



TURNING POINT

The ECO-ACTIVE guide to the Science and Impacts of Climate Change in Jersey

Planning and
Environment
Department



States 
of Jersey

SUMMARY

Accelerated climate change as a result of human activity is an urgent issue. We have reached a turning point that requires an immediate response which policy makers and planners must consider without delay for the sake of future generations. The most recent evidence announced by leading global climate scientists at the Copenhagen climate change summit in March 2009 led to the conclusion that the situation is 'even worse than feared' and it is becoming increasingly difficult to avoid catastrophic climate change.

'Turning Point' examines the science and impacts of climate change on Jersey. The first part of this publication examines natural and human influences which change the Earth's climate. It shows that climate change, in the form of a global warming trend, is now firmly established as fact by all leading scientists, by the independent International Panel on Climate Change (IPCC) and is endorsed by the Royal Society. Furthermore, a large part of the warming can be confidently attributed to human influences, while sophisticated computer model forecasts all indicate the warming will continue for centuries, with debate confined to the degree of warming.

The second part examines the impact of the warming in Jersey, looking at the likely impact on the island's industries, its flora and its fauna, but just as important at the attendant rise in sea level which threatens our low lying coastal areas. 'Global warming' is happening now and this publication examines what it is likely to mean for Jersey.

ACKNOWLEDGEMENTS

In the autumn of 2007 '*Planet Guernsey - Towards a Sustainable Future*' was published under the editorship of Dr. Andrew Casebow. This was an accomplished document giving in-depth information on the critical issue of climate change from a wide range of expert contributing authors yet it was highly readable and was warmly welcomed by members of the public.

The success of '*Planet Guernsey*' made it clear there was a demand for well researched locally relevant scientific information and it inspired this publication which explores the science of climate change and its impacts on Jersey. It is with our utmost appreciation that we acknowledge the assistance and co-operation of Andrew Casebow and his co-authors, in producing this 'sister-volume'.

We have also turned to a number of local experts to interpret many of the subject areas specifically for Jersey. Biographies of all of the contributing authors are provided at the end of this publication and represent a wide breadth of local and national experience in this field.



FOREWORD



The spectacular development and economic growth of the Western World in the 19th and 20th Centuries was matched by a parallel growth in the use of energy. One has driven the other. Consider for instance heating, lighting, travel and transport, food production, manufacture of goods and materials, and electrical devices from carpet cleaners to computers. Without access to large quantities of energy our society across the developed world would grind to a halt.

Unfortunately this technological miracle has significant consequences. We are only just beginning to understand and appreciate the major impacts they will have on our world and the future world of our descendants. Our thirst for energy has been quenched by the burning of vast quantities of fossil fuels - including oil, gas and coal - all of which produce carbon dioxide (CO₂) along with other pollutants during combustion. Evidence compiled by the Intergovernmental Panel on Climate Change (IPCC) is overwhelming. The IPCC attribute the observed changes in the Earth's climate predominantly to the over production of carbon dioxide.

The IPCC is an independent scientific body and is a key player in the understanding and appraisal of the evidence of human-induced climate change. Their role is to assess the 'latest scientific, technical and socio-economic literature produced worldwide relevant to the understanding of the risk of human-induced climate change, its observed and projected impacts and options for adaptation and mitigation' .

In Oslo on the 10th of December 2007 the IPCC and Albert Arnold (Al) Gore Jr. were awarded the Nobel Peace Prize:

"for their efforts to build up and disseminate greater knowledge about man-made climate change, and to lay the foundations for the measures that are needed to counteract such change".

This publication aims to present the scientifically endorsed facts on the way the world's climate is changing and to interpret what that means for Jersey. Only by fully understanding the problem and its effects can we commit to action to minimise (mitigate and counteract) the effects of climate change.

Tackling climate change is the most important challenge facing humankind in the 21st Century and can not be ignored. This appraisal clearly highlights the urgency with which we need to act.

Senator Freddie Cohen
Minister for Planning and Environment
April 2009

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A satellite image of Earth showing two large, swirling cyclones over the ocean. The cyclones are characterized by dense, white cloud bands spiraling inward to a central eye. The surrounding ocean is visible in shades of blue and green. The text "CHAPTER 1 A CHANGING WORLD..." is overlaid in white, sans-serif font in the upper left quadrant.

CHAPTER 1 A CHANGING WORLD....

Image Credit: NASA, Image of the Day Gallery
<http://www.nasa.gov/multimedia/imagegallery/iotd.html>

CHAPTER 1 - A CHANGING WORLD

The climate is forever changing, with a multitude of factors that influence its behaviour over time. Historical records show there have been numerous global, as well as local, shifts in the climate. This chapter identifies why these changes have occurred. To understand how climate may change in the future, it is first important to determine how and why it changed in the past.

CHAPTER 1 — A CHANGING WORLD

Natural Climate Change

- 1.1 How Does the Atmosphere Work?
- 1.2 How the Earth's Natural Cycles Affect Climate
- 1.3 What Else Influences the Climate?

Evidence of Natural Climate Variability

- 1.4 Long Term Climate Change
- 1.5 The Present Interglacial Period
- 1.6 How has Jersey's Climate Changed over the Last 500,000 years?
- 1.7 Jersey's Changing Landscape Over the Last 20,000 years

The media has for some time now been awash with climate change 'buzzwords' such as greenhouse gases, carbon footprint and global warming.

However, before addressing the influence that humans have had on the atmosphere, it is important to understand the basics of how the climate has been operating for hundreds of thousands of years without the increased levels of greenhouse gases that we now observe.

This chapter addresses the issue of natural climate variation.

It considers the different factors that 'force' the climate. These include the position of the sun, the absorption of the sun's energy and interactions that go on within the atmosphere itself.

It goes on to examine the contributory factors that have resulted in long term variations in the global climate and how they have related to changes in the landscape and coastline of Jersey.

1.1 HOW DOES THE ATMOSPHERE WORK?

James Le Ruez

To fully understand climate change, it is essential to appreciate how our climate has changed in the past. Why are there ice caps at the poles? Why is it stormy in Jersey in winter and why is it fine in summer? The answers lie with the Earth's energy and radiation balance - how the Sun's energy is absorbed and redistributed around the world.

As the Earth is spherical the Sun's energy is not received equally at all points on the surface. The nature of the atmosphere and the angle of the Sun's rays means sunlight received at the equator is much more intense than at the poles. It is this higher intensity of sunlight at the equator that results in the equatorial region being warm compared to the poles.

However, it is not *always* hotter in the south compared to the north. This is because the energy from the Sun is absorbed and redistributed around the globe. To maintain a balanced temperature across the globe heat is transferred north and south by winds and currents.

