CODE's multi-GNSS orbit solution

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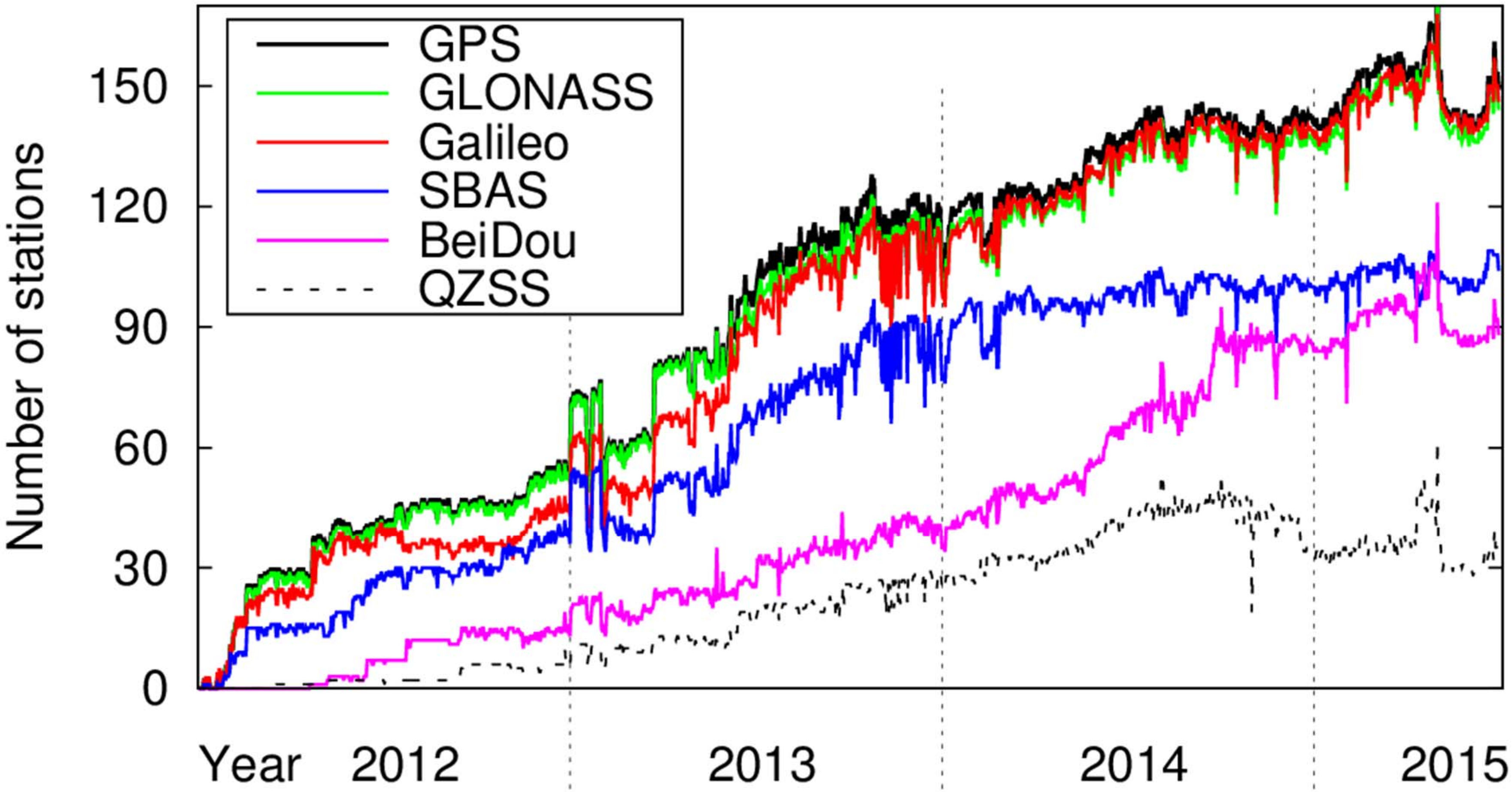
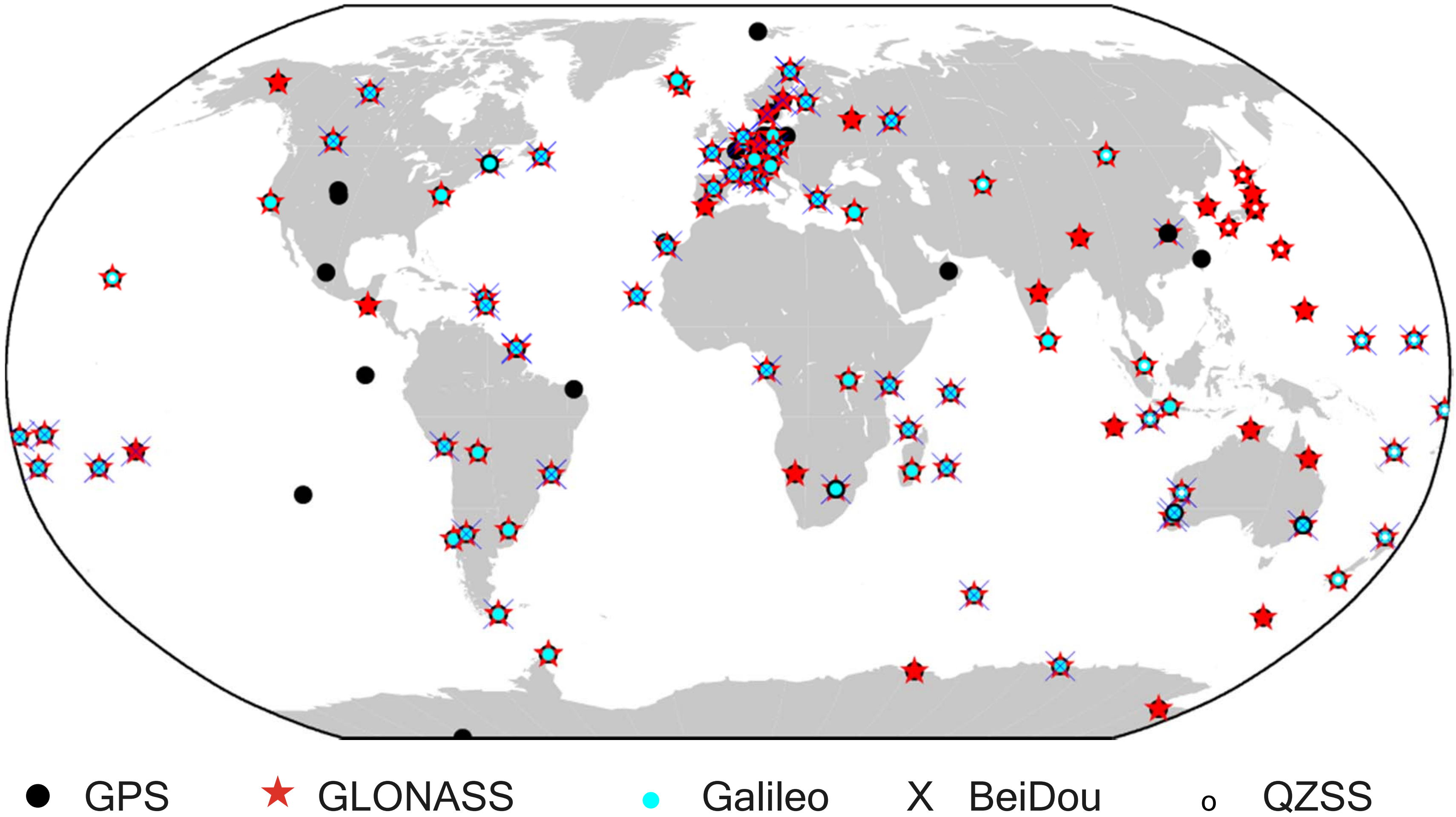
MGEX data monitoring

Number of stations providing daily RINEX3 files included in CODE's raw data monitoring (data sources IGS-MGEX and EPN)



