

The general circulation: global winds

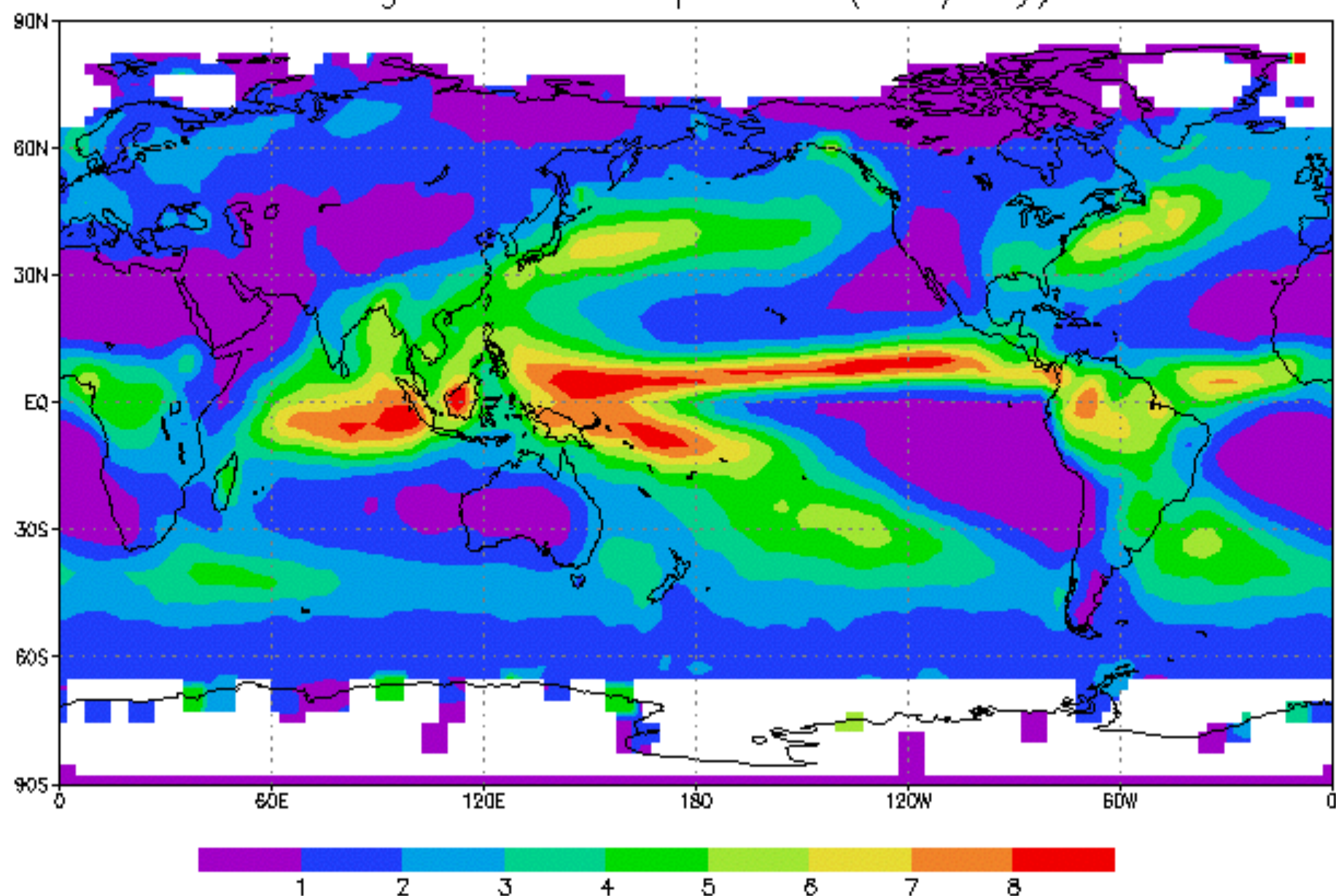
Question:

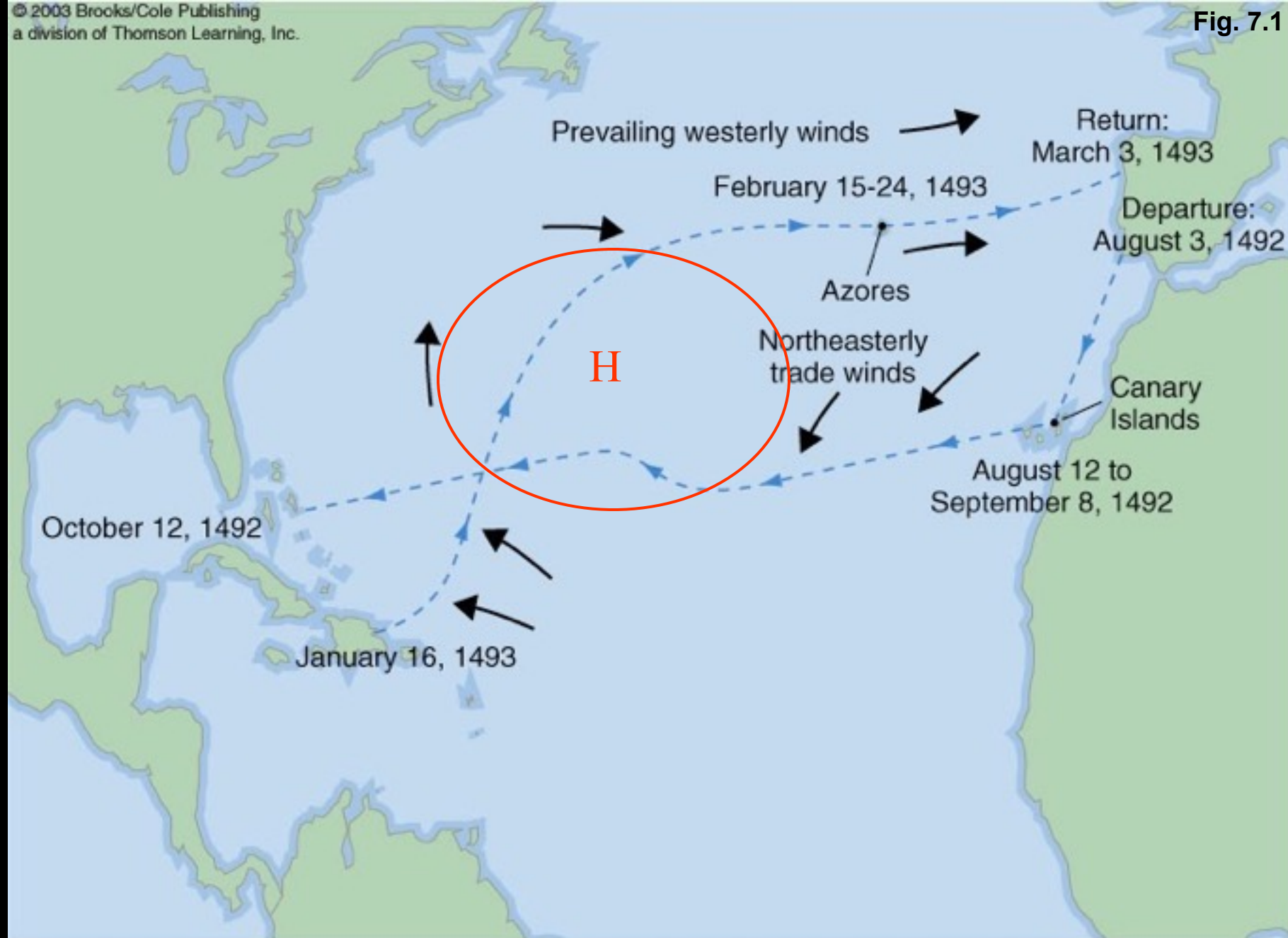
What are the prevailing winds across the globe ??

Modern World



Annual Average GPCP Precipitation (mm/day): 1988–96





← Prevailing wind direction

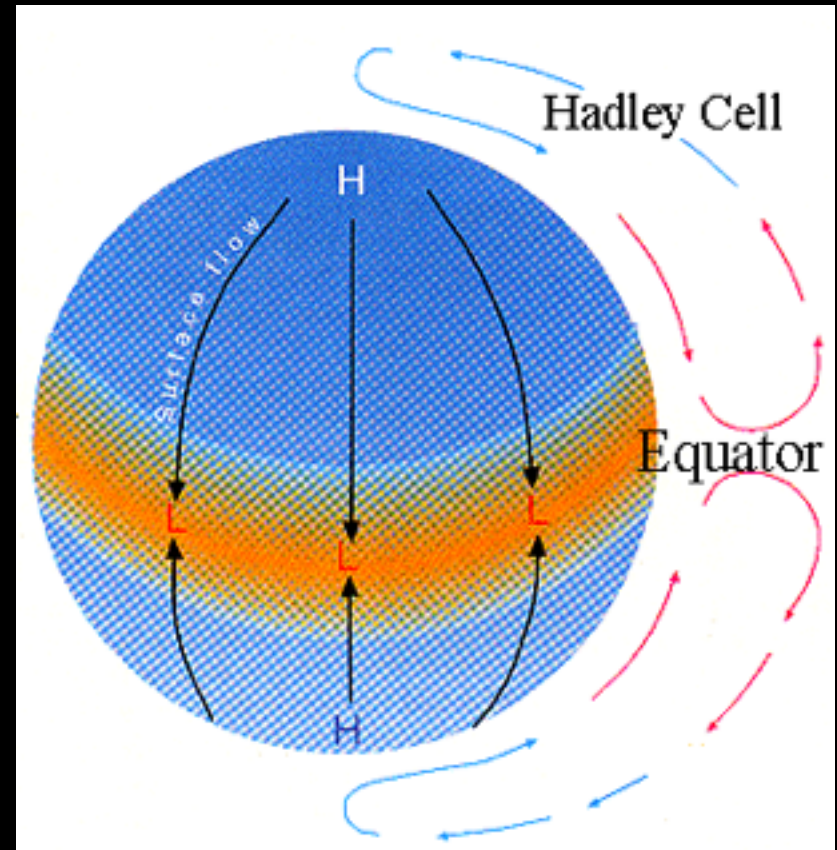
--- Voyage route of Christopher Columbus

In 1735, George Hadley proposed that a large thermal circulation cell would dominate the circulation of air in each hemisphere.

In each cell he suggested that warm air would rise in the tropics and cold air would sink over the poles.

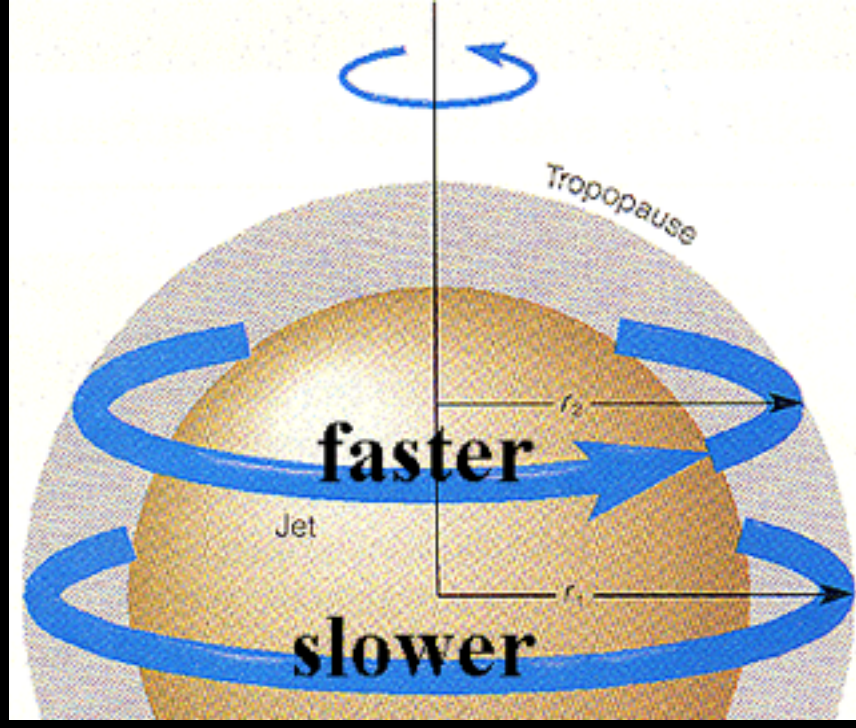
Note the circulation 'cells'. They are thermally direct.

