

This paper uses historical climate reanalysis, paleoclimate simulations and a geochemical weathering model to explore the effect of ENSO on silicate weathering, aiming to test the idea that Pliocene permanent El Nino conditions led to changes in Earth's surface weatherability, such that removal of these conditions may have contributed to long-term CO₂ removal and cooling. This is an interesting idea, and the relatively minor effect that is found seems reasonable.

I think the paper can be published with some minor revision. My main points are:

- While the text starts brilliantly, the discussion and conclusions need much more proofreading. I found a lot of grammatical issues in this section.

We carefully proofread these sections. A significant part of these sections was also rewritten.

- Section 3.2 which introduces the climate modelling strategy should be explained more clearly. It is really tough to get through at the moment. I would recommend a paragraph at the start of this section clearly setting out what they ultimately want to simulate and how they will do it, before going into the details.

We rewrote section 3.2 to keep the focus on the slab ocean simulations, that are what we ultimately want to simulate. Most of the former section is now in Appendix B. We hope that the text gained in readability.

Minor comments:

- Given that this is a more interdisciplinary paper which focuses mostly on chemical weathering, the authors might consider a higher level explanation of the Walker circulation, Bjerknes feedback and southern oscillation.

We added, in the introduction, a sentence shortly explaining what is the Walker circulation (lines 30–32), and another for the Bjerknes feedback (lines 33–34), at the first mention of both.

- Biotic weathering enhancement may play a role here? Plants are very dependent on water. Could the authors acknowledge this? Does their modelling hint at how strong this effect might be?

While plants are not explicitly represented in the weathering model, their effect on weathering (at least a part of it) is likely implicitly incorporated in its parameters, because of the parameter optimization to fit the data. For instance, the parameter k_w describes the sensitivity of weathering rate to runoff rate, and the parameter k_d is also linked to the sensitivity of weathering rate to climatic conditions. The model “learned” the sensitivity of weathering rate to runoff through measurements of weathering in natural systems (rivers). Those systems largely exhibit higher weathering rates with higher runoff, and part of it is because of biotic weathering enhancement (in addition to reactive-transport considerations). Therefore, this process, present in the data, was integrated in the parameters that are optimized to fit the data.

What the weathering model does not represent is the direct effect on weathering of plant fertilization by CO₂ (like increased GPP and production of organic acids), for the simple reason that all the data were collected at current (late 20th/early 21st century) atmospheric CO₂. We, however, want to stress that the

effects of plant fertilization by CO₂ on evapotranspiration, and hence runoff, is represented by the land module (CLM) of the CESM climate model, so at least a part of the overall “CO₂ fertilization effect” is implicitly integrated in GEOCLIM.

Nonetheless, because of this implicit integration rather than an explicit representation, there is no way to determine how strong the effect of biotic weathering enhancement is.

We briefly acknowledged this implicit consideration of vegetation in section 2.1, describing the weathering model (lines 112–115).

- Line 205: “we apply the method of Burls and Fedorov (2014) to seeks to reproduce Pliocene SST.” A typo here?

Done (now line 439, in Appendix B1)

- First part of section 3.2 and figure 7 could be explained more clearly. It is not clear at the start of this section what the motivation is for producing these different sets of runs with the full or tropical-only SSTs, and what the comparison in figure 7 is really showing. Some introductory text would be useful.

Section 3.2 was rewritten, it now solely focus on the coupled ocean-atmosphere simulation and the slab ocean simulations (the intermediate simulations needed to design the slab ocean ones are presented in Appendix B). Similarly Fig. 4 (former Fig. 7) now shows the SST from the coupled ocean-atmosphere simulation and the SST-like field (skin temperature) of the slab ocean simulations. We hope that the two aims of Fig. 4: comparing the coupled ocean-atmosphere SST to the SST proxy, and assessing how well the slab simulations reproduce the coupled simulations SST, are more evident in the text (lines 227–237) and in Fig. 4 caption.

- Line 367 “If carbon cycle was left to reach balance”, missing word? E.g. “the carbon cycle” And “CO₂ would decrease until temperature is back around pre-industrial one” perhaps change to “CO₂ would decrease until temperature returned to the pre-industrial value”

This is a good suggestion. This sentence was however modified following comments of Reviewer #3. It is now “If **the** carbon cycle was left to reach balance, with pre-industrial degassing, CO₂ would decrease, but it is not possible to determine what would be the equilibrium temperature.” (lines 355–356).

- Line 377: “meridional and tropical zonal gradient of temperature” change to “meridional and tropical zonal temperature gradients”?

Done (now line 365)

- Line 394: “the results agree on a moderate warming effect of permanent El Niño”. It would be useful to re-state the actual temperature increase here. Also, this is described as minor in the abstract and I would agree. Moderate, in the context of Pliocene warmth, would probably be more like 1C?

We replaced “moderate” by “modest” and state the value of the warming (0.4°C) (now line 384). We also added the sentence “Though its amplitude is small, this warming is robust across all weathering model parameterizations” (lines 385–386).

- Line 396: “that is ~ 2.5 C than pre-industrial”, missing word “warmer”?

Indeed. This was corrected (now line 387)

- Line 398: “If flatter meridional temperature gradient”, missing word “the”?

We replaced the sentence by “if a flatter meridional temperature gradient” (now line 389)

- Line 400: “This raise the question”, typo “raises”

Corrected (now line 391)

- Line 418: “the difference of a permanent El Niño climate state on global silicate weathering”. Suggest change “on” for “for”

This sentence was removed when rewriting the conclusion.

- Line 421: “particularly on tropical weathering hotspots”, change “on” to “in”

Done (now line 414)