NOAA Integrated Cal/Val System (ICVS) for Radio Occultation Performance Monitoring and Data Quality Assurance

Xinjia Zhou[1,2], Shu-peng Ben Ho[1], Changyong Cao[1]

1. NOAA STAR;
2. GST, Inc.

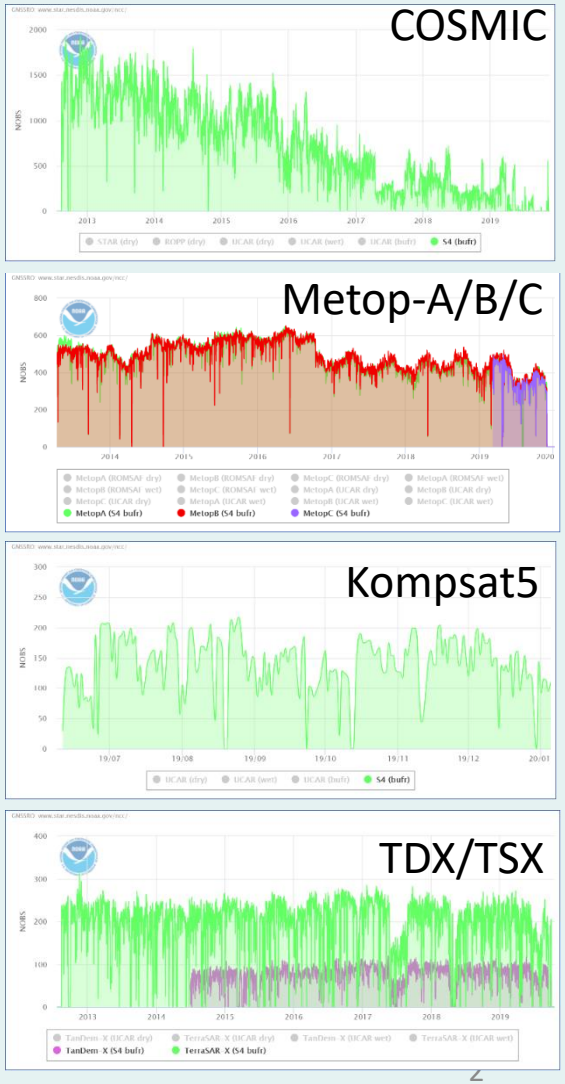
Operational GNSS-RO for NOAA NWP

Currently ~2000 daily RO profiles are available for NWP operations

- Declining number of profiles from COSMIC1
- Metop A/B/C, ~1200 daily
- KOMPSAT-5, ~150 daily
- TDX/TSX, ~ 300 daily

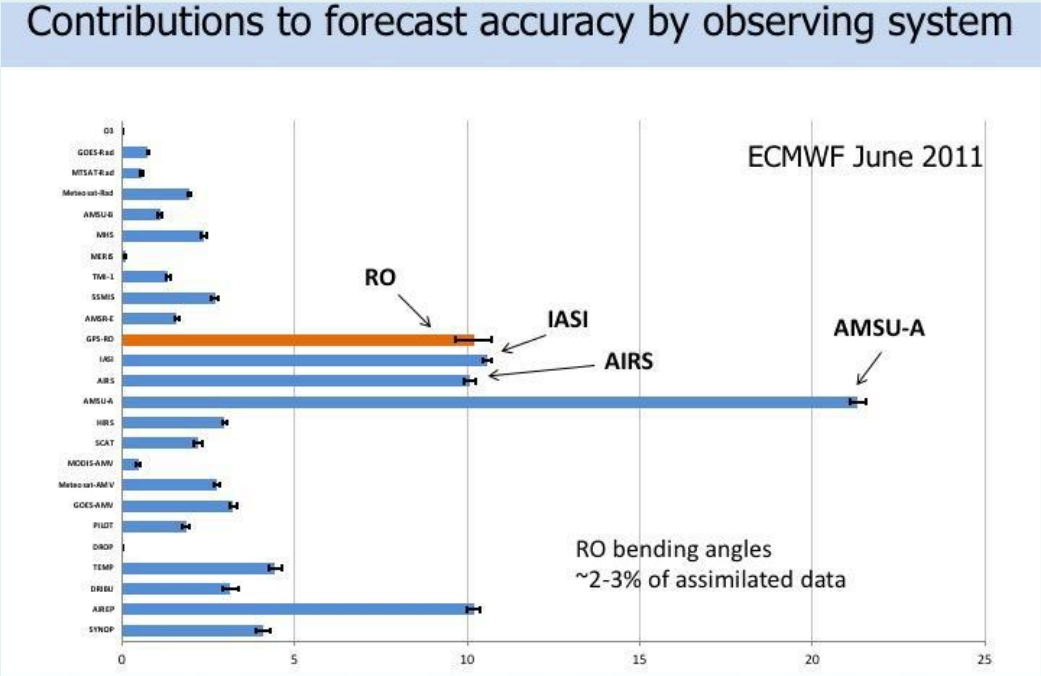
Several RO missions is on the way

- COSMIC2, ~ 4000 profiles daily, not yet used
- PAZ, ~200 daily, not yet used
- CWDP, not yet used
- GRACE-FO, not yet used



