

Interactive comment on “Burial-nutrient feedbacks amplify the sensitivity of carbon dioxide to changes in organic matter remineralisation” by R. Roth et al.

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General comments

The paper describes experiments with the Bern3D model in which the remineralization depth is shifted upwards and downwards by 25 m intervals. This is meant to represent temperature dependent remineralization in a warming/cooling ocean on glacial/interglacial time scales. The model is integrated for 100 to 200 kyr either in 'open system' mode (with an active sediment) or in 'closed system' mode (without an active sediment). Atmospheric pCO₂ and δ¹³C are analyzed from these experiment and the main finding of the study is that pCO₂ changes are, on longer time scales than 1000

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yr, significantly higher when nutrient deposition in the sediment is taken into account. This assumes that weathering fluxes are constant in time. The authors provide also a value of change in atmospheric pCO₂ per metre shift of the remineralization profile. As such it provides a valuable contribution to the impact of changes in remineralization of organic matter on the carbon cycle, in particular regarding glacial/interglacial time scales.

The paper is generally well written and figures and tables are well thought out. At some points it could be a bit more precise, and the guidance of the reader could be improved. Below are more specific comments that hopefully will improve the paper.

Specific comments

General: POC/POM/POP are used, I suggest to stick to one name (POM seems most frequent)

you do not discuss changes in surface alkalinity due to reduced productivity in the open system experiments. Is this because you found that it is irrelevant?

Title: I suggest to state that atmospheric carbon dioxide is meant

Abstract p474 l3: I suggest to change 'provide a positive feedback under climate change' to sth like 'provide a positive feedback mechanism with atmospheric CO₂ and hence climate change'

l5 CO₂ -> atmospheric CO₂

l5/6 it is stated that the response of tracer fields for which observations and paleo proxies exist is analyzed, but there is never a comparison with proxies in the ms. nor are the proxies simulated that are mentioned in the 'Discussion and conclusion' section. so I suggest to either be more specific and come back to this in the text or remove the statement. (also p477 ln 5)

l8 it is not the 'initial' response, but the 'long term' response in atm. CO₂ which is

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amplified by the sediment burial-nutrient feedback (see Fig. 7a) (also p477 l18)

l8/9 why is this called a 'temporary' imbalance? (It is called 'transient' on p476 l17, which I find more appropriate, and 'sustained imbalance in Sec 3.1.2, p489 l6)

l13/14 I suggest to insert 'atmospheric' before $\delta^{13}C$ signatures and CO₂ sensitivity

Introduction

l26 'calls for' too strong? what about pCO₂ as driver of temperature changes? suggest to replace 'tight coupling' by 'larger temperature changes than one would expect from delta pCO₂ based on climate sensitivity of current climate models' if that is meant

l27 I suggest to change CO₂ drawdown 'during' the Last Glacial Maximum to 'leading to' the last LGM

p475 l14 to 'increase viscosity and thus the speed of sinking particles'?? sign correct

I would expect a smaller sinking velocity for increased viscosity.

It should be ...'to decrease viscosity and thus to increase the speed of sinking particles'

Taucher et al. 2014: 'As rising temperatures reduce seawater viscosity, the sinking velocity of particles will accelerate'

l17/18 I suggest to delete the 'increase' before 'respired carbon storage'.... 'such changes' refers also to Bendtsen et al, Taucher et al., and there the changes will result in decreased respired carbon storage in the deep ocean

l19 Also the 'As a result' assumes that changes in remin-depth lead to 'increased' storage in the deep. Deleting 'As a result' is an easy way out here, then the two sentences are correct.

p476 l3 'all these studies neglect ocean-sediment interactions' this is not strictly true, e.g., the model of Segsneider & Bendtsen includes a sediment (see their Fig. 6) - for the time-scales of 100 yr they discuss, the sediment is of minor importance, as also

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seen in Fig. 7a of this ms. Also Tschumi et al. 2011 have an active sediment included and discuss briefly the amplification of the closed system by taking into account ocean-sediment interactions (their Section 2.3.3). I suggest to be a bit more specific about how this study differs from the one of Tschumi et al. 2011 (e.g., different focus, constant physics...)

l19 Change 'These consequences' to 'The consequences of this imbalance' have not been discussed...?

p480 l12 an e-folding depth (L_POM): e-folding depth 'as length scale' (L_POM) would make it more easy to understand why it is called 'L_POM') and could avoid confusion throughout the text (where 'depth', 'mean remineralisation depth', 'profile', 'POM deepening' and 'length scale' are used for 'L_POM')

l21 Is there really 'advection' in the sediment?

p483 l20 I suggest to change 'during the experiments' to 'during our experiments' to make clear that not the experiments in the referenced studies are meant

Results

p485 l2 3.1 L_POM changes: I suggest a slightly more informative heading

l4 I would not start the Results section by 'We start discussion by'....

