

Chapter 5: Atmospheres

Topics:

Density of Atmosphere w/ Height

Atmospheric Composition

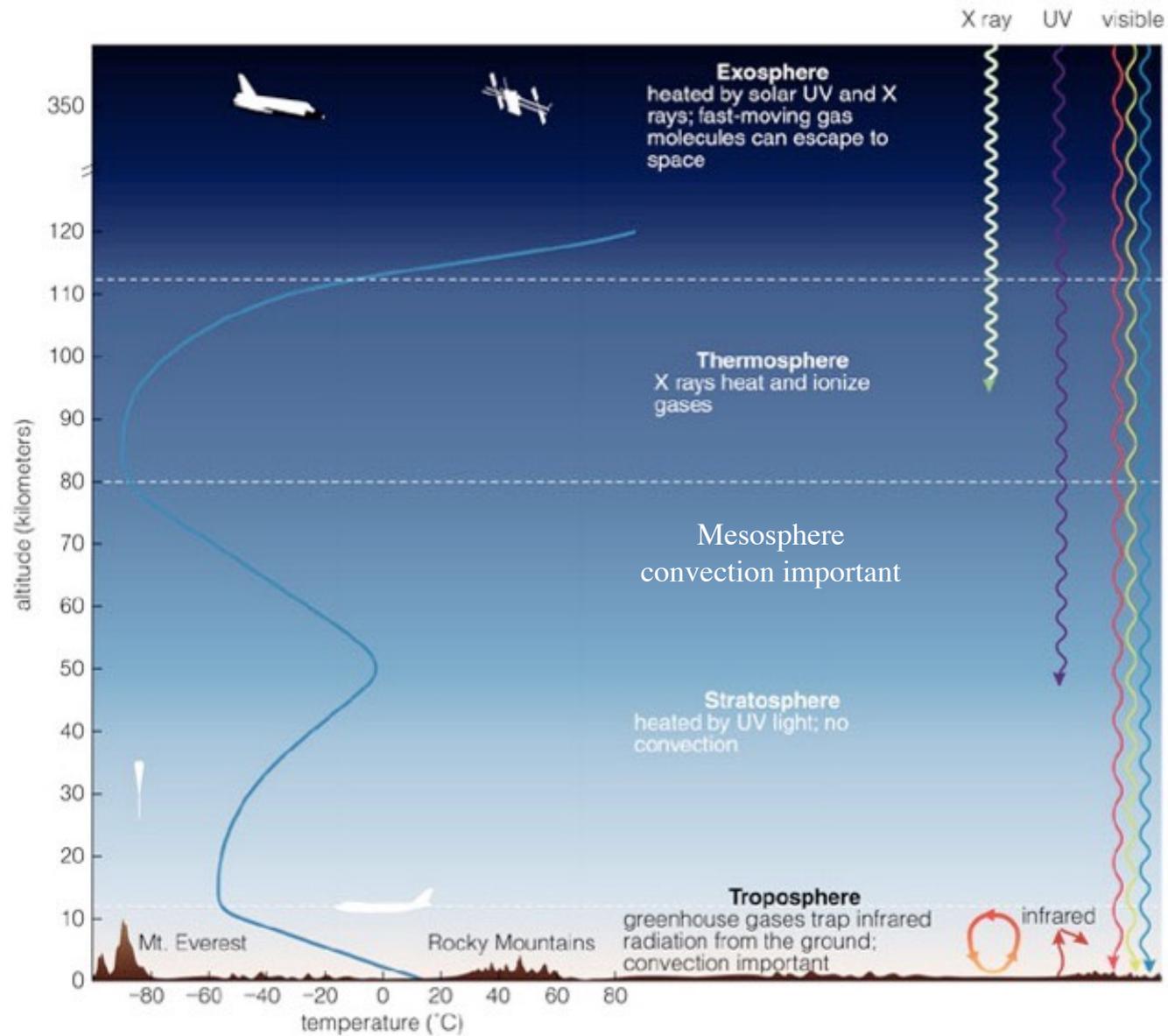
Temperature of Atmosphere w/ Height

Greenhouse Effect

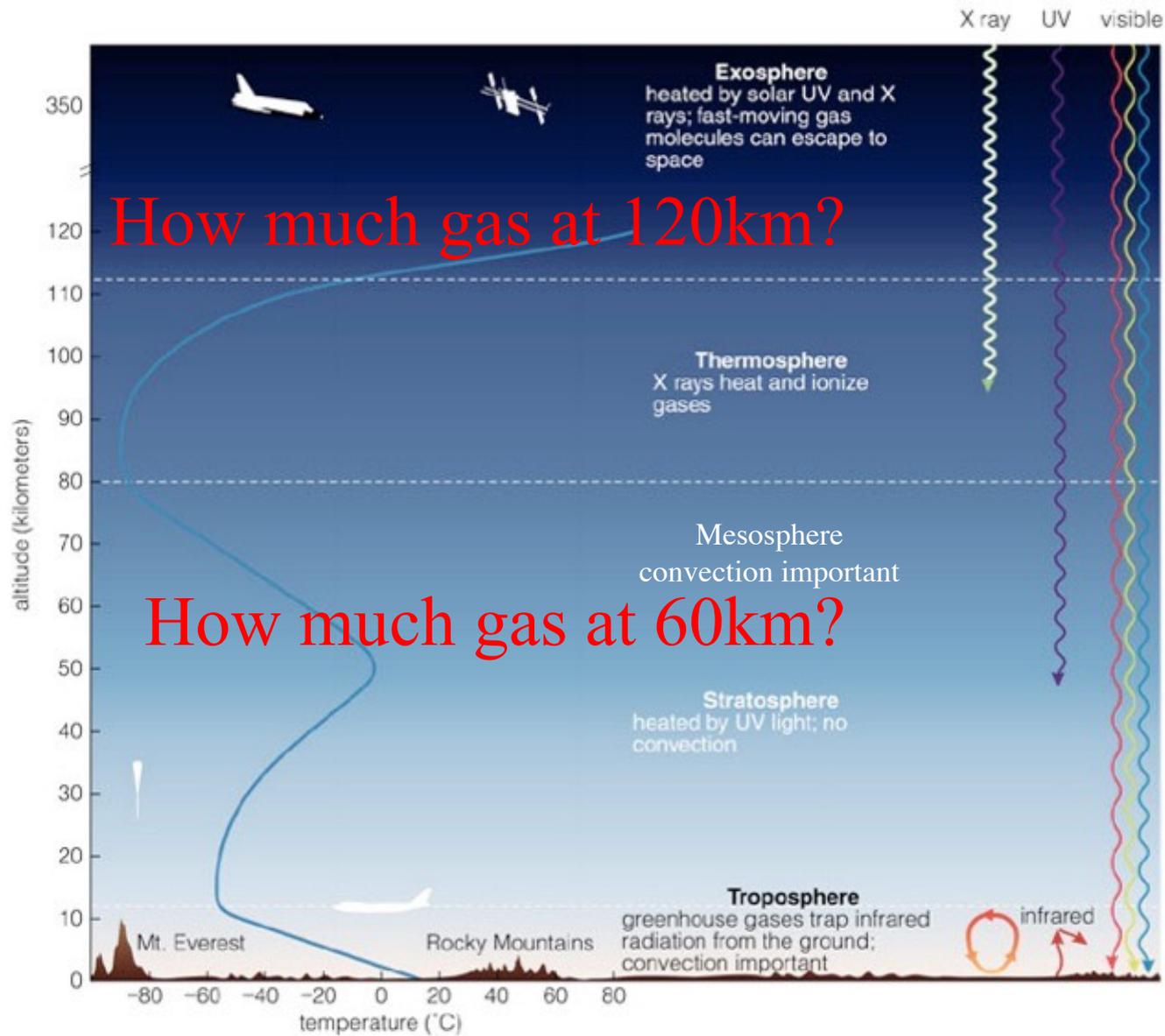
Ozone Layer

The atmosphere forms an extremely thin layer (100km) around terrestrial planets

Atmospheric Temperature



Atmospheric Temperature



Make an Estimate:

Earth's Scale Height $\sim 10\text{km}$, so the atmospheric density drops by a factor of 2 every $\sim 6\text{km}$

1. How much gas at 60km ?

2. How much gas at 120km ?

Make an Estimate:

Earth's Scale Height $\sim 10\text{km}$, so the atmospheric density drops by a factor of 2 every $\sim 6\text{km}$

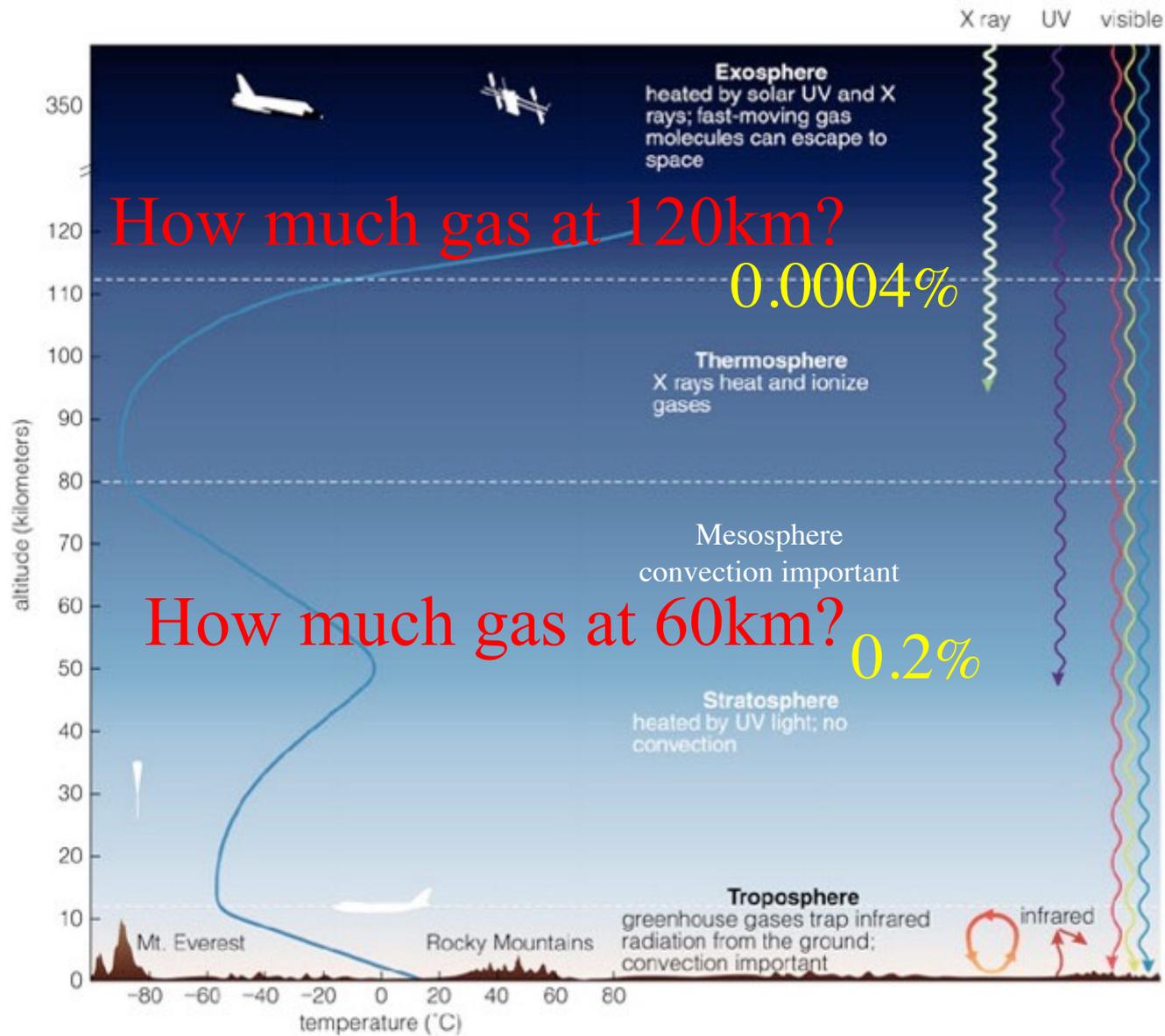
1. How much gas at 60km ?

Estimate: $2^{-10} \sim 0.001$

2. How much gas at 120km ?

Estimate: $(2^{-10})^2 \sim (0.001)^2 \sim 10^{-6}$

Atmospheric Temperature



Can You ID this Planet?

