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Biogeosciences Discussions

Interactive comment on "Towards spatial assessment of carbon sequestration in peatlands: spectroscopy based estimation of fractional cover of three plant functional types" *by* G. Schaepman-Strub et al.

G. Schaepman-Strub et al.

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Answers (A) to comments by Referee O. Sonnentag (S.)

We wish to acknowledge this reviewer for his extensive and constructive review. Please find the answers to the specific comments below.

S. However, I would suggest re-organizing some parts of the Methods section to make it more accessible to readers outside the remote sensing community who might not be familiar with SMA and its variants such as MESMA (see my specific comments below).

A. We added more references with extensive discussions on the variants of the spec-

tral mixture model and its inverse problem that have been published in various remote sensing journals. However, the main scope of this manuscript emphasizes the application of SMA and its inverse problem in peatlands and its uncertainty, to support carbon cycle studies.

Specific comments

S. There are some minor stylistic and linguistic problems here and there (e.g., consistency: the acronym for "plant functional type&" is introduced as "PFT" [page 1296, line 4] but in places "plant functional types" is used [e.g., page 1300, line 10]; the same for "carbon" vs. "C" that should be addressed, together with at least some of my specific comments below, ...

A. Revised.

S. [1] page 1294/ starting line 1: The introduction doesn't say anything about the biomass component of this manuscript.

A. Added (i.e. biomass is used as a proxy for the current status of carbon sequestration, while changes in vegetation composition indicate changes in carbon sequestration potential on the long-term).

S. [2] page 1295/ starting line 6: "Particularly the cover and productivity of the bryophyte component, dominated by the genus Sphagnum ..." The moss endmember in this study is of the genus Sphagnum, but not all peatlands are dominated by Sphagnum mosses. I would suggest being a bit more specific and include a few words on which types of peatland are dominated by Sphagnum mosses vs. brown mosses (especially with regard to the field site of this study with heath vs. bog [page 1297, line 17]).

A. Specified (the study only covers the ombrotrophic patches, and thus brown mosses are not of major importance in the observed plots).

S. [3] page 1295/ line 25: Please provide references for these statements.

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A. References added on the control of the carbon balance in peatland soil by near-surface wetness:

Belyea, L.R., Baird, A.J.: Beyond the limits to peat bog growth: cross-scale feedback in peatland development, Ecol Mon, 76, 299-322, 2006.

Robroek, B.J.M., Schouten, M.G.C., Limpens, J., Berendse, F., Poorter, H.: Interactive effects of water table and precipitation on net CO2 assimilation of three co-occurring Sphagnum mosses differing in distribution above the water table, Glob Change Biol,14, 1-12 ,2008.

S. [4] page 1296/ starting line 4: At several places throughout the manuscript "mosses" is used as an alternative for "Sphagnum". This paragraph highlights the different spectral characteristics of red Sphagnum species vs. vascular plants, which differ as outlined in the manuscript. Also, the dependence of the moss spectral characteristics on moss moisture content is addressed. However, since the general term "mosses" is used, I think the authors should include a few words on the spectral characteristics of brown mosses and their abundance in certain types of peatlands. Also, what about the spectral characteristics (and sometimes to some degree spectral similarities) of green Sphagnum species vs. brown mosses vs. vascular plants and their implications for applying remote sensing techniques to different types of peatlands?

A. We have carefully revised the usage of the terms 'moss' versus 'Sphagnum'. This study concentrated on the ombrotrophic patches, covered by Sphagnum mosses only, therefore the brown mosses were not considered.

S. [5] page 1296/ line 6: Please define "monocots" and "diocots".

A. Terms removed and replaced by 'vascular plants' as the distinction is not further used within the manuscript.

S. [6] page 1296/ line 20: Define LAI before its first usage. A. Added.

S. [7] page 1297/ line 6: Please define "ericoid". A. Added.

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S. [8] page 1298/ line 13: "For the chosen experimental plots this means that the continuous Sphagnum layer ... ... if no ericoid or graminoid leaves are covering it." Are there any potential implications (uncertainty?) of this assumption/ "indirect" measurement (i.e. the observation in the field that the Sphagnum cover is more or less continuous for all plots) on the transferability of the results of this study to other sites with considerably less than 95% Sphagnum moss ground cover (e.g., lack of Sphagnum moss ground cover under shrubs)?

