theWeather Club

+ Newsletter
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Winter 2015:

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My Weather
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And finally...

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The World Meteorological Organization’s (WMO) provisional statement of the status of global climate in 2015 was released on 25th November, with WMO Secretary General, Michel Jarraud, stating that it ‘will make history for a number of reasons’.

The report highlighted that 2015 is likely to be the warmest on record and that 2011-2015 is expected to be the warmest five-year period, with global average surface temperatures reaching the ‘symbolic and significant’ milestone of 1°C above pre-industrial levels for the first time.

The HadCrUT dataset (for January to September 2015), jointly run by the Met Office and the Climate Research Unit at the University of East Anglia, shows 2015 global mean temperature is 1.02°C (±0.11°C) above pre-industrial levels (1850-1900).

Scientists say that the 1 degree mark will be broken in 2015 due to a combination of carbon emissions and the impact of the El Niño weather phenomenon.

Stephen Belcher, Director of the Met Office Hadley Centre, said: “We have seen a strong El Niño develop in the Tropical Pacific this year and that will have had some impact on this year’s global temperature. We’ve had similar natural events in the past, yet this is the first time we’re set to reach the 1°C marker and it’s clear that it is human influence driving our modern climate into uncharted territory.”

2014 was the warmest year since records began, and it is likely that 2015 will exceed this - scientists also expect 2016 to show a similar trend.

Peter Stott, Head of Climate Monitoring and Attribution, said: “This year marks an important first, but that doesn’t necessarily mean every year from now on will be a degree or more above pre-industrial levels, as natural variability will still play a role in determining the temperature in any given year. As the world continues to warm in the coming decades, however, we will see more and more years passing the 1 degree marker - eventually it will become the norm.”

If this figure is indeed realised, the world would then be half way towards the 2°C threshold, however the later the CO2 emissions peak, the faster the subsequent emissions cuts would need to occur in order to limit the rise. This new data is therefore expected to add pressure on political negotiations in Paris later this month aimed at securing a new global climate treaty.

2015 is also a historic year for greenhouse gas levels. Michel Jarraud, WMO Secretary-General, highlighted that “levels of greenhouse gases in the atmosphere reached new highs and in the Northern hemisphere spring 2015 the three-month global average concentration of CO2 crossed the 400 parts per million barrier for the first time,” calling it “bad news for the planet.”

The information on the status of the global climate will help to inform negotiations at the U.N. Climate Change Conference in Paris, taking place at the start of December. COP2 - the 21st Conference of the Parties – is the annual meeting of all countries wanting action on climate change. The conference objective is to achieve a legally binding and universal agreement on climate, from all the nations of the world (see this issue, p. 12-13).
UK autumn and the A-Z of storms

September - November 2015

Autumn as a whole started out relatively dry and settled with fairly average temperatures. Although September began cool and showery, it quickly became dominated by high pressure, with a period of more changeable weather mid-month. Much of October’s weather was also influenced by high pressure, bringing periods of dry, settled weather and spells of sunshine, but also some overnight frost and fog.

November was notably mild and, unlike September and October, sunshine was far less abundant in most places throughout the month, with provisional statistics indicating it was the dullest November on record. However November brought about a period of more active and changeable weather. On 1st November, Britain experienced its warmest November day on record after temperatures hit 22.4°C at Trawsgoed in west Wales as southerly winds and high pressure brought warm air in from the continent. At the same time, other parts of Britain saw dense fog.

November also brought us the first storms of the season. This year, the Met Office and Met Eireann are piloting a project aimed at naming wind storms that are expected to affect the UK and Ireland through the autumn and winter 2015/16. It is hoped that this endeavour will help raise awareness of severe weather and ensure greater safety of the public. Suggestions for names of the storms were opened up to the general public and so far, three named storms have occurred: Abigail, Barney and Clodagh.

On 12th-13th November, Storm Abigail brought heavy downpours, flooding, wintry showers and lightning to parts of the UK, with gusts of up to 84 mph in north and northwest Scotland. It left thousands of homes without power and closed a number of schools in Scotland. Following this storm, remnants of Hurricane Kate brought heavy rain and river flooding to parts of northwest England, Yorkshire, north Wales and Northern Ireland over the weekend of the 14th-15th November.

The second storm to be named, Storm Barney, hit the UK during 17th-18th November, bringing damaging winds and heavy rain to large swaths of Wales, central and southern England. Once again, thousands were left without electricity and trains were disrupted following gusts of up to 85 mph which brought down trees and other infrastructure.

A change in air mass on 20th November brought sub-zero temperatures and snow flurries to parts of the UK over the weekend - particularly the north and east, where some accumulations of snow occurred. November ended on a rather wet and windy note with the arrival of the third storm, Clodagh, on the 29th. Impacts were most severe in the Republic of Ireland with gusts of more than 70 mph leaving 3,500 people without electricity.

