

Was the extreme storm season 2013-14 over the North Atlantic and the UK triggered by changes in the West-Pacific Warm Pool?

Wild, Simon; Leckebusch, Gregor; Befort, Daniel

DOI:

[10.1175/BAMS-EEE_2014_ch7.1](https://doi.org/10.1175/BAMS-EEE_2014_ch7.1)

License:

None: All rights reserved

Document Version

Publisher's PDF, also known as Version of record

Citation for published version (Harvard):

Wild, S, Leckebusch, G & Befort, D 2015, 'Was the extreme storm season 2013-14 over the North Atlantic and the UK triggered by changes in the West-Pacific Warm Pool?', *Bulletin of the American Meteorological Society*, vol. 95, no. 12, pp. 29-34. https://doi.org/10.1175/BAMS-EEE_2014_ch7.1

[Link to publication on Research at Birmingham portal](#)

Publisher Rights Statement:

Checked for eligibility: 21/12/2015

General rights

Unless a licence is specified above, all rights (including copyright and moral rights) in this document are retained by the authors and/or the copyright holders. The express permission of the copyright holder must be obtained for any use of this material other than for purposes permitted by law.

- Users may freely distribute the URL that is used to identify this publication.
- Users may download and/or print one copy of the publication from the University of Birmingham research portal for the purpose of private study or non-commercial research.
- User may use extracts from the document in line with the concept of 'fair dealing' under the Copyright, Designs and Patents Act 1988 (?)
- Users may not further distribute the material nor use it for the purposes of commercial gain.

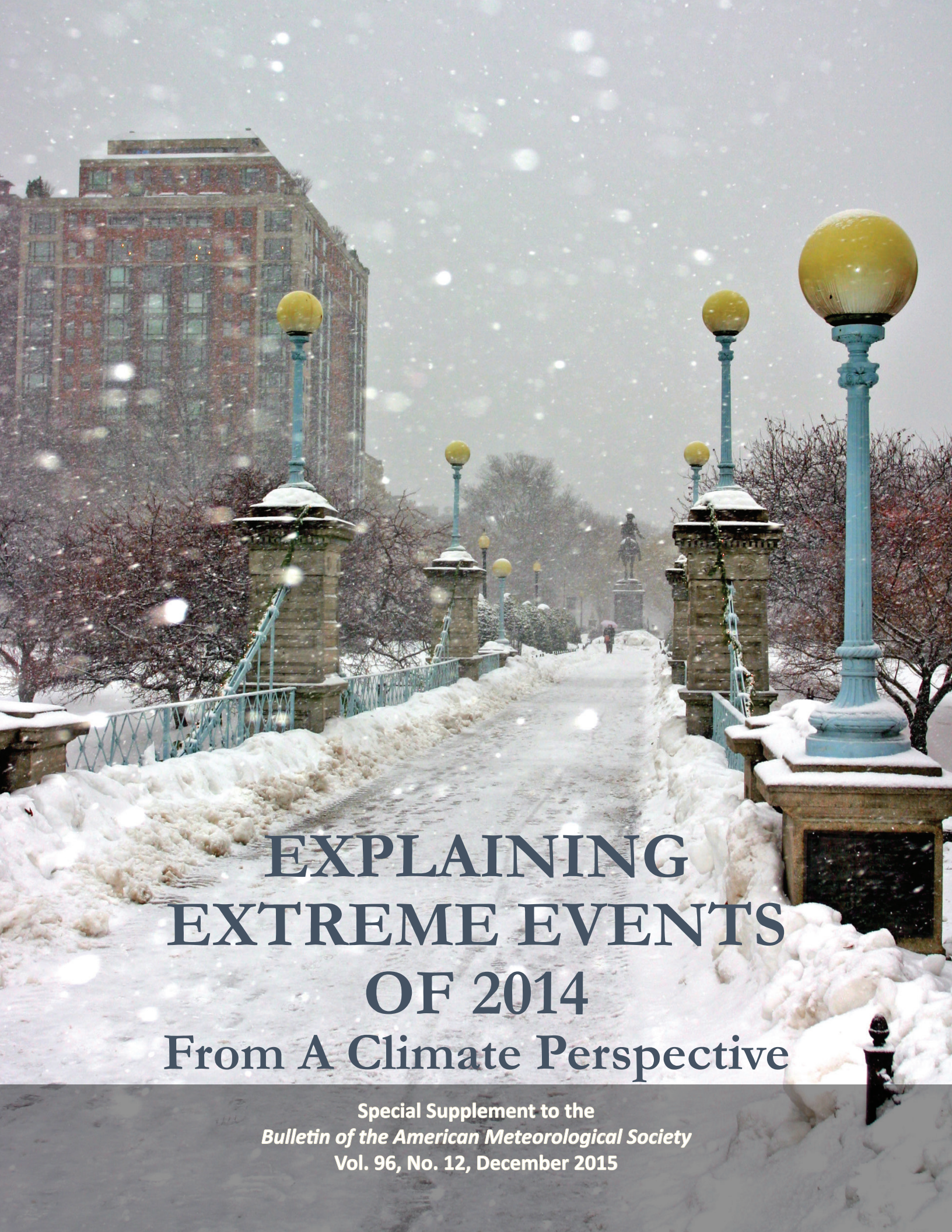
Where a licence is displayed above, please note the terms and conditions of the licence govern your use of this document.

