Meteorology 3110

# General Circulation/Fronts

# Precipitation Types

- Rain
- Snow
  - growth of ice crystals through deposition, accretion, and aggregation.
- Freezing Rain
  - Rain freezes when it hits the surface.
- Sleet
  - Usually starts out as snow or ice.
  - Falls through a warm layer and melts.
  - Falls through a lower layer below freezing and freezes again. Common with warm fronts.
- Graupel
  - Growth of ice crystal through accretion.
  - Accretion not significant enough to be called snow.

# Quick Quiz

- Question #1:  What is the primary cause of the seasons?
- Question #2: When is the Earth the closest to the Sun?
- Question #3: What is the significance of an equinox?
- Question #4: What is the significance of a solstice?

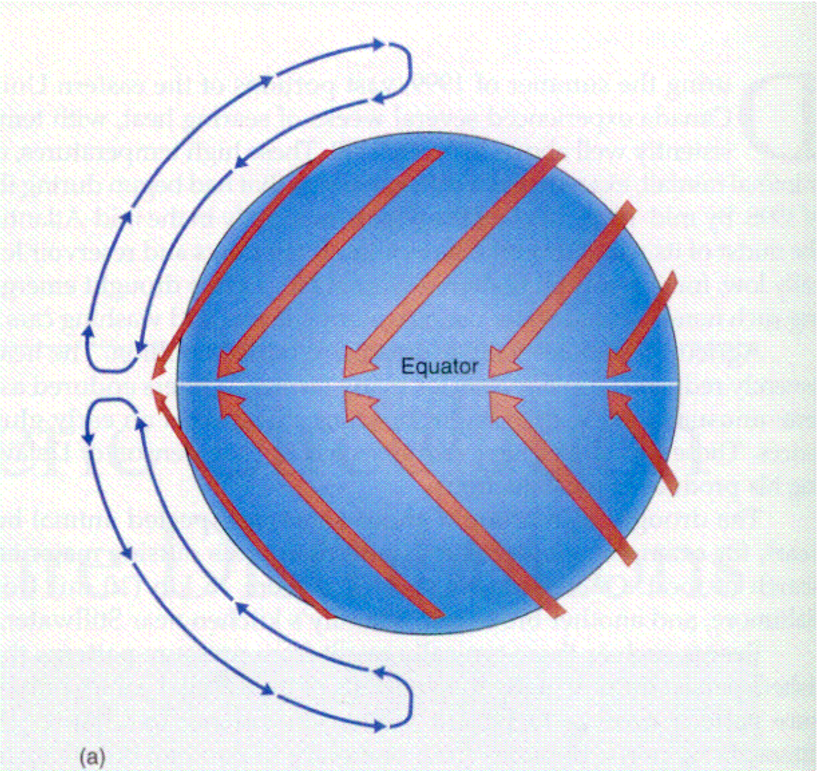
# General Circulation

- Seasons
  - Tilt of the Earth’s axis.
  - Equatorial regions receive much more solar energy than poles.

- Systems form and bring equatorial heat toward the pole and polar cold air toward the equator.

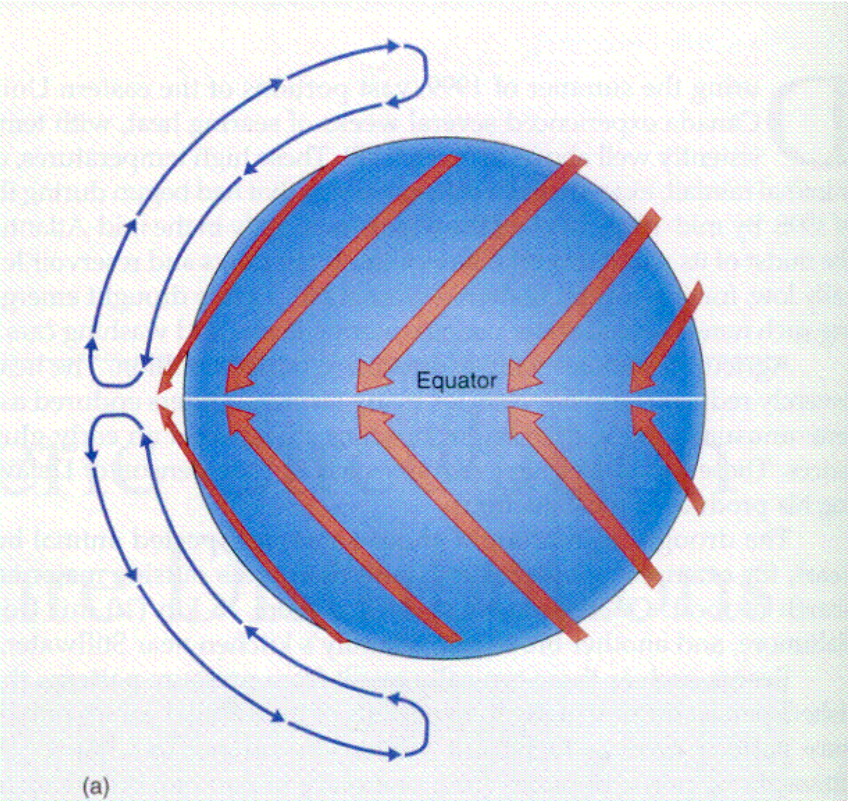
- One the long term, the Earth has a general circulation that is rather persistent.
  - What we (mid-latitude) think of as weather is generally the small-scale perturbations on the larger circulatation.

# Single Cell Model



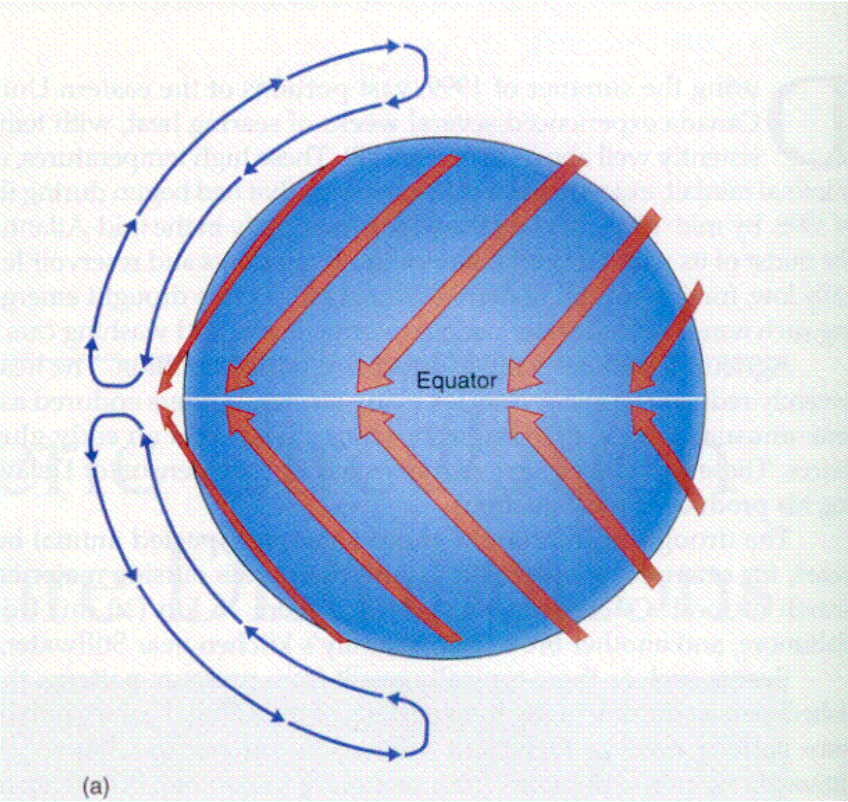

- Hadley (1735)
- Trying to describe why sailors experienced zonal winds in the lower latitudes.
- Assumed planet was covered by a single ocean and a fixed sun that remained over the equator.

