Biogeosciences Discuss., 5, S2478–S2488, 2008
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Biogeosciences Discussions

Interactive comment on "Using MODIS derived fPAR with ground based flux tower measurements to derive the light use efficiency for two Canadian peatlands" *by* J. Connolly et al.

J. Connolly et al.

Received and published: 18 December 2008

Both referees agree that this work would make a useful contribution to the monitoring of peatland carbon dynamics in the future. The weaknesses identified by both referees have been addressed both in the text and below in the responses to the referees comments.

We wish to thank the referees for giving their time and comments which have improved the paper. The referee comments are in italics and the author responses are bold.

G. Schaepman-Strub (Referee # 1) Comment 1. The linear relationship between biomass production and PAR as expressed by the light use efficiency model of Monteith is valid when growth is not limited by water, adverse climatic conditions, or nutrient

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shortage. The article analyses the growth limiting factors vapor pressure deficit and minimum temperature. It is essential to discuss also potential nutrient limitation when adopting the Monteith model to peatlands which are know for their nutrient-poor conditions (i.e. mention site-specific nutrient conditions/ Sphagnum nitrogen and potential seasonal variation).

Response: (Correction made in text Page 5 Lines 1-4) The nutrient conditions in peatlands and especially in ombrotrophic peatlands are poor. However, the vegetation that grows in these peatlands is adapted to these nutrient-poor conditions and therefore the nutrient effect should be manifested through reflectance. The LUE approach using remote sensing is effective for capturing relatively short-term fluctuations in access to resources, but those long-term fluctuations (such as nutrients) are implicitly built into the structure of the plant architecture and LAI thus the measure of photosynthetic potential which is APAR (via FPAR and PAR).

Comment 2 It is well know that the light use efficiency varies among crops and I would expect also among different vegetation types within peatlands. In this article, an average LUE for all vegetation types is derived. I would expect that different plant functional types may react differently on e.g. water availability. Water contents in Sphagnum mosses above the optimum for net photosynthesis may reduce the photosynthesis through restriction of diffusion of CO2 into the moss chloroplast (e.g., K. Eric Van Gaalen et al.,2007, Oecologia 153, 19-28).

Response When water contents in Sphagnum mosses are above the optimum for net photosynthesis this indicates that there is too much water in the system. The maximum WTD for the Mer Bleue during the four years of study was 70 cm beneath the surface. Therefore this does not seem to be an issue for this Bog during the period of study. When the water content is below the optimum this indicates a dessication of the mosses and this can be seen in figure 5 for 2001 where GPP is reduced due to reduced summer rainfall.

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Comment 3 Some of the variation of the LUE versus VPD relationship could result from the different response of the different plant functional types within the fetch of the flux tower and the MODIS pixel. Given the physiological dependence of the LUE, I wonder how reasonable it is to determine the LUE for peatlands at the ecosystem scale.

Response This method of determining LUE at the 1km scale yielded values similar to those attained by Kari et al. (2003) and to Ahl et al. (2004) using ground plot measurements and EC towers. This would suggest that the LUE values that we have attained can be used and this is backed up by our use of Beers law in the text. The issue of vegetational heterogeneity at the 1 km scale is a complex one and would need very fine resolution imagery to correct. Individual species may respond differently, but by nature this is an integrated measure, we are capturing what the ecosystem does as a whole. It is very difficult to pull out individual plant responses in such an analysis and for a particular species, the response would have to be very large to be seen (there is some consistency as to how these species react to environmental stimuli). Besides, there are a range of species represented here, likely individual species responses are averaged out in the integrated mean. We believe that as a first estimate of the LUE of peatlands this paper lays the foundation for future improvements in this area.

Comment 4 MODIS fPAR I miss an indepth evaluation and advise a careful treatment of the MODIS data

Response: (Addition of text: Page 8 lines 20 to page 9 line 7)

Comment 5 - How reliable are the data for the peatland area, i.e. how might the biome misclassification affect the MODIS fPAR values.

Response: (Addition of text: Page 12 lines 12-15 and Page 12/13 lines 23-2) In this case the misclassification had no effect on the final result. We used beers law to examine the effect of the misclassification on the FPAR. The results from ground based data were very similar to those from the satellite data through the four years at the Mer Bleue and therefore it was decided that the misclassification in the IGBP MODIS has

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little effect on MODIS FPAR.

