RADIO OCCULTATION DATA PROCESSING AT UCAR'S CDAAC

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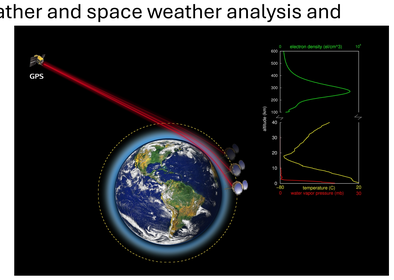
(1) Introduction

The COSMIC Data Analysis and Archive Center (CDAAC) is an end-to-end processing and analysis system for ground- and space-based Global Navigation Satellite System (GNSS) measurement data focusing on radio occultation (RO) applications. We process data and publish products from a variety of space missions in near-real-time (NRT), post-processing, and reprocessing modes. Near real-time products are delivered to operational centers for assimilation into weather and space weather analysis and prediction systems.

We present some of CDAAC team's operational activities including NRT monitoring and evaluation of data quantity, quality for neutral atmosphere and space weather products as well as product delivery statistics to operational centers and the public research community.

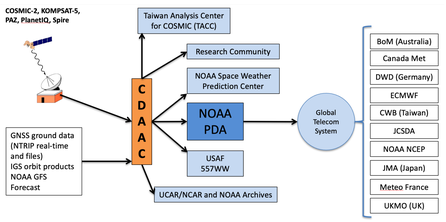


Highlights:

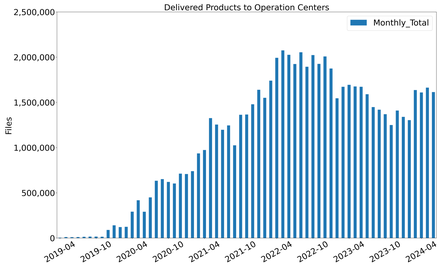
- GPS, Galileo, GLONASS and BeiDou RO processing for neutral atm and ionosphere
- Low latency processing
- Federal Information Security Management Act (FISMA) IT security
- Consistent processing of a large number of missions

(2) Near Real-Time Operations

- The COSMIC Data Analysis and Archive Center (CDAAC) processes radio occultation (RO) data from several missions such FORMOSAT-7/COSMIC-2 (C2), Paz, Kompsat-5, Spire and PlanetIQ in near real-time
- Our NRT Data Processing Center uses both Mesa Lab as well as the NCAR-Wyoming Supercomputing Center to provide redundant, geographically separate processing centers In order to meet the 99.7% uptime requirement
- In addition to data processing, the team also oversees data management systems, downlink scheduling, telemetry data transfer, payload commanding as well as daily processing and data ingest monitoring
- Collaboration between Security, System Administration, and Software DevOps to consistently maintain FISMA compliance and Authorization to Operate (ATO) since 2018
- The derived data products are forwarded in near real time to NOAA PDA, USAF 557WW, NOAA SWPC, as well as globally via GTS
- Currently delivering ~8K neutral atm. and ~12K total electron content products daily in near real-time



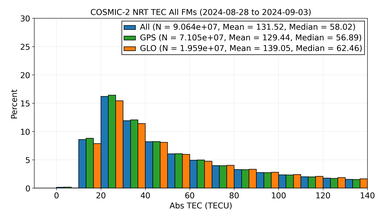
CDAAC processing flowchart



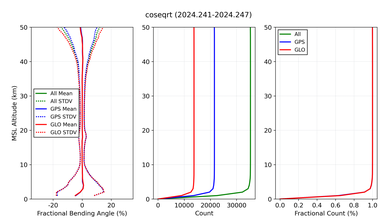
Products delivered to operation centers in NRT

(3) COSMIC-2

- US/Taiwan partnership (NOAA, USSF, NASA, NSF, TASA)
- Launched June 25, 2019
- 6 satellites, orbit inclination 24 deg, altitude ~520 km
- 10 downlink stations, 3 with uplink capability
- Up to ~6000 occultations per day
- Under 30 min (median) product latency
- Payloads: GNSS JPL/BRE TriG receiver, ion velocity meter, tri band RF beacon
- Products:
  - GPS, GLONASS and soon Galileo
  - Total electron content (TEC) occultation data from s/c altitude to 90 km altitude
  - Scintillation: Record high rate phase and amplitude data for entire occultation when onboard S4 measurement exceeds a specified threshold
  - UCAR and BC developed advanced methods to geo-locate iono irregularity regions causing scintillation



Absolute total electron content



BA statistics by GNSS

(4) Commercial RO Missions

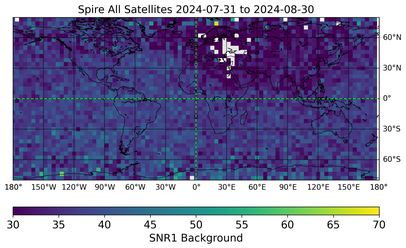
NOAA Commercial Data Program - Radio Occultation Data Buy -2 (RODB-2)

