EDITORIAL OPEN

Extreme weather and climate

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Humans and ecosystems struggle to cope with extreme weather and climate conditions. The articles in this collection examine a range of weather and climate phenomena that are extreme either in their rarity, intensity, or both. Such research aims to help societies better anticipate and manage the challenges of the most impactful future weather and climate events, be they weeks or decades from now.

Scientific interest in weather and climate extremes has exploded in recent years. Extreme events such as hurricanes, heatwaves, and drought have always had disproportionate impacts compared to those of "everyday" weather. Now, however, scientists increasingly have more to say about expected changes in the frequency and intensity of such extremes. First, there is a growing understanding of how weather and climate extremes may change under anthropogenic warming. Second, there is a new and emerging ability to predict the likelihood of extreme weather over the next few weeks or month—the subseasonal-to-seasonal (S2S) time range. Interest in S2S forecasts, especially of extremes, has been the impetus for several national and international research programs as described by Mariotti and her colleagues.[1] Using a new forecast database from one of those programs, Vitart and Robertson[2] found compelling evidence that, even with current methodologies, heatwaves and tropical cyclone activity could be predicted weeks in advance.

S2S prediction of extremes also raises new questions, including how best to evaluate the quality of such forecasts. Ford and coauthors[3] proposed a seamless method for assessing the quality extreme heat forecasts from days to weeks ahead. This approach identified problems with currently available forecast models and possible strategies for their improvement.

Extreme rainfall along the west coast of North America is often associated with "atmospheric rivers" (ARs), which transport large amounts of moisture. Mundhenk and coauthors[4] report on the relationship between AR activity and the Madden-Julian Oscillation (MJO), which is known to be predictable several weeks in advance. This finding provides a scientific basis and method for skillful, subseasonal forecasts of AR activity and extreme rainfall. However, a warmer climate may lead to enhanced moisture transport by ARs. Lu and coauthors[5] examined climate projections and found that longer and more frequent landfalling ARs in the future would increase hydrological extremes over the northeastern Pacific and western United States by the end of the 21st century.

In other areas of the world, tropical cyclones are responsible for the most extreme rainfall events, and a warming climate is expected to increase rainfall rates.[6] Kossin[7] found that tropical cyclone translation speed has decreased globally by 10% since the middle of the twentieth century, and that this slowdown is likely to have led to increases in rainfall totals tropical cyclones, such as the unprecedented rainfall totals associated with Hurricane Harvey over Texas in 2017.

In addition to impacts on rainfall and tropical cyclones, warming oceans also impact ecosystems. Frölicher and colleagues[8] studied historical and simulated marine heatwaves (MHWs), finding that MHWs have already become more frequent, intense, and longer-lasting in the past few decades. This trend is expected to accelerate with further global warming, leading to adverse, and possibly irreversible, impacts on marine organisms and ecosystems.

Climate extremes have impacts in the soil as well as the oceans. Basto and coauthors[9] examined the natural soil seed bank where dormant seed are stored underground. Extended periods of drought had detrimental effects on grassland species above ground, but several species disappeared altogether from the underground seed bank after multiple years of drought.

Tornadoes are not rare in the United States, more than 1000 are reported each year, but they can cause loss of life and intense damage. Trapp and Hoogewind[10] find a new and unexpected robust statistical relation between tornado activity and Arctic sea ice extent (SIE) during boreal summer, with decreases in SIE being correlated with decreases in tornado activity. These findings are unexpected and contrast with studies that associate increases in extreme weather with declining SIE.[11] While the number of tornadoes reported in the United States has been fairly steady, Gensini and Brooks[12] find that where those tornadoes occur is changing, which has important implications for managing risk.

Weather and climate extremes pose scientific challenges as well as societal ones. Much of the recent progress can be traced back to improvements modeling and simulation. Extremes such as heavy rainfall depend on physical processes that occur on short time scales and small spatial scales. Increased computational power has allowed higher time and space resolution that provide more realistic depictions of extremes for numerical weather prediction and climate change projections. Nonetheless, uncertainties remain, especially at regional scales, as to how a changing climate will change the frequency and intensity of extremes, and continued efforts are needed to better understand the wide range of time and space scales that are involved in weather and climate extremes.

ADDITIONAL INFORMATION

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