OCCULTATION PREDICTION WITH 4 WEEKS LEAD TIME / STATISTICAL ANALYSIS OF COSMIC RO DATA AGAINST GRUAN SONDES

Axel von Engeln, Yago Andres, Viju Oommen John

EUMETSAT

Also included : Results from University of Graz:
F. Ladstädter, A. Steiner, M. Schwärz, G. Kirchengast

Overview

- Occultation Forecasting
- GRUAN vs. COSMIC Statistics
- EUMETSAT Mission Overview
- EUMETSAT Reprocessing
- Conclusion
- Questions

- University of Graz Results

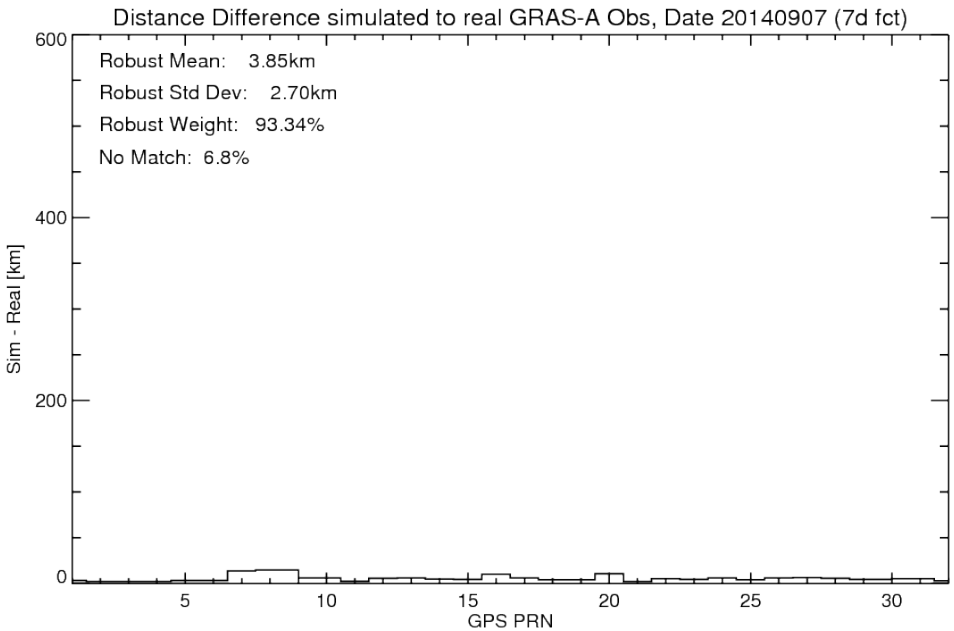
Occultation Prediction: Setup

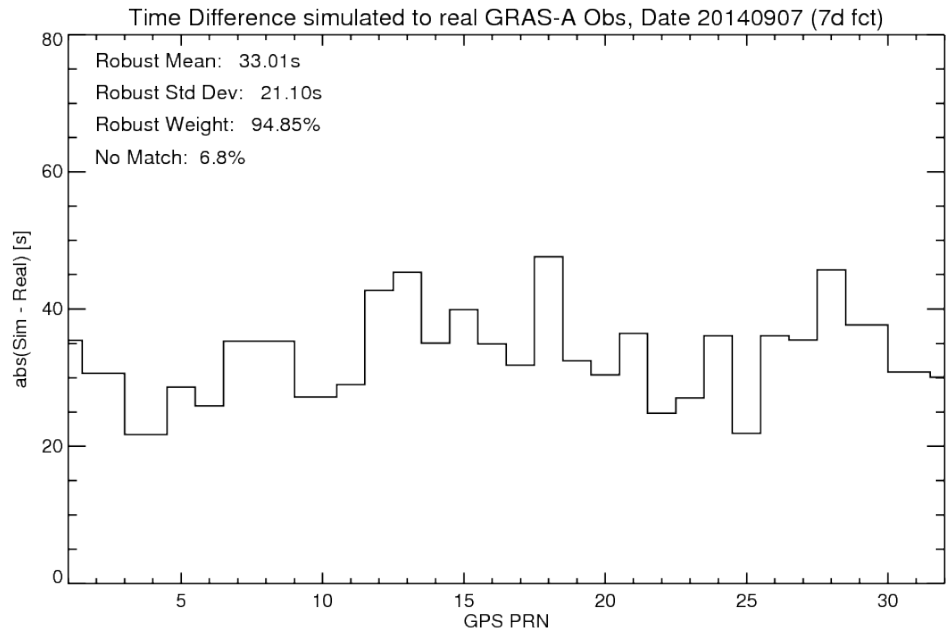
- NAPEOS S/W for precise orbit prediction:
  - GPS orbits:
    - latest, precise GPS orbits, as provided by EPS/Metop GNSS service (GSN)
    - fitted with the NAPEOS model over 24h
    - propagated up to 30 days in advance
  - LEO orbits:
    - latest LEO Near Real Time orbit derived over the last 7 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

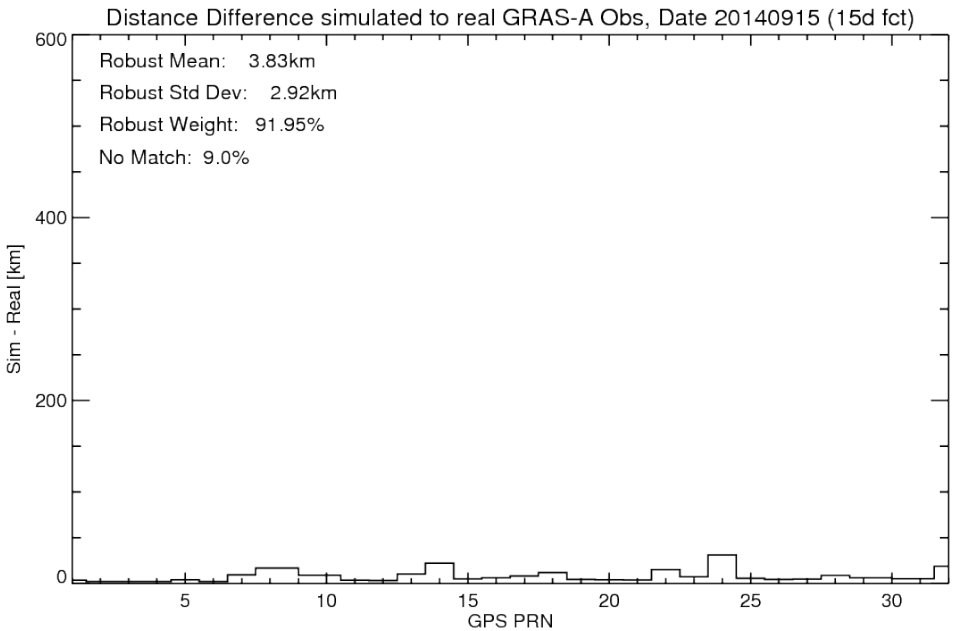
Occultation Prediction: Metop Results (7d fcts)

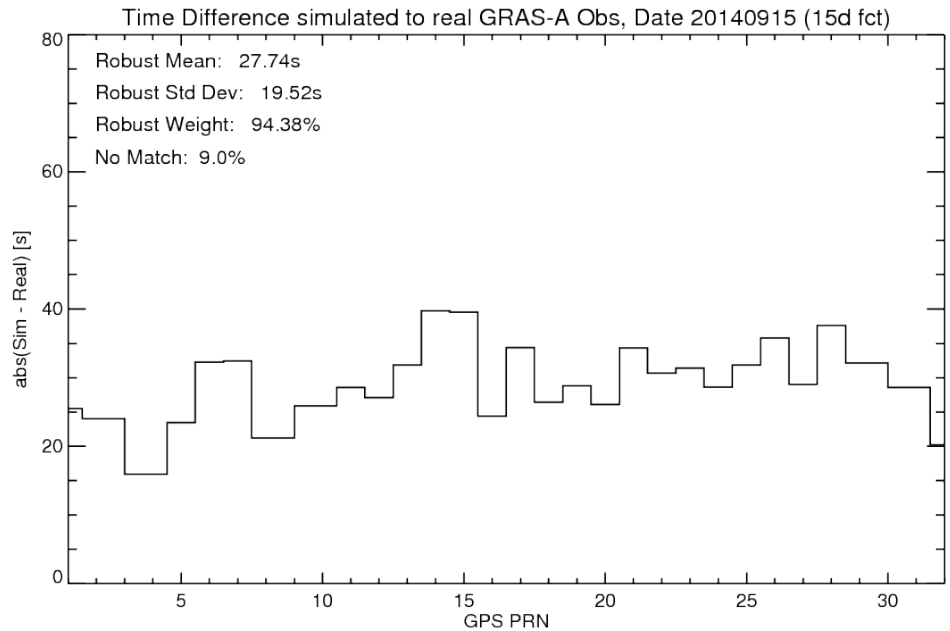




Mean (non-robust) simulated to actual observation differences, left distance, right time, separated by GPS satellite PRN. Legend gives robust estimates for full data set.

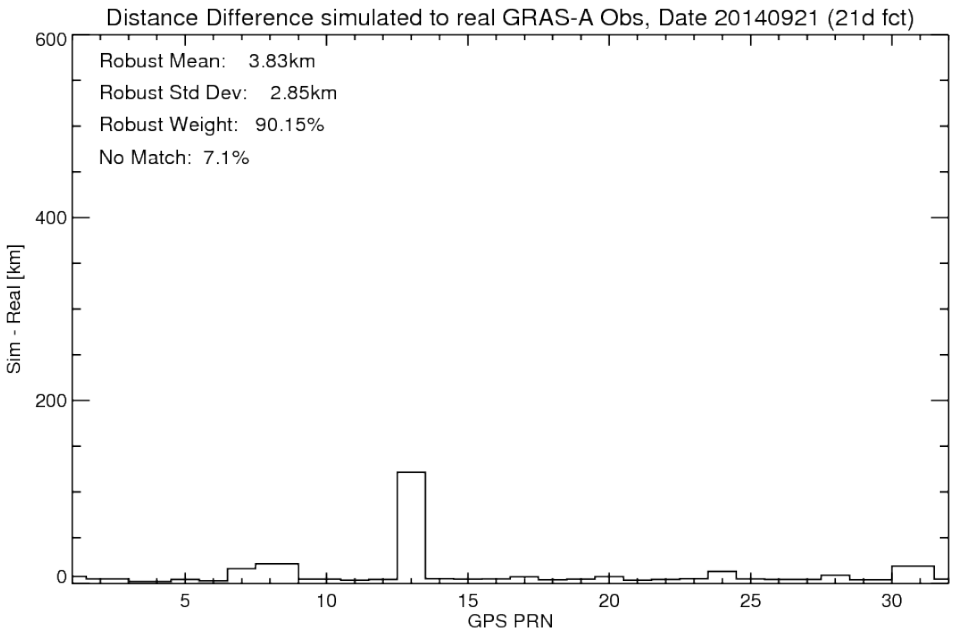
Occultation Prediction: Metop Results (14d fcts)

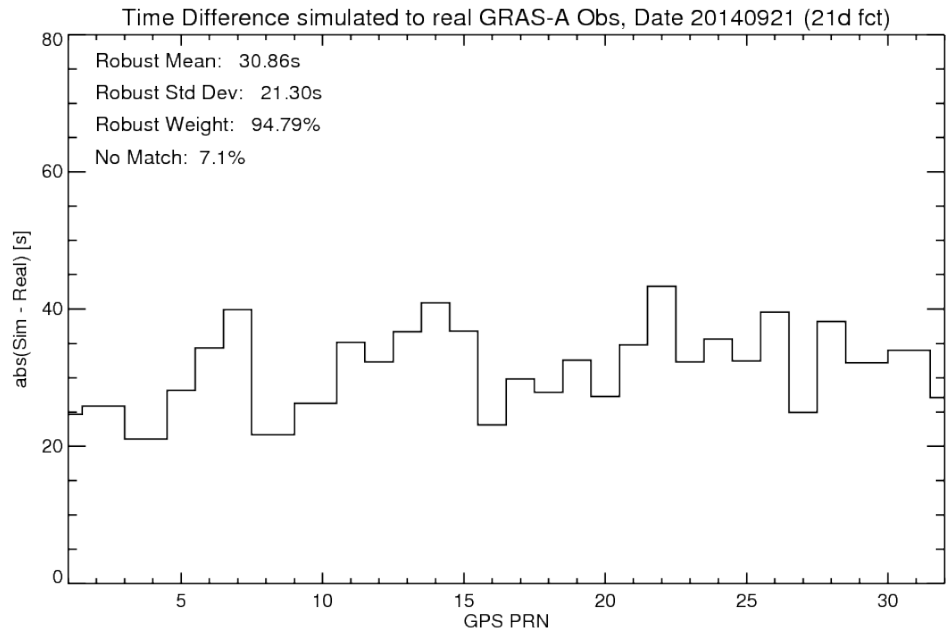




Mean (non-robust) simulated to actual observation differences, left distance, right time, separated by GPS satellite PRN. Legend gives robust estimates for full data set.