Clues:

Atmosphere Visible from Space

Surface Visible from Space

Lots of Craters

Red Color



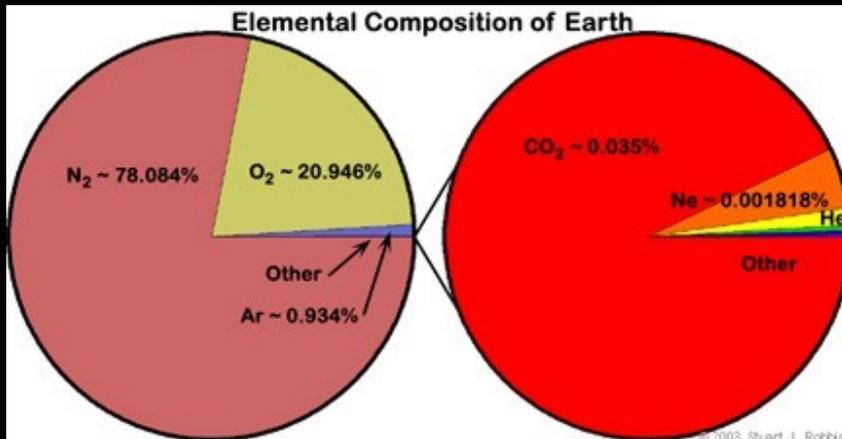
Best Terrestrial Atmosphere

100 times denser
atmosphere than Earth

Note the “V” shaped
cloud pattern on Venus

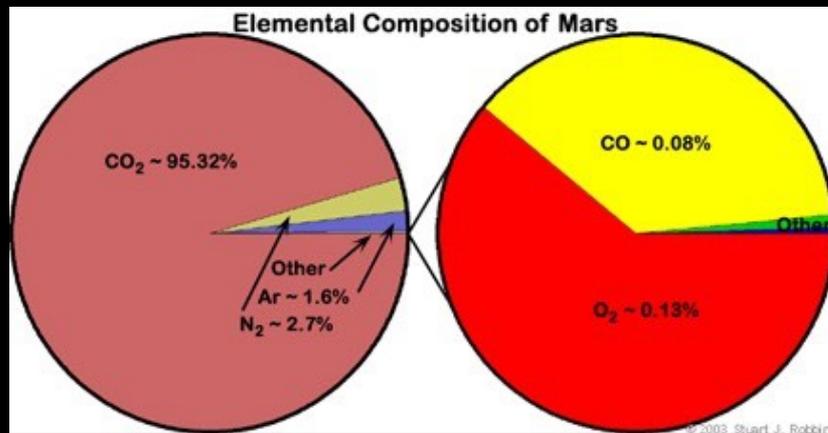


Atmospheric Composition

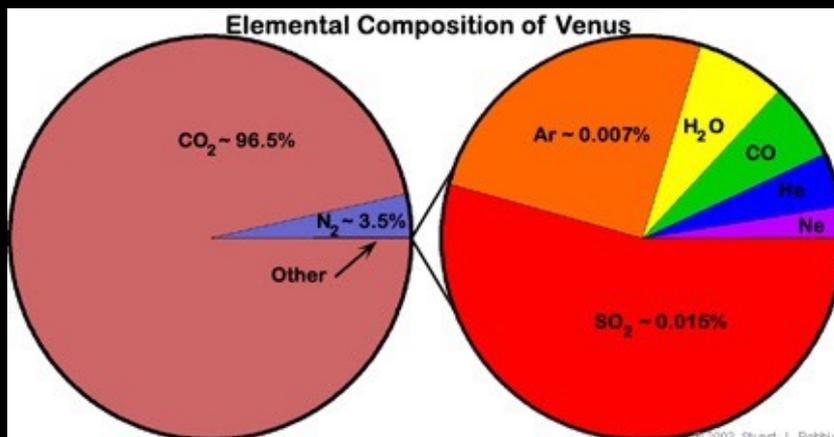


Earth

Why so much Oxygen at Earth? Why so little Carbon Dioxide?



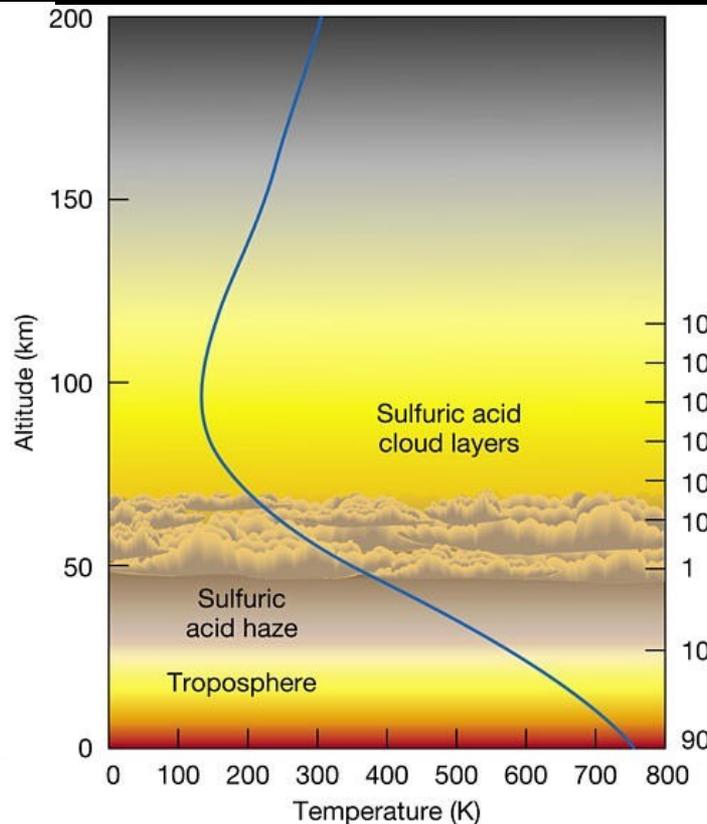
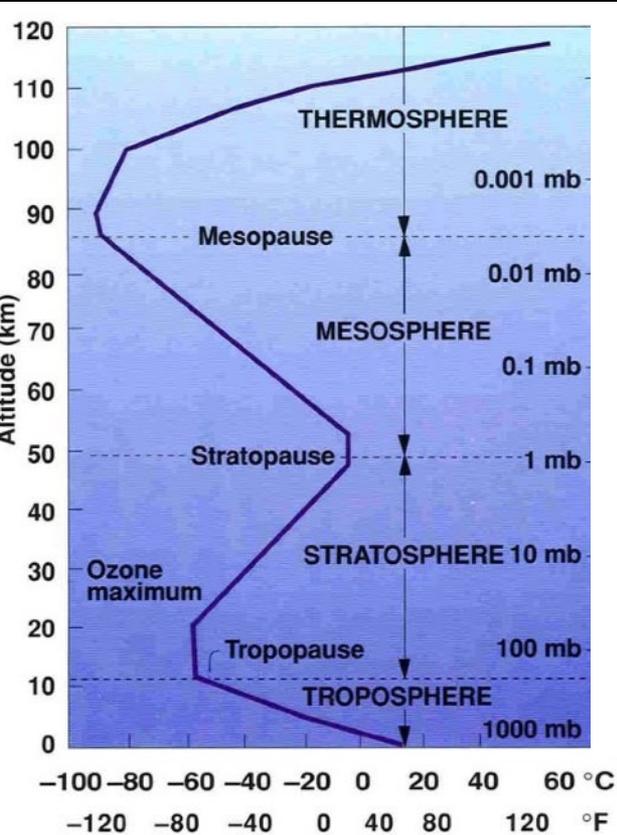
Mars



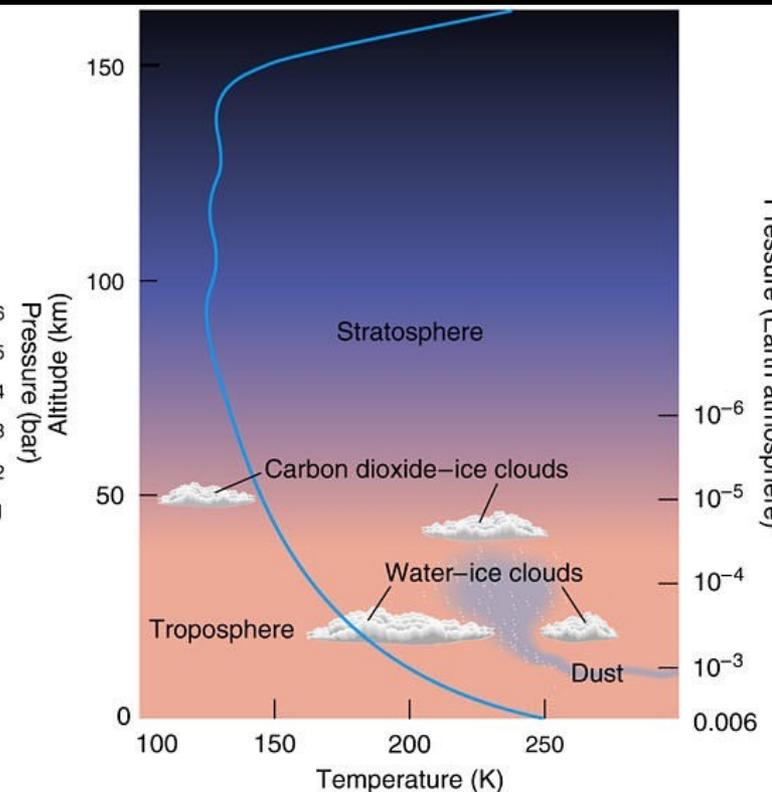
Venus

Why any Sulfur Dioxide at Venus?

How does Temperature vary with Height?



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173 K 333 K

Earth

Venus

Mars

Why is Earth's profile so strange?

Why is Venus so hot?

Why does T rise at high altitudes on all planets?

What Determines a Planet's Temperature?

Energy In (from Sunlight) = Energy Out (radiated heat)

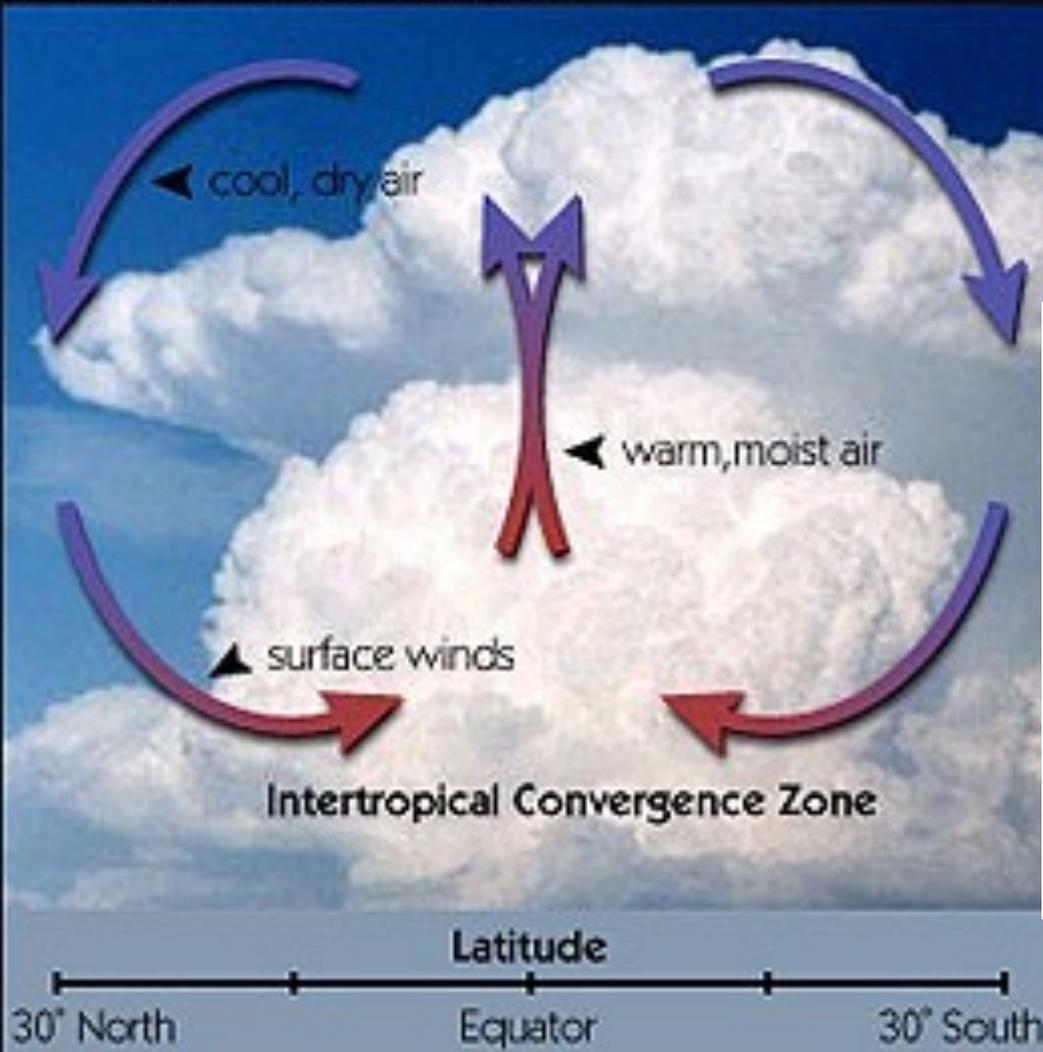
This Energy Balance determines the Effective Average Surface Temperature.

