Agronomy 406
World Climates

January 25, 2018

The atmospheric general circulation

Homework assignment due Tuesday (Jan 30). See Tuesday's entry in the course schedule.

Review for today:

Online textbook: 1.2.2 General circulation of the atmosphere

For Tuesday:

Online textbook: 1.3.1 (Sea water) Composition and properties.

Global energy transports: the general circulation

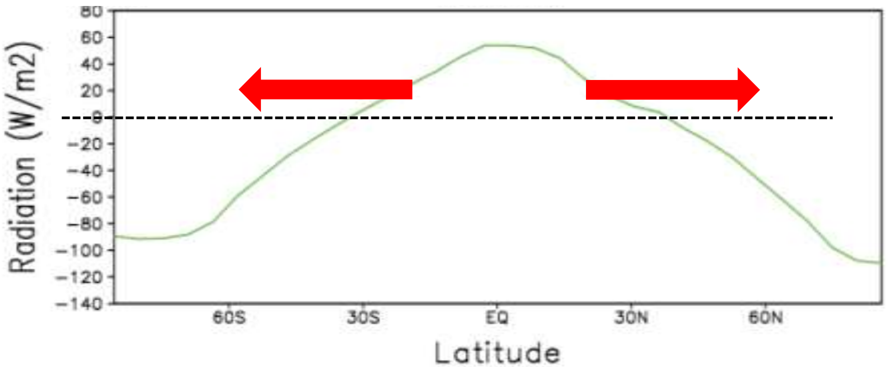
Three main ways to transfer energy:

Transport sensible heat (warm or cold air) in the atmosphere.

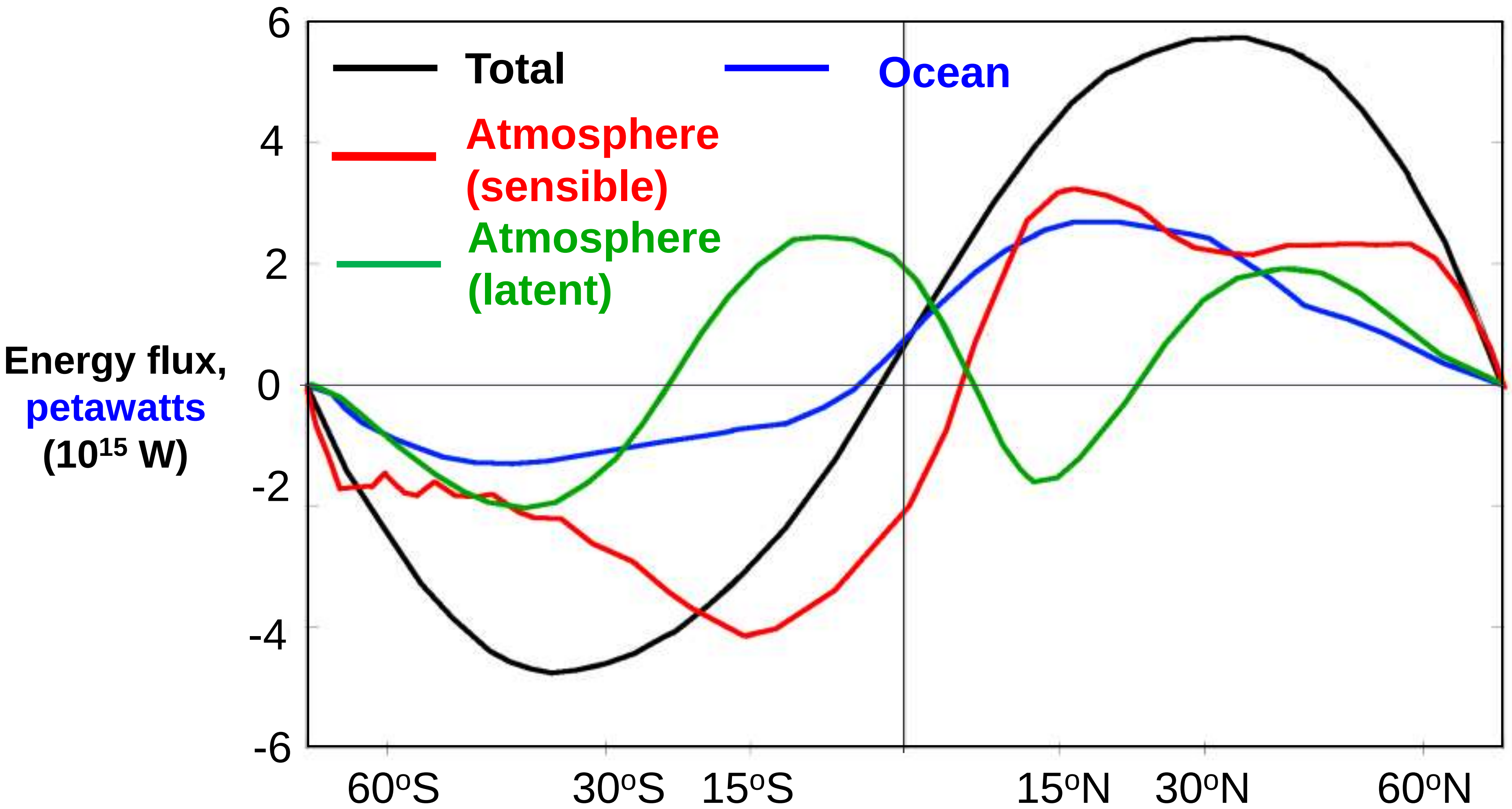
Transport latent heat (water vapor) in the atmosphere.

Transport sensible heat in the oceans.

Earlier we looked at **vertical** movement of sensible and latent heat. Now we are look at the same processes, except in the **horizontal.**



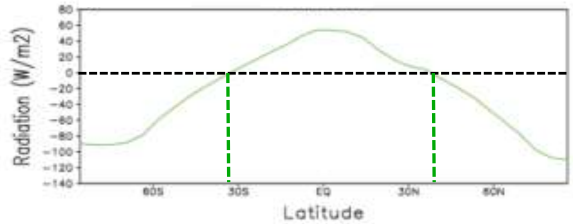
Energy transport by sensible and latent heat fluxes

