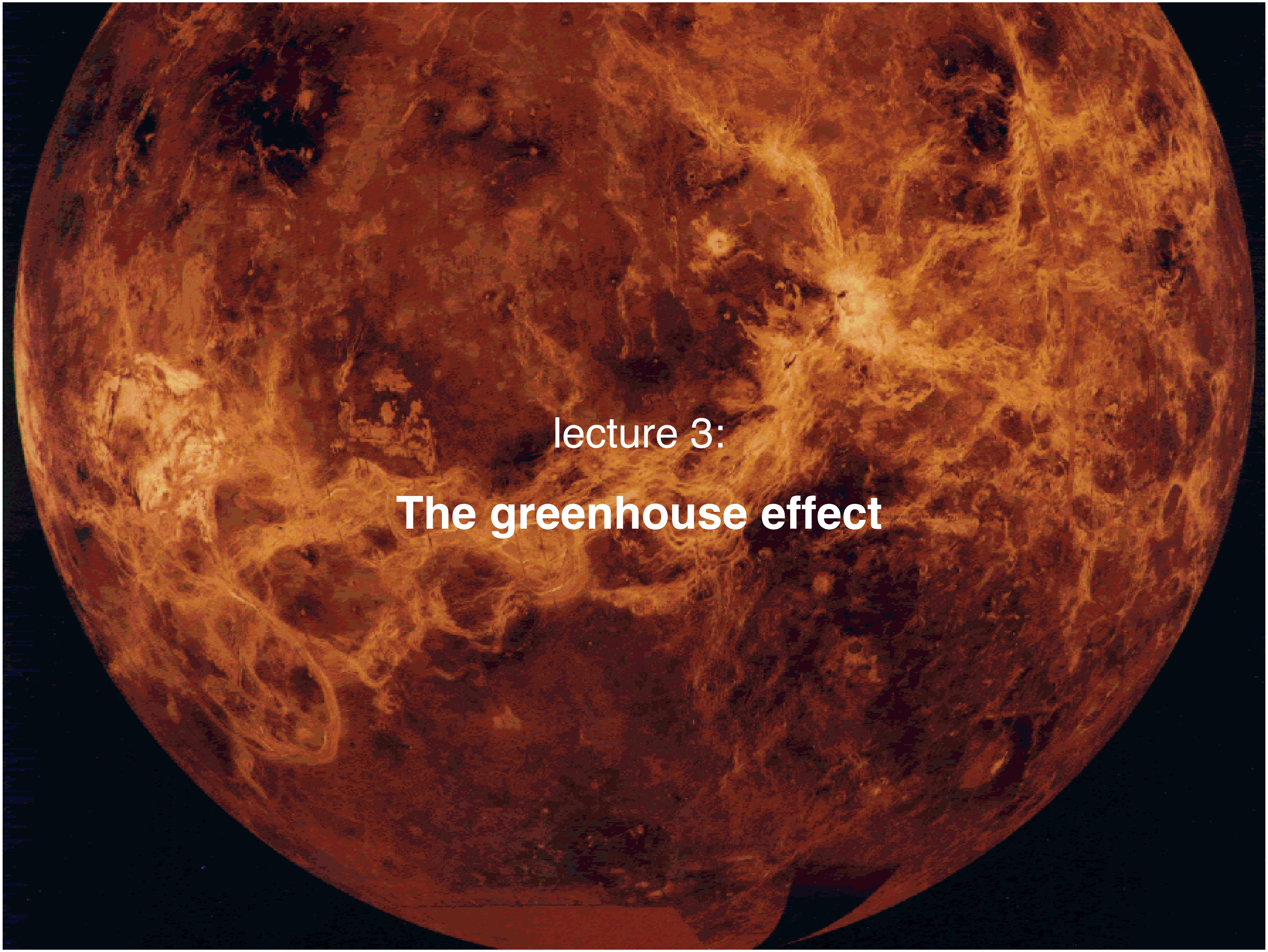

lecture 3:
The greenhouse effect

<u>Other concepts from Lecture 2</u>

Temperature Scales

Forms of Heat Transfer

