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Biogeosciences Discussions

Interactive comment on "The CO_2 exchange of biological soil crusts in a semiarid grass-shrubland at the northern transition zone of the Negev desert, Israel" *by* B. Wilske et al.

B. Wilske et al.

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We thank the referee for the comments and recognition of our efforts. We think our results contribute substantially to the recent discussion on the contribution of BSC in semiarid/arid ecosystems (Wohlfahrt et al., 2008; Stone, 2008). Below we respond to the specific points.

Anonymous Referee #1: This paper represents a lot of work and certainly addresses an area where more information would be valuable but I would have difficulty recommending it for publication at present for several reasons. First, the actual measurement system is curious in that any particular sample is measured against one of the so-called controls. It is difficult to see how this does anything except introduce errors. The gas

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exchange of a sample can be measured on its own and then one gets the net CO_2 exchange for that sample. Instantaneously measuring it against another sample simply introduces a subtraction error from that sample. I cannot find a justification for this methodology in the paper.

Authors reply: The methodology used was based on extensive experience and testing. To further clarify this we added the following explanation to chapter 2.3 section (3): The measurement system was tested in the laboratory and under field conditions in Sayeret Shaked and two other sites in the Negev Desert. We compared three types of measuring BSC-related CO_2 flux: (1) Single BSC and soil samples were measured separately in the absolute mode by enclosing only one sample type at a time, while the reference channel of the infrared gas analyzer (IRGA) was flushed with atmosphere air purged through the chemical cartridge providing CO_2 and H_2O-free air. (2) Single BSC and soil samples were measured separately and the reference channel of the IRGA was flushed with air from a blank cuvette (C_a). (3) BSC-related fluxes were measured in the differential mode by enclosing simultaneously one BSC and one soil sample and flushing the IRGA sample and reference channel with air from the BSC- and the soil enclosure, respectively. A small offset between the absolute modes using atmosphere air or from the blank cuvette was corrected by subtracting the offset between two blank cuvettes (C_a versus C_a). BSC-related CO_2 fluxes were then calculated from single sample measurements as the difference between the results from an individual BSC sample and an individual soil sample. Based on 10-min averages of consecutive measurements of dry and wet samples during nights and over-casted days, a difference of 0.1 μmol mol^{-1} was not significant between results of both types of calculated BSC-related fluxes and as obtained from the differential mode. Therefore, the differential mode allowed a more rapid measurement of BSC-related fluxes except for periods when precipitation changed the moisture conditions significantly. To obtain maximum sensitivity and precision in this low flux system, measurements in differential mode were routinely checked against ambient air from a blank cuvette.

Anonymous Referee #1: Second, it would be better if the authors could stick with one

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set of units. I find instantaneous rates in μmol m^{-2} s^{-1}, and also per 15 h and per 24 h. It would be much easier to follow if the actual measurements in daily cycles were in μmol m^{-2} s^{-1} and then the actual net uptake or loss can be calculated on longer time spans, per day would be obvious, why 15 h I am not sure.

Authors reply: The point of the need to streamline units is well taken, although this of course has no effect on the result. We note that using the same units for different measurements and scales can also introduce confusion. Non-continuous measurements and continuous measurements with data gaps due to instrument failure etc. rely on interpolation, gap-filling, and other estimates. We aimed at transparency by providing measurement data, as well as estimates for periods including higher and lower certainty. Different units are used to explain different-scale relations. The unit μmol m^{-2} s^{-1} is commonly used to explain instantaneous fluxes depending on changing environmental conditions. Flux units per day (d^{-1} or 24h^{-1}) are commonly used to provide the basis for longer term assessments. Mmol per 24h avoids confusingly large values. We used one unit below the day-level and explained in the context of page 1778/79 and the lines 2–4 on page 1979 that a 0:00–15:00 day included the most consistent data set with respect to the 20 presented days of measurement. The particular 15-h time scale was imposed by the complex logistics and activity period in this unique field campaign. Previous studies showed that desiccation of BSC occurred quickly during the day, and without precipitation events, the net gas exchange rates were low or not detectable during afternoon. Hence, each field trip included three days. Day 1 (not shown in Figure 3) included mainly set up and system checks. Break down of the set up started the afternoon of day 3 (i.e., second day in Figure 3). Regular measurements started and ended between 16:00–22:00 of day 1 and between 14:00–16:00 of day 3, respectively. The sum over the 15-h period therefore represented the most reliable value, which we can compare for all days of measurement.

Anonymous Referee #1: In the section on flux triggering the units μmol m^{-2} s^{-1} per 100 μmol m^{-2} s^{-1} PAR are used and I do not understand this at all. Why not simply quote actual maximal rates.

