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Interactive comment on "The influence of the ocean circulation state on ocean carbon storage and CO_2 drawdown potential in an Earth system model" *by* Malin Ödalen et al.

Anonymous Referee #1

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Review of Odalen et al. "The influence of the ocean circulation state on ocean carbon storage and CO2 drawdown potential in an Earth system model"

IMPORTANCE: Earth system models are essential tools for understanding of climate-carbon linkages, both for ocean carbon uptake in the past, and for understanding how future carbon emissions will translate into ocean carbon uptake and global temperature change. Models that conduct these experiments are generally tuned to modern conditions, but this tuning process can result in several initial states (with different initial ocean carbon storage), which may affect the model-ocean's capacity to take up carbon.

SUMMARY: The purpose of this study is to quantify the influence of the initial, equi-

librium state of 12 different model versions (in which vertical and horizontal diffusivity, atm diffusivity, and wind stress were modified) on their initial ocean C storage and CO2 uptake potential. Simulations with higher initial overturning rates tend to have lower total initial ocean C storage, largely attributed to reduced solubility and soft tissue pumps (because of shorter residence times of nutrients at the surface). In contrast, simulations with lower overturning rates (from low wind stress and reduced vertical diffusivity) tend to have higher global nutrient utilization (P*), higher initial carbon storage, and lower C uptake capacity. The initial state of nutrient utilization efficiency (P*) is a strong determiner of CO2 uptake capacity and varies by 50 ppm between initial model states, with versions with low initial efficiencies having higher uptake capacities. Different initial average global ocean temperatures can result in a ∼25-30ppm differences in initial pCO2atm (comparable magnitude to glacial-interglacial effects of temperature-dependent solubility); colder simulations with higher C storage due to saturation responses tend to have lower drawdown potentials.

REVIEW: This is going to be an important paper for highlighting the impact of initial equilibrium state – both for modern and LGM conditions – on modeled ocean capacity to take up carbon, and I look forward to seeing it published. However, at the moment, there is a lot going on in this paper... (1) One major concern is its length and level of detail which dilutes its most important points. On the one hand, I appreciate that the authors are attempting to describe a complex system clearly and completely. The background and methods sections do provide thorough definitions of the different carbon pumps, controls on alkalinity, and nutrient utilization efficiency, as well as a very detailed description of how the different carbon components are estimated in the model. At the same, all these components have been defined previously, so the paper might be shortened by placing large chunks into an appendix. The results section is similarly very wordy; it mixes methods, results, and discussion together; many points that take multiple paragraphs to make could be simplified to 1-2 sentences. I suggest a thorough attempt to go through this paper and streamline the writing. As one example, the entire top of page 13 describes how figure 2 will be put together, with only two half-sentences (regarding ensemble range of pH and pCO2atm) that describe results. Some additional examples (there are more): LN 12-17 on pg 14 – this section does not describe any results presented. Pg 15 LN 18-31 – the average global temperature of simulations has a range of 2.3-4.9°C, which results in a range in delta pCO2atm from Csat of -16 – +17 ppm or -13 to +12ppm (depending upon how the calculation is made). Glacial-interglacial implications belong in discussion.

(2) Figure 2 summarizes all results, but its current presentation makes it very difficult to distill anything more than the general magnitudes. I suggest (1) providing the labels of the sensitivity experiments and sorting them somehow, perhaps by the anticipated magnitude of total effects, from largest to smallest; (2) separating this figure in to 3-4 panels: biological, residual, solubility, and total (indicating on the total plot the largest contributor to the total change).

(3) Pg 9 Methods: Are the ranges for vertical diffusivity, wind stress, horizontal diffusivity, etc that are used in the sensitivity experiments comparable to the range of values that are normally used to tune models? Would be useful to provide this information here, so that the reader can assess whether your sensitivity experiments represent values that might normally be used.

MINOR POINTS:

Pg. 9 LN 13 – confusing – do you mean that you hold ALK and P constant in your experiments? Pg 9 LN 14-20 – Upon first reading, it was unclear what delta (ïĄĎ) represents. Please define specifically that you are comparing the carbon estimates from PIES278 with equilibrium values from SE(n). Pg 9 and then again on Pg 10 – when you describe the experiments in which you have implemented artificially fast gas exchange to remove Cdis, please identify this experiment with its number listed in Table 1. Pg 14 LN 27 – here and throughout this discussion, the authors indicate that horizontal diffusivity affects Csat and Cres more than Csoft, but the more obvious result is the minimal impact on deltaTC overall. This is worth noting. Pg 15 LN 28 –

"In ensemble members in which horizontal diffusivity in the ocean is changed, _Csat is larger than _Csoft." When horizontal diffusivity is reduced or increased? Specify that it is larger whether horizontal diffusivity is increased or decreased. It is near impossible from Figure 2 to discern this. Pg 15 ln 29-37 – estimating the implications of the relationship between Csat and aveT for the glacial ocean is a point for discussion, not results Pg 20 LN 17 – Technically the authors have not shown the role of "AMOC strength," which refers specifically to the Atlantic overturning limb. The plots calculate the difference between northern (Atlantic) and southern source components and thus combine the roles of the no

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