The extreme European summer 2012

Article

Published Version

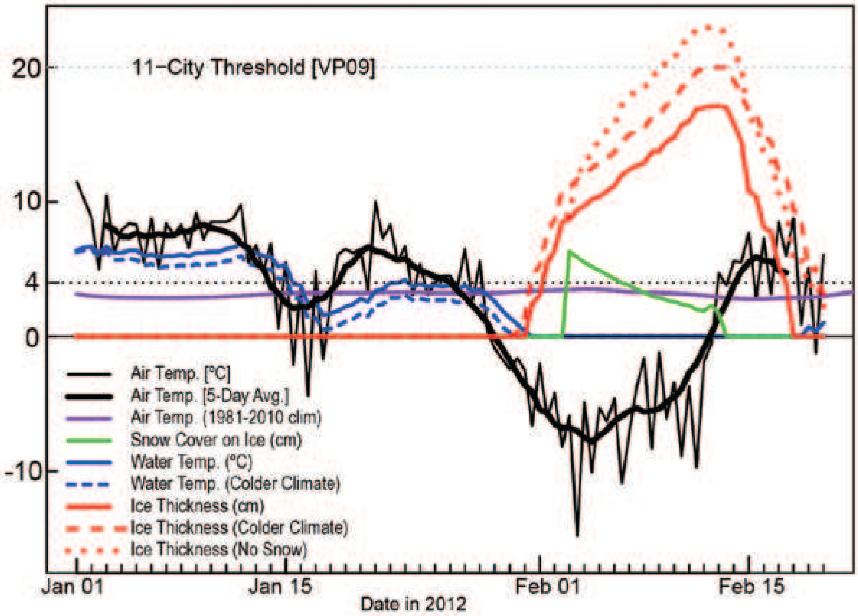

Fig. 9.2. The cold spell 2012 as simulated by the KNMI ice model (de Bruin and Wessels 1988), showing observed snow depth (green), 12-hourly temperature (thin black), five-day average (thick black), 1981–2010 climatology (purple), simulated water temperature (blue), and ice thickness (red). The dashed lines indicate a simulation in a colder climate, while the dotted line indicates the ice growth without snow. (Source: KNMI.)

since 1950 (Kattenberg et al. 2008). This is actually a conservative estimate as the cold spells warm more strongly because of the stronger warming of Siberia (de Vries et al. 2012a). The resulting ice growth curve leads to a marginal situation where the ice thickness would have been almost equal to the historic threshold.

Conclusions. We have analyzed the February 2012 cold spell from the perspective of its ability to generate sufficient ice thickness to organize the classic 200-km ice-skating 11-City Tour in the Netherlands. Despite very low temperatures, the ice was too thin in many locations. We investigated whether global warming could be responsible for this. A simulation with the KNMI ice-growth model, however, points to another more important cause. Snowfall on the thin ice that had just formed is shown to limit the ice growth more strongly than the effect of warming. This study emphasizes that interpreting the role of global warming in the cases of extreme winter European cold spells has to be carried out with care, as the natural variability in these events is large, leading to low signal-to-noise ratios. A remaining question is whether future cold spells will be accompanied by increasingly frequent snowfall events. There are indications from both observations and global climate models that the opposite is the case (de Vries et al. 2012b), but this has to be verified in more detail using regional climate models.

10. THE EXTREME EUROPEAN SUMMER 2012

Buwen Dong, Rowan Sutton, and Tim Woollings

Introduction. The summer of 2012 was marked by strongly contrasting precipitation anomalies across Europe. For example, the United Kingdom experienced its wettest summer (JJA) since 1912, which lead to widespread flooding. Spain, in contrast, suffered drought and wildfires associated with the second lowest summer rainfall in the last 60 years (see "The Record Winter Drought of 2011–12 in the Iberian Peninsula" in this report). These extremes were associated with a clear dipole in precipitation anomalies, indicating a northward concentration of European precipitation (Fig 10.1b). Here we show that the precipitation anomalies can be understood as consequences of anomalies in the large-scale atmospheric circulation. We also present preliminary investigations into the potential role of anomalous SSTs in forcing the atmospheric circulation.

Large-scale circulation. The JJA 2012 anomalies in European precipitation were related to a large-scale dipole pattern in sea level pressure (SLP) over the North Atlantic (Fig 10.1a), with low-pressure anomalies stretching from the Atlantic across the British Isles and Scandinavia (tracking the region of high precipitation) and high pressure over Greenland. This pattern projects strongly onto the negative phase of the summer North Atlantic Oscillation (SNAO; Folland et al. 2009).