When citing, please reference the published version.

Take down policy

While the University of Birmingham exercises care and attention in making items available there are rare occasions when an item has been uploaded in error or has been deemed to be commercially or otherwise sensitive.

If you believe that this is the case for this document, please contact UBIRA@lists.bham.ac.uk providing details and we will remove access to the work immediately and investigate.

A photograph of a park path covered in snow. On the left, a tall brick building is visible. The path is lined with ornate blue and gold lampposts. In the distance, a statue on a pedestal is visible. The sky is overcast and snow is falling.

EXPLAINING EXTREME EVENTS OF 2014

From A Climate Perspective

Special Supplement to the
Bulletin of the American Meteorological Society
Vol. 96, No. 12, December 2015

EXPLAINING EXTREME EVENTS OF 2014 FROM A CLIMATE PERSPECTIVE

Editors

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

Special Supplement to the

Bulletin of the American Meteorological Society

Vol. 96, No. 12, December 2015

AMERICAN METEOROLOGICAL SOCIETY

CORRESPONDING EDITOR:

Stephanie C. Herring, PhD
NOAA National Climatic Data Center
325 Broadway, E/CC23, Rm 1B-131
Boulder, CO, 80305-3328
E-mail: stephanie.herring@noaa.gov

COVER CREDITS:

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

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

HOW TO CITE THIS DOCUMENT

Citing the complete report:

Herring, S. C., M. P. Hoerling, J. P. Kossin, T. C. Peterson, and P. A. Stott, Eds., 2015: Explaining Extreme Events of 2014 from a Climate Perspective. *Bull. Amer. Meteor. Soc.*, **96** (12), S1–S172.

Citing a section (example):

Yoon, J. H., S.-Y. S. WANG, R. R. GILLIES, L. HIPPS, B. KRAVITZ, AND P. J. RASCH, 2015: Extreme fire season in California: A glimpse into the future? [in “Explaining Extremes of 2014 from a Climate Perspective”]. *Bull. Amer. Meteor. Soc.*, **96** (12), S5–S9.

EDITORIAL AND PRODUCTION TEAM

Riddle, Deborah B., Lead Graphics Production, NOAA/NESDIS National Centers for Environmental Information, Asheville, NC

Love-Brotak, S. Elizabeth, Graphics Support, NOAA/NESDIS National Centers for Environmental Information, Asheville, NC

Veasey, Sara W., Visual Communications Team Lead, NOAA/NESDIS National Centers for Environmental Information, Asheville, NC

Griffin, Jessica, Graphics Support, Cooperative Institute for Climate and Satellites-NC, North Carolina State University, Asheville, NC

Maycock, Tom, Editorial Support, Cooperative Institute for Climate and Satellites-NC, North Carolina State University, Asheville, NC

Misch, Deborah J., Graphics Support, LMI Consulting, Inc., NOAA/NESDIS National Centers for Environmental Information, Asheville, NC

Osborne, Susan, Editorial Support, LMI Consulting, Inc., NOAA/NESDIS National Centers for Environmental Information, Asheville, NC

Schreck, Carl, Editorial Support, Cooperative Institute for Climate and Satellites-NC, North Carolina State University, and NOAA/NESDIS National Centers for Environmental Information, Asheville, NC

Sprain, Mara, Editorial Support, LAC Group, NOAA/NESDIS National Centers for Environmental Information, Asheville, NC

Young, Teresa, Graphics Support, STG, Inc., NOAA/NESDIS National Centers for Environmental Information, Asheville, NC

