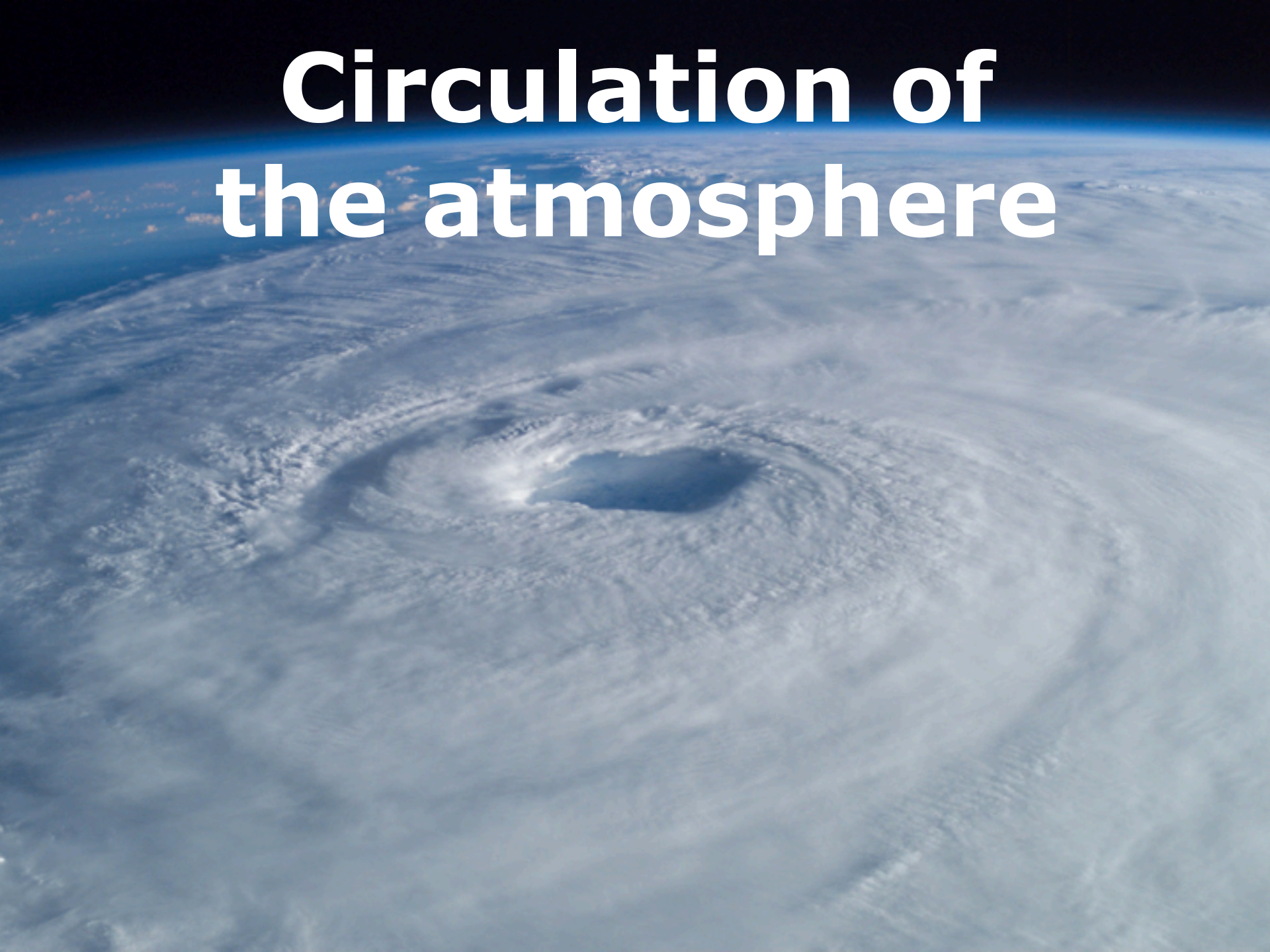
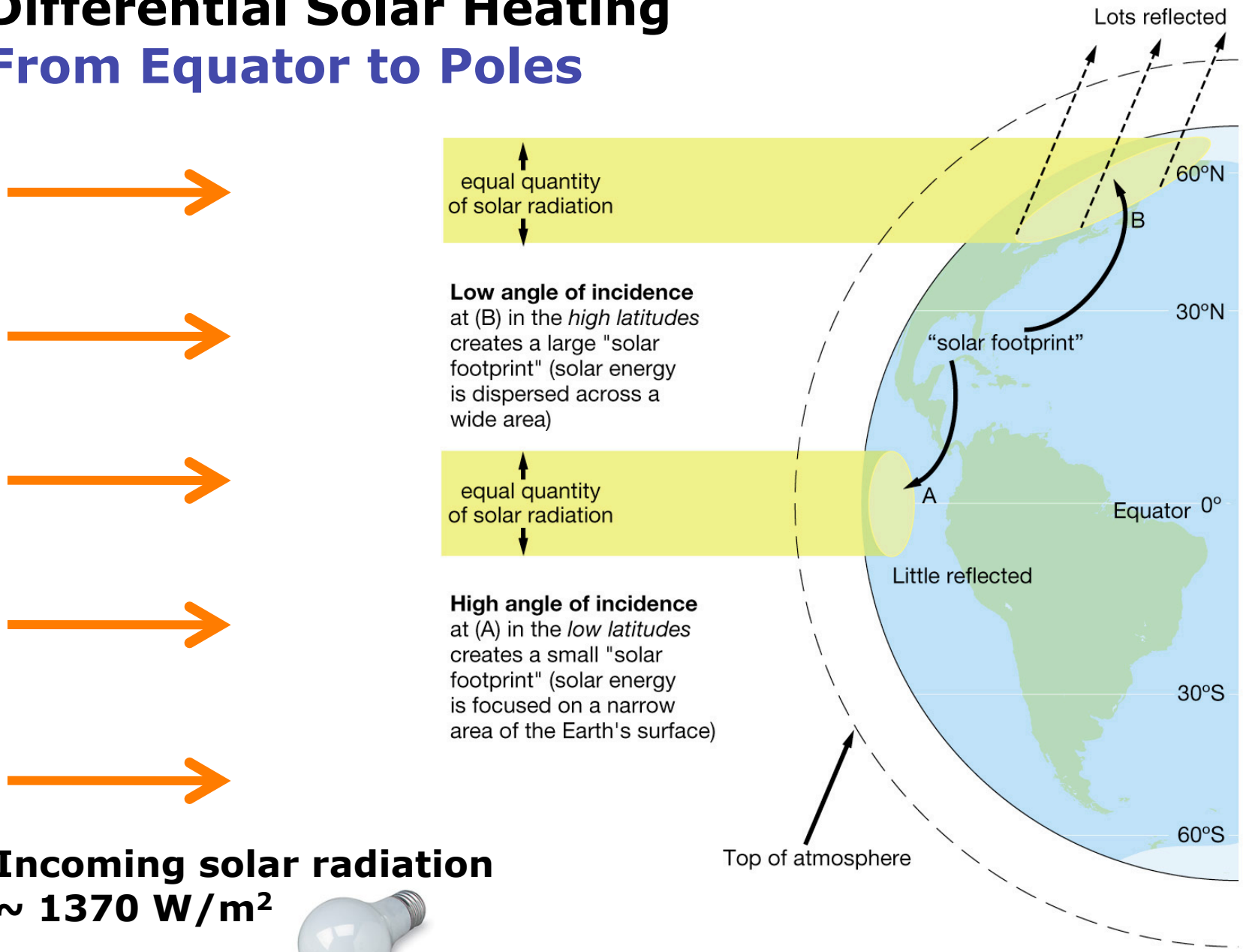
Circulation of the atmosphere



What drives the atmospheric circulation?

