Project: 1471

Project title: Scale interaction in Land-Atmosphere feedback - Land-Atmosphere Feedback Initiative (LAFI)

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Overview

The scientific objective of this project is to improve our understanding of how processes linked to land-atmosphere interactions are represented in ESMs, and how these interactions depend on model resolution. As part of the DFG-funded project 'Land Atmosphere Feedback Initiative', it contributes to a joint effort to understand and quantify land-atmosphere feedbacks using synergistic observations and simulations. For the year 2026, our target was to: (a) conduct hectometer-scale simulations over the LAFI observation sites (b) assess the importance of input parameters and initial conditions for model performance, and (c) validate the model with observations from the LAFI project. We achieved the first objective and made progress on the second. We are currently collecting observational data from the different subprojects and expect to complete the model evaluation by the end of 2026. The coupling of ICON with JSBACH at hectometer-scale resolution, which was originally planned for 2026, has been postponed to 2027. We decided to prioritize our first scientific study to ensure that results can be published within a favourable timeframe of the PhD project and contribute to the planning of LAFI Phase 2. With a working model setup available, we were able to carry out the planned simulations and make effective use of the computing resources allocated for 2026. These simulations also allowed us to verify our estimates of the node-hours required per simulation day, providing a more reliable basis for estimating computing resource requirements in the proposal.

Large-Eddy Simulations

We conducted large-eddy simulations (LES) over the LAFO site using a nested model configuration, starting at a horizontal grid spacing of 1.25 km and progressively refining the resolution to approximately 75 m. We then performed a preliminary analysis to assess model performance at these scales and investigate how different land-cover types affect surface fluxes and vertical profiles of turbulent quantities. To assess the results under different environmental conditions, we also conducted simulations over the DWD Observatory in Lindenberg, which differs from LAFO in terms of topography, vegetation types, artificially built surfaces and water bodies, and prevailing wind conditions. The simulations focused on selected days with favourable meteorological conditions and available observational data from the LAFI project.

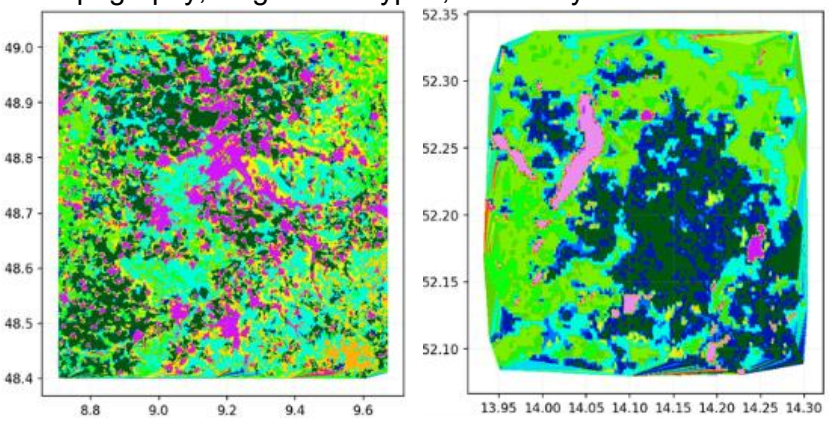


Figure 1: Land use maps for the two sites: LAFO (left) and Lindenberg (right) from EXTPAR data for the finest (75 m) domain.

Importance of input data

Analysis of the simulation output showed that the choice of input data and the availability of high-resolution external parameters are important factors determining model performance. We initially used IFS forecasts (ECMWF) to drive the limited-area model (LAM) simulations, as required by LAFI. However, we found that the large resolution difference between the driving IFS data (~10 km) and the coarsest simulation grid (1.25 km), together with differences in the representation of land-surface and soil processes, introduced substantial artefacts when the simulations were initialized without sufficient spin-up. These artefacts were particularly pronounced in the initial soil moisture fields and subsequently affected the evolution of the simulations. Figure 2 illustrates the spatial differences in the initial soil moisture conditions from the IFS forcing data (left) and the resulting distribution of

surface sensible heat flux at 11:00 on the simulated day over Hohenheim (right), highlighting the influence of soil moisture initialization on the simulated surface energy exchange.