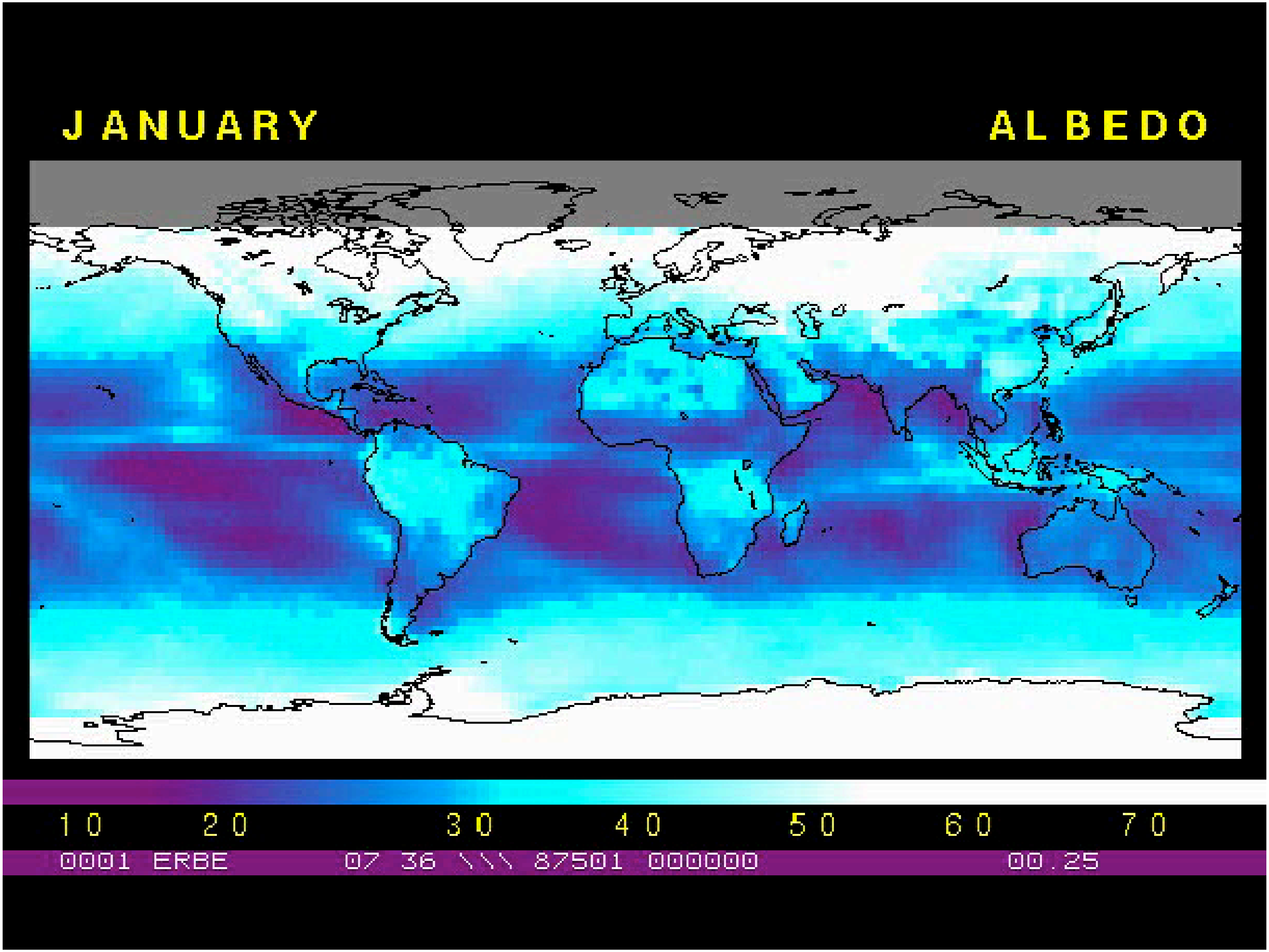
Electromagnetic Spectrum

Stefan-Boltzmann Law

Inverse Square Law

Reflectivity or Albedo

