Authors' response to reviewer comments on "Net ecosystem carbon exchange of a dry temperate eucalypt forest" *by Hinko-Najera et al.* (bg-2016-192)

Reviewer 1:

The authors addressed well my concerns raised in the first review round with detailed analysis that improved the quality of the manuscript. I only have a few minor comments on this second version of the manuscript.

Lines 16 to 18, Line 83: There seems to be some confusion in the manuscript about the use of coniferous, deciduous, broadleaf and evergreen. On line 18, it would be clearer if instead of stating coniferous vs. deciduous, you would write broadleaf vs. coniferous OR evergreen vs. deciduous. Same throughout the manuscript.
Response: We have adjusted the used terms of "temperate coniferous" and "temperate deciduous" forests throughout the manuscript to "temperate evergreen coniferous" and "temperate deciduous broadleaved" forests as suggested by reviewer in line 360-361.

Lines 49 to 52: The entire manuscript only discusses about NEE so no need to introduce NEP. Same for the rest of the introduction. Please replace NEP by NEE.
Response: We agree with the reviewer and replaced the term NEP with the term NEE throughout the manuscript.

Line 152: A comma is missing after In February 2012.
Response: We corrected the text accordingly.

Line 218: Please rearrange equation 1 to remove NEP, i.e. NEE=ER-GPP
Response: We rearranged equation 1 accordingly.

Lines 221-222: the second part of the sentence linked to NEP can then be removed.
Response: We adjusted the sentence accordingly.

Line 259: either remove "this issue" or add in before
Response: We corrected the text accordingly.

Line 278: remove the extra period after SWC
Response: We corrected the text accordingly.

Line 315: "a increase" should be "an increase"
Response: We corrected the text accordingly.

Line 346: comma missing after Overall

Response: We corrected the text accordingly.

Lines 360-361: "Although daily maximum GPP rate at our forest site (14.7 g C m-2 d-1) were comparable with those from temperate evergreen coniferous forests (16.6-26.3 g C m-2 d-1), they were much lower than those reported for temperate deciduous broadleaved forests (22.4-31.0 g C m-2 d-1) during growing seasons (Falge et al., 2002)."

Response: We corrected the text accordingly.

Line 370: Remove link to unpublished literature, the reference to Fig. S2a is sufficient.

Response: We removed the citation of unpublished literature.

Line 402: There is a negative sign missing in front of 930.

Response: We corrected the text accordingly.

Reviewer 2:

The revised version has a core of methods, results, and interpretations that are acceptable for publication. The analysis of environmental drivers still needs to be improved. Below are suggestions for removal of a portion of the analysis, and replacement of this section by alternative methods that would provide more useful and powerful insights.

1) The authors have done a good job of revising their use of the eddy covariance technique, particularly the post-processing of data, to provide the best available dataset they can and in alignment with common practices. It is reassuring to see that results were so surprisingly robust to all of the changes that were made.

2) This lends needed confidence in all results up to the analyses of environmental drivers, and Figures 5, 6, and 7. Analyses of environmental drivers have also been significantly revised to remove circularity. However, the analyses still do not adequately address the second stated objective of the paper, to "identify the environmental controls of these CO2 ecosystem fluxes". Unfortunately, this portion of the paper is still not well designed and provides disappointingly limited insight.

Response: We agree with the reviewer and have extensively revised the analyses of environmental drivers in the manuscript to address our second objective (please see responses below). We also clarified the time scales in our objective as follows in section 1 of the manuscript: *"... 2) identify the environmental controls of these CO_2 ecosystem fluxes on seasonal and inter-annual time scales, ..."*

3) Analysis of Environmental Drivers: The random forest analysis attempts to estimate the relative importance of 4 environmental variables for determining midday-average NEE or early nighttime-average NEE for each month of the year and separately across the three years of study. Presumably there are thus at best only 30 or so observations in each bin on which the random forest is trained, which seems rather data scarce, and the reality is in fact far worse (<15) in many cases. Results in Fig 6 indicated that many of the months have fewer than 10 observations, and some have 2. How can a random forest possibly devise meaningful relationships regarding variable importance with so few observations? Apologies but this seems ludicrous. I recommend that analyses and results relating to Figures 5 and 6 be cut from the paper. (Note: For Figures 5 and 6, captions need to explain the numbers below the months on the x-axes, indicating the number of observations for each RF.) Figure 7 still has something to offer, but it could be replaced by something much better.

