A photograph of a snowy park path, likely in Central Park, New York. The path is covered in a thick layer of snow, with footprints visible. On either side of the path are ornate blue and gold lampposts. In the background, a large brick building is visible. The sky is overcast and it appears to be snowing.

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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FRONT: ©iStockphotos.com/coleong—Winter snow, Boston, Massachusetts, United States.

BACK: ©iStockphotos.com/nathanphoto—Legget, California, United States – August 13, 2014: CAL FIRE helicopter surveys a part of the Lodge Fire, Mendocino County.

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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.

10. EXTREME RAINFALL IN THE UNITED KINGDOM DURING WINTER 2013/14: THE ROLE OF ATMOSPHERIC CIRCULATION AND CLIMATE CHANGE

NIKOLAOS CHRISTIDIS AND PETER A. STOTT

Extreme winter rainfall in the United Kingdom becomes eight times more likely when the atmospheric circulation resembles winter 2013/14, whereas anthropogenic influence is only discernible in extremes with a shorter duration.

Introduction. The winter of 2013/14 in the United Kingdom was characterized by an exceptional clustering of vigorous storms driven by the North Atlantic jet stream. The jet stream, in turn, gained momentum from this sequence of low pressure systems and was about 30% stronger than in recent decades (Slingo et al. 2014). The succession of deep depressions triggered tidal surges across coastal parts of the country, while the sustained rainfall over saturated ground culminated in widespread floodplain inundations, pronounced river flows, and record accumulated runoff totals (Huntingford et al. 2014). Coastal erosion and extended flooding led to damage in transport infrastructure and to business and residential properties and cost the U.K. government more than GBP 560 million in recovery schemes (DCLG 2014).

The positioning of a more southerly storm track increased the amount of moisture steered towards the United Kingdom over the winter season. Apart from a possible contribution from the positive phase of the North Atlantic Oscillation, possible drivers of the severe winter weather originating in the tropics have also been identified. The strengthening of the Atlantic jet stream may, for example, be linked to anomalously high precipitation in the West Pacific akin to La Niña conditions via Rossby wave interactions (Ineson and Scaife 2009) and the establishment of a pronounced temperature gradient between North America and the tropical Atlantic (Palmer and Owen 1986). The strong westerly phase of the Quasi-Biennial Oscillation during boreal winter may be another possible contributor to excessive storminess in the United

Kingdom (Marshall and Scaife 2009). Although an increase in the number of deep winter depressions driven to the United Kingdom from the mid-latitude North Atlantic has not been established, new evidence suggests an increase in their intensity since the 1870s (Wang et al. 2013).

The aspect of the extreme event that we focus on in our study is rainfall. Persistent storminess throughout winter resulted in the highest rainfall amount averaged over the entire U.K. land area since 1931, as estimated with the HadUKP observational dataset (Alexander and Jones 2001). Here we consider a wider U.K. region (10°W–2°E, 48°–60°N) that is better resolved by global climate models. Rainfall data from the NCEP–NCAR reanalysis (Kalnay et al. 1996) indicate that 2013/14 was the wettest winter in the region (Fig. 10.1a) since the beginning of the record in 1948. In addition to the seasonal mean, we also employ an index for shorter events (R10x), defined as the wettest period during the year over 10 consecutive winter days. Estimates of R10x with reanalysis data also show a maximum in 2013/14 (Fig. 10.1b). The reanalysis data used here are found to be in good agreement with HadUKP. Emerging evidence suggests an increase in the frequency and intensity of extreme U.K. rainfall (Jones et al. 2013; Maraun et al. 2008), consistent with the detection of human influence on changes in extreme precipitation over larger spatial scales (Zhang et al. 2013).

