7. EVIDENCE OF CLIMATE CHANGE

Andrew Casebow

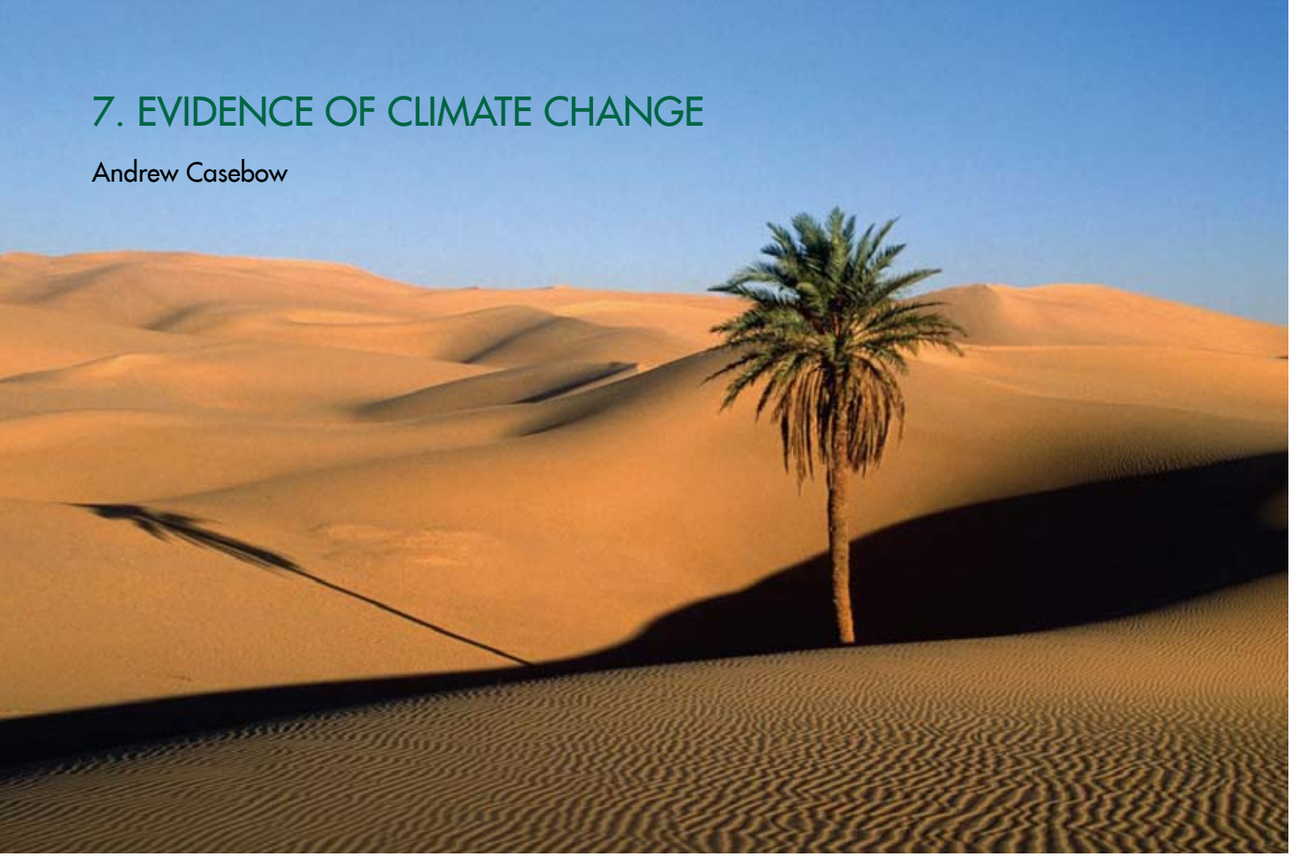

Figure 7.1 *Global warming is likely to cause the expansion of deserts in the future.*

As each year passes there is an increasing amount of evidence to confirm that climate change caused by global warming is really occurring. We may think that the climate is stable and we may even think that it has always been the same as it is now, but that is because we live for such a short period of time, and our memories are so limited and imperfect. We have to look back into written records and other evidence to realise that the climate has never been stable.

But what do we mean by terms such as 'climate change' and 'global warming'?

The weather that we experience is caused by the fluctuating state of the atmosphere around us. The 'climate' is often thought of as 'average' weather, but in fact it is 'the synthesis of weather over a long period, including extremes as well as averages'.[1] The climate that is normally experienced in Guernsey is different to the climate that we would expect if we went on holiday to a hot dry climate, for instance, to a country such as Morocco in North Africa; or to a very wet and humid climate that might be found in a rain forest in Borneo, or the Amazon. Changes in climate have caused famines, mass migration and the collapse of civilisations in the past.

The earth's climate is in a very delicate balance. 'Normal' climate change is caused by many different naturally occurring cycles, mainly concerned with the earth's movement around the sun,[2] that influence the amount of heat energy that is absorbed. These cycles continue over many thousands, and hundreds of thousands of years. The climate change that is occurring now, that we refer to as 'global warming', is caused by a difference in the concentrations of gases and chemicals in the earth's atmosphere. This is called the 'greenhouse' effect.

