Atmospheric Profiles from KOMPSAT-5 Radio Occultation : A Simulation Study

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Abstract

KOMPSAT (KOrea Multi-Purpose SATellite)-5 for the earth observation and scientific research is scheduled to launch in 2009. The second payload, AOPOD (Atmosphere Occultation and Precision Orbit Determination) system, consists of a space-borne dual frequency GPS receiver and a laser retro reflector. GPS radio occultations from AOPOD system can be used to generate profiles of refractivity, temperature, pressure and water vapor in the neutral atmosphere with a high vertical resolution. Also the radio occultation in the ionosphere provides an inexpensive tool of vertical electron density profile. Currently, many LEO missions with GPS radio occultation receivers are on orbit and more GPS occultation missions are planed to launch in the near future. In this paper, we simulated radio occultation measurements from KOMPSAT-5 and retrieved atmospheric profiles using the simulated data.

Keywords: KOMPSAT- 5, GPS receiver, GPS radio occultation, atmospheric profiles

1. Introduction

KOMPSAT (Korea Multi-Purpose SATellite)-5 for the Earth observation and scientific research is scheduled to launch in 2009. The secondary payload, AOPOD (Atmosphere Occultation and Precision Orbit Determination) system, consists of space-borne dual frequency GPS receiver and LRR (Laser Retro Reflector). The main missions of AOPOD system are providing POD(Precision Orbit Determination) data and GPS radio occultation measurements.

Radio occultation research started by the probe of planetary atmosphere in the early 1960s has become a new method to sense the Earth atmosphere by using the GPS system in 1990s. The radio occultation data obtained from GPS signal can be used to generate profiles of refractivity, temperature, pressure and water vapor in the neutral atmosphere and electron density in the ionosphere. Several LEO missions with GPS radio occultation equipment such as GPS/MET, CHAMP and SAC-C, has been in operation successfully and numerous occultation data have been analyzed. Melbourne[1], Kursinski[2], Wickert et al.[3][4] and Hajj et al.[5] derived vertical profiles of atmospheric density, pressure and temperature with high accuracy. Recently, COSMIC (Constellation Observing System for Meteorology Ionosphere and Climate) program exhibits the dense populated observation mesh by using the constellation of six satellites around the globe. This new constellation expands the global coverage, and enhances the accuracy of atmospheric monitoring performance..

In this paper, we retrieve the vertical profile from simulated KOMPSAT-5 GPS radio occultation. EGOPS4 (End-to-End GNSS Occultation Performance Simulator) developed by Univ. of Graz is used to simulate occultation measurements.

2. GPS Radio Occultation

The signal from GPS receiver to LEO(Low Earth orbit) is refracted as passing through the Earth's atmosphere. A schematic description of GPS occultation is given in Figure 1[6].

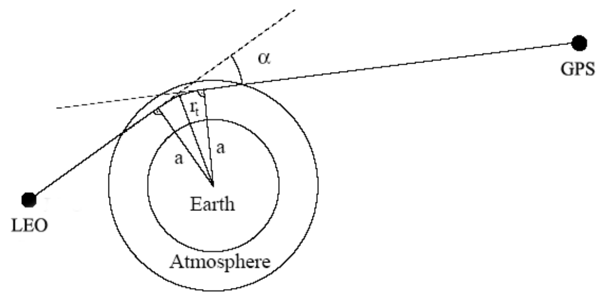

Figure 1. GPS radio occultation geometry

In Figure 1, α is bending angle of refracted signal from GPS. The bending can be transformed to atmospheric refractive index by using Abel transformation. Vertical profiles of atmospheric parameters such as temperature and water vapor can be retrieved from refractive index.

Figure 2 shows the coverage of occultation and conventional radiosondes distribution [7]. The occultation coverage is simulated for one day of COSMIC Mission.. As shown in figure 2, GPS radio occultation provides a well-distributed global coverage of observation, while the conventional radiosonde covers the limited areas.

