EOSC 112: Lecture Summary: Wednesday, September 26

Announcement: First mini-essay assigned

The marking criteria are now available with the essay assignment at:
`http://www.eos.ubc.ca/courses/eosc112/essay1.html`

Text Coverage: Atmospheric Circulation System continued: Chap.4 pp. 61-71

Review:
From last time recall three fundamental features of the Earth's atmospheric circulation:

- Warm air rises and cold air sinks (buoyancy)
- What goes up must come down (conservation of mass)
- The *Corriolis force* (an apparent force) pushes air to the right of the direction of motion in the northern hemisphere, and to the left of the direction of motion in the southern hemisphere.

Some additional points:

- Buoyancy is driven by density differences between an *air parcel* and its *environment*. (Just like bubbles rising through water). The *general (ideal) gas law (p. 60)* says that density decreases with increasing temperature. Solar heating in the tropics produces large temperature (density) differences between surface air and the upper atmosphere. That, plus the condensation of water vapor, powers air parcels that rise from the surface all the way to the tropopause.
- Compare Figure 4-4 to Figure 5-16, p. 95 to see how the excess heating in the tropics is transported north, reaching a maximum between 30-60 N latitude.
- As warm air rises, air must flow in to replace it. This is called *convergence*. The inflow is driven by horizontal differences in pressure (highs and lows).
- Eventually, this rising air has to turn around and descend somewhere on the planet, because it can't push through the tropopause. The descent is called *subsidence*. Subsiding air causes *divergence* at the surface.
- Figure 4-6 shows the *inter tropical convergence zone* and the *Hadley cell* circulation that is the product of this cycling of air. Note that the air comes down at about 30° N and S. These regions tend to also have higher pressure (why?) and are called the *sub-tropical highs*.
- Since the average circulation shown in Figure 4-6 varies in a north-south direction or along lines of longitude (*meridians*) it is called the *meridional circulation*.

High latitude circulation
As you get closer to the poles, temperature gradient become stronger and the atmospheric circulation more vigorous.

- Figures 4-9 and 4-10 show the collision between warm and cold air at the polar front.
- Figure 4-11 shows a possible model of the surface winds which turns out to be **wrong**.

What's wrong with Figure 4-11? It neglects the *Corriolis effect*.

As Figure 1 shows below, as you go north from the equator, you get closer and closer to the earth's axis of rotation. During a 24 hour day, air at rest with respect to land at the equator travels 2π*6383 km or 1669 $\mathrm{km\,hr^{-1}}$ with respect to a spot at the north pole. In contrast, air at rest in downtown Vancouver travels 2π*4184. or 1095 $\mathrm{km\,hr^{-1}}$ with respect to the north pole. If air was somehow moved instantaneously from the Equator to Vancouver, it would move to the east with a velocity of 1669 - 1095 = 574 $\mathrm{km\,hr^{-1}}$.

