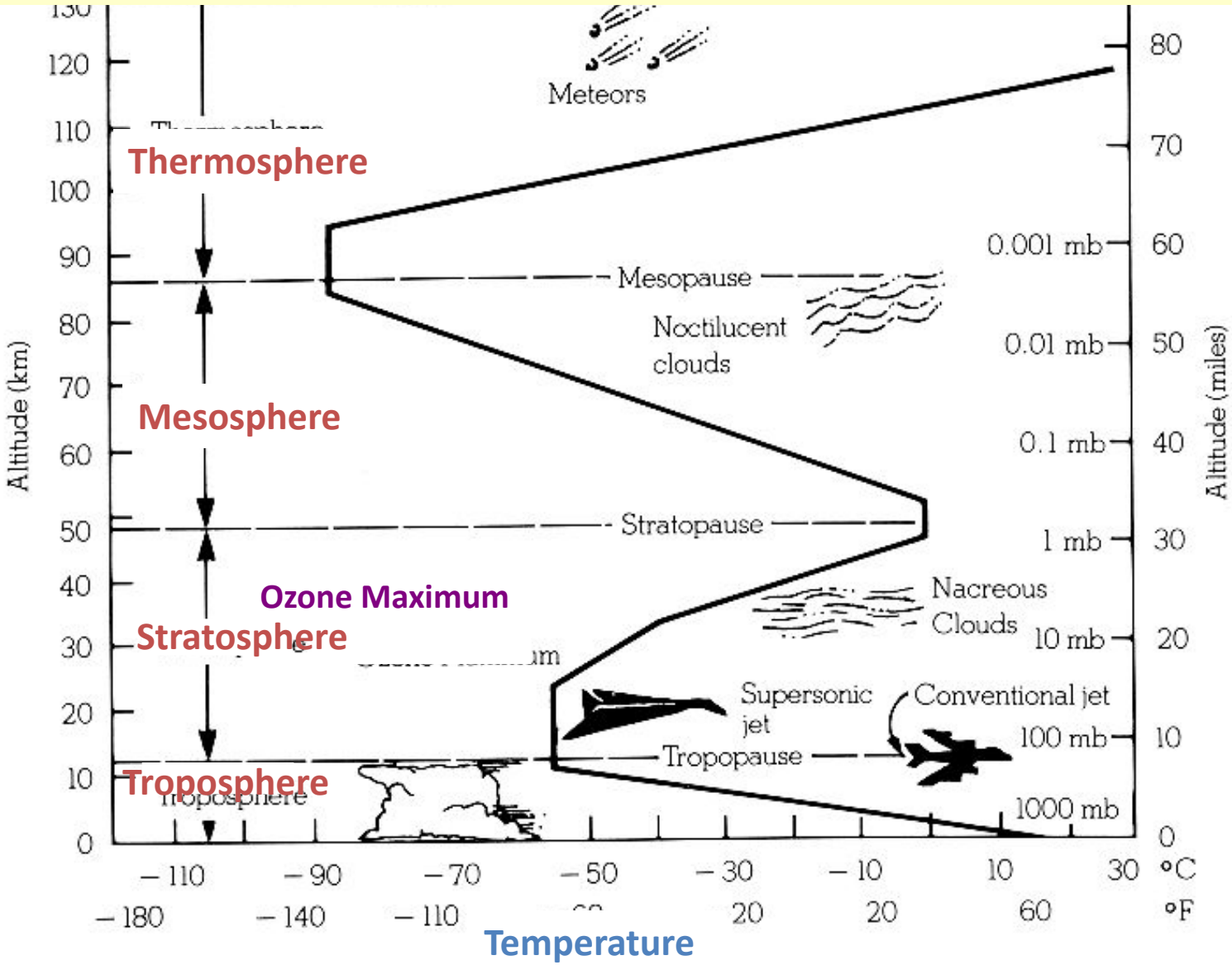
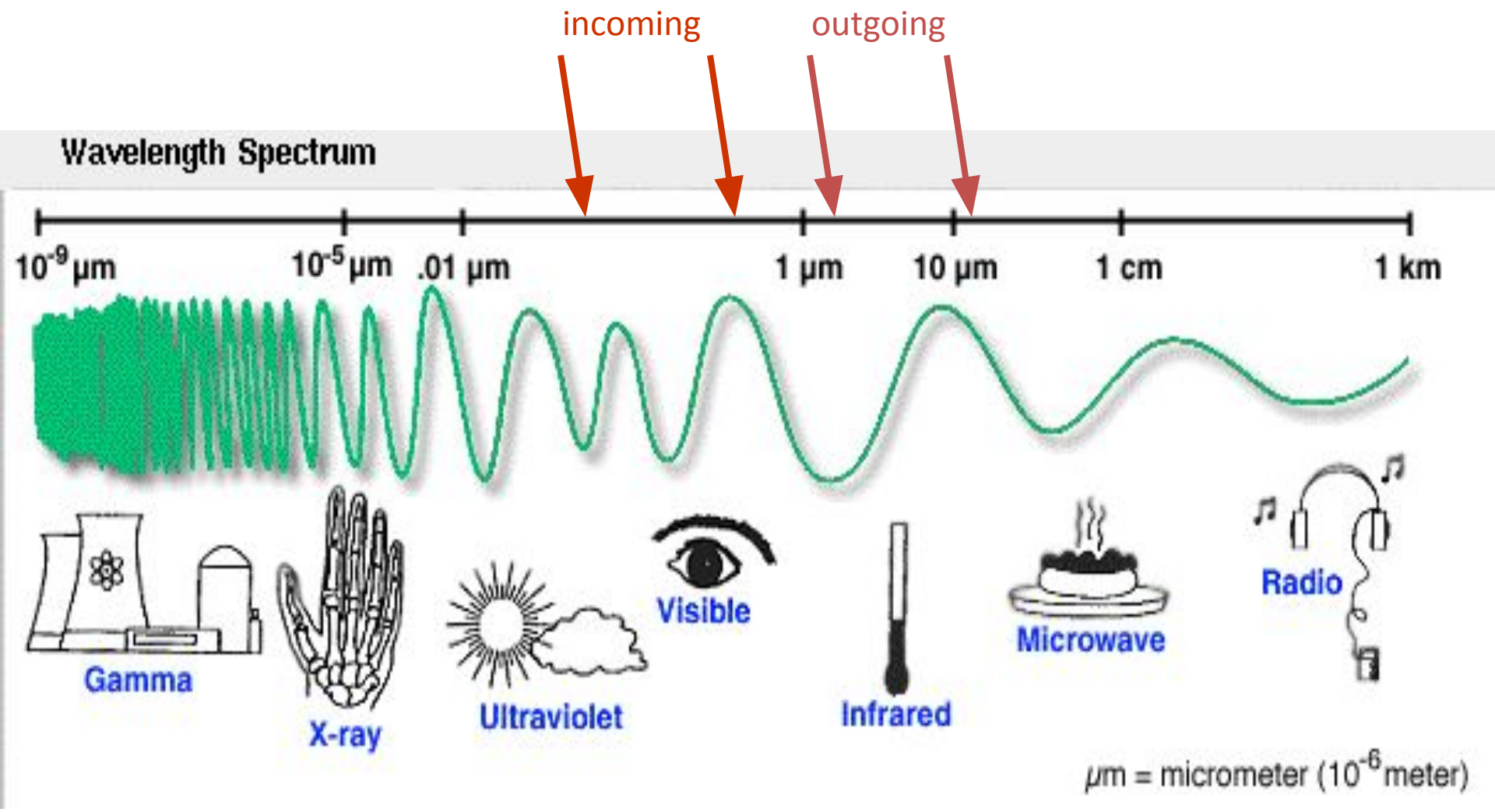