Response: We agree with the reviewer and have removed Figures 5 and 6 as well as the Random Forest analyses all together (please see point 4) below). We acknowledge that during some time periods (i.e. particularly during winter) data observations were not sufficient to analyse individual months per year. Moreover, we did not identify inter-annual differences in environmental controls of NEE and hence, we have pooled data across years for each month for seasonal analyses of environmental controls of NEE. Please see our response below regarding our revised analysis of environmental controls in point 4).

4) As suggested by Reviewer 2 in the prior review, the RF approach is rather indirect for gleaning insights into underlying processes. The paper does not provide a clear diagnosis of environmental controls on CO2 fluxes, but it could. Alternative, more fruitful approaches are available. As stated by R2.6, the random forest analysis could be replaced by analysis of functional relationships, conditionally sampling data to reveal light response parameters (e.g. NEE at light saturation and with low to modest VPD and for low versus high soil moisture), and similarly for VPD response, soil moisture response, and temperature response. The author's comment in open review ignored this suggestion / critique by R2 altogether. Numerous studies have shown how this can be done with eddy covariance data but this study does not follow those leads for some reason.

Response: We followed the advice from the reviewer and analysed functional relationships between NEE (day time and night time) and selected environmental drivers. We would like to point out that the results of this analysis, particularly the seasonal variability in the environmental controls for day time and nigh time NEE, were in agreement with those from the Random Forest analysis and did not change the overall outcome of environmental controls on NEE in this forest during the presented study period. However, we entirely replaced the Random Forest analysis with the new analysis of environmental drivers based on functional relationships. The analysis is outlined below and we have revised the relevant sections (2.4, 3.3, 4.2) in the manuscript accordingly.

As previously outlined in the manuscript we used daily means of quality controlled half-hourly non gap filled midday NEE (hours 11:00 – 13:00) for day time NEE and daily means of half-hourly quality controlled non gap filled and u* filtered night time NEE. We would like to note that while daily means have been used, no change in results of analyses were found using daily means or half-hourly observations of selected data as the above outlined data selection already excludes any diurnal influence on the analysis of seasonal environmental controls.

4.1) In regard to day time NEE: We analysed the dependency of day time NEE on incoming solar radiation (Fsd) using a rectangular hyperbolic light response curve (LRC) or *Michaelis-Menten* equation (Carrara et al., 2004; Falge et al., 2001; Flanagan et al., 2002; Lasslop et al., 2010; Michaelis and Menten, 1913). We would like to note that other published variations of a LRCs were tested but they either performed inferior to the above mentioned LRC or resulted in arbitrary parameter estimates: modifications of the rectangular hyperbolic curve (Falge et al., 2001), a non-rectangular hyperbolic curve (Gilmanov et al., 2007; 2003) and a logistic sigmoid function (Eugster et al., 2010; Wolf et al., 2011). As midday NEE represents the peak of photosynthetic activity we found that the respiration parameter was marginal and insignificant for the fit of the function or the parameter of maximum NEE (i.e. uptake rate of the canopy) at light saturation. Therefore we removed the respiration parameter to improve significance of curve fit and slope of LRC (i.e. the canopy light utilization efficiency) (Flanagan et al., 2002).

Residuals of the LRC were then used to analyse the dependency of NEE on either air temperature (Ta) or vapour pressure deficit (VPD) given the dependency of VPD on Ta and thus strong auto correlation (Carrara et al., 2004; Chen et al., 2002). Relationships between residuals of the LRC and Ta or VPD were tested with linear and non linear regressions, i.e. exponential temperature sensitivity functions according to Lloyd and Taylor (1994) for Ta and a logarithmic power model according to Chen et al. (2002) for VPD. However, for both, Ta and VPD, linear relationships resulted in the best fits whereas non linear regressions consistently resulted in arbitrary or insignificant parameter estimates.

