CENTRE NATIONAL D'ÉTUDES SPATIALES

GPS zero-difference integer ambiguity fixing for Jason

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History

- Integer ambiguity fixing brought noticeable improvement to IGS orbits both in precision and in stability
- Whether or not integer ambiguity fixing improves precision and centering of LEO orbits has been the subject of debates over the last ten years
- JPL Jason-1 research proposal on this issue in 2001 (M. Watkins)
  - Y. Yoon Ph.D. work (U. Colorado, S. Nerem thesis director)
  - standard double difference integer ambiguity fixing
  - insufficient orbit precision and lack of good antenna correction map limited ambiguity fixing capability
- New technique for zero-difference ambiguity fixing on a global network (F. Mercier, D. Laurichesse, 2007)

Key concept

Ionosphere delay

Emitter - Receiver clocks

Standard GPS model

Too simple !
does not account
for biases

Pseudo-range

$$
\begin{aligned}
P_1 &= D_1 + e + \Delta h \\
P_2 &= D_2 + \gamma\, e + \Delta h
\end{aligned}
$$

Phase

$$
\begin{aligned}
\lambda_1 L_1 &= D_1 + \lambda_1 W - e + \Delta h - \lambda_1 N_1 \\
\lambda_2 L_2 &= D_2 + \lambda_2 W - \gamma\, e + \Delta h - \lambda_2 N_2
\end{aligned}
$$

Propagation
including
troposphere
and antenna
delays

Windup

Integer ambiguities

Key concept

Extended GPS model

Ionosphere delay

equivalent to a clock per data type and per frequency

Pseudo-range

$$P_1 = D_1 + e + \Delta h_P + \Delta \tau_P$$

$$P_2 = D_2 + \gamma e + \Delta h_P + \gamma \Delta \tau_P$$

Phase

$$\lambda_1 L_1 = D_1 + \lambda_1 W - e + \Delta h + \Delta \tau - \lambda_1 N_1$$

$$\lambda_2 L_2 = D_2 + \lambda_2 W - \gamma e + \Delta h + \gamma \Delta \tau - \lambda_2 N_2$$

Propagation including troposphere and antenna delays

Windup

Integer ambiguities

Processing concept

- Double differencing phase equations cancels biases
  - this is the standard approach for integer ambiguity fixing
  - used to produce IGS orbits
- GPS satellites clocks are lost in the double differencing scheme
  - IGS clocks are produced outside of the ambiguity fixing process, they contain biases
  - clocks are essential for LEO zero-difference POD
- Mercier-Laurichesse approach based on clever isolation and identification of biases
  - produces GPS clocks consistent with integer phase ambiguities and emitter biases
  - well suited for LEO POD

Basics of Mercier-Laurichesse approach

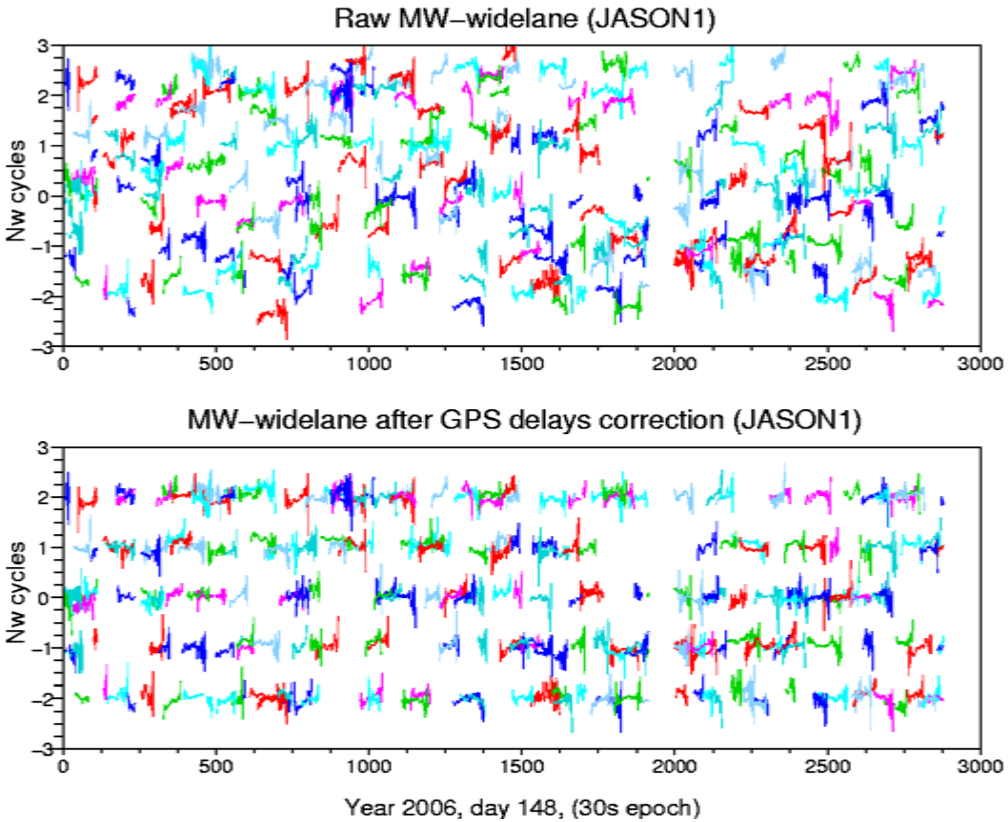
- **First step**
  - uses ionosphere-free geometry-free Melbourne-Wübbena widelane
  - identify emitter biases (relatively stable)
  - fix widelane ambiguity $N_w = N_1 - N_2$ for each receiver

