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Interactive comment on "Deep ocean ventilation, carbon isotopes, marine sedimentation and the deglacial CO₂ rise" *by* T. Tschumi et al.

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The response to the minor comment #8 of review #1 (p. 1917, l.1–5 and p. 1917, l.14–15) has been slightly modified. The new paragraphs now read:

> "The biological pump strongly dominates the net CO_2 response subsequent to wind stress changes in our model (see also Tschumi et al. (2008)). The effect of the solubility pump is minor as simulated changes in (potential) deep ocean temperature (below 2000 meters) are ∼0.5°C at most (Table 2). This translates into a maximum effect on atmospheric CO_2 of roughly 5 ppm given the sensitivity of CO_2-solubility to temperature in seawater

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(e.g. Sigman and Boyle (2000)). On the other hand, the imposed changes in ocean ventilation have a strong impact on the marine biological carbon pumps. Enhanced (reduced) ocean ventilation implies increased (diminished) upwelling of nutrients, thus promoting (weakening) biological export from the surface.

Table 2 indicates that organic matter export diagnosed at 2 kyr after the wind stress switch scales roughly linearly with ventilation in case of the on-states (rising by 2.9% per 100-year reduction in global deep water age). The marine silica cycle reacts substantially more sensitively to the ocean ventilation changes than the organic matter cycle: Opal export at 2 kyr increases by 8.6% upon a 100 year-reduction in global deep water age and decreases by 7.6% per 100 year-increase. The full time-dependent response in POC and opal export is shown in Fig. 6c and 6d.

Note that the efficiency of the soft-tissue pump P*, defined here as the ratio between regenerated and total phosphate in the deep ocean (Ito and Follows (2005)), behaves conversely, i.e. P* increases as export production decreases parallel to slowed ventilation (Table 3). As long as NADW formation is active, a linear relation is found between atmospheric CO_2 and P* (Figure 8), which reflects a maximum impact of the biological pumps of 336 ppm at full efficiency. This value is close to the 312 ppm found by Ito and Follows (2005) on the basis of a simple theory combining the mass balance for carbon and nutrients in the ocean-atmosphere system and the linearization of carbonate chemistry. The relatively close correspondence between this theoretical value and the sensitivity of atmospheric CO_2 to P* found in our experiments indicates that the predominant part of the simulated CO_2 response to changes in SO deep water formation is due to changes in the biological pump efficiency.

The simulated relation between atmospheric CO_2 and the soft-tissue pump efficiency P* deviates from linearity as soon as NADW formation shuts down in response to weak SO winds (Figure 8). Thus, the anomalous CO_2 reduction of ∼10 ppm due to the AMOC collapse cannot be explained with changes in the biological carbon pumps. Further, the absence of a drop in simulated global mean deep water temperature and in the global rain ratio (Table 2) seems to preclude a dominant role of the solubility and carbonate pumps. We conjecture that the simulated anomalous CO_2 drop in response to collapsed AMOC results primarily from an increase in the deep water DIC disequilibrium component (Marinov et al. (2008)).

The simulated interplay between ocean ventilation, marine carbon cycling and atmospheric CO_2 displayed in our wind stress-experiments is in good qualitative agreement with the results of Schmittner et al. (2007) who find a similar response in marine biogeochemistry to changes in the global strength of wind stress. However, the effect of AMOC shutdowns on marine carbon cycling in our experiments cannot be readily compared with the corresponding results of Schmittner et al. (2007) since AMOC is suppressed by freshwater forcing in the North Atlantic in their experiments rather than by weak SO winds."

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