Maximum Entropy Production and the Carbon Cycle
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Terrestrial vegetation is an important component of the climate system. Vegetation, through its form and functioning, affects the exchange fluxes of energy and mass at the land surface and the overlying atmosphere. It is unique in its ability to adapt to its climatic environment at the individual plant scale and through changes in ecosystem composition. This adds many degrees of freedom and flexibility to land surface; allowing the exchange fluxes of energy and mass to be partitioned in many different ways. This implies that the energy and mass balances simply act to constrain possible vegetation activity, but are insufficient to determine the full nature of land surface functioning and vegetation-climate interactions.

We hypothesize that vegetation adapts optimally in such a way that it maximizes its productivity thereby leading to to a characteristic partitioning of energy and mass fluxes at the land surface. This approach stems from the principle of Maximum Entropy Production (MEP), which originates from the theory of statistical mechanics of non-equilibrium thermodynamic systems and has been fundamentally derived from information theory. The MEP principle states that the macroscopic steady state of a dissipative process given sufficient degrees of freedom is one at which the rate of entropy production is maximized. Previous studies have applied the MEP principle to vegetation activity and demonstrated that a maximization of photosynthetic activity, or gross primary productivity (GPP), leads to a maximization in entropy production.

One approach that has been used in previous studies, mainly at the level of individual plants, assumes that terrestrial vegetation adapts optimally to its environmental conditions in terms of its form and functioning, thereby maximizing its productivity. Here, we conduct many sensitivity simulations with a coupled dynamic vegetation-climate system model to demonstrate that the large-scale functioning of terrestrial vegetation is also optimal in terms of its productivity given the constraints of the climatological surface energy- and water balances. The simulations show that vegetation adds flexibility to the land surface allowing for a wide range of biologically possible climate-vegetation states that differ in their productivity. The characteristic partitioning of radiative to turbulent fluxes found in the sensitivity climates with the highest productivities is largely consistent at the biome scale with observations from the ECMWF ERA-40 climate reanalysis.