Agronomy 406
World Climates

January 23, 2018

Climate News presentation: Team 3

Review quiz

The Earth's energy budget: Heat transport.

Review for today:

Online textbook: 2.1.5 Heat storage and transport
2.1.5.1 Heat storage
2.1.5.2 Heat transport

For Thursday:

Online textbook: 1.2.2 General circulation of the atmosphere

Review and summary

On average, there is a **net radiation gain** Q* of 98 W m^{-2} at Earth's surface. **Radiation is not balanced.**

Earth's surface maintains (very nearly) **energy balance** by transferring this energy to the atmosphere.

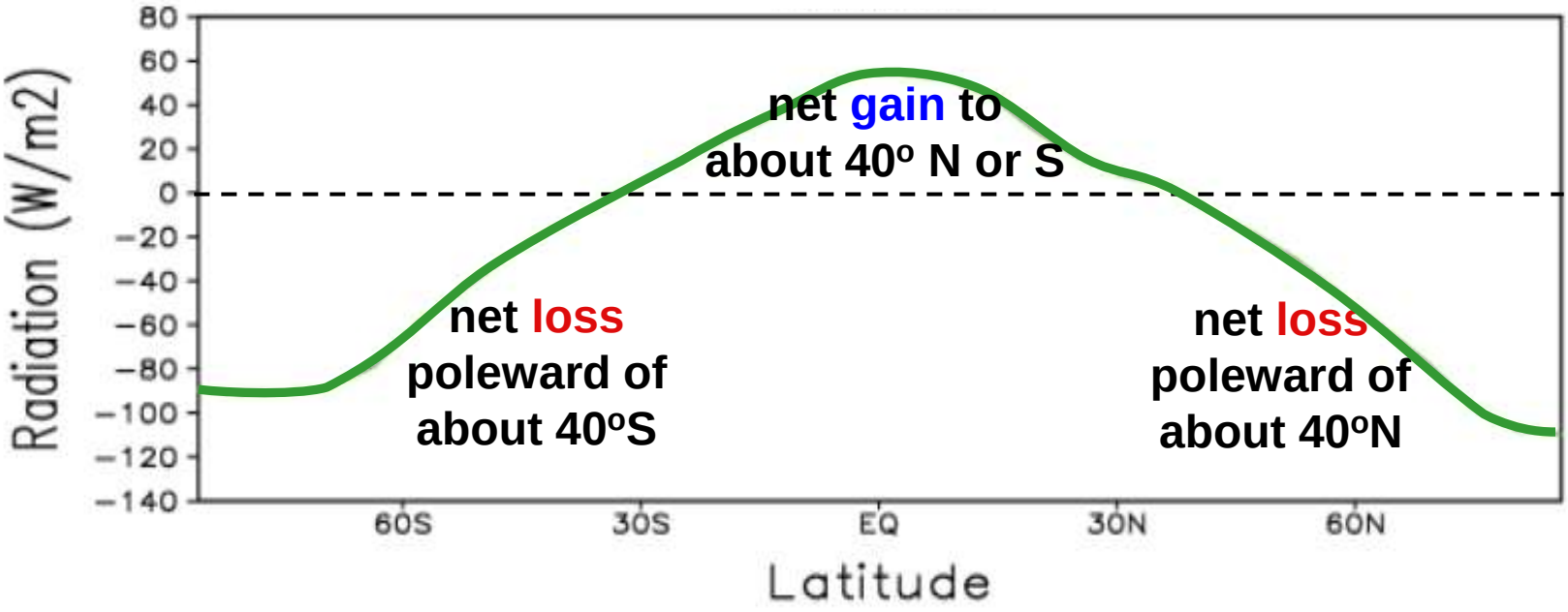
Sensible heat flux – movement of warm or cool air.

Latent heat flux – transfer of water vapor, and thus of the energy that was used for its evaporation.

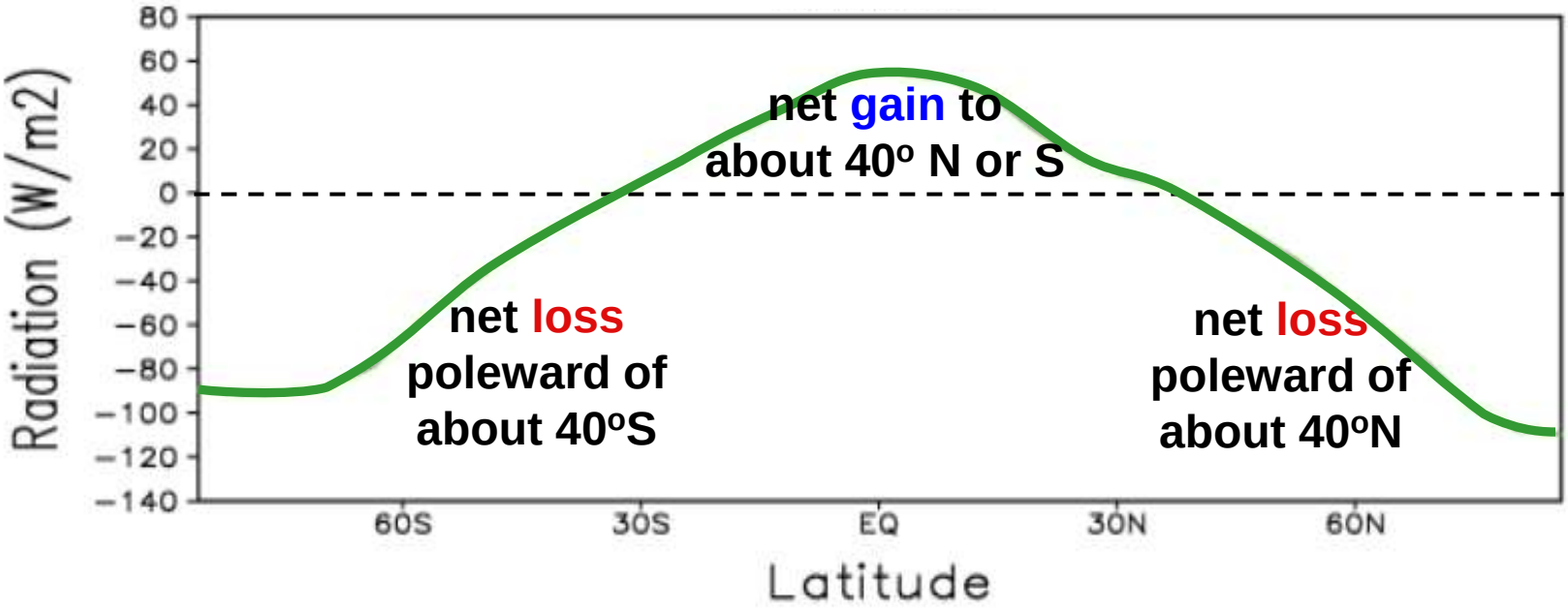
Currently there is a small accumulation of heat in the system, mostly going into the oceans.

Locally, energy fluxes (radiation, sensible heat, latent heat) vary throughout the day and the year.

The big picture



This is arguably the most important diagram for all of climate

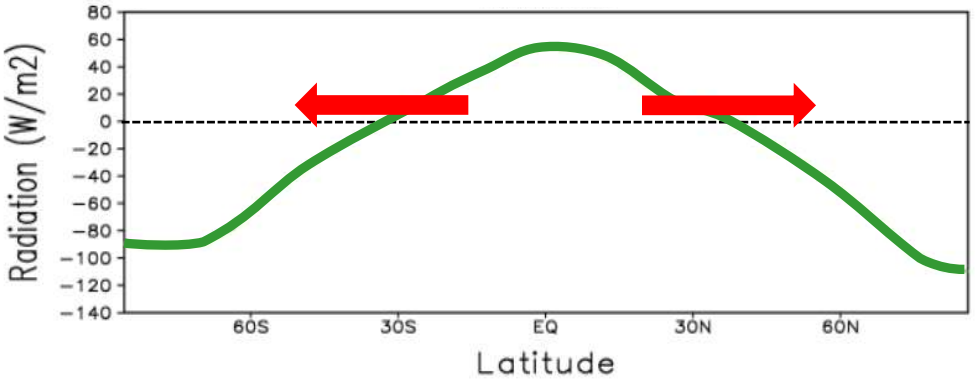


The transfer of energy from regions where there is a net gain to the regions where there is a net loss is what drives Earth's climate and its variations.

