BGD, 6, C1916-C1918, 2009, Vesala et al

Dear Editor

We thank two Reviewers for careful reading of the paper and good comments, which are taken into account in the following way. “C” refers to the original comment/question and “A” to our response (Rev 1).

On behalf of all authors, Timo Vesala

Reviewer 1

C1. Effect of thinning on component fluxes.

A1. More information is now given from the thinning and it is stressed that the thinning did not cover the whole stand and the ongoing work (not published yet) shows that the thinning affected GPP and TER also marginally.

C2. Partitioning NEE into TER and GPP

A2. The base respiration Re_0 is determined in moving windows, thus it varies with time as expected by the referee. Only the shape of temperature response is fixed over the course of the year.

C3. Mixing day-to-day and interannual variability in correlation analysis

A3.We are aware that in the correlation analysis shown in Fig.1 (former Fig. 3) day-to-day variability and inter-annual variability are mixed. This is done because we want to show how the role of the different environmental variables (temperature, radiation etc.) controlling the carbon fluxes changes during the season. Thus, the emphasis here is on “average” behavior not on the extremes or short-time changes on a given year and therefore data from all years was pooled before the correlations were calculated on moving 30 day window providing 29 day overlap. The other option would have been to calculate the correlations separately for each year and taking the average of *r* afterwards. Note also that for the same reason the year 2006 was excluded from the analysis – the late summer was exceptionally dry and including it changed the correlations beyond “typical” values.

C4: Partial correlations.

A4: Partial correlations are now added (Table 2).

C5: Also I recommend looking separately at night and day-time temperatures, since it might strengthen the evidence of the impact of cold nights.

A4: This is a valid point, but mainly to the spring period, which is not in focus in this paper.

C6: GPP PAR correlations are 0.56 in the text, 0.53 in the Table 1. Also I wonder what the effect of soil moisture is. In Table 1 it also correlates negatively with both PAR and GPP, i.e. when this is partialized out the GPP-PAR relation should even become stronger.

A6: There was a mistake in the text – the true correlation between GPP and PAR in early autumn is 0.53. We decided to introduce the partial correlations in separate table (table 2) and calculated them as follows: The most important driving variables were selected by performing linear multiple regression analysis where the environmental variables were independent and the cumulative carbon fluxes (i.e. GPP or TER) were dependent variables. The analysis showed that T_a, (or T_s), PAR (or global radiation) and soil moisture (θ) were the only variables that had practical (although not always statistical) significance determined by changes in R^2. For partial correlation analysis we selected T_a, PAR and θ; T_s was neglected because of collinearity with T_a and for the same reason only one variable describing the radiation was kept. The partial correlation coefficients (table 2) carbon fluxes and a given environmental variable were calculated then by controlling the effect of the other two variables.

The role of soil moisture in regulating GPP during autumn is minor. When the effect of T_a and θ were controlled the partial correlation GPP-PAR was 0.60 ($p>0.05$) in early and 0.33 ($p>0.05$) in late autumn.

C7: Interpretation of results in light of Piao et al. 2009. (or 2008?)

A7: This study and Piao et al. operate quite on different scales, point measurement and boreal region, respectively. However, the idea to this study was partly triggered by Piao et al. Some more discussion to Piao et al. has been added and generally, two studies corroborate each other.

C8: Generalization of the results – other NECC –sites

A8: We do not know any other published peer-reviewed paper based on EC data on this topic (beside Piao et al).

C9: Speculative discussion about the timing of respiration – warm autumn and high respiration could decrease TER in next spring

A9: Yes, this is possible. However, we would like to keep it out of the scope of this study, since its detailed investigation is not straightforward task and would require some effort.

Referee 2

General comments

A: We have modified the paper in the direction of the comments:

i) we have reorganized so that the former Fig. 3 is now Fig. 1, this should now give a better view and background for the rest of the paper, which includes the most important parts and results

ii) we have changed "warming" in the title to "temperature" to avoid the interpretation that we are investigating climate change and future predictions to the boreal forest, which is not the focus, but the temperature response and its implications

iii) Hypothesis is added (last paragraph in Introduction) and the main goal is clarified

iv) Abstract has been rewritten

v) The autumn period defined as 1st Sept-31st Dec contributes significantly to annual TER but less so to annual GPP: The annual TER is on average 823 gCm-2 (range 763-858) and of this the autumn contributes on average 26% (range 19.5-32%, the maximum occurs in 2006 which was the warmest autumn and minimum in 2002 which was the coldest). Thus, autumn is important both because it's roughly 1/4 of annual but also because the variability of autumn TER (max=260, min 165, variability 95 gCm-2) is comparable to the annual variability (136 gCm-2). The annual GPP is on average 1032 gCm-2 (952 - 1104) of which autumn contributes only 4.0% (range 3.6-4.3). This discussion is added to the paper.

vi) We have added a separate table (table 2) where we show the partial correlation coefficients between GPP, PAR, NEE and the main driving variables (T_a, PAR and θ). The calculation of partial correlations is now shortly described in the text (see also response to reviewer 1, comment C5).

vii) Language has been polished.

viii) Other general comments are taken into account by the following specific comments.

