

## ***Interactive comment on “Diurnal, seasonal and long-term behaviour of high arctic tundra-heath ecosystem dynamics inferred from model ensembles constrained by time-integrated CO<sub>2</sub> fluxes” by Wenxin Zhang et al.***

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Anonymous Referee #2 Received and published: 16 August 2018 Zhang et al. calibrated the Coup model using Zackenberg NEE eddy covariance measurements. In my view this manuscript needs a major revision of text and figures before submitting again.

(Response by authors)

R: We thank the reviewer very much for his/her review and comments. We agree that the language in the manuscript should be further refined. We should also make the

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purpose of this work much clearer. We would appreciate the reviewer for the second review on our revised manuscript.

(1) The language seems to be inadequate. It is hard for me to understand all methods and results.

R: We are sorry that the reviewer did not fully understand our methods and results, likely because of wording issues. The language should definitely be improved in our revised manuscript. Meanwhile, to address the reviewer's confusion, we make the following clarification about the motivation of this study.

The aims of the study are (1) to show how three calibration methods minimize uncertainties in ensembles of model candidates to describe within a day, seasonal or long-term variabilities of CO<sub>2</sub> fluxes and (2) to elucidate what important parameters or processes tightly control these temporal variabilities based on the posterior parameterization distribution. For most land models or dynamic vegetation models in simulating CO<sub>2</sub> fluxes for the sites, they are commonly calibrated against measurements using a fixed time resolution. Temporal pattern of model errors may be hidden since the model-measurement residuals are often assumed to be random following a normal distribution for the entire period. Few models have ever tried to discuss how the patterns of errors are allocated within a day, a year or a long-term and if these patterns depend on the calibration approach or not. This study is motivated to search for patterns of errors by using a filter applying time integration of data to different lengths of time windows (daily, yearly and long-term). Our results have demonstrated the success of each model ensemble to best describe the targeted temporal behavior. The crucial links between parameters/processes and model performance have been identified and used to indicate the controlling factors that are critical to explaining CO<sub>2</sub> flux variabilities across time scales. The relative importance of abiotic and biotic processes across time scales have been discussed by some studies (e.g. Richardson et al., 2007; Wu et al., 2017). However, for the High-Arctic ecosystems, characterized by permafrost thawing, snow dynamics and how young and old carbon decomposition responses to rapid warming,

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our study may be the first study to explore drivers of these processes across different time scales. Particularly, the soil decomposition processes in the CoupModel account for the vertical distribution of organic carbon (old and young carbon) and nitrogen, dynamics of which are tightly coupled with heat and water exchange during soil freezing and thawing. The complexity of the processes makes the model as one of the state-of-the-art ecosystem models. Figure 9 shows key indications from the calibrated model ensemble, that is, the normalized drivers of photosynthesis and respiration across time scales. These indications are important to improve our understanding of the drivers of the Arctic ecosystem processes and future modeling.

(2) One example is on lines 308-310 but the manuscript is full of sentences that I do not understand.

R: For the lines 308-310, "We counted the number of posterior parameters with the Pearson correlation coefficient for linear regression ( $r > 0.3$  or  $r < -0.3$ ) to the posterior  $R^2$  of the measurement variables and grouped them into the processes they belonged to."

We revised it as "The Pearson correlation coefficient ( $r$ ) for a linear regression between posterior values of each parameter and posterior  $R^2$  of  $CO_2$  fluxes was calculated. We counted the total number of posterior parameters with  $r > 0.3$  or  $r < -0.3$  in each ecosystem processes"

(3) Figures show wrong units, miss axes titles and units. Figure captions are not always understandable. Fig 4: Scaling ME to +/- 10 (units?) makes it hard to understand the figure.

R: The units are correct, but there is a typo in Figure4. "MR" should be changed to "ME", abbreviated for mean error. Mean error uses the same unit as the measurement variables. The purpose of rescaling the mean error between [-10, 10] is to make errors from different measurement variables more comparable. We interpreted it in the figure caption. The actual error range can be attained by multiplying the scaling factors.

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(4) It is hard to identify any research question / hypothesis in introduction, discussion and conclusion. From the start of the discussion it seems that the research question of this study could be: Will tundra ecosystems move from a C sink towards a C source in future? It seems the authors want to calibrate the coup model using eddy covariance measurements from a specific site in order to address this question. Calibrating and running the model into the future using a climate scenario could give a first answer. Instead, the authors present a lot technical details about the calibration procedure which even does not show any technical advancement with respect to model calibration exercises.

R: See our response to your first comment.

(5) Methods: A lot of text is written about the coup model which can be found also in the online documentation of the model. In contrast, methods important to the presented manuscript are described superficially, e.g. calibration procedure, wavelet analysis and model ensemble.

R: The CoupModel is a flexible platform, in which users can easily set up the model structure and choose the schemes with a certain level of complexity based on their assumption. Therefore, the online documentation of the CoupModel gives a general introduction on the available processes the model consists of. Our Method section only focusses on the most relevant aspects of the model about this study. We have restricted our model introduction to the only four key processes, in which the model assumption and setting details are described. We agree that more details of model calibration and how to generate model ensembles should be further clarified in our revision.

(6) What is a behavior model ensemble? What are the three specific behavior model ensembles and how are they defined? This reviewer gets a clue about it after reading the whole manuscript but it remains unclear from the methods section.

R: We agree that some terms we used should be clearly explained in the revised

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manuscript. The behavior model ensemble means we used optimum posterior runs to describe the measurement behavior, which in this study refers to the temporal variability of CO<sub>2</sub> fluxes. This is different from a deterministic model which only used one optimum run as its estimate.