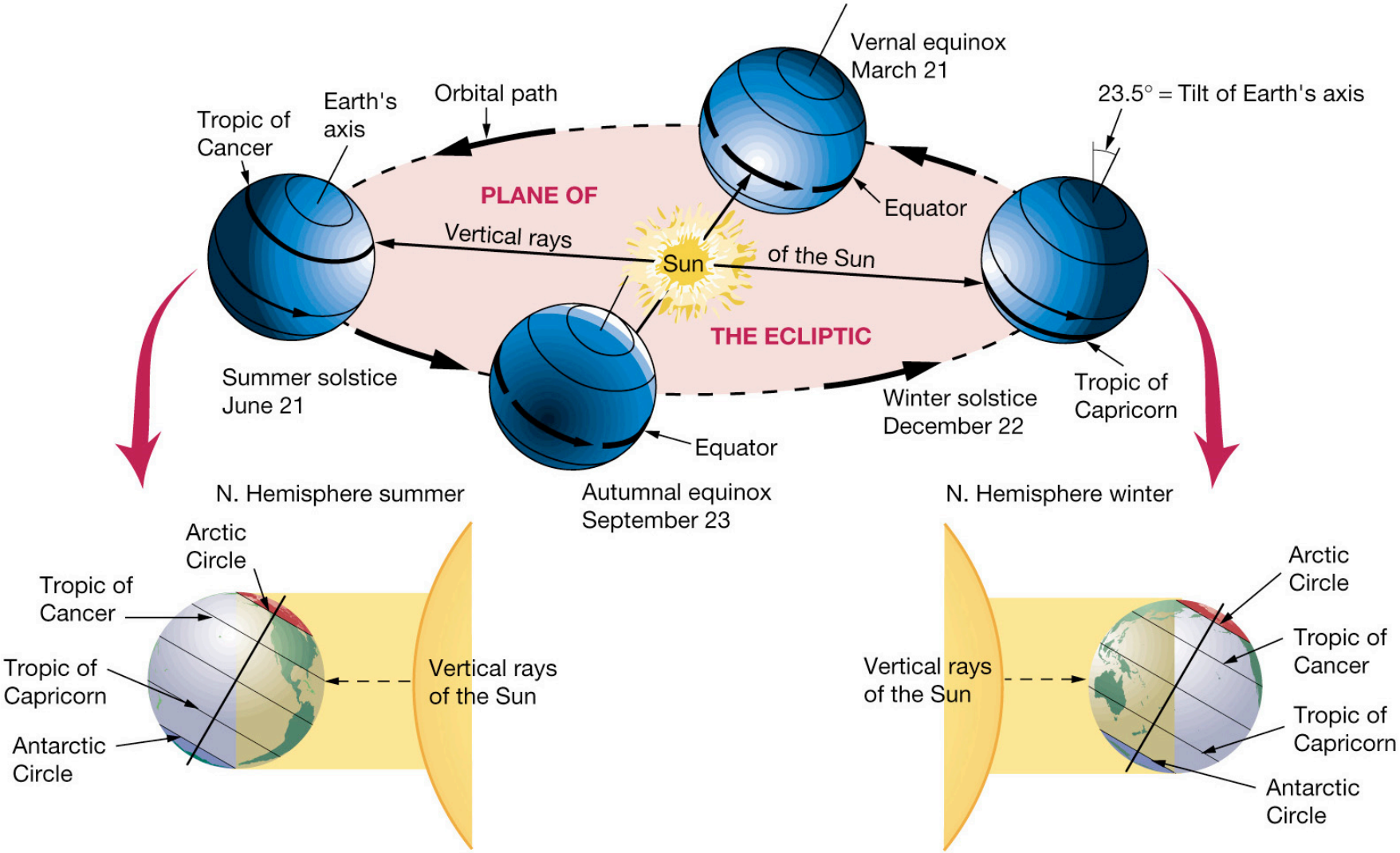
- Two fundamental mechanisms
  - Differential heating by the sun
  - Rotation of the planet

Differential Solar Heating
From Equator to Poles

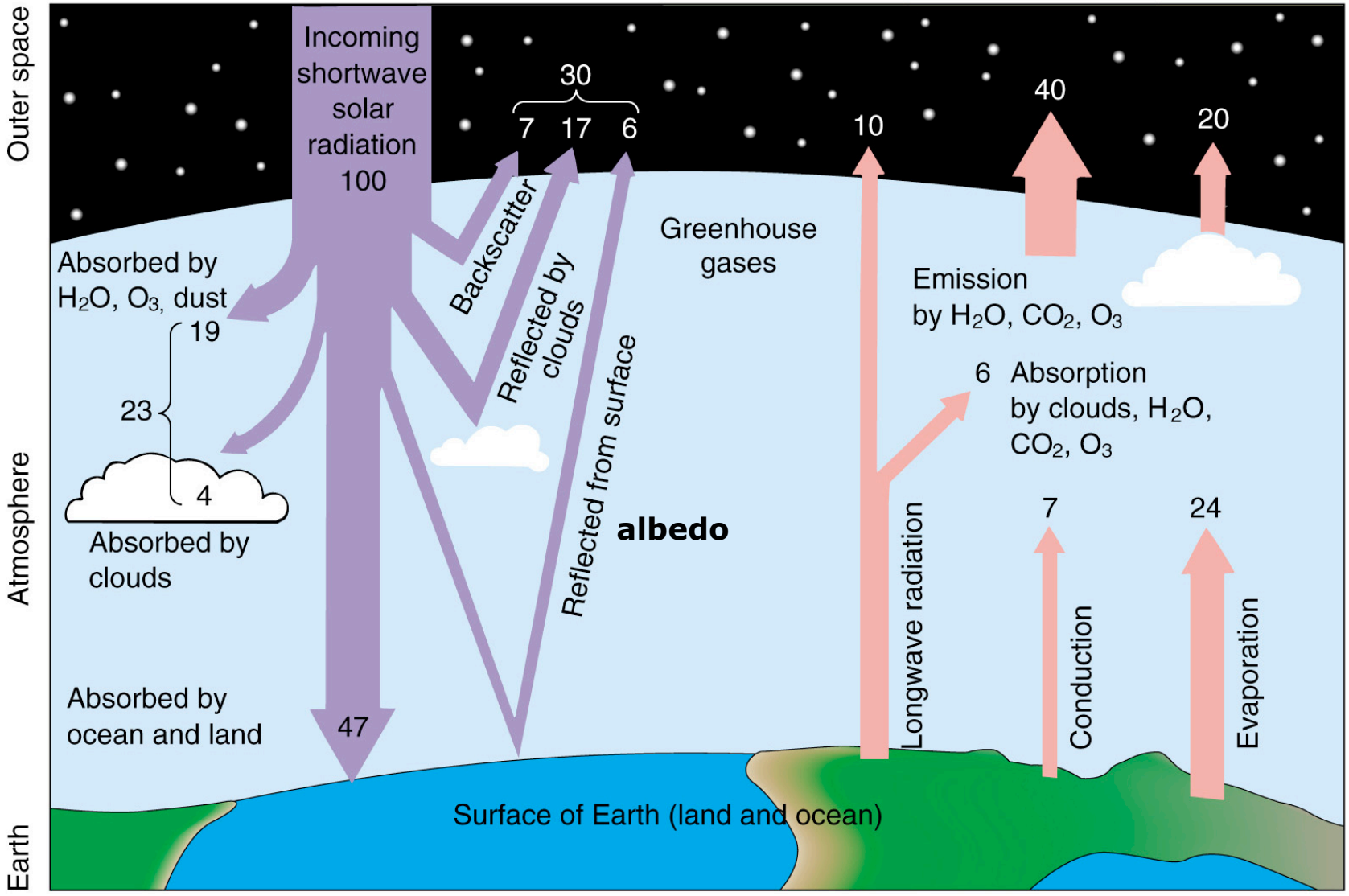


Incoming solar radiation
~ 1370 W/m²

Seasonal Heating



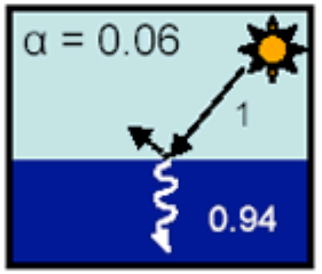
Radiative Budget



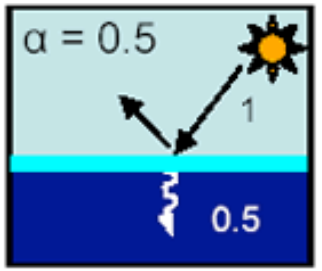
Reflectivity and albedo

- Albedo = fraction of energy reflected
  - Fully absorbing surface: $\alpha = 0$
    - Black surface ~ sea water
  - Fully reflecting surface: $\alpha = 1$
    - White surface ~ snow
- At high latitudes
  - Cold ice/snow reflects solar radiation, making it even colder
  - Positive ice-albedo feedback

