

CODE's multi-GNSS orbit and clock solution

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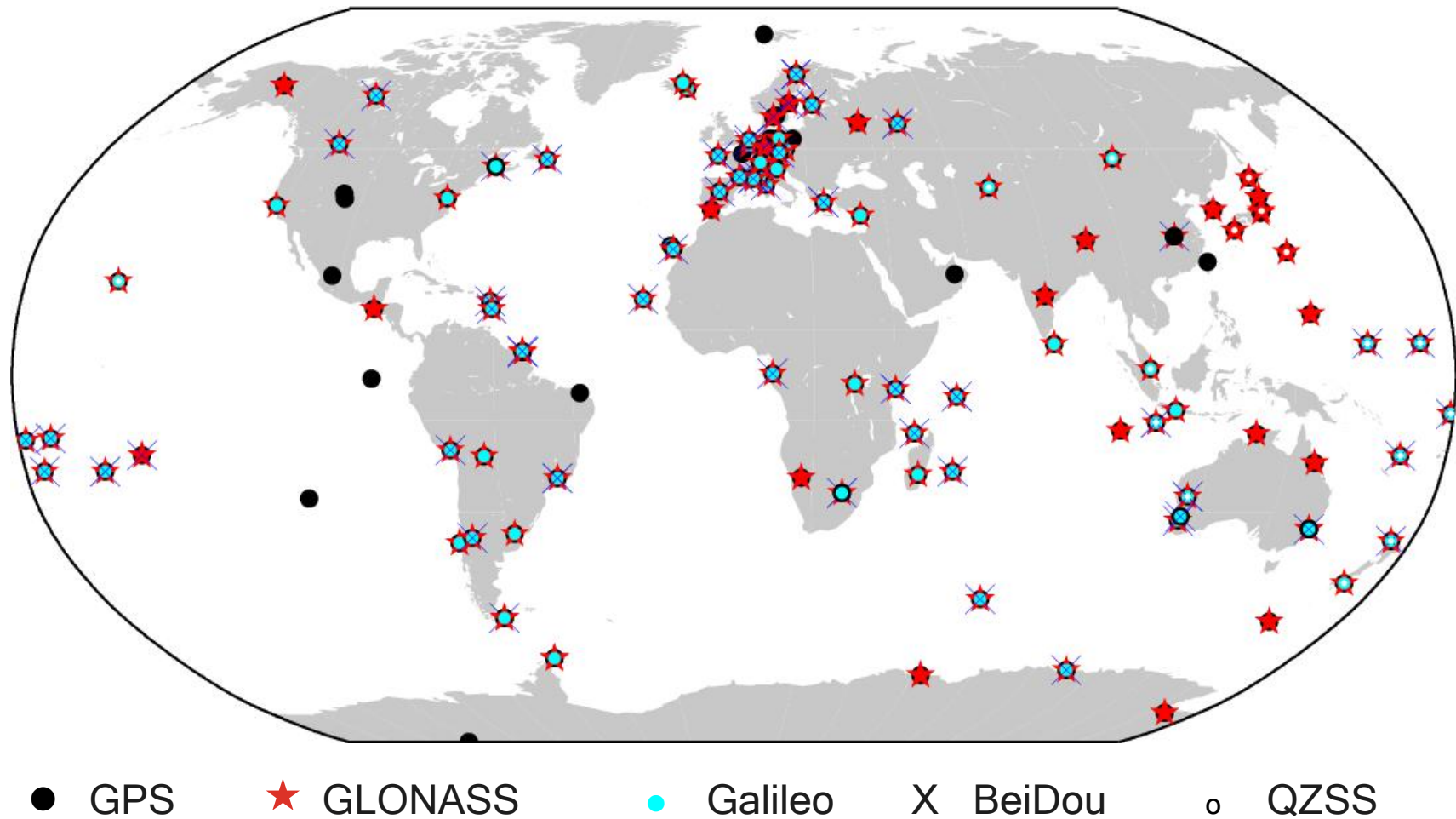
EGU General Assembly 2015, 12-17 April 2015,
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Contents

- CODE MGEX orbit solution
- CODE MGEX clock solution
- Impact of CODE's new radiation pressure model
- Summary and outlook

Tracking network

Station distribution for orbit solution (DOY 15/030)



L. Prange et al.: CODE's multi-GNSS orbit and clock solution
EGU General Assembly 2015, Vienna, Austria, 12–17 April 2015

CODE MGEX orbit solution

GNSS considered:	GPS + GLONASS + Galileo + BeiDou (MEO+IGSO)+ QZSS (70 SV)
Processing mode:	post-processing / 2 weeks delay (since 2015)
Timespan covered:	GPS-weeks 1689-1838 (DOY 12/146-15/094)
Number of stations:	130 (GPS), 110 (GLONASS), 85 (Galileo); 55 (BeiDou); 20 (QZSS)
Processing scheme:	double-difference network processing (observable: phase double differences)
Signal frequencies:	L1+ L2 (GPS + GLO+ QZSS); E1 (L1) + E5a (L5) GAL; B1 (L1) + B2 (L7) BeiDou
Orbit characteristic:	3-day long arcs; RPR: ECOM / ECOM2 (since 2015)
Reference frame:	IGS08 (until week 1708); IGB08 (since week 1709)
IERS conventions:	IERS2003 (until 1705); IERS2010 (since 1706)
Product list:	daily orbits (SP3) and ERPs
Distribution:	ftp://cddis.gsfc.nasa.gov/gnss/products/mgex/
Designator:	comwwwwd.???Z

CODE MGEX clock solution

GNSS considered:	GPS + GLONASS + Galileo + BeiDou + QZSS (70 SV)
Processing mode:	post-processing / 2 weeks delay (since 2015)
Timespan covered:	GPS-weeks 1710-1838 (DOY 12/288-15/094)
Number of stations:	130 (GPS), 35 (GLO), 45 (Galileo); 50 (BeiDou); 20 (QZSS)
Processing scheme:	zero-difference network processing (observable: code+phase undifferenced)
Signal frequencies:	L1+ L2 (GPS + GLO+ QZSS); E1 (L1) + E5a (L5) GAL; B1 (L1) + B2 (L7) BeiDou
A priori information:	orbits, ERPs, coordinates, and troposphere from CODE MGEX orbit solution introduced as known
Reference frame:	IGb08
IERS conventions:	IERS2010
Product list:	epoch-wise (300s) satellite and station clock corrections in daily clock RINEX files; daily inter-system biases for mixed stations in Bernese DCB and BIAS-SINEX (BIA) format
Distribution:	ftp://cddis.gsfc.nasa.gov/gnss/products/mgex/
Designator:	comwwwwd.???.Z

New Empirical CODE radiation pressure Model

- MGEX-reprocessing for 2014 using ECOM (5 RPR par.; Springer et al., 1999) vs. ECOM2 (9 RPR par., Arnold et al., 2015 => see presentation on Wednesday)
 - Validation with SLR residuals and satellite clock corrections
 - The new ECOM takes into account the varying cross section of the satellite body wrt. the Sun
- => Improvements expected for GLONASS, Galileo, QZSS

ECOM1 (old):

$$D(u) = D_0$$

$$Y(u) = Y_0$$

$$B(u) = B_0 + B_C \cos(u) + B_S \sin(u)$$

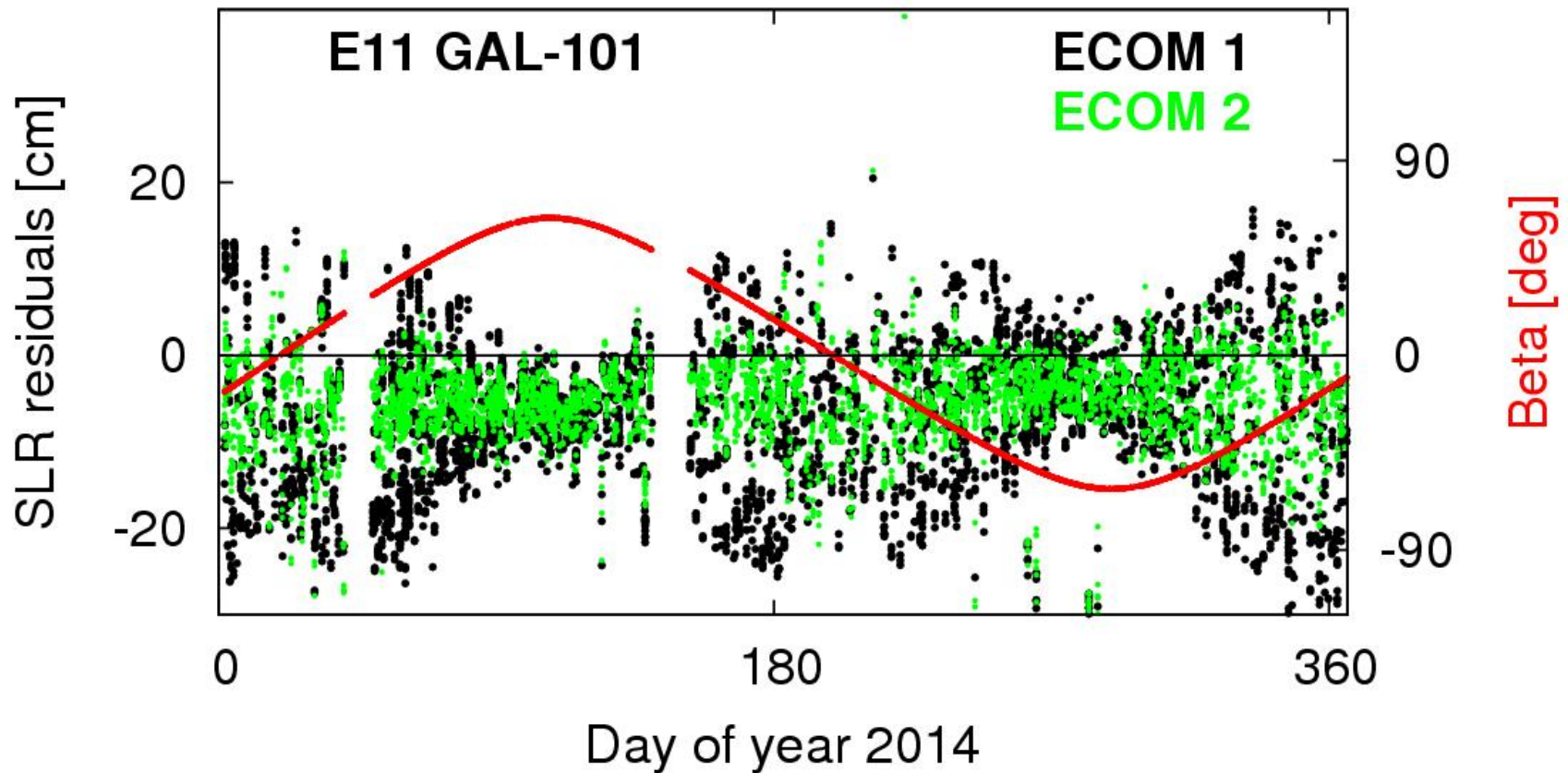
ECOM2 (new):

$$D(u) = D_0 + D_{2C} \cos(2\Delta u) + D_{2S} \sin(2\Delta u) \\ + D_{4C} \cos(4\Delta u) + D_{4S} \sin(4\Delta u)$$

$$Y(u) = Y_0$$

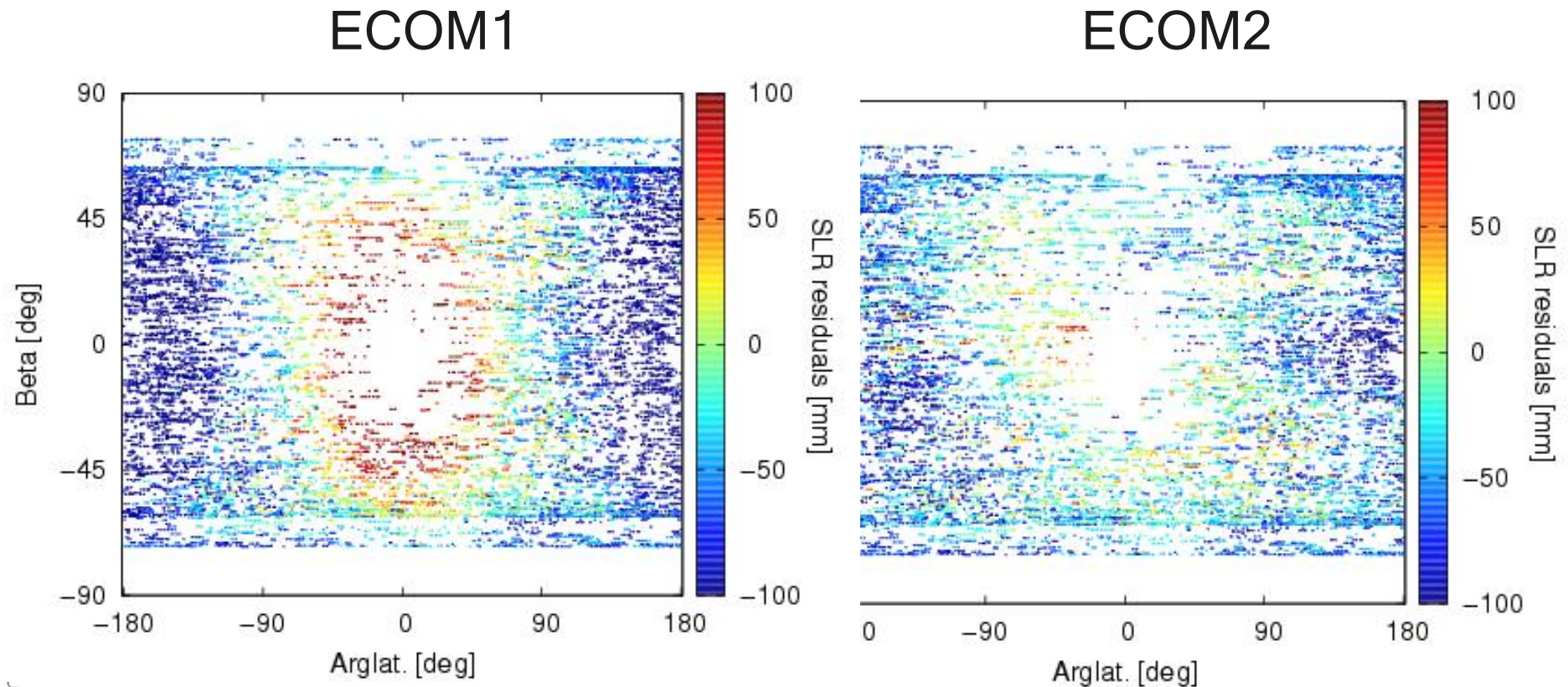
$$B(u) = B_0 + B_C \cos(\Delta u) + B_S \sin(\Delta u)$$

Impact of new ECOM on Galileo orbits



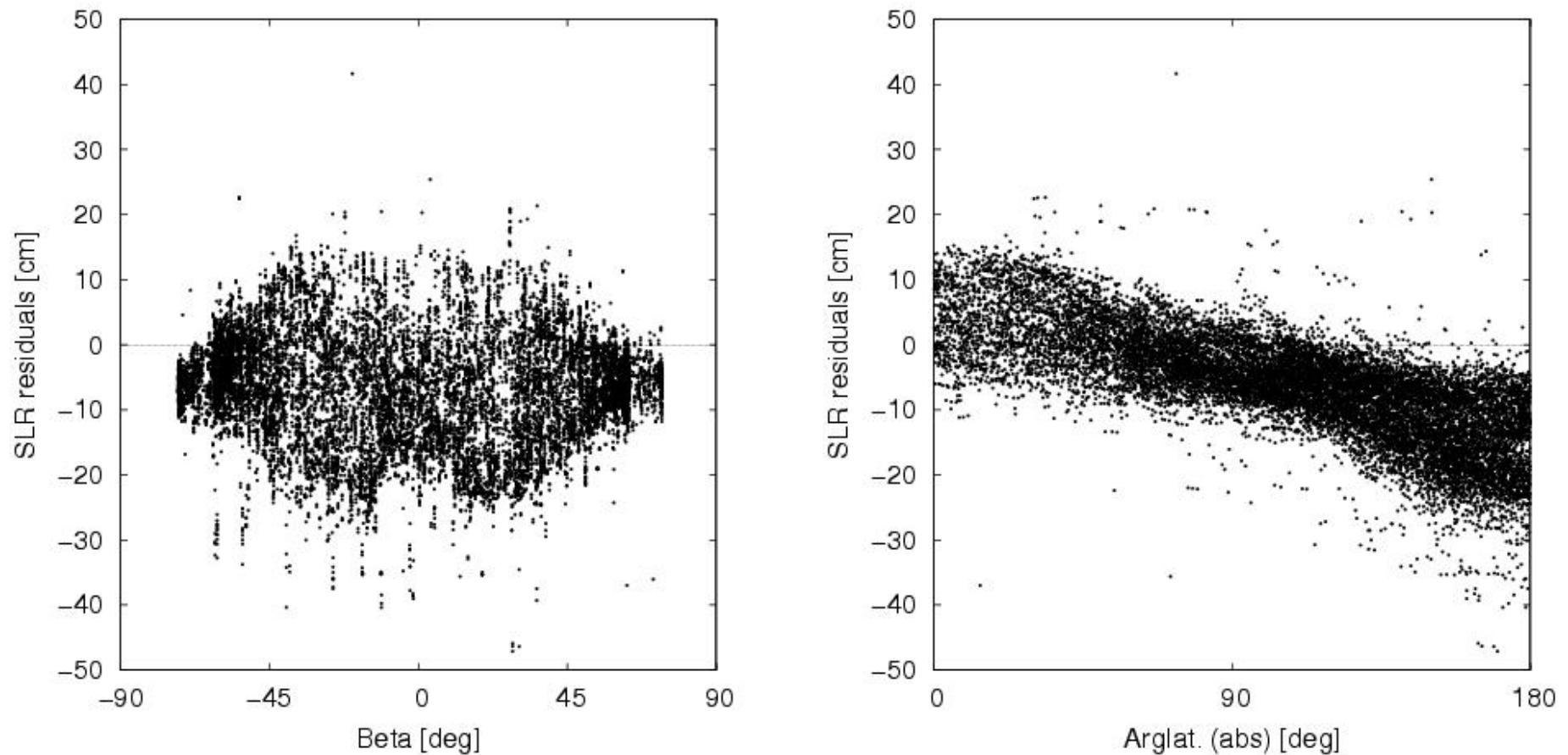
=> Significant reduction of size and dependency of SLR residuals on the Beta-angle (elevation of the Sun above the orbital plane)

