GRUAN radiosondes applied in preparation and validation of specific humidity profiles derived from radio occultations
-a users perspective

J. K. Nielsen

ROM SAF

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DMI

Outline

Preparation of ROM SAF CDR v2

- Same as ICM-14

Remarks on temperature

Remarks on Humidity; RO is the weak part here

ERA5, RO, GRUAN random uncertainty and error correlations

- Generalized Three Cornered Hat (G3CH)

Error components

- Representativeness uncertainty
- Dealing with different vertical footprints

Random uncertainty

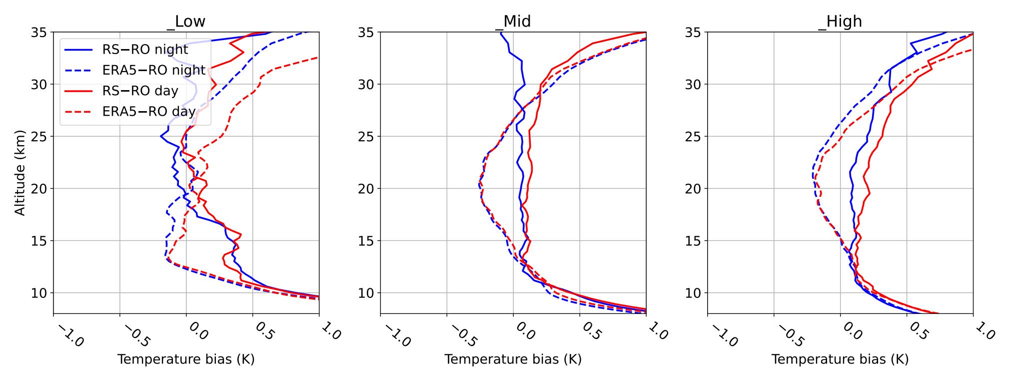
Vertical correlations

Conclusions

Planning ROM SAF CDR v2

- Missions: COSMIC 1, Metop A-B-C, CHAMP, GRACE, ...
- Time span: 2001-present
- Variables: Bending angle, Refractivity, Dry temperature, Temperature, Spec. humidity, Pressure, Surface pressure + gridded data
- GRUAN radiosondes to be used to estimate random uncertainty (error covariance matrices).
- Improved ionosphere, troposphere, boundary layer parameters
- Uncertainty and error covariance from G3CH analysis

