Using Radio Occultation to validate Radio Sonde Datasets

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~~EUMETRAVES: Overview of EUMETSAT's Radio Sonde Service~~

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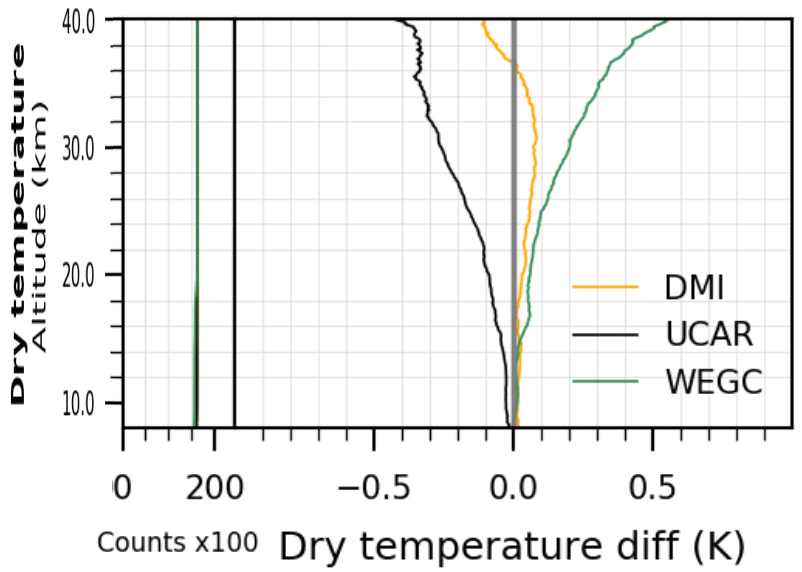
Motivation

- Comparisons of radiosondes are often done in radio occultation (RO) level 2 temperature space
- However, processing RO data to temperature introduces biases, which depend on the processing setup (that's one reason why NWP centres assimilate low level bending angle data)
- Comparisons in bending angle space removes that level 2 processing impact, and:
  - RO can benefit from lower altitude sonde data, where (a) temperature and water vapour both contribute to bending angles; (b) high variability/low SNR
  - Radiosondes can benefit from RO bias assessments at altitudes > 10km

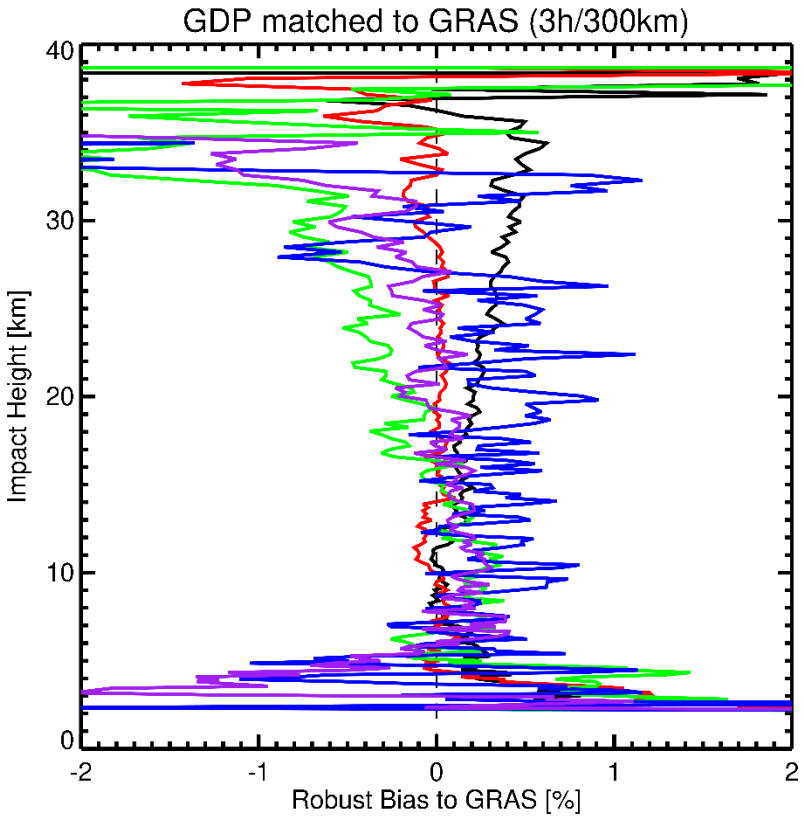


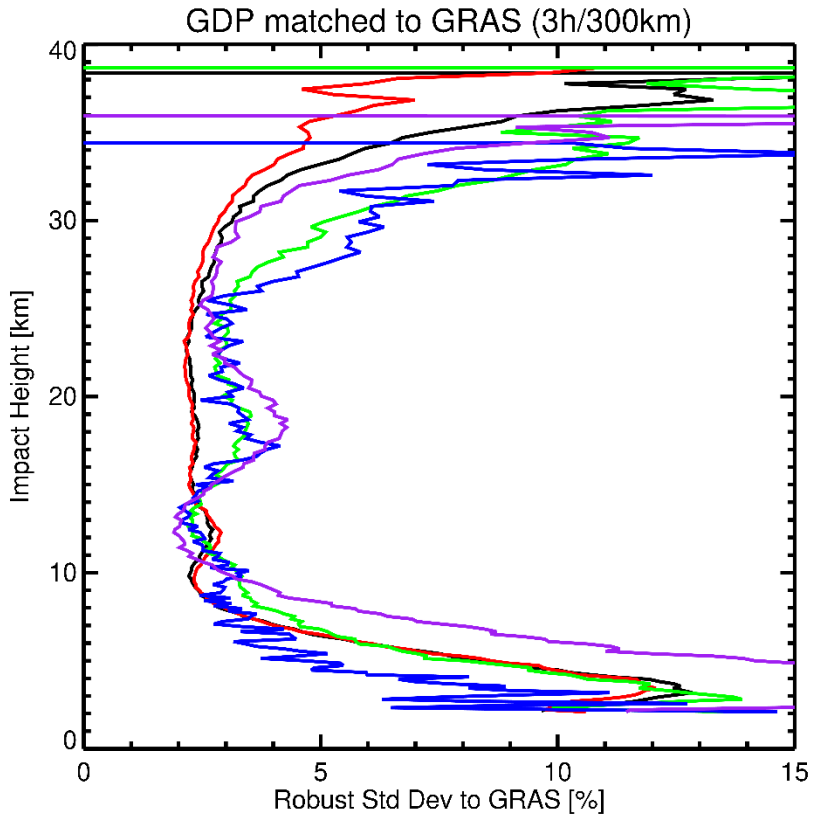
Metop/GRAS temperature profile comparison of different RO processing centres, showing the difference to the processing mean of all centres (plot from Steiner et al., https://doi.org/10.5194/amt-13-2547-2020