TABLE OF CONTENTS

Abstract.....	ii
1. Introduction to Explaining Extreme Events of 2014 from a Climate Perspective	1
2. Extreme Fire Season in California: A Glimpse Into the Future?	5
3. How Unusual was the Cold Winter of 2013/14 in the Upper Midwest?.....	10
4. Was the Cold Eastern Us Winter of 2014 Due to Increased Variability?	15
5. The 2014 Extreme Flood on the Southeastern Canadian Prairies	20
6. Extreme North America Winter Storm Season of 2013/14: Roles of Radiative Forcing and the Global Warming Hiatus.....	25
7. Was the Extreme Storm Season in Winter 2013/14 Over the North Atlantic and the United Kingdom Triggered by Changes in the West Pacific Warm Pool?	29
8. Factors Other Than Climate Change, Main Drivers of 2014/15 Water Shortage in Southeast Brazil.....	35
9. Causal Influence of Anthropogenic Forcings on the Argentinian Heat Wave of December 2013	41
10. Extreme Rainfall in the United Kingdom During Winter 2013/14: The Role of Atmospheric Circulation and Climate Change.....	46
11. Hurricane Gonzalo and its Extratropical Transition to a Strong European Storm.....	51
12. Extreme Fall 2014 Precipitation in the Cévennes Mountains	56
13. Record Annual Mean Warmth Over Europe, the Northeast Pacific, and the Northwest Atlantic During 2014: Assessment of Anthropogenic Influence.....	61
14. The Contribution of Human-Induced Climate Change to the Drought of 2014 in the Southern Levant Region.....	66
15. Drought in the Middle East and Central–Southwest Asia During Winter 2013/14.....	71
16. Assessing the Contributions of East African and West Pacific Warming to the 2014 Boreal Spring East African Drought	77
17. The 2014 Drought in the Horn of Africa: Attribution of Meteorological Drivers.....	83
18. The Deadly Himalayan Snowstorm of October 2014: Synoptic Conditions and Associated Trends	89
19. Anthropogenic Influence on the 2014 Record-Hot Spring in Korea	95
20. Human Contribution to the 2014 Record High Sea Surface Temperatures Over the Western Tropical And Northeast Pacific Ocean	100
21. The 2014 Hot, Dry Summer in Northeast Asia.....	105
22. Role of Anthropogenic Forcing in 2014 Hot Spring in Northern China	111
23. Investigating the Influence of Anthropogenic Forcing and Natural Variability on the 2014 Hawaiian Hurricane Season.	115
24. Anomalous Tropical Cyclone Activity in the Western North Pacific in August 2014	120
25. The 2014 Record Dry Spell at Singapore: An Intertropical Convergence Zone (ITCZ) Drought.....	126
26. Trends in High-Daily Precipitation Events in Jakarta and the Flooding of January 2014	131
27. Extreme Rainfall in Early July 2014 in Northland, New Zealand—Was There an Anthropogenic Influence?	136
28. Increased Likelihood of Brisbane, Australia, G20 Heat Event Due to Anthropogenic Climate Change	141
29. The Contribution of Anthropogenic Forcing to the Adelaide and Melbourne, Australia, Heat Waves of January 2014	145
30. Contributors to the Record High Temperatures Across Australia in Late Spring 2014	149
31. Increased Risk of the 2014 Australian May Heatwave Due to Anthropogenic Activity.....	154
32. Attribution of Exceptional Mean Sea Level Pressure Anomalies South of Australia in August 2014	158
33. The 2014 High Record of Antarctic Sea Ice Extent.....	163
34. Summary and Broader Context.....	168

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.

7. WAS THE EXTREME STORM SEASON IN WINTER 2013/14 OVER THE NORTH ATLANTIC AND THE UNITED KINGDOM TRIGGERED BY CHANGES IN THE WEST PACIFIC WARM POOL?

SIMON WILD, DANIEL J. BEFORT, AND GREGOR C. LECKEBUSCH

The all-time record number of storms over the British Isles in winter 2013/14 cannot be linked directly to anthropogenic-induced warming of the tropical west Pacific.

Introduction. In winter 2013/14, the United Kingdom experienced exceptionally stormy and rainy weather conditions. The period from December 2013 to February 2014 was the stormiest for at least 20 years according to the Met Office (Met Office 2014). Two further studies also revealed this season to have been the stormiest in the United Kingdom since 1871. Matthews et al. (2014) found the highest value of a combined index of cyclone counts and intensity in the winter 2013/14, while a study by the Climate Research Unit at the University of East Anglia derived an unprecedented number of severe gale days with a circulation weather type analysis from mean sea level pressure fields (CRU 2014). While the United Kingdom was hit by several high-intensity storms, surface temperatures over large parts of central North America fell to near record minimum values (NCDC 2014; Environment Canada 2014). These low temperatures have been connected to warm sea surface temperatures in the North Pacific (Hartmann 2015; Lee et al. 2015). A potential driver for positive sea surface temperature anomalies in the North Pacific and cold conditions in central North America further downstream is warm surface waters in the tropical west Pacific (Palmer 2014; Hartmann 2015). It has been suggested that increasing sea surface temperatures in the tropical west Pacific could also be the cause for extreme weather over the British Isles (Huntingford et al. 2014; Slingo et al. 2014; Kendon and McCarthy 2015). In line with this hypothesis, we first quantify the interannual variability of winter windstorm fre-