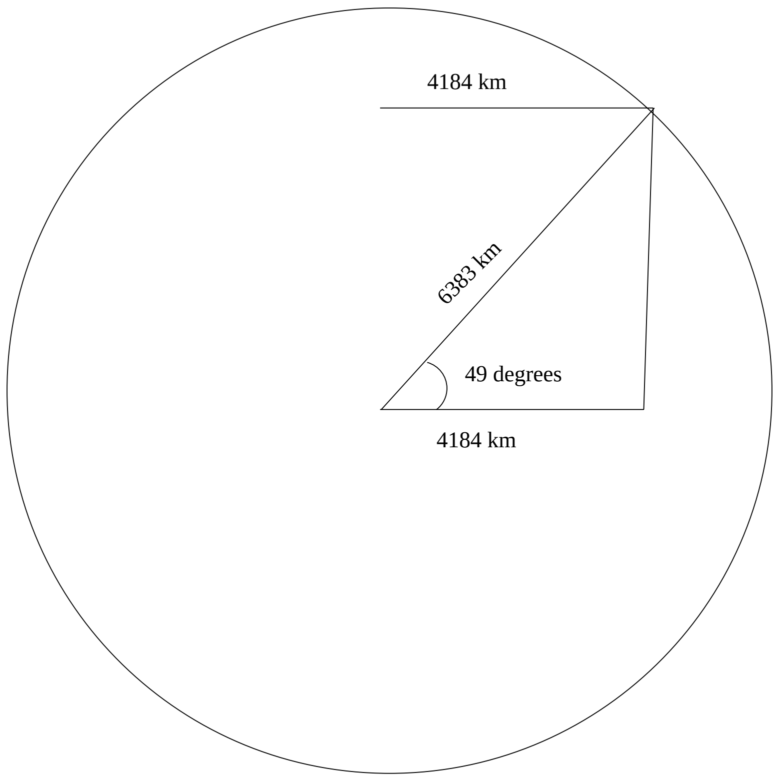

Figure 1: Vancouver (49° N latitude) is 4184 km away from the Earth's spin axis, compared to a city on the equator, which is 6383 km away

The result of this conservation of momentum for air parcels moving north or south is to turn to the right with respect to the spinning surface (they really are doing their best to go straight, as viewed in a reference frame that is moving along with the earth in its orbit.

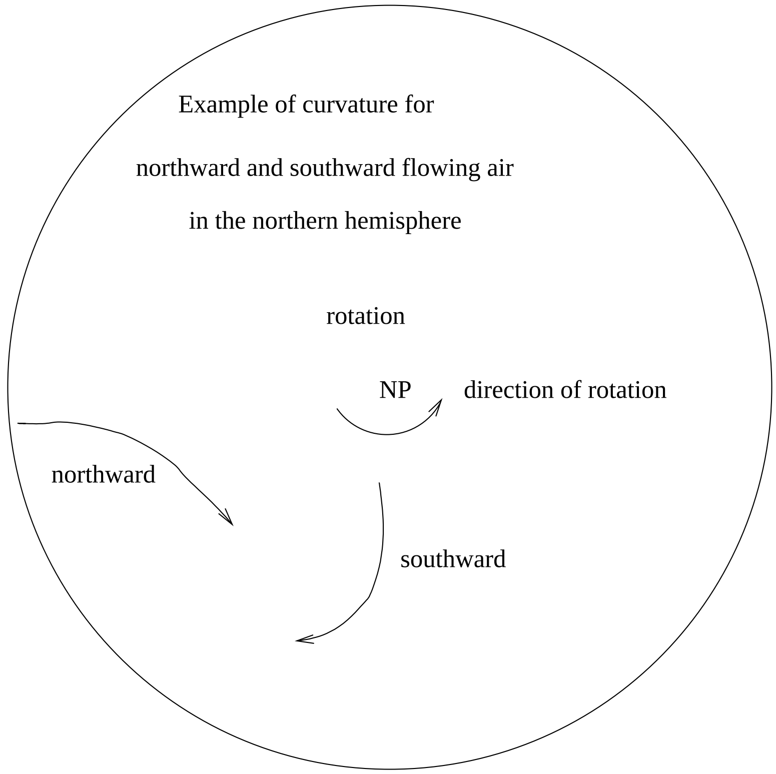

Figure 2: Coriolis effect in the northern hemisphere

As Figure 4-13 shows, there is a similar apparent force acting on air traveling to the east in the northern hemisphere. The earth bulges at the equator in response to this. When an air parcel moves faster than the earth's surface to the east, it appears to be lifted up (i.e. it's weight is reduced) and pushed to the south.

What about the southern hemisphere? As viewed from above the south pole, the earth is spinning *clockwise*, so now the air at the equator is carrying extra clockwise momentum, and turns to the east (left) as it heads towards the south pole.