# Single Cell Model



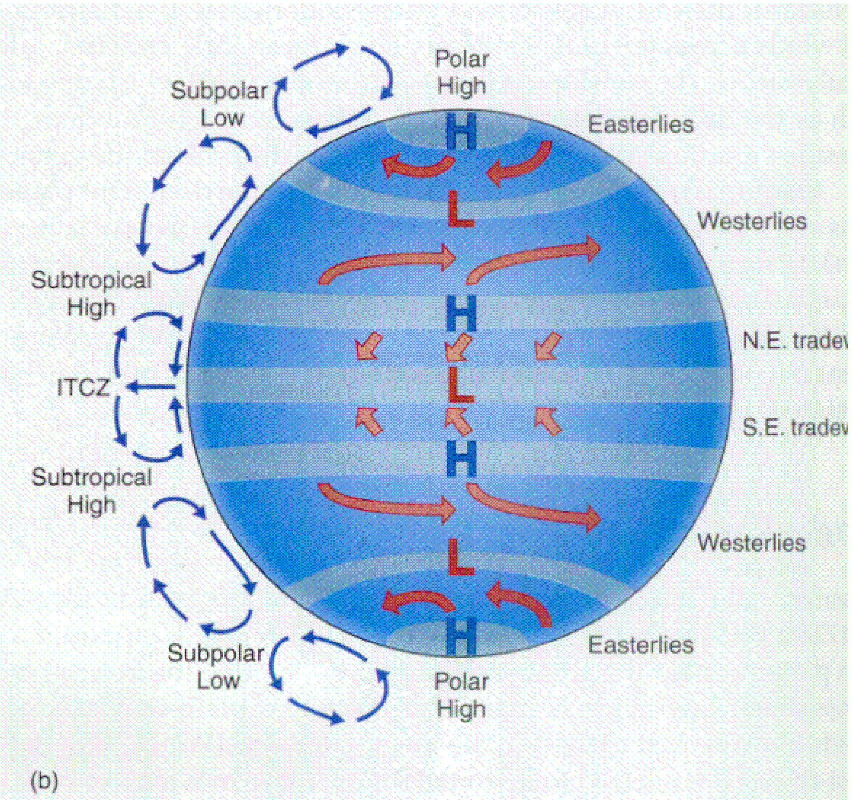

- Strong heating
- Air expanded vertically
- Diverged toward both poles
- Sank back to surface at the poles
- Returned to the equator.

# Single Cell Model



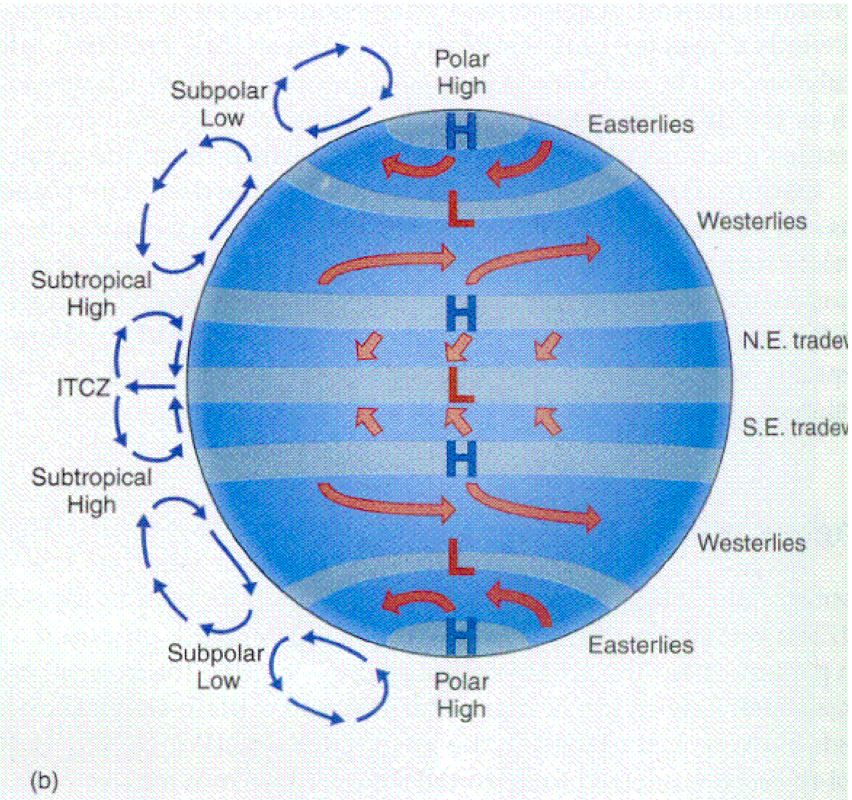

- Rotation of earth caused deflection to right in N.H. and left in S.H..
- Differences in heating give rise to persistent large-scale motions.
  - Thermally direct circulations.
- Zonal winds can result from the deflection of meridional winds.