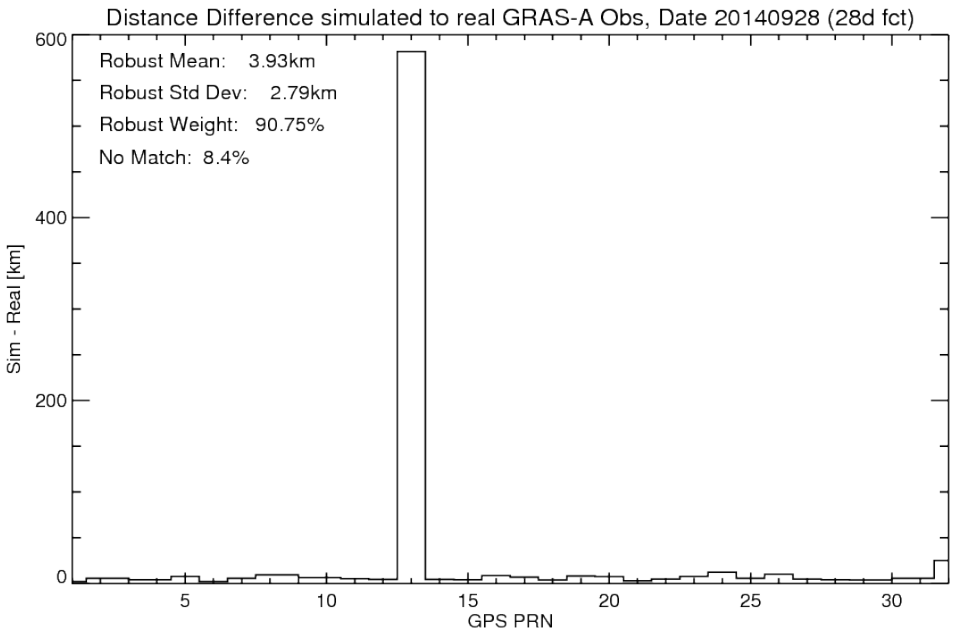
Occultation Prediction: Metop Results (21d fcts)

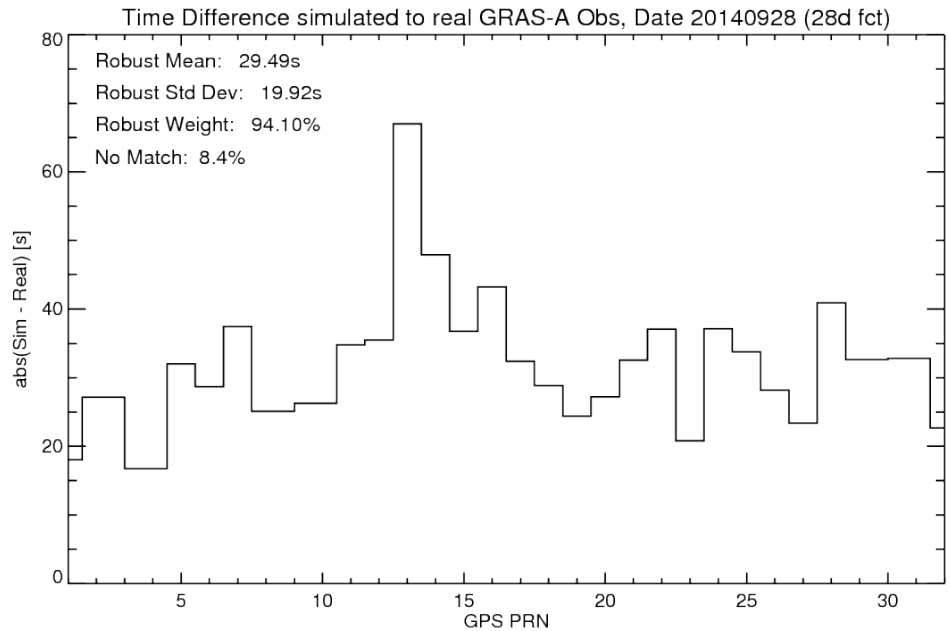




Mean (non-robust) simulated to actual observation differences, left distance, right time, separated by GPS satellite PRN. Legend gives robust estimates for full data set.

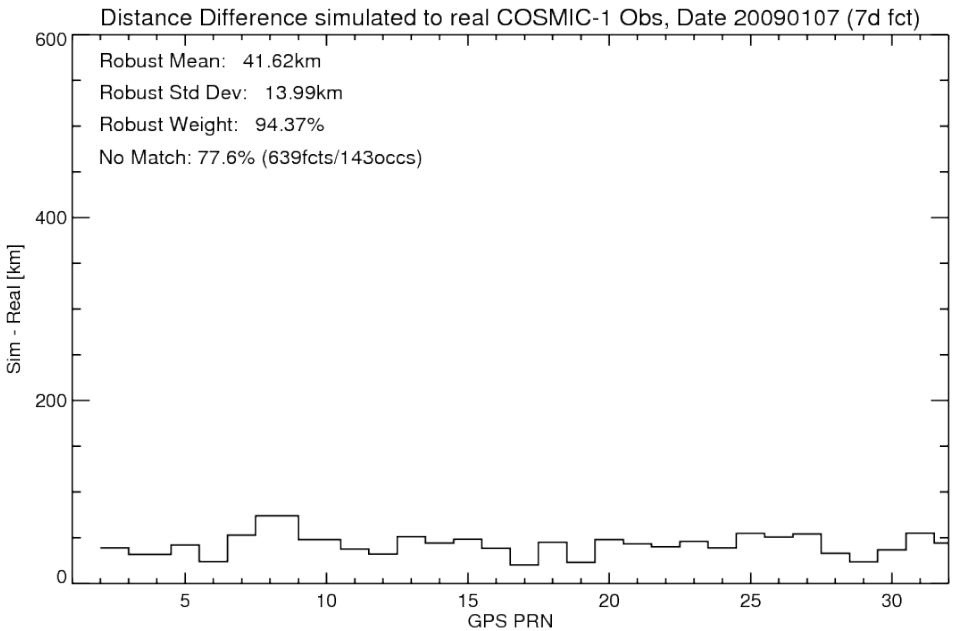
Occultation Prediction: Metop Results (28d fcts)

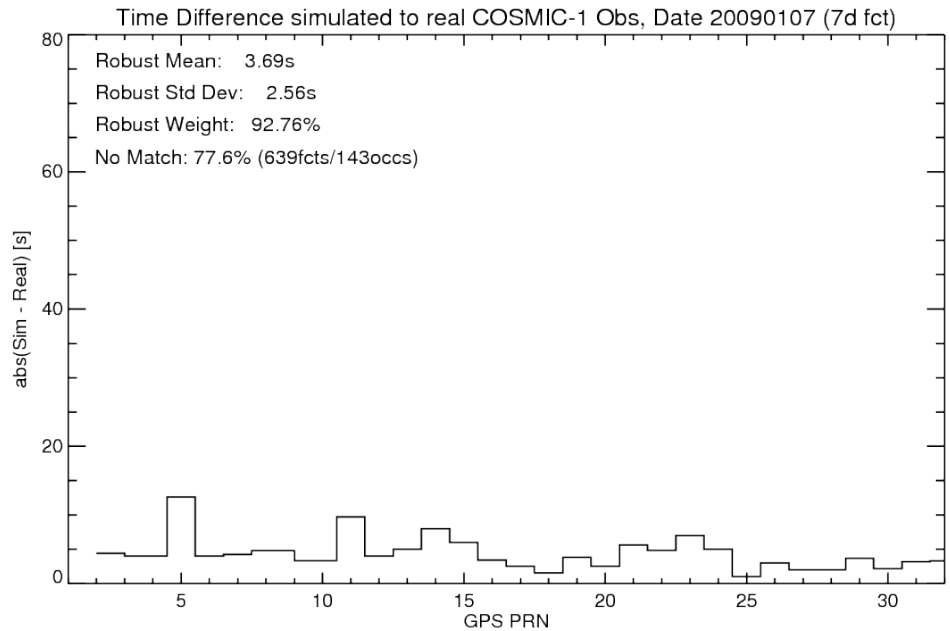




Mean (non-robust) simulated to actual observation differences, left distance, right time, separated by GPS satellite PRN. Legend gives robust estimates for full data set.

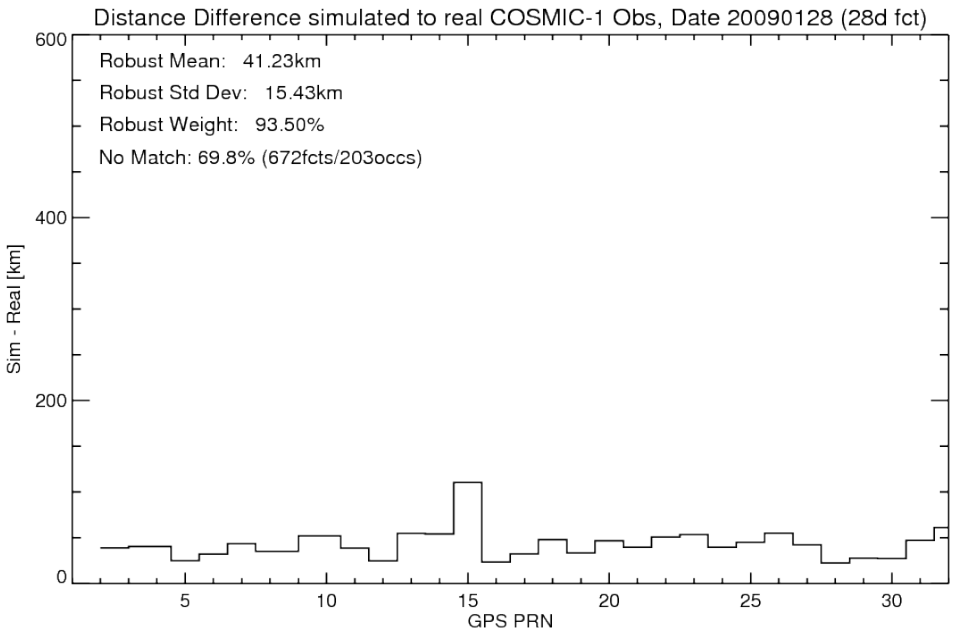
Occultation Prediction: COSMIC-1 Results (07d fcts)

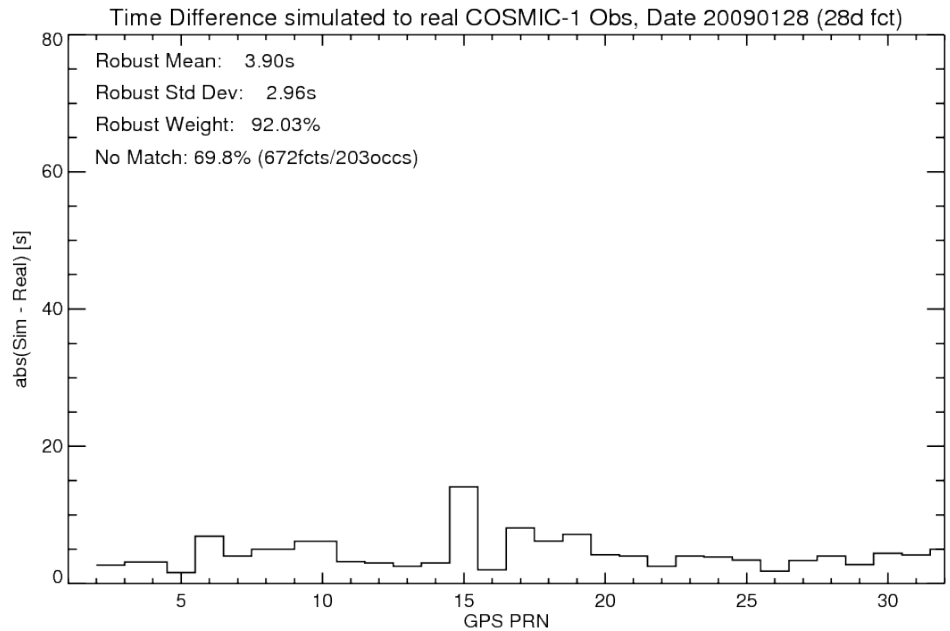




Mean (non-robust) simulated to actual observation differences, left distance, right time, separated by GPS satellite PRN. Legend gives robust estimates for full data set.

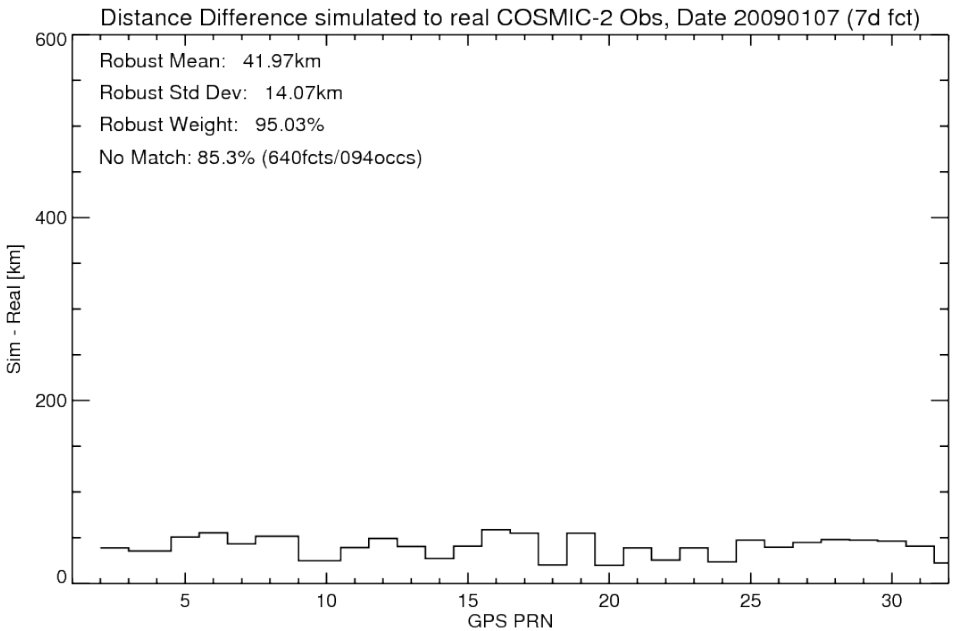
Occultation Prediction: COSMIC-1 Results (28d fcts)

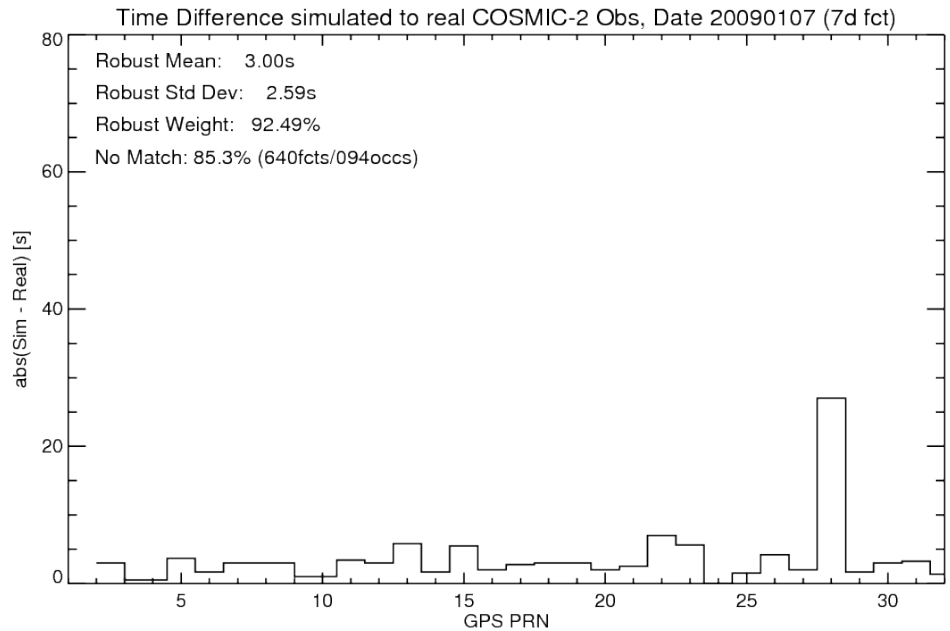




Mean (non-robust) simulated to actual observation differences, left distance, right time, separated by GPS satellite PRN. Legend gives robust estimates for full data set.

