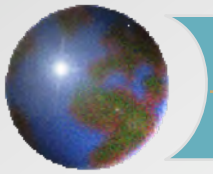


Global Circulations

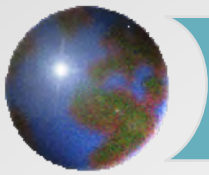
GEOG/ENST 2331 – Lecture 13

Ahrens: Chapter 10

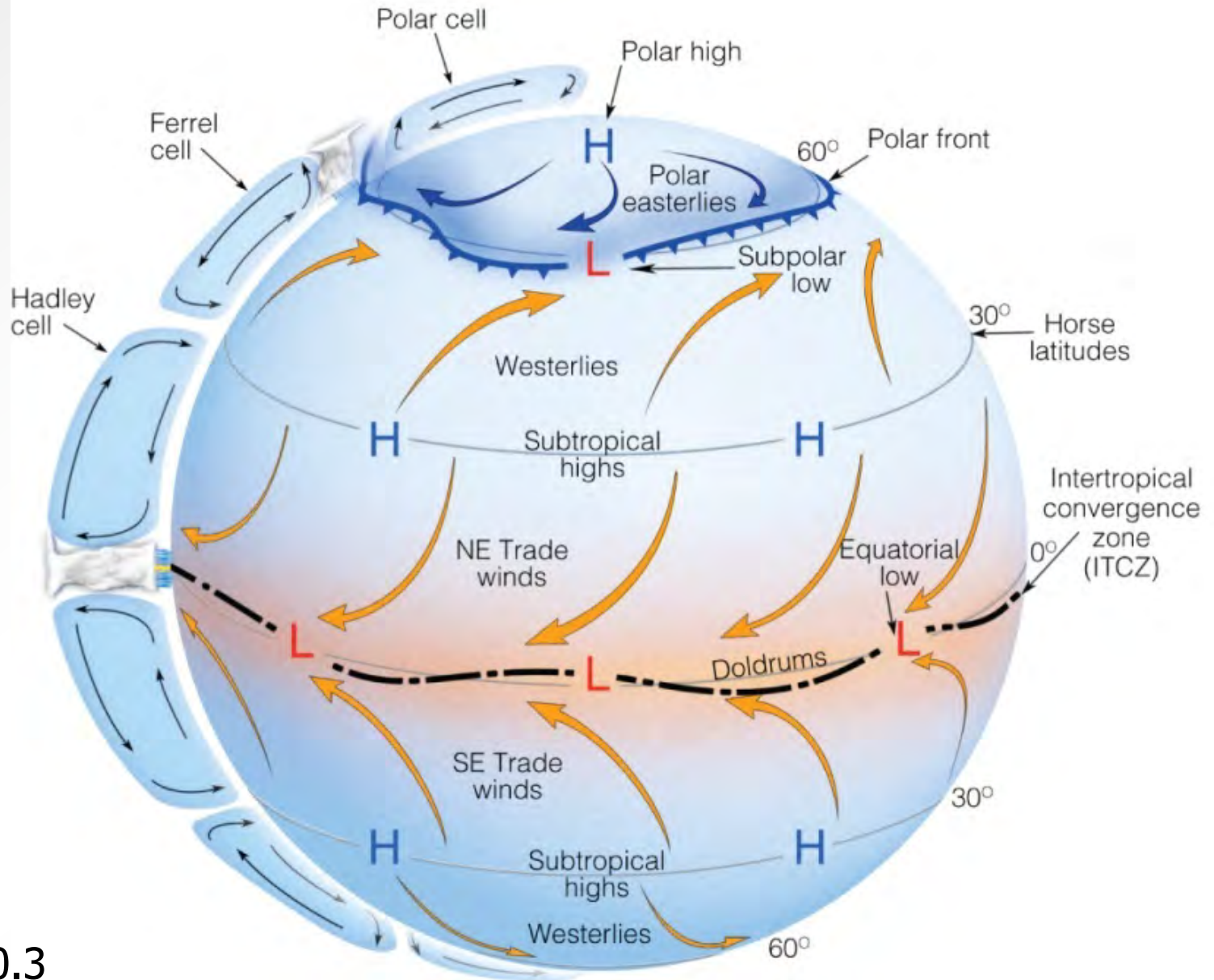


Last lecture

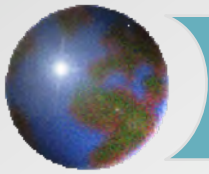
- ⊕ Microscale (turbulence)
- ⊕ Mesoscale (land/sea breeze)
- ⊕ Synoptic scale (monsoon)
- ⊕ Global scale (3 cell circulation)



Three Cell Model



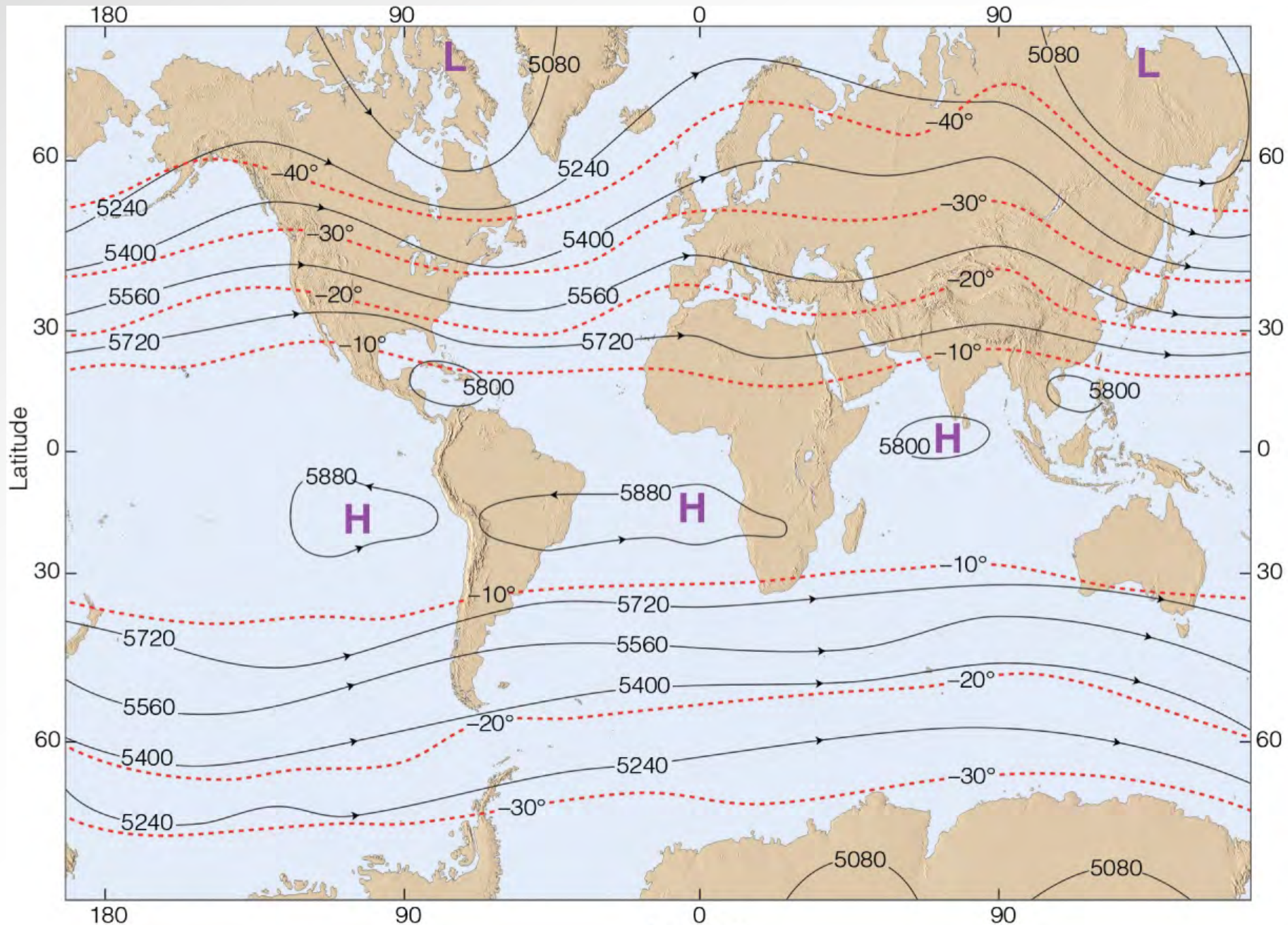
Ahrens: Fig. 10.3



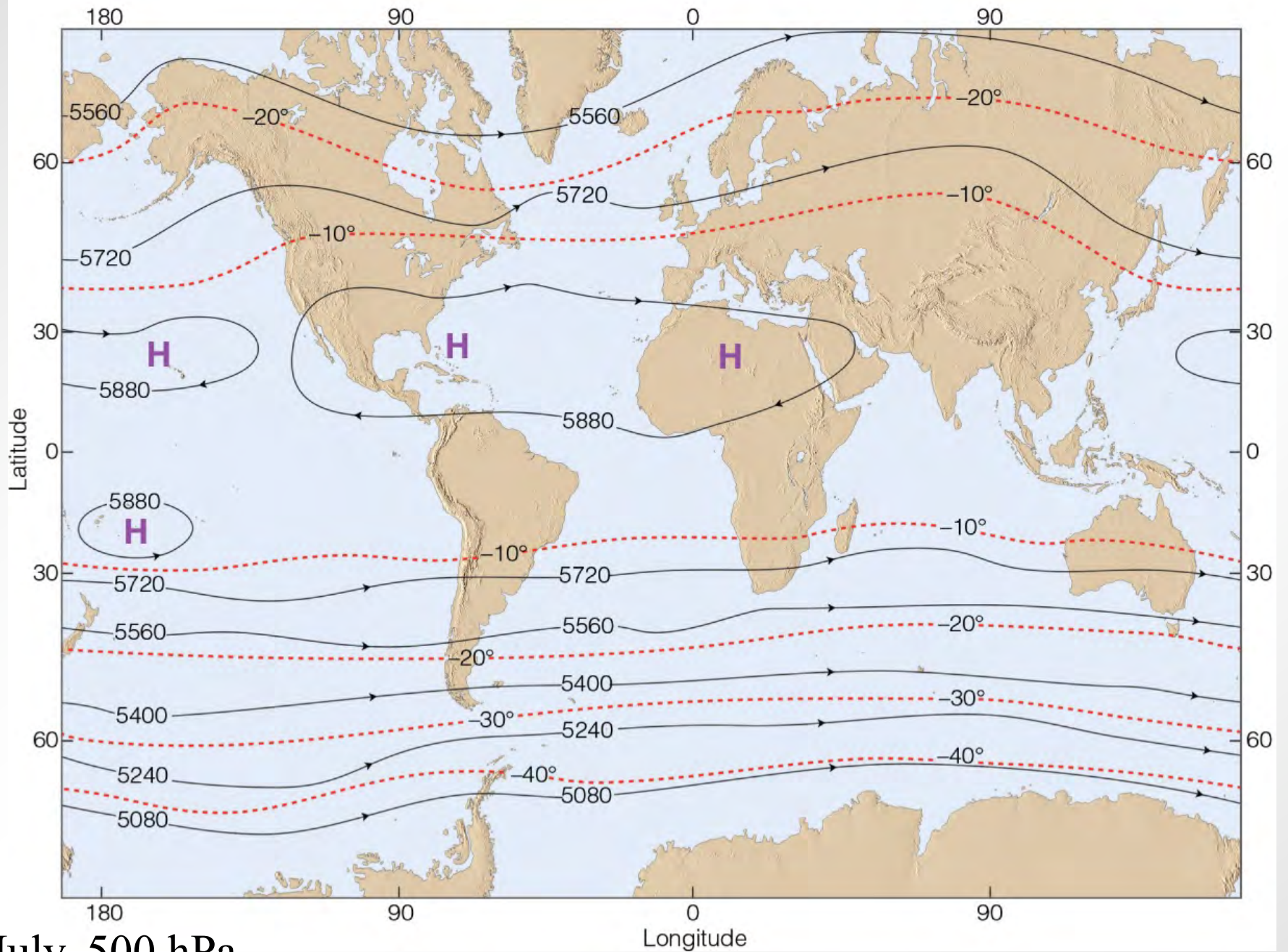
Upper level flow

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

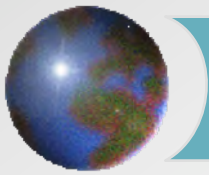
- ✦ Impacts of seasons and continents
 - ✦ Circulation still shifts with the seasons
 - ✦ Land/sea contrast less evident