Our calibration approach is based on the transformed CO<sub>2</sub> fluxes. For the original carbon flux in a high Arctic tundra heath ecosystem, the diurnal, seasonal and long-term C fluxes exhibit distinct behaviors, as shown in Figure 1S. Before calibration, we transformed the time series of CO<sub>2</sub> measurements by accumulating the hourly values into a daily cumulative time series, which always starts from the first measurement in that day. The second time step of the transformed time series was the sum of the first and second measurements. The same procedure applies for the rest time steps in the day. We made a similar transformation of CO<sub>2</sub> fluxes based on the yearly and long-term time window. The transformed cumulative fluxes look like Figure 2S. So, our three behavior model ensembles were generated based on the calibration of these three transformed data sets. We don't fill the gaps in the measurement. So, the transformed data sets also have the gaps. But we decide to delete the section of wavelet analysis in the revision. The purpose of using the wavelet analysis was to justify how three models reproduced well the variance of CO<sub>2</sub> along with a time series. As the Figures 3, 4 and 5 have already demonstrated details of model errors, there is no need to come up with another evaluation approach.

(7) Model initialization: Unclear which CO<sub>2</sub> concentration is used during the spin-up. Using 1996 climate can lead to extreme biases in state variables, and also is not expected to represent pre-industrial conditions.

R: The CO<sub>2</sub> fertilization effect is not accounted for in our photosynthesis approach (light use efficiency), which only considers the limitation of temperature, water, light, nutrients. Within this 15-year time frame, we assume the impacts of atmospheric CO<sub>2</sub> is trivial. The purpose of spin-up is to adjust the initial states of soil temperature and moisture conditions, carbon pool and vegetation biomass to reach a reasonable level

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closer to the measurements. We will mention more details of model initialization in our revision.

(8) Model evaluation: I suggest first two plots for model evaluation: 1) model vs. measurement time series of NEE, temperature, etc. and 2) scatter plots.

R: We agree that time series comparison plots and scatter plots are good examples to demonstrate the model performance. However, in our study, we are not only interested in the efficiency of a model, but we also want to understand how model errors are distributed, particularly, how the errors are allocated at different time scales (daily, yearly and long-term).

#### Literature

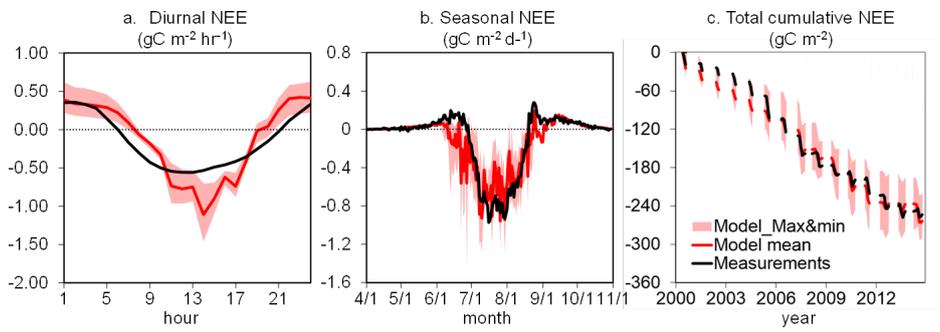
Richardson, A. D., Hollinger, D. Y., Aber, J. D., Ollinger, S. V., and Braswell, B. H.: Environmental variation is directly responsible for short- but not long-term variation in forest-atmosphere carbon exchange, *Glob. Chang. Biol.*, 13, 788-803, 2007.

Wu et al., 2017.: Partitioning controls on Amazon forest photosynthesis between environmental and biotic factors at hourly to interannual timescales, *Glob. Chang. Biol.*, 23, 1240–1257, doi: 10.1111/gcb.13509, 2017.

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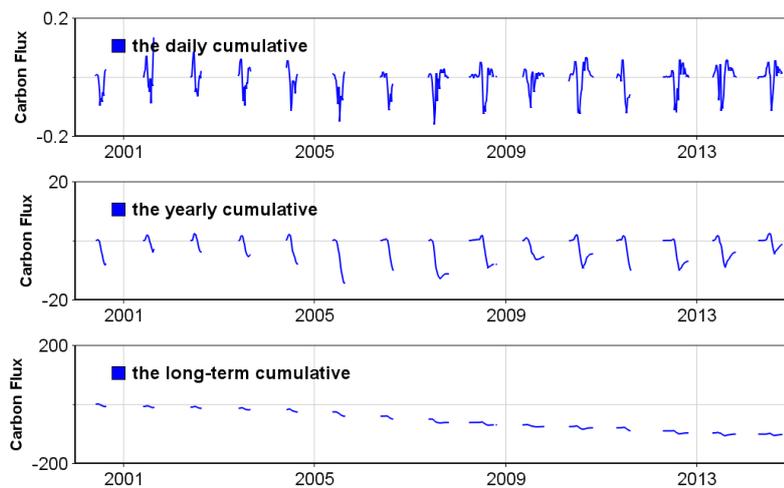
Interactive comment on Biogeosciences Discuss., <https://doi.org/10.5194/bg-2017-382>, 2017.

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**Fig. 1.** The diurnal, seasonal and long-term behavior of CO<sub>2</sub> fluxes (models: red; measurements: black).

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**Fig. 2.** The daily, yearly and long-term cumulative CO<sub>2</sub> fluxes.

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