Tracking network

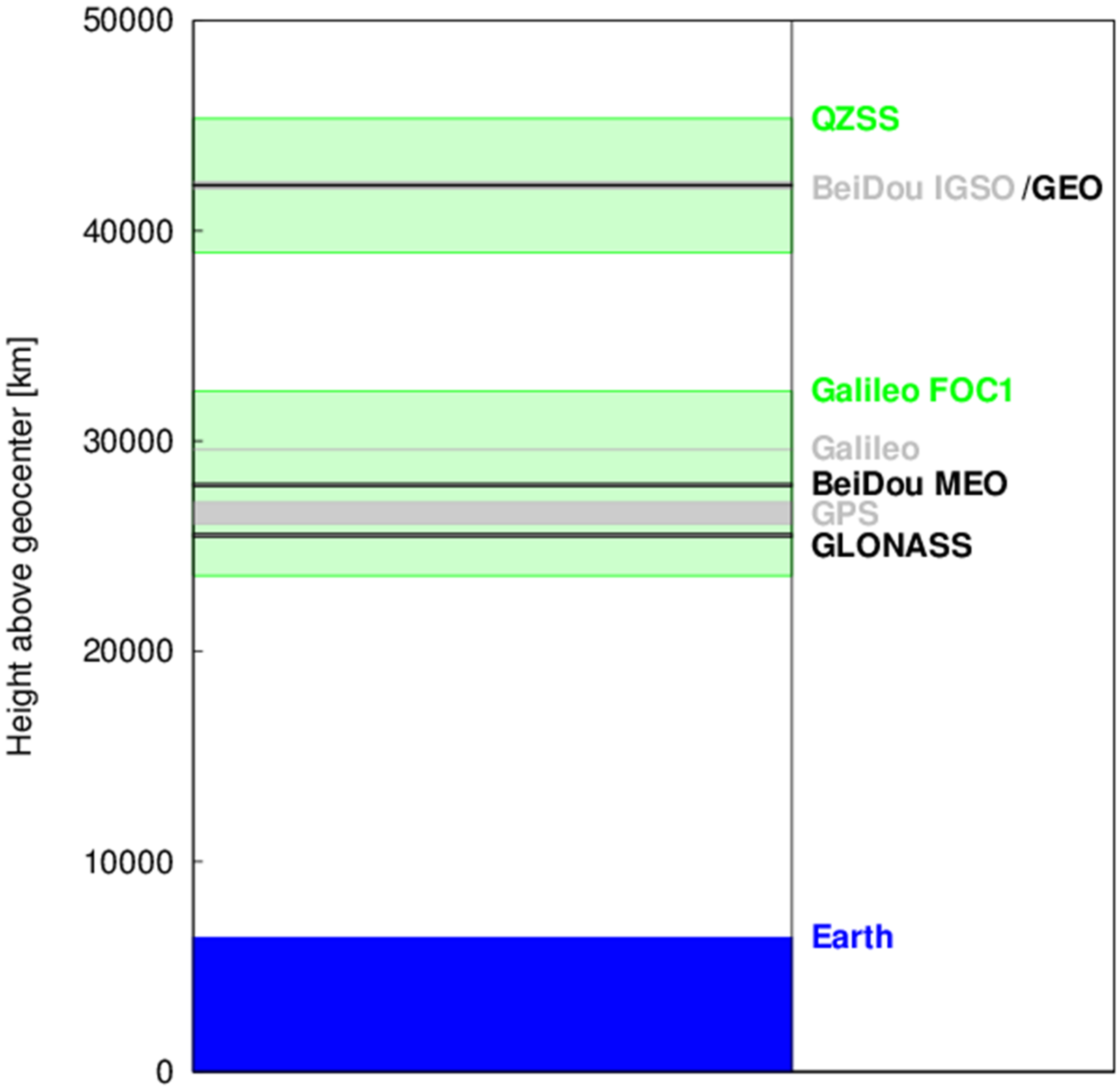
Station distribution for orbit solution (DOY 15/030)



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 - today
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

Involved satellite systems

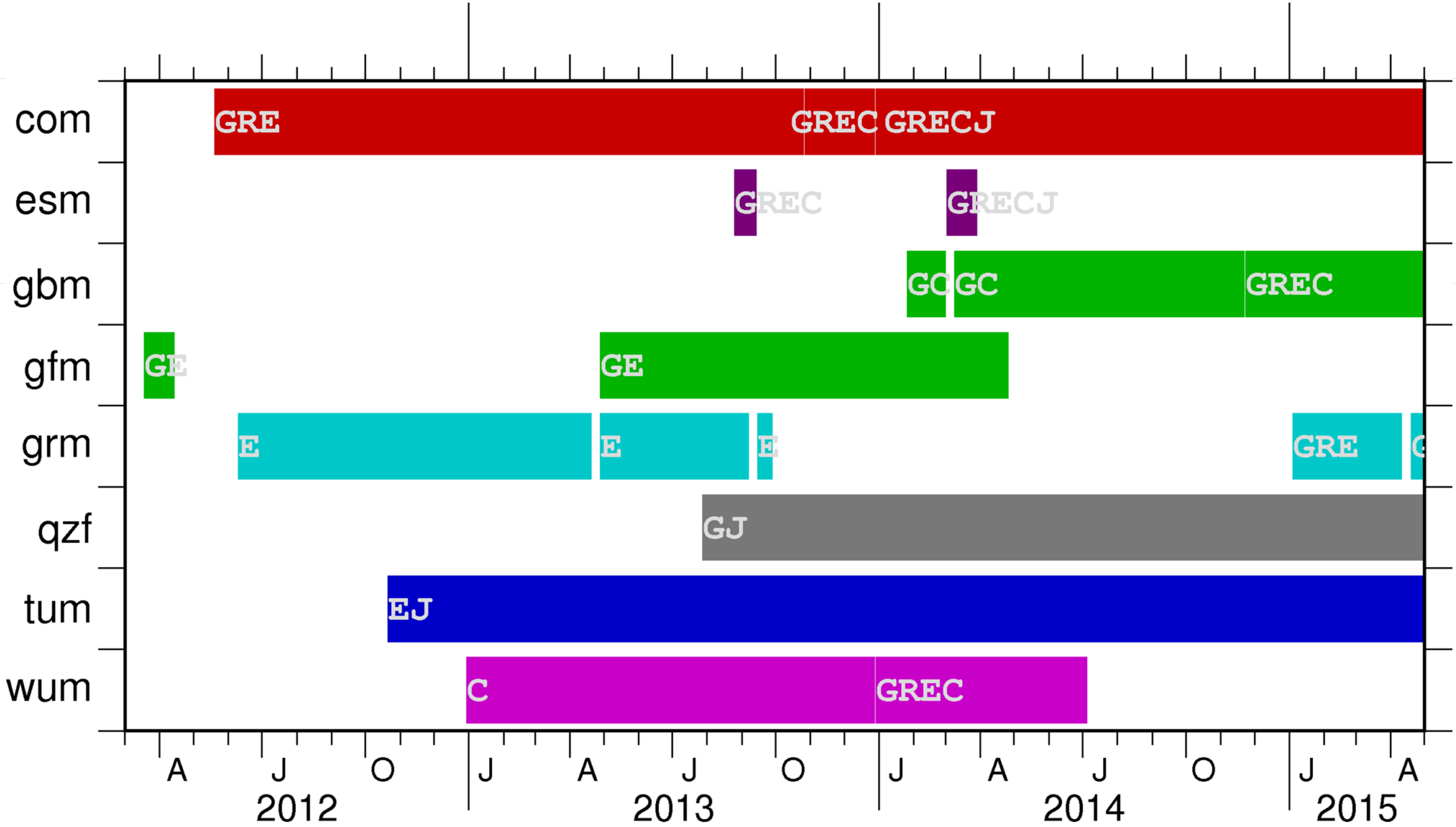


>70 GNSS and RNSS satellites with different orbit characteristics (orbit height, excentricity, inclination), signals, tracking modes

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 - today
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