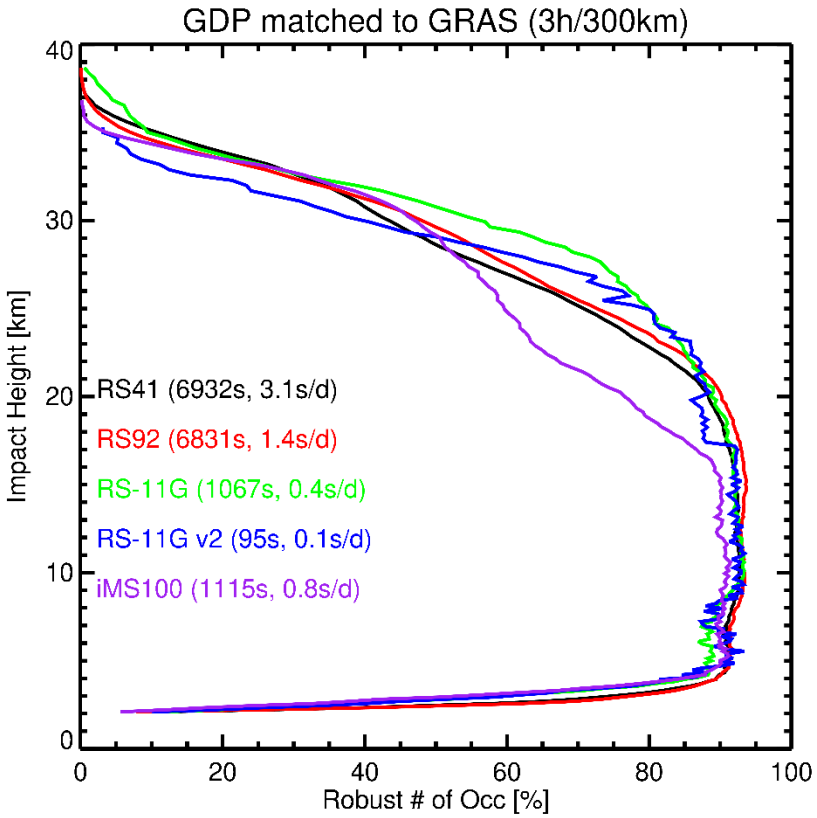
Data Sets / Pre-Processing

- Radio Sondes:
  - Data Sets: RS92 GDP.2, RS41 GDP.1, RS11G, RS11G-2, iMS100 (note: last 3 data sets with very limited coverage)
  - Pre-Processing: removal of data with larger gaps (~2%), “ordering” altitudes, removing upper 10 points, up-sampling to uniform 1m resolution, box average over 150m
- Radio Occultation:
  - EPS Metop-A, -B reprocessed data (v2.0, few years old, covering up to 06/2020)
  - EPS Metop-C (v4.0, latest reprocessing, up to 31/12/2024; Metop-A, -B also available but time ran out)
  - Sentinel-6A (NTC operational processing, thus not consistent, up to mid-2025)
  - Collocations: 300km/3h
- ECMWF:
  - ERA5, 6h resolution, 137 vertical levels, 0.5 Degree resolution, time and space interpolation
- Bending Angle Calculation:
  - ROPP-like implementation (v11), allowing to ignore multi-path / super refraction filter
  - Correcting upper altitude with ERA5
  - Correcting collocation error with ERA5 (for selected comparisons)

