Vertical error covariance and representativeness errors from triplets of ROMEX RO profiles

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(1) Overview

- With up to three times the typically available data, the Radio Occultation Modeling Experiment (ROMEX) provides a unique opportunity to characterize and intercompare radio occultation (RO) bending angle (BA) data.
- Random errors and their vertical correlations are important characteristics of these observations for understanding intrinsic data quality and for their use in data assimilation systems.
- Here we present estimates of random error statistics of ROMEX data using collocated RO observations and model data.
- Future outcomes include 1) better understanding and specification of random error variances for assimilation and 2) guidance on adjusting these variances due to oversampling between model levels.

(2) Data and methods

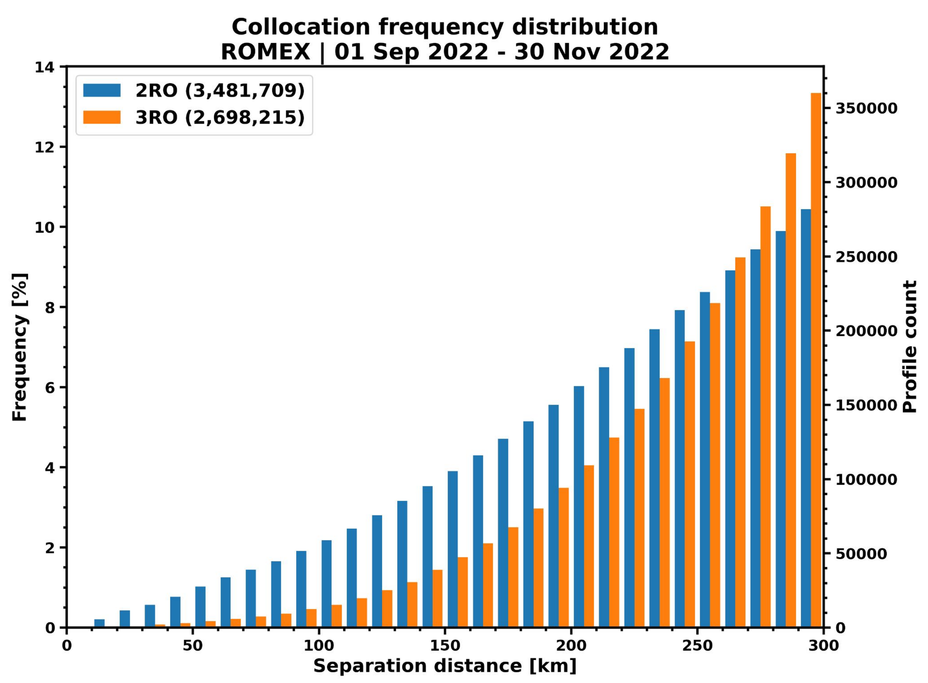

Fig. 1: Frequency distribution and profile counts for RO pairs (blue) and triplets (orange) as a function of separation distance (maximum distance following the RO tangent point drift). Bin steps are 10 km. Total counts are in the legend.

- SON 2022 ROMEX BA data from COSMIC-2, Spire, and Yunyao, all processed by CDAAC.
- BA are computed for ERA5 and JRA-3Q short-range forecasts interpolated to observations using a 1D forward model.
- Collocate RO profiles within 3 hours and 300 km based on the maximum distance following the tangent point drift.
- Use generalized three-cornered hat (3CH) method [1] for accurate estimates of error covariance matrices using three data sets.
- Triplets of RO avoid representativeness differences but are relatively rare at very small collocation distances (Fig. 1).
- Accurate estimates of uncertainty (error standard deviation) can be derived using RO pairs in RO-RO-model 3CH setups [2].