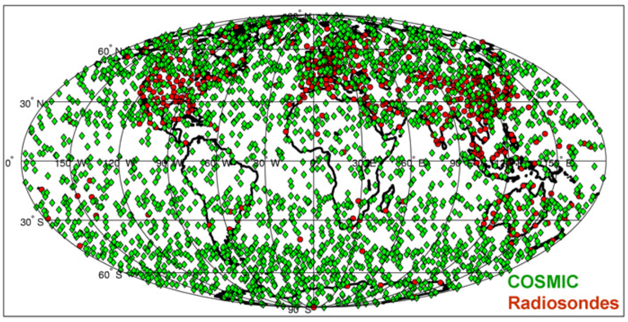

Figure 2. COSMIC occultation & high accuracy radiosondes

Presently COSMIC provides around one thousand neutral atmospheric profiles per day. One of the early atmospheric profile results is shown in Figure 3[7].

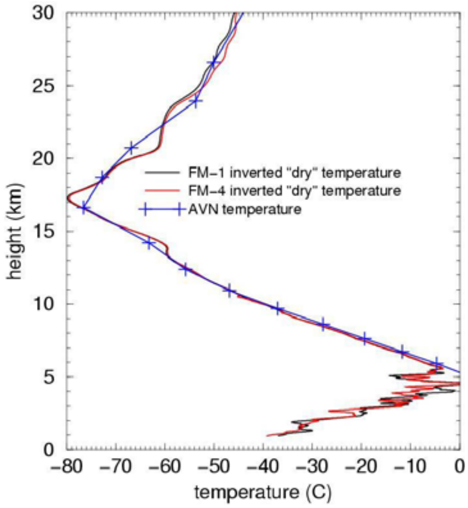

Figure 3. Temperature profile using COSMIC data

3. KOMPSAT-5 GPS Radio Occultation

3.1 AOPOD System

AOPOD System in KOMPSAT-5 consists of a dual frequency GPS receiver, a LRR, GPS tracking antennas, and occultation antennas. For the space-borne dual frequency GPS receiver, Black Jack from NASA/JPL has been used for the most of LEO program such as SAC-C, CHAMP, and GRACE. Figure 4 shows IGOR (Integrated GPS Occultation Receiver) developed by Broad-Reach Engineering (BRE) based on the heritage of JPL's Black Jack. IGOR will be installed in KOMPSAT-5 AOPOD system. Recently, IGOR has been installed on COSMIC satellites and operating successfully on orbit. In Figures 5 and 6, the POD antenna and occultation antenna are shown, respectively. Two pairs of POD and occultation antenna are installed on the KOMPSAT-5 as shown in Figures 7 and 8. Occultation antennas are attached on the panel of velocity and anti-velocity direction in order to acquire more occultation observation.

In AOPOD system, a LRR will be installed for the POD validation of KOMPSAT-5. Many types of LRR have been developed for the various missions. For the KOMPSAT-5, four corner cube type LRR is planed to install. In Figure 9, the LRR developed by GFZ (Geo Forschungs Zentrum) is shown. The LRR in Figure 9 is currently used in CHAMP and GRACE Mission and will be used for KOMPSAT-5 AOPOD system.

