GLOBAL GENERAL CIRCULATION OF THE ATMOSPHERE

GEOG/ENST 3331 – Lecture 6

Ahrens: Chapter 10; A&B: Chapter 8; Turco: Chapter 2.4

Lecture outline

- **Global circulation**
  - **One and three cell theories**
  - **Continental effects**
  - **Seasonality**
- Global circulation and surface winds
- Jet streams

Scales of analysis

Scale	Size	Example
Microscale	m	Turbulent eddies
Mesoscale	km	Land/sea breeze
Synoptic scale	1 000 km	Cyclones
Global scale	5 000 km	Planetary waves

- Synoptic and global scales are sometimes grouped together as ‘Macroscale’

Global Circulation

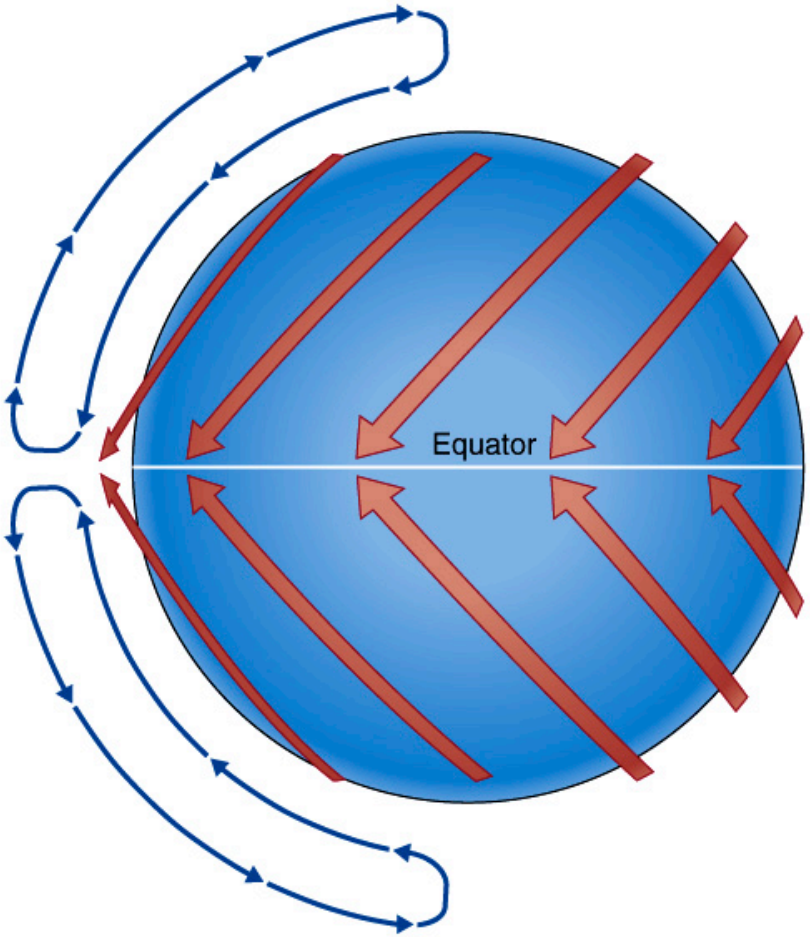
Observation: There is more energy released in the polar regions than is received from the sun. The reverse is true for the equatorial region.

How can we account for this?

The atmospheric circulation must provide a poleward transport of energy

One Cell Theory

- Consider a hypothetical planet…
  - Prevailing wind from the east at the surface
- Not observed
- Need a better theory

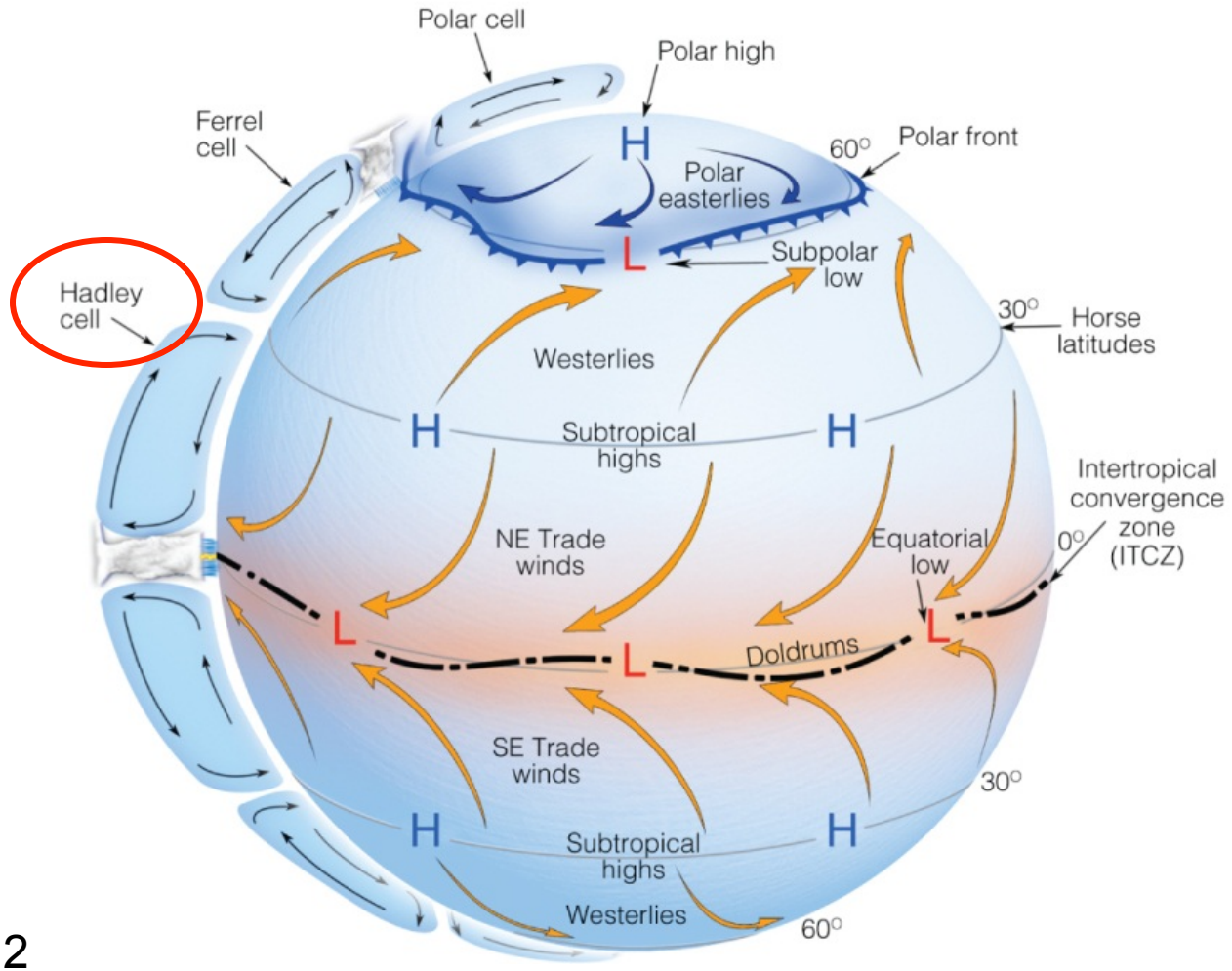


A&B: Figure 8-2

Three Cell Theory

Hadley cell near the equator.

Air rises at the equator, moves poleward and sinks at 30°N and 30°S.

