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Soil moisture memory in AGCM simulations: Analysis of Global Land-Atmosphere Coupling Experiment (GLACE) data

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Soil moisture memory, in essence the fact that the soil can remember a wet or dry anomaly long after the conditions responsible for the anomaly are forgotten by the atmosphere, is a key aspect of land-atmosphere interactions and has major implications for seasonal forecasting. Indeed, due to its inherent memory, soil moisture is one of the major slow drivers of the climate system and possibly the chief source of forecast skill for summer precipitation over land in the mid-latitudes. A detailed understanding of the processes controlling soil moisture memory is therefore necessary for assessing the predictability associated with soil moisture on subseasonal to seasonal time scales, and for characterizing important mechanisms impacting land-atmosphere interactions on that scale.

The present study examines and contrasts the soil moisture memory characteristics of eight AGCMs participating in the Global Land-Atmosphere Coupling Experiment (GLACE). The analysis framework is an equation that relates the autocorrelation of soil moisture in a given climate model to 4 distinct terms: 1) the seasonality of soil moisture, 2) the variation of evaporation with soil moisture, 3) the variation of runoff with soil moisture, and 4) the correlation between the atmospheric forcing and antecedent soil moisture, which reflects both the memory of the external forcing and land-atmosphere feedbacks. Soil moisture memory in the analyzed AGCMs is mostly controlled by the evaporation and runoff sensitivity terms. For a majority of the models, soil moisture memory is controlled by the former in dry areas and by the latter in humid areas; it is highest in regions of medium soil moisture content, where both terms are small. The seasonality term has generally little impact on the overall soil moisture memory, but is seen to compensate the evaporation sensitivity term in some dry areas. Land-atmosphere feedback is rarely large enough to impact overall soil moisture memory, except in regions with strong land-atmosphere coupling.

Overall, the investigated AGCMs present similar global patterns of soil moisture memory. Outliers are characterized by either anomalous water-holding capacity, biases in atmospheric forcing (mostly radiation), or exaggerated land surface sensitivity due to extreme dry soil moisture conditions. Comparisons with soil moisture observations from the Global Soil Moisture Data Bank demonstrate that the models' average soil moisture memory is generally close to the observed values.