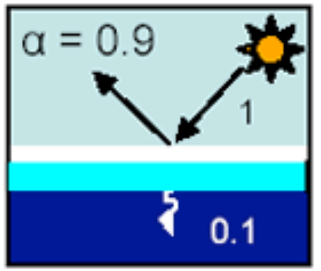
I. Open ocean



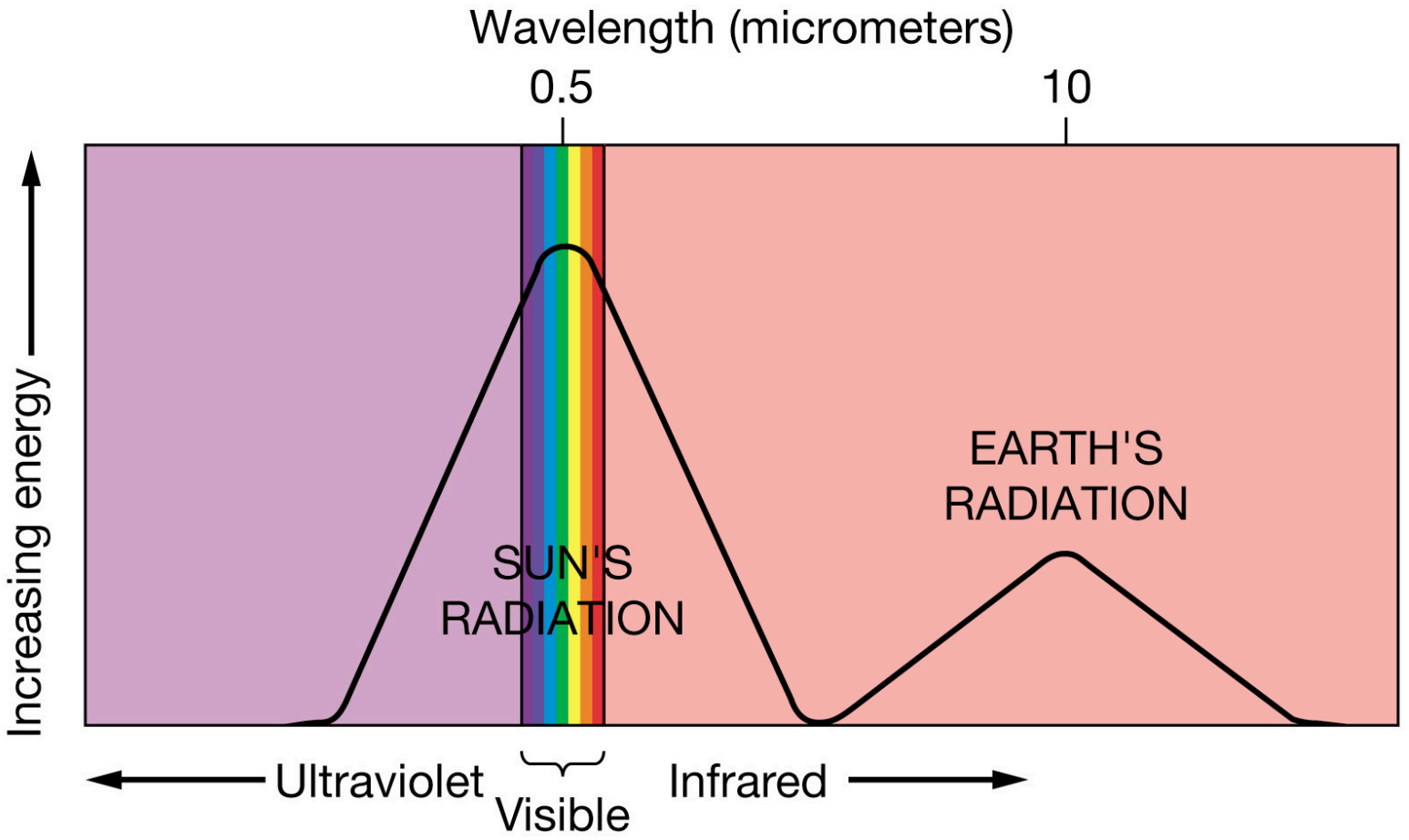
II. Bare ice



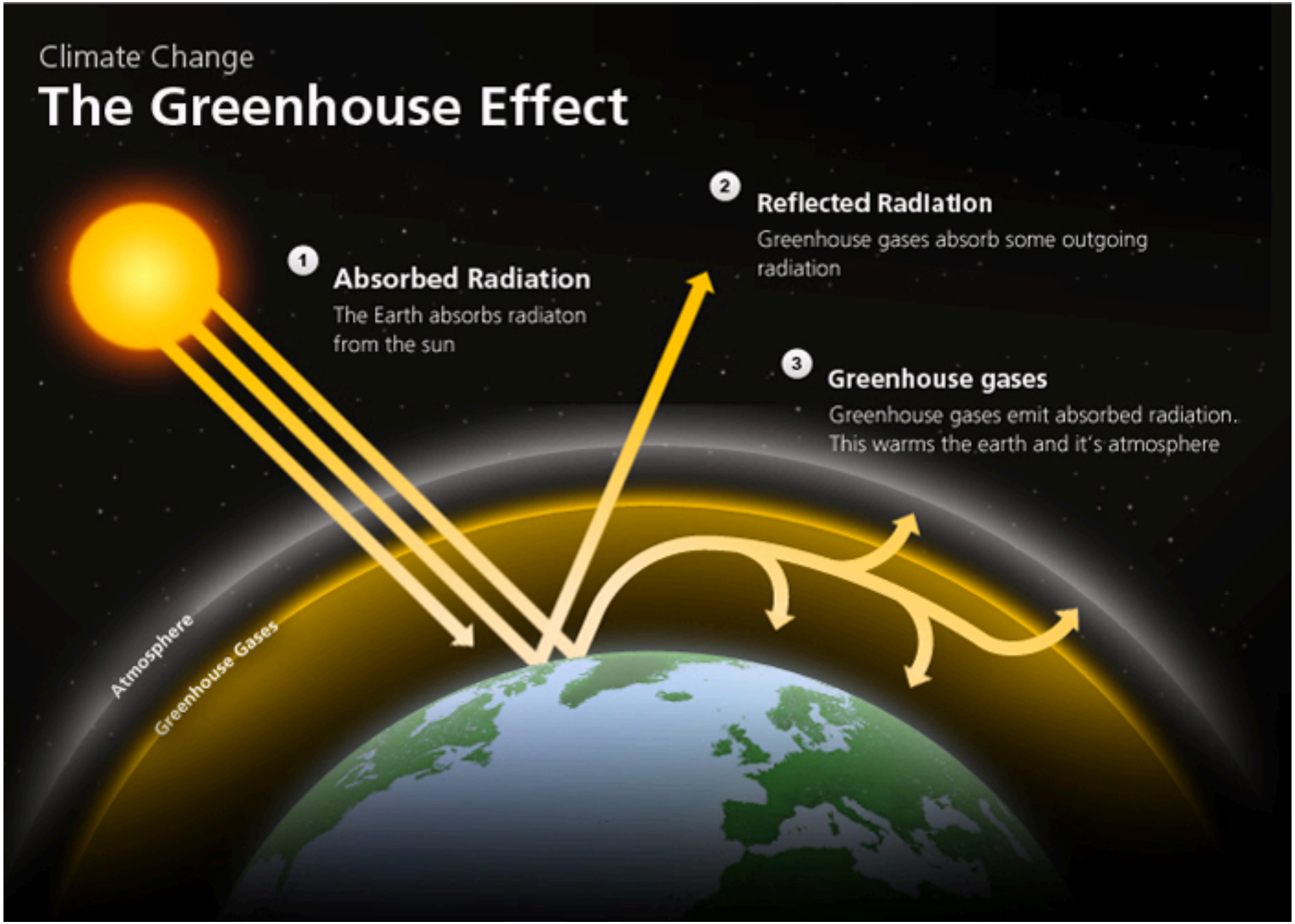
III. Ice with snow



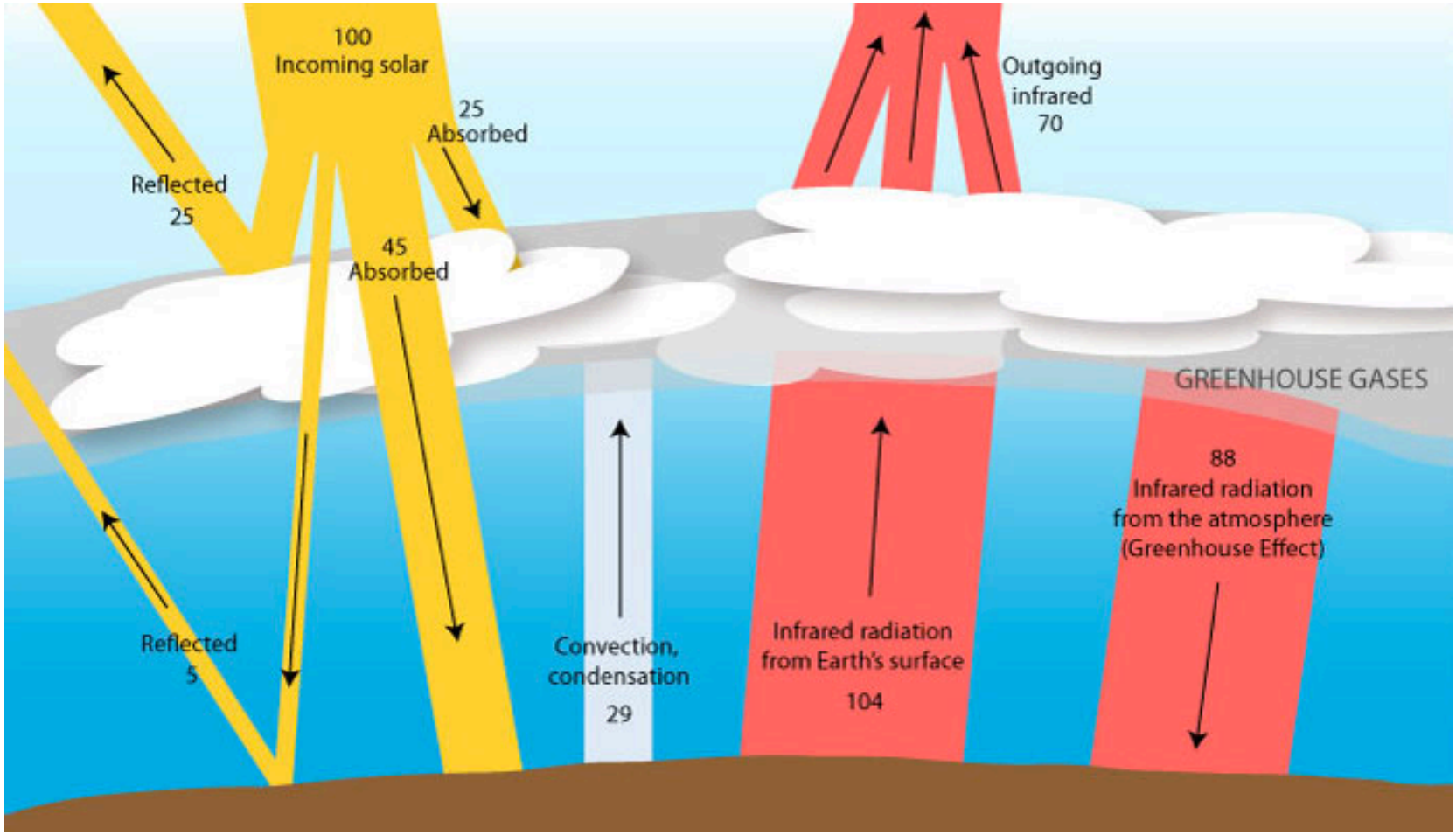
Radiative balance



- Solar radiation is mostly in the visible band
- Earth’s radiation is in infrared band
- The type of radiation depends on the temperature of the body


Climate Change
The Greenhouse Effect
1
Absorbed Radiation
