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Forecasting European Droughts using the North American Multi-Model Ensemble (NMME)

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Soil moisture droughts have the potential to diminish crop yields causing economic damage or even threatening the livelihood of societies. State-of-the-art drought forecasting systems incorporate seasonal meteorological forecasts to estimate future drought conditions. Meteorological forecasting skill (in particular that of precipitation), however, is limited to a few weeks because of the chaotic behaviour of the atmosphere. One of the most important challenges in drought forecasting is to understand how the uncertainty in the atmospheric forcings (e.g., precipitation and temperature) is further propagated into hydrologic variables such as soil moisture. The North American Multi-Model Ensemble (NMME) provides the latest collection of a multi-institutional seasonal forecasting ensemble for precipitation and temperature. In this study, we analyse the skill of NMME forecasts for predicting European drought events.

The monthly NMME forecasts are downscaled to daily values to force the mesoscale hydrological model (mHM). The mHM soil moisture forecasts obtained with the forcings of the dynamical models are then compared against those obtained with the Ensemble Streamflow Prediction (ESP) approach. ESP recombines historical meteorological forcings to create a new ensemble forecast. Both forecasts are compared against reference soil moisture conditions obtained using observation based meteorological forcings. The study is conducted for the period from 1982 to 2009 and covers a large part of the Pan-European domain (10°W to 40°E and 35°N to 55°N).

Results indicate that NMME forecasts are better at predicting the reference soil moisture variability as compared to ESP. For example, NMME explains 50% of the variability in contrast to only 31% by ESP at a six-month lead time. The Equitable Threat Skill Score (ETS), which combines the hit and false alarm rates, is analysed for drought events using a 0.2 threshold of a soil moisture percentile index. On average, the NMME based ensemble forecasts have consistently higher skill than the ESP based ones (ETS of 13% as compared to 5% at a six-month lead time). Additionally, the ETS ensemble spread of NMME forecasts is considerably narrower than that of ESP; the lower boundary of the NMME ensemble spread coincides most of the time with the ensemble median of ESP. Among the NMME models, NCEP-CFSv2 outperforms the other models in terms of ETS most of the time. Removing the three worst performing models does not deteriorate the ensemble performance (neither in skill nor in spread), but would substantially reduce the computational resources required in an operational forecasting system. For major European drought events (e.g., 1990, 1992, 2003, and 2007), NMME forecasts tend to underestimate area under drought and drought magnitude during times of drought development. During drought recovery, this underestimation is weaker for area under drought or even reversed into an overestimation for drought magnitude. This indicates that the NMME models are too wet during drought development and too dry during drought recovery.

In summary, soil moisture drought forecasts by NMME are more skillful than those of an ESP based approach. However, they still show systematic biases in reproducing the observed drought dynamics during drought development and recovery.