A potential influence of soil water content (SWC) on day time NEE was tested with linear regressions between SWC and residuals of LRC and 2^{nd} residuals from the linear relationships between LRC residuals and Ta as temperature and soil moisture are often negatively correlated in this forest ecosystem (Hinko-Najera et al., 2015).

In addition we analysed LRCs with data divided into various Ta bins, VPD bins and SWC bins (see Table R3).

Results of the LRC fits and linear fits with T and VPD per year and seasons are given in Table R1 and overall fit is displayed in Figure R1.a,b and c. Overall Fsd could explain 25% of the temporal variability in midday NEE which did not considerable vary between observation years. Similarly both T and VPD explained about 18% or 23% of the overall temporal variability in midday NEE and again no considerable inter-annual differences were determined. However, a clear distinct seasonal pattern was shown in the dependencies of midday NEE on Fsd, T and VPD when coefficients of determinations are plotted for each month (Figure R2.a). While Fsd was the dominant environmental driver during mid/ late autumn and winter months (36 – 47%, mean = 42%), Ta and VPD were the main controlling environmental variables during spring, summer and early autumn months (23 – 56%, mean = 40% for Ta and 15 – 48%, mean = 31% for VPD). LRCs fitted for various Ta bins and VPD bins (Table R3) show a strong decrease in the net carbon uptake at temperatures above 20°C or VPD values above 1.2 kPa. A clear differentiation between Ta and VPD was very difficult because of the strong correlation between VPD and Ta. While overall and annual variability in residuals of midday NEE were marginally better explained by VPD than Ta, variability of midday NEE residuals from spring to early autumn correlated stronger with changes in Ta than VPD. Considering the high rainfall during the observation years including summer months it is likely that midday NEE is limited by higher temperatures (i.e. increasing ER) than high VPD or water stress on photosynthetic activity.

In accordance with a greater temperature effect than effect of water stress on midday NEE during spring and summer months is the absence of a clear influence of SWC on residuals of NEE (Table R1.c, R3)

4.2) In regard to night time NEE:

The dependency of night time NEE on temperature was analysed using an Arrhenius-type model function (LT) (Lloyd and Taylor, 1994). Relationships were analysed with either Ta or soil temperature at 10 cm soil depth and consistently best fits were achieved with air temperature for every subset of data. Residuals of LT were then used to analyse the dependency of night time NEE on SWC with linear regressions. We also unsuccessfully tested non-linear regressions (hyperbolic function) between LT residuals and SWC. In addition we analysed LTs with data divided into various SWC bins (Table R2).

Results of LT and linear fits with SWC for various subsets of data are given in Table R2 and overall temperature sensitivity of night time NEE is displayed in Figure R1.d. Overall 36% of the temporal variability in u* filtered night time NEE was explained by temperature which varied from 30% in 2012 to 31% in 2010 and 49% in 2011. On seasonal time scales the dependence of night time NEE on Ta strongly varied being greatest during spring (39 – 44%, mean = 42%) followed by summer months (31 – 45%, mean = 38%) and lowest during autumn months (15 – 30%, mean = 24%) (Figure R2.b). No significant relationships could be determined during winter months where greater data gaps occurred compared to other months. Neither LT fitted for SWC bins (Table R2) nor linear relationships between SWC and LT residuals (not shown) showed an influence of SWC on night time NEE with the exception of the winter month July where night time NEE decreased with increasing SWC (R^2 = 0.26 ***). This would indicate a limitation of respiration due to high water content, however such an indication is precautious as data availability was lowest (<50%) during July.