l11 'subsurface water' - you could be a bit more precise here. Is the water directly below the euphotic layer or within the euphotic layer meant?

l12 how robust is the decrease in global export with respect to the neglect of remineralisation within the euphotic layer? If you would consider remineralisation in the euphotic layer, a downward shift of the remineralization profile would cause increased export.

l14 'leads to an initial spike in POM deposition' does not give the sign, so I suggest to change it to 'spike-like increase' and to add a ref to Fig.3d

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l22ff would it be useful to add at the end of the sentence 'Second (the) whole ocean...'
...after the step change 'due to reduced productivity in the euphotic zone'?

p486 l6 suggest to replce 'Finally' by 'Eventually' (I guess this is meant)

l22 I suggest to insert 'decreased' between 'by' and 'calcite burial' to make the sentence easier to follow or perhaps reverse it: The loss of carbon due to enhanced burial of POM is counteracted by a small gain due to reduced calcite burial, while....

p487 l7 suggest to add (Fig. 4a) after ocean

l17 suggest to add (Fig. 4c) after deposition

p488 l1 suggest to add (Fig. 5a) after PO4 inventory

l6 'As expected, this pattern is mirrored ...by DIC, oxygen, d13C

In the closed system, the patterns of oxygen and CO3 are inverse to the pattern of PO4 (see Fig. 5a, 5c, 5g) whereas for DIC it is similar (Fig.5e) so I doubt that 'mirrored' is meant. I also assume that CO3 is meant, not d13C, which is not shown in Fig. 5? Also I suggest to point to the figure panels and to add a 'not shown' for variables not in Fig. 5 (d13C, ALK, CaCO3) in the text. (Alk is discussed reatively heavy in this section so you might want to show it in Fig.5)

l25 I suggest to start a new subsection here and discuss the EOFs in more detail, or to skip this para and to skip Fig. 6 Why are the EOFs computed for (only) CO3?

l27 I would change 'by 2' to 'the first two'

l28 and insert 'of the principal components' after 'corresponding time series'

l28/29 'The resulting patterns strongly resemble those shown with (in) Fig.5g and h, i.e. the open(-) and closed(-)system response'.....

I recommend to be more precise:

1st EOF resembles open system (Fig. 5h), 2nd EOF resembles closed system (Fig. C144

5g)

p489 l14 'The CO2 decrease is more than 100ppm for a change in I_POM to 375m'
Can you say if the implied temperature change is in agreement with LGM temperature?

l21 check use of 'standard experiment' here. It has been referred to as I_POM=250m, here it seems to be used for I_POM=275m (also line 25)

l22 'to disentangle the influence of the reduced export flux vs. the change in remineralisation profile'

is this possible using this setup? Also, by disentangling, I would expect some more elaborate results, e.g., change in remin causes this and export causes that, not just the factor of 2-4 for the (unrealistic) constant export exp.

p490 l3 It might be useful to explain why these experiments have been made. Is there a reason to assume that changes in remin-depth have occurred in confined regions during glacial periods?

p491 l10 what is meant by 'checked by' here? balanced?

Discussion and conclusion

p494 l22 It is shown that 'on long time scales' ocean sediment interaction...

p497 l5 Gangstoe et al. 2011 ...did not apply a sediment model. Even though Gangstoe et al do not mention a sediment module, PISCES usually runs with active sediment, so it may be worthwhile to check if this statement is correct.

Fig. 8a any idea why the red lines (d13C open system) in Fig.8a cross all at ~50 kyr and at the level of the control experiment?

Fig. 10 does not show a 'map'.

also it would be helpful to state the times for which the plots are produced

is it easy to understand why the open system amplification is highest around I_POM =

250m? I guess this is due to the division by small numbers (closed system response is close to zero for $L_{POM}=250m$), so this may be a bit misleading as it implies that the open system amplification is particularly strong for small perturbations of L_{POM} .

Technical errors

p474 l 10 ...lead to sustained changes 'in' the ('in' missing)

p475 l 21 This mechanisms (sgl/pl)

p478 l3 correct 'arithmically'

p479 l3 correct calcifer

p480 l17 change 'lengthscale' to length scale

p483 l16 change 'as induces' to 'as induced'

p481 l23 change 'prescribed to' to 'set to' or 'prescribed as'

p482 l2 change 'Global integrated' to 'Globally integrated'

p484 l7 change 'describe' to 'describes'

p487 l2 change to ...after 32kyr (Fig.3g) (not 3f)

l18 change 'region' to 'regions'

l20 change Indian ocean to Indian Ocean

p488 l16 change 'As a results' to 'As a result'

l21/22 change This ... 'anomalies are' to 'anomaly is' (or 'These...')

p490 l3 change 'pumps' to 'pump'

p492 l16 dot is missing after 'in sensitivity simulations'

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