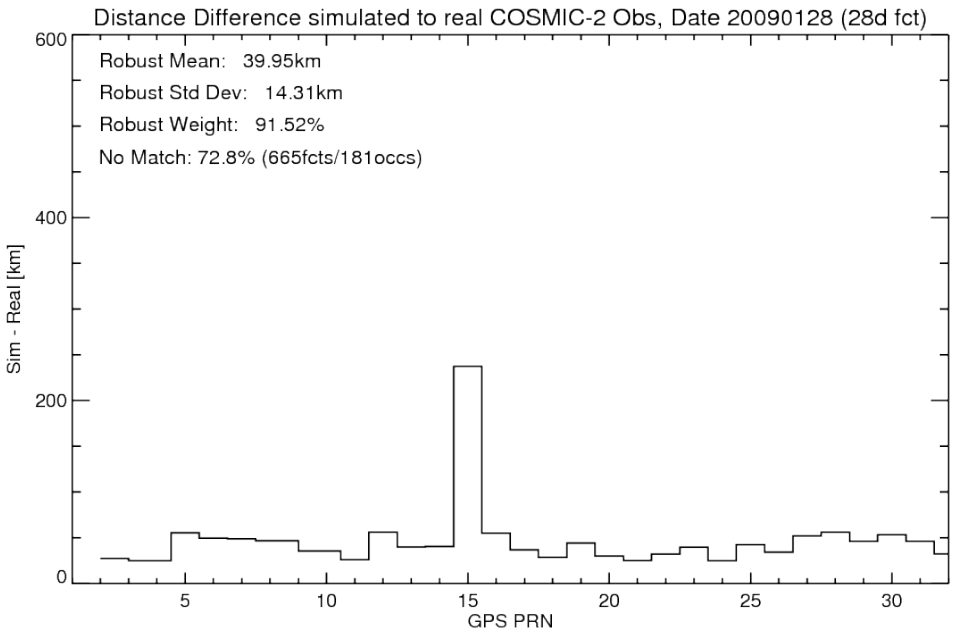
Occultation Prediction: COSMIC-2 Results (07d fcts)

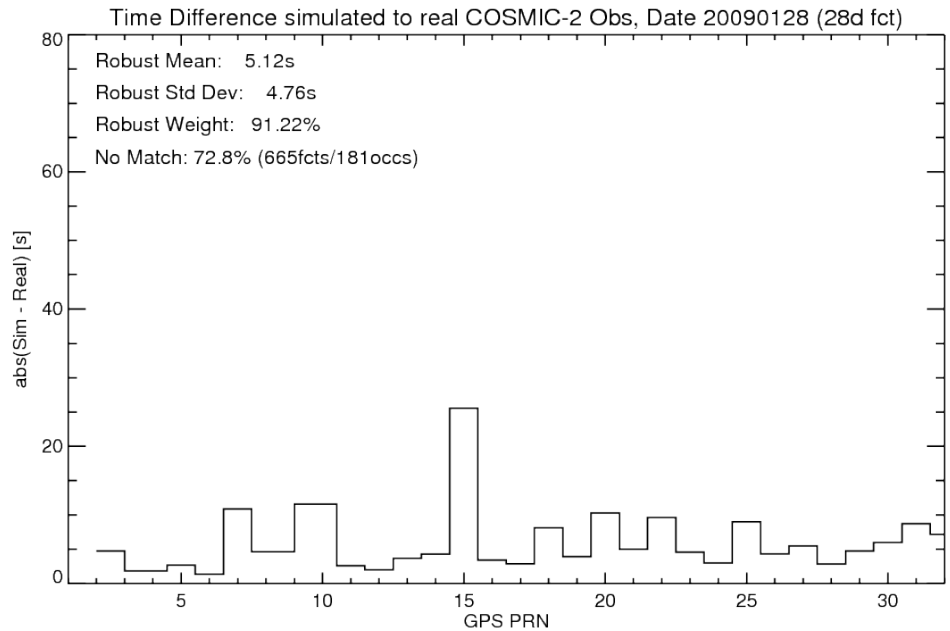




Mean (non-robust) simulated to actual observation differences, left distance, right time, separated by GPS satellite PRN. Legend gives robust estimates for full data set.

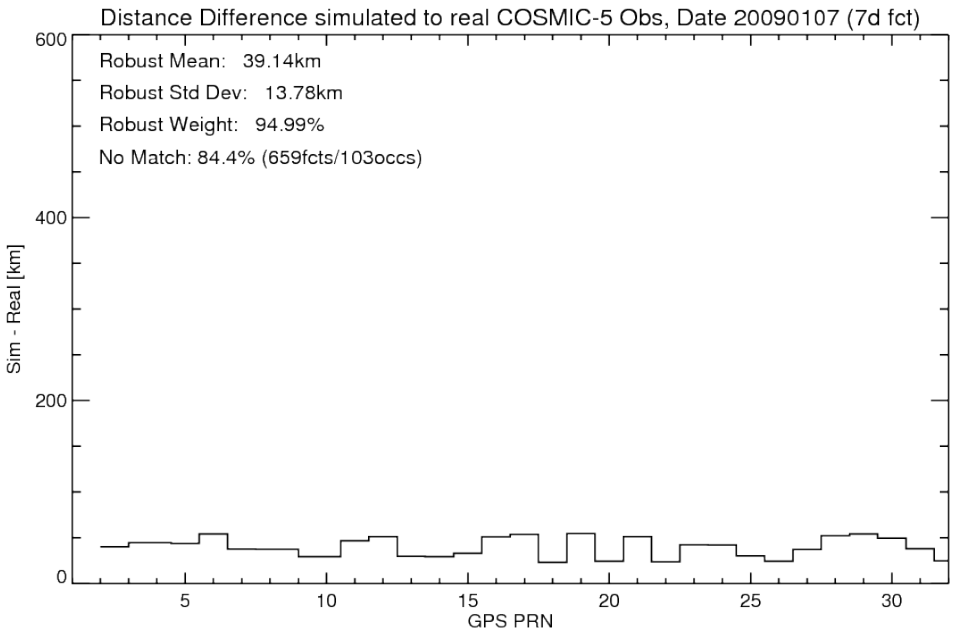
Occultation Prediction: COSMIC-2 Results (28d fcts)

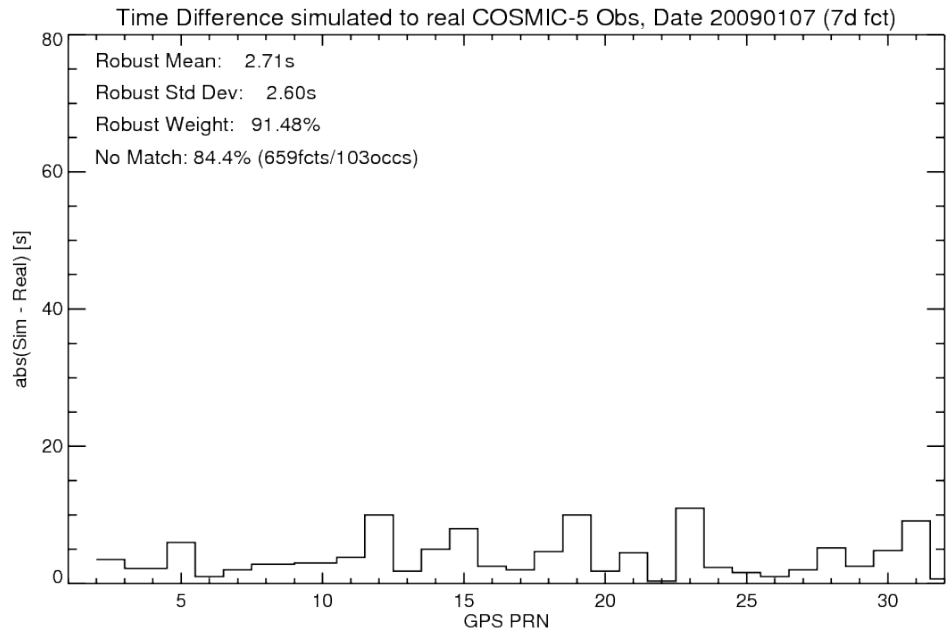




Mean (non-robust) simulated to actual observation differences, left distance, right time, separated by GPS satellite PRN. Legend gives robust estimates for full data set.

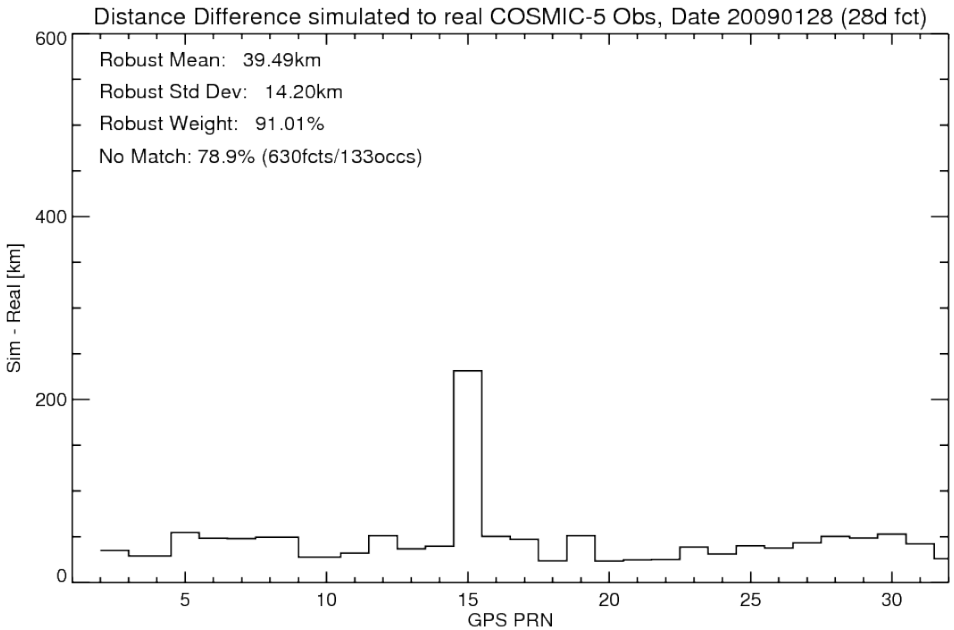
Occultation Prediction: COSMIC-5 Results (07d fcts)

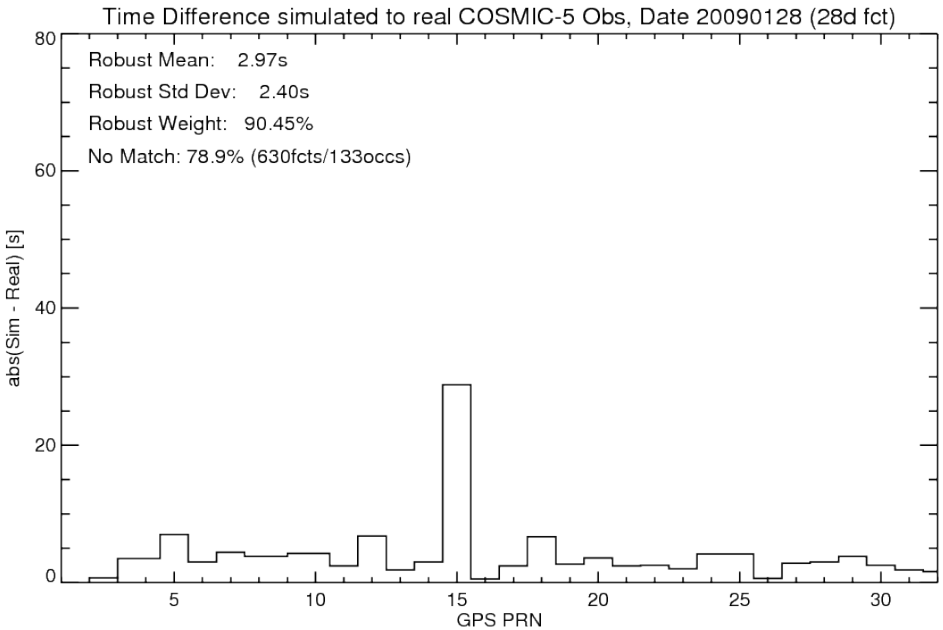




Mean (non-robust) simulated to actual observation differences, left distance, right time, separated by GPS satellite PRN. Legend gives robust estimates for full data set.

