# *Are recent wet northwestern European summers a response to sea ice retreat?*

Article

Published Version

Tett, S. F. B., Deans, K., Mazza, E. and Mollard, J. (2013) Are recent wet northwestern European summers a response to sea ice retreat? Bulletin of the American Meteorological Society, 94 (9). S32-S35. ISSN 1520-0477 doi: https://doi.org/10.1175/BAMS-D-13-00085.1 Available at https://centaur.reading.ac.uk/89174/

# 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

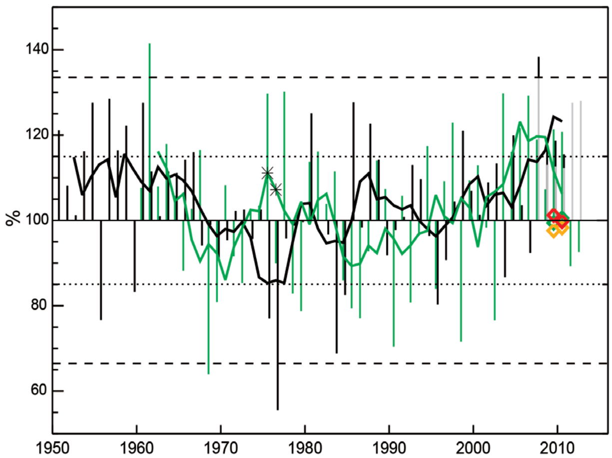


**Fig. 11.1. Mean JJA percentage of normal (1961–90) precipitation in northwest Europe for GPCC reanalysis precipitation (black bars), 1960–2012 HadAM3P simulation (green bars), and GPCC monitoring data (gray bars). Observed precipitation is displaced rightwards from simulated precipitation. Also shown are the five-year running average values for combined GPCC data (thick black); Historical simulation (thick green); and from 12-member Historical ensemble (green diamonds), Ice85_89 ensemble (orange diamonds), and Ice85_90-NH ensemble (red diamonds). Dashed (dotted) lines show 2-σ range from five-year smoothed (unsmoothed) intra-ensemble variability. Black line outside that range indicates observed or simulated values significantly different from normal. Asterisked values on the simulated smoothed time series show where model and observations are significantly different.**

period of overlap. These biases are generally between -10% and 10%, though larger in dry regions. For NW Europe the area-average bias is about 4% (Fig. 11.1), though with some year-to-year variability. In addition to the precipitation record, we also use the variance reduced HadSLP2r record (Allan and Ansell 2006).

The observed precipitation time series shows considerable year-to-year variability ranging from 55% to 140% of the 1961–90 normals (Fig. 11.1). The five-year running mean time series has a smaller range of 85%–125% of normal and has its largest values for the 2007–11 average. The six-year average for June–August (JJA) 2007–12 has anomalously high precipitation across most of northern Europe (Fig. 11.2a) with the exception of northern Norway. Parts of western Scotland, Iceland, Greenland, Svalbard, and southern Europe are also anomalously dry. This is consistent with the mean sea level pressure (MSLP) anomalies with a low centered on Britain and a high over Greenland with only small changes in MSLP in the Mediterranean region. As suggested by others (e.g., "The Extreme European Summer 2012" in this report), this is consistent with a southwards shift of the summer storm track. While NW Europe is anomalously wet, southern Europe has about 50%–75% of normal precipitation.

We explore three hypotheses for the recent NW European rainfall anomaly: (i) internal atmospheric variability, (ii) forced by recent changes in *both* SST and sea ice, and (iii) forced only by changes in SST.

To explore these hypotheses we used the HadAM3P Atmosphere General Circulation Model (Rowell 2005), which is a N96 (1.25° × 1.875°) resolution version of HadAM3 (Pope et al. 2000) with some other changes. We drove it with the HadISST dataset (Rayner et al. 2003) with both SSTs and sea ice area-averaged to N96 resolution. HadISST uses SSM/I (Special Sensor Microwave Imager) data to estimate sea-ice. SSMI degraded in early 2009 and was replaced with data from AMSR-E (Advanced Microwave Scanning Radiometer - Earth Observing System). Screen (2011) investigated the impact of this and found it had a large impact in the southern hemisphere but found no apparent step-changes in Arctic sea-ice extent. Nevertheless, there remains the possibility of time-varying biases in the HadISST record.

The model was also driven with historical concentrations of greenhouse gases, and both the direct and indirect effect on cloud brightness (Jones et al. 2001) were included with $SO_2$ emissions using the historical IPCC emissions. Land-surface values were set to standard climatological values, and ozone values used the ozone forcing dataset of Tett et al. (2007). A single simulation driven with these boundary conditions was run from December 1959 to August 2012 ("Historical"). A further 11 simulations were started from the December 2006 state with small random perturbations. In addition to this "factual" ensemble, we carry out two "counterfactual" ensembles in which sea ice was set to monthly average conditions for 1985–89. Both ensembles start with December 2005 conditions from the Historical simulation and run for seven years (Table 11.1).