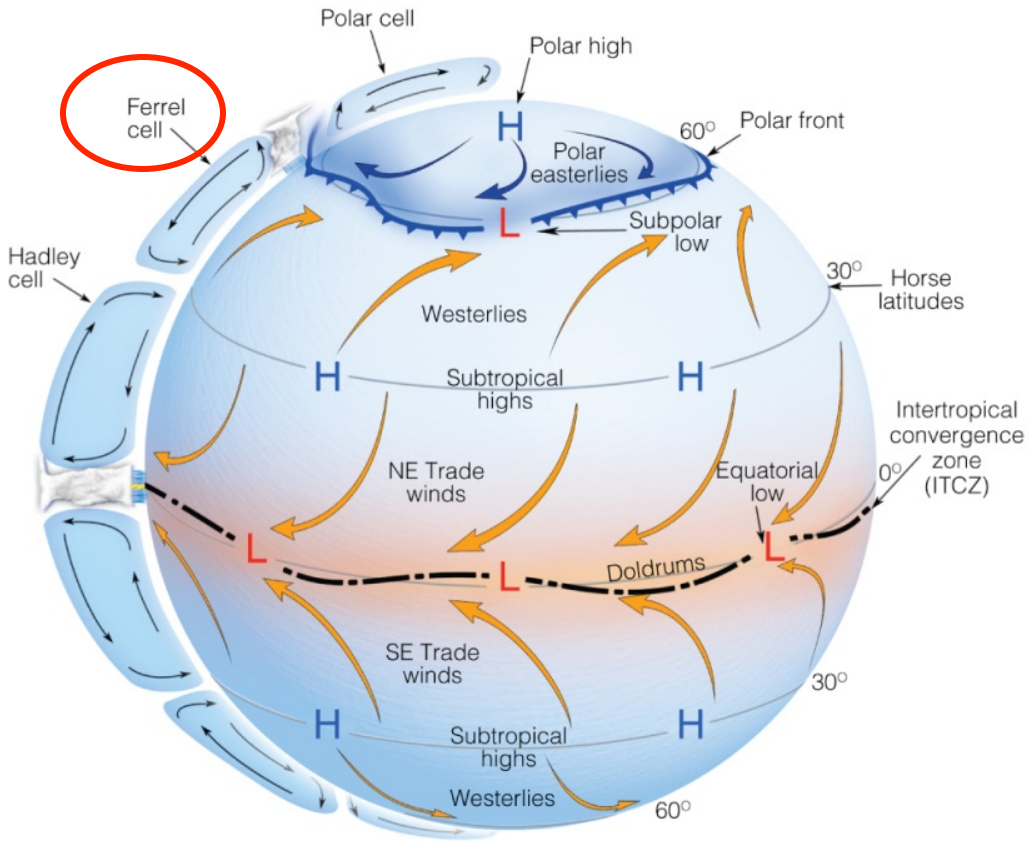


Ahrens: Fig. 10.2

Three Cell Theory

Ferrel cell exists roughly between 30° and 60° in each hemisphere

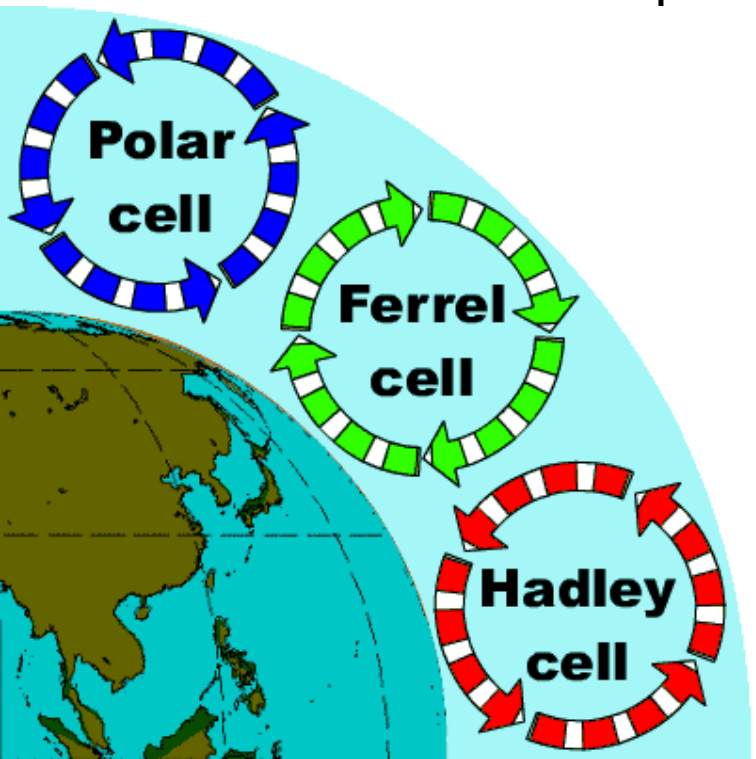
- Thermally indirect, i.e. warm air sinks and cold air rises
- Surface winds travel north and producing the prevailing westerlies.

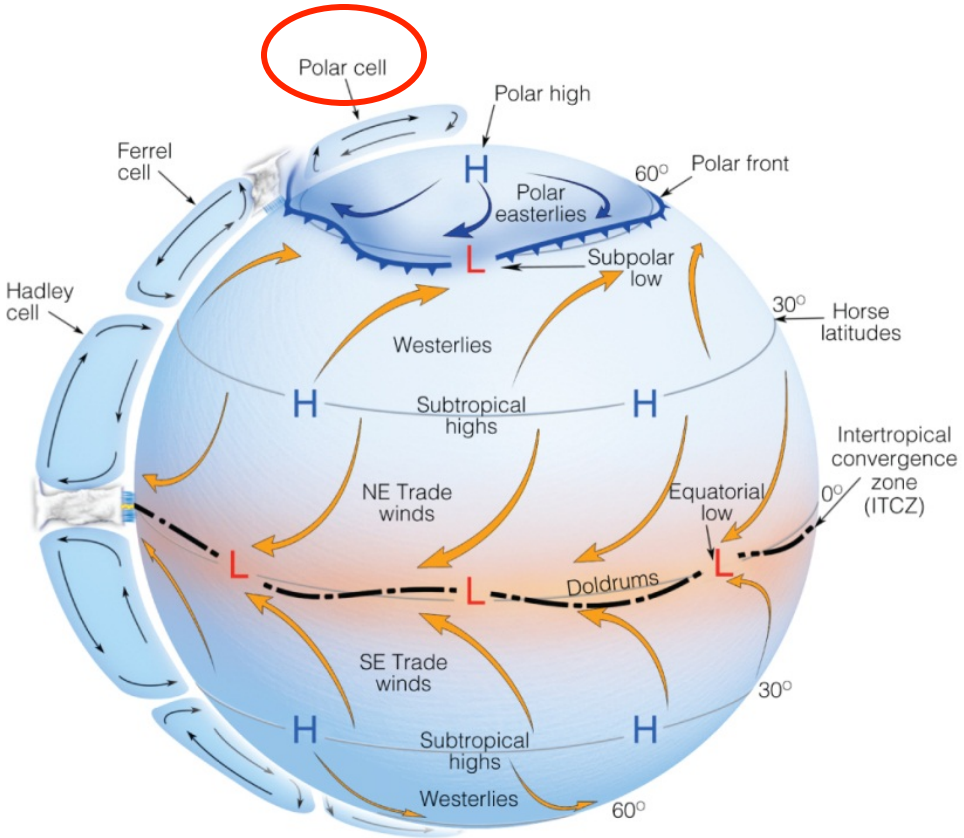


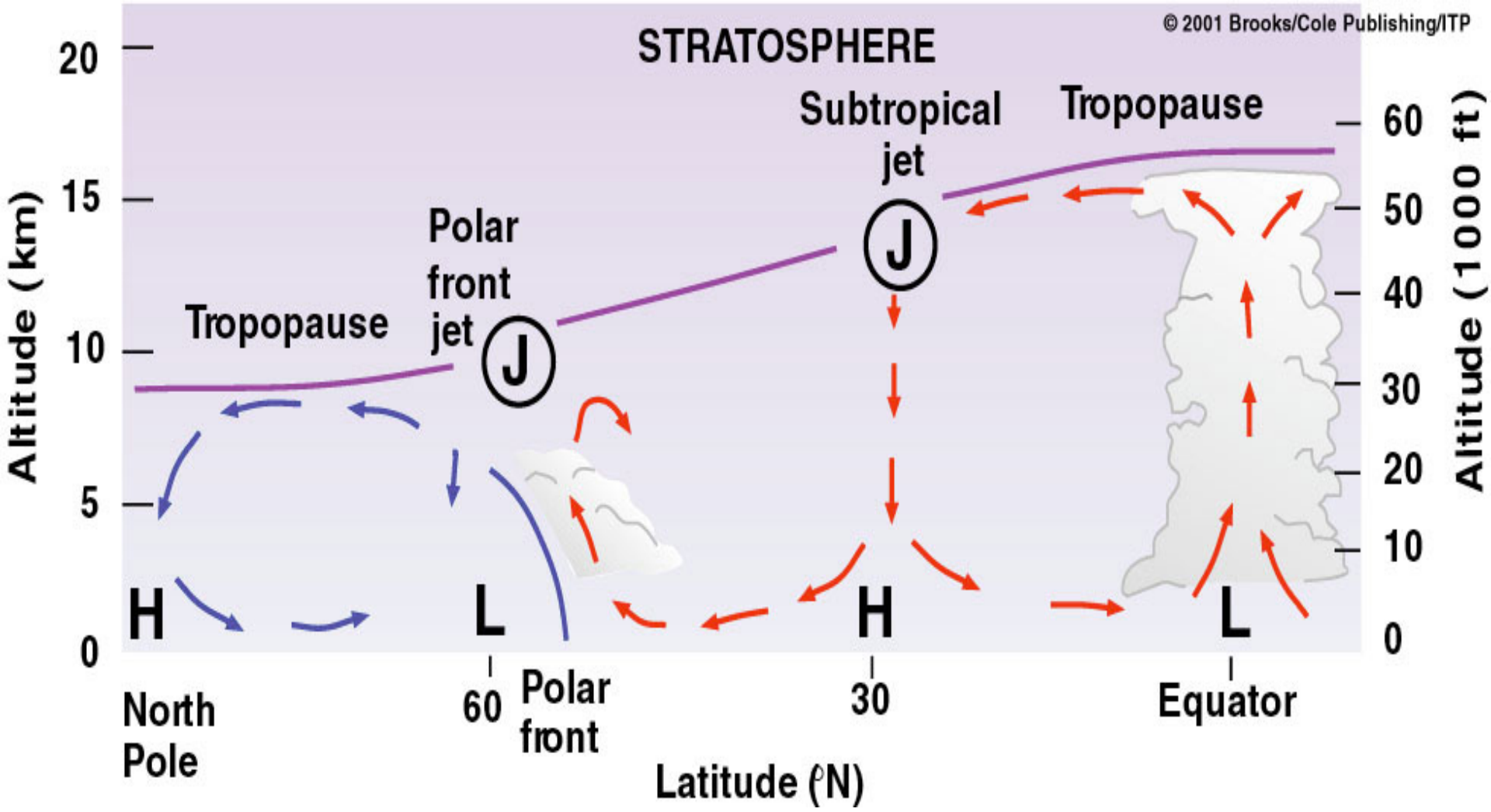
Three Cell Theory

Polar cell

- Sinking at the poles, rising at 60°.
- Polar easterlies are produced.



