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Multiple Preferential States in Soil Moisture, Climate and Vegetation Dynamics in Arid and Semiarid Ecosystems: The Effect of Non-Linearity and Feedbacks

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There is general consensus that dryland ecosystems are particularly prone to catastrophic shifts in their state under the effect of climate fluctuations and other disturbances. Interactions between soil moisture, precipitation, and vegetation may lead to the emergence of multiple preferential states and to abrupt phase transitions.
The temporal dynamics of bistable, water-limited ecosystems are investigated here through minimalist ecohydrological models based on the soil water balance. Non-linearities inherent to these systems as well as positive feedbacks between soil moisture and precipitation, or vegetation and soil moisture are studied as important sources of bistability. These models are applied to different arid, semiarid, and seasonally water-limited ecosystems to investigate the occurrence of phase transitions induced by stochastic fluctuations of precipitation.
It is found that (a) nonlinearities in the dependence between soil moisture and evapotranspiration - combined with interannual climate fluctuations - may lead to the emergence of two preferential states in soil moisture dynamics; (b) systems characterized by vegetation-soil moisture feedbacks exhibit two stable states. Interannual climate variability causes interesting phase transitions between these states; (c) multiplicative noise in the soil water balance equation leads to bimodal behavior in the variability of the soil water content. The results of these analyses are used to characterize the stability and resilience of dryland ecosystems.