Preliminary Assessment of the Airborne GNSS Radio Occultation Sounding Capability from Airbus Commercial Aircrafts

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NIGHT CREW LABS

Expansion of GNSS RO

- More GNSS Transmitters

US Russia European-Union China Japan

- More Satellite Receivers (RO Missions)
  - COSMIC-2A (~5000 daily)
  - COSMIC-1/ GRAS-A/B (~3000-4000 daily)
  - GNOS (FengYun-3C), ROSA etc.
  - GPS/Met, GRACE,CHAMP,SAC-C,TerraSAR-X, etc.

Expansion of GNSS RO

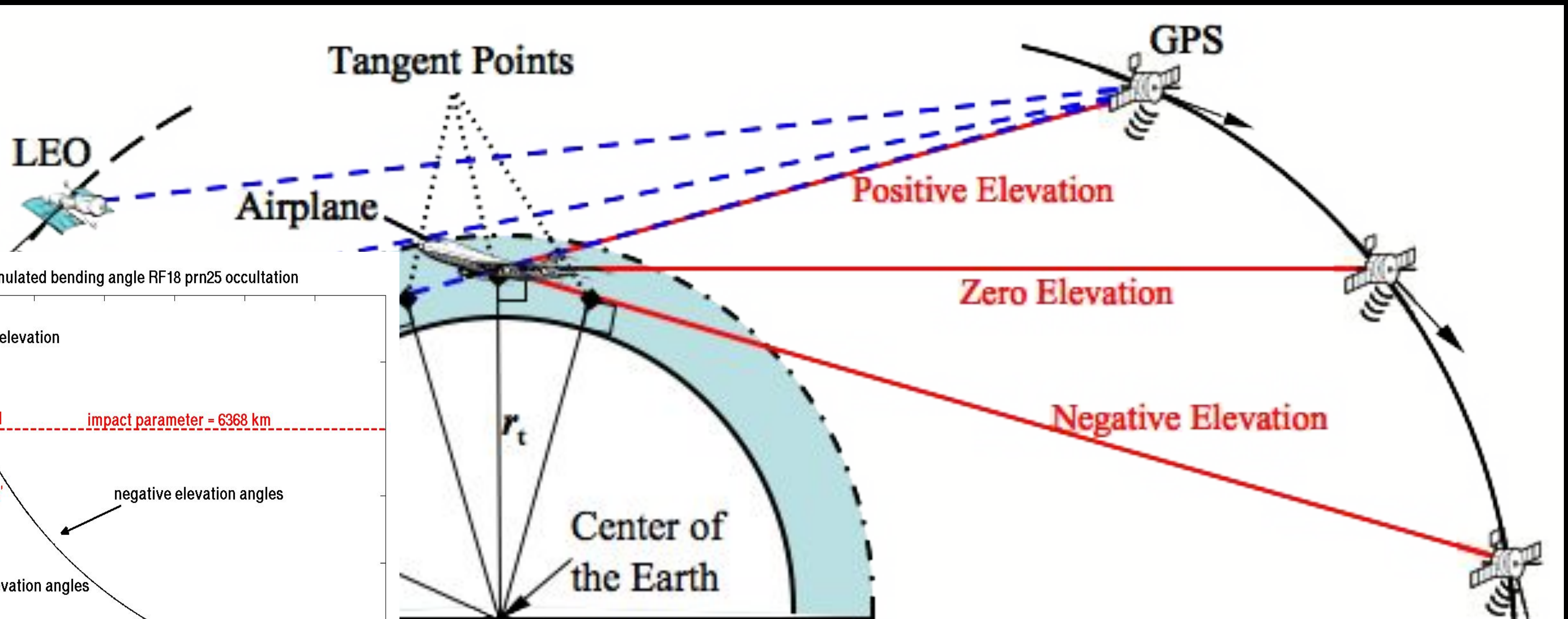
- More RO Receivers (cont'd)
  - Commercial RO Satellites (NOAA-contract)
    - Spire / GeoOptics / Planet-iQ

