Multi-technique combination of space geodesy observations

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Study Context — A

- Multi-technique combination: simultaneous use of observations of the different space geodesy techniques (DORIS, GNSS, SLR, VLBI) to derive geodetic parameters

→ allows to combine the technique advantages while mitigating their weaknesses

- Ground ties / local ties: necessary in order to obtain a homogeneous multi-technique reference frame
- Some restrictions: low number, poor distribution, precision varying with sites, discrepancies with space geodesy estimates (37% at > 1cm, [Altamimi et al., 2011])
- Multi-technique combination including the Jason-2 satellite's GPS, SLR and DORIS observations.
  - ➢ effect on the GPS and Jason-2 satellites' orbit determination.
  - ➢ effect on the GPS stations' ambiguity resolution.
  - ➢ effect on the ground network positions.

Space ties – Multi-technique satellites — B

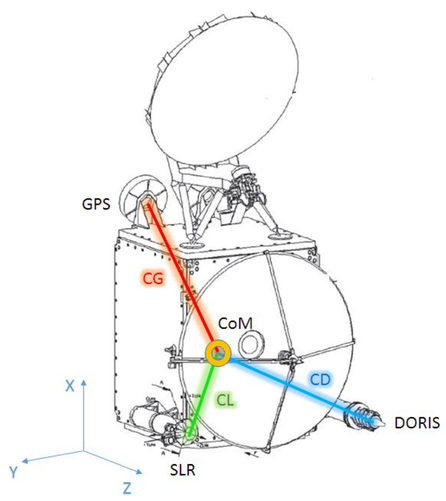


Figure 1 : http://www.nasa.gov/ - Jason-2

Multi-technique satellites : co-location sites in space

Idea: tying the techniques by using the space ties found on multi-technique satellites such as Jason-2

Advantages:

- Densified co-locations
- Inter-technique calibration
- Allows external validation of local ties

But the ST values are not always well known...
→ Re-evaluation needed?

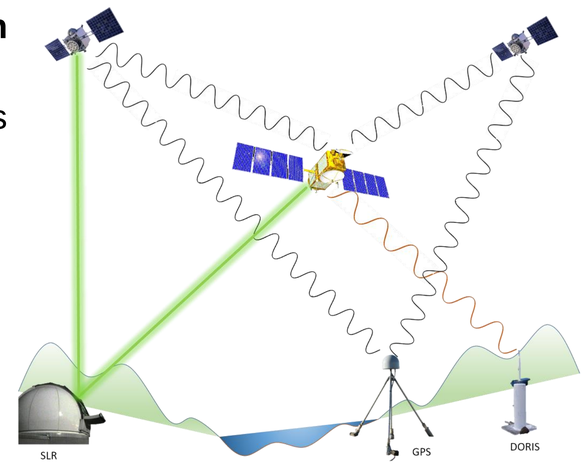


Fig. 2: LEO as a space tie

Orbit estimation parameters — C

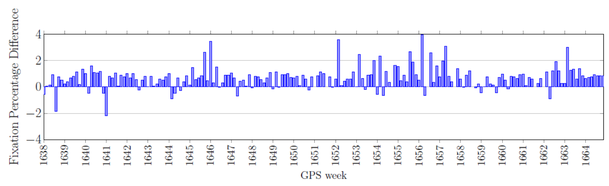
Processing:

- 6 month period including CONT 2011 (20/05/2011 – 03/12/2011).
- Data used: GPS observations of 121 stations (IGS network), GPS, DORIS and SLR observations of Jason-2 satellite.
- GPS observations' sampling at 300s, as a compromise between computing time and resulting orbit quality.
- GINS/DYNAMO software.
- Models and specifications according to CNES/CLS IGS AC.
- Orbit interpolation: 300s for GPS satellites, 60s for Jason-2.
- CNES Julian Date Day 0 : 1950-01-01 T00:00:00.

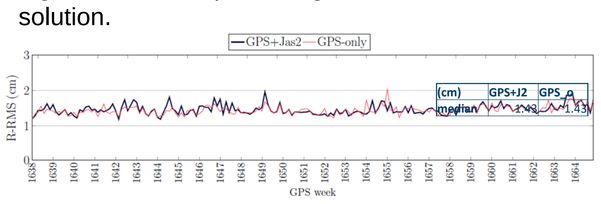
Effect of Jason-2 observations on ambiguities and orbits

Results:

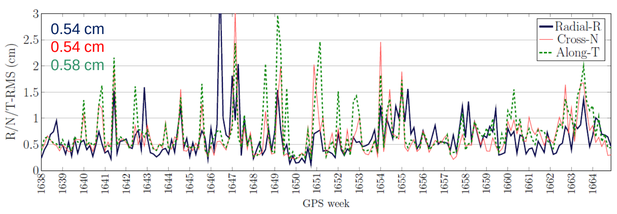
- GPS orbits were estimated (1) with GPS stations observations only (GPS_only solution) and (2) with GPS stations + Jason-2 (GPS, SLR, DORIS) observations (GPS+JAS2 solution).
- Jason-2 orbits were also estimated in a POD type solution (fixed GPS orbits).
- GPS stations receivers' ambiguities resolved in both cases and compared
- Comparison of resulting orbits with reference solutions



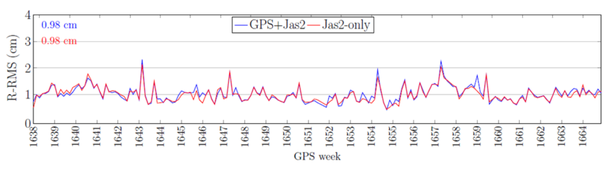
Graph 1: Ambiguities of GNSS stations were fixed for both GPS_only and GPS_JAS2 solutions. The fixation percentages on each day were compared between solutions. A positive value indicates a higher fixation percentage for the GPS+JAS2 solution.