Comment 6 Is the biome classification used in the fPAR full/backup algorithm?

Response: The back full algorithm uses MODIS Surface Reflectance Product (MODAGAGG) and the MODIS Land Cover Product (MOD12Q1). The MOD12Q1 product, in collection 4, uses a 6 biome land cover. If the Full algorithm fails the backup algorithm is triggered to estimate LAI and FPAR using vegetation indices.

Comment 7 -Spatial resolution and coverage: How well do the reprojected data after the rigorous transformationfit the tower footprint. p. 1772, line 20: flux tower footprint depends on measured variable (radiation or carbon fluxes) and environmental conditions (e.g. wind speed). Maybe some site-specific footprint analysis have been performed which could be referenced? Also, it depends on how representative the flux tower covered area is for the larger area

Response: (Change in text: Page 12 line 7–10) The flux tower is located 200m from the western edge of the MODIS FPAR pixel in which it falls. Since 80% of the flux comes from within 200m of the tower, this means that the value for the MODIS FPAR pixel fit the tower foot print.

Comment 8 p. 1773, line 13-21: data formats and programs are not relevant, however a bilinear interpolation does not allow using quality flags (they are integers) and it is unclear what is meant by rigorous transformation

Response: The text on a bilinear interpolation and rigorous transformation refers to a tool within the ERDAS IMAGINE software. This text was deleted to prevent confusion.

Comment 9 Temporal compatibility of data from different sources: The composited MODIS fPAR product corresponds to the highest fPAR value within 8 days, while incoming PAR, NEE and ER are averaged for 8 days. This results in mixing up different conditions in the Monteith model. LUE might differ for variable illumination conditions (clear sky versus cloudy sky), while MODIS data correspond to rather clear skies. How

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severe is the loss of the diurnal variability of the LUE?

Response: The method presented here is the first effort to estimate LUE for peatlands. This objective of this paper is to match well established methodologies (i.e., MODIS and tower data). It is difficult to address this comment because the data for daily FPAR are not available for this method. We acknowledge the shortcoming here, but we are working with the tools available. Because we are working with 8 day time stamps the determination of the diurnal variability is beyond the scope of this paper.

Comment 10 Some MODIS fPAR technical comments: Please indicate the exact name (e.g., MOD15A2) and download website of product, this is important as several versions are available.

Response: Corrected Website: http://edcimswww.cr.usgs.gov/pub/imswelcome/

Comment 11 The official collection 4 data has the following issue: A bug was found in the code generating Collection 4 MOD15A2 FPAR product: FPAR under diffuse radiation was produced instead of fPAR under direct solar radiation, as required by the product specifications. The correction scheme to calculate FPAR under direct radiation for MOD15_BU was proposed, and MOD15_BU FPAR data set was re-processed in January 2005. The reprocessed version of MOD15_BU LAI/FPAR products is called C4.1. ftp://primavera.bu.edu/pub/datasets/MODIS/readme.pdf

Response: The data for this paper were downloaded in March 2005 after the re-processing in January 2005.

Comment 12 It seems like the quality flag data were not used whereas they are important to identify bad quality (technical problems) and backup algorithm data,

Response: Quality flagged data were used in this paper. We identified several technical problems (satellite breakdowns) and the data for these events were omitted as they were not and could not be used in the formulation of the LUE.

Technical changes: p. 1769, line 5: 0.4 to 0.7 um (not mm) Corrected

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p. 1770, line 23: with a mean annual temperature of is Corrected

p. 1772, lines 14-15, different spatial resolutions of products not used in this study are not relevant Changed

p. 1772, line 18: 8-period should be 8-day period Corrected

p. 1772, line 20: flux tower footprint depends on measured variable (radiation or carbon fluxes) and environmental conditions (e.g. wind speed). Maybe some site-specific footprint analysis have been performed which could be referenced? Also, it depends on how representative the flux tower covered area is for the larger area Changed (see response 7 above)

