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Cover credits:

Front: Breezy Point, New York, November 14, 2012, in the wake of Hurricane Sandy.
U.S. Navy photo by Chief Mass communication Specialist Ryan J. Courtade/Released

Back: Herder moving cattle through a barren landscape in eastern Africa.
U.S. Geological Survey, Department of the Interior/USGS, U.S. Geological Survey/photo by Michael Budde

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independent days among the 184, i.e., a de-correlation time of about 10 days, which might, however, be a strong hypothesis in the case of persisting hot events involving long-memory processes such as soil moisture deficit.

Conclusions. In conclusion, the record hot spring of 2012 over the eastern United States can be mainly explained by atmospheric dynamics. Conversely, while large-scale circulations were favorable to anomalously high temperatures over this region in summer, other local factors, possibly linked to the exceptionally hot spring and the persisting drought throughout summer, shaped the spatial pattern of the following summer heat wave. In a long-term climate perspective, Fig. 4.2b reveals a positive trend over the last 20 years (1993–2012) in spring maximum temperatures over the eastern United States, which is found to be statistically significant at the 5% level and consistent with the flow-analogue temperature reconstruction. By contrast, no significant trend is found in summer for maximum temperatures (Fig. 4.2c), albeit additional observations show a significant increase of 0.5 σ per decade over the past 40 years (1973–2012) for minimum temperatures, partially explained by flow-analogues (not shown). This trend analysis, nevertheless, reaches the limits of daily unadjusted GHCN temperatures, since homogenized USHCN monthly temperatures exhibit a one-to-two times larger warming over recent years (but still not significant for summer maximum temperatures). The contribution of potential changes in circulation to the recent long-term warming in the United States, therefore, requires further research.

5. THE EXTREME MARCH–MAY 2012 WARM ANOMALY OVER THE EASTERN UNITED STATES: GLOBAL CONTEXT AND MULTIMODEL TREND ANALYSIS

Thomas R. Knutson, Fanrong Zeng, and Andrew T. Wittenberg

Introduction. We survey the globe for seasonal and annual mean surface temperature extremes that occurred during 2012. We define an extreme seasonal mean anomaly as one that ranks first, second, or third in the period of record, using the HadCRUT4 observations (Morice et al. 2012). Anomalous warmth over the eastern United States during March–May (MAM) is found to be particularly extreme and spatially extensive. To place this seasonal extreme warmth in the context of long-term climate change, we analyze the time series for this region, comparing observed trends with model simulations of internal climate variability and modeled responses to both anthropogenic and natural forcings using 23 Coupled Model Intercomparison Project phase 5 (CMIP5) models (Taylor et al. 2012).

Where did record or near-record seasonal mean surface temperatures occur in 2012? Global maps of the seasonal- and annual-mean temperature anomalies for 2012 are shown in Fig. 5.1 (left column). Maps in the right column depict where the anomalies were the first, second, or third most extreme in the record—either warm (red colors) or cold (blue colors). The results show a predominance of warm versus cold extreme occurrences. For extreme annual means, the percent of global analyzed area with first, second, or third warmest in the record, starting as early as 1851, was 15.3% compared with zero cold extremes. The ratios of warm-extreme-to-cold-extreme percent areas were 6.2% : 0.1% for December–February (DJF); 7.7% : 0.2 % for MAM; 11.4% : 0.7 % for June–August (JJA); and 12.5% : 0.1 % for September–November (SON).

A pronounced broader-scale feature in the extremes maps is the record MAM warmth over the eastern continental United States, which was also highly anomalous for the annual means. Much of the Mediterranean region experienced record or near-record JJA and SON warm anomalies. The SON map also shows near-record Atlantic Ocean warmth off the east coast of the United States, which spanned the time of occurrence and extratropical transition of Hurricane Sandy in this region. Other extreme seasonal warmth occurred near the Somali current (western Indian Ocean) during SON and other scattered locations around the globe.

How much did anthropogenic forcing contribute to the extreme eastern U.S. warm anomalies during MAM 2012? Having established where extreme seasonal

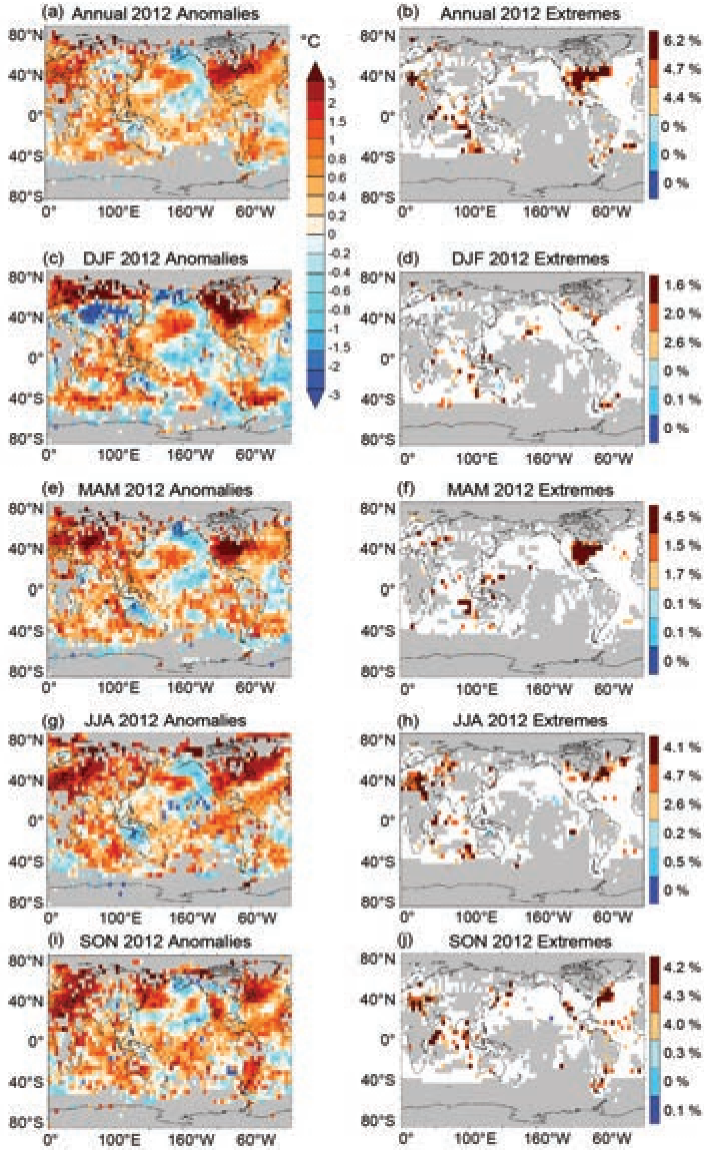

Fig. 5.1. (Left column) Annual (a) or seasonal (c), (e), (g), (i) mean surface air temperature anomalies (°C) for 2012 (1961–90 base period) from the HadCRUT4 dataset. The seasons are DJF (Dec 2011–Feb 2012), MAM (Mar–May), JJA (Jun–Aug), and SON (Sep–Nov). (Right column) Colors identify grid boxes with annual (b) or seasonal (d), (f), (h), (j) mean warm anomalies that rank first (dark red), second (orange-red), or third (yellow-orange) warmest in the available observed record, with blue colors for cold extremes. Gray areas did not have sufficiently long records, defined here as containing at least 100 available annual or seasonal means, with an annual mean requiring at least four available months and a seasonal mean requiring at least two of three months to be available.

and annual mean temperatures occurred in 2012, we now examine the extensive warm anomalies over the eastern United States during MAM in more detail.

Using the Hegerl et al. (2009) guidance paper on detection and attribution methods, we first explore a "multistep attribution" approach. This involves, in general, assessments that attribute an observed change in a variable of interest (in this case, seasonal mean temperature extremes) to a change in climate and/or environmental conditions (in this case, century-long trends in seasonal mean temperatures), plus separate assessments that attribute the change in climate and/or environmental conditions to external drivers and external forcings. We first posit that it is likely that increases in seasonal mean temperatures caused by anthropogenic warming will eventually lead to increases in the extremes (e.g., record or near-record values) of seasonal mean temperatures, but that it may take a substantial record length for this signal to be apparent in the data.

The next step is to assess whether there is detectable warming that is attributable to anthropogenic forcing in the MAM mean temperatures for the eastern U.S. region. For this, we rely on a more extensive trend assessment study that provides further details on our methods and evaluation of model internal variability (Knutson et al. 2013).

Figure 5.2a shows the MAM time series averaged over the region of the eastern United States and southern Canada where the MAM 2012 anomalies were warmest in the record (dark red colors in Fig. 5.1f). The HadCRUT4 observations show a gradual rising trend, with a distinct positive anomaly in 2012 that was nearly twice as warm as the previous record season. The observations lay within the range of the CMIP5 ensemble members, although 2012 is near the upper edge of this range.