# Three-cell model



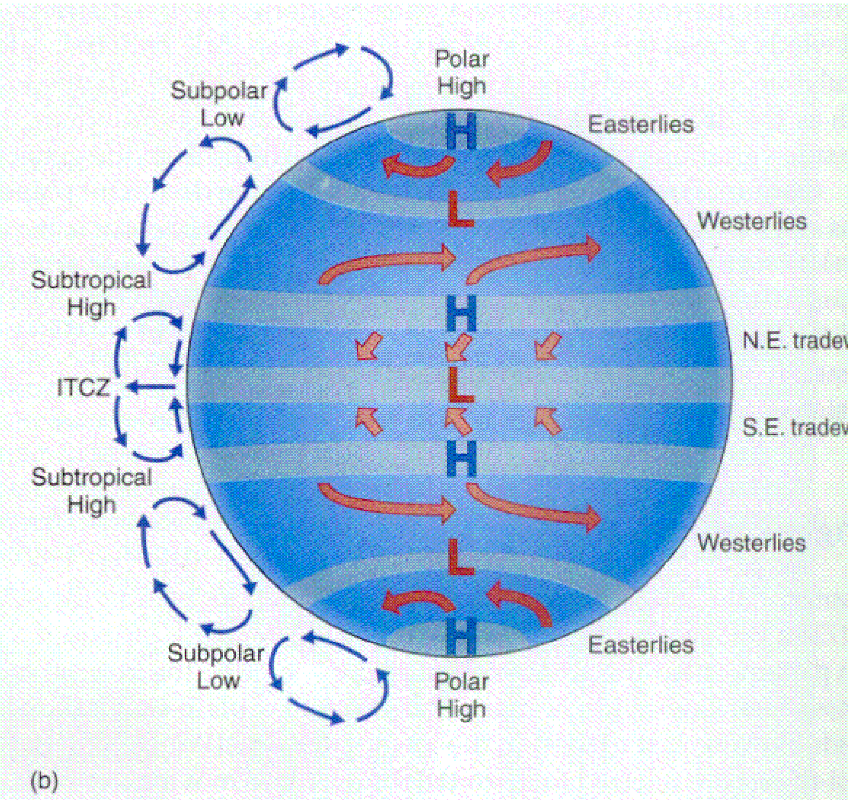

- Ferrel (1865)
- Hadley: tropics and sub-tropics
- Ferrel: mid-latitudes (30-60º)
- Polar

# Hadley Cell



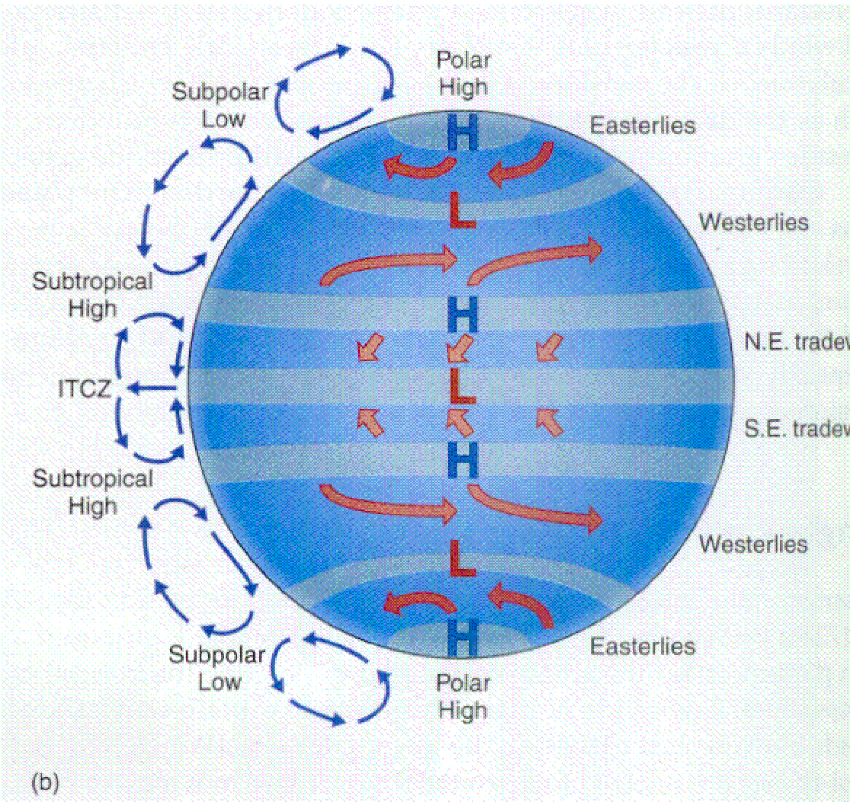

- Strong solar heating at equator.
- Equatorial low and the ITCZ.
  - Inter-Tropical Convergence Zone
- Upper troposphere moves poleward to sub-tropics (20-30º).
- Air acquires increasing zonal component.
  - Very strong. Circles the earth several times.

# Hadley Cell



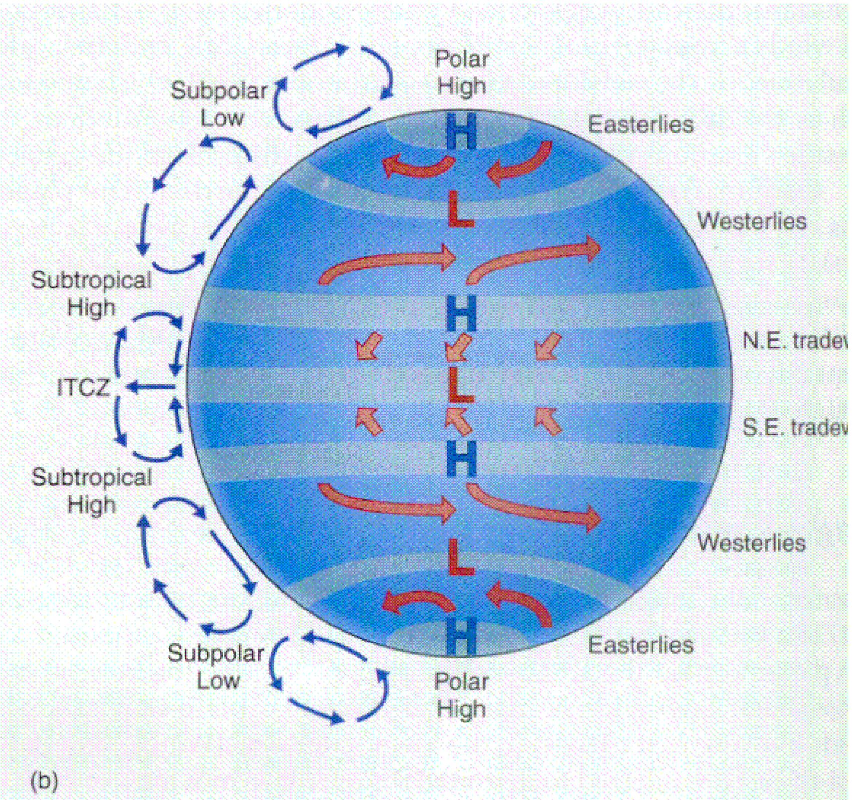

- Air sinks toward surface as it cools.
- Forms sub-tropical high.
- Air warms adiabatically, results in warm, cloud free conditions.
  - Weak pressure gradients and light winds.
- Strongest in the winter when temperature gradient is the strongest.