THE ATMOSPHERE

The atmosphere is constantly transporting heat. This is easily observed on the island - in the winter a northerly wind will feel cold whereas a southerly wind will be milder. The wind is bringing the air masses from the north and south respectively and as it does the heat contained within the air is redistributed. But how do winds work on a global scale?

Hot air rises and cold air sinks. Therefore, due to the different intensities of sunlight, warm air will rise at the equator and sink at the poles (Box 1a). However, this 'single cell system' is a simplified version of reality - the warm air that rises at the equator does not travel all the way to the poles before sinking. A three cell system has been suggested by scientists (Box 1b) which takes into account the spin of the Earth which causes winds at the surface to be deflected to flow diagonally. Winds (and currents) are shifted to the right in the northern hemisphere and left in the southern hemisphere.

Box 1

(a) In this simplified case the globe is made entirely of land and does not rotate. The air within the equatorial region heats up, becomes less dense and rises. In contrast, cold air at the poles is dense (and heavy) so stays near the surface and spreads as it has nowhere else to go. This creates a 'cell' where the heating and cooling of the air masses creates a wind at the surface transporting cold air from the poles toward the equator.

(b) In reality the warm air that rises at the equator does not have enough energy to be transported all the way to the poles. Therefore, three 'cells' are set up in each hemisphere with air rising at the equator and 60°N and descending at the poles and the tropic of cancer. The rotation of the Earth and the distribution of land and sea shifts these north/south winds to their diagonal directions.

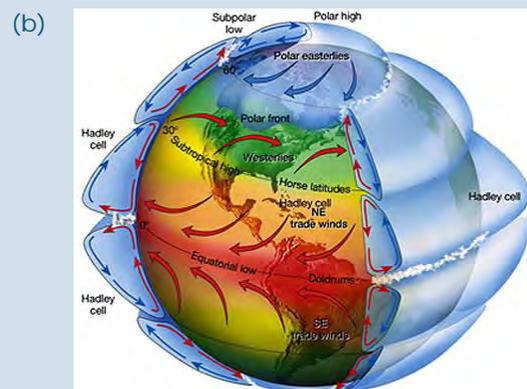
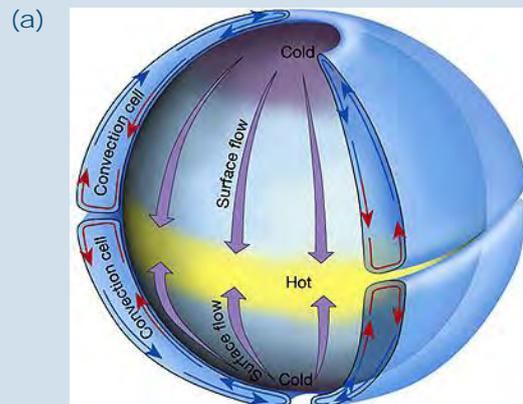


Image Credit: http://www.fas.org/irp/imint/docs/rst/Sect14/ect14_1c.html



Image Credit: James Le Ruez

Box 2

We can see the influence of the global circulation locally. This tree overhanging the 5 Mile Road in St Ouen has grown leaning north-east as a result of the prevailing south-westerly winds. Jersey is located around 49°N and Box 1b highlights how these 'westerlies' are an expected part of the global circulation at the Island's latitude.

The sun's influence gives the atmosphere its overall structure but many other factors must be considered. Land and oceans absorb heat differently. Land warms and cools very quickly, therefore large landmasses are very hot in summer and very cold in winter. In contrast, oceans take a long time to heat up and cool down and therefore do not show such large temperature variations. This means that the theoretical three cell circulation pattern is disturbed and differs seasonally.

For instance, the heat of Russia in the summer causes air to rise over the continent (low pressure) but in the winter it causes air to cool and sink (high pressure). However, the three cell circulation is still the major influence on local climate in most locations (see Box 2).

THE DEEP OCEANS

As water is significantly more dense, it can 'store' far more heat than air. This means, when water moves around the Earth, it transports a lot more heat than the air. The oceans are therefore the most important mechanism in maintaining a globally balanced climate.

Water, like air, becomes more dense when cold; it therefore sinks at the poles. This cold water at the bottom of the ocean doesn't get heated by the Sun - but it does mix with the warmer water above. It is forced to move around the ocean due to differences in the density of the surrounding water. This process drives the global deep water ocean circulation (Box 3).

Ocean currents are also influenced by the water's salinity as this effects water density. For example, in the Mediterranean the hot climate evaporates large amounts of water from the ocean. This leaves warm water with high concentrations of salt which is therefore relatively dense. This water sinks and is pushed into the Atlantic Ocean despite its relative warmth.

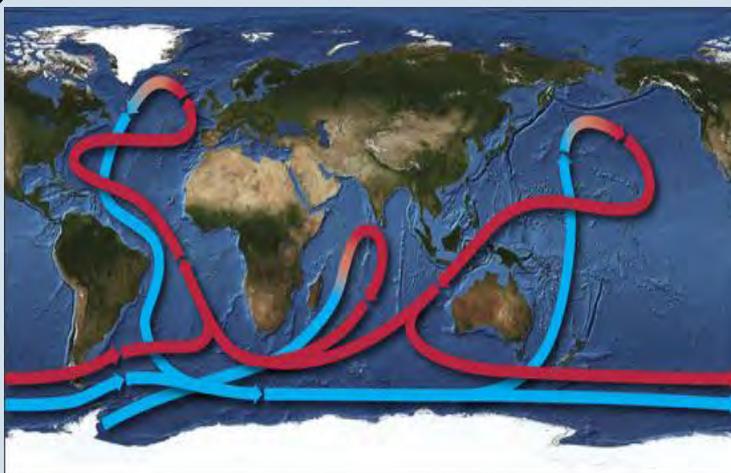


Image Credit: Woods Hole Oceanographic Institution, <http://www.whoi.edu/oceanus/viewImage.do?id=47168&aid=20727>

Box 3

Global ocean circulation is key in transporting heat to different regions of the Earth. The top few metres of the ocean transport as much heat as the entire atmosphere. As the oceans are on average 3.7 kilometres deep, they are responsible for the majority of heat transportation around the globe. At the surface, ocean currents are driven primarily by wind and do not move in a similar pattern to deep ocean currents.

1.2 HOW THE EARTH'S NATURAL CYCLES AFFECT CLIMATE

Andrew Casebow and Chris Regan

The cycle of ice ages and shorter interglacial periods (and the changes of climate within the ice ages), and even seasonal changes, are caused by cyclical changes in our planet's movement around the sun. They are called Milankovitch Cycles after the astronomer who first calculated them, and there are three main cycles: -

1. Eccentricity—The Earth's Orbit around the Sun

The Earth's orbit around the sun is not a circle (Box 1), but an ellipse. The effect of this is to change the distance that the Sun's short wave radiation must travel to the Earth in the different seasons.

