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Multiple vegetation states in a warm climate

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Using the Max Planck earth system model, multiple steady states in vegetation cover are evaluated for preindustrial and Early Eocene boundary conditions. By setting the soil albedo either to a value similar to vegetation albedo or to a value much higher than vegetation albedo, the hydrological and the albedo effect of vegetation on climate are separated.

Considering only the hydrological effect, multiple solutions for the Early Eocene vegetation cover exist. In central Asia, a desert evolves. This desert is smaller when the simulation is started with trees on all continents instead of bare soil. Started with trees, the climate in central Asia is more humid than when started with bare soil. In the more humid climate, more vegetation grows. For the preindustrial climate, only one solution for vegetation exists. The atmospheric circulation prevents multiple solutions for vegetation in the Sahara. Strong subsidence prevails over the Sahara. Under strong subsidence the hydrological effect becomes ineffective.

Considering the hydrological and the albedo effect of vegetation, only one solution for Early Eocene and preindustrial vegetation exists. Starting the simulations with trees, the Early Eocene central Asia and preindustrial Sahara start from a humid climate, but the initial climate is not humid enough to allow a dense vegetation cover. With shrinking vegetation cover, surface albedo increases. Increasing albedo amplifies aridification by inducing the Charney effect. The vegetation cover shrinks further until a dry desert state is reached.

This study shows that the existence of multiple steady vegetation states depends on the boundary conditions, such as continent distribution. This result implies that the existence and the driving mechanisms of multiple stable vegetation states differ for present day, past, and probably future conditions.