Final Authors Response

We thank both reviewers for their extensive and insightful feedback.

Anonymous Reviewer #1

The paper by Räsänen et al. explores carbon dioxide fluxes measured with the eddy covariance method for three years at a grazed savanna grassland in Welgegund, South Africa. The material is appropriate for a scientific study and the data obtained appear to be high-quality. It is relevant for many African ecosystems to focus on CO2 fluxes response to environmental drivers in order to better predict fluxes patterns in the context of climate change. Therefore, the work is interesting and worthy of publication in Biogeosciences Journal because of the lack of knowledge regarding the carbon cycle for Africa continent. However, I have a number of issues with the paper which lead me to suggest that it requires major revisions before it becomes acceptable for publication in BG.

General Comments:

1) Firstly, while the study site is located on a savanna grassland which is grazed by cattle and sheep, authors did not provide any information on the average stocking rate and the management of the site during the studied period. Is the site grazed intensively or not? What was the stocking rate? How the grassland was managed?

Authors' response: Unfortunately more detailed measurements of cattle respiration were not available for this study. We added a paragraph to the site description about the farm management which is a typical commercial farm in South Africa.

"The measurement site is located at a commercial farm which has about 1300 head of cattle which varies ± 300 depending on the year. During a wet year there are more animals than during a dry year. The cattle are grazing on an area of approximately 6000 ha, which consists of natural grazing (e.g. at the measurement site), planted grazing and maize/sunflower fields that are grazed after harvesting. This form of farming is considered large-scale commercial farming. Due to the semi-arid climate, the carrying capacity of the grazing fields tends to be low and thus the grazing area is large. The farmers cannot keep track of the grazing patterns, but they do move the cattle around to optimize grazing and protect the field against overgrazing."

What is the slope of the field? At the measurement height what is the fetch? Was the fetch adequate to characterize the carbon dioxide and water vapor fluxes of the vegetation type? These are important for understanding and interpreting the results.

Authors' response: The measurement site is surrounded by flat homogeneous thornveld. As shown by the footprint climatology and the land-use map, the fetch is adequate for measuring fluxes over this vegetation type.

2) It is also well known (see references below) that grazing affects a range of ecological and biogeochemical processes and properties, including plan community composition, soil physical

properties, soil C and nitrogen content and the magnitude of C and carbon dioxide exchanges which in turn influence soil organic carbon storage. This study could have been more attractive if the impact of grazing on carbon dioxide exchange had been investigated. This probably would help to better assess for example the relation between the total ecosystem respiration and environmental drivers.

Authors' response: It is true that there is heavy grazing within the measurement footprint and that affects a range of processes. Unfortunately, more detailed study of the grazing effects was not possible here.

3) Authors used the Kaimal cospectra in the computation of the correction factors that are used to correct the high frequency losses (L129 – 130). However, recent studies (Mamadou et al., 2016) showed that Kaimal cospectra can be significantly different from sensible heat cospectra, and the high-frequency loss correction for CO2 using these different cospectra resulted in the large difference in CO2 flux calculations, i.e., using Kaimal cospectra can result in an overestimation of CO2 fluxes even if the site could not be considered as difficult (i.e., fairly flat, homogeneous, low vegetation, sufficient measurement height). Especially, at their studied site, authors found that the choice of Kaimal rather than sensible heat cospectra reversed the annual carbon balance from being a net C sink to being a weak C source. Did the authors verify if their kaimal cospectra differ or not from sensible heat cospectra before chosen them as idealized cospectra?

Authors' response:
The use of the so-called Kaimal cospectra is a common practice in eddy covariance studies (e.g. Aubinet et al.: Eddy Covariance, A Practical Guide to Measurement and Data Analysis, 2012). We followed this practice and used Kaimal cospectra with a system-specific transfer function for correcting for the flux losses in question. Mamadou et al. (2016) have very recently (unavailable at the time of writing of our paper) published a paper that indicates that, for an unspecified reason, the local cospectra at their site differ from the generic Kaimal cospectra. While this is an interesting observation that deserves attention in the future, it is not obvious that the implications of the potential differences would be as significant at other sites as their results may imply. It should be noted that the cut-off frequency of their measurement system was 0.37 Hz, while we were able to resolve much higher frequencies (half-power frequency 1.6 Hz). Thus our flux loss corrections are much smaller than those applied by Mamadou et al. (2016), 5% on average and <10% in 98% of the data. If we assume that our correction coefficients are uncertain by a factor similar to that estimated by Mamadou et al. (2016), the flux uncertainty resulting from these small correction coefficients would be minor. Therefore, in the present study, we do not pursue the issue of spectral corrections any further; however, we did add the uncertainty related to flux loss corrections in our uncertainty estimate for the annual CO_2 balance.

4) Most of results presented in the section 3.4 are too much qualitative, superficial and descriptive and should be supplemented with additional statistical analyses in order to provide more quantitative rigor.

Authors' response: The data covered only three years and thus a statistical analysis of annual averages is not very meaningful. To improve the presentation, the differences between the years were analysed from monthly data, including statistical analysis.

