Nov. 1, 2017

- Today
  - Finish Vertical Atmospheric Structure, Origin, Escape
  - Start Atmospheric Circulation (may finish in 2nd lecture, on Friday)
  - A few words of introduction on Pluto
- Friday
  - 11AM: Student presentations on Pluto
  - Noon: last makeup lecture. Finish atmospheres -- then Pluto and Titan
- Reading:
  - Pluto overview, plus two student presentation papers
- Midterm exam Wednesday Nov. 8. Review Monday

Circulation Patterns

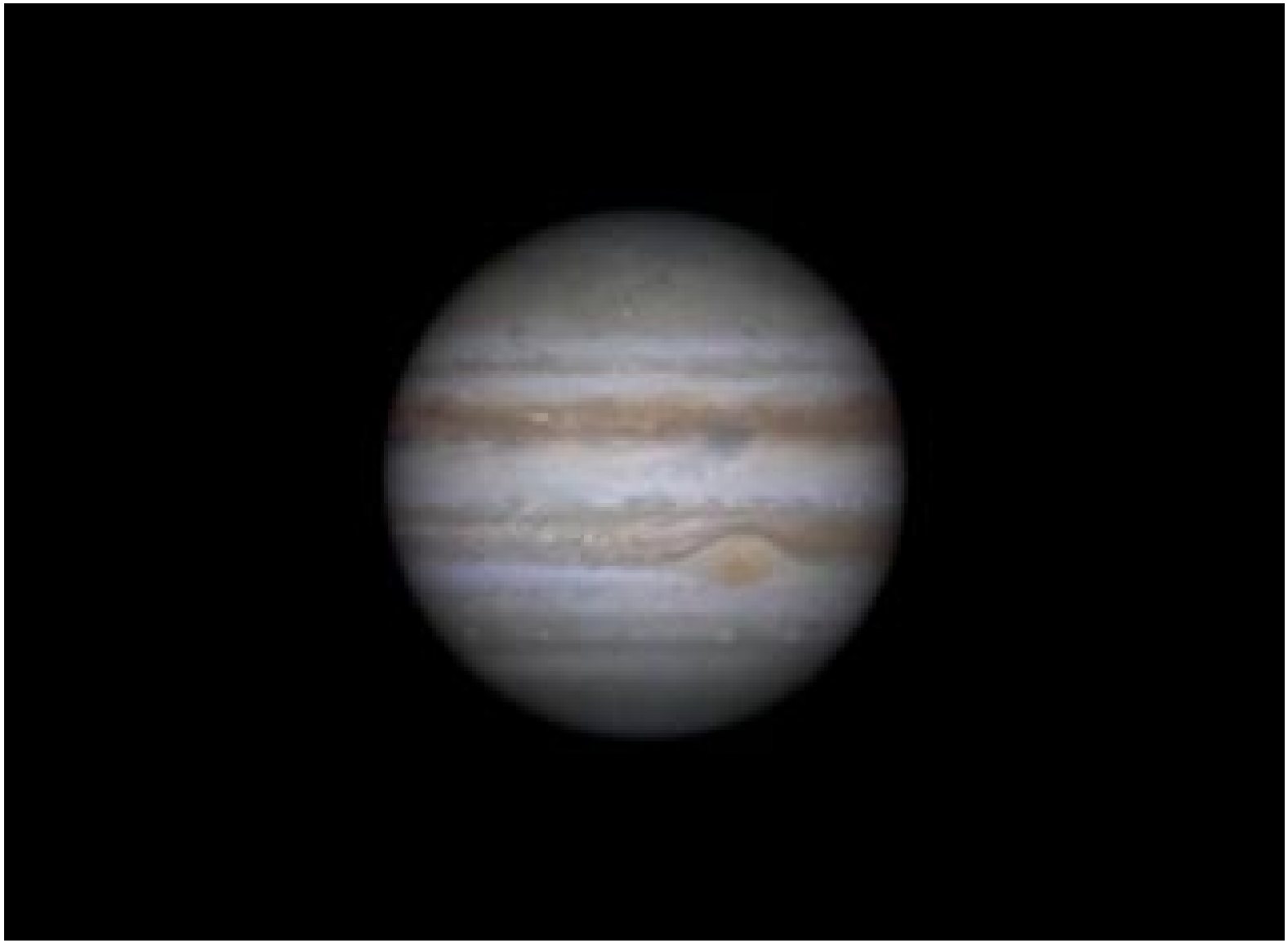
Incoming solar energy input primarily at the equation