This circulation pattern would exist if the Earth did not rotate.

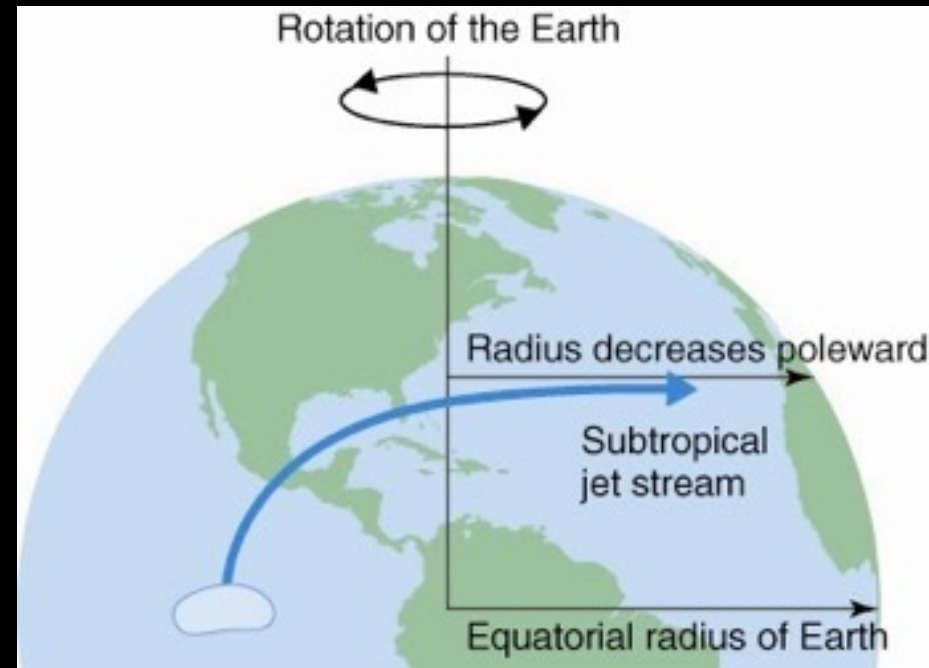


On Earth, warm surface air does indeed rise in the tropics, and cold dense air does sink down over the poles.

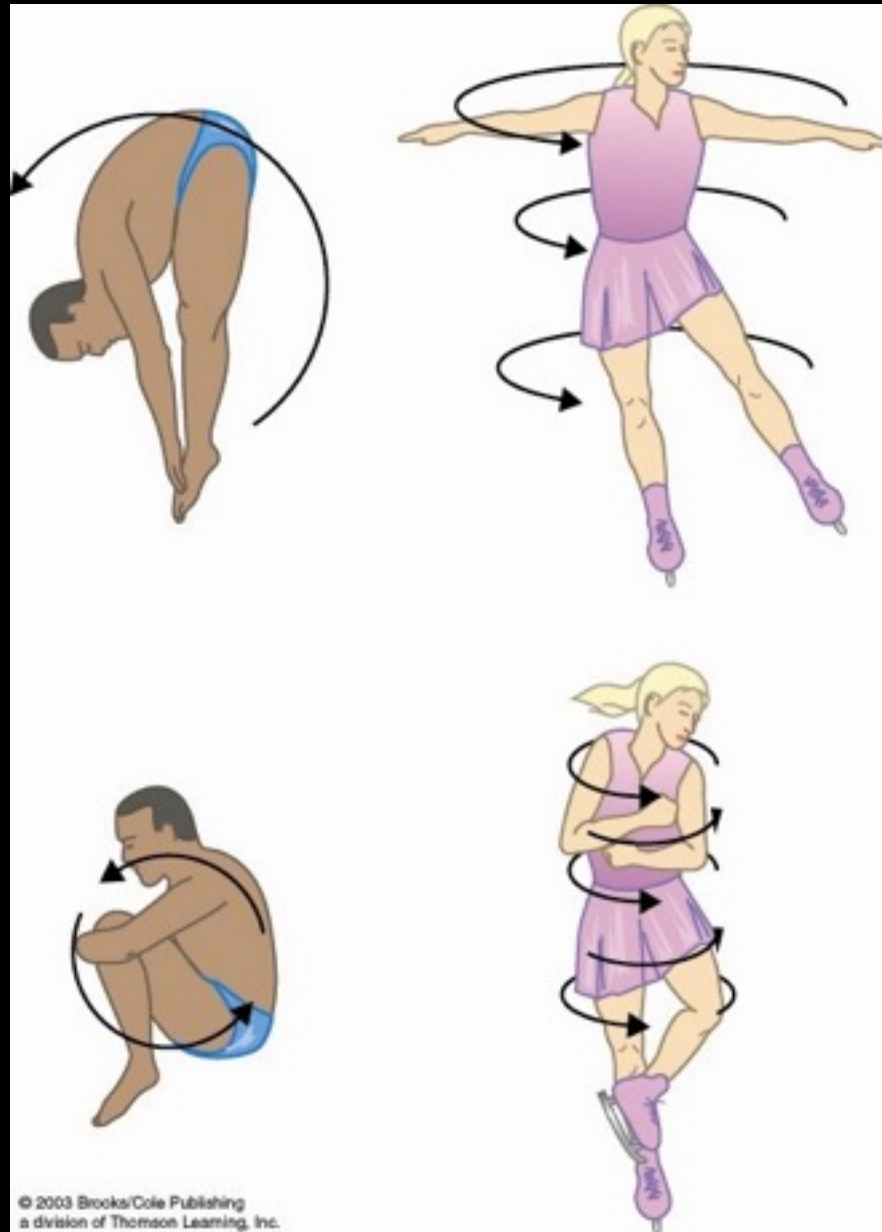
However, because the Earth rotates, air flowing to and from the poles is deflected by the **Coriolis Force**.



The **Hadley cell** still exists, but only at low latitudes, where the Coriolis force is small.

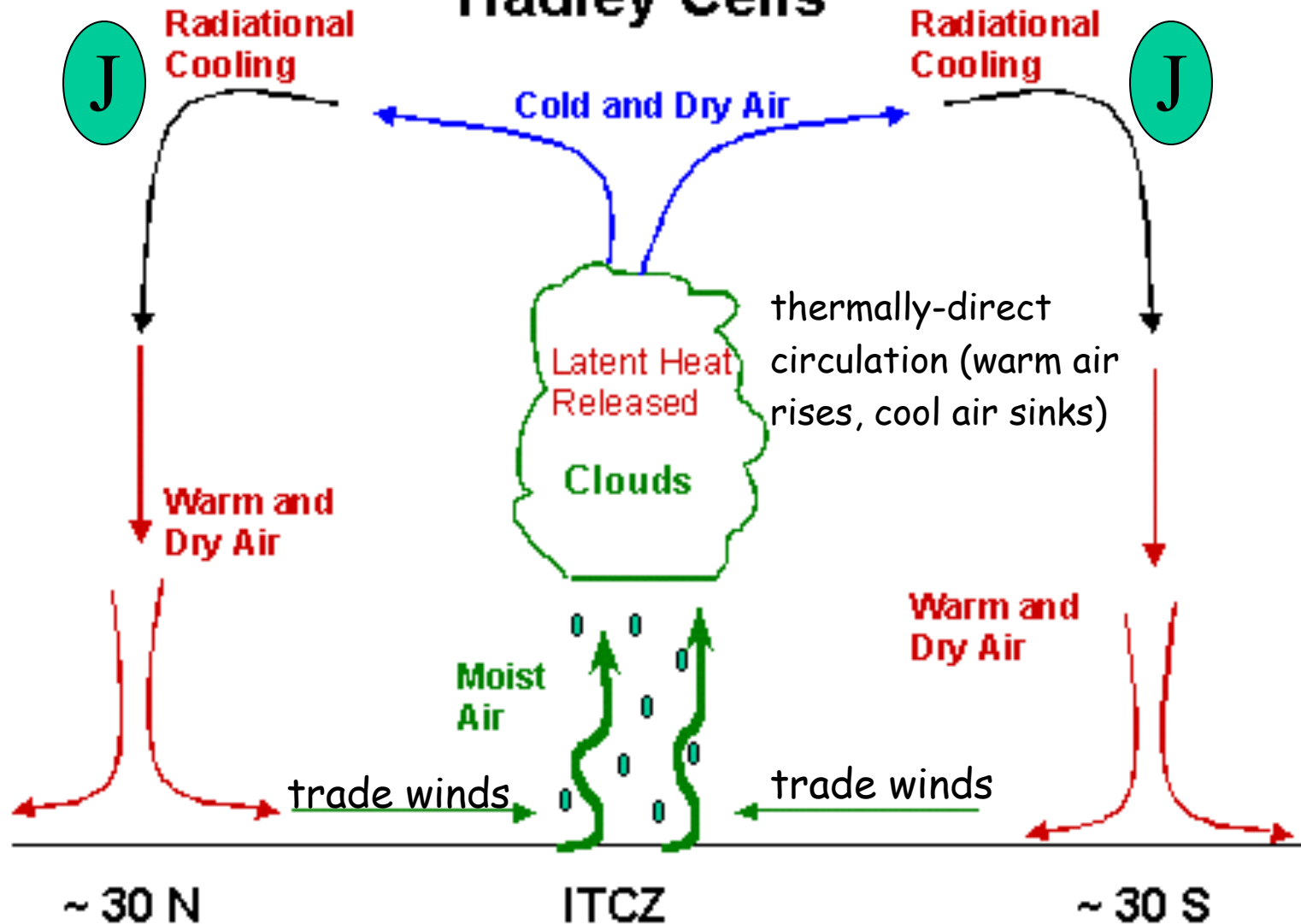


The Coriolis force can be thought of, in part, as due to angular momentum conservation



