Satellite Precise Orbit Determination Using Real Time and Near Real Time GPS constellation products

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Introduction — Toward a faster Precise Orbit Determination (POD) for LEO satellites using GPS data

CNES POD team computes two different orbits for altimetry satellites :

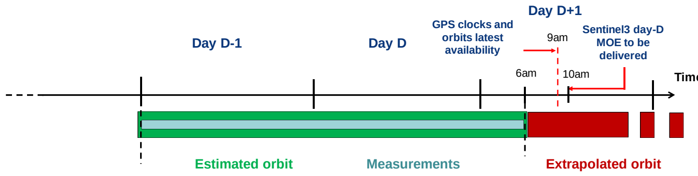
- **MOE** (Medium precision Orbit Ephemerid) : low-latency orbit, computed on a daily basis, accuracy better than 2cm on the radial component
- **POE** (Precise Orbit Ephemerid) : reference orbit, computed within a month, accuracy better than 1cm on the radial component, using several types of measurement : DORIS, laser (and GPS for satellites Jason1, Jason2 and Hy2A)

This study assesses the quality of Jason-2 POD using GPS constellation data from IGS and IGN.

Background — About MOE

- MOE delivered on day D+1 contains the estimated orbit of day D, plus some extrapolated orbit depending on the mission
- Until now : only DORIS measurements are used (current MOE).
- Interest of using GPS measurements : required by Sentinel project, ensures product redundancy, .
- Some recently created GPS constellation products meet the availability requirements
  - SGU (IGN ultra-rapid solution, low latency)
  - RTS (Real time IGS solution)
- In this study, these products are used to compute two other MOEs : RTS MOE and SGU MOE, over 6 months (from January 4, 2013 to July 4, 2013)

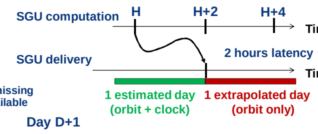
MOE of day D : Availability requirements

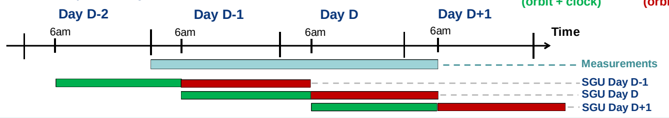


Available products

SGU

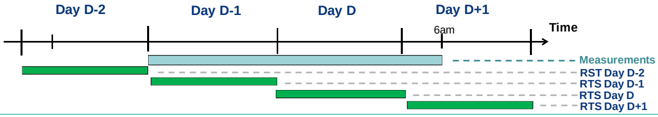
- IGN best-effort solution (French Mapping Agency)
- Freely available on the IGN FTP
- Computed every 2 hours
- Availability for SGU MOE over the 6 months study : 100% (H=6 a.m.)
- Nominal computation of MOE : 99,2% : 2 constellation solutions at H=6 a.m. missing Could be improved using 8a.m. and 10 a.m. SGU orbits when 6a.m. is not available





RTS

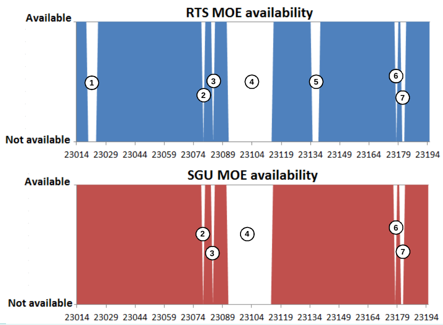
- IGS solution (International GNSS Service)
- Real-Time service (official service since summer 2012)
- Data flux collected to construct 1-day files (orbit and clock)
- Availability for RTS MOE over the 6 months study : 97,5%
- Nominal computation of MOE : 97,5% : 2 constellation solutions missing (IGS data storage problem)



Context

- **RTS and SGU MOE** : computed every day from January 4, 2013 to July 4, 2013 (6 months) on Jason 2 satellite
- **Low-latency product** : no stabilized values for ancillary information from external sources available (inputs to atmospheric density models, updates on Earth Orientation, …)
- **Problem of RTS availability***
  - ① 23020-23024
  - ⑤ 23135-23138
- **Problem in measurements**
  - ② 23079: errors in Jason2 rinex
  - ③ 23084 : no measurements
  - ④ 23092-23114 : Jason2 in Safe Mode
  - ⑥ 23178 : errors in Jason2 rinex
  - ⑦ 23181-23182 : errors in Jason2 rinex

