NESDIS RO Science Studies and Quality Assurance through the STAR Integrated Cal/Val System: Initial Validation of COSMIC-2 Data

Shu-peng Ben Ho, Xinjia Zhou, Stanislav kireev, Lok Adhikari,

and

NOAA STAR GNSS RO team

IROWG, Sep. 18-25, 2019

NOAA/STAR in-house Expertise to support CWDP/COSMIC-2 Tasks

Data Assimilation

Data Assimilation

- Non-local Bending Angle (Ray-tracing)
- Local Bending Angle (Forward Abel)
- Local Refractivity
- JCSDA and TMP project

As JCSDA partners, STAR and NCEP work together closely to perform impact assessment

Multi-sensor Validation

Validation

- Radiosonde (Dr. Xi Shao from CICS)
- Microwave Sounders ATMS, AMSU-A (CICS)
- Infrared Sounders CrIS, AIRS, IASI (Dr. Erin Lynch from CICS)
- Retrievals (temperature, water vapor)
- ECMWF model

Well established NOAA system NPROVS for sounding validation

Integrated Cal/Val System (ICVS) for Monitoring

Performance Monitoring

- Operational monitoring
- RO measurements
- Parameters for all RO data levels
- Statistics
- Long-term monitoring
- (Mr. Xinjia Zhou GST
- Dr. Yuxiang He GST
- Dr. Ling Liu CICS)

Well established system for all NOAA satellites expanded to include RO; tested using KOMPSAT5, KOMPSAT5, COSMIC, Metop-A, -B, -C GRAS data data

RO Data Processing

Independent Verification

- Time delay (L0-L1): Dr. Bin Zhang, Jun Dong from CICS and Yuxiang He from GST)
- Excess phase
- POD
- Bending angle (L1- L2): Dr. Lok Adhikari (CICS)
- Impact parameter
- Refractivity
- Geometric height
- Temperature, water vapor, pressure: Dr. Stanislav Kireev (GST)

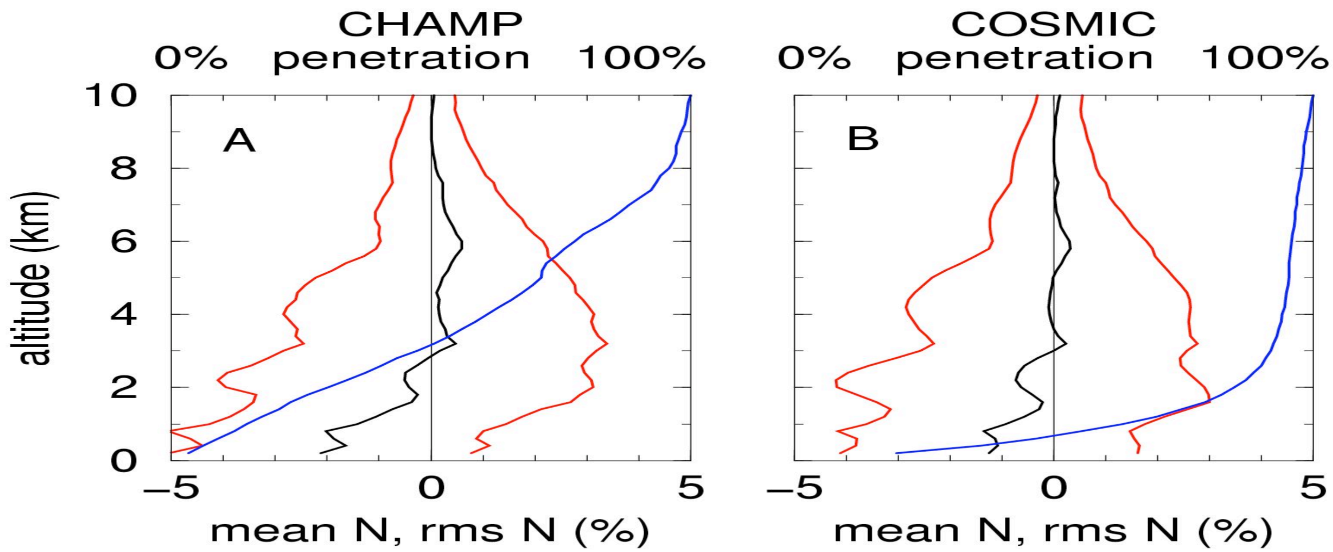
Tested & verified using ROPP (EUMETSAT) and KOMPSAT5, COSMIC, Metop-A, -B, -C GRAS data

Four major focus areas of Cal/Val work have been defined

Motivation

Is the quality of COSMIC-2 data consistent or better than those of COSMIC-1 in terms of precision, long term stability, accuracy in the lower stratosphere, troposphere, particularly in the lower troposphere ?

High precision (<0.05K), No mission dependent bias (Ho et al., TAO, 2009; Ho et al., JGR, 2009; Anthes, 2007; **Ho et al., 2019, BAMS)**



Anthes et al., 2007 (BAMS)

Fig. 5. Statistical comparison of CHAMP and COSMIC RO-retrieved refractivities between 30S and 30N to ECMWF global analysis for 28 August-22 September 2006. Black and red lines show mean deviation and +/- standard deviation around the mean. Blue lines show the percentage of retrieved profiles that penetrated to a given altitude.

Outlines

Data: **UCAR COSMIC-2 from 6 LEO satellites from 07/16/2019 - 08/15/2019**
in situ RS41 and RS92 radiosonde data, AMSU/ATMS, IASI/CrIS data, and STAR processed C2 bending angle, temperature, and water vapor profiles.

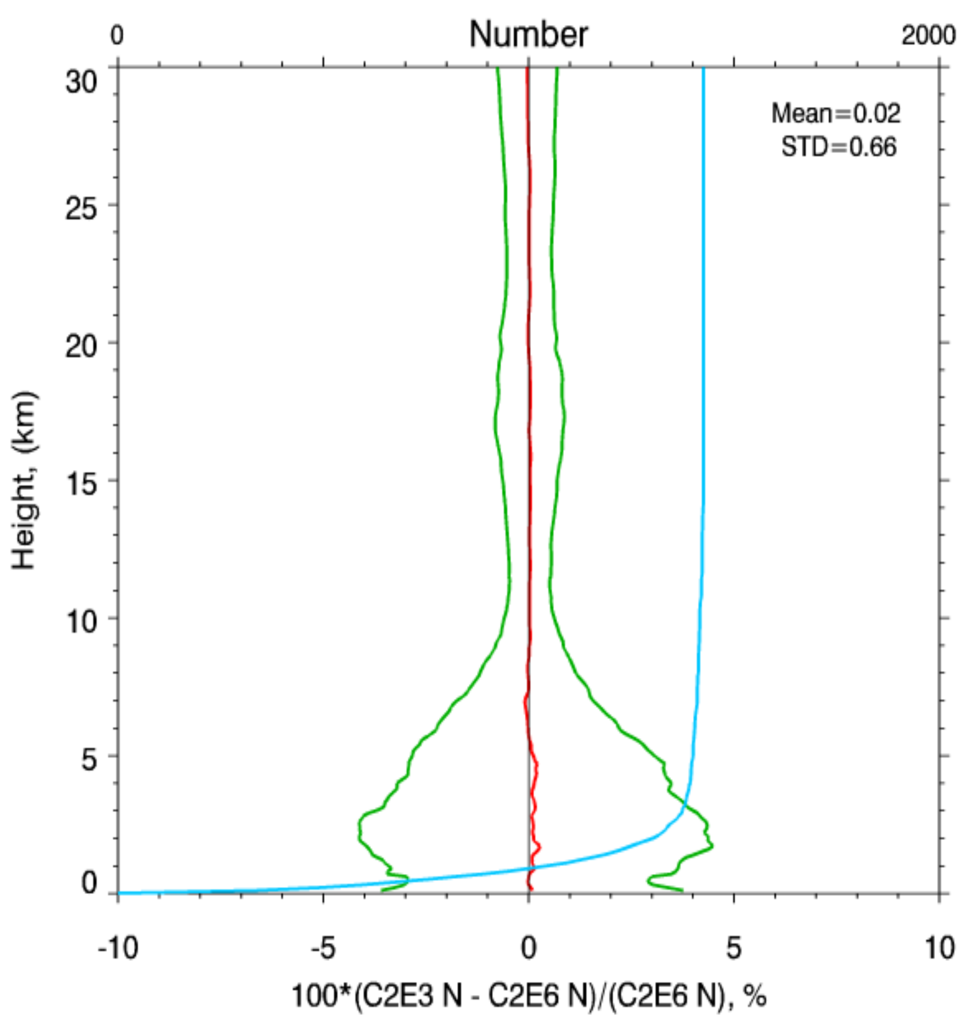
Approaches

1. Precision : Inter-comparison of C2 early orbit data
2. Long term stability : Comparing C2 atmPrf to KOMSAT5 atmPrf
3. Accuracy of water vapor and temperature: Comparing C2 wetPrf to RAOB data
4. Structure uncertainty of retrievals: Comparing C2 atmPrf to STAR ROPP atmPrf and STAR retrievals
5. Structure uncertainty of water vapor retrieval: Comparing C2 wetPrf to STAR 1Dvar
6. Accuracy of water vapor retrieval: Comparing C2 atmPrf/wetPrf to GFS forecast
7. Is COSMIC-2 better than COSMIC-1: Uncertainty of RO data in the lower troposphere: Fractional DBAOE comparisons

