OVERVIEW OF RADIO OCCULTATION ACTIVITIES AT EUMETSAT

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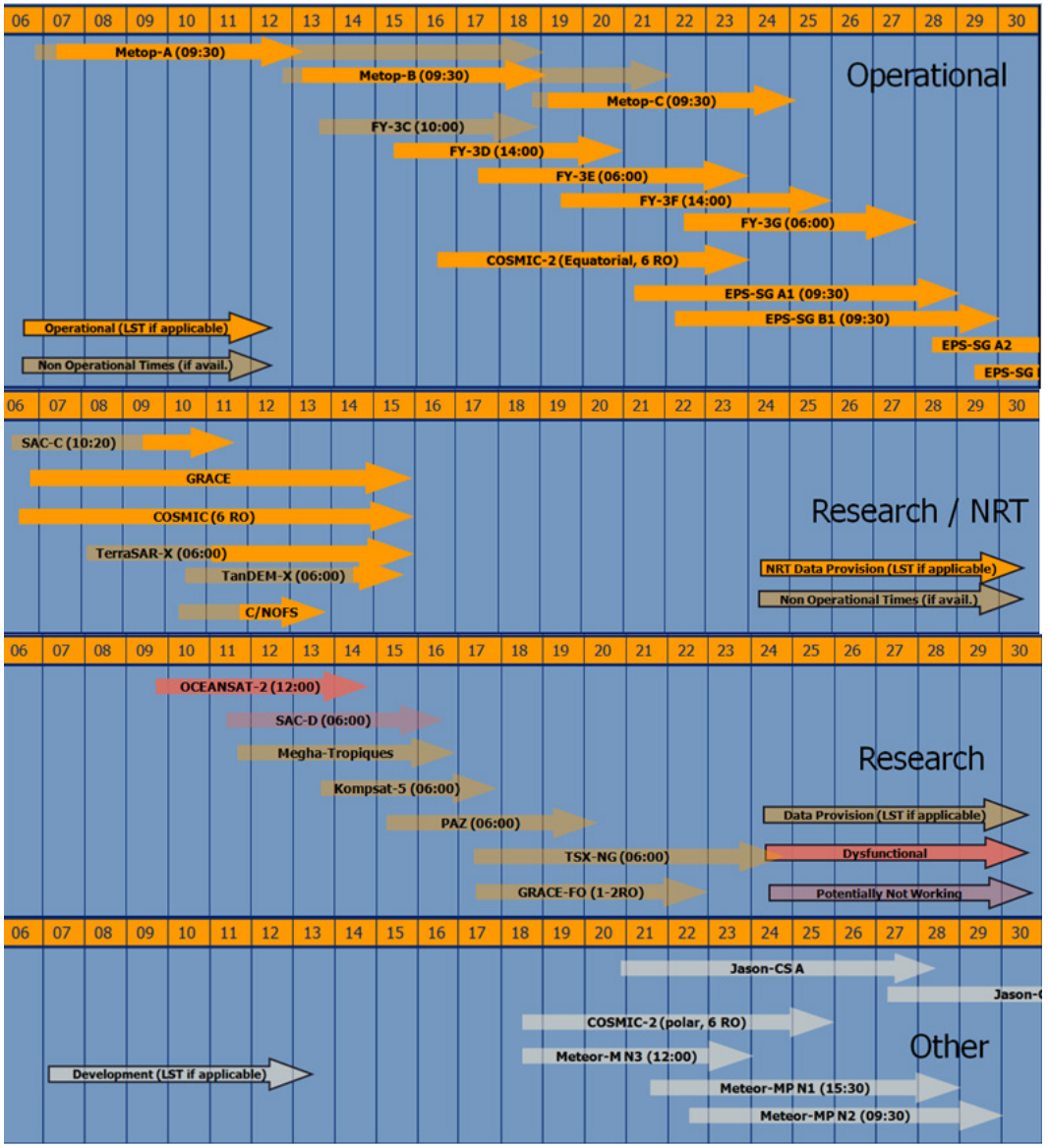
EUMETSAT

Overview

- EUMETSAT/RO Mission Overview
- GRUAN Radio Sonde Work
  - Occultation Forecasting
  - GRUAN vs. COSMIC Statistics
- EUMETSAT Reprocessing
- Conclusion
- Questions

EUMETSAT/RO Mission Overview



EUMETSAT involved in:

- Mandatory Program:
  - EPS (3 sats, up to mid 2020s),
  - EPS-SG (6 sats, up to > 2040)
- Optional Program:
  - Jason-CS (2 sats, up to 2033)

EPS is Europe's contribution to the Initial Joint Polar System (IJPS) established with NOAA

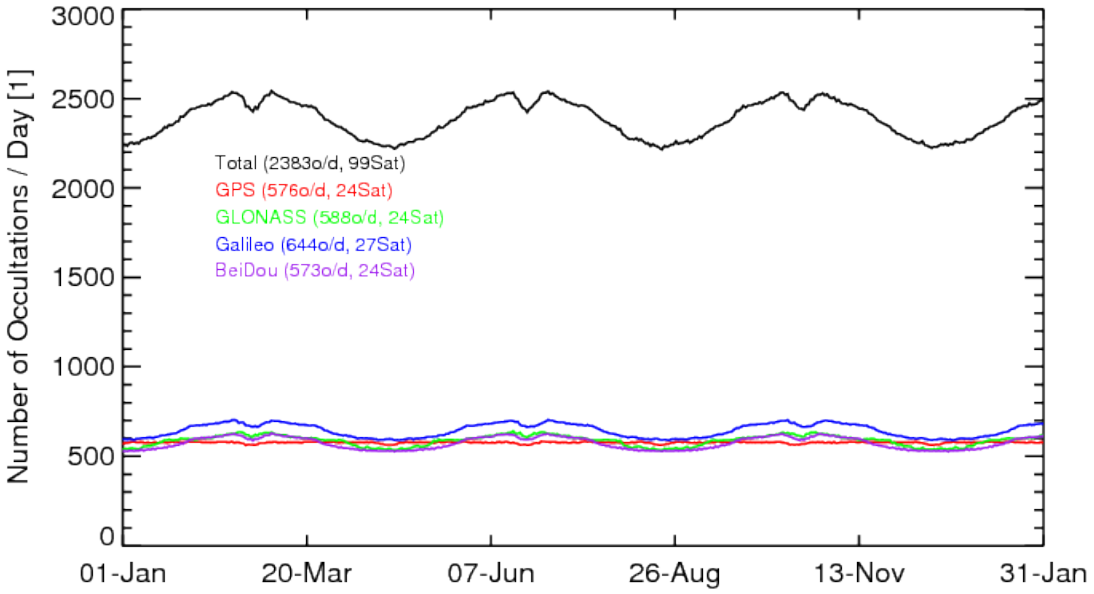
EPS-SG will be part of the NOAA/EUMETSAT Joint Polar System (JPS) Service

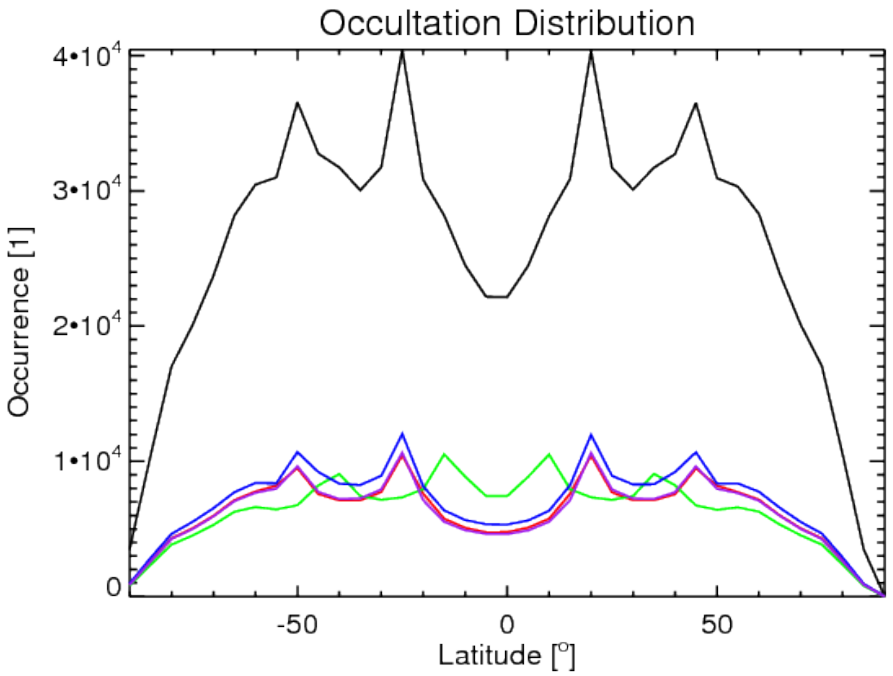
Jason-CS is planned to embark the COSMIC-2 TriG, NRT processing at UCAR, Offline at UCAR/EUM