Our study investigates how the interplay between anthropogenic forcings and the circulation pattern prevalent in winter 2013/14 (Fig. 10.1e) may impact the likelihood of extremely high precipitation (seasonal and R10x) in the U.K. region. We set out to answer two questions: 1) Are rainfall extremes more likely under a persistent southwesterly flow? 2) Given the characteristic winter circulation pattern, does human influence favor the occurrence of extremes? A

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FIG. 10.1. Rainfall in the U.K. region (10°W – 2°E , 48° – 60°N). Panels (a)–(d) illustrate the time series of the regional DJF rainfall (a,b) and the R10x index (c,d). Time series with data from the NCEP–NCAR reanalysis are plotted in black, and 2013/14 is marked by an asterisk. Time series from model simulations with all forcings (ALL) and natural forcings (NAT) only are shown in orange (a,c) and blue (b,d) respectively. The means of the ALL and NAT simulations are represented by the red and dark blue lines respectively. The vertical dotted lines mark the last 20 years of the model simulations used in the study to represent the recent climate. Panels (e)–(f) depict the geopotential height (red lines) and wind (blue arrows) winter mean anomalies at 500 hPa relative to the climatological period 1961–90. The map shown in panel (e) is constructed with NCEP–NCAP reanalysis data for 2013/14 and the one in panel (f) with the mean of winters extracted from the last 20 years of simulations with the ALL experiment, for which the circulation pattern correlates well (coefficient greater than 0.6) with the 2013/14 reanalysis pattern over the region marked by the black box.

complementary analysis with an atmosphere-only model driven by prescribed oceanic conditions indicates that anthropogenic climate change increased the chance of getting an extremely wet winter in 2013/14 in parts of the United Kingdom (Shiermeier 2014). Following up, we employ coupled models that span the full range of possible oceanic conditions in

an attempt to disentangle the possible contributions from synoptic conditions and externally forced factors.

Data and Methods. We estimate changes in the frequency of extreme rainfall based on simulations with models that contributed data to the Coupled Model Intercomparison Project Phase 5 (CMIP5). We use two multimodel ensembles of simulations, one with the effect of both natural and anthropogenic forcings and one without the anthropogenic effect. A total of seven models are employed for which both types of experiments are available (details in online supplemental material). The models provide 43 simulations with all forcings (ALL) and 33 with natural forcings only (NAT) that end in 2012. Values of R10x are estimated with fewer simulations, as two of the models did not provide the necessary daily rainfall data. As in previous work, a bias correction is applied to the data of each model to bring the simulated rainfall averaged over a climatological period (1961–90) in agreement with the reanalysis (Christidis et al. 2013). Model evaluation assessments (online supplemental material) indicate that the ALL simulations used here produce realistic rainfall distributions and return times of extreme seasonal and 10-day long events. Modeled time series of winter (December–February, or DJF) rainfall and R10x generally encompass the range of the reanalysis data (Figs.

10.1a–d), though the DJF maximum of 2013/14 is only exceeded once in a single NAT simulation. No notable long-term change is evident in the time series. However, we find that the least-square fit to the ensemble mean of the model simulations yields trends that are significantly different than zero for both DJF and

R10x, but only when human influence is accounted for.

Samples of DJF rainfall and R10x are generated by selecting the last 20 years of the simulations (marked by the dotted vertical lines in Figs. 10.1a–d), as a proxy of the near-present-day climate. Ideally, the selected period should be centered on the year of the event, but this is not possible as the NAT simulations are not extended beyond 2012. Given the small trends in rainfall, years of the recent past should represent current climatic conditions sufficiently well, as also assumed in other studies (Christidis et al. 2015). We next partition the modeled winters between those that correlate well with the 2013/14 circulation patterns over a wider U.K. region shown in Fig. 10.1e (correlation coefficients above 0.6) and those with weaker correlations. We thus create high- and low-correlation ensembles with ALL and NAT forcings, which we later use to construct rainfall distributions and obtain likelihood estimates for extreme events. Figure 10.1f shows the 500-hPa field averaged over the winter season that corresponds to the mean of the high-correlation ensemble with ALL forcings, which displays a distinct southwesterly flow into the United Kingdom similar to winter 2013/14 (Fig. 10.1e). In contrast, the mean circulation estimated from all the winters extracted from the ALL simulations displays a more zonal flow, which agrees well with the climatological pattern from reanalysis data (online supplemental material).

