Model based scenarios of drought in Europe
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1) **Definitions of drought**
The talk provides five different definitions of **droughts**: climatological droughts (caused by rainfall deficit), agro-meteorological droughts (soil water deficit), river flow drought (river flow deficit), groundwater drought (groundwater recharge deficit) and an operational drought (water demand is larger than water supply).
As part of a "hierarchy of droughts" hydrological droughts are the consequence of meteorological and agricultural droughts (in case of a sufficient duration).

2) **WaterGAP**
WaterGAP (**water - global assessment and prognosis**) is a global scale model focusing on hydrological droughts. It works on a 0.5°*0.5° grid (based on the resolution of the globally available GCM output) on a monthly time step.
The model WaterGAP consists of two major parts: a global hydrology model and a global water use model. The model focuses on the reduction of discharge and on the water stress which is derived by dividing withdrawals by the availability. As the model has to be based on globally available input data only basic processes and input data are used.
Main hydrological components of the hydrological model are calculation of evapotranspiration, soil water storage and snow melt, while the water use model approximates domestic water use, industrial water use as well as irrigation.
The validation of the water gap model is performed by comparing simulated and observed long-term mean monthly discharges using discharge data of the global runoff data centre.

3) **Drought frequency**
The Kassel research group has identified low flow indicators to be useful for definition of droughts. Therefore the values Q90, Q95 and Q99 (99% of the daily values of stream flow exceed this value) of simulated and observed stream flow data are compared. The model efficiency (Nash & Sutcliffe, 1970) is always acceptable.
For the analysis of (hydrological) drought frequencies the definition of a threshold seems to be useful. Two different threshold types are proposed: a threshold which is constant over the entire year and a threshold which follows the long-term monthly medians. Using one of these thresholds a deficit volume of an actual hydrograph can be calculated. WaterGAP makes use of the simple linear threshold to calculate "deficit volume = water stress". For validation purposes the drought frequency curves of simulated and observed "deficit volumes" are compared, and the model efficiency is acceptable again.

4) **Impact of global change on water availability, water use and droughts**
To assess the impact of global change on water availability and on water use (and therefore on water stress) the results of the SRES scenarios are integrated in the model application. For the hydrological model changes in climate and land cover are considered while for the water use model assumptions for the three considered sectors have to be made (domestic, industrial, irrigation). The water intensity of these three sectors is related to income by simple functions (based on empirical data) considering also the narratives. Based on assumptions on the (future) income of an area (simulation unit) possible future developments can be predicted.

5) **Application of SRES scenarios**
Two SRES scenarios have been applied on WaterGAP to analyse two different time slices (2020 and 2070): A2 and B2. Therefore the "predictions" of two climate models (ECHAM4 and HeadCM3) are used. The climate model predictions are integrated not only into climate input to WaterGAP but also into the water use model.

Changes in water availability and water withdrawals using the input of the two climate models seem to be plausible for the two different future time slices. They coincide with expectations (plausibility). Analysing the WaterGAP results changes in drought frequency and severity caused by climate change can be detected. Severe drought events will become more likely and droughts with the same probability will become more severe. But it is also obvious that different climate models predict different possible futures which (may) lead to different spatial patterns of drought frequencies (e.g. in Europe) in future.

6) **Conclusions and discussion**

- The model WaterGAP seems to deliver acceptable results for low-flow discharge analysis at the macro-scale
- Drought frequencies react sensitively to climate and land use changes
- Different GCM's imply different effects of the predicted future climate on the flood frequency.
- Up to now WaterGAP does not consider the water demand by tourism, the water transport of "real" and "virtual" water from one pixel to another and the water use of (limited resources) of fossil water

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