Project: **891**
Project title: **Forest management in the Earth system**
Principal investigator: **Julia Pongratz**
Report period: **2023-11-01 to 2024-10-31**

	Allocated for 2024	Consumed (22. Oct 2024)	Projection of consumption by end of 2024
Computing time [node hours]	15 405	3 052	15364
Levante storage [TiB]	64	44	64
Archive project [TiB]	2	1	1
Long term archive [TiB]	2	0	0

The scientific work under bm0891 during the reporting period focused on a more profound understanding and better quantification of land-related carbon fluxes, applying and developing process-based (JSBACH) and bookkeeping models (BLUE), and assessing Earth system consequences. Due to delays from project partners in the RESCUE project, the most computational expensive simulations planned for this year within bm0891 had to be postponed but are anticipated to be taken up in November/December 2024 as outlined below.

BLUE In 2024, we developed BLUE further, such that it can now quantify all terms of the terrestrial carbon budget in a consistent way. Specifically, BLUE now considers environmental effects on land-use emissions (ELUC) and the impact of land-use changes on the natural land sink (SLAND). The results show that state-of-the-art process-based models overestimate SLAND by 23% and that ELUC increases by 14% when considering environmental effects (Dorgeist et al., 2024). We also refined our analysis of the terrestrial carbon deficit and spatially explicit carbon densities, incorporating additional data and recalculating estimates based on reviewer feedback (Ganzenmüller et al., in review). Our work now integrates high-resolution carbon stock data and state-of-the-art datasets across climate, soil, and land cover, allowing us to more accurately estimate carbon pools in vegetation and soils. Moreover, we developed new methodologies to enhance the Plant Functional Types (PFTs) in BLUE, which will improve the precision of land-use emissions estimates by accounting for PFT variability and providing uncertainty ranges. We additionally performed simulations with BLUE to quantify Carbon Dioxide Removal (CDR) via re- and afforestation for the 2nd State of CDR Report (Smith et al., 2024, Pongratz et al., 2024) and to quantify land-use change emissions for the Global Carbon Budget 2024 (GCB2024; Friedlingstein et al., in preparation). Further, BLUE data were used in the studies of Obermeier et al. (2024) and Rosan et al. (2024).

TRENDY For participation in GCB2024, simulations with JSBACH3.2 were conducted following the TRENDY protocol. The TRENDY version of JSBACH3.2 (extended by PFT-level output), was updated with changes from the latest version of the main JSBACH3.2 branch. Updated data for land use and wood harvest from LUH2-GCB2024, population density, climate (CRUJRAv2.5) and CO2 was transferred to Levante and remapped to T63 resolution. As in previous years, the climate forcing will be made available to all DKRZ users in /pool by the end of the year. Due to a technical bug in last year's (TRENDYv12) spin-up data, the spin-up was started from the TRENDYv11 equilibrium state. The specified target accuracy of the equilibrium state was reached after 5000 years of model spin-up. Four experiments (4x223 years) were conducted branching off the spin-up. Bugs in the CMOR post-processing of PFT-level output were fixed. Jupyter-hub was used to monitor and visualise the progress of the model integrations and results (Fig. 1). Aside of the inclusion into GCB2024, our results with JSBACH3.2 will be made available to the wider scientific community as part of TRENDYv13 and are also included into the most recent inter-comparison and benchmarking of land surface models at a global and regional scale (ILAMB). In preparation for cycle v14, along the established version control (gitlab repositories at DKRZ) the existing documentation and task list (to adhere to FAIR principles) were updated.

RESCUE In 2024, resource utilisation was lower than expected in the first three quarters due to delays in receiving scenario inputs for Earth System Model (ESM) simulations. The delays were due to updates to the REMIND-MAgPIE model and an iterative exchange between the integrated assessment model (IAM) and Earth System Model (ESM) teams, aimed at better translating IAM outputs into ESM inputs and creating more realistic scenario inputs. As one of the ESM teams in RESCUE, we continuously assessed the gridded scenario inputs and provided feedback throughout the process. A key outcome was the addition of new gridded and non-gridded variables, providing more detailed information on bioenergy crops and other CO2 removal processes, which is crucial for accurately representing carbon removal within the broader carbon cycle and preparing inputs for emission-driven experiments in the 7th Coupled

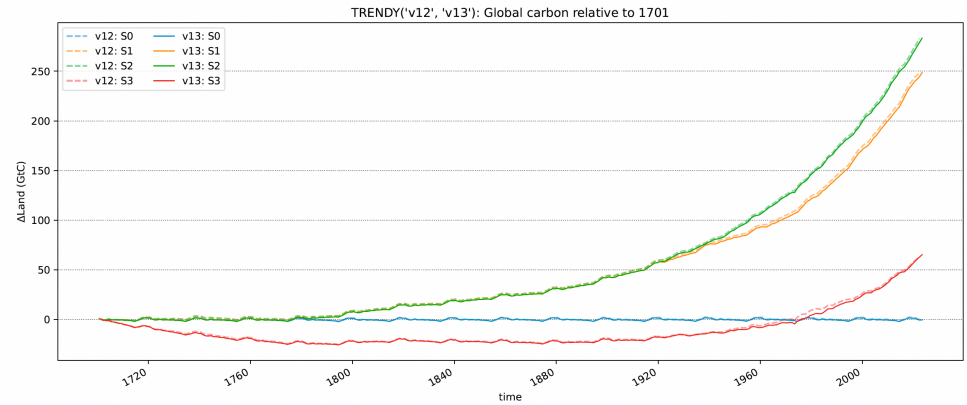

Fig. 1: Time series of land carbon relative to 1701 of TRENDY experiments S0-3 for this year's cycle v13 (GCB2024) compared to last year's v12 (GCB2023).