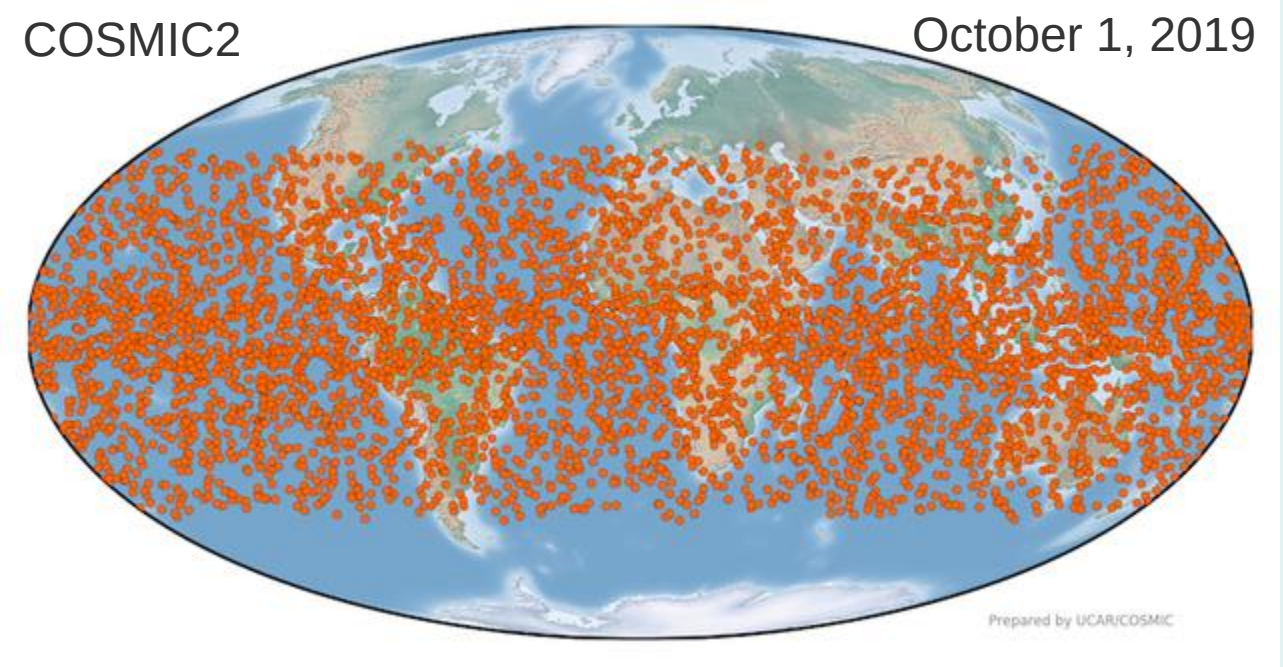
GNSS-RO key role recognition

- GNSS radio occultation (RO) has been recognized as a key observable for Numerical Weather Prediction (NWP) and climate change detection.
- It has matured to become an important, sustained component of NOAA satellite observations and contributor to NWP, complementing microwave and infrared sounding measurements.



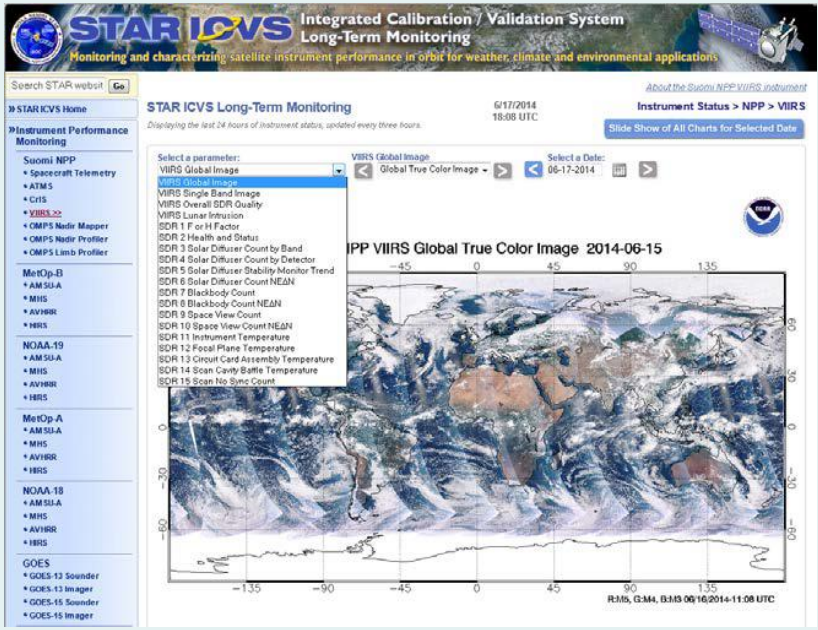
New era for GNSS-RO

- The successful launch of FORMOSAT-7/COSMIC-2 marks a new era of RO for operational NWP, which will have profound impacts on all activities related to atmospheric sounding.
- NOAA is strengthening support for COSMIC2, recognizing its significance, transiting GNSS RO from research to operations for weather forecast.
- COSMIC2, together with Metop/Meotop SG, is expected to become an on-orbit reference for atmospheric sounding, establishing consistency for all measurements.
- It is important to ensure the consistency, accuracy, precision of the measurements with well understood uncertainties. **NOAA ICVS system** is critical important for the purpose.



NOAA ICVS: Background

NOAA ICVS system is a well known near real-time performance monitoring for all NOAA environmental satellites and instruments



- Near real time and long term instrument status, performance monitoring, and anomaly diagnosis
- Near real time and long term level 1 data product quality monitoring
- Provide real time support for sensor calibration activities
- Provide rapid and preliminary estimate of satellite data impact in NWP applications
- Ensure the integrity of the climate data records from all satellite instruments

NOAA ICVS: Extension

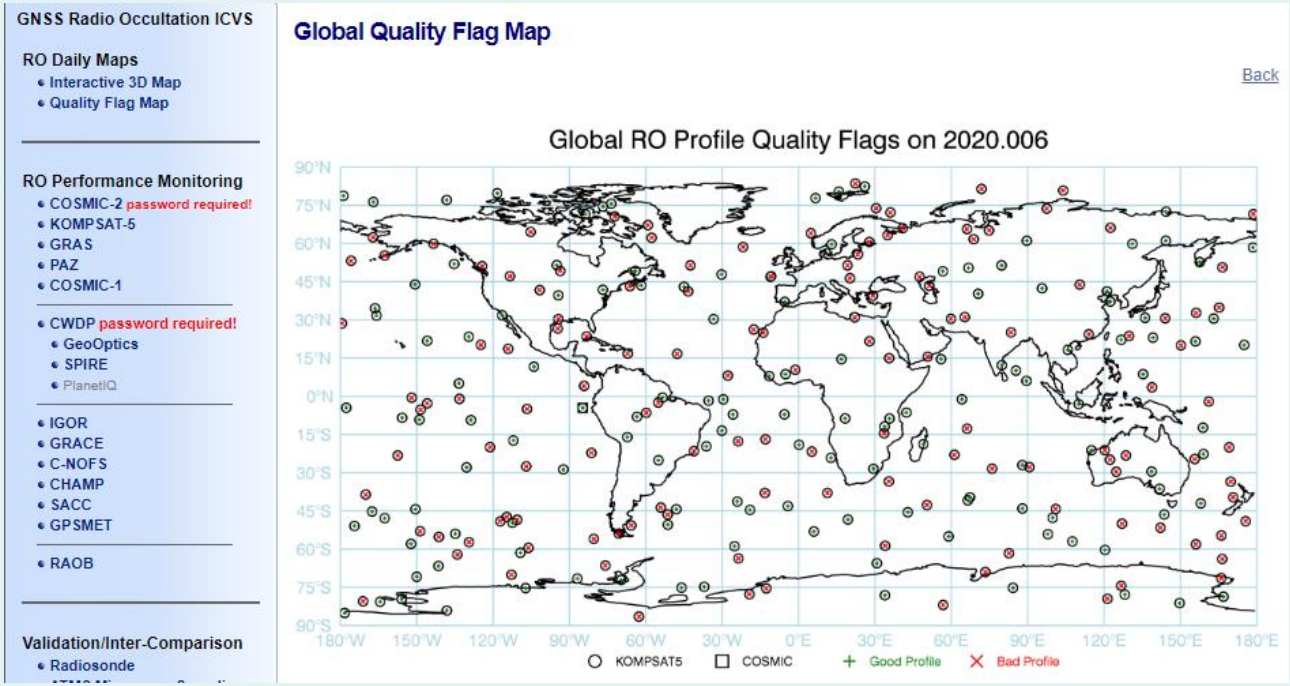
GNSS RO ICVS is a natural extension of the NOAA ICVS system, with more dynamic and interactive capabilities. The system includes:

- Monitoring RO product parameters and instrument performance at all levels.
- Routine comparison of atmospheric profiles with other satellite observations and retrievals including microwave, and infrared.
- Routine comparison of profiles with those from Radiosondes.
- Dynamic web interface with many capabilities.
- Long-term monitoring of the parameters.

WebGL Earth interactive plots

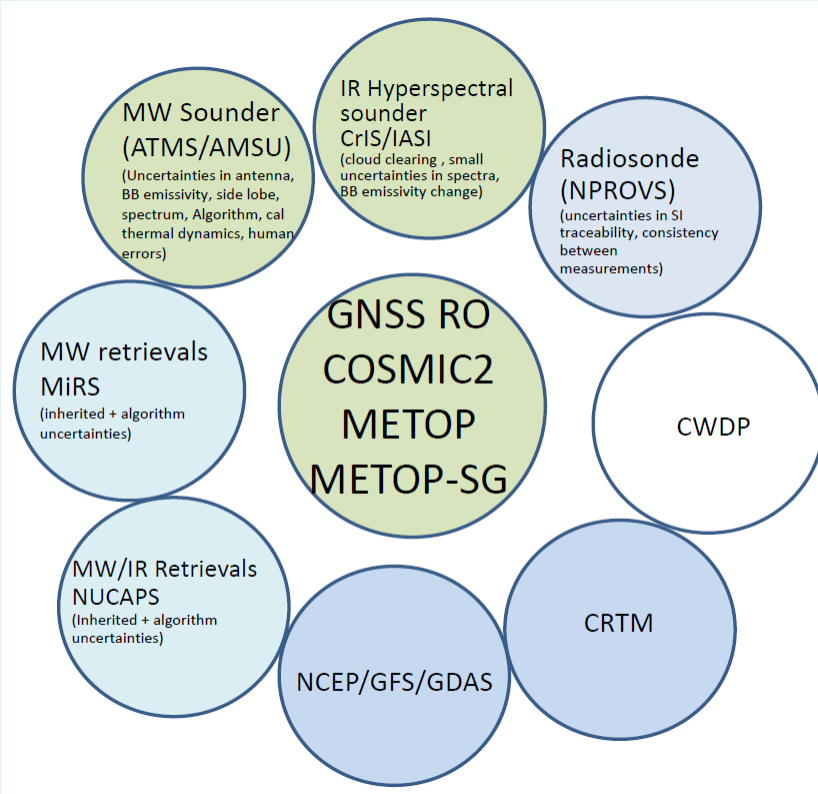
NOAA ICVS for RO: Introduction

- Currently, RO data from 12 publicly available missions are included, from GPSMET collected in 1995 to COSMIC2 data in 2019.
- RO data producer: UCAR, ROMSAF, ROPP and STAR (under testing).
- References: Weather Model, reanalysis, other RO data, Radiosonde



NOAA ICVS for RO: References

- Working online
  - NCEP/GFS/GDAS
  - Model reanalysis, era/merra/nra/jra
- Working offline, will eventually transit online
  - GNSS-RO inter-comparison
  - Radiosonde
  - Retrievals: MiRS/NUCAPS
  - MW sounder: ATMS/AMSU-A
  - IR sounder: CrIS/AIRS/IASI

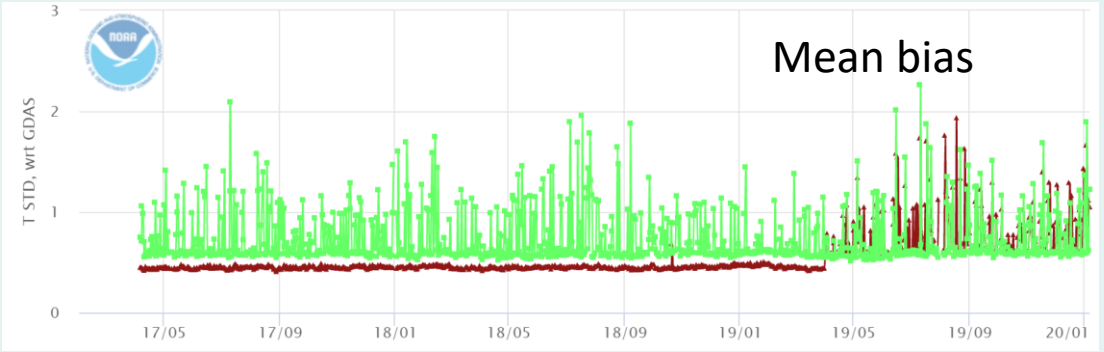


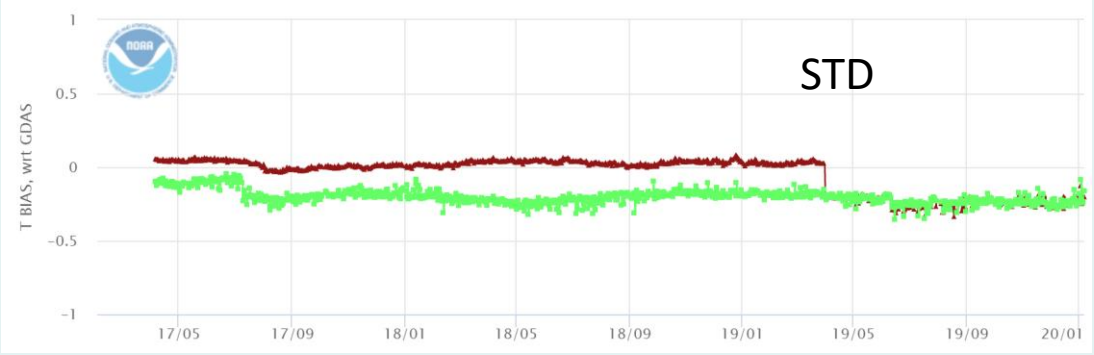
NOAA ICVS for RO: Model comparison

Get a big picture of RO behavior.