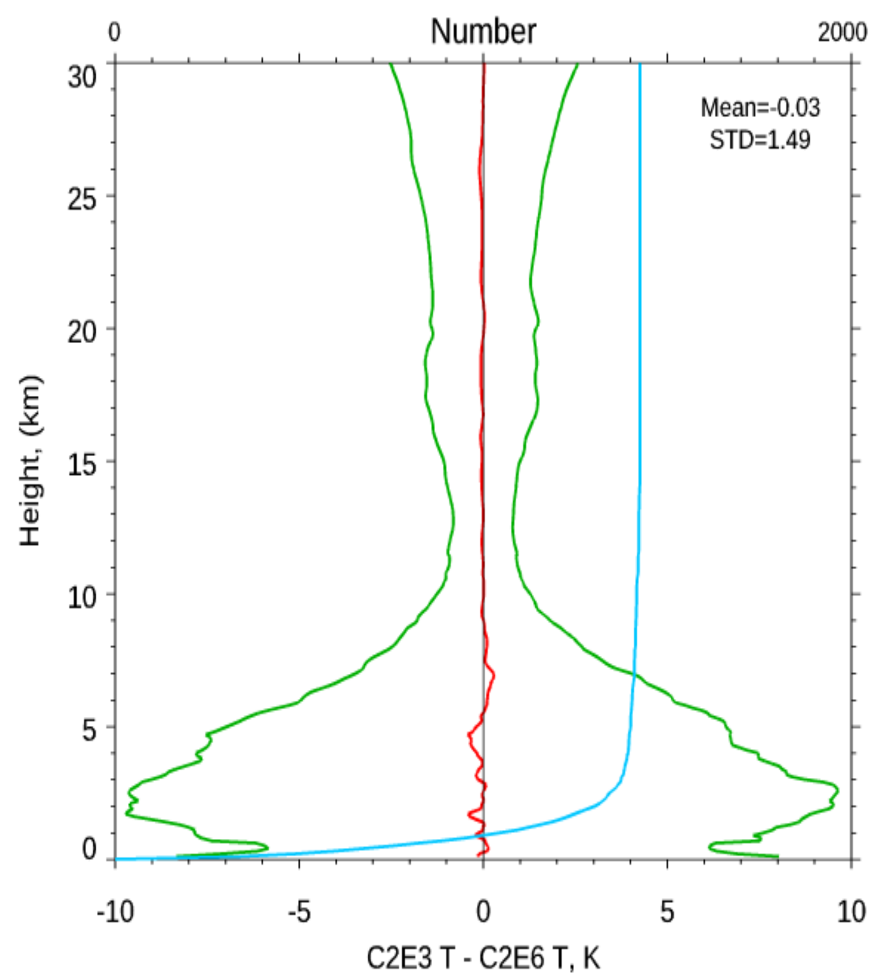
Conclusions

1. Precision: C2 inter-comparison for early orbit data (within 300 km and 1200 seconds)

COSMIC -2 FM3 – FM6
Fractional Refractivity Difference (%)

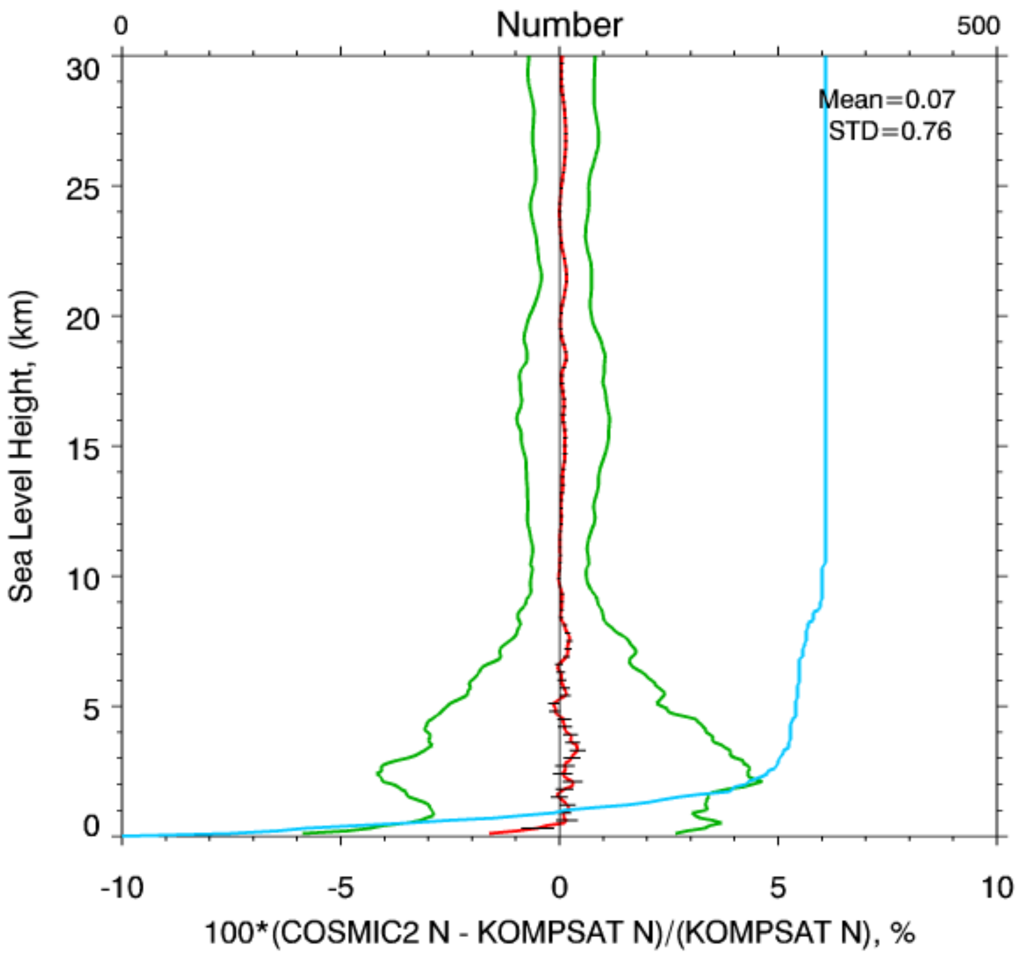


COSMIC -2 FM3 – FM6
Temperature Difference (%)