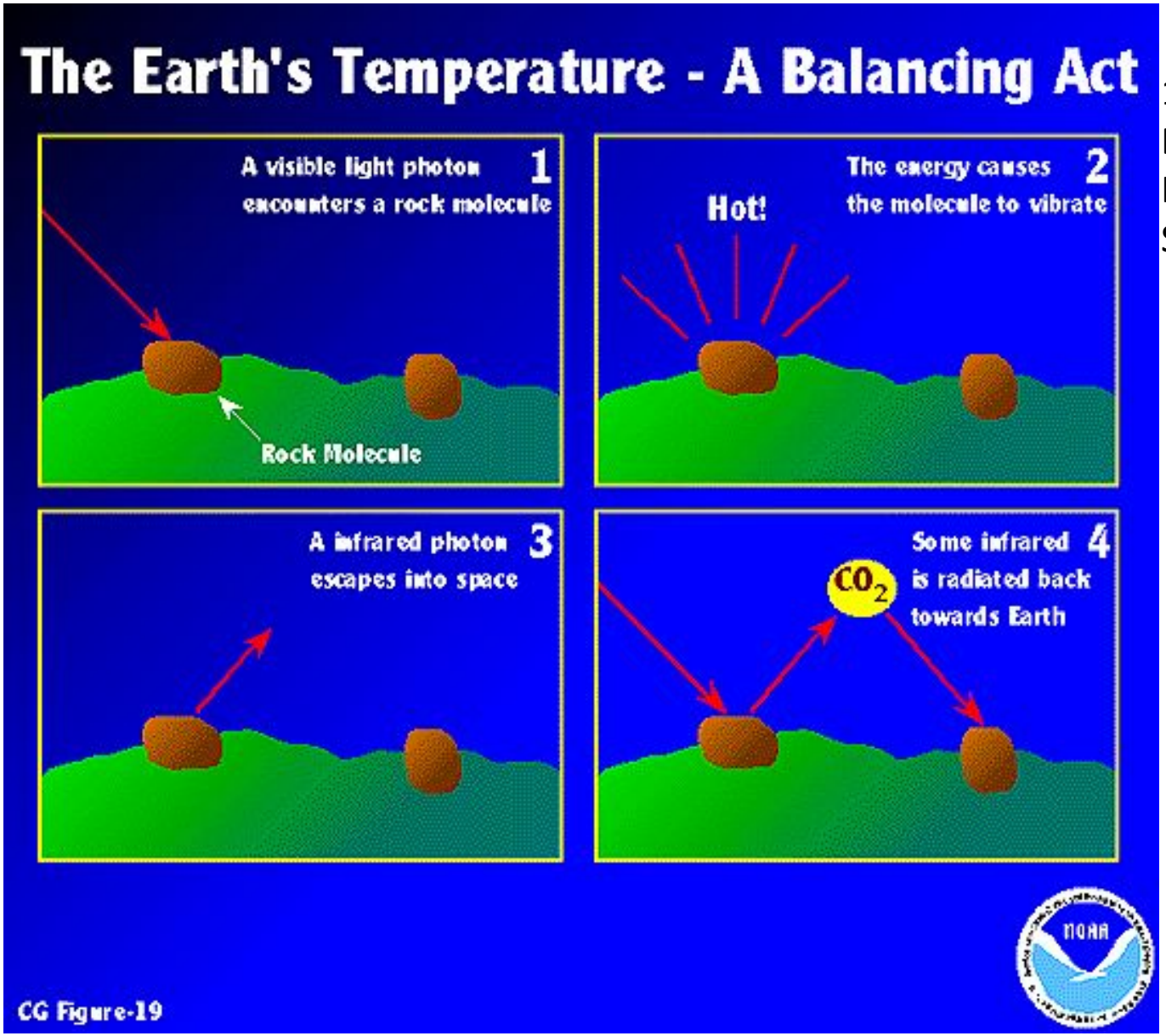
GHG
Water vapor

