The Atmosphere

ES 383

Colby at Bigelow, September 2019

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To understand the motion of the atmosphere (and the ocean), we use fluid dynamics:

Navier-Stokes equations

$$\frac{dv}{dt} = -(1/\rho)\nabla p - g(r/r) + (1/\rho)\left[\nabla \cdot (\mu \nabla v) + \nabla(\lambda \nabla \cdot v)\right]$$

$$c_v \frac{dT}{dt} + p\frac{d\alpha}{dt} = q + f$$

$$\frac{d\rho}{dt} + \rho\nabla \cdot v = 0$$

$$p = \rho RT.$$

To understand the motion of the atmosphere (and the ocean), we use fluid dynamics:

Navier-Stokes equations

Equations are chaotic, which limits prediction time frame

Turbulence is approximated

The main variables are pressure, density, temperature, and velocity

- Reference pressure = sea level = 1 atm = 1013 mbars = 760 mm Hg
  - air density < average ➔ low pressure, hence rises
  - air density > average ➔ high pressure, hence sinks

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Atmospheric circulation: Begin with non-rotating earth

Energy is spread unevenly on a sphere

1. Footprint…

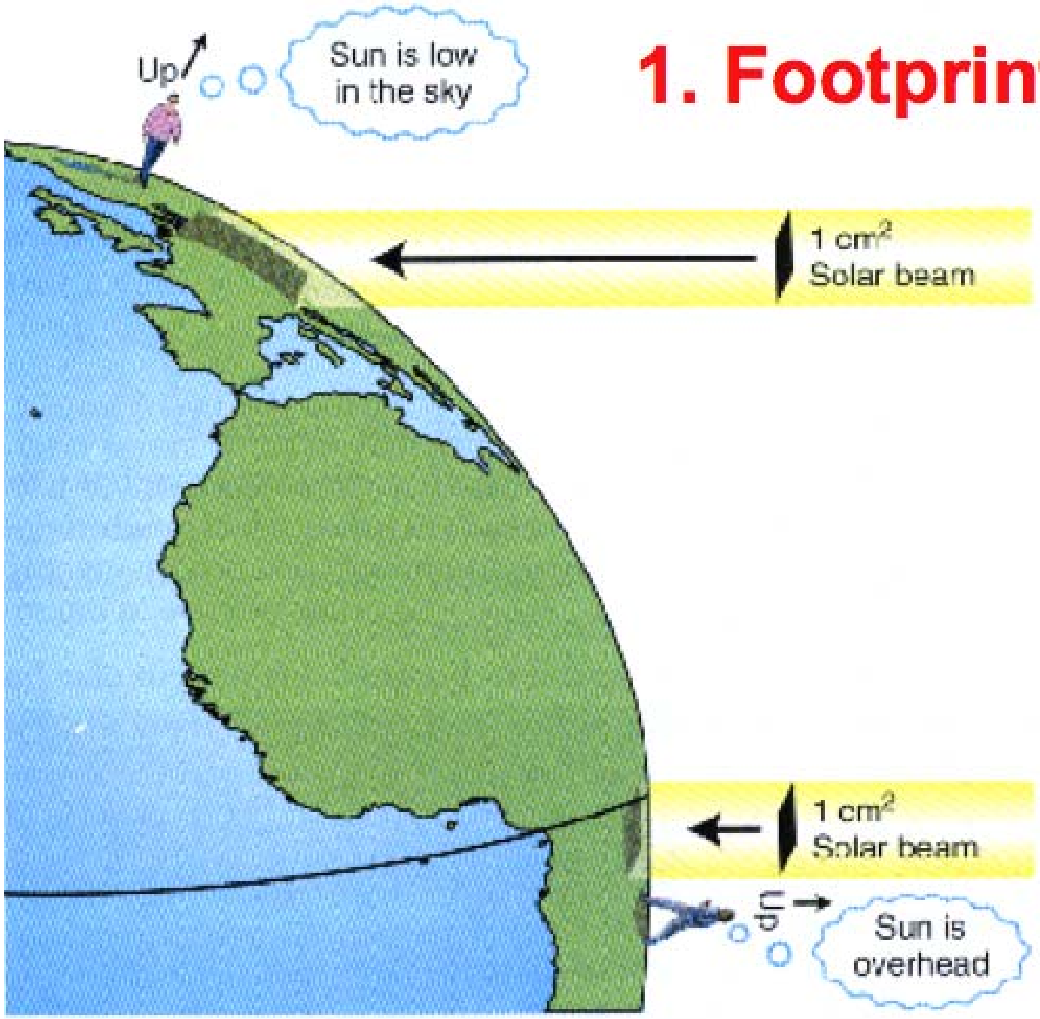
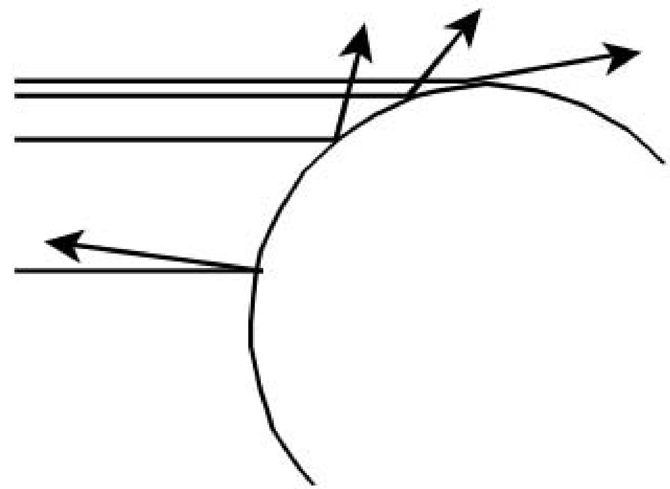
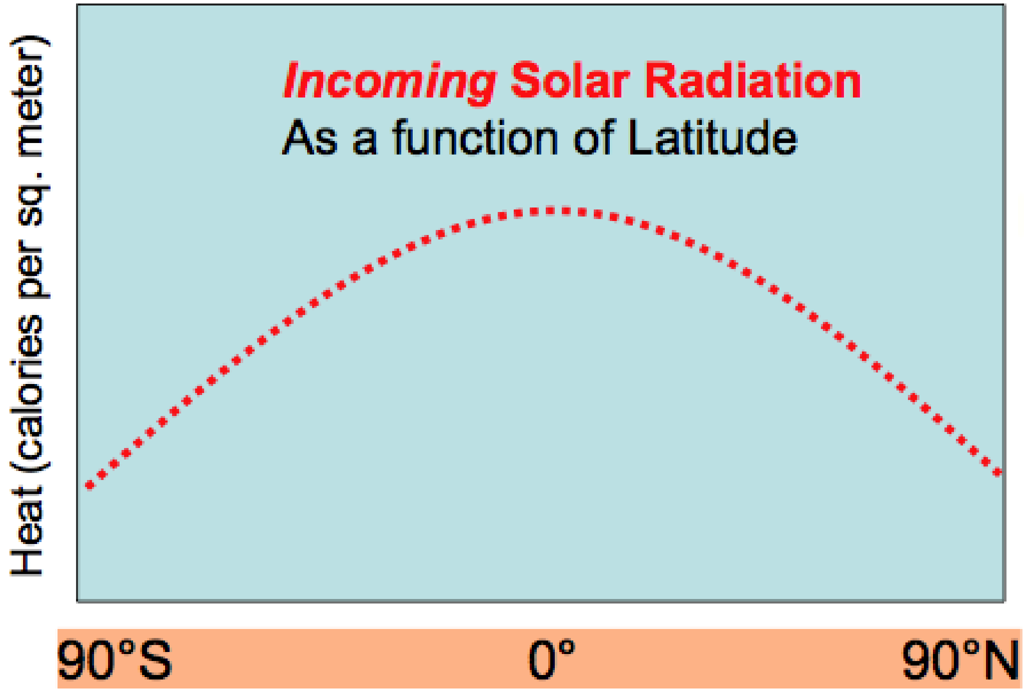
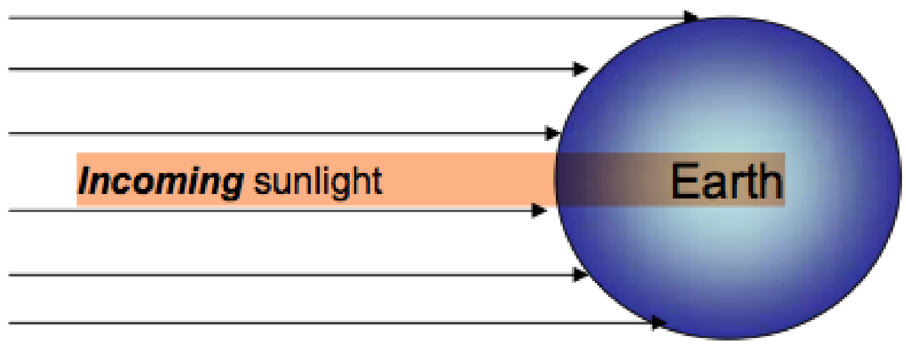


Image: David Townsend

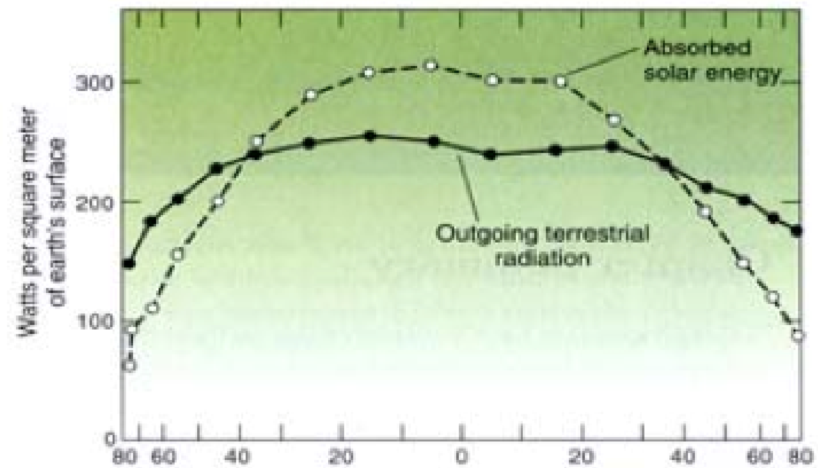
2. Reflection

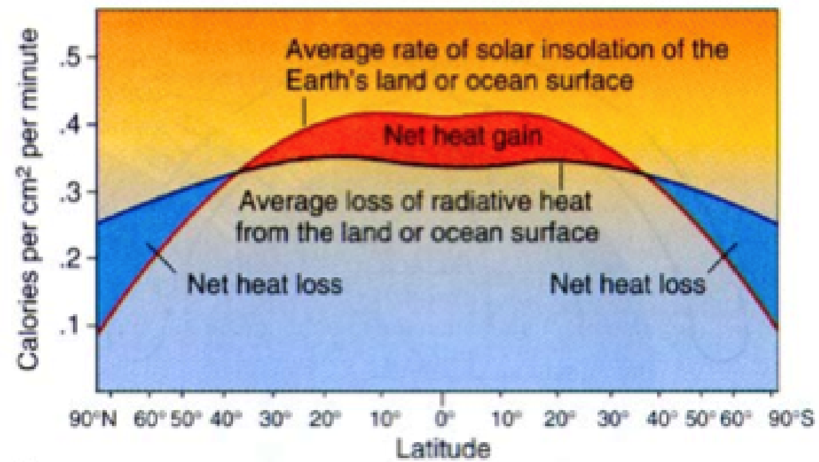






Incoming vs. Outgoing Radiation





? How can more heat be lost at poles than received? …

Image: David Townsend

Net Energy Transport Systems:

