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Preliminary results of global biosphere productivity reconstruction over Heinrich Stadial 4 from the triple isotopic composition of air oxygen trapped in NEEM ice core

Ji-Woong Yang\textsuperscript{1,2}, Amaëlle Landais\textsuperscript{2}, Thomas Blunier\textsuperscript{1}, Stéphanie Duchamp-Alphonse\textsuperscript{3}, and Frédéric Prié\textsuperscript{2}

\textsuperscript{1}Niels Bohr Institute, University of Copenhagen, Copenhagen, Denmark (ji.woong.yang@nbi.ku.dk)
\textsuperscript{2}Laboratoire des Sciences du Climat et de l’Environnement/Institut Pierre-Simon Laplace, Université Paris Saclay/CEA/CNRS/UVSQ, Gif-sur-Yvette, France
\textsuperscript{3}Géosciences Paris-Saclay, Université Paris Saclay, Orsay, France

Global biosphere primary productivity via photosynthesis is the largest carbon uptake flux from the atmosphere. The Earth biosphere currently absorbs near half of the carbon emitted by anthropogenic activities (Friedlingstein et al., 2020). Therefore, for a better projection of future carbon cycle, it is important to understand how the global biosphere would respond to abrupt climate changes which occurred in the past. The last glacial period is punctuated by a number of rapid shifts between relatively cold (stadial) and warm (interstadial) stages named Dansgaard-Oeschger events (DO). Some stadials are also associated with abrupt, massive iceberg discharge event and are called Heinrich Stadials (HSs). The high-resolution CO\textsubscript{2} reconstruction from polar ice cores demonstrated millennial-scale CO\textsubscript{2} variations over HS-DO events (Bauska et al., 2021). The gradual rising of CO\textsubscript{2} over HS has been attributed to ventilation changes in Southern Ocean (Gottschalk et al., 2016; Menviel et al., 2018) and/or reduced biological uptake (Ahn et al., 2012; Gottschalk et al., 2016; Schmittner and Lund, 2015). However, the role of the global biosphere is not well understood because of difficulties in estimating global biosphere productivity from local reconstructions based on indirect tracers.

To address this, here we use the triple isotopic composition of air oxygen ($\Delta = \ln(\delta^{17}\text{O}+1) - \lambda_{\text{ref}}\ln(\delta^{18}\text{O}+1)$, $\lambda_{\text{ref}} = 0.516$), which is a biogeochemical tracer of global biosphere primary productivity (Luz et al., 1999). We measured $\Delta$ of trapped air in the NEEM ice core over 36 to 42 ka interval, covering HS4 and DO8 events. The new NEEM $\Delta$ data show no significant change over HS4, while CO\textsubscript{2} records from multiple ice cores indicate near $\sim$20 ppm increase (e.g., Ahn and Brook, 2014; Bauska et al., 2021). By using the box models describing $\Delta$ systematics between biosphere-troposphere-stratosphere (e.g., Landais et al., 2007; Blunier et al., 2012), our preliminary results suggest that global biosphere productivity increases during HS4. This result is inconsistent with previous estimates based on ice-core records of non-sea-salt Na and Ca (Fischer et al., 2007), and the marine sediment core opal flux record (Gottschalk et al., 2016), both indicating a reduction of Southern Ocean biological productivity. More $\Delta$ samples remain to be measured up to the General Assembly 2022 and we hope to have a clearer picture by then.