

Interactive comment on “Response of carbon and water fluxes to environmental variability in two Eastern North American forests of similar-age but contrasting leaf-retention and shape strategies” by Eric R. Beamesderfer et al.

Anonymous Referee #1

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The authors present two long-term eddy covariance carbon dioxide and water vapor flux data sets from two distinct forest ecosystems in Canada. One site is a deciduous broadleaf forest, the other one an evergreen needleleaf forest. The authors report results from modeling and partitioning these fluxes and address impacts of driver variability on different temporal scales on the variability of the fluxes. In particular, the authors found a reduction of net annual carbon dioxide uptake in both forests as a result of above average mean summer air temperatures and a larger reduction of annual net carbon dioxide uptake at the coniferous forest compared to the deciduous forest

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during drought years. The data and conclusions are highly relevant and clearly within the scope of the journal.

The manuscript is fairly well written, although editing could have been conducted more thoroughly at times.

General formal points are:

- Latin plant names should consistently be printed in italic font.
- Definitions of abbreviations appear repeatedly throughout the text, they should only be introduced on their first occurrence.
- The verbs "to experience" and "to respond" are used excessively and sometimes not in the appropriate context. It is clearly a matter of taste but I would advise to revise some sentences. Fluency could partly be improved by language simplification.
- Tenses are not always used consistently, please revise (see line comments).

Scientific issues:

- "Carbon" is partly used interchangeably with "carbon dioxide". There are more components to the carbon cycle in forests than vertical CO₂ exchange. Therefore, sometimes statements are not entirely correct, please review.
- Measurement and model uncertainty are not addressed. The authors should add some information on this topic. The ranges of the annual flux sums given in the abstract likely describe inter-annual variability (not measurement/model uncertainty), I assume using mean and standard deviation of the six annual flux sums per forest. An explanation should be added.
- The description of the used partitioning models (equations 1 and 2) is very concise, at least units should be added. For equation 1 a citation is provided, the short description is defensible. Equation 2, however, is not clearly referenced and therefore definitely needs more explanation. The optimization process of the temperature, VPD

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and soil moisture functions behind the scaling terms need to be described better, to only mention the sigmoidal shape is not enough in my opinion.

- Some of the conclusions about the effects of drought rely on the analysis of the especially warm and dry year 2012. The fact that there was a disturbance (thin cutting) in one of the forests in this year is not discussed comprehensively enough. The authors should for example include the effect of a diminished leaf area on CO₂ exchange fluxes in their interpretation of this (and the next?) year's budget and explore if for the interpretation of the data set from 2012 to 2017 post disturbance effects should be considered.

Line comments:

Page 1, Line 3 (Title) "similar-age" should not be hyphenated.

Page 1, Line 19 I would suggest replacing the somewhat complicated sentence "...the evergreen forest saw greater annual reduction" with e.g. "...net CO₂ uptake was reduced more at the evergreen forest than at the deciduous forest."

Page 1, Line 22 "Annual ET was driven by changes in air temperature" Are you sure? Is T change really the driver? It sounds like the slope of a T change determines ET. If so, which timescale do you refer to? Maybe average temperature actually is the driver?

Page 1, Line 23 "During drought years,..." It is a bit hard to follow the logic. The preceding sentence says that dry periods greatly reduced ET at the deciduous forest. Now it is stated that the sensitivity of ET to temperature changes (?) at the deciduous forest is comparably low. Maybe say: ET is sensitive to dry periods/increased T at both sites. ET reduction at TP39 is comparably larger.

Page 1, Line 25 "If longer periods..." Longer than what? Can you give us an idea about time scales (hours, days, months)?

Page 1, Line 26 "...the carbon sink capacity [...] will continue." is a bit complicated. Maybe "...will continue to act as a sink..." "...while that of..." is not very elegant, consider

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reformulating.

Page 1, Line 29 Remove comma before "through". "Absorption of CO₂ emissions" can be replaced by "CO₂ uptake".

Page 1, Line 30 remove "processes"

Page 2, Line 38 I would add "events" after "extreme weather". Remove "stress". Stress is the consequence of extreme weather not an example for an extreme event.

