Clim. Past Discuss.,
https://doi.org/10.5194/cp-2018-149-RC1, 2019

Climate of the Past Discussions

Interactive comment on "Simulating the Climate Response to Atmospheric Oxygen Variability in the Phanerozoic" *by* David C. Wade et al.

Kasting (Referee)

jfk4@psu.edu

Received and published: 10 January 2019

This paper describes an exhaustive study of the effects of changing pO2 on Phanerozoic climates. The calculations are carried out with two different state-of-the-art climate models, one of which is an Earth system model that includes coupling between the atmosphere and the biota (forests in particular). This paper responds to a disagreement between the original 3-D climate simulations by Poulsen et al. (2015) and subsequent 1-D simulations by Goldblatt (2016) and Payne et al. (2016) (the latter of which is my own research group). The Poulsen et al. model predicted that higher pO2 leads to lower surface temperatures; the two 1-D models predicted just the opposite. The new paper basically agrees with the 1-D models, i.e., high pO2 leads to higher surface temperatures. But the results are more complicated. High pO2 can actually lead to

lower surface temperature when the starting state is a warm climate. In general, the calculations seem to be well done, and the results are well described. I have a few minor comments below. But this paper should be useful in close to its present form. The basic conclusion, which is restated in point 4 below, is that changes in pO2 are secondary drivers of Phanerozoic climate. The main driver is changes in pCO2, and also in solar luminosity, which is not mentioned too many times explicitly but which is implicit in the calculations.

1. (p. 3, l. 2) 'Indeed, there is support for elevated O2 by carbon isotope measurements (Beerling et al., 2002).'

–Elevated O2 during what time period?

2. (p. 9, l. 1) 'Proxy data for the Maastrichtian was obtained..'

–Proxy data..were obtained. ('Data' is plural.) This same mistake is found elsewhere.

3. (p. 19, l. 18) 'The changes in terrestrial carbon storage are equivalent to 56% of the atmospheric CO2 content in the Asselian and 16% in the Wuchiapingian which suggests that pO2 induced Earth system feedbacks could have significant impacts on atmospheric pCO2.'

–No, I don't buy this argument. Think of the numbers and the relevant time scales. Today, the atmospheric CO2 reservoir is about 1/60th the size of the dissolved inorganic carbon (DIC) reservoir in the ocean. On long time scales (> 0.5 m.y.), what changes is the total CO2 content of the combined atmosphere-ocean system. Sequestering 56% of atmospheric CO2 in forests is a trivial change to this combined reservoir. Forests can only directly affect atmospheric CO2 if they are chopped down or regrown on very short time scales, less than the time required for the atmosphere and ocean to equilibrate.

4. (p. 27, l. 11) 'pO2 therefore remains a secondary contribution to climatic variability in the Phanerozoic but most likely to be important during the Permian.'

–The first part of this statement is essentially what we said in the conclusion section of Payne et al. (2016): 'Given the large uncertainties in past levels of both O2 and CO2, we agree with Berner [2006] that Phanerozoic climate has been driven largely by changes in atmospheric CO2 and solar luminosity, coupled with changes in continental geography.' So, we are in fundamental agreement on this question.

5. (p. 27, l. 17) 'If pCO2 and pO2 are intimately linked such that cooler climates tends to increase pO2 this would suggest that pO2 responses have helped to prevent Snowball Earth initiation in the Phanerozoic.'

–Cool! I like this result. The effect of pO2 on climate is not strong, but it may help to prevent Phanerozoic Snowball Earth events.

Jim Kasting Penn State

Interactive comment on Clim. Past Discuss., https://doi.org/10.5194/cp-2018-149, 2018.