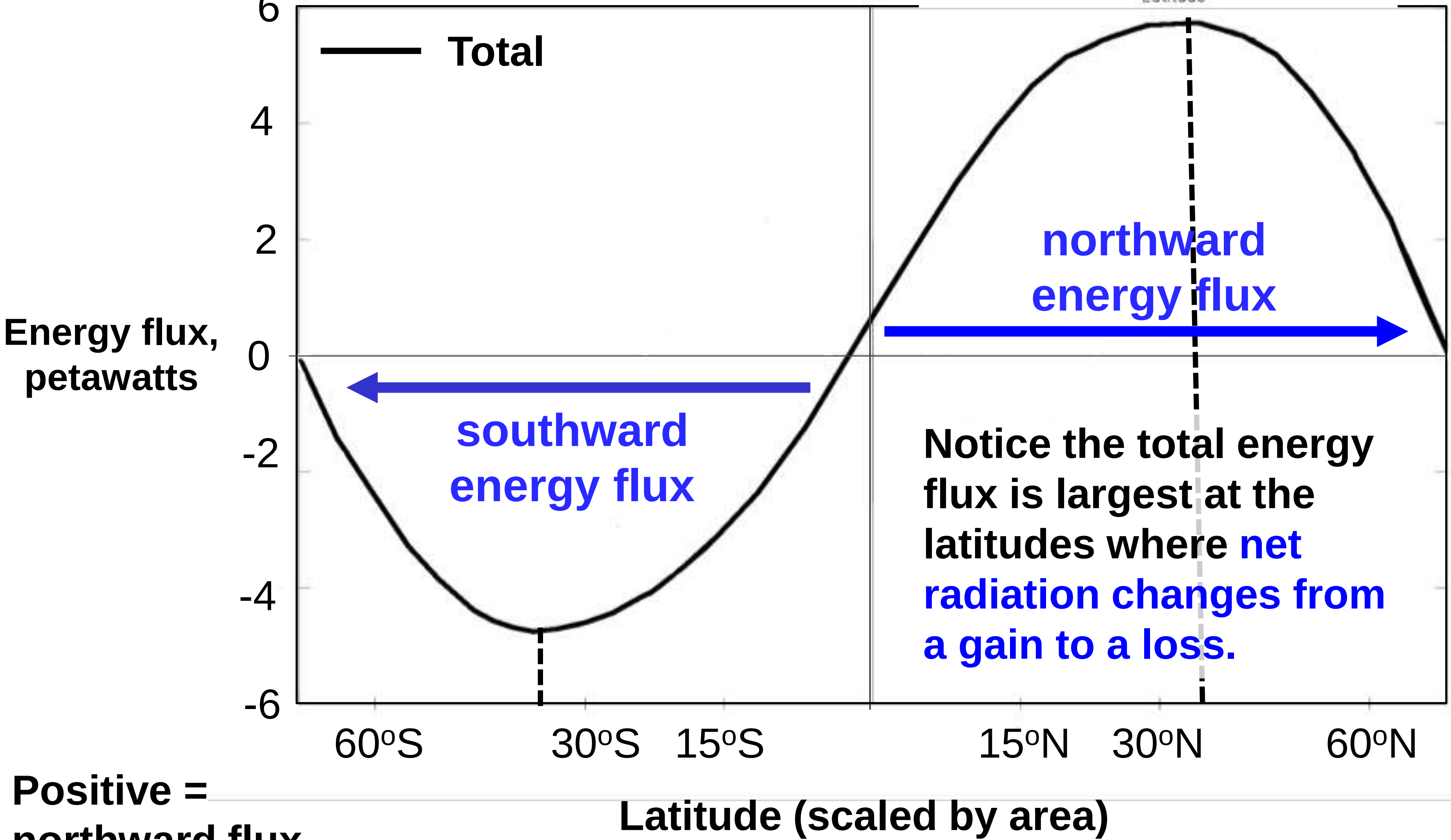


Positive = northward flux

adapted from Bryden (2004)

Total energy flux





Positive = northward flux

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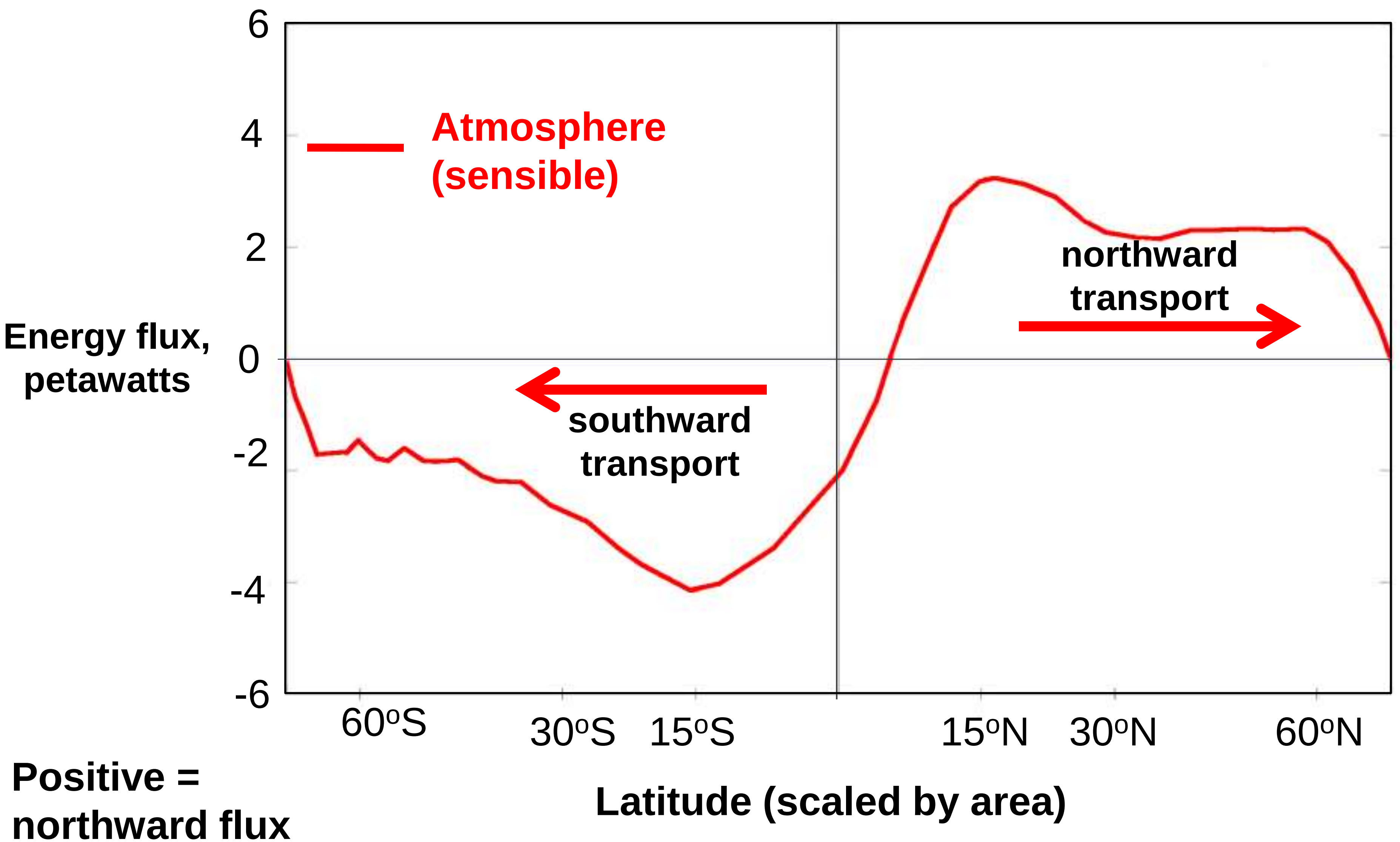
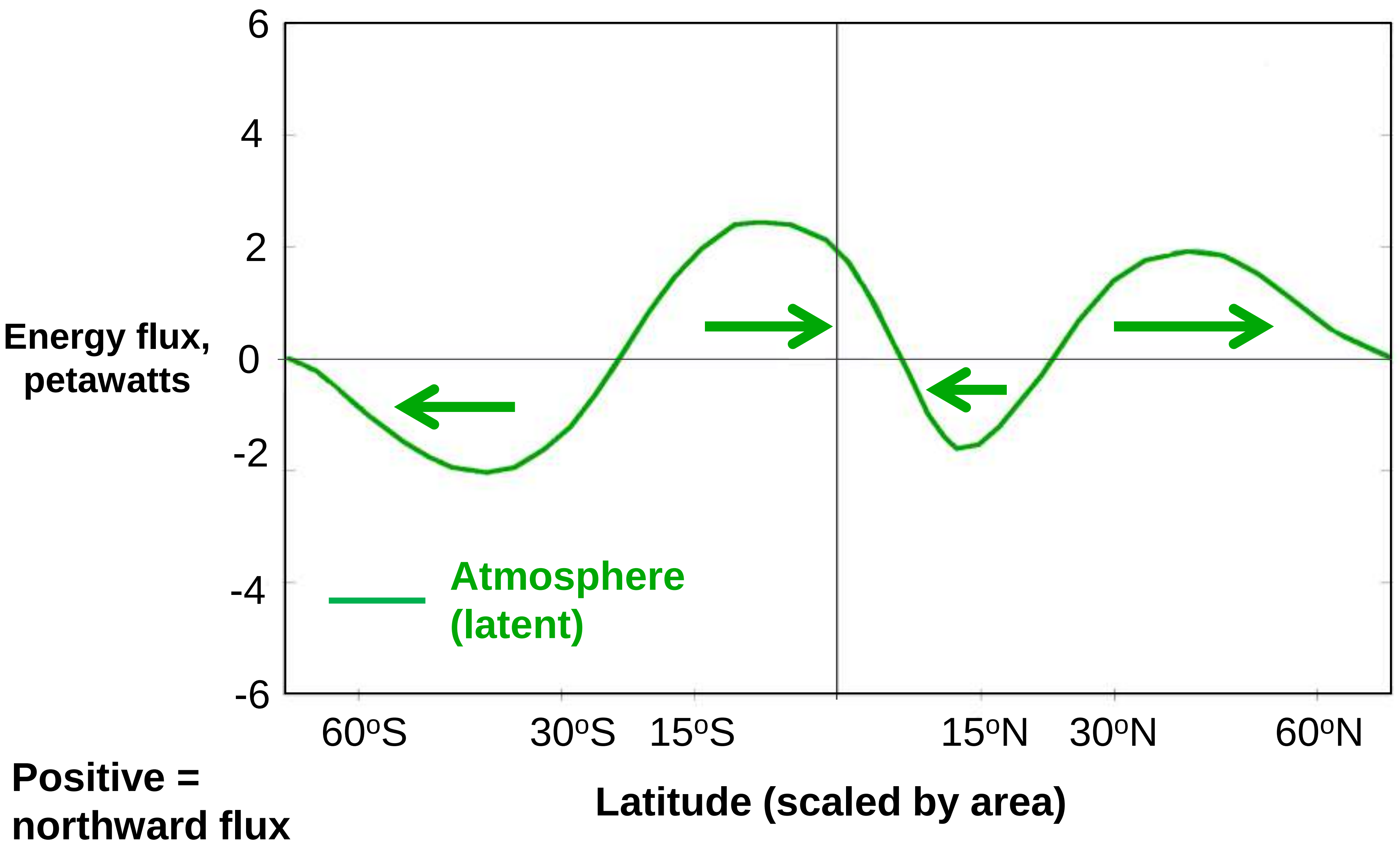
Sensible heat flux in the atmosphere