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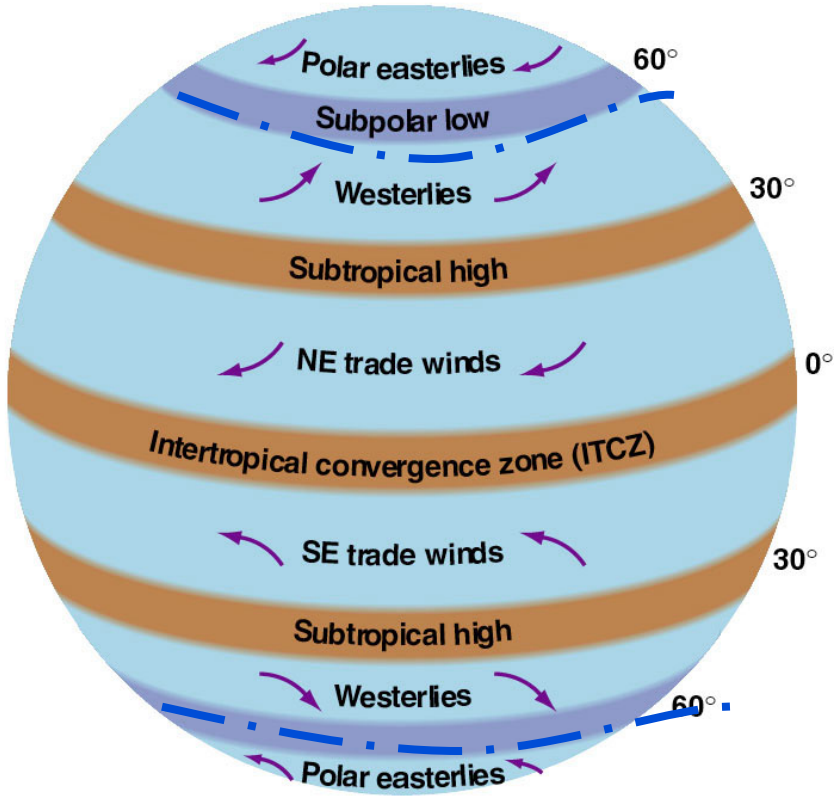
STRATOSPHERE
Subtropical jet
Tropopause
Polar front jet
Tropopause
J
J
H
L
H
L
Altitude (km)
20
15
10
5
0
Altitude (1000 ft)
60
50
40
30
20
10
0
North Pole
60
Polar front
30
Equator
Latitude (°N)

Surface zones

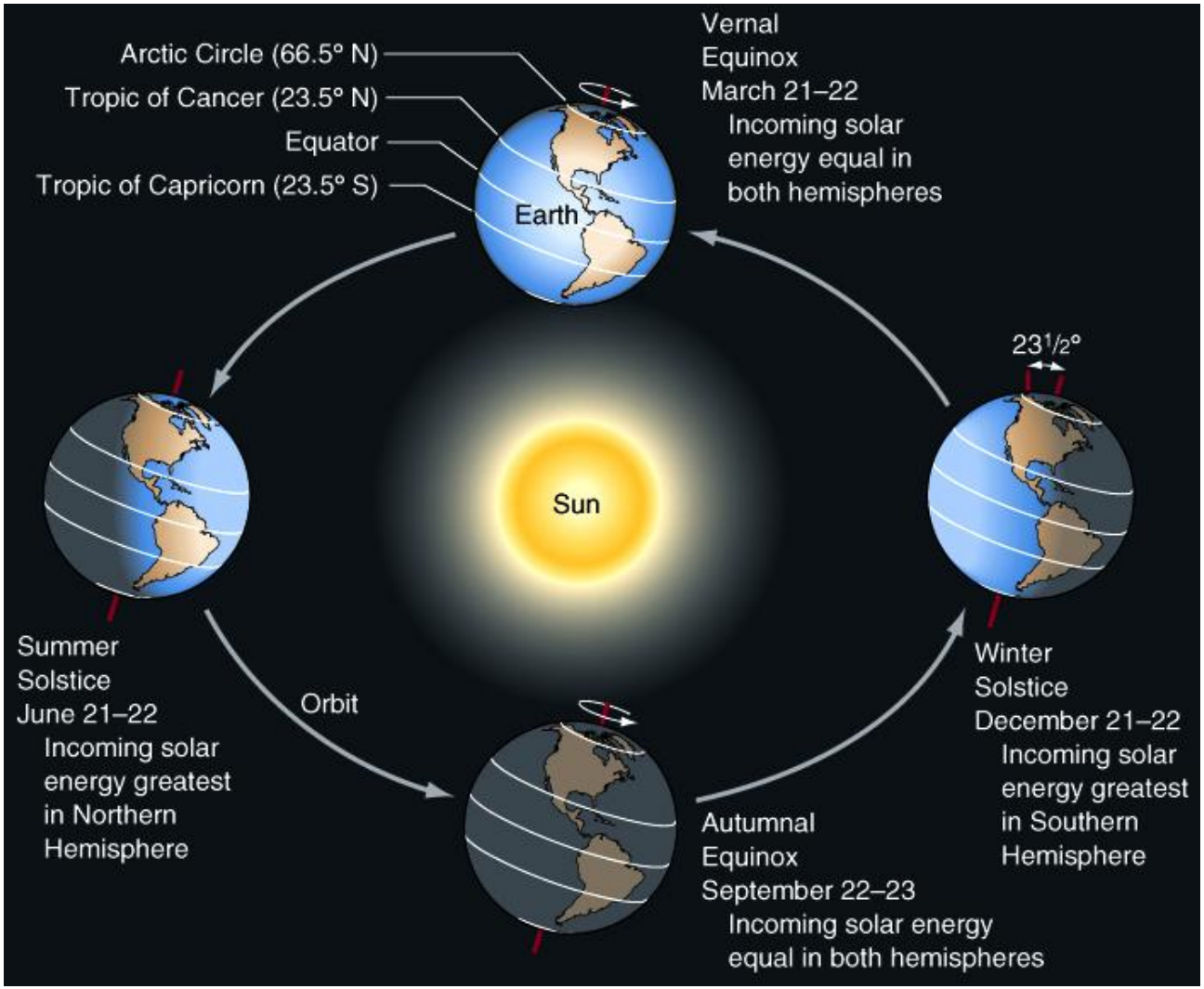
- Intertropical Convergence Zone (ITCZ) (Doldrums)
- Trade Winds
- Subtropical high (Horse latitudes)
- Westerlies
- Polar Front
- Polar easterlies



(b)

The ITCZ is observable as a band of clouds extending from northern South America into the Pacific

