We would like to thank both reviewers for their comments that helped improve our manuscript. Please see below replies to all comments. The reviewers' (RC2) comments are in black, our replies in blue, and any updated or new text from the revised manuscript in "*quoted blue italics*". All line numbers mentioned below are from the submitted manuscript.

Reviewer 2.

This manuscript introduces an asynchronous coupling framework between the NASA GISS ModelE atmosphere/climate model and the dynamic global vegetation model LPJ-LMfire. The framework is applied to mid- to late-Holocene (2.5 ka) simulations, exploring how dynamic vegetation and fire affect vegetation cover, albedo, and regional climate. The idea is timely and valuable: asynchronous coupling between atmosphere models and DGVMs can help advance palaeoclimate simulations and improve the realism of land–atmosphere interactions. However, it lacks sufficient novelty. In its current form, it lacks sufficient methodological transparency, reproducibility, and robustness in validation to meet GMD standards.

Major comments:

1. The coupling strategy must be documented in a way that allows others to reproduce it. The current description is too brief. Please provide a step-by-step description of the asynchronous loop (order of model runs, frequency of exchanges, number of iterations). A complete list of exchanged variables, with units, spatial grids, interpolation method, temporal aggregation, and post-processing. Table 1 can be expanded to contain these details, or a detailed flow chart can be added. Any bias correction, spin-up, or equilibration applied between iterations. How did you validate the model results fit with reality? All of these need to be shown and discussed.

The requested details are already included in the manuscript in detail, following the logical flow of the modeling framework described in Section 2 (*Models and Methodology*) and Section 3 (*Experiment Designs*). This is clarified below, including some additional details we included in the revised manuscript.

Please provide a step-by-step description of the asynchronous loop (order of model runs, frequency of exchanges, number of iterations). These details are already included in Section 2.3: the flow of the asynchronous coupling is visualized in Fig. 1; a stepwise description is provided in lines 185-267; the post-processing details are mentioned along with each step in the framework description. However, added more text to clarify the specific points made by the reviewer.

order of model runs: [in section 3 at L282 and L287] "*Run '1850_PI_ctrl' (row 1 in table 2) was performed to evaluate the vegetation mapping scheme and to select the appropriate scheme for asynchronous coupling, whereas '2.5k_PI_ctrl' (row 2 in table 2) is used as the 0^{th} order control run for 2.5ka period with present-day vegetation distribution*"

"....and extended the 0^{th} order 2.k control ('2.5k_PI_ctrl') before branching out the experiments '2.5k_GS_x_GISS' and '2.5k_GS_BC_GISS'"

Frequency of exchange: Figure 1[Flow diagram] is modified to illustrate this detail.

number of iterations : This already exists in Table 2 column 5.

Units of exchange variables: Units are added to the columns 1 and 2 of Table 1.

Spatial grid and interpolation method: Already listed in Figure 1 (flow diagram) and L 264-266, L218, L285.

Postprocessing : Postprocessing details for both sets of data are already described in respective steps of the asynchronous coupling between GISS-ModelE and LPJ (see sections 2.3.1, 2.3.2, 2.3.3 and 2.3.4).

Table 1 can be expanded to contain these details, or a detailed flow chart can be added. Any bias correction, spin-up, or equilibration applied between iterations. A flow chart (Figure 1) is provided under the framework description at L190. A single table for all these had too much information due to the many different steps, thus we decided to separate these into 2 in the submitted manuscript, based on a) directly related with the asynchronous coupling framework and b) experimental setup chosen.

How did you validate the model results fit with reality? Section 3.1 (Evaluation and Validation of mapping methodologies) already covers the model validation. Also, in section 5 of the manuscript, we performed an extensive model-data comparison.

Other relevant finer details related with the PFTs mapping schemes and the initial vegetation distribution is already provided in the supplement. However, motivated by the reviewer's comments above, we modified the paragraph at the end of the introduction by summarizing the relevant details at L114, as given below. Further, we modified some section titles too: L120: Modified section 2 title as "Models and asynchronous coupling framework"; L162: modified section 2.2 title as "2.5ka simulation setup (initial control run using ModelE)".