Figure 5.2b summarizes a trend analysis for the MAM eastern U.S. time series in Fig. 5.2a, comparing models and observations. Each of the models contributes equally to the multimodel distribution from which the percentiles are derived. The distribution of trends broadens for later start dates, because these represent shorter randomly sampled trends in the control runs, and models can produce larger trend rates by chance for smaller trend lengths. The spread of the All-Forcing (anthropogenic and natural combined) multimodel ensemble (pink) is slightly wider than that of the control run ensemble

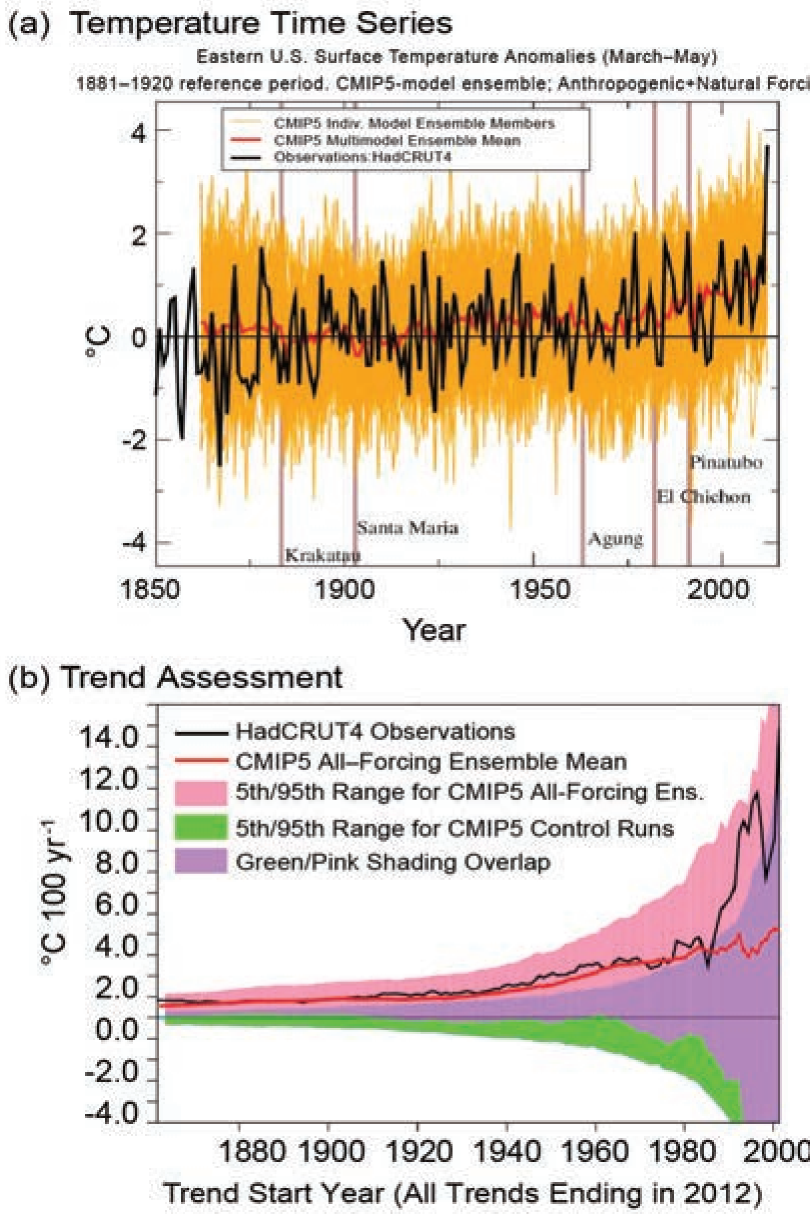

Fig. 5.2. (a) Time series of Mar–May (MAM) averaged surface air temperature anomalies (°C) averaged over the region in Fig. 5.1f of record MAM warmth in the eastern United States and southern Canada during 2012. The black line depicts the observed (HadCRUT4) anomalies; the dark red line depicts the multimodel ensemble anomalies from the CMIP5 All-Forcing runs, with each of the 23 models weighted equally; and the orange lines are individual ensemble members making up the CMIP5 multimodel ensemble. The All-Forcing simulations for this region included both anthropogenic and natural forcings from about 1860 to the present, with data from RCP4.5 runs used to extend the time series through 2012 where necessary. All time series shown are adjusted to have zero mean over the period 1881–1920. (b) Trends (°C 100 yr^{-1}) in the area-averaged MAM mean surface temperature series in (a) as a function of starting year, with all trends ending in 2012. The black curve shows trends from observations (HadCRUT4). The thick red curve shows the ensemble mean trends from the 23-member CMIP5 All-Forcing ensemble. The pink shading shows the 5th–95th percentile range of the distribution of trends obtained by combining random samples from each of the 23 CMIP5 model control runs together with the corresponding model's ensemble-mean forced trend (All-Forcing runs) to create a multimodel distribution of total trends that reflects uncertainty in both the forced response and the influence of internal climate variability. The green-shaded region shows the 5th–95th percentile range of the trends from the 23 model control runs. Purple shading indicates where the pink- and green-shaded regions overlap.

(green) because it also includes the uncertainty due to the different ensemble mean responses of the individual models. See Knutson et al. (2013) for more discussion and details.

The observed trends in Fig. 5.2b (black line) generally lie outside of the control run 5th–95th percentile range, indicating that (according to the model-generated variability) the observed trends are inconsistent with internal climate variability alone. The observed trend also lies within the pink- or purple-shaded region for all start dates, indicating that the observed MAM trends for the region are consistent with the CMIP5 All-Forcing multimodel ensemble. Using the control run internal variability as a surrogate for natural variability (generally a good assumption for relatively long trend lengths; see Knutson et al. 2013), we conclude that the observed trend is both inconsistent with natural variability and consistent with anthropogenic plus natural forcing runs, meaning that the warming in the observations is very likely attributable in part to anthropogenic forcing.

Since the anomalous warmth of MAM 2012 occurred in a region with detectable long-term anthropogenic warming, we conclude that anthropogenic forcing also likely contributed significantly to the observed anomalies of MAM 2012 over the eastern United States. A rough estimate of the anthropogenic contribution based on Fig. 5.2a would be about 35% (based on the modeled value of ~1.3°C near 2012 and the 2012 observed anomaly of ~3.7°C). Under the assumption that the real-world uncertainty is well represented by the multimodel ensemble mean plus aggregated control-run distribution (i.e., that there is no change in the variability about the mean) and interpreting the difference between the All-Forcing and control-run distributions as the anthropogenic influence, we can conclude the following regarding the 2012 MAM eastern U.S. anomaly. This 3.7°C event was 2.8 times stronger than the expected ensemble-mean contribution of 1.3°C due to anthropogenic forcing in 2012—so, internal variability almost certainly played a substantial role. Based on the model ensemble, an event this warm or warmer would occur with probability 0.07% (unforced) or 0.85% (forced)—a factor of 12 increase in risk. Under the forced scenario, the fraction of risk of such an extreme warm event that is attributable to the forcing is (0.0085 - 0.0007) / 0.0085 = 92%. These estimates of change in risk are sensitive to the baseline period assumed. Here we use the period 1881–1920 as the baseline; if we use 1861–2012 as the baseline period, the risk of the event increases by about a factor of 5 rather than 12, and the fraction of attributable risk is estimated as 78%. As a further sensitivity test, we examined the occurrence of anomalies larger than an alternative threshold equivalent to the second warmest MAM anomaly in the observed series (2.04°C in 1991). Anomalies exceeding this level occur about 11 times more often in the forced simulations than in the unforced runs.

Discussion and conclusions. From the viewpoint of seasonal or annual mean extreme temperatures, 2012 was characterized by a much greater occurrence globally of warm extremes than cold extremes. Notable large-scale regions with extreme seasonal warmth included the United States east of the Rocky Mountains during MAM and much of the Mediterranean region during July–November. The extreme warmth over the eastern United States occurred in a region where there has also been longer-term warming that our model-based assessment attributes at least in part to anthropogenic forcing.

Although the long-term warming during MAM over the eastern U.S. region of record 2012 warmth in Fig. 5.1f was assessed as detectable, a number of caveats apply. For example, when we tested the warming trends since 1901 for individual grid points around the globe, a number of grid points in the eastern U.S. region did not have significant trends (Supplementary Fig. S5.1i). Previous studies have suggested a lack of statistically significant long-term warming over the eastern United States; in particular, Portmann et al. (2009) discussed possible physical explanations for this feature and showed that there is a statistical relationship between the trends in daily maximum temperatures across the United States and the climatological mean precipitation. However, our results illustrate the potential effects of spatial averaging for this type of detection/attribution analysis. After averaging over the entire region of anomalous record warmth in the eastern United States, we *do* find a detectable trend-to-2012 across a wide range of possible start dates. Differences between our results and previous studies may also be due to the averaging area or season chosen and the inclusion of the very warm 2012 anomalies. Our region definition tends to enhance the influence of the very warm anomalies occurring in MAM 2012.

Other caveats to our analysis include remaining uncertainties in estimates of internal variability of the climate system, in climate forcing agents, and in model sensitivity to the forcings. We have found that the models' low-frequency (>10 yr) internal climate variability in this region is larger than our current best estimate of the real climate system's low frequency internal variability (e.g., Fig. 2 of Knutson et al. 2013). If internal climate variability were in fact overestimated by the models, this would make it overly difficult for a climate signal to be detected above internal variability noise in our analysis, so the detection result would be robust to such a bias. Such a bias would also widen the envelope of the forced simulations, possibly obscuring an underestimate of the warming by the forced models.

The anthropogenic contribution to the extreme seasonal (MAM) warmth over the eastern United States can be estimated as about 35%, or in terms of risk, anthropogenic forcing leads to a factor of 12 increase in the risk of such an event according to our calculations. An important issue for future studies is to explore potential changes in the shape of the temperature distributions under climate change and its effect on the risk estimates for extreme events in the tails of the distribution.

The much larger fraction of global analyzed area with extreme warm seasonal-mean anomalies in Fig. 5.1 (right column), compared to the fraction of area with extreme cold seasonal-mean anomalies, suggests another future approach to multistep attribution. For example, we plan to further explore the rates of occurrence of seasonal warm and cold extremes in the observations and compare the observed changes with those simulated in the All-Forcing runs.

6. HURRICANE SANDY INUNDATION PROBABILITIES *TODAY AND TOMORROW*

William Sweet, Chris Zervas, Stephen Gill, and Joseph Park

Introduction. Hurricane Sandy slammed into the U.S. mid-Atlantic seaboard on 29–30 October 2012 causing widespread damage and functional disruption to critical infrastructure resulting in repair and mitigation expenditures funded at $60.2 billion U.S. dollars (GPO 2013). Sandy's impacts exposed many unrealized sector-specific thresholds and general-public vulnerabilities across a region generally accustomed to Nor'easters (Hirsch et al. 2001; Colle et al. 2010; Sweet and Zervas 2011), but not hurricane strikes. As rebuilding occurs, concerns remain as to how sea level rise (SLR) will change probabilities of future events leading to recurring economic losses within an increasingly crowded coastal zone (http://stateofthecoast.noaa.gov/population). Here, we summarize tide gauge water level statistics from Sandy and discuss how the probabilities of exceeding its peak impact elevations (relative to *today's* reference frame) have changed since the mid-20th century from relative SLR (SLR_{rel}) and provide future estimates based upon SLR_{rel} scenarios.

