Project title: **Potentials and vulnerabilities of future terrestrial carbon sinks under different pathways**

Principal investigator: **Julia Pongratz**

Abstract: Natural climate solutions (e.g. forest restoration) have become a strong focus of recent scientific discourse, as they offer large potentials for Carbon Dioxide Removal and can therefore make a major contribution towards reaching net-zero emissions until 2050 under the Paris agreement. However, there is still a large disagreement on how much carbon can be sequestered in the future by the natural sinks on land, which strongly depend on the future greenhouse gas concentration pathway and the impact of climate change on the vulnerability of terrestrial ecosystems. The project "High-resolution monitoring of avoided carbon emissions and carbon restoration potentials from land use change", funded by the Stifterverband/Volkswagen AG, aims at quantifying the variability of sub-component carbon fluxes (e.g. forest degradation) and their drivers (anthropogenic vs. natural). In the first phase of the project we have assimilated observations of vegetation biomass in a modeling framework to use this data-model framework to separate the observed carbon stock changes into the two terrestrial terms of the anthropogenic carbon budget (Friedlingstein et al., 2020), namely net land-use change emissions and the natural terrestrial sink. We have found that in particular the natural sink term is highly variable, more so than studies with dynamic global vegetation models have previously suggested (Bultan et al., in prep). In the study by Loughran et al. (2021), we have investigated the role of internal climate variability (as represented by the MPI-ESM large ensemble) for the two terrestrial budget terms, finding large variability in the natural sink term in response to internal variability. This high variability sheds doubt on the reliability of the terrestrial carbon sinks in the future, be they natural or induced by land-use changes such as afforestation for Carbon Dioxide Removal. In a next step, we therefore want to analyze the role of internal variability for the terrestrial carbon budget terms under future climate change scenarios. Building upon the model setup in Loughran et al. (2021), we will force the Land Surface Model JSBACH3 (Reick et al., 2021) with climate data from the MPI-ESM-Grand Ensemble (GE) (Maher et al., 2019). We will adjust the setup used in Loughran et al. (2021) to a higher temporal resolution and the inclusion of further emissions scenarios to analyze a) how future carbon sink potentials differ depending on the greenhouse gas scenario, b) which regions will be especially vulnerable in the future due to climate change induced disturbances (e.g. droughts) and the occurrence of extreme events, and which regions will provide large potentials for natural climate solutions. The use of sub-daily climate forcing and daily output for JSBACH3 ensures a large amount of simulated time steps, which is especially valuable for the analysis of extreme events.

References

Friedlingstein, P., O'Sullivan, M., Jones, M. W., Andrew, R. M., Hauck, J., Olsen, A., Peters, G. P., Peters, W., Pongratz, J., Sitch, S., Le Quéré, C., Canadell, J. G., Ciais, P., Jackson, R. B., Alin, S., Aragão, L. E. O. C., Arneth, A., Arora, V., Bates, N. R., Becker, M., Benoit-Cattin, A., Bittig, H. C., Bopp, L., Bultan, S., Chandra, N., Chevallier, F., Chini, L. P., Evans, W., Florentie, L., Forster, P. M., Gasser, T., Gehlen, M., Gilfillan, D., Gkritzalis, T., Gregor, L., Gruber, N., Harris, I., Hartung, K., Haverd, V., Houghton, R. A., Ilyina, T., Jain, A. K., Joetzjer, E., Kadono, K., Kato, E., Kitidis, V., Korsbakken, J. I., Landschützer, P., Lefèvre, N., Lenton, A., Lienert, S., Liu, Z., Lombardozzi, D., Marland, G., Metzl, N., Munro, D. R., Nabel, J. E. M. S., Nakaoka, S.-I., Niwa, Y., O'Brien, K., Ono, T., Palmer, P. I., Pierrot, D., Poulter, B., Resplandy, L., Robertson, E., Rödenbeck, C., Schwinger, J., Séférian, R., Skjelvan, I., Smith, A. J. P., Sutton, A. J., Tanhua, T., Tans, P. P., Tian, H., Tilbrook, B., van der Werf, G., Vuichard, N., Walker, A. P., Wanninkhof, R., Watson, A. J., Willis, D., Wiltshire, A. J., Yuan, W., Yue, X., & Zaehle, S. (2020). Global Carbon Budget 2020. *Earth System Science Data*, *12*(4), 3269-3340. https://doi.org/10.5194/essd-12-3269-2020

Loughran, T. F., Boysen, L. R., Bastos, A., Hartung, K., Havermann, F., Li, H., Nabel, J. E. M. S., Obermeier, W. A., & Pongratz, J. https://doi.org/10.1002/essoar.10506639.1

Maher, N., Milinski, S., Suarez-Gutierrez, L., Botzet, M., Dobrynin, M., Kornblueh, L., Kröger, J., Takano, Y., Ghosh, R., Hedemann, C., Li, C., Li, H., Manzini, E., Notz, D., Putrasahan, D., Boysen, L., Claussen, M., Ilyina, T., Olonscheck, D., Raddatz, T., Stevens, B., & Marotzke, J. (2019). The Max Planck Institute Grand Ensemble: Enabling the Exploration of Climate System Variability. *Journal of Advances in Modeling Earth Systems*, *11*(7), 2050-2069. https://doi.org/10.1029/2019ms001639

Reick, C. H., Gayler, V., Goll, D., Hagemann, S., Heidkamp, M., Nabel, J. E. M. S., Raddatz, T., Roeckner, E., Schnur, R., & Wilkenskjeld, S. (2021). JSBACH 3 - The land component of the MPI Earth System Model: documentation of version 3.2. *Berichte zur Erdsystemforschung*, *240*. https://doi.org/10.17617/2.3279802