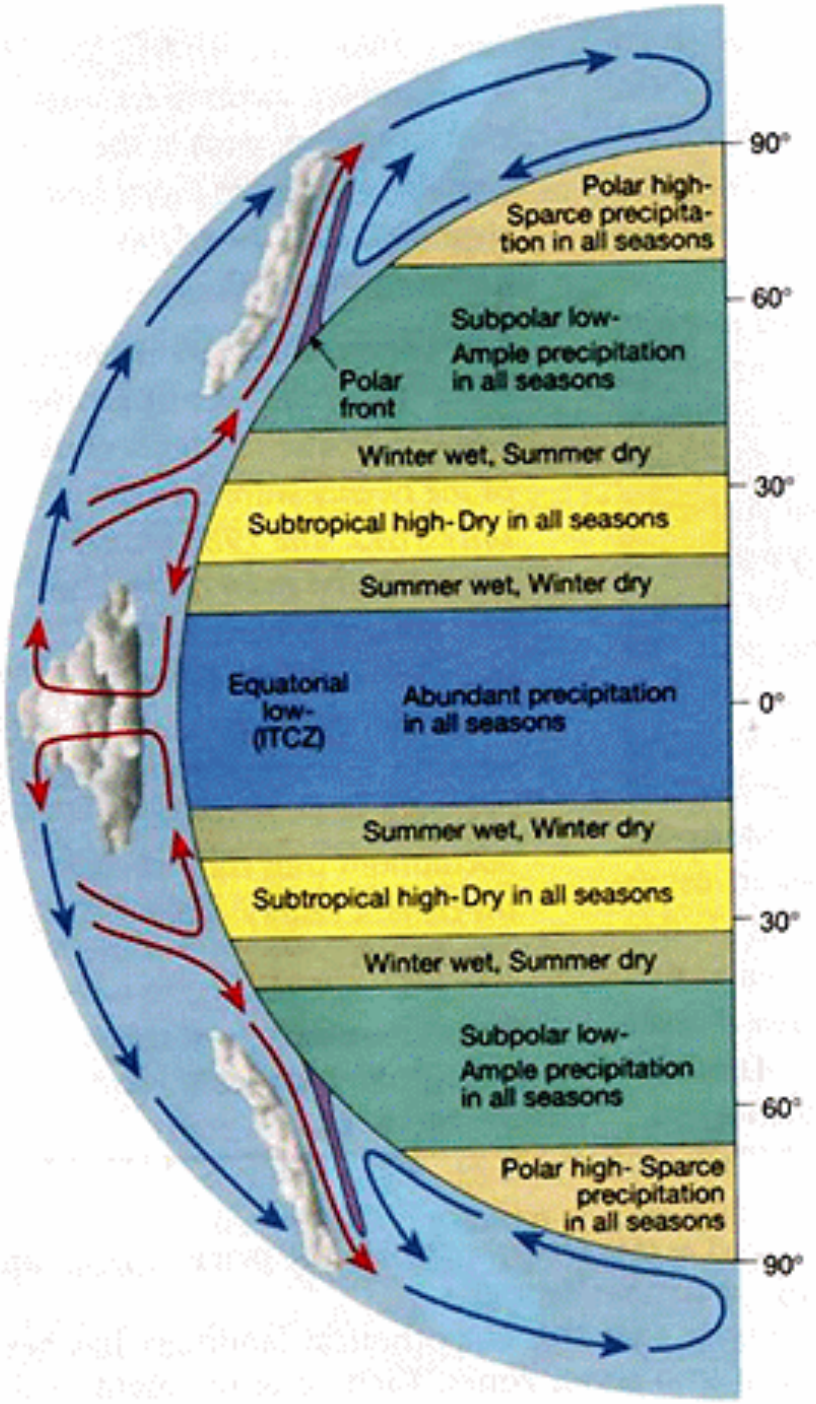
Axial tilt in Earth's orbit

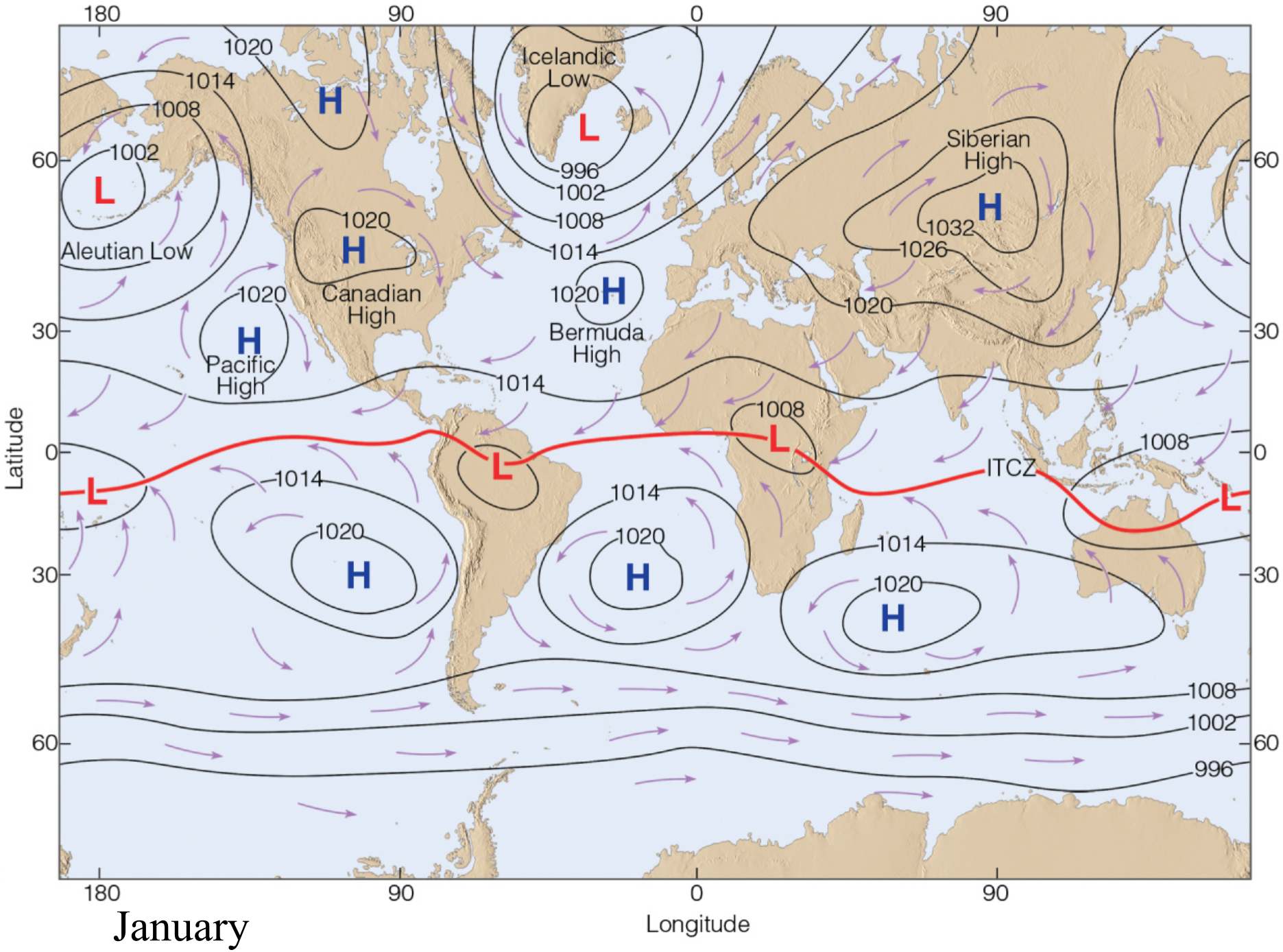


Seasons and continents

- Impact of seasons
  - General circulation features shift north in JJA, south in DJF
  - This is most evident in the Northern Hemisphere
- Impact of continents
  - Land masses warm up and cool down faster as the seasons change

Global Precipitation Pattern Produced by the General Circulation




180
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90
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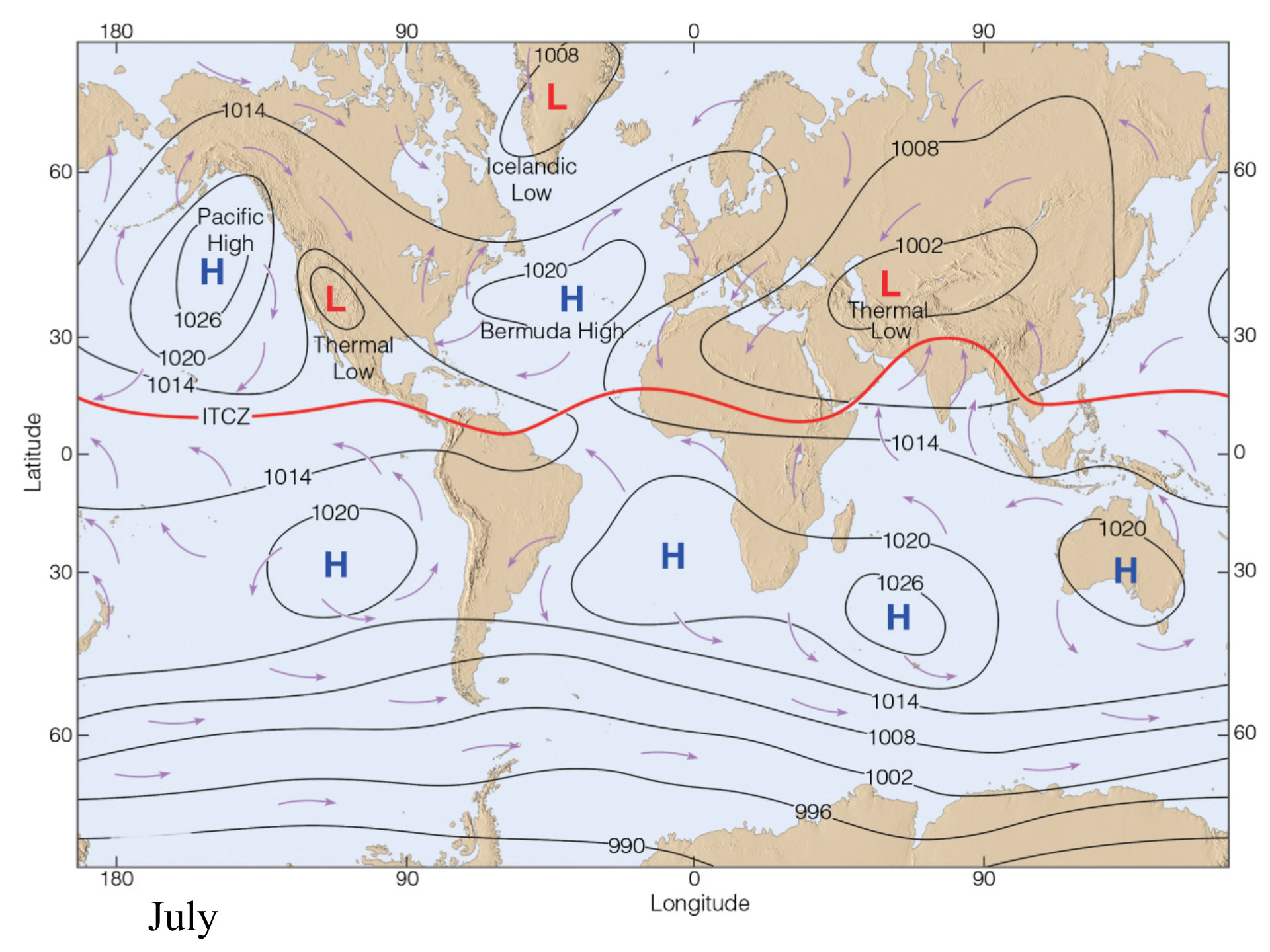
Latitude
Longitude
Icelandic Low
L
996
1002
1008
1014
1020
H
Siberian High
1032
1026
Aleutian Low
Canadian High
Bermuda High
Pacific High
ITCZ