	Venus	Earth	Mars
Effective Temp:	238	263	224
Actual Temp:	733	288	222
Difference:	505	25	2

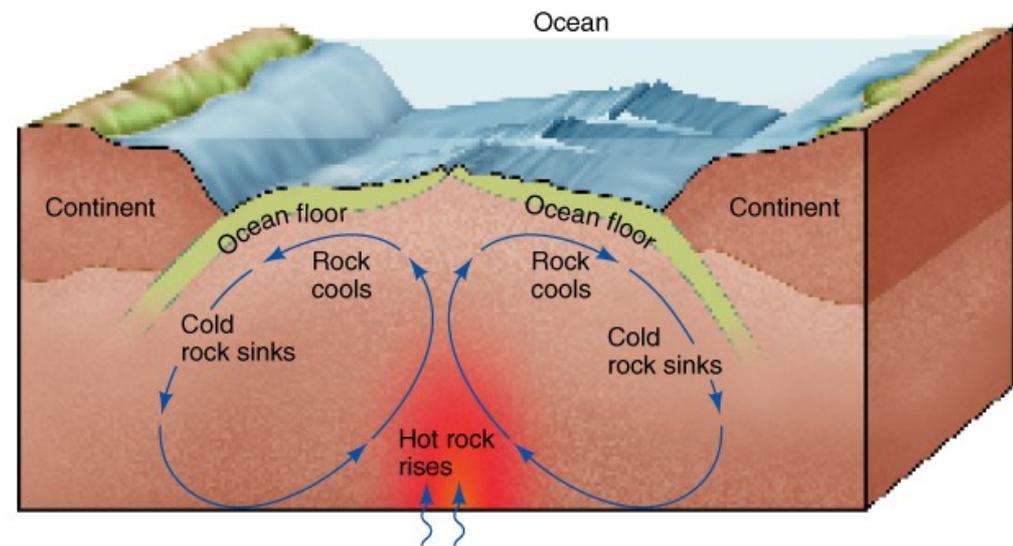
Why is Venus predicted to be Colder than Earth? Clouds.

Atmospheric Convection

Figure 2: Hadley Cell Circulation



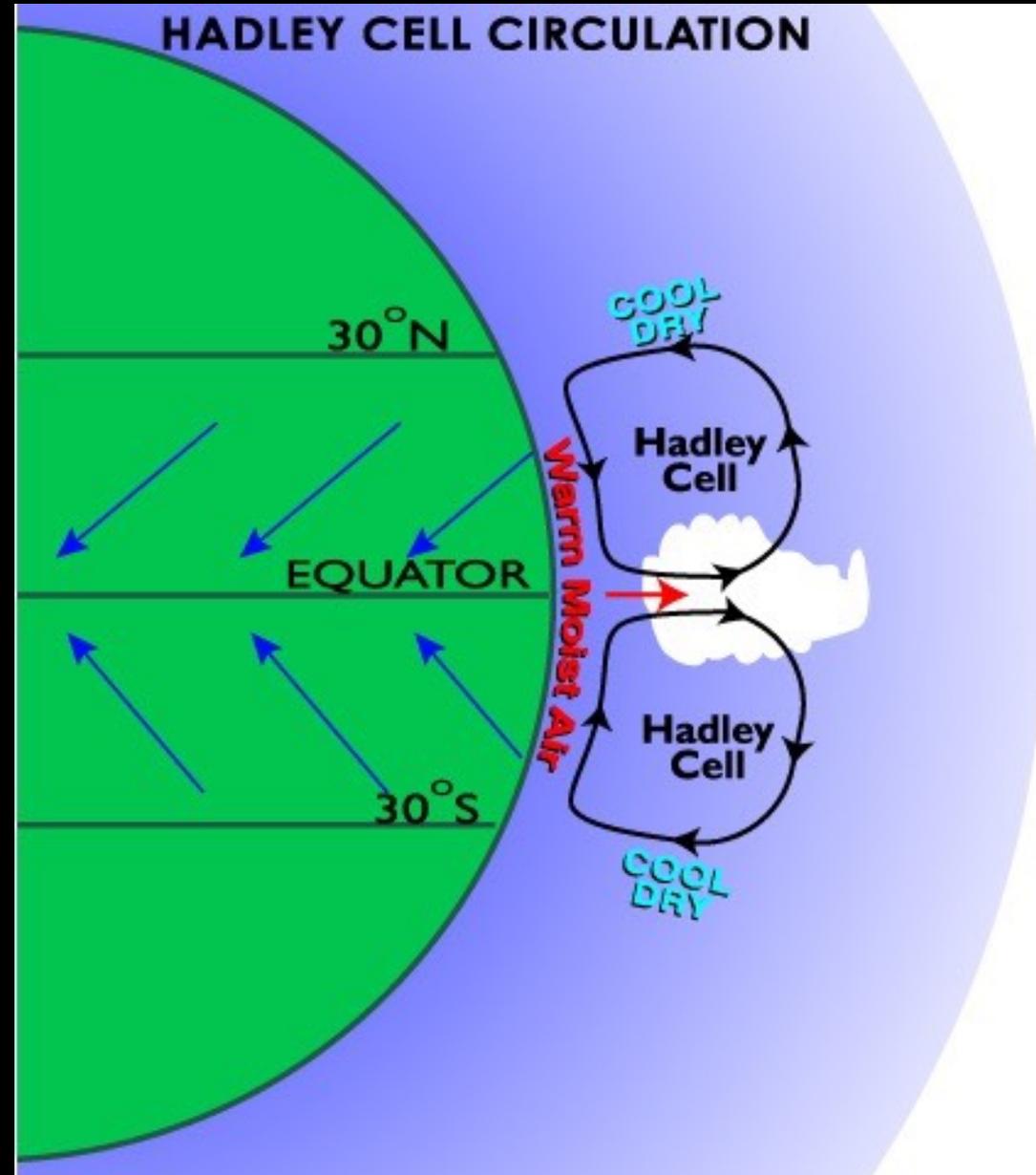
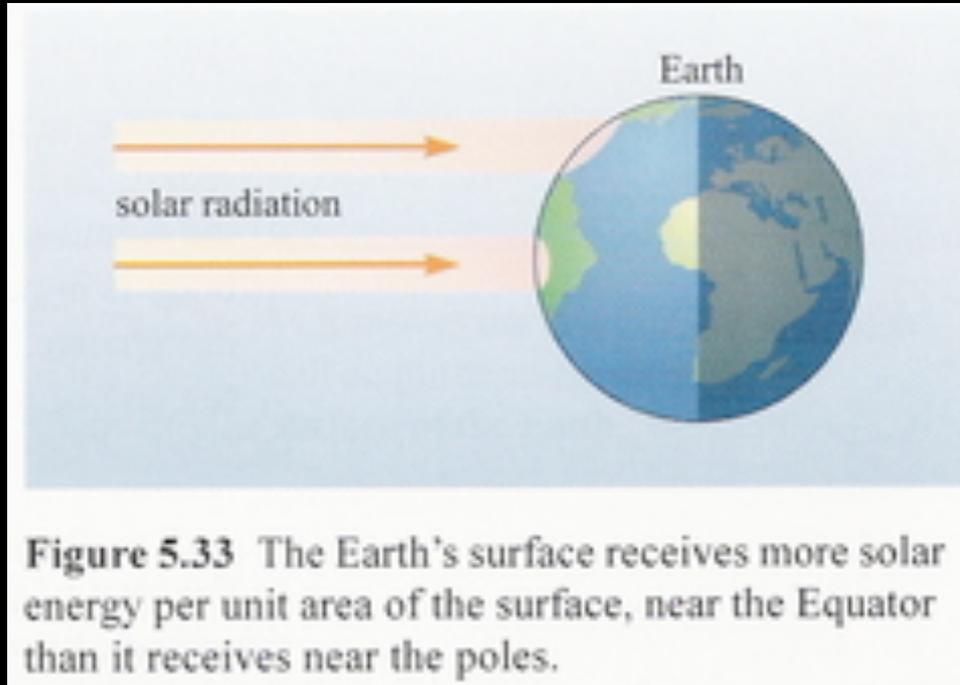
These are called
Hadley Cells



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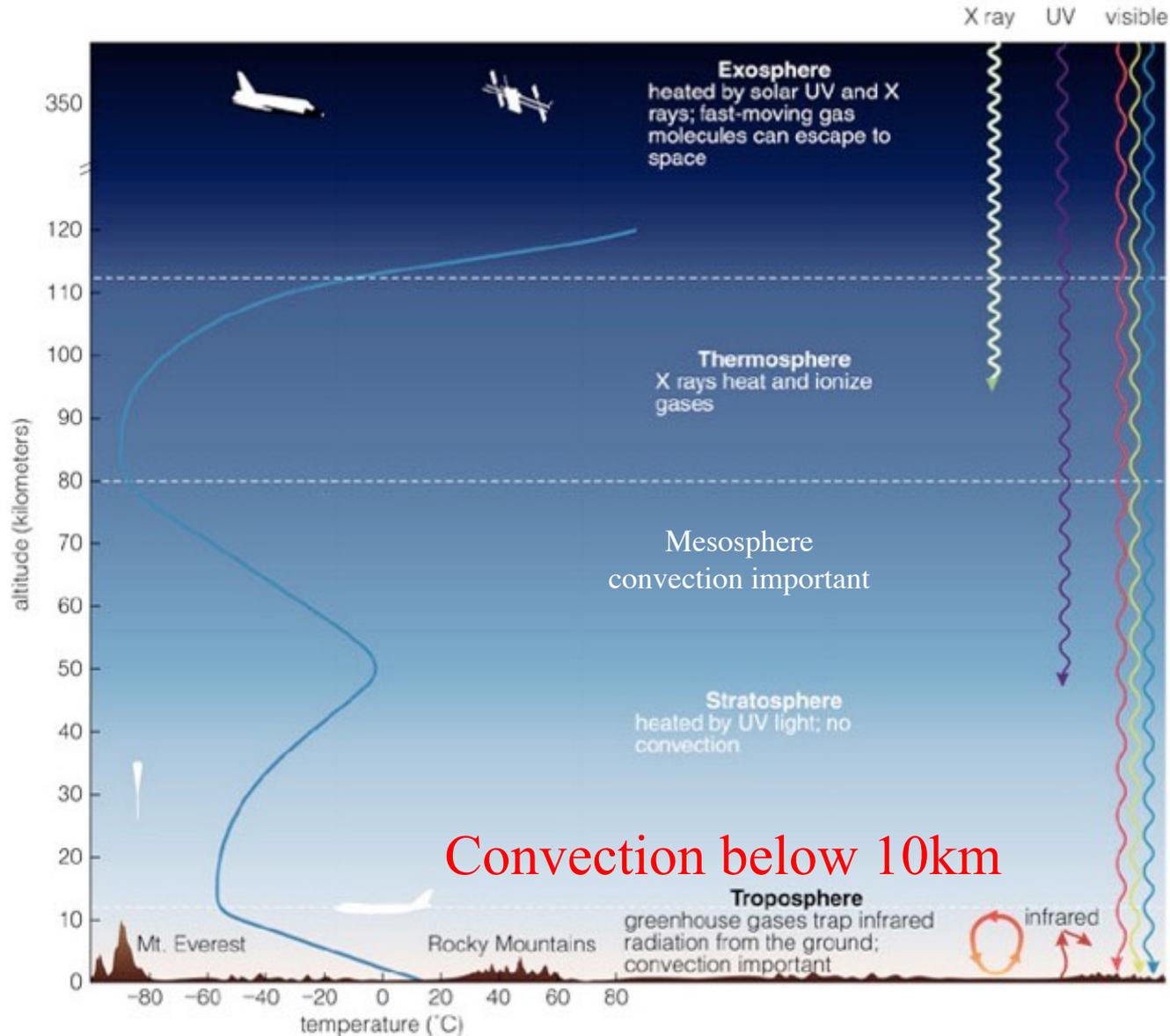
Hadley cells are similar to
convection in Earth's mantle.

