CLIMATE CHANGE Opinion

Climate Change Indicators Are Not Enough

Extreme events capture the public's attention, but gradual climate shifts will more profoundly affect civilization and life on Earth. Scientists must get better at conveying this to the public.

The glacial lake near Cholatse Peak in the Everest region of Nepal grows in size as the glacier retreats, increasing the threat of an outburst flood. This is a visible example of interconnected changes on a global scale that often escape the public's attention until they produce an extreme event. Credit: Birendra Raj Bajracharya, Global Landscapes Forum, CC BY 2.0

By Alan K. Betts 14 July 2017

Dealing with climate change will require transforming both science and society in the coming decades. Society is struggling to accept the idea that Earth's climate will change radically this century unless we double or triple energy efficiency and rapidly shift from burning fossil fuels to renewable energy sources.

Scientists, who were trained to think of climate as 30-year averages, are struggling to understand a complex physical, ecological, and social system that is changing every decade. We are all faced with an uncertain future and mounting risks that could overwhelm our societies unless we change direction very soon [*Oreskes and Conway*, 2014].

Ironically, political and scientific interests alike can use our limited understanding of the complexity of the Earth system to rationalize waiting either for greater certainty or for more data. The desire of politicians to protect vested interests is clear, but scientific reticence is looking foolish as extremes of weather and climate increase. Earth science itself needs a paradigm shift.

A Shifting Baseline

Science deals with measurable quantities: We search for the clearest indicators of climate change that we can present to the public so that they can understand what is happening, face reality, and adapt. Clear examples are the shrinking of the Arctic ice cap in summer, the shortened duration of the Northern Hemisphere's cold season, and the rising sea level caused by warming oceans and the melting of grounded ice sheets.

Although year-to-year records show strong variability, the decadal trends are clear. The 60-year record of rising atmospheric carbon dioxide levels documented at the Mauna Loa Observatory in Hawaii and the satellite record of the summer melting of the Arctic ice cap are striking evidence of change.

But for society, slow changes can be ignored, especially if the interannual variability is large. In contrast, extremes of precipitation and flooding, strong hurricanes and storm surges, heat waves and severe drought cannot be ignored, although they can be dealt with as one-time events that are unlikely to recur.

Some belief systems may attribute these events to factors that are beyond our control. For science, extremes are challenging because they are statistically rare, and our statistics of extremes must necessarily use scarce data from the past.

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A still greater challenge is that because the climate has changed, the weather statistics from the past are no longer valid [*Milly et al.*, 2008]. So the public is confused when it hears that a disaster was a "100-year flood" when it knows there have been several similar floods in recent decades.

This dependence for comfort on statistics from the past that are known to be obsolete illustrates the challenge of facing and accepting climate change. Risks are mounting, and given the large costs and lead times needed to build new infrastructure, society needs guidance now to deal with extremes in the future. But the scientific community is struggling to find satisfactory models to deal with extremes outside the historic range [*Serinaldi and Kilsby*, 2015].

Those who would rather stall for time and argue that it is wise to wait for greater certainty will find instead that the climate system is moving into new unexpected regimes.

Understanding Interconnected Systems

Science is important in providing new understanding of the changing climate, especially in the face of false information provided by many vested interests. For example, it's critical for local communities in northern latitudes to understand that the rapid melting of the Arctic sea ice in summer in the past 30 years is driven by the same chain of processes that decrease snow cover and produce the warmer winters that they are experiencing.

Less snow or ice cover reduces the reflection of sunlight from Earth's surface in the daytime and also increases the evaporation of water into the air. This evaporation reduces the amount of heat that radiates into space because water vapor is a powerful greenhouse gas that traps heat within Earth's atmosphere. Less reflection of sunlight and more water vapor in the atmosphere increase the warming and melt even more snow and ice. As a result, snow cover on land acts as a fast climate switch [*Betts and Tawfik*, 2016]. In fact, the average temperature of winter increases directly with the decrease in the number of days with snow cover [*Betts et al.*, 2014].

Similarly, small lakes at northern latitudes provide local communities with clear, undeniable evidence of their warming winter climate [*Hodgkins et al.*, 2002; *Betts*, 2011]. For example, the freeze-up and ice-out (thaw) dates have been recorded over a span of decades for a small lake in northern Vermont called Stile's Pond. Since 1970, the winter frozen period has shrunk on average by 7 days per decade. But in recent years the variability between one winter and the next has been very large, and communities want to understand why.