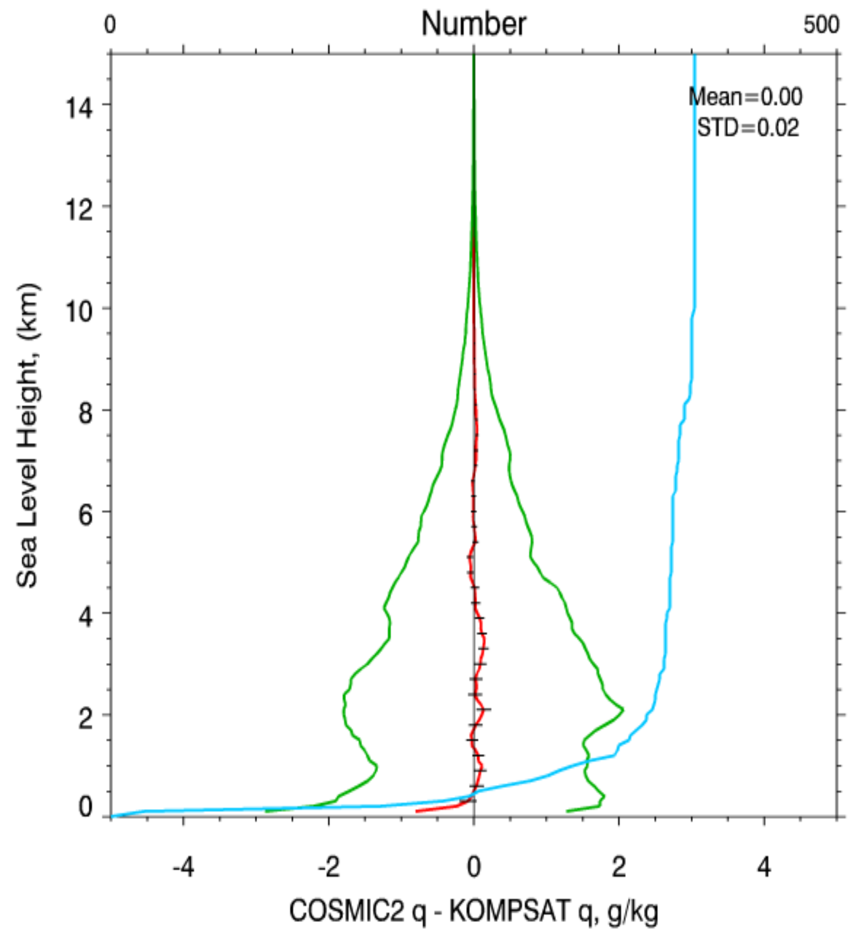


2. Checking the long term stability: comparisons between C2 and KOMSAT-5 (within 300 km and 2 hours)

Fractional refractivity differences
UCAR KOMSAT-5 vs. UCAR C2



Specific humidity
KOMSAT-5 vs. COSMIC-2



3. Comparisons with RS41 Radiosondes (within 300 km and 2 hours)

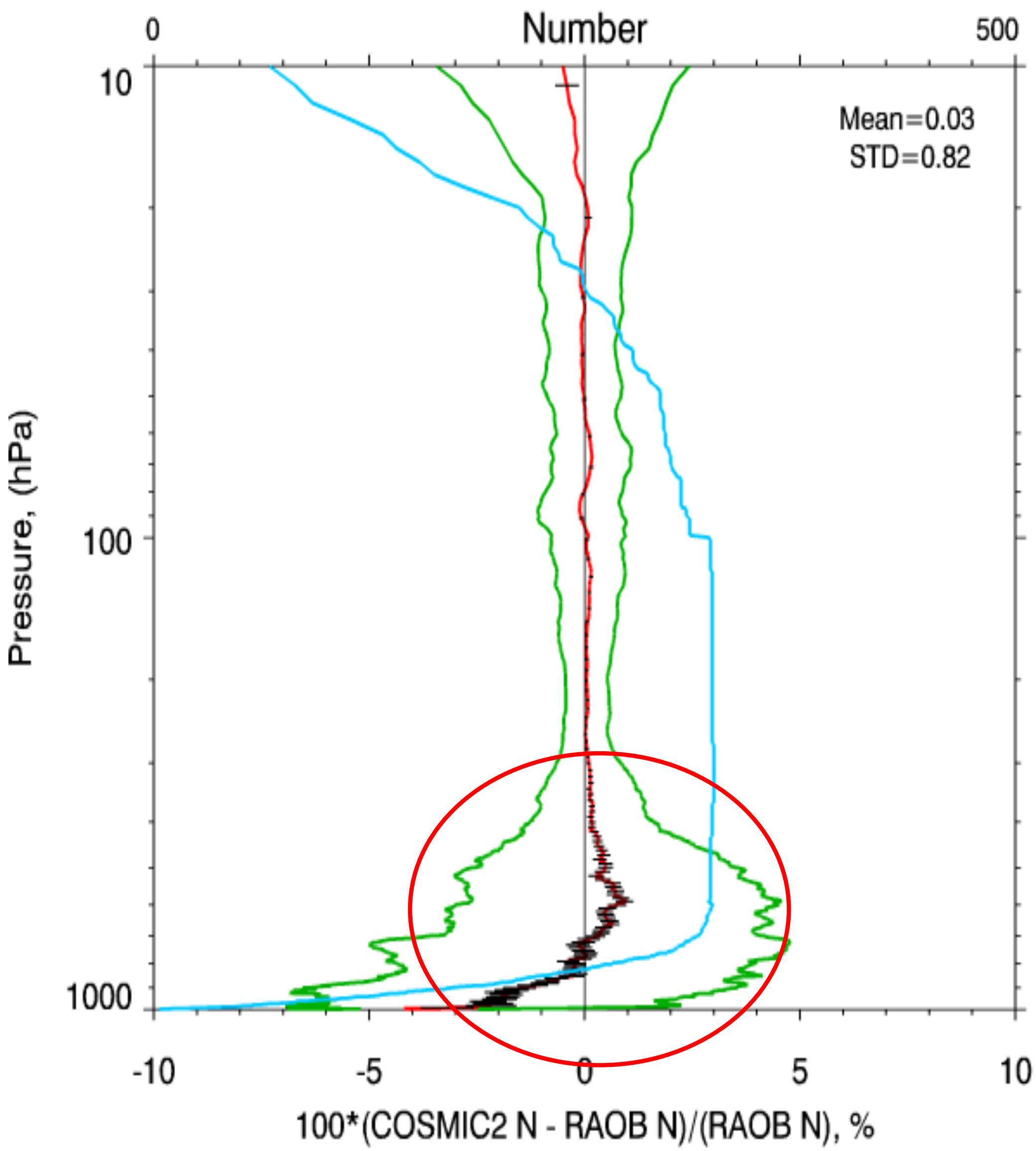
WMO ID	type description	match number
111	Sippican LMS6 w/Chip Thermistor	37
114	Vaisala RS92/DigiCORA MW41	23
117	Graw DFM-09 (Germany)	69
123	Vaisala RS41/DigiCORA MW41	45
131	Taiyuan GTS1-1/GFE(L) (China)	11
132	Shanghai GTS1/GFE(L) (China)	97
133	Nanjing GTS1-2/GFE(L) (China)	13
141	Vaisala RS41/DigiCORA MW41	253
142	Vaisala RS41 with pressure derived from GPS height/ AUTOSONDE (Finland)	12
152	Vaisala RS92-NGP/Intermet IMS-2000	54
177	Modem GPSonde M10 (France)	120
182	Lockheed Martin LMS-6	101
21	VIZ/Jin Yang MARK I MICROSONDE (Korea)	25
35	Vaisala RS18	128
61	Vaisala RS80/Loran/Digicora I,II or Marwin (Finland)	17
80	Vaisala RS92/Digicora III (Finland)	96
9	No radiosonde - system unknown or not specified	13
99	BAT-4G (South Africa)	16

Choose Vaisala RS41 (WMO ID: 123,141,142) as reference

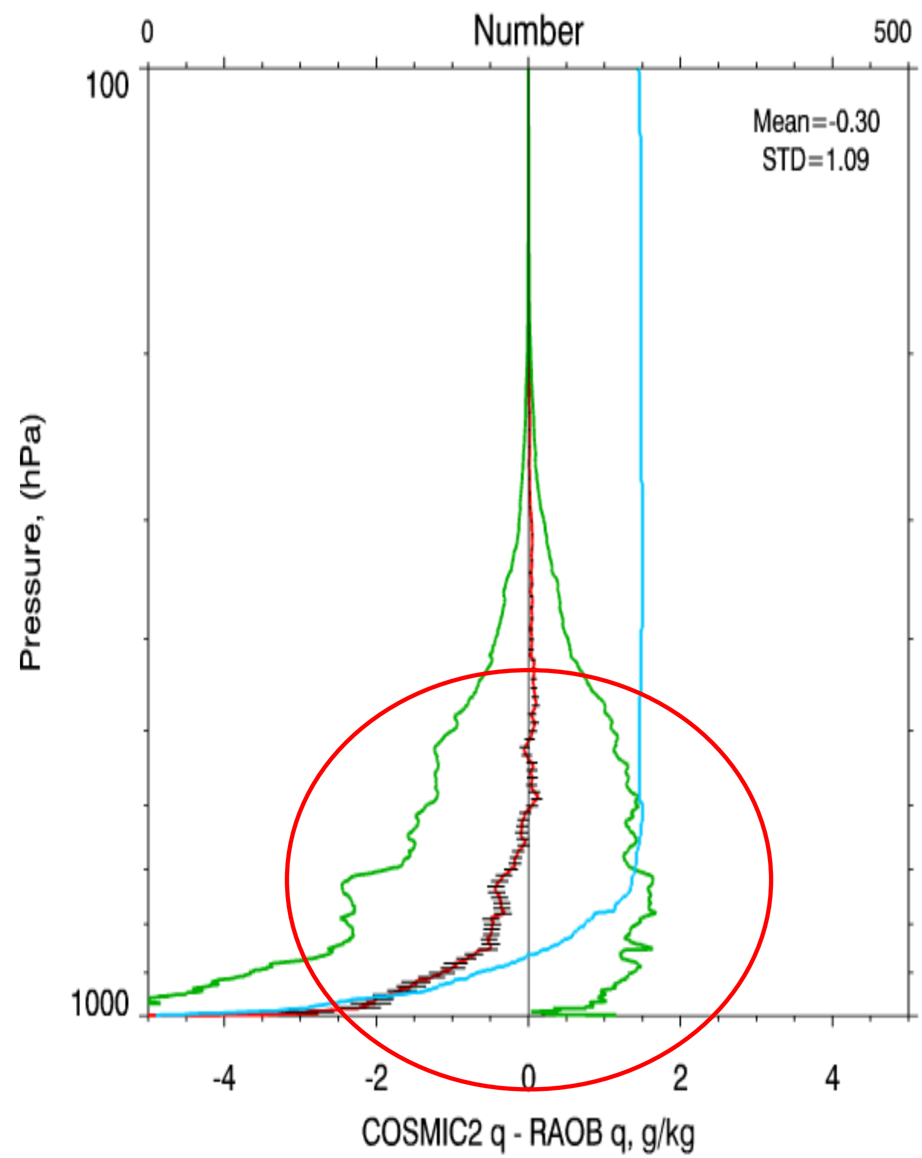
**Vaisala RS92 (WMO ID: 114, 152, 80) could be another reference

Ho et al., (2017, ACP), He and Ho (2009, GRL), Ho et al., (2010, BAMS)