Data and methods. Peak water level measurements during Sandy were recorded by National Oceanic and Atmospheric Administration (NOAA) tide gauges (Fig. 6.1; http://tidesandcurrents.noaa.gov). In the case of the Sandy Hook gauge, which was destroyed before reaching its peak, an average of two high-water marks at the adjacent U.S. Coast Guard base (McCallum et al. 2012) were used instead of the last value recorded. Exceedance probabilities are quantified by a generalized extreme value (GEV) model of annual maxima whose cumulative distribution is described by location (centering), scale (dispersion), and shape (distribution tail) parameters (Coles 2001).

We provide time-dependent return intervals (expected time between recurring events and the inverse of the exceedance probability) associated with peak Sandy storm tide levels (tide + surge; referred to as impact levels) based upon GEV models shown with 95% confidence intervals at http://tidesandcurrents.noaa.gov/est. The return curves are based upon records through 2010 (Fig. 6.1a), except for the Battery, Bridgeport, and Sandy Hook where impacts from Sandy warranted a recomputation of the stations' probability models through 2012 since GEV models are sensitive to outlier influences (Fig. 6.1a). The GEV models are also sensitive to record length, implying that if Sandy Hook's record was as long as the Battery's, its return interval for Sandy would be longer (Fig. 6.2a). All levels are relative to 1983–2001 epoch mean higher high-water (MHHW; http://tidesandcurrents.noaa.gov/datum_options) tidal datum to normalize for varying tidal ranges.

Current (2012) and historical (1950) return intervals for Sandy's impact levels are obtained by raising or lowering, respectively, a station's GEV model by its long-term relative mean sea level (MSL) trend (http://

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, doi:10.1006/asle.2001.0025.

Allan, R. J., and T. J. Ansell, 2006: A new globally complete monthly historical mean sea level pressure data set (HadSLP2): 1850-2004. *J. Climate*, **19**, 5816–5842.

——, and C. K. Folland, 2012: [Global climate] Atmospheric circulation: 1. Mean sea level pressure [in "State of the Climate in 2011"]. *Bull. Amer. Meteor. Soc.*, **93** (7), S35–S36.

Allen, M. R., 1999: Do-it-yourself climate prediction. *Nature*, **401**, 642–642.

——, 2003: Liability for climate change. *Nature*, **421**, 891–892.

——, and W. J. Ingram, 2002: Constraints on future changes in climate and the hydrologic cycle. *Nature*, **419**, 224–232.

AMS, cited 2013: Top 10 most read articles. Accessed July 18. [Available online at http://journals.ametsoc.org/.]

Balmaseda, M. A., L. Ferranti, F. Molteni, and T. N. Palmer, 2010: Impact of 2007 and 2008 Arctic ice anomalies on the atmospheric circulation: Implications for long-range predictions. *Quart. J. Roy. Meteor. Soc.*, **136**, 1655–1664.

Berg, P., C. Moseley, and J. O. Harter, 2013: Strong increase in convective precipitation in response to higher temperatures. *Nature Geosci.*, **6**, 181–185, doi:10.1038/NGEO1731.

Boon, J. D., 2012: Evidence of sea level acceleration at U.S. and Canadian tide stations, Atlantic Coast, North America. *J. Coast. Res.*, **28**, 1437–1445.

Brayshaw, D., B. Hoskins, and M. Blackburn, 2011: The basic ingredients of the North Atlantic storm track. Part II: Sea surface temperatures. *J. Atmos. Sci.,* **68**, 1784–1805.

Bureau of Meteorology, 2012: Exceptionally heavy rainfall across southeast Australia. Special Climate Statement 39, 19 pp.

Cai, W., P. van Rensch, T. Cowan, and A. Sullivan, 2010: Asymmetry in ENSO teleconnection with regional rainfall, its multidecadal variability and impact. *J. Climate,* **23**, 4944–4955.

Cane, M. A., and Coauthors, 1997: Twentieth-century sea surface temperature trends. *Science*, **275**, 957–960.

Cassou, C., L. Terray, and A. Phillips, 2005: Tropical Atlantic influence on European heat waves. *J. Climate*, **18**, 2805–2811.

Cattiaux, J., and P. Yiou, 2012: Contribution of atmospheric circulation to remarkable European temperatures of 2011 [in "Explaining extreme events of 2011 from a climate perspective"]. *Bull. Amer. Meteor. Soc.*, **93**, 1054–1057.

——, R. Vautard, C. Cassou, P. Yiou, V. Masson-Delmotte, and F. Codron, 2010: Winter 2010 in Europe: A cold extreme in a warming climate. *Geophys. Res. Lett.*, **37**, L20704, doi:10.1029/2010GL044613.

Catto, J., N. Nicholls, and C. Jakob, 2012: North Australian sea surface temperatures and the El Niño Southern Oscillation in observations and models. *J. Climate*, **25**, 5011–5029.

Caussinus, H., and O. Mestre, 2004: Detection and correction of artificial shifts in climate series. *J. Roy. Stat. Soc. Ser. C Appl. Stat.,* **53**, 405–425.

CEH, 2012: An overview of the 2010-12 drought and its dramatic termination. Centre for Ecology & Hydrology, 4 pp. [Available online at http://www.ceh.ac.uk/data/nrfa/nhmp/other_reports/2012_Drought_Transformation.pdf.]

Chang, F.-C., and J. M. Wallace, 1987: Meteorological conditions during heat waves and droughts in the United States Great Plains. *Mon. Wea. Rev.,* **115**, 1253–1269.

Christidis, N., and P. A. Stott, 2012: Lengthened odds of the cold UK winter of 2010/2011 attributable to human influence [in "Explaining extreme events of 2011 from a climate perspective"]. *Bull. Amer. Meteor. Soc.*, **93**, 1060–1062.

——, ——, 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.

Church, J. A., and N. J. White, 2011: Sea-level rise from the late 19th to the early 21st Century. *Surv. Geophys.*, **32**, 585–602, doi:10.1007/s10712-011-9119-1.

Clement, A. C., R. Seager, M. A. Cane, and S. E. Zebiak, 1996: An ocean dynamical thermostat. *J. Climate*, **9**, 2190–2196.

CMA, 2013: *China Climate Bulletin 2012*. China Meteorological Administration, 54 pp.

Coles, S., 2001: *An Introduction to Statistical Modeling of Extreme Values*. Springer, 208 pp.

Colle, B. A., K. Rojowsky, and F. Buonaito, 2010: New York City storm surges: Climatology and an analysis of the wind and cyclone evolution. *J. Appl. Meteor. Climatol.*, **49**, 85–100.

Compo, G. P., and P. D. Sardeshmukh, 2010: Removing ENSO-related variations from the climate record. *J. Climate*, **23**, 1957–1978.

Cook, K. H., and E. K. Vizy, 2013: Projected changes in East African rainy seasons. *J. Climate*, in press, doi:10.1175/JCLI-D-12-00455.1.

de Bruin, H. A. R., and H. R. A. Wessels, 1988: A model for the formation and melting of ice on surface waters. *J. Appl. Meteor.*, **27**, 164–173.

de Vries, H., and R. van Westrhenen, 2012: Weer (g)een Elfstedentocht. *Meteorologica*, **21**, 4–7.

——, R. J. Haarsma, and W. Hazeleger, 2012a: Western European cold spells in current and future climate. *Geophys. Res. Lett.*, **39**, L04706, doi:10.1029/2011GL050665.

——, ——, and ——, 2012b: On the future reduction of snowfall in western and central Europe. *Climate Dyn.*, in press, doi:10.1007/s00382-012-1583-x.

Dee, D. P., and Coauthors, 2011: The ERA-interim reanalysis: Configuration and performance of the data assimilation system. *Quart. J. Roy. Meteor. Soc.*, **137**, 553–597.

Diffenbaugh, N. S., M. Ashfaq, and M. Scherer, 2011: Transient regional climate change: Analysis of the summer climate response in a high-resolution, century-scale ensemble experiment over the continental United States. *J. Geophys. Res.*, **116**, D24111, doi:10.1029/2011JD016458.

Ding, Q., and B. Wang, 2005: Circumglobal teleconnection in the Northern Hemisphere summer. *J. Climate*, **18**, 3483–3505.

Donlon, C. J., M. Martin, J. D. Stark, J. Roberts-Jones, E. Fiedler, and W. Wimmer, 2012: The Operational Sea Surface Temperature and Sea Ice Analysis (OSTIA) system. *Remote Sens. Environ.*, **116**, 140–158.

Doyle, M., and M. Harvey, 2012: A storm like no other. *Newsline: the mag*, Issue 267, 2–4. [Available online at http://www.tasman.govt.nz/tasman/newsline-online/2012/newsline-267-27-january-2012/.]

Environmental Modeling Center, 2003: The GFS Atmospheric Model. NCEP Office Note 442, Global Climate and Weather Modeling Branch, EMC, Camp Springs, MD. [Available online at http://www.emc.ncep.noaa.gov/GFS/.php.]

Evans, J. P., and I. Boyer-Souchet, 2012: Local sea surface temperatures add to extreme precipitation in northeast Australia during La Niña. *Geophys. Res. Lett.*, **39**, doi:10.1029/2012GL052014

Ezer, T., L. P. Atkinson, W. B. Corlett, and J. L. Blanco, 2013: Gulf Stream's induced sea level rise and variability along the U.S. mid-Atlantic coast. *J. Geophys. Res.*, **118**, doi:10.1002/jgrc.20091.

Fanelli, C., P. Fanelli, and D. Wolcott, 2013: Hurricane Sandy. NOAA Water Level and Meteorological Data Report, 60 pp. [Available on line at http://tidesandcurrents.noaa.gov/publications/Hurricane_Sandy_2012_Water_Level_and_Meteorological_Data_Report.pdf.]

Feldstein, S. B., 2007: The dynamics of the North Atlantic Oscillation during the summer season. *Quart. J. Roy. Meteor. Soc.*, **133**, 1509–1518.

Fetterer, F., K. Knowles, W. Meier, and M. Savoie, 2009: Sea ice index. Ice extent. National Snow and Ice Data Center, Boulder, CO, digital media. [Available online at http://dx.doi.org/10.7265/N5QJ7F7W.]

FEWS NET, 2012a: East Africa Food Security Alert: Poor forecast suggests that increased food insecurity is likely in the eastern Horn. 6 April 2012. [Available online at http://www.fews.net/docs/Publications/East%20Region_Alert_2012_04_06_final.pdf.]