* Not computed MOE could be reduced from 4 to 3 days

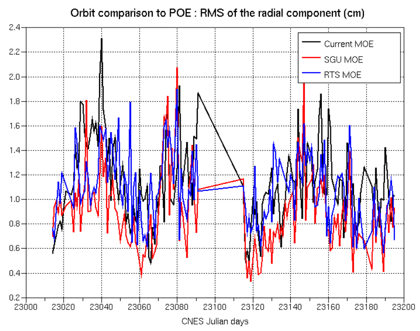


- Models used (GDRD standard) [2]:

Settings	Comment
Static gravity field	EIGEN-GRGS_RL02bis_MEAN-FIELD
Time varying gravity field	Drift+Annual+Semiannual 50x50
3rd body gravity	Analytical series expansions of luni-solar coordinates and planets
Solid Earth tides	IERS 2003
Ocean tides	FES 2004
Atmospheric Tides	Horwitz & Cowley Model
Earth radiation	Knocke-Ries albedo and IR model
Polar motion	IERS/IGS
Satellite model	Box and wings model
Direct Solar radiation pressure	Fixed
Atmospheric drag	DTM94 density model, solar activity from NOAA (daily 10.7 cm solar flux) and geomagnetic activity from GFZ (3-hour planetary Kp-index)
Atmospheric gravity	NCEP-derived 20x20 field at 6 hrs interval (AGRA service at GSFC)
Empirical forces	Along-track and cross-track 1/rev every 12 hrs, Along-track bias every 3,7 hrs (2 orbits)
Measurements	ionosphere-free combination for pseudo-range and phase, 300-second sampling one clock bias per epoch
GPS orbits and clocks	Reference orbits are taken from JPL Clocks are floating, JPL GPS maps used
GPS antenna maps	JPL maps extended to 17°
Other	Use of quaternion

Results (comparison and independent validation)

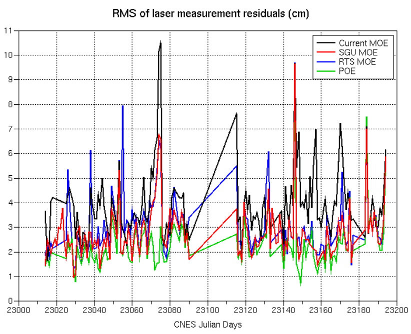
MOE orbits comparison to POE



Orbit	SGU MOE	RTS MOE	Current MOE
RMS (cm)	0,94	1,12	1,18

- RTS MOE performs as well as current MOE.
- SGU MOE performs slightly better.

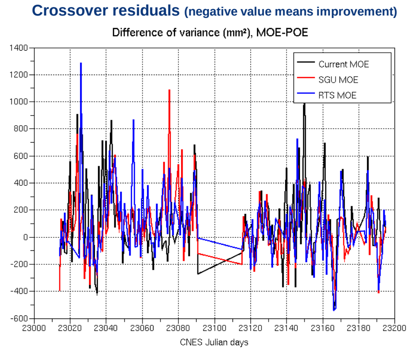
Laser RMS of the measurement residuals



Orbit	SGU MOE	RTS MOE	Current MOE	POE
RMS (cm)	3,02	3,56	4,24	2,46

- RTS and SGU MOEs have lower RMS of laser residuals than the current MOE.

Crossover residuals (negative value means improvement)



Orbit	SGU MOE	RTS MOE	Current MOE
RMS (mm²)	65	85	115

- RTS and SGU MOEs have lower crossover points residuals than the current MOE.
- SGU performs better

Conclusions

- SGU and RTS Near real-time products allow us to compute MOE with a good precision
- Future improvements :
  - Better performance : reduced dynamics may improve performance by compensating the models errors
  - Better robustness : using constellation data at 8a.m. and 10 a.m. when 6a.m. is not available (SGU)

References

1. Cerri, L. and al .(2010) 'Precision Orbit Determination Standards for the Jason Series of Altimeter Missions', Marine Geodesy, 33: 1, pp 379 — 418
2. J.-P. Dumont, V. Rosmorduc, N. Picot et al., « OSTM/Jason 2 Products Handbook », 29-31, 2011
3. M. Caissy and al. « "The International GNSS Real-Time Service", GPS World, June 2012»