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On the climatic influence of CO_2 forcing in the Pliocene

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The Pliocene (~3 million years ago) is of great interest to the palaeoclimate community as a potential palaeoclimate analogue for future climate change. It was the most recent period of sustained warmth above pre-industrial levels, was recent enough to have similar-to-modern continental configuration, and had similar-to-modern atmospheric CO_2 concentrations around 400 ppm. If we are to use the Pliocene as a palaeoclimate analogue for our warmer future, it is important to consider the drivers of Pliocene climate change as well as its comparable large-scale climate features.

We implement a novel, simple linear factorisation method to assess the relative influence of CO_2 forcing in Pliocene climate change compared to non-CO_2 forcings such as changes to ice sheets, orography and vegetation. Outputs of this method are termed "FCO_2" and reflect the relative influence of CO_2, where 1 represents wholly dominant CO_2 forcing and 0 represents wholly dominant non-CO_2 forcing.

The accuracy of the FCO_2 method is evidenced by comparison to an energy balance analysis using a method previous used in Pliocene climate research, and the energy balance analysis also adds nuance to the FCO_2 results and highlights feedbacks that arise from CO_2 forcing.

We apply the FCO_2 method to seven models from the PlioMIP2 ensemble (CCSM4-UoT, CESM2, COSMOS, HadCM3, IPSLCM5A2, MIROC4m and NorESM1-F) which are found to be representative of the ensemble in terms of the modelled climate sensitivity and global mean surface air temperature anomaly.

CO_2 forcing is found to be the most important driver of surface air temperature change in six of the seven models (global mean FCO_2 of ensemble = 0.56), and five of the seven models for sea surface temperature (global mean FCO_2 of ensemble = 0.56). CO_2 forcing is also the most important driver for precipitation change (global mean FCO_2 of ensemble = 0.51), but spatial patterns in precipitation change are predominantly driven by non-CO_2 forcings and the effects of these must not be overlooked.

CO_2 forcing being the most important driver of change in the climate variables considered here suggests that the Pliocene is a relevant analogue for our warmer future, but attention must also be paid to the significant effects of non-CO_2 forcing in the Pliocene which may be less analogous to

the present and near-term future.

Our results also have implications for the interpretation of Pliocene proxy data and data-model comparison. For example, by assessing FCO_2 in regions with large data-model discord it could become possible to highlight where the implementation of boundary conditions is largely responsible for the discord and, hence, where model boundary conditions should be modified. Given the spatial and latitudinal patterns seen in the FCO_2 results, it may also be possible to suggest new sites from which additional proxy data would be most useful.

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