MGEX activities at CNES-CLS Analysis Center

S. Loyer* (sloyer@cls.fr), F. Perosanz**, F. Mercier**, H. Capdeville*
*CLS, Toulouse, France **CNES, Toulouse, France

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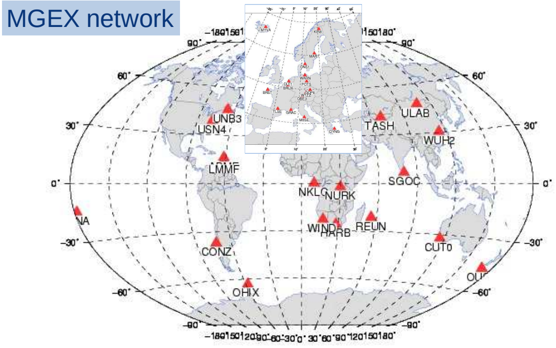
Introduction

The common CNES-CLS team joined the group of the IGS Analysis Centers in 2008. The main motivations are to propose an alternative software (CNES POD GINS), an alternative processing strategy and to participate in the improvement of the combined IGS products. Since the beginning of 2012 (March), multi-GNSS data in RINEX3 format are available in the frame of the IGS-MGEX experiment. We focus here on the hybrid Galileo /GPS orbit processing. We performed several weeks of Galileo orbit and clock restitution using this recently installed MGEX receivers data together with classical IGS network data.
The paper describes the MGEX data used and the different strategies applied to include Galileo/Giove MGEX data in our multi-GNSS un-differenced processing. The obtained preliminary orbits quality is accessed.

MGEX data - GPS

Types	GPS Observations (Rinex3 Code G)	Receivers
GPS type 1	C1C C2W/C2X C5X L1C L2W/L2X L5X	conz cut0 (d153) dlf1 harb kir8 m0se mar7 myva nklg ohix ons1 tlse wtzr
GPS type 2	C1C/C1W C2W/C2X C5X L1C/L1W L2W/L2X L5X	nurk nya2 obe3 ous2 pots sgoc tash ulab wtzz wuh2
GPS type 3	C1C C2W C5X L1C L2W L5X	abmf brst grac lmmf reun
GPS type 4	C1C/C1W C2L/C2W C5Q L1C L2W L5Q	brux usn4
GPS type 5	C1C C2P C5X L1C L2P L5X	gra2
GPS type 6	C1C C2X C5X L1C L2X L5X	grab
GPS type 7	C1C C2W/C2X C5X L1C L2W L5X	gop6 (L2X missing vs type 1)
GPS type 8	C1C/C1W C2P/C2X L1C/L1W L2P/L2X	warn
GPS type 9	C1C C2W/C2X C6I L1C L2W/L2X L7I	cut0 (d119)
GPS type 10	C1C C5Q L1C L5Q	usn5

MGEX network



MGEX data - Galileo

Type	Galileo Observations (Rinex3 Code E)	Receivers
Galileo type 1	C1X C5X C7X C8X L1X L5X L7X L8X	abmf brst cut0 dlf1 grac harb kir8 lmnf mar7 nklg ons1 reun tlse
Galileo type 2	C1X C5X C7X C8Q L1X L5X L7X L8Q	gop6 gra2 m0se myva (type 1 with C8Q in place of C8X)
Galileo type 3	C1C C5Q C7Q C8Q L1C L5Q L7Q L8Q	brux usn4 (type 2 with C5Q/C7Q in place of C5X/C7X)
Galileo type 4	C1X C5X C6X C7X C8X L1X L5X L6X L7X L8X	grab
Galileo type 5	C1X C5X C6X C7X C8Q L1X L5X L6X L7X L8Q	ohix (like grab with C8Q instead of C8X
Galileo type 6	C1X C5X L1X L5X	nurk nya2 obe3 ous2 pots sgoc tash ulab wtzz wuh2
Galileo type 7	C1C C5Q L1C L5Q	usn5
Galileo type 8	C1X C6I C7X C8X L1X L7I/ L7X L8X	cut0 (d119)
Galileo type 9	C1X C5X C7X L1X L5X L7X	gra2 (d119)
Galileo type 10	C1 C5X C7X C8 L1 L5X L7X L8	nklg tlse (d119)
Galileo type 11	C1 L1	warn
Galileo type 12	No Galileo observation	conz wtzr

The different families/kind of data encountered from the various receivers of the MGEX experiment are summarized in the two tables (GPS on the left and Galileo the right). Our preprocessing has been modified accordingly to take into account all these characteristics. The families of receivers marked in grey in the two tables are not used. The headers problems for **cut0** (C6I) **nklg tlse** (C1/L1) are now corrected. The **conz** files contain corrupted data (not compatible with the Rinex3 format). The pseudo-range data set on frequency 1 for IOV2 (E12) is corrupted before June 27, 2012 for the Trimble receivers (red), with constant values or excessively large values. Receivers **gra2 seyg usn5** and **grab** are not yet included in our processing. *(Note: Giove A & B have also PRN numbers 01 & 16 on Leica GRX and 32 & 31 on Septentrio PolarX* files) .

The 32 MGEX receivers providing Galileo L1/L5 data in our processing

	GRAC	TLSE	BRST	MYVA	NYA2	ONS1	MAR7	KIR8	GOP6	TASH	M0SE	DYNG	BRUX	DLF1	POTS	OBE3	WUH2	ULAB	HARB	WIND	NKLG	NURK	UNB3	USN4	OUS2	CUT0	OHIX	FTNA	ABMF	LMMF	REUN	SGOC
E11	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x
E12	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x
E51	x	x	x		x	x	x	x		x		x	x	x	x	x	x	x	x	x		x	x	x	x	x	x		x	x	x	x
E52	x	x	x		x	x	x	x		x		x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x

The 21 MGEX receivers providing Galileo L1/L7 data in our processing

	GRAC	TLSE	BRST	MYVA	NYA2	ONS1	MAR7	KIR8	GOP6	TASH	M0SE	DYNG	BRUX	DLF1	POTS	OBE3	WUH2	ULAB	HARB	WIND	NKLG	NURK	UNB3	USN4	OUS2	CUT0	OHIX	FTNA	ABMF	LMMF	REUN	SGOC
E11	x	x	x	x		x	x	x	x			x	x	x					x		x		x	x		x	x	x	x	x	x	
E12	x	x	x	x		x	x	x	x			x	x	x					x		x		x	x		x	x	x	x	x	x	
E51	x	x	x			x	x	x				x	x	x					x				x	x		x	x		x	x	x	
E52	x	x	x			x	x	x				x	x	x					x		x		x	x		x	x	x	x	x	x	

Data selection

-We process Iono free observations (two frequencies only) covering 4 weeks between GPS week 1692 and 1695
-We use 4 different frequency « couples » in our combined GPS+Galileo processing (either one or the other to avoid correlation between measurements) :

GPS data: **GPS freq. L1/L2** or **GPS freq. L1/L5**
Galileo data: GAL freq. L1/L7 (E5b)
or **GAL freq. L1/L5 (E5a)**

Models

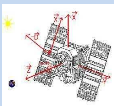
Iono-free GPS + GALILEO Pseudo Range + Phase equations (data from MGEX Network, 32 receivers)

$$\frac{\gamma\lambda_1 L_1 - \lambda_2 L_2}{\gamma - 1} = D + \Delta t + \lambda_c d_{windup} + R$$

$$\frac{\gamma P_1 - P_2}{\gamma - 1} = D + \Delta t + (B_{InterSyst})$$

Iono free Phase fixed GPS equations (data from grg classical network, ~120 receivers) :

$$\frac{\gamma\lambda_1 L_1 - \lambda_2 (L_2 + N_w)}{\gamma - 1} - (\lambda_c d_{windup} - \lambda_c N_1) = D + \Delta t$$



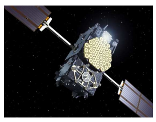
The complete force modeling is the grg-usual one (Loyer et al, 2012) with the same set of empirical forces for GPS and Galileo.
- B&W a priori model for solar pressure and albedo (solar panels only).
- Adjusted empirical coefficients : scale on solar pressure force, Y bias, and once per rev terms in the (B,D) plane (6 parameters).
-Daily arcs (24h + 3h for overlaps)
- Center of phase offsets arbitrarily set to 0 for Galileo(s) , ANTEX08 for GPS

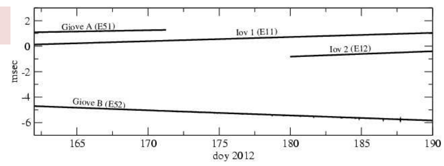
Satellite #	Mass (kg)	Box&Wing
E11	582.8	Solar Panel (13.64 m²)
E12	497.6	Solar Panel (31.0 m²)
E51	700.0	Solar Panel (12.0 m²)
E52	700.0	Solar Panel (12.0 m²)

Main Galileo events (between GPS week 1692 and 1695)

E11 (IOV 1) and E52 (Giove B) are tracked continuously
E12 (IOV 2) : Before the June 27, 2012 we faced with incorrect pseudo range measurements mainly on Trimble receivers. After this date, where an onboard time resynchronization event occurred, the E12 data had been processed correctly.
E51 (Giove A) : Very few data after June 20, 2012 . End of mission June 30.

Observed Galileo satellite clocks →



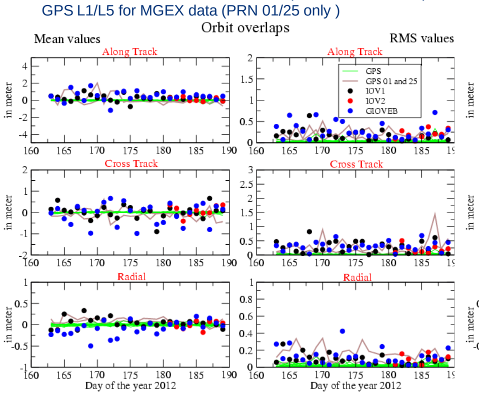


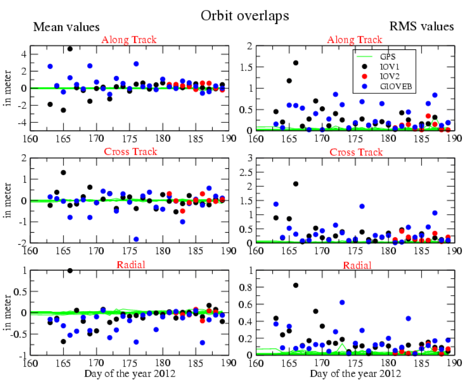
Orbit computation results

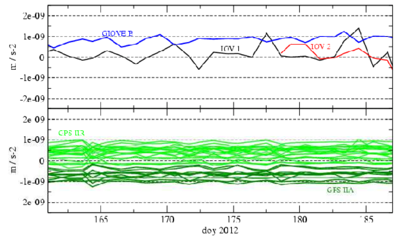
We performed two different processing with combined GPS + Galileo data from IGS classical Rinex2 and MGEX Rinex3:

Processing 1: L1/L2 and L1/L5
GAL L1/L5 for MGEX data (all Galileo satellites)
GPS L1/L2 for IGS and MGEX data (without PRN 01/25)
GPS L1/L5 for MGEX data (PRN 01/25 only)

Processing 2: L1/L2 and L1/L7
GPS L1/L2 for IGS and MGEX data (all GPS satellites)
GAL L1/L7 for MGEX data (all Galileo satellites)



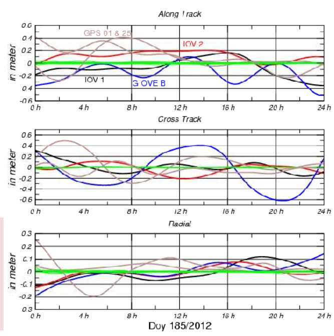




Galileo adjusted Y-biases exhibit larger variations in time in comparison to GPS-ones. This may indicate an inappropriate surface force modeling and/or an insufficient tracking coverage.

RMS	Radial	Cross & Along-track
E11 E12 (Iov 1 & 2)	< 10 cm	< 40 cm
E52 (Giove B)	< 15 cm	~50 cm

Galileo orbit quality estimation



The plots here above represent the unweighted orbits overlaps of Galileo (IOV & Giove B) satellites over the 4 processed weeks (1692-1695). The grg-GPS overlaps (similar to usual grg-official products) are shown (in green) for comparison. For L1/L2 and L1/L5 processing we processed the GPS 01 and 25 with the L1/L5 MGEX data only (with the same network and same observables as for Galileo satellites). In this case, the orbit overlaps (top left) of these two GPS satellites are similar to the Galileo ones indicating that this observed orbit quality can be only due to the sparse data coverage. An independent test giving a good evaluation of the Galileo orbit quality is done by comparing the orbits of the two experiments (rigth plot). The Galileo differences between the two processing are similar to the GPS 01 and GPS 25 differences .The numerical results of orbit evaluation at the end of the period (when the number of station is increasing) are summarized in the table.

Conclusions

The MGEX data allow today to process routinely the Galileo orbits at the decimeter level.
The MGEX network provides more Galileo data on E5a frequency (E5b is not available on ~30% of the network).
Further studies will focus on the dynamical modeling and the handling of the inter-systems biases on the different frequencies.

Reference : Loyer S, Perosanz F, Mercier F, Capdeville H, Marty J.C (2012) Zero-difference GPS ambiguity resolution at CNES-CLS IGS Analysis Center, J of Geod, published on line (April 2012). doi: 10.1007/s00190-012-0559-2