January, 500 hPa



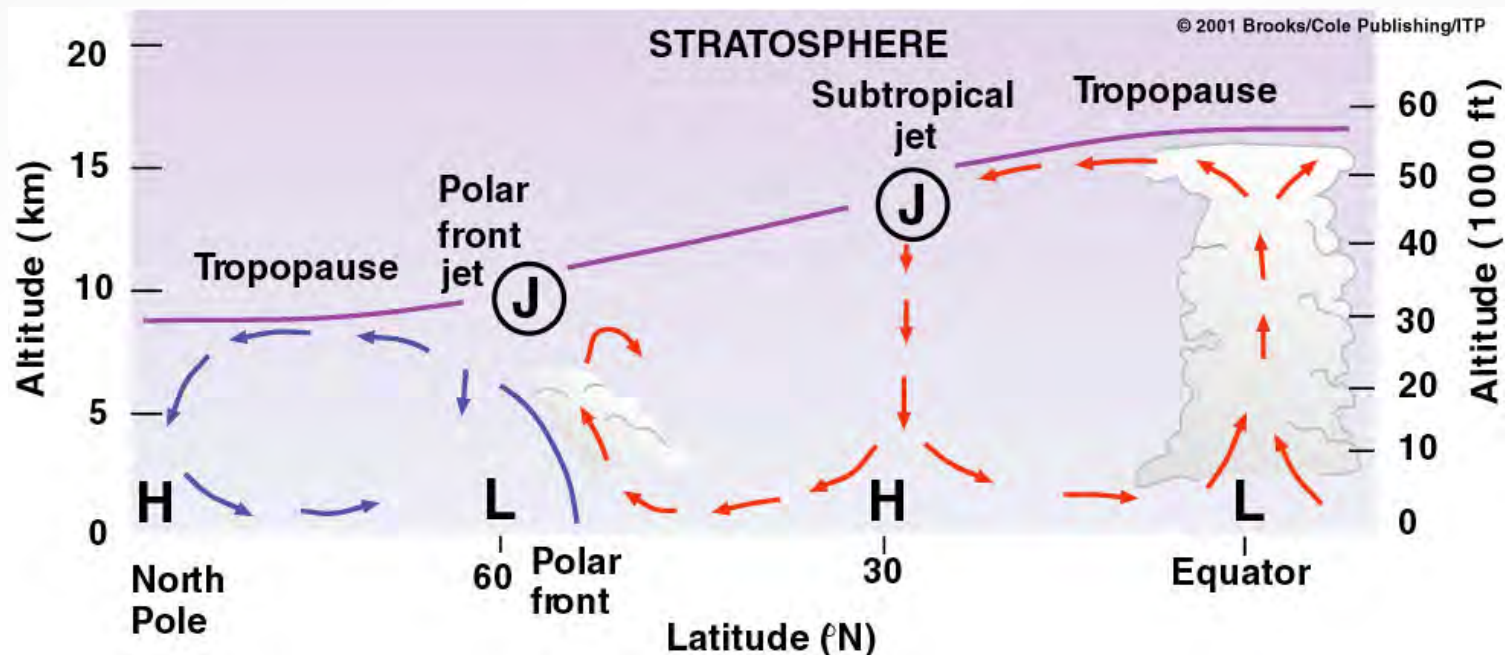
July, 500 hPa

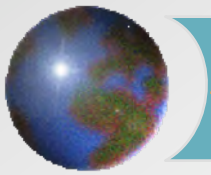


Jet Streams

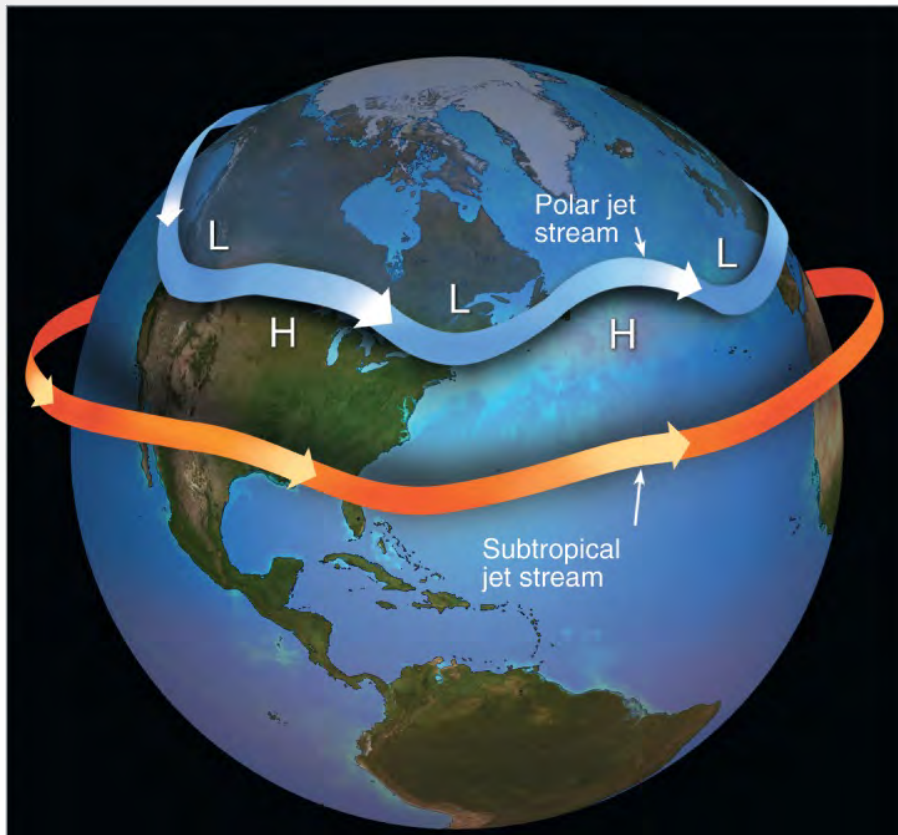
Swift flowing current of air

- 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.

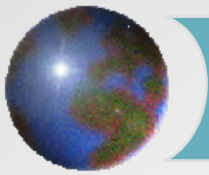




Polar Jet

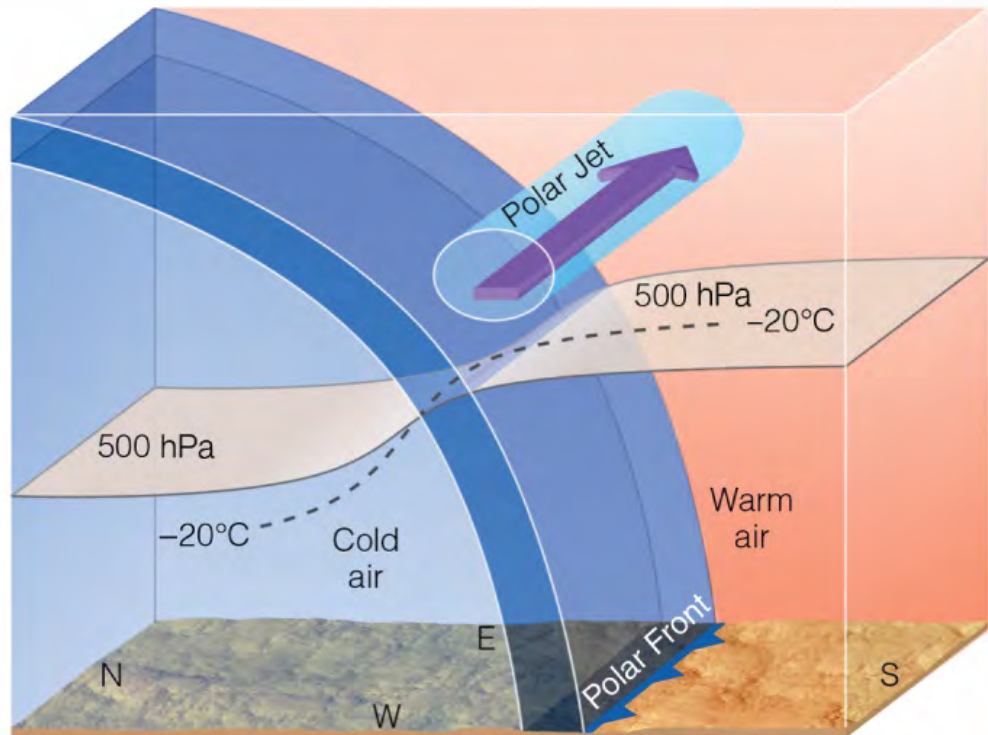


- ✪ For midlatitude regions the polar jet is more important.
- ✪ Boundary between cold and warm air.
- ✪ Surface features, such as air masses and storms, tend to follow the direction of the upper level jet stream.

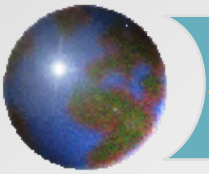


Polar Jet

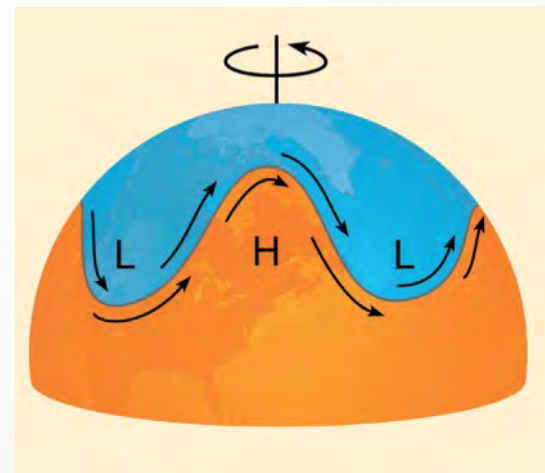
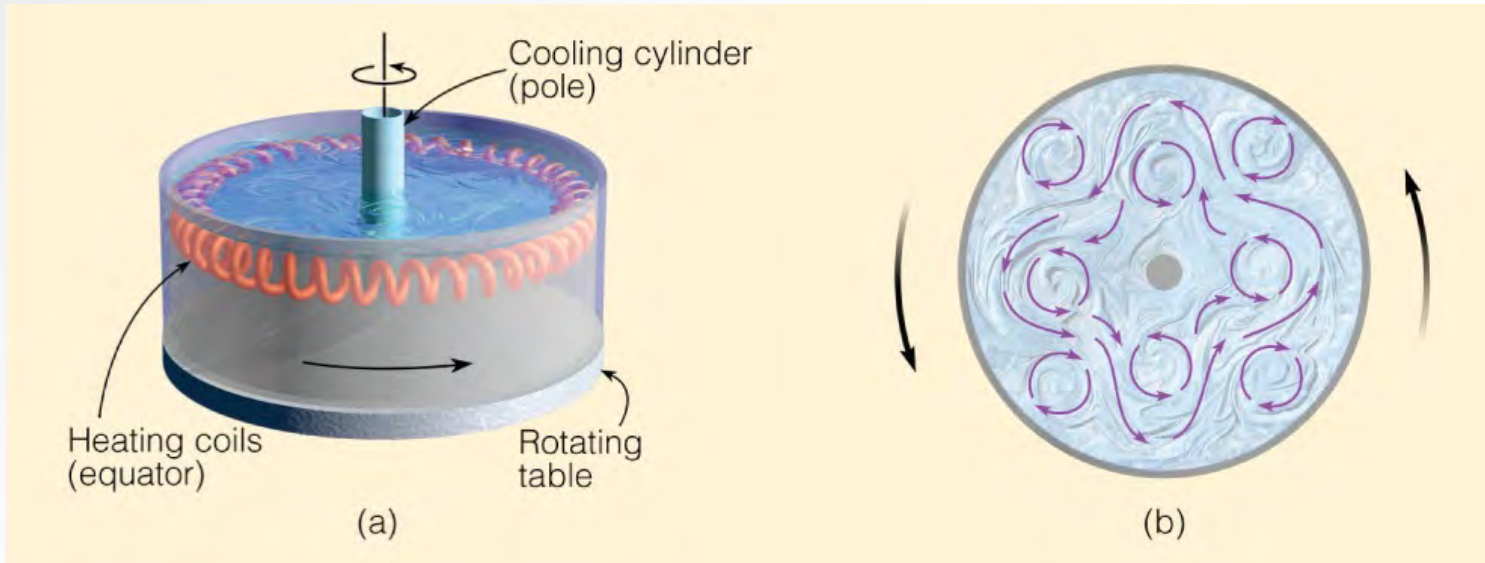
- ✦ Strong temperature gradient between Polar and Ferrel cells leads to strong horizontal pressure gradient.
- ✦ Geostrophic balance causes a strong wind parallel to isobars.



