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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 #3**

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The authors used previously published theoretical frameworks to interpret their sensitivity runs from an Earth system model of intermediate complexity. They first explored the oceanic storage of DIC equilibrated with a preindustrial atmospheric CO2 condition by changing ocean circulation patterns. Then the authors used the preindustrial equilibrium states as initial conditions to the experiment where they maximized the nutrient utilization efficiency (i.e., all of PO4 is utilized by biology). Their major conclusion is that the drawdown potential of atmospheric CO2 differs with different initial states, i.e., different circulation patterns. This could explain earlier model intercomparison studies where atmospheric CO2 response to the same perturbation shows a large spread among models.



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Discussion paper

Such model sensitivity experiments and extensive analyses using an Earth system model are unprecedented and have a potential to improve our understanding of the past changes in the carbon cycle. However, the present manuscript has some parts that are not clear, and also lacks novelty.

The conclusion that the oceanic storage of DIC and the drawdown of atmospheric CO2 in response to nutrient depletion all depend on the ocean circulation patterns (including the overturning strengths of NADW and AABW, and the volume fraction of the ocean last ventilated from the North Atlantic vs. Southern Ocean) is not new. The circulation effects on the ocean carbon pumps have been extensively studied using models and theoretical frameworks: the solubility pump (e.g., DeVries and Primeau, Atmospheric pCO2 sensitivity to the solubility pump: Role of the low-latitude ocean, GBC 2009), the biological pump (references already cited in the manuscript) and the disequilibrium pump (e.g. Ito and Follows, Air-sea disequilibrium of carbon dioxide enhances the biological carbon sequestration in the Southern Ocean, GBC 2013). One of the new points in this study is that the authors discussed the relative role of the three pumps in the net change of the simulated carbon cycle. But, because the forcing used to generate the different circulation patterns is arbitrary, their discussion of the relative roles does not seem very interesting. Overall, I feel that the authors need to highlight what new findings or insights this study can provide.

Fig. 10 showing the CO2 drawdown potential as a function of a change in the mean ocean temperature does not convey any messages. There seems no relationship between the two. Plus, if my reading is correct, water temperature does not control the strength/efficiency of the biological pump in the model. Therefore, there is no reason that the CO2 drawdown potential should be correlated with ocean temperature. Why don't the authors use other metrics such as the initial preformed PO4 as an X-axis instead, as was done in Marinov et al., 2008?

The way the biological pump is simulated in the model is unclear. The authors included the carbonate pump in their models and analyses (expressed as Ccarb), but there is no description on how the carbonate pump is represented in the model. For example, are the sedimentation processes included in the model? How are the production and dissolution of calcifying organisms represented in the model? How is the strength/efficiency of the carbonate pump affected by the drawdown experiment? In the drawdown experiment (specified in lines #31-33 of page #9), the remineralization length scale of sinking organic particles is made very deep (10,000m), so that "any carbon that is taken up in organic material to be highly efficiently trapped in the deep ocean and not undergo any significant remineralization". Does it mean that most of inorganic nutrient is converted to organic form and stored in the abyss without being remineralized back to inorganic form? If this is the case, then the amount of organic matter would increase substantially in the drawdown experiment, and the carbon fixed in organic material should be an important component in the mass balance equations and can't be ignored in the theoretical derivations presented in the manuscript. Likewise, the equation "Ppre=P-Preg" would be incorrect. This needs to be clarified.

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