——, 2012b: East Africa Food Security Alert: Crisis levels of food insecurity will persist following below-average March to May rains. 14 June 2012. [Available online at http://www.fews.net/docs/Publications/East%20Region_Alert_2012_06_final.pdf.]

——, 2013: Mortality among populations of southern and central Somalia affected by severe food insecurity and famine during 2010-2012. 1 May 20213. [Available online at http://www.fews.net/docs/Publications/Somalia_Mortality_Estimates_Final_Report_1May2013_upload.pdf.]

Fichefet, T., and M. A. M. Maqueda, 1997: Sensitivity of a global sea ice model to the treatment of ice thermodynamics and dynamics. *J. Geophys. Res.*, **102** (C6), 12 609–12 646.

Field, C. B., and Coauthors, Eds., 2012: *Managing the Risks of Extreme Events and Disasters to Advance Climate Change Adaptation*. Cambridge University Press, 582 pp.

Fischer, E. M., S. I. Seneviratne, D. Lüthi, and C. Schär, 2007a: Contribution of land-atmosphere coupling to recent European summer heat waves. *Geophys. Res. Lett.* **34**, L06706, doi:10.1029:2006GL029068.

——, ——, P. L. Vidale, D. Lüthi, and C. Schär, 2007b: Soil moisture–Atmosphere interactions during the 2003 European summer heat wave. *J. Climate*, **20**, 5081–5099.

Folland, C. K., and Coauthors, 2009: The summer North Atlantic oscillation: Past, present, and future. *J. Climate*, **22**, 1082–1103.

Funk, C., 2012: Exceptional warming in the western Pacific–Indian Ocean warm pool has contributed to more frequent droughts in eastern Africa [in "Explaining extreme events of 2011 from a climate perspective"]. *Bull. Amer. Meteor. Soc.*, **93**, 1049–1051.

——, M. D. Dettinger, J. C. Michaelsen, J. P. Verdin, M. E. Brown, M. Barlow, and A. Hoell, 2008: Warming of the Indian Ocean threatens eastern and southern African food security but could be mitigated by agricultural development. *Proc. Natl. Acad. Sci. USA*, **105**, 11 081–11 086.

Ganter, C., and S. Tobin, 2013: [Regional climates] Australia [in "State of the Climate in 2012"]. *Bull. Amer. Meteor. Soc.*, **94** (8), S196–S198.

García-Herrera, R., D. Paredes, R. M. Trigo, I. F. Trigo, H. Hernández, D. Barriopedro, and M. T. Mendes, 2007: The outstanding 2004-2005 drought in the Iberian Peninsula: The associated atmospheric circulation. *J. Hydrometeor.*, **8**, 483–498.

Gillett, N. P., V. K. Arora, G. M. Flato, J. F. Scinocca, and K. vonSalzen, 2012: Improved constraints on 21st-century warming derived using 160 years of temperature observations. *Geophys. Res. Lett.*, **39**, L01704, doi:10.1029/2011GL050226.

Gimeno, L., R. Nieto, R. M. Trigo, S. M. Vicente-Serrano, and J. I. López-Moreno, 2010a: Where does the Iberian Peninsula moisture come from? An answer based on a Lagrangian approach. *J. Hydrometeor.*, **11**, 421–436.

——, A. Drumond, R. Nieto, R. M. Trigo, and A. Stohl, 2010b: On the origin of continental precipitation. *Geophys. Res. Lett.*, **37**, L13804, doi:10.1029/2010GL04371.

——, R. Nieto, A., Drumond, R. Castillo, and R. Trigo, 2013: Influence of the intensification of the major oceanic moisture sources on continental precipitation. *Geophys. Res. Lett.*, **40**, 1443–1450, doi:10.1002/grl.50338.

Giorgi, F., and R. Francisco, 2000: Uncertainties in regional climate change prediction: A regional analysis of ensemble simulations with the HADCM2 coupled AOGCM. *Climate Dyn.*, **16**, 169–182.

Gleckler, P. J., and Coauthors, 2012: Human-induced global ocean warming on multidecadal timescales. *Nature Climate Change*, **2**, 524–529.

Goosse, H., and T. Fichefet, 1999: Importance of ice-ocean interactions for the global ocean circulation: A model study. *J. Geophys. Res.*, **104** (C10), 23 337–23 355.

——, O. Arzel, C. M. Bitz, A. De Montety, and M. Vancoppenolle, 2009: Increased variability of the Arctic summer ice extent in a warmer climate. *Geophys. Res. Lett.*, **36**, L23702, doc:10.1029/2009GL040546.

Gordon, C., C. Cooper, C. A. Senior, H. Banks, J. M. Gregory, T. C. Johns, J. F. B. Mitchell, and R. A. Wood, 2000: The simulation of SST, sea ice extents and ocean heat transports in a version of the Hadley Centre coupled model without flux adjustments. *Climate Dyn.*, **16**, 147–168.

GPO, 2013: Disaster Relief Appropriations Act for 2013 (HR 152) and An Act To Temporarily Increase the Borrowing Authority of the Federal Emergency Management Agency for Carrying Out the National Flood Insurance Program (HR 41).

Grinsted, A., J. C. Moore, and S. Jevrejeva, 2012: A homogeneous record of Atlantic hurricane surge threat since 1923. *Proc. Natl. Acad. Sci. USA,* **109**, 19 601–19 605.

——, ——, and ——, 2013: Projected Atlantic hurricane surge threat from rising temperatures. *Proc. Natl. Acad. Sci. USA*, **110**, 5369–5373, doi:10.1073/pnas.1209980110.

Gu, G., and R. F. Adler, 2013: Interdecadal variability/long-term changes in global precipitation patterns during the past three decades: Global warming and/or Pacific decadal variability? *Climate Dyn.*, **40**, 3009–3022 .

Guemas, V., F. J. Doblas-Reyes, K. Mogensen, Y. Tang, and S. Keeley, 2013: Ensemble of sea ice initial conditions for interannual climate predictions. *Climate Dyn.*, submitted, CLIDY-D-13-00147.

Guo, Q. Y., 1983: The summer monsoon intensity index in East Asia and its variation (in Chinese). *Acta Geograph. Sin.*, **38**, 207–217.

Hall, T. M., and A. H. Sobel, 2013: On the impact angle of Hurricane Sandy's New Jersey landfall. *Geophys. Res. Lett.*, **40**, doi:10.1002/grl.50395.

Haylock, M. R., and Coauthors, 2008: A European daily high-resolution gridded dataset of surface temperature and precipitation. *J. Geophys. Res.*, **113**, D20119, doi:10.1029/2008JD10201.

Hegerl, G. C., and Coauthors, 2007: Understanding and attributing climate change. *Climate Change 2007: The Physical Science Basis.* S. Solomon, et al., Eds., Cambridge University Press, 663–745.

——, O. Hoegh-Guldberg, G. Casassa, M. P. Hoerling, R. S. Kovats, C. Parmesan, D. W. Pierce, and P. A. Stott, 2009: Good practice guidance paper on detection and attribution related to anthropogenic climate change. *Meeting Report of the Intergovernmental Panel on Climate Change Expert Meeting on Detection and Attribution of Anthropogenic Climate Change*, T. F. Stocker, et al., Eds., University of Bern, Switzerland, 1–8. [Available online at https://www.ipcc-wg1.unibe.ch/guidancepaper/IPCC_D&A_GoodPracticeGuidancePaper.pdf.]

Hewitt, H. T., D. Copsey, I. D. Culverwell, C. M. Harris, R. S. R. Hill, A. B. Keen, A. J. McLaren, and E. C. Hunke, 2011: Design and implementation of the infrastructure of HadGEM3: The next-generation Met Office climate modelling system. *Geosci. Model Dev.,* **4**, 223–253.

Hirsch, M. E., A. T. DeGaetano, and S. J. Colucci, 2001: An East Coast winter storm climatology. *J. Climate*, **14**, 882–899.

Hirschi, M., and Coauthors, 2011: Observational evidence for soil-moisture impact on hot extremes in southeastern Europe. *Nature Geosci.*, **4**, 17–21.

Hoerling, M. P., and A. Kumar, 2002: Atmospheric response patterns associated with tropical forcing. *J. Climate*, **15**, 2184–2203.

——, and ——, 2003: The perfect ocean for drought. *Science*, **299**, 691–694.

——, J. Eischeid, and J. Perlwitz, 2010: Regional precipitation trends: Distinguishing natural variability from anthropogenic forcing. *J. Climate*, **23**, 2131–2145.

——, ——, X.-W. Quan, H. F. Diaz, R. S. Webb, R. M. Dole, D. R. Easterling, 2012a: Is a transition to semipermanent drought conditions imminent in the U.S. Great Plains? *J. Climate*, **25**, 8380–8386.

——, ——, J. Perlwitz, X. Quan, T. Zhang, and P. Pegion, 2012b: On the increased frequency of Mediterranean Drought. *J. Climate*, **25**, 2146–2161.

——, and Coauthors, 2013a: Anatomy of an extreme event. *J. Climate*, **26**, 2811–2832.

——, and Coauthors, 2013b: An interpretation of the origins of the 2012 central Great Plains drought. NOAA Drought Task Force/National Integrated Drought Information System (NIDIS), 44 pp. [Available online at http://cpo.

noaa.gov/ClimatePrograms/ModelingAnalysisPredictionsandProjections/MAPPTaskForces/DroughtTaskForce/2012CentralGreatPlainsDrought.aspx.]

Hong, S. Y., and E. Kalnay, 2000: Role of sea surface temperature and soil-moisture feedback in the 1998 Oklahoma-Texas drought. *Nature*, **408**, 842–844.

Hoskins, B. J., and K. I. Hodges, 2002: New perspectives on the Northern Hemisphere winter storm tracks. *J. Atmos. Sci.,* **59**, 1041–1061.

Hunter, J., 2010: Estimating sea-level extremes under conditions of uncertain sea-level rise. *Climatic Change*, **99**, 331–350, doi:10.1007/s10584-009-9671-6.

