CORRESPONDENCE:

Drivers of the 2013/14 winter floods in the UK

To the Editor — In their section on 'Weather and climate change drivers', Huntingford *et al.*[1] propose various driving mechanisms for the record precipitation that caused flooding in southern England in the winter of 2013/14: the North Atlantic Oscillation (NAO), Atlantic Multi-Decadal Oscillation (AMO), Indonesian precipitation via cold weather in North America, the Quasi-Biennial Oscillation (QBO), Arctic sea ice, and solar activity (sunspots). One would expect evidence for these drivers to be apparent in the historical record if they played a significant role in driving a single year's record seasonal mean precipitation. However, past data reveal only weak associations (linear and nonlinear) between each of these drivers and precipitation in southern England, where all of the notable floods occurred (Fig. 1). Most of the correlations are small and not significantly different from zero at the 5% level (far right column) and the smooth non-linear fits (bottom row) have confidence intervals that could easily include horizontal lines showing no effect on precipitation for all values of the predictor.

The strongest relationship with precipitation in southern England, and the only one that is possibly not explainable by chance sampling, is with NAO, but even this has only a small correlation of 0.23. The underlying problem is that almost all of these mechanisms are described in multiple steps. The simplest example is the first sentence: 'For the UK, the single largest indicator of winter atmospheric circulation, including storm track position and strength, is the state of the NAO, characterized as the atmospheric pressure difference between the Azores and Iceland.'[1] The precipitation was indeed caused by a shift in the storm track, sending a stream of depressions to southern England.

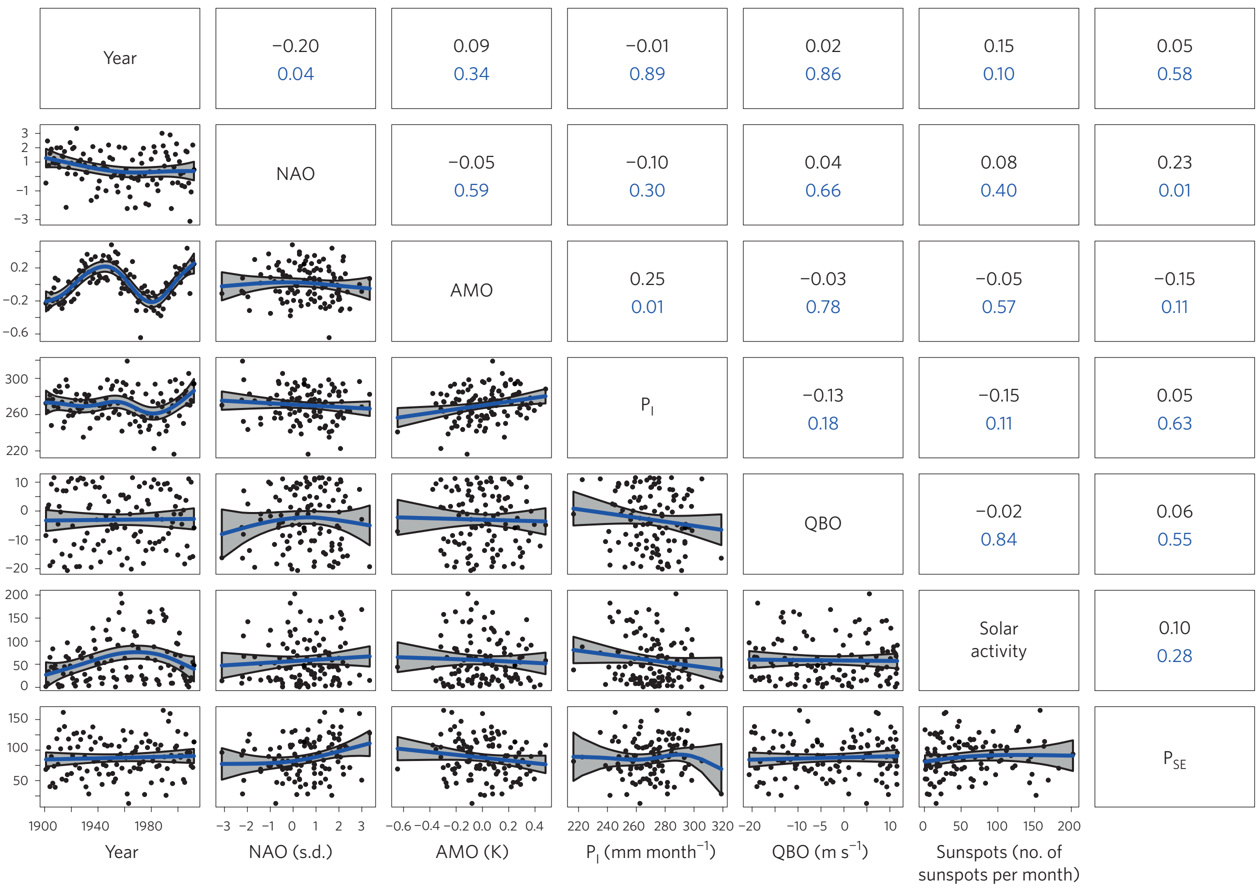

Figure 1 | Panel plot summary of the pairwise relationships between precipitation in southern England and several potential driver variables. The leftmost column shows time series of each of the variables for the 112 winters from 1901–2012. The bottom row shows how precipitation in southern England (P_{SE}) depended on each of the other variables before 2013/14. Smooth trend fits (blue curves) and 95% confidence intervals (grey shading) have been estimated using a Gaussian general additive model[8]. Upper right panels give Pearson product moment correlations and their *P* values (blue) for a two-sided *t*-test for zero correlation for each pair of variables. Arctic sea-ice cover has been left out because reliable observations are not available before 1979. P_I, Indonesian precipitation.

