We thank the reviewer for taking the time to review our manuscript and provide constructive comments.

In revising our manuscript, we noted that our model simulations had used a fixed pre-industrial nitrogen deposition rate. In our resubmission, we reflected that it would make more sense to show results from LPJ-GUESS with the nitrogen cycle switched off. This was because the principal aim of our paper was to explore the sensitivity of the carbon cycle to 'expressions' of El Nino and we might expect that this sensitivity would be greatest using the C-only version of LPJ-GUESS as carbon uptake is not limited by nutrient availability (which may decline with water availability in dry years, when nitrogen immobilisation rates increase). Nevertheless, as one of our main regions of interest was the tropics, we would not expect a strong limitation by nitrogen (Vitousek et al. 1984) and as a result, we do not anticipate a strong sensitivity in our results to our choice of biogeochemical cycle. To assure the Editor/Reviewer of this insensitivity we have shown the results of both cycles (N-cycle on/off) below (Fig 1). We also used this opportunity to update the model comparison against the more recent TRENDY v7 runs.

Overall, we found that LPJ-GUESS is close to the TRENDY v7 ensemble mean and simulations are mostly within the model range (i.e. across TRENDY models) when we switch the nitrogen cycle off. The spatial distribution of the summed composite GPP anomalies (see fig. 2) shows that LPJ-GUESS picks up the main anomalies associated with EP El Nino events and remains within the TRENDY models' range. Finally, LPJ-GUESS has a strong negative bias in Australia. As our results show, Australia does not make a large contribution to long-term changes in any of the carbon fluxes and pools.

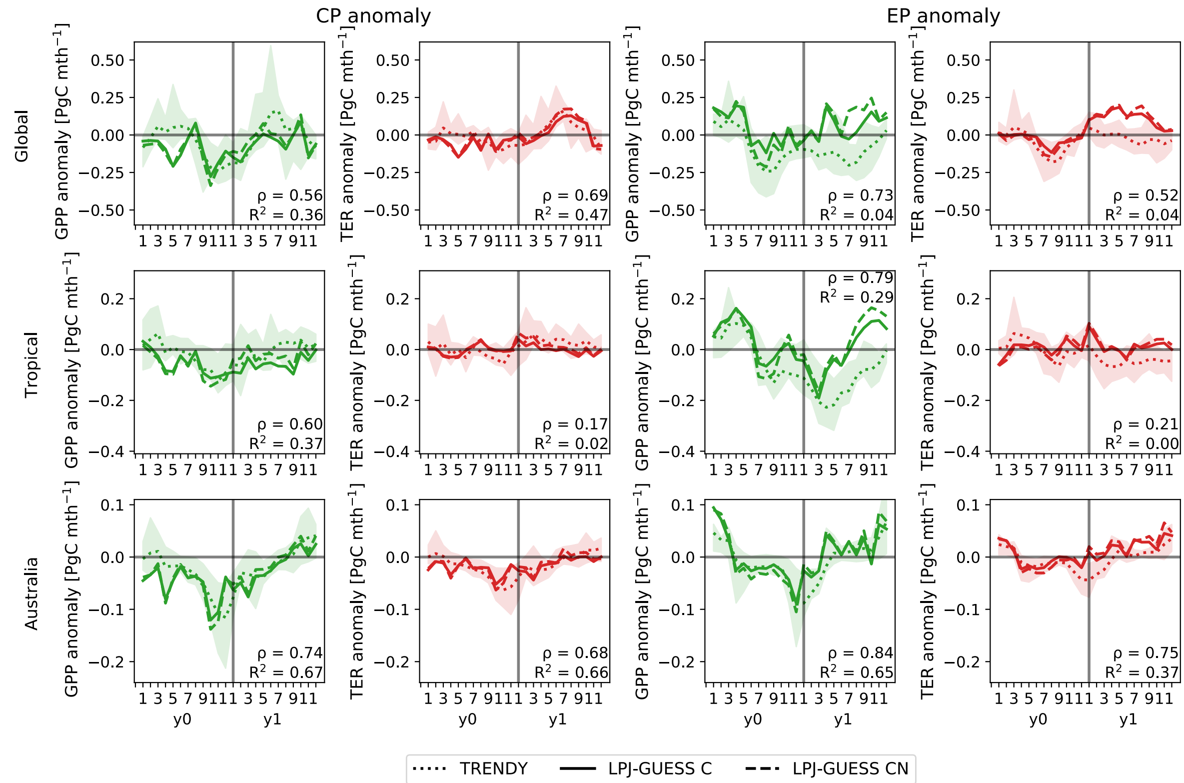

Fig. 1. Monthly composite anomalies during the El Nino developing (y0) and decaying (y1) year in gross primary production (GPP; green lines) and terrestrial ecosystem