January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Bermuda High
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H
1020
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1026
H
1014
1008
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1002
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990
180
90
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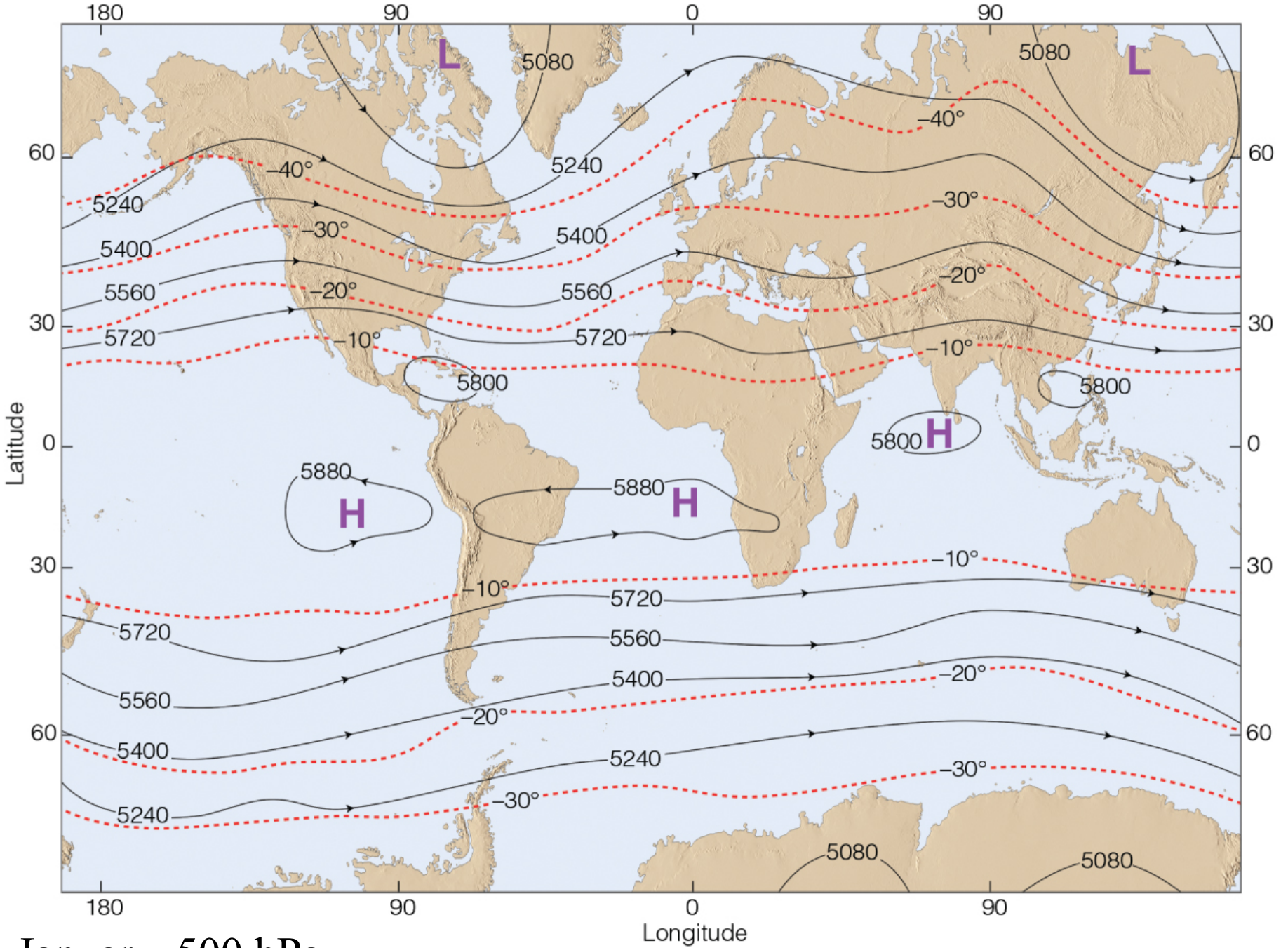
90
Latitude
Longitude
July

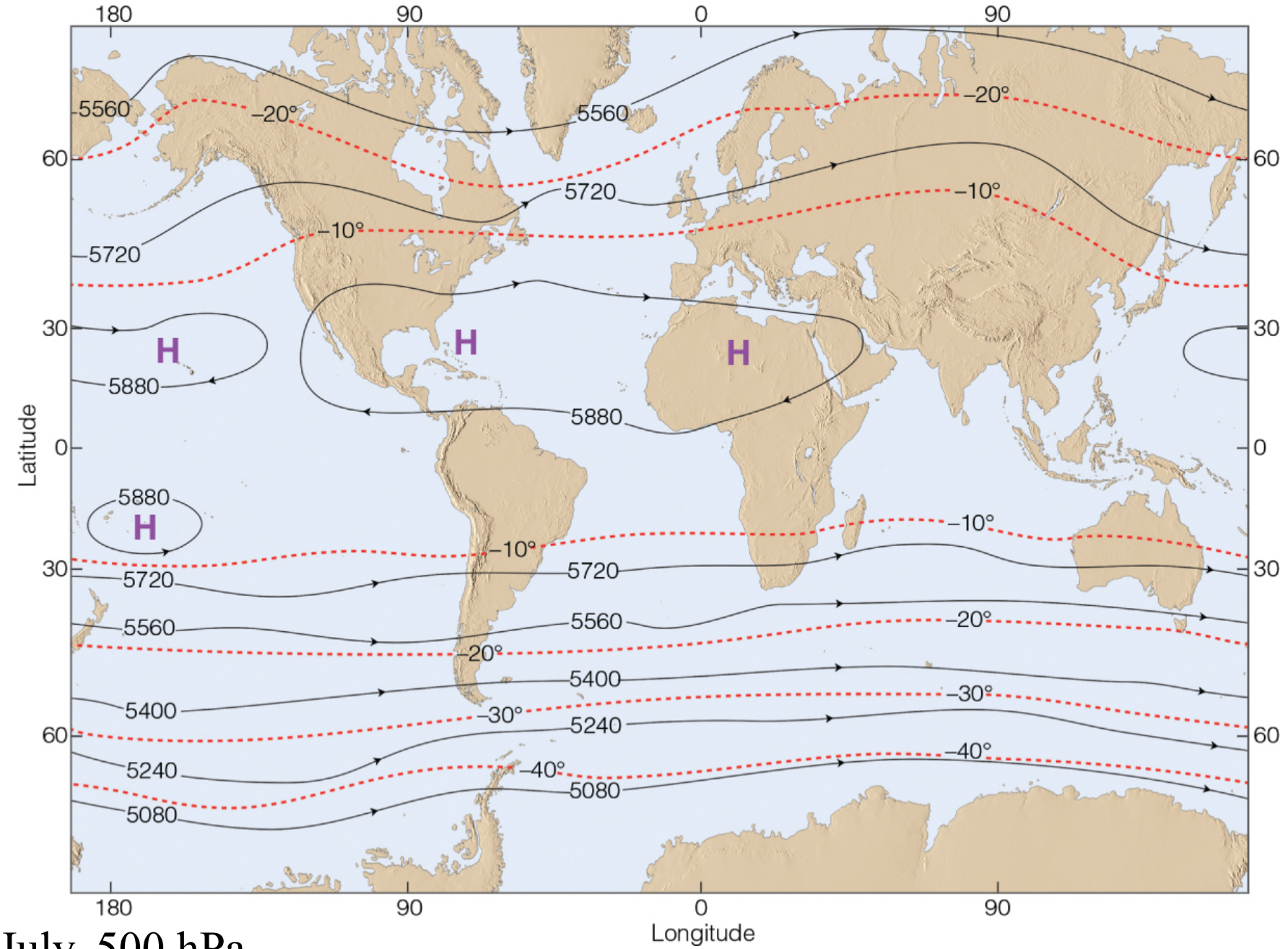
Upper level flow

- Much less friction; winds are geostrophic
  - There is much less *meridional* heat transport
  - Strong *zonal* heat transport

- Impacts of seasons and continents
  - Circulation still shifts with the seasons
  - Land/sea contrast less evident



January, 500 hPa


180
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60
Latitude
Longitude
5560
−20°
5720
−10°
5880
H
5400
−30°
5240
−40°
5080

