The CNES real time Integer PPP demonstrator

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Introduction

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

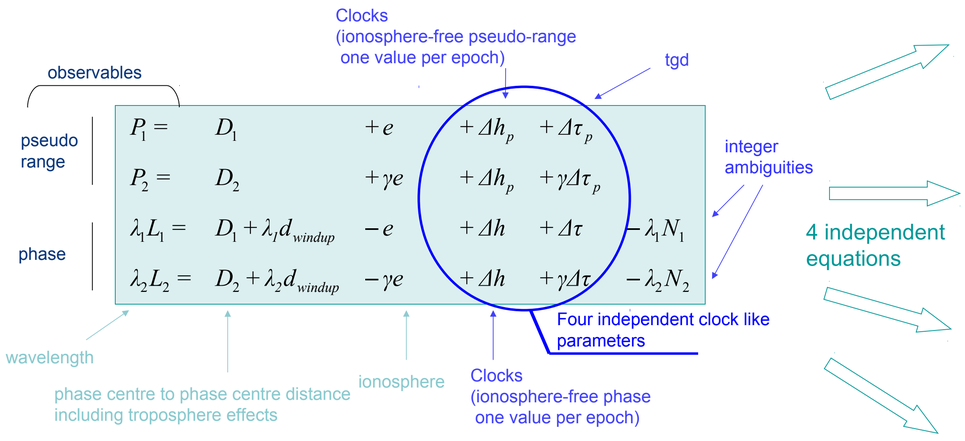
PPP is a powerful technique for positioning, but standard PPP does not take advantage of the integer nature of phase ambiguities.. Phase integer ambiguity fixing is usually only applied to double differenced data in order to eliminate unknown biases and clocks.

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, IGS Workshop 2008, Navigation 2009), and real-time processing (ION NTM 2008, ION ITM 2009, EGU 2010, ION GNSS 2010, ION GNSS 2011).

Formulation

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



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

Ionosphere free pseudo-range

$$P_c = D_c + \Delta h_p$$

Clock, satellite i — Clock, receiver j

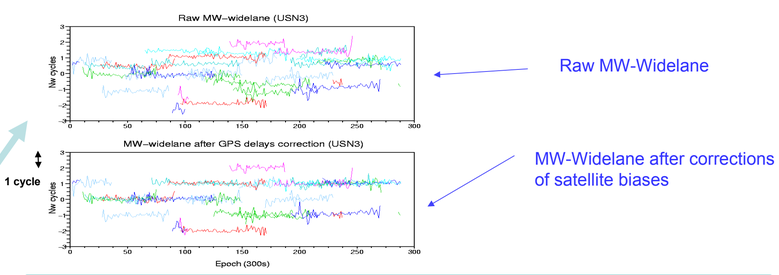
notation : $\Delta h = h_j - h^i$

Widelane

receiver widelane bias (per epoch); integer ambiguity (per pass); emitter widelane bias (per epoch)

$$f(L_2 - L_1, P_1, P_2) = -N_w + h_{w\,j} - h_w{}^i$$

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



Ionosphere free phase

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

Ionosphere content

….

Ionosphere free phase with identified integer N_w

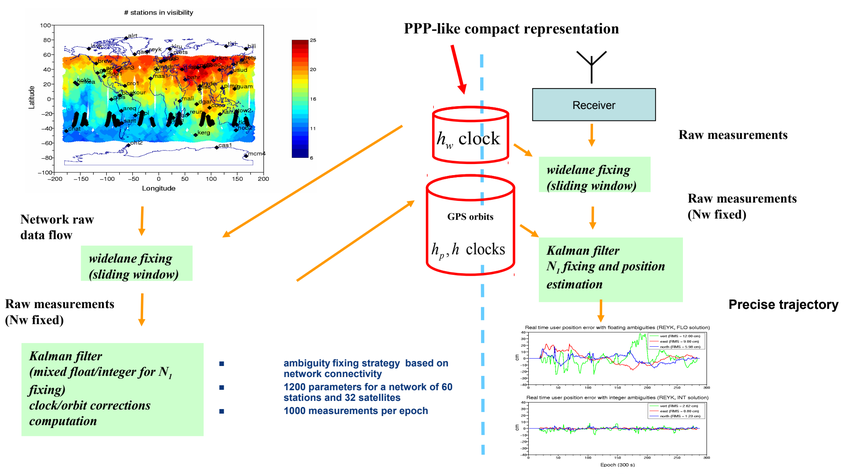
integer phase clocks (per epoch); integer (per pass)