As in winter, this dominant pattern of variability describes meridional shifts of the storm track and the associated eddy-driven jet. However, the seasonal migration of the storm tracks means that over Europe, the precipitation response is opposite to that in winter, so that a northward shift of European precipitation is associated with a negative SNAO and a southward shift of the Atlantic storm track and jet (Dong et al. 2013, manuscript submitted to *Environ. Res. Lett.*). These features are illustrated for JJA 2012 in Figs. 10.1e–h. Compared to climatology, the jet in summer 2012 was displaced south over the eastern North Atlantic and extended into central Europe. The climatology of cyclone track density (Fig. 10.1g) shows a split into two preferred cyclone paths, one passing to the south of Iceland and into the Nordic Seas and the other across the British Isles and into southern Scandinavia. In the summer of 2012, almost all cyclones took the southern path, following the northern flank of the jet across the British Isles (Fig. 10.1h). The European precipitation anomalies are, therefore, consistent with the modulation of preferred cyclone paths and the large-scale circulation.

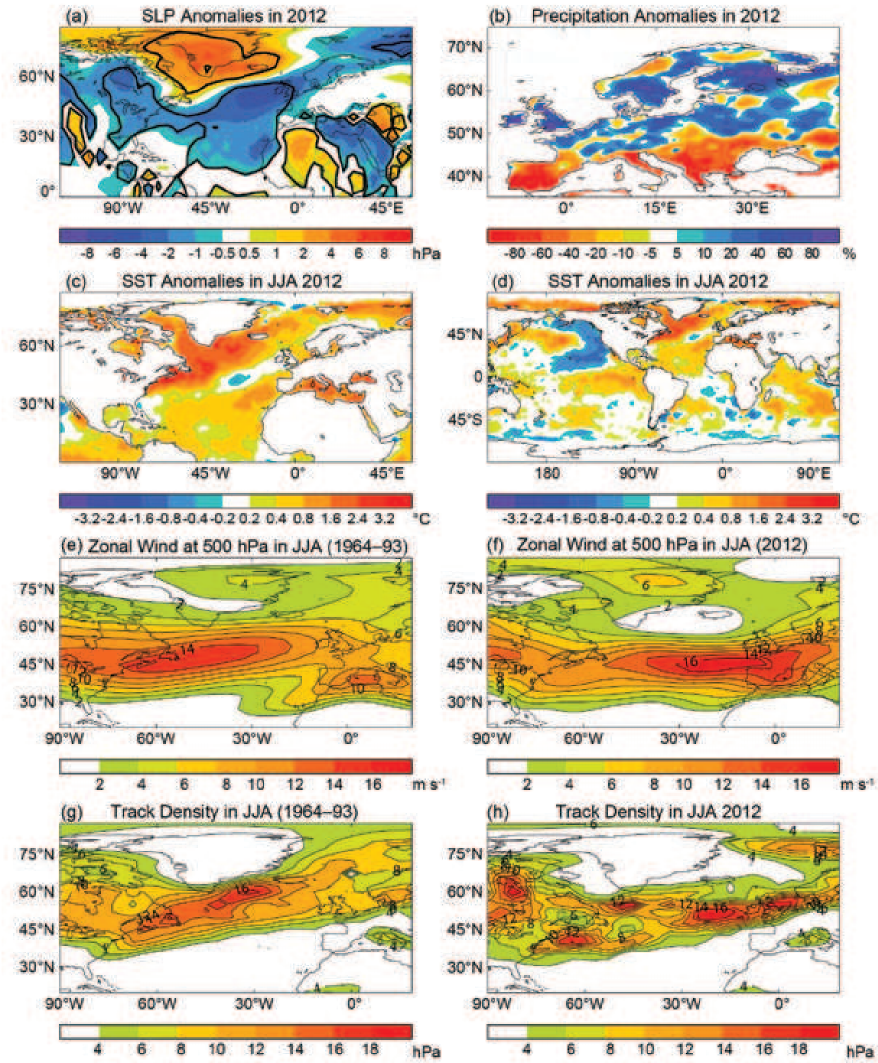

Fig. 10.1. Anomalies for JJA 2012 from the climatological period 1964–93 for (a) SLP (hPa) from HadSLP2, and (b) percentage precipitation change (%) from the daily gridded E-OBS precipitation (version 7.0) over Europe (Haylock et al. 2008). (c), (d) SSTs (°C) from HadISST (Rayner et al. 2003). 500-hPa zonal wind (m s^{-1}) from the NCEP reanalysis for (e) the climatological period 1964–93 and (f) 2012. Cyclone track density as in Hoskins and Hodges (2002) for (g) the climatological period and (h) 2012. Track density is in unit of numbers per month per unit area, where the unit area is equivalent to a 5° spherical cap (about 10^6 km^2). Note that this climatological period is dominated by cold AMO conditions and is the period used for the climatological model simulations. Thick lines in (a) highlight regions where the differences are statistically significant at the 90% confidence level using a two-tailed Student's t test.

