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—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.

26. TRENDS IN HIGH-DAILY PRECIPITATION EVENTS IN JAKARTA AND THE FLOODING OF JANUARY 2014

Siswanto, Geert Jan van Oldenborgh, Gerard van der Schrier, Geert Lenderink, and Bart van den Hurk

The January 2014 floods paralyzed nearly all of Jakarta, Indonesia. The precipitation events that lead to these floods were not very unusual but show positive trends in the observed record.

Introduction. In the period 10–20 January 2014, Jakarta and surrounding areas experienced heavy rains causing river overflows and flooding. Thousands of buildings were flooded and much infrastructure was damaged. The Provincial Agency for Disaster Management (BPBD) DKI Jakarta reported that losses reached up to 384 million U.S. dollars (http://koran-jakarta.com/?4767) with 26 reported deaths. Jakarta is regularly affected by flooding during the wet season, but the number of casualties in 2014 was among the highest since 2003, with only 2007 and 2013 more severe in this aspect.

On 11 January 2014 the Indonesian meteorological services (BMKG) recorded heavy precipitation (50 mm day^{-1}) in the larger Jakarta area. The day after, extreme rainfall (100 mm day^{-1}) was observed in the southern part of the city (see Supplemental Table S26.1). These high rainfall amounts were also observed in the TRMM satellite precipitation (Fig. 26.1a). The initial flood on 12 January was associated with heavy storms on 11–12 January over the Ciliwung catchment south of Jakarta and southern Jakarta (Fig. 26.1a and inset), with accumulated precipitation as much as 200 mm. A second flood episode was generated by severe storms on 17–18 January, when most of the precipitation fell in central to northern Jakarta.

The synoptic analyses (wind and relative humidity anomalies at 850 hPa) from the NCEP/NCAR Reanalysis-1 shows an intensified monsoon with the northerly component penetrating more to the south than usual, especially over the South China Sea (Figs. 26.1b,c). The Borneo vortex (Tangang et al. 2008; Trilaksono et al. 2012; Koseki et al. 2014), clearly visible in the 11–14 January wind field of Fig. 26.1b (white arrows), strengthened the cross-equatorial flow and transferred wet and humid air evaporated from the sea to the Sumatera and Java islands where it converged as indicated by the updraft velocity in these areas. The course of events is similar to the case of 2 February 2007 (Trilaksono et al. 2011), which was one of the most extensive floodings in Jakarta. The high humidity values in those areas, up to 15% more than the long-term average, fueled strong activity from convective showers. The event of 17–18 January 2014 was also associated with a stronger than usual northerly monsoon and cross-equatorial flow (Fig. 26.1c). Although the relative humidity and updraft velocity were weaker than the 11–14 January episode, accumulated precipitation was higher at some stations in this second episode of flooding. Figure 26.1d shows that the January 2014 precipitation at Jakarta Obs. reached 699 mm, and ranks fifth since 1900, slightly below the January 1965 value. January 2014 ranks 11th when monthly precipitation from all months is considered.

Figure 26.2a shows a time series of major floodings in Jakarta, for the early period derived subjectively from newspaper articles. Major floodings are defined as extensive inundation of structures and roads or where casualties or significant evacuations of people and/or necessity of transferring property to higher elevations are reported. Recently, major floods were recorded in 2013, 2014, and 2015 after events of extreme precipitation. The swampy plain on which Jakarta is built is a delta of 13 rivers. Rapid urban development of Jakarta makes the area increasingly vulnerable to flooding. About 40% of this area is sinking at rates of 3–10 cm yr^{-1} due to excessive groundwater extraction (Abidin et al. 2011, 2015). A cumulative land subsidence of −4.1 m has been observed over the period 1974–2010 in the northern Jakarta area (Deltares

AFFILIATIONS: Siswanto—Agency for Meteorology, Climatology, and Geophysics (BMKG), Republic of Indonesia, and Royal Netherlands Meteorological Institute (KNMI), Netherlands; van Oldenborth, van der Schrier, Lenderink, and van den Hurk—Royal Netherlands Meteorological Institute (KNMI), Netherlands
DOI:10.1175/BAMS-D-15-00128.1