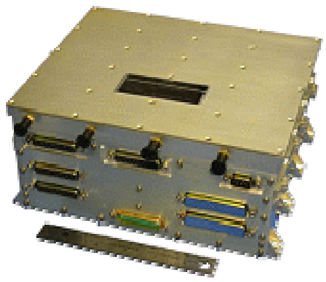
Figure 4. IGOR dual frequency receiver

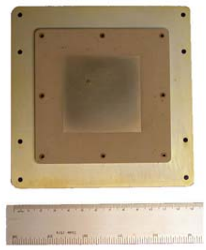
Figure 5. GPS POD antenna patch


Figure 6. Four patch array GPS occultation antenna

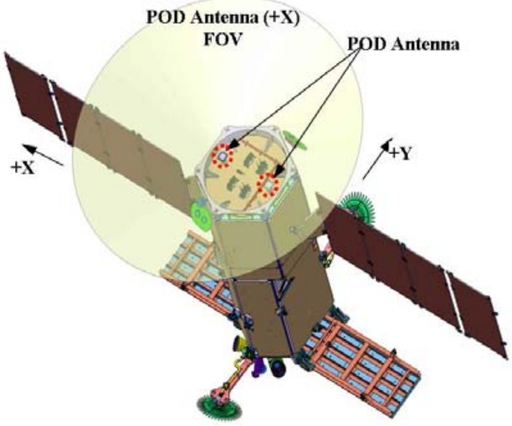

Figure 7. POD antennas on KOMPSAT-5

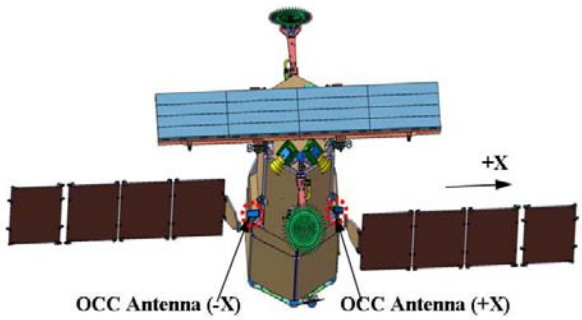

Figure 8. Occultation antennas on KOMPSAT-5

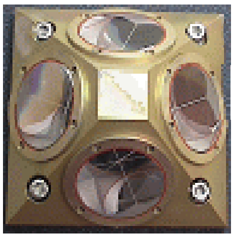
Figure 9. Laser Retro Reflector (LRR)

3.2 Occultation Simulation and Data Processing

Simulated occultation events of KOMPSAT-5 are shown in Figure 10[8]. The orbital element used for the simulation is described in Table 1. For one day period, more than five hundred occultation events are obtained globally.

Table 1. Orbital elements of KOMPSAT-5

Orbital element	Value
Semi-Major Axis (km)	6928.1
Eccentricity	0.001
Inclination (deg)	97.6
R. A of Ascending Node (deg)	339.7
Argument of Perigee (deg)	90.0
Mean Anomaly	270.0

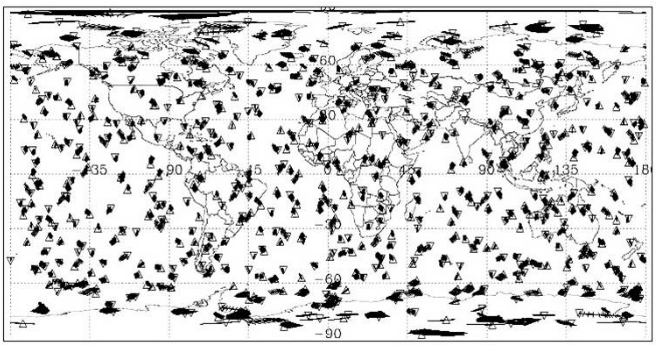
Figure 10. KOMPSAT-5 occultation events

In order to simulate the occultation data from KOMPSAT-5, MSIS90 atmosphere model, Double-Chapman ionosphere model, and full 3-D ray tracer was used for forward modeling. Full 3-D ray tracer of EGOPS4 calculates the amplitude and phase of the ray path with sub-millimeter accuracy. The observation system modeling includes receiving system, antenna system, receiver performance, multipath and differencing treatment and clock modeling. EGOPS4 provides four different bending angle retrieval tools such as "IAP Differential Correction & Ionosphere & Bending Angle Retrieval", "IGAM/UG Ionosphere Correction & Bending Angle Retrieval", "DMI Standard Ionosphere Correction & Bending Angle Retrieval" and "DMI Enhanced Ionosphere Correction & Bending Angle Retrieval"[9]. IAP Differential Correction & Ionosphere & Bending Angle Retrieval used for KOMPSAT-5 data simulation provides backpropagation method as a differential correction. Canonical transform[10] is also provided as another differential correction. In general, the atmospheric refractivity is derived by using Abel transform and atmospheric vertical profiles are retrieved from this refractivity. Figure 11 shows a total retrieving algorithm of EGOPS4[11].

