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Entropy production by evapotranspiration and its geographic variation

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The hydrologic cycle is a system far from thermodynamic equilibrium that is characterized by its rate of entropy production in the climatological mean steady state. Over land, the hydrologic cycle is strongly affected by the presence of terrestrial vegetation. In order to investigate the role of the biota in the hydrologic cycle, it is critical to investigate the consequences of biotic effects from this thermodynamic perspective. Here I quantify entropy production by evapotranspiration with a climate system model of intermediate complexity and estimate its sensitivity to vegetation cover. For present-day conditions, the global mean entropy production of evaporation is 8.4 mW/m^2/K, which is about 1/3 of the estimated entropy production of the whole hydrologic cycle. On average, ocean surfaces generally produce more than twice as much entropy as land surfaces. On land, high rates of entropy production of up to 16 mW/m^2/K are found in regions of high evapotranspiration, although relative humidity of the atmospheric boundary layer is also an important factor. With an additional model simulation of a "Desert" simulation, where the effects of vegetation on land surface functioning is removed, I estimate the sensitivity of these entropy production rates to the presence of vegetation. Land averaged evapotranspiration decreases from 2.4 to 1.4 mm/d, while entropy production is reduced comparatively less from 4.2 to 3.1 mW/m^2/K. This is related to the reduction in relative humidity of the atmospheric boundary layer as a compensatory effect, and points out the importance of a more complete treatment of entropy production calculations to investigate the role of biotic effects on Earth system functioning.

Keywords:

hydrologic cycle; evapotranspiration; land surface; entropy production; principle of Maximum Entropy Production; vegetation effects

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