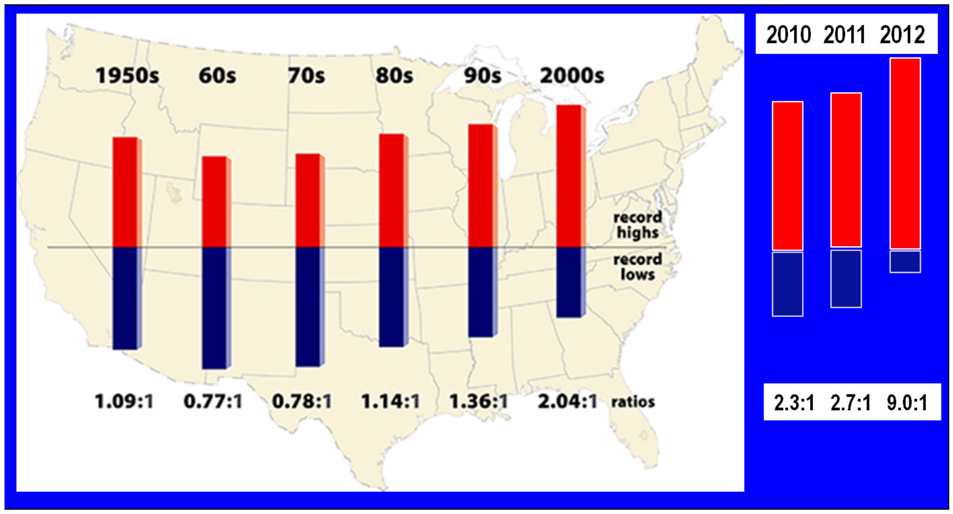
The New Normal

by Kevin Trenberth

The following commentary is the speech delivered by Kevin Trenberth, director of the National Center for Atmospheric Research (NCAR) Climate Analysis Section, at the NOAA 37th Climate Diagnostics and Prediction Workshop in Fort Collins convened October 22–25, 2012. This article was originally published in the Global Energy and Water Exchanges Newsletter in February 2013.



The ratio of record daily highs (red) to record daily lows (blue) at about 1,800 weather stations in the 48 contiguous United States from January 1950 to September 2009 (Meehl et al., GRL, 2009). Updated at right using NOAA data through June 2012; from climatecommunication.org

The answers I frequently get to the question "What is climate?" are commonly along the lines of "the average weather" or "climate is what we expect and weather is what we get." Firstly, those are statistical statements, and secondly, an average is obviously dependent upon the time of the average. If it is a very "long-term" average to avoid interannual variability, then by definition there is no climate change. This conundrum was recognized back in the 1970s when it was proposed that we speak about "climate states." This perhaps relates to what is now commonly known as a "base period." The classic base period is a 30-year period (as defined by the World Meteorological Organization) that traditionally gets updated. Hence we went from the 1961–1990 normal to the 1971–2000 normal, and now 1981–2010 is the "New Normal."

For the U.S., the new normal is about 0.3°C warmer than the previous normal in minimum temperature and 0.1°C for maximum temperature overall. Globally, the new normal for sea-surface temperatures (SSTs) is over 0.3°C warmer in many places, although some regions have cooled. We must remember that the new normal vs. the old is actually the 2000s minus the 1970s divided by three. So, an overall change of about 0.2°C is actually a warming between those decades of 0.6°C.

Too little attention has been paid to the fact that the normals are now changing a lot (i.e., climate change is happening). When we speak about how anomalous the recent climate has been, we often fail to factor in the differences associated with the new normal. This clearly colors perceptions about the degree to which things are indeed anomalous or abnormal.

Given all of these considerations, how then can we talk about climate change in a more enlightened way? We have "climate dynamics" as a growing field, and the climate is indeed continually varying and changing. Therefore, I suggest that simply using statistics is not good enough. Instead I suggest that we think about and define climate in a different way, and we do this from a physical standpoint.

"Weather" happens in the atmosphere. Most of it is internal to the atmosphere and arises from instabilities, whether it is convective instability that gives rise to clouds and thunderstorms, or baroclinic instability that leads to major cyclones and anticyclones, cold and warm fronts, and all the associated day-to-day weather.

"Climate" happens when the atmosphere interacts non-trivially with the rest of the climate system and externalities. The climate system consists not just of the atmosphere, but also the oceans, land, land-surface water, and cryosphere. The externalities include the orbit of the Earth around the sun, changes in the sun, changes in the Earth (e.g., continental drift), changes in the composition of the atmosphere, and anthropogenic effects. The diurnal cycle is a climate phenomenon and so is the annual cycle of the seasons. The El Niño–Southern Oscillation (ENSO) is a climate phenomenon as it is inherently a coupled phenomenon.

The atmosphere is always being conditioned by climate influences. Hurricanes are treated as a weather phenomenon, but it is increasingly clear that the cold wake churned up behind a hurricane through strong winds, causing mixing and huge surface fluxes that produce evaporative cooling of the ocean, play a vital role in the hurricane's subsequent development and track. Therefore, is a hurricane really a climate phenomenon or a weather phenomenon? What about the Madden-Julian Oscillation?