Page 2, Line 39 "Adversely impacting [...] forest-atmosphere interactions" What does that mean? Sounds like there is no interaction anymore due to extreme weather, you clearly do not mean that. Also: replace hyphen with en-dash in expression "forest-atmosphere".

Page 2, Line 40 The authors state that there are positive and negative feedbacks but give only an example for a process leading to a positive feedback. Example for the opposite case?

Page 2, Line 46 I do not get the reasoning. "The result of a shifting climate..." [which result?] impacts both forest types differently because broad-leaved species are replaced by needle-leaved species? I do not understand the cause-effect concept behind the statement, consider revising.

Page 2, Line 50 I assume you refer to a disturbance of regional cycles and not within forest cycling, can be formulated more clearly.

Page 2, Line 51 "Conversely,..." I do not see an opposition to the previous statement, which is about photosynthetic rate. This sentence talks about season length.

Page 2, Line 58 "...have the ability to...conduct research..." is needlessly convoluted. Consider replacing with e. g. "Few studies have reported multi-annual time series." Also: omit "sufficiently long". Otherwise you need to explain which timescale would be sufficient for what and why.

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Page 2, Line 59 In my opinion, there is no need to construct ("Such a study would...") the need for the current study. I would omit lines 59 to 63 and go straight to Page 3, Line 73 ("This study...").

Page 2, Line 61 The "benefit" of forests to "terrestrial-atmosphere gas exchange" seems vague. Gas exchange takes place anyway, there only is a benefit if you prescribe a service of forests (e. g. carbon sink function), which is not mentioned here. As stated before, I would omit the whole section.

Page 3, Lines 64 to 69 Should be moved to section 2.1 (Study sites)

Page 3, Lines 70 to 73 As no results of the previous studies are mentioned here, listing them is not very informative. I would move this section to the results or discussion section and mention the results of previous studies there in comparison/relation to the current study.

Page 3, Line 80 "will be used". The choice of tense is confusing to me. Starting in line 73, present tense is used, future here.

Page 3, Line 83 What is "natural terrain"? What would be the difference to unnatural terrain?

Page 3, Line 83 "The forest is classified". By whom? Is there a citation or a classification system this subsumption refers to?

Page 3, Line 91 "Conifer species including make up..." Sentence incomplete.

Page 4 Line 106 Personally, I do not like the frequent use of the verb "experience". For this sentence a more simple way could be: "While edaphic and climatic conditions are similar between both sites, they differ in vegetation cover and canopy structure."

Page 4 Line 107 What do you mean by "historically defined"? That past events (ice age) shaped the landscape or that authors in the past defined the landscape like this?

Page 4 Line 109 It would be easier for international soil scientists to understand if the

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name according to the FAO World Reference Base would be given additionally to the name according to the national Canadian system.

Page 4, Line 113 "Help" is not ideal. How does the lake control cold temperatures?

Page 4, Line 114 "...were 8 °C and..." past tense? The mean is still the mean. Next sentence present tense again.

Page 4, Line 116 The citation is incomplete. Based on the information provided, the given data cannot be verified.

Page 4, Line 116 Last sentence of paragraph can be omitted, it is poorly formulated. Information also given in "Data availability" section.

Page 4, Line 121 Omit ", though". Start new sentence with "Measurements".

Page 4, Line 124 Supplementary material would be a separate pdf-file I think. Table A1 seems to be in the appendix.

Page 4, Line 124 "...are calibrated". Present tense? Paragraph starts in present perfect (... "have been measured").

Page 4, Line 125 The expression "Environment Canada Greenhouse gas specified CO₂" is not understandable. Which concentration did the span gas have?

Page 5, Line 127 It comes as a surprise that there is more than one IRGA per EC setup. In line 123 singular was used ("...an IRGA"). I would stress this type of setup more as it is typical and necessary for forest EC.

Page 5, first two paragraphs A mixture of tenses is used. "is completed", "were assumed", "have been conducted", "are measured", "will focus". Check for consistency.

Page 5, Line 139 Unclear what "Environment Canada Delhi CDA" is. Why mention if precipitation data is not used after all (as stated in line 141)?

