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Lessons from a high CO₂ world: an ocean view from ~3 million years ago

Erin McClymont¹, Heather Ford², Sze Ling Ho³, Julia Tindall⁴, Alan Haywood⁴, Montserrat Alonso Garcia^{5,6}, Ian Bailey⁷, Melissa Berke⁸, Kate Littler⁷, Molly Patterson⁹, Benjamin Petrick¹⁰, Francien Peterse¹¹, Christina Ravelo¹², Bjorg Risebrobakken¹³, Stijn De Schepper¹³, George Swann¹⁴, Kaustubh Thirumalai¹⁵, Jessica Tierney¹⁵, Carolien van der Weijst¹¹, and Sarah White¹⁶

¹Durham University, Department of Geography, Durham, United Kingdom of Great Britain and Northern Ireland (erin.mcclymont@durham.ac.uk)

²School of Geography, Queen Mary University of London, London, U.K.

³Institute of Oceanography, National Taiwan University, 10617 Taipei, Taiwan.

⁴School of Earth and Environment, University of Leeds, Leeds, LS29JT, U.K.

⁵Department of Geology, University of Salamanca, Salamanca, Spain.

⁶CCMAR, Universidade do Algarve, 8005-139 Faro, Portugal.

⁷Camborne School of Mines & Environment and Sustainability Institute, University of Exeter, Exeter, U.K.

⁸Department of Civil and Environmental Engineering and Earth Sciences, University of Notre Dame, Notre Dame IN 46656, USA.

⁹Department of Geological Sciences and Environmental Studies, Binghamton University SUNY, 4400 Vestal Pkwy E, Binghamton, New York USA.

¹⁰Max Planck Institute for Chemistry, Climate Geochemistry Department, 55128 Mainz, Germany.

¹¹Department of Earth Sciences, Utrecht University, Utrecht, 3584 CB, the Netherlands.

¹²Department of Ocean Sciences, University of California, Santa Cruz, CA, USA,

¹³NORCE Norwegian Research Centre and Bjerknes Centre for Climate Research, 5007 Bergen, Norway.

¹⁴School of Geography, University of Nottingham, Nottingham, NG7 2RD, U.K.

¹⁵Department of Geosciences, The University of Arizona, Tucson, AZ 85721, USA

¹⁶Dept. of Earth and Planetary Sciences, University of California, Santa Cruz, USA.

A range of future climate scenarios are projected for high atmospheric CO₂ concentrations, given uncertainties over future human actions as well as potential environmental and climatic feedbacks. The geological record offers an opportunity to understand climate system response to a range of forcings and feedbacks which operate over multiple temporal and spatial scales. Here, we examine a single interglacial during the late Pliocene (KM5c, ca. 3.205 +/- 0.01 Ma) when atmospheric CO₂ concentrations were higher than pre-industrial, but similar to today and to the lowest emission scenarios for this century. As orbital forcing and continental configurations were almost identical to today, we are able to focus on equilibrium climate system response to modern and near-future CO₂. Using proxy data from 32 sites, we demonstrate that global mean sea-surface temperatures were warmer than pre-industrial, by ~2.3 °C for the combined proxy data (foraminifera Mg/Ca and alkenones), or by ~3.2°C (alkenones only). Compared to the pre-industrial, reduced meridional gradients and enhanced warming in the North Atlantic are

consistently reconstructed. There is broad agreement between data and models at the global scale, with regional differences reflecting ocean circulation and/or proxy signals. An uneven distribution of proxy data in time and space does, however, add uncertainty to our anomaly calculations. The reconstructed global mean sea-surface temperature anomaly for KM5c is warmer than all but three of the PlioMIP2 model outputs, and the reconstructed North Atlantic data tend to align with the warmest KM5c model values. Our results demonstrate that even under low CO₂ emission scenarios, surface ocean warming may be expected to exceed model projections, and will be accentuated in the higher latitudes.