

A thick black L-shaped frame surrounds the text. The top-left corner is a horizontal bar extending to the right, then a vertical bar extending downwards. The bottom-right corner is a vertical bar extending upwards, then a horizontal bar extending to the left.

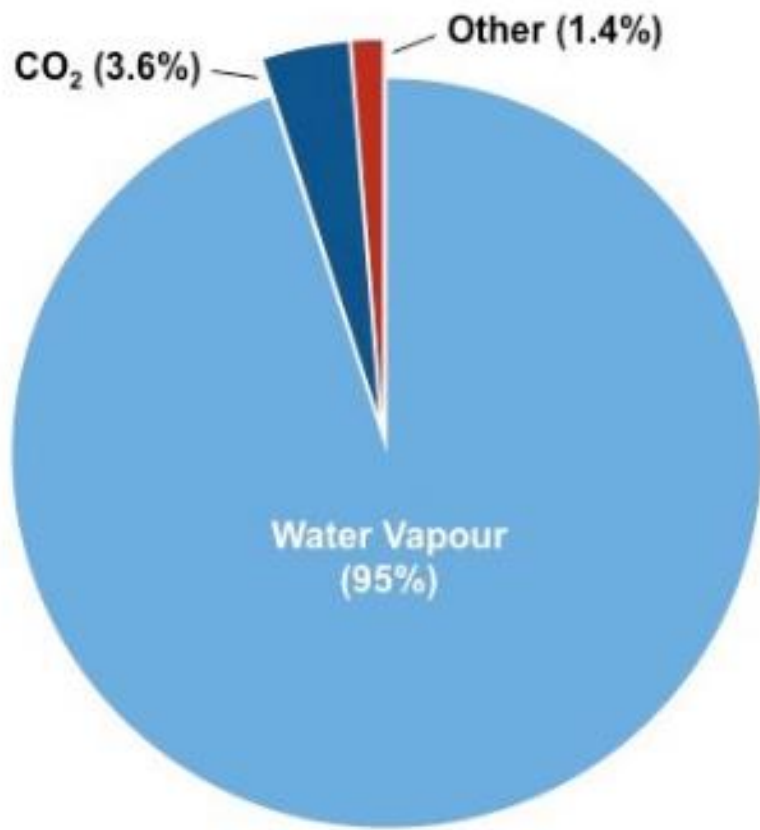
4.4 CLIMATE CHANGE

Concentrations of gases in the atmosphere affect
climates experiences at the Earth's surface

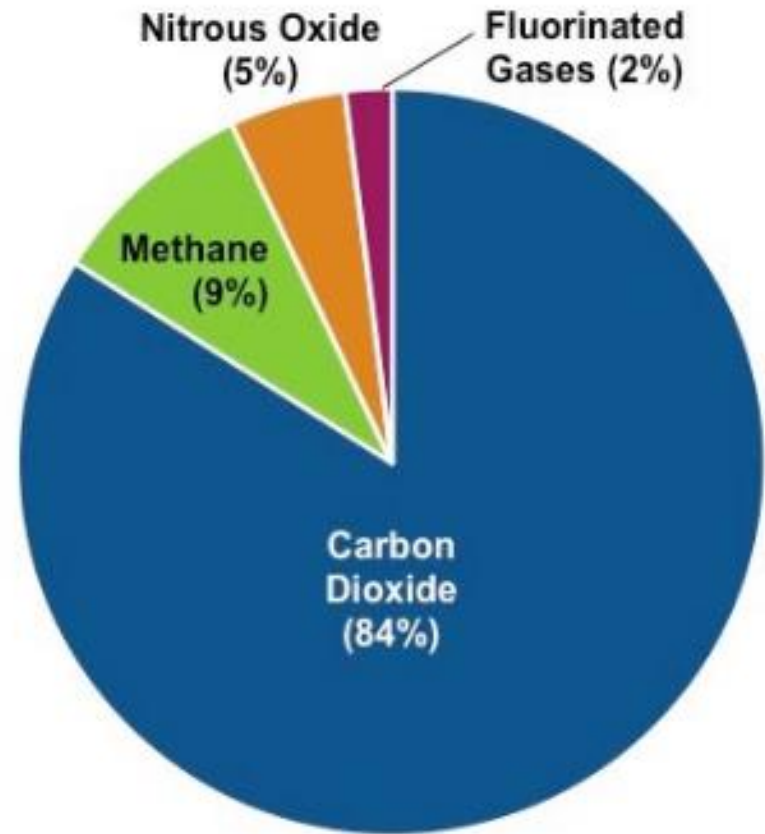
Greenhouse Gases (GHG)