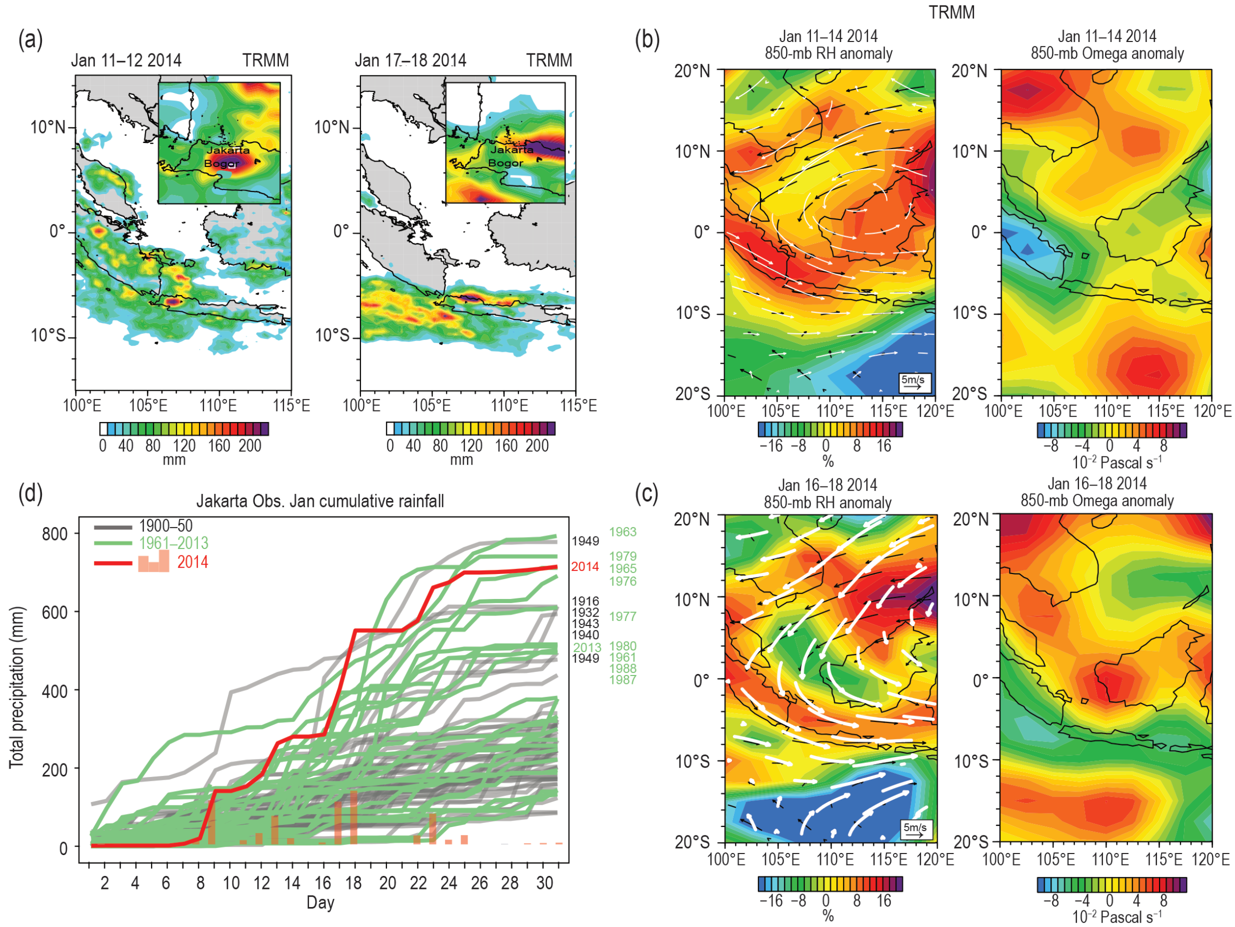

Fig. 26.1. (a) TRMM 3B42 accumulated rainfall for the two heavy rainfall events on 11–12 and 17–18 Jan 2014. (b) 11–14 Jan 2014 composite anomaly of 4-days consecutive (left) 850-hPa wind and relative humidity (%) and (right) omega (10^{-2} Pa s^{-1}) relative to Jan 1981–2010 climatology (shaded). The white (black) vectors denote the 11–14 Jan 2014 composite (climatology) of the wind field (m s^{-1} with reference vector). Negative values of omega indicate convective processes. (c) As in (b), but for 16–18 Jan 2014. (d) The Jakarta Obs. cumulative rainfall for Jan in 2014 (red line) in comparison to historical Jan between 1900–50 (gray lines) and 1961–2012 (green lines). Red bars indicate the daily amount of rainfall in 2014.

