

Review Report

Summary

This paper, “Response of marine post-frontal clouds to Gulf Stream variability” by Chen et al., presents a well-structured and insightful modeling analysis of how variations in Gulf Stream (GS) sea surface temperature (SST) mean state and gradients modulate post-frontal cloud (PFC) morphology during a cold-air outbreak (CAO) over the western North Atlantic. Using high-resolution WRF simulations and complementary Lagrangian trajectory analysis, the authors effectively isolate the effects of uniform SST warming and enhanced SST gradients on boundary layer thermodynamics, cloud structure, and air mass origins. The study provides valuable mechanistic understanding relevant to marine cloud feedback and ocean–atmosphere coupling. The paper is scientifically sound, well-motivated, and clearly written. However, some aspects require clarification or refinement, particularly regarding experiment generality and several grammatical or formatting inconsistencies. I recommend minor to moderate revision before acceptance.

General Revisions (Major Comments)

Scope of Analysis – Limited Case Study (p.8–9, §2.2–2.3)

The paper bases its findings on a single CAO event (March 1, 2020). While the case is well validated and mechanistically relevant, the generalization to long-term Gulf Stream variability should be qualified. Please clarify that the results represent a single-case process study rather than a statistical climatology and discuss how these findings might extend (or not) to other CAO regimes.

Quantitative Uncertainty and Statistical Significance (p.13–14, L277–287, Fig. 3)

Differences between experiments (e.g., “+20.8% reduction”, “–15.5% decrease”) are reported without statistical context. Please indicate whether these differences exceed natural variability or are visually interpreted only. Adding standard deviations or domain-averaged variability estimates would strengthen the conclusions.

Aerosol–Cloud Interaction Context (p.6–7, §1)

The discussion of aerosol sources and composition is excellent background but is not directly analyzed in the experiments. Please clarify whether aerosol loading and composition were held constant across runs.

Terminology Consistency (entire text)

“GradPlus” and “Gradplus” are used interchangeably. Standardize to one form throughout (e.g., GradPlus). Likewise, ensure consistent symbol formatting for θ_e , q_v , q_l , etc.

Reference Formatting (p.29–33)

Several references contain duplicated author names (e.g., “Andrea F. Corral, Andrea F. Corral”; “Florian Tornow, Florian Tornow”). This appears to be a BibTeX export artifact. Please review and correct the bibliography for duplication and capitalization consistency.

Minor Revisions (Editorial / Language)

Introduction

p.5, L69: “drive mesoscale air-sea interactions significantly influence...” → “drive mesoscale air-sea interactions that significantly influence...”

p.6, L92–93: “composited to warming-induced SST increases and gradient weakening— affect cloud macro- and microphysical properties.” → “comprising both SST warming and gradient weakening—can affect cloud macro- and microphysical properties.”

p.7, L123–124: Remove duplication: “field campaign field campaign” → “field campaign.”

Methods

p.10, L199–203: Redundant phrase — keep one:

“(A1F1 scenario with intensive fossil fuel burning and rapid economic growth, IPCC, 2023)”
→ remove the repeated description after parentheses.

Discussion

p.23, L425–426: “interfere with the interactions of θ and q_v between north and south of the GS.” → “interfere with the interactions of θ and q_v between regions north and south of the GS.”

p.24, L440–441: “dominate within the boundary layer in the middle and southern regions” → “dominate within the boundary layer of the middle and southern regions.”

Conclusions

p.27, L506: “Mean SST warming (+4 K) leads to a warmer, moister boundary layer, promoting larger cloud sizes.” → Add comma after “layer.”

p.27, L521–523: Long sentence can be split for readability. Suggest:

“This study introduces two novel approaches: (1) isentropic analysis to isolate energy transport and (2) Lagrangian tracer tracking to quantify air mass sources. These methods reveal nonlinear PFC responses to SST variations.”