# Polar Cell

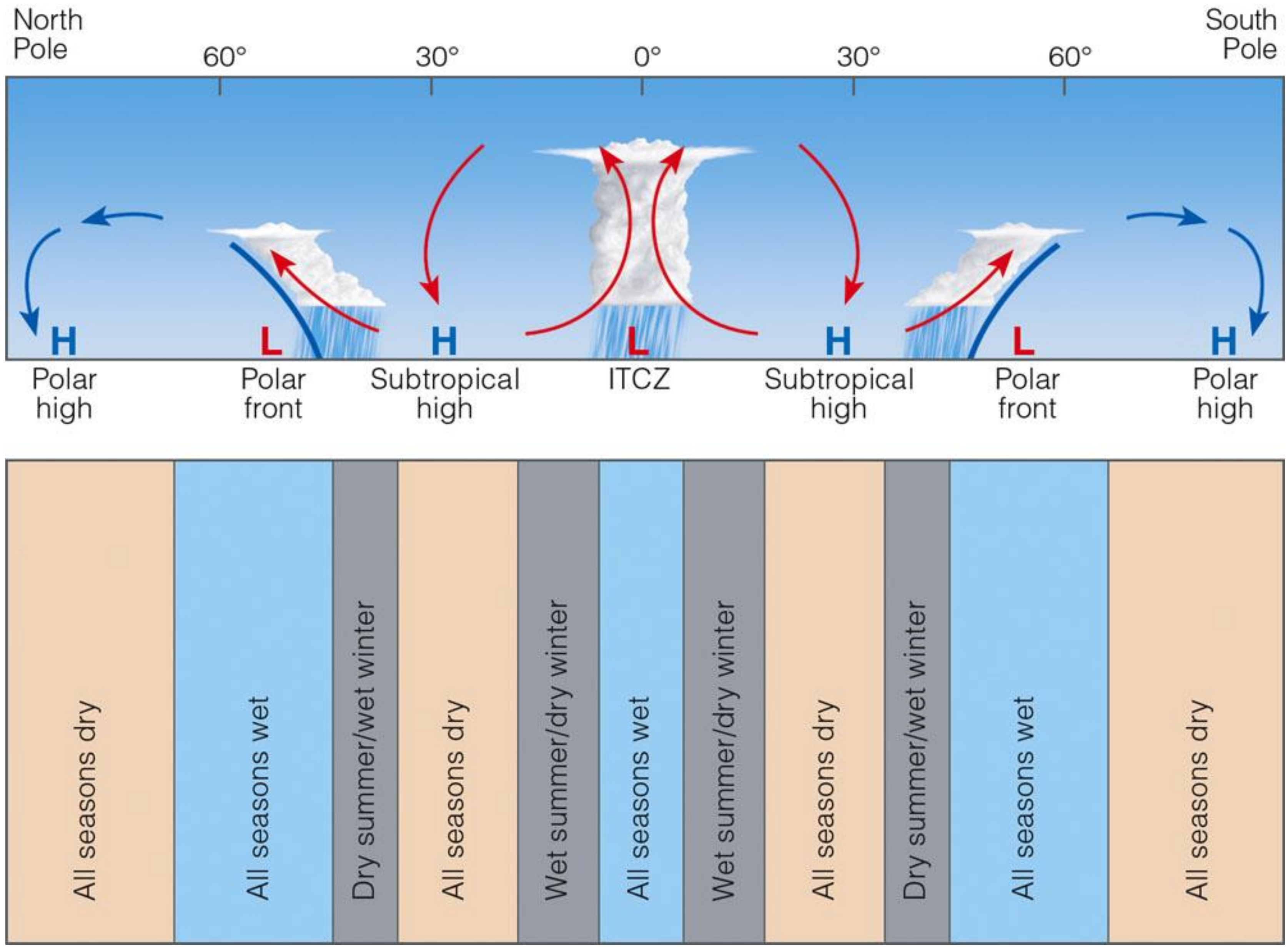



- Air mass moves from polar high to sub-polar low.
- Slightly warmer air at sub-polar locations rises.
- Very cold air at poles causes the polar high.
- Coriolis results in the polar easterlies.

# Ferrel Cell



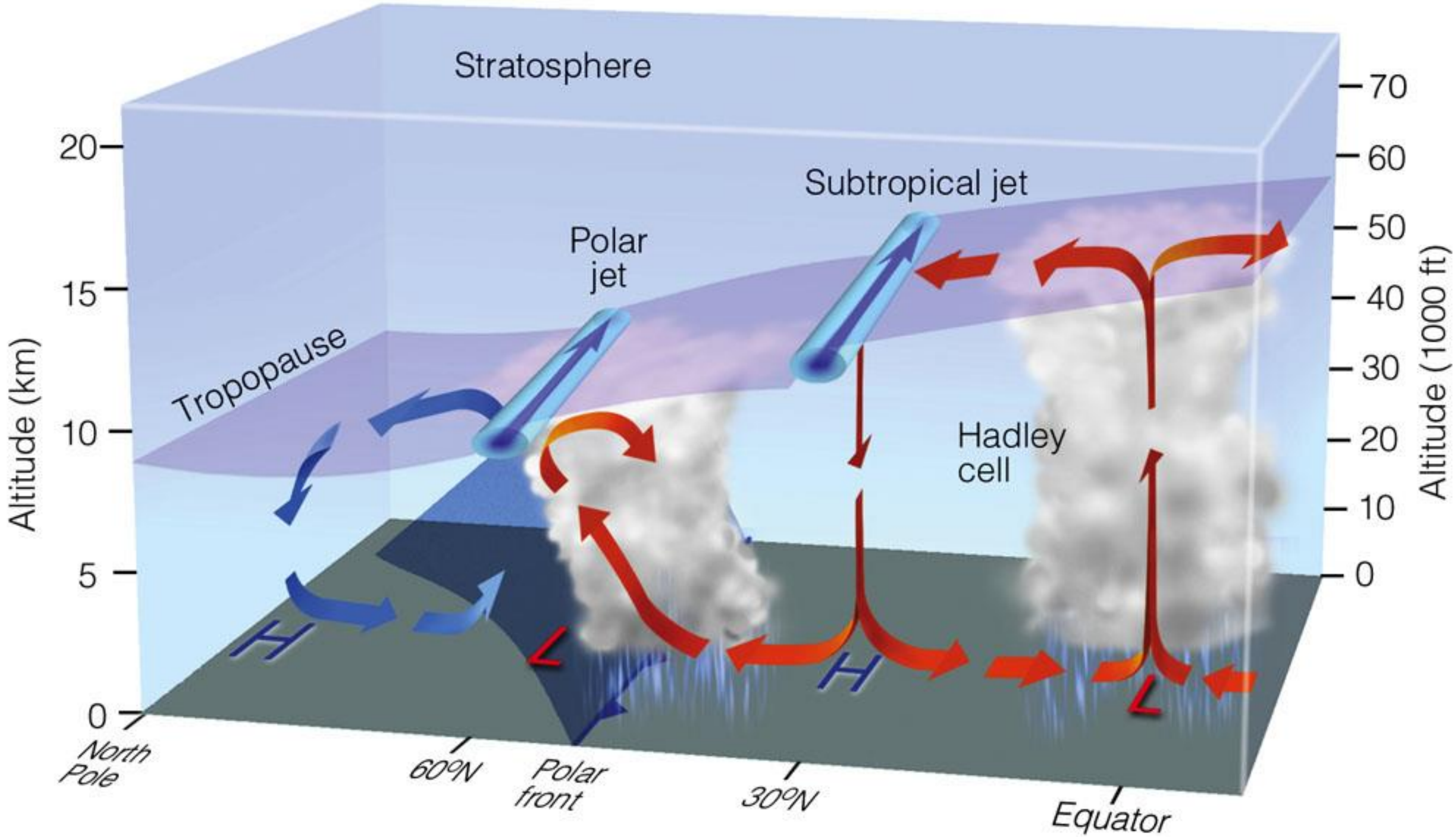

- Indirect cell
  - Caused by turning of the two adjacent cells.
- Coriolis results in Westerlies.



