The Amazon rainforest (ARF) is among the elements in the climate system that have been labeled as “tipping elements”. There is concern that as global warming and Amazonian deforestation progress, nonlinear thresholds and positive feedbacks will amplify the projected drying of the rainforest, leading to large-scale loss of forest cover, carbon pools, and biodiversity. Two important positive feedbacks between vegetation and atmosphere have been identified which could lead to self-amplified Amazon dieback. First, on large spatial scales, the strong atmospheric water recycling over the Amazon could amplify the reduction in precipitation as trees transpire less water in a world with lower soil moisture, higher air temperature and higher CO_2. Second, on small spatial scales, increased fire frequency can sustain an alternative savannah state where forest trees cannot compete anymore with more fire-prone grasses. Observations support the “tipping” hypothesis by showing multiple modes of tree cover for the same annual mean precipitation (Hirota et al., 2011; Staver et al., 2011), but other explanations have also been put forward.

So far, studies have investigated the potential drivers and feedbacks associated with forest loss in a variety of models. The scenario of a self-amplified dieback (Cox et al., 2004) however is still more a hypothesis than a scientific result. Data-driven predictions typically rely on empirical moisture-recycling estimates (Dirmeyer et al., 2007) and strict assumptions on their invariance in a future climate. Current simulations with coupled complex climate models like in CMIP6 project a tendency of Amazon drying and enhanced respiration, but no large-scale forest loss. However, these models are also known to have substantial biases due to their limited realism of crucial processes and limited resolution, and have never been thoroughly tested in their response to a range of potential forcing scenarios apart from standard SSP scenarios.

In this project, we will be performing numerical simulations with a coupled vegetation-atmosphere model to establish the plausibility of an Amazonian “tipping point” under various scenarios of climate change and deforestation patterns. We will also assess the impacts of a potential forest loss by imposing large-scale forest removal in the model. These activities will be performed with MPI-ESM and will also be compared to similar simulations with other models as part of the Horizon 2020 project ClimTip which starts in March 2024. The simulations will also be the basis for dynamical and statistical downscaling activities in other work packages of ClimTip, and follow-up impact assessments.

Our experiments can help bridge the gap between the highly complex real world and conceptual models, improve our understanding of whether human activities are moving the Amazon forest closer to a tipping point, and understand in more detail what the ecological and societal impacts would be.