In Guernsey, the Island's Meteorological Office has been recording information on air temperatures, rainfall patterns, the amount of sunshine that we enjoy, the wind, and the wintertime frosts and snow fall since 1843. Met Officer, Tim Lillington, has analysed this information and will explain how the air temperatures in Guernsey have progressively increased in recent years, resulting in fewer frosts in the winter; and how rainfall patterns have changed making our climate drier in the summer months. These are all changes that we might expect to occur if the earth's climate was warming, and so they are an early indication that the change is caused, not by the earth's natural cycles, but by the effect of global warming.

In recent years the Intergovernmental Panel on Climate Change (IPCC) has been working to improve the understanding of climate change. The Panel has produced four reports – in 1990, 1995, 2001, and in 2007. The latest report confirms the earlier findings and provides very persuasive evidence that climate change caused by global warming is occurring. The key findings are that:

- Warming has now been observed throughout the world - in the atmosphere, on the land and from below the surface of the oceans, so "there is now greater certainty that the planet is undergoing warming".[3]
- Human activity, through the generation and release of greenhouse gases, has been a significant contributory factor in the global temperature rise.
- Research shows that the climate is changing faster and in a more dramatic fashion than has previously been reported.

Most recently, it was reported in September 2007 that the extent of the Arctic sea ice had diminished to such an extent that the 'North-West passage' linking Northern Europe with Asia, had become open and free of ice. It remained navigable for about 5 weeks from 11th August 2007. Scientists at the University of Colorado's 'Snow and Ice Data Centre' suggest that at the current rate of decline the Arctic will be ice-free by the summer of 2030 [4].

References

1. Phillip Eden (2003). The Daily Telegraph Book of the Weather, Continuum, London.

2. The changes of climate, with successive 'glacial' 'interglacial' periods, is caused by cyclical changes in our planet's movement around the sun. See page 14.

3. http:/www.metoffice.gov.uk/research/hadleycentre/ar4/wg1report.html.

4. http://nsidc.org.

Figure 7.2 The Greenhouse Effect

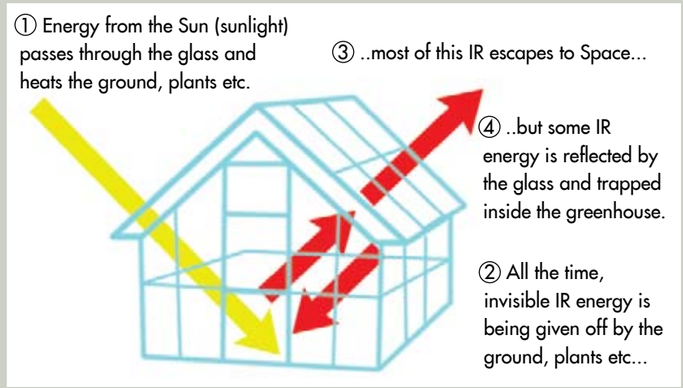

Figure 7.2a *Some of the energy from the Sun is 'trapped' within the greenhouse in the form of heat. IR energy refers to the infra-red part of the energy spectrum.*

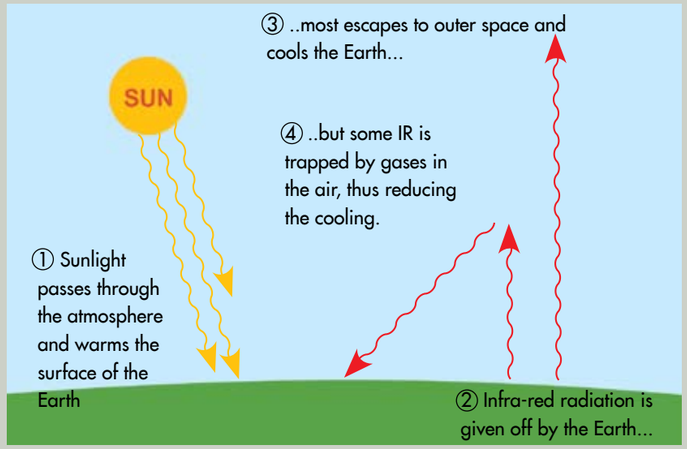

Figure 7.2b *The 'Greenhouse' analogy. Certain gases in the Earth's atmosphere 'trap' energy which increases the temperature. This is namely the 'Greenhouse Effect'.*

Source Hadley Centre Climate Briefing 2005.

8. CAUSES OF THE GREENHOUSE EFFECT

Andrew Casebow

We rely upon the Earth's 'greenhouse effect' to keep us warm. Natural greenhouse gases, such as carbon dioxide, methane and water vapour, act as a blanket to keep in the warmth generated by the sun's rays. Without it our climate would be similar to that of Mars, with temperatures below zero; life as we know it could not survive.