Results. We first compare rainfall distributions with strong and weak correlations to the 2013/14 general circulation pattern in the “real world,” that is, under the influence of all climatic forcings (Figs. 10.2a,c). The characteristic flow increases the chance of heavy rainfall as the distribution shifts towards a wetter regime. A two-sided Kolmogorov–

FIG. 10.2. The impact of the 2013/14 winter circulation pattern and anthropogenic forcings on DJF rainfall and R10x. Panels (a) and (c) illustrate the DJF and R10x rainfall distributions in the near-present-day climate based on simulated winters with high (orange) and low (green) correlations with the 2013/14 flow pattern. Panels (b) and (d) also illustrate the DJF and R10x rainfall distributions but for high-correlation cases only from model experiments with (red) and without (blue) anthropogenic forcings. A rainfall event is classified as extreme if the rainfall exceeds the amount associated with a 1-in-10-yr event (vertical black lines) estimated with reanalysis data since 1948. The 2013/14 rainfall amount is represented by the vertical dashed line. The distributions in panels (a)–(d) are constructed from simulated winters during the 1993–2012 period. Panel (e) shows the change in the likelihood of occurrence of extreme events under the influence of a circulation flow similar to 2013/14. Panel (f) shows the change in the likelihood due to anthropogenic forcings when the winter flow resembles the one of 2013/14. Best estimates of the change in the likelihood are marked by the square symbols and the 5%–95% uncertainty range by the vertical whiskers. The dashed horizontal line marks the ratio of 1, which suggests no likelihood change.

Smirnov test applied to the high- and low-correlation distributions confirms that they are significantly separated (near-zero p values). We next quantify how differences in the circulation may change the likelihood of an extreme event, defined as a 1-in-10-yr return level and estimated with reanalysis data since 1948/49. We compute the probabilities of exceeding the threshold using the generalised Pareto Distribution if the threshold lies at the tails. Uncertainties in the probability estimates are derived using a Monte Carlo bootstrap procedure (Christidis et al. 2013; online supplemental material). Figure 10.2e shows that in winters with circulation patterns similar to 2013/14 the chance of extreme rainfall increases by a factor of about eight for DJF and three for R10x. The effect is greater for DJF, as the persistent pattern leads to high accumulated rainfall over the whole season, whereas extreme precipitation over shorter time scales may in some years be associated with conditions not necessarily representative of the whole season.

Figures 10.2b,d,f illustrate the effect of human influence on extreme rainfall for synoptic conditions similar to 2013/14. The ALL and NAT (high-correlation) ensembles are not distinguishable for both DJF and R10x based on Kolmogorov–Smirnov tests (p values greater than 0.2). However, a minor (not statistically significant) shift to wetter conditions due to anthropogenic forcings is identified for R10x, translating to an increase in the chances of getting an extreme event by a factor of about seven. No change in the likelihood is found for DJF. Consistent with our findings, a larger ensemble of CMIP5 models shows no significant change in rainfall over the United Kingdom during cold seasons until the second half of the century, when wet winters are projected to increase in frequency (van Oldenborgh et al. 2013).

Conclusions. The prevalent southwesterly flow over the United Kingdom in winter 2013/14 provided favorable conditions for extreme rainfall. Although the atmosphere can hold more water in a warming climate (Allan and Soden 2008), associated rainfall increases are more difficult to detect on small (e.g., sub-continental, regional) scales. Here, we find some evidence for a human-induced increase in extreme winter rainfall in the United Kingdom, for events with time scales of 10 days.