Solar and Terrestrial Radiation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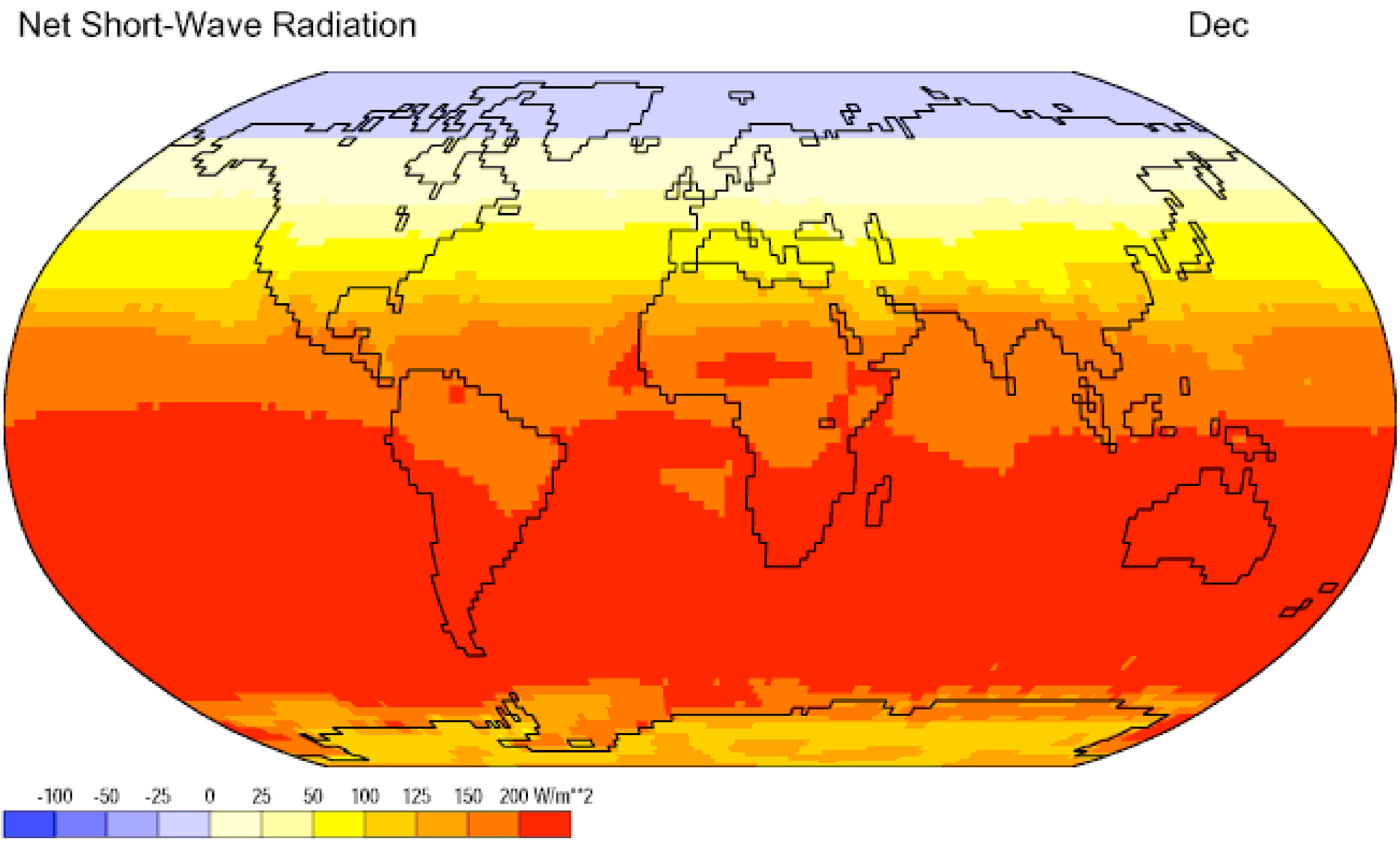
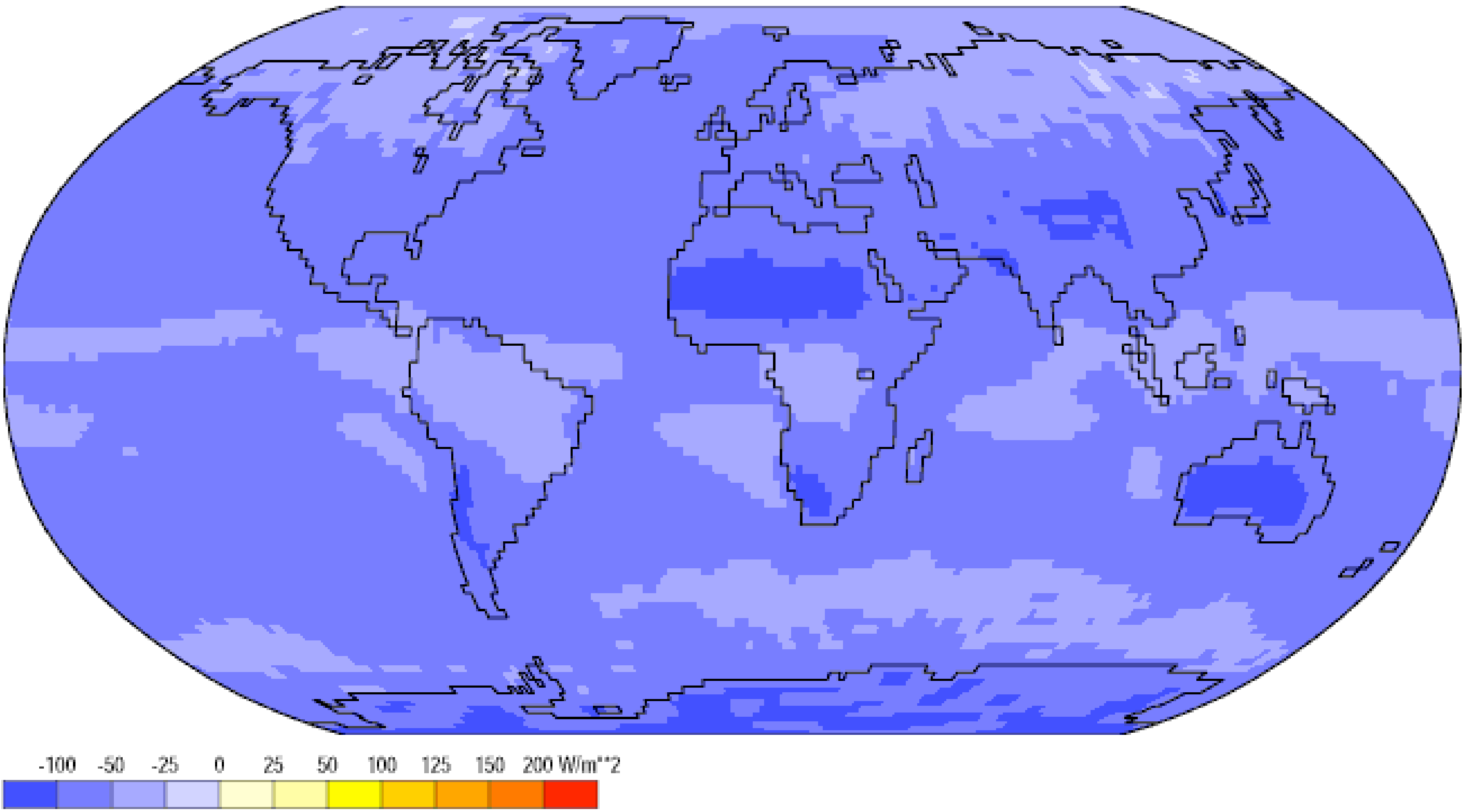