The Earth absorbs radiaton from the sun
2
Reflected Radiation
Greenhouse gases absorb some outgoing radiation
3
Greenhouse gases
Greenhouse gases emit absorbed radiation. This warms the earth and it's atmosphere
Atmosphere
Greenhouse Gases

Greenhouse radiative balance



Greenhouse gases

Water vapor (H2O)

Carbon dioxide (CO2)

Methane (CH4)

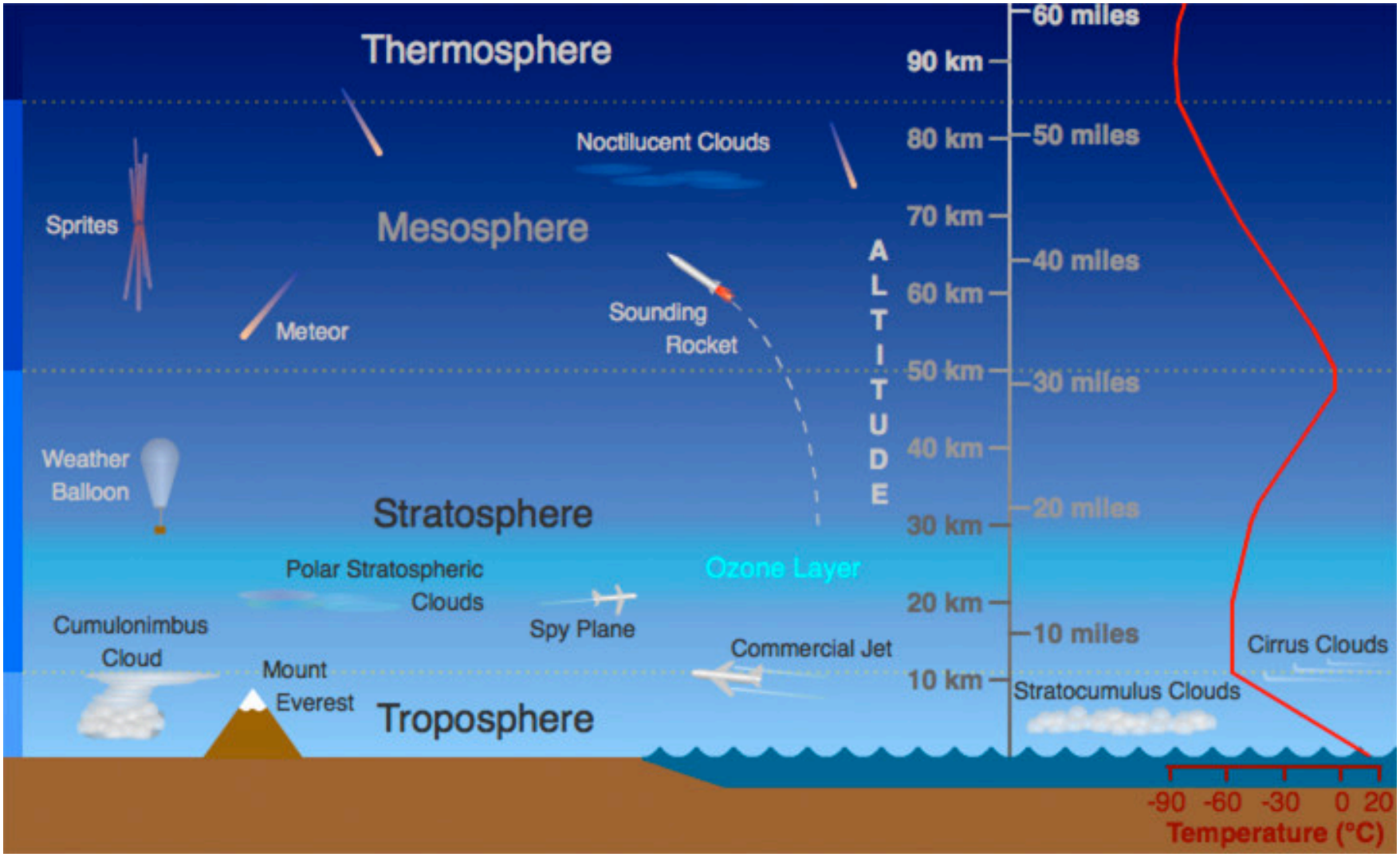
Nitrous oxide (N2O)

Ozone (O3)

Chlorofluorocarbons (CFCs)