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REFERENCES

- Alexander, L. V., and P. D. Jones, 2001: Updated precipitation series for the U.K. and discussion of recent extremes. *Atmos. Sci. Lett.*, **1**, 142–150.
- Allan, R. P., and B. J. Soden, 2008: Atmospheric warming and the amplification of precipitation extremes. *Science*, **321**, 1481–1484.
- Christidis, N., P. A. Stott, A. Scaife, A. Arribas, G. S. Jones, D. Copsey, J. R. Knight, and W. J. Tennant, 2013: A new HadGEM3-A based system for attribution of weather and climate-related extreme events. *J. Climate*, **26**, 2756–2783, doi:10.1175/JCLI-D-12-00169.1.
- , —, and F. W. Zwiers, 2015: Fast-track attribution assessments based on pre-computed estimates of changes in the odds of warm extremes. *Climate Dyn.*, doi:10.1007/s00382-014-2408-x, in press.
- DCLG, 2014: Winter 2013/14 severe weather recovery report. Department for Communities and Local Government [UK], 35 pp. [Available online at www.gov.uk/government/publications/winter-2013-to-2014-severe-weather-recovery-progress-report].
- Huntingford, C., and Coauthors, 2014: Potential influences on the United Kingdom's floods of winter 2013/14. *Nat. Climate Change*, **4**, 769–777, doi:10.1038/nclimate2314.
- Ineson, S., and A. A. Scaife, 2009: The role of the stratosphere in the European climate response to El Niño. *Nat. Geosci.*, **2**, 32–36.
- Jones, M. R., H. J. Fowler, C. G. Kilsby, and S. Blenkinsop, 2013: An assessment of changes in seasonal and annual extreme rainfall in the UK between 1961 and 2009. *Int. J. Climatol.*, **33**, 1178–1194, doi:10.1002/joc.3503.
- Kalnay, E., and Coauthors, 1996: The NCEP/NCAR 40-year reanalysis project. *Bull. Amer. Meteor. Soc.*, **77**, 437–470.
- Maraun, D., T. J. Osborn, and N. P. Gillett, 2008: United Kingdom daily precipitation intensity: improved early data, error estimates and an update from 2000 to 2006. *Int. J. Climatol.*, **28**, 833–842.
- Marshall, A. G., and A. A. Scaife, 2009: Impact of the QBO on surface winter climate. *J. Geophys. Res.*, **114**, D18110, doi:10.1029/2009JD011737.

- Palmer, T. N., and J. A. A. Owen, 1986: A possible relationship between some severe winters in North America and enhanced convective activity over the tropical west-Pacific. *Mon. Wea. Rev.*, **114**, 648–651.
- Schiermeier, Q., 2014: Climate change makes extreme weather more likely to hit UK. *Nature News*, doi:10.1038/nature.2014.15141.
- Slingo, J., and Coauthors, 2014: The recent storms and floods in the UK. Met Office and Centre for Ecology and Hydrology, 27 pp. [Available online at www.metoffice.gov.uk/media/pdf/1/2/Recent_Storms_Briefing_Final_SLR_20140211.pdf.]
- van Oldenborgh, G. J., and Coauthors, Eds., 2103: Annex I: Atlas of global and regional climate projections. *Climate Change 2013: The Physical Basis*. T. F. Stocker et al., Eds., Cambridge University Press, 1311–1393.
- Wang, X. L., Y. Feng, G. P. Compo, V. R. Swail, F. W. Zwiers, R. J. Allan, and P. D. Sardeshmukh, 2013: Trends and low frequency variability of extra-tropical cyclone activity in the ensemble of twentieth century reanalysis. *Climate Dyn.*, **40**, 2775–2800, doi:10.1007/s00382-012-1450-9.
- Zhang, X., H. Wan, F. W. Zwiers, G. C. Hegerl, and S.-K. Min, 2013: Attributing intensification of precipitation extremes to human influence. *Geophys. Res. Lett.*, **40**, 5252–5257, doi:10.1002/grl.51010.

Table 34.I. 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

† 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

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