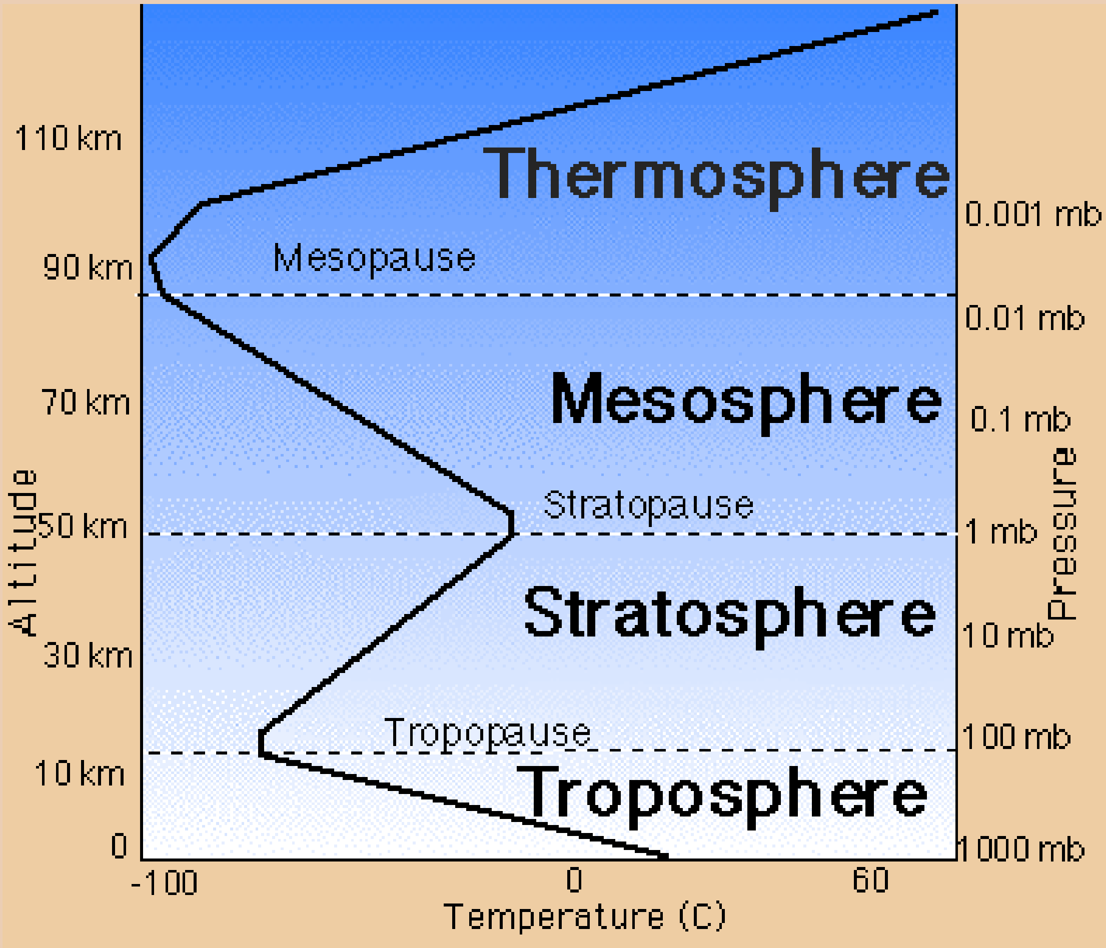
Data: NCEP/NCAR Reanalysis Project, 1959-1997 Climatologies
Animation: Department of Geography, University of Oregon, March 2000

Net Long-Wave Radiation Dec



Data: NCEP/NCAR Reanalysis Project, 1959-1997 Climatologies
Animation: Department of Geography, University of Oregon, March 2000

Thermal structure of the atmosphere



Keep in mind: 90% of the atmosphere's mass is in the troposphere.

The greenhouse effect of Venus

From geometry, we can calculate the average solar flux over the surface of Venus. It is approximately **661 W/m^2**.

Venus is very reflective of sunshine. In fact, it has a reflectivity (or albedo) of 0.8, so the planet absorbs approximately 661 X 0.2 = **132 W/m^2**.

By assuming that the incoming radiation equals the outgoing radiation (**energy balance**), we can convert this into an effective radiating temperature by invoking the Stefan-Boltzmann law (total energy = σT^4). We find that **T=220K**.

But Venus' surface has a temperature of **730K**!!!

The explanation for this huge discrepancy is the planet's greenhouse effect.

The greenhouse effect of Earth

From geometry, we can calculate the average solar flux over the surface of Earth. It is approximately **343 W/m^2**.

The earth has a much lower albedo than Venus (0.3), so the planet absorbs approximately 343 X 0.7 = **240 W/m^2**.

By assuming that the incoming radiation equals the outgoing radiation, we can convert this into an effective radiating temperature by invoking the Stefan-Boltzmann law (total energy = σT^4). We find that **T=255K**.

Earth's surface has a temperature of **288K**

While much smaller than Venus' greenhouse effect, earth's is crucial for the planet's habitability. Without the greenhouse effect, the temperature today in Los Angeles would be about 0 degrees Fahrenheit.

Main Constituents of the Earth's Atmosphere

Nitrogen	78%
Oxygen	21%
Argon	1%
Water Vapor	0-4%
Carbon Dioxide	0.036% (increasing)

Nitrogen, Oxygen, and Argon hardly interact with radiation. On the other hand water vapor and carbon dioxide both interact with infrared radiation---the type emitted by the earth and its atmosphere.

A greenhouse gas is defined as a gas that absorbs significantly the radiation emitted by the earth and its atmosphere.