However, man has removed forests and has burnt coal, oil and gas in ever-greater quantities, and this has increased the amount of carbon dioxide in the atmosphere. An expanding human population also produces huge quantities of methane from decomposing rubbish and animal production. The increased concentration of these gases in the atmosphere makes it trap more of the earth's incoming heat and so our planet heats up, and more water vapour is produced (Figure 8.1).

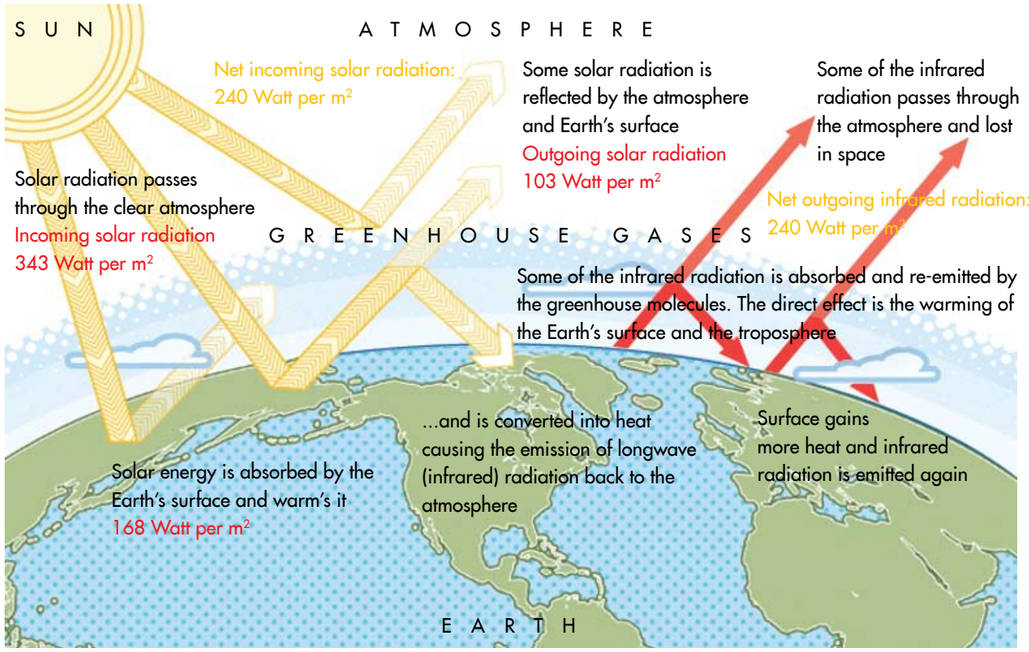

Figure 8.1 *Schematic diagram showing the Earth's energy cycles and the 'Greenhouse Effect'.*

It takes a huge amount of energy to warm the water in the world's oceans, and so they warm up very slowly and will take a long time to cool down again. The result is that the weather system has more energy, derived from the sun's heat and, as a consequence, the weather becomes more extreme. There is more evaporation of water, more clouds, heavier rain and stronger winds.

The concentration of greenhouse gases in the atmosphere has been steadily increasing. During the last ice age the concentration of carbon dioxide (CO_2) in the atmosphere was between 200 and 220 parts per million (ppm), but over the past 20,000 years as man cut down and burnt woodland and forests this gradually increased.

By the beginning of the 19th Century the concentration of CO_2 in the atmosphere was about 280 parts per million, and it was still only about 316ppm by 1960. From Figure 8.2 it can be seen to have been rising steadily since regular monitoring began in 1959. The concentration increases every winter and reduces each summer because of photosynthesis, converting CO_2 into plant growth. Rather poetically, this effect has been described as the earth 'breathing'.

It is known that the concentration of CO_2 in the atmosphere is very closely linked to the earth's temperature. Dangerous climate change is likely to occur if the earth's mean temperature rises by more than 2°C, which relates to a level of CO_2 in the atmosphere of 400 - 450ppm.

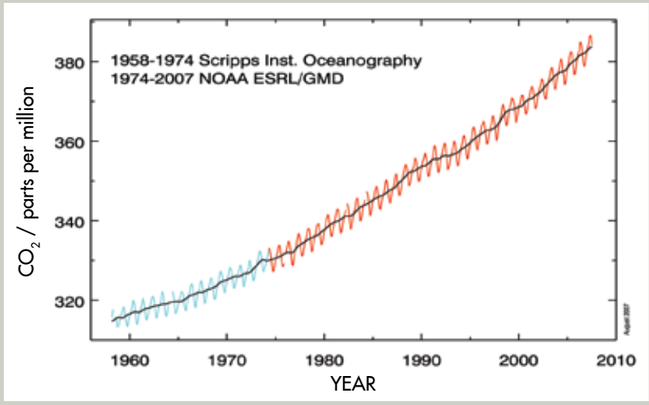

Figure 8.2 *Monthly average carbon dioxide in the atmosphere from 1955 to 2005.*

Source: National Oceanic and Atmospheric Administration (NOAA), Climate Monitoring and Diagnostics Laboratory (CMDL), Carbon Cycle Greenhouse Gases.

