Which IGS products for PPP with integer ambiguity fixing ?

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Introduction

Since November 2009, the GRG solution (CNES/CLS IGS analysis center) delivers to the IGS coordinators specific phase clock products (sp3 and clk files), which allow integer ambiguity fixing in PPP mode (IPPP : 'Integer' PPP).

First, the modeling hypotheses using GRG phase clock solution are summarized (use of the widelane Melbourne-Wubbenna, iono-free pseudo-range and phase combinations).
The new parameters necessary to achieve the correct modeling for ambiguity fixing are defined. We follow the definitions given by J. Kouba in 'A GUIDE TO USING INTERNATIONAL GNSS SERVICE (IGS) PRODUCTS'.
A complete example is shown. This can be used to help implementation testing at user level.

Many conventions are possible for the bias/clocks parameters, either definitions close to the initial raw measurements (one bias for each observable), or definitions close to the solved expressions (widelane, pseudo-range and phase iono-free clocks). For example, the current IGS PPP formulation in floating mode is close to the second approach while other igs products (P1P2 biases for example) remain close to the initial observations.

When the IPPP user models are defined, it is simple to combine different orbits/clocks/biases solutions in order to produce the best residual for the user. Some results are shown for the comparison of two independent phase clocks solutions (grg solution and cnes real time solution). This shows that a combined solution can be constructed.

PPP models

Standard PPP iono-free equations (J. Kouba , 2009) :

$$\frac{P_2-\gamma P_1}{1-\gamma} = \rho + c(dT-dt) + T_r + \epsilon_P$$

$$\frac{\lambda_2\phi_2-\gamma\lambda_1\phi_1}{1-\gamma} = \rho + c(dT-dt) + T_r + N\lambda + \epsilon_\phi$$

floating ambiguity; receiver clock offset; satellite clock offset

$$\lambda = \frac{\lambda_2\lambda_1}{\lambda_2+\lambda_1}$$

The modified equations for ambiguity fixing are :

Widelane:

$$\phi_2-\phi_1+a_1P_1+a_2P_2 = K-(\tau_T-\tau_t)$$

PPP:

$$\frac{P_2-\gamma P_1}{1-\gamma} = \rho + c(dT-dt) + T_r + \epsilon_P$$

$$\frac{\lambda_2(\phi_2-K)-\gamma\lambda_1\phi_1}{1-\gamma} = \rho + c(dT_\phi-dt_\phi) + T_r + N\lambda + \epsilon_\phi$$

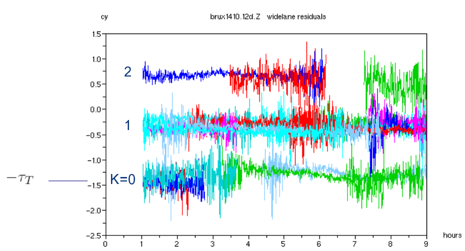
- integer K (one value for each pass) is reported in the phase equation
  satellite widelane bias τ_t is produced by the grg solution
  must be consistent with the phase clock dt_ϕ (clk or sp3 file)
- phase equation now uses phase clocks
- N is an integer
- equations can be solved directly (with ambiguities and receiver clock) or in single difference mode (elimination of receiver clock)

Examples

1 – Widelane residuals

File brux1410.12o
For each pass we apply a preliminary integer correction
to align phase on pseudo-ranges
then the satellite widelane biases from grg solution are applied
(ftp://ftpsedr.cls.fr/pub/igsac/Wide_lane_GPS_satellite_biais.wsb)

Plot : $\phi_2-\phi_1+a_1P_1+a_2P_2-\tau_t$

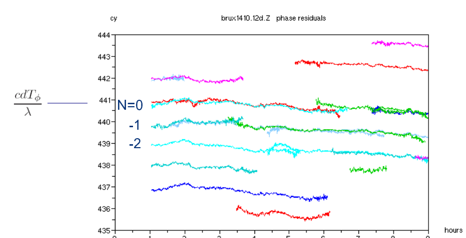


2 – Iono free phase residuals

File brux1410.12o
Identified widelane correction applied (K)