EPS-SG RO vs. EPS GRAS Capabilities

Requirement	RO on MetOp-SG	GRAS on Metop
Bending Angle Accuracy	0.5 μrad @ 35km	0.5 μrad @ 35km
Occultations/Day	~ 1100 occ/day (GPS+Galileo) ~ 2200 occ/day (above + GLONASS, Compass)	~ 500 occ/day (req.) ~ 650 occ/day (actual)
GNSS constellations	GPS, Galileo, GLONASS, Compass	GPS only
Closed Loop	Yes, @ L1 and L5, up to 250Hz	Yes, @ L1 and L2, 50Hz
Open Loop for low altitudes tracking	Simultaneous Open Loop @ L1 and L5, Doppler Model and Range Model, 250Hz	Open Loop @ L1, Doppler Model, 1KHz
Use of Pilot Signals	Yes, better performance for closed loop	Not applicable
Minimum SLTA	-300 km	-250 km
Maximum SLTA	+80km atmosphere, 500km ionosphere	+80 km atmosphere
Autonomous Start-Up	Yes, for GPS and Galileo	No, Almanac needed
Reliability	0.84 @ 7.5 years	0.8 @ 5 years

EPS-SG Occultations Coverage Simulation





Expected occultations per day from one EPS-SG satellite observing all four GNSS (left); latitudinal coverage (right). Assumes aligned Galileo, GLONASS, BeiDou orbit planes (thus peaks/troughs).

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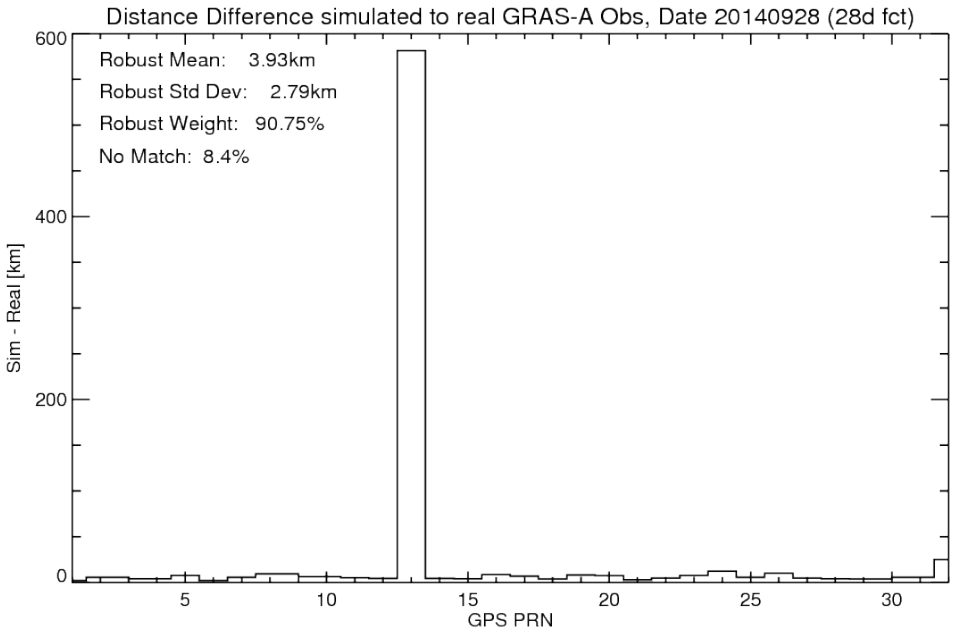
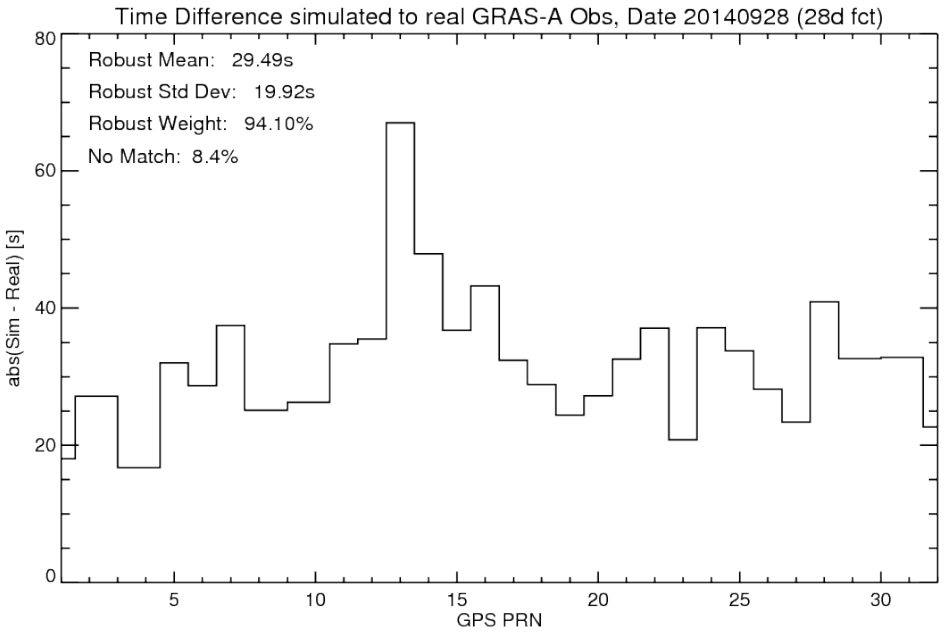
Occultation Prediction: Setup

- NAPEOS S/W for precise orbit prediction:
  - GPS orbits:
    - latest, precise GPS orbits, as provided by EPS/Metop GNSS service (GSN)
    - fitted with the NAPEOS model over 24h
    - propagated up to 30 days in advance
  - LEO orbits:
    - latest LEO Near Real Time orbit derived over the last 7 days (where possible, COSMIC has larger coverage gaps)
    - fitted with the NAPEOS model (the 7 days give more stable orbits)
    - propagating them for 30 days
- Period investigated:
  - Metop: first day of propagation 01 September 2014
    NOTE: EUMETSAT uses geometric dependent mean occultation position (0km SLTA)
  - COSMIC: first day of propagation 01 January 2009
    NOTE: UCAR uses atmospheric dependent mean occultation position (-40km SLTA)
- Forecasts:
  - in house occultations simulator
  - up to 4 weeks in advance, daily, results shown for weekly periods
- Research/Evaluation exercise

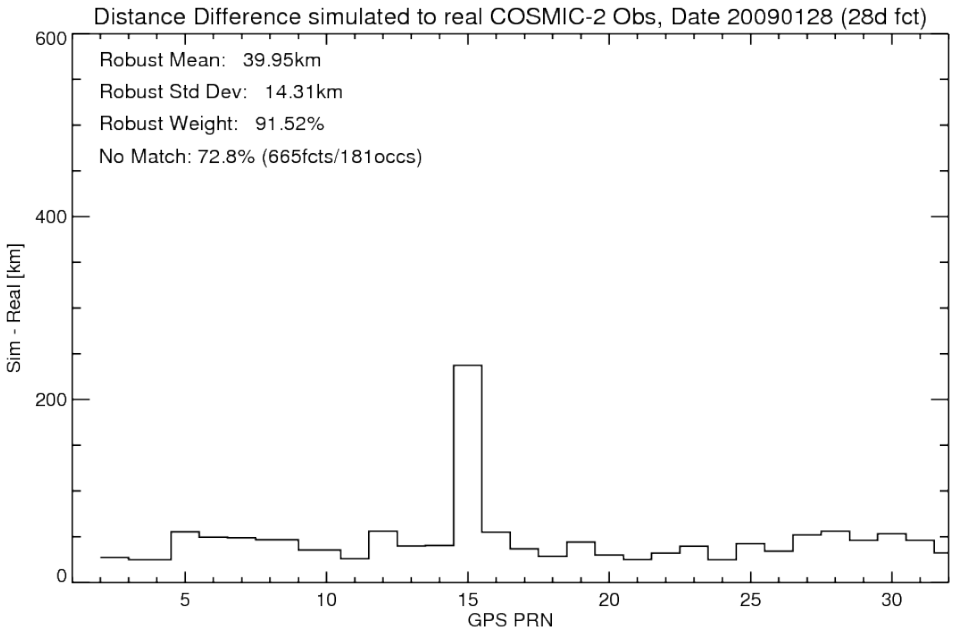
Occultation Prediction: Metop-A Results (28d fcts)

