We are grateful to the referees for their time and energy in providing helpful comments and guidance that have improved the manuscript. In this document, we describe how we have addressed the reviewers' comments. Referee comments are shown in black italics and author responses are shown in blue regular text. A manuscript with tracking changes is attached at the end.

Reviewer #1

This manuscript presents and evaluates a new model framework that integrates the widely used ECHAM6 atmospheric general circulation model with the dynamic vegetation model iMAPLE. The evaluation compares simulated carbon and water fluxes and other variables such as soil temperature and moisture against observational benchmarks as well as against the ECHAM6 model coupled with the land surface model JSBACH.

While the manuscript itself is well presented and the figures are overall of good quality, I would argue that the manuscript requires substantial revision and restructuring before it can be published. The following main points would need to be addressed:

- Thank you for your positive evaluations. In this revision, we have made these major changes following your comments:
  (1) We clarified that the primary objective of this study is to investigate whether improved carbon and water flux simulations by iMAPLE can enhance climate simulations in the original ECHAM6 framework with the JSBACH vegetation module.
  (2) We emphasized the central role of land–atmosphere coupling and added more detailed descriptions of the related parameterizations and processes.
  (3) We revised Figures 5 and 6 to more clearly demonstrate how ECHAM6-iMAPLE reduces the simulation biases present in ECHAM6-JSBACH.

1) As noted by the authors, both JSBACH and iMAPLE have already been extensively evaluated within the Global Carbon Budget (GCB) framework (the latest version being Friedlingstein et al. 2026, Figure S11), with results also publicly available online. The GCB2025 effort evaluates the same variables, using mostly the same benchmarks and *evaluation metrics. It is thus unclear what gap this study fills other than repeating this analysis (at least for carbon and water fluxes as well as LAI). The key difference is that both models here were coupled to ECHAM6, whereas GCB2025 evaluates the model 'offline' (i.e. using a common, prescribed forcing). The manuscript should therefore clearly articulate what coupling to the atmosphere changes and what additional insight is gained. I recommend restructuring the paper to focus more explicitly on coupling effects, as partially illustrated in Figures 5 and 6.*

- We sincerely thank you for these insightful comments. We agree that the original manuscript failed to emphasize the central role of land–atmosphere coupling. In the revised manuscript, we have restructured the framing around land–atmosphere coupling rather than repeating an offline evaluation:

  In the Introduction section, we have clarified the motivation for coupling iMAPLE into ECHAM6 as follows:
  "The original ECHAM6 model employs the Jena Scheme for Biosphere-Atmosphere Coupling in Hamburg (JSBACH) to represent vegetation dynamics and terrestrial carbon cycling (Giorgetta et al., 2013). Here, we replace the carbon and water simulations by JSBACH with iMAPLE, a global dynamic vegetation model designed to simulate plant growth and terrestrial carbon cycle interactively (Yue et al., 2024). Both JSBACH and iMAPLE have been evaluated offline in the multi-model intercomparison project for Global Carbon Budget, where iMAPLE shows improved performance in simulating key carbon and water fluxes compared with JSBACH (Friedlingstein et al., 2025). We evaluate the dynamically simulated carbon and water fluxes from ECHAM6-iMAPLE, and compare them with simulations using the original ECHAM6-JSBACH framework. In particular, we investigate whether the updated vegetation representation improves the simulation of critical land-surface variables, including soil temperature, soil moisture, near-surface air temperature, and precipitation." (Lines 84-97)

  In the Methods section, we have provided a detailed description of the key land-atmosphere coupling processes. Please see our response below.

2) Related to this, the Methods section needs to better reflect the Results. It is unclear *why the Methods description focuses on photosynthesis even though this is the same as in the offline models, which have already been evaluated. The Methods should focus more on the coupling aspect of the model, i.e. addressing the question of how land-atmosphere feedbacks differ between the models and what effects this has on soil moisture, temperature, and other variables.*

- Thank you for this constructive suggestion. In the revised paper, we have restructured Methods section accordingly. Detailed photosynthesis equations have been substantially shortened. Instead, we have expanded Section 2.3 to explain how key land-state variables from iMAPLE replace the corresponding JSBACH fields, how these replacements revise the surface energy and water balances, and how the resulting heat and moisture fluxes form the atmospheric lower boundary:

