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Japanese Altimetry Mission, COMPIRA

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Abstract. *Japan Aerospace Exploration Agency (JAXA) has proposed a new altimetry mission, COMPIRA (Coastal and Ocean Measurement mission with Precise and Innovative Radar Altimeter). COMPIRA will carry a wide-swath altimeter with two synthetic aperture radar antennas, named SHIOSAI (SAR Height Imaging Oceanic Sensor with Advanced Interferometry), having 80 km swath in both left and right sides. To meet the accuracy requirement of sea surface (~7.5 cm, with spatial resolution of 5 km), precise orbit determination is important. In addition to GPS receiver, LRA (Laser Retroreflector Array) will be mounted to calibrate biases of GPS-determined orbits and to obtain combined precise orbits from SLR/GPS measurements with the cooperation of ILRS stations. JAXA developed the GNSS precise orbit and clock software, "Madoka", and performance was evaluated using GPS observation data in GRACE-A satellite. The result indicates that the software will have a good performance to meet requirements for the COMPIRA precise orbit products.*

Introduction

Measurements of sea surface height (SSH) by satellite are important for government, operational, and scientific use, as well as other oceanic data such as sea surface temperature, marine meteorology, ocean salinity, and ocean color. Japan Aerospace Exploration Agency (JAXA) has proposed a new altimetry mission, COMPIRA (Coastal and Ocean Measurement mission with Precise and Innovative Radar Altimeter) [Uematsu et al., 2013]. There are three main purposes of the COMPIRA mission; ocean currents forecast for various human activities over the ocean including ship navigation, fishery for estimating fishing places, and scientific outcomes including ocean submesoscale phenomena, sea-level rise phenomena, and improvement of Tsunami forecast model. To obtain sea surface height data over the coastal region, wide-swath measurement is quite effective. Therefore, COMPIRA will carry a wide-swath altimeter with two synthetic aperture radar antennas, named SHIOSAI (SAR Height Imaging Oceanic Sensor with Advanced Interferometry), having 80 km swath in both left and right sides. To meet the accuracy requirement of sea surface height (~7.5 cm, with spatial resolution of 5 km), POD (Precise Orbit Determination) is quite important. Therefore, LRA (Laser Retroreflector Array) will be mounted to calibrate biases of GPS-determined orbits and to obtain combined precise orbits from SLR/GPS measurements with the cooperation of ILRS stations. Also, it is necessary to improve POD software to meet the requirements. Therefore, JAXA developed the new GNSS precise orbit and clock software, "Madoka", and recently, performance was evaluated.
In this paper, we present overview of the COMPIRA mission, and a result of performance evaluation of the POD software is also presented.

Mission Requirements

Mission requirements for the COMPIRA mission has been established and shown in Table 1. To meet needs both for latency and accuracy, there are three types of products depending on the latency: Near-real-time, General, and High-precision products. The near-real-time and the general products are aimed mainly for operational usage. The high-precision product is mainly for scientific use. The spatial resolution of SHIOSAI will be 5 km. This will make it possible to observe the submesoscale ocean using the observed data. The observed ocean area, shown in Figure 1, covers less than 51° of latitude from the Persian Gulf to the U.S. west coast, including the sea around Japan except for the southwestern Indian Ocean. The ground track coverage will be 98% at the sea around Japan (35°N latitude). The observation frequency will be 2 times in 10 days for more than 80% of the sea area around Japan (35°N latitude).

Orbit is non-sunsynchronous with altitude of 937.49 km, inclination of 51.2° and repeat period of 10 days. This will make it possible to separate the height component from the tidal component of the measured SSH.

Satellite Configuration

The sensor system of the COMPIRA mission consists of the following three components: wide-swath altimeter (SHIOSAI), Nadir-pointing radar altimeter, and Microwave radiometer. SHIOSAI is a X-band (9.6 GHz) interferometric synthetic aperture radar altimeter with a wide swath of 80 km (in each side) for left and right sides and with sea surface height accuracy of 4.2 cm with 5 km spatial resolution.

