Surface temperature at Dome Fuji during the last interglacial period

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The last interglacial period (LIG, Marine Isotope Stage 5e) attracts much attention as a potential future analogue for an anthropogenically warming world. According to various paleoclimatic reconstructions, the LIG was warmer than the pre-industrial late Holocene, and the global sea level was higher than today by about 5 to 9 m (contributions from both Greenland and Antarctic ice sheets; IPCC SROCC, 2019). However, the LIG temperatures on the polar ice sheets are not well constrained. The LIG surface temperatures on the East Antarctic plateau estimated from oxygen and hydrogen isotopic ratios in ice cores are ~4 – 10 K higher than pre-industrial, which are broadly consistent with modern spatial relationship between the surface temperature and isotopic ratio (e.g., Sime et al., 2009; Uemura et al., 2012; 2018). However, determining the temperature-isotope relationship is indeed complex, thus independent surface temperature estimates are highly desired (Buizert et al., 2021).

Recently, a new method to estimate the past surface temperature has been developed (Buizert et al., 2021), in which the age difference between air and ice (Δage) and $\delta^{15}N$ of N_2 in ice cores are inverted with a firn densification-heat transport model to reconstruct the surface temperature and accumulation rate. Buizert et al. (2021) estimated that the amplitude of surface temperature change in East Antarctic inland between the last glacial maximum (LGM) and pre-industrial is around 4 K, which is about half as the estimates from traditional interpretation of water isotopes (e.g., Uemura et al., 2018). An altered temperature inversion during the LGM may reconcile the new estimate with previous isotope-based ones.

In this study, we used published $\delta^{15}N$ and $\delta O_2/N_2$ data (Oyabu et al., 2022) and new CH_4 concentrations and stable water isotope ratios from the Dome Fuji (DF) ice core around the LIG, and applied the inversion method of Buizert et al. (2021) to estimate the surface temperature at about the peak of LIG warmth (~129 kyr BP). The analytical precisions of DF gas data are 0.005 ‰ for $\delta^{15}N$ and 0.1 ‰ for $\delta O_2/N_2$, and the typical time resolution is ~500 years. The CH_4 concentrations and stable water isotope ratios were measured with a Continuous Flow Analysis (CFA) system at the National Institute of Polar Research. The inversion method with the firn densification model requires an ice age scale, Δage and $\delta^{15}N$. The ice age scale was constructed using a Bayesian dating tool (Paleochrono, Parrenin et al., 2021) with various types of age markers including the new $\delta O_2/N_2$ tie points. Preliminary Δage around the LIG was estimated by assuming synchroneity (bipolar seesaw) between the highest $\delta^{18}O$ in the broad LIG peak and the abrupt CH_4 increase at the end of Termination II, both in the discrete data, and by converting the depth difference between gas and ice depths (Δdepth) to Δage using the ice age scale. The uncertainties of the ice age and Δage around the LIG are estimated to be ~1000 and ~800 years, respectively (2σ). Our preliminary result shows that the LIG surface temperature at DF was ~2 K higher than preindustrial, which is lower than traditional estimates from water isotopes. We are currently working on the CFA data for LIG, and it may provide more precise Δage and thus the temperature estimate.

References

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