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

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

Implementation of the method in real-time: the CNES real-time integer PPP demonstrator



Network side (orbit and clock estimation) — User side (PPP trajectory)

RTIGS Pilot Project participation

- CNES has developed a demonstrator based on real-time integer PPP
  - PPP-WIZARD: Acronym for "*Precise Point Positioning With Integer And Zero-difference Ambiguity Resolution Demonstrator*"
- In the framework of the RTIGS Pilot Project, the demonstrator has two objectives:
  - To contribute as an analysis center to the improvement of the combined product
  - To provide the full state space representation to users, including additional quantities for integer ambiguity resolution (using our own caster)
- CNES real-time analysis center since January 2011
  - GPS products since January 2011
  - GPS+Glonass products since December 2011
- CNES solution part of the combination since February 2011

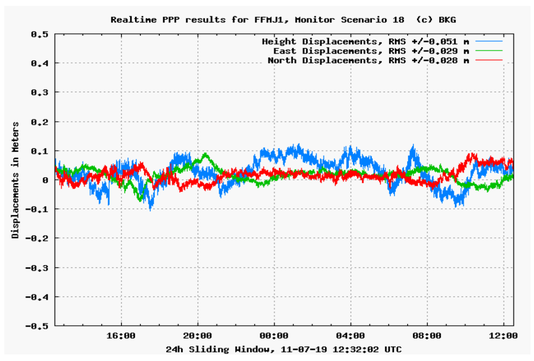
Contents of the demonstrator dynamic web server: www.ppp-wizard.net

- ODTS network monitoring & current status updated in real-time.
- A PPP software modified for real time ambiguity resolution. Freeware, source code available, as well as a precompiled version for windows.
- Free access to real-time products
  - An anonymous access to the orbits/clocks stream dedicated to ambiguity resolution, from the CNES caster (CLK93 mountpoint).
  - A link to the current widelane biases compatible with this orbits/clocks stream.
  - A quick guide (ICD) on how to perform ambiguity resolution using CNES products.
- A set of PPP monitoring stations scenarios
  - Uses the PPP freeware with integer ambiguity resolution.
  - Uses the anonymous real-time stream dedicated to ambiguity resolution.
  - Displays errors in real-time.
- Daily consolidated products, to perform ambiguity resolution off-line (sp3 and clk files).

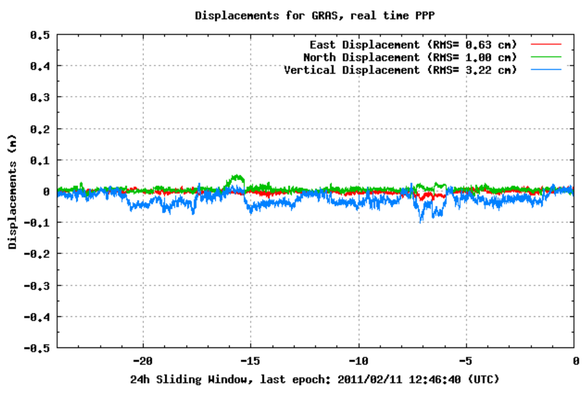
Actual results

Real-time PPP monitoring, floating mode (BKG)

http://igs.bkg.bund.de/ntrip/ppp

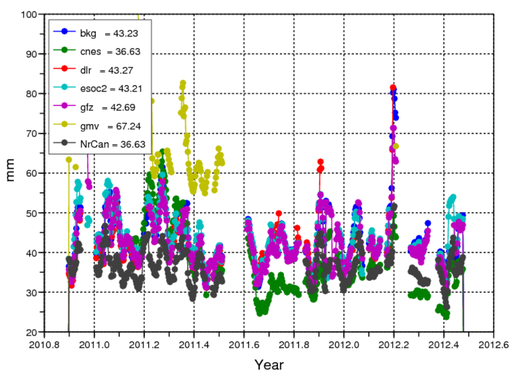


Real-time PPP monitoring with integer ambiguity resolution



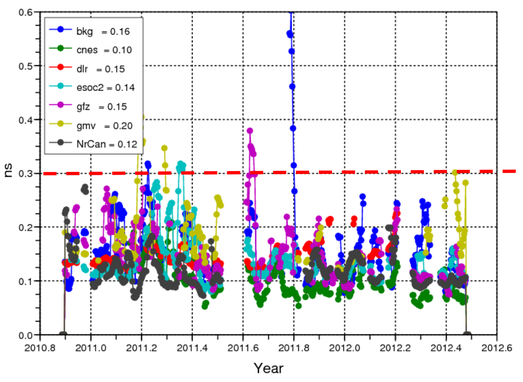
Real Time IGS Pilot Project reports (ESOC), when available
ftp://cddis.nasa.gov/gps/products/rtpp/

