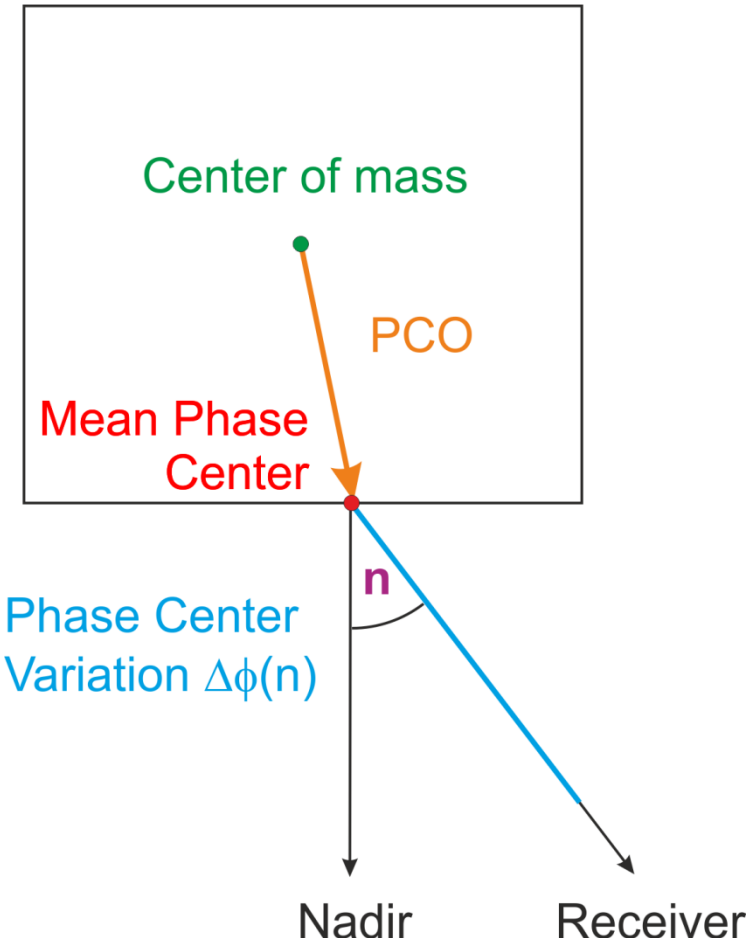
Galileo Satellite Antenna Modeling

Peter Steigenberger, Oliver Montenbruck
German Space Operations Center (DLR/GSOC)

Rolf Dach, Lars Prange
Astronomical Institute, University of Bern (AIUB)

GNSS Satellite Antenna Modeling



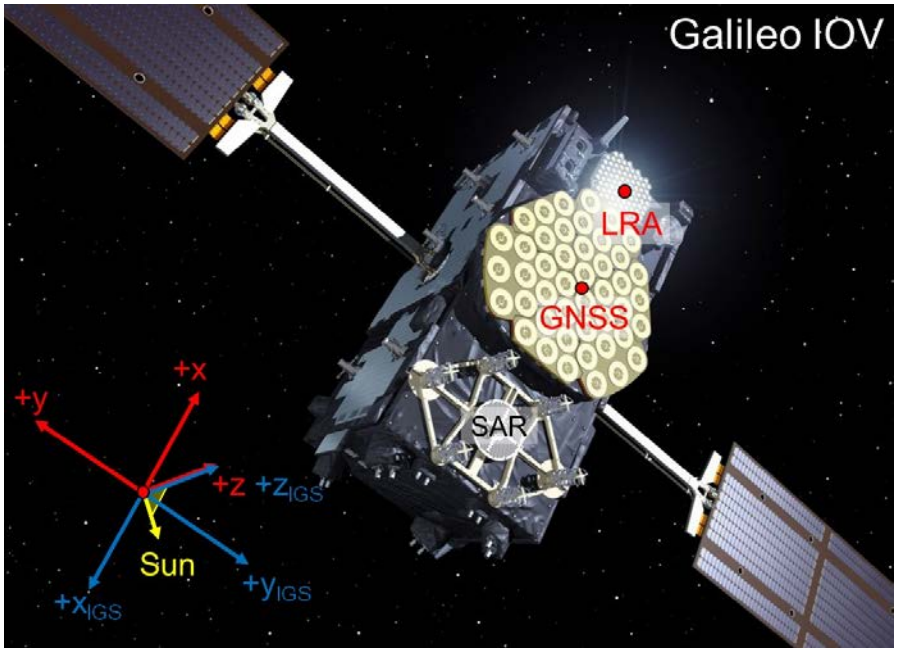
- Precise satellite orbits refer to the center of mass
- GNSS measurements refer to the actual phase center of the transmit antenna