"Section 2 describes the models used in this study (Section 2.1), the initial control run for 2.5ka, and a stepwise description of the asynchronous coupling framework, including variable exchange and processing (Sections 2.2 and 2.3). Section 3 presents the experimental design for implementing the asynchronous coupled system and evaluates the PFT mapping schemes. In Section 4, we evaluate the simulated 2.5ka climate using the ModelE–LPJ asynchronous coupling framework against multi-proxy temperature reconstructions (Kaufman et al., 2020) and additionally utilized the model's capabilities to simulate the isotopic composition of water in precipitation ($\delta^{18}Op$) to compare with the Speleothem Isotope Synthesis and Analysis (SISAL) version 2 database (Comas-Bru et al., 2020). Section 5 provides the analysis and comparison of model-simulated climate under various experimental configurations."

2. The manuscript does not clearly specify how many experiments/ensembles were conducted, nor their lengths. Please add a concise experiment table with experiment names, forcings applied, spin-up duration, ensemble size, and control/baseline. Clarify whether ensemble spread reflects internal variability or parameter uncertainty.

All the requested details are explicitly provided in Section 3 (line 269). Specifically, information regarding the experimental design, including their duration, number of iterations, applied forcings, and constraints etc. are already presented in Table 2.
The simulated spread of our results reflects the modeled interannual (internal) variability, not the model's parametric uncertainty. We now mention that in the text: L531 and several other places in section 4.1 "*5-95 percentile range (interannual variability)*".

3. State explicitly which CO2/greenhouse gas values and orbital forcings were used for each experiment, with citations to PMIP4 or other sources. A dedicated table listing GHG concentrations would be helpful.

This experiment uses time period–specific forcings (2.5 ka and PI), including GHG concentrations (CO_2, N_2O, CH_4) and orbital configuration, which are explicitly described in Section 2.2 (lines 167-171). Section 2.2 was specifically designed to consolidate all relevant time-specific details, and since these are just a few numbers, We also added the forcing details in table 2 (row 1 & 2) for better comparison.

4. The choice of monthly coupling is not justified. Either show sensitivity to coupling interval (e.g., monthly vs seasonal/annual) or provide a discussion, with references, of the limitations and expected impacts of this choice.

The coupling between ModelE and LPJ-LMfire is based on monthly climatological means, i.e., multi-year monthly averages. ModelE uses static vegetation distribution fields from LPJ-LMfire as boundary conditions for the subsequent runs, which remain constant across monthly and interannual timescales. The models are designed to update their vegetation boundary conditions on a monthly basis, consistent with the standard approach used in CMIP and paleoclimate simulations (Otto-Bliesner et al., 2017). Altering vegetation distribution seasonally or even annually would not capture vegetation variability with sufficient temporal resolution. Moreover, there is not enough information available to implement changes more frequently than monthly.

We modified figure 1 (flow diagram) to specify the temporal frequencies of inputs to LPJ and GISS ModelE.

5. The manuscript compares simulations with reconstructions but lacks detail on datasets and metrics. Please list all proxy datasets used, with version numbers and coverage. Describe the model-data comparison method (regridding, seasonality, temporal windows). Provide quantitative metrics (bias, RMSE, correlation, significance tests) and report proxy uncertainties.

The submitted manuscript compares the model simulated 2.5ka climate against the global mean surface temperature (GMST) and a latitude band of 30 degree from 90S to 90N from Kaufman et al. (2020) as shown in figure 12 (now fig 6 after revision). All the necessary data and related information such as total number of proxies (L608) from Kaufman et al. (2020) that have been used, including how we estimated the different uncertainty metrics using the estimates from 5 methods used in Kaufman et al. (2020), are already explained in L614-L617. More details can be found in Kaufman et al. (2020), and we believe it does not add value to repeat them in this manuscript.
Similarly, the details of Speleothem Isotope Synthesis and Analysis (SISAL) version 2 database (Comas-Bru et al., 2020), including the number of sites for the 2.5ka period, is provided in section 5.2 (now section 4.2 after revision). Specifically, lines 641-649 describe the methodology for the site-based comparison with model simulations, while details of statistics (RMSE, correlation, standard deviation) are thoroughly discussed across section 5.2. Figure 13 (Section 4.2 after revisions), Figure 14 and Figure 15 clearly support the summarized discussion related to site locations, regional demarcation and the statistical estimates for the regional comparison of model simulated climate conditions for 2.5ka period. Figure S4 also adds to the discussion here.

