Clim. Past Discuss., 2, S499–S502, 2006
www.clim-past-discuss.net/2/S499/2006/


Climate of the Past Discussions

CPD

2, S499–S502, 2006

Interactive Comment

# *Interactive comment on* "Glacial – interglacial atmospheric $CO_2$ change: a simple "hypsometric effect" on deep-ocean carbon sequestration?[1]" *by* L. C. Skinner

**Anonymous Referee #1**

Received and published: 25 October 2006

I was fascinated when I first read the abstract of this manuscript, because the author proposed a sensitivity of atmospheric CO2 that is exactly the opposite of what I would expect. My expectations are as follows. In a hypothetical ocean with an infinite gas exchange rate at the sea surface, the strength of the biological pump can be framed in terms of the mean preformed nutrient content of the ocean subsurface [e.g., Ito and Follows, 2005; Sigman and Boyle, 2000; Toggweiler, et al., 2003]. This parameter essentially indicates whether the nutrients held in the ocean interior were deposited there through the respiration of organic matter or instead if those nutrients were subducted

[1]Invited contribution by L. Skinner, one of the EGU Outstanding Young Scientist Award winners 2006

Full Screen / Esc

Printer-friendly Version

Interactive Discussion

Discussion Paper



EGU

with the water at the ocean surface. If the preformed nutrient content of the deep sea is low, then most of the nutrients were deposited with organic carbon, in which case $CO_2$ has been extracted from the surface ocean and atmosphere and sequestered in the deep sea; all else held constant, this would result in lower atmospheric $CO_2$. Since the preformed nutrient concentration of North Atlantic Deep Water is much lower than that of the Antarctic Bottom Water, a simple mechanism for lowering $CO_2$ during ice ages is to reduce Antarctic Bottom Water formation while maintaining North Atlantic overturning [Toggweiler, 1999]. In previous model simulations, this dynamic remains even when you allow for incomplete equilibration of $CO_2$ exchange in the polar regions.

So what dynamic has the author tapped to give the opposite effect, of lower $CO_2$ as a greater volume of the ocean is filled from the Southern Ocean? Referee 2 (whose review I have read) may have hit the nail on the head: the author may have carried out a calculation in which he effectively increases the nutrient (i.e. phosphorus) reservoir of the ocean, with the replacement of North Atlantic-sourced deep water by Southern Ocean-sourced deep water. Of course, the ocean could not have done this without an imbalance between nutrient inputs and outputs, so how could this have happened in the model? The author appears to have combined a box model with a thought experiment, which is to say, he did not just take his model and run an experiment. Rather, he appears to have changed the architecture of the model by unphysical means: he reassigned volumes of boxes, with the boxes maintaining their interglacial chemistries. The author raises the point that previous box model studies have not explored changing model architecture between interglacial and glacial states - this is a good example of why one would choose not do that.

One uncertainty I have, however, involves dissolved inorganic carbon and alkalinity. Presumably, these reservoirs were also increased when the volume ratio of NA- and SO-sourced deep waters were changed. The DIC addition would have worked to weaken the atmospheric $CO_2$ decrease associated with the nutrient reservoir change. But my instinct is that this weakening would have been a modest effect. In any case,



CPD
2, S499–S502, 2006
Interactive Comment



EGU

such alkalinity and DIC changes, applied through box volume changes, is as ad hoc as the nutrient reservoir change.

The nutrient reservoir change hypothesis was one of the first put forward for glacial/interglacial CO2 change (Broecker, 1982). The author's apparent mistake makes an interesting point about the ice age nutrient reservoir: if SO-sourced deep water has more phosphate in it and it fills the more of the ocean interior during the last ice age, then this implies more phosphate in the ocean. But the d13C of DIC in the interior, in its simplest interpretation, is a measure of preformed nutrient concentration, not the entire nutrient pool (which is the sum of preformed and regenerated nutrients). The global ocean distribution of benthic foraminiferal d13C is thus not a reliable indicator of glacial/interglacial changes in whole ocean nutrient reservoir. In any case, it was not the intention of the author to reassert the nutrient reservoir hypothesis for glacial/interglacial CO2 change.

If my understanding of what has been done in Figure 8 is correct, then this paper seems unpublishable. If this assessment is incorrect, it is at least partially due to the author's failure to describe what he has done, and the paper needs to be revised and re-reviewed.

I do not find any mitigating value in the additional experiments on increasing polar productivity and polar overturning (Figure 9). The knobs being turned here have already been explained better in previous work. The author does not link the export production and overturning changes to the changes in surface nutrient concentration that would result, which others have done and which clarify why one gets the sense of CO2 changes observed in these experiments. In the same vein, there is no attempt to compare the model output with the constraints on productivity and nutrient changes. The decrease in Southern Ocean overturning (Figure 9a) and the increase in Southern Ocean productivity (Figure 9c) cause CO2 reductions that the reviewer appropriately explains, as they have been discussed in detail in previous work. However, I am not convinced that the author understands why CO2 decreases as northern overturning is



CPD

2, S499–S502, 2006

Interactive Comment



EGU

reduced. Indeed, nothing is written about it, beyond its effect on the relative volumes of northern and southern sourced waters - I have already indicated that I think this idea is incorrect.

---

Interactive comment on Clim. Past Discuss., 2, 711, 2006.