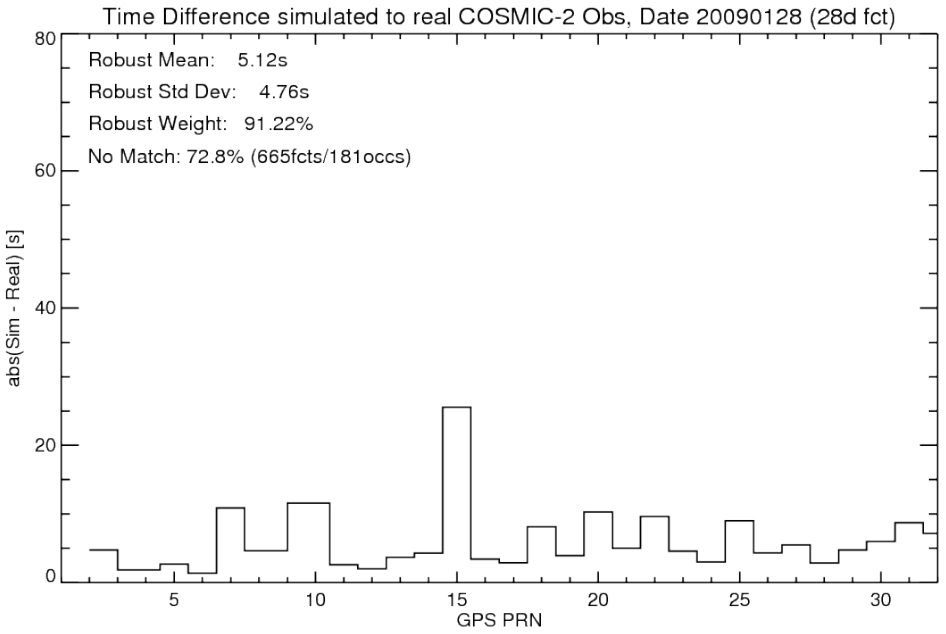




Mean (non-robust) simulated to actual observation differences, left distance, right time, separated by GPS satellite PRN. Legend gives robust estimates for full data set.

Occultation Prediction: COSMIC1-2 Results (28d fcts)





Mean (non-robust) simulated to actual observation differences, left distance, right time, separated by GPS satellite PRN. Legend gives robust estimates for full data set.

GRUAN vs. COSMIC Stats: GRUAN Background

GCOS is establishing a reference network for upper-air climate observations (GRUAN).

GRUAN is expected to provide long-term, highly accurate measurements of the atmospheric profile, complemented by ground-based state of the art instrumentation, to constrain and calibrate data from more spatially-comprehensive global observing systems (inc. satellites and current radiosonde networks), in order to fully characterize the properties of the atmospheric column and their changes.

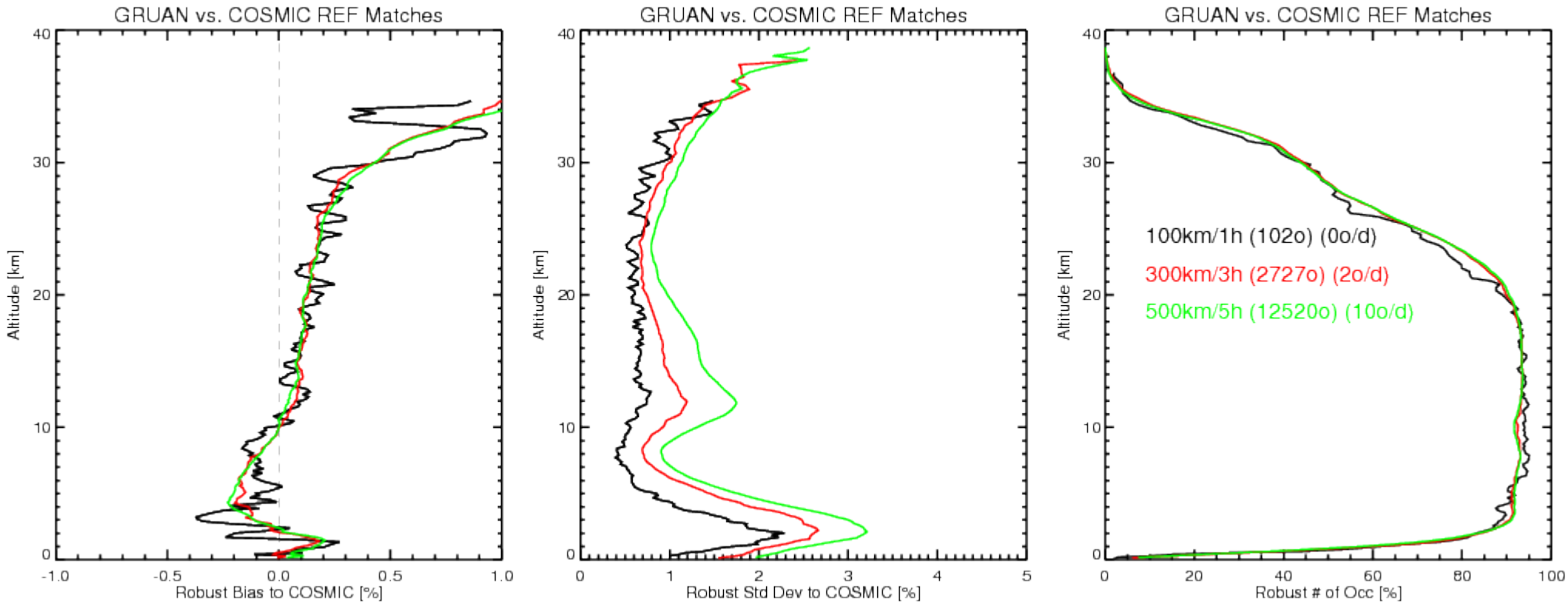
From: http://www.wmo.int/pages/prog/gcos/index.php?name=GRUAN

- Primarily use RS92 Vaisala sondes, with an upgrade to RS41 within the next 2 years expected
- High resolution data
- Cover mostly 2010 onwards

GRUAN vs. COSMIC Stats: Setup

- Using version 002 of GRUAN data
- Using COSMIC “offline” or “reprocessed 2013” data
- Using ECMWF operational 12h forecasts at RO position
- Matching within 1h/100km to 5h/500km
- Using location at 10km sonde profile, mean tangent point of RO

GRUAN vs. COSMIC Stats: Impact of Non-Ideal Gas



Refractivity GRUAN vs. COSMIC/UCAR offline matches for **ideal** gas compressibility, bias (left), std. dev. (middle), robust weight (right, indicating the number of outliers in the statistics). Limited period covered.

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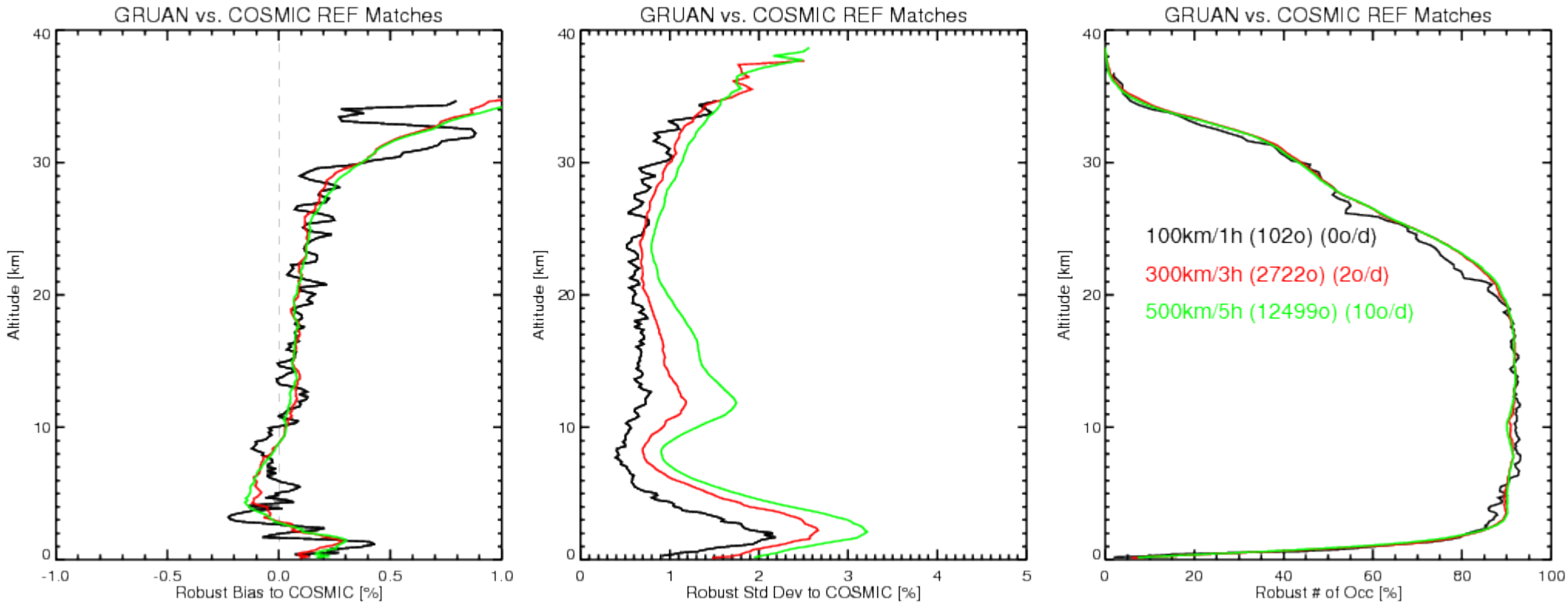
GRUAN vs. COSMIC Stats: Impact of Non-Ideal Gas



Refractivity GRUAN vs. COSMIC/UCAR offline matches for **non-ideal** gas compressibility, bias (left), std. dev. (middle), robust weight (right, indicating the number of outliers in the statistics). Limited period covered.

