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Interactive comment on "Differential effects of extreme drought on production and respiration: synthesis and modeling analysis" *by* Z. Shi et al.

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Reply to Reviewer #1

Response: We wish to thank reviewer #1 for the detailed comments on our manuscript, which are greatly useful for us to improve our manuscript. Please see detailed reply to each comment.

Reviewer: This is an exceedingly well-written piece of scholarship that I enjoyed reading. The study explores differential effects of various drought severities (with emphasis on extreme) on C fluxes using single model runs at 4 grassland sites and a literature review.

Response: Thanks for the reviewer's positive comments on this manuscript.

Reviewer: Some minor comments are listed below. My main concern here is that only a single model was used. I've been involved in a few MIPs and can relate first-hand that drought response in models is not uniform. How can the authors substantiate that TECO is a good exemplar? I understand that a mini-MIP for a single manuscript is a huge burden but I feel that this question needs to be addressed in some form.

Response: The reviewer made a great point that MIPs often show great variations in simulations among models. In spite of the fact that we did not do model inter-comparison for this study, findings from previous MIP can provide evidence for the robustness of our conclusion. For example, using four ecosystem carbon models, Luo et al. (2008) explored potential individual and interactive effects of climate warming, altered precipitation amount and elevated CO2 concentration across a broad range of biomes. They found that half precipitation reduced net primary production more than heterotrophic respiration, and as a result decreased net ecosystem production. We have revised the manuscript to clarify this point in section 4.5.

Reviewer: Otherwise I have a few more technical issues contained in the minor comments below: Just to be clear: You are focused on two types of drought: Seasonal drought with emphasis on rainforest and droughts in the context of interannual variation?

Response: In our data synthesis, we focus on seasonal drought in rainforest and drought in the context of interannual variation for other ecosystems.

Reviewer: I would prefer more treatments. Is not one aspect of your study to find some "tipping point" in drought response? Put another way, you are chasing a response surface and you have only 3 points (baseline and 2 variants of 33% reduction). I'm also curious why 33% was chosen? Is that value informed by some credible forecast of changes in precipitation in the study domain? Such forecasts are iffy at best, which reinforces the idea of a response surface. This might be a framing issue but I could not shake this question even after re-reading the paper.

BGD

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Response: Identifying the tipping point is not the focus of our study. The purpose of imposing two types of drought was to investigate whether altered rainfall variability had different effect from just reducing rainfall amount. Knapp et al. (2008) predicted that altered rainfall variability could potentially have different impact on ecosystem carbon cycling in different ecosystems. The selection of 67% rainfall reduction in the model was based on analysis of long-term rainfall records in central US grasslands. Multi-year drought similar to 67% rainfall reduction occurred but only for 4-6 times in a 70-year record for semi-arid Colorado and 108-year record for mesic Kansas. The explanation of why chose 67% reduction has been updated (Lines 192-195).

Reviewer: P 16056: I do not follow your last sentence here, can you clarify?

Response: The last sentence is "Frequent small rainfall events (the ESR treatment) can potentially alleviate chronic water stress, whereas the longer dry period under REN inhibited early leaf and root development and consequently decreased production". The long, dry period under REN treatment could affect early leaf and root growth due to constantly under the threshold of certain soil water content level. The under-developed leaf and root can have legacy effect on photosynthesis and water uptake later on and therefore decreased production more.

Reviewer: Re: 4.4 Implications for future experimental studies Could you add something on capturing legacy effects in experimental studies? Especially in treed systems (trees may lay down wood with different hydraulic properties if the drought is severe enough) this lagged effect is highly relevant, and not well-incorporated in LSMs.

Response: Vegetation mortality due to carbon starvation or hydraulic failure or both (McDowell et al., 2008) is likely to occur if the drought is severe enough and can therefore have legacy effect on most aspects of ecosystem carbon cycling. It is difficult for land surface models (LSMs) to accurately capture plant mortality due to the lack of relevant data and thorough understanding on the mechanisms (Xu et al., 2013, McDowell et al., 2013, Reichstein et al., 2013). In order to improve LSMs to adequately model drought-caused dieback and consequently the legacy effects, experimental studies in multiple-year severe drought which is specially designed to induce mortality is needed (e.g., Plaut et al., 2012). Mortality in grasslands differs from that in forested ecosystems. In a forest, when large area of mortality occurs, the whole ecosystem would have to start over from secondary succession and also have lagged, possibly long-lasting effect (Reichstein et al., 2013), whereas grassland ecosystems characterized by the high recovery potential of plant growth would recover to its original states in a very short time and had less impact on carbon cycling than forested ecosystems. This part has been updated (in section 4.5).

Reviewer: Table 2: Define monsoon Rs.

Response: Monsoon Rs is cumulative soil respiration during monsoon season from July through September in Sevilleta desert grassland (Thomey et al., 2011). It has been updated in the Table 2.

Reviewer: Table 3: I think this is better placed in the SI, like the non-rainforest summary table.

Response: Table 3 provides the main information in differential responses of GPP and ER to extreme seasonal drought in tropical rainforest. The non-rainforest summary table (Table S1) provides supplementary information to Figure 2. Thus, we think that it would be more proper to put it in the main text.

Reviewer: Fig 1: This is a proof of concept figure that should allay reader reservation(s) that TECO can be used to explore ESR/REN. But I'm not sure I am comforted by this figure. Could you say a bit more about model skill in hindcast mode before moving to your treatments?

Response: Figure 1 in combination with Table 2 showed that our TECO model can well simulate different types of ecosystem carbon variables. In TECO, rainfall reduction affects ecosystem carbon cycling mainly through its effect on soil water dynamics. Soil water content is a net result of rainfall, evapotranspiration and runoff. There is a moisture scalar in the model, $\omega = (Wsoil - Wmin)/(Wmax - Wmin)$ where Wmax is soil water holding capacity, Wmin is the permanent wilting point and Wsoil is soil water content. Photosynthesis and plant growth rate are reduced whenever ω is less than 0.3. This part was described in method section (Lines 158-167).

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Please also note the supplement to this comment:
http://www.biogeosciences-discuss.net/10/C7060/2013/bgd-10-C7060-2013-supplement.pdf

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