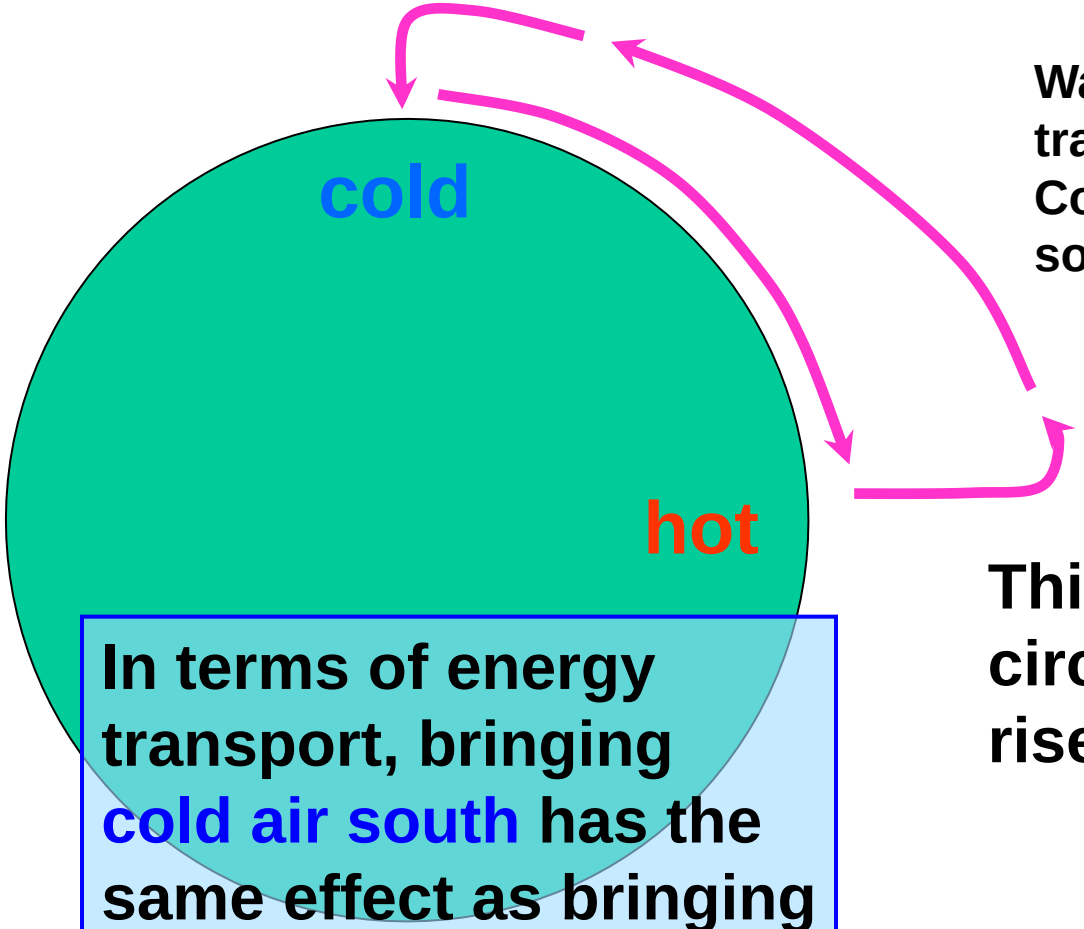
Ways the energy surpluses and deficits at different latitudes get evened out

Three main ways to transfer energy around the globe:

- Transport sensible heat (warm or cool air) in the atmosphere.
- Transport latent heat (water vapor) in the atmosphere.
- Transport heat in the oceans.



Simplest idea of energy redistribution: Hadley cell

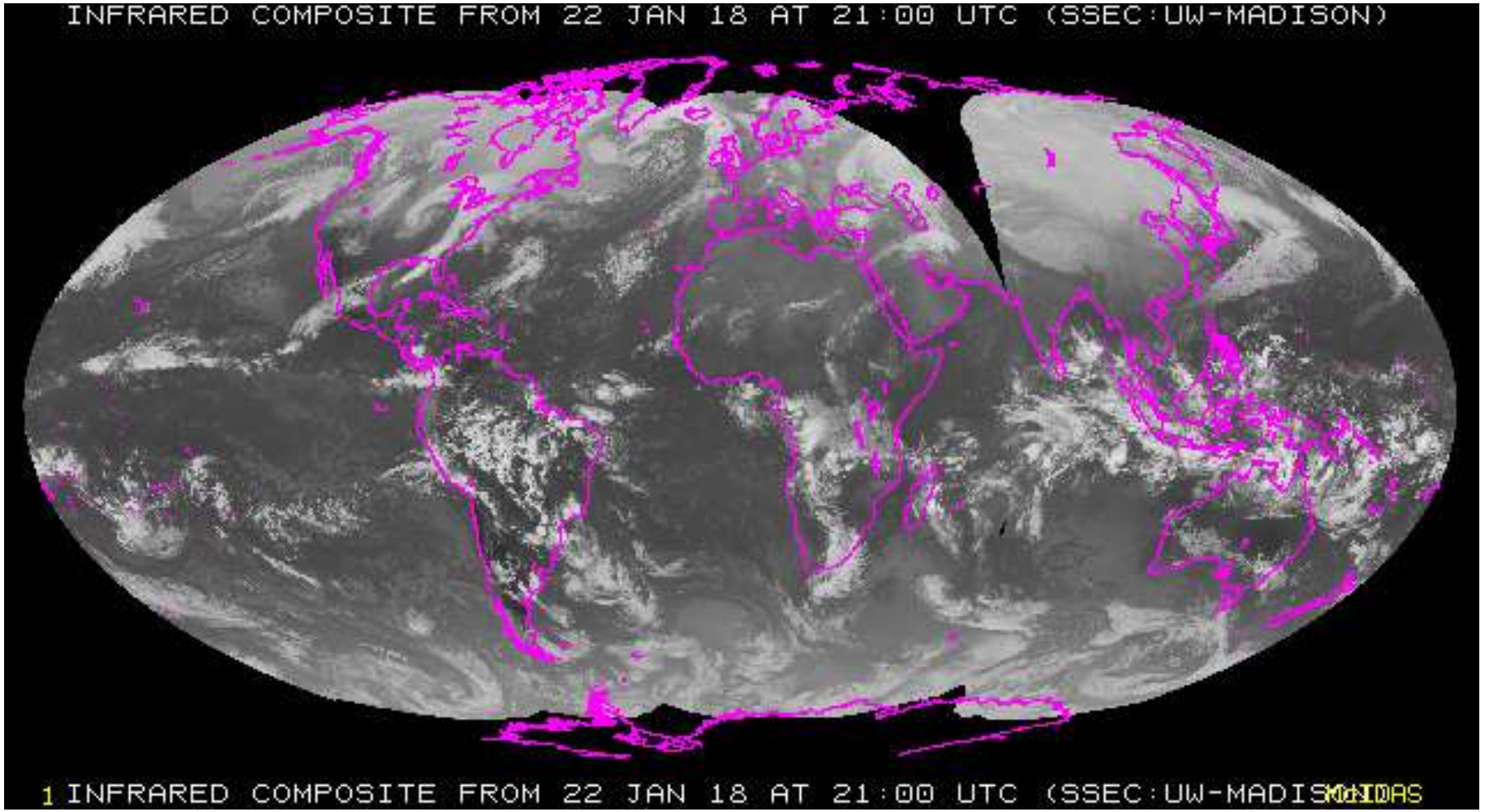


Warm air rises and is transported northward aloft. Cold air is transported southward at the surface.