North Pole
60°
30°
0°
30°
60°
South Pole
H
L
H
L
H
L
H
Polar high
Polar front
Subtropical high
ITCZ
Subtropical high
Polar front
Polar high
All seasons dry
All seasons wet
Dry summer/wet winter
All seasons dry
Wet summer/dry winter
All seasons wet
Wet summer/dry winter
All seasons dry
Dry summer/wet winter
All seasons wet
All seasons dry

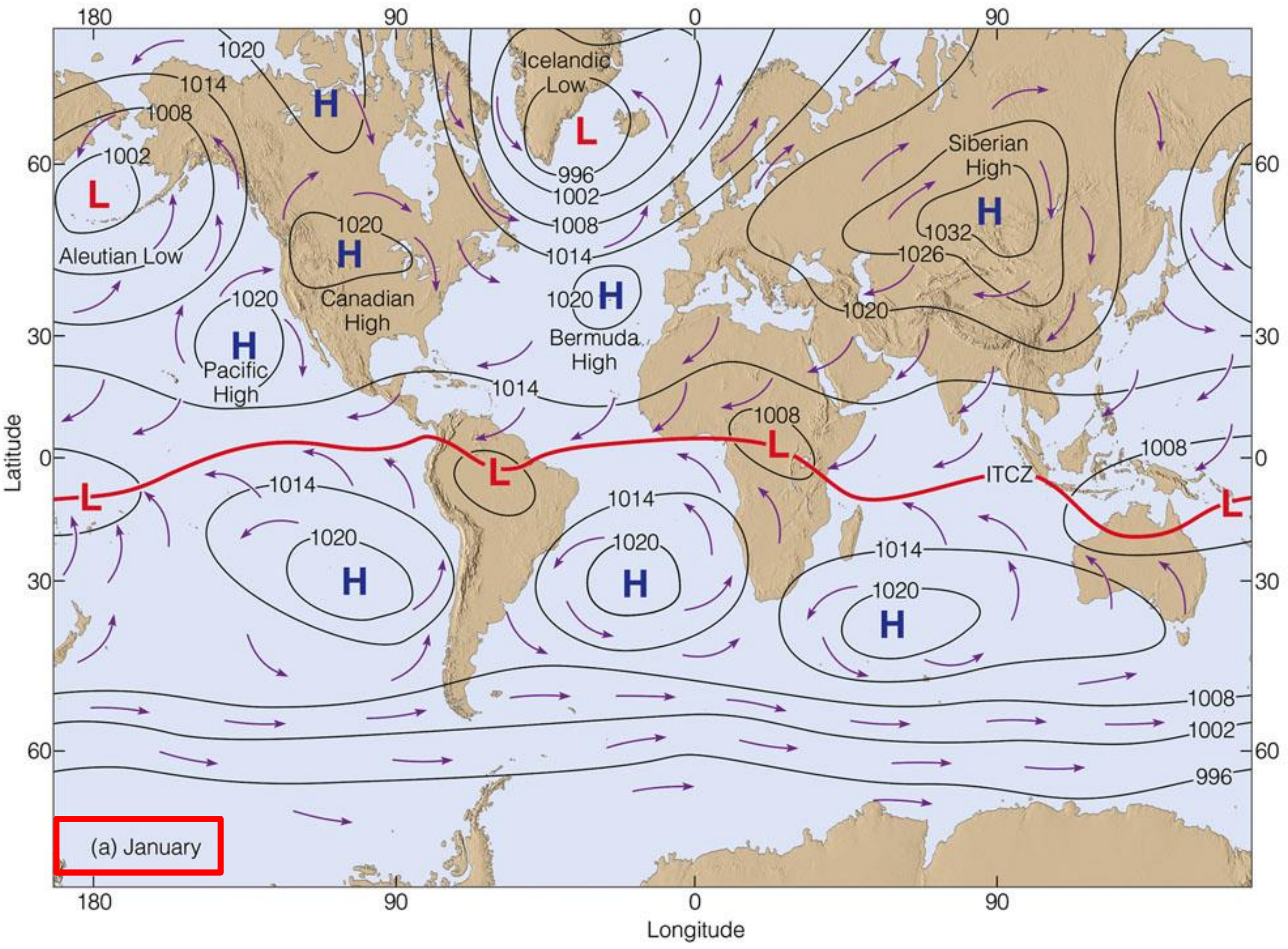
# Three-cell vs. Reality

- Hadley cell does a good job of low latitude motions.
- Ferrel and polar cells not quite as well represented.
  - Central U.S. is dominated by a southerly flow during the summer.
  - Polar easterlies only emerge in long term averages.
- Upper level model is not realistic at all
  - Ferrel cell implies easterly motion in the upper troposphere: Overwhelming westerly wind.
- Three-cell model provides a starting point for a more detailed account.
  - Doesn’t consider land-ocean contrasts or topography.