2011). There is growing concern that the apparent clustering of major flooding in recent years may not be exclusively related to the location of Jakarta in a slowly sinking delta and other hydrological factors, but that climate change may contribute as well (Firman et al. 2011; Ward et al. 2011, 2014). The aim of this paper is to assess whether the 2014 event became more likely due to trends in extreme precipitation.

Data. A subjective list of 31 major flood occurrences in Jakarta in the period 1900–2015 has been compiled using newspaper sources for 1900–1980 (www.merdeka .com; http://green.kompasiana.com) and since 1981 the official classification of BPBD DKI Jakarta. This is not used to study the trend but only the association of floods with extreme precipitation. We use the long hourly observed precipitation series measured at Jakarta Observatory (hereafter Obs.) from the Digitisasi Data Historis (DiDaH) project (www.didah.org), aggregated to the daily level (Siswanto et al. 2015, manuscript submitted to *Int. J. Climatol.*; Können et al. 1998). We use the data starting at 1900 because of evidence of a discontinuity before that (Siswanto et al. 2015, manuscript submitted to *Int. J. Climatol.*). Precipitation analyses from surrounding stations over the period 1971–2014 were retrieved from the Southeast Asian Climate Assessment & Dataset (SACA&D; http://sacad.database.bmkg.go.id/).

Return Times and Trends. Flooding in Jakarta usually occurs in December to February (DJF) at the peak of the wet season. Analysis of major flood events between 1900 and 2015 as in Fig. 26.2a revealed that 15 of 24 major flooding events for which precipita-