- **Second step**
  - once N_w is known, ionosphere-free phase equation reduces to a single frequency problem with ambiguity N_1 and wavelength 10.7 cm
  - solve this problem globally for a world-wide network of stations keeping the geometry fixed

- **Can be applied with IGS orbits to recover ambiguities, biases and associated clocks**

Application to Jason-1 POD – step 1

- Same approach work with LEO data once GPS biases and clocks are known
- First step is M-W ambiguity fixing
- Once GPS biases are corrected Nw ambiguities clearly appear

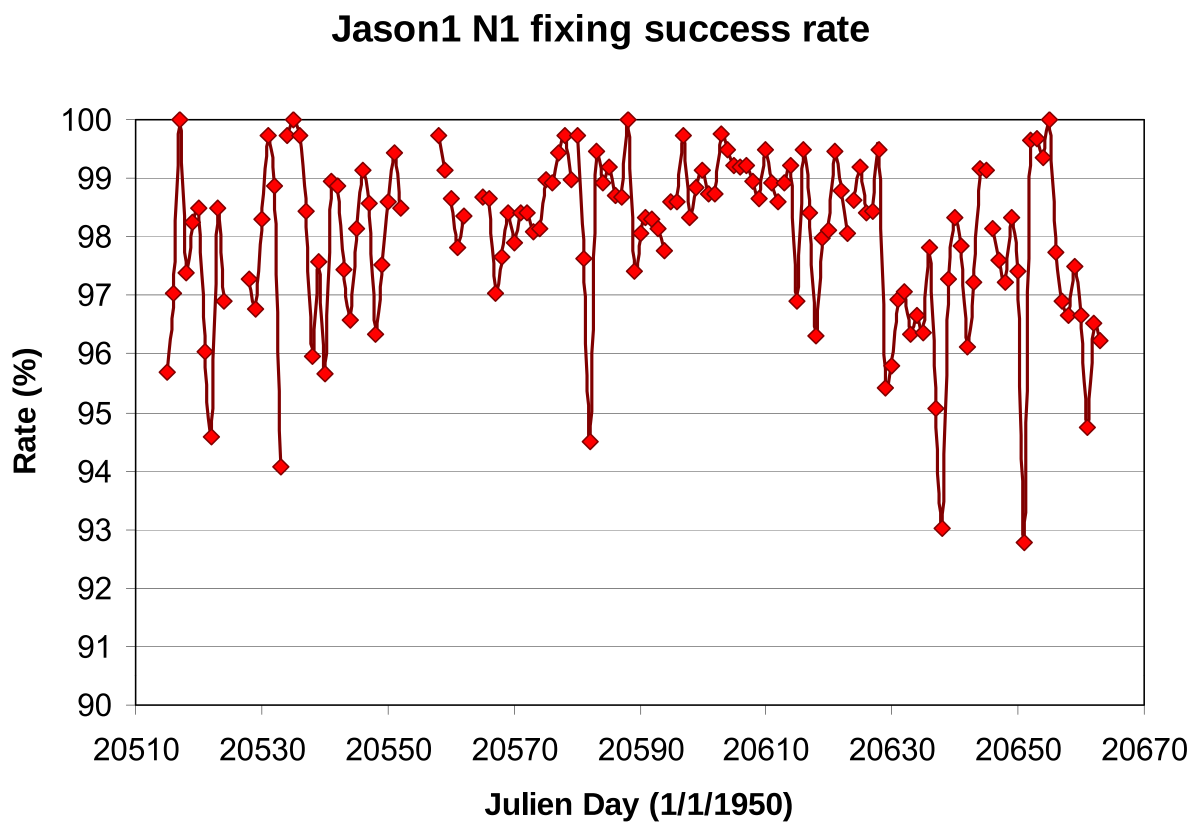


Application to Jason-1 POD – step 2

- Second step is N1 ambiguity fixing using ionosphere-free equation
  - however, starting Jason-1 orbits are not good enough to be able to reveal ambiguities
- Orbit error in error in along- and cross-track needs to be reduced
  - apply empirical short-arc orbit corrections in along- and cross-track directions (5 min long arcs)
  - time-correlated corrections
- Integer fixing solution computed 1 day at a time solves for
  - one integer ambiguity per pass (about 400 passes).
  - one along- and cross-track corrections per short-arc (2*288).
  - one stochastic clock at each epoch (2880 values).
- Integer ambiguities obtained by bootstrap method