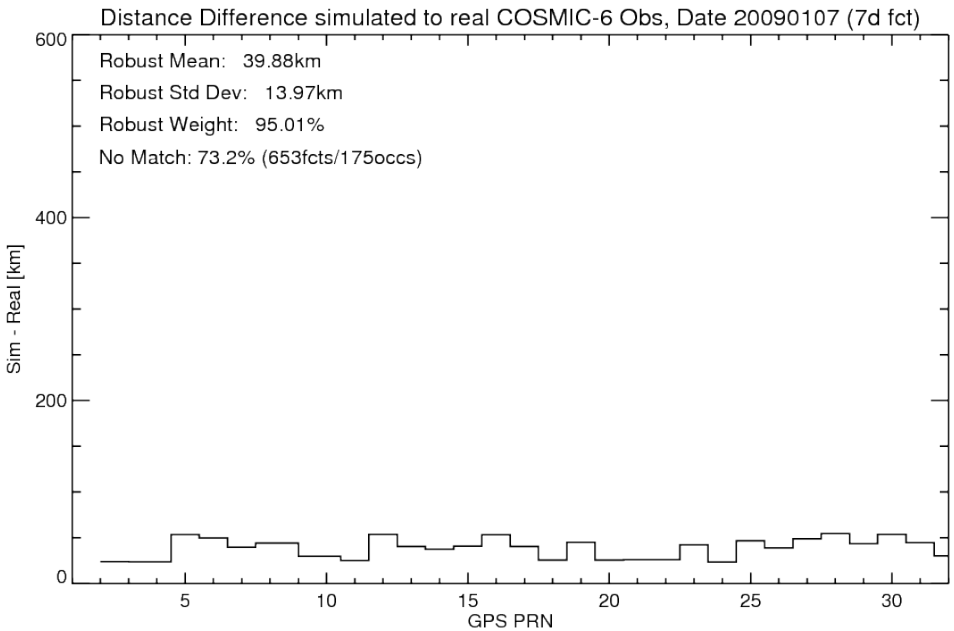
Occultation Prediction: COSMIC-5 Results (28d fcts)

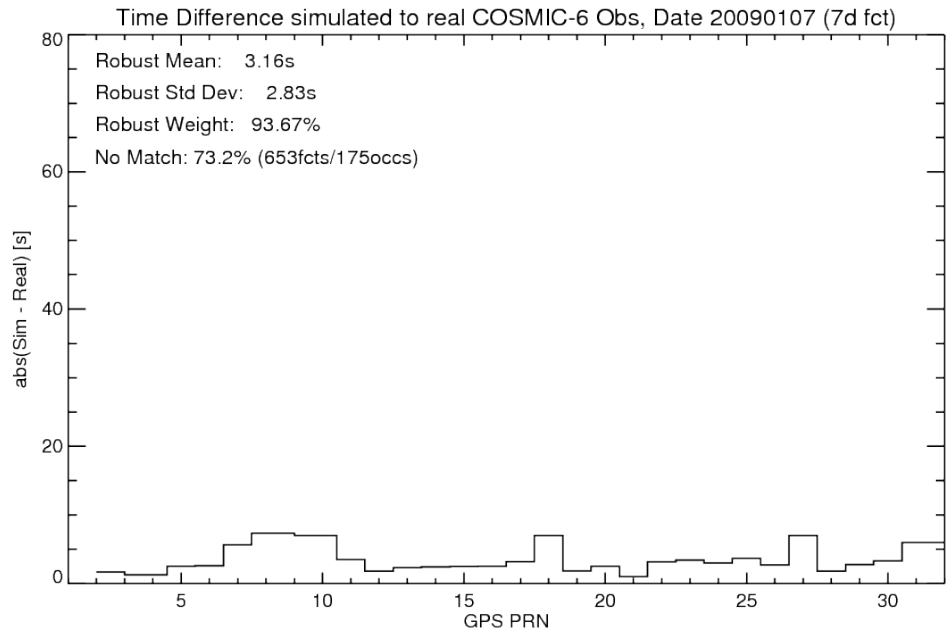




Mean (non-robust) simulated to actual observation differences, left distance, right time, separated by GPS satellite PRN. Legend gives robust estimates for full data set.

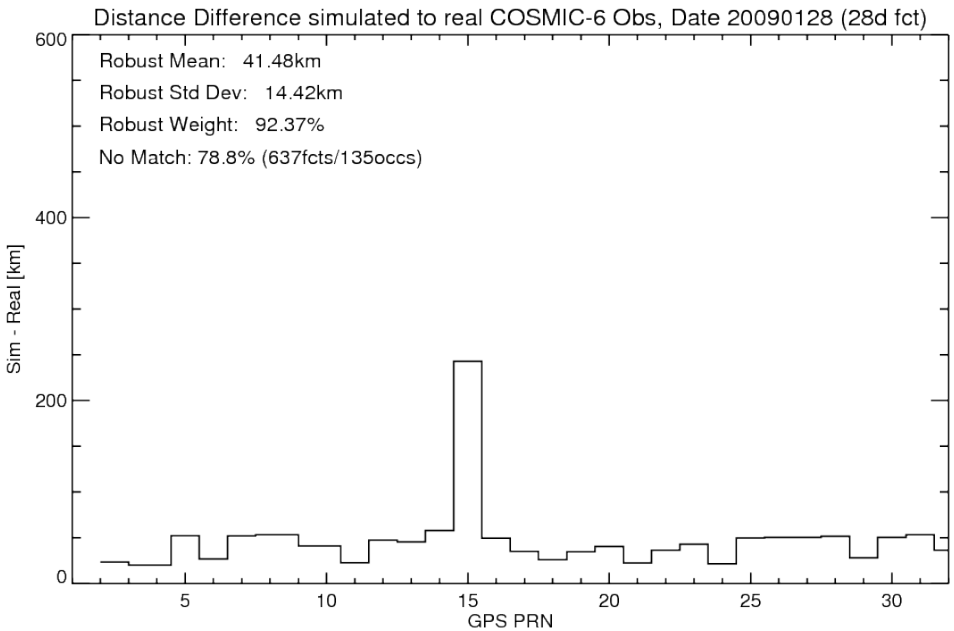
Occultation Prediction: COSMIC-6 Results (07d fcts)

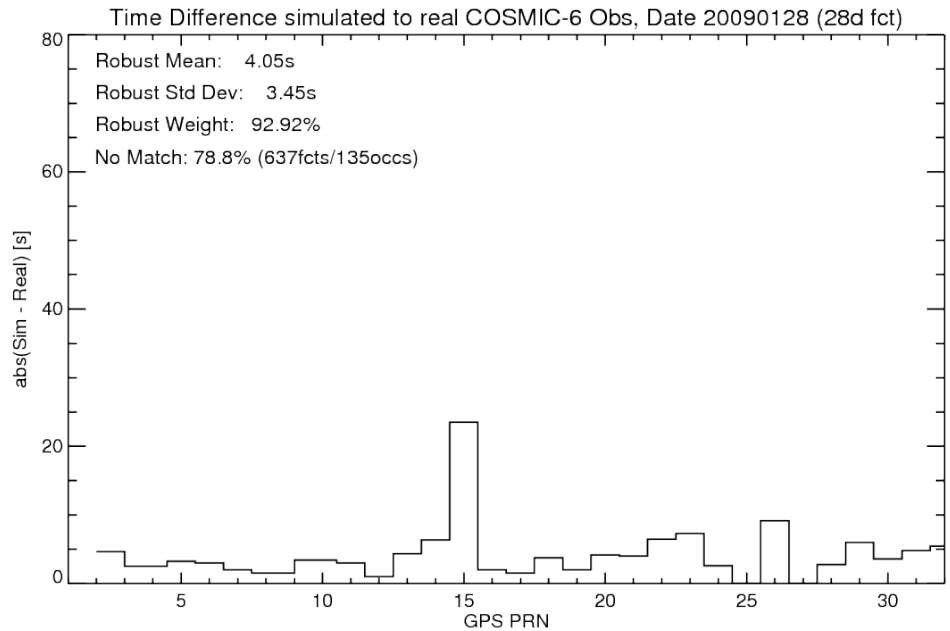




Mean (non-robust) simulated to actual observation differences, left distance, right time, separated by GPS satellite PRN. Legend gives robust estimates for full data set.

Occultation Prediction: COSMIC-6 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.

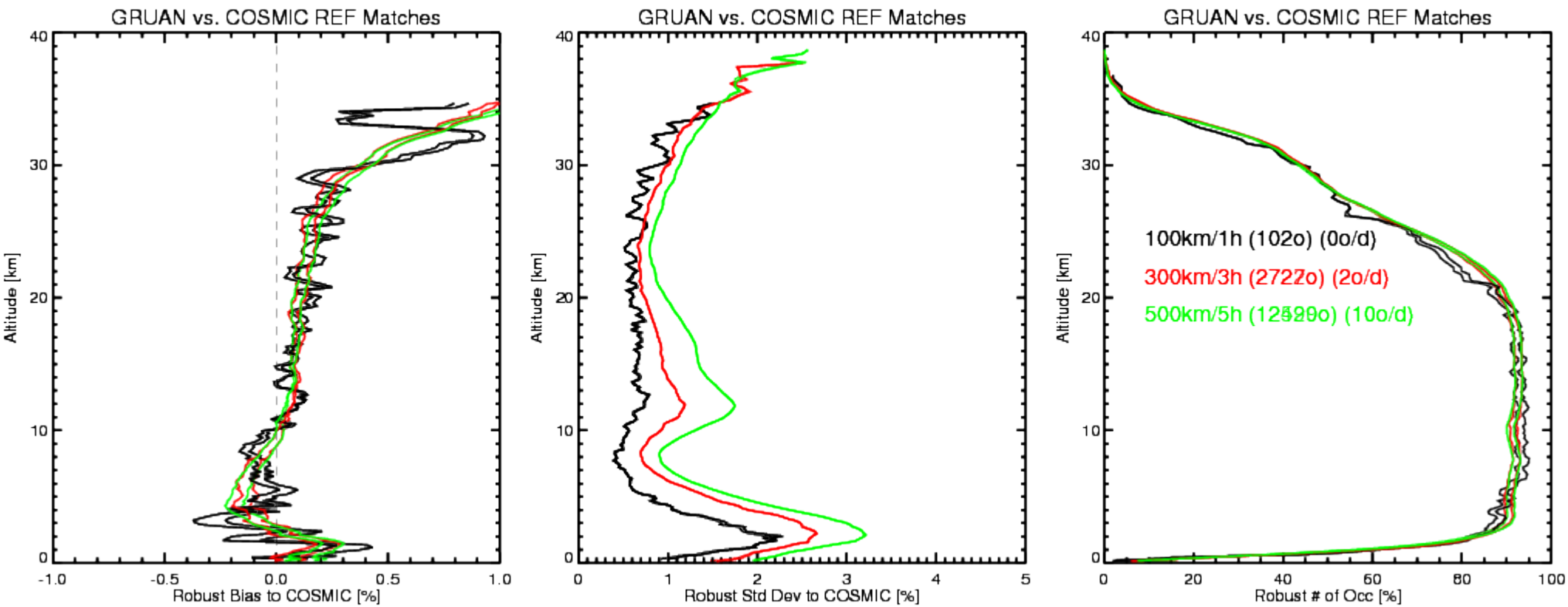
From: http://www.wmo.int/pages/prog/gcos/index.php?name=GRUAN

- 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

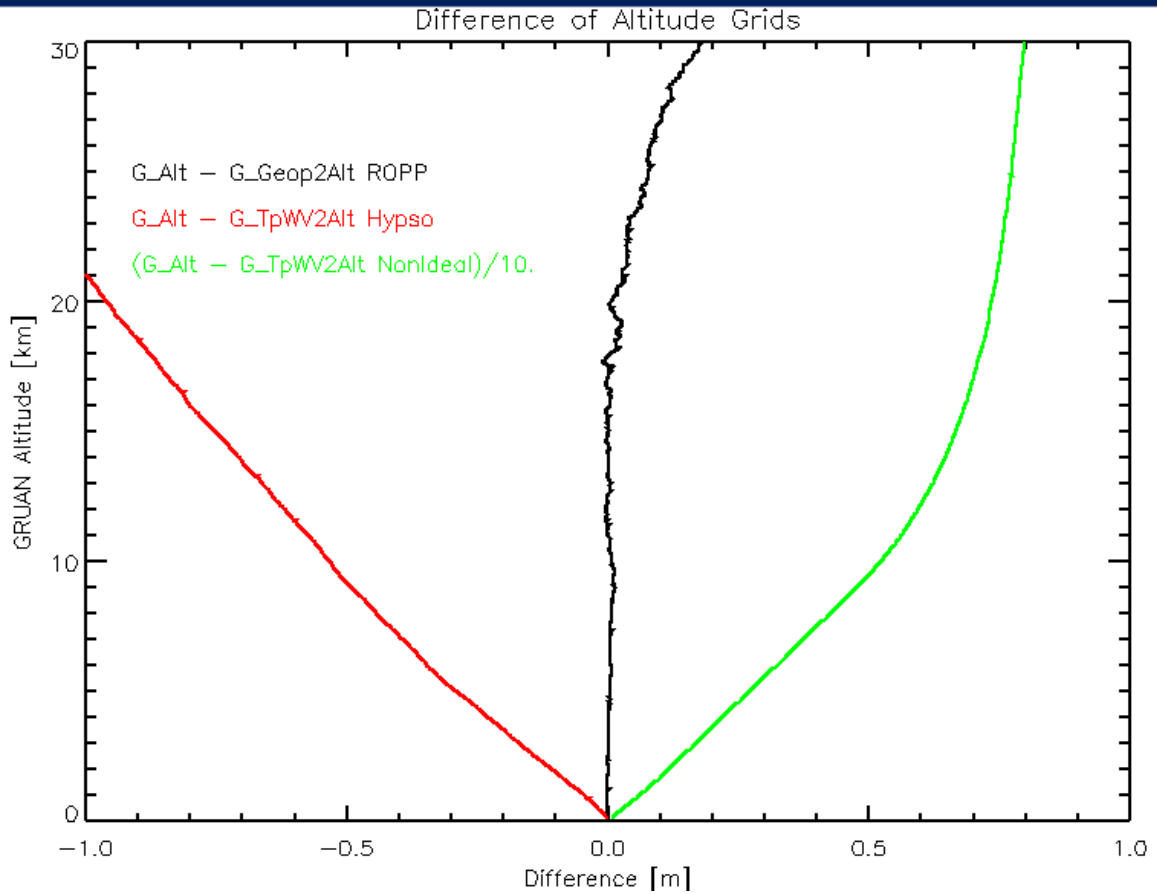
GRUAN vs. COSMIC Stats: Impact of Non-Ideal Gas