Huntingford, C., R. G. Jones, C. Prudhomme, R. Lamb, J. H. C. Gash, and D. A. Jones, 2003: Regional climate-model predictions of extreme rainfall for a changing climate. *Quart. J. Roy. Meteor. Soc.*, **129**, 1607–1621.

JBA Risk Management and Met Office, 2012: UK Flooding April to July 2012. JBA Rick Management and Met Office, [4 pp.] [Available online at http://www.metoffice.gov.uk/media/pdf/e/s/JBA_and_Met_Office_Bulletin_UK_Flooding_April_July_2012.pdf.]

Jones, A., D. L. Roberts, M. J. Woodage, and C. E. Johnson, 2001: Indirect sulphate aerosol forcing in a climate model with an interactive sulphur cycle. *J. Geophys. Res.*, **106** (D17), 20 293–20 310, doi:10.1029/2000JD000089.

Jones, C. D., and Coauthors, 2011: The HadGEM2-ES implementation of CMIP5 centennial simulations. *Geosci. Model Dev.*, **4**, 1–28.

Jones, D. A., W. Wang, and R. Fawcett, 2009: High-quality spatial climate data-sets for Australia. *Aust. Meteor. Ocean. J.,* **58**, 233–248.

Jones, R. G., M. Noguer, D. C. Hassell, D. Hudson, S. S. Wilson, G. J. Jenkins, and J. F. B Mitchell, 2004: *Generating High Resolution Climate Change Scenarios Using PRECIS*. Met Office Hadley Centre, 40 pp.

Junker, N. W., R. H. Grumm, R. Hart, L. F. Bosart, K. M. Bell, and F. J. Pereira, 2008: Use of normalized anomaly fields to anticipate extreme rainfall in the mountains of northern California. *Wea. Forecasting*, **23**, 336–356.

Kalnay, E., and Coauthors, 1996: The NCEP/NCAR 40-year reanalysis project. *Bull. Amer. Meteor. Soc.,* **77**, 437–471.

Kattenberg, A., and Coauthors, 2008: *De Toestand van het Klimaat in Nederland 2008*. KNMI, 47 pp. [Available online at http://www.knmi.nl/cms/mmbase/attachments/67092/Toestand2008geheel.pdf.]

Kharin, V. V., G. J. Boer, W. J. Merryfield, J. F. Scinocca, and W.-S. Lee, 2012: Statistical adjustment of decadal predictions in a changing climate. *Geophys. Res. Lett.*, **39**, L19705, doi:10.1029/2012GL052647.

Kimoto, M., and M. Ghil, 1993: Multiple flow regimes in the northern hemisphere winter. Part I: methodology and hemispheric regimes. *J. Atmos. Sci.*, **50**, 2625–2643.

King, A. D., L. V. Alexander, and M. G. Donat, 2013: Asymmetry in the response of Eastern Australia extreme rainfall to low-frequency Pacific variability. *Geophys. Res. Lett.*, **40**, 2271–2277, doi:10.1002/grl.50427.

Kistler, R., and Coauthors, 2001: The NCEP-NCAR 50-year reanalysis: Monthly means CD-ROM and documentation. *Bull. Amer. Meteor. Soc.*, **82**, 247–267.

Klein-Tank, A., and Coauthors, 2002: Daily dataset of 20th-century surface air temperature and precipitation series for the European Climate Assessment. *Int. J. Climatol.*, **22**, 1441–1453.

Knight, J. R., C. K. Folland, and A. A. Scaife, 2006: Climate impacts of the Atlantic Multidecadal Oscillation. *Geophys. Res. Lett.*, **33**, L17706, doi:10.1029/2006GL026242.

Knutson, T. R., F. Zeng, and A. T. Wittenberg, 2013: Multi-model assessment of regional surface temperature trends: CMIP3 and CMIP5 20th century simulations. *J. Climate*, in press, doi:10.1175/JCLI-D-12-00567.1.

Kosaka, Y., H. Nakamura, M. Watanabe, and M. Kimoto, 2009: Analysis on the dynamics of a wave-like teleconnection pattern along the summertime Asian jet based on a reanalysis dataset and climate model simulations. *J. Meteor. Soc. Japan*, **87**, 561–580.

Kushnir, Y., and Coauthors, 2002: Atmospheric GCM response to extratropical SST anomalies: Synthesis and evaluation. *J. Climate*, **15**, 2233–2256.

Kusunoki, A., J. Yoshimura, H. Yoshimura, A. Noda, K. Oouchi, and R. Mizuta, 2006: Change of Baiu rain band in global warming projection by an atmospheric general circulation model with a 20-km grid size. *J. Meteor. Soc. Japan*, **84**, 581–611.

Large, W., and S. Yeager, 2004: Diurnal to decadal global forcing for ocean and sea-ice models: The data sets and flux climatologies. NCAR Tech. Note NCAR/TN460+STR, 111 pp.

L'Heureux, M. L., S. Lee, and B. Lyon, 2013: Recent multi-decadal strengthening of the Walker circulation across the tropical Pacific. *Nature Climate Change*, **3**, 571–576, doi:10.1038/nclimate1840.

Li, H., A. Dai, T. Zhou, and J. Lu, 2010: Responses of East Asian summer monsoon to historical SST and atmospheric forcing during 1950-2000. *Climate Dyn.*, **34**, 501–514.

Lin, N., K. A. Emanuel, M. Oppenheimer, and E. Vanmarcke, 2012: Physically based assessment of hurricane surge threat under climate change. *Nature Climate Change*, **2**, 462–467, doi:10.1038/NCLIMATE1389.

Liu, H., T. Zhou, Y. Zhu, and Y. Lin, 2012: The strengthening East Asia summer monsoon since the early 1990s. *Chin. Sci. Bull.*, **57**, 1553–1558, doi:10.1007/s11434-012-4991-8.

Lorenz, E., 1969: Atmospheric predictability as revealed by naturally occurring analogues. *J. Atmos. Sci.*, **26**, 636–646.

Lott, F. C., N. Christidis, and P. A. Stott, 2013: Can the 2011 East African drought be attributed to human-induced climate change? *Geophys. Res. Lett.*, **40**, 117–1181, doi:10.1002/grl.50235.

Lyon, B., and D. G. DeWitt, 2012: A recent and abrupt decline in the East African long rains. *Geophys. Res. Lett.*, **39**, L02702, doi:10.1029/2011GL050337.

Madden, R. A., and J. Williams, 1978: The correlation between temperature and precipitation in the United States and Europe. *Mon. Wea. Rev.*, **106**, 142–147.

Madec, G., and Coauthors, 2008: *NEMO ocean engine*. Note du pole de modélisation, No. 27, Institut Pierre-Simon Laplace, 357 pp.

Massey, N., and Coauthors, 2006: Data access and analysis with distributed federated data servers in climate*prediction*.net. *Adv. Geosci.*, **8**, 49–56.

——, T. Aina, C. Rye, F. E. L. Otto, R. Wilson, R. G. Jones, and M. R. Allen, 2012: Have the odds of warm November temperatures and cold December temperatures in central England changed? *Bull. Amer. Meteor. Soc.*, **93**, 1057–1059.

Massonnet, F., T. Fichefet, H. Goosse, C. M. Bitz, G. Philippon-Berthier, M. M. Holland, and P.-Y. Barriat, 2012: Constraining projections of summer Arctic sea ice. *Cryosphere*, **6**, 1383–1394.

Mastrandrea, M. D., K. J. Mach, G.-K. Plattner, O. Edenhofer, T. F. Stocker, C. B. Field, K. L. Ebi, and P. R. Matschoss, 2011: The IPCC AR5 guidance note on consistent treatment of uncertainties: A common approach across the working groups. *Climate Change*, **108**, 675–691.

McBride, J. L., and N. Nicholls, 1983: Seasonal relationships between Australian rainfall and the Southern Oscillation. *Mon. Wea. Rev.*, **111**, 1998–2004.

McCallum, B. E., and Coauthors, 2013: Monitoring storm tide and flooding from Hurricane Sandy along the Atlantic coast of the United States, October 2012. USGS Open-File Report 2013–1043, 42 pp. [Available online at http://pubs.usgs.gov/of/2013/1043.]

McKee, T. B., N. J. Doesken, and J. Kleist, 1993: The relationship of drought frequency and duration to time scales. *Proc. Eighth Conf. on Appl. Climatol.*, Anaheim, CA, Amer. Meteor. Soc., 179–183.

McRoberts, D. B., and J. W. Nielsen-Gammon, 2011: A new homogenized climate division precipitation dataset for analysis of climate variability and climate change. *J. Appl. Meteor. Climatol.*, **50**, 1187–1199.

Meehl, G. A., and C. Tebaldi, 2004: More intense, more frequent, and longer lasting heat waves in the 21st century. *Science*, **305**, 994–997.

Menéndez, M., and P. L. Woodworth, 2010: Changes in extreme high water levels based on a quasi-global tide-gauge data set. *J. Geophys. Res.*, **115**, C10011, doi:10.1029/2009JC005997.

Meng, Q., M. Latif, W. Park, N. S. Keenlyside, V. A. Semenov, and T. Martin, 2012: Twentieth century Walker Circulation change: Data analysis and model experiments. *Climate Dyn.*, **38**, 1757–1773.

Menne, M. J., C. N. Williams, and R. S. Vose, 2009: The United States Historical Climatology Network monthly temperature data - version 2. *Bull. Amer. Meteor. Soc.*, **90**, 993–1107.

Merrifield, M. A., and M. E. Maltrud, 2011: Regional sea level trends due to a Pacific trade wind intensification. *Geophys. Res. Lett.*, **38**, L21605, doi:10.1029/2011GL049576.

Met Office, cited 2013: Annual 2012. [Available online at http://www.metoffice.gov.uk/climate/uk/2012/annual.html.]

Morice, C. P., J. J. Kennedy, N. A. Rayner, and P. D. Jones, 2012: Quantifying uncertainties in global and regional temperature change using an ensemble of observation estimates: The HadCRUT5 data set. *J. Geophys. Res.*, **117**, D08101, doi:10.1029/2011JD017187.

Mueller, B., and S. Seneviratne, 2012: Hot days induced by precipitation deficits at the global scale. *Proc. Natl. Acad. Sci. USA,* **109**, 12 398–12 403, doi:10.1073/pnas.1204330109.