adapted from Bryden (2004)

Latent heat flux



Positive = northward flux

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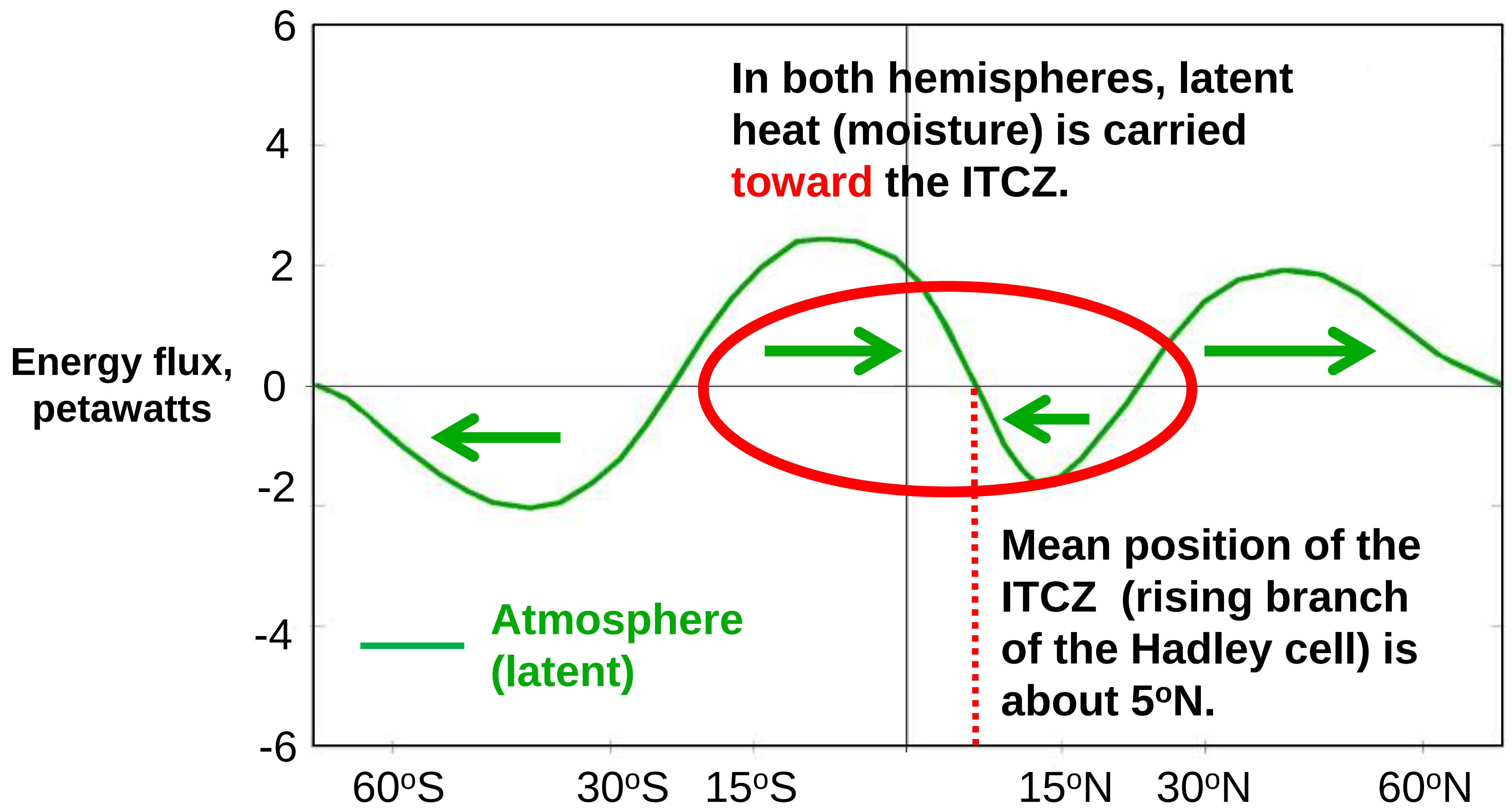
Latent heat flux

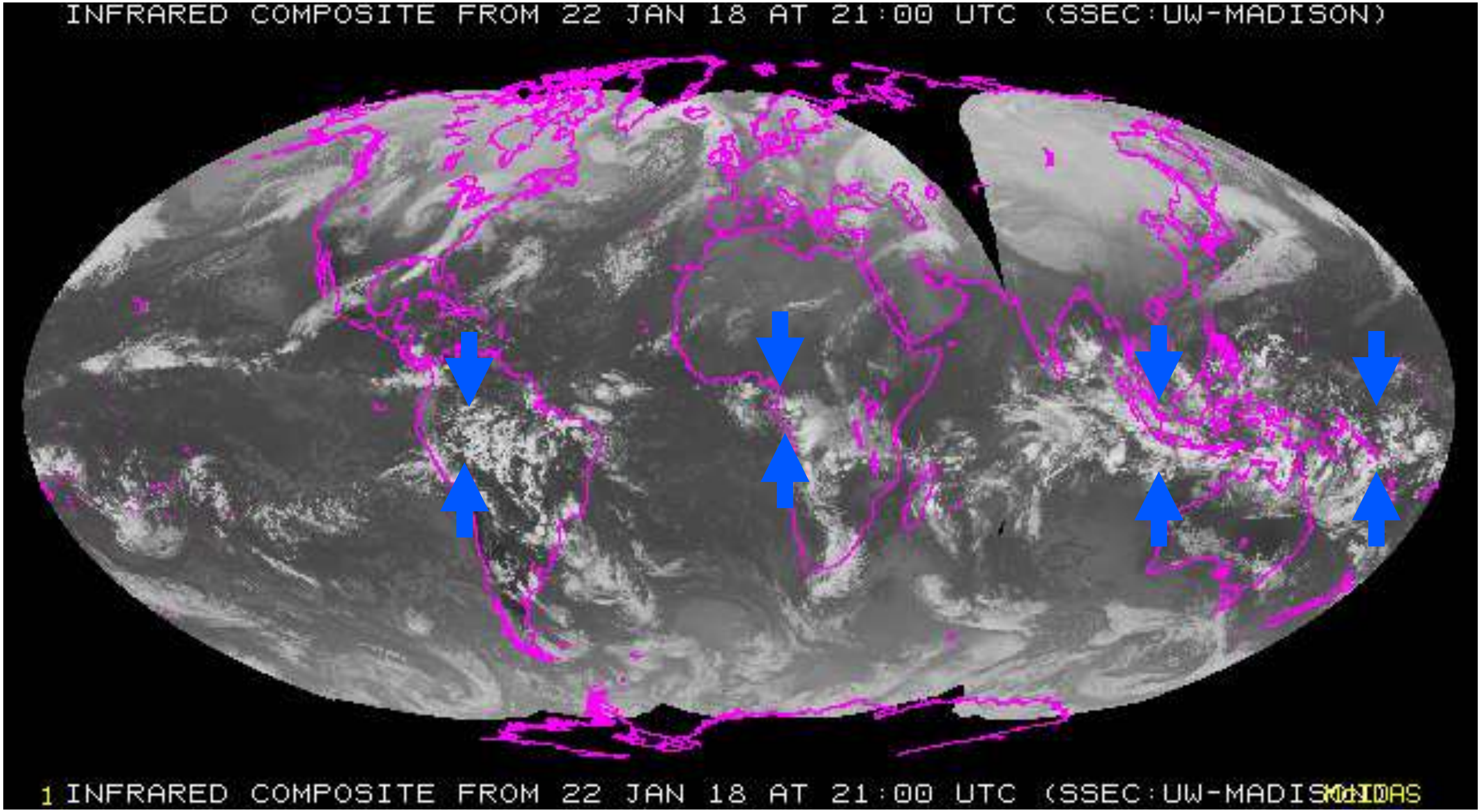


Positive = northward flux

adapted from Bryden (2004)