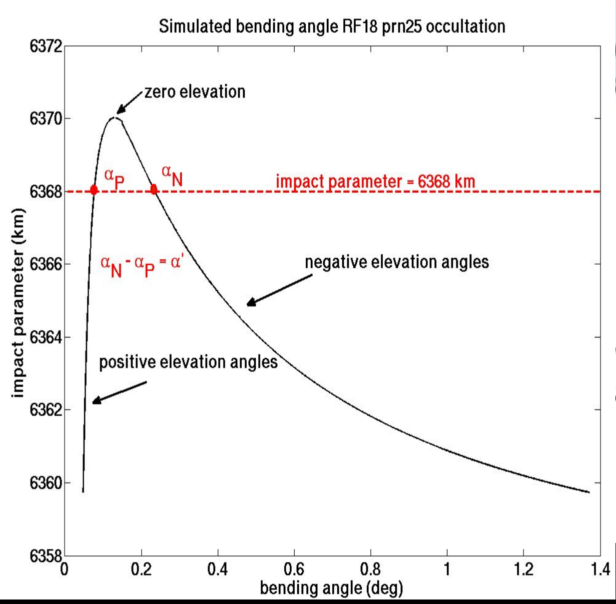
Limited regional sampling: ~ 3000 per day (COSMIC)
1 daily profile every 400 km x 400 km grid

A single RO satellite – 250/500 soundings
Not the most cost-efficient way to increase targeting soundings

  - Mountain-top
  - Airborne Platform
    - Aircraft based (Haase et al. 10:30AM, Apr. 8, Oral)
    - Balloon based (Chan et al., 11:05AM, Apr. 9, Poster)

Airborne GPS Radio Occultation

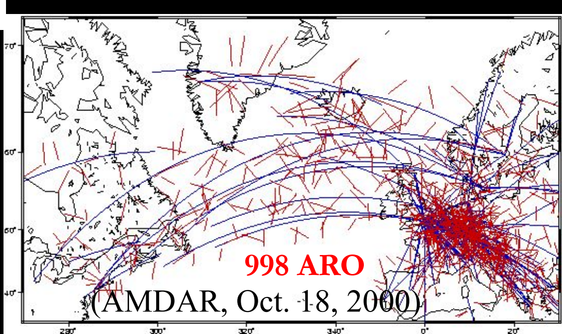




$$\alpha'(a) = \alpha_N(a) - \alpha_P(a) = -2a \cdot \int_{r_t}^{r_R} \frac{1}{n}\frac{\mathrm{d}n}{\mathrm{d}r}\frac{\mathrm{d}r}{\sqrt{(nr)^2 - a^2}}$$

$$n(a) = n_R \exp\left[\frac{1}{\pi}\int_{x=a}^{n_R r_R} \frac{\alpha'(x)\mathrm{d}x}{\sqrt{x^2 - a^2}}\right]$$

Healy et al., 2002



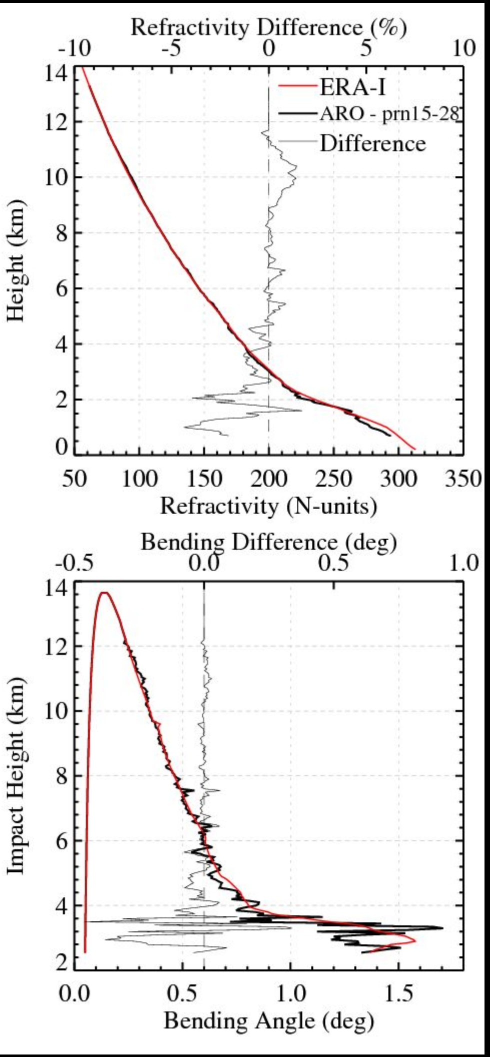
- Provide dense RO sounding over targeted region
- Higher SNR as receiver is inside the atmosphere

Airborne RO from a Single Zenith Antenna

- Purdue GISMOS led by Drs. Jennifer Haase and Jim Garrison

- The surprisingly good quality of recordings from a very simple antenna on top of an aircraft increases the feasibility of developing an operational tropospheric sounding system.