Impact of new ECOM on Galileo orbits



=> Reduced amount of SLR residuals with extremely large or small values close to or opposite to the direction of the Sun

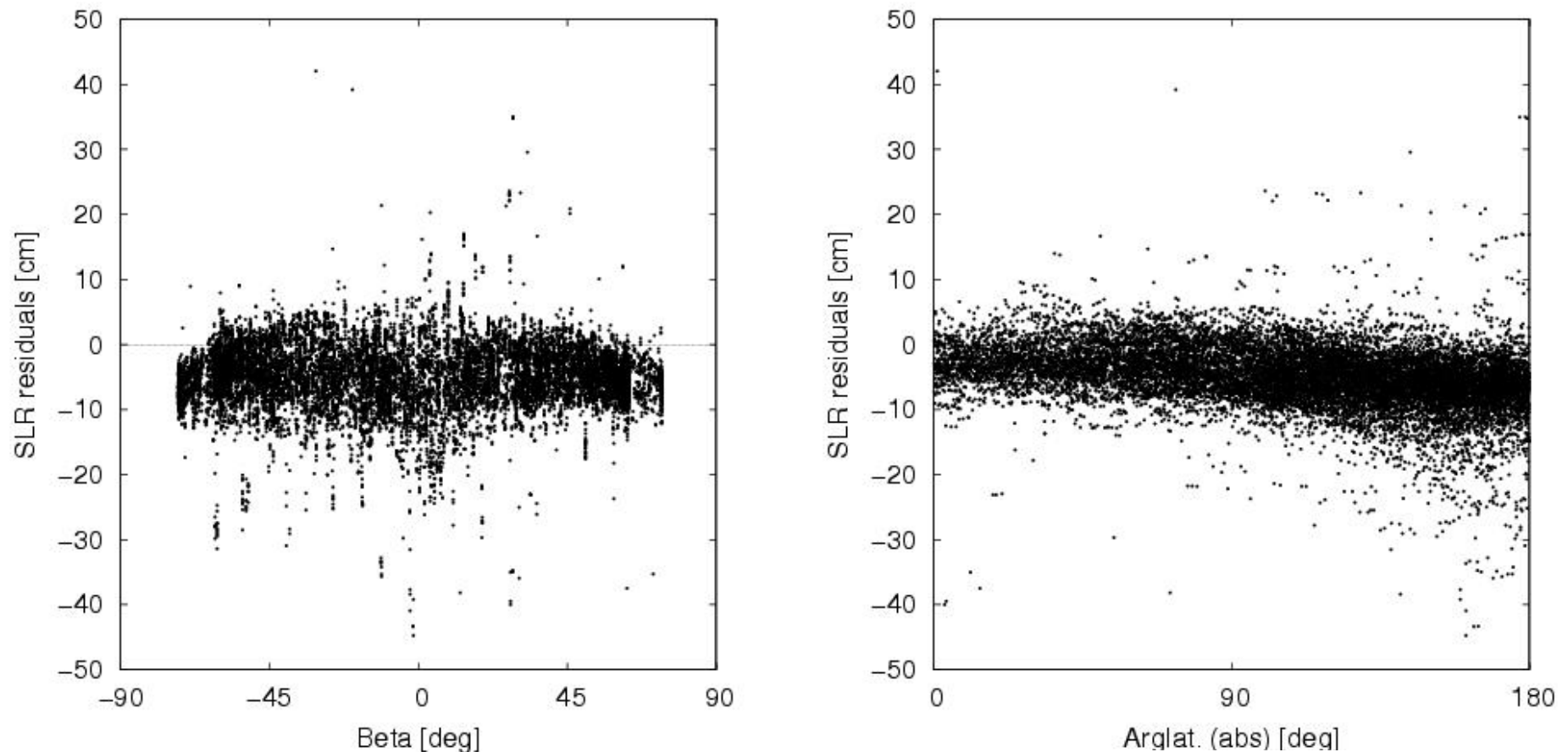
Impact of new ECOM on Galileo orbits



ECOM1 (all Galileo satellites):

=> Large SLR residuals for low and medium Beta angles and for argument of latitude around 0 and +-180 degrees

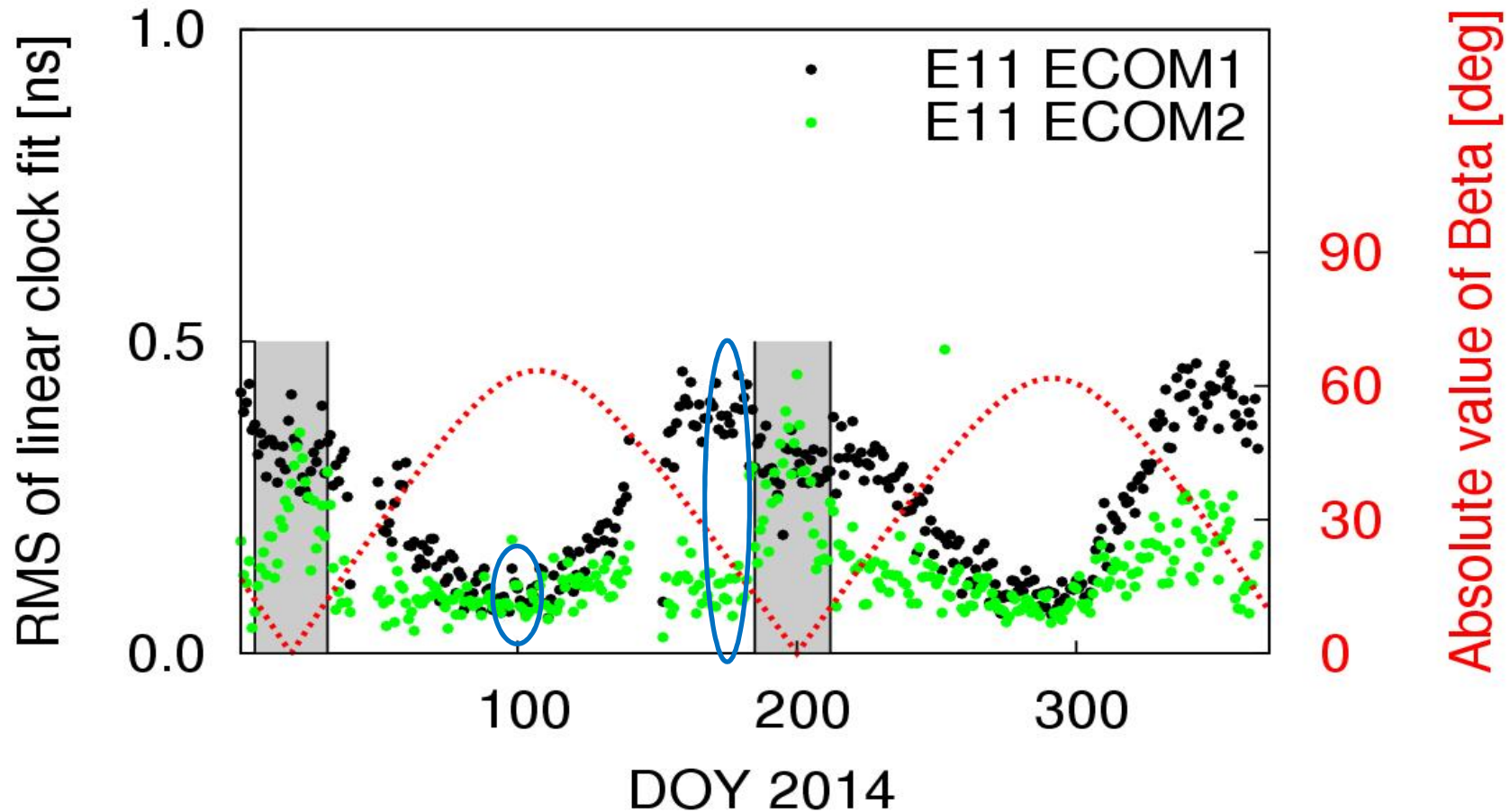
Impact of new ECOM on Galileo orbits



ECOM2 (all Galileo satellites):