quency over the North Atlantic/European region, which can be related to very low temperatures over North America. Secondly, we test whether a mechanism originating in the tropical Pacific continues beyond the North American continent affecting storminess over the North Atlantic and Europe.

Data and Methods. All our analyses cover the core winter months, December–February, from 1979/80 to 2013/14. (A list of all datasets used can be found in the online supplemental material.)

Strong wind events associated with extratropical cyclones are identified with an objective algorithm developed by Leckebusch et al. (2008) using exceedances of the local 98th percentile of the 10-m wind speeds. Events with a lifetime shorter than 18 hours are neglected to focus on wind fields caused by synoptic-scale extratropical cyclones. Cyclones over the North Pacific are determined by a cyclone identification and tracking algorithm (Murray and Simmonds 1991) that locates a minimum of mean sea level pressure (MSLP) in the vicinity of a maximum in the Laplacian of the MSLP. Local system track density for both types of tracks (windstorms and cyclones) are calculated in agreement with settings used in Neu et al. (2012) with a search radius of 500 km around the center of each box in a $2^\circ \times 2^\circ$ grid.

The stormy winter 2013/14 over the British Isles and upstream conditions. Compared to the long-term seasonal mean, we find an increase of up to 200% in the number of identified windstorm events in the eastern North Atlantic for the winter season 2013/14. This corresponds to an increase of about 10 systems per winter or to more than three times the interannual standard deviation. Considering the period from 1979 to 2014, the winter 2013/14 showed the highest storm

AFFILIATIONS: WILD, BEFORT, AND LECKEBUSCH—School of Geography and Environmental Sciences, University of Birmingham, Birmingham, United Kingdom

DOI: 10.1175/BAMS-D-15-00118.1

A supplement to this article is available online (10.1175/BAMS-D-15-00118.2)

