Department of Meteorology



Storylines of UK drought based on the 2010-2012 event



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Chan et al. (under review) *HESS*

Introduction and motivation

- Climate change is expected to impact global water resources with changes projected for both floods and droughts
- The UK has experienced several periods of severe hydrological droughts since the 1950s (incl. "benchmark" 1976, 1988-93, 2004-06 and 2010-12)
- Droughts can be classified as meteorological, hydrological and soil moisture droughts. This study focuses on hydrological droughts characterized by the standardized streamflow index (SSI) at different accumulation periods



UKCEH Drought Inventory

Cascade of uncertainty

- Hydrological climate change impact assessments have been dominated since mid-1990s by a GCM-driven approach which is topdown and scenario driven
- Characterized by a top-down modelling approach and the *cascade of uncertainty*



Impossible to fully consider all sources of uncertainty



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- Lack of adequate consideration of outcomes beyond GCM projections
- Uncertainty in atmospheric circulation-related aspects within GCM projections (Shepherd 2014)



Storyline approach

- **Storylines**: pathways of plausible outcomes that need not have probabilities attached to them (Shepherd 2019)
- Approaches to search for worst-case scenarios/situations are still in its infancy
- Downward counterfactual thinking: ways in which an event could have turned out worse



Aims and objectives



Analyze development and geographic variation of the 2010-2012 drought and identify clusters of similar drought response



Create a number of event-based counterfactual storylines representing alternative unfolding of the drought



Compare counterfactual storylines with severe droughts in the past

The 2010-2012 UK drought

- Most recent spatially extensive drought in the UK
- Drought orders used to supplement reservoir stocks; temporary hosepipe and water use bans affected 20 million people
- Standardized Streamflow Index (SSI) used to cluster similar drought response at 100 UK catchments
- Clusters 4 and 5 most affected southern England with C4 including catchments underlain by aquifers





What if winter and autumn contribution were different?

Replace observed winter and autumn precipitation with climatology to investigate the relative role of winter and autumn in drought development

- Importance of the replenishment seasons in the development of multiyear drought conditions
- Autumn conditions were determinant of the timing of drought inception and winter was determinant of the drought's eventual length.



What if the drought was preceded by drier preconditions? Precondition length

Changes to the drought by prescribing progressively drier preconditions at 4 return levels

- Drought conditions sensitive to even slightly drier preconditions, particularly for fast responding catchments
- Recovery time from drier preconditions highlight catchments with large groundwater storage
- Drought response to drier preconditions
 → combination of drought's spatial
 footprint and hydrogeology



What if there were three dry winters?

Repetition of dry year **before** and **after** 2010-12 drought. Widespread concern of continued dry conditions in early 2012 before unexpected drought termination

"Three dry winters" – well-known concern of water resources industry

- Fast responding catchments (C1-3) more susceptible to Dry year before
- Quantified how much worse drought conditions could be for slow responding catchments (C4-5) if dry conditions persisted as feared



What if the drought was situated in a warmer world?

UKCP18 regional projections applied using delta method in a time sampling approach for 4 global warming levels

- Drought conditions all projected to increase relative to the baseline under four GW levels across all clusters
- Key modulating effects of wetter winters notable in Cluster 1 particularly at high GW levels (>3°C)
 - Magnitude of change for drought conditions at 4°C is smaller than previous GW levels



Comparison with past droughts

DB: Dry year before DP: Driest precondition DA: Dry year after GW: 2°C warming

Cluster 4: Eastern England

- Drought impacts of the counterfactual storylines vary by SSI accumulation periods with all four storylines exceeding the "benchmark" 1976 drought at SSI-12 for slow-responding catchments (e.g. Cluster 4)
- "Three dry winter" storylines does not exceed the severe 1988-93 drought in East England but a 2°C warming would have exceeded it (red box)



Relative to 1988-93 drought



Summary

- An event-based storyline approach can complement existing methods to anticipate risks of hydrological extremes and stress test hydrological systems
- Storylines of the 2010-12 drought showed how the drought could have turned out worse given perturbations to different event attributes
 - Changes to winter and autumn conditions important for drought development
 - Vulnerability to "third dry winter" across whole of UK
 - Drought projected to worsen under climate change
 - Comparison with past droughts show that "three dry winters" can match conditions of past severe regional droughts in southern/eastern England (e.g. 1988-93) and a 2°C warming can exceed conditions of the 1976 drought across all of UK

References

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- Shepherd, T.G., 2019. Storyline approach to the construction of regional climate change information. *Proceedings of the royal society A*, 475(2225), p.20190013.
- Wilby, R.L. And Dessai, S., 2010. Robust adaptation to climate change. Weather, 65(7), pp.180-185.

For details, feel free to check out preprint under review at Hydrology and Earth System Sciences:

Chan, W.C.H, Shepherd, T.G., Smith, K.A., Darch, G., Arnell, N.W. (under review) **Storylines of UK drought based on the 2010-2012 drought**. *Hydrology and Earth System Sciences Discussions.*



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