Global indicators for monitoring climate change, changing levels of risk, and the attribution of extreme climate events

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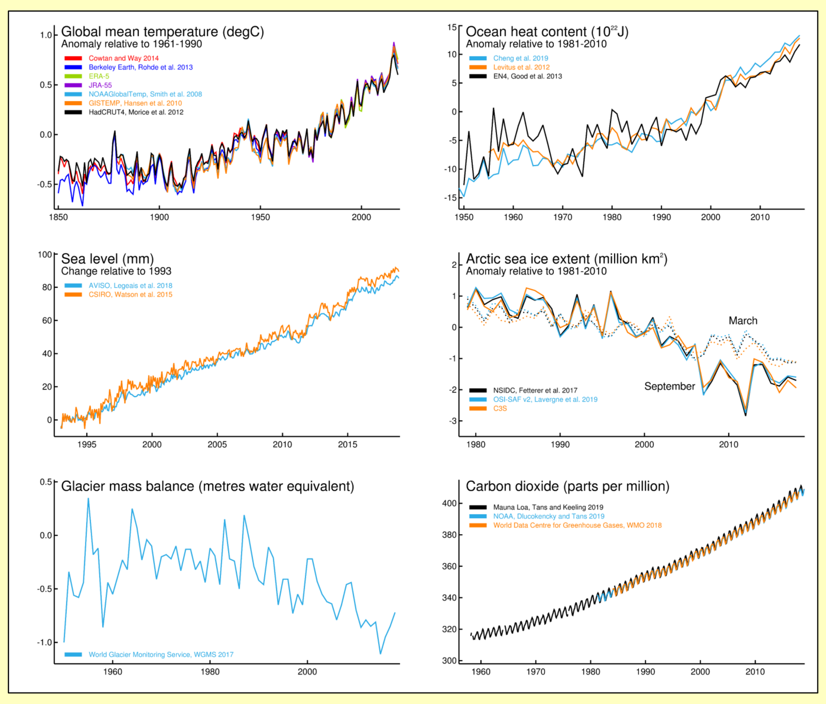
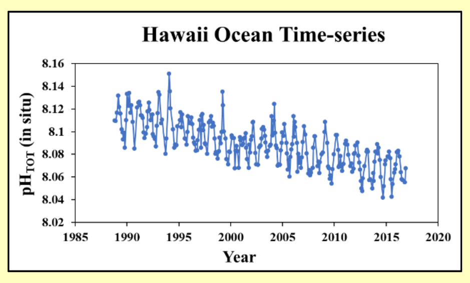
WORLD METEOROLOGICAL ORGANIZATION

The WMO Global Climate Indicators

WMO has defined a set of Global Climate Indicators for use in its regular publications. These indicators are a set of parameters which describe the changing climate without reducing climate to only temperature.

The seven *State of The Climate* indicators have been identified by scientists and communication specialists. They are complemented by a set of subsidiary indicators that provide additional information.





Time series of available data for the seven indicators: (left) global time series for six indicators from various data sets (source: John Kennedy, U.K. Met Office). (top right) Ocean acidification as measured by an ocean pH time series at a site near Hawaii.

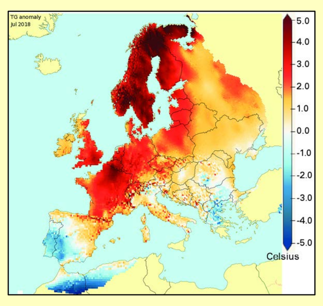
The availability, quality and timeliness of the data varies between the seven indicators. Global mean surface temperature is covered by several data sets and is usually available within 2 to 3 weeks of the end of the month. On the other hand, ocean acidification is currently only monitored through time series at a few specific points, while glacier mass balance data, which relies on annual end-of-summer surveys, is often a year or more in arrears. We have high confidence in estimates of global mean surface temperature and CO2 concentrations in the pre-industrial period, but for some other indicators, such as ocean heat content and ocean acidification, we have only very limited information prior to the last few decades.

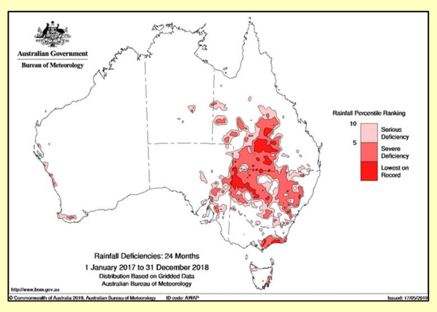
One key purpose of the indicators is to measure how much values have changed from a baseline period. This includes the 1850-1900 period which is used to represent the pre-industrial period (and hence how much temperatures have changed from it, the key indicator of the Paris Agreement), as well as more recent periods such as 1981-2010 (used in operational climate monitoring) and 1995-2014 (used to represent the recent period in IPCC). Not all indicators have data available for older baseline periods.

WMO scientists are currently preparing a paper which documents the Global Climate Indicators, the data sets which underlie them and key uncertainties, including how confidently we can determine how values in recent years differ from the pre-industrial period. This paper is expected to be submitted for publication later in 2019.

