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Geoscientific Instrumentation Methods and Data Systems Discussions

# *Interactive comment on* "Digital photography for assessing vegetation phenology in two contrasting northern ecosystems" *by* M. Linkosalmi et al.

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We would like to thank Referee #3 for comments and suggestions that helped us to improve the manuscript. Below our response (AR) to referee comments (RC).

RC: The paper demonstrates the possibility of the application of digital repeat photography to monitoring the phenology at two northern locations. The observations are compared to CO2 flux and meteorological measurements. Some interesting correlations are observed.

RC: The language in sections 2 and 3 is excellent and the figures are well presented. I have some concerns regarding the content of the abstract, introduction and conclu-



sions where the text needs some attention.

1. Abstract

RC: The sentence 'The GCC of wetland developed in tandem with the daily photosynthetic capacity estimated from the atmosphere-ecosystem flux measurements' doesn't make sense to me. It needs to be rephrased somehow.

AR: Rephrased for clarity: "The daily GCC of wetland correlated well with the daily photosynthetic capacity estimated from the CO2 flux measurements."

RC: Also in the paper you make use of flux and meteorological measurements at both sites so this needs to be mentioned in the abstract.

AR: Sentence added to the abstract as suggested.

2. Introduction

RC: The content in the introduction needs to more directly describe the authors' motivation for the work. The first paragraph is good but the other paragraphs don't clearly indicate to the reader what the 'need' is for the work. The last two paragraphs of the introduction are poorly written and need to be clearer. Regarding the last two paragraphs perhaps the text from the last paragraph could be incorporated with the first two sentences of the previous paragraph. Then a new paragraph could start with 'The objectives of this study ...' Also I suggest including a paragraph at the end of the introduction that outlines the structure and content of the paper. This would help the reader.

AR: The introduction has been improved by removing the last paragraph, explicitly stating the objectives (that also specify the motivation) and including a paragraph outlining the structure and content of the paper, as suggested.

3. Conclusions

RC: In the introduction you say that one motivating factor is that there is the possibility

of using your measurements to support the interpretation of the micrometeorological measurements of CO2 fluxes. Then in the conclusions you say that you made the observations and the discrepancies may be due to differences on temperature. That's good but this is one of the most interesting aspects of the paper and needs to be highlighted more. In your opinion do the observations actually help? Could your parallel measurements help understand just CO2 measurements? Generally, in what respect would your work help with understanding the connection with the climate and growing season length? Would your work help with land surface models? The last paragraph is not clear. Is the second sentence connected to the first sentence? There doesn't seem to be daily observations featured in any of the figures in the paper. The first sentence (and the second sentence?) would be better placed in the results section.

AR: This section was largely rewritten and more general conclusions added. (Rewritten Conclusions chapter below)

We demonstrated the feasibility of digital repeat photography for assessing the link between vegetation phenology and CO2 exchange for two contrasting high-latitude ecosystems. While the seasonal changes in the greenness index GCC are more obvious for those ecosystems where the vegetation is renewed every year (here an open wetland), seasonal patterns can also be observed in the evergreen ecosystems (here a coniferous forest). We examined the illumination sensitivity of our digital camera system by analyzing the images of a grey reference plate, which was included in the camera view. Limited solar radiation restricts the use of images during the wintertime as well as during the night-time. At our sites in northern Finland, the daytime radiation levels were sufficient for image analysis from February to October. During that period, a diurnal window of 10:00–14:00 (local winter time) provides stable GCC data. Our results show that the variability in cloudiness and solar zenith angle during the daytime do not play a significant role in the GCC analysis. However, it would be relevant to investigate the seasonal dependence of GCC on sun elevation, especially for the coniferous forest. We observed a clear seasonal GCC cycle at both study sites. At



the wetland, GCC correlated well with the daily photosynthetic capacity estimated from the ecosystem–atmosphere flux measurements. The interannual variation in GCC was also consistent with the observed CO2 exchange and meteorological conditions. At the forest site, the seasonal GCC cycle correlated well with the flux data in 2015 but showed more deviations during the summer of 2014. For both ecosystems, the correlation between GCC and CO2 exchange was highest during the spring. In addition to depicting the seasonal course of ecosystem functioning, we showed that GCC responds to environmental changes on a shorter time scale. We observed that at both sites the increase of GCC and photosynthesis ongoing in June was ceased during a two-week-long cold and wet period. For an unknown reason, the GCC values even slightly decreased during that period. It is possible that such a reduction is an artefact caused by wet surfaces, for example, rather than a response to an actual decrease in the chlorophyll concentration in leaves and needles. Due to the low cost of the instrumentation involved, phenology monitoring can be established in a much larger number of locations than ecosystem–atmosphere flux measurements, thus providing a wider geographical basis for improvement of the phenological and photosynthesis components of land surface models that need more calibration and validation. The digital repeat images allow the detection of phenological events, such as shoot elongation and the start of needle growth that cannot be obtained from CO2 flux measurements alone. Therefore, they should be utilized to enhance the analysis of flux data. Furthermore, as our results show, the seasonal cycle of different vegetation types within the footprint of the flux measurements can be determined. This could help decomposing the integrated CO2 flux observations, when the distribution of the vegetation types within the area is known.

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