



Estimation of satellite antenna phase center offsets for Galileo



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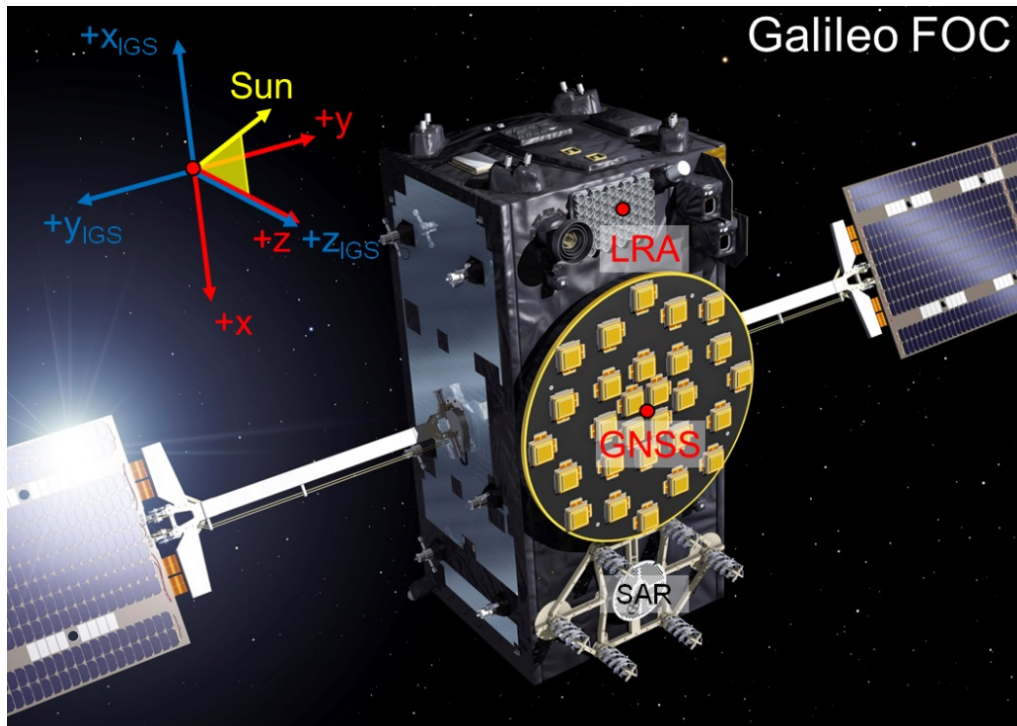
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Deutsches Geodätisches Forschungsinstitut (DGFI-TUM)

Galileo Phase Center Offset Estimation

- Phase Center Offset (PCO): center of mass \rightarrow mean antenna phase center
- Global GNSS solutions including estimation of station coordinates, troposphere parameters, ERPs, and satellite orbits



PCO estimation:

- NAPEOS@DLR
- EPOS@GFZ

PCO validation:

- NAPEOS@DLR
- Bernese@AIUB

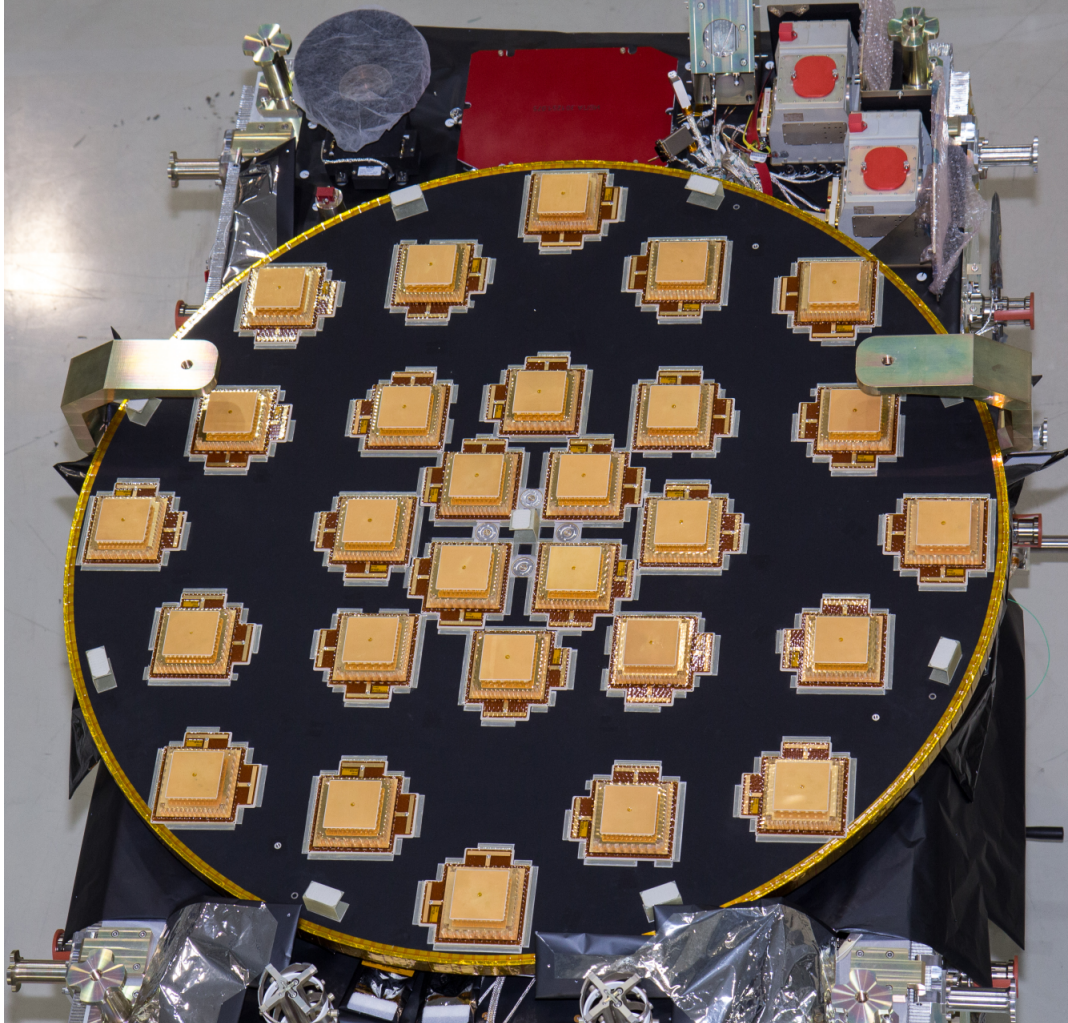


Galileo In-Orbit Validation (IOV) Antenna

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



Galileo Full Operational Capability (FOC) Antenna



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

- Launch anomaly of first pair of FOC satellites resulting in highly eccentric orbit
- Center of mass changes for GAL-201/202 due to orbit raising maneuvers



Orbit Modeling

1. Empirical CODE Orbit Model (ECOM)

Constant plus sine and cosine terms in a Sun-oriented DYB frame

2. ECOM-2

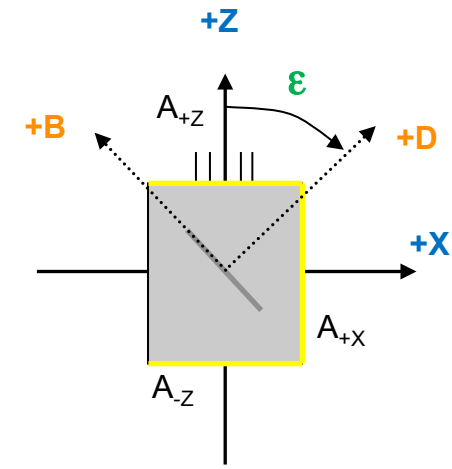
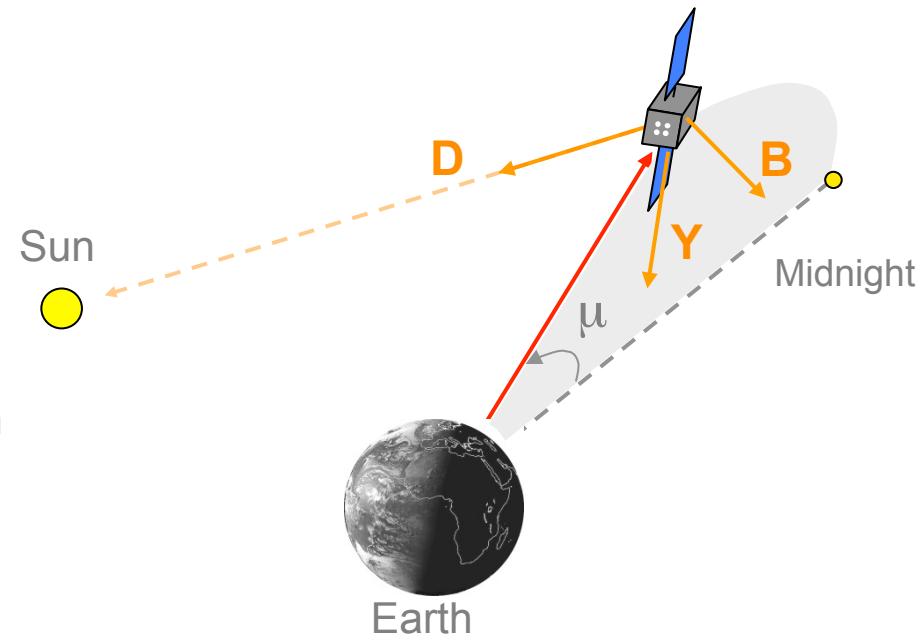
Additional estimation terms:

