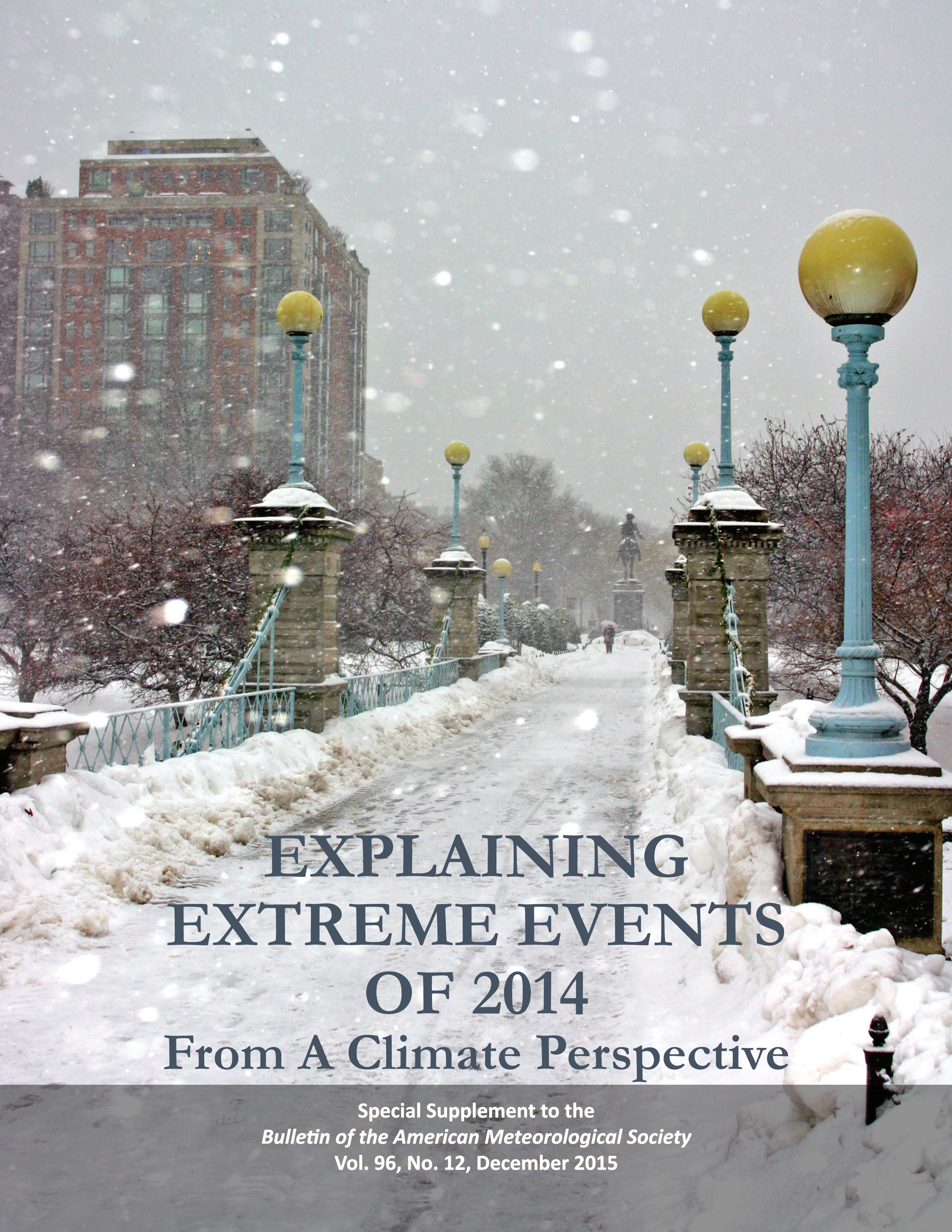

EXPLAINING EXTREME EVENTS OF 2014

From A Climate Perspective

Special Supplement to the
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Editors

Stephanie C. Herring, Martin P. Hoerling, James P. Kossin, Thomas C. Peterson, and Peter A. Stott

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ABSTRACT—Stephanie C. Herring, Martin P. Hoerling, James P. Kossin, Thomas C. Peterson, and Peter A. Stott

