Response to Reviewer 4

The authors thank Anonymous Reviewer #4 for his or her time in reviewing our manuscript, and for their helpful comments. Addressing them has enabled us to improve this manuscript. Our point-by-point responses are indicated in blue below.

How Does Assimilating a Large Commercial GNSS RO Dataset Impact HAFS Hurricane1 Forecasts? An Evaluation in Support of the ROMEX Experiment?

William J. Miller, Yong Chen, Shu-Peng Ho, Xi Shao

This study presented in this manuscript uses the well-publicized ROMEX multi-RO source dataset to carry out RO data denial experiments, for purposes of evaluating the impact of any one or more RO data sources upon TC intensity and track forecast. The operational NOAA HAFS operational forecast model is used to assimilate the RO bending angles using the GSI and a 1-D bending angle operator.

General Comments

General. The study is somewhat compromised by model configuration, since the RO denial experiments don't apply to the HAFS outer domain, only to the inner 12x12-deg nest (initial and lateral boundary conditions are downscaled from the operational GFS model), given the way that HAFS is designed. To the extent that the impact would be different when assimilating the same RO into both nests is unknown and a subject for a future evaluation. This limitation is clearly stated and does not take away from the results presented. However, could you provide some better insight on how this impacts these results? Most of the bending angle information arises from the lower ~200-km path centered near the Earth tangent point, and your nest is about 6x that (~1200 km) in both dimensions.

We agree that our manuscript would benefit from some additional discussion of how results could be impacted by assimilating nonlocal bending angle observations in the HAFS regional nest. Since we are using a one-dimensional forward operator to assimilate the RO bending angles, we don't need to deal with ray tracing through the background (either extrapolated or downscaled from a global model) outside the nest boundaries, as we would if we were implementing a two-dimensional forward operator in HAFS. However, one limitation worth mentioning for our experiment setup is the potential for the HAFS 12 x 12-degree data assimilation domain boundaries to cutoff the horizontal spread of observation information by the background error covariance matrix, especially for observations assimilated near the domain's lateral boundaries.

We added this passage to the last paragraph of the Summary and Conclusions (lines 799-808):

"When interpreting our results, it is also worth noting that RO bending angles are nonlocal observations that depend mostly on atmospheric fields along the tangent point-centered ~ 200-km ray path, which is about one-sixth of the HAFS-A inner nest width. Although HAFS-A's one-dimensional bending angle forward operator uses only the vertical column of background data above the tangent point, the analysis impacts of observations assimilated near the nest's lateral boundaries could be limited by the boundaries truncating the horizontal spread of observation information by the regional background error covariance matrix. Miller et al. (2023), for example, showed that COSMIC-2 bending angles assimilated in HWRF could adjust lower-to-middle tropospheric analysis water vapor fields $\gtrsim$ 100 km away by at least 0.3 g kg^{-1} (see their Fig. 10)."

Line 283. These satellites orbit in known patterns and the locations of RO predictable and are not "random". Like other satellite observations that arise from low Earth orbit and associated repeat/revisit locations, there could be very fortuitous alignment of multiple satellite observations at a critical time in the TC evolution. Or not. I think a better word here is "variability".

We agree that "randomness" is not good word choice when describing RO receiver satellite orbits. We revised this sentence, and it now reads as (lines 318-319):

"Therefore, we attribute the differences in Spire profile availability over DA cycles mostly to variability in Spire occultation swath locations over the TC case study periods."

Line 701: COSMIC-2 receivers orbit asynchronously in the tropical and mid-latitudes, whereby Spire receivers' orbit in synchronous orbits (less data in tropical latitudes). Given this, the line "...the incremental benefits of assimilating additional RO data may be proportionally greater outside the tropics". Given the focus on TC regions, it is suggested to mention the need to sustain future RO data that cover tropical latitudes with COSMIC-2-like sampling density.

Thank you for this comment. Yes, we agree that it's important to mention the need to sustain COSMIC-2 like sampling density over the tropics after the mission ceases to provide data, and our study provides evidence supporting the usefulness of COSMIC-2 data for TC track and short-range intensity forecasting. We added a new sentence to the Summary and Conclusions that mentions the need to sustain COSMIC-2 like profile coverage with future missions, and it reads as (lines 789-793):

"Additionally, by showing Control_noC2's short-range intensity and medium-range track forecast degradations relative to Control, this study supports previous work showing positive impacts of COSMIC-2 assimilation on regional model TC forecasts (Miller et al. 2023; Teng et al. 2023) and the need to sustain COSMIC-2-like coverage over the tropics in future RO satellite missions."

Side note: The authors may be interested in a RO-related TC impact study, that uses recent advanced polarimetric radio occultations. These data may prove useful for evaluating the selection of HAFS (or other) model microphysics (which admittedly was not part of this evaluation, but a suggestion for future HAFS evaluation). A good example is here: https://doi.org/10.5194/amt-18-5265-2025

Thank you for letting us know about this polarimetric radio occultation TC impact study. We will take a look and think about performing a future study using polarimetric radio occultation data to evaluate accuracy of the different microphysics parameterizations available for use with

HAFS. Finding observations to use for verifying TC regional models' microphysics schemes has traditionally been a challenge.