Extreme events of 2018

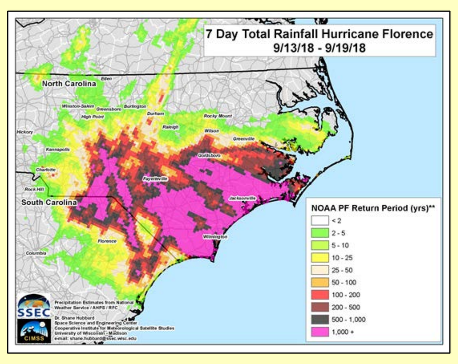
Many of the most significant impacts of climate change and variability manifest themselves through extreme events. Like most recent years, 2018 had many extreme events, leading to heavy casualties and/or major economic losses.

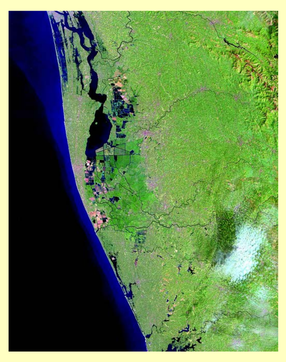


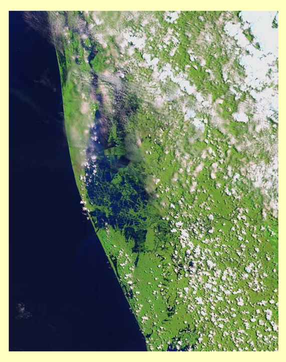


(Left) Temperature anomalies from a 1981-2010 average for Europe in July 2018 (Copernicus Climate Change Service) (right) Rainfall deficiencies for Australia for the two-year period 2017-18 (Australian Bureau of Meteorology)

Extreme heatwaves affected many parts of the world in 2018, including Canada, eastern Asia and Australia. Perhaps most significant was persistent heat in northern Europe in late spring and summer, with seasonal temperatures in many areas far above previous records. Many of these heatwaves were accompanied by severe drought, and sometimes wildfires.

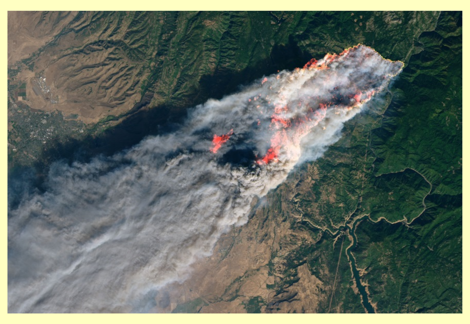


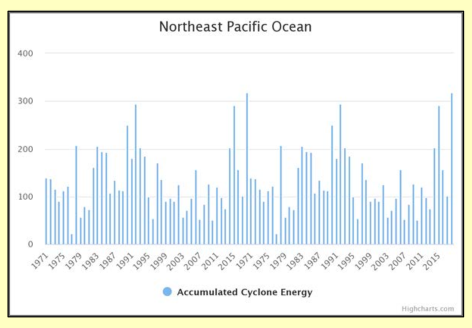




Left: total accumulated rainfall during Hurricane Florence. Right: Kerala, India, before (left) and after (right) severe flooding in August 2018.

It was an active tropical cyclone season in the Northern Hemisphere, especially in the northeast Pacific which had its highest recorded value of Accumulated Cyclone Energy (ACE). Hurricanes *Florence* and *Michael* both resulted in losses exceeding US$10 billion in the United States, whilst *Mangkhut* badly affected Hong Kong and Guangdong province of China, and *Jebi* was the strongest landfall in Japan since 1993. There were also major non-tropical cyclone floods in Kerala (India) and Japan, both leading to hundreds of deaths and billions of dollars in losses.





(left) Smoke plume from the Camp Fire in California, November 2018 (NASA Earth Observatory). (right) Northeast Pacific Accumulated Cyclone Energy (ACE). (Source: Colorado State University).

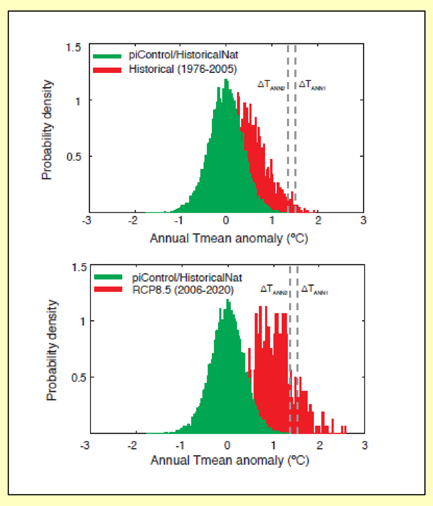
Some of the most destructive wildfires on record also occurred in 2018. A July fire in Greece had the heaviest casualties for a wildfire in Europe for many decades, whilst the Camp fire in California in November was the deadliest in the United States since 1918.

How has climate change affected the risk of extreme events?

Determining the extent to which the risk of an extreme event has been influenced by climate change is a developing area of science.

