Simulating selected time intervals during the Quaternary using MIROC-ES2L earth system model in comparison with paleo-proxy data

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Simulating paleoclimate is a valuable opportunity to evaluate climate models on simulating climate change significantly different from the present day. We performed numerical experiments targeting several time periods during the Quaternary, Last Glacial Maximum (LGM, 21,000 years before present), mid-Holocene (6ka) and the last millennium (LM) using an earth system model, MIROC-ES2L.
MIROC-ES2L is an earth system model (ESM) (Hajima et al. 2019) which was developed to simulate future climate projection and to contribute Coupled Model Intercomparison Project phase 6 (CMIP6).
In this presentation, we describe how we simulated the paleoclimate experiments, compare the output with paleo-proxy data and discuss the agreements and discrepancies between them. The reference experiment is pre-industrial control (PI), which was submitted to CMIP6 as “piControl”.
We performed the experiments following protocol of Paleoclimate Modelling Intercomparison Project (PMIP) phase 4 (PMIP4, Kageyama et al. 2017). For LGM, we began a spin-up experiment using the physical core of MIROC-ES2L. An experiment is branched from PI and the greenhouse gas levels (GHGs) are changed to the LGM values. After integration for 2,640 years, the other LGM conditions are applied step by step manner and the total spin-up reached 6,760 model years. The initial conditions at the 6,760th year of the spin-up experiment were used to initiate an experiment using MIROC-ES2L. Finally, the length of the integration reached 9,060 years from the beginning of the spin-up and the last 100 year climatology was submitted to PMIP4/CMIP6. Tropical temperature cooling of LGM relative to PI is -2.0 degree Celsius. This is comparable with paleo-proxy archives (Bartlein et al. 2011, MARGO project members 2009). The temperature anomaly over the mid to high latitudes varies more than in the tropics. For the central Greenland, the cooling of the LGM experiment resulted -11.1 degree Celsius relative to PI, which is about the half of the estimate by ice core data (Johnsen et al. 1995, Dahl-Jensen et al. 1998). The large discrepancy would be attributed to the difficulty of the realization of ocean thermohaline state in the model experiment.
6ka is known from the warming of the northern hemisphere and from associated strengthen of the boreal summer monsoons. We branched the simulation from PI and gave the orbit and GHGs of 6ka condition (Otto-Bliesner et al. 2017), and extended 1500 model years. The climatology of the last 100 year was used for the analyses and was submitted to CMIP6/PMIP4. The temperature anomaly during boreal summer showed the warming as expected from the radiation anomaly. Strengthen of boreal summer monsoons were simulated in the experiment, consistent with proxy data qualitatively, but quantitatively underestimated. This is persistent tendency of modelling studies under PMIP model configurations. We would either need further components of model or improve experimental conditions.
The initial state of LM is obtained by an experiment forced with 850 CE condition constantly for 200 model years. LM was started from the end of this experiment. LM is a time varying experiment for 1000 years from 850 CE until 1850 CE, conducted in the same manner with historical experiments following Jungcluas et al. (2017). The resulting time series of the northern hemisphere mean temperature revealed repeating clear cooling responses to huge volcanic eruptions. The responses to the other forcing were not clear. Further investigations and sensitivity experiments would be necessary but the other forcing supposed to be too weak compared to the internal variabilities. The LM is followed by a historical experiment (HIST) until 2014 CE. HIST experiment represented multi-decadal climate variabilities during

the industrial era as well as the other standard historical experiments submitted for CMIP6.

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