In the first ensemble ("Ice85_89"), we set all sea ice fractions to the 1985–89 seasonal-average. In the second ensemble ("Ice85_89-NH") we only do this in the Northern Hemisphere. In all cases sea ice fractions below 0.1 were set to zero. Where sea ice fractions were set to their 1985–89 average, we also set SST to the 1985–89 value. A few times and locations had sea ice but no sea ice in the 1985–89 average. For those

| Table 11.1. Summary of numerical experiments and experiment IDs. | | | | |
|---|---|---|---|---|
| Experiment | Historical: Dec 1959–Aug 2012 | Historical: 11-member ensemble Dec 2006–Aug 2012 | Ice85_89: 12-member ensemble Dec 2005–Nov 2012 | Ice85_90-NH:12-member ensemble Dec 2005–Nov 2012 |
| Boundary Conditions | HadISST SST and sea ice + forcings | HadISST SST and sea ice + forcings | Mean 1985–89 sea ice, HadISST SST + forcings | Mean 1985–89 NH sea ice, HadISST SST and sea ice + forcings |
| Experiment ID | xhod#g/xhsw#a | xhsw#n-#w | xija#a-#l | xijj#a-#l |

locations, we set the sea ice to zero and SST values to the 1985–89 average. Locations and times where there was no sea ice and none in the 1985–89 average were unmodified.

*Results*. Before using a model to evaluate recent changes we need to have some confidence in its ability to simulate observed means and variability. The climatological JJA MSLP from the Historical simulation is broadly consistent with the observed climatology (Fig. 11.2b,c) though missing the arc of low pressure in northern Europe. Both simulations and observations show the least precipitation in the Mediterranean and the most in the West. The simulation is generally drier than the observations so further analysis focuses on the percentages of normal.

For our study we assume that both the simulations and observations consist of deterministic and unpredictable components with the latter arising from internal climate variability. We estimate the unpredictable component from the pooled intra-ensemble variances of the three 12-member ensembles for 2007–12. This is about 70% of the Historical simulation's variance. Cautiously assuming that simulated and smoothed intra-ensemble variability for the 2007–12 period is representative of the entire 1960–2012 period, then SST variability contributes about 30% of the variance in NW European precipitation.

The results from the single Historical simulation are largely consistent at the two-sigma level with observations for 1960–2012 (Fig. 11.1). However, there is one period around 1975 when the difference between the two-filtered time series is significant. In a time series, we would expect differences to arise solely by chance, and to test for this possibility, we use a Kolmogorov-Smirnov test on the two datasets and an F-test on the sum-of-squares of the differences weighted by twice the intra-ensemble variance. We applied both these tests on the summer averages and on five-year smoothed summer averages (sampling every fifth point) and found no significant differences. We also compared the simulated and observed standard deviations and found simulated values were larger, though not significantly so, than the observed values. The simulated and observed lag-1 autocorrelations are also not significantly different from one another. Overall, this suggests that we can use the variability in HadAM3P to evaluate the observed changes.

Among recent summers, only 2007 is outside 2σ of the 1961–90 climatology (Fig. 11.1). This illustrates the difficulty in analyzing individual events when there is a great deal of internal variability and so we focus on longer timescales. On five-year timescales, the recent run of wet summers is extremely unusual with observed values at about 120% of normal, corresponding to a deviation of more than 2.5 standard deviations. For each of the factual, counterfactual, and counterfactual-NH ensembles the average NW Europe precipitation for 2007–12 is close to 100% (Fig.11.1). These are all inconsistent with observations. The maximum percentage of normal precipitation from any single simulation in the three ensembles is 112%. This suggests that the recent changes cannot be explained by sea ice changes or internal variability, as simulated by HadAM3P.

Where the observations have anomalously low pressures (Fig. 11.2a), the differences between them and the 2007–12 Historical ensemble average (Fig. 11.2d) are significant at the 2σ level. MSLP differences are also significant over Greenland and Russia. Precipitation percentage differences are significant over Ireland, Wales, much of Scotland, and around the Baltic. Interestingly, in the Mediterranean region, the differences are less significantly different suggesting that HadAM3P is capturing the observed drying there.