Understanding how long-term global change affects the intensity and likelihood of extreme weather events is a frontier science challenge. This fourth edition of explaining extreme events of the previous year (2014) from a climate perspective is the most extensive yet with 33 different research groups exploring the causes of 29 different events that occurred in 2014. A number of this year's studies indicate that human-caused climate change greatly increased the likelihood and intensity for extreme heat waves in 2014 over various regions. For other types of extreme events, such as droughts, heavy rains, and winter storms, a climate change influence was found in some instances and not in others. This year's report also included many different types of extreme events. The tropical cyclones that impacted Hawaii were made more likely due to human-caused climate change. Climate change also decreased the Antarctic sea ice extent in 2014 and increased the strength and likelihood of high sea surface temperatures in both the Atlantic and Pacific Oceans. For western U.S. wildfires, no link to the individual events in 2014 could be detected, but the overall probability of western U.S. wildfires has increased due to human impacts on the climate.

Challenges that attribution assessments face include the often limited observational record and inability of models to reproduce some extreme events well. In general, when attribution assessments fail to find anthropogenic signals this alone does not prove anthropogenic climate change did not influence the event. The failure to find a human fingerprint could be due to insufficient data or poor models and not the absence of anthropogenic effects.

This year researchers also considered other human-caused drivers of extreme events beyond the usual radiative drivers. For example, flooding in the Canadian prairies was found to be more likely because of human land-use changes that affect drainage mechanisms. Similarly, the Jakarta floods may have been compounded by land-use change via urban development and associated land subsidence. These types of mechanical factors re-emphasize the various pathways beyond climate change by which human activity can increase regional risk of extreme events.

34. SUMMARY AND BROADER CONTEXT

Stephanie C. Herring, Martin P. Hoerling, James P. Kossin, Thomas C. Peterson, and Peter A. Stott

This special supplement on explaining extreme events has now published 79 papers over the past four years. Over half of these papers have shown that human-caused climate change influenced an event's frequency and/or intensity in a substantial manner. It could be argued that because all of these events occurred in the context of a warmer world, there are impacts on all extremes whether or not the influence is detectable with current methods and available observations. While potentially true, to make attribution results informative to adaptation decisions, scientists must take on the questions of whether the risk or magnitudes of such events have increased or decreased, by how much, and what level of confidence supports the claims. This is the challenge the authors who have contributed to this report have taken on. The summary table (Table 34.1) is provided to give readers a general overview of their results. However, it is a highly simplified categorization of the results and does not include information about the size of the signal detected and the confidence in the results. This information is present within each individual report, and provides essential context for understanding and interpreting results for any individual event.

This year's report covers an unprecedented geographic range that looks at events from North America, South America, Europe, the Middle East, Africa, Asia, the western Pacific, Australia, and Antarctica. Also, this year event types include tropical cyclones, sea level pressure, sea surface temperature, forest fires, and Antarctic sea ice extent in addition to heat, cold, floods, and drought. We are pleased to see both the geographic distribution and event types continuing to expand.

Perhaps most importantly, this report and the field of event attribution science continue to provide evidence that human influences on climate have changed the risk of a wider class of extreme events. This year's report shows increasing risk of event types including forest fires in California and snow storms such as the one in Nepal. The analysis of California forest fire showed fires have been increasing recently in part because of drought. While the direct mechanism linking the 2014 fires to warming is not made, the authors do show that global warming likely will exacerbate fire intensity and risk in California in the future. This result is consistent with the most recent national climate assessment which concluded that western forests in the United States will be increasingly affected by large and intense fires that occur more frequently due to climate change (Melillo et al. 2014).

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As in past years, results for heat events continue to overwhelmingly show the impact of human caused climate change. Heat events in this report—from Argentina, Europe, China, Korea, Australia, and the northern Atlantic and Pacific Oceans—showed a climate change signal. Over the past four years only one (Cattiaux and Yiou 2012) out of 22 papers that looked at extreme heat events did not find a detectable climate change influence. While these reports represent a small and non-random sampling of extreme events from around the world, these results add to the preponderance of evidence that the climate change impact on heat waves is pronounced (Field et al. 2012; Melillo et al. 2014).