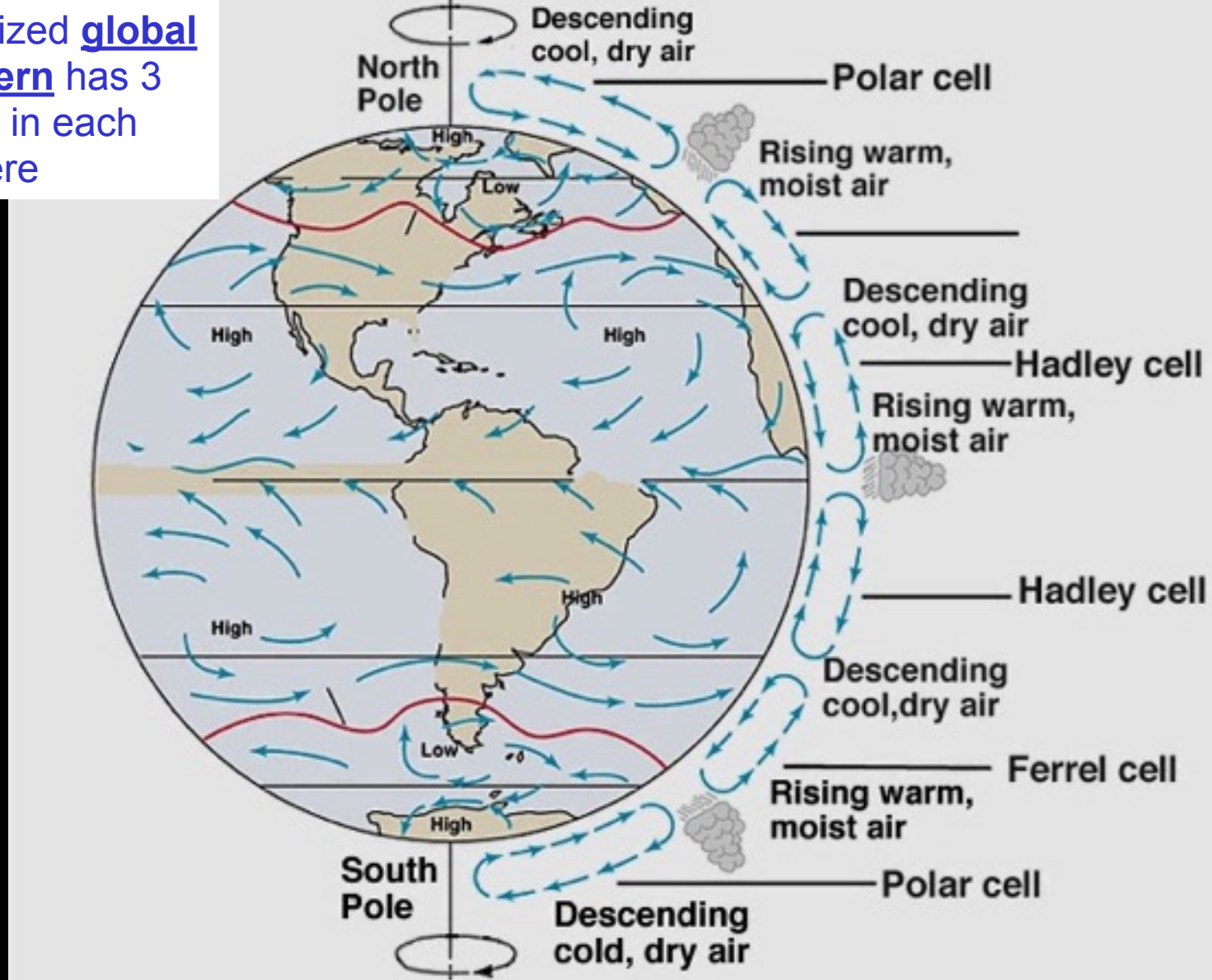
youtube illustration

Hadley Cells



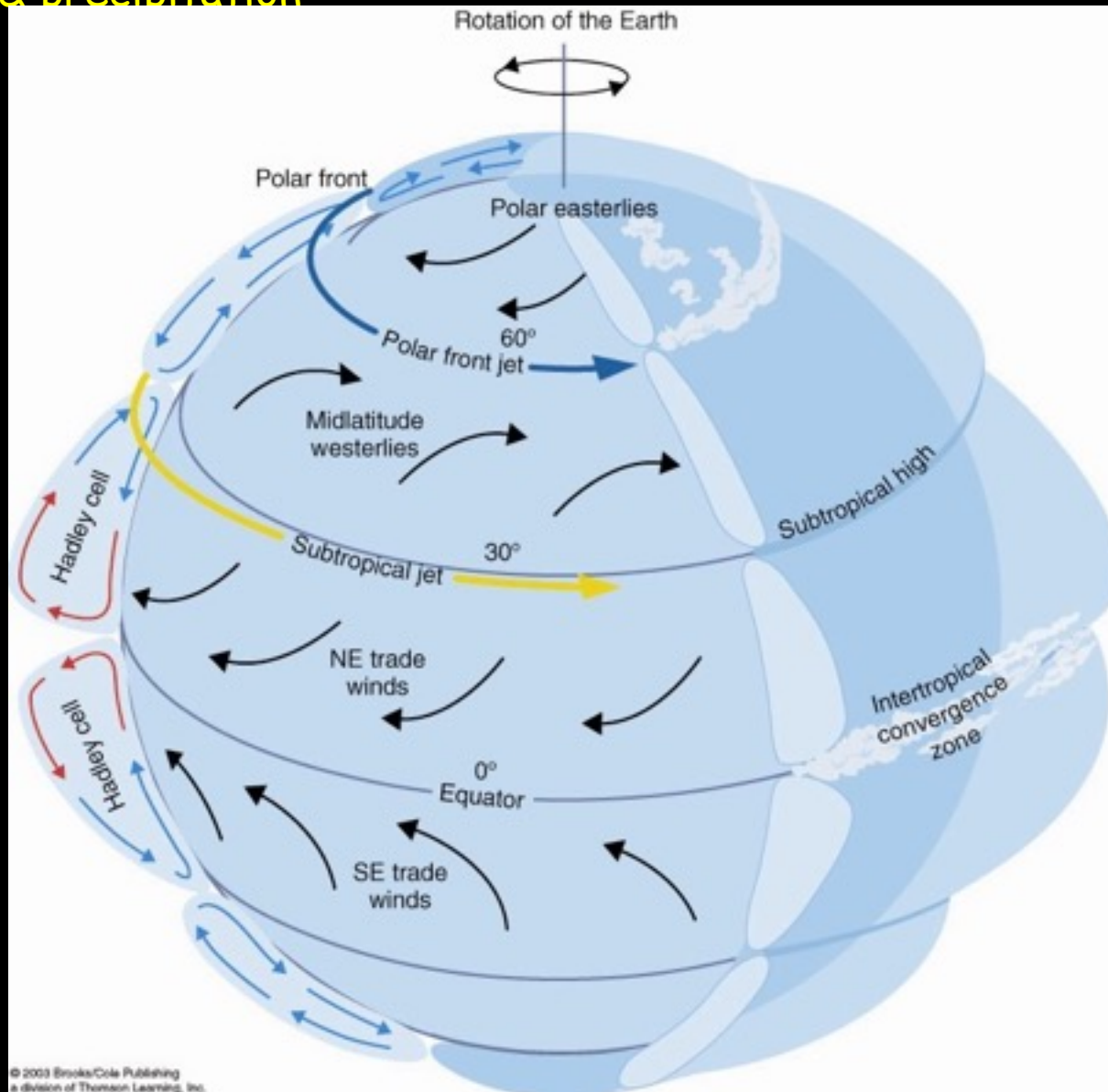
The **Coriolis Force** deflects the surface flows, creating NE and SE winds (the trade winds) in the sub-tropics of the northern and southern hemispheres ...

The resulting idealized global circulation pattern has 3 circulation cells in each hemisphere

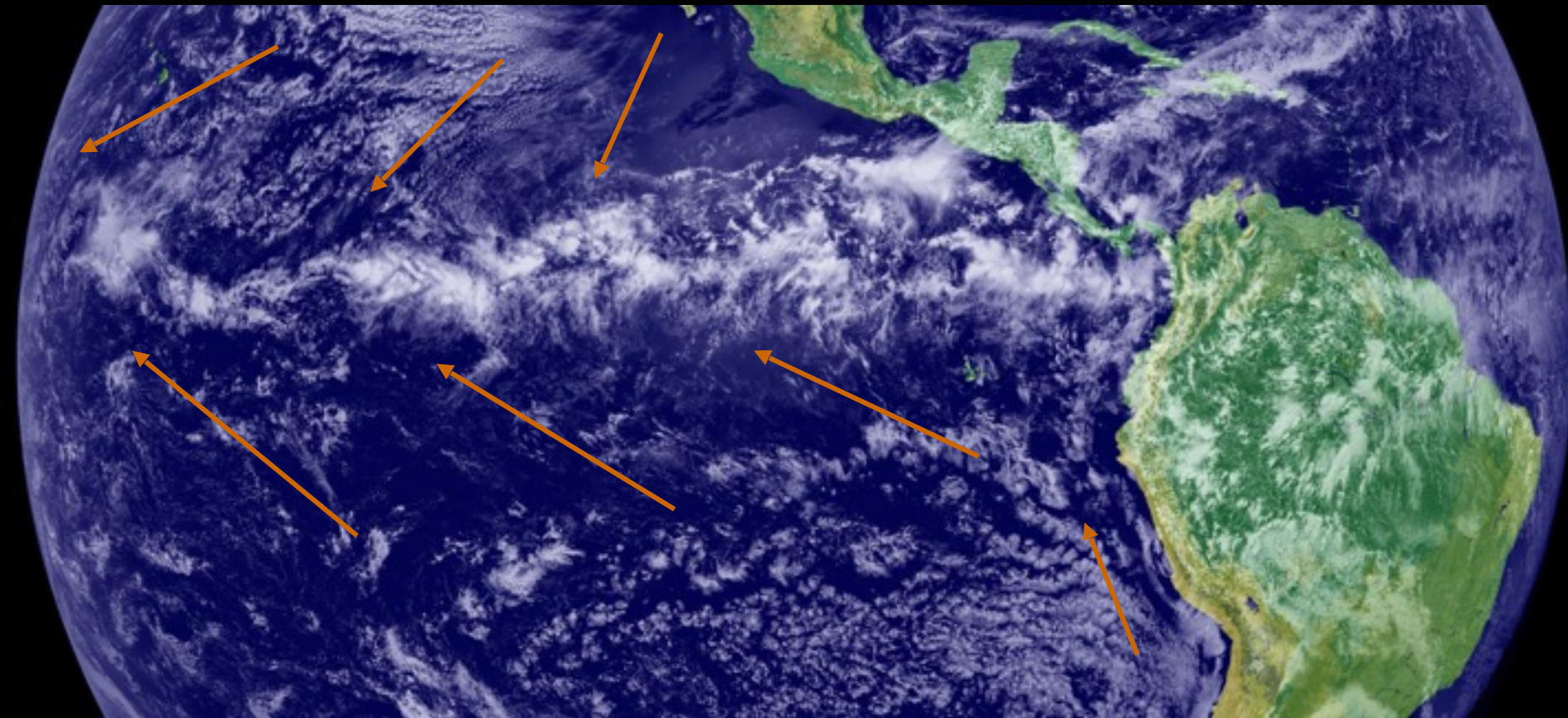


The mid-latitude surface westerlies converge with the polar easterlies at the polar front. Air rises above the polar front to complete both the mid-latitude **Ferrel Cell** and the **Polar Cell** in high latitudes.

Lower pressure and convergence at the surface occurs along the ITCZ in the tropics and at the polar front, resulting in rising air. This promotes cloudy skies & precipitation



Convergence occurs at the Intertropical Convergence Zone (ITCZ) where air from the northern and southern hemispheres flows together. The ITCZ is marked by a band of deep clouds.

