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# *Interactive comment on* "Multi-variate factorisation of numerical simulations" *by* Daniel John Lunt et al.

**Anonymous Referee #2**

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This study is well written, and very interesting. It presents a new development to Lunt et al., (2012) investigation of the factorization method used in paleoclimate modeling. The goal is to achieve completeness, uniqueness and symmetry of the factorization, and eliminate the synergy term. Mathematically, it is a fine solution. But I do have a couple questions:

1. The completeness is achieved by averaging out different additive paths of applying climate forcings (eq. 6) or sharing the synergy term proportionally with the generated warming by the individual "forcing" factors (eq. 15). I actually quite like the synergy term, because the synergy term has the physical meaning of capturing the non-linear effects of changing vegetation, ice sheet, topo/geography and CO2. Beyond what is shown in Fig. 2, additional axes are needed to capture these non-linear effects. In fact,



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the points seemingly overlapping at T111 could be a visual illusion, and separable with additional axes of non-linear interactions. Wouldn't it be better to leave the synergy terms alone? Additionally, Fig. 4 is a natural result of absorbing residuals into the calculation with corrections. I am worried that the physical meaning of factorization is contaminated through this absorption instead of being enhanced. Specifically, how to interpret the differences between the left, middle and right column in a physically meaningful way? (- due to the attributions of nonlinear effect to different forcings?)

2. For LGM, whether the symmetry is a feature of climate response to CO2 forcing is questioned (e.g., Zhu et al., 2020, Clim. Past. https://doi.org/10.5194/cp-2020-86). This study shows that changes in CO2 and ice sheet have different forcing efficacies under the LGM and preindustrial climate conditions. Similarly, asymmetric vegetation, ice sheet, and CO2 forcings might be prevalent for past climates. Would it be more useful to use the proposed framework to understand the asymmetry of climate forcings and responses instead of trying to force symmetry, which might not be a real feature in climate system?

3. Lastly, this framework is described in the context of LGM, showing the LGM results would be more consistent.

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