In terms of energy transport, bringing cold air south has the same effect as bringing warm air north.

This is a thermally direct circulation: warm air rises and cold air sinks

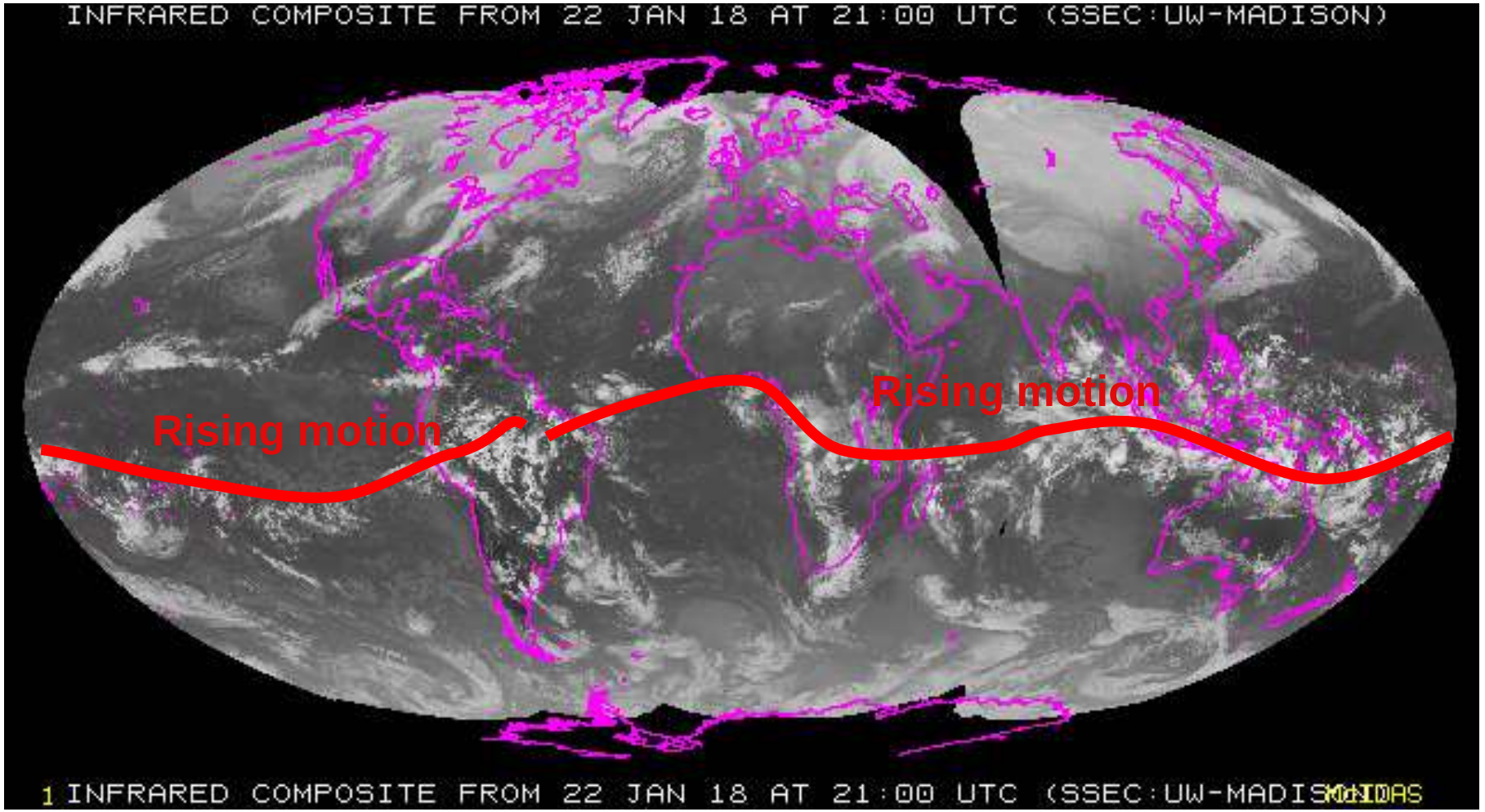
Intertropical Convergence Zone (ITCZ): the rising branch of the Hadley cell



as of Monday (1/22)

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

Intertropical Convergence Zone (ITCZ): the rising branch of the Hadley cell



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A problem with the global Hadley cell

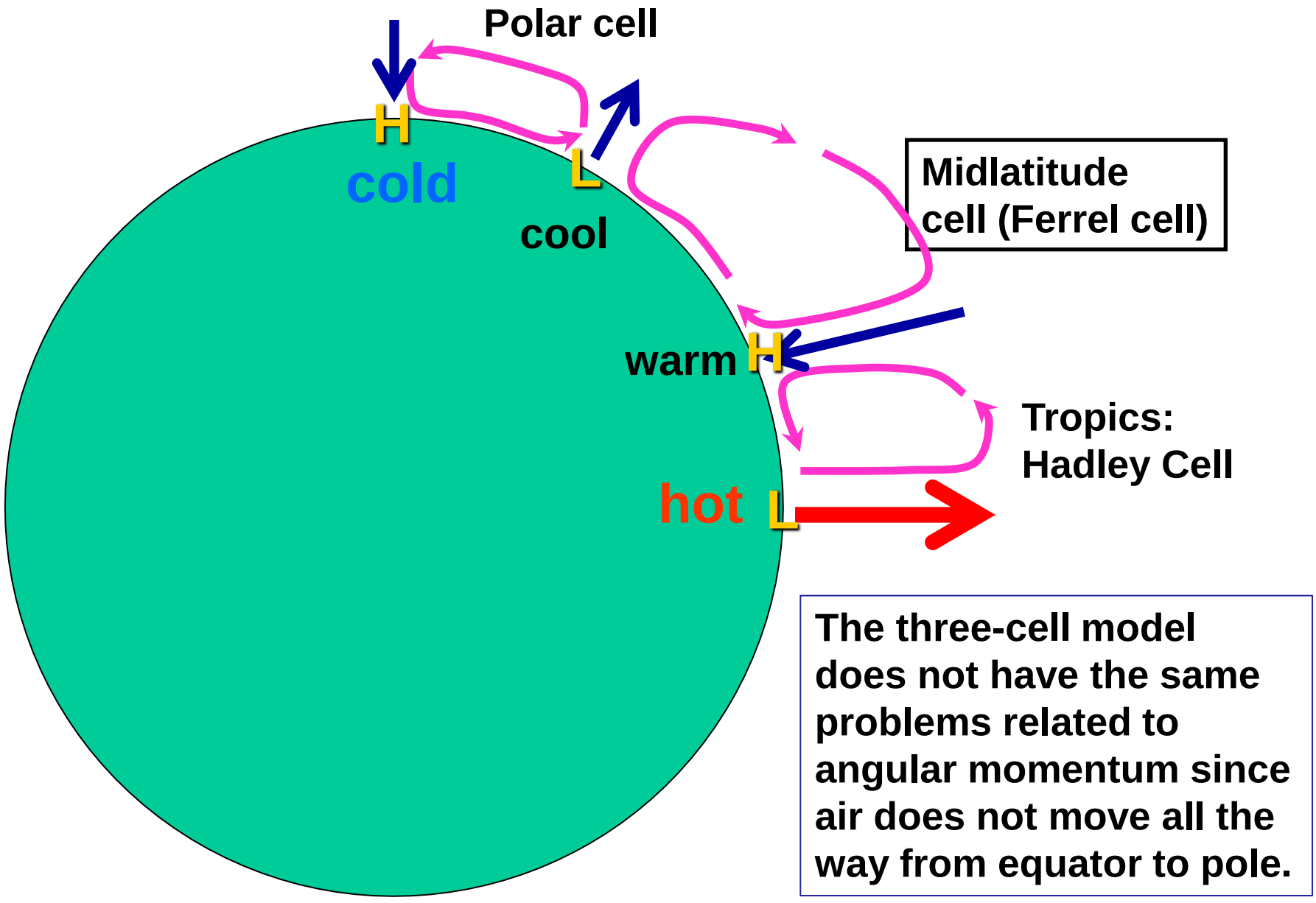
Earth's angular momentum (roughly, speed of circular motion) varies with latitude.