= Latitudinal Heat Pump

1. Atmospheric Circulation
2. Ocean Currents.

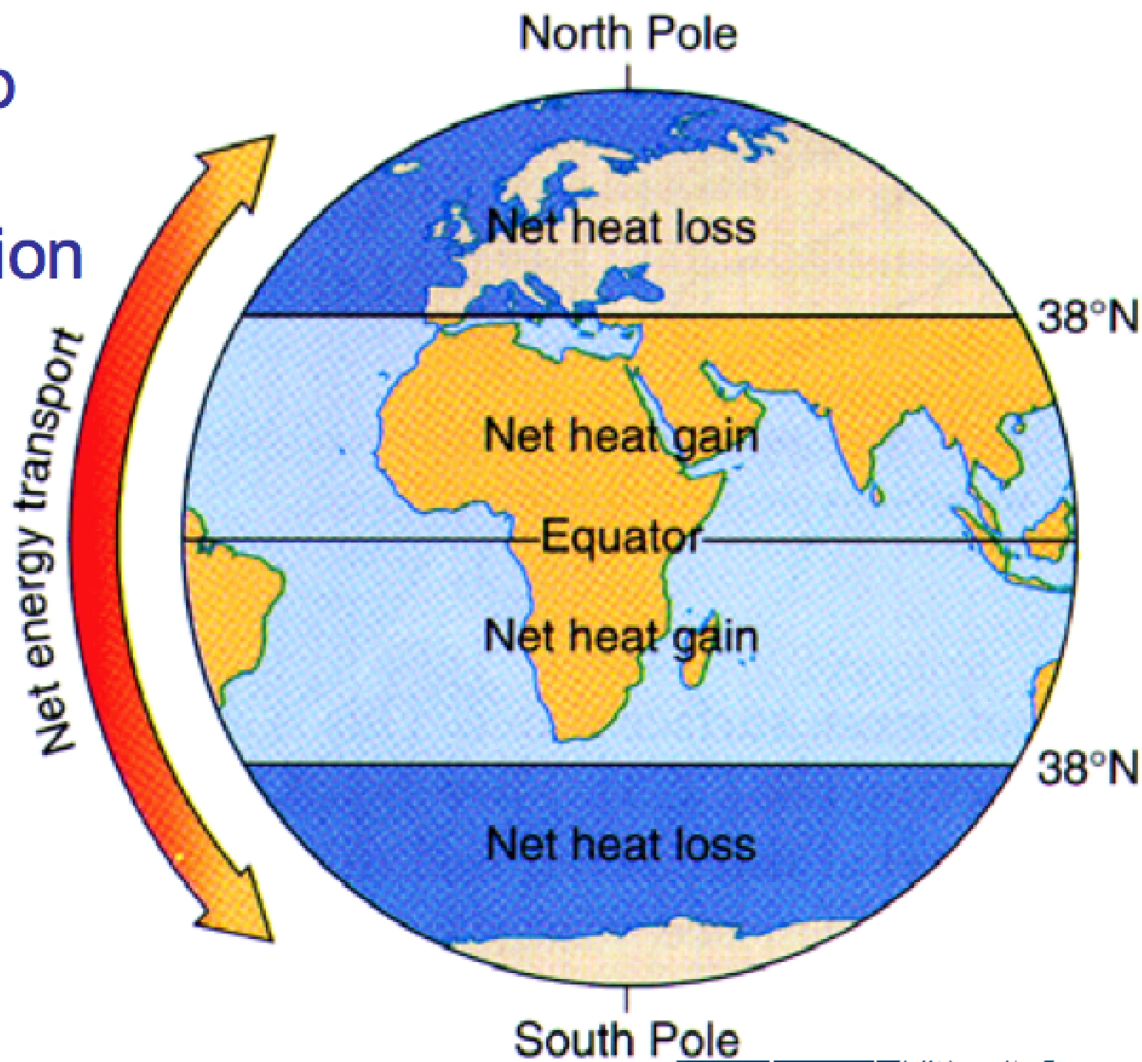


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Image: David Townsend

Basic Principle of an Atmospheric Convection Cell

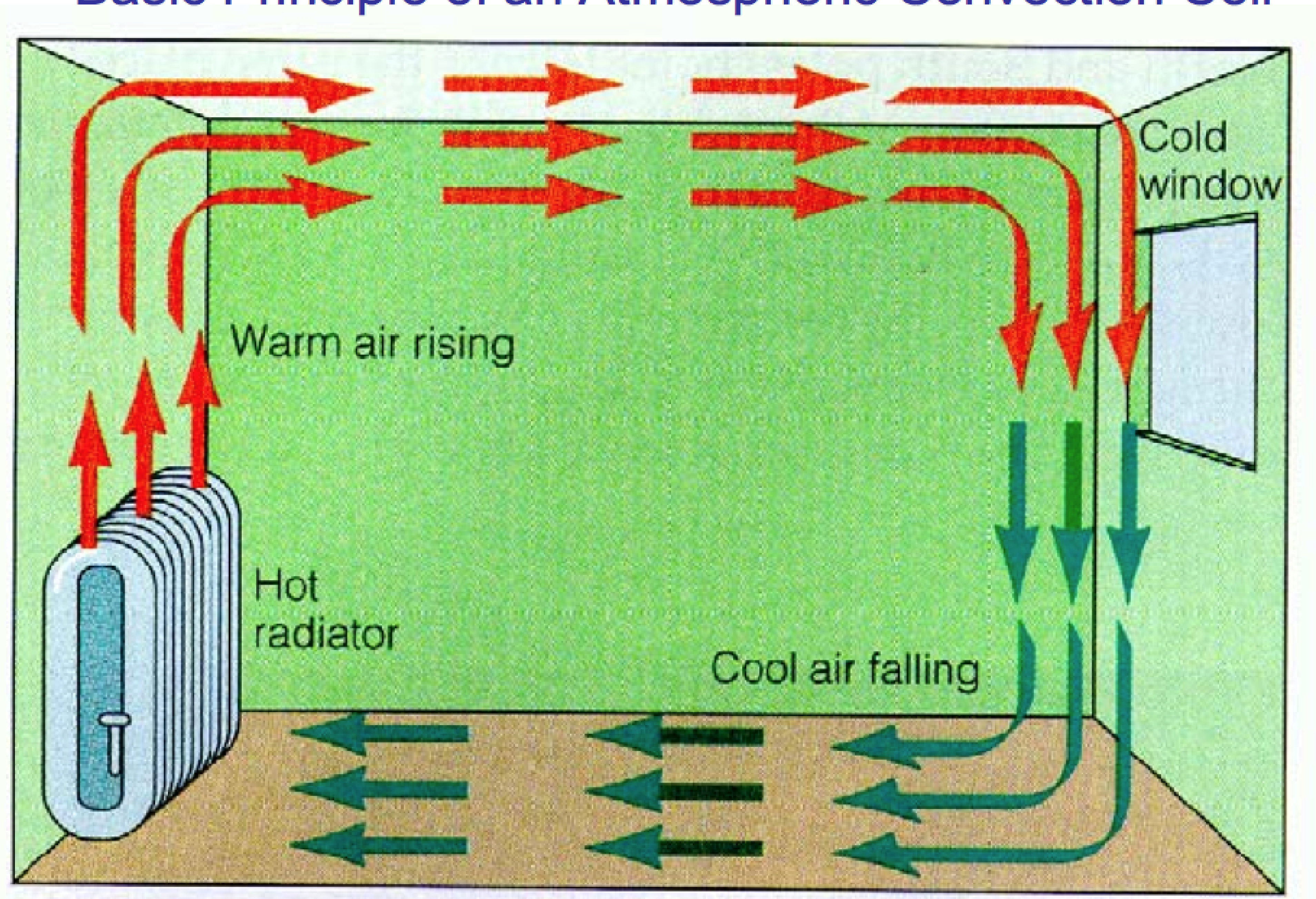
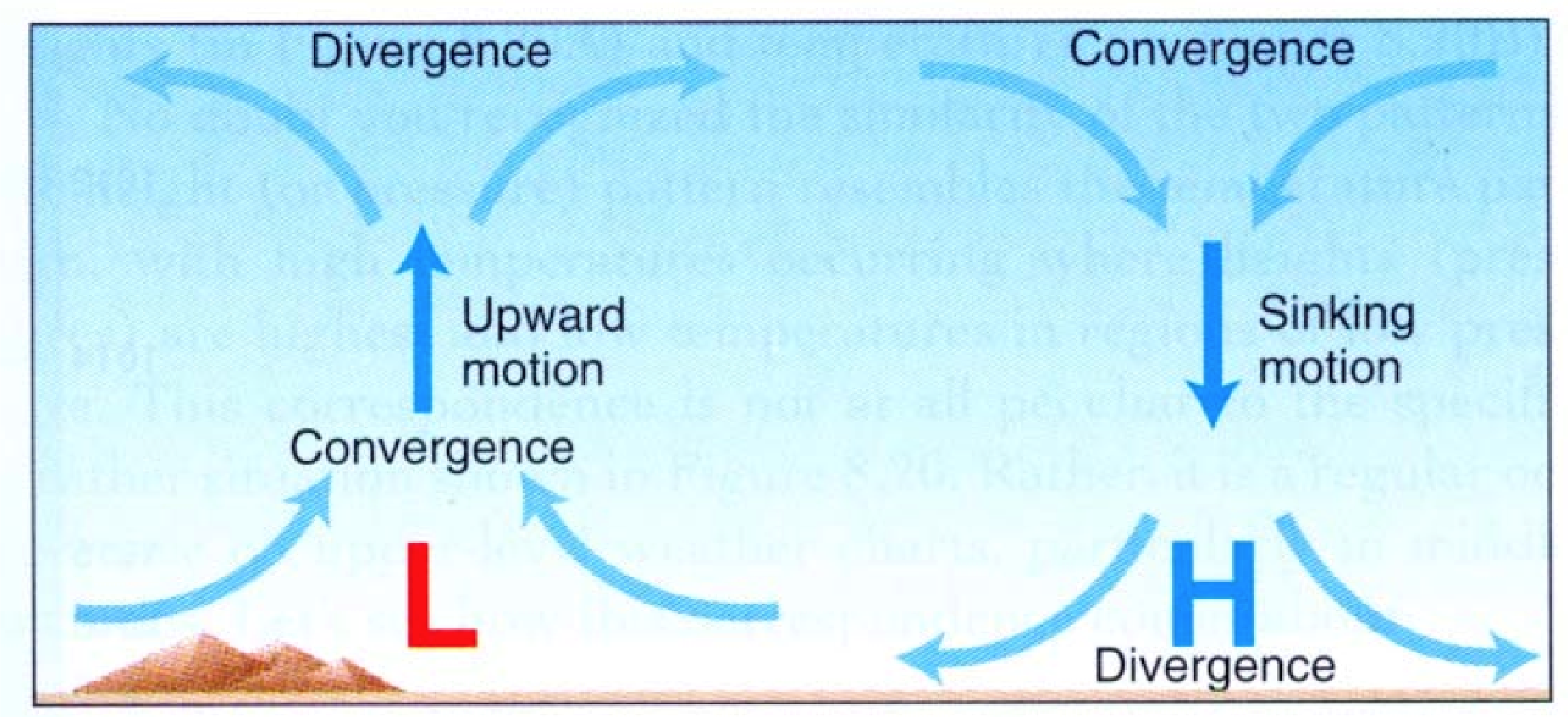


