Increasingly extreme future weather

Good news for British conversation: the weather will continue to give us something to talk about. *Jon Herbert* looks at complex relationships between climate and weather.

The butterfly that can theoretically alter the world's weather with a gentle flap of its wings could well be putting in overtime, given the number of extreme events the world witnessed during 2017 continuing into 2018.

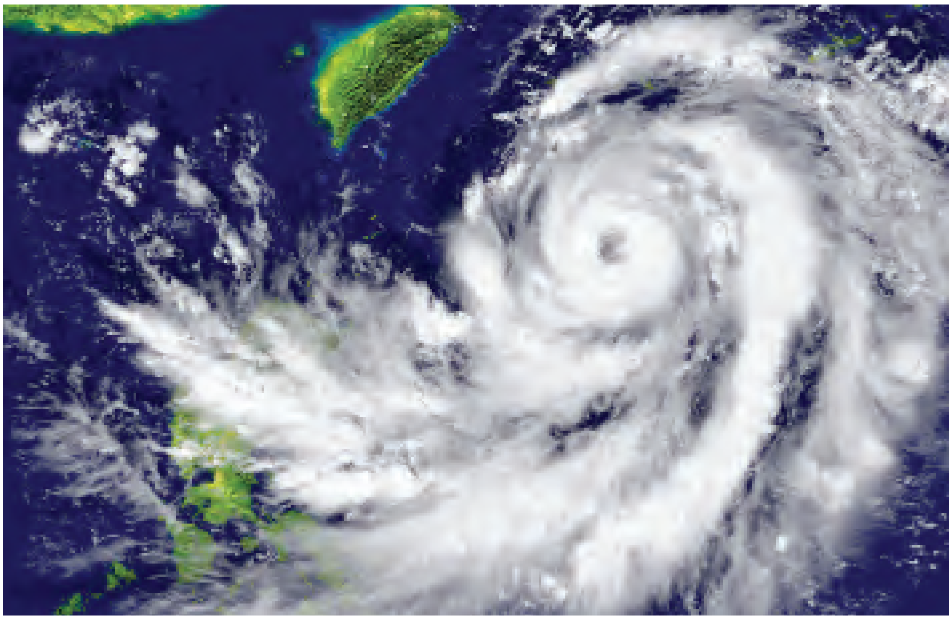
Deadly Asian typhoons. Caribbean havoc caused by hurricanes, their western hemisphere cousins. Wet autumn storms battering the UK from the south. Cold winter onslaughts from the north. Most may have a chaos theory element at their roots. However, the chaos they cause is definitely not theoretical.

Behind the poor old butterfly's labours — the principle that in complex systems like world weather, tiny variations can be amplified very quickly into huge impacts — research is uncovering much more about the actual mechanisms that seem to produce extreme weather.

US statistics show why this might be so important. Scientists at the Scripps Institution of Oceanography recently calculated that hurricane Harvey dropped 127 billion tonnes of water on Texas last August. Meanwhile, the US National Oceanic and Atmospheric Administration (NOAA) says 2017 was a record year for US losses from fires, hurricanes and other weather-related disasters: the total damage was $306 billion.

Some events that have a strong chance element are random and difficult to predict. An example is local air conditions over the Ethiopian Highlands that strengthen as they move westwards via low air pressure "atmospheric troughs" known as "tropical easterly waves". Picking up energy from the warming Atlantic, they produce monster tropical storms in the Caribbean. So hurricanes are born, some of which to the temperate north are increasingly hammering the UK.

Other events have deeper roots in the oceans that are more cyclical. Here, research is gradually uncovering more detail about their remote and global effects on the atmosphere year by year.



> "In the UK we have a tradition of being nonplussed by approaching bad weather events and caught out when they arrive."

UK in the firing line

Unfortunately, in the UK we have a tradition of being nonplussed by approaching bad weather events and caught out when they arrive. We also forget them quickly. As a result, we are generally poorly prepared for the next assault.

The Met Office's new policy of naming major storms in early autumn is designed to increase preparedness and make them and their effects more memorable. Who remembers Angus, Barbara, Conor, Doris and Ewan in 2016–2017? When the Met Office issued warnings in February 2017 for Storm Doris, its awareness score was 89%; 94% of responders reported that they found the severe weather alerts useful.