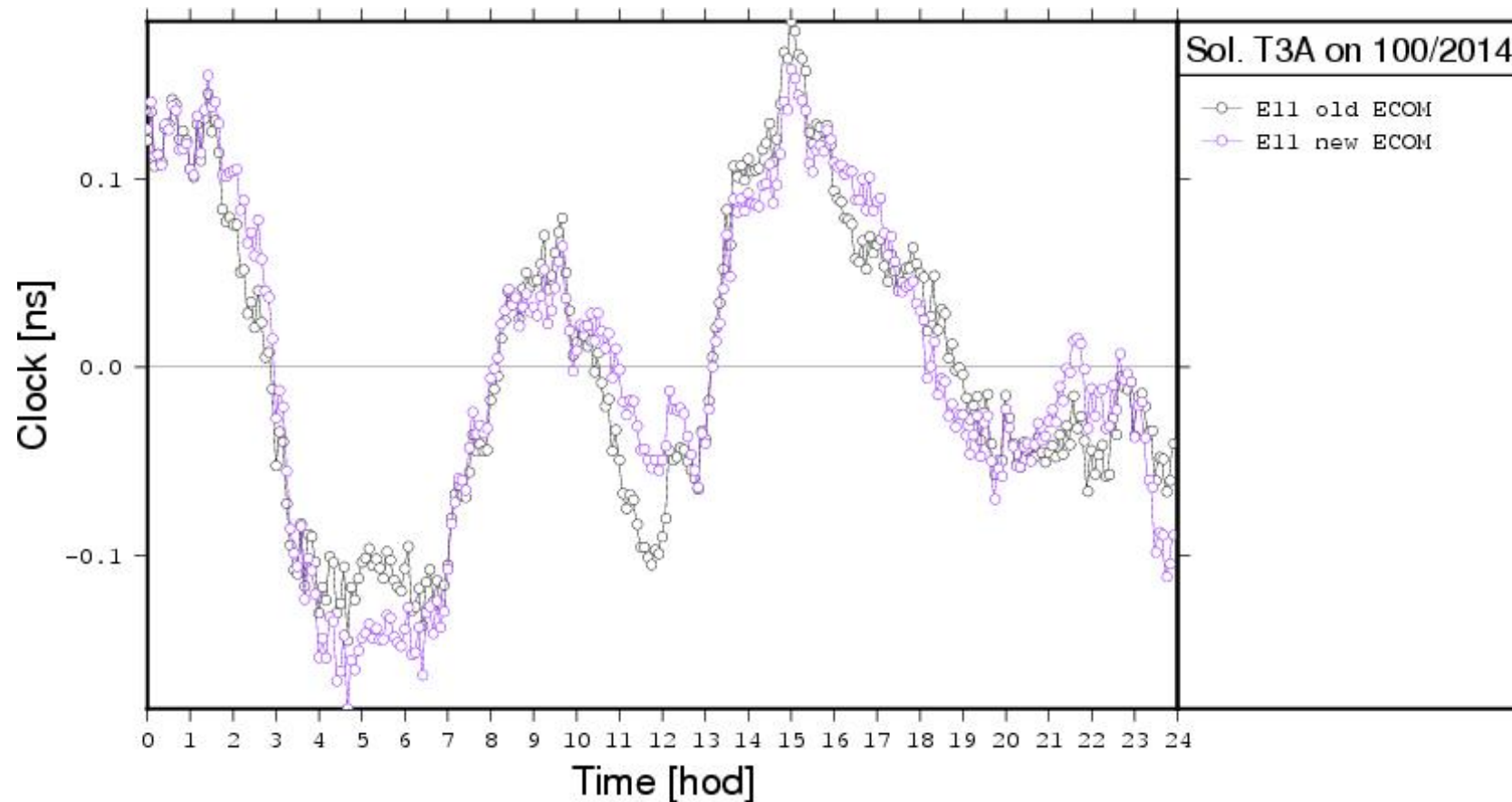
- => Systematics in the SLR residuals are significantly reduced
- => SLR offset of about 5 cm (less for FOC) remains

Impact of new ECOM on Galileo clock corrections



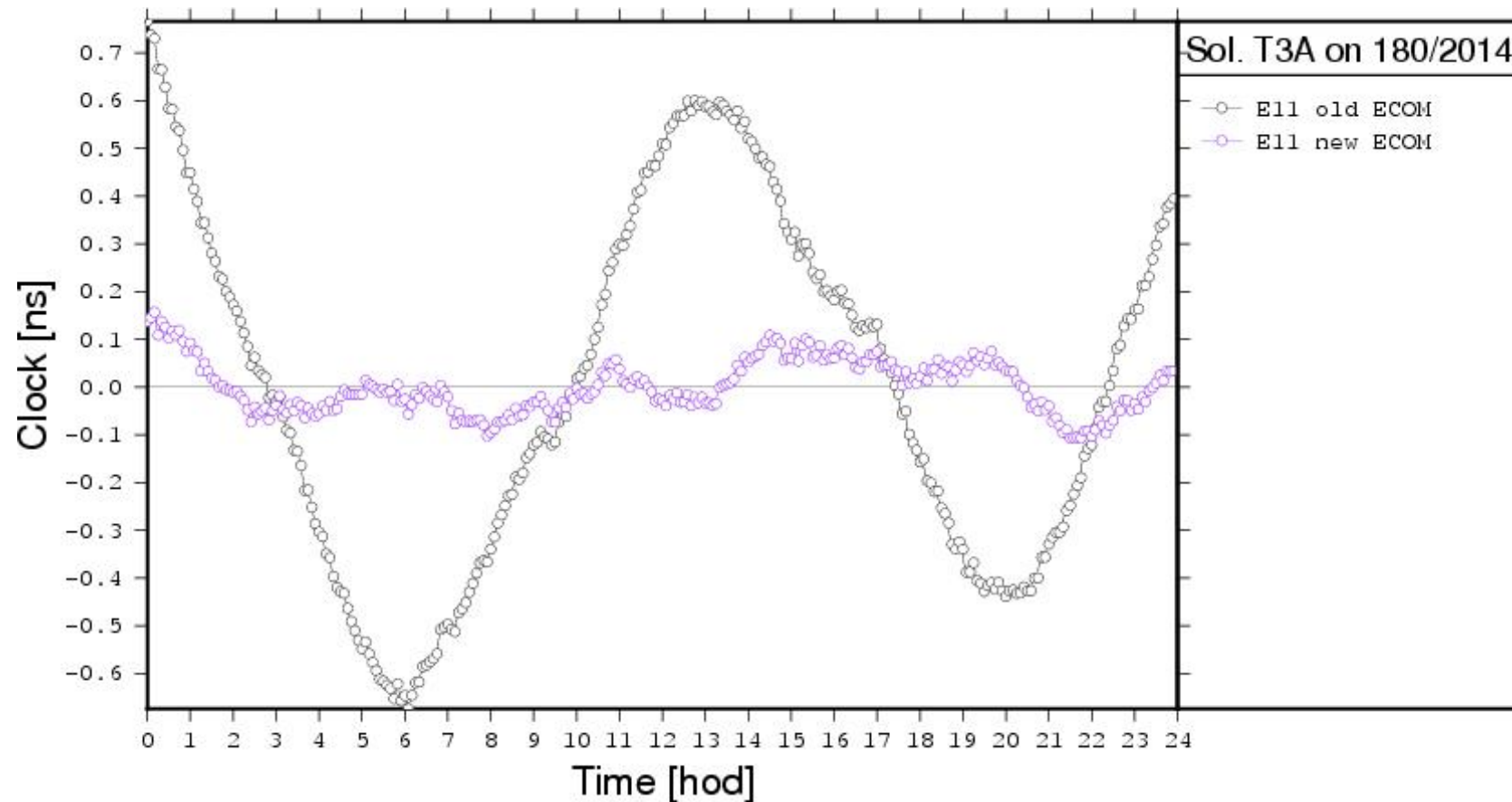
- => Significant reduction of Beta angle dependency
- => Pronounced signal remains during eclipse season or close-by (=> impact of mis-modelled attitude?)