Image: David Townsend

Convection happens in the atmosphere because air masses acquire properties of land or ocean beneath them (e.g. temperature, moisture), ***altering their densities.***



+ heat (land?)

Image: David Townsend

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Simplified Theory:

Pattern of winds on ***an "Earth" that isn't Rotating…***

- The Result of Differential Heating

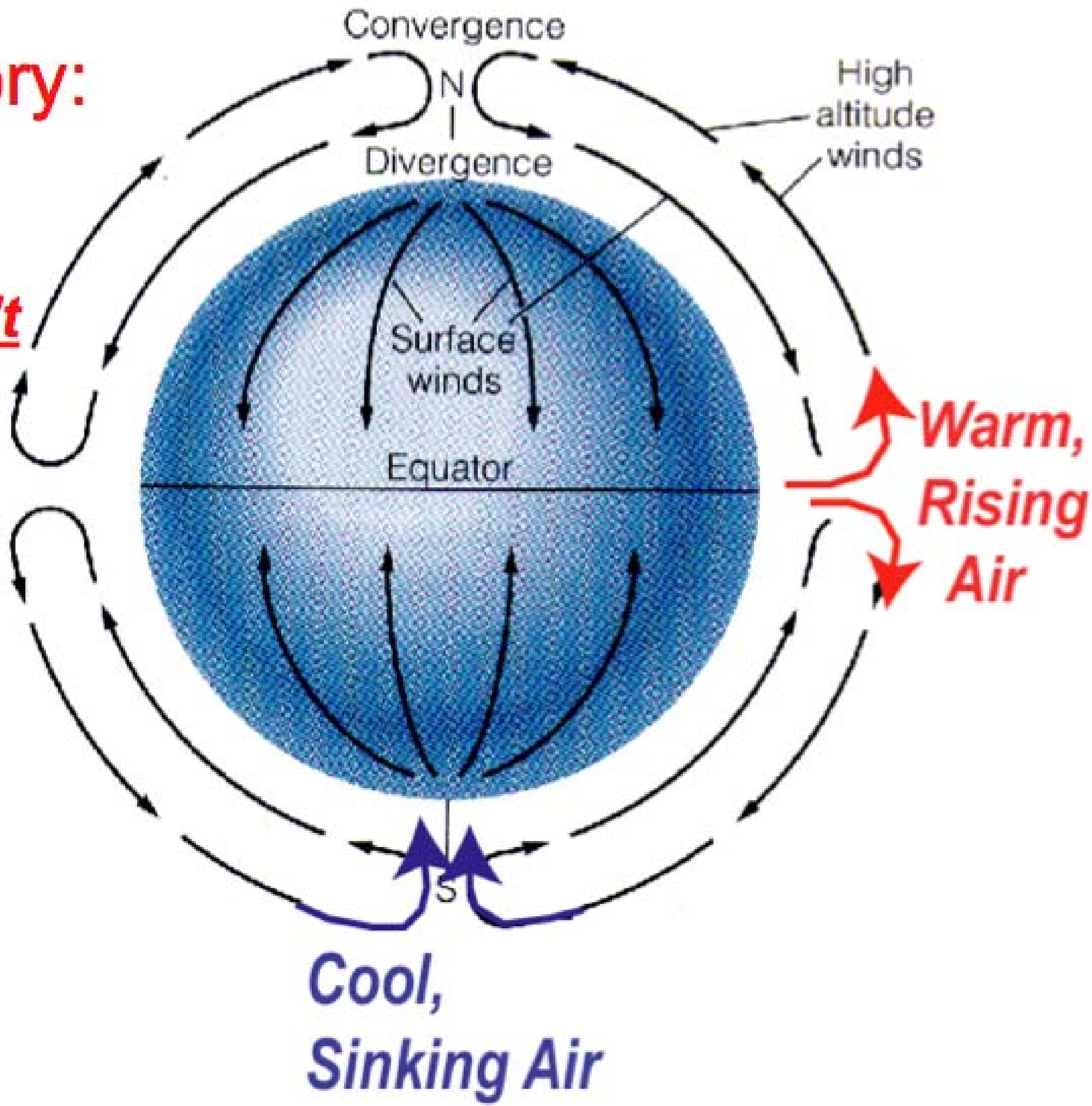

Image: David Townsend