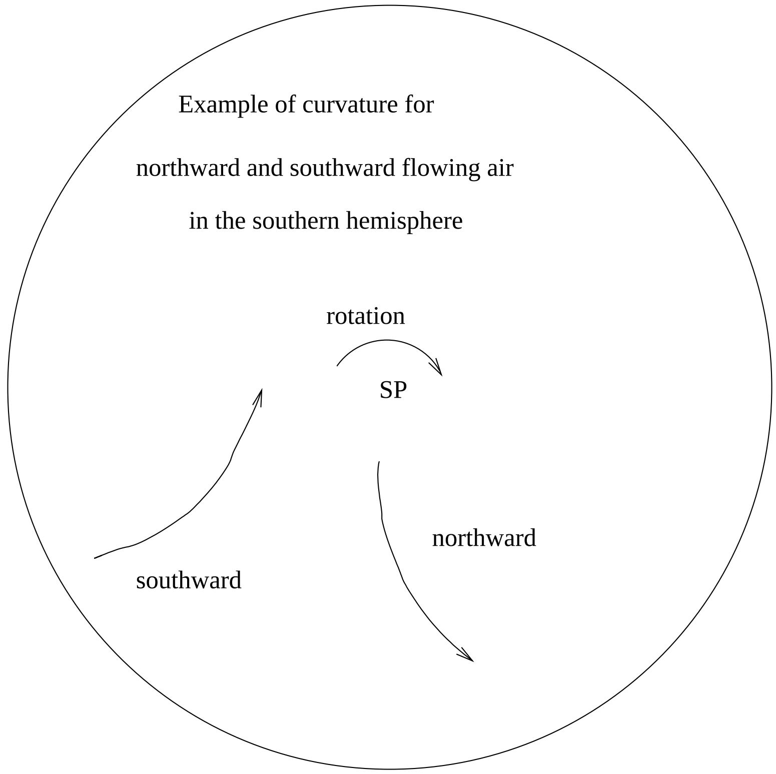

Figure 3: As in Figure 2, but for the southern hemisphere

Finally, here's the force balance for a parcel of air moving east in the southern hemisphere:

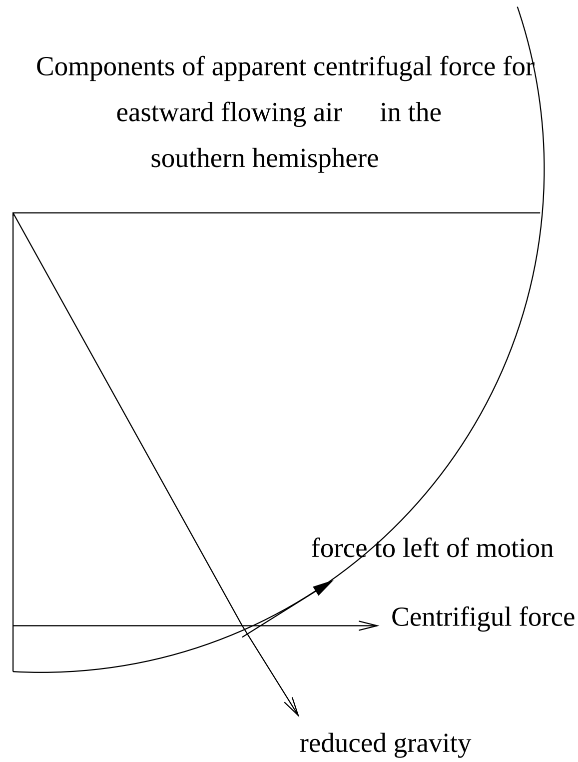

Figure 4: Force balance for air moving east in the southern hemisphere, following Figure 4-13

- With the Coriolis effect accounted for, Figure 4-14 now gives an accurate depiction of the surface winds.
- Differential heating between land and ocean also accounts for important features of atmospheric circulation.
  - Locally heating/cooling produces land and sea breezes.
  - On continental scales, this phenomenon produces monsoons.