2. Climate Change

Long term changes in the climate as a result of the redistribution of the continents around the globe, and changes in the Earth’s orbit and the Sun’s output have shaped the landscape we know today. The Exe Estuary is a drowned river valley, or ria, inundated by a sea level rise of 120 metres that took place from the end of last Ice Age 18,000 years ago to about 4,000 B.C. Whilst we do not expect changes of that magnitude to take place in the coming century as a consequence of human-induced climate change caused by greenhouse gas emissions, some of the physical attributes of the Exe Estuary will change during our and our children’s lifetimes.

The evidence for climate change is irrefutable and the 2013 Fifth Assessment Report from the Intergovernmental Panel on Climate Change has concluded that it is very likely that human activities that emit greenhouse gases has been the main cause of the observed warming since the mid-20th century.

Weather or Climate?

Weather and climate are distinctly separate. Weather is a description of the environmental conditions that occur at a particular moment in time, i.e. the temperature, cloud cover or rainfall that is seen from a glance through the kitchen window.

Climate is a representation of average weather over longer periods of time. The timescale used by the United Nation’s Intergovernmental Panel on Climate Change to describe a region’s climate is 30 years.
Devon’s Prevailing Conditions

The South West Peninsula is the warmest area in Britain being surrounded by the sea and it is the first landmass to be affected by prevailing Atlantic weather systems. This maritime location produces a warm, temperate and humid climate with only occasional frost that is tempered throughout the year by the influence of the sea.

Temperature

The seas surrounding the South West peninsula are the warmest of the UK with a mean annual temperature of between 11°C and 12°C. The South West prevailing winds travel over the sea before coming ashore which helps maintain onshore air temperatures in coastal areas. Inland, the mean temperature decreases with height. For example, Princetown at an altitude of 414m on Dartmoor has an annual mean temperature of just 8°C (see Figure 2a).

Due to Devon’s proximity to the sea the range of seasonal temperature is smaller than in most other parts of the UK. The seas are at their coldest between February and March and so February is generally the coldest month in Devon with mean minimum temperatures falling to around 1.5°C inland. Very low temperatures are usually prevented due to Devon’s proximity to the sea but away from the shoreline temperatures well below freezing have been recorded, such as -15.0°C at Exeter Airport on 24th January 1958.

The average maximum temperature in Teignmouth is 20.6°C which occurs in July and is slightly lower than the 22.5°C enjoyed by the Home Counties. In July the Exe, Teign and Dart valleys on Devon’s south coast are some of the County’s warmest locations (Figure 2b).

Extreme high temperatures are rare and occur when south easterly winds bring hot air from mainland Europe and are accompanied by sunshine. The highest temperature recorded in Devon reached 35.4°C at Saunton Sands on 3rd August 1990. The occurrence of frosts can be relatively high in certain locations. There are up to 23 days a year with air frost in coastal areas rising to between 47 and 78 on Dartmoor and Exmoor. The warmth of the sea following summer usually prevents coastal autumn frosts.

Figure 2a: Long-term average annual temperature in Devon (1971 – 2000)
Source: The Met Office 2014

Figure 2b: Long-term average July maximum temperature in Devon (1971 – 2000)
Source: The Met Office 2014
Sunshine

Coastal areas in the South West have average annual sunshine totals above 1600 hours (Figure 2c). Whilst this is more favourable than many areas in the UK it is not as high as the South East coast where almost 1850 hours can be expected in Eastbourne. Inland in Devon the annual sunshine totals are between 1300 and 1600 hours.

Rainfall

The highest monthly rainfall falls in December and January when the sea is still warm enough to ensure high levels of air humidity and the Atlantic depressions are most active. April to July is the driest period when the sea is relatively cool. Coastal areas have 900 - 1,000mm annually, but up to double this amount falls on Dartmoor and Exmoor (Figure 2d). Areas sheltering in the lee of high ground receive less such as 800mm near Exeter. In comparison, the driest parts of eastern England receive around 500mm and over 4,000mm falls in the western Scottish highlands.

Monthly rainfall is also highly variable between years. Most months of the year have recorded totals below 20mm in coastal districts but, for example, at Plymouth, every month has had more than 100mm at some point in time.

