Response to Reviewer 1 comments

We thank Reviewer#1 for the positive evaluation of this manuscript, and for having contributed to its improvement. According to his general comments, extra evaluations were done to ascertain whether the variation in EBR results that we found were instrument-related or due to seasonality and weather conditions. Further analysis was also done to assess surface energy balance partitioning as influenced net radiation and vapour pressure deficit. We hope that this effort will improve the manuscript, by strengthening the weak points highlighted by the Reviewer. We tried to answer every specific comment in detail as shown below:

P1-L16. The abstracts should be more specific about the paper findings, it seems more focused on just listing what the paper will be looking at.

The abstract now reads:

L16-35: Flux towers provide essential terrestrial climate, water and radiation budget information needed for environmental monitoring and evaluation of climate change impacts on ecosystems and society in general. They are also intended for calibration and validation of satellite-based earth observation and monitoring efforts, such as assessment of evapotranspiration from land and vegetation surfaces using surface energy balance approaches.

In this paper, 15 years of Skukuza eddy covariance data, i.e. from 2000 to 2014, were analysed for surface energy balance closure and partitioning. The surface energy balance closure was evaluated using the ordinary least squares regression (OLS) of turbulent energy fluxes (sensible (H) and latent heat (LE)) against available energy (net radiation (Rn) less soil heat (G)). Partitioning of the surface energy during the wet and dry seasons was investigated, as well as how it is affected by atmospheric vapor pressure deficit (VPD), and net radiation.

After filtering years with bad data, our results show an overall mean surface energy balance closure of 0.93. Seasonal variations of EBR also showed summer had best EBR with winter having the least closure. Nocturnal surface energy closure was lowest, and this was linked to low friction velocity during night-time, and an increase in friction velocity showed an increase in closure. The high surface energy balance closure gives confidence on the usability of these data for calibrating and validating

The surface energy partitioning of this savanna ecosystem showed that sensible heat flux dominated the energy partitioning between March and October, followed by latent heat flux, and lastly the soil heat flux, except during the wet season where latent heat flux was larger than sensible heat flux. An increase in net radiation was characterised by an increase in both LE and H, with LE showing a higher rate of increase than H in the wet season, and the reverse happening during the dry season. An increase in VPD is characterised by a decrease in LE and increase in H during the wet season, and an increase of both fluxes during the dry season.

P2-L67. The OLS could also be explained with a line if text or so a bit more in this context
The sentence now reads:
P2-L64-67: The surface energy balance closure is an accepted validation procedure of eddy covariance data quality (Twine et al., 2000; Wilson et al., 2002), and different methods have been used to assess the energy closure and partitioning, including ordinary least squares regression (OLS) method, i.e. a plot of turbulence fluxes (H+LE) against available energy (Rn-G), the residual method, i.e. Residual = Rn-G-H-LE, and the energy balance ratio, i.e. EBR = LE+H/Rn-G.

P2-L78. "Research on the South African savanna, i.e. using data from the Skukuza EC system", strange sentence, all research in South African savannah is linked to once EC system?
This sentence has been revised:
P2-L76-77: Research using data from the Skukuza EC system has focused mainly on the carbon exchange, fire regimes, and in global analysis of the energy balance…

P2-L84. EBR is defined, but not EB on its own, presumably Energy Balance.
P2-L82: energy balance added.

P4-L144. Not sure I understand the line "data without gaps". Does it refer to the original ½ hour data being gap-filled, or to the seasonal averages?
Deleted the sentence.

P4-L154. I am confused here, what do random errors mean here? I have problems understanding that the Rn and G observations at the station are free from random errors, as I imagine that there is always some instrumental noise in the observations.
The sentence has been modified, and now reads:
P4-L152-154: This method is only valid when there are no random errors in the independent variables, i.e. Rn and G, which of course is an incorrect assumption.

P4-L159. Potential to "remove"?
P4-L158: Neglect has been replaced by remove as recommended.

P5-L182. Mean of 1.19 +- 0.21, could you state what +-0.21 means?
± means standard deviation.

P5-L183. Wm-? 2 missing?
Corrected.

P5-L184. The variation in the slopes and EBRs are scarily large. The authors are not looking for explanations? Assuming that the environmental conditions at the tower have not changed, and that the soil/vegetation covered by the fetch of the tower observations remains similar along the years, the variability has to be related to the effect of missing data (not all years are sampled equally) and /or instrumental issues (e.g., instrumentation replacement). The latter is possibly more likely. For instance, I noticed that 2006-7-8 have slopes around 1.4, while 2009-10-11 around 0.9, with a change of Rn instruments in 2009. The authors should be looking into these things to help building confidence in the data record.

Thank you for the comment. The explanation has been given as:

L205-211: Between 2000 and 2004, the CNR2 net radiometer was used to measure long and shortwave radiation, and these were combined to derive Rn. However, when the pyrgeometer broke down in 2004, Rn was derived from measured shortwave radiation and modelled longwave radiation until the CNR2 was replaced by the NRLite net radiometer in 2009. This was a high source of error, as shown by the low EBR between 2004 and 2008. The closed-path gas analyser was also changed to open-path gas analyser in 2006. An analysis of the 2006 data (which had very low data completeness of 7.59 %) showed that there were no measurements recorded until September, possibly due to instrument failure.

P5-L191. Absence of negative Rn-G because those times of the day were not measured, or because of issues with the instruments operating at those times?

Thank you for the comment.

Please see the above response.

P6-L219. Figure 2 shows a larger number of outliers for summer and spring, any reasons for that?

Thank you for the comment.

For the seasonal EBR assessment, we had not filtered out the 2004-2008 data; after doing so, we saw improved results (see Fig 3).

L238-241: A large number of outliers is observed in summer due to weather conditions like clouds and rainfall events that make the thermopile surface wet, thus reducing the accuracy of the net radiometer. A study comparing different the performance of different net radiometers by Blonquist et al. (2009) shows that the NR-Lite is highly sensitive to precipitation and dew/ frost since it the sensor is not protected.

(Figure 1)

P7-L242. The references point towards the EC measurements not being reliable at night-time (low turbulence, advection, etc). What about the net radiation measurements at night-time? More trustable than the EC ones?

Thank you for your comment.

L271-275: Another source of error in the nocturnal EBR is the high uncertainty in night-time measurements of Rn. At night, the assumption is that there is no shortwave radiation, and Rn is a product of longwave radiation. Studies show that night-time measurements of longwave radiation were less accurate than daytime measurements (Blonquist et al., 2009). The RN-Lite, for instance has low sensitivity to longwave radiation, resulting in low accuracy in low measurements.

P7-L252. There seems to be things to comment on Figure 4. What happens with the daily means in 2006? Why the Rn from 2004-2010 looks different form the other years? Inter-annual variability or instrumental issues? The LE, H, and G look more consistent from year to year.

Thank you for the comment.

L284-287: The gap in 2006 indicates the absence of the surface energy measurements in that year, a result of instrument failure. Between 2004 and 2008, the Rn was calculated as a product of measured shortwave radiation and modelled longwave radiation, which was a high source of error in the estimation of Rn. These years are also characterised by low EBR.

P7-L275. Even if references are given, it will be good to explain the links between cloudiness and precipitation and the observed Rn seasonal variability. Clouds should increase the downward longwave component and reduce the downward shortwave. I'm not an expert, but it is not that obvious that the overall effect is an increase in the net radiation. Also, it may have helped to understand this figure to have Figure 5 plotted as monthly means, instead of a time series.

Thank you for the question.

We removed the section.

P8-L301. The findings of Gu 2006 correspond to a temperate forest site, so the environmental conditions are in principle different for the location of the study, which is a semi-arid savannah environment. It is worth mentioning.

Thank you. The sentence now reads:

L333-334: Gu et al. (2006) examined how soil moisture, vapour pressure deficit (VPD) and net radiation control surface energy partitioning at a temperate deciduous forest site in central Missouri, USA.

P8-L302. The "concave" and "convex" mentioning requires further explanations, can it be illustrated with the data at the Skukuza station? It does not seem obvious from the figures shown so far in the paper, or I am missing something.

Thank you for the comment.

L320-332: The influence of VPD and Rn on surface energy partitioning was investigated. Results show that there is an increase in H and decrease in LE with an increase in VPD in the wet season (Fig 9).As illustrated earlier (Fig 1), VPD is higher when there is little or no rain (low soil water availability), which explains the increase in Bowen ratio with a rise VPD. In this instance, although the evaporative demand is high, the stomatal conductance is reduced due to absence of water in the soil, resulting in smaller LE and higher H, and thus higher Bowen ratio. Rn, on the other hand, is partitioned into different fluxes, based on other climatic and vegetation physiological characteristics. Figure 10 illustrates that both latent and sensible heat flux increase with increase in net radiation, although their increases are not in proportion. During the wet season, the rate of increase of LE appears to be higher than that of H, whereas in the dry season the reverse is true. The rate of increase of LE is controlled by the availability of soil water (precipitation), and during the wet season it increases steadily with increasing Rn, resulting in a convex, whereas the rate of increase of H is concave, showing saturation with an increase in Rn. The opposite is true during the dry season, with limited water availability, the rate of increase of LE slows down with increase in Rn giving a concave, and a steady increase of H with Rn increase.