Fractional refractivity differences

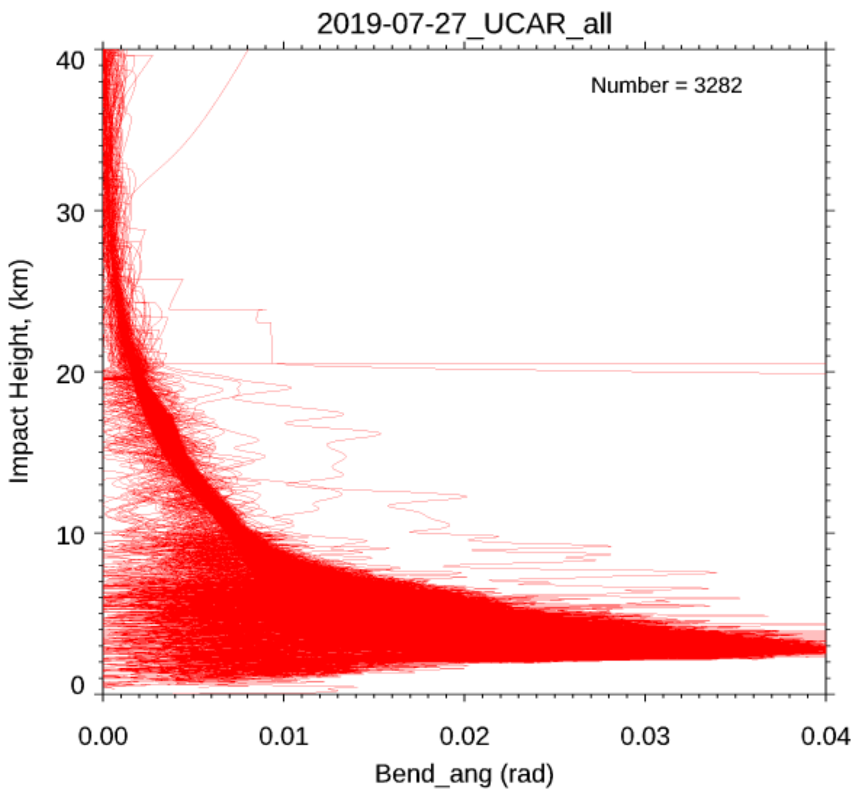


wet temperature differences

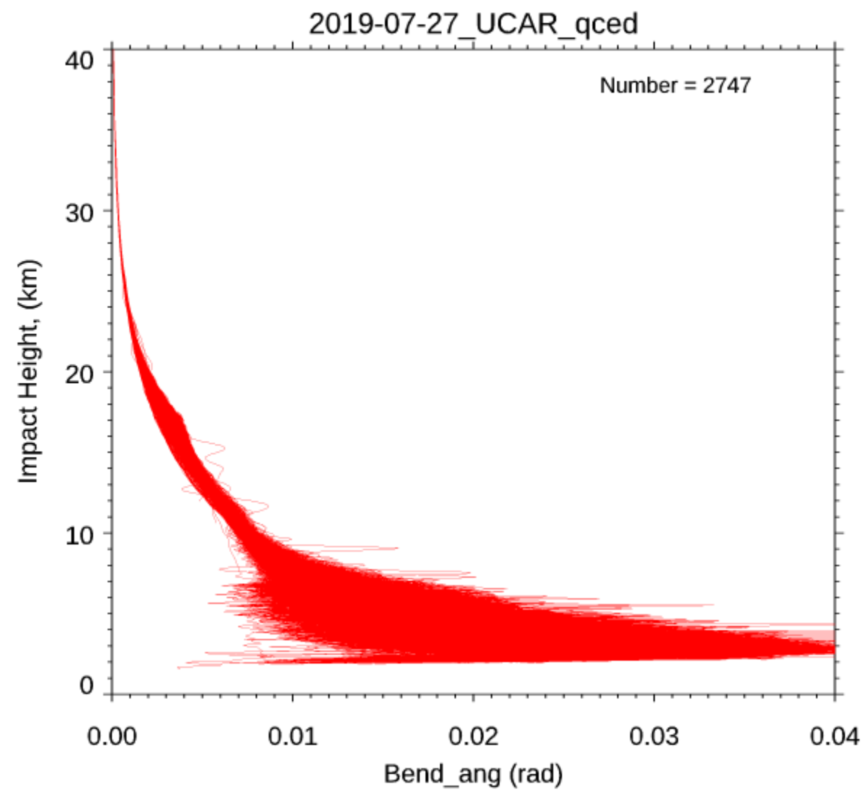


4. Comparison with STAR ROPP Retrievals

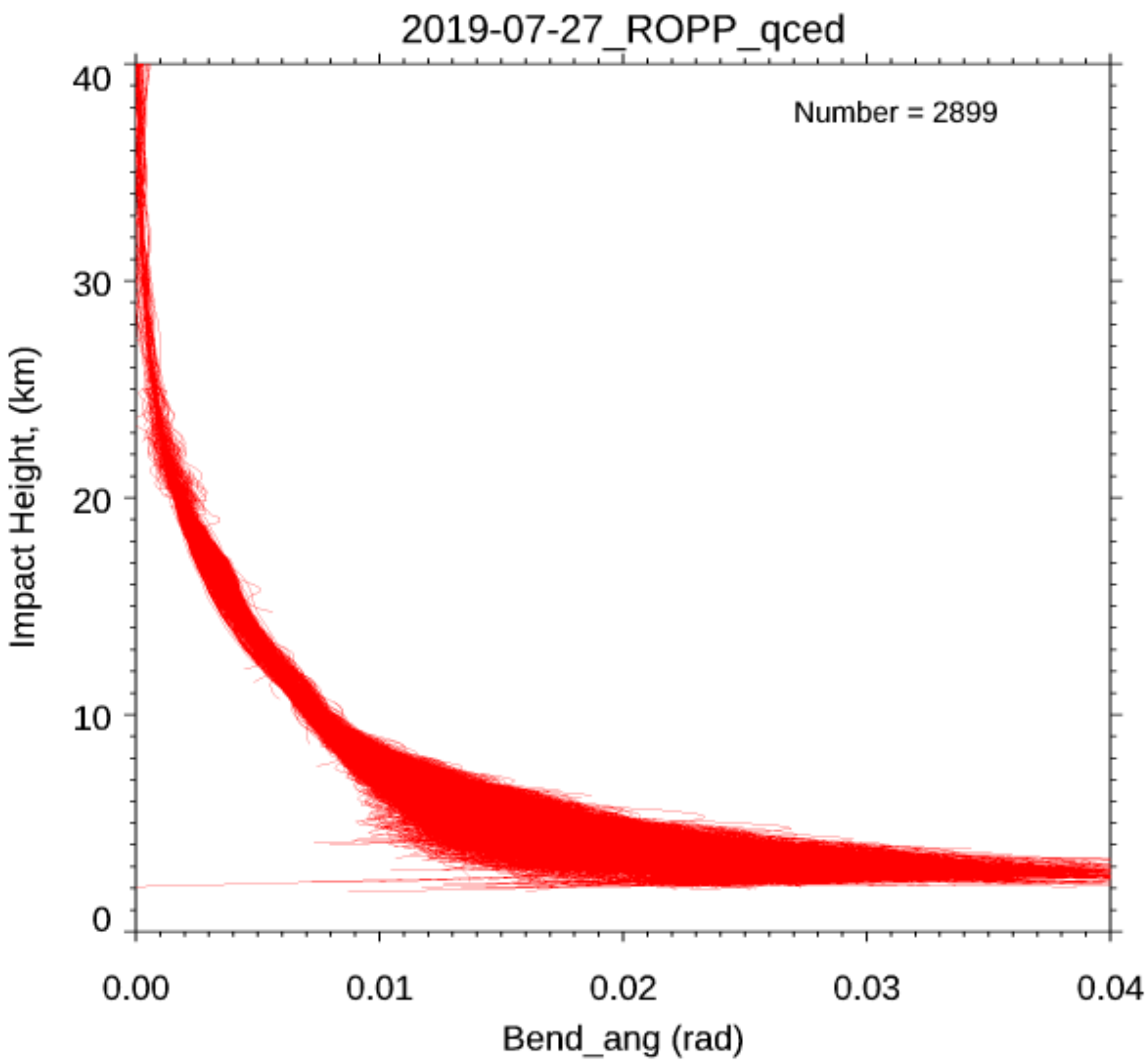
UCAR all profiles



UCAR profiles after QC (removing ~ 20% of data)