Summer 2012 in the context of recent variability. The Atlantic/European summer of 2012 should not be viewed in isolation but as the latest in a succession of very similar summers. A dipole in precipitation anomalies resembling that in Fig. 10.1b was very clear in all of the summers from 2007 to 2011, with the exception of summer 2010 (Supplementary Fig. S10.1). Similarly, the SNAO has been negative for all of the last six summers (e.g., Allan and Folland 2012). Taking JJA means of the daily SNAO index from NOAA's Climate Prediction Center gives values of -0.8, -1.9, -1.6, -1.1, -2.0, and -2.2

standard deviations for the summers from 2007 to 2012. These summers contain four out of the five in the record since 1950 that have an index with less than -1.5 standard deviations. Similarly, in the England and Wales precipitation record (Alexander and Jones 2001), 2012 was the wettest summer since 1912, and the average anomaly of the last six summers is 1.15 standard deviations (with respect to the last 100 years, 1913–2012). This string of recent European summers is consistent with the high importance of decadal variability in shaping European summer climate. Sutton and Dong (2012) demonstrated clear variations on decadal timescales in SLP and precipitation patterns across Europe, which are very similar to those seen in summer 2012. This is consistent with the low-frequency variability of the SNAO (Folland et al. 2009), which suggests the influence of some factor external to the atmosphere.

These decadal variations in large-scale circulation are well correlated with basin-wide fluctuations in Atlantic Ocean SSTs, known as the Atlantic Multidecadal Oscillation (AMO). The recent summers occurred during a period of warm SSTs not seen since the 1950s, and it is likely that these Atlantic temperatures have played a role in influencing the SNAO (Knight et al. 2006; Folland et al. 2009; Sutton and Dong 2012). The North Atlantic SST anomalies for JJA 2012 (Fig. 10.1c) show a similar structure to that associated with the AMO and with interannual variations of the summer storm track (Dong et al. 2013, manuscript submitted to *Environ. Res. Lett.*). Warm SSTs are evident across the subtropics but especially in the subpolar North Atlantic, where anomalies exceed 2°C. This anomaly pattern reflects the superposition of the mixed layer ocean response to the atmospheric anomalies and the low-frequency warming associated with the AMO (Dong et al. 2013, manuscript submitted to *Environ. Res. Lett.*).

Global SST anomalies for the same season are given in Fig. 10.1d, showing close to neutral ENSO conditions in the tropical Pacific. Outside of the North Atlantic, the strongest anomalies are in the subtropical/midlatitude North Pacific. Warm anomalies are evident in the Arctic, consistent with the continuing decline of sea ice. The rate of this decline might have been enhanced by recent atmospheric circulation anomalies related to the SNAO (Overland et al. 2012), and these sea ice extent anomalies may have had an influence on the atmospheric circulation (Balmaseda et al. 2010).

Investigating the potential role of external forcing. We now briefly report on preliminary numerical model experiments to assess the importance of the SST and sea ice anomalies seen in summer 2012. We use the atmosphere configuration of the UK Met Office Hadley Centre Global Environment Model version 3 (HadGEM3-A), similar to the version used by Hewitt et al. (2011), with a resolution of 1.875° longitude by 1.25° latitude and 85 levels in the vertical. The experiments performed are summarized in Table 10.1; the last 25 years of each experiment are used for analysis. The CONTROL experiment reproduces the observed SLP and precipitation patterns very realistically for JJA (Supplementary Fig. S10.2).

The SLP changes in the GLOBAL simulation show a significant low-pressure response around 30°N over North America, the Atlantic Ocean, and North

Table 10.1. Summary of Numerical Experiments

Experiments	Boundary Conditions	Length of Run
CONTROL	Forced with monthly climatological SST and sea ice averaged over the period 1964–93 using HadISST (Rayner et al. 2003)	32 years
GLOBAL	Forced with monthly SST and sea ice from Dec 2011 to Nov 2012	27 years
ATLANTIC	Forced with SST and sea ice from Dec 2011 to Nov 2012 over the Atlantic sector (including the southern Atlantic Ocean) in the longitude range 32.5°W–17.5°E and climatological SST and sea ice outside the Atlantic	27 years
NORTH ATLANTIC	Forced with SST and sea ice extent from Dec 2011 to Nov 2012 over the North Atlantic (north of 35°N with SST linearly smoothed southward to the climatology at 30°N) but climatological SST and sea ice outside the North Atlantic	27 years