UK Weather

<table>
<thead>
<tr>
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<th>Oct 2015</th>
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<tr>
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<td>Anomaly</td>
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<tr>
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<tr>
<td>Average Min</td>
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<td>Mean Temp</td>
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<td>Rainfall</td>
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‘Once-in-a-millennium’ downpour floods parts of South Carolina

October 2015

A ‘once-in-a-millennium’ downpour flooded large parts of South Carolina in October, as unrelenting Joaquin-fuelled rains dumped more than 450 mm of rainfall in 24 hours on parts of central Southern Carolina - more than the state usually receives for the entire month of October. Hurricane Joaquin, a category 4 storm formed on 27th September, first battering the Bahamas causing flooding, before moving out to the Atlantic.

Although Joaquin did not directly hit the Carolinas, the resulting rains caused at least seven deaths and left thousands without power, with 200 people rescued from vehicles stranded in flooded roads.

The state’s governor, Nikki Haley, said parts of the state were hit with rainfall that would be expected to occur ‘once in 1,000 years’ (indicating that such flooding could only reasonably be expected to occur once in any given 1,000 year). The Congaree River flowed at its highest level since 1936.

Homes are inundated by flood waters (Image by Sean Rayford)
Weather Report

UK Weather

<table>
<thead>
<tr>
<th>Nov 2015</th>
<th>1981 - 2010</th>
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<tr>
<td>Actual</td>
<td>Anomaly</td>
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<tr>
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<tr>
<td>Rainfall</td>
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Active Pacific typhoon season continues...

September-October 2015

**Typhoon Etau:** Two people were killed, 27 injured and more than 100,000 people ordered to leave their homes as torrential rains caused widespread flooding in east Japan in September. Several towns were submerged under water, and houses in Joso - a town of approximately 65,000 people - were destroyed after Etau caused the Kinugawa river to burst its banks sending a torrent of muddy water into the town. Etau - the northwest Pacific’s 20th named tropical storm of the season - made landfall early on 10th September. The heaviest rainfall was observed in Tochigi prefecture where more than 650 mm was recorded in a 24-hour period, more than twice the average monthly total for September. “This is a downpour on a scale that we have not experienced before,” forecaster Takuya Deshimaru told an emergency press conference.

**Super Typhoon Djuan:** At the end of September, super typhoon Djuan (the 21st typhoon of the season) killed 2 people and injured more than 300 as it swept across Taiwan bringing torrential rainfall and winds exceeding 150 mph. More than 12,000 people were evacuated and half a million left without electricity. Severe winds uprooted trees and smashed windows and the heavy rains triggered multiple landslides. The heaviest rain was in north-east Taiwan in the mountainous Wulai district where more than 900 mm fell – nearly a third of the country’s annual rainfall. This region was recently damaged by severe flooding and landslides as a result of Typhoon Soudelor, which caused at least eight deaths in Taiwan (see tWC issue 11).

**Typhoon Koppu:** The active Pacific typhoon season continued into October as Typhoon Koppu hit northern Philippines, killing 54 people and displacing tens of thousands as winds exceeding 150 mph ripped off roofs and tore down trees and pylons. Heavy rain caused river and surface flooding resulting in landslides across the main island of Luzon. The deadliest and strongest typhoon to hit the Philippines - Super Typhoon Haiyan (see tWC issue 4) - destroyed entire towns in the central islands in November 2013, leaving more than 7,350 people dead or missing.

Hurricane Patricia: Strongest hurricane ever recorded in the Eastern Pacific

October 2015

At the end of October, Hurricane Patricia became the strongest hurricane ever recorded in the Eastern Pacific, with winds exceeding 200 mph and a central pressure of 892 mb – the lowest pressure ever measured in a Pacific Hurricane. At its peak, whilst out at sea its power was comparable to that of Typhoon Haiyan. It made landfall along Mexico’s Pacific coast on 23rd October as a category 5 storm bringing downpours, flooding and mudslides, surging seas and strong winds, before being downgraded to a tropical depression.

The lack of fatalities or significant damage was due to the fact that Patricia’s centre made landfall in an area of Jalisco state with very few towns, and a mountainous region which bore the brunt of the 200 mph winds. The nearest large city, Manzanillo, was outside the extent of the storm’s hurricane-force winds, which were located in a small radius of 5 to 10 miles from the eye of the storm.

The remnants of Patricia preceeded to hit southeast Texas, giving brief respite to the recent drought and forest fires, although it did trigger flash flooding and landslides in Houston and Dallas, before moving onto Arkansas and Louisiana.

The hurricane was boosted by the El Niño, which has warmed the Pacific waters to 30.5 °C – about 2 degrees above average - and whipped up the extreme winds, creating ideal conditions for strong hurricanes.