Application to Jason-1 POD – step 2

- Ambiguity fixing rate is high

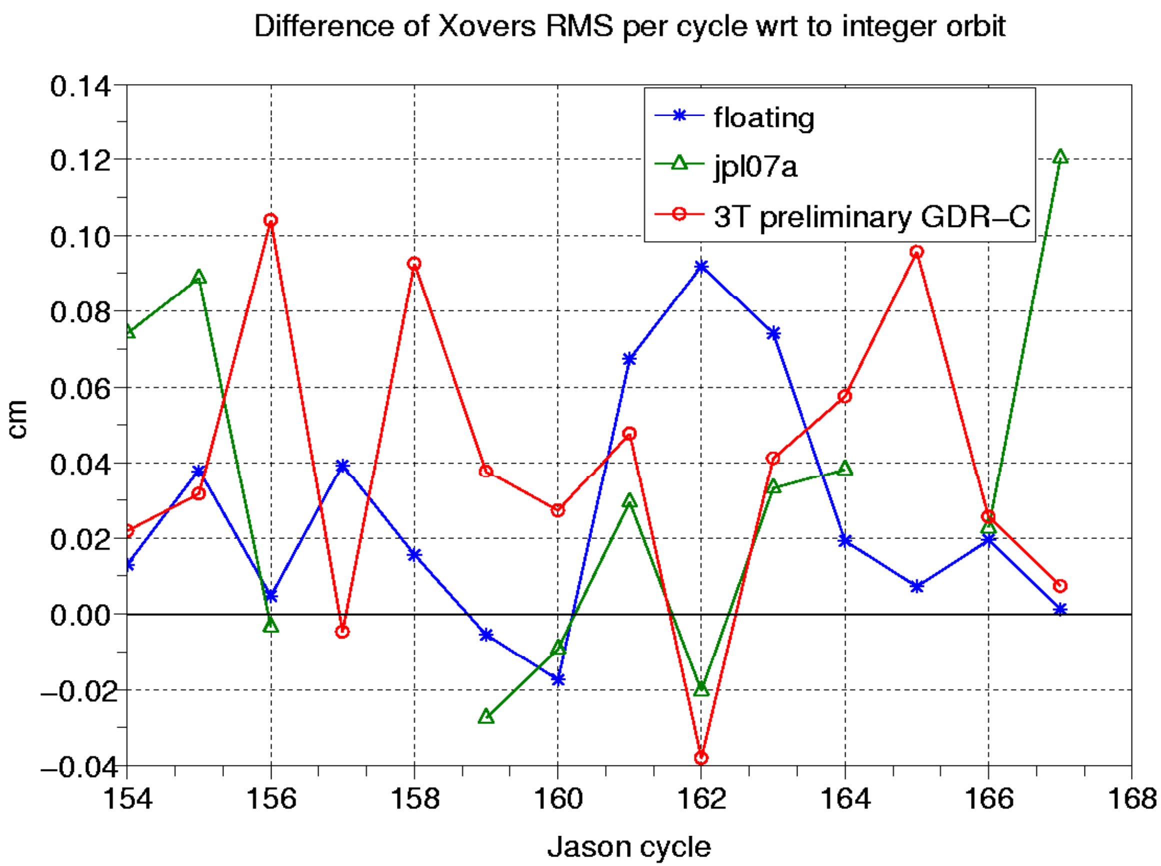


Application to Jason-1 POD – step 3

- Ambiguities are fixed at their integer values and a standard POD solution is computed