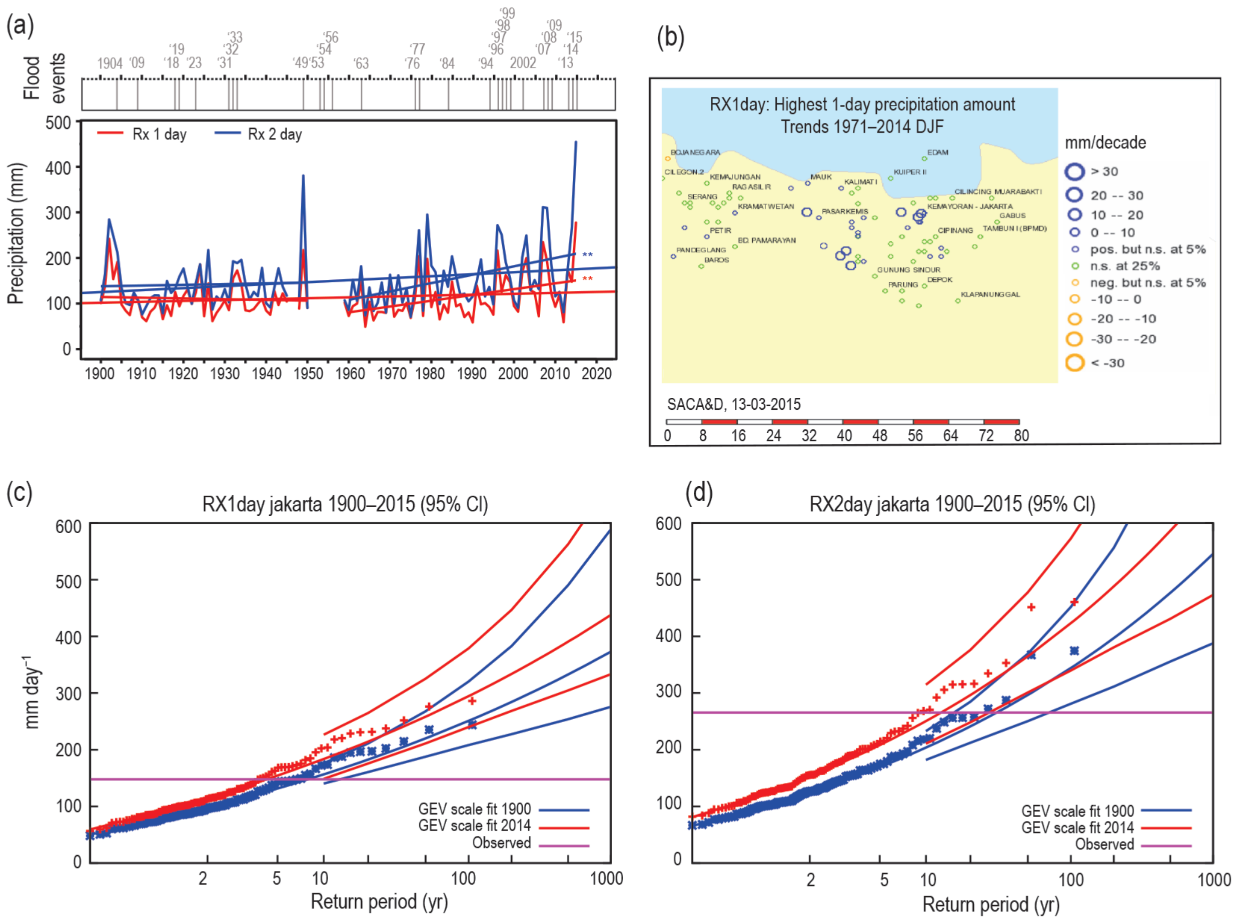

Fig. 26.2. (a, top) Observed major flood events in Jakarta during 1900–2015. The historic data from 1900–80 is gathered from national newspapers; more recent data is recorded by the BPBD DKI Jakarta. (a, bottom) Time series of RX1day (red) and RX2day (blue) including trend assessments for the whole period 1900–2015 and for the last 54 years. Symbols (**) and (*) indicate the significance level for $p < 0.01$ and $p < 0.05$, respectively. (b) The trend map of the DJF highest precipitation amount, RX1day (mm decade^{-1}) for 1971–2014 in the Greater Jakarta and Banten area as retrieved from the SACA&D system. (c) Return period of Jakarta RX1day over 1900–2015. The generalized extreme value (GEV) position and scale parameters (μ, σ) vary together with the smoothed global mean temperature. Blue lines correspond to the fit parameters for the climate of 1900, red lines for 2014 with the 90% confidence interval estimated with a non-parametric bootstrap. The observations are also shown twice: once scaled down with the fitted trend to 1900, and once scaled up to 2014. The purple line represents the observed value of Jan 2014. (d) As in (c), but for RX2day.

tion data is available could be associated with the 24 highest single-day precipitation extremes (flash floods; ADPC 2010), while 11 events are related to the 24 highest 2-day extreme precipitation events (cf. Liu et al. 2015), two of which are not also high 1-day events. The association is weaker in the beginning of the century when the floods are not as well-defined. The 2014 and 2015 floods were associated with two and one 2-day events, respectively; the 2-day precipitation event of 2015 (with 485.5 mm) is the highest in the precipitation history since 1900. Therefore, here we also consider the trend in the 2-day annual maximum. Most of the major floodings relate to excessive precipitation in the Jakarta area itself, while some floods relate to heavy precipitation upstream of the catchment of Jakarta's rivers, which is not recorded in the time series of Fig. 26.2a.

The highest daily rainfall of 2014 (RX1day) is 148 mm day^{-1} and occurred on 17 January. Rainfall on this day ranks 20th of annual highest daily rainfall since 1900. In terms of the maximum 2-day accumulated rainfall (RX2day), 16–17 January 2014 is more exceptional. The 266 mm recorded is the eighth largest 2-day precipitation sum observed at the Jakarta Obs. station since 1900.

The heaviest 1% of all daily precipitation events from the centennial series of Jakarta Obs. shows a positive linear trend over 1866–2010. The number of days with rainfall exceeding 50 mm day^{-1} and 100 mm day^{-1} has shown a statistically significant increase (Siswanto et al. 2015, manuscript submitted to *Int. J. Climatol.*). The trend is larger for the 1961–2010 period.

