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Interactive comment on "Impact of nitrogen fertilization on carbon and water fluxes in a chronosequence of three Douglas-fir stands in the Pacific Northwest" *by* X. Dou et al.

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Dear Reviewer #3,

Thank you for your your constructive review, which has helped us improve our manuscript. Please find our point by point responses to your questions and suggestions below.

Comment #1:

Here a short review Dou et al. focussing on the ANN method. The ms investigates the effect of nitrogen fertilization by training an artificial neural network (ANN) on no

fertilized flux data of the years 1998-2004, validating it with data from 2005 and 2006, and comparing the fluxes after fertilization with the ANN predicted fluxes. In principle, the ANNs are very useful as benchmark for explaining past trends as demonstrated for example in Keenan et al. (2012) GCB. However, there is a key difference between the two manuscripts: Keenan at al. used the original half-hourly time step whereas this ms uses monthly aggregated sums/means. Since the responses of an ecosystem to the meteorological drivers are generally instant, they should thus preferably be investigated at the according time scale. Aggregated scales will only show aggregated effects and could potentially even smear out any real underlying effects. Hence, an approach with monthly data is very coarse. This is even more crucial, since the ms is lacking any kind of statistical analysis to determine the uncertainty in the flux estimates.

Response:

We thank the referee for these comments.

Since one of our objectives was to compare our results with the MLR approach in Jassal et al. (2010), we decided to be consistent in using the monthly time step. We should emphasize that for such long data sets the monthly time step has been found to be effective in modelling seasonal and inter-annual variability in C fluxes in these stands (Jassal et al. 2010), which is supported by the high values of the coefficient of determination and the low values of the RMSE.

Following to reviewer's suggestion, we further examined the performance of ANN in assessing the effect of N fertilization at half-hour time step in the mature and stable DF49 stand. The relevant results (Figs. S1 and 2 in this response below) have been added in this response. Half-hour simulations for the model calibration period before 2005, explained about 87%, 74% and 80% of the variance of monthly GPP, R, and NEP, respectively (Figs. S1a and 2a-c), which are all significantly lower than monthly simulations in this study, with R2 close to 1 in all three C fluxes in the same stand. In addition, the linear regression analysis between modeled and EC-measured at half-hour time step shows that RMSE=0.022, 0.044 and 0.072 g C m-2 half-hour-1, approximately equal to 32, 63, 104 g C m-2 mon-1, for GPP, R and NEP, respectively, which are all significantly higher than that of monthly time step, with RMSE=6, 12 and 11 g C m-2 mon-1. For the period of verification (2005-2006), the linear regression analysis comparing calculated and EC-measured at half-hour time step shows that R2=0.87,0.69,and 0.81 for GPP, R and NEP, respectively (Figs. S1b and 2d-f), which are also significantly lower than monthly simulations in this study. Simulated results above showed that using half-hour time step didn't significantly increase the value of the coefficient of determination (i.e., R2>0.90), Which is similar to the previous studies by Melesse and Hanley (2005) and He et al. (2006) using hourly and half-hour time step for BPNN model for C flux modeling in forest ecosystem, respectively. Therefore, it was worthwhile to assess the impacts of N application at monthly time scale as a alternative step, and compared to higher resolution time scales such as half-hourly and hourly, using monthly time step may be more effective in this study. We have now further strengthened the discussion above in Section 4.5 of the revised manuscript (see lines 3 to 18 page 26).

Moreover, using the same three stands as this study, Krishnan et al. (2009) found that there was a strong correlation between environmental variables and C fluxes at the monthly timescale as well as at half hourly and daily timescales. The results from Krishnan et al. (2009) and Jassal et al. (2010) were characterized by using the MLR model at a monthly step. The ANN model with its powerful advantage in investigating the complicated non-linear effects was able to discern the relationship between environmental variables and C and water fluxes during the pre-fertilization period in the three stands, with R2 close to 1, even in the youngest stand (HDF00) with R2 =0.92, as shown in Table 1 and Fig. 5. According to the fitted model above from the ANN model, it was more effective in simulating the C and water fluxes during the post-fertilization period, due to its strong generalization ability in extrapolating the implied and captured law between environmental variables and C and water fluxes from the period of pre-fertilization to post-fertilization.

