

Complex systems analysis of changing rainfall regimes in South America and their implications for the Amazon rainforest

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The Amazon is the world's largest and most biodiverse rainforest, giving home to 10% of all known species and containing around 25% of the global plant diversity. Its enormous capabilities of recycling carbon dioxide have earned it the nickname "Lung of the Earth", making it a crucial part of the global climate system. While the Amazon rainforest has been constituting a stable ecosystem for the last 55 million years, climate change and ongoing deforestation are now threatening its sustenance. It is even thought that the Amazon rainforest is a climatological tipping element that might change its state drastically once certain environmental factors such as temperature and precipitation cross specific tipping thresholds. This thesis investigates the impact of changes in frequency and amount of precipitation in the Amazon rainforest and analyzes its development under the changing conditions due to global warming.

In this context, complex network theory is utilized to investigate the South American monsoon system. The precipitation correlation structure reveals hidden features of the system, such as the transition from a disordered to an ordered monsoon system. Further developing existing network methods towards multilayer network tools allows for the investigation of the root causes for droughts in the central Amazon basin. By using a bivariate network between monthly precipitation in the central Amazon and Atlantic sea surface temperatures, distinct oceanic regions are identified to have a strong influence on central Amazonian precipitation. The formation of a climatological dipole between the northern and southern tropical Atlantic sea surface temperatures is found to precede droughts. As a result, this study is the first to give an early warning for droughts in the Amazon. To investigate the influence of rainfall variability on vegetation, a potential landscape is constructed from precipitation and Amazonian tree cover data. The resilience of the forest is found to directly depend on the local rainfall variability in the long-term past, thereby reflecting a vegetational training effect under specific environmental conditions. Considering climate change projections, this effect could be decisive for the future survival of the present rainforest vegetation state. In order to cover long-term influences of global warming, this thesis additionally investigates the effects of a slowing down of the Atlantic meridional overturning circulation and the direct influence of global warming on the southern Amazon rainforest. It is revealed that these effects, although caused by global warming, have competitive impacts on precipitation in the Amazon basin, with a stabilizing effect of an Atlantic meridional overturning circulation slowdown on the Amazon rainforest.

This dissertation provides newly developed, as well as adjusted methods to enhance our understanding of the considered climatological and vegetational systems. Together, they provide the basic tools for a further investigation of these complex systems. Furthermore, the findings of this thesis enhance the knowledge about the South American climate and ecosystems and their development in the future.