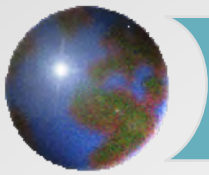
Ahrens: Fig. 10.12



The “Dishpan Experiment”



Ahrens: Figs. 1 and 2, p. 288



Rossby Waves

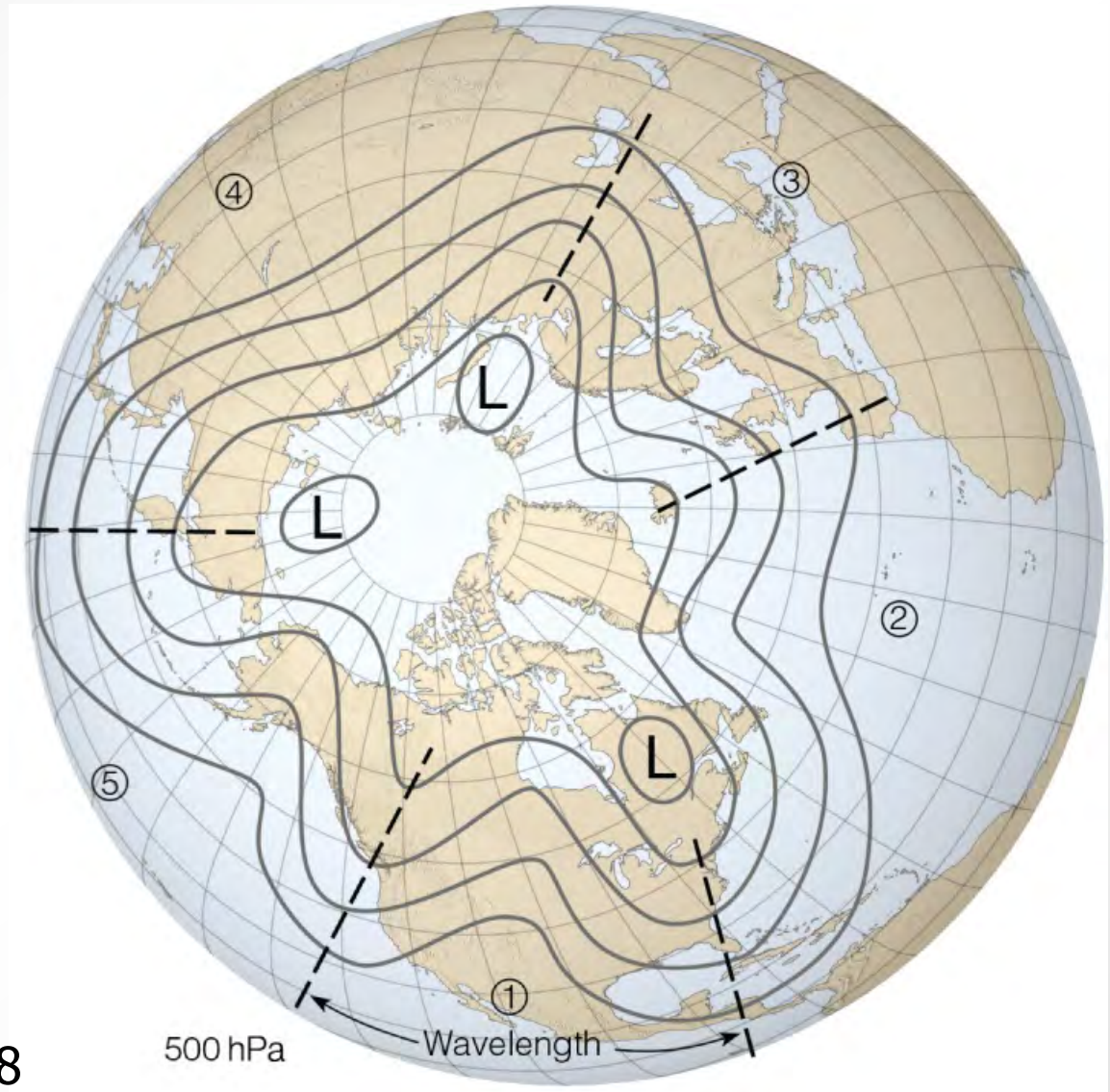
- Also known as longwaves or planetary waves

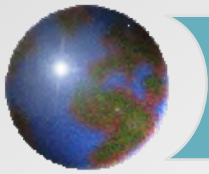
Upper air flow

- At any given time there are 3-6 Rossby waves.

C.G. Rossby – famous meteorologist in early 20th Century.

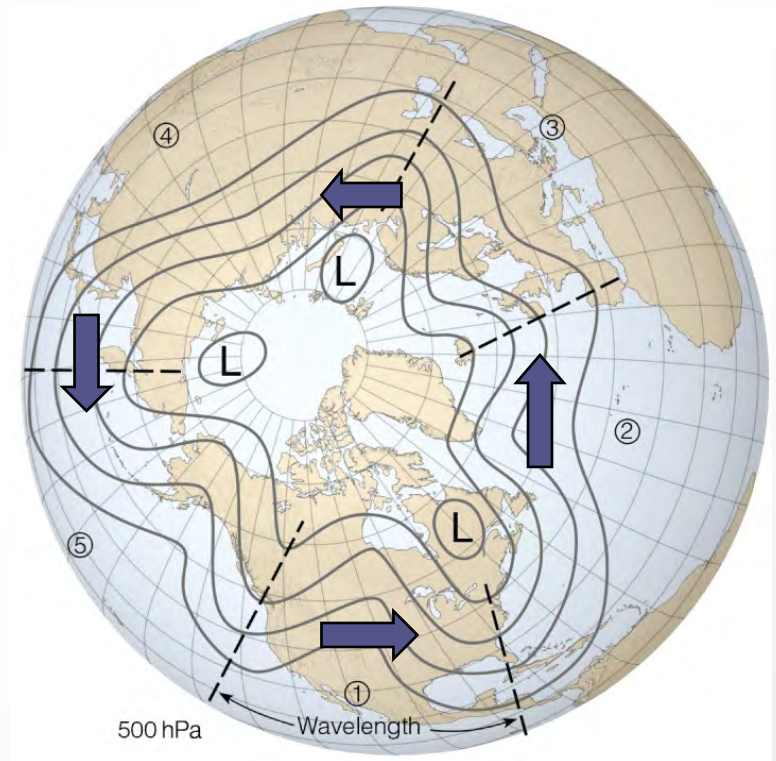
Ahrens: Fig. 12.8





Rossby Waves

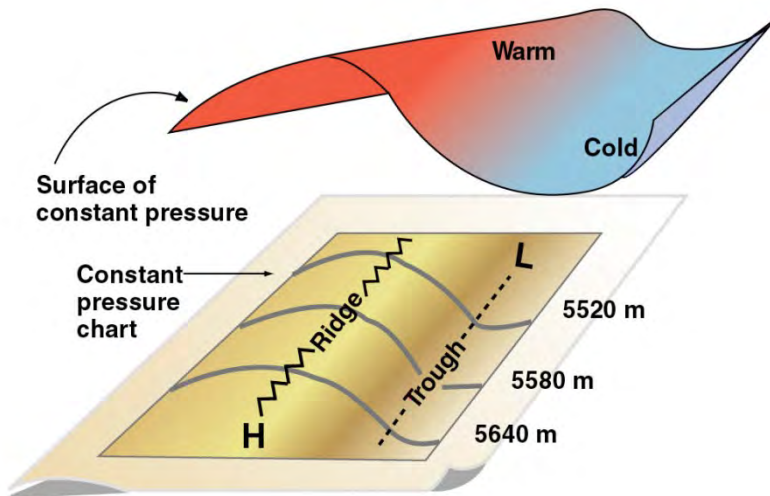
- ✦ Slow moving
 - ✦ Can be stationary for months
 - ✦ Migrate slowly west to east
 - ✦ Sometimes east to west
- ✦ Winter
 - ✦ Waves are fewer, longer, stronger

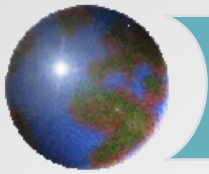




Troughs and Ridges

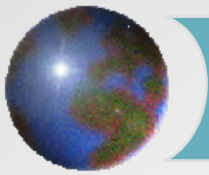
A&B: Figure 8-11



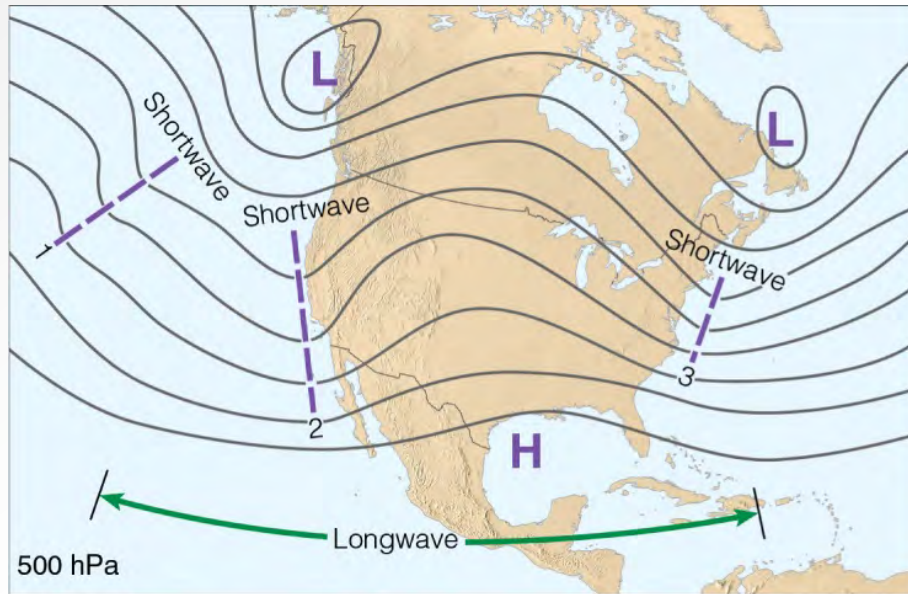


Shortwaves

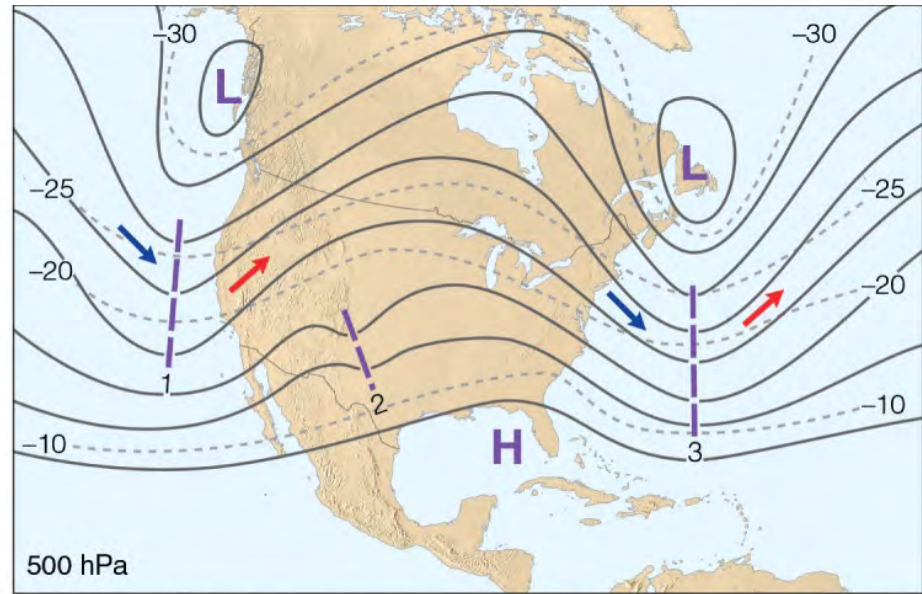
- ❖ Small disturbances or ripples embedded in Rossby waves,
- ❖ Faster-moving and travel eastward along the Rossby waves.
- ❖ Shortwaves become stronger near the troughs and weaker near the ridges of Rossby waves.



Shortwaves and Longwaves (Rossby waves)

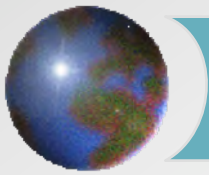


(a) DAY 1

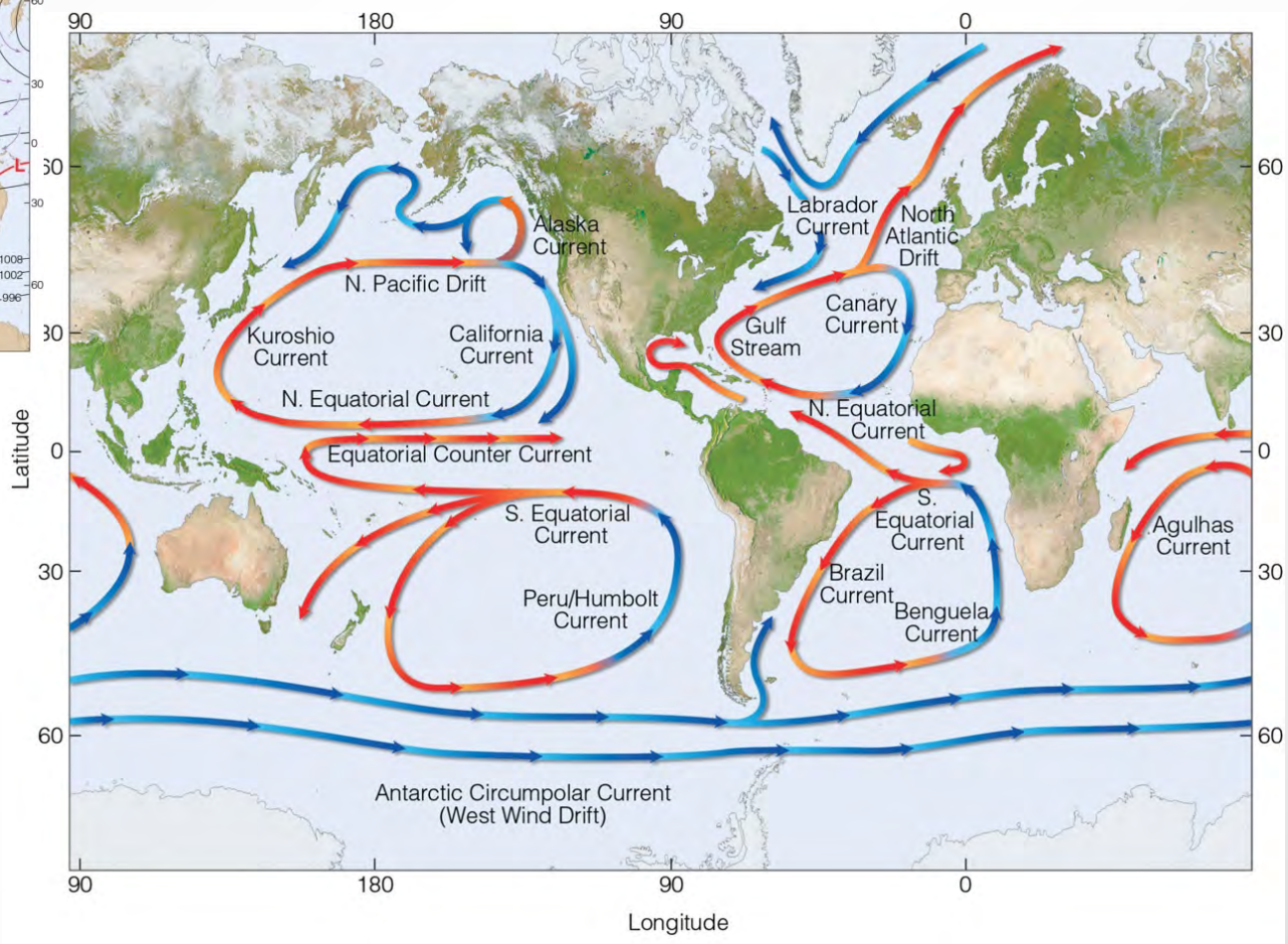
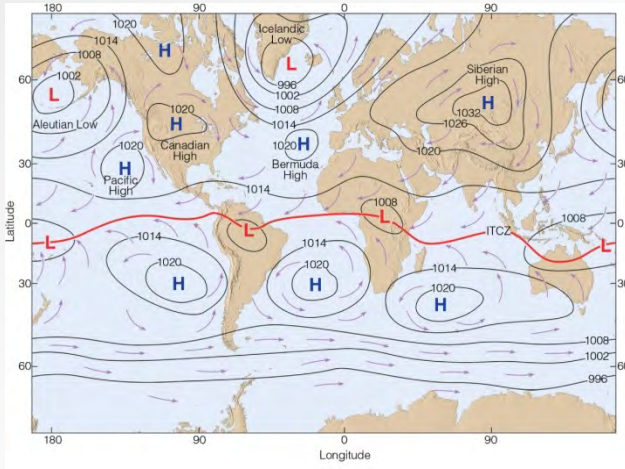


