

# Supporting Information for ‘No consistent simulated trends in the Atlantic Meridional Overturning Circulation for the past 6,000 years’

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## **AWI-ESM-2**

The Holocene transient simulation with AWI-ESM-2 starts from 6 ka BP to 0 ka BP (Present is defined as 1950 CE), and accounts for the dynamic vegetation changes in the JSBACH model. The AWI-ESM-2 model uses the ECHAM6 as the atmospheric module with a resolution of  $1.875^\circ \times 1.875^\circ$  and 47 vertical levels. The FESOM is the oceanic module in AWI-ESM-2 which has multi-resolution capability with 46 vertical levels. The oceanic resolution can be as fine as 25 km in the polar regions and along the coastlines (Shi et al., 2020). It has an orbital forcing derived from Berger (1978). The past ice core records, alongside the measurement of the atmospheric samples that conducted recently, provide the GHG concentrations for this transient run (Köhler et al., 2017). The mid-Holocene spin-up run has been integrated for 1000 model years with the AMOC in the final years being in its quasi-equilibrium state. A detailed description about this simulation can be found in Shi et al. (2020) and Sidorenko et al. (2019).

## **CCSM3**

The TraCE-21ka simulation is a long transient run with CCSM3 with a dynamic global vegetation model (DGVM), but without flux adjustment (Collins et al., 2006). The atmospheric model in CCSM3 is the Community Atmospheric Model 3 (CAM3), which has a resolution of  $3.75^\circ \times 3.75^\circ$  and 26 vertical levels. The ocean model is the NCAR implementation of the Parallel Ocean Program (POP). The oceanic model has 25 vertical levels and its longitudinal resolution is  $3.6^\circ$  and the latitudinal resolution is variable, with finer resolution near the equator ( $\sim 0.9^\circ$ ) (Liu et al., 2009). This simulation covers the

past 21,000 years, from the Last Glacial Maximum (LGM) to present. This long-run transient simulation has successfully simulated many key deglacial climate evolutions and abrupt climate changes, which shows the model has a reasonable climate sensitivity (Liu et al., 2009). The TraCE-21ka transient simulation was started from a previous LGM simulation from Otto-Bliesner et al. (2006), the orbital parameters and associated insolation changes are computed following Berger (1978), the atmospheric GHG concentrations (carbon dioxide (CO<sub>2</sub>), methane (CH<sub>4</sub>), and nitrous oxide (N<sub>2</sub>O)) are set based on the ice-core records from Joos and Spahni (2008). Additionally, the land ice-sheets and coastlines are forced according to Peltier (2004), and meltwater flux which sourced from the Northern Hemisphere ice-sheets to the North Atlantic and Gulf of Mexico, is calculated based on a rate that is consistent with the recorded sea-level rise record (Peltier, 2004; Clark & Mix, 2002).

### **CESM1.2.1**

The HT-11.5ka Holocene transient simulation performed with CESM1.2.1 spans from 11.5 ka to 0.1 ka BP without acceleration. It has an atmospheric resolution of approximately  $1.9^{\circ} \times 2.5^{\circ}$  with 26 vertical levels using NCAR Community Atmosphere Model version 4 (CAM4), and an oceanic resolution of approximately  $1^{\circ}$  horizontal grid with 60 vertical levels using the Parallel Ocean Program version 2 (POP2) (Tian et al., 2022). This transient run has its orbital parameters evolving with time throughout the Holocene according to Berger (1978). The main atmospheric GHG concentrations – carbon dioxide (CO<sub>2</sub>), methane (CH<sub>4</sub>), and nitrous oxide (N<sub>2</sub>O) are varying with time following Bereiter

et al. (2015), Loulergue et al. (2008), and Schilt et al. (2010), respectively. The ice-sheet extent and topography changes are calculated based on the ICE-6G\_C reconstruction (Argus et al., 2014; Peltier et al., 2015). Tian et al. (2022) provides a more detailed description on this transient run.

### **EC-Earth3-veg-LR**

The transient simulation with the EC-Earth3-Veg-LR model has a duration from 8 ka BP to 0 ka BP with dynamic global vegetation (using LPJ-GUESS model (Smith et al., 2014), which is coupled to the land component). The EC-Earth3-veg-LR model using the Integrated Forecasting System (IFS) model (including a land model H-TESSSEL) developed at the European Centre for Medium-Range Weather Forecasts (ECMWF) as the atmospheric component with a T159 horizontal spectral resolution (roughly  $1.125^\circ$ , approximately 125 km) with 62 vertical levels. Its ocean component is based on the Nucleus for the European Modelling of the Ocean (NEMO) model (Madec et al., 2008) which includes a sea-ice model LIM3 (Rousset et al., 2015). It has a nominal horizontal resolution of  $1^\circ$  and 75 vertical levels (Döscher et al., 2022). The orbital parameters in this run are computed using the method in Berger (1978). The greenhouse gas (GHG) concentrations are forced according to Köhler et al. (2017). More detailed information for the palaeo-simulations setup and for the description of the EC-Earth3 model are available in Zhang et al. (2021) and Döscher et al. (2022), respectively.