Impact of new ECOM on Galileo clock corrections



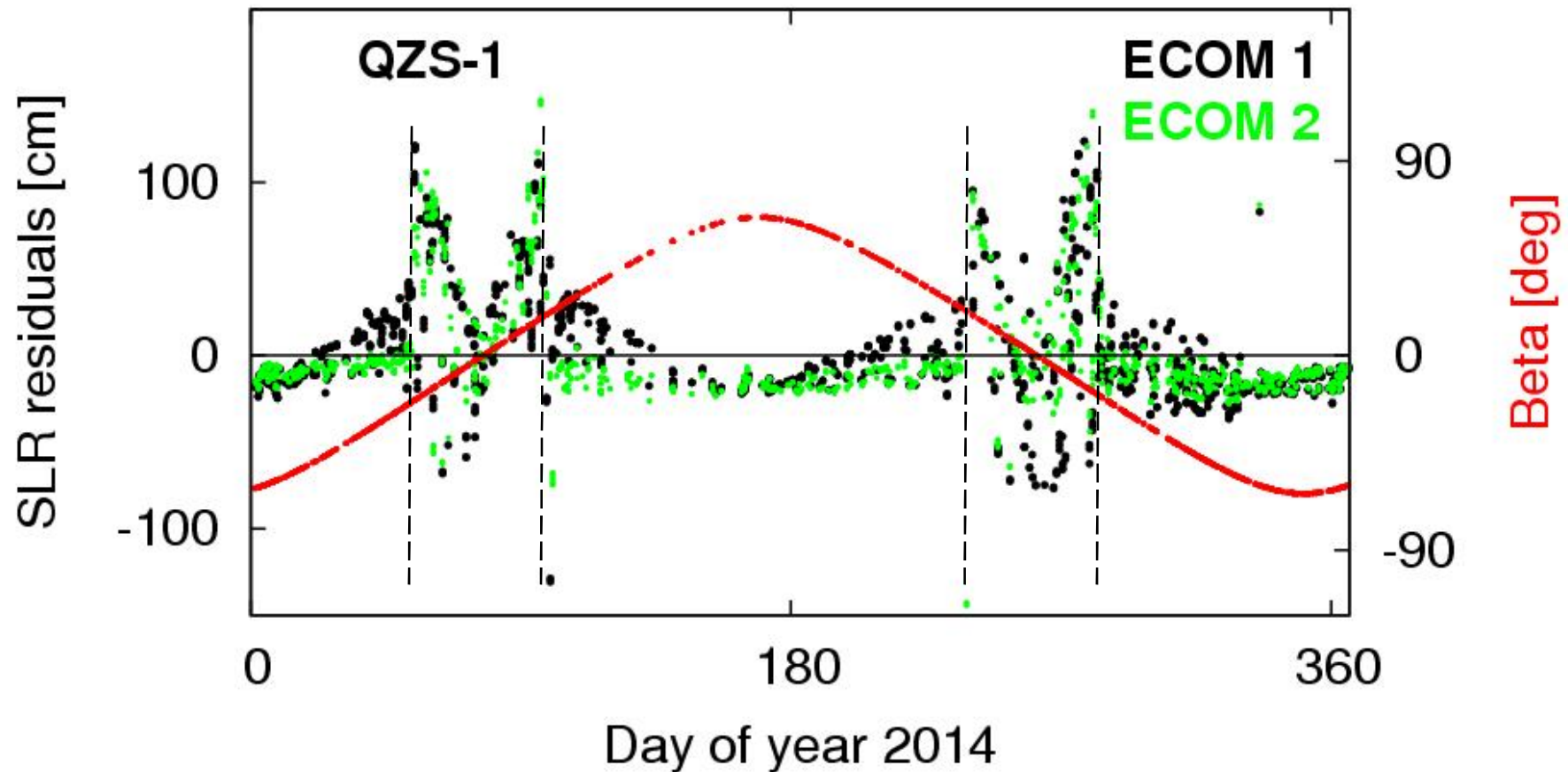
DOY 14/100: Beta-angle is large (i.e., cross-section of satellite body wrt. the Sun is more or less constant)
=> No improvement (variation in clock signal about ± 0.15 ns)

Impact of new ECOM on Galileo clock corrections



DOY 14/180: Beta-angle is low (i.e., cross-section of satellite body wrt. the Sun varies periodically during each orbital revolution)
=> Periodic signal caused by mis-modelled orbit is significantly reduced (+- 0.75 ns -> +- 0.15 ns)

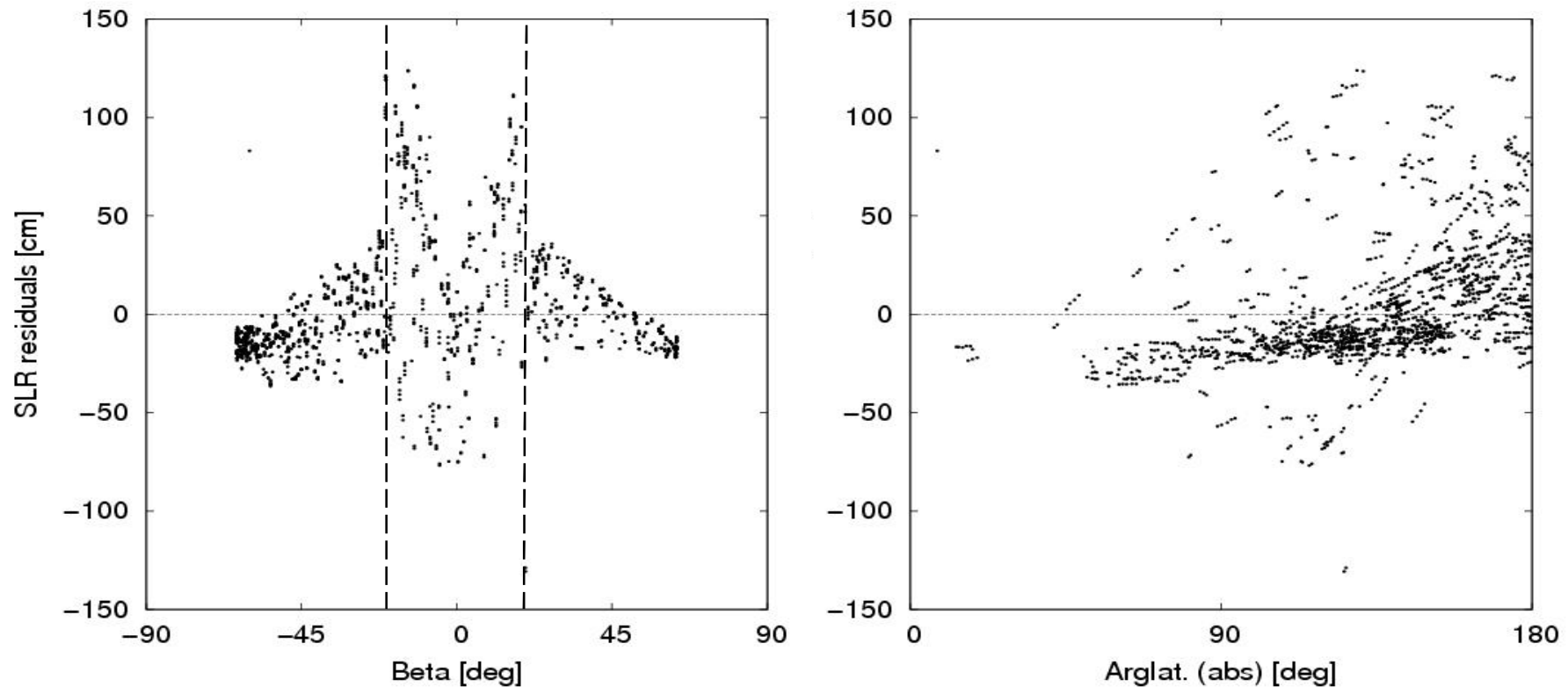
Impact of new ECOM on QZSS orbits



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- => Improvement (dependency on Beta angle is reduced)
- => Unconsidered normal attitude mode dominates orbit errors at low Beta angles (< 20 degrees)