Image: A satellite image of Hurricane Patricia (Source: NOAA)
Dark aerosols linked to earlier melting of snow

A new study by NASA scientists have used a climate model to examine the impact of aerosols on Northern Hemisphere snowpacks, such as how it affects snow amount and ground heating in spring. Aerosols are tiny particles suspended in the air – such as dust, organic carbon and black carbon, the latter two being produced during the burning of fossil fuels, biofuels and biomass. They can darken - or ‘dirty’ - the snow and ice causing it to absorb more of the sun’s energy. Until recently, however, scientists rarely considered the effect of all light-absorbing aerosols in climate models.

The research, published in Geophysical Research (http://onlinelibrary.wiley.com/doi/10.1002/2014JD022977/full), involved using NASA’s GEOS-5 climate model to analyse the impacts of incorporating aerosols into the model by comparing model runs conducted with and without incorporating aerosols on snow. By comparing simulations from 2002 to 2011, they determined that the aerosols did indeed play a role in absorbing more of the sun’s energy.

In fact, over parts of the Northern Hemisphere, the darkened snow caused surface temperatures to increase by around 5 degrees Celsius compared to pristine snow conditions, resulting in less accumulated snow in spring for these areas.

The study also found that the snow-darkening effect of dust significantly contributes to surface warming in Central Asia and the western Himalayas, whilst black carbon’s snow-darkening effect had a larger impact primarily in Europe, the eastern Himalayas and East Asia. Organic carbon’s snow-darkening effect was relatively less but played a role in regions such as southeastern Siberia, northeastern East Asia and western Canada.

A video explaining this can be viewed here: https://youtu.be/4ns13IhmDm8.

Study shows links between major weather events

New research conducted by scientists from the Universities of Loughborough, Liverpool and Birmingham has found the UK’s most costly weather events are most likely to be linked rather than independent of each other.

The scientists analysed time-series of weather and insurance data, and identified intra-annual links between windstorms, shrink-swell damage (associated with drought), and flooding. The results show that the likelihood of both a major flood and windstorm event happening in a year could be up to one-and-a-half times more likely than caused by random chance – this includes pairing that occurs close in time, but also those occurring at different times throughout the year (for example, the extensive rainfall in winter and summer 2007).

The findings, published in IOP Science, could have implications for the insurance industry and agencies involved in planning our resilience to natural hazards, both of whom currently consider these major weather events independently of each other.

Dr Hillier explained that the analysis “demonstrates a systematic, long-term link between major non-synchronous weather events, which means that multi-hazard weather challenges such as the storms and flooding of 2013/14 could occur more often that we might expect. This is important because if two serious events happen in the same period, our ‘worst case’ becomes worse, and agencies and insurers need to have thought about this to put adequate plans in place.”

He added, “The next step is to extend the study to include more data and see how this pattern varies in strength and impact in different areas across the country, to understand what processes drive the linkages, and to identify any other correlations.”

The full article can be read here: http://iopscience.iop.org/article/10.1088/1748-9326/10/10/104003
Winter weather & transportation

Snow, ice, wind, storms, floods, fog - the winter season can bring a host of extreme weather which can impact on all transportation networks. As such, there is an obvious need for regular weather forecasts and updates (i.e. for informing gritting routes, applying speed restrictions etc).

Roads and railways are extremely vulnerable to extreme winter weather, yet they are integral to everyday life.

Ice is difficult to forecast since microclimates and local conditions can effect whether or not it manifests in a particular location. For example, exposed roads are more likely to develop ice overnight, whereas tunnels can result in temperatures remaining above freezing point. Marginal conditions - i.e. when temperatures fluctuate around freezing point - also prove difficult for forecasters, since it is hard to determine whether surface water will freeze or remain liquid. All these factors influence if, and indeed where, grit is laid.

Similarly, snow accumulation can be difficult to forecast - small changes in local temperatures can determine whether snow remains frozen and thus accumulates, or whether it melts. ‘Warmer’ urban areas and regions where elevation varies over short distances prove particularly problematic to forecasters.

As such, route-based forecasting and even real-time, localised data are being increasingly used in order to identify stretches of roads and rails requiring action. This ultimately reduces the resources spent on winter maintenance - such as gritting, de-icing, speed restrictions - in areas not requiring action, but more importantly, has the potential to save lives in circumstances where weather varies considerably, both spatially and temporally.

Furthermore, storms and strong winds can topple trees, high-sided vehicles and other infrastructure - this can lead to road and rail blockages, and even loss of life. Areas likely to be vulnerable to strong gusts (i.e. exposed, open roads) need to be identified and risk-assessed in conjunction with localised forecasts. In addition, flooding - particularly that which is enhanced by impervious surfaces ('pluvial flooding') - can also cause major problems on transportation networks, leading to the closure of certain routes following heavy rainfall.

Aviation is similarly affected by extreme weather but with additional issues, such as in-flight icing, strong cross-winds, and fog causing reduced visibility and ceiling height.

There are also cascading effects. For example most other service sectors, such as retailers, schools, delivery services, businesses etc, all rely on transportation for integral service functions, such as for enabling staff or students to get to work or school, or customers or deliveries to reach their destination. Thus the impacts are further reaching than simply having an effect on transportation networks - they have wider cascading economic implications.

