Lecture 8—Thunderstorms, hurricanes, and rainfall intensity

We left off talking about unstable and stable air, and the likelihood of precipitation. I'd like to talk for a bit about one type of precipitation that we seem to get a lot of here—the thunderstorm. Thunderstorms occur when warm, moisture-laden, *unstable* air is forced to rise (alternatively, it rises because it warms so much during the day). This air starts to condense at successively higher elevations (remember, it's unstable, so it wants to keep rising). The heat lost during condensation allows for continued updraft, and the condensed rain droplets can be kept in the storm for some time. When the rain (or hail) gets large enough, it can no longer be kept in suspension and rain begins to fall. At the same time, cooler, drier, air is being sucked into the warm updraft, cooling it to the point that a lower part of the storm develops a strong downdraft. This is the cold wind that one often feels in front of a storm. When the cloud hits the "cap" we talked about last time, where the air is no longer unstable, it flattens out, forming the well-known anvil head to the top of a thunderstorm.

From here I'd like to branch out into the large-scale thunderstorm; the cyclonic storm. These go by many names—in the US they are called *hurricanes*, in Japan, *typhoons*, while the Australians prefer the more simple *cyclone*. Whatever you call them, they're intense storms, and substantially bigger than your average thunderstorm. In bulk, though, that's what they are. Very moist, very warm air is induced to rise, then sets up a thunderhead. The lack of a cap at altitude, however, allows the storm to continue rising. Then the trouble starts. Let me back off for a second to explain.

In 1735, George Hadley proposed the idea that, if the earth were covered entirely with water, and the sun always shone on the equator, than heating of air at the equator would cause that air to rise, thus inducing cold air to shoot in from temperate or boreal regions and fill in the gap. This, in turn, would cause the warm air to shoot polewards in the upper atmosphere, descending as it cooled to close the loop. This concept is called *Hadley circulation*, and the loop is referred to as a *Hadley cell*.

Ok, it turns out there's a few problems with this. One is that the planet actually *turns*. This creates a problem because of the conservation of angular momentum. Angular momentum is defined as:

$$A = mvr$$

where m is the mass being moved, v is the speed of rotation, and r is the radius of rotation. As air moves poleward from the equator, it starts to speed up. The result of this is that it's forced to bend to maintain angular momentum—this is commonly called the *coriolis effect*. Ok, the other problem is that there isn't one big conveyor belt—there are three. The equatorial one is called the *Hadley cell*, because it acts the most like the original concept. The most polar one is called, naturally, the *polar cell*, and the weak one connecting the two is called the *Farrel cell*. The net result of all this is a complex global system of winds.

Which brings us back to hurricanes. If thunderheads develop in the South Atlantic, and are allowed to continue to develop, they will start to be affected by this global circulation pattern. In fact, they start to be affected on two scales—one causes the thunderhead, or group of thunderheads, to spin about the lowest pressure, while on another scale, the whole whirling mass starts to follow the pattern we just mentioned. The storm takes on a life of its own when a third circulation pattern joins the fray. Here warm air is being sucked towards the low pressure center and is forced upwards, then is spat out the top. Great quantities of moisture are thereby added to the storm and it become self-sustaining. The only thing that eventually dooms such a storm is that it either travels far enough north that sea surface temperatures cool to the point that the air entering the storm doesn't carry enough moisture to replace the water lost (and because this air is more stable), or because the storm strikes land, where its source of moisture is again cut off.

The circulation we talked about suggests why the southeastern US gets most of our hurricanes. Take a look—if you put the US on the fake globe, it's right in the path of the northern trade winds. This also explains why Japan gets nailed with typhoons, and why we don't hear about Europe or the Pacific NW getting them. Last question—which coast of Australia gets the cyclones?

This big circulation concept has another ramification. In some parts of the world, namely large tropical continents, the land heats considerably faster than the oceans surrounding the continent. The continent heats, and eventually sets up a very large circulation causing cooler (compared to the continent, anyway, which is *stinking* hot), moisture laden air, to flow inward to the continent. This tends to happen in late summer, and is called the *monsoon*.

This is all a long way of saying, it's not just a matter of how much rain falls; it's also a matter of how fast it falls. We care about this because if rain falls faster than it can infiltrate, it has to run off. So, our hydrologic cycle actually needs information on rainfall intensity as well as quantity. This is only a problem because of how rain gauges work.

{Bring in the NWS rain gauge}

Basically, the NWS rain gauge consists of a funnel (in this case 8" in diameter) that leads to an aluminum tube for a collector. Just like when you check fuel oil for your furnace, you literally come out with a dipstick and stick it in. If you get to more than 2", the rain flows into the overflow area, for later collection. Yep, that's really how it works. What this *means* is, that you tend to get time discrete data, like on the overhead. This data is collected at 15 minute intervals, which is honestly quite a lot, because it does involve some poor guy running out and measuring it every 15 minutes. Ok, there's one improvement to this system—you *can* get rain gauges that record the weight of rain in the bucket on a strip chart recorder (see overhead).

Now, we *wanted* rainfall intensity. Turns out that would be the slope on the *cumulative mass diagram* we got from the rain gauge. Basically, if you take:

$$\frac{change\ in\ amount\ of\ rain}{time\ \mathrm{int}\,erval}$$

you get rainfall intensity (in mm/hr, for example). A diagram of rainfall *intensity* with time, as shown at the bottom of the overhead, is a *hyetograph*. Hyetographs are a basic input to the hydrologic equation, and linking them to streamflow will be a major topic of the rest of class.