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's Hadley Centre. Figure 8.3 shows average annual temperature and model predictions based on natural cycles, including known emissions from volcanoes and the effects of sunspots and other factors, and there is a wide differential between what actually occurred and the model prediction over the past 30 years.

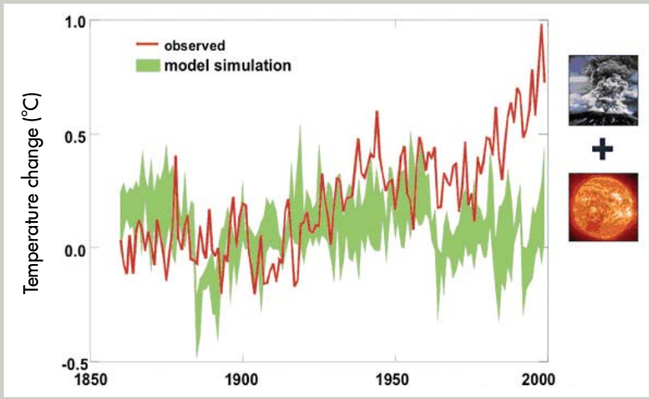

Figure 8.3 *Mean annual temperatures and model predictions based on natural solar and volcanic cycles. The past 30 years show a widening disparity.*

Source: Met Office Hadley Centre.

However, when the known emissions of CO_2 were added into the model, then the model simulation matched the actual temperature almost exactly, suggesting that the temperature increase was caused by the higher concentration of man-made CO_2 in the atmosphere (Figure 8.4).

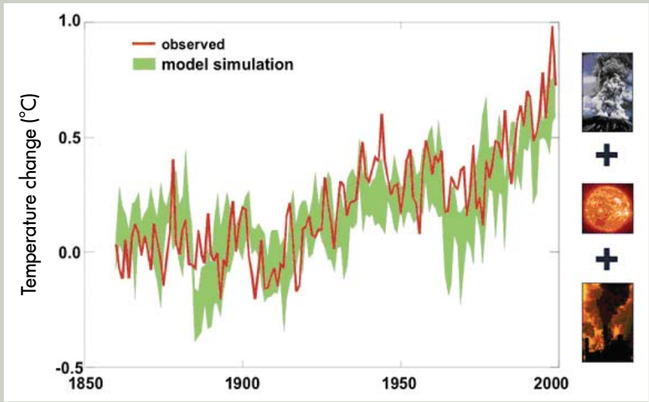

Figure 8.4 *Mean annual temperatures and model predictions based on natural cycles and human activity are similar, this suggests disparity in Figure 8.3 is man-made.*

Source: Met Office Hadley Centre.

9. THE INTERGOVERNMENTAL PANEL ON CLIMATE CHANGE (IPCC)

Andrew Casebow

Figure 9.1 *The IPCC 4th Assessment reports that human activity is almost certainly the cause of 'Global Warming'. CO_2 emissions from oil fired powerstations is just one of many contributors to this effect.*

This year has been 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[1] 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)[2] and the United Nations Environment Programme (UNEP)[3] 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 full reports and summaries are available at http://www.ipcc.ch.

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

Carbon dioxide is the most important greenhouse gas caused by human intervention. "*The global atmospheric concentration of carbon dioxide has increased from a pre-industrial value of about 280ppm*[4] *to 379ppm in 2005. The atmospheric concentration of carbon dioxide 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*[5] *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 are due to 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 carbon dioxide 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.*"[6] However, a number of climate change sceptics 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."

References

1. Intergovernmental Panel on Climate Change: http://www.ipcc.ch/.

2. http://www.wmo.ch/.

3. http://unep.org/.

4. Parts per million.

5. Parts per billion.

6. http://www.royalsoc.ac.uk/.

10. RECORDED CHANGES TO AIR TEMPERATURES IN GUERNSEY

Tim Lillington [1]

Figure 10.1 *Sunbathers at Petit Bôt Bay.* *Image courtesy of VisitGuernsey.*

Annual mean air temperature

Most of us are aware that in the last few years air temperatures in Guernsey have been generally higher than normal. The memorable 2003 summer heat wave led to a maximum air temperature of 34.3°C being recorded at the airport observatory on August 9th, beating the previous record of 32.8°C set in 1990.

2003 also turned out to be the warmest year since records began in 1843, with local record breaking temperatures in March, April, May, July, August and September. Across the English Channel, a milestone was reached when Faversham in Kent recorded 101.3°F (38.5°C) – the first time in recorded history that air temperatures in the UK had topped the 100°F mark.

So how warm has it really been and is the perceived rise in air temperatures purely a blip or part of a longer term trend? To find the answer we need to study the record and analyse the data.