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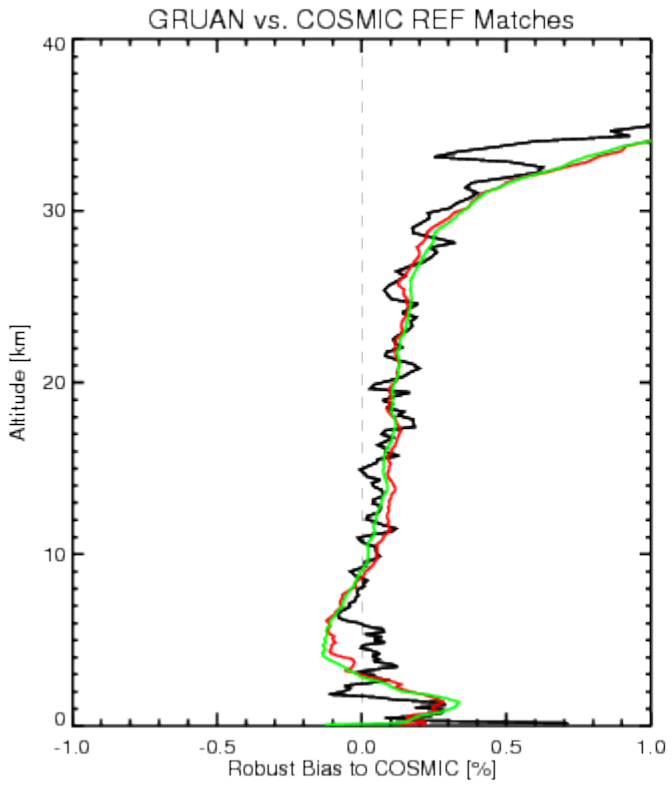
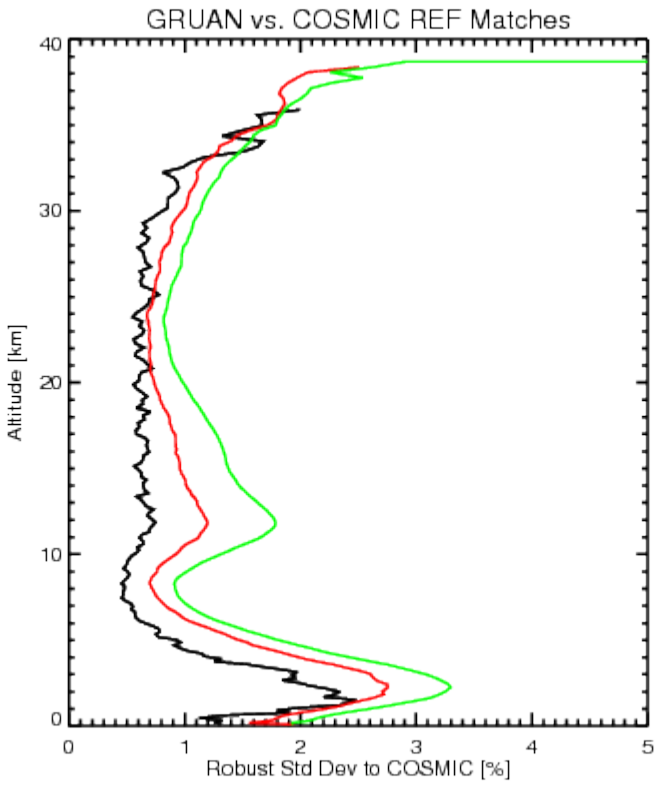
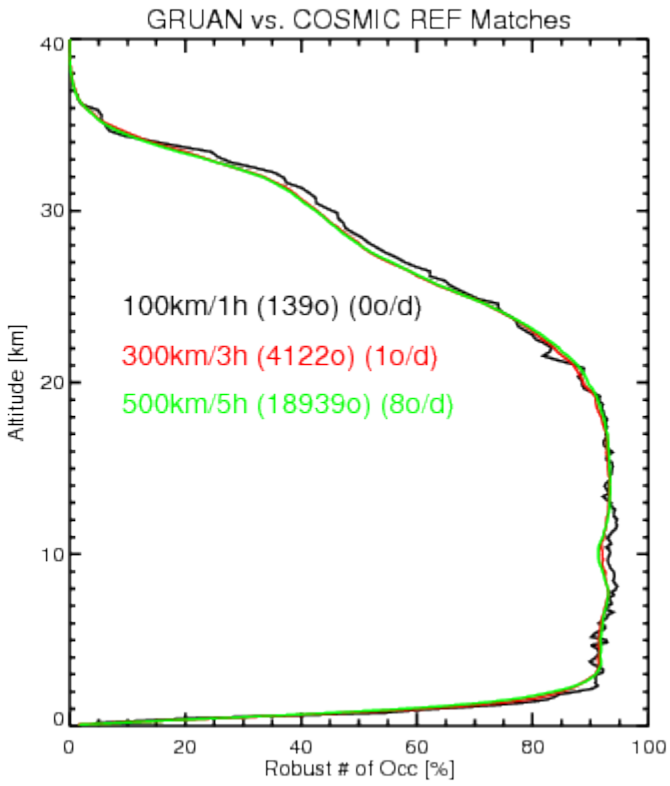
GRUAN vs. COSMIC R2013 Stats: Refractivities