Matches of GRAS to several GDPs





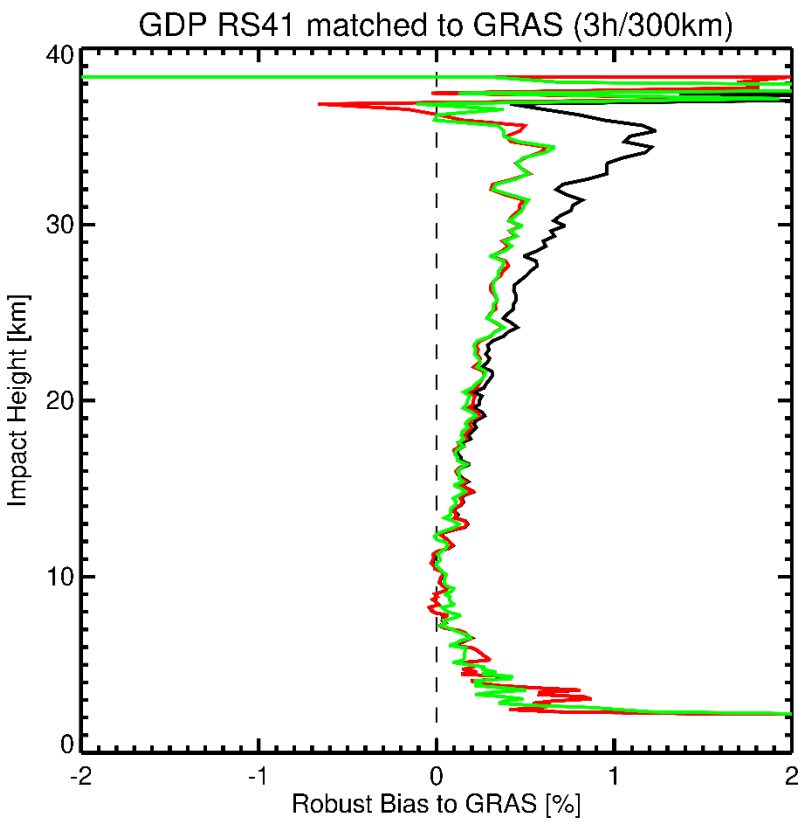


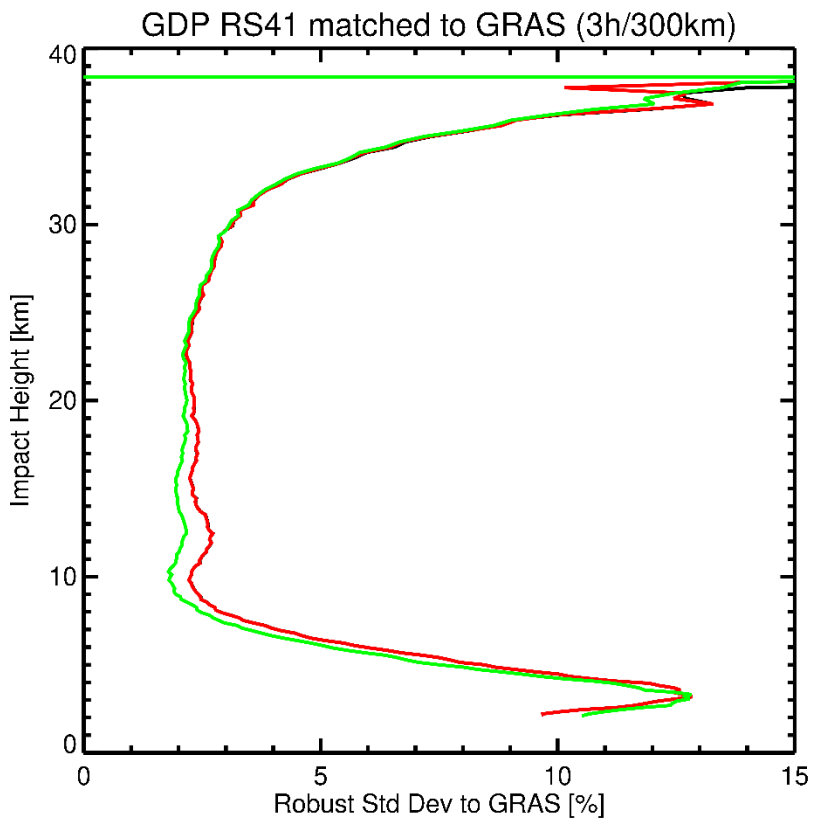
Matches of GRUAN GDPs with GRAS-A,B: (left) robust bias; (middle) standard deviations; data availability/Gaussian-ness (right) for different GRUAN radiosondes. Shown are the (RS-RO)/RO stats.

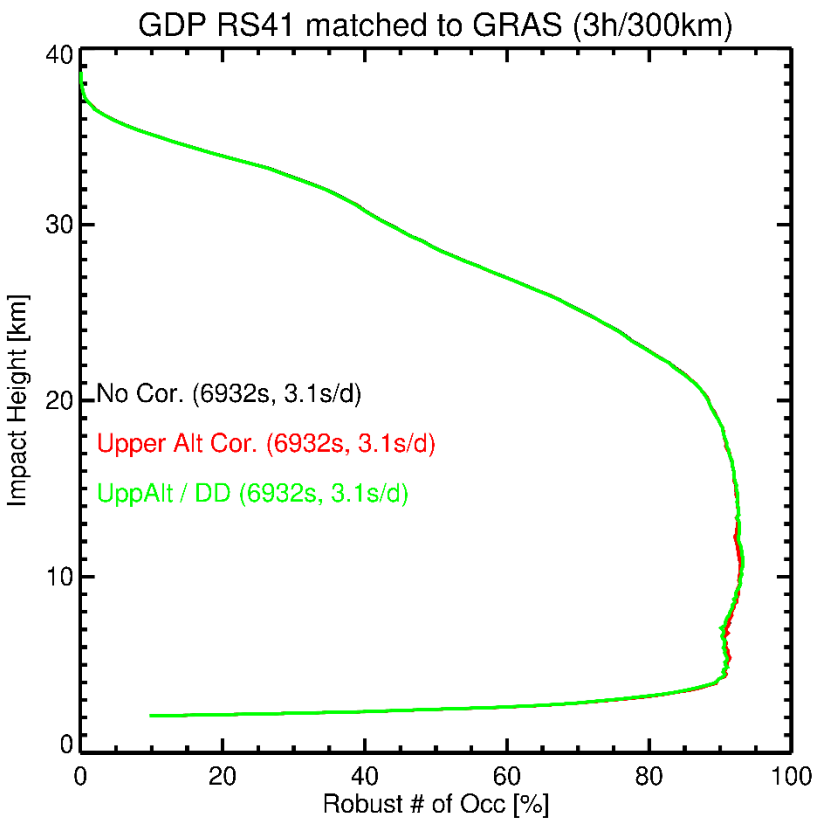
⇒ RS-11G, RS-11G-2, iMS100 have very limited coverage for this GRAS data set and could lead to systematic uncertainties, as GRAS measurements are always at certain local times and launches are primarily at certain UTC times