At the other end of the event spectrum, North America had a very unusual pattern of winter storms in 2013/14, in which there were far fewer storms than normal along the West Coast of the United States and more storms than normal in a region extending from central Canada down to the midwestern United States. This pattern of storm activity was linked to unusual winds in the tropical Pacific and not anthropogenic climate change. Analysis of specific features of the cold North American winters of 2013/14 showed different links to climate change. The daily variability of temperatures over the Midwest and eastern United States was found to be neither increasing nor decreasing as a result of climate change. Also, the seasonal extremes during the past winter were not unusual historically. However, it was found that seasonal mean cold conditions such as occurred over the greater Upper Midwest in 2013/14 are now 20–100 times less likely than in the late 19th century due to long-term warming.

Drought continues to be an event type where the results require significant context, and easy answers often remain elusive because of the many meteorological, hydrological, and societal drivers that combine to cause drought. In particular, conclusions about the influence of human-caused climate change could depend on whether authors looked at the role of temperature or precipitation on the drought. An analysis of precipitation deficits related to the devastating drought in southeastern Brazil did not find that human influences on climate played a role. Two analyses of the East Africa drought, using different methods, arrived at different conclusions regarding how human-caused climate change affected the reduced rainfall in 2014. Other drought mechanisms, especially human-induced surface warming, may have increased the drought's intensity. While no role for human-caused climate change was found in the large drought covering the Middle East and central–southwest Asia, the drought in Syria was determined to have been made worse because climate change reduced rainfall. No role for human-caused climate change was found for the droughts in northeast Asia or the record dry spell in Singapore.

This year only two events examining extreme precipitation showed climate change increased the strength and/or likelihood of the event (Table 34.1). Over the past four years this supplement has published 20 attribution studies on precipitation, and they are split between events that did and did not find human influences on precipitation events. Changes in precipitation trends are anticipated to vary by location (Field et al. 2012).

This year we are also excited to have several contributions on tropical cyclones (TC). The very active TC season in the Hawaiian region was shown to be substantially more likely due to human-caused factors, but was also affected by ENSO. The transition of Hurricane Gonzalo into a very strong extratropical storm that affected Europe was found to lie within the range of natural variability. However, one of these studies reflects the challenges with doing attribution work on these complex events. The anomalous TC behavior during the 2014 western North Pacific typhoon season could not be confidently linked to human factors with CMIP5 models because of the models' inability to capture the relevant environmental features.

Improving the communication of attribution research. As we have noted in past years, being able to deliver scientifically robust attribution statements about an extreme event in a timely manner is an important first step in supporting informed decision making. This year, in an effort to further improve the communication and understanding of attribution results, we have added some detail to the summary table (Table 34.1). Authors have identified whether their results show human influences changed the intensity and/or frequency of the event, because these results often have different implications for improving resilience to extremes. While the summary table is valuable for providing a high level view of the results in this report there is a great deal of information not included in the table. Each of the authors has been asked to provide a summary capsule of their findings which is included at the head of each contribution and provides a starting point for interpretation of their results. Also, it is important to point out that a conclusion of "no influence" may be because the methodology or observations are not sufficient to detect the influence. Despite the need to dig deeper into the individual analysis to make the most effective use of attribution results, the overarching result is clear: because of the on-going strengthening of human-caused climate change, investigations of the extreme weather we are experiencing around the world are increasingly likely to have a detectable human fingerprint found at the scene.

Future directions. As we look ahead to the future of this report a few very exciting opportunities are evident to the editors. Firstly, event attribution has the ability to become increasingly relevant to society by also considering other human-caused drivers of extreme events beyond the usual radiative drivers. For example, flooding in the Canadian prairies was found to be more likely because of human impacts on precipitation as well as land use changes that affect drainage mechanisms. Similarly, the Jakarta floods may have been compounded by land use change via urban development and associated land subsidence. These types of mechanical factors reemphasize the various pathways beyond climate change by which human activity can increase regional risk of extreme events. This type of information about the various ways in which human actions impact extreme events is critical for decision making.

