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How Amazonian deforestation can alter the South American circulation regime: Insights from a non-linear moisture transport model

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A key driver of South American climate are the low-level trade winds from the tropical Atlantic Ocean towards the continent. After crossing the Amazon Basin, they are blocked by the Andes mountain range, and forced southward to the subtropics. These winds are crucial for the atmospheric moisture supply in most parts of South America. In particular, the hydrology of the two largest river basins of the Continent, namely the Amazon and the La Plata Basins, strongly depend on the moisture inflow provided by the trade winds. In turn, the Amazon rainforest can be assumed to have a strong influence on this low-level moisture circulation over South America by exchanging moisture with the atmosphere through precipitation and evapotranspiration. A pronounced positive feedback in this context is established through precipitation-induced release of latent heat over the Amazon Basin, which significantly enhances the moisture inflow from the tropical Atlantic Ocean toward the continent and can thus be considered to be crucial for the existence of today's South American climate. Ongoing deforestation and resulting reduction in evapotranspiration rates in particular in the eastern Amazon carry the risk of a strongly nonlinear response in these interactions with the low-level atmosphere. We propose a simple differential transport model describing the cascading moisture transport from the eastern coast of South America across the Amazon Basin to the Andes, taking into account the nonlinearity associated with the release of latent heat. The results of the model suggest that the system is indeed very sensitive to relatively small reductions of the evapotranspiration rates in the eastern Amazon Basin. These reductions increase river runoff, but limit the moisture availability farther west. This leads to a reduction in precipitation rates and thereby diminishes the release of latent heat which, in turn, reduces the overall moisture inflow. We show that, according to our model, there exist critical thresholds on the spatial extents and intensities of deforestation. Beyond these thresholds, the positive feedback between the Amazon rainforest and the low-level circulation would collapse, resulting in substantial reductions in moisture available for precipitation in the western part of the Amazon Basin and further downstream of the low-level flow, including most of subtropical South America.