Model Intercomparison Project (CMIP7). A collaborative paper by Gidden et al. (in preparation) based on the outcomes of these iterative exchange is currently underway, highlighting the challenges in aligning assumptions between IAMs and ESMs. The RESCUE consortium has now agreed to start fully coupled simulations of selected Tier 1 scenarios by November 2024, comprising four emission-driven experiments of the CDR scenarios with four ensemble members each. The estimated computing time for these simulations is 12312 node hours (= 4*4*285 model years*2.7 node hours per model year) and simulation output will use 25.52 TiB Levante storage space (which requires us to free up some disk space beforehand). Thus, we hope to use most of the allocated computation resources for the whole year until the end of the allocation period, in which case we will exceed the quarterly allocated limit for the last quarter of 2024.

In addition to the quality checks of the scenario data for the requirements of MPI-ESM, DKRZ resources were primarily spent in preparation of preprocessing scripts to prepare model inputs and model readiness in order to adapt implementations of both ocean and land-based CDR methods in a single model version. Most of the utilized node hours reflect test simulations related to technical implementations of herbaceous biomass plantations in MPI-ESM/JSBACH 3.2 (Egerer et al., in review) in coupled mode.

ForestNavigator Our role in the ForestNavigator project is to project climate impacts of varying intensities and types of forest management, including both biophysical effects and the ensuing carbon dynamics. Currently the harvesting process that is required to achieve this, is still missing from ICON-Land/JSBACH4. The work in the past year has mainly been focused around implementing the harvesting process within the ICON-Land framework. Further development, more extensive testing, and ultimately the application of the process, are planned for the year 2025, and will then be published in a scientific paper.

Publications

Dorgeist, L., **Schwingshackl**, C., **Bultan**, S. et al., 2024: A consistent budgeting of terrestrial carbon fluxes. Nat Commun 15, 7426. https://doi.org/10.1038/s41467-024-51126-x.

Egerer, S., **Falk**, S., Mayer, D., **Nützel**, T., **Obermeier**, W., and **Pongratz**, J.: How to measure the efficiency of terrestrial carbon dioxide removal methods, EGUsphere [preprint], https://doi.org/10.5194/egusphere-2024-1451, in review.

Friedlingstein, P., et al. (incl. **Pongratz**, J., **Schwingshackl**, C., **Nützel**, T.): Global Carbon Budget 2024, in preparation for Earth System Science Data.

Ganzenmüller, R, **Obermeier**, W. A., **Bultan** S., Spawn-Lee, S. A., Zabel, F., **Pongratz**, J.: Humans have depleted global terrestrial carbon stocks by a quarter, One Earth, in review.

Gidden, M. J. et al. (incl. **Gupta**, S., **Pongratz**, J.): Forcing datasets for earth system models of emissions-driven temperature stabilization and overshoot scenarios including multiple carbon dioxide removal methods, in preparation.

Obermeier, W. A., **Schwingshackl**, C., Bastos, A., Conchedda, G., Gasser, T., Grassi, G., Houghton, R. A., Tubiello, F. N., Sitch, S., and **Pongratz**, J (2024).: Country-level estimates of gross and net carbon fluxes from land use, land-use change and forestry, Earth Syst. Sci. Data, 16, 605–645, https://doi.org/10.5194/essd-16-605-2024.

Pongratz, J., Smith, S. M., **Schwingshackl**, C., Dayathilake, L., Gasser, T., Grassi, G., Pilli, R., 2024: Chapter 7: Current levels of CDR. in The State of Carbon Dioxide Removal 2024 – 2nd Edition (eds. Smith, S. M. et al.). https://www.stateofcdr.org, doi:10.17605/OSF.IOZXSKB.

Rosan, T.M., et al. (incl. **Pongratz**, J., **Schwingshackl**, C., **Falk**, S.), 2024: Synthesis of the land carbon fluxes of the Amazon region between 2010 and 2020. Commun Earth Environ 5, 46. https://doi.org/10.1038/s43247-024-01205-0.

Smith, S. M., Geden, O., Gidden, M. J., Lamb, W. F., Nemet, G. F., Minx, J. C., Buck, H., Burke, J., Cox, E., Edwards, M. R., Fuss, S., Johnstone, I., Müller-Hansen, F., **Pongratz**, J., Probst, B. S., Roe, S., Schenuit, F., Schulte, I., Vaughan, N. E. (eds.), 2024: The State of Carbon Dioxide Removal 2024 - 2nd Edition. DOI 10.17605/OSF.IO/F85QJ.