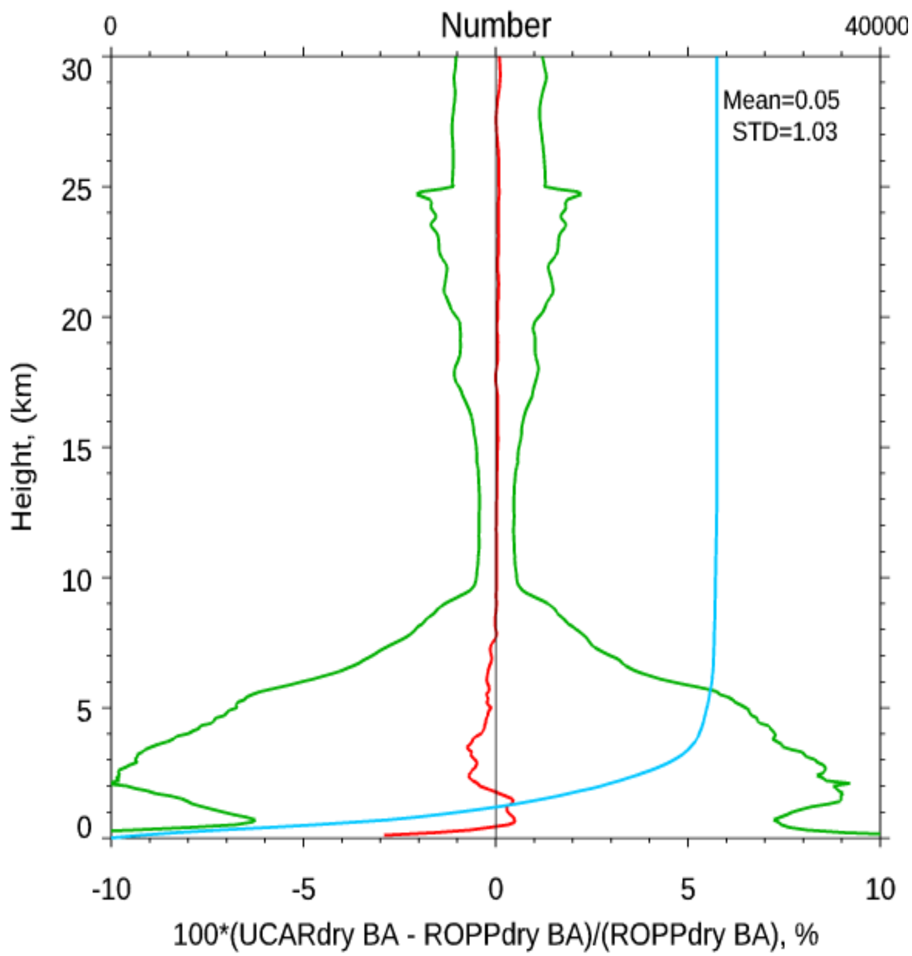


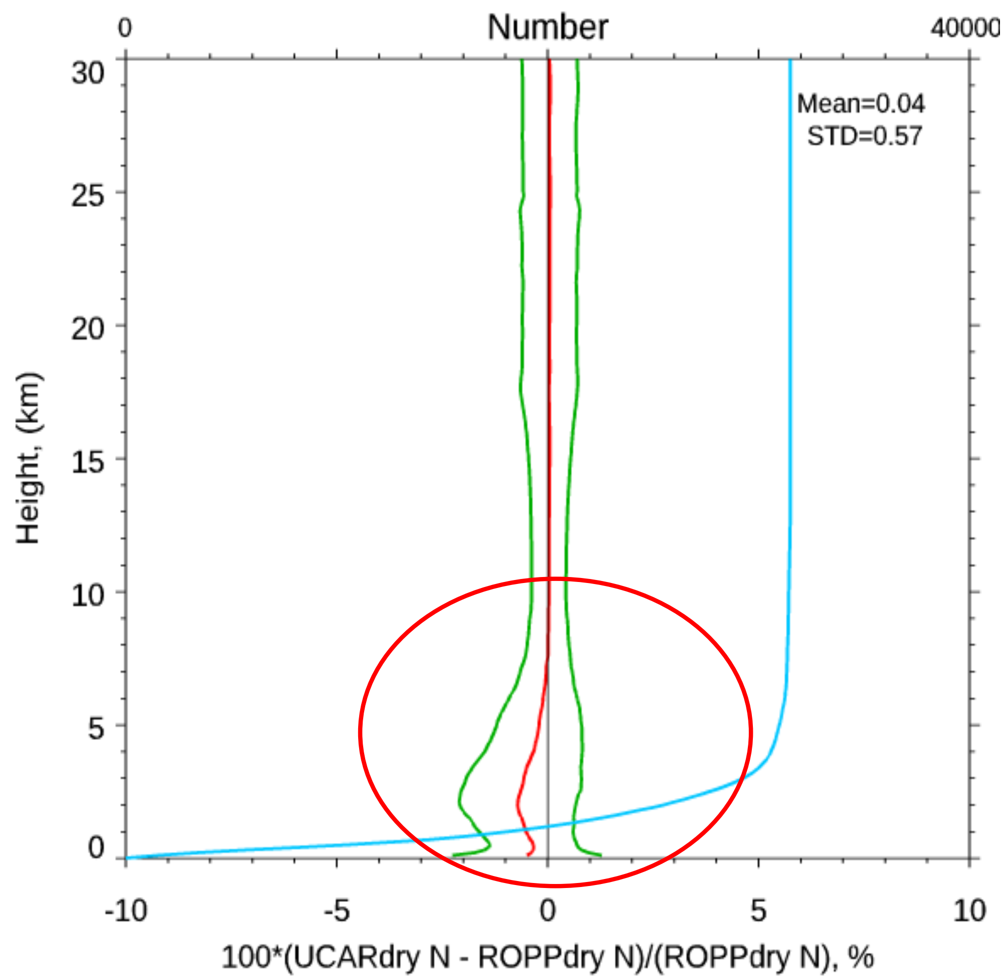
STAR ROPP profiles after QC (removing ~ 20% of data)



4. Comparison with STAR ROPP Retrievals

Fractional Bending angle differences (in %)
UCAR vs. STAR ROPP

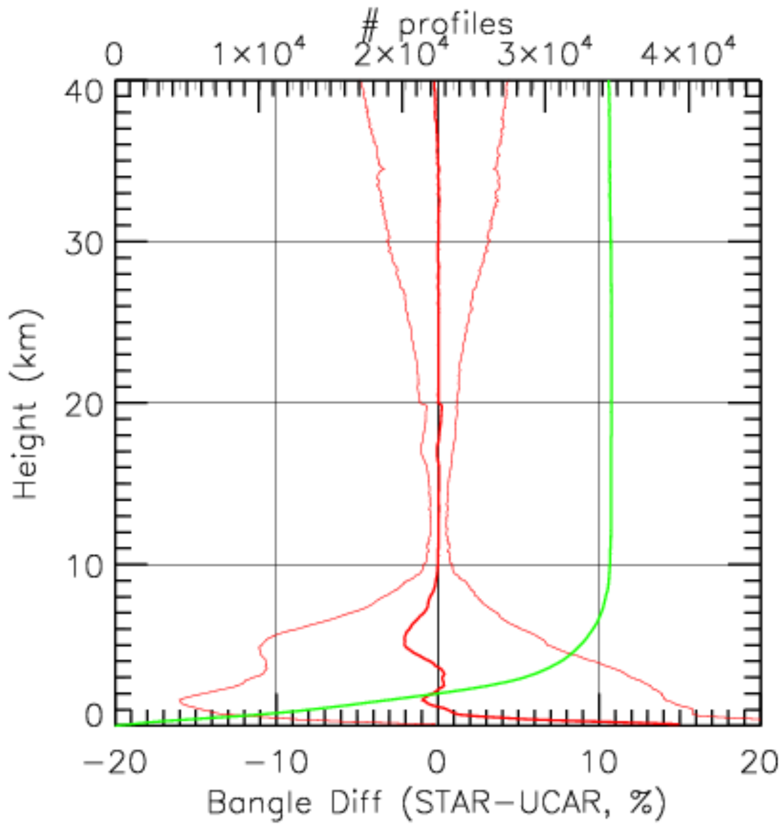




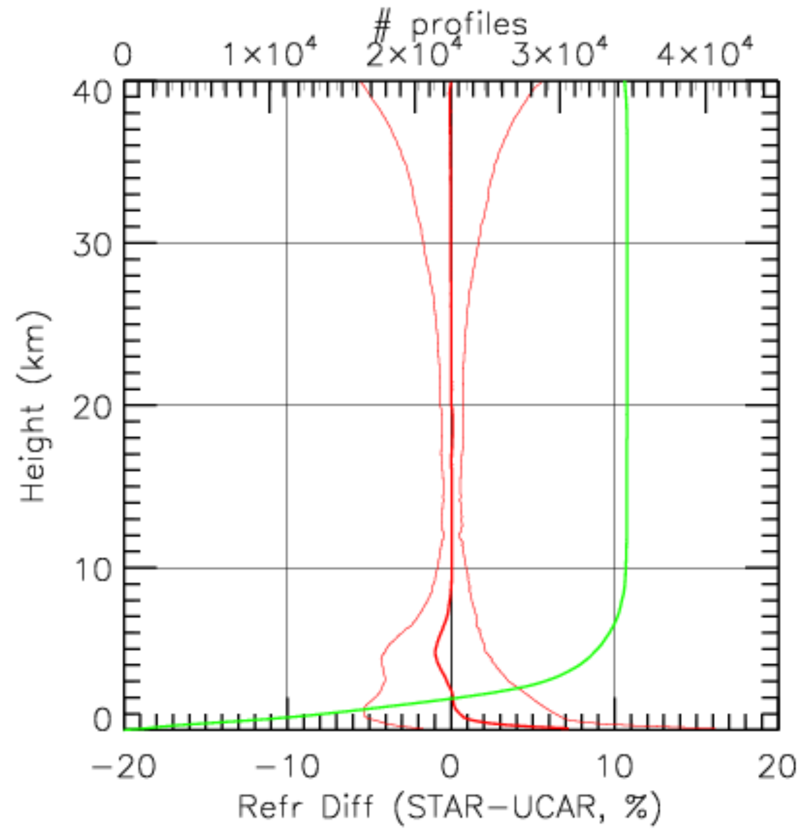
4. Comparison with STAR Retrievals

STAR COSMIC-2 Bending Angle Profiles using FSI (full spectrum inversion) method Comparison with UCAR Bending Angle

Bending Angle Comparison with UCAR



Refractivity Comparison with UCAR

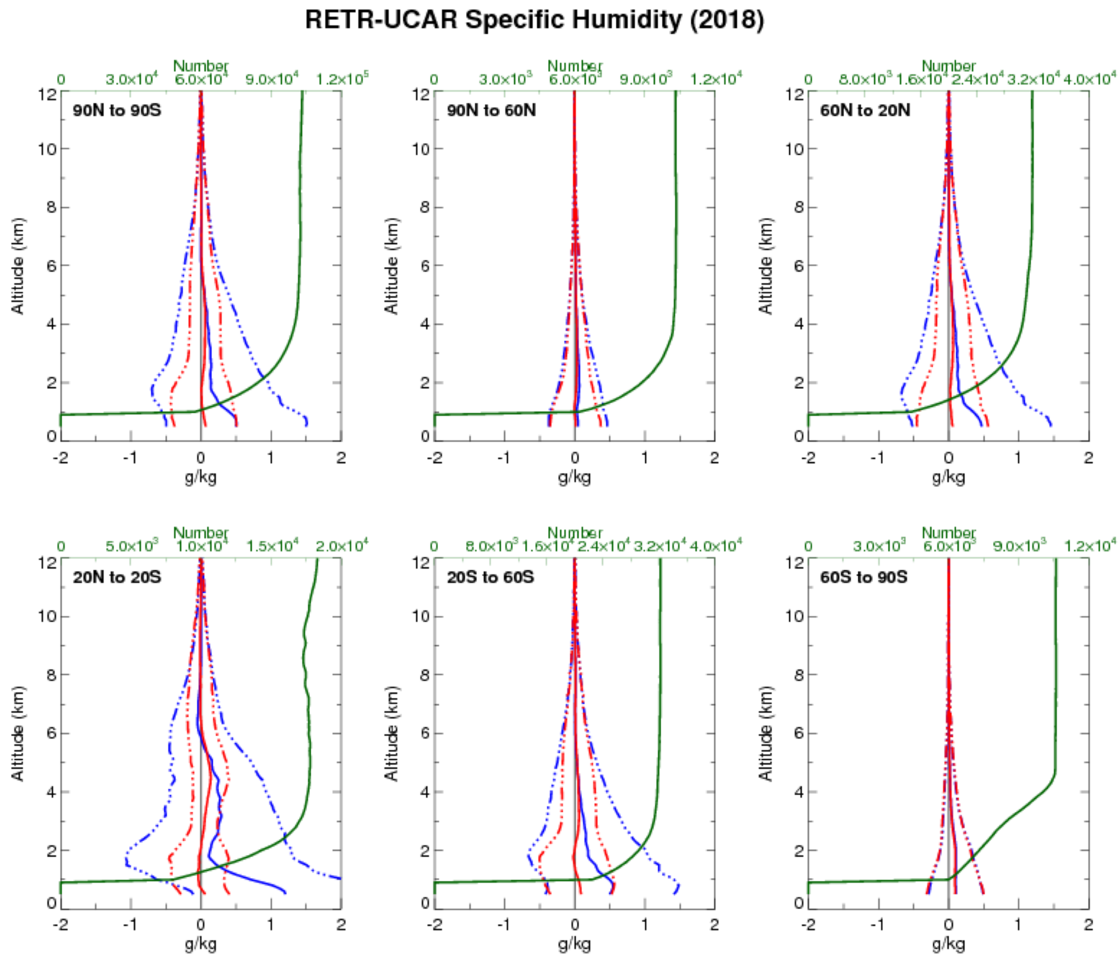


The comparison is done using 'good' UCAR profiles with all STAR profiles. Out of 48590 profiles that passed STAR QC, 41466 profiles matched UCAR QC passed profiles