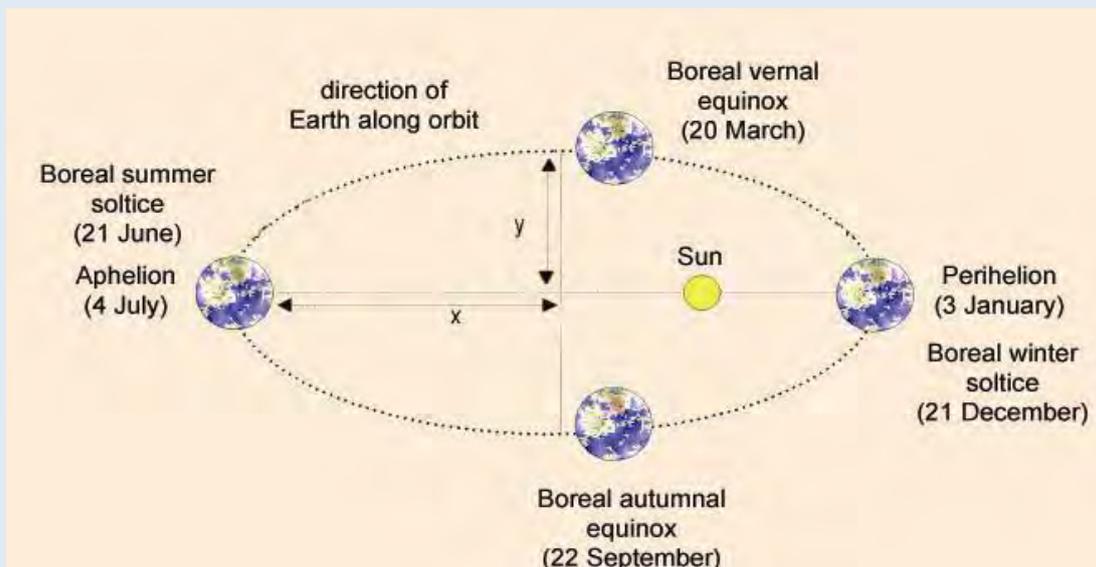
At the present time the orbit is at its least elliptical, which means that a difference of only 3% occurs between the extremes, but this still means that the earth receives 6% more solar energy in January than it does in July each year. When the Earth's orbit is most elliptical (on a cycle of about 100,000 years), then the seasonal difference in solar energy would be 20-30%. This changing amount of received solar energy results in substantial changes in the Earth's climate, and in the change from glacial periods (ice ages) to interglacial periods.

The current stage of the cycle may mean that the world is nearing the end of its current 'interglacial period' and without global warming mean temperatures might have started to fall. However, temperature change would be very small compared to the large increases of temperature that are likely to be caused by global warming.

2. Axial Tilt—The angle of the earth's orbit to the sun

The Earth's tilt (Box 2) at the Equator varies from between 21.6° and 24.5° degrees in a periodic manner of about 41,000 years. The tilt today is about 23.5°. These changes in the earth's tilt affect the severity of the earth's seasonal changes and these seasonal changes are much more apparent towards the North or South Pole, away from the Equator.

One suggestion is that the lower axial tilt might promote the growth of ice sheets. The reason for this is that warmer winters could support greater atmospheric moisture and then heavier snowfall. Summer temperatures would be cooler, leading to less melting of the winter snowfall, and greater annual accumulation.



Box 1

The eccentricity, e , of the Earth's orbit around the Sun is given by the equation $e^2 = 1 - \frac{y^2}{x^2}$. The term 'aphelion' means furthest point and 'perihelion' the nearest point from the Sun.

Image Credit: Planet Guernsey, 2007

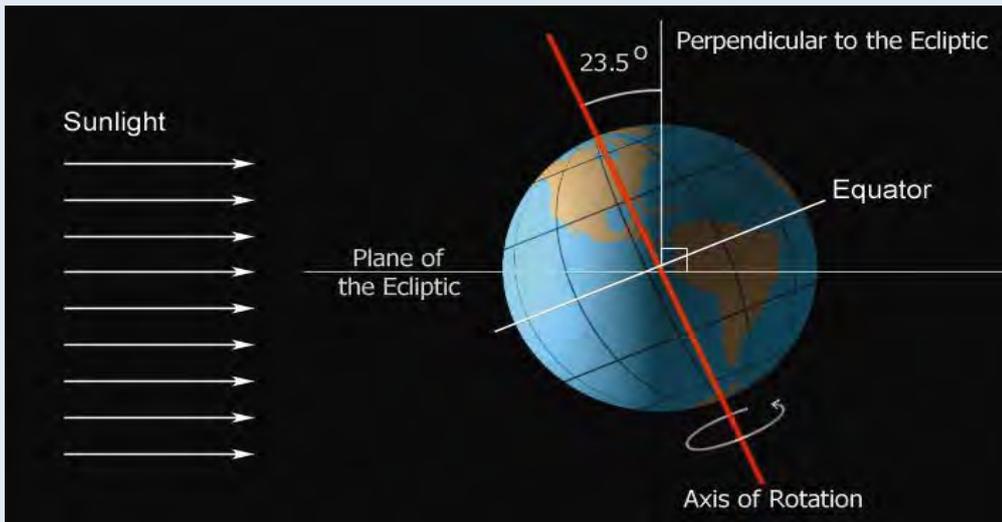


Image Credit: Planet Guernsey and Chris Regan, 2007

Box 2

The axial tilt of the earth's orbit to the sun varies. Currently it is at an angle of 23.5°.

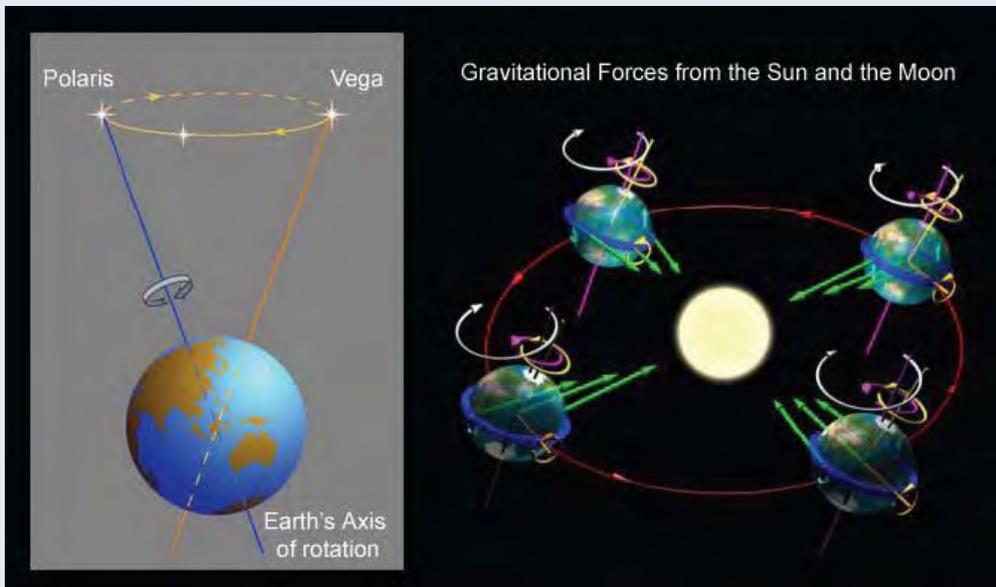


Image Credit: Planet Guernsey and Chris Regan, 2007

Box 3

The Earth's precession, or slow wobble as it spins, is caused by the differential gravitational forces of the Sun and Moon on the Earth. Currently it is very close to the winter solstice which means our winters are generally longer and summers shorter.