- Carbon dioxide and water vapour are the most significant greenhouse gases.
- Other gases including methane and nitrogen oxides have less impact.
- GHG absorb and emit long-wave (infrared) radiation, trapping and holding heat within the atmosphere.
- GHG collectively make up less than 1% of the Earth's atmosphere.
- GHG that have the largest warming effect
 - *Water vapour is created by evaporation of water bodies (oceans) and transpiration – it is removed by precipitation (rain)*
 - *Carbon dioxide is made by cell respiration and burning fossil fuels – it is removed by photosynthesis and absorption by oceans.*

- Other GHG include methane and nitrogen oxides – these have less impact on the overall warming effect.
 - *Methane is emitted from waterlogged habitats (like marshes) and landfills – it is also a gaseous waste produced by ruminants.*
 - *Nitrogen oxides are released naturally by certain bacteria and also is emitted in the exhaust of certain vehicles.*



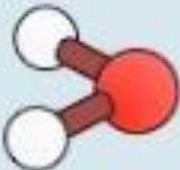



**Greenhouse Gases
in Atmosphere**



**Anthropomorphic (Man-Made)
Greenhouse Gases**

- **The impact of a gas depends on its ability to absorb long-wave radiation as well as its concentration within the atmosphere.**
- There are two factors which determine how much of an impact a GHG will have in warming the atmosphere.
- **1. Ability to absorb long-wave radiation.**
 - Gases that have a greater capacity to absorb long-wave radiation will have a greater warming impact (per molecule).
- **2. Concentration within the atmosphere.**
 - The greater the concentration of a gas, the greater its warming impact will be within the atmosphere.
 - The concentration of a gas will be determined by both its rate of release and persistence within the atmosphere.

- The overall impact of a GHG will be determined by the combination of both these factors.
 - *Methane has a larger capacity to absorb long-wave radiation than carbon dioxide, but is significantly less abundant.*
 - *Water vapour enters the atmosphere rapidly but only remains for short periods, while carbon dioxide persists for years.*
 - *Human activity is increasing the amount of GHG (except water vapour) and increasing their impact.*

	Water	Carbon Dioxide	Methane	Nitrous Oxide
				
Atmospheric Concentration	0.01–4%*	385 ppm	1797 ppb	322 ppb
Rate of Increase	n/a	1.5 ppm/yr	7.0 ppb/yr	0.8 ppb/yr
Atmospheric Lifetime	Very short 1–5 days	Variable 5–200 yr	12 yr	120 yr
Global Warming Potential (GWP)	n/a†	1	21	310

* The amount of water vapor in the air varies according to temperature and density of air (usually ~1–3% of troposphere)

