How Can Thermal Effects Be Explained?

Lesson 6, Part 2: Climate Science

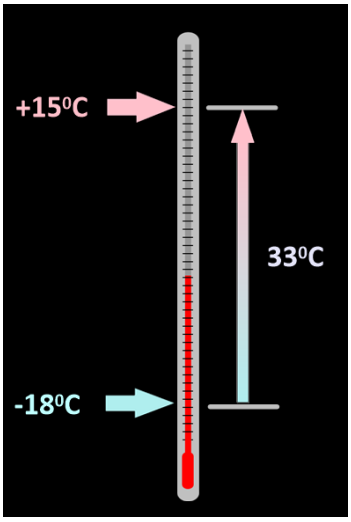
What determines the Earth's temperature?

Stefan-Boltzmann prediction for earth's surface temperature

-18^{0}C

Actual average earth surface temperature since last ice-age

15^{0}C



How can this 33^{0}C difference be explained?

Earth's Atmosphere

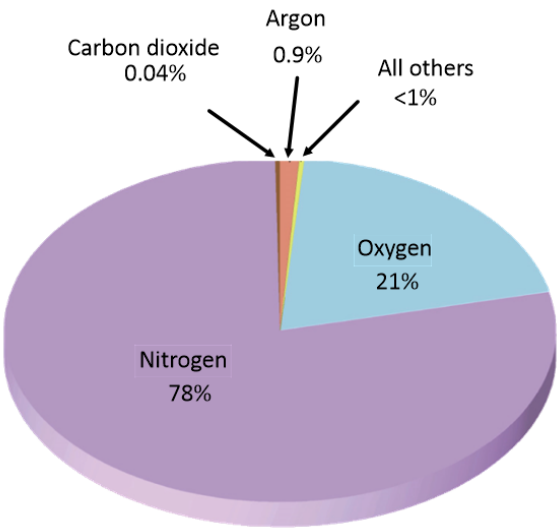
Radius of Earth = **..... km**

Majority of atmosphere = **..... km**

Some atmospheric gases to **30km**

Like the skin of an apple.

Composition of dry air (no water vapour)



Water vapour contributes about 1%

Nitrogen (N_2), Oxygen (O_2) and Argon (Ar) compose more than ..... % of the atmosphere.

These molecules have one or two atoms.

They block some ultra-violet radiation from the Sun

They allow ..... and ..... radiation through and hence contribute very little to the Earth's surface temperature.

With an atmosphere of Nitrogen, Oxygen and Argon, the surface temperature would be ..... ^{0}C.

The Greenhouse Effect

Earth is surrounded by a blanket of ……. **gases**, mainly water vapour and carbon dioxide which traps outgoing radiation.

Greenhouse gases allow radiation from the Sun to pass through them but ……radiation from the Earth, heating up the atmosphere in the process.

This is called the G…… effect

Greenhouse Gases (100%)

Water Vapour (95%)

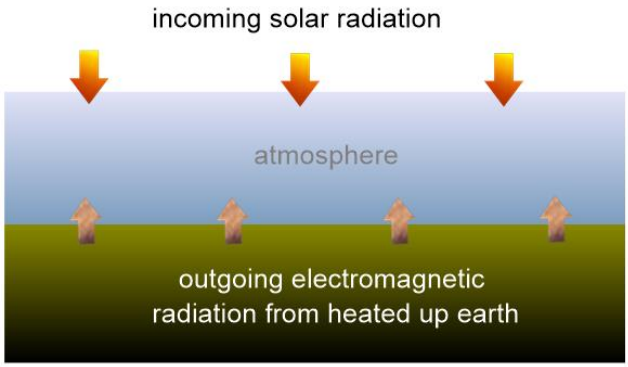
Carbon Dioxide (3.5%)

Nitrous Oxide (0.9%)

Methane (0.3%)

Other (0.07%)

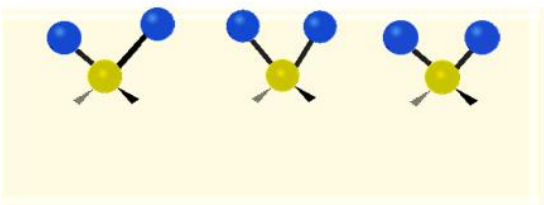
Incoming electromagnetic radiation from the sun has a much ……. wavelength (and higher frequency) than out-going radiation from the heated up Earth.