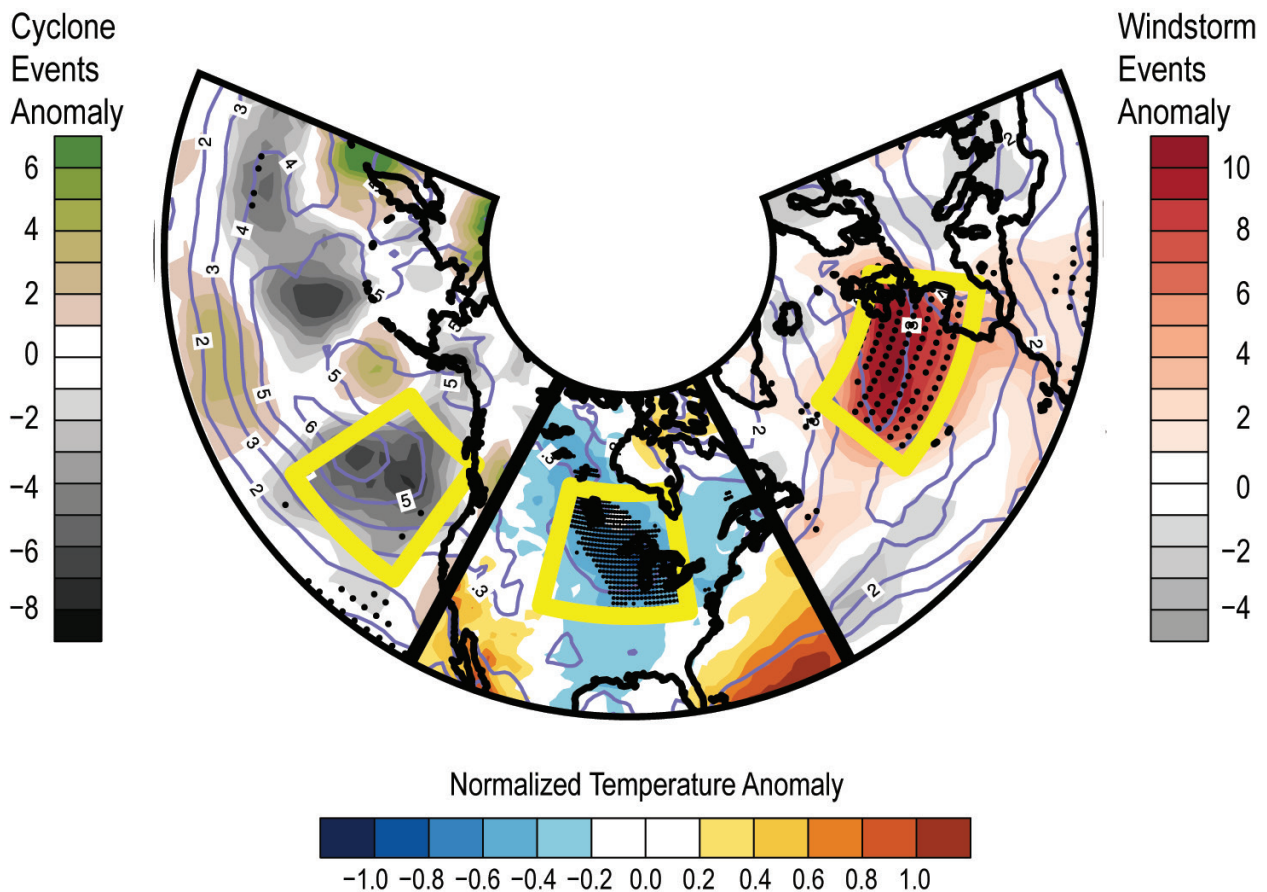


FIG. 7.1. Anomalies (ERA Interim) for Dec 2013–Feb 2014 compared to long-term climatology (1979–2014) in shadings; interannual standard deviation in contours. (right) 60°W–30°E, 25°–70°N; absolute windstorm events anomaly; black dots indicate a maximum in winter 2013/14. (center) 120°–60°W, 25°–70°N; 2-m temperature seasonal normalized anomaly mean; black dots indicate a minimum in winter 2013/14. (left) 150°E–120°W, 25°–70°N; absolute cyclone events anomaly; black dots indicate a minimum in winter 2013/14. Yellow boxes mark regions used for the calculation of correlation coefficients for Table 7.1.

frequency on record (Fig. 7.1, right panel). The main area of this positive windstorm anomaly extends from about 35°W to the Greenwich meridian along a latitudinal belt from about 40°N to 55°N, and it includes large parts of the British Isles. These results about pure windstorms corroborate findings of previous studies about cyclone counts or gale days derived from pressure data (e.g., Matthews et al. 2014; CRU 2014).

Concurrently, further upstream over the central North American continent, 2-m temperatures dropped extremely below normal conditions. The interannual standard deviation (one value per season) of the normalized temperatures (one value every six hours) shows values between 0.3 and 1.0 below the long-term seasonal mean setting the overall temperature minimum for large parts of the U.S. Midwest, the southern part of the Canadian prairies,

and southwestern Ontario for the whole investigated period (Fig. 7.1, central panel).

The North American extreme cold temperatures are strongly linked to an equatorward shift of the circumpolar vortex (Ballinger et al. 2014). The circumpolar vortex accompanied by the upper tropospheric jet was deflected to the north over the eastern North Pacific (Slingo et al. 2014) allowing polar air masses to flow over North America on the trough upstream side. Associated with large amplitude Rossby waves in the mid and upper troposphere with a ridge over the North Pacific, anomalously high mean sea level pressure can decrease the number of cyclone systems and increase temperatures in the region of the climatological Aleutian Low (e.g., Lau 1988; Honda et al. 2001). In the winter 2013/14, the number of cyclones was indeed strongly reduced compared to the long-term climatology with a reduction of about 30%–60%,

equivalent to about 5–10 fewer cyclones per grid point over the eastern North Pacific (Fig. 7.1, left panel).

The Pacific–North American Pattern (PNA) can be regarded as one mode of variability that links the tropical and extratropical Pacific on a monthly to seasonal scale and is known to be strongly related to the surface temperature over North America (e.g., Leathers et al. 1991; Ning and Bradley 2014). In the winter 2013/14, the PNA was weakly positive in January and strongly negative in December and February.

Sea surface temperatures in the tropical west Pacific were exceptionally high in winter 2013/14 (Lee et al. 2015) causing enhanced convective activity, indicated by negative outgoing longwave radiation (OLR) anomalies, in this region (Supplemental Fig. S7.1).