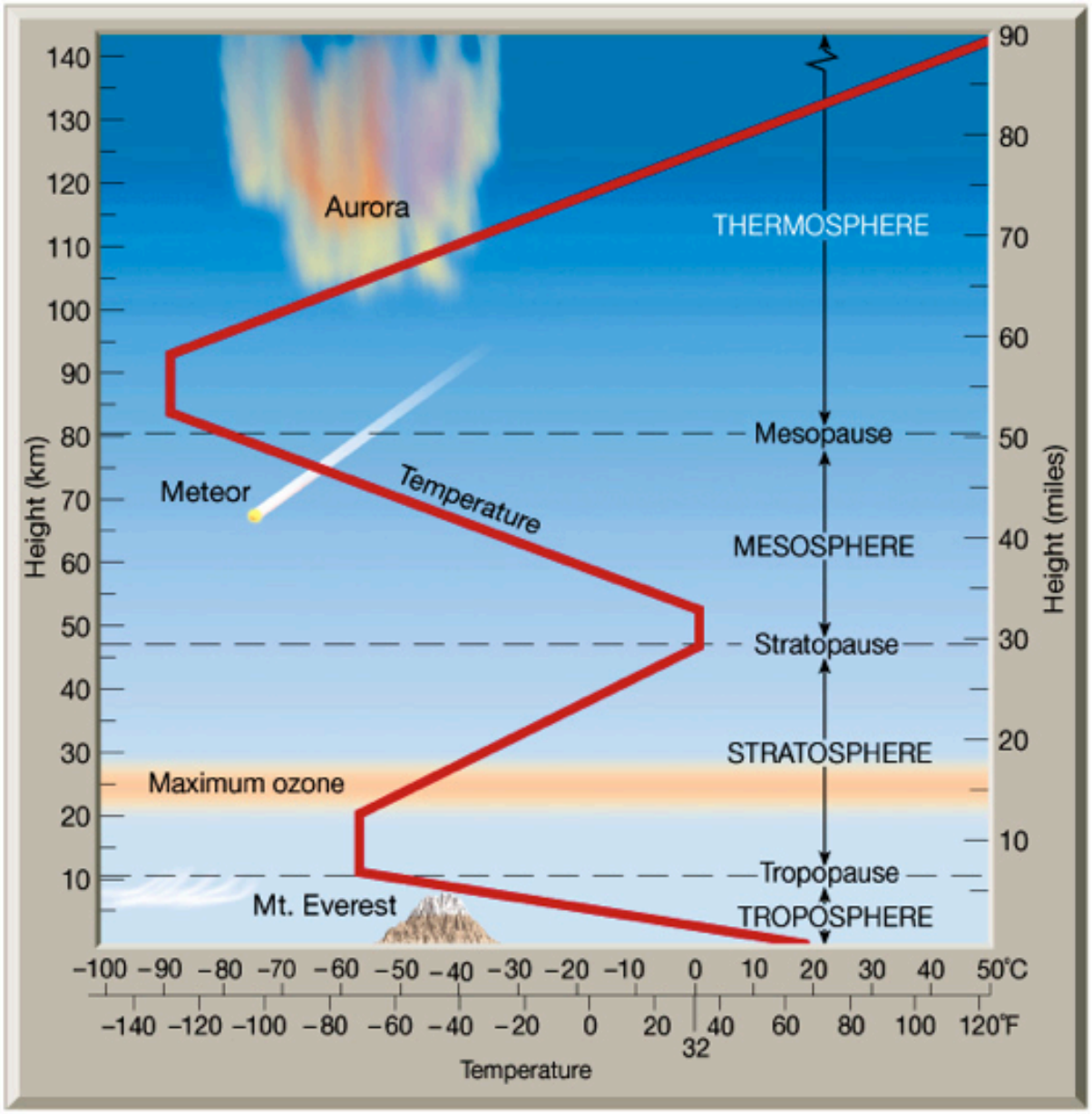
Influenced by human activities

Layers of the Atmosphere



We will focus on the tropopshere

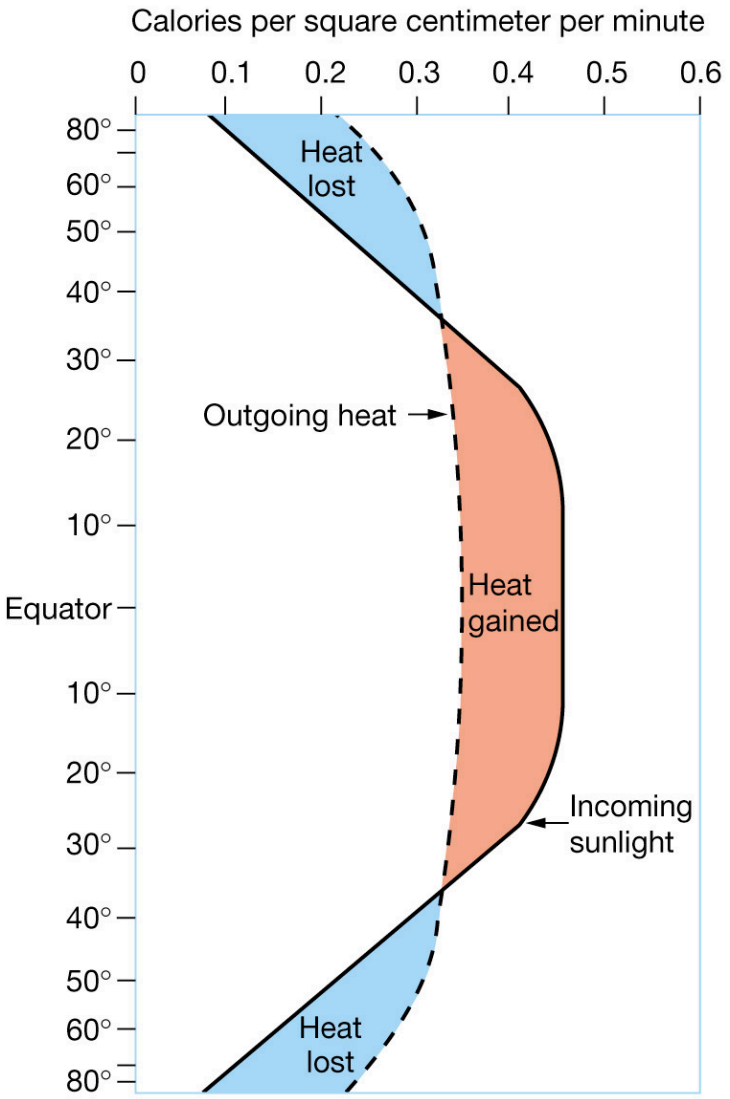
Layers and structure of the Atmosphere



The **Thermosphere** absorbs much of the energy from the sun. It absorbs x rays and ultraviolet radiation from the sun and converts it into heat. The **Thermosphere** doesn't feel warm even though it is at up to 2500 C because it is **so** close to being a vacuum.

http://www.weather-climate.org.uk/02.php

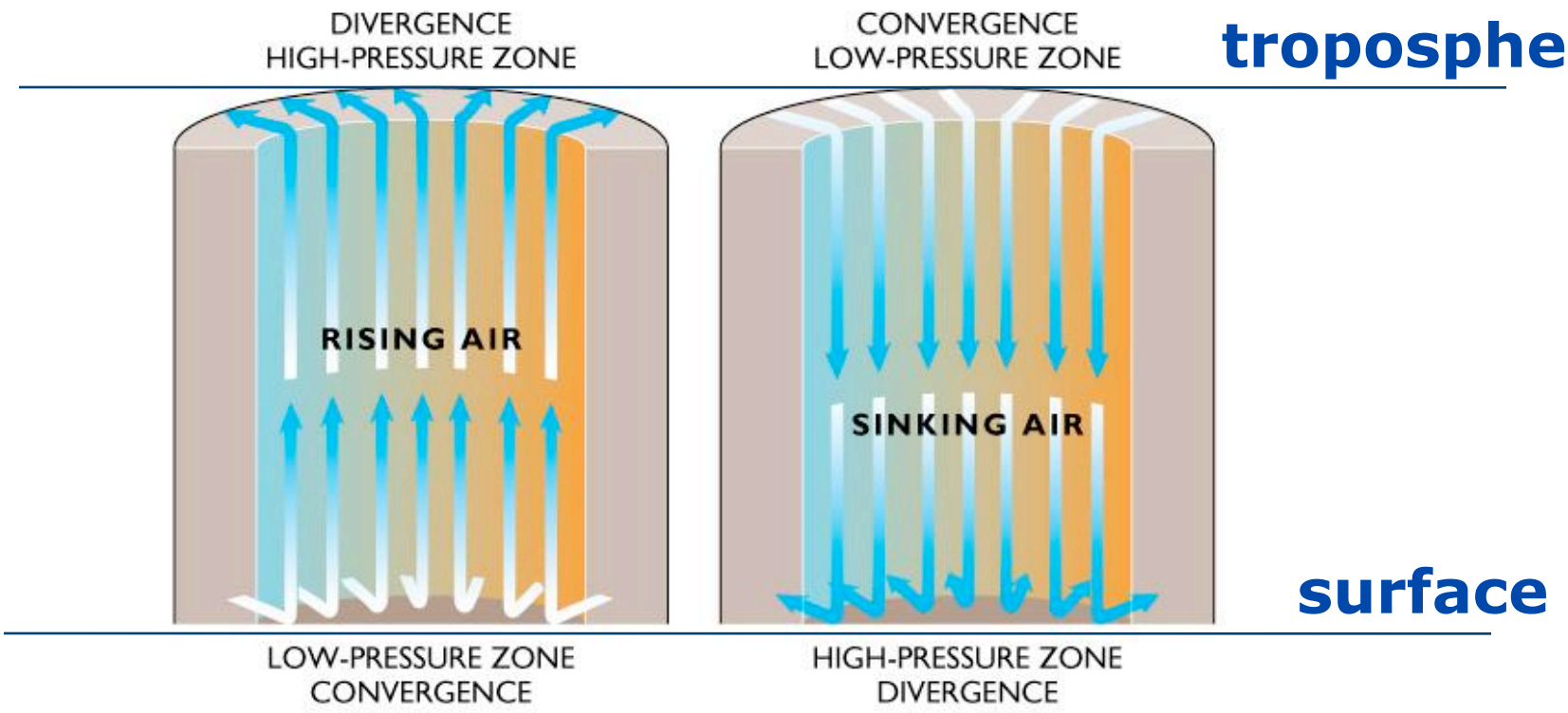
Flow of energy in the atmosphere



- Net heat gain in tropics
- Net heat loss at high-latitudes
- Atmospheric circulation is in part driven by the pole-equator differential heating
- Atmospheric and oceanic circulations transport heat from low to high latitudes

