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Biogeosciences Discussions

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Interactive Comment

Interactive comment on "Modeling carbon dynamics in two adjacent spruce forests withdifferent soil conditions in Russia" *by* J. Kurbatova et al.

J. Kurbatova et al.

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Responses to Comments

We highly appreciate the detailed comments and suggestions from all the four referees. The comments were very helpful for us to modify the manuscript. Since some comments were commonly raised by more than one referees, we tried summarizing the comments based on their contents and made our responses accordingly. Below-listed are our responses (marked with [Response]) to the general and specific comments (marked with [Comment]).

Responses to General Comments:

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[Comment 1]: The Discussions section in the manuscript needs to be enhanced by indicating the implication of the study as well as the strengths and weaknesses of the modeling approach used in the paper. (Referees 1, 2 and 3)

[Response]: The suggestion has been accepted. The Discussions section has been reorganized to indicate the importance of wetland studies as well as the strengths and weaknesses of the modeling approach utilized for the study. Two additional paragraphs, which have been added in the Discussions section, are shown as follows:

NEE measurements have been conducted worldwide during the past decades. Most of the measurements were carried out for upland forests with only a few for wetland forests maybe due to the difficulties in field measurement. The measured NEE data indicated that most of the tested upland forests appeared to be sinks of atmospheric CO2 while some wetland forests showed as sources of atmospheric CO2 (e.g., van der Molen et al., 2007). Globally, wetland soils contain a significant proportion of the terrestrial soil C (20 - 25%), despite the relatively small proportion of the total land area (2-3%) occupied. When considered on a unit area basis, upland forest soils typically have less than 3 kg C m-2, whereas forested wetland soils may contain from 9 to 90 kg C m-2 (Trettin and Jurgensen 2003). It is apparently important to understand the feedbacks between the wetland C storage and global climate change. There is a hypothesis that the large amount of organic carbon stored in wetland soils could readily be released into the atmosphere if the climate becomes warmer and dryer in the high latitude areas. The six-year NEE measurements at the two adjacent spruce forests at Fyodorovskoe in Russia provided a unique case for us to test the hypothesis. Based on the field observations, the two forests shared similar climate and vegetation structure but differed in soil conditions; and the measured NEE data indicated the wetland spruce forest (WSF) was a source of atmospheric CO2 while the dry spruce forest (DSF), like most other upland forests, remained as a sink (van der Molen et al., 2007). In this study, we utilized a process-based model, Forest-DNDC, to interpret the observed differences between the two forest stands. The modeled results were in agreement with

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observations that WSF and DSF were in negative and positive C balances, respectively. The modeled data further indicated that the accelerated soil decomposition and the depressed forest growth under the anaerobic condition at WSF could be the major reason to switch the wetland ecosystem into a source of atmospheric CO2. A series of sensitivity tests were conducted by varying the water table depth for WSF. The results showed that the SOC stored in WSF was very sensitive to changes in the water table dynamics. The conclusion from this modeling study could be applicable for a wide range of wetland ecosystems that contain high contents of soil organic C while suffer from hydrological changes driven by the climatic or land-use changes.

In this modeling study, the Forest-DNDC model was employed for simulations. Forest-DNDC is a process-oriented, biogeochemistry model, which has been widely tested against field data of C sequestration and trace gas emissions observed worldwide. The model is capable of simulating both aerobic and anaerobic processes that has enabled Forest-DNDC to serve not only upland but also wetland studies. In comparison with most other C models, such as CENTURY, CASA or Roth-C, which were developed mainly focusing on upland ecosystems, Forest-DNDC possesses a relatively complete set of biogeochemical processes such as decomposition, nitrification, denitrification, fermentation etc., driven by a wide range of soil redox potential values (from 650 to -150 mV). This feature enables Forest-DNDC to model the transition between aerobic and anaerobic conditions driven by climate change or alternative management practices. However, Forest-DNDC is relatively weak in simulating forest community. The forest growth sub-model embedded in Forest-DNDC was adopted from a forest physiological model, PnET, developed by Aber and Federer (1992). PnET has well developed physiological processes but is lack of forest structure functions. To overcome the weakness, a three-layer vegetation structure was developed in Forest-DNDC to allow the users to construct a forest ecosystem by defining its upper story, under story and ground growth (e.g., sedge, moss etc.) (Zhang et al., 2002; Li et al., 2004). The upper story and under story can be defined as two different species of trees to make up a multi-species forest. For example, in this study, the modeled spruce forests in Russia