3. Precession

'Precession' (Box 3) is the Earth's slow wobble as it spins on its axis, which causes a change in the timing of the annual equinoxes. The axis of the Earth wobbles from pointing towards Polaris (the North Star) to pointing towards the star Vega. Each cycle of this 'wobble' takes 23,000 years.

When the Earth's axis is pointed towards Vega the Northern Hemisphere will experience longer winters because this hemisphere is furthest from the Sun. This results in greater seasonal contrasts. At present the Earth is nearest to the sun very close to the winter solstice.

Conclusion

These variables are important because most of the world's landmasses are in the Northern

Hemisphere. When the Northern Hemisphere summers are coolest because they are furthest from the Sun (due to greatest orbital eccentricity and precession) and the winters are warmest (due to minimum tilt), snow can accumulate and cover large areas of northern America and Europe. At present only precession is in the glacial mode, whilst tilt and eccentricity are not favourable to the formation of glaciers.

Even when all the cycles favour the formation of glaciers, the increase in winter snowfall and decrease in summer melt is barely sufficient to trigger glaciation, and not sufficient to develop large ice sheets. The growth of ice sheets requires the support of a positive feedback loop. One such 'loop' might be the fact that ice masses reflect more of the sun's radiation back into space, thus cooling the climate and allowing glaciers to expand.

1.3 WHAT ELSE INFLUENCES THE CLIMATE?

James Le Ruez

The Sun is the key driver of the Earth's climate and the amount of energy received is dependant on astronomical factors. The distribution of this energy around the globe creates circulation patterns in each hemisphere with the influence of land and sea causing regional circulation cells.

These regional patterns of high and low pressure essentially determine the day to day weather experienced on the ground. For example, British winters are generally either wet and windy or cold and dry, see Box 1.

MICRO-CLIMATE

Numerous additional interactions can cause changes on a local scale. Some of these are permanent and therefore generate a local climate trend. For instance:

HILLS AND MOUNTAINS – Mountains or hills can force air parcels upwards. Water vapour cools and condenses creating local cloud or rain 'shadows'.

LOCAL WINDS – In the summer land heats up more than the ocean. This causes air to rise over the land and sucks in air off the sea causing an onshore breeze. Such sea breezes are noticeable in late afternoon on long coastal strips in warm climates.

URBAN EFFECT – In urban areas the dense materials making up the infrastructure (e.g. buildings and roads) absorb heat during the

day and slowly release it at night. As a consequence urban areas can be warmer (by as much as 1°C) than the countryside.

There are so many different factors that influence the climate and the daily weather that it is impossible to forecast the weather or climate with 100% accuracy. The difficulty of accurately forecasting climate is discussed further in Chapter 3.

FEEDBACK EFFECTS

In addition to micro-climate influences, climate studies must also consider feedback processes. In some systems, a certain influence will create a cyclical effect and return an impact back into the system.

Climate feedbacks can work to enhance an initial input (a positive feedback) or reduce it (a negative feedback). Box 2 details three important feedback mechanisms and explains why they may be important in a changing climate.

VOLCANOES

Volcanic eruptions have long been recognised as contributors to short term climate. In the immediate aftermath of a volcanic eruption particles in the atmosphere act like clouds. Particles low in the atmosphere have a life of only 1-3 weeks. However, if the eruption is strong enough to send matter into the stratosphere

Box 1

THE BRITISH WINTER

In case (a) storms are crossing the Atlantic from the south west, creating wet weather. Temperatures are relatively mild as the air has absorbed heat from the warm ocean.

In case (b) the regional patterns work against the global circulation. The less intense low pressure and stronger high pressure diverts storms away from the UK towards the Mediterranean or Greenland. The UK experiences dry, cold weather as the air masses arrive from the cold Eurasian land mass.

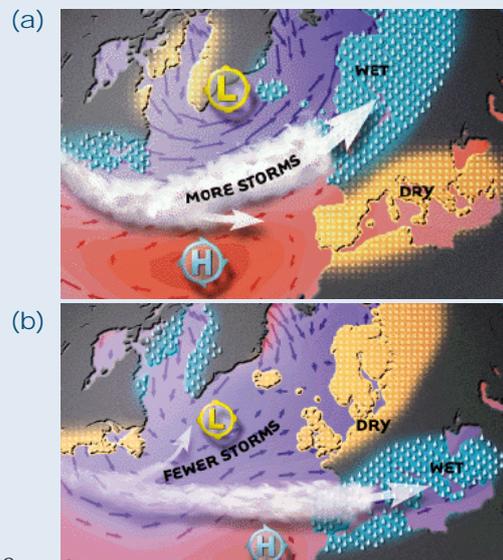


Image Credit: Martin Visbeck, <http://www.kleo.columbia.edu/NAO>

(approximately 10km high) the aerosols last for 1-3 years. In both cases the aerosols affect the reflection of the Sun's rays, reducing the amount of heat penetrating the atmosphere and actually absorbing heat themselves. The culmination of these effects results in the warming of the middle of the atmosphere and cooling at the surface.

Mt. Pinatubo erupted in the Philippines on June 15, 1991, and one month later Mt. Hudson in southern Chile also erupted. Their combined aerosol plume diffused around the globe in months. The data collected after these eruptions show that mean world temperatures decreased by about 1°C over the subsequent two years.

Volcanic emissions include CO₂ but as we shall discuss later, account for less than 1% of the emissions due to human activities. Therefore they play only a minor role in atmospheric CO₂ increases compared to other sources.

EL NIÑO

El Niño is a short term climate influence that can raise temperatures globally through releasing large amounts of heat from the ocean to the atmosphere. A weakening of the trade winds and surface current allows the warm pool of water to spread across the Pacific towards South America. El Niño occurs as an event lasting several months, with no fixed cycle and intervals ranging from 2-7 years.

'La Nina' conditions occur when trade winds converge at the equator causing a surface ocean current that pushes sun-warmed water into the Indo-Australasian region. Off the coast of Peru nutrient rich water 'upwells' from the deep to replace that moving westward.