Figure 2 shows the measurement concept. Role for the SHIOSAI is to obtain wide-swath relative sea surface height (SSH) data. Role for the nadir-pointing radar altimeter is to obtain the absolute SSH with a high accuracy of several centimeters, because SHIOSAI does not satisfy the requirement of absolute measurement accuracy without an nadir altimeter. We can obtain the absolute SSH with both high accuracy and a wide swath by using the sensors of both SHIOSAI and the nadir-pointing radar altimeter. In addition, a microwave radiometer will be installed to correct the range delay due to water vapor.

To obtain precise orbit determination data, GPS receiver and LRA (Laser Retroreflector Array) will also be mounted. The satellite and sensor configuration is shown in Figure 3.

Requirements for Precise Orbit Determination

Requirements for the orbit determination is shown in Table 2. For the near-real-time products, GPS is used for orbit determination. For general and high-precision products, in addition to GPS measurements, data obtained by Satellite Laser Ranging (SLR) observations are used to calibrate biases of GPS-determined orbits and to obtain combined precise orbits from SLR/GPS measurements with the cooperation of ILRS (International Laser Ranging Service) stations. POD (Precise orbit determination) will be conducted using GPS-based POD software developed by JAXA.

POD Software and Its Evaluation

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 [Miyoshi et al. 2012]. In

order to evaluate above requirements of COMPIRA orbit determination, 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 were already implemented to MADOCA. Procedure for the POD processing is shown in Figure 4. The key functions of the POD software are as follows; orbit determination for GNSS, orbit determination for LEO satellites, Integer carrier-phase ambiguity resolution, Phase Center Variation (PCV) estimation for GPS receiver antennas, and SLR residual evaluation.

In order to evaluate the POD software for COMPIRA, orbit determination tests were conducted using GPS observations received in GRACE-A satellite on 1 Jan 2011 (NASA/JPL) [Case et al., 2002]. The GNSS precise ephemeris and clock offsets were fixed to the IGS final orbit and IGS high-rate clock products [Kouba, 2009], respectively. Moreover, the ground GPS observations in 40 IGS (International GNSS Service) stations shown in Figure 5 were processed with integer carrier-phase ambiguity fixing procedure.

Figure 6 shows the GRACE-A orbit error with regards to the precise ephemeris derived form JPL level-1B products [Case et al., 2002]. This result indicates that the POD software developed by JAXA will have a good performance to meet the requirements of COMPIRA precise orbit products.

Conclusion

We are now studying the Japanese new altimetry mission COMPIRA The measurements will be expected to be used in various fields such as fishery location exploitation and understanding of ocean tides and currents in the coastal region and marginal seas. We presented the overview of the COMPIRA mission. We also developed the POD software, evaluated performance using the GRACE-A satellite data, and result indicates that the developed software will have a good performance to meet the POD requirements for COMPIRA mission to archive high accuracy SSH measurements.

Table 1. Requirements for the COMPIRA mission.

Item		**Specification**		
Spatial resolution		5 km		
Time to offer product		Near-real-time 6–12 h	General 3 days	High-precision 60 days
Accuracy (Average in swath)	relative	5.4 cm	5.4 cm	5.3 cm
	absolute	12.2 cm	7.5 cm	6.9 cm
Frequency		Twice per 10 days		
Observational area		Sea around Japan, from the Persian Gulf to the west coast of the U.S.		
Distance to coastal line		10 km		
Rain error		1%		
Coverage		98% (35°N latitude)		
Product		Sea surface height, sea level anomaly, absolute sea surface height, Geophysical Data Record		
Tide		Observation for computable harmonic constant of main tide		

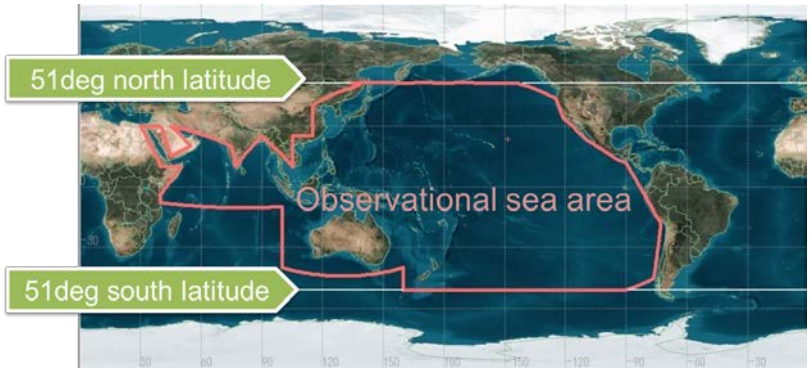

Figure 1. Observational sea area.

