Biogeosciences Discuss., 8, C4809–C4817, 2011
www.biogeosciences-discuss.net/8/C4809/2011/

Biogeosciences Discussions

Interactive comment on "Effects of soil rewetting and thawing on soil gas fluxes: a review of current literature and suggestions for future research" *by* D.-G. Kim et al.

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Received and published: 13 December 2011

Review 2

The manuscript presents a literature review on the effect of soil rewetting and thawing on the soil gases CO2, CH4, N2O, NH3 and NO fluxes by gathering more than 330 studies carried out in the field and in the laboratory. The main mechanisms and drivers responsible for the responses to rewetting and thawing of different gas fluxes are discussed. Furthermore, the paper highlights the need for a more process-based understanding and for including these responses into models and suggests future research directions on this topic.

As the authors themselves discuss in the manuscript, future climate change scenarios predict more frequent extreme events including extended drought periods, increased sudden rainfall events in some areas and in freeze-thaw events. Therefore, it is clear that this review is most relevant as there is a clear need for improved understanding of the response of gas fluxes to these events as well as their impact at ecosystem, regional and global scales. I think that the review is very timing and has done a good job at compiling a large number of field and laboratory studies that have been carried out over the last 50 years. It is surely of interest to Biogeosciences readers and to a broader scientific community addressing a very relevant scientific question for the prediction of the response of terrestrial ecosystems to climate change.

The main strong points of the review are: (1) The presentation of an extensive literature review on the effects of rewetting and thawing impact on soil gas fluxes that can be very useful (although some studies are missing) for the understanding of gas emissions in terrestrial ecosystems, (2) the consideration, for the first time, of the response of several gases, not just CO2 (although it is not clear how many studies have considered several gases), (3) a clear presentation of the different mechanisms involved in the response of each gas flux and, (4) the identification of current gaps and future research directions.

The review presents novel aspects and in general, the review is well written, well structured, clear, and discussed in depth. The title is very good and reflects the contents of the paper accurately. However, the manuscript needs further improvement and deeper analyses of the studies presented to produce more general results exploiting such a large database. In particular, I think that some parts are very descriptive and detailed (in particular the section 3) and others too general (uncertainties and conclusions). The conclusions reached could be more specific to the analyses done on the studies considered (although it is not clear whether such analysis have actually been done) with more general conclusions about different ecosystem types, vegetation types, timing and intensity of events, etc. The methods should be explained in more detail to

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understand whether the comparison between the responses of different gases, different ecosystems, etc, has been done and how (see below). The description of the experiments included in this review is not sufficiently presented. As explained below the abstract could be improved in some parts.

Thus, I think that the manuscript could be improved considerably. My main general concern is that I think that the review is rather descriptive and much more information and conclusions could be drawn from the studies considered. Since a large number of studies have been gathered, I wonder whether it could be possible to analyse the data by vegetation type (grasslands, croplands, forests, savannahs and deserts etc.), ecosystem type (arid, temperate, tropical, boreal, etc.), etc. as the response will clearly differ among them and may help explaining observed patterns. Instead of describing individual studies in such detail, it would be much more interesting to the reader and it would make a much more interesting review on the topic, if the authors presented the results in a more general manner by drawing conclusions of the different studies by vegetation type, ecosystem type, type of experiment, etc.

Other aspects most relevant for the response, such as duration of the drought prior to rewetting, thawing, intensity of the event, etc, could also be analysed and prove very useful for a more general but thorough discussion on the mechanism behind the observed responses or trends. As stated in the Abstract, the database revealed conflicting results but the explanations behind are not properly addressed and the analyses suggested may help elucidate whether such conflicting results may be clarified.

Meanwhile, mechanisms could be separated more clearly into biological and physical processes mediating the observed responses.

The other main concern regards the main conclusion drawn from this review as explained below.

Other minor comments follow.