Despite the changes in ocean temperature and atmospheric circulation being concentrated in the South Pacific, El Niño has a warming influence on global temperatures. For example, it causes torrential rain and flooding in the Andean states and drought and water shortages in Indonesia. There is also a clear statistical relationship between El Niños and hurricanes / typhoons. The strengthening of

Box 2

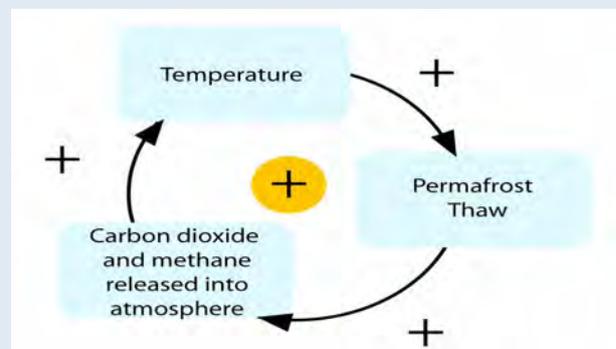
FEEDBACK EFFECTS

Albedo is a measure of how reflective a surface is. A high albedo surface (e.g. ice and cloud) reflects a lot of light.



Small increases in ice at the poles results in more sunlight being reflected, less surface absorption and in turn more ice.

Cloud formation can stimulate a 'negative feedback' process. In hot regions air rises and forms clouds which cause shade and cool surfaces down.



Permafrost are areas of permanently frozen ground. With increases in temperature some such areas are thawing. This results in methane and other greenhouse gases trapped within this frozen land becoming released to the atmosphere.

'jet streams' in the upper atmosphere by El Niño has been proposed as a likely cause of the wet weather and flooding in the UK in the winter of 2007/08.

El Niño is important within the climate change debate as it has a warming influence on global temperatures. This means the warmest years on record tend to be linked to El Niños. For example, the anomalously high temperatures observed in 1998 (14.54°C, 0.52°C above the 1961-1990 global average) have been attributed to global warming combined with an extreme 18 month El Niño.

The El Niño phenomenon is very complex and it is unclear how it will be affected and thus go on to affect climate change. However, it does appear that the El Niño pattern is changing.

1.4 LONG TERM CLIMATE CHANGE

Professor Nicholas McCave

We are living in an Ice Age. We don't know whether we are in the middle or near the end, but it has been going on for around 30 million years so far.

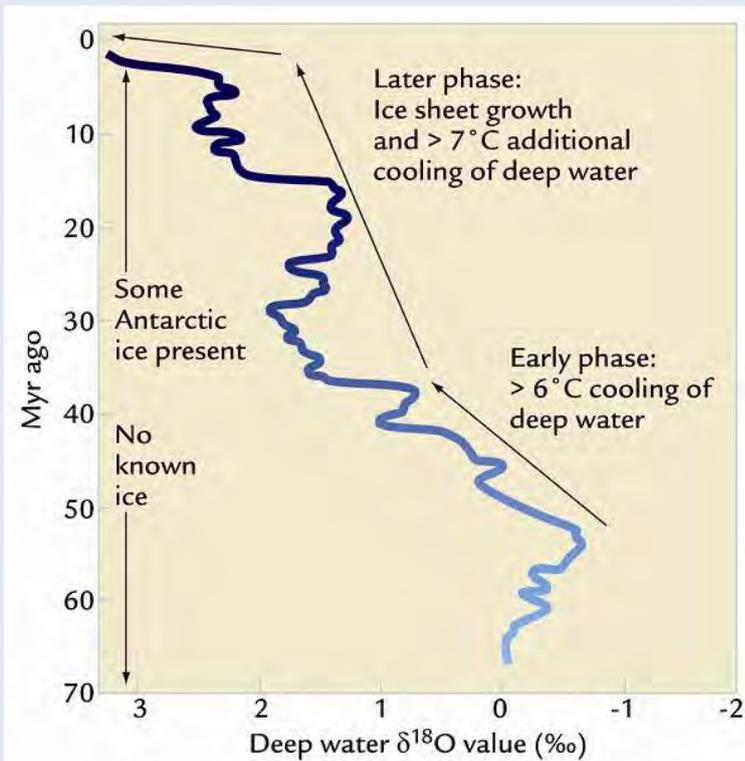
The last major ice age lasted 50 million years; from around 330 to 280 million years (Myr) ago during what geologists know as the Carboniferous and Permian Periods. More recently, between 100 and 50 million years ago we can find little evidence of any ice at all, because the world was much warmer then. The evidence for these deductions lies in the distribution of fossils. For instance, trees grew in the far north (at a palaeolatitude of 80° N) in warm periods, and sediments such as ice-rafted gravel in deep-sea mud can be found much closer to the equator (at 35° N) during cold times.

The Earth's climate has been anything but stable in the long term. Box 1 shows results from the most powerful climate indicator that we have, the ratio of oxygen isotopes in marine shells, called foraminifera. This indicator combines the effect of ice volume and temperature over the last 70 million years. The development of cooler climates

over the past 50 million years is clear, and particularly the cold of the last 3 million years.

In the last million years, perhaps the peak of the present ice age, climate has also been most unstable with around 10 major glacial periods of 100 thousand years duration. These glacial periods that we normally think of as 'ice ages', each lasted some 80-90 thousand years of cold conditions and 10-20 thousand years of warmer conditions. In the last million years there have been very few times when the global temperature has been as warm as it is now, and in the last 11,000 years during which human civilisation has developed. These three most pronounced warm periods, known as 'interglacials', occurred at around 420, 330 and 125 thousand years ago.

Box 2 contains a graph showing the ratio of oxygen isotopes for the last 500 thousand years, and from them you can see the sequence of warm and cold periods following each other, with warm peaks at about every 100 thousand years. In the diagram, warm periods have odd numbers and one can see that only numbers 5, 9 and 11, which represent interglacial periods that occurred



Box 1

Ratio of oxygen isotopes ($\delta^{18}\text{O}$) in marine shells over the last 70 million years.



Ice ages can be shown by oxygen isotopes measured in foraminifera - see illustration above.

Graph & Image Credit: Planet Guernsey, 2007
Source: Ruddiman, W.F. 2001 *Earth's Climate: Past and Future*. WH Freeman, New York 465 pp

1.5 THE PRESENT INTERGLACIAL PERIOD

Professor Nicholas McCave

Anthropologists have argued that the relative climatic stability of the past 10 thousand years has allowed development of modern human civilisation, including the farming of plants, the domestication of animals, and the building of cities. It was only in the past 25 thousand years that our species *Homo sapiens* emerged as the dominant hominid with the decline of the Neanderthals. However, the period from 25 to 11 thousand years ago saw huge climate shifts in the transition from full glacial (with ice down to the Isles of Scilly) to present interglacial conditions, with both major warmings and coolings; which was not favourable for the establishment of stable human communities.

