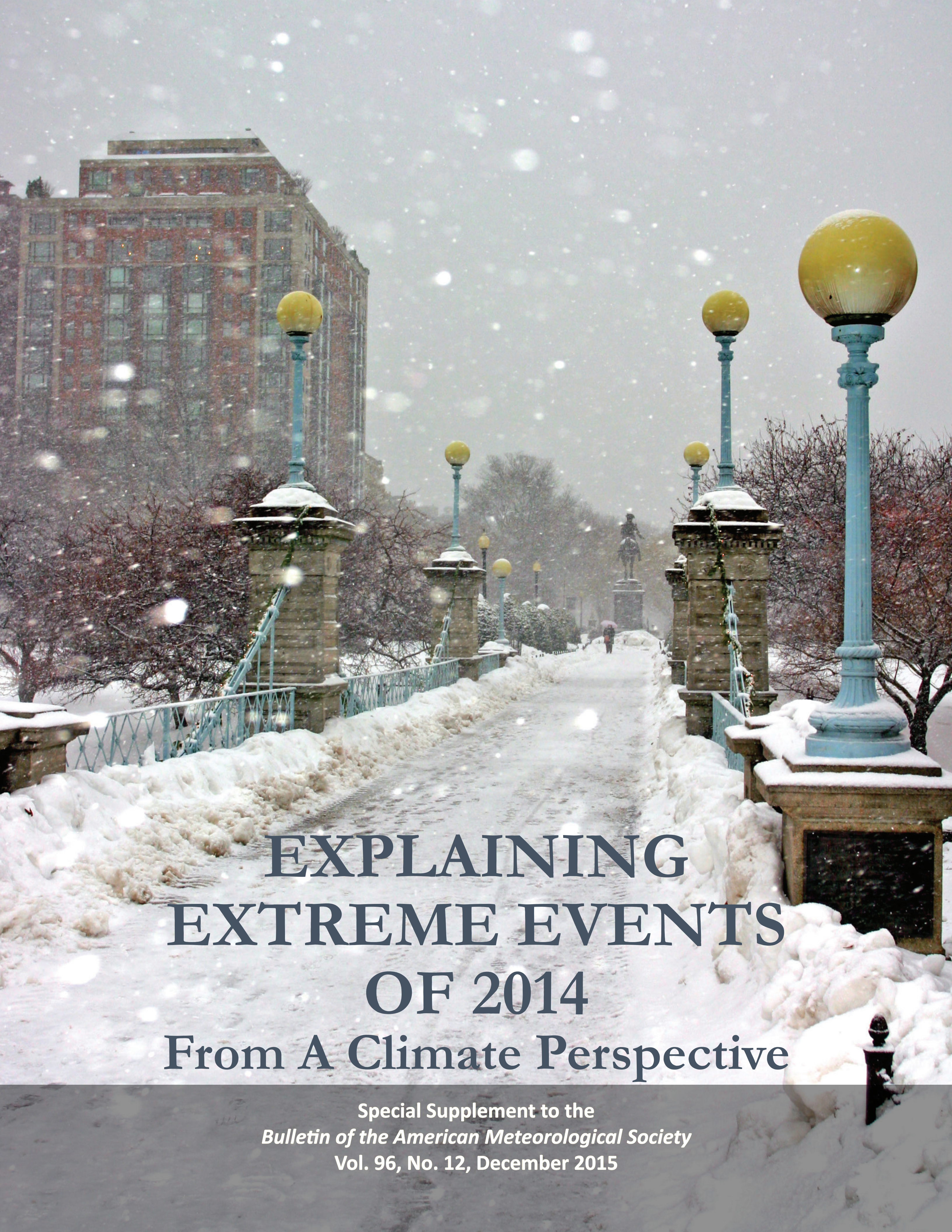

EXPLAINING EXTREME EVENTS OF 2014

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 Centers for Environmental Information
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, California, 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, Jessicca, 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—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.

15. DROUGHT IN THE MIDDLE EAST AND CENTRAL–SOUTHWEST ASIA DURING WINTER 2013/14

Mathew Barlow and Andrew Hoell

Of three identified proximate drought factors, climate change does not appear important for two. The third factor, western Pacific SSTs, exhibits a strong warming trend but attribution is an open question.