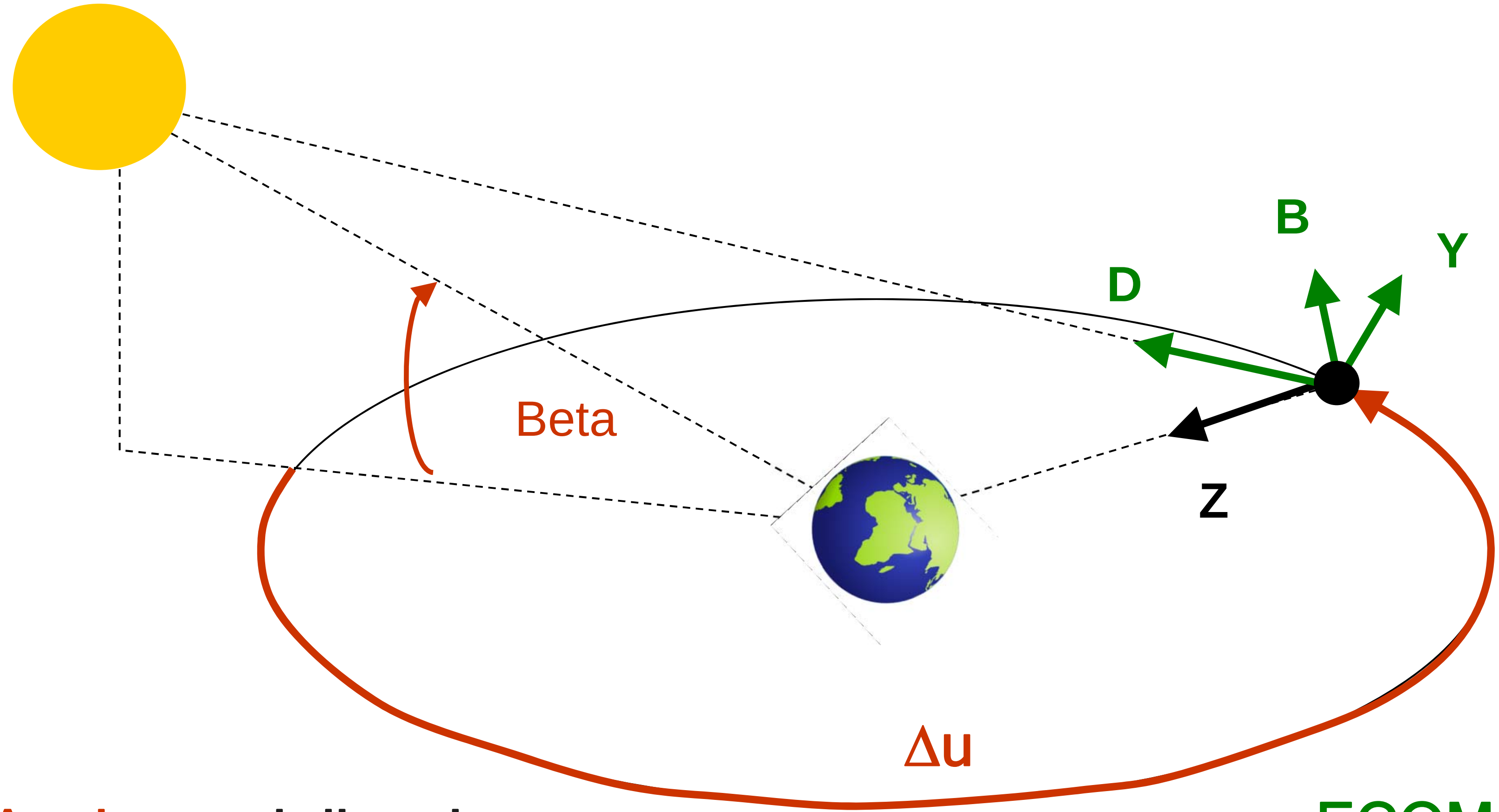
MGEX products availability



Status: 01-May-2015

Satellite system IDs according to the content of the precise orbit files at ftp://cddis.gsfc.nasa.gov/pub/gps/products/mgex/

Orbit description and Yaw attitude



Angles and directions:

Beta: Elevation of Sun above orbital plane

Δu: Argument of latitude

Z: Direction satellite -> Earth (antenna direction)

ECOM axes:

D: Direction satellite -> Sun

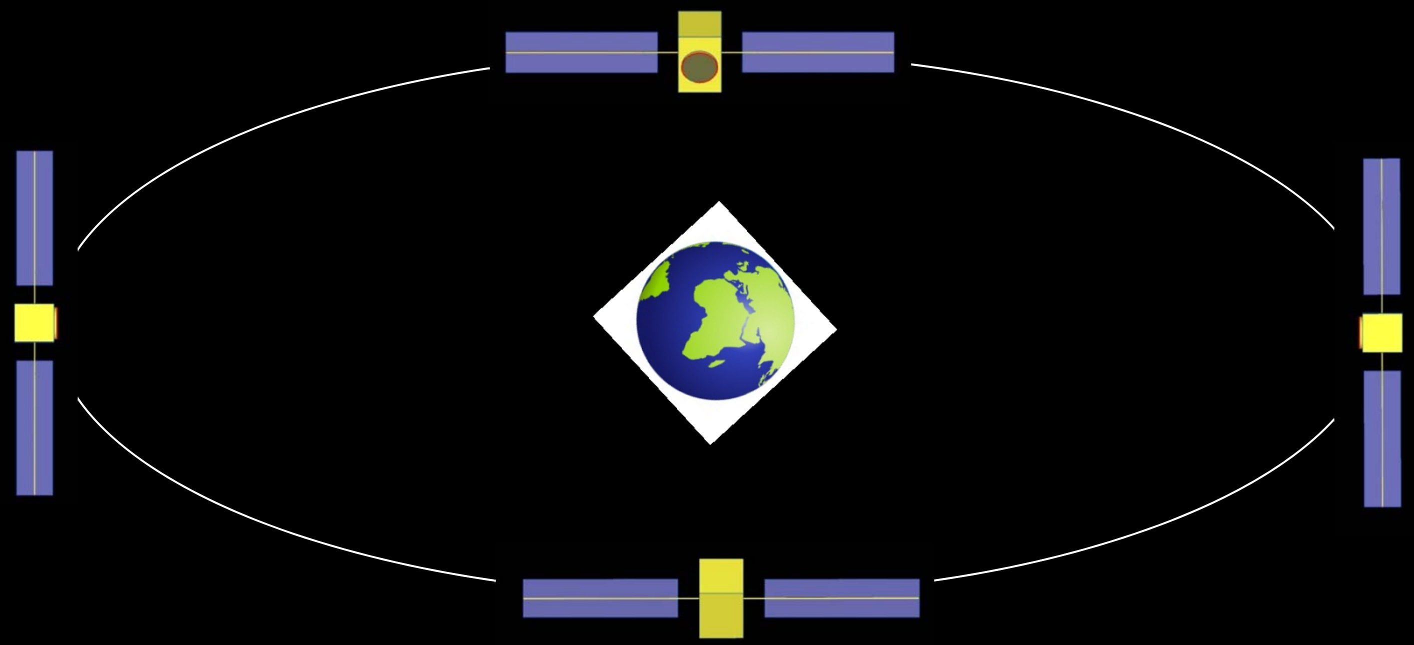
Y: Solar panel axis

B: Third ECOM axis

Solar radiation pressure

Satellite cross-section as seen from the Sun (Beta ≈ 30°) during one orbital revolution:

=> solar panel area does not change



=> but: cross-section of long satellite bodies w.r.t. the Sun varies

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)
- Validation with SLR residuals and satellite clock corrections
- The new ECOM takes into account the periodically changing cross section of the satellite body wrt. the Sun

=> Improvements expected for Galileo, GLONASS, QZSS

ECOM1 (old):

$D(u) = D_0$

$Y(u) = Y_0$

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

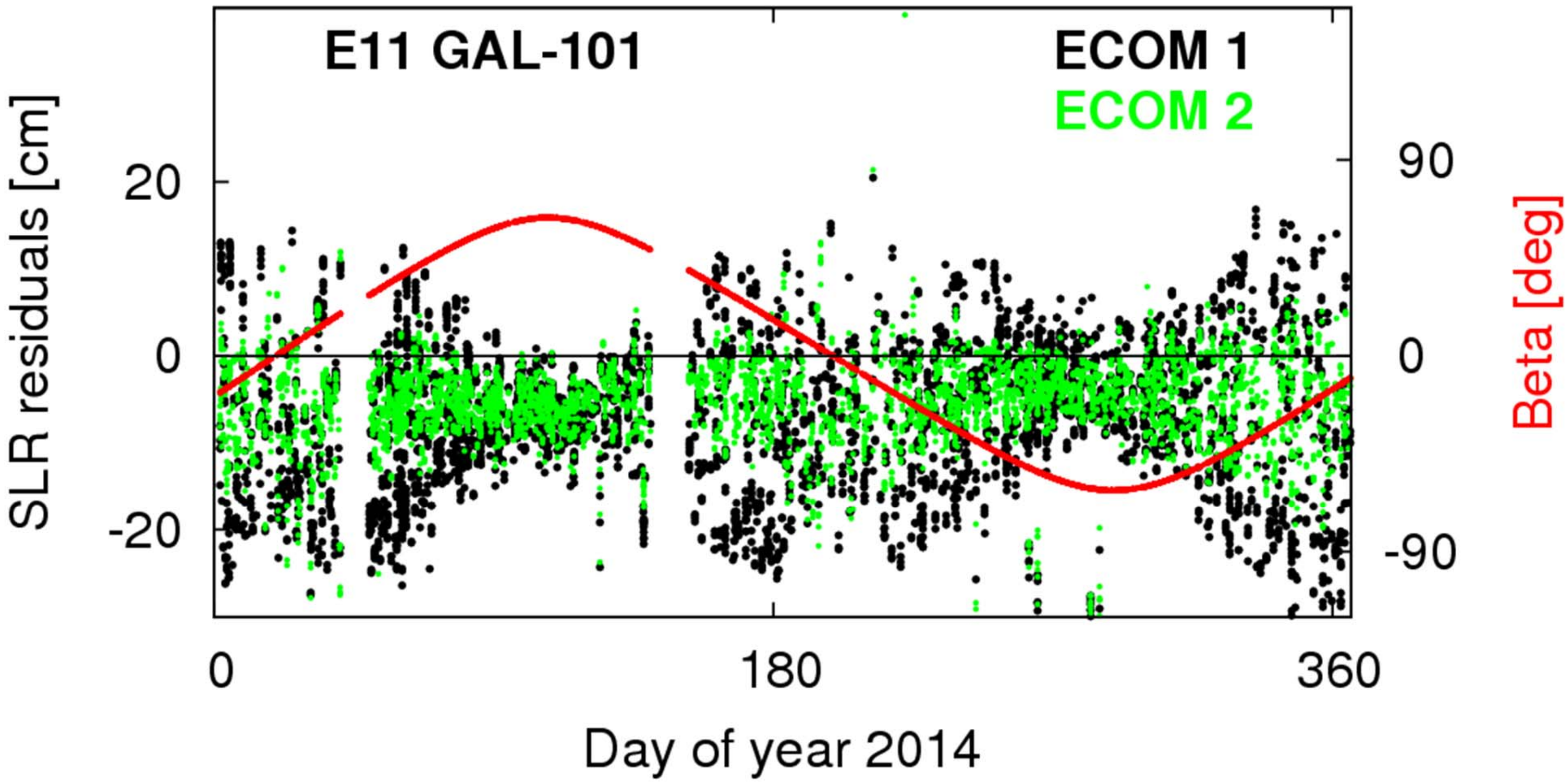
ECOM2 (new):

