We appreciate the reviewers' and the editor's valuable comments and constructive suggestions, which have helped us greatly improve the manuscript. We have carefully revised the manuscript according to these comments. Point-by-point responses are provided below. The original comments from the reviewers are in black; our responses are in blue; and the quotations of the corresponding revisions from our manuscript are in *italics*.

Replies to Reviewer #2

In this study, the authors perform a set of experiments using the fully coupled WRF-ROMS to understand the effect of aerosols on Hurricane Katrina. The results are quite interesting and the authors examine multiple aspects of aerosol effects on the storm. The main takeaway is that the storm gets weaker in its inner-core, but precipitation is enhanced, especially away from the storm center. They also conduct some mechanistic analysis to explain their results. Overall, I like the study and believe it'll be a good contribution, provided they address a few concerns listed below.

Line 20: I would just call them intense storms. The phrase 'with a high Saffir-Simpson scale' sounds a bit strange.

Revised as suggested.

Lines 80-86: Ekman upwelling is only important for slow moving storms. The main reason for sea surface cooling under TCs is vertical mixing.

We agree with the reviewer that Ekman upwelling is only important for slow moving storms and it is vertical mixing mainly responsible for the sea surface cooling under TCs. As such, we replaced the term 'upwell cooling' with 'vertical mixing cooling' in all the related places through the manuscript, particularly in following statements:

Line 33-35: *The ocean feedback following the aerosol microphysical effects tends to mitigate the vertical mixing cooling in the ocean mixing layer and offsets the aerosol-induced storm weakening…*

Line 82-85: *One such typical air-sea interaction is sea surface cooling due to vertical mixing, sometimes due to the Ekman upwelling for slowly-moving storms, as TCs pass by the ocean, which can lead to negative feedback to storm intensity because the cooler deep ocean temperature underneath the TC storm…*

Line 101-103: *…a 3-D ocean model coupled with the atmosphere model is a more advanced tool to obtain more accurate vertical mixing and/or upwelling cooling and thereby more accurate aerosol effect on TC power.*

Although there is some uncertainty in the aerosol effect on TCs, some previous work has been done to address this that must be acknowledged (eg. Souri et al. (2020))

We have now discussed Souri et al. (2020) and added the following description regarding their findings:

Line 78-80: *More recently, Souri et al. (2020) reported the aerosols over Houston tend to cause a moderate increase in precipitation, but the reference simulation was not comprehensively evaluated by observations.*

Is there a reason why the authors chose the case of Hurricane Katrina for this study? Considering that there have been other impactful storms in the Gulf more recently (eg. Harvey), I wonder what the motivation might be to pick this particular storm.

Comparing to other hurricanes over the Gulf, Hurricane Katrina can better serve our research goals which aim to evaluate the combined effects of aerosol and ocean coupling feedback on the destructiveness of a typical tropical cyclone, including heavy precipitation, storm surge, and strong winds. The specific reasons of choosing Katrina over Harvey are provided as followed: 1) Hurricane Katrina is well known for producing the most severe storm surge on record. It caused widespread devastation and flooding, especially in New Orleans. The storm surge from Katrina reached a peak exceeding 10 m in Pass Christian, Mississippi, which is the highest surge ever measured in the U.S. Although Hurricane Harvey also caused severe storm surge with a peak of 4 m, it is much less significant than Katrina; 2) the ocean coupling feedback likely played a role in modulating the destructiveness power of Katrina since the severe damages caused by Katrina occurred when it just made a landfall. In contrast, the ocean coupling feedback likely contributed little to the power of Hurricane Harvey when it made significant precipitation over Houston region because the heavy precipitation associated with Harvey occurred several days after its landfall. As such, Harvey is not a good case for examining the ocean coupling feedback on the destructiveness (i.e., heavy precipitation and thereby urban flooding). We added some description about the motivations to use Katrina as the study object as below:

Line 119-123: *Hurricane Katrina is selected as the case for this modeling study is because it can well serve our research goals aiming to evaluate the combined effects of aerosol and ocean coupling feedback on the destructiveness of a typical tropical cyclone due to 1) its most severe storm surge on record in U.S. and 2) the like role of ocean coupling feedback in modulating the destructiveness power of the storm.*

Lines 234-235: I'm not sure this is the correct interpretation. When the storm moves slowly, cooling is enhanced due to more sustained mixing and upwelling.