- Zenith/top antenna: occultations can be tracked without losing lock during aircraft turns and consistently tracked as low as 4 - 6 km or even lower.



Xie et al., AMT 2018

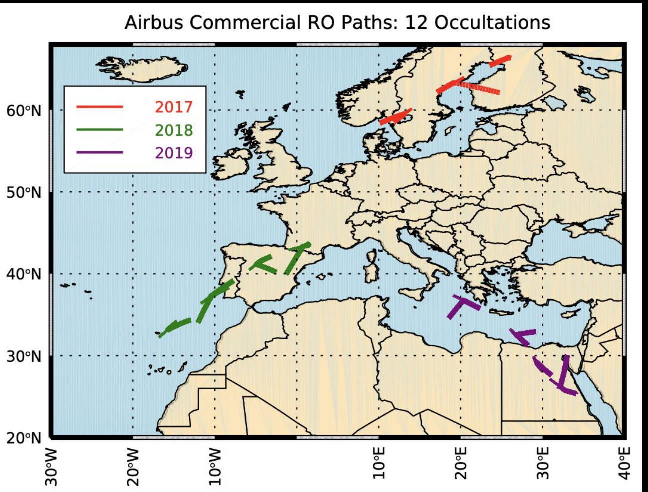
Airbus Commercial Aircraft

Explore the feasibility of using the operational GNSS zenith antenna & receiver system onboard commercial aircraft to provide a large number of airborne radio occultation soundings for direct assimilation in numerical weather prediction models