Therefore, in this study, we focused on removing the effects of inter-annual climate variability on C fluxes and ET in the three stands during the pre-fertilization period to estimate the effects of N fertilization on carbon and water fluxes during the post-fertilization four years and reduce uncertainties in the two previous studies (Chen et al., 2011 and Jassal et al., 2010). We have included the above discussion in Section 4.5 of the revised manuscript.

Comment #2:

Another important point missing in the statistics is the bias error. The latter explains the offset between predicted and measured. If the ANN has an inherent bias error, this would potentially offset the fertilization effects. There is also no objective criteria for the choice of the optimal ANN model provided. According to the text, these were chosen by attempts (page 2009, line 24) and being convinced (page 2010, line 9).

Response:

We agree that it is important to consider the objective criteria for the choice of the optimal ANN model. As to the objective criteria in our study, the experimental procedure was described in detail below.

First, due to the differences of stand age among these three stands, the ANN model was applied to each site individually. To ensure high precision in the period of model prediction, we used multi-year monthly climate variables and EC-measured C fluxes and ET before 2005 to train the ANN. In this calibration period, aiming at obtaining the hidden node number and avoiding over-fitting in the training period, we used a trial and error method to select the optimal solution through altering the number of hidden nodes. Second, the trained model was verified with measurements in 2005 and 2006. In this step, the optimized ANN model was determined depending on the coefficient of determination (R2) and the root mean squared error (RMSE) between predicted and measured C fluxes and ET. We selected the optimized network trained with the maximum coefficient of determination and the minimum of RMSE. For this validation period, the statistical parameters from the most optimal model were summarized and illustrated in Table 1 and Figure 5. Finally, when we felt confident that the optimized ANN model could successfully simulate the multiyear seasonal variations of C ïňĆuxes and ET, the input values for the post-fertilization period were brought into the trained ANN to predict the GPP, R and ET for 2007 to 2010. The optimized model, with R2 close to 1, as shown in Table 1 and Fig. 5, was more effective in simulating C and water fluxes during the post-fertilization period, due to its strong generalization ability in extrapolating the implied and captured law between environmental variables and C and water fluxes from the period of pre-fertilization to post-fertilization. The resulting differences between the measurements and predictions were used to discern the impact of fertilization.

The powerful advantage of the ANN approach in investigating the complicated non-linear relationship between environmental variables and C and water fluxes has been demonstrated in a number of studies, e.g., (Melesse and Hanley, 2005; Moffat et al., 2010; Papale et al., 2003; Ooba et al., 2006).

Comment #3:

That there might be potential problems with this coarse approach can be depicted in figure 5 (i). Despite the good modeling performance in GPP and RE (with high R2 of the ANN of 0.94 and 0.97), their difference NEP shows little correlation (R2 of the ANN 0.45). I therefore recommend to repeat the analysis on a higher time resolution, preferably the original half-hourly time stamp.

Response:

According to our further verification test as suggested by reviewer in Comment #1, the correlation coefficient of NEP in the post-fertilization four years between EC-measured and ANN modeled indeed increased from R2=0.45 to 0.82 (Fig .S2 in this response below). However, the determination coefficients of calibration and verification periods at half-hour time step were both lower than our results using monthly time step. Detailed

comparison can be found in response to Comment #1 above. Therefore, our modeling of NEP should be able to more reliably estimate the C sequestration induced by N addition. On the other hand, the low correlation between measured and modeled NEP in the 61 yr-old DF49 was due to an increase in N-induced GPP and a decrease in R. In the other words, significantly increased NEP induced by N fertilization was the result of combination of GPP and R influenced by N fertilization in the four post-fertilization years in all three stands. These results are consistent with the results obtained in 61 yr-old stand (DF49) in the first post-fertilization year by Chen et al. (2011), and are also consistent with the results obtained by Jassal et al. (2010a) in 61 yr-old DF49 and 22 yr-old HDF88 for the two post-fertilization years.

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Please also note the supplement to this comment:
http://www.biogeosciences-discuss.net/11/C3153/2014/bgd-11-C3153-2014-supplement.pdf

Interactive comment on Biogeosciences Discuss., 11, 2001, 2014.