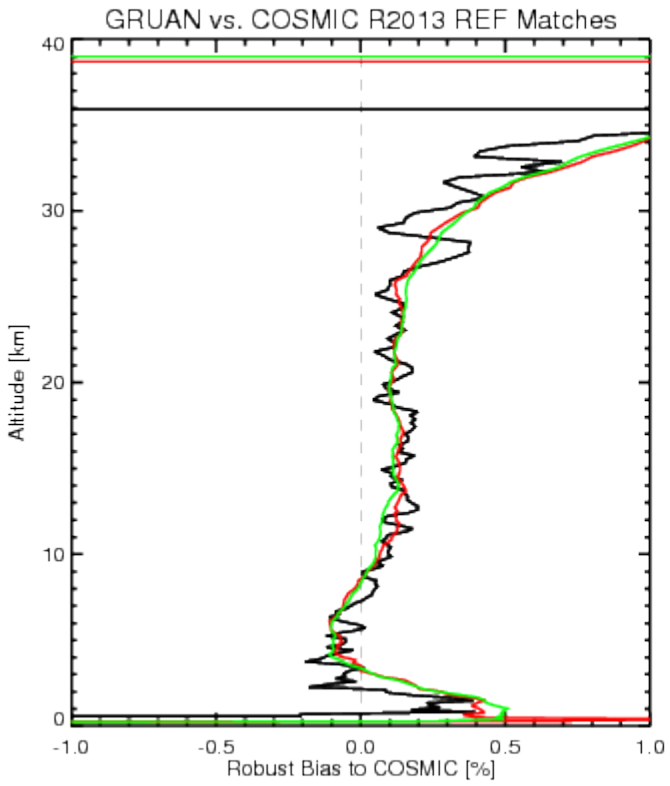


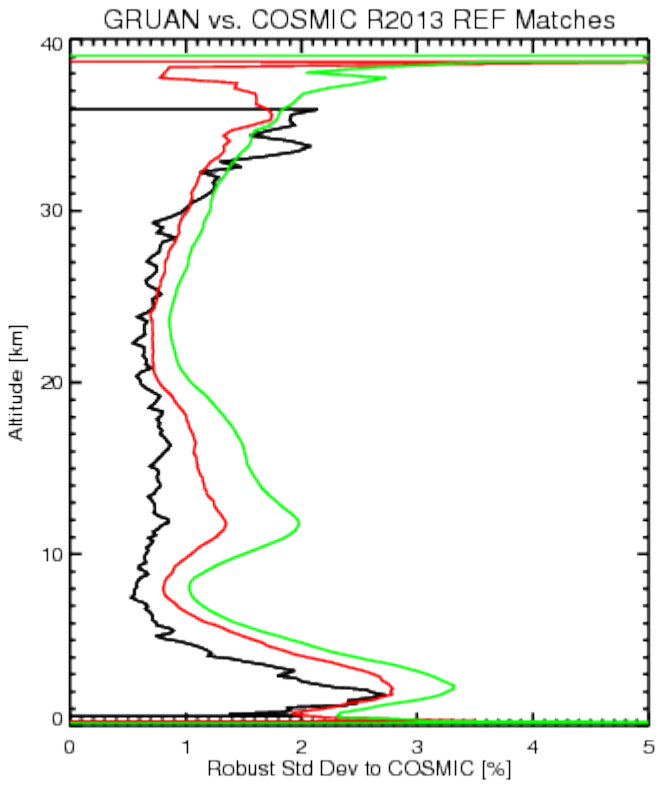


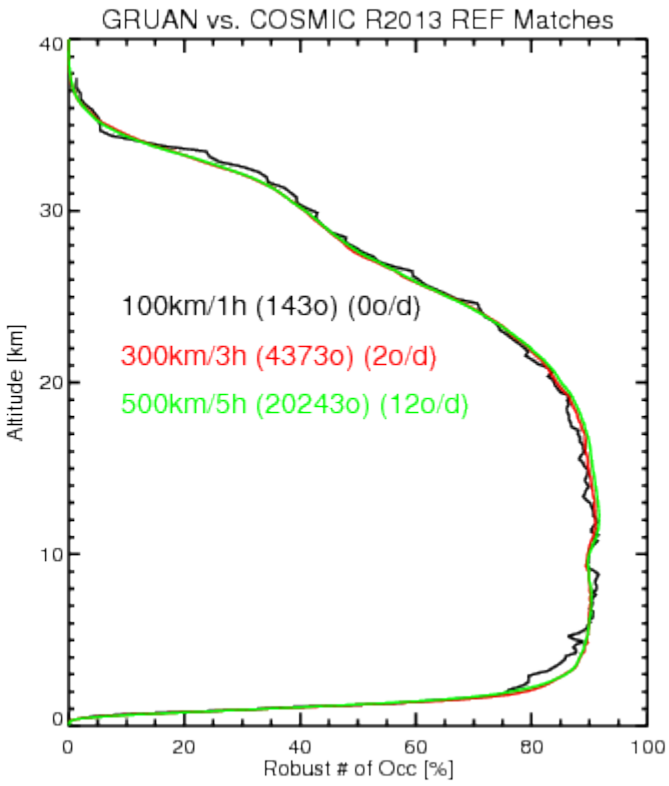
Refractivity validation of GRUAN vs. matched **offline** COSMIC/UCAR, bias (left), std. dev. (middle), robust weight (right, indicating the number of outliers in the statistics).

Note: COSMIC Repro 2013 provided more occultations, hence larger number of matches

GRUAN vs. COSMIC R2013 Stats: Refractivities







Refractivity validation of GRUAN vs. matched **reprocessed 2013** COSMIC/UCAR, bias (left), std. dev. (middle), robust weight (right, indicating the number of outliers in the statistics).

Note: COSMIC Repro 2013 provided more occultations, hence larger number of matches

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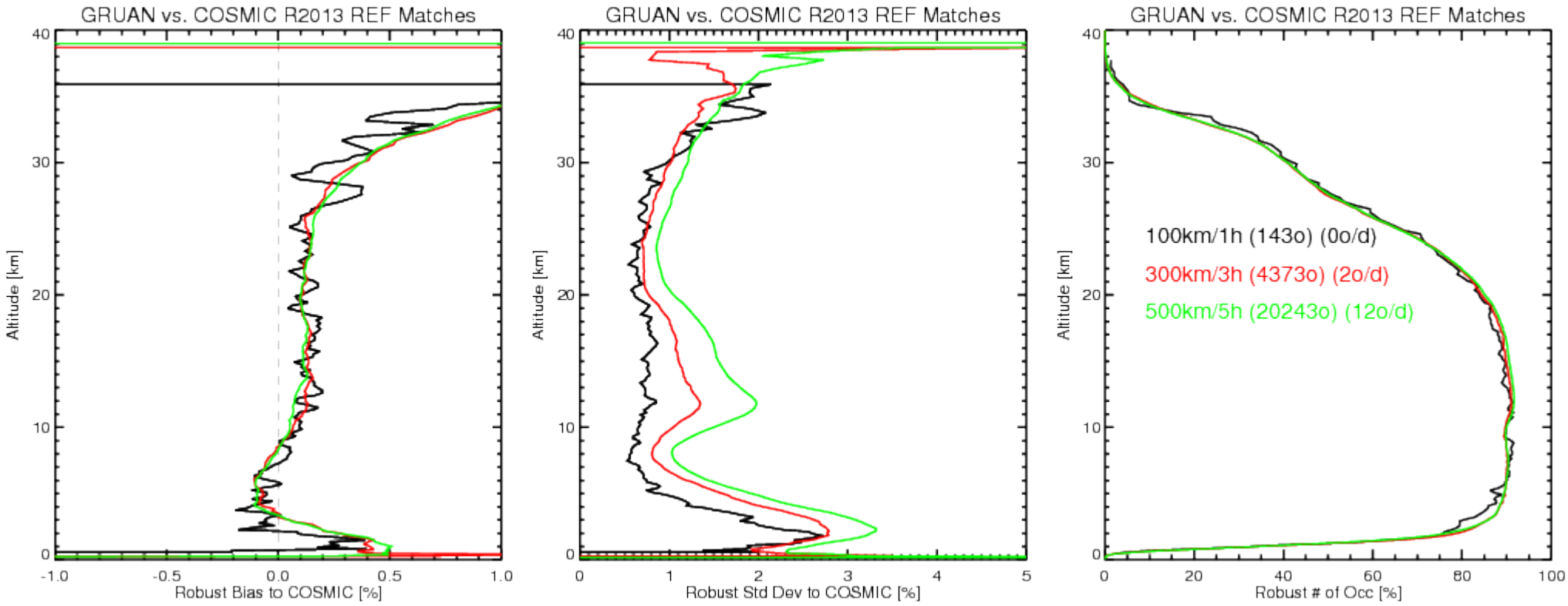
GRUAN vs. COSMIC/ECMWF R2013 Stats: Refractivities



Refractivity validation of GRUAN vs. matched reprocessed COSMIC/UCAR **Repro 2013**, bias (left), std. dev. (middle), robust weight (right, indicating the number of outliers in the statistics).

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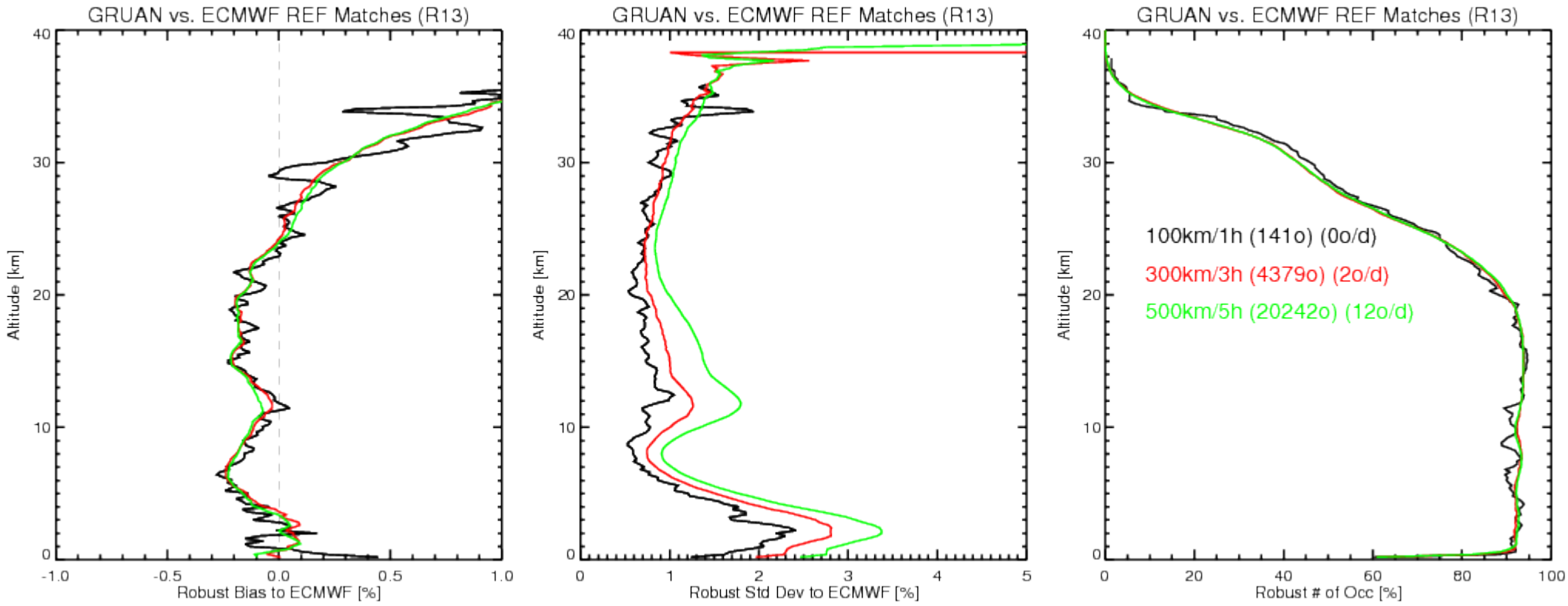
GRUAN vs. COSMIC/ECMWF R2013 Stats: Refractivities



Refractivity validation of GRUAN vs. matched **ECMWF forecast at RO location**, bias (left), std. dev. (middle), robust weight (right, indicating the number of outliers in the statistics).