Discussion and attribution to climate change. This study tests and quantifies a proposed mechanism linking convective activity over the tropical west Pacific and storminess over Europe. If such a link exists, the record number of storms over the British Isles in winter 2013/14 could be seen as an enhanced response of the climate system triggered by increased sea surface temperatures in the tropical west Pacific, which themselves stem from anthropogenic influences (e.g., Palmer 2014; Chan and Wu 2015). Thus, anthropogenic influences would act via a natural link leading to anomalously high storm frequency over Europe.

We diagnose that the year-to-year variability of storm frequency over the northeast Atlantic and the British Isles is significantly anticorrelated to surface temperatures in central North America (Table 7.1, re-

gions outlined as yellow boxes in Fig. 7.1). We further confirm the link between the interannual variability of surface temperatures over North America and the PNA. The PNA is in turn significantly linked to cyclone activity in the northeast Pacific, sea surface temperatures in the North Pacific, and convective activity (OLR) over about half of the west Pacific warm pool (cf. Table 7.1, the role of the PNA in the online supplemental material, and Supplemental Fig. S7.2).

The direct relation between windstorm frequency anomalies over Europe and sea surface temperatures in the west Pacific warm pool, respectively OLR anomalies, is however weak and not significant (Table 7.1).

Thus, we find that parts of the proposed mechanism in previous studies (Huntingford et al. 2014; Slingo et al. 2014; Kendon and McCarthy 2015) linking the tropical west Pacific and European storminess show significant covariability, but we cannot find evidence for a direct relation from the beginning to the end of such a mechanism. In addition, the correlation between North American temperatures and windstorm anomalies drops to insignificant values when the winter 2013/14 is excluded from the analysis.

We thus conclude that the conditions in the Pacific and its induced anomalies over the North American continent are generally not sufficient to explain the extraordinary high winter windstorm frequency over the northeast Atlantic and the British Isles. The induced conditions were favorable to increase the number of storms in winter 2013/14, but the explained variability is too small to attribute this particular

Table 7.1. Spearman rank correlation coefficient between area-averaged detrended time series from 1979/80 to 2013/14. NAT: Northeast Atlantic/British Isles (40°–55°N, 35°W–0°); NA: North America (38°–55°N, 105°–80°W); NEP: Northeast Pacific (33°–52°N, 150°–128°W); SST NP: Sea surface temperature, North Pacific (35°–60°N, 160°E–145°W); WP: tropical west Pacific. (25°S–25°N, 90°–170°E,). For regions, see also yellow boxes in Figs. 7.1 and Supplemental Fig. S7.1. Statistically significant values in bold ($p < 0.05$).

	OLR, WP	PNA	SST, NP	Cyclone Events, NEP	Temperature, NA
Windstorms, NAT	–0.05	–0.22	–0.05	–0.21	–0.38
Temperature, NA	0.41	0.46	–0.40	0.37	
Cyclone Events, NEP	0.17	0.41	–0.12		
SST, NP	–0.14	–0.48			
PNA	0.36				

