Sub-seasonal droughts in Europe: dynamics, predictability and teleconnections

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Sub-seasonal "flash" drought events are rapidly developing, multi-week periods of elevated temperatures and evapotranspiration, but reduced soil moisture and precipitation. Flash droughts during the growing season can severely damage agriculture. Many flash drought events coincide with heatwaves, which increase stress on humans and ecosystems. However, most of the scientific literature on droughts focuses on conventional, slowly developing, seasonal-scale droughts. Recent research, including studies by the supervisory team, have identified continental Europe as a region at risk from flash drought events. Other "hot-spot" regions of flash drought events include central North America and eastern Asia. Despite these advances, the atmospheric and land-surface mechanisms behind flash droughts remain unclear. It is also not clear how well these events can be predicted in sub-seasonal forecast models. Early and effective warnings of flash droughts may allow the agricultural sector to take mitigating action in advance of an event.

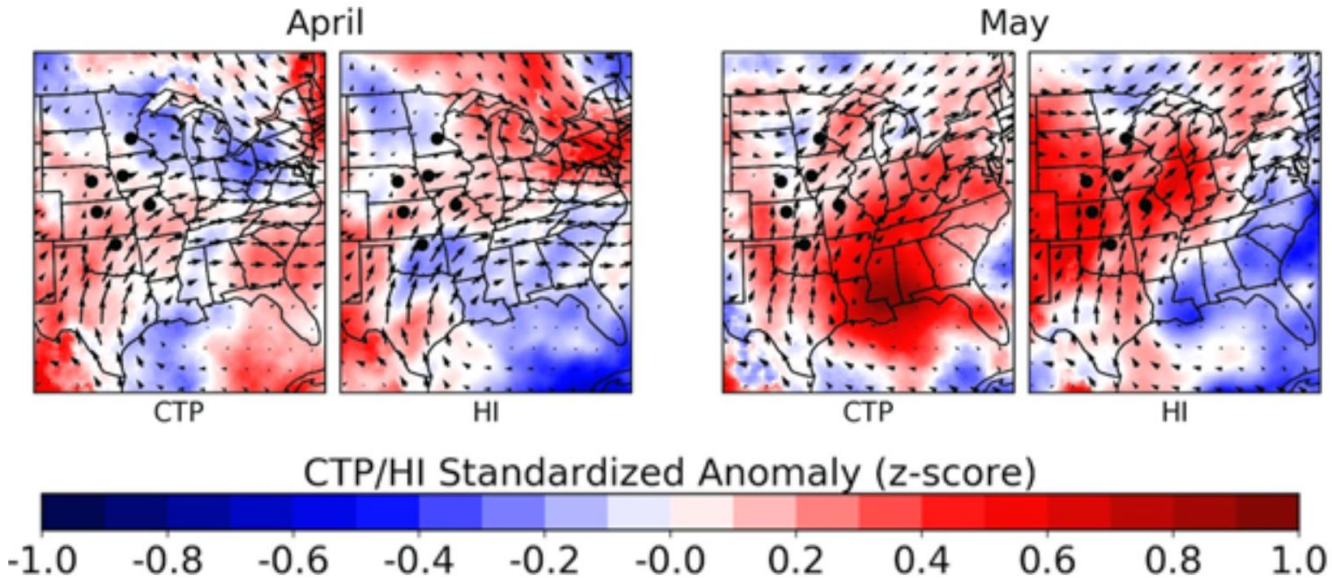
This PhD project aims to investigate the mechanisms of flash drought events and their predictability, with a focus on Europe. The student would begin by identifying flash drought events in the satellite-era historical record, by applying detection algorithms developed by the supervisory team to reanalyses such as the newly available fifth-generation ECMWF reanalysis (ERA5), and the E-OBS gridded ground observation dataset. The student would examine the role of land-surface feedbacks in intensifying flash drought events (e.g., through correlations of soil moisture, evaporation and temperature, supplemented by experiments using the JULES land surface model). The student would also examine the large-scale atmospheric circulation anomalies associated with flash drought events (e.g., through composites of ERA5 winds or by examining changes in blocking activity). This analysis may include an identification of sub-regions within Europe that experience flash drought events at the same time, for instance through cluster analysis or Empirical Orthogonal Teleconnections. Identification of such regions would enhance the composite-based analysis. The student would examine the modulation of flash drought events over Europe by major modes of sub-seasonal and seasonal climate variability with known links to European circulation, such as the El Nino-Southern Oscillation, the North Atlantic Oscillation and the Madden-Julian Oscillation.

Following the initial historical analysis, the student would use reanalysis to examine teleconnections between flash drought events over Europe and events in other "hot-spot" regions for flash drought activity, such as North America and Europe. The hypothesis is that global atmospheric extra-tropical

wavetrains, such as quasi-stationary Rossby waves, enhance the risk of flash drought events across the Northern Hemisphere. The supervisory team have global and regional catalogues of flash drought events that could be interrogated for this analysis.

Finally, the student would use sub-seasonal reforecasts from the Subseasonal-to-Seasonal (S2S) prediction project database to analyse prediction skill for flash drought events in Europe. The student would apply forecast skill and reliability metrics, such as the Brier Skill Score, to determine the lead times at which ensemble-based predictions of flash drought events are useful. The student would also examine whether the models accurately capture the modulation of flash drought events by large-scale modes of variability, such as the MJO.

The student will produce novel understanding of the atmospheric and land-surface mechanisms behind rapidly developing drought events, which have received relatively little attention in the literature despite their considerable effects on human and environmental systems. The student will also increase our knowledge of the extent to which flash drought events in one region (Europe) are correlated with those in other regions, and the extent to which these events are controlled by larger-scale atmospheric variability. Advances in this area would offer the potential to predict flash drought events, or the changes in flash-drought risk, using statistical modelling. This student will also evaluate whether flash-drought events can be predicted using contemporary sub-seasonal prediction systems, at the lead times required for the agricultural and health sectors to take mitigating action to reduce the damage caused by these events. To date there is little research on prediction skill for flash drought events, despite the growing body of literature on sub-seasonal predictions more generally.



Development of flash drought in spring 2012 over central North America, at locations shown by black dots. The arrows show winds at 850 hPa. The shading shows anomalies of Convective Triggering Potential (CTP) and Humidity Index (HI), with where positive values indicate warm and moist air. Figure from Basara et al. (2019).

Training opportunities:

The student will benefit from the opportunity to visit the University of Oklahoma and engage with Dr. Basara's research group. The student will also benefit from the opportunity to engage with ongoing research in NCAS at Reading on flash-drought events in China, including the opportunity to visit Chinese project partners for collaborative analysis of teleconnections between flash-drought events in Europe and Asia.

Student profile:

We seek to recruit a student with excellent knowledge of statistics and experience analysing large datasets, as most of the proposed relies on applying statistical techniques (e.g., correlations, composites, Empirical Orthogonal Teleconnections) to large and/or high-resolution datasets (e.g., modern reanalysis data, sub-seasonal reforecasts). We seek to recruit a student with a good background in physics and mathematics, as the project involves understanding physical mechanisms involving the atmospheric circulation and land-atmosphere interactions.

References:

Basara, J., Christian, J., Wakefield, R., Otkin, J., Hunt, E. and Brown, D. (2019). The evolution, propagation, and spread of flash drought in the Central United States during 2012. *Environmental Research Letters*, 14(8), p.084025.

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