### **HadCM3-M2.1d**

The HadCM3-M2.1d (Valdes et al., 2017) Holocene transient run spans almost the entire Holocene period, from 10 ka BP to 0 ka BP. The HadCM3 model has an atmospheric resolution of  $3.75^\circ \times 2.5^\circ$  with 19 vertical levels, and an oceanic resolution of  $1.25^\circ \times 1.25^\circ$  with 20 vertical levels. This transient simulation considers the dynamics of the vegetation according to the TRIFFID Dynamic Global Vegetation Model (Cox, 2001). The orbital forcing is derived from Berger (1978), and the ice core records provide the GHG forcing (Veres et al., 2013; Bereiter et al., 2015; Loulergue et al., 2008). The global ICE-6G\_C (VM5a) model is used for obtain the ice-sheet and sea-level forcing (Argus et al., 2014; Peltier et al., 2015). The xokm series used here includes palaeo-informed updates to atmospheric parameters (particularly convective entrainment/detrainment) and dynamic vegetation moisture stress. This model version therefore captures the greening of the Sahara. Further details of the model setup are described in Hopcroft and Valdes (2021).

### **IPSL-CM5**

The IPSL-CM5 transient simulation covers the mid-Holocene to present (6 ka BP to 0 ka BP) with a spin-up time of 2,000 years. The IPSL-CM5 model using the LMDZ as an atmospheric component with a resolution of  $1.875^\circ \times 3.75^\circ$  and 39 vertical levels. The Oceanic component is based on the NEMO model with 31 vertical levels and a  $2^\circ \times (0.5\sim 2)^\circ$  resolution. Finer resolutions of roughly  $0.5^\circ$  can be seen near Equator (Crosta et al., 2018). The orbital parameters are calculated from Berger (1978), with the trace gases concentrations ( $\text{CO}_2$ ,  $\text{CH}_4$  and  $\text{N}_2\text{O}$ ) stem from the ice core reconstruction data from Joos

and Spahni (2008). Interactive vegetation is calculated within the model. Braconnot et al. (2019) provides a more comprehensive description of the IPSL transient simulation.

## KCM

The Holocene transient simulation with KCM consists of the atmospheric general circulation model ECHAM5 (Roeckner et al., 2003) with a horizontal resolution of T31 ( $3.75^\circ \times 3.75^\circ$ ) and 19 vertical levels, coupled to the ocean sea-ice model NEMO/LIM2 (Madec et al., 2008) with a horizontal resolution of  $2^\circ \times 2^\circ$  with 31 vertical levels, and enhanced meridional resolution of  $0.5^\circ$  close to the Equator. The KCM model simulates reasonably well a present-day mean climate (Park et al., 2009) and its variability, as well as changes of the hydrological cycle during the Holocene as indicated by lake level data (V. Khon et al., 2010). The KCM has been used extensively for palaeomodeling studies, in particular to simulate the last interglacial climate (Schilt et al., 2010; V. Khon et al., 2010; V. C. Khon et al., 2018; Salau et al., 2012; Jin et al., 2014). This KCM Holocene transient simulation is forced by varying orbital parameters (eccentricity, obliquity and precession) following Berger and Loutre (1991). The GHG concentrations are obtained from the PMIP database based on ice cores from the EPICA site (Augustin et al., 2004). Changes in total solar irradiance (TSI), sea level, changes in ice sheets (neither topography nor albedo), freshwater input into the North Atlantic, or volcanic aerosols are not considered in this transient simulation (Segschneider et al., 2018). More thorough descriptions for the orbital and GHG forcing are shown in Segschneider et al. (2018).

## MPI-ESM

The MPI-ESM model has been used to perform two Holocene transient run from 8 ka BP to 0.15 ka BP. The atmospheric component (ECHAM6) is run with a resolution of  $1.875^\circ \times 1.875^\circ$  (lon  $\times$  lat) and 47 vertical levels, and the ocean component MPIOM has a nominal horizontal resolution of  $1.5^\circ$  and 41 uneven vertical levels (Mauritsen et al., 2019). The interactive vegetation is obtained using the JSBACH land-surface model. The orbital parameters and GHG forcing in this run are derived from Berger (1978) and Brovkin et al. (2019) ice core records, respectively. The SLO0043 (TRSF) experiment includes solely GHG and orbital changes whereas the SLO0050 (TRAF) experiment includes additional forcings from volcanic aerosols and solar irradiance changes. The solar total and spectral irradiance are calculated based on the SATIRE model and solar-related changes in ozone are included using a simple scaling parameterisation (see Bader et al., 2020). Stratospheric sulfate aerosol injections imitating volcanic eruptions are prescribed from the Easy Volcanic Aerosol (EVA) forcing generator (Toohey et al., 2016), read annually, but calculated daily by linear interpolation. The forcing used here has been reconstructed based on ice-cores from both hemispheres to better identify volcanic eruptions with global impact on the climate (see Dallmeyer et al., 2021, for details). In addition, SLO0050 includes land-use forcing for the time period, where a reconstruction is available (i.e. 850 – 1850 CE) (Hurtt et al., 2011; Lawrence et al., 2016).

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