Climate of the Past Discussions

Clim. Past Discuss., referee comment RC3
https://doi.org/10.5194/cp-2022-46-RC3, 2022

Comment on cp-2022-46

Anonymous Referee #3

Referee comment on "Impact of iron fertilisation on atmospheric CO_2 during the last glaciation" by Himadri Saini et al., Clim. Past Discuss., https://doi.org/10.5194/cp-2022-46-RC3, 2022

Saini et al. present an interesting modeling study in which the authors investigate the response of the global marine ecosystem to an increase in the supply of dust - and by inference Fe – to the ocean surface at the last glacial inception, 70 ka. The scarcity of Fe is indeed considered to limit biological/export production in large swaths of the world ocean, in particular in polar regions today and in the past.

Their sensitivity experiments indicate that increased availability of Fe conduces to a strengthening of the marine biological carbon pump, which contributes to sequester C in the ocean interior, decreasing atmospheric CO2 concentrations (4-16 ppm). What's more, their model outputs suggest that most of the action is centered in the Southern Ocean (SO). Furthermore, the experiments suggest that the strengthening of the biological carbon pump consequent to Fe fertilization rapidly saturates as a result of complex interactions involving downstream effects, to me, the most interesting conclusion of the work.

The study is certainly interesting and worth publishing, yet I feel is it not sufficiently anchored in available palaeoceanographic records. High-resolution EP reconstructions across the MIS4/MIS5 interval are arguably limited, yet available records are often at odds with the model outputs - notably in the subsarctic North Pacific and the SO - which warrants a much more detailed/nuanced discussion. What's more, given the sensitivity of the SO to increased supply of dust/Fe, I would urge the authors to distinguish the SAZ and AZ, as these regions have responded very differently in terms of EP.

Please find my comments below, which I hope the authors will find constructive.

l. 39 - Interestingly, d13CO2 data suggest that the drop in atmospheric CO2 centered around 70 kyrs was likely related to a combination of factors including enhanced C storage in the ocean subsurface and decreased air-sea gas exchange in the SO (Eggleston et al., 2016; Menking et al., 2022).

l. 49-51 & 227-233 - I find this argument somewhat misleading. I would encourage the authors to discuss the SAZ and AZ separately, as mentioned above. Palaeoceanographic data indeed suggest an increase in EP in the SAZ at the MIS4/5 transition (e.g. Martinez-Garcia et al., 2011/2014; Lamy et al., 2014; Thöle et al., 2019; Amsler et al., 2022). However, palaeoceanographic records from the AZ suggest a simultaneous decrease in EP (e.g. Anderson et al., 2009; Jaccard et al., 2013; Studer et al., 2015; Thöle et al., 2019; Amsler et al., 2022).

Fig. 1 – maybe the authors could include ice core d13CO2 data (Eggleston et al., 2016; Menking et al., 2022) in the figure?

l. 92/115 & Table 1 – could the authors provide some more context related to the dust flux estimates used in the simulations? The reason I'm asking is that the reconstructed dust/Fe fluxes to Antarctica based on ice cores measurements are much larger when compared to Fe fluxes quantified based on marine sediments. These differences may relate to different transport pathways and/or atmospheric dynamics over the SO and Antarctica during the last ice age.

l. 150 – is the AMOC both weaker and significantly shallower in the 70 kyr simulation?

l. 154-156 & 234-236 - Interesting… but these observations seem at odds with paleoceanographic reconstructions, which generally show a decrease in EP at the MIS4/MIS5 transition (e.g. Jaccard et al., 2005; Gebhardt, et al., 2008). These observations are consistent with paleoceanographic reconstructions spanning the last deglaciation, which consistently indicate lower EP during the LGM, even though Fe supply might have been higher then (e.g. Kohfeld & Chase, 2011 for a review)

l. 153 – I'm not sure to understand what is meant by "strength of the deep water masses"?

l. 156 – what do you mean by "general phytoplankton"?

l. 157-163 – again, I would recommend discussing the SAZ and AZ separately.

l. 168-169 – why is that? Are ecosystems rapidly becoming N-limited as Fe availability increases?

l. 178-182 & 283 – This is not really surprising as EP was likely limited by the scarcity of N (or P) outside of the SO during the last ice age.

l. 179-188 – this conclusion is at odds with existing paleoceanographic reconstructions. Data suggest that the SAZ was particularly responsive to aeolian Fe supply, while ecosystems in the AZ mainly responded to (micro)nutrient supply from below via upwelling and vertical mixing (e.g. Jaccard et al., 2013). Moreover, N-isotope data suggest that the relative uptake of nitrate increased both in the SAZ (Martinez-Garcia et al., 2014) and the AZ (Studer et al., 2015; Ai et al., 2020) at the MIS4/MIS5 transition.

l. 211 - does the reduction in terrestrial vegetation and soil moisture imply more dust production (positive feedback)?

l. 247 – these observations would be consistent with a general decrease in deep ocean oxygenation at the onset of MIS4 (e.g. Jaccard et al., 2016; Amsler et al., 2022).