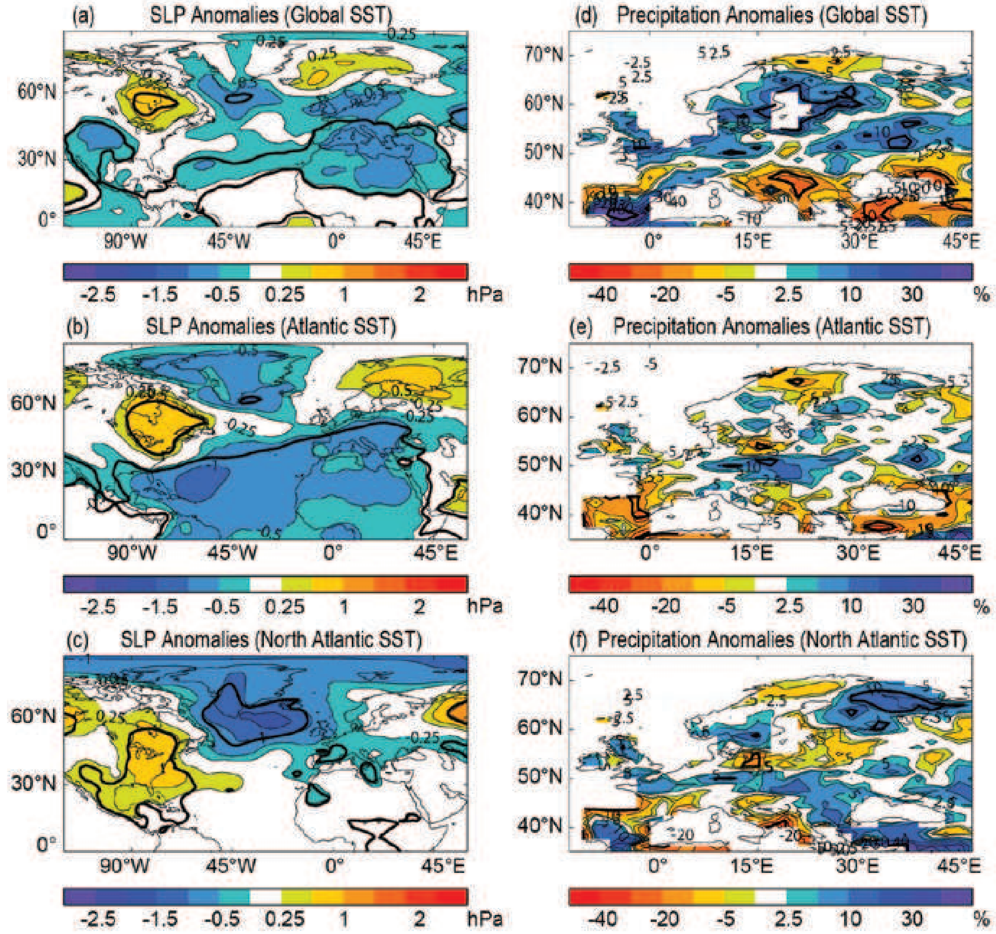

Fig. 10.2. (a)–(c) SLP anomalies (hPa) and (d)–(f) precipitation changes (%) in the model simulations forced by different configurations of SST and sea ice in 2012 relative to the control simulation forced by climatological SST and sea ice (1964–93 mean). (a) and (d) Forced by global SST and sea ice in 2012; (b) and (e) forced by SST and sea ice in 2012 over the Atlantic sector but with climatological SST outside the Atlantic; and (c) and (f) forced by North Atlantic (northward of 35°N) SST and sea ice in 2012, with climatological SST and sea ice outside the North Atlantic. Thick lines highlight regions where the differences are statistically significant at the 90% confidence level using a two-tailed Student's *t* test.

Africa, also extending into Southern Europe (Fig. 10.2a). Over Northern Europe, a pattern resembling the negative phase of the SNAO is simulated, but the anomaly is much weaker than that observed (Fig. 10.1a) and is not significant. The pattern of simulated European precipitation anomalies (Fig. 10.2d) is consistent with the negative phase of the SNAO, and is, therefore, very similar to the observations (Fig. 10.1b), but the magnitudes are again much weaker.

The ATLANTIC experiment shows a much stronger SLP response in the tropical North Atlantic (Fig. 10.2b). This is part of a baroclinic response (vertical structure not shown) that is not consistent with the observations and suggests that the influence of SST anomalies outside the Atlantic damps the direct response to Atlantic SSTs in this region. Negative precipitation anomalies are again simulated in southern Europe, but the pattern further north is very noisy (Fig. 10.2e).