Sunlight Drives Hadley Cells



This is how clouds form!
(hot moist air rises, cools,
and water droplets
precipitate out).

Atmospheric Convection



Prevailing Winds

Hadley cells do not flow solely North-South - they get deflected to the East and West for reasons that you will explore in a HW question. Planets with faster rotation have more deflection, and the single Hadley cells breaks into several independent ones.

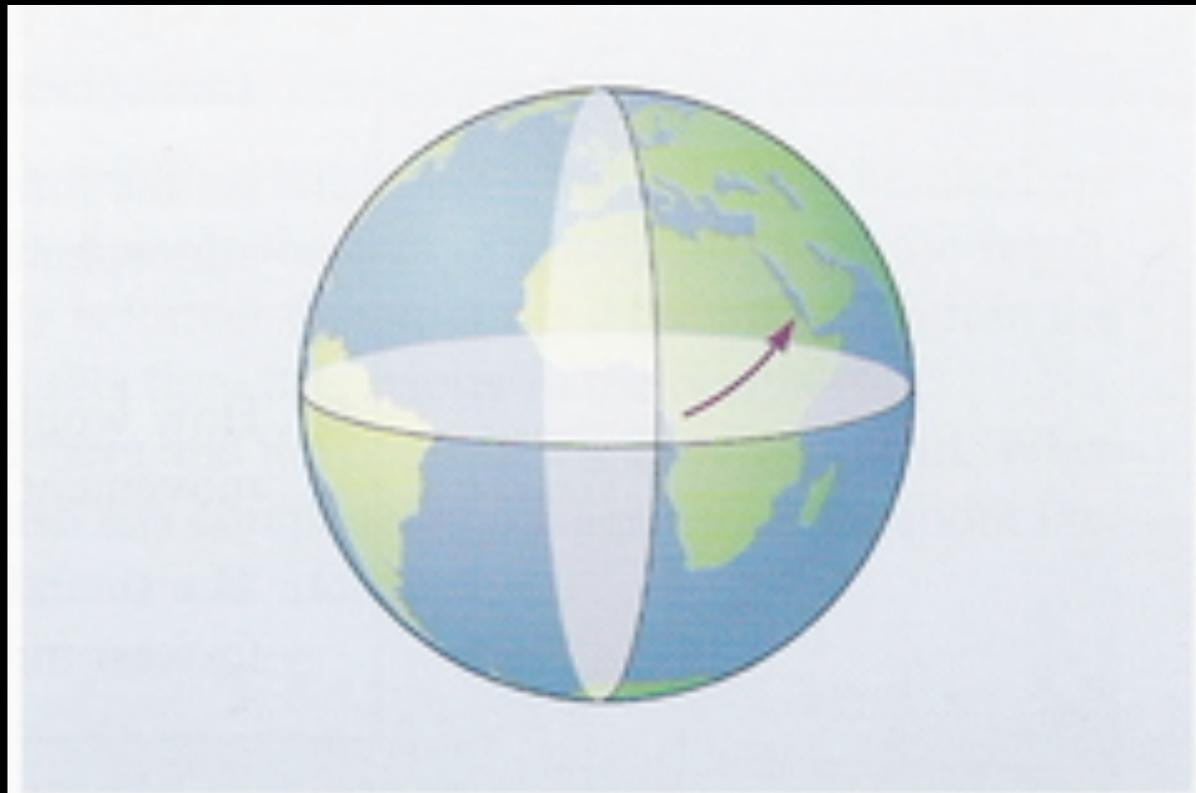
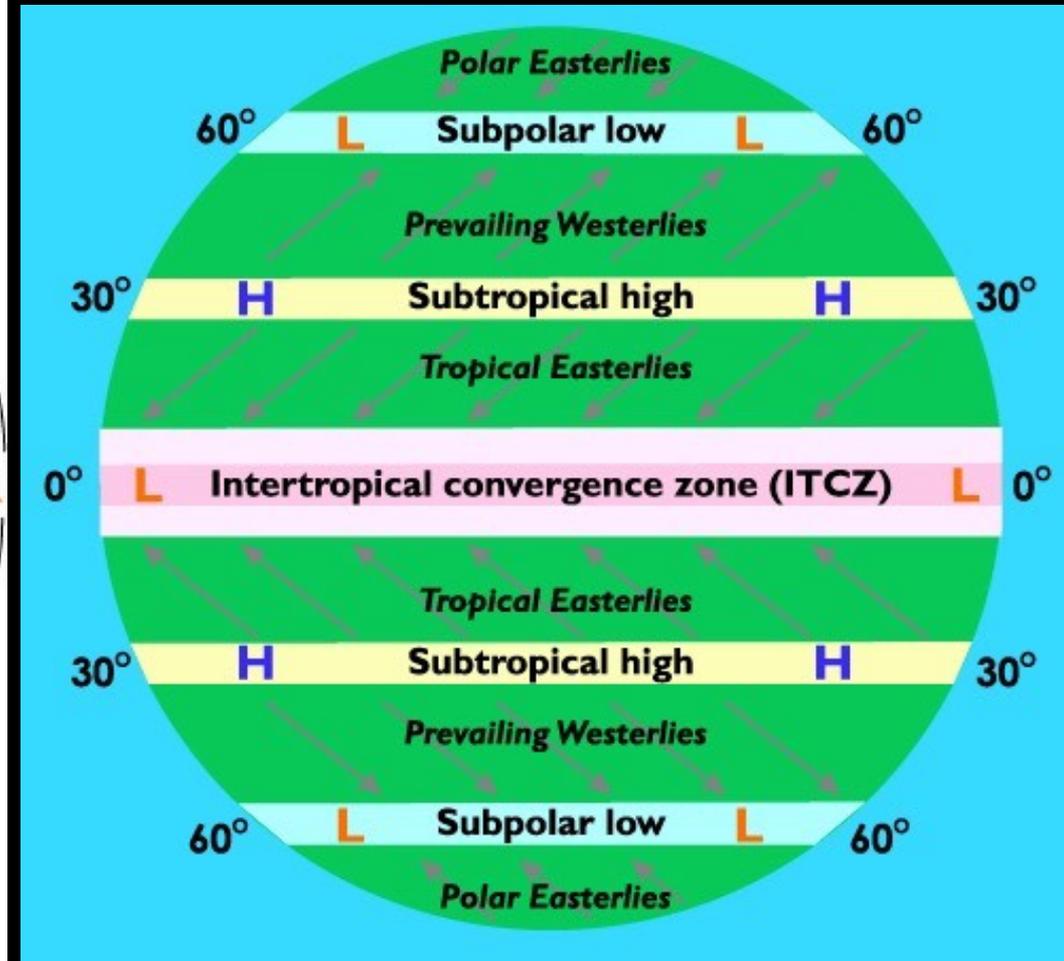
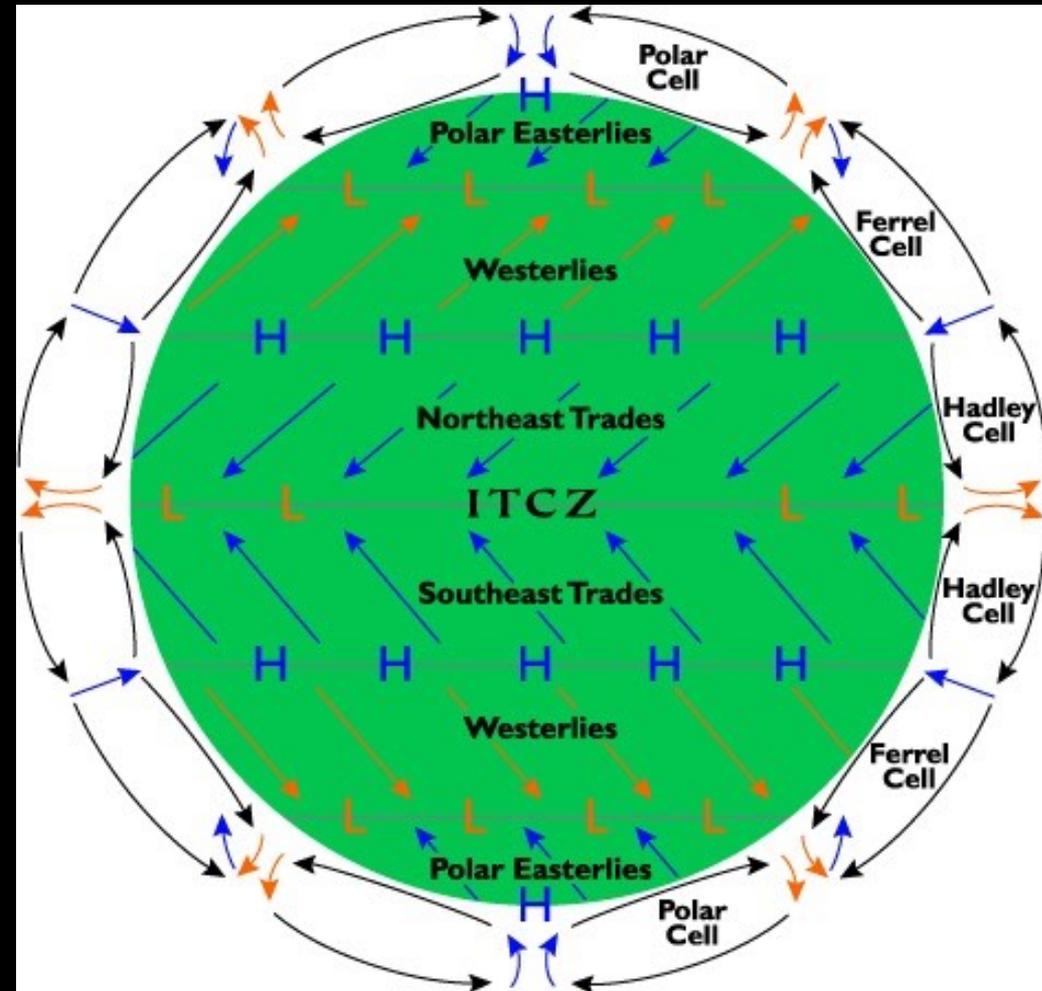


Figure 5.36 As it moves northwards, the top layer of the Hadley cell acquires an easterly motion relative to the surface of the Earth.

