How Can Thermal Effects Be Explained?

Lesson 6, Part 3: Climate Science

VICTORIAN VIRTUAL LEARNING NETWORK

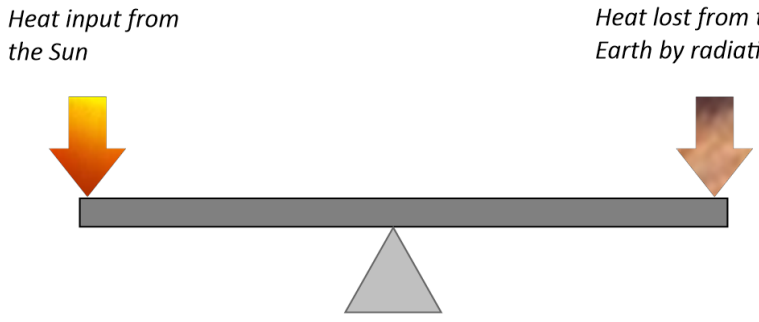
The Enhanced Greenhouse Effect

Before the industrial revolution of the 1800s, and going back to the last ice-age many thousands of years ago, this system maintained a relatively steady average global temperature of 15^0C

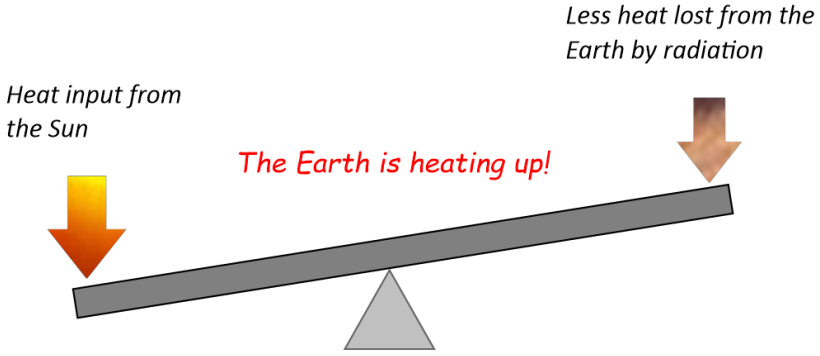
Human activities such as the burning of fossil fuels (coal, oil and natural gas) , land clearing and agricultural practices have increased the concentration of greenhouse gases such as CO_2 in the atmosphere.

*This increase is often referred to as the **Enhanced Greenhouse effect**.*

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



Because of excess …….. gases produced by …… activity, the Earth's energy budget is no longer in balance.



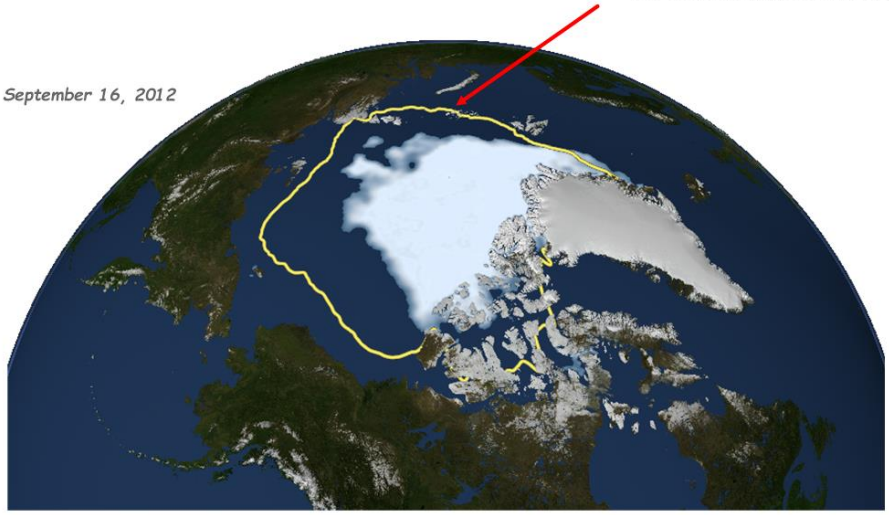
Evidence for the Enhanced Greenhouse Effect

Muir Glacier, Alaska

Vanishing Glaciers

Reduced extent of Arctic sea ice

Average extent of summer sea ice over the past 30 years.

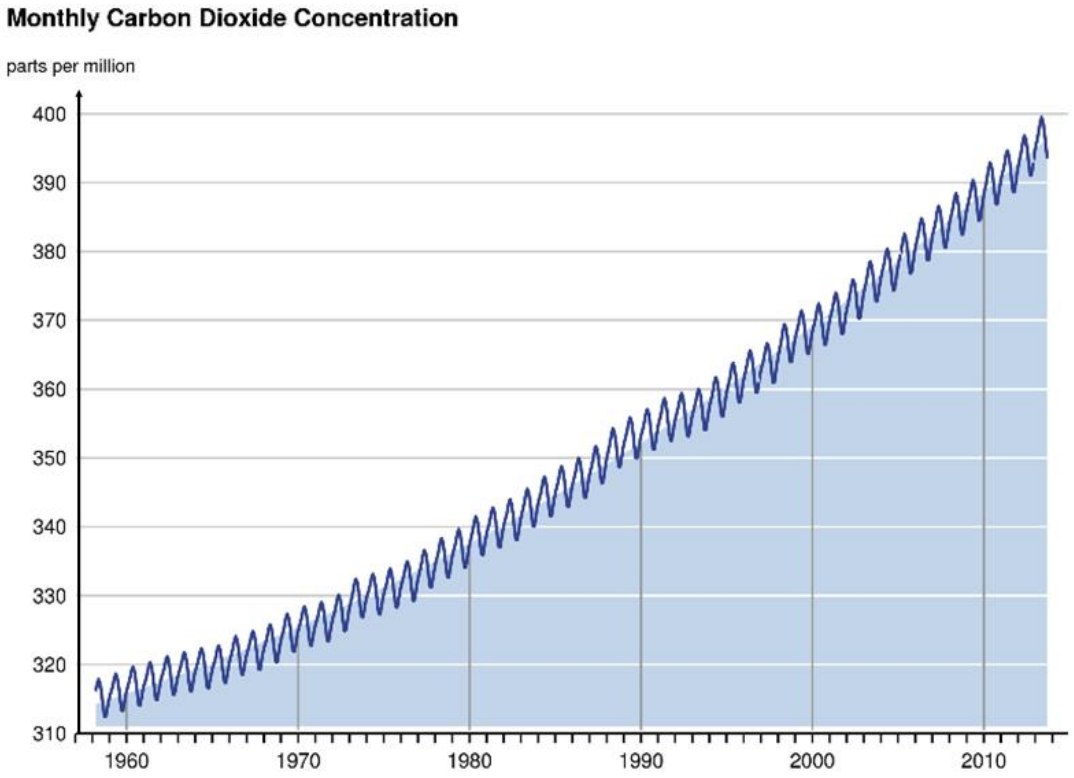


Greenland Ice Sheet

The Greenland summer ice melt is getting larger at a worrying rate.

Evidence for the Enhanced Greenhouse Effect (Continued)

The Keeling Curve



Data from Muana Loa observatory in Hawaii shows the seasonal variations in CO_2 concentration due to plant growth (mainly in the …… hemisphere).

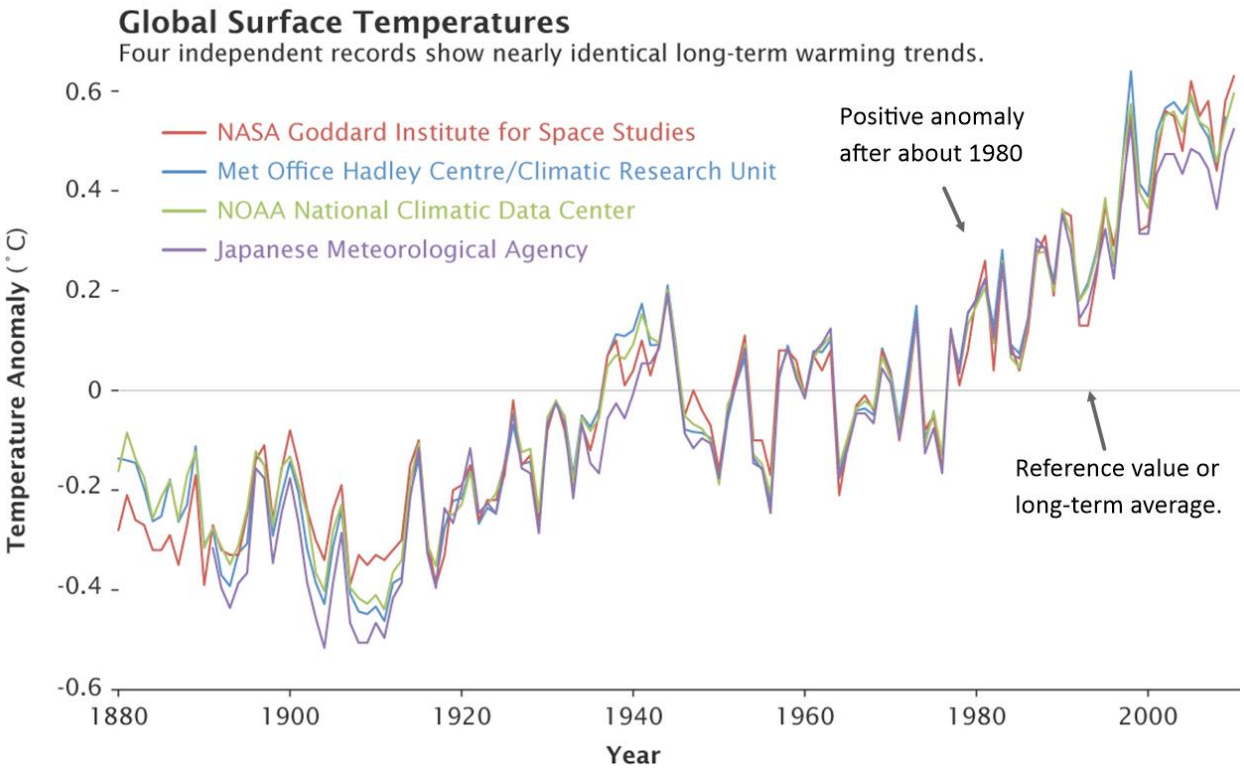
Note the relentless upward trend from 315 ppm in 1960 to almost …… ppm now.

Tending upwards at an average of …….. parts per million (ppm) per year due to human activity.

Extra Notes:

Evidence for the Enhanced Greenhouse Effect (Continued)

Increases in Average Global S…….. Temperatures



The term **temperature anomaly** means a departure from a reference value or long-term …….. The positive **anomaly** after about 1980 indicates that the observed **temperatures** were warmer than the …….. value.

The Intergovernmental Panel on Climate Change (IPCC)

The **Intergovernmental Panel on Climate Change** (IPCC) is a body set up by the United Nations in 1988 .

The objective of the IPCC is to bring together the findings on thousands of climate scientists, world-wide with the aim of stabilising the levels of …… gases in order to prevent dangerous human-induced (anthropogenic) interference with the climate system.

http://www.ipcc.ch/

Climate Models

A **climate model** attempts to apply the Laws of Physics and Chemistry to the atmosphere of the Earth, including ……, sea and …….

This is an extremely complex system.

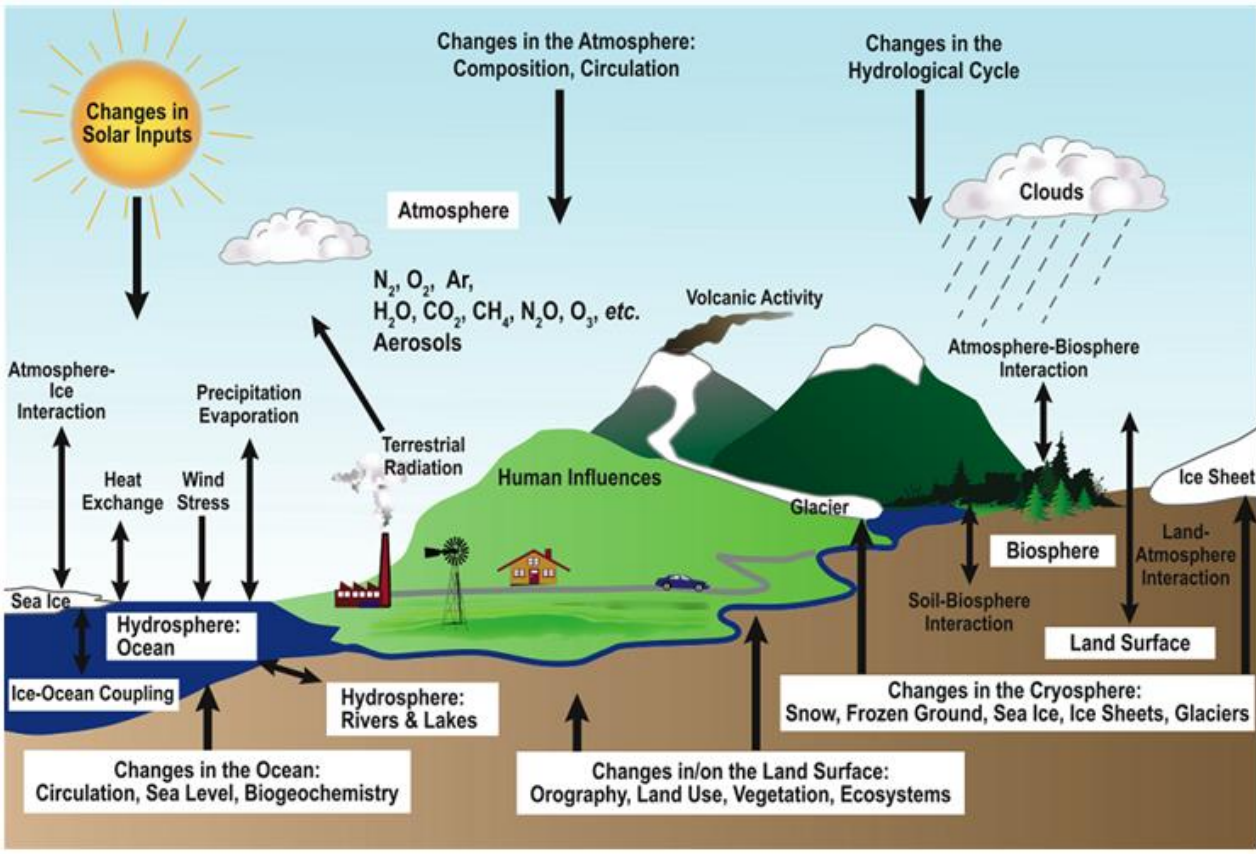
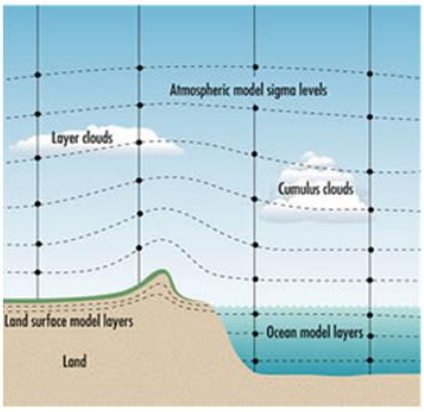


Diagram from the International Panel on Climate Change (IPCC)

Computer models divide the whole Earth into sections called …… for analysis.



Source: Australian Bureau of Meteorology

Climate Models (Continued)

Models attempt to predict future trends in …… patterns, humidity, …… level rise, ocean ……., wind strength and air ……..

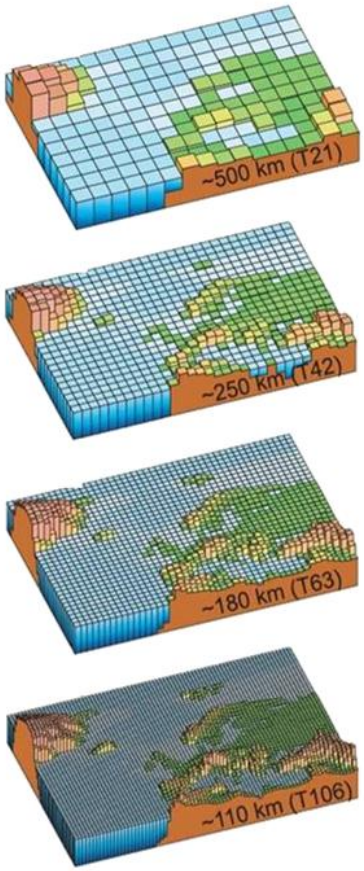
How do climate models work?

The equations are applied to the cells of air and water to see how much air/heat flows between each pair of cells.

This is repeated all around the Earth.

The models have improved by making the cells …….

They are now about 110 km square by 1 km high.



Extra Notes

Climate Models (Continued)

How do we test the accuracy of climate models?

Any scientific model should be capable of explaining the current state of knowledge and also be able to …… what might happen in the future.

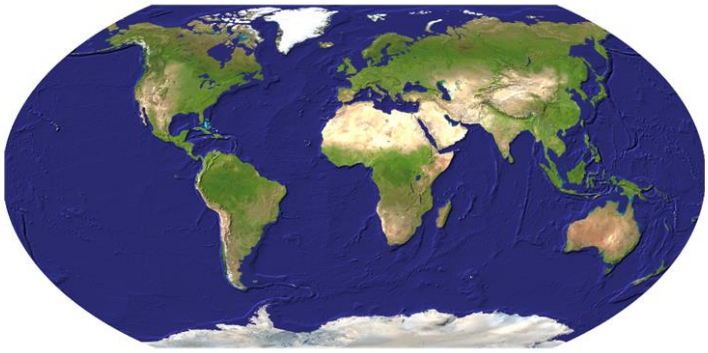
Climate models are first applied to the Earth's atmosphere as it was some time ago, say in 1900, to calculate the expected climate for the next 100 years.

Climate model …… are the compared to actual climate data to judge how close to reality the predictions were.

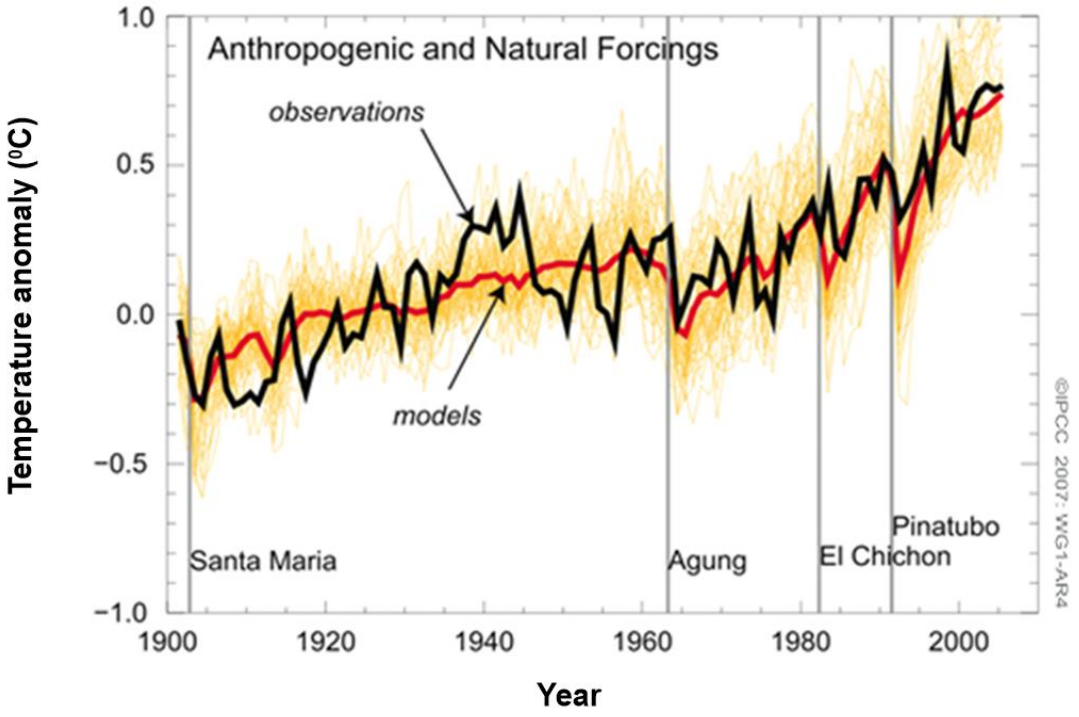
If the model is accurate it can then be used to calculate the …… climate.

Many different scientific organizations from many countries produce their own climate models.

Greater accuracy is obtained by ……. out the predictions (multi-modal data) from many models.



Climate Model predictions for 1900 to 2000



KEY: Black line = Actual Temperature Measurements.

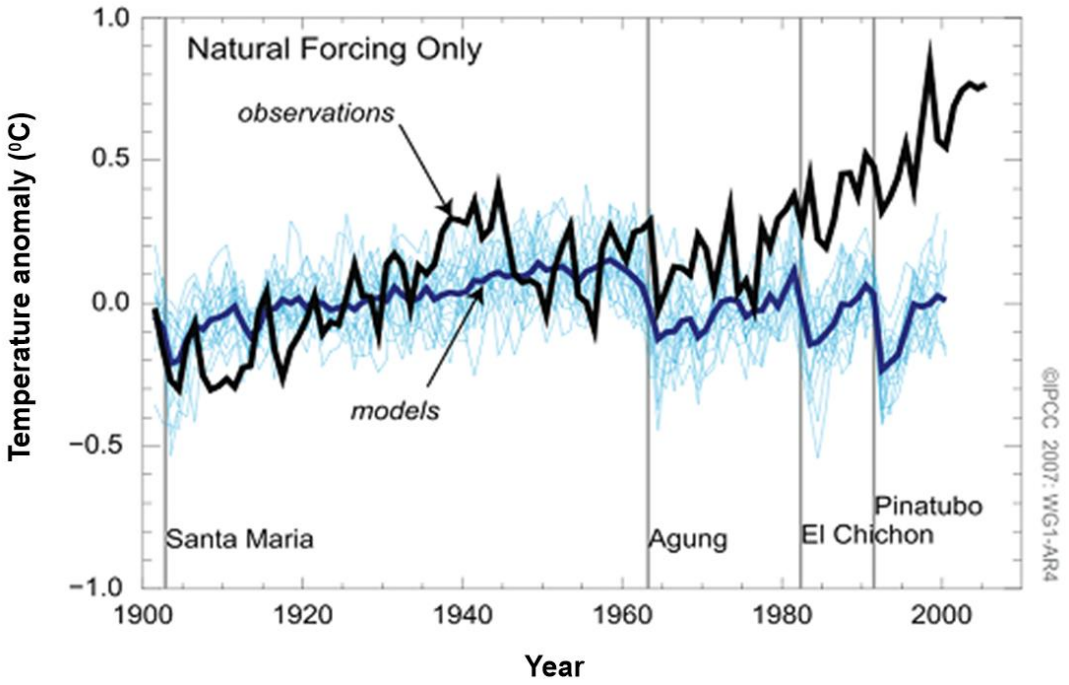
Red Line = Predictions by models (multi-modal) assuming ……. factors such as CO_2 emissions, as well as natural ones such as …….. cycles and …….. eruptions.

Climate Models (Continued)

Climate Model predictions for 1900 to 2000

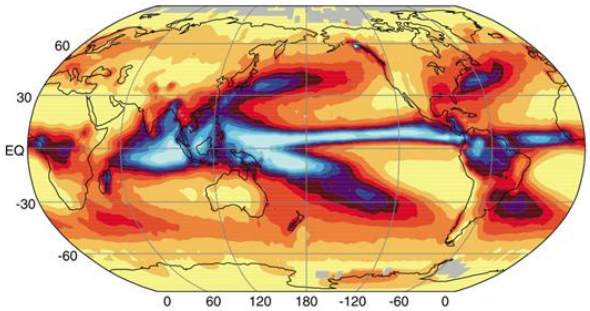
This simulation compares actual temperature observations (in **black**), with predictions of what would have happened assuming natural factors only, that is, …… human factors such as CO_2 emission from fossil fuels (in **blue**).

The world would have continued to have average temperatures in line with the long terms average since the last …….-age.



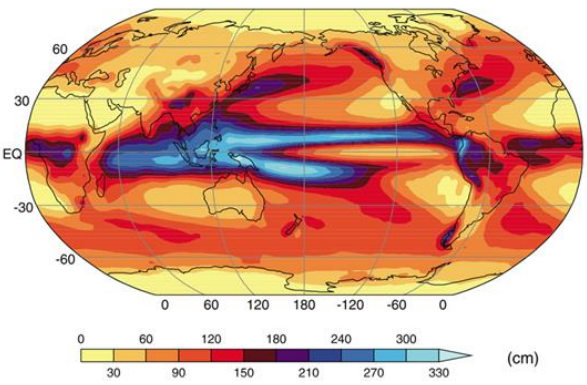
Climate Model Predictions Annual Average Rainfall 1980-99

Observations: 1980-99 →



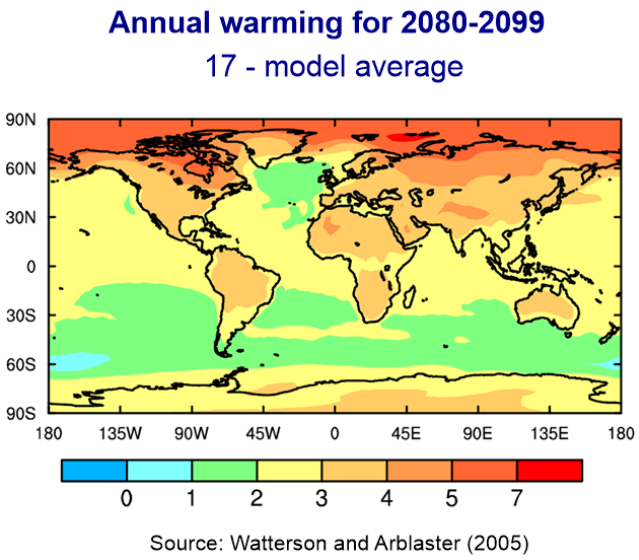
Multi-modal average: 1980-99

(Average of many models) →



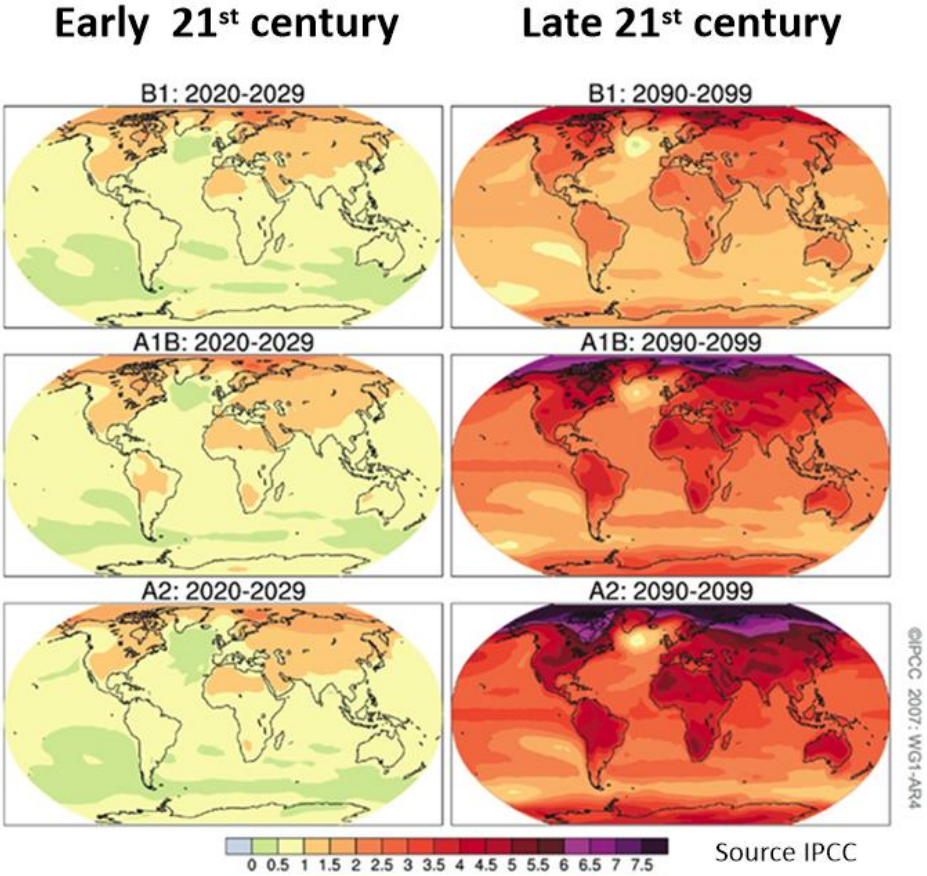
Climate Models (Continued)

Climate Model Predictions for the Future Climate



Source: Watterson and Arblaster (2005)

Extra Notes



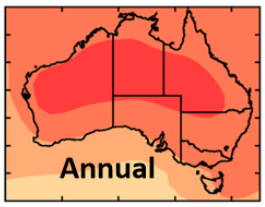
Source IPCC

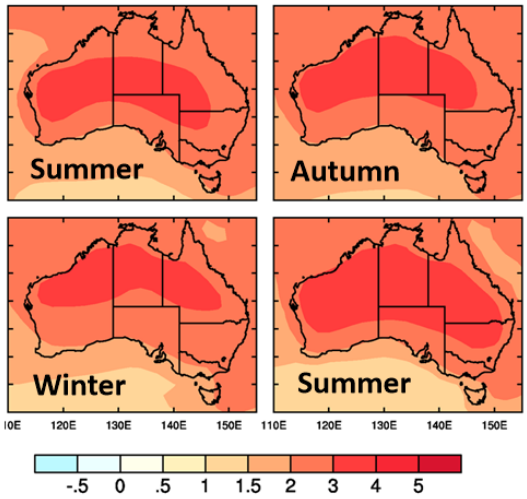
Extra Notes

Climate Models (Continued)

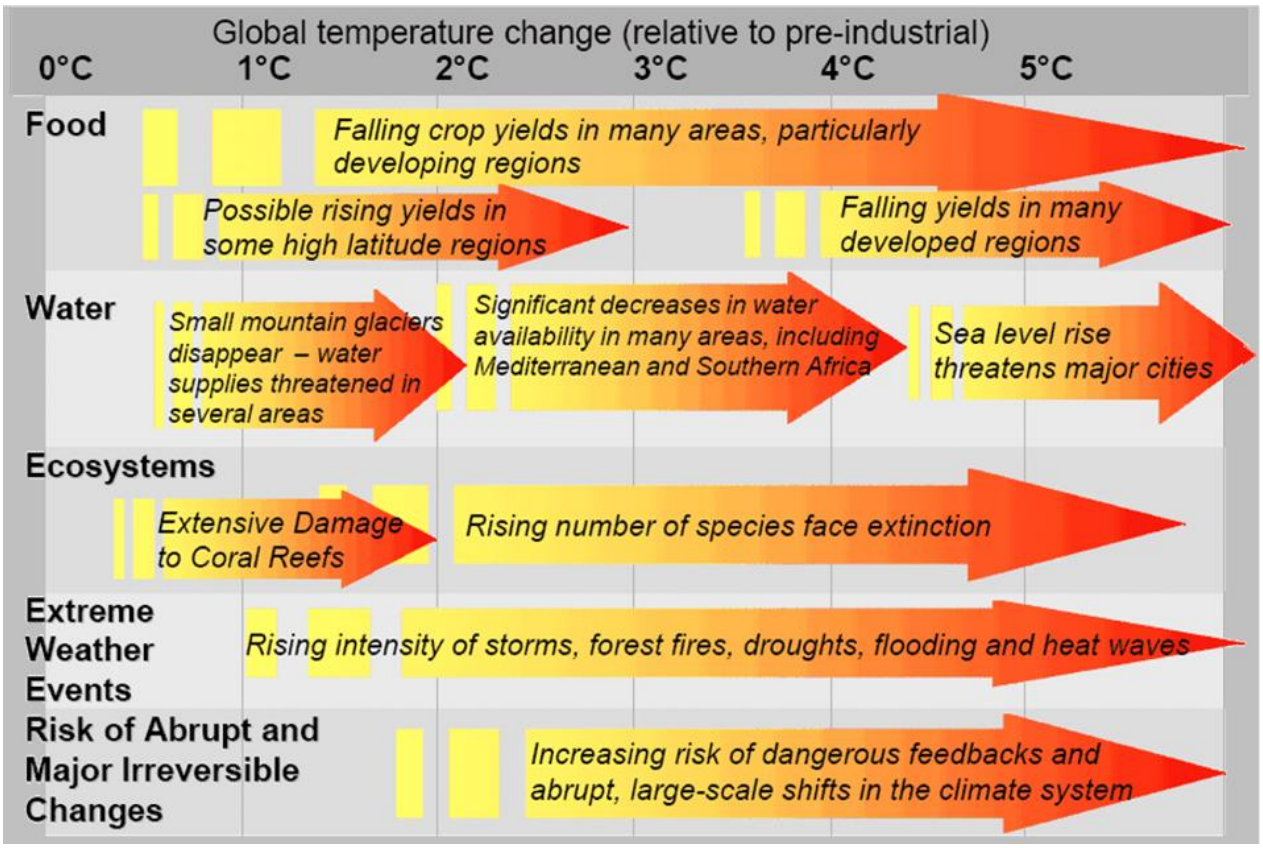
Predictions for Future Climate of Australia

Average of the change in temperature (relative to 1990) by **2070**, predicted by 15-models.





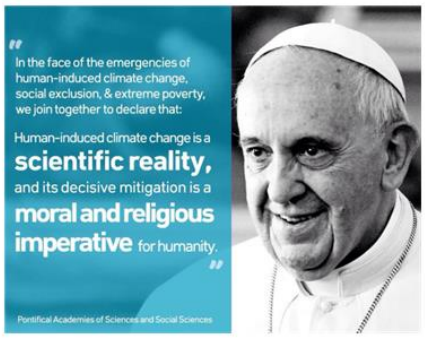
Projected impacts of Climate Change

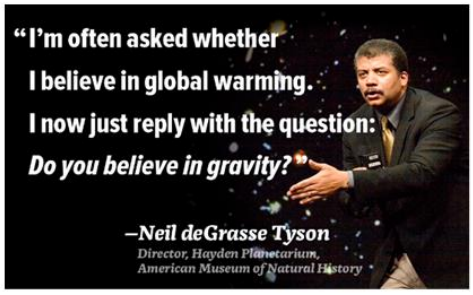


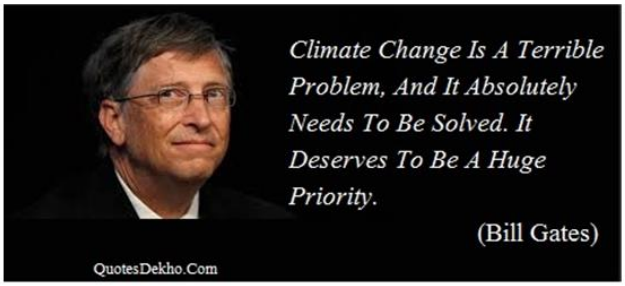
Extra Notes

Summary

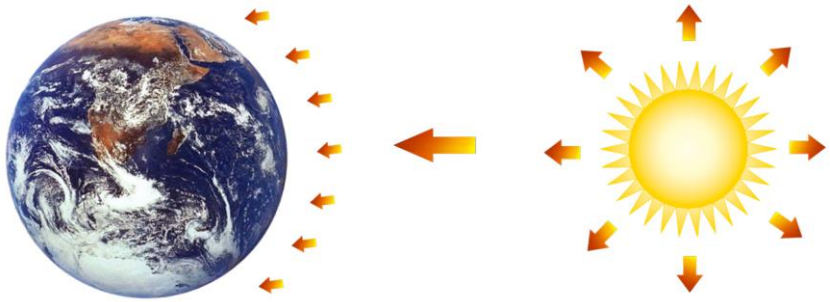
Climate change is the major, overriding environmental issue of our time.



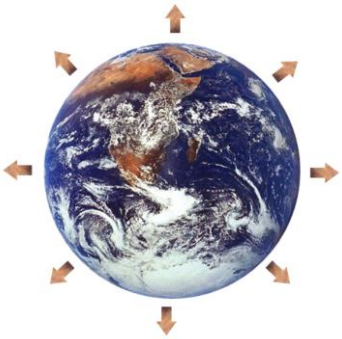




To understand Physics behind climate change, we need to know about the **radiation** from the **Sun** that **heats** up the **Earth**.

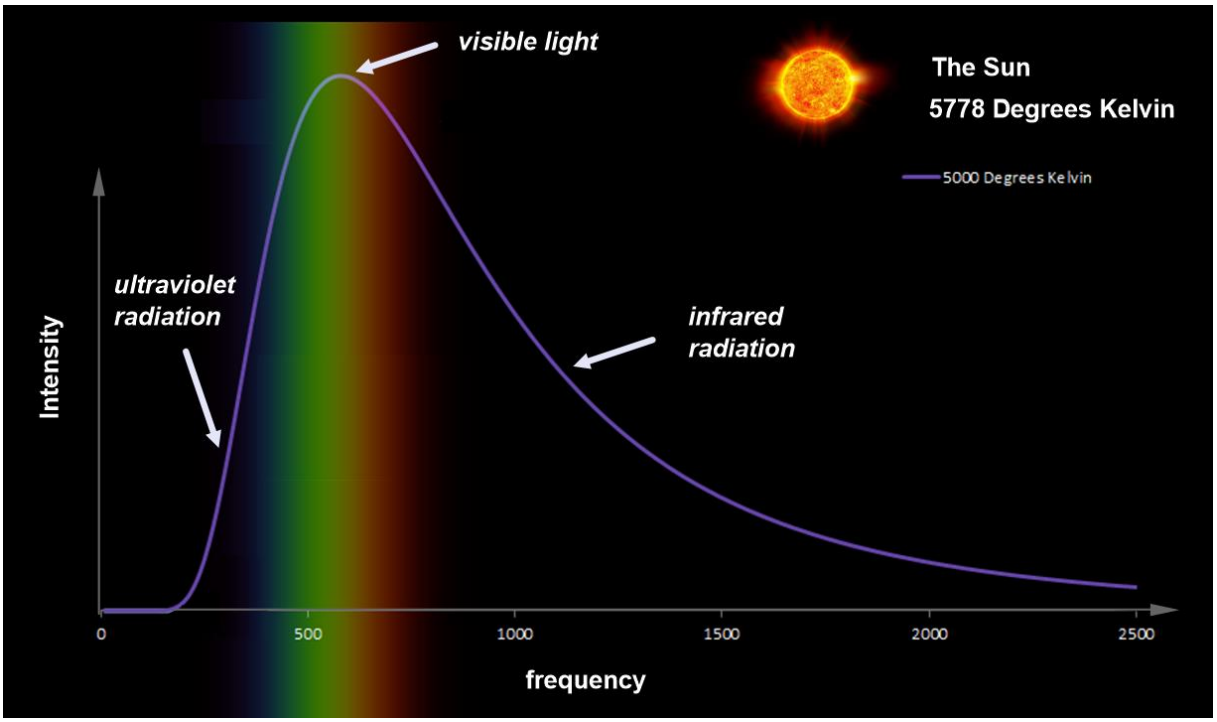


and the **radiation** from the **heated up Earth** that heats up our **atmosphere.**



Summary (Continued)

The Sun can be modelled a black body radiator which emits electromagnetic radiation according the graph below.



The Sun emits radiation in the Ultraviolet, visible and infra-red parts of the electromagnetic spectrum.

Wien's Law

$\lambda_{max} T$ = constant

Where

λ_{max} = wavelength of maximum light intensity emitted by black body radiator at temperature T (m)

T = Temperature of black body radiator (K)

Wien's constant = 2.9×10^{-3} metre-Kelvin (mK)

Stefan-Boltzmann Law

$P \propto T^4$ **Power ∝ Temperature⁴**

or $P = \sigma T^4$

Where

P = Power of thermal radiation from a black body radiator (Wm^{-2})

T = Temperature of black body radiator (K)

σ = Stefan-Boltzmann's constant = 5.67×10^{-8} $Wm^{-2}K^{-4}$

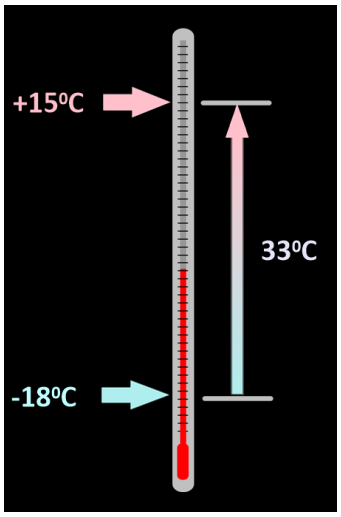
Wien's Law allows you to calculate the **wavelength of maximum intensity radiation**, λ_{max} (in metre) given an objects **Temperature, T** (in Kelvin).

The **Stefan-Boltzmann** equation allows you to predict the **power** output (in Wm^{-2}) of any body as long as you know its **temperature**, T (in Kelvin)

Summary (Continued)

Wien's Law tells us that the heated up Earth re-emits electromagnetic radiation entirely in the **infra-red** part of the spectrum.

The **Stefan Boltzmann** equation predicts that the Earth's average surface temperature due to this radiation would be **-18^{0}C.**



Since the last ice-age, thousands of years ago, this system maintained a relatively steady average global surface temperature of **15^{0}C**

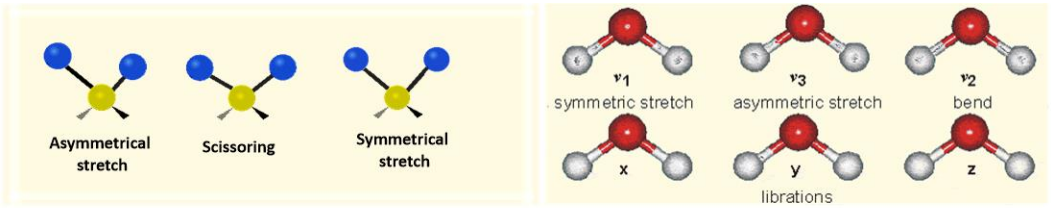
The Earth's surface is **33^{0}C** warmer than it would be if it had no atmosphere.

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

This is known as the **Greenhouse effect**

Greenhouse Warming

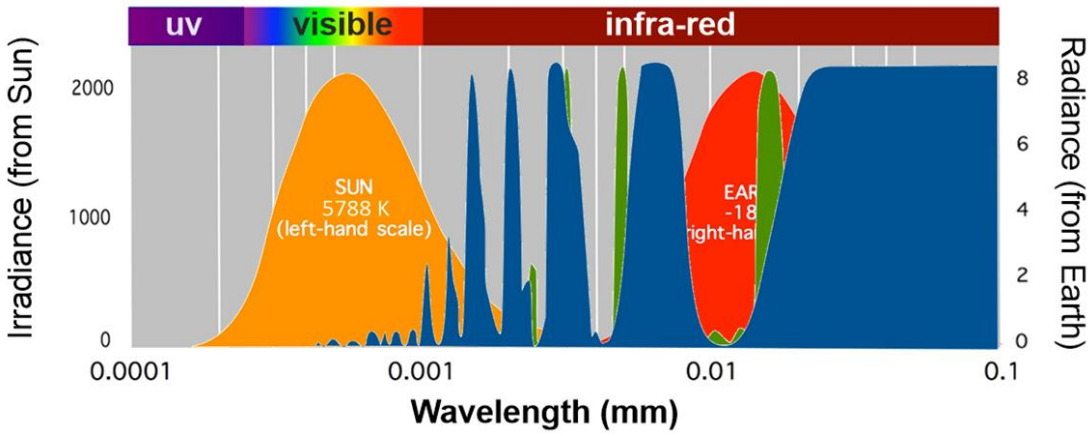
CO_2 and H_2O are able to vibrate in many different ……, and their natural frequencies of vibration are in the **……** part of the electromagnetic spectrum.



H_2O **CO_2**

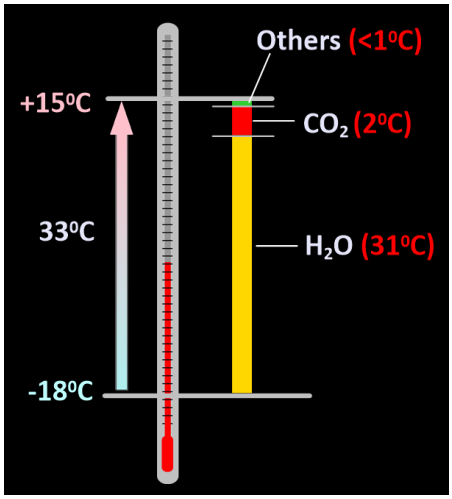
They are the Earth's blanket for …….. certain infrared frequencies back down to Earth.

Water Vapour and Carbon Dioxide absorb infrared radiation from the Earth's surface (see below) and later re-radiate it in …….. directions, warming the atmosphere as a result.



Summary (Continued)

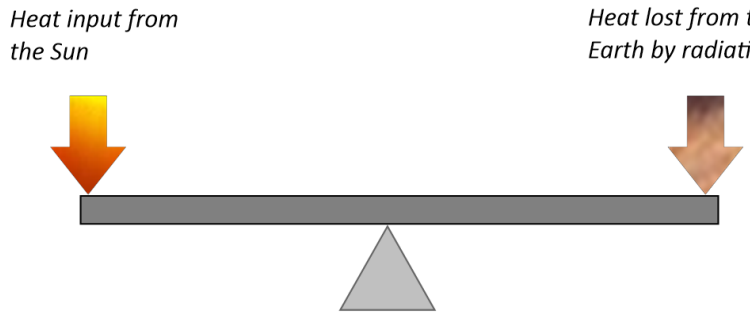
Greenhouse Warming (Continued)



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

The Earth's Energy Budget

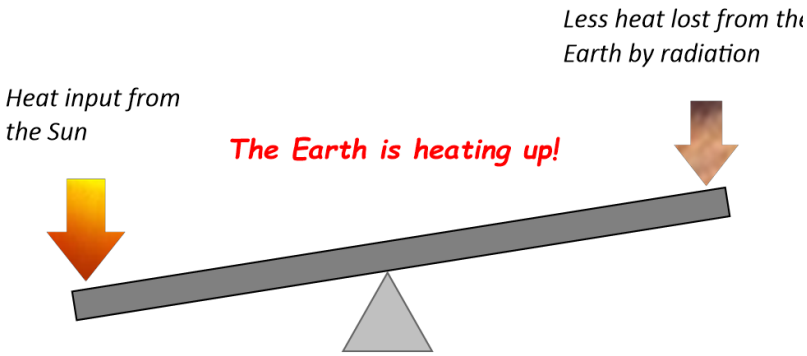
As long as the energy budget is in **balance**, then the Earth will remain in a state of **thermal equilibrium** and its average temperature will remain …….. over time.



The Enhanced Greenhouse Effect

Human activities such as the burning of fossil fuels (coal, oil and natural gas), land clearing and agricultural practices have …….. the concentration of greenhouse gases such as CO_2 in the atmosphere.

Because of excess greenhouse gases produced by human activity, the Earth's energy budget is no longer in balance.



Summary (Continued)