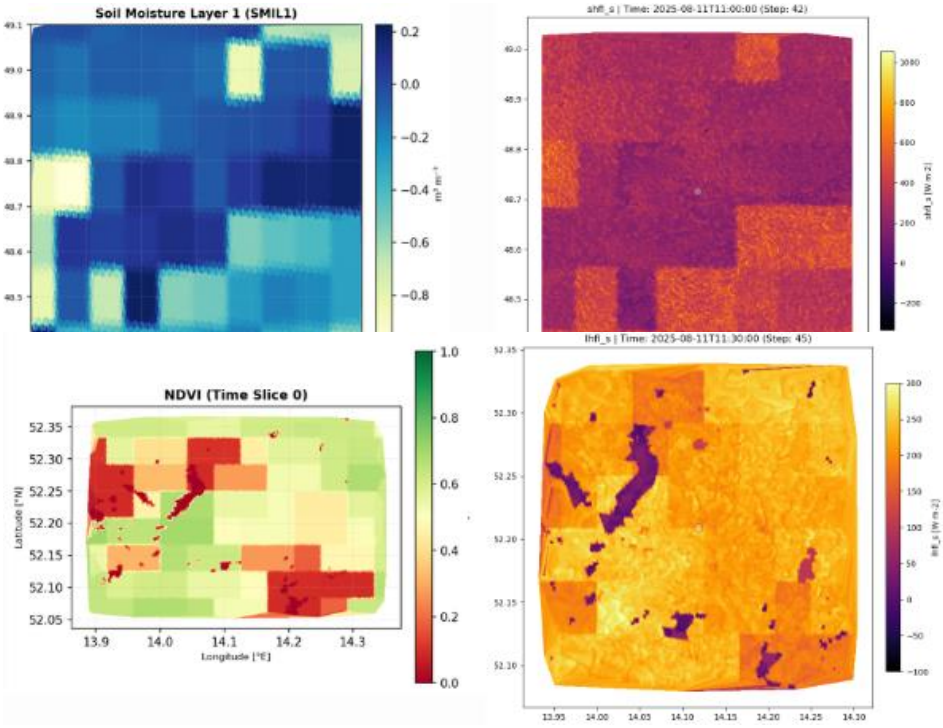


Figure 2: (left) Soil moisture index at the surface taken from IFS forcing data and (right) Spatial map of surface sensible heat flux for the same region at 11:00 am on the simulated day over Hohenheim.

Based on these results, we switched to ICON-D2 analysis data to drive the simulations. ICON-D2 belongs to the same model family, uses a consistent land-surface representation, and provides finer spatial resolution (~2 km) and soil moisture fields constrained by observations through data assimilation. We therefore repeated the simulations using the new driving data. However, we found that the NDVI data available through EXTPAR are based on SeaWiFS observations with a spatial resolution of approximately 3-4 km, which is still too coarse for our hectometer-scale simulations. The limited spatial detail in the NDVI input data is reflected in the simulated patterns of surface latent heat flux (Fig. 3).

Figure 3: (left) NDVI data from EXTPAR used for simulation and (right) spatial map of surface latent heat flux for the same region surrounding Lindenberg (time frame at 11:30 UTC is given as an example).

We are therefore currently updating the EXTPAR data using high-resolution remote-sensing products provided by collaborators within the LAFI project. We plan to assess whether these improved input datasets lead to better model performance by comparing the simulation results with observations.

Model evaluation

Having conducted a series of simulations over different regions and using different forcing and input datasets, we are now collecting observational data (scintillometer, lidar, eddy-covariance tower measurements, evapotranspiration partitioning, etc.) from collaborators within LAFI. We plan to complete the evaluation of the different model configurations by the end of the year. This will allow us to quantitatively assess which configurations best reproduce the observations and are therefore suitable for the sensitivity analyses planned for next year, as well as identify input datasets that require further improvement.