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Weather and Climate Extremes: How Can We Improve Our Understanding?

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Introduction

Weather and climate extremes are major drivers of change in both natural and socioeconomic systems. Evidence points to substantial changes in many extremes with a warming world. These include increases in heat waves, droughts, warm days and nights. These increases in warm extremes have been and will be accompanied by decreases in cold extremes such as cold waves (Alexander et al. 2006, CCSP 2008). Similarly changes in precipitation include increases in heavy precipitation events in many areas (Groisman et al. 2005, CCSP 2008). Rather than document observed and projected changes in climate extremes, the focus of this paper is to examine a number of issues in examining changes in climate extremes, their impacts and adaptation strategies.

Vulnerability and Impacts

Understanding human and monetary costs due to weather and climate extremes is problematic. There is a lack of consistency between the various data bases compiled to link costs with the event. Comparing results from two such data bases shows large differences in monetary cost estimates for extreme weather events in the United States since 1980, although both point to an increase in standardized costs during this period. Clearly part of this increase is due to the fact that there is increasing population and infrastructure in harm’s way, but there is also likely a climate change component to this increase as well. There are similar issues with data bases documenting human mortality and morbidity with events. One recommendation in the U.S. Climate Change Science Program report on extremes (CCSP 2008) is to develop a data base linking extremes with their costs, both human and monetary costs.

Impacts of extremes depend on changes in both the natural and socioeconomic vulnerability. Vulnerability is determined by factors such as population shifts and dynamics, economic status, and adaptation measures such as changes in building codes and disaster preparedness. However, in some instances, adaptation measures can create major problems when extremes occur. For instance, developing flood control measures often leads to development in flood plains and can result in large losses of life and property when a major flood occurs.

Multiple and Compound Extremes.

As the climate warms some rare extreme events will occur more frequently and others less frequently. As we have more frequent events the time available for recovery after an event is reduced. Similarly the ability to adapt after an event is impacted as well. The result is that often recovery from one extreme event is still occurring with little time for adaptation before another similar extreme event occurs.

Compound extreme events are when two different extremes occur simultaneously in a given location. Just as extremes often are clustered together in time, climate conditions often are conducive to multiple types of extremes occurring at the same time. One example is the simultaneous occurrence of heat waves and air stagnation events. These events can place a large burden on the health of people who are particularly susceptible to these kinds of environmental conditions.

Issues in Analyzing Extremes

By definition climate extremes are rare events, thus there is a lack of observed climate data documenting these events. The data often have problems such as missing data, a lack of precision, or just are not available for a given region. If data are available they may not have the proper sampling resolution. For instance monthly averaged temperature data is readily available for most parts of the world for relatively long periods of time (e.g. since 1950), however to examine most extremes daily or even hourly data are necessary. Long-term data with this kind of temporal resolution is often not readily available even for regions with monthly averaged data.

Since extremes are rare, many researchers have defined “extremes” in such a way as to increase the number, but this results in events that may not be truly extreme. For example, studies examining the observed record have defined unusually warm or unusually cold days using the 90th percentile or 10th percentile resulting in 10% of the observations being unusually warm and 10% being unusually cold (Alexander et al. 2006). Similarly for precipitation heavy and extreme daily rainfall events have been defined using the 90th and 99th percentiles (Groisman et al. 2005).

Uncertainty is also an issue, particularly in examining some extremes such as changes in tropical storms or tornadoes. Tropical storm occurrence has been well documented during the satellite era (starting in the 1960s), since satellites provide complete spatial coverage. Also, aircraft reconnaissance documented most storms regardless of whether they made landfall. However, prior to the aircraft reconnaissance era (mid-1940s in the North Atlantic), some storms were never observed if they didn’t make landfall or were encountered by a ship. Thus there is very likely some under-reporting of the number of tropical storms in the early part of the 20th century. This has led to debate about how to adjust the observed record to account for these missing storms, and has impacted conclusions about whether there has been a detectable increase in hurricanes in the North Atlantic (see CCSP 2008). A similar problem exists in the USA for tornadoes. As population density has increased in tornado-prone areas, an artificial increase in the number of tornadoes has occurred. When adjusted for this increase in population, a strong increase in the number of tornadoes since 1950 disappears.

Lastly, to examine how extremes may change in the future, or to perform detection/attribution studies climate model simulations are required. Model output presents an additional set of problems since observational data and model simulations are not directly comparable at least not on a point by point basis. The observational data is usually from a climate observing station and represents one location, but model output is more representative of an area-average over the model grid box (Osborn and Hulme 1997). Furthermore, due to differences in the observed and model climatologies, especially for precipitation, future changes in extremes are usually defined as a change from the model climatology for some period such as 1971-2000. Different climate models are better at simulating some variables than others. For instance one model might do well in simulating precipitation in the tropics, but less well at simulating temperature, while another model does the reverse.

Recommendations

There are numerous issues that should be addressed in examining changes in climate extremes, their impacts and adaptation strategies. Following are a few recommendations that can help improve our understanding of these events.

Assuring continued capability for documenting climate system evolution

Essential climate variables are not being adequately monitored. How can we do a better job of detecting changes in essential climate variables such as temperature, precipitation, water vapor, etc.?

Determine best models

There are now well over a dozen global climate models. What models are best for what purpose? Can more reliance be placed on some models?

Improve regional projections

Climate change information is particularly important for local and regional decision making. How can we provide local-scale climate change information to decision makers?

Understand how the climate system responds to change

Earth system feedbacks to global climate change are not generally modeled. What potentially important effects are they ignoring?

Expand emission scenarios

Global carbon emissions now exceed the highest IPCC emission scenarios of future change. What can be done to better inform policy?

Monitor and project extreme events

Extreme events have tremendous impacts, yet many kinds of events are not being accurately observed and adequately projected. How can this be addressed?

Calculate thresholds

Crossing certain thresholds can lead to dramatic effects. Are there other thresholds we should be watching for?

Understand multiple stresses

Multiple stresses are common in society and the environment. And so we need to be prepared to deal with multiple stresses. Is climate change likely to produce other complex stresses that we should know about?

Quantify natural benefits

Nature provides us with many benefits such as food, fuel and fiber as well as many services we take for granted such as the cleansing of air and water. Are there benefits that we depend upon that are in jeopardy?

Assess impacts on human health and well being
Climate change is going to impact many aspects of human health and well being. Are these impacts being adequately measured and projected so we can take action before a problem gets too serious?

Determine reversibility of impacts
Some aspects of climate change appear to be irreversible. Are the irreversible impacts being monitored adequately so that we can take precautions?

Incorporate climate change in planning
We didn't pay much attention to climate change in the past and our country developed just fine. Why do we need to pay so much attention to it now?

Better understanding of evolving nature of adaptation
Climate is no longer constant. It will now continuously evolve so adaptation must also be dynamic. How can this adaptation be most effective?

Determine unintended consequences
We've seen food prices sky rocket around the world while more corn is being turned into fuel forcing corn growth for food onto more marginal land. This consequence was not widely discussed when ethanol policy was being debated. Are there other unintended consequences awaiting us?

Estimating costs and benefits of adaptation actions
The US Climate Change Science Program Unified Synthesis Product (CCSP 2009) outlines a number of adaptation strategies to help society cope with climate change in the context of other stresses. Do we have adequate methods to carry out cost-benefit analyses for such adaptation strategies?

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