

Authors' Response to the Review Comments

Response: We sincerely appreciate the time and effort invested by the editor and reviewers in providing helpful suggestions and constructive comments on this manuscript. We have carefully addressed all the comments raised in their review reports. Detailed point-by-point responses to the specific comments are provided below (in blue).

Review #2

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 postfrontal 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 airmass 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.

Response: Thank you for the encouraging feedback and constructive suggestions. We have carefully considered all the points raised and have undertaken a comprehensive revision accordingly.

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.

Response: We have added the following clarification in lines 542–543: “Nevertheless, as this study examines a single case, extending these findings to long-term Gulf Stream variability requires further investigation.”

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.

Response: In lines 262 – 264, the numbers refer to variations in the spatial area of each zone. For this quantity, each zone has a single area value; therefore, domain-averaged values and standard deviations are not applicable. Nonetheless, we have replaced the word “coverage” with “spatial area” to avoid confusion in line 262.

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.

Yes, we use the Morrison two-moment microphysical scheme (as indicated in line 175), and the cloud droplet number concentration is held constant across all runs. The aerosol – cloud interaction context is instead inferred from air-mass trajectories, which have strong implications for aerosol sources, given that marine locally sourced aerosols and aerosols originating from continental regions are known to differ substantially. In Lines 497-503, we have revised the sentences to “Aerosols linked to clouds in the examined regions are influenced by a mix of continental and marine sources. Our results regarding the air parcel origins implicitly suggest that SST variations associated with the GS trigger distinct shifts in aerosol composition. Specifically, marine aerosols influence Boxes 2-4 in Ctrl experiments and all four boxes in Plus4 experiments via air parcels originated from sea surface, while continental aerosols influence the other boxes through air parcels originated from continents. This subsequently alters aerosol-cloud interactions over the WNAO region.” to avoid the confusion.

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 , etc.

Response: We have now checked the manuscript and revised the text to make the terminology consistent.

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.

Response: We have fixed the formatting issues and ensured consistency.

Minor Revisions (Editorial / Language)

Introduction

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

Response: We have corrected the sentence in lines 69-70.

p.6, L92–93: “composed 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.”

Response: We have revised the sentence in lines 92-93.

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

Response: We have removed the duplication in line 124.

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.

Response: We have removed the redundant phrase in lines 200-202.

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.”

Response: We have corrected the sentence in lines 439-440.

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.”

Response: We have corrected the sentence in line 454.

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

Response: Done.

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 airmass sources. These methods reveal nonlinear PFC responses to SST variations.”

Response: We have revised the sentences in lines 538-540.