To understand, they have to see the global picture (Figure 1), which contrasts the global mean temperature anomalies for January–February–March periods in 2015 and 2016. The Northern Hemispheric patterns are radically different between the 2 years. In 2015, there was a strong cold anomaly over eastern North America that lasted all 3 months, with 3 months of snow cover in northern New England. The strong temperature contrast between the cold land and the warm ocean produced a series of strong coastal storms that gave Boston a record 9 feet (2.7 meters) of snow. In 2016, this same region was very warm, with very little snow cover. Stationary patterns like this produce climate extremes, but the public needs to know that we cannot yet forecast them on seasonal timescales.

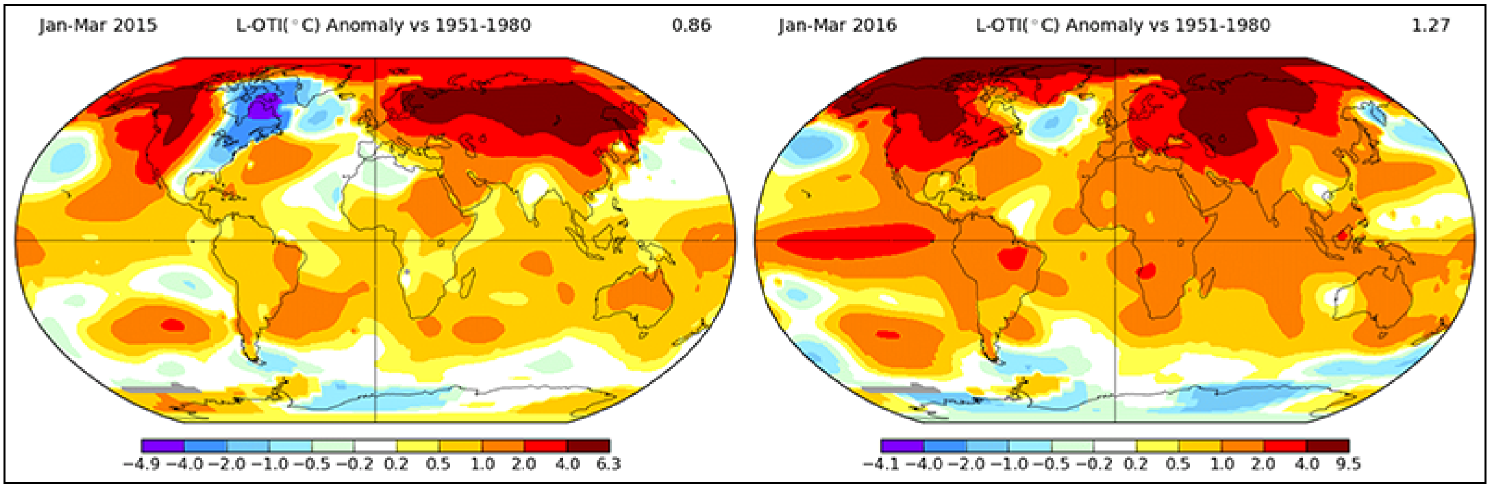

Fig. 1. Contrasting global temperature anomaly patterns for January–March of (left) 2015 and (right) 2016. Data are from NASA Goddard Institute for Space Studies.

The Challenge of Extremes

The public may simply accept these decadal climate changes coupled with large interannual variability. However, society reacts to extreme events. A large earthquake can lead to new building codes, even though such disasters are rare and generally unpredictable. A major flood from Tropical Storm Irene galvanized Vermont to rethink its river buffers and flood plain management.

Hurricane Sandy caused devastating flooding to New York City and New Jersey. The flood hazard assessment for New York Harbor [*Orton et al.*, 2016] estimated that similar flooding could recur in 260 years, but after a 1-meter rise of sea level that return period shrinks to a few decades. Remarkably, the certain rise of sea level in coming decades, which will continue for centuries, has not prompted the radical rethink of coastal management that is needed.

Choosing a Path Forward

Science, like much of society, clings to traditional ways: the deification of rationality, the objectification of the living natural world, and the dream that we have power and control over the natural world. All of these are partial truths, which we inherited from our traditions, but they are inadequate to deal with climate change.

Humanity is embedded in a deeply interconnected living Earth system, whereas science is funded by a society embedded in a consumer-market-growth economy based on the exploitation of the finite resources of the planet.

The shift from the arrogance of our own power to a frame where we understand and cooperate with the living Earth system will not be easy. Earth's physical climate and

The shift from the arrogance

ecosystem are simply adapting to changing atmosphere and oceans; climate change is accelerating. The 2015 Paris agreement is global recognition of the challenge we face, but the global transition that is needed will require a transformation of science as well as society in the coming decades.

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For scientists, this change will require a new willingness to engage strongly with society, from the local to the national and international levels. I have provided some suggestions on how scientists and lay people can engage to address this issue on my website. Climate change indicators are powerful tools, but they are not enough.

Acknowledgment

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