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Biogeosciences Discussions



# *Interactive comment on* "Amplification and dampening of soil respiration by changes in temperature variability" *by* C. A. Sierra et al.

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## Response to general comments

We thank anonymous reviewer # 2 for his comments on our manuscript. In the list below we address each of these comments (highlighted in italics):

- *I agree with the need for this work but at the same time I am critical of the current content of the paper as it does not provide any new insight or any applicable finding from what it has been already known*.

  It is unfortunate that we were not able to express more clearly the contribution of our analysis. The reviewer points out that the implications of Jensen's inequality

have been already explored and therefore our analysis is not novel. We disagree with this statement. Previous analyses have focused exclusively on the direct implications of Jensen's inequality. These direct implications concern the differences obtained in average respiration rates when one uses spatial or temporal averages of temperature versus the complete temperature (un-averaged) dataset. This was the main topic in the analyses of Ågren & Axelsson (1980) and Kicklighter et al. (1994), the most important publications on this subject. These publications did not address the question of the effects of changes in temperature variance on respiration. Analyses using numerical models have not addressed this question either. The work by Notaro (2008) and Medvigy (2010) compare numerical simulations using average climate data versus high frequency climatic datasets, finding important differences on a set of ecosystem variables. These studies do not compare simulations in which climate variance changes from one value to another, they only compare a situation with and without variance. This is precisely what Jensen's inequality predicts, not a change from one value of variance to another.

Our contribution is to derive a mathematical expression, an inequality that goes beyond Jensen's, that expresses the effects of a change in temperature variance on respiration. For this reason we strongly disagree with the statement of the reviewer that: *'this paper is an applied example of the well-known inequality'*. Our paper is, to our knowledge, the first to explore the effects changes in temperature variance. On the contrary, the previous work by Kicklighter et al. (1994), Notaro (2008) and Medvigy (2010) can be described as examples of Jensen's inequality.

- *I suggest the authors specifically state what it is that needs to be changed/implemented in current temperature-based models, and how this implementation is 1) realistic given our current sampling design and sampling limitations; and 2) quantitatively necessary given current predictions of soil respired CO2, which would be much different should these findings be applied.*



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This is a good point that deserves some discussion in our manuscript. Here it is important to highlight that the problem is not as much about the models as it is for the datasets used to run models. The models do not need to be changed to include the effects of changes in climate variability. However, temperature datasets used to predict respiration fluxes should be of high enough frequency to include possible changes in temperature variance over time. This can be achieve in different ways. 1) For predictions of past respiration fluxes at a site, data from meteorological stations, eddy-flux towers, or automated systems for soil monitoring can be used to predict high frequency respiration fluxes. The temperature data can be plotted in a MSC diagram, as in our study, to explore possible changes in temperature variance. 2) For predictions of past respiration fluxes at larger scales, re-analysis high-frequency data can be used. These data can be obtained in 6-hourly format from NCAR's website or from the European Centre for Medium-Range Weather Forecasts. 3) A random weather generator can be used for exploring future changes in the variance of temperature. The procedure is basically the same as the used in the numerical simulations in our analysis. It consists of sampling random numbers from a probability distribution with known mean and variance. The values of variance can be changed over time to simulate plausible changes in the climatic regime.

These recommendations were introduced in a paragraph within the Implications section.

- *A major criticism is that the authors do not recognize that soil temperature varies with depth (the temperature used comes from three different depths) and the reader is left to assume that either soil temperature is considered constant with depth or that soil respiration occurs at only one depth.*

  The fact that soil temperature changes with depth is an important issue in modeling soil respiration. However, the reviewer's criticism is unfair to our work. If the decline in soil temperature with depth is critical for modeling soil respiration,



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then all models should include this behavior. From all the soil respiration models reviewed by Luo & Zhou (2006) none of them consider changes in temperature with depth. We believe the main reason for this omission is the macroscopic behavior of soil respiration in relation with temperature measured at the surface; so most models behave reasonably well without explicitly considering the change in soil temperature with depth. Our analysis therefore, takes advantage of this macroscopic behavior of the temperature-respiration relationships already tested under different situations.

It is not necessary to perform our analysis at different depths as suggested by the reviewer if the relationship developed for a specific site has this macroscopic behavior. Similarly, it is not necessary to make the models more complicated as suggested by the reviewer. If it is known that a model works for specific sites, it is only necessary to explicitly include changes in the driving variables to account for changes variability, but without making changes in model structure.

- *My fundamental criticism of this study is that pointing out a problem without providing a practical solution does not advance our field and it only limits the potential impact that this paper may have.*

  As mentioned previously, the potential effects of changes in temperature variability on respiration can be explored with the already available models. It only requires better temperature data that explicitly address changes in temperature variance.

  A detailed quantitative analysis of specific changes in temperature variance is beyond the scope of this manuscript. It would require a careful parameterization of a model for a site or a set of sites. It also would require detailed choices of changes in temperature variance for specific time periods.

  The main objective of our analysis was different. It was to derive a mathematical expression that can tell us about the potential effects of changes in temperature



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variance on soil respiration. Mathematically, these effects of changes in temperature variance cannot be derived from Jensen's inequality alone, so a new mathematical expression was required. One of the main advantages of our approach is its generality, which comes at the expense of specificity for particular situations.

**Response to 'other minor comments'**

- The reviewer suggests that the emphasis in the introduction should be on making accurate predictions of soil respiration across a wide range of temperatures instead of the current emphasis on changes in the probability distribution of temperature. However, the topic of making accurate predictions that consider temperature variability has been the focus of other papers, particularly Kicklighter et al. (1994). We wanted to focus in our manuscript on future changes in temperature variance, because 1) it has not been addressed explicitly in previous studies, and 2) it offered the possibility for developing the mathematical inequality that we derived. Changing this focus in the introduction would lead to a different question and most likely to a completely different analysis.
- The sentence on page 8985 was deleted as suggested.
- We agree, RWC=75% is somewhat high. A more realistic value would be RWC=50%. We changed the calculations in our manuscript to this value, which also led to a change in Figure 6. The results did not change the conclusions previously found.
- Since the sections on the geometric and probabilistic argument provide mathematical expressions derived in this analysis we prefer to keep them in the Results section.



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