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

EUMETSAT

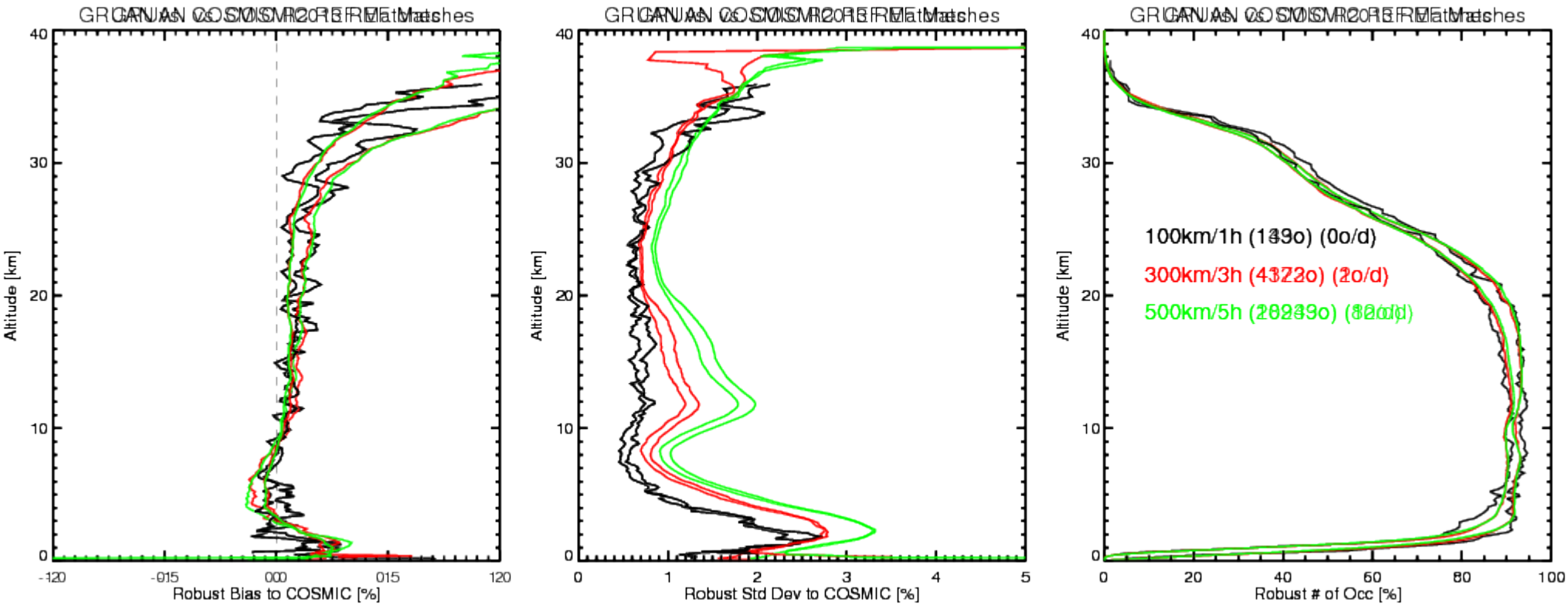
GRUAN vs. COSMIC Stats: Altitudes



Altitude differences of GRUAN Altitudes from netCDF file (G_Alt) to altitudes generated from GRUAN geopotential and ROPP geopotential to altitude conversion (G_Geop2Alt ROPP), altitudes generated from GRUAN temp, press, wv using hypsometric equation, altitude generated from GRUAN temp, press, wv and non ideal gas compressibility (NOTE: factor 10 larger!).

Note: Pressure is also corrected, this is not shown here!
ROPP Report on refractivity available here: http://www.romsaf.org/general-documents/gsr/gsr_09.pdf

GRUAN vs. COSMIC R2013 Stats: Refractivities

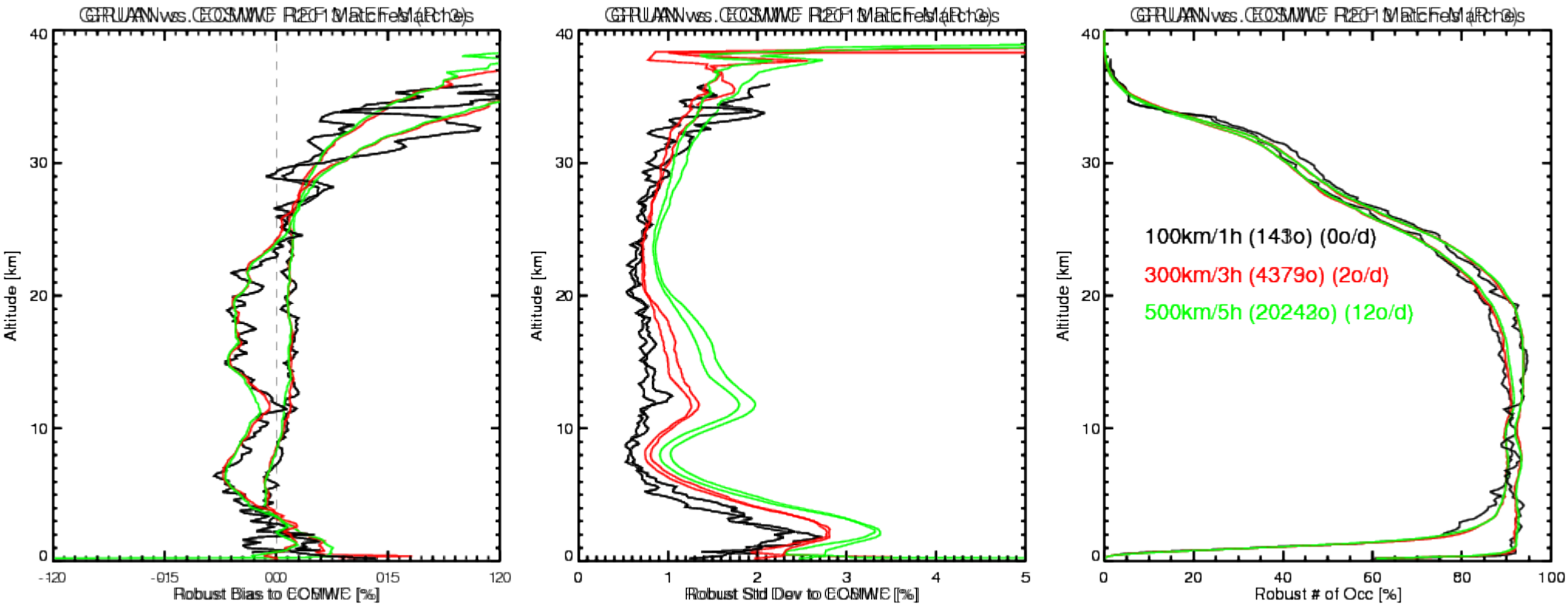


Refractivity validation of GRUAN vs. matched offline or reprocessed 2013 COSMIC/UCAR, bias (left), std. dev. (middle), robust weight (right, indicating the number of outliers in the statistics).

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

EUMETSAT

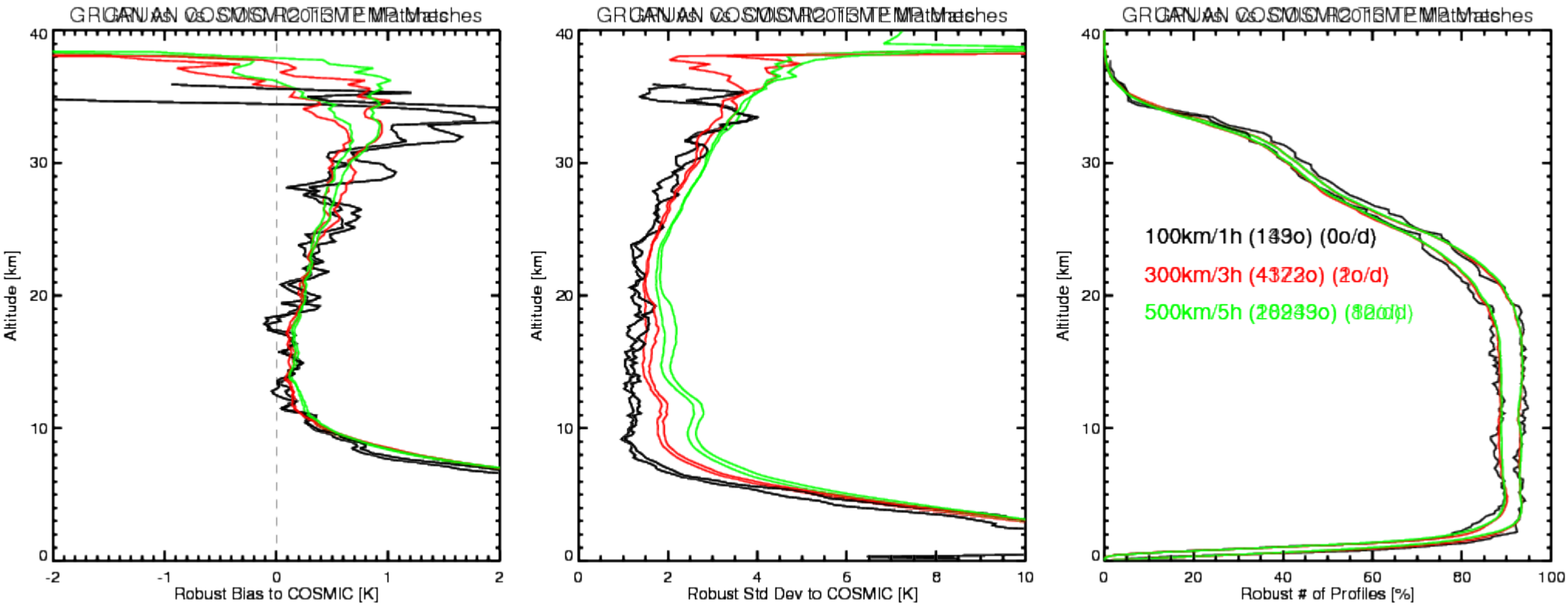
GRUAN vs. COSMIC/ECMWF R2013 Stats: Refractivities



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

EUMETSAT

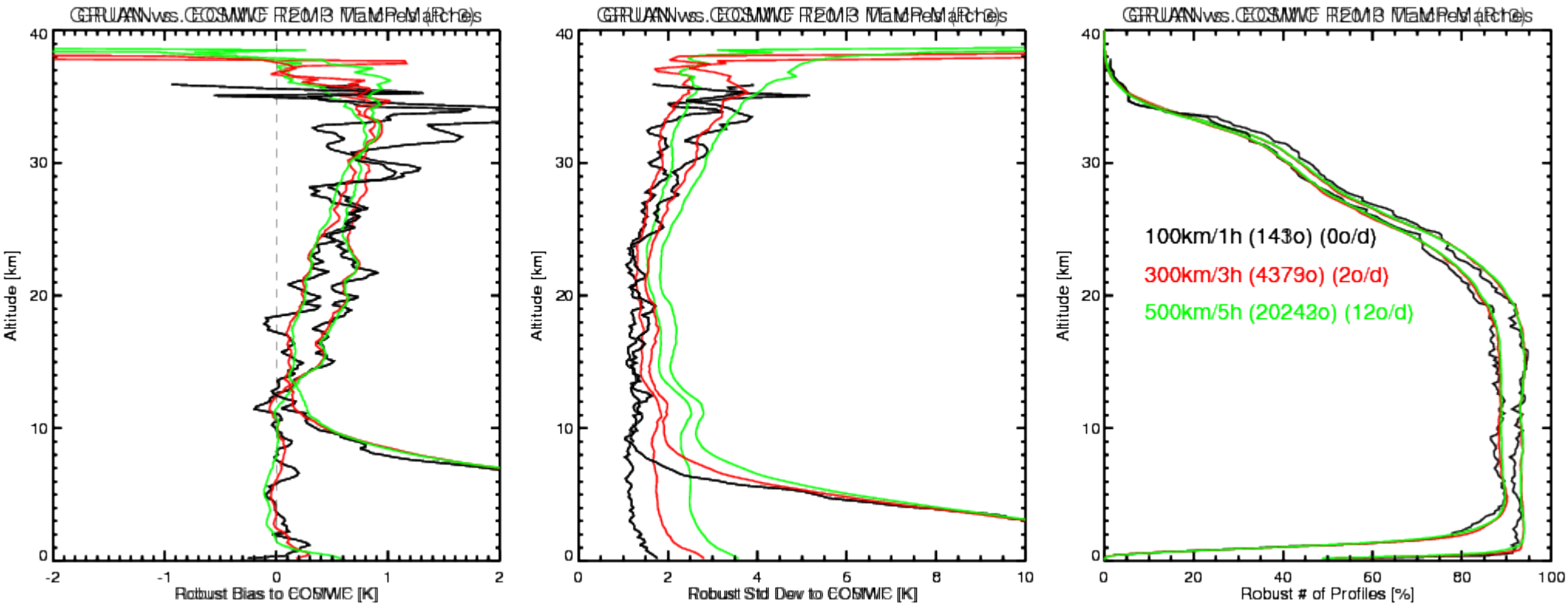
GRUAN vs. COSMIC R2013 Stats: Temperatures