Table 34.1. ANTHROPOGENIC INFLUENCE

ON EVENT STRENGTH †			
	INCREASE	**DECREASE**	**NOT FOUND OR UNCERTAIN**
Heat	**Australia** (Ch. 31) **Europe** (Ch.13) **S. Korea** (Ch. 19)		**Australia, Adelaide & Melbourne** (Ch. 29) **Australia, Brisbane** (Ch.28)
Cold		**Upper Midwest** (Ch.3)	
Winter Storms and Snow			**Eastern U.S.** (Ch. 4) **N. America** (Ch. 6) **N. Atlantic** (Ch. 7)
Heavy Precipitation	**Canada**** (Ch. 5)		**Jakarta****** (Ch. 26) **United Kingdom***** (Ch. 10) **New Zealand** (Ch. 27)
Drought	**E. Africa** (Ch. 16) **E. Africa*** (Ch. 17) **S. Levant** (Ch. 14)		**Middle East and S.W. Asia** (Ch. 15) **N.E. Asia** (Ch. 21) **Singapore** (Ch. 25)
Tropical Cyclones			**Gonzalo** (Ch. 11) **W. Pacific** (Ch. 24)
Wildfires			**California** (Ch. 2)
Sea Surface Temperature	**W. Tropical & N.E. Pacific** (Ch. 20) **N.W. Atlantic & N.E. Pacific** (Ch. 13)		
Sea Level Pressure	**S. Australia** (Ch. 32)		
Sea Ice Extent			**Antarctica** (Ch. 33)

† Papers that did not investigate strength are not listed.

†† Papers that did not investigate likelihood are not listed.

* No influence on the likelihood of low rainfall, but human influences did result in higher temperatures and increased net incoming radiation at the surface over the region most affected by the drought.

** An increase in spring rainfall as well as extensive artificial pond drainage increased the risk of more frequent severe floods from the enhanced rainfall.

*** Evidence for human influence was found for greater risk of UK extreme rainfall during winter 2013/14 with time scales of 10 days

**** The study of Jakarta rainfall event of 2014 found a statistically significant increase in the probability of such rains over the last 115 years, though the study did not establish a cause.

	ON EVENT LIKELIHOOD ††			Total Number of Papers
	INCREASE	DECREASE	NOT FOUND OR UNCERTAIN	
Heat	**Argentina** (Ch. 9) **Australia** (Ch. 30, Ch. 31) **Australia, Adelaide** (Ch. 29) **Australia, Brisbane** (Ch. 28) **Europe** (Ch. 13) **S. Korea** (Ch. 19) **China** (Ch. 22)		**Melbourne, Australia** (Ch. 29)	7
Cold		**Upper Midwest** (Ch.3)		1
Winter Storms and Snow	**Nepal** (Ch. 18)		**Eastern U.S.**(Ch. 4) **N. America** (Ch. 6) **N. Atlantic** (Ch. 7)	4
Heavy Precipitation	**Canada**** (Ch. 5) **New Zealand** (Ch. 27)		**Jakarta****** (Ch. 26) **United Kingdom***** (Ch. 10) **S. France** (Ch. 12)	5
Drought	**E. Africa** (Ch. 16) **S. Levant** (Ch. 14)		**Middle East and S.W. Asia** (Ch. 15) **E. Africa*** (Ch. 17) **N.E. Asia** (Ch. 21) **S. E. Brazil** (Ch. 8) **Singapore** (Ch. 25)	7
Tropical Cyclones	**Hawaii** (Ch. 23)		**Gonzalo** (Ch. 11) **W. Pacific** (Ch. 24)	3
Wildfires	**California** (Ch. 2)			1
Sea Surface Temperature	**W. Tropical & N.E. Pacific** (Ch. 20) **N.W. Atlantic & N.E. Pacific** (Ch. 13)			2
Sea Level Pressure	**S. Australia** (Ch. 32)			1
Sea Ice Extent			**Antarctica** (Ch. 33)	1
			TOTAL	**32**

Also, in the past four years we have seen huge strides in the ability of event attribution methodologies to be carried out in a routine manner. In particular, attribution of heat events now relies on several established methodologies. And much like other routine analysis, such as an operational seasonal forecast, statements made about heat events using these methods do not necessarily need to go through the peer-reviewed literature to be considered credible (Met Office 2014). However, heat events are unique in this respect and we hope this report can continue to drive analyses of other extreme event types in this same direction.

Finally, of the 79 papers from the past four years, 32 are in this year's report. The annual growth in the report speaks to both the increasing interest and broadening scope of attribution science. As we look ahead to future explaining extreme events reports, we will continue to look for opportunities to serve the detection and attribution community, and help the results of this body of research become increasingly relevant to society.

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