Case Study: Snow and road chaos in Central England 2004

Sometimes, however, even good weather forecasts and advance warning can lead to travel chaos. In 2004 a quick succession of weather systems had a detrimental effect in central England, resulting in ice and snow rapidly accumulating on roads. A study by John Thornes (see this issue, page 14-15) in *Weather* (http://onlinelibrary.wiley.com/doi/10.1002/wea.22004/abstract) explored this event, explaining how two active cold fronts rapidly passed over the Midlands between 1500 and 1600 GMT. The first one was a polar front, producing heavy rain which washed away salt that had already been laid that morning. This rain then turned to snow as the second arctic front passed over, causing accumulations to develop which, once the sky cleared, froze hard, turning roads and footpaths into ice-rinks. Numerous motorists were forced to abandon their cars with many deciding to walk home (indeed, something the author was forced to do!), walk back to their offices to sleep overnight, or spend the night in their cars.
Wind is one of those elements we can feel when outdoors and see its effects such as on a stormy day with tree branches swaying or waves crashing on a beach. You may well have seen some type of anemometer, an instrument meteorologists use to record wind speed, generally these are attached on to a mast or on a rooftop. Some form part of an automatic weather station. There are a number of handheld instruments for measuring wind speed available on the market and details can be found in tWC issue 4.

However one of the latest and most innovative to come on the market works with your smartphone or tablet. Vaavud (Norse meaning Wind), http://vaavud.com/, a Danish company now offer two instruments and a free app for iOS and Android phones and tablets which you can download from the Google Play Store.

The Vaavud Mjolnir (in Norse mythology meaning the hammer of Thor who was the god of thunder) is designed to capture wind speed using two rotating cups along with internal magnets to communicate seamlessly with your device. Its unique design makes it pocket friendly and super rugged. Simply plug the instrument into the headphone jack of your smartphone or tablet, launch the app and it’s ready to measure the wind speed. The Vaavud Sleipnir (in Norse mythology meaning the eight legged horse of Odin who was the god of gods) is designed to capture wind speed using two curved blades. The internal optic sensor records 44,100 measurements per second allowing for extreme accuracy.

The free app has many clever features, once you have gone through some simple settings; you have a choice of knots, m/s, mph or Beaufort scale. If you are using the Mjolnir instrument then you will see a display similar to that shown in the photo above. When using the Sleipnir device, wind wirection is also displayed as above. Wind direction is obtained by using the internal optic sensor and algorithm to finding patterns in the rotation speed and combining this information with the phones compass.

Once you start the app, the instrument logs not only the current wind speed but the average along with the maximum gust and a nice moving graphic display in seconds as the data is recorded.

The app also has the ability to store your readings and recall them in the history screen (the app is available in English). Another clever feature of the software uses the GPS feature on your smart phone to display the location of your wind data recordings and is able to see other user’s data captured in the past 24 hours in the units chosen by the user (knots, mph etc).

Whatever your outdoor activity may be or if you take part in hobbies that are sensitive to the wind, especially wind speed, such as wind surfing, sailing, flying model aircraft, hang gliding or hillwalking then this device is for you. It doesn’t require any power and there are no electronic components to break down.

Both instruments can be purchased online (visit www.rmets.org/instrumentation).

The Vaavud Mjolnir wind meter turns your smartphone into a high-tech meteorological tool. It takes accurate wind readings, at wind speeds from 2 – 20 m/s (Up to 24 m/s on iPhone 5S and up to 48 m/s on some Android phones), with a precision of +/- 4%. It comes with a practical neoprene bag enabling you to take the instrument with you anywhere and costs about £35 depending on the exchange rate of the euro. The Sleipnir enables you to take accurate wind readings, at wind speeds from 2 – 40 m/s, with a precision of +/- 4%, AND measure the wind direction with a precision of +/- 4%. It also comes with a practical neoprene bag and costs around £37 , again depending on the exchange rate of the euro. Vaavud state that the features on both instruments have been tested by the Danish Institute of Technology in their professional wind tunnel to obtain the figures quoted above.

Richard demonstrating how easy the Vaavud is to use, allowing wind measurements to be taken anywhere.
A traveller’s guide to the Denmark
By Dr Catherine Jex, Science Journalist, ScienceNordic.com

Denmark, officially the third happiest place on earth and home to the Vikings, Legoland, and the now iconic Noma restaurant, which kick started the new-Nordic cuisine that has since swept across all of Scandinavia. It boosts a thriving countrywide cycling culture, is home to gripping Scandi-noir crime series like The Killing and The Bridge, as well as countless iconic design pieces, and that most Danish of all things - hygge.

Denmark was once at the head of a large seafaring kingdom that encompassed Sweden and Norway. Today, Denmark is a small country of just over 5.5 million people, though it still maintains two self-governing dependencies - Greenland and the Faroe Islands.

