Climate of the Past Discussions

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Reply on CC1

Takasumi Kurahashi-Nakamura et al.

Author comment on "Glacial state of the global carbon cycle: time-slice simulations for the last glacial maximum with an Earth-system model" by Takasumi Kurahashi-Nakamura et al., Clim. Past Discuss., https://doi.org/10.5194/cp-2022-8-AC1, 2022

Dear Peter Köhler,

We thank you for the thoughtful comments on our manuscript.

As you pointed out, indeed the model used in this study is a suitable tool to examine the degree of local (dis)equilibrium of the partial pressure of CO_2, or pCO_2, between the atmosphere and the surface ocean. We tailored the model forcing for the LGM carbon-cycle state both in physical (e.g. radiative forcing) and biogeochemical (e.g. dust input) ways, so that we would be able to provide a more reliable quantitative estimate of the glacial pCO_2 in the surface water, hence the degree of equilibrium, compared to the previous estimate by Völker and Köhler (2013). Moreover, the sensitivity experiments with additional freshwater forcing can offer an opportunity to test the sensitivity of the estimate to perturbed states, which brings another support for the robustness of the estimate.

The attached figure shows the global maps of the difference in pCO_2 between the surface ocean and the atmosphere (ΔpCO_2) for the three LGM experiments in this study. Every simulation had clear disequilibrium of pCO_2 in most regions, which showed a remarkable zonal structure. For example, pCO_2 in the surface water was higher than in the atmosphere (i.e. ΔpCO_2 is positive) in the low latitude band irrespective of the longitude, where ΔpCO_2 was typically 30-40 ppm in the equatorial Atlantic, 0-40 ppm in the western equatorial Pacific, and 40-80 ppm in the eastern equatorial Pacific.

The differences in ΔpCO_2 between each LGM simulation and the pre-industrial run are also shown in the figure (the right column) to demonstrate how variable ΔpCO_2 is depending on different ages or different climate regimes. The modelled glacial ΔpCO_2 fields were significantly different from the modern one, revealing patchy distributions of the anomaly that was up to +-50 ppm apart from some marginal seas. Among the different LGM runs, the ΔpCO_2 fields were comparatively similar to one another, which added to the robustness of the contrast between the LGM and PI.

These results suggest that the state of local equilibrium or disequilibrium of pCO_2 is substantially variable and that the modern state is not always applicable to other ages that had a different climate state, although this study only offers test cases for one time slice. We will extend the manuscript on the next revision to include a similar description and discussion to contribute to better interpretations of relevant proxy data.

Sincerely,
Takasumi Kurahashi-Nakamura

References: Völker, C., and P. Köhler (2013), Responses of ocean circulation and carbon cycle to changes in the position of the Southern Hemisphere westerlies at Last Glacial Maximum, Paleoceanography, 28, 726-739, doi:10.1002/2013PA002556.

Please also note the supplement to this comment:
https://cp.copernicus.org/preprints/cp-2022-8/cp-2022-8-AC1-supplement.pdf