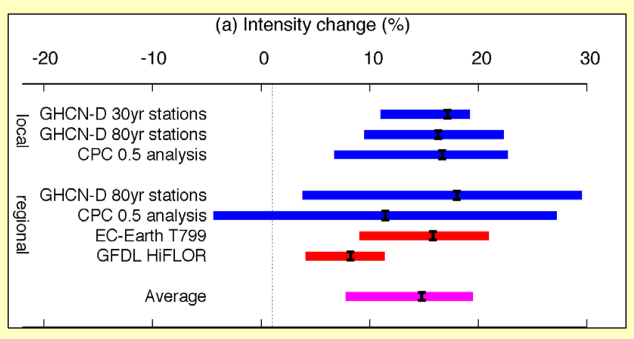
The major channel for publishing peer-reviewed studies in this field is an annual supplement to the Bulletin of the American Meteorological Society. This reports on a range of events, including heatwaves, extreme precipitation (high and low), extreme sea levels and fire weather. Over the period 2013 to 2017, 88 of the 128 events reported here show a significant anthropogenic influence on the event's occurrence.

The most robust and consistent results are for the anthropogenic signal in temperature extremes, with climate change increasing the risk of heat extremes and decreasing the risk of cold extremes. In some cases, particularly for temperatures averaged over large areas at a monthly or seasonal timescale, the extremes which have occurred in recent years would have been almost impossible in a pre-industrial climate.



Probability distribution of model-simulated Australian mean temperature anomalies: natural forcings (green), 1976-2005 historical forcings (red, top) and 2006-20 RCP 8.5 forcings (red, bottom). The record high 2013 value and the second highest value are shown with vertical dotted lined. From Lewis and Karoly (2014).

The only event for which an attribution study found a result opposite to that consistent with a warming trend was a frost event in Western Australia in 2016.



Changes in 3-day extreme precipitation totals in the U.S. Gulf Coast area (affected by Hurricane Harvey) from 1880 to 2017, from observations (blue), model simulations (red) and average (magenta). From van den Oldenborgh et al. (2017).

Results for hydrological events are less consistent. An increasing number of studies show some level of anthropogenic contribution to some high precipitation extremes, whilst noting that the full picture is often complex. Climate change can also make an indirect contribution, by influencing the chance of circulation patterns favourable to extremes. About half (21 out of 40) of published studies of extreme precipitation or drought show a significant anthropogenic signal.

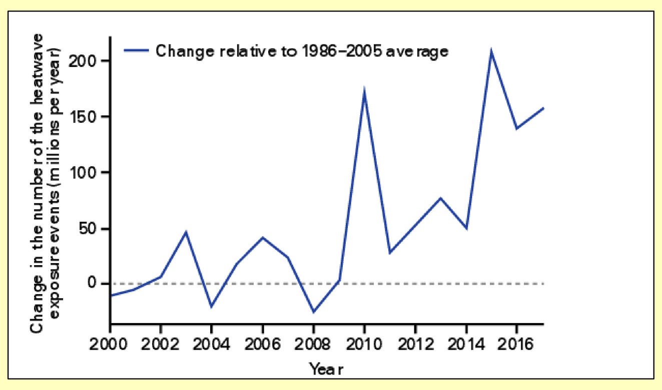
Because of the time lag involved in the peer-reviewed literature, few such studies of 2018 events are available to date. Some groups publish near real-time attribution results for certain events, particularly temperature extremes, for which attribution methods are relatively well-understood. The WMO Expert Team on Operational Climate Monitoring will be seeking to strengthen the capacity of WMO member countries to carry out operational attribution.

Impacts of extreme weather and climate events

Extreme weather and climate events affect many people around the world. In 2018, 62 million people were affected by natural hazards, most related to weather and climate, including 35 million by floods, while 2 million were reported as having been displaced by extreme events. In 2017, food insecurity associated with climate affected 59 million people in 24 countries in Africa. The WMO works closely with other UN organisations to monitor the impacts of extreme events.

Extreme weather and climate events can have particularly severe impacts in regions which are already fragile, for example because of poverty or armed conflict. Drought in the Greater Horn of Africa (left), especially Somalia, from 2016 to early 2018 contributed to 2.7 million people being in need of food assistance.

Extreme events can also expose unexpected vulnerabilities, even in developed countries. One of the impacts of the 2018 European drought was that levels on the River Rhine (above) dropped low enough to disrupt river transport, which is critical to many parts of the regional economy. The resultant losses contributed to negative economic growth in Germany in the later part of 2018.



Heatwaves are posing an increasing risk to human health in many parts of the world. Since 2000, the average number of people exposed to heatwaves each year (left) has increased by 125 million. This increase is expected to continue with further warming.

References

Lewis, S.C. and Karoly, D.J. 2014. The role of anthropogenic forcing in the record 2013 Australia-wide and spring temperatures. *Bull. Amer. Met. Soc.*, 95, 531-534.

Van den Oldenborgh and coauthors. 2017. Attribution of extreme rainfall from Hurricane Harvey, August 2017. *Env. Res. Lett.,* 12, 124009. DOI: 10.1088/1748-9326/aa9ef2.

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