5. comparison with STAR 1d var ret

Moisture Comparison: STAR – UCAR Retrievals

COSMIC-1 (2018)



Yearly average for $W_{RTR}^{STAR} - W_{RTR}^{UCAR}$

W_{RTR}^{UCAR} are taken from *wetPrf* files.

Blue = $W_{FG} - W_{RTR}^{UCAR}$

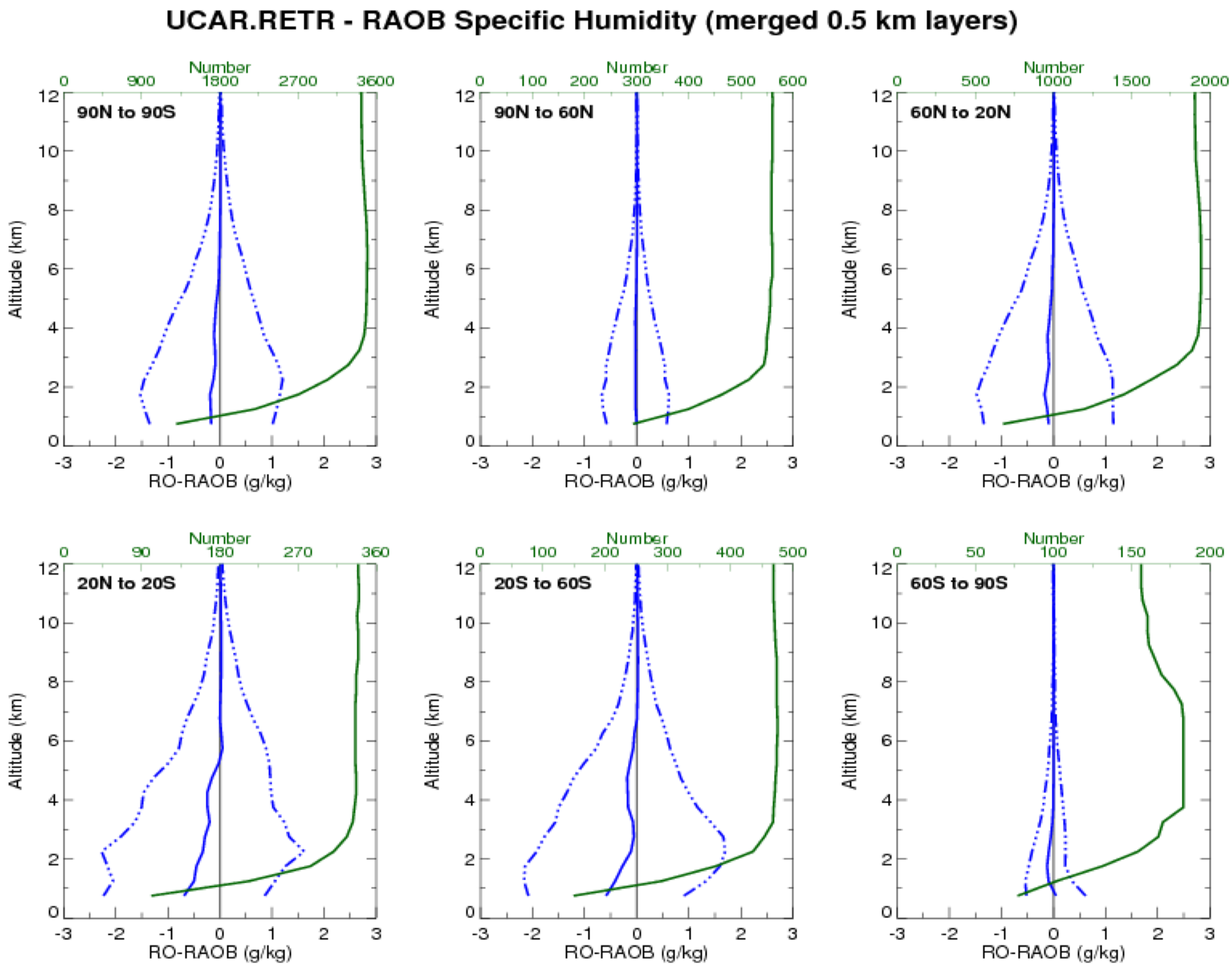
Red = $W_{RTR}^{STAR} - W_{RTR}^{UCAR}$

Green = sample size

Solid line is *bias* and dash-dot line is *bias* $\pm$ *rmsd*

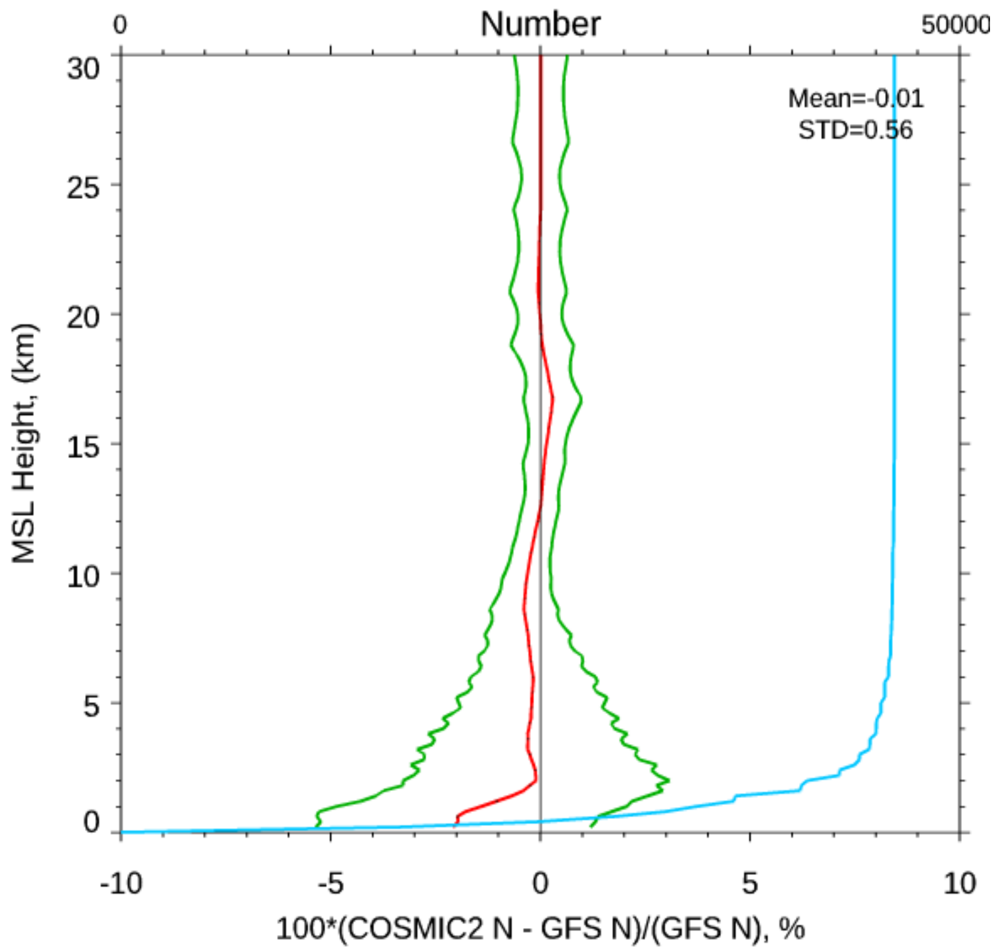
Both kinds of retrievals are not biased vs each other and compensate positive bias of the GFS-based First Guess for water vapor below 2 km.