Namias, J., 1982: Anatomy of Great Plains protracted heat waves (especially the 1980 US summer drought). *Mon. Wea. Rev.*, **110**, 824–838.

Nicholls, N., 1984: Seasonal relationships between Australian rainfall and North Australian sea surface temperatures. *Extended Abstracts, Conf. on Australian Rainfall Variability,* Part 2, Arkaroola, South Australia, Australian Academy of Science & Bureau of Meteorology, 71–73.

——, 2004: The changing nature of Australian droughts. *Climatic Change,* **63**, 323–336.

——, W. Drosdowsky, and B. Lavery, 1997: Australian rainfall variability and change. *Weather*, **52**, 66–71.

Nitta, T., 1987: Convective activities in the tropical western Pacific and their impact on the Northern Hemisphere summer circulation. *J. Meteor. Soc. Japan*, **65**, 373–390.

NOAA, cited 2013a: Climate change and Hurricane Sandy. [Available online at http://www.esrl.noaa.gov/psd/repository/entry/show/PSD+Climate+Data+Repository/Public/Interpreting+Climate+Conditions+-+Case+Studies/Climate+Change+and+Hurricane+Sandy?entryid=98c8065f-d639-496a-a684-fe4762e1d1be.]

——, cited 2013b: National Climate Data Center state of the climate. National overview–Annual 2012. [Available online at http://www.ncdc.noaa.gov/sotc/national/2012/13.]

——, cited 2013c: NOAA National Climate Data Center. Billion-Dollar Weather/Climate Disasters. [Available online at http://www.ncdc.noaa.gov/billions/events.]

Obeysekera, J., and J. Park, 2013: Scenario-based projection of extreme sea levels. *J. Coastal Res.,* **29**, 1–7.

Ogallo, L. J., 1988: Relationships between seasonal rainfall in East Africa and the Southern Oscillation. *Int. J. Climatol.*, **8**, 31–43.

O'Gorman, P. A., and T. Schneider, 2009: The physical basis for increases in precipitation extremes in simulations of 21st-century climate change. *Proc. Natl. Acad. Sci. USA*, **106**, 14 773–14 777.

Otto, F. E. L., N. Massey, G. J. van Oldenborgh, R. G. Jones, and M. R. Allen, 2012: Reconciling two approaches to attribution of the 2010 Russian heat wave. *Geophys. Res. Lett.*, **39**, L04702, doi:10.1029/2011GL050422.

Overland, J. E., and M. Wang, 2013: When will the summer Arctic be nearly sea ice free? *Geophys. Res. Lett.*, **40**, doi:10.1002/grl.50316.

——, J. A. Francis, E. Hanna, and M. Wang, 2012: The recent shift in early summer Arctic atmospheric circulation. *Geophys. Res. Lett.*, **39**, L19804, doi:10.1029/2012GL053268.

Pal, J. S., F. Giorgi, and X. Bi, 2004: Consistency of recent European summer precipitation trends and extremes with future regional climate projections. *Geophys. Res. Lett.,* **31**, L13202, doi10.1029/2004GL019836.

Pall, P., M. R. Allen, and D. A. Stone, 2007: Testing the Clausius-Clapeyron constraint on changes in extreme precipitation under CO2 warming. *Climate Dyn.*, **28**, 351–363.

——, T. Aina, D. A. Stone, P. A. Stott, T. Nozawa, A. G. J. Hilberts, D. Lohmann, and M. R. Allen, 2011: Anthropogenic greenhouse gas contribution to flood risk in England and Wales in autumn 2000. *Nature*, **470**, 382–385, doi:10.1038/nature09762.

Parkinson, C. L., and J. C. Comiso, 2013: On the 2012 record low Arctic sea ice cover: Combined impact of preconditioning and an August storm. *Geophys. Res. Lett.*, **40**, 1356–1361, doi:10.1002/GRL.50349.

Parris, A., and Coauthors, 2012: Global sea level rise scenarios for the US National Climate Assessment. NOAA Tech Memo OAR CPO-1, 37 pp.

PCMDI, cited 2013: CMIP5 - Data Access - Availability. [Available online at http://cmip-pcmdi.llnl.gov/cmip5/availability.html.]

Peterson, T. C., and R. S. Vose, 1997: An overview of the Global Historical Climatology Network temperature database. *Bull. Amer. Meteor. Soc.*, **78**, 2837–2849.

——, P. A. Stott and S. Herring, Eds., 2012: Explaining extreme events of 2011 from a climate perspective. *Bull. Amer. Meteor. Soc.*, **93**, 1041–1067.

Pierce, D. W., T. P. Barnett, K. M. AchutaRao, P. J. Gleckler, J. M. Gregory, and W. M. Washington, 2006: Anthropogenic warming of the oceans: Observations and model results. *J. Climate*, **19**, 1873–1900.

Pope, V., M. Gallani, P. Rowntree, and R. Stratton, 2000: The impact of new physical parameterizations in the Hadley Centre climate model: HadAM3. *Climate Dyn.*, **16**, 123–146.

Portmann, R. W., S. Solomon, and G. C. Hegerl, 2009: Spatial and seasonal patterns in climate change, temperature, and precipitation across the United States. *Proc. Natl. Acad. Sci. USA*, **106**, 7324–7329.

Power, S., T. Casey, C. Folland, A. Colman, and V. Mehta, 1999: Inter-decadal modulation of the impact of ENSO on Australia. *Climate Dyn.*, **15**, 319–324.

——, M. Haylock, R. Colman, and X. Wang, 2006: The predictability of interdecadal changes in ENSO activity and ENSO teleconnections. *J. Climate,* **19**, 4755–4771.

Quesada, B., R. Vautard, P. Yiou, M. Hirschi, and S. I. Seneviratne, 2012: Asymmetric European summer heat predictability from wet and dry southern winters and springs. *Nature Climate Change*, **2**, 736–741, doi:10.1038/nclimate1536.

Ralph, F. M., and M. D. Dettinger, 2012: Historical and national perspectives on extreme west coast precipitation associated with atmospheric rivers during December 2010. *Bull. Amer. Meteor. Soc.*, **93**, 783–790.

Rayner, N. A., D. E. Parker, E. B. Horton, C. K. Folland, L. V. Alexander, D. P. Rowell, E. C. Kent, and A. Kaplan, 2003: Global analyses of sea surface temperature, sea ice, and night marine air temperature since the late nineteenth century. *J. Geophys. Res.*, **108** (D14), 4407, doi:10.1029/2002JD002670.

Redmond, K. T., 2002: The depiction of drought: A commentary. *Bull. Amer. Meteor. Soc.*, **83**, 1143–1147.

Rowell, D. P., 2005: A scenario of European climate change for the late twenty-first century: seasonal means and interannual variability. *Climate Dyn.*, **25**, 837–849.

Rudolf, B., and U. Schneider, 2005: Calculation of gridded precipitation data for the global land-surface using in-situ gauge observations. *Proc., 2nd Workshop of the International Precipitation Working Group (IPWG)*, Monterey CA, World Meteorological Organization, 231–247.

Rupp, D. E., P. W. Mote, N. Massey, C. J. Rye, R. Jones, and M. R. Allen, 2012: Did human influence on climate make the 2011 Texas drought more probable? [in "Explaining extreme events of 2011 from a climate perspective"]. *Bull. Amer. Meteor. Soc.*, **93**, 1052–1054.

Sallenger, A., K. Doran, and P. Howd, 2012: Hotspot of accelerated sea-level rise on the Atlantic coast of North America. *Nature Climate Change*, **2**, 884–888, doi:10.1038/NCLIMATE1597.

Scaife, A. A., and Coauthors, 2012: Climate change and stratosphere–troposphere interaction. *Climate Dyn.*, **38**, 2089–2097, doi:10.1007/s00382-011-1080-7.

Scheff, J., and D. M. W. Frierson, 2012: Robust future precipitation declines in CMIP5 largely reflect the poleward expansion of model subtropical dry zones. *Geophys. Res. Lett.*, **39**, L18704, doi:10.1029/2012GL052910.

Schiermeier, Q., 2011: Extreme measures. *Nature*, **477**, 148–149.

Schneider, U., A. Becker, A. Meyer-Christoffer, M. Ziese, and B. Rudolf, 2011: Global Precipitation Analysis Products of the GPCC. Global Precipitation Climatology Centre (GPCC) Deutscher Wetterdienst, Offenbach a. M., Germany. [Available from ftp://ftp-anon.dwd.de/pub/data/gpcc/PDF/GPCC_intro_products_2008.pdf.]

Schubert, S. D., M. J. Suarez, P. J. Pegion, R. D. Koster, and J. T. Bacmeister, 2004: On the cause of the 1930s Dust Bowl. *Science*, **303**, 1855–1859.

Scileppi, E., and J. P. Donnelly, 2007: Sedimentary evidence of hurricane strikes in western Long Island, New York. *Geochem. Geophys. Geosyst.*, **8**, Q06011, doi:10.1029/2006GC001463.

Screen, J. A., 2011: Sudden increase in Antarctic sea ice: Fact or artifact? *Geophys. Res. Lett.*, **38**, L13702, doi:10.1029/2011GL047553.

——, and I. Simmonds, 2012: Declining summer snowfall in the Arctic: Causes, impacts and feedbacks. *Climate Dyn.*, **38**, 2243–2256.

——, ——, C. Deser, and R. Tomas, 2013: The atmospheric response to three decades of observed Arctic sea ice loss. *J. Climate*, **26**, 1230–1248.

Seneviratne, S. I., T. Corti, E. L. Davin, M. Hirschi, E. G. Jaeger, I. Lehner, B. Orlowsky, and A. J. Teuling, 2010: Investigating soil moisture-climate interactions in a changing climate: A review. *Earth-Sci. Rev.*, **99**, 125–161.

——, and Coauthors, 2012: Changes in climate extremes and their impacts on the natural physical environment. *Managing the Risks of Extreme Events and Disasters to Advance Climate Change Adaptation*, C. B. Field, et al., Eds., Cambridge University Press, 109–230.

Sheffield, J., and E. F. Wood, 2008: Projected changes in drought occurrence under future warming from multi-model, multi-scenario, IPCC AR simulations. *Climate Dyn.*, **31**, 79–105, doi:10.1007/s00382-007-0340-z.