In the NORTH ATLANTIC experiment, the model simulates a substantial low-pressure anomaly over the midlatitude North Atlantic, with a weak extension into western Europe (Fig. 10.2c). This is similar to the response found (using a different model) by Sutton and Hodson (2005) and suggests a significant response to the warm SST anomalies in the northwest Atlantic (Fig. 10.1c), but one which is sensitive to the influence of lower latitude Atlantic SST anomalies (implied by comparison Figs. 10.2b and 10.2c). The response is equivalent barotropic (not shown), which indicates a significant role for eddy-mediated processes (e.g., Kushnir et al. 2002;

Feldstein 2007). Consistent with the observations (Fig 10.1a), the simulated SLP response implies enhanced westerly winds to the southwest of the United Kingdom, but the response is weaker than the observed anomalies and is displaced northwards.

Overall, the model results suggest that the atmospheric circulation over the North Atlantic and European region in summer 2012 (negative phase of the SNAO), which was largely responsible for the observed extreme anomalies in European precipitation, was influenced by global SST and sea ice extent anomalies, and that it is likely that SST anomalies in the North Atlantic played a particularly important role (consistent with Dong et al. 2013, manuscript submitted to *Environ. Res. Lett.*; Sutton and Hodson 2005). Differences between the simulated responses and observed anomalies—in terms of both spatial patterns and the much weaker magnitude of the simulated anomalies—require some explanation. The simplest explanation would be internal variability. However, the fact that 2012 is only the latest in a series of negative SNAO European summers makes this possibility unlikely. Furthermore, the level of internal variability in the model simulations is insufficient to account, with significant likelihood, for the magnitude of the observed anomalies (not shown). Other possible factors include an important role for coupled ocean-atmosphere interactions in shaping the response (Sutton and Mathieu 2002; Dong et al. 2013, manuscript submitted to *Environ. Res. Lett.*) and the direct impact of changes in radiative forcings from greenhouse gases and aerosols, which were not considered in the experiments discussed here. Model biases may also be a factor. Investigating these possibilities is the subject of ongoing research.

Conclusions. The European summer of 2012 was marked by strongly contrasting rainfall anomalies, which led to flooding in northern Europe and droughts and wildfires in southern Europe. This season was not an isolated event, rather the latest in a string of summers characterized by a southward shifted Atlantic storm track as described by the negative phase of the SNAO. The degree of decadal variability in these features suggests a role for forcing from outside the dynamical atmosphere, and preliminary numerical experiments suggest that the global SST and low Arctic sea ice extent anomalies are likely to have played a role and that warm North Atlantic SSTs were a particular contributing factor. The direct effects of changes in radiative forcing from greenhouse gas and aerosol forcing are not included in these experiments, but both anthropogenic forcing and natural variability may have influenced the SST and sea ice changes.

11. ARE RECENT WET NORTHWESTERN EUROPEAN SUMMERS A RESPONSE TO SEA ICE RETREAT?

SIMON F. B. TETT, KIRSTEN DEANS, EDOARDO MAZZA, AND JAMES MOLLARD

Introduction. Since 2007, UK and northwestern (NW) European summers have been anomalously wet, with summer 2007 being notable for significant flooding in southern England. Arctic sea ice extent had record low values in September 2007 and 2012 (Parkinson & Comiso, 2013). To explore the potential impact of these changes in sea ice on precipitation, we carried out a set of numerical simulations of the high-resolution version of HadAM3 (Pope et al. 2000) driven with different sea surface temperature and sea ice boundary conditions.

Observational data and experimental design. We focus on percentage of 1961–90 precipitation from the Global Precipitation Climatology Centre GPCC reanalysis V5 1° × 1° product for which we use 1950–2006. From 2007 to 2012, we use the GPCC monitoring product (Schneider et al. 2011) to give a homogeneous dataset from 2007 and allow consideration of 2011 and 2012 in near-real time. We processed the GPCC datasets so that in each 1° × 1° grid box where there are no stations the data was set as 'missing'. Precipitation was conservatively regridded to the 1.25° × 1.875° grid of the model and converted to percentage of the 1961–90 seasonal average. We then area-averaged the percentage of normal precipitation for the northwest European region—the western half (48°N–75°N, 10°E–15°W) of the northern European region of Giorgi and Francisco (2000). We find that the GPCC monitoring dataset is biased with respect to the reanalysis dataset, so we correct the monitoring product by the difference between it and the reanalysis product for the 2007–10