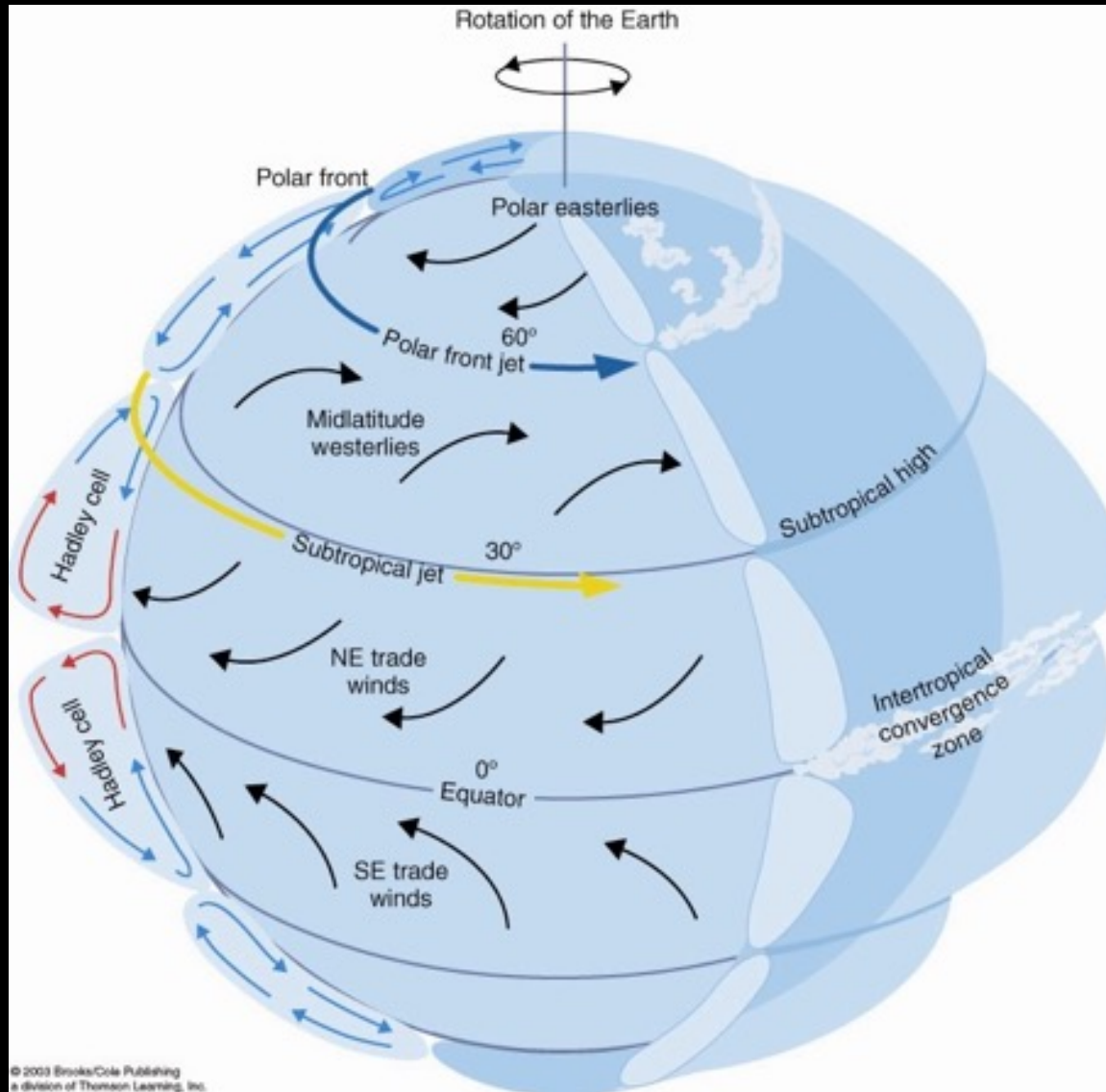


The ITCZ and Hadley cells move seasonally



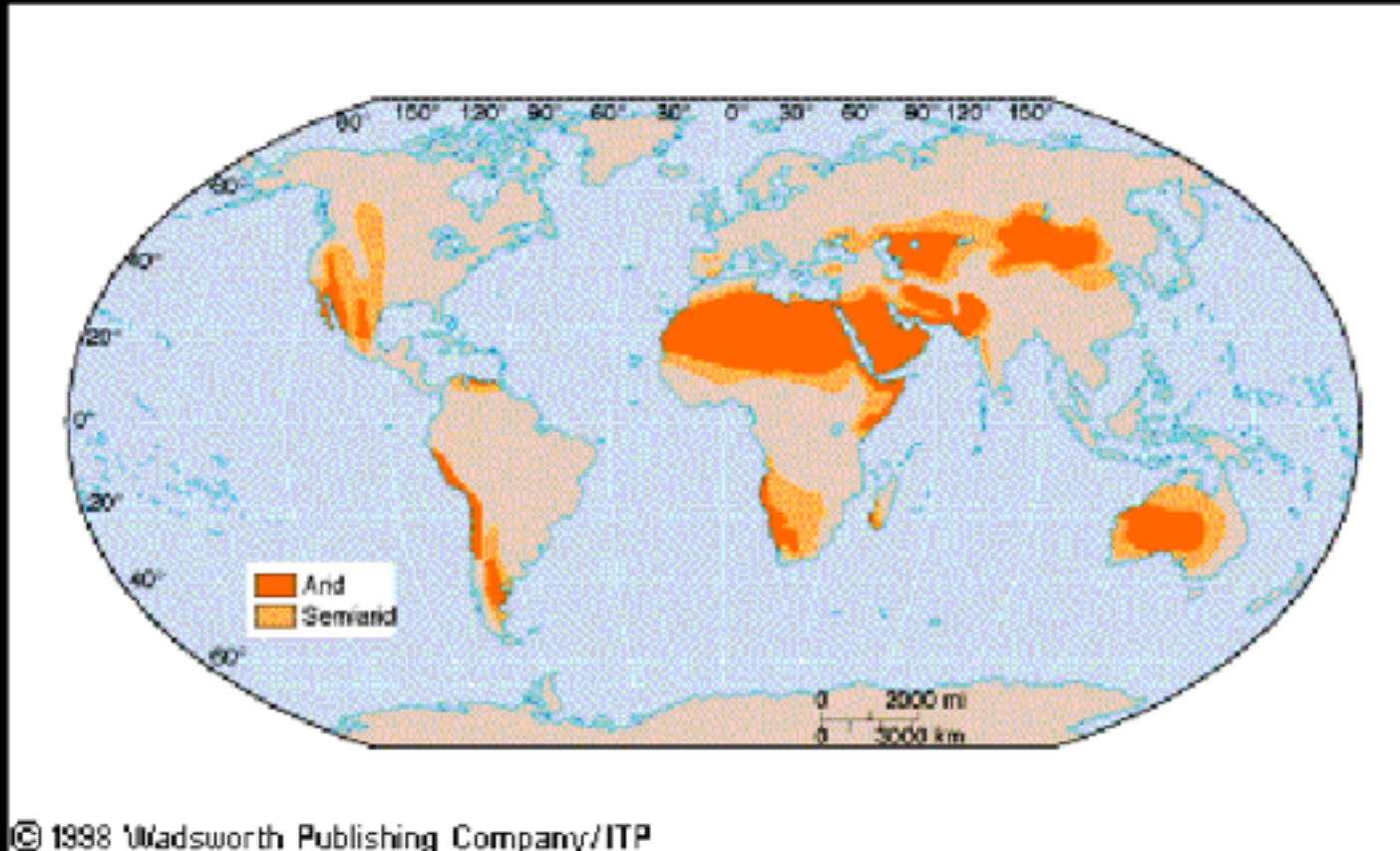
to see an animation of the annual cycle of global cloud cover, click [here](#)

High pressure and divergence at the surface occurs at about 30° latitude and at the poles. The convergence aloft at these latitudes results in sinking air.



Regions of subsidence experience clear skies and little precipitation.