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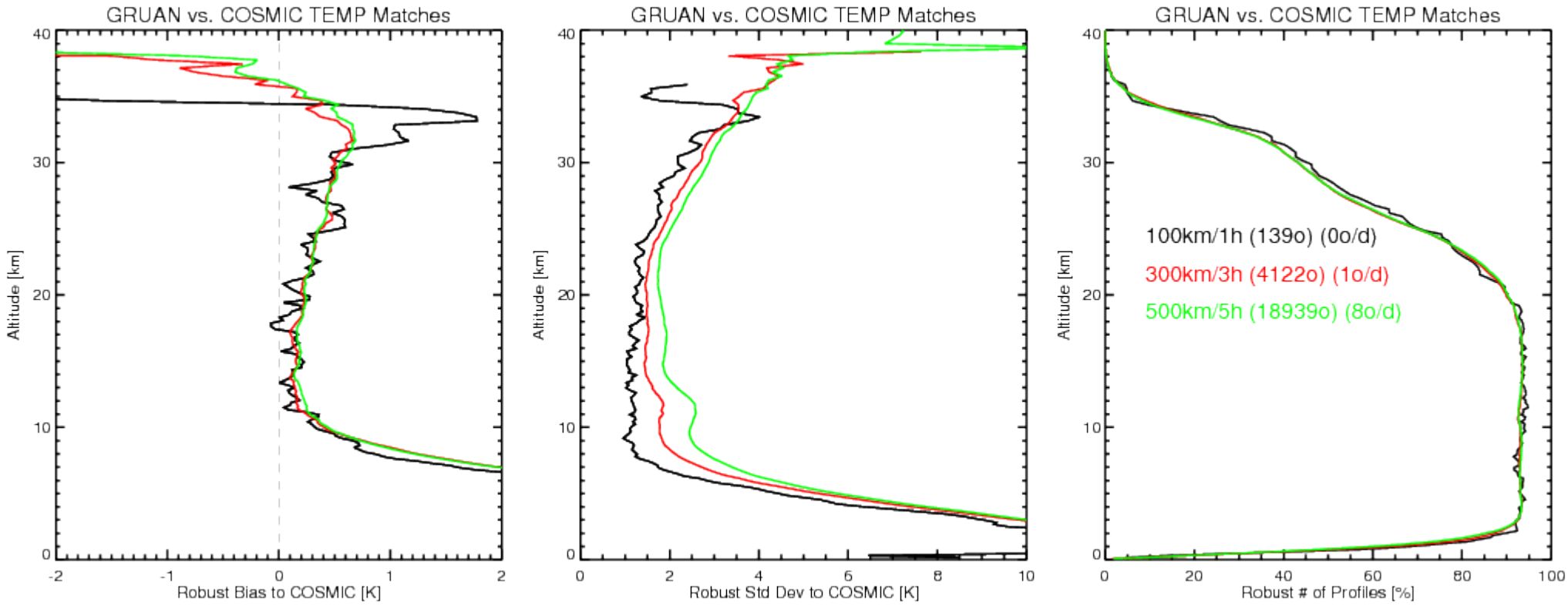
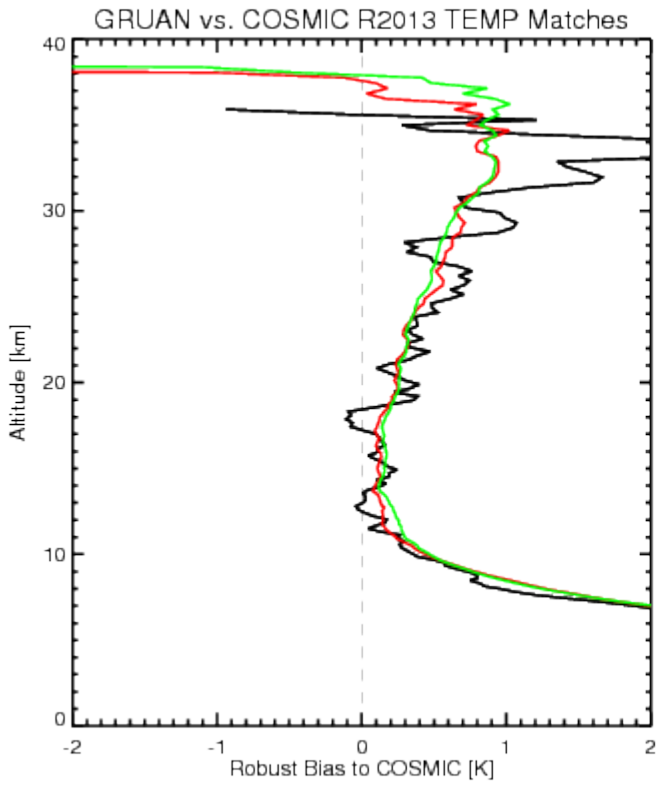
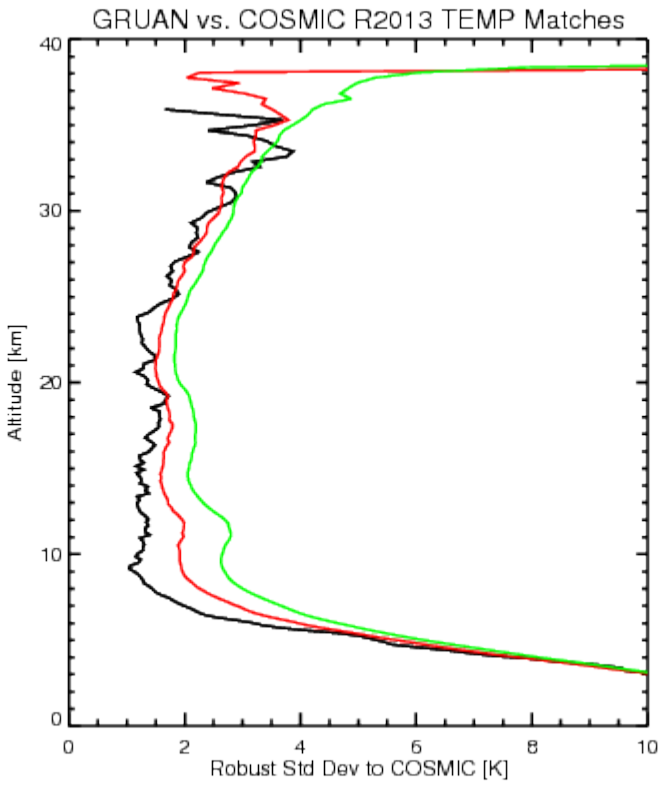
GRUAN vs. COSMIC R2013 Stats: Temperatures

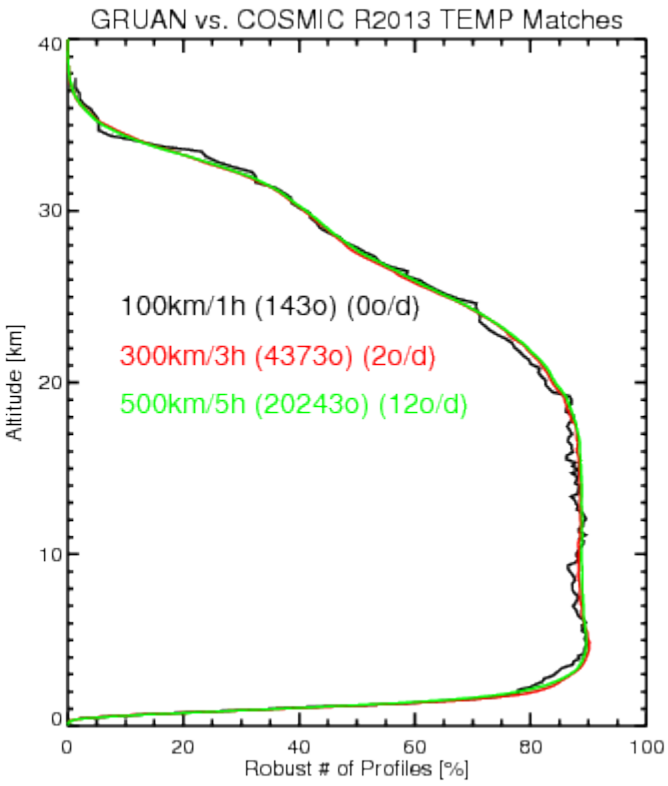


Temperature validation of GRUAN vs. matched **offline** COSMIC/UCAR (dry), bias (left), std. dev. (middle), robust weight (right, indicating the number of outliers in the statistics).