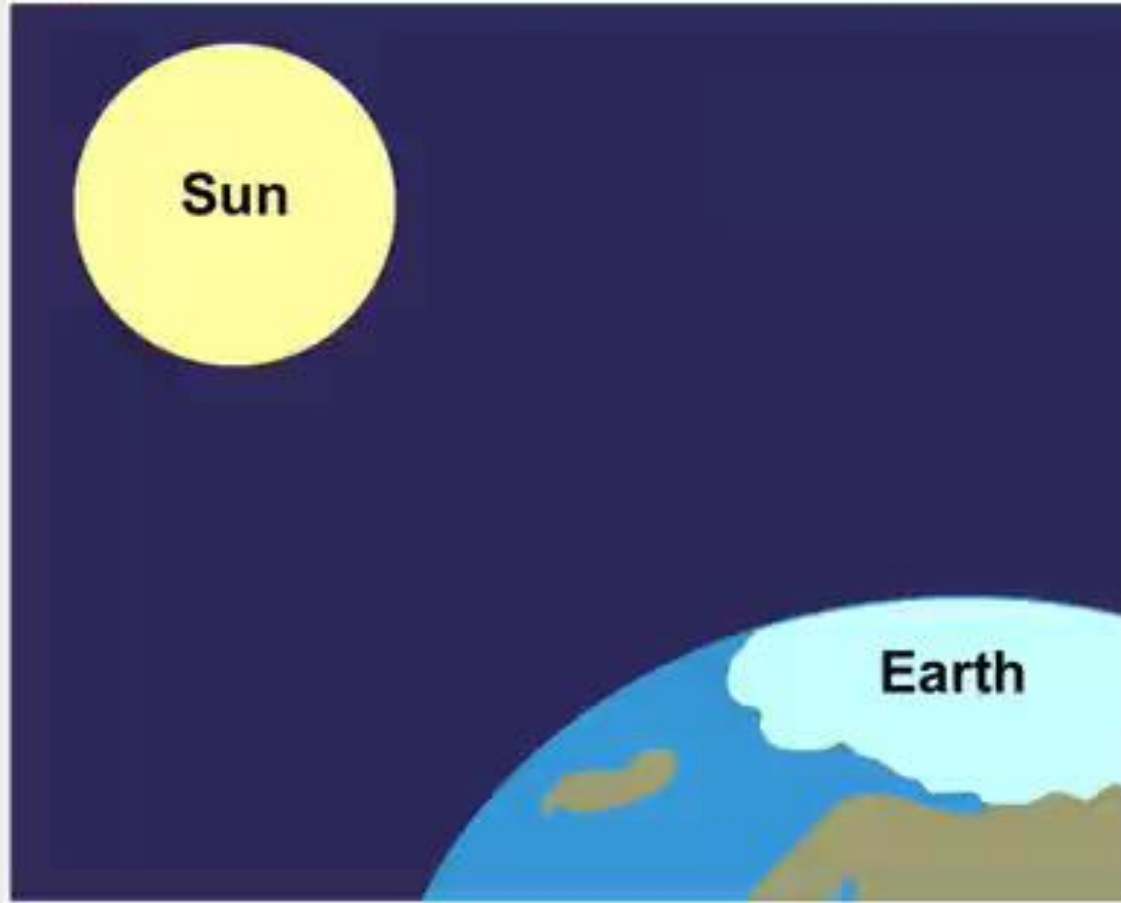
† Water vapor levels vary strongly according to region, so rates of change and warming potential cannot be assessed