Structure of the Atmosphere



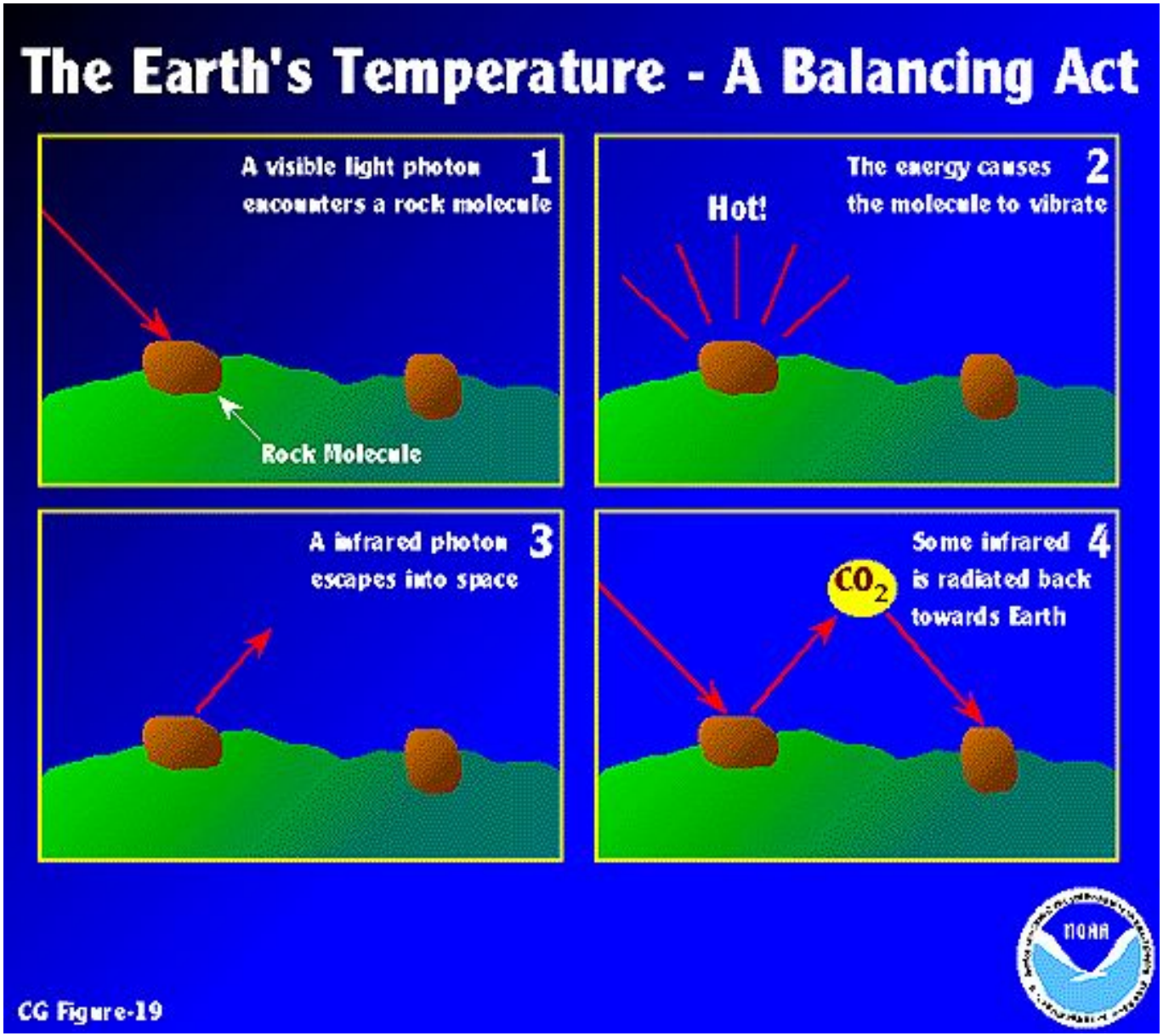
Electromagnetic Spectrum





1. Shorter, high Energy wavelengths Hit the earths Surface

2. Incoming energy Is converted to heat



3. Longer, infrared Wavelengths hit Greenhouse gas Molecules in the atmosphere

4. Greenhouse gas Molecules in the Atmosphere emit Infrared radiation Back towards earth

78% nitrogen

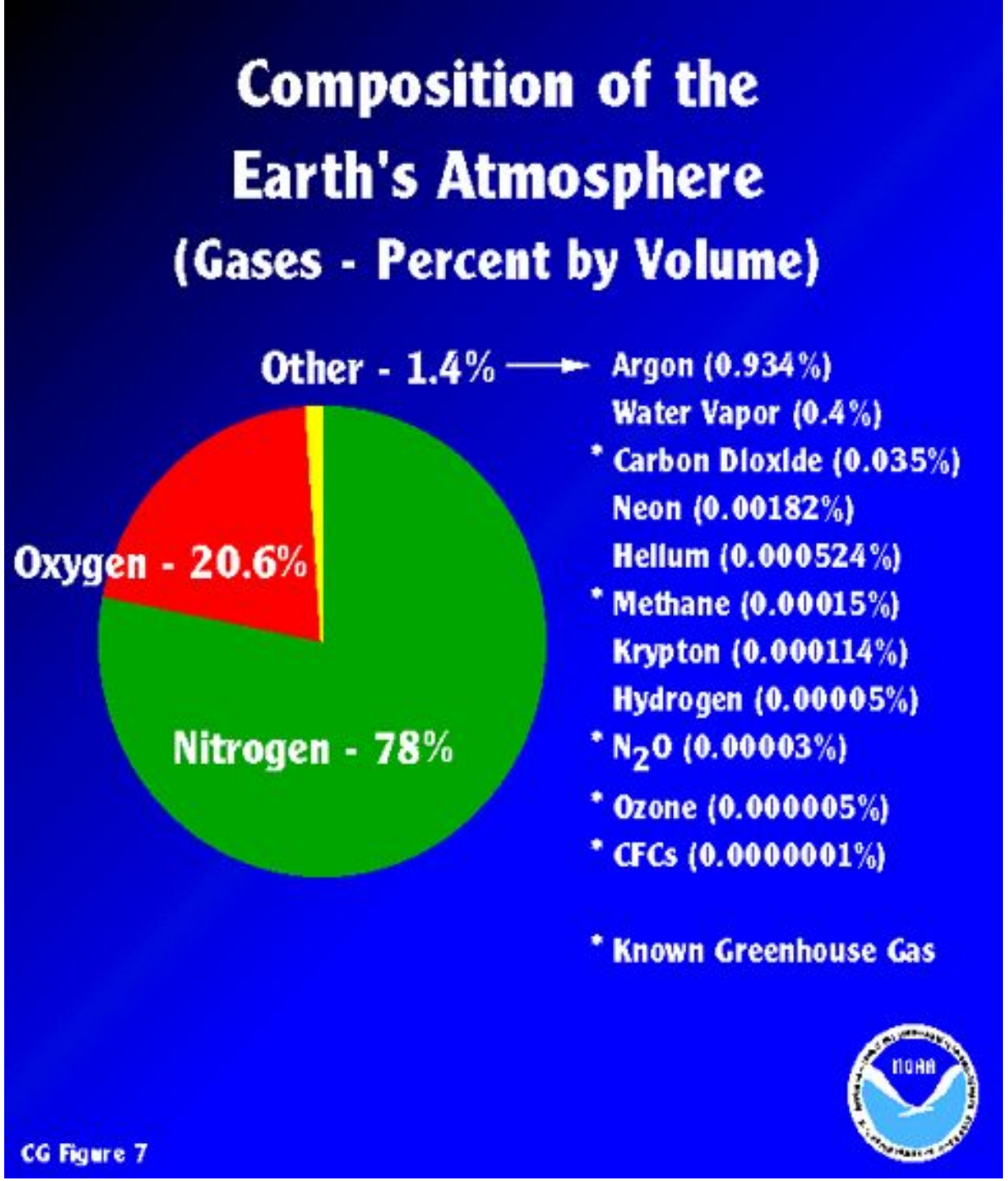
20.6% oxygen

< 1% argon