(b) DAY 2 (24 hours later)

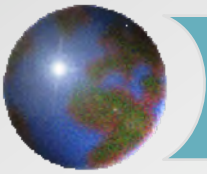
Ahrens: Active Fig. 12.9



Global Ocean Circulation



Ahrens: Fig. 10.15

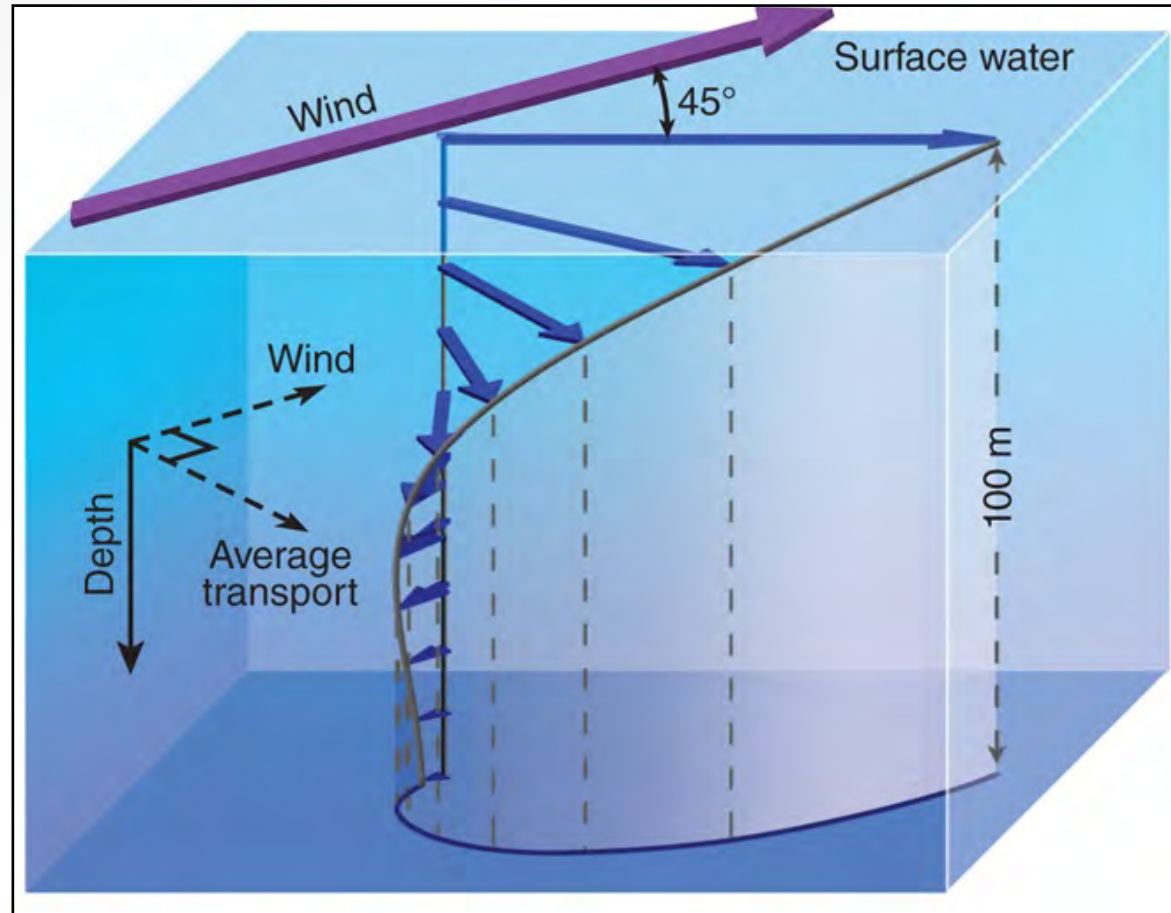


Ekman Spiral

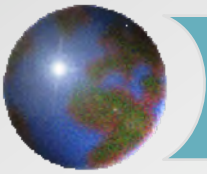
Wind drag pushes the surface waters 45° to the right (in the NH)

Deeper water is dragged along at successively greater angles

Around 100 m direction is opposite surface winds and current dies out



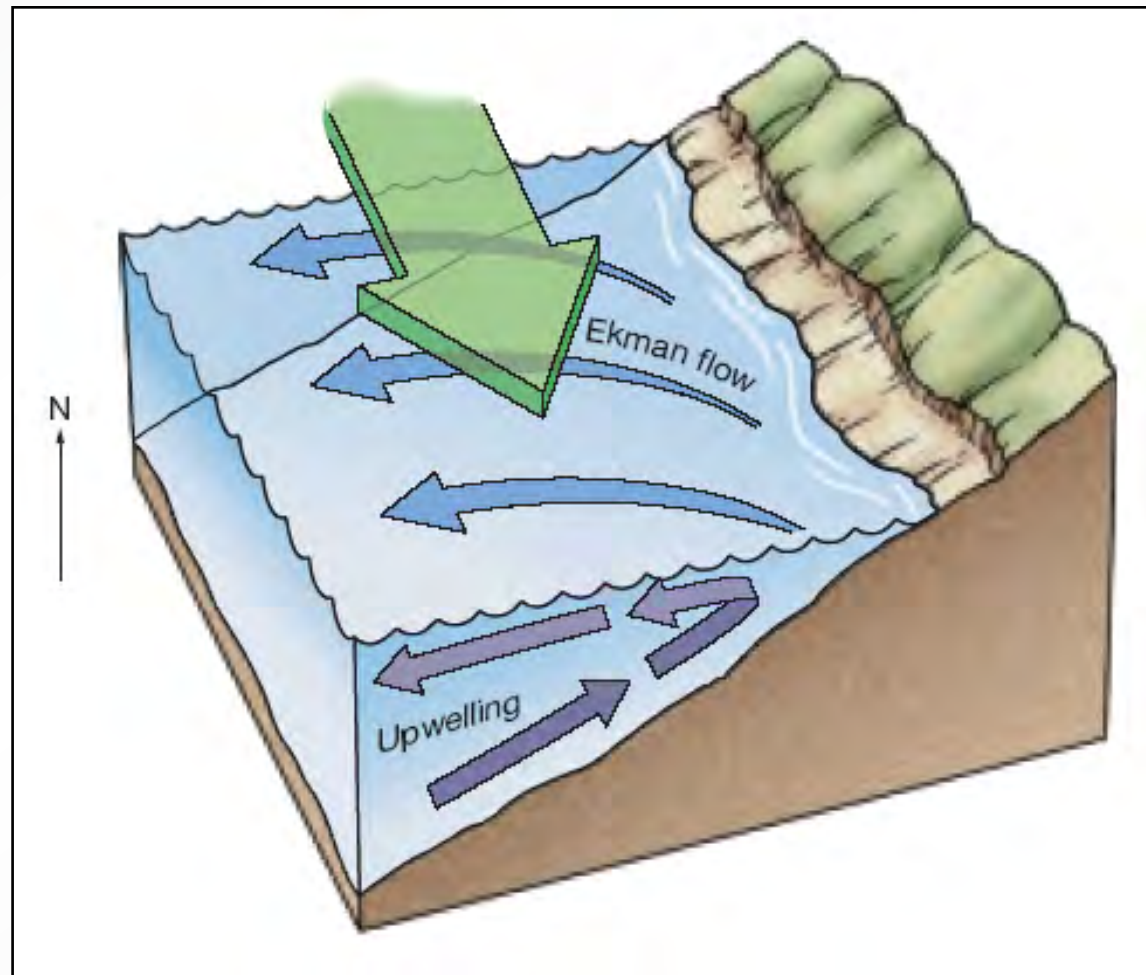
Ahrens: Fig. 10.18

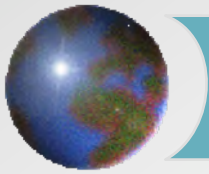


Upwelling

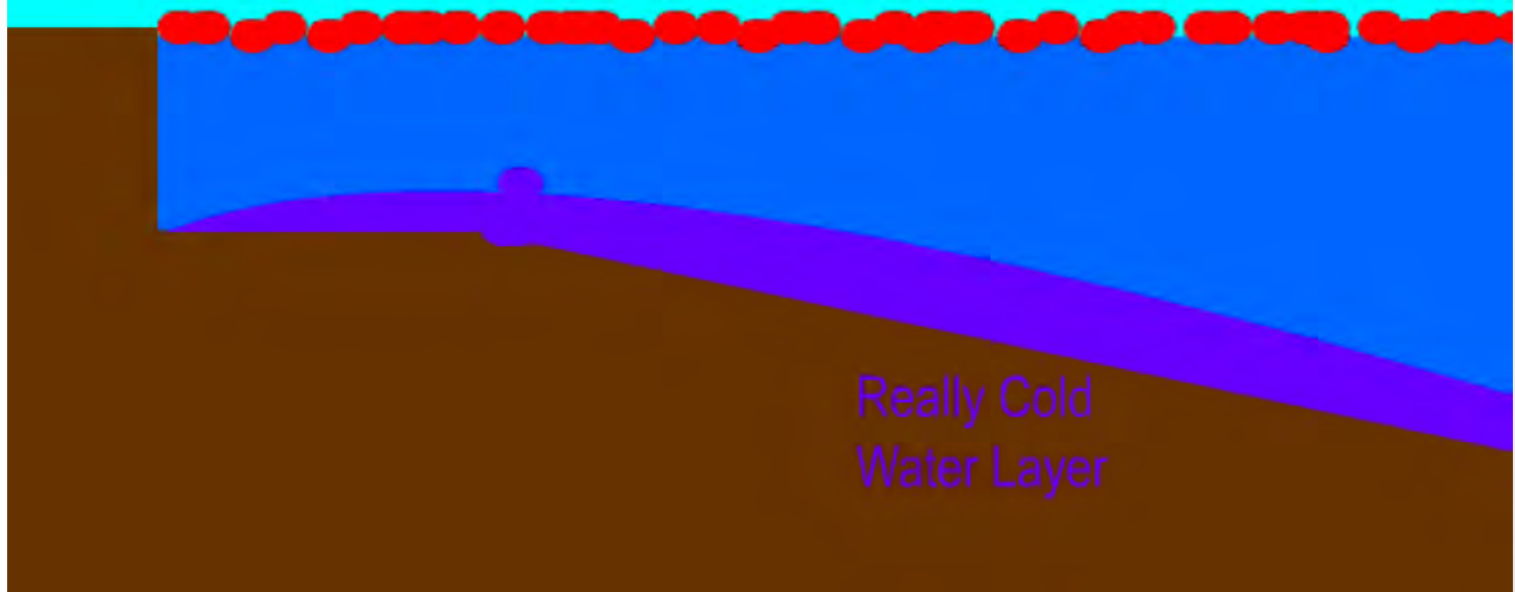
Offshore winds, and even parallel-to-shore winds drag away the surface water and cause upwelling of **cold**, nutrient-rich water from below.

