GPS-Based Precise Orbit Determination for LEO Satellites with Carrier-Phase Integer Ambiguity Resolution

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ABSTRACT

1. Introduction

Integer carrier-phase ambiguity resolution (IAR) has been demonstrated to be a powerful technique in precise orbit determination (POD) as well as in geodetic applications. JAXA has implemented the ambiguity fixing procedure in GPS-based POD software package, which can estimate orbits of Low Earth Orbit (LEO) satellites with accuracy of a few centimeters, to meet the requirements of Japanese ocean surface topography mission JAXA has proposed. This paper explains a brief overview of the POD tool and accuracy evaluation results of GRACE and ALOS orbits.

2. POD Software Development

JAXA developed the GNSS precise orbit and clock estimation software “MADOCA” in 2011 and 2012, which can estimate GNSS orbits with accuracy of a few centimeters. In order to meet special requirements for orbit determination of LEO satellites (e.g. ocean surface topography mission), JAXA has developed a new POD software by expanding the capabilities of MADOCA to cover both GNSS and LEO satellites making use of the measurement and dynamic model, as well as the parameter estimation algorithm that had been already implemented to MADOCA. The key functions of the POD software are as follows.

1) Orbit determination for GNSS with IAR
2) Orbit determination for LEO satellites with IAR
3) Phase Center Variation (PCV) estimation for GPS receiver antennas
4) SLR residual evaluation

The ambiguity resolution strategy integrated into the POD software is based on the double-difference IAR as well as single-difference technique, which estimates fractional cycle biases (FCBs) for all satellite pairs derived from ambiguity-float network solutions.

3. POD Strategy and Procedure

The procedure of the orbit determination for LEO satellites using the POD software is shown in Figure 1. The GNSS precise ephemeris and clock offsets are fixed during the orbit estimation process for LEO satellites. The measurement models implemented in this software are compliant with the IERS conventions 2010 and other latest related models. In order to compensate the un-modeled atmospheric drag of LEO satellites, a reduced dynamic strategy, which complements imperfect dynamics with empirical accelerations, is applied to their orbit determination.

4. Preliminary Evaluation Results

In order to evaluate the performance of the POD software, orbit determination tests were conducted using GPS observations received in GRACE-A satellite (NASA/JPL). The GNSS precise ephemeris and clock offsets were fixed to the IGS final orbit and IGS high-rate clock products, respectively. Moreover, the ground GPS observations in 40 IGS (International GNSS Service) stations were processed with integer carrier-phase ambiguity fixing procedure.

Figure 2 shows the GRACE-A orbit error with regards to the precise ephemeris derived form JPL level-1B products. The statistical results during the estimation period (7 days) are summarized in Table 1, which includes SLR residuals. According to the table, GRACE-A orbit differences between JAXA and JPL are 1.4 cm (3DRMS) and SLR residuals are also about 1.5 cm (RMS). This shows that the POD software can estimate the orbit of GRACE-A satellite with higher accuracy of less than 2.0 cm (RMS).

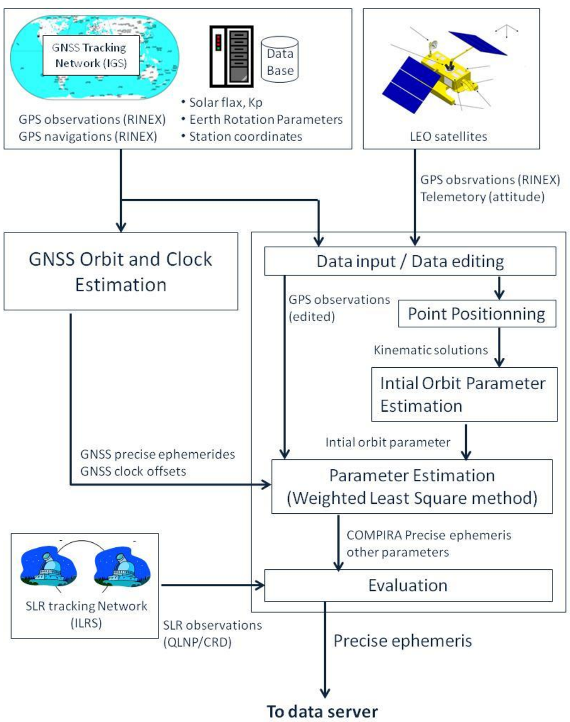

Figure 1. POD Software Procedure

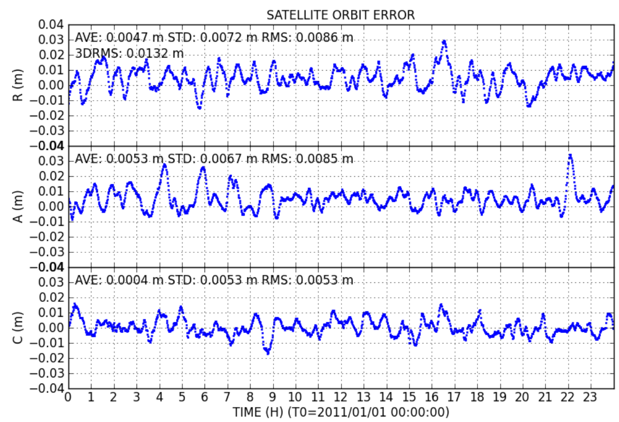

Figure 2. GRACE-A Orbit Differences from the JPL Ephemeris. * Above: Radial, Middle: Along-track, Bottom: Cross-track

AR-ON	JAXA-JPL [cm] rms				SLR Residuals [cm] rms
	R	A	C	3D	
2011-01-01	0.9	0.9	0.5	1.3	1.1
2011-01-02	0.9	0.9	0.6	1.4	3.0
2011-01-03	0.9	0.9	0.6	1.4	0.6
2011-01-04	0.9	1.0	0.6	1.5	0.4
2011-01-05	0.9	0.9	0.7	1.5	1.5
2011-01-06	0.8	0.9	0.7	1.4	2.0
2011-01-07	0.7	0.8	0.8	1.4	1.9
Mean	0.9	0.9	0.6	1.4	1.5

Table 1. GRACE-A Orbit Estimation Summary