Biogeosciences Discuss., 7, C5269–C5281, 2011
www.biogeosciences-discuss.net/7/C5269/2011/

Biogeosciences Discussions

Interactive comment on "Spatial and seasonal variability of heterotrophic and autotrophic soil respiration in a winter wheat stand" *by* N. Prolingheuer et al.

N. Prolingheuer et al.

n.prolingheuer@fz-juelich.de

Received and published: 24 March 2011

General

We thank the anonymous reviewers for their very constructive and helpful comments and suggestions on our manuscript. We hope capturing all aspects of their review and implemented them in the revised manuscript to improve its scientific quality. Due to the required 'major revisions' following main changes were made:

- The objectives of the study were specified by adding a clear scientific question on which this study is based and we formulated main hypotheses.

- All values of R_h and thus R_a based on field averages (this includes also the CV) were corrected to the water content of the 7 cm collars. This includes also Table 1 and 2, Figures 2-4.
- Section 2.3 and 3.2 dealing with soil temperature, water content and phenology controls on soil respiration, were shortened and partially rewritten, now concentrating on the full models including both temperature and water content giving significant results. We also pointed out that a separated analysis of the influence of T and θ on soil respiration was not possible due to the limited number of sampling days. We think that this subsection contains relevant information showing a significant dependence of soil respiration on water content and soil temperature justifying in our opinion this section.
- We added a new subsection in the combined results and discussion section, where we discuss the used approach of indirectly separating soil respiration into its heterotrophic and autotrophic component. This section also includes a discussion of possibly added variance as mentioned by Reviewer #2.
- As mentioned by all reviewers we moderated our statements in the conclusions section and included critical discussions on the reviewers comments.

Our answer to the reviewers comments is listed below in the following way: Comments with overlaps between the reviewers are discussed in the section "General points mentioned with overlaps between the reviewers". Specific comments of the three authors were answered separately.

BGD

7, C5269–C5281, 2011

General points mentioned with overlaps between the reviewers

Generalisation of conclusions.

We strongly moderated our statements in the conlusions section and included a critical discussion on parts of our method, based on the reviewers comments. We further pointed out that the results of our study have to be corroborated by long-term observations of the spatial and temporal variability of soil respiration and its components.

Methodology/Different water contents in deep and shallow collars.

The approach, using long and short collars to measure R_h and R_s, respectively, entails differences in water content between the two treatments due to root water uptake in the shallow collars.

A significant influence of water content was observed only for the field averages of R_s and R_h, where changes in water content explained 27% of the changes in R_h and 68% of the changes in R_s. Thus, water content changes likely have a higher influence of the autotrophic fraction of R_s than on the heterotrophic fraction. We corrected all field averages and standard deviations of R_h to the water content of R_s. A potential function for the relationship between water content and R_h and σ_{R_h} was used. Due to the indirect calculation of R_a their values also changed after re-calculation. The CV was also corrected as well as Table 1 and 2, Figure 2-4, 6, dealing all with field averages.

We also calculated the influence of θ_h for measured R_h at all sampling points for all measurement days and we found no significant influence (linear model: $r^2{=}0.03$; quadratic model: $r^2{=}0.04$). There was also no significant influence of θ_s on R_s using all measurements (linear model: $r^2{\approx}0$; quadratic model: $r^2{\approx}0$). Therefore, this difference

BGD

7, C5269–C5281, 2011

in water content between the treatments has only influence dealing with field averages. An influence on the spatial analysis of soil respiration is thus not given.

