Major historical droughts in Europe as simulated by an ensemble of large-scale models

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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)

Period drought indices

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

Conclusion

The model ensemble allowed the identification of the 10 most extreme drought periods in Europe in terms of mean annual drought area, of which 1975-76 and 1989-90 rank the highest with nearly 50% of the model domain in drought at the time of maximum extent. The model variability was higher in daily as compared to annual series, which was also reflected in the validation with observations, with some models producing about twice as many events as observed. This suggests a runoff response during drought that is too fast, which can likely be related to the conceptualization of hydrological processes, in particular water storage and release, in the different models.

Objective

To analyse key characteristics of major streamflow droughts in Europe over the period 1963-2000, including affected area, severity and persistence, as simulated by an ensemble of large-scale hydrological models.

The table (below) ranks the 10 most extreme drought years in Europe according to the simulated mean annual drought area.

The ensemble median and most models simulated the largest drought area in 1976, followed by 1989/1990. A widespread drought also occurred in winter 1964 and in 1996.

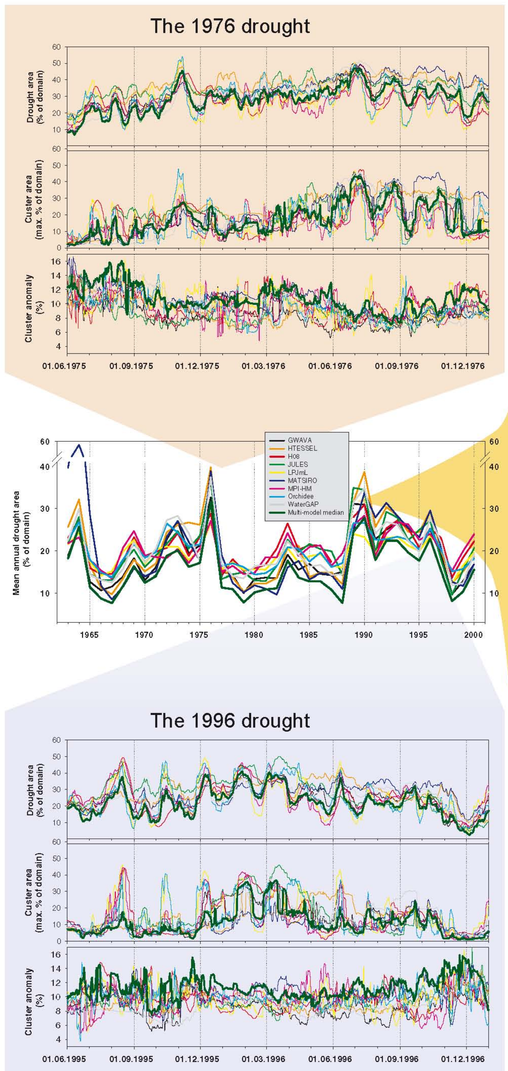
		Rank									
		1	2	3	4	5	6	7	8	9	10
	Median	1976	1990	1964	1989	1996	1993	1992	1973	1994	1972
	GWAVA	1976	1989	1990	1973	1993	1964	1996	1992	1991	1972
	HTESSEL	1976	1990	1964	1989	1992	1996	1993	1974	1975	1973
	H08	1990	1976	1989	1964	1993	1983	1994	1996	1992	1973
Model	JULES	1976	1989	1990	1992	1964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

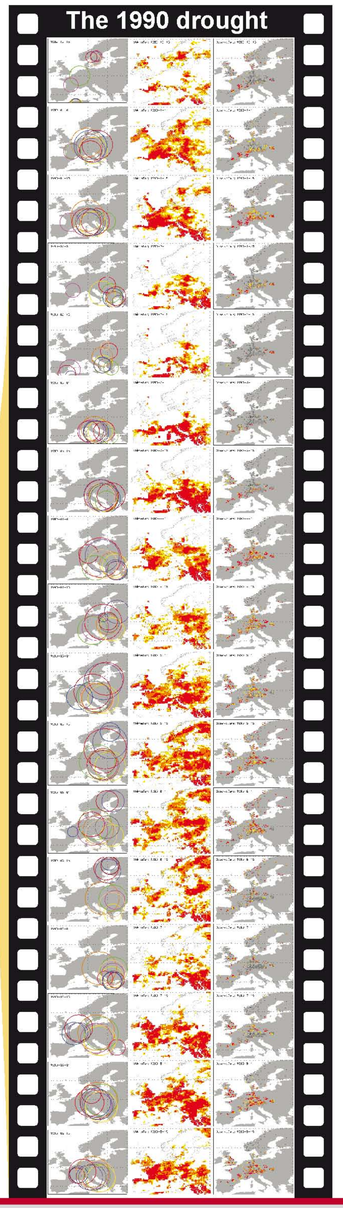
The graphs (right) illustrate the drought development at different time resolutions:
annual series (1963-2000),
daily snapshots (1990 event) and
daily series (1975-76 and 1996 event).

Models were consistent in reproducing the annual variability in drought area, but varied substantially in the simulated daily series of:
drought area (top),
cluster area (middle) and
cluster anomaly (bottom)
location (left column of snapshots).

Agreement was better for drought area and location at the time of maximum daily drought extent, potentially when the influence of the common forcing dominates.

Major Droughts





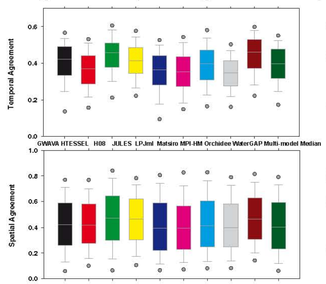
Data

- 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

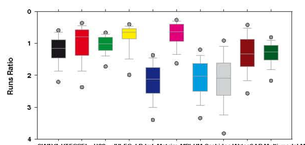
Comparison of observed and simulated drought time series in the 293 grid cells (in drought if below q20):



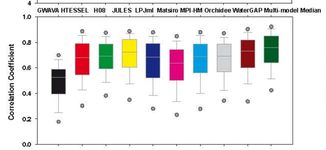
Temporal Agreement Index
summarizes the daily agreement of two indicator series (in drought or not) over all grid cells.

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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