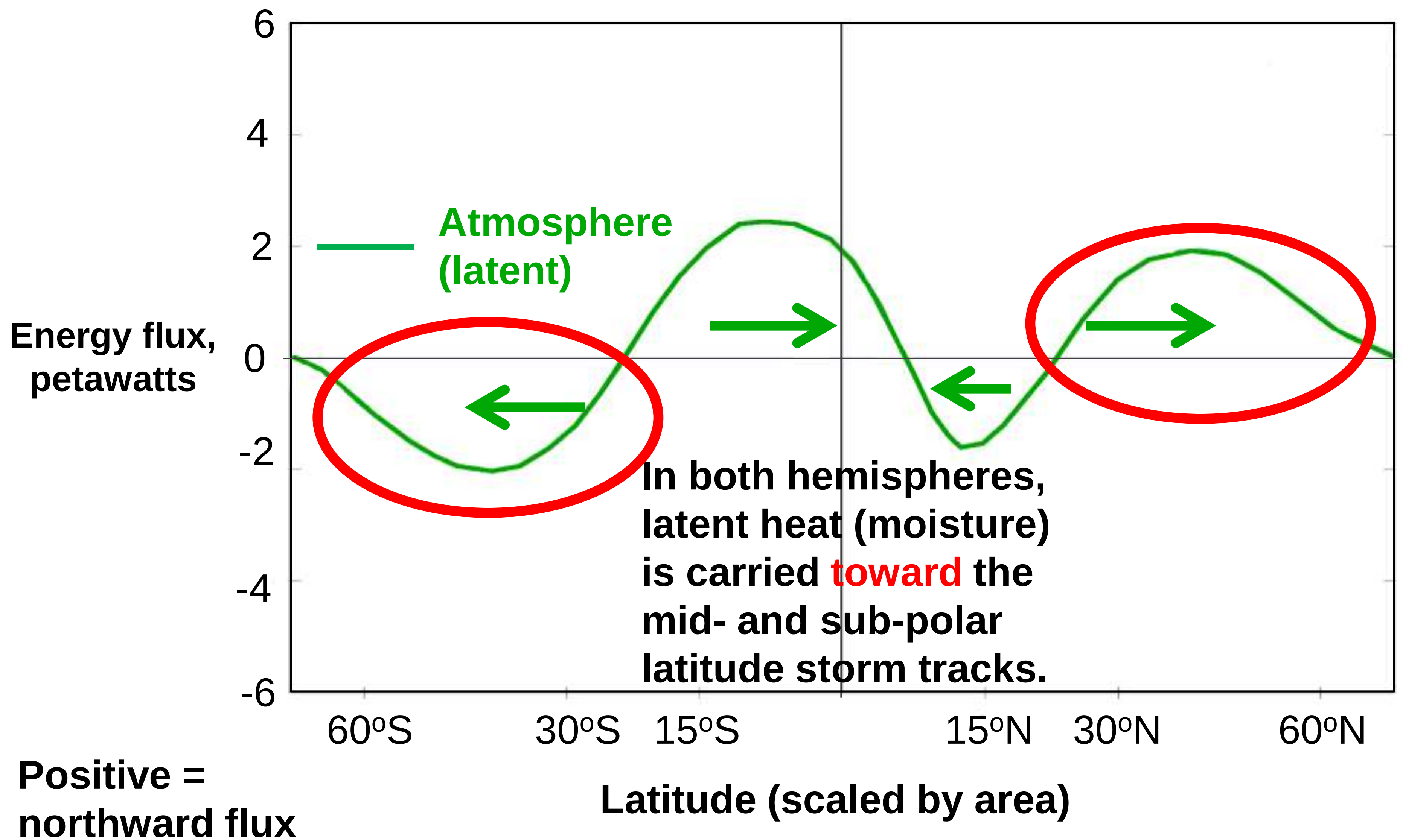
Moisture transport toward the ITCZ

as of Monday, 22 January



http://www.ssec.wisc.edu/data/comp/latest_moll.gif

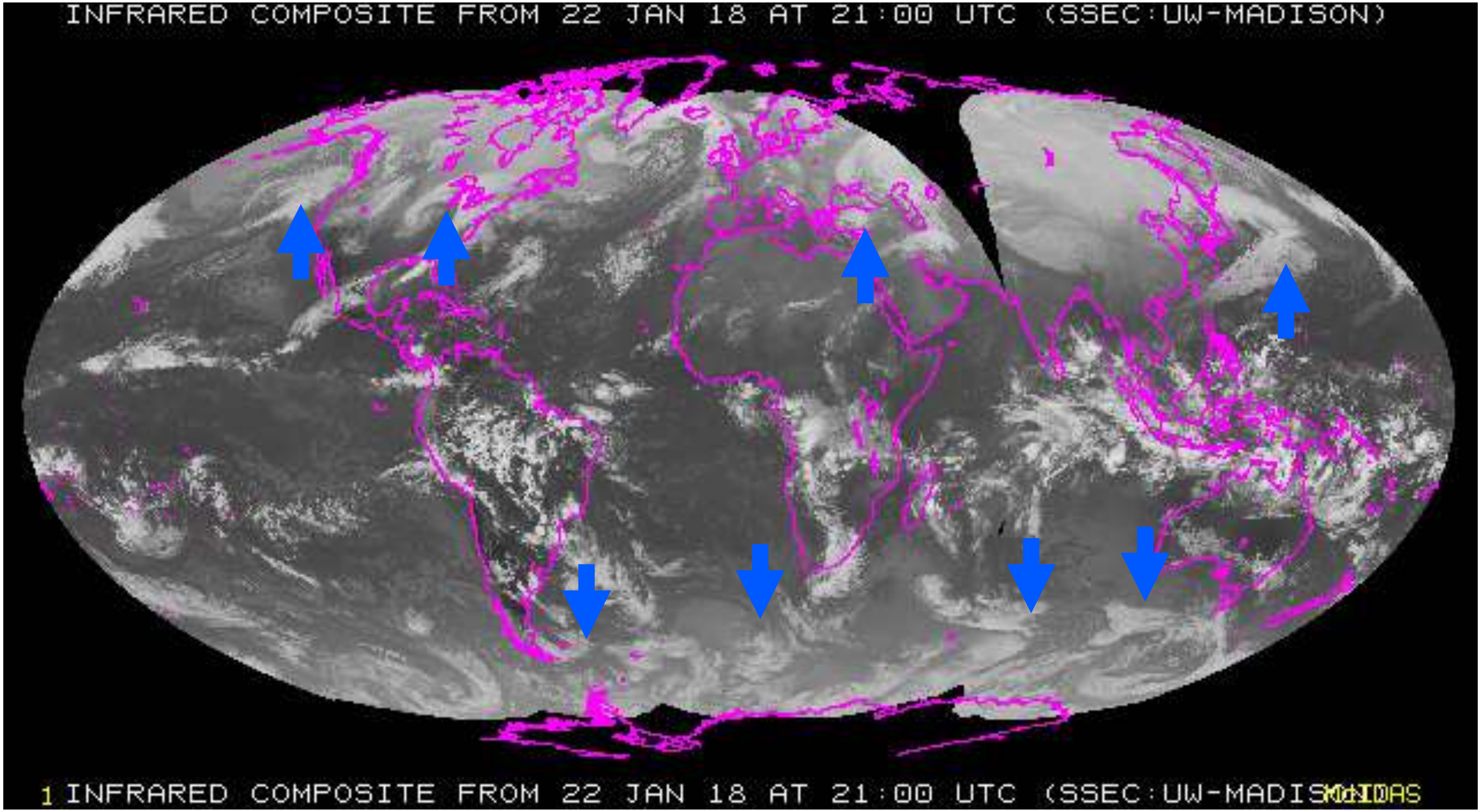
Latent heat flux



Positive = northward flux