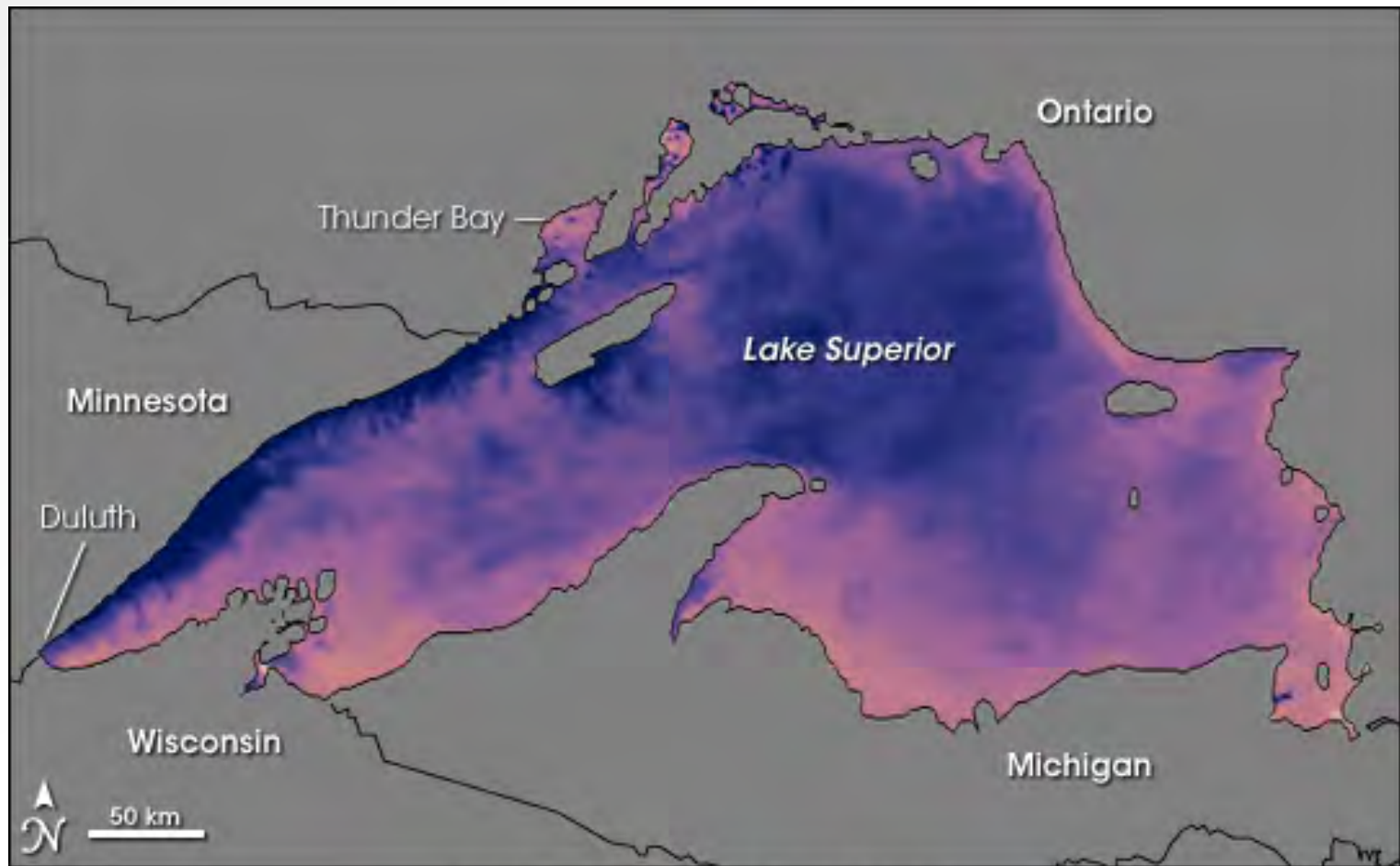
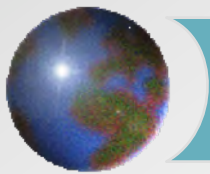
A&B: Figure 8-17



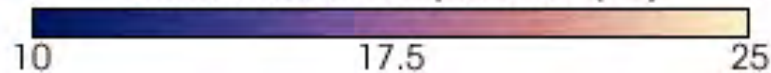


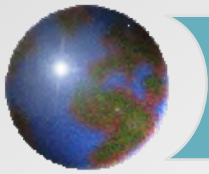
Upwelling:
Wind Pushes Warm Layer Away From Shore
Really Cold Water From Bottom





Water Surface Temperature ($^{\circ}\text{C}$)

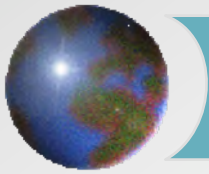




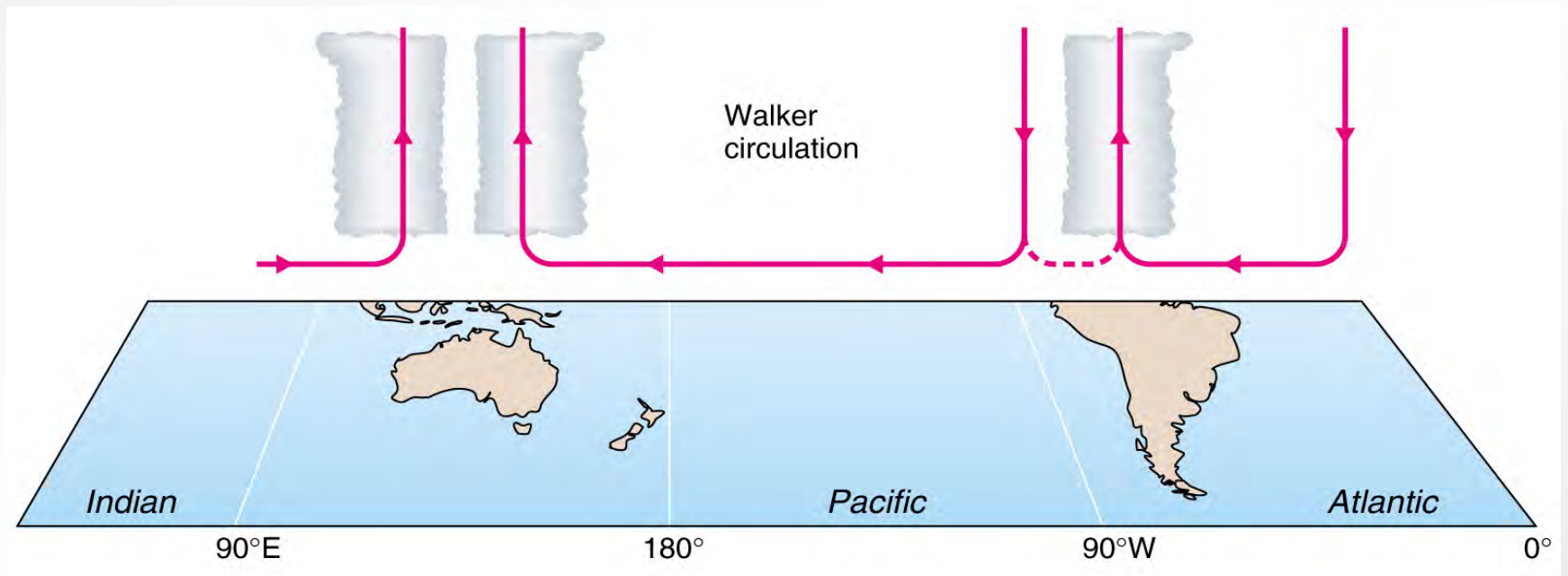
ENSO

El Niño / Southern Oscillation

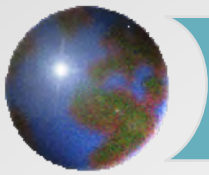
- ❖ 4 to 7 year oscillation in tropical Pacific Ocean temperatures and associated changes in atmospheric circulation
- ❖ Multiple causes: linked to changes in the Asian monsoon season, long-range transport of sub-surface waves, etc.
- ❖ Irregular cycle
- ❖ Once in process weather predictions for the next season or two can be made, often with considerable accuracy.



The “Normal” Walker Circulation

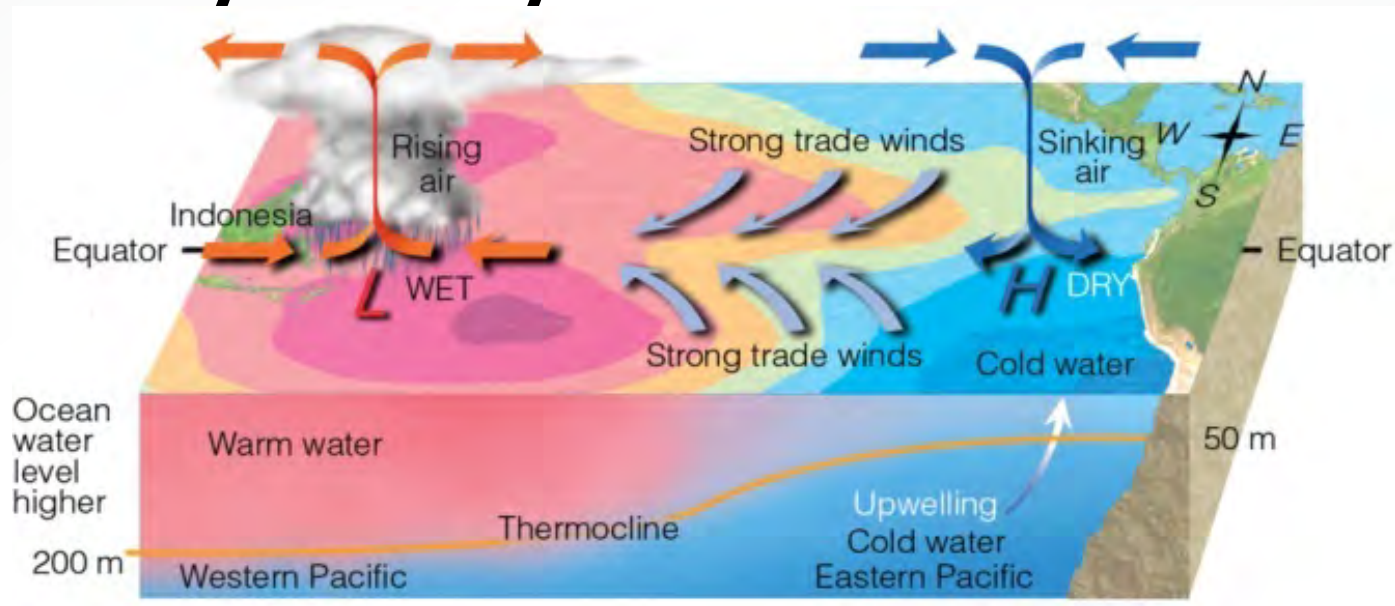


A&B: Figure 8-27

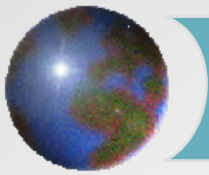


Walker Circulation

- Easterly trade winds
- Low pressure, rising air and heavy rain over western Pacific
- Winds push surface water away from South America, causing cold water to well up from below
- **Particularly intense years are called La Niña**