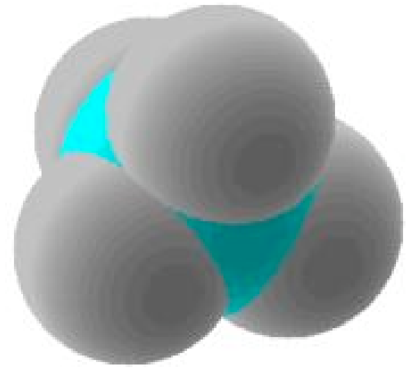
Important Greenhouse Gases

(concentrations in parts per million volume)

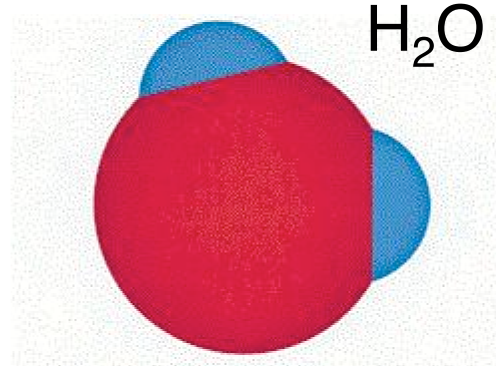
water vapor	0.1-40,000
carbon dioxide	360
methane	1.7
nitrous oxide	0.3
ozone	0.01
chlorofluorocarbons	~0.0007

Why do certain gases interact with radiation?

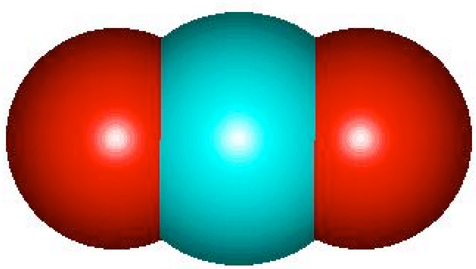
When radiation impinges on a molecule, it can excite the molecule, either by vibrating or rotating it. Molecules of a particular kind of gas have a different shape from molecules of another type of gas, and so are excited by radiation in different ways.



CH_4

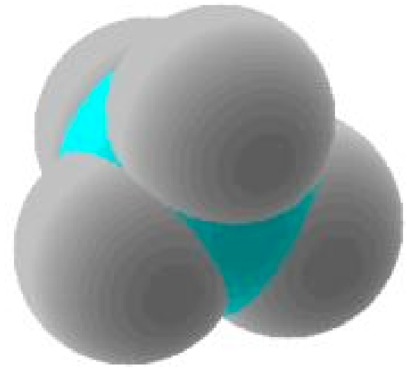


H_2O



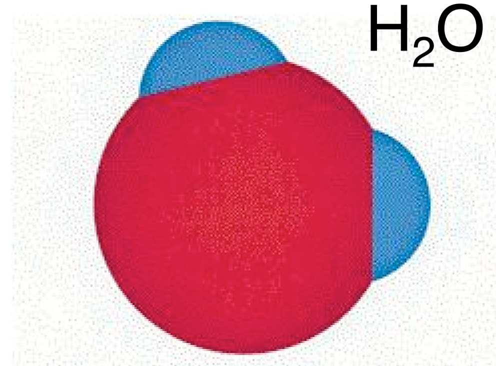
CO_2

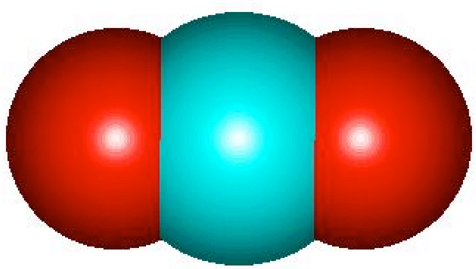
Because of their varying geometries and sizes, different molecules absorb radiation of different wavelengths. For example, CO_2 tends to absorb radiation of a wavelength of 15 microns (this wavelength excites bending vibration of the CO_2 molecule), whereas H_2O tends to absorb at wavelengths around 12 microns (rotation of the H_2O molecule) .



CH_4

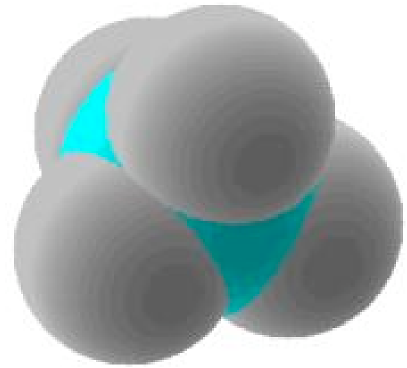
H_2O





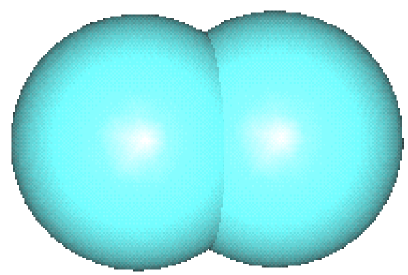
CO_2

Molecules with more than two atoms tend to absorb radiation more effectively than diatomic molecules such as N_2 and O_2. This is because the more atoms a molecule contains, the more ways it can vibrate and rotate. This is why diatomic nitrogen and oxygen are not greenhouse gases.