⇒ Focus for further plots on more robust RS92 and RS41 data set

Matches of GRAS to RS41 – processing corrections





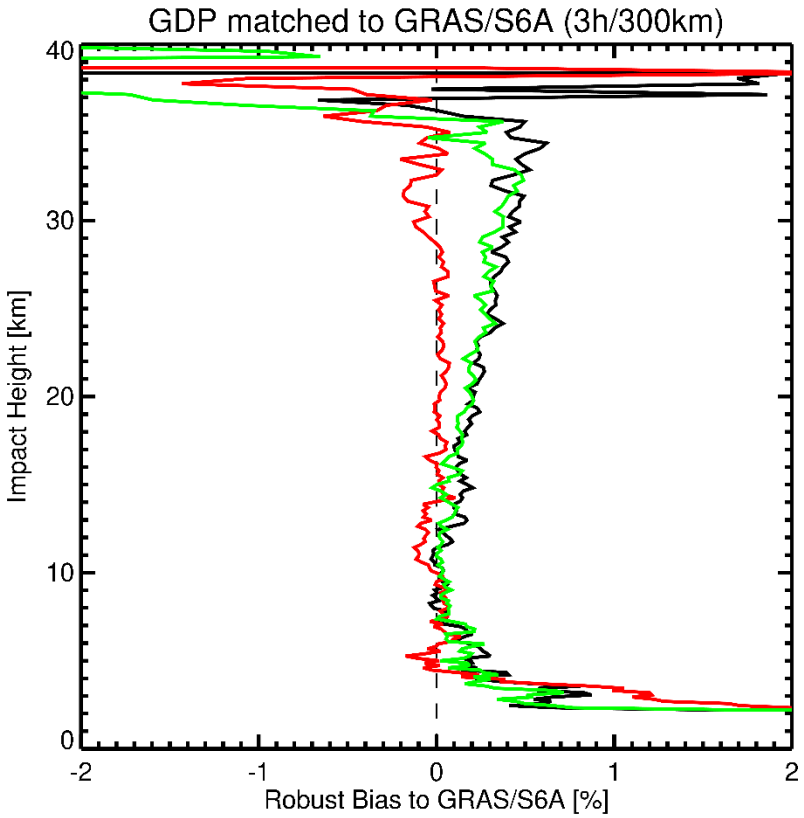


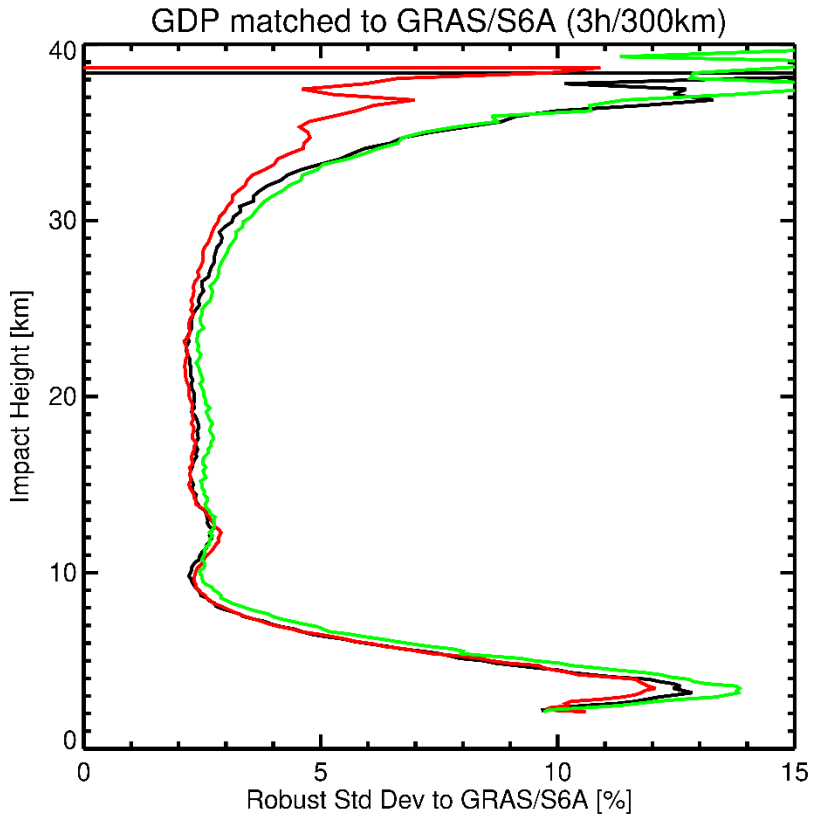
Matches of GRUAN RS41 GDPs with GRAS-A,B: (left) robust bias; (middle) standard deviations; data availability/Gaussian-ness (right) for different data corrections. Shown are the (RS-RO)/RO stats.

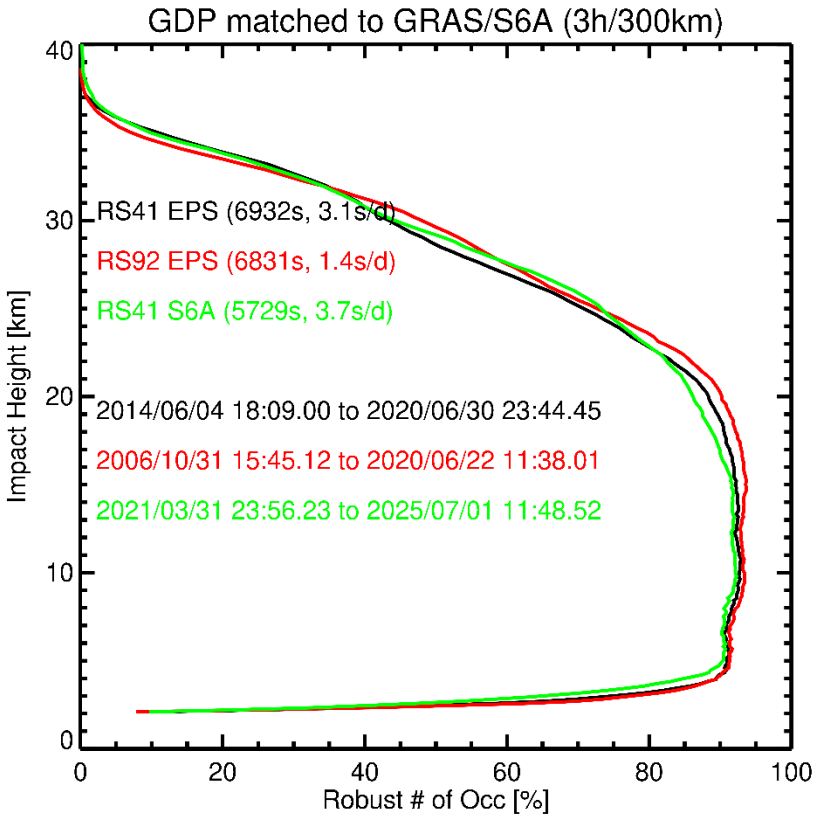
⇒ Upper altitude correction removes part of bias

⇒ Collocation correction (DD) has no/small impact on bias for well distributed matches, though improving standard deviation

