DKRZ resources request 2027 for project: ILModelS - 2026 report

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Project title:
Impact of Land Model depth on climate and climate change scenario Simulations (ILModelS).
The new project is called *Effects of Improving Land Physics in Earth System Model Simulations of the Common Era and Climate Change Scenarios (ELEModelS)*

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1. Background

The ILModelS (project n. 1026) consortium is an international initiative with cooperation partners from the Max Planck Institute for Meteorology (MPI-M, Germany), the Instituto de Geociencias, IGEO (CSIC-UCM; Spain), the CIEMAT (Spain), and the Helmholtz-Zentrum Hereon (Germany), with active funding by the Spanish Ministry of Science since 2015 (ILModelS in 2015-2018, GReatModelS in 2019-2022, and SMILEME in 2023-2026). Lastly, the group has been granted a new project in the latest call of 2025, ELEModelS (Effects of Improving Land Physics in Earth System Model Simulations of the Common Era and Climate Change Scenarios; REF: PID2025-174030OB-I00; 2026-2029), which guarantees the continuity of the ILModelS collaboration in the coming years.

In the ILModelS consortium we tested the effects of improving the subsurface representation of the thermodynamics of the MPI-ESM (Mauritsen et al., 2019) Land Surface Model (LSM), JSBACH (Reick et al., 2021). The motivation was that most of the state-of the-art LSMs within ESMs incorporate a shallow zero-heat-flux Bottom Boundary Condition Placement (BBCP) and a poor vertical layer discretization when resolving underground thermal transfer. Results derived within ILModelS have proved that an insufficient BBCP depth constrains the land heat uptake because of global warming (García-Pereira et al., 2024a), biasing the terrestrial energy partition (Steinert et al., 2024), and the representation of the permafrost active layer and extent (García-Pereira et al., 2025). To realistically represent the subsurface temperature variability and global warming trends, the BBCP depth must be detached from the ground surface (González-Rouco et al., 2021; Steinert et al., 2021a). In the frame of ILModelS, we have also assessed the relevance of incorporating a more realistic representation of the soil hydrology in JSBACH, both in standalone and fully-coupled simulations. The impacts are especially relevant in the Arctic, which comprehends vast extensions of permafrost soils. Permafrost hydro-thermodynamics has been studied in an ensemble of fully-coupled MPI-ESM simulations of the historical (1850-2014) and future SSP periods (2015-2300; Fig. 1) with a modified version of JSBACH under three different hydrological configurations (WET/DRY/REF, de Vrese et al. 2023) and vertical configurations (5-, 11-, and 18-layer simulations), the MPIESM Permafrost Physics Ensemble (MPIESM-PePE, see last year's proposal). The assessment of MPIESM-PePE shows remarkable differences in permafrost temperatures, active layer thickness and extent (García-Pereira et al., 2025), Arctic amplification of global warming (Meabe-Yanguas et al., 2026) and global circulation patterns (Martínez-Vila et al., 2026).

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

As a result of the activity of ILModelS in Nov 2025 - Oct 2026, an article was published in The Cryosphere (García-Pereira et al., 2025). Two more articles assessing the role of the BBCP in the surface energy balance, and the recent permafrost retreat in the Common Era are expected to be submitted in the coming weeks (García-Pereira et al., 2026a,b). Two more publications analysing the Arctic amplification and the large-scale circulation response in the MPIESM-PePE ensemble are in preparation (Meabe-Yanguas et al., 2026; Martínez-Vila et al., 2026). Additionally, the activity of ILModelS led to one PhD defense in November 2025 at Universidad Complutense de Madrid (García-Pereira, 2025) and a short stay by F. González at the MPI-M in Hamburg in July 2026.

Regarding the ongoing modeling activity linked to last year's allocation request, our efforts have been focused on studying the influence of a more realistic representation of permafrost thermo-hydrodynamics in reshaping the Arctic's response to the current climate change in fully-coupled MPI-ESM simulations in the Common Era (0-2100). Using the modified version of JSBACH allowing hydro-thermodynamical coupling in permafrost areas (HTCp) by de Vrese et al. (2023), we performed an ensemble of three MPI-ESM fully-coupled experiments (MPIESM-PePE) varying the hydrologic configuration (OFF or standard JSBACH, WET, DRY), the Permafrost Physics Ensemble to the Common Era (MPIESM-PePECE, Fig. 2). Last year, we could solve the technical problem that prevented the completion of this ensemble in 2024, an indexing error in the computation of evaporation minus precipitation over glaciers in the mo_surface.f90 routine. This has allowed us to complete the three simulations and extend the MPIESM-PePECE to other complementary experiments of the last millennium, all completed as follows:

- **Canonical simulations (1–2100 CE):** WET, DRY and REF 18-layer past2k simulations, continued over the historical period (1850–2014) and three SSP scenarios (SSP1-1.9, SSP3-7.0 and SSP5-8.5) until 2100.
- **LSM depth ensemble (1250–2100):** REF simulations with 10 to 17 soil layers, i.e. with progressively deeper BBCPs, covering the last600 period, the historical period and the SSP5-8.5 scenario.
- **Natural-forcing simulations (1850–2014):** historical WET, DRY and REF 18-layer simulations driven by natural forcing only, with and without land-use and land-cover change (LULC).
- **ALLbut-forcing experiments (1250–2100):** REF simulations including all forcings but volcanic (VOL) and all forcings but solar (SUJ), covering the last600 period, the historical period and the SSP5-8.5 scenario.
- **WET2DRY experiments:** test pre-industrial control (piC) and historical simulations initialized from the WET configuration, in which the DRY configuration is directly imposed. These experiments allow us to assess how the Arctic feedbacks respond to an abrupt change in soil hydrology.

To our knowledge, an ensemble exploring the sensitivity of the climate system to soil hydro-thermodynamics in transient simulations spanning the whole Common Era is unique in the paleoclimate modelling community. The analysis of these simulations has started, with a model-data comparison of global and regional simulated temperatures with reconstructions from PAGES 2k (PAGES 2k Consortium, 2013, 2019). The MPIESM-PePECE simulations have also been used to place the recent permafrost retreat in the context of the last two millennia (Fig. 3; García-Pereira et al., 2026). First results were presented at the EGU General Assembly 2026 (see Section Outreach activity in the frame of ILModelS).

3. Acknowledgements

The Spanish team would like to highlight the great importance of DKRZ/MPI in supporting this project with its resources. We are aware of our commitment to manage these resources responsibly. Last, we would like to thank the previous year's reviewers for the revision process and their constructive feedback on the report. We attempted to include all the suggestions we were provided to improve this report.

An extended version of this report (with figs. and refs.) is included here:
http://ucmfgr.es/downloads/inandout/20261031_ILModelS_report2026-DKRZ_for2027_final.pdf