In HadAM3P during 2003–07, the NW European precipitation is more than 120% of normal and so is comparable with the recent observed extreme values. The percentage precipitation and MSLP patterns for

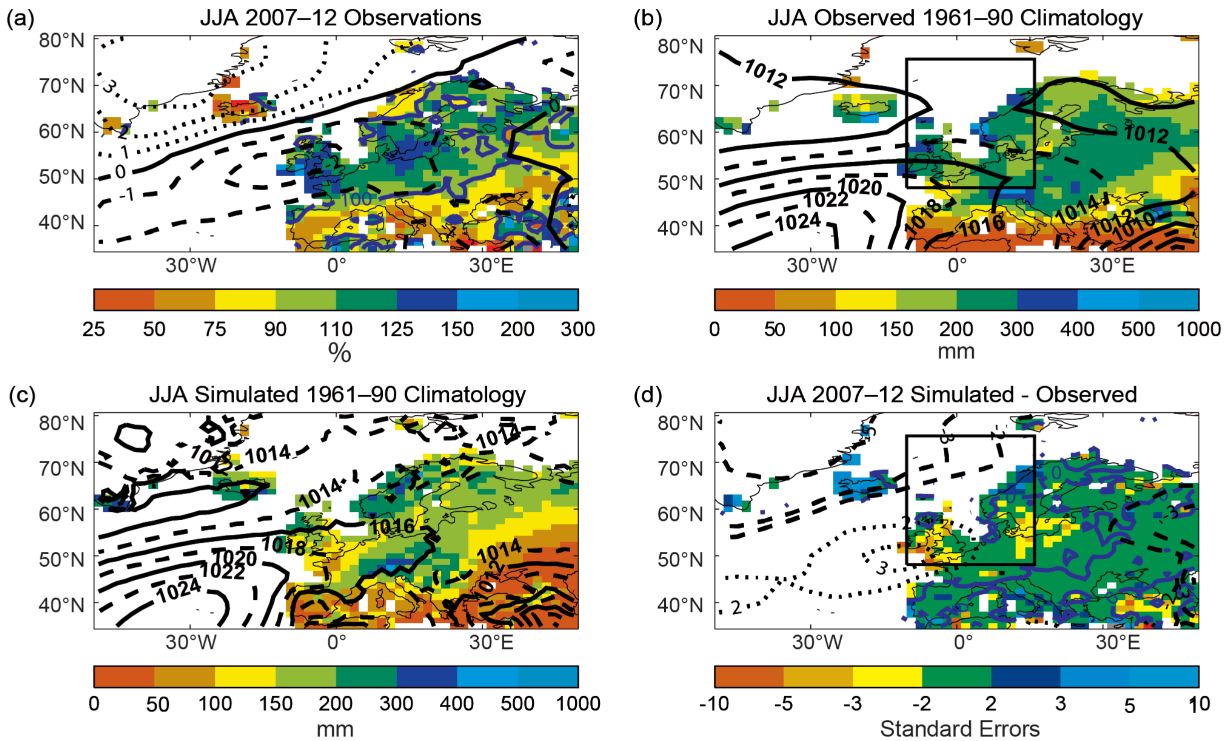


**Fig. 11.2. (a) Percent of 1961–90 precipitation (color scale) and difference from 1961–90 mean sea level pressure (contours every hPa). Blue contour line shows 100% precipitation. (b) Summer total land precipitation (mm) from GPCC reanalysis (color scale) and HadCRUT2r MSLP (contours every 2 hPa) for 1961–90. (c) Same as (b) but for HadAM3P simulation. MSLP pressure has been adjusted by difference (about 2 hPa) between global average JJA climatological and simulated MSLP. (d) Difference in standard errors (see main text) between adjusted GPCC monitoring product and 12-member historical ensemble for precipitation (color) and MSLP (contour lines). Blue line shows zero difference. Values are at -10, -5, -3, -2, 2, 3, 5, and 10 standard errors. The black box in plots (b) and (d) show the NW Europe region.**

this period (not shown) are different from the observed pattern in 2007–12. The observations are characterized by a southwards shift of the storm track, while the model has an east/west dipole suggesting a westward shift of the storm track. This suggests that the earlier extreme precipitation event in the model is not comparable with the recent observed precipitation anomalies.

*Conclusions.* Recent summers in NW Europe have been unusually wet with the 2007–11 average having the largest percentage of normal precipitation for 1950–2012 and are, based on model variability, significantly different from the 1961–90 normal. The circulation anomaly associated with this event is consistent with a southward shift in the summer storm track. We find no evidence that declines in sea ice can explain these recent wet summers, with the expected response to changes in sea ice since the late 1980s being small. Our results support the findings of Screen et al. (2013) who found (their Fig. 7) no significant precipitation response in summer to sea ice decline over NW Europe.

HadAM3P did not, in any of 36 simulations, produce a precipitation anomaly for 2007-2011 or 2008-2012 similar to that observed. The simulated 5-year average from 2003-2007 had average NW Europe percentage precipitation comparable to the observed values for 2007-2011. In this case the mechanism appears different with a westward shift of low pressure over Europe rather than a southwards shift as observed. Thus we conclude that the recent precipitation anomalies over North Western Europe likely represent an unusual event not well represented in HadAM3P. Given that HadAM3P is not capable of simulating the recent heavy precipitation, the possibility remains that recent European summer precipitation anomalies are due to other drivers in the climate system rather than chance.