Introduction. During November 2013–April 2014, drought occurred over an area extending from the Mediterranean coastal Middle East, northward through Turkey and eastward through Kazakhstan, Uzbekistan, and Kyrgyzstan. An estimate of precipitation deficits during the drought is shown in Fig. 15.1a. Data issues mandate caution (e.g., Hoell et al. 2015; Barlow et al. 2015) but reports from throughout the region are consistent with the general area of drought, including for Syria (UNICEF 2014; WFP 2014), Turkey (Gokoluk 2014), Israel (Ackerman 2014), Kazakhstan (Kazinform 2014; Thomson Reuters 2014), and Kyrgyzstan (FAO 2014). Notably, the eastern (main) basin of the Aral Sea dried up for the first time in modern history (NASA 2014; Howard 2014). Although the long-term draining of the Aral Sea is due to agricultural withdrawals (Micklin 1988; Micklin and Aladin 2008), the current state of minimal storage may represent a new regime where yearly fluctuations are strongly affected by climate.

A time series of November–April precipitation anomalies averaged over the main drought region (black box in Fig. 15.1a) is shown in Fig. 15.1b. A statistically-significant downward trend is observed over the 1950–2014 period, with the post-1999 rainfall declines playing an important role and 2013/14 having the lowest value in the period, although data scarcity and continuity issues make confident trend analysis difficult in this region.

The goal of this analysis is to identify important factors in the drought, considered in the next section, and to examine those factors in the context of global warming, considered in the third section.

AFFILIATIONS: Barlow—Department of Environmental, Earth, and Atmospheric Sciences, University of Massachusetts Lowell, Lowell, Massachusetts; Hoell—NOAA Earth System Research Laboratory, Physical Sciences Division, Boulder, Colorado

DOI:10.1175/BAMS-D-15-00127.1

A supplement to this rticle is available online (10.1175/BAMS-D-15-00127.2)

Proximate drought factors. Three factors were active during the season that have been previously identified as important for drought in the region, based on both observational and modeling analyses as noted below: the North Atlantic Oscillation (NAO), a cold central Pacific, and a warm western Pacific. Here we consider whether each factor had a magnitude consistent with an important influence on drought based on previous events.

The NAO has been shown to influence precipitation in the western part of the region by Cullen and Demenocal (2000), Aizen et al. (2001), Cullen et al. (2002), Mann (2002), Krichak et al. (2002), Syed et al. (2006), and Black (2011). Based on the SST-derived NAO index of Cullen et al., the NAO was at its sixth-largest value in the last 65 years during the 2013/14 drought, with its overall pattern evident in the large-scale circulation anomalies, including a ridge extending into the western part of the domain (Supplemental Fig. S15.1).

The cold central Pacific SSTs associated with La Niña have also been shown to influence precipitation in the region by Price et al. (1998), Barlow et al. (2002), Nazemosadat and Ghasemi (2004), Mariotti et al. (2002, 2005), Syed et al. (2006), Mariotti (2007), Hoell et al. (2014a, 2014b), Yin et al. (2014), and Krichak et al. (2014). The values during the 2013/14 drought were similar to previous droughts, although of roughly two-thirds the magnitude (Supplemental Fig. S15.2).

Finally, warm anomalies in the western Pacific have been linked to drought in the region, generally in association with central Pacific cold anomalies (Agrawala et al. 2001; Barlow et al. 2002, 2015; Hoerling and Kumar 2003; Trigo et al. 2010; Hoell et al. 2012, 2014a,b). During the 2013/14 season, large positive SST anomalies were observed in the western Pacific (Fig. 15.1c), as part of a notable positive trend