Now add rotation

Coriolis

In reality, the earth rotates

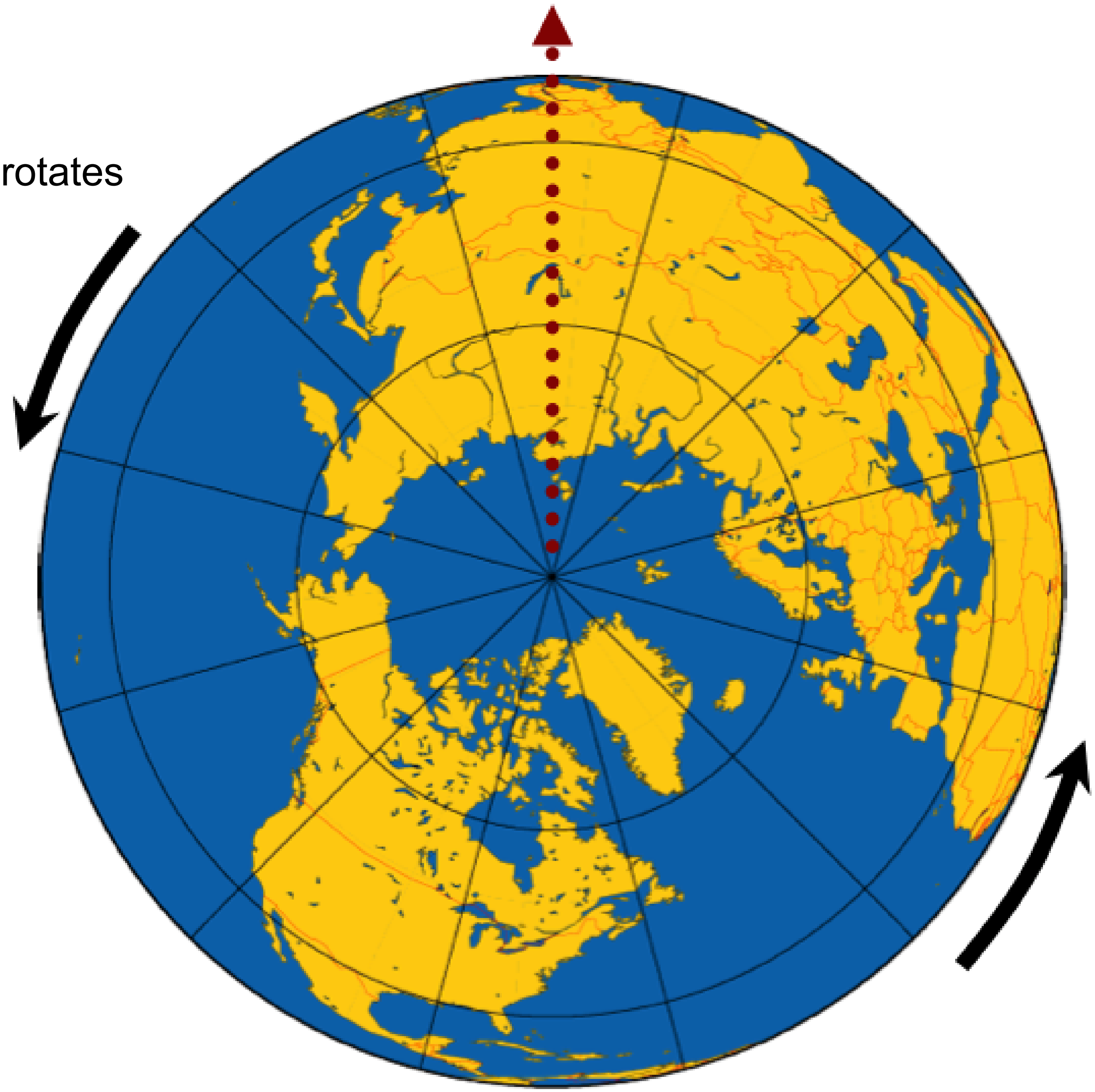

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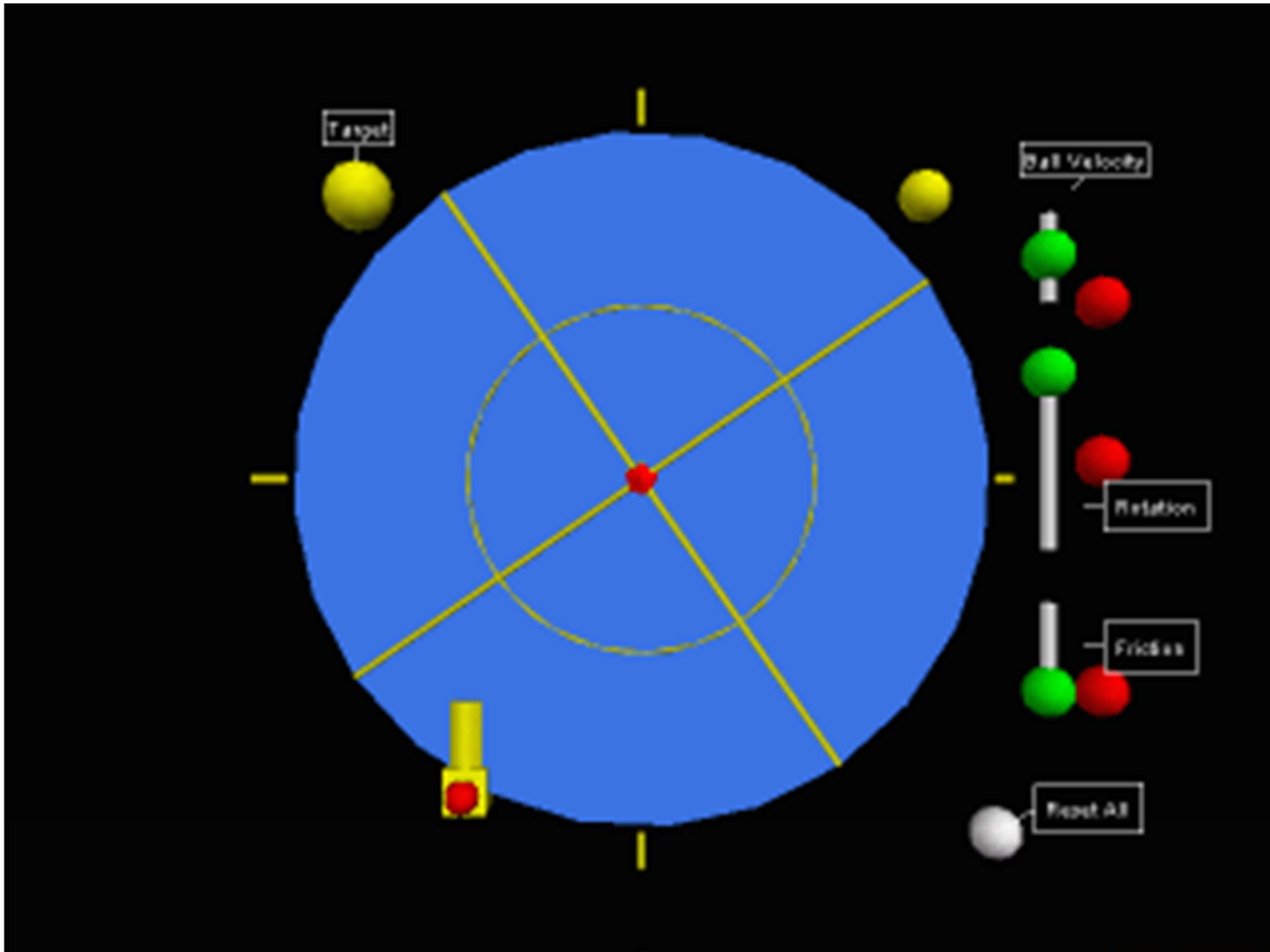
Image: David Townsend



Example http://www.youtube.com/watch?v=_36MiCUS1ro

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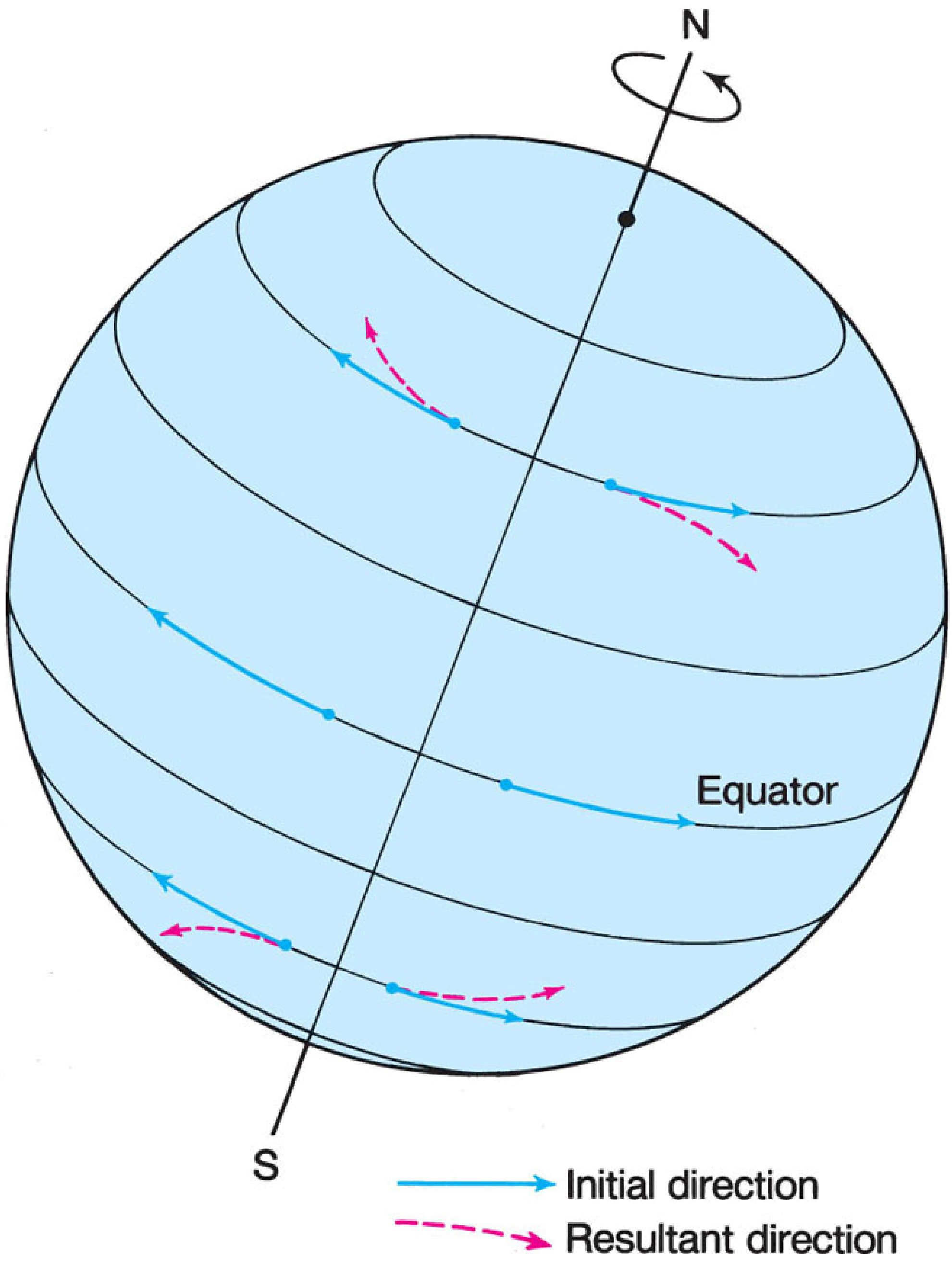
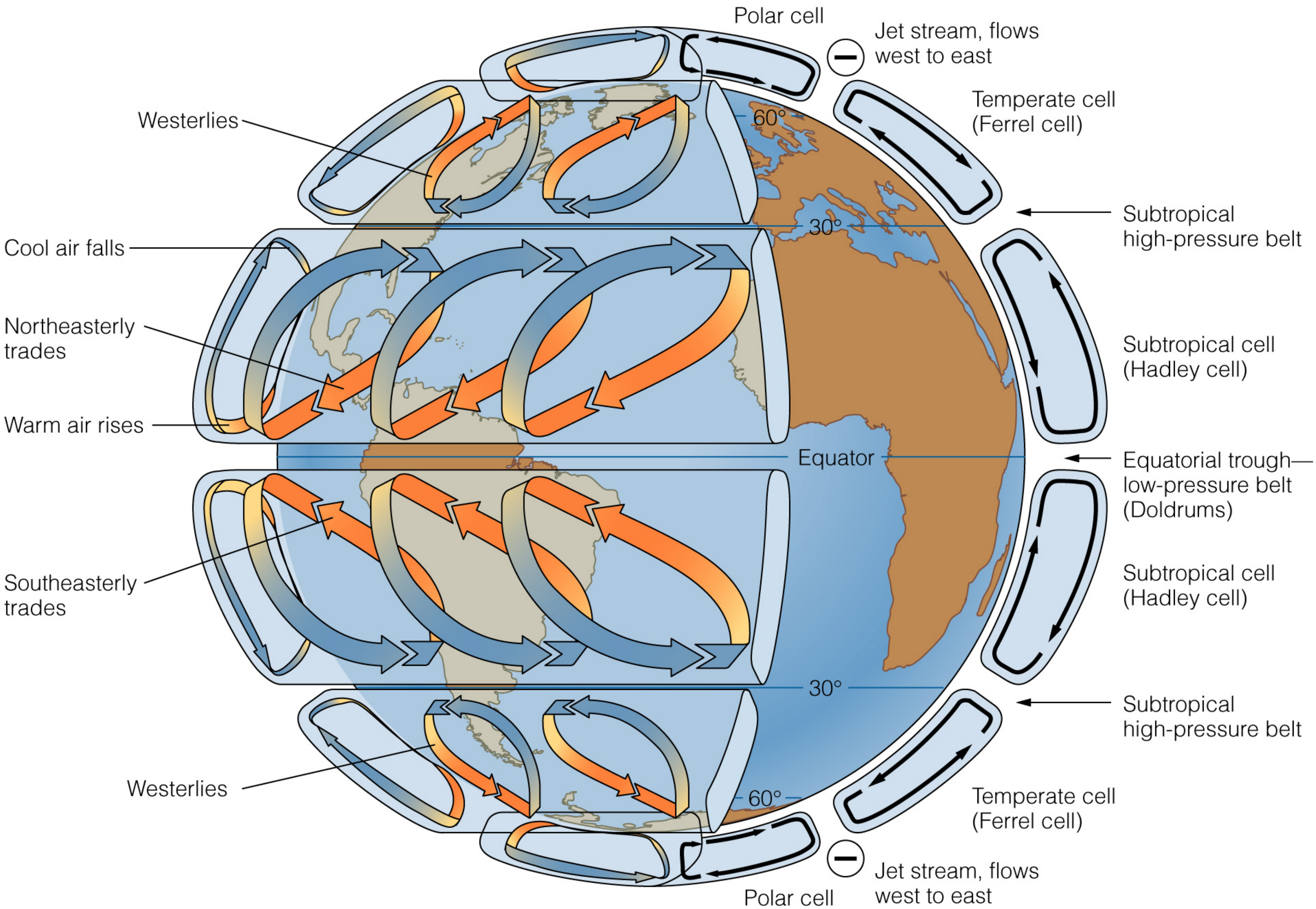
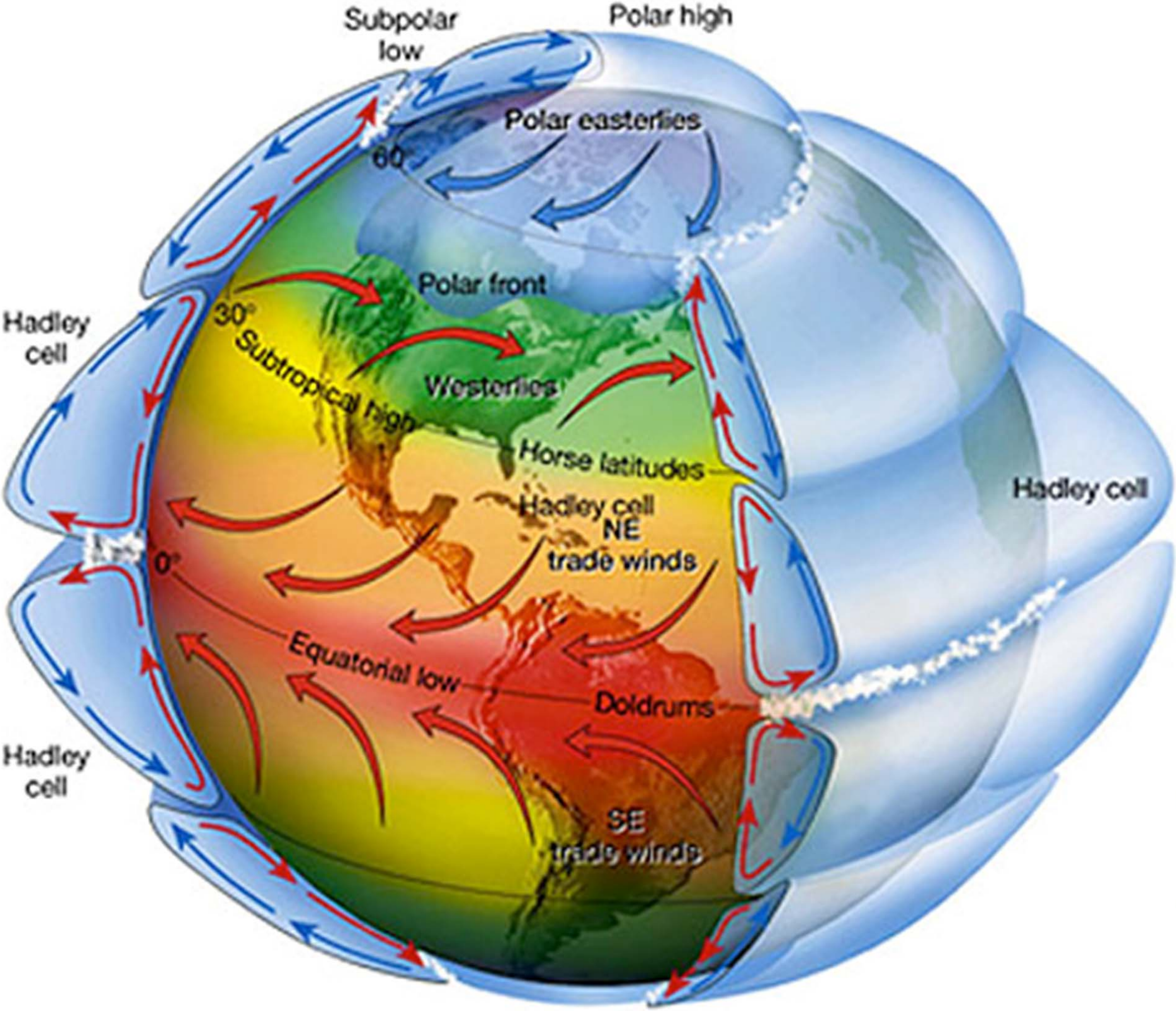


