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National Oceanic and Atmospheric Administration
NATIONAL ENVIRONMENTAL SATELLITE, DATA, AND INFORMATION SERVICE
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SUBJECT: Assessment of Solution-Agnostic Observational Needs for Global Navigation Satellite System-Radio Occultation (GNSS-RO) Data

1. Scope:

This memo provides background information and recommendations and guidance for solution-agnostic observational needs for Global Navigation Satellite System-Radio Occultation (GNSS-RO or, simply, RO) data. These needs are assessed for scientific applications in weather, climate, and space weather areas. RO profiles are among the most impactful observations in numerical weather prediction (NWP) and other science applications. Data sources include, but are not limited to, government, commercial, and partner sources.

2. Background:

RO is one of the most impactful observations for NWP and science. RO profiles contribute to weather, climate, and space weather observations. Observations are accurate and precise and can be assimilated into NWP models without bias correction. RO provides high vertical resolution (200-300 m) observations in all weather (clear and cloudy) and there are no emissivity issues over land or sea. Studies have shown that the impact to NWP increases steadily to at least 125,000 RO profiles per day.

Currently, RO profiles are available through Government data sources and through commercial data buys. RO data has been operationally assimilated into NWP models since 2021. Users of RO commercial data include the US Government, international partners, and researchers who received delayed data access. Commercial data purchases include specific data sharing policies, which are not only relevant to RO, but also to the commercial development of microwave sounders, scatterometers, long-range balloons,

radar precipitation measurements, and more. Having free and open sharing of commercial data in real time without restrictions is a major benefit to scientific users in all countries.

3. Facts and Findings:

a. Facts

- (1) The current NOAA requirement for collection of RO data is a minimum of 8000 occultations per day distributed globally located between 45°N and 45°S.
- (2) RO missions provide data for ionosphere, lower mesosphere, stratosphere, and troposphere, so there are no special satellites needed to get information on the different layers of the atmosphere.
- (3) The current data purchases for RO profiles are used for deriving neutral atmospheric and ionospheric products. There has been increasing data volume and expanded data sharing with each delivery order.
- (4) The WMO International Radio Occultation Working Group (IROWG) recommended at least 20,000 RO profiles per day. Studies show that NWP would continue to gain benefits when there are at least 128,000 profiles per day (Harnisch, et al. 2013). The most rapid increase of impact of observation is in the first 30,000 profiles, which suggests that this may be close to the highest cost/benefit value.

b. Findings

- (1) A US Government source of 10,000 profiles per day, that are shared without restriction, would provide a level of quality from known, stable instruments, which is important for climate and numerical weather prediction (NWP) applications.
- (2) GNSS-RO data can be used for an independent calibration of infrared and microwave sounding data.
- (3) GNSS-RO data does not provide information on every space weather variable, but it does provide valuable information on space weather geophysical parameters, including total electron content, scintillation indices, and electron density profiles.
- (4) If data sharing is restricted to only NOAA or only the US Government, then other countries and organizations may not share their data with NOAA, diminishing the maximum NWP benefit of RO profiles from various sources.

4. Recommendation:

The SAT recommends that NOAA should follow the recommendations of the IROWG:

- a. Collect at least 20,000 globally distributed occultations per day. These will provide a good sampling of diurnal cycle, which is important for NWP, climate, space weather,
- b. Any commercial data should be purchased with an unrestricted license, so the data are freely available to all,

- c. Ensure that all information is included to allow for NWP centers to process raw level 0 data (phase, amplitude, orbit data, including metadata and associated documentation) to climate products.
- d. NOAA should ensure long-term archiving of RO data,
- e. Provide a source of US government RO data that includes a long-term commitment to continue providing such data.
- f. Ensure continuity and long-term availability of climate-quality RO measurements, with global coverage, over all local times.
- g. Collect, as a minimum, the following space weather data:
 - (1) TEC (total electron content in electrons/m²)
 - (2) Data for the calculation of the S4 amplitude scintillation index
 - (3) Data for the calculation of the Sigma-phi phase scintillation index
 - (4) Electron number density profiles 100-600 km
- h. Participate in the RO Modeling Experiment (ROMEX) by:
 - (1) Providing as much data as possible to the research team
 - (2) Provide assistance to the study for processing the RO data and carrying out the modeling experiments

5. References

Harnisch, F., S. Healy, P. Bauer, and S. English, 2013: Scaling of GNSS radio occultation impact with observation number using an ensemble of data assimilations. *Mon. Wea. Rev.*, 141, 4395– 4413. DOI: <https://doi.org/10.1175/MWR-D-13-00098.1>

Important note: This memo was developed based on the deliberations and discussions among the core-SAT, which consist of federal employees only. These recommendations were made following extensive scientific fact-finding, review of the scientific literature, and SAT discussions with scientific experts and others knowledgeable in the field.