D_2 for GPS, D_2 and D_4 for Galileo

3. Box-wing model (BW)

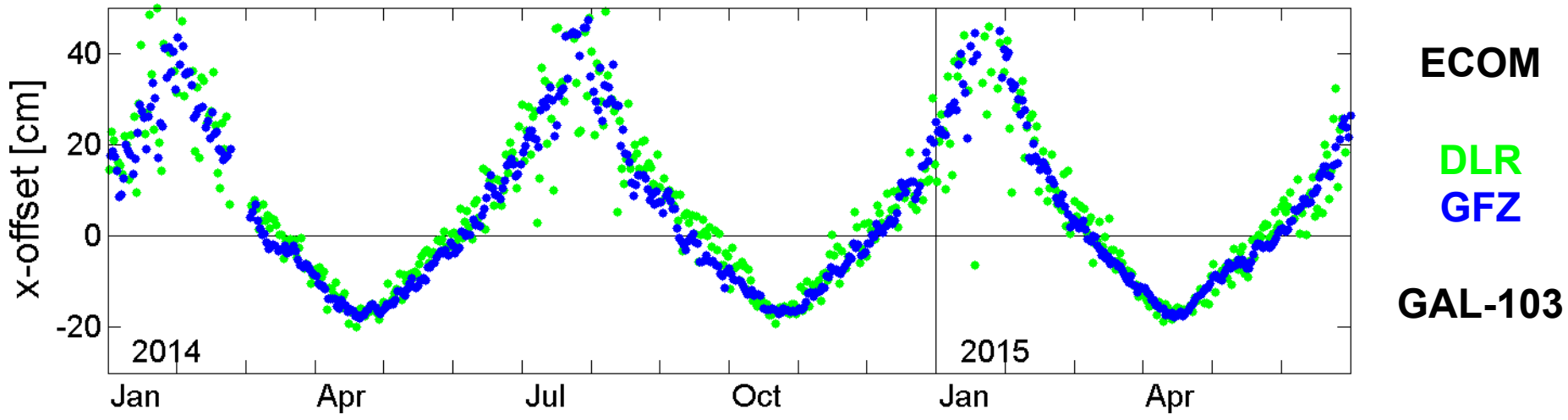
“Cubicness” and “stretchedness” parameters based on a_{+z} , a_{+x} , and a_{-z}

4. Box-wing model and D_0 constraint



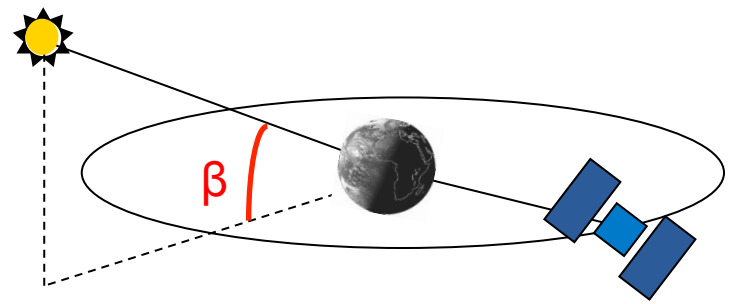
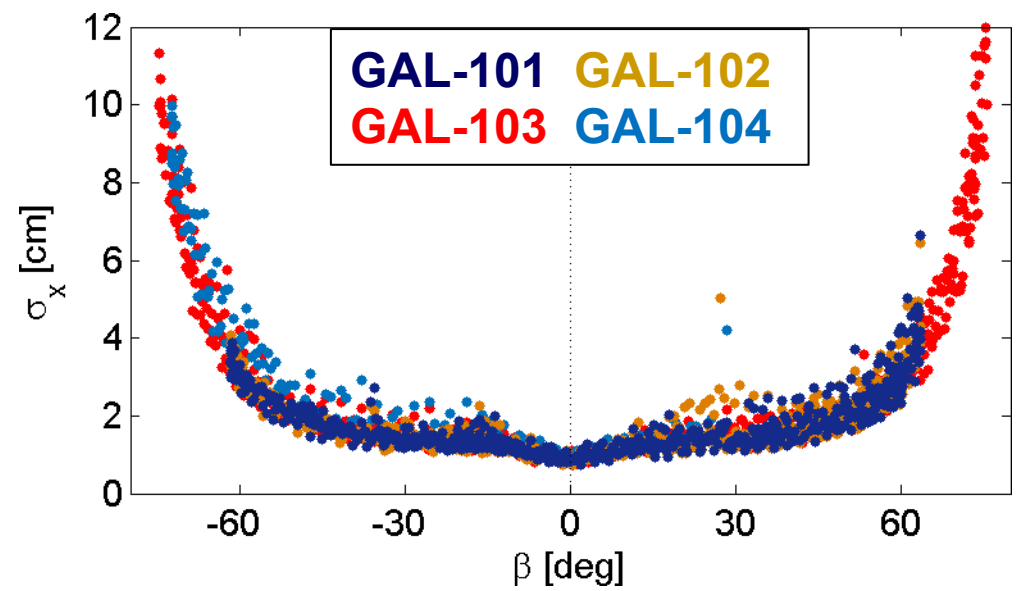
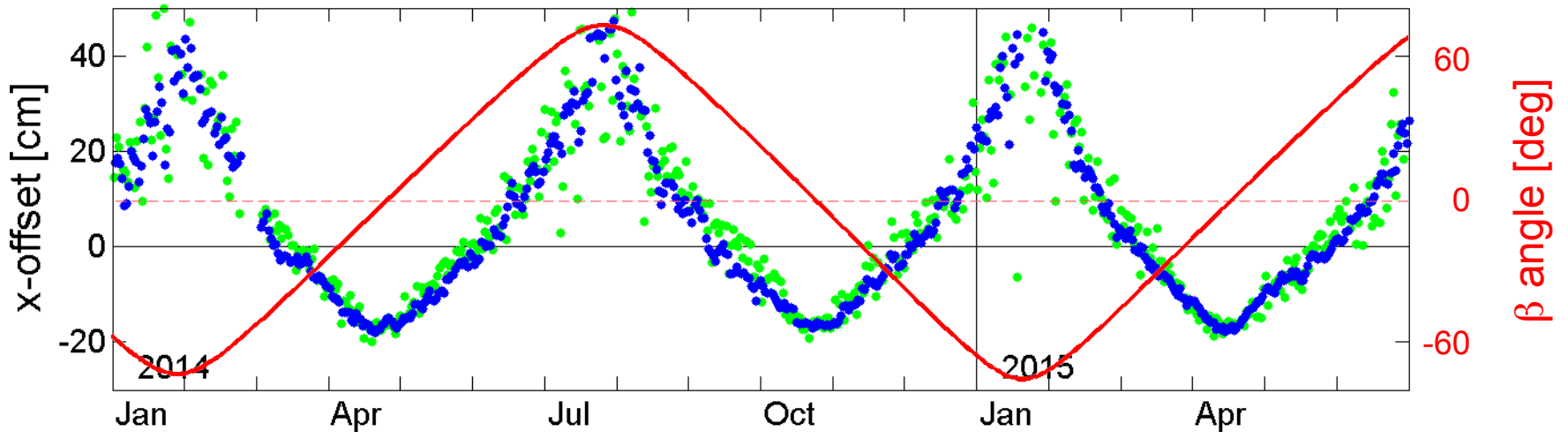


Impact of Orbit Modeling on x-Offset Estimation (1)



