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Interactive comment on "Comparative validation of UAV based sensors for the use in vegetation monitoring" *by* S. von Bueren et al.

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Overall: The authors present an interesting paper describing the operational deployment of a range of multispectral sensors on board two types of UAV – a Quadcopter multirotor platform and a Falcon8. The main research question being addressed is whether the quality of data delivered from a UAV platform is useful for addressing questions about vegetation condition. The authors state that 'New sensors need to be trialed and validated against state of the art reference instruments' which is a good aim, since many other studies have not looked at this data quality question, nor at the issue of measurement reproducibility. The methods used are described quite well and the use of in-field calibration targets is also useful and informative for cross-comparison studies, athough they clearly had some challenges in using these (e.g. saturation effects). There are some interesting insights in the paper but there are also some issues. I do wish to raise some concerns about the paper and the way that it the research is framed, as follows:

The cross-comparison between instruments mounted on a UAV and a ‘reference standard’ instrument on the ground (ASD fieldspec pro) is good, in principle. However in practice there would seem to be a missing link here. I was left wondering about why a UAV was even needed to answer some of these cross-comparability questions. Surely some of the comparisons could have been made by comparing solar reflected radiation measured by these instruments simultaneously measuring the same target in the field? This would provide a baseline comparison of their radiometric capabilities without the need to launch on a UAV. Perhaps this should have been the first step in the experiment – e.g. a ground-based comparison of instrument radiometric returns from close range, where other factors could be better controlled. Then, putting the instruments into the UAV as a secondary aim as a means of discussing the various extraneous factors and their impact on data quality and reproducibility (e.g. GPS positioning uncertainty, different spatial support, geometric platform wobble, vibration etc).

The cross-comparison to the ASD measurements itself poses challenges. There is a scale issue – e.g. the sensors are measuring areas of different spatial support, and this would be expected to have some effect on the measured radiant flux. This effect would have been negated at close range (e.g. as suggested above), allowing a more comparable set of measurements to have been obtained, and thus enabling a more complete description and intercomparison of the various instrument capabilities. As it stands, the differences reported could be a combined effect of both spatial support, platform wobble in flight, and radiometric differences in sensor capability. This complexity is currently not discussed in the paper.

The ‘overview’ images – line 22-25 – captured all of the areas of interest in a single photograph. However, there would have been angular differences across teh field of view of these imagers, and whilst the effect may have been slight, this is not discussed

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or mentioned. Perhaps a better approach would have been to fly over these as waypoints too, so that the centre of the camera's FOV was aimed at the centre of each of the areas of interest. An 'overview' image could then have been used to test this angular dependency (if it existed).

The Quadcopter and Falcon8 systems would benefit from a photograph or figure showing the main differences between them. Table 1 is good but if there is scope to add a photograph here it would be a useful addition.

In relation to the two platforms used – it is not really very clear what purpose it served to have two different UAVs. What question was being asked of these two platforms? I could not clearly see why both were used, it would surely have been more comparable to use a single UAV with the different sensors installed on it. Otherwise you just introduce another factor causing variability, which is difficult to untangle in the results. Can the role of these different platforms be clarified please.

In response to "The green band (551nm) achieves lowest correlations with ASD convolved reflectance values (R2=0.68) with MCA6 reflectance factors overestimated over all waypoints" and the fact that for NIR data, the R2 values are around 0.7 – this would seem to be the two areas where if one wanted to discover something about biochemical processes in vegetation, one would need the most accurate information – how do the author's respond to this. i.e. the lowest accuracies seem to be in the most important parts of the spectrum for assessing vegetation state?

The same issue as the above is true for the UAV spectrometer which reported largest differences in the NIR when compared to the ASD on the ground. I suspect this discrepancy is entirely down to the different spatial support (and possibly even the different portion of the land surface being sampled) by both instruments. A field-based campaign before putting the instruments onto a UAV would have answered this question quite easily.

The issue of footprint matching is quite important – presumably the GPS on the UAVs was a standard type with nominal accuracy of +/-10 m. If that's the case, then the fine spatial resolution offered by the sensors is somewhat negated by this spatial positioning precision issue. Without improvement on this, the issue of image matching is a very difficult thing to address. Perhaps a differential GPS correction of the images to a more precise location prior to use of the spectral data would have been a good method to use.

For me, one major element is missing and this is the link to the "vegetation monitoring" part. Sure, there are some field spectra in the paper that show the classic vegetation spectrum but I think an end user of the technology would want to know how these data actually relate to something about the vegetation properties of the landscape you were monitoring. Of course, we all accept that from a vegetation spectrum, one can derive various other parameters but for your site, what information do these data carry, specifically? E.g. Ryegrass pastures – what is useful to know about the productivity of these areas and can this be derived from the systems you used (and to what extent in the multispectral vs optical vs hyperspectral systems). I think this connection needs to be made in relation to some kind of field data (e.g. Leaf Area Index, chlorophyll content, carbon content or some other biophysical parameter).

Discussion – "Four optical sensors were flown over ryegrass pastures and validated; including the first available UAV based micro spectrometer" – This is not strictly true in my view – the validation can only be claimed if one had a good match in space, and time between the data collected from the UAV and the data on the ground. I can't agree that spatial and temporal matching was possible to within a good enough level of accuracy to accept that this constitutes a robust validation. At best, it is more a cross-comparison of data points with different spatial support, where there is some certainty that the different instruments were viewing a similar point on the ground (but not the exact same point). The temporal offset in the timing of the ASD measurements and the UAV survey would also mean that some BRDF effects in the data are likely, and these are not considered in the discussion.

“ground reflectance data calculated from the four UAV based sensors correlated significantly” – again this is slightly misleading because this was true when all the data were aggregated but on a band-by-band basis the correlations were slightly compromised.

“The novel high resolution STS spectrometer can now be regarded as a fully characterised stand-alone UAV spectrometer system, capable of reaching data quality in the range of an ASD.” – again, this is still not quite fully evaluated in the results. Earlier in the text, you said, “depending on the status of the vegetation target the ASD derived reflectance factors can be up to 1.5 times (Fig. 4) higher than the UAV spectrometer measurements”. So, I think the claim is over-stated in the discussion.

Specific comments – In the abstract, line 10, data were (data = plural) Abstract – line 12, multispectral camera is not really the same as an imaging spectrometer. The two things are completely different. So I think it is best to just say this was a multispectral camera.

Last line of abstract – I think that the claim “The high resolution spectrometer was validated and found to deliver spectral data that can match the quality of ground spectral measurements.” Is overstated (see more detailed comments). I think you could possibly argue that it matches the ‘information content’ but the quality does not appear to be the same if you look at statements made in the results section. I think this is also a ‘fine spectral resolution’ spectrometer.

Line 35 - Camera settings, such as exposure time and white balance settings were optimized and fixed to the illumination conditions. Please specify these settings otherwise others will find this difficult to interpret and repeat.

Section 2.2 – what autopilot software was used. Did you use some kind of algorithm in that software to get a good overlap? Were the cameras gimballed or levelled so that they were always viewing the ground from a fixed position / geometry?

Section 2.4 – GPS survey. I assume this is just a standard GPS survey or was it a

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differential system? Not clear from the description of the method.

Table 2: canon powershot – 'zoom lens' is not a helpful description. What's the focal length? What setting was used (Aperture priority? Etc...).

Table 2 – STS spectrometer spatial resolution – single point is too vague. Surely for the hovering height of the UAV one could calculate for a fixed FOV a nominal 'spot size' on the ground?

Figure 4 – label UAV OO confused me. I think this should be STS?

In figure 3c the alignment of the 6 cameras is mentioned as being an issue but I cannot see where the method for aligning the camera views is discussed or explained in the text. How is this achieved?

Interactive comment on Biogeosciences Discuss., 11, 3837, 2014.

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