However, it is a syllogistic fallacy to conclude that the record precipitation was caused by the NAO, since other circulation patterns are known to have stronger influences on the storm track in this region. Historical data shows that the NAO accounts for only 5.4% of the variance in precipitation — its influence is predominantly over northwestern parts of the UK (Supplementary Fig. 2), where flooding was unexceptional in 2013/14. Conversely, a pressure pattern with a low to the west of Scotland rather than over Iceland (Supplementary Fig. 1c) accounts for 80% of the variance in precipitation in southern England and had an exceptionally low index in 2013/14. Hence, despite precipitation in the region being a small area-average, there does appear to be a highly correlated atmospheric driver, which is substantially different from the NAO. This is not surprising, because previous studies have shown that combinations/mixtures of several major modes/regimes are required to adequately describe local storminess (refs 2,3, for example).

Similarly, we find in end-to-end analyses that a positive AMO index on average was associated with slightly less rain in southwestern England. There is no empirical or published evidence of Indonesian sea surface temperature (or rainfall) nor the QBO nor solar activity (including lags) affecting rainfall in southern England.

Previous studies of observational data have found no evidence for more persistent flow regimes due to Arctic sea-ice melting[4], and there is no evidence of an influence in western Europe even in a large ensemble of simulations with one climate model[5]. Details can be found in the Supplementary Information.

To conclude, due to the lack of any strong associations with precipitation in southern England, we find it difficult to believe that any of the proposed drivers could have been responsible for the extreme event in winter 2013/14. Even a multiple linear regression model containing all the drivers shown in Fig. 1 explains only 5.5% of the total variance in precipitation. Furthermore, Huntingford *et al.*[1] fail to mention in the 'Weather and climate change drivers' section other more relevant drivers — such as more appropriate atmospheric circulation patterns and atmospheric moisture content, which has risen due to global warming[6,7]. Exceptional flood events are often strongly localized in space and so can be expected to have drivers that depend on the specific target region rather than large-scale modes of variability. ❐

References

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Additional information

Supplementary information is available in the online version version of the paper.

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Reply to 'Drivers of the 2013/14 winter floods in the UK'

Huntingford *et al.* reply — Our Perspective[1] on the potential factors in the UK floods of December, January and February 2013/14 (DJF1314) discusses potential links between remote drivers in the climate system, Atlantic atmospheric circulation and storminess and UK precipitation. Based on a correlational analysis, van Oldenborgh *et al.*[2] are critical of these links, arguing for instance that winter rainfall amounts for parts of the UK have only a correlation of 0.23 when compared with the North Atlantic Oscillation (NAO). The disagreement is essentially one of spatial scale: their arguments are based on a particularly localized measure of rainfall for southern England, rather than the Atlantic atmospheric circulation or more UK-wide precipitation and river flows that we discussed.

We agree with van Oldenborgh *et al.*[2] that the scale-dependence of the response to remote drivers has important practical implications: if the response to a particular driver is only evident on very large scales, and not at the scale of a river catchment, then its utility may be quite limited in terms of analysis and prediction of specific flood events. Improved understanding of the role of remote drivers in the overall synoptic situation in DJF1314 may, nevertheless, provide improved warnings for flood-prone areas. This is valid, even if it does not translate into a substantial improvement in a simple correlation skill for local rainfall.

van Oldenborgh *et al.* question our use of the NAO index when discussing DJF1314, arguing that other pressure patterns are better related to rainfall in the UK. While we agree that the observed sea-level pressure pattern from last winter is not simply characterized by the NAO, the sea-level pressure NAO index for winter 2013/14 was ~12hPa (1.5 standard deviations) above normal. This is an atmospheric pattern that is known to emerge in response to a multitude of external climate drivers, including those discussed in our Perspective and the references therein.

Interactions between drivers can also result in relationships being obscured in correlation analyses. As an example (albeit not specifically relevant to DJF1314), El Niño is well established as a particularly strong driver of the global climate state[3] with recently verified influence on northern European winter climate[4,5] yet it occurs only episodically, every five years or so. In the years when El Niño is inactive, the atmospheric circulation will continue to vary due to internal fluctuations and external drivers. A correlation across all years can therefore easily mask the influence of El Niño in the years when it is active. For many of the drivers we highlighted, multiple modelling and observational studies show statistically significant influences on Atlantic–European surface climate when they are active.

Our Perspective reviews the enormous literature that relates particular phases