- **Phase Center Offset (PCO)**
  - **Center of mass**
  - **Mean phase center**

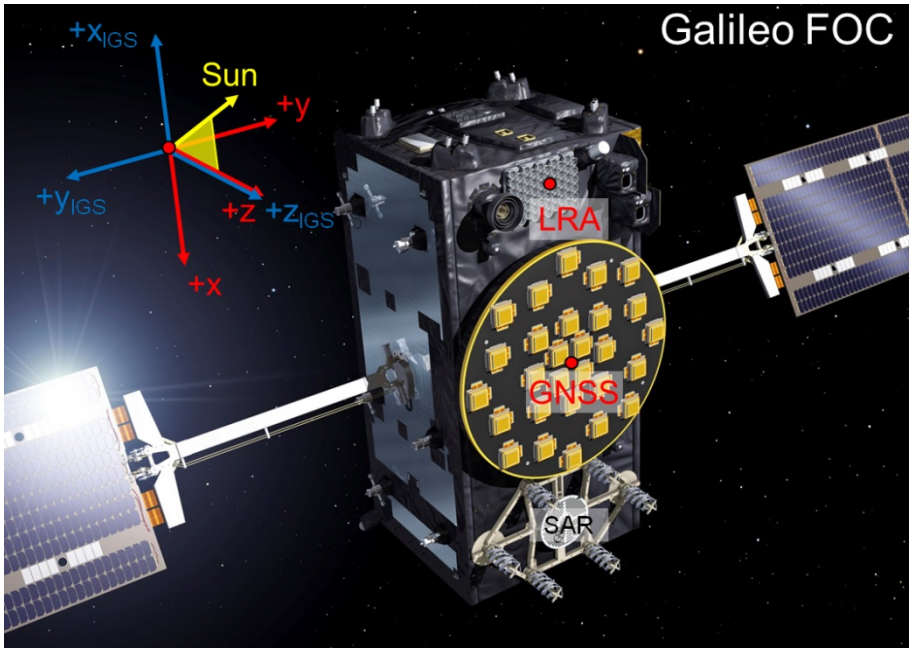
- **Phase Center Variation (PCV)**
  - Correction depending on the **nadir angle n** (and the azimuth) of the observation direction as seen from the satellite

The Galileo Satellites

In-Orbit Validation (**IOV**)



Full Operational Capability (**FOC**)



Built by Astrium

- 4 satellites launched in 2011 and 2012

Built by OHB

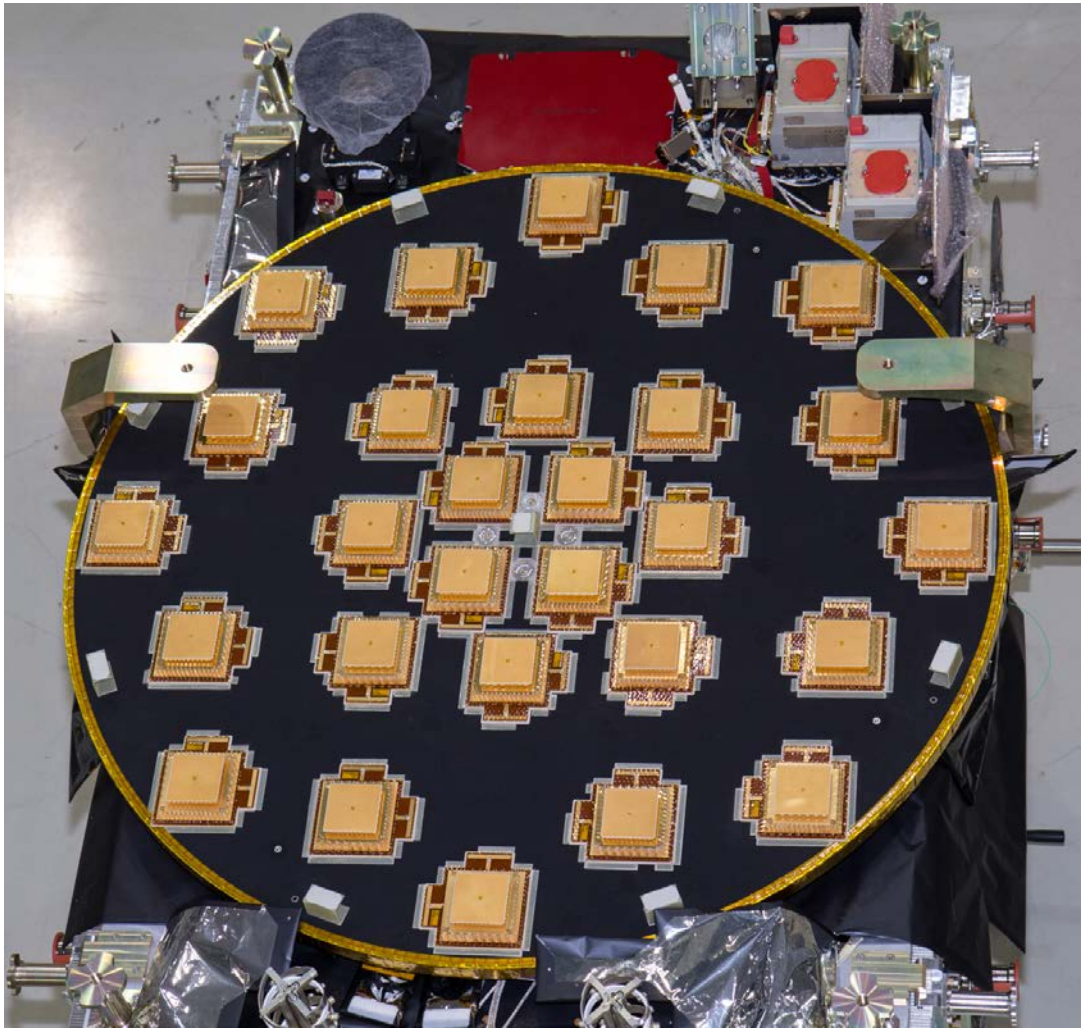
- 4 satellites launched in 2014 and 2015
- Contract for 22 satellites

Galileo IOV Antenna

- Dual band right hand circular polarized
- Array of 45 photo-printed stacked patch elements

Galileo FOC Antenna

- Similar to GIOVE-A antenna
- Dual band right hand circular polarized
- Array of 28 stacked patch elements



OHB

IGS Multi-GNSS Experiment (MGEX)

- No public information about Galileo PCOs and PCVs available
- Conventional Galileo IOV PCOs based on images and models of the satellites

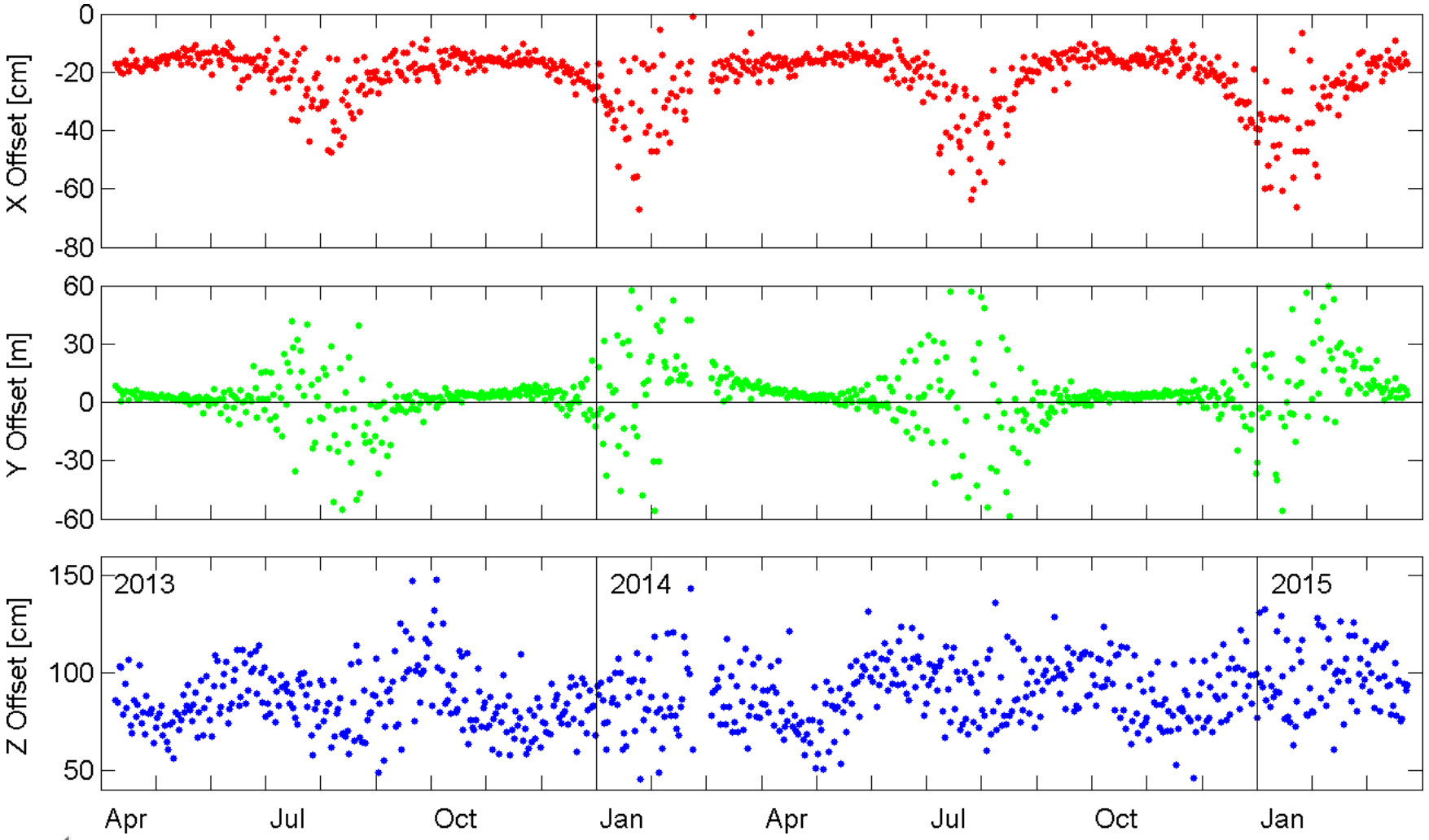
Satellite	x_{MGEX} [cm]	y_{MGEX} [cm]	z_{MGEX} [cm]
Galileo IOV	-20.0	0.0	$+60.0$
Galileo FOC	$+15.0$	0.0	$+100.0$

- PCVs ignored
- Nominal yaw steering attitude assumed

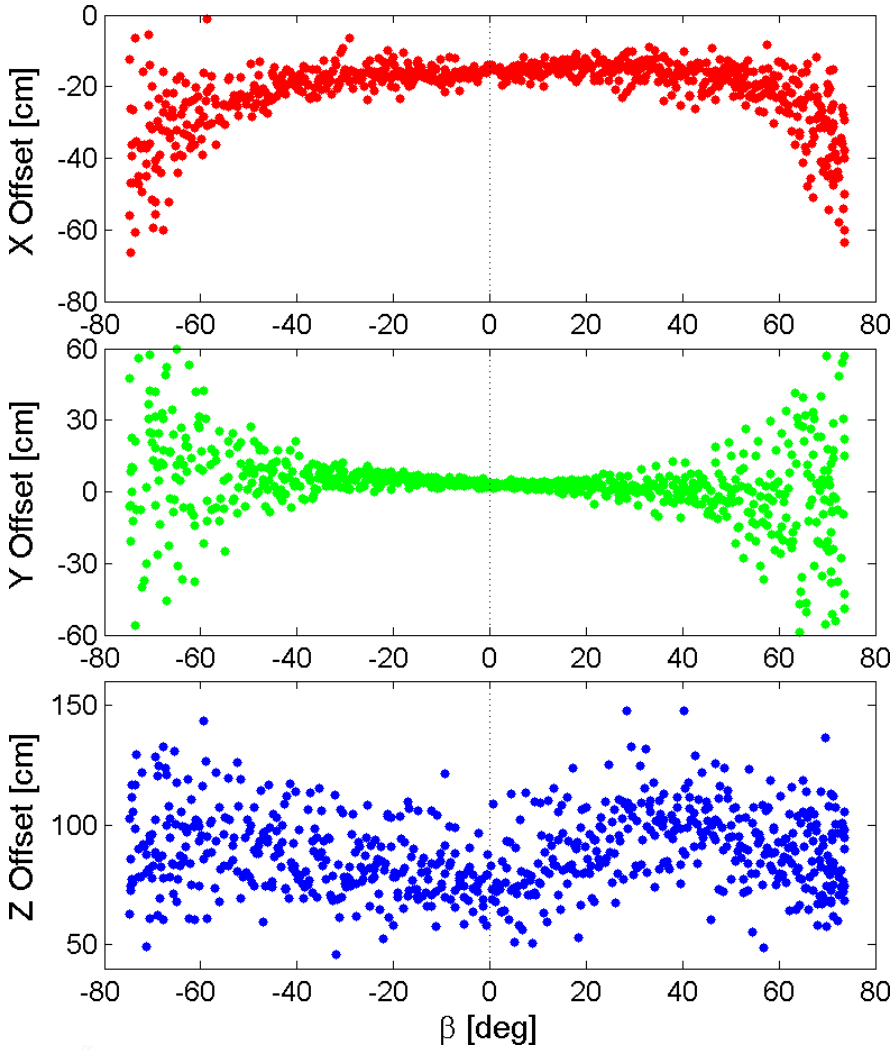
GNSS Processing

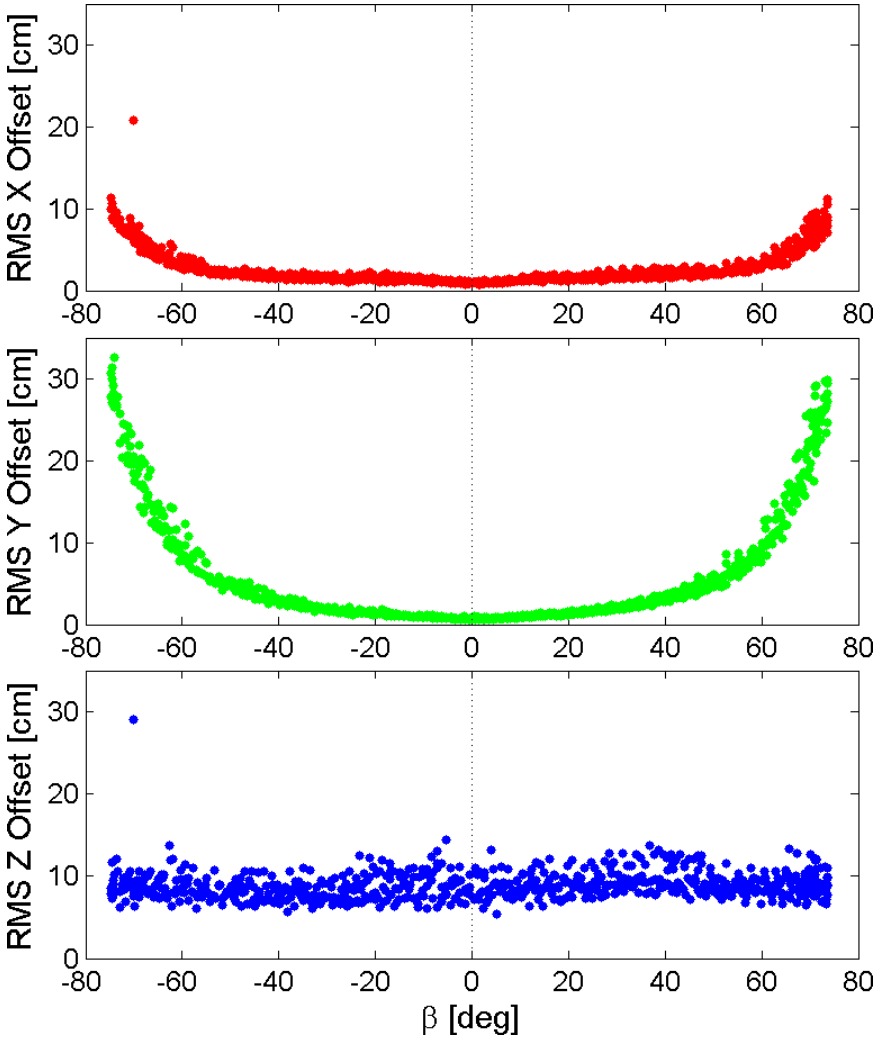
	AIUB	DLR
Time interval	4/2014 – 67/2015	100/2013 – 84/2015
Software	Bernese GNSS Software 5.3	Napeos 3.3.1
GAL stations	~ 85	~ 70
GPS stations	~ 130	~ 130
Differencing	Double difference	Undifferenced
Arc length	3 days	1 day
Orbit model	Enhanced ECOM	A priori box model and 5 ECOM parameters
PCO interval	1 week	1 day
GPS PCVs and PCOs fixed to igs08.atx		

DLR PCO Time Series IOV-3

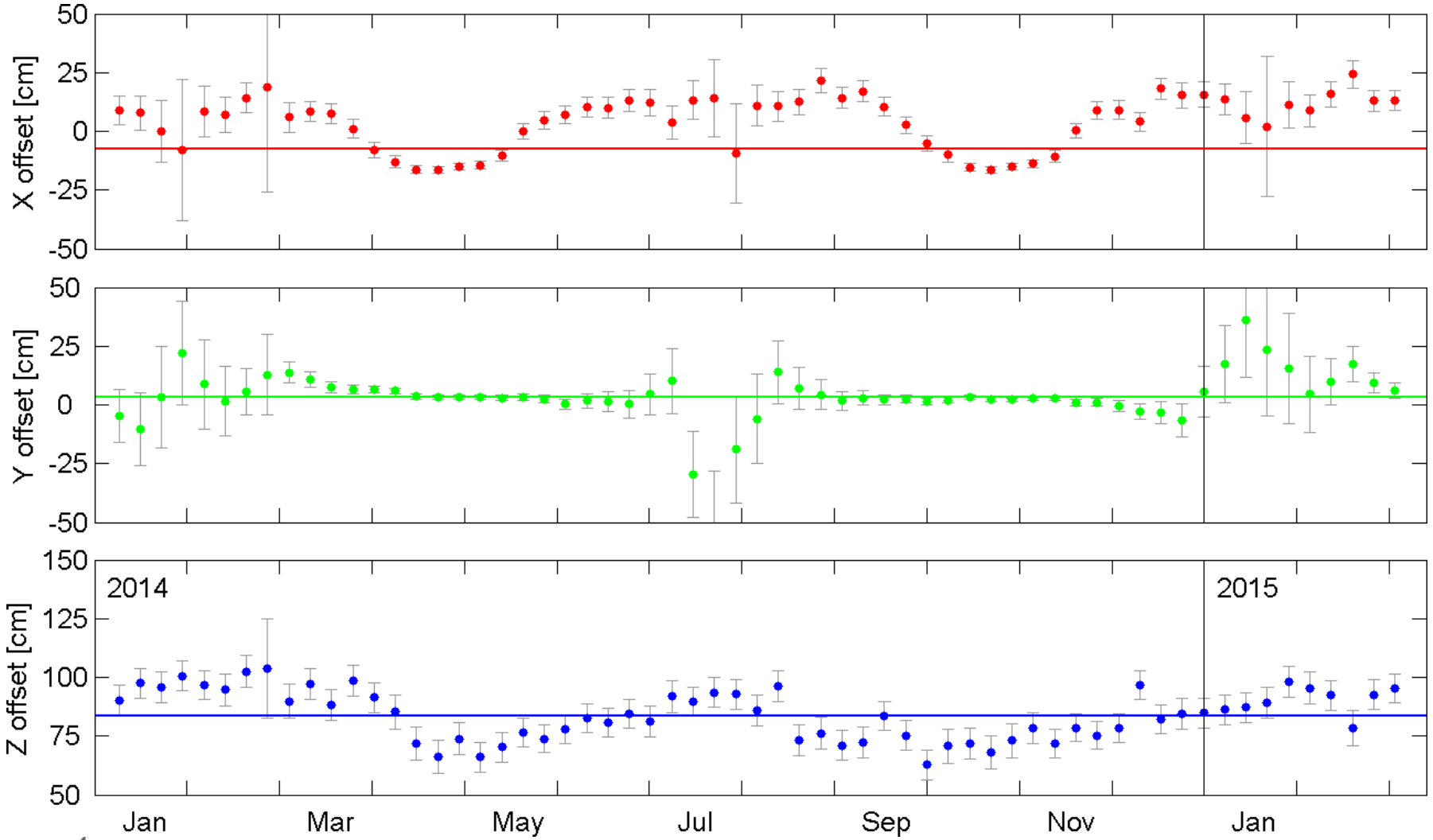


Systematic Effects in Galileo IOV PCO Estimates

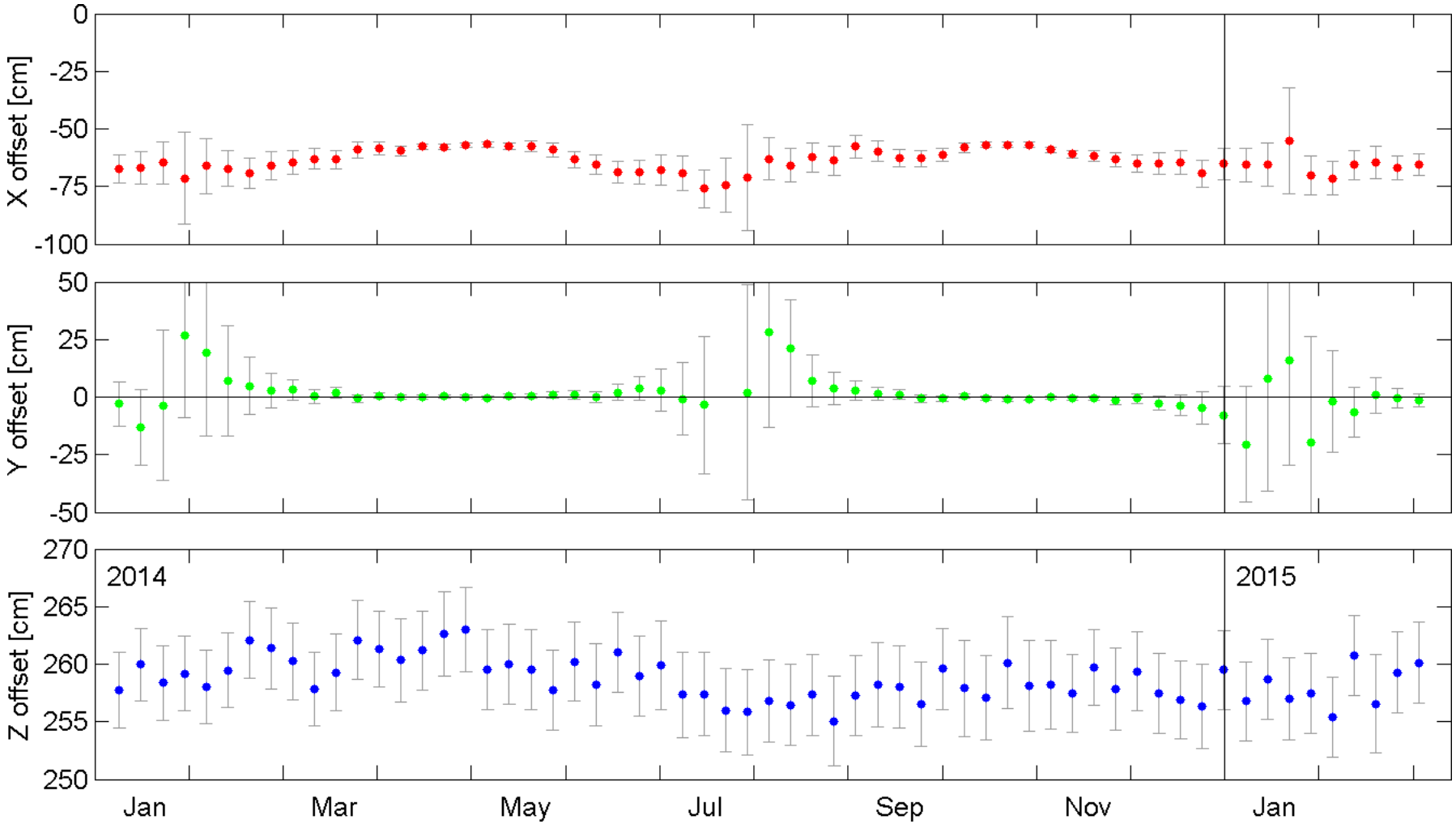




AIUB PCO Time Series IOV-3



AIUB PCO Time Series GLONASS 745

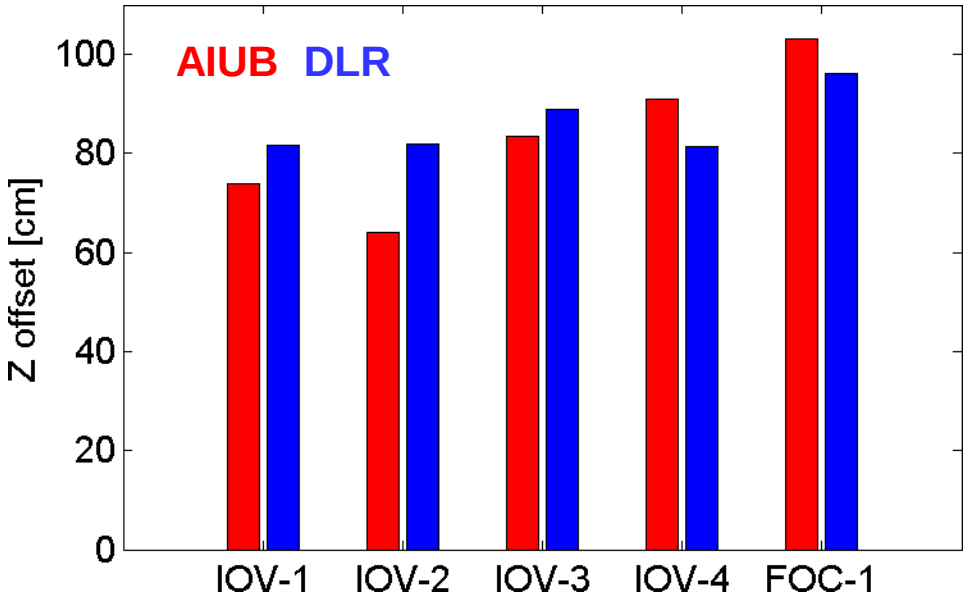


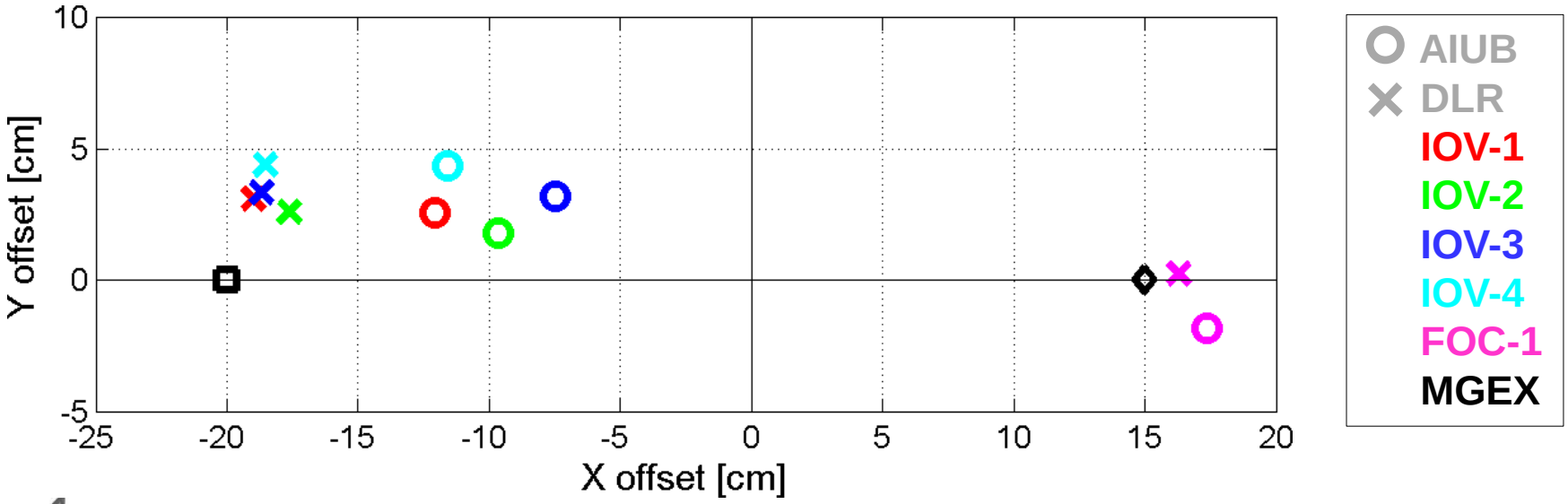
Mean Galileo PCOs

AIUB: Combination on NEQ level

