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Interactive Comment

Interactive comment on "Net ecosystem exchange of carbon dioxide and water of far eastern Siberian Larch (Larix dahurica) on permafrost" *by* A. J. Dolman et al.

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We welcome the comments of the referees, and as far as concerns the editorial remarks, we will implement these in the revised manuscript. We will also show the concentration profiles and graphs in the final version related to this comment, as this was not possible in this author's comment.

The main criticism on our approach is our treatment of storage fluxes. There is no doubt that measurement of the CO2 concentration just above and through and below the crown is the most preferable method to estimate these fluxes. These were unfortunately not available on a continuous basis and hence we tried to estimate the magnitude of the errors involved. We provide some additional evidence and reasoning in this comment to support that approach. We also note that this uncertainty only affects the overall annual NEE estimates and does not affect our subsequent analysis of evaporation and NEE controls as this is based on daytime observation, during which the storage flux is negligible.

The eddy correlation method measures the fluxes of heat, water vapor and carbon dioxide through the plain at which the measurements are taken. The measured fluxes are equal to the ecosystem fluxes (the exchange of heat, water and CO2 between the ecosystem and the air) under conditions that (1) there is no storage of heat, water and CO2 in the air between the level of measurements and the ground or (2) there is no net horizontal flux. Normally these conditions are quite well satisfied in the daytime, when the atmosphere is well mixed, but during the night a stable layer may develop wherein particularly respired CO2 may accumulate. The CO2 thus stored in the profile is not accounted for in the nighttime eddy correlation flux, but may appear in the early morning measurements, when the stored carbon dioxide is flushed out of the profile when the nocturnal boundary layer breaks up and if this happens, the annual total carbon flux is not affected by nighttime storage. There is, however, a problem that is likely to occur if the measurement location is on a slope and cold, CO2 rich air is being drained down the slope. The area around the tower in the Larch forest in the Yakutsk area is rather flat.

We provide further evidence for the validity of the two assumptions mentioned above and we estimate the sensitivity of the annual carbon flux to possible errors. The following methods are used to validate the representativity of the eddy correlation fluxes during nighttime conditions.

1. The relationship between the turbulence intensity as expressed in u* and the night time CO2 flux (fnight) is analyzed for indications of a reduction in the observed flux under calm, stable conditions. Because the relationship between u* and fnight is disguised by the effect of variations in temperature on the respiration rate, the temperature related variation is removed by converting fnight to its value at a reference temperature of 10 oC using a Q10 function derived with observations under turbulent nighttime conditions.

The function (Eq. 1) was fitted to the binned averages, resulting in Ro = 0.34 mmol m-2 s-1 and Q10 = 3.34. This relationship was applied to convert fnight to a value at a reference temperature of 10 oC in order to remove the effect of temperature variations in fnight . The resulting reference night time carbon dioxide flux as a function of u*, indicates that the eddy correlation system increasingly underestimates the ecosystem fluxes at night when u* decreases below 0.4 m s-1 although the amount of unexplained variation is quite large. This is possibly a result of the temperature gradient between the height of the eddy correlation system and the ground level, the effect of variations in soil moisture and the depth of the thawed layer in the permafrost. It is important to note that the u* dependency of the night-time flux is quite sensitive to the form of the conversion of fnight to the reference temperature.

At low turbulence intensities (u* $<$ 0.4 m s-1) mixing is insufficient and carbon dioxide respired from plants and soil accumulates near the ground. This conclusion is in accordance with the observation that the carbon dioxide concentration increases during the night. Consequently there is a potential for underestimation of the eddy correlation fluxes, when horizontal drainage occurs or carbon is flushed non-homogeneously in the morning.

2. The diurnal cycles of carbon dioxide flux are inspected for signs of flushing of carbon dioxide stored nocturnally. Close inspection of the diurnal cycle of CO2 uptake in Figure 2 in the original submitted manuscript of Dolman et al. (2004) reveals a slow buildup of the size of the flux, with no noticeable morning flush. In our data averaging this would have shown up, provided morning release of nighttime CO2 would be a significant contribution to the total flux. We conclude that there are no indications that nocturnally stored carbon dioxide is not suddenly flushed in the morning.

The absence of morning flushing either indicates that the carbon dioxide stored at night below the measurement level is gradually mixed into the boundary layer or that it is flushed at a location other than where the tower is. Given the rather homogeneous forest stand at a scale of hundreds of meters around the tower, the latter alternative seems unlikely and we are inclined to assume a gradual mixing in the morning, which appears reasonable given the gradual increase in solar intensity at these Northern latitudes. A gradual release of stored carbon dioxide would increase the confidence in our eddy correlation measurements.

3. The amount of carbon dioxide stored below the measuring height is calculated from concentration profile measurements. Observations of the carbon dioxide profile in the forest were performed in 2001, although infrequently. We have selected a period of 15 days from 31 May 2001 during which observations were available for at least six levels. From these observations, average diurnal cycles were derived for general and calm (u* $<$ 0.25 m s-1 or u $<$ 2 m s-1).

Average profiles of carbon dioxide at 0:00, 3:00, 6:00, 9:00, 15:00 and 21:00 h LT were obtained in 2001. It becomes evident that the profile is well mixed at daytime and storage of CO2 occurs at night and mainly at ground level and at the level of the highest leaf density (˜13 m). The amount of carbon dioxide stored in these profiles indicates that build-up of storage occurs from about 16:00 LT and has a maximum between 2:00 and 4:00 LT, the time of early sun rise in Yakutsk. The storage flux is associated with changes in the amount of CO2 in the profile. The storage flux is in the order of 1-1.5 mmol m-2 s-1, which appears reasonable at night-time temperatures of 5 - 19 oC.

We conclude that the storage flux is of similar magnitude as the respiration fluxes that we would expect at this location and from this point of view there is no indication that nocturnally respired carbon dioxide is drained horizontally. This again enhances our confidence that the eddy correlation measurements provide a true estimate of the net ecosystem carbon fluxes.

4. The sensitivity of the monthly and annual total carbon flux to possible underestimations during calm conditions is estimated by replacing fnight with the respiration rate as calculated with the Q10 function when u* is below a certain threshold.

We replaced eddy correlation data measured at low turbulent intensities (u* $<$ u* threshold) with the respective flux calculated with Eq. 1. This was done for a threshold u* of 0.25 and 0.4 m s-1. Results are given in Tables 1a-c. Overall the annual estimates vary from 17.24 mol m-2 yr-1 without any correction to 11.64 mol m-2 yr-1 with a u* correction below 0.4 ms-1 and 11.92 mol m-2 yr-1 with a u* correction below 0.25 ms-1 We note that there is little difference between the two estimates using a u* correction, and also with the value quoted in Dolman et al (2004) that used a threshold of 0.6 ms-1. In the absence of concentration measurements for the full period, and independent soil respiration measurements, we cannot conclude which estimate is the more reliable. We note however, there for the short period we have independent observations of storage, the buildup during the evening and early night appears fully compensated by release later in the night and morning. The net storage flux would thus be small (3). If that is the case, then our estimates using the friction velocity correction should be considered as conservative estimate of the annual NEE of this forest, and the real value may be closer to our estimate that is not corrected for low values of friction velocity. A comparison of the storage flux with soil respiration rates and eddy correlation flux estimates would provide us with an ultimate answer.

Table 1a Monthly average NEE (mmol m-2 s-1) without u* correction

2000 2001 NEE month all day night all day night April 0.22 0.25 0.16 May 0.63 0.64 0.59 June -3.59 -5.62 0.88 July -2.63 -4.36 1.18 -2.55 -4.10 0.84 August -2.02 -3.66 1.58 -1.61 -2.63 0.64 September 0.75 0.47 1.37 0.24 0.23 0.25 October 0.10 0.12 0.04 November 0.03 -0.01 0.13 December

The total flux for 2001 = 17.24 mol C m-2 yr-1 (calculated as the monthly mean multiplied by the number of days)

Table 1b Monthly average NEE with u* correction (fco2 = Ro .* Q10 .ˆ (T/10) (u* < 0.4) With Q10 = 3.3386 and Ro = 0.3415

2000 2001 NEE month all day night all day night April 0.28 0.25 0.36 May 0.76 0.64 1.02 June -3.21 -5.62 2.09 July -2.25 -4.36 2.38 -1.69 -4.10 3.60 August -2.08 -3.66 1.38 -1.19 -2.63 1.98 September 0.66 0.47 1.09 0.39 0.23 0.75 October 0.19 0.12 0.33 November 0.04 -0.01 0.15 December

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The total flux for 2001 = 11.64 mol C m-2 yr-1 (calculated as the monthly mean multiplied by the number of days).

Table 1c. Monthly average NEE with u* correction (fco2 = Ro .* Q10 .^ (T/10) (u* $<$ 0.25) With Q10 = 3.3386 and Ro = 0.3415

NEE month all day night all day night April 0.28 0.25 0.36 May 0.75 0.64 0.99 June -3.22 -5.62 2.06 July -2.27 -4.36 2.31 -1.73 -4.10 3.49 August -2.09 -3.66 1.35 -1.22 -2.63 1.89 September 0.66 0.47 1.09 0.37 0.23 0.68 October 0.18 0.12 0.31 November 0.05 -0.01 0.17 December The total flux for 2001 = 11.92 mol C m-2 yr-1 (calculated as the monthly mean multiplied by the number of days)

References

Dolman, A.J., T. C. Maximov, E. J. Moors, A. P. Maximov, J. A. Elbers, A. V. Kononov, M. J. Waterloo and M. K. van der Molen (2004). Net ecosystem exchange of carbon dioxide and water of Far Eastern Siberian Larch (Larix dahurica) on permafrost. Biogeosciences Disc. 1, 275-309.

Interactive comment on Biogeosciences Discussions, 1, 275, 2004.