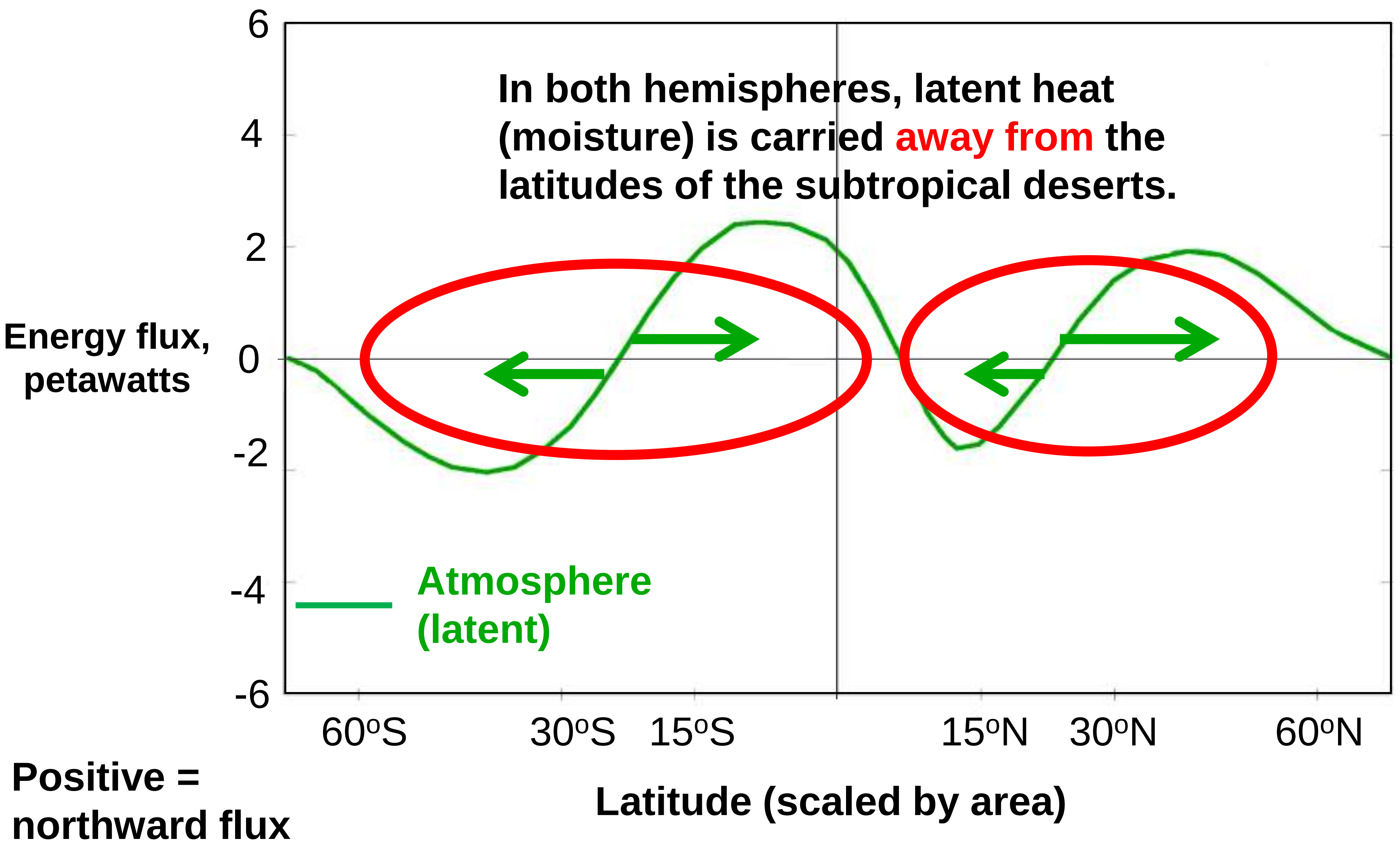
adapted from Bryden (2004)

Moisture is transported toward the mid-latitude storm tracks



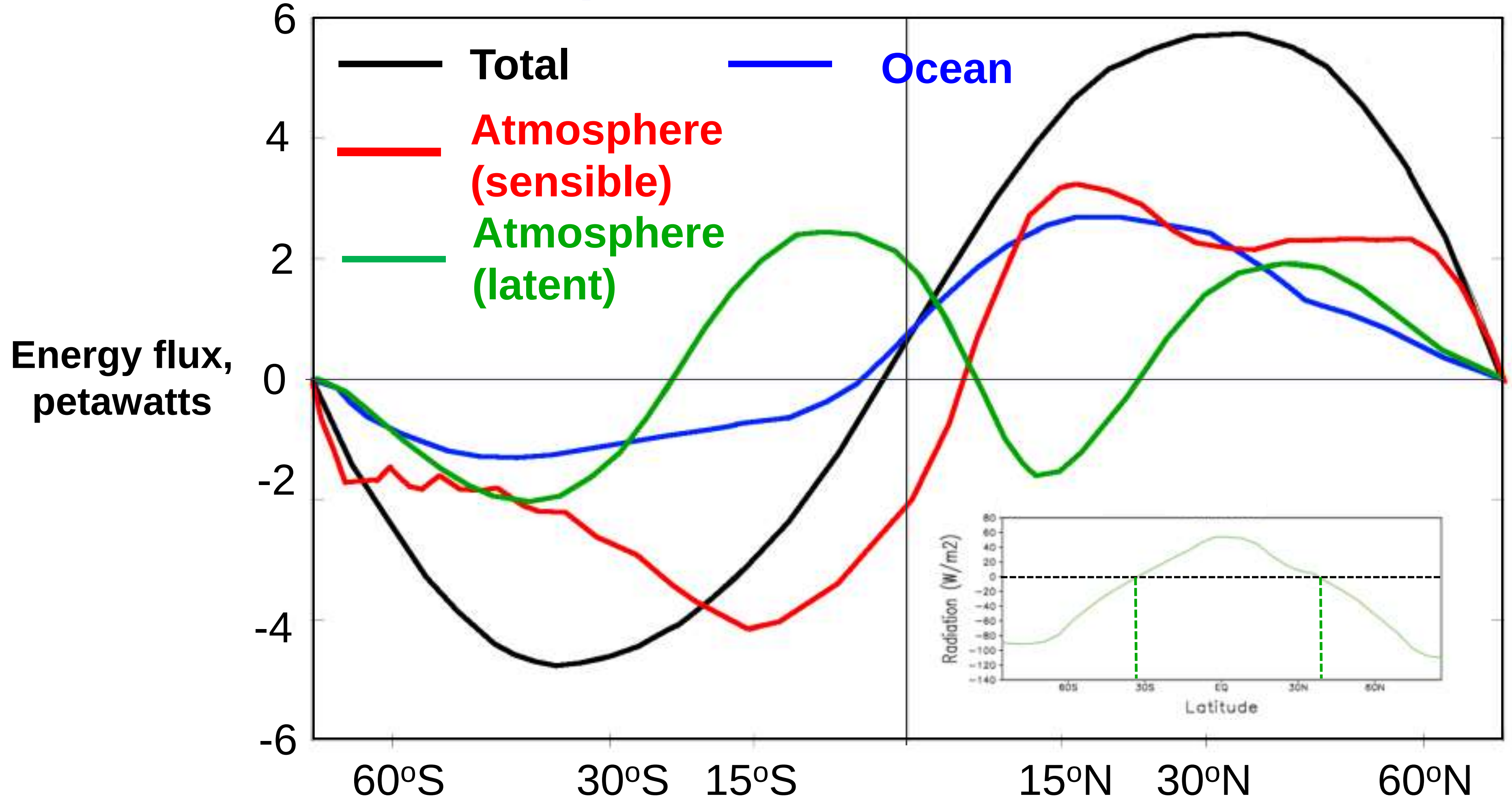
http://www.ssec.wisc.edu/data/comp/latest_moll.gif