5. comparison with STAR 1d var ret when UCAR COSMIC refractivity profiles are used as inputs

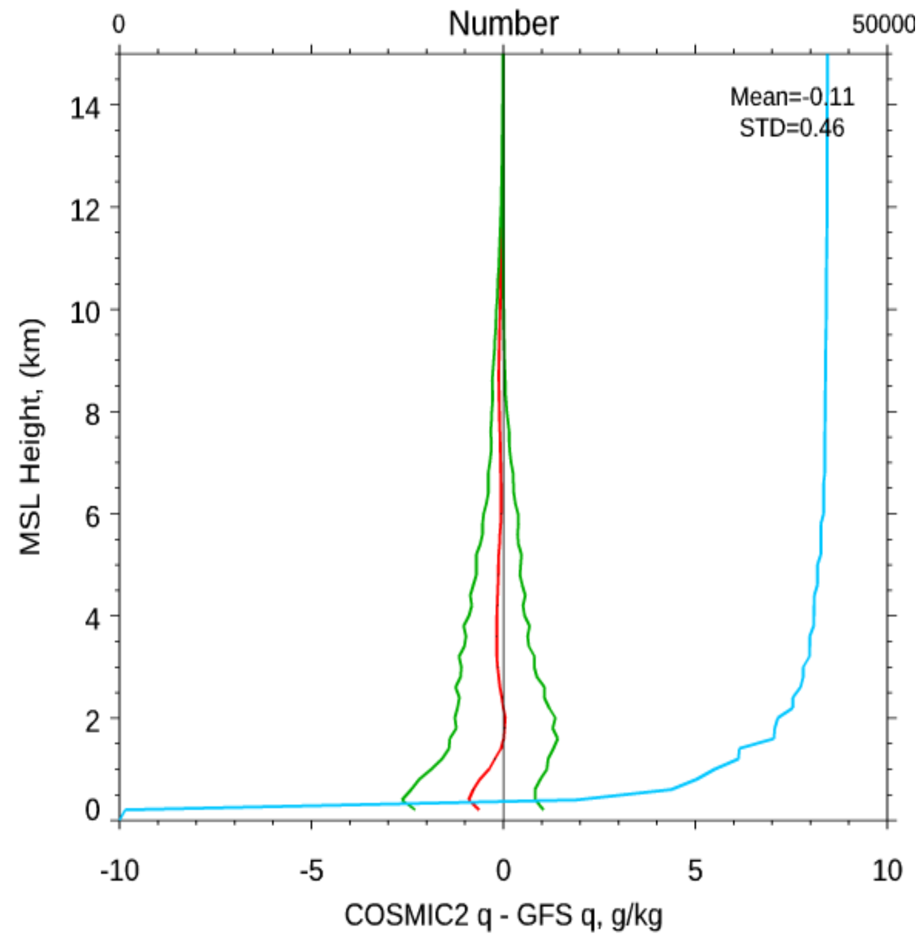


6. comparison with GFS 6h

Fractional refractivity differences, atmPrf



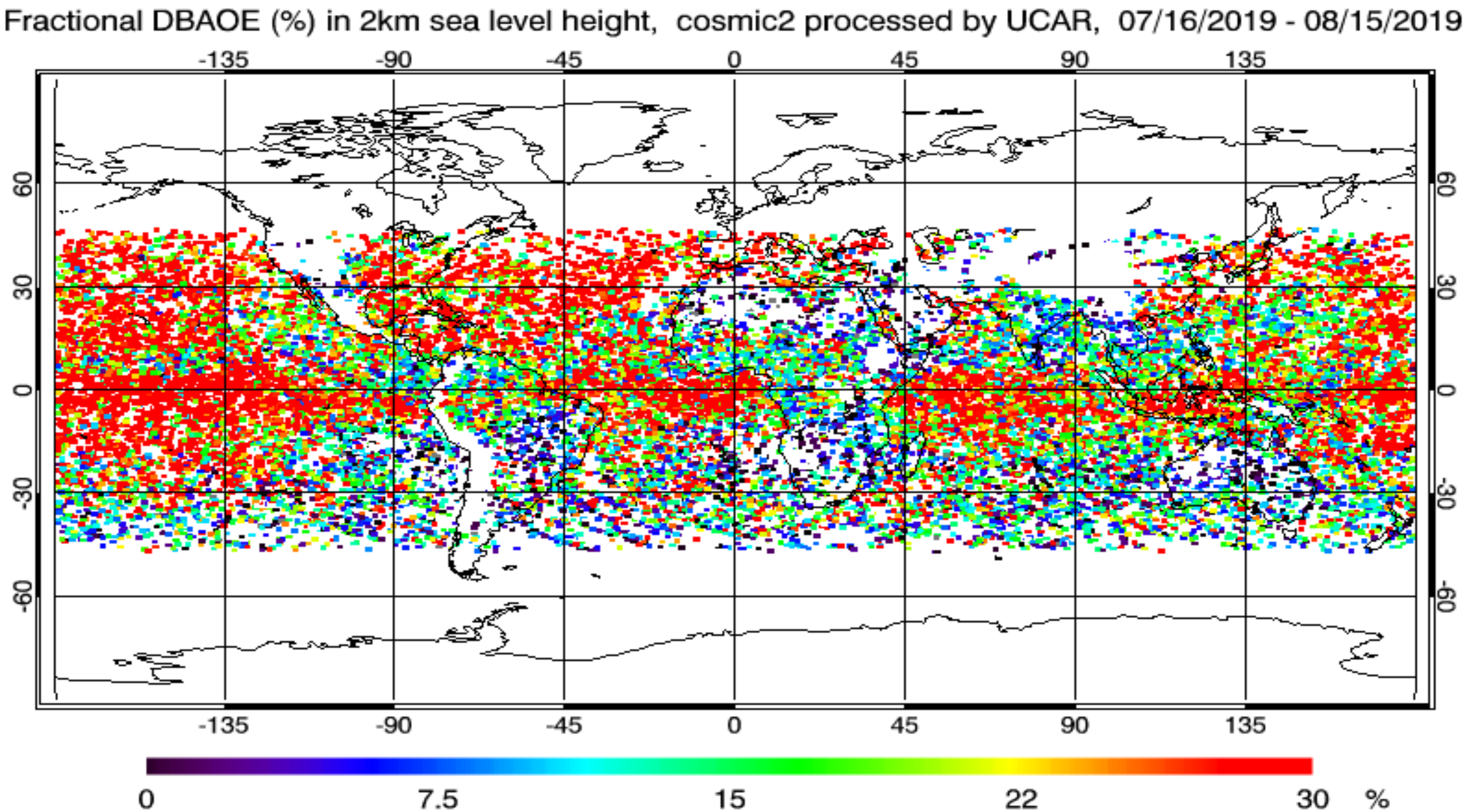
Specific humidity, wetPrf



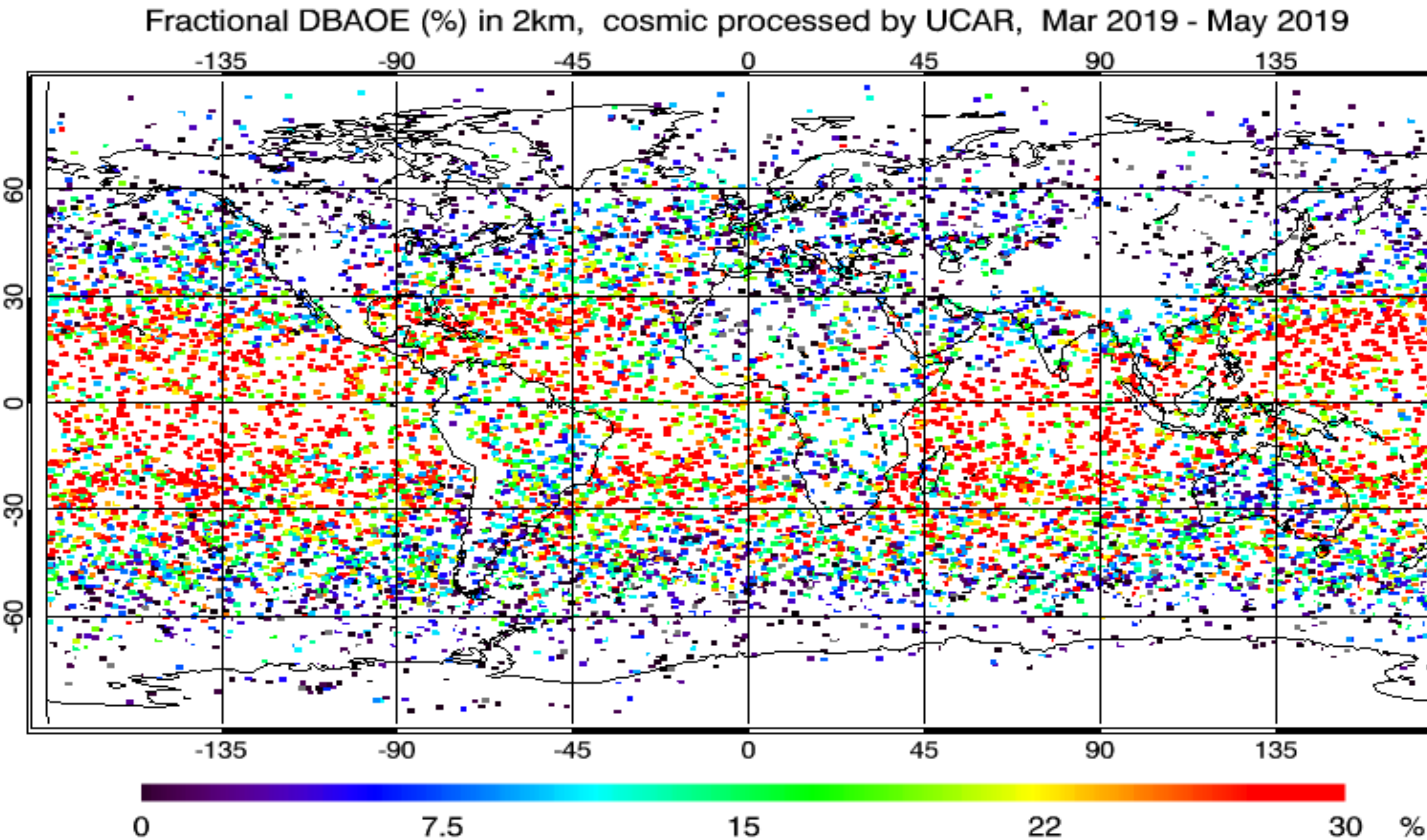
7: Fractional DBAOE comparisons (local spectral width)

Fractional DBAOE is defined as 100% x LSW/2 / bending angle.