Help users to locate suspicious profiles quickly, and easily deep dive to find the source.

ROM SAF processed MetopA w.r.t. ERA5

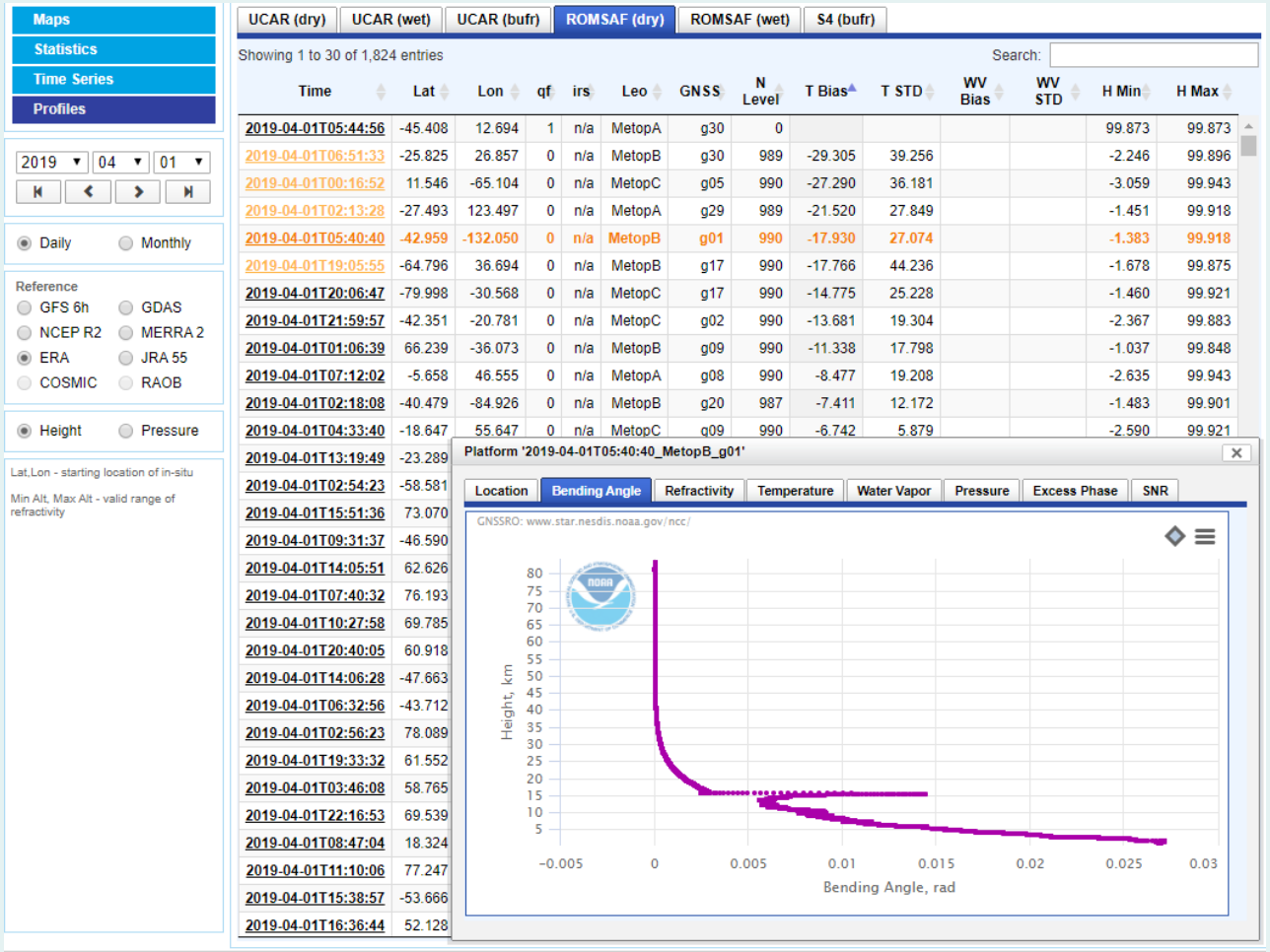




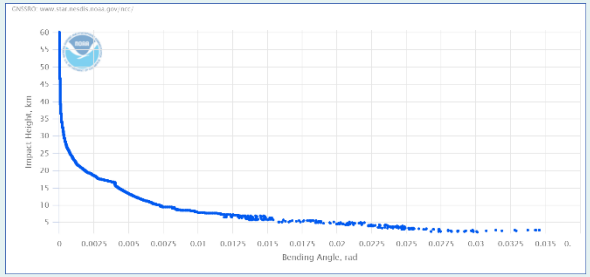
Brown line before 2019-03-31 is from ROM SAF CDR, after 2019-03-31 is from ROM SAF NRT;

Green line is from GDAS.

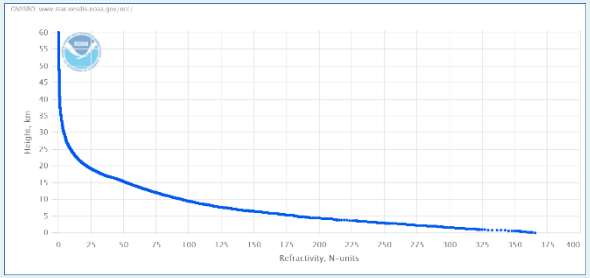
By sorting the title of each columns, uses is capable to find the interesting individual profiles and display the whole profile.



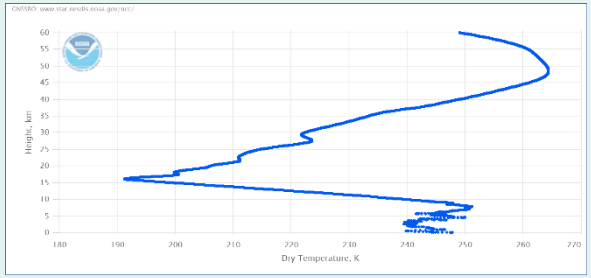
Individual profiles are monitored for L1b (excess phase, signal to noise ratio) and L2 (bending angle, refractivity, dry temperature, temperature, water vapor pressure, pressure).