Shiogama, H., M. Watanabe, Y. Imada, M. Mori, M. Ishii, and M. Kimoto, 2013: An event attribution of the 2010 drought in the South Amazon region using the MIROC5 model. *Atmos. Sci. Lett.*, in press, doi:10.1002/asl2.435.

Sillmann, J., V. V. Kharin, F. W. Zwiers, X. Zhang, and D. Bronaugh, 2013: Climate extremes indices in the CMIP5 multi-model ensemble. Part 1: Model evaluation in the present climate. *J. Geophys. Res.,* **118**, doi:10.1002/jgrd.50203.

Silverman, B. W., 1986: *Density Estimation for Statistics and Data Analysis.* Chapman and Hall, 175 pp.

Simmonds, I., and I. Rudeva, 2012: The great Arctic cyclone of August 2012. *Geophys. Res. Lett.*, **39**, L23709, doi:10.1029/2012GL054259.

Solomon, A., and M. Newman, 2012: Reconciling disparate twentieth-century Indo-Pacific ocean temperature trends in the instrumental record. *Nature Climate Change*, **2**, 691–699.

Sousa, P., R. M. Trigo, P. Aizpurua, R. Nieto, L. Gimeno, and R. Garcia-Herrera, 2011: Trends and extremes of drought indices throughout the 20th century in the Mediterranean. *Nat. Haz. Earth System Sci.*, **11**, 33–51, doi:10.5194/nhess-11-33-2011.

Stark, J. D., C. J. Donlon, M. J. Martin, and M. E. McCulloch, 2007: OSTIA: An operational, high resolution, real time, global sea surface temperature analysis system. *Proc., Oceans 2007 - Europe*, Aberdeen, Scotland, IEEE, 331–334.

State Department, 2012: Increase in U.S. funding to drought relief in the Horn of Africa. U. S. State Department Press Release, 5 April 2012.

Stott, P. A., and Coauthors, 2013: Attribution of weather and climate-related extreme events. *Climate Science for Serving Society: Research, Modelling and Prediction Priorities*, G. R. Asrar and J. W. Hurrell, Eds., Springer, 307–337.

Stroeve, C. J., V. Kattsov, A. Barrett, M. Serreze, T. Pavlova, M. Holland, and W. N. Meier, 2012: Trends in Arctic sea ice extent from CMIP5, CMIP3 and observations. *Geophys. Res. Lett.*, **39**, L16502, doi:10.1029/2012GL052676.

Sutton, R. T., and P. P. Mathieu, 2002: Response of the atmosphere–ocean mixed-layer system to anomalous ocean heat-flux convergence. *Quart. J. Roy. Meteor. Soc.*, **128**, 1259–1275.

——, and D. L. Hodson, 2005: Atlantic Ocean forcing of North American and European summer climate. *Science*, **309**, 115–118.

——, and B.-W. Dong, 2012: Atlantic Ocean influence on a shift in European climate in the 1990s. *Nature Geosci.*, **5**, 788–792, doi:10.1038/ngeo1595.

Sweet, W. V., and C. Zervas, 2011: Cool-season sea level anomalies and storm surges along the U.S. East Coast: Climatology and comparison with the 2009/10 El Niño. *Mon. Wea. Rev.,* **139**, 2290–2299.

——, ——, and S. Gill, 2009: Elevated East Coast sea level anomaly: June–July 2009. NOAA Tech. Rep. NOS CO-OPS 051, 30 pp.

Taylor, K. E., R. J. Stouffer, and G. A. Meehl, 2012: An overview of CMIP5 and the experiment design. *Bull. Amer. Meteor. Soc.,* **93,** 485–498.

Tebaldi, C., B. H. Strauss, and C. E. Zervas, 2012: Modeling sea level rise impacts on storm surges along US coasts. *Environ. Res. Lett.*, **7**, 014032, doi:10.1088/1748-9326/7/1/014032.

Tett, S. F. B., and Coauthors, 2007: The impact of natural and anthropogenic forcings on climate and hydrology since 1550. *Climate Dyn*., **28**, 3–34, doi:10.1007/s00382-006-0165-1.

Tierney, J., J. Smerdon, K. Anchukaitis, and R. Seager, 2013: Multidecadal variability in East African hydroclimate controlled by the Indian Ocean Peer reviewed article. *Nature*, **493**, 389–392.

Trenberth, K. E., A. Dai, R. M. Rasmussen, and D. B. Parsons, 2003: The changing character of precipitation. *Bull. Amer. Meteor. Soc*., **84**, 1205–1217.

——, and Coauthors, 2007: Observations: Surface and Atmospheric Climate Change. *Climate Change 2007: The Physical Science Basis*. S. Solomon, et al., Eds., Cambridge University Press, 235–336.

Trigo, R. M., D. Pozo-Vazquez, T. J. Osborn, Y. Castro-Diez, S. Gámis-Fortis, and M. J. Esteban-Parra, 2004: North Atlantic oscillation influence on precipitation, river flow and water resources in the Iberian Peninsula. *Int. J. Climatol*., **24**, 925–944.

——, M. A. Valente, I. F. Trigo, M. Miranda, A. M. Ramos, D. Paredes, and R. García-Herrera, 2008: North Atlantic wind and cyclone trends and their impact in the European precipitation and Atlantic significant wave height. *Ann. N. Y. Acad. Sci*., **1146**, 212–234, doi:10.1196/annals.1446.014

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

UCAR, 2012: Doping the atmosphere. *AtmosNews*, February 6, 2012. [Available online at http://www2.ucar.edu/atmosnews/attribution/doping-atmosphere.]

USACE, 2011: Sea-level change considerations in civil works programs. U.S. Army Corps of Engineers Circular 1165-2-212, various paging. [Available online at http://publications.usace.army.mil/publications/eng-circulars/EC_1165-2-212.pdf.]

USDA, cited 2013a: Crop production 2012 summary. [Available online at http://usda.mannlib.cornell.edu/MannUsda/viewDocumentInfo.do?documentID=1047.]

——, cited 2013b: Livestock, dairy, and poultry outlook, February 2013. [Available online at http://usda.mannlib.cornell.edu/MannUsda/viewDocumentInfo.do?documentID=1350.]

——, cited 2013c: National Agricultural Statistics Service Agricultural prices database. [Available online at http://www.nass.usda.gov/Charts_and_Maps/Agricultural_Prices/Index.asp.]

van Aalst, M. K., T. Cannon, and I. Burton, 2008: Community level adaptation to climate change: The potential role of participatory community risk assessment. *Global Environ. Change*, **18**, 165–179.

van der Schrier, G., A. P. van Ulden, and G. J. van Oldenborgh, 2011: The construction of a Central Netherlands temperature. *Climate of the Past*, **7**, 527–542.

van Ulden, A. P., and G. J. van Oldenborgh, 2006: Large-scale atmospheric circulation biases and changes in global climate model simulations and their importance for climate change in Central Europe. *Atmos. Chem. Phys*., **6**, 863–881, doi:10.5194/acp-6-863-2006.

Vautard, R., and P. Yiou, 2009: Control of recent European surface climate change by atmospheric flow. *Geophys. Res. Lett*., **36**, L22702, doi:10.1029/2009GL040480.

——, and Coauthors, 2007: Summertime European heat and drought waves induced by wintertime Mediterranean rainfall deficit. *Geophys. Res. Lett*., **34**, L07711, doi:10.1029/2006GL028001.

Vicente Serrano, S. M., 2006: Spatial and temporal analysis of droughts in the Iberian Peninsula (1910–2000). *Hydrol. Sci. J*., **51**, 83–97.

Visser, H., and A. C. Petersen, 2009: The likelihood of holding outdoor skating marathons in the Netherlands as a policy-relevant indicator of climate change. *Climatic Change*, **93**, 39–54, doi:10.1007/s10584-008-9498-6.

Viste, E., D. Korecha, and A. Sorteberg, 2012: Recent drought and precipitation tendencies in Ethiopia. *Theor. Appl. Climatol*., **112**, 535–551, doi:10.1007/s00704-012-0746-3.

Watanabe, M., and Coauthors, 2010: Improved climate simulation by MIROC5: Mean states, variability, and climate sensitivity. *J. Climate*, **23**, 6312–6335.

WCRP, cited 2013: WCRP grand challenges. Accessed July 18. [Available online at http://www.wcrp-climate.org/grandcha.shtml.]

Williams, A. P., and C. Funk, 2011: A westward extension of the warm pool leads to a westward extension of the Walker circulation, drying eastern Africa. *Climate Dyn*., **37**, 2417–2435.

Winton, M., 2011: Do climate models underestimate the sensitivity of northern hemisphere sea ice cover? *J. Climate*, **24**, 3924–3934.

WMO, 2012: Building country-wide support for the Global Framework for Climate Services (GFCS). World Meteorological Organization, 10 pp. [Available online at http://www.wmo.int/pages/gfcs/documents/GFCS_general_2012_web_en.pdf.]

——, cited 2013: WMO Commission for Climatology Structure. [Available online at http://www.wmo.int/pages/prog/wcp/ccl/cclstructure.php.]

Woollings, T., J. M. Gregory, J. G. Pinto, M. Reyers, and D. J. Brayshaw, 2012: Response of the North Atlantic storm track to climate change shaped by ocean–atmosphere coupling. *Nature Geosci.,* **5**, 313–317, doi:10.1038/NGEO1438.

Xoplaki, E., and Coauthors, 2012: Large-scale atmospheric circulation driving extreme climate events in the Mediterranean and its related impacts. *The Climate of the Mediterranean Region: From the Past to the Future*, P. Lionello, Ed., Elsevier, 347–417.

Yasui, S., and M. Watanabe, 2010: Forcing processes of the summertime circumglobal teleconnection pattern in a dry AGCM. *J. Climate*, **23**, 2093–2114.

Yin, J., M. E. Schlesinger, and R. J. Stouffer, 2009: Model projections of rapid sea-level rise on the northeast coast of the United States. *Nature Geosci.,* **2**, 262–266.

Yiou, P., R. Vautard, P. Naveau, and C. Cassou, 2007: Inconsistency between atmospheric dynamics and temperatures during the exceptional 2006/2007 fall/winter and recent warming in Europe. *Geophys. Res. Lett.*, **34**, L21808, doi:10.1029/2007GL031981.