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

$Y(u) = Y_0$

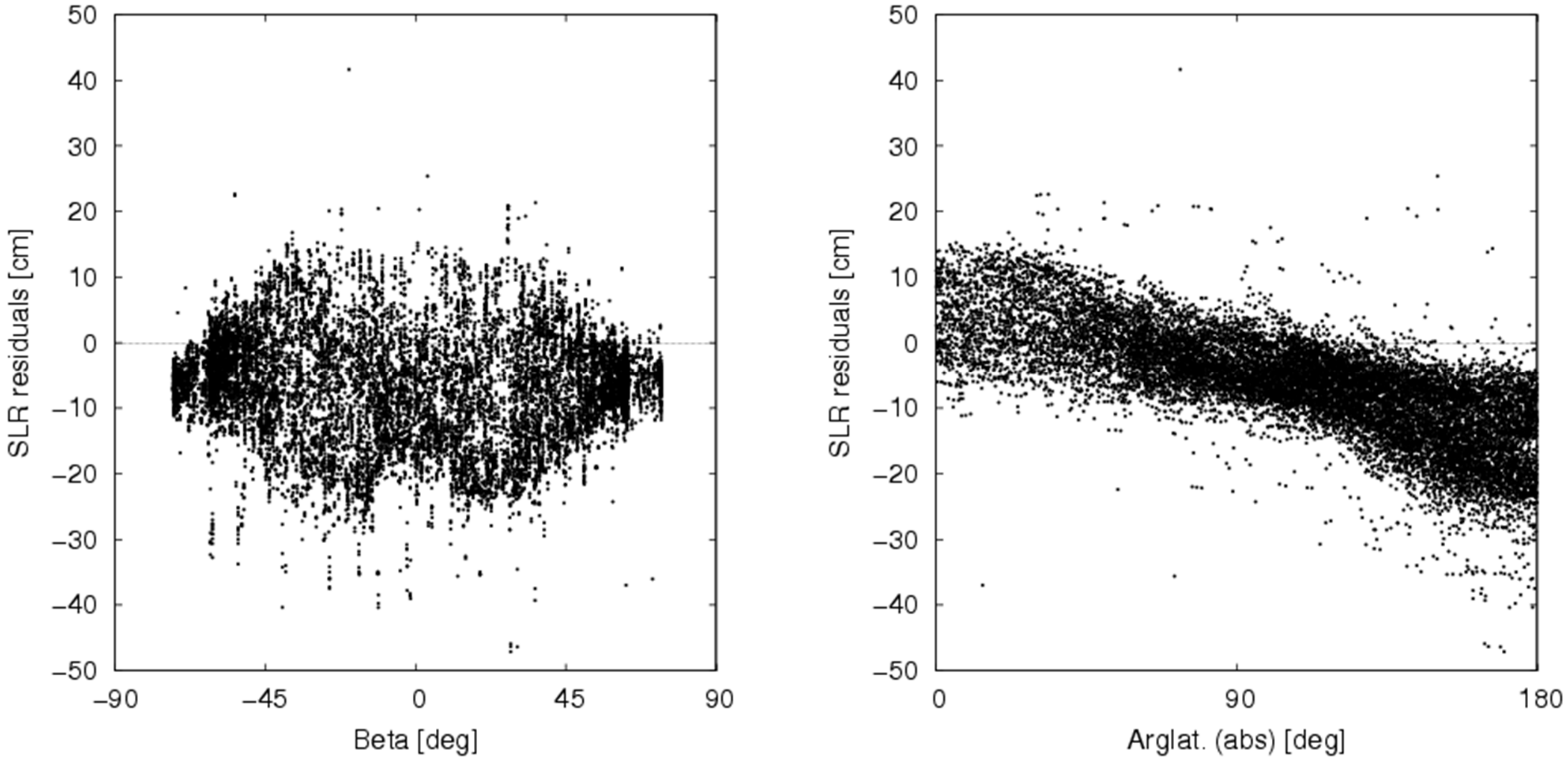
$B(u) = B_0 + B_C \cos(\Delta u) + B_S \sin(\Delta u)$

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)