It is a correct interpretation. The slow-moving storm leads to more sustained mixing and upwelling and thereby more intensive cooling. We have modified the statement below for clarification:

Line 239-241: …*the storm translation affects SST since vertical mixing and upwelling of cold deep ocean water would be more sustained when the storm moves more slowly and thereby the cooling can be stronger.*

Lines 256-258: Is the storm dissipation stage related to landfall? If so, how can ocean coupling affect the storm when it is interacting with land?

No, the dissipation started after 48 hours from the simulation started while it landed around the 60th hour. Hence, the ocean coupling can make impacts on the storm strength between 48 – 60 hours. To avoid confusion, we indicated the landfall time in the statement as below:

Line 260-264: *As the storm starts to dissipate after 48 hours but before 60 hours, the difference in minimal SLP (maximal surface wind speed) for the coupled simulation pair is larger (more negative) than the uncoupled one. In other words, the ocean coupling effect at the storm dissipating stage (48-60 hours) can sustain a longer and more significant aerosol weakening effect than the case without ocean coupling.*

Lines 282-284: Are we saying that under aerosols, the storm produces more precipitation despite being in a weakened state?

Yes, the polluted storm produces more precipitation despite being in a weakened state (measured by the maximum wind speed and minimal surface pressure near the eyewall). The reason is because the weaken storms were enlarged in size and thereby associated with a larger precipitation area and more precipitation (see Figs. 5d and e).

Section 3.3: While the effect of aerosols on precipitation is more straightforward to understand, the impact on storm surge is less clear. Surge depends not just on the intensity of the storm, but also on the orientation of the winds relative to the coastline. In other words, the integrated kinetic energy could be a metric of the destructive potential, but its direct relevance to storm surge is unclear. On the other hand, the examination of sea-level heights is a step in the right direction. Can you also plot the wind vectors in the right column of fig. 9? It'll be interesting to understand the alternating high and low sea-level anomalies near the Mississippi-Alabama coast.

As suggested by the reviewer, we have now added wind vectors in Fig. 9c. The reviewer raised a good point that the orientation of the winds relative the coastline also contributes to the storm surge development. As indicated by the reviewer, from Fig. 9a at 65 hours the sea-level height anomalies near the Mississippi-Alabama coast were negative at west (about 89.5 °W) but changed to positive at east (about 88.0 °W, where the Dauphin Island is located). It is found that these alternating high and low sea-level anomalies near the Mississippi-Alabama coast indeed can be better interpreted when we combined the effect of the changes in wind intensity (Fig. 9b) with the wind orientation relative to coastline (Fig. 9c). For example, the wind vectors in the P_C case (blue arrows in Fig. 9c) appears less perpendicular to the coastline than that in the C_C case in the coastal regions to the west of the Dauphin Island, which was less efficient for water pileup over the shore in the P_C case and thereby the negative anomalies in sea-level height from clean to polluted aerosol conditions (Fig. 9a). At or to the east of Dauphin Island, the two cases show very similar wind directions, but the wind speed in P_C is stronger than that in C_C (the warm color shading in Fig. 9b), resulting in more water piling up over the shore and thereby the positive anomalies in sea-level height from clean to polluted aerosol conditions (Fig. 9a). We have added these new findings based on the new panels in Fig. 9c into the manuscript body text and modified some original discussions as below:

Line 337-351: *Given that storm surge associated with tropical cyclones can be determined by both the strength and orientation of winds relative to coastline, we derive and examine three snapshots of the wind speed difference between the coupled polluted and clean simulations (Fig. 9b) as well as wind vectors for the two cases (Fig. 9c) over New Orleans coastal area when Katrina passed over. The alternating high and low sea-level height anomalies can be interpreted by the combined effects of the changes in wind intensity and orientation when storm approaches the coastal regions. For instance, the stronger surface wind (i.e., positive differences in wind speed) cyclonically around the storm in the polluted simulation are found over certain shore regions, e.g., near Shell Beach at 64 hours or Dauphin Island at 65 hours.*

The enhanced wind can push more water toward the shore, and more water can pile up over the shore, eventually leading to more severe storm surge under the polluted condition. As for the significant negative anomalies in sea-level height from clean to polluted aerosol conditions, e.g., at 65 hours over the Mississippi-Alabama coast to the west of the Dauphin Island site (Fig. 9a), it is found that there are the less perpendicular wind vectors to the coastline in the P_C case than that in the C_C case, resulting in less efficient water pileup in the P_C case when the wind push water to the shore.