Then about 10 thousand years ago the climate became relatively stable, with estimated global mean temperature shifts of less than 1° C (compared with around 5° C glacial to interglacial change). There was one 'blip' on this stable warm climate, that occurred about 8,200 years ago. This was caused by the final collapse of the Canadian ice cap. This produced a sudden discharge of fresh water, that had gathered in a vast lake as the ice melted, into the North Atlantic. It is thought that this sudden influx of cold, fresh water caused a temporary weakening of the current system that brings warm waters from the Gulf of Mexico to north-western Europe. This system - The Gulf Stream and North Atlantic Drift at the surface - depends on the water being dense enough to sink in the Norwegian Sea

when it gives up its heat, but the extra fresh water made it too light, thereby slowing the system down.

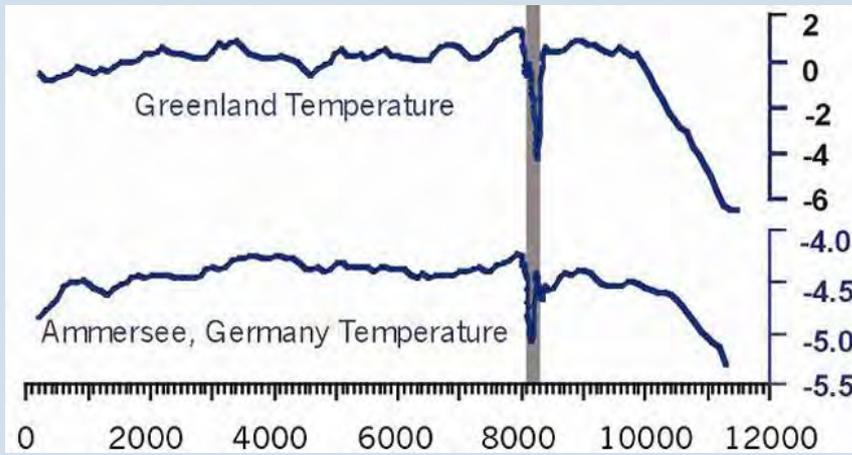
Box 1a shows that ice and sediment records from Greenland and from a German lake show the same story; that a sudden dramatic fall in temperature occurred about 8,200 years ago. The warmer temperatures seem to have returned after about 200 years, probably as the circulation returned to normal interglacial conditions.

Since then there have been minor oscillations of climate, shown by sediments excavated from the Atlantic. This suggests 8 cooler periods in the last 10 thousand years. Box 1b shows a higher percentage of sand grains (dropped from icebergs) which indicates colder conditions.

The most recent of these warm/cool oscillations was the Medieval Warm Period that peaked between 1000-1200 AD, when there were vineyards in England as far north as Leicestershire; and the succeeding Little Ice Age that peaked between 1550-1800, when the Thames used to freeze over in winter (see Box 1c). This temperature fluctuation is clearly evident when tree-rings, that record the conditions when the tree was growing, are analysed. From this it can be seen that at no time in the last 2,000 years has it been warmer than the present, and that the current trend is taking global temperatures beyond the maximum attained in the past half million years.

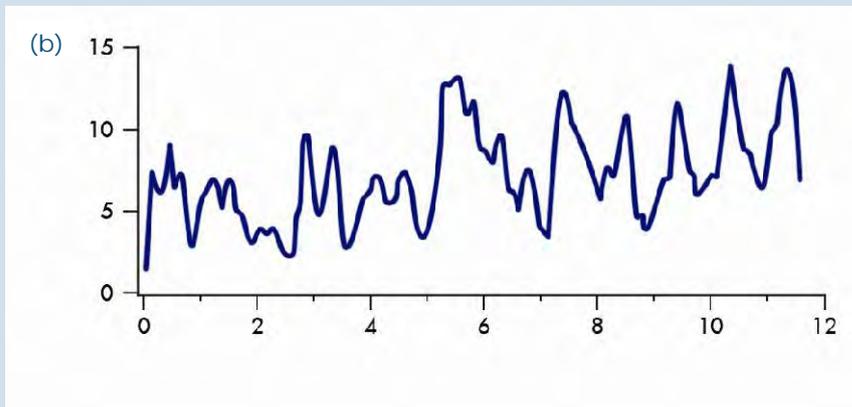
We are entering uncharted territory.



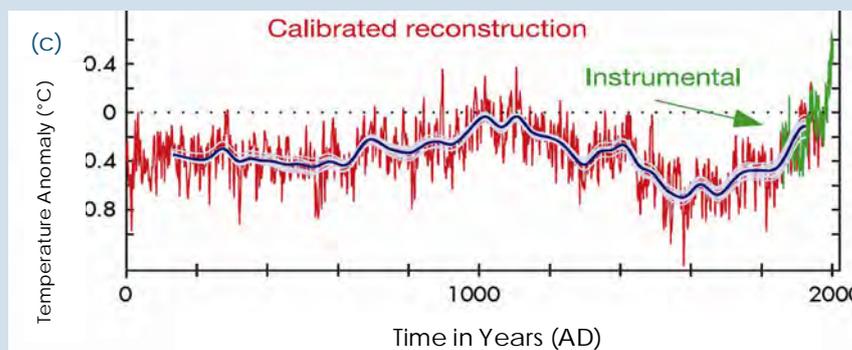


Box 1

(a): Temperatures both on the Greenland ice cap and in a record from a central German lake show at least 1°C of change.



(b): A higher percentage of sand grains indicate colder conditions.



(c): Temperature variations over the past 1,000 years, clearly showing the Medieval Warm Period (peak 1,000-1,200) and the Little Ice Age (peak 1,550-1800).

All Graphs Courtesy of: Planet Guernsey, 2007
 Sources : a) Von Grafenstein, U. and others 1998 *Climate Dynamics*, Vol 14 73 - 81
 b) Bond, G.C. and others, 2001, *Science*, Vol 294: 2130 - 2136
 c) Moberg, A. and others, 2005, *Nature*, Vol 453: 613 - 617

It may be salutary to reflect that whatever we do, the Earth will continue, with or without us. That is the lesson of the cataclysms recorded in the rocks.

As Ronald Wright has so pungently put it:

“If we fail - if we blow up or degrade the biosphere so it can no longer sustain us – Nature will merely shrug and conclude that letting apes run the laboratory was fun for a while but in the end a bad idea.”

1.6 HOW HAS JERSEY'S CLIMATE CHANGED OVER THE LAST 500,000 YEARS?

John Renouf

There have been five major interglacial periods during the past 500,000 years and these are related to the astronomical cycles discussed in Article 1.2. Each lasted in the order of ten to twenty thousand years with the four intervening colder periods of much longer duration.

