Project: **1404**
Project title: **Model-informed assessment of the risk of Amazon rainforest dieback**
Principal investigator: **Julia Pongratz**
Report period: **2024-11-01 to 2025-10-31**

In this project we aim to investigate the Amazon rainforest climate “tipping points”, as part of the EU Horizon project ClimTip. For this assessment, we perform numerical simulations with MPI-ESM to better understand the response of the forest to different drivers, such as global warming and deforestation, as well as the climate feedbacks associated with forest loss. The data from these simulations will also be used by other work packages of ClimTip, focusing on different aspects related to socio-economical and biodiversity impacts of crossing these tipping points.

In the reporting period we completed the first main task of our ClimTip work package, which was to simulate a complete dieback of the Amazon rainforest. Three main experiments were completed: (1) piControl, (2) stable global temperature at 2-degree warming relative to piControl, and (3) stable global temperature at 2-degree warming with imposed removal of the Amazon rainforest. Selected monthly mean values from these simulations are publicly available at https://zenodo.org/records/16784935 . To reach a 2-degree warming scenario, we use the 1pctCO2 simulation from CMIP6 as a “ramp up”, and the stable scenarios are branched off from the year that this ramp up period reaches the 2-degree warming mark. To have global temperatures stable in this period the simulations are concentration driven and the CO2 concentrations required for stable global temperatures are estimated using equations from Geoffroy et al (2013). Figure 1 shows the time series of global mean temperature of the three experiments.

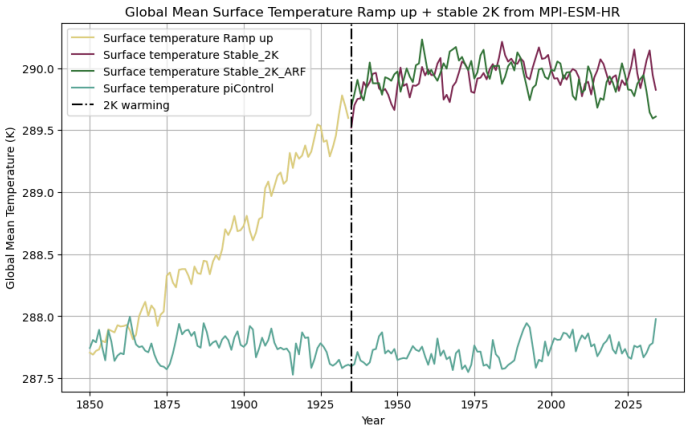

Figure 1 – Global mean temperatures for ClimTip simulations (using MPI-ESM-HR) from the work package main task 1: piControl, ramp up + stable temperature at 2K warming, and ramp up + stable temperature at 2K warming with Amazon rainforest removal.

The second task of the work package is investigating the non-linearities of the response of the Amazon rainforest land-atmosphere feedbacks to deforestation. For this purpose, we set up different deforestation experiments and switched on dynamical vegetation after parts of the forest were removed. In each experiment we imposed increasing extents of deforestation (25, 50 and 75% of the entire Amazon rainforest) with different spatial patterns. Three deforestation patterns were included in the first set of simulations: (1) following the direction of the oceanic moisture influx i.e. from northeast to the southwest, (2) following the opposite direction of the oceanic moisture influx i.e. from southwest to northeast, and (3) a “checkerboard” pattern. Figure 2 shows the average annual precipitation in the Amazon basin for each one of these deforestation scenarios.

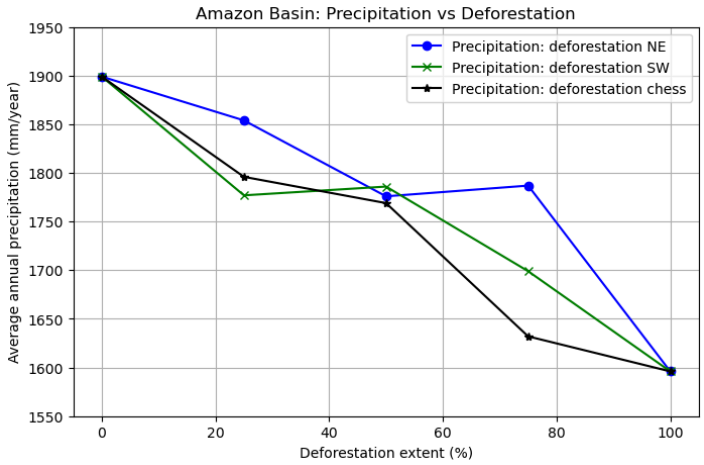

Figure 2 - Average annual precipitation (in mm/year) for progressive deforestation following three different spatial patterns of deforestation.

Because of the use of dynamic vegetation (i.e., the distribution of plant functional types changes in response to climate), a spin-up run had to be conducted in order to achieve a stable vegetation distribution before imposing the deforestation patterns planned. This spin-up took 100 model years and resulted in a reduction of ~9% of forest cover in the Amazon, especially caused by a strong negative bias in precipitation in the northeast of the Amazon in MPI-ESM (already reported in the model documentation). The experiments are partially finished and the initial results are being put together in a study that aims to investigate the response of different hydroclimatic indicators to different levels and patterns of deforestation. The next steps of this work package in the ClimTip project involve a long-term hosing experiment with MPI-ESM-HR, to add to the hosing experiments performed in the scope of ClimTip by other research groups (data which is also publicly available at https://zenodo.org/records/16784935).

References

Geoffroy, O., Saint-Martin, D., Olivié, D. J., Voldoire, A., Bellon, G., & Tytéca, S. (2013). Transient climate response in a two-layer energy-balance model. Part I: Analytical solution and parameter calibration using CMIP5 AOGCM