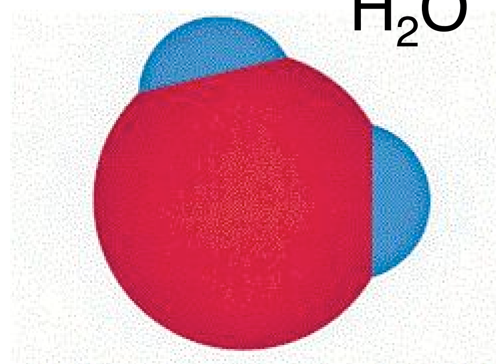


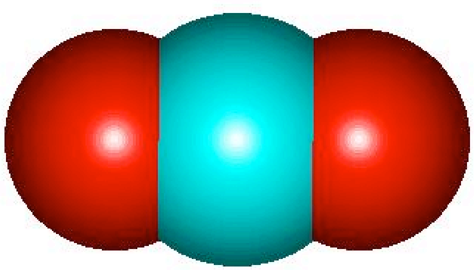
CH_4

O_2



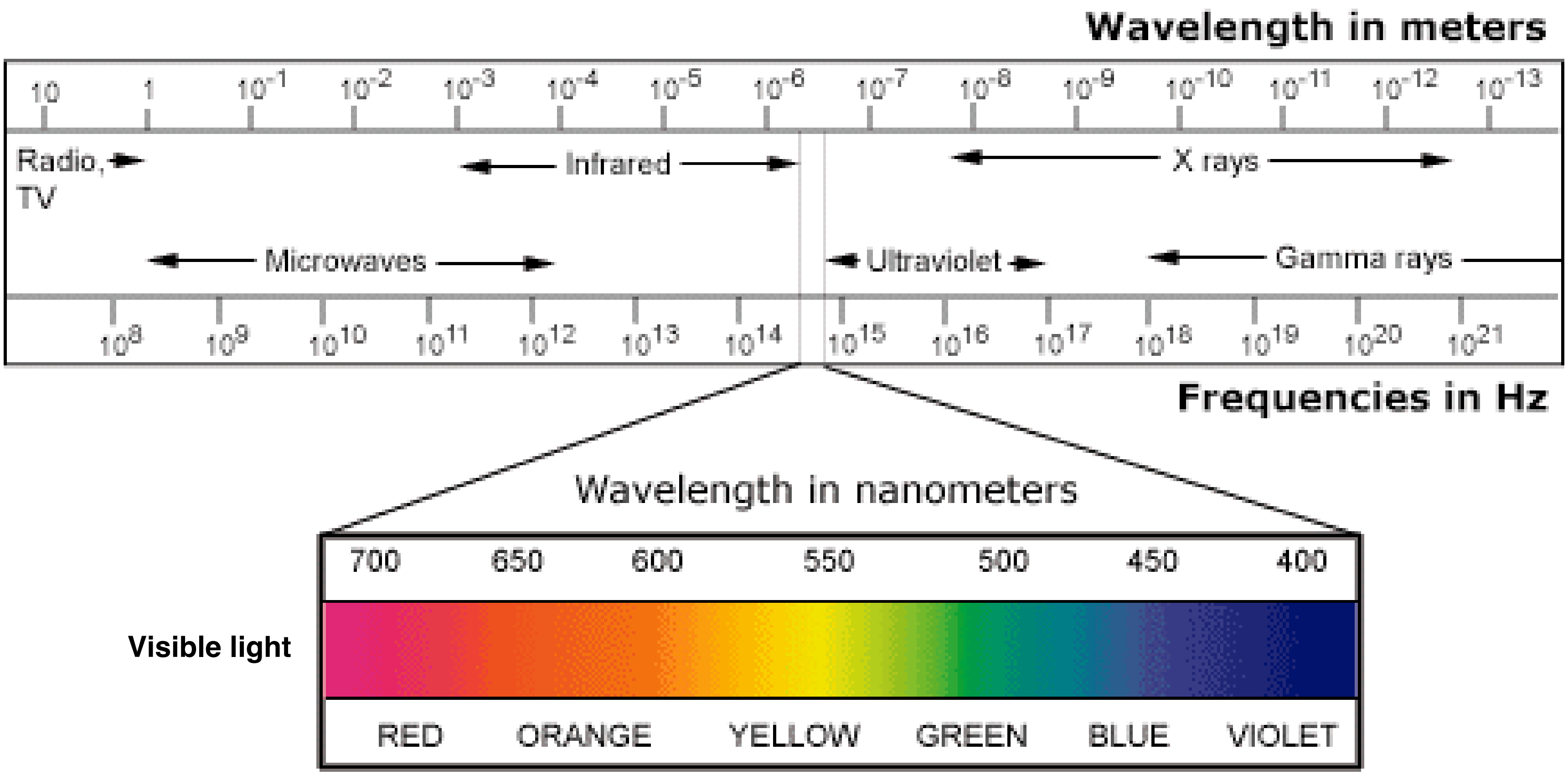
H_2O





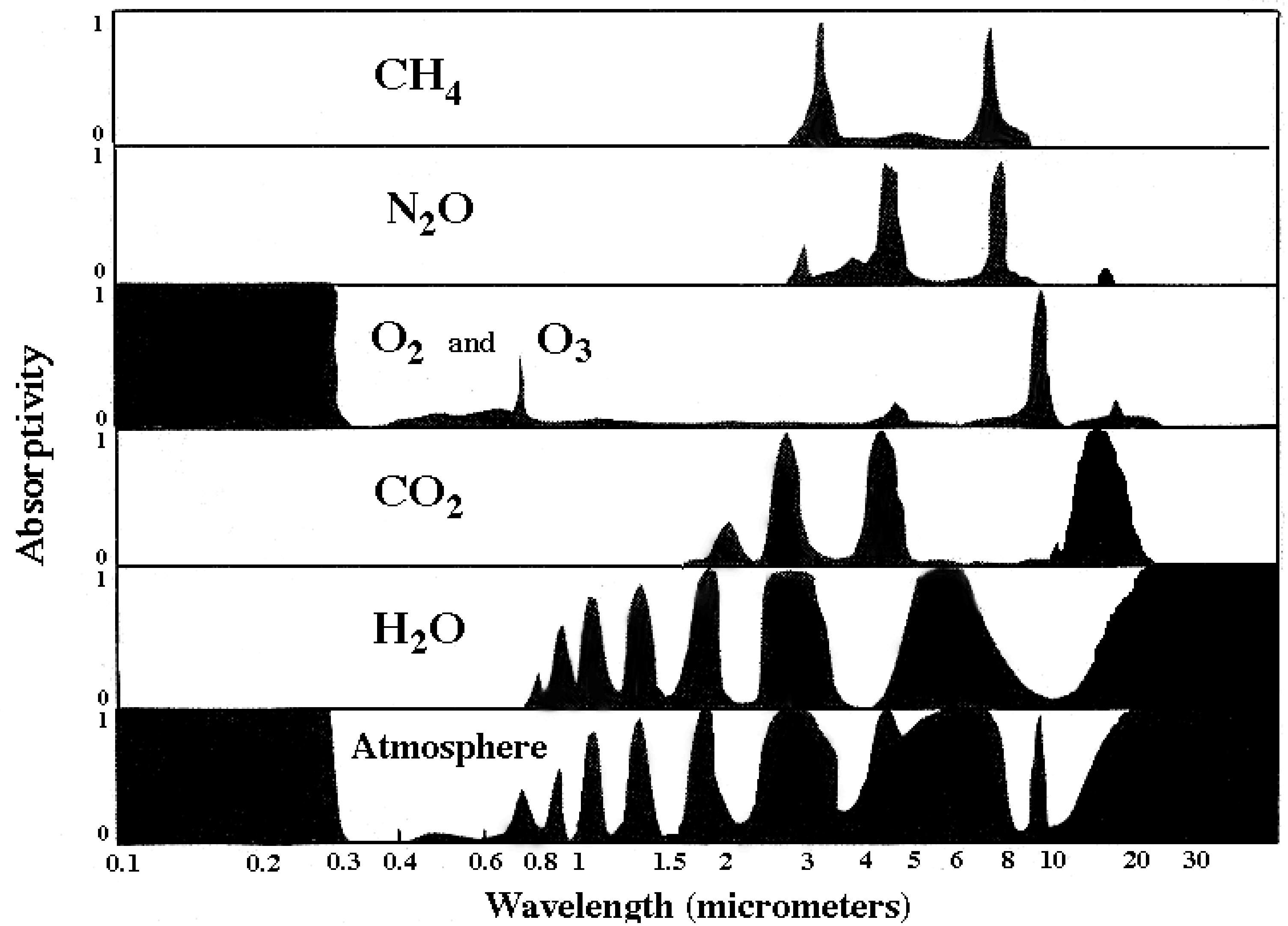
CO_2