Outgoing infrared radiation from all of the planet

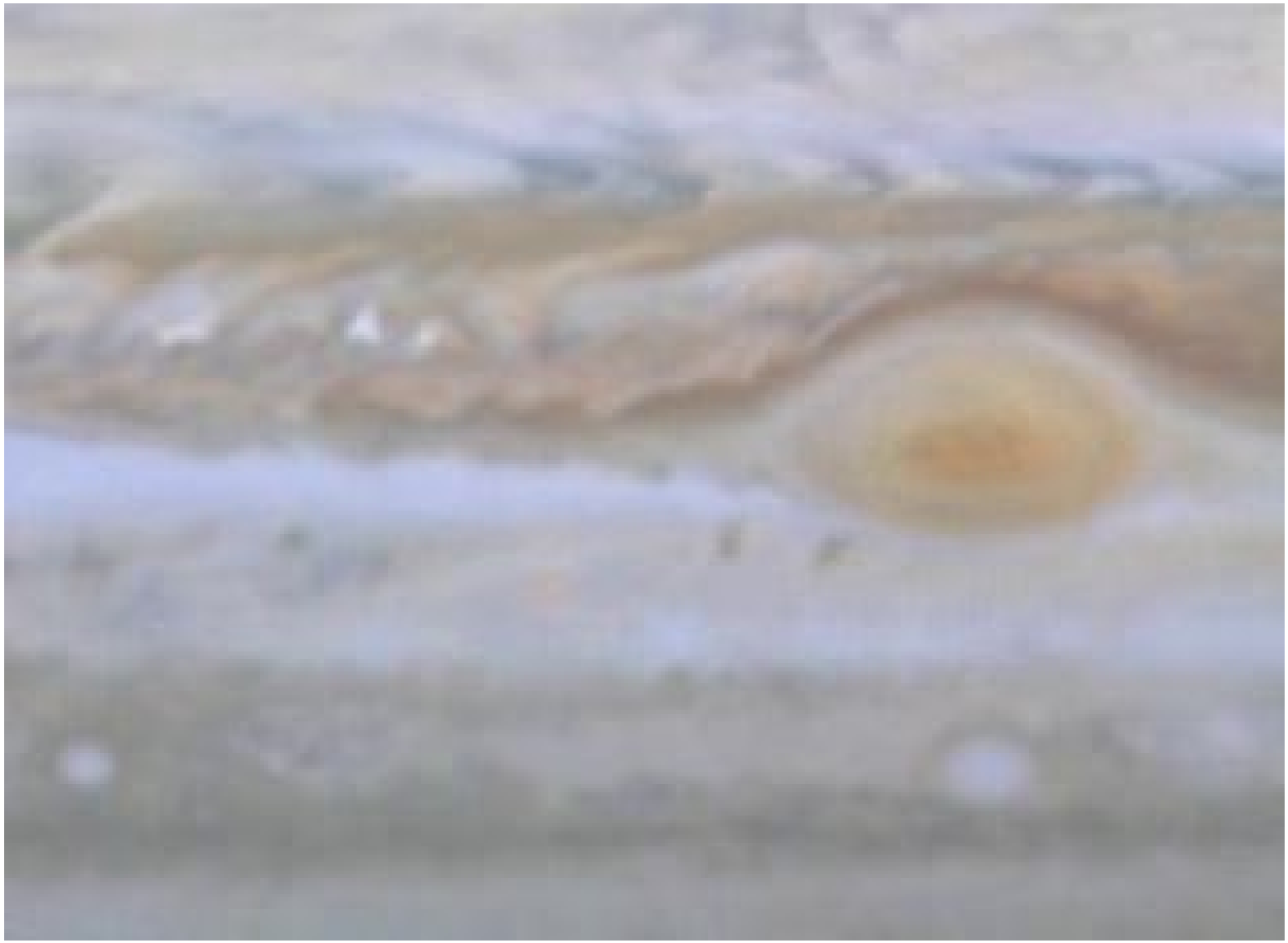
Temperature difference between poles and equator drives air circulation attempting to equalize temperatures

Coriolis force (due to rotation of planet) plays critical role in nature of cirrculation