Nestled in the Northwest of Europe, Denmark’s climate is heavily influenced by the prevailing westerly winds that blow in off the Atlantic and the North Sea, and bring with them fronts, extratropical cyclones, and changeable, unsettled weather.

The warm Gulf Stream makes Denmark’s climate relatively mild for its northerly latitude, which is roughly the same as Hudson Bay in Canada or Siberia. Winters are typically mild and humid, though snow and late winter cold snaps are common, whilst summers are usually mild and changeable.

Denmark’s relatively flat landscape - the highest peak of Møllehøj is a modest 171 metres - ensures a rather homogenous climate throughout the country. The biggest climate contrast may be said to be between the windy and exposed west coast of mainland Denmark and the less exposed eastern islands, which includes the country’s capital, Copenhagen, and the small Island of Bornholm in the middle of the Baltic Sea.

Westerly winds bring mild Atlantic weather

Mainland Jutland is joined with Germany to the south and sits in the far west of the country, jutting up from the North Sea in the west, and the Kattegat to the east - the narrow stretch of sea between Sweden and Denmark, which marks the entrance to the Baltic Sea.

Northern Jutland bares the brunt of the stormy Atlantic weather, and the string of depressions that bring with them windy and rainy weather. In winter, this often falls as snow if it follows particularly cold and frosty weather. In summer, it brings cool and wet weather, so visitors should always be prepared.

Strong winds often accompany extratropical cyclones, and are common in this part of
Denmark. Gales are especially common in autumn and early winter when Scandinavia is cooling rapidly whilst southern Europe is still relatively warm.

Central Jutland is Denmark’s coldest (average temperature 7.4°C, 1961 to 1990) and wettest region (over 900 mm a year of rain, 1961 to 1990).

Average annual temperature for the entire country is 7.7°C (defined for the period 1961-1990), and rainfall is around 712 mm a year. But Denmark has become both warmer and wetter in recent decades: Average temperatures have risen to 8.8°C and average rainfall is 765 mm a year (both measured between 2001 and 2010). (Data provided by John Cappelen, Danish Meteorological Institute)

Jutland is perhaps most famous for its wide fjords, still thriving fishing industries, and the vast mobile sand dunes that line Jutland’s northern coast.

Visitors to the region should head to Skagen, a town and beachside area that marks the northern-most tip of Jutland and the whole of Denmark. Here you can dip your toes in the water where the North Sea crashes into the Baltic, and stroll along the beaches made famous by 19th century impressionist painters, referred to as the Skagen Painters, who flocked to the area to capture the unique light scattered by the sands and sea.

**Continental easterlies: a sharp contrast**

A network of bridges and ferries connect Jutland to the large islands of Funen and the largest island, Zealand, which is home to the capital city, Copenhagen, in the east of the country.

Denmark is made up of around 443 named islands that dot the North Sea, the Kattegat, and the Baltic Sea, and cement the maritime influences on both Danish culture and climate.

Copenhagen is arguably the design capital of Scandinavia. It is a bustling but small city, where tourists can soak up the history and atmosphere associated with some of Denmark’s most famous cultural icons such as novelist Hans Christian Andersen, or physicist Neils Bohr, and designers Arne Jacobson and Georg Jensen.

Sweden is also just a thirty-minute train ride away, across the Øresund Bridge made famous recently by the Scandi-noir crime series, The Bridge.

Though much less common than westerly winds, a change to easterly and southerly winds brings continental weather to the whole of Denmark. This means warm weather on long summer days, and cold, often dry, weather in winter.

Easterly winds are most common during late winter and spring, where cold and stable high pressure sits over Scandinavia and Russia and produces cold, windy weather for days or weeks at a time. An easterly wind in early winter meanwhile can mean increased rainfall or snow as the cold air passes over the still relatively warm Baltic Sea on its way to Denmark.

**Winter hygge: grey skies, snow, and candles**

Winter in Denmark is characterised by short and often gloomy winter days. Grey skies, rain and winds brought from the Atlantic often mean that Danes rush home after work to enjoy that most Danish of all concepts - hygge. Crudely translated as ‘cosiness’, hygge encompasses so much more than that. It is best described as a way to feel cozy, surrounded by family, friends, and of course, candles.

**Climate of Copenhagen**

Average min temperature range: -3°C in February to 14°C in July/August

Average max temperature range: 2°C in January to 22°C in July

Average driest month: March with 32 mm and 12 rain days

Average wettest month: July with 71 mm and 14 rain days

Average daily sunshine: 1 hours in November to January to 8 hours in May, June, July
Climate Sensitivity

How much warming results from increases in atmospheric carbon dioxide (CO₂)?

The amount of warming which would accompany increasing levels of carbon dioxide (CO₂) in the atmosphere – or ‘climate sensitivity’ - is at the heart of the scientific debate on anthropogenic climate change, and also the public debate on the appropriate policy response to increasing carbon dioxide in the atmosphere. Climate sensitivity, and its range of possible values, is a key input into the economic models that drive cost-benefit analyses and estimates of the social cost of carbon.

