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Assessment of soil moisture drought uncertainty using mHM and TERRA-ML simulations in Germany

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Currently, the hydro-meteorologic mechanisms originating droughts are relatively well understood but our ability to predict them remains unsatisfactory despite the fact that substantial amount of research has been carried out during the previous decades. As a result, drought which is among the most costly natural disasters, remain as one of the least understood natural hazards. The main reasons for the lack of skill of the predictive models are the uncertainty related with the forcings, the conceptualization of dominant processes, and their parametrization at a given spatio-temporal scale. As a result, modeling the soil moisture dynamics at large-scales (from 500 m to 50 km) is becomes extremely difficult as was originally demonstrated by the PILPS project and subsequent studies.

The main goal of this study was to quantify the degree of statistical dependence between monthly soil moisture fields obtained with two land surface models (LSM) (i.e TERRA-ML and mHM) for Germany from 1971 to 2001. A particular goal was to understand how the parametric uncertainty of mHM affect a monthly soil moisture index and derived statistics such as area under drought, severity, magnitude. The effects of modelling scale were also investigated. TERRA-ML is a LSM implemented within the nonhydrostatic regional climate model (RCM) COSMO-CLM (www.clm-community.eu). In this study, COSMO-CLM was forced with ERA40 reanalysis data (www.ecmwf.int) to generate finally aggregated monthly soil moisture fields at 7×7 km resolution covering Germany and its surrounding during the period 1971 to 2001. Due to the computational burden of this model, only one run could be completed for this study. mHM, on the contrary, is a mesoscale distributed hydrological model operated here as a LSM (Samaniego et al. 2010). It was forced with grided daily precipitation and temperature data at 4×4 km resolution from 1950 to 2010. Daily time series for more than 5600 rain gauges and about 1120 meteorological stations (DWD) were interpolated with external drift Kriging to produce highly consistent fields of meteorological variables. Land cover changes during this period were also considered. It should be noted that, mHM aims at a consistent analysis of soil moisture based on available observations whereas the COSMO-CLM simulation describes the atmospheric and the soil processes consistent with the in- and outflows at the outer boundaries of the modelling domain from the ERA40 re-analysis.

The best hundred parameter sets obtained for mHM were employed to generate a 100-member ensemble of daily soil moisture fields. Using these ensemble, the effects of parameter uncertainty on the soil moisture index (SMI) and related statistics were estimated. Results indicated that the ensemble mean of SMI exhibited an excellent agreement with extreme drought events reported in the literature. Parametric uncertainty of the SMI is, however, considerably during some periods. The uncertainty of the area under drought and severity, however, indicate that a single simulation is not enough to draw conclusive results. A non-parametric test was be applied to investigate the existence of significant trends in soil moisture simulations. Preliminary results indicated the existence of a negative significant trend (p-value 5%) in soil moisture during summer months which is the consequence of observed downward trend in precipitation and upward trend in temperature. On the contrary, soil moisture simulations in winter months did not exhibit significant trends. Finally, canonical correlation analysis will be employed to identify the maximum correlation between the monthly soil moisture fields obtained with both LSMs.