(3) Intrinsic uncertainty and representativeness

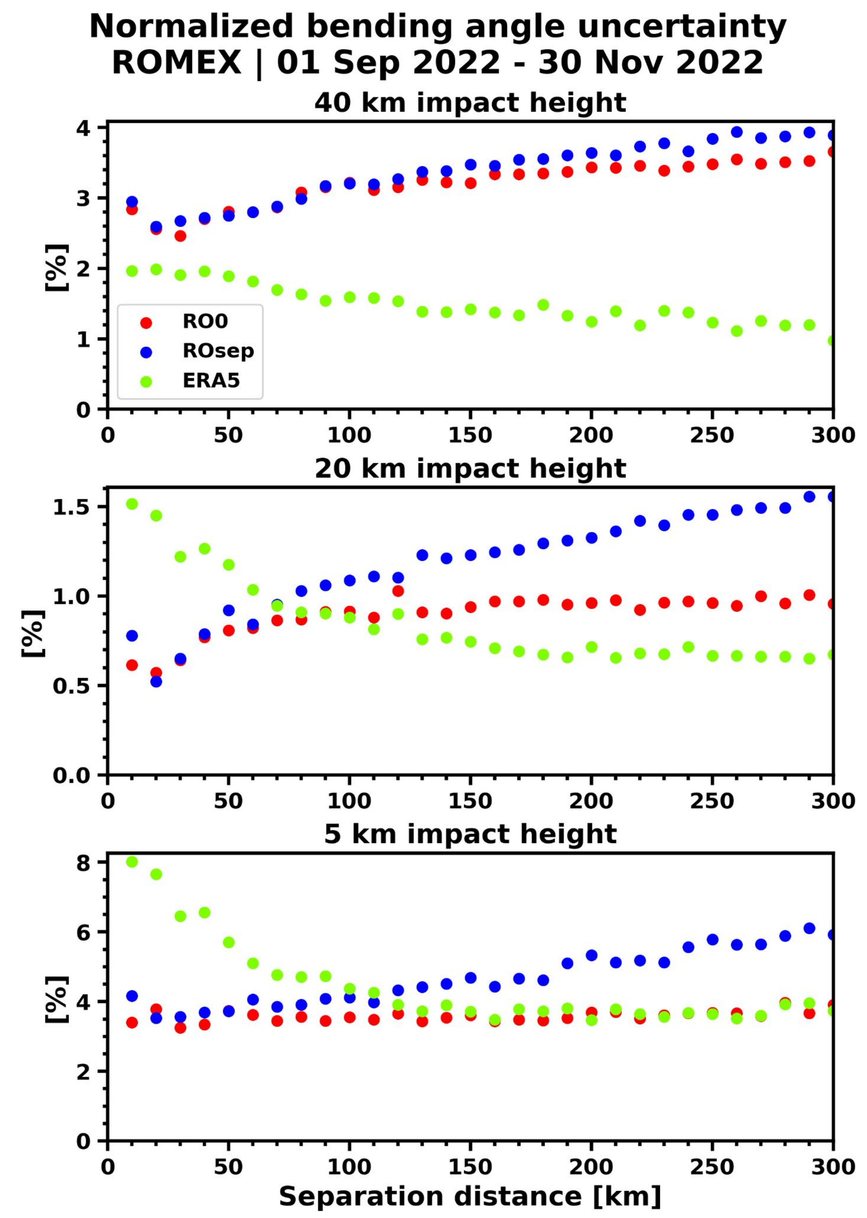

Fig. 2: Normalized BA uncertainty vs separation distance for collocated RO ("RO0"; red) and ERA5 (green), and separated RO ("ROsep"; blue) at 40 (top), 20 (middle), and 5 km impact height (bottom).