Greenhouse Effect

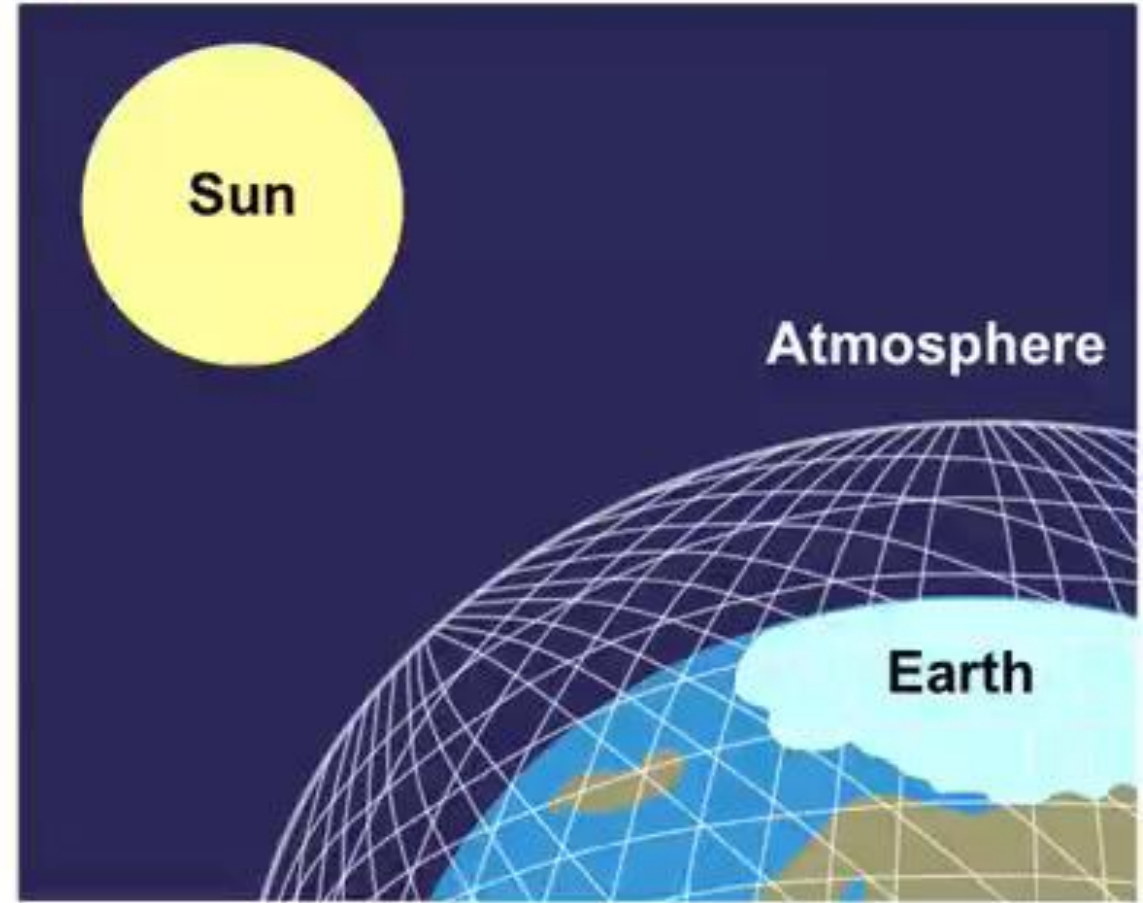
- The warmed Earth emits longer wavelength radiation (heat)
- Longer wave radiation is absorbed by GHG that retain the heat in the atmosphere.
- The greenhouse effect is a natural process the atmosphere behaves like a greenhouse to trap and retain heat.
 - *This ensures the Earth maintains the moderate temperatures needed by organisms to maintain life processes.*
 - *Without the greenhouse effect, Earth's temperature would drop significantly at night in the absence of direct sunlight.*