Over the same period the whole area of southern England, the Channel and northern coastal regions of France has been undergoing a continuing, if somewhat irregular, uplift of the land of somewhere under 10 cm per 1000 years; this uplift is thought to result from earth movements linked to still continuing distant Alpine compression and deep-seated movements in the Bay of Biscay.

During the Interglacials the sea level was approximately at its present day height. However, the land that was at sea level 400 thousand years ago is now some 30 to 40 m higher, as a result of the uplift referred to above. Just as now, that sea of 400 thousand years ago had its share of pebble beaches and wave cut platforms and these are now found at heights approaching between 32 and 40 m JD (Jersey Datum) as at South Hill, St Helier.

Other raised beaches and platforms represent other Interglacials:

- 20 to 25 m (300 thousand years old) 500m east of St Clement's Church on the rise of the Grande Route de St Clement
- 15 to 18 m (200 thousand years old) at localities such as Le Pinnacle, Les Landes, St Ouen
- Just above the present high water mark of spring tides (120 thousand years ago) e.g. Le Pulec, L'Etacq (Box 1).

What is noticeable is the long duration of the Glacial periods when sea levels were low and the Channel Islands would have had a much colder climate. At these times they would have been part of mainland France and England for long periods.

The map in Box 2 is a coloured version of one published by Sinel (1912) and shows that beneath the sea around Jersey at these times there was a land mass with river



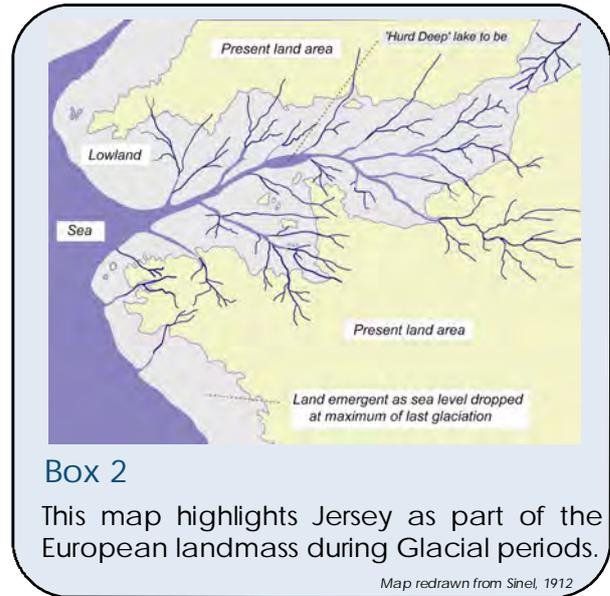
Box 1

We can see evidence of changes in sea level in the Island's recent geology. This example in a gully at Le Pulec, just above the present high tide mark, shows a notch eroded and smoothed by the sea of about 120,000 years ago. This is filled with sea rounded pebbles at the base overlain by angular stones above, termed 'head', formed during the last Glacial period.

systems; the pattern of river valleys is revealed not least by the underwater contours.

Each climatic cycle was represented in broad terms by an Interglacial and Glacial period. During the latter the sea level was much lower and the area around the Channel Islands was dry land. As the climate changed and moved towards the maximum of the succeeding Interglacial so the sea level rose worldwide as ice sheets melted and water was returned to the oceans. The very last cycle of all, represented by our present Interglacial high sea level, showed the same rise from a very low level as in

previous cycles. Box 3 reveals this change through a series of maps spanning from 18,000 years ago to the Present. We should remember that there are several uncertainties inherent in evaluating the scientific evidence of sea level rise. As a result, there are a range of possible options for the detail of sea level rise. Combined with these uncertainties are those stemming from the use of radiocarbon dating. The net result is that the dates attached to specific sea levels should be read with full awareness of the uncertainties involved, suggesting that a plus or minus factor of 500 years should be kept in mind for each.



Box 2

This map highlights Jersey as part of the European landmass during Glacial periods.

Map redrawn from Sinel, 1912

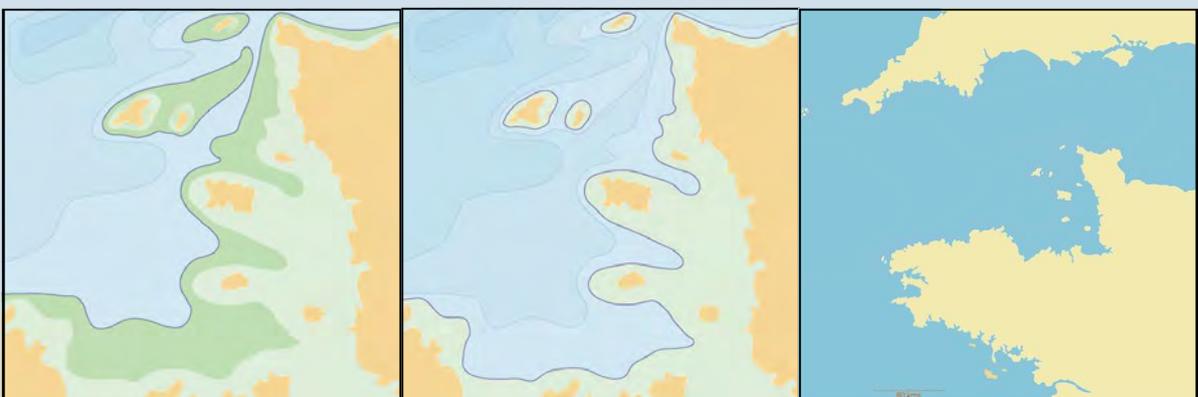
Box 3



18,000 Years ago.
Sea level over 100m lower than today.
At the height of the last glacial maximum the seashore is well out in the Western approaches and the Hurd Deep is a lake.

14,000 years ago.
Sea level about 75m lower than today.
As the great northern ice sheets began melting the sea level rose rapidly and will soon rejoin with the Hurd Deep.

About 11,400 years ago.
Sea level about 50 metres lower than today.
The Hurd Deep is now a deep in the sea. Sea level is rising rapidly at this time.



About 10,200 years ago.
Sea level about 30 metres lower than today.
Jersey remains attached to the continent but Guernsey, Alderney and Sark are now cut off from France.

About 9,400 years ago.
Sea level about 20 metres lower than today.
Guernsey, Alderney and Sark are now separating from each other. Jersey will shortly separate from the continent.

Present time.
Within the last 10,000 years each of the Channel Islands and associated offshore reefs have separated.

1.7 JERSEY'S CHANGING LANDSCAPE OVER THE LAST 20,000 YEARS

John Renouf

Evidence of the climate that prevailed in the Channel Islands area towards the end of the last ice age comes from a number of localities.

