CENTRE NATIONAL D'ÉTUDES SPATIALES

Zero difference ambiguity fixing for spaceborne GPS receivers

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Introduction

Zero difference ambiguity fixing: a new approach for Precise Point Positioning (PPP) and orbit determination

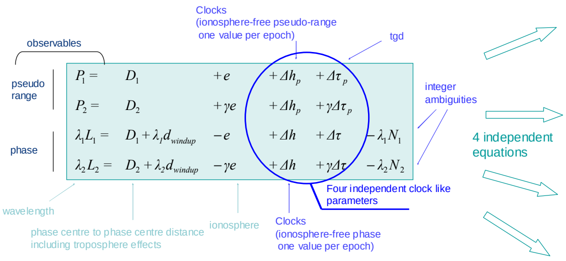
PPP is a powerful technique for positioning, but standard PPP does not take advantage of the integer nature of phase ambiguities.. Phase integer ambiguity fixing is usually only applied to double differenced data in order to eliminate unknown biases and clocks.

Recently, a zero difference ambiguity fixing method has been introduced. This method is based on the fact that some biases in the GPS system are stable enough to perform integer ambiguity fixing on zero difference measurements collected by a network of geodetic dual-frequency receivers. It brings improvement to the overall observability, and to the constellation clock solutions, for time transfer, PPP and LEO orbit determination.

This approach has been successfully applied to ground receiver positioning (ION GNSS 2007), time transfert (EFTF 2008) and real-time processing (ION NTM 2008).

Formulation

Dual frequency semi-codeless receiver, rinex notations, one GPS, one receiver



Clocks
(ionosphere-free pseudo-range
one value per epoch)

tgd

observables

pseudo range

phase

$$\begin{array}{llllll}
P_1 = & D_1 & +e & +\Delta h_p & +\Delta\tau_p & \\
P_2 = & D_2 & +\gamma e & +\Delta h_p & +\gamma\Delta\tau_p & \\
\lambda_1 L_1 = & D_1 + \lambda_1 d_{windup} & -e & +\Delta h & +\Delta\tau & -\lambda_1 N_1 \\
\lambda_2 L_2 = & D_2 + \lambda_2 d_{windup} & -\gamma e & +\Delta h & +\gamma\Delta\tau & -\lambda_2 N_2
\end{array}$$

integer ambiguities

Four independent clock like parameters

wavelength

phase centre to phase centre distance including troposphere effects

ionosphere

Clocks
(ionosphere-free phase
one value per epoch)

4 independent equations

Ionosphere free pseudo-range

$$P_c = D_c + \Delta h_p$$

Clock, satellite *i*

Clock, receiver *j*

notation : $\Delta h = h_j - h^i$

Widelane

integer ambiguity (per pass)

receiver widelane bias (per epoch)

emitter widelane bias (per epoch)

$$f(L_2 - L_1, P_1, P_2) = -N_w + \mu_j - \mu^i$$

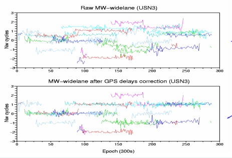
for all measurements on a pass between receiver *j* and emitter *i*

Ionosphere free phase

$$\frac{\gamma\lambda_1 L_1 - \lambda_2 L_2}{\gamma - 1} = D_c + \lambda_c d_{windup} + \Delta h - \lambda_w N_w - \lambda_c N_1$$

Ionosphere content

....



Raw MW-Widelane

MW-Widelane after corrections of satellite biases

Ionosphere free phase with identified integer N_w

integer phase clocks (per epoch)

integer (per pass)

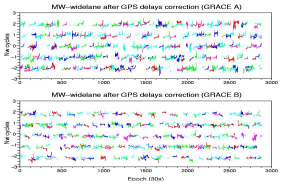
$$Q_c = D_c + \lambda_c d_{windup} + \Delta h - \lambda_c N_1 \qquad \lambda_c = \frac{\gamma\lambda_1 - \lambda_2}{\gamma - 1} \approx 10.7cm$$

various methods can be used to solve these equations :
- double differences or single differences (time transfer on a baseline)
- zero-difference network solution -> advantage: clocks are not eliminated in the process

Resulting clocks have "integer nature", allowing PPP with ambiguity fixing for isolated receivers

