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Biogeosciences Discussions

Interactive comment on "Ecosystem carbon exchange of a subtropical evergreen coniferous plantation subjected to seasonal drought, 2003–2007" *by* X.-F. Wen et al.

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General comments: Q1: There are frequent misunderstandings of correlation versus causation when interpreting the cause of change in NEP. For example, are high air temperatures limiting NEP during drought as suggested on 8700 l.10? Probably not. Lower NEP likely follows from reduced GEP due to water limitations from droughts that also correspond to higher temperatures. See also the last sentence of the conclusions. A1: Revised. "The reduction of NEP in 2003 and 2007 was induced by droughts resulting from the coupling effects of higher temperature (Fig. 2a) and lower soil water content (Fig. 2b). Lower NEP likely followed from reduced GEP due to water limitations

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from droughts."

Q2: Another major concern is the dearth of biological explanations for the observed fluxes including the coupling of GEP and RE through plant and microbial activity. How did drought impact leaf area index (LAI) and how may this have impacted fluxes? The reader gets some indication that canopy function was somewhat compromised if senescence was induced (8699 l. 25). A2: Revised. "Under such conditions, Slash pine, Masson pine and Chinese fir even appeared senescence in 2003, but Slash pine was more serious than the other two (Wen et al., 2006). The leaf area index (LAI) of whole canopy also showed a descending trend (Huang et al., 2007)."

Q3: I am also concerned about the quality of the flux measurements from this area of complex terrain. I recommend that the authors perform a sensitivity analysis on annual fluxes which may reveal that a stricter ustar criterion is justified. A3: Revised. Sensitivity analysis of u* on annual fluxes of NEP, GEP and RE were done. An example in 2003 and 2006 was also given in Figure S1. "Lastly, to avoid possible underestimation of the fluxes under stable conditions during the night, the effect of friction velocity u* was examined according to the methods of Reichstein et al. (2005) during the 2003-2007. When the value of u* was less than 0.19 m s-1 , which was the maximum u* threshold among 2003-2007, the values observed of NEP and ET in the night were excluded." "Sensitivity analysis on annual fluxes of NEP, GEP and RE showed that they were reasonable values, although it also revealed them to be somewhat on the high end of Carbon sequestration."

Specific comments: Q1: 8692 l. 6: 'out of step' is colloquial. A1: Revised. "Seasonal distribution of precipitation and temperature was inconsistent during the summer, which resulted in droughts frequently."

Q2: 8692 l. 10: This sentence does not make sense to me; it appears to hinge on the readers' definition of 'sensitivity'. A2: Revised. "The monthly GEP and RE increased exponentially with air temperature, but the monthly NEP was less sensitive and only

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increased linearly with air temperature."

Q3: 8692 1.26: replace this speculative statement with a clearer and more powerful statement from the interesting Meehl and Tebaldi 2004 paper. A3: Revised. "In the future warmer climate with increased air temperatures, future heat waves in areas of Europe and North America will become more intense, more frequent, and longer lasting (Meehl and Tebaldi, 2004)."

Q4: 8693 l. 10: The wording of this passage is somewhat awkward. The challenge is that NEP is usually the measured term and GEP and RE are the ecosystem-level processes that respond to biological and environmental cues. A brief re-wording will clarify this point for the non-expert. A4: Rephrased. "The challenge is that NEP is usually the measured term, and GEP and RE are the ecosystem-level processes that respond to biological and environmental cues. However, it's possible to statistically partition the NEP into GEP and RE, which allows a better interpretation of the fluxes in terms of ecosystem carbon processes (e.g. Reichstein et al., 2005)."

Q5: 8694 l. 20: Measurements from both predominant wind directions (all wind directions given Figure 1) will be compromised by the substantial topography including advective fluxes and leeward rotors behind hilltops. Whereas the methods are largely sound I encourage the authors to take more care in data thresholding as discussed later. A5: Done. "Lastly, to avoid possible underestimation of the fluxes under stable conditions during the night, the effect of friction velocity u* was examined according to the methods of Reichstein et al. (2005) during 2003-2007. When the value of u* was less than 0.19 m s-1 , which was the maximum u* threshold among 2003-2007, the values observed of NEP and ET in the night (Solar elevation angle <0) were excluded. Sensitivity analysis on annual fluxes of NEP, GEP and RE showed that they are reasonable values, although it also revealed them to be somewhat on the high end of Carbon sequestration. Likewise, positive NEP fluxes at night (i.e. apparent photosynthesis) were also taken out of the database."