Orbits RMS per A.C. (mm)



Orbit quality better than 5 cm
NrCan and CNES solutions slightly better (3.6 cm)

Clocks sigmas per A.C. (ns)



Clocks standard dev. around 0.1 ns
Initial project target 0.3 ns

On-going work: three carrier undifferenced ambiguity resolution

- First step: solve for the extra-widelane ambiguity (N5-N2)
  - Wavelength 5.86 m, straightforward
- Second step: form the key combination : iono-free combination of widelanes in meters

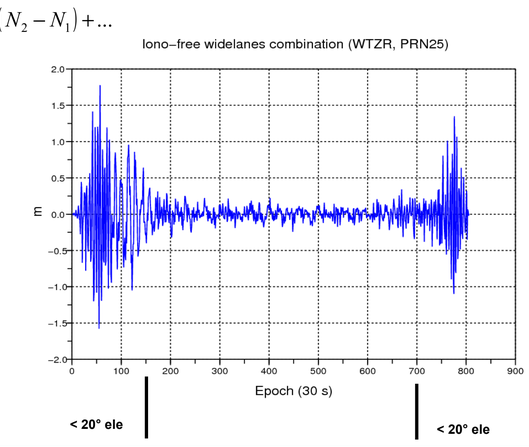
$$f\left[\left(L_3 - L_2\right), \left(L_2 - L_1\right)\right] \approx D + \lambda_w\left(N_2 - N_1\right) + \ldots$$

- Then, the wavelength of the (L1-L2) widelane ambiguity equals 3.4 m easy to solve with the help of the geometry
- Phase amplification factors of this combination:

L1	L2	L5
3.4	-20.7	17.3

- Mainly phase multipath errors
- Strong dependency with elevation

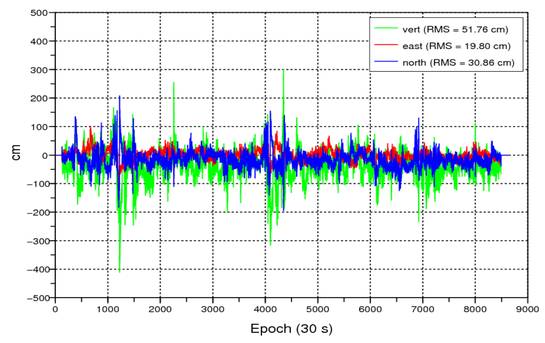
Iono−free widelanes combination (WTZR, PRN25)



PPP using the widelanes combination

- Based on real measurements (BRUS)
- Noise profile based on elevation and real 3-freq. meas.
- Weighting of measurements with a function of elevation
- 10 cm class accuracy
- No convergence time (instantaneous)
- No pseudo-ranges involved (phase only solution)

Real time user position error with integer ambiguities (BRUS)



Advantages and drawbacks of the method (summary)

	PPP 2,3 frequencies	RTK 2,3 frequencies	Integer PPP 2-frequencies	Integer PPP 3-frequencies Widelanes ambiguities only	Integer PPP 3-frequencies All ambiguities
Geometry	Global	Local (< 50 km)	Global	Global	Global
Convergence time (TTFF)	Convergence : < 30 cm Kick start: 1 min static: 15 min dynamic: 30 min	Convergence : ~ 1 cm Instantaneous	Convergence : ~ 1 cm Kick start: 1 min static: 30 min dynamic: 90 min	Convergence : < 30 cm Instantaneous	Convergence : < 1 cm ~5 min
Horizontal accuracy	10-50 cm	~ 1 cm	~ 1 cm	10-50 cm	~ 1 cm

Very promising three-carrier combination !

References

Formulation

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Real time applications

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PPP-Wizard demonstrator

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