July, 500 hPa

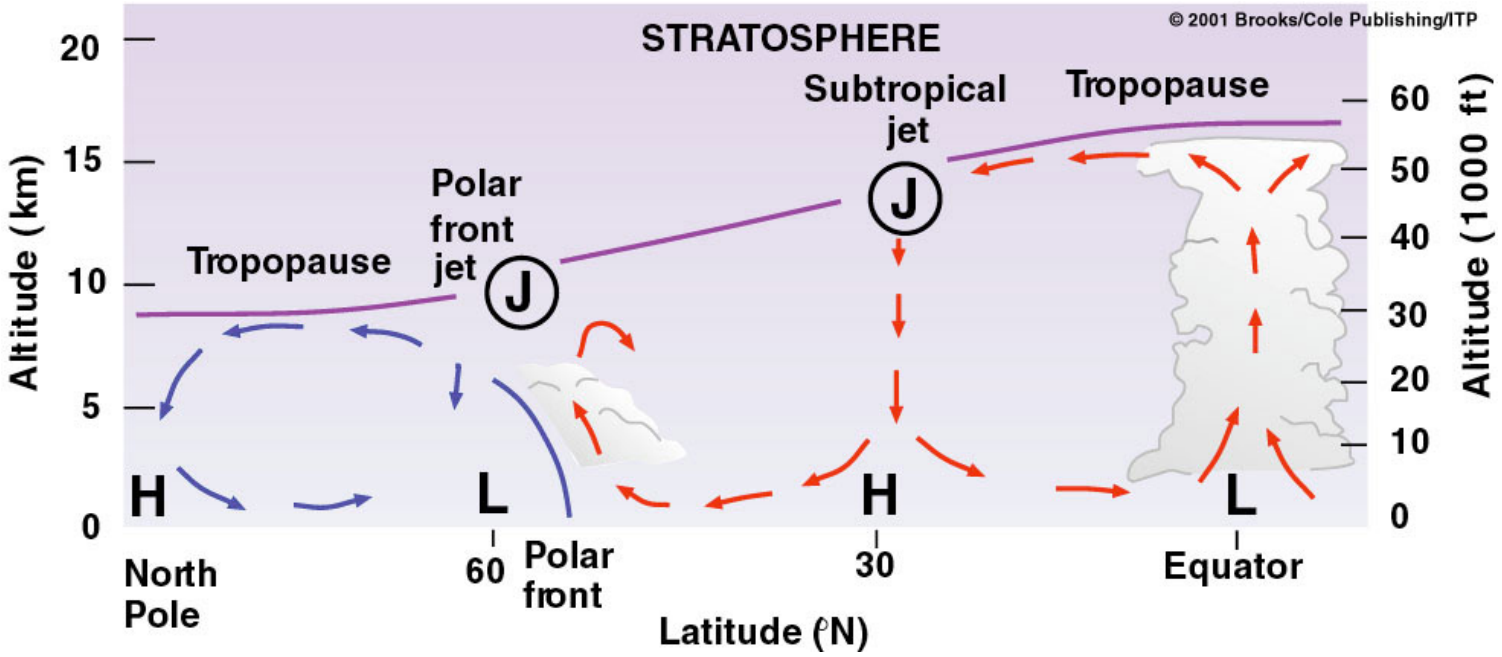
Lecture outline

- Global circulation
- Global circulation and surface winds
- **Jet streams**
  - **Polar jets**
  - **Rossby waves**

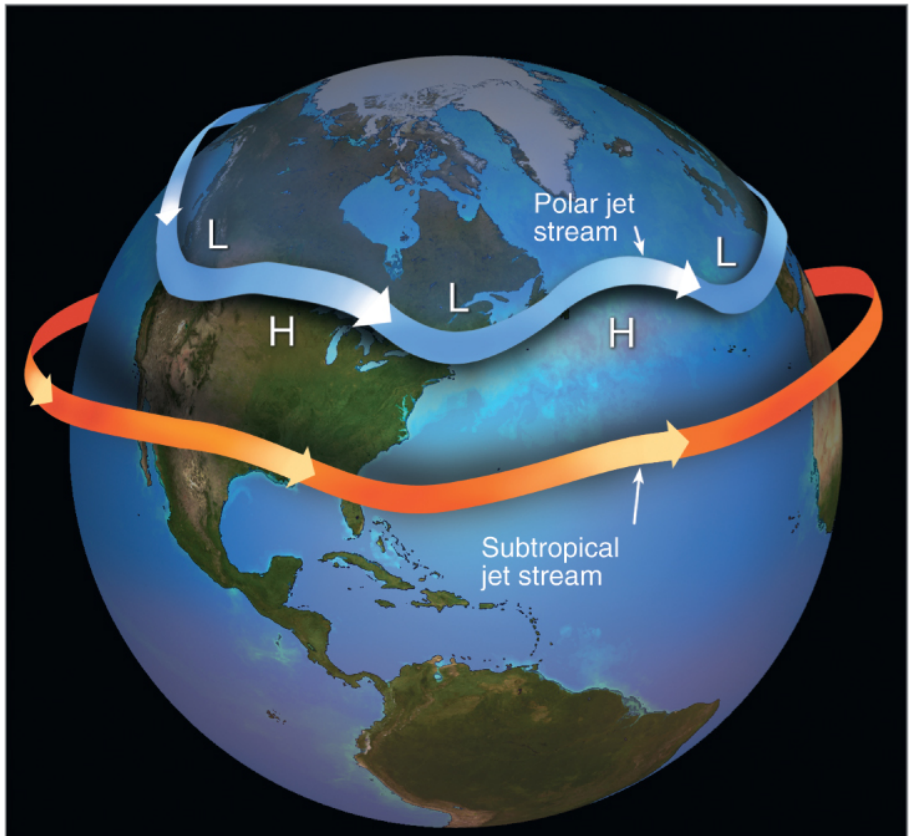
Jet Streams

Swift flowing current of air

- Thousands of km long, a few hundred km wide, a few km thick and 10-15 km above the surface.
- Speed ranges from 150 to 300 km/h.
- Jets occur at the divisions of the three cells.



Polar Jet

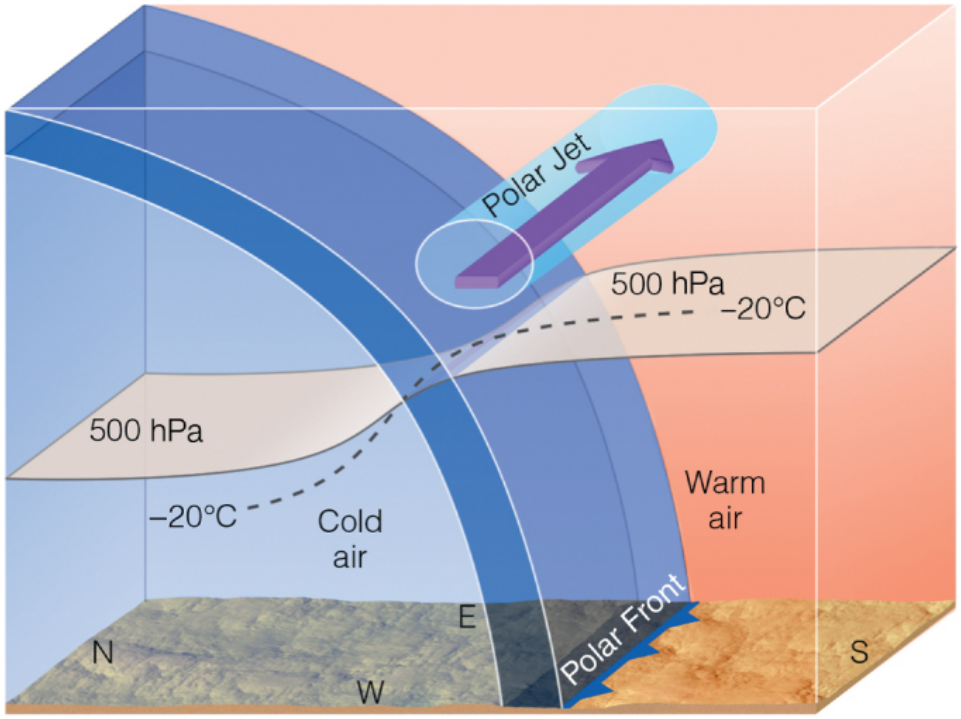


Ahrens: Active Fig. 10.10

- For midlatitude regions the polar jet is more important.
- Boundary between cold and warm air.
- Surface features, such as air masses and storms, tend to follow the direction of the upper level jet stream.

Polar Jet

- Strong temperature gradient between Polar and Ferrel cells leads to strong horizontal pressure gradient.
- Geostrophic balance causes a strong wind parallel to isobars.