respiration (TER; sum of autotrophic and heterotrophic respiration; red lines) for all CP and EP El Nino events listed in appendix table A1 averaged over the globe, the tropics (23°S–23°N) and Australia. The dotted lines show the TRENDY v7 composite, the solid lines are the individual LPJ-GUESS run where we switch of the nitrogen cycle, the dashed lines show the model runs with dynamic nitrogen cycling (compare Wang et al., 2018). ρ and R^2 show the correlation coefficients and R^2 values between the LPJ-GUESS and the TRENDY ensemble mean. The shaded area shows the model spread of the individual TRENDY models.

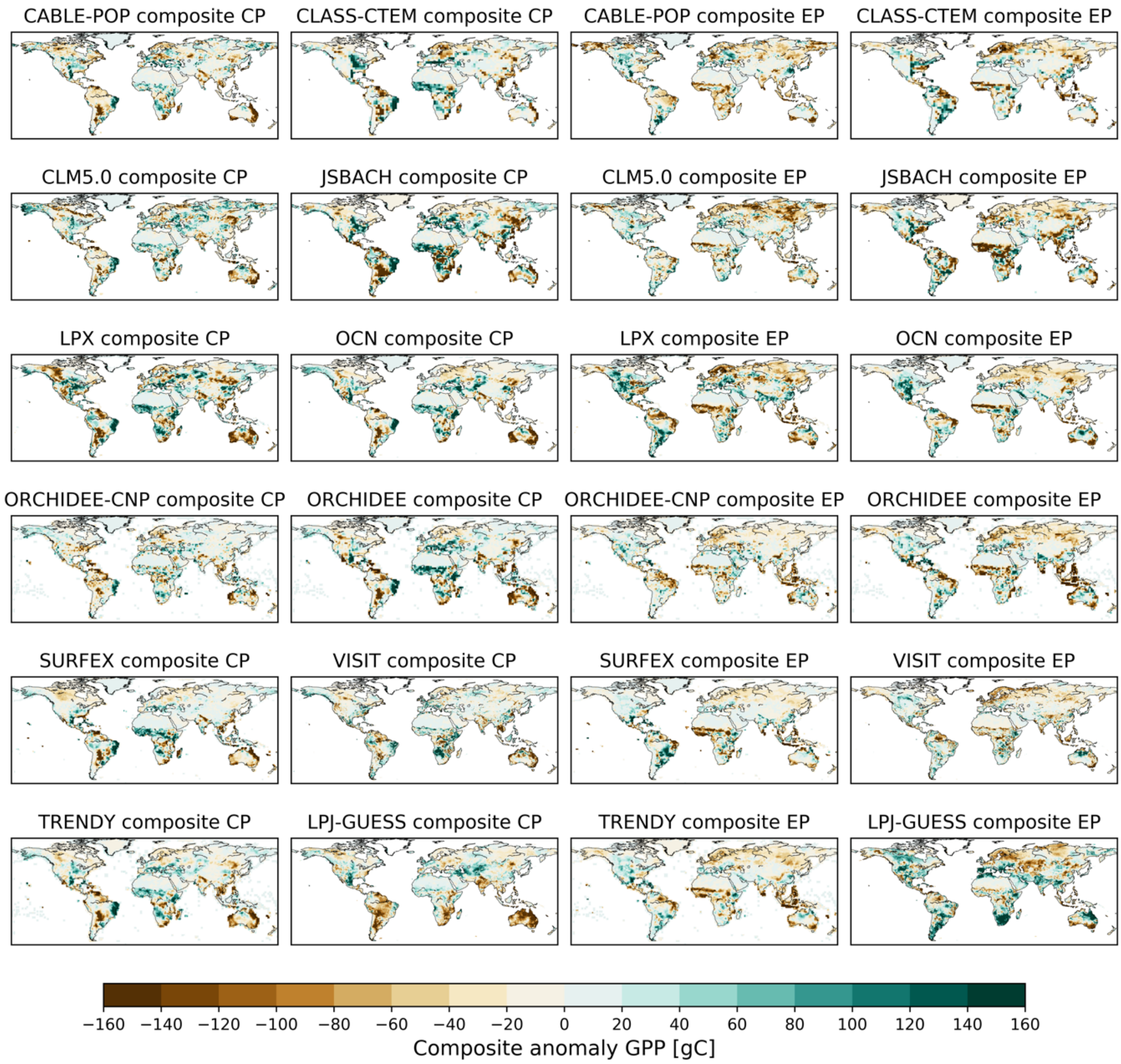

Fig. 2: Composite anomalies in gross primary production (GPP) summed over the the El Nino developing and decaying year for all CP and EP El Niño events listed in tab. B1 for the individual TRENDY models, the TRENDY composite and the individual LPJ–GUESS run (compare Wang et al., 2018).