Arid Regions

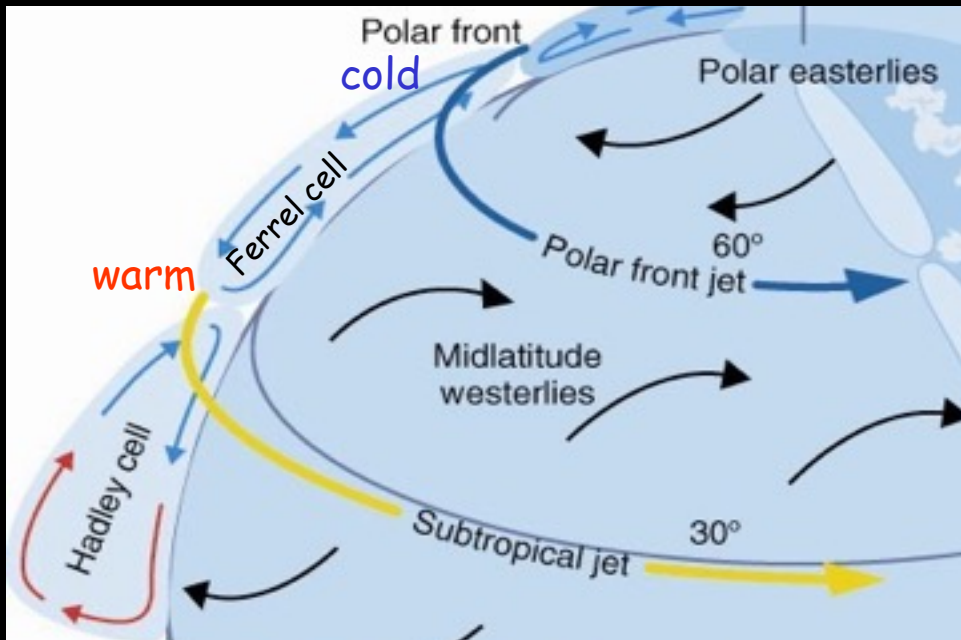


Find the ITCZ, the
subtropical subsidence,
the midlatitude frontal
systems



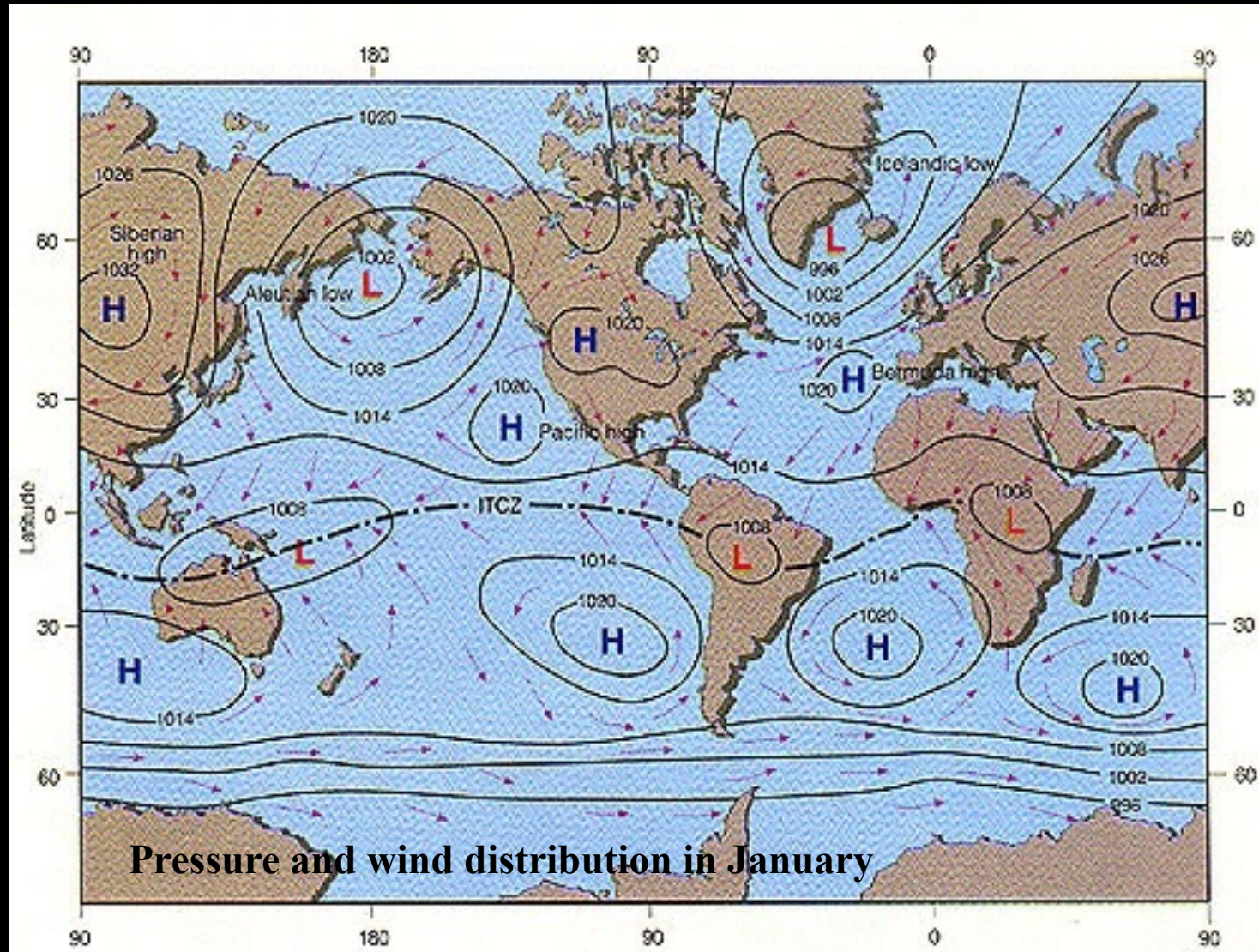
Pop quiz

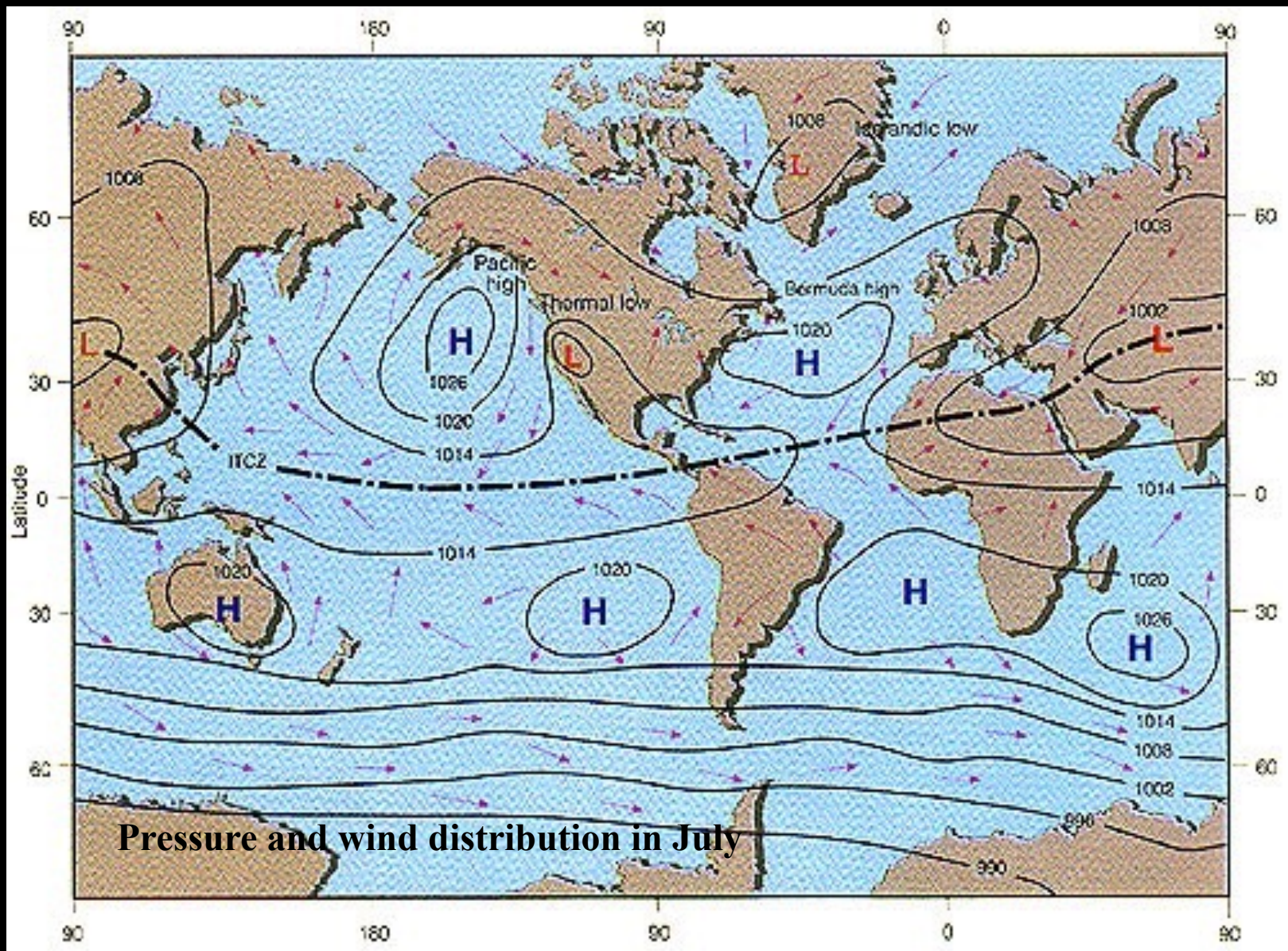
- The Ferrel Cell is thermally indirect because:
 - A: warm air rises and cold air sinks
 - B: cold air rises and warm air sinks
 - C: it is rainy in the warm air and dry in the cold air
 - D: it is dry in the warm air and rainy in the cold air



The Ferrel cell is counter-intuitive. It extracts energy from the jet stream.

How do the predicted pressure and global circulation patterns compare with those observed?





It looks like our model of the general atmospheric circulation overlooked something. What?

- Seasons
- Land vs ocean (esp in the NH)

The observed pressure and wind distributions resemble the idealized predicted distributions more closely in the southern hemisphere than in the northern hemisphere, because there is more ocean in the South.

Some observations:

The ITCZ and the principal wind belts move *south* in January and *north* in July.

Ocean:

- Subtropical highs are stronger in **summer**.
[Pacific High, the Bermuda High, and their SH counterparts]
- Midlatitude lows are stronger in **winter**.
[the Aleutian and Icelandic Lows]

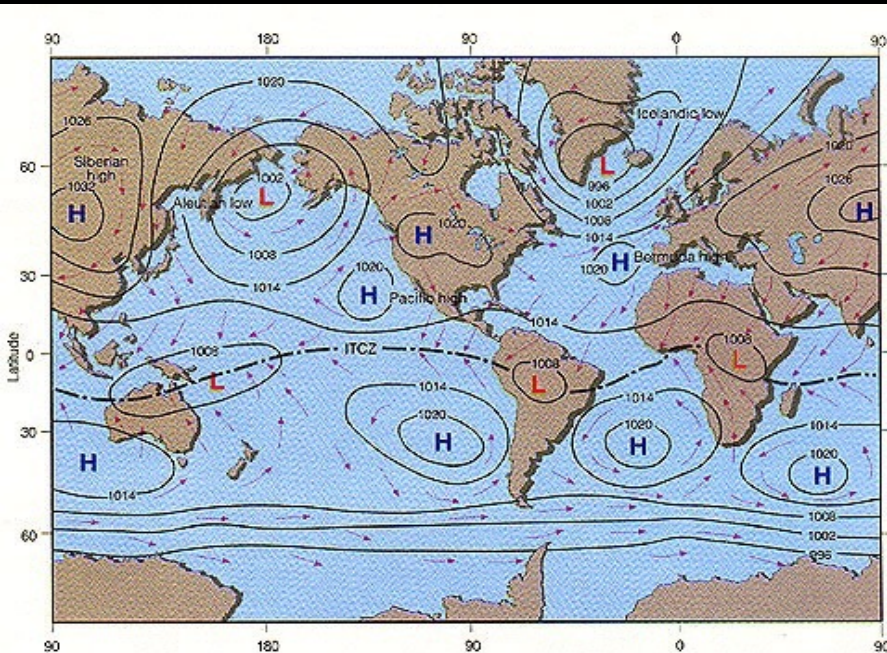
Land:

- Subtropical heat lows in **summer**.
[Sonora Low, the Pakistani Low, and their SH counterparts]
- Midlatitude cold highs in **winter**.
[the Intramountain High and Siberian High]

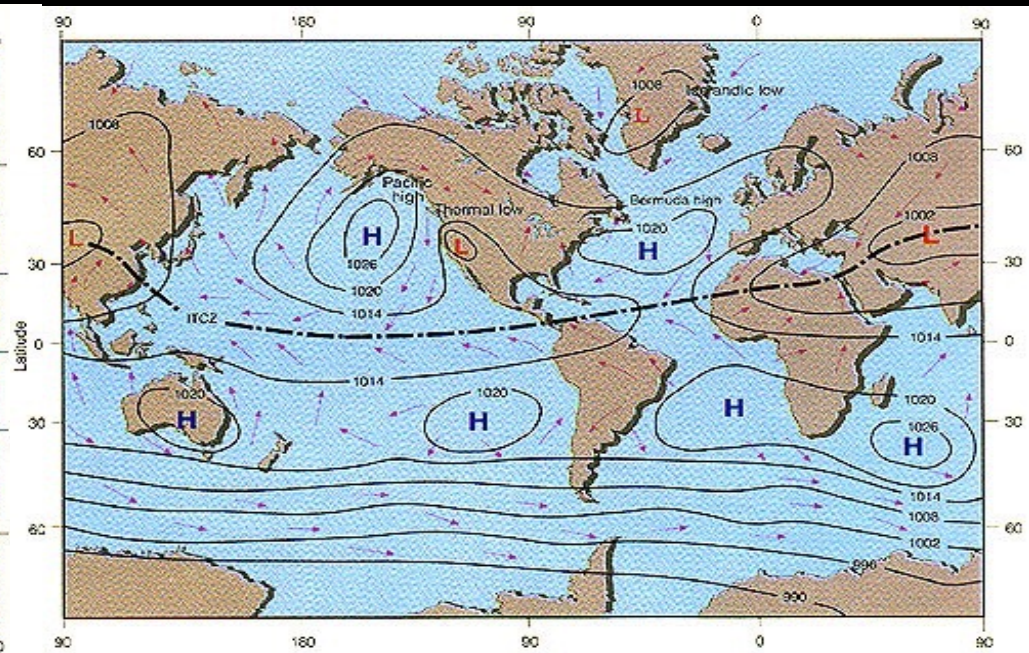
Pop quiz

- Which is true?
 - A: Highs over land are stronger in winter
 - B: Highs over the ocean are stronger in summer
 - C: Lows over land are stronger in summer
 - D: Lows over the ocean are stronger in winter
 - E: All of the above