Table R1: Parameters, standard errors and/or coefficient of determination (R^2) of (a) the rectangular hyperbolic light response curve (LRC) between daily means of midday NEE and incoming radiation (Fsd), (b) linear fits between residuals of LRC and air temperature (Ta) or vapour pressure deficit (VPD) and (c) linear fits between 2nd residuals (b) with Ta and soil water content (SWC) for subsets of data, α: initial slope of LRC and canopy light utilization efficiency (μmol CO_2 J^{-1}), β: maximum NEE (i.e. uptake rate of the canopy) at light saturation (μmol CO_2 m^{-2} s^{-1}); significance level: *** <0.001, ** <0.01, * <0.5, ns: not significant

data subset	**(a) Fsd**							**(b) T**		**VPD**		**(c) SWC**		**nr**
	α (se)			**β (se)**			**R^2**	**R^2**		**R^2**		**R^2**		
All data	-0.14	0.01	***	-21.8	0.0	***	**0.25**	**0.18**	***	**0.23**	***	**0.05**	***	792
2010	-0.11	0.02	***	-22.5	0.0	***	**0.28**	**0.19**	***	**0.25**	***	**0.05**	***	213
2011	-0.13	0.02	***	-21.9	0.0	***	**0.27**	**0.21**	***	**0.21**	***	**0.10**	***	292
2012	-0.17	0.02	***	-21.3	0.0	***	**0.22**	**0.15**	***	**0.24**	***	**0.04**	***	287

Table R2: Parameters, standard errors and/or coefficient of determination (R^2) of (a) the temperature response function after Lloyd and Taylor (1994) between daily means of u* filtered night time NEE and air temperature (Ta) for subsets of data, R_{ref}: basal respiration rate at 10°C (μmol CO_2 J^{-1}), E: activation energy related parameter; significance level: *** <0.001, ** <0.01, * <0.5, ns: not significant

LT	**R_{ref} (se)**			**E (se)**			**R^2**	**nr**
All data	3.0	0.1	***	310	16	***	**0.36**	694
2010	3.6	0.2	***	215	23	***	**0.31**	214
2011	2.8	0.2	***	405	27	***	**0.49**	234
2012	2.8	0.2	***	306	31	***	**0.30**	246
SWC bins								
0.1-<0.15	2.1	0.5	***	349	94	***	**0.34**	37
0.15-<0.20	3.0	0.3	***	285	44	***	**0.27**	138
0.20-<0.25	3.1	0.2	***	339	34	***	**0.38**	146
0.25-<0.30	3.4	0.2	***	337	30	***	**0.38**	200
>0.30	3.3	0.2	***	527	40	***	**0.42**	173

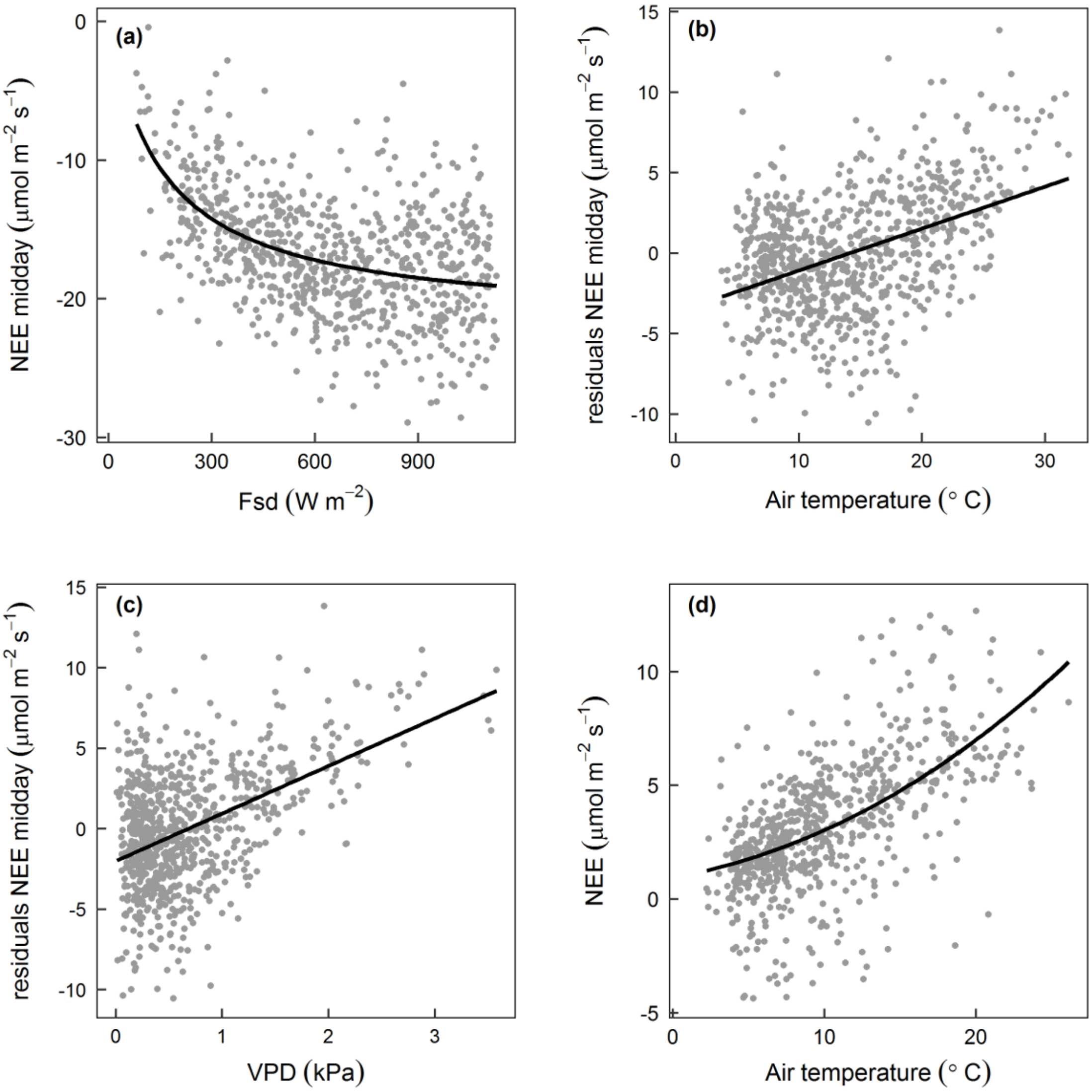

Figure R1: (a-c) Relationship between daily means of midday NEE and (a) incoming radiation (Fsd) in a rectangular hyperbolic light response curve (LRC), linear fits between residuals of LRC and (b) air temperature (Ta) or (c) vapour pressure deficit (VPD) and (d) relationship between daily means of u* filtered night time NEE and air temperature as temperature (Ta) response function after Lloyd and Taylor (1994), R^2 are given in Table R1 and R2