A major variant at the UK's latitude is the west-to-east flowing high-altitude jet stream that can drop huge volumes of warm ocean-derived rain on Gloucestershire one season, Yorkshire shortly after, Cumbria, Somerset, Lancashire and where else next? On a small scale, such as the size of Britain, it is still not possible to predict where and when the next 1-in-a-100-year floods could strike. On a larger scale, however, some inroads into the more extreme causes of weather are being made.

If not the frequency, then certainly the intensity of storms seems to be increasing, with the higher air and sea temperatures associated with global warming. This depends on how strength is defined. Faster winds, winds over a wider area, lower pressure at the storm's "eye", higher precipitation levels and more storm surges of the type that devastated New Orleans are all popular metrics used to describe the scale of humongous storms.

Rising sea levels and very high sea surface temperatures may have a dramatic effect. But these can't necessarily be attributed directly to global warming. What storms do have in common is that they are atmospheric disturbances which redistribute heat. They need moisture, an energy source and specific wind conditions to form and generate clouds, precipitation and winds.

Warm storms

However, storms take their power from latent or stored heat for which the oceans form a vast repository. This does suggest a link between global warming and increasing storm strengths. Put simply, a hotter atmosphere produces warmer seas which in turn can release their hidden energy quickly to fuel larger storms.

One study of sea surface heights using satellite data showed that hurricanes are now getting stronger faster than a century ago. Wind speeds are also some 5% higher than they were 20 years ago. At the same time, rising air columns within storms now hold 4% more water vapour than they did 25 years ago, again due to the extra heat energy present. Rainfall totals seem to be rising too, especially in tropical cyclones.

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Typhoons are tropical cyclones containing a low-pressure area spinning anti-clockwise around columns of rising warm air. These form in the western Pacific Ocean with winds of at least 75mph. They take their name from the Arabic word *tufan*, "great wind". Hurricanes in the eastern Pacific and Atlantic take their name from the Caribbean word *huracan*, "big wind".

The formation of tropical cyclones has several requirements that are now becoming more common, the main two being a cluster of thunderstorms, plus a body of water at a minimum of 27°C.

There is recent evidence that the destructive power of typhoons experienced in China, Japan, Korea and the Philippines has grown by 50% in the past 40 years due to warming seas. Continuous global warming is expected to make these even stronger, to the detriment of Asia's large coastal communities and dense populations.

Typhon Haiyan in 2013 killed at least 6300 people in the Philippines and affected 11 million more. Typhoon Nina dropped a metre of rain in one day in China in 1975, leading to 229,000 deaths and 6 million destroyed buildings. Tropical Storm Tembin in December 2017 added 200 more Filipino fatalities to this total caused by flooding and landslides.

Meanwhile, a 2016 study showed that typhoons in the northwest Pacific have been on average 12% to 15% more intense since 1977. In some regions, the proportion of category 4 and 5 storms doubled, and even tripled. Damage is caused by high winds, surges, intense rains and floods; a 15% rise in intensity multiplies destructive power by 50%. It also reaches further inland.

Sea surface temperatures in the Gulf of Mexico, where Storm Harvey intensified this summer, were recorded to be some 0.5°C–1.0°C warmer than current prevailing temperatures for the region. This is around 1.0°C–1.5°C higher than comparative measurements made between 1980 and 2010.

In the abyss

However, no global picture is complete without factoring in what is happening to the deep seas that cover 71% of the planet's surface.

One dramatic phenomenon now known to be linked to climate change is the cyclical variation in the Pacific Ocean known as the El Niño Southern Oscillation, and its La Niña counterpart. Both existed in the Holocene period 10,000 years ago and oscillate over several years, separated by a neutral phase. However, the speed of oscillation seems to be increasing with warmer oceans.

El Niño, caused by warmer-than-normal surface waters, suppresses Atlantic hurricane activity by reducing the natural upwelling of cool deeper water and increasing atmospheric stability. La Niña, the result of cooler-than-normal water, has opposite impacts in the Pacific and Atlantic. Cutting off cold sea water acting as a carbon sink leaves more atmospheric carbon dioxide (CO_2) to intensify global warming. Jointly, the two phases are responsible for extremes now associated not only with cyclical storms and wet weather, but also droughts and bush fires around the world.

A more immediate effect is that the prevailing trade winds that blow around the world from east to west change direction and become weaker. This allows western Pacific warmer waters to move towards the western coast of South America, disrupting the marine food chain. Fishing economies in countries like Ecuador and Peru suffer.