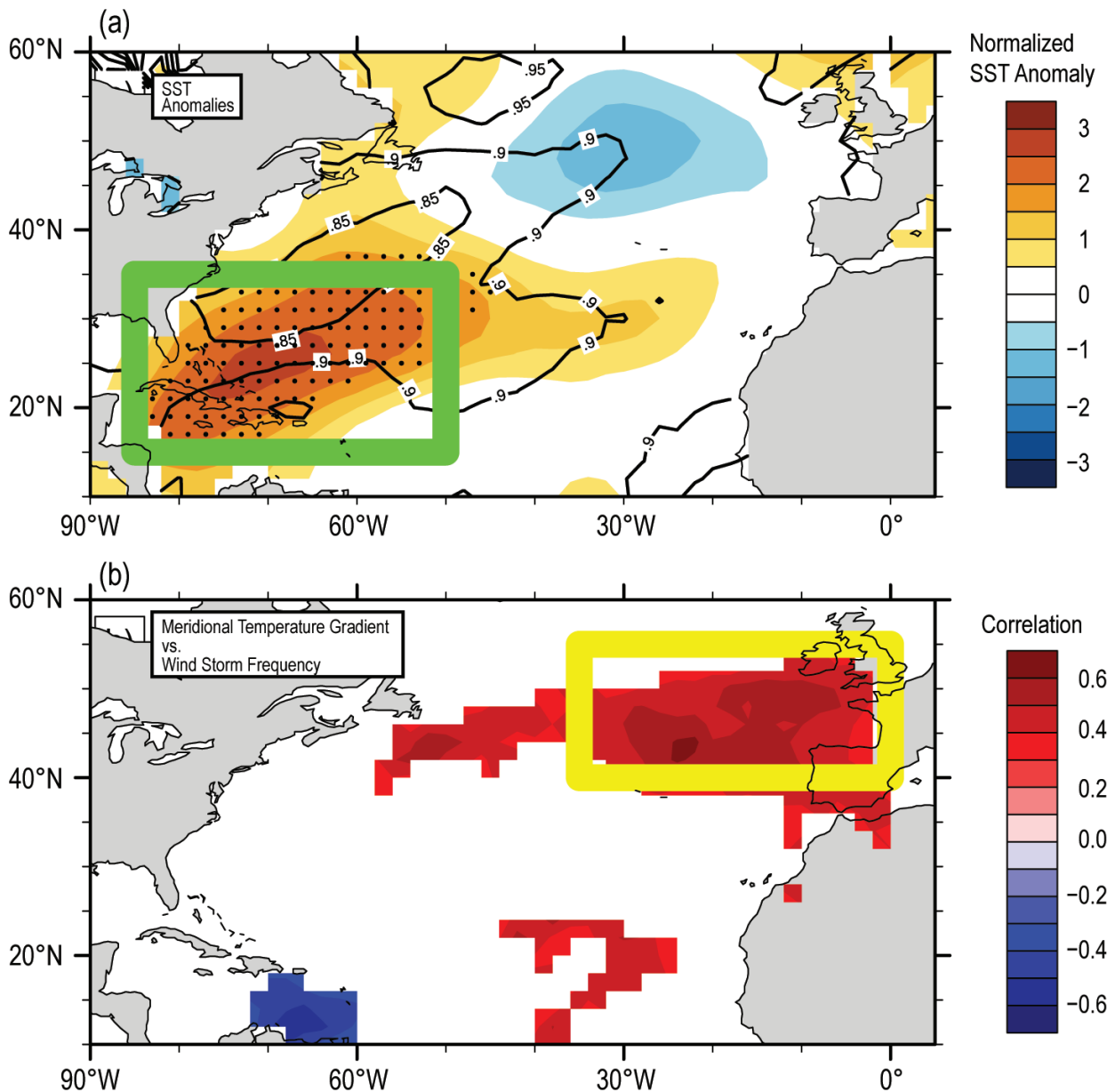


FIG. 7.2. (a) Normalized sea surface temperature (SST) anomalies (ERSSTv4) for Dec 2013–Feb 2014 compared to long-term climatology (1979–2014) in shadings; interannual standard deviation in contours. Black dots indicate a maximum in winter 2013/14 for the considered time period from 1979 to 2014. **(b)** Interannual correlation coefficient (Pearson) between winter windstorm frequency and meridional temperature gradient index from 1979/80 to 2013/14. The meridional temperature index is calculated by subtracting the area-averaged sea surface temperature value for the west Atlantic (15°–35°N, 85°–50°W; green box in Fig. 7.2a) minus the area-averaged 2-m temperature value for central North America (38°–55°N, 105°–80°W; yellow box in center panel of Fig. 7.1). Correlations below the 95% significance level are omitted. (For clarity: Yellow box in Fig. 7.2b corresponds to yellow box in right panel in Fig. 7.1.)

extreme mainly to conditions in the tropical Pacific and its imprinted anthropogenic signal.

One alternative potential driver partly explaining the anomalously high storm frequency in 2013/14 could have been the unprecedented anomalies of sea surface temperatures in the west Atlantic (Fig. 7.2a). High sea surface temperatures in the subtropical west

Atlantic (green box, Fig. 7.2a) and low temperatures over North America (yellow box, center panel Fig. 7.1) are unrelated (the correlation equals 0.03), but when occurring concurrently, they substantially increase the meridional temperature gradient over the core genesis region of extratropical cyclones. This meridional temperature gradient is positively related

to windstorm frequency over the North Atlantic and Europe (Fig. 7.2b). Baroclinic instability in this region can be positively influenced through a strong temperature gradient, leading to enhanced cyclogenesis and potentially strong deepening of cyclones responsible for high wind speeds.

Conclusion. The anomalous high number of windstorms in winter 2013/14 over the northeast Atlantic and the British Isles cannot directly be attributed to anthropogenic-influenced factors as apparent in the tropical west Pacific. Very suitable conditions of natural internal interannual variability, including conditions over the tropical and North Pacific, North America, and the west Atlantic, favored the record number of storm counts.

ACKNOWLEDGMENTS. We would like to thank the ECMWF for providing ERA Interim data and NOAA for providing PNA, OLR, and ERSST data. We are also very grateful to three anonymous reviewers and editor Jeff Rosenfeld for their constructive criticism and helpful suggestions as well as to Stephanie Herring and Jim Kossin for their guidance throughout the drafting process of this manuscript. Research by GC Leckebusch is supported by EU FP7-MC-CIG-322208 grant.