P9-L321. I am having some problems understanding Figure 8. If the aim is to discuss the partitioning of the heat fluxes, perhaps it could have been better to normalize with the available energy, i.e., the ratio of LE and H with Ae=Rn-G and only plot LE/Ae and H/Ae. This is because the energy closure shown in the figure seems very poor sometimes, so I am wondering if we can draw any conclusions about the fluxes partitioning at those times of the day. If we are plotting LE/Rn, H/Rn, and G/Rn, the sum LE/Rn+H/Rn+G/Rn = Rn/Rn =1 if energy closure was perfect and there were no missing terms. Now, if we take just before 18 hours in spring, LE/Rn_=4, H/Rn_=2, G/Rn_=-2, so the net sum is 4 instead of 1 (for perfect closure). Or, in other words, the energy required for that situation is 4 times larger than the available Rn. A similar thing happens in summer around the same time, in winter around 6 hours. Is there a source of energy missing, or is it related to instrumental issues (small value of the fluxes and ratios between them)?

This section was removed.

P9-L325. In summer before the sun sets, there is a new peak of positive LE not too different in magnitude from the peak associated to the presence of dew. What can be the cause for that?

P9-L332. The conclusions are too short and too general. A food example is the last sentence "The results also show that water availability land vegetation dynamics play a critical role in energy partitioning, whereby when it rains, vegetation growth, leading to an increase in latent heat flux / evapotranspiration", which is certainly true, but sort of common knowledge.

Table 1. Any specific reasons to replace "at" by "@" in the text of the Table? Figure 1. Years should be added to the individual plots.
Corrected.

Figure 2. For consistency with Figure 1, it would be more useful to have the EBR in the plots, instead of the number of points.
Done, see Fig 3.

Figure 5. Is air humidity also measured at the station in a routine basis? Given the study of the heat flux partitioning, something like VPD would have been nice to have and analyse. Figure 6. It would have been nice to have a new bar with the H+LE+G, so it could be compared with Rn and used to assess the seasonal energy balance closure.
Thank you for your comment. We have analysed how VPD influences surface energy partitioning:
L320-332: The influence of VPD and Rn on surface energy partitioning was investigated during the wet and dry seasons. Results show that there is an increase in Bowen ratio with an increase in VPD in the wet season (Fig 9). As illustrated earlier (Fig 1), VPD is higher when there is little or no rain (low soil water availability), which explains the increase in Bowen ratio with a rise VPD. In this instance, although the evaporative demand is high, the stomatal conductance is reduced due to absence of water in the soil, resulting in smaller LE and higher H, and thus higher Bowen ratio. Rn, on the other hand, is partitioned into different fluxes, based on other climatic and vegetation physiological characteristics. Figure 10 illustrates that both latent and sensible heat flux increase with increase in net radiation, although their increases are not in proportion. During the wet season, the rate of increase of LE appears to be higher than that of H, whereas in the dry season the reverse is true. The rate of increase of LE is controlled by the availability of soil water (precipitation), and during the wet season it increases steadily with increasing Rn, resulting in a convex, whereas the rate of increase of H is concave, showing saturation with an increase in Rn. The opposite is true during the dry season, with limited water availability, the rate of increase of LE slows down with increase in Rn giving a concave, and a steady increase of H with Rn increase.

Figure 7. The labels, legends, and lines are difficult to read, they need to be made larger. The a, b, c, d symbols are missing in the figures.
This Fig 7 has been removed.

Figure 8. Same as figure 7, we can hardly read the labels or identify the colours of the lines.
This Fig 8 has been removed.

References

Blonquist, J., et al. (2009). "Evaluation of measurement accuracy and comparison of two new and three traditional net radiometers." Agricultural and Forest Meteorology **149**(10): 1709-1721.Gu,

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Twine, T. E., Kustas, W., Norman, J., Cook, D., Houser, P., Meyers, T., . . . Wesely, M. (2000). Correcting eddy-covariance flux underestimates over a grassland. Agricultural and Forest Meteorology, 103(3), 279-300.

Wilson, K., Goldstein, A., Falge, E., Aubinet, M., Baldocchi, D., Berbigier, P., . . . Field, C. (2002). Energy balance closure at FLUXNET sites. Agricultural and Forest Meteorology, 113(1), 223-243.