Quantifying UK hydroclimatic variability on centennial timescales

Lead Supervisor: Jamie Hannaford, UK Centre for Ecology & Hydrology
Email: jaha@ceh.ac.uk

Co-supervisors:

Ed Hawkins, Len Shaffrey, University of Reading

Stuart Allen, Environment Agency

Water resources management systems have evolved to accommodate the range of hydrological variability experienced over decades – typically, the period from the 1960s/1970s, which is when most UK river flow records commenced. In a warming world, the range of hydrological variability is likely to change. Hydrological extremes (both floods and droughts) are likely to become more severe, but hydrological regimes will become more variable in general – potentially with longer periods of flooding or drought, and swings from wet to dry extremes, or vice versa. It is vital to quantify past patterns of variability, to detect any emerging changes, and project into the future, in order to inform appropriate adaptation response to hydro-climatic change.

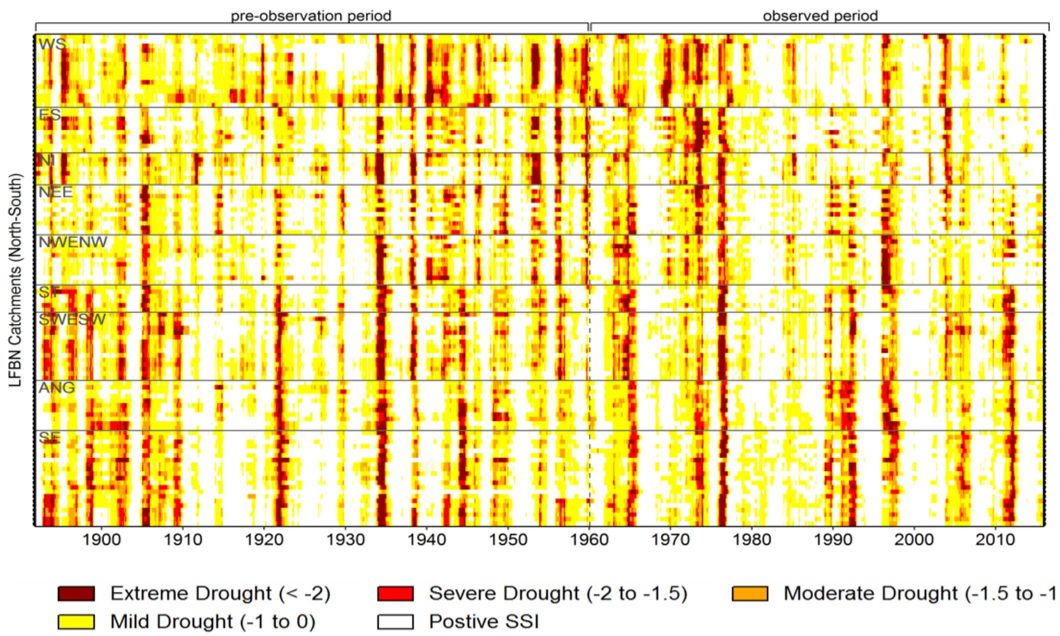
To this end, there have been many studies of hydrological trends (see e.g. the review of Hannaford et al. 2015, and a more recent study, Hannaford et al. 2021). However, typically these have investigated linear trends in hydrological variables, such as an index of flooding or drought, and these have invariably been treated separately. There is also an expansive literature on future projections (e.g. Watts et al. 2015), but with a focus on quantifying changes between current conditions and future time-slices (typically 30-year periods) rather than examining how variability will change. Hence, few studies have sought to capture the full range of variability in river flows, whether past or projected future, largely because of the relative brevity of river flow records, and the lack of appropriate nationally-consistent future flow projections. This represents a major gap in research. As recent extreme events have shown, it is not just the changing magnitude of floods or droughts that are important – but their duration, frequency, spatial extent, persistence or recovery, and the transition from one extreme to the other (e.g. the record-breaking winter 2020 floods (Sefton et al. 2020) were followed by extreme low flows only a few months later).