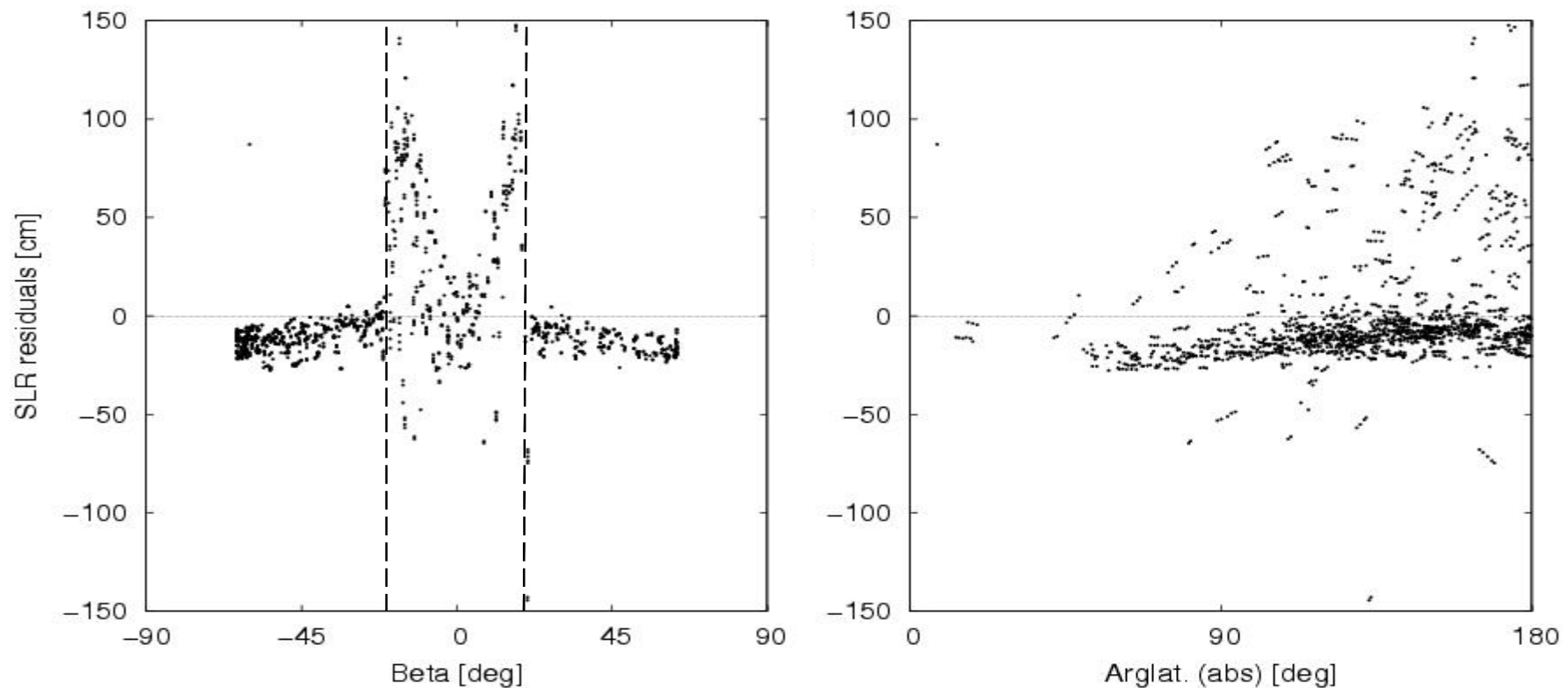
Impact of new ECOM on QZSS orbits



ECOM1:

- => $\text{abs}(\text{Beta}) < 20$ degrees: SLR residuals dominated by unconsidered orbit normal attitude mode
- => $\text{abs}(\text{Beta}) > 20$ degrees: correlation with Beta angle and argument of latitude

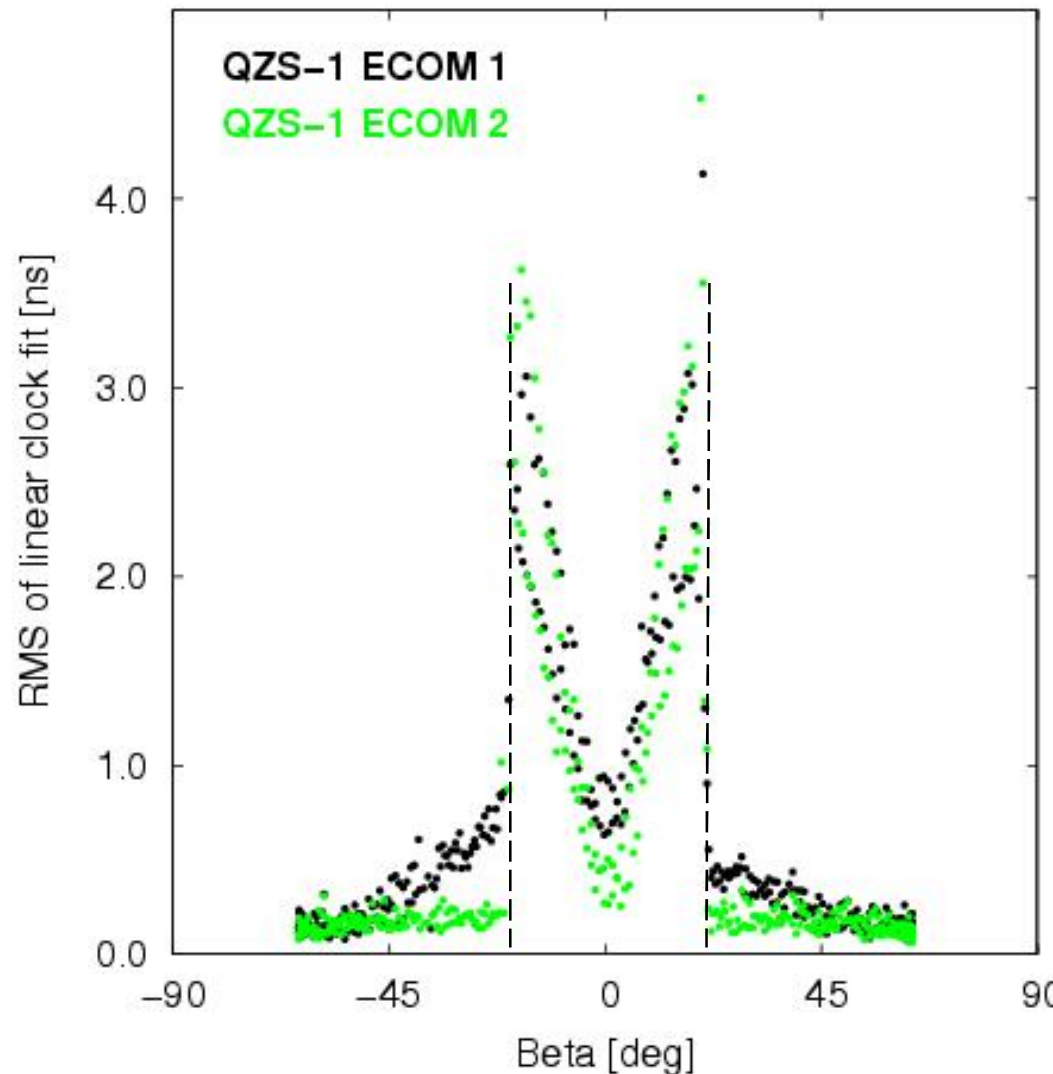
Impact of new ECOM on QZSS orbits



ECOM2:

- => $\text{abs}(\text{Beta}) < 20$ degrees: no big change
- => $\text{abs}(\text{Beta}) > 20$ degrees: systematics in the SLR residuals are reduced
- => SLR offset remains

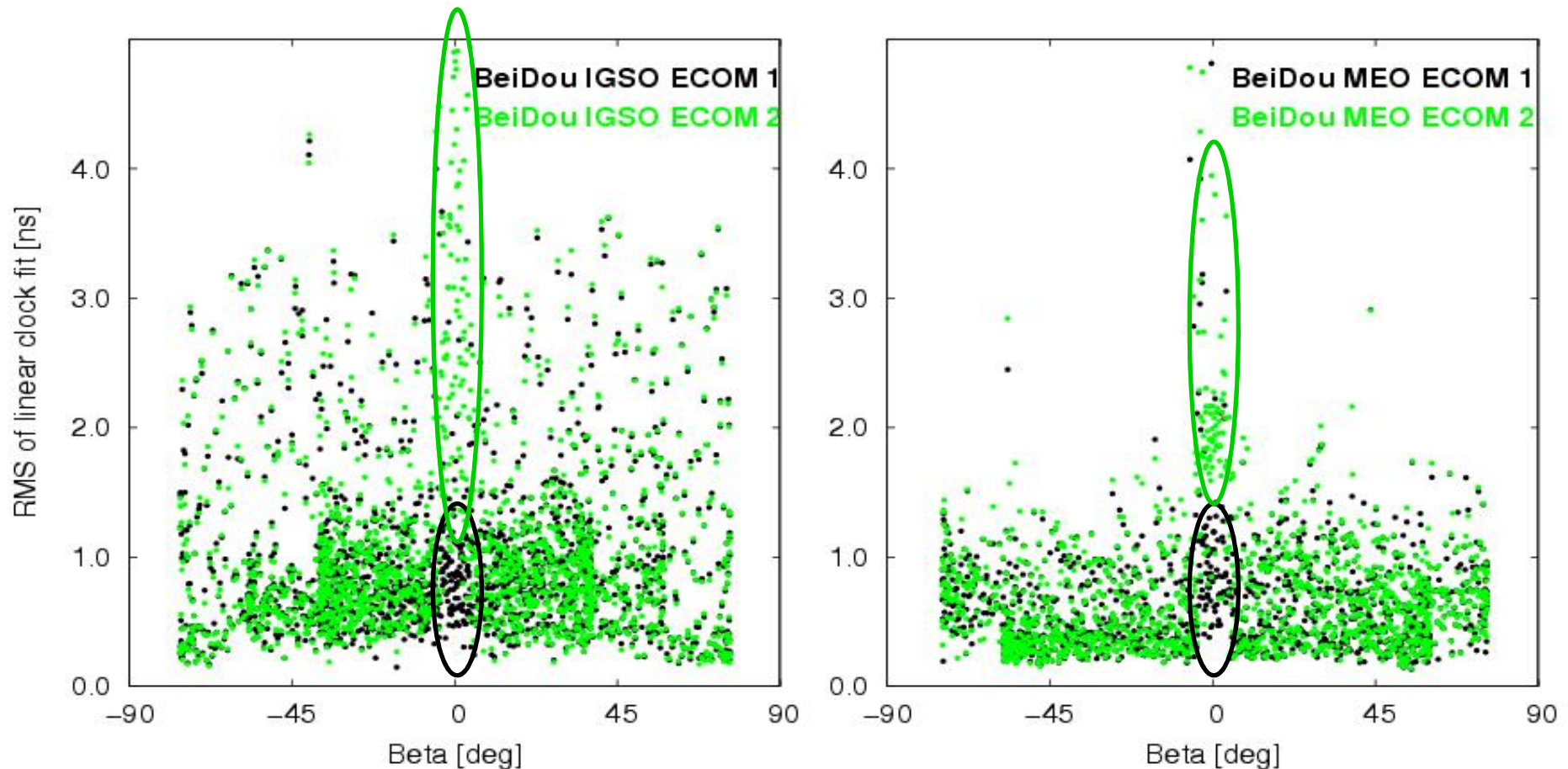
Impact of new ECOM on QZSS clock corrections



QZS-1:

- => $\text{abs}(\text{Beta}) > 20$ degrees: very good performance of satellite clock becomes obvious (RMS of linear fit < 0.1 ns possible)
- => Clocks are suited for orbit validation
- => Orbit errors and unmodelled normal attitude are directly mapped into satellite clock estimates (see $\text{abs}(\text{Beta}) < 20$ degrees)

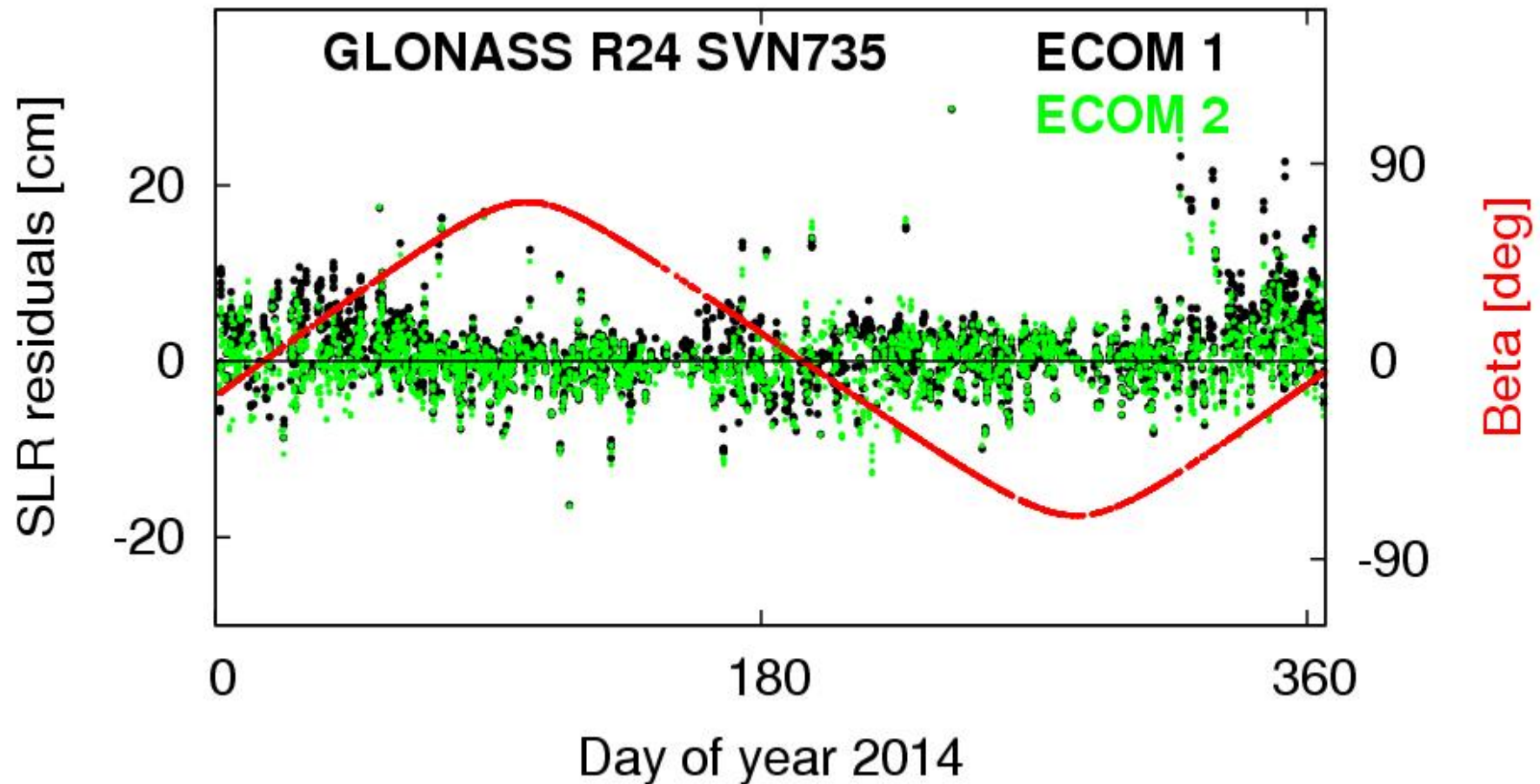
Impact of new ECOM on BeiDou clock corrections



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- => No significant impact of new ECOM on BeiDou satellite clock corrections, but
- => Increased RMS of clock fit for very small Beta angles (confirming changed attitude mode at $\text{abs}(\text{Beta}) < 4$ degrees)

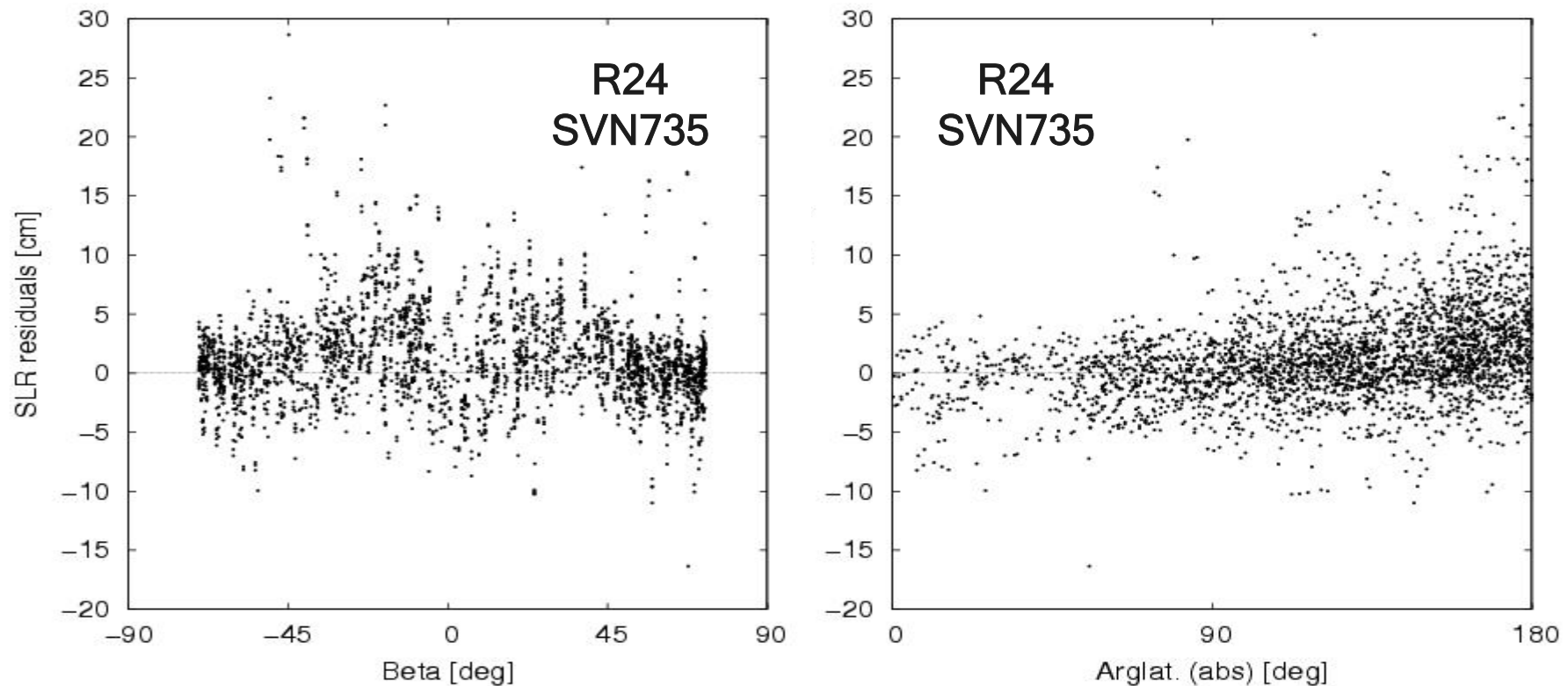
Impact of new ECOM on GLONASS orbits



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=> Moderate reduction of SLR residuals at low Beta angles
for majority of satellites

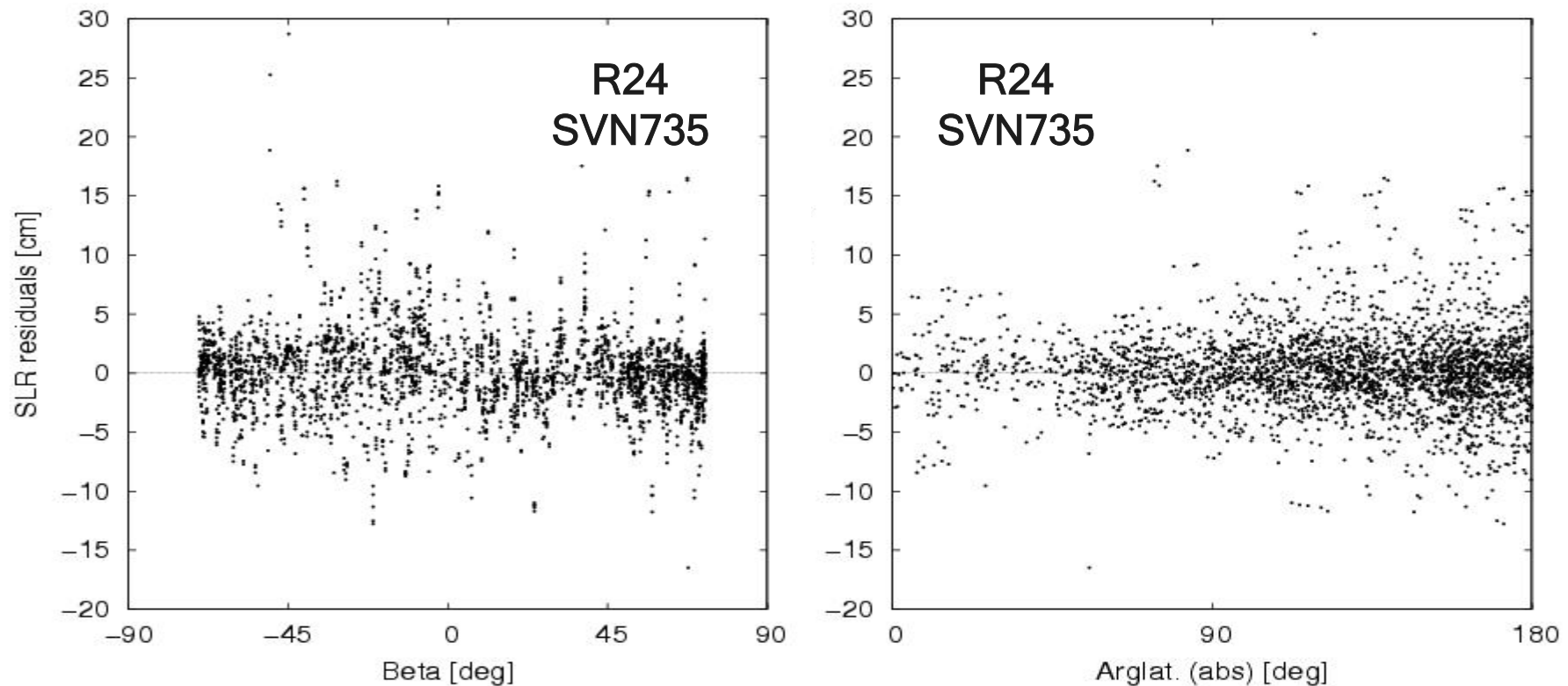
Impact of new ECOM on GLONASS orbits



ECOM1:

=> Moderate correlation of SLR residuals with Beta angle and argument of latitude

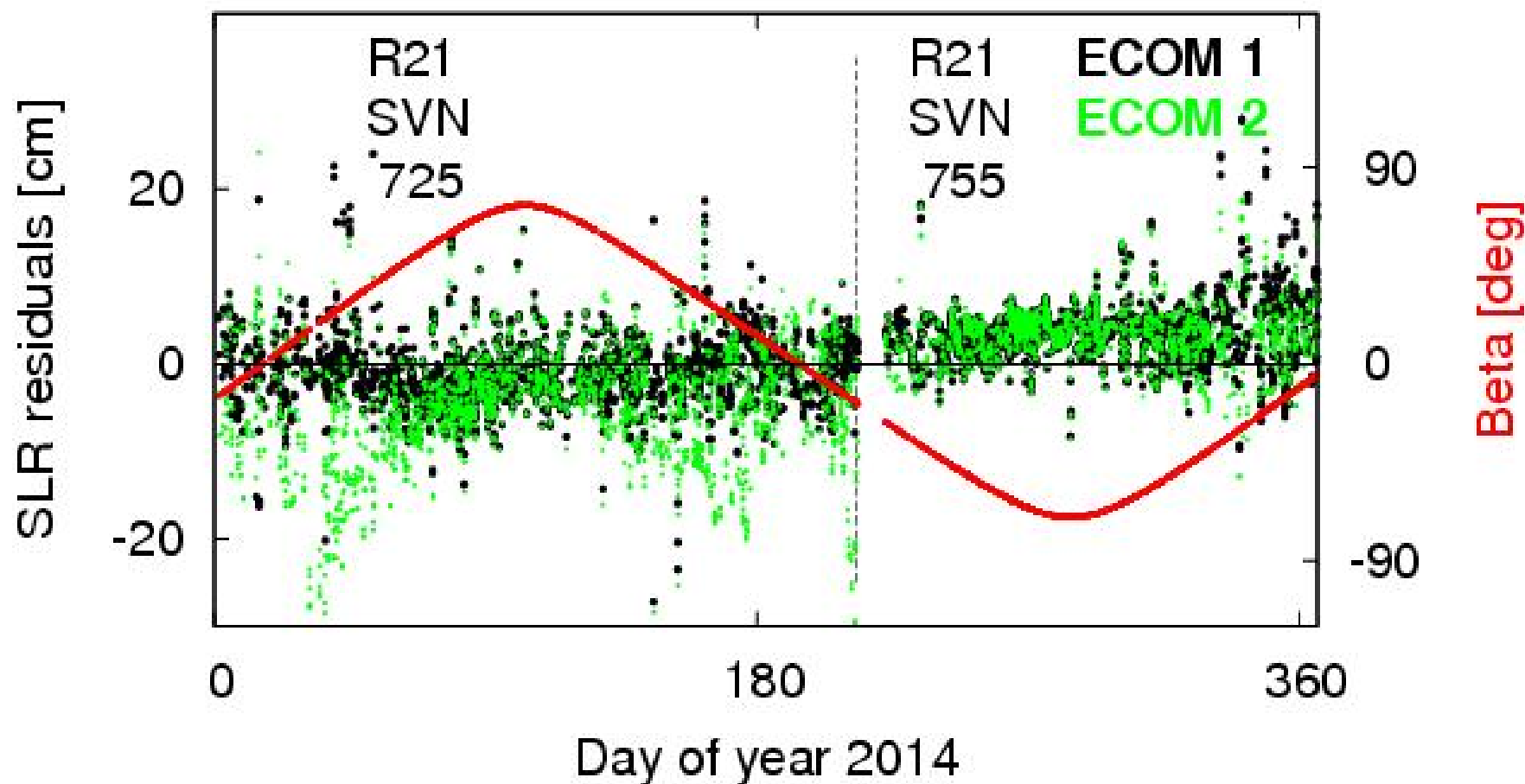
Impact of new ECOM on GLONASS orbits



ECOM2:

=> Systematics in the SLR residuals are reduced

Impact of new ECOM on GLONASS - exceptions



=> ECOM2 does not work well for all GLONASS satellites

Summary

- CODE provides an MGEX-based, fully integrated, five-system orbit and clock solution:
GPS+GLONASS+Galileo+BeiDou+QZSS
- CODE MGEX products are available via CDDIS FTP =>
<ftp://cddis.gsfc.nasa.gov/gnss/products/mgex/>
- Since early 2015 the CODE MGEX products are delivered on a regular basis with a delay below 2 weeks and using the new ECOM2 radiation pressure model
- Galileo benefits most from the new ECOM2, QZSS benefits also significantly, GLONASS moderately (at least the majority of the satellites); no benefit for GPS and BeiDou

Outlook

- Analysis of orbit model impact on different GNSS to be continued
- Analysis of attitude model impact on different GNSS
- Why do some GLONASS satellites react differently to the change of the radiation pressure model? (attitude keeping,...?)
- Estimation of satellite antenna phase center corrections is under way (=> see presentation of Peter Steigenberger)

Thank you
for
your interest!