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

EUMETSAT

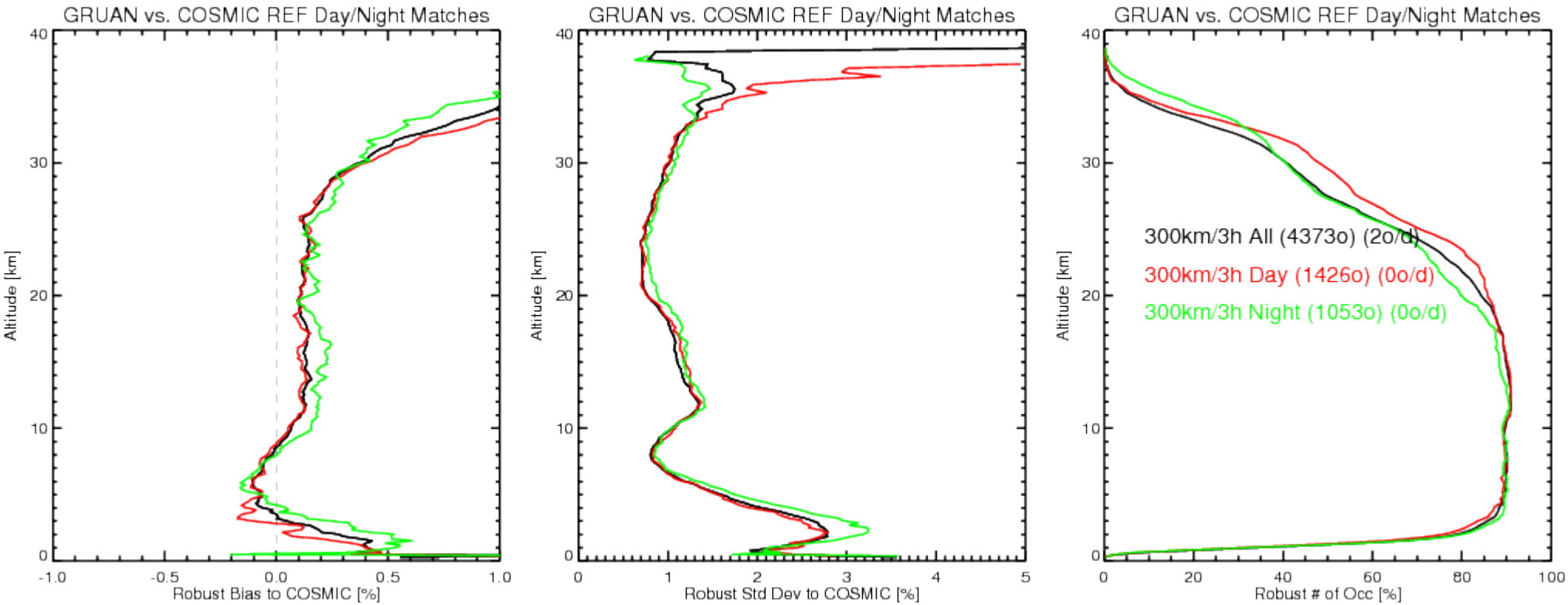
GRUAN vs. COSMIC Repro 2013 Stats: Temperatures



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

EUMETSAT

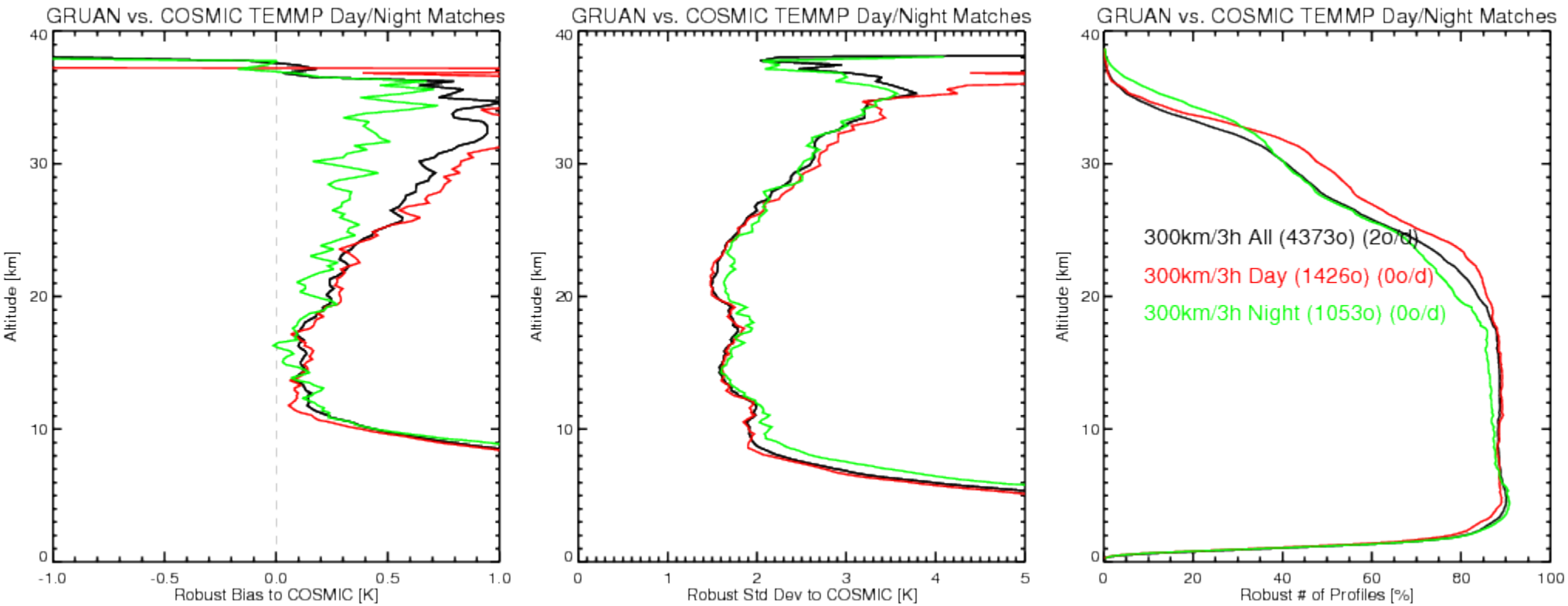
GRUAN vs. COSMIC Repro 2013 Stats: Day/Night REF



Refractivity validation of GRUAN vs. matched reprocessed 2013 COSMIC/UCAR at RO location for all, day and night, bias (left), std. dev. (middle), robust weight (right, indicating the number of outliers in the statistics).

EUMETSAT

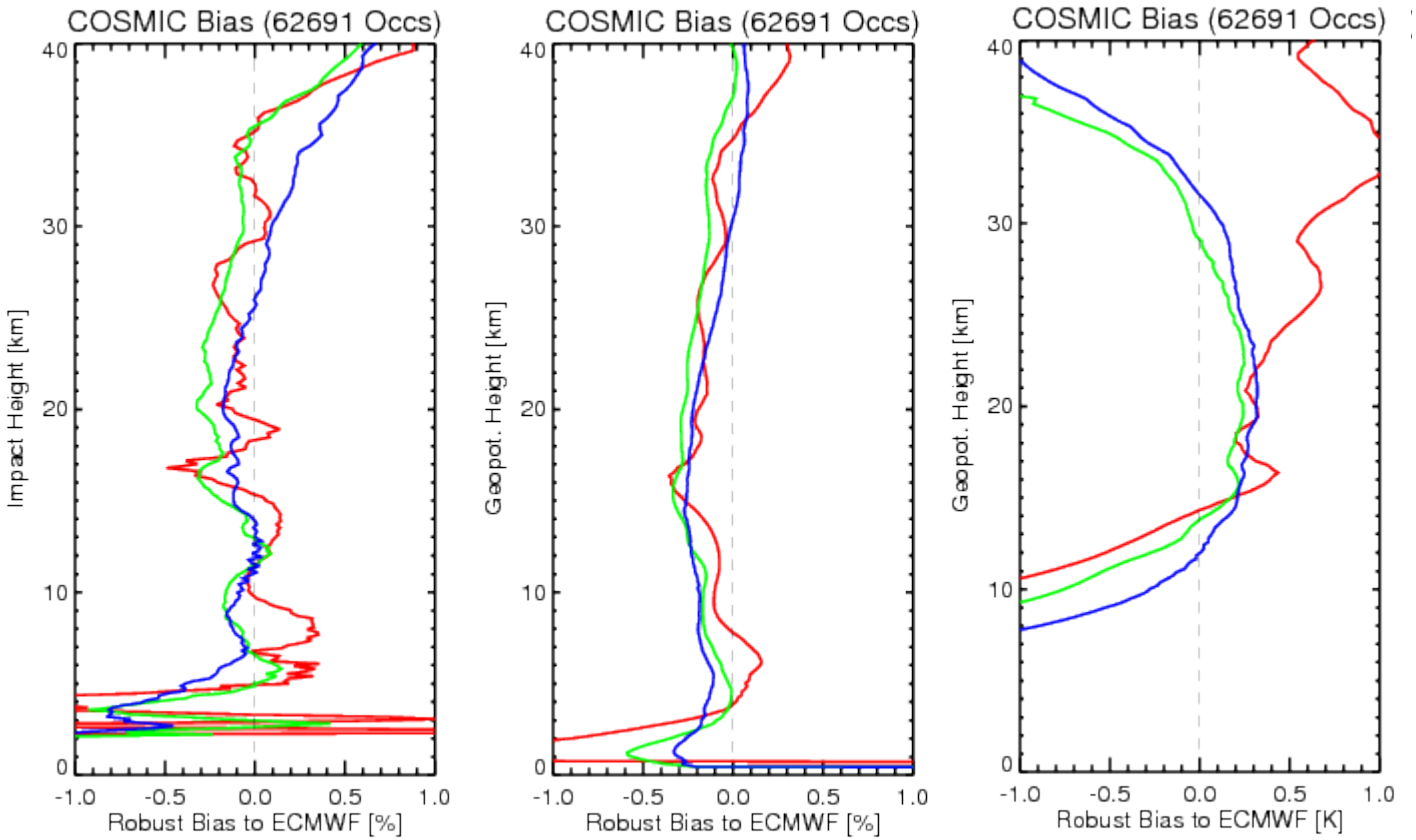
GRUAN vs. COSMIC Repro 2013 Stats: Day/Night TEMP



Temperature validation of GRUAN vs. matched reprocessed 2013 COSMIC/UCAR (dry) for all, day and night at RO location, bias (left), std. dev. (middle), robust weight (right, indicating the number of outliers in the statistics).

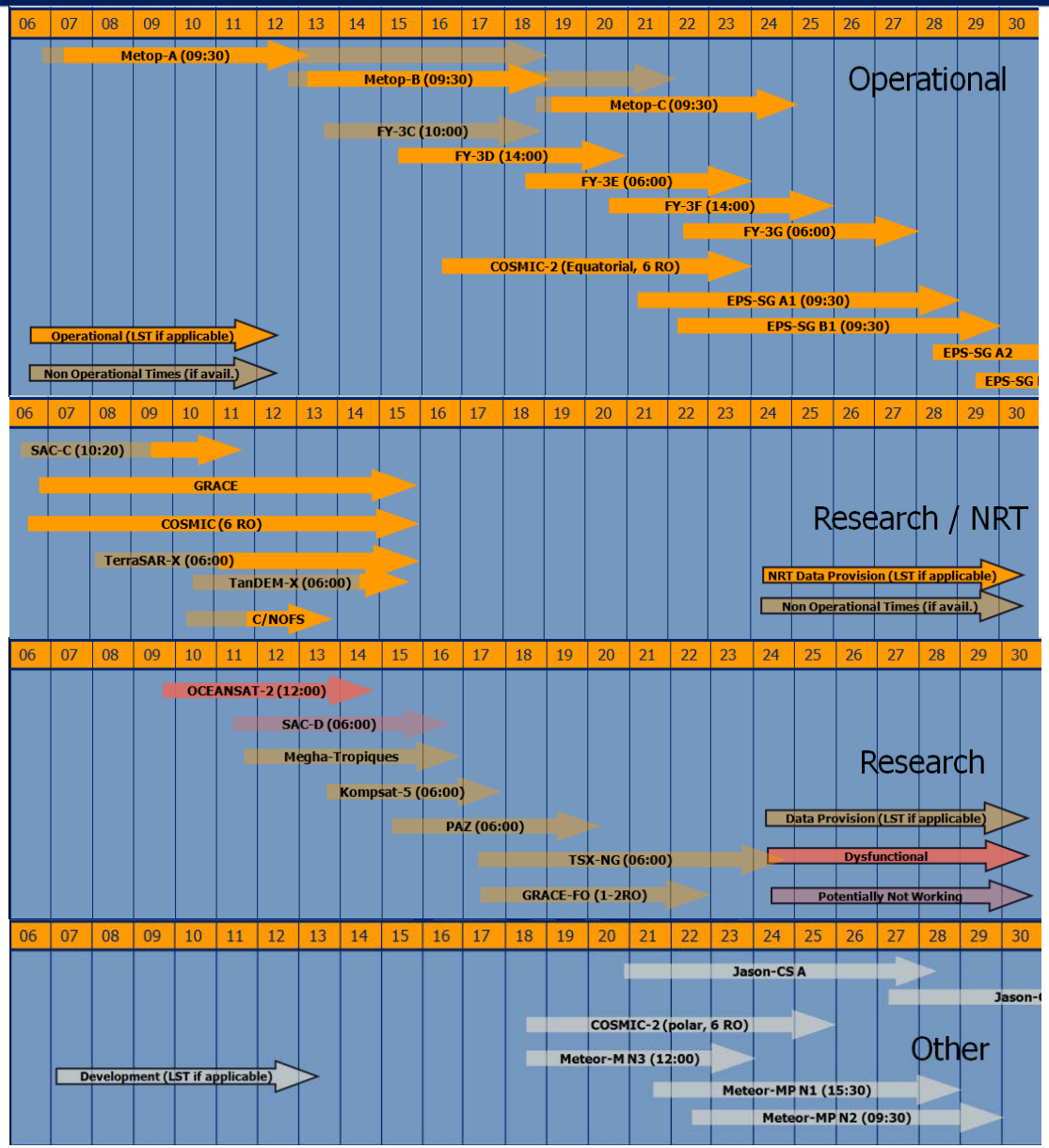
EUMETSAT

ECMWF vs. COSMIC Repro 2013 Stats: July 2010



Temperature validation of GRUAN vs. matched reprocessed 2013 COSMIC/UCAR (dry) for all, day and night at RO location, bias (left), std. dev. (middle), robust weight (right, indicating the number of outliers in the statistics).

