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Interactive Comment

# *Interactive comment on* "Multi-annual droughts in the English Lowlands: a review of their characteristics and climate drivers in the winter half year" *by* C. K. Folland et al.

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This is a well-written and considered manuscript that addresses a topic with much significance to security of water supply in southeast England. The high vulnerability of the region to below average winter rainfall and multi-year drought is clearly articulated. The headline message is the discovery of an association between La Niña episodes and the winter rainfall deficits responsible for some major multi-season drought episodes in the region. However, this assetion should be tempered in the light of earlier work.

Fraedrich (1990) was probably the first to show that extreme ENSO phases imprint characteristic responses on atmospheric circulation patterns at the European scale, with strongest signals in winter anticyclonic weather following La Niña episodes. This finding was confirmed for the British Isles by Wilby (1993) using Lamb Weather Types and England and Wales Rainfall which show higher than expected frequencies of anticyclone events, and below normal rainfall in winters (and especially February) linked to La Niña. Fraedrich (1994) subsequently produced a nice review of ENSO impacts on Europe.

Lloyd-Hughes (2002) and Lloyd-Hughes & Saunders (2002) specifically consider the feasibility of linking ENSO extremes to drought across Europe, and the extent to which the relationship is modulated by sea surface temperatures (SSTs) in the North Atlantic. Lloyd-Hughes (2002) even applied the Standardised Precipitation Index (SPI) as in the present study. Overall, they found that spring is the most predictable season for European precipitation (given ENSO extreme and North Atlantic SSTs) but the relationship appears to be non-stationary between decades.

Others have also explored the seasonal predictability of UK hydrological anomalies using SSTs (Colman and Davey, 1999; Svensson and Prudhomme, 2005), the North Atlantic Oscillation index (Wilby, 2001), and a wide variety of other teleconnection indices (Wedgbrow et al., 2002; Wilby et al., 2004; Svensson and Prudhomme, 2005; Wedgbrow et al., 2005). Admittedly, these studies tend to focus on summer drought given preceding predictors (e.g. winter SSTs, NAO and ENSO). However, some use autocorrelation or persistence tests for the chosen drought metric (e.g. low flow, Palmer Drought Severity Index) to benchmark forecast model skill. Overall, these studies find that summer rainfall absence (drought) is more predictable than rainfall excess. Given the incidence of a winter drought (say under La Niña) it would be helpful to consider how this initial condition links to subsequent summer drought either by hydrological persistence, or lagged teleconnection forcing.

For example, Wilby (2007) analysed the frequency-duration of multi-season drought using the updated reconstructed river flow series of Jones et al. (2006) and very long



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monthly rainfall records. Given above/ below average rainfall for winter/summer half years it was shown (for the example case of the River Medway) that a dry-to-dry season transition has 53% likelihood. Historically, the longest multi-season drought persisted for ten seasons (i.e. the five years April 1883 to March 1888) (Figure 1). Applying the matrices for dry-to-dry season transitions in a Markov model simulation yielded return periods of 7, 26 and 95 years for droughts lasting 3, 5 and 7 half-years respectively. The authors might consider replicating this simple form of analysis in order to estimate return periods for the multi-season droughts of the wider English Lowlands.

A few other points should be addressed:

P12936: The authors concede that the long-term outlook for multi-season drought risk is uncertain. However, given that the UKCP09 projections point to increased risk of summer drought and winter excess, on average the expectation might be for shorter duration, perhaps more intense droughts with rapid recharge/recovery in between. On the other hand, even modest winter rainfall deficits following or preceding more intense summer drought (exacerbated by higher temperatures and lower rainfall) could result in operational difficulties. These plausible (but highly uncertain) possibilities merit further discussion.

P12940: River flow records for the Thames at Kingston were naturalised to remove the influence of abstractions. However, what if any account was taken for inter-basin transfers to the Thames or for effluent returns? Low flows are particularly susceptible to these influences.

P12941: To what extent might the multi-decadal risk of multi-season, river/ groundwater drought be driven by rising temperatures and/or changes in actual evaporation, as well as by precipitation anomalies?

P12949: The authors might consider displaying the results of their composite analysis (Tables 1 and 2) graphically (as in Figure 2, below). This will clearly show the preponderance for drought under La Nina as well as those events that fall outside of this expectation.

P12950: Note also the North Atlantic SST analysis of Lloyd-Hughes (2002) and of Svensson and Prudhomme (2005).

P12951: Please provide a brief explanation of the physical processes linking major tropical volcanic eruptions with positive phases of winter NAO. Likewise, please elaborate the solar effects.

To conclude, this is a thought-provoking analysis that leads to well-conceived suggestions for further research. However, the authors should moderate claims of 'first time' and give due acknowledgement to the body of earlier research which has been corroborated by their helpful analysis.

Supporting materials

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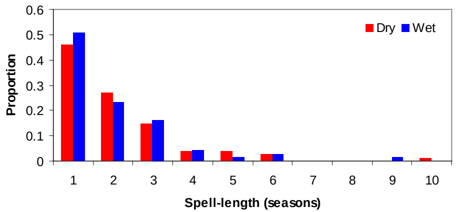


**Fig. 1.** Multi-season wet- and dry-spell persistence in the River Medway 1850-2002. Seasons are defined as winter (October-March); summer (April-September).

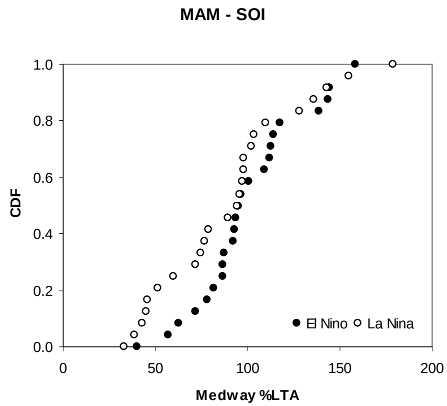


**Fig. 2.** Conditioning spring (March-May) precipitation anomalies (% long term average, LTA) in the Medway catchment on ENSO extreme showing increased likelihood of below average rainfall following La Nina