Matches of GRAS/S6A to RS92/41



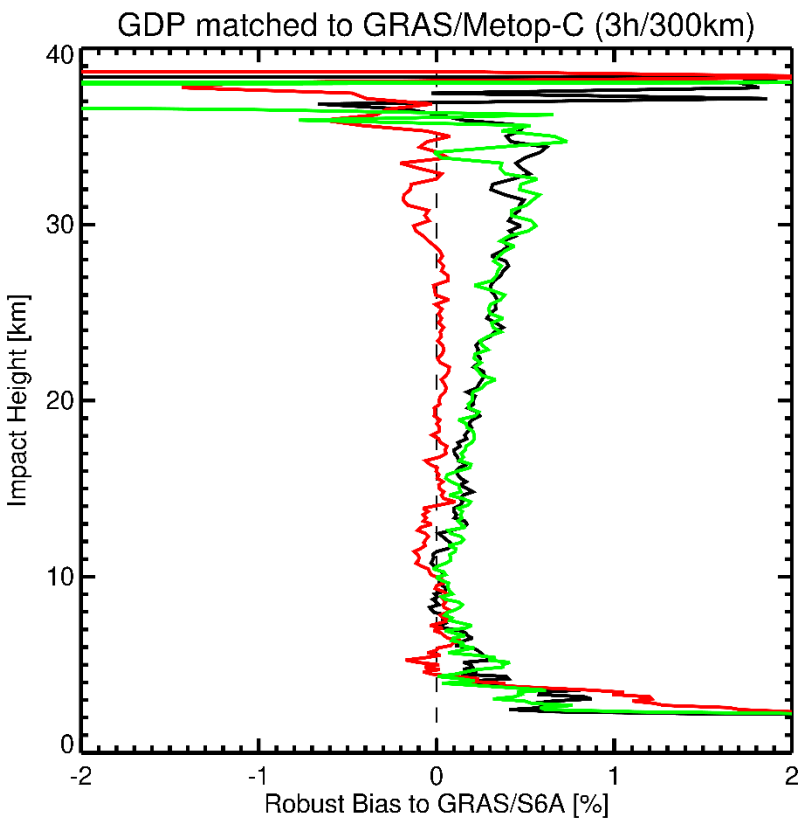


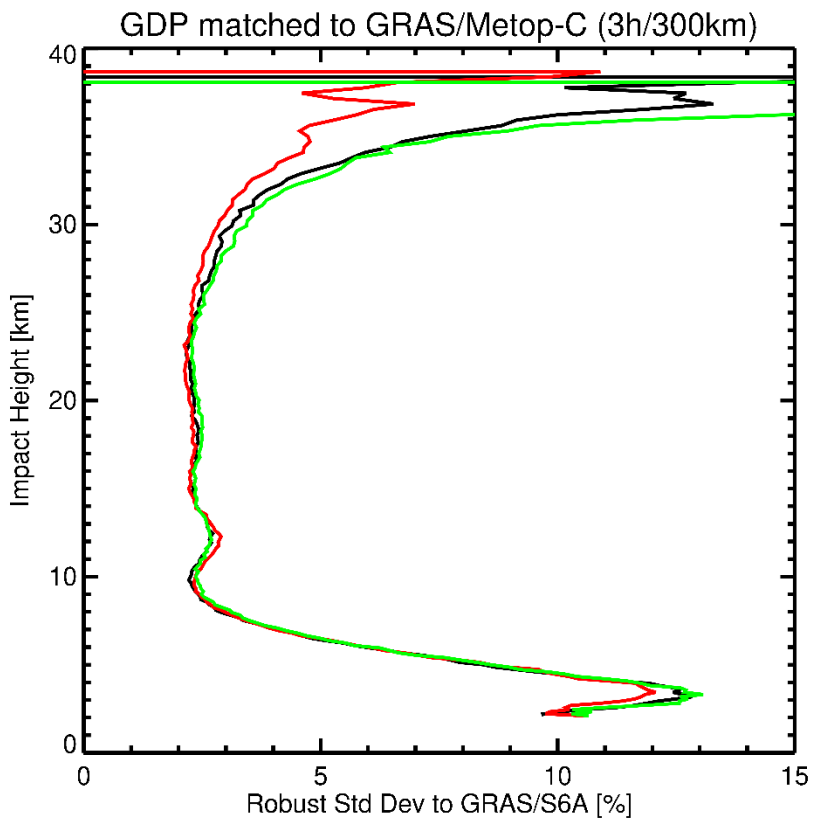


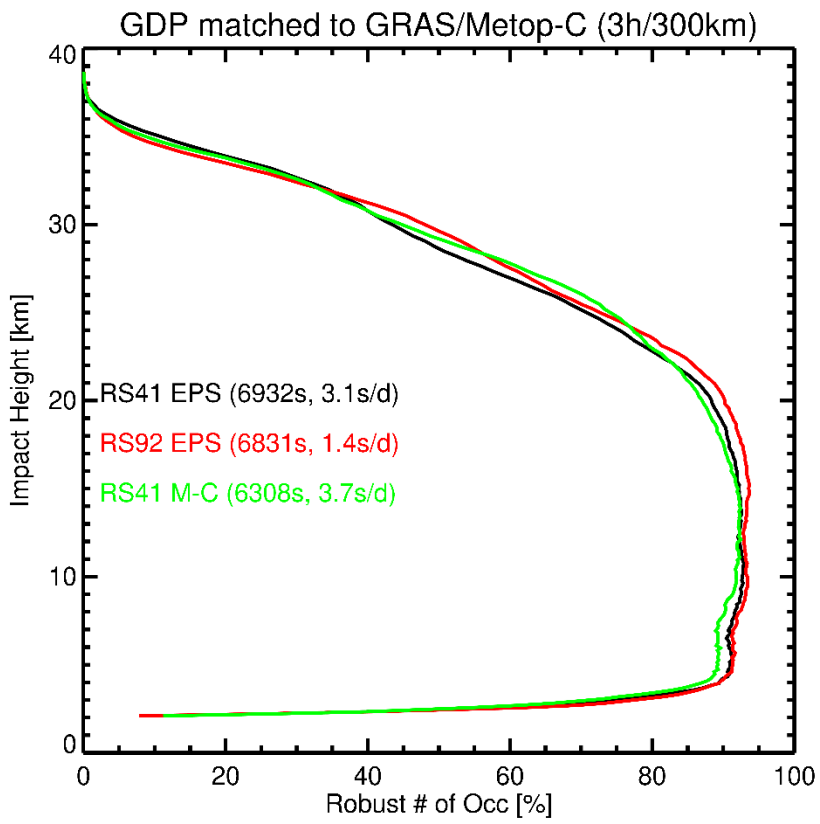
Matches of GRUAN RS92 and RS41 GDPs with GRAS-A,B and Sentinel-6A: (left) robust bias; (middle) standard deviations; data availability/Gaussian-ness (right). Shown are the (RS-RO)/RO stats.

