Consistency of antenna products in the MGEX environment

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IGS Workshop 2017, 4. July 2017

Outline

Galileo IOV Pattern

Evaluation of the IOV patterns
- GNSS inter-system translation biases comparison
- IOV orbit comparison

Chamber calibrated receiver stations
- Availability from EPN
- Inter-system translation biases

Conclusion

Galileo IOV Pattern

- Officially disclosed by ESA (December 2016)
- Chamber calibrated PCO and PCV for the 4 IOV satellites (SVN 101-104)
- 3 IOV satellites currently active (E11, E12, E19)
- Goal: Impact of the released patterns compared to the current IGS values (estimations) (based on MGEX solutions)

Table: Ionosphere-free linear combination PCO (L1/L5) [m]

SVN (PRN)	E	N	U
IGS (IOV)	-0.1700	0.0300	0.9500
101 (E11)	-0.1688	0.0344	0.8369
102 (E12)	-0.1742	0.0325	0.9242
103 (E19)	-0.1737	0.0323	0.8237

Galileo IOV Pattern

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Table: Difference IOV-IGS PCO (IF: L1/L5) [m]

SVN (PRN)	E	N	U
IGS (IOV)	-0.1700	0.0300	0.9500
101 (E11)	0.0012	0.0044	-0.1131
102 (E12)	-0.0042	0.0025	-0.0258
103 (E19)	-0.0037	0.0023	-0.1263

Galileo IOV Pattern

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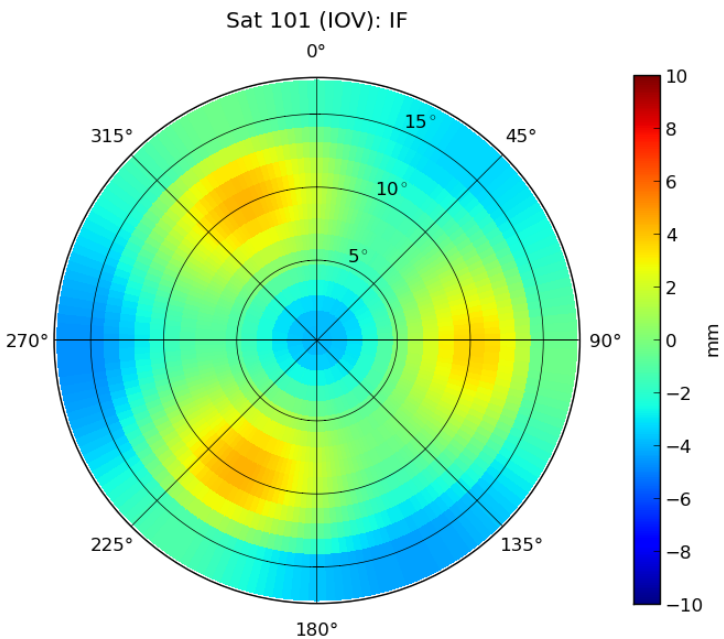

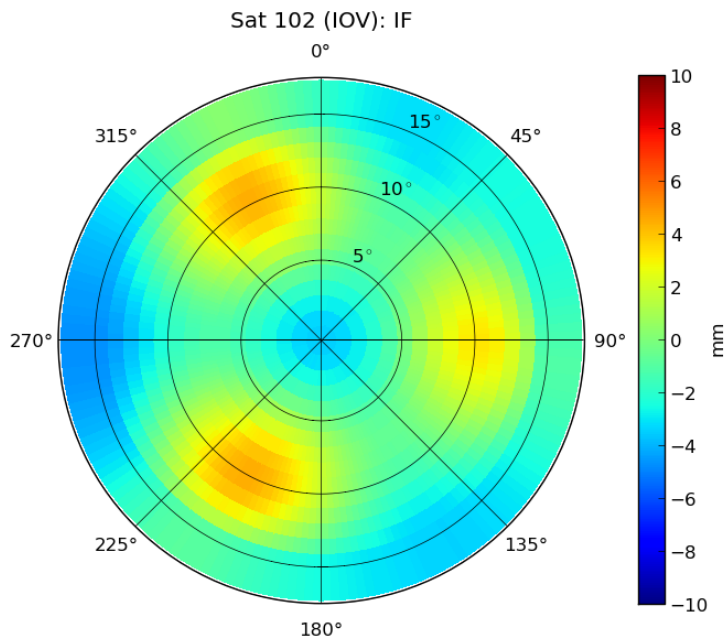

Evaluation of the IOV patterns

- Orbit comparison between IGS PCO and released IOV PCOs and PCVs
- Introducing station-wise inter-system translation biases (GTRA) One set for FOC and one set for IOV satellites
- Solutions based on MGEX (140 stations) for doy 60 to 120 in 2017

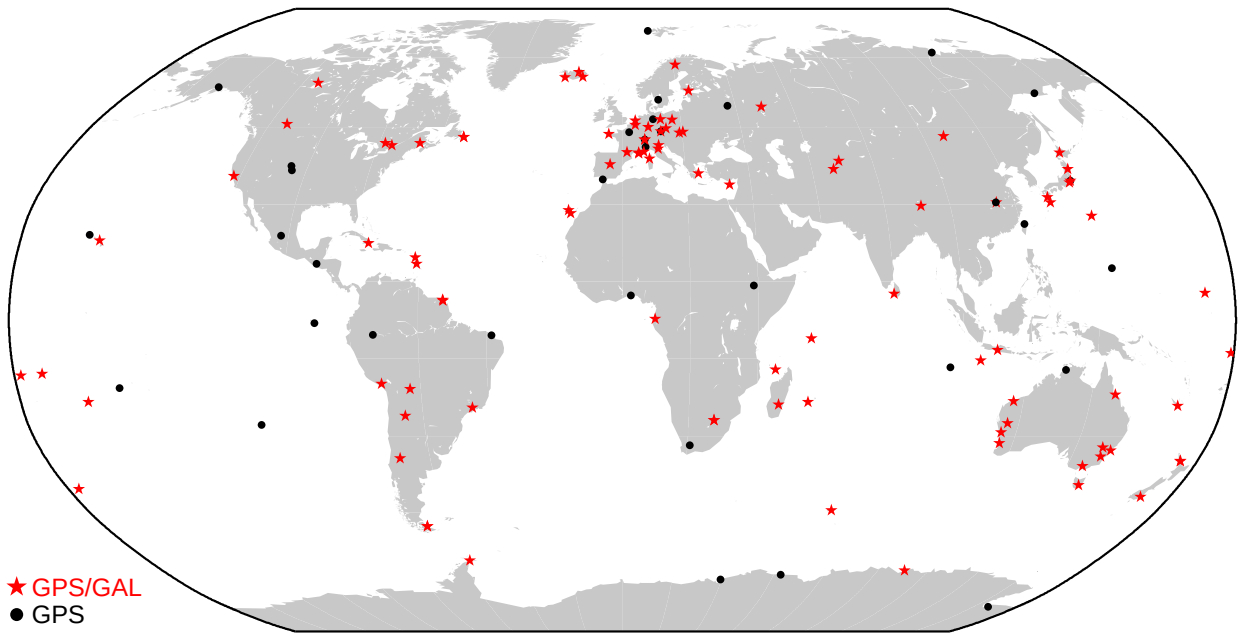

Figure: Used MGEX network for day 2017-060

Evaluation of the IOV patterns

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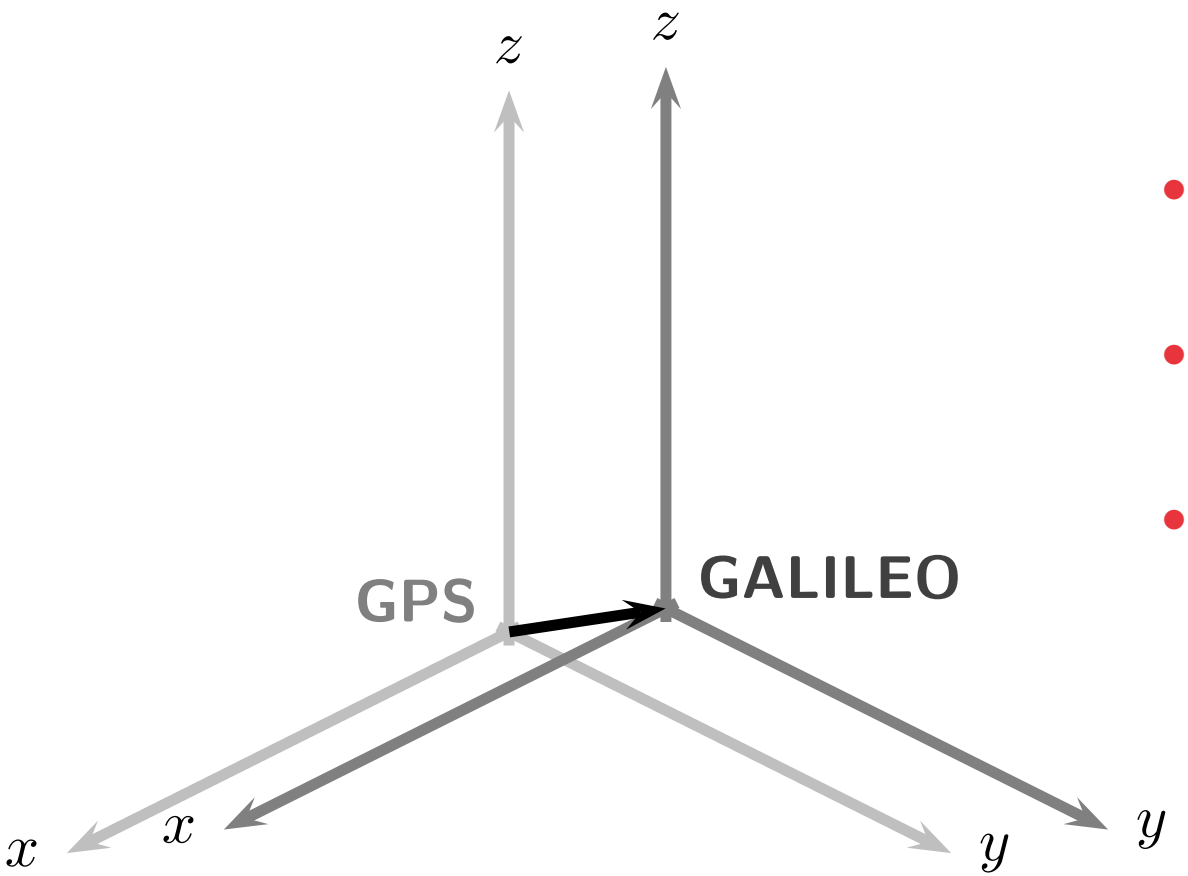
4 Test scenarios:

Description	used for
MGEX solution: IGS PCOs, no GTRAs	orbit comparison
Scenario 1: IGS PCOs, GTRAs	GTRAs comparison
Scenario 2: IOV PCO and PCV, no GTRAs	orbit comparison
Scenario 3: IOV PCO and PCV, GTRAs	GTRAs comparison

Inter-system translation biases (GTRA)

- Orbit-Solution (double-difference): Zero mean condition applied: translation and rotation
- PPP-Solutions: No constrains applied



- **Station coordinates from GPS-only**
- **Station coordinates from GALILEO–only**
- **Vector between GPS– and GALILEO–coordinates**

Orbit comparison between IGS and IOV patterns

- Comparison between IGS and IOV pattern solutions for doy 60 in 2017

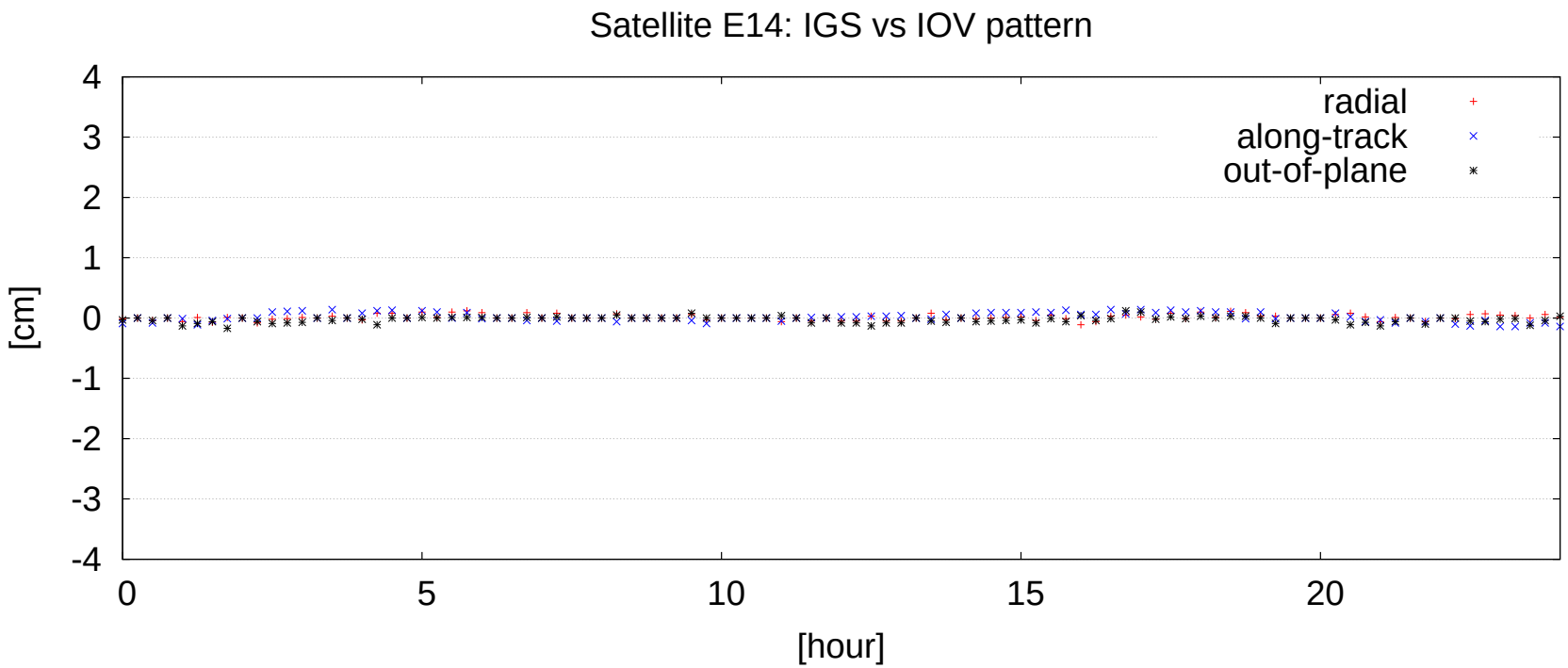


Figure: PCO difference between solutions: 0.0cm

Orbit comparison between IGS and IOV patterns

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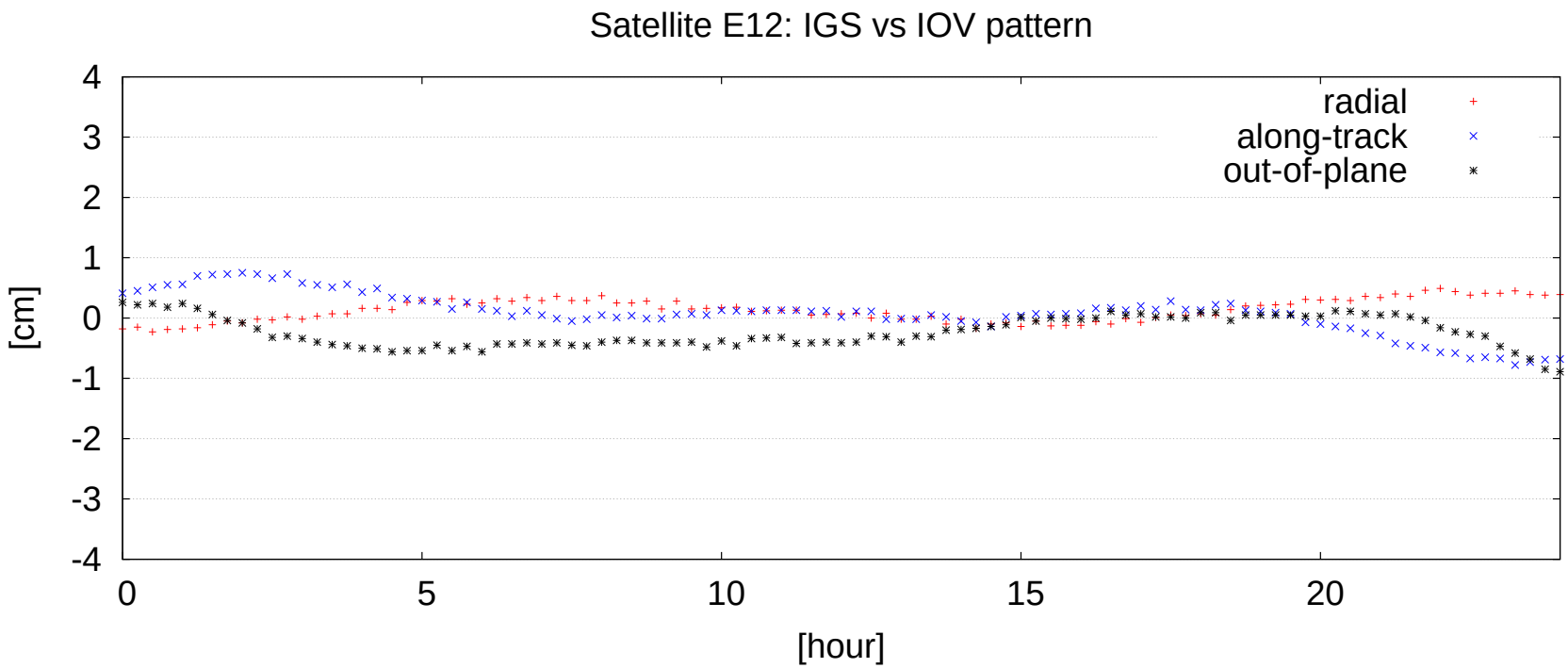

Figure: PCO difference between solutions: 2.6cm

Orbit comparison between IGS and IOV patterns

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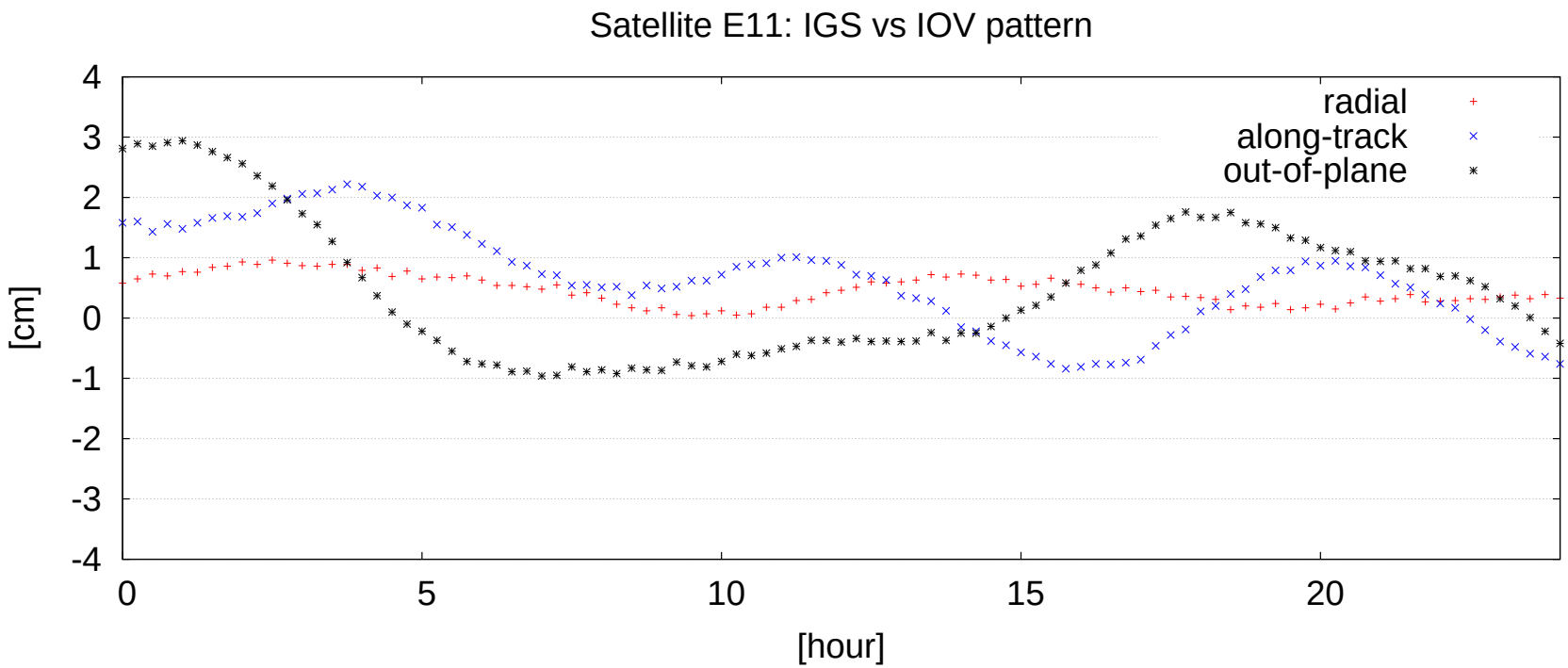


Figure: PCO difference between solutions: 11.3cm

Orbit comparison between IGS and IOV patterns

- Comparison between IGS and IOV pattern solutions for doy 60 in 2017

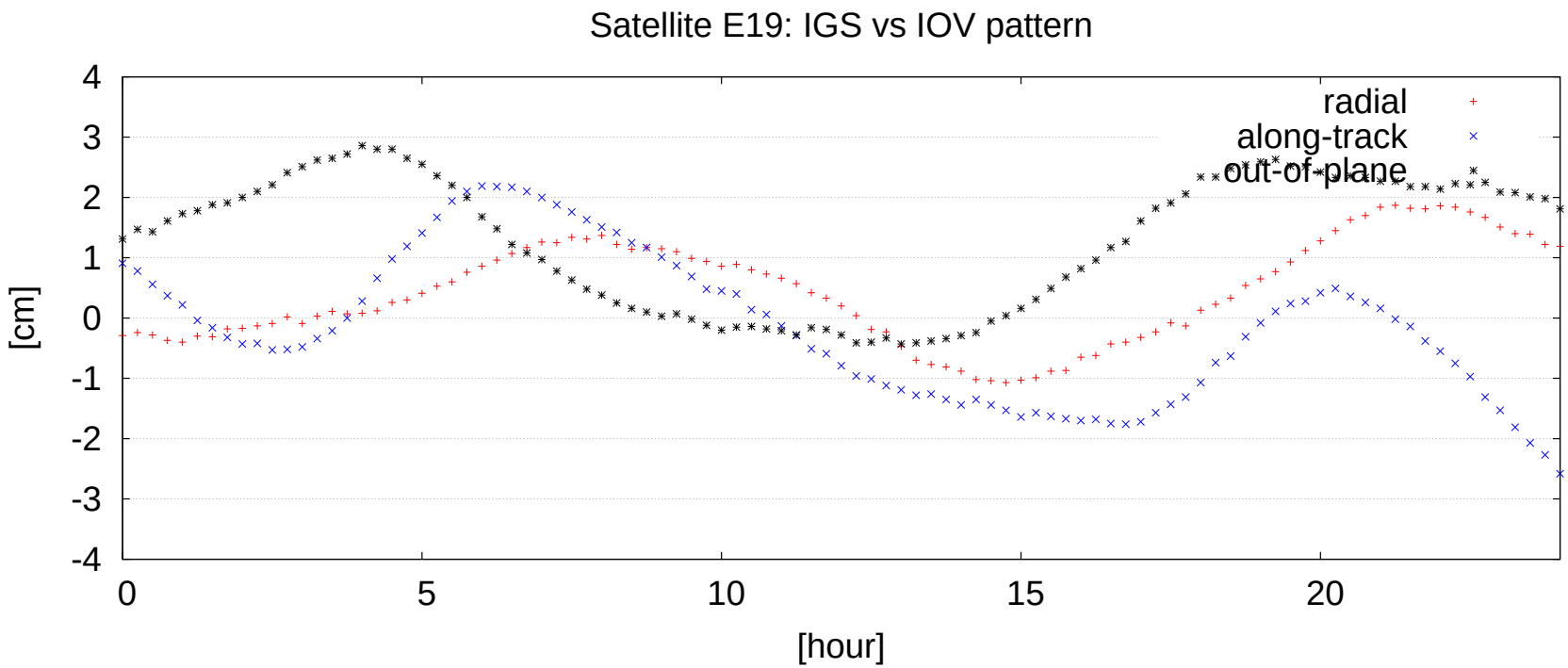


Figure: PCO difference between solutions: 12.6cm

Midnight epoch overlaps

- Overlap between midnight epochs of one day arcs
- Comparison between MGEX solution and IOV pattern solution

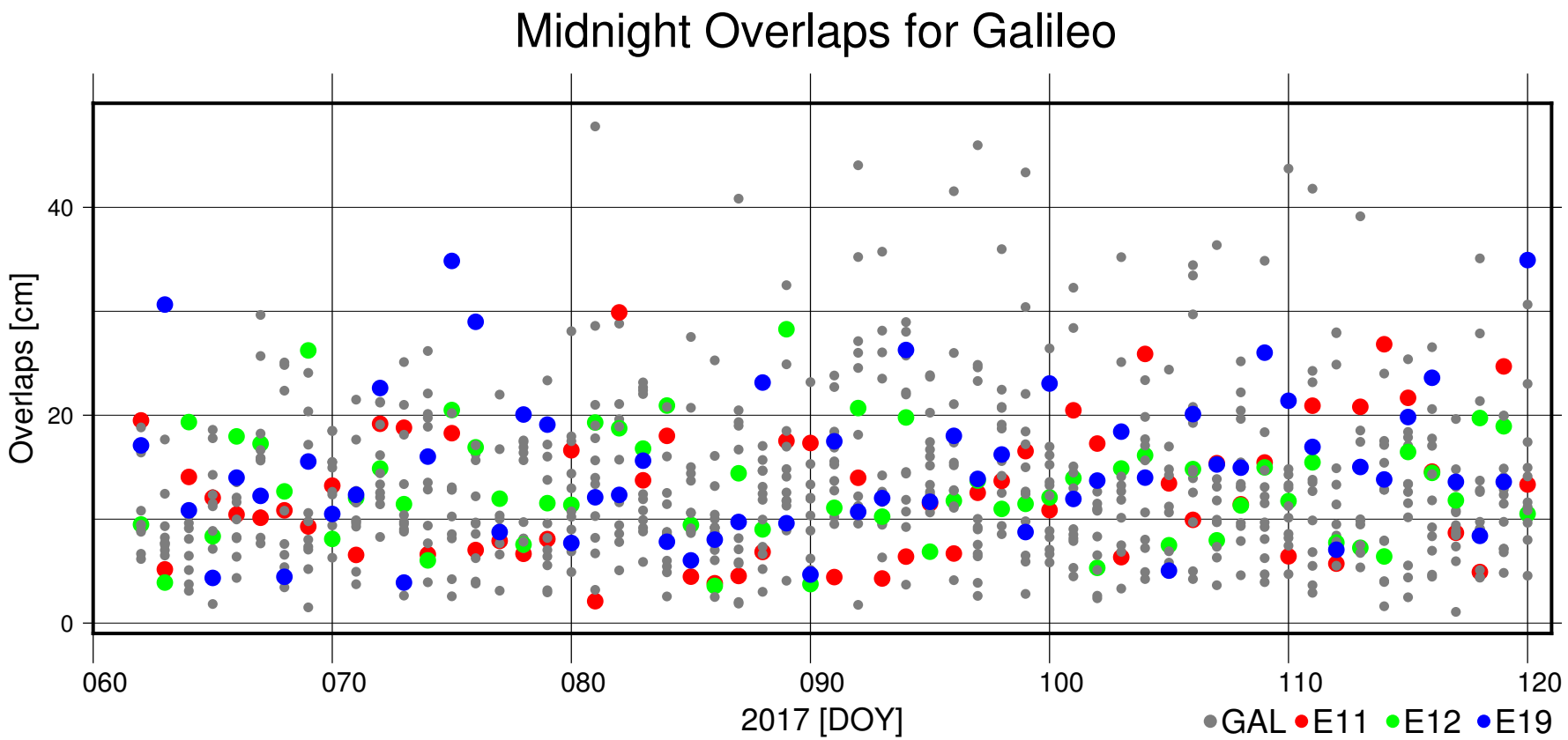


Figure: Midnight overlap of all Galileo satellites (using IGS PCOs)

Midnight epoch overlaps

- Overlap between midnight epochs of one day arcs
- Comparison between MGEX solution and IOV pattern solution

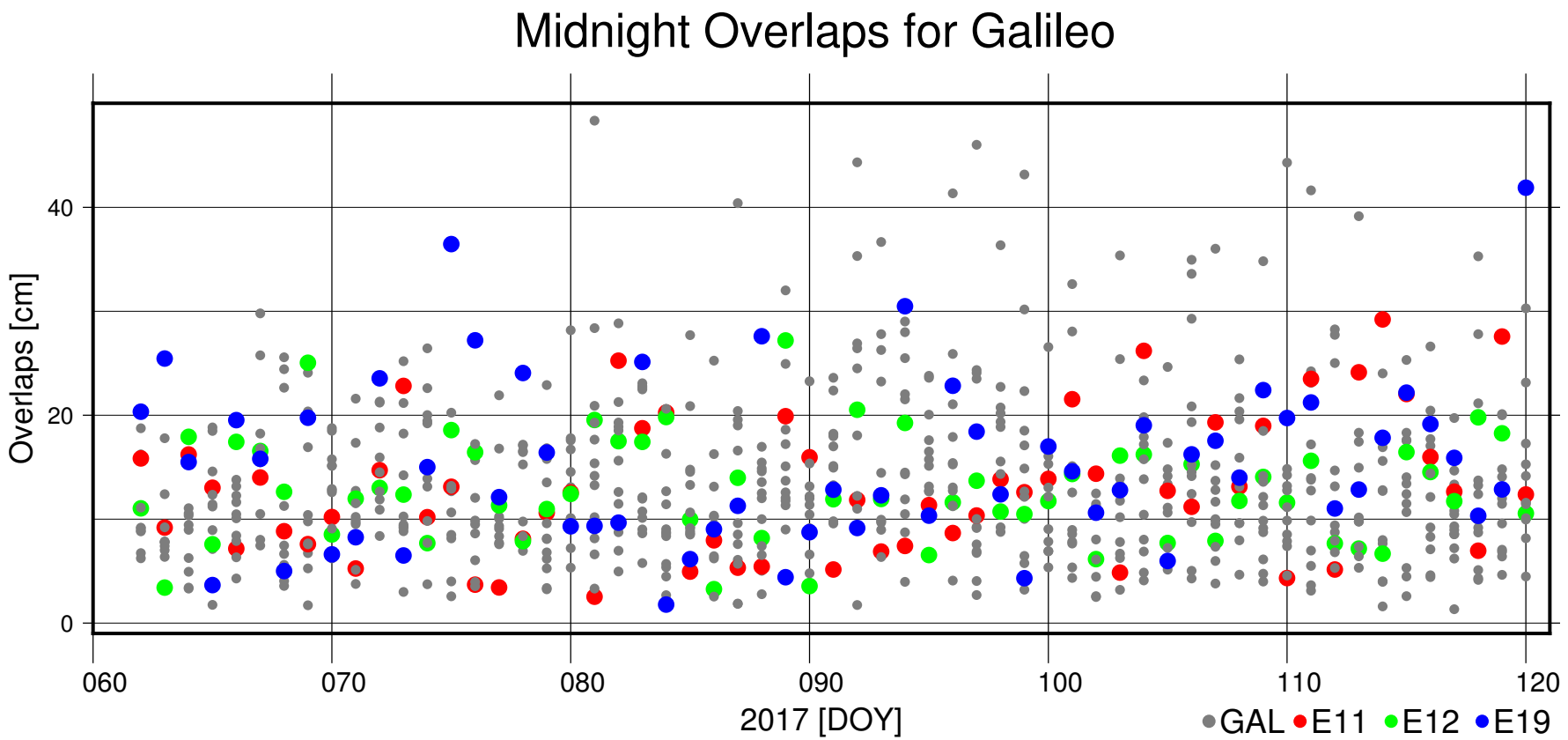


Figure: Midnight overlap of all Galileo satellites (using IOV PCOs and PCVs)

Midnight epoch overlaps

- Overlap between midnight epochs of one day arcs
- Comparison between MGEX solution and IOV pattern solution

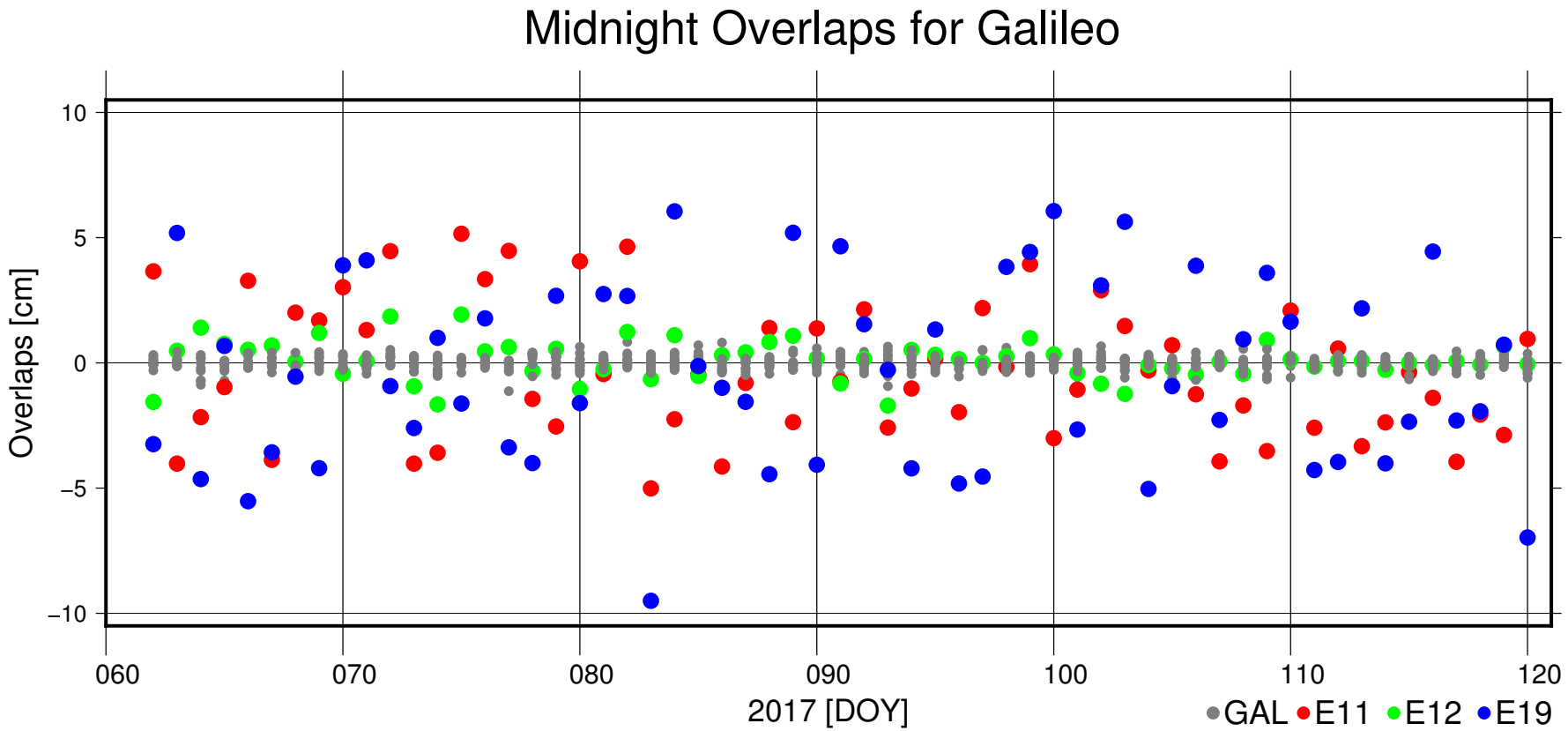


Figure: Midnight overlap of all Galileo satellites: Difference IGS - IOV

GNSS inter-system translation biases comparison

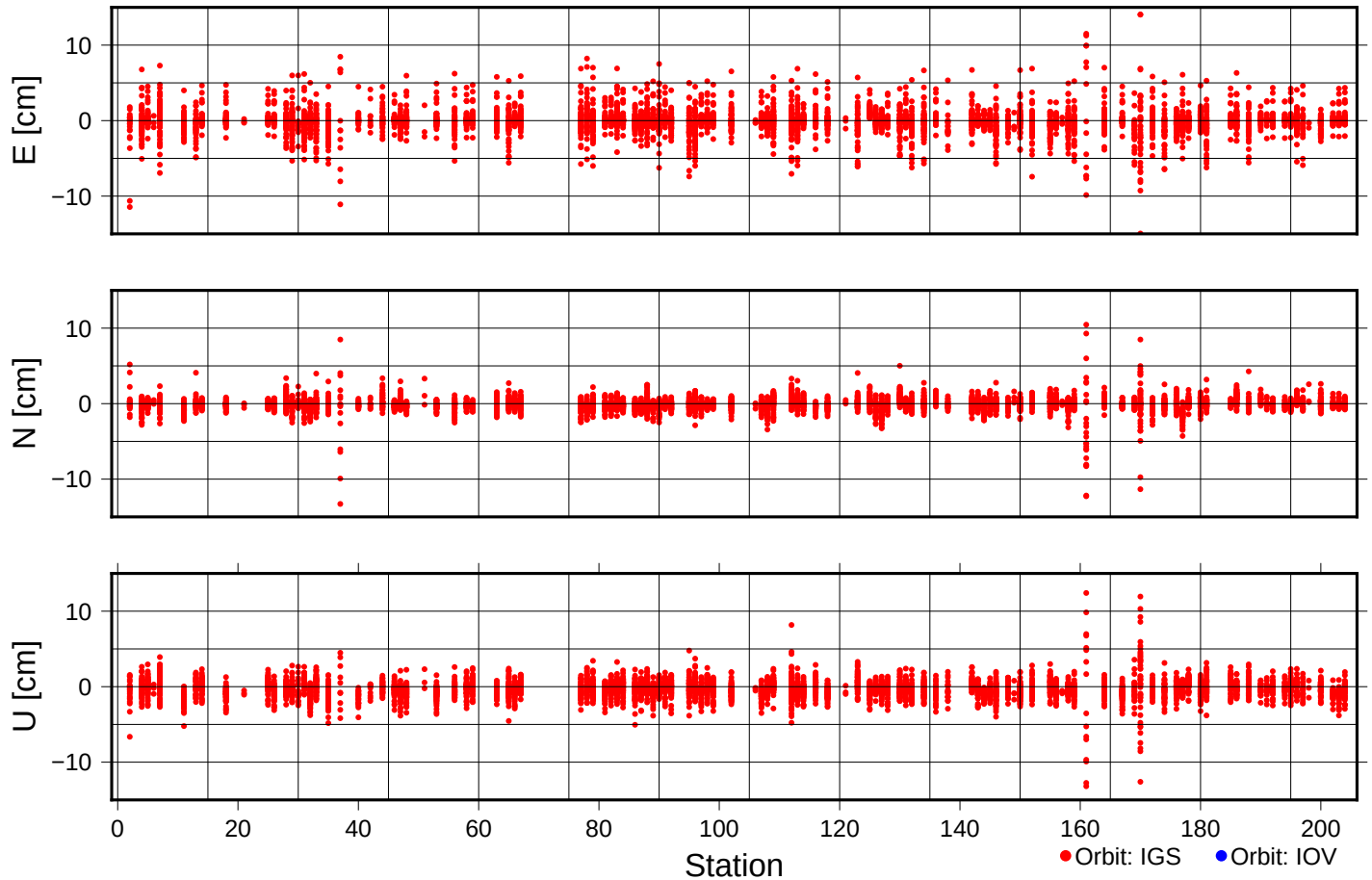
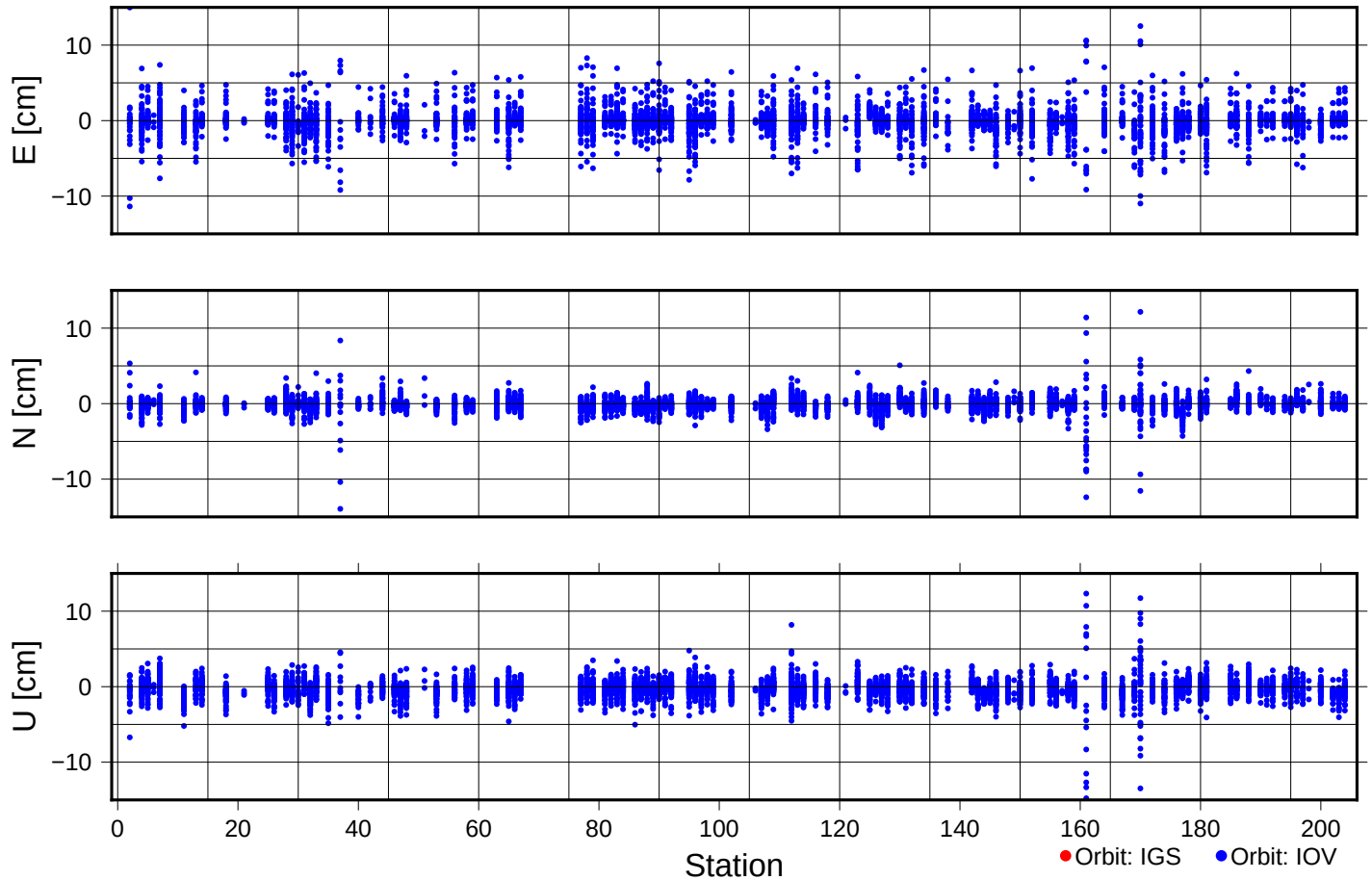


Figure: Galileo FOC satellites , PCO/PCV: IGS

GNSS inter-system translation biases comparison



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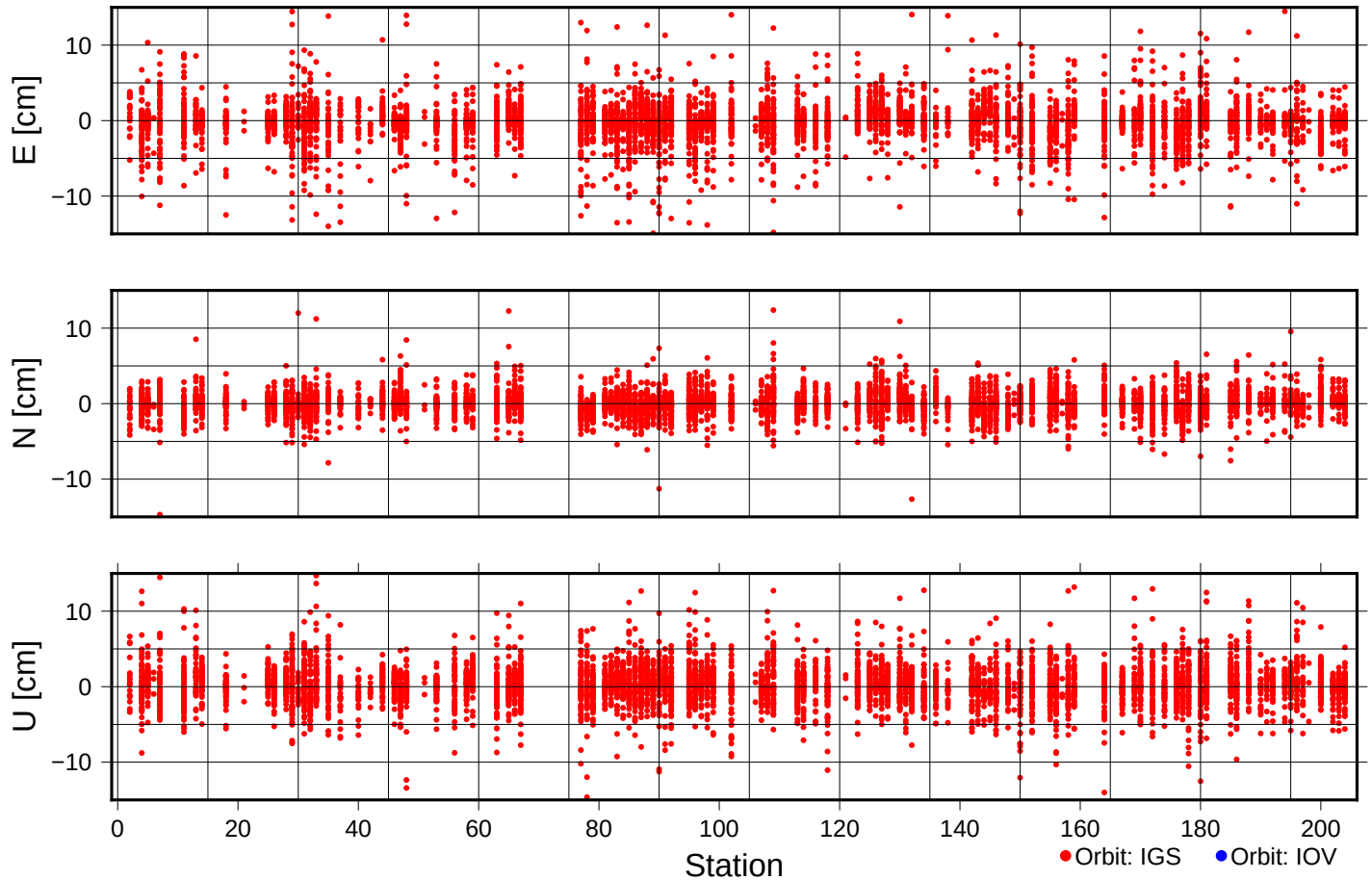


Figure: Galileo IOV satellites , PCO/PCV: IGS

GNSS inter-system translation biases comparison

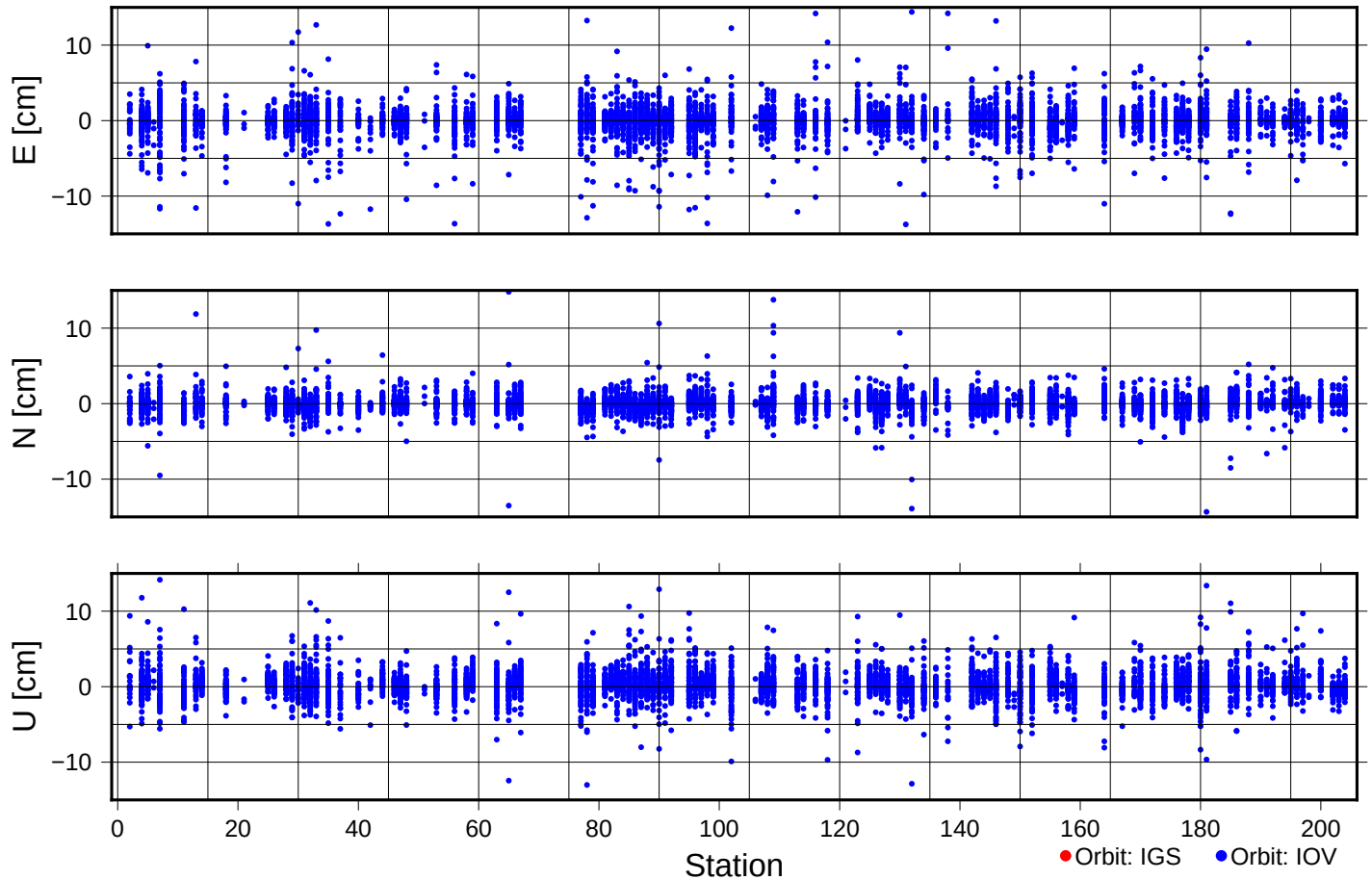


Figure: Galileo IOV satellites PCO/PCV: IOV

GNSS inter-system translation biases comparison

Table: Average inter-system bias for Galileo (except IOV) in cm

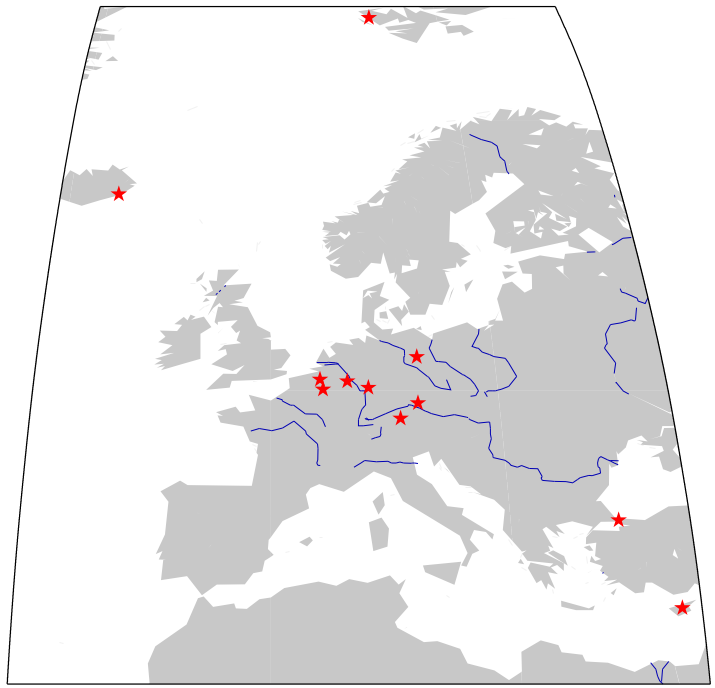
Sol	East	North	Up	σ_{East}	σ_{North}	σ_{Up}
IGS	-0.97	-0.53	-5.83	20.37	8.51	15.97
IOV	-0.92	-0.53	-5.83	20.76	8.62	16.01
DIF [%]	5.0	-0.7	0.1	-1.9	-1.3	-0.3

Table: Average inter-system bias for IOV satellites (E11,E12,E19) in cm

Sol	East	North	Up	σ_{East}	σ_{North}	σ_{Up}
IGS	-2.19	-0.15	2.27	32.02	16.56	33.10
IOV	-0.96	-0.23	1.70	22.54	11.47	19.69
DIF [%]	56.1	-59.1	24.9	29.6	30.7	40.5

Chamber calibrated receiver stations

- Individual calibrated EUREF ANTEX file contains 12 chamber calibrated antennas with frequency L5
- Impact of using L5 antenna pattern instead of L2
- Estimation of Inter-System Translation Bias for Galileo and IOV satellites using either L1/L2 or L1/L5 pattern.



Chamber calibrated antenna patterns

Ionosphere-Free Linear Combination

- Galileo: IGS is using L1/L2 patterns (taken from GPS)
- No Galileo patterns available
- EUREF: 12 chamber calibrated antenna patterns available
- Difference of L1/L2 and L1/L5 PCOs between -1 and -10 mm

STA	Antenna type	PCO (IF) L1 / L2 [mm]	PCO (IF) L1 / L5 [mm]	Δ PCO [mm]
BRUX	JAVRINGANT_DM NONE	65.19	56.62	-8.56
POTS	JAV_RINGANT_G3T NONE	48.97	39.75	-9.22
OBE4	JAV_RINGANT_G3T NONE	49.18	39.28	-9.90
NYA2	JAV_RINGANT_G3T NONE	50.40	41.17	-9.23
BADH	LEIAR10 NONE	96.22	94.74	-1.49
WRLG	LEIAR25.R3 LEIT	151.72	148.89	-2.84
DOUR	LEIAR25.R3 NONE	146.59	143.55	-3.04
REYK	LEIAR25.R4 LEIT	149.68	145.31	-4.36
HOFN	LEIAR25.R4 LEIT	149.12	144.92	-4.20
NICO	LEIAR25.R4 LEIT	148.09	143.56	-4.54
EUSK	LEIAR25.R4 LEIT	149.52	145.20	-4.32
ISTA	LEIAR25.R4 LEIT	155.77	149.24	-6.53

Chamber calibrated antenna patterns

Ionosphere-Free Linear Combination

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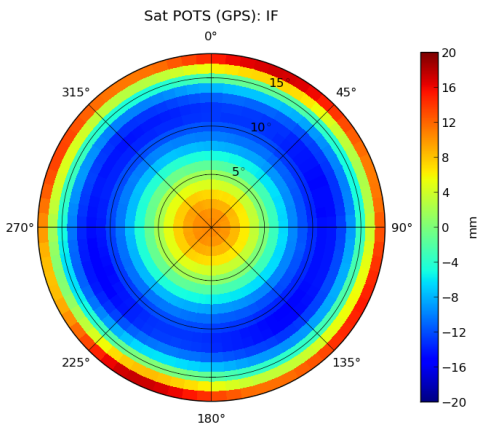

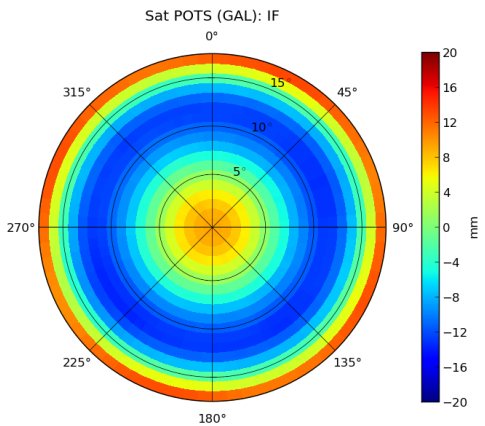

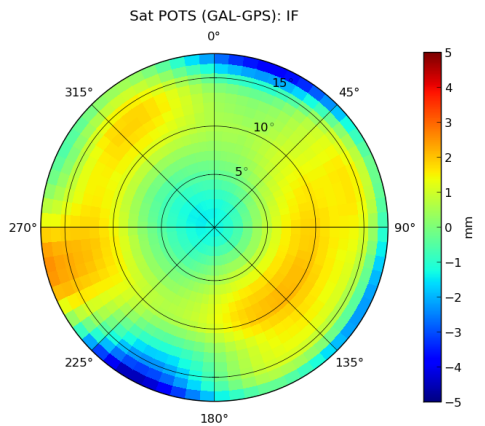

Inter-system translation biases: PPP

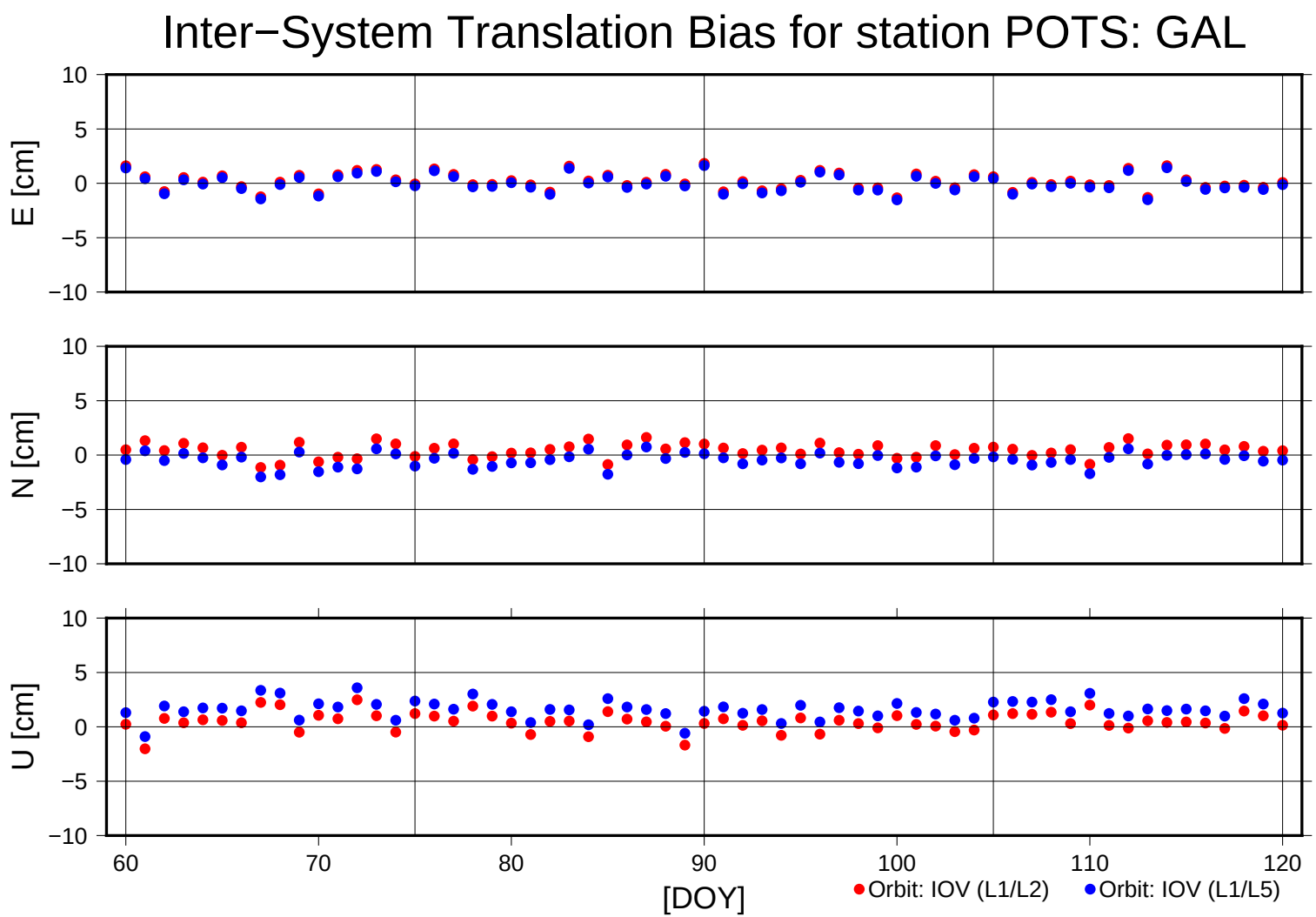

Figure: Galileo Inter-system translation bias: Station POTS

Inter-system translation biases

STA	Antenna type *Used PCO and PCV:*	GTRA L1/L2 [mm]	GTRA L1/L5 [mm]	Δ GTRA [mm]	Δ PCO [mm]
BRUX	JAVRINGANT_DM NONE	3.7	15.0	-11.3	-8.56
POTS	JAV_RINGANT_G3T NONE	4.9	15.9	-11.0	-9.22
OBE4	JAV_RINGANT_G3T NONE	5.6	17.1	-11.5	-9.90
NYA2	JAV_RINGANT_G3T NONE	-0.8	7.1	-7.9	-9.23
BADH	LEIAR10 NONE	10.2	13.5	-3.3	-1.49
WRLG	LEIAR25.R3 LEIT	7.6	15.7	-8.1	-2.84
DOUR	LEIAR25.R3 NONE	-	-	-	-3.04
REYK	LEIAR25.R4 LEIT	2.3	10.3	-8.0	-4.36
HOFN	LEIAR25.R4 LEIT	2.9	10.1	-7.2	-4.20
NICO	LEIAR25.R4 LEIT	7.9	16.2	-8.3	-4.54
EUSK	LEIAR25.R4 LEIT	10.0	18.1	-8.1	-4.32
ISTA	LEIAR25.R4 LEIT	6.5	14.6	-8.1	-6.53

Conclusion

Galileo IOV Pattern tests:

- no orbit improvement or degradation
- improved IOV-translation bias repeatability with released pattern
- Recommendation to introduce IOV PCOs (and PCVs) within the MGEX community

Test of chamber calibrated receiver antennas (EPN)

- L5 frequency PCO and PCV pattern are necessary (also for other frequencies)