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

Standard GPS model

\[ P_1 = D_1 + e + \Delta h \]
\[ P_2 = D_2 + \gamma e + \Delta h \]
\[ \lambda_1 L_1 = D_1 + \lambda_1 W - e + \Delta h \]
\[ \lambda_2 L_2 = D_2 + \lambda_2 W - \gamma e + \Delta h \]

Ionosphere delay
Emitter - Receiver clocks
Too simple! does not account for biases

Pseudo-range
Phase

Propagation including troposphere and antenna delays
Windup
Integer ambiguities
Key concept

Extended GPS model

\[ P_1 = D_1 + e + \Delta h_P + \Delta \tau_P \]
\[ P_2 = D_2 + \gamma e + \Delta h_P + \gamma \Delta \tau_P \]
\[ \lambda_1 L_1 = D_1 + \lambda_1 W - e + \Delta h + \Delta \tau - \lambda_1 N_1 \]
\[ \lambda_2 L_2 = D_2 + \lambda_2 W - \gamma e + \Delta h + \gamma \Delta \tau - \lambda_2 N_2 \]

Ionosphere delay

Equivalent to a clock per data type and per frequency

Pseudo-range

Phase

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

Jason1 N1 fixing success rate

Julien Day (1/1/1950)

Rate (%)
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

![Graph showing the difference of Xovers RMS per cycle wrt to integer orbit.](image)
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