NO GREENHOUSE GASES



GREENHOUSE EFFECT



How the Greenhouse Effect Works

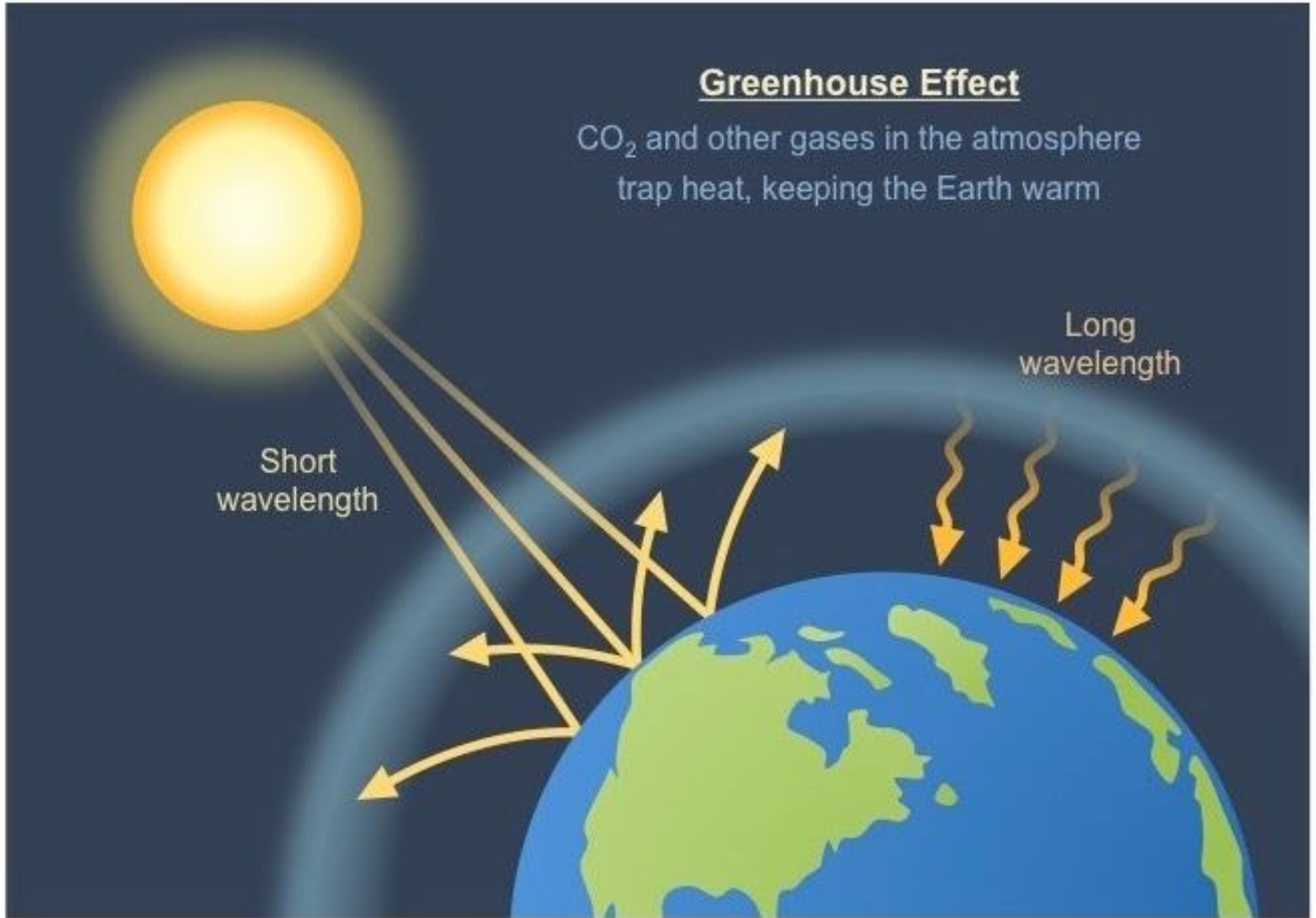
- The greenhouse effect functions to trap heat within the atmosphere and prevent rapid temperature fluctuations.
 - *Incoming radiation from the sun is shorter wave radiation (UV and the visible spectrum)*
 - *The surface of the Earth absorbs short wave radiation and re-emits it at a longer wavelength. (infra-red/heat)*
 - *GHG absorb and re-radiate this longer wave radiation and retain the heat within the atmosphere.*

Greenhouse Effect

CO₂ and other gases in the atmosphere trap heat, keeping the Earth warm

Short wavelength

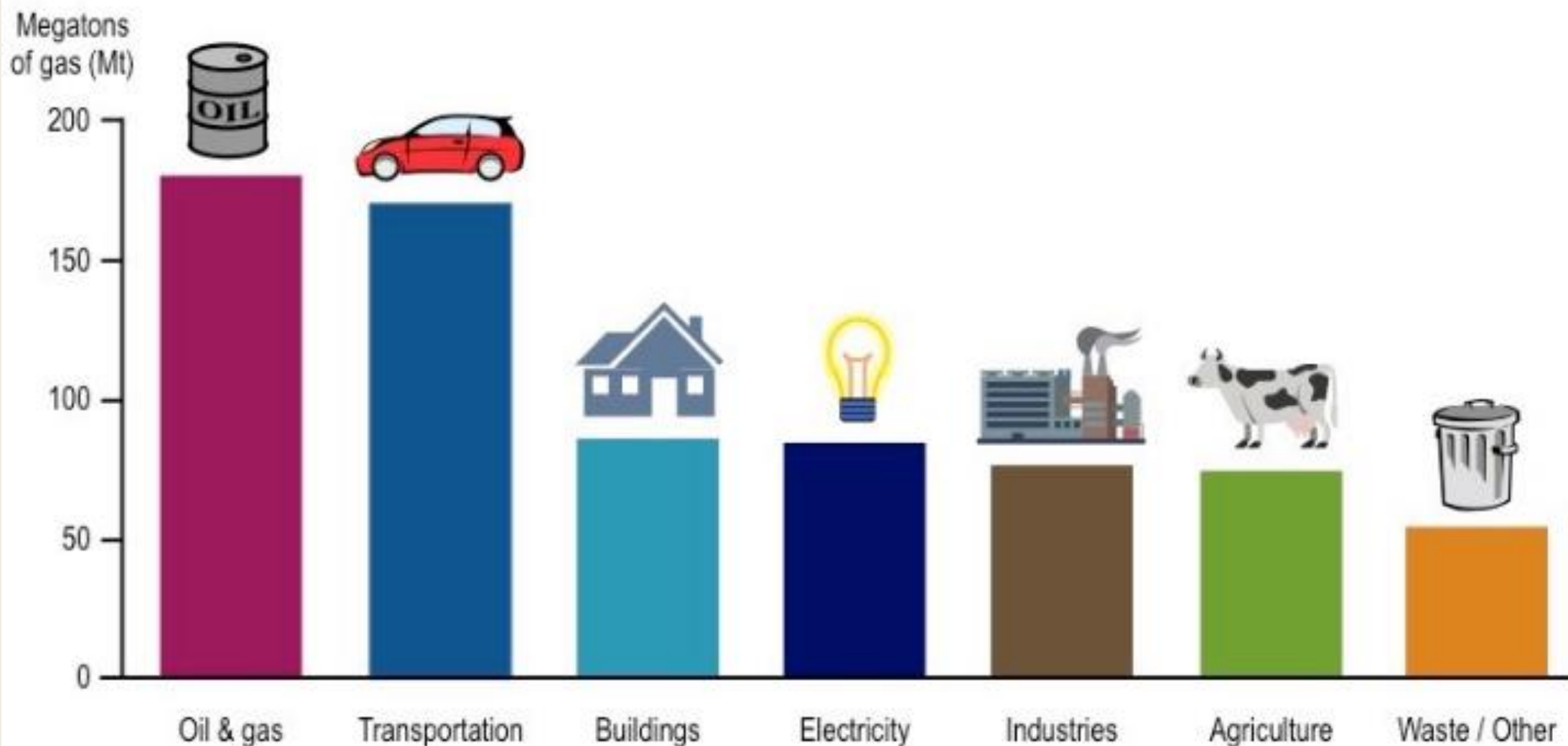
Long wavelength



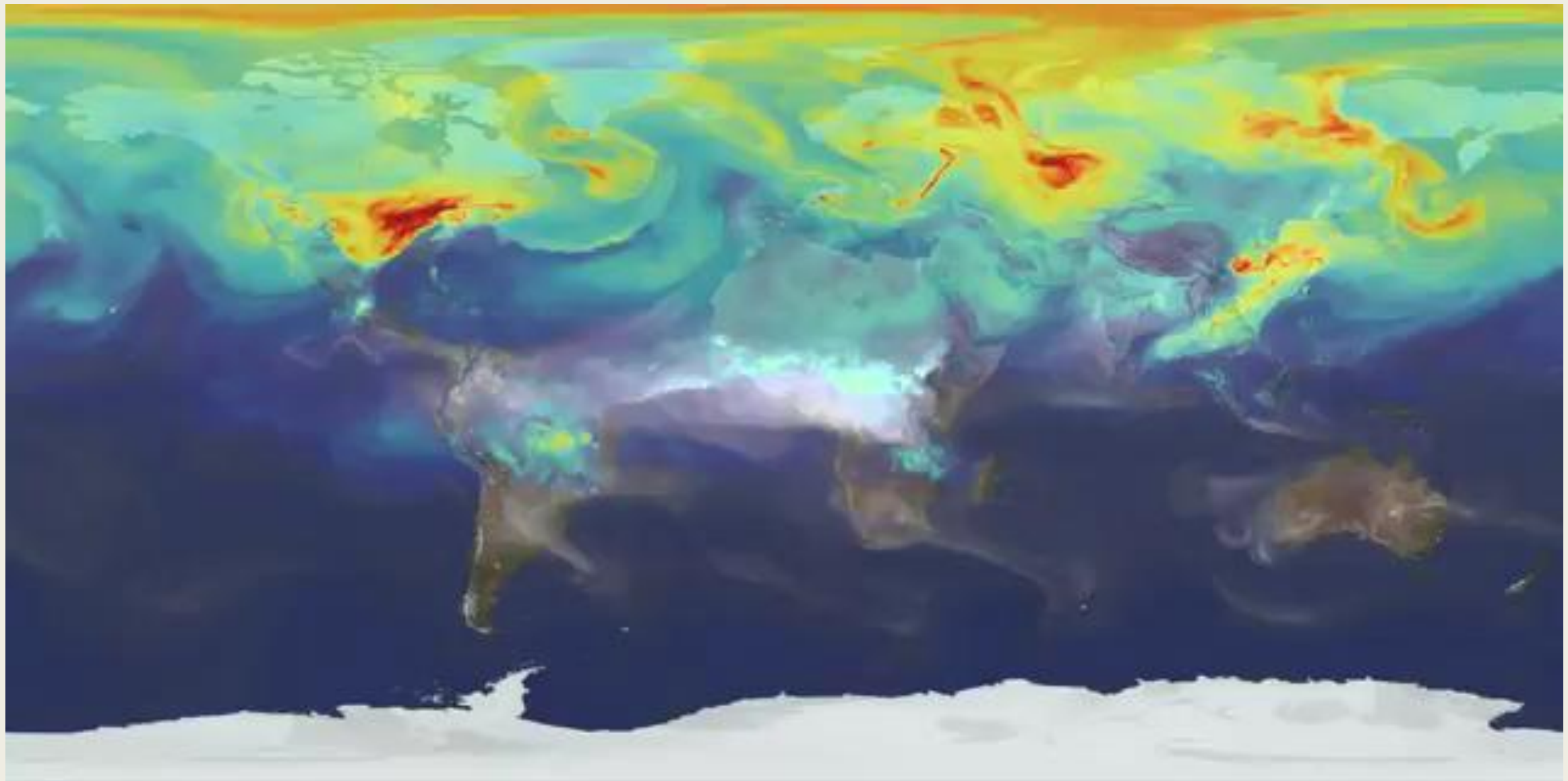
CO₂ Concentrations

- Recent increases in atmospheric CO₂ are largely due to increases in the combustion of fossilized organic matter.
- GHG's occur naturally, but man is increasing GHG emissions.
 - *Deforestation*
 - *Increased farming/agriculture.*
- GHG that is increasing most rapidly in the atmosphere is carbon dioxide and the main cause is combustion.
 - *When fossil fuels are combusted to release energy, carbon dioxide gas is released as a by-product.*
 - *The increased reliance on fossil fuels following the industrial revolution has resulted in 38% increase in CO₂ levels.*
 - *These are now efforts to reduce our reliance on fossil fuels by exploiting alternative energy source (solar powere)*

Greenhouse Gas Emissions by Sector



(Data represents the distribution of greenhouse gas emission by economic sector in Canada, 2013)



2006 / 01 / 01

Global Modeling and Assimilation Office

Carbon Monoxide Column Abundance [$1.0e18$ molec cm^{-2}]



Carbon Dioxide Column Concentration [ppmv]