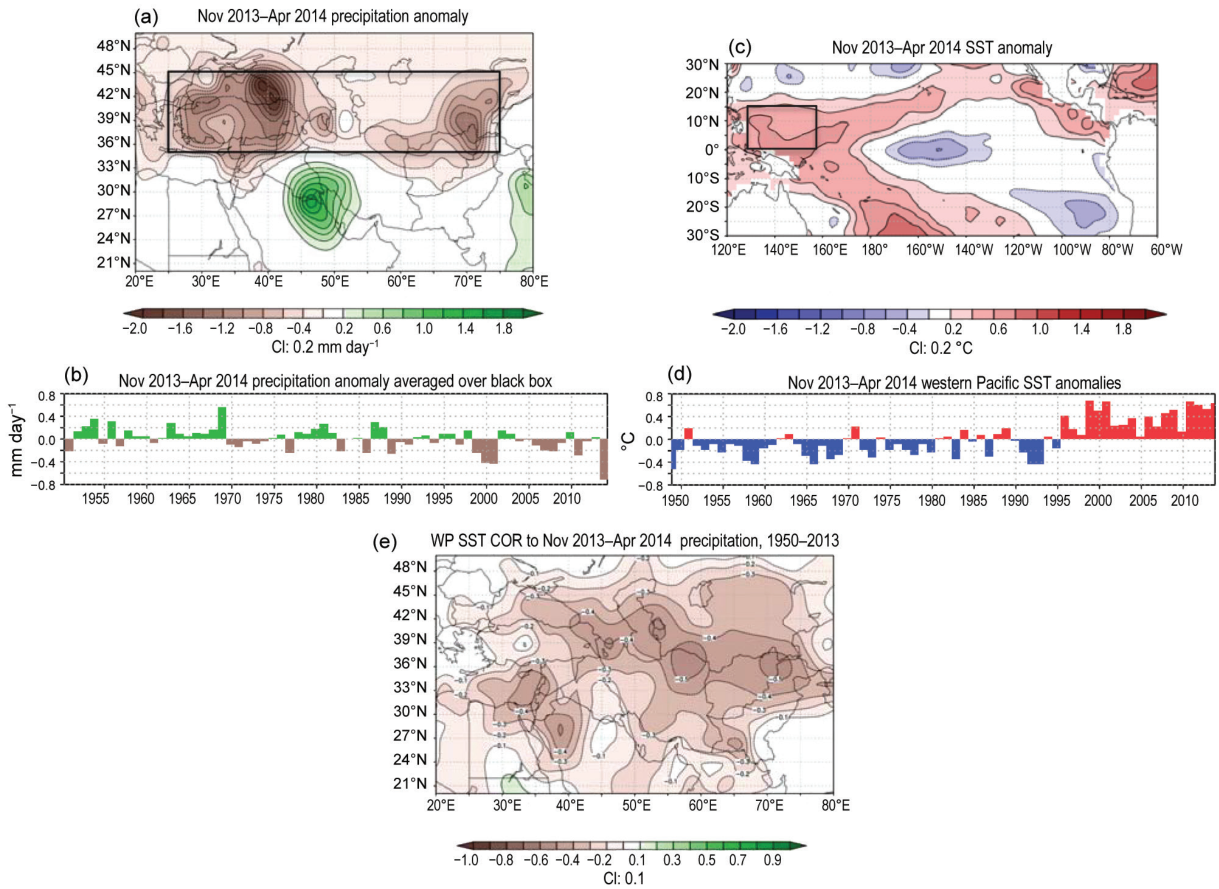

Fig. 15.1. Observational analysis: (a) Precipitation anomalies for Nov 2013–Apr 2014, contoured at 0.2 mm day^{-1}; (b) time series of Nov–Apr precipitation anomalies (mm day^{-1}) over the main drought region [black box in (a)]; (c) tropical Pacific SST anomalies for Nov 2013–Apr 2014, with a contour interval of 0.2°C; (d) time series of Nov–Apr SST anomalies (°C) over the western Pacific [black box in (c)], and (e) correlation of western Pacific SST anomalies to precipitation for 1950–2013, with a contour interval of 0.1. Precipitation is from the PREC dataset (Chen et al. 2002) and SST is from the ERSST dataset (Smith et al. 2008).

in the region (Fig. 15.1d; cf. Cravatte et al. 2009). To focus on the western Pacific–precipitation link, Fig. 15.1e shows the correlation between western Pacific SSTs and regional precipitation for 1950–2014. The largest correlation is −0.57 for this 65-year period.

Examination of the role of global warming in drought factors. Of the three factors, neither the NAO index nor the central Pacific SSTs exhibit a clear trend over the past 65 years, which strongly suggests that global warming has not played a direct role in these factors over that period.

