

## Paleo-ICON-XPP: Simulating the climate for selected periods of the late Quaternary with different paleo versions of ICON-XPP

With the advent of a new generation of Earth System Models including unstructured grids, new avenues are opened up, also in the context of paleo climate simulation experiments. For the first time, it will be possible to use the same model for simulations in the historical and the paleo context, which allows a better basis for the assessment of past, present and future climate, in contrast with previous studies conducted with different model versions and different resolutions. A special asset of the upcoming simulations that will be carried out in the upcoming CMIP7 framework is that the protocol for the paleo simulations will be better tailored to the historical and scenario simulations, which further allows a better and more consistent comparisons between simulations carried out for the past, historical and future time spans.

The envisaged proposal will target three periods: the last two millennia, the mid-Holocene and the Last Interglacial (127 kyr BP). The ICON model will be configured with specific setups related to the changes in the external forcings specific to those periods. Beyond global simulations, we also plan experiments addressing highly resolved simulations over Europe linking paleoclimate conditions with societal impacts. In addition, these simulations will serve as a data basis to train AI-foundation models emulating the coupled climate models. The latter can be beneficial by using information collected from shorter simulations and extending to longer time scales of the order of several millennia.

In the present proposal, we request computing time only for initial experiments and simulations, as the full CMIP7 protocol is expected to be finalised by the beginning of 2026. Nonetheless, shorter test simulations are required to test and compare the newly configured ICON model system with previous simulations carried out with earlier generations of comprehensive Earth System Models under CMIP6. The experiments will also incorporate pre-releases of the newly generated CMIP7 paleo protocol to set up the simulations and adapt the model system to the technical prerequisites of the new paleo protocol(s).

In contrast to the previous CMIP6/PMIP4 simulations, CMIP7 experiments carried out with the new ICON modelling setups will have considerably higher spatial resolution, thus offering a better comparison with proxy data. In addition, the new paleo protocol also provides an up-to-date version of past external forcings, specifically related to volcanic and solar changes. These changes are especially important prior to 1850 AD, when changes in greenhouse gas concentrations were not as substantial compared to those of the present time.

A completely new pillar of paleo simulations relates to ICON-regional simulations, using global simulations with a high-resolution regional nest over Europe. To our knowledge, this kind of experiments have not yet been carried out and therefore, this part of the proposed work also foresees most resources for test simulations to generate a robust model system integrating the regional scales into the global domain. Also, this approach is relevant to test whether it can solve an entire portfolio of challenges encountered in the classical downscaling paradigm. The use of global simulations with a downscaling cascade with regional climate models in different resolutions, requires the implementation of the ESM boundary forcing as well as the implementation of consistent changes of external forcings

inside and outside the domain of the regional climate model. These technical problems disappear with the variable resolution provided by ICON, however, the results need to be thoroughly assessed and evaluated.

The initiatives related to the regional and past1000 activities are also embedded into an externally reviewed ERC Synergy Grant A Novel Understanding of Pandemic Disease in Preindustrial Europe (1300-1800): Combining History, Machine Learning and Natural Sciences, EURO Pest (Project: 101166700, ERC-2024-SyG) (MPI for Geoanthropology, Leipzig and CMCC, Bologna).