Spatial coherence of European Droughts

Interim Science Summary SC070079/SS

science summary

Environment Agency

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Background and objectives

Drought can cause serious problems across much of Europe. Many droughts are localised and short, but others are widespread and have environmental and social effects that cross international boundaries. Some of the most important UK droughts were also significant droughts across much of Europe.

This project has considered the potential for developing new approaches to forecasting drought by asking:

- Is there any systematic time lag between the onset and development of droughts in different parts of Europe?
- Can the onset and development of droughts in some parts of Europe provide an early warning for the development of droughts in other parts of Europe, and in particular, in the UK?
- Can these relationships be used to build reliable and robust operational tools for UK drought forecasting?

The project is jointly funded by the Environment Agency and DEFRA.

Approach

The method, which draws on a unique archive of flow and rainfall data from across much of Europe[i], involved the following steps.

1. Calculate a normalised deficiency index for each site – a measure of drought that allows comparison between locations with different climatological and hydrological regimes
2. Cluster catchments with similar drought characteristics into regions
3. Develop standardised flow and rainfall deficiency indices for these regions
4. Analyse relationships between regions and develop statistical models to predict drought.

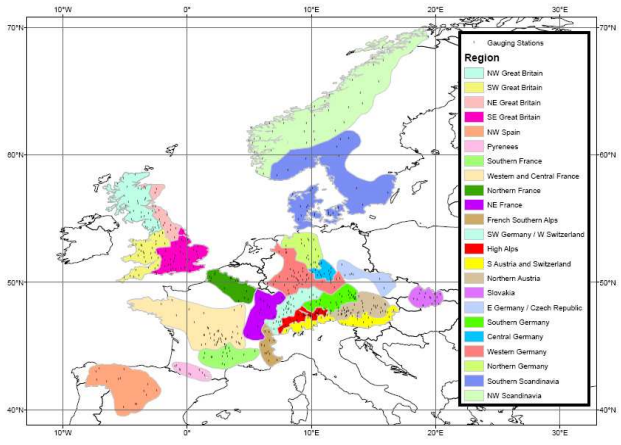

Figure 1. Regions showing simultaneous streamflow deficiencies

Results

Twenty-four regions were identified across Europe having simultaneous streamflow deficiencies (Figure 1). Four distinct geographical regions emerged in the UK. A further group, comprising very slow-responding catchments (Base Flow Index > 0.8), was identified in southeast England.

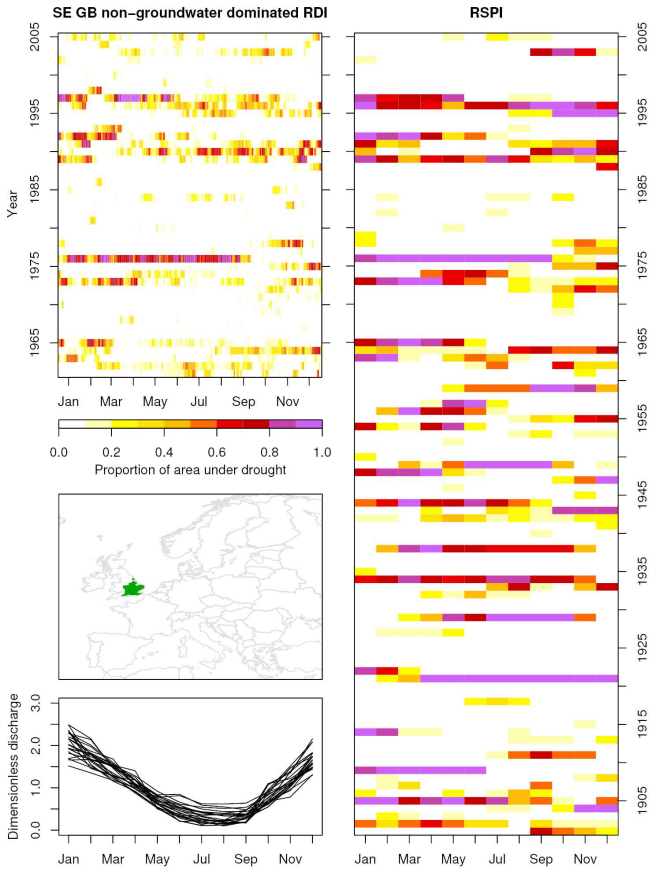

Figure 2. Droughts in southeast England. Darker colours show droughts covering most of the area, with purple showing droughts covering all of the area. River flow droughts (top left) show droughts clearly in 1976, 1989-91, and 1995-96. Rainfall droughts back to 1900 (right) add widespread droughts in 1905, 1921, 1933-34, 1943-44 and 1959.