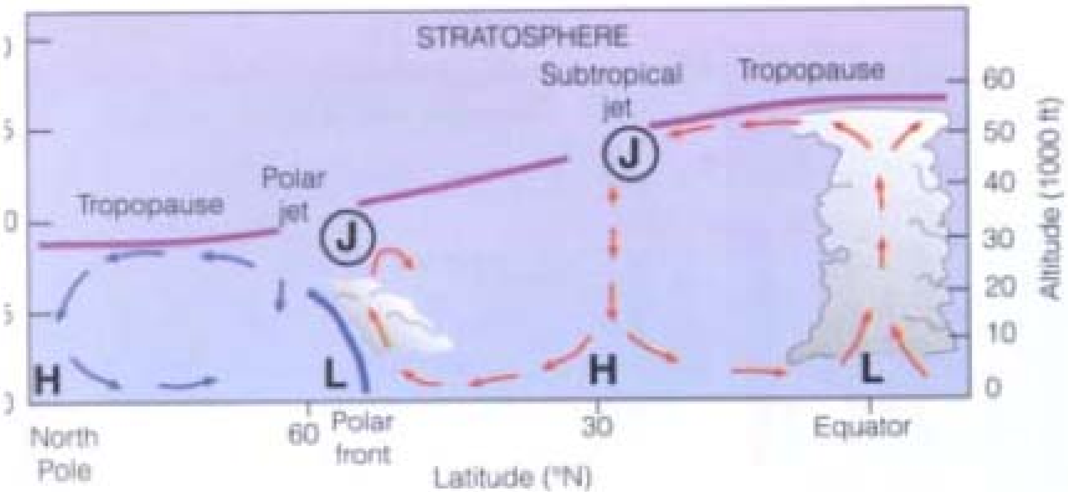
E-W movement

Coriolis effect on convection cells: Hadley Cells




Subpolar low
Polar high
Polar easterlies
60°
Polar front
Hadley cell
30°
Subtropical high
Westerlies
Horse latitudes
Hadley cell
NE trade winds
Hadley cell
0°
Equatorial low
Doldrums
Hadley cell
SE trade winds

Bi



A Cross-Section…

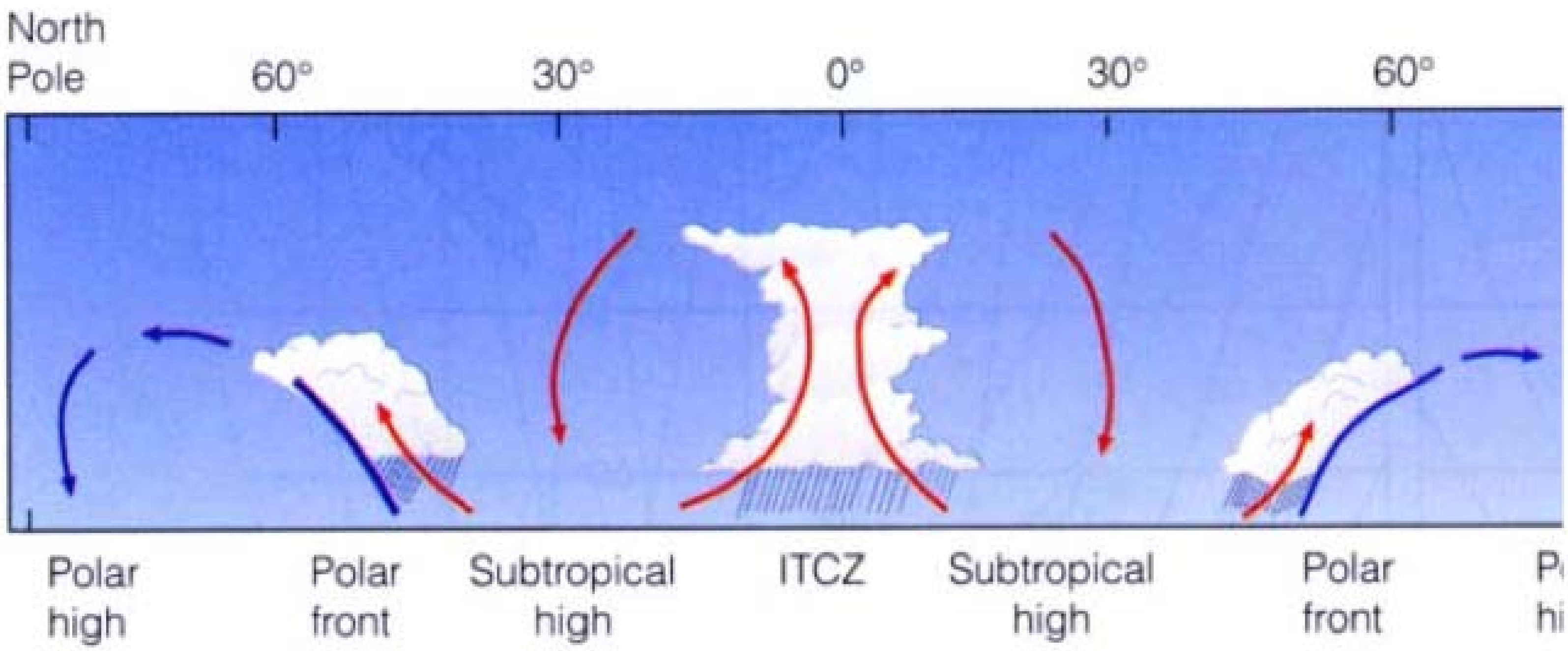
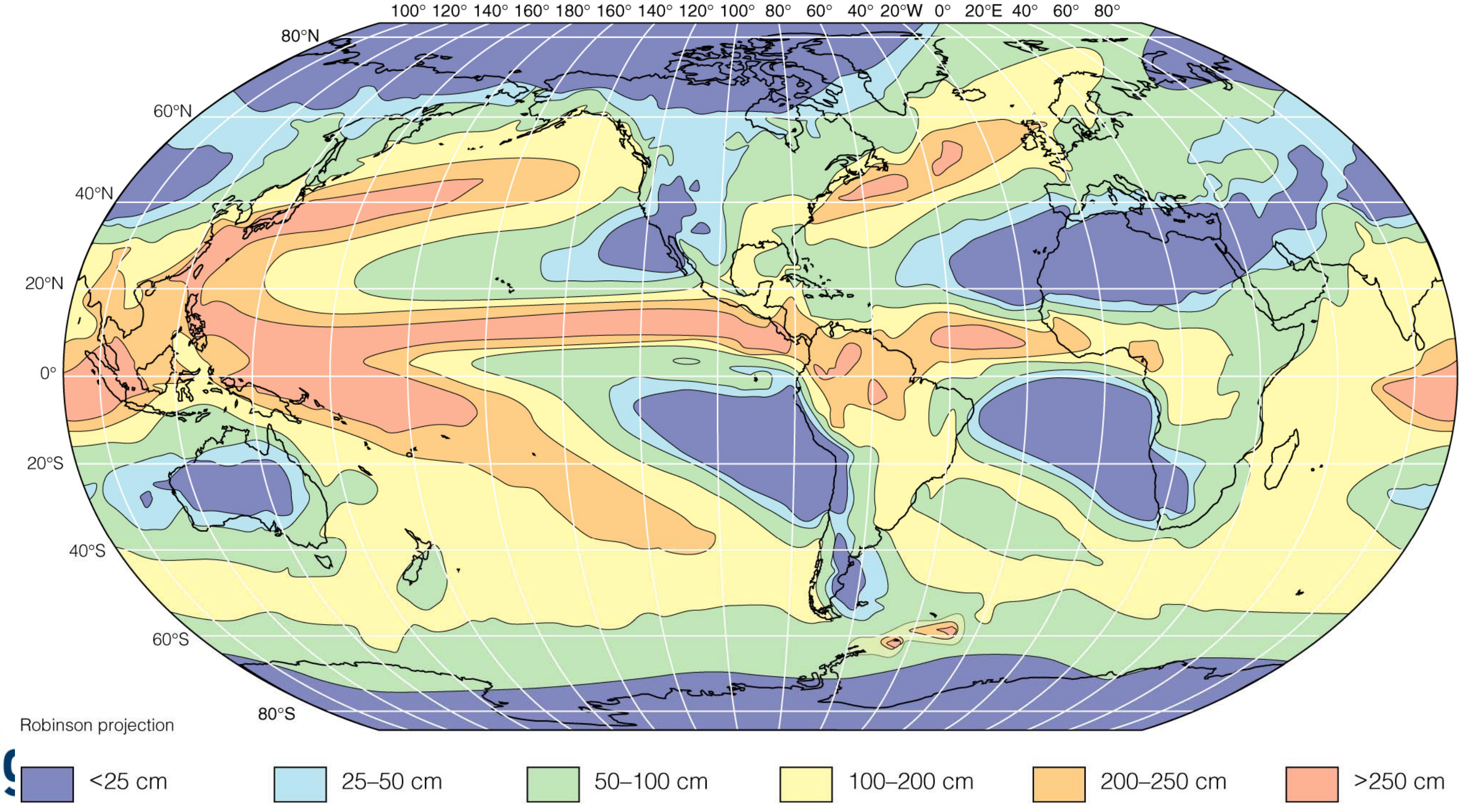


