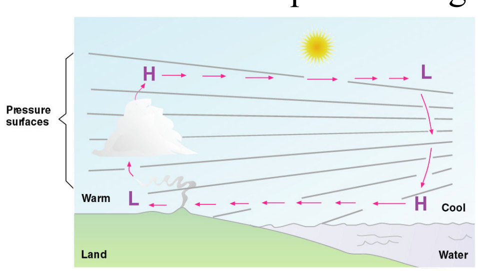
Chapter 11, Part 1

General Circulation of the Atmosphere

General Circulation

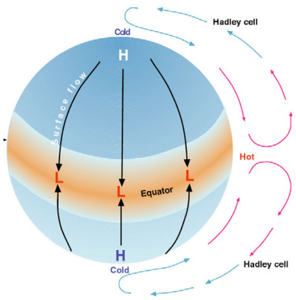
- Average air flow – actual winds at a given place and time may vary considerably.
- Explains why prevailing surface winds are northeasterly in Honolulu and westerly in New York City.

Wind due to Unequal Heating



- Last lecture we learned that unequal heating over land and water causes local sea breezes.
- This is an example of a thermally driven convection cell.

Single Cell Model

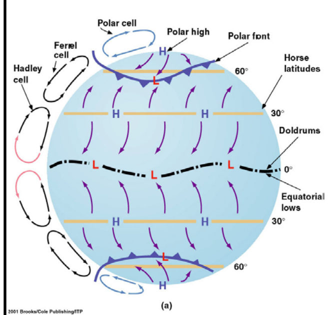


- Assumptions of the model:
  1. Earth's surface covered by water
  2. Sun always over equator
  3. No Coriolis force
- Leads to large thermally driven convection cells (Hadley cell).

Problems with Single Cell Model

- Coriolis force in Northern hemisphere would deflect south moving surface air to produce easterly winds at all latitudes.
- This does not happen. In the middle latitudes the winds blow from the west.

1. Three Cell Model



- Still assume surface covered by water and sun over equator, but now include the Coriolis force.
- The single cell breaks up into three cells.

2. Three Cell Model

- Doldroms – region over equator where pressure gradients are weak and winds are light.
- The warm air near the equator rises and moves towards the poles.
- As it moves north it cools and compresses, producing subtropical highs near 30^o.
- Weak pressure gradients at center of high lead to light winds (horse latitudes).

3. Three Cell Model

- From the horse latitudes ($\sim 30^o$) some of the surface air moves towards the equator.
- In the northern hemisphere the Coriolis force causes wind from the northeast (southeast in southern hemisphere). = Trade Winds
- The trade winds converge near the equator in the intertropical convergence zone (ITCZ).

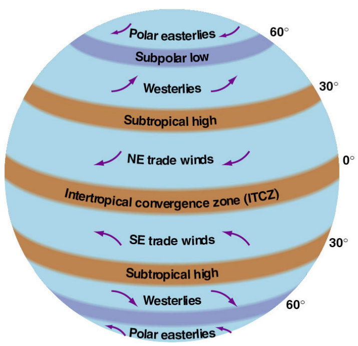
4. Three Cell Model

- Some of the air at the horse latitudes moves towards the poles and is deflected towards the east – producing the westerlies.
- These are common from Texas into Canada.
- This air encounters cold air moving south from the poles.
- The two air masses do not readily mix at the boundary – polar front, producing a subpolar low at approximately 60^o.

5. Three Cell Model

- At the polar front, some of the rising air returns at high levels to the horse latitudes, completing a thermally indirect cell or Ferrel cell.
- North of the polar front, cold air from the N. pole is deflected by the Coriolis force to produce the Polar easterlies.
- At the polar front some of this air rises and flows back N. creating a the weak polar cell.

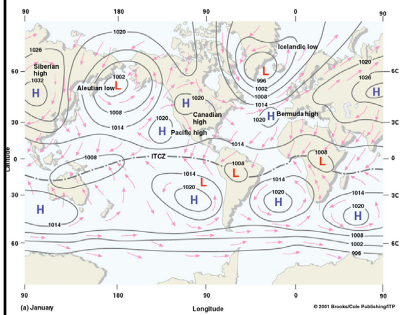
Summary of Three Cell Model



Comparison to Observations

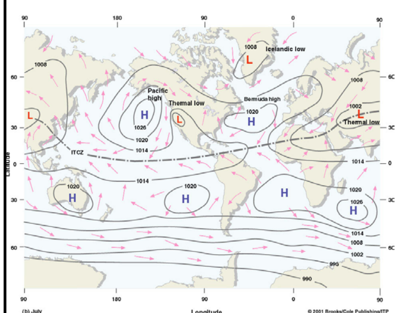
- As shown in the following slides, the three cell model gets the wide direction roughly correct, and
- there are highs at around 30^{o} and lows near the equator.
- Rather than seeing the three cell model as a way to make predictions, it should be seen as a way to make sense of global weather patterns.

