Status of Precise Orbit Determination for Jason-2 using GPS

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1. Abstract

The JASON-2 satellite, launched in June 2008, is the latest follow-on to the successful TOPEX/Poseidon (T/P) and JASON-1 altimetry missions. JASON-2 is equipped with a TRSR BlackJack GPS dual-frequency receiver, a laser retroreflector array, and a DORIS receiver for precise orbit determination (POD).

The most recent time series of orbits computed at NASA GSFC, based on SLR/DORIS data have been completed using both ITRF2005 and ITRF2008. These orbits have been shown to agree radially at 1 cm RMS for dynamic vs SLR/DORIS reduced-dynamic orbits and in comparison with orbits produced by other analysis centers (Lemoine et al., 2010; Zelensky et al., 2010; Cerri et al., 2010). We have recently upgraded the GEODYN software to implement model improvements for GPS processing. We describe the implementation of IGS standards to the Jason2 GEODYN GPS processing, and other dynamical and measurement model improvements.

Our GPS-only JASON-2 orbit accuracy is assessed using a number of tests including analysis of independent SLR and altimeter crossover residuals, orbit overlap differences, and direct comparison to orbits generated at GSFC using SLR and DORIS tracking, and to orbits generated externally at other centers. Tests based on SLR and the altimeter crossover residuals provide the best performance indicator for independent validation of the NASA/GSFC GPS-only reduced dynamic orbits. For the ITRF2005 and ITRF2008 implementation of our GPS-only obits we are using the IGS05 and IGS08 standards. Reduced dynamic versus dynamic orbit differences are used to characterize the remaining force model error and TRF instability. We evaluate the GPS vs SLR & DORIS orbits produced using the GEODYN software and assess in particular their consistency radially and the stability of the altimeter satellite reference frame in the Z direction for both ITRF2005 and ITRF2008 as a proxy to assess the consistency of the reference frame for altimeter satellite POD

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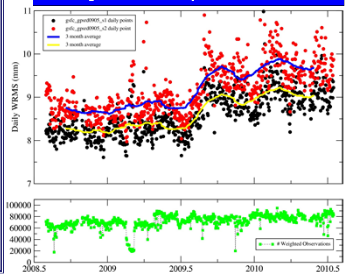
2. GPS strategy

- 38 IGS05 and IGS08 stations
- Tracking data : DD LC iono-free tracking data
- GPS PCOs and PCVs : igs05.atx and igs08_1604_woGLO_final
- IGS05 and IGS08 (w station corrections) TRF
- 1/hr scale(wet+dry) troposphere (GMF/GPT-hopfield) s1
- Float ambiguities
- J2 JPL GPS antenna PCV map
- J2 revised LC GPS antenna PCO values
- Solutions S1 : troposphere is adjusted /1 hr using 2 paths (1 station + 2 GPS s/c) during the POD
- Solutions S2 : troposphere is adjusted /1 hr using 4 paths (2 stations + 2 GPS s/c) in a ground network solution

Fig. 1 : OSTM LC phase residuals



3. GPS POD

The dense and highly precise Jason-2 GPS tracking provides significant improvement for POD capability. We base our POD strategy on the concept of a reduced-dynamic (RD) solution. An RD solution is based on the denser geometrically stronger GPS tracking data rather than the force model accuracy (Wu et al. 1990, Luthcke et al. 2003). In our GEODYN RD implementation once per-rev (OPR) along & cross-track accelerations are estimated every 30 min with sigma=1.e-09 and correlation time of 1hr.

3.1 GPS data Performance

Our main objective is to compare the GPS system performance to that of the SLR/DORIS -- in terms of POD performance -- and to compare the consistency of the reference frames as evaluated within one software package with a consistent dynamical strategy. Secondarily and since our POD strategy is primarily based on the density of the GPS tracking , we are interesting in monitoring GPS system performance through time (deCarvalho et al. 2011) .

Table 1 : J2 orbit performance summary cycles 3-14

Cy 03 – 74	Mean points			Mean RMS residuals			RMS Orbit difference to Jpl11a			
	doris	slr	xover	DORIS (mm/s)	SLR (cm)	Xover (cm)	Radial (mm)	Tx (mm)	Ty (mm)	Tz (mm)
gsfc_gpsrd0905_s1	147624	4011	5072	0.3706	1.397	5.404	7.5	2.1	-3.5	0.7
gsfc_gpsrd0905_s2	147624	4011	5072	0.3707	1.440	5.418	7.9	1.9	-3.4	0.3
std1007_cr (dyn)	147624	4011	5072	0.3704	1.119	5.434	8.8	1.4	-3.4	2.2
std1110 (dyn)	147624	4011	5072	0.3704	1.093	5.419	8.6	2.3	-0.3	3.0
red_std1110	147624	4011	5072	0.3697	1.018	5.384	6.7	1.9	-1.7	2.4
cnes_ldg_gdrc	147624	4011	5072	0.3706	1.130	5.478	9.0	2.1	-3.5	6.6
cnes_ldg_gdrd	147624	4011	5072	0.3703	1.101	5.442	7.1	2.2	1.2	1.8
esoc_gds_v3 (esa)	147624	4011	5072	0.3702	1.367	5.390	6.4	4.3	-0.3	1.5
jpl_gpsr_rlse11a	147624	4011	5072	0.3701	1.105	5.337	-	-	-	-

* Independent SLR data

Looking at Fig.1 we observe that our daily post-fit iono-free phase residuals start to increase noticeably after the second half of 2009 and towards the end of the same year. The total increase is around 1 mm and it seems to have a positive trend with time. Probably the current degradation is related to the same cause observed by JPL (deCarvalho et al. 2011) related to a combination of an increase in the tracking data over the SAA and un-detected half-integer cycle slips occurring simultaneously on L1 and L2.