Page 5, Line 145 What is the difference between quality control, filtering and cleaning?

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If you do not want to go into detail just mention the citation and say e. g. "processed as described by Brodeur (2014)".

Page 5, Line 147 How was the frequent cross-checking with AmeriFlux done? Statement seems vague.

Page 5, Line 148 How were outliers identified?

Page 5, Line 150 There are other EC towers at Turkey Point Observatory? Where are they? Can you expect them to be representative for your site? Only then using them to gap-fill your data would make sense. More information needed.

Page 5, Line 150 What is "mean flux recovery"? Percentage of half-hourly measurements left after filtering? Including or excluding times of instrument maintenance/malfunction?

Page 5, Line 159 Omit "where daytime and nighttime"; it means all fluxes, correct? No need to specify then.

Page 6, Line 160 It is stated that filtered NEE was gap-filled using soil temperature. Why is "flux recovery" after gap-filling only 49 %. Check if this gap-filling step was actually applied. It seems unlikely. Later more complicated methods for flux partitioning and gap-filling are described. The simple NEE-Ts model seems redundant.

Page 6, Line 164 Symbol for soil moisture appears here first. Explanation too late in line 163.

Page 6, Line 164 Partitioning of NEE into GEP and RE has not been introduced. The reader does not know the RE time series at this point. If you talk about gaps in it you have to introduce it first.

Page 6, Line 166 What is the definition of nighttime? A radiation threshold?

Page 6, Line 166 It is stated that nighttime NEE was modeled as a function of soil temperature and moisture in order to (!) describe the relationship of RE and Ts which

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represents diurnal air temperature variability. Check meaning of the sentence. It seems incoherent to use nighttime measurements to describe diurnal variability of something.

Page 6, Line 173 What are the units of the model parameters, especially of a_1 and a_2 ? a_1 and a_2 are not a function of soil moisture (as stated) when looking at equation 1. I assume all four parameters were fit during the same optimization process.

Page 6, Line 173 "...acting to scale the RE relationship" to what?

Page 6, Line 180 Explanation of equation 2 needs more detail. How are these sigmoidal functions set up? Do they have parameters? Are all parameters optimized at the same time?

Page 6, Line 187 Seems inconclusive. Don't you need the modeled GEP time series in order to calculate phenologically-derived summer months? For the GEP model you in turn need the derived summer months. Please explain.

Page 6, Line 189 Sentence starting with "Furthermore..." ending in line 191 with "both sites" can be omitted, unnecessary/circular information. Yes, in the growing season plants grow, therefore it is a key season of CO₂ uptake.

Page 7, Line 201 Omit first sentence of paragraph, contains no new information.

Page 7, Line 208 "water or heat stressed periods", check meaning, the periods are not under stress.

Page 7, Line 210 Contents of last paragraph can be moved to results, stays a bit vague here anyway.

Page 8, Line 237 GEP might not be gap-filled, still it is not direct measurement data but modeled as the difference of RE (modeled) and NEE (=EC Fc, measured). Could be stressed here, it took me a while to get my head around this fact.

Page 8, Line 240 The approach does not calculate, the computer calculates according to the approach.

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Page 8, Line 241 "logistic curve" instead of "logistics curve"

Page 8, Line 241 "The second derivative estimated the end of greenup..." How? Time when derivative turns zero or similar?

Page 8, Line 242 "while the third derivatives calculated..." see two comments above.

Page 8, Line 251 accumulation

Page 8, Line 257 Ta responds to what?

Page 8, Line 258 "Record warm Ta conditions". Expression unclear to me. Annual mean above 30-year average? Most days/half hours above 30-year average of corresponding DOY/half hour?

Page 8, Line 260 What does extreme mean in terms of values? What does "magnitude of extreme cold days" mean exactly?

Page 9, Line 261 "record Ta outside the normal peak summer period" Unclear, what does record and normal mean? Temperature is outside the period? Check meaning of sentence.

Page 9, Line 262 The sites are not growing, the vegetation is.

Page 9, Line 263 "Meteorological conditions between the sites were [...] examined". Check meaning. Consider replacing with "Differences in meteorological conditions between the sites were examined" or "Meteorological conditions at both sites were examined"

Page 9, Line 263 "..., beginning with the amount..." Sequence of analysis steps not relevant.