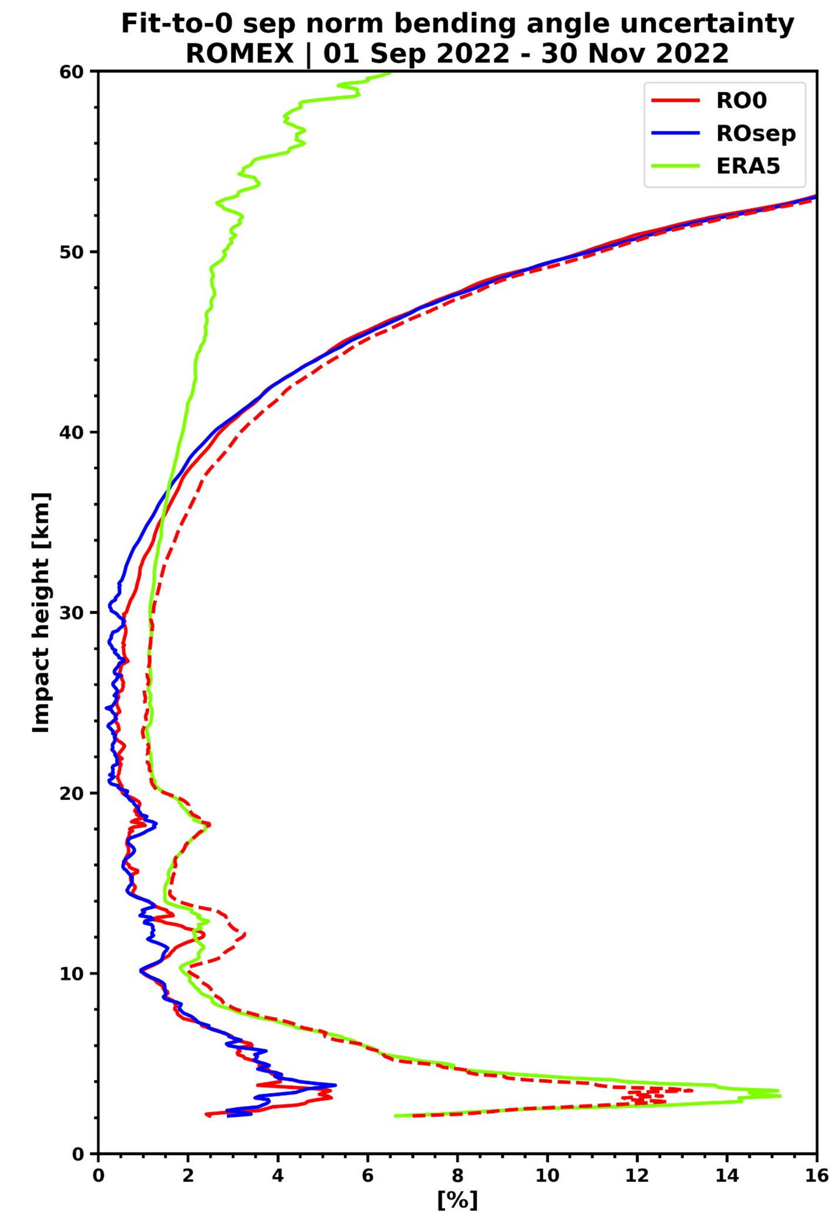

Fig. 3: Fit-to-zero normalized BA uncertainty for collocated RO ("RO0"; red) and ERA5 (green), separated RO ("ROsep"; blue), and RO0 from RO-ERA5-JRA3Q triplets (dashed).

- We find at small separations that 1) RO estimates converge and 2) ERA5 estimates increase due to representativeness differences (Fig. 2).
- At large separation, collocation errors dominate ROsep.
- Fit-to-zero separation estimates agree at nearly all levels for RO, and highlight increased uncertainty near the tropopause and planetary boundary layer (Fig. 3).
- Difference between RO0, ROsep (solid red and blue) and RO0 estimates from RO-ERA5-JRA3Q triplets (dashed red) approximates uncertainty due to representativeness differences between RO and models.