Climate sensitivity is often expressed as the temperature change in °C associated with a doubling of the concentration of CO₂ in the atmosphere. Two types, appropriate for different situations, are:

1. Equilibrium climate sensitivity (ECS) is an estimate of the increase in global surface temperatures after the climate system has fully adjusted to a doubling of CO₂ concentrations — a process assumed to take centuries or longer due to slow heat uptake by the oceans.

2. Transient climate response (TCR) is the estimated increase in global surface temperatures at the time when CO₂ doubling is reached during an increase of 1% per year. At this rate, doubling the CO₂ levels takes 70 years.

Estimates of both types of climate sensitivity are generally presented as a range due to incomplete knowledge of the behaviour of some aspects of the climate system. ECS is larger than TCR because of the longer timescales for adjustment.

ECS is a key variable in climate model predictions of eventual global warming many centuries after greenhouse gas concentrations have stabilised. In the fifth assessment report (AR5) of the IPCC (Intergovernmental Panel on Climate Change) the different lines of evidence were combined to conclude that the ECS is likely in the range from 1.5°C to 4.5°C. A ‘best estimate’ was not given in AR5 because of “a lack of agreement on values across assessed lines of evidence”. However, the IPCC AR5 had high confidence that ECS is extremely likely to be larger than 1°C, but with less confidence on the upper limit.
The range of estimates has been broadly consistent over the last three IPCC assessments, and confidence has increased because of the availability of more lines of evidence.

In many respects TCR is more policy relevant than ECS as it is a benchmark for the rate of change of temperature over the coming century. The recent IPCC AR5 report gave a likely range of 1°C to 2.5°C with TCR extremely unlikely to exceed 3°C.

Neither measure of climate sensitivity can be observed directly, but both can be estimated using climate models, or a combination of climate models and observations from recent or past climates. Studies based on observations from the instrumental period (1850-2014) combined with relatively simple models of the climate system generally arrive at moderate values for ECS and TCR. Estimates using more complex climate models generally result in higher estimates for ECS. The ranges of TCR estimated from past observed warming and from climate models agree better than for ECS, giving more confidence in projections of future temperature change over the 21st century than for longer term climate change.

Confidence in model estimates is limited by our ability to represent some key relevant climate processes. The usefulness of observations is limited because we do not accurately know all the factors that have influenced the observed climate, or to what extent their effect may differ from that of increasing carbon dioxide. In particular, it is difficult to quantify the proportion of climate change which is due to natural variability, independent of changes due to human activity.

Further reading:

1 In the language of the IPCC, ‘likely’ refers to >66% probability, ‘extremely likely’ refers to >95% probability, ‘extremely unlikely’ refers to <5% probability.
The climate is what you expect; the weather is what you get

In 1992 the world’s countries came together, in Rio de Janeiro, at what became known as the Earth Summit to agree the UN Framework Convention on Climate Change (UNFCCC), a treaty to address the global effects of climate change. The main objective of the treaty is to “stabilize greenhouse gas concentrations in the atmosphere at a level that would prevent dangerous anthropogenic interference with the climate system”.

You might be surprised that the treaty sets no emissions targets and has no means to enforce the stabilising or lowering of greenhouse gas emissions. So although it now has 196 countries as signatories, the objective is not in any real sense legally binding. Instead, what the UNFCCC does is to provide a framework for a series of protocols to set limits and targets. Probably the most famous of these, and perhaps any UN treaty, is the Kyoto Protocol. It was agreed in 1997 and now has 192 signatories, one notable exception being the USA, and Canada surprised many when it, in effect, withdrew in 2012.

The UNFCCC actually came into force in 1994. Each year since then the signatory countries have come together at a Conference of the Parties (COP) to discuss progress against the objectives of the UNFCCC. In many regards it will come of age when it meets in Paris in December 2015 and celebrates its 21st birthday.

The Convention also established a “subsidiary body for scientific and technological advice”. This is what we now know as the Intergovernmental Panel on Climate Change (the IPCC). I do not think it is possible to talk about any of these international bodies without an over enthusiastic use of acronyms! Acronyms aside, there are some interesting parts of the Convention which do not often get much coverage. For example, it says countries should “strengthen systematic observance and national scientific and technical research capacities and capabilities”. It also states countries should share and involve the public more, with greater “awareness programmes” and “access to information”, and develop many more opportunities for “public participation in addressing climate change and its effects and developing adequate responses”. In the UK we have undoubtedly strengthened the science programmes, and public awareness and information is probably as high as it has ever been. However, like in every other country I can think of, there has been little progress on how the public can more actively participate in tackling these challenges apart from replacing a few light bulbs.

It has never been more obvious for the need for systematic observations, and in particular long time series datasets to help us understand what is actually happening to our climate; the longer the better. This is somewhere the public, at least a small subset, has been very actively involved. In fact some of our longest and most valuable national datasets have been kept going by public volunteers, whether that is climatological data or biodiversity records like information on plant flowering times. We have also been able to make use of datasets not originally designed for climate studies. One outstanding example of this are the satellite measurements of stratospheric temperature over some 30 years, which, through the careful and considered work of scientists, have given us some real insights to changes in temperature at the top of the atmosphere.