Regridding, seasonality and temporal window: We assume that this question is regarding the model output and reconstruction comparison. These specifics were not directly related with the proxy reconstructions we used here, however for the Kaufman et al. (2020) temperature reconstruction is only available as the latitudinal band and global means. Regarding the SISAL v2, which is a site-based data and the comparison methodology is described in detail in section 5.2 (After revision 4.2).

6. Discuss uncertainties more systematically: (i) forcings, (ii) internal variability, and (iii) mapping of LPJ PFTs to ModelE classes. If multiple mapping schemes were tested, please include the results or add them to the Supplement.

(i) forcings: We used the time periods (2.5k and preindustrial) specific GHG, Ozone and orbital forcings from the literature and this aspect is discussed there (Köhler et al., 2017; Loulergue et al., 2008; Otto-Bliesner et al., 2017; Schneider et al., 2013; Siegenthaler et al., 2005). Evaluating the impacts of the uncertainty in these forcings is beyond the scope of this study.

(ii) internal variability : To account for internal variability, we performed a Student t-test to assess statistical significance at the 5-95% confidence level with respect to the 100-year equilibrated control run. Stippling on the spatial plots indicates regions that are not statistically significant. Thus we only discussed the statistically significant changes.

(iii) mapping: Section 3.1 describes how we used different LPJ-LMfire-to-ModelE PFT mapping schemes and evaluated them for the preindustrial period. A detailed discussion on how various mapping schemes influence the surface temperature, rainfall and albedo is also presented. Further, the finalized mapping scheme is compared against the land cover used for preindustrial simulations. A supplementary table TS1 is included to summarize the details of different mapping schemes.

7. Clarify how fire is represented in LPJ-LMfire for these experiments: which ignition sources are included, how burned area is calibrated, and whether fire emissions feedback to ModelE. If emissions are excluded, state this explicitly.

Only lightning ignitions were included in the LPJ-LMfire simulations. Emissions of greenhouse gases and aerosols from simulated wildfires do not give feedback on the ModelE simulations as this would require the representation of atmospheric chemistry and transport processes that are not included in the version of ModelE we used.
We added the following in section 2.3.2:

"Lightning density was estimated based on modelled convective mass flux following Magi (2015). However, the feedback to climate due to fire-driven emissions are not included, as accounting for them would require active atmospheric chemistry and transport, which are not included in LPJ-LMfire".

8. Improve figure captions so each is interpretable without referring to the main text. All figures must include units, baseline (difference relative to what), averaging period, and statistical significance.

We revisited all figure captions to include the relevant details.

Minor comments:

1. Be consistent with "2.5 ka" wording – clarify whether you mean 2.5 ka BP (2500 years before present), 2.5kyr, or "mid-Holocene" and give exact calendar years used.

Thanks for pointing this out. We modified the text to be consistent with 2.5 ka and mid-Holocene (6 ka).

2. The manuscript lists a few CO_2 values (e.g., 271.4 ppm, ~279 ppm, 284 ppm). Make sure each value is linked to the correct experiment and source citation. Possibly a single table listing GHGs for each experiment would be useful.

Thanks for pointing this out, we modified the citation (Köhler et al., 2017) and since these are few values for specific time periods, We also added the GHG forcings details into table 2 (row 1 and 2).

3. You mention testing several LPJ-GISS PFT mapping schemes. Please show results (or at least diagnostics) illustrating how sensitive your key climate metrics are to the mapping choice.

Section 3.1 presents the analysis for the 3 mapping schemes we compared, and details about them are presented in table TS1 of the submitted manuscript.

4. A few citations seem incomplete or inconsistently formatted. Please check the references for completeness and adhere to the journal style.

Thanks for pointing this out, we made all necessary corrections.

5. In the discussion, the text implies strong climate impacts from the coupling that are not fully supported by the presented evidence. Tone down causal language where results are suggestive rather than robust and clearly label speculative statements.

In the discussion section, at L710 “strong influence” refers to the influence of including/excluding the bias correction in the coupling process. This is justified as the model drift towards colder climate conditions in the absence of a bias correction. However, we replaced this with the more suitable word “pronounced”.

References (Both RC1 & RC2)

Aleinov, I. and Schmidt, G. A.: Water isotopes in the GISS ModelE land surface scheme, Glob. Planet. Change, 51, 108–120, https://doi.org/10.1016/j.gloplacha.2005.12.010, 2006.