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Q6: 8695 l. 1: The contributions of Pinus elliottii make for an interesting potential comparison with the slash pine flux studies in the Florida slash pine plantation (Clark et al., 2004; Clark et al., 1999; Gholz and Clark, 2002; Powell et al., 2008) A6: Revised. In appropriate places, comparisons with Powell et al. (2008) were done. “Powell et al. (2008) also pointed that RE was an exponential function of air temperature, with rates further modulated by soil moisture.”; “Estimated annual NEP ranged from 158 to 192 g C m-2 yr-1 in a naturally regenerated longleaf pine/slash pine flatwoods ecosystem in the Austin Cary Memorial Forest (ACMF) (Powell et al., 2008). ” Powell, T.L., Gholz, H.L., Clark, K.L., Starr, G., Cropper JR, W.P., Martin, T.A.: Carbon exchange of a mature, naturally regenerated pine forest in north Florida, Global Change Biology, 14, 2523–2538, 2008.

Q7: 8695 l. 6: please provide a more scientific description of the soil type to add value to this study in future comparisons. A7: Provided. “The soil parent material consists of red sandstone and mud stone, and soils are mainly red earth (UdicFerrisols), which weathered from red sand rock (Wang et al., 2004).” Wang, S.Q., Liu, J.Y., Yu, G.R., Pan, Y.Y., Chen, Q.M., Li, K.R., Li, J.Y.: Effects of land use change on the storage of soil organic carbon: A case study of the Qianyanzhou Forest Experimental Station in China, Climate Change, 67, 247-255, 2004.

Q8: 8696 l. 14: quantify ‘abnormal’ Section 2.3: The effects of the hilly topography may necessitate some form of ‘angle of attack’ filter where half-hourly flux calculations are ignored if the ratio of mean vertical and horizontal wind velocities exceeds some threshold. Nighttime data must be approached with substantial caution given the likelihood for advective flux at night in this terrain. The u* threshold of 0.19 m/s is likely too low for a relatively tall canopy in such a terrain in a warm climate with the potential for substantial thermal inversions. At the minimum, some u* sensitivity analysis should be performed; the work of Reichstein et al. (2005) is a good place to start. This being said, the annual sums strike me as very reasonable given the vegetation and site description although a sensitivity analysis may reveal them to be somewhat on the high end of C

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sequestration. A8: Quantified. “The problems were largely related to rainfall, water condensation, system failure, or turbulent mixing during the night (Wen et al., 2006).” Revised. Sensitivity analysis on annual fluxes of NEP, GEP and RE were also done. “The effect of friction velocity u* was examined according to the methods of Reichstein et al. (2005) during 2003-2007. When the value of u* was less than 0.19 m s-1 , which was the maximum u* threshold among 2003-2007, the values observed of NEP and ET in the night were excluded. Sensitivity analysis on annual fluxes of NEP, GEP and RE showed that they were reasonable values, although it also revealed them to be somewhat on the high end of Carbon sequestration. ”

Q9: 8696 l. 20: defining nighttime by radiometer output rather than orbital characteristics like the zenith angle induces some ambiguity for flux partitioning. A9: Revised. We had used two methods including radiometer and Solar elevation angle to define the nighttime, and no difference was found. “the values observed of NEP and ET in the night (Solar elevation angle <0) were excluded.”

Q10: 8699 l. 23: please quantify precisely the magnitude of these droughts here in the Results section. A10: I did not find an appropriate way to quantify precisely the magnitude of these droughts in Results section. I rephrased this sentence. “This plantation was subject to episodic summer droughts during the investigated period. For example, extremely dry summers occurred in 2003 and 2007 because carbon assimilation and plant growth rate were obviously suppressed by environmental stresses.”

