How mineral dust aerosol during LGM affects temperature surrounding of the Antarctica

Rumi Ohgaito[1], Ayako Abe-Ouchi[2,1], Toshihiko Takemura[3], Akinori Ito[1], Ryouta O'ishi[2], Tomohiro Hajima[1], Shingo Watanabe[1] and Michio Kawamiya[1]

[1]*JAMSTEC,* [2]*AORI, U. Tokyo,* [3]*RIAM, Kyushu Univ.*

Deposition flux of mineral dust aerosol (dust) synchrnously fluctuates with temperature through glacial-interglacial cycle of the Quaternary, which is known from various proxy data (Dome Fuji Ice Core Project members 2017, Sci. Adv., Winckler et al. 2008, Science). Here we evaluate the effect of high dust flux due to enhanced glacial activity during Last Glacial Maximum (21,000 years before present, LGM) using numerical experiments.

We use an Earth System Model, MIROC-ESM (Watanabe et al. 2011, GMD), which consisits of atmosphere, land, river (AGCM) and ocean modules. Each module calcurates physical variables, and carbon cycle every discretized time steps and exchange these values through a flux coupler. Additional experiments are conducuted using the AGCM part of MIROC-ESM.

We conducted a LGM experiment (LGMglac.e) (Sueyoshi et al. 2013, GMD) following the protocol of Paleoclimate Modelling Intercomparison Project phase 3 (PMIP3) (Abe-Ouchi et al. 2015, GMD). However, LGM.e failed to represent the enhancement of dust deposition recoreded in the proxy data especially in the southern hemisphere. Hence, we performed an additional experiment, which is the identical to the LGM.e but with additional "glaciogenic dust" emissions (Mahowald et al. 2006, JGR) to achieve better fitting for the proxy data archive (Kohfeld et al. 2013, QSR, Albani et al. 2014, JAMES) (hereafter, called LGMglac.e). See Table 1 for the explanation. LGMglac.e obtained better representation of dust distribution at LGM. Especially, a strong glaciogenic dust from Pampas region in LGMglac.e spreads over the Southern Ocean ranging up to the higher troposphere. Additional sensitivity experiments using the AGCM are listed in Table 2. LGM.a corresponds to LGM.e and LGMglac.a to LGMglac.e, only sea surface is prescribed. There were no significant differences between these two paired (.e) and (.a) experiments in the southern hemisphere.

Dust loading is enhanced in LGMglac.a compared to LGM.a (Fig. 1), centered in the South America, distributed over the Southern Ocean and the Antarctica. And, warming of LGMglac.a is observed around the Antarctica compared to LGM.a, i.e., less cooling compared to the present day (Fig. 2). The resulting temperature anomaly at the LGM is pronounced at the surrounding of the Antarctica, but not very significant over the high plateau of the Antarctica. The model results of the sensitivity experiments suggest that the aerosol-cloud interaction in the upper troposphere plays an important role in warming the lower atmosphere. On the other hand, ageing effect of snow by dust deposition is not the reason of this temperature change around the Antarctica. These experiments and analyses are detailed in Ohgaito et al. (2018, CPD). It should be noted that we need further improvement on the amount and method of glaciogenic dust emission for quantitative conclusions.

Table 1. Experiments using MIROC-ESM

Experiment names	Explanation
LGM.e	The lgm experiment submitted to PMIP3.
LGMglac.e	LGM.e + adding glaciogenic dust flux following Mahowald et al. (2006)

Table 2. Experiments using the AGCM part of MIROC-ESM

Experiment names	Explanation
LGM.a	The same with LGM.e but the sea surface temperature and sea ice are taken from LGM.e
LGMglac.a	LGM.a + adding glaciogenic dust flux following Mahowald et al. (2006)
LGM.naging.a	LGM.a + no ageing of snow albedo
LGMglac.naging.a	LGMglac.a + no ageing of snow albedo

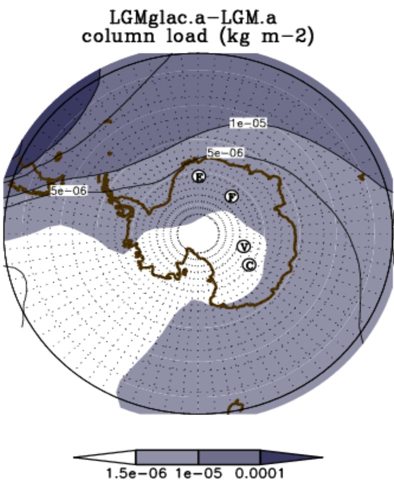

Figure 1. Anomaly of column loading of dust in the atmosphere for LGMglac.a-LGM.a (kg m-2). Circled alphabets over the Antarctica show the locations of 4 ice core sites, E for EDML, F for Dome Fuji, V for Vostok, and C for Dome C.

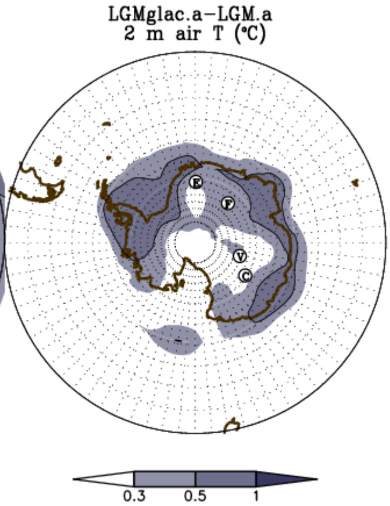

Figure 2. Air temperature anomaly at 2 m height for LGMglac.a-LGM.a (kg m-2). Circled alphabets are the same with Fig. 1