(4) Vertical error covariances

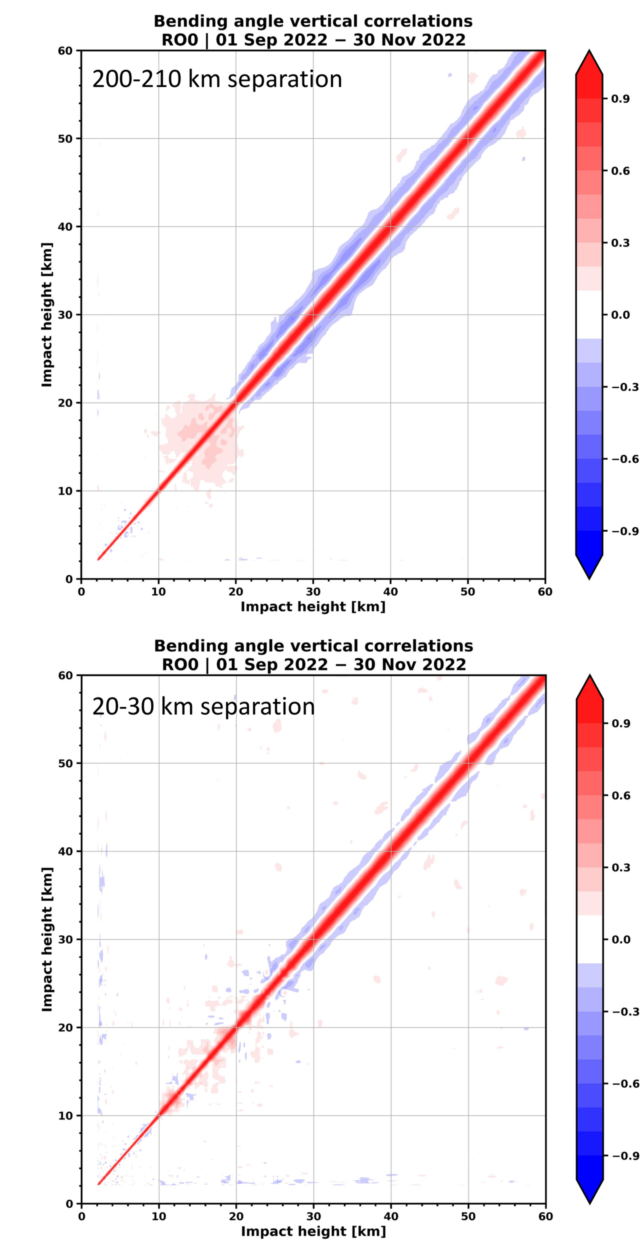

Fig. 4: Vertical error correlation matrices for RO0 where ROsep is separated by 200-210 km (top) and 20-30 km (bottom).

