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Multi-technique combination of space geodesy observations: Impact of the Jason-2 satellite on the GPS satellite orbits estimation

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Abstract

In order to improve the Precise Orbit Determination (POD) of the GPS constellation and the Jason-2 Low Earth Orbiter (LEO), we carry out a simultaneous estimation of GPS satellite orbits along with Jason-2 orbits, using GINS software. Along with GPS station observations, we use Jason-2 GPS, SLR and DORIS observations, over a data span of 6 months (28/05/2011–03/12/2011). We use the Geophysical Data Records-D (GDR-D) orbit estimation standards for the Jason-2 satellite. A GPS-only solution is computed as well, where only the GPS station observations are used. It appears that adding the LEO GPS observations results in an increase of about 0.7% of ambiguities fixed, with respect to the GPS-only solution. The resulting GPS orbits from both solutions are of equivalent quality, agreeing with each other at about 7 mm on Root Mean Square (RMS). Comparisons of the resulting GPS orbits to the International GNSS Service (IGS) final orbits show the same level of agreement for both the GPS-only orbits, at 1.38 cm in RMS, and the GPS + Jason2 orbits at 1.33 cm in RMS. We also compare the resulting Jason-2 orbits with the 3-technique Segment Sol multi-missions d'ALTimétrie, d'orbitographie et de localisation précise (SSALTO) POD products. The orbits show good agreement, with 2.02 cm of orbit differences global RMS, and 0.98 cm of orbit differences RMS on the radial component.

Keywords: Jason-2; Precise Orbit Determination; Multi-technique combination; GPS; LEO

1. Introduction

Precise Orbit Determination (POD) is an essential component of today's high accuracy Reference Frame realization. POD is necessary in order to obtain high precision orbits for the GPS, DORIS and SLR tracked satellites. Having precise orbits leads to a more precise estimation of the various geodetic references, such as ground station positions and Earth orientation parameters (EOP) (Štěpánek et al., 2014). Some of these satellites, feature tracking instruments from more than one technique. These multi-technique satellites, present a special interest for POD, through the possibility of combining several techniques in order to estimate their orbits.

POD plays a major role for satellite altimetry, where the altimetric satellite orbit is used as a reference in order to compute geocentric mean sea level from sea surface height observations. The required quality for sea level monitoring can only be achieved if the Earth monitoring satellites have

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highly accurate orbits. Moreover, the availability of precise orbits is important to the calibration of altimetric instruments, as well as intercalibration of different altimetric missions (Fu and Haines, 2013). In satellite altimetry, the radial component of the orbit is directly related to sea level measurements, making it of primary importance in the satellite's orbit determination.

The precision and accuracy of POD products are sensitive to multiple error sources. They can be affected by errors in the models, the Terrestrial Reference Frame (TRF) and the observations (Beckley et al., 2010). In Bertiger et al. (2010), Jason-2 orbits from Jet Propulsion Laboratory (JPL, GPS orbits), Centre National d' Etudes Spatiales (CNES, SLR/DORIS/GPS orbits, Geophysical Data Records C modeling – GRDC (Cerri et al., 2010)), and Goddard Space Flight Center (GSFC, SLR/DORIS orbits (Lemoine et al., 2010)) show differences with an overall RMS of 4–5 mm, but geographically correlated differences are seen, up to 1.5 cm.

A study performed on the TOPEX/Poseidon (T/P), Jason-1 and Jason-2 satellites (Lemoine et al., 2010), showed that the RMS of fit are around 1.79 cm for T/P SLR data, and 1.06 cm for the SLR data and 0.373 mm/s for the DORIS data for Jason-1. For Jason-2, RMS radial orbit differences between the GSFC reduced-dynamic and JPL reduced-dynamic orbits were of 0.70 cm, which is considered as a good agreement since these two sets of orbits rely on totally independent tracking systems (SLR/DORIS vs. GPS), and it was concluded that the radial accuracy of the Jason-2 orbits was very close to 1 cm.

In the case of GPS-derived orbits, particular attention has to be paid to the ephemerids and clocks used as references, for any error in them may contaminate the LEO's orbit. In Couhert et al. (2015), a comparison was made between GDR-D type Jason-2 orbits, which are derived from JPL GPS orbits, and Jason-2 orbits derived from IGS GPS orbits. The results show stable radial differences over two years of data span, with an overall RMS of about 1.5 mm.

In this study we examine the effects of a multi-technique combination in a simultaneous orbital restitution of the GPS constellation and the Jason-2 LEO. To carry out such a combination, we use the GPS observations of ground stations and of the Jason-2 satellite, as well as the SLR and DORIS observations on the Jason-2 satellite. The main purpose of this study is to investigate the possibility to improve POD for both the GPS constellation and the LEO, by solving for all parameters simultaneously. A secondary objective is to enable future research regarding TRF realization with the use of the Jason-2 satellite as a space tie, if the obtained orbits are of satisfying quality.

From the various orbits for altimetric satellites derived from measurements of more than one space geodesy technique, it is implied that combining observations of different techniques can help to improve the accuracy of said orbits. Moreover, the importance of multi-technique combination regarding TRF determination has been pointed out in the various realizations of the International Terrestrial Reference Frame (ITRF) (Altamimi et al., 2011). The *Groupe de Recherche de Géodesie Spatiale* (GRGS) has been carrying out research on multi-technique combinations since the early 2000s (Yaya, 2002; Coulot, 2005; Coulot et al., 2007; Pollet, 2011; Pollet et al., 2014). Using a LEO in a combination to obtain a TRF implies that its orbit determination should be of high precision. Moreover, the addition of the LEO should not deteriorate the GPS orbit estimations. In this study, we show results from a combined GPS + Jason-2 solution. We first show results on the effects of the additional LEO observations on the ambiguity resolution of the ground stations. We show the effect of this combined solution on the orbits of the GPS satellites by comparing them to orbits resulting from a GPS-only solution, which was obtained by estimating the GPS satellite orbits by using only the GPS station observations. We also show the effect of the combined solution on the Jason-2 satellite orbits by comparing them to those resulting from a Jason-2-only solution, where the Jason-2 satellite orbits were estimated by using only the Jason-2 satellite GPS, SLR and DORIS observations. Moreover, to assess the quality of the combined GPS + Jason-2 solution, as well as the quality of both GPS-only and Jason-2-only solutions, we compare the orbits resulting from these solutions with the IGS final products for the GPS satellite orbits, and the SSALTO and LCA POD products for the Jason-2 satellite orbits.

2. Data, software and parametrization

For this study, we used an observation period of 6 months in 2011, from 28/05/2011 to 03/12/2012. We used the same models and software for all techniques, in order to achieve high internal consistency. In the usual approach, LEO orbits are estimated in a POD process, by using the satellite's GPS, DORIS or SLR observations, or a combination of these, while keeping the GPS orbits fixed to a reference solution (e.g. IGS final orbits, Lemoine et al., 2010). In this study, instead of fixing the GPS orbits, we estimate them simultaneously with the Jason-2 orbits, creating therefore a multi-technique combined solution.

2.1. Data used

We used the GPS observations from 121 IGS stations, based on the IGS08 core network (Rebischung et al., 2012). The criteria for the choice of our network were to optimize the geographical distribution, and maximize the number of co-located stations. We also used the GPS observations (Dow et al., 2009) of the Jason-2 satellite, provided by AVISO.[1] The sampling rate of the GPS observations was set at 300 s, as a compromise between orbit quality and processing time. The GPS data were

[1] ftp://avisoftp.cnes.fr/AVISO/pub/doris/jason-2/gps_rinex/.