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were constructed with a 150 years old spruce as the upper story and a 25 years old birch as the under story. By changing the proportions of the two species, the bulk photosynthesis, respiration and other physiological parameters of the forest can be adjusted to match the corresponding observations. However, this simplification may not adequately applicable for complex forest communities. This weakness will need to be addressed in the future development of the model.

[Comment 2]: The figures showing the modelled and measured data comparisons are not very clear; some quantitative estimate of the goodness of fit between modelled and measured data needs to be presented. (Referees 1 and 2)

[Response]: Indeed, putting the measured and modeled 6-year daily NEE data into a figure made it massy. To improve the readability of the figure, we converted the daily fluxes into monthly or annual NEE fluxes and used the integrated data to make new figures. In addition, the correlation coefficients were calculated with R-squared values reported in the figures to quantitatively indicate the correlations between the measured and modeled results. The new figures have been incorporated into the manuscript. (We did not include the figures and tables in this document as the format for the response documents only accepts plain text files.)

The same conversion was also applied for the figures of the two validation cases in Tharandt, Germany and Griffin Aberfeldy, UK. The old figures for the two cases have been replaced.

[Comment 3]: Water table (WT) depth data are crucial for wetland C dynamics. However, in the study, WT was only measured in 2004 and at the same values were repeatedly used in the other years. The methodology may need to be improved to reflect the variability in climate between the six years. A brief table summarizing monthly precipitation and temperature over the measurement period would be appreciated. (Referee 1)

[Response]: As a wetland model, Forest-DNDC has three options to obtain water table (WT) data to drive the soil biogeochemical processes. The options are (1) using measured WT depth data, (2) using a group of empirical hydrological parameters to calculate WT depth driven by daily weather data, and (3) using a spatial distribution hydrological model driven by topography, vegetation, soil and climate data. In the original manuscript, we repeatedly applied the WT depth data measured in 2004 for the rest years from 1999-2004. To respond the comment, we shifted the WT-generating method to the empirical parameters. In Forest-DNDC, a group of hydrological parameters have been embedded, whose values can be empirically adjusted with the fitting-tuning method to match observations for a specific site. As soon as the values of the parameters are fixed, they can be used to predict future WT dynamics based on the future climate data for the site (Zhang et al., 2002). In this study, we used the measured daily WT depth data of 2004 to determine the values of the six hydrological parameters, namely initial WT depth, lowest WT depth ceasing surface outflow, lowest WT depth ceasing ground outflow, fraction of precipitation for surface inflow, intensity of surface outflow and intensity of ground outflow. The values of the six parameters for site WSF were -16 cm, -15 cm, -60 cm, 15, 0.9 and 0.05, respectively. With the fixed values, the six parameters were then utilized to produce daily WT depth data for 1999, 2000, 2001, 2002, 2003 and 2004 driven by their real meteorological data observed at WSF. With this method, the six-year daily WT depth data were generated by adequately utilizing all the available information (i.e., the observed WT of 2004 and the actual meteorological data for all the six years). A new figure has been made to show the relation between the observed and modeled WT dynamics for 2004; and a new table has been made to show the relationships among the precipitation, temperatures and modeled WT depth for 1999-2004 as the Referees suggested. The new figure and table have been added in the manuscript.