The western Pacific SST, however, does exhibit a strong increase during this period. To further investigate this we have examined CAM4 model output for three sets of experiments: an ensemble of SST-forced runs of the 2013/14 season compared to climatology, a set of runs that isolate the influence of the western Pacific over the last 34 years, and a set of runs that isolate the influence of increased greenhouse gases (GHGs).

The SST-forced realization of the 2013/14 seasonal anomalies (Fig. 15.2a) shows considerable similarity to the observed anomalies, with dry over much of the observed drought region and some wet anomalies to the south. The modeled drought has a strong wet anomaly in the westernmost part of the domain, in distinction from observations, which may be related to the likely role of the NAO in the observed drought. Overall, the CAM4 provides further support for the influence of SST in the drought episode.

To isolate the effect of the western Pacific Ocean warming on Southwest Asia climate, a set of experiments was considered where a warm western Pacific Ocean SST (Supplemental Fig. S15.3a) was added to the monthly time-varying 1979–2013 SST trend (Supplemental Fig. S15.3b). The SST pattern added to the monthly climatology was used to force the

CAM4 model for 50 years. This model simulation was compared with a similar 50-year run of CAM5 that was forced only by the monthly time-varying 1979–2013 SST trend added to the monthly climatology. The difference between the two runs shows the forcing of Southwest Asia climate by the western Pacific. The result, shown in Fig. 15.2b, shows that the western Pacific itself is a strong drought forcing for the region, consistent with previous modeling and observational work, as well as the analysis shown in Fig. 15.1e. Since the western Pacific precipitation anomalies (Fig. 15.2b) are considerably stronger than the all-SST precipitation anomalies (Fig. 15.2a), it appears that some aspects of the global SSTs played a counteracting role, which would be a useful topic for future research.

Finally, model runs were analyzed to compare the behavior of precipitation in the current climate to the behavior of precipitation in the climate of the 1880s. In this experiment, precipitation from an SST-forced simulation of the observed climate was compared with precipitation from an SST-forced experiment where the SSTs were detrended to the equivalent 1880s mean conditions while GHG and ozone were adjusted to their 1880s values. (Please see NOAA ESRL's FACTS for further information: www.esrl.noaa.gov/psd/repository/alias/facts.) The net effect in the CAM4 model is shown in Fig. 15.2c. The effect of the current climate produces drying throughout Southwest Asia relative to the 1880s climate during November–April 1979–2012 (the years of the run), with a match in sign and magni-

