]

Four Ways to Lift Air (Fig. 12.8)
Orographic lifting; rain shadow (Sierra Nevada, Great Basin)

Fronts between air masses

Convergence (not common in California)

Local thermals (birds, hang-gliders)

Specific cloud types (cirrus, stratus, nimbus) usually form at specific heights (Fig. 12.15); cool stuff, but not on the exam. For our purposes, the only key point from p. 319-324 is that water vapor in air condenses on small bits of dust (ash, salt, smoke, etc.)—**condensation nuclei**.

Fog: a cloud with its base at or near ground level.

How advective (our West Coast) fog forms Warm, moist Pacific air blows over the cold California ocean current coming down from Alaska; the air cools and condenses to form fog.

[For an explanation of the *marine layer*, see link on course Web site/Wind & Weather.]

<u>Precipitation</u>
How it forms: LT p. 329 (not on exam)
Types of precipitation: rain, drizzle (smaller drops!); snow; sleet; hail (details not on exam)

Winds

Air pressure

Exerted by air column above, but acts in all directions (thus, we aren't shaped like pancakes). Air pressure is measured with barometers (sometimes referred to as the level of "mercury"), and is shown on weather maps in millibars (e.g., 1016 on Fig. 13.5).

Wind = Horizontal air motion. Air flows from higher-pressure areas to lower-pressure areas (because gravity rules your life).

Wind balances differences in pressure.

Differences in pressure are due to differences in temperature.

Differences in temperature are due to unequal heating by the Sun.

The **pressure gradient** determines wind speed. The higher the gradient (i.e., the larger the pressure difference), the faster the wind will move.

On weather maps (Fig. 13.5): isobars are lines of equal pressure; closer spacing = higher pressure gradient, stronger winds (near the L).

Wind direction is not perpendicular to the isobars because Earth is rotating; the **Coriolis effect** deflects winds (and rockets, baseballs, etc.) to the right (in northern hemisphere) (Fig. 13.6).

Upper-air winds follow the isobar contours, e.g., jet streams (Fig. 13.8, 13.8).

Surface winds (below a few thousand feet) are slowed and diverted by friction with Earth's surface, causing them to cross isobars and head toward lower-pressure areas.

To see how winds can spread dusts of various kinds over the globe, see **links on course Web site**: Chinese Dust Storm of 2001, and Ash From Mt. Pinatubo.

Lows and Highs (cyclones and anticyclones)

Tendencies (Fig. 13. 8, 13.9)

Lows: air converges and is forced to rise, clouds & precipitation

Highs: air diverges and descends; clear skies

<u>Global Circulation</u>

If Earth didn't rotate (Fig. 13.13): upper air to poles, lower air to tropics.

On an idealized rotating Earth (Fig. 13.14): circulation breaks down into smaller cells; same patterns persist near poles and tropics. Important features include

equatorial low: converging warm air masses, much precipitation

subtropical highs: zones where dry, warm air sinks; deserts in Asia and Australia

trade winds and **westerlies**: driven by the Coriolus effect

On the real Earth (Fig. 13.15), patterns are more complex than those shown in Fig 13.14, chiefly due to seasonal pressure changes over the continents.

<u>Weather</u>

Air masses: huge (≥1000 mi across) air bodies w/internally uniform temperature and moisture. Source regions labeled as in Fig. 14.2; mP, cP, mT, cT (Fig. 14.2)

Fronts are the boundaries that separate air masses (10 to 100 mi wide), w/warmer air above.

Warm front: warm air displaces (climbs) cool air (Fig. 14.4)

Cold front: cold air displaces (undercuts) warm air (Fig. 14.5)

<u>Severe Weather</u>

Thunderstorms: Storms with lightning and thunder, caused by rising warm, moist air. Rare in CA, more common in Great Plains, abundant in Florida (Fig. 14.11).

Tornadoes: Rotating vortex (think of it as a concentrated cyclone) w/very low pressure, sucks in surrounding air at high speed; extremely hazardous. Associated with thunderstorms and cold fronts, so very rare in CA, common in Great Plains (Dorothy!) (Fig. 14.16).

Hurricanes (aka typhoon, cyclone, chubasco): Super-cyclones (pressures down to 950 mbar), winds >75 mph to over 150 mph. These heat engines need very warm ocean water, so they never form in the north Pacific. However, tropical Pacific hurricanes do affect southern California, Arizona, and Baja California.