GRUAN vs. COSMIC R2013 Stats: Temperatures

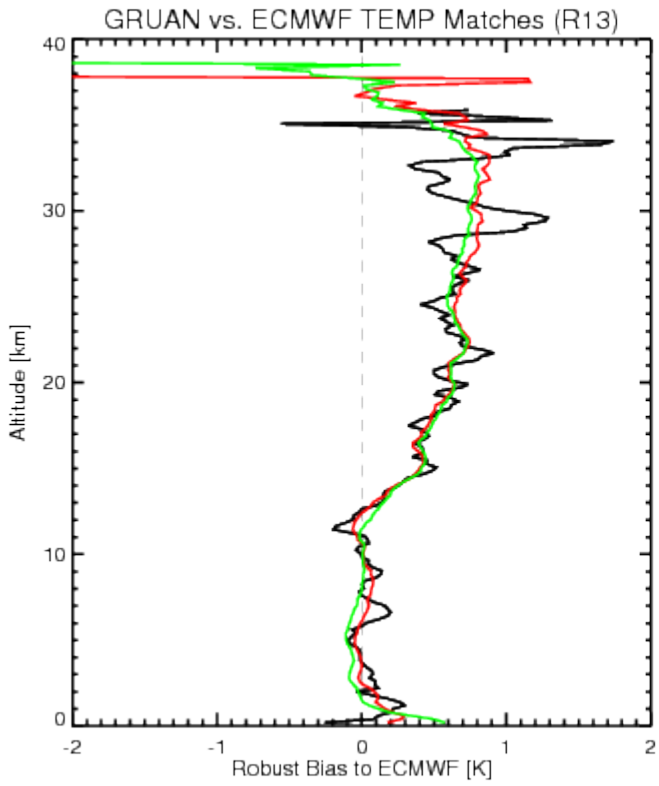


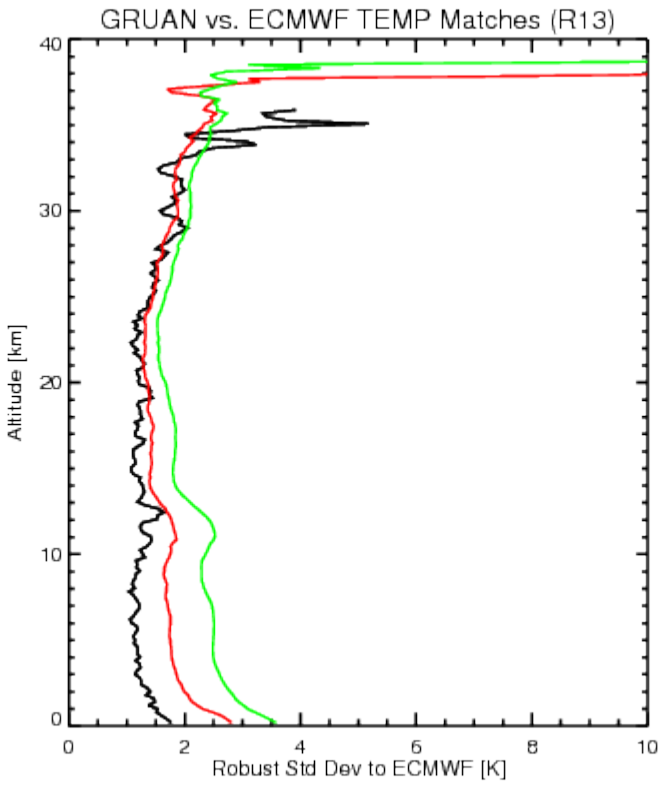


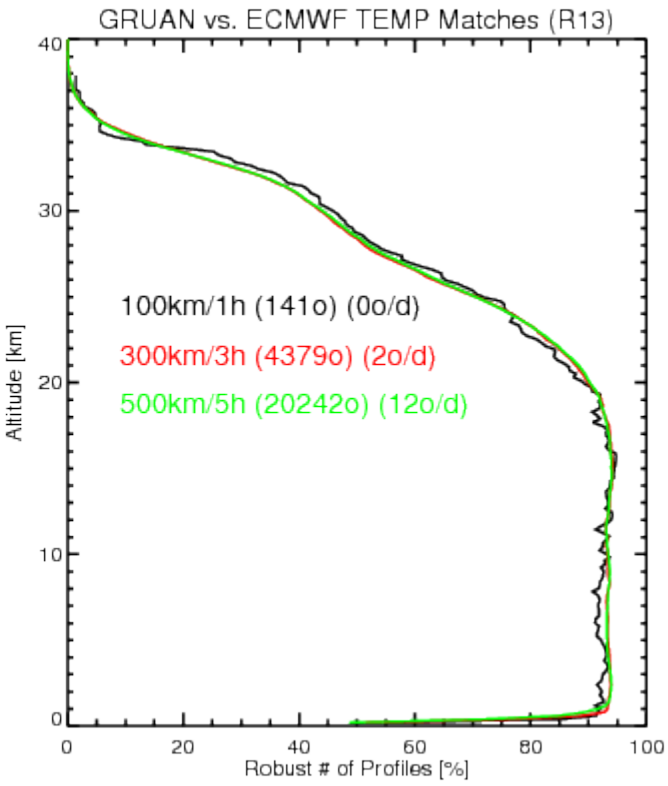


Temperature validation of GRUAN vs. matched **reprocessed 2013** COSMIC/UCAR (dry), bias (left), std. dev. (middle), robust weight (right, indicating the number of outliers in the statistics).

GRUAN vs. COSMIC Repro 2013 Stats: Temperatures

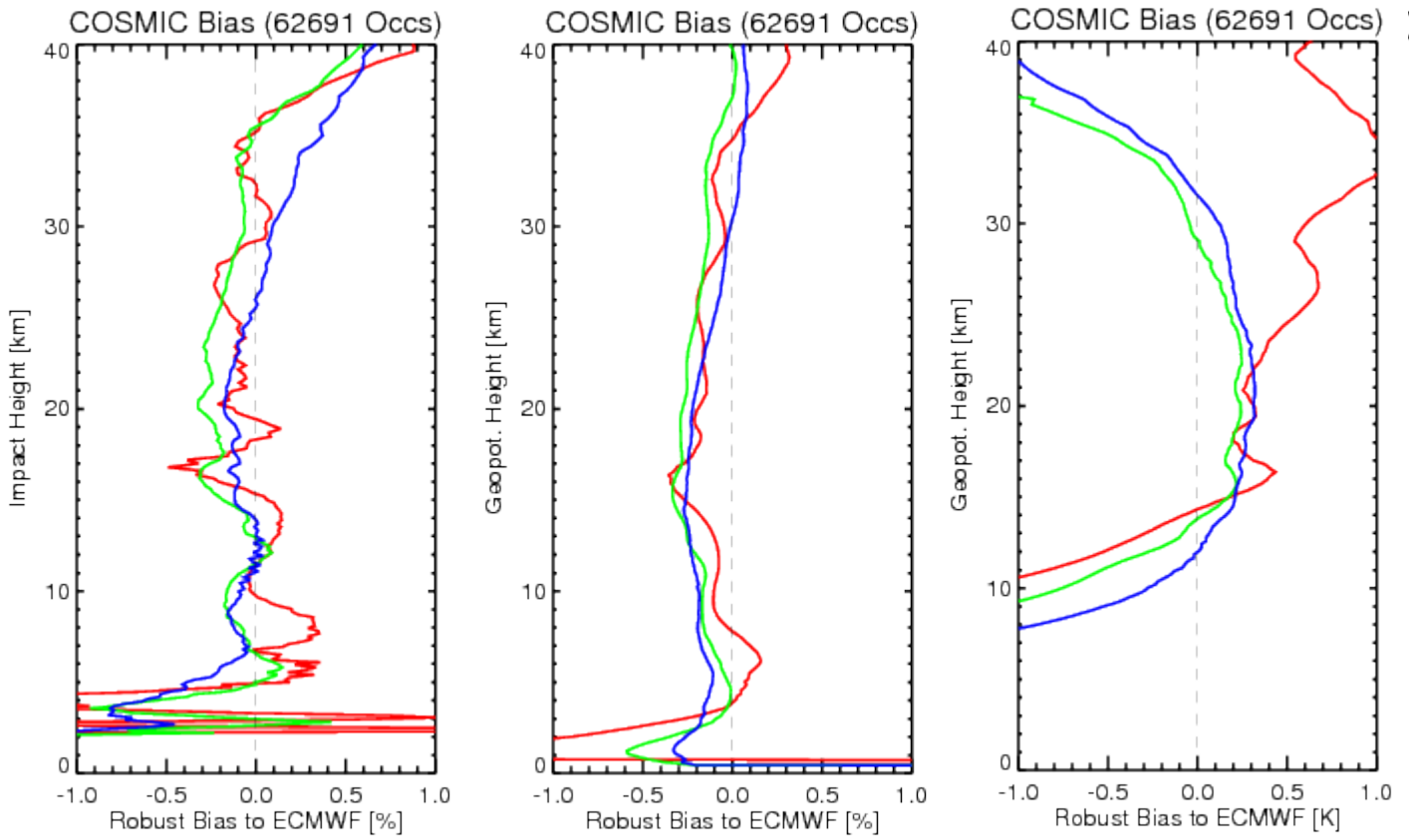






Temperature validation of GRUAN vs. matched **ECMWF forecast at RO location**, bias (left), std. dev. (middle), robust weight (right, indicating the number of outliers in the statistics).