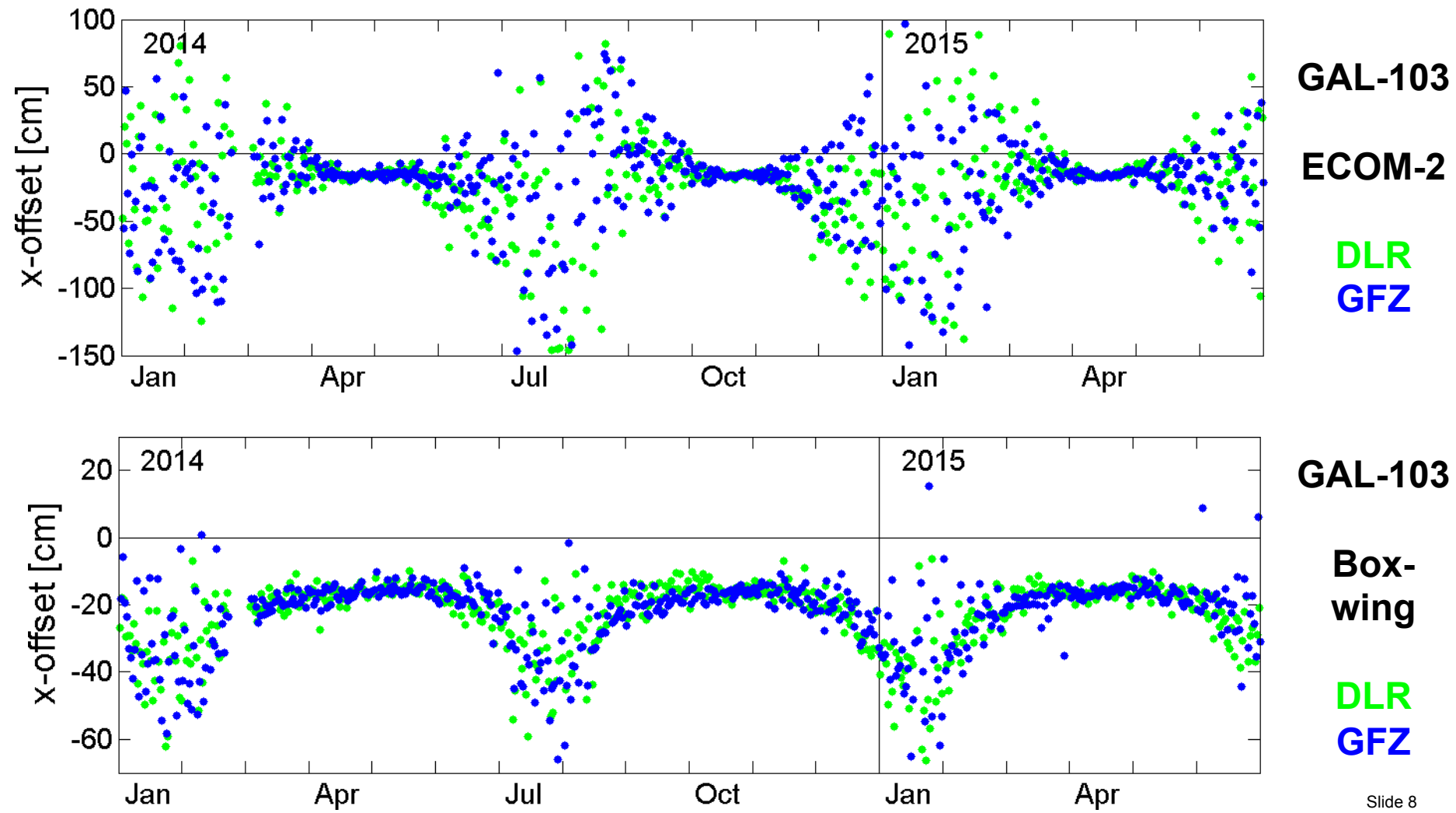


Impact of Orbit Modeling on x-Offset Estimation (1)



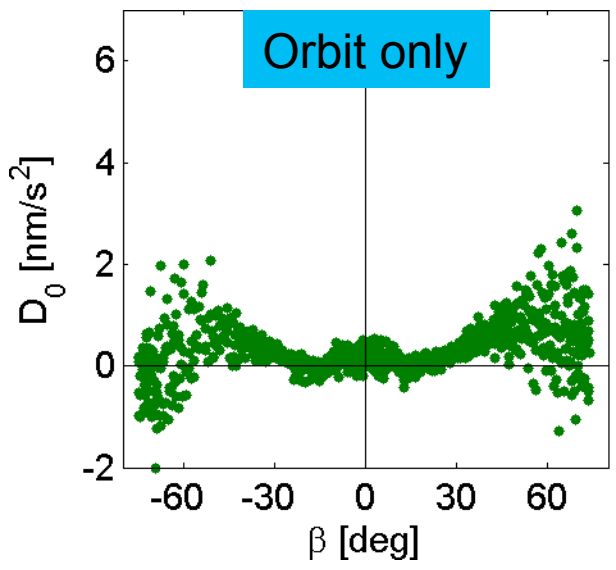


Impact of Orbit Modeling on x-Offset Estimation (2)



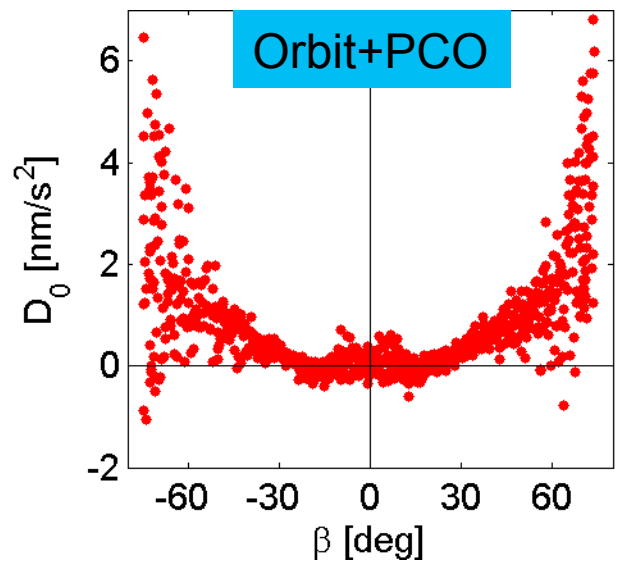
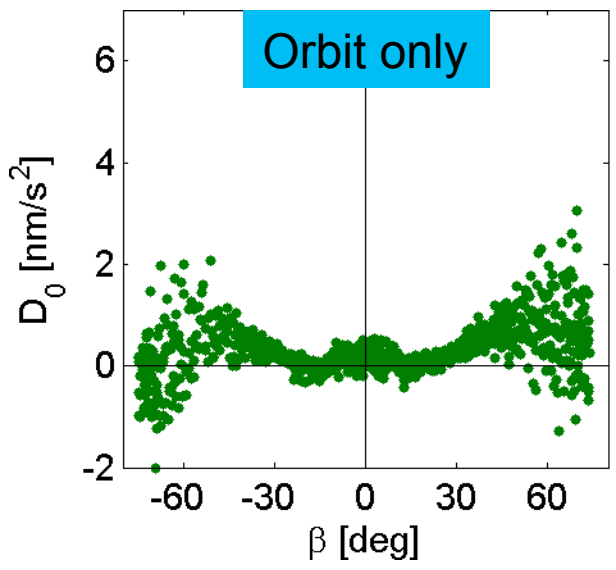


Correlations between PCOs and Orbit Parameters



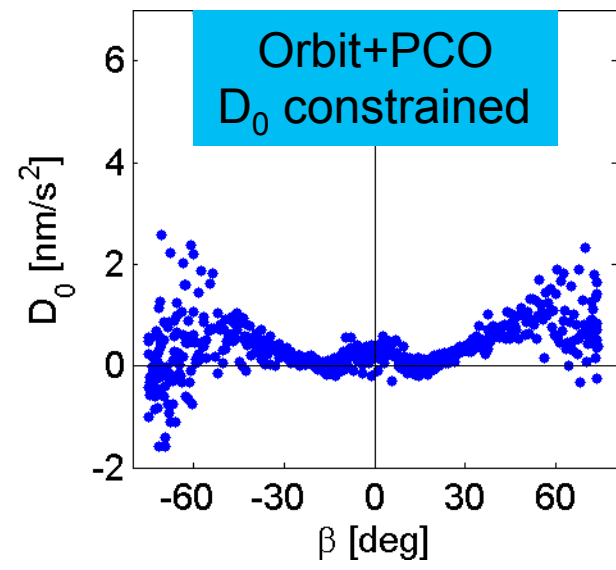
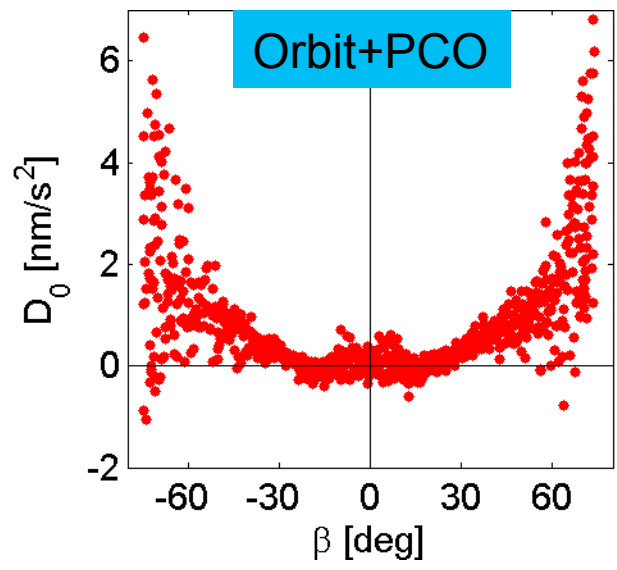
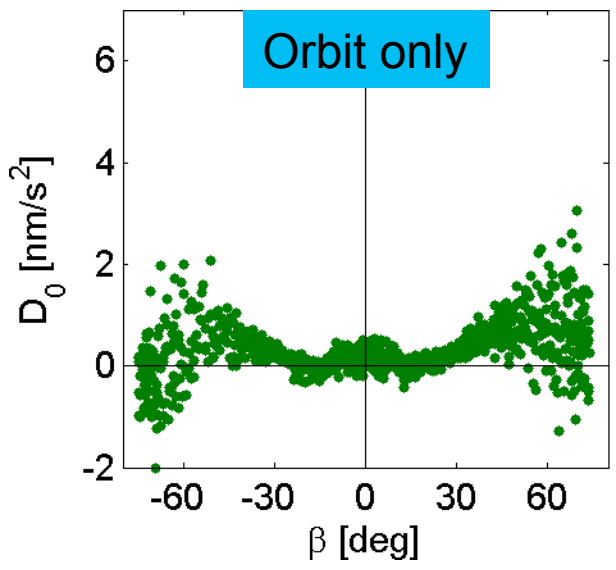


