

Fig. 6. Global deep ocean $\delta^{18}\text{O}$. Black line: Westerhold *et al.* (2020)¹ data in 5 kyr bins until 34 MyBP and subsequently 2 kyr bins. Green line: Zachos *et al.* (2001) data at 1 Myr resolution. Lower left: velocity² of Indian tectonic plate. PETM = Paleocene Eocene Thermal Maximum; EECO = Early Eocene Climatic Optimum; Oi-1 marks the transition to glaciated Antarctica; MCO = Miocene Climatic Optimum; NAIP = North Atlantic Igneous Province.

Global Warming in the Pipeline

19 May 2023

James Hansen

Sorry to be slow in revising “Global Warming in the Pipeline.” It became apparent that looking at the whole Cenozoic era (past 66 million years) allowed the most persuasive case of where the planet is headed with today’s human-made climate forcings. With the help of Makiko Sato and Isabelle Sangha, I added a section on the Cenozoic, now perhaps the most informative part of the paper. For example, the present greenhouse gas forcing is 70% of the forcing that made Earth’s temperature in the Early Eocene Climatic Optimum at least +13°C relative to preindustrial temperature.

We are sending the paper today to the non-local co-authors and putting it on arXiv. It will likely take a couple of weeks for co-authors to review it, so there is the opportunity for others to make suggestions in the meantime, which we would welcome. I will ask the co-authors not to discuss the paper with the media until it is submitted, accepted, and is near publication.

The Cenozoic analysis is simple. The essential assumption is that there are 60 m of sea level in the Greenland and Antarctic ice sheets between today and an ice-free planet and an additional 120 m of sea level between today and the last glacial maximum. Sea level change is assumed to be linear in the oxygen isotope $\delta^{18}\text{O}$ between today and either of those two states. Temperatures and sea level deduced from ocean core $\delta^{18}\text{O}$ agree well with available independent data (Figs. 9 and S6).

The draft paper is available [here](#). We will resume monthly communications on global temperature next month and deal with a backlog of other communications.

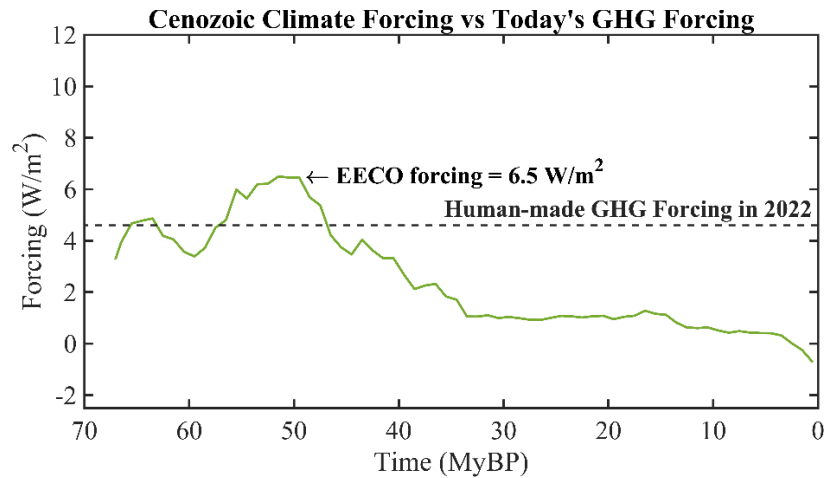


Fig. 24. Forcing required to yield Cenozoic temperature for today's solar irradiance, compared with human-made GHG forcing in 2022.

¹ Westerhold T, Marwan N, Drury AJ *et al.* [An astronomically dated record of Earth's climate and its predictability over the last 66 million years](#). *Science* 2020;**369**:1383-7

² Yatheesh V, Dymant J., Bhattacharya GC *et al.* [Detailed structure and plate reconstructions of the central Indian Ocean between 83.0 and 42.5 Ma \(chrons 34 and 20\)](#). *J Geophys Res: Solid Earth* 2020,**124**:4303-4322