⇒ Sentinel-6A has matches up to mid-2025, RS41 bias structure though very similar

Matches of GRAS-A,B/-C to RS92/41



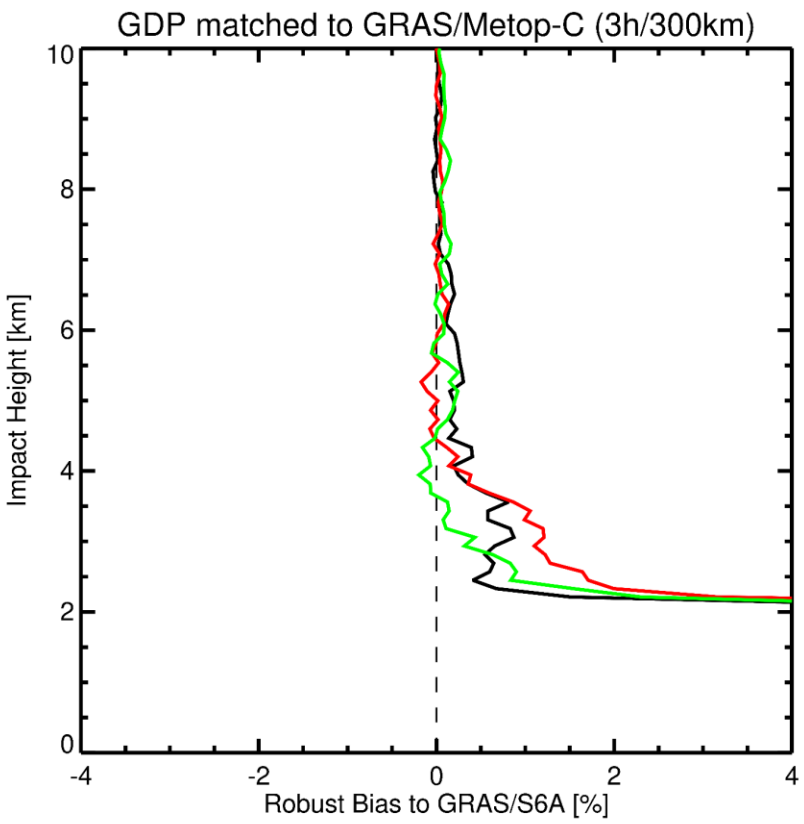


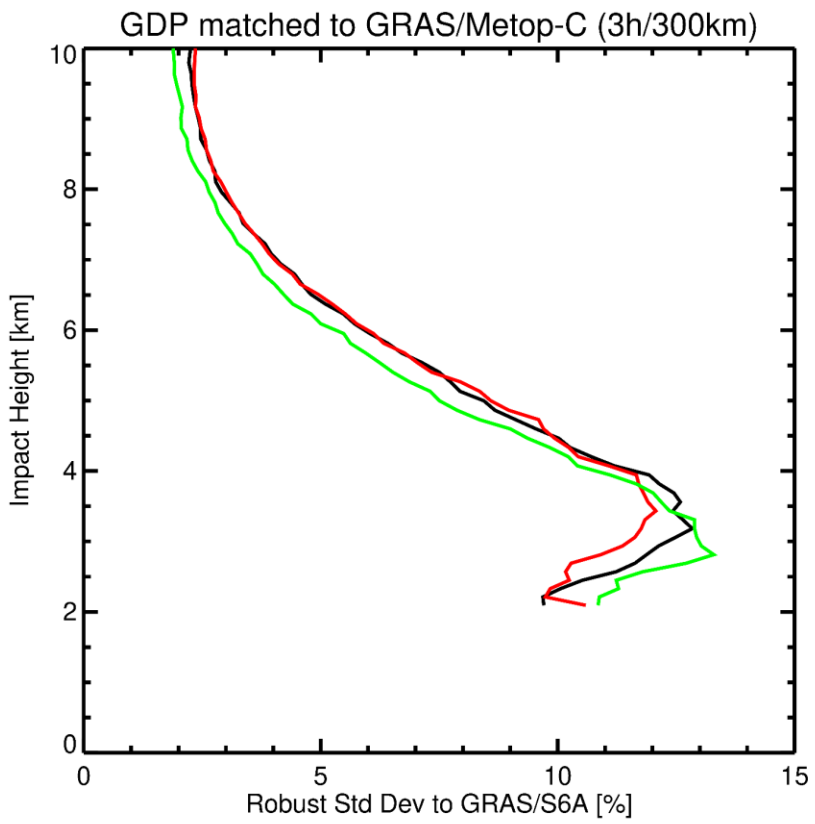


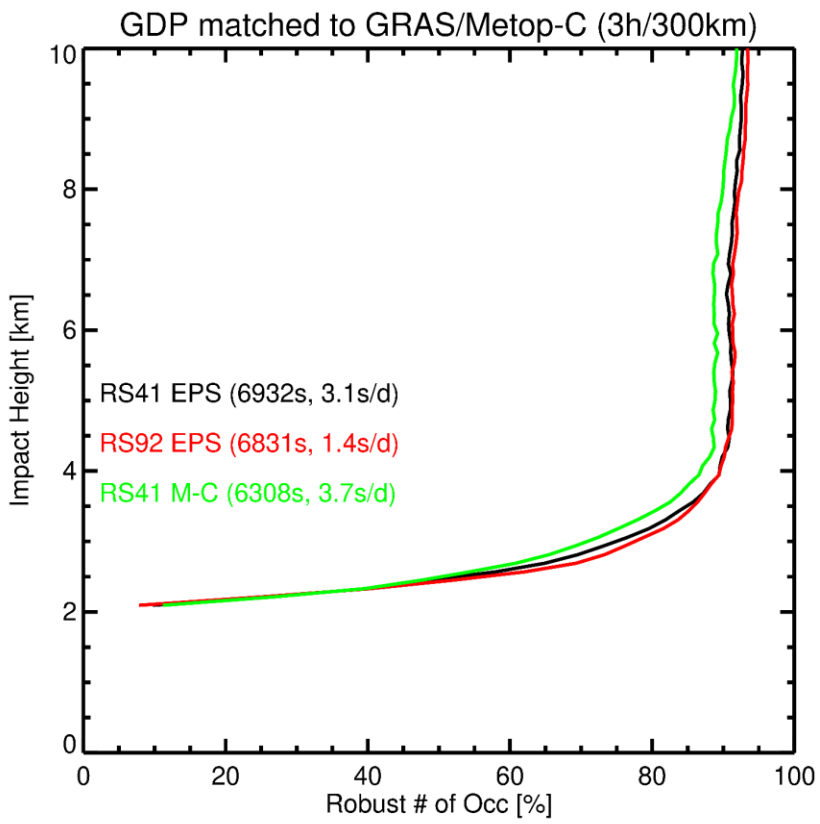
Matches of GRUAN RS92 and RS41 GDPs with GRAS-A,B and GRAS-C: (left) robust bias; (middle) standard deviations; data availability/Gaussian-ness (right). Shown are the (RS-RO)/RO stats.