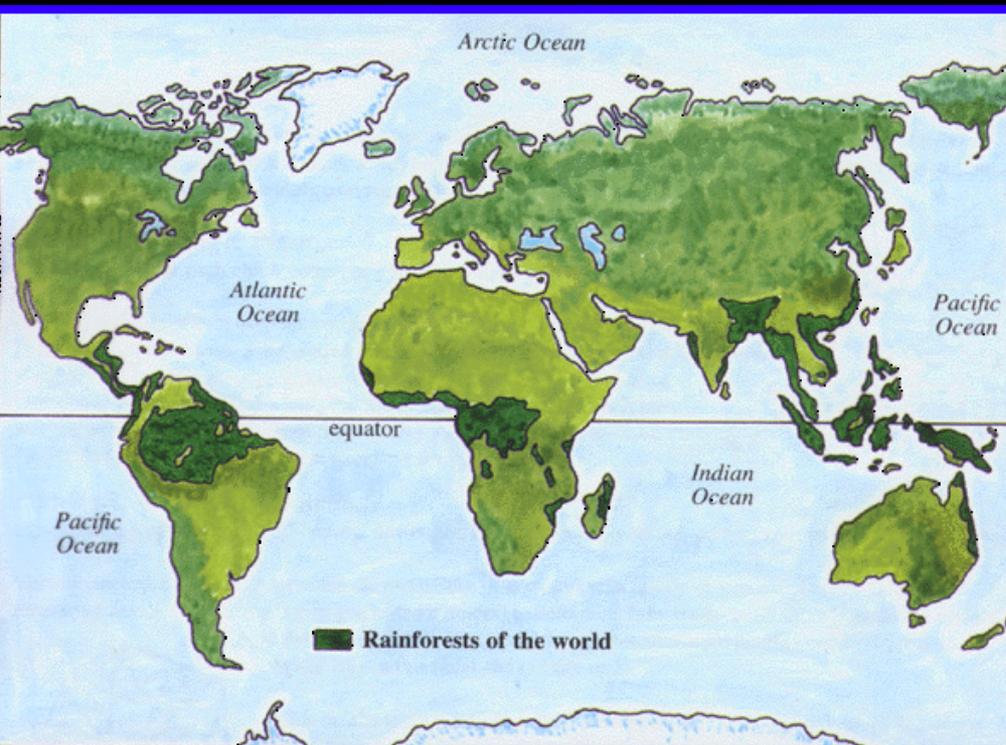
Hadley Cells and Surface Winds



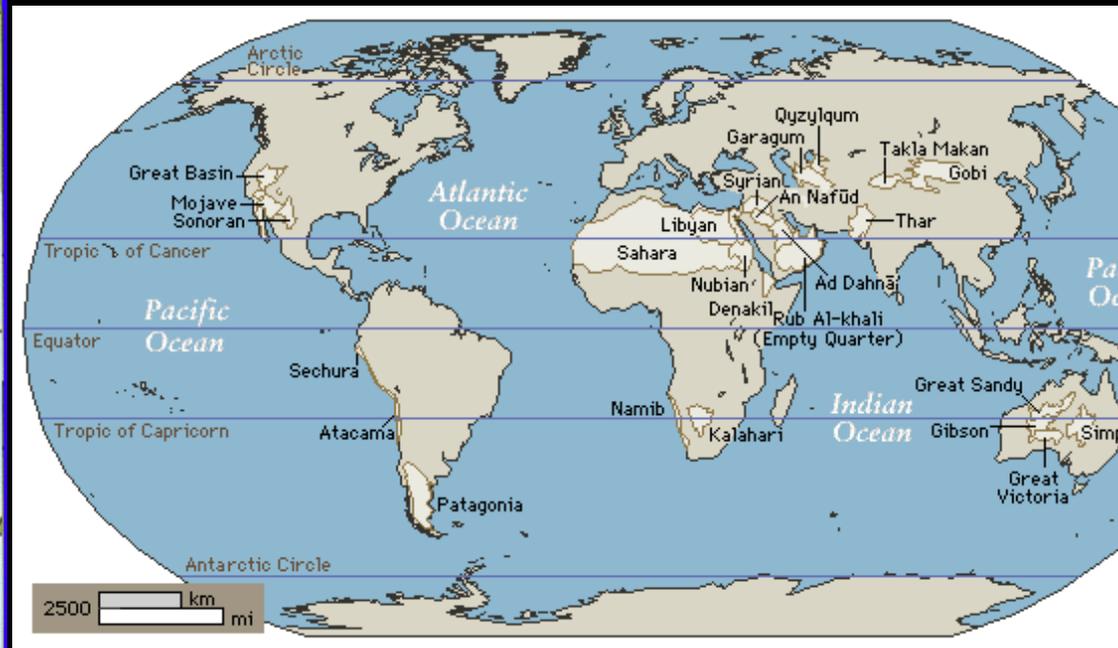
World Climate

Rainforests occur where air is forced upward - it cools, clouds form, and rain falls.

Deserts occur when cool dry air descends - no clouds form.



Tropical Rainforests



Deserts

Earth has 24 Hour Rotation

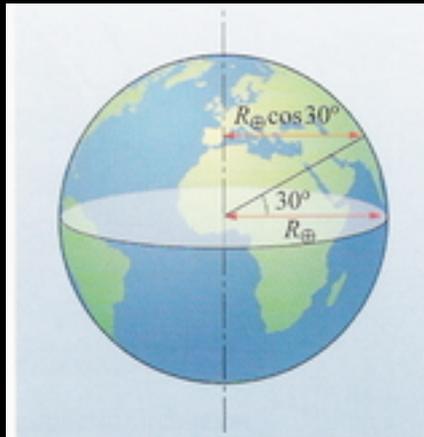


Figure 5.35 The air in a Hadley cell moves closer to the Earth's spin axis as it travels towards the pole. At 30° N the distance has decreased from R_{\oplus} to $R_{\oplus} \cos 30^{\circ}$.

Earth's Radius

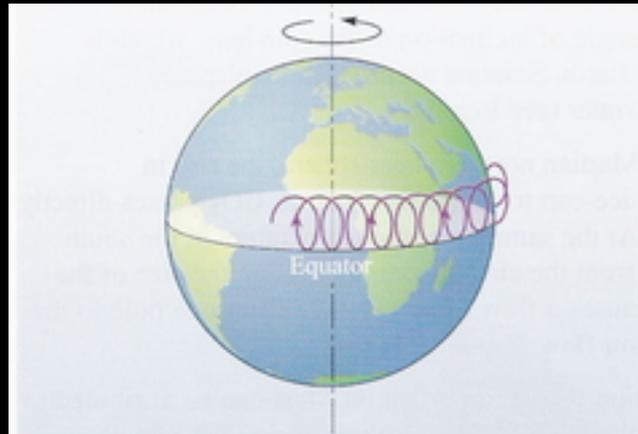
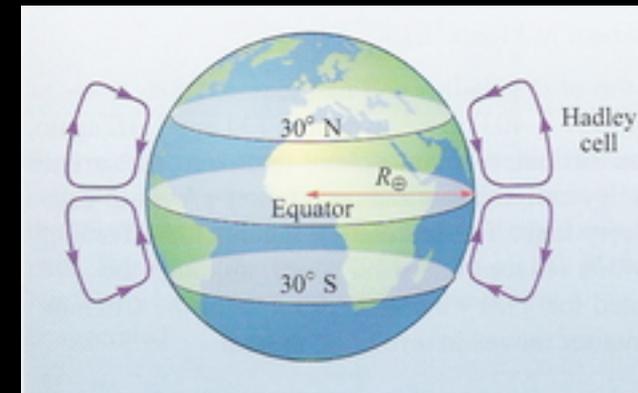


Figure 5.37 The Earth's rotation causes the Hadley cell to spiral. A piece of atmosphere that remains in the Hadley cell follows this flattened and tilted spiral path. This figure shows part of the tropical cell in the Northern Hemisphere; the vertical component is exaggerated.

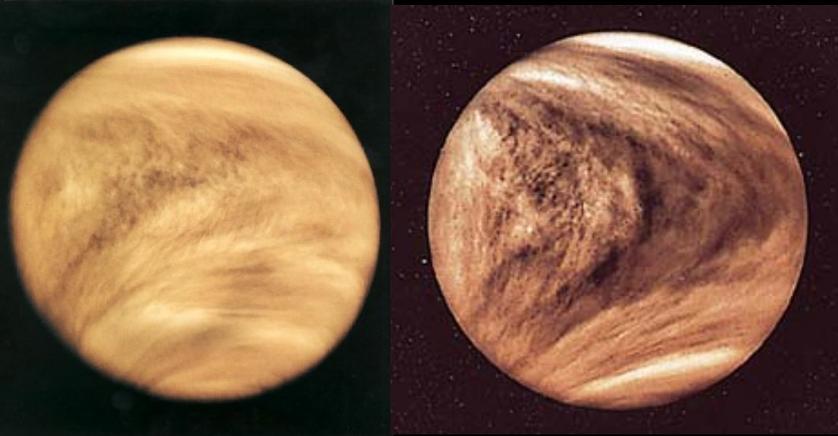
How Hurricanes get to the US



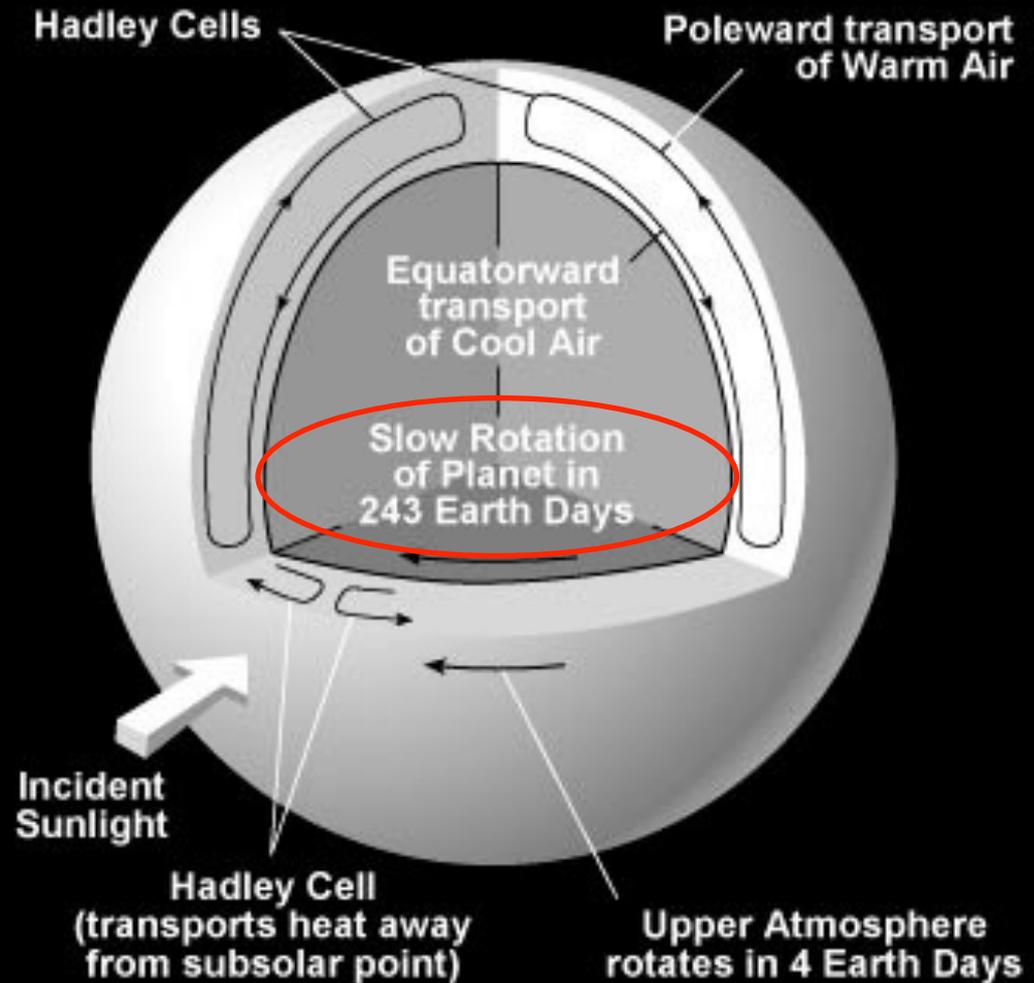
3 Hadley Cells North of Equator

Hadley Cells on Venus

What are Hadley Cells?
Convection!

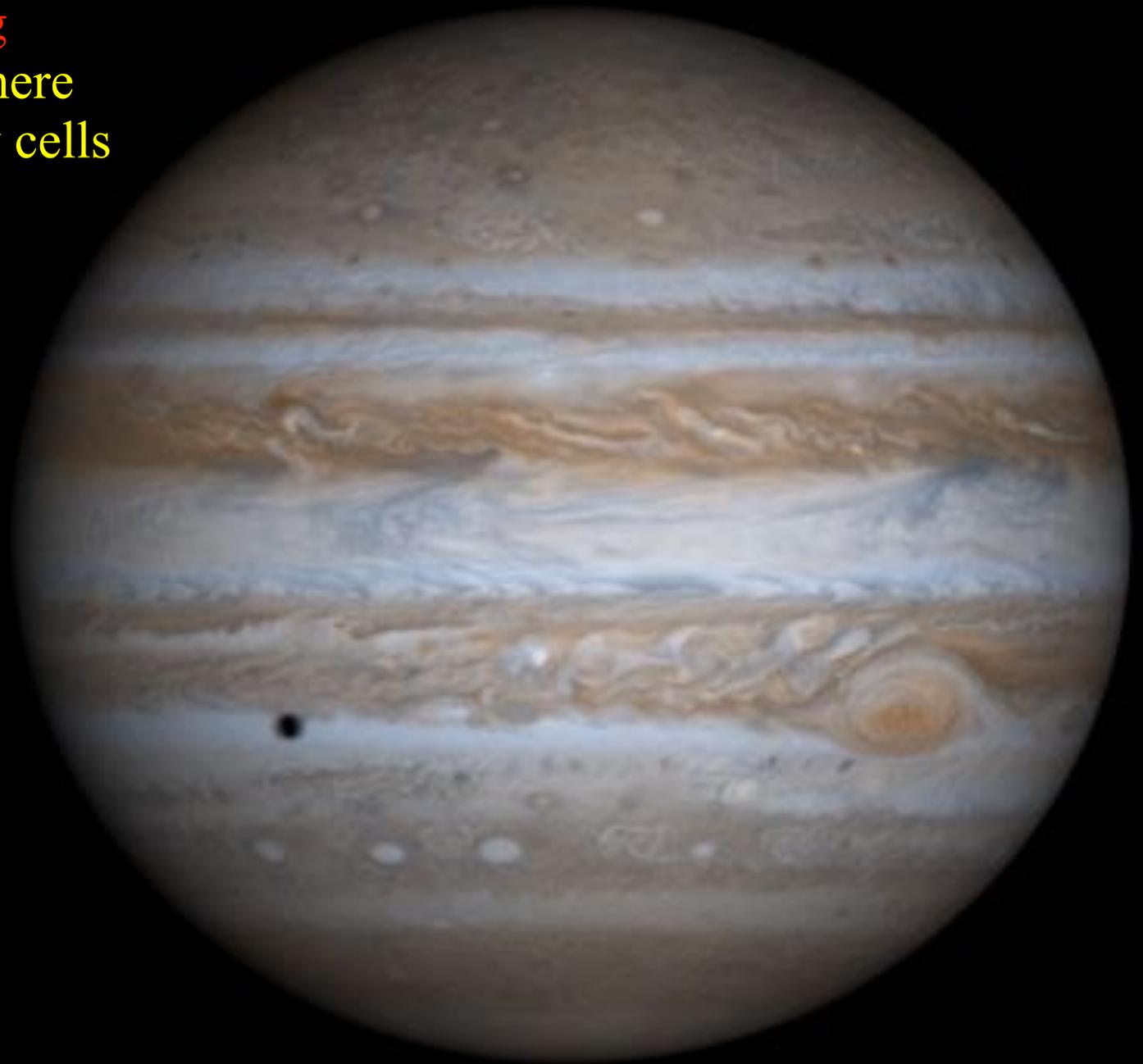
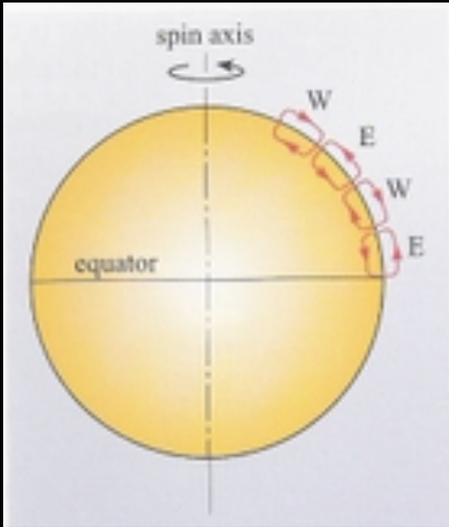


On a **slowly-rotating** planet like Venus, there is one Hadley cell in the N. hemisphere and one in the South.

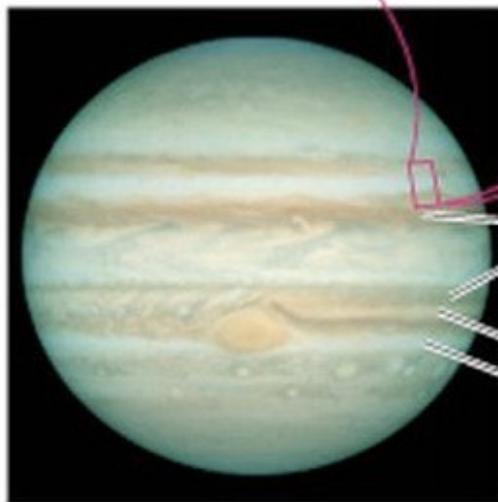
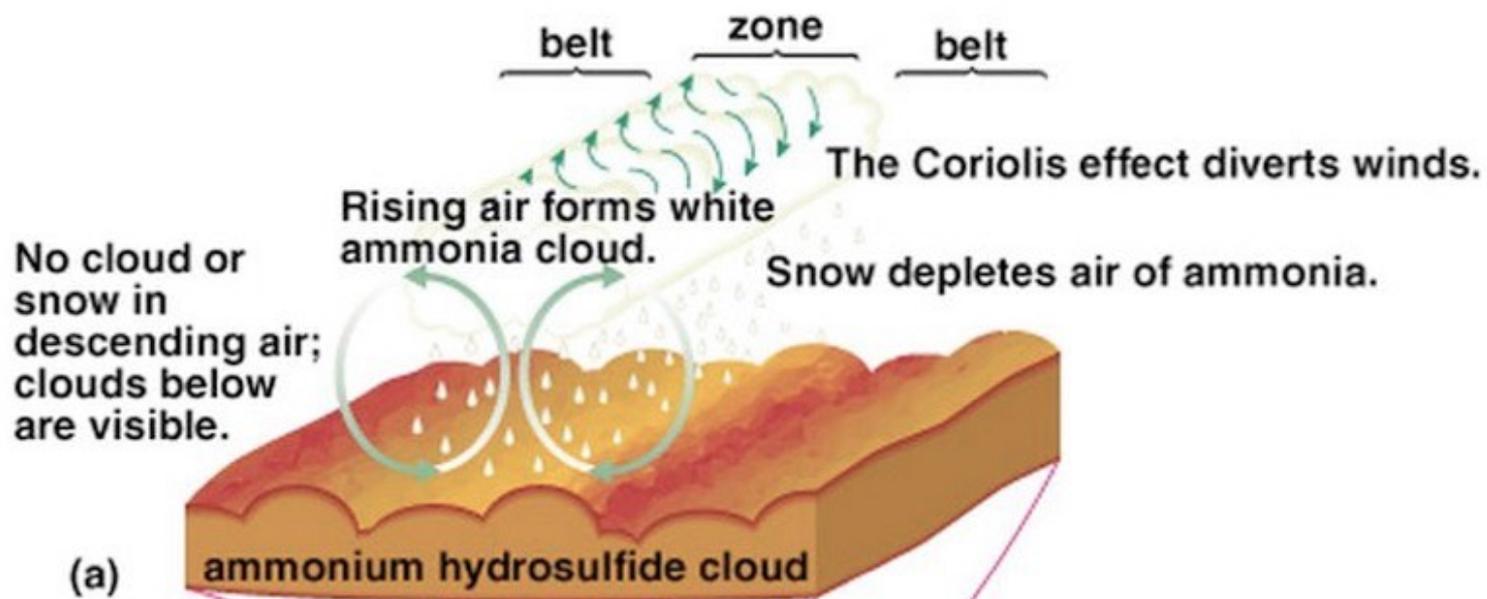


Hadley Cells on Jupiter

On a rapidly rotating planet like Jupiter, there are about six Hadley cells per hemisphere

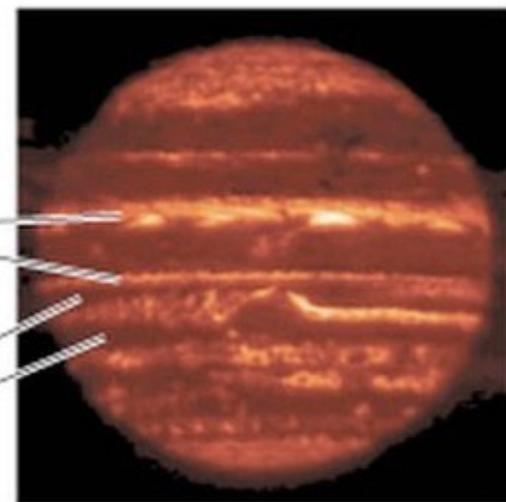


Belts and Zones



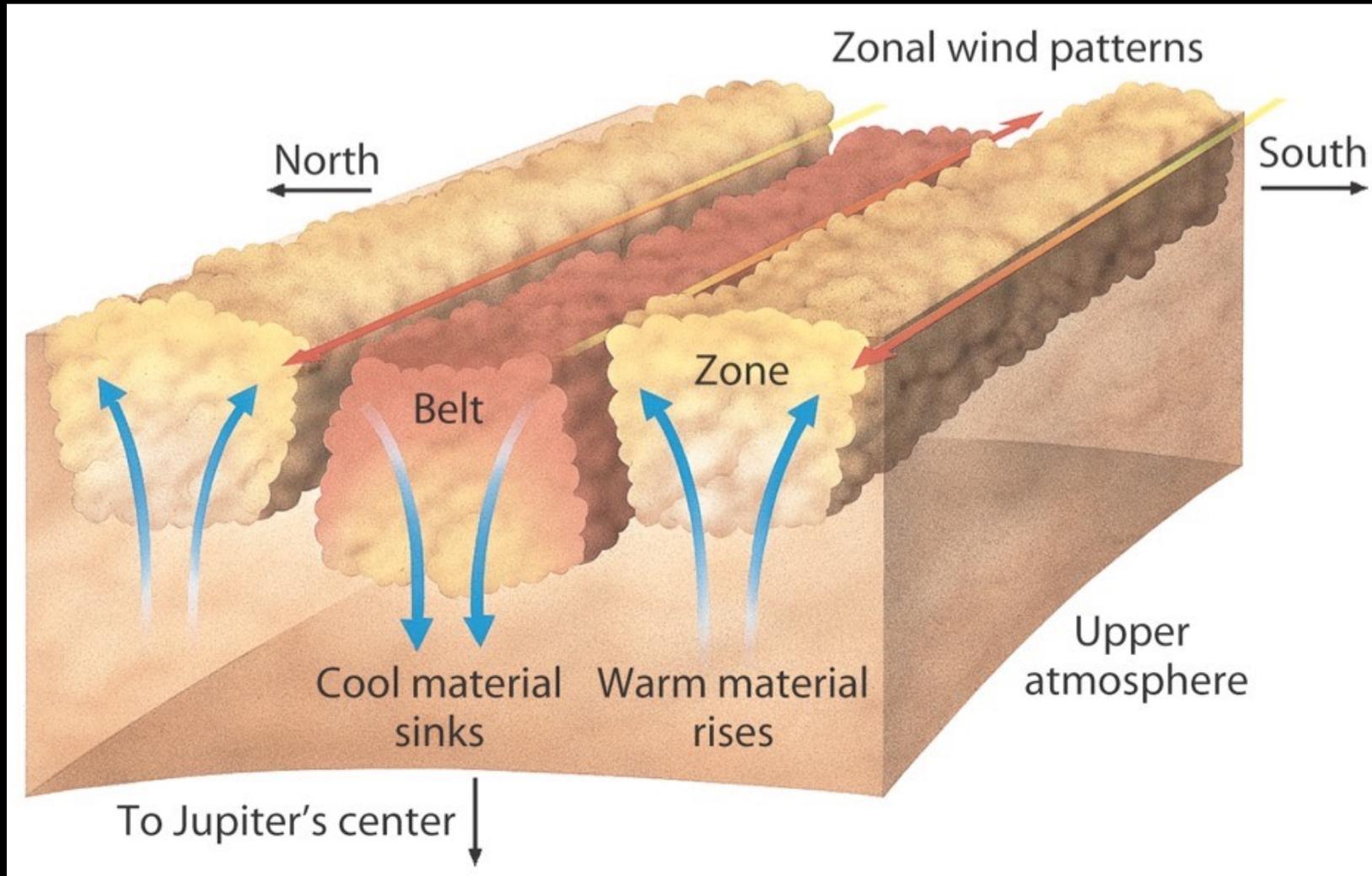
Belts are warm, red, low-altitude clouds.

Zones are cool, white, high-altitude clouds.