The aim of the project will be to develop novel approaches to characterize hydrological variability, taking a full-regime perspective rather than looking at floods or droughts independently. To this end, the project will quantify historical patterns of river flow variability, looking back to at least the late 19th century, and (depending on student interests) will seek to address how hydrological variability will change in future, and what this may mean for water resources management. Crucially, the project will seek to identify how variability has changed over time, and determine to what extent these changes can be explained by changing drivers, i.e. variations in ocean-atmosphere patterns (such as the North Atlantic Oscillation, the Atlantic Multidecadal Oscillation) as well as anthropogenic forcing.

The project will capitalize on a range of new hydrological datasets that bring an unparalleled opportunity to fully characterise hydrological variability on a range of timescales. In addition to using the primary UK observational hydrometric archive, the NRFA (https://nrfa.ceh.ac.uk/), the project can exploit new datasets that far extend into the past and future: notably, a set of daily-resolution river flow reconstructions from 1890 (Barker et al. 2019, see image below) and a set of transient, daily river flow projections to 2100, the eFLaG dataset (https://www.ceh.ac.uk/our-science/projects/eflag-enhanced-future-flows-and-groundwater).

The project will employ a range of innovative methods for indexing hydrological variability, quantifying change, and disentangling the different components of variability, including the application of methods previously applied in meteorology (e.g. signal-to-noise ratios, Osso et al. 2021; and time-of-emergence, Hawkins & Sutton, 2012). There will be an opportunity to capitalize on newly rescued meteorological datasets (Hawkins et al. 2021, submitted) and to run these through hydrological modelling frameworks to push back our understanding of hydrological variability into the early 19th century. There will also be an opportunity to advance our understanding of the atmosphere-ocean patterns that drive hydrological variability, ideally taking a global view to build on recent advances in our process understanding (Svensson & Hannaford, 2019).

Finally, the project will also consider the potential significance of the identified changes in hydrological variability for UK water resources and environmental management. This will be facilitated through close-working and exchanges with the Environment Agency, who have operational responsibility for flood risk and water resources management in England. Understanding hydrological variability is key to management decisions they must make both now and in adapting to a future climate.



Heatmap showing historical droughts in the reconstructed flow records. The observed period back to c.1960 is marked, and the previous period shows the much-extended range of variability captured using the reconstructions. From Barker et al. (2019)

Training opportunities:
In addition to the standard research skills training and development activities at UKCEH and Reading, the student will develop specialist skills in hydro-climatology, programming, GIS, data and code management (including manipulation of large datasets) and statistical analysis. This will be a mix of formal training and mentoring. Formal training courses available include the UKCEH organized training portfolio for programming and technical skills (R, Python, GIS) and statistics (e.g. multivariate methods, time series analysis). Specialist courses and summer schools will also be encouraged, e.g. the Aberdeen Catchment science summer school. The student will benefit from working in a multi-disciplinary environment at UKCEH, with staff working on a wide range of applied environmental science problems.

The student will work closely with the CASE partners, the Environment Agency, who as well as co-supervising will provide a 3-month placement working in the Research section of the EA Chief Scientists Group (Climate Change and Resource Efficiency team).

The supervisory team are embedded in several international research networks including UNESCO 'FRIEND' programme of international hydrological research (http://undine.bafg.de/servlet/is/7397/?lang=en) and the HEPEX network (http://hepex.irstea.fr/). Opportunities will be sought for collaboration and possibly an international stay with these network partners in Europe.

Student profile:

This project would be suitable for students with a degree in earth/environmental sciences, physics, mathematics or a closely related discipline. The applicant needs to be numerate and have an understanding of applied statistics. Previous experience of programming in any language would be an advantage, but particularly in python or R. Existing knowledge of hydrology, climatology or meteorology would also be advantageous. Experience of the analysis of hydrological or climatological data sets (or other large complex data sets) would be a useful asset, although training and supervision in these aspects would be provided as required. The applicant should have good communication skills, be self-motivated and have enthusiasm for the subject.

Funding particulars:
CASE Studentship (£1,000) from the Environment Agency

References: (optional)

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