Image: David Townsend

Precipitation (annual)



Bi

CORIOLIS EFFECT - Summary

- increases with latitude
- Increases with speed of moving air parcel
- Depends on rate of rotation of earth
- NH: deflection to the right
- SH: deflection to the left
    - Air/water moving equatorward, deflects to the W
    - Air/water moving poleward, deflects to the E

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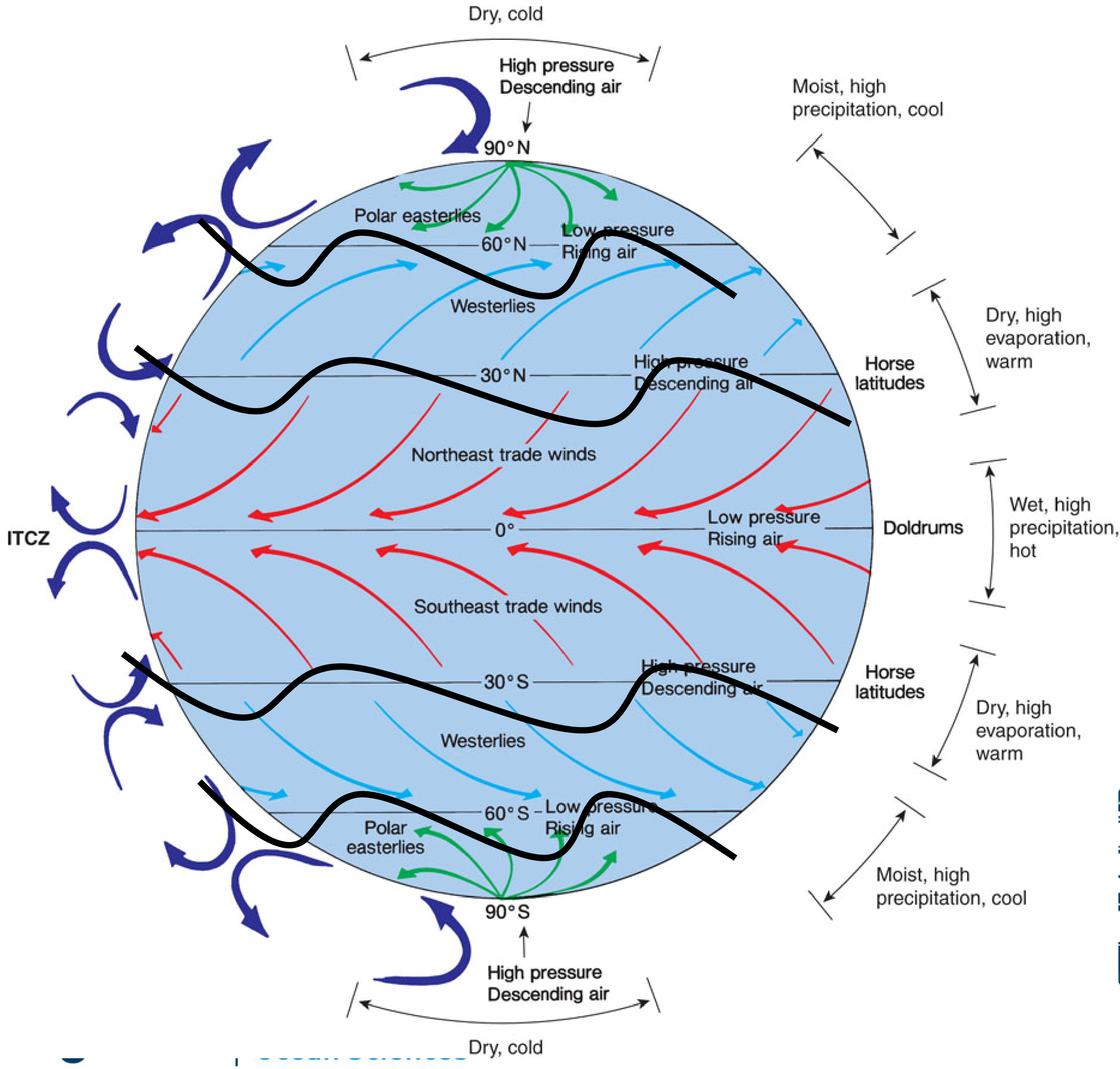
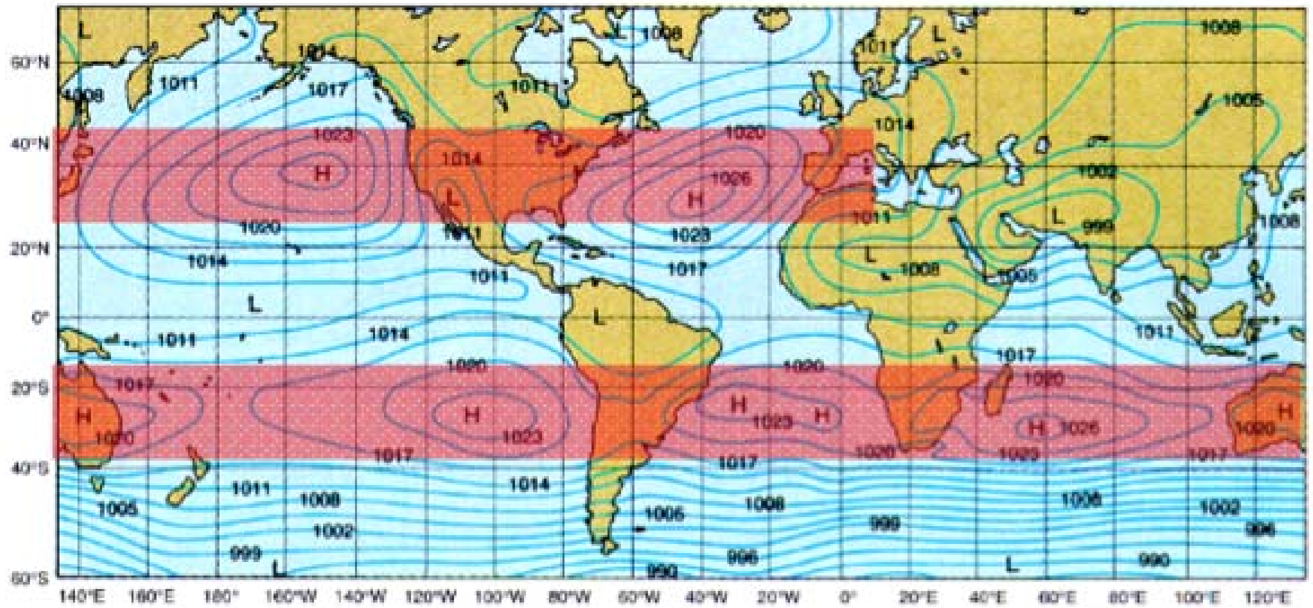