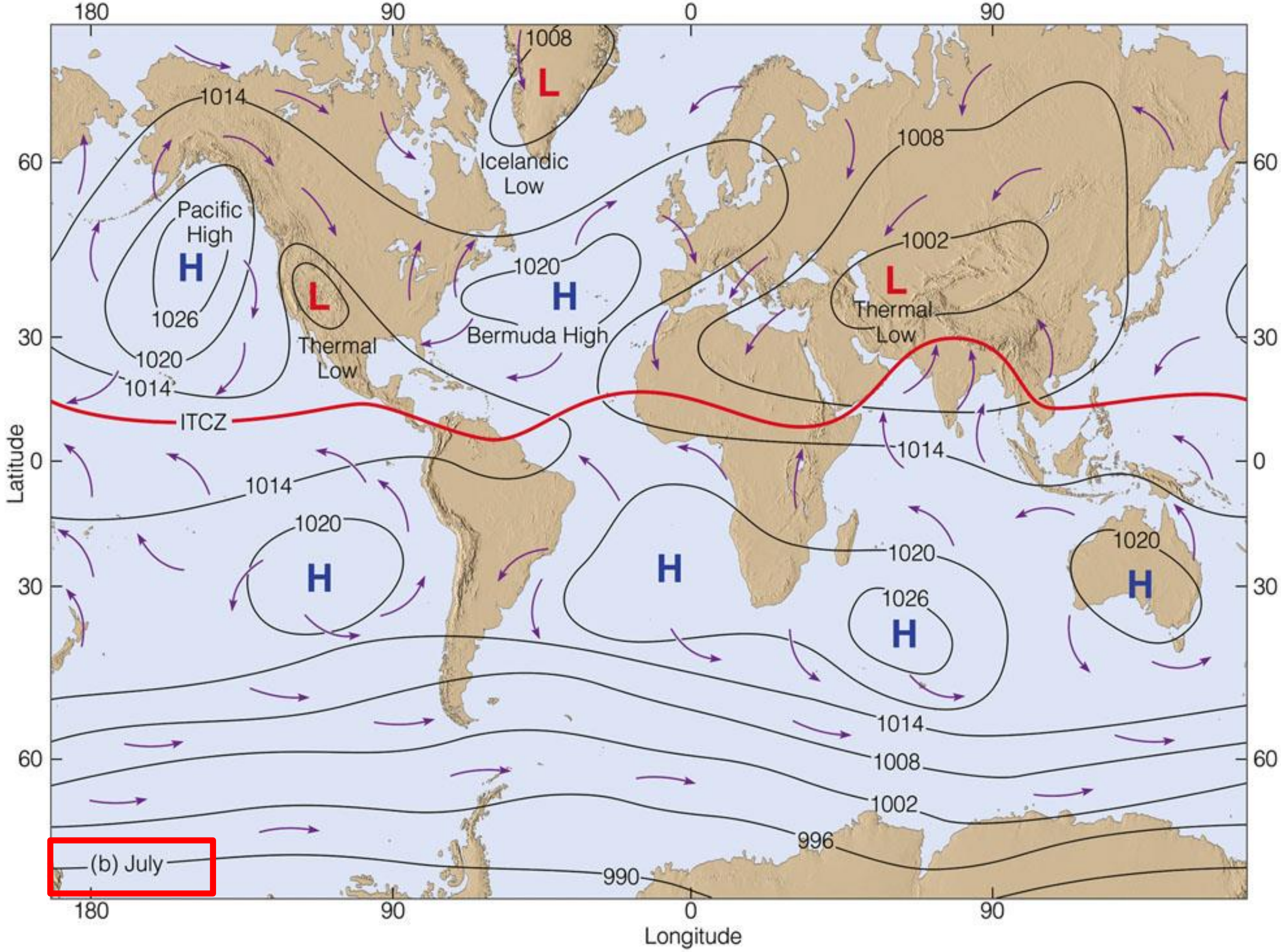


Stratosphere
Subtropical jet
Polar jet
Tropopause
Hadley cell
H
L
H
L
Altitude (km)
0
5
10
15
20
Altitude (1000 ft)
0
10
20
30
40
50
60
70
North Pole
60°N
Polar front
30°N
Equator

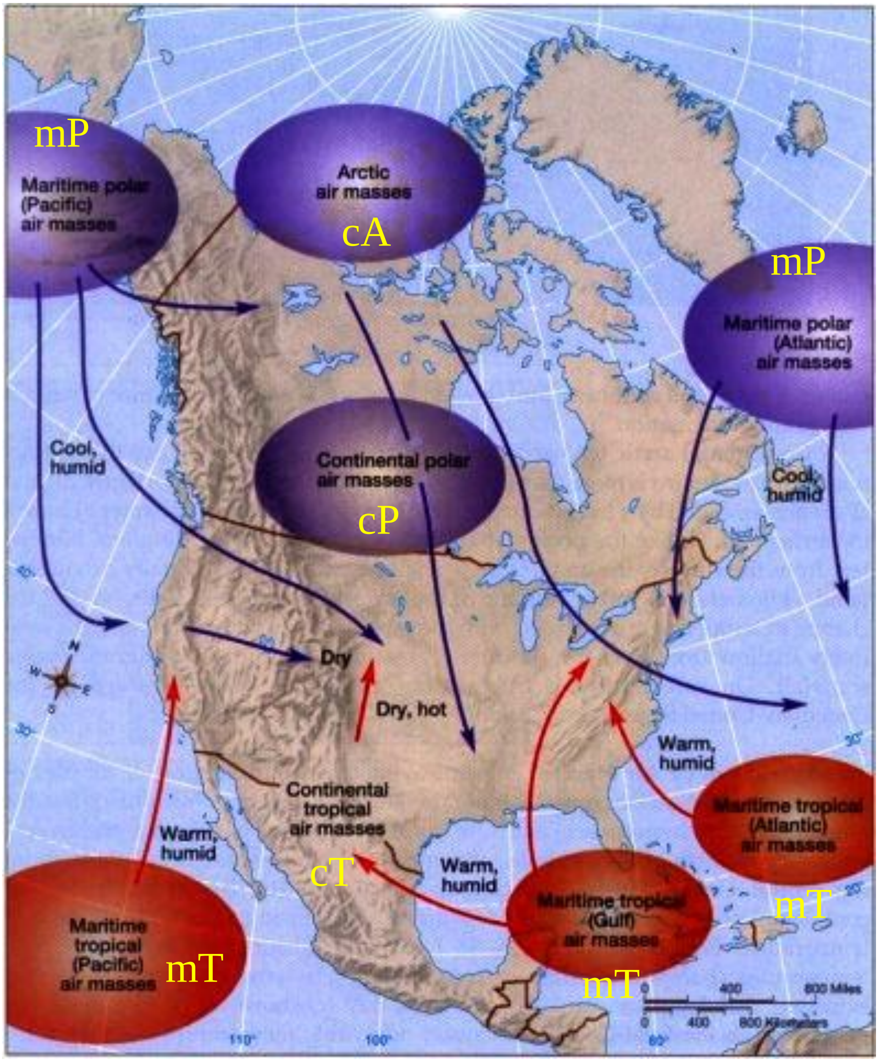
# Semi-permanent Cells



# Semi-permanent Cells



# Air Masses




- Air masses form when air remains over a given region of a substantial length of time.
- Air takes on characteristic of that region.
- Labeled by mositure (c,m), temperature (T,P,A).
- Why don’t characteristic air masses originate over mid-latitudes?
- What are boundaries between air masses called?

# Fronts

- Fronts separate different air mass types.

- Thickness gradient defines the approximate location of the front.
  - Front is located on the **warm** side of the gradient.

- Type of front depends on movement of the <u>colder</u> air.