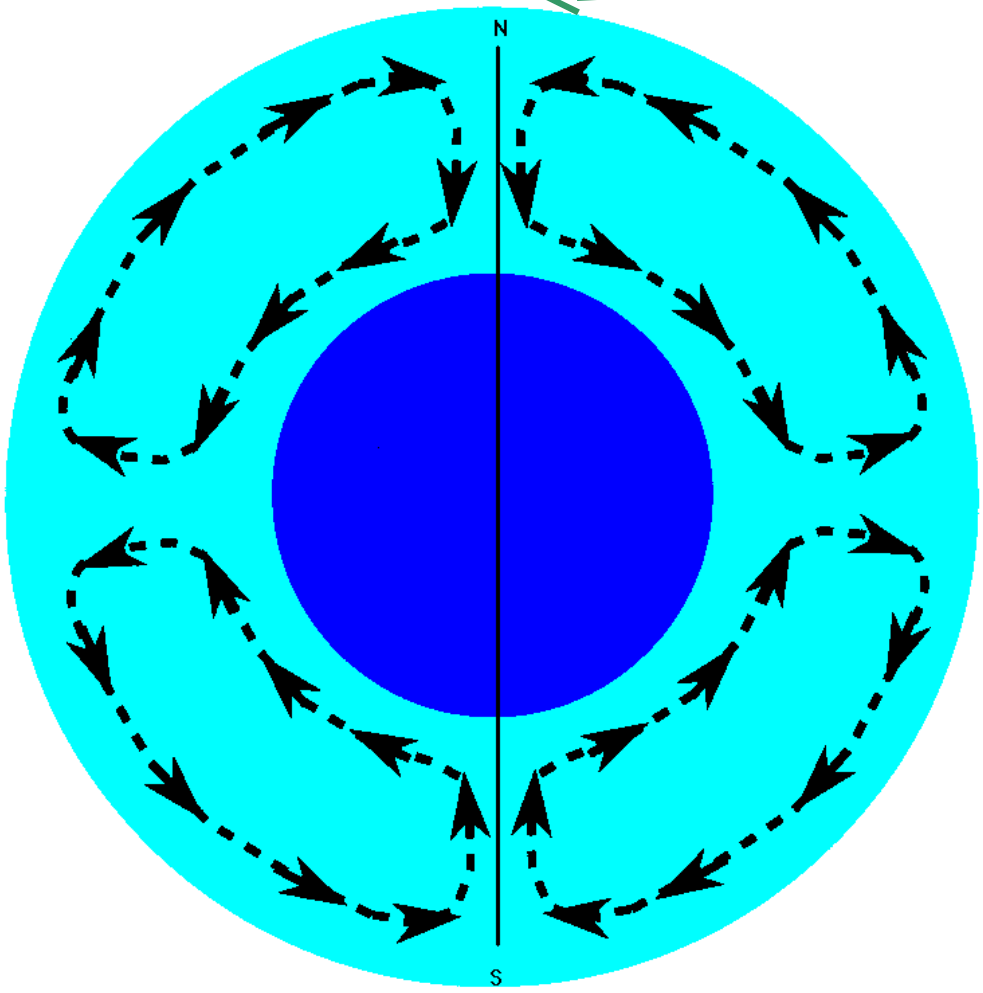
Winds on Jupiter



Winds near the Great Red Spot



Air circulation in a very slowly rotating planet



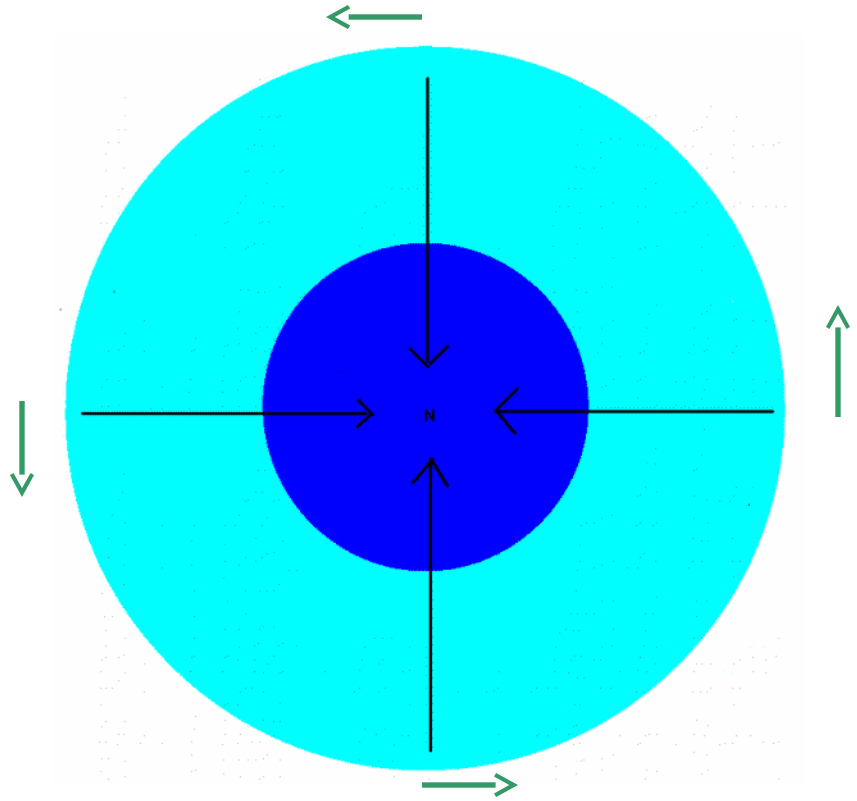
Cool air sinks over poles

Hot air rises over equator

As seen from over the North Pole
all the air is moving in towards the center

But remember all of this is rotating

View of Earth
as seen from
over the N Pole

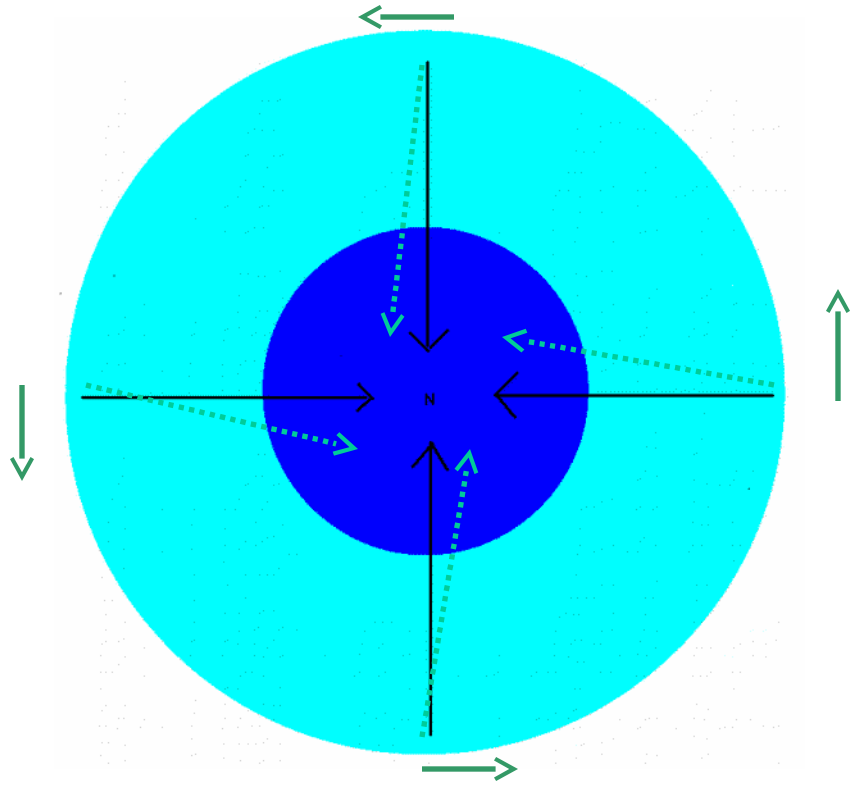


Like the spinning ice skater pulling in her arms,
the air will try to rotate faster as it moves in towards the axis

Like the spinning ice skater pulling in her arms,
the air will try to rotate faster as it moves in towards the axis

If the air rotates faster than the planet, as seen from the planet
the air will appear to drift east.

View of Earth
as seen from
over the N Pole



Someone on the planet who didn't know about rotation would think
a mysterious force was making the air curve to its right.