In the absence of friction or other forces, angular momentum is **conserved** as air moves.

> If a blob of air moved from equator to pole while conserving its angular momentum, it would be circling the Earth faster than the speed of sound.

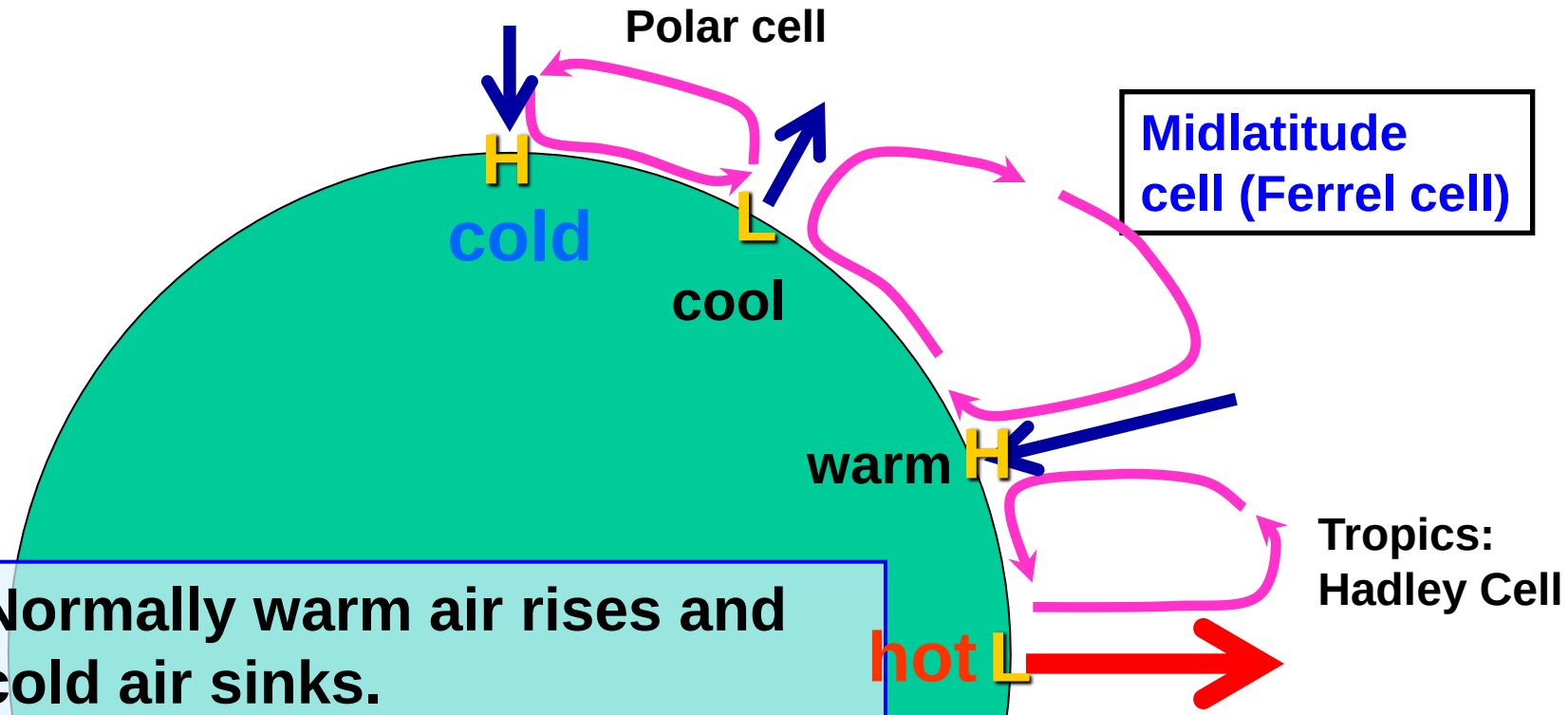
In the 1800s William Ferrel realized this and proposed a new type of circulation cell.

Ferrel's 3-cell model



The three-cell model does not have the same problems related to angular momentum since air does not move all the way from equator to pole.

3-cell model

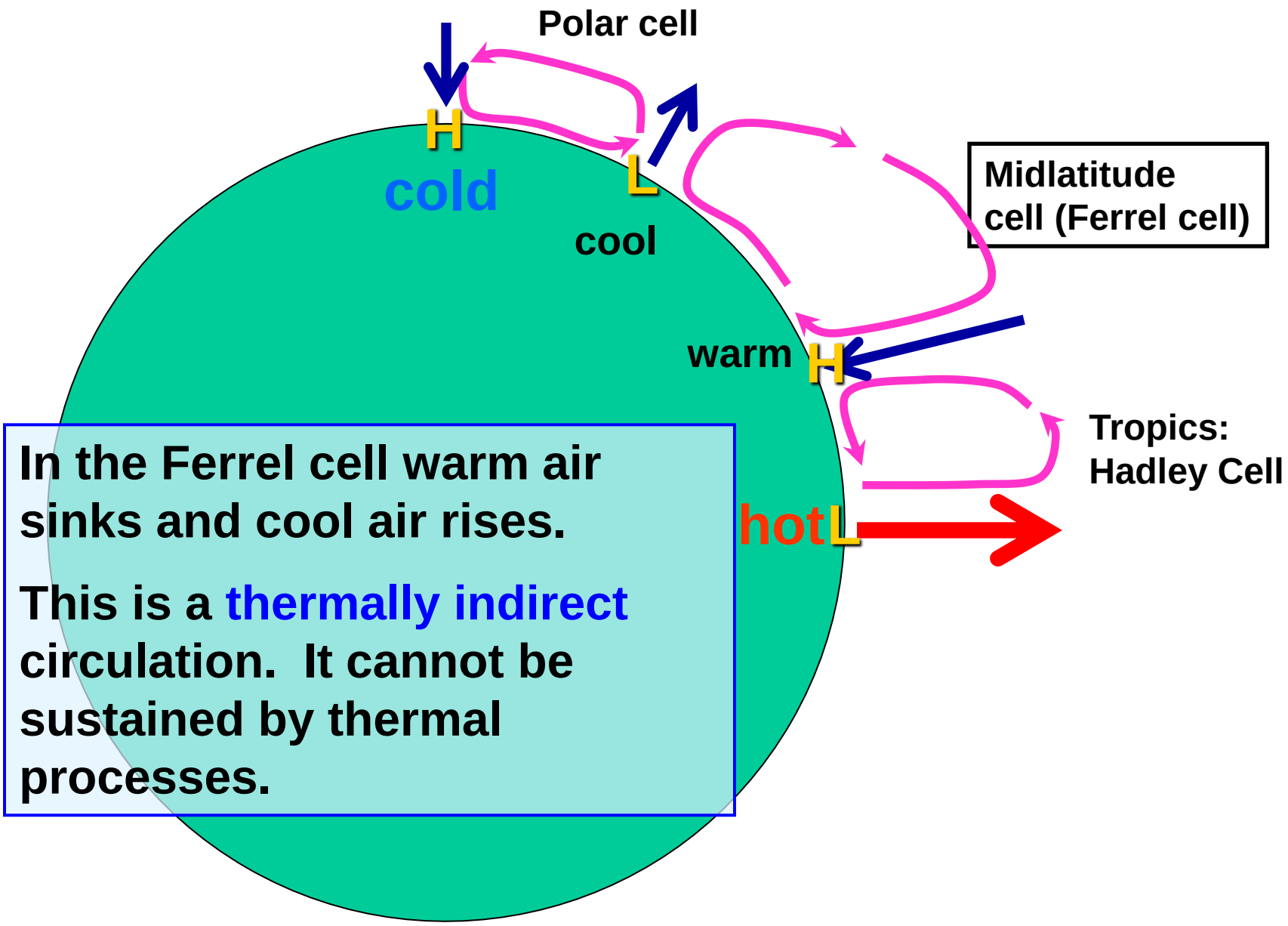


Normally warm air rises and cold air sinks.