Page 9, Line 264 Sentence "However, the shapes..." is circular and can be omitted. It says: The seasonal course of APAR depicts the course of absorbed PAR, meaning APAR is APAR.

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Page 9, Line 267 "APAR was similar throughout the year". Not true, see figure 2. Relative quantity FPAR might be about constant during annual course, APAR is not.

Page 9, Line 270 Cloudy conditions along with a reduction in incoming radiation are not a coincidence.

Page 9, Line 278 Could replace "followed closely to Ta" with "follow Ta closely"

Page 9, Line 281 replace "of TPD" with "at TPD".

Page 9, Line 282 replace "similar patterns between sites" with "similar patterns at both sites"

Page 9, Line 283 Soil moisture deficit compared to what? At which value does it start to be deficient?

Page 9, Line 283 "In summer" comma missing

Page 9, Line 285 "while all other times of the year TP39 was higher". Soil moisture was higher not TP39.

Page 9, Line 292 Consider replacing unit "day" with unambiguous "day of year (DOY)" throughout manuscript, first occurrence here.

Page 10, Line 295 Check meaning. "The response [...] to changes in GDD was considered as a trigger for SOS." The response is the trigger? I think GDD change is the trigger and the response of the forest to this trigger manifested in SOS.

Page 10, Line 296 "cumulative GDD" GDD is cumulative by definition, is it not?

Page 10, Line 297 Cumulative heat is not expressed directly in GDD, GDD is a proxy for absorbed heat as correctly stated above. I would omit the half-sentence "However, [...], which we calculated as"

Page 10, Line 299 "represented" not any more? check tense.

Page 10, Line 303 replace "start" with "are reached"

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Page 10, Line 314 Omit first sentence of paragraph, it is a bit vague. "influenced by a certain degree of cooling"?

Page 10, Line 316 replace "were found to be highly correlated" with "were highly correlated"

Page 10, Line 325 "At first glance..." Sentence seems vague. What do you mean by similar? Which properties of the forests responded similar to which forcings? What does "seasonal irregularities" mean? Difference between same season of different years or within one year between seasons? How do these irregularities govern annual fluxes (cumulative fluxes?). Highest contribution to sum during periods when forcings deviate from average behavior? Consider restructuring or omitting sentence.

Page 11, Line 327 replace "within" with "at"

Page 11, Line 337 "...did not greatly benefit the forest..." seems unassertive. What do you mean? No increase in CO₂ uptake? If the latter is meant, I would question the statement. Sure, when you look at average daily GEP, a longer spring increases n for the conifer forest and adds mostly low values (from earlier in the year) lowering the average. Looking at spring GEP/NEP sums might lead to a different interpretation.

Page 11, Line 339 Details about statistical tests could be inserted here. I am not sure what the p-value refers to, a t-test?

Page 11, Line 341 I would replace "minimums/maximums" with "minima/maxima", might be a matter of taste.

Page 11, Line 341 How is a maximum significant? Consider removing.

Page 11, Line 342 RE was modeled not measured.

Page 11, Line 344 replace "let the year to have" with "led to"

Page 11, Line 346 see previous comment

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Page 11, Line 349 response to what?

Page 11, Line 351 check meaning. Ta always high between rain events?

Page 12, Line 363 Should it be "sink" instead of "source"?

Page 12, Line 369 Check meaning. "NEP [...] exceeded TP39"

Page 12, Line 385 "to" missing, should be "let to rates"

Page 12, Line 387 Consider replacing "deviations" with "variability expressed as standard deviation" and omitting the plus-minus sign in brackets.

Page 12, Line 391 "WUE varied [...] due to different [...] overall GEP and ET". Check statement, seems circular to me. Does it say: "The ratio of GEP and ET varies because GEP and ET vary"?

Page 13, Line 394 "...the SOS began..." Reformulate, now it says "the start began"

Page 13, Line 396 remove "forest"

Page 13, Line 400 Same number for TPD and TP39. Also: What is the uncertainty of these slope estimates?

Page 13, Line 405 monthly GEP and APAR sums or averages?