Latent heat flux



adapted from Bryden (2004)

Atmospheric circulation transports sensible and latent heat to compensate for radiative imbalances

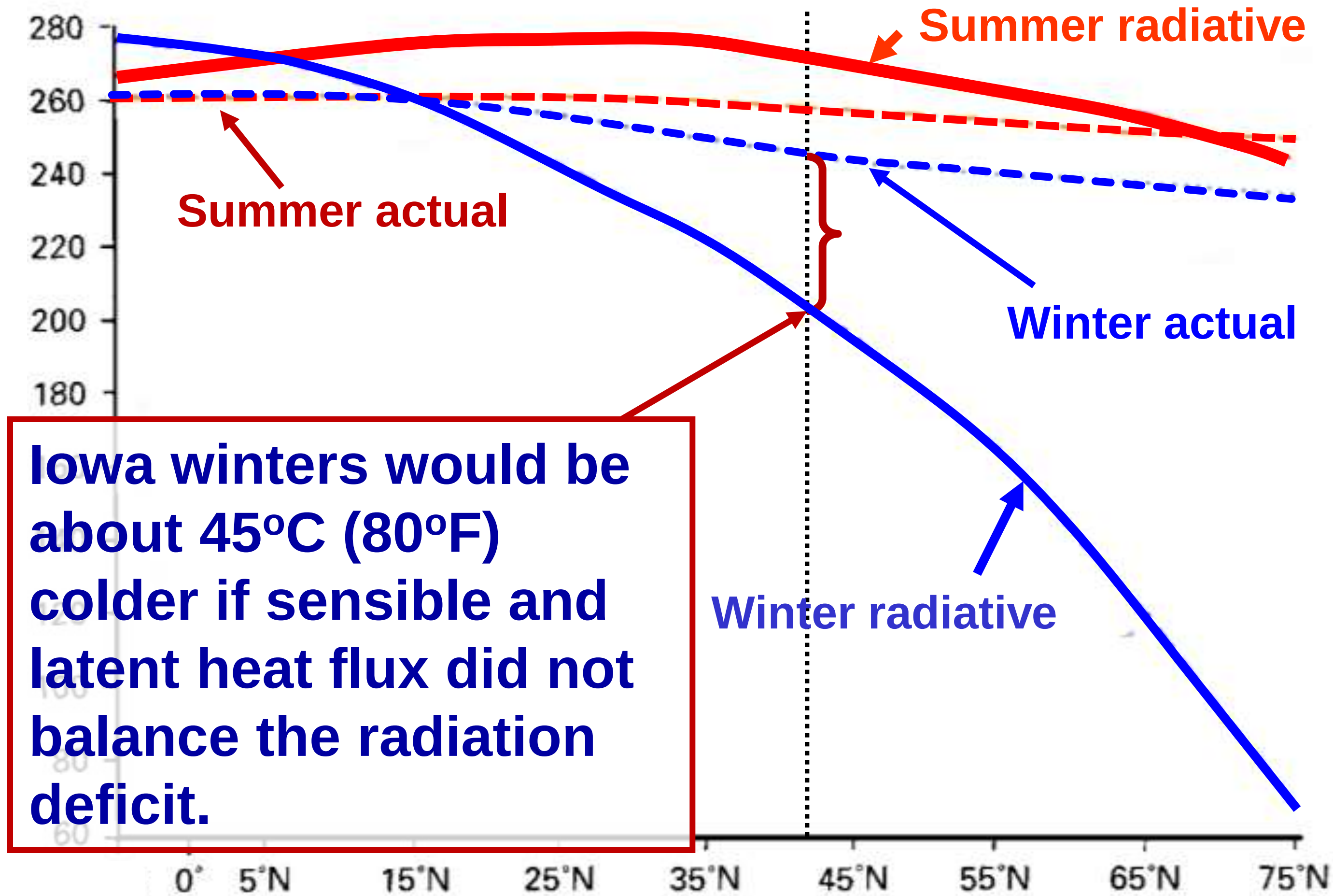


Positive = northward flux

adapted from Bryden (2004)

A practical effect

Temperature of lower atmosphere if radiation was the only process transporting energy (solid lines) versus actual temperature (dashed).



Mean temperature of lower atmosphere (K)

Latitude

What causes the motions that transport sensible and latent heat?

Forces that affect the wind:

- pressure gradient force
- Coriolis force
- friction

Pressure gradient force and friction are easy to understand. We will review the Coriolis force.

The Coriolis force

Results from the rotation of the Earth.

The Coriolis force **ALWAYS** acts **90 degrees to the right** of the motion in the Northern Hemisphere (to the **left** in the Southern Hemisphere).

The faster the motion, the greater the Coriolis force, $\mathbf{F_c}$:

$$F_c = f\,V$$

where **V** is speed and **f** is the **Coriolis parameter.**

The Coriolis parameter varies with latitude:

$$f = 2\,\Omega\,\sin\phi$$

where ϕ is latitude and $\Omega = 2\pi$ / (23 hours 56 minutes) $= 7.29 \cdot 10^{-5}\ s^{-1}$ is the angular velocity of Earth.

What is the value of f at the equator?

What is the value of f at Ames?

Geostrophic wind

The geostrophic wind is a **theoretical wind** produced when the Coriolis force exactly balances the pressure gradient force.

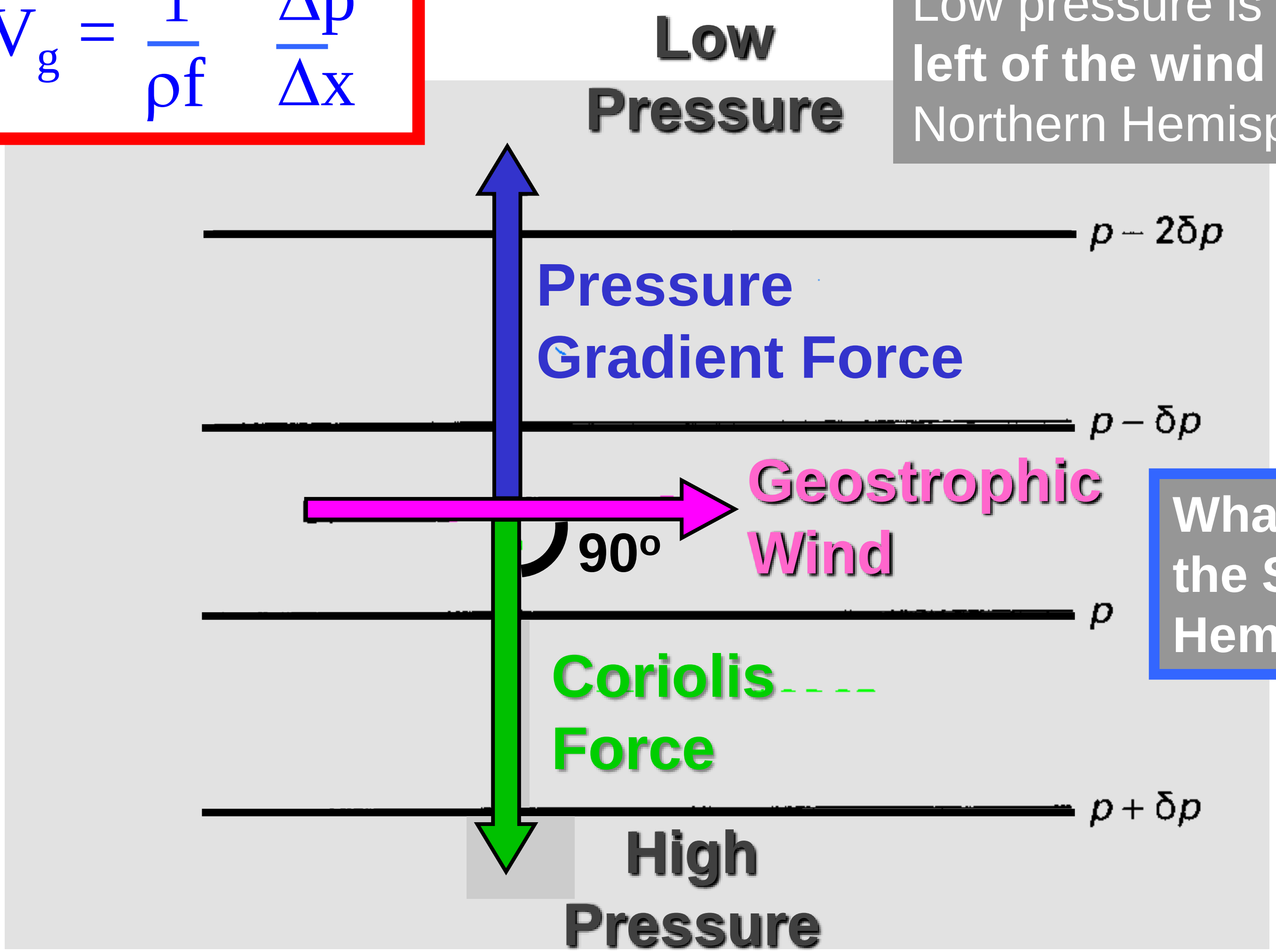
Since the Coriolis force acting on the geostrophic wind balances the pressure gradient force, it must be in the **opposite direction** of the pressure gradient force.