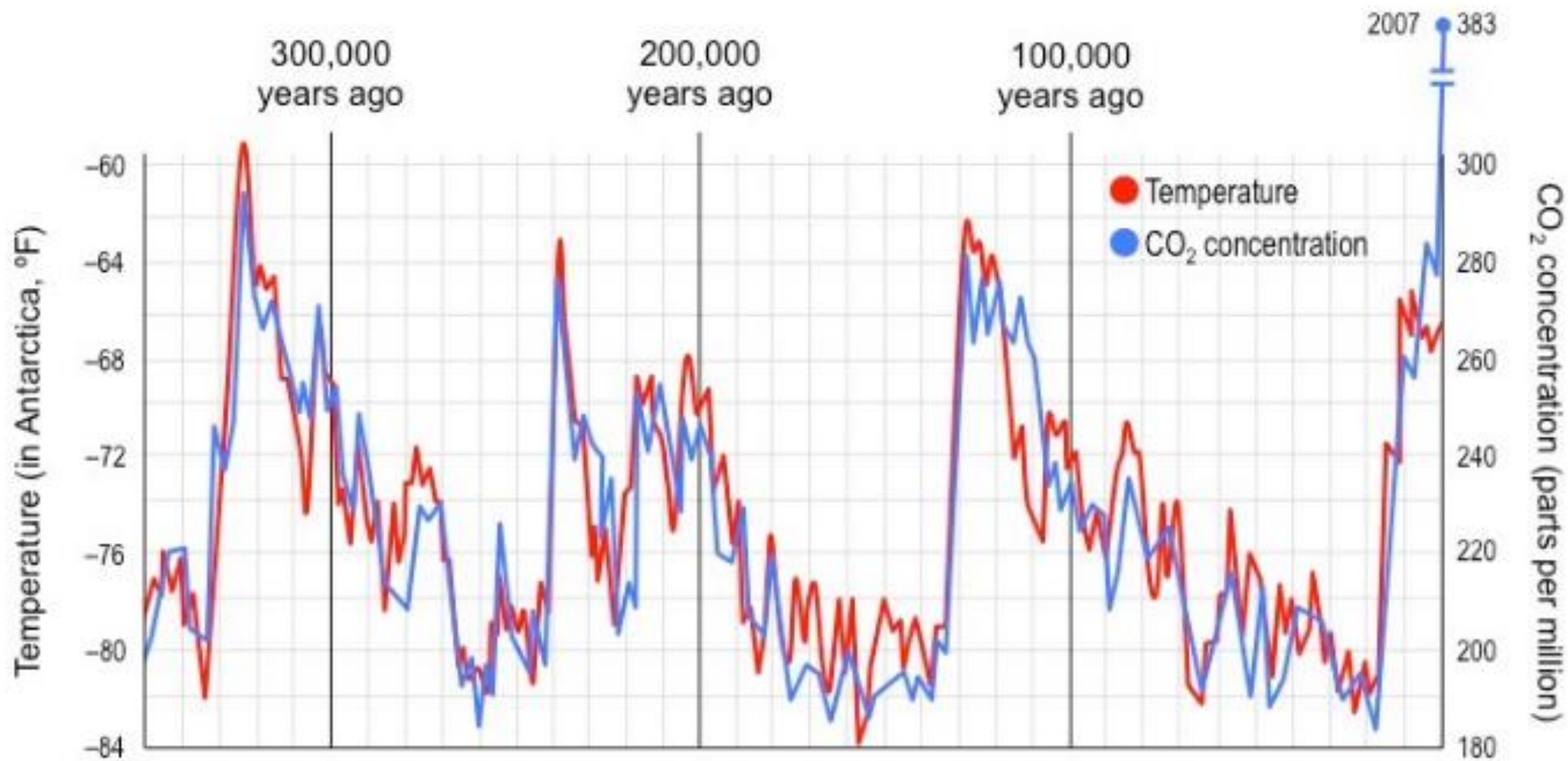
Climate Changes

- **Global temperatures and climate patterns are influenced by concentration of GHG.**
- GHG play a pivotal role in determining global temperatures and climate patterns due to their capacity to retain heat.
 - *As these gases trap heat, increases in GHG concentrations should correlate with an increase in global temperature*
 - *Long term weather patterns (climate) may also be influenced by GHG concentrations.*

Scientists predictions

- Scientists predict that increases in GHG concentrations will lead to an enhanced greenhouse effect; resulting in:
 - *More frequent extreme weather conditions (heat waves, cyclones, more powerful tropical storms)*
 - *Some areas to become more drought affected, while others areas become more prone to periods of heavy rainfall.*
 - *Changes to circulating ocean currents – which may cause longer El Nino (warming) and La Nina (cooling) events.*

Vostok Ice Core Data – Temperature versus Carbon Dioxide Concentration



Ocean Acidification

- **Threats to coral reefs from increasing concentrations of dissolved carbon dioxide.**
- The oceans are a major carbon sink and absorb roughly a third of all human produced CO₂ emissions.
- CO₂ solubility is temperature dependent (more soluble when cooler), so less CO₂ will be absorbed as temperature rise.

Long Term Climatic Cycles from the Vostok Ice Core