  "ECHAM6 provides hourly meteorological variables to iMAPLE, including precipitation, surface air temperature, wind speed, humidity, surface pressure, CO_2 concentrations, direct and total radiation. In return, iMAPLE feeds back simulated soil temperature, soil moisture, and ET to ECHAM6. These variables further change the surface energy and water balance, thereby altering heat and moisture fluxes that define the atmospheric lower boundary conditions and regulate near-surface climate. Land-atmosphere energy exchange is governed by the surface energy balance, which constrains the transfer of energy between the land surface and the atmosphere:

  $$C\frac{\partial T_{surf}}{\partial t} = R_{net} + H_{sensible} + H_{latent} + G \quad (15)$$

  where T_{surf} is the surface temperature, C is the heat capacity of topmost soil layer, R_{net} denotes the net radiation, $H_{sensible}$ is the sensible heat flux, H_{latent} is the latent heat flux. G represents the ground heat flux, which is obtained from the soil temperature profile:

  $$G = -\lambda_s \frac{\partial T}{\partial z}\Big|_{Z_{surf}} \quad (16)$$

  where λ_s is the soil thermal conductivity and z is the depth. Replacing soil temperature therefore revises the near-surface thermal gradient and G, which in turn shifts the tendency of T_{surf} and the partitioning of surface energy into sensible heat. The latent heat flux is linked to ET as follows:

  $$H_{latent} = L * ET \quad (17)$$

where L is the latent heat of vaporization. Replacing ET revises H_{latent} and affects the surface energy balance. The replacement of near-surface soil moisture updates the land hydrological state, thereby modifying available soil water and regulating subsequent land-atmosphere moisture exchange. The resulting surface heat and moisture fluxes provide the lower boundary conditions for vertical turbulent transport of dry static energy and specific humidity in ECHAM6. Specifically, an implicit surface-atmosphere coupling scheme uses surface dry static energy and saturated surface humidity, constrained by the surface energy balance, as lower boundary conditions, after which the atmospheric column is updated upward from the lowest model level. Consequently, changes in land surface states, including soil temperature, soil moisture, and ET, propagate to near-surface air temperature and humidity, and further influence the atmospheric column through turbulent diffusion." (Lines 298-328)

3) Paper framing: in addition to the points above, both the abstract and the introduction would need to make clear that this manuscript is not just about an evaluation of ECHAM6-iMAPLE but also, in large parts, a comparison with ECHAM6-JSBACH. It is a bit surprising that JSBACH is mentioned fairly late in the manuscript (section 2.1.2).

- In the revised paper, we state explicitly that the study evaluates ECHAM6–iMAPLE relative to ECHAM6–JSBACH:

  In the Abstract:
  "… (iMAPLE v1.0) into the ECHAM6 atmospheric general circulation model, replacing carbon and water fluxes simulated by the original JSBACH vegetation module. The coupled model is evaluated against reanalysis, benchmark, and satellite datasets. Compared with the original ECHAM6–JSBACH configuration, ECHAM6-iMAPLE substantially improves simulations ..." (Lines 26-31)

  In the Introduction:
  "The original ECHAM6 model employs the Jena Scheme for Biosphere-Atmosphere Coupling in Hamburg (JSBACH) to represent vegetation dynamics and terrestrial carbon cycling (Giorgetta et al., 2013). Here, we replace the carbon and water simulations by JSBACH with iMAPLE, a global dynamic vegetation

model designed to simulate plant growth and terrestrial carbon cycle interactively (Yue et al., 2024)." (Lines 84-88)

"We evaluate the dynamically simulated carbon and water fluxes from ECHAM6-iMAPLE, and compare them with simulations using the original ECHAM6-JSBACH framework. In particular, we investigate whether the updated vegetation representation improves the simulation of critical land-surface variables, including soil temperature, soil moisture, near-surface air temperature, and precipitation." (Lines 92-96)

Furthermore, both the abstract and the conclusion refer to modelling aspects or improvements (e.g. carbon allocation, parameterisation of Vcmax) that are not described in the Methods, and it remains unclear which model differences drive the reported results. If these processes are used to explain differences between models, a more targeted analysis (e.g. sensitivity experiments or clearer attribution) would be needed to support these interpretations.