Figure 10.2 clearly illustrates that Guernsey has not escaped the global warming phenomenon. Annual mean air temperature data has been used to calculate a 30-year average on a decadal, i.e. ten yearly, basis. This is a very conservative method of indicating trends that are undistorted by short term fluctuations or occasional extreme events. The earliest and latest averaging periods are, of necessity, not fully thirty years, but are long enough to be included for comparison.

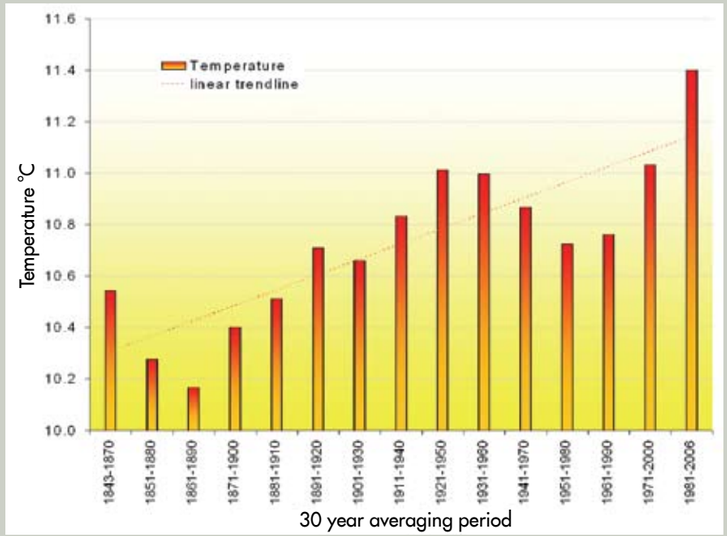

Figure 10.2 *Decadal 30-year running average of mean air temperature.*
Source: Guernsey Met Office

The graph illustrates a real and significant rise in mean air temperature in the order of 1°C over the period 1843 to 2006. The rise is particularly noticeable in the last averaging period (1981-2006).

A more detailed monthly look

So, having established a general trend of rising air temperatures over the period since records began in 1843, we can now look more closely at the monthly figures to identify how these changes have occurred.

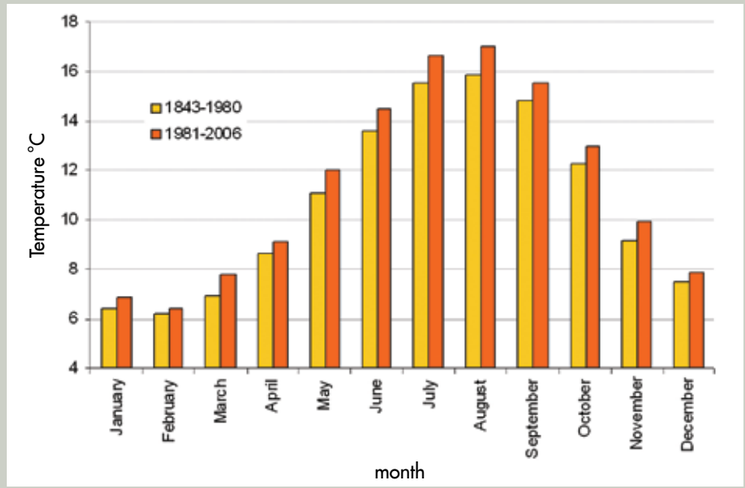

Figure 10.3 *Comparison of the longer-term period average of 1843 - 1980 against the most recent period average of 1981 - 2006.* *Source: Guernsey Met Office.*

The graph indicates that each month of the year is getting warmer. The summer months show the biggest change with both July and August showing an increase of 1.1°C. Interestingly March and November show relatively large increases (0.9°C and 0.8°C respectively) while the smallest increases occur in February (0.2°C) and December (0.4°C).

Summary

1. Air temperature in Guernsey has risen in the order of 1°C since records began in 1843.
2. Every month has become warmer with the summer months showing the biggest change (+1.1°C), but with spring and autumn temperatures also increasing significantly.

References

1. Tim Lillington is the Senior Meteorological Officer at Guernsey airport and has been observing and recording the weather at the observatory for 37 years. He has been involved with a number of UK government research based publications on climate change including the 2003 British-Irish Council report on climate change scenarios for islands within the BIC region.

11. RECORDED CHANGES TO THE FREQUENCY OF FROST EVENTS IN GUERNSEY

Tim Lillington

Figure 11.1 *Snow covered cars at the Guernsey airport, a rare scene nowadays.* *Pictures reproduced courtesy The Guernsey Press Co Ltd..*

One noticeable absentee from our weather in recent years seems to have been frost. "*We need a good cold snap to kill off the bugs*" goes the old adage - and how true it is that the absence of a few good days of freezing temperatures during the winter and early spring seems to bring with it a whole host of problems for much of the flora and fauna of Guernsey.

By restricting our analysis to the post war figures we can get a dependable idea of what is really happening to our lower air temperatures. Figure 11.2 indicates the number of days that air temperatures have fallen below zero (0°C) over the winter period. For this exercise, early year frosts are included in the previous year's figures to provide an overall "winter figure".