Satellite orbits/clocks from grg solution :
grg16890.sp3 and grg16890.clk

Plot : $\frac{1}{\lambda}\left(\frac{\lambda_2(\phi_2-K)-\gamma\lambda_1\phi_1}{1-\gamma} - \rho + c dt_\phi - T_r\right)$ (cycles)



Remarks :

- ρ must be corrected with phase windup for phase equation
  must be consistent with the convention used for satellite phase clocks
  (definition of satellite axes ant attitude laws)
  grg phase clocks are related to the axis convention of radiation models
  (change between II and IIr)
- 1 cy error in widelane ambiguity fixing produces ~0.5 cy in phase equation $\frac{\lambda_2}{(\gamma-1)\lambda} \approx 3.5$
- a phase clock solution is not unique at receiver level
  one unknown integer bias for all K values
  (global bias goes the receiver widelane bias)
  one unknown integer bias for all N values
  (global bias goes the receiver phase clock)

see solutions combination below

Phase clocks solutions combination

Remark : a standard IGS satellite clock solution is not unique
there is a global bias at each epoch due to choice of the reference clock
(term $c(dT-dt)$)

this is corrected before solution combination

Similar situation occurs for widelane solution, with added characteristics due to the modulo
1 - there is a global widelane bias common to all satellites (floating)
2 - the integer part of each satellite bias is unknown

For the phase solution, it is also necessary to take into account the consistency with the widelane solution part
(radial orbit difference correction is supposed to be applied)

1 - there is a global bias at each epoch for the phase clock (as for standard IGS solutions)
2 - the phase clock floating offset depends on the integer part of the widelane biases
3 - there is an arbitrary integer number of wavelength on each phase clock
(more precisely, each phase clock continuously identified, as for phase measurements)

Complete parametric description of the phase solutions :
solution a and solution b are equivalent for user point of view

solution a	solution b
τ_t^i	$\tau_t^i + k^i$
K	$K - k^i$
cdt_ϕ^i	$cdt_\phi^i - \frac{\lambda_2}{1-\gamma}k^i + \lambda l^i$

k^i and l^i are integer (satellite i)

(the bias/clock term common to all satellites and stations is not shown)

Remarks :

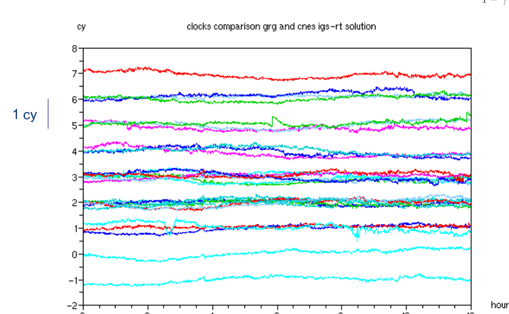
Using the widelane and phase equations (which can always be constructed at user level), all solutions can be compared and combined for PPP user ambiguity fixing.

This is possible for other biases definitions : for example in the case of biases defined for each observable, widelane and iono-free combinations can be constructed and compared.

It is important to use consistent satellite widelane biases along time
(for example the grg daily biases are aligned : no jump between successive daily solutions, k^i term is null)
As a consequence, the only indetermination between two grg clock solutions is an integer number of λ wavelength (this can be observed on overlapping solutions)

Some λ jumps in the phase clocks may remain (complete measurement interruptions at some epochs), this must be taken into account by the PPP user

Example : difference of grg IGS solution (a) and CNES real time solution (b)
widelane integer part differences corrected (k^i) $((cdt_\phi^i)^b - (cdt_\phi^i)^a - \frac{\lambda_2}{1-\gamma}k^i)/\lambda$



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Conclusion

The user equations for PPP with ambiguity fixing are similar to the equations currently used for IGS products. The modeling is identical. The only point to check is the satellite reference frame definition used for windup computation. A convention for these satellite axes must be defined.

Complete results are shown for widelane and iono-free phase equations, in order to help the user to validate the implementation of a PPP solution with ambiguity fixing.

The measurement equations at user level allow a straightforward comparison of any orbits/clocks/biases constellation solution allowing user ambiguity fixing. This is applied on a representative example, for two independent solutions (widelane biases/orbits/phase clocks).