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The impact of bathymetry on the simulated carbon at the Last Glacial Maximum

Fanny Lhardy[1], Nathaelle Bouttes[1], Didier Roche[1,2], Ayako Abe-Ouchi[3], Zanna Chase[4], Ruza Ivanovic[5], Markus Jochum[6], Masa Kageyama[1], Hidetaka Kobayashi[3], Laurie Menviel[7], Juan Muglia[8], Roman Nuterman[6], Akira Oka[3], Andreas Schmittner[9], Guido Vettoretti[6], and Akitomo Yamamoto[10]
[1]LSCE (CNRS), Gif-sur-Yvette, France (fanny.lhardy@lsce.ipsl.fr)
[2]Vrije Universiteit Amsterdam, Amsterdam, The Netherlands
[3]The University of Tokyo, Tokyo, Japan
[4]University of Tasmania, Hobart, Australia
[5]University of Leeds, Leeds, England
[6]Niels Bohr Institute, University of Copenhagen, Copenhagen, Denmark
[7]Climate Change Research Centre, the University of New South Wales, Sydney, Australia
[8]Centro Nacional Patagonico, Puerto Madryn, Argentina
[9]Oregon State University, Corvallis, USA
[10]Japan Agency for Marine-Earth Science and Technology, Yokosuka, Japan

Understanding the processes causing variations in the carbon cycle is critical to accurately simulate the future carbon cycle and climate. Paleoclimate models can provide insights about these processes since they are used under different conditions than present-day's and evaluated against paleoproxy data. In particular, the Last Glacial Maximum (LGM) has been a focus of the Paleoclimate Modelling Intercomparison Project (PMIP) as it is well-documented thanks to numerous paleoclimate archives. Around 21,000 years ago, the LGM was a colder period with extensive ice sheets in the Northern Hemisphere and a resulting lower sea-level. Although this period has been studied for years, the causes of the lower atmospheric CO_2 concentration at the time (around 186 ppm, against 280 ppm at the pre-industrial) remain unclear, and models struggle to simulate this low CO_2 value. The ocean is thought to have played a significant role due to different processes (through changes of the biological pump efficiency, ocean circulation, sea-ice, and CO_2 solubility due to colder temperatures), but no consensus has been reached yet as to their contribution (Khatiwala et al. [2019], Yu et al. [2016], Marzocchi and Jansen [2019]).

Despite the carbon cycle being simulated by more and more climate models, it has not been systematically analysed within the framework of PMIP multimodel comparisons. In this context, the ongoing PMIP-carbon project aims at comparing climate-carbon interactions in LGM simulations, and includes results from both intermediate complexity models and general circulation models. The PMIP protocol proposes standardized forcing parameters and boundary conditions (Kageyama et al. [2017]) and specifies a few recommendations for ocean biogeochemistry models (adjustment of salinity, dissolved inorganic carbon, alkalinity, and

nutrients to account for the change in ocean volume). Indeed, the bathymetric changes associated with a sea-level drop of 133 m entail a change of the reservoir size and potential technical issues concerning the conservation of carbon.

In this study, we use outputs from PMIP-carbon models and other models available on the ESGF (MIROC4m-COCO, MIROC-ES2L, CESM, IPSL-CM5A2, UVic, LOVECLIM, iLOVECLIM, CLIMBER_2P ; GISS-E2-R, MRI-CGCM3, MPI-ESM-P, CNRM-CM5, MIROC-ESM) to compute total ocean volumes and compare them to high resolution topographic data (etopo1 for the PI, GLAC-1D and ICE-6G-C for the LGM). We show that the deglacial volume change is rarely accurate. We then use the iLOVECLIM model with a new bathymetry implementation method (Lhardy et al. [in review, 2020]) to demonstrate the effect of an improved ocean volume on the simulated oceanic carbon content, resulting in an increase of the already overestimated atmospheric CO_2 concentration. We also quantify the effect of the mentioned adjustments of salinity, alkalinity, and carbon. The results reinforce the idea that a realistic ocean volume is needed, as well as consistency between models in dealing with large changes in bathymetry.