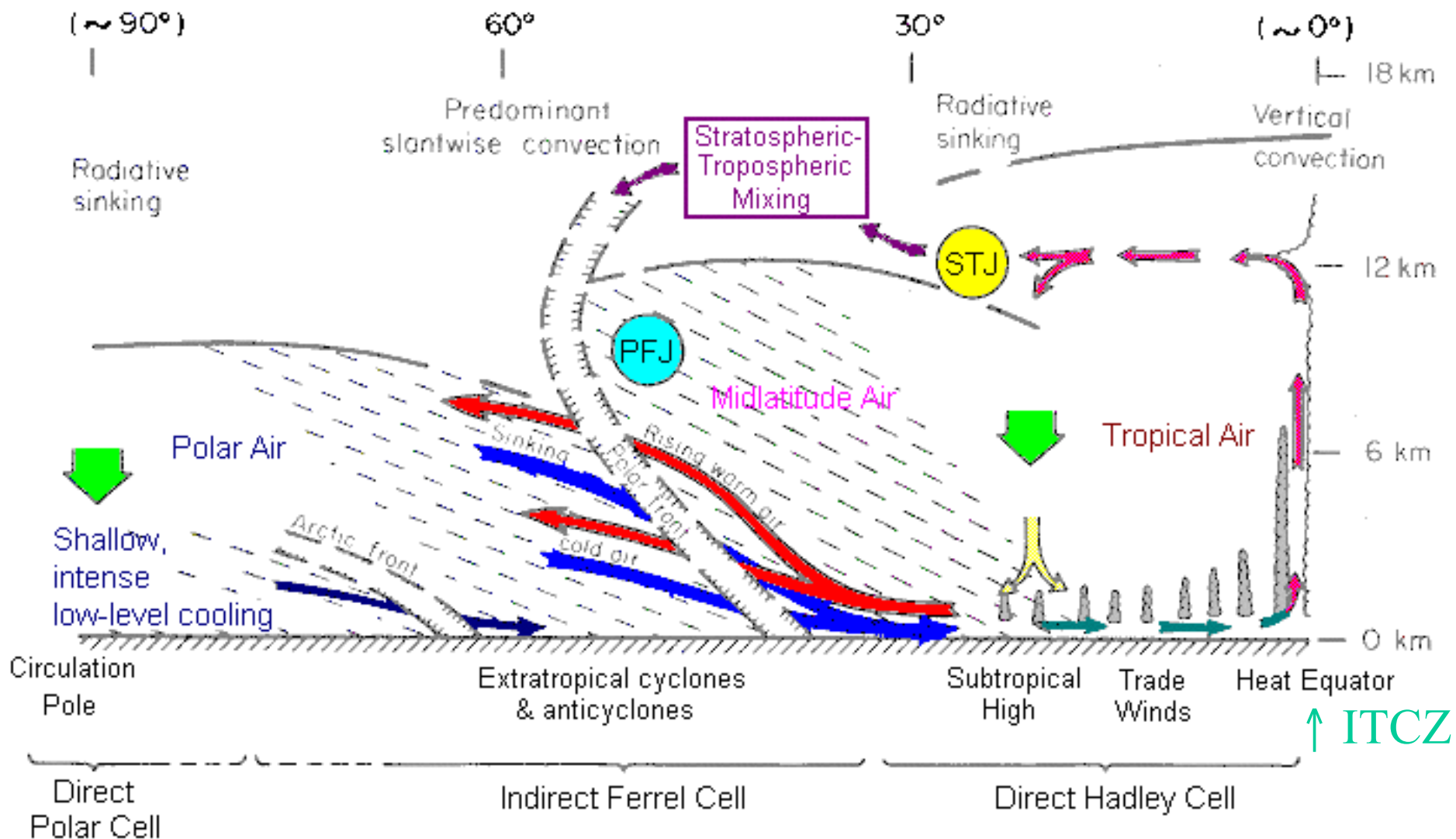
January



July



Now we focus on the mid-latitude belt

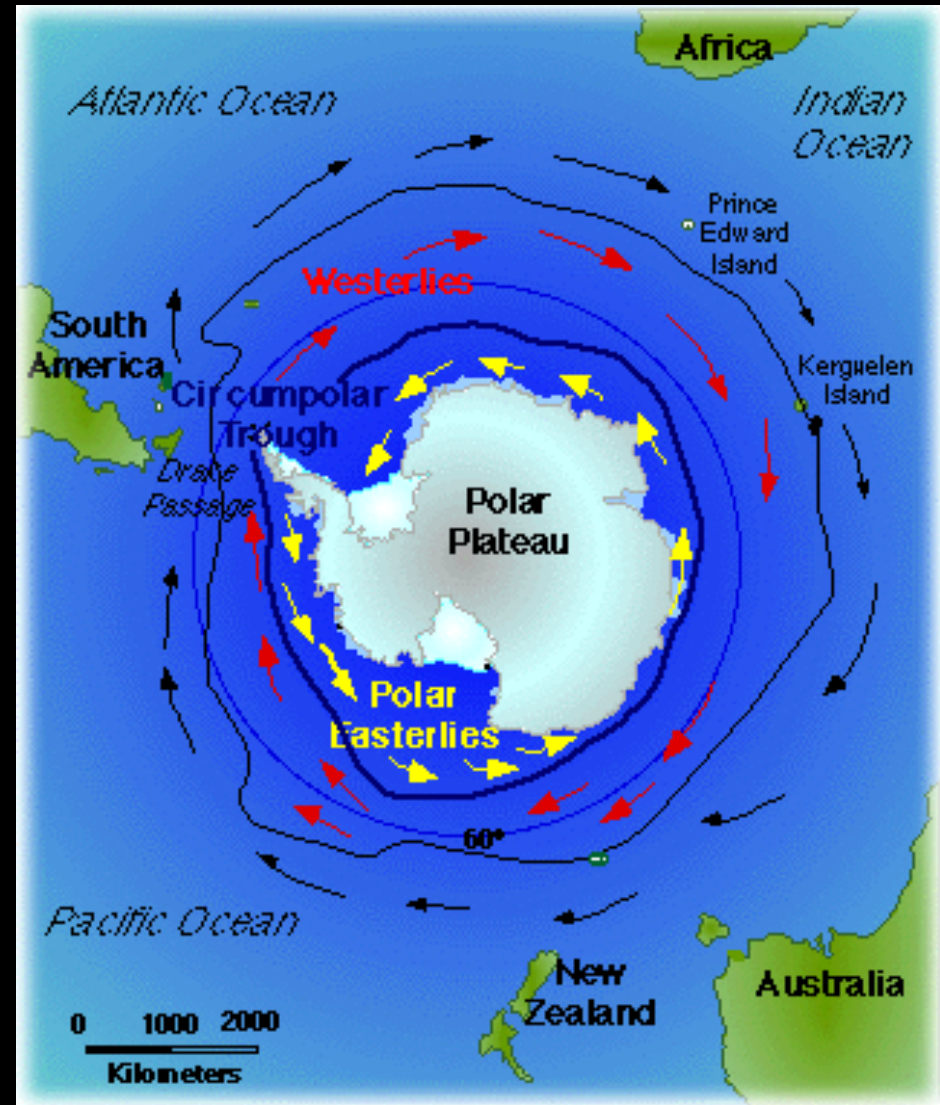


At the poles, very cold polar easterlies circulate within the Polar Cell at the surface, while warmer westerlies blow at lower latitudes.

The Polar Front is marked by a large temperature gradient

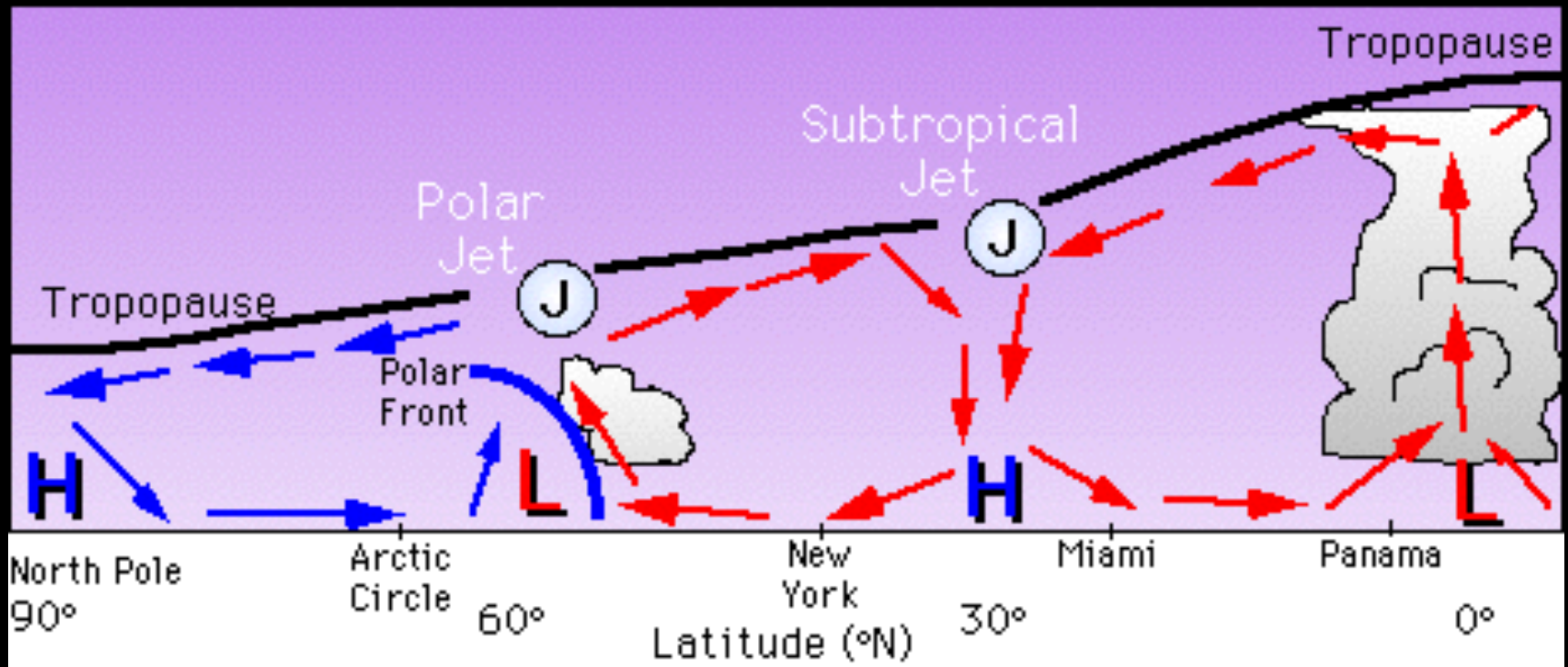
What does this T gradient imply???

any wind aloft??

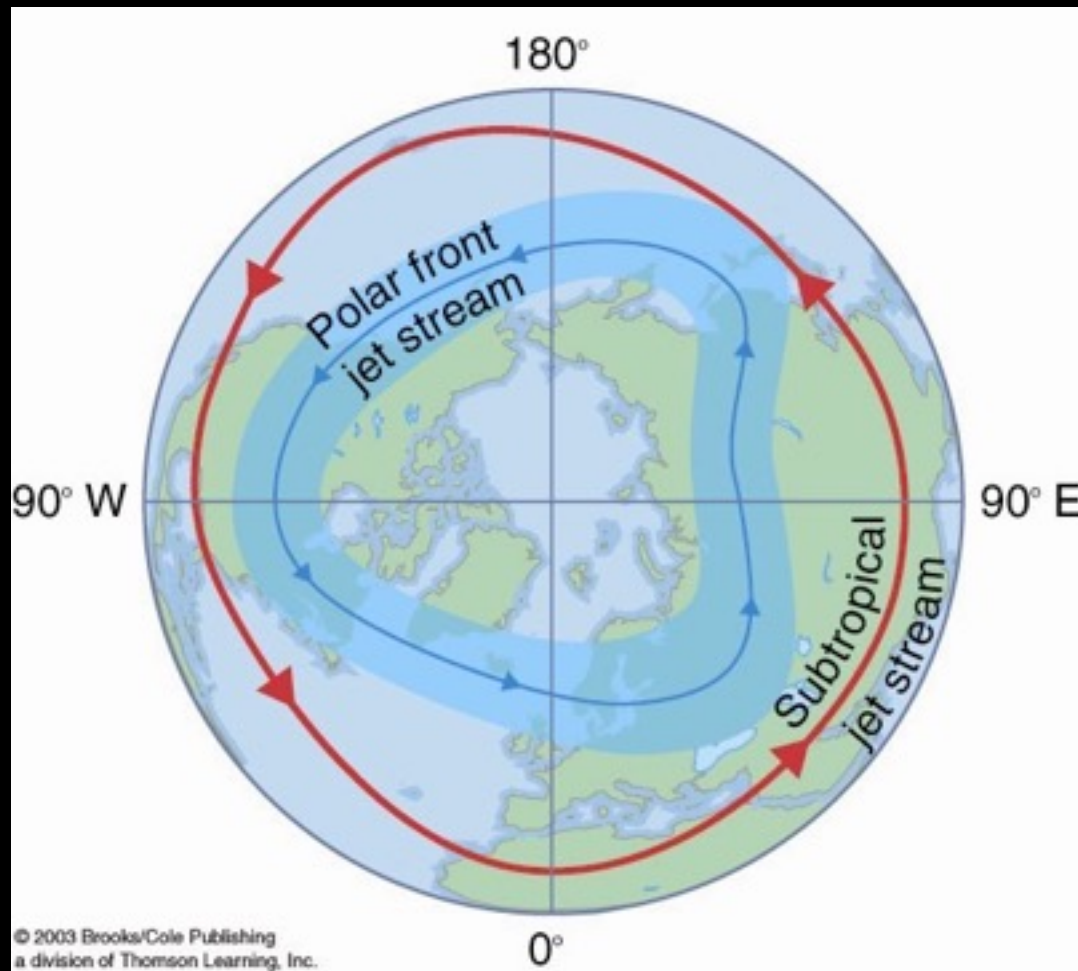


A Jet stream !!!

Sometimes the T gradient is split in two, and then you have 2 jets aloft, the polar jet and the subtropical jet.