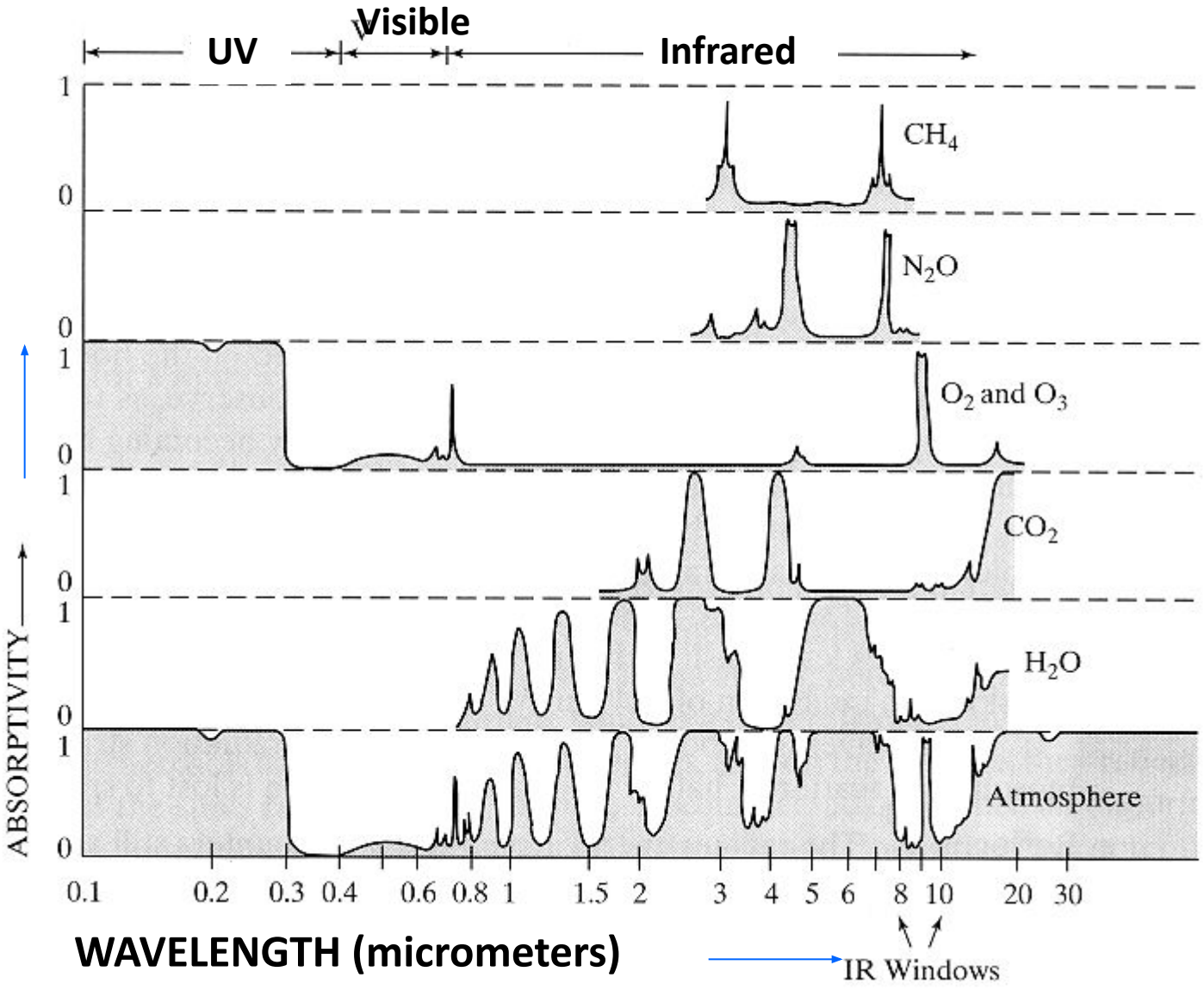
0.4% **<u>water vapor</u>**

0.036% **<u>carbon dioxide</u>**

traces gases:
Ne, He, Kr, H, O_3
<u>Methane</u>, **<u>Nitrous Oxide</u>**



Absorption Spectra of Atmospheric Gases



CH_4

N_2O

O_2 & O_3

CO_2

H_2O

atmosphere

Anthes, p. 55

Greenhouse gases absorb infrared radiation and prevent it from escaping to space.

Carbon dioxide, methane, and nitrous oxide are very good at capturing energy at wavelengths that other compounds miss

