



## **The CMIP6/PMIP4 Last Millennium Simulations**

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Climate has varied considerably during the late Holocene and these changes left their traces in history (Medieval Climate Optimum, Little Ice Age). However, the relative magnitude of natural fluctuations due to internal variability of the Earth's climate system and to variations in the external forcing and the present global warming, attributed to anthropogenic greenhouse gases, is still under debate. Investigating the response to (mainly) natural forcing under climatic background conditions not too different from today is crucial for an improved understanding of climate variability, circulation, and regional connectivity. Simulations over the last millennium (LM) allow assessing climate variability on decadal and longer scales and provide information on predictability under forced and unforced conditions. In providing in-depth model evaluation with respect to observations and paleoclimatic reconstructions, LM simulations serve to understand origins and consequences of systematic model biases.

PMIP4 Tier-1 includes the standard LM simulation covering 850 to 1849 CE and a subsequent "historical" (1850 – 2010 CE) experiment as a minimum requirement. In addition to changes in Earth's orbit and greenhouse gas concentrations, the models are forced by variations in solar irradiance, volcanic aerosol load, and anthropogenic land-cover. As part of Tier-2, the modeling groups are asked to provide additional simulations in the form of ensembles, single forcing experiments, as well as sensitivity runs using alternative forcing combinations. The extension of the simulations to cover the complete last two millennia (0 CE to present) is also part of Tier-2.

We describe the experimental design of the LM simulations and discuss the protocol on new forcing and boundary conditions. We discuss recent advances in the reconstruction of solar, volcanic, and land-cover changes and their implementation in the CMIP6 models. PMIP4 aims to provide forcing datasets that are consistent with the forcing for "historical" simulations, both in terms of technical implementation and smoothness of transition between "LM" and "historical".

The PMIP LM working group (WG Past2K) is closely cooperating with the PAGES initiative PAGES2k promoting regional reconstructions of climate variables and variability modes. We suggest common analyses for integrated assessment of reconstructions and simulations leading to progress in model evaluation and process understanding.