Jet stream at 60°N&S, 30°N&S in upper troposphere

High & Low atmospheric pressure bands <u>are actually present</u>

-- but in Cells

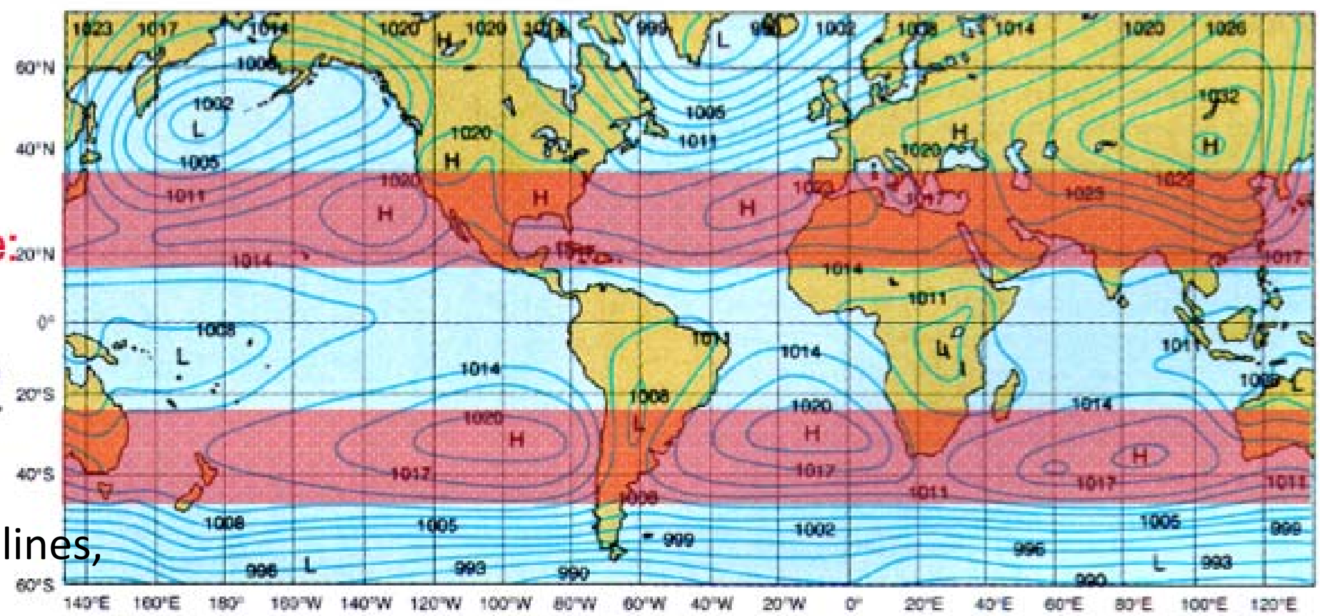
Summer



(a) July

Seasonal changes in atmospheric pressure

Winter



(b) January

Cells result because:

- Land heats up faster than oceans, and cools off faster

Isobars; the closer the lines, the stronger the winds

Image: David Townsend

Weather

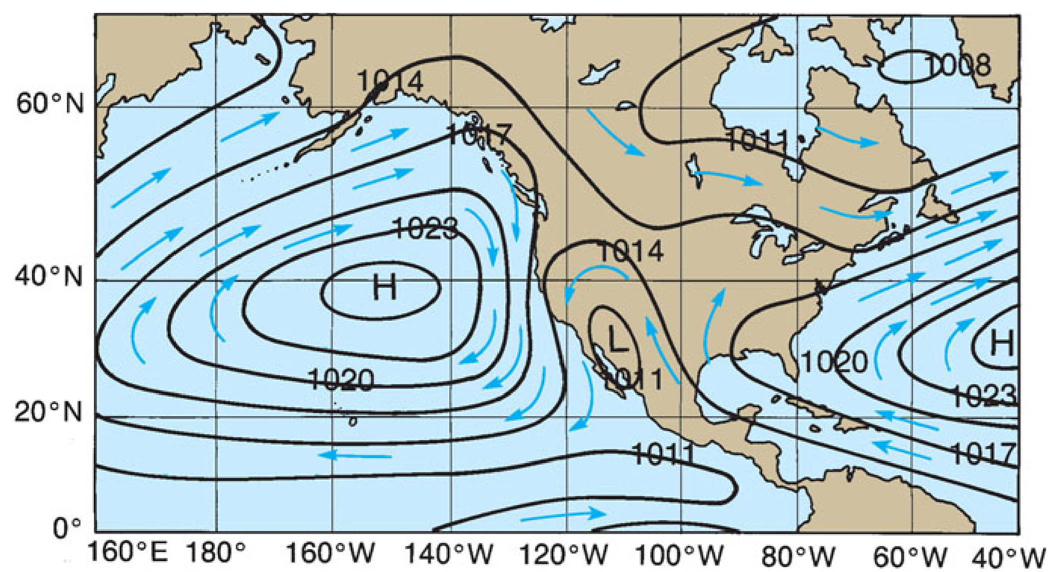
Air motion around pressure cells:

clockwise around high

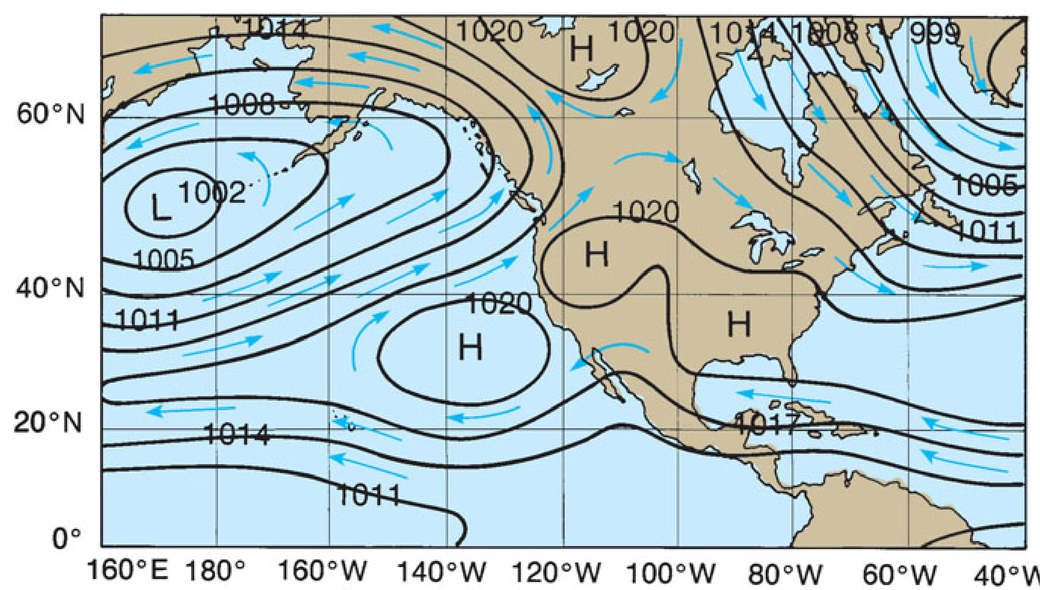
Counter clockwise around low

** Opposite in Southern Hemisphere

Weather maps show pressure isobars to indicate motion and direction



(a) July



(b) January

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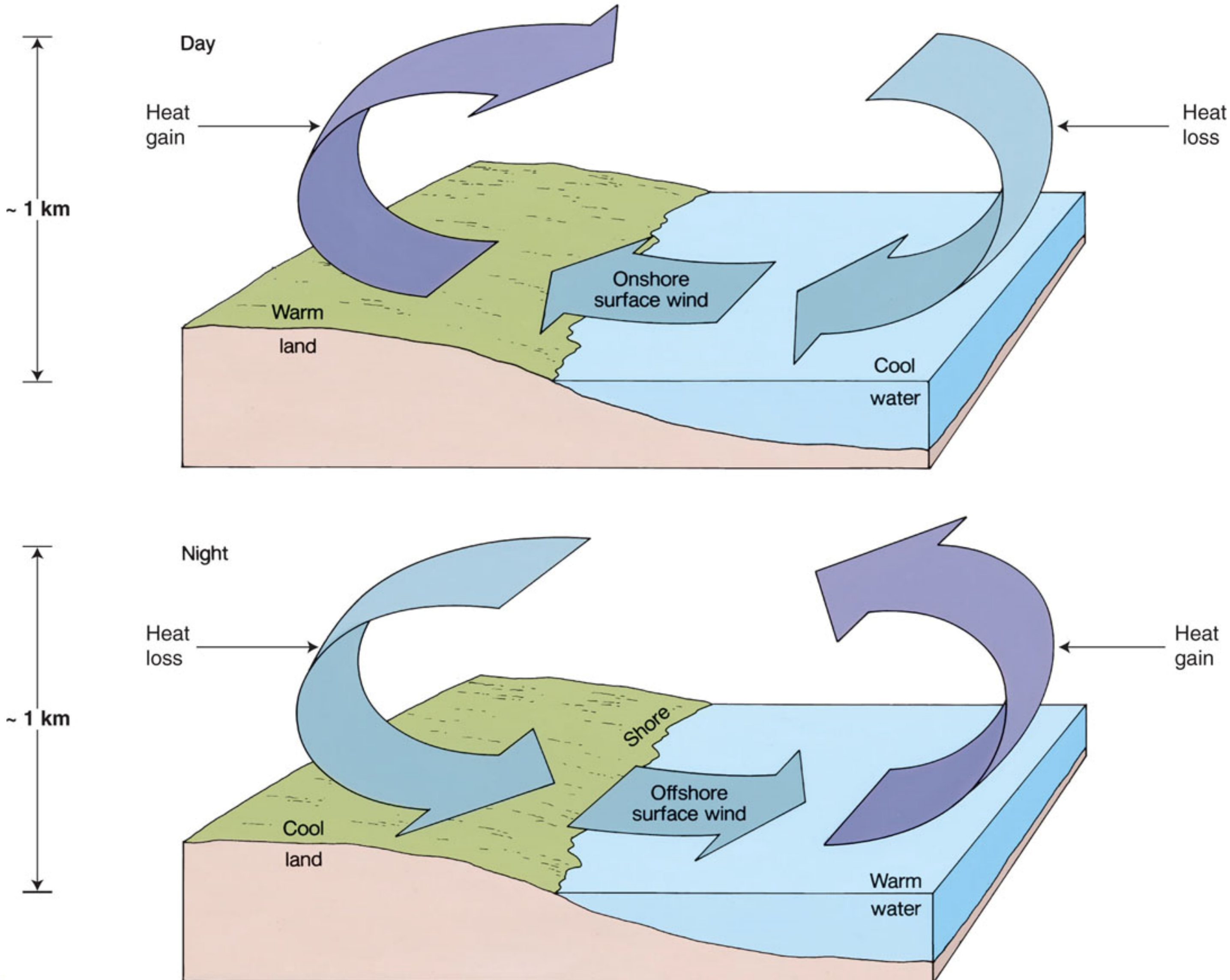
Local Processes

Sea breeze

(local, daily scale)