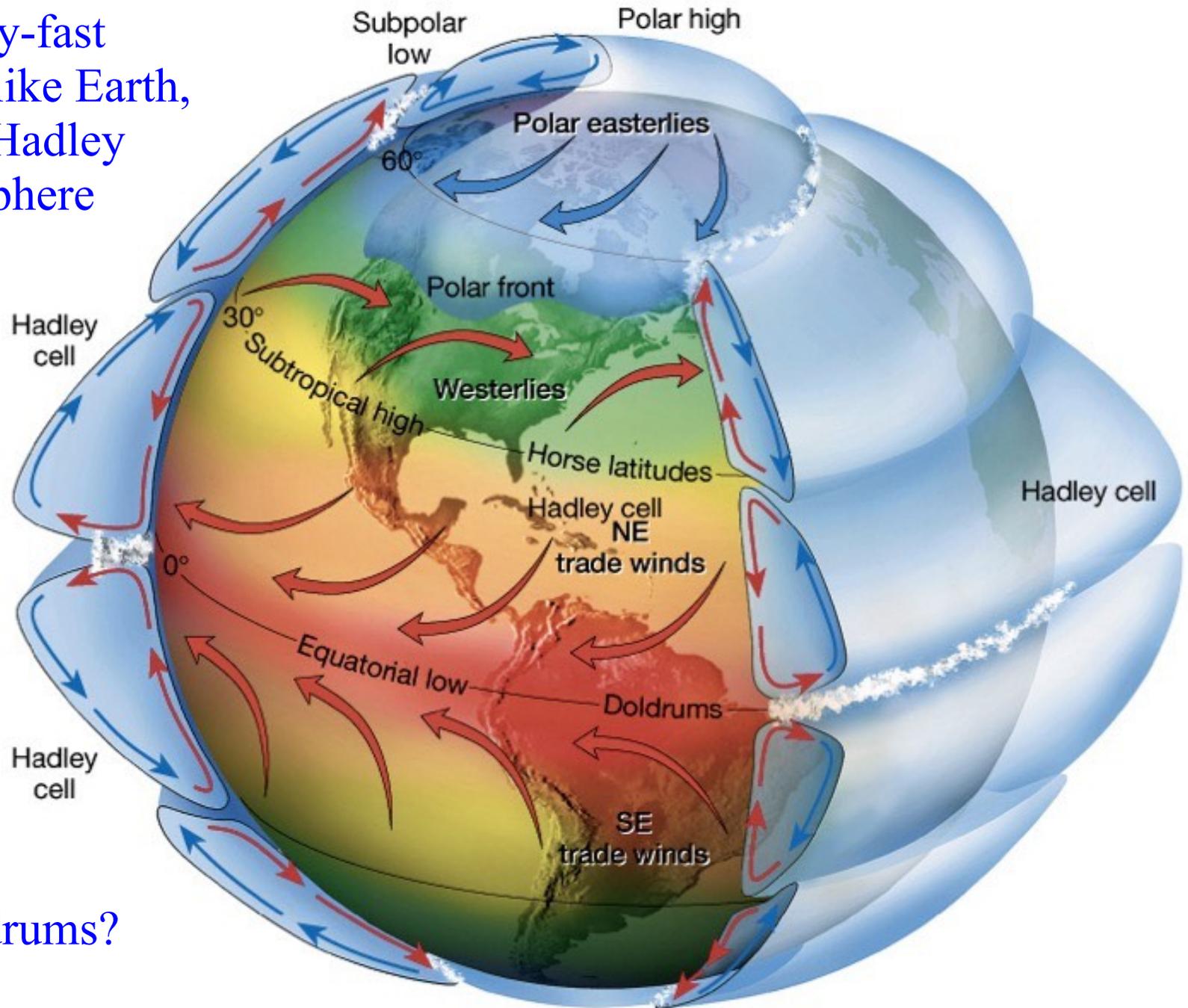
Belts (downflow) and Zones (upwelling air)

Cloud formation on the Giant Planets



Hadley Cells on Earth

On a moderately-fast rotating planet like Earth, there are three Hadley cells per hemisphere

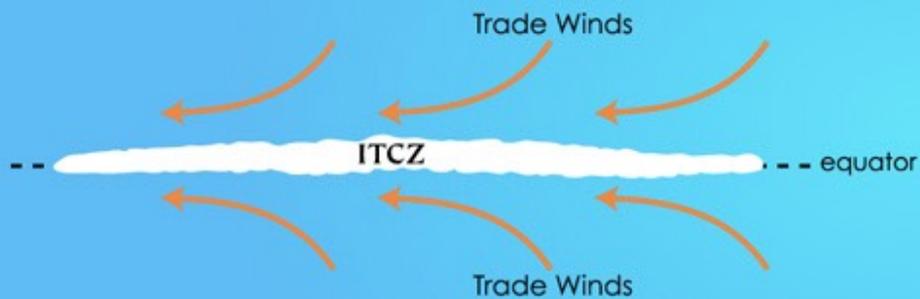


What are Doldrums?

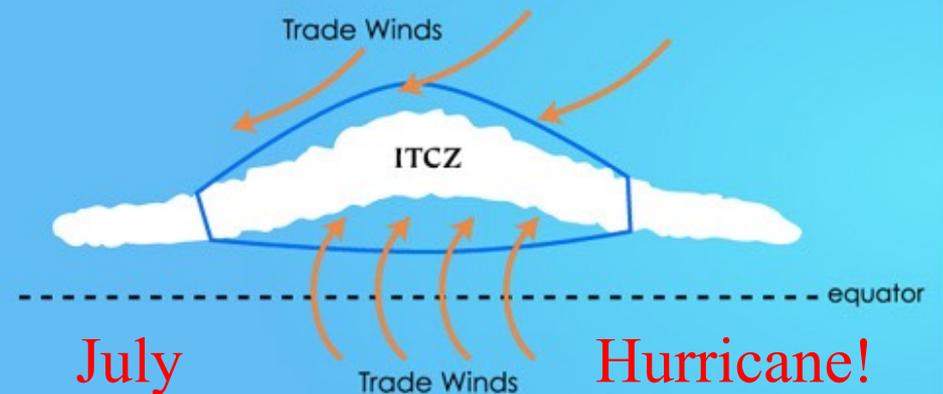
Hurricane Formation



ITCZ



January: No Hurricane!



July

Hurricane!

Hurricanes!



Hurricanes!

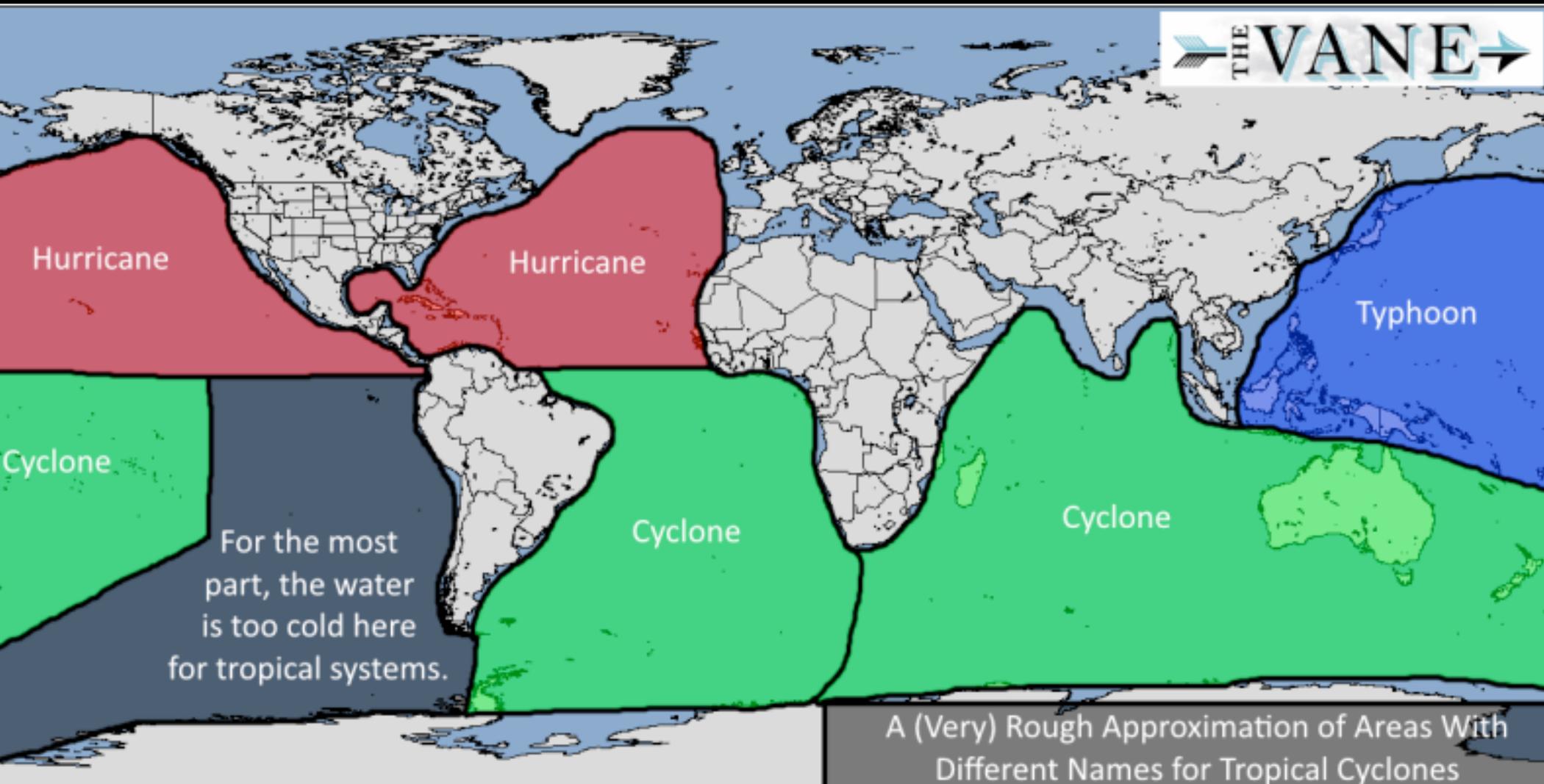
- 100 mph winds
- cyclone motion
- all aimed at U.S.

Hurricane, Typhoon, Cyclone?

Hurricanes - Atlantic, Eastern Pacific

Typhoon - Western Pacific

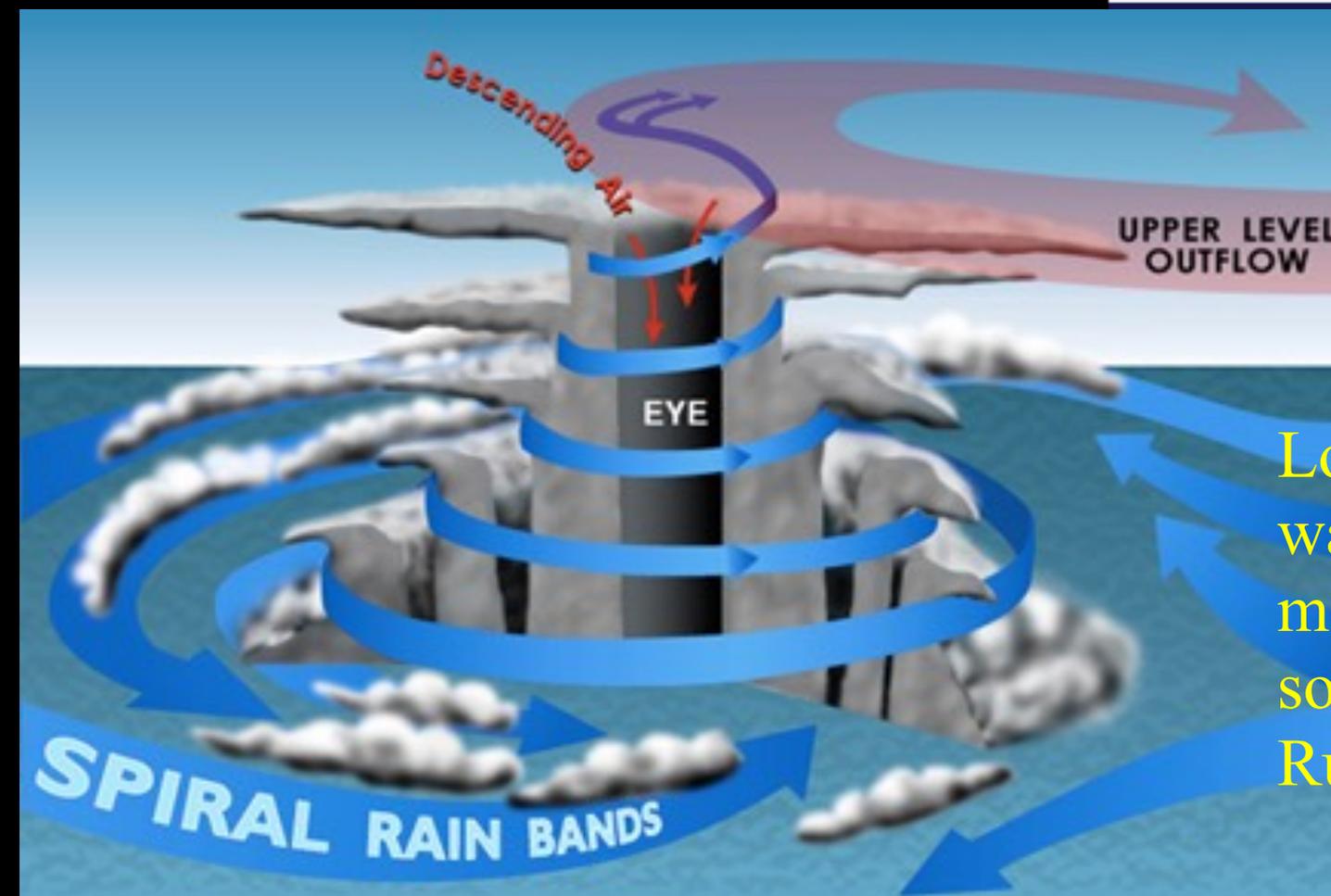
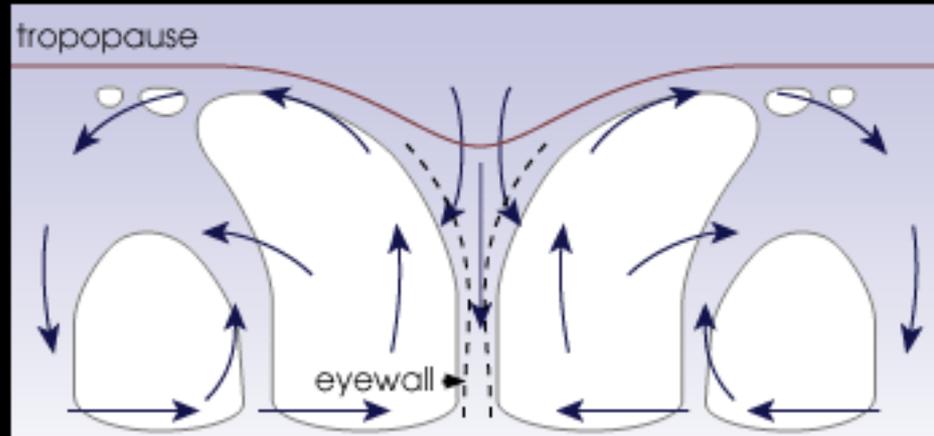
All are called Tropical Cyclones



