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Multiple stable states of tree cover in a global land surface model due to fire - vegetation feedback

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The presence of multiple stable states has far reaching consequences for a system's susceptibility to disturbances, including the possibility of abrupt transitions between the stable states. Tree cover is an ecosystem characteristic for which the occurrence of multiple stable states is supported by ecological theory, conceptual simple models and global satellite observations. Fire has been identified as an important process in those ecosystems. Global dynamic vegetation models usually represent the vegetation dynamics in a simplified way with only one equilibrium state for certain environmental conditions. The equilibrium state then does not depend on the history and vegetation would always recover to the equilibrium state.

Here, we describe the occurrence of multiple stable states in a global simulation with the JSBACH-SPITFIRE model, the land surface model in the MPI-ESM. With the improved process representation of fire, the equilibrium state of vegetation depends on the initial conditions. Model initialization with only woody species leads to a higher global tree covered area in equilibrium compared to an initialization with only grass species. The potential bistability occurs for gridcells with intermediately strong fire regimes in the transition zones between grasslands and forests. We find regions in mainly Africa and Asia to have multiple stable vegetation states. By performing sensitivity simulations and simplifying the relevant model equations we show that the multiple states occur due to a strong feedback between fire and forest cover. This is corroborated by comparing the model behavior to a fire model without fire-vegetation feedback in which no multiple stable states occur. Our results support the view that changes in vegetation cover can be irreversible due to the fire-vegetation feedback.