DLR: Outlier rejection for

- $RMS_{X,Y}$ > 5 cm
- RMS_Z > 20 cm

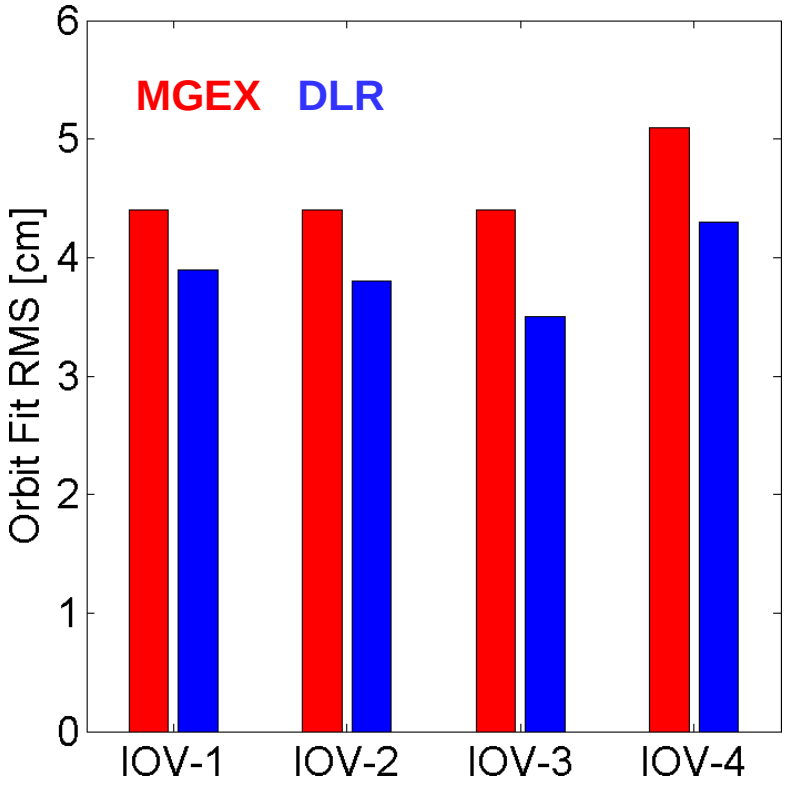




Validation

- Orbit solutions with MGEX and DLR PCOs for 2014

2-day orbit fit RMS



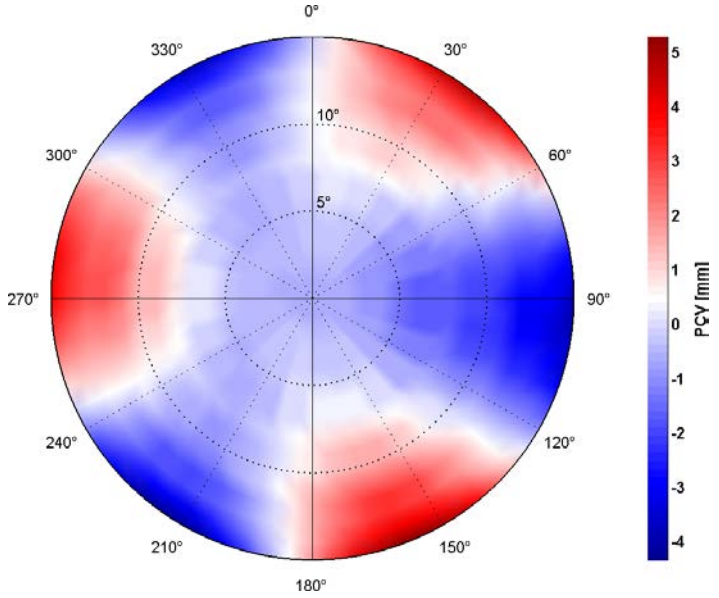
SLR residuals

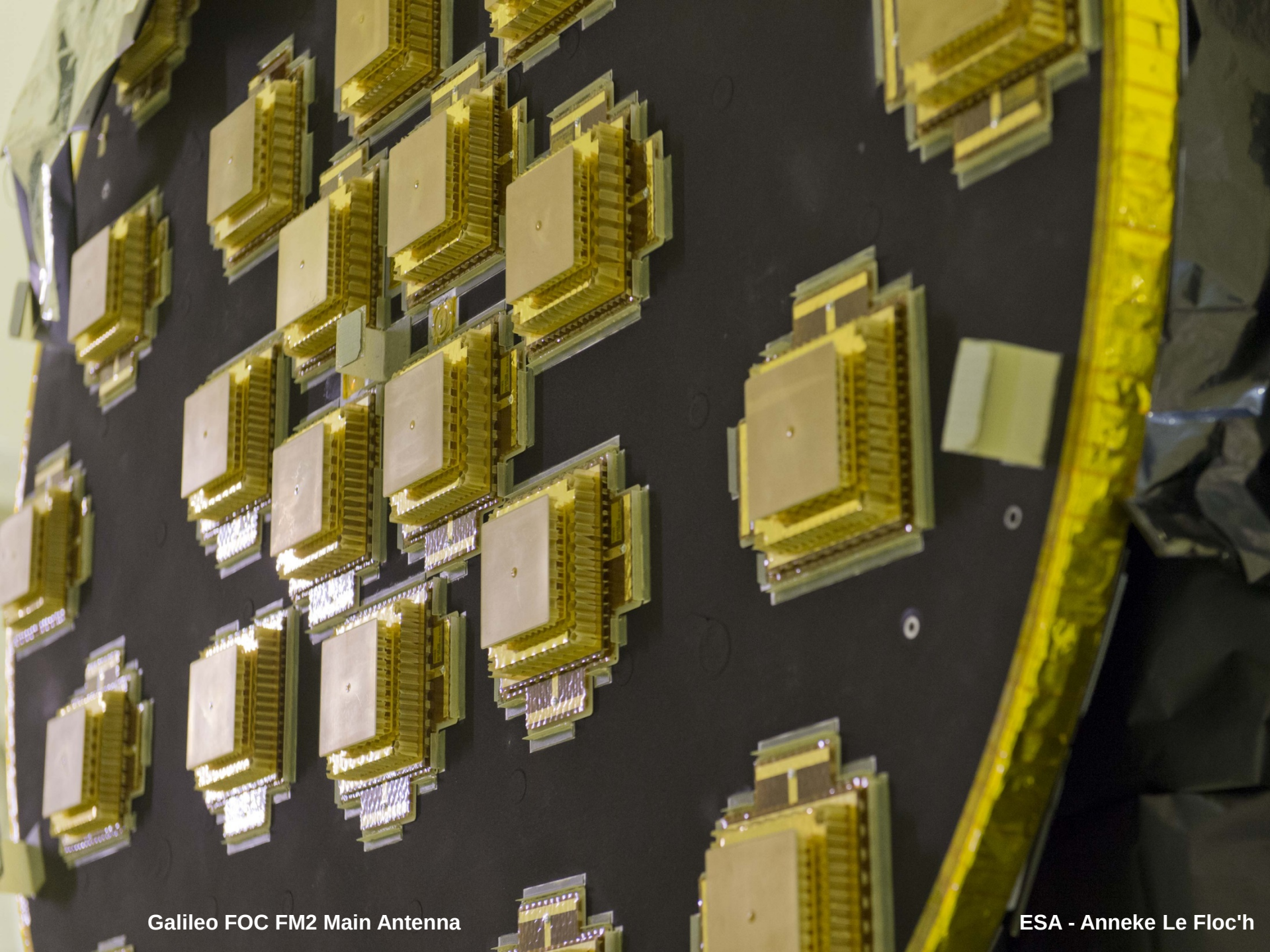
Satellite	MGEX	DLR
	Offset [cm]	
IOV-1	−0.3	−1.2
IOV-2	−0.2	−1.2
IOV-3	−0.2	−1.3
IOV-4	−0.7	−1.5
	STD [cm]	
IOV-1	5.0	4.9
IOV-2	5.0	4.8
IOV-3	4.9	4.7
IOV-4	4.2	4.1

Summary and Outlook

- Pronounced beta-dependent effects in horizontal PCO estimates, strong correlations with solar radiation pressure parameters
- Few cm level agreement of AIUB/DLR mean PCOs for FOC X/Y and IOV Y offsets, discrepancies for IOV X offsets, 5-10 cm level agreement for Z offsets
- Application of new PCO values results in improved consistency of orbit products
- PCV estimation pending
- Pronounced azimuth-dependent pattern in Galileo IOV residual maps
- Extension of analysis interval for Galileo FOC, inclusion of FOC-2, 3, 4

IOV residual map, 1st iteration





Galileo FOC FM2 Main Antenna

ESA - Anneke Le Floc'h