Characterization of the specific humidity product in ROM SAF reprocessed data records

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DMI

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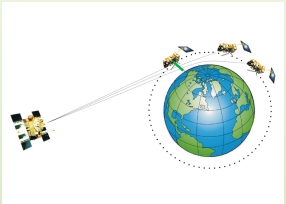
Outline

The RO technique

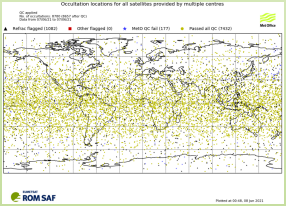


Bending angle $\rightarrow$ Refractivity

$$N = k_1 \frac{P_{\text{dry air}}}{T} + k_2 \frac{P_{\text{water}}}{T} + k_3 \frac{P_{\text{water}}}{T^2}$$

$$N = \mathbf{y}^o$$

$$J(\mathbf{x}) = \frac{1}{2}(\mathbf{x}-\mathbf{x}^b)^T\mathbf{B}^{-1}(\mathbf{x}-\mathbf{x}^b) + \frac{1}{2}(\mathbf{y}^o-\mathbf{h}(\mathbf{x}))^T\mathbf{R}^{-1}(\mathbf{y}^o-\mathbf{h}(\mathbf{x})),$$



600-700 daily profiles per LEO

- Vertical resolution < 250 m
- Horizontal resolution < 300 km

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:

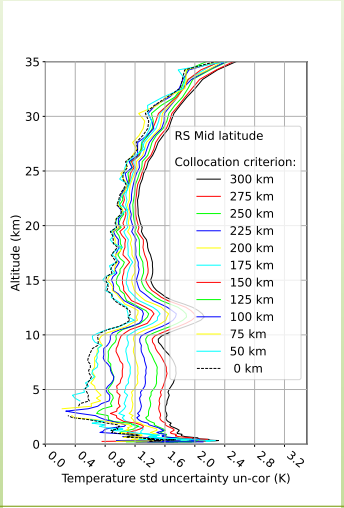
$$\varepsilon_{\mathrm{G3CH}} = \varepsilon^{I} + \varepsilon^{R} + \varepsilon^{C} + \varepsilon^{X} \tag{1}$$

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

$$\varepsilon = \varepsilon^{I} + \varepsilon^{R} \tag{2}$$

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 uncertainty



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

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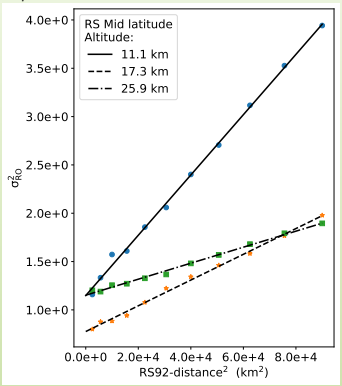
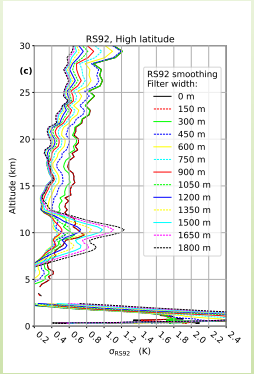


Extrapolation of temperature error variance of RO to zero collocation criterion at 3 different altitudes.

The issue with vertical correlations

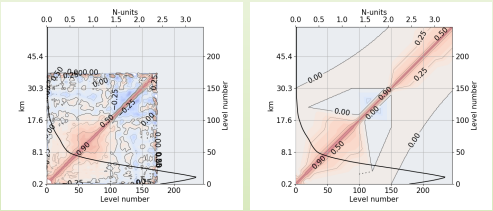
- ERA5 footprint > RO footprint > RS footprint
- RS is blamed for highly resolved features which are interpreted as noise by the G3CH
- Method: Filter to the (vertical) footprint least well resolved data set.
- Uncertainties stated with respect to vertical footprint 500 m



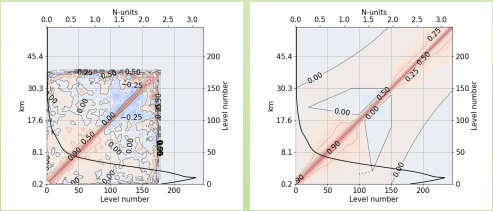
Smoothing of RS92 brings it closer to ERA5 and RO.