EUMETSAT Mission Overview



EUMETSAT involved in:

- Mandatory Program:
  - EPS, EPS-SG
- Optional Program:
  - Jason-CS

EPS is Europe's contribution to the Initial Joint Polar System (IJPS) established with NOAA (>2023)

EPS-SG will be part of the NOAA/EUMETSAT Joint Polar System (JPS) Service (>2040)

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

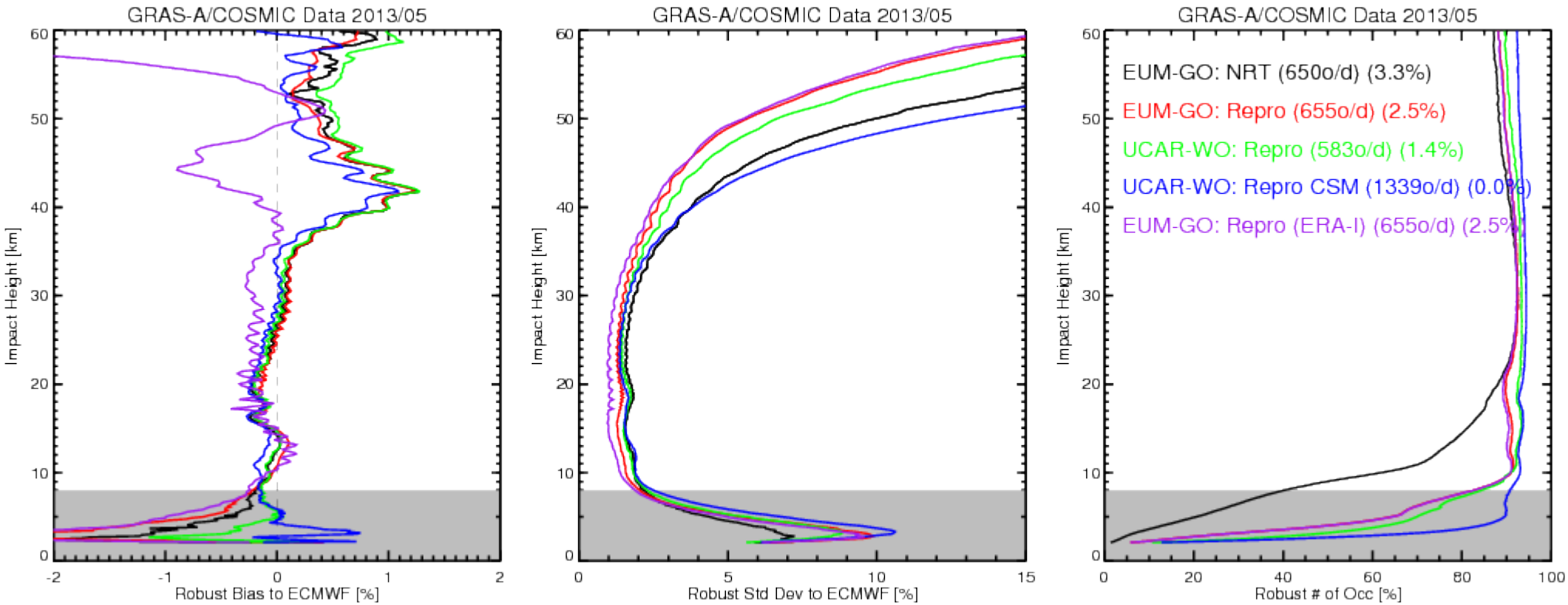
EUMETSAT

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 FSI (or PM) 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**

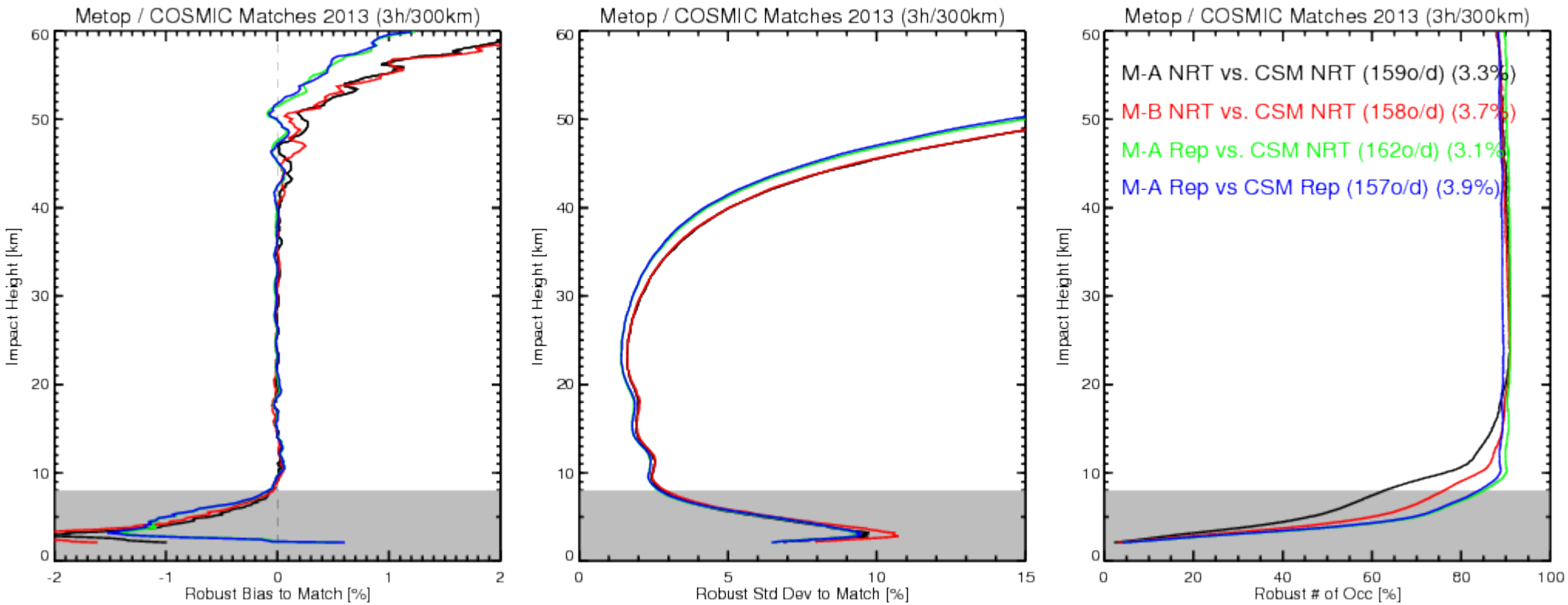
Some early validation plots of GO data on next slides

EUMETSAT Reprocessing Stats: ECMWF



Validation of GRAS Metop-A data vs. ECMWF fcts and ERA-I analysis, May 2013: oper. NRT, repro, 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 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

- 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 (GRUAN to consider?)
  - refractivity differences < 0.2% bias, although bias > 30km
  - dry temp differences < 0.3K bias (12-30km), inconclusive
  - day/night bias inconclusive between REF and TEMP
  - better to do comparisons at lower level (best BA, then REF, then TEMP)
- EUMETSAT programs to cover RO > 2040
- Reprocessing
  - GRAS data set available ‘15, COSMIC, CHAMP later ’15 (currently requires refractivity, would be better to do this in bending angles space)

University of Graz Results

Atmos. Meas. Tech. Discuss., 7, 11735–11769, 2014
www.atmos-meas-tech-discuss.net/7/11735/2014/
doi:10.5194/amtd-7-11735-2014

Atmospheric Measurement Techniques Discussions
Open Access

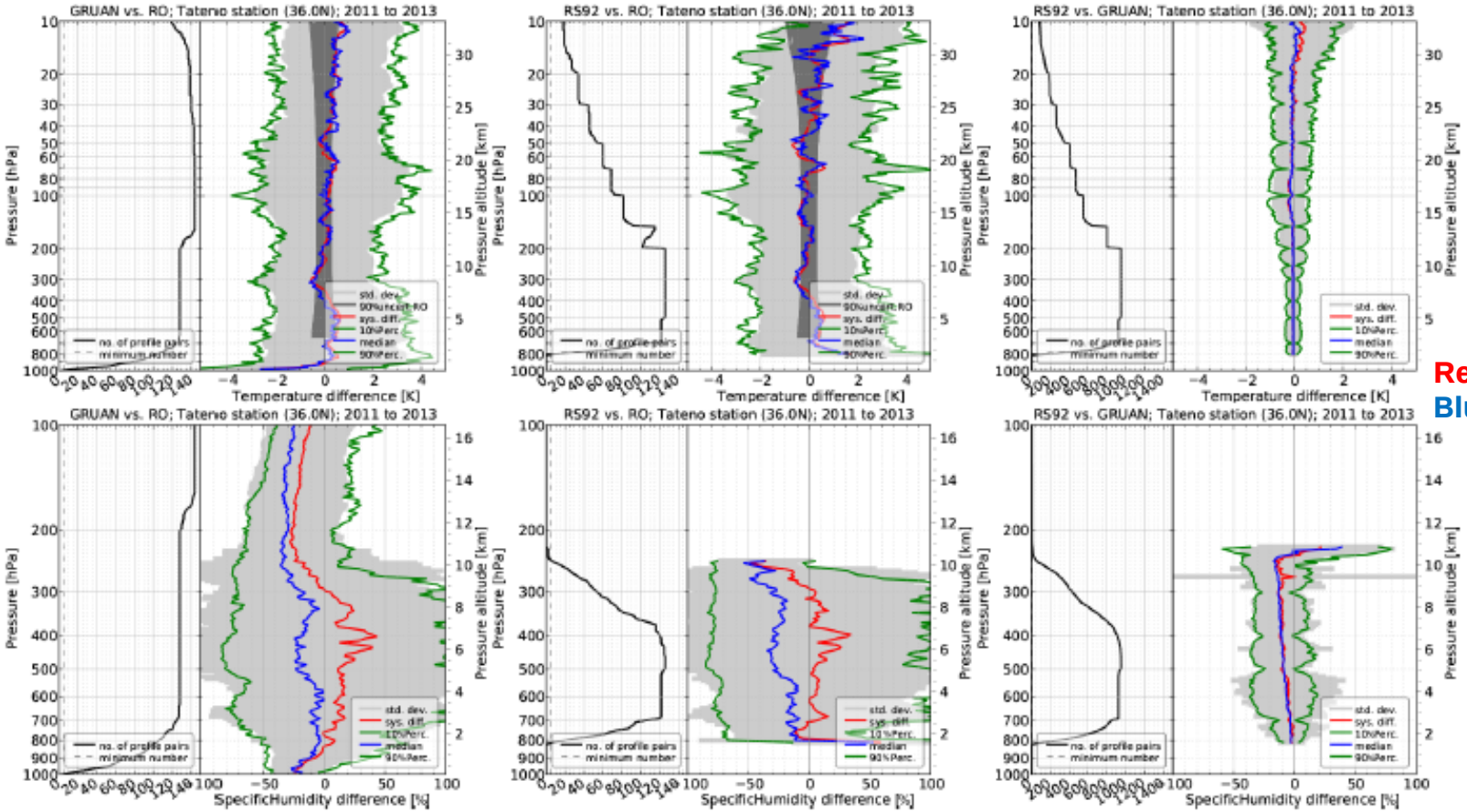
Climate intercomparison of GPS radio occultation, RS90/92 radiosondes and GRUAN over 2002 to 2013

F. Ladstädter[1], A. K. Steiner[1], M. Schwärz[1], and G. Kirchengast[1,2]

[1]Wegener Center for Climate and Global Change, University of Graz, Graz, Austria
[2]Institute for Geophysics, Astrophysics, and Meteorology/Institute of Physics, University of Graz, Graz, Austria

Selected results, full discussion (!!!) article available at:
http://www.atmos-meas-tech-discuss.net/7/11735/2014/amtd-7-11735-2014.pdf

University of Graz Results (Tateno, Japan)



Red: Systematic
Blue: Media

Figure 7. Comparison of temperature (top) and specific humidity (bottom) for the GRUAN station in Tateno, Japan. Differences are shown for GRUAN vs. GPSRO (left), RS92 vs. GPSRO (middle), and RS92 vs. GRUAN (right).

EUMETSAT

University of Graz Results (Lindenberg, Germany)

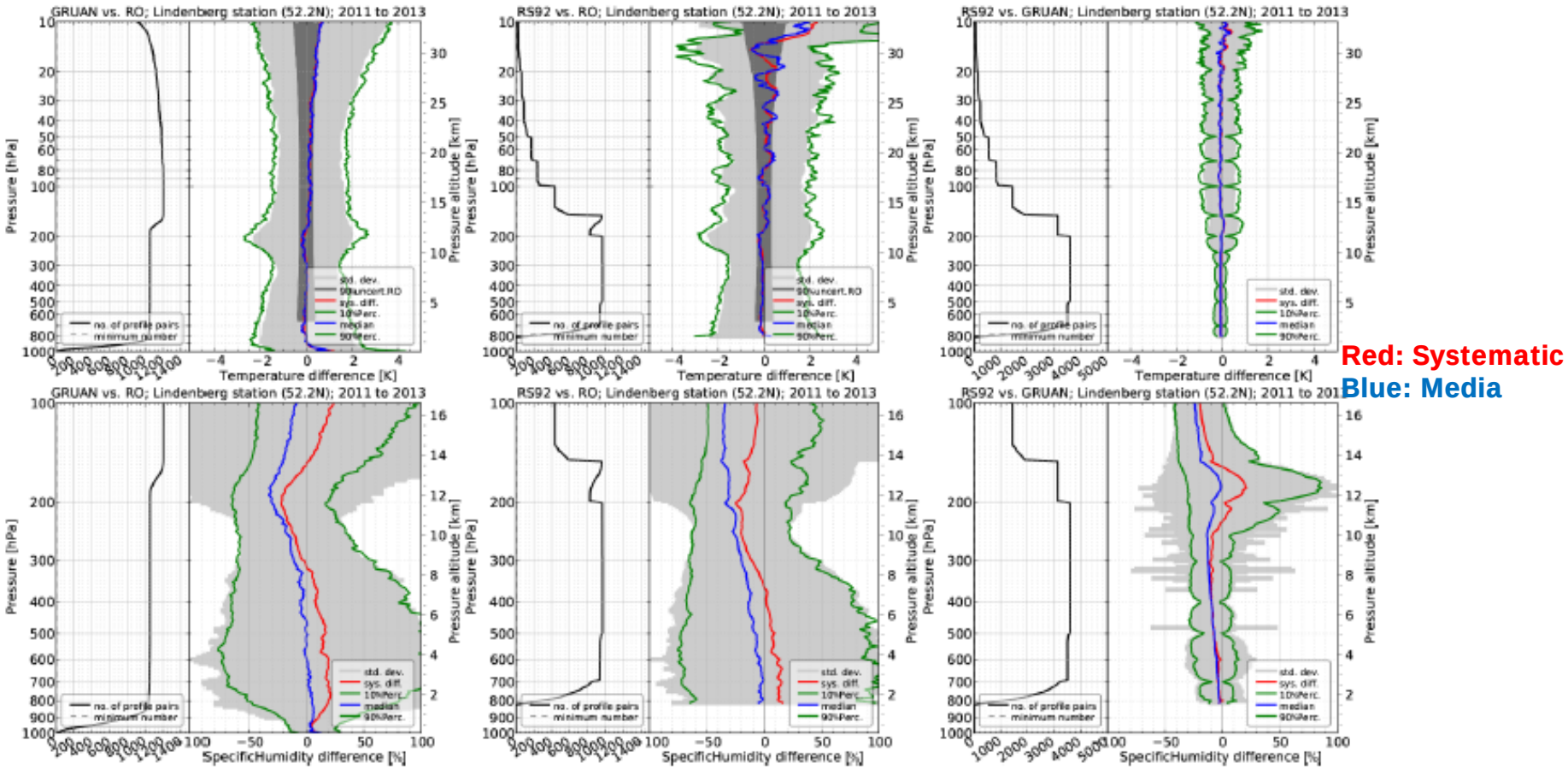


Figure 8. Same layout as Fig. 7, but for the GRUAN station in Lindenberg, Germany.