REFERENCES

- Ballinger, T. J., M. J. Allen, and R. V. Rohli, 2014: Spatiotemporal analysis of the January Northern Hemisphere circumpolar vortex over the contiguous United States. *Geophys. Res. Lett.*, **41**, 3602–3608, doi:10.1002/2014GL060285.
- Chan, D., and Q. Wu, 2015: Attributing observed SST trends and subcontinental land warming to anthropogenic forcing during 1979–2005. *J. Climate*, **28**, 3152–3170, doi:10.1175/JCLI-D-14-00253.1.
- CRU, 2014: Lamb weather types: UK Jenkinson gale index: Threshold counts. Climate Research Unit, University of East Anglia, 1 p. [Available online at www.cru.uea.ac.uk/cru/data/lwt/webdocs/NDJFMA_G_thresh_counts_UK.pdf.]
- Environment Canada, 2014: Climate trends and variations bulletin – Winter 2013–2014. Environment Canada, 4 pp. [Available online at www.ec.gc.ca/adsc-cmda/383F5EFA-508D-45E8-89AD-4B14B53B429E/CTVB_Winter_2013_2014_E.pdf.]
- Hartmann, D. L., 2015: Pacific sea surface temperature and the winter of 2014. *Geophys. Res. Lett.*, **42**, 1894–1902, doi:10.1002/2015GL063083.
- Honda, M., H. Nakamura, J. Ukita, I. Kousaka, and K. Takeuchi, 2001: Interannual seesaw between the Aleutian and Icelandic lows. Part I: Seasonal dependence and life cycle. *J. Climate*, **14**, 1029–1042.
- 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.
- Kendon, M., and M. McCarthy, 2015: The UK's wet and stormy winter of 2013/2014. *Weather*, **70**, 40–47, doi:10.1002/wea.2465.
- Lau, N.-C., 1988: Variability of the observed mid-latitude storm tracks in relation to low-frequency changes in the circulation pattern. *J. Atmos. Sci.*, **45**, 2718–2743.
- Leathers, D., B. Yarnal, and M. Palecki, 1991: The Pacific/North American teleconnection pattern and United States climate. Part 1: Regional temperature and precipitation associations. *J. Climate*, **4**, 517–528.
- Leckebusch, G. C., D. Renggli, and U. Ulbrich, 2008: Development and application of an objective storm severity measure for the northeast Atlantic region. *Meteor. Z.*, **17**, 575–587.
- Lee, M.-Y., C.-C. Hong, and H.-H. Hsu, 2015: Compounding effects of warm sea surface temperature and reduced sea ice on the extreme circulation over the extratropical North Pacific and North America during the 2013–2014 boreal winter. *Geophys. Res. Lett.*, **42**, 1612–1618, doi:10.1002/2014GL062956.
- Matthews, T., C. Murphy, R. L. Wilby, and S. Harrigan, 2014: Stormiest winter on record for Ireland and UK. *Nat. Climate Change*, **4**, 738–740, doi:10.1038/nclimate2336.
- Met Office, 2014: Winter 2013/14. [Available online at www.metoffice.gov.uk/climate/uk/summaries/2014/winter/.]
- Murray, R., and I. Simmonds, 1991: A numerical scheme for tracking cyclone centres from digital data. Part I. Development and operation of the scheme. *Aust. Meteor. Mag.*, **39**, 155–166.
- NCDC, 2014: Nov 2013 – Jan 2014 divisional ranks: Temperature. National Climatic Data Center, 1 p. [Available online at www.ncdc.noaa.gov/sotc/service/national/divisionaltavgrank/201311-201401.gif.]
- Neu, U., and Coauthors, 2012: IMILAST: A community effort to intercompare extratropical cyclone detection and tracking algorithms. *Bull. Amer. Meteor. Soc.*, **94**, 529–547, doi:10.1175/BAMS-D-11-00154.1.

- Ning, L., and R. S. Bradley, 2014: Winter climate extremes over the northeastern United States and southeastern Canada and teleconnections with large-scale modes of climate variability. *J. Climate*, **28**, 2475–2493, doi:10.1175/JCLI-D-13-00750.1.
- Palmer, T., 2014: Record-breaking winters and global climate change. *Science*, **344**, 803–804, doi:10.1126/science.1255147.
- 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/n/i/Recent_Storms_Briefing_Final_07023.pdf.]

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

**** 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.