Summary PhD Thesis: Feedbacks between vegetation and rainfall in the Amazon region – A complex network approach

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The distribution of rainfall and vegetation are closely interconnected in the Amazon basin. Rainforests maintain atmospheric humidity by evapotranspiration, which eventually contributes to continental rainfall. A comprehensive understanding of the complex interactions among the terrestrial and atmospheric components of the hydrological cycle as moist air is transported by winds over land is missing. The first aim of this thesis is to fill this gap of knowledge by means of complex network analysis of water fluxes from the sources to the sinks of rainfall on the continent. This novel approach allows to introduce the concept of "cascading moisture recycling" defined as moisture recycling on the continent involving "re-evaporation cycles" (evaporation of precipitating moisture in the same location) along the way. A methodological framework is developed to quantify the importance of cascading moisture recycling and to identify key regions where re-evaporation cycles are taking place. Applied to several combinations of observation-based gridded climate data in South America, it reveals, for instance, that the southern part of the Amazon basin is not only a direct source of rainfall for the La Plata basin as previously thought but also an intermediary region that re-distribute moisture evaporating from the entire Amazon basin towards the subtropics. This new concept lays the foundation for evaluating the vulnerability of the Amazon forest to environmental perturbations, which is the second aim of this thesis. Land-use and rainfall variability are expected to be intensified at the end of the twenty-first century and may push the south-eastern part of the Amazon forest towards a grass-dominated ecosystem. Such a forest loss would reduce local dry-season evapotranspiration and the resulting moisture supply for down-wind rainfall. In turn, this might erode the resilience of the remaining forest and lead to further forest losses. Using a complex network approach, the concepts of forest resilience and cascading moisture recycling are combined in a data-driven modeling framework. Key regions are identified where deforestation would greatly destabilize the remaining forest, as well as tipping points in dry-season intensification for large-scale self-amplified Amazon forest loss. The findings highlight the need to maintain the diversity and connectivity of forest patches in order to sustain the ecological integrity of the largest remaining tropical forest on Earth.