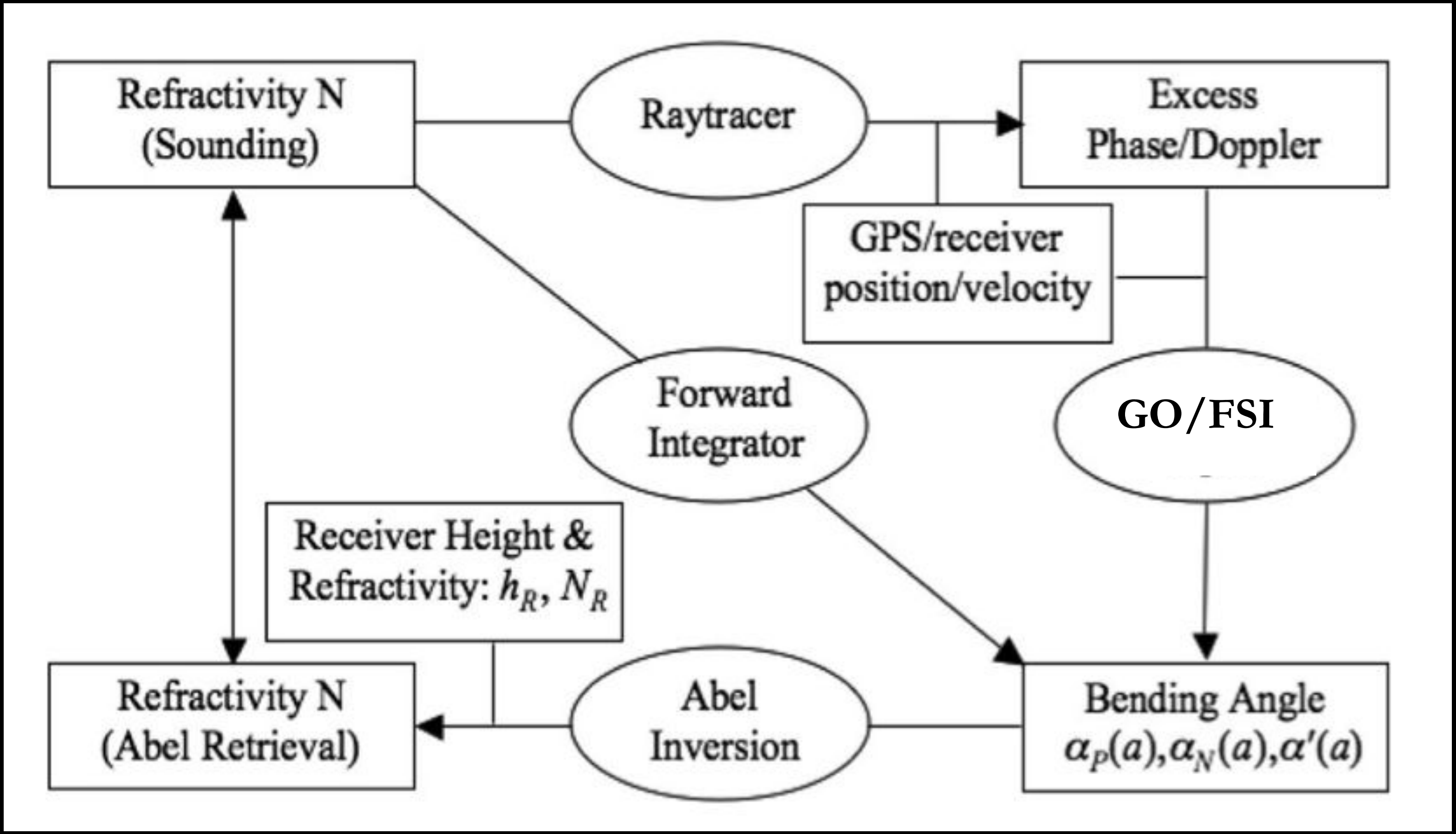
Airbus RO Data

A/C	MSN	FTI GNSS Antenna
A320	6101	Trimble AV37
A321	6673	AeroAntenna AT2775-80
A330	1795	AeroAntenna AT2775-80
A330	1813	AeroAntenna AT2775-80

- Airbus GNSS antenna & receiver
  - Dual frequency GPS L1 & L2 tracking
  - Capable of GLONASS tracking but not activated
- Low elevation GNSS recording
  - 12-DEC-2019 dataset - no ROs could be attained
  - 25-MAR-2019 dataset had very poor low-elevation GPS data, no data below 0 deg elevation was attained.
  - 22-FEB-2019 dataset (flight B) contained 20 potential ROs, 4 were analyzed for further study. The remaining did not achieve negative elevation angles or collect > 20 m excess phase.
  - 06-FEB-2017 dataset (flight C) contained 11 potential ROs, 3 were analyzed for further study. The remaining did not achieve negative elevation angles or collect > 20 m excess phase.
- Airbus GNSS Data Sets (~25 hours)
  - Airbus_Dataset1 - 10hr - A330
  - Airbus_Dataset2 - 4hr - A320
  - Airbus_Dataset2 - 5hr - A330
  - Airbus_Dataset2 - 2hr - A321
  - Airbus_Dataset2 - 4hr - A330