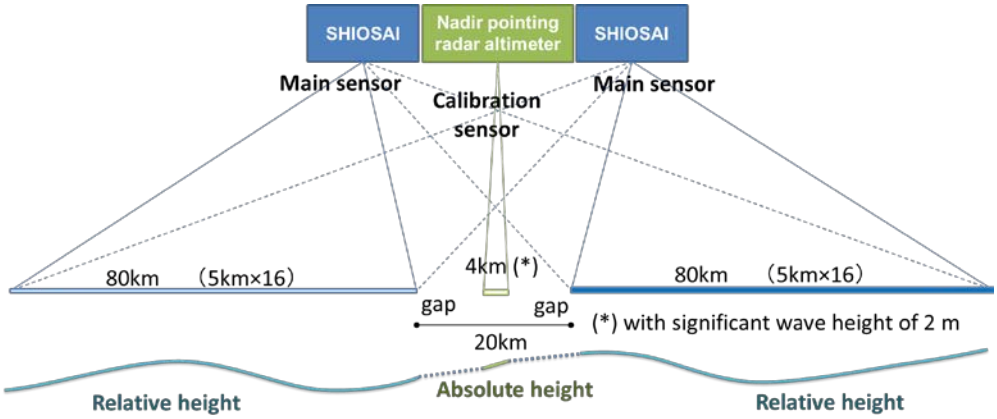

Figure 2. COMPIRA measurement concept.

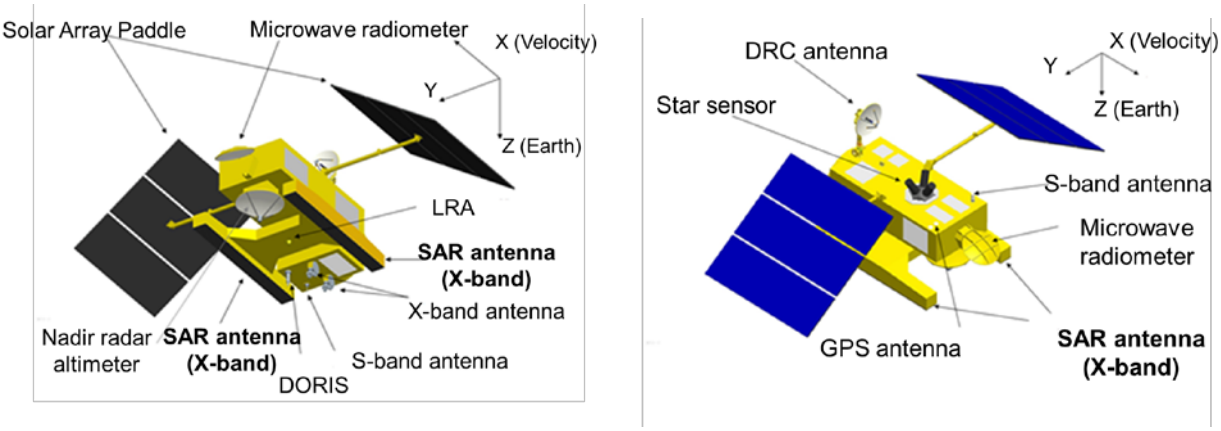

Figure 3. Satellite configuration.

Table 2. Requirements for the precise orbit determination.

Products	Latency	Orbit Accuracy(radial)	Measurements
Near-real-time	6-12 hours	10 cm (RMS)*	GPS
General	Nominal:1 day with orbit control:3 days	4 cm (RMS)	GPS (+SLR)
High-precision	60 days	3 cm (RMS)	GPS + SLR

* Orbit accuracy will be measured with regard to the High-precision ephemeris.