Graph 2: GPS orbits, estimated from GPS_only and GPS+JAS2 solutions, were compared with IGS final orbits. The figure shows the RMS of the differences on the radial component. The medians show that both orbits have the same level of agreement with the IGS orbits.



Graph 3: Comparison between the GPS orbits of both GPS-only and GPS+Jas2 solutions. The figure shows the RMS of the differences on the three orbital components. Same level of agreement between components. The observed peaks are under investigation.



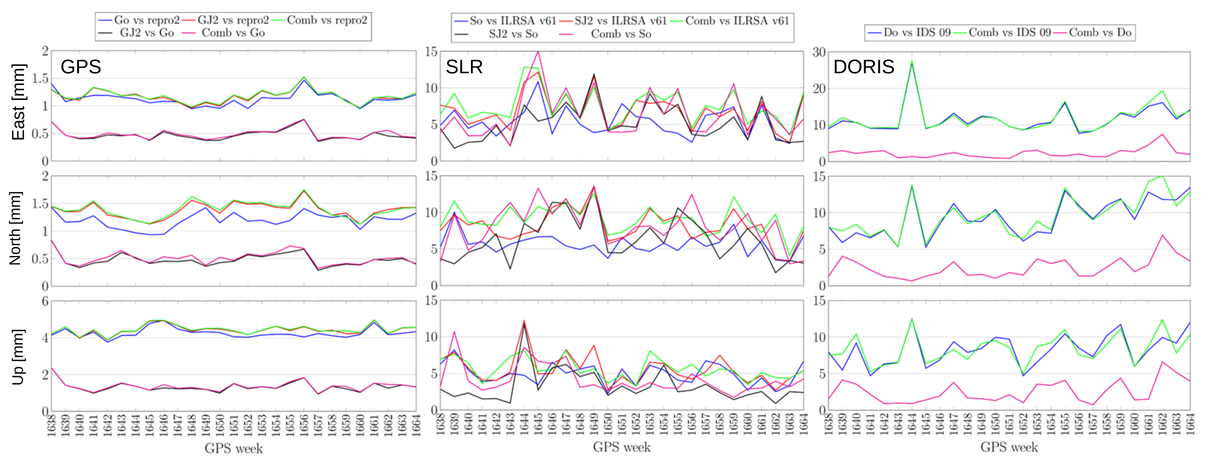
Graph 6: RMS of the differences on the radial component from the comparison of calculated Jason-2 orbits from both GPS+Jas2 and Jas2-only solution to SSALTO GPS+SLR+DORIS orbits. Both orbit sets are in good agreement with the SSALTO orbits..