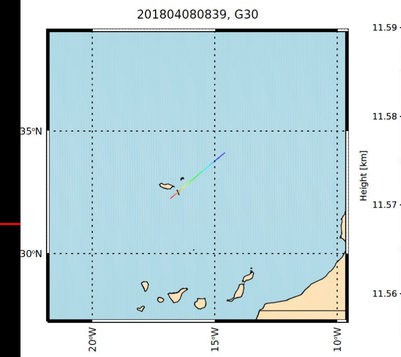


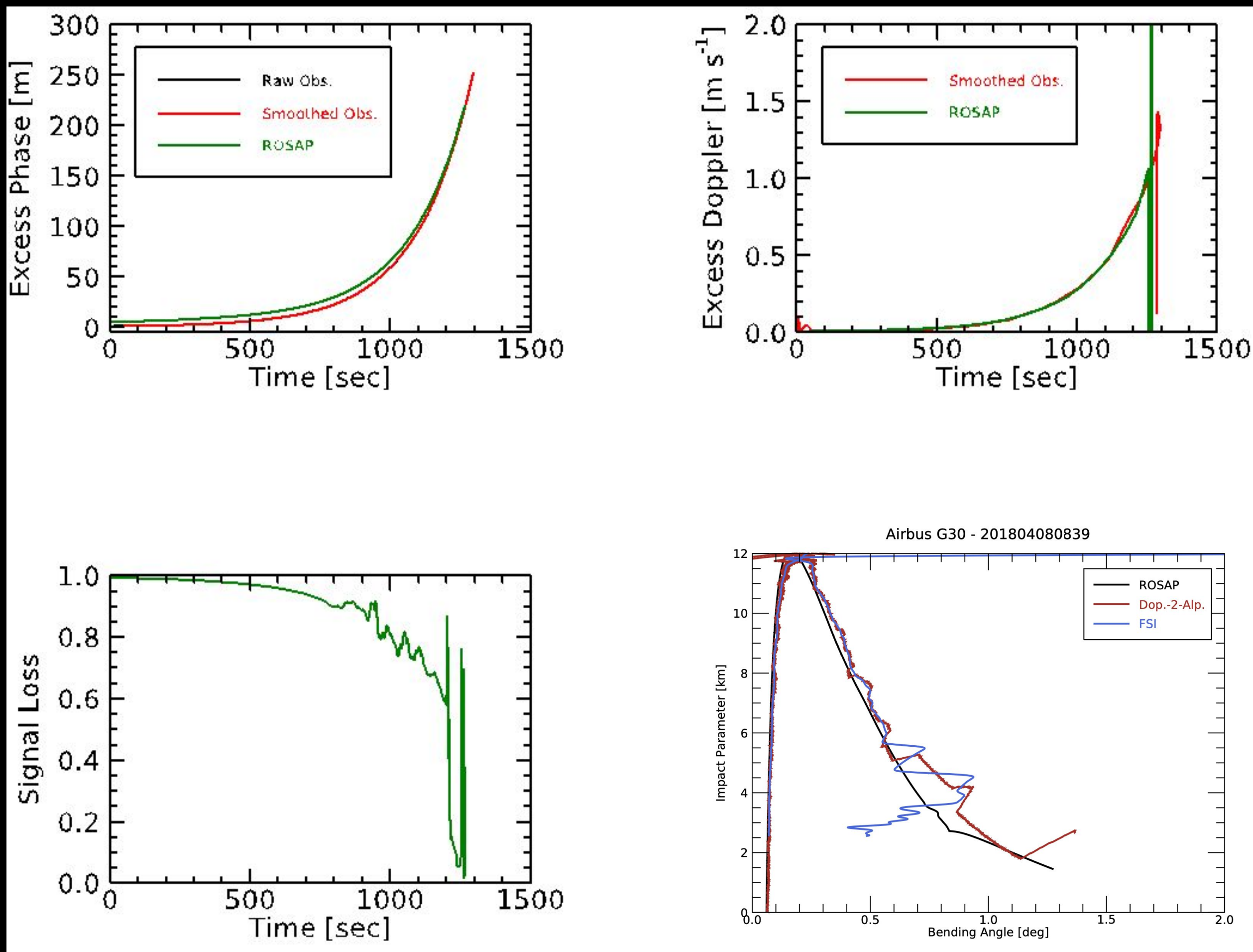
An End-to-end Simulation System



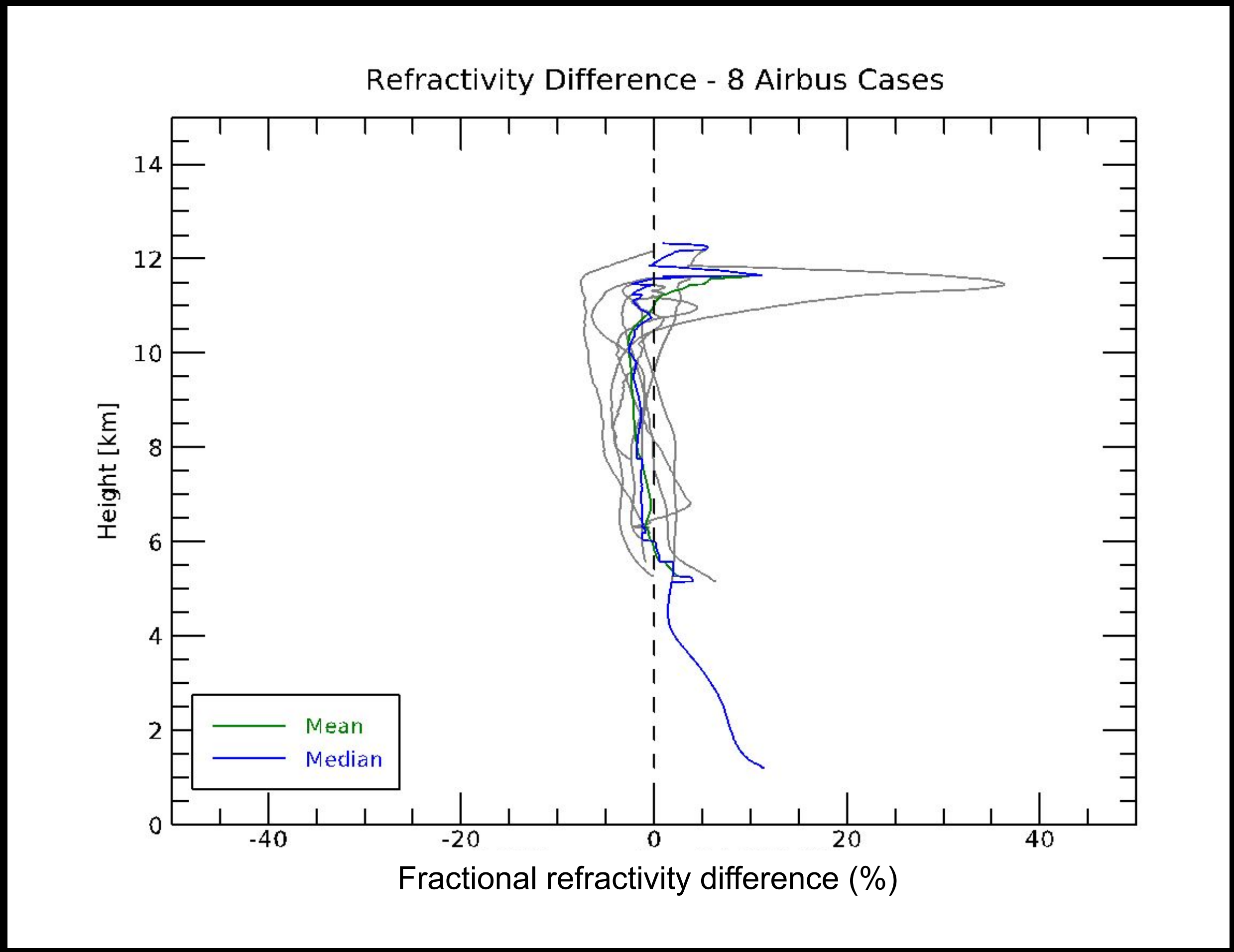
Airbus Case Study

(G30 – 201804080839)





Airbus Refractivity Retrieval vs ERA5



Airbus Refractivity Retrieval Difference from Collocated ERA-5 Profile

Conclusions & Future Remarks

- GNSS Radio Occultation (RO) soundings have significantly increased but still lack of targeting dense sounding capability. The Airborne RO from commercial aircraft fleets could fill the gap.
- For the first time the ARO bending angle and refractivity profiles were successfully retrieved from the conventional GNSS RO recording of the Airbus commercial aircrafts.
- The Airbus RO soundings offer relatively high quality of refractivity retrieval within ~2% between ~5 and 10 km. Only a handful soundings reach down to the surface. But most soundings do not penetrate below 4 km and require further investigation.
- The large body of Airbus aircraft could be beneficial for the relatively good quality RO measurements.
- Further study of ARO sounding collected from more commercial flights as well as from the high-altitude balloon are in progress.

Conclusions & Future Remarks

- The relatively limited low elevation occulting GNSS satellite tracking need to be further studied. A potential upgrade of the recording system setting could be proposed to improve lower troposphere sensing.
- A tool to quickly identify or predict the valid GNSS ARO measurements (e.g., close to zero elevation and negative elevation recording) is needed to facilitate ARO processing.
- The ARO from commercial aircraft could be integrated into the AMDAR (Aircraft Meteorological Data Relay) system, contributing aircraft-based observations to World Weather Watch Programme.
- Such commercial aircraft RO data could be assimilated into the global weather prediction model similar to the spaceborne RO soundings and help improve the global weather forecasting.

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