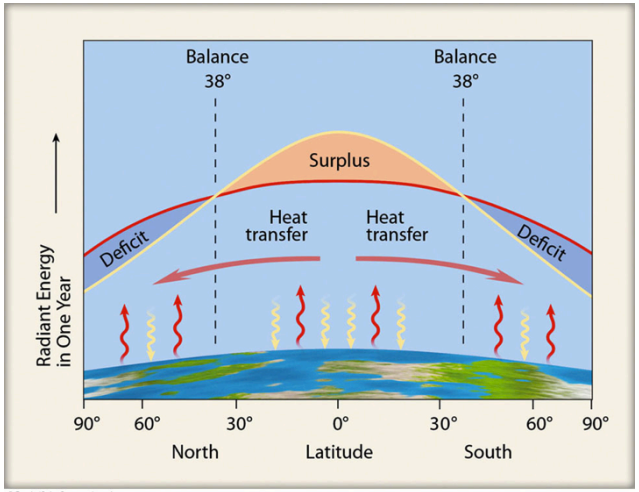
Atmospheric General Circulation (Ch 10)

The circulations of the atmosphere and oceans are ultimately driven by ….

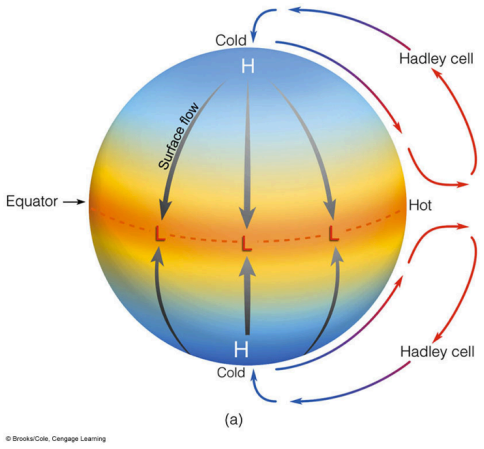


Solar Radiation

- The poles receive much less solar radiation than the low latitudes
  - Difference in the sun's angle of incidence
  - Tilt of the earth's axis results in no solar radiation pole-ward of the arctic circle for six months each year
  - Arctic and Antarctic ice reflect considerable solar radiation back to space

What a single cell convection model would look like for a non rotating earth

- Thermal convection leads to formation of convection cell in each hemisphere
- Energy transported from equator toward poles
- What would prevailing wind direction be over N. America with this flow pattern on a rotating earth?



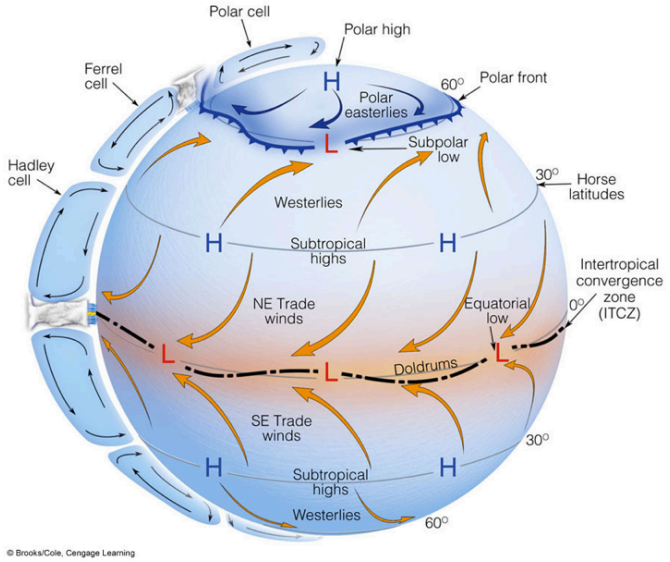
What's wrong with the 1-cell

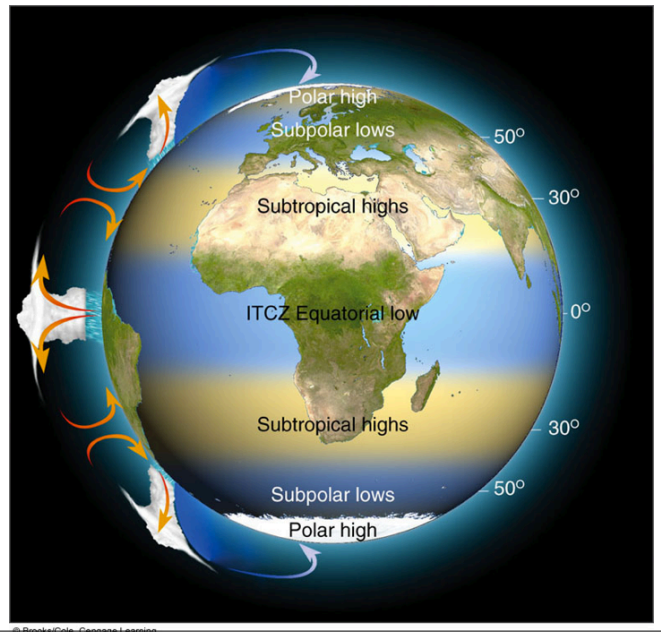
- Neglects effect of rotation

- with rotation, winds would cause earth to spin down

- with rotation, the upper level winds would accelerate to unphysical speeds near the pole.