⇒ GRAS-C has matches up to end-2024, RS41 bias structure though again very similar

Matches of GRAS-A,B/-C to RS92/41: Low Altitudes





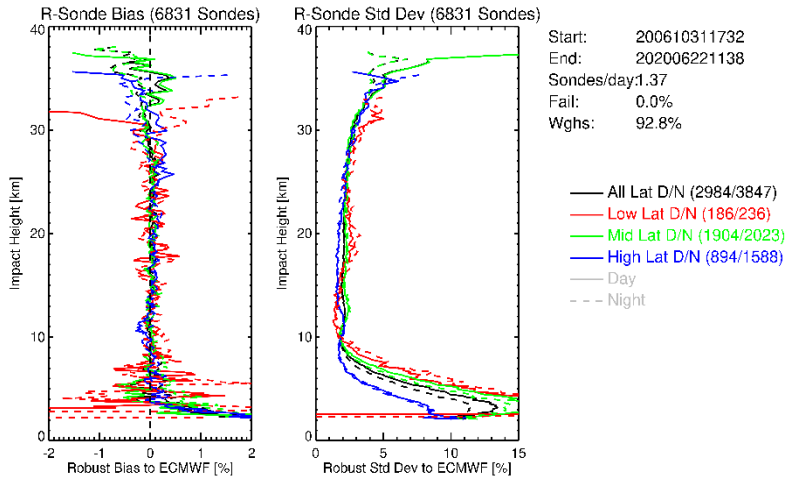


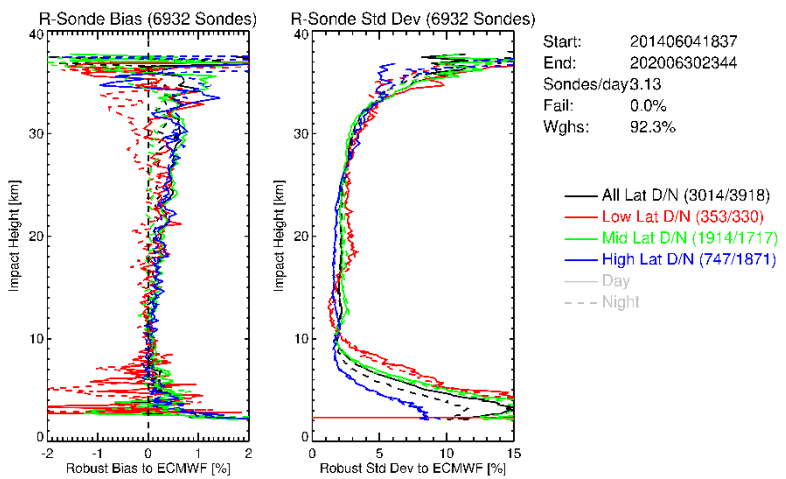
Matches of GRUAN RS92 and RS41 GDPs with GRAS-A,B and GRAS-C: (left) robust bias; (middle) standard deviations; data availability/Gaussian-ness (right). Shown are the (RS-RO)/RO stats. Low altiitudes.

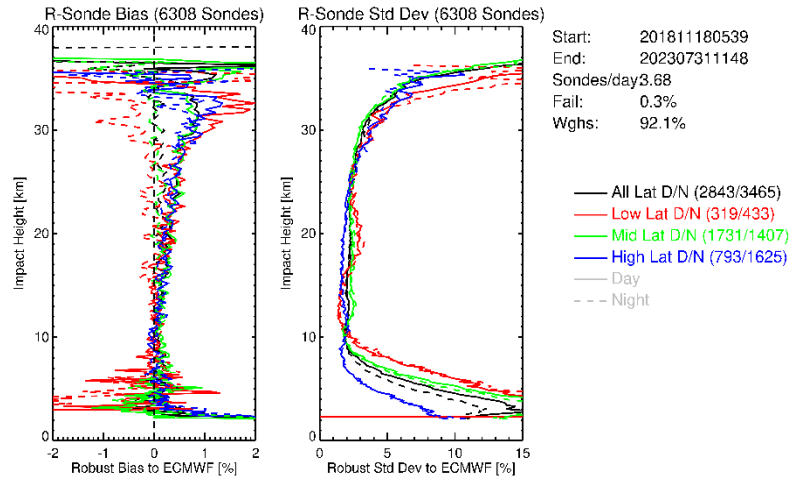
⇒ GRAS-C reprocessing has lower bias in the lowest few km, though has still the negative bias.