Is this what happens in the Ferrel cell?

Assume temperature is always warm toward the south and cold to the north.

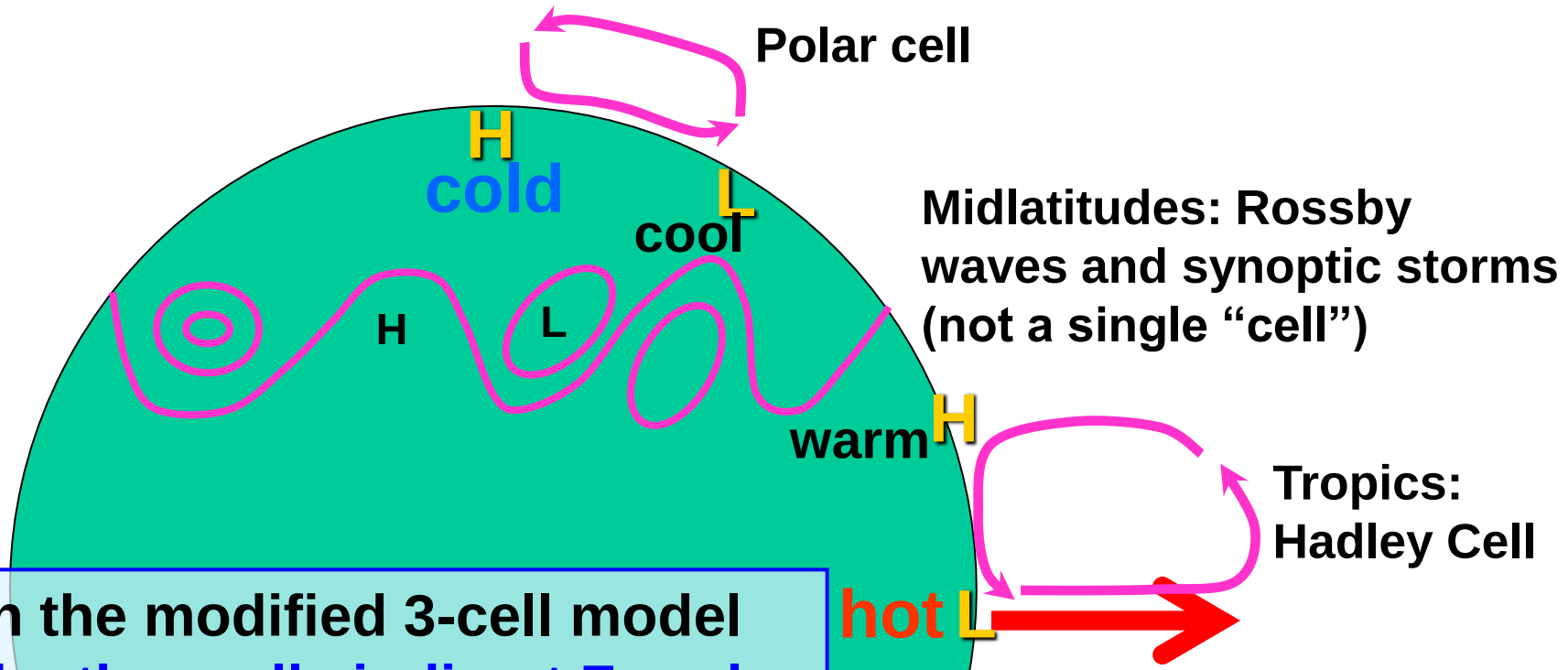
3-cell model



In the Ferrel cell warm air sinks and cool air rises.

This is a thermally indirect circulation. It cannot be sustained by thermal processes.

Modified 3-cell model

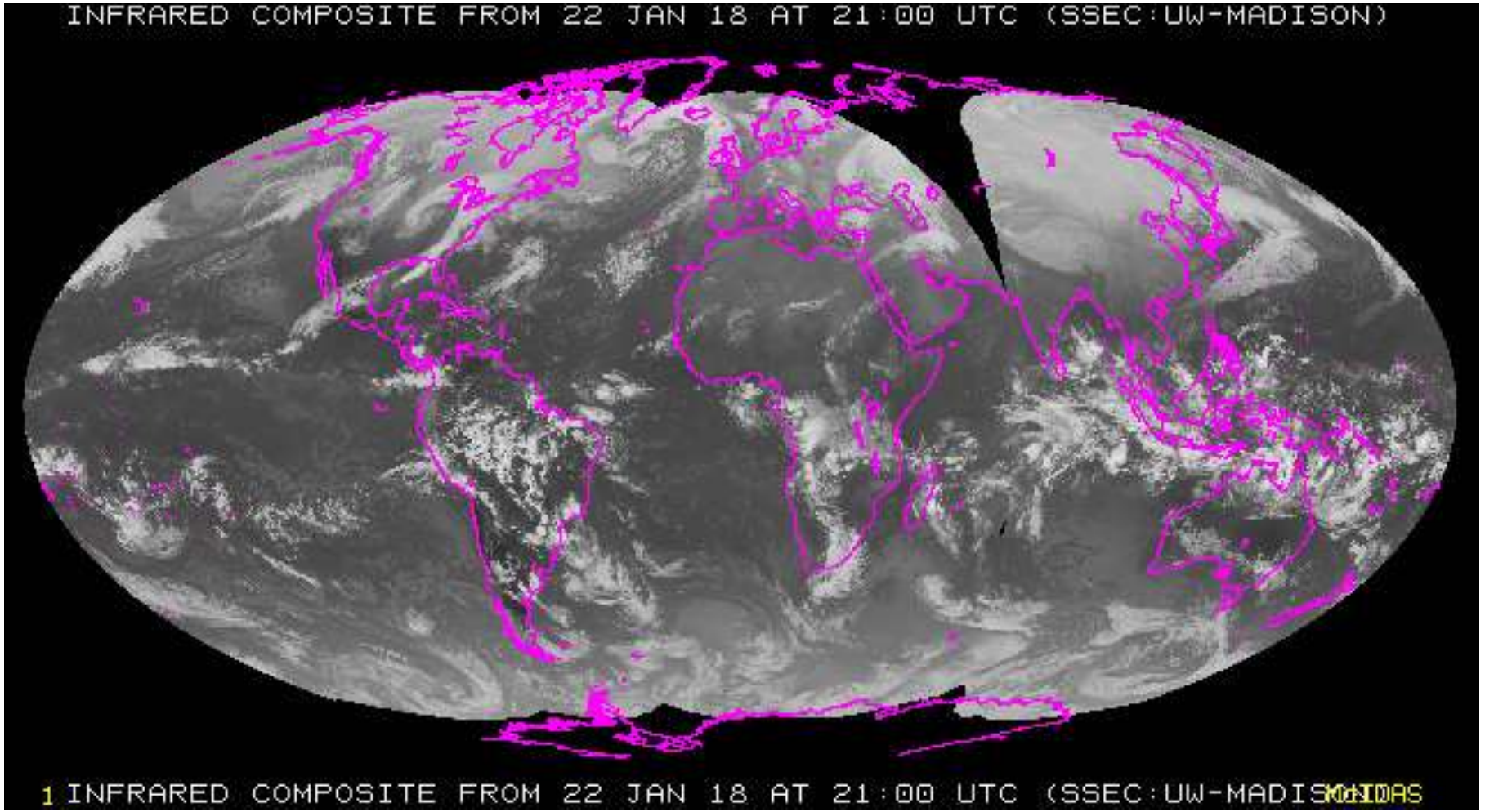


In the modified 3-cell model the thermally indirect Ferrel cell is replaced by a zone of mixing.

The mixing is done mostly by transient eddies - traveling pressure disturbances.

