A Model Study on Data distribution Characteristics of the GPS Radio Occultation Measurements

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Conventional satellite remote-sensing obtains data along the orbit. But, data location (tangent point) of GPS RO depends on the relative positions between the GPS and LEO satellites.

We study characteristics of GPS RO data distribution with a numerical model assuming realistic orbits for GPS and LEO satellites.
GPS RO Data Density /\((100 \text{ km})^2\) for Different Inclination Angle(\(\theta\))

- \(\theta = 0^\circ\)
- \(\theta = 20^\circ\)
- \(\theta = 60^\circ\)
- \(\theta = 80^\circ\)
- \(\theta = 40^\circ\)

Orbit altitude=700 km

6 LEO at \(\theta = 72^\circ\) and 5 LEO at \(\theta = 27^\circ\)
Inter Tropical Convergence Zone (ITCZ) centered at about 10° in N.H. and S.H.

Satellite image (MTSAT-1R) 00UTC on 31 December 2011
GPS RO Data Distribution with LEO Satellite on an Equatorial Orbit

**Orbit at 700 km**

**Orbit at 200 km**

SLATS: Super Low Altitude Test Satellite
- ion engine
- about 300 kg
- orbit altitude = 180-250 km
We assume two LEO satellites on the same equatorial orbit at 700 km altitude, but time delay of 5 minutes.

GPS RO events with two LEO occur nearly simultaneously with horizontal distance of 1-300 km.

About 90 minutes later, the same LEO satellites return to the same longitude region.

Development of meteorological disturbances in the tropics can be monitored every about 90 min.
Localized GPS RO Data Distribution

**QZSS (TX) vs 6 LEO (RX):**
- Quasi-Zenith Stationary Satellite (Michibiki by JAXA)
- LEO orbit
  - altitude=700km
  - Inclination=30°
- No. Data = 162/day

**GPS (TX) vs 6 Geostationary Satellites (RX):**
- GPS RO Receivers on board Six Geostationary Satellites at the longitude of 200°, 206.5°, 213°, 219.5°, 226° and 232.5°E
- No. Data = 312/day (48 around Japan)
We conducted an airplane GPS RO experiment in 2004.
From airplane GSP RO experiments, we successfully retrieved a refractivity profile at 1-6 km altitude using Abel inversion of partial bending angle. The retrieved N profile shows reasonable agreement with nearby radiosonde observations.
Validation of N at low altitude

Using Meso-Scale Model of MRI/JMA, the effect of horizontal inhomogeneity on the ray path near TP is investigated.
Distribution of GPS RO data by using GPS receivers equipped on commercial airplanes.

- Number of daily flights: 210 by JAL
- Airports: 9 major AP
  - Chitose, Sendai, Narita (Tokyo), Chubu, Itami (Osaka), Kansai (Osak), Fukuoka, Kagoshima, Naha
- Number of GPS RO data points: 1,114
  - (5/100x100km²)
- Using all available flights the total data number increases by about 5 times.
Figure 5.10: Data distribution of the airborne GPS RO measurements between Jakarta and Surabaya in Indonesia. Black lines are the flight paths. Red lines represent the tangent points between an altitude of 1 km and 9 km.
Effects of FOV of RO antenna pattern

Although GPS RO events were expected to occur by considering the relative satellite orbits, they were outside of FOV of the RO antenna. Data loss appears mostly at low latitudes.

Rejection through the data quality check

Failure to retrieve atmospheric profiles occurs more frequently in the Eastern Asia; ASEAN, China, Taiwan, southern Japan.
Error rate in the retrieval procedure

Jun-Jul-Aug (Summer in N.H.)

Atmospheric profiles were not obtained due to weak SNR of L2 below about 20 km.

Dec-Jan-Feb (Summer in S.H.)

Black line; Geomagnetic Latitude
Number of GPS RO data from January to June 2008 in a longitude-latitude cell of $10^\circ \times 10^\circ$

Number of sporadic E events

Occurrence rate of sporadic E events
Error rate in the retrieval procedure

Jun-Jul-Aug (Summer in N.H.)

![Map of occurrence rate of sporadic E from January to June 2008]

The data loss generally distributes following the geomagnetic latitudes, which is generally similar to the sporadic E distribution.

Effects of ionospheric disturbances seem to be the main reason for GSP RO data loss in East Asia.

Dec-Jan-Feb (Summer in S.H.)

![Map of occurrence rate of sporadic E from January to June 2008]
SUMMARY
✓ Data location of GPS RO measurements (tangent point) is determined by the relative positions between the GPS and LEO satellites.
✓ We investigate characteristics of GPS RO data distribution with a numerical model assuming realistic orbits for both GPS and LEO satellites.
✓ A circular orbit at high inclination angle provides a global coverage, but the data rate is small at low latitudes.
✓ A combination of LEO satellites at low and high inclination angles can realize a uniform data distribution along latitude.
✓ Localized GPS RO data distribution in a particular region can be achieved with geostationary, quasi-zenith and equatorial orbits.
✓ We also investigated data distribution for an airborne GPS RO, which can produce a large number of data in a particular area.
✓ We studied statistics of the data deficit after quality test included in the data processing system for the COSMIC data.
✓ The effects of the ionosphere irregularities (sporadic E) appear more dominantly around East Asia.