Charney, J., Quirk, W. J., Chow, S., and Kornfield, J.: A Comparative Study of the Effects of Albedo Change on Drought in Semi–Arid Regions, 1977.

Charney, J. G.: Dynamics of deserts and drought in the Sahel, Q. J. R. Meteorol. Soc., 101, 193–202, https://doi.org/10.1002/qj.49710142802, 1975.

Comas-Bru, L., Rehfeld, K., Roesch, C., Amirnezhad-Mozhdehi, S., Harrison, S. P., Atsawawaranunt, K., Ahmad, S. M., Brahim, Y. A., Baker, A., Bosomworth, M., Breitenbach, S. F. M., Burstyn, Y., Columbu, A., Deininger, M., Demény, A., Dixon, B., Fohlmeister, J., Hatvani, I. G., Hu, J., Kaushal, N., Kern, Z., Labuhn, I., Lechleitner, F. A., Lorrey, A., Martrat, B., Novello, V. F., Oster, J., Pérez-Mejías, C., Scholz, D., Scroxton, N., Sinha, N., Ward, B. M., Warken, S., Zhang, H., and SISAL Working Group members: SISALv2: a comprehensive speleothem isotope database with multiple age–depth models, Earth Syst. Sci. Data, 12, 2579–2606, https://doi.org/10.5194/essd-12-2579-2020, 2020.

DeFries, R. S., Field, C. B., Fung, I., Justice, C. O., Los, S., Matson, P. A., Matthews, E., Mooney, H. A., Potter, C. S., Prentice, K., Sellers, P. J., Townshend, J. R. G., Tucker, C. J., Ustin, S. L., and Vitousek, P. M.: Mapping the land surface for global atmosphere-biosphere models: Toward continuous distributions of vegetation's functional properties, J. Geophys. Res. Atmospheres, 100, 20867–20882, https://doi.org/10.1029/95JD01536, 1995.

Doughty, C. E., Loarie, S. R., and Field, C. B.: Theoretical Impact of Changing Albedo on Precipitation at the Southernmost Boundary of the ITCZ in South America, https://doi.org/10.1175/2012EI422.1, 2012.

Kaufman, D., McKay, N., Routson, C., Erb, M., Dätwyler, C., Sommer, P. S., Heiri, O., and Davis, B.: Holocene global mean surface temperature, a multi-method reconstruction approach, Sci. Data, 7, 201, https://doi.org/10.1038/s41597-020-0530-7, 2020.

Kim, Y., Moorcroft, P. R., Aleinov, I., Puma, M. J., and Kiang, N. Y.: Variability of phenology and fluxes of water and carbon with observed and simulated soil moisture in the Ent Terrestrial Biosphere Model (Ent TBM version 1.0.1.0.0), Biogeosciences, https://doi.org/10.5194/gmdd-8-5809-2015, 2015.

Köhler, P., Nehrbass-Ahles, C., Schmitt, J., Stocker, T. F., and Fischer, H.: A 156 kyr smoothed history of the atmospheric greenhouse gases CO_2, CH_4, and N_2O and their radiative forcing, Earth Syst. Sci. Data, 9, 363–387, https://doi.org/10.5194/essd-9-363-2017, 2017.

LeGrande, A. N. and Schmidt, G. A.: Global gridded data set of the oxygen isotopic composition in seawater, Geophys. Res. Lett., 33, https://doi.org/10.1029/2006GL026011, 2006.

Loulergue, L., Schilt, A., Spahni, R., Masson-Delmotte, V., Blunier, T., Lemieux, B., Barnola, J.-M., Raynaud, D., Stocker, T. F., and Chappellaz, J.: Orbital and millennial-scale features of atmospheric CH_4 over the past 800,000 years, Nature, 453, 383–386, https://doi.org/10.1038/nature06950, 2008.

Magi, B. I.: Global Lightning Parameterization from CMIP5 Climate Model Output, https://doi.org/10.1175/JTECH-D-13-00261.1, 2015.

Matthews, E.: Global Vegetation and Land Use: New High-Resolution Data Bases for Climate Studies, 1983.