Large scale cells

as of Monday, 22 January



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Large scale cells

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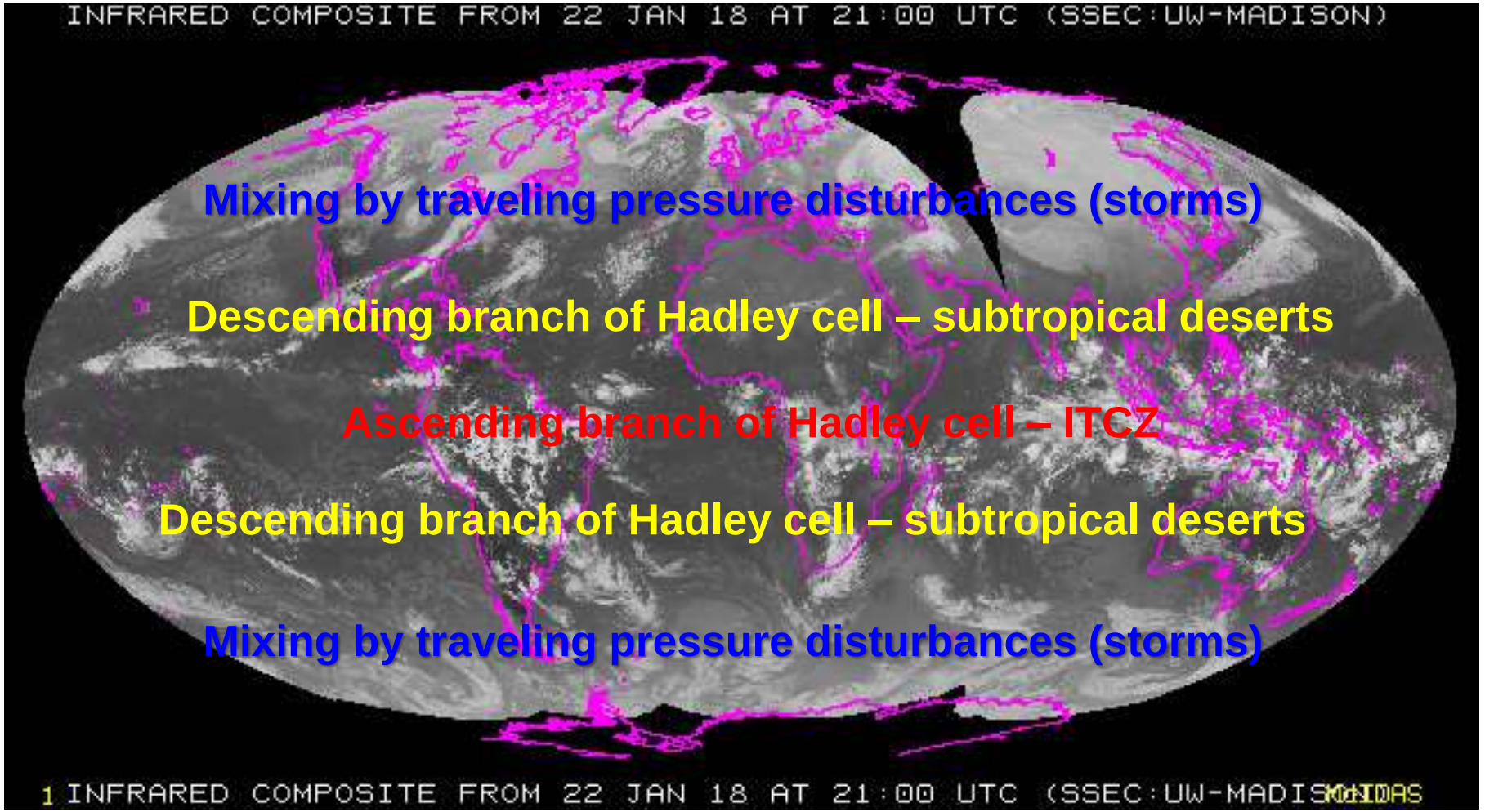

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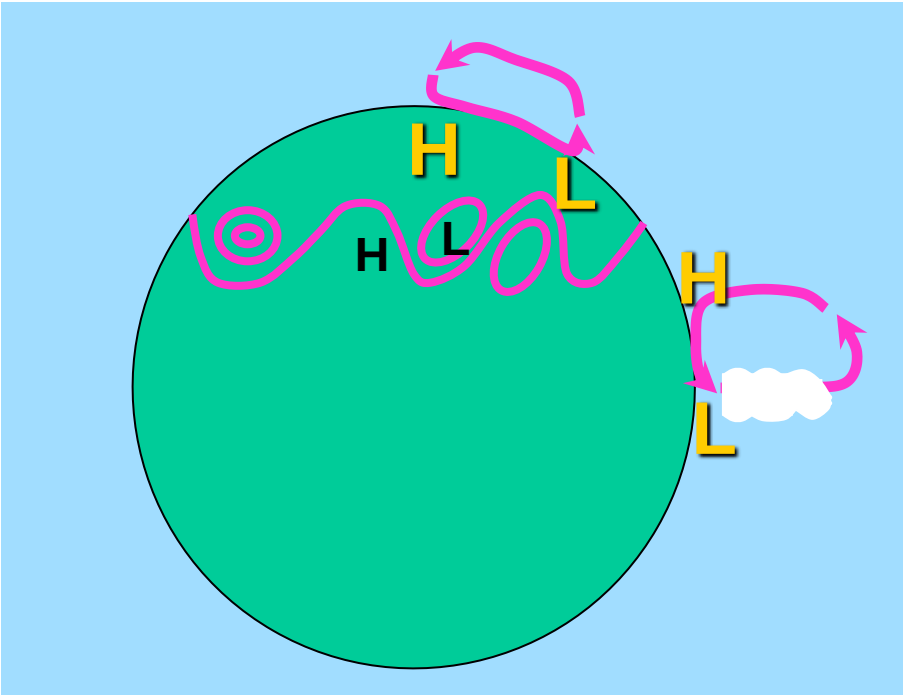
Summary

The three-cell model shows us some of the important features of Earth's climate:

- Tropical rain band at the ITCZ.
- Deserts at the descending branches of the Hadley cell.
- Mid-latitude storm tracks.

Now let's take a closer look at the energy transports (energy fluxes).

