Response to review comments 2

We want to express our gratitude for the detailed comments of reviewer 2 on the manuscript "Observation-inferred resilience loss of the Amazon rain forest possibly due to internal climate variability". In this document we will respond and discuss in detail the submitted comments.

The manuscript is well written, concise and offers a thorough explanation of the objectives, methods and a good overview of the results. The work follows some of the steps taken by Boulton et al (2022), using lag-1 year auto-correlation (AR(1)) of changes in forest vegetation optical depth (VOD) and Leaf Area Index (LAI) as an early warning signal before reaching critical threshold for forest dieback.

In the results, the authors remark that it is impossible, based solely a single data record, to figure out whether observed changes and trends in auto-correlation of VOD are caused by external forcing or internal variability. To address this problem, they mention that common approaches to detect external (forced) changes are the use of multiple climate model runs, based on different codes, or to use models that start from different initial conditions. They then show, as an example, 30 simulations of the historical experiment, comparing it to one CMIP6 model (MPI-ESM1-2-LR). They show that the observed spatially averaged trend of AR(1) falls within the range of trends of the ensemble members for the same period. They also mention the possibility of investigating simulations of equal length as the historical data, but modeled for a pre-industrial context. After mentioning both examples, they state that the forced response of the Amazon rain forest is not needed to generate an AR(1) increase of similar magnitude as the observed one. And just then they mention that not all models are equally fit for the purpose of simulating the dynamics of the forest in accordance with observations. They then apply the KS test to verify if each ensemble member could have been drawn from the same underlying distribution as the observations, and only four of the nine models pass the test. The model used in both examples mentioned above is one that passes the KS test (MPI-ESM1-2-LR), as it should be. But presenting the above-mentioned examples first, with an important argument for the conclusion, and then showing the "screening" made by using the KS test, may cause some confusion. Thus, I suggest the KS test result is presented before the examples are shown, for increased clarity of the text.

Whereas we can see the reviewers point of the presentation order can leave some readers concerned, we think the approach taken here is easier to comprehend for the uninitiated and hence more pedagogical. We will therefore keep the order of our presentation.

Also, after the second example, the authors state (line 125) "The shorter-term deviations appear slightly muted in this case compared to the historical ensemble, and even if encapsulating the longer term trend the shorter variations are clearly less than those observed, therefore possibly suggesting an influence from historical forcing. Overall, however, the displayed model ensemble suggests that the forced response of the Amazon rain forest is not needed to generate an increase in AR(1) of similar magnitude to that observed". In other words, two arguments that support an influence from historical forcing are shown, and then a generic argument is given to argue that forced response is not important. Since the main conclusion of the manuscript is that external forcing do not generate a significant change in AR(1), I think a more detailed discussion to support this at this point would be interesting.

Changes made to lines 126 – 127. We note that the short term deviations of the control simulation appear slightly muted compared to the histrocial experiment. However, when comparing the magnitude of the maximum trends (maximum tau in control = 0.79 and in historical = 0.73) and the overall trend ranges, the AR(1) series suggest that the forced response in LAI resilience is rather marginal or slightly negative in MPI-ESM1-2-LR. This is supported by Fig. 4 later in the manuscript. Moreover, the largest trend is found among the control runs, hence the occurrence of the observational trend is more likely in this experiment.

In the conclusions, the authors state: "Of the four well performing model ensembles, three of them showed trends similar to observations also in their unforced control simulations. These results suggest that the observed trend could simply be an expression of internal variability, and that longer data records would be needed to show that the opposite is the case." Is it possible to give an educated guess on how much longer should the data records be?

One could calculate the trend distribution over different time scales from the control simulations, and in principle it should become narrower with time. However, we do not have longer observational records available so we do not know the trend that we will observe on longer time scales.

Boulton et al (2022) argue that the Amazon is showing signs of resilience loss during a period with three "one-in-a-century" droughts, and the higher frequency of extreme droughts leads to ecological changes, but the replacement of drought sensitive tree species by drought resistant ones happens in a slower pace, which may reduce forest resilience even further. If data was available, could the inclusion of the latest extreme drought (2023) to adjust the models significantly change the outcome of the analysis of this manuscript?

The extension of the data record is highly desirable, as increasing drought risk e.g. in the Eastern Amazon is predicted for the future (Duffy et al., 2015). It is therefore possible that the outcome of the manuscript changes with more data being available.

The authors also conclude that "This result is further corroborated by the spatial distribution of the increasing trend in AR(1) in the model simulations. Here it is found that ensemble members with substantial positive or negative trends show these in relatively large regions, but not necessarily in those regions with large anthropogenic deforestation. This suggests that such anomalies are associated with large scale weather events." Boulton et al. (2022) compare AR(1) in pixels that are in 50 km bands of distance to areas with human activities to determine the importance of the internal forcings in the resilience loss. Would it be possible to make a similar approach with the modeled data, comparing AR(1) auto-correlation values on a pixel basis, in fixed distance bands to impacted areas? Another possibility is the approach used by Wang et al. (2023), who used forest degradation and deterioration maps to test the human impact on auto-correlation values.

Due to the low resolution of the GCMs of effectively 100 km – 500 km, an approach like this does not seem very promising in our case.

Below are a few suggestions of corrections:

- *Line 58: "…prior critical transitions,…" should read "… prior to critical transitions,…*

  Changes made to line 58.

- *Legend Table 2: I suggest the authors include the explanation of "piControl" in the legend of the table*
  Changes made to caption of Table 2.
- *Correct citation: Boulton et al (2022) is incorrectly cited as Boulton et al. 2020 in line 171.*
  Changes made to line 171.
- *In lines 176/177 the phrase "and one model with 33 realisations did clearly under performs." should read "underperform".*
  Changes made to line 176 – 177.

References

Boulton, C. A., Lenton, T. M., and Boers, N.: Pronounced loss of Amazon rainforest resilience since the early 2000s, Nature Climate Change, 12, 271–278, https://doi.org/10.1038/s41558-022-01287-8, 2022.

WANG, Huan et al. Anthropogenic disturbance exacerbates resilience loss in the Amazon rainforests. Global Change Biology, v. 30, n. 1, p. e17006, https://doi.org/10.1111/gcb.17006, 2023.

Philip B. Duffy, Paulo Brando, Gregory P. Asner, and Christopher B. Field: Projections of future meteorological drought and wet periods in the Amazon, Proceedings of the National Academy of Sciences, 43, 112, 13172-13177, doi:10.1073/pnas.1421010112, 2015.

***Citation**:* https://doi.org/10.5194/egusphere-2023-2734-RC2