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Soil moisture-precipitation feedback: reconciling negative spatial coupling with a positive temporal feedback via moisture recycling

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Soil moisture-precipitation coupling, i.e. the impact of soil moisture on precipitation, conveys some of the largest uncertainties in land-atmosphere interactions. In addition to a direct positive effect via moisture recycling, a number of indirect effects have been identified, where surface turbulent fluxes impact temperature and humidity in the boundary layer, its growth and thereby indirectly many variables that can support or inhibit convection triggering, such as atmospheric stability, entrainment, or mesoscale circulations. Due to the complexity of the involved interactions, the sign and strength of this feedback remains heavily debated in the literature, despite important advances in recent years.

Traditional “temporal” perspectives often highlight positive relationships, i.e. rain falling more often over wet soils [e.g., 1], albeit with difficulties in attributing these relationships to a coupling due to atmospheric persistence [e.g., 2]. On the other hand, recent studies focusing on the impacts of spatial differences in soil moisture have highlighted that rain falls preferentially over soils that are drier than their surrounding [3]. This is likely due to negative indirect effects, such as mesoscale circulations that are induced by the underlying spatial soil moisture patterns [4]. These results from “temporal” and “spatial” perspectives may first appear contradictory and dependent on the underlying datasets. However, they could also refer to different processes that determine when and where it rains. In other words, the presence of negative spatial coupling may not necessarily be incompatible with the concept of positive temporal coupling.

Using global satellite-based data, we compare spatial and temporal perspectives using metrics that relate precipitation events to prior spatial and temporal soil moisture patterns. We find that relationships between soil moisture and subsequent precipitation can be spatially negative while temporally positive, with implications on the interpretation of both perspectives. While the causality of temporal relationships remains difficult to assess, these findings suggest that a positive coupling could induce persistence in precipitation and soil moisture, while a negative spatial coupling could act to redistribute soil moisture spatially. Our results show that it rains preferentially over patches that are drier than the surrounding but at times in which they are wetter than their own climatology.

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