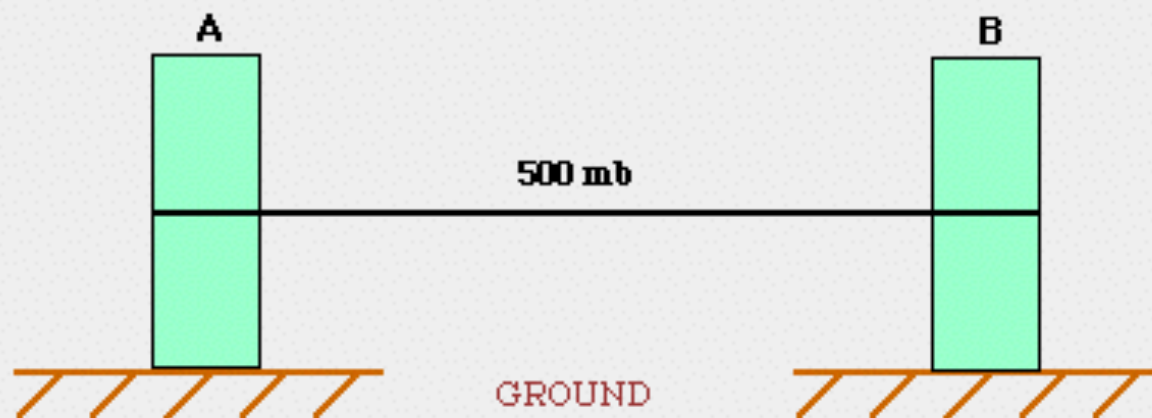


Revisiting a topic we learned about in Chapter 6: What explains the jet streams?



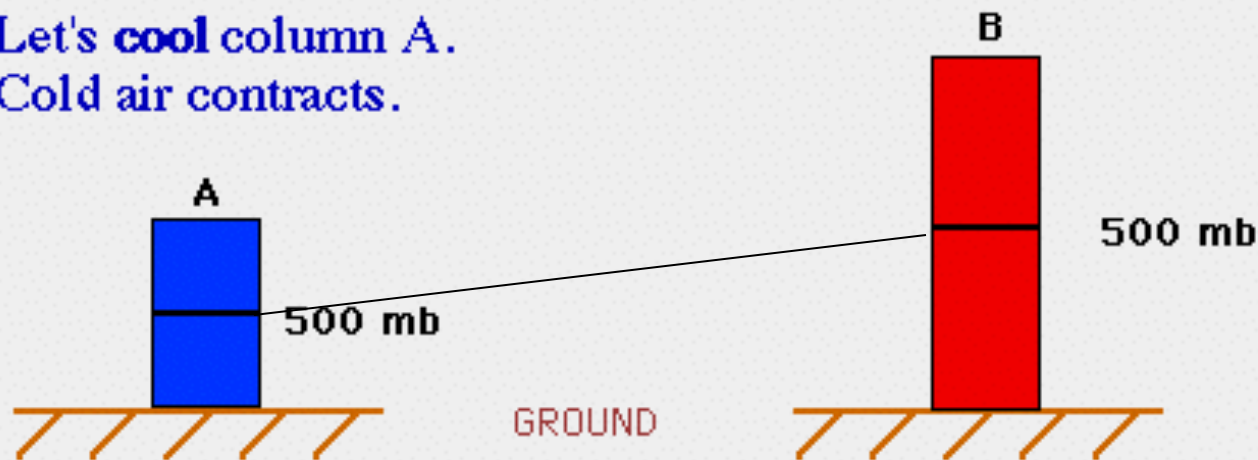
Formation of a jet stream

Consider two identical columns of air (A and B) above the ground. Since they are identical, the 500 mb surface is found at the same height in each column.



Let's **heat** column B.
Warm air expands.

Let's **cool** column A.
Cold air contracts.

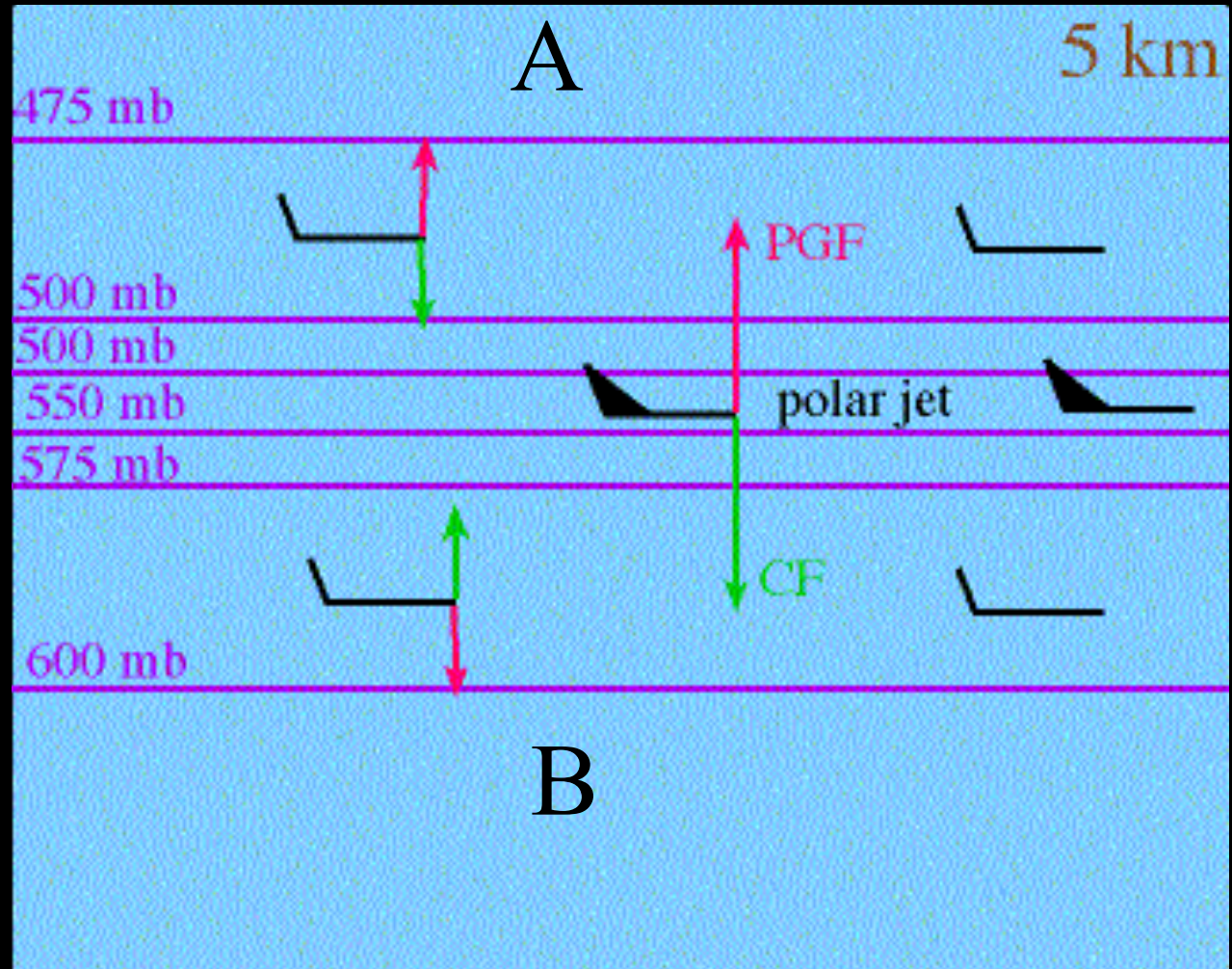


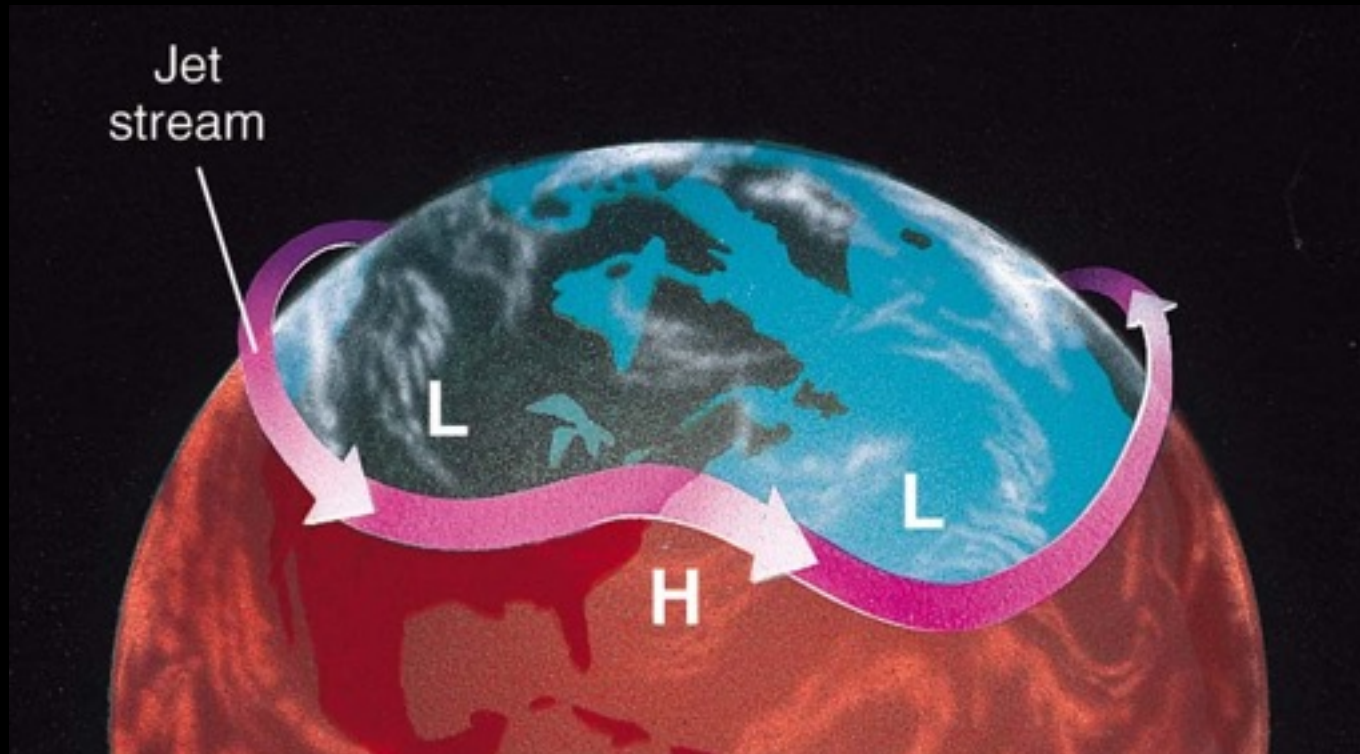
The 500 mb surface is found at a lower height in the cool air than in the warm air.

Jet formation

The temperature difference below causes steeply sloping height surfaces.

