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Leads and lags between the Antarctic temperature and carbon dioxide during the last deglaciation

Léa Gest (1), Frédéric Parrenin (1), Dominique Raynaud (1), and Tyler J. Fudge (2)

(1) Université Grenoble Alpes, UMR5183 - CNRS, Laboratoire de Glaciologie et Géophysique de l'Environnement (LGGE), Grenoble 38041, France (gest.lea@gmail.com), (2) Department of Earth and Space Sciences, University of Washington, Seattle, WA 98195, USA (tjfudge@uw.edu)

To understand causal relationships in past climate variations, it is essential to have accurate chronologies of paleoclimate records. Ice cores in Antarctica provide important paleoclimate variables, such as local temperature and global atmospheric CO_2. Unfortunately, temperature is recorded in the ice while CO_2 is recorded in the enclosed air bubbles. The ages of the former and of the latter are different since air is trapped at 50-120 m below the surface. For the last deglacial warming, 18,000 to 11,000 years ago, Parrenin et al. (Science, 2013) inferred that CO_2 and Antarctic temperature started to increase in phase while CO_2 lagged temperature at the beginning of the Holocene period. However, this study suffers from various uncertainties that we tried to address in the current study.

First, Antarctic temperature was inferred from a stack of 5 Antarctic ice cores that were not always accurately synchronized. Here we use a stack of 4 Antarctic ice cores which are all accurately synchronized thanks to volcanic peak matching. Second, Parrenin et al. (Science, 2013) used a relatively low-resolution CO_2 record from the EPICA Dome C ice core. Here, we use the more recent and higher resolution CO_2 record from the West Antarctic Ice Sheet Divide ice core. Third, the air trapping depth was deduced on the low accumulation EPICA Dome C ice core using the gravitational enrichment of the δ^{15}N isotopes and assuming a zero convective depth, a hypothesis that was not proved. Here, we use the higher accumulation WAIS Divide ice core, where the ice-air age shift is one order of magnitude smaller, and therefore better constrained. Finally, we use an improved mathematical method to infer break points in the Antarctic temperature and atmospheric CO_2 records.

We find that, at the onset of the last deglaciation and the onset of the Bølling-Allerød period, the phasing between CO_2 and Antarctic temperature is negligible within a range of 130 years. Then CO_2 slightly leads by 200 $\pm$ 90 years at the onset of the Younger-Dryas period. Finally, Antarctic temperature significantly leads by 460 $\pm$ 95 years at the onset of the Holocene period. Our results further supports the hypothesis of no convective zone at EPICA Dome C during the last deglaciation, as assumed by Parrenin et al. (Climate of the past, 2012, On the gas-ice depth difference (Delta depth) along the EPICA Dome C ice core)