Project: **1404**
Project title: **Model-informed assessment of the risk of Amazon rainforest dieback**
Principal investigator: **Julia Pongratz**
Report period: **2023-11-01 to 2024-10-31**

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.

ClimTip started in March 2024 and the relevant work package (WP8) started in April 2024. Three 100-year high resolution (MPI-ESM-HR) simulations were projected for the first semester of the project: (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. Simulation (1) is similar to the piControl simulations from CMIP6, however, within the ClimTip framework this data will also be used to force regional climate models and moisture recycling models. Therefore, we need to provide to colleagues a list of output variables in 6-hour intervals, and not all of these variables were available from the CMIP6 output. For this reason, a piControl simulation is necessary. In simulation (2), we run 100 years with stable global temperatures 2 degrees warmer than piControl, and this is similar to simulation (3) where the same global temperature scenario is used, but the tree cover in the Amazon rainforest is replaced with grass. 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).

The exchange with project partners to prepare and test the simulations and the outputs in the regional climate models required some complex coordination between different groups, and this delayed the start of the three long-term simulations mentioned, which only started in September. As a consequence, the next steps of the research were also delayed for a few months, and this resulted in an underutilization of the computing resources. With the start of the experiments, this scenario changed to the fourth quarter of 2024. Without other complex organizational aspects expected in the near future, an underutilization of the resources is projected to also not be a concern for the next allocation period.

Whenever possible, tests were performed using low resolution (MPI-ESM-LR), aiming to optimize the resource utilization. This is going to become a much more important aspect in the next allocation period. An example can be seen in figure 1, showing global mean surface temperatures from simulation (1) [in this case, the CMIP6 LR output] and (2) from MPI-ESM-LR. After all necessary tests and preparation, simulations (1) and (2) were started and have finished. Simulation (3) is in process of implementation. Future tasks of this project involve the simulation of more realistic deforestation scenarios, aiming to investigate the non-linearity of the forest response and feedbacks, and the imposing of North Atlantic hosing in addition to deforestation of the Amazon rainforest.

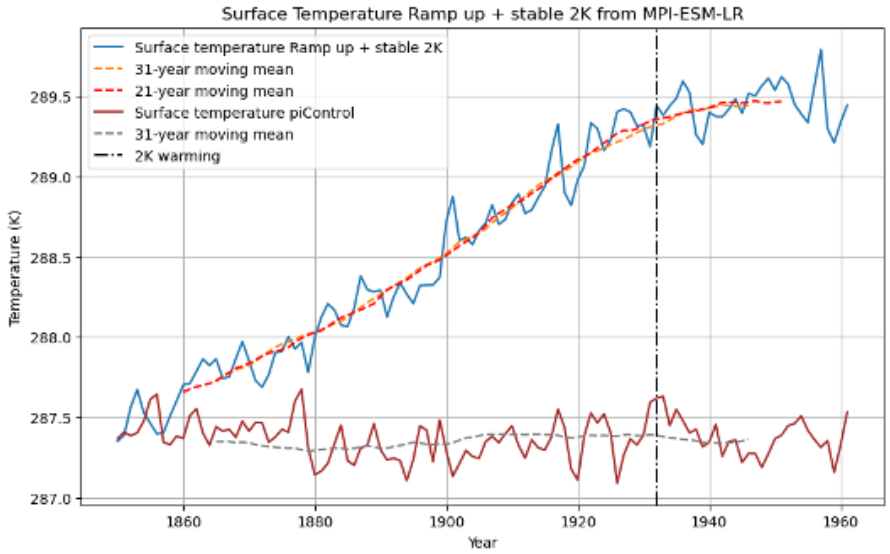

Figure 1 – Global mean temperatures for test simulations of piControl (in this case CMIP6 outputs) and ramp up + stable temperature at 2K warming (CMPI6 1pctCO2 output + concentration driven run) using MPI-ESM-LR.

In addition to the above mentioned tasks from the ClimTip protocols, we successfully completed the study on attributing Amazon forest loss to land-use change and climate change using CMIP6 Earth System Models. The study is now under review at Proceedings of the National Academy of Sciences (PNAS). Building upon our gained expertise on the impact of natural and anthropogenic drivers on forests from the CMIP6 study, we started examining how different types of prior human disturbances (e.g., deforestation, degradation) influence forest resilience and mortality during extreme events such as droughts and wildfires. Our aim is to understand how current land management practices may shape forest vulnerability to large-scale dieback and tipping points in the future. We started processing the data for this study, which we will feed into different machine learning algorithms in a next step.

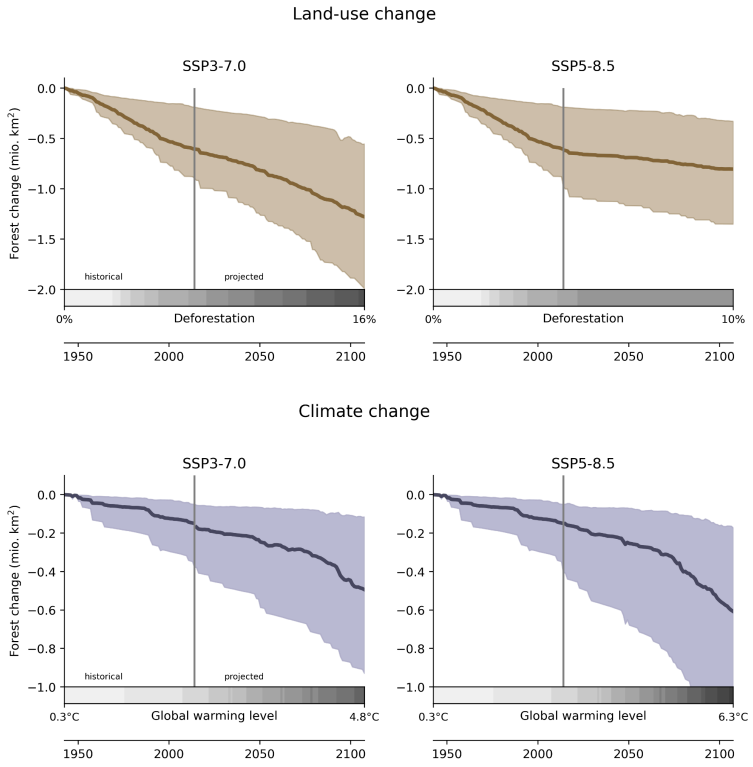

Figure 2: Regional forest decline per driver for 1950-2100. Annual forest decline across the Amazon basin is shown for the two drivers, land-use change and climate change, and two pathways (SSP3-7.0 and SSP5-8.5). Forest decline is shown in relation to the deforested area (fraction of the 1950 forest area) from the LUH2 land-use forcing and the global warming level relative to 1850 (model average), respectively. The solid lines represent the model average and
the shaded area represents the model range

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