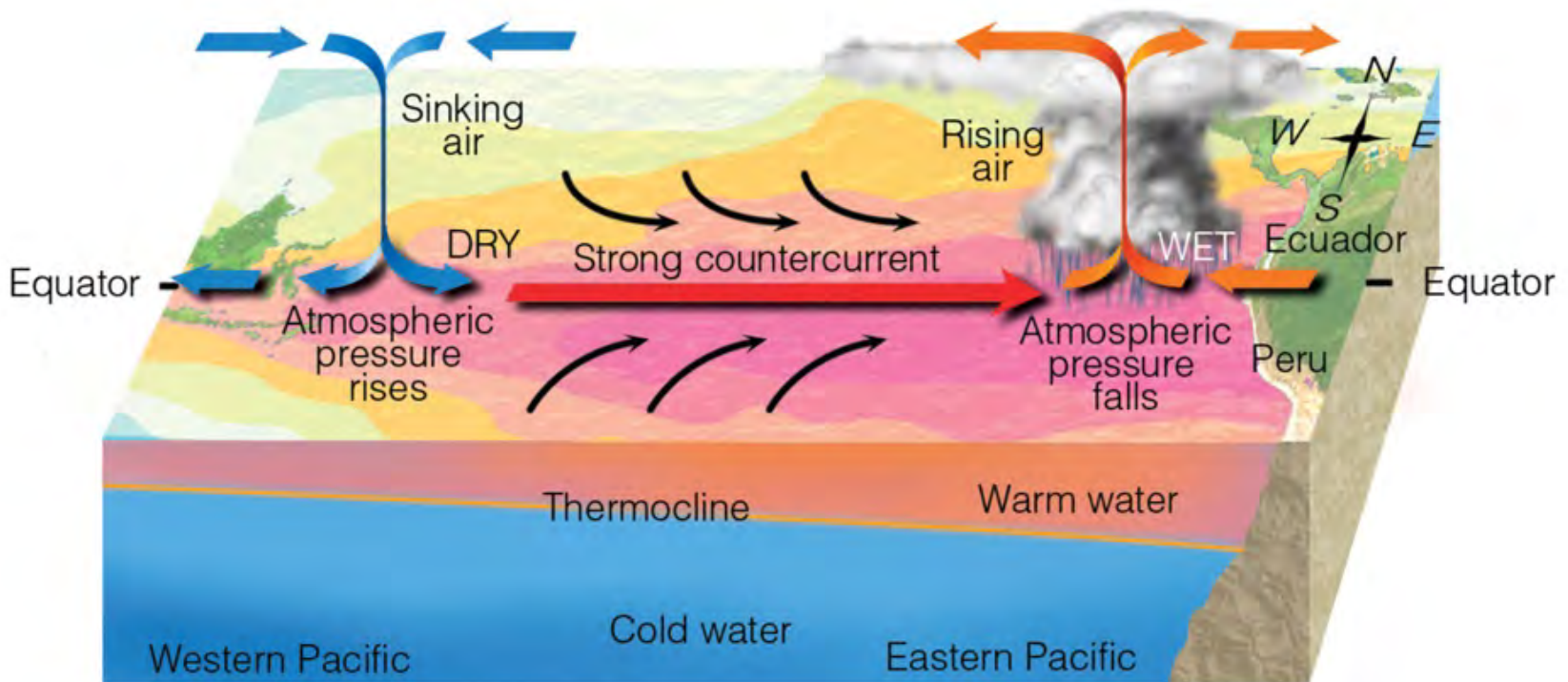


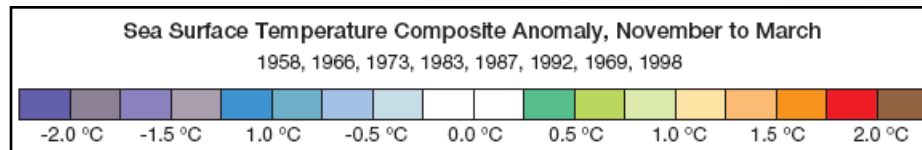
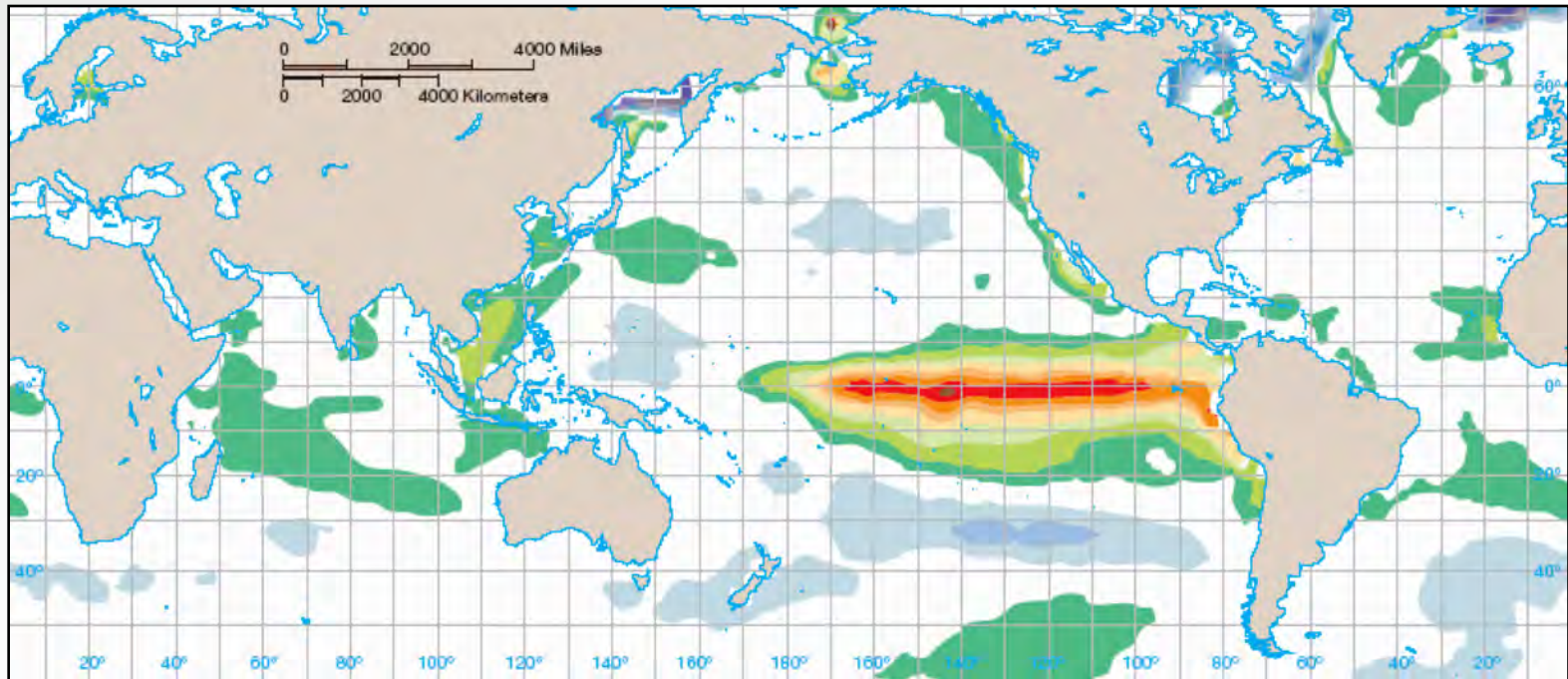
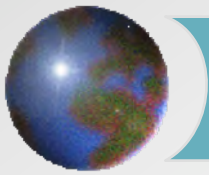
Ahrens: Fig. 10.20



El Niño

- Winds weaken or reverse
- High pressure, subsiding air, drought over western Pacific
- Upwelling in eastern Pacific stops, surface temperatures rise





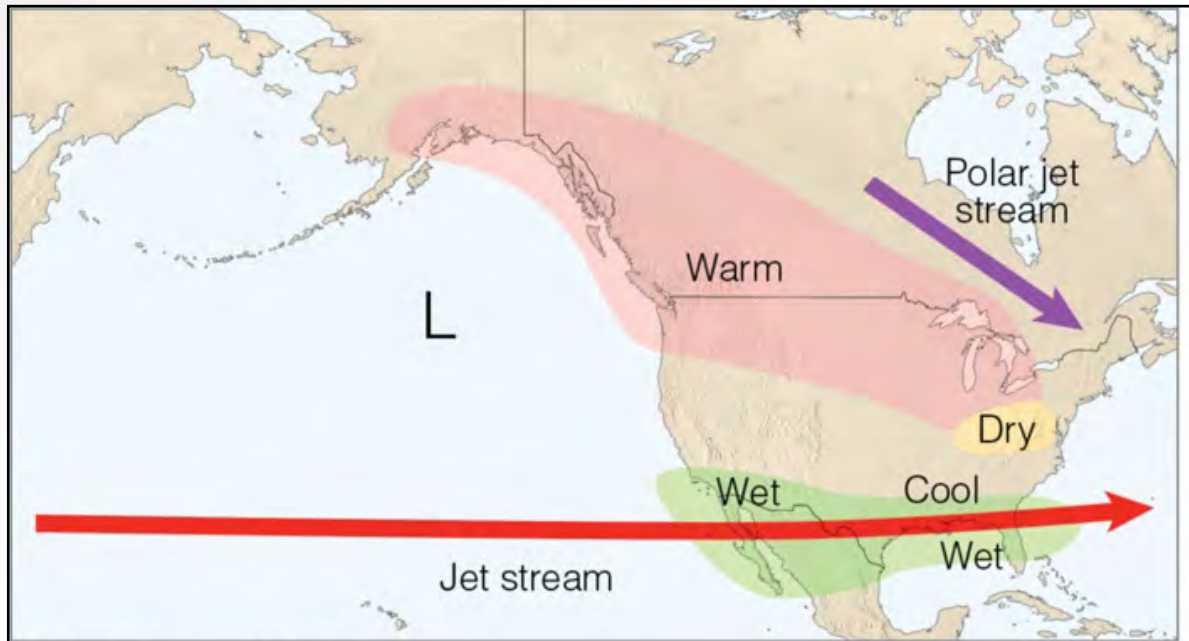
Average sea surface temperature differences from normal during the November through March period for eight El Niño episodes.

A&B: Figure 8-29

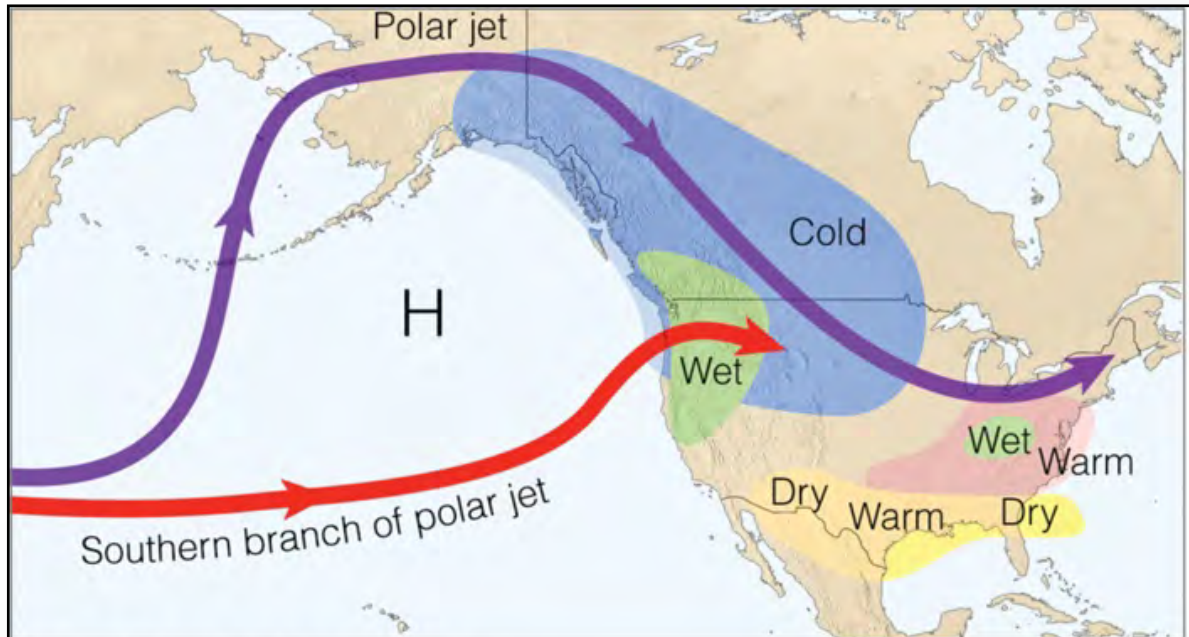
Teleconnections

Relationships between climatic patterns at widely separated locations

ENSO affects upper level flow and position of jet streams.

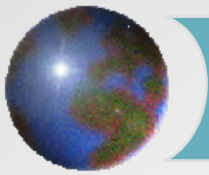


(a) El Niño winter conditions



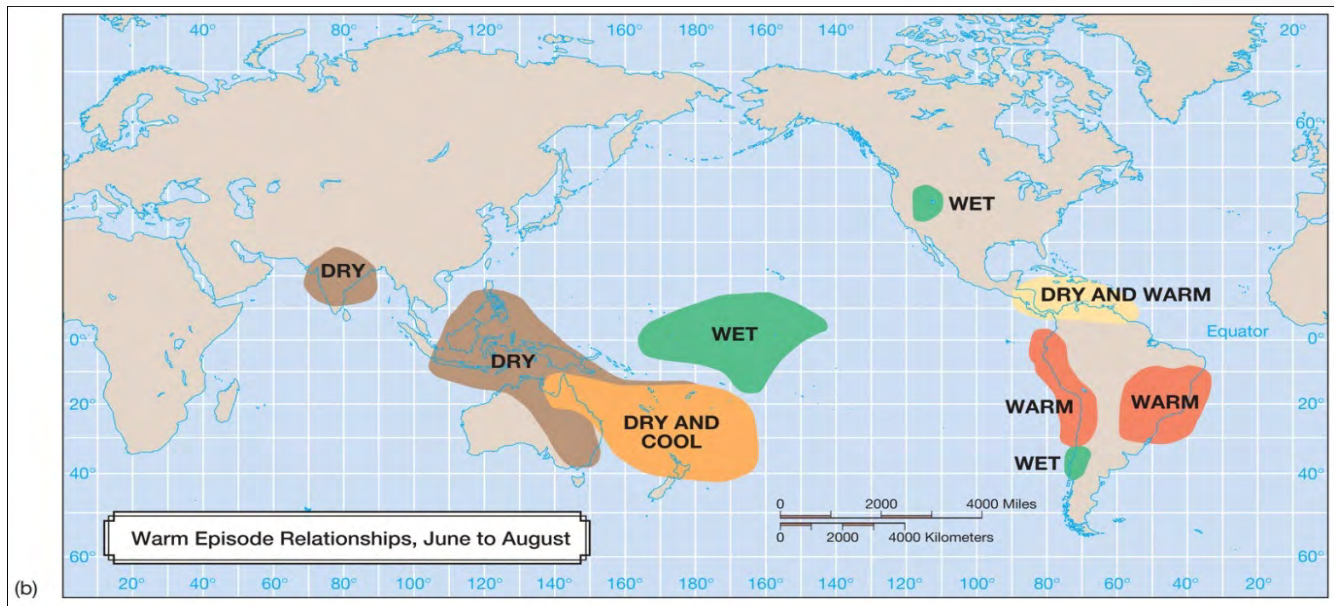
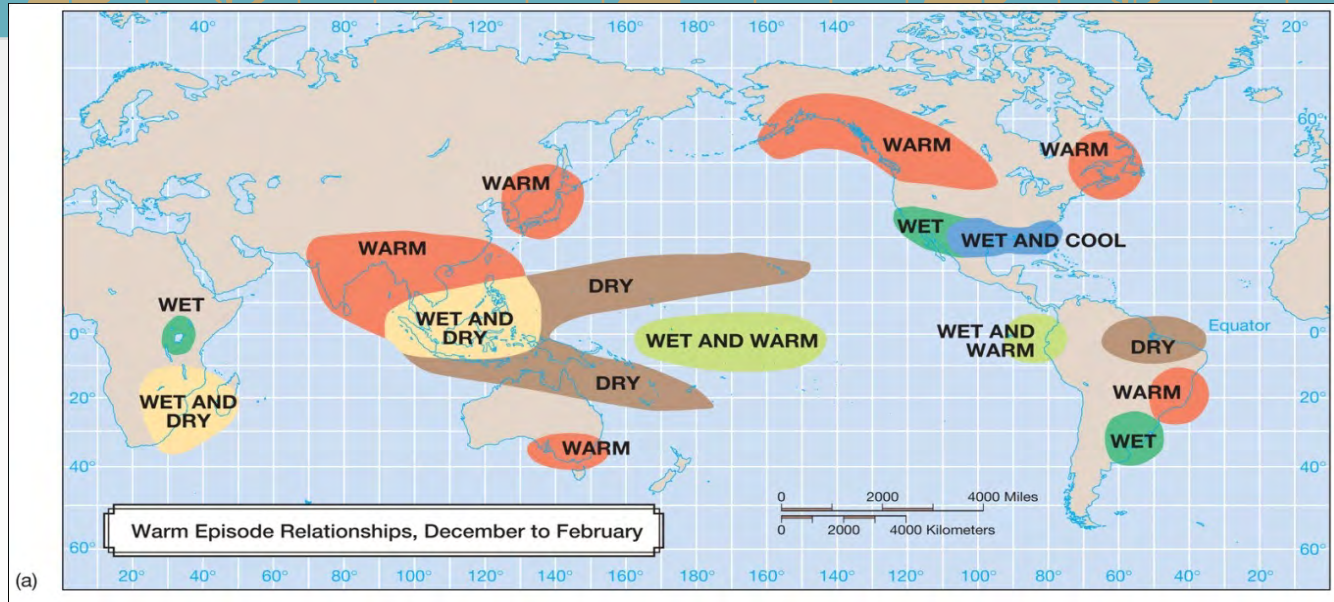
(b) La Niña winter conditions