Q11: 8699 l. 25: This point is interesting but qualitative. Senescence was induced in what species (or all?) during the 2003 drought? How did this impact the LAI? These sorts of biological explanations would go a long way toward a comprehensive interpretation of surface fluxes at this site. A11: Revised. “Under such conditions, Slash pine, Masson pine and Chinese fir even appeared senescence in 2003, but Slash pine was more serious than the other two (Wen et al., 2006). The leaf area index (LAI) of whole canopy also showed a descending trend (Huang et al., 2007).”

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Q12: 8700 l. 10: it was not determined that NEP was decreased due to higher temperatures from higher RE; decreased available water and consequent limitations to GEP is a more likely explanation of the observations. A12: Revised. “The reduction of NEP in 2003 and 2007 was induced by droughts resulting from the coupling effects of higher temperature (Fig. 2a) and lower soil water content (Fig. 2b). Lower NEP likely followed from reduced GEP due to water limitations from droughts.”

Q13: 8700: l. 15: four significant digits for annual flux sums is optimistic, especially for partitioned sums. Two significant digits is a more conservative representation (see also line 21). A13: I agree with your suggestion.

Q14: 8700 l. 17: It has yet to be substantiated that NEP is lowest in 2005 because of low air temperature and net radiation; low temperatures may decrease respiration depending on the response of RE to substrate availability, temperature and moisture. A14: Revised. “The NEP was the lowest in 2005 because of the lowest net radiation (Table 1), although the lowest air temperature might also decrease respiration depending on the response of RE to substrate availability, temperature and moisture.”

Q15: 8701: What is the relationship between vapour pressure deficit and GEP? How is it determined that air temperature is ‘almost sufficiently high’? Annual averages may not capture the duration of low temperature events that decrease enzyme kinetics well below their optimum. The results section should delve into the seasonal dynamics that may emerge to become important at the longer time scales because analyses of mean values can obscure the mechanisms, especially nonlinear processes, that are important for explaining flux in this ecosystem, especially when a focus of this paper is on the response of NEP and its constituent processes to drought. A15: Revised. See Figure S2. “Similar behavior of monthly GEP, RE, NEP to vapor pressure deficit occurred.” “Response of GEP, RE and NEP to air temperature are nonlinear processes, and showed a descending trend while air temperature was higher than 28°C. Moreover, such kinds of function relationship failed when air temperature was higher than 28°C, accompanying with relatively lower soil moisture.” “GEP showed low rates dur-

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ing seasonal drought because higher temperature and lower soil water content events decreased enzyme kinetics well below their optimum."

Q16: 8702 l. 7: RE is controlled by substrate availability (including recent photosynthetic assimilates; it is coupled to GEP), and this includes biomass. There is a large biological element to land surface exchange that is largely missing from this paper. For example in the next line GEP is controlled by photosynthetically active radiation, temperature, atmospheric water demand and root-zone water supply, but also by the amount of leaves in the canopy (the leaf area index, LAI) and the distribution and function of these leaves in different parts of the canopy. A16: Revised. "RE is controlled by temperature, soil water content and substrate availability (including recent photosynthetic assimilates; it is coupled to GEP), while GEP is mainly controlled by radiation, air temperature, water vapor deficit, the water amount of root uptake, the amount of leaves in the canopy (the leaf area index, LAI) and the distribution and function of these leaves in different parts of the canopy (e.g. Reichstein et al., 2002)."

Q17: 8702 l. 11: No evidence was presented that soul water from deeper soil layers supplied the canopy during the early stages of drought. A17: Revised. "During the early days of drought, soil drying could decrease the activities of roots and soil microorganisms and inhibited their respiration, since sufficient water was essential for normal root and microbial function. At the same time, water that could be withdrawn from the deeper soil column by roots supported photosynthesis. The water in the deep soil would be exhausted with the process of the intensified drought."