One final reflection on the UNFCCC is that in all of its 24 pages it never once mentions ‘weather’. You might rightly say that in a document about climate why would we expect it to? But of course the implications of a changing climate are very much seen through our weather. It is Mark Twain who is famously credited with the quote that “the climate is what you expect; the weather is what you get.” I suspect he had little thought that he would summarise so well one of the biggest challenges in both predicting and communicating the impact of our changing climate. Understanding what the changes in the Earth’s climatology will mean for our weather and attributing changes in our weather to changes in our climate are both harder than you might think.

I understand why we use terms like global average temperature, a single number for the temperature of the globe, as it helps people understand the idea that the planet is getting warmer, but at a practical level it does not help much. It hides the fact that the distribution of temperature is very different across the globe for lots of reasons, like whether a part of the earth is closer to the sun or not in any particular season, whether the surface is land, water or ice, or what the cloud cover is like. Weather patterns are a very good way of moving heat, and moisture, around the planet. So if we change some of the thermal characteristics of our atmosphere and oceans, then it is obvious that weather patterns will also change.

When we try to assess whether changes in climate cause changes in weather we call these ‘attribution studies’. There are different ways to go about these, but they are all basically trying to do the same thing. They look to see how likely the weather events would have been without the change in climate compared to how likely they are with the changes.

Attribution studies have concluded it is likely that, on a global scale, cold days and nights have decreased and warm days and nights have increased as a result of changes in climate. The studies also show a connection to increases in the frequency of heatwaves, more than doubling heatwave occurrences in some locations.

We often talk in terms of temperature, for example ‘global warming’, but one could argue the most challenging impacts from a changing climate will be due to water, either having too little or too much of it at once. Unfortunately this has much greater uncertainty than conclusions we can draw about temperature. But recent studies have had more of a breakthrough, and we have begun to see that the heavier rainfall events are increasing, bringing with them increased flood risk.
Zero carbon world

It’s official! 2015 is likely to be the warmest year on record, over 1°C warmer than the pre-industrial era. This will be partly due to a strong El Niño event, during which global temperatures peak, and human induced global warming. With world leaders gathering in Paris in the latest attempt to secure global targets for reducing greenhouse gas emissions, it seems fitting then to think about alternative worlds – for example a zero carbon world.

Of course a zero carbon world is something of a misnomer... carbon is after all one of the building blocks of life, but in this context it means a world in which anthropogenic carbon emissions are dramatically reduced. At a recent meeting hosted by the Royal Meteorological Society, experts on global temperature, the carbon cycle, economics, health, policy and behaviour change exchanged views on if, and how, such a world was possible.

A major topic at the meeting was the effect of so-called INDCs. In the lead up to COP21 in Paris, countries have been making pledges to reduce their greenhouse gas emissions – promises known as ‘intended nationally determined contributions’ (INDCs). As at 29th November, 184 out of 196 parties had submitted their pledge, covering 98.4% of the world’s territorial emissions (excluding international aviation and shipping for which it is hard to assign emissions to any one country). The success of any new climate agreement, and the rate at which action is taken to tackle climate change after 2020, depends on these pledges, which vary from country to country. I was encouraged to see that although the INDCs would still be very far from a zero carbon world and unlikely to keep us below the critical 2°C global temperature change, they would make a significant difference.

Meeting those INDC pledges would need substantial reductions in greenhouse gas emissions from a combination of national policy changes, and individual actions. Key areas for decarbonisation include transport, buildings and energy. Improving fuel economy of the entire world-wide car fleet to that of the best hybrid vehicles (assuming decarbonised energy supply), changing all lights from incandescent bulbs to fluorescent bulbs, and larger scale initiatives based on existing technologies such as changing from coal to gas, nuclear fission, carbon capture storage, wind turbines and solar would get us part of the way there.

Policy experts suggested that deep decarbonisation is feasible but would need a strong legal basis in order to guard against political ‘mood swings’ – this is why COP21 agreements need to be legally binding. Potential offsets to the cost of moving to a low carbon environment could come from reduced health care costs from measures such as more active travel or reduced black carbon emissions.

To change the demand side of the equation, we need to change attitudes and habits relating to fossil fuel use. Social science researchers suggested that culture, identity and sense of place, as well as fairness, are highly relevant to individuals who are faced with decisions around climate change adaptation or mitigation. Climate policies and initiatives only have an impact if they are reframed in terms of individuals’ values around climate change. Interventions are apparently most successful if they occur at points in time when behaviour is changing for other reasons. Perhaps the Royal Meteorological Society can play a role in supporting decarbonisation by providing ideas for living a low carbon life for new members!