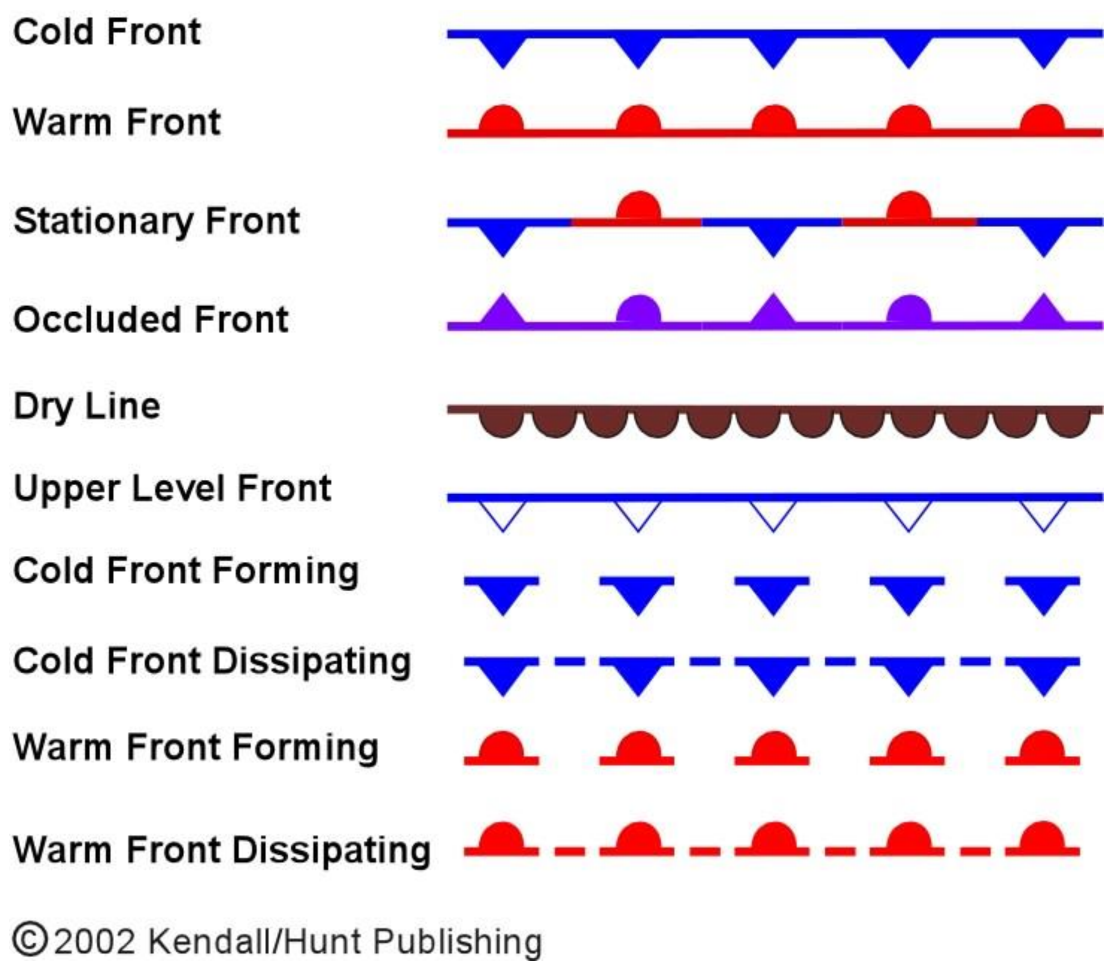
# Fronts - Location

- Wind shift line
- Pressure trough
- Temperature discontinuity
- Dew Point temperature discontinutity
- Pressure tendency pattern
- Horizontal visibility variations
- Horizontal variation in precipitation type

# Fronts – 5 types

- Cold
- Warm
- Stationary
- Cold Occlusion
- Warm Occlusion

# Front Symbols



# Nomenclature

- Frontogenesis: Convergent low-level flow in the presence of a thickness gradient at low-levels.

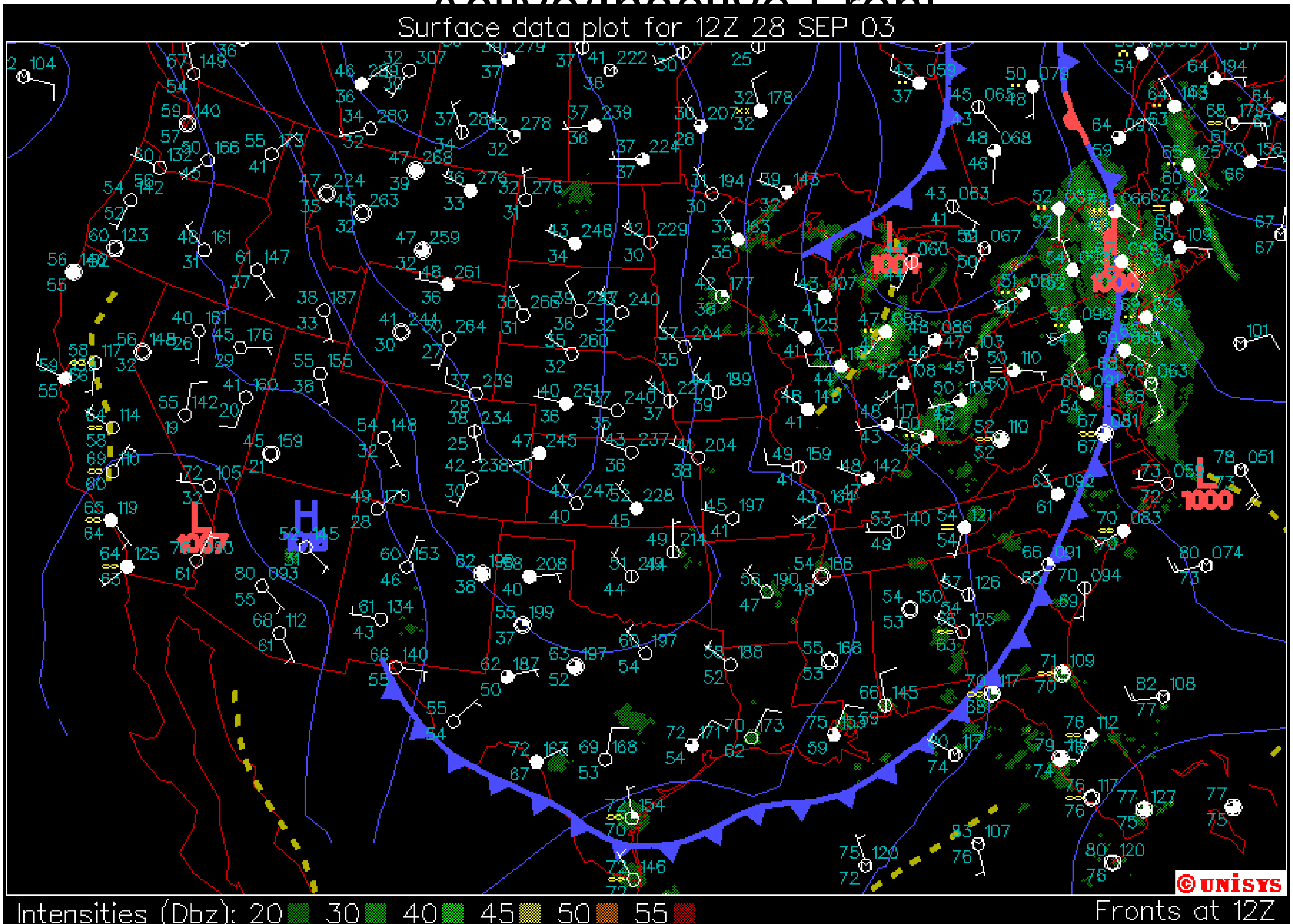
- Frontolysis: Divergent low-level flow around an existing front.

# Active/Inactive Fronts

- Active front: The warm air has a wind component with respect to the frontal motion **toward** the front.
  - Over a significant depth of the atmosphere.

- Inactive front: no warm air component toward the front.