Effect of Jason-2 observations on ground network position estimation — E

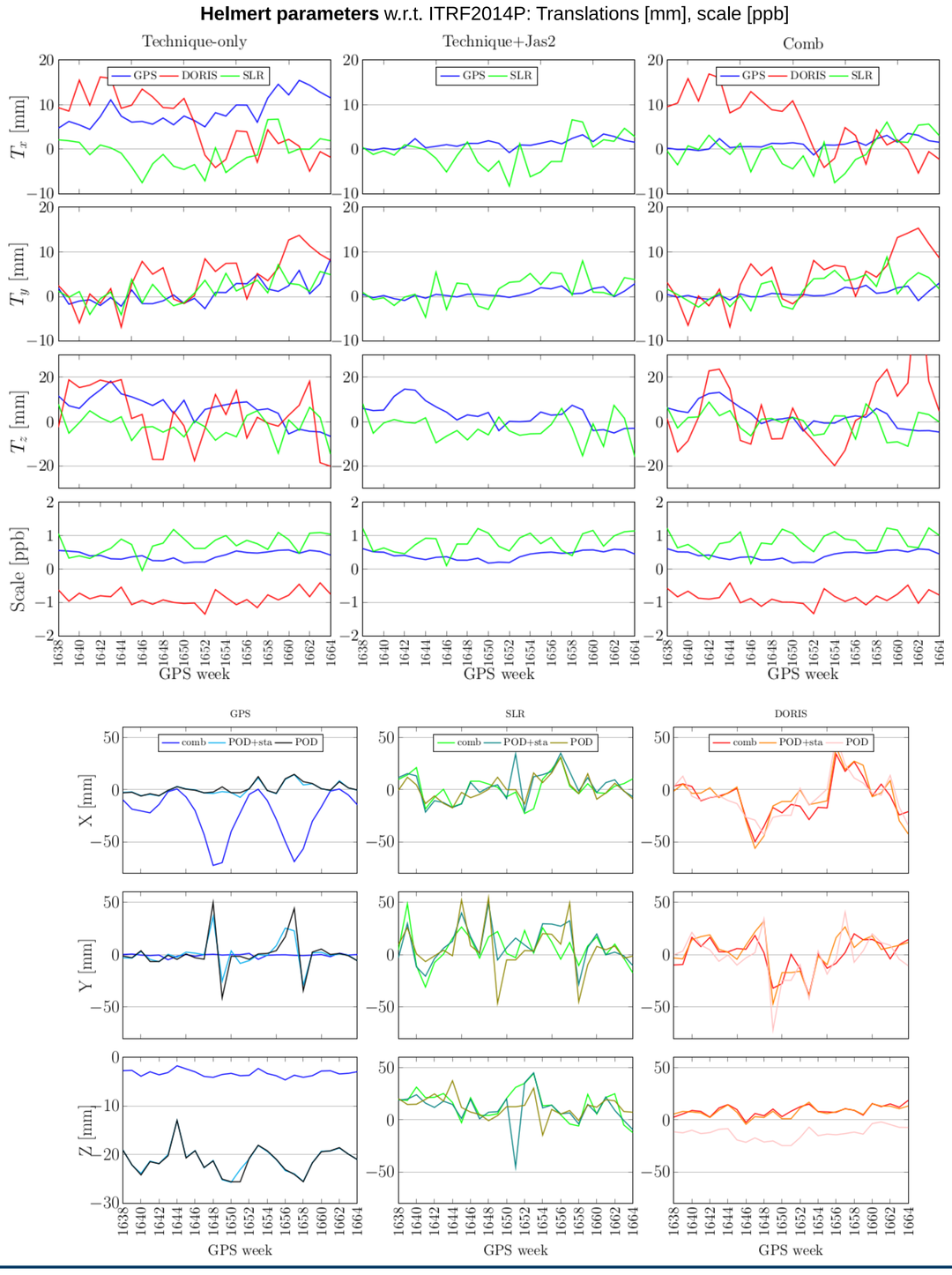
We derived different series of weekly terrestrial frame solutions in order to study the impact of the Jason2 observations and of the multi-technique combination on ground network position estimates:

- GPS_only: Ground GPS observations only.
- GPS+Jas2: Ground + Jason2 GPS observations.
- SLR_only: SLR observations to Lageos 1/2.
- SLR+Jas2: SLR observations to Lageos 1/2 and Jason 2.
- DORIS_only: DORIS observations to Envisat, Cryosat-2, SPOT 4/5 and Jason2.
- comb: multi-technique solution (no local ties, NNR constraints only).

We compared each series of weekly terrestrial frames with the weekly solutions submitted to ITRF2014 (IGS repro2; ILRS v61; IDS 09). The figures on the right show WRMS [mm] of the residuals from weekly 7-parameter Helmert comparisons.



Helmert parameters w.r.t. ITRF2014P: Translations [mm], scale [ppb]



Time series of weekly estimated space tie parameters:

- Comb: combined solution with Jas2 as a space tie
- POD+sta: Jas2 orbits estimated with GPS orbits fixed to IGS products, DORIS and SLR station positions estimated
- POD: DORIS and SLR stations positions fixed

We stacked our multi-technique combined weekly solutions into a long-term solution including:

- Station positions + velocities.
- Constant range biases for the SLR stations tracking Jason2.
- Constant Jason2 space ties.

Different constraints were used to define the long-term frame:

- **Positions:** NNR on the GPS network, NNR+NNT on the 3 techniques, NNR+NNT+NNS on the 3 techniques.
- **Velocities:** NNR on the GPS network, strong constraints on ITRF2014P.

➢ Only the TZDORIS seems affected by adding NNS constraints w.r.t. the ITRF2014P, because of its link with the DORIS network scale.

➢ Orbits and stations positions were estimated by taking into account the newly estimated values for the Jason-2 space ties. **The effects on orbits and stations positions are negligible.**

Conclusion — F

- ➢ Our combined solutions are of equivalent quality to the GRGS AC solutions.
- ➢ The addition of Jason2 observations seems to slightly degrade the North component of the GPS and SLR station position estimates.
- ➢ Our multi-technique combination with Jason2 as space tie has marginal impact when comparing the combined solutions with the technique-only (+Jason2) solutions.
- ➢ The addition of Jason2 observations improves the T_X and T_Z parameters of GPS, but the observation period is too short to conclude about geocenter motion.
- ➢ The multi-technique combination has little effect on Helmert parameters. The technique scales are in particular unaffected.
- ➢ Space ties increments are absorbed mostly by other parameters such as laser range biases, frequency biases, clock parameters, ambiguities on Jason-2 etc.
- ➢ Extend study period
- ➢ Use a constellation of multi-technique satellites
- ➢ Track down the orbit modeling errors that contaminate some of the weekly space tie estimates
- ➢ Re-evaluate technique-specific biases simultaneously with space ties: GPS satellite phase center offsets, SLR range biases, DORIS frequency biases