Title: Wintertime carbon uptake of managed temperate grassland ecosystems may influence grassland dynamics
Authors: G. Katata et al.

Author response to reviewer comments

Response to Anonymous Referee #1

○General Comments: Overall, the paper does an excellent job using a process-based model to look at a critical period associated with montane grassland plants, the winter. Grasslands store lots of carbon belowground as roots and create a rich OM soil layer. The authors build a good argument for why they want to look at carbon fluxes and allocation during the winter months. The presentation of model results is good, and their conclusions adhere to what was found in their results. I do not have any major concerns with this paper as it stands.

Response: We appreciate your giving positive comments on our manuscript. We revised the manuscript based on your specific comments as follows. We hope that the manuscript is now ready to be published.

Specific Comments:

○The authors discuss low temperature photosynthesis in both the introduction and conclusion but do not go further in depth about temperature thresholds other than 5C when rubisco is very limited by temperature. I would suggest that the authors give a little more in the introduction about cold stress dynamics in relation to rubisco.

Response: We admit the description of physiological processes and acclimation dynamics to cold stress was insufficient. To emphasize the physiological importance of our work, we added the sentences with relevant publications into Introduction and Discussion as: "As reviewed in Sage and Kubien (2007), most C3 plants show an increase in photosynthetic rate below the thermal optimum (cooler temperature) due to cold acclimation, associated with enhancements of starch and sucrose synthesis, electron transport capacity, and Rubisco content." (l.38-40) and "In our simulations, we treated these acclimation responses as a parameter change, although in future developments they might be described mechanistically in dependence on temperature development (Kumarathunge et al. 2019; Mediavilla et al. 2016). Other mechanisms are however, already implicitly considered in the photosynthesis model. For example, the limitation of photosynthesis and thus the optimum temperature shifts under low air temperature from electron-transport limited to Rubisco-limited (Sage and Kubien, 2007)." (l.242-246).

Kumarathunge, D. P., Medlyn, B. E., Drake, J. E., Tjoelker, M. G., Aspinwall, M. J., Battaglia, M., et al. (2019). Acclimation and adaptation components of the temperature dependence of plant photosynthesis at the global scale. *New Phytol.* 222, 768-784. doi: 10.1111/nph.15668

Mediavilla, S., González-Zurdo, P., Babiano, J. and Escudero, A. (2016). Responses of photosynthetic parameters

to differences in winter temperatures throughout a temperature gradient in two evergreen tree species. *Eur. J. Forest Res.* 135, 871-883. doi: 10.1007/s10342-016-0980-9

Sage, R. F. and Kubien, D. S. (2007). The temperature response of C3 and C4 photosynthesis. *Plant Cell Environ.* 30, 1086-1106. doi: 10.1111/j.1365-3040.2007.01682.x

○The second aspect of the carbon dynamics that should be addressed is how water movement is impacting photosynthesis and carbon allocation within the grassland at these low temperatures. The dynamics associated between photosynthesis and water need to be stated, especially when discussing freezing conditions that occur during winter.

Response: It is correct that drought as well as freezing could influence photosynthesis and growth behavior of plants. However, drought does not play a major role at our sites which has been explicitly addressed as "No drought stress to grasslands was apparent in the simulations at both sites during the study period (not shown in the figure)." (l.195-196).

○The last specific comment I have is that the authors talk about the grasslands as fodder for livestock and its importance in the introduction, but the authors do not revisit this broader impact in the discussion.

Response: As you suggested, we added a paragraph to the discussion that points to the importance of wintertime carbon uptake for livestock: "Therefore, the increased photosynthesis in the warmer winter does not necessarily increase grass yields, and thus fodder in mountainous regions. In order to quantify the impact on livestock supply, further research needs to investigate to which degree additional biomass is directed into above- and below-ground storages." (l.277-279).

Technical Corrections:

○Pg 2 lines 25-27 – This is an awkward sentence.

Response: We corrected the sentence as "For example, winter conditions that are characterized by low temperature limits the productivity of grassland vegetation either directly due to its effects on photosynthesis or indirectly by inducing senescence and dormancy, particularly at high elevation areas." (l.26-28).

○Pg 2 line 33 – I do not understand what is meant by ": : : the above change in snow cover conditions: : :", please state what changes in snow cover conditions, make the readers job easy to remember conditions or treatments.

Response: We acknowledge the complaint and revised the sentence as "These differences between grassland sites at different altitudes clearly indicate the importance of considering the responses to environmental changes that are expected under climate change. This particularly refers to the snow-free winter periods that affect air and soil temperatures and thus the whole carbon cycle in mountain grassland ecosystems." (l.34-36).

○Pg 8 lines 220-225 – Please look at Sage and Kubien 2007 Plant, Cell and Environment. This article discusses how temperature influences Rubisco, maybe a useful article for refence to help.

Response: Thank you so much for useful information. We considered this information in the introduction and discussion sections as mentioned above (l.242-246).

○Figure 1 – This is an extremely complicated figure and hard to understand. This figure might be better suited as a supplementary figure. To help improve clarity of the figure I would suggest decomposing the figure into easier to understand panels. For instance, maybe have one panel that focuses on atmospheric parameters, another on plant processes, and another on soil processes. I do understand that many of the processes are inter-connected.

Response: As you suggested, Fig. 1 was moved to the supplement (Fig. S1). Furthermore, the figure was decomposed to four panels for each submodel(s) as reader-friendly.

○Figure 3 – The choice of having red and green on same figure is not color blind friendly. If one of the colors could be changed to a color-blind friendly palette that would enhance the clarity of the figure for all readers.

Response: The color of triangles in old Fig. 3 (now Fig. 2) was changed from green to orange as you suggested.

○Figure 6 – When printed in black and white the two colors orange and grey are too similar, please darken the grey to create a greater contrast between the two for improved interpretability when printed.

Response: The colors in old Fig. 6 (now Fig. 5) were revised for the black and white colored style.