The South West peninsula is subject to rare, but very heavy, rainfall events lasting from 5 to 27 hours. The Lynmouth storm on 15th August 1952 was one of these, when one weather station on Exmoor recorded 228mm in 12 hours. More recently, in July 2012, the South Devon and East Devon regions experienced intense rainfall resulting in the flooding of over 230 residential and commercial properties across Devon.
Snowfall

On average, the number of days with falling snow is fewer than 10 per winter on the coast, and 8-15 days is common inland. In upland areas more than 25 days per year are possible (Figure 2e). Lying snow is not frequent and in lowland areas about a third of years do not record any. Coastal areas can expect fewer than three days of lying snow per year on average. This increases to 5-10 days per year further inland and Dartmoor and Exmoor have more than 20. This is still relatively low compared with Balmoral, Aberdeenshire, which has about 60 days with lying snow.

Despite being the mildest region of the British Isles, the South West peninsula has experienced some of the most severe blizzards to affect the UK. If cold easterly winds from Europe meet a slow-moving Atlantic depression off south-west England then persistent snowfall accompanied by high winds is possible. On the 18th February 1978 fine snow accompanied by 25 knot winds at temperatures as low as -2°C resulted in 50cm of snow in inland Devon and over 90cm on Dartmoor and Exmoor.
Wind

The South West of England experiences average wind speeds that are exceeded only by Western Scotland. Mean speeds and gusts are strongest in the winter. Speeds are generally lower inland but Exmoor and Dartmoor are likely to experience speeds similar to those on the coast.

The most frequent and strongest winds come from between the South and North-West. In spring, winds from the North-East are common due to the high pressure over Scandinavia at this time of year. Calm winds with no preferred direction occur less than 6% of the time in the coastal districts. This increases to about 15% of the total time in inland areas, which is relatively low in comparison to central England where light winds occur approximately 25% of the time.

The highest gusts recorded in Devon during the period 1971 to 2000 were on 25th January 1990. This included 84 knots at Plymouth and 74 knots at Exeter Airport (hurricane force 12 on the Beaufort scale). The maximum hourly mean speed was 60 knots at Plymouth (violent storm force 11 on the Beaufort scale) which caused widespread damage to buildings and overturned vehicles.

Climate Change in the 20th Century

On average, temperatures in England have risen by about one degree Celsius since 1980, with 2006 being the warmest on record. Plymouth has recorded an increase of 0.75°C since 1900, Exmouth 1.05°C and Ilfracombe 0.64°C. The hottest temperature recorded in Devon was 35.4°C at Saunton Sands in August 1990, while the highest figures for Exmouth (31.2°C) occurred in June 1976.

Annual mean precipitation over England and Wales has not changed significantly since records began in 1766. Seasonal rainfall is highly variable, but appears to have decreased in summer and increased in winter, although with little change in the latter over the last 50 years. All regions of the UK have experienced an increase in the contribution to winter rainfall from heavy precipitation events between 1961 and 2006. In summer all regions except NE England and N Scotland show decreases in rainfall.

Severe windstorms around the UK have become more frequent in the past few decades. The 1990s saw 14 strong wind events, compared to 4, 5 and 8 in the 1960s, 1970s and 1980s respectively. These observations are correlated with the strength of the North Atlantic Oscillation for which no trend is identifiable.

Sea Level

As global temperatures rise, the oceans absorb heat from the atmosphere and expand, resulting in rising sea levels. Increasing temperatures melts glaciers and ice on land, which further increases sea level. The South West of England has the highest rate of relative sea level rise in the UK because the land is very slowly sinking as a result of isostatic rebound affecting the northern half of the country. This is caused by melting of the ice on the land after the last glaciation. During the Ice age, the weight of ice compressed the land in the North of the UK but now this is bouncing back. The effect of this land movement adds to the sea level rise caused by climate change.

Measurements of relative sea level (sea level taking into account changes in land height) around the UK coast are made through the UK National Tide Gauge Network (NTGN), which records tide elevations at 44 locations round the UK coast. A process of datum control is used to ensure that tide gauge instrumentation remains stable over time. Data from the NTGN is managed by the British Oceanographic Data Centre, itself part of the National Tide and Sea Level Facility. The tide gauge at Newlyn, in Cornwall, has been collecting sea level data continuously since 1915, far longer than any other tidal gauge in the South West. Data from this location indicates that mean sea level has risen steadily by approximately 18cm over the last 100 years, which equates to a sea level rise of about 3mm per year as indicated in Figure 2f.
Climate Change Projections for the South West

The 2009 UK Climate Projections (UKCP09) are the latest to be published. There is still uncertainty within climate modelling which is why a range of figures is given. Current global emissions of CO₂ are reportedly at levels similar to that assumed within the high emissions scenario models (Le Quéré et al., 2010). Therefore, ranges of projected climate change in the South West under the high emissions scenario are presented in the table below. The UKCP09 projections also give additional figures for the other emissions scenarios.