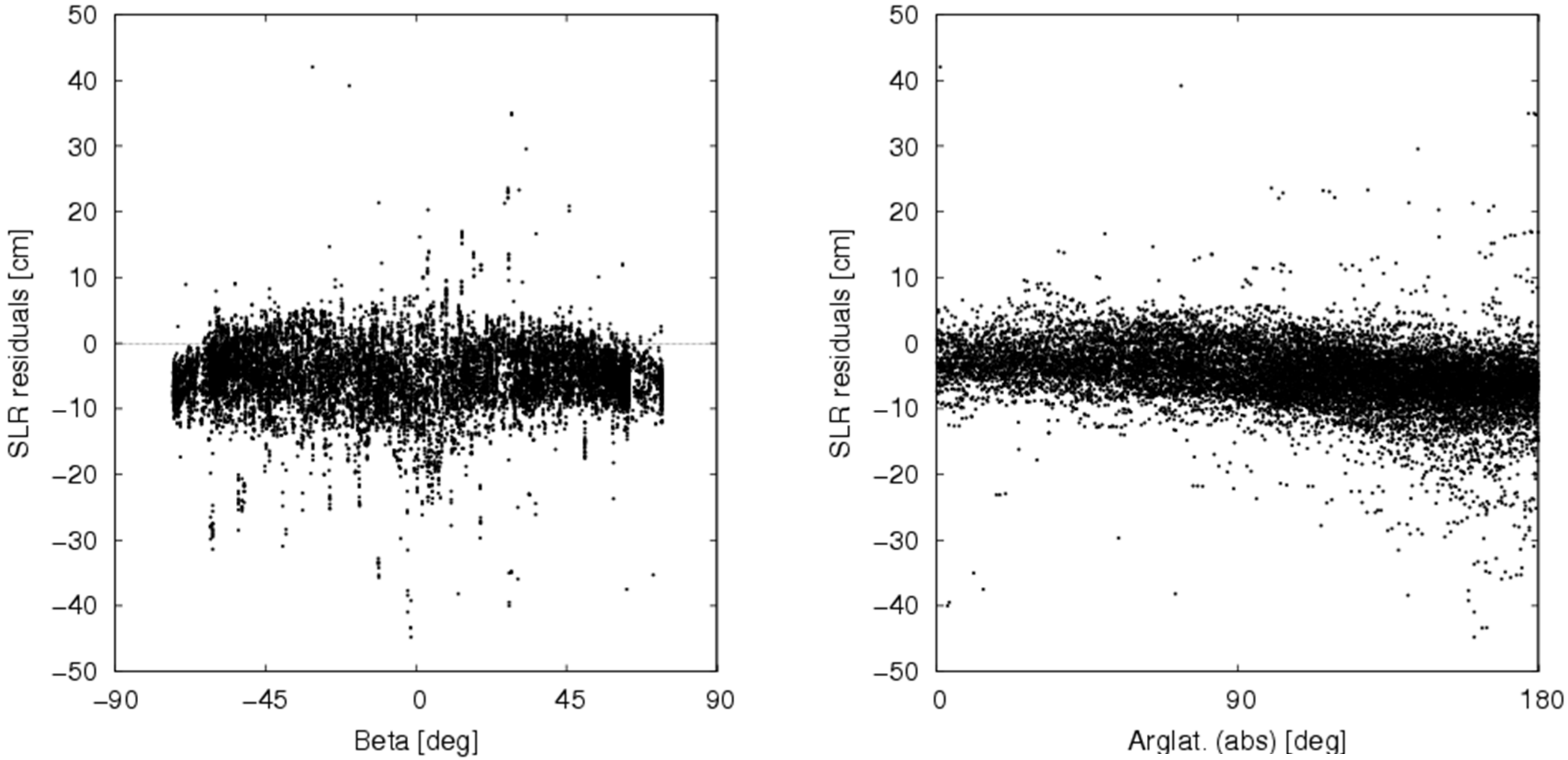
Impact of new ECOM on Galileo orbits



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

Orbits of Galileo FOC1 satellites

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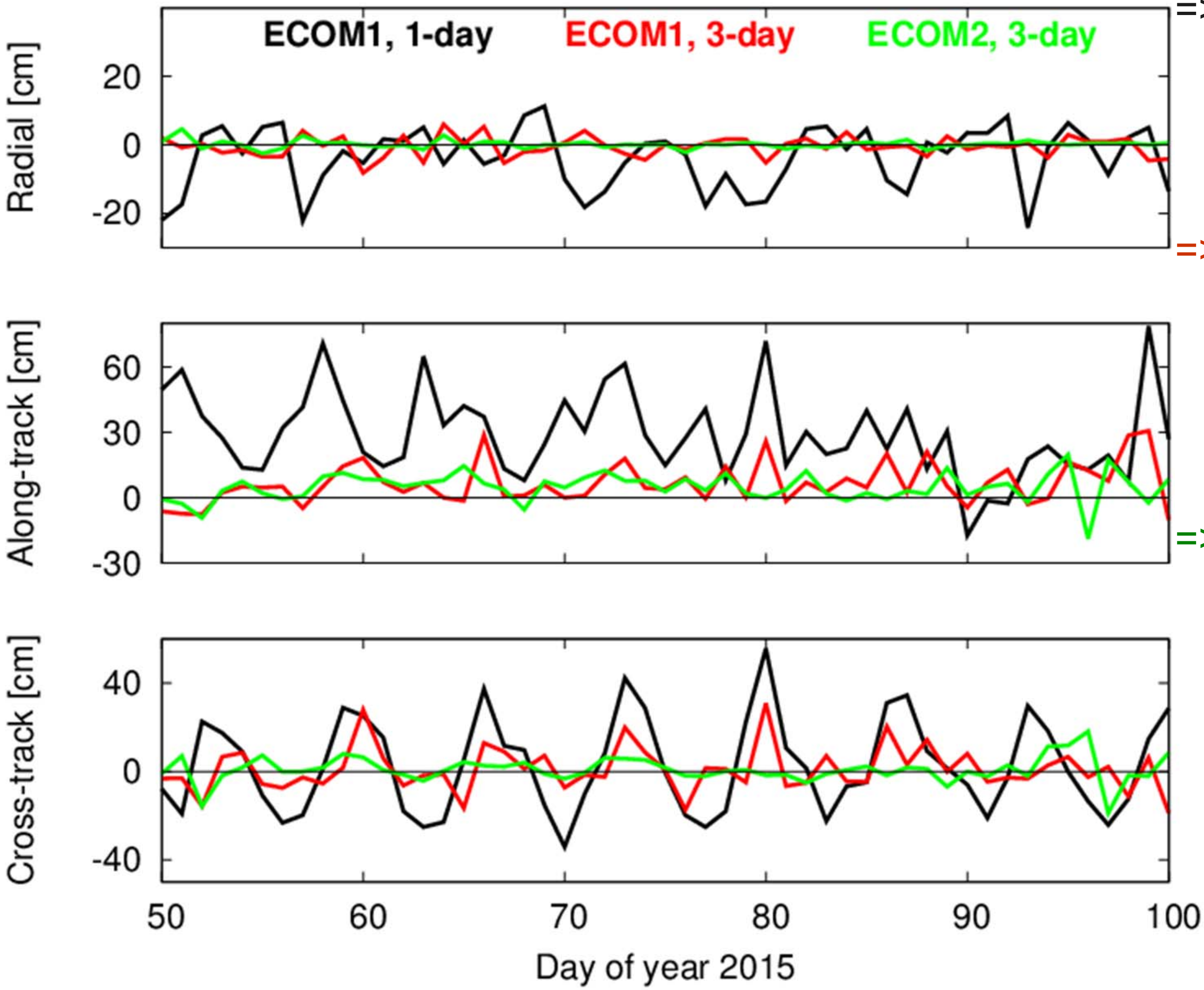


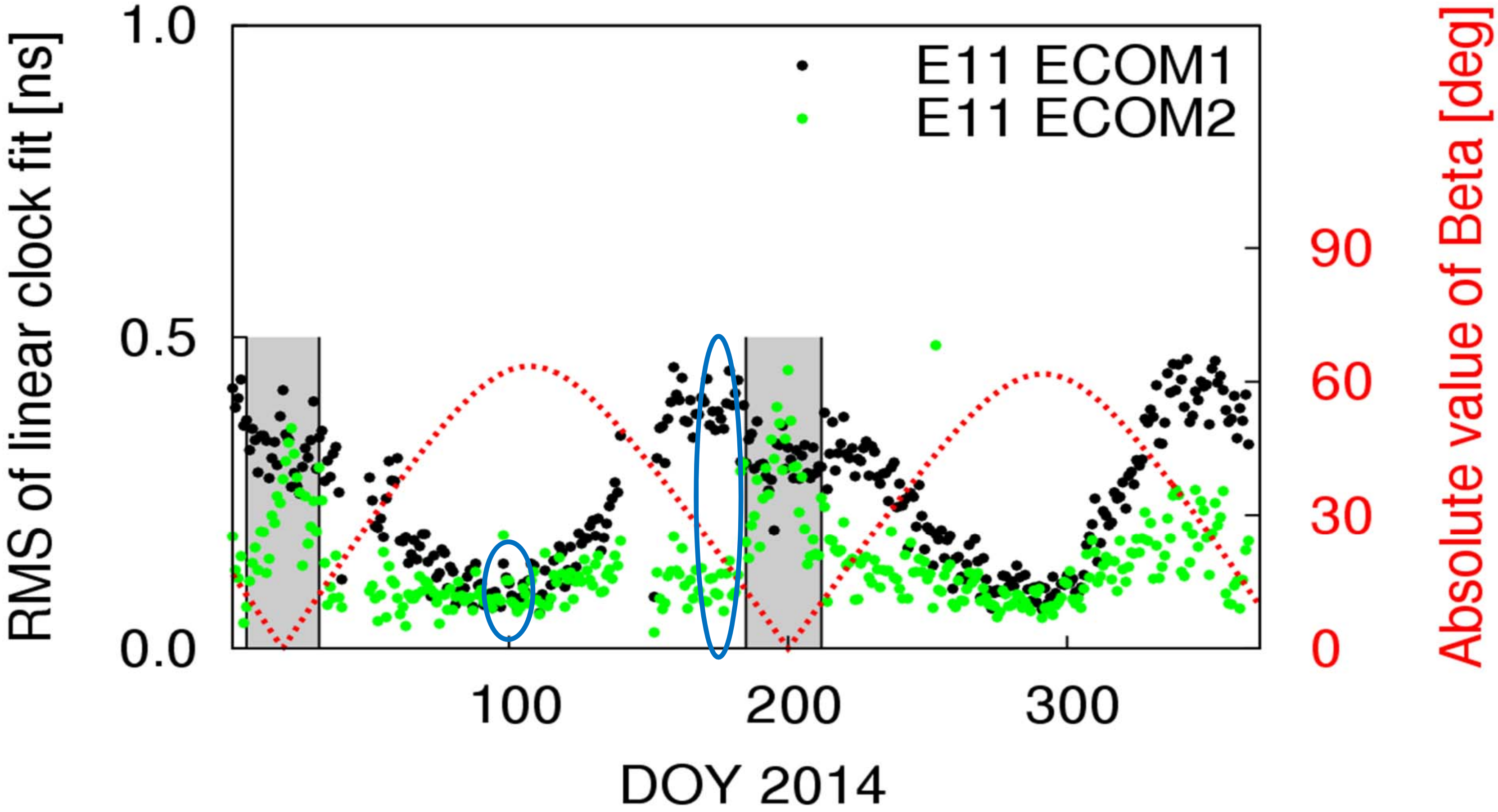
=> Systematic orbit errors (periodic signal + offset) with ECOM1 and 1-day arcs

=> Signal and offset significantly reduced in radial and along-track and signal partly reduced in cross-track with 3-day arc

=> Remaining cross-track signal significantly reduced with ECOM2

Orbit quality of FOC1 satellites comparable to other Galileo satellites with ECOM2 and long arcs

