Biogeosciences Discuss., 9, C5759–C5766, 2012
www.biogeosciences-discuss.net/9/C5759/2012/

Biogeosciences Discussions

Interactive comment on "Impact of an 8.2-kyr-like event on methane emissions in northern peatlands" *by* S. Zürcher et al.

Anonymous Referee #1

Received and published: 20 November 2012

Overview

This study aims to quantify the role of Northern peatlands in the 80ppbv reduction in atmospheric CH_4 documented during the 8.2kyr abrupt cooling event. A process-based model of northern peatland CH_4 emissions (Bern LPJ) has been driven with climate model simulations with NCAR CSM1.4, which have been perturbed with freshwater forcing, causing a widespread cooling over the Northern Hemisphere. The results show a small contribution (24ppbv) from northern peatlands and so the authors suggest that tropical wetlands may play an important role in the decline in CH_4 during the 8.2kyr event.

General comments

The authors make use of a vegetation/peatland model which resolves many processes missing in previous paleo-CH_4 modelling (e.g. vertically resolved soil temperature, CH_4 transport processes, permafrost). Additionally the model appears to have been carefully evaluated against site data which increases confidence that it can realistically resolve the latitudinal and seasonal changes in peatland methane emissions. The model output is carefully analysed and a thorough forcing and parameter sensitivity analysis is provided.

However, the climate scenario is not representative of the 8.2kyr event, since it is based on pre-industrial boundary-conditions. The climate simulations were performed and analysed by Bozbiyik et al. (2011), but there they are compared with the Younger-Dryas (Y-D) cooling event ($\sim$12kyr), which has a much stronger change in atmospheric CH_4. This calls into question the use of these simulations as 8.2kyr -like events, as done here, and this undermines the primary conclusions of the work. Unfortunately I cannot comment on the new ebullition mechanism described in section 2.2 and the appendix as this falls outside of my area of expertise.

I suggest that the authors should change the title and abstract to more faithfully represent the simulations performed, namely the response of the modern peatlands to a freshwater hosing or AMOC shutdown. The authors can then go on to relate their experiments to events in the paleoclimate record, such as the 8.2kyr or Younger-Dryas (as did Bozbiyik et al., 2011), but discussing the limitations involved in this. Once this is clarified in the text, I believe that this work would be of interest to many. Therefore I recommend publication after moderate revisions.

Specific comments

- The authors suggest that the freshwater forced pre-industrial climate simulation can be used as an 8.2kyr-like event. This is difficult to justify especially in the context of CH_4 emissions modelling. At 8.2kyr BP incident solar insolation had a more pronounced seasonality over the Northern Hemisphere compared to the pre-industrial. This may have had an influence on both the climate response to freshwater forcing as well as on the vegetation productivity and hence the response of peatland CH_4 emissions. Since neither of these influences is quantified in this study it becomes difficult to assess the significance of the primary conclusion of the paper (as it is framed), namely that only 23% of the atmospheric CH_4 reduction during the 8.2kyr event can be explained by Northern peatlands.

- A further difficulty arises in using the pre-industrial simulation as an 8.2kyr-like event, because there is no comparison between the simulated climate anomaly and the reconstructed paleo-climate changes. If the modelled climate anomaly is much smaller or larger than the real event, then this may also explain the mismatch between the simulated CH_4 emissions and ice-core record of atmospheric concentrations. The authors should elaborate how well the model simulation compares with the reconstructions of the climate anomalies during the 8.2kyr event, e.g. Kobashi et al. (2007) or Morrill and Jacobsen (2005), and possibly compare this briefly with previous modelling studies (e.g. LeGrande et al., 2008; Tindall and Valdes, 2011).

- Introduction: In a few sentences previous studies are referenced but not discussed in much detail. Previous studies have found it difficult to replicate the magnitude of change in atmospheric CH_4 for the G-IG and abrupt events. How might the present study fit in with this prior literature?

- Page 13263, line 24. As mentioned in the text, MacDonald et al. (2006) reconstructed a smaller peatland area at 8ka BP than during the pre-industrial, but predicted that the total CH_4 emission was of a similar level to modern. Could an altered spatial distribution (especially over North America where warming is simulated) alter the overall model sensitivity of the peatlands to the types of climate anomalies applied in this work?

- Page 13245: Lines 25-28: I think it should be emphasised that abrupt climate variations are not understood well, for example see Clement and Peterson (2008).