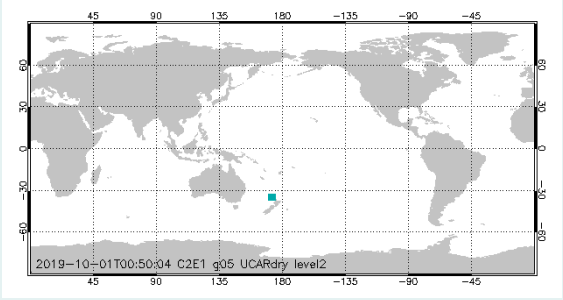
Bending angle



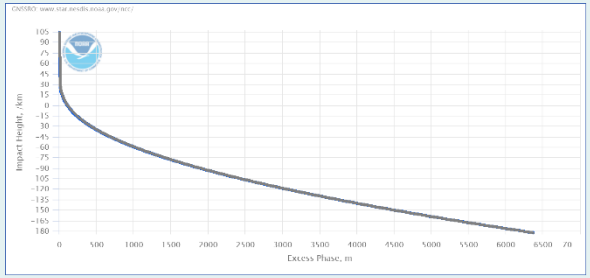
Refractivity



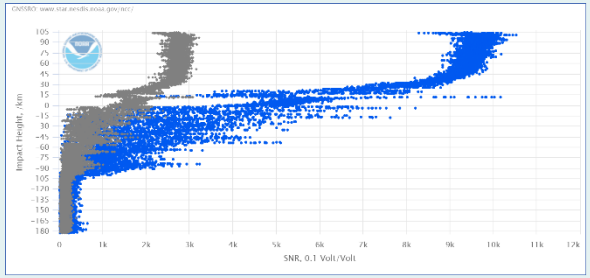
Temperature



Map



Excess phase (L1/LS)

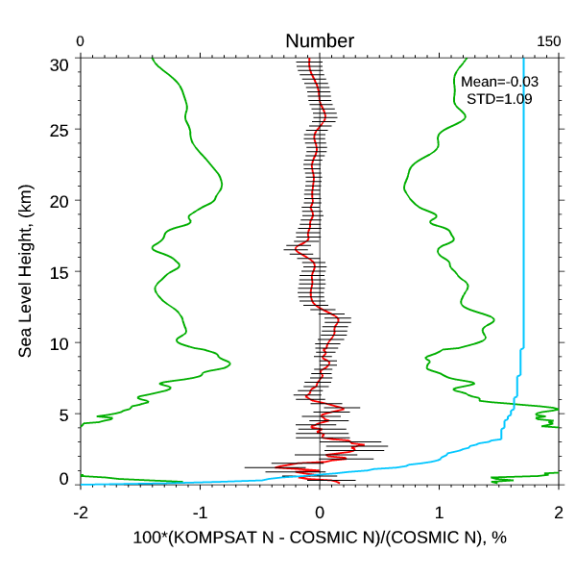


Signal to noise ratio (L1/L2)

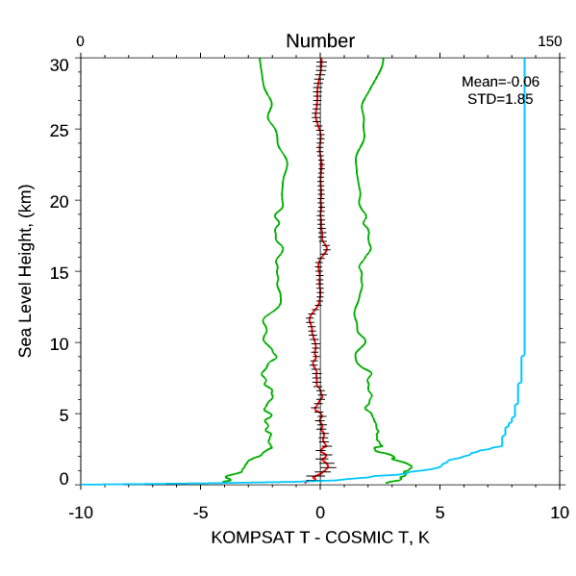
NOAA ICVS for RO: RO inter-comparison

- Colocation RO inter-comparison cross platform
- One-to-one RO inter-comparison cross center