Specific comments

p. 7054, former line 10: the name has added, it is COCA.

former line 11: modified as suggested

former lines 19-24: rewritten

p. 7056, former lines 5-8: details are presented in Piao et al, to which quite long discussion has been already devoted, thus more numbers are not added; “asymmetric” replaced by “complex”

former line 10: modified and NEE, GPP and TER are clarified

former line 14: Hari and Kulmala replaced by two earlier references

p. 7057, former line 5: modified

former lines 13-12: hypothesis is added

p.7058 former lines 20-21. The eddy-covariance measurements were made 23.3m above the ground with exception of the period Oct 1998 – June 2000 when the measurement height was 46.6m. The mean forest height increased from 12-13m to 15-16m during the eleven years studied. This point is clarified in the text.

former lines. 27-28. we reformulated the sentence. We divide the autumn into two periods because TER and GPP have different role and in NEE and their environmental drivers changes during the autumn.

7059, former line 12: modified

p.7061

former line 14: modified

former line 22: description added

former line 27: The ORCHIDEE model runs now include 2007. The figure 6 and the text have been changed accordingly.

p.7062 former line: 3 There were three autumns when the climate conditions when the conditions were very different than in “typical” autumns. Two of these are shown separately in Fig.2 (former 1) and necessary details are given in text. In 2006 October was ~3 degC warmer than average and there was a short cold spell in early November followed by an extremely warm December. The soil moisture was depleted after the summer and remained low until October when rapid re-charge occurred. In 2002 the Oct-Dec period was the coolest, driest and clearest (Fig.2, former 1) . Autumn 2000 was warm and moist throughout (not shown separately)

former lines 21-24: The focus is on the autumn temperature and why we present the whole year in Fig. 1 (former Fig. 3) is now explained more thoroughly.

p. 7063 former line 4: The emphasis of the paper is to describe the effect of climate, particularly temperature, variability on carbon balance during the autumn. We can use the current 11 yr dataset to study how the temperature variability (including the extremes) has influences the NEE and its components. We can only speculate these results in context of projected climate warming – this is now brought up in the text and the title is modified accordingly.

Based on above, our opinion is that Fig. 1 and 2. represent the the best compromises to synthesize this multi-year dataset and preserve necessary details on the extremes.

former line 6: “cumulative” was removed from the text – the forest turned into a source of carbon; NEE became positive

former line 16: We agree that daily includes the nights and thus removed the “nights included”. We decide to keep the commonly used units of μmol $m^{-2}s^{-1}$ for direct comparison to other studies.

former lines 18-19: PAR is important for GPP in early autumn. We represent the bivariate and partial correlation coefficients in table 1 and 2. and refer now to them in the text. Extremely cloudy period in September 2001 corresponds to the lower edge of the shaded area in Fig. 2c (former Fig. 1). During the period the radiation was about ½ of the mean values for mid-September. A comment on this was added in text.

former lines 24-27: Please see response to general comments

p. 7064 former line 4: modified everywhere

former line 6-7: Please see response to general comments

former line 10: We have tried to improve the clarity of the figure. Moreover, we change the order of figures and represent this figure as Fig.1. in revised manuscript. We want to keep the whole-year correlation analysis since it provides necessary background information on the seasonal dynamics of the environmental control variables. For instance, this figure answers to the referee comment on the negative correlation between T_a and PAR in autumn.

p.7065 former lines 9-10: The correlation coefficients were added.

former line 12: A more complete description on the calculation of partial correlations is added to the text. See also response to the C5 of Referee 1.

former lines 15-16: The negative correlation between temperature and radiation in Oct-Feb is a very natural and intuitive result for a Scandinavian people. During the northern autumn – winter the clear skies are normally associated with low temperatures. There are two simple inter-related explanations to this:

In wintertime or late autumn the sun angles are very low, days are short and the incoming short-wave radiation is low in absolute sense (Wm^{-2}). Thus, although any decrease in cloudiness leads to increase in Rg but the increase in the effective long-wave cooling exceeds the increased short wave radiation input and, thus, the temperature decreases. Largest diurnal temperature amplitudes are observed in these conditions.

During the autumn and winter the weather conditions in Scandinavia / Finland are strongly determined on the larger-scale circulation patterns and their dynamics. To put it short, the synoptic-scale lows associated with westerlies bring moist warm air from the Atlantic ocean. The conditions in Scandinavia are typically warm and the precipitation is high during these frequent events. On the other hand, when the large scale flow is from the North – East direction, cold and dry Arctic air masses are transported over Finland. These conditions are characterized by cold temperatures, clear skies and low precipitation.

We added a short note on the typical climate dynamics on the region.

The "intuitive" positive relationship between temperature and radiation is recovered in the summer (see the seasonal correlations).

P.7067 former lines 4-5: This hypothesis is based on the prevailing climate dynamics and weather conditions in Scandinavia described above and present regional climate scenarios

former lines 13-14: clarified

page 7069 former lines 22-26: rewritten.

Technical corrections

all done.