

LIG is a poor analog for future warming, when it comes to the Southern Ocean C cycle

Anonymous Referee #1

Referee comment on "Marine carbon cycle response to a warmer Southern Ocean: the case of the last interglacial" by Dipayan Choudhury et al., Clim. Past Discuss., <https://doi.org/10.5194/cp-2021-98-RC1>, 2021

This paper analyses the Southern Ocean carbon cycle from simulations of the Australian Community Climate and Earth System Simulator Earth System Model, ACCESS-ESM1.5, which has been applied for the PMIP4 scenario lig127k on the Last Interglacial (LIG). The argument is made that since this was the warmest interglacial of the last 1 million year it might serve as an analog for changes which might be expected in the future due to anthropogenically caused global warming.

The methods and results are well written, and the figure are very informative. I suggest some improvement in the introduction during the framing of the research question (see details below).

However, my major point is that I have some difficulties with this suggested analogy of the Last Interglacial with future warming. The analysis presented here shows that during the simulated LIG the westerly winds have been shifted equatorwards resulting in weakened winds south of 50°S. This process is then responsible for different upwelling pattern and is important for quite a bit of changes in the Southern Ocean carbon cycle. For the future warming, it is now anticipated that westerly winds will shift polewards and get stronger, thus the opposite of what has been found for the LIG. I therefore strongly suggest to reframe the article in a way that its interpretation is largely restricted to the LIG. This reframing probably includes a change in the title. I would even go so far in pointing out in the discussion, that due to these shifts in wind pattern found here the LIG is no good analog for what to expect from future warming for the Southern Ocean carbon cycle. The reason for these differences in winds patterns are suggested to be due the the changes in orbital parameters (which seems to make sense), and this shows that past analogies for the future are often problematic.

Details:

- lines 18-19: „of which 40% has been attributed to the SO“ It is not clear on what this

40% is related to since before it is said "Both land and ocean act as sink". Does it refer only to the ocean part? And you probably mean that land and ocean EACH absorbs 25% of the anthropogenic emissions. You might furthermore consider citing the most recent version of the global carbon project here, thus „Friedlingstein et al 2020" (instead of 2019) <https://doi.org/10.5194/essd-12-3269-2020>â□"

- line 35: „The Last Interglacial (LIG, 129-115 thousand years ago, ka) was the warmest interglacial of the last million years". This statement is problematic, since the paper PAGES2016 cited here analyse only the last 800 kyr.

- line 36ff: „The warmer climate at the LIG is primarily attributed to a stronger northern hemispheric summer insolation (Laskar et al., 2004) owing to the orbital configuration of higher eccentricity and obliquity (Berger, 1978), rather than higher greenhouse gas concentrations as projected for the future". The role of orbital forcing vs greenhouse gases on temperature have been analysed in detail in Yin and Berger 2012 DOI 10.1007/s00382-011-1013-5.

- line 38: „The LIG is associated with sea levels 6-9 m higher than pre-industrial (PI) (Dutton et al., 2015)". This knowledge on LIG sea level has recently been revised downward, please reframe according to Dyer et al (2021) <https://doi.org/10.1073/pnas.2026839118>.

- lines 91-94: Two different DIC tracers. I cannot remember that one of the tracers (the one not being constant at 280 ppm) is ever mentioned again. If so, it can be deleted here. You should also mention here, that since atmospheric CO₂ is prescribed this approach misses the feedbacks which are related to CO₂ in/outgassing. Also, absolute CO₂ fluxes are biased since the C cycle is simplified by this fixed CO₂, which is acceptable for these interglacial conditions, but nevertheless might introduce a bias.

- line 110: $\gamma_{\text{SST}} = 0.0423^{\circ}\text{C}^{-1}$ is called the Revelle factor. I am completely lost here. For me, the Revelle factor R is the relative change in atm CO₂ over the relative change in DIC (unitless) $R = \Delta(\text{CO}_2)/\text{CO}_2 / \Delta(\text{DIC})/\text{DIC}$, eg. Egleston et al (2010) doi:10.1029/2008GB003407, while you here describe some temperature-dependency. Please revise, or explain.

- line 19: weaker and stronger upwelling: by how much stronger or weaker?

- Fig 3g: xaxis title is missing