  - final orbit solution is a reduced dynamics solution, not an empirically patched orbit
- A floating ambiguity solution is also produced at that step for comparison purposes
- Orbit quality is evaluated using standard tests

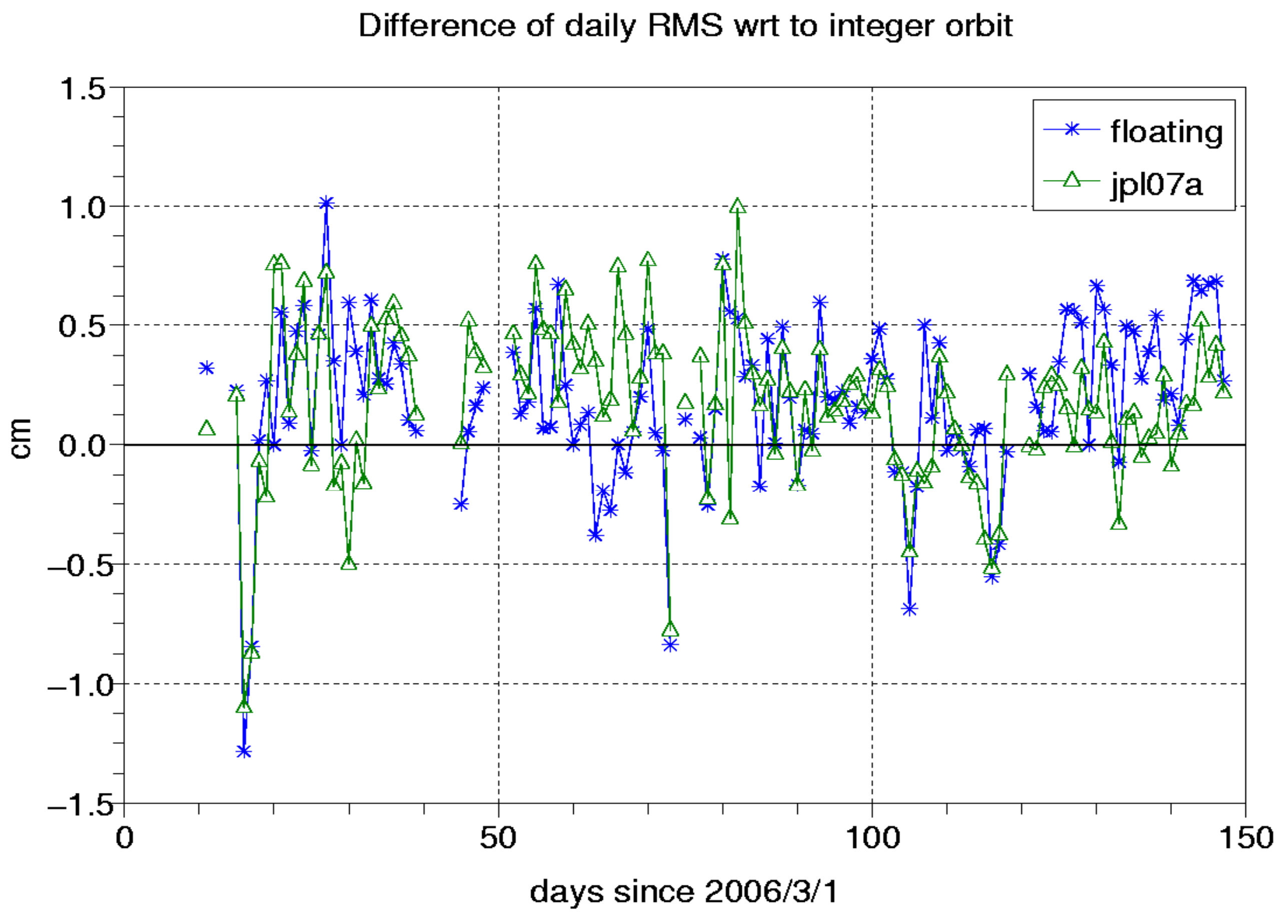
Orbit quality check using altimeter data