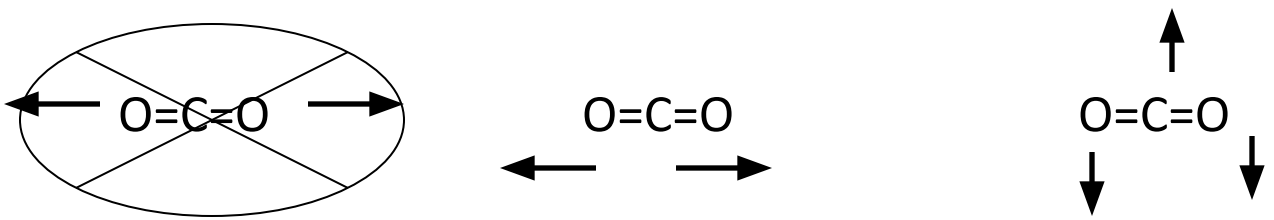
Climate Change

- Greenhouse Gases

- To be an effective greenhouse gas, a molecule must:

  - absorb light in the infrared region (must have dipole moment for vibration mode)

  - 3 modes of vibration for CO_2 shown



Symmetric vibration not allowed

Earth's Atmospheric Gases

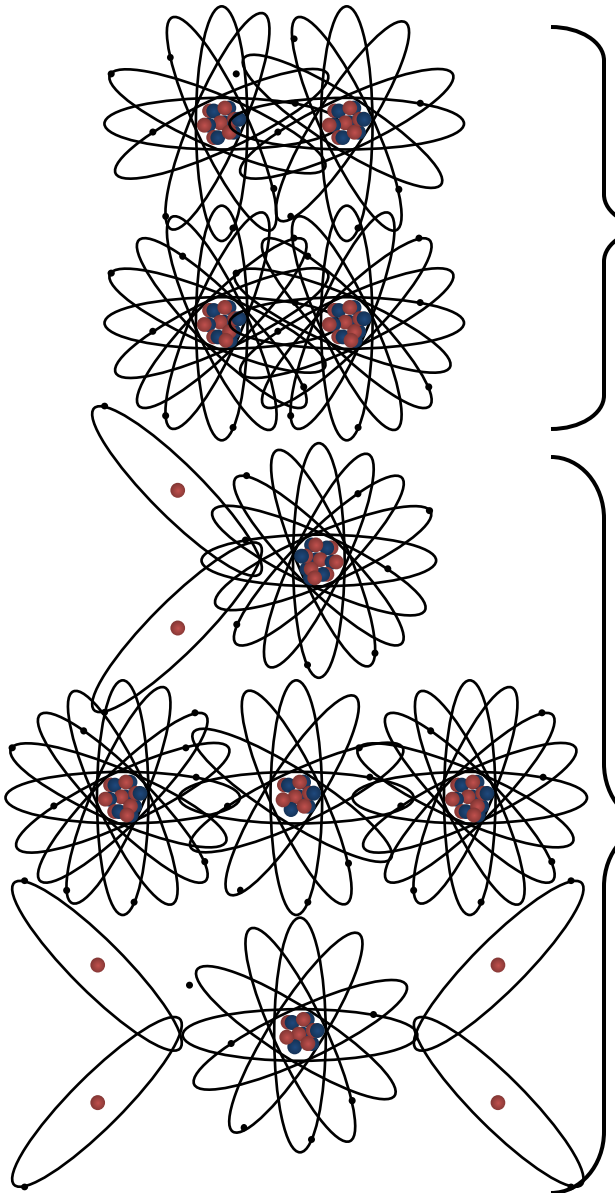
Nitrogen (N_2)

Oxygen (O_2)

Water (H_2O)

Carbon Dioxide (CO_2)

Methane (CH_4)