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Abstract

- The abstract states that the analyses done revealed conflicting results ranging from large increases in gas fluxes to no responses. The following sentence states the main conclusions of the review is that the responses follow a power function with no significant differences among gases. This may seem contradictory and in any case not clear enough. The “database” and the “published field studies” do not refer to the same thing? Are the published field studies part of the complete database? Are the results only applicable to field studies? What about the lab studies? Figure 3 shows both field and laboratory experiments.

- Apart from that minor thing of the wording, the concern refers to the main conclusion of the study: (1) that the response to rewetting/thawing is the same, an increase described by a power function (not linear), and (2) that the response is the same for all gases considered. With regard to the first conclusion, it is not clear how it has been tested. As for the second conclusion, it is not clear whether the response is observed because all gases were plotted together with higher fluxes for CO2 and N2O and smaller fluxes of the other gases. Is the power function applicable for each individual gas?. In that case, are all individual gas curves the same? And therefore, the second conclusion stands, otherwise, it is not correct to assert that there were no significant differences between gases.

- The relevance of these major results and the mechanisms behind are not really discussed, but instead the individual mechanisms of each gas.

- Another important outcome of the study stated in the abstract is the importance of temporal resolution in order to capture the responses of gas fluxes since the responses are often transient and disappear after a few days. However, it is not clear whether this conclusion has been drawn from the studies analysed here altogether, or from the individual studies. One of the main conclusions of the literature review (although it is not clear if that is what they have found) and thus a consideration for future research,

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is the need for a more intensive temporal sampling in order to properly estimate the relevance and contribution of the observed responses to the total annual gas budgets.

- A very important point highlighted at the end of the abstract but that I feel it has not been properly addressed in the text, is the need to separate clearly biological from physical responses, as they are controlled by different drivers.

- A sentence to end the abstract with the major conclusions for future research directions would be desirable.

Introduction

- Very good introduction. Only some minor comments. First, in page 9850 line 5 it is stated that sudden flushes of water and nutrient that occur upon rewetting and thawing lead to major changes in plant and microbial activity. However, I think this depends very much on the intensity and timing of the rainfall event (in the case of rewetting) as sometimes rainfall events large enough to activate microbial communities are not enough to trigger plant activity. Therefore, the sentence should be rephrased.

- In paragraph 25 a very important point is discussed, the contribution of such responses to the total gas balance at annual scale. Jarvis et al. 2007 quantified the importance of such losses at ecosystem scale in several Mediterranean ecosystems. Some other studies missing are: Harper et al. 2005, Rey et al. 2005 who carried out specific studies on rewetting. These references should be included. Meanwhile, the phenomenon of an increase in fluxes upon rewetting is well known and was first described by Birch who has not been cited.

- Throughout the text when the authors write “response” do they mean increase?

Methodology

- The number of studies that measured each gas is not clearly specified and would be most useful for interpretation. Meanwhile, other details about the studies would be desirable, manipulation versus natural, intensity of events, etc. A more comprehensive

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description of the studies used in the review is needed. Maybe a detail description of the experiments included in the review could be presented in another table.

- Individual gas flux change rates were calculated but did they plot the response per gas individually or just altogether? How was it tested that the response of the different gases was the same? Between the two processes? Not statistics is described.

- I like how this section is presented following each gas where the general patterns and the mechanism behind the observed responses are discussed. However, each section could specify how many studies are included. The results should be presented rather than individually which is rather tedious for the reader and less informative for the conclusions, by grouping them according to the observed responses, ecosystem type, type of experiment, etc.

- A discussion of how different ecosystem types may respond to the same event would be good.

- I would rather see the biological and physical responses discussed separately.

- At least three major processes may contribute to the rapid apparent stimulation of soil respiration following rainfall. First, large amounts of CO2 stored in the air spaces resulting from inorganic sources and soil microbial activity during the dry period are physically displaced and released-physical process (Huxman et al., 2004). Second, precipitation pulses can liberate carbon held in large soil pools of soil carbonates-when ecosystems are placed on carbonate soils (Emmerich, 2003; Inglima et al., 2009). Third, soil rewetting rapidly increases decomposition processes of readily available carbon accumulated during the previous dry period-biological response (Kieft et al., 1998). Inorganic carbon is not mentioned and may be relevant in some cases.

