

Interactive comment on “Hysteresis response of daytime net ecosystem CO₂ exchange during a drought” by N. Pingintha et al.

Anonymous Referee #1

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General

The manuscript "Hysteresis response of daytime net ecosystem CO₂ exchange during a drought" by N. Pingintha et al. addresses a question of broad interest to the carbon flux community: (1) Can the gap-filling of daytime CO₂ fluxes for vegetation under variable water stress be improved, if we use more of the environmental variables at hand than only photosynthetic active radiation and temperature? In doing so, it also addresses the inevitable follow-up question: (2) How could an improved version of the empirical gap-filling model be constructed? Finally, the explanations offered for the way in which NEE deviates from its average dependence on light, touch a basic research question of ecophysiology: (3) What can we tell about stomatal control from the typical suite of data provided by an eddy-covariance station, and is there a genuine hysteresis

C3585

effect involved? All of these questions are within the scope of BG(D) and of interest to a significant part of the readership, making the manuscript clearly a well-placed and relevant one.

In terms of originality and scientific soundness, we would like to distinguish between the three questions identified above. The first one clearly can be identified as the main concern of the authors, and equally clearly is addressed in the most original and sound way. Existing literature evidence is acknowledged; and yet the crop and moisture variability under study here clearly make the authors' results worthwhile publishing. The methodology, though subject to some minor shortcomings mentioned below, succeeds to establish beyond doubt that at least one additional variable, which is connected to stomatal closure and causes a hysteresis-like response curve of NEE to PAR, should be taken into account - be it as an additional predictor variable, or be it as a binning criterion as suggested here. Though this is probably not entirely new to the community, it is addressed here in an explicit and elaborate way that is likely to provide a helpful contribution to future developments. The other two questions are addressed in a more superficial and less convincing way. Given the clear priority of the first question in the manuscript structure chosen by the authors, we nevertheless recommend to accept it with minor revisions. We hope however, that our comments below provide some help in at least formulating the conclusions drawn with respect to these two questions in a more careful way. We think that a more elaborate evaluation of these two questions in future publications is of great potential relevance, and that the analyses shown here provide valuable starting hypotheses for this future work, rather than answers. The authors or editor might decide, of course, to include more convincing answers to these questions already to the present paper, in which case the revisions would be major rather than minor. In our opinion, the first option is more realistic given the fact that the present manuscript has a convenient number of pages and figures, and a convincing answer to the further questions might in some cases require new or additional measurements.

C3586

Major comment

Depending on the subject at hand, hysteresis loops in the response curve of one variable to another have been explained by different mechanisms, many of which involve the presence of an additional unknown variable. Here, the authors hint at the undoubtedly role of VPD and soil moisture in co-determining NEE via stomatal closure; but when it comes to the causal discussion of the phenomenon (page 10719) draw a premature conclusion that would in fact be a very interesting hypothesis for further research. In line 11-12, it is suggested that "Stomatal sensitivity to VPD increased in the afternoon...", but the data presented (or maybe only the way they are presented) do not support the necessity of this conclusion. As correctly indicated in P 10717 L 23, the g_s value calculated by Eq. 2, inserting actual rather than potential Evapotranspiration, only gives a bulk information about water availability, independent of whether limitations occur in the soil, at the plant-atmosphere interface, or anywhere between. For simplicity, however, let us assume in the following that g_s well describes stomatal closure.

If we assume that stomatal closure reacts in a mechanistic way free of "genuine" hysteresis to VPD on days with low soil water availability, what is shown in Fig. 5d and 7b could still be explained by the fact that VPD increases during the day, reaching its maximum in the afternoon and not dropping below its late morning values before sunset (Fig. 5c). In this case, the presence of the predictor variable VPD and its retardation with respect to PAR would imply a hysteresis effect, but it would not be necessary to explicitly include hysteresis in an empirical model of NEE. With measured values of soil water and VPD ready at hand, it would be more straightforward to include these variables into the gap-filling relation in addition to PAR. The way chosen by the authors of instead using only soil water and daytime as binning criteria, and determining a quadratic PAR-NEE relation for some bins may succeed statistically in providing reasonable gap-filling values for the typical study conditions. But it has the disadvantage of implying that at high PAR, -NEE decreases again. The manuscript contains no explicit

C3587

effort to explain this behaviour (such as e.g. negative effects of radiation), but from its overall reasoning it supports the hypothesis that PAR co-varies with other factors determining NEE (e.g. temperature, or VPD or time via stomatal closure). This would be a somewhat unsatisfying suggestion for an improved gap-filling model (research question 2).

On the other hand, it might be shown by another analysis of the data or by lab experiments, that significant hysteresis in the PAR-NEE relation can be observed even if VPD (and soil water availability) was constant during the day (which is indicated by the text in line 11-12 but not proved). In this case, several processes providing the plant with a "memory" of the temporal evolution of its water consumption may be thought of. E.g., at some critical point in the soil-plant system the downward gradient flow of water might be too slow to maintain the water potential behind. This point might e.g. be the soil water in the direct vicinity of the roots (Schröder et al. 2009), which will not be captured by volume-averaging soil water content measurements, or any point in the xylem or leaf. In this case, as the controlling variable cannot be directly accessed by the measurement methods used at most eddy covariance stations, it would be justified to introduce a genuine hysteresis into the model. Even then, however, the creation of a morning and afternoon bin would only be a rough first-aid means. A more physically based solution might be to include the cumulative amount of transpired water (maybe using ET as a proxy) since morning.