Figure 26.2a shows that the annual RX1day and RX2day have increased during the last 112 years. The increasing trend of RX2day is statistically significant at p-value <0.05 (one-sided, as we expect short timescale extremes to increase in this area; O'Gorman 2012). The trend in annual RX1day and RX2day during the last 54 years shows significant increases with rates of 13 mm decade^{-1} and 18 mm decade^{-1} respectively ($p < 0.01$). Increasing trends of RX1day over 1971–2014 are consistent in the area around Jakarta (Fig. 26.2c).

To compute the return time in the current climate and address the question whether the probability of occurrence of the recent extreme events has increased over time, we fitted the annual RX1day and RX2day data to a GEV distribution with position and scale parameters μ, σ simultaneously varying with the global mean temperature (smoothed with a 5-year running mean to suppress ENSO variability) as a first approximation of possible effects of global warming using a maximum likelihood method (available at http://climexp.knmi.nl; see also Schaller et al. 2014). The dependence is fitted simultaneously. Confidence intervals were estimated using a non-parametric bootstrap. The GEV describes the 1- and 2-day annual maxima better than the normal distribution implied by a least-square fit, and using the smoothed global mean temperature as covariate instead of a linear trend acknowledges that global warming has not been linear over the period 1900–2015. Finally, scaling rather than shifting the distribution is more appropriate for extreme precipitation.

The fit is shown for the parameters in 2014 representing the current climate and in 1900 as the climate of historic times. The observations are also shown twice, scaled with the fitted trend to these years. Figure 26.2c shows that the return period based on modern climate has very likely decreased compared to an analysis based on climate data from the past. The return time of the observed highest daily precipitation (148 mm day^{-1}) associated with the 2014 flood event is found to be about 4 years presently (95% CI: 2–10 years). This would have been 5–13 years in 1900. The ratio of these return times is about 1.8, different from one at $p < 0.1$ (one-sided), in agreement with the linear trend analysis of Fig. 26.2a.

Similarly, for annual RX2day, the return period of 13 years for the 2014 event in the current climate (95% CI: 5–27 years) is shorter than the 30-year (16–70) return period based on data from the past climate (Fig. 26.2d). The ratio of about a factor 2.4 is significant at $p < 0.01$ (one–sided). To conclude, we find increases in both 1-day and 2-day precipitation sums in the historical record that are unlikely due to natural variability. Just like in the seasonal mean rainy season precipitation we do not find a connection between annual maxima Jakarta precipitation and December–February sea surface temperature, in particular with El Niño (van Oldenborgh 2003).

Conclusion. Daily precipitation amounts during the 2014 floods have not been very exceptional, with estimated return periods of roughly 4 to 13 years for the one-day and two-day accumulated precipitation sums respectively. Our analyses give evidence that yearly maximum rainfall amounts, as observed in the 2014 event, have become more likely, both for daily (roughly 1.8 times more likely, $p < 0.1$) and two-day (roughly 2.4 times more likely, $p < 0.05$) rainfall amounts over the last 115 years. It should be stressed that this concerns only the meteorological aspects of the flooding. Subsidence and other hydrological factors that also affect the flooding have not been included. However, the trends in the frequency of the annual maximum of 1- and 2-day precipitation, about a factor two over the last century, do increase the risk of flooding in Jakarta. We have not established whether global warming, the urban heat island, or other effects cause these extreme precipitation trends.

ACKNOWLEDGEMENTS. This study was supported by the Joint Cooperation Program between KNMI, BMKG, PusAir, and Deltares and by the FP7 EUCLEIA project under Grant # 607085.

REFERENCES

Abidin, H. Z., H. Andreas, I. Gumilar, Y. Fukuda, Y. E. Pohan, and T. Deguchi, 2011: Land subsidence of Jakarta (Indonesia) and its relation with urban development. *Nat. Hazards*, **5**, 1753–1771, doi:10.1007/s11069-011-9866-9.

——, ——, ——, and I. R. R. Wibowo, 2015: On correlation between urban development, land subsidence and flooding phenomena in Jakarta. *Proc. IAHS*, **370**, 15–20, doi:10.5194/piahs-370-15-2015.