Below we address the reviewer's comments point by point. We add our replies in italics and highlight suggested modifications in the manuscript in red.

Referee #2

In this manuscript, Teckentrup et al. used LPJ-GUESS forced by manipulated climate datasets to study the influences of two expressions of El Nino (CP and EP) on the terrestrial carbon cycle. The authors suggested that the expressions of El Nino only influence interannual variability of NBP (e.g. CP caused larger IAV in NBP than EP at the global scale) but not the long-term change in NBP. They concluded that the relative frequency of CP and EP is not critical in models as CP/EP did not yield detectable changes in long-term NBP. The science question is interesting, the story is well told and there is no major flaw in the method. That being said, there are a few questions that puzzled me after reading the manuscript, which I hope the authors could clarify a bit before I could support it.

We thank the reviewer for their assessment and the acknowledgement of our contributions.

1. One of the novel points presented is that "impact (of CP and EP) on longer timescales is not well understood". El Nino, either CP or EP, is known to dominate the interannual variability of terrestrial carbon cycling. It is not clearly stated in the Introduction why we would expect an influence of CP/EP El Nino at longer timescales in the first place. In another word, would it be a surprise that CP/EP El Nino exert no change on long-term NBP, as we already known that El Nino influences IAV rather than long-term variability of the carbon cycle. Perhaps the relative more frequent CP occurrences in the future could be an issue long term but the current models may not include proper mechanisms (i.e. shift in species composition, acclimations) to answer the question.

   We agree that El Nino studies have mostly focused on interannual timescales. However, in a recent study, Park et al. 2020 found that decadal variability in ENSO influences the long term terrestrial global carbon cycle. Further, as noted by the reviewer, a shift in El Nino patterns could alter cumulative net biome production, which may alter competitive patterns of plant species, both of which may influence the carbon stored in vegetation and soil. Similarly, interannual variability in precipitation patterns induced by different types of El Nino might change vegetation dynamics in semiarid areas/savanna ecosystems. As a result, we do think the focus of our study is warranted.

   Our results imply that the expression of El Nino did not lead to any of the changes described in earlier studies. We agree with the reviewer that it is possible that this may in part relate to missing mechanisms that would capture species composition changes. Yet we think this is unlikely to be the explanation, given that El Nino events are very short-lived and spatially variable which likely prevents a direct shift in vegetation in most biomes due to changes in meteorology. Whilst this summary of our findings agrees with the reviewer's point above, we still had to do the exploratory work to determine whether this was in fact true.

   We have amended the motivation text in the introduction to more clearly capture these issues:

'A shift in El Nino patterns could change cumulative net biome production, which may alter competitive patterns of plant species, both of which may influence the carbon stored in vegetation and soil. Similarly, interannual variability in precipitation patterns induced by different types of El Nino might change vegetation dynamics in semiarid areas/savanna ecosystems (cf. Scheiter and Higgins, 2009; Whitley et al., 2017).'

2. The study is aimed at studying the sensitivity of the terrestrial carbon cycle to CP/EP El Nino. And the author did so by replacing the climate anomalies during CP to EP and vice versa. CP is reported to cause larger global IAV than EP.

   Yes – that is correct.

   My concerns is: (using global simulation as an example) is this larger sensitivity of the terrestrial carbon cycle to CP is due to the changes in the inherent climate sensitivity of carbon during CP/EP, or is this simply caused by the generally larger climate anomalies during CP (Fig. B5). I would assume the reason is the latter, as the inherent climate sensitivity of carbon cycle is essentially predefined by the model (in this case LPJ-GUESS) structure, so what we see here (IAV of NBP in CP > EP) is perhaps just because the IAV of climate in CP > EP.

