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Using fuzzy-rule based Circulation Patterns to identify trend signals in 1h-rainfall intensities

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The hydrologic conditions in Central Europe are changing. Statistical trend analysis of precipitation data show that the overall annual precipitation volume has significantly increased in the recent decades. In the same time a shift in the seasonal cycle was observed. The winter appears to be more humid while the summer seems to get dryer. General Circulation Models (GCM) that are used for climatic predictions suggest that these trends will intensify in the future.
However, resolution of the GCM output is limited (typically to a grid of about 2.5° times 2.5° in space and 6 to 24 hours in time) - hence for many hydrological applications not sufficient. Sewage system design is one such example. Sewage systems are very fast responding systems and therefore high local rainfall intensities are generally more crucial for system failures than the overall volume of an event on the regional scale. Thus, for sewage system design, trends in the 1h-rainfall intensities are of much higher importance than trends in the overall annual rainfall volume or the seasonal distribution.

A downscaling scheme is required to bridge the gab between the coarser resolution of the GCM and the finer resolution demanded by the hydrological applications. For this the distribution of observed 1h-rainfall intensities on a local scale are conditioned by the global information of the weather conditions over Europe. The aim is to identify those atmospheric Circulation Patterns (CP) that are responsible for high 1h-rainfall intensities.

The downscaling scheme was set up for a case study with 30 rainfall gauges in Southern Germany. The observations range from 1991 to 2003. As a representation of the

atmospheric circulation 6-hourly NCEP/NCAR reanalysis of the sea level pressure were considered. A simulated annealing algorithm was used to find the optimal CP classification system for this data. The optimisation continuously alters a set of fuzzy rules representing the different Circulation Patterns. A fuzzy rule consists of a number of relevant sea level pressure grid-points with associated pressure values. Each of the fuzzy rules corresponds to one CP. At each optimisation step the sea level pressure grid of every time-step is compared with the current fuzzy rules set and the best fitting CP is assigned. The optimal classification is found when the differences in the 1h-rainfall distribution of the days belonging to the different CPs are maximised.

From a comparison of the 1h-rainfall intensity distributions of the optimal CP classification system it was found that high intensities are always associated with the same CPs. Other CPs mainly lead to fair dry weather.
Furthermore, it could be shown that the hydrologic conditions associated with any CP are highly temperature-dependent. In that effect they will alter considerately with the increase in surface temperatures that is predicted by the Global Circulation Models. For most CPs the rainfall probability is highest if the CP occurs on a cool day. But in the same time only low intensities are observed. For hot days the rainfall probability is very low. But if rainfall occurs on a hot day, the probability of extreme intensities is 4 to 5 times higher.

In a next step this classification was used to generate a CP time-series for the whole range of available NCEP/NCAR reanalysis data from 1958 to 2003. It could be shown that the CP-sequence has significantly changed during that period, especially in summer. CPs leading to fair dry weather occur more frequent than they used to while the frequency of CPs leading to wet conditions have decreased.

By conditioning on Circulation Pattern two overlaying trend signals in the hydrological scheme of Southern Germany could be separated: Higher temperatures are associated with more extreme rainfall events even if the rainfall amounts in summer are decreasing on the larger time scale.

In the presentation the method of the automated weather classification will be introduced briefly. Then a detailed analysis of the hydrological trends in Southern Germany on the 1h-time resolution will be given.