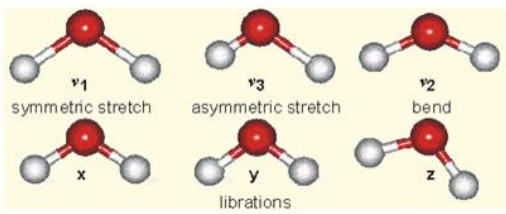
The greenhouse gases make up less that 1% of the Earth's atmosphere, but raise the average temperature by 33^0C.

The two main Greenhouse gases are Water Vapour (H_2O) and Carbon Dioxide (CO_2).

CO_2 and H_2O are able to vibrate in many different ……, and their natural frequencies of vibration are in the **infrared** part of the electromagnetic spectrum.



H_2O



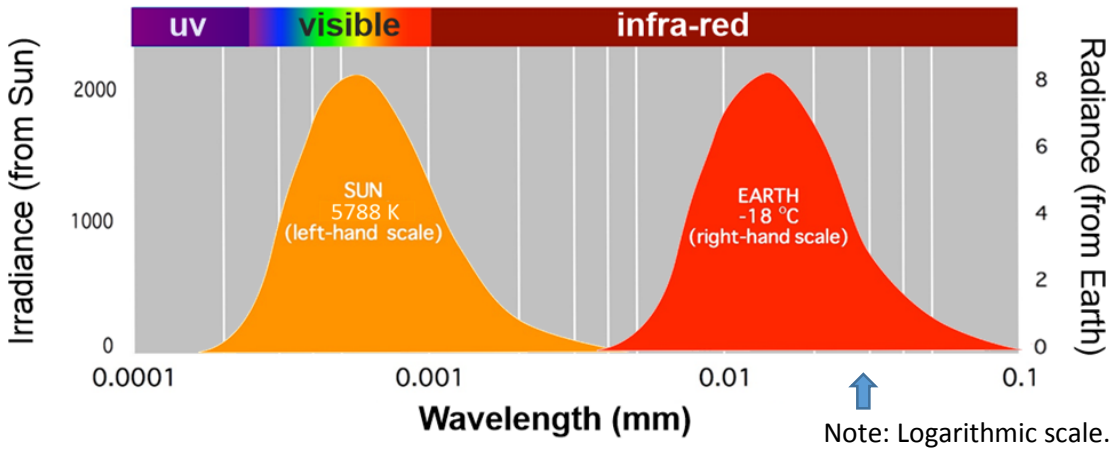
CO_2

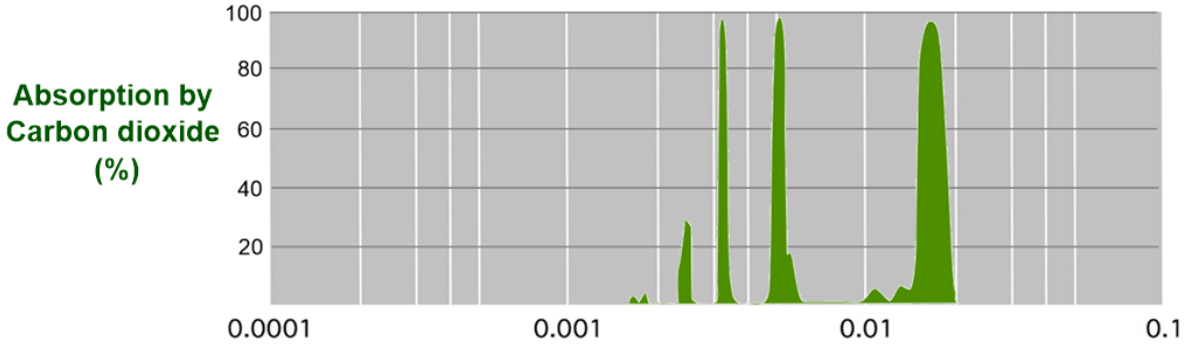
They are the Earth's blanket for reflecting certain …….. frequencies back down to Earth.