G3CH estimate of error covariance matrices

Rising:

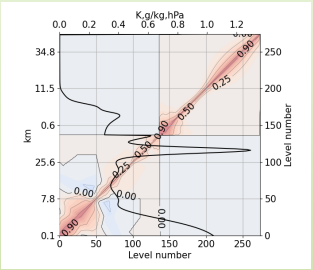


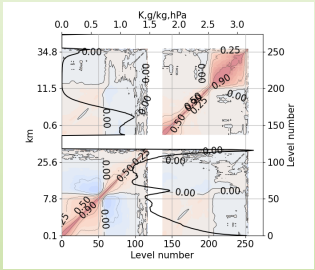
Setting:



Refractivity error covariance, mid latitudes, with superimposed standard deviation as function of height (black line).

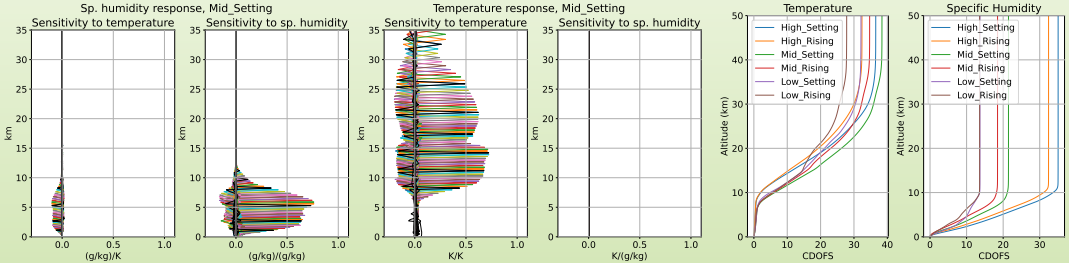
The **B** matrix





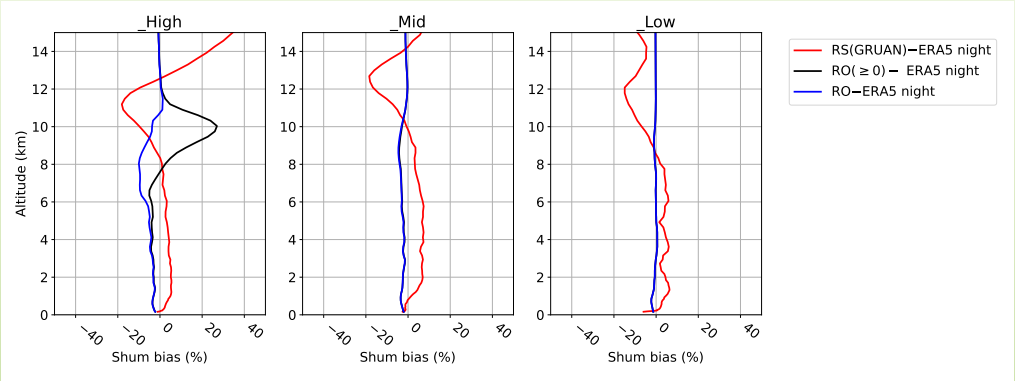
Constructing **B** out of consistency requirement. (Desroziers)
Left: parameterized **B**
Right:ERA5-GRUAN covariance, mid lat.

Performance of 1D-Var



- Mean of averaging kernels, for mid latitudes.
- The Cumulated degrees of freedom plot (CDOF, right) shows how many independent data points we can expect to retrieve in a single RO profile. For humidity CDOF reaches 12 in the tropics and more that 30 in polar regions.

Specific humidity GRUAN versus RO



RO is relatively constant 5-8 % dry everywhere
Ground based GNSS has the same bias (just saying)
Removing negative q values introduces a positive bias

Conclusions

- 3CH allows estimation of a consistent set of ECVs for 1D-Var
- RO does contain humidity information up to 11 km
- Radio occultations are a bit dry, compared to radiosondes, at all altitudes
- Potential for relaxing background accuracy, and background influence, e.g. by using climatological background.