All storms interact with the Earth's surface, but for years we have run atmospheric models with specified fixed SSTs for numerical weather prediction (NWP). This means that we are indeed dealing with weather. However, increasingly the evidence suggests that this is actually a limitation in NWP and that having the

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SSTs respond and feed back into weather systems is essential, especially for second week weather forecasts and those beyond.

Issues of attribution and how we talk about it

All too often we hear meteorologists say, "it was due to the jet stream," "it was a thunderstorm that stalled," "it was the blocking anticyclone," or "it was tropical storm Irene," and so on. The explanation is given in terms of the weather phenomenon. That is, in fact, not an explanation or attribution at all! Instead, it is a description of the other aspects of the event: a more complete description of the phenomenon. The flood was due to the storm and the drought was due to the blocking anticyclone, etc.

As an explanation, the question should be, "why did that weather phenomenon behave the way it did?" In particular, what influences external to the atmosphere were playing a role and what climate factors were in play? Why did the blocking anticyclone last as long as it did and why was it so intense? Why was there enough rain in this weather system to cause flooding? As soon as we ask these different kinds of questions, we can talk sensibly about attribution and causes through the external influences on the weather. The main cause we can point to is almost always anomalous SSTs and the predominant influence of ENSO on anomalous weather patterns.

For example, we can say that the reason we had "snowmaggedon" in Washington, DC in 2010 is: (1) we had winter and there was plenty of cold continental air; (2) there was a storm in the right place; and (3) the unusually high SSTs in the tropical Atlantic Ocean (1.5°C above normal) led to an exceptional amount of moisture flowing into the storm, which resulted in very large snow amounts. It is this last part that then relates to anomalous external influences on the atmosphere.

Human effects on climate and weather

Without doubt, the SSTs in the Atlantic Ocean were warmer by about 0.5°C due to human influences, and so by itself that led to a 4 percent increase in moisture flowing into the storm. There is a lot of natural variability, and the Atlantic Multidecadal Oscillation and other things are in play, at times adding to and at times subtracting from the human component. Human-induced climate change occurs on long timescales, and 20 years is a reasonable estimate for noticeable significant changes. Once we realize that, it becomes clear that the proper way to think about this is that there is an underlying new normal of a warmer background that the shorter-term variability is superposed upon. Of course, this is linear thinking and some effects are clearly nonlinear, but it works quite well and clears the mind on how to talk about and think of human influences.

How big is the human component? The natural flow of energy through the climate system is equivalent to about 240 Wm^{-2}. The carbon dioxide radiative forcing is about 1.6, greenhouse gas forcing is about 3, and net forcing with aerosols is about 1.6 Wm^{-2}. Water vapor feedback roughly doubles that, so the net value is 1–2 percent of the natural flow. Of course the system has responded and the water vapor feedback is part of that response, so that the net imbalance in energy at the top of the atmosphere is closer to 1 Wm^{-2} or less than 1 percent. It is small on a day-to-day basis and negligible, but it is always in one direction. It builds up in time and accumulates; hence the main effect on climate and weather is not the instantaneous effect but the changed environment in which all weather systems are operating in the "new normal." In particular, the main memory is in the oceans, and the oceans have warmed by 0.5°C since the 1970s and the atmosphere above the oceans is warmer and moister as a result. On average the water vapor has increased by 4 percent since the 1970s over the oceans.

Since all storms reach out about four times the radius of their precipitating area to grab moisture and bring it into the storm, most storms are influenced by ocean changes. The storms are bigger in winter and a storm dumping snow in the Ohio River valley is bringing in moisture from 3500 km away from the Gulf of Mexico and the subtropical Atlantic. In summer the storms are smaller and there is greater dependence on land moisture and recycling.

What does the science community say? "You can't blame a single event on climate change." As a result the media loses interest and the public immediately turns off. What nonsense! When we break records like we did in 2012 in the U.S., at a rate of nine hot records to one cold one for the first 6 months, it is a clear signal of climate change. Just because we zoom in on one of those records or events doesn't make it otherwise. The odds are that most of these records would not have occurred without climate change! It won't be the same this year, but the odds are that similar events will occur somewhere (currently it seems in Australia). We are experiencing climate change in action.

We can talk about it in terms of changing odds, as many others have done. The odds have increased for these kinds of extremes to occur. But we can also talk about it in physical terms. In particular, we have a new normal! The environment in which all weather events occur is different than it used to be. All storms, without exception, are different. Even if 95 percent of them look just like the ones we used to have, they are not the same.

In that respect, another way of looking at it is to regard the new normal as a shift in the seasons. The amplitude of the annual cycle of SSTs is only 2°C in the Southern Hemisphere and up to 5°C in the Northern Hemisphere. So a 0.6°C increase is like moving the seasons by 1–3 weeks toward summer. The resulting weather is familiar but it occurs at a somewhat different time of year. In 2012 we had June temperatures in March in the U.S.! This means that we may be missing the core winter and in summer we venture into unknown territory.

This commentary is intended to provide food for thought and encourage readers to think seriously about how to better communicate these issues of changing climate and changing risk of extremes with climate change.