General patterns due to rotation

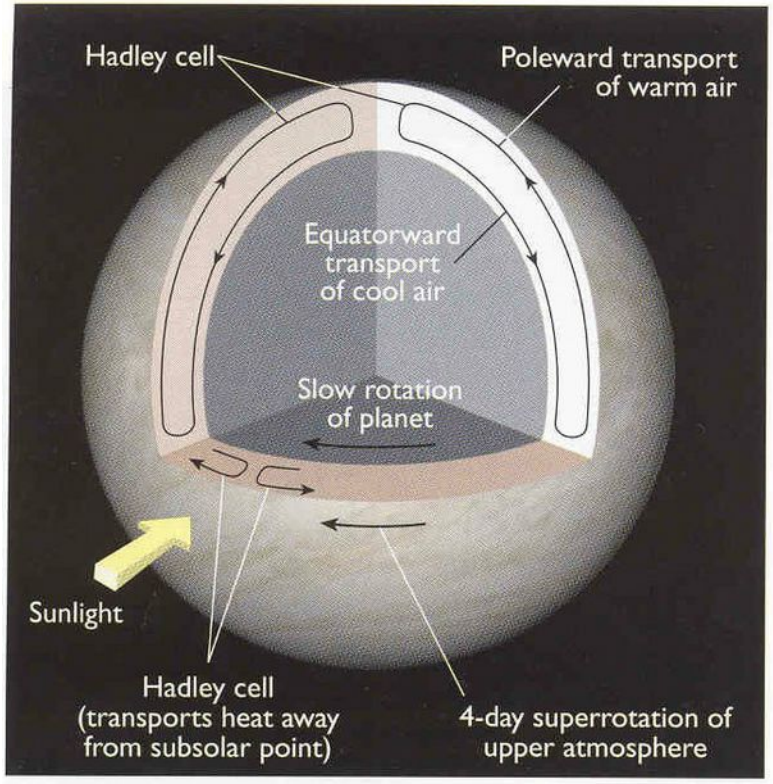
- If the air moves north towards the axis it spins faster and drifts east – to *its* right.
- If the air moves south away from the axis it spins slower and drifts west – again to its right.

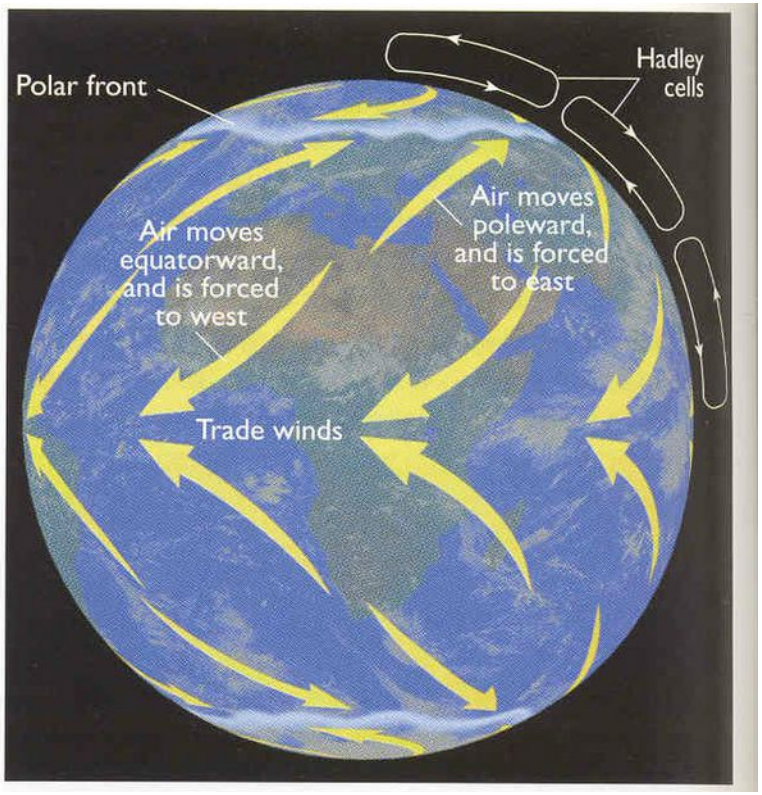
- More detail arguments show that the rotation always deflects the wind to its right (in the northern hemisphere)

  CORIOLIS FORCE
  - Going N, deflected E
  - Going W, deflected N
  - Going S, deflected W
  - Going E, deflected S

- The effect is the opposite in the southern hemisphere
- The effect is stronger the faster the planet is rotating

Modified Circulation Pattern on Earth





From "The New Solar System" by Beatty et al.

- Near equator Coriolis force less important – get simple Hadley cell
  - High altitude N moving air deflected right = east
  - Low altitude S moving air deflected right = west ⇒ trade winds

- At higher latitudes Coriolis force more important – badly disrupts circulation.

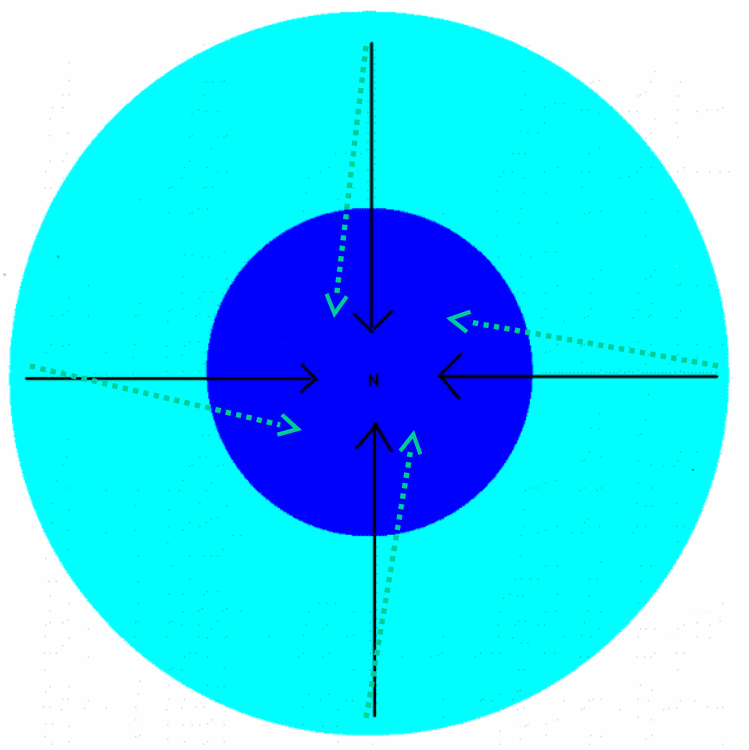
Also have additional cells – circulating like alternating ball bearings

  - In mid latitude reverse cell: low altitude N moving air deflected E (That is the dominant wind pattern for us in Laramie)

A better way to think about circulation at mid latitudes

As air tries to rush in to fill up the low pressure region, Coriolis force deflects it to the right. It starts to circulate counterclockwise.