[Comment 4]: Calibration/validation issue: Why no wetland site was chosen to validate the model? How to demonstrate the model was adequately validated for both upland and wetland forests? (Referee 3)

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[Response]: Forest-DNDC has been validated against observed NEE and trace gas data for a number of upland and wetland forests. To respond the comment, we added a new forested site to show the model validation for both upland and wetland forests, which existed within the same site. The site was located 15 km northeast of Gainesville, Alachua County in north central Florida, USA. The site was a flatwoods landscape consisting of wetland pond cypress swamps (Taxodium ascendens Brongn.) and upland slash pine (Pinus elliottii Engelm.) stands. NEE fluxes were measured with eddy covariance method in the two stands in 1996. The measured NEE data suggested that cypress wetlands had highly contrasting daytime and nighttime carbon flux patterns when compared to nearby drier pine flatwoods ecosystems. On an annual basis, wetlands accumulated less carbon than pine uplands mainly due to their lower photosynthesis rates, higher respiration rates and being leafless during winter (Clark et al., 1999; 2004; Sun et al., 2006). Forest-DNDC was applied for the two adjacent forest stands with the local climate, soil and vegetation conditions. The modeled patterns and magnitudes of NEE fluxes were basically in agreement with observations for the two stands. On an annual basis, the slash pine forest (upland) was a strong sink of atmospheric carbon with a measured NEE of 7.4 t C/ha (modeled 6.72 t C/ha) while the cypress swamp (wetland) was a weaker sink with measured NEE at 0.84 t C/ha (modeled 0.65 t C/ha). A new figure has been added in the validation section of the manuscript. The new figure has been added to the manuscript.

[Comment 5]: What is the contribution of tree species composition and structure to the difference between the wet and dry spruce forests? (Referee 3)

Forest-DNDC has detailed processes describing impacts of temperature, radiation, soil moisture and nitrogen availability on forest growth but is lack of the functions quantifying the effects of long-term flooding on forest photosynthesis or respiration. In fact, we knew little about how a same species could behave differently if growing in wetland or upland. The model could be improved in the aspect when more observations become available in future. In this study, Forest-DNDC simulated the forest growth only based on the stresses of temperature, water and nitrogen. The above-stated problem has been added in the Discussions section of the manuscript.

[Comment 6]: How modeled results on N2O and CH4 are reliable given no field data measured at the WSF and DSF sites; Nitrogen is not adequately discussed in the paper. (Referees 1 and 2)

[Response]: We agree with the comments. To accept the suggestion from the Referees, we have deleted all the statements related N2O or CH4 from the manuscript. The revised manuscript only focuses on carbon issues.

[Comment 7]: Use of observed NEE data need to be authorized by the data authors and acknowledged in the paper (Referees Papale and Seufert)

[Response]: Thank Papale and Seufert for their detailed information about how to correctly obtain and cite the measured NEE flux data. We have contacted Drs. Christian Bernhofer and John Moncrieff for their permissions to use their NEE data published at the CarboeuropeIP database (http://gaia.agraria.unitus.it/database). Two new references (Moffat et al., 2007 and Papale et al., 2006) have been cited. In the Acknowledgements, thanks have been given to all the authors for their kindness providing the access and information to the data sets.

[Comment 8]: The methods used for NEE data processing need to be described. The method used to fill the gaps in the two Russian datasets needs to be specified. (Referees Papale and Seufert)

[Response]: The methods for gap filling procedure and estimating of average annual NEE have been described in detail by Van der Molen et al. (2007). The methods can be summarized as follows: Eddy Covariance Data acquires and primary process with the software Eddymeas (Kolle and Rebmann, 2007). On the next stage the half-hourly data sets were processed using a standardized methodology described in Papale et al. (2006); Reichstein et al. (2005). The fluxes of CO2 were corrected for within-canopy CO_2 storage, filtering for low-turbulence night conditions using a friction velocity threshold criterion, spikes are detected. The u*-thresholds varied between 0.32 and 0.38 m s-1 in different years. During the period analyzed (1999-2004) the different quality tests discarded part of the measured NEE data, leading yearly data coverage of 39-47 % for night time and 58-71% for day time datasets. For gapfilling procedure was performed Marginal Distribution Sampling (MDS) method (Reichstein et al., 2005; Moffat et al., 2007).