⇒ Difference of RS92 vs. RS41 is currently not understood

Matches of GRAS-A,B/-C to RS92/41: Day/Night





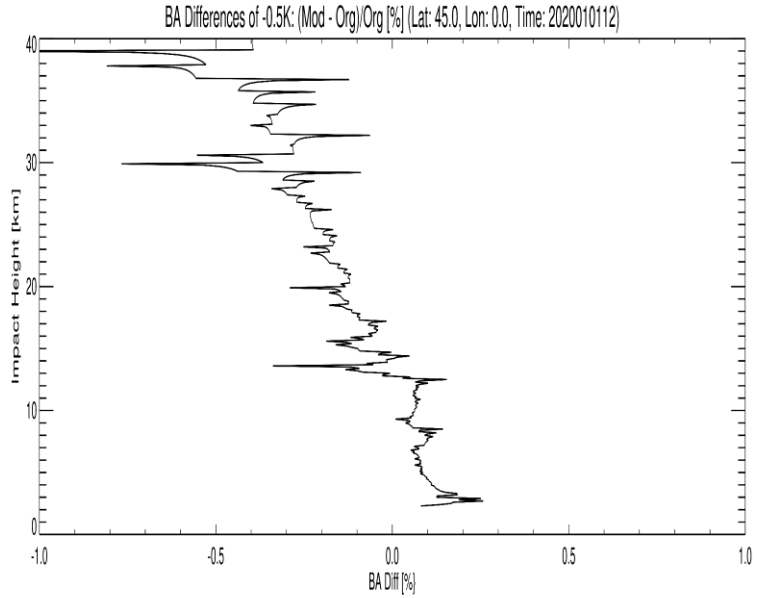


Matches of GRUAN sondes with GRAS: (left) RS92, GRAS-A,B; (middle) RS41, GRAS-A,B; (right) RS41, GRAS-C. Each plot shows robust bias (right) and standard deviations (left), for different latitude bands and day/night. All data with collocation correction. Shown are the (RS-RO)/RO stats.

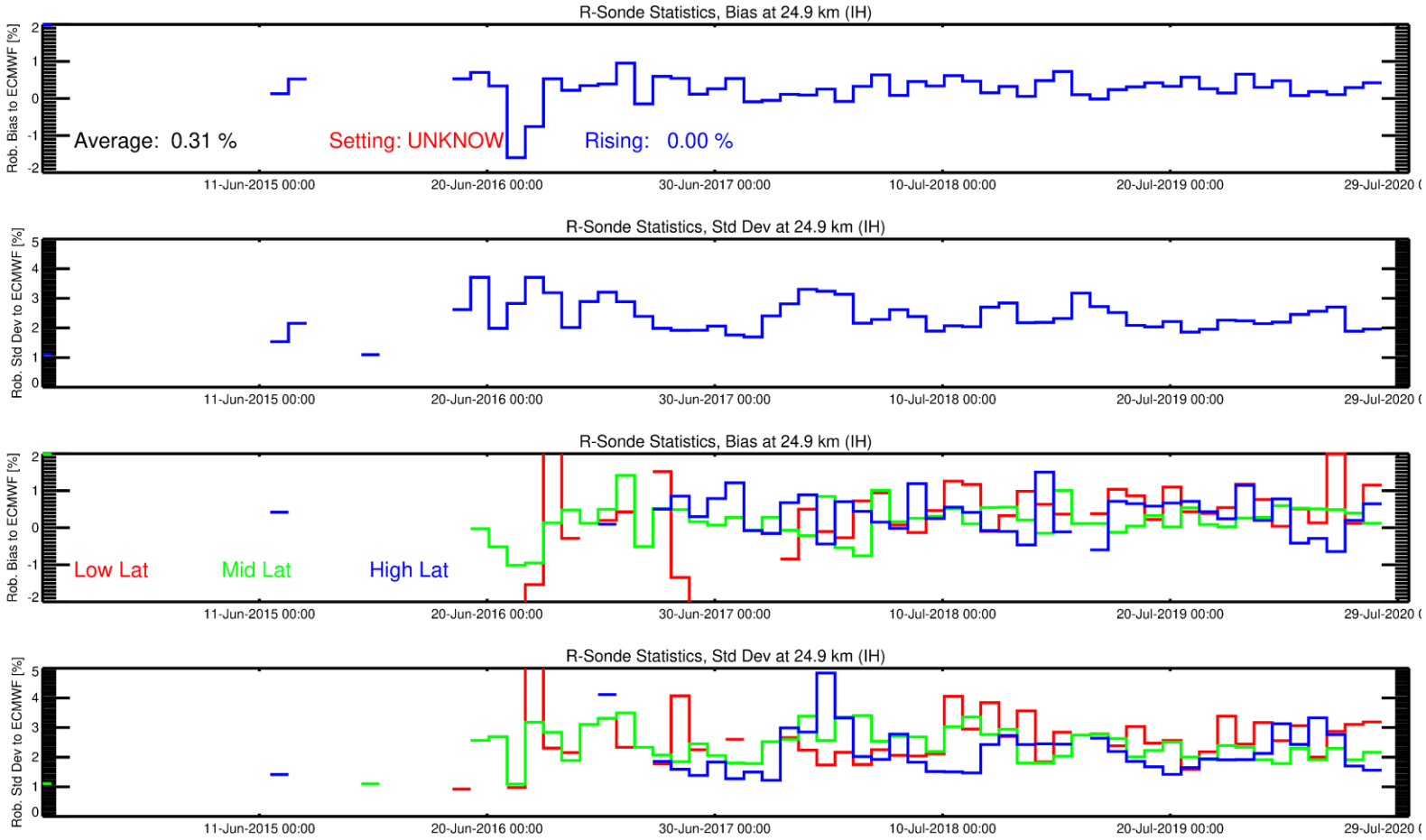
⇒ RS92 day/night differences very small, overall bias very small

⇒ RS41 day/night shown different bias, both for Metop-AB (middle), and Metop-C (right)

⇒ RS41 overall bias is similar to a temperature offset of about -0.2K vs. RS92 or RO (lower right shows -0.5K correction)



Matches of GRAS-A,B to RS41: Trends



Trends of GRUAN RS41 matches with GRAS robust statistics at 25km: (top) overall bias, (2. plot) overall standard deviations, (3. plot) bias by latitude band, (bottom) standard deviation by latitude band. All data with collocation correction. Shown are the (RS-RO)/RO monthly stats.

Conclusions

- Taking into account all identified corrections, RO vs RS gives very reasonable results
- Shows reasonable agreement in lower troposphere, where RO has trouble – latest reprocessing improves the statistics
- Temperature based RO vs RS92/RS41 assessments do though show different temperature offsets at higher altitudes
  - Other satellite assessments suggest a positive bias
    - maybe the altitude referencing is not consistent?