Page 13, Line 409 Sentence incomplete. "To better understand and the water...."

Page 13, Line 410 remove "first". Sequence of analysis steps irrelevant.

Page 13, Line 412 "the impact of winter soil water storage..." on what?

Page 13, Line 419 Consider reformulating "responses between". I would expect "the response of something to something else"

Page 13, Line 425 Maybe there is no linear relationship between GEP and meteorological variables. There should, however, definitely be relations with PAR. As far as I understand GEP was modeled using PAR, you should see the saturation curve you

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prescribed in the model (eqn. 2) in a PAR-GEP plot.

Page 13, Line 426 There is an extra space after the closing bracket and "resulted"

Page 14, Line 429 Why "most importantly"? Mean or cumulative summer NEP?

Page 14, Line 431 "was seen" is not very elegant. Consider simplifying the sentence, e.g. "...spring was shorter due to..."

Page 14, Line 431 "Higher summer Ta". Season average or half-hourly or daily peaks?

Page 14, Line 431 "relationship between RE and spring Ta". timescales? annual RE, spring RE, sums or averages?

Page 14, Line 437 "Lastly,...", "Ultimately,..." can be omitted. Sequence of analysis irrelevant.

Page 14, Line 428 They sites do not emphasize, you do.

Page 14, paragraph starting in line 439 This paragraph requires more explanation. How were the model parameters examined? The methods section is not detailed enough about this type of analysis, Table 5 is also ambiguous ("GPP:Ta" sounds like correlation analysis. Should it be $f(Ta)$ as in eqn. 1 to denote that the scaling factor is meant?). The scaling method is very interesting, it deserves a proper explanation for others to be able to reproduce it.

Page 14, Line 445 "Outside of Ts". Sounds strange to me. Do you mean "apart from"?

Page 14, Line 447 Similar response of what to what?

Page 14, Line 448 What do you mean with "predicted daily rate"? The observed fluxes were the result of a prediction? I do not understand, consider clarifying.

Page 14, Line 451 replace "experienced by" with "at"

Page 14, Line 451 Typical meteorological conditions? Introduction says air temperature was consistently above the 30-year average.

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Page 14, Line 455 "certain differences were primarily influenced" is a bit vague, which differences, why primarily. What about relief position, water content or soil type?

Page 14, Line 456 "In this case" Soil temperature is always linked to incoming radiation.

Page 14, Line 457 Mean Ts or each half-hourly value?

Page 15, Line 459 What does "highly clumped" mean? High compared to what?

Page 15, Line 459 Minor variations in APAR? Maybe true for fPAR, looking at Figure 2 APAR seems highly variable throughout an annual course.

Page 15, Line 461 "Incoming radiation was directly absorbed by the soil" All of it? What about LE etc.? Not all energy goes into ground heat flux.

Page 15, Line 464 Incomplete sentence. "...similar trends VPD..."

Page 15, Line 469 "species specific responses shaped the timing of phenological events" Responses to what? Isn't it obvious that species type determines phenology?

Page 15, Line 480 There is only one SOS per year. How can SOS have high variability in a warm year when there is only one value per year?

Page 15, Line 486 Seems contradictory. Either timing of senescence and soil moisture are not related ("insignificant") or the forests experienced "later senescence dates with decreased soil moisture". If the finding opposes previous studies it would be interesting to read about possible reasons (water stress?).

Page 16, Line 496 replace "in the deciduous site occurred a month (31 days) before that of the evergreen..." with "at the deciduous site occurred one month (31 days) earlier compared to the evergreen..."

Page 16, Line 497 omit "experienced"

Page 16, Line 500 "only limited by their specific leaf strategy". This seems to be a major argument (Title!). Can you expand more, why "only" limited by this strategy?

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Page 16, Line 503 "Ta anomalies [...] strongly determine the carbon sequestered". Check meaning. Ta determines the carbon? Maybe the amount of carbon? Are you sure the anomalies determine C uptake as opposed to the average temperature?

Page 16, Line 505 "... higher Ta..." Anomalies, average, min/max?

Page 16, Line 506 "drawback" only if maximum sink strength is the goal. why judge?