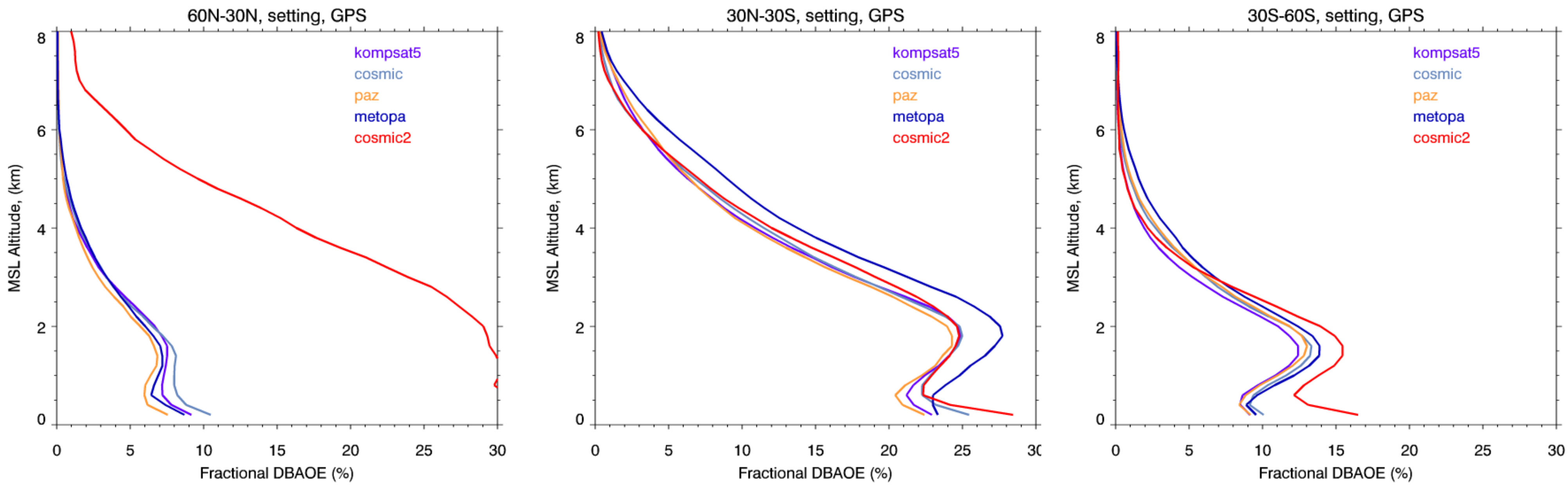
COSMIC2



cosmic, 2019 spring



Mean Fractional DBAOE, 2019 spring , setting, GPS



Conclusions and Discussions

1. Early orbit comparisons

2. Stability : C2 vs. KOMSAT-5

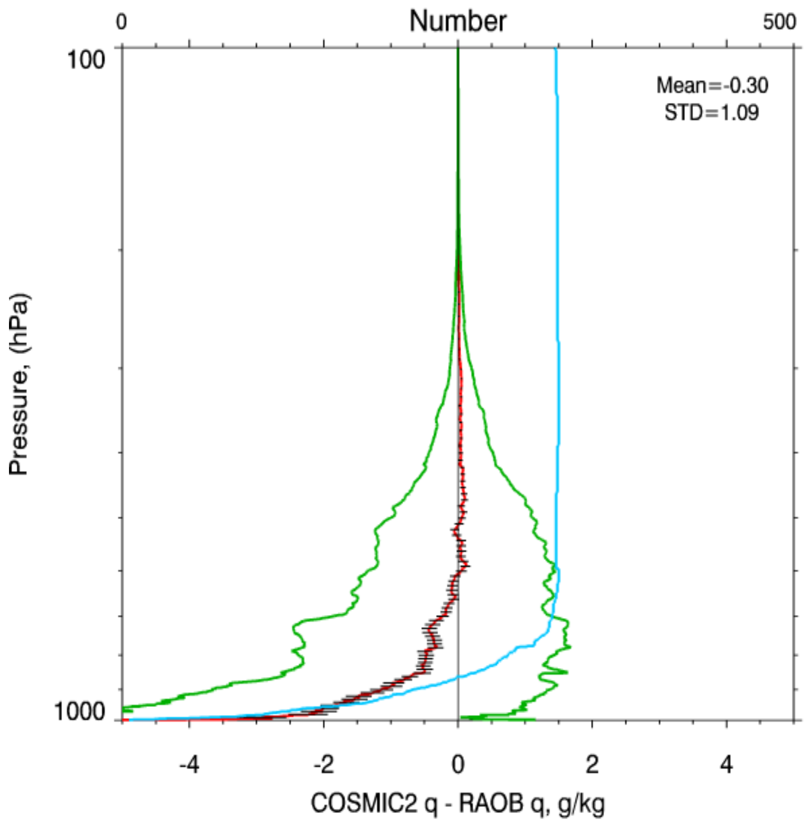
3. Accuracy : C2 vs. RS41 and RS92

4. Structural uncertainty: UCAR C2 vs. STAR C2
   Bending angle and refractivity profiles

5. Structural uncertainty : UCAR 1d var vs.
   STAR 1d var

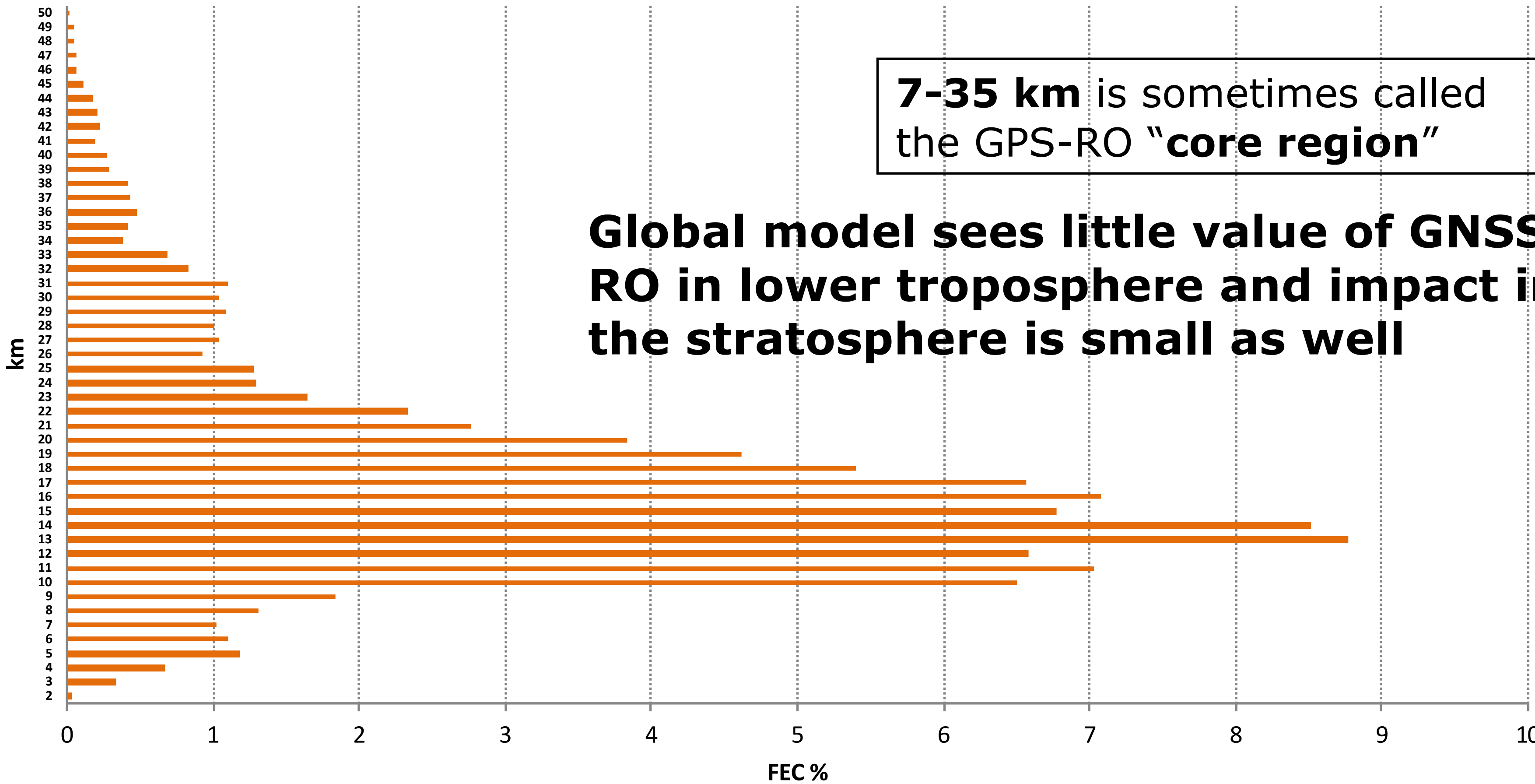
6. Accuracy Uncertainty: C2 vs. GFS 6 h forecast

7. Is the quality of COSMIC-2 better than that of
   COSMIC in the tropical lower troposphere:
   estimated observation errors comparisons



Challenges of GNSS RO Weather Applications

Heights where GNSS-RO is reducing the 24hr forecast errors



7-35 km is sometimes called the GPS-RO "**core region**"

Global model sees little value of GNSS RO in lower troposphere and impact in the stratosphere is small as well

Florian Harnisch, Sean Healy, Peter Bauer, Steve English, Nick Yen, 2013