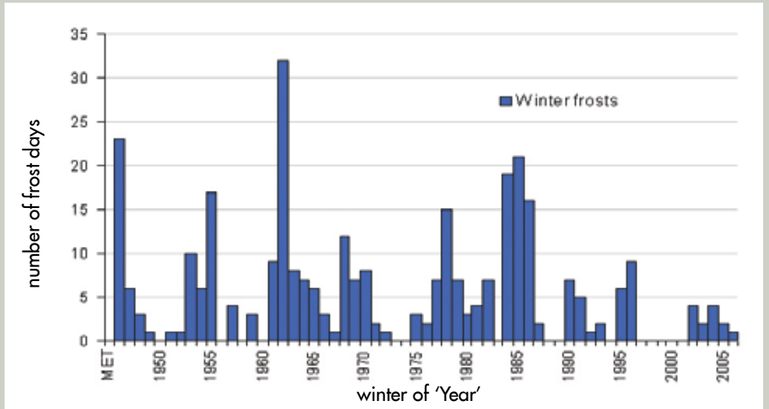

Figure 11.2 *Days of winter air frosts (Air temperature < 0°C).*

Source: Guernsey Met Office.

The figure indicates a significant reduction in air frosts. In total, 15 winters have been frost-free since 1946, five of those in the last decade. A total of 317 days of frost have been recorded throughout this period of 60 winters - an average of 5.3 a year. The last 10 winters have only produced 13 days of air frosts - an average of 1.3 a year - a 75% reduction in real terms.

Severe frosts now seem to be a thing of the past and again we can provide a simple graph that illustrates the validity of that impression. Figure 11.3 shows severe frosts, defined as those days when air temperatures fall below -2.4°C.

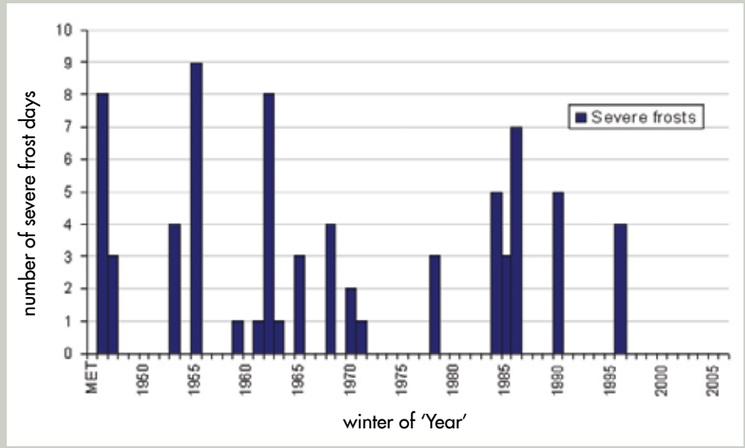

Figure 11.3 *Days of severe winter air frosts (Air temperature < -2.4°C).*

Source: Guernsey Met Office.

The graph clearly identifies a decline in severe air frosts in recent years. None have been recorded in the last decade and out of a total of 72 recorded since the war - an average of 1.2 a year, only 9 have occurred in the last twenty years - an average of 0.4 a year - a 66% reduction in real terms.

Figure 11.4 *Snow fall in early spring.* *Pictures reproduced courtesy The Guernsey Press Co Ltd..*

Summary

1. Air frosts are becoming rarer. There has been a 75% decrease in the incidence of air frosts since the Second World War.
2. Severe air frosts have declined to the point of extinction with none being recorded in the last decade.

12. RECORDED CHANGES IN RAINFALL PATTERNS IN GUERNSEY

Tim Lillington

Figure 12.1 *Flooding in the Talbot Valley.* *Pictures reproduced courtesy The Guernsey Press Co Ltd.*

Annual rainfall

The general perception of rainfall patterns in any location is generally influenced by the most recent events, such as a prolonged wet spell or a period of drought. Of course, some years are noticeably extreme; 1317 millimetres (mm) of rain fell in 1960 in Guernsey compared to only 531mm in 1989. The current 30 year average is 824mm.

In 1917, Adolphus Collenette, a local chemist and meteorologist, published a map of the local distribution of rainfall in Guernsey. This was the result of many years work involving collating the data from rainfall recording sites scattered across the Island. Because of his work, and using the appropriate corrections, we are able to look at and compare the complete record of rainfall data since 1843.