p. 1772, line 21: reference Lafleur Corrected

p. 1773, line 2: reference should read Sonnentag (instead of Sonnetag) and is missing in the reference list (I did not doublecheck the rest of the references) Corrected

p. 1773, line 3: this is not a proper equation Corrected

p. 1773, line 13-21: data formats and programs are not relevant, however a bilinear interpolation does not allow using quality flags (they are integers) and it is unclear what is meant by rigorous transformation Removed

p. 1774, line 18: which means Corrected

p. 1774, line 20: reference Bubier should not be italic Corrected

p. 1775, line 8: the estimated the canopy fPAR Corrected

p. 1775, line 11: incoming PAR is not named consistently throughout the article (i.e. sometimes only PAR, sometimes incoming PAR, sometimes arrow down with PAR) Corrected

p. 1776, lines 2-3: as mentioned earlier, malfunctions of the sensor are indicated in the quality flag Corrected

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p. 1776, line 18: too cold Corrected

p. 1776, line 17 and Fig. 4: is epsilon driven by zero GPP only or is fPAR really low due to snow cover? How could the temperature threshold difference of Mer Bleue and Western peatland be explained? Or might this indicate that the uncertainties of the epsilon estimation are really high? Given Fig. 4 it remains unclear the temperature threshold mentioned in the text was derived (or is it derived based on GPP?). see response 13 above)

p. 1778, line 21: missing second bracket after references Corrected

p. 1779, line 16: as expected when were compared Corrected

p. 1781, line 29: given the American origin, I guess that it should be a technical report Corrected

p. 1784, line 8: IEEE T Geosci Remote is a peer-reviewed journal while IGARSS 03 is a conference proceedings Corrected

p. 1786, table title: indicate the meaning of the parameters Corrected

p. 1787, Fig. 1, 2, 5, 7: to increase readability and allow for a better comparison, it would be useful to have the same scale for the time axis for the Mer Bleue and Western peatland graph, the time axis is not very helpful (esp. Fig. 5), given that dates such as September 24 (This date is not mentioned anywhere in the text) are described whereas it is hard to find back these data in the graphs. Corrected

p. 1788, Fig. 2 title: (A) 2000-2003 (instead of 2002-2003) for Mer Bleue Corrected

p. 1789, Fig. 3 title: you might stick with the Greek sign for epsilon or write out light use efficiency Corrected

p. 1790, Fig. 4: it would be useful to calculate the relationship and its significance, indicate site in figure title Corrected

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p. 1791, Fig. 5: (B) 2003-2004 Corrected

p. 1792, Fig. 6 title: site is missing, change (Dashed line) to (dashed line) Corrected

p. 1794, Fig. 8: Why does the time axis range from 1-46 (cannot be days or Julian days) Corrected comment 23.

Anonymous Referee #6

Comment 1 It was surprising to read a scientific paper without a single occurrence of the word "uncertainty". Strictly speaking numbers do not mean anything without an estimate of their associated uncertainties. Because of this the reader cannot judge, for example, if the difference between the reported GPP at Mer Bleue and Western Pearland is significant or not. For several reasons it may not be possible to carry out a rigorous error analysis and provide a formal uncertainty estimate for each number. However, at least there should be a discussion of the uncertainties involved in this method and some indication of its expected overall accuracy.

Response: This is a fair point and the text was amended at the following places to address this: Page 12 line 12 Addition of text uncertainty Page 13 Line 20 Addition of text Page 13/14 Line 23/1 Addition of text Page 15 lines 13/14 Addition of text Page 16 lines 1/4 Addition of text Page 17 lines 8/10 Addition of text Page 18 Lines 2/5 Addition of text

Comment 2 In my understanding eddy flux measurements yield only NEE. To convert NEE to GPP assumptions are needed for RE. The way to deal with this may be obvious to experts in eddy covariance, which, however, nevertheless needs further explanation. It raises the question, for example, how applicable the assumptions are to the case of wetlands.

Response: (Correction made in text Page 7 lines 7-8) RE - nighttime NEE is taken to be a direct measurement of ER from LaFluer et al., (2003). We use this value to develop models of ER versus temperature that are then used to gap fill and compute daytime

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values of ER (http://www.nasaids.unh.edu/pdfs/Lafleur_et_al_gbc03_MB-2.pdf) page 7.