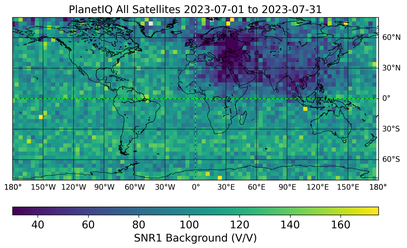
Spire

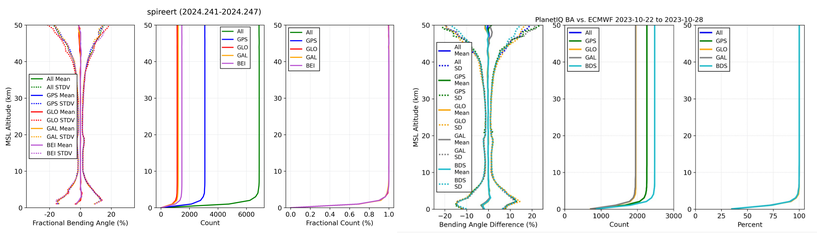
- ~25 3U satellites participating
- 1 upward looking POD antenna and 1-2 limb pointing radio occultation antennas
- POD+RO antennas used for ionosphere profiling

PlanetIQ

- 1-2 6U satellites participating
- 2 upward looking POD antennas and 2 limb pointing radio occultation antennas
- POD antennas used for ionosphere profiling



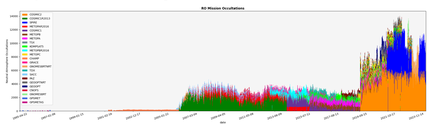




- BeiDou GNSS has been added for both PlanetIQ and Spire
- BeiDou has lowest BA st. dev. above ~45 km for PlanetIQ

(5) Missions of Opportunity

- The COSMIC Program integrates data available from other mission to increase the number of RO soundings available to the research and operations communities
- The PAZ and Kompsat-5 missions are included in our NRT processing
- Active missions are post-processed with latencies of about 6 weeks on a continuing basis
- We also periodically reprocess the existing RO data using consistent models and processing software
- All together, we have above 77 million neutral atmospheric and ionospheric products freely available to our users

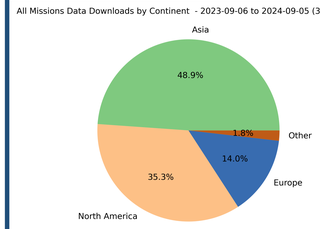


All RO missions processed at CDAAC since 1995 to present day
Image credit: Mike Perrotta

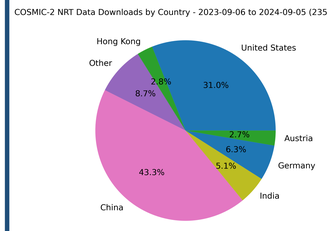
Mission	Total NA	Total EDP	Total TEC
CHAMP	468029	306318	1045940
CNOFS	62027	0	0
COSMIC1	7080247	4708330	7088915
COSMIC2	9320861	6423296	14573890
GEOOPT	289328	28695	495127
GPSMET	4863	0	0
GPSMETAS	4577	0	0
GRACE	457069	211096	1338668
KOMPSAT5	1009384	0	0
METOPA	3071940	0	1818796
METOPB	2149316	0	1410661
METOPC	687449	0	530098
PAZ	370829	0	0
PLANETIQ	405799	179020	678255
SACC	351580	0	13481
SPIRE	3889848	0	3547767
TDX	408586	0	661212
TSX	1043642	0	1614806
Total	**31075374**	**11856755**	**34817616**

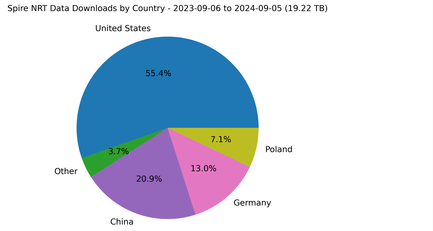
Total atmospheric, ionosphere and total electron content counts as of 2024-09-05

(6) Data Publishing



- Products are made freely available to the research community on our data portal website: **https://data.cosmic.ucar.edu/**
- We are currently making available ~15 RO missions in near real-time and/or post-processing modes providing neutral atmosphere and ionosphere products
- Commercial RO data is also made available in NRT via Unidata's Internet Data Distribution





https://data.cosmic.ucar.edu/ data download statistics

(7) Summary

- Operational processing, delivery, and monitoring of neutral atmospheric and space weather products
- Scintillation geolocation
- GPS/GLONASS/Galileo and BeiDou GNSS and RO processing
- Missions and product set growing
- Products made freely available to the research community

Acknowledgements: