CHAPTER 2
THE HUMAN INFLUENCE...

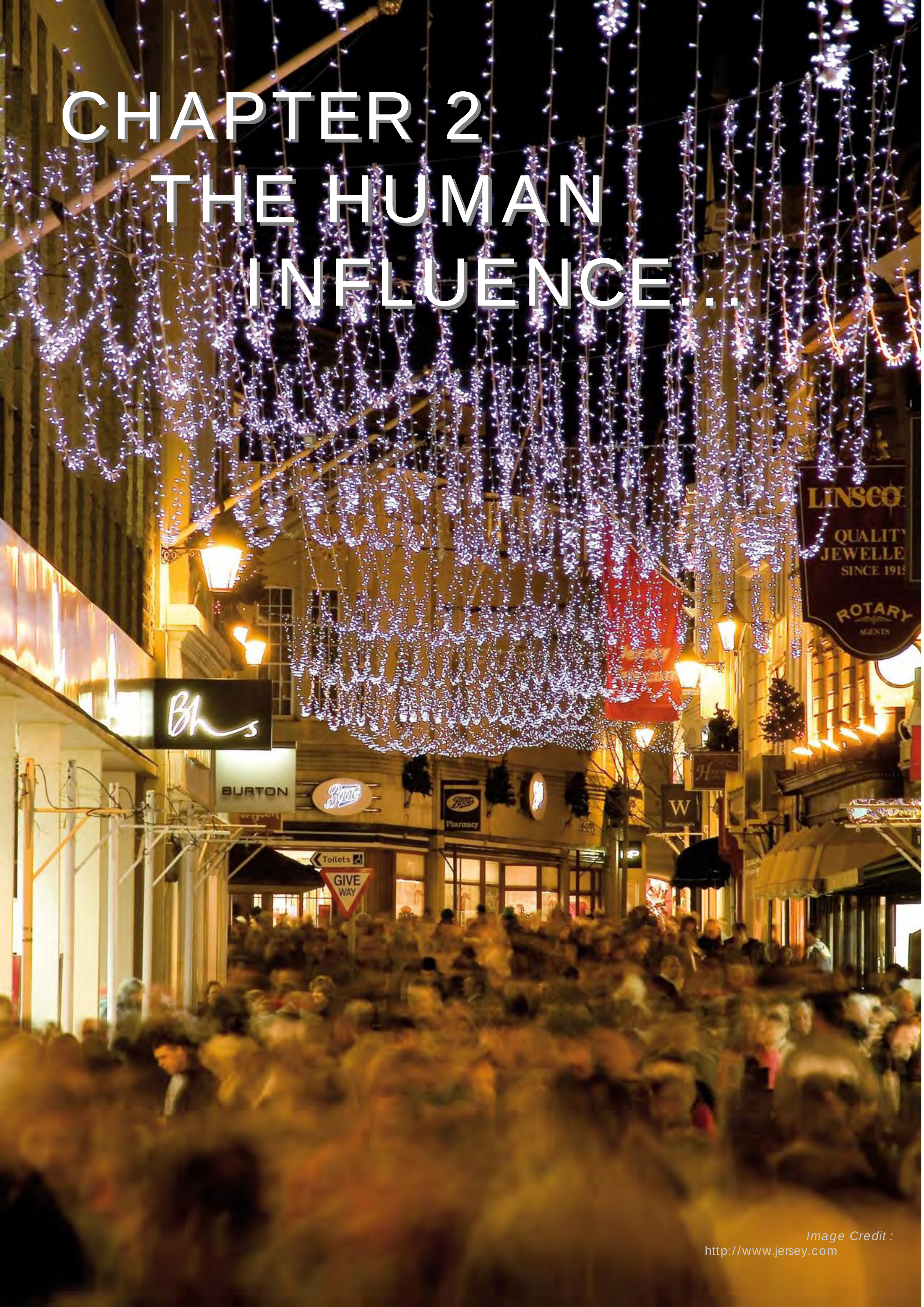


Image Credit :
http://www.jersey.com

CHAPTER 2 - THE HUMAN INFLUENCE

The global debate on climate change is over, most governments now accept that emissions from human sources are largely responsible for global warming. Over the last 150 years our activities have changed the way the earth's climate behaves and this chapter discusses the science behind the theory of global warming and the evidence that supports it.

CHAPTER 2 - THE HUMAN INFLUENCE

Science advances by constructing theories and testing them using data as supporting evidence.

Climate change theory is no different. It argues that human influence has altered the composition of the atmosphere and in doing so has changed the way it absorbs radiation from the sun.

This theory is not new. As early as 1895 Swedish chemist and Nobel laureate Svante Arrhenius argued that increased atmospheric CO_2 could lead to a warmer climate, with a rise of 5 to 6°C with CO_2 doubled.

The degree of warming recently observed has increased the urgency of the debate.

This chapter reviews the science behind the climate change debate, showing that human influence has contributed to observed warming, particularly in the last 30 to 40 years.

Finally, a review of several common arguments used by 'climate sceptics' is provided, exposing the lack of evidence to support their arguments.

2.1 AN INTRODUCTION TO CLIMATE CHANGE

Andrew Casebow

Climate change due to human activities represents the biggest challenge facing the world in the 21st century.

'Greenhouse' gases, such as water vapour and carbon dioxide (CO_2), act as blankets over the Earth's surface, keeping it warmer than it would otherwise be. They do this by absorbing infra-red radiation or 'heat' emitted from the earth's surface. The existence of this natural 'greenhouse effect' has been known for nearly 2000 years and is essential if we are to maintain the climate to which ecosystems and humans have adapted.

Since the beginning of the Industrial Revolution around 1750, CO_2 has increased by nearly 40% and is now more highly concentrated in the atmosphere than for many thousands of years. Chemical analysis shows the increase is due largely to burning of fossil fuels - coal, oil and gas. If no action is taken to curb these emissions, by the end of the century, CO_2 concentration is forecast to reach two to three times the pre-industrial level.

The climate record over the last thousand years shows a good deal of natural variability, as highlighted in Section 1, but the increase in global average temperatures (and the rate of rise) particularly in the last 30 to 40 years is well outside the range of this known natural variability.

This century the global average temperature is projected to rise by between 2 and 6°C from the pre-industrial level. The range depends on two factors a) differing assumptions as to the levels of emissions over the next century and b) the sensitivity of climate models used to make the estimates.

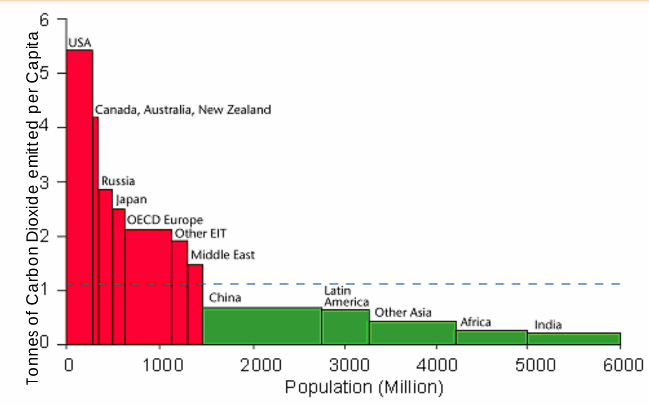
The magnitude of this rise can perhaps be better understood if we consider that the difference between the middle of an ice age and the middle of a warm period between ice ages is about 5 or 6°C, while the temperature rose by a mere 0.6°C between 1900 and 2000.

EMISSIONS OF CARBON DIOXIDE INTO THE ATMOSPHERE

Emissions of CO_2 into the atmosphere by burning fossil fuels are currently nearly 7 billion tonnes a year and rising rapidly. Unless urgent measures are taken they could reach two or three times this level this century. To stabilise CO_2 concentrations, emissions need to reduce to a fraction of the present level well before the end of the century.

The reduction in emissions will need a concerted world-wide effort, but the issue is complicated by big differences in greenhouse gas emissions from one country to another. In tonnes per person per year, they vary from about 5.5 in the USA to 2.5 tons in Europe to 0.7 tonnes in China and 0.2 tonnes in India (Box 1). Ways will need to be found to achieve realistic and equable reductions.

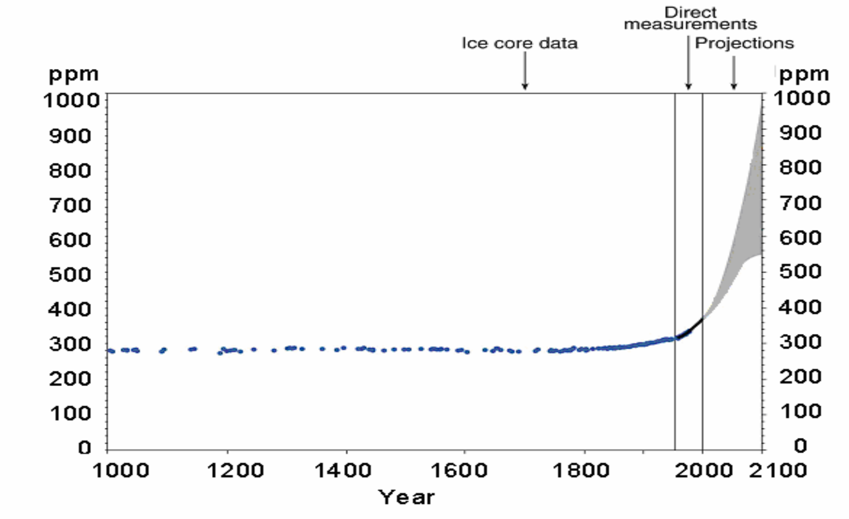
Developed countries have benefited from abundant fossil fuel energy over many years, so the demands on their stewardship take on a special poignancy, because the adverse impacts of global warming are likely to fall disproportionately on poorer nations and



Box 1

Carbon dioxide emissions in the year 2000. The area of each bar is representative of total emissions i.e. China and OECD Europe emit similar amounts of carbon dioxide in total due to China's much larger population.

Graph Credit: M Grubb, 2003 and Planet Guernsey, 2007



Box 2

Past and future atmospheric CO_2 concentrations. All measures before 1950 are ice core data, 1950-2000 are direct measurements and 200 onwards are projections.

Graph Credit:
IPCC 2001 Synthesis Report.

tend to exacerbate an increasingly large divide between rich and poor.

The aim must be to stabilise carbon emissions to as low a level as possible to avoid a damaging change in climate. In 1996 the European Commission proposed a 2°C limit on the rise in average global temperature from the pre-industrial level. This implies a stabilisation level for CO_2 at about 430 parts per million (ppm) allowing for the effect of other greenhouse gases at their 1990 levels. Without action to secure this stabilisation atmospheric CO_2 could go much higher - see Box 2.

If carbon dioxide is stabilised at 500 ppm and the effect of other greenhouse gases at their 1990 levels is added, it is about equivalent to double the carbon dioxide at its pre-industrial level, and will therefore produce a rise in global average temperature of about 2.5°C .

Although global warming may eventually be halted, the impacts at such a level would be large. A steady increase in sea level would continue, heat waves such as experienced in Europe in 2003 would be more common, floods and droughts would also be more common. The aim should be to stabilise at a lower level. But is this possible?

The UK government has taken a lead on this issue, agreeing to a modest target of reducing greenhouse gas emissions by 80% by 2050. The cost will not be great if action is taken quickly. UK Government Treasury economists have estimated the cost to the UK economy, assuming growth of 2.25% per annum, as no more than the equivalent of 6 months growth over the 50-year period.

The need for action on global warming is urgent for three reasons:

1: *Scientific*. There is a lag in the response of climate to increasing greenhouse gases because the oceans take a long time to warm and cool. The greenhouse gas emissions that have already occurred will continue to change the climate for the next 30-50 years.

2: *Economic*. The energy infrastructure (power stations etc.) is typically designed for 30-50 years, so it is more cost effective to phase in infrastructure changes than having to make them much more rapidly later.

3: *Political*. Countries such as China and India are industrializing very rapidly. In order to provide an example of effective leadership we need to start now.

Both the challenges and opportunities for all of us are unmistakable.

> *"No one made a greater mistake than he who did nothing because he could do so little".*
>
> *Edmund Burke*

2.2 WHAT ARE 'GLOBAL WARMING' AND THE 'GREENHOUSE EFFECT'?

Andrew Casebow

What do we mean by the terms 'climate change' and 'global warming' and 'the greenhouse effect'?

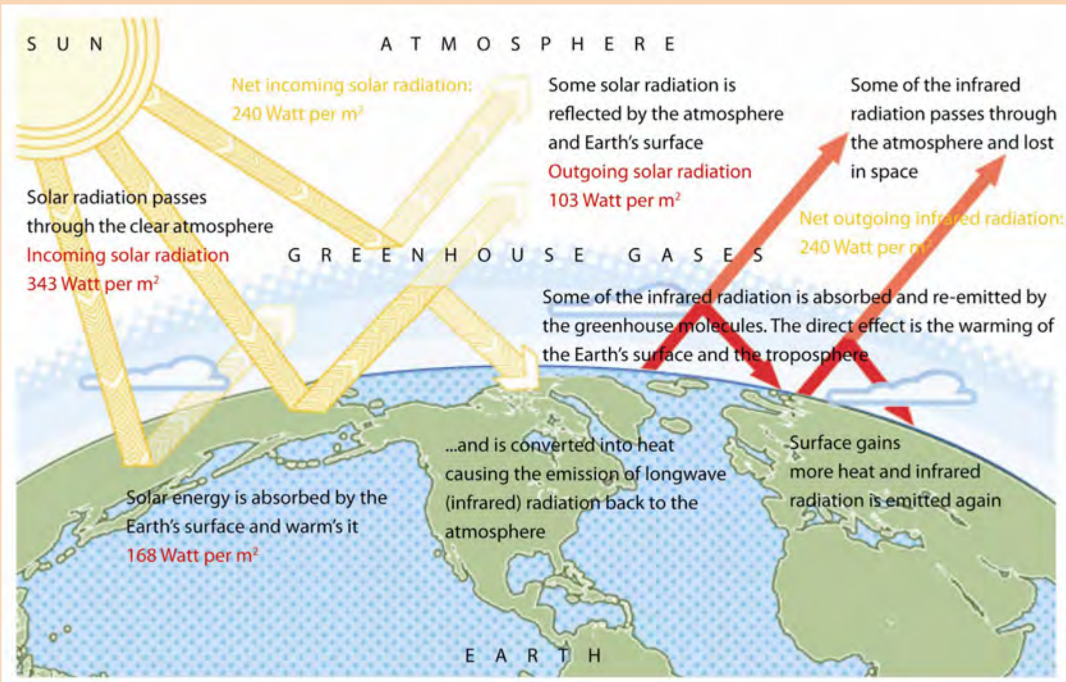
Section 1 showed the Earth's climate is in a very delicate balance. Climate change is caused by various naturally occurring cycles, including the Earth's movement around the sun and factors such as volcanic eruptions. Some cycles occur over periods of a few years, others over thousands of years and some over hundreds of thousands of years. The climate change occurring now, which we refer to as 'global warming', is caused by increasing concentrations of gases and chemicals in the Earth's atmosphere from human sources. These gases are accentuating the 'greenhouse' effect.

We rely on the earth's 'greenhouse' effect to keep us warm, because natural greenhouse gases, such as CO_2, methane and water vapour act as a blanket, preventing the escape of heat from the Earth. Without them our climate would be more like that of Mars, with temperatures below zero; life as we know it could not survive. The schematic diagram (Box 1) highlights how the effect works, with 'greenhouse gases' absorbing and re-emitting radiation to warm the Earth's surface and lower atmosphere.

Over the last few hundred years, man has cleared forests and has burnt coal, oil and gas in ever greater quantities, so increasing the amount of CO_2 in the atmosphere. The expanding human population also produces larger quantities of methane from decomposing rubbish and increased animal production. With more of these gases in the atmosphere, more of the Earth's outgoing radiation is trapped, resulting in increasing temperatures.

Climate change is not confined to changes in air temperature alone. Oceans contain a vast amount of energy and although temperature change in the ocean is very slow even a small rise in temperature results in a lot more energy in the atmosphere. The result is that the weather system has more energy and as a consequence, the weather becomes more extreme. Increased evaporation of water means more clouds, heavier rain and stronger winds.

Research has shown that in the last ice age the concentration of CO_2 in the atmosphere

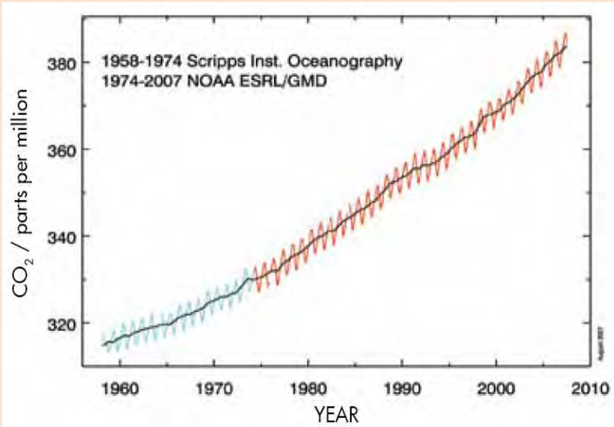


Box 1

Schematic diagram showing the Earth's energy cycles and the 'Greenhouse Effect'.

Image Credit: Planet Guernsey and Chris Regan, 2007 was between 200 and 220 parts per million (ppm). Man has been cutting down and burning woodland for around 20,000 years, but with social and technological changes in more recent times this has increased. From about 1700 a slow increase in the amount of CO_2 in the atmosphere took place to reach 280ppm by the early 19th century.

By 1960, when more accurate monitoring started the figure was 316ppm. Box 2 illustrates how CO_2 concentrations have been rising steadily since monitoring began in1959. The concentration increases every winter and reduces each summer due to photosynthesis converting CO_2 into plant growth.



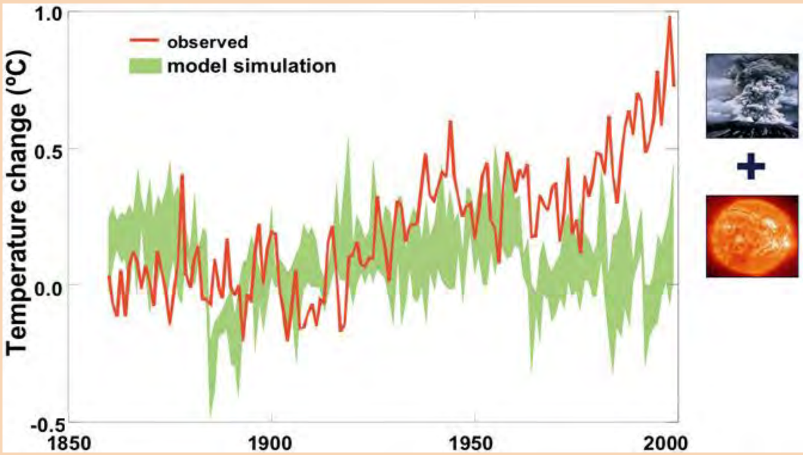
Box 2

Monthly average CO_2 in the atmosphere from 1955 to 2005.

Source: National Oceanic and Atmospheric Administration, Climate Monitoring and Diagnostics Laboratory.

Box 3 Mean annual temperatures and model predictions

a) Predictions based on natural solar and volcanic cycles



b) Predictions based on natural cycles and human activity

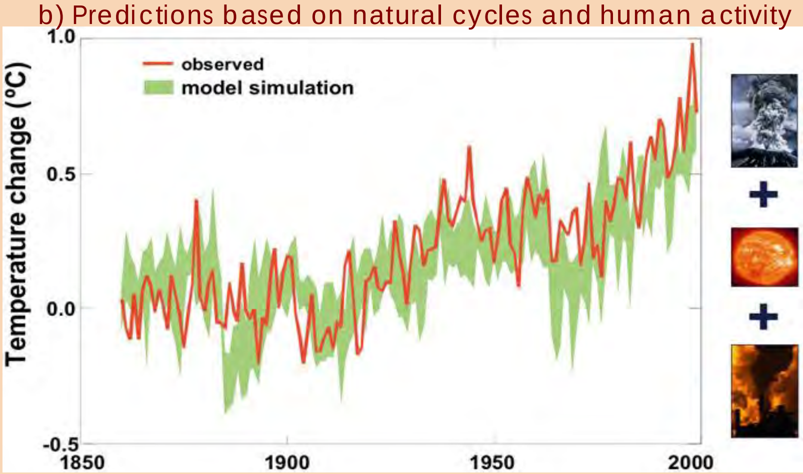


Image Credit: Met Office Hadley Centre and Planet Guernsey, 2007
Image Credit: Planet Guernsey, 2007. Originally, Met Office, Hadley Centre
Graph Source: Adapted from NOAA/GMD by Planet Guernsey

To investigate the extent to which global warming may be natural or man-made, a model of the climate system was developed by the UK Met Office's Hadley Centre.

Box 3, graph (a) shows average annual temperature and model predictions based on the natural factors discussed in Chapter 1, primarily the sun, volcanoes and internal feedback influences. Note the wide difference between what actually occurred and what the model predicted over the past 30 years.

When the known emissions of CO_2 were incorporated in the model (b), the simulation matched the actual temperature very closely, suggesting that the temperature increase was caused by the higher concentration of man-made CO_2 in the atmosphere.

2.3 The Intergovernmental Panel on Climate Change (IPCC)

Andrew Casebow

2007 was a watershed. Previously, some Governments had chosen not to accept the overwhelming evidence that climate change was occurring. Many people considered that there was still a 'debate' about whether or not climate change caused by global warming was a reality. There was still a lot of misinformation and discussion about the causes of climate change and whether it was a naturally occurring phenomenon. Then the 4th Assessment Report from the IPCC was published.

The report shows that it is virtually certain that climate change induced by human activity is happening, and is occurring faster than had been previously anticipated.

The Intergovernmental Panel on Climate Change is the world's leading authority on climate change. It was set up by the World Meteorological Organisation (WMO) and the United Nations Environment Programme (UNEP) in 1988.

"The role of the IPCC is to assess on a comprehensive, objective, open and transparent basis the scientific, technical and socio-economic information relevant to understanding the scientific basis of human induced climate change, its potential impacts and options for adaptation and mitigation'.

The IPCC provided its first major assessment report in 1990, a second in 1996, a third report in 2001 and its most recent fourth report in 2007. Together, they provide the most comprehensive scientific information available, prepared by teams of the world's leading climate scientists.

The reports carefully distinguish between what is known with reasonable certainty, and the areas where uncertainties remain. The language used is very 'measured' and conservative, and for findings to be incorporated into the report they must have a very wide degree of international acceptance that they are correct.

The IPCC 2007 report points out that: *"Global atmospheric concentrations of carbon dioxide, methane and nitrous oxide have increased markedly as a result of human activities since 1750 and now far exceed pre-industrial values determined from ice cores spanning many*

Climate Campaigns
The IPCC shared the 2007 Nobel Peace Prize with Al Gore for their efforts to promote and raise awareness of climate change globally.

The full reports and summaries are available at http://www.ipcc.ch

Box 2

The IPCC produce individual reports on the science, impacts and mitigation of climate change as well as a synthesis by assessing the latest scientific, technical and socio-economic literature.

thousands of years. The global increase in CO_2 concentration is due primarily to fossil fuel use and land use change, whilst those of methane and nitrous oxide are primarily due to agriculture".

CO_2 is the most important greenhouse gas caused by human intervention. *"The global atmospheric concentration of CO_2 has increased from a pre-industrial level of about 280 parts per million (ppm) to 379ppm in 2005. The atmospheric concentration of CO_2 in 2005 exceeds by far the natural range over the last 650,000 years".*

"The global atmospheric concentration of methane has increased from a pre-industrial level of about 715ppb to 1732ppb in the early 1990's and was 1774ppb in 2005. It is very likely that the increase in methane is due to human activities, mainly agriculture and fossil fuel use. The concentration of nitrous oxide has increased from a pre-industrial level of about 270ppb to 319ppb in 2005. More than a third of all nitrous oxide emissions come from human activity and are primarily due to agriculture".

There are still some individuals and organisations that seek to undermine the science of climate change and the work of the IPCC. The Royal Society of London believes that *"they appear motivated in their arguments by opposition to the UN Framework Convention on Climate Change and the Kyoto Protocol, which seek urgent action to tackle climate change through a reduction in greenhouse gas emissions."*

"It has been claimed that the rise in atmospheric concentrations of CO_2 *is actually a consequence of climate change, rather than a cause. The IPCC report pointed out that the chemical analyses of the carbon dioxide show that the increase in the atmosphere, and an accompanying decrease in oxygen concentrations, are primarily due to the burning of fossil fuels and deforestation".* However, a number of climate change skeptics still continue to believe, despite the scientific evidence, that climate warming is caused by natural phenomena, and have been arguing for a business-as-usual approach. In response Sir Martin Rees, President of the Royal Society, has said:

"Global temperature is increasing. This warming threatens the future health and wellbeing of many millions of people throughout the world. This is especially true of those in the developing countries who are the least able to adapt and who are likely to be the worst affected. Many factors play a part in global warming but there is significant scientific evidence that greenhouse gas emissions, particularly carbon dioxide, are responsible for most of the temperature rise. If present trends continue the projected climate change will be far greater than that already experienced. Greenhouse gas emissions are something that we can and must take action on".

"Those who promote fringe scientific views but ignore the weight of evidence are playing a dangerous game. They run the risk of diverting attention from what we can do to ensure the world's population has the best possible future." ."
(Royal Society press release 9 March 2007)

2.4 HOW DO WE MEASURE GLOBAL CLIMATE CHANGE?

James Le Ruez

Can we be confident in records of 'global climate'?

Measuring the climate is not a simple task. It requires long series of records over large areas to establish climate means. Even basic equipment, such as thermometers and rain gauges, has only become widely available in the last 150 years.

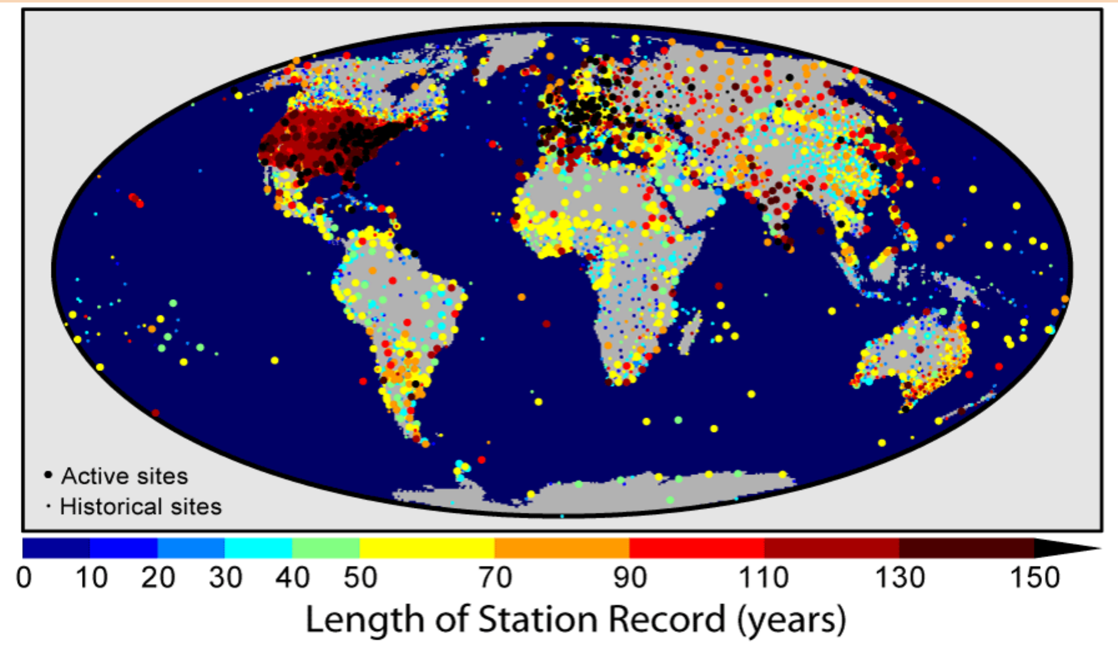
Prior to the mid 19th century a good approximation of the climate for some regions of the world has been established using methods such as tree ring, lake sediment and ice core analysis as well as qualitative written observations. Such records can be pieced together to analyse how climate has changed during the 20th century.

Temperature has proved the most reliable and well-documented of records, with global datasets maintained by the UK Met Office's Hadley Centre, NASA and others. Each institution employs specialist researchers who recreate global climate from the available data, using sophisticated statistical methods to make data series compatible or calculate any uncertainty associated with these climate re-constructions.

Any unreliable or unrepresentative data is identified and discarded during a vigorous statistical analysis process. Measures of uncertainty are given with the data and these provide an indication of the degree of confidence held in the data.

The uncertainty in annual measurements of the global average temperature calculated by the Hadley Centre is ~0.05°C since 1950 and ~0.15°C in the early part of the instrumental record.

Uncertainty in the data can stem from incomplete records. Climate datasets are not comprehensive for several reasons:



Box 1
The network of observation stations used in the University of East Anglia Climatic Research Unit (CRU) dataset. Note the high concentration of long records (red) in developed regions (e.g. USA and Europe) in contrast with large areas with scarce measurements (e.g. Siberia, central Africa and the Amazon).

Box 2

The concentration of CO_2 in the atmosphere is measured in remote locations to avoid the influence of local sources such as traffic or industry. The longest record of CO_2 concentration is maintained by the Mauna Loa Observatory, Hawaii, where its height of 3,397 metres provides ideal conditions for measurements free of such influences.

Image Credit: http://mlso.hao.ucar.edu/

LENGTH OF RECORDS

Box 1 shows that the longest climate records are predominately from the developed world where technology and a stable social environment have encouraged record keeping. Some parts of the world, such as the polar regions, South America and Africa have much shorter periods of records.

SPATIAL COVERAGE

In many less developed nations, records can be sparse. Box 1 shows that spatially many regions have very few records of significant length.

Records of sea surface temperature, which are important in recreating past climates, are even more sparsely distributed. The greater land area of the northern hemisphere holds a far greater number of measurements than the southern hemisphere.

POINT MEASUREMENT

In order to establish regional climate patterns, numerous atmospheric measurements taken at single points over the representative area are combined. In data - sparse areas one point measurement may be required to represent the climate of an unrealistically large area.

INSTRUMENTS USED

In addition, measurements from different stations, using different instruments and data collection methodologies can cause inconsistencies in the data. Therefore corrections have to be made.

For example, sea temperature historically was sampled by collecting seawater over the side of the ship in a canvas bucket. Now the temperature of the engine intake water is sampled. This resulted in a 'blip' in the records, which had to be corrected to make the two sets of records compatible.

SATELLITES

Satellites may provide an answer to many of these issues in the future. However, they have been operating for a relatively short time period and early measurements have suffered from instrument problems.

As more sophisticated measurement instruments are used and data is collected more widely around the globe, the climate datasets will become more complete. With time the certainty in which we hold global climate change measurements will increase.

Global climate is changing, temperatures increasing, rainfall and atmospheric circulation patterns varying, oceans warming and sea levels rising. Despite the reservations above, the IPCC states with 90% confidence that these effects are due to human influences.

2.5 HOW HAS GLOBAL CLIMATE CHANGED IN RECENT TIMES?

The summaries below highlight the most significant conclusions made by the IPCC in their 4th Assessment Report.

TEMPERATURE

Increasing global temperature 'anomalies' since 1850 (Box 1) - A linear trend line drawn through the global mean surface temperatures over the last 100 years (1906–2005) indicates a temperature rise of 0.74°C (± 0.18°C). The rate of warming over the last 50 years is almost double that over the last 100 years.

2005 was one of the two warmest years on record - The warmest years in the instrumental record were 1998 and 2005. 1998 ranks first in one estimate (Box 1) but 2005 is slightly higher in the other two estimates. 2002 to 2004 were the 3rd, 4th and 5th warmest years in the series since 1850. 11 of the last 12 years rank among the 12 warmest years on record.

Land regions have warmed at a faster rate than the oceans - Surface air temperatures over land have risen at about double the ocean surface rate since 1979 (more than 0.27°C vs. 0.13°C per decade). This is because some heat is absorbed by the ocean and mixed to greater depths.

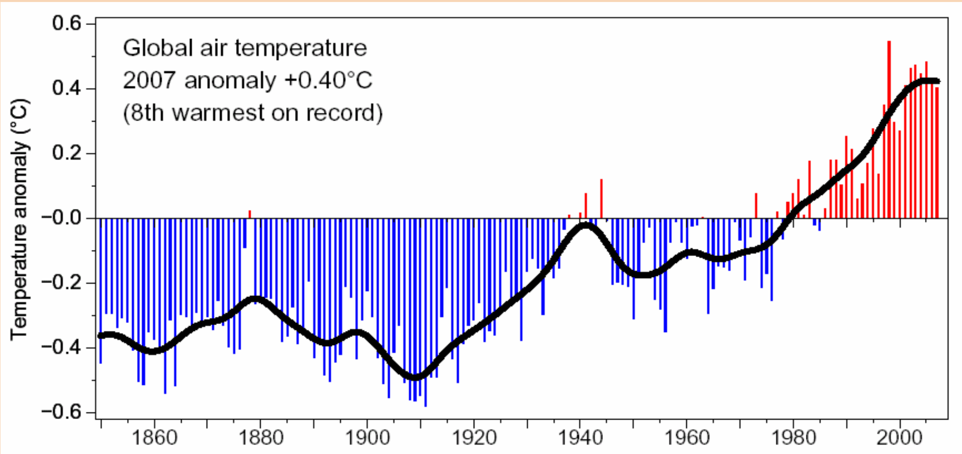
Changes in extremes of temperature are consistent with warming of the climate - A widespread reduction in the number of frost days in mid-latitude regions, an increase in the number of warm extremes and a reduction in the number of daily cold extremes has been observed in 70 to 75% of land regions.

PRECIPITATION

From 1900 to 2005, precipitation has generally increased in areas north of 30°N but decreased in the Tropics since the 1970s - It has become wetter in eastern parts of the Americas, in northern Europe and northern and central Asia. Conversely, in the Sahel, Mediterranean, southern Africa and parts of southern Asia it has become drier. Precipitation change is more spatially and seasonally variable than temperature change.

Heavy precipitation events are becoming more frequent - Evidence suggests there have been increases in the number of heavy precipitation events, even in regions where there has been a reduction in total precipitation. Such observations are consistent with forecasts of climate change.

Droughts have become more common, especially in tropical regions, since the 1970s - In the past 30 years droughts have been more intense, longer, and affected a wider area due to decreased land precipitation and increased temperatures enhancing



Box 1

This graph represents the climate 'anomalies' using the 1961-1990 average temperature as the reference period. This reveals how global temperatures have increased since 1980.

Graph Source: University of East Anglia, Climatic Research Unit, http://cru.uea.ac.uk evaporation. The extreme nature of droughts in Australia and Europe, suggest links to climate change.

ICE REGIONS (THE CRYOSPHERE)

Temperature increases are consistent with observed changes in the cryosphere - Consistent with higher surface temperatures there has been a global reduction in glacier and small ice cap mass and extent in the 20th century (excluding Antarctica and Greenland). Snow cover has decreased in many regions of the northern hemisphere and the extent of sea ice has decreased in the Arctic (Box 2), particularly in spring and summer. In addition the oceans are warming and sea level is increasing.

Average Arctic temperatures increased at almost twice the global average rate in the past 100 years. Mean Arctic sea ice extent continues to decline by 2.7 ± 0.6% per decade since 1978 - Submarine-derived data for the central Arctic, supported by model-based reconstructions, indicate that the average sea ice thickness in the central Arctic has very likely decreased by up to 1 metre from 1987 to 1997.

Mass loss of glaciers and ice caps is estimated to be 0.50 ± 0.18 mm/yr in sea level equivalent (SLE) between 1961 and 2004, and 0.77 ± 0.22 mm/yr SLE between 1991 and 2004 - The biggest contributions to sea level rise came from Alaska, the Arctic and the Asian high mountains. Thickening in central regions of Greenland has been more than offset by increased melting near the coast. Flow speed has increased for some Greenland and Antarctic outlet glaciers, which drain ice from the interior.

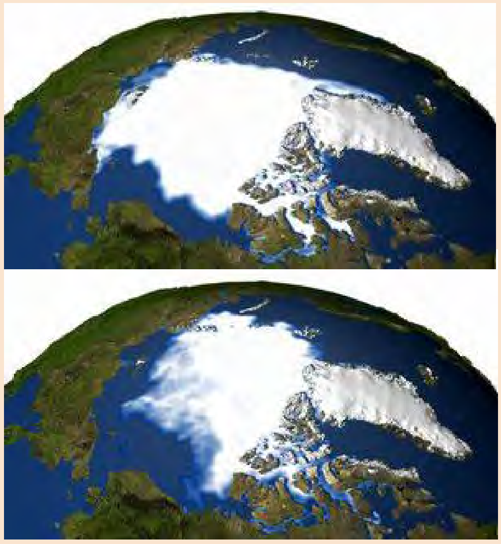
Temperature at the top of the permafrost layer has increased by up to 3°C since the 1980s in the Arctic - The permafrost base has been thawing at a rate ranging from up to 0.04 metres per year in Alaska since 1992 and 0.02 metres per year on the Tibetan Plateau since the 1960s.

MARINE CLIMATE

The oceans are warming - Over the period 1961 to 2003, global ocean temperature has risen by 0.10° C from the surface to a depth of 700 metres.

The chemistry of our oceans is changing - The total inorganic carbon content of the oceans increased by approximately 118 gigatonnes of carbon between the end of the pre-industrial period (about 1750) and 1994 and continues to increase. It is more likely than not that the fraction of emitted CO_2 that was taken up by the oceans has decreased. NB 1 Giga tonne = 1,000,000,000 tonnes

Global mean sea level has been increasing - From 1961 to 2003, the average rate of sea level increase was approximately 1.8 mm per year. There is high confidence that the rate of sea level increase has risen between the mid-19th and 20th centuries. Sea level change is extremely varied and in some regions rates are up to several times the global mean rise, while in other regions sea level is decreasing. There is evidence of an increase in the occurrence of extreme high water world-wide related to storm surges and variations in extremes.



Box 2

The evidence shows that the poles are warming at a higher rate in comparison to other areas of the planet. The reduction in sea ice between 1979 and 2003 is evident in these satellite images. In recent years the rate of ice melt has increased to unprecedented rates.

Image Source: NASA Press Release, 'Recent Warming of Arctic may affect worldwide climate'

REFERENCES
Sourced from the IPCC 4th Assessment Report. For the full report go to http://www.ipcc.ch/

2.6 HAVE WE OBSERVED CHANGES TO THE ISLAND'S CLIMATE?

Jersey Meteorological Department

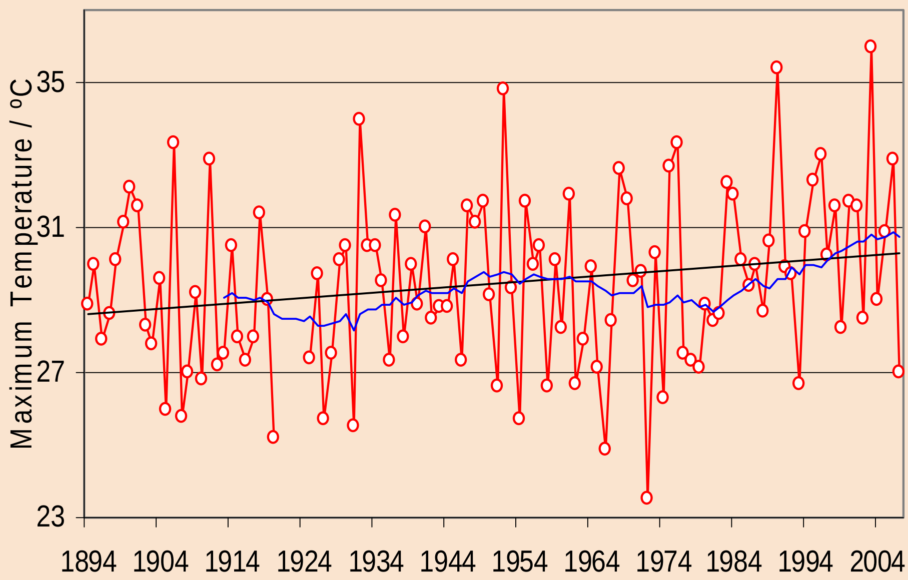
As we have seen, climate can be regarded to some extent as an average of the weather observed in a location. To establish that climate a long record is needed. In Jersey we are fortunate to have the records from the Maison St Louis Observatory (Box 1), currently run by the Jersey Meteorological Department, where daily observations stretch back to 1894.

To establish whether there has been change in our local climate, one method recommended by the World Meteorological Organisation and World Climate Research Programme and adopted here is to convert some of the readings into 'indices'.

This analysis uses examples from the recommended set of 27 indices, each intended to give a recognisable measure of the climatic conditions of a location from which changes can be assessed. A seasonal approach has been adopted for rainfall as this method proved more revealing. The summaries below assess how several indices of interest have changed over the last 100 years.

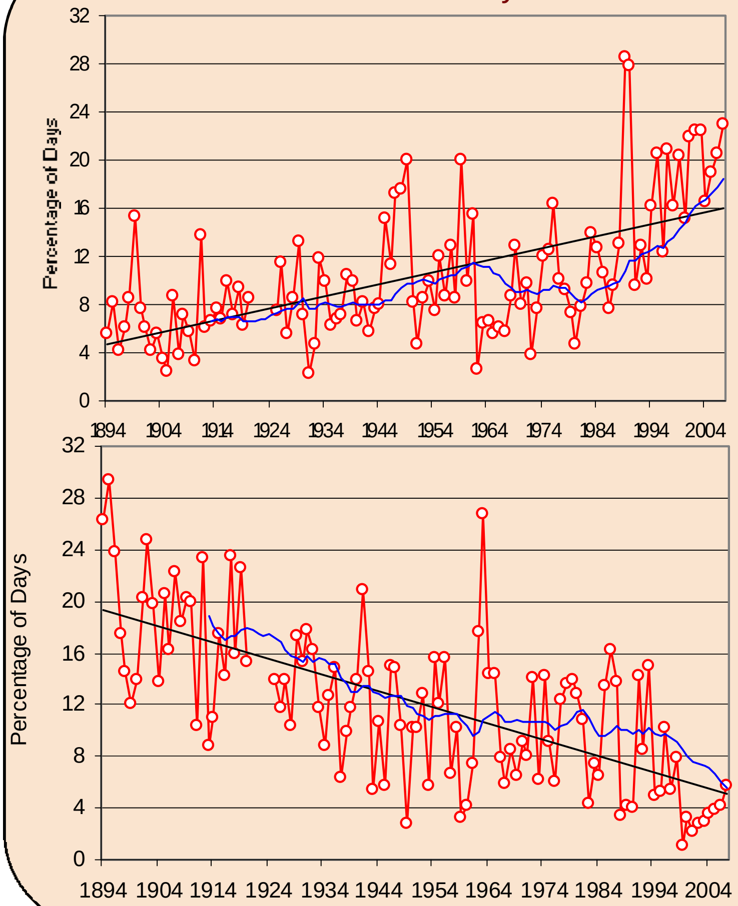
Box 1
The weather station at the Maison St Louis observatory.

Maximum Temperature



This index shows the maximum temperature recorded in Jersey for each year since 1894. Note a large degree of year to year variation. The straight line regression shows a steady increase through the period with the annual maximum temperature below 29°C in 1894 but now above 30°C. The trend is not constant as shown by the blue line which is the 20 year moving average (each point represents the average maximum temperature in the previous twenty years). We see that in the 1920s and the 1970s annual maximum temperatures were not so high, but from 1980 onwards the tendency towards higher maximum temperatures. The highest temperature recorded in Jersey so far was 36.0°C in August 2003. There has been a similar rise of about 1°C in the annual minimum temperature, where the annual minimum temperature was about -4°C in 1900 compared to -3°C in 2000.

Warm and Cool Days

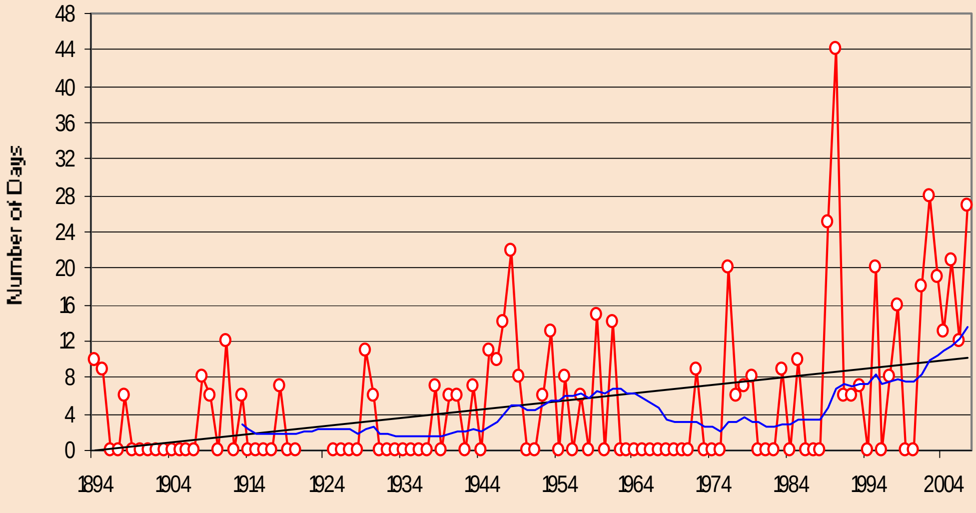


The upper and lower plots show the percentage of warm and cool days each year. The average temperature for each day is calculated to determine whether it falls into the 10% of warmest or coldest days for the entire 1894-2007 period.

The index reveals a significant upward trend in the number of warm days across the observation period. As with maximum temperatures above, there has been a distinct rise in the number of warm days observed recently, particularly since about 1970.

In contrast, the lower plot reveals a very steep decline in the number of cool days recorded. These analyses strong suggest that summer days are becoming increasingly warmer and winter days increasingly milder.

Warm Spell Duration



A warm spell is defined as a period of at least 6 consecutive days when the maximum temperature is higher than the 90th percentile (in Jersey's case 21.3°C). If no 6 day warm period is observed in a year, the index is zero otherwise it returns the combined number of days from the warm periods recorded. For instance, a warm period of 11 consecutive days would have an index of 11, while two periods of 6 days each or one period of 12 days would show an index of 12. Although the most common result in this dataset is zero, the range extends up to an aggregated 44 days over five warm spells in 1990. The long term trend shown by the black line indicates warm spells have become more likely and now average 10 days each year, compared with the early period when there were very few warm spells. The running mean (blue line) shows a slight increase in the frequency of warm periods in the middle of the 20th century.

2.6 CONTINUED...

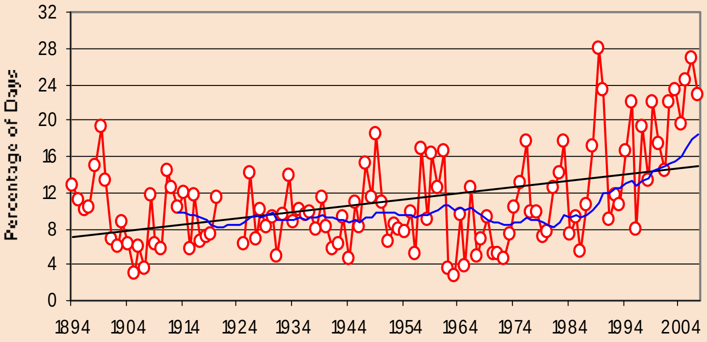
Jersey Meteorological Department

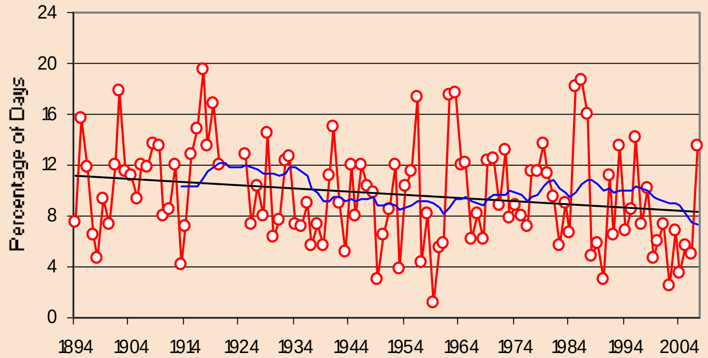
Warm and Cool Nights

Changes in the night time climate are similar to those in the day. As an indicator of night time climate we use here the minimum temperature, which typically occurs just after dawn.

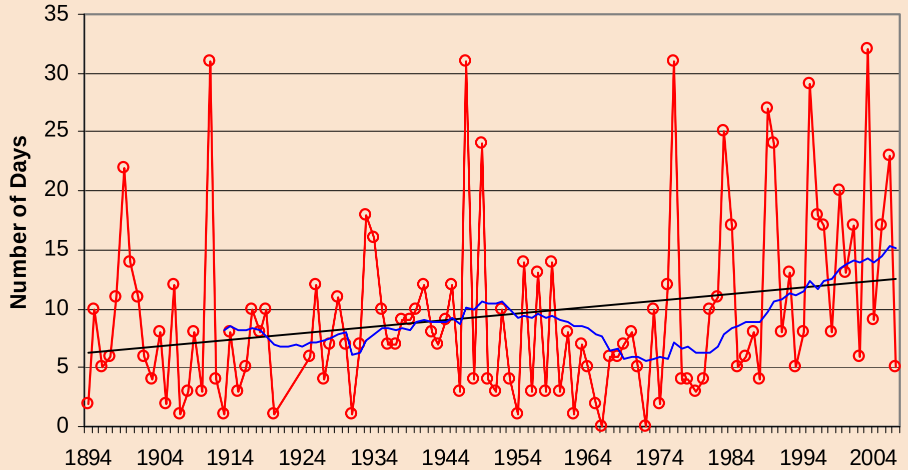
In the upper graph warm nights are plotted showing the percentage of days each year when the minimum temperature exceeded the 90th percentile (14.4°C).

Cool nights are plotted in the lower graph, where the percentage of days each year when the minimum temperature was below the 10th percentile (2.0°C). The running mean for warm nights reveals a relatively constant climate.





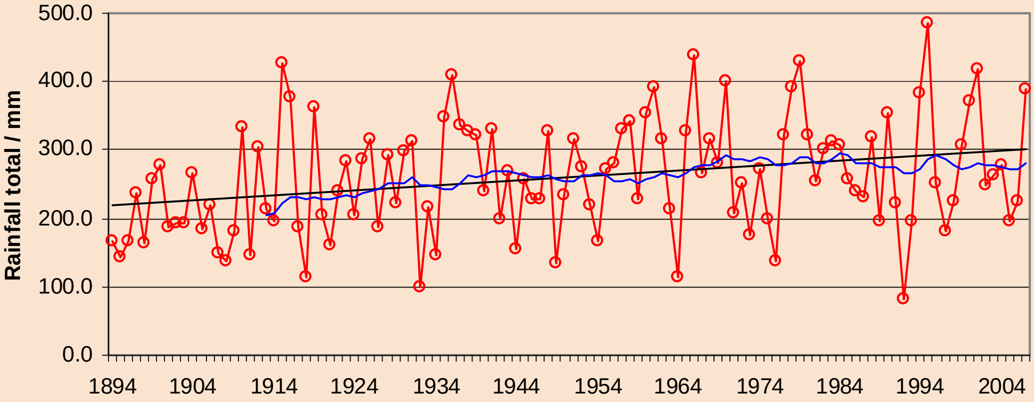
Summer Days



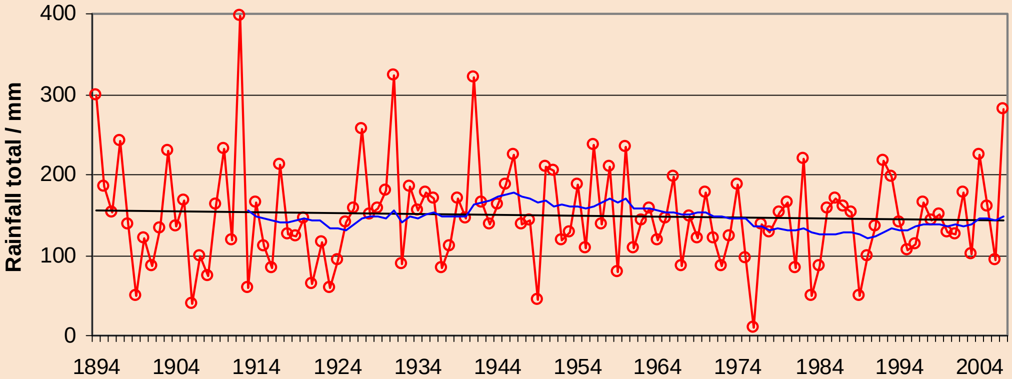
A 'summer day' is defined as having a maximum temperature above 25°C. Again we see a large year to year variation but the linear trend in black highlights a steady increase in the number of summer days in recent times. The running mean reveals a period of fewer summer days in the 1960s and early 1970s, but a noticeable increase has occurred in the last thirty years. This is highlighted by the fact that of 12 years with more than 20 summer days, 8 have occurred since 1975.

Seasonal Precipitation

Winter Rainfall



Summer Rainfall



Local rainfall shows an increase in winter rainfall through the 20th century, while summer rainfall has decreased. The variability of the running mean since 1894 compared with the linear trend is relatively small, without the large variation since the 1970s we noted in the temperature record. Of interest, is that winter precipitation has increased more than summer precipitation has decreased. However, as water is in greatest demand in the summer this does not necessarily mean there is more 'useful' water on the Island although winter rainfall can charge the water table for the summer (see also Article 4.19).

From the analysis above, it seems reasonably clear that the Jersey climate has been changing over the period of the Maison St. Louis record, with an increase in warmth and winter rainfall. Variability is considerable for year to year, but it is the long term change which may have important consequences for the environment, planning and society in general.

The long-term changes are highlighted in the regression lines and running means on the graphs. They show trends in line with the global pattern of climate change, particularly the marked warming trend over the last 30 years. Scientific consensus is that much of this warming is the result of human activity - the main debate has moved on and now concerns what proportion is due to human activity and what should be done about it.

2.7 IS THE LOCAL MARINE CLIMATE CHANGING?

Jersey Meteorological Department

SEA TEMPERATURE

Sea temperature has been recorded at St Helier Harbour since 1933, with a gap during the Occupation. Despite the linear trend line showing a clear warming (Box 1) it is noticeable that the 20 year running mean (blue Line) shows relatively little change in sea temperature until 1989. Indeed, the 1970's and early 1980's appear to be slightly cooler than the 1950's.

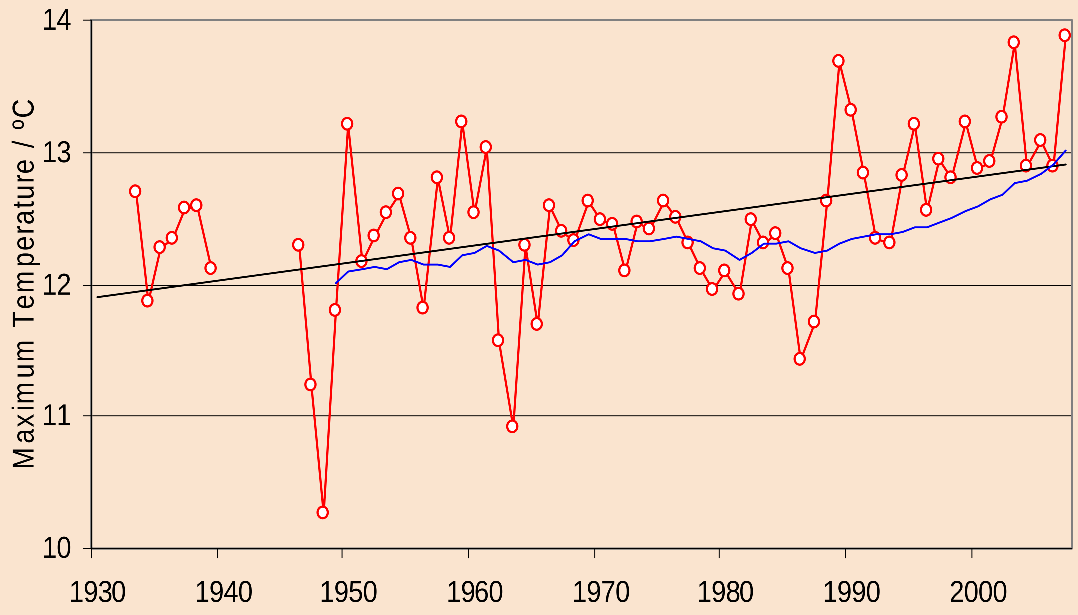
If the last 10 to 15 years are considered alone, there is a clear warming trend with 8 of the 10 warmest years on record occurring since 1989. This is highlighted in Box 2, as well as the clear increase in the running mean plotted below. Taking two respective averages highlights how much the mean sea temperature has increased over the observation period.

Considering the short time series available, it appears reasonable to take a twenty year average, which shows the St Helier mean sea temperature has increased from an average of 12.2°C between 1946 and 1965 to an average of 13°C between 1988 and 2007.

No.	Year	Mean Temp
1	2007	13.9
2	2003	13.8
3	1989	13.7
4	1990	13.3
5	2002	13.3
6	1959	13.2
7	1999	13.2
8	1995	13.2
9	1950	13.2
10	2005	13.1
11	1961	13.0
12	1997	13.0
13	2001	12.9
14	2004	12.9
15	2006	12.9
16	2000	12.9
17	1991	12.8
18	1994	12.8
19	1998	12.8
20	1957	12.8

Box 2

The twenty warmest sea temperatures recorded show a high proportion of results from recent years.



Box 1

There has been a clear increase in the long term sea temperature measured at St Helier. Temperatures appear to have risen sharply since the late 1980s.

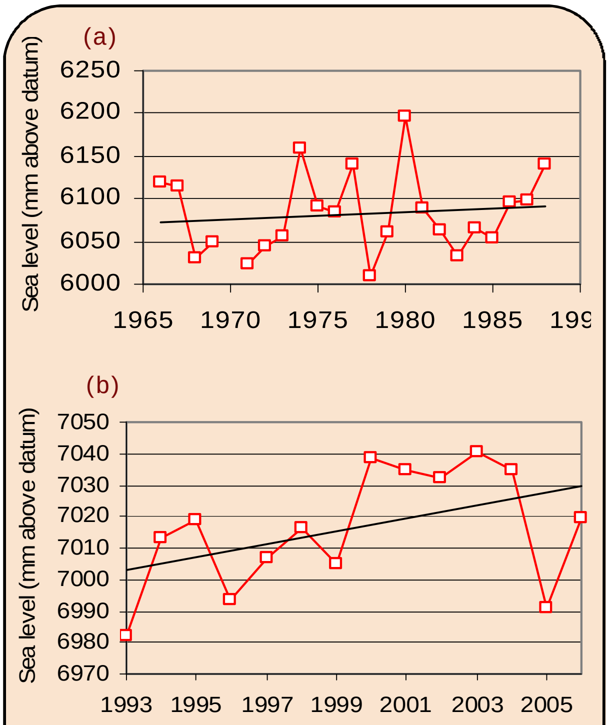
SEA LEVEL INCREASE

Tide heights were recorded at the St Helier Harbour from 1966 to 1988 and although not complete this time series gives a good indication of the change in sea level in that period. After a gap of several years a digital gauge was installed in 1993, with the Proudman Oceanographic Laboratory taking responsibility for the measurements, but using a different point of reference.

Around the world an increase in sea level of about 170mm has been measured since 1870. This increase has not been constant, with a noticeable upward trend in yearly rate of increase since about 1930.

In Jersey the 1966 to 1988 period (Box 3a) shows year to year variation without any obvious rise over the 23 years. A line of best fit illustrates a 0.6mm increase each year, equating to an increase of 14mm in the 23 years. In the 14 years between 1993 and 2007 (Box 3b) a sea level increase of 2.9 mm each year is indicated by the linear trend. Despite the more recent period being 9 years shorter, sea level rose by 4mm, or nearly three times more quickly than the previous period, highlighting the increase in the rate of sea level rise.

The measured increase in sea level cannot be purely attributed to rising water levels as land masses also rise and fall (known as isostatic rebound). However, Jersey is considered to be geologically stable, so most of the observed sea level rise is likely to be caused by thermal expansion of seawater due to warmer temperatures, rather than isostatic rebound.



Box 3

Despite inconsistencies in the record there is a clear upward trend in sea level since records began in the mid-1960s.

Sources: Proudman Oceanographic Laboratory.

Storm Surges

A storm surge is produced when the movement of a storm, barometric pressure and strong winds combine to produce an increase in sea level above the predicted astronomical tide.

In the North Sea surges frequently exceed 1 m but are rarely of this magnitude in the English Channel. Typically two or three surges of 60 cm or more occur each year in the Channel Islands. The largest measured surge in Jersey was 1.67 meters in the October 1987 storm, but it occurred on a neap tide so no flooding resulted. With such a large tidal range, only surges coinciding with a high spring tide are likely to cause flooding in Jersey. By the 2080s the British Irish Council Hadley Report predicts the 1 in 50 year storm surges around the Channel Islands may be 0.5m higher than at present. Such events, particularly when combined with an increase in sea level, could result in flooding and potentially serious damage to property and the environment as witnessed in the severe weather of 10th March 2008 when a surge of 1.15 meters was recorded at the time of high tide.

2.8 ARE GREENHOUSE GASES REALLY TO BLAME?

James Le Ruez

The Royal Society is one of the most respected scientific institutions and elects only the most eminent scientists as members. In April 2007 the Society published a response to eight of the most popular arguments put forward by 'climate sceptics'. Accompanying this guide was the following authoritative statement:

'Our scientific understanding of climate change is sufficiently sound to make us highly confident that greenhouse gas emissions are causing global warming. Science moves forward by challenge and debate and this will continue. However, none of the current criticisms of climate science, nor the alternative explanations of global warming are well enough founded to make not taking any action the wise choice.'

The following sections summarise the response of the Royal Society to the eight main arguments:

ARGUMENT 1

The Earth's climate is always changing and this is nothing to do with humans. Even before the industrial revolution, when humans began pumping CO_2 into the atmosphere on a large scale, the earth experienced warm periods i.e. the medieval warm period.

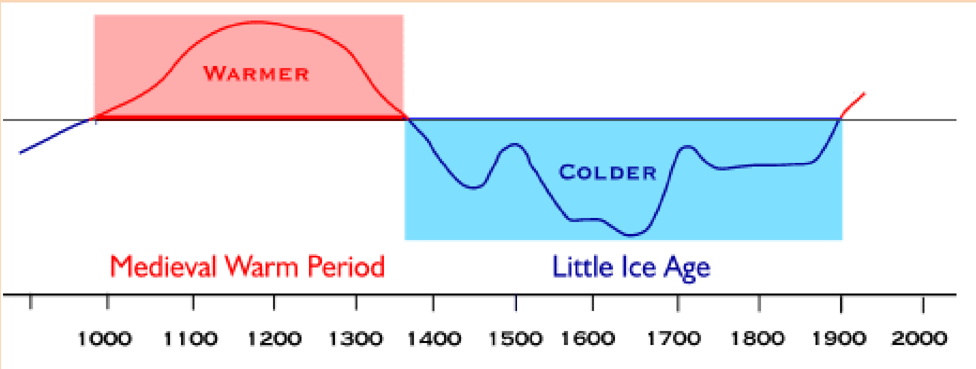
The Earth's climate has experienced warmer and cooler periods in the past. As well as the global effects of ice ages there have also been regional changes such as the 'Medieval Warm Period' and the 'Little Ice Age' (Box 1). However, in contrast to these *regional* climate phases, the increase of three-quarters of a degree centigrade in average *global* temperatures that we have seen over the last century is larger than can be accounted for by natural factors alone. Natural effects do not explain the changes in temperature recently observed.

We know from gases trapped in polar ice that the levels of CO_2 in the atmosphere are now 35% greater than they have been for at least the last 650,000 years. Tests of the gas show that this is mainly due to the burning of fossil fuels. The increase in global temperature is consistent with what science tells us we should expect when the levels of CO_2 and other greenhouse gases in the atmosphere increase in the way that they have.

ARGUMENT 2:

CO_2 only makes up a small part of the atmosphere and so cannot be responsible for global warming.

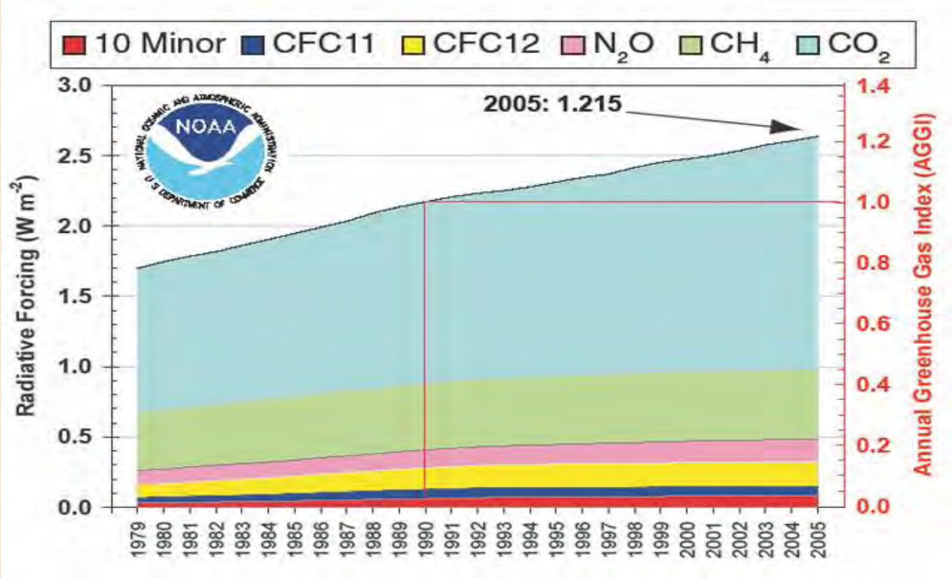
The properties of greenhouse gases such as CO_2 mean that they strongly absorb heat, a fact that can be easily demonstrated in a simple laboratory experiment. The effect of a greenhouse gases is quantified by their 'radiative forcing' as explained in Box 2. While there are larger concentrations of



Box 1

The Medieval Warm period and Little Ice Age existed but both phenomena were regionally limited to within the North Atlantic region. This does not prevent sceptics from suggesting that these were periods of 'global' warming and cooling.

Graphic adapted from: http://www.spirasolaris.ca/liav3l3s2.gif



Graph Credit: National Oceanic and Atmospheric Administration: http://www.noaa.gov/

Box 2

Increased radiative forcing is the change in the rate at which additional energy is made available to the earth-atmosphere system due to increased concentration of a "greenhouse" gas. This graph reveals how the increasing concentrations of greenhouse gases have changed the global radiative forcing since 1979. The largest contribution is clearly made by carbon dioxide (CO_2) followed by methane (CH_4) and nitrous oxide (N_2O).

other gases in the atmosphere, (e.g. nitrogen) they do not have these heat trapping qualities and therefore have no effect on warming the climate.

Water vapour is the most significant greenhouse gas. Although it occurs naturally, global warming will indirectly affect how much is in the atmosphere through, e.g. increased evaporation from oceans and rivers. This will, in turn, cause either cooling or warming depending on what form the water vapour takes such as different types of clouds.

ARGUMENT 3:

Rises in the levels of CO_2 in the atmosphere are the result of increased temperatures, not the other way round.

The fluctuations in temperatures that caused the ice ages were initiated by changes in the Earth's orbit around the Sun which, in turn, drove changes in levels of CO_2 in the atmosphere. Data from ice cores shows that increases in temperature came first and were followed by increases in CO_2 levels up to several hundred years later. The reasons for this are not yet fully understood. They can be partly explained by the fact that oceans emit CO_2 as they warm up and absorb it when they cool down. In addition soil and permafrost release greenhouse gas when they warm up. These increased levels of greenhouse gases in the atmosphere then further enhanced warming, creating a 'positive feedback'.

In contrast to this natural process chemical analysis tells us that the majority of the recent steep increase in the level of CO_2 - some 30 per cent in the last 100 years - has come from the burning of fossil fuels not natural processes.

CO_2 from anthropogenic sources is responsible for most of the temperature increase over the last 50 years. There is much evidence to back up this explanation - but none that conflicts it.

REFERENCES
This article is sourced from a document completed by the Royal Society 'Climate Change Controversies, A Simple Guide'. *http://royalsociety.org/*

2.8 CONTINUED...

ARGUMENT 4:

Observations of temperatures taken by weather balloons and satellites do not support the theory of global warming.

Some have argued that climate change, as a result of human activities, isn't happening because early measurements taken from satellites and weather balloons indicated that little warming was happening in the lower atmosphere.

Errors have since been found in the data. For example, satellites were found to be slowing and slightly dropping in orbit, leading to inconsistencies in their measurements. Variations between the instruments on different satellites and weather balloon also led to discrepancies. Furthermore, a mathematical error was found to have occurred in one of the original analyses of satellite data.

Once adjustments are made to take account of these and other issues, the warming in the troposphere was shown to be broadly consistent with the temperature trends we see on the Earth's surface.

Box 1

There is no doubt the Medieval Warm period and Little Ice Age existed but both were limited to the North Atlantic region. This does not prevent sceptics from suggesting they were periods of 'global' warming and cooling.

ARGUMENT 5:

Computer models which predict the future climate are unreliable and based on a series of assumptions.

Modern climate models have become increasingly accurate in reproducing how the real climate 'works'. They are based on our understanding of basic scientific principles, observations of the climate and our understanding of how it functions, as detailed in Chapter 3.

While climate models are now able to reproduce past and present changes in the global climate rather well, they are not yet sufficiently well-developed to project accurately detailed impacts at regional or local levels. They do give us a reliable guide to the direction of future climate change. The reliability also continues to improve through the use of new techniques and technologies.

ARGUMENT 6:

It's all to do with the Sun - for example there is a strong link between increased temperatures on Earth with the number of sunspots on the Sun.

As we saw in Section 1, solar activity contributes to climate change together with volcanic and anthropogenic emissions to the atmosphere. Change in solar activity cannot on its own account for all the changes in global average temperature that we have seen in the 20th Century.

Changes in the Sun's activity influence the Earth's climate through small but significant variations in its intensity. When it is in a 'more active' phase as indicated by more sunspots on its surface, it emits more light and heat. While there is evidence of a link between solar activity and some of the warming in the early 20th Century, satellite measurements show that there has been very little change in underlying solar activity in the last 30 years. There is even evidence of a detectable decline and so this cannot account for the recent increases we have seen in global temperatures.

ARGUMENT 7:

The climate is affected by cosmic rays.

The potential effect of cosmic rays on the climate is not yet well understood. If there is an effect it is likely to be small. Cosmic rays are fast moving particles which come from space, and release an electric charge in the atmosphere.

Laboratory experiments hint that cosmic rays could influence the development of tiny particles that may in turn play a part in the formation of clouds. This process may enhance the influences of the Sun on the climate. When the Sun is more active its magnetic field is stronger and therefore deflects cosmic rays away from the Earth.

The argument follows that a more active Sun would lead to fewer cosmic rays reaching the Earth, resulting in fewer clouds and therefore a warmer Earth.

However, observations of clouds and cosmic rays show that any link between them at most has a small effect. Even if cosmic rays were shown to have a more substantial impact, the level of solar activity has changed so little over the last few decades that the process could not explain the recent observed increases in temperature.

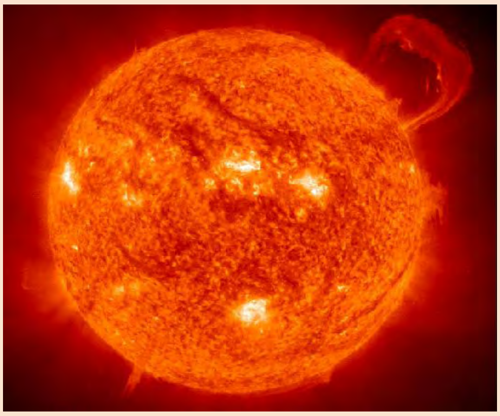


Image Credit: NASA

Box 2

As highlighted in Chapter 1, the Sun is the major force that governs how the climate behaves. In the last 100 years the variation in the Sun's activity is not nearly large great enough to account for the change in observed temperatures.

ARGUMENT 8:

The scale of the negative effects of climate change is often overstated and there is no need for urgent action.

As previously discussed, the IPCC is the world's leading authority on climate change. Under one of its mid-range estimates, it projected a global average temperature increase of 2 to 3ºC this century - a larger climate change than the world has experienced for at least 10,000 years. The impact and pace of this change would make adaptation by people and ecosystems difficult.

In the short term, some parts of the world could initially benefit from climate change. For example, more northerly regions of the world may experience longer growing seasons and yields may increase as higher levels of carbon dioxide have a fertilising effect on plants.

The IPCC has pointed out that as climate change progresses negative effects are likely to dominate almost everywhere. Increasing temperatures are likely to increase the frequency and severity of weather events such as heat waves, storms and flooding.

There are real concerns that in the long term rising levels of greenhouse gases in the atmosphere could set in motion large-scale and potentially abrupt changes in our planet's natural systems. Some of these could be irreversible. Increasing temperatures could lead to the melting of large ice sheets with major consequences for low lying areas worldwide.

Finally, it is predicted that the impacts of climate change will fall disproportionately on developing countries and the poor, those who can least afford to adapt. Thus a changing climate will exacerbate inequalities in health and access to adequate food and clean water.

REFERENCES
This article is sourced from a document completed by the Royal Society 'Climate Change Controversies, A Simple Guide'.
http://royalsociety.org/