The spectra of Electromagnetic radiation from the Sun and re-radiated from the heated up Earth are shown next page.

Absorption Spectra for CO_2 and H_20 are overlayed to show which wavelengths are absorbed by greenhouse gasses.

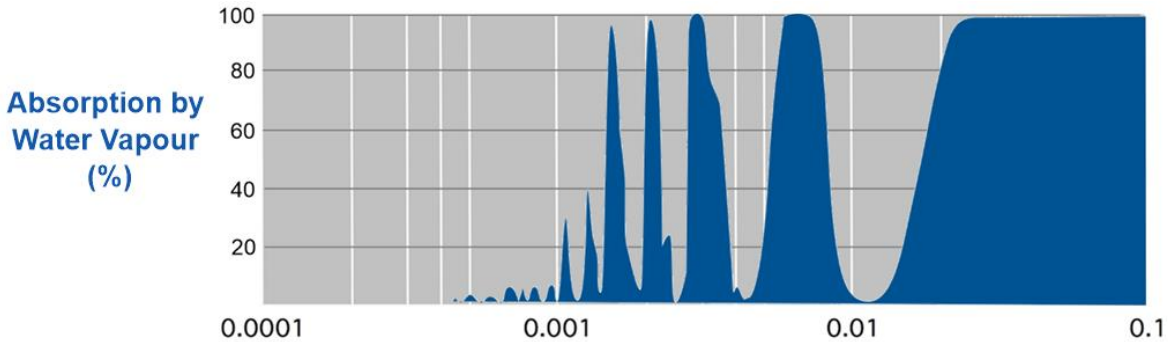
Infrared Radiation absorbed by Water and Carbon Dioxide



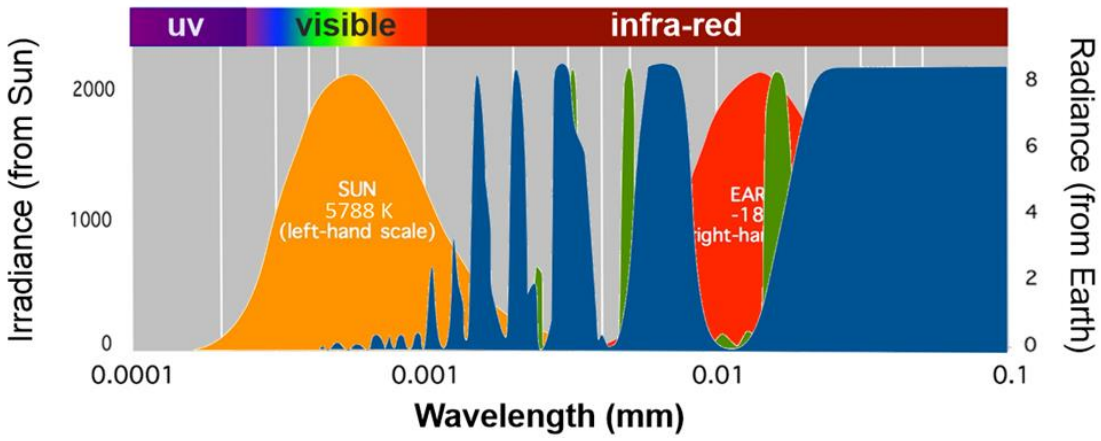


CO_2 molecules absorb certain parts of infra-red radiation coming from the Earth's surface.

Once a CO_2 molecule absorbs infra-red radiation, it re-emits it but in a ……. direction



H_2O molecules contribute independently of CO_2 molecules to the green-house effect.