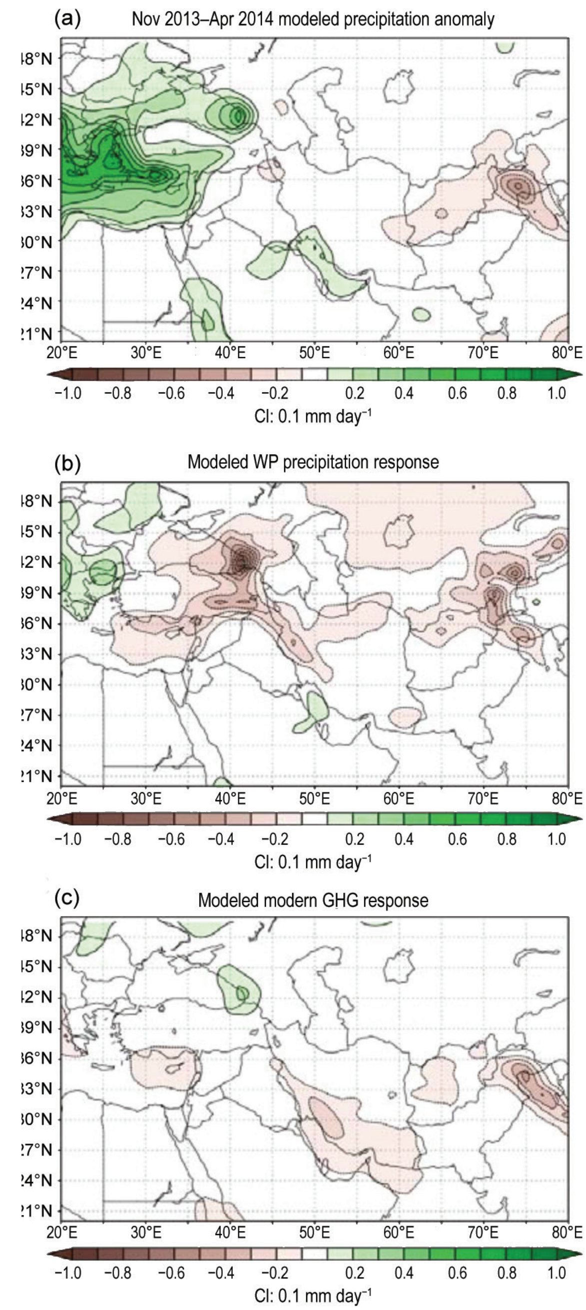

Fig. 15.2. Modeling analysis: (a) *CAM4 simulation of 2013–14 drought:* Precipitation anomaly for Nov 2013–Apr 2014 simulated by the average of 30-ensemble simulations of the CAM4 model driven by observed SST; (b) *Western Pacific forcing:* Precipitation difference for Nov–Apr between a 50-yr SST simulation of western Pacific SST added to the 1999–2012 SST trend superimposed on the monthly climatology and a 50-yr SST simulation of the 1999–2012 SST trend superimposed on the monthly climatology simulated by the CAM4 model. Stippling denotes significant differences at $p < 0.10$; and (c) *Climate change*: Precipitation difference for Nov–Apr 1979–2012 between the average of 30-ensemble simulations of the CAM4 model driven by observed SST and 30-ensemble simulations of the CAM4 model driven by detrended SSTs meant to simulate the 1880s climate. All precipitation anomalies are contoured and shaded at 0.1 mm day^{-1}.

tude over Afghanistan for the 2013/14 drought. This can be taken as an indication that climate change may have an effect on Southwest Asia precipitation, though further research is needed.

Discussion. Three factors previously identified as important for drought in the region were active during the 2013/14 season: the NAO, a cold central Pacific, and a warm western Pacific. Based on historical relationships, all three factors were of a magnitude consistent with an important role in the drought. The NAO and the central Pacific did not exhibit clear trends over that period and so do not appear to have been directly affected by climate change. The western Pacific, however, did experience a notable warming trend from 1950–2013, in conjunction with a statistically significant downward trend in precipitation over the drought region. Model experiments also show an important influence of the western Pacific on regional drought.

Consensus climate model projections, however, do not indicate increased drying over most of the region or preferential warming over the western Pacific (Stocker et al. 2014). If the models are correctly reproducing the relevant dynamics, then the observed warming trend in the western Pacific and associated influence on drought in the region is likely due to multidecadal variability. Unfortunately, there are several reasons to withhold full confidence in the model projections: there are problems with the models' regional seasonal cycle of precipitation (Stocker et al. 2014, chapter 9), the models' ability to reproduce the basic variability for the region hasn't been fully validated (Stocker et al. 2014, chapter 14), and the models' limitations in reproducing observed SST trends (e.g., Jha et al. 2014) call into question their predilection for projecting uniform warming of SSTs. Thus, it is not clear how closely the observed regional trend in western Pacific SSTs and associated regional drought is related to global warming: this is a critical problem for the field.

In summary: Of the three identified proximate factors in the drought—the NAO, the central Pacific, and the western Pacific—climate change does not appear to have played a strong role in the first two. The third factor, western Pacific SSTs, exhibits a strong warming trend but whether this trend is an expression of multidecadal variability or a signature of climate change is an important open question. Additionally, in model experiments, the increased GHG forcing during the last 34 years dries the region.

ACKNOWLEDGMENTS. We gratefully acknowledge the Facility for Climate Assessments (FACTS) database provided online by the Physical Sciences Division of NOAA's Earth System Research Laboratory.

REFERENCES

Ackerman, G., 2014: Israel suffering from unprecedented drought: Water agency. Bloomberg. [Available online at www.bloomberg.com/news/articles/2014-03-04/israel-suffering-from-unprecedented-drought-water-agency.]

Agrawala, S., M. Barlow, H. Cullen, and B. Lyon, 2001: The drought and humanitarian crisis in central and Southwest Asia: A climate perspective. IRI Special Rep., 01-11, 20 pp. [Available online at http://reliefweb.int/sites/reliefweb.int/files/resources/F5881844EEA93151C1256B1F005B3F62-iri-asiadrought-30nov.pdf.]

