Drought characteristics in Europe from a multi-model ensemble of simulated runoff

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Introduction
Drought commonly covers large areas and lasts for a long time, and spatial and temporal characteristics are important measures of the severity and potential impacts of an event. Drought occurrence, area extent and temporal evolution are climate driven primarily, whereas variability within the affected area and persistence are influenced by land properties.

Drought Characteristics

Drought identification
- A grid cell or observation is in drought if the runoff is below the 20% non-exceedance frequency of the empirical runoff distribution on the respective day.
- A drought cluster is defined as a minimum of 10 spatially contiguous grid cells in drought on a given day.

Annual drought indices
- Mean and maximum drought area and cluster area
- Mean and maximum average anomaly and severity
- Number of drought days

Conclusion
The model intercomparison shows a consistent behaviour among models for annual indices such as the mean drought area, but reveals differences for event characteristics. The validation with observations also showed larger differences at the event scale with some models producing about twice as many events as observed, suggesting a runoff response during drought that is too fast. This can be likely related to the conceptualization of hydrological processes, in particular water storage and release, in the different models. Agreement is better at the time of the largest drought extent when the influence of the common forcing dominates.

Objective
To evaluate the performance and variability of an ensemble of nine large-scale models to simulate streamflow drought characteristics in space and time across Europe.

Model intercomparison

The 10 most extreme drought years in Europe (simulated mean annual drought area)

Data
- WATCH Forcing Data, derived from the ERA-40 reanalysis product, interpolated to half-degree resolution and bias corrected.
- Multi-model ensemble of nine global hydrological and land surface models from the EU-funded WATCH project.
- Daily simulated runoff (fast + slow component) for 1963-2000.
- Observed daily near-natural streamflow from the WATCHHEVA data set. Basins are sub-scale to the size of a model grid cell and only cells with one or more stations were used.

Validation
Comparison of observed and simulated drought time series in the 293 grid cells (in drought if below q20):

Temporal Agreement Index
Summarizes the daily agreement of two indicator series (in drought or not) over all grid cells.

Spatial Agreement Index
Summarizes the grid cell agreement of the indicator series over all time steps.

Spatial and temporal agreement are low (med. ~ 0.4) and model differences small for the spatial index. Correlation between observed and simulated number of drought days is high (med. ~0.7) and model differences small. Runs Ratio shows the largest differences among models with a tendency to overestimate the number of events (med. ~1.2).

A similar median number of drought clusters is found with rather small model differences, whereas the cluster displacement is highly skewed and varies considerably among models.

Daily time series in 1975-76 depict high variability among models for drought area (top), cluster area (middle) and cluster anomaly (bottom). Models agree better at the time of the maximum daily drought extent. Multi-model time series of mean annual drought area reveal two major dry periods in 1975-76 and 1985-89, and a high consistency amongst models.

293 grid cells with paired time series of observed and simulated runoff (mm) for at-site validation.

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