A. The first-hit point intercept method corresponds well with fractional vegetation cover. However, the poor correlation of the fractional cover inferred from MESMA results with destructive biomass sampling results shows the limitation of the linear unmixing approach for deriving Sphagnum biomass. This is mentioned in Section 3.3.

S. [9] page 1298/ line 17: "On 5 June, 2006..." A. Revised.

S. [10] page 1299/ starting line 10: Did the authors look at how the reflectance spectra measured in the field differ from "pure" reflectance spectra measured in the lab (integrated sphere) in terms of the influence of background material (in this case I guess mostly Sphagnum mosses, litter, woody components, bare soil, dead material, etc.)?

A: The transfer of naturally illuminated species (hemispherical-conical) to laboratory conditions (biconical, or hemispherical-conical without direct illumination) has been investigated (Dangel et al., 2005), however not for this particular case. We argue in this case that the background scattering originating from brown pigments and other non-photosynthetic vegetation as well as soils is distributed randomly within the plots. SMA is particular insensitive against random scattering and therefore their influence is considered being low. Also, the robustness of the SMA profits substantially, when similar illumination conditions are being used for the measurements. If this is not the case (e.g. when comparing laboratory and field measurements), then the SMA is highly dependent on distinct absorption features present in all endmembers. Consequently the suggestion of the reviewer is correct by saying that when using laboratory spectra

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of pure endmembers (species) in combination with naturally illuminated endmembers, NPV and soil must be added as individual endmembers. See also the discussion about shade endmembers below (Roberts et al., 1993).

Dangel, S., Verstraete, M., Schopfer, J., Kneubühler, M., Schaepman, M.E., & Itten, K.I. (2005). Toward a Direct Comparison of Field and Laboratory Goniometer Measurements. IEEE Transactions on Geoscience and Remote Sensing, 43, 2666-2675

S. [11] page 1299/ starting line 21: I suggest reorganizing section 2.5 on MESMA to make it more accessible to readers not familiar with mixture decomposition techniques commonly used in optical remote sensing (since Biogeosciences is not a remote sensing journal per se). Such a reorganization could start with a general description of linear SMA (in contrast to non-linear mixture decomposition) supported by references for its applications, followed by further developments/ variants of SMA such as MESMA (again supported by references for its numerous applications). The way it stands right now it reads as if MESMA and SMA are nothing but two similar mixture decomposition techniques. Furthermore, was the mixture decomposition with MESMA performed using VIPERTOOLS (plug-in for ENVI from the University of California at Santa Barbara) or coded from scratch? Especially the critical step of selecting representative endmembers deserves discussion (and references).

A. We changed the title of Section 2.5 to linear spectral unmixing, which includes the general mathematical basis of the linear mixture model, as well as an additional reference describing the inverse problem of the linear mixing model by Roberts et al., 1993. Further, more information on how MESMA differs from linear spectral unmixing as implemented in commonly known software packages was added.

S. [12] page 1300/ starting line 23: "The main reason being that the endmember ... ... thus all endmembers get a fraction assigned." What about the fact the fixed set of endmembers additionally has constant spectral characteristics, i.e. one reflectance spectra per endmember?

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A. This aspect is now more explicitly covered in the above mentioned addition on differences between linear spectral unmixing implementations.

S. [13] page 1301/ line 2: Remove the "and" between "assigns" and "abundances".

A. Obsolete as sentence was reformulated in the framework of above comments.

S. [14] page 1301/ line 4: Why not use them all and let MESMA select the most representative one as part of the mixture decomposition? What criteria were used to determine the representativeness of individual reflectance spectra?

A. This paragraph might be confusing. In fact, the selection was done in the field by measuring vegetation patches with high dominance of single-species. When selecting endmembers, it is necessary not to use mixtures, but select pure reflectance spectra representing a class without being mixed with other classes. This is however difficult in well-mixed, natural ecosystems. The selection of the measurement spots, and therefore endmembers, is now mentioned more explicitly in the text.