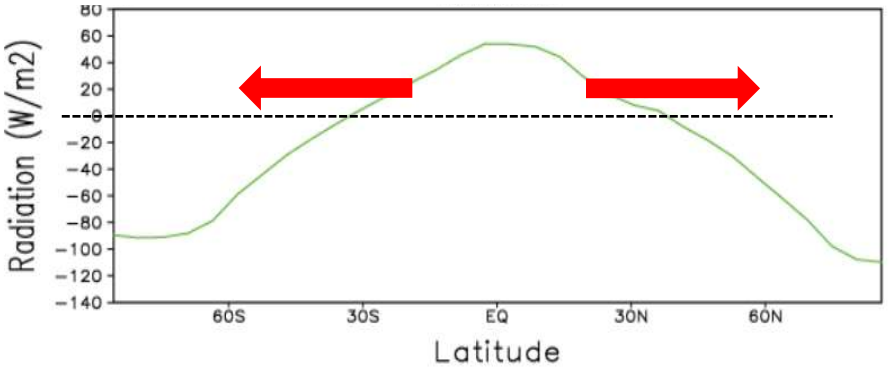


Global energy transports: the general circulation

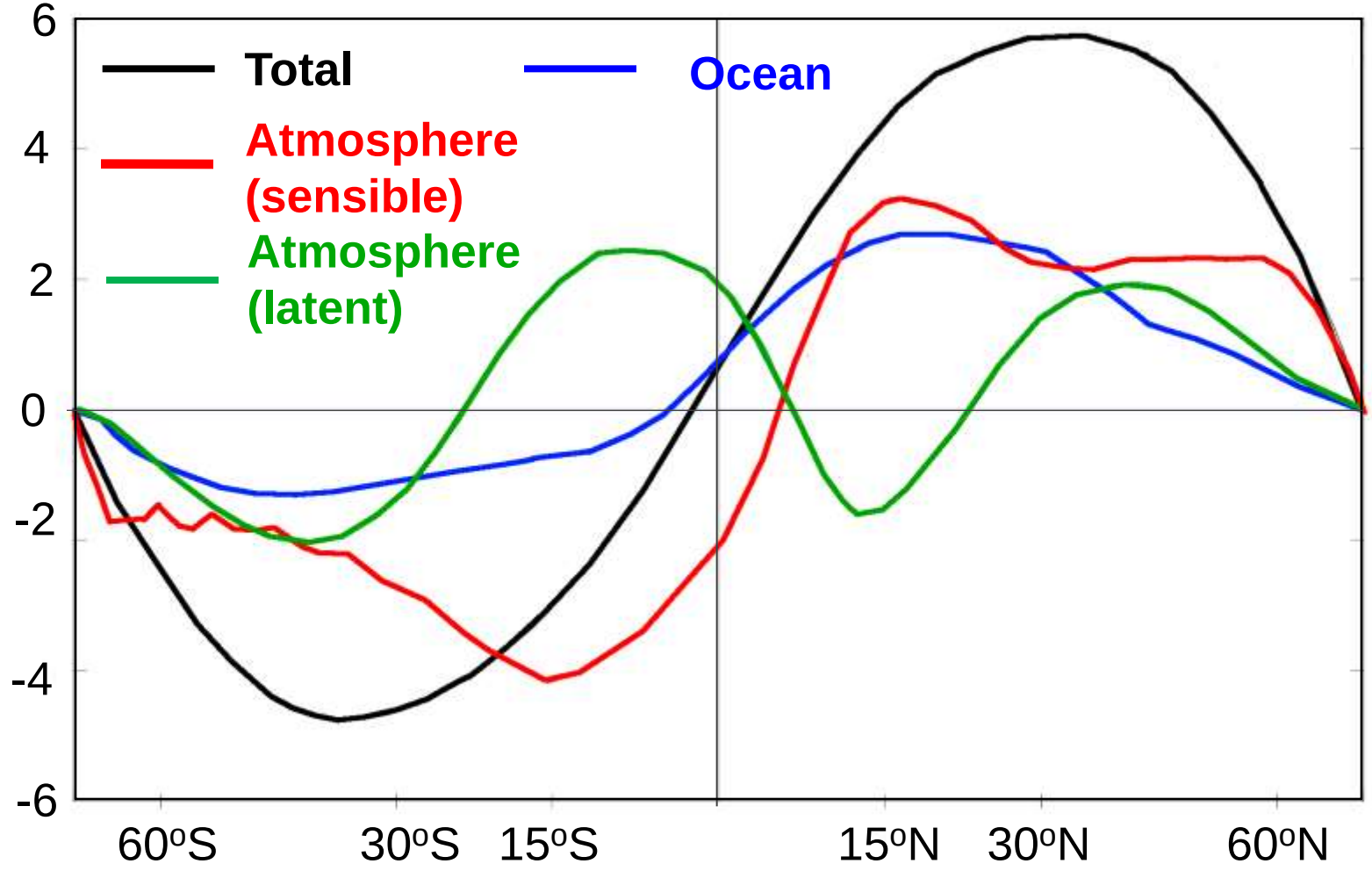
Three main ways to transfer energy:

- 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.**

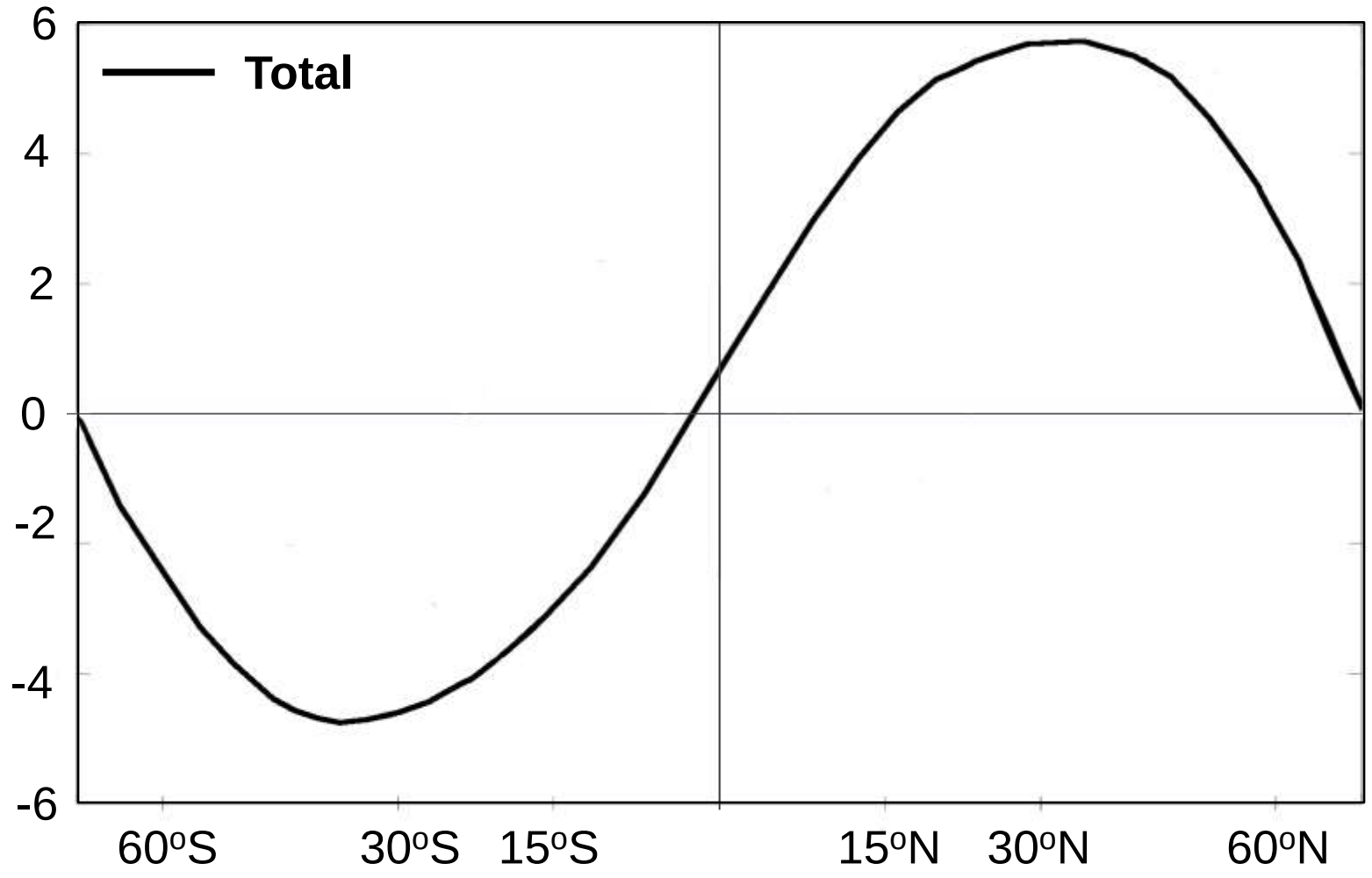


Energy transport by sensible and latent heat fluxes



adapted from Bryden (2004)