   We agree with the reviewer that the model simulations suggest that the results largely follow the climate anomalies. Employing a DGVM provides the opportunity to explore possible lag effects, such as changes in fire dynamics, and changes vegetation composition. These lag processes that might be captured by a DGVM allowed us to explore the reviewer's question about the 'inherent climate sensitivity of carbon during CP/EP'. In fact, we found that the perturbations forced on the vegetation were too small to cause significant carryover effects, and conclude therefore that climate anomalies were the key control for the observed changes. As with the reviewer's previous point about 'long-term responses', we do not think the answer is self-evident and felt it was important to explore the model sensitivities.

3. missed chance on the spatial and phenology of carbon fluxes. While I have doubts about the reported difference between CP and EP at interannual or longer time scales, I feel their difference is perhaps more pronounced at seasonal scales and spatial, when CP and EP show apparent contrasting temporal patterns (e.g. Fig 1). As was also noted by Chylek et al. 2018, the time delay of CO2 rise after SST increase is one of the pronounced differences, and the difference is only around 3 months. Focusing on longer time scales might easily just averaged out these important characteristics. I think the authors have done a nice job in demonstrating the spatial difference of carbon sinks under CP/EP, and these results perhaps worth more highlights.

   We agree with the reviewer that changes are likely more significant at seasonal timescales. As the reviewer notes, our results show that even if there are strong impacts on shorter timescales, these effects disappear on decadal timescales which *is a key conclusion in our paper. We therefore choose not to further explore shorter timescales given this is already something that has been reported in the literature.*

4. With that, I would also say it maybe a stretch to say CP/EP is not critical in future models, as their major difference is likely to be clearer seasonally and spatially (e.g. different carbon sink distribution, phenology of carbon uptake).

   We agree with the reviewer that the different expressions of El Nino affect the terrestrial carbon cycle on interannual timescales and that individual events potentially have large impact on specific regions. However, our results suggest that the perturbations linked to the expression of El Nino might be too small to trigger changes in vegetation dynamics that last longer than a season or a year. Nevertheless, we have adjusted the future directions:

   'Based on this analysis we suggest that our model sensitivity would likely be similar to that displayed by the other TRENDY models, although we would anticipate subtle regional differences, particular in the tropics if an alternative DGVM had been used'

   and the conclusions:

   'Our results therefore suggest that the impact of different expressions of El Nino on the carbon cycle on long time scales is likely to be small.'

5. L11. Please specify what kind of longer time scale effect (i.e. decadal mean, decadal variation or trend?)

   We used 'longer time scale effect' to describe the effect a climate with only CP El Nino or only EP El Nino events might have on terrestrial vegetation after 45 years. We do not analyse decadal mean, variation or trend but rather assess the effect by comparing the final year of the two different scenarios to that of the control run (where both expressions of El Nino occur).

6. L84 and L104. If CRU-NCEP v7 covers 1901-2016, why not consider the 2015/2016 El Nino in the analysis.

   We chose the year 2013 as the last year of our experiment run because it is ENSO-neutral.

7. L84. By saying CRU, did you mean CRUNCEP.

   Thank you, yes and we changed the text accordingly.

8. L119-120. I am not sure I understand how to choose the replacements for CP and EP correctly. Why there is a need to resample climate anomalies using ONI and how do we locate the CP that is used to replace a EP (in the same 10-year window shown in Fig 1?).

We use the approach according to Yu and Kim, 2009. They use the ONI index to identify El Nino events which comprise both CP and EP El Nino events. Based on four different indices, they then further differentiate between CP and EP El Nino events. We changed the description in the 'Identification of El Nino events' section to:

'They first classified El Nino events based on the Oceanic Nino Index (ONI) which comprise both CP and EP El Nino events. Based on four indices, they then further differentiate between CP and EP El Nino events.'

We also use the ONI index as a guidance for the replacement of the individual El Nino events. We replaced an EP El Nino event with a CP type (and vice versa), when both events start, end and peak at the similar times in the year according to the ONI index and have similar magnitudes in the ONI index (see methods).
We updated the methods section:

'We used the ONI index to define the start, end and strength of the individual El Nino events and resampled the climate anomalies based on the ONI. We replaced anomalies in the climate forcing associated with El Nino events according to the best fit in duration and amplitude in ONI, i.e. events that start and end at a similar time in the year and have a similar timing and magnitude of the peak in ONI.'

9. L210. Does LPJ-GUESS have a component to simulate species composition?

   Thanks for pointing out this potential confusion. LPJ-GUESS represents vegetation in form of plant functional types, not individual species. We replaced 'species composition' with 'vegetation composition'.

10. B1-B4: Unit of carbon fluxes in supplementary figures. Per m2?

    Thank you for pointing this out, we changed it accordingly and updated the figures.

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