Page 16, Line 507 typo: "differing forest[s] responses"

Page 16, Line 508 "season length in 20123 was the second shortest despite..." Maybe there is another factor co-controlling season length then?

Page 16, Line 509 Maybe not "despite" but "because" high air temperatures. There could be an temperature optimum (parabolic function) for GEP. What does "record Ta" mean? Daily/Half-hourly maximum, mean, average above long-term average?

Page 16, Line 510 Why "also"? Section already talks about the outlier year 2012.

Page 16, Line 512 "due to thinning performed..." Definitely! This fact is introduced too late. Such a disturbance could single-handedly be responsible for budget deviations in 2012 and override all possible reasons stated before. The disturbance must be stressed and discussed more and earlier.

Page 16, Line 513 "higher Ta and low theta" Annual/seasonal mean or each/most half-hours/days? Replace "acted to enhance" with "enhanced"

Page 16, Line 525 replace "due to comparable decreases" with "due to comparably large decreases"

Page 17, Line 535 "very similar NEP" at both sites vs. Page 17, Line 538 "led the conifer forest [...] to have a greater magnitude of annual NEP". Is NEP similar or different?

Page 17, Line 543 "...some of the highest rates..." Highest single half-hourly fluxes?

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Page 17, Line 543 "especially the deciduous forest)." remove extra full stop.

Page 17, Line 543 What is the definition of a "normal" year? Is this really the conclusion of Griffis et al and Gonsamo et al.? Do they use the term "normal"? Are you surprised that the forests adapted to average site conditions? Before, I read the conclusion that the deciduous forest NEP could profit from comparably dry conditions.

Page 17, Line 548 Statement in first sentence of paragraph is trivial, omit sentence.

Page 17, Line 549 "With insufficient water availability annual tree growth and productivity may be limited". Seems circular to me: When you say insufficient, I suspect you implicitly have in mind that water availability is not sufficient for optimal productivity? To me the sentence says then: When productivity is limited it is limited.

Page 17, Line 555 "ET responds year-round" What do you mean? There is no particularly rainy season?

Page 17, Line 555 "...so warmer spring or autumn periods often lead to annual increases in ET" Warm summer did not impact ET?

Page 18, Line 559 "An opposing ET response..." To what? "...was measured in the coniferous forest" Any idea why?

Page 18, Line 564 "...little summer and annual P removed most of the water from the system, significantly reducing ET" There is no negative precipitation, removal is the wrong term here. The process that (vertically) removes water from the soil is evapotranspiration, why is ET reduced then? Please clarify.

Page 18, Line 565 "timing of summer P" I do not understand, what is meant by timing? Is there only one rain event during summer? Do you mean a peak precipitation event?

Page 18, Line 565 "...the availability of rainfall [...] led to the greatest demand for water" Sorry, I do not get it, consider revising.

Page 18, Line 566 "...differing response" to what?

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Page 18, Line 574 "...to respond similarly" to what?

Page 18, Line 577 Is there a reason you picked the forest in Ohio for comparison?

Page 18, Line 578 "..., this implies..." What does "this" refer to. I cannot follow.

Page 19, Line 610 "significant abnormalities were measured between sites" Strange wording, do you mean "differences between sites"?

Page 19, Line 610 "...meteorology was shown to greatly impact fluxes at both sites, though to varying degrees" Either the impact is great or it is sometimes great and sometimes minor (= varying degrees).

Page 19, Line 614 Why "Conversely"? No contradiction to sentence before (which talks about drought years), this sentence about all years. Secondly, NEP is also the result of respiration and photosynthesis at the broad-leaved forest.

Page 19, Line 618 "Both sites saw average ET, but increased NEP during 'normal' years,..." What is the definition of a normal year, 30-year average? What is your baseline for a "normal" NEP? Should be average NEP during average years, shouldn't it? How can NEP deviate (be increased) from the average during an average year then? Please clarify.

Page 19, Line 621 "...while the response of the conifer forest remains uncertain." Sure, there is uncertainty, which is true for the projections about the deciduous forest's sink strength as well. Why not report some of the ideas about conifer forest in a future climate developed before in the discussion?

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