ECMWF vs. COSMIC Repro 2013 Stats: July 2010



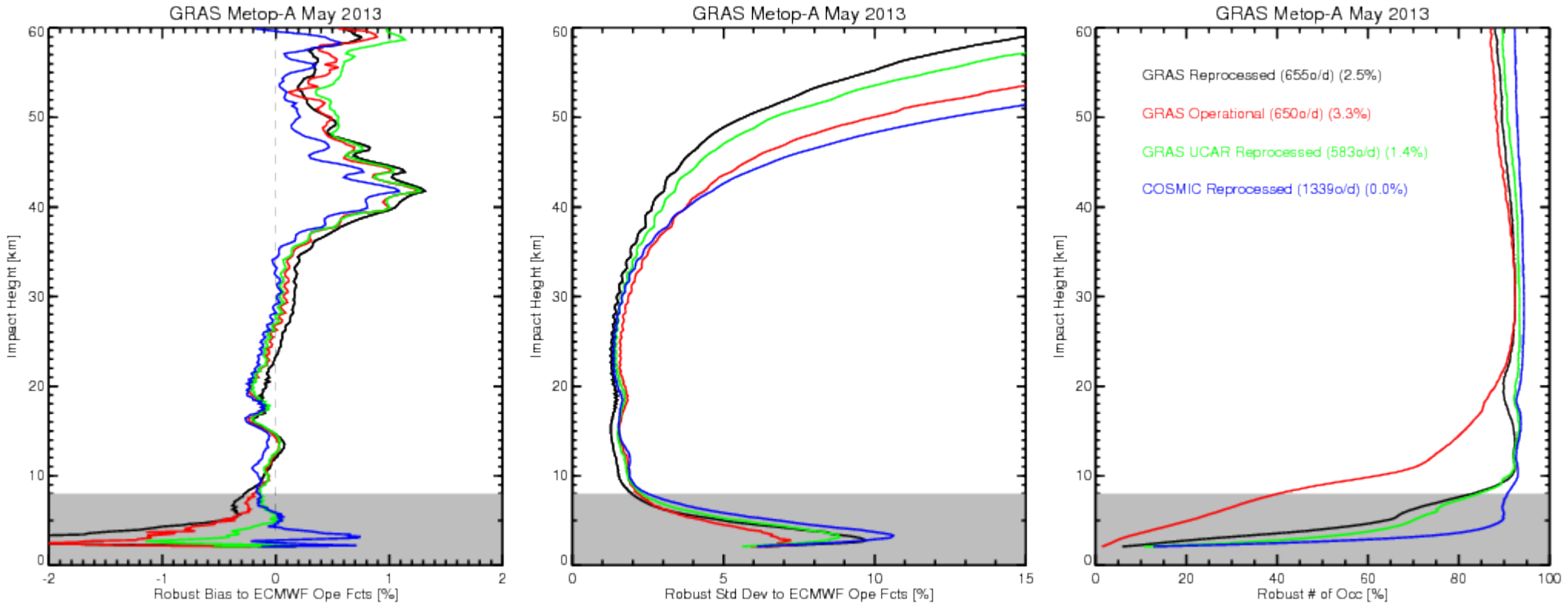
Bending angle bias (left), refractivity bias (middle), dry temperature bias (right) of reprocessed 2013 COSMIC/UCAR data against co-located ECMWF forecast data, forward modelled to bending angles and refractivity using the ROM SAF ROPP S/W.

EUMETSAT Reprocessing Info

- Currently running a reprocessing of Metop-A and -B data up to end 2014
  - Data formats (netCDF4, ROPP tools), GO processing finalized
  - Fine tuning of Wave Optics ongoing (on L1, L2, over all altitudes)
  - Based on in-house prototype
- Early delivery of Metop-A GO data for ECMWF ERA-CLIM in July and to ROTrends
- Full data set, including documentation available later 2015
- Next step is reprocessing of CHAMP, COSMIC, ... from level 0. Available ~end 2015
- Refractivity and temperature processing at the ROM SAF, after EUMETSAT data delivery
- **More info was provided in Yago Andres**

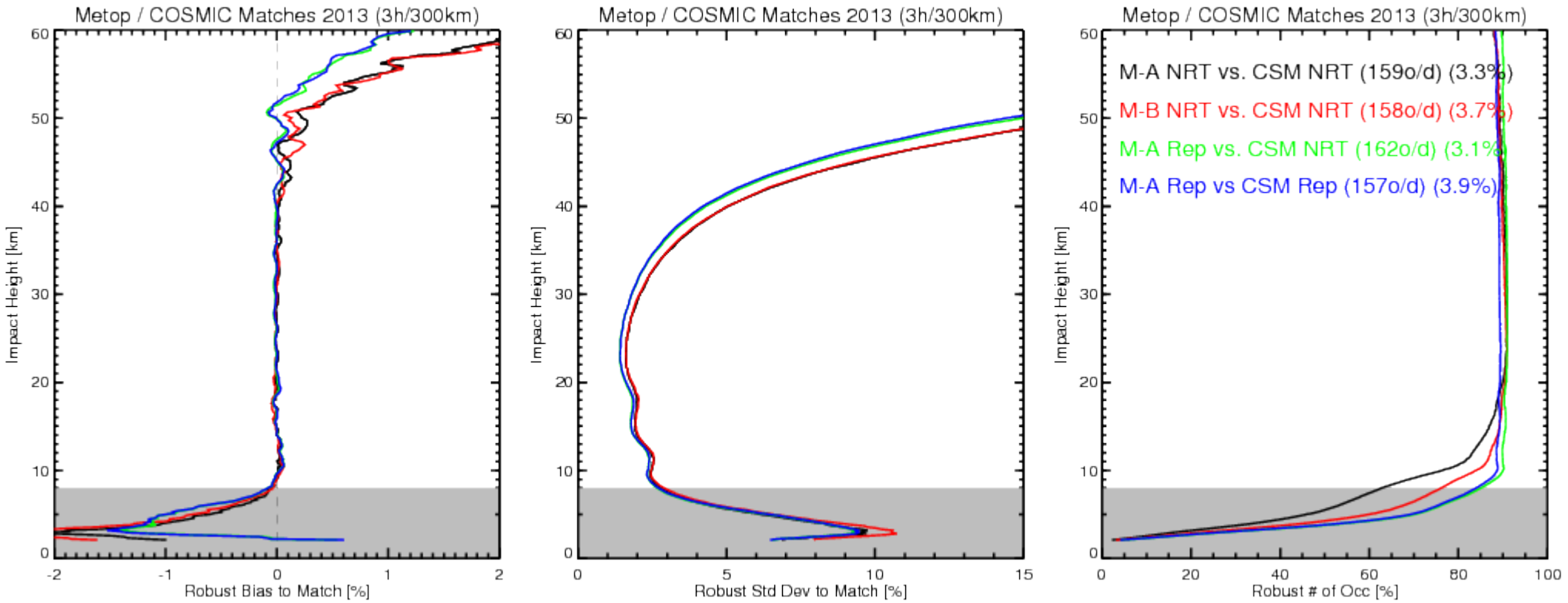
Some early validation plots of GO data on next slides

EUMETSAT Reprocessing Stats: ECMWF



Validation of GRAS Metop-A data vs. ECMWF fcts, May 2013: Reprocessed, NRT, UCAR GRAS repro, UCAR COSMIC repro. Bias (left), std. dev. (middle), robust weight (right, indicating number of outliers). Notes: (1) EUM NRT, Repro only GO, thus lowest 8km grey shaded; (2) bias, std dev ripples at higher altitude due to ECMWF model resolution (reduced with updated ROPP); (3) UCAR does a more rigorous COSMIC QC

EUMETSAT Reprocessing Stats: Matches



Matches of Metop-A and Metop-B within 3h/300km with COSMIC data. Near-Real-Time and Reprocessing shown. Bias (left), std. dev. (middle), robust weight (right, indicating number of outliers). Notes: (1) EUM NRT, Repro only GO, thus lowest 8km grey shaded; (2) M-A NRT uses different on-board tracking parameters to M-B, and different lower troposphere processing.

Conclusions

- EUMETSAT programs to cover RO > 2040
- Forecasting of occultations
  - Metop and COSMIC forecasting up to 4 weeks within a minute and a few km (depends on use of reference point though, and definition of start occ)
  - Caveats: manoeuvre impacts, forecasted COSMIC occs often not occurring, potentially include tangent point movement
- GRUAN - COSMIC Validation
  - non-ideal gas compressibility improves refractivity fit
  - refractivity differences < 0.2% bias, although bias > 30km
  - dry temp differences < 0.3K bias (12-30km), inconclusive
  - better to do comparisons at lower level (best BA, then REF, then TEMP)
- Reprocessing
  - GRAS data set available ‘15, COSMIC, CHAMP later ’15
  - plan to repeat GRUAN validation with GRAS data (with ROM SAF REF)