Whilst Devon specific climate projections can be extracted from the UKCP09 database they will not be distinguishably different to those for the South West. Projections can be generated on a 25km grid square resolution using the UKCP09 online user interface.

Projected change in climate for the South West under the high emissions scenario (UKCP09)

<table>
<thead>
<tr>
<th>Projected change is...</th>
<th>Winter mean temp</th>
<th>Summer mean temp.</th>
<th>Summer mean max temp.</th>
<th>Annual mean precip.</th>
<th>Winter mean precip</th>
<th>Summer mean precip.</th>
<th>Relative sea level</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>2020s</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Very likely to be &gt; than</td>
<td>0.5°C</td>
<td>0.5°C</td>
<td>0.6°C</td>
<td>-5%</td>
<td>-2%</td>
<td>-24%</td>
<td>6cm</td>
</tr>
<tr>
<td>Very likely to be &lt; than</td>
<td>2°C</td>
<td>2.6°C</td>
<td>3.8°C</td>
<td>6%</td>
<td>18%</td>
<td>18%</td>
<td>18cm</td>
</tr>
<tr>
<td><strong>2050s</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Very likely to be &gt; than</td>
<td>1.3°C</td>
<td>1.4°C</td>
<td>1.5°C</td>
<td>-6%</td>
<td>3%</td>
<td>-45%</td>
<td>13cm</td>
</tr>
<tr>
<td>Very likely to be &lt; than</td>
<td>3.5°C</td>
<td>5.1°C</td>
<td>5.5°C</td>
<td>6%</td>
<td>41%</td>
<td>8%</td>
<td>41cm</td>
</tr>
<tr>
<td><strong>2080s</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Very likely to be &gt; than</td>
<td>2.1°C</td>
<td>2.7°C</td>
<td>3.0°C</td>
<td>-7%</td>
<td>8%</td>
<td>-58%</td>
<td>20cm</td>
</tr>
<tr>
<td>Very likely to be &lt; than</td>
<td>5.1°C</td>
<td>7.9°C</td>
<td>11.9°C</td>
<td>10%</td>
<td>73%</td>
<td>4%</td>
<td>69cm</td>
</tr>
</tbody>
</table>

**NB:**  1. Either end of the range of projected change is equally likely to occur. The mid point of the range does NOT indicate an average projected change and must not be used as such.
2. ‘Very Likely’ in this context refers to 90% statistical certainty, except for Relative Sea Level where it refers to 95% certainty.
Climate Change

Future Temperatures

The general headline message for the future is warmer, wetter winters and drier, hotter summers. The opportunity for extreme changes in climate becomes greater towards the end of the 21st century. For the Exe Estuary projections suggest mean summer temperatures may increase by around 3.9°C by the 2080s if the high emissions scenario is followed with the mean winter temperature increasing by 2.8°C.

Figure 2g: Change in mean summer temperature (°C) in Devon

Figure 2gi: Baseline mean summer temperature (°C) (1961 – 1990)

Figure 2gii: Change in mean summer temperature (°C) by the 2050s for the high emissions scenario

Figure 2giii: Change in mean summer temperature (°C) by the 2080s for the high emissions scenario

Source: Devon County Council Climate Change Strategy (2005)
Future Storms and Winds

The frequency of storm events (depressions) passing over the UK shows little change up to 2080 under UKCP09. The previous projections (2002) suggested an increase in storm event frequency over the UK. This highlights the inherent uncertainty in climate modelling. It is suggested that wind speed generally will change little by the 2080s, though summer wind speed may increase by up to 6% (Brown et al., 2009). However, as the atmosphere warms up and holds more energy, more frequent and severe storms are predicted by some climate models, although the exact details are still difficult to quantify.
Future Precipitation

The future increase in winter precipitation (including snow, hail, sleet and rain) projected by UKCP09 suggests that winter precipitation events will become more intense or longer in duration, rather than more frequent. Seasonally, around the Exe Estuary (Exmouth, Teignmouth and Newton Abbot) summers may become up to 55% drier by the 2080s. In the same time frame winters may become up to 26% wetter. We are already committed to the level of climate change projected for the 2020s as a result of historic and present global emissions. Any action we take today to reduce emissions will not have an impact on climate until the mid 21st century.

