

Project: 1445

Project title: **Breathing Nature – Connecting biodiversity, climate, and human behavior**

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Submitted DFG Cluster of Excellence

Reporting period: **2025-05-01 to 2026-04-30**

Summary of project goals of Breathing Nature (BN):

The **Breathing Nature project** seeks to establish a comprehensive understanding of the interconnected dynamics between climate change, biodiversity, and human behavior. The research program focuses on three main areas:

Connectivity: Investigating mechanisms that link biodiversity, climate, and human activity.

Agency and Responsibility: Examining human influence on climate and biodiversity.

Alternative Futures: Modeling sustainable future scenarios integrating climate, biodiversity, and human factors. The sub-project **Agency and Responsibility** currently requires climate modeling with CESM2 to conduct attribution studies across these domains. Using both factual and counterfactual simulations, Breathing Nature/Agency and Responsibility aims to assess human impacts on climate and ecosystems (incl. biodiversity) across various subprojects, leveraging DKRZ resources to simulate climate attribution scenarios to causal drivers.

Resource use in the past reporting period:

Since May 2025, Breathing Nature has utilized computational resources primarily to perform further experiments within the importance sampling and nudged circulation storylines frameworks.

Total Resource Use: Approximately 30071node hours and 78 TB of storage utilized as of 2026-04-30. We used all the granted resources, and we would therefore like to apply for new allocation of resources.

We describe the state of the simulations in more detail below (some of these simulations are carried out in synergy with our contribution to the climXtreme II / PATTETA project):

Circulation nudging experiments in CESM2

Within the reporting period, we continued to perform several large-scale CESM2 simulations as part of our storyline attribution framework. Our research focused on updating and extending previous simulations:

1. Producing historical and natural forcing simulations for the period 1970 to 2025 to support a detailed understanding of precipitation-related processes. These simulations include daily output of precipitation, as well as relevant precursors for precipitation.
2. Testing the CESM2 nudged circulation setup in a fully coupled mode with an interactive ocean: we ran CESM2 simulations with constant CO₂ forcing while nudging horizontal winds to ERA5. Initially we aimed to run the simulation until the global climate reaches its equilibrium, however, this was not possible, and we ended the simulations after 80 years.
3. Initial experiments to set up a nudged circulation simulation with ICON-XPP.
4. We noticed an inconsistency in our generation of counterfactual ocean forcing data, and reproduced the “NAT” and “high CO₂” simulations.

The results of the nudged circulation storyline experiments continue to be used by several external partners from the UFZ, ETHZ and at Leipzig University. We use the simulations from the nudged circulation simulations in three parallel projects for the attribution of fire risk. One study is led by

Istvan Dunkl on the role of circulation-induced changes on wildfire risk in the Iberian Peninsula (EGU presentation Dunkl et al, 2026), the other two studies are on the global trend in burned area (EGU presentation Eifler et al, 2026), and the drivers of changing wildfire risk in Europe. Our partners at the UFZ Leipzig are using the nudged circulation experiments for the attribution of hydrological extremes, such as an in attribution study on the amplification of floods caused by storm Boris (Miersch et al., nd), intensification of whiplash events (Merz et al., nd).

The simulations were also used as a benchmark case of statistical and machine learning methods to separate dynamical from thermodynamical temperature trends (Pfleiderer et al., 2025).

Further, we initialized a nudged circulation intercomparison project, based on our simulations together with simulations from AWI, HEREON, and ECMWF, with the aim to establish a common framework for model assessment.

CESM2 importance sampling experiments

We continued the work on importance sampling experiments using a rare event algorithm (Ragone and Bouchet, 2021, *Geophysical Research Letters*, doi:10.1029/2020GL091197).

- Part of this work is our setup to simulate potential worst-case years for the European ecosystem carbon balance. This is a highly policy-relevant topic, as the European natural carbon sink is used for carbon accounting, and European natural carbon sinks have declined in recent years. We sampled worst-case MAM and JJA carbon uptake over Europe, and compare these to the samples in the CESM2-Large ensemble. Our results show that the climate-carbon dynamics over Europe follow diverse pathways, with regions of positive, and negative feedbacks between spring and summer carbon uptake.
- The second set of importance sampling experiments analyze the role of initial soil moisture conditions before hot summers in western Europe. These simulations provide a better understanding on the mediation of heatwaves by land-atmosphere coupling, but are also used to validate importance sampling with pre-selection of initial states against large ensemble simulations.
- In a third set of simulations, we analyze the role of extremely low North Atlantic Eddy Kinetic Energy (EKE) on summer seasons.

Miersch, P., Dunkl, I., Sánchez-Benítez, A., Athanase, M., Rakovec, O., Klotz, D., Sippel, S., Goessling, H., Zscheischler, J., Climate change amplifies floods more than extreme precipitation: evidence from 2024 Storm Boris, *Science Advances* under review, nd.

Merz, N., Zscheischler, J., Dunkl, I., Sippel, S., Sánchez-Benítez, A., Goessling, H., John, A., Feser, F., Bevacqua, E., Disentangling the anthropogenic influence on recent hydroclimate whiplash events via multiple nudged climate simulations, in preparation for npj Climate and Atmospheric Science

Pfleiderer, P., Merrifield, A., Dunkl, I., Durand, H., Cariou, E., Cattiaux, J., and Sippel, S.: The contribution of circulation changes to summer temperature trends in the northern hemisphere mid-latitudes: A multi-method quantification, *EGUsphere*, 1–28, <https://doi.org/10.5194/egusphere-2025-2397>, 2025.

Eifler, L., Dunkl, I., Sippel, S., and Bastos, A.: From Observation to Attribution: Evaluating Nudged-Circulation CESM2 Burnt Area Simulations, EGU General Assembly 2026, Vienna, Austria, 3–8 May 2026, EGU26-11842, <https://doi.org/10.5194/egusphere-egu26-11842>, 2026.

Dunkl, I., Mindlin, J., Turco, M., and Sippel, S.: Process-Based Attribution of the 2025 Iberian Wildfire Season Using a Storyline Framework, EGU General Assembly 2026, Vienna, Austria, 3–8 May 2026, EGU26-20208, <https://doi.org/10.5194/egusphere-egu26-20208>, 2026.