Comment 3 The main conclusion of this study is that VPD is not a growth-limiting factor at the investigated sites. This seems inconsistent with the interpretation of the observed interannual variation, which is attributed primarily to variations in water availability –

Response: The main conclusion of the study is that E can be derived through the use of Satellite data and EC methods. We also conclude that VPD has no effect but temperature has an affect. The variations in water availability were attributed to differences in temperature which has an affect on the GPP as can be seen in figure 5 for 2001 where GPP is reduced due to reduced summer rainfall.

Comment 4 Of course VPD and precipitation are not the same, but there is nevertheless a relation between the two. The question is why there is no relationship between GPP and VPD if there is a relationship between GPP and wet versus dry conditions.

Response: There is no reason to believe there should be a relationship between pptn / WTD and VPD. At the synoptic scale air mass VPD (moisture in the air) and water available to the root system of a plant (driven by pptn and WTD) will not reach any stable equilibrium except in VERY rare period of VERY stable atmosphere with negligible wind. For the vast majority of the time this condition will not occur so no correlation should arise. At the micrometeorological scale there is a poor relationship because of continuous localized airmass movement and local instability.

Comment 5 It is not clear how the eddy flux measurements were sampled to derive 8-day composites.

Response: A daily value for the eddy flux measurements was originally acquired and these values were added together to give an 8-day total for the time periods defined by the 8-day time stamp of the MODIS fPAR data.

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Comment 6 In the case of MODIS the sampling is not even, but in fact biased to fair weather conditions.

Response: Yes, this is a limitation of the approach but does not mean that the step presented in the paper is invalid. This is how the data are presented as a final product and at present this is the best product available for this type of work.

Comment 7 Further information is needed to allow to reader to judge whether or not short-term variations in fPAR may be significant. It is stated somewhere that the procedure leads to a loss of the day-to-day variation. This suggests there is variation, which might become relevant if it introduces a bias.

Response: fPAR follows a seasonal pattern. It has been explained in this work that we are working on a 8-day time period. This work is being developed to look at the light use efficiency for peatlands over a four year and 1 and a half year period. Therefore the loss of day-to-day variation is acceptable as this a first attempt to estimate LUE for peatlands.

Comment 8 p. 1794, Fig. 8: Why does the time axis range from 1-46.

Response: Because the data was divided into 8-day time periods and there are 46 and a bit of those in a year.

SPECIFIC COMMENTS page 1772, line 21: ";The footprint of an EC ... calculate epsilon." What is the evidence that the footprint of the eddy flux tower is 1 km2? It is used as an argument that MODIS and in-situ measurements can be compared. However, as pointed out in this sentence the signal at the EC tower is in fact mostly representative of the nearest 200m. In that case additional justification is required for comparing satellite and in-situ measurements. There is, for example, no information on the representativeness of the direct vicinity of the EC site for its surroundings. More information is needed. (Change in text: Page 12 line 7–10) The flux tower is located 200m from the western edge of the MODIS FPAR pixel in which it falls. Since 80% of

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the flux comes from within 200m of the tower, this means that the value for the MODIS FPAR pixel fit the tower foot print.

Page 1773, equation 4: There is no parameter on the left hand site of this equation. It should be reformulated. Corrected

Page 1773, line 13: "The MODIS fPAR ... communication, 2005)" I consider information on data formats out of the scope of the study, which makes this sentence redundant. Corrected

Page 1773, line 16-21: "The reprocessing .... observation tower" The acronyms in this part should be explained, if they are really needed at all. Corrected

Table 1: The meaning of the parameters a, b, c, d should be explained for example in a footnote under the table. Corrected

Figure 6: The site should be mentioned in the caption. Corrected

Figure 7: This figure shows a comparison of the fitted equation 5 and the data, not estimates of the length of the growing season and the peak in epsilon as suggested by the caption. Corrected

Figure 8: "predicted epsilon" suggests that some method is used to estimate epsilon independent of the data. What is shown, however, is derived from a fit to the data and is therefore not a prediction. Corrected

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Interactive comment on Biogeosciences Discuss., 5, 1765, 2008.