EUMETSAT

University of Graz Results (Sodankyla, Finland)

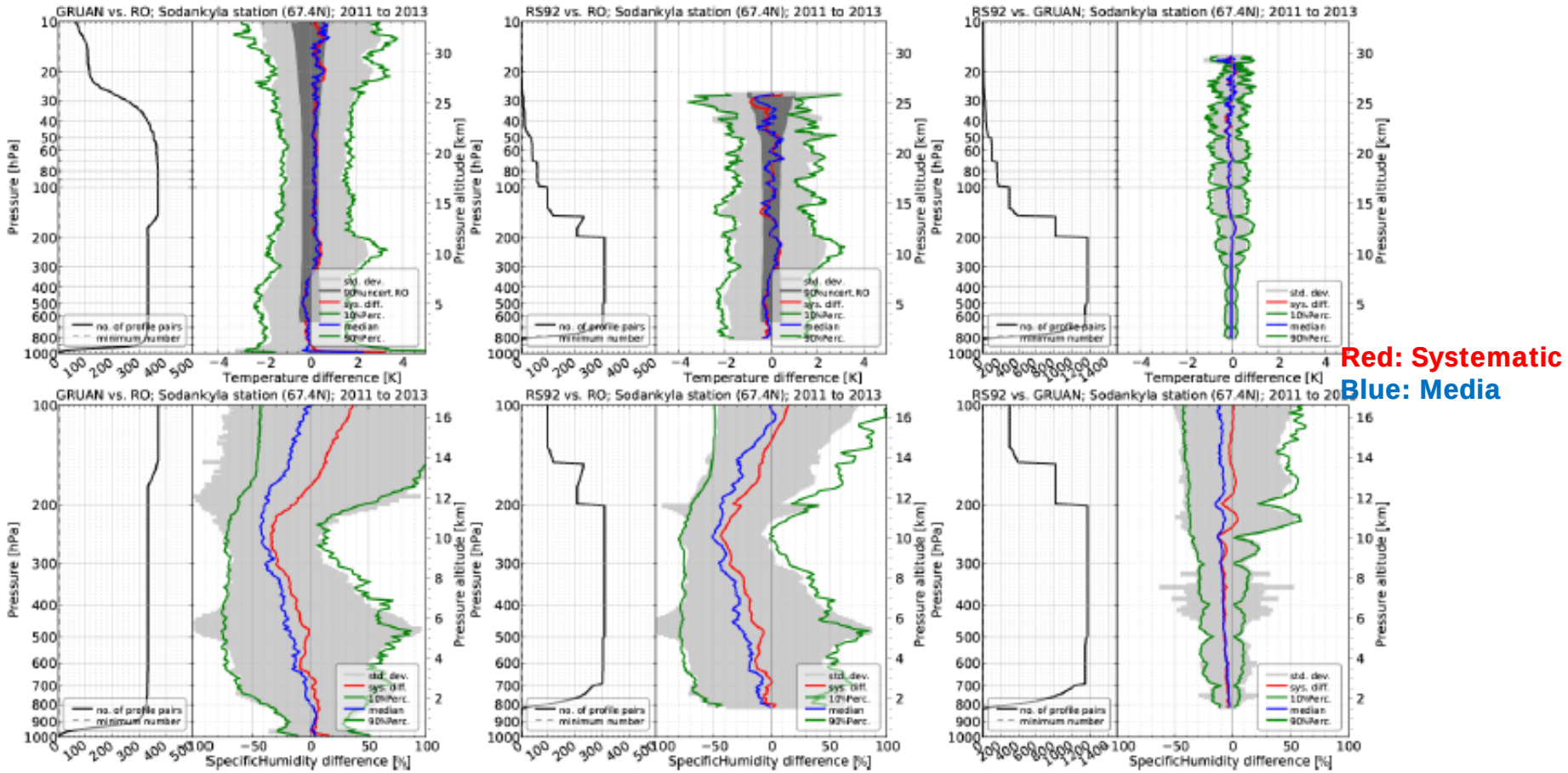
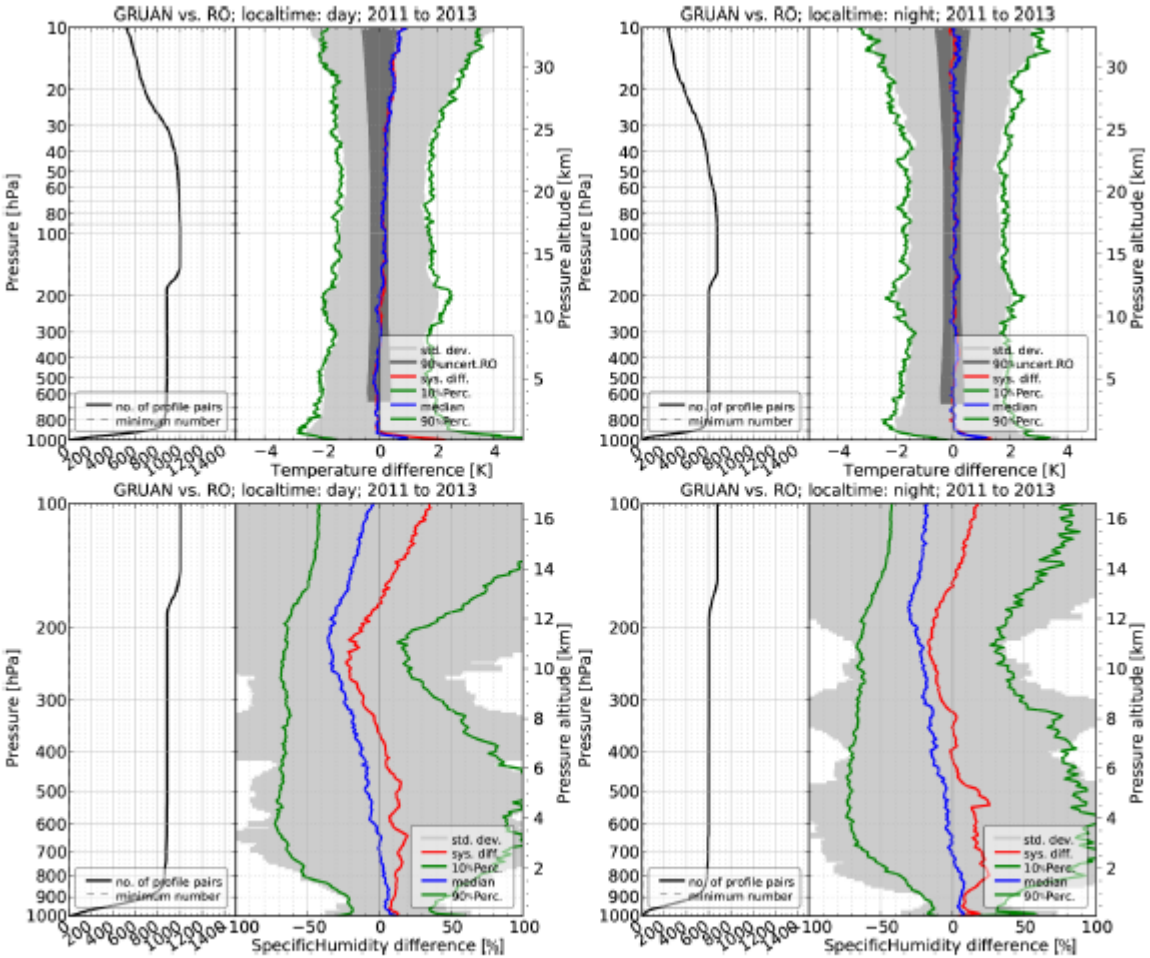


Figure 9. Same layout as Fig. 7, but for the GRUAN station in Sodankylä, Finland.

EUMETSAT

University of Graz Results (Day/Night Separation)

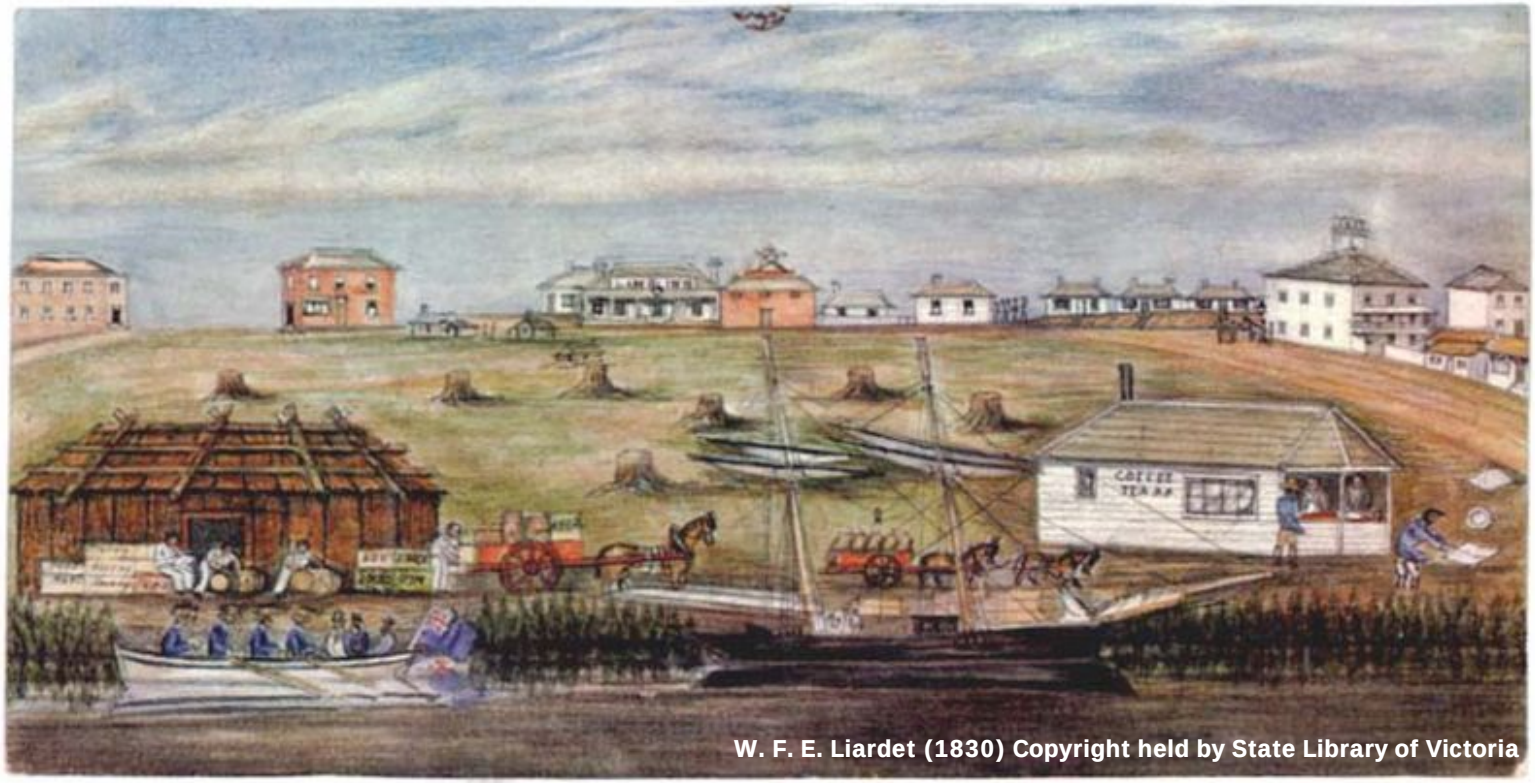


Red: Systematic
Blue: Media

Figure 10. Daytime (left) and nighttime (right) differences as function of pressure/altitude of GRUAN vs. GPSRO, for temperature (top) and specific humidity (bottom).

EUMETSAT

IROWG-4 Workshop



W. F. E. Liardet (1830) Copyright held by State Library of Victoria

IROWG-4 will be hosted at the Bureau of Meteorology and the Centre for Australian Weather and Climate Research in Melbourne, Victoria, Australia from 16th to 22nd of April 2015. More info on IROWG Mailing List and the IROWG website: http://www.irowg.org.

Coordination Group for Meteorological Satellites

IROWG INTERNATIONAL RADIO OCCULTATION WORKING GROUP

CGMS