Review of The Earth system model CLIMBER-X v1.0 – Part 2: The global carbon cycle

By Matteo Willeit et al.

In this paper, Willeit et al detail the implementation of the carbon cycle in the new CLIMBER-X model. They explain the choices made in the atmosphere, ocean, land, and sediments and present results for the modern and historical periods, comparing with existing data. CLIMBER-X is a very promising model. Its rapidity is an asset, as well as the inclusion of many processes relevant for long-time scales, making it a very comprehensive model and a very good alternative to box models to study changes over periods longer than a few thousand years and up to a million years, a deed that more complex models are not capable of.

The paper is well organised and the model description and results well presented. However, the result section remains very descriptive, and it would greatly improve the paper to have more explanation and discussion on differences between model and data, and their potential causes. The simplifications and low resolution of CLIMBER-X are necessary to make it very efficient, but it is also important to have an idea of the limitations, their causes, and the possibilities for future improvements.

l. 29. There is a typo problem in the reference to "Raymo M.E. and Ruddiman W.F., 1992", it should read: "Raymo and Ruddiman, 1992"

Figure 1 (and Figure 3). For the molecules, could you put the numbers of atoms in subscript, such as for CO2, O3… -> CO_2, O_3…

l.111-112. Why have you modified the stochiometric ratio?

l. 127-128. Could you specify the variables involved for photosynthesis?

l.142. in "The rubisco-limited photosynthesis rate the version of PALADYN model": is there a missing "in"? -> The rubisco-limited photosynthesis rate **in** the version of PALADYN model

l. 278-280. what is the impact of the simplification?

Section4.1. When discussing the global values of Table 1 or 2 it would be useful to give the numbers in the text.

Table 1. The legend could be slightly expanded, e.g. Global values of the main ocean biogeochemical variables for the present-day.

l. 299. which models from CMIP6 are included?

l. 314-315. Why is the NPP in the Southern Ocean lower in climber-X ?

Figure 6. The zonal profiles are presumably global, are there differences between basins?

Figure 7. Since P is not limiting anywhere, could it be removed from the colorbar?

Figure 8. a,b,c,d are missing. Dust deposition is high everywhere in Africa in CLIMBER-X, especially in the southern part of Africa contrary to other models where the values are lower in the southern part compared to the northern part of Africa: why?

Figure 9. You could change the x and y labels, e.g. “modelled dust deposition” or “dust deposition in the model”, and for the y axis: “observed dust deposition” or “dust deposition in observations”.

l.334-l.335 what is the reference for the CMIP6 surface iron concentration? Could it be added to Figure 10?

l. 351-353 and Table 1. The surface silicate values are much higher than in the observation: why?

l.364-366. There are large biases in the $\delta^{13}C$ distribution: why?

l. 368-369. How are the winds in the model? Are they indeed underestimated? If the winds were higher and the mixing enhanced, would it not change also the nutrient distribution, which seems relatively good?

What is the explanation for the biases in the Southern Ocean for $\delta^{13}C$ and $\Delta^{14}C$?

l. 371 Why is there too little $CaCO_3$ in the Pacific?

l. 373 (and l.377) The table is referred to as “Tab.1” but before in the text (l.304) it has been referred to as “Table1”.

l.374-375 Why is the opal content in sediments overestimated?

Table 2. As for table 1, the legend could be expanded, e.g. Global values for the main variables of the land carbon cycle.

l.385 Table 2 is referred to as “Tab.2”, but “Table2” l.383.

l. 390-393. In Table 2, the data for soil carbon indicate a mean value of 4000 GtC , while CLIMBER-X simulates 2187 GtC, this seems like a large difference, could you discuss it?

l.395 Table 2 indicate that the carbon stock in permafrost has a mean value of 1300 Gtc, but CLIMBER-X simulated only 861 GtC: why is there so little carbon in permafrost? Is the permafrost area not large enough or the carbon storage too small? Are there missing processes? Or is it due to climate biases?

L419. Why is the silicate weathering low compared to data while the carbonate weathering is relatively high?

Section 4.2. Does it make a difference if you simulate the evolution during the historical period in the closed or open configurations? Presumably the impact of long-term processes on such a short period should be very limited but have you tried to simulate both to test this?

Conclusions. Could you discuss the biases, their potential causes, and what could be done to improve the model?