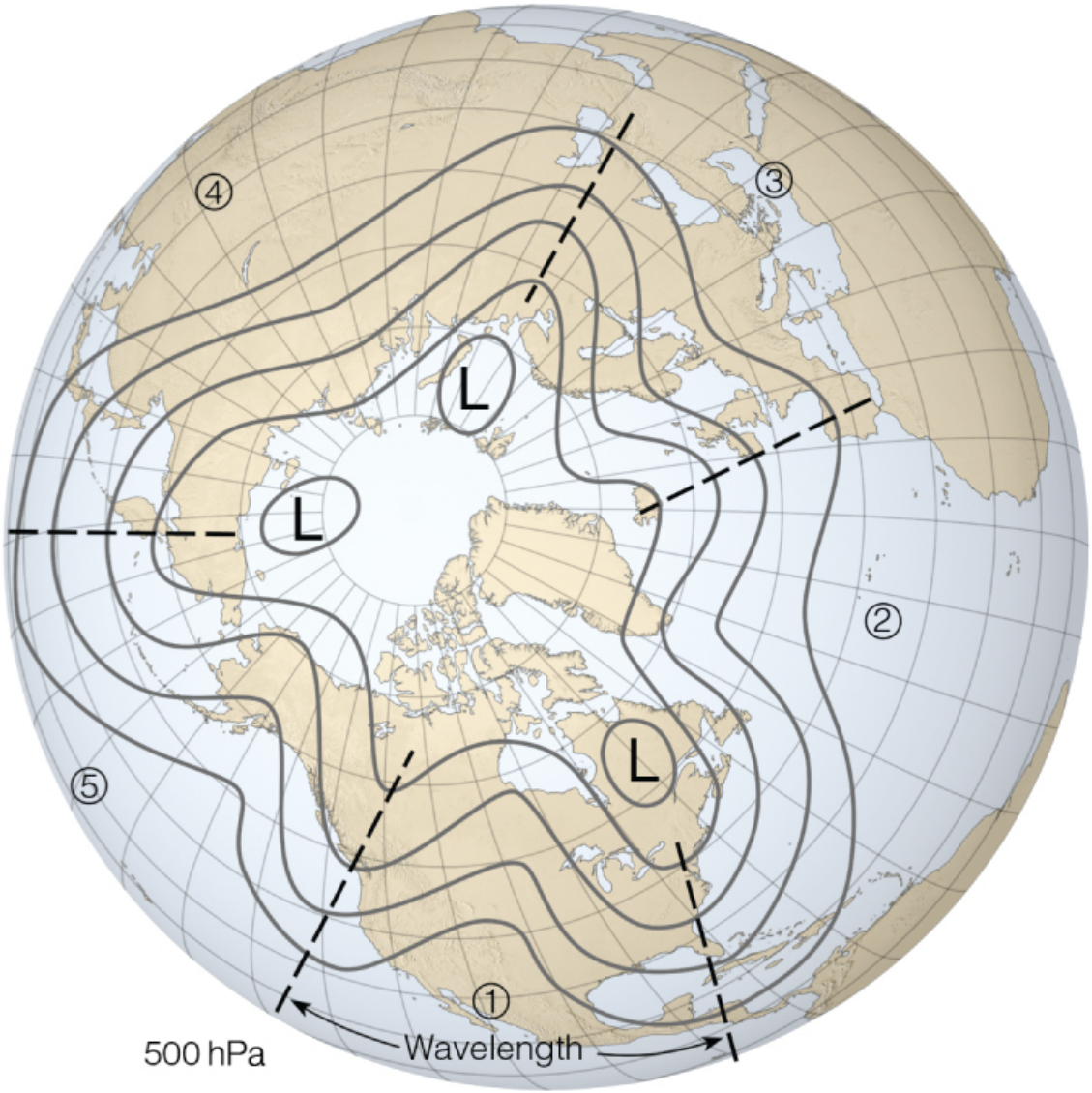


Ahrens: Fig. 10.12

Rossby Waves

Upper air flow

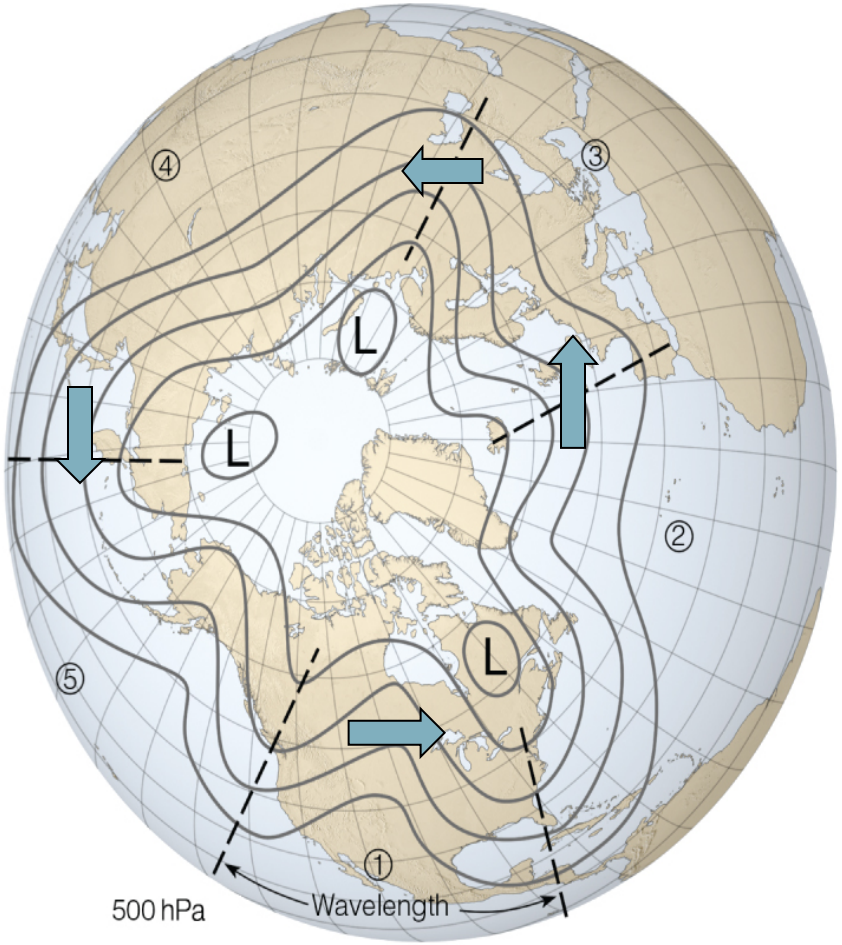
At any given time there are 3-6 planetary waves or longwaves.



Ahrens: Fig. 12.8

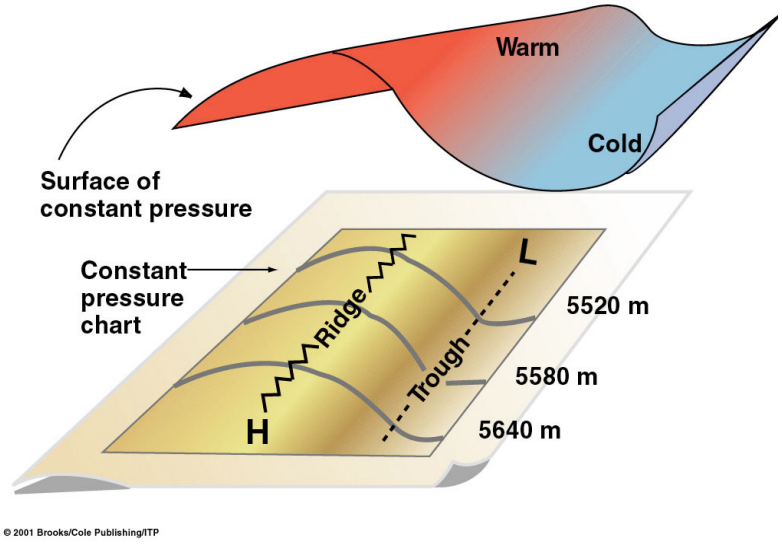
Planetary Waves

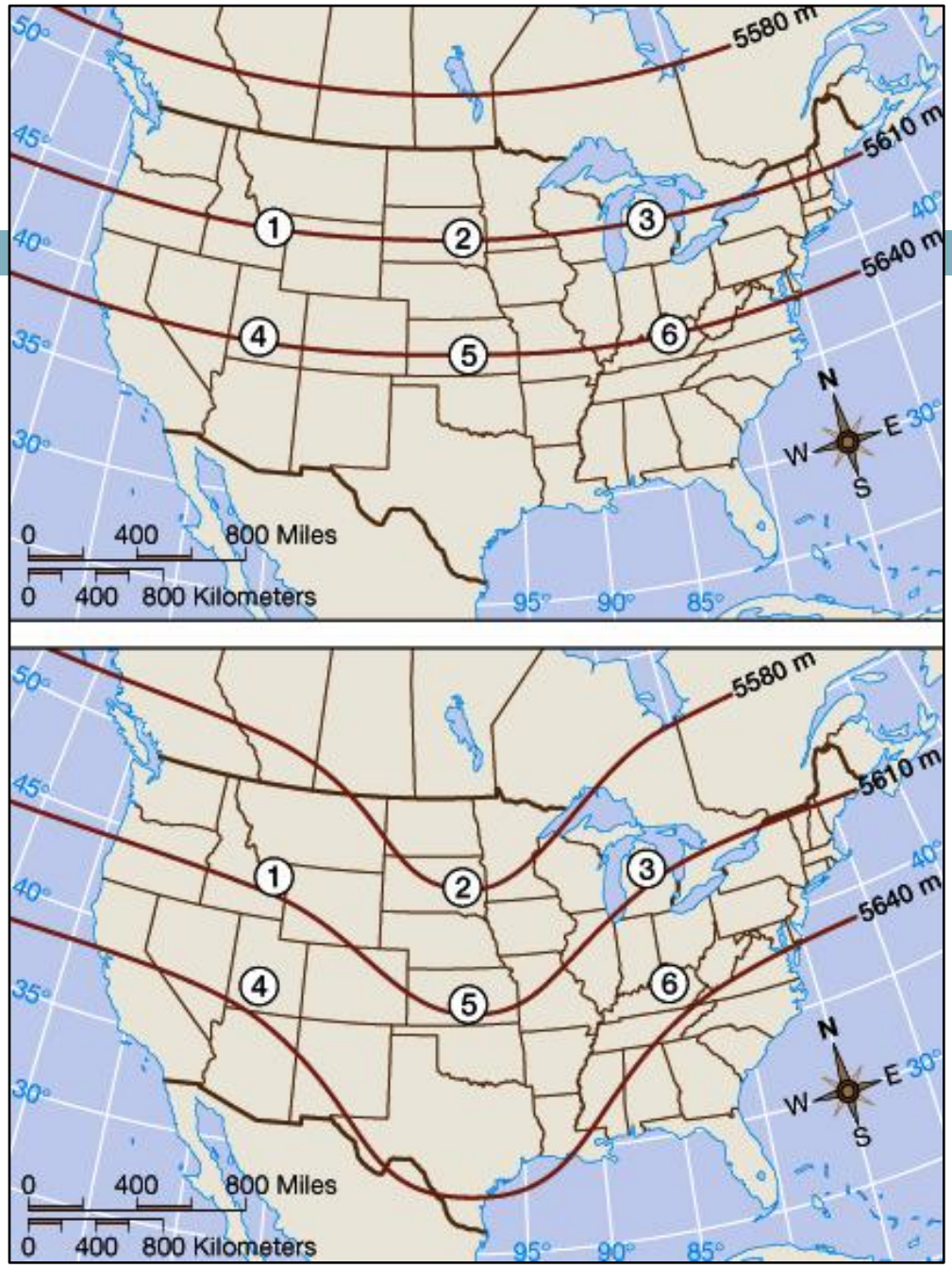
- Slow moving
  - Can be stationary for months
  - Migrate slowly west to east
  - Sometimes east to west
- Winter
  - Fewer, longer, stronger



Troughs and Ridges

A&B: Figure 8-11

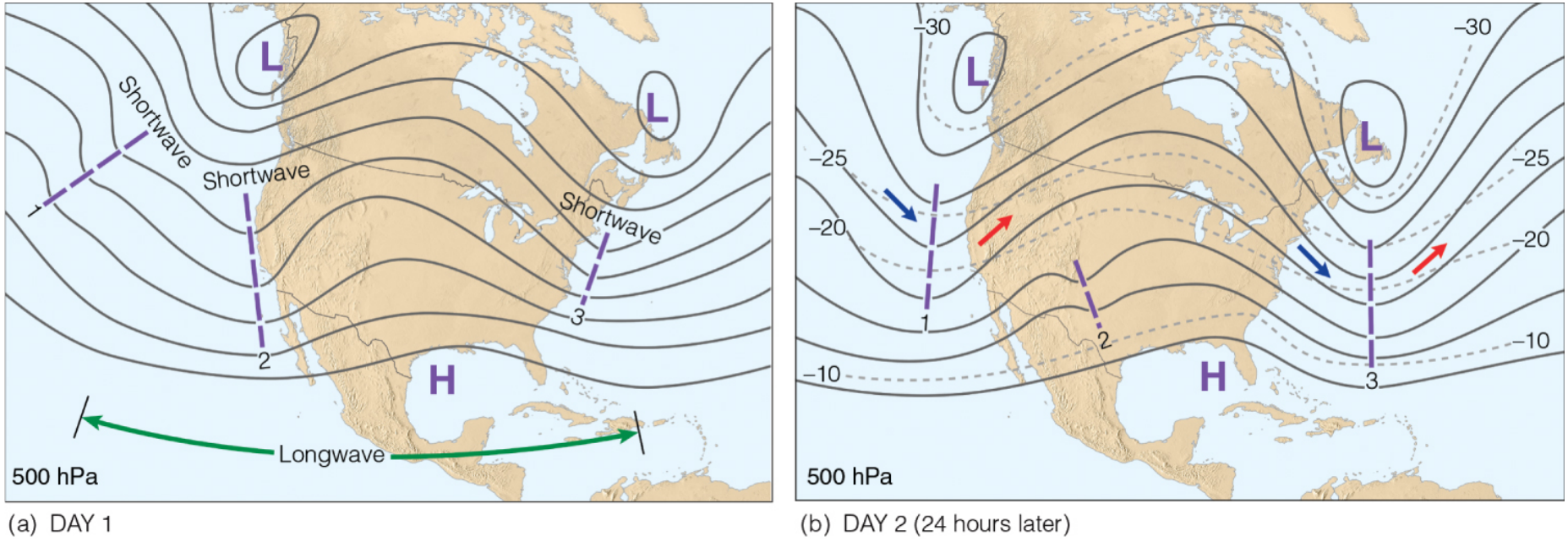




Shortwaves

- Rossby waves that travel eastward along the longwaves.
- These are smaller, shorter, faster-moving disturbances.
- Shortwaves become stronger near the troughs and weaker near the ridges of longwaves.

Shortwaves and longwaves



Ahrens: Active Fig. 12.9

Rossby Waves

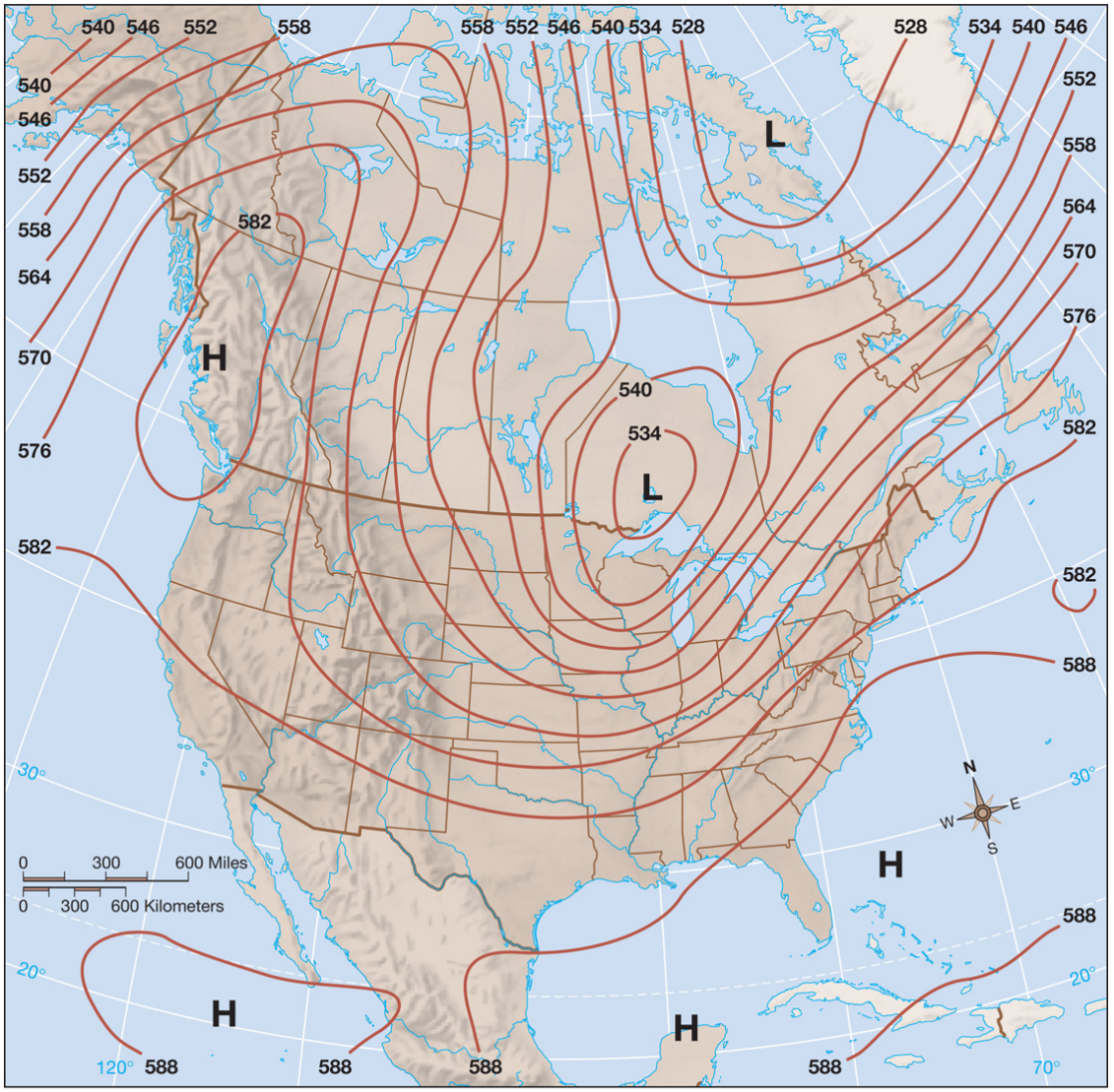
Surface flow follows upper atmosphere flow

Mild in Yukon

Cold over plains, central US

September 22, 1995

A&B: Figure 8-13(a)



(a)

Coming up

- Atmospheric observation
- Weather prediction
- Numerical modelling