Pressure and Wind in January



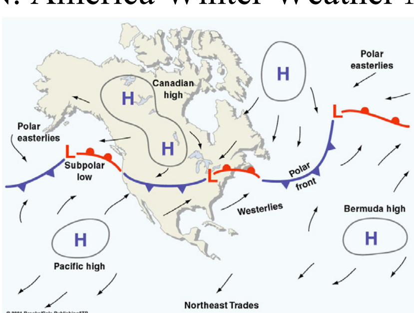
- Semipermanent (move only slightly during year) highs:
  - Bermuda
  - Pacific
- Semipermanent lows:
  - Icelandic
  - Aleutian
- Also, Siberian & Canadian highs.

Pressure and Wind in July



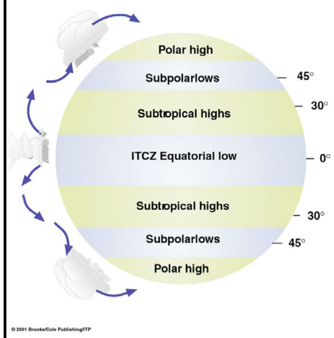
- Subpolar lows less well developed.
- ITCZ drifts north.

N. America Winter Weather Map



- Prevailing westerlies exist south of the polar front, which has moved southward in the winter.

General Circulation & Precipitation



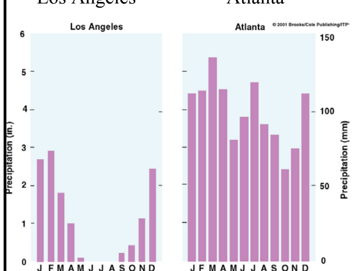
- Expect abundant rainfall where the air rises and little where it sinks.
- More rainfall in tropics where humid air rises (ITCZ) and between 40° to 55° latitude (polar front forces air upwards).

Summer Rainfall in the U.S.

- During the summer, the Pacific high moves northward causing dry weather on the West coast.
- The Bermuda high also moves northward, but continues to bring humid air.

Rainfall in East and West Coast

Los Angeles Atlanta



- The summer is the dry season on the West Coast.
- In the winter the Pacific high moves south, allowing the polar front and storms to come in.

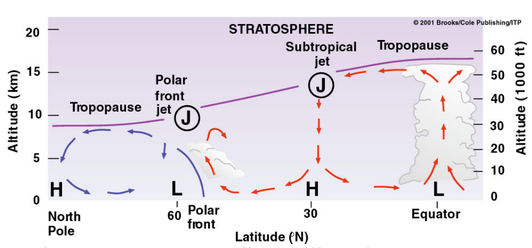
Jet Streams

- Jet streams are fast flowing air currents, which are 1000’s of km long, few 100 km wide, one a few kilometers thick.
- Wind speeds at the core often exceed 100 knots, and occasioanlly exceed 200 knots.
- They are usually found in the tropopause between 10 and 15 km in elevation.

Why do jet streams form?

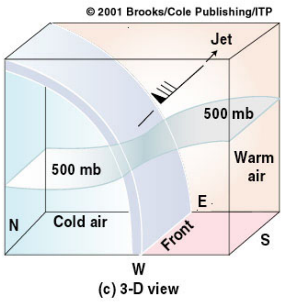
- Recall that away from the ground, wind flows parallel to pressure contours.
- The more closely spaced the isobars, the faster the wind.
- At the polar front there is a sharp change in temperature, creating a sharp change in pressure.
- A similar rapid change in temperature can occur near the subtropical high.

Position of Two Jet Streams



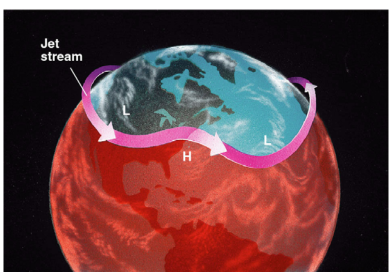
- The same pressure gradient will produce stronger winds for less dense air. This causes wind speeds to increase with height. (Also, no ground friction.)
- The horizontal pressure gradients increase up to the tropopause.

Formation of Polar Front Jet



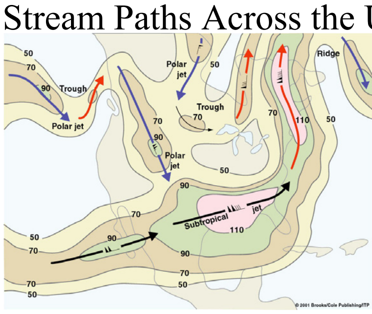
- The polar front jet forms due to the rapid pressure change across the front, which produces a large pressure gradient force.

Path of a Jet Stream



- Note that the path is not straight, but rather wavy.

Jet Stream Paths Across the U.S.



- Here, the Polar and Subtropical Jets actually merge.
- The jet streams help to mix warm and cold air masses, and hence to transport energy.

Summary

- Global circulation patterns are caused be unequal heating of the earth’s surface.
- The three-cell model explains the rough wind directions, as well as the location of some persistent highs and lows.
- Jet streams occur where there are rapid changes in temperature and hence pressure such as at the polar front and the subtropical high.