[Comment 9]: p.275, line 15-16: How does the location of the tower in a shallow depression affect the measured CO_2 flux (e.g. advection, storage term)? What does [with a heterogeneous territory] mean? (Referee 3)

[Response] The original expression was not very accurate. We have replaced the old sentence with [The measurement tower is located on a flat surface with homogenous vegetation cover]. The original term was proposed by our colleagues in the sphere of landscape researches. However apparently it was misleading in our case. In fact, the territory within the scope of footprint is flat without any slopes. So we did not use any processes to correct the air currents.

[Comment 10]: Are there any chamber measurements of respiration from the forest floor? The modeled results indicate that processes leading to soil C turnover govern the net C balance in the studied ecosystems. Eddy covariance NEE data are not easily amenable to partitioning into component C flow processes, especially for complex ecosystems such as forests. (Referee 2)

[Response] We agree with the referee that it would be perfect if the eddy tower and chamber methods could have been utilized at our site simultaneously. However, we did test the chamber measurement for only a short term due to the lack of necessary equipments. We did not include the incomplete results of the chamber measurements in the paper.

[Comment 11]: p. 276, line 10-12: Is a flow rate of 4-5 l min-1 high enough to ensure

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turbulent flow inside the sampling tube and minimize high frequency attenuation, especially if you are to measure at 20 Hz? Ameriflux recommends a Reynold number (Re) between 3000 and 3500 and I calculated Re above 3000 only under very cold conditions and when the sampling flow rate is at its upper limit (5 l min-1). We have corrected the text of the paper. (Referee 3)

[Response] Measurements of the fluxes were conducted in the project framework of Eurosiberian Carbonflux and TCOS-Siberia. The measurements were made meeting the policy of quality control. And the measurements correspond with the requests of eddy measurement standards. During the long period of measurements we regularly changed the tubing and pumps. Presently the flow rate is about 6 l min-1. We have corrected the text of the paper.

Responses to Technical Comments:

[Comment]: Use [was] instead of [were] in the first line on page 272. (Referee 2) [Response]: Accepted.

[Comment]: Line 18 p 272: Replace [proved] by [suggested]. (Referee 2) [Response]: Accepted.

[Comment]: Insert [such] after [programs] in line 18 on page 273. (Referee 2) [Response]: Accepted.

[Comment]: p.273, line 25-27: I would avoid the use of the word [preliminary] because it could give the reader a false sense that published analyses of observed NEE fluxes are either incomplete or not self-sufficient (i.e. they can not contribute significantly to our understanding of C dynamic in terrestrial ecosystems by themselves). Please rephrase. Also, there are numerous notable analyses published before and particularly after Falge et al. (2002), some of them could be easily added. (Referee 2) [Response]: Accepted.

[Comment]: Lines 5-7 on 273 - Vegetation composition and structure in natural forest

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ecosystems are far too complex. I do not believe that any of the existing biogeochemical models are adequate enough yet to treat these issues with a fare degree of accuracy. (Referee 2) [Response] Vegetation composition is really complex. The sentence has been corrected.

[Comment]: Replace [governing] by [govern the] in line 11 on page 274. (Referee 2) [Response]: Accepted.

[Comment]: Remove the extra space after the cited reference 18 on page 274. (Referee 2) [Response]: Accepted.

[Comment]: Replace [governing] by [govern the] in line 11 on page 274 (Referee 2) [Response]: Accepted.

[Comment]: Line 23-24, p.275: Is it Acer platanoides rather than Acer plaNtanoides? [Response]: Accepted.

[Comment]: Line 19 p 280. ..."we re-ran" not" we re-run". (Referees 1, 2) [Response]: Accepted.

[Comment]: Line 9 page 282 - replace [spare] by [sparse]. (Referee 2) [Response]: Accepted.

[Comment]: Replace [proved] by [suggested]. (Referee 3) [Response]: Accepted.

[Comment]: Correct the sentence in line 6 on page 275. (Referee 2) [Response] The sentence has been corrected. The new text is [The two measured sites, the wet and dry spruce forests, are located about 2 km apart from each other. The sites have similar climatic conditions with average annual temperature 3.9C and precipitation 711 mm for the 1990s (Milyukova et al., 2002).]