——, K. Goubanova, Z. X. Li, and M. Nogaj, 2008: Weather regime dependence of extreme value statistics for summer temperature and precipitation. *Nonlin. Processes Geophys.*, **15**, 365–378.

Yu, R., and T. Zhou, 2007: Seasonality and three-dimensional structure of the interdecadal change in East Asian monsoon. *J. Climate*, **20**, 5344–5355.

——, B. Wang, and T. Zhou, 2004: Tropospheric cooling and summer monsoon weakening trend over East Asia. *Geophys. Res. Lett.,* **31**, L22212, doi:10.1029/2004GL021270.

——, J. Li, W. Yuan, and H. Chen, 2010: Changes in characteristics of late-summer precipitation over eastern China in the past 40 years revealed by hourly precipitation data. *J. Climate*, **23**, 3390–3396.

Zervas, C. E., 2003: Long term changes in tidal response associated with the deepening of navigational channels. Proc., *Coastal Zone 03: Coastal Zone Management Through Time*, Baltimore, MD, NOAA Coastal Services Center.

——, S. Gill, and W. V. Sweet, 2013: Estimating vertical land motion from long-term tide gauge records. NOAA Tech. Rep. NOS CO-OPS 65, 22 pp.

Zhang, J., R. Lindsay, A. Schweiger, and M. Steele, 2013: The impact of an intense summer cyclone on 2012 Arctic sea ice retreat. *Geophys. Res. Lett.*, **40**, 720–726, doi:10.1002/grl.50190.

Zhang, X., L. Alexander, G. C. Hegerl, P. Jones, A. Klein Tank, T. C. Peterson, B. Trewin, and F. W. Zwiers, 2011: Indices for monitoring changes in extremes based on daily temperature and precipitation data. *Wiley Interdiscip. Rev. Climate Change*, **2**, 851–870.

Zhou, T., D. Gong, J. Li, and B. Li, 2009: Detecting and understanding the multi-decadal variability of the East Asian Summer Monsoon - Recent progress and state of affairs. *Meteor. Z.*, **18**, 455–467.

Zhu, Y., H. Wang, W. Zhou, and J. Ma, 2011: Recent changes in the summer precipitation pattern in East China and the background circulation. *Climate Dyn.*, **36**, 1463–1473.

S5. THE EXTREME MARCH–MAY 2012 WARM ANOMALY OVER THE EASTERN UNITED STATES: GLOBAL CONTEXT AND MULTIMODEL TREND ANALYSIS

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The analysis in Fig. 5.2 of the main paper shows how observed and simulated trends from model All-Forcing runs, control runs, and observations can be compared quantitatively, using control-run variability to estimate confidence intervals on the modeled trends. This same methodology (which is described in greater detail in Knutson et al. 2013) can be applied in a similar manner to time series at individual grid points around the globe. Locations where warming trends are inconsistent with the control runs (detectable) and either consistent with or greater than the All-Forcing runs according to the methodology described in the main text are assessed as having a detectable anthropogenic contribution to the long-term trend.

The red-orange or dark red areas on the maps in Fig S5.1 (right column) depict grid points in the HadCRUT4 dataset that have some detectable warming due to anthropogenic forcing according to this criterion. We find that about 80% of the analyzed global area for March–May (MAM) seasonal means meets these criteria, with similar percentages for other seasons or the annual means.

The white regions in the maps (right column) show where the observed trend is classified as not detectable compared with model control run variability. Interestingly, the region of the eastern United States that had such anomalously warm (record) MAM anomalies in 2012 is also a region that does not have a detectable warming trend during MAM for a number of the individual grid points in this region over 1901–2012 according to this analysis (Fig. S5.1i). However, after spatial averaging over the entire region of record MAM warmth, the trend since 1901 assessed as significant (Fig. 5.2 in the report). In addition, parts of the eastern tropical and subtropical Pacific and much of the extratropical North Atlantic also do not exhibit detectable (distinguishable from natural variability) long-term warming trends in any season at the gridpoint scale (Fig. S5.1f,i,l,o). We conclude that there is only marginal significance for an anthropogenic contribution to the extreme seasonal warmth during MAM 2012 over the eastern United States at the gridpoint scale based on this assessment.

Most of the other larger features in the seasonal extremes maps shown in the middle column of Fig. S5.1—e.g., June−August (JJA) warm anomalies in the Mediterranean region, in the Somali Current region off the east coast of Africa in JJA and September−November (SON), and the warming off the northeast coast of the United States and Canadian maritime provinces in JJA and SON—tend to occur in regions that have some detectable anthropogenic contribution to the 1901−2012 trends, according to our assessment.

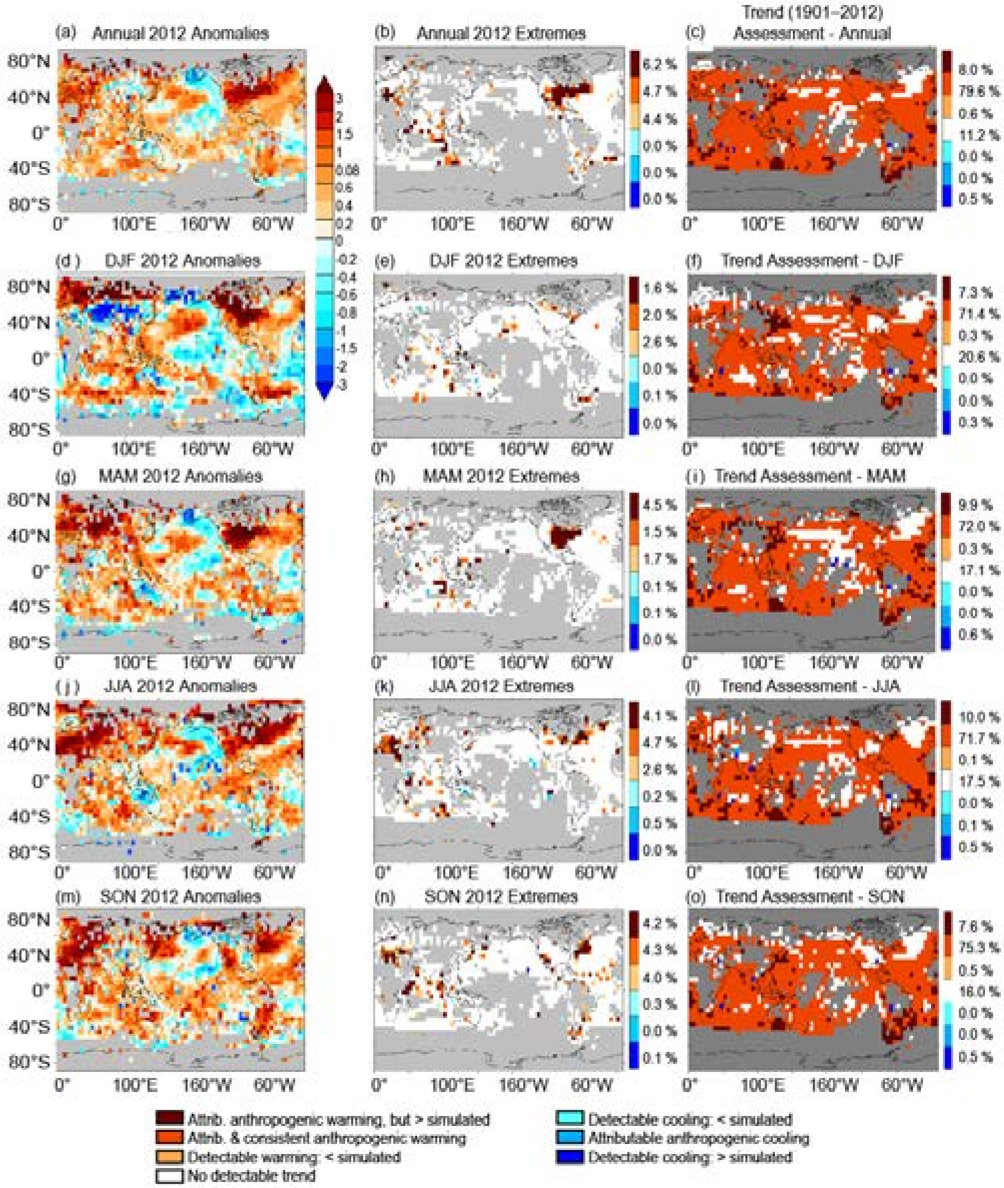

FIG. S5.1. (Left column) Annual- (a) or seasonal- (d,g,j,m) mean surface air temperature anomalies for 2012 (1961–90 base period) from the HadCRUT4 dataset (unit: °C). The seasons are DJF (Dec 2011–Feb 2012), MAM (Mar–May), JJA (Jun–Aug), and SON (Sep–Nov). (Middle column) Colors identify grid boxes with annual- (b) or seasonal- (e,h,k,n) mean anomalies that rank first (dark red), second (red-orange), or third (yellow-orange) warmest or first (dark blue), second (medium blue), or third (light blue) coolest in the available record. Gray areas did not have sufficiently long records, defined here as containing at least 100 available annual or seasonal means, with an annual mean requiring at least four available months and a seasonal mean requiring at least two of three months to be available. Left and middle columns are repeated from Fig. 5.1 in the report for ease of comparison. (Right column) Colors identify categories of trend assessment results for annual means (c) and various seasons (f,i,l,o), which were assessed by comparing the observed trends over the period 1901–2012 with modeled trends in either the All-Forcing (anthropogenic and natural combined) or the Control runs. Locations where no detectable observed trend was found are white (i.e., consistent with Control-run variability). Locations where observed trends are detectable and consistent with All Forcing runs are red-orange. Locations where observed trends are detectable and significantly greater than the All-Forcing run trends are dark red. Locations where observed trends are detectable but significantly less than the All-Forcing runs trends are yellow-orange. Consistent here means that the observed trend lies within the multimodel distribution (5th–95th percentiles) for a given forcing scenario (i.e., All-Forcing scenario or Control run with no external forcing), where the All-Forcing model distribution incorporates the uncertainty from the models due to both differences in response to forcing between the different models and the spread due to internal variability in the model control runs. See Knutson et al. (2013) for further details.