Of particular interest are the lowermost soft sediments found when excavating for the dam in Queen's Valley. From here Dr Robert Jones and colleagues have described a cold, arctic climate with a low ground cover of herbs and shrubs, possibly with some birch, poplar and pine trees. The cold is confirmed from beetle studies suggesting about 9° C for the average temperature of the warmest month (a modern figure is almost double this). The deposits are dated to the mid-11th century BC, the last very cold spell before the Holocene warmth truly set in. The sea coast was still many miles to the west of the island.

The recent find by Dr Arthur Hill in 2001 of a single mammoth tooth in silty sediments on the foreshore off La Rocque is likely to indicate an even colder time several thousand years before this when perhaps the very last of the mammoths in our part of the world were roaming the low plains that then surrounded Jersey.

Alongside the changes in sea level of the last 20,000 years there were also rapid changes in the natural landscape of the Island. These are outlined in Box 1 and were followed by a period of rapid warming after 10,000 BC, approximately the technical end of the last ice age.

By and large, within approximately a thousand years, a well established forest was widespread, though quite open in character. Birch, hazel and pine were quite common but by 8,750 BC, the forest was much more closed and birch and pine formed a lesser proportion of the trees. Pollen bearing sediments are not common in Jersey over this period and it is not until after about 6000 BC that pollen and other plant material again becomes abundant enough to deduce a quite detailed climatic history.

The absence of evidence over this period is likely to be related to increased rainfall scouring out valleys rather than depositing sediments. This record is fully documented in Jones *et al.*, 1990.

The first indications of Neolithic peoples in the



Box 1

Changing Vegetation of the Island:

- a) 16,000 BC: Open, dry, steppe-like tundra is typical of the Channel Islands' climate.
- b) 11,000 BC: Low scrub vegetation with patches of open woodland is the norm.
- c) After 10,000 BC: The birch, hazel and pine forests shown here is rapidly replaced by a mixed oak-hazel woodland.

Channel Islands appear on the cusp of 5,000 BC when the natural vegetation was essentially the same as it would be at the Present were it not for the modifications engineered by peoples' activities since, such as clearances for agriculture and other purposes. The temperatures at this time are generally taken to be 1° C warmer on average than now.

The early Neolithic is also interesting in that the still rising sea level was now close to that of the present very low tide mark (Box 2) and records the time when Jersey was becoming a true island separated from the adjacent French mainland; Guernsey had been separated several thousand years earlier.

The time interval 5,000 to 1,000 BC was dominated by a sea level that was still rising but now interacting for the first time with the zone represented by our present coastal plains.

During this final rise of the sea to present levels just described, the tussle between land and sea resulted in the creation of the wedge of soft sediments that fill Jersey's low lying coastal plains. In many areas much of the sediment, anything up to ten or more metres in thickness, are fine sands and silts derived from the interior of Jersey and brought down by the streams that drain the plateau. Before the sea level rose above that of the low tide of today, all this land-derived sediment was moved away from our present coasts down the river system shown on the Sinel map (Box 2, previous article). With the rise in sea level the silt became trapped between barrier sand pushed up in front of the rising sea and the old fossil cliffs backing the coastal plains. The scenario presented here is general in nature, and varies almost infinitely in detail.

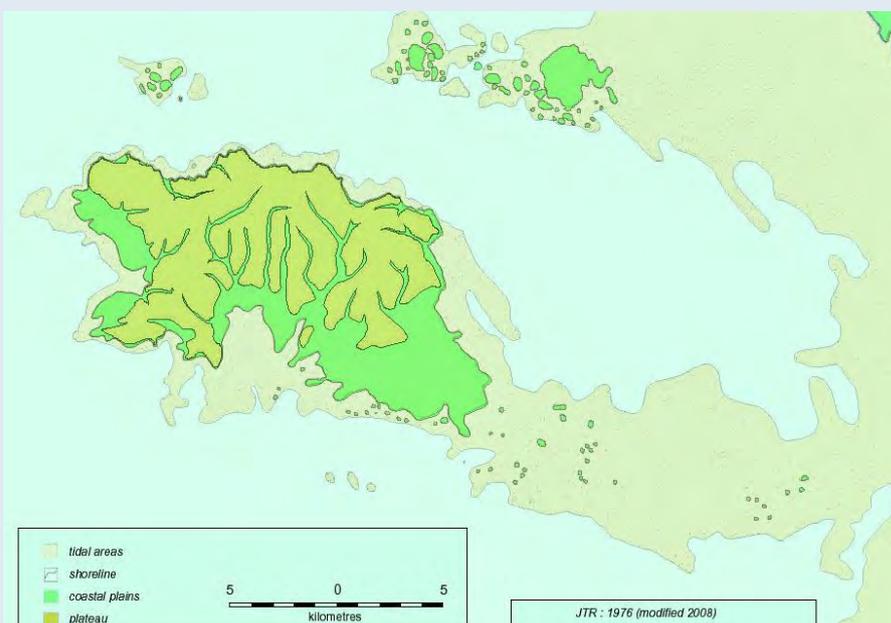
The rise of sea level was all but over during the first millennium BC as sea level reached more or less its present height though the tension between land and sea has continued to exist down to the present day. An

understanding of the processes at work during this long time span is crucial for the shaping of responses to any sea level rise we may see in the future as discussed in Article 4.18.

The feature of sand blowing contemporaneously is found on many archaeological sites ranging from the Mesolithic through to the Middle Ages and later. Such episodes may reflect short term 'weather' changes ranging over months or years or may result from longer term climatic shifts. At Le Pinnacle, the Bronze age occupation layers are in sand separated off from the Neolithic horizons below; an Iron Age site off Broad Street, St Helier was overlain by blown sand. Particularly important, however, is the evidence from the Middle Ages when serious wind blow and sea encroachment, associated with much increased storminess, is both well documented for the 14th century. It is further proven by such excavations as those in the Hue Street/Old Street area of St Helier in the early 1970s. This was part of the general climatic deterioration of the time moving into the Little Ice Age. Later dune building, particularly on the island's east and west coasts, testify to relatively lengthy periods of wind blow.

Box 2

An indication of how Jersey's coast may have looked in early Neolithic times as sea level approached the current low tide mark. A land bridge, perhaps mostly tidal, still connects Jersey to the continent and coastal plains exist in our current inter-tidal zone.



REFERENCES

The following articles were referred to in Articles 1.6 and 1.7 :

Jones, R.L., D.H. Keen, J.F. Birnie & P.V. Waton. 1990. *Past landscapes of Jersey : Environmental changes during the last ten thousand years*. Société Jersiaise, Jersey.

Jones, R.L., C.E. O'Brien & G.R. Coope. 2004. Palaeoenvironmental reconstruction of the Younger Dryas in Jersey, UK Channel Islands, based on plant and insect fossils. *Proc. Geol. Assoc.*, 115 : 43-53.

Renouf, J. & J. Urry. 1976. *The first farmers in the Channel Islands: The Neolithic in an insular environment*. Education Department, Jersey