Same process drives monsoons at a seasonal scale



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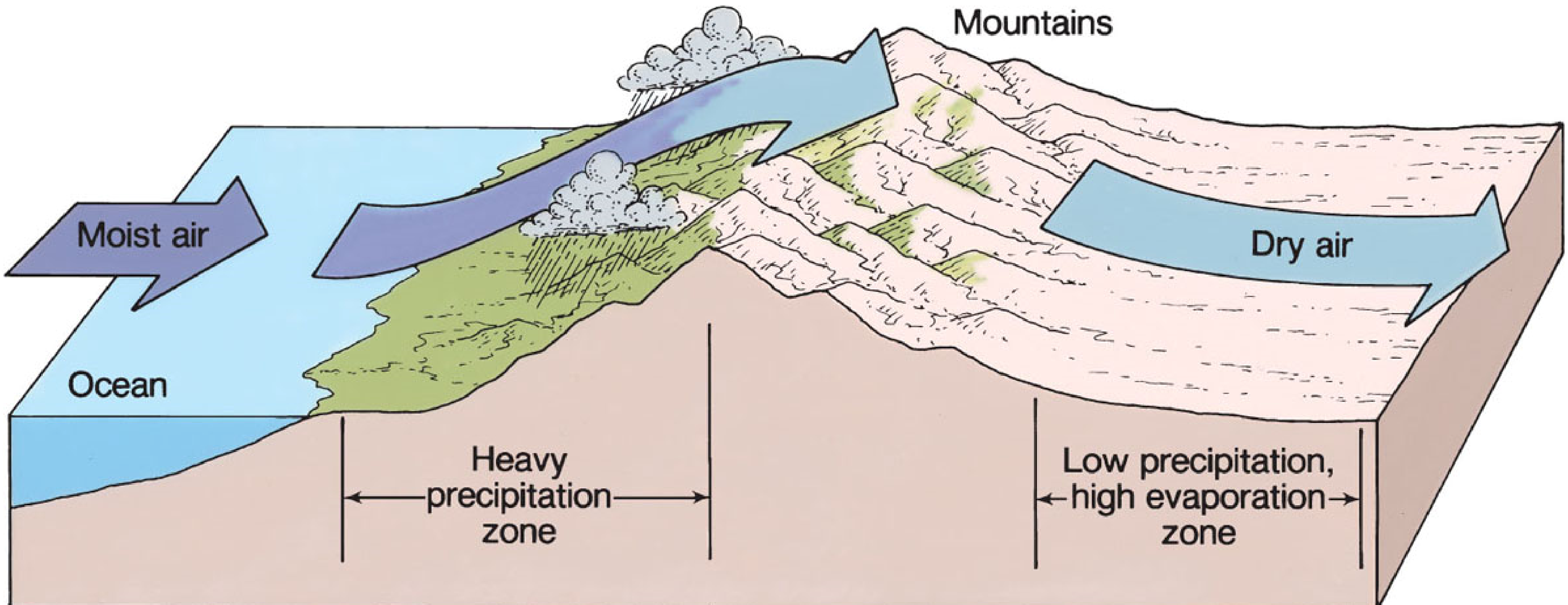
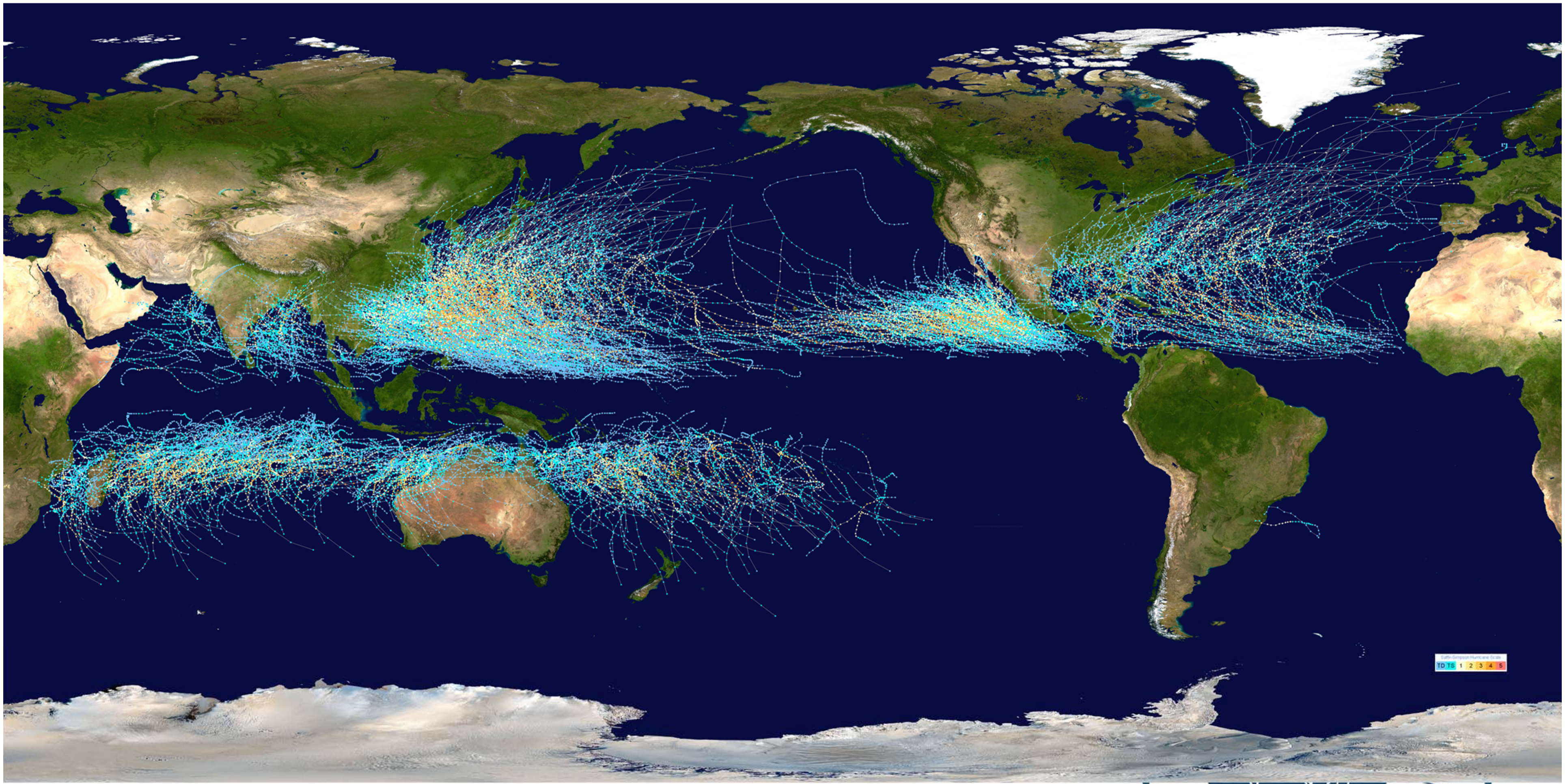
Topographic = orographic effect

(also monsoon!)



Global tracks of tropical **storms, hurricanes** (Atlantic) and **cyclones** (Pacific, Indian) 1985-2005



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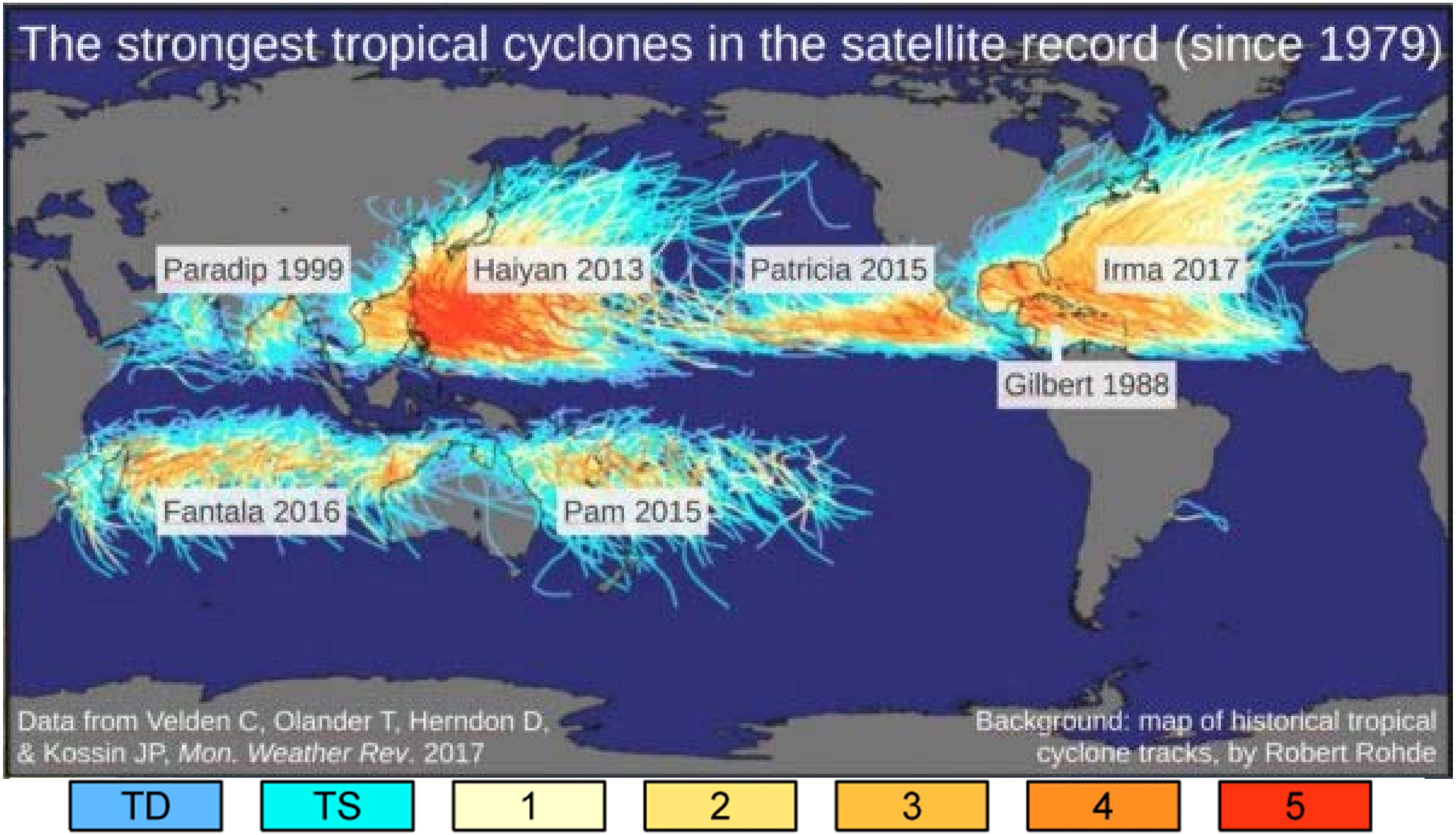

Saffir-Simpson Hurricane Intensity Scale

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