

# Certain uncertainty

A report that assesses a decade of extreme events provokes thoughts on weather, climate change and what is to come.

In July, the World Meteorological Organisation (WMO) released a report entitled 'The Global Climate 2001–2010: A Decade of Climate Extremes'. Its conclusions are based on a survey of 139 national meteorological and hydrological services (<http://go.nature.com/aqxso>). Although there has been much discussion of late on the recent hiatus in global warming, the WMO found that the decade accounts for nine of the ten warmest years on record, with 2010 being the hottest. 2008 was the exception and experienced a La Niña event — the cool counterpart to El Niño — but it is the warmest recorded La Niña year.

The complexity of the physical climate system makes it difficult to separate change from variability. In the most basic terms, the Earth's climate is powered by the Sun. Differential warming and the associated heat transport across the globe create ocean currents, the atmospheric circulation and the hydrological cycle of precipitation and evaporation. If only it was that simple to grasp. Study of the physical system needs to encompass each of these areas including their interactions and associated feedbacks.

The day-to-day weather and longer-term climate are different phenomena, although there are strong links between them. The interplay between the many facets of the climate system can have big impacts in the short term, affecting the weather. Take for example the northern jet stream — a key determinant of weather patterns in the Northern Hemisphere and a hotly discussed topic in Europe and the US. Climate scientists who gathered at the UK's Met Office in June pointed the finger of blame at variation in the Atlantic multi-decadal oscillation for a succession of washout summers, as had previously been noted by Rowan Sutton and Buwen Dong (*Nature Geosci.* 5, 788–792; 2012). The meeting also highlighted that a shift in the jet stream contributed to Europe's unusual seasonal weather over recent years.

The jet stream is driven by climate; it is created by the temperature difference between the cold Arctic region and the warmer low latitudes. When there is a large disparity, the jet stream is stronger and faster, meaning it runs straighter. However, the temperature difference has decreased in recent years because the Arctic is warming

more rapidly than the rest of the planet, resulting in a weaker and slower jet stream.

The decreased jet stream speed results in large north–south meanders. It is these shifts that produce unseasonal weather patterns over Europe/the Northern Hemisphere. If the jet stream sits to the north it brings the warm weather from the lower latitudes. Conversely, if the jet stream meanders to the south it can bring unsettled weather and colder temperatures.

The WMO report notes that 2010 was not only the warmest year on record, but also the wettest globally. Floods were the most frequent extreme events during 2001–2010, and this trend appears to be continuing; so far this year we have seen significant floods in eastern Australia, central Europe, India and Canada.

Weather is often at the forefront of the general public's mind, influencing their thoughts on climate change. But such anthropogenic effects cannot be considered in the short term. They are expected to manifest as changing patterns outside the normal range of variability, such as that associated with long-term natural climate cycles, and an increase in the frequency and intensity of extreme weather events. But attributing individual events, or even runs of such events, to climate change is ill advised without a deep understanding of underlying physical causes and an appreciation of the statistical probability of these events given long-term natural variability. For example, Timothy Hall and Adam Sobel (*Geophys. Res. Lett.* 40, 2312–2315; 2013) estimate that Hurricane Sandy was a 1 in 714-year event, but was it climate change related? Warmer sea surface temperatures and atmospheric blocking patterns (near stationary pressure fields associated with meanders in the jet stream) contributed to the size and strength of the storm.

The number of extreme events seems to be increasing. Work by Dim Coumou and Stefan Rahmstorf published last July (*Nature Clim. Change* 2, 491–496; 2012) investigated the link between climate change and extreme events of all types; some show strong relationships but for others the evidence is less conclusive. Christian Huggel and co-workers (page 692) consider this general issue of attribution in the broader context of the loss and damage related to

extreme weather events, including questions of risk and liability.

Returning to the 'hiatus' in global warming, the discussion on the slowdown in warming is often misconstrued in the media. It is not that warming has stalled, but rather that the rate of increase has not been as high as predicted. The reasons for this are not entirely clear, but may reflect uncertainty about climate sensitivity to greenhouse gas emissions and the cooling effect of small aerosol particles in the upper atmosphere.

Climate models use past observations and knowledge of dynamics to predict what may happen, with various degrees of confidence. The models are limited by the historical climate information that is available. Observational records vary in length and areal cover, with the Southern Hemisphere having fewer records than the Northern Hemisphere. Satellite records — despite providing global coverage — are short, with the first data being of sea surface temperature, dating back to 1967, and there are sea-ice records extending back to 1979. Indirect data for past climates, such as tree rings and ice cores, are available to expand the records back in time, but such proxy data need to be carefully interpreted.

Even armed with knowledge of the historical climate system and how driving mechanisms work, it is difficult to predict how it will behave on short and long timescales. Each component of the system will have uncertainties associated with it, which combine to reduce confidence in projections, and many research hours are dedicated to constraining them. Bodman and colleagues (page 725) use observations of the carbon cycle and climate to help constrain uncertainties in carbon cycle feedbacks. As observations increase, uncertainties should become smaller, but for now they remain stubbornly large, as noted by Chris Huntingford (page 704).

A good understanding of the climate system is essential to allow society to prepare for the future. Increasing populations, diminishing resources, changing weather patterns and extreme events in combination with water scarcity and changing crop yields will all put pressure on communities. The only sure thing is that the climate and weather in the coming years will continue to have a degree of uncertainty and surprise us. □