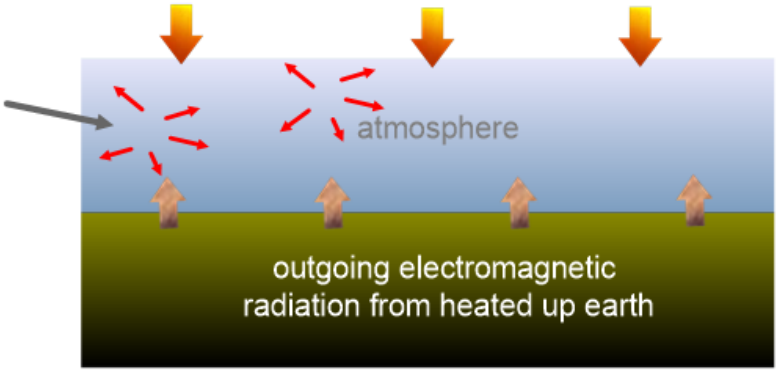
Greenhouse Warming

Certain wavelengths of outgoing electromagnetic radiation from the heated-up Earth are absorbed by water vapour and carbon dioxide molecules.

Methane CH_4 molecules also contribute in a similar way to the green-house effect but have far less influence than H_2O and CO_2.

Water vapour and Carbon dioxide re-emit absorbed radiation in random directions.

Some re-emitted radiation goes back to Earth increasing its temperature. This is called back radiation.

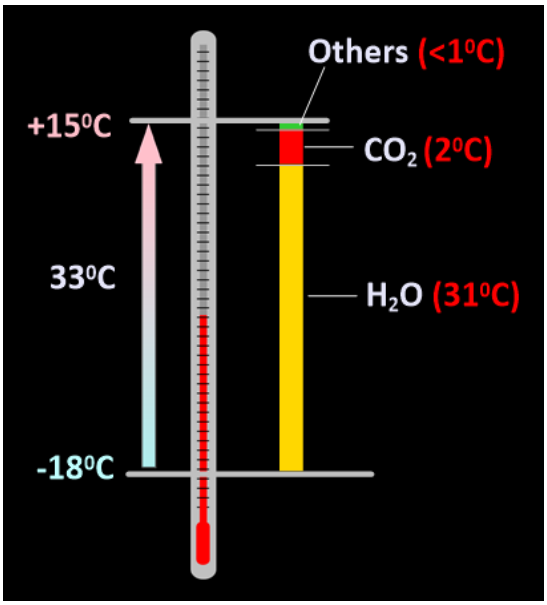


Some is directed upwards and heats up other air molecules, some goes out into space.

Overall, ……of the re-emitted radiation comes back to Earth's surface.

Earth is surrounded by a blanket of **greenhouse gases**, mainly water vapour and carbon dioxide which traps …… radiation.

The relative contributions of both H_2O and CO_2 and other greenhouse gases are shown.



