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Interactive comment on "Interpreting canopy development and physiology using the EUROPhen camera network at flux sites" *by* L. Wingate et al.

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General comments

This study presents an good overview of the camera network installed at European eddy covariance flux tower sites, and the possibility of monitoring canopy development through the calculation of RGB color fractions from the images, and the automatic detection of phenophases. In addition, a radiative transfer model is used to demonstrate how information on leaf physiology can be determined from these data. This article is beneficial in showing the community how this network and this modeling framework could be used to further our understanding of the phenological functioning of different types of ecosystems, and its relationship to the carbon and energy fluxes that are also measured at these sites.

Overall I think this is a well described and comprehensive study that provides a valuable

contribution to the phenology- and flux-related literature. The main point I'd raise is that the manuscript could be improved with a more detailed description of the radiative transfer modelling, as well as a fuller explanation of the function linking the reflectance that is output from the PROSAIL model and the DN values derived from the camera images (i.e. equation 2). This will aid the interpretation of results in Section 3.2. In addition, the assumptions behind this type of RT model should be discussed. Finally, the use or possible applications of these data and the modeling framework could be expanded upon in the discussion or conclusions.

Specific comments for each section:

Introduction

The introduction gives a nice and clear overview of the background of why these measurements are important. However I think it would benefit from a brief evaluation of the previous PHENOCAM studies (some of which are referred to later in the text) and how this study goes further than those studies.

In addition perhaps it is worth mentioning here what complementary information these data will bring to phenology metrics derived from satellite data. For example the data are available smaller scale at the location of flux towers which opens up the opportunity to understand differences between growing season length and carbon uptake period, in addition to linking the trends in phenology with net C fluxes in order to determine the impacts of greening on the balance of C uptake and respiration. Or this could be added in the discussion.

Methods

Section 2.1

P8 Lines 14-16: Please can you describe why this is necessary in a bit more detail – for readers who are not familiar with more technical aspects of cameras? Also are the same lenses used on each camera? Are the aperture size, shutter speed, ISO and sensor gain kept constant? What is the difference in sensor size between the two types of cameras?

P 9 Line 18: For the calculation of the mean color fraction is the mean value of ncolor, nred etc is calculated for all pixels in the ROI, and then the Color Fraction is calculated? Or is the color fraction calculated per pixel and then the mean taken?

Section 2.2.4

This is a nice and thorough validation exercise. It is interesting to see a consistent bias between the visually inspected dates and the automatic piecewise linear regression. Did you investigate what the breakpoint-derived dates might correspond to in the images? For example, the first breakpoint may be 30% leaf out, instead of 50%? Does it correspond to a particular change in photosynthetic parameters, or C fluxes?

It may also be interesting to investigate if there was as consistent a (or similar) bias if: a) A different breakpoint was analysed for each phenophase (for example using the 2nd breakpoint for leaf out). b) A different automatic detection method was used, such as the DOY at half maximum which could be site specific and therefore might account for the issue of different camera set-ups?

Also for sites where more than these 3 breakpoints were detected, did you investigate what the other breakpoints might correspond to?

Do you think the same procedure should be used for all vegetation/canopy types?

These “discussion points” might be a useful addition to the description of this validation exercise and help readers who may want to use these data in the future.

One final point here: perhaps this validation could be added as a section to the beginning of the results, given it is an analysis, rather than a description, of the method used?

Section 2.3

P 12 Line 10: How is the spectral efficiency defined? Is it just the spectral response curve that is used? A fuller explanation of this and the derivation of the BRGB parameter would help to explain the function (here I will call it an observation operator or OO for the sake of brevity) define in Equation 2. It would be valuable to detail the issues with the camera specifications such as the response functions and how they impact the derivation of GRGB. Also, an initial sentence explaining that you need this type of function to match the DN values measured by the camera sensor to the reflectance simulated by the PROSAIL (taking into account the camera/set-up specific characteristics) model may help readers that are not familiar with this topic. Are any of the camera sensor characteristics not taken into account? And if so are these mostly lumped into the BRGB parameter?

P12 Line 21: Perhaps for the general reader it may help to detail that the SAIL part of the model essentially scales from leaf to canopy. A bit more information on what type of RT model it is (i.e. turbid medium) and the assumptions that are made about the canopy structure for this model.

It would be good to explain why this type of RT model was used and not another (e.g. a Geometric-Optic model, or a multi-layer or 3D RT model).

Results and discussion

In general these sections present a very in-depth and nice discussion of the events causing changes in the RGB color fractions derived from these images. One point to note. Mostly the green fraction is described in the results, but given the model results in section 3.2, perhaps more helpful to look at all color fractions as it is a relative measure? Though I see this is discussed more in Section 3.3.

Section 3.1.1

How might the automatic detection of phenophases be improved for coniferous sites do you think? Might it be improved if all the color fraction time series were included in the analysis?