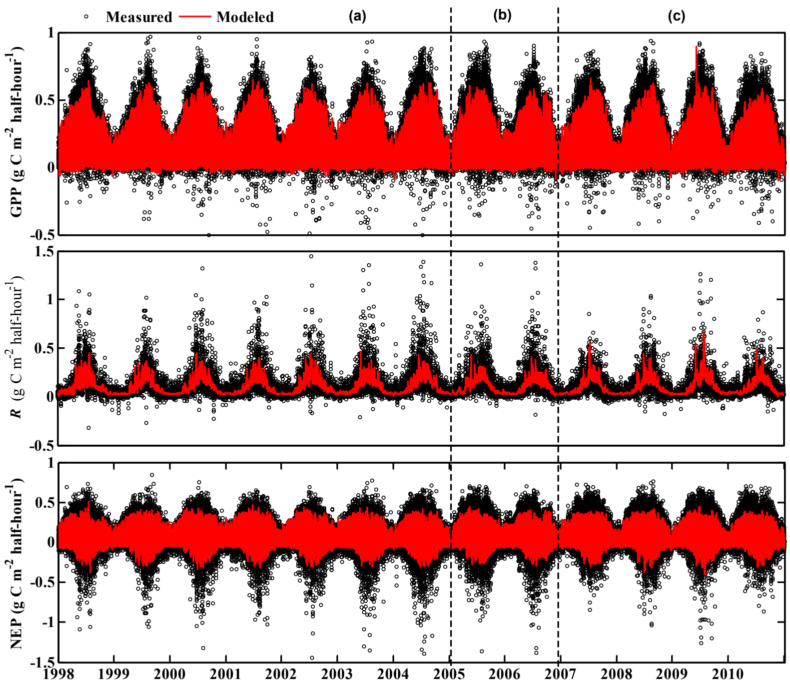

Fig. 1. Fig. S1. ANN simulated and EC-measured half-hourly C component fluxes at DF49 from 1998 to 2010. (a) for the ANN calibration years 1998–2004, (b) for the model validation years 2005–2006, and (c) for

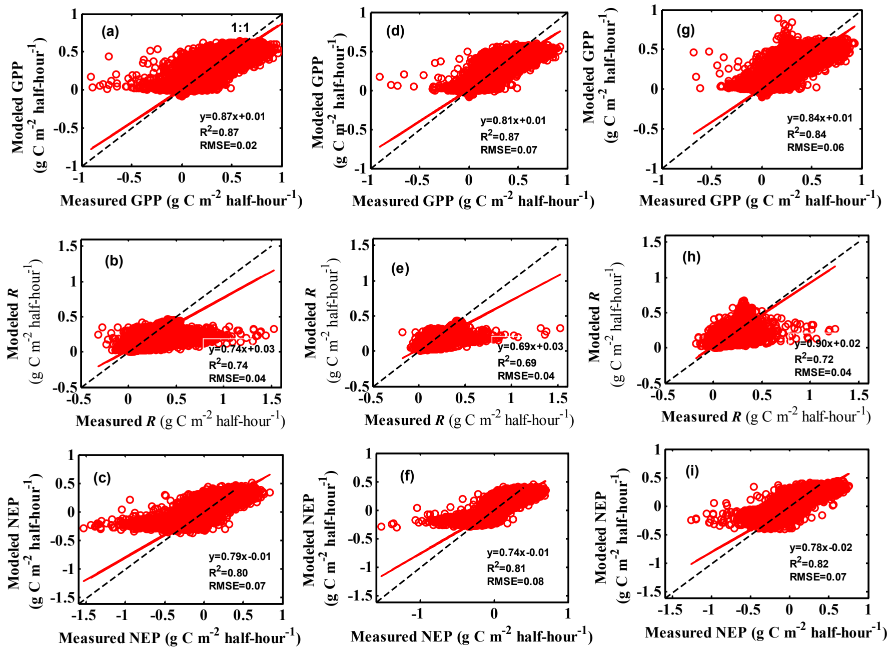

Fig. 2. Fig. S2. Comparisons of ANN simulated and EC-measured half-hourly C component fluxes at DF49 from 1998 to 2010. (a)–(c) for the ANN calibration years 1998–2004, (d)–(f) for the validation years 2005–2