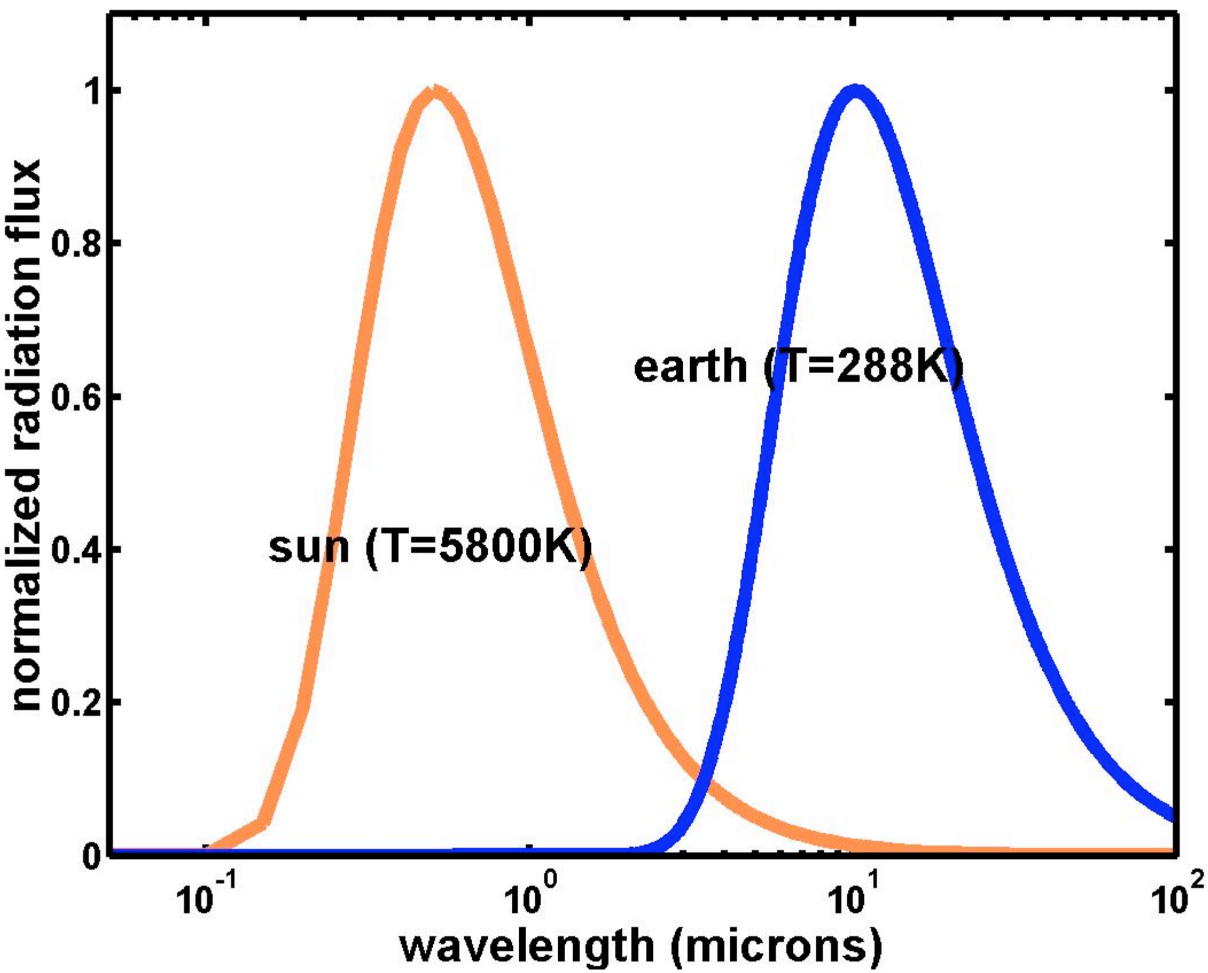
The various forms of radiation are organized according to their wavelengths (and hence energy levels), creating the **electromagnetic spectrum**.