Now think of this as view looking down on a low pressure region

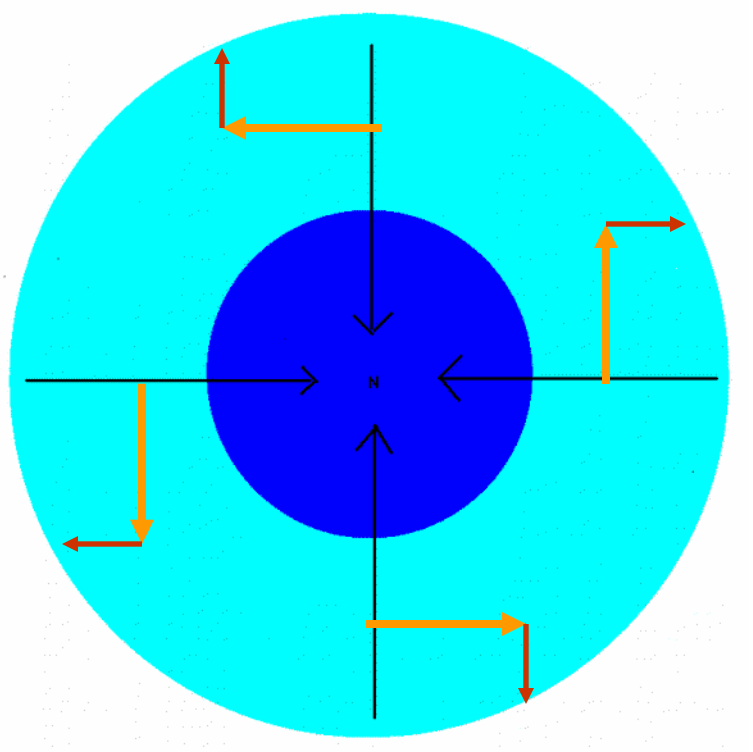


The more the air tries to rush in to the low pressure area, the faster it circulates.
This is like a gyroscope – which moves at right angles to the way you try to turn it.

Balance of Pressure Force and Coriolis Force

Instead of just rushing in to the low pressure area, the air is also forced to rotate counterclockwise around it.

Now think of this as view looking down on a low pressure region



But the Coriolis force acting on this circulation velocity again tries to deflect the material to the righ, i.e. outward, opposing the inward force from the low pressure.

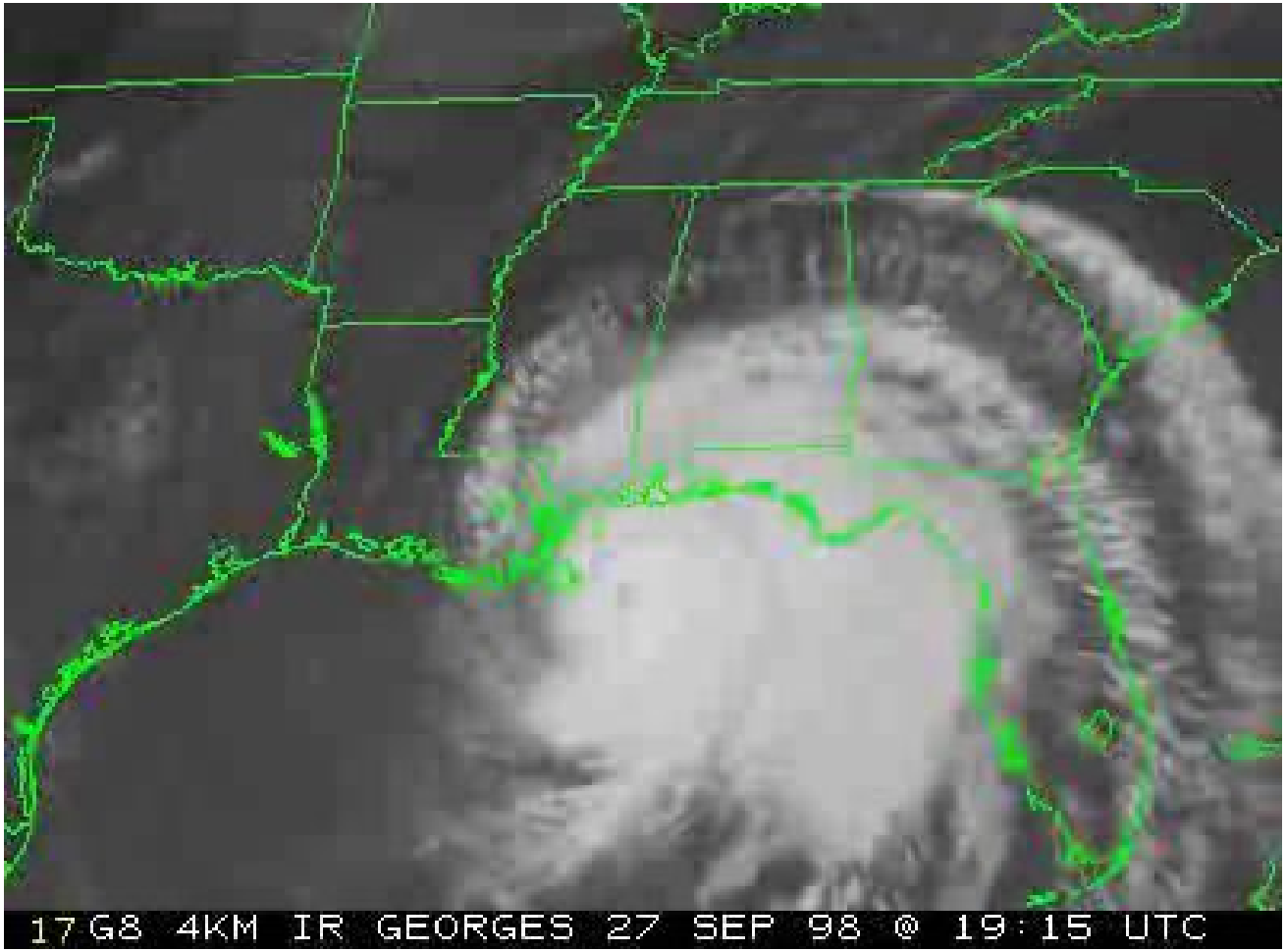
On earth the circulation velocity usually builds up till the outward Coriolis force almost exactly balances the inward pressure force: "Geostrophic Approximation"

Hurricanes exist because

Low Pressure trying to turn winds to the left

almost balance

Coriolis Force trying to turn winds to the right.