Aizen, E. M., V. B. Aizen, J. M. Melack, T. Nakamura, and T. Ohta, 2001: Precipitation and atmospheric circulation patterns at mid-latitudes of Asia. *Int. J. Climatol.*, **21**, 535–556.

Barlow, M., H. Cullen, and B. Lyon, 2002: Drought in central and southwest Asia: La Niña, the warm pool, and Indian Ocean precipitation. *J. Climate*, **15**, 697–700.

——, B. Zaitchik, S. Paz, E. Black, J. Evans, and A. Hoell, 2015: A review of drought in the Middle East and Southwest Asia. *J. Climate*, in press, doi:10.1175/JCLI-D-13-00692.1.

Black, E., 2011: The influence of the North Atlantic Oscillation and European circulation regimes on the daily to interannual variability of winter precipitation in Israel. *Int. J. Climatol.*, **32**, 1654–1664, doi:10.1002/joc.2383.

Chen, M., P. Xie, J. E. Janowiak, and P. A. Arkin, 2002: Global land precipitation: A 50-yr monthly analysis based on gauge observations. *J. Hydrometeor.*, **3**, 249–266.

Cravatte, S., T. Delcroix, D. Zhang, M. McPhaden, and J. Leloup, 2009: Observed freshening and warming of the western Pacific warm pool. *Climate Dyn.*, **33**, 565–589.

Cullen, H. M., and P. B. Demenocal, 2000: North Atlantic influence on Trigris–Euphrates streamflow. *Int. J. Climatol.*, **20**, 853–863.

Cullen, H. M., A. Kaplan, and P. A. Arkin, 2002: Impact of the North Atlantic Oscillation on Middle Eastern climate and streamflow. *Climatic Change*, **55**, 315–338.

FAO, 2014: GIEWS Update Kyrgyzstan: Severe drought in northern parts affects 2014 wheat production. [Available online at http://reliefweb.int/report/kyrgyzstan/giews-update-kyrgyzstan-severe-drought-northern-parts-affects-2014-wheat.]

Gokoluk, S., 2014: Turkey's lira drops most in two weeks as drought spurs inflation. Bloomberg. [Available online at www.bloomberg.com/news/articles/2014-09-02/lira-set-for-biggest-drop-in-2-weeks-as-drought-spurs-inflation.]

Hoell, A., M. Barlow, and R. Saini, 2012: The leading pattern of intraseasonal and interannual Indian Ocean precipitation variability and its relationship with Asian circulation during the boreal cold season. *J. Climate*, **25**, 7509–7526, doi:10.1175/JCLI-D-11-00572.1.

——, C. Funk, and M. Barlow, 2014a: The regional forcing of Northern Hemisphere drought during recent warm tropical west Pacific Ocean La Niña events. *Climate Dyn.*, **42**, 3289–3311, doi:10.1007/s00382-013-1799-4.

——, ——, and ——, 2014b: La Niña diversity and northwest Indian Ocean rim teleconnections. *Climate Dyn.*, **43**, 2707–2724, doi:10.1007/s00382-014-2083-y.

——, ——, and ——, 2015: The forcing southwest Asia teleconnections by low frequency Indo-Pacific sea surface temperature variability during boreal winter. *J. Climate*, **28**, 1511–1526, doi:10.1175/JCLI-D-14-00344.1.

Hoerling, M., and A. Kumar, 2003: The perfect ocean for drought. *Science*, **299**, 691–694.

Howard, B. C., 2014: Aral Sea's eastern basin dry for the first time in 600 years. National Geographic. [Available online at http://news.nationalgeographic.com/news/2014/10/141001-aral-sea-shrinking-drought-water-environment/.]

Jha, B., Z. Z. Hu, and A. Kumar, 2014: SST and ENSO variability and change simulated in historical experiments of CMIP5 models. *Climate Dyn.*, **42**, 2113–2124, doi:10.1007/s00382-013-1803-z.

Kazinform, 2014: Drought causes low wheat yields in S Kazakhstan – Agriculture Ministry. [Available online at www.inform.kz/eng/article/2685521.]

