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Detecting causation mechanisms of soil moisture patterns in Germany

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Detecting trends, feedbacks, and causation mechanisms in hydrometeorologic variables such as soil moisture is a challenging task because of the nonlinear dynamics of the atmosphere-land-vegetation system, the assimilation of noisy observations, and the structural and parametric uncertainty of land surface models (LSM). Quite often, wrong conclusions can be drawn because uncorrelated variables may be assumed to have no causal relationship with presupposed predictors.

The main goal of this study is to test whether a significant “Granger causality” (Granger 1969) exist between monthly soil moisture fields over Germany and large-scale circulation patterns, characterized by anomalies of sea level pressure over the Northern Hemisphere or geopotential height and atmospheric humidity over Europe. The advantage of this testing framework stems from the fact that it is based on predictability instead of correlation to identify causation, as it is the case with standard correlation-based approaches.

Two contrasting modeling paradigms, the land surface NOAH model and the process-based hydrologic model mHM (Samaniego et al. 2012) are employed to estimate daily soil moisture over Germany during the period from 1989 to 2009. WRF/NOAH was forced with ERA-Interim data at the boundary of the EURO-CORDEX Region (www.meteo.unican.es/wiki/cordexwrf) with a spatial resolution of 0.11°. To ease comparison, mHM was also forced with daily precipitation and temperature fields generated by WRF during the same period at 4×4 km resolution. Main physiographic characteristics in NOAH such as land cover and soil texture are represented with a 1×1 km MODIS data set and a single horizon, coarse resolution FAO soil map with 16 soil texture classes, respectively. The multiscale parameter regionalization technique (MPR, Samaniego et al. 2010) embedded in mHM allows to estimate effective model parameters based on detailed input data (100×100 m) obtained from Corine land cover and soil texture fields for various horizons comprising 72 classes. mHM global parameters, in contrast with those of NOAH, were obtained by closing the water balance in major German river basins. For the "Granger causality" test, variables such as sea level pressure or geopotential height at 500 hPa (dss.ucar.edu/datasets/ds010.0/, data-portal.ecmwf.int/data/d/interim_daily) are used as predictor fields including the lagged values of these variables.

Results indicate that the subgrid variability of the land surface properties and the parametrization schemes have greater influence on soil moisture simulations. Mann-Kendall tests performed with mHM data indicated the existence of a negative 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 exhibited significant trends. The Granger-causation mechanisms of these trends are under investigation.