# Active/Inactive Front



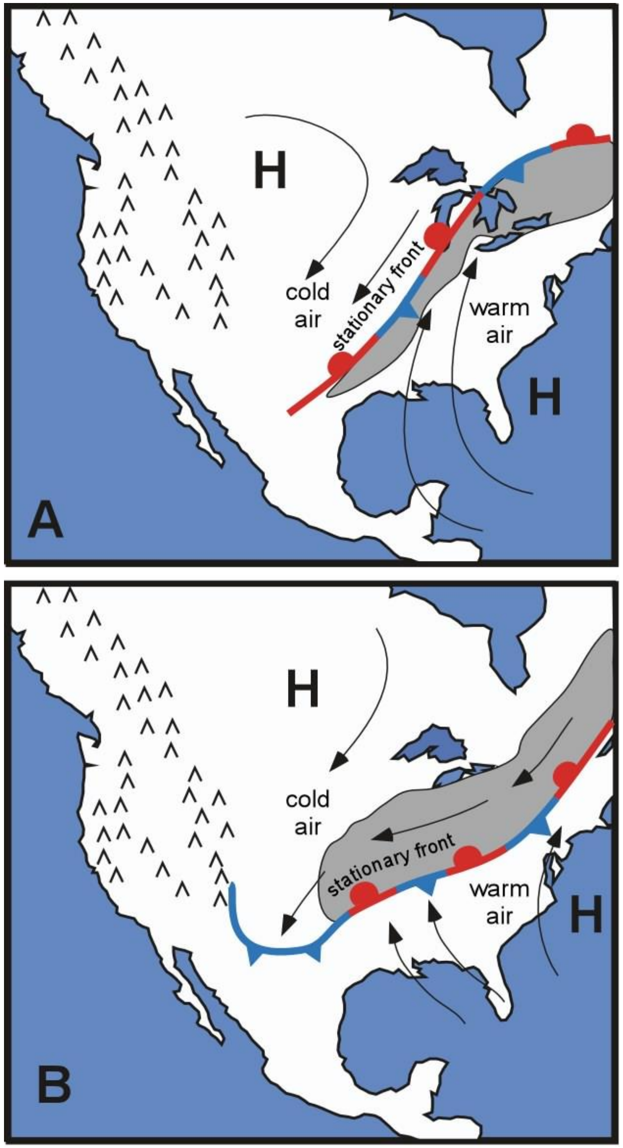
# Cold Front

- Temperature
  - Colder at the surface behind the front with lower thicknesses.
- Dew Point
  - Lower dew point temperatures found behind the front.
- Winds
  - South-Westerly ahead of front, often gusty near the front
  - Winds veer to north or northwest as front passes, and increase in strength.
- Pressure tendency
  - Pressure falls ahead of the front, rises behind the front.
  - Pressure trough exists along front.
- Precipitation types
  - Deep convection ahead, possible shallow convection behind.

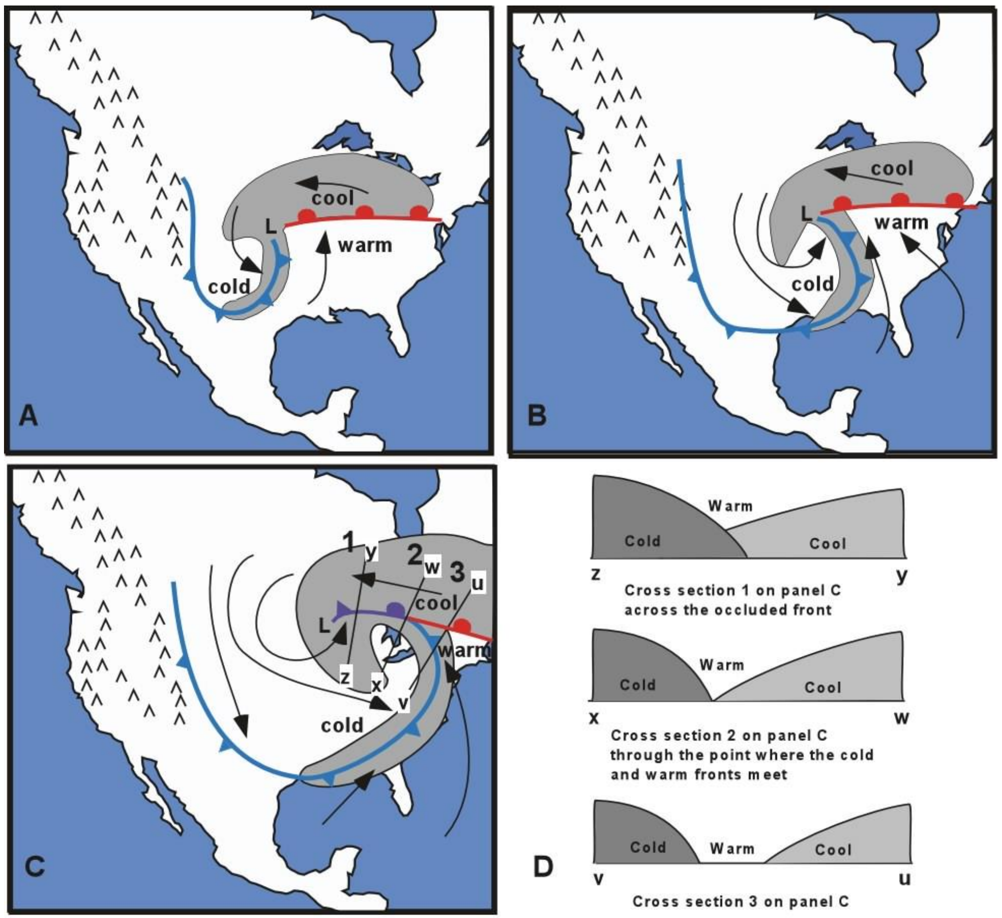
# Warm Front

- Temperature
  - Cold air ahead of warm front.  Temperature gradient is smaller than cold front (friction).
- Dew Point
  - Lower dew points ahead of front, although larger RH values are typically found here.
- Winds
  - South-easterly to northeasterly ahead of front in cool air.  Little gustiness.
  - Winds veer to southwest or south as front passes.
- Pressure tendency
  - Pressure falls ahead slowly ahead of warm fronts unless trough is intensifying rapidly.
  - Steady or slowly rising behind the front.
- Precipitation types
  - Often steady ahead of front.  No precipitation behind.

# Stationary Fronts



# Occlusion



cool
warm
cold
L
A
cool
warm
cold
L
B
1
y
2
w
3
u
cool
L
warm
z
x
v
cold
C
Warm
Cold
Cool
z
y
Cross section 1 on panel C
across the occluded front
Warm
Cold
Cool
x
w
Cross section 2 on panel C
through the point where the cold
and warm fronts meet
Cold
Warm
Cool
v
u
Cross section 3 on panel C
D

# Occlusions

- Cold occlusion
  - Typical occluded front seen in North America.
  - See previous image.
- Warm occlusion
  - Overtaking cold front encounters colder air associated with the warm front.
  - Typically found along the west coast of continents.
    - Relatively cool maritime air over takes colder continential air associated with warm front.