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Statistical analysis of simulated global soil moisture and its memory in an ensemble of CMIP5 general circulation models

Felix Wiß (1,2), Tobias Stacke (1), and Stefan Hagemann (1)

(1) Max-Planck-Institute for Meteorology, Hamburg, Germany (felix.wiss@mpimet.mpg.de), (2) University of Innsbruck, Innsbruck, Austria

Soil moisture and its memory can have a strong impact on near surface temperature and precipitation and have the potential to promote severe heat waves, dry spells and floods. To analyze how soil moisture is simulated in recent general circulation models (GCMs), soil moisture data from a 23 model ensemble of Atmospheric Model Intercomparison Project (AMIP) type simulations from the Coupled Model Intercomparison Project Phase 5 (CMIP5) are examined for the period 1979 to 2008 with regard to parameterization and statistical characteristics.
With respect to soil moisture processes, the models vary in their maximum soil and root depth, the number of soil layers, the water-holding capacity, and the ability to simulate freezing which all together leads to very different soil moisture characteristics. Differences in the water-holding capacity are resulting in deviations in the global median soil moisture of more than one order of magnitude between the models. In contrast, the variance shows similar absolute values when comparing the models to each other. Thus, the input and output rates by precipitation and evapotranspiration, which are computed by the atmospheric component of the models, have to be in the same range. Most models simulate great variances in the monsoon areas of the tropics and north western U.S., intermediate variances in Europe and eastern U.S., and low variances in the Sahara, continental Asia, and central and western Australia. In general, the variance decreases with latitude over the high northern latitudes.
As soil moisture trends in the models were found to be negligible, the soil moisture anomalies were calculated by subtracting the 30 year monthly climatology from the data. The length of the memory is determined from the soil moisture anomalies by calculating the first insignificant autocorrelation for ascending monthly lags (insignificant autocorrelation folding time). The models show a great spread of autocorrelation length from a few months in the tropics, north western Canada, eastern U.S. and northern Europe up to few years in the Sahara, the Arabian Peninsula, continental Eurasia and central U.S. Some models simulate very long memory all over the globe. This behavior is associated with differences between the models in the maximum root and soil depth. Models with shallow roots and deep soils exhibit longer memories than models with similar soil and root depths. Further analysis will be conducted to clearly divide models into groups based on their inter-model spatial correlation of simulated soil moisture characteristics.