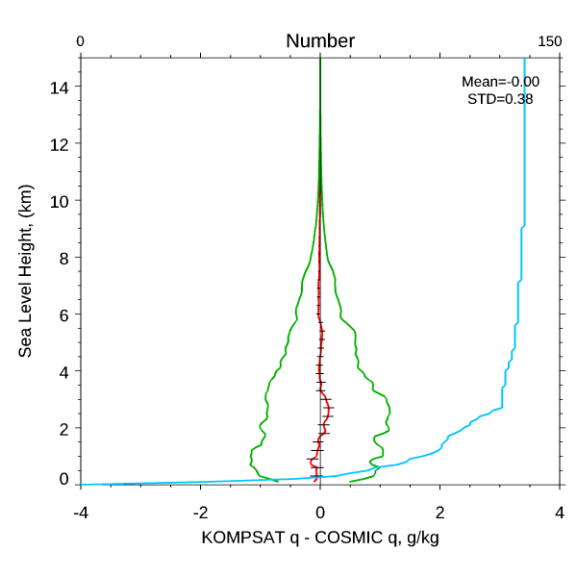
Fractional refractivity diff



Temperature diff



Specific Humidity diff

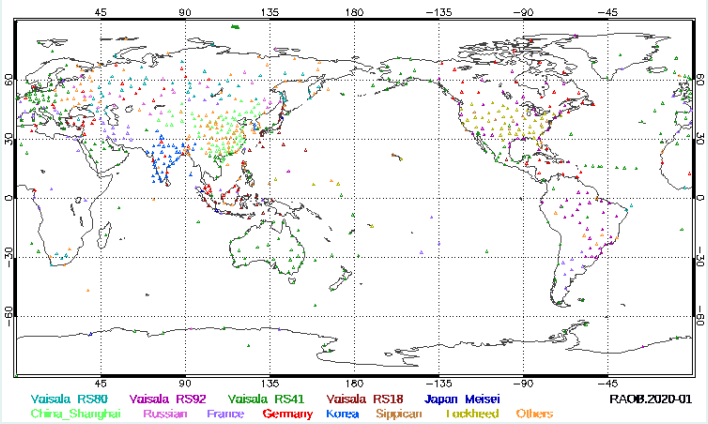


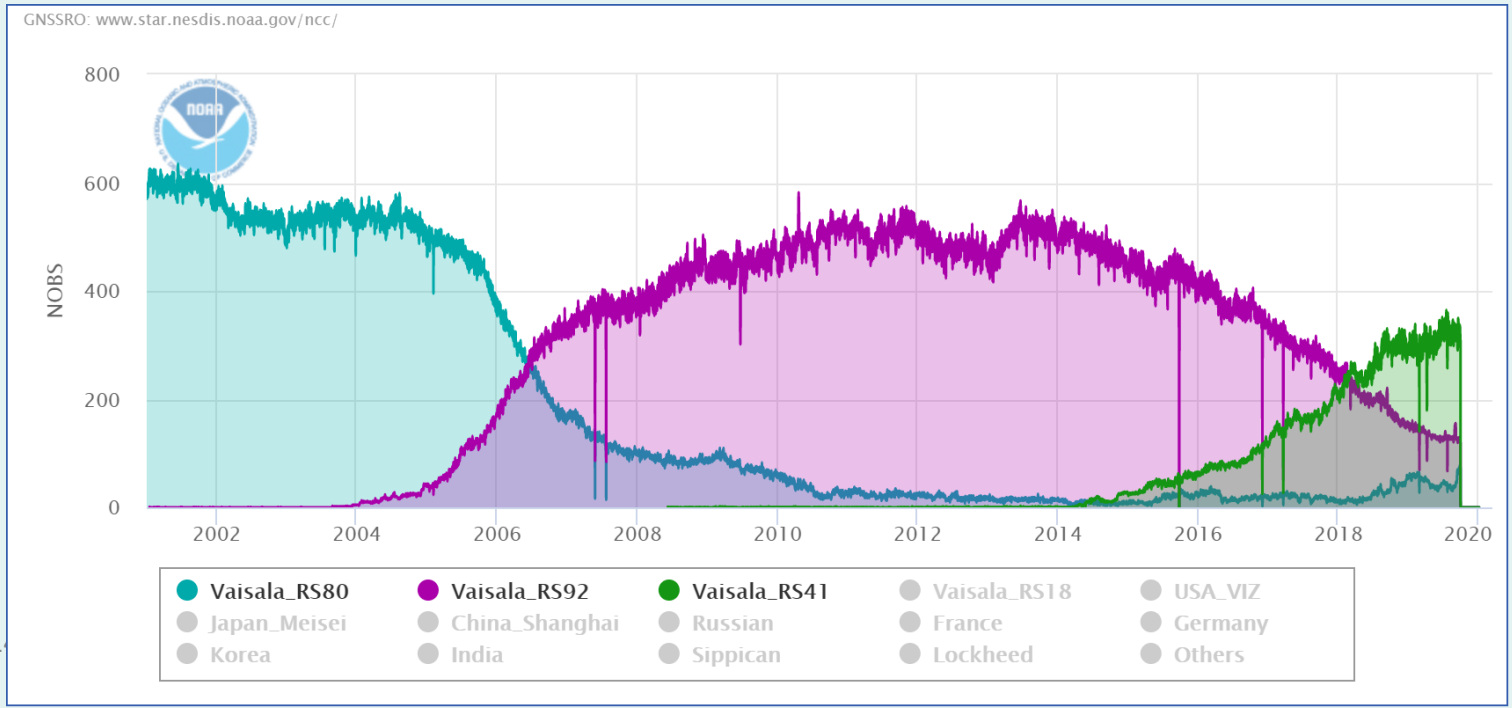
UCAR KOMPSAT5 vs. UCAR COSMIC

NOAA ICVS for RO: RAOB comparison

- There are over 15 radiosonde instrument types.
- Vaisala RS80 and RS92 used to be the reliable reference.
- Staring from 2018, Vaisala RS41 exceed RS80/92.