Reviewer #1

Paragraph 1 and 5: Objectives of the study. *The objectives are independent from a clear scientific question. Add the original research question and hypotheses. There is an overlap on the objectives 2 and 3.*

Objectives 2 and 3 of our study differ in the aspects of spatial variability. Objective 2 deals only with the amount of spatial variability which can be described simply with the CV and the coefficient of correlation. Objective 3, however, deals with the spatial structure, which requires geostatistical analysis. To clarify the objectives of the study we added our research question and defined the objectives more precisely by formulating hypotheses. We changed the objectives in the following way:

"Due to the heterotrophic and autotrophic sources of R_s there must be differences in their contribution to both the seasonal and temporal variability of R_s. Although, heterotrophic respiration is known to be less variable in time compared to its autotrophic counterpart, its variability in space can quite differ. From this, we want to answer the following questions on spatial and temporal variability of soil respiration in a winter wheat stand: (1) Is the seasonal variability of R_s mainly driven by its autotrophic fraction and how does this variability depend on soil temperature, water content and leaf area index? (2) Which fraction, heterotrophic or autotrophic respiration, accounts for the spatial variability of R_s? (3) Does the spatial pattern of R_s clearly feature characteristics of its underlying heterotrophic and autotrophic spatial patterns?"

Paragraph 2: Generalization of conclusions. See section "General points men-

BGD

7, C5269–C5281, 2011

tioned with overlaps between the reviewers".

Paragraph 3: Root exclusion and initial spatial variability. *When was the treatment for root exclusion done? There is no measurement about the initial terms of fluxes or organic carbon in the soil, especially when considering that variation of heterotrophic respiration is randomly distributed in the study plot.*

50-cm long soil collars were installed at the end of March. Plants were very small small and the ones inside the collars were removed completely. We have no information about organic C for the analysed plot in this study to draw conclusion where the randomness of the heterotrophic component had its source. However, the randomnes of the heterotrophic component was observed also in a previous study for an adjacent plot, see Herbst et al. (2009). We mentioned this also in the discussion part. During our study, we also did measurements of heterotrophic respiration on an adjacent 50$\times$50 m bare plot based on the same sampling setup - using only the short soil collars. Measurements showed also a predominantly random structure of heterotrophic respiration. But we used this data not in our study because this field was kept bare since 2006, causing a reduced carbon content.

We added details about the installation of the collars in the following way: "The installation of the 7 cm soil collars was done at the beginning of March and the installation of the 50 cm soil collars were installed at the end of March. Wheat plants inside the collars were totally removed."

Paragraph 4: Wording. *I understand that most of total soil respiration is controlled by a random distribution of R_h and not by the organized spatial structure of R_a. This may be a matter of wording. Also some confusion in the wording is found in the conclusion where there is stated that the R_a shows a strong spatial dependence attributed to the*

BGD

7, C5269–C5281, 2011

heterogeneity of local root development.

There seems to be a misunderstanding. The contribution of R_a to R_s was still underestimated in this study, due to missing measurements for the early growing period (see p. 9149, ll. 4-7). We also showed in our study, that an organised spatial structure was only found for the autotrophic component of R_s. Because R_s showed also often an organised spatial structure this concludes that the autotrophic component controls the spatial structure of R_s.

We agree with your following comment: *"Also some confusion in the wording is found in the conclusion where there is stated that the R_a shows a strong spatial dependence attributed to the heterogeneity of local root development."*. We wanted to point out, that from the architecture of wheat planting, one suggests that the underlying root system must be quite homogeneous leading also to a homogeneous structure of R_a. But we found a clear spatial structure of R_s which must have its causes in a structured root development. We modified this sentence accordingly in the conclusions section in the following way:

"Total soil respiration and the autotrophic component showed moderate to strong spatial dependence in contrast to a predominantly random distribution of R_h in space. This results in a defined large-scale pattern of root distribution or root activity due to a spatial gradient e.g. in the soil properties leading to a spatially dependent autotrophic component."

in conclusion: Maybe an explanation about how the heterogeneity of root distribution leads to a strong spatial dependence in contrast with the random distribution of RH (where there is no heterogeneity of roots but maybe in the substrate pools for heterotrophic activity)
Based on this comment we added an explanation in the conclusions part as follows:

BGD
7, C5269–C5281, 2011

"Whereas the heterotrophic component was not affected by a large scale spatial dependent variable but affected by e.g. heterogeneity in the substrate pools, acting on a smaller scale as observed in this study."