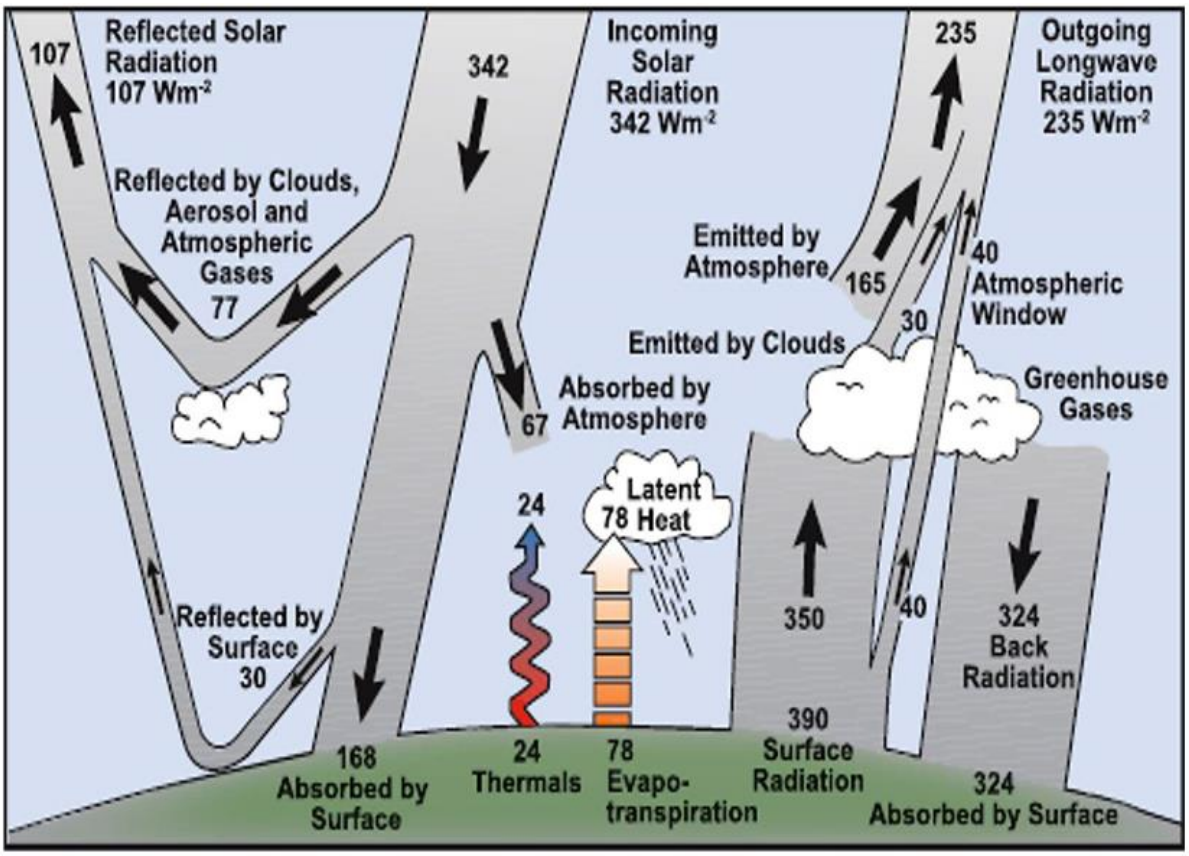
Extra Notes

The Earth's Energy Budget

This is an account of all the energy that flows from the Sun into the Earth, where it goes in the atmosphere and at the surface, and how the outgoing energy leaves the Earth.

As long as the energy budget is in ……., then the Earth will remain in a state of **thermal equilibrium** and its average temperature will remain **stable** over time.

In the following energy budget diagram, the numbers indicate the amount of energy flowing through an area of 1 square metre every second.



Energy budget from the International Panel on Climate Change (IPCC)

Whole Earth Energy Balance

Incoming energy (from Sun) = ... W/m²

Outgoing energy = 77 + 30 + 165 + 30 + 40 = ... W/m²

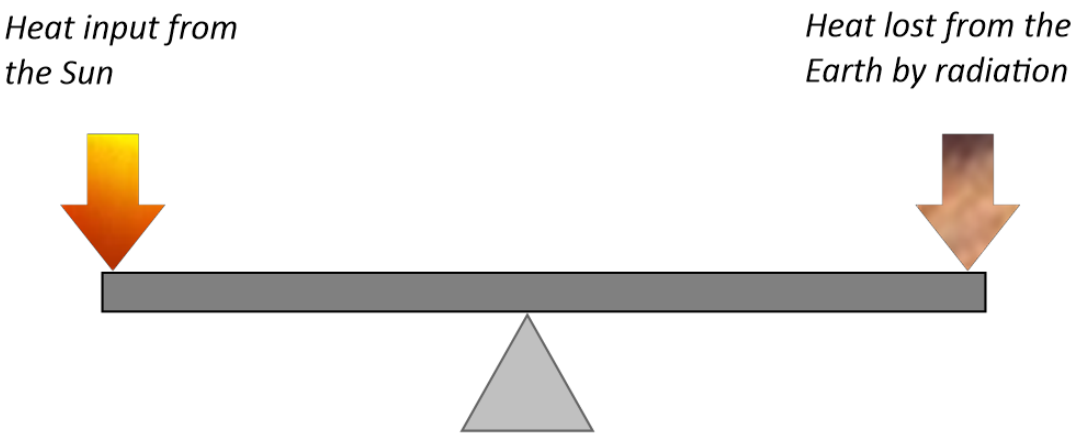
Earth Surface Energy Balance

Incoming energy = 163 + 324 = ... **W/m²**

Outgoing energy = 24 +78 + 350 + 40 = ... **W/m²**

The Earth's Energy Budget (Continued)

The Earth will maintain **thermal equilibrium** (constant stable temperature level) if the energy coming in is …….. by the energy going out.



Extra Notes