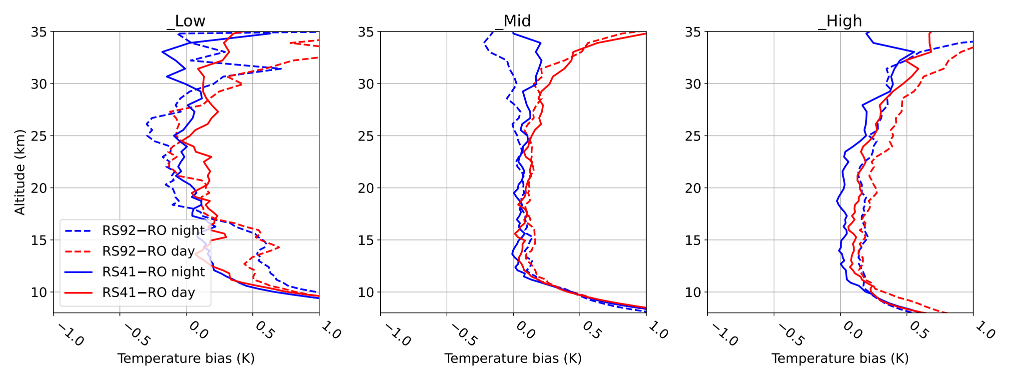
Temperature day v. night



ERA5 (dashed) also has a daytime bias

RS bias at high latitude above 25 km

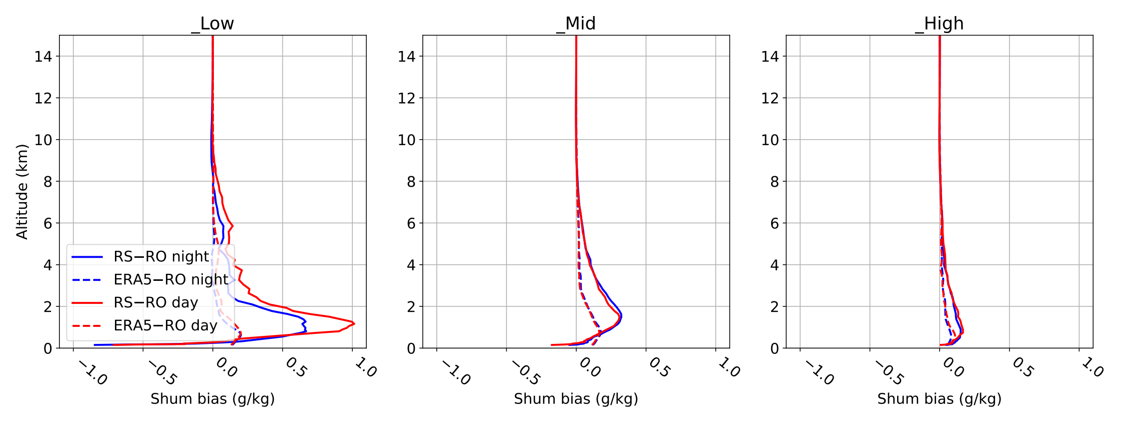
Temperature RS41 v. RS92



RS92 warm in TTL

RS have daytime warm bias above 25 km

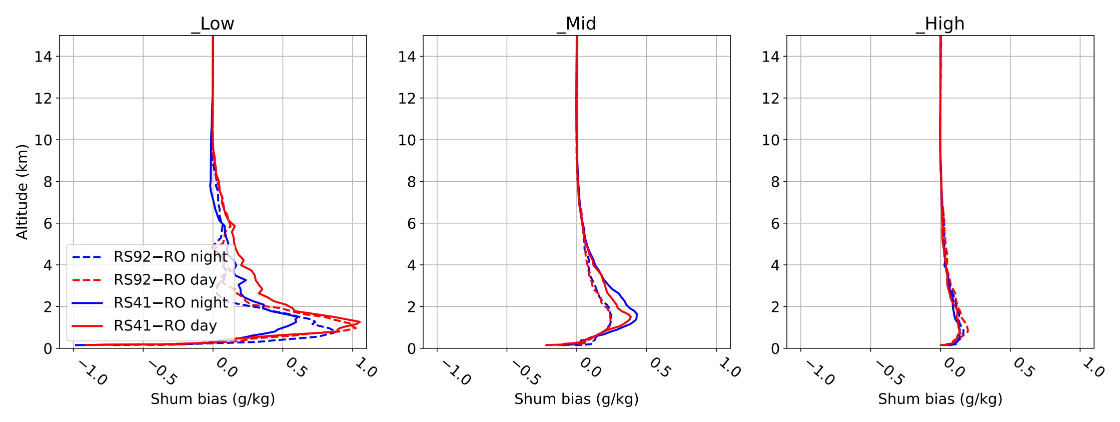
Sp humidity day v. night



RO is strongly negatively biased around 2 km

Tropical wet bias in daytime

Sp. Humidity RS41 v. RS92



RS92 agrees best with RO in mid troposphere

Empirical determination of observation error covariance matrices

- Collocated ERA5 forecast, GRUAN radiosondes and RO profiles are used to estimate random uncertainty (error covariance matrices) for refractivity and temperature.
- Three independent data sets meaning: Zero error cross correlation. $\langle \varepsilon_{\mathrm{ERA5}} \varepsilon_{\mathrm{RO}} \rangle = 0$, $\langle \varepsilon_{\mathrm{RO}} \varepsilon_{\mathrm{GRUAN}} \rangle = 0$, $\langle \varepsilon_{\mathrm{ERA5}} \varepsilon_{\mathrm{GRUAN}} \rangle = 0$
- 35000 collocations, dist < 300km, t < 3 h
- G3CH; algebraic estimation of vertical uncertainty covariance matrices: $\mathrm{Cov}(g) = \frac{1}{2} \langle (g-b)(g-b)^T + (g-r)(g-r)^T - (r-b)(r-b)^T \rangle$
- Can in principle handle large bias and random noise of GNSS RO dry temperature
- T_{dry} is calculated directly from refractivity, with the assumption that $q = 0$

Error components

Raw G3CH yields a combination of instrument, representation, collocation and cross correlation errors:

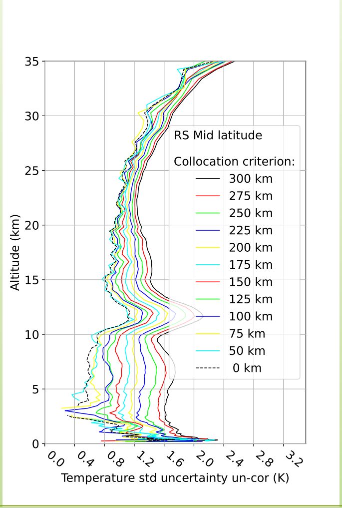
$$\varepsilon_{\mathrm{G3CH}} = \varepsilon^{I} + \varepsilon^{R} + \varepsilon^{C} + \varepsilon^{X} \qquad (1)$$

We are able to remove ε^{C} and the ε^{X} components of the three data sets. So:

$$\varepsilon = \varepsilon^{I} + \varepsilon^{R} \qquad (2)$$

The final estimate of ε is stated with reference to a common vertical footprint of the three data sets, determined by the data set with the largest vertical footprint, ERA5. There is still a residual representativeness uncertainty due to different geometries of measurements.