Are Hurricanes Damaging?



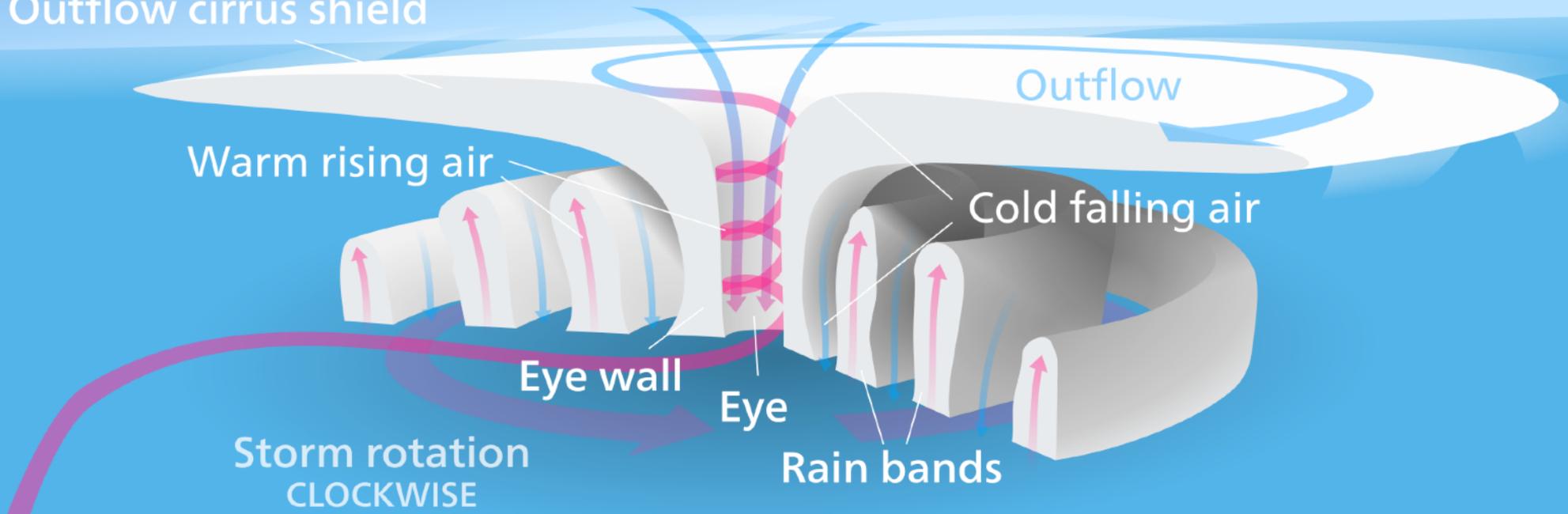
How Does a Hurricane Work?



Local convection system.
warm sea water leads to
moist air and a power
source for the hurricane.
Runaway condensation!



Outflow cirrus shield



Outflow

Warm rising air

Cold falling air

Eye wall

Eye

Rain bands

Storm rotation
CLOCKWISE

Hurricane interference

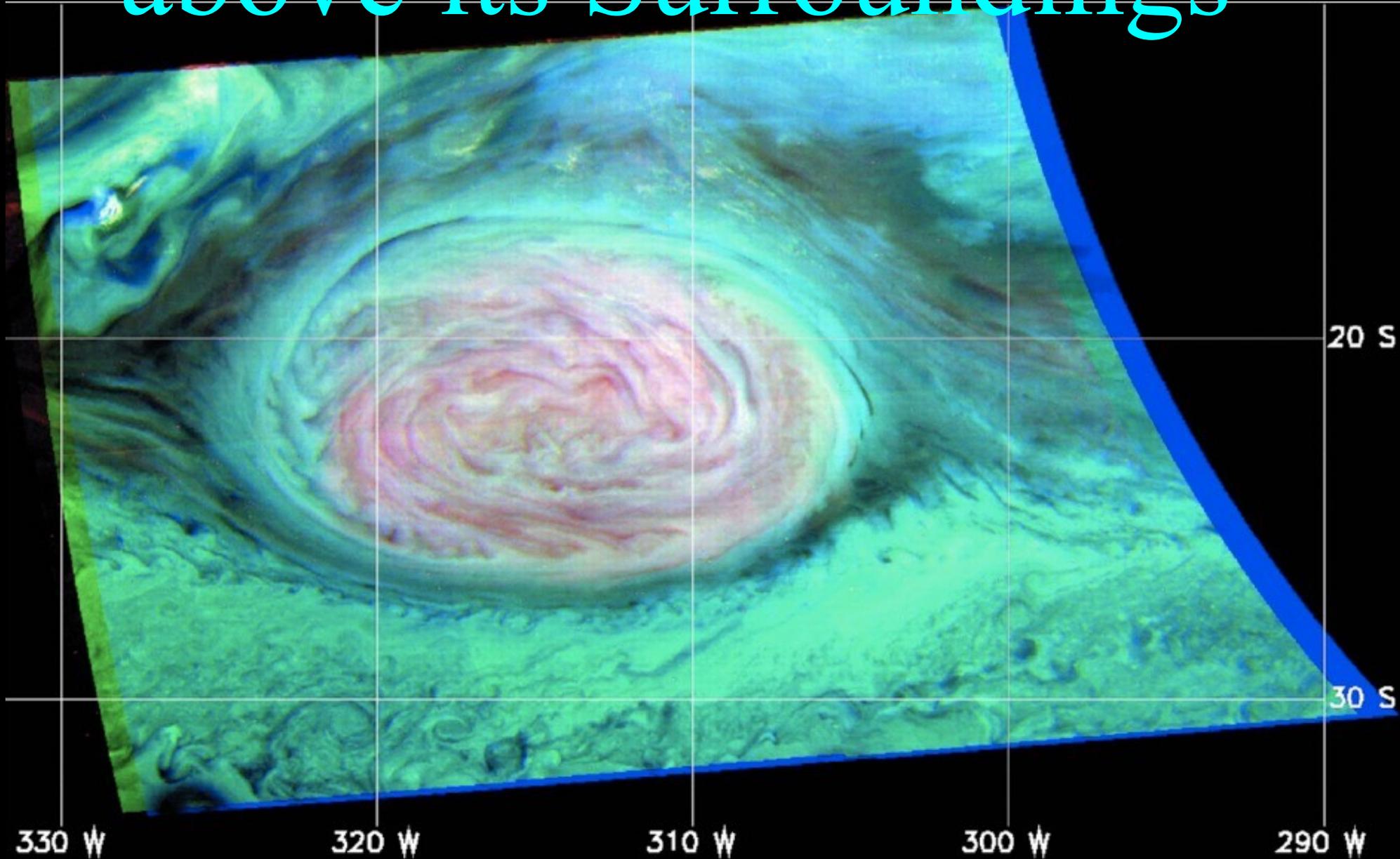


Cooler ocean temperatures in blue. The second hurricane weakened significantly when it crossed the path of the first.

Jupiter **Red** Spot is a giant
spinning Hurricane!



The Red Spot is $\sim 8\text{km}$
above its Surroundings



Gone but not Forgotten: Neptune's Hurricane

- 
- Neptune's Great Dark Spot
 - imaged by Voyager in 1989
 - similar in size and location to Jupiter's Great **Red** Spot
 - major changes over the flyby
 - gone by 1994! (HST data)
 - then a new spot formed in the Northern Hemisphere!

Condensation Flow on Mars

On Mars, in southern winter, 1/3 of Mars' atmosphere condenses out at the South Pole!

The main component of the atmosphere can freeze!

Earth: Water is liquid, gaseous, or solid
Mars: Carbon dioxide is gaseous or solid

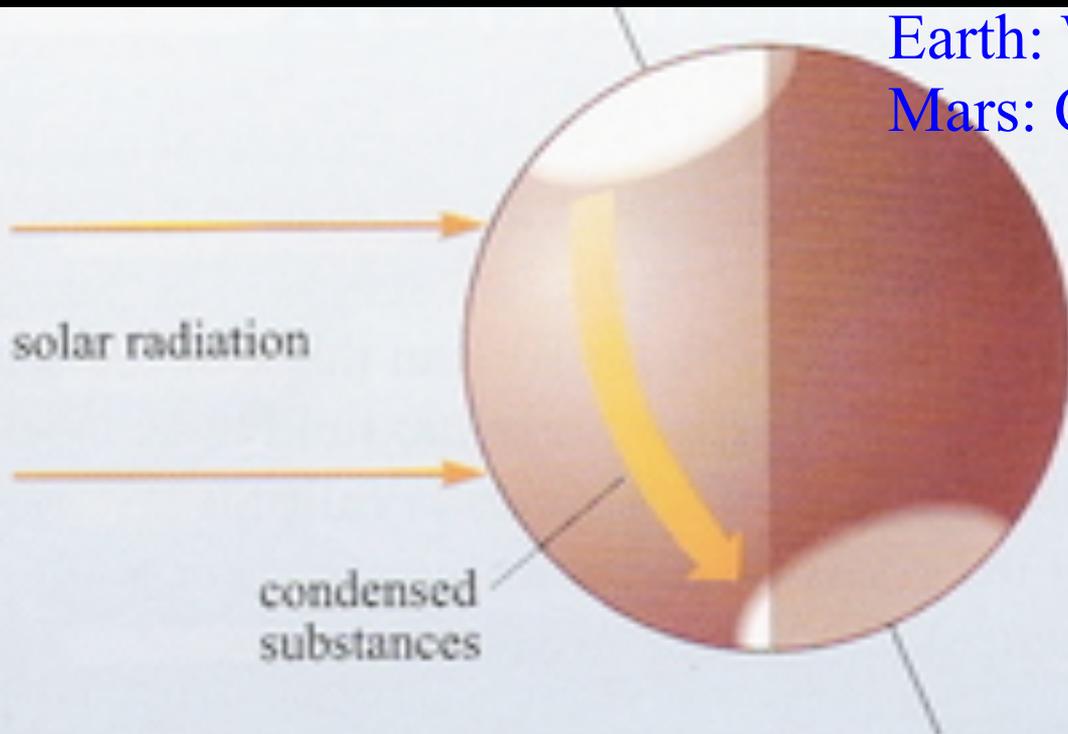


Figure 5.41 During summer in the Martian northern hemisphere, condensed substances (mostly CO_2 with some H_2O) evaporate and migrate to the southern pole, where they condense as ices.