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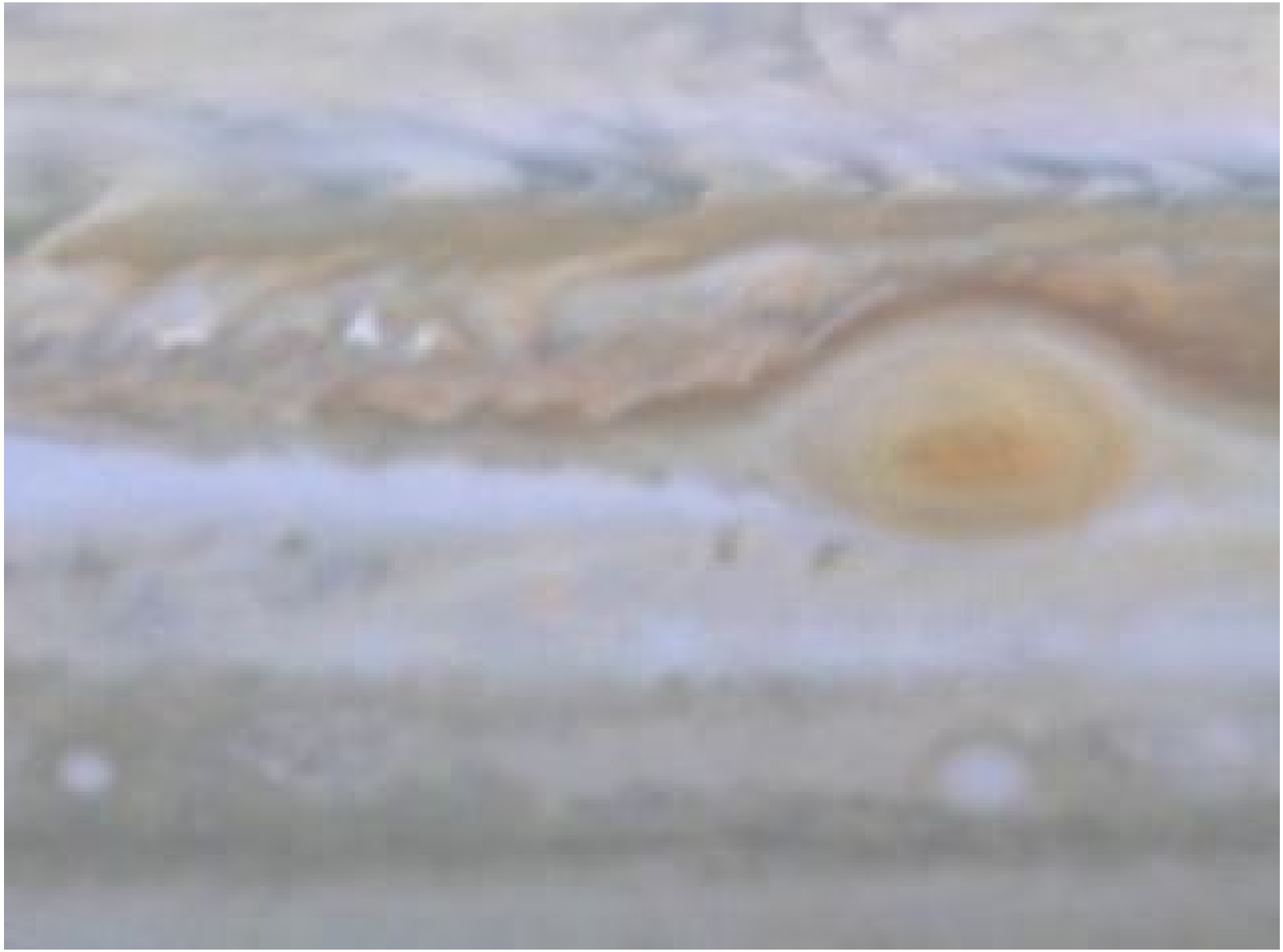


Mid latitude circulation and the jet stream

- Solar heating at low latitudes expands the air – causing higher pressure at attitude.

- The high altitude air tries to move north to where the pressure is lower

- The Coriolis force deflects that north-moving air to the east

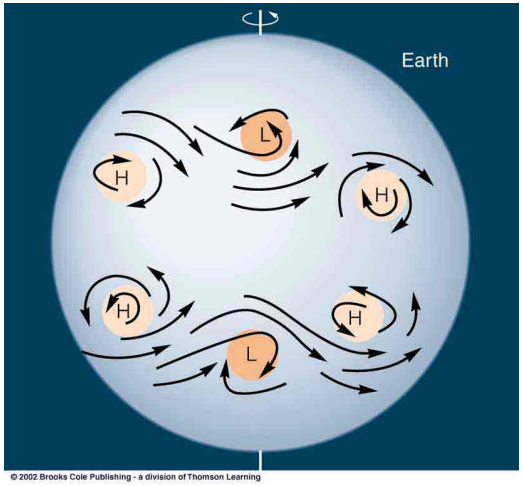
- The east moving wind builds up till the right (south) Coriolis force from it almost balances the northward pressure force