Krichak, S. O., P. Kishcha, and P. Alpert, 2002: Decadal trends of main Eurasian oscillations and the Eastern Mediterranean precipitation. *Theor. Appl. Climatol.*, **72**, 209–220.

——, J. S. Breitgand, S. Gualdi, and S. B. Feldstein, 2014: Teleconnection—extreme precipitation relationships over the Mediterranean region. *Theor. Appl. Climatol.*, **117**, 679–692, doi:10.1007/s00704-013-1036-4.

Mann, M. E., 2002: Large-scale climate variability and connections with the Middle East in past centuries. *Climatic Change*, **55**, 287–314.

Mariotti, A., 2007: How ENSO impacts precipitation in southwest central Asia. *Geophys. Res. Lett.*, **34**, L16706, doi:10.1029/2007GL030078.

——, N. Zeng, and K. M. Lau, 2002: Euro-Mediterranean rainfall and ENSO—a seasonally varying relationship. *Geophys. Res. Lett.*, **29** (12), doi:10.1029/2001GL014248.

——, J. Ballabrera-Poy, and N. Zeng, 2005: Tropical influence on Euro–Asian autumn rainfall variability. *Climate Dyn.*, **24**, 511–521, doi:10.1007/s00382-004-0498-6.

Micklin, P. P., 1988: Dessication of the Aral Sea: A water management disaster in the Soviet Union. *Science*, **241**, 1170–1176.

——, and N. V. Aladin, 2008: Reclaiming the Aral Sea. *Sci. Amer.*, **48** (4), 64–71.

NASA, 2014: The Aral Sea loses its eastern lobe. NASA Earth Observatory. [Available online at http://earthobservatory.nasa.gov/IOTD/view.php?id=84437.]

Nazemosadat, M. J., and A. R. Ghasemi, 2004: Quantifying the ENSO-related shifts in the intensity and probability of drought and wet periods in Iran. *J. Climate*, **17**, 4005–4018.

Price, C., L. Stone, A. Huppert, B. Rajagopalan, and P. Alpert, 1998: A possible link between El Niño and precipitation in Israel. *Geophys. Res. Lett.*, **25**, 3963–3966, doi:10.1029/1998GL900098.

Smith, T. M., R. W. Reynolds, T. C. Peterson, and J. Lawrimore, 2008: Improvements to NOAA's historical merged land–ocean temperature analysis (1880–2006). *J. Climate*, **21**, 2283–2296, doi:10.1175/2007JCLI2100.1.

Stocker, T. F., and Coauthors, Eds., 2014: *Climate Change 2013: The Physical Science Basis*. Cambridge University Press, 1535 pp., doi:10.1017/CBO9781107415324.

Syed, F. S., F. Giorgi, J. S. Pal, and M. P. King, 2006: Effect of remote forcings on the winter precipitation of central southwest Asia part 1: Observations. *Theor. Appl. Climatol.*, **86**, 147–160, doi:10.1007/s00704-005-0217-1.

Thomson Reuters, 2014: Thomson Reuters Commodities Research & Forecast analysts report forecasted rain critical for wheat crop in key regions. [Available online at http://blog.financial.thomsonreuters.com/dry-weather-threat-wheat-crop-key-regions/.]

Trigo, R. M., C. M. Gouveia, and D. Barriopedro, 2010: The intense 2007–2009 drought in the Fertile Crescent: Impacts and associated atmospheric circulation. *Agric. For. Meteor.*, **150**, 1245–1257.

UNICEF, 2014: Drying up: The growing water crises facing Syria and the region. UNICEF, 6 pp. [Available online at http://childrenofsyria.info/wp-content/uploads/2014/06/UNICEF-Syria-Region-water-alert-FINAL-En.pdf.]

WFP, 2014: Special focus: Syria—Will drought worsen the impact of conflict on food insecurity? World Food Programme, 8 pp. [Available online at www.wfp.org/content/syria-special-focus-will-drought-worsen-impact-conflict-food-insecurity]

Yin, Z. Y., H. Wang, and X. Liu, 2014: A comparative study on precipitation climatology and interannual variability in the lower midlatitude East Asia and central Asia. *J. Climate*, **27**, 7830–7848, doi:10.1175/JCLI-D-14-00052.1.

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**

† 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.