How warm was climate over the Phanerozoic and why?

BENJAMIN J. W. MILLS[1], ALEXANDER J. KRAUSE[1], CHRISTOPHER R. SCOTESE[2], DANIEL J. HILL[1], GRAHAM A. SHIELDS[3] & TIMOTHY M. LENTON[4].

[1]School of Earth and Environment, University of Leeds, Leeds LS2 9JT, UK.
[2]Department of Earth and Planetary Sciences, Northwestern University, Evanston, IL, 60201, USA.
[3]Department of Earth Sciences, University College London, London WC1E 6BT, UK.
[4]Global Systems Institute, University of Exeter, Exeter EX4 4QE, UK.

The current cold climate state is unusual in terms of the Phanerozoic Eon (the last 540 Million years). Earth has hosted ice caps at the poles for less than a quarter of this time, indicating that the climate was generally warmer than today. These observations are backed up by numerous geochemical methods for interpreting Earth's ancient temperature, although obtaining a clear signal of previous global temperatures is difficult.

Expanding on recent work[1], we compile global temperature estimates, including novel methods, to create a combined global temperature record for the Phanerozoic, and compare this to the complete proxy record for CO_2 concentrations. This comparison shows a clear link between surface temperature and CO_2 concentration over the ~400 million years for which there is reasonable data coverage, and implies a long-term climate sensitivity of around 5K.

Understanding whether an ancient warm climate state is the result of changes to CO_2 inputs or outputs is critical, as this determines the total carbon throughput of the system, and thus sets critical parameters such as global NPP. We therefore investigate the ability of long-term biogeochemical models to reconstruct the known variations in CO_2 and temperature alongside the behaviour of multiple independent geochemical isotope proxies, in order to reconcile input-driven and output-driven warm states.

1. B.J.W. Mills et al. *Gondwana Research* **67,** 172-186 (2019).