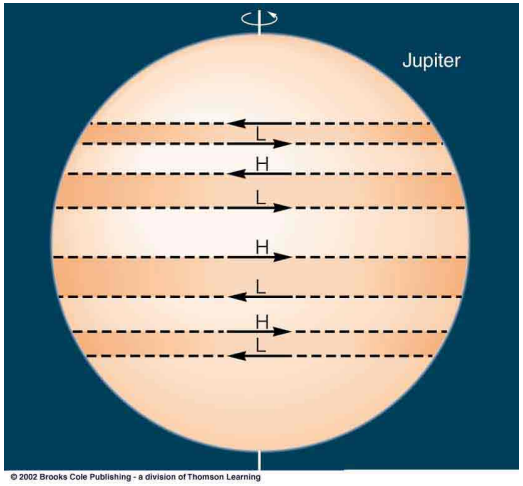
- There is usually one spot where there is a big N-S temperature gradient
- That temperature difference causes a big pressure difference aloft
- The big pressure difference causes a high speed wind from E-to-W
- That W-to-E wind prevents poleward transport of heat

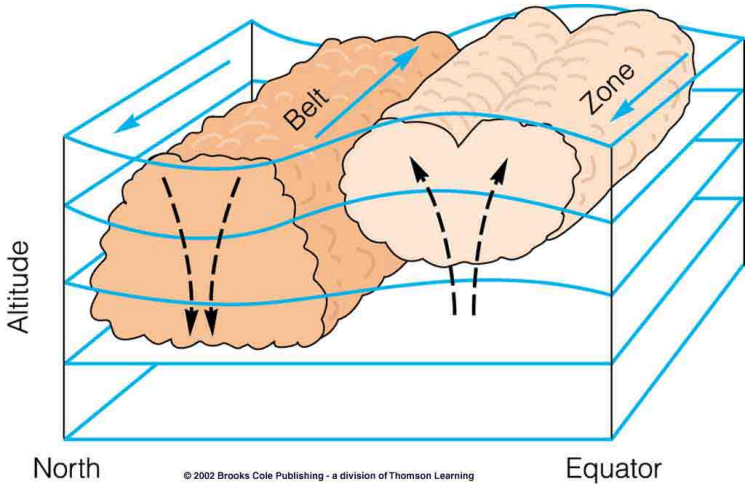
- The process builds up till the wind gets too strong.
- It acts sort of like a loose garden hose – and swings from N to S
- That N-S deflection of wind eventually carries the heat from S to N

- Thermal wind equation: Wind at altitude proportional to horizontal ∇T

Comparison of atmospheres







From Horizons, by Seeds

- Air for most part just circles counterclockwise around lows
- At surface it does converge somewhat –and is forced to rise
  - Rising air creates clouds: Low pressure areas = "zones"
  - Sinking air is clear: High pressure areas = "belts"

- Jupiter's fast (10 hr) rotation makes Coriolis Force more important

Terrestrial Planetary Waves

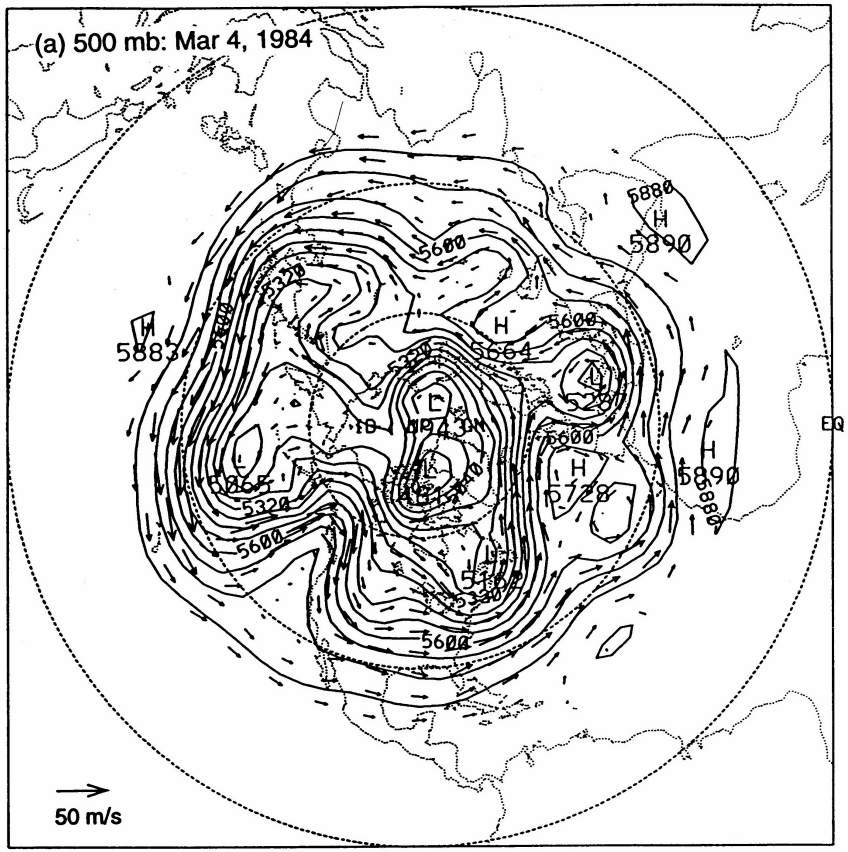


Figure 1.9 (a) Height (contours) of and horizontal velocity (vectors) on the 500-mb isobaric surface for March 4, 1984. (*continues*)