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Authors reply: We agree and indeed individual maximum deposition rates are presented in the paper, too (see e.g., p. 1978). In chapter 3.2 (p. 1979) and Figure 4 we present the change of BSC-related CO_2 fluxes in relation to temperature and light including a large range of PAR. Significant effects from small changes in PAR were restricted to low temperatures. We found that increases of 100 μmol m^{-2} s^{-1} PAR can better describe changes under higher temperatures and light conditions, which started prevailing already after mid morning hours. The unit 100 μmol m^{-2} s^{-1} PAR also allows quick estimates of CO_2 deposition at certain temperatures and light conditions using the regression equations. In contrast, changes in the flux due to changes of for example 20 μmol m^{-2} s^{-1} PAR may vary depending on the hydration status of the BSC. Finally, the results represent the light and temperature dependent changes in CO_2 flux due the association of organisms and not the light response curve of one species. We suggest adding the following explanation as third sentence in chapter 3.2: Minor changes in light intensity were only effective under low temperature conditions, whereas larger changes in light intensity were required to significantly change the BSC-related CO_2 fluxes under higher temperatures conditions, which usually started prevailing after mid morning hours.

Anonymous Referee #1: Better units would make the paper much easier to follow. There are obvious difficulties in extrapolating from point measurements to daily and seasonal net exchanges and the authors are aware of this. However, why not summarise the problems and how it was done at one place and not mention it several times.

Authors reply: See reply concerning units and extrapolation above.

Anonymous Referee #1: Terminology The use of the words emission and deposition (in particular) is curious. Deposition is incorrect and should be replaced by uptake, and emission by loss.

Authors reply: The terminology does not affect the results. We investigated the exchange of CO_2 between biological soil crusts and the atmosphere with enclosures.

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What we measure are net fluxes, normally composed of either up- or downward fluxes, and as a result of production and consumption, adsorption and desorption processes. We assume the referee tries to discern between micrometeorological flux studies and enclosure studies, thus regarding the terms <emission> and <deposition> as micrometeorological terms. We note that <emission> and <deposition> represent standard terms to describe both the direction of exchange processes and fluxes of water vapor, trace gases (incl. CO_2), aerosols and particulate matter between the biogeo- (hydro-) -sphere and the atmosphere. Abundance of previous publications used the terms relative to trace gas exchange measurements conducted with enclosures.
Emission and deposition do generally not distinguish whether they derive from processes of biological production and consumption or from physico-chemical processes or transport. The terms uptake and loss, for example by vegetation, are regarded to include consumption or production and release by metabolic processes. We measured net CO_2 flux between BSC and the atmosphere, but the method does not allow discerning between physico-chemical and biological processes. For example, wet-soaked surfaces of BSC may include a certain amount of wet deposition, which will be released during subsequent desiccation. Vice versa, CO_2 in soil pores can be displaced by infiltration of rain. To our knowledge, there is no publication which defines these the terms but both terms are widely used and accepted relative to trace gas exchange (see e.g. <Slanina, S. (ed.) 1997. Biosphere-atmosphere Exchange of Pollutants and Trace Substances. Springer, 528 pp.>,<Singh, S.N. 2000. Trace gas emissions and plants. Kluwer Academic, 328 pp.>). Thus, as long as we are not able to discern between the contributions of physico-chemical and biological processes, we prefer to use the words emission and deposition.

Anonymous Referee #1: The abbreviation LTER for the research site is also confusing. As far as I can see it is not an LTER (see LTER pages on web) so perhaps LTR might be better.
Authors reply: The authors are very grateful to the referee, because the website obviously changed recently to http://lter.bgu.ac.il/sites/ssd.aspx. However, one may also

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find LTER Sayered Shaked via http://www.lternet.edu/sites/ by further selecting <More LTER>, <International LTER>, <Israel from the map>, and then <LTER Site Information>.

Anonymous Referee #1: The phrase soil dwelling BSC seems unnecessary, is there any other type?
Authors reply: For example, the book <Biological Soil Crusts: Structure, Function, and Management (2001) edited by Belnap and Lange> reports about various types of BSC including for instance lichens growing on rocks. Different heat and water-holding capacities of different substrates may affect the activity periods of BSC. This may justify the emphasis on <soil dwelling> BSC.

Anonymous Referee #1: The format for time 00:00 to 15:00 means from midnight to 3 pm, but I am not sure this is what is meant in the paper. If it is a 15 hour period it should simply be written as 15h.
Authors reply: The time format 00:00 to 15:00 does mean from midnight to 3 pm (see above).