Collocation error



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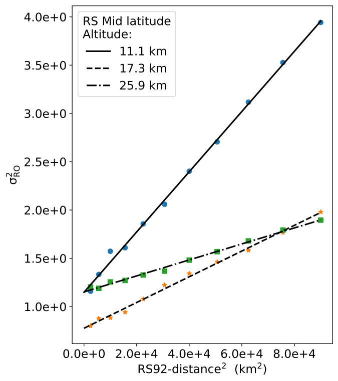
Temperature uncertainty of radio occultations for a series of collocation criteria. Black dashed curve shows extrapolation to zero collocation distance.

→

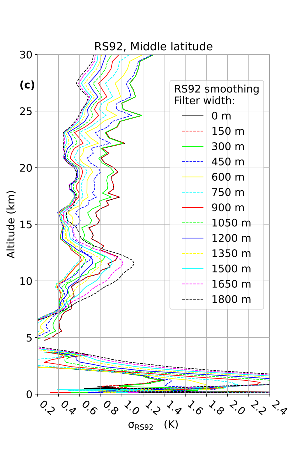


Extrapolation of temperature error variance of RO to zero collocation criterion at 3 different altitudes.

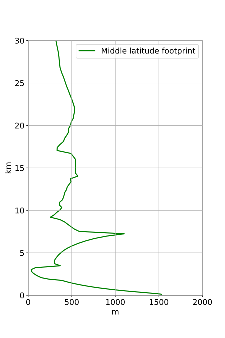
The issue with vertical correlations

- ERA5 footprint > RO footprint > RS footprint
- RS is blamed for highly resolved features which are interpreted as noise by the G3CH
- Method: Filter to the (vertical) footprint least well resolved data set.
- Uncertainties stated with respect to vertical footprint 500 m

Effect of smoothing on error standard deviations

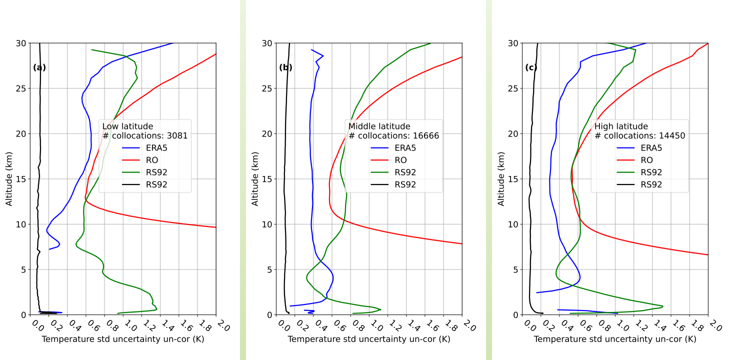


Smoothing of RS92 up to 1800 m brings it closer to ERA5, and only slightly further from RO. — Except at the tropopause.



The ERA5 vertical footprint is applied as filter on all three data sets

Temperature STDV and vertical correlations.

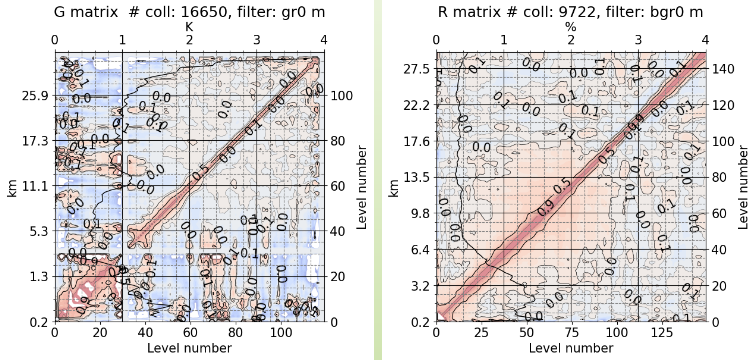


Tropospheric dry temperature uncertainty (RO) is overestimated due to humidity, but it does not matter.

Black curve: RS92 u_std_temp, RS41 $\frac{1}{2}$temp_uc_ucor.

RS temperature random uncertainty: green thick curve. ERA5 and RO have comparable horizontal footprints, hence 3CH attributes the residual representativeness uncertainty component to RS

G3CH estimate of error covariance matrices (RS92 only)



Left: Temperature vertical error covariance matrix. Right: Refractivity vertical error covariance. Middle latitude, with superimposed standard deviation as function of height (black line).

Conclusions

- Radiosondes are warm in the TTL and at high latitude above 25 km
- RO humidity is strongly negatively biased around 2 km, would indeed help with smaller k_2 or k_3 :-)
- Radiosondes have tropical wet bias in daytime
- For specific humidity, RO agrees best with RS92 in mid troposphere
- Residual RS92 and RS41 uncertainty is probably due to horizontal representativeness issues of RO and ER5
- Little vertical error correlation in RS