Figure 2I: Percentage change in mean summer precipitation in Devon

Figure 2I: Baseline mean summer precipitation (mm) (1961 – 1990)

Figure 2II: Percentage change in mean summer precipitation by the 2050s for the high emissions scenario

Figure 2III: Percentage change in mean summer precipitation by the 2080s for the high emissions scenario

Source: Devon County Council Climate Change Strategy (2005)
Climate Change

Figure 2j: Percentage change in mean winter precipitation in Devon

Figure 2ji: Baseline mean winter precipitation (mm) (1961 – 1990)

Figure 2jii: Percentage change in mean winter precipitation by the 2050s for the high emissions scenario

Figure 2jiii: Percentage change in mean winter precipitation by the 2080s for the high emissions scenario

Source: Devon County Council Climate Change Strategy (2005)
Climate Change Impacts

The 2006 Stern Review on the Economics of Climate Change, commissioned by HM Treasury concluded that, without intervention, the overall costs of climate change impacts will be equivalent to losing between 5% and 20% of global GDP each year, now and forever. Encouragingly, mitigating Greenhouse Gas emissions to avoid the worst impacts of climate change will cost only 1% of GDP each year by 2050.

Climate change will affect all sectors of society. Industry and commerce will be affected by changing demands for goods and services, as well as higher insurance costs and the financial implications of interruptions to logistics caused by the weather. Utilities, infrastructure and buildings will have to be designed to withstand new temperature, rainfall and UV light ranges. And the health sector will need to adapt to new health complaints and an increased incidence of heat related conditions.

There will be several impacts on the natural environment as well. Particularly in the Exe Estuary, the inter-tidal areas such as saltmarsh, sandbanks and mudflats, which are visible at low tide, will be under water for more of the time as the sea level rises. These important habitats will be prevented from moving further up the shore by the presence of man-made defences, such as sea walls. This process is known as “coastal squeeze”. The loss of these habitats, which are legally protected by both UK and European law, will affect resident and visiting wildlife including many internationally important wading birds. Current law requires that coastal squeeze is either avoided or compensated for by creating new areas of suitable replacement habitats (further information at Section 7).

More information about climate change in the Exe Estuary and how this compares with coastal areas across the channel in Normandy, France can be found in the Two Countries One Sea report at www.licco.eu.
Climate Change

Image 2b: **Storm impact at Exmouth seafront**
Source: David Weatherly

Image 2c: **Severe storm at Dawlish Warren in 2014**
Source: EA
2.2 Adapting to Coastal Change

It's easy to think that our local coastline has always looked like it does now. In fact, the Exe Estuary coastline has evolved over thousands of years. Storm waves, high spring tides and gale force winds have battered our coast, resulting in erosion of cliffs and beaches, whilst on-going coastal processes like longshore drift and tidal currents move sand and sediments around on a major scale. Land reclamation, construction of flood defences, transport links, such as railway lines, and housing development have also all played their part in shaping the coastline that we know and love today.

To prepare for the likely effects of climate change a number of organisations undertake monitoring activities around the Exe Estuary in order to identify and assess the coastal process taking place on the Estuary and the vulnerability of sites and habitats. Engagement activities are also undertaken so that local people and organisations have an opportunity to have a say in how their coast is managed. Appropriate management measures have been developed to manage the risks of sea level rise and coastline erosion for people, properties and the environment.

Please see section 7 for more details about the Flood and Coastal Management of the Exe Estuary.

Living with a Changing Coast

The “Living with a Changing Coast” (LiCCo) project is a three year cross-channel project launched in 2011 and part funded by the EU INTERREG programme. The project aims to help coastal communities to better understand, prepare for and adapt to the impacts of climate change, sea level rise and erosion on the natural and human environment. Partner organisations including the Exe Estuary Management Partnership, Dorset County Council, the National Trust and a number of bodies in Normandy are working together, with leadership provided by the Environment Agency.