Vertical motions driven by heating / cooling

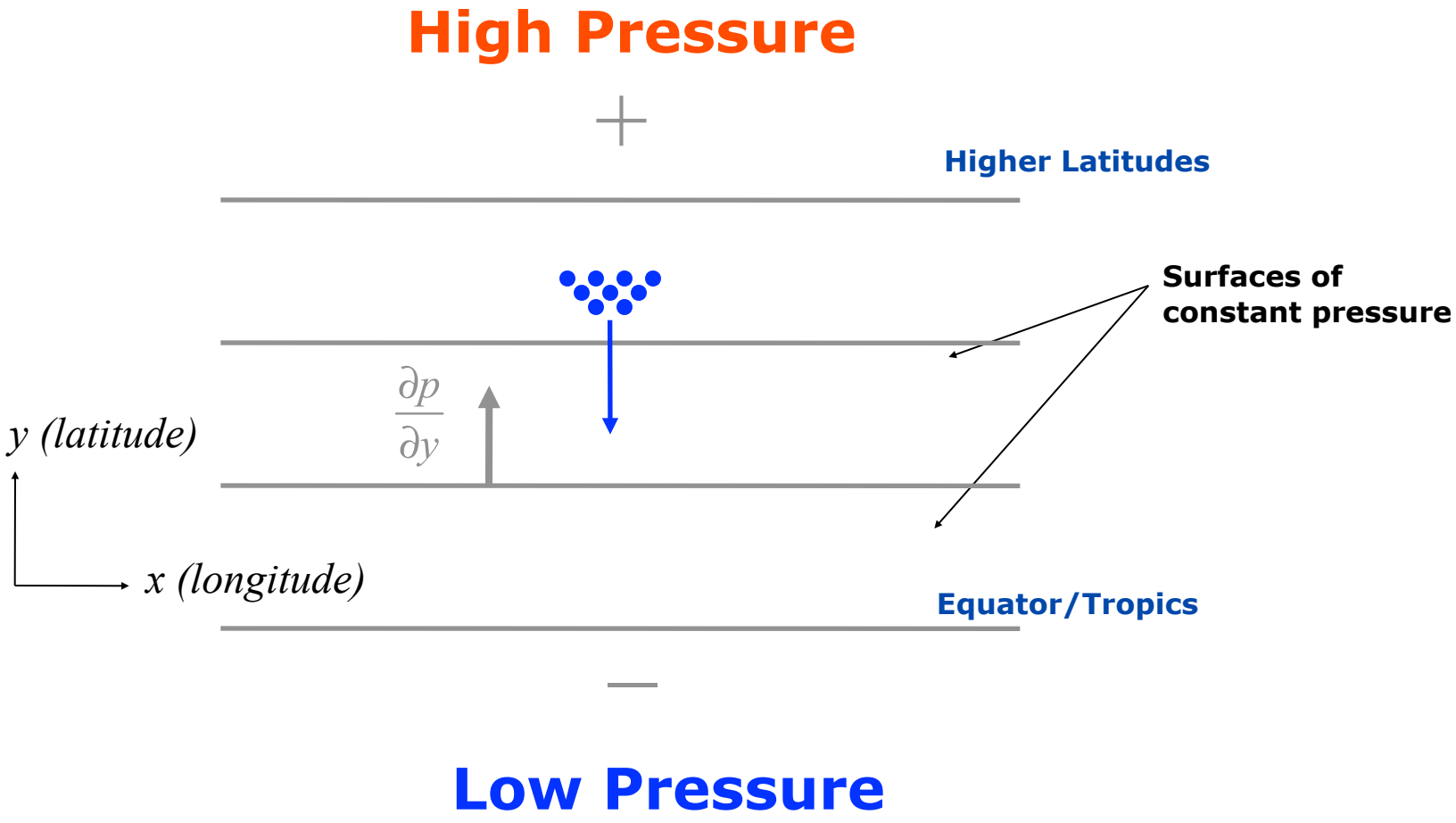
Heating by the sun → AIR PRESSURE



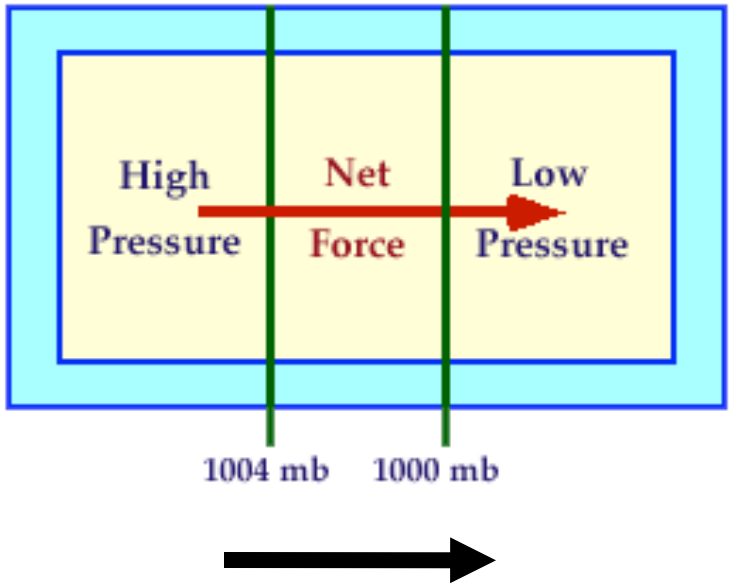
Equator/Tropics

Higher Latitudes

Horizontal view of air pressure at the surface

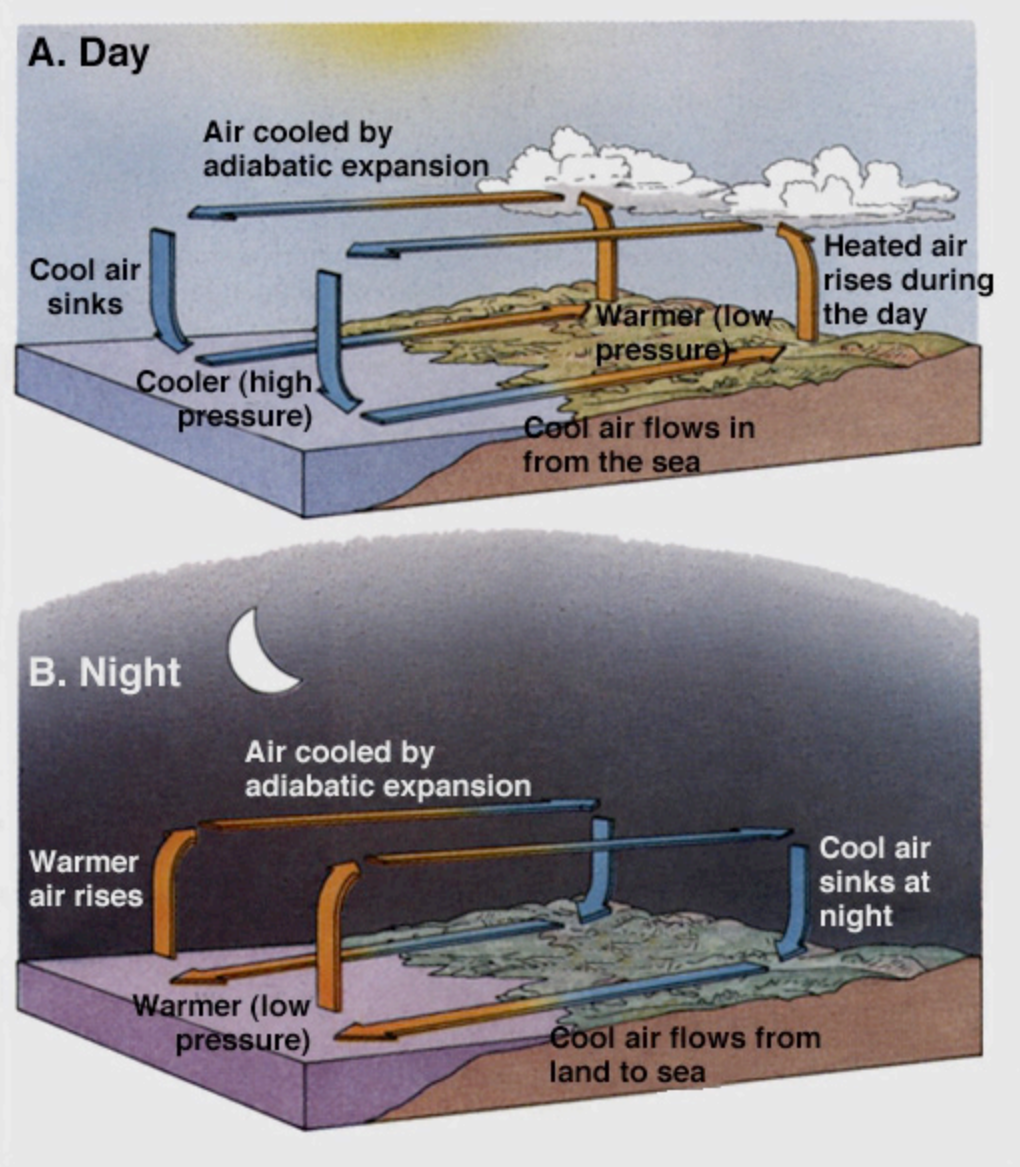


Fluid accelerates towards low pressure regions



$$-\nabla p$$

Land-Sea Breeze

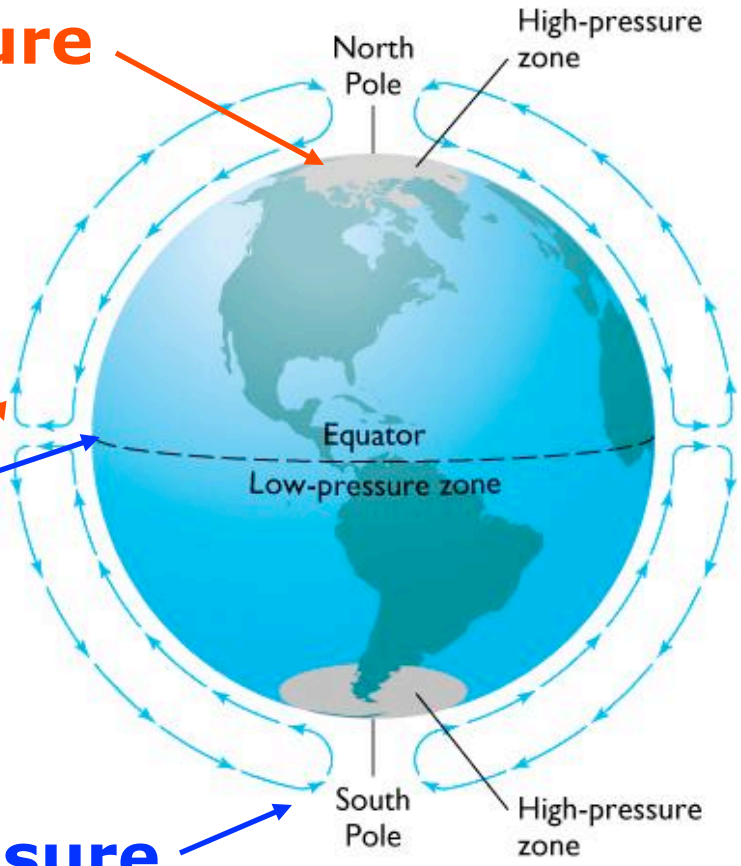


Vertical view of air pressure (horizontal convection)