Wind patterns on a rotating earth

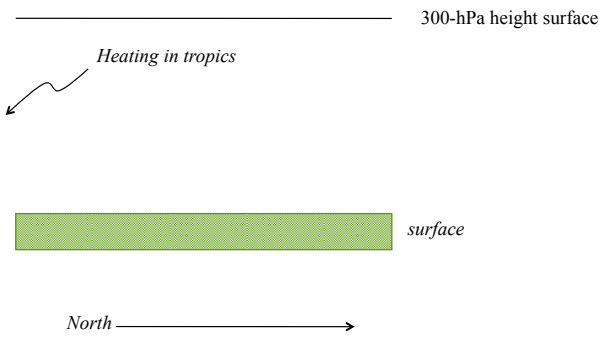




Key features of three cell model

- **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
- **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 Hadley Cell



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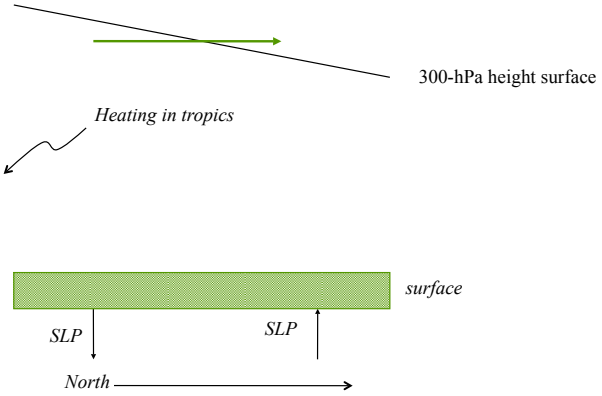
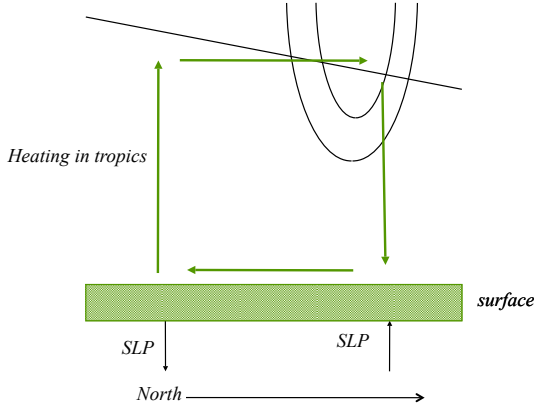


The Hadley Cell



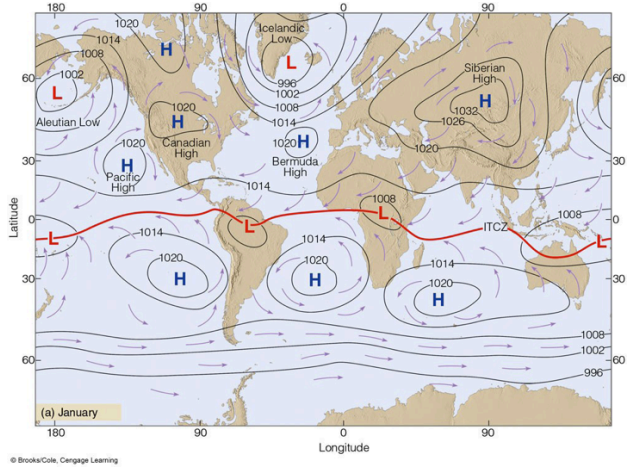
The Ferrell Cell....