- Jarvis et al. 2007 present a historical review of mechanisms involved in rewetting responses.

- The section on CO2 is much more detail for rewetting response than for thawing

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effects. Is that because there are many less studies? Less well known?. This should be explained.

- Page 9854. line 7. Correct hypothesized for spelling consistency

- The mechanisms are not really discussed just described. Why would the response be larger in colder temperatures?. Because mineralization is limited and thus more carbon sources are accumulated and available at thawing?

- Page 9855. Line 11. This result is very interesting and could be included in the abstract, the value of SWC below which an increase in CO2 fluxes are observed.

- Page 9856, line 16. peatlands.

- Page 9856. 4.1. Remove OF

- Page 9856. Line 17. tropical forests-

- Page 9857. Line 1. g dry mass

- Page 9857. Line 10. peatlands or in a peatland

- The presentation of the results is too specific to the individual case studies and more general results should be presented. Again, how many studies? It is just said that there are many less published studies reporting CH4 fluxes.

- For N2O similar problem, separate biological from physical effects, separate by ecosystem type, etc.

- There are many more studies on CO2 than in other gases and therefore, the sole power function fitted to all data may be misleading and surely the conclusion that there are no differences in the response of different gases must be taken with caution.

- Page 9867 Line 2. Jarvis et al. 2007 is missing.

Uncertainties and conclusions

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- I would not say that there are few studies when more than 300 studies are reported in this review. Please, remove.

- I think that this section is too general. It basically says that there are not many studies, which is not the case, but more in depth uncertainties should be discussed.

- The discussion on the N2O fluxes is too detailed and probably should be moved the corresponding section on Mechanisms and drivers of this gas instead. It does not fit in this section.

- Although the temporal and spatial resolution of flux measurements is crucial for a good understanding of the effect of these processes, it is not clear to me whether these conclusions are drawn from a thorough analyses of the studies included in the review. Please, specify. Again, it would be much more relevant if the uncertainties and future research needs are directly drawn from a deeper and clear analysis of the studies presented.

- 4.4. Experimental designs rather than settings.

- The study of microbial community analyses and isotopic techniques is very important but it is not really explained how they can contribute to improve our understanding of the responses of soil gas fluxes to rewetting and thawing. The paragraph is too general.

- Although the blog is an excellent idea and this kind of initiatives should continue to grow and be encouraged, I am not sure whether this is the place to advertise it. It may be included in the Appendix or Acknowledgement Section by shortening it.

- Again the final conclusion is rather general and does not really relate to what it has been found in the review. It should be more focused.

Tables and Figures

- A table containing the detail information of the studies is needed as mentioned earlier.

- Fig 1 seems the same (apart from the control baseline of panel b). Is it really needed?

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- Fig 4. Not clear, symbols do not differ sufficiently. In any case, it is not clear whether all gases respond in the same way.

Other references to be included: Harper et al. 2005. Increased rainfall variability and reduced rainfall amount decreases soil CO2 flux in a grassland ecosystem. Global Change Biology 11, 322–334. Munson et al. 2010. Soil carbon flux following pulse precipitation events in the shortgrass steppe. Ecol Res 25: 205–211 Rey et al. 2005. Effect of temperature and moisture on rates of carbon mineralization in a Mediterranean oak forest soil under controlled and field conditions. European Journal of Soil Science 56, 589–599. Jarvis et al. 2007. Drying and wetting of Mediterranean soils stimulates decomposition and carbon dioxide emission: the “Birch effect”. Tree Physiology 27, 929–940. Birch, H.F. 1964. Mineralisation of plant nitrogen following alternate wet and dry conditions. Plant Soil 20:43–49.

Interactive comment on Biogeosciences Discuss., 8, 9847, 2011.