- RMS altimeter range cross-over residuals
- Values relative to the ambiguity-fixed orbit



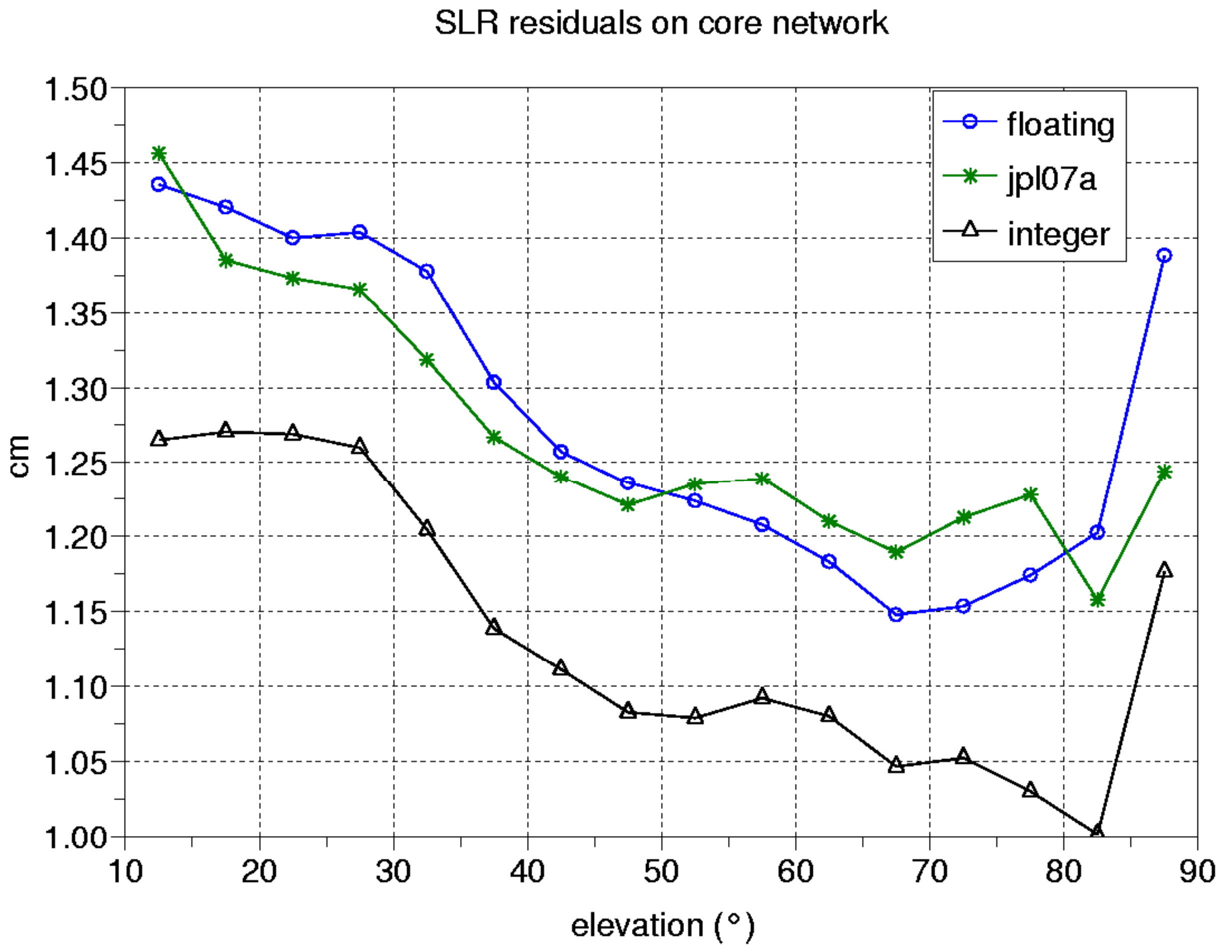
Orbit quality check using SLR data

- SLR residuals daily RMS
- Values relative to the ambiguity-fixed orbit



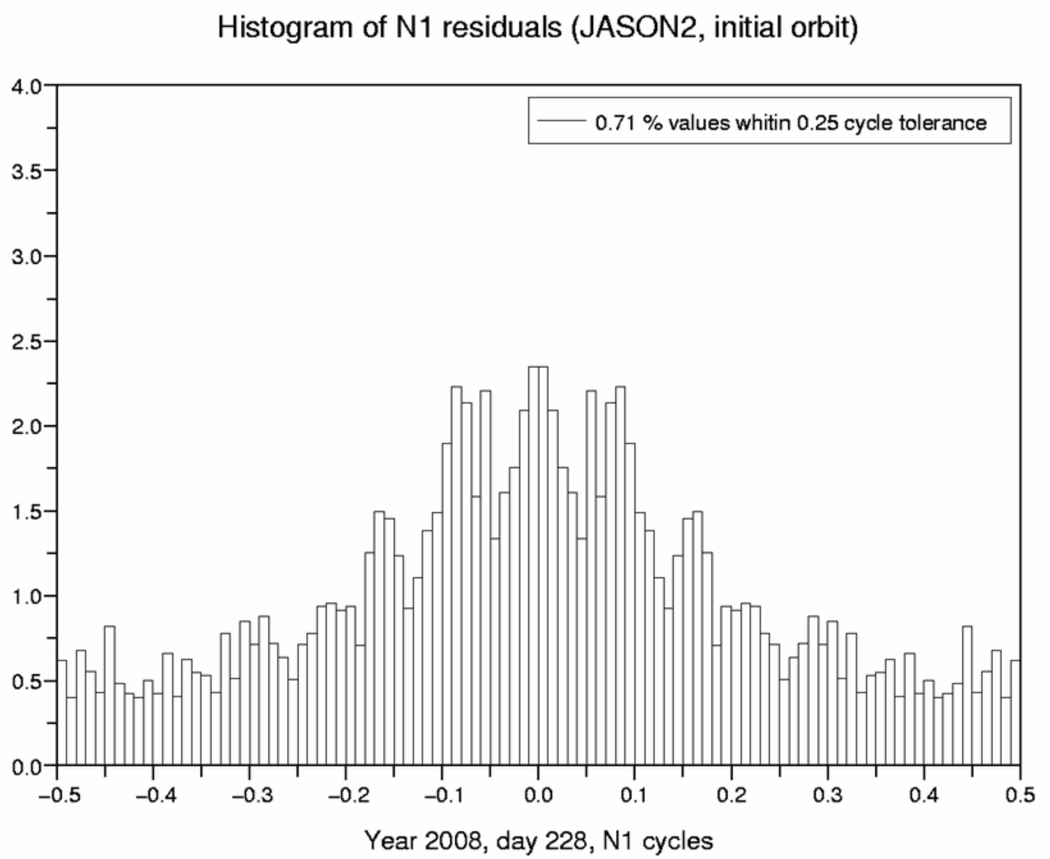
Orbit quality check using SLR data

- SLR residuals versus elevation
- Ambiguity fixed orbits appear globally better



Jason-2

- **The widelane ambiguity fixing (first step) works well on Jason-2**
- **N1 residuals appear similar to those of Jason-1 before orbit correction**
- **However, N1 ambiguity fixing does not work**
    - **might be related to half cycle jumps (see poster by F.Mercier)**



Conclusion

- The zero-difference integer ambiguity fixing method works well for Jason-1 (it has also been successfully tested on GRACE)
- Ambiguity fixing appears to improve orbit precision
  - independent orbit quality checks based on SLR data and altimeter crossover residuals show that ambiguity fixed orbits are slightly but consistently more precise compared to state of the art solutions
- For some unknown reason the process does not work with Jason-2
  - probably a problem at receiver level
  - needs to be investigated and corrected
- The full potential of ambiguity fixing for LEOs remains to be explored
  - It should be possible to make further progress in orbit precision and thus in force modeling