Correlations between PCOs and Orbit Parameters



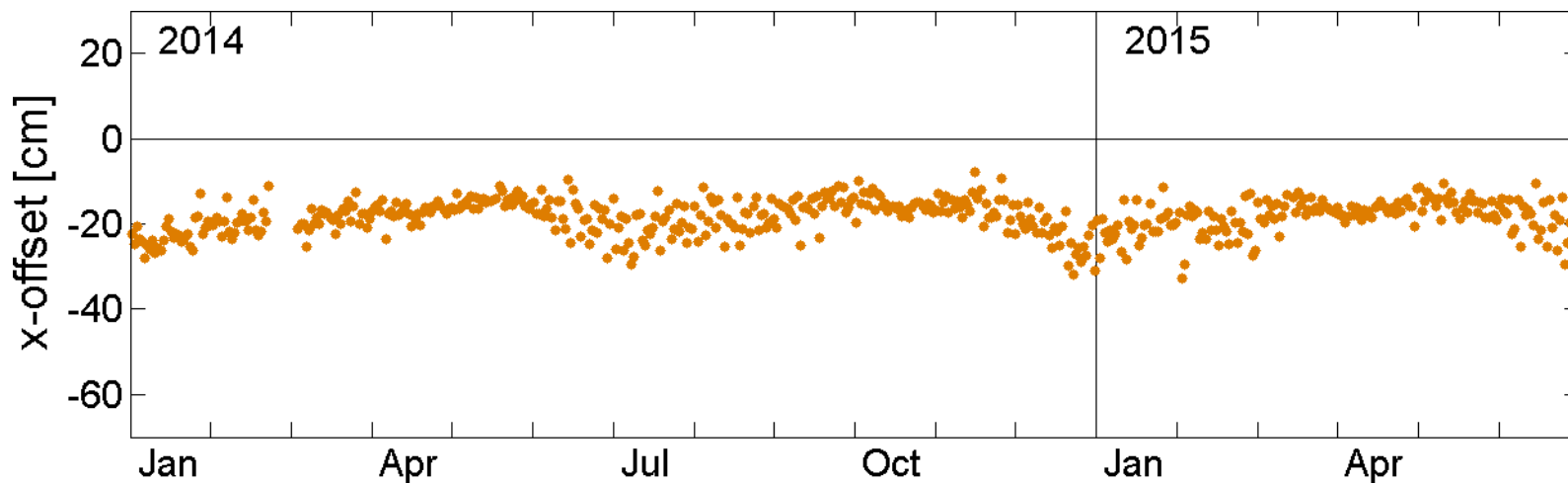
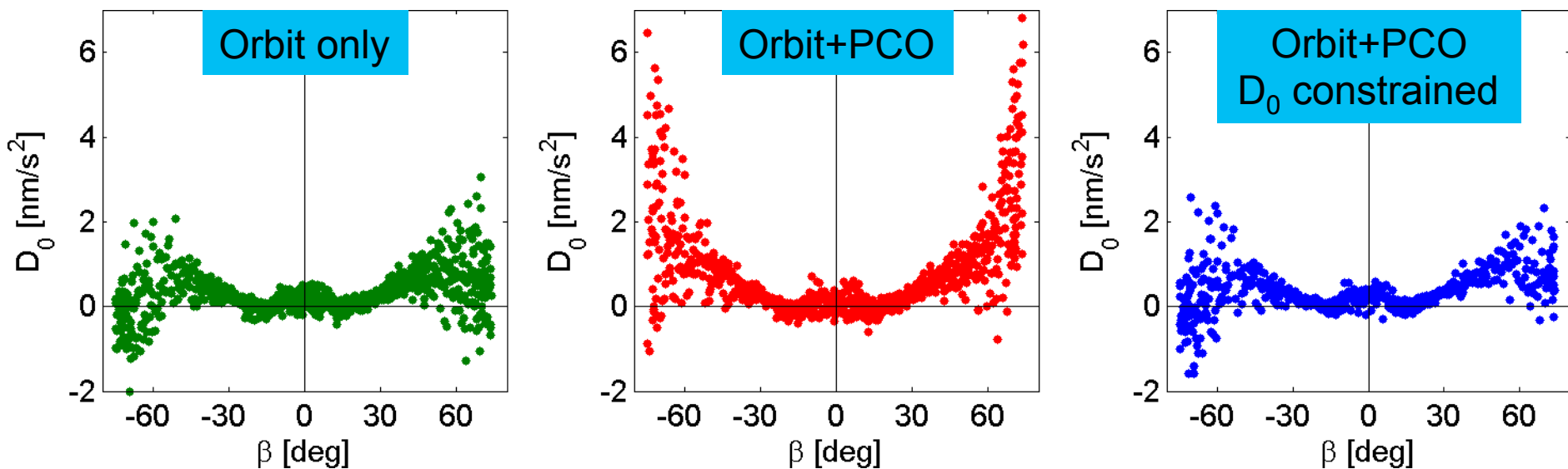