- Page 13247: Lines 6-9. What about ice-core based top-down approaches (e.g. Fischer et al., 2008)?

- Page 13247: Lines 10-12: Did van Huissteden (2004) or Hopcroft et al. (2011) explain the full magnitude or rapidity of abrupt events? If not, what explanation(s) were given, and could you here address any of these here?

- Page 13247: Line 20. The CH_4 model used by Singarayer et al. (2011), explicitly includes functions of both surface air temperature and water table, following the Cao et al. (1996) formulation, and so this sentence is incorrect.

- Page 13247: Line 20. Valdes et al. (2005); Kaplan et al. (2006) and Singarayer et al. (2011), all consider changes in the atmospheric CH_4 lifetime in order to explain G-IG change in CH_4, but this is not commented on here.

- Page 13248, lines 1-4: The authors mention that ICE-5G indicates relatively little coverage of peat grid-cells at the time of the 8.2kyr event. Would it be worthwhile to use ICE-5G to mask out emissions in LPJ simulations to assess how important this could be?

- Section 2.3, lines 1-8: It is not clear from the description of the site-level comparison, whether you use the actual climate years relating to the observations in your comparison, or whether the years used are average equilibrium conditions. Please clarify and justify your choice if you have opted for the latter.

- Page 13523, Lines 8 onwards. How did you choose the parameter values that you evaluated?

- Page 13253: Lines 5-7 and figure 2: Can you describe in more detail how the improved ebullition scheme changes the seasonal timing of emissions and therefore improves the model-data comparison compared to the previous work of Wania et al. (2010)?
- Page 13255: lines 10-19: This paragraph needs clarification, the climate simulations are pre-industrial plus water hosing. Perhaps provide a reference paper for the climatology of CCSM1.4.
- Page 13260, line 5: What would the reduction in CH_4 emissions have been if it was a fixed proportion of NPP?
- Page 13260, lines 9-14, Given that the proportions of different components remains similar in different climatic states what does this imply for sensitivity of the model and the inclusion of these processes? How does this relate to the changing ratio of CH_4 emitted to NPP?
- Page 13261, line 15: Does this imply that the exploration of parametric uncertainty has been too conservative?
- Page 13262, line 28: A reference for the climate conditions referred to here would be helpful.
- Page 13263, line 2. The reference to Weber et al, here does not really make sense, please check.
- Page 13264, line 11. Which other estimates do you refer to here?
- Page 13265. This final paragraph is a bit mixed up and could do with reorganisation. Refer to other comments above. I think more emphasis and discussion is needed in terms of relating this modern climate simulation to the past.

- Figure 3: It would be good to show error bars where possible on these point values.
- Figure 5: Though it is subjective, I would plot the climate anomalies without masking the peat grid cells. This might make it easier to assess the overall magnitude and pattern of the simulated climate anomaly.
- Figure 7. The anomaly plot (b), might be clearer if it was given as % reduction.
- Figure 8. Could you remove 's1,' from the the legends and put it once elsewhere in these two plots?

Technical corrections

- Page 13246: Lines 19-22. Change regulating to regulates and affecting to affects in this sentence.
- Page 13249: Line 7. *Sphagnum* should be in italics.
- Page 13251: Line 15. Remove 'do'.
- Page 13257: Line 19. Write 'A slight warming is even simulated . . . '
- Page 13259: Line 6. Change '(GPP) by' to '(GPP) of'.
- Page 13259: Line 16. Remove 'of' from 'and not of a decrease'
- Page 13259: Give these numbers to less significant figures, and possibly include plus-minus 1 standard deviation.
- Page 13259: lines 16-19: This sentence starting with 'Note that the soil carbon' does not make sense.

- Page 13261: Line 10. Change to 'after the freshwater perturbation barely depends'.
- Page 13261: Line 15. Change '... ebullition have as well a small ...' to '... ebullition also have a small..'.
- Page 13262: Line 12. Change to something like '.. ecosystems to the simulated climate change'.
- Page 13262: Line 22. Replace 'E.g.' with 'For example' or similar.
- Page 13264: Line 3. These brackets are not closed.
- Page 13264, line 15. Reword this sentence beginning 'Moreover temporal changes also ..' as it does not make sense, although I can see what you mean.
- Page 13265: Line 6. 'Extend' should be 'Extent', but see general comments regarding this concluding paragraph.

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