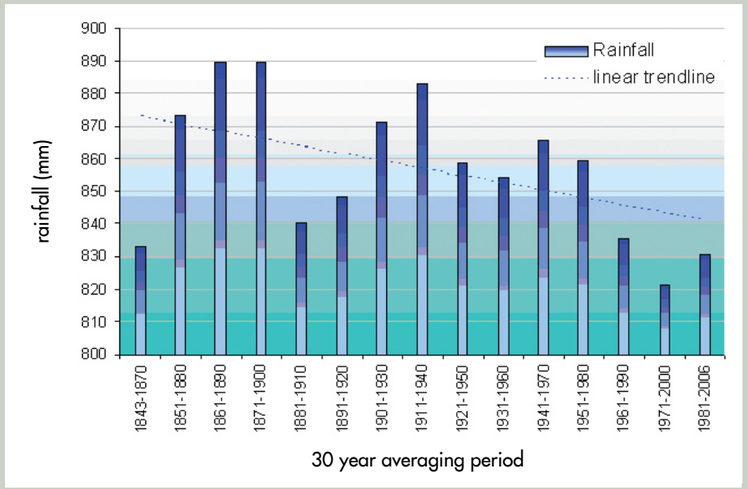

Figure 12.2 *Decadal 30-year running average of annual rainfall.* *Source: Guernsey Met Office.*

Comparison of annual totals over a reasonable period of time is the only way to determine any overall trend so, by using a similar technique to that used for mean air temperature in the previous chapter, Figure 12.2 illustrates the recorded changes to the 30 year average annual rainfall since 1843. The graph indicates a general decrease in annual rainfall of the order of 35mm over the period.

A seasonal look

Sticking to the principle of comparing the decadal 30-year running averages, analysis has shown that a pattern is emerging with seasonal trends. Figure 12.3 compares the winter/spring (DJFMAM) rainfall patterns to those of the summer/autumn (JJASON) period. The graph clearly indicates a long term reduction in summer/autumn rainfall in the order of 16% whereas the winter/spring rainfall has shown a 10% increase. Our findings in Guernsey are already similar to predicted climate change scenarios of drier summers and wetter winters.

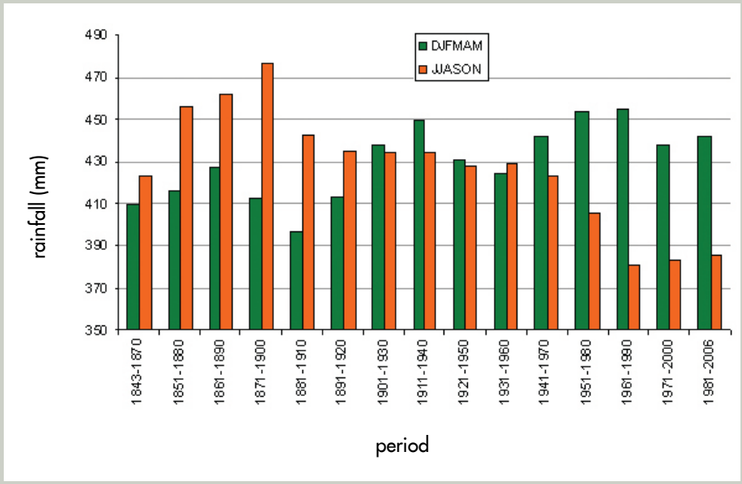

Figure 12.3 *Decadal 30-year running average of seasonal rainfall (winter/spring plotted against summer/autumn). The wet summer of 2007 bucked the trend of drier summers and illustrates the wisdom of using thirty year averaging periods to determine climatic trends.*

Source: Guernsey Met Office.

Figure 12.4 *Winter/spring rainfall is up 10% and wetter winters are predicted.*

Pictures reproduced courtesy The Guernsey Press Co Ltd.

Summary

1. Annual rainfall in Guernsey has fallen by about 4% since records began in 1843.
2. During that period, summer/autumn rainfall has fallen by 16% and winter/spring rainfall has risen by 10%.

13. RECORDED CHANGES IN LOCAL SUNSHINE AND WIND

Tim Lillington

Figure 13.1 *Strong winds transport sand across the dunes at Vazon.* *Pictures reproduced courtesy The Guernsey Press Co Ltd.*

Sunshine and wind are perhaps the poor relation in terms of climate change science and do not get paid much attention. But change there has been and the two elements are worthy of a closer look.

Sunshine records have only been kept since 1894 and Figure 13.2 below again uses the decadal thirty year running average to highlight any long term shifts in sunshine. The results are fairly un-dramatic and indicate that following a slow and steady decline, current levels are clawing their way back to the long term average of 1870 hours.

What is interesting is the 1961 to 1990 low of just over 1800 hours. This may well indicate in which direction sunshine totals were heading before the civilised world starting cleaning up its act with regard to particulate pollution. 1981 was the dullest year on record with 1532 hours and 1959 the sunniest with 2263 hours. It is worthy of note that the sunniest year on record (1959) was followed by the wettest year on record this century (1960).

Having decided that nothing significant is happening as far as local annual sunshine levels are concerned, we can dig a bit deeper and examine the monthly statistics. In Figure 13.3, we have used the last full thirty year averaging period (1971-2000) and compared the monthly figures to the long term (1894-2006) average. The results are fairly surprising.