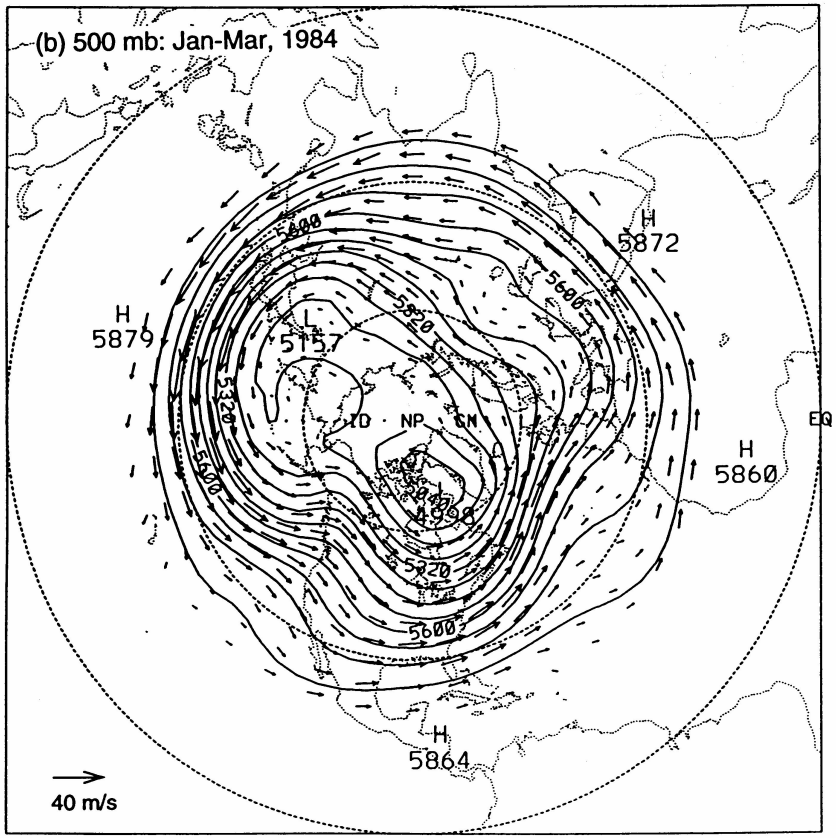


Figure 1.9 (*Continued*) (b) Time–mean height of and velocity on the 500-mb isobaric surface for January–March 1984. Isobaric heights shown in meters. From National Meteorological Center (NMC) analyses.

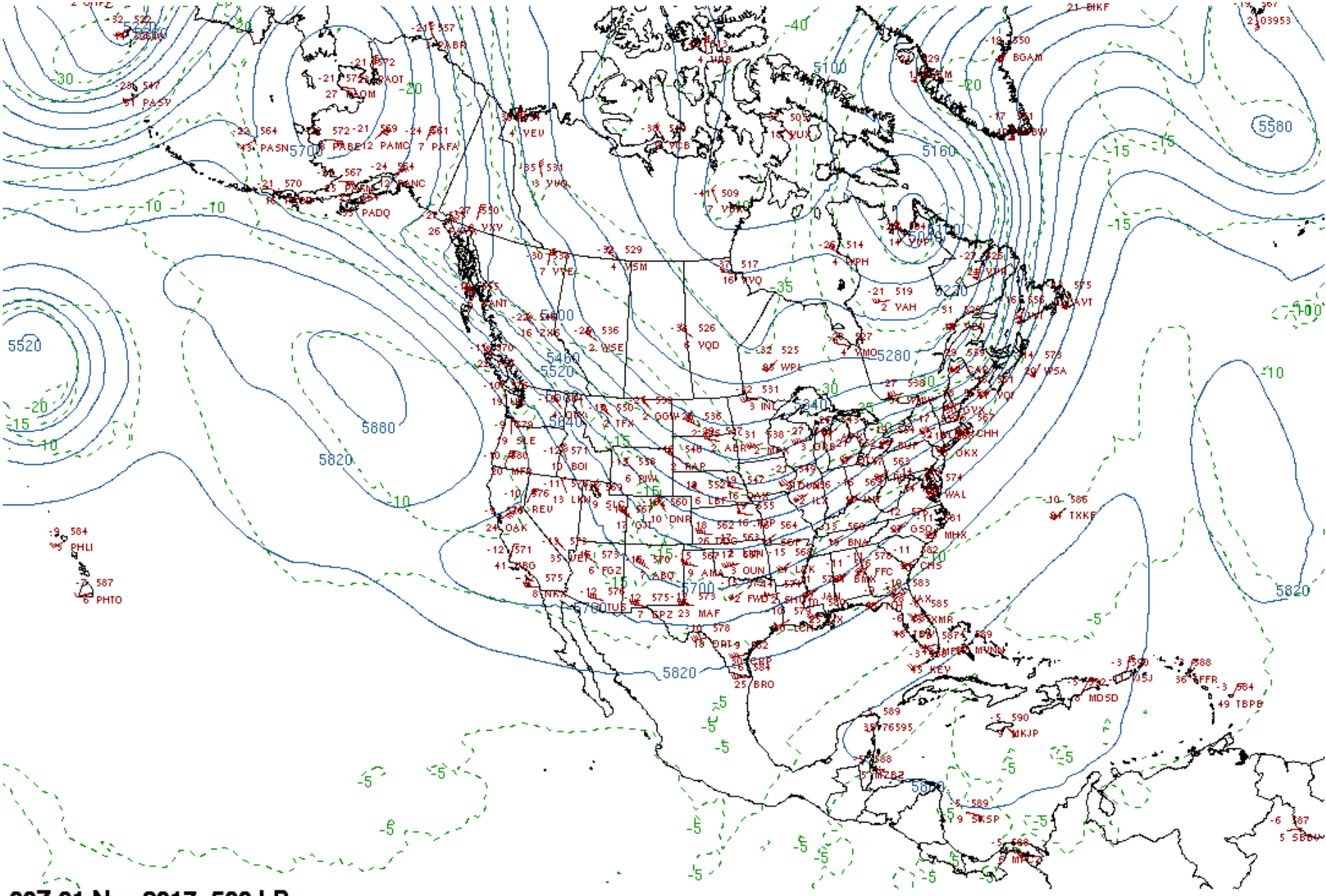
- Waves carry energy towards pole

From Salby 1996

- Daily value

Mean value
(influenced by continents)

Upper atmosphere today



Upper atmosphere today