Summary

This manuscript examines how tropical rainfall clusters at large scales and how this clustering affects Earth's radiation budget. The authors quantify clustering using the average size of contiguous regions where rainfall exceeds the top 5% threshold, analyzing patterns in both year to year variations and long-term climate projections under global warming. The study combines observational data with climate model simulations to reveal several key findings. Notably, clustering is sensitive to Pacific sea surface temperature gradients, with the strongest clustering occurring during El Niño events in both observations and models. Under future warming, models project an increase in clustering, though with substantial inter-model spread. While clustering influences cloud cover and humidity patterns, its relationship to climate feedback remains unclear. It is worth highlighting that the narrowing of heavy rainfall toward the equator, a key manifestation of increased clustering, accounts for approximately 45% of the variance in projected tropical drying. Despite these valuable insights, the manuscript needs improvement in several areas to enhance its scientific rigor and clarity through better explanation of concepts, reorganization of structure, and more detailed elaboration of key points.

General comments

1. The definition and interpretation of the *degree of clustering* require further clarification. The authors define heavy precipitation features as 8-connected contiguous regions exceeding the top 5% rainfall threshold and use the mean area of these features (A_m) as their clustering metric. While this is a useful quantitative measure, A_m alone does not unambiguously represent spatial organization.
    - Incorporating the number of clusters (N) already identified in your analysis or using combined metrics such as A_m/N could better isolate true aggregation effects. Including a simple schematic illustrating how A_m, A_f, and N are derived and interrelated would also help readers visualize how these metrics capture different aspects of precipitation organization.

    - Providing justification or sensitivity testing for the 5% rainfall threshold would further strengthen the robustness of the analysis.
2. The title suggests that the study examines large-scale clustering and its radiative implications across timescales, but the analyses presented primarily focus on interannual variability (e.g., ENSO-related changes) and long-term climatological projections under warming. If shorter timescales (e.g., intraseasonal or daily variability) were not explicitly analyzed, the phrase *"across timescales"* may be misleading. Please consider revising the title to better reflect the actual scope of the analysis.

Specific comments

1. Abstract

- The abstract effectively introduces the study's core focus but is somewhat verbose and contains subjective statements that should be distilled into an objective summary. It should follow a structured, concise format emphasizing the study's motivation, main methods, key findings, and implications without overgeneralizations.

2. Introduction

- The introduction provides an excellent synthesis of literature but lacks a clear statement of the research question and novelty.
- The discussion of prior work (Bony et al., 2020; Wing et al., 2018; Schiro et al., 2022) is strong but lacks critical integration, what gaps remain unresolved?

3. Data and Methods

- The decision to fix $A_f = 0.05$ is elegant for cross comparison but may distort physical interpretation, since heavy precipitation areas vary seasonally and regionally. Discuss implications of this constraint.

- The partial correlation approach (Eq. 2) is well explained, but no uncertainty estimates or sensitivity analyses are shown. How robust are results to the detrending method or to using different SST indices?
- The section would benefit from a schematic illustrating how A_m, A_f, C_z, and C_m are related.
- The high-resolution IFS-FESOM dataset is interesting, but the limited period (2025–2049), make it less convincing as an independent test case. Discuss its limitations more explicitly.

3. Spatial Patterns and Variability

- The discussion of A_f vs. A_m correlations are strong but should be supported by a physical rationale (e.g., do changes in A_f correspond to energetic constraints on tropical precipitation area fraction?).

4. SST Controls

- The link between El Niño–like SST gradients and clustering is one of the strongest contributions of the paper. However, the interpretation in Section 4 could better distinguish between *internal variability* (ENSO-driven) and *forced responses* (warming induced SST patterns).
- The regression of A_m onto ONI (Fig. 7) is convincing, but the authors should discuss causality: is clustering a *response* to SST anomalies, or does it feedback onto them via radiative effects?
- Figures 8–9: Clarify whether SST changes are computed over the full tropical belt or Pacific-only. Also, the regression strength (R^2 values) should be indicated.

5 Cloud and Humidity Effects

- The conclusion that clustering has “little connection” to radiative feedbacks (lines 479–485) contradicts some earlier findings and is not fully supported statistically. Provide a correlation matrix or model ensemble summary table linking Am changes to RH, LCFd, and ECS.

- Figures 10–12 are crucial but need more concise interpretation. For example, explain why observed RH changes vanish after controlling for Af, while model behavior diverges.
- The 45% explained variance in projected drying (lines 510–513) is intriguing but based on only a few models with outlying behavior, please include a robustness test.

6. Summary and Discussion

- The summary and discussion (Section 6) accurately synthesizes results but lacks a critical evaluation of uncertainties.
- The claim that clustering changes do not constrain ECS should be tempered; perhaps "current metrics of clustering do not provide robust constraints on ECS."
- Consider figures emphasizing key mechanisms (e.g., a schematic linking clustering → SST gradient → humidity/cloud response).