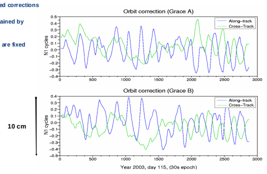
Grace

Grace A and B: Bias-corrected Nw residuals all ambiguities can be fixed



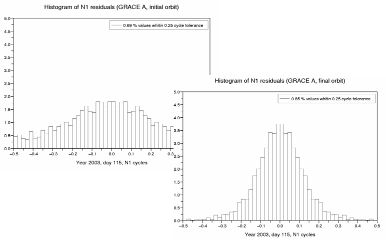
N1 fixing

- **Initial floating solution: JPL orbit from PODAAC website**
  - **3 cm 3D RMS accuracy, not precise enough to observe directly the integer values of N1**
  - **radial component is the most precise**
- **Identification of short-arc orbit corrections to improve the integer characteristics of the N1 ambiguities**
  - **corrections only applied in along- and cross-track directions**
  - **short-arcs are 5 minutes long (ten 30-second sample epochs per arc)**
  - **time-correlated corrections**
- **Integer solution obtained by a bootstrap method**
- **98 % of ambiguities are fixed**



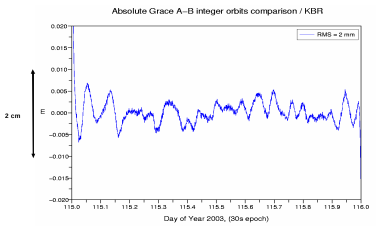
Integer property of the orbit

- **New dynamic solution using unambiguous phase measurements**
- **Improvements of the integer property of the orbit**
  - **Visible on the statistics of single difference residuals between GPS satellites**



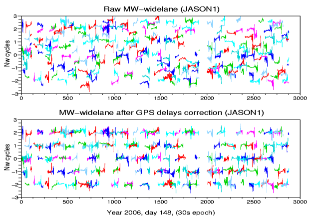
Comparison with the inter-satellite K-band range (KBR)

- **KBR residuals using the Grace A and B ambiguity-fixed absolute orbits**
- **2 mm RMS, close to the best single baseline relative solutions**



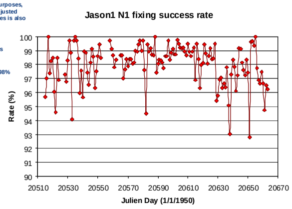
Jason 1

Nw fixing: all ambiguities can be fixed



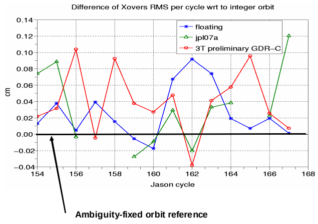
N1 fixing

- **Same strategy as for Grace**
  - **short-arc corrections applied to operational CNES precise orbits (POE)**
  - **ambiguity fixing**
  - **dynamical orbit determination with ambiguities fixed**
  - **for comparison purposes, a solution with adjusted floating ambiguities is also produced**
- **Extended study over 15 Jason-1 10-day cycles (148 days processed)**
- **N1 fixing success rate: 98%**

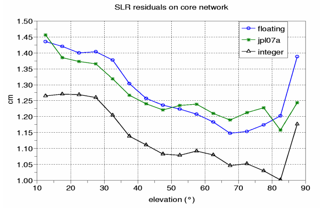


Independent quality check using altimeter cross-over residuals analysis

- RMS altimeter range cross-over residuals analysis
- Relative values with respect to the ambiguity-fixed orbit

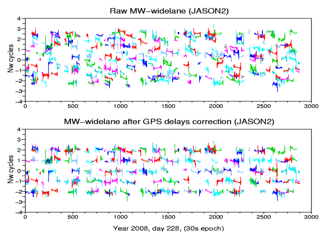


Independent quality check using SLR data: elevation dependant RMS



Jason 2

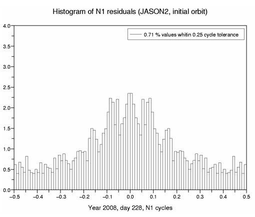
Nw fixing: all ambiguities can be fixed



N1 fixing

- **Same strategy as for Grace**
  - **short-arc corrections applied to operational CNES precise orbits (POE)**
  - **ambiguity fixing**
  - **dynamical orbit determination with ambiguities fixed**
- **One day processing for test purposes**
- **Initial orbit N1 residuals exhibits similar behavior as GRACE or Jason1**
- **N1 fixing procedure used on GRACE and Jason1 does not work: N1 fixing success is 75%**

Single difference residuals between GPS satellites (POE)



Further investigations are needed (see also Poster on GPS Jason 2 measurements processing)

References

Formulation

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