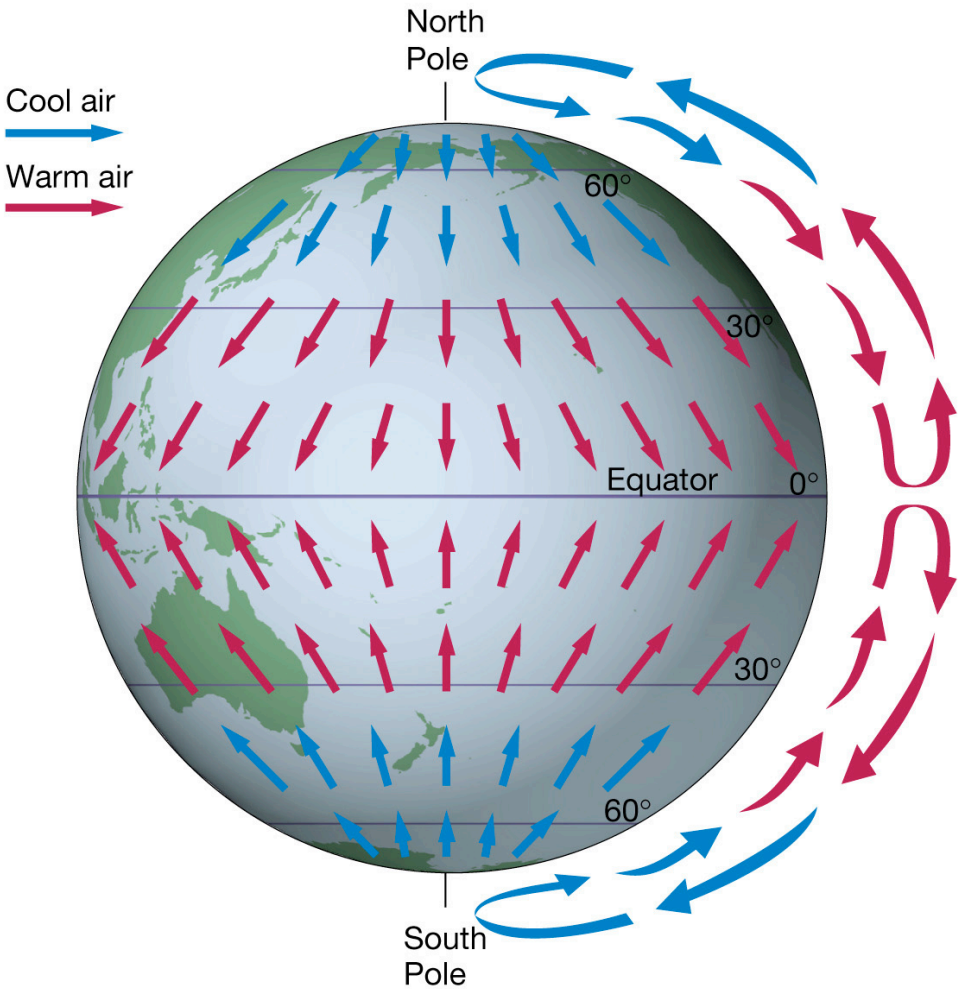
High Pressure

Low Pressure

Low Pressure

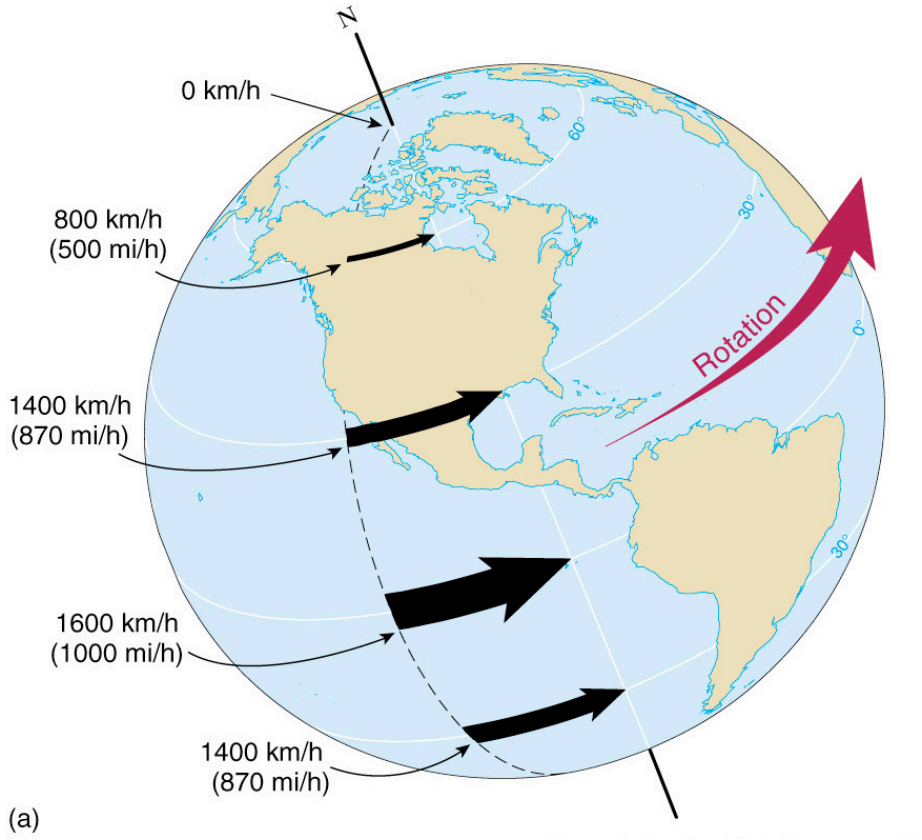


Non-rotating view of Atmospheric Circulation



Hadley circulation: Tropics

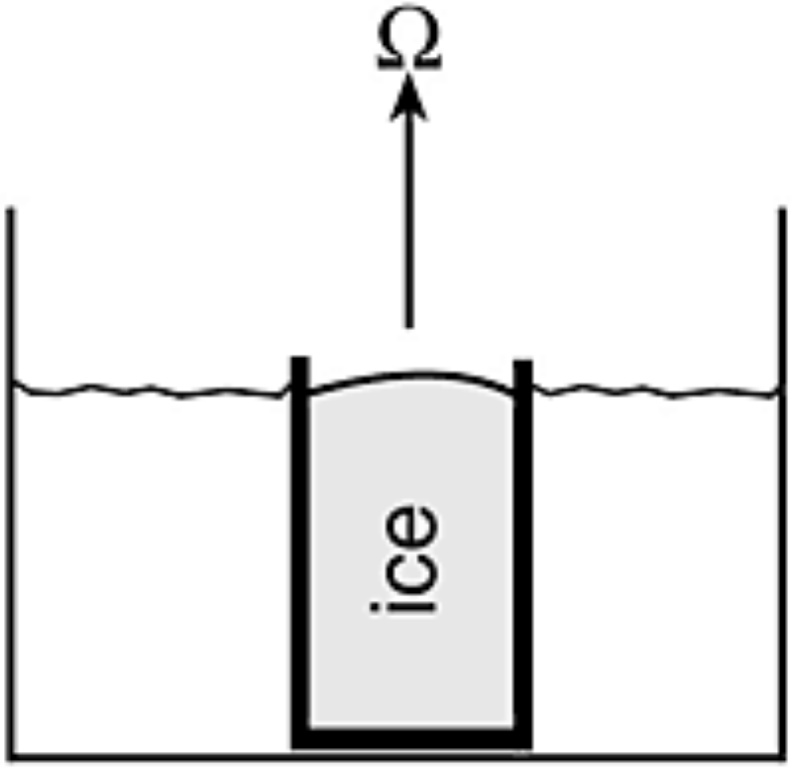
Rotation effect



We are in the rotating frame of reference

Tank demo

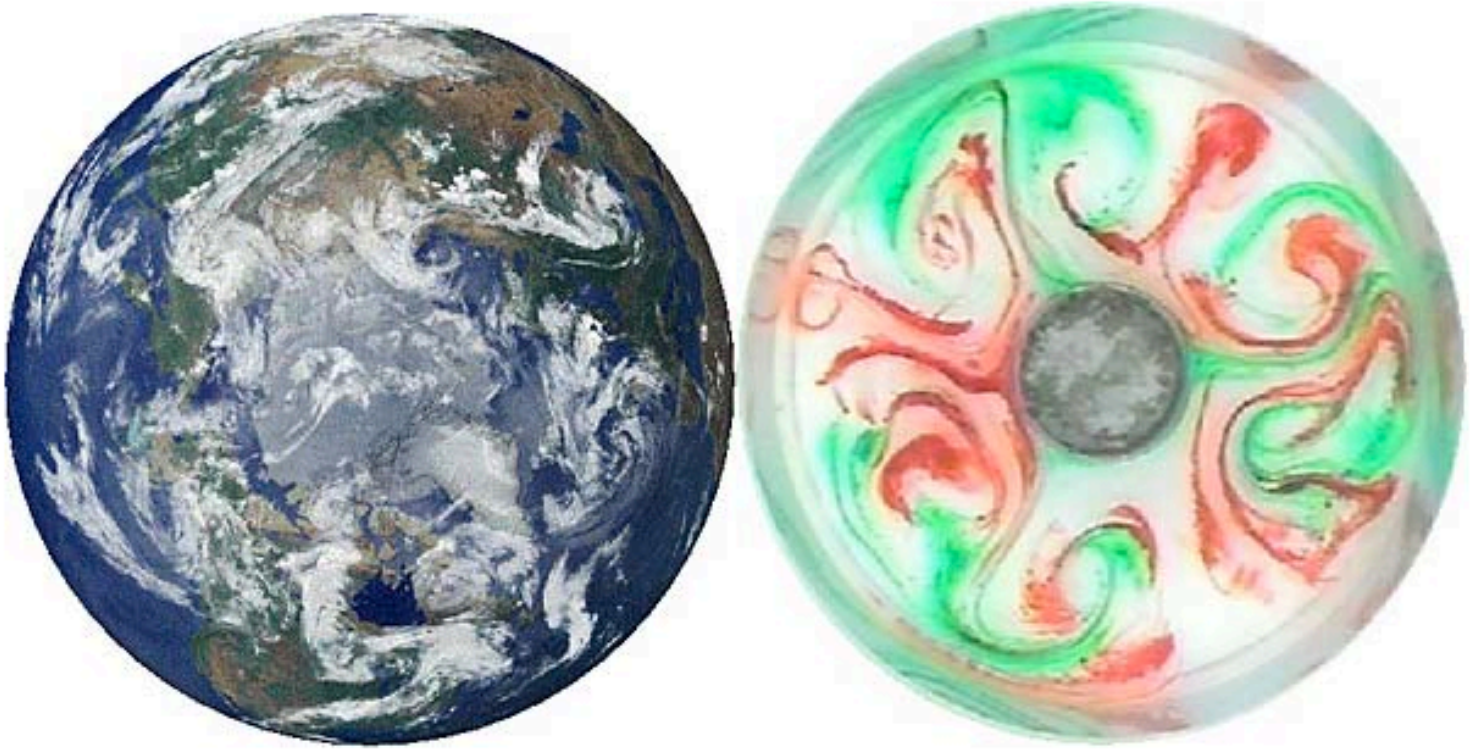
Differentially heated annulus experiment



Low lat. **"Pole"** **Low lat.**