5) The uncertainties associated to the annual carbon dioxide balance estimation are not evaluated. This remains a great lack for the study. The authors also clearly mentioned in their introduction that environmental drivers for the inter-annual variation in NEE are poorly understood. Unfortunately no progress regarding this point has been made within the present study.

Authors' response: New subsection about error estimation was added to the methods section and the uncertainty of annual carbon dioxide balance was estimated.

Specific comments

L18-19: What about the dependence, at monthly scale, of the nighttime respiration on soil moisture or soil temperature?

Authors' response: For the gap-filled monthly sum of the night-time respiration, the relation with soil temperature is exponential. For the soil moisture the relation is not clear.

L24-25: by increasing autotrophic respiration?

Authors' response: Probably, but we cannot infer that from total ecosystem respiration.

L32: The seasonal cycle of what? Please clarify.

Authors' response: Rephrased. "The savanna ecosystems are generally characterized by alternating wet and dry seasons, during the latter of which wildfires can occur."

L32-33: The alternation of "wet and dry seasons" cannot in my view be generalized for the "whole Africa". In other regions of Africa, the dry and wet seasons are separated for example by two transitional seasons...

Authors' response: Added a sentence about transtional seasons.

L67, in site description section: Please, give values of the roughness length, zero-displacement height and site's slope.

Authors' response: The median of the aerodynamic roughness length was estimated to be 0.42 m assuming a low zero-plane displacement height.

L102-103: Specify the sampling rate of the meteorological variables.

Authors' response: The meteorological variables were sampled every minute and 15 min averages were recorded.

L113: Specify the type of the gas analyzer.

Authors' response: Specified.

L115-118: What are the characteristics of the sampling tube (inner diameter etc.), the pump and the gas used for the zero and span?

Authors' response: Corrected. *"The material of the inlet tube (ID 4mm, OD 6mm) was PTFE, and the pump was Dürr A-062 E1. The gas analyzer was calibrated every month with a high-accuracy CO_2 span gas (378 ppm verified by the Cape Point GAW station), and Afrox instrument grade synthetic air with CO_2 < 0.5 ppm was continuously used as a reference gas."*

L127: Give an indication of the magnitude of low frequency correction factors.

Authors' response: We added statististics on the magnitude of spectral corrections to the text according to the data presented above.

L129-130: Provide an illustration of kaimal and the sensible heat cospectra according atmospheric stability to attest that both cospectra match.

Authors' response: Since the flux loss corrections required for our data are small, irrespective of the reference cospectrum adopted, we did not study the spectral characteristics further here; however, we included a related uncertainty estimate, as explained above.

L133: Replace the calculated fluxes by "the corrected fluxes".

Authors' response: Corrected.

L133: What was the fraction of data excluded this way?

Authors' response: u* filtering excluded 18 % of the data.

L133-136: Do you only use u* filtering criteria to discard bad data? if Yes, explain why.

Authors' response: *"In addition, CO_2 fluxes were filtered by setting an acceptable range for average CO_2 concentration (300–500 ppm), Licor pressure (50–120 kPa) and CO_2 concentration variance (0–10 ppm^2), which resulted in a 3 % loss of flux data in total."*

L181: Complete "air" with temperature.

Authors' response: Corrected.

L182: You never indicated how water vapor data have been treated. What is the cut-off frequency for H2O fluxes? How these data have been corrected for low and high frequency losses? Which criteria have been used for the filtering of bad data?
L183: Explain how high evapotranspiration rate were due to higher precipitation and transpiration rate during the rainy season? What about soil evaporation?

Authors' response: The evapotranspiration data were excluded from the present analysis.

L206: air or soil temperature?

Authors' response: Soil temperature

L211- 215: The low (high) values of the correlation coefficients cannot only be used to attest the robustness of dependences. These must be accompanied with the p-values.

Authors' response: The method comparison was removed and the Lloyd and Taylor (1994) model was used for fitting the night-time respiration data. The modelled respiration rates agreed well with the measured respiration (R^2=0.56, p-value < 0.01).

L225- 226: showed how?

Authors' response: The peak carbon uptake can be seen from the darkest pixels in Figure 6. Peak radiation was checked from data (data not shown).

L232: I cannot get this conclusion...

Authors' response: Added supporting figure to the supplement. Relationship between bin averaged VPD and daytime NEE was plotted.

L223–L233: Why is there so much interpretation in the results?

Authors' response: The text in this section was rephrased and an analysis of diurnal cycle of GPP, respiration and VPD was added to the section.

L301: most or must?
Authors' response: most

L305-310: I am afraid that because of the difference of their climate, the Dahra site and cannot be easily compared to the Welgegund site. You should mention this in your discussion.

Authors' response: Removed the sentence and added "The large difference in the carbon balance is due to much larger carbon uptake at Dahra during the rainy seasons which might be explained by moderately dense C_4 ground vegetation and high soil nutrient availability."

L315, L317: Write Nalohou not Nolohou. . .

Authors' response: Corrected.

L475: Figure 1 and also in the title: "air" or "soil" temperature?

Authors' response: Corrected.

L500: Figure 3: Is it necessary to show evapotranspiration curve?

Authors' response: The evapotranspiration curve was removed.

L522: Figure 4: bin averaged for how many data?

Authors' response: The figure shows 2814 values and each bin contains at least 100 values.