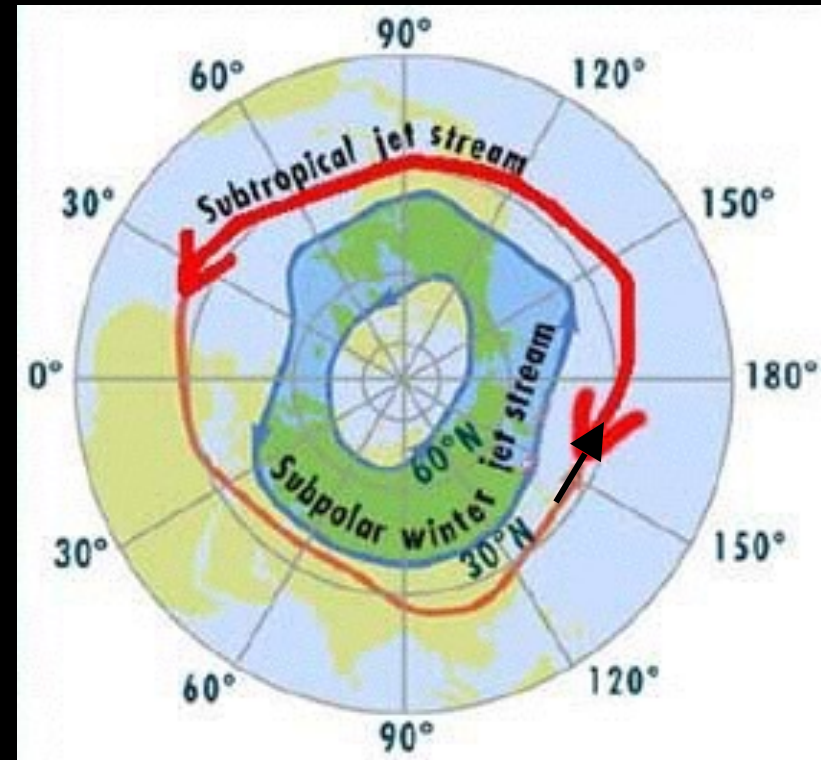
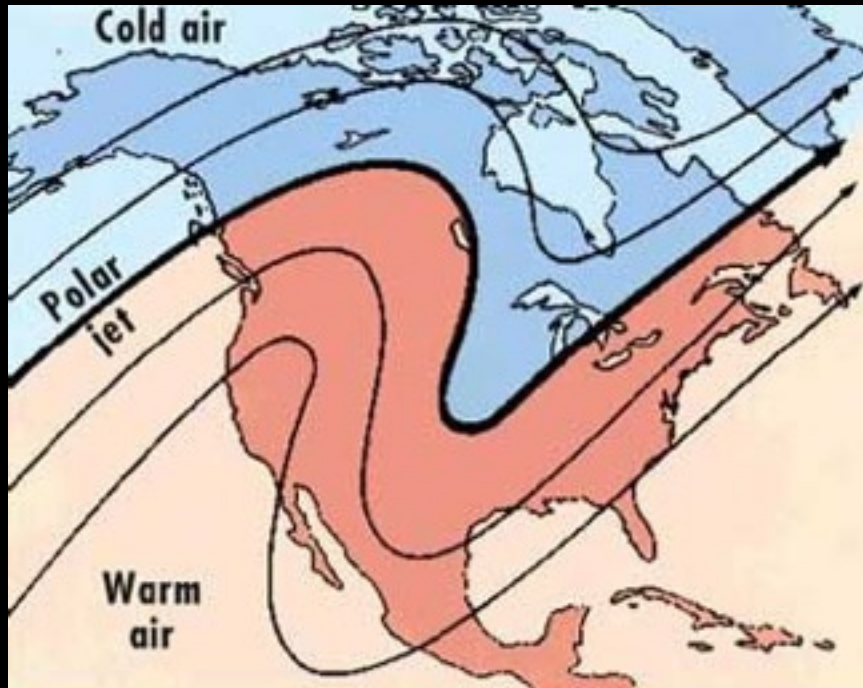
This slope really acts like the Pressure Gradient Force (PGF), which leads to high speed west-to-east **geostrophic flow**.





As the temperature gradient across the front is greatest in winter, jet speeds are higher at that time of year.

The Polar Jet flows in a 'looping' pattern west to east, above the polar front. These are **Rossby waves**.

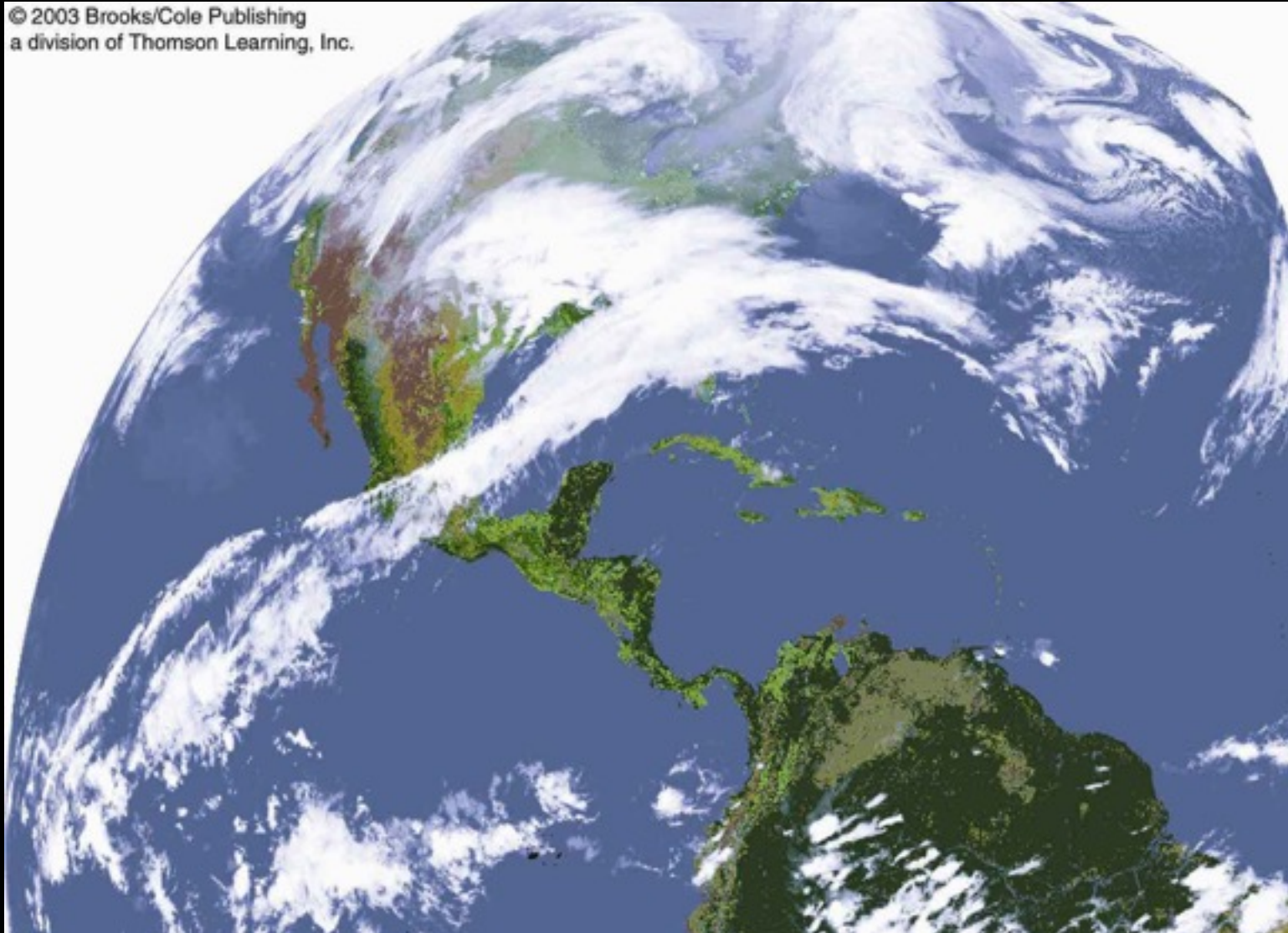


Rossby waves tend to amplify and break off

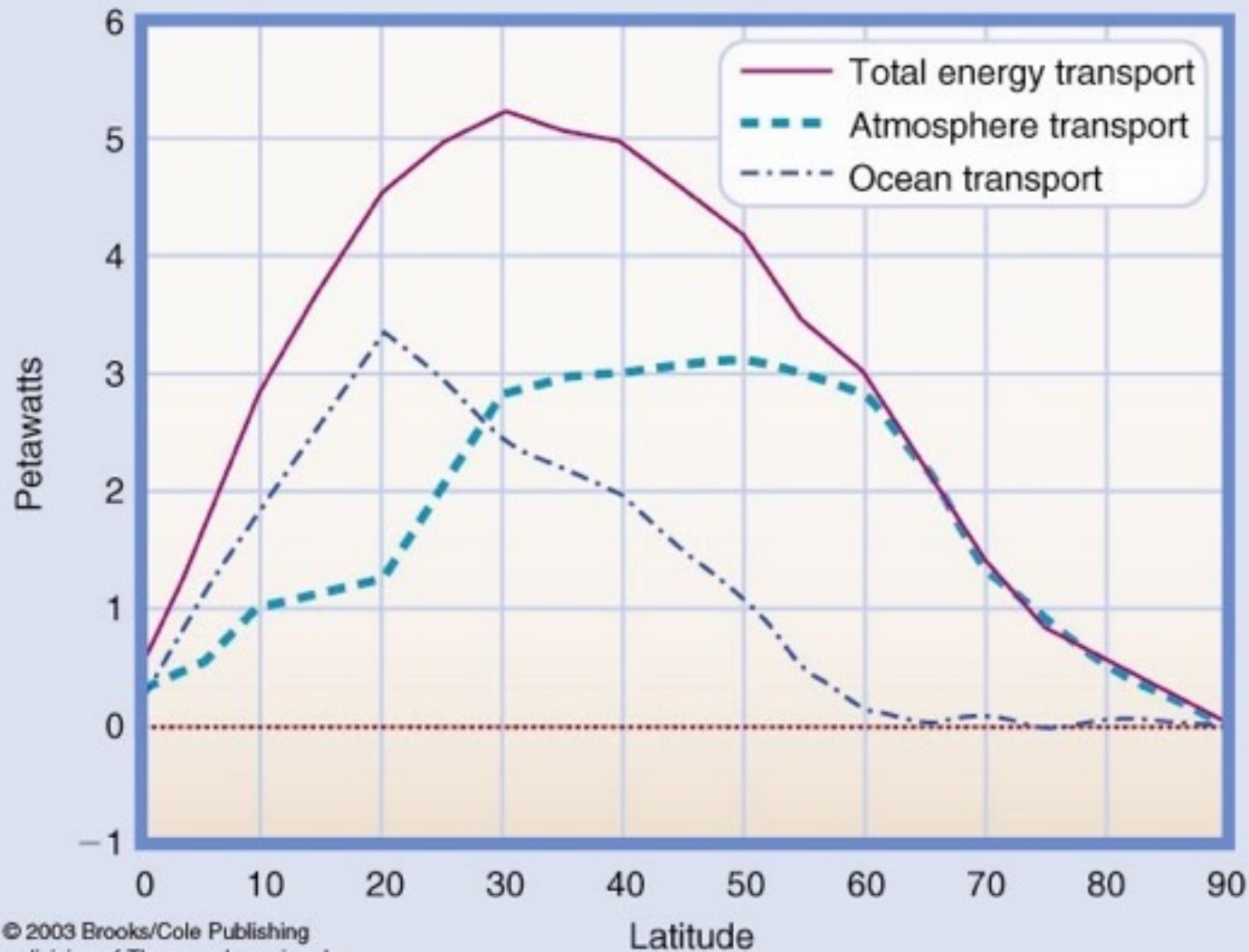


The Rossby (short) waves in the jet drive mid-latitude frontal disturbances

© 2003 Brooks/Cole Publishing
a division of Thomson Learning, Inc.



These frontal disturbances contribute towards the poleward energy transfer that is needed to offset the pole-to-equator net radiation imbalance (see chapter 2)



Pop quiz

- Rossby waves ...
 - A: occur in the (polar) jet stream
 - B: move about and vary in amplitude
 - C: have a significant impact on weather below
 - D: all of the above is true

Summary

- The general circulation is marked by three meridional cells in each hemisphere.
 - the Hadley and polar cells are thermally direct and quite noticeable
 - the Ferrel cell is hard to notice amidst all the frontal disturbances
 - poleward heat transfer is not in the vertical plane, but on a map
- Mid-latitude weather is controlled by the vagaries of the UT jet stream
 - Rossby waves control the structure & evolution of frontal disturbances
 - the jet stream is consistent with an airmass temperature contrast below
- Ocean currents are largely forced by winds