Q18: 8702 l. 24: how so is GEP exponentially related to air temperature? There is certainly some nonlinear relationship between leaf temperature and GEP that is poorly-represented by a quadratic approximation (quadratic relationships have little mechanistic meaning; remove them from figures 5 and 7. A 3rd order or higher polynomial would by definition fit the data better and there is little justification for any higher-order polynomial when explaining surface fluxes. See also 8701 l. 25, all quadratic explanations for what is ultimately a mechanistic relationship should be removed.) A18: Revised.

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Quadratic relationships have been removed them from Figures 5 and 7. “This apparent response emerged through relationships to other processes to which GEP responds more strongly in places where temperature was rarely limiting, namely photosynthetic photon flux density. The exponential response of GEP to air temperature resulted from a logarithm relationship between air temperature and photosynthetic photon flux density, and nonlinear relationship between leaf temperature and GEP.”

Q19: 8702 l. 25: This statement is indicative of the correlation/causation confusion alluded to before. GEP doe s not ‘respond’ exponentially to air temperature (although there would be an extremely fast decline at the enzyme denaturation point). This apparent response emerges through relationships to other processes to which GEP responds more strongly in places where temperature is rarely limiting, namely PPFD. A19: Revised. “The seasonal drought altered the parallel exponential response of monthly GEP and RE to air temperature in some degrees, and monthly NEP was less sensitive to air temperature than monthly GEP and RE (Fig. 4a). This apparent response emerged through relationships to other processes to which GEP responds more strongly in places where temperature was rarely limiting, namely photosynthetic photon flux density.”

Q20: 8703 l. 7: How is it determined that soil moisture conditions are not in the ‘optimal’ condition across most soils? This is an extremely sweeping statement that hinges heavily on one’s definition of optimum. A20: Revised. “Since water contents of soils are not in their optimal ranges under most natural conditions in this plantation,”

Q21: 8704 l. 8: this statement is inconsistent, soil moisture is both related and unrelated to annual flux sums? A21: Revised. “Annual GEP, RE and NEP totals were linked to the site water balance.”

Q22: 8704 l. 27: is there evidence that GEP is relatively higher under diffuse light environments (for a given PPFD) in this canopy? I’m assuming that there is a substantial contribution of shaded leaves that arguably benefit from increased diffuse irradiation.

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A22: Revised. “This unexpected result occurred because less rain was associated with fewer clouds, which made more available light duration and increased GEP.”

Q23: 8705 l. 20: The table of sites with 5+ years of data is somewhat arbitrary and could either be made comprehensive or chosen for the purposes of comparison with plantation and/or evergreen forests in the temperate zone. A23: This plantation is a subtropical evergreen coniferous forest. In appropriate places, comparisons were done with slash pine plantation (Powell et al. 2008). However, the dataset was also used for other section in the text.

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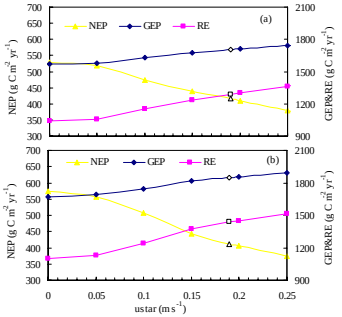

S1. Sensitivity analysis of u* on annual fluxes of NEP, GEP and RE, (a) 2003, (b) 2006

Fig. 1. S1. Sensitivity analysis of u* on annual fluxes of NEP, GEP and RE, (a) 2003, (b) 2006

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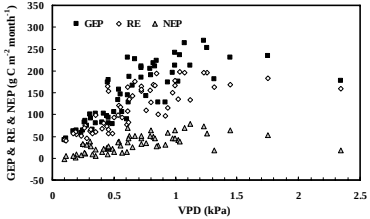

S2. Response of monthly gross ecosystem photosynthesis (GEP), ecosystem respiration (RE), net ecosystem production (NEP) to vapor pressure deficit (VPD) during 2003 to 2007 at Qianyanzhou site.

Fig. 2. S2. Response of monthly gross ecosystem photosynthesis (GEP), ecosystem respiration (RE), net ecosystem production (NEP) to vapor pressure deficit (VPD) during 2003 to 2007 at Qianyanzhou site.

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