ADPC, 2010: Safer cities 27: Flood preparedness initiatives of high-risk communities of Jakarta. Asian Disaster Preparedness Center, 8 pp. [Available online at www.adpc.net/igo/category/ID226/doc/2013-c28Jbn-ADPC-Safer_Cities_27.pdf.]

Deltares, 2011: Sinking cities: An integrated approach towards solutions. Deltares–Taskforce Subsidence, 12 pp. [Available online at www.deltares.nl/app/uploads/2015/01/Subsidence-Sinking-cities_Deltares.pdf.]

Firman, T., C. Izhar, I. Surbakti, and H. Simarmata, 2011: Potential climate change related vulnerabilities in Jakarta: Challenges and current status. *Habitat Int.*, **3**, 32–37, doi:10.1016/j.habitatint.2010.11.011.

Können, G. P., P. D. Jones, M. H. Kaltofen, and R. J. Allan, 1998: Pre-1866 extensions of the Southern Oscillation index using early Indonesian and Tahitian meteorological readings. *J. Climate*, **11**, 2325–2339.

Koseki, S., T.-Y. Koh, and C.-K. Teo, 2014: Borneo vortex and mesoscale convective rainfall. *Atmos. Chem. Phys.*, **14**, 4539–4562, doi:10.5194/acp-14-4539-2014.

Liu, J., C. D. Doan, S.-Y. Liong, R. Sanders, A. T. Dao, and T. Fewtrell, 2015: Regional frequency analysis of extreme rainfall events in Jakarta. *Nat. Hazards*, **75**, 1075–1104, doi:10.1007/s11069-014-1363-5.

O'Gorman, P. A., 2012: Sensitivity of tropical precipitation extremes to climate change. *Nat. Geosci.*, **5**, 697–700, doi:10.1038/ngeo1568.

Schaller, N., F. E. L. Otto, G. J. van Oldenborgh, N. R. Massey, S. Sparrow, and M. R. Allan, 2014: The heavy precipitation event of May–June 2013 in the upper Danube and Elbe basins [in "Explaining Extreme Events of 2014 from a Climate Perspective"]. *Bull. Amer. Meteor. Soc.*, **96** (9), S69–S72.

Tangang, F. T., L. Juneng, E. Salimun, P. N. Vinayachandran, Y. K. Seng, C. J. C. Reason, S. K. Behera, and T. Yasunari, 2008: On the roles of the northeast cold surge, the Borneo vortex, the Madden-Julian Oscillation, and the Indian Ocean dipole during the extreme 2006/2007 flood in southern Peninsular Malaysia. *Geophys. Res. Lett.*, **35**, L14S07, doi:10.1029/2008GL033429.

Trilaksono, N. J., S. Otsuka, S. Yoden, K. Saito, and S. Hayashi, 2011: Dependence of model simulated heavy rainfall on the horizontal resolution during the Jakarta flood event in January–February 2007. *SOLA*, **7**, 193–196, doi:10.2151/sola.2011-049.

——, ——, and ——, 2012: A time-lagged ensemble simulation on the modulation of precipitation over West Java in January–February 2007. *Mon. Wea. Rev.*, **140**, 601–616, doi:10.1175/MWR-D-11-00094.1.

van Oldenborgh, G. J., 2003: The influence of El Niño – Southern Oscillation on West Java. *Jakarta Kota Pantai*, **3**, 8–9. [Available online at http://climexp.knmi.nl/publications/westjava.pdf.]

Ward, P. J., M. A. Marfai, Poerbandono, and E. Aldrian, 2011: Climate adaptation in the City of Jakarta. *Climate Adaptation and Flood Risk in Coastal Cities*, J. Aerts et al., Eds., Earthscan, 285–304.

——, and Coauthors, 2014: Jakarta climate adaptation tools (JCAT). Delta Alliance No. 8; KvK Rep. KfC 139/2014, National Research Programme Knowledge for Climate (KvK), 137 pp. [Available online at www.delta-alliance.org/news/delta-alliance-news/10853039/Final-Report-Jakarta-Climate-Adaptation-Tools-JCAT.]

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.