September 21 lecture notes

California air, mountains, and weather

In this lecture we explored how the mountains of California, such as the CA Coast Ranges and Sierra Nevada Mountains, influence weather and climate across California as air moves from the ocean towards the interior of the continent. To understand this completely, we first discussed some physics:

<u>I. Heat and adiabatic processes (heating and cooling)</u>

Heat (as defined by biologists): the kinetic energy (motion) of, and consequent collisions among, particles or molecules in an object or system (temperature is a measure of this).

Adiabatic heating: heating of a gas caused by increased pressure of the gas

Adiabatic cooling: cooling of a gas caused by decreased pressure of a gas

We'll consider important weather/climate consequences of adiabatic heating and cooling during our trip to the Sierra Nevada, and during our chaparral lecture/field trip.

The key to understanding adiabatic heating and cooling is to remember that heat (and our measurement of it, namely, temperature) is caused by the collisions of molecules in a gas (or any object).

So, imagine we have two volumes of an identical gas. If we rapidly decrease the volume of one (while maintaining the same number of molecules), then we can increase its temperature. Recall the "fire piston" from class – we decreased the volume (and thus increased the pressure) in the piston by compressing the gas molecules into a smaller volume. Air molecules in the piston then had more frequent collisions with each other, which heated the air in the piston and caused the paper to ignite. The piston lost heat after a few minutes as it emitted it to the surrounding environment.

> (By the way: The physics of this is explained by the Ideal Gas Law (PV=nRT), which we might have discussed in class, and which is explained below. I won't test you on this – but you might find it useful for understanding adiabatic heating/cooling.)

To summarize:

- Instantaneously (i.e., very quickly) increasing the pressure of a gas also increases its temperature. (We demonstrated this with the "fire piston" in lecture, and also with the bicycle pump/soda bottle apparatus). After the initial warming, the systems cooled as heat energy was lost to their surrounding environments.)
  …conversely….
- Instantaneously (i.e., very quickly) decreasing the pressure of a gas decreases its temperature. (We demonstrated this with the bicycle pump/soda bottle apparatus – when we "opened" the soda bottle and release the high pressure air, the temperature dropped abruptly.)

II. Elevation, ATM pressure, and air temperature

1) Atmospheric (ATM) pressure is highest at sea level, and decreases with gains in elevation/altitude.

Given point #1, and given the relationship between pressure and temperature (see above), the following points #2 and #3 are true:

2) A parcel of ATM air that is lifted to an elevation farther above the earth's surface results in an approximate temp decrease of 5.4°F to 3.5°F per 1000 feet.(Lentz 2013, Holland and Keil 1995). (The parcel expands due to lower pressure at higher elevation, and thus the molecules have less frequent collisions and thus less heat!).

3) A parcel of ATM air that is lowered from its current elevation to an elevation closer to the Earth's surface results in an approximate temp increase of 5.4°F to 3.5°F (Lentz 2013, Holland and Keil 1995). (The parcel compacts due to higher pressure, and the air molecules have more frequent collisions and thus more heat).

Bullet item2 is an example of adiabatic cooling, and bullet item #3 is an example of adiabatic heating.

III. Humidity

- **Humidity**: water vapor in air
- **Absolute humidity (AH):** is the actual amount of water vapor in air.
- **Relative humidity (RH)**: expressed as a percent, measures the current absolute humidity *relative* to the maximum possible water vapor for that temperature.

IV. Air temperature humidity

1) Warm air can contain more water vapor than cool air.

Given point #1, the following points #2 and #3 are true:

2) As warm air with high relative humidity is cooled, water vapor often condenses to form fog (tiny water droplets suspended in the ATM), clouds, or precipitation (water in the ATM that falls due to gravity).

3) As cool air is heated, its relative humidity drops and it can "absorb" more water from its surroundings (e.g., the leeward slope of a rainshadow) and maintain a higher absolute humidity than if the air remained cool.

- **Dewpoint**: for any specific AH, the temperature at which air is saturated with water vapor; the temperature at which dew forms (Temps. below the dewpoint result in condensation of vapor as dew, fog, rain, snow, etc).

Before we move on, recall that air can be heated or cooled by changes in elevation. This will, in turn, change the relative humidity (and possibly the absolute humidity!). Let's put this all together and follow a parcel of moist coastal air as it moves inland across California…

V. What happens when moist coastal air moves inland across California

In lecture, we applied the physical properties of gasses and H_20 (listed above) to describe what happens to the water content and temperature of air as it travels from low elevation (e.g., sea level) and moves inland over mountains, down the leeward side, up over additional mountains, etc...

Essential terms and concepts from this conversation:

Orographic lift: lift that occurs as an air mass is forced from low elevation to high elevation as it passes over a mountain or other terrain (from orography – the study of topographic relief of mountains).

Orographic precipitation: precipitation that forms due to orographic lift
Adiabatic heating: see notes above
Adiabatic cooling: see notes above

Rainshadow: a dry area on the leeward (downwind) side of a mountain. Caused when air masses are orographically lifted over mountains, thus cooled adiabatically and thus lose their moisture as precipitations, then the air mass descends down the leeside and heats up adiabatically, and because it has low relative humidity it does not deliver precipitation and can actually absorb moisture from soils and plants.