Paragraph 5: *I appreciate that the authors used the AIC for model selection, but there is no indication in the objectives about the interest in understanding the empirical relationships between the drivers and soil respiration. This is why I think a clear scientific question is needed to better understand the goal and objectives of the study...(see lines 1-5 in page 9140 for a description of drivers).*

We added this in our objective formulation. See our answer to Paragraph 1 above. Also, we shortened the modelling section and focussed only on the full models including both T and θ.

Paragraph 6: *I encourage the authors to test the differences between Ra and Rh or Rs with statistical tests in order to support the statements that one is higher than the other.*

We used a paired t-test to support the statements, which variable is higher than the other and implemented the p-values in the manuscript.

Paragraph 7: Section 3.2., Model selection.
We have rewritten and shortened the full section focussing on the full models including T and θ and additional LAI for R_s and R_a.

Paragraph 8: Interpretation of results. *Do not over interpret the data and consider the limitations of a one-time sampling experiment. Maybe the discussion should be*

BGD
7, C5269–C5281, 2011

focused on agricultural crops.

We moderated our conclusions and focused now mainly on crops. The following was added in the conclusions:

"However, this may in part be a specific result for winter wheat based on observations during one growing period. Further long-term observations covering several growing periods are needed to corroborate the findings of this study."

However, there is still a gap in literature about the spatial variability of the autotrophic component of R_s.

Specific comments

Lines 8-10, page 9139: *To my understanding autotrophic respiration is considered to be by roots and mycorrhizal associations even if the mycorrhizal fungus by itself is considered a heterotrophic organism.*

We strongly agree. This statement was mainly given to point out that autotrophic respiration consisted of two fractions, respiration by roots and mycorrhizal associations, however, we did not separate between both fractions in this study.

Section 2.5.1: *Is this section needed? Maybe a few citations about variogram estimation is enough along with lines 15-21.*

Spatial analysis were a main focus in our study, wherefore we think a detailed description of variogram estimation is necessary. Nevertheless, we shortened this section.

BGD

7, C5269–C5281, 2011

Line 7, page 9148: *The information about organic carbon would be very useful to understand the spatial and temporal variations explained here.*

We have no spatial information about organic carbon content at the investigated plot. However, this topic was investigated at the adjacent bare soil plot Herbst et al. (2010). Within that study, a strong relation between Corg and the spatial variation in heterotrophic respiration was clearly not given (see table 1), which was also detected by other authors. The heterotrophic fluxes probably rather depend on the availability of certain carbon pools than on total Corg. However, this is far beyond the scope of this manuscript.

Lines 12-19, page 9149: *The authors state that TDR probes were not working properly. For how long this problem persisted? When was it corrected? Does the problematic values were used in the empirical models?*

The installation of the TDR probes in the 50 cm soil collars were done about 3 weeks later than the installation of TDR probes in the 7 cm soil collars. Therefore the TDR probes in the 50 cm collars might had been not full contact with soil. Past experiences have shown that in this depth, 6 cm, a small rain event is enough to cause full soil contact of the rods. We did not use the problematic values for the analysis of the temporal variability, which concern the first two measurement dates of the 50 cm soil collars. The spatial variability analysis using geostatistics is not affected by this underestimation effect, because it depends rather on the differences between points than on the absolute values.

Lines 19-28, page 9149: *This is somehow repetitive from the introduction.*

BGD

7, C5269–C5281, 2011

We agree. As mentioned before, we completely rewrote this section.

Reviewer #2

Addressed Problems

Paragraph 1: Contribution of fluxes.

See section "General points mentioned with overlaps between the reviewers". We corrected field averages of Rh to the 'normal' moisture level.

Paragraph 2: Temperature and moisture effects.

As mentioned before (see section Reviewer #2) we have completely rewritten this section including all your suggestions, focussing now only on the full models including both T and θ. We also pointed out that a differentiated analysis/quantification of the influence of soil temperature, water content and LAI would be biased due to the reduced temporal resolution of the data and interferences between these driving variables.

Paragraph 3, 4 and 5 (first sentence): Flux calculation and variability, added variance and its possible spatial gradient.