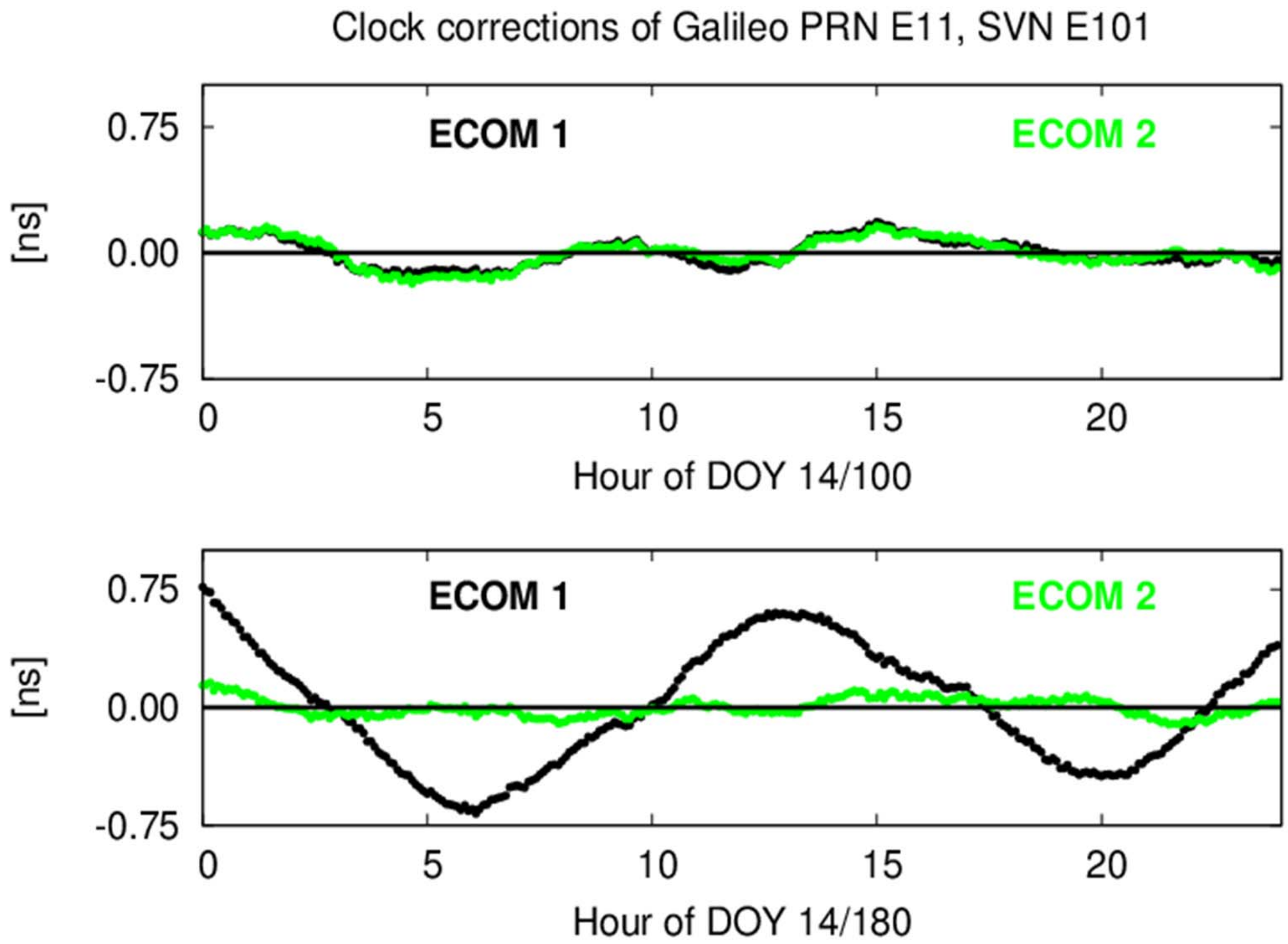
Impact of new ECOM on Galileo clock corrections



=> Significant reduction of Beta angle dependency

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

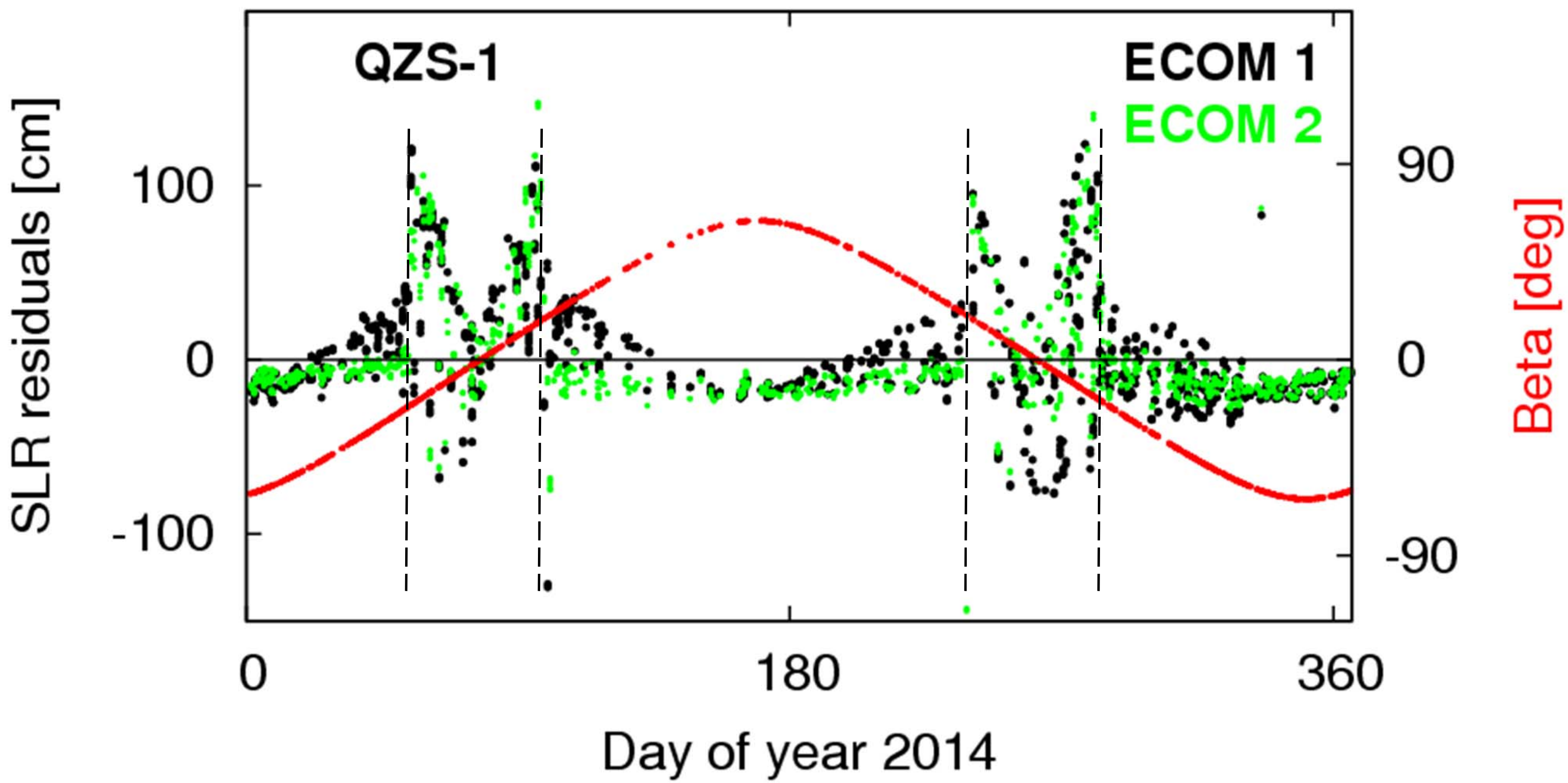
Impact of new ECOM on Galileo clock corrections



Large beta-angle:
=> Small clock signal
(about +-0.15 ns)

Low beta-angle:
=> Periodic signal caused by mis-modelled orbit
=> significantly reduction (+-0.75 ns -> +-0.15 ns)

