Response to Anonymous Referee #1

Received and published: 26 March 2015

The manuscript shows an interesting study on the use of multiangular spectral measurements to describe the physiological status of the vegetation canopy in a complex tree-grass ecosystem. In this context it contributes to the research done within scientific networks such as Fluxnet, SpecNet , Eurospec, Optimise, etc. that have worked on the integration and standardization of in situ optical and flux-tower measurements with the ultimate goal of determining ecosystem fluxes in a spatially and temporally continuous mode. It is extremely difficult to obtain accurate/reliable in situ spectral measurements, particularly in a continuous and multiangular mode due to a number of potential errors caused by instrumental and environmental factors. Therefore, the manuscript represents a substantial contribution in that field due to the scientific significance of the in situ dataset analyzed. Also the study site selected in this paper is very interesting from the remote sensing perspective as, in this savanna ecosystems, the estimation of biophysical properties is still an issue owing to the challenge of determining some variables in a highly heterogeneous canopy. The research questions addressed are relevant and clearly fall within the scope of Biogeosciences.

Response: We would like to take the opportunity to thank the reviewer for these valuable comments. We found the review to be highly constructive and after implementing most of the revisions we feel the paper has improved a great deal.

Specific comments addressing particular scientific issues:

1. Abstract and introduction are concise and summarize relevant research to provide context. However, in the introduction I miss a review of previous works on continuous multiangular hipersepectral observations for ecosystem monitoring such as the ones from T. Hilker using the AMSPEC system.

Response: A section reviewing previous works on continuous multiangular hyperspectral systems for monitoring ecosystems in situ is included in the revised introduction.

2. In the methods section some key information on data acquisition is missing. This information is necessary in order to properly interpret the results, especially in the case of the hyperspectral reflectance measurements but also for the ecosystem properties. In the manuscript there is only one paragraph describing hyperspectral reflectance data acquisition. Authors refer to the work of Huber et al (2014) for additional information, however, the importance of this data in the context of the paper justifies a more detailed description in the methods section. One of the key issues related with continuous spectral observations are the potential errors caused by instrumental and environmental factors. Those should be at least briefly described in the paper. Another important information which should be included regarding spectral measurements is the area observed by the sensor which, in this ecosystem, is assumed to be a mixture of trees, grass and tree-shadows at the different viewing angles (including nadir observations). This is a relevant issue because authors are building empirical models comparing spectral measurements with some ecosystem parameters as GPP which results from the mixed contribution of the different ecosystem fractions and others (as is the case in biomass) where the information comes only from the grass fraction.

Response: Thanks, we have provided more information regarding the biomass sampling, the eddy covariance measurements, and the spectral radiometer measurements in the revised method section. Possible errros in the measurements are also mentioned in the revised manuscript.

Thank you very much for pointing out to us that it was unclear regarding the instantaneous field of view (IFOV) by the sensor; this requires a bit more elaborate explanation (also included in the revised manuscript). There is no influence from trees in the hyperspectral data set used in this manuscript as the entire IFOV constitutes of herbacous ground vegetation. In the analysis for relationships between seasonal dynamics in ecosystem properties and hyperspectral reflectance, we used nadir observations. The site only constitutes of 3% tree cover, and there are neither trees nor shading of trees in the IFOV for the nadir observations. For the analysis of anisotropy, we used angular measurements measured between (12:00 an 14:00), and there is no influence of trees nor any tree shading for this part of the day in the IFOV of the angular measurements. It is emphasized in the revised manuscript that the IFOV covers only herbaceous vegetation.

The biomass measurements is also only covering the herbaceous vegetation. The FAPAR measurements are done in the vicinity of the tower containing the radiometers, and thereby influenced by the same herbaceous vegetation as the radiometric measurements. GPP and light use efficiency is based on eddy covariance data with a median 70% cummulative footprint of 388 m. These estimates are thereby influenced by both herbaceous vegetation and the tree cover. However, as the tree cover is only 3%, we consider that the major part of these variables also depend on the herbaceous vegetation. Information regarding the fetch and footprint of the measured variables is included in the revised manuscript.

3. Another key issue in this paper is the representativeness of the empirical relations found. There is an obvious limitation of the dataset in the spatial domain as it is only one instrument providing spectral observations. However, for the temporal domain, there are a large number of observations (1.5 years) that would allow an independent validation by using only part of the observations to calibrate the statistical model and another one to validate it.

Response: In the parameterisation of the statistical models, we used a bootstrap simulation methodology where the datasets were copied 200 times (Richter et al., 2012). When bootstraping, a data set with the same number of data points as included in the original data set is created; some of the data points are left-out, and some ot the data points are included several times. We used the data points that were included within each bootstrap run to parameterise the models, whereas the remaining ones were used for validating the models. So for each of the 200 runs we parameterised a statistical model, which was validated against the left-out subsample by calculating a root-mean-square-error. We estimated a median and a standard deviation from the 200 runs. This information is emphasized in the revised manuscript.

4. Authors should better justify the negative correlations found between NIR bands and biomass. Previous works have demonstrated negative correlations in the visible but positive in the NIR both for total and green biomass (could the tree and shadow fractions of the ecosystem included in the sensor FOV be influencing this relationship?)

Response: Thank you very much for pointing this out to us, this is very interesting. As there are no trees in the IFOV of the sensors, the trees do not influence this relationship. The signal is based on reflectance from a IFOV only containing herbaceous vegetation. When fitting a correlation to vegetation water content, there is a positive correlation. But when the correlation is done versus dry weight biomass, these positive relationships to NIR HCRF turns negative. It is included in the revised discussion that these strong negative NIR HCRFcorrelation with dry weight biomass should be studied further to better

understand the respective importance of canopy water and leaf internal cellular structure for the NIR HCRF of herbaceous vegetation characterised by erectophile leaf angle distribution (LAD).

5. An interesting issue addressed by the paper is the effects of sun and sensor viewing geometry on NDSI. Did the authors analyzed how the mixed effect of the different ecosystem fractions (proportions) observed by the sensor at the different observation angles is contributing to these directional effects? Discussion about the potential of this dataset for BRDF modeling would be needed.

Response: The mixed effect of different ecosystem fractions is a very interesting point, and it would make a very interesting future study. However, it would require that the entire system is put on a higher tower. At the present height of the tower, only herbaceous vegetation is seen.
It is included in the revised discussion that this data set can potentially also be used for BRDF (bidirectional reflectance distribution function) modelling.

Specific comments addressing formal/technical corrections: (Line/page numbers are referred to the marked up version of the manuscript)

Abstract
Line 115. Use hemispherical conical reflectance factor (HCRF) instead of reflectance (also throughout the paper)

Response: Thank you for mentioning this. We have now included the terminology of HCRF throughout the manuscript and included a footnote in the introduction clarifying this.

Introduction
Lines 137-138. Review commas in these sentences

Response: This is taken care of.

Line 152-153. Suggest to change ": : :.indices are ratio type of indices" by : : :"those based on band ratios" in order to avoid repetition

Response: This is taken care of.

Line 175-176. Suggest to change "The influence from sun-sensor variantions: : :" by "The influence of sun-sensor geometry: : :"

Response: This is taken care of.

Lines 177-179. Not only goniometers but also multiangular satellite data, as the one provided by Chris Proba, has been used to analyze these effects.

Response: We have now added the Chris-Proba, MISR and POLDER satellite instruments including refs.

Line 187.Avoid repetition in the same sentence "hyperspectral reflectance"

Response: This is taken care of

Materials and method

Line 220. Review the sentence. : : :grass and (other) herbaceous vegetation: : :.?

Response: This is taken care of.

Line 259. The second sensor head is a cosine receptor? If so, please specify

Response: This is taken care of.

Lines 311-312. How the ANIF thresholds for data filtering were stablished?

Response: The threshold values of 0.8 and 1.2 indicate that the bias due to directional effects in the NDSI related to the variable view zenith angles are not larger than 20%. This is the same threshold value as was chosen for the effects of variable solar zenith angles. This is included in the revised manuscript. Honestly, the chosen level of 20% is somewhat arbitrary; it is a compromise between not incorporating too large bias, and not excluding too much data.

Lines 313-317. Move to section 2.4

Response: This is taken care of.

Lines 369-370. Those relationships obtained using filtered or not filtered data? Please specify also for other ecosystem properties.

Response: They are based on filtered data, this is specified in the revised manuscript.

Figures

Figure 1. I would suggest replacing pictures by a high resolution image with the location of the towers and showing the area observed by the spectroradiometer. Additional information on the location of the biomass sampling plots and the EC mean footprint would be also useful.

Response: This is a very good suggestion. We have decided to keep figure 1, but we included more photos in the figure. We have now photos of both towers, and the IFOV/footprint of both the spectroradiometers and the Eddy covariance measurements. In addition, we added a high resolution image includig the location of the towers, the biomass sampling plots and the EC footprint.

Figure 5. How the authors explain the correlations peaks in all the graphs at approximately 1200 nm? Also the information included in the figure caption would be quite useful in a separated table in the methods section summarizing the main characteristics of the different datasets (units, n) but also data range, aggregation (if any), data gaps, etc.

Response: The correlation peak at about 1150 nm is caused by the water absorption peak around this wavelength (Thenkabail et al., 2012). The lower the reflectance in this peak, the higher the water content, and hence the higher the biomass. This information is included in the revised manuscript.
A table is included in the revised method section with the requested information.

References:

Richter, K., Atzberger, C., Hank, T. B., and Mauser, W.: Derivation of biophysical variables from Earth observation data: validation and statistical measures, APPRES, 6, 063557-063551-063557-063523, 10.1117/1.JRS.6.063557, 2012.

Thenkabail, P. S., Lyon, J. G., and Huete, A.: Advances in hyperspectral remote sensing of vegetation and agricultural croplands, in: Hyperspectral Remote Sensing of Vegetation, edited by: Thenkabail, P. S., Lyon, J. G., and Huete, A., CRC Press, Taylor and Francis Group, Boca Raton, FL, 3-35, 2012.