Atmospheric General Circulation
(Chapter 10)
The length/time scales in meteorology

- **Global scale**: 5000 km
- **Synoptic scale**: 2000 km
- **Mesoscale**: 20 km
- **Microscale**: 2 m

Rotation is important.
The circulations of the atmosphere and oceans (winds and currents) are ultimately driven by net heating at low latitudes and net cooling at high latitudes.
Thermal convection creates a single convective cell in each hemisphere, a large Hadley cell with rising motion at the Equator and sinking at the Poles.

Energy (heat) is transported from the equator towards the poles.

Sun is directly over the Equator to provide symmetry between hemispheres.

The Earth does not rotate in this model.
What’s wrong with the 1-cell model?

Neglects effect of rotation
- with rotation, the surface winds would cause the Earth to spin down. Why?
Also neglects impacts of topography (mountains)
The three cell model describes the basic aspects of Earth’s general circulation. When topography is added, the circulation patterns become a bit more complex but the basic structure is preserved.

This is the 3-cell model. **Hadley, Ferrel and Polar cells.**

Note the basic wind patterns and the impact of the Coriolis force. For example, in the N. Hemisphere, wind flowing from the sub-tropical highs is deflected to the right. This causes the easterly trade winds in the tropics and westerlies in the mid-latitudes. Deflection to the left takes place in the S. Hemisphere, also producing easterly flow in the tropics and westerlies in the mid-latitudes.
The three cell model

• Hadley cell (thermally direct cell)
  - driven by meridional gradient in heating
  - air rises near equator and descends near 30 degrees
  - explains deserts; trade winds; ITCZ

• Ferrel Cell (thermally indirect cell)
  - driven by heat transport by wintertime storms
  - air rises near 60 degrees and descends near 30 degrees
  - explains surface westerlies from 30-60 degree latitude

• Weak winds found near
  – Equator (Doldrums)
  – 30 degrees (Horse Latitudes)

• Boundary between cold polar air and mid-latitude warmer air is the *polar front*
The physics of the Hadley Cell are analogous to the physics of the land/sea breeze. Except the scales are much larger, and so the rotation of the Earth matters.
Just like land/sea breeze....

Differential heating between tropics and higher latitudes drives thermal circulation.
Weather in the mid-latitudes occurs at the interface between the Ferrel and Polar cells.
"jet streams"
Two jet streams meander around the globe. The polar jet was discovered at the start of World War II when aircraft traversed the Atlantic ocean.
Even more messy: the real world

- Many features of the 3 cell model can be observed in the earth’s general circulation. Nevertheless, the presence of continents, mountains, and ice fields alters the general circulation from the ideal 3-cell model.

- Semipermanent high and low pressure systems persist throughout large periods of the year
  - During winter, highs form over land; lows over oceans. Vice versa during summer. Consistent with differences in surface temperature.
  - Bermuda high and Pacific high form near 30 degrees north, in response to air convergence aloft (particularly true during NH summer).
  - Features change from winter to summer.
January: 500 mb heights
January: SLP
July: 500 mb heights
July: SLP
Key concepts in understanding the general circulation

1. Driven by differential solar heating between the equator and poles. Atmospheric general circulation acts to move heat poleward.

2. In the Hadley cell, warmer fluid rises and moves poleward.

3. In the Northern Hemisphere, wind is deflected to the right; in the Southern Hemisphere, wind is deflected toward the left.

- Pole to pole Hadley cell is unstable in the presence of rotation; hence the 1-cell model breaks down.

- 3-cell model explains global distribution of winds.
Some basic aspects of the ocean—strongly tied to atmospheric pressure and wind patterns
Warm, poleward currents found on the eastern edges of continents.

Cold, equatorward currents found on the western edges of continents.

Currents driven by wind patterns in the atmosphere.

Warm currents are in red. Cold currents in blue.
Coastal upwelling—driven by circulation around sub tropical high pressure in atmosphere. So upwelling contributes to the cold waters off of California for example.
Equatorial upwelling is caused by the trade winds which blow from east to west, dragging surface water to the west. This water is replaced by the upwelling of colder water from below the surface.

Water piles up in the west Pacific Ocean compared to the east Pacific. Sea level is about 1 meter higher in the W. Pacific.
Can you link these precipitation patterns to features of the general circulation?
Famous “dishpan” experiment done in a basement laboratory at the U. of Chicago in the mid-1950’s.

This experiment simulated many aspects of Earth’s general circulation. The interior column of the pan was cooled with ice while the outer wall was heated with a coil through which a current was passed through. When there was no rotation, one large circulation developed with warm water flowing from the “Equator” to the “pole” and cold water flowing the opposite direction.

When the pan was placed on a rotating turn table, wave patterns developed that allowed for the efficient transport of heat from the “Equator” to the “pole”. These large scale waves mimic those in our atmosphere. These waves are Rossby waves.