Lecture 7—Precipitation

Ok, at this point we're going to start our way through the hydrologic cycle. For whatever reason, we traditionally start this with either evaporation or precipitation. I can tell you that marine evaporation, anyway, is *really boring*, so we'll get that out of the way quickly. The sun shines on the ocean, and some of the water evaporates. There. I said it. Honestly, we'll talk about evaporation as part of precipitation.

Just to keep focus, the next topic will be the various fates of water striking the ground, after which we'll focus on runoff and streamflow, which is where we'll stay for the rest of the course.

Ok, so how about that rain? Is it the heat, or the humidity? Here we go:

Let's start with a parcel of air at the earth's surface. It's generally unsaturated, meaning that it could hold a little more water if we tried. However, if it *rises*, then the pressure on it decreases, and it cools off. Cool air holds less water, so it starts to saturate. Now for the fun part—if it saturates, then the excess water comes out as condensation. BUT, remember from the properties of water that this releases heat, which warms the air parcel, which increases its ability to hold heat. Let's talk about this in more concrete terms. The unsaturated decrease in temperature because of *adiabatic* (pressure-decrease) cooling is about 10°C per 1000 meters. This is called the *dry adiabat*. Above the condensation point, however, air cools more slowly, only about 5°C per 1000 m. This is the *wet adiabat*. I'll hand out a chart that helps explain all this. [chart]

A problem: A parcel of moist air at 15°C initially at 500 m is forced to pass over a mountain ridge at 3000 m, then descends to its original elevation. Assuming that a rise of 1500 m produces saturation and precipitation, what is the final temperature of the air parcel?

[overhead]

Ok. This gets us partway home. Why does *rain* happen, though, and not just clouds? It turns out that if the rising on the wet adiabat takes place sufficiently slowly, there are literally millions of tiny droplets of condensation in the air per cubic centimeter—these are so small that even small updrafts are sufficient to keep them suspended in the air. What causes rain is accretion of these tiny drops into larger ones, often because they nucleate on ice particles. Clearly, if updrafts are strong, larger raindrops can be kept suspended (up to about 5 mm, above which the drop fragments), which accounts for why you get the giant "bug blatter" raindrop in thunderstorms. Normal rain, just for edification, is about 0.5 mm.

From the preceding, it becomes clear that not only do you need moist air, but you also need that air to rise. No rise, no condensation, no condensation, no rain. What makes air rise? Well, there's effectively three things. One, and this is the easy one, is mountains. In order to get over high mountains, air has to rise, and this often causes precipitation on one side (this is *orographic* precipitation). [slides] A second way for air to rise is *frontal* precipitation—warm air can be ramped up over cool air where two fronts meet. But the last, and perhaps the oddest, is simply unstable air. What happens normally to air is that a warm parcel of air starts to rise, but as it rises, it cools, becoming more dense than air above it, so it sinks. On the other hand, if the air is *unstable*, the rising parcel will find itself warmer than the overlying air and continue to rise—depending on the size of the instability this can send warm, moisture laden, air to great altitudes.

So how to find out what will happen? Despite Doppler radar and satellite imagery, much of the weather data collected in the US is still done the old-fashioned way, with weather balloons. Take a look! [slides].

This data is plotted on a *Skew-T* diagram, so called because temperature is skewed to the left to allow for most atmospheric conditions to plot as a straight line. The solid line is the atmospheric temperature, the dotted the wet-bulb temperature (the dewpoint temperature). When the two meet, condensation is occurring. The barbs on the right side show wind—one short feather is 5 kts, long 10 kts, and a triangle is 50 kts. The red line in the middle talks about the theoretical cooling path of a parcel of air at the surface. If this path is to the left of the actual air temperature, the air is *stable*, to the right, *unstable*.

So, this is how precipitation is generated. Next we'll talk about rainfall pattern and intensity, and two causes for weird precipitation—thunderstorms and hurricanes.