Spring and early summer months show a sharp drop in sunshine totals whereas the end of the year is slightly sunnier. The drop in March sunshine totals is the most dramatic, having fallen by a full 10% and the four consecutive months of March through to June are 5% down in total. However, this may not be as surprising as it seems. All seasons are becoming warmer, and after a mild, wet winter, the rise in spring warmth leads to increased evaporation adding to the amount of water vapour in the atmosphere. This in turn will often result in greater cloud cover and reduced sunshine amounts. It has already been seen in the previous chapter on air temperatures that March has experienced one of the largest rises in mean air temperature in recent years.

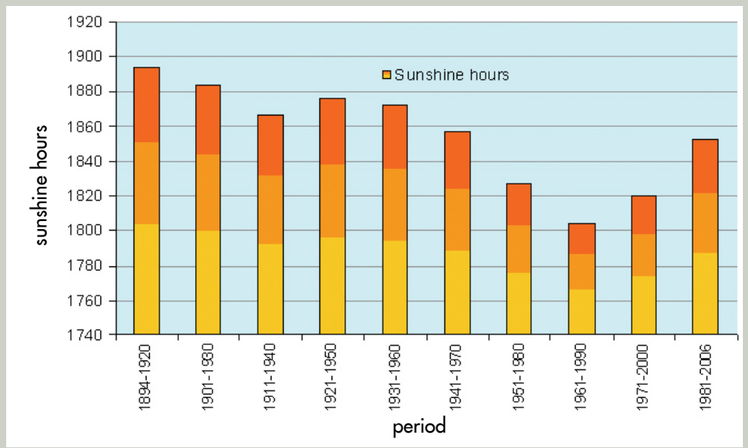

Figure 13.2 *Decadal 30-year running average of sunshine.*
Source: Guernsey Met Office.

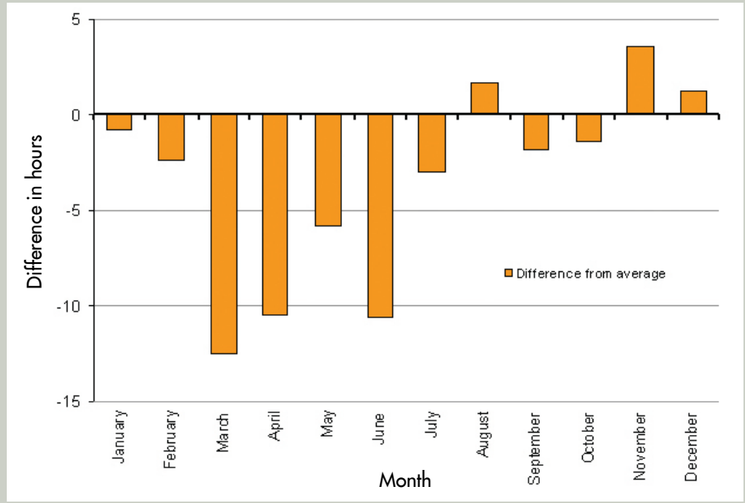

Figure 13.3 *Monthly sunshine totals. Current 30-year average (1971-2000) compared to overall (1894-2006) average.*

Source: Guernsey Met Office.

Unfortunately, wind records are still in the process of being analysed and if we want to study high wind (gale) figures, we can currently only go back to 1975. However, wind patterns complete the picture as far as the main climatic elements are concerned and Figure 13.4 below shows the number of days when a gale was recorded over the last 32 years. (A gale is recorded when the mean wind speed reaches 34 knots or more).

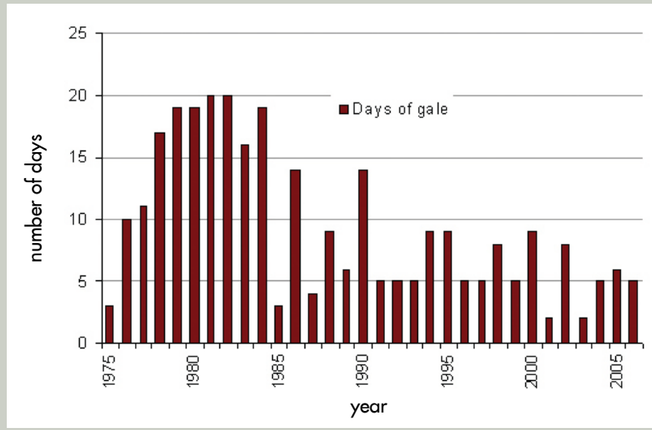

Figure 13.4 *Number of gale days per year 1975 - 2006.*

Source: Guernsey Met Office.

It will come as no surprise that the decade 1975 - 1984 was far windier than of late. The number of local disasters at sea during that spell lingers in the minds of those Islanders old enough to remember.

Summary

1. Generally, sunshine totals have fallen since records began by nearly 5% but recent decades have seen a recovery.
2. Monthly sunshine figures show that March, April, May and June sunshine is down by about 5% in total with March showing the largest fall of 10%.
3. The limited data on gales indicate that they are becoming less frequent.