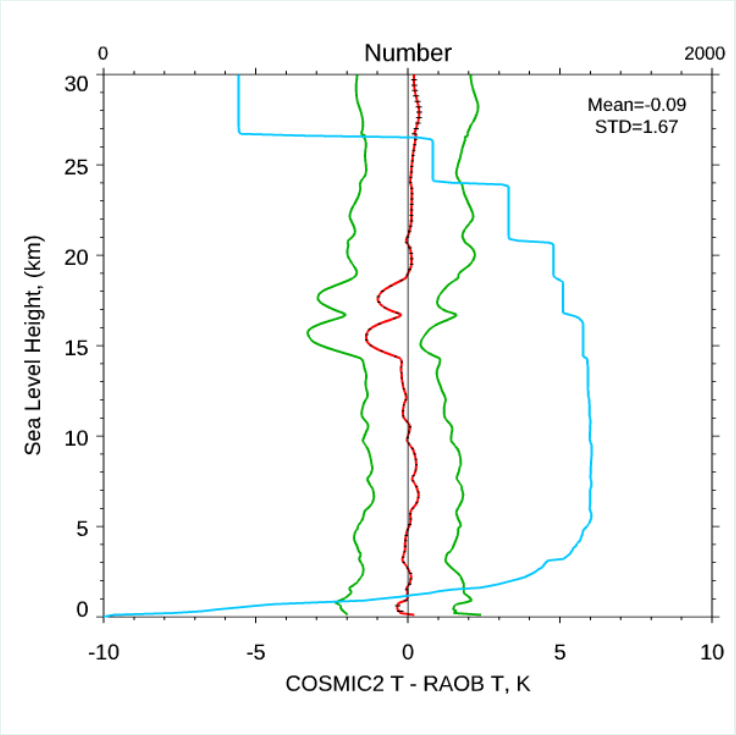
RAOB distribution in Jan 2020



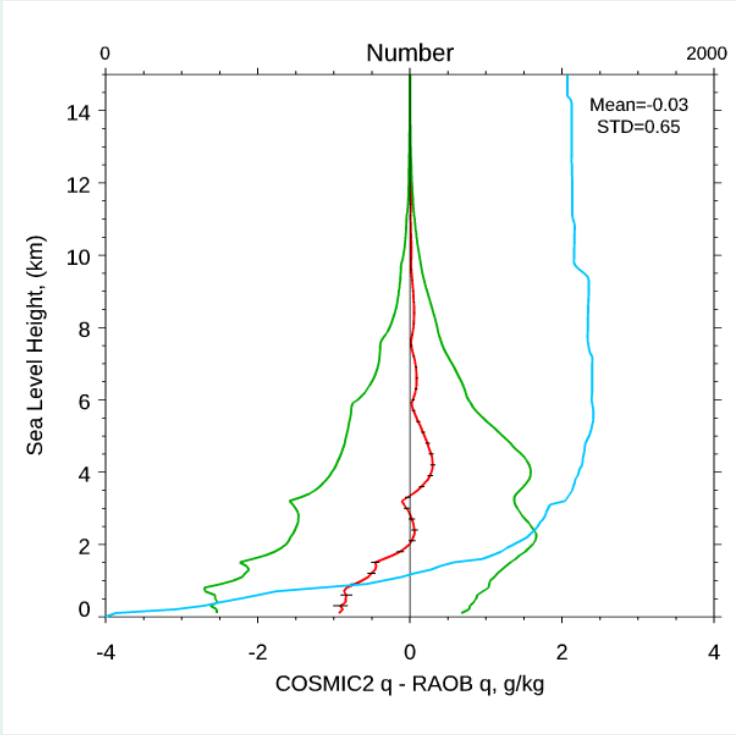


NOAA ICVS for RO: RAOB comparison

Temperature differences

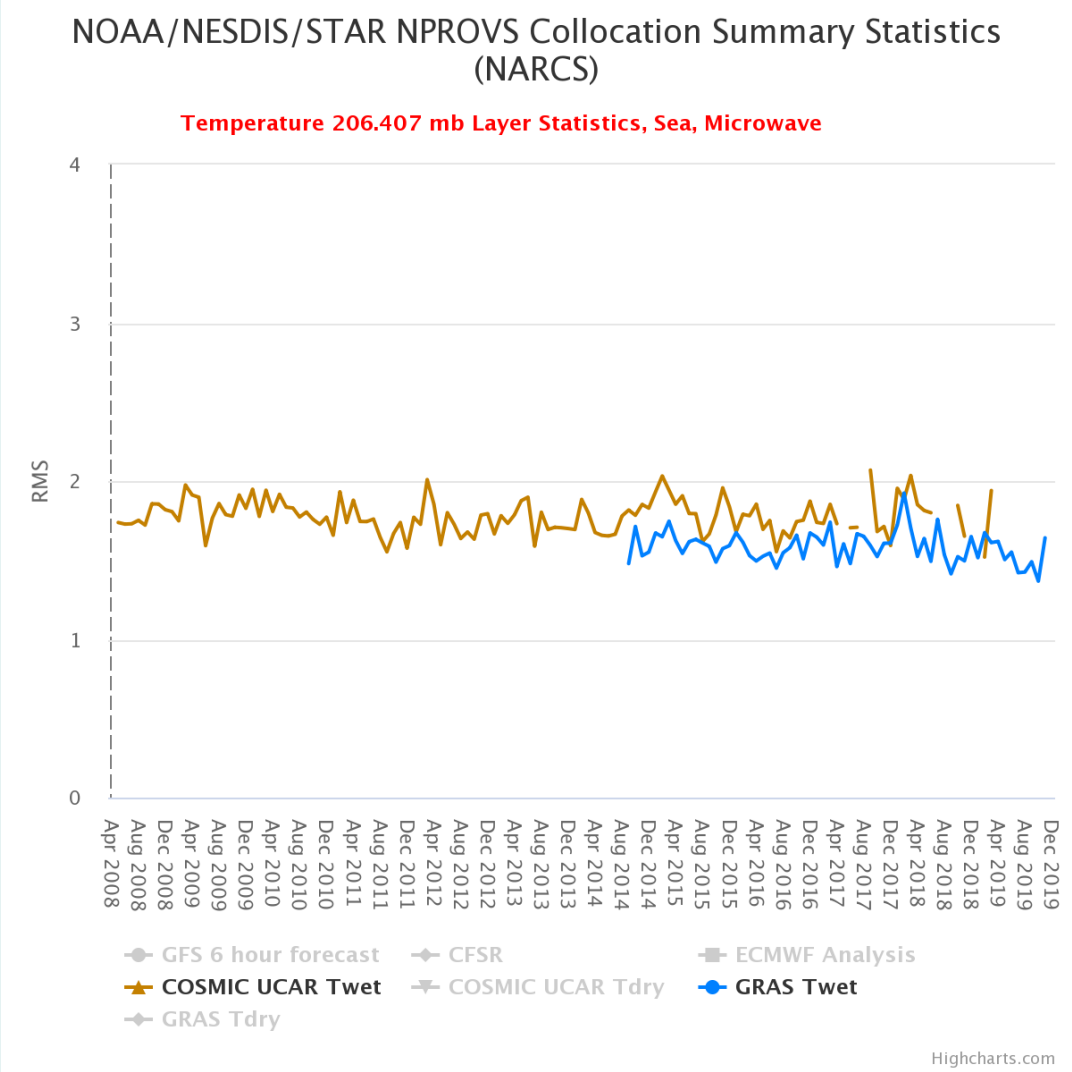


Specific Humidity differences

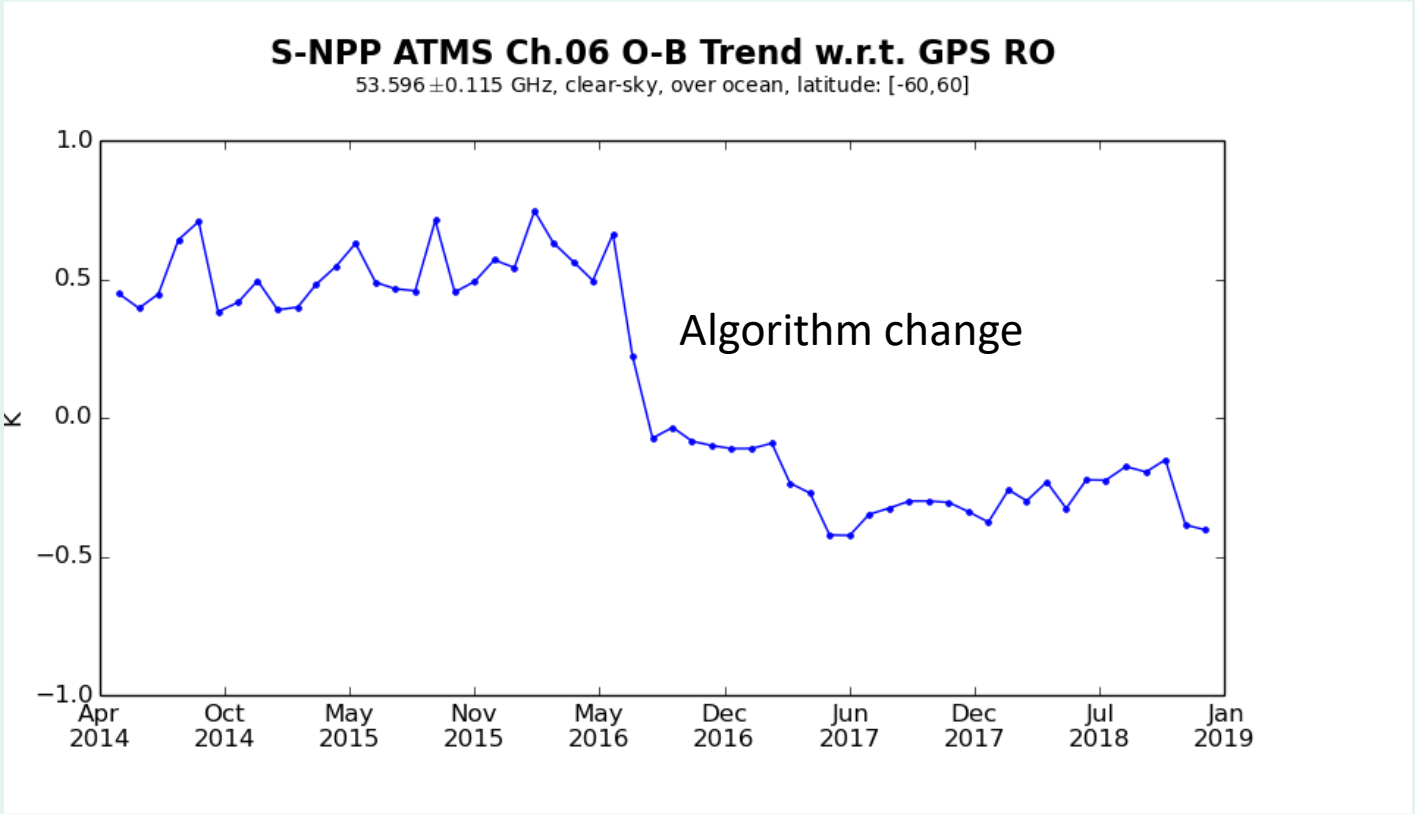


UCAR COSMIC2 vs. Vaisala RS41

NOAA ICVS for RO: RAOB comparison



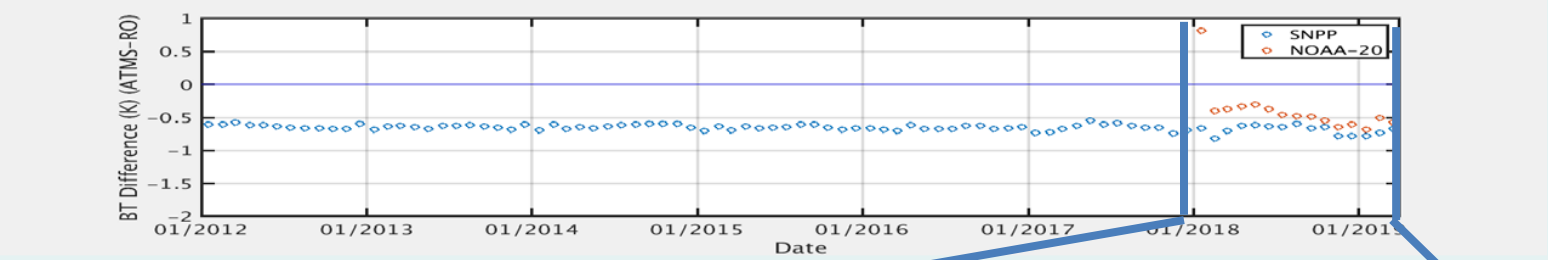
NOAA ICVS for RO: MW comparison against RO

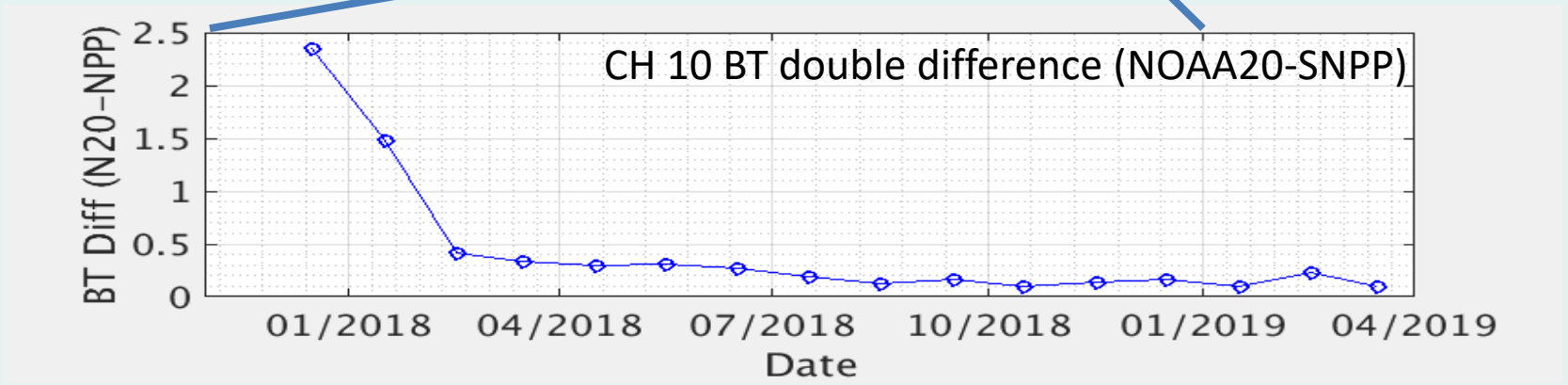


Bias between ATMS and RO are routinely monitored; anomalies are investigated

NOAA ICVS for RO: MW comparison using RO for double difference

SNPP/NOAA-20 ATMS CH10 BT bias relative to RO simulated





- NOAA-20/ATMS early orbit bias due to calibration issues
- Use RO-CRTM for double differencing to study biases between ATMS on SNPP and NOAA-20

Summary

- NOAA STAR has developed a comprehensive integrated cal/val system (ICVS) to ensure the data quality of all NOAA satellite measurements, including Radio Occultation, for which COSMIC2 will play an important role in many areas.
- This web-based system supports instrument performance monitoring, inter-comparisons with other independent measurements, and data assimilation in collaboration with data users.
- Radio occultation is becoming increasingly important for numerical weather prediction, which requires similar level of support as for microwave and infrared sounding instruments.
- The next step is to develop low level processing capabilities & incorporate it in ICVS (Level 0/RDR->Level 1/SDR->Level 2/EDR) to support full chain processing validation.
- We are committed to support ICVS for our community users and partners. Ongoing development and improvements are based on user's needs and feedback

Acknowledgements

- Thanks to the COSMIC2 team for the hard work, including NSPO, UCAR, NOAA/NESDIS/OPPA, NOAA/NESDIS/STAR, JCSDA, USAF, and others
- Thanks to EUMETSAT, ROM SAF for collaboration and technical assistance
- Special thanks to Rich Ullman of NOAA/NESDIS/OPPA for initiating the COSMIC2 cal/val project at STAR