Correlations between PCOs and Orbit Parameters





Correlations between PCOs and Orbit Parameters

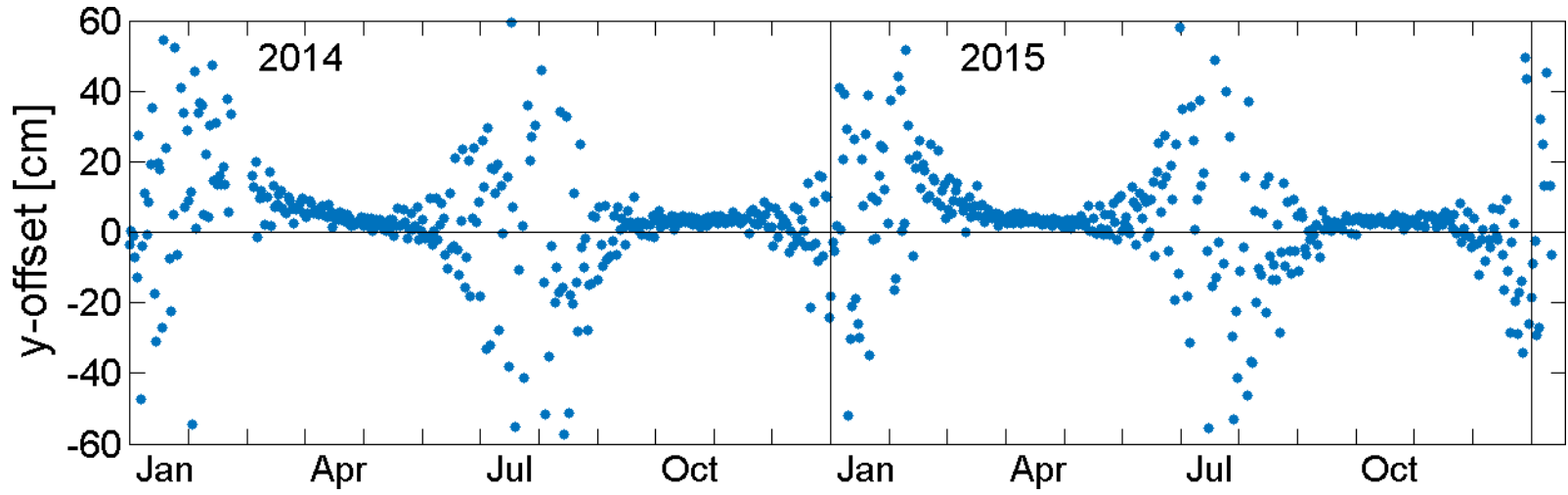


GAL-103

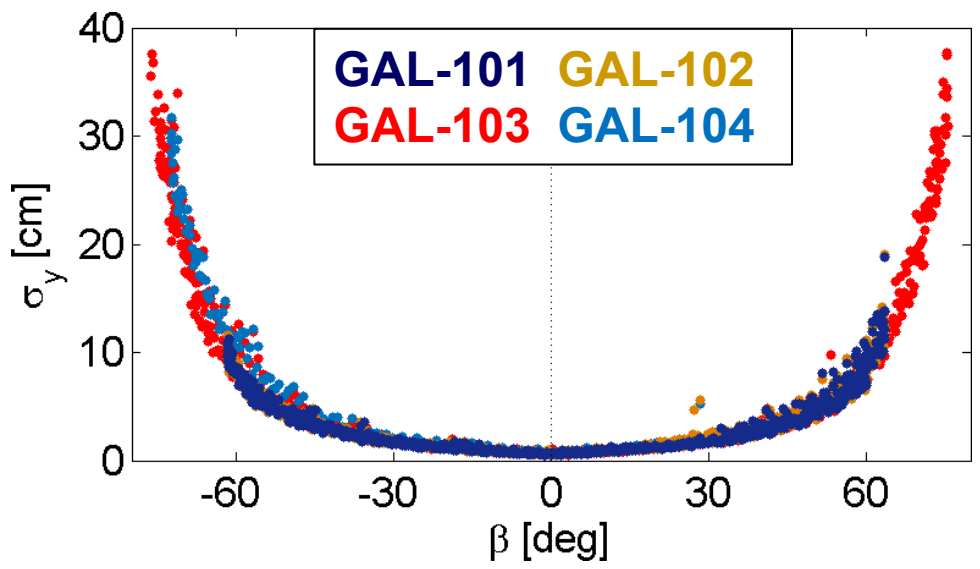
**BW
constr.**



Galileo IOV y-Offsets



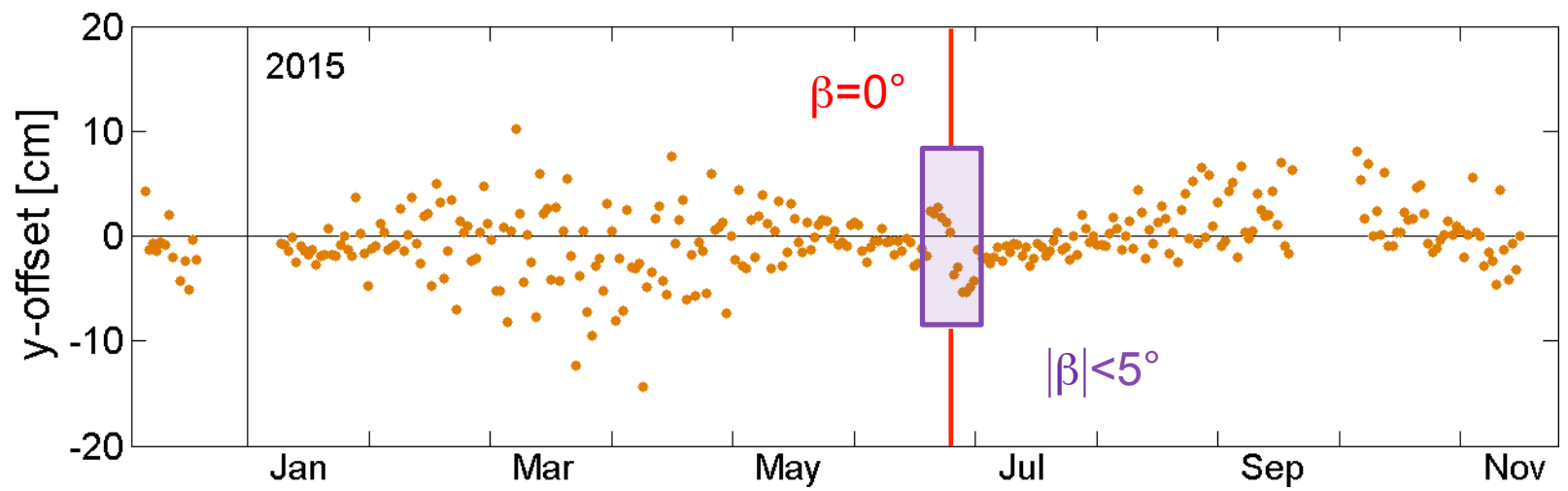
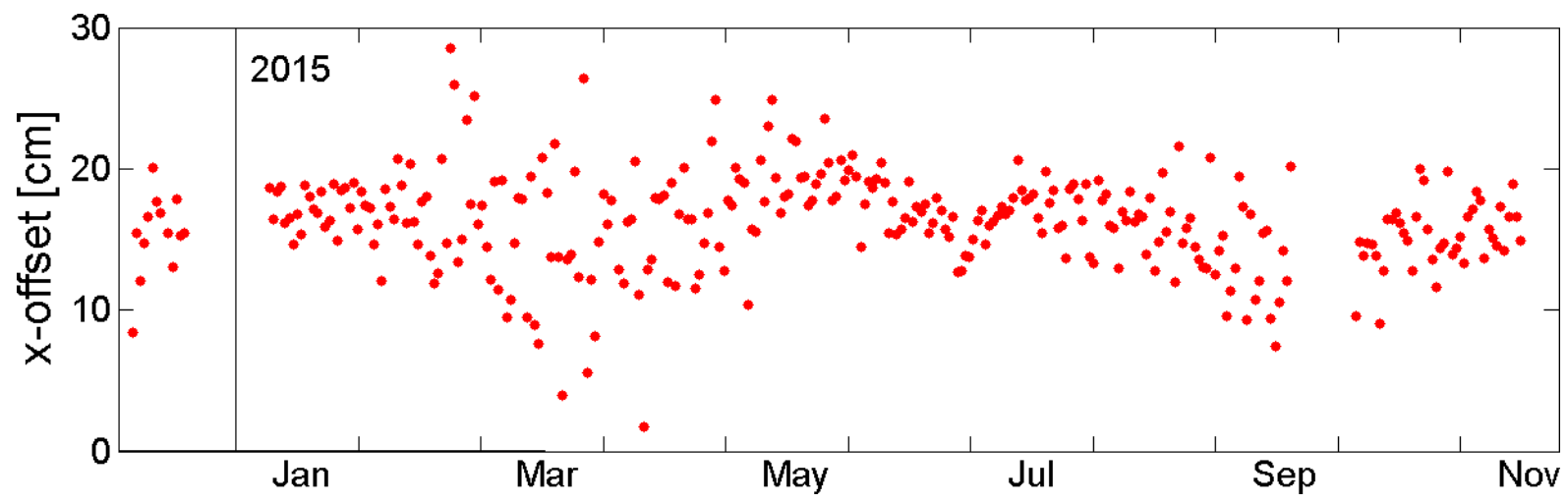
GAL-103
BW



- No impact of orbit modeling on y-offset estimation
- Different approaches to form mean values agree within few mm

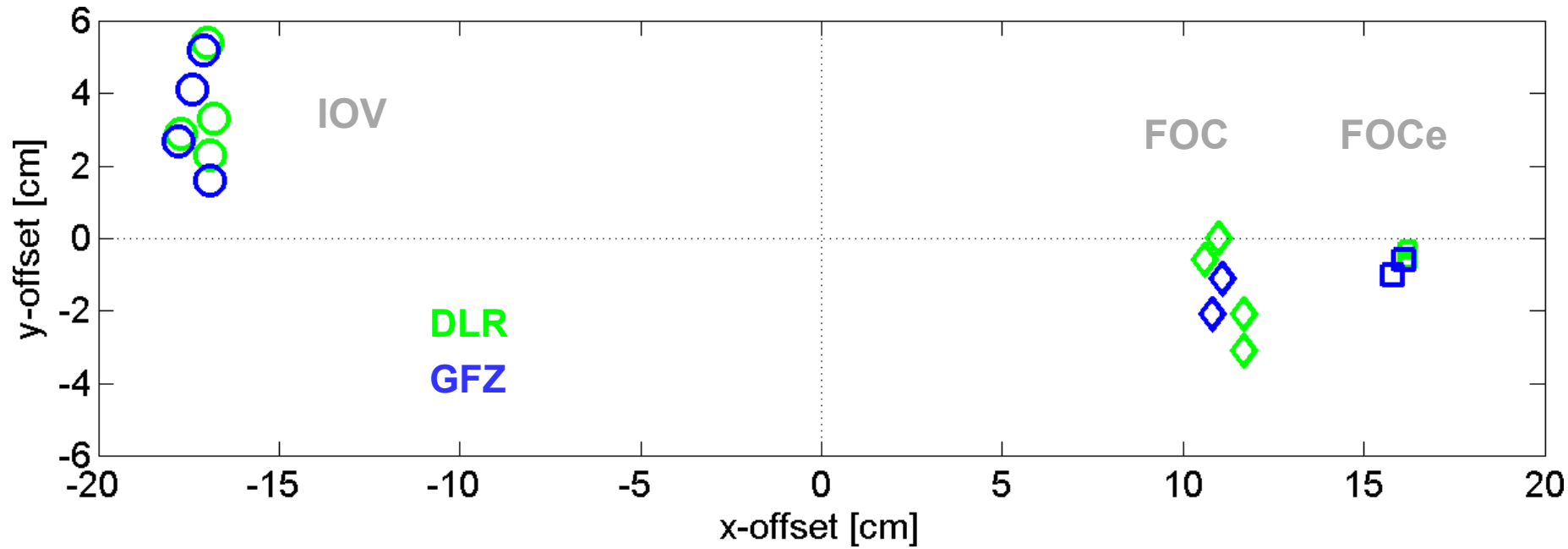


Galileo FOC Horizontal PCOs





Mean Horizontal Galileo PCOs



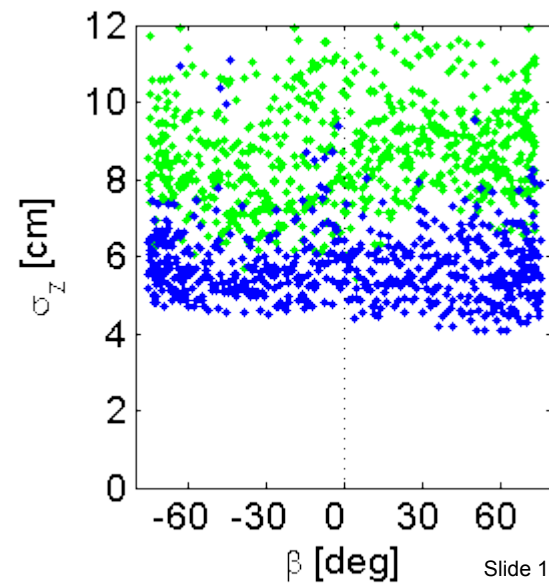
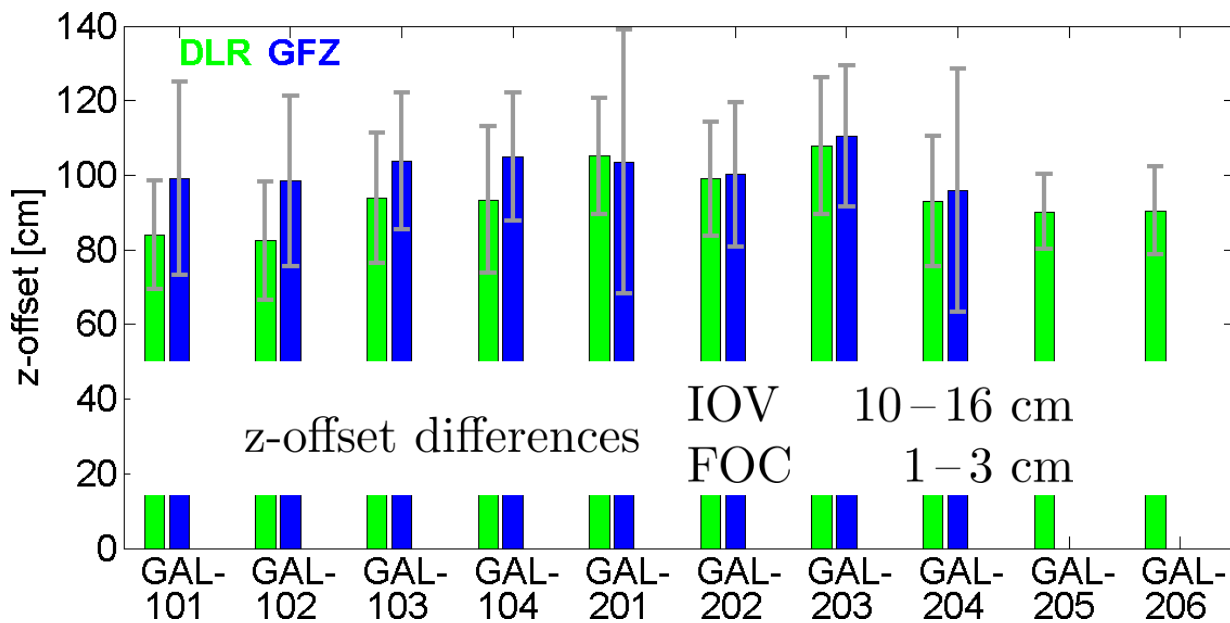
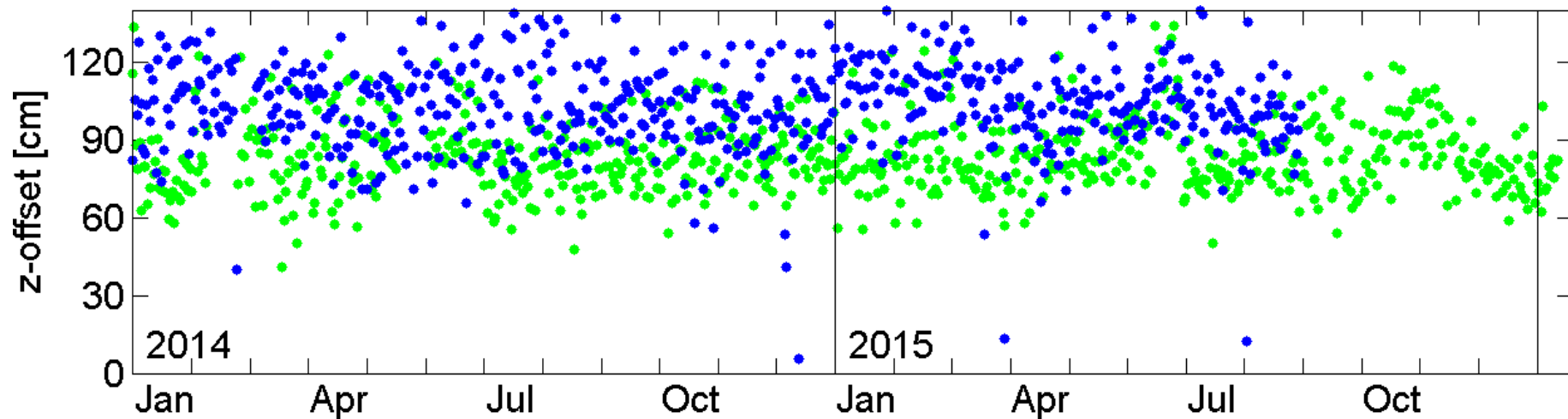
- Significant x-offset bias for FOC satellites in eccentric orbit due to fuel consumption
- AC agree on the 1-2 cm level
- Mean values per satellite group rounded to 1 cm

Satellite	x [cm]	y [cm]
Galileo IOV	-17	+3
Galileo FOCe	+16	-1
Galileo FOC	+12	-1



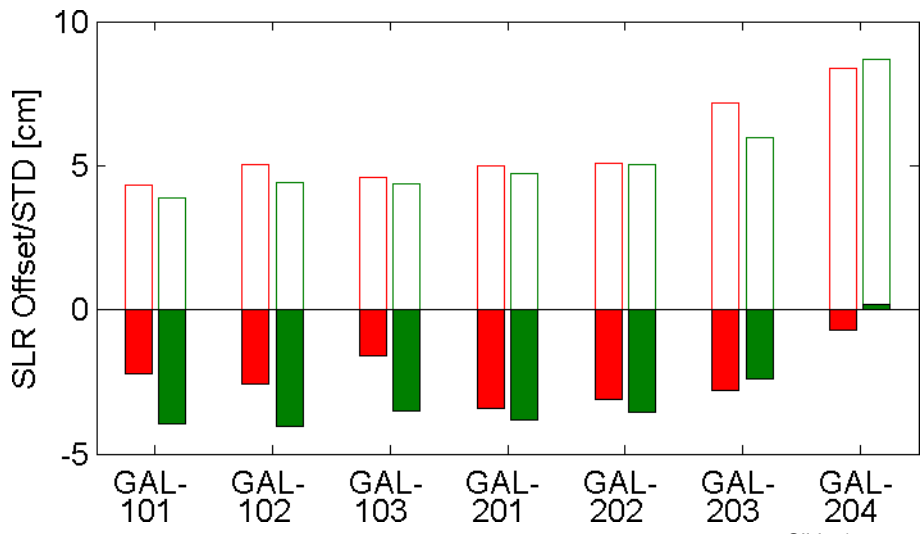
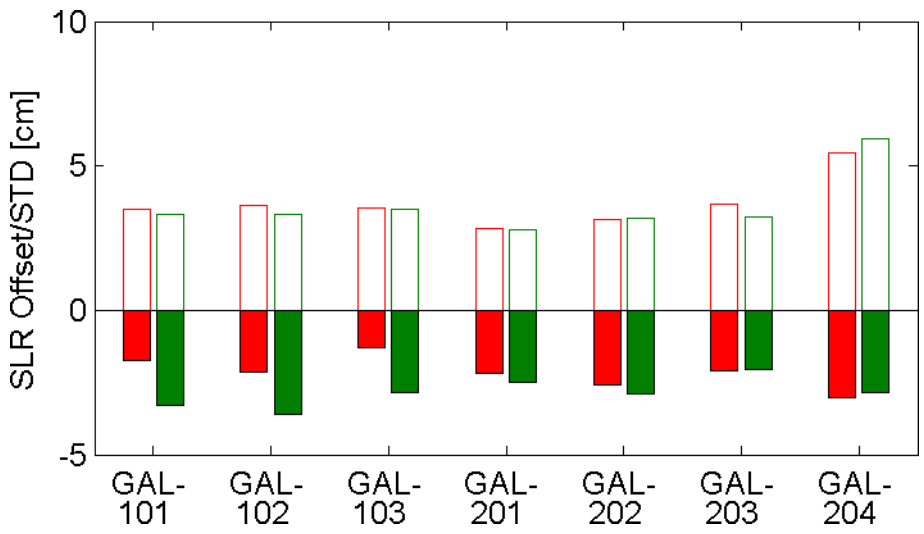
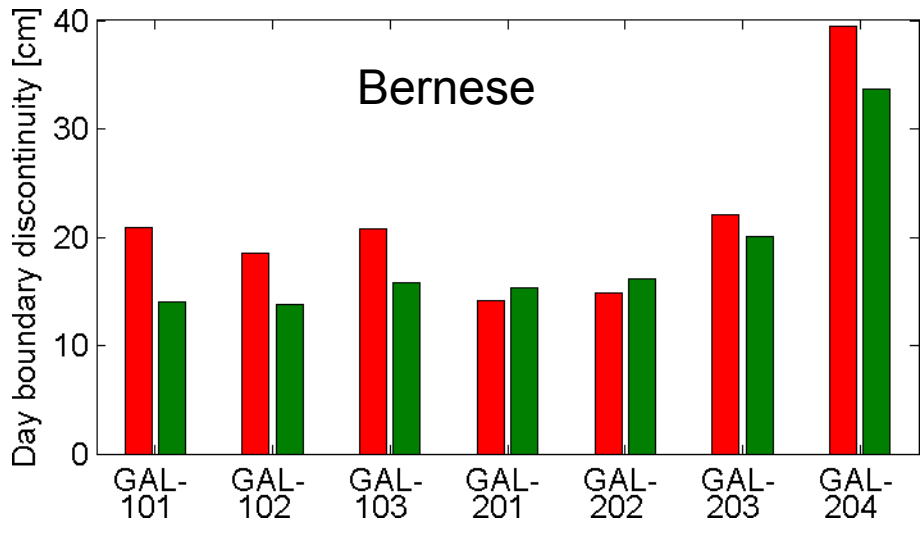
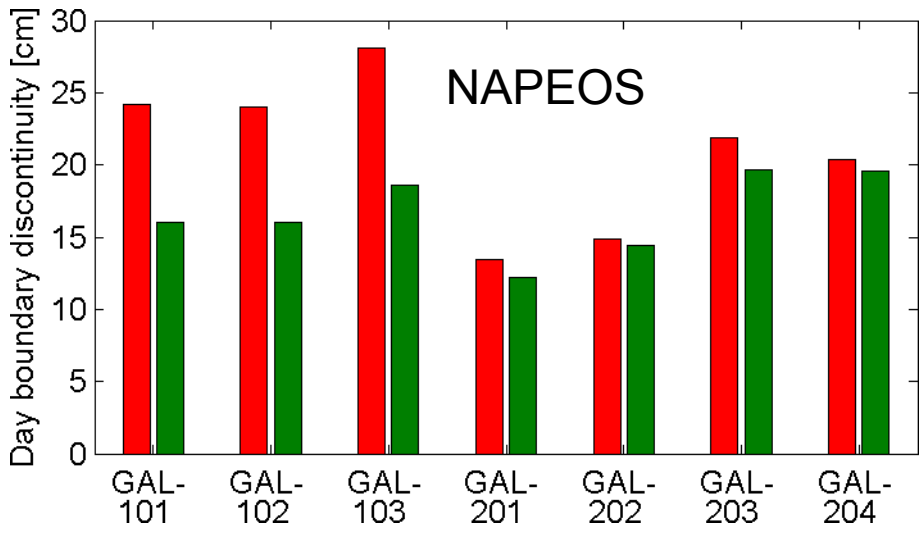
Z-Offsets

GAL-103 DLR GFZ





Validation of **MGEX** and **New PCOs**

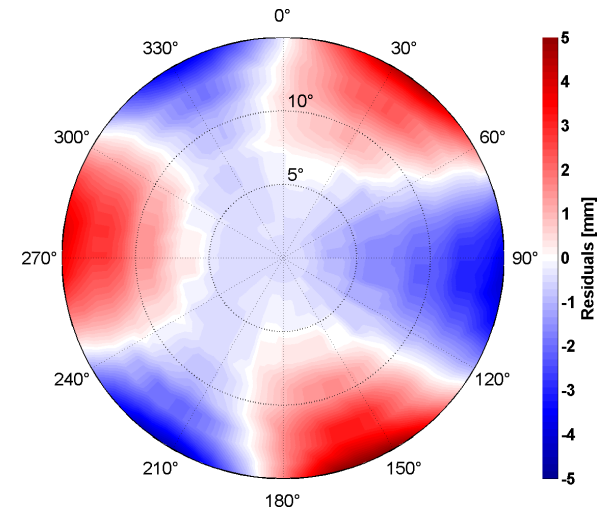




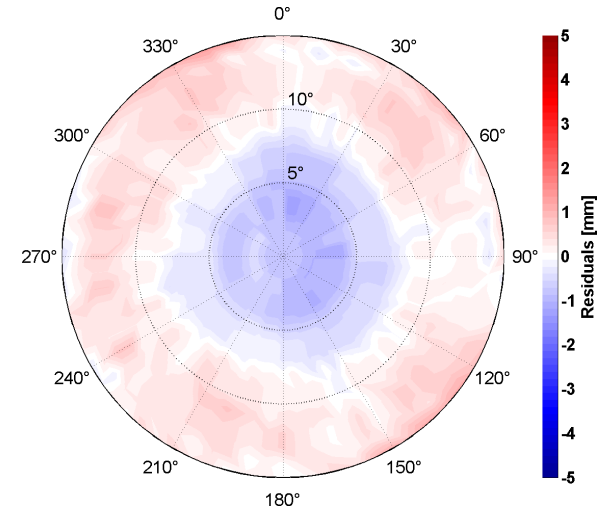
Summary and Outlook

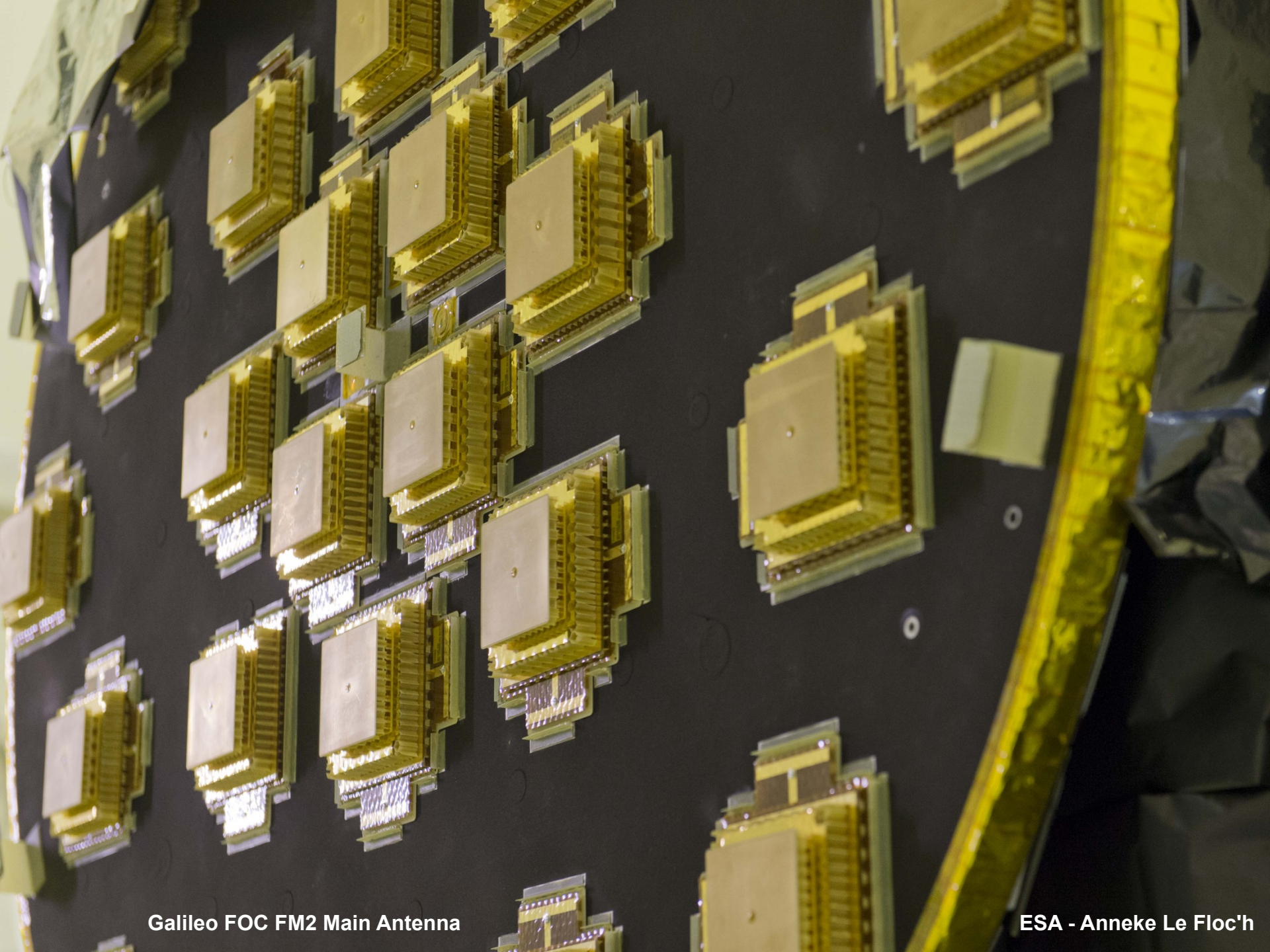
- Pronounced β -dependent effects in horizontal PCO estimates, strong correlation with solar radiation pressure parameters
- Few cm level agreement for DLR/GFZ mean horizontal PCOs, 2-15 cm level agreement for z-offsets
- Appropriate orbit modeling essential for reliable and stable PCO estimation
- Update of conventional MGEX PCOs recommended, in particular for IOV
- Distinct differences in IOV and FOC phase residual maps
- Next step: estimation of satellite antenna PCVs

IOV



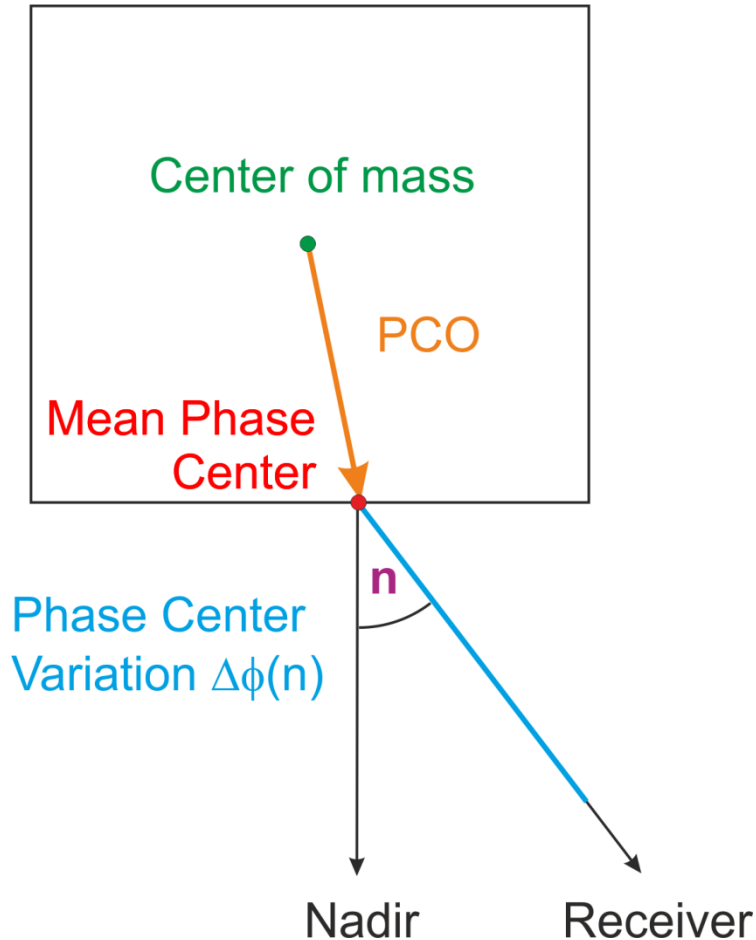
FOC





Galileo FOC FM2 Main Antenna

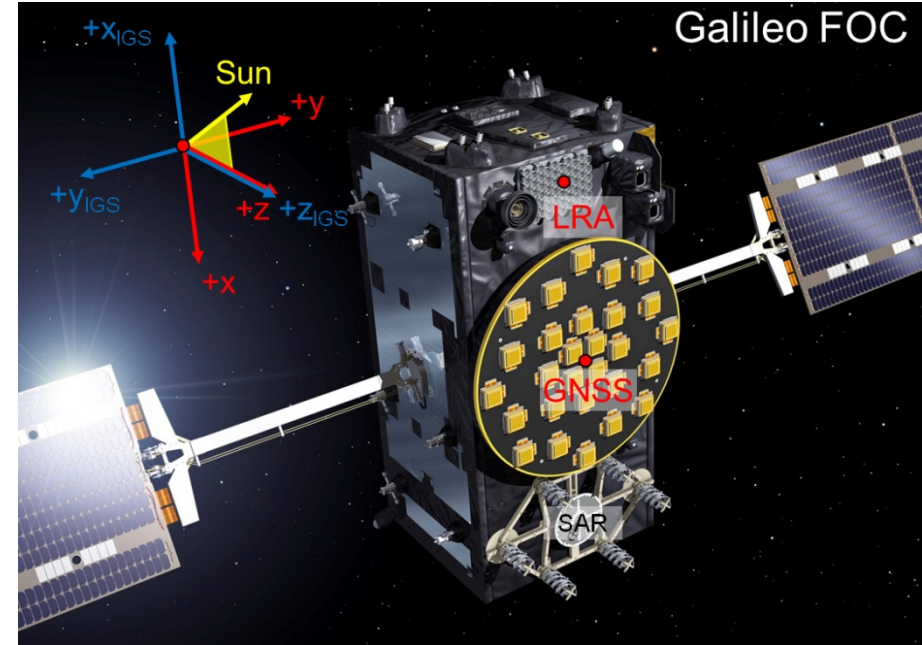
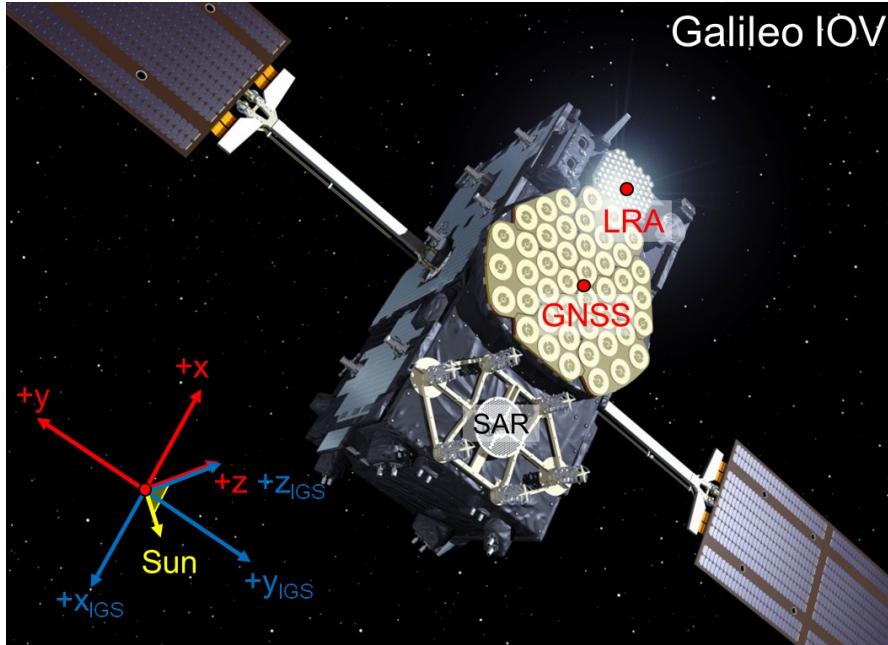
GNSS Satellite Antenna Modeling



- 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



Built by Astrium

- 4 satellites launched in 2011 and 2012
- 3 operational satellites

Built by OHB

- 2 satellites in eccentric orbit
- 6 satellites in nominal orbit



Impact of Orbit Modeling on x-Offset Estimation (1)