You should have the details of this story in your notes…expect to see it, or explain it, on the final exam(s). This was the bulk of our lecture.

The physics or adiabatic heating/cooling:
(this material will not appear on the final exam , but it is the basis for adiabatic processes)
For those of you familiar with the Ideal Gas Law, adiabatic heating and cooling should feel very comfortable:

The Ideal Gas Law: $PV = nRT$

Where, for a gas in a system:
P = pressure of a gas
V = volume of a gas
n = number of molecules of the gas (for a closed or sealed system, a fixed number)
R = a coefficient (here, and always, a fixed number!!)
T = temperature of the gas

For a gas in closed (i.e., sealed) system (which, for convenience, we assume our winds to be…), the number of molecules of that gas does not change (no gas molecules are added or removed). Under such conditions, when one of variables P, V, or T changes, our equation (PV=nRT) indicates that one (or more) of the others must also change. For example, according to PV=nRT, as the pressure (P) exerted on a gas increases, either the volume (V) will decrease or the temperature (T) will increase, or both will happen. Remember: The value of “PV” must remain equal to “nRT”!!

<u>Major plant communities of our Sierra Nevada field trip</u>

<u>Chaparral</u>
<u>Riparian</u>
<u>Oak woodland/savannah</u>
<u>Forest (various)</u>

Forest: Plant community dominated by closely spaced trees, such that their crowns (the uppermost layer of vegetation) overlap and form a contiguous canopy. Dense canopies prevent direct sunlight from striking the ground, thus forest understories often are very low and open.

Woodland: Plant community dominated by trees that are more widely spaced than in a forest, such that the canopy is incomplete in places and therefore allows direct sunlight to penetrate to the ground. Woodland understories are often taller and more developed than in forests.

Savannah: Grassland plant community with trees that are sufficiently spaced such that the canopy is not closed. Understory dominated by grasses.

Canopy: The upper layer of vegetation formed by the crown(s) of plants. In forest ecology, the term canopy also refers to this top layer as a habitat layer and includes resident organisms (e.g., canopy birds, epiphytic plants, arboreal mammals, etc.).

Understory: The layer of vegetation underneath the canopy.

<u>Fellfield (and/or subalpine fellfield)</u>

Fellfield (fell-field): a treeless rock-strewn area at high elevation (alpine or subalpine) dominated by low-growing plants (especially cushion plants).

Cushion plants: perennial plants that grow low to the ground

Alpine: above timberline
Subalpine: Immediately below timberline
Timberline (tree line): On a mountain, the line or altitude above which no trees grow. Trees are absent above timberline due to environmental stresses (typically cold temps and low moisture – the latter often a function of low snow accumulation).

Fellfields are found scattered across the very highest mountains of California. They make up less than 1% of the state's vegetation – but they are fascinating!

Fellfield plants have a number of adaptations for cold and dry conditions they endure:
Cushion or krummholz growth form
Deep roots
Small leaf surface area
Light color

Krummholz: short, stunted, crooked vegetation form in some trees or shrubs growing near timberline on mountains. Caused by extremely cold winds and snow that prune tree such that growth is mostly near the ground

<u>Mixed montane coniferous forests (MMCF)</u>

Montane: on or pertaining to a mountain

Montane forests: forests that grow on mountains. The elevation at which these forests grow varies greatly in different areas of the planet. The upper elevation is defined by timberline, and the lower elevation is defined by a transition to non-forest plant communities (e.g., Pinyon-Juniper desert woodlands, oak woodlands/savannah, desert scrub, chaparral).

Mixed montane coniferous forests: montane forests dominated by *mixed* species of conifers.

MMCF are very abundant in California, Holland and Keil (1995) estimate that 20% of CA land area is covered in MMCF.

MMCF communities are characterized by deep and well-developed soils, high plant biomass, and abiotic stresses that are different from the deserts or alpine regions that often flank them (i.e., less extreme high temps than lower elevations, less extreme cold temps that higher elevations, 'more' precipitation than neighboring plant communities – in subalpine forests snow pack and subsequent melt is a crucial water storage and delivery system that effectively delivers "more" water to plant roots over time than an equal volume of rain).

<u>Desert scrub</u>

Desert scrub: shrublands that occur in deserts, characterized by low density and biomass, with woody shrubs (not trees) that are widely spaced such that bare ground is prominent.

Desert: regions and associated communities characterized by low and irregular precipitation, and prolonged periods of drought.

Deserts of California typically receive ≤ 8 inches (20cm) of annual precipitation (Holland and Keil 1995).

What adaptations to heat and low water availability should we notice?

<u>Pinyon-juniper woodlands</u>

Pinyon-juniper woodlands: woodlands dominated by pinyon pines (*Pinus monophylla*) and juniper species (in the Sierra Nevada/Owens/White Mtns, *Juniperus osteosperma*; in the SB region, *Juniperus californica*).

These are desert woodlands, and are found in rainshadows. Note that trees are more sparsely scattered (hence referred to as woodlands and not forests…). They are typically found at higher elevations than desert scrub communities, and thus have lower mean summer temperatures that limit plant growth and biomass. Sometimes the two communities intergrade, as we did/will see on our field trip!