Anonymous Referee #1: Section 3.2, Flux triggering sounds great but is really incorrect, fluxes are always present but sometimes with a value of zero or below detection level. Flux dependency is better, perhaps. To put it another way, fluxes are not triggered by light, if the light is removed then one gets loss rather than uptake.
Authors reply: We agree, the title may be interpreted in the wrong way. But some trace gas fluxes can be triggered (caused) by light i.e. Isoprene and Monoterpenes for example are mostly observed only in the light, because of their biosynthesis depending on light. We propose to change the chapter title into <Flux affecting conditions> and to exchange <to trigger> against <to affect>.

Anonymous Referee #1: The long sections on the effects of water should be rewritten so that they are much shorter and more clearly state what was found.
Authors reply: We did our best to shorten this section in the revised version.

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Anonymous Referee #1: Fig 4, the regressions and symbol description should be put into the captions. Why no line for 15° and why no R^2 when they turn up elsewhere. The figure is a little confusing as well, are these light response curves or?
Authors reply: We explained the absence of the correlation for 15°C category in the text (p. 1979, line 22–23), but the referee is correct in pointing out, that the explanation has to be included in the figure caption, too. With respect to the inserted table with symbols and regression equations, we think this allows the reader to quickly estimate fluxes, and e.g., compare with light and temperature levels they find in the field. Thus, the inserted table includes more information than a figure explaining caption. Please, see also our reply above concerning the unit of <100 PAR>.

Anonymous Referee #1: Fig. 5, The R^2 in this graph are very low for many lines, if below 0.5 then the line is best left out as it has little value in predicting results.
Authors reply: We included the regression for all data sets indicating the quality of correlation for all data sets. Thus, important and less important correlations can be easily recognized. We think this may help the reader who considers similar relations.

Anonymous Referee #1: Fig. 6, this can be left out, it is a presentation of correlations that can be put into the text. I suspect it could be better presented and I am not sure what the correlation with frequency means.
Authors reply: Usually the most important results merit a figure. Figure 6 presents highly condensed results and we think these are better represented by a figure than by a long description. Figure 6 indicates that BSC and BSC-related CO_2 fluxes show a memory effect relative to precipitation despite the absence of roots, internal water reservoir or else. Figure 6 also suggests that the effect may be not exclusively linked with the amount of precipitation that accumulated within a certain preceding period, but that it may also dependent on how often or how long BSC were active during the period. For example, the total activity period may be longer if 5 mm PPT per 5 days were received during five days instead of one day.

Anonymous Referee #1: It is not possible to write about annual patterns because the

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investigation only occupied part of a year. If the authors want to address annual patterns in the results then perhaps the section right at the end of the discussion should be brought forward in order to better justify the concept. The space allocated to these topics in the results and discussion are somewhat long. This does not detract from the results which do look good. In the discussion it is odd to me that efflux is discussed first when perhaps either the daily cycles or the net carbon gains might be a more interesting start.

Authors reply: We present data showing precipitation before, during (93% of the yrs total), and after the campaign period. With respect to poikilohydric organisms, and in agreement with a cited reference, this gives some certainty to discuss the BSC contribution to CO_2 fluxes including the month with no or little precipitation. Furthermore and as also relevant to other aspects, we prefer to present/discuss the results in the sequence from higher to lower certainty. Soil CO_2 efflux is not the main focus of the paper, but it is of high importance (1) because of its permanency and (2) because it represents the level against which temporary BSC-related fluxes are compared.

Anonymous Referee #1: To me, the discussion could be better organised and much more directed, also briefer.

Authors reply: We will of course try to improve the discussion but on a first view we do not know what the referee means with <better organised>. We will try to restructure and see whether it reads better.

Anonymous Referee #1: Overall, I personally found the paper hard to follow because of the curious terminology, the lack of clear focus in some sections and the mixture of units. I really suggest that it be rewritten carefully separating the instantaneous results from the calculations of net CO_2 exchange.

Authors reply: We think that we were able to explain the terminology, which from our point of view is not curious. Of course every paper can be improved and we will try to do our best to point out and focus. We do not agree that there is a mixture of units, but hope that we were able to explain (see above) why units were adapted to special

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questions.

Literature cited

Wohlfahrt, G., Fenstermaker, L.F., Arnone II, J.A. (2008). Large annual net ecosystem CO_2 uptake of a Mojave Desert ecosystem. Global Change Biology 14(7): 1475–1487.

Stone, R. (2008) Have desert researchers discovered a hidden loop in the carbon cycle? Science 320, 1409–1410.

Interactive comment on Biogeosciences Discuss., 5, 1969, 2008.