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Interactive comment on "On the relationship between ecosystem-scale hyperspectral reflectance and CO₂ exchange in European mountain grasslands" *by* M. Balzarolo et al.

Anonymous Referee #1

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General Comments:

This manuscript uses hyperspectral data to identify spectral regions that can be used to estimate biophysical characteristics of three grassland sites in Europe using three simple types of vegetation indices. The models are very simplistic considering the complexity of the BPCs examined, i.e. Gross Primary Production (GPP). Most approaches to estimate GPP use multiple inputs, thus, the approach in this study to estimate GPP using VIs developed by all possible band combinations performed poorly across all three sites. While non-linear relationships with BPCs and VIs may produce

low error estimates in calibration, they perform poorly when validated, especially when applied to sites not included in the validation. The study should focus on the linear models and provide readers a sense of stability of the bands selected by using a calibration/validation or cross-validation approach. The authors have a rich data set that can be very beneficial to the scientific community; however, the approach to analyze this data needs improvement. Other smaller issues include (1) a very weak methods section that did not provide enough detail regarding the data collection, (2) poor presentation of the results in complicated tables and figures, and (3) needless duplication of figures in the supplemental that could be presented in the manuscript.

Specific Comments:

2.2 Hyperspectral reflectance measurements

P10328L13: Reflectance should be collected near solar noon. In many locations the midday times may be offset from this ideal period of data collection due to local/national rules and regulations such as the implementation of daylight savings. Indicate when the reflectance measurements were collected in reference to solar noon at the summer solstice or the rough time for much of the growing season.

P10328L14: Indicate the model number here. While all details are probably not warranted, do not expect readers to read the previous publication. Even the cited publication is lacking some details and refers to another publication. Why not refer to the original here? It is already cited in the manuscript?

P10328L18-22: Hemispherical reflectance is very unusual as it is easy to have contamination of the nadir view by the sky as the field of view (FOV) is very wide. What is the model of the cosine diffuser used? What is the FOV of the diffuser? What steps were taken to reduce/eliminate the user/tripod from contaminating the FOV?

P10328L20: It is assumed that the 1.5 m was above the ground, but it was not explicitly stated. Why not above the canopy? This would result in the same area seen by the

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sensor at the top of canopy. Thus, when the grasses are taller, the less of an area the sensor will be seeing.

2.3 CO2 flux measurements

P10329L5-16: More details are needed to describe the CO2 flux measurements. What brand/models were used? Describe the methods as they are critical to the interpretation. The book by Aubinet et al 2012 describe multiple methods and it is CRITICAL that readers know exactly which methods were used and why. How was Reco modeled? Daytime estimates are confounded by both plant photosynthesis and different meteorological conditions (e.g. temperature, wind speed). It is quite possible that different models and methods are driving the differences between the sites.

Were key supporting meteorological variables also measured (soil heat flux, humidity, incident solar radiation, etc.)? If so, at least list these variables so users understand what kind of gap-filling strategies could be used without needing to directly look up the cited publication and to see if the suggest gap-filling methods make sense for the site.

P10329L5-8: For an empirical study with mixed results, this seems like a very small sample size (1 year of data for 2 sites and 2 years of data for 1 site).

2.4 Estimation of grassland ecophysiological parameters

P10330L1: Be specific on how the extinction coefficient was calculated. It would be assumed for grasslands, but it should be explicitly stated not just referenced. Also identify that this k was determined for grasslands different from the site.

P10330L15: Citation needed for the Levenberg-Marquardt algorithm.

P10330L10-19: It is not clear how respiration was measured and/or fitted. Were nighttime measurements used to estimate daytime measurements?

2.5 Hyperspectral data analysis

P10331L13-17: Most individuals know how to calculate R2 and RMSE. These equa-

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tions and associated descriptive text can be deleted.

P10332L12-18: While AIC is a valid approach to determine if added complexity improves the model accuracy, the purpose of this study was to "develop a common framework for predicting grassland GPP based on optical remote sensing data." Thus, a model that is high accuracy in calibration may not be very useful when validated. This is a critical concern when using non-linear models as the VI becomes insensitive to the biophysical characteristic (BPC; e.g. GPP, NEE). This will reduce scatter (thus increase R2 and reduce RMSE), but be unusable for practical purposes as similar VI values can represent a wide range of BPC (this problem is especially prominent when using NDVI to estimate LAI). A better metric to use for both linear and non-linear relationships would be noise equivalent (NE). Unfortunately for non-linear models, the NE will change based on the value of the BPC. Thus, in some ranges of BPC they will work better than others. This information could not be easily presented in correlograms. This reviewer suggest eliminating non-linear relationships and focus on linear ones as they are (a) easier to use and (b) more reliable throughout the entire dynamic range of each BPC if the relationship is truly linear. This could be easily tested by plotting the best bands for each VI against the BPC.

P10330L20-P10332L18: Why not divide the data into calibration/validation data sets or use a leave-one-out procedure to test the sensitivity of these selected bands? If the goal is to estimate GPP using remote sensing data, then determining a robust set of wavebands that works for each site should be the initial goal with a secondary goal of finding a set of wavebands that works for all three sites.

3.2 Hyperspectral data and their relation to CO2 fluxes and ecophysiological parameters

P10333L23-25: Figure 3c does not follow this pattern. The spectra for the highest LAI has lower NIR than the spectra for the next two highest LAI.

P10333L27-P10334L1: It is impractical to compare exponential relationships using R2

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values (even RMSE values should not be used) as different slopes/intercepts make it very difficult to conceptualize their real differences. As these relationships were never presented, it is impossible to compare these relationships in this manuscript.

P10334L15-18: One of the problems with correlograms is the end result does not explain causation, only that some correlation exists. There has been quite a bit of research in understanding why specific spectral regions can explain various BPCs. There is no discussion of this research and how it supports the results from the correlograms.

P10334L24-28: Significance is not a good predictor of accuracy as significance can be improved by sample size.

P10334L18-28: It seems that this model is extremely simple and this is why it fails. It is already well known that GPP is controlled by many different factors (temperature, water stress, etc.). One reason VIs are widely used is that they remove some variation (i.e. two different sets of reflectance can yield the same VI value). Thus, VIs may not capture all of the necessary variation to explain GPP. There are GPP models that use multiple VIs to help address each of these components.

P10339L29-P103340L1-3: The MOD17 algorithm is a very low bar. Most researchers active in the field know it is too simplistic, thus for most site-specific applications, they do incorporate at least several of these aspects.

Tables

Table 2: Chlorophyll index is not a normalized difference VI. It is more similar to simple ratio with the exception of the ratio being subtracted by 1. The CI presented in the table would be more accurately called the Red Edge NDVI. A better citation for CI would be Gitelson et al. 2005, doi:10.1029/2005GL022688.

Tables 3 and 4: These are too complex to be able for readers to digest easily. Eliminate the exponential relationships. The number of significant digits is not appropriate for all metrics. For example the RMSE for α and ε is not 0.0. Readers cannot make any valid

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comparisons with insufficiently presented tables.

Eliminate the AIC from the tables as the AIC values should only be compared between models with increasing complexity using the same data set (i.e. the same VI estimating the same BPC). The table makes it appear that these AIC values can be compared across VIs, when this is not the case due to the different values/dynamic ranges of VIs.

Figures

Figure 1: It is difficult to read the VI text on the figure. Define all abbreviations in figure captions so readers do not need to find them in the text.

Figures 4-9: Use the figures in the supplemental. The information in the poor relationships are just as valuable.

Figure 10: It does not matter if the model is more "accurate" if a significant portion of the dynamic range is insensitive to changes in GPP.

It would be helpful to readers if a figure using the proposed VIs vs. BPCs were presented.

Other Notes:

These correlation matrices are not ideal for identifying the best bands except for very simple cases. An approach that would have yielded a more informative conclusion would be a GA-PLS analysis which can provide insight into more complex interactions between different wavebands.

Technical Corrections:

P10325L4: The word "lately" implies very recent papers, 2007-2010 are recent, but not very recent. Delete the word or find more recent publications.

P10326L12: Misplaced comma after "and"

Interactive comment on Biogeosciences Discuss., 11, 10323, 2014.