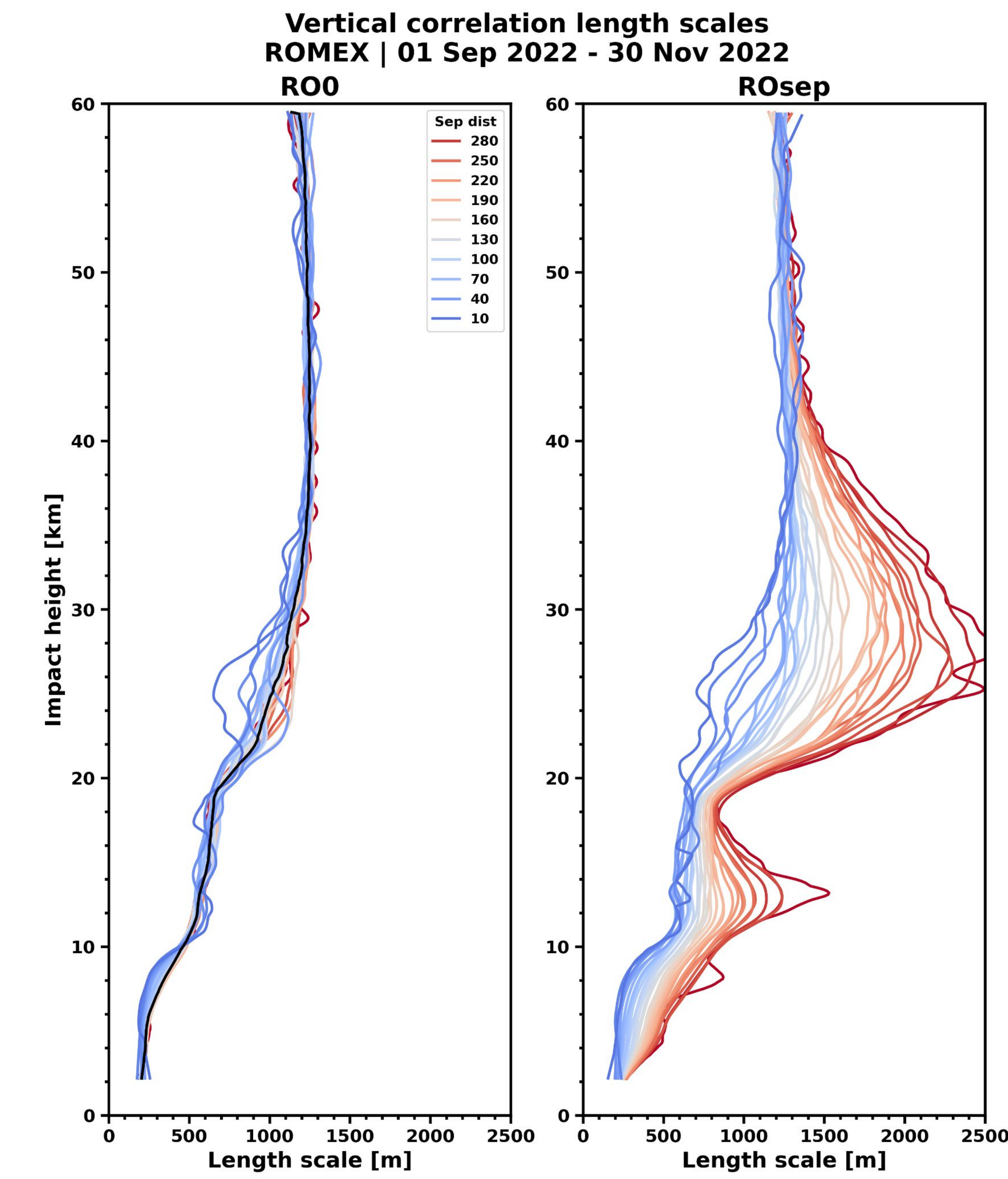

Fig. 5: Representative vertical correlation length scales for RO0 (left) and ROsep (right), and the median RO0 length scale (black, left).

- As separation decreases, negative error correlations approach zero (Fig. 4).
- Vertical length scales decrease somewhat for RO0 but have a strong relationship with separation distance for ROsep (Fig. 5).

(5) Discussion

- These results highlight the value of the dense ROMEX sampling across missions for studying RO error characteristics.
- The unprecedented sampling of nearby RO pairs allows for detailed analyses of how error covariance and uncertainties change with separation distance.
- Intrinsic uncertainty and model-by-model representativeness errors can be approximated well from fit-to-zero separation estimates.
- >100 km separations appreciably increases estimated uncertainties and vertical correlation length scales; many studies use collocated pairs with up to 300 km separation.

References

[1] Nielsen, J. K., H. Gleisner, S. Syndergaard, and K. B. Lauritsen, 2022. *Atmos. Meas. Tech.*, **15**, 6243–6256, DOI: 10.5194/amt-15-6243-2022.

[2] Sjoberg, J. P., R. A. Anthes, and T. Rieckh, 2021. *J. Atmos. Ocean. Tech.*, **38**, 555–572, DOI: 10.1175/JTECH-D-19-0217.1.

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