The Enhanced Greenhouse Effect and Climate Change

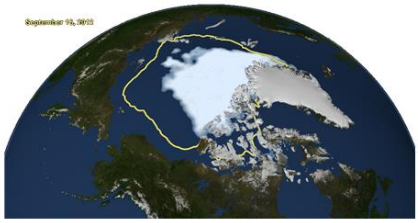
Evidence

Vanishing **Glaciers**

Reduced **Arctic Sea Ice**

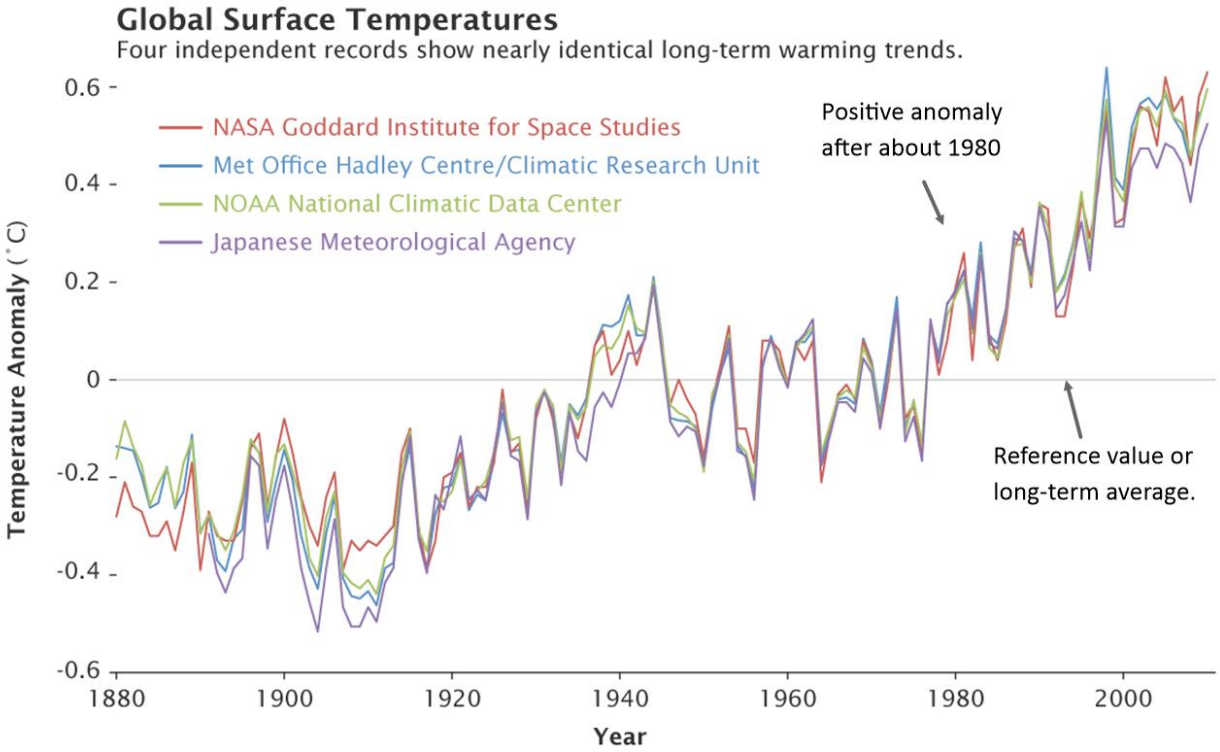
Larger Greenland

Summer **Ice Melts**



*The **Keeling Curve** showing increased level of Carbon Dioxide in the ……..*

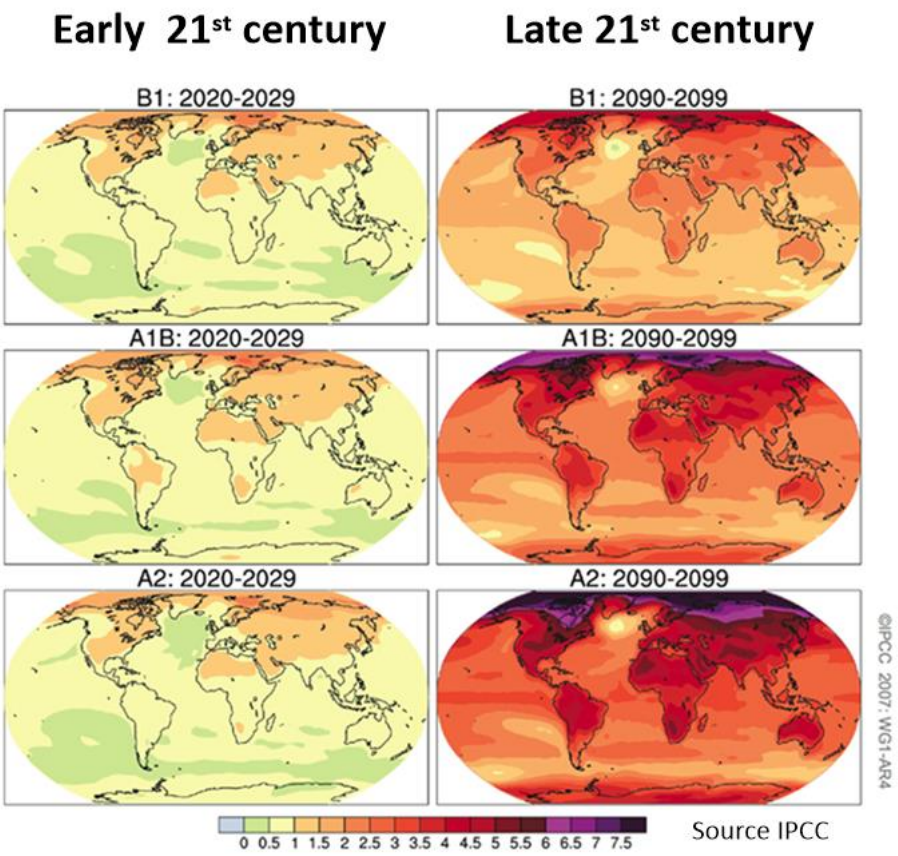
Global Surface Temperature measurements.



Summary (Continued)

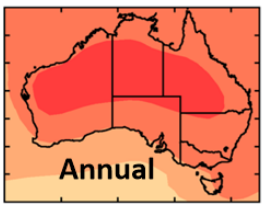
The Enhanced Greenhouse Effect and Climate Change (Continued)

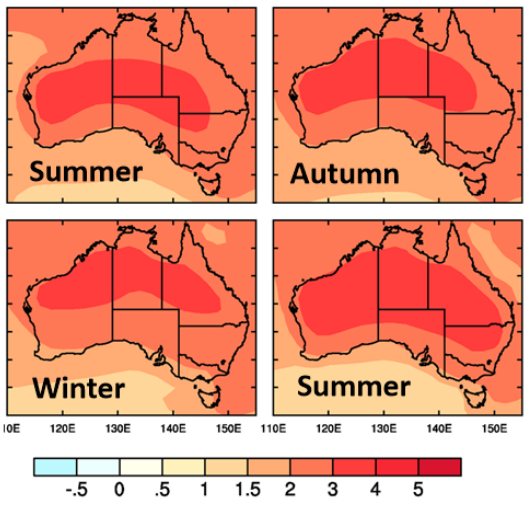
Climate Model Predictions.



Predictions for Australia

Average of the change in temperature (relative to 1990) by **2070**, predicted by 15-models.





Issues Related to Climate Change

You should now be able to apply your knowledge of thermodynamics to at least one the following environmental **issues** related to the enhanced greenhouse effect.

Proportion of National energy use due to heating and cooling of homes.

Comparison of the operation and efficiencies of various kinds of domestic heating and cooling systems

Possibility of homes that do not require any active heating or cooling at all.

Use of thermal imaging and infrared thermography in locating heating losses in buildings and cost saving implications.

Determination of the energy ratings of home appliances and fittings, insulation, double glazing and window size.

Cooking alternatives and appliance options (microwave, convection, induction) and fuel options (gas, electricity, solar, fossil fuel).

Automobile efficiencies: Fuels options (diesel, petrol, LPG and electric); engine air delivery options (naturally aspirated, supercharged and turbocharged); and fuel delivery option (common rail, direct injection and fuel injection).