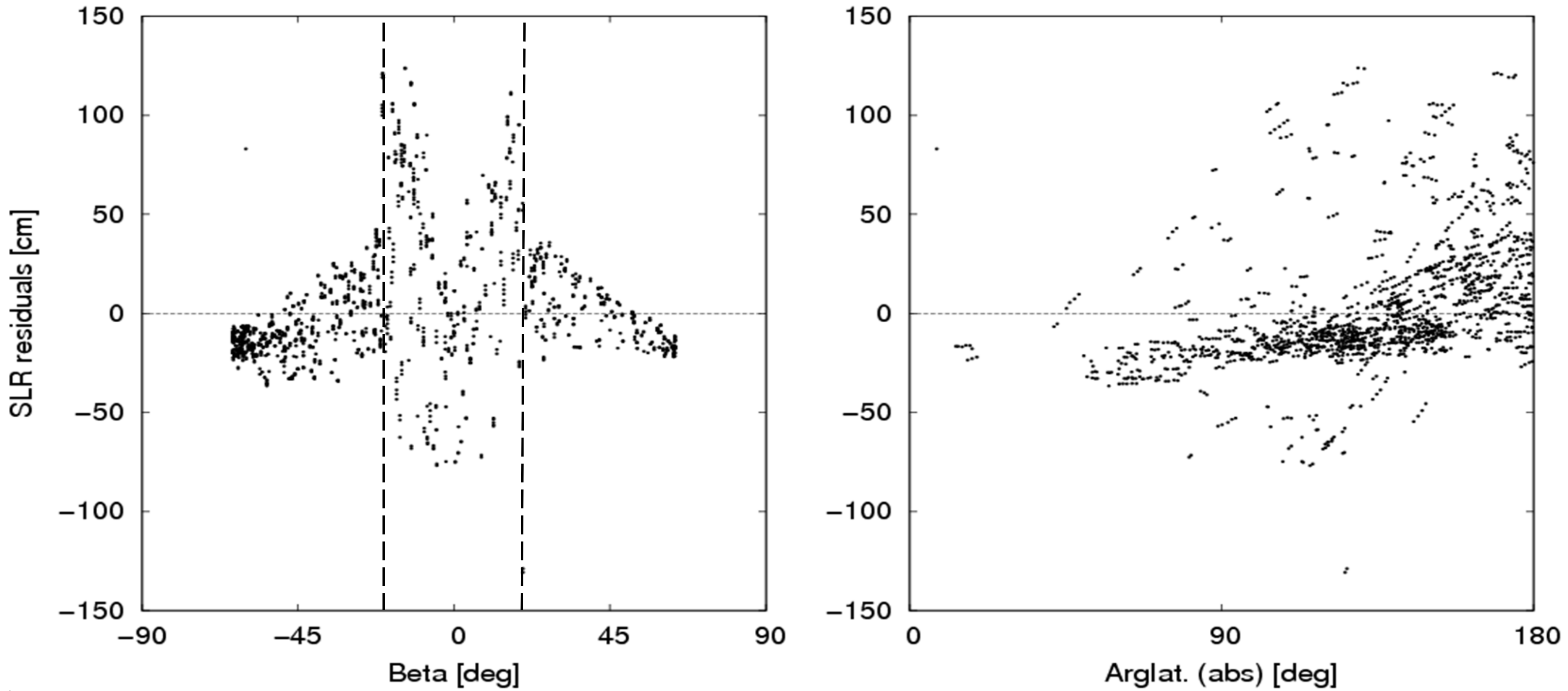
Impact of new ECOM on QZSS orbits



=> Improvement (dependency on Beta angle is reduced)

=> Unconsidered normal attitude mode dominates orbit errors at low Beta angles (< 20 degress)

Impact of new ECOM on QZSS orbits

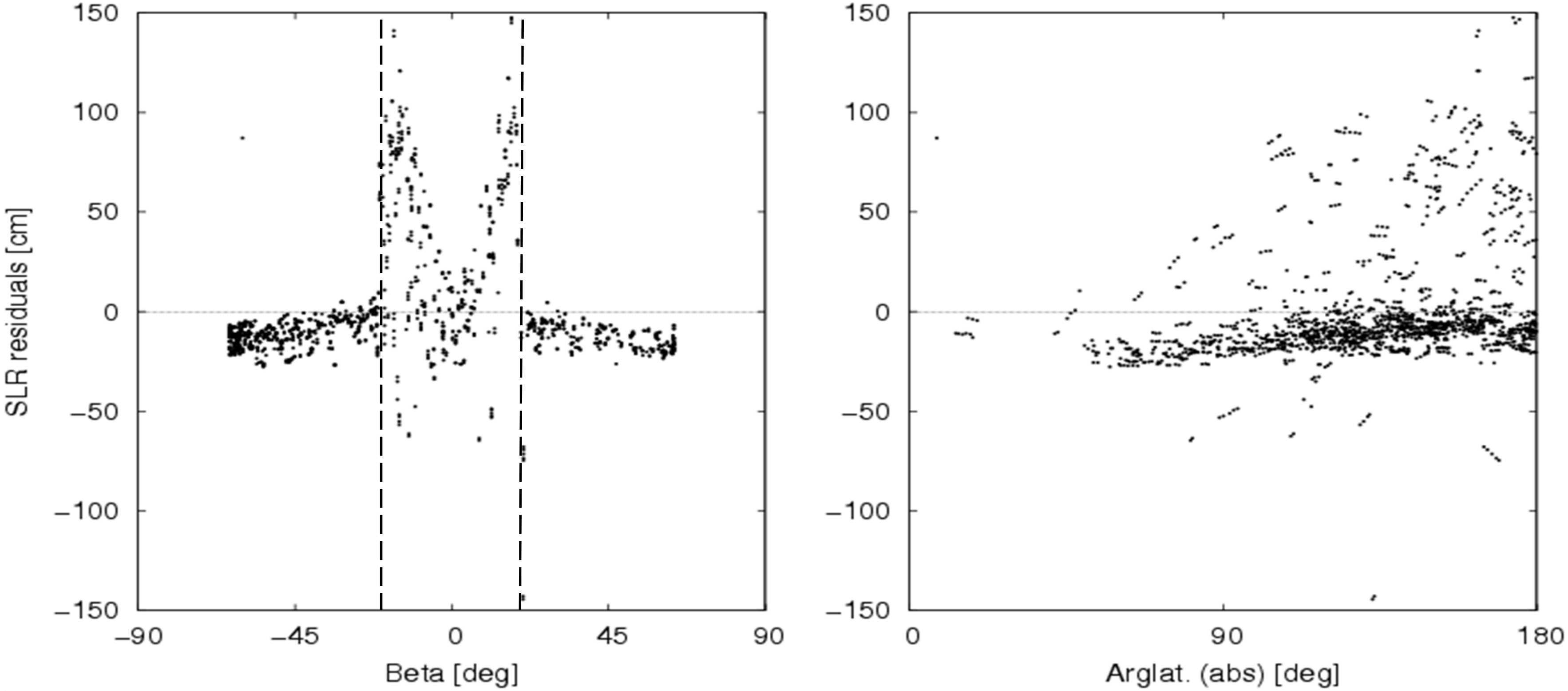


ECOM1:

=> abs(Beta) < 20 degrees: SLR residuals dominated by unconsidered orbit normal attitude mode

=> abs(Beta) > 20 degrees: correlation with Beta angle and argument of latitude

Impact of new ECOM on QZSS orbits



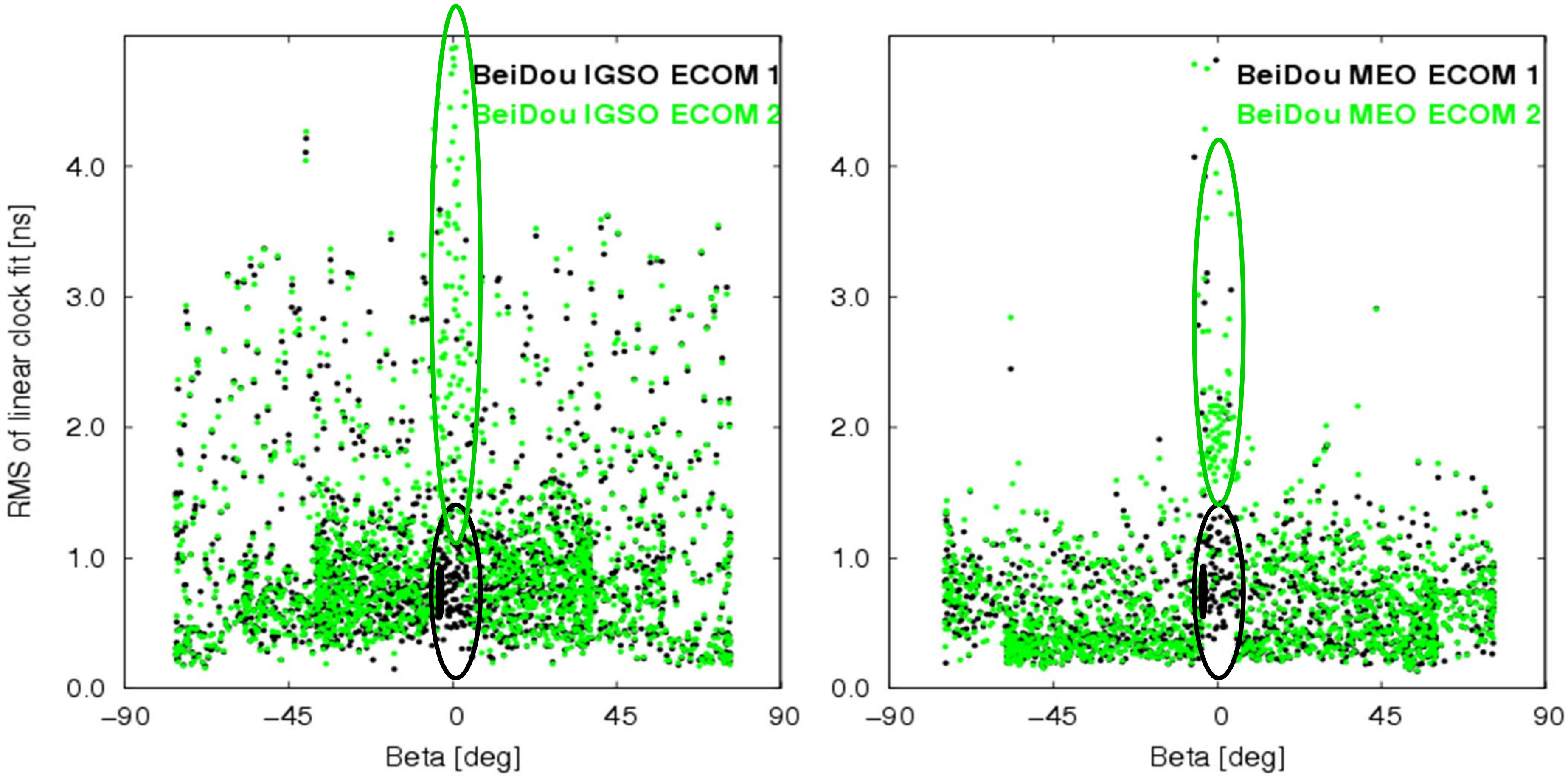
ECOM2:

=> abs(Beta) < 20 degrees: no big change

=> abs(Beta) > 20 degrees: systematics in the SLR residuals are reduced

=> SLR offset remains

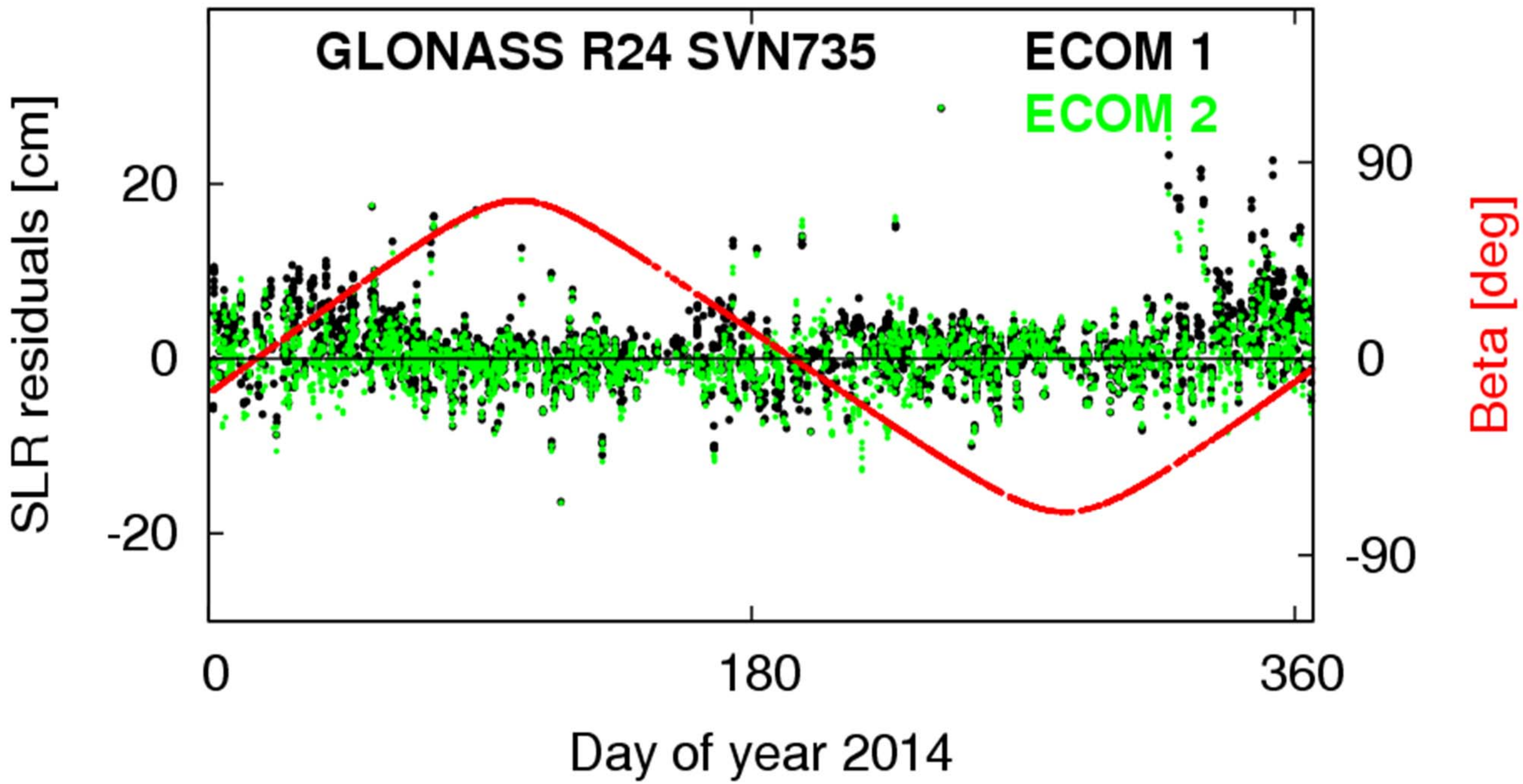
Impact of new ECOM on BeiDou clock corrections



=> No significant impact of new ECOM on BeiDou satellite clock corrections, but

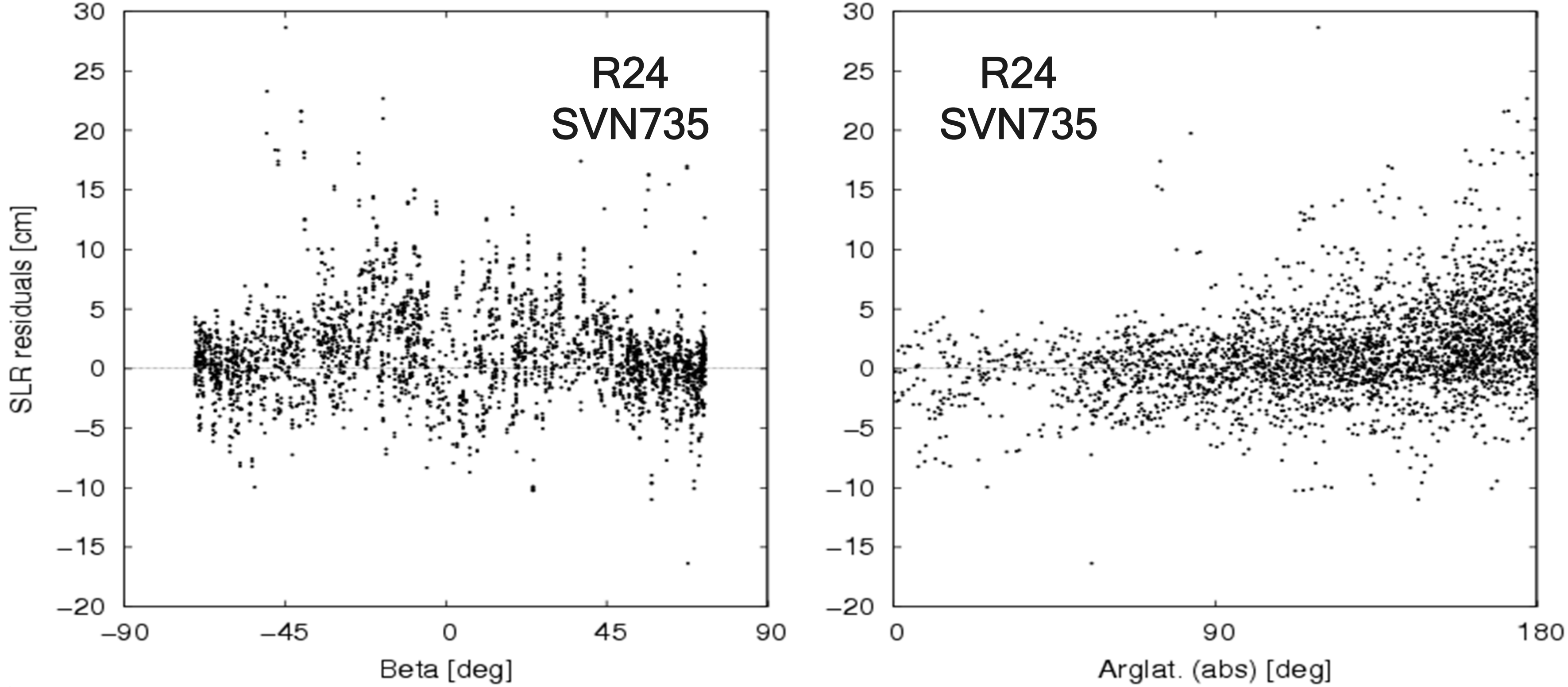
=> Increased RMS of clock fit for very small Beta angles (confirming changed attitude mode at abs(Beta) < 4 degrees)

Impact of new ECOM on GLONASS orbