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USE OF SLR OBSERVATIONS TO IMPROVE GALILEO GIOVE-B ORBIT AND CLOCK DETERMINATION

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OVERVIEW

- Introduction
- Considerations
- Scenario description
- Analysis & Results
- Conclusions

INTRODUCTION

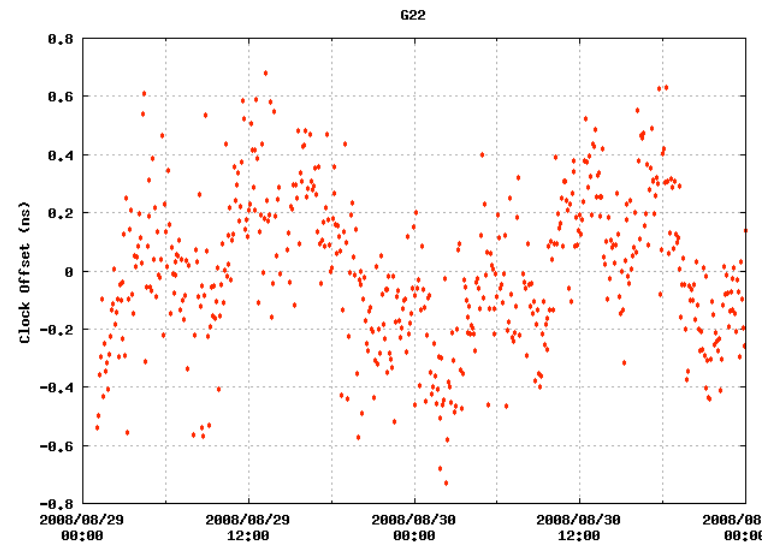
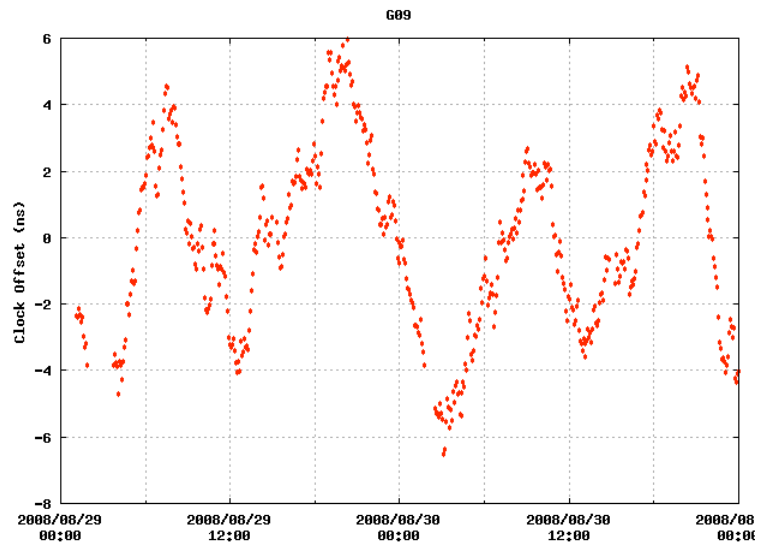
■ **Objective:** ESA has launched two experimental Galileo satellites, GIOVE-A and GIOVE-B, equipped with atomic clocks

→ Try to characterise the behaviour of the GIOVE-B Passive Hydrogen Maser clock (first ever on a satellite).

■ **Background:** GNSS microwave measurements depend on satellite on-board clocks (and on receiver clocks).

- From user point of view, it is important to have predictable (stable) clocks.
- Satellite/station clocks offsets estimated (or eliminated) at each observation epoch (IGS: 5 min). Orbit and clock estimation come usually together.

INTRODUCTION



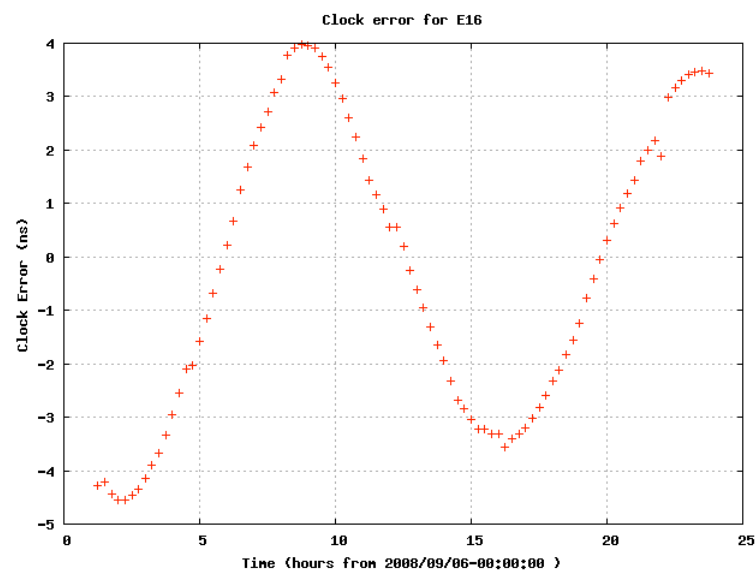
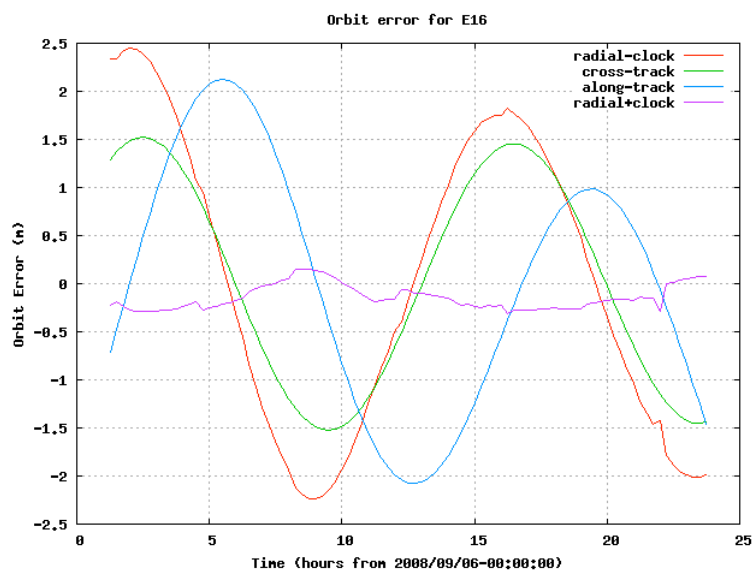
IGS clock estimation after removal of quadratic model.

CONSIDERATIONS: GPS+GIOVE

- Precise clock orbits and clock determination cannot be done processing one or two GIOVE satellites.
- GNSS satellite orbit determination from microwave measurements performs better with a bigger number of satellites [better estimation of receiver clocks] → **Process GPS + Giove-B**
- **Not perfect:** 'signal clocks' at receivers are different for GPS and GIOVE constellations, due to hardware delays. Only constant part is estimated → **some mismodelling.**
- "Signal Clock" = "True Clock" + "HW Delays and Instabilities".

CONSIDERATIONS: USE OF SLR

- Orbit radial direction and clock offsets are correlated. Clock estimation contaminated by orbit errors.
 - Only 13 microwave sensor stations.
- ➔ Use SLR measurements, not dependent on clocks, to help disentangle orbit and clocks.



CONSIDERATIONS: ODTS

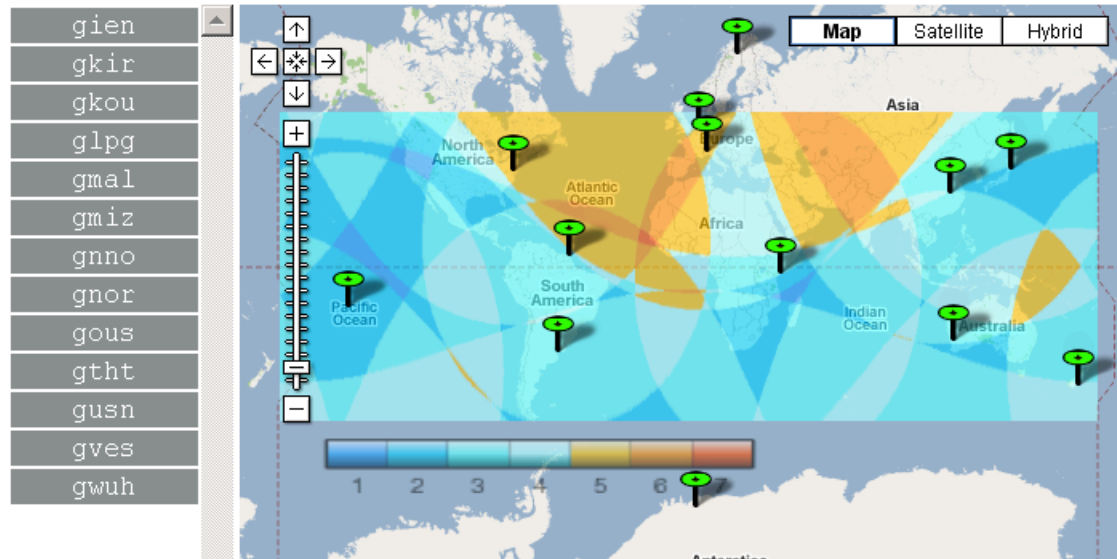
- **ODTS** stands for *Orbit Determination & Clock Synchronisation*
- GPS + Galileo processing:
 - Microwave data from GIOVE global network of stations (GESS) with dual receivers.
 - SLR data of GIOVE satellites from ILRS.
 - Dual receivers inter-system bias to be estimated.
- Two running modes:
 - GPS satellites orbits and clocks are estimated.
 - GPS satellites orbits and clocks fixed to IGS final products.
- Configuration of CoM to CoP of microwave antenna and LRR is very important.

SCENARIO DESCRIPTION (1/3)

- Data span processed: 29th August - 8th September 2008
- Configured satellites: 25 GPS + GIOVE-B
- Channels:
 - GPS: P1/P2 code, L1/L2 phase.
 - GIOVE-B (L1/E5b): C1C/C7Q code, L1C/L7Q phase.
- GIOVE-B using PHM clock during this period
- Arcs length: 2 and 3 days, with overlaps of one day

SCENARIO DESCRIPTION: GESS (2/3)

GIEN	INRiM, Turin
GKIR	Kiruna
GKOU	Kourou
GLPG	La Plata
GMAL	Malindi
GMIZ	Mizusawa
GNNO	New Norcia
GNOR	ESA, Noordwijk
GOUS	Dunedin
GTHT	Tahiti
GUSN	USNO, Washington
GVES	Vesleskarvet
GWUH	Wuhan



- GIEN is the master GSS: defines the reference time.

SCENARIO DESCRIPTION: SLR STATIONS (3/3)

Station	Site Name	Num. Obs.
7237	Changchun	15
7839	Graz	50
7105	Greenbelt	20
7840	Herstmonceux	16
7308	Koganei	5
7110	Monument Peak	5
7825	Mount Stromlo	6
7406	San Juan	41
8834	Wetzell	4
7090	Yagardee	32
7810	Zimmerwald	34

There is a total of 228 SLR observations in the time span considered.

RESULTS [ARC LENGTH = 2d]

	GPS satellites	GIOVE-B
Estimated GPS solutions		
Orbit error wrt IGS (2 days RMS)	10.1 cm	--
Clock error wrt IGS (2 days RMS)	0.60 ns	--
Orbit overlap (1 day RMS)	10.2 cm	14.5 cm
Clock overlap (1 day RMS)	0.25 ns	0.56 ns
GPS fixed to IGS solutions		
Orbit overlap (1 day RMS)	--	14.6 cm
Clock overlap (1 day RMS)	--	0.46 ns

RESULTS [ARC LENGTH = 2d]

Fixing GPS solution to IGS	Without SLR	With SLR
Orbit overlap (RMS)	14.5 cm	12.6 cm
Clock overlap (RMS)	0.46 ns	0.39 ns
Radial - Clock overlap (std)	12.1 cm	10.1 cm
GIOVE-B clock fit residuals	0.29 ns	0.21 ns

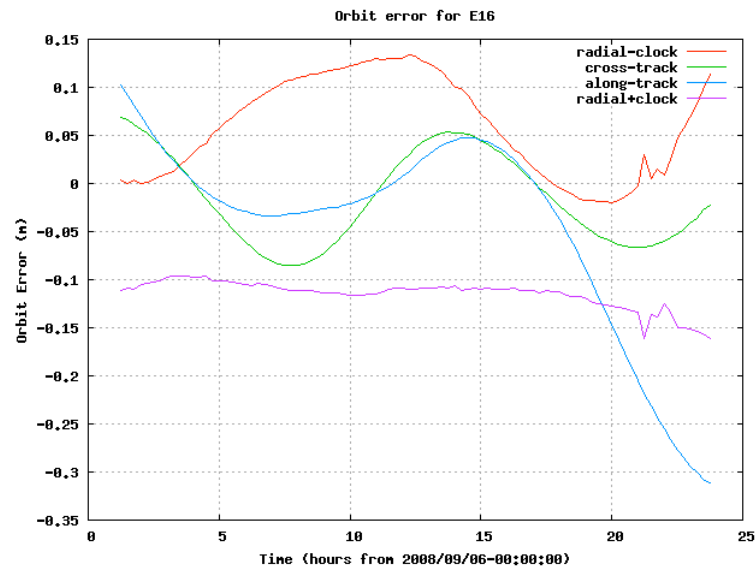
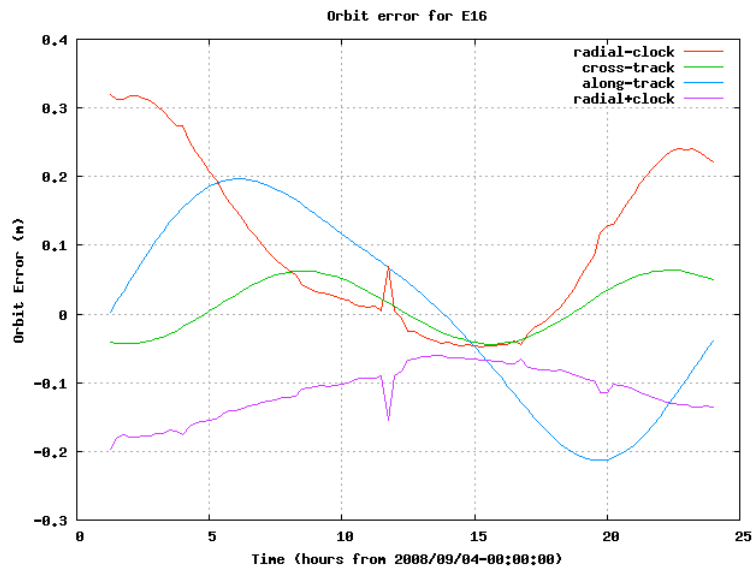
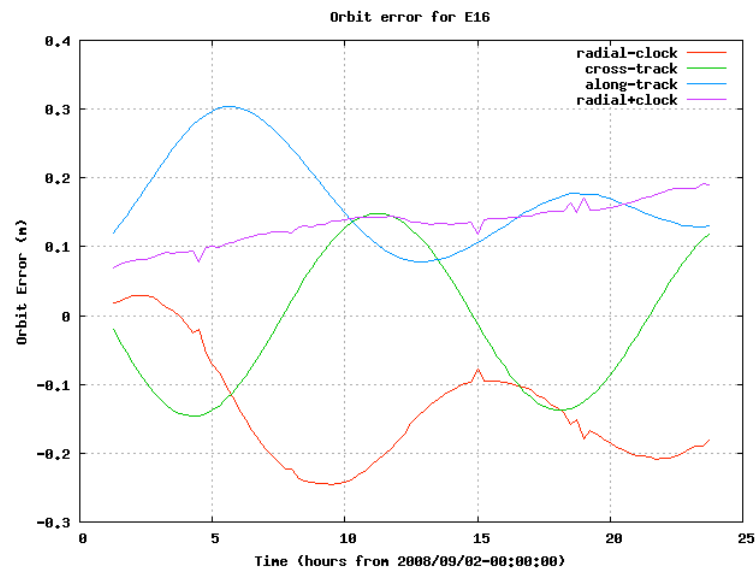
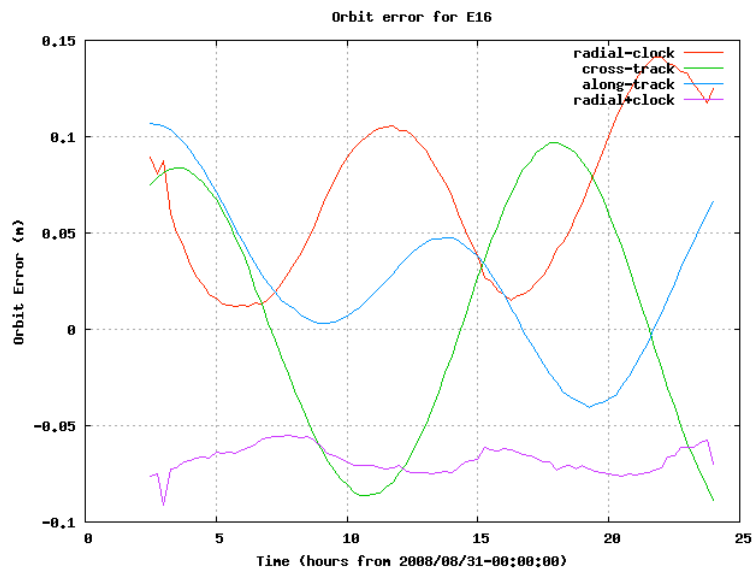
RESULTS [ARC LENGTH = 3d]

	GPS satellites	GIOVE-B
Estimated GPS solutions		
Orbit error wrt IGS (3 days RMS)	10.6 cm	--
Clock error wrt IGS (3 days RMS)	0.61 ns	--
Orbit overlap (1 day RMS)	14.3 cm	10.1 cm
Clock overlap (1 day RMS)	0.29 ns	0.40 ns
GPS fixed to IGS solutions		
Orbit overlap (1 day RMS)	--	8.8 cm
Clock overlap (1 day RMS)	--	0.38 ns

RESULTS [ARC LENGTH = 3d]

Fixing GPS solution to IGS	Without SLR	With SLR
Orbit overlap	8.8 cm	8.6 cm
Clock overlap	0.38 ns	0.38 ns
Radial - Clock overlap (std)	8.5 cm	8.0 cm
GIOVE-B clock fit residuals	0.26 ns	0.23 ns

RESULTS: OVERLAPS



RESULTS: SLR RESIDUALS

Two-way residuals:

	Microwave only	Microwave + SLR
3 days / est GPS	16 cm	12 cm
3 days / fix GPS	18 cm	14 cm

CONCLUSIONS

- Microwave and SLR observations show a good coherency
- Arcs 3 days long preferred
- There is an improvement when using microwave + SLR measurements, specially in the arcs 2 days long
- But probably it is necessary to have more SLR measurements per day in order to have more observability
- Processing of longer periods of data should give more conclusive results



Thank you

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