World impacts

The particularly cold winter of 1912, when Edwardian Antarctic pioneer Captain Falcon Scott and his exploration team failed to be the first to reach the South Pole, was an El Niño year. The ill-fated German 1941 military incursion into Russia, when troops had no winter clothing, also took place in an El Niño year. It has even been claimed that El Niño helped to sink the Titanic in 1912: excessive warming could have helped to break up the ice-pack that set free the fatal berg.

Jet stream — closer to home

One more piece of 2017 research is thought to have revealed a link between climate change and the jet stream circling the northern hemisphere that defines much of the UK's weather. Using climate modelling, Penn State University researchers studied a combination of some 50 international climate models probing specific scenarios that produce simulated data which can be evaluated easily.

The team found that extreme weather patterns form and persist when the jet stream becomes stationary, with its peaks and troughs locked in place. These usually disperse over time but under certain conditions are constrained by an atmospheric wave guide. The result is very large north–south amplitude swings in the jet stream as it circles the globe. This "rollercoaster" only forms when some six, seven or eight pairs of peaks and troughs around the Earth behave as a guide; north and south barriers are created that cannot be crossed.

Stefan Rahmstorf of the influential Potsdam Institute for Climate Impact Research (PIK) put this finding into context for long-suffering people on the ground by explaining that, "If the same weather persists for weeks on end in one region, then sunny days can turn into a serious heat waves and droughts, and lasting rains can lead to flooding".

Although models as a tool for forecasting individual extreme weather events are still coarse, they do reproduce largescale temperature changes. Real-world observations confirm this temperature pattern associated with extreme weather events in late spring and summer, and also that greenhouse gas rises are responsible for the increase. The next step is to look at future model projections to see if they can be confirmed by the researchers.

Carbon lies, damned lies and statistics

Against this background, the recent global track-record for reducing worldwide carbon emissions is hardly inspiring. What the 2016 figures identified was a CO_2 concentration of 403.3ppm (parts per million) compared to 400ppm in 2015.

The figures are based on measurements taken from weather stations in 51 countries around the globe that record CO_2, methane and nitrous oxide levels. The World Meteorological Organization (WMO) publishes figures that are the residual balance of the volume of gases emitted, minus those absorbed by the Earth's "sinks" — the seas, natural biosphere and planted forests.

Dr Oksana Tarasova, chief of the WMO's global atmospheric watch programme, was reported as having described the statistics as "the largest increase we have seen in the 30 years we have had this network".

Sea level and temperature El Niño rises across the eastern Pacific affect the amount of carbon in the atmosphere by causing droughts that limit how trees and plants absorb CO_2. Although human carbon sources have decreased recently, the historic cumulative total lasts for centuries.

The net result, according to the WMO report, is that the atmospheric CO_2 level over the past 70 years is about 100 times larger than at the end of the last Ice Age. The big unknown for scientists is coming to grips with unpredictable changes to the climate system. Unlike the past, when changes took place over tens of thousands of years, they are now expected to occur worryingly fast.

The last comparable period is said to have been the mid-Pliocene era between 3–5 million years ago where, with temperatures 2°C–3°C higher than now and sea levels elevated by 10m–20m as major ice-sheets melted.

Carbon dioxide is not the only problem. Methane mentioned earlier is a far more precocious greenhouse gas which has been detected in unexplained volumes recently, not only from the melting arctic tundra but also in the tropics and sub-tropics. Carbon isotopes in the methane are not fossil fuel derived. There is speculation that this is an as-yet-unknown climate change feedback effect.

Another eight-year study, this time from the BIOACID (Biological Importance of Ocean Acidification) project, finds that while some sea creatures, such as seaweeds, could benefit from the increased acidification CO_2 brings to sea water, almost all infant marine creatures suffer, with the risk of major feed web shifts.

Climate change, plus the other man-made impacts of pollution, coastal developments, over-fishing and agricultural fertilisers, are said to be to blame. Since the start of the Industrial Revolution, average ocean surface water pH values have fallen from pH8.2 to pH8.1. That is an increase of circa 26%.

Action this day

Without urgent action, extreme weather could kill an estimated 150,000 European citizens annually by the end of the century, and expose hundreds of millions more to heatstroke, heart and breathing problems, let alone flash flooding, food shortages and an increased risk of being killed by disease, infection, and rural ravages such as wildfires. ■

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