Lines 387-397: Can aerosols directly affect SSTs through a modulation of the cloud radiative feedbacks? In other words, what is the effect of the aerosols on the pre-storm environment?

Aerosols can directly affect SSTs through a modulation of the cloud radiative feedbacks through the Twomey effect, i.e., brighter and more reflective clouds in the presence of aerosols, and the Albrecht effect, i.e., delayed precipitation and more persistent clouds in the presence of aerosols. Both effects presumably reduce the amount of solar radiation that reaches the surface and thereby lower SSTs, particularly in the pre-storm environment. However, our simulations in this study started on August 27, 2005, when the storm of Hurricane Katrina had already formed and soon developed into the rapid intensification stage. It is a good question for a separate study.

The radial profiles of wind stress (Fig. 12) show that in the aerosol case, the peak winds shift farther from the center. Does it mean that the hurricane eye tends to be larger in the presence of aerosols.

Yes, the shift of the peak winds farther from the center indeed means that the hurricane eye tends to be larger in the presence of aerosols. This is also evidence in Fig. S1b. We added this point into text as below:

Line 464-465: *Also note that the peak winds shift farther from the center, suggesting that the eye of the polluted hurricane gets larger, which is evident in Fig. S1b as well.*

Finally, how much can we generalize based on this case study.

Our primary goal by conducting the case study of Hurricane Katrina is to provide physical insights into the mechanism behind the combined effect of aerosol and ocean coupling on hurricane storm development and thereby destructiveness. The identified mechanisms and modeling technique of this study are generalizable for the study of aerosol-tropical cyclone interactions.

First, the application of the 3D cloud-resolving, aerosol-aware atmosphere-ocean coupled modeling technique (WRF-ROMS) in this study paves the way for its utilization in investigating other case studies involving interactions between aerosols and tropical cyclones. Notably, our study showcases the superior performance of the WRF-ROMS model compared to a 1-D ocean model coupled with WRF, particularly in accurately simulating vertical mixing and upwelling cooling induced by the passage of storms.

Secondly, through the modeling sensitivity study on this case we have elaborated the physical mechanisms by which the combined effects of aerosols and ocean feedback modulate the storm thermodynamics and thereby its destructiveness. For example, we found that because of decreasing moist static energy supply and enhancing vorticity Rossby wave outward propagation, which were both caused by aerosols, the storm tends to be enlarged at the cost of intensity in polluted environment. Also, the ocean feedback following the aerosol microphysical effects tends to mitigate the vertical mixing and/or upwelling cooling and offsets the aerosol-induced storm weakening, by invigorating cloud and precipitation near the eyewall region. While acknowledging the case-specific nature of these relationships, it is conceivable that the elucidated physical mechanisms hold varying degrees of significance across diverse hurricane systems, contingent upon aerosol pollution conditions and thermodynamic contexts. Hence the direct generalizability may vary, but the insights gleaned from our study can serve as a valuable reference point for future inquiries that seek to unravel the complexities of hurricane behavior under polluted oceanic conditions.

As such, we have now added some discussions into the manuscript as below to underscore the possible generalization of the findings drawn from our case study:

Line 508-520: *Despite a case study conducted, the identified mechanisms and modeling technique of this study are generalizable for the study of aerosol-tropical cyclone interactions. Specifically, the application of the 3D cloud-resolving, aerosol-aware atmosphere-ocean coupled modeling technique (i.e., WRF-ROMS) in this study paves the way for its utilization in investigating other case studies involving interactions between aerosols and tropical cyclones. Notably, our study showcases the superior performance of the WRF-ROMS model compared to a 1-D ocean model coupled with WRF in accurately simulating vertical mixing and upwelling cooling under TC storms. Moreover, while acknowledging the case-specific nature of these relationships, it is conceivable that the elucidated physical mechanisms hold varying degrees of significance across diverse hurricane systems, contingent upon aerosol pollution conditions and thermodynamic contexts. Hence the direct generalizability may vary, but the insights gained from our study can serve as a valuable reference point for future inquiries that seek to unravel the complexities of hurricane behavior under polluted oceanic conditions*.

Last but not least, our results of this case study have meaningful implications for the hurricane forecast community. That is, as indicate in our abstract part (Line 35-38), our results highlight '*the importance of accounting for the effects of aerosol microphysics and ocean-coupling feedbacks to improve the forecast of TC destructiveness, particularly near the heavily polluted coastal regions along the Gulf of Mexico*'.