S. [15] page 1301/ line 25: At this point it would be appropriate to include a few words on the role of shade in mixture decomposition and the effect of shade measured on different backgrounds (references?). Roberts et al. (1993) discuss the use of shade endmembers extensively. It is mainly used to account for brightness variations within a scene. Brightness variations are related to the anisotropic reflectance properties of natural surfaces, whereas three main factors are important, namely the sun angle, the viewing geometry, and the structure of the canopy (i.e. the density and distribution (vertical and horizontal) of the scattering components). Since our measurements are taken with constant viewing angle and under limited changes in solar angle, variations of the fraction of shade for different sites are mainly related to differences in shrub density. Ericoid shrubs with their branches and thick leaves are assumed to be the main shadow-casting components for our site (as compared to sphagnum and grasses). The above is added to the corresponding section.

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Additionally, we have added the below reference in the manuscript. We however do not expect major implications by the background as the background is not varying significantly (mainly Sphagnum). Roberts, D.A., Smith, M.O., Adams, J.B. (1993) Green vegetation, nonphotosynthetic vegetation, and soils in AVIRIS data. Remote Sensing of Environment, 44 (2-3), pp. 255-269.

S. [16] page 1301/ line 9: I think the rationale behind this step requires more explanation.

A. This comment probably refers to page 1302. We added a corresponding paragraph to the section (see response to comment 15).

S. [17] page 1304/ line 2: On page X, line Y it says 95% ... A. Adjusted, it is indeed $>$ 90%.

S. [18] page 1304/ starting line 4: This needs some clarification. Also, what does "their" refer to? First-hit data or is it a mistake and "its" signal refers to vascular plant cover?

A. The above is revised and extended.

S. [19] page 1304/ line 6: Significant at what level?

A. Level of significance added for scenario 2.

S. [20] page 1304/ line 5: What characteristics of graminoids/ measurements have the potential to result in this less tight relationship?

A. Graminoids were not well developed yet and contained a high fraction of dead standing litter for some species which might not be well represented in the graminoid endmember spectra. The endmember spectra for the graminoids might be not optimal. This is added to the explanation of the weak results for graminoids.

S. [21] page 1304/ line 26: "This indicates that results based ... ... explained by provided endmembers)." This sentence is awkwardly constructed. Please consider rewriting it. A. Changed.

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Interactive Comment

S. [22] page 1305/ starting line 12: The sequence of analysis steps should be outlined more clearly in an earlier section, i.e. the results from the fractional cover determination are used in a final step to derive information on biomass. A. Added (see new section 2.5.2).

S. [23] page 1307/ line 2: Awkward wording: I wouldn't refer to endmember fractions as "suitable solutions"...

A. Rephrased (mathematically suitable solutions to the inversion problem).

S. [24] page 1307/ line 5: Awkward wording: "operationally operated". A. Changed.

S. [25] page 1307/ line 22: I don't really understand this part .... what's the benefit of mapping open Sphagnum moss ground cover whereas no information on Sphagnum moss ground cover under vascular plants can be derived? How does the index look like? Are any activities in this regard planned for the future?

A. Applying a water-based index to pure open Sphagnum patches will tell about the general hydrological conditions of these patches. As they form one hydrological whole with the surrounding Sphagnum vegetation, changes in the open patches will partly reflect those of the surrounding moss. In this way the open patches may be used as a proxy to monitor and assess drought conditions.

S. [26] page 1308/ line 6: "... results for more temperate peatlands would suffer...." In what way? Implications? A. Extended.

S. [27] page 1308/ line 13: What is meant here exactly? Shadow cast by graminoids and shrubs on different materials, e.g. graminoids shadow cast on graminoids vs. graminoids shadow cast on the Sphagnum moss ground cover. A. Added.

S. [28] page 1308/ line 23: I don't really see this as a conclusion of the present study.

A. Rewritten not to be a direct conclusion any more.

Interactive comment on Biogeosciences Discuss., 5, 1293, 2008.