[Comment]: Provide a measure of dispersion around the WSF mean NEE. (Referee 2) [Response] We have provided a measure of dispersion mean NEE in WSF. The dispersion has been included in the text.

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[Comment]: I do not think we can accept the DSF mean value as the site average as it is based on to limited data. If the authors have a sound reasoning to treat the value as the site average, please elaborate. (Referee 2) [Comment]: p.277, line 21-23: How can an average annual NEE be estimated with less than one year of data (July 02 to May 03 which, moreover, badly represents the annual cycle since it includes two different growing seasons)? Are measurements available at other time during the 1999-2004 period? Can a brief description of what was done by Van der Molen et al. to estimate an average annual NEE for the DSF site be provided? (Referee 3) [Responses]: The original description of the measurements for the DSF stand was not accurate. In fact, CO2 fluxes were measured since October 7, 1999 when the flux tower was erected; and the measured, qualified NEE data covered the time periods of October 7- November 21 in 1999; June 7- September 5 in 2000; June 18- July 7 and July 27- December 31 in 2002; January 1-May 15 and August 26-November 10 in 2003; and May 31- June 30 and July 28-September 20 in 2004. The multi-year average NEP flux value for DSF was calculated based on all the observed datasets and reported in van der Molen et al. (2007). We simply cited the value for our manuscript. We have modified the manuscript with the correction.

[Comment]: p.276, line 16-18: What is the precision of the known CO2 concentrations? (Referee 3) [Response] The precision of the known CO2 concentrations is 0.1ppm.

[Comment]: p.276, line 21-24: What was the purpose of measuring multi-level CO2 concentrations? Presumably for storage term calculation to be included in NEE estimation but it is not mentioned in the text. (Referee 3) [Response] The storage was included in NEE estimation. We have added in the text the description of gap filling procedure.

[Comment]: p.276-277: Please make sure to include all the appropriate information when referring to instrument manufacturers. (Referee 3) [Response] We have modified the text to include all the appropriate information of the instrument manufacturers.

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[Comment]: p.277, line1-15: It is not obvious to me how all these variables are used in the study especially given the fact that climate data used in the model are from the local weather station (as stated on p. 279, line 23-25). At line 13-15, a [comparison with half-hourly eddy flux data] is mentioned, but what comparison? Either add a sentence stating how you used all these climate measurements or edit out this enumeration of instruments. (Referee 3) [Response] The data were used for the procedure of gap filling. The data which we had not used for calculations were excluded from the text. We have used the data of local weather station for precipitation. We have corrected the text. The new text is “The eddy tower was also equipped with instruments to measure environmental factors which have been used for the procedure of gap filling: incoming photosynthetic photon flux density (model LI-190SA, Lincoln, NE USA), humidity and temperature (model HMP35D, Vaisala, Helsinki, Finland), shortwave downward and upward radiation (CM14, Kipp and Zonen, Delft, Holland). Precipitation was collected under the canopy on the height of 1 m above ground and was measured by a tipping bucket rain gauge (model 52202, R.M. Young Company, Traverse City, USA). Soil temperature was measured by platinum resistance thermometers (Geratherm, Geschwenden, Germany) at two profiles at depths of 5, 15, 50 and 100 cm and then averaged for every depth. All meteorological data were collected every 10 s, and 10 min averages or sums (precipitation only) were stored in the datalogger (Dl3000, Delta-T, Burwell, UK). For comparison with half-hourly eddy flux data, 30 min averages of the environmental data were subsequently calculated. The data of local weather station for precipitation were used during the period of disturbances of a tipping bucket rain gauge.”

[Comment]: p.278, line 1-2: Water table depths were measured using what probes? Please include this information with all the other information regarding climate measurements. (Referee 3) [Response] The water table depth was measured by a ruler at the observation wells once a week. The description has been added in the text of the revised manuscript.

New References

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We tried our best to make the responses precise and concise. However, we may have some thing missing or made improperly. If that is a case, we will be pleased to make further amendments.

Interactive comment on Biogeosciences Discuss., 5, 271, 2008.