The vertical profile of atmospheric refractivity and dry temperature using simulated KOMPSAT-5 occultation data is shown in Figure 12 and Figure 13, respectively.

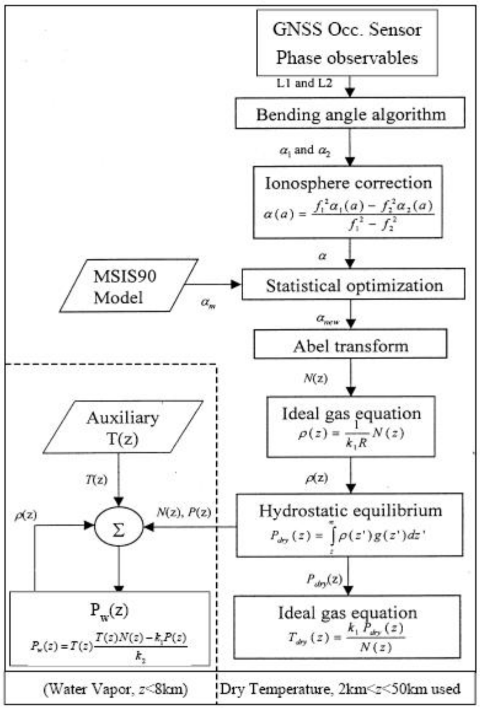

Figure 11. Retrieval algorithm of EGOPS4

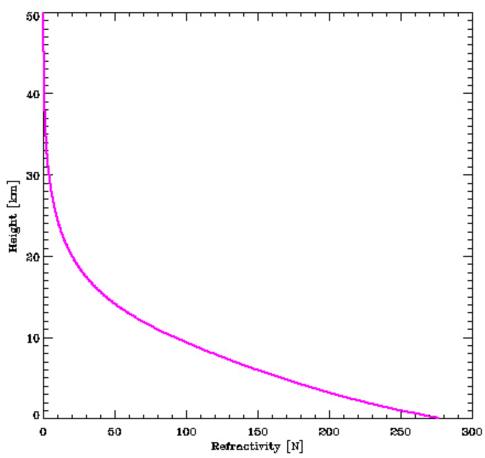

Figure 12. Example of the simulation results - the vertical profile of refractivity using K-5 simulated data

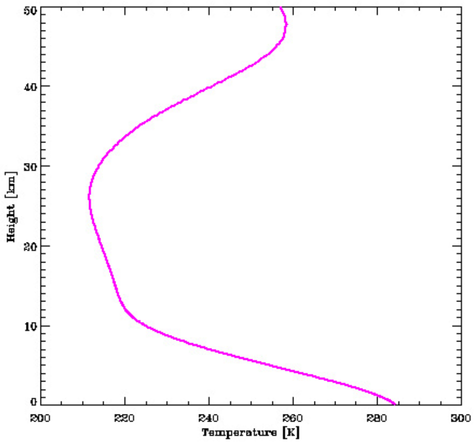

Figure 13. Example of the simulation results – the vertical profile of temperature using K-5 simulated data

4. Conclusions

The vertical profile of atmospheric parameters was retrieved using simulated KOMPSAT-5 occultation data.

Currently, KASI is developing an occultation data processing system. KOMPSAT-5 GPS radio occultation data will be archived and combined with the data from other occultation programs such as COSMIC, CHAMP, and GRACE. GPS observation data from ground GPS stations can also be combined with the occultation data to improve the atmospheric and ionospheric profiling results.

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