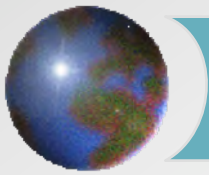
Ahrens:
Fig. 10.24



Impacts of El Niño

Ahrens:
Fig. 10.25





Blocking (associated with ENSO)

Omega block
over western
North America

–
Warmer and
drier
within the
block

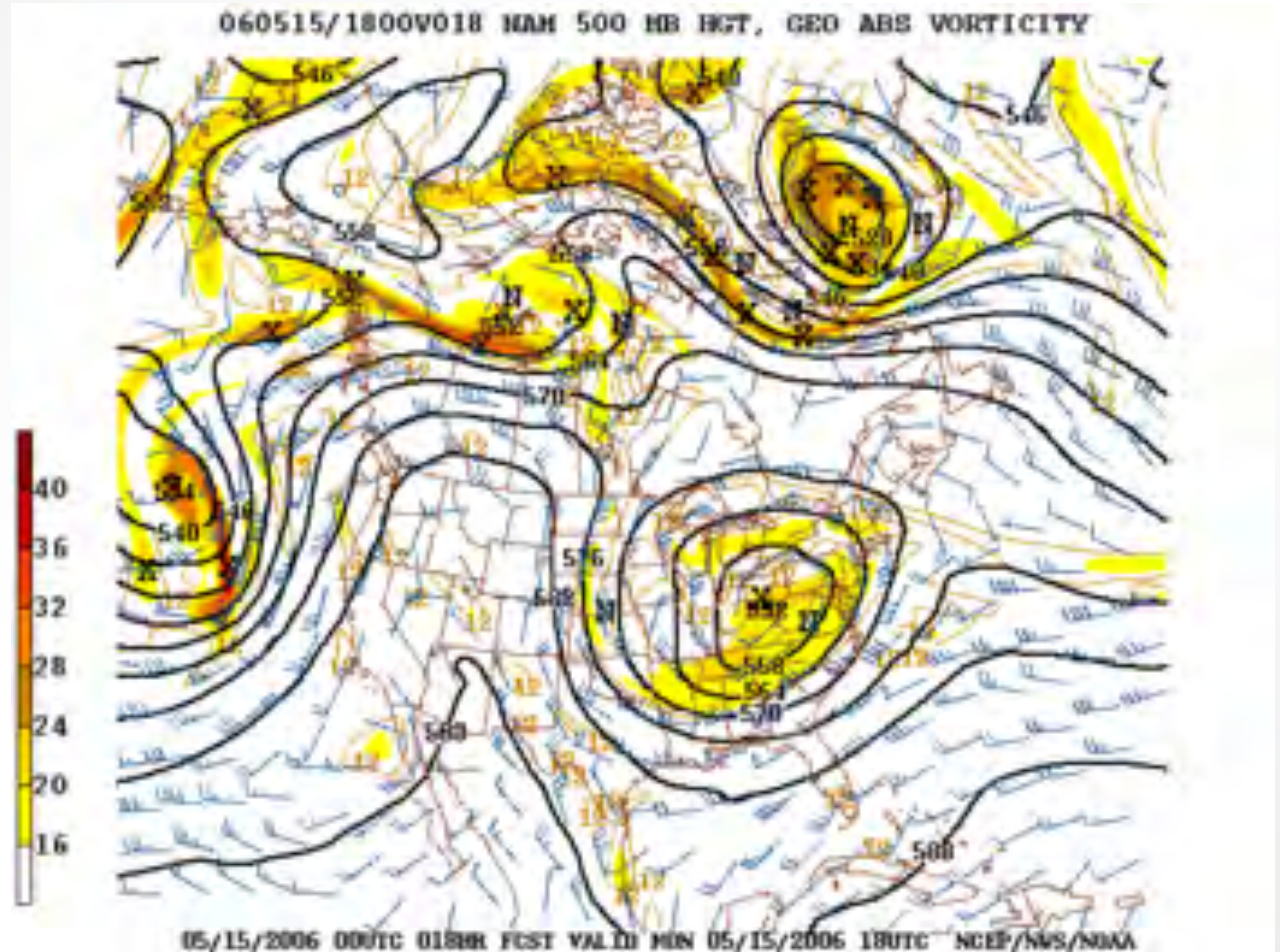
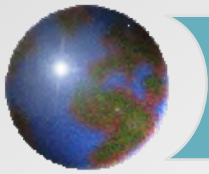
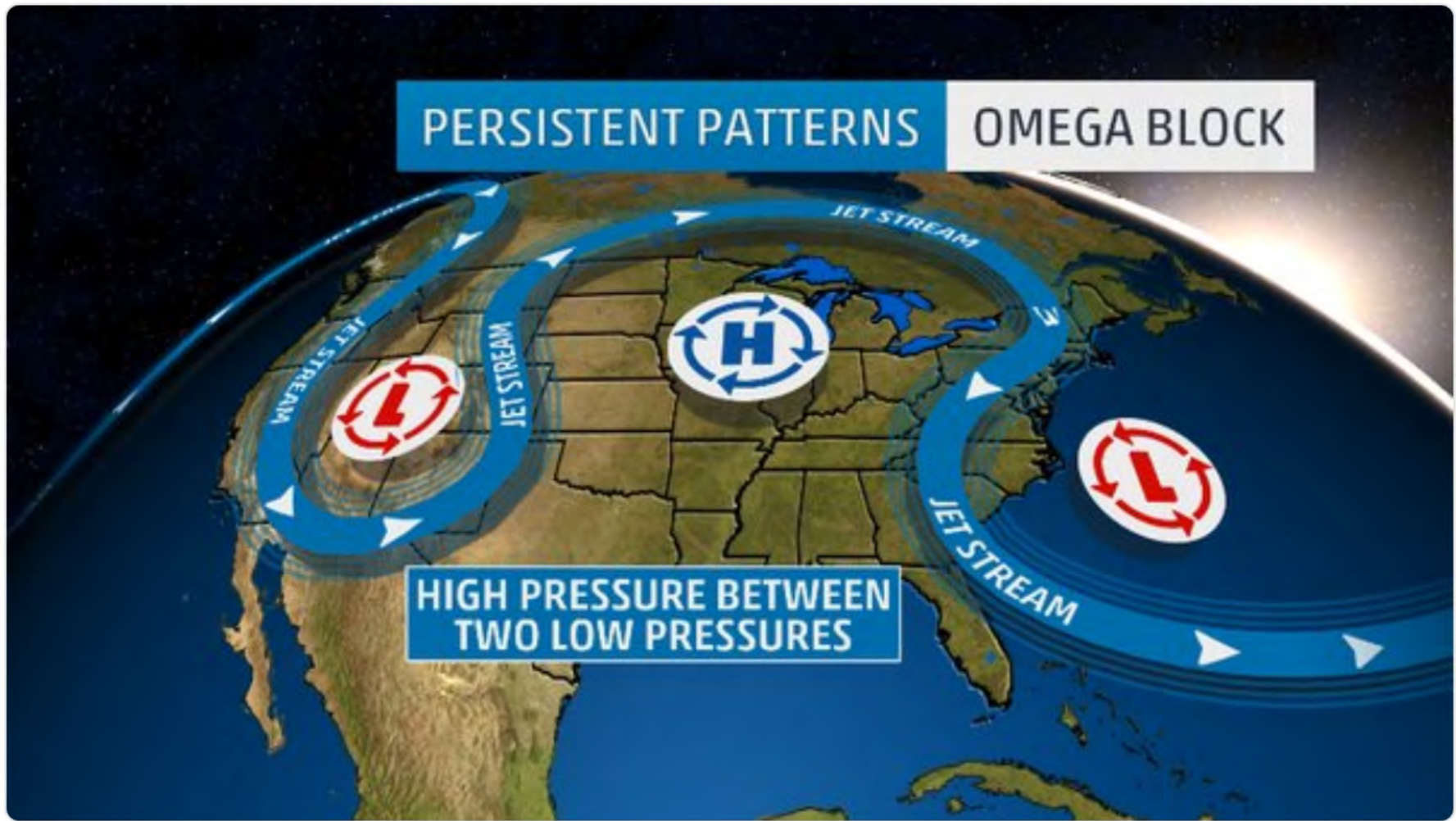


Figure
May 2006

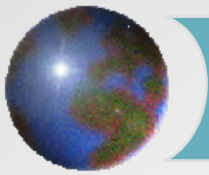


PERSISTENT PATTERNS

OMEGA BLOCK

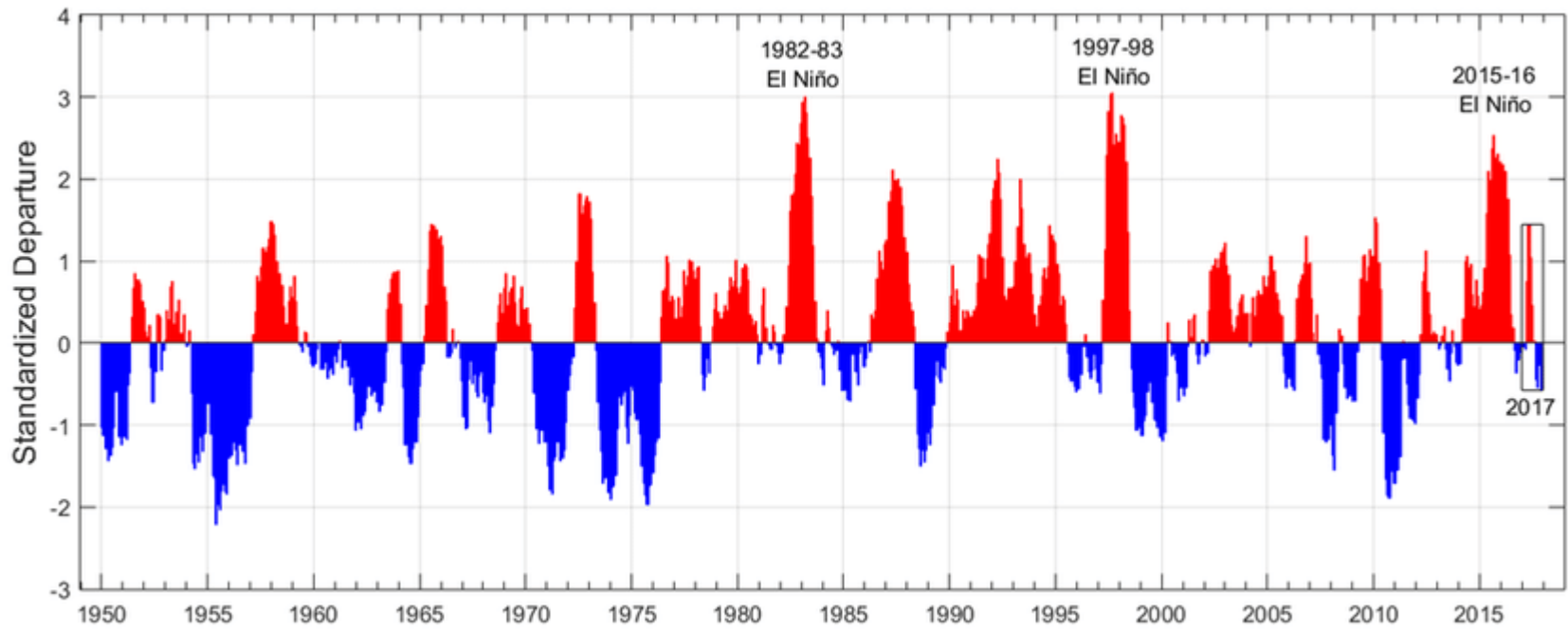


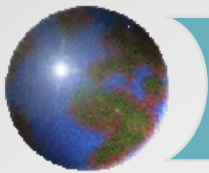
HIGH PRESSURE BETWEEN
TWO LOW PRESSURES



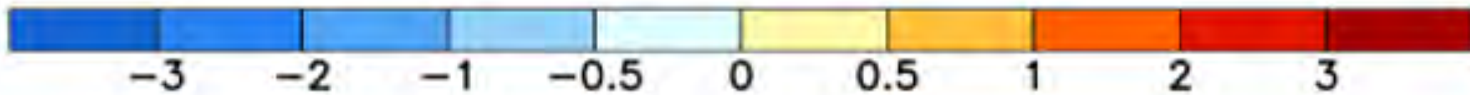
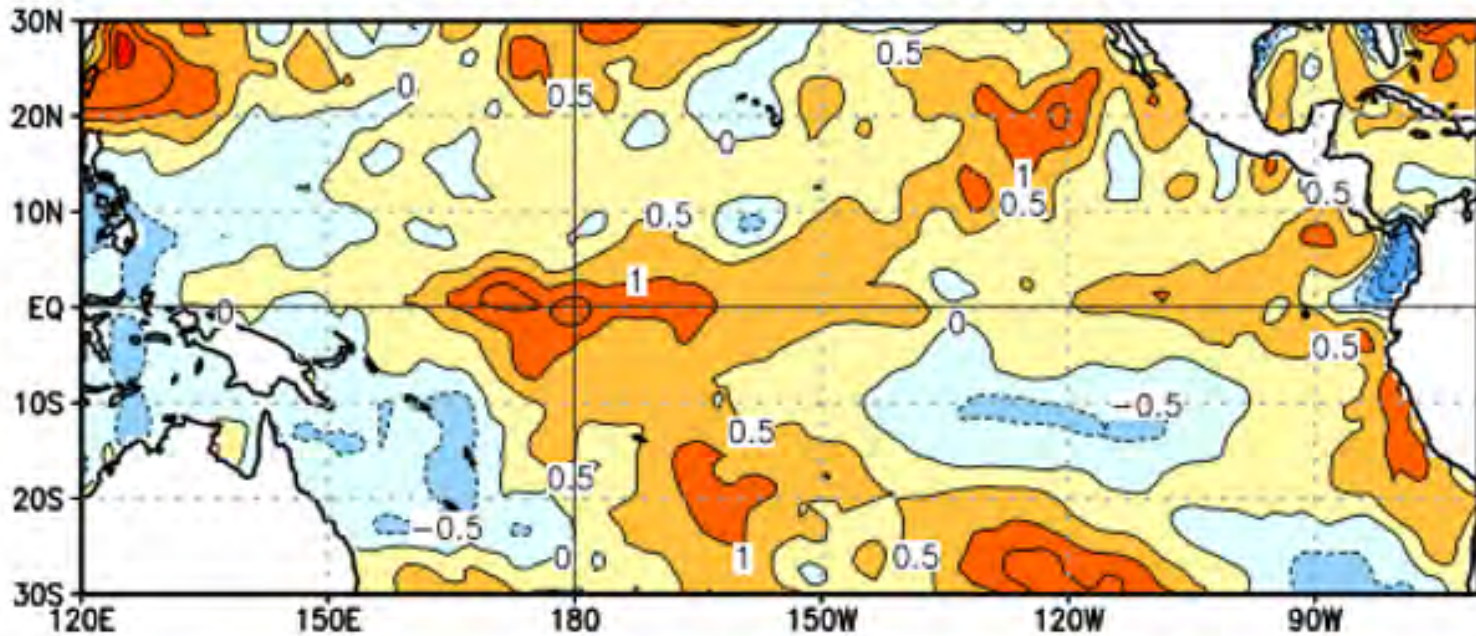
ENSO Index

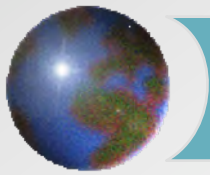
- ✚ Strong positives are El Niño
- ✚ Strong negatives are La Niña



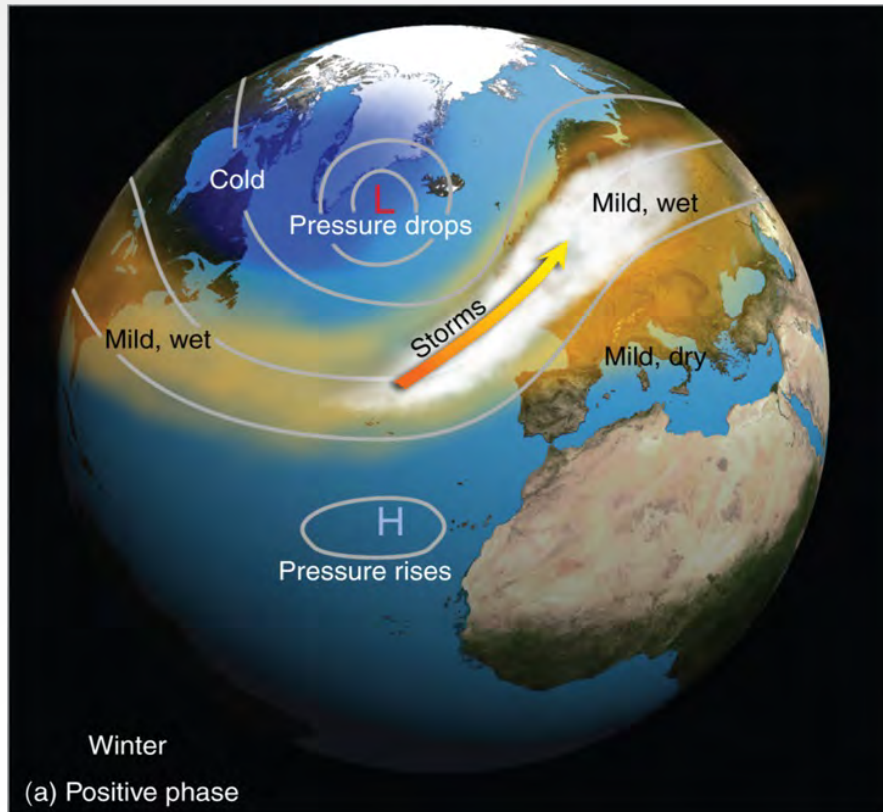


Average SST Anomalies 27 JAN 2019 – 23 FEB 2019

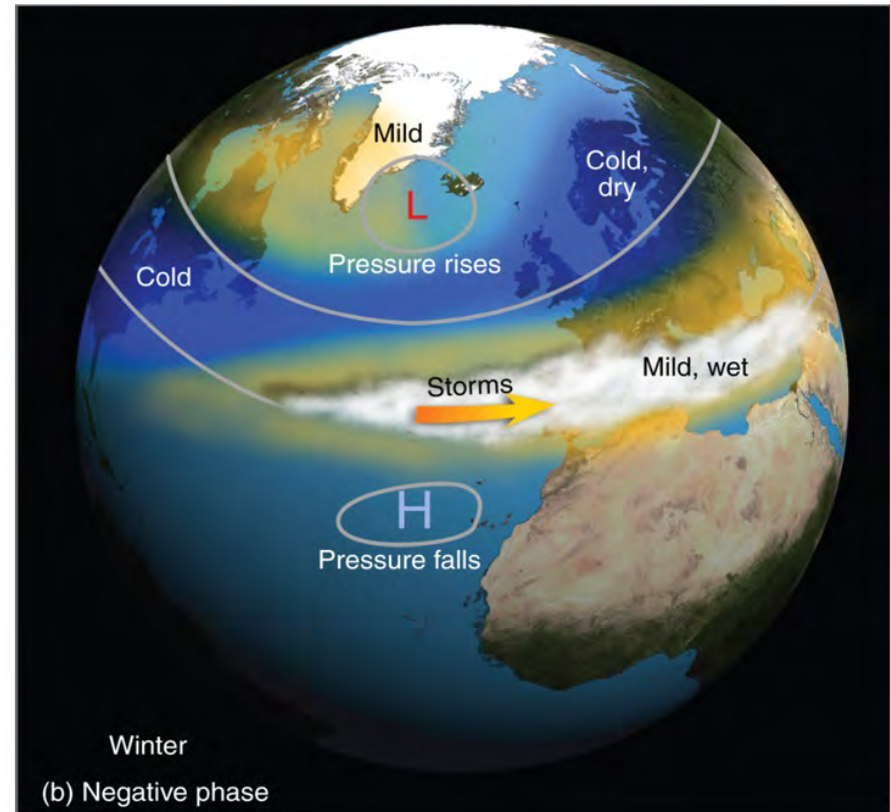




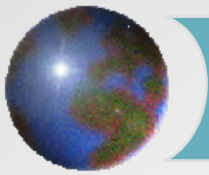
North Atlantic Oscillation (NAO)



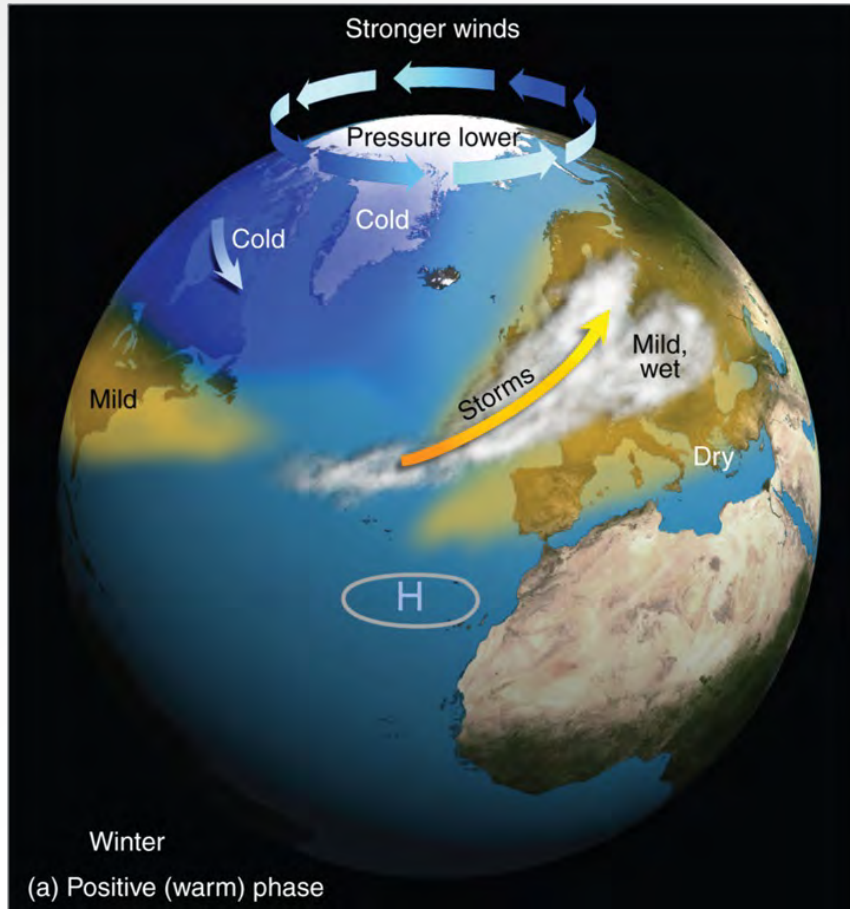
Positive



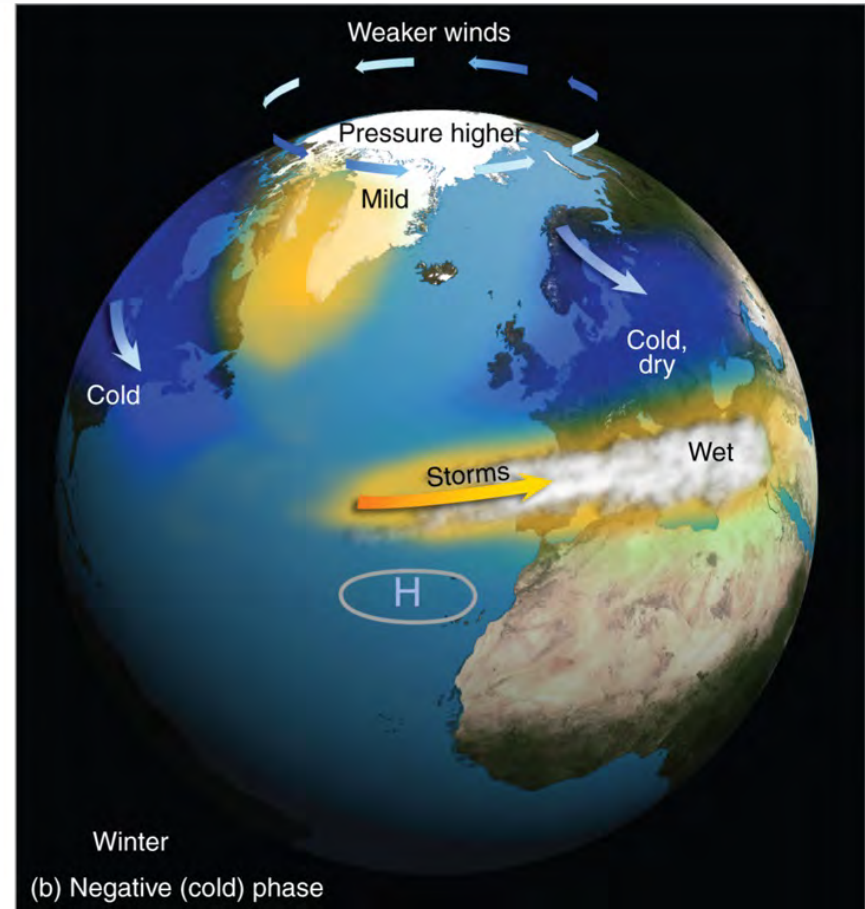
Negative



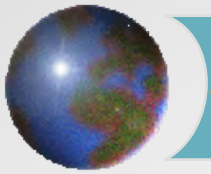
Arctic Oscillation (AO)



Positive



Negative



Next lecture

- ✚ Air Masses and Fronts
- ✚ Ahrens: Chapter 11