For each region, time series of regional streamflow and rainfall deficits were defined and a catalogue of regional drought severity developed. All major droughts of the last century were thus captured, enabling analyses of drought length, seasonality and severity (e.g. Figure 2). For all post-1961 major streamflow droughts, a comprehensive description of extent and spatio-temporal development is provided.

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Analysis

Most droughts appear to have different characteristics, length and strength. For example, a contrast was found between the 1976 drought, that was spatially consistent across North Europe and was combined with a rainfall deficiency the preceding winter (1975) and a heat wave in the summer (1976), and the 1995-1997 drought, which was interspersed by wet episodes and had little long-lasting spatial coherence over Europe.

Correlation analysis, multidimensional scaling and statistical modelling revealed:

- Weak correlations exist between regional drought deficiency time series of different regions
- The correlation patterns for hydrological and meteorological droughts are similar, albeit slightly higher for the latter
- The strongest relationships are amongst adjacent regions
- Correlations with the rest of Europe are stronger in winter than in summer for northern and western Britain, but are of similar magnitude all year round for southeast England
- Generally, lagged correlations are weaker than simultaneous ones, with no marked seasonality
- Lagged correlations are not significant for north west Scotland where droughts are generally short
- Weak relationships exist between the length of a UK drought and the number of regions contemporaneously experiencing drought elsewhere in Europe
- Some significant relationship exist between drought severity and temperature in the UK
- Some long droughts result from a combination of both winter and summer deficiencies

For each UK region, a separate statistical model was built to calculate the number of drought months that may occur in the next 6 months. The model forecasts droughts in groundwater-dominated catchments in southeast England reasonably well (Figure 3). In northwest Britain, however, the predictive capability is less good.

Conclusion

The complex and distincti
the major droughts observ
makes UK drought predict
occurrence of other droug
However, some clear modes of variability of drought occurrence have emerged, and offer potential for further research.

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The project provides a consistent approach to analyse and characterise the major droughts and highlights different mechanisms of drought development since the 1960s in Europe. Conclusions are as follows:

- No systematic mechanism for drought development emerges from this approach
- Droughts tend to develop in the UK before they reach a high severity in western Europe
- The method enables to forecasts winter droughts as well as summer droughts
- Developed models forecast droughts in most UK regions relatively well, especially in groundwater-dominated regions
- The end of droughts is relatively well predicted
- Models could be used to forecast potential intensification/end of long, multi-season droughts
- Some similarities exist between drought occurrence and large-scale atmospheric modes
- More work on circulation patterns associated with different drought types would be needed

Products

The project delivered three final products and presented its finding in an invitation-only workshop, hosted by DEFRA, attended by over 60 academics, stakeholders, UK Government departments (DECC, Defra, WAG) and European Union representatives.

- Final technical report describing methodology, models and results (SC070079/SR3)
- European and UK drought catalogues, including description of drought characteristics of the 24 study regions (SC070079/SR1)
- Drought summaries for five major droughts, discussing their spatio-temporal development (SC070079/SR4)

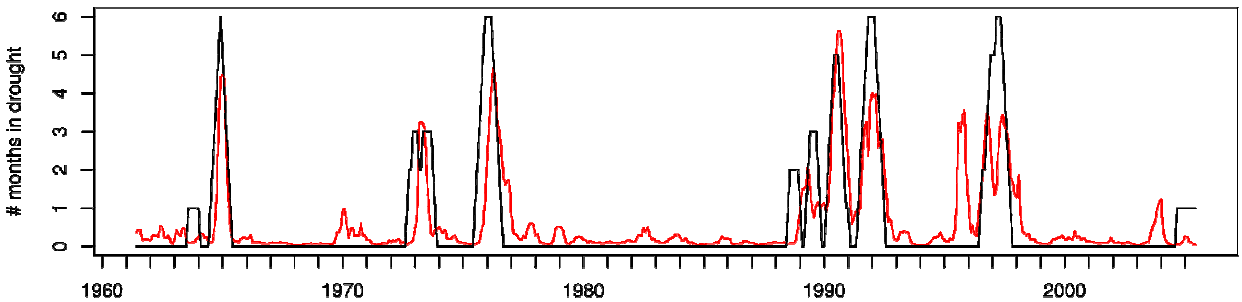

Figure 3. Prediction of number of drought months in the next 6 months observed (black) and modelled (red) – southeast England, groundwater-dominated catchments

[i] River flow: FRIEND EWA http://ne-friend.bafg.de
Banque Hydro: http://www.hydro.eaufrance.fr/; NRFA : http://www.ceh.ac.uk/data/nrfa/
Rainfall : BADC http://badc.nerc.ac.uk/browse/badc/cru