We discussed this as a new subsection in the discussion part as follows: "The ap-

BGD
7, C5269–C5281, 2011

proach, using different treatments for an indirect calculation of R_a bares the disadvantage of potentially added variance in the autotrophic component. This variance has its source in the difference between observed R_h in the 50 cm collars and transformed R_h in the 7 cm collars. The following assumptions can be made regarding this possible added variance:

1. The mean of this variance is zero for each sampling day. The difference between observed and transformed R_h can either be positive or negative resulting in a normal distribution of the variance with zero mean.

2. The variance is not effected by small-scale variability of R_h. Herbst et al. (2009) detected a range of spatial autocorrelation of 2.7 m for R_h at an adjacent bare field. The smallest spacing in their sampling setup was 0.25 cm and thus smaller as the distance of 1 m between 7 cm and 50 cm soil collars in our study. Thus, the small-scale variability which occurred on a scale smaller than 0.25 cm will not effect the transformed fluxes of R_h.

3. Its spatial distribution is random. This resulted from the random spatial distribution detected for observed R_h.

4. The added variance is very small compared to the true variance of R_a. If the added variance would be larger than the true variance of R_a the indirect calculated R_a would not be spatially correlated due to the spatial randomness of the added variance.

Thus, it is unlikely that the added variance caused a spatial gradient in the indirectly calculated autotrophic component of R_s."

Paragraph 5: *The average spacing in the study is too large to detect autocorrelations at smaller scales, e.g. reflecting root patterns. The ranges of correlations given up to*

BGD
7, C5269–C5281, 2011

20 m are likely a result of soil and terrain differences proper to the site. But this is not explained. A generalization of the results to other sites is thus not possible.

We specified the sources which might caused the spatial autocorrelation in the autotrophic component. Maybe it was more a problem of wording also mentioned by Reviewer #1. The average spacing was 4.61 m but our smallest distance between to sample locations was 1.26 m. Nevertheless, this was too large to detect the characteristic row-interrow pattern of winter wheat. However, the detected spatial autocorrelation of R_a could also be a reflection of the large-scale related root distribution which is, as you mentioned, likely the result of soil differences proper to the site but also heterogeneity in the distribution of, e.g nutrients. But we have no information about that.

Paragraph 5: Section 4. *Several conclusions are not valid: The high spatial variability of Ra - Attributing the variability of Ra to root development (this was not measured) - Spatial correlations and dependence of Rs on Ra.*

The explanations above make these conclusions valid, except the attribution of the variability of Ra to root development. This was moderated.

Reviewer #3

A simple small trenching (piping) approach is used to separate soil respiration.
The method is simple but there are not many comparable studies measuring soil respiration in such a high spatial resolution at the plot/field scale.

BGD
7, C5269–C5281, 2011

To derive autotrophic respiration, one has to assume heterotrophic respiration remains the same in the trenched (50 cm collar) as the control area (7 cm collar). My major concern on the methodology is that 1) changes in soil water contents resulting from the 50 cm collars

See section "General points mentioned with overlaps between the reviewers". We corrected R_h to the water content in the 7 cm collars.

.. and 2) changes in heterotrophic respiration resulting from the absence of fresh carbon supplies from roots (root exudates) with 50 cm collars.

In the introduction we defined autotrophic respiration as the sum of respiration by roots and root exudates by e.g. microbial funghi despite the heterotrophic nature of the mycorrhizal fungus. Therefore, there is no need for a correction of R_h due to root exudates.

References

Herbst, M., Prolingheuer, N., Graf, A., Huisman, J., Weihermüller, L., and Vanderborght, J.: Characterisation and understanding of bare soil respiration spatial variability at plot scale, Vadose Zone J., 8(3), 762–771, 2009.

Herbst, M.; Prolingheuer, N.; Graf, A.; Huisman, J.; Weihermüller, L.; Vanderborght, J. and Vereecken, H.: Multivariate conditional stochastic simulation of soil heterotrophic respiration at plot scale, Geoderma, 160,74–82, 2010.

Interactive comment on Biogeosciences Discuss., 7, 9137, 2010.