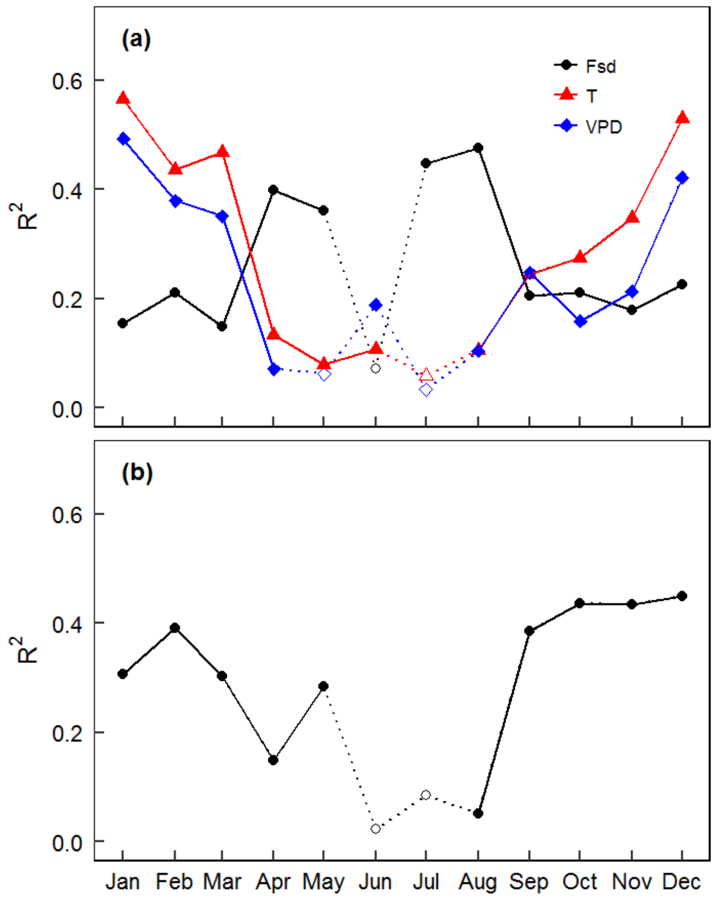

Figure R2: Seasonal variability in environmental controls of day time and night time NEE; coefficients of determination (R^2) of (a) the rectangular hyperbolic light response curve (LRC) between daily means of midday NEE and incoming radiation (Fsd, black lines and circles), linear fits between residuals of LRC and air temperature (Ta, red lines and triangles) or vapour pressure deficit (VPD, blue lines and diamonds) and (b) the temperature response function after Lloyd and Taylor (1994) between daily means of u* filtered night time NEE and air temperature (Ta, black lines and circles) per month pooled over three years; open symbols indicate non significant R^2; nr per month for (a) from Jan to Dec: 62, 74, 77, 76, 58, 42, 56, 60, 74, 75, 66, 72; nr per month for (b) from Jan to Dec: 55, 69, 63, 66, 52, 45, 41, 57, 63, 63, 52; 68

Table R3: Parameters, standard errors and/or coefficient of determination (R^2) of the rectangular hyperbolic light response curve (LRC) between daily means of midday NEE and incoming radiation (Fsd) for various Ta bins, VPD bins and SWC bins; α: initial slope of LRC and canopy light utilization efficiency (μmol CO_2 J^{-1}), β: maximum NEE (i.e. uptake rate of the canopy) at light saturation (μmol CO_2 m^{-2} s^{-1}); significance level: *** <0.001, ns: not significant

LRC	α (se)			β (se)			R^2	nr
Ta bins								
<8	-0.14	0.02	***	-23.6	0.0	***	**0.39**	133
8-12	-0.09	0.01	***	-29.3	0.0	***	**0.55**	205
12-16	-0.07	0.01	***	-30.4	0.0	***	**0.50**	172
16-20	-0.07	0.01	***	-27.9	0.0	***	**0.37**	124
20-24	-0.08	0.02	***	-20.7	0.0	***	**0.19**	97
24-28	-0.06	0.03	ns	-20.5	0.1	***	0.13	49
VPD bins								
<0.4	-0.10	0.01	***	-28.7	0.0	***	**0.46**	324
0.4-0.8	-0.07	0.01	***	-30.5	0.0	***	**0.44**	232
0.8-1.2	-0.05	0.01	***	-32.9	0.0	***	**0.47**	103
1.2-1.6	-0.62	1.39	ns	-16.7	0.7	***	0.00	68
1.6-2.0	-0.16	0.25	ns	-16.3	0.5	***	0.02	25
2.0-2.4	-0.06	0.05	ns	-18.7	0.2	***	0.09	26
2.4-2.8	-0.05	0.03	ns	-15.1	0.2	***	0.47	7
2.8-3.2	-			-			-	
>3.2	-0.08	0.27	ns	-12.7	0.8	***	0.05	4
SWC bins								
<0.22	-0.11	0.02	***	-22.35	0.0	***	**0.18**	258
>=0.22	-0.14	0.01	***	-21.88	0.0	***	**0.29**	534

5) Furthermore, the existing analysis of which variables had greatest importance for driving within-month or within-year variability leaves us wondering what the relationships look like. Is there a positive or negative relationship between sunlight and midday NEE? How strong is the relationship? Same for all of the other potential drivers.

Response: We agree with the reviewer and we have addressed these questions in our response to point 4) above.

6) The methods description does not indicate how data were binned for the random forest analysis of within-year variability.

Response: This clarification is no longer relevant as we replaced the Random Forest analysis with the above described analysis of environmental drivers with functional relationships.

References:

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