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Entropy Production of Soil Hydrological Processes

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The soil hydrological cycle plays an important role for biogeochemical processes, connecting hydrosphere, atmosphere and terrestrial vegetation by means of exchange flows of matter and energy. An understanding of soil hydrological processes is thus crucial for the prediction of changes in earth system dynamics.
In spite of a large number of already existing soil hydrological models, thermodynamic approaches have not been frequently used yet. The advantage of methods from non-equilibrium thermodynamics is the possibility of consistently describing processes at the surface-vegetation-atmosphere interface. The state of water, for example, can be quantified by the value of water potential in each reservoir of the soil hydrological cycle. Movement of water between reservoirs can then be universally expressed as a function of a gradient in water potential.
Furthermore, the use of thermodynamics allows for the quantification of the entropy budget of the soil hydrological cycle. The production of entropy is a general feature of soil hydrological processes. The potential energy of runoff, for instance, is transformed into kinetic energy and lost as heat on the way to the oceans due to friction. The heat emitted corresponds to the entropy produced during runoff.
The entropy production associated with a hydrological flow contains additional information about the dynamics of the system, compared to the magnitude of the flow alone. The entropy production of soil water redistribution, for example, can be used to capture spatio-temporal variability on smaller scales, since frequent wetting and drying of soil produces more entropy than a uniform wetting throughout the year. This difference cannot be represented by the annual mean soil moisture. We test these concepts using a bucket model on a global scale that is coupled to a simple vegetation model.