Suppose that at a location in the Northern Hemisphere we have low pressure to the north and high pressure to the south. **Draw vectors showing the force balance and the geostrophic wind at this location between the low and high.**

Wind in geostrophic balance blows parallel to lines of constant pressure

$$V_g = \frac{1}{\rho f} \frac{\Delta p}{\Delta x}$$

Low pressure is **to the left of the wind** in the Northern Hemisphere



What happens in the Southern Hemisphere?

Pressure and Winds

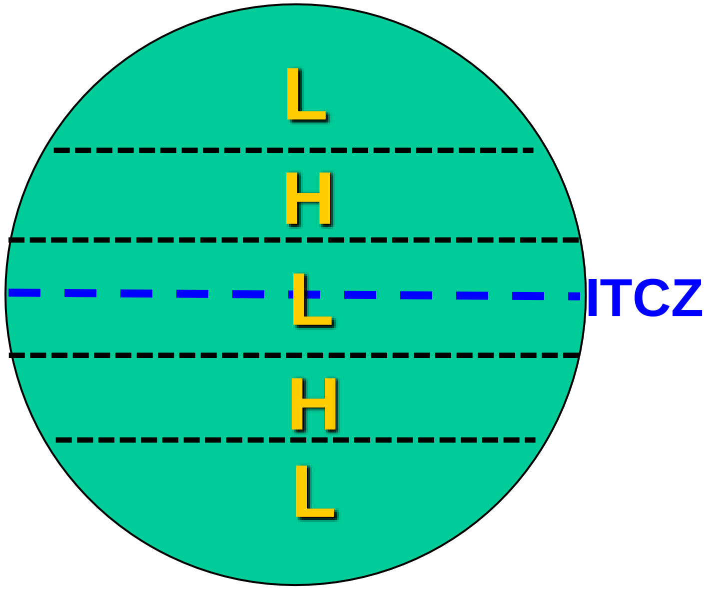
Think of the three-cell model. We have

- a **band** of low pressure near the ITCZ
- a subtropical **band** of high pressure in the sinking branch of the Hadley cell (around 30º N and S)
- a **band** of lower pressure poleward of the subtropical high pressure (around 30 to 60º N and S).

What do we expect the global distribution of surface winds to look like?

Assume geostrophic balance.

Keep in mind these are alternating <u>bands</u> of low and high pressure - not traveling pressure systems.



Friction changes wind speed and direction

Friction slows the wind near the ground.

Friction not only slows the wind but changes its direction because the Coriolis force is proportional to wind speed.

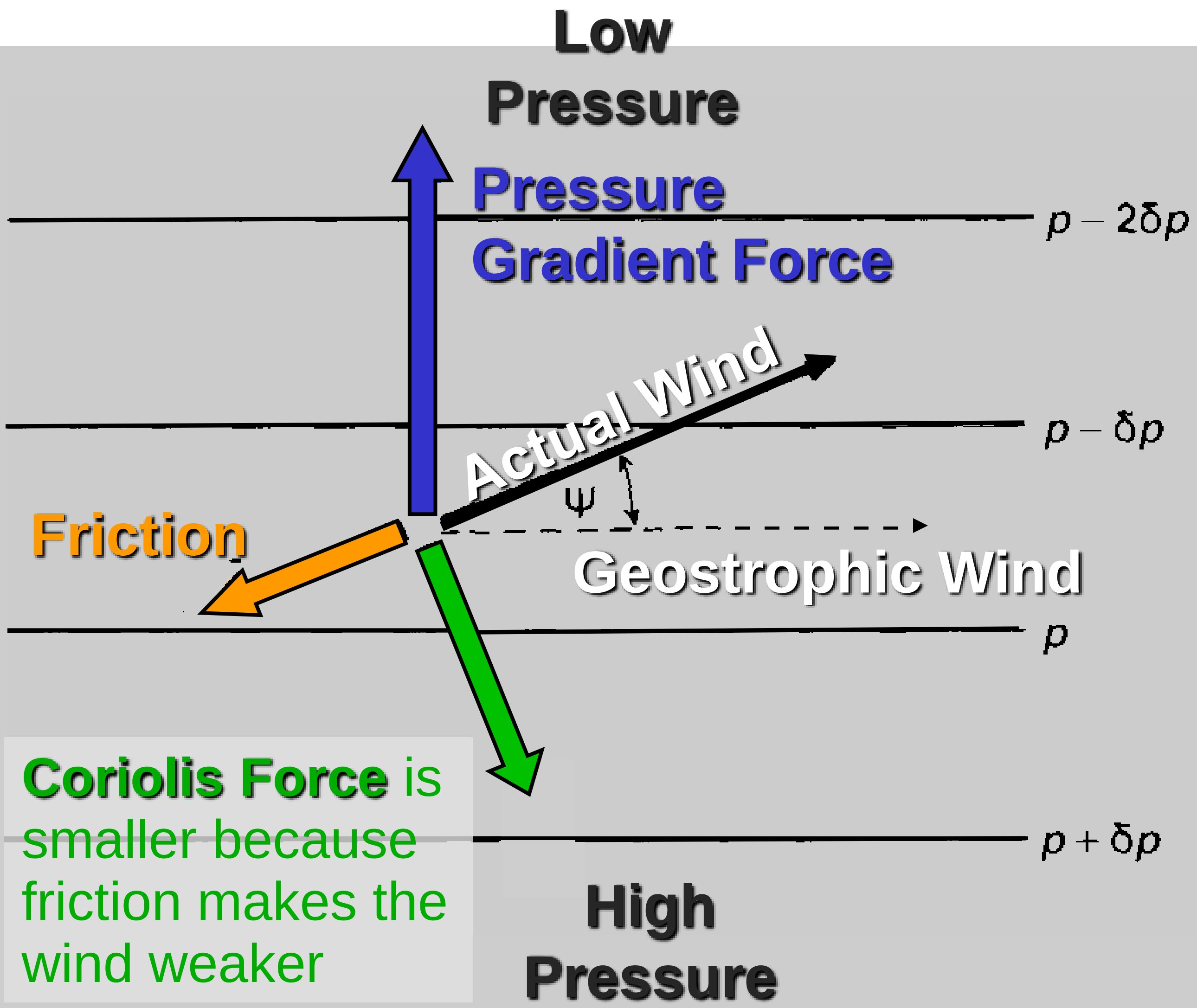
- Remember:

  $$\text{Coriolis force} = f\,V$$

  So when friction makes V smaller, the Coriolis force also becomes smaller.

- The smaller Coriolis force no longer completely balances the pressure gradient force.
- This makes the wind point somewhat toward low pressure when there is friction. (Not **directly** toward low pressure.)