- **analogous to the Hadley Cell, but driven by heat fluxes by storms (sketch on board).**

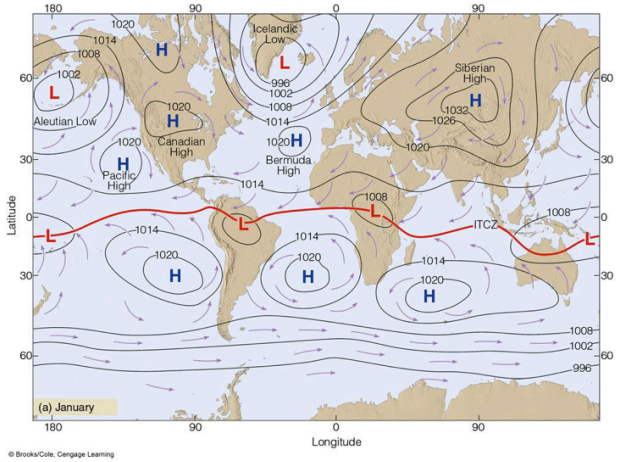
Even more messy: the real world

- 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.
- The Intertropical Convergence Zone (ITCZ) shifts toward south in January and toward north in July. Why?

General Circulation - January

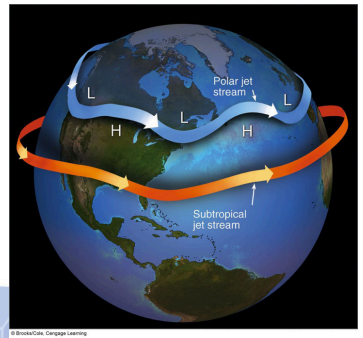


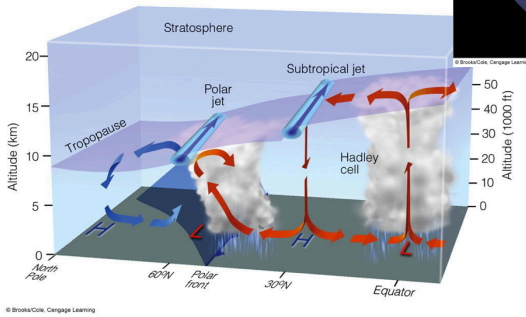
General Circulation - July



Jet Streams

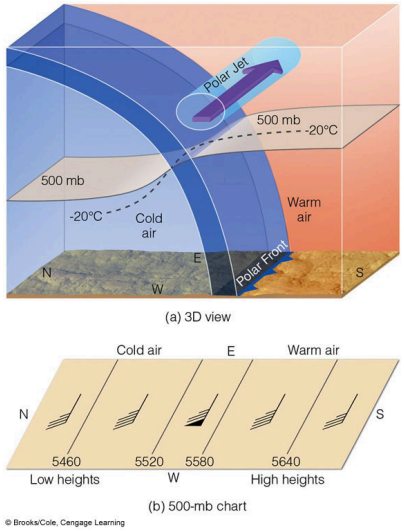
- Fast air currents, 1000's of km's long, a few hundred km wide, a few km thick
- Typically find two jet streams (subtropical and polar front) at tropopause in NH
- When would you expect the jets to be strongest?





Polar Front Jet Stream

- Polar front jet stream forms along polar front where strong thermal gradient causes a strong pressure gradient
- Strong pressure gradient force and Coriolis force produce strong west wind parallel to contour lines
- Polar jet sometimes splits into north and south branches

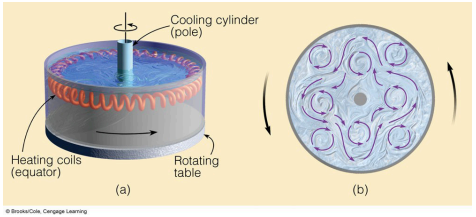


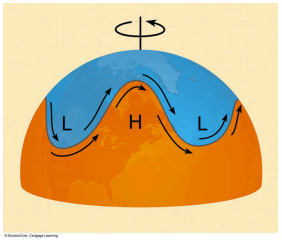
The Role of Midlatitude Storms

• (Angular/rotational) momentum is transferred from the Earth to the atmosphere in the trade wind belt.
• (Angular/rotational) momentum is transferred from the atmosphere to the Earth in midlatitudes.
• Midlatitude Storms (Eddies) transfer eastward (westerly) momentum (and heat) poleward in the upper troposphere and to the surface.
• This helps drive the Ferrel cell but also weakens slightly the Hadley cell.
• Comparing the overall overturning strength, the Ferrel cell is much weaker than the Hadley cell.

The dishpan experiment

- A dishpan with a hot equator and a cold pole is rotated
  - Troughs, ridges and eddies are produced, similar to patterns observed in earth's general circulation





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 Hadley cell, warmer fluid rises and moves poleward.
3. Ferrel cell is driven by heat fluxes by midlatitude storms.
4. In the Northern Hemisphere, a fluid is deflected to the right as it moves; in the Southern Hemisphere, it 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.
- Earth gives momentum to the atmosphere in the tropics; atmosphere gives momentum to the Earth in middle latitudes.