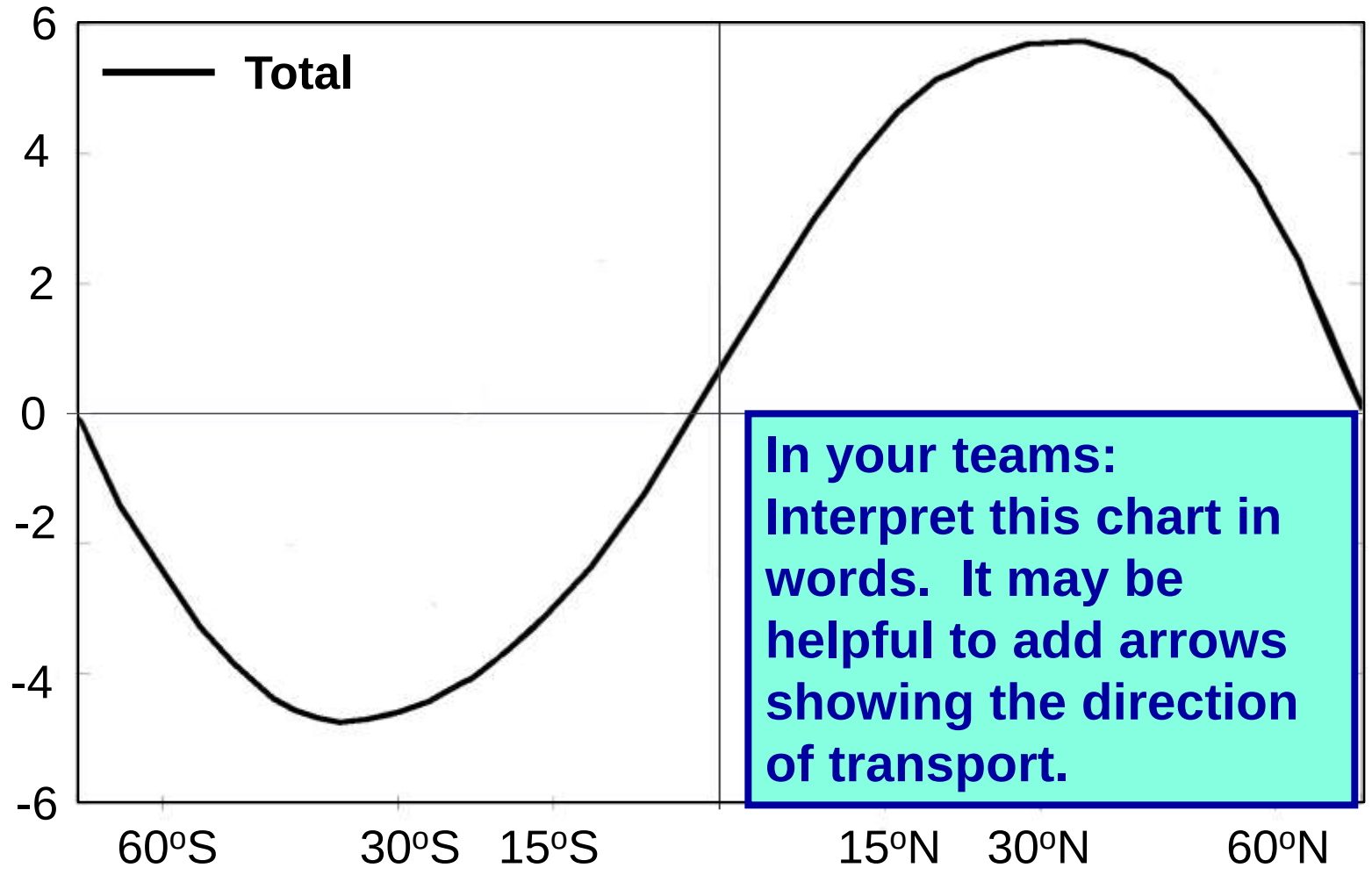
Total energy flux



Positive = northward flux

adapted from Bryden (2004)

Total energy flux



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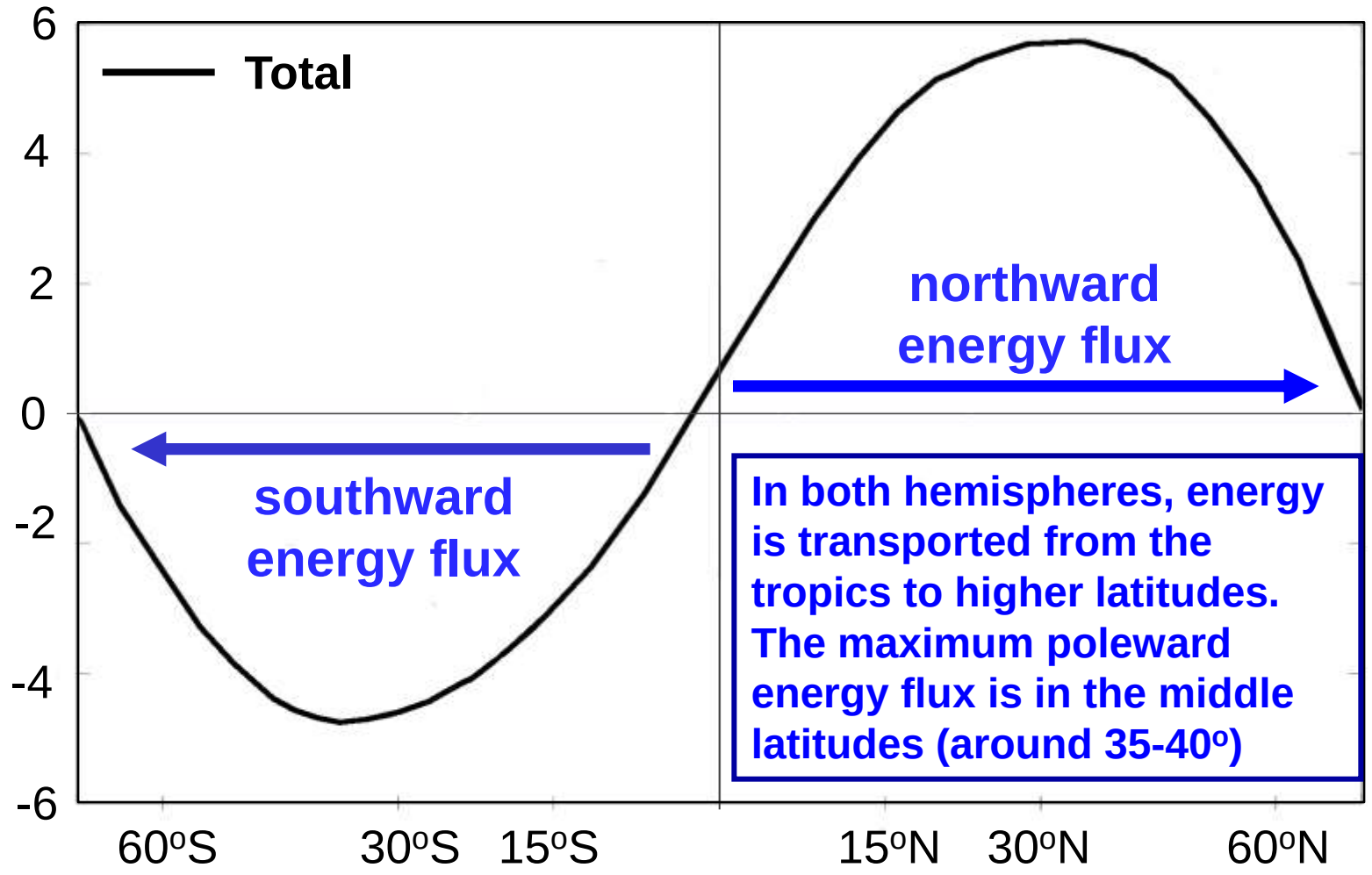


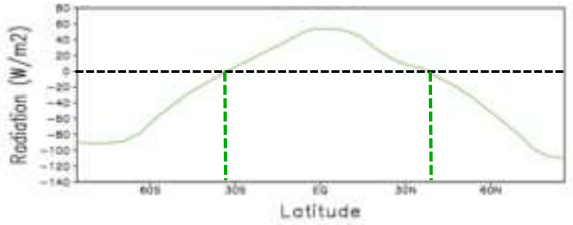
Energy flux, petawatts

Positive = northward flux

Latitude (scaled by area)

adapted from Bryden (2004)

Total energy flux



Total

northward energy flux

southward energy flux

Notice the total energy flux is largest at the latitudes where net radiation changes from a gain to a loss.

Energy flux, petawatts

6
4
2
0
-2
-4
-6

60°S 30°S 15°S 15°N 30°N 60°N

Latitude (scaled by area)

Positive = northward flux

adapted from Bryden (2004)