Differentially heated, rotating flow

Baroclinic wave/vortices → "Weather events"



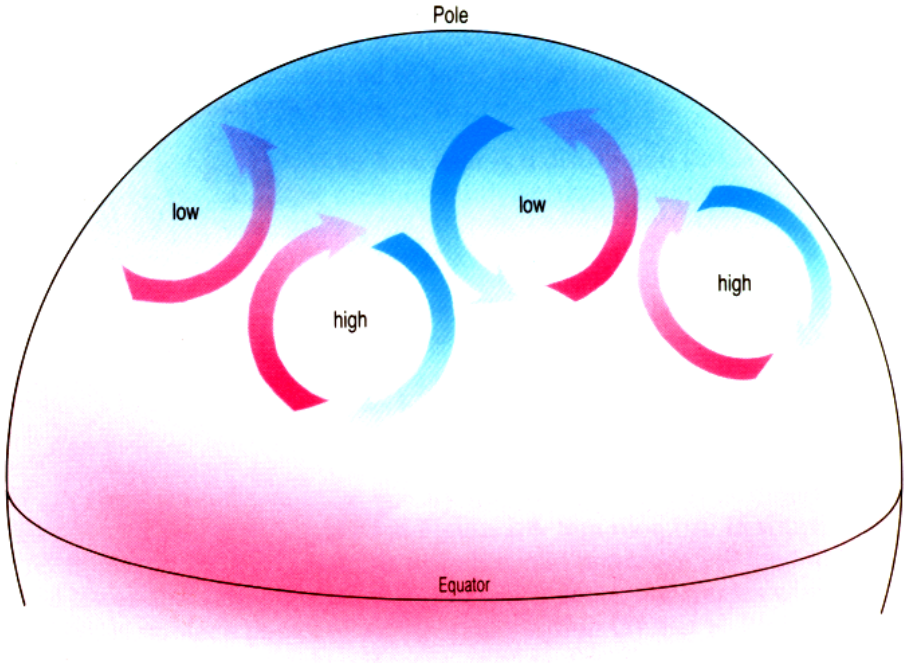
Look at the IR satellite images

http://www.meteo.psu.edu/~gadomski/SAT_NHEM/atlanim16wv.html

Differentially heated, rapidly rotating flow

Wave/vortex motion naturally emerges:

→ Mid-latitude cyclones: weather events



Ocean eddies

Same mechanism: planetary rotation +
temperature gradient