1. INTRODUCTION

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One of us distinctly remembers in graduate school when a professor put the first ever satellite image of a tropical cyclone on the screen and explained various features of the storm. Then he proceeded to editorialize by pointing out that someone wrote his entire PhD dissertation based on this one image and how we started graduate school too late because all the easy projects have been done. Now with decades of definitely not easy scientific analyses under our collective belts, we can look back and realize how wrong the professor was. The "easy" science of decades ago only looks easy now because its results seem obvious. Their work was difficult then and our work is difficult now.

However, among the difficult work we have before us, a few grand challenges arise. These are challenges (i) that have specific barriers preventing progress, (ii) where targeted research efforts would have the likelihood of significant progress over the next 5–10 years, (iii) that have measurable performance metrics, (iv) that can be transformative, (v) that are capable of capturing the public's imagination, and (vi) that can offer compelling storylines (WCRP 2013). The World Climate Research Programme (WCRP) has identified six grand challenges that meet these criteria. Prediction and attribution of extreme events is one of them. It is gratifying to see that scientists from across the world are taking on this grand challenge. This includes the scientists that contributed to this collection of analyses, which assess the causes for 12 specific extreme events that took place around the world in 2012 (Fig. 1.1).

Extreme climate-related events command attention, and these are increasingly demanding prompt and credible scientific explanations. Last year's paper, "Explaining Extreme Events of 2011 from a Climate Perspective" (Peterson et al. 2012), which was published as an article in the July issue of *BAMS*, is, at the time of this writing, the "most read" article of the previous 12 months from any AMS journal (AMS 2013), attesting to a broad interest not only in the wider audience of the public, policy makers, and stakeholders, but also within the scientific community itself. One of the more interesting questions in response to the article was, "If you can attribute an event to specific forcings, could the event have been anticipated?" The answer depends on whether the particular forcing is itself predictable and whether the forcing altered the odds of the event happening or altered its intensity. From the practical perspective of being able to foresee the event and perhaps thereby mitigate its effects, the specificity with which forcing can explain the precise timing and location for an event is critical. Prediction and attribution are thus seen as related challenges. "Attribution of 2012 and 2003–12 Rainfall Deficits in Kenya and Somalia" (in this report) explains a drought that was, indeed, predicted and thereby facilitated prepositioning of humanitarian assistance.

Another interesting question that arose in response to last year's paper was, "Are you able to attribute extremes in terms of costs, both in money and in lives?" No attribution of costs or lives to climate variability and change was performed for last year's or this year's report. That work can come later and is quite complex involving both the domains of social scientists and atmospheric scientists. For example, it would require consideration of preparations before and during an extreme event and the extent to which such preparations were informed by the predictability of the event and the capability of the people affected to use such information. Additionally, the cost of past

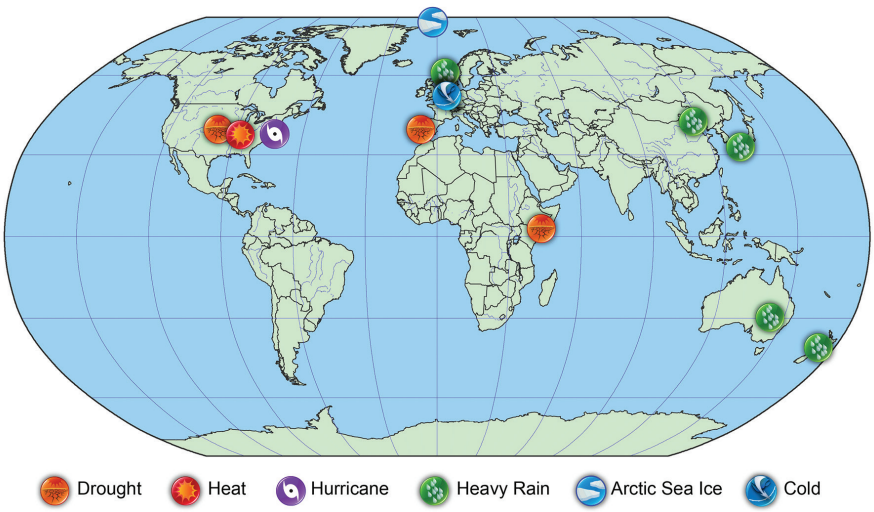

Fig. 1.1. Location and type of events analyzed in this paper.

adaption that reduced the vulnerability to an extreme event might need to be factored in as well. The work in these pages, however, can guide such analyses as well as help determine what the appropriate responses are to the particular extremes examined.

Extreme events, by definition, can be both rare at any given location and common in a global sense. In any one place, the chance of a once in a 100−year heat extreme is so rare that, in principle, it only occurs, on average, once every 100−years. This also means that, on average and with a stationary climate, every year one percent of the world would be expected to experience a once in a 100−year heat extreme and one percent a cold extreme. On the other hand, a few extremes such as an EF-5 tornado are rare even in a global sense, while other extremes such as loss of sea ice are limited to specific regions. The fact that "The Extreme March–May 2012 Warm Anomaly over the Eastern United States: Global Context and Multimodel Trend Analysis" (in this report) found 15.3% of the world experiencing its first, second, or third warmest year, while no grid box experienced their first, second, or third coldest year implies that expectations based on the assumption of a stationary climate may no longer be fully applicable.

Hurricane Sandy is an example of an extreme event that required many different factors to come together to create the major impacts that it did (NOAA 2013a). Therefore, Sandy is probably one of the most difficult extreme events of 2012 to fully explain. One group, however, assessed how a storm like Sandy occurring in 2012 may have inflicted greater impacts this past year than it would have had the sea level been at the height it was a half century earlier (see "Hurricane Sandy Inundation Probabilities *Today and Tomorrow*" in this report). Hurricane Sandy, given its meteorological complexity and its great importance as a societal watershed event in the United States, provides but one example of an extreme event from 2012 that will continue to require ongoing, careful, and detailed assessment.

Such work will be critical toward meeting the grand challenges outlined earlier, even if such studies do not appear in this issue owing to our tight space and time constraints. In order for papers in this report to be of interest to a wide variety of readers and not create an excessively long report, each submission was limited to 1500 words and two figures. Additionally, in order to go through peer-review and be published with the September issue of *BAMS,* while people are still interested in extreme events of the previous year, we had to submit our paper for peer-review by the middle of April. We moved the month of publication from July to September to help accommodate the research needs required for conducting thorough and rigorous assessments of events having occurred as recently as 2012. Yet, this timeline was still a considerable challenge for all the authors; as computers, software, and suddenly arising urgent demands on scientists' time do not always pay attention to one's plans. Despite these various constraining aspects, each paper has been subjected to critical peer-review.

In last year's paper, six groups explained six different extremes. This year 18 different groups wrote 19 analyses explaining 12 different extreme events. Because four extreme events, high temperatures in the United States; record low levels of Arctic sea ice; and heavy rain in northern Europe, and eastern Australia, were each assessed by at least two different groups, this year we gain the added benefit of being able to compare and contrast the results of different types of analyses and from that improve our understanding of the potential error bars associated with the grand challenge of extreme event attribution.