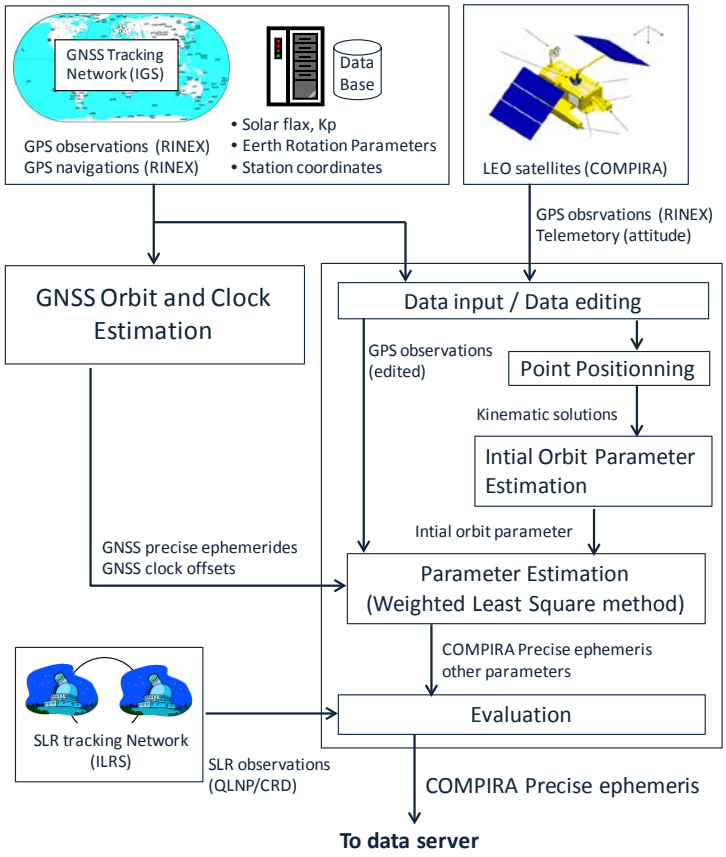

Figure 4. Procedure for the POD processing.

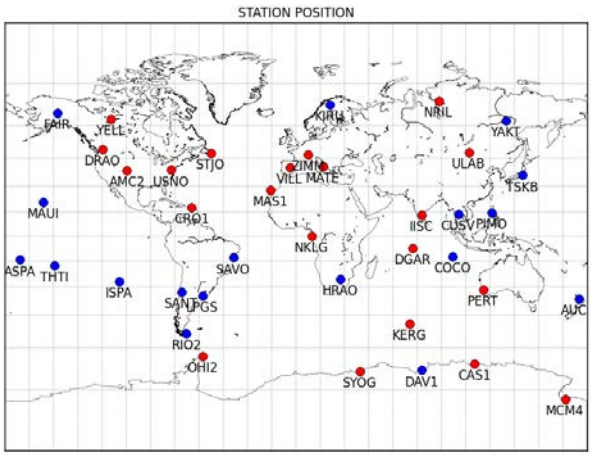

Figure 5. IGS Tracking Network (40 stations).

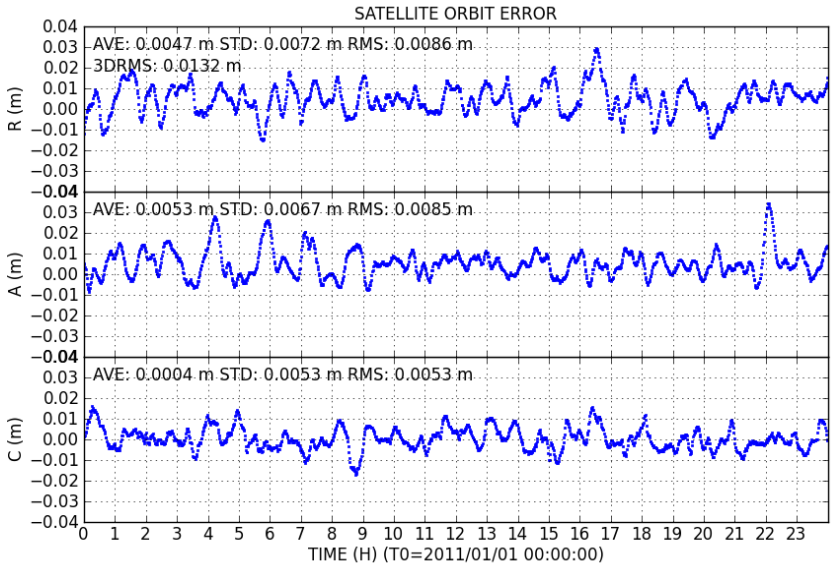

Figure 6. GRACE-A orbit differences @ 1st Jan, 2011 (JAXA-JPL).

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