Minor comments on the content

P 10708 L 10 ff.: Mention the direction / kind of hysteresis observed.

L 21: Though "many" will never be exactly wrong, this statement may be misleading. In fact the latest IPCC report (e.g. Fig. 3.3 of synthesis report) indicates increases or an uncertain fate of precipitation for larger parts of the globe than decreases. It does, however, state that droughts will affect larger areas (e.g. Table 3.2 in the synthesis report). Maybe the difference may be attributed to the role of changing evapotranspiration as

C3588

well as the localization of precipitation decreases at the border of already semi-arid regions (including many regions important in agriculture in general and peanut cultivation in particular). So a slight rewording should be sufficient to avoid misunderstandings and a reference would surely be helpful.

P 10709 L 21: After giving quite some references for the various gap-filling methods mentioned above, no reference at all is given for what is described as the traditional standard method(s) and the one(s) of particular interest for this manuscript. Some references that might fit here are given elsewhere in the manuscript, more might be found e.g. in Ruppert et al. (2006).

P 10710 L 12: This sentence needs clarification, I (and presumably a large part of the readership) am not sure what it aims at.

L 21: Add a hint to the different methodology used at that scale (e.g. clamp-on leaf chambers, if applied).

P 10711 L 14: To increase the value of the treatment description for the world-wide readership, indicate if it was typical of the region and crop studied.

L 18: A measurement height of 1.5 m above ground (and thus still lower above the crops displacement height) is near the low edge of reported measurement heights (e.g. Neftel et al. 2007, Wohlfahrt et al. 2008). It can be justified by small footprint requirements (which was obviously not the case in this study, with a minimum fetch of 210 m in all directions) or other particular research questions. But it should be noted that it will result in a considerable underestimation of fluxes due to the role of small eddies, if no correction for attenuation in the short-wave range of the turbulence spectrum is applied (e.g. Moore 1986, Massman 2000). Fortunately the manuscript conclusions mainly rely on relative contrasts between fluxes (such as the Bowen ratio) or during the day, but even these values may be systematically affected e.g. if the separation between anemometer and gas analyzer (which is not reported here) is much larger than the measurement path of each of these instruments. Either a report on the energy bal-

C3589

ance closure (if possible with the available sensors) or a rough estimation of the overall magnitude of the underestimation according to one of the above references would be helpful to get an idea of the uncertainties in further parameters relying on these flux data, such as stomatal conductance.

P 10714 L 3, see also Table 1: A disadvantage of determining R as a constant (for each subperiod, that is) is that its short-term dependence on temperature is neglected. This will affect e.g. the analysis in Fig. 4a and 7, where any variation of R with T or hour of the day changes the apparent sensitivity of photosynthesis to PAR and its hysteresis. It would have been preferable to first estimate R(T) based on nighttime CO₂ flux and temperature data, and then apply Eq. 1 without the offset to the resulting estimate of GPP. R(T) may show its own hysteresis effects, which may be attributed either to the fact that temperature is out of phase between the different levels from leaf to deep soil contributing to R (Gaumont-Guay et al. 2006, Pavelka et al. 2007, Reichstein and Beer 2008, Graf et al. 2008), to a lagged response of root respiration to light (Tang et al. 2005, Moyano et al. 2008), or both (Bahn et al., 2008). If this is not possible due to infrequent valid nighttime flux data as indicated in the previous section, this source of uncertainty should at least be discussed and maybe the average R (Table 1) and some common first-approximation estimate of R(T), e.g. Q₁₀ = 2, can be used to prove that even without such confounding effects, a considerable part of the hysteresis in Fig. 7 would still be found (of which I am quite convinced).

L14: Maybe replace "air conductance" by "aerodynamic conductance"

Detailed technical, linguistic, and formal comments

P 10709 L 17: "look-up tables" or "a look-up table"

L 24: "a non-linear equation" or "non-linear equations"

P 10712 L 5: Replace "were" by "was"

L 10: Delete "then"

C3590

L 17: Delete 2nd "to"

L 20-22: The second sentence seems to provide the reference of how the u^* threshold determination was done while the first one names the particular implementation tool, therefore they should be reverted and maybe can be united.

L 22: The sentence about gaps in radiation etc. would be more easily understood after introducing how these data were mainly measured, which is done in the next paragraph.

L 24: Drop a "D"

P 10713 L 3: Replace "was" by "were"

L 8: Replace "measurements" by "measurement"

L 9: Replace "The" by "An"

L 25: Use either a blank or a dot vertically centered to indicate the multiplications

P 10715 L11: Check grammar ("due to...by")

L 22: "considered with respect.." is unclear. Maybe "determined separately for each growing stage, using bins of about 10 consecutive days of data".

References (To this review. Some are just to underline our arguments, from others you may want to pick to complete the revised manuscript)

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C3591

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