Visible light

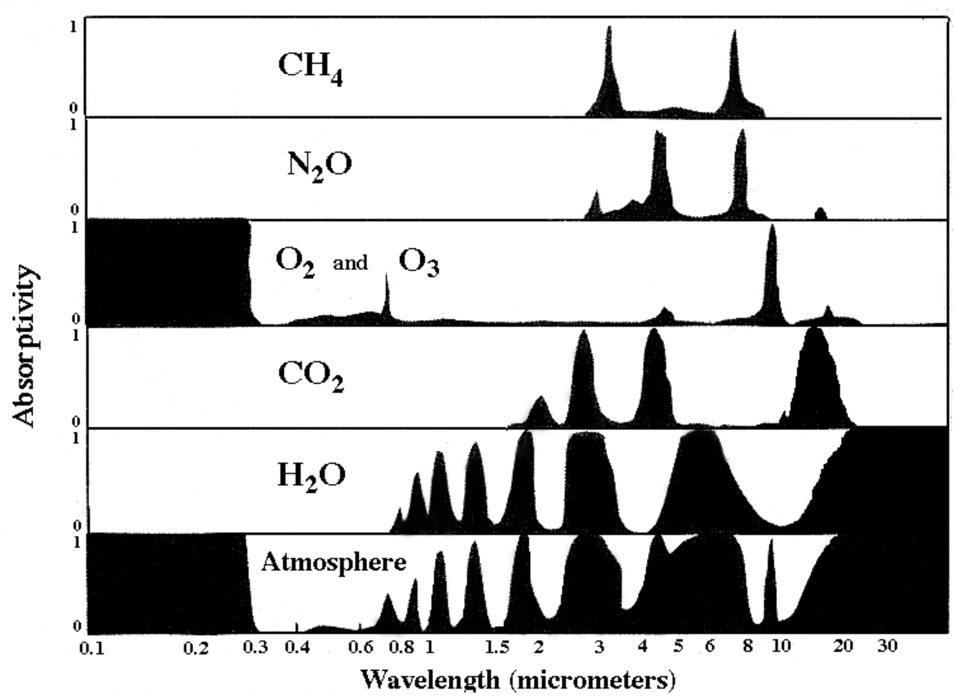
Interaction of the atmosphere with radiation

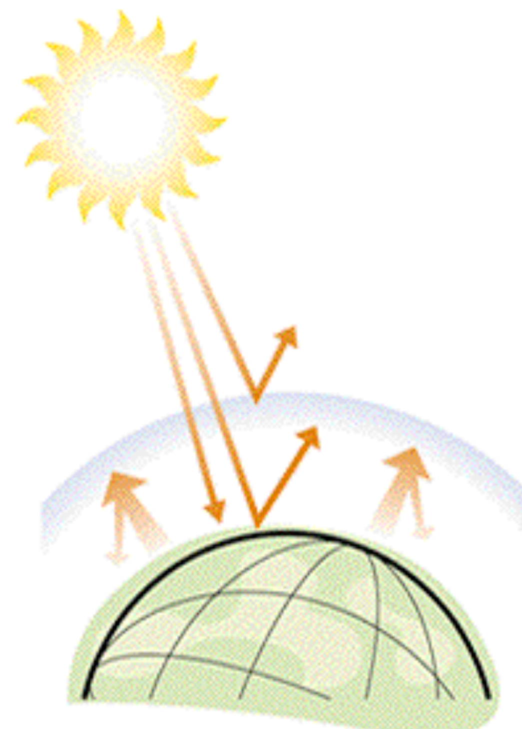




Note that the separation between the solar and terrestrial spectra occurs at about 2 microns

So how does this create a greenhouse effect? The greenhouse effect occurs because the atmosphere is relatively transparent to the wavelengths of solar radiation, while it absorbs infrared radiation. So a large chunk of the sun's radiation makes it to the earth's surface. At the same time, the atmosphere containing greenhouse gases absorbs the radiation emitted by the earth's surface, and re-emits it back to the surface, increasing the total energy the surface receives. This forces the earth's surface to become warmer than it would be otherwise.





The greenhouse effect is a naturally-occurring phenomenon on the earth as it is on Venus. The enhancement of this effect by increasing greenhouse gases is the reason for concern about climate change.