Project 1513

Project title **Ecosystem disturbances in the Earth System**

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Report period 2025-05-01 to 2026-06-30

1 Background

In this project we use the ICON-Land model with QUINCY configuration and JSBACH soil physics (IQJ), which represents ecosystem biophysical and biogeochemical processes, and has been recently implemented in ICON to use the soil physics modules of the JSBACH LSM. Nevertheless, IQJ does not currently include a representation of wildfires nor insect outbreaks, thus the model does not represent important disturbances affecting global forests. In the reporting period, we aimed to implement parameterizations for fire spread and impacts and insect disturbance impacts in the IQJ model. Furthermore, we aimed to assess the sensitivity of the simulated vegetation and soil moisture to alternative formulations of soil hydrological parameters in order to improve representation of drought impacts.

2 Progress of the work: a summary and contributions of the collaboration

For the reporting period, we planned for three tasks:

T1 Implementation and evaluation of new parameterizations for fire and insect disturbances in IQJ.
T2 Quantify impact of ecosystem disturbances on carbon, water and energy fluxes in offline simulations with IQJ.
T3 Evaluation of sensitivity in vegetation responses to drought to soil hydrology parameterizations.

Below, we report the results from Tasks T1 and T2 separately for fire (T1.1, T2.1) and insects (T1.2 and T2.2), followed by T3.

Tasks 1.1 and 2.1 (Fire impacts)

Task 1.1 In the reporting period, the original formulation of SPITFIRE [1] has been successfully implemented in IQJ and tested for the C nutrient mode in three selected regions: the Amazon forest (topical humid), Southern Africa (semi-arid) and western Iberian Peninsula (Mediterranean and temperate). We further tested the model for the CN nutrient mode, which has been implemented in the main branch of IQJ. The implementation for CNP nutrient mode has not been completed since the IQJ CNP scheme is still in evaluation by MPI-BGC colleagues.

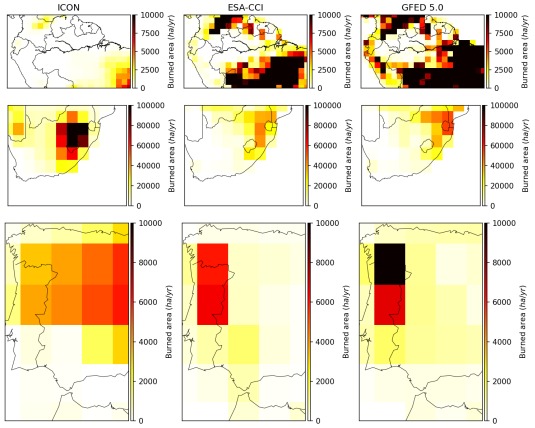

Figure 1: Simulated mean annual burned area (km^2, C nutrient mode) in the three selected regions, compared to satellite-based datasets.

Task 2.1 To evaluate the physical realism of the IQJ SPITFIRE implementation, we ran historical offline simulations (1850–2020) for the C and CN nutrient modes, including a 500 years spinup for these regions, and compared the resulting burned area with available satellite data from ESA Fire CCI [2] and the recently published GFED5 [3], as shown in Fig. 1. We planned to run the model with ERA5 forcing, but ERA5 was not a standard forcing of ICON, so that for the preliminary historical simulations we have used GWSP3 forcing (see Task 3). The model performs according to the expected dynamics of SPITFIRE as

reported in other models, including its shortcomings. These include too high burned area for grassland-dominated regions and a strong underestimation of burned area over forests. Therefore, we have launched global simulations for C and CN nutrient modes (control + fire), which have been completed shortly before the submission of this report, and thus not yet evaluated. Given delays in the implementation and evaluation of the new module, analysis of resulting carbon, water and energy fluxes was not completed.

Tasks 1.2 and 2.2 (Insect disturbance impacts)

In this reporting period, we aimed to implement a new insect disturbance impacts scheme that has been developed for QUINCY Standalone (QS) (Task 1.2) and then use it for historical simulations to analyse impacts on carbon, water and energy exchanges (T2.2). During the reporting period, the description of the insect disturbance impacts scheme been submitted to *JAMES*. However, the preparation of this manuscript and consolidation of a final version of this scheme took longer than anticipated, so that only in February 2026 did we start implementing the module in IQJ. The implementation of the insect disturbance impacts scheme in IQJ further requires considerable changes compared to the QS version, especially in the way disturbance is prescribed. Therefore, we have also worked on preparing disturbance maps to be read-in by IQJ. This set back explains the incomplete use of resources in this reporting period and we therefore request resources to complete the insect disturbance impacts module during the next allocation period.

Task 3 - Sensitivity of vegetation responses during drought to soil parameterizations

Simulations for assessing the sensitivity of the ICON-JSBACH LSM to soil hydraulic parameters were successfully completed during the past allocation period. The model was forced with ERA5 climate forcing and increasing CO_2 from 1970-2024. Since ERA5 forcing was not among the standard forcings available in the ICON repository, we have produced scripts to prepare ERA5 forcing for ICON-Land (merge request !386). We then ran perturbed soil hydrology parameter simulations, in which we considered parameters for soil hydraulic conductivity, soil field capacity, and wilting point derived from alternative pedotransfer functions, in comparison with the standard configuration of the model. The simulated hydrology of the model was very sensitive to uncertainty in the parameters considered, with some parameterizations resulting in non-physical results. The simulated vegetation variables, such as gross primary productivity and leaf area index, also presented changes in the global trajectory that corresponded to the changes in soil moisture under different parameterizations, but relative responses to extreme events did not differ markedly between simulations, which was unexpected. A potential explanation is the fact that key biophysical and biogeochemical processes in JSBACH are not explicitly dependent on water stress. Therefore, for the new phase we have requested resources to perform the analysis of selected drought events with the IQJ model.

3 Acknowledgements

The project team highlights the importance of DKRZ in supporting the project with its resources. Without the access to the Levante HPC, the allocated resources of computation and storage, and without the highly efficient implementation of the IQS framework, this project could not achieve its goals. All members of the project team are commited to use the allocated resources responsibly.

References

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2. Chuvieco, E. *et al.* A new global burned area product for climate assessment of fire impacts. *Global Ecology and Biogeography* **25,** 619–629 (2016).
3. Van der Werf, G. R. *et al.* Landscape fire emissions from the 5th version of the Global Fire Emissions Database (GFED5). *Scientific Data* **12,** 1870 (2025).