3.2 GPS POD Performance

As indicated by the independent crossover residuals the gsfc_gpsrd0905_s1, red_std1110, esoc_gds_v3 and jpl_gpsr_rlse11a orbits show the greater accuracy over cycles 03-74 (Table 1). All orbits compare to the sub-mm level. The lowest crossover residuals come from jpl_gpsr_rlse11a orbits with 5.337 cm. Our gsfc_gpsrd0905_s1 orbits under-preform by 0.7 mm higher.

In terms of radial orbit error budget (systematic and random contributors to the 1-cm radial error) the gsfc_gpsrd0905_s1 orbits compare 7.5 mm (Table 1, Fig. 2) to the jpl_gpsr_rlse10a in the satellite frame. All orbits compare within 1 cm radially. The best inter-technique agreement in the orbit frame comes from GPS-only orbits.

The SLR fit residuals (Table 1, Fig. 3) are not an independent metric for the orbits that use SLR. Independent high elevation SLR ranges are the only independent test to demonstrate the radial orbit accuracy. At the present case the gsfc_gpsrd0905_s1 orbits perform at 1.397 cm whereas the jpl_gpsr_rlse11a perform at 1.105 cm.

Fig.2: Ja2 JPL_rlse11a - Test orbit radial RMS differences

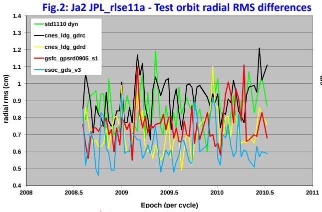
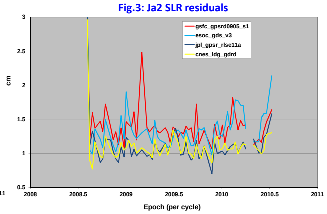


Fig.3: Ja2 SLR residuals



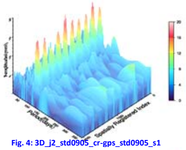


Fig. 4: 3D_j2_std0905_cr-gps_std0905_s1

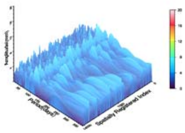


Fig.5: 3D_j2_jpl_gpsr_rlse11a-gps_std0905_s1

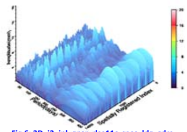


Fig.6: 3D_j2_jpl_gpsr_rlse11a-cnes_ldg_gdrc

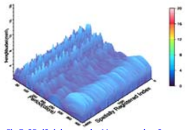


Fig.7: 3D_j2_jpl_gpsr_rlse11a-esoc_gds_v3

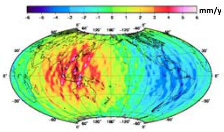


Fig.9 : lrate_j2_jpl_gpsr_rlse11a-gps_std0905_s1-3sig

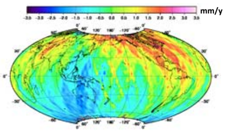


Fig. 10 : lrate_j2_jpl_gpsr_rlse11a-cnes_ldg_gdrc

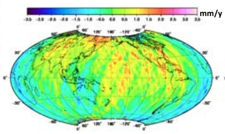


Fig. 11: lrate_j2_jpl_gpsr_rlse11a-std1007-3sig

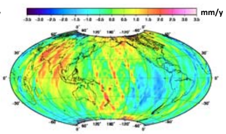
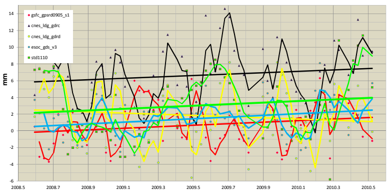


Fig. 12: lrate_j2_jpl_gpsr_rlse11a-cnes_ldg_gdrd

Fig.8: Jason-2 bias per cycle wrt jpl11a (GPS-only) orbits



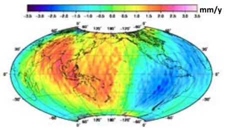


Fig. 13: lrate_j2_jpl_gpsr_rlse11a-esoc_gds_v3

3.2.1 Spectral analysis (Fig. 4 – 7)

The Jason-2 dynamic orbits show that the 118-day signal is dominant. This is the precise draconic (beta-prime) period for the Jason satellites and suggests orbit error due to SRP mis-modeling. The analysis between the SLR-DORIS dynamic orbit and the gsfc_gpsrd0905_s1 reduced-dynamic orbits shows that the gps reduced-dynamic removes much of the SRP error present in the SLR+DORIS solutions.

Smaller amplitude signals are observed in the differences between the reduced-dynamic orbits from the various analysis centers. Those appear at 118-d and 360-d terms. One case presents special interest : the differences between the jpl_gpsr_rlse11a and esoc_gds_v3 orbits where the most significant peak appears at the 59-d term of an amplitude of 3.5 mm.

3.2.2 Relative centering (Fig. 8)

One can also look at the relative centering of the ITRF-based orbits obtained. In this case we tested all orbits with respect to the jpl_gpsr_rlse11a. All orbits that contain SLR are positively biased with respect to the JPL orbits except for the gsfc_gpsrd0905_s1 GPS-only orbits. Also the drifts presented are of the order of 1 mm/y.

Fig. 9 – 12 demonstrate the radial orbit rates with the annual and semiannual terms removed. A N/S component is observed between the JPL and the SLR/DORIS and GDR-C orbits. The JPL vs GSFC GPS-only and ESOC comparison shows an E/W component.

3.3 Future work

- Process the rest of the J2 GPS cycles with the current std0905 and release the 1st series of GSFC GPS-only orbits.
- Implement the editing of the Jason-2 GPS data to detect the half-cycle slips
- Implement the ambiguity fixing

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