Non-Greenhouse Gases 99%

Greenhouse Gases 1%

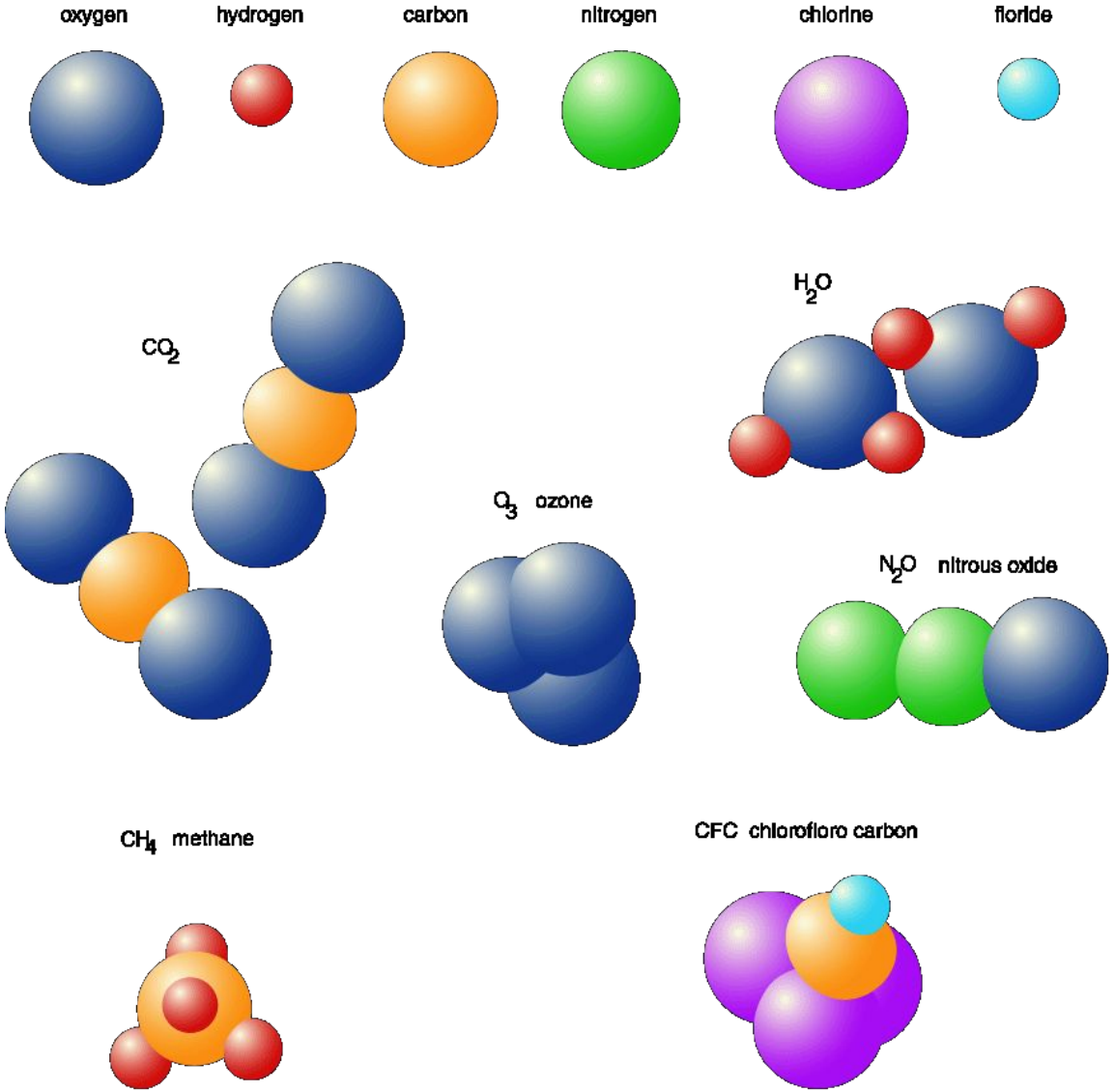
Greenhouse Gases

Carbon Dioxide

Water

Methane

Nitrous Oxide



Greenhouse Gases

- Molecules must absorb light in the right regions

  - roughly 7 to 25 μm region

  - however, in some regions (5 to 7 and 13 to 17 μm), essential no light from surface makes it to space due to current gases present

  - for this reason, CO_2 is less effective as a greenhouse gas (at least for additional CO_2)

- Greenhouse Gases

- Molecules absorbing light in the "IR window" regions are more effective
- Additional CO_2 is not as effective as additional N_2O (absorbs at 7.5 to 9 μm) on a forcing per ppm basis

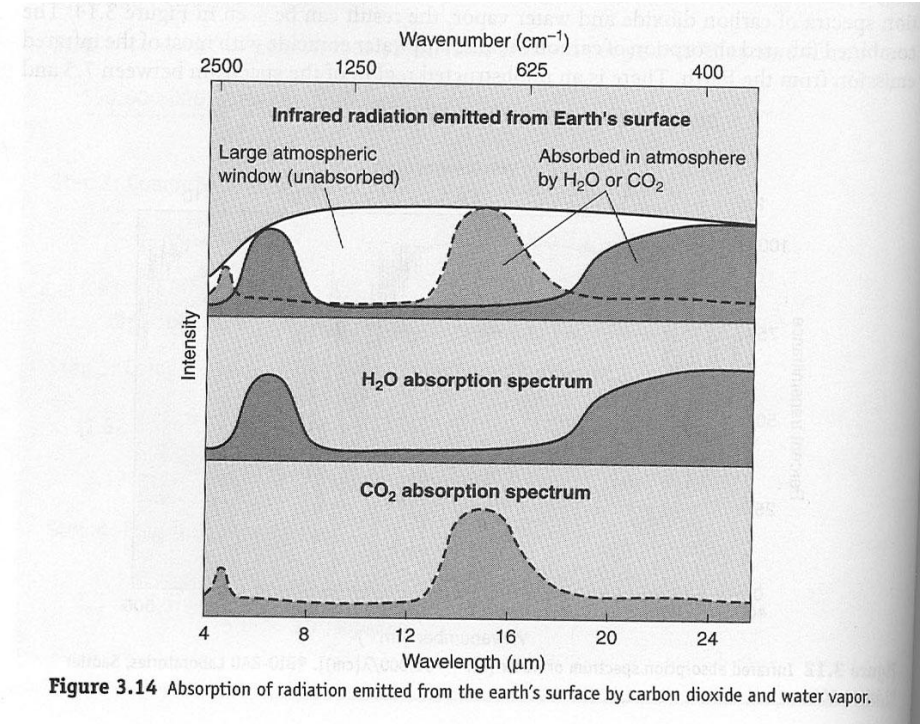


Figure 3.14 Absorption of radiation emitted from the earth's surface by carbon dioxide and water vapor.

From Girard (old text)

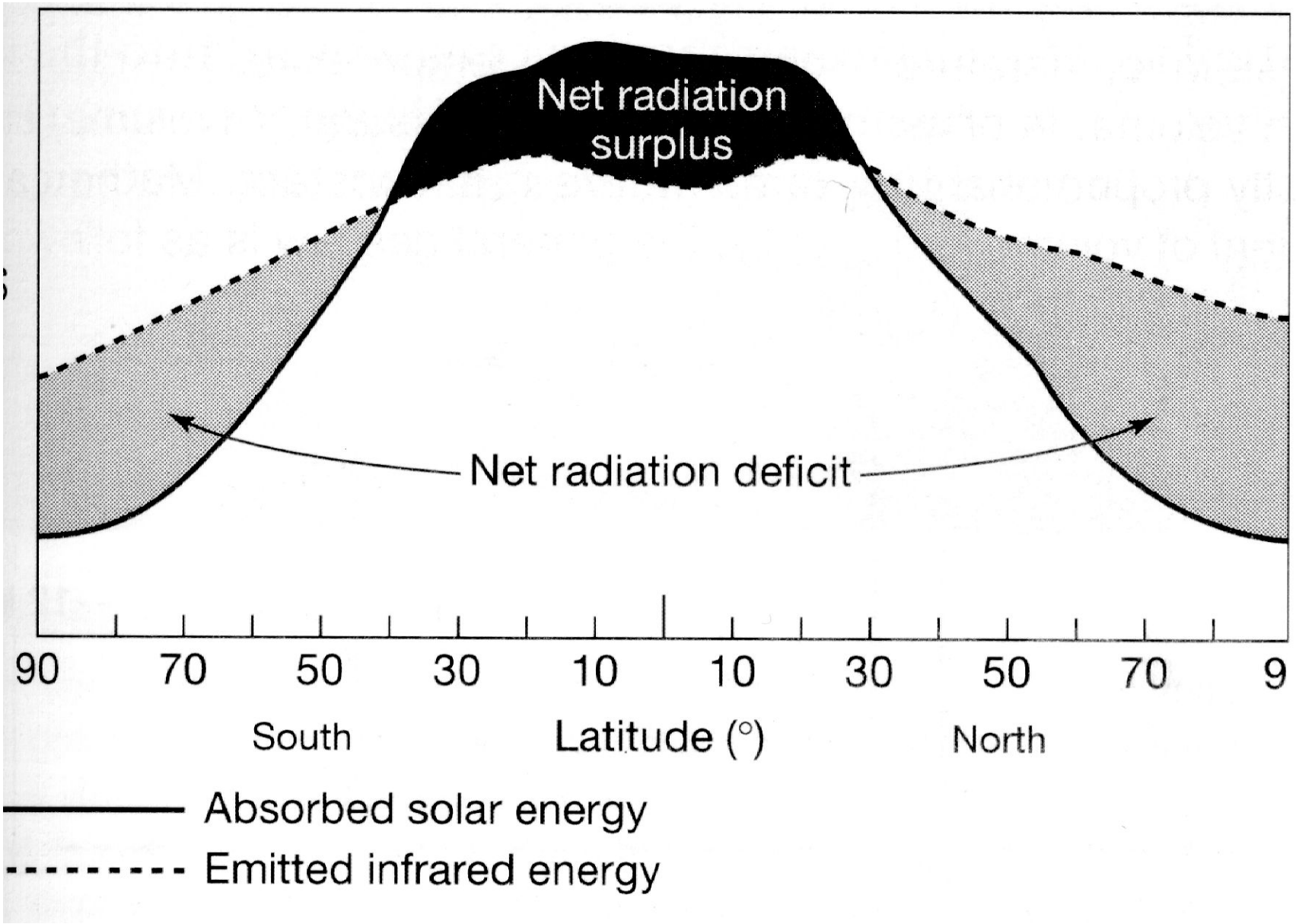
Selected Greenhouse Gases

- **Carbon Dioxide (CO_2)**
  - Source: Fossil fuel burning, deforestation
  - Anthropogenic increase: **30%**
  - Average atmospheric residence time: **200 years**
- **Methane (CH_4)**
  - Source: Rice cultivation, cattle & sheep ranching, decay from landfills, mining
  - Anthropogenic increase: **145%**
  - Average atmospheric residence time: **7-10 years**
- **Nitrous oxide (N_2O)**
  - Source: Industry and agriculture (fertilizers)
  - Anthropogenic increase: **15%**
  - Average atmospheric residence time: **140-190 years**

Greenhouse Effect & Global Warming

- The ***"greenhouse effect"*** & ***global warming*** are **not** the same thing.
  - Global warming refers to a rise in the temperature of the surface of the earth
- An increase in the ***concentration of greenhouse gases*** leads to an increase in the the ***magnitude of the greenhouse effect***. (Called enhanced greenhouse effect)
  - This results in global warming

Global Energy Redistribution



Radiation is not evenly distributed over the
Surface of the earth. The northern latitudes have an energy deficit and the low latitude/ equator has an excess. But the low latitudes don't indefinitely get hotter and the northern latitudes don't get colder.

Why?

The atmosphere and ocean transfer energy from low
latitudes to high

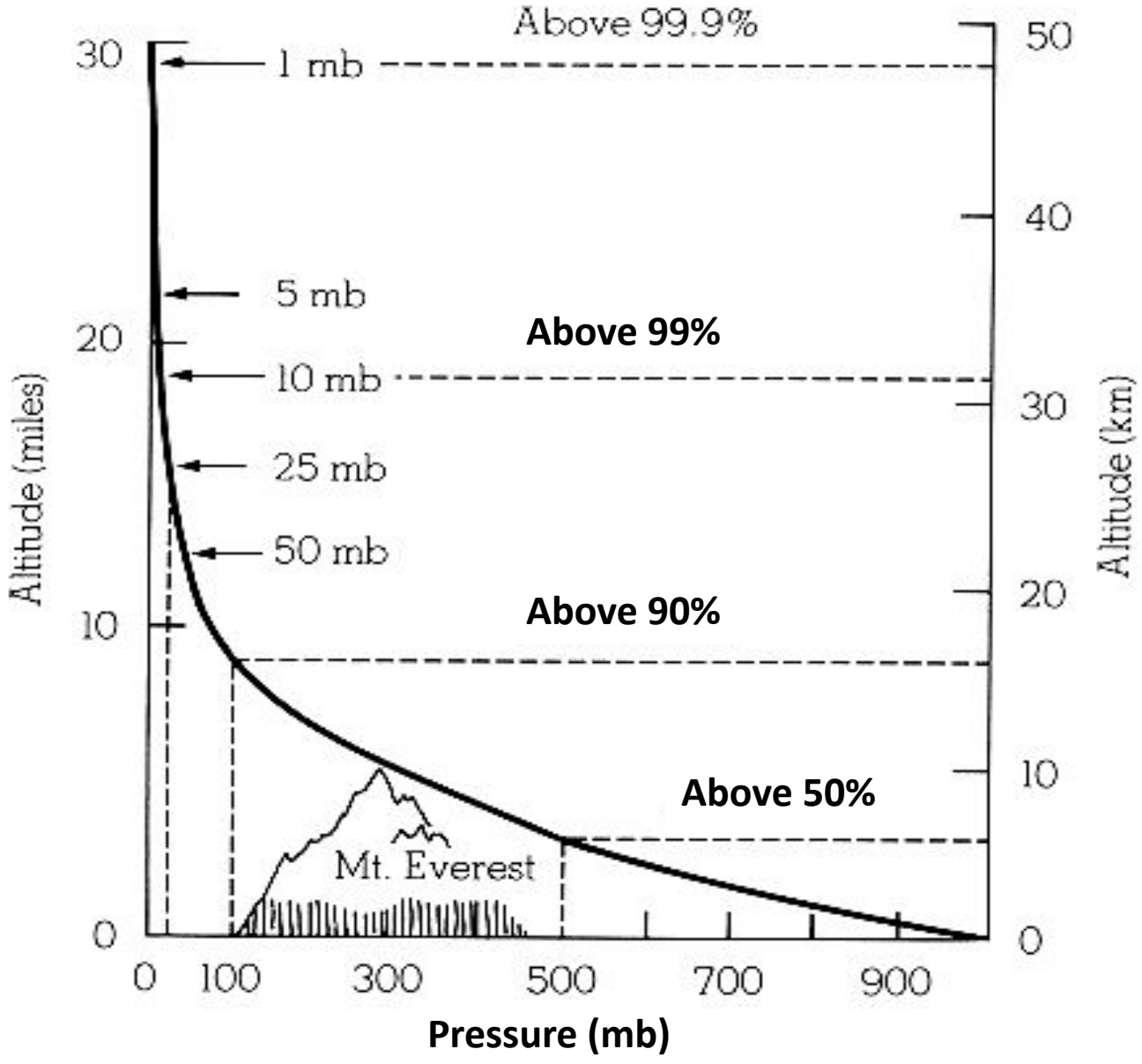
The climate engine II

- Since earth does rotate, air packets do not follow longitude lines (Coriolis effect)
- Speed of rotation highest at equator
- Winds travelling polewards get a bigger and bigger westerly speed (jet streams)
- Air becomes unstable
- Waves develop in the westerly flow (low pressure systems over Northern Europe)
- Mixes warm tropical air with cold polar air
- Net transport of heat polewards

Atmospheric Pressure Decreases With Height

Most of the energy is captured close to the surface

That energy drives climate and weather



50 percent of mass of the atmosphere is within 6 km of the surface

Cloud effects

- Low clouds over ocean
  - more clouds reflect heat (cooling)
  - fewer clouds trap heat (warming)
- High clouds
  - more clouds trap heat (warming)

- high: 5-14 km; low < 2km

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Fig. 19-10, p. 513

- Greenhouse Gases

- H_2O as a greenhouse gas

  - the molecule responsible for the most greenhouse effect heating

  - the third most prevalent molecule in the atmosphere (on average, but composition is variable)

  - direct anthropogenic sources are insignificant (at least outside of deserts and the stratosphere)

  - also responsible for cooling through increasing albedo (in clouds) so normally kept separate from other greenhouse gases

  - water vapor is important indirectly as planet heating increases water vapor (this is covered under feedbacks)

- The sun plays a key role in the earth's temperature
- Researchers think that atmospheric warming is not due to an increase in energy output from the sun
  - Since 1975
    - Troposphere has warmed
    - Stratosphere has cooled

- Warmer temperatures create more clouds
  - Thick, low altitude cumulus clouds – decrease surface temperature
  - Thin, cirrus clouds at high altitudes – increase surface temperature

- Water vapor is one of the most important elements of the climate system. A greenhouse gas, like carbon dioxide, it represents around 80 percent of total greenhouse gas mass in the atmosphere and 90 percent of greenhouse gas volume.
- Water vapor and clouds account for 66 to 85 percent of the greenhouse effect, compared to a range of 9 to 26 percent for CO2. So why all the attention on carbon dioxide and its ilk? Is water vapor the real culprit causing global warming?
- The answer is that water vapor is indeed responsible for a major portion of Earth's warming over the past century and for projected future warming. However, water vapor is not the cause of this warming. This is a critical, if subtle, distinction between the role of greenhouse gases as either forcings or feedbacks. In this case, anthropogenic emissions of CO2, methane, and other gases are warming the Earth. This rising average temperature increases evaporation rates and atmospheric water vapor concentrations. Those, in turn, result in additional warming.

Atmospheric Feedbacks