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 q20 (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.

Daily drought indices

- Drought area (fraction of Europe)
- Average anomaly (non-exceedance percentile of all drought cells)
- Drought severity (drought area times average anomaly)
- Number of drought clusters
- Cluster area and anomaly (of the largest cluster)
- Cluster location (coordinates of the centroid of the largest cluster)
- Cluster displacement (distance between the locations of two time steps)

Period drought indices

- Number of events (runs of consecutive days in drought at site or grid cell)

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.

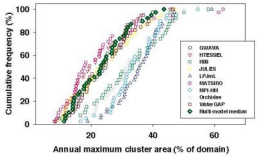
Objective

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.

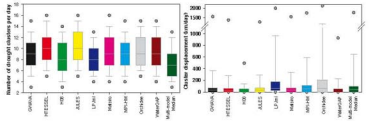
The 10 most extreme drought years in Europe (simulated mean annual drought area)

Rank	Median	GWAVA	HTESSEL	H08	JULES	LPJmL	Matsiro	MPI-HM	Orchidee	WaterGAP
1	1976	1976	1976	1990	1976	1976	1964	1990	1976	1976
2	1990	1989	1990	1964	1989	1964	1963	1976	1964	1990
3	1964	1990	1964	1989	1990	1989	1976	1993	1990	1989
4	1989	1973	1989	1964	1992	1996	1990	1994	1989	1964
5	1996	1993	1992	1993	1964	1993	1992	1989	1972	1973
6	1993	1964	1996	1983	1993	1990	1996	1969	1996	1996
7	1992	1996	1993	1994	1996	1992	1965	1983	1973	1972
8	1973	1992	1974	1996	1995	1969	1993	1992	1993	1992
9	1994	1991	1975	1992	1973	1963	1991	1996	1992	1993
10	1972	1972	1973	1973	1975	1994	1973	2000	1991	1974

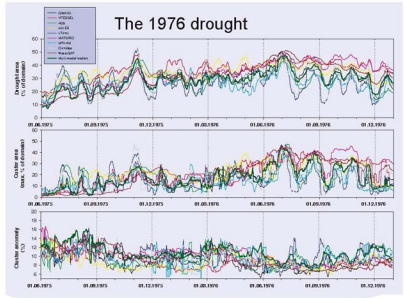
Cumulative frequency plots for largest cluster area reveal large model differences, with two groups of models

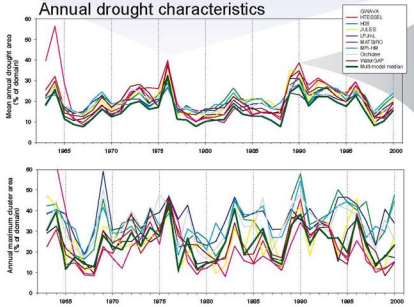


A similar median number of drought clusters is found with rather small model differences, whereas the cluster displacement is highly skewed and varies considerable among models

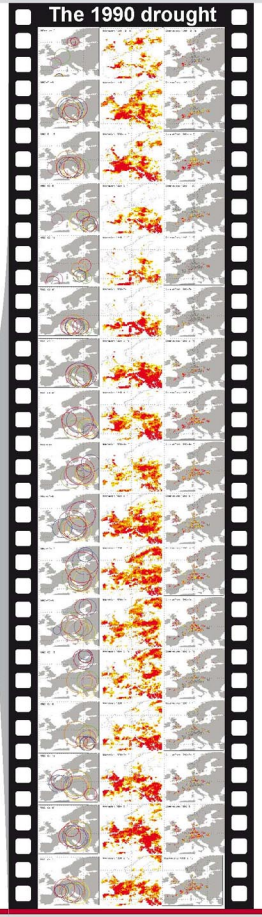


Model intercomparison





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 1989-90, and a high consistency amongst models.



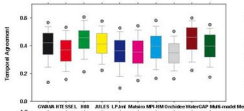
Data

- 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 WATCH/EWA data set. Basins are subscale to the size of a model grid cell and only cells with one or more stations were used.

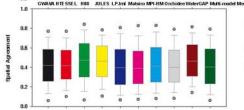
➡ 293 grid cells with paired time series of observed and simulated runoff (mm) for at-site validation.

Validation

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

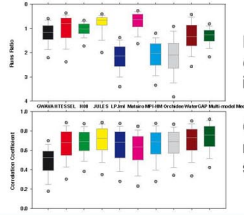


Temporal Agreement Index
summarizes the daily agreement of two indicator series (in drought or not) over all grid cells.



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).



Runs Ratio
compares the number of drought events in observed and simulated runoff series.

Correlation Coefficient
relates observed and simulated annual series of number of drought days

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