By visual comparison do the breakpoints detected for evergreen sites correspond to any obvious phenophases? Is the leaf flush and browing that you describe on P 15 Line 19 onward evident when you examine the images, or are the dates of this leaf flush etc (i.e. arrows in Figure S4) for each particular site/year known from field measurements?

P15 Line 24 – it would be easier to examine Figure 4 if you gave rough dates for the phenological events you describe in the text (as you have done for leaf flushing) given the multiple points of increase and decrease for the evergreen sites.

Figure 4 (and 6): given these are latitudinal comparisons it may be nice to have the approximate latitude given on each plot.

Figure 5: it might be beneficial to extent the dashed lines up through the temperature and PPFD?

P16 Lines 16-18: Interesting that although the green fraction increased around the time of a short spell of increased temperature, the GPP did not change (bp4). How might this be explained?

Overall what's your advice for using these data for evergreen trees? Are the difficulties regarding detection of phenophases using piecewise regression a limitation? Do you think a slightly different detection protocol is needed for evergreen stands?

Section 3.1.2

P18 Lines 4-6: The fact you can detect the impact of flowering and cutting is indeed interesting. What type of grass and flowers are at this site? Do you have any photos that you could add into the supplementary information (as for Figure S5)?

P18 Lines 9 and 10: "Even more challenging" is repeated. I am unclear as to why having 8 breakpoints made it more difficult to detect the start and end of the growing season. Please could you explain this in more detail?

P19 Line 2: Migliavacca repeated.

P19 Lines 2-4: This is a very modestly described caveat of the method used, but surely it would be the same with any method used? If the grass is buried under litter than no sensor (or method) will detect the start of new leaf growth.

P19 Lines 6-25: This analysis is of course true but I suspect that it is not a lack of knowledge of different crop sowing and harvest dates that results in the crops being treated as grasses in models but rather the difficulties of prescribing these dates and different crop management strategies. I do not know but are there not country/EU-wide datasets that give the broad dates of sowing and harvest dates for different crop types? Nonetheless these data do indeed present a good demonstration of this issue.

Section 3.1.3

P20 Lines 4 and 5: For a second I wondered why the red and blue signals decreased, and then I remembered that these are relative signals. Perhaps others will not need this clarification but it may be even more informative to remind readers of that here?

P20 Line 12: It may be useful to give examples of the Mediterranean sites in the text as you have done for the continental sites.

P20 Lines 15-17: What do you think is the cause of this variability if not a climatic driver?

Section 3.2.1

This section presents very thorough and informative sensitivity analyses.

Figure S6: The axes font is very small and may not be readable on paper

P 23 Line 15 on: This is a nice extension of the first sensitivity analysis. Was the sensitivity analysis presented in Figure 11 conducted over the same time period as in Figure S6, even though the constraints are only defined for the spring green up? If so, it may be helpful to the reader to put the LAI, Chl and Car columns of the original sensitivity analysis in Figure S6 next to the 3 columns in Figure 11 to see the impact on the sensitivity brought by the extra constraints, but this is not needed. If not, then this should be detailed in the text and caption of Figure 11.

How general are these constraints? Could they be applied for all ecosystems (albeit with different ratios for different ecosystems)? Or do these constaints break down elsewhere? Have these constraints ever been applied to the PROSAIL model before?

Section 3.2.2

P 24 Line 22: By adapted PROSAIL model I assume you mean with the fucntional constraints applied in the previous section?

In Table 2 do you mean to refer to Figure 12 and not 13?

Figure S7: Do you mean to refer to Figure 12 and not 13?

P 26 Line 2: Indeed it would be good to re-do this analysis for years where pigment concentration data (or other parameters) are available for extra validation.

Section 3.3

This seems to be a very rigorous assessment of the technical difficulties. P28 Line 20: Mizunuma et al. repeated.

Conclusions

P 31 Line 14: spelling mistake for “archives”

Further possible points for discussion:

- I have already mentioned this and do not wish to repeat myself, but what are your overall suggestions of improvements to or usage of the piecewise regression method for detecting phenological events. It seems that that visual inspection may be needed for evergreen and managed ecosystems as you’ve described. Or would another metric like a threshold useful?

- These data and the RT modeling could be used to see if you can see the same events (and validate) satellite data. Coming back to Section 3.1.3 (P21 Lines 17-21) following the modeling discussion. Perhaps the model could be used to derive NDVI which could be more readily compared with ground-based measurements as well as satllite data products?

- Of course this is a preliminary exploratory study; however, the thorough analysis could be complemented by discussing the impact of this type of RT (turbid medium) model and the assumptions used. For more complex canopies (vertical heterogeneity and/or a mix of under- and over-story) the PROSAIL model assumptions may break down, particularly as these are near canopy measurements and therefore local-scale effects such as clumping are probably not properly accounted for.

- As well as using the modeling to quantify and monitor plant physiological status, how else might you use this framework? You mentioned improving the phenology models of dynamic vegetation models in the introduction what other applications can you see from these data? Are any of the time series long enough for trend analysis for example?

Interactive comment on Biogeosciences Discuss., 12, 7979, 2015.