Otto-Bliesner, B. L., Braconnot, P., Harrison, S. P., Lunt, D. J., Abe-Ouchi, A., Albani, S., Bartlein, P. J., Capron, E., Carlson, A. E., Dutton, A., Fischer, H., Goelzer, H., Govin, A., Haywood, A., Joos, F., LeGrande, A. N., Lipscomb, W. H., Lohmann, G., Mahowald, N., Nehrbass-Ahles, C., Pausata, F. S. R., Peterschmitt, J.-Y., Phipps, S. J., Renssen, H., and Zhang, Q.: The PMIP4 contribution to CMIP6 – Part 2: Two interglacials, scientific objective and experimental design for Holocene and Last Interglacial simulations, Geosci. Model Dev., 10, 3979–4003, https://doi.org/10.5194/gmd-10-3979-2017, 2017.

Pausata, F. S. R., Messori, G., and Zhang, Q.: Impacts of dust reduction on the northward expansion of the African monsoon during the Green Sahara period, Earth Planet. Sci. Lett., 434, 298–307, https://doi.org/10.1016/j.epsl.2015.11.049, 2016.

Pfeiffer, M., Spessa, A., and Kaplan, J. O.: A model for global biomass burning in preindustrial time: LPJ-LMfire (v1.0), Geosci. Model Dev., 6, 643–685, https://doi.org/10.5194/gmd-6-643-2013, 2013.

Schmidt, G. A.: Oxygen-18 variations in a global ocean model, Geophys. Res. Lett., 25, 1201–1204, https://doi.org/10.1029/98GL50866, 1998.

Schneider, R., Schmitt, J., Köhler, P., Joos, F., and Fischer, H.: A reconstruction of atmospheric carbon dioxide and its stable carbon isotopic composition from the penultimate glacial maximum to the last glacial inception, Clim. Past, 9, 2507–2523, https://doi.org/10.5194/cp-9-2507-2013, 2013.

Siegenthaler, U., Stocker, T. F., Monnin, E., Lüthi, D., Schwander, J., Stauffer, B., Raynaud, D., Barnola, J.-M., Fischer, H., Masson-Delmotte, V., and Jouzel, J.: Stable Carbon Cycle□Climate Relationship During the Late Pleistocene, Science, 310, 1313–1317, https://doi.org/10.1126/science.1120130, 2005.

Singh, R., Tsigaridis, K., LeGrande, A. N., Ludlow, F., and Manning, J. G.: Investigating hydroclimatic impacts of the 168–158 BCE volcanic quartet and their relevance to the Nile River basin and Egyptian history, Clim. Past, 19, 249–275, https://doi.org/10.5194/cp-19-249-2023, 2023.

Sitch, S., Smith, B., Prentice, I. C., Arneth, A., Bondeau, A., Cramer, W., Kaplan, J. O., Levis, S., Lucht, W., Sykes, M. T., Thonicke, K., and Venevsky, S.: Evaluation of ecosystem dynamics, plant geography and terrestrial carbon cycling in the LPJ dynamic global vegetation model, Glob. Change Biol., 9, 161–185, https://doi.org/10.1046/j.1365-2486.2003.00569.x, 2003.

Stocker, B. D., Roth, R., Joos, F., Spahni, R., Steinacher, M., Zaehle, S., Bouwman, L., Xu-Ri, and Prentice, I. C.: Multiple greenhouse-gas feedbacks from the land biosphere under future climate change scenarios, Nat. Clim. Change, 3, 666–672, https://doi.org/10.1038/nclimate1864, 2013.

Thonicke, K., Spessa, A., Prentice, I. C., Harrison, S. P., Dong, L., and Carmona-Moreno, C.: The influence of vegetation, fire spread and fire behaviour on biomass burning and trace gas emissions: results from a process-based model, Biogeosciences, 7, 1991–2011, https://doi.org/10.5194/bg-7-1991-2010, 2010.

Tiwari, S., Ramos, R. D., Pausata, F. S. R., LeGrande, A. N., Griffiths, M. L., Beltrami, H., Wainer, I., de Vernal, A., Litchmore, D. T., Chandan, D., Peltier, W. R., and Tabor, C. R.: On the Remote Impacts of Mid-Holocene Saharan Vegetation on South American Hydroclimate: A Modeling Intercomparison, Geophys. Res. Lett., 50, e2022GL101974, https://doi.org/10.1029/2022GL101974, 2023.