The project focuses on seven coastal study areas in England and Normandy, France. Within the South West of England the study areas are the Exe Estuary and Poole Harbour. In the Exe Estuary the Environment Agency works closely with the Exe Estuary Management Partnership, and several engagement activities have already been completed as part of the project. A film showing different stakeholder views around the Exe Estuary and schools resources focusing on the Exe Estuary are just some of the resources available online at www.licco.eu/exe-estuary.

Image 2d: LiCCo workshops around the Exe Estuary
Source: EA
Activities undertaken by the LiCCo project include:

- **Using history to tell the story of coastal change** by encouraging communities to share and record their memories of the coast;
- **Improving understanding** of climate change, sea level rise and coastal erosion and what this means at a local scale over the next 20 – 100 years;
- **Engaging with local organisations and communities** to seek their views and enable them to have their say on developing future policies to manage increasing flood risk caused by rising sea levels; including the Exe Estuary Flood & Coastal Erosion Risk Management (FCERM) Strategy;
- **Developing tailored learning resources** which explain coastal issues in a meaningful way;
- **Embedding understanding** of coasts and climate change into Devon’s schools;
- **Raising awareness** amongst coastal communities of how they can prepare for and protect themselves from increased coastal flood risk;
- **Sharing learning and best practice** between project partners and other similar projects within the UK and internationally;
- **Improving knowledge about coastal habitats**, and plant and animal species that act as indicators of climate change.

Image 2e: **Historical photos of Exmouth and Dawlish Warren**  
Source: EEMP
2.3 Carbon Emissions and Energy Use

Devon (excluding Plymouth and Torbay) produced the equivalent of 5.2 million tonnes of carbon dioxide in 2011, from ‘industry and commercial’, ‘domestic’ and ‘transport’ (see Figure 2k).

![Figure 2k: CO₂ emissions by sector from Devon in 2011](source: Local and Regional CO₂ Emissions Estimates for 2011, produced by Ricardo AEA for Department of Energy and Climate Change)

The Table 2a below illustrates that Devon’s CO₂ emissions decreased by 16% between 2005 and 2011, and per capita emissions fell by 7.1% over the same period. The CO₂ emissions are split equally between the industrial and commercial, domestic and transport sectors.

<table>
<thead>
<tr>
<th>All Devon</th>
<th>Industry</th>
<th>Domestic</th>
<th>Road Transport</th>
<th>Total</th>
<th>Per Capita</th>
</tr>
</thead>
<tbody>
<tr>
<td>2011</td>
<td>1,628 kt</td>
<td>1,621 kt</td>
<td>1,789 kt</td>
<td>5,275 kt</td>
<td>7.1 t</td>
</tr>
<tr>
<td>2009</td>
<td>1,727 kt</td>
<td>1,748 kt</td>
<td>1,840 kt</td>
<td>5,576 kt</td>
<td>7.5 t</td>
</tr>
<tr>
<td>2007</td>
<td>1,929 kt</td>
<td>1,880 kt</td>
<td>1,931 kt</td>
<td>5,970 kt</td>
<td>8.1 t</td>
</tr>
<tr>
<td>2005</td>
<td>2,185 kt</td>
<td>1,952 kt</td>
<td>1,951 kt</td>
<td>6,291 kt</td>
<td>8.7 t</td>
</tr>
</tbody>
</table>

Table 2a: Total Carbon Dioxide Emissions (ktonnes) per year by source
The contribution of energy use to climate change is a driver in the development of renewable energy schemes. Devon is rich in renewable energy resources and currently it leads the South West region on installed renewable heat capacity, as shown in Figure 2I. Future trends indicate further growth and provision of renewable energy in Devon and the region is well positioned to take a central role in delivering the 2020 national renewable energy target.

Figure 2I: Total renewable energy generation in the South West in 2012/2013
Source: Regen SW (2013)

Renewable Energy within the Exe Estuary Partnership Management Boundary

The potential for large scale renewable energy such as wind turbines does not exist on the Exe Estuary, but there may be scope for small scale, domestic or commercial generation of renewable energy. At present there are no significant examples of renewable energy generation being practised on the Exe, but solar energy could be used to run outdoor, public facilities such as parking meters. Using renewable sources to generate energy would not only reduce the environmental impact of daily life on the Estuary, but could also bring financial savings and benefits for individuals or businesses pursuing renewable energy generation.