(Note: this article is based on discussions and presentations from a meeting hosted by the Royal Meteorological Society in November 2015: http://www.rmets.org/events/transforming-zero-carbon-world-challenges-and-opportunities)
I have always been interested in the impact of weather and climate on society and how the atmosphere is taken for granted by everyone despite it being such a precious resource. We breathe about 15 cubic metres of air per day and yet we pollute it freely! The atmosphere is so precious we need to manage it much more effectively!

I owe my early interest in the weather to my father who ran his own weather station in our garden in Batley, Yorkshire. Not only did he monitor the weather with a collection of homemade instruments; he kept a daily weather diary for over 45 years. He was meticulous with his observations and became the Batley weather ‘guru’ having his own weather column in a variety of local magazines and newspapers. Quite an act to follow! One of my first memories relate to him emptying the rain gauge contents into the measuring cylinder. What was he doing I wondered?

As I grew up in this atmospheric environment it is no surprise that I wanted to be a meteorologist! When my parents went away for a few days I would eventually be entrusted to carry out the daily observations and diary entries myself.

When we were studying the weather in Geography O-level at school, the teacher asked me to explain to the class the 10 basic cloud types and the likely accompanying weather. I soon realised that I probably knew more about the weather than the teacher and this got me thinking that I should write to the Met Office to find out what qualifications would be needed to become a meteorologist. They wrote back to confirm that maths and physics were the key — and so for A-levels I studied Maths, Further Maths, Physics and Geography and ended up doing Physics at Manchester University. However I was disappointed to discover that there was very little meteorology in the ‘quarks to quasars’ syllabus. So I ‘sat in’ voluntarily on a climatology module in the Geography Department given by Professor Percy Crowe whose book ‘Concepts in Climatology’ I immediately bought and got hooked.

I transferred to Geography after my first year and applied to work at the Met Office as a ‘vacation student’ at the end of my second year. I spent 6 very enjoyable weeks at the Met Office in Bracknell and this set the tune for my future career – as an academic.

I was given a project to improve the
forecast of road surface temperatures, to help improve decision making for highway authorities, as to when to salt the roads in winter (see this issue, page 6). I came up with a new methodology which was published in the ‘Meteorological Magazine’ in January 1972 – my first publication.

I then did the MSc in Applied Meteorology and Climatology at the University of Birmingham. A course I was later to spend 30 years helping to teach. During the MSc I successfully applied for a lectureship at University College London where I replaced Professor Tony Chandler as the Geography Department’s one and only Climatologist!

In trying to make climatology more popular I became interested in the skies of the artist John Constable and the writings of the art critic John Ruskin. Their visual perception of skies gave the ‘invisible’ atmosphere new meaning. This interest eventually led to a book on ‘John Constable’s Skies’ and the development of a new area of study: ‘cultural climatology’.

Meanwhile I was developing my interests in forecasting road surface temperatures and having returned to Birmingham I was involved in developing the concept of the ‘Thermal Mapping’ of roads using a vehicle mounted infra-red camera. Today virtually every road in the world that needs salting has been thermally mapped! We set up a ‘spin-out’ company ‘Thermal Mapping International’ which was eventually sold to Vaisala – a Finnish meteorological company.

I was later awarded the ‘FitzRoy Prize’ by the Royal Meteorological Society for services to the international winter maintenance of roads. We then set up another company ‘Entice Technology’ which forecast precisely when and where roads needed to be salted in winter using sophisticated energy balance modelling and easy to use mapping technology. This company was then sold to the Weather Channel in the United States.

Since then I have been fascinated by the concept of ‘Atmospheric Services’ to account for all the things that the atmosphere does for life on Earth. Twelve services have been identified varying from the air that we breathe to music to the natural global warming of 33 degrees Celsius.

I have now retired from the University of Birmingham and work part-time for Public Health England as a Principal Climate Change and Air Pollution scientist. My two main projects involve predicting the impact of severe weather on ambulance response times and monitoring air quality in the ‘New’ New Street Station in Birmingham. I am still researching the skies of John Constable and I am an active member of the Royal Meteorological Society’s Special Interest Group, WAM (Weather, Art and Music): www.rmets.org/about-us/special-interest-groups/weather-arts-and-music-wam
Weather Facts

Air in the narrow centre of a lightning channel can briefly reach 30,000°C

In April 1989 the Daulatpur–Saturia tornado in Bangladesh killed more than 1,300 people

Lowest temperature ever recorded on earth is -89.6°C at the Vostok in Antarctica on 21st July 1983.

1st November 2015 hottest November day since records began with 22.4°C at Trawsgoed, Wales

Are you passionate about weather? Do you want to be part of a community of like-minded weather enthusiasts?

Join the Royal Meteorological Society today!

For more information visit: www.rmets.org/membership

BBC WEATHER WATCHERS

The Royal Meteorological Society are the official partner for the BBC’s new crowdsourcing initiative - sign up at www.bbc.co.uk/weatherwatchers and submit your local observations and weather photographs!