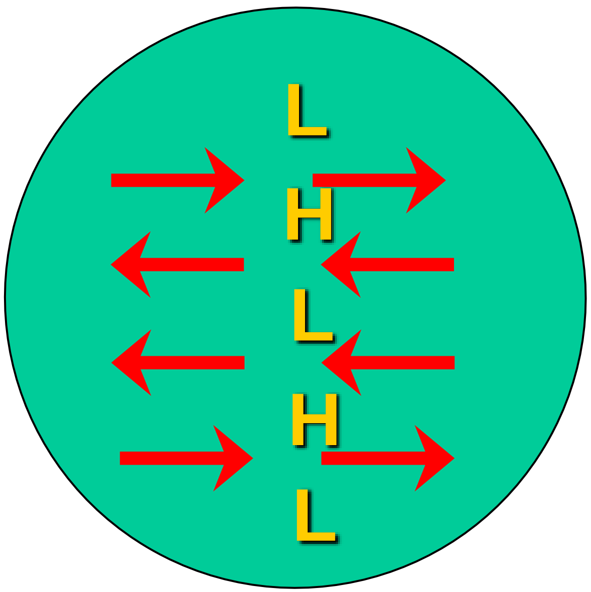
Effect of friction is to make the wind point somewhat toward low pressure

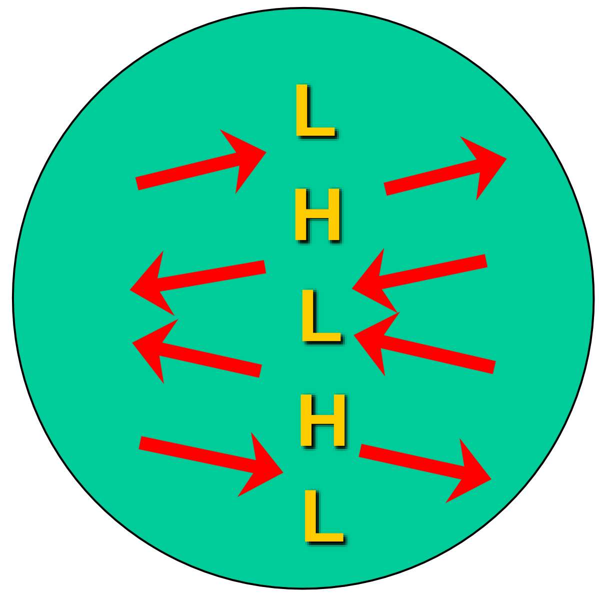


Coriolis Force is smaller because friction makes the wind weaker

Effect of friction

Friction causes the winds to turn slightly toward lower pressure.

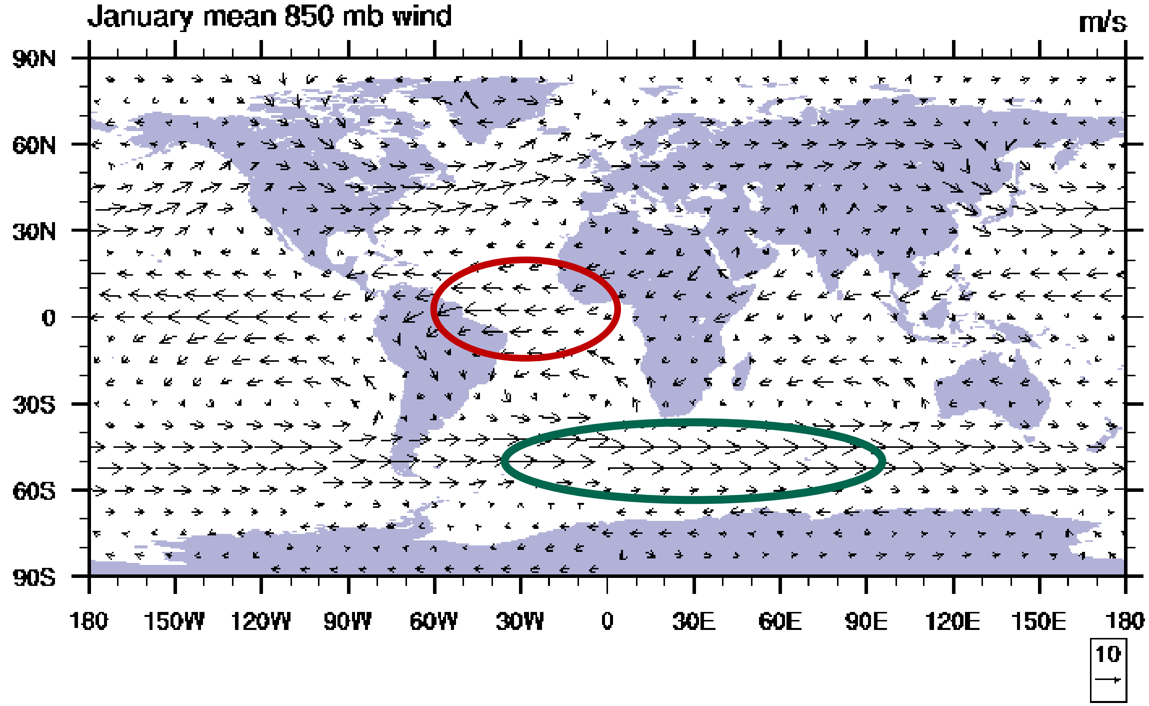




Mean January winds

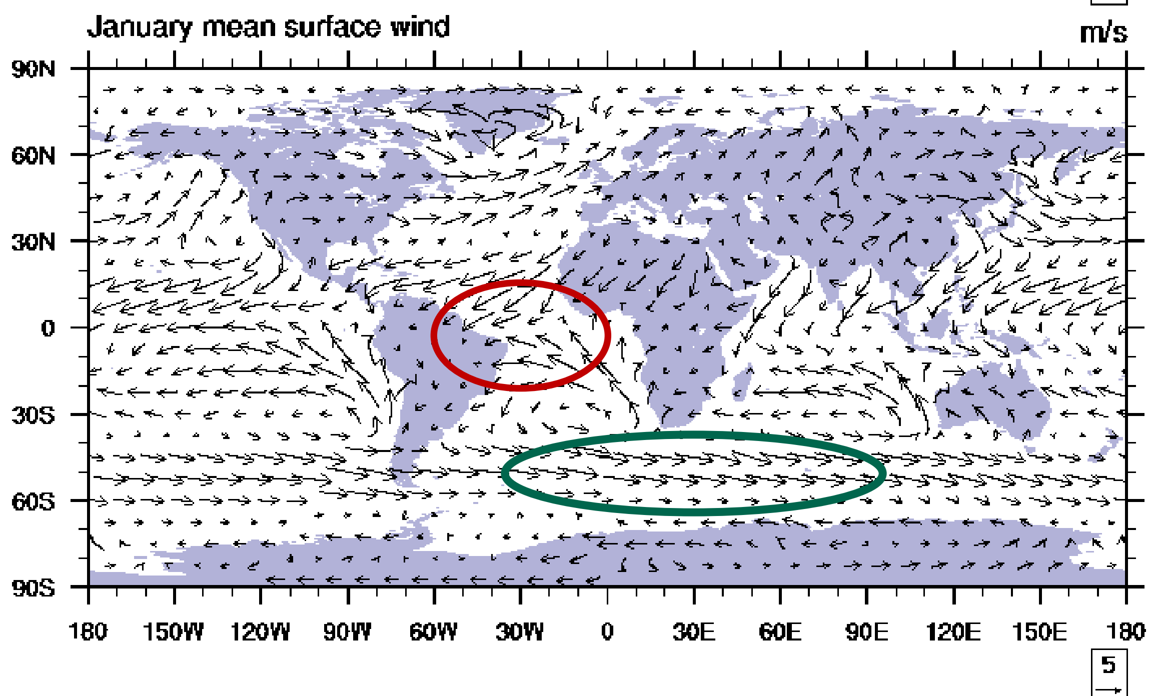
850 mb (about 1500 m or 5000 ft):

Friction is small.
Wind is close to geostrophic.



Surface:

Friction is large.
Wind points somewhat toward low pressure.



Perturbations to the general circulation

The basic picture of the general circulation can be changed by factors such as

- Land-sea contrasts
- Major mountain ranges
- Seasonal changes in land cover and snow or ice cover

Monsoons

Supply rain for **agriculture.**

Can cause **floods.**

Monsoons are caused by land-sea contrasts.

Monsoon flooding in Gauhati (India), September 2014.

from cnn.com