- We agree that key model configurations (e.g., Vcmax, phenology, and carbon allocation) should be described in greater detail in the Methods section. In the revised manuscript, we have provided a more comprehensive description of these physiological parameters to explicitly clarify the differences between the models.

For iMAPLE:

"The rates J_c, J_e, and J_s are parameterized as functions of environmental meteorological conditions and photosynthetic capacity, including the maximum carboxylation rate (V_{cmax}, μmol m^{-2} s^{-1}) (Collatz et al., 1991; Collatz et al., 1992). V_{cmax} is derived from its optimum value at 25 °C (V_{cmax25}) through a temperature-dependent Q_{10} function. PFT-specific V_{cmax25} values have been calibrated against extensive site-level eddy covariance measurements from more than 200 FLUXNET sites (Yue et al., 2024)" (Lines 134-140)

"Phenology in iMAPLE is represented by a prognostic phenological factor (f) that is updated daily. The phenology scheme is based on the framework of Kim et al. (2015) and was refined using multi-year LAI measurements at four U.S. forest sites and leaf phenology records from hundreds of ground sites within the U.S. National

Phenology Network (Yue et al., 2015). For short-stature vegetation such as tundra, savanna, and shrubland, the phenological state is governed by temperature and/or soil moisture, with the dominant control set by PFT and regional climate (Delbart and Picard, 2007). Deciduous forests likewise use temperature- and moisture-dependent thresholds, whereas evergreen needleleaf and evergreen broadleaf PFTs adopt a constant phenological factor, with frost hardening applied to reduce V_{cmax} for needleleaf forests in cold seasons. Cropland phenology is prescribed from planting and harvest calendars. LAI is updated at 10-day intervals based on total leaf carbon and vegetation phenology:

$$LAI = f \times LAI_b \tag{3}$$

Here, LAI_b is related to vegetation carbon, which is the sum of leaf (C_1), root (C_r), and stem pools (C_w):

$$C_{veg} = C_1 + C_r + C_w \tag{4}$$

As a result, carbon assimilation determines the total carbon available for allocation, whereas carbon allocation dynamically regulates vegetation development (Cox, 2001; Clark et al., 2011)." (Lines 149-167)

For JSBACH, the photosynthetic parameterizations differ from those in iMAPLE. In addition, key parameters such as Vcmax have not undergone global calibration. Furthermore, although LAI is dynamically simulated, it is decoupled from carbon allocation processes. We clarified in Section 2.2.1 with following key points:

"In JSBACH, photosynthesis of C_3 plants is represented using the Farquhar model (Farquhar et al., 1980), consistent with iMAPLE. For C_4 plants, JSBACH utilizes the Collatz model (Collatz et al., 1992). The primary difference between the Collatz and Farquhar formulations lies in their parameterization of the carboxylation rate (J_c) and the electron transport rate (J_e)" (Lines 240-244)

"LAI is dynamically simulated using the phenological model of LoGro-P, which does not feed carbon allocation back into leaf phenology (Dalmonech and Zaehle, 2013; Dalmonech et al., 2015)." (Lines 262-264)

4) Benchmark datasets, particularly MERRA-2, need to be described in more detail. For example, how is soil moisture calculated in MERRA-2 and what assumptions are made? In addition, details on the simulation setup is required to ensure reproducibility *of the analysis.*

- In the revised manuscript, we have expanded Section 2.4 to clarify the MERRA-2 soil-moisture definition and conversion, and we have added further details of the simulation setup in Section 2.3 for reproducibility:

  "Near-surface soil moisture was derived from the MERRA-2 surface wetness variable GWETTOP, which represents relative saturation in the topmost soil layer. GWETTOP was converted to volumetric water content ($m^3\ m^{-3}$) by multiplying it by the grid-cell soil porosity." (Lines 360-363)

  "The experiments were driven by observed sea surface temperature and sea ice fraction without atmospheric nudging. The interactive HAM/MOZ chemistry and aerosol modules were disabled. Greenhouse gas concentrations followed the CMIP6 historical pathway. Both ECHAM6-iMAPLE and ECHAM6-JSBACH simulations used identical atmospheric settings at T63L47 resolution for the period of 2000-2014. The first five years were used for model spin-up, and the remaining ten years were averaged for analysis and performance assessment." (Lines 342-348)

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