



Open Research Online

Citation

Kemppinen, Krista M. S.; Holden, Philip B.; Edwards, Neil R.; Ridgwell, Andy and Friend, Andrew D. (2019). Coupled climate–carbon cycle simulation of the Last Glacial Maximum atmospheric CO₂ decrease using a large ensemble of modern plausible parameter sets. *Climate of the Past*, 15 pp. 1039–1062.

URL

<https://oro.open.ac.uk/61964/>

License

(CC-BY 4.0) Creative Commons: Attribution 4.0

<https://creativecommons.org/licenses/by/4.0/>

Policy

This document has been downloaded from Open Research Online, The Open University's repository of research publications. This version is being made available in accordance with Open Research Online policies available from [Open Research Online \(ORO\) Policies](#)

Versions

If this document is identified as the Author Accepted Manuscript it is the version after peer review but before type setting, copy editing or publisher branding

Supplement of *Clim. Past*, 15, 1039–1062, 2019
<https://doi.org/10.5194/cp-15-1039-2019-supplement>
© Author(s) 2019. This work is distributed under
the Creative Commons Attribution 4.0 License.



Supplement of

Coupled climate–carbon cycle simulation of the Last Glacial Maximum atmospheric CO₂ decrease using a large ensemble of modern plausible parameter sets

Krista M. S. Kemppinen et al.

Correspondence to: Krista M. S. Kemppinen (krista.kemppinen@asu.edu)

The copyright of individual parts of the supplement might differ from the CC BY 4.0 License.

S1

The ensemble was integrated for another 10 kyr after stage 3 (yielding 20 kyr of LGM climate in total) to simply verify, by analysing a subset of the ensemble, that the sediments (being the slowest component in the model) were in equilibrium by 10 kyr.

S2

ENS₃₁₅ has a mean atmospheric CO₂ concentration of 278.1 ± 1.3 ppmv (standard deviation). The ensemble mean and range for the eight modern climate plausibility metrics of Holden et al., 2013a are shown in Table S2.1. The ensemble response is additionally reported in Table S2.2 for the annual average global ocean carbon inventory, sea surface temperature and sea ice area, and compared with observations. The ensemble mean ocean carbon inventory is close to the 36,000 PgC equilibrium preindustrial ocean carbon inventory predicted by GENIE-1 in Lenton et al. (2006), below reconstructed estimates of ca. 38,000 PgC (Houghton et al., 1990), largely attributable to an underestimated ocean volume at our low resolution (Lenton et al 2006). The ensemble mean sea surface temperature (SST) exceeds observations but the error is still comparable to that associated with previous model predictions (e.g. Kim et al., 2003). The ensemble mean sea ice area (SIA) lies within the range of observed estimates.

Table S2.1. The eight modern climate plausibility metrics. The first two columns show the mean (plus minus one standard deviation) and range of ENS₃₁₅, the second and third, the same metrics but for the Holden et al. (2013a), H13, ensemble (Table 2). All values are annual averages, except for the Antarctic sea ice area.

	ENS ₃₁₅ mean	ENS ₃₁₅ range	H13 Mean	H13 range
Global surface air temperature (°C)	13.7 ± 1.1	11.8 to 16.2	13.6 ± 1.1	11.7 to 16.2
Atlantic overturning stream function maximum (Sv)	17.5 ± 3.2	8.4 to 25.8	17.5 ± 3.2	10.0 to 25.8
Atlantic overturning stream function minimum (Sv)	-4.1 ± 1.0	-6.9 to -0.9	-4.1 ± 1.0	-6.8 to -1.0
31 st December Antarctic sea ice area (million km ²)	6.7 ± 2.7	1.2 to 13	6.8 ± 2.8	1.2 to 12.9
Global VegC (PgC)	499.9 ± 94.5	328.6 to 765.5	492 ± 94	326 to 762
Global SoilC (PgC)	1329.7 ± 279.2	896.1 to 2353.2	1351 ± 308	896 to 2430
Surface sediment wt% CaCO ₃	34.4 ± 7.9	19.1 to 51.5	34.1 ± 7.8	20.0 to 50.0
Global ocean O ₂ (µm kg ⁻¹)	164.1 ± 19.3	121.8 to 217.5	165 ± 20	117 to 216

Table S2.2. Preindustrial ocean carbon inventory, sea surface temperature and sea ice area. All values are annual averages.

	ENS ₃₁₅ mean	ENS ₃₁₅ range	Observations
Global ocean carbon inventory (PgC)	36056.2 ± 252.4	35280.5 to 36655.7	38000 Houghton et al. (1990)
Global sea surface temperature (°C)	18.9 ± 1.2	16.4 to 21.9	15.9 NCDC, 2015
Global sea ice area (million km ²)	23 ± 4.2	16.3 to 38.6	19 to 27 Lemke et al. (2007)

References

- Holden, P. B., Edwards, N. R., Oliver, K. I. C., Lenton, T. M. and Wilkinson, R. D.: A probabilistic calibration of climate sensitivity and terrestrial carbon change in GENIE-1, *Clim. Dyn.*, 35(5), 785–806, doi:10.1007/s00382-009-0630-8, 2010a.
- Holden, P. B., Edwards, N. R., Müller, S. A., Oliver, K. I. C., Death, R. M., and Ridgwell, A.: Controls on the spatial distribution of ocean $\delta^{13}\text{CDIC}$, *Biogeosciences*, 10, 1815-1833, <https://doi.org/10.5194/bg-10-1815-2013>, 2013a.
- Houghton, J. T., Jenkins, G. J., Ephraums, J. J.: *Climate Change. The IPCC Scientific Assessment.* Cambridge University Press, Cambridge, 1990.
- Kim, S.-J., Flato, G., and Boer, G.: A coupled climate model simulation of the Last Glacial Maximum, Part 2: approach to equilibrium, *Clim. Dyn.*, 20, 635-661, <https://doi.org/10.1007/s00382-002-0292-2>, 2003.
- Lemke, P., Ren, J., Alley, R. B., Allison, I., Carrasco, J., Flato, G., Fujii, Y., Kaser, G., Mote, P., Thomas, R. H., and Zhang, T.: Observations: Changes in Snow, Ice and Frozen Ground. In: *Climate Change 2007: The Physical Science Basis. Contribution of Working Group I to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change* [Solomon, S., D. Qin, M. Manning, Z. Chen, M. Marquis, K.B. Averyt, M. Tignor and H.L. Miller (eds.)]. Cambridge University Press, Cambridge, United Kingdom and New York, NY, USA, 2007.
- Lenton, T. M., Williamson, M. S., Edwards, N. R., Marsh, R., Price, A. R., Ridgwell, A. J., Shepherd, J. G., and Cox, S. J.: Millennial timescale carbon cycle and climate change in an efficient Earth system model, *Clim. Dyn.*, 26(7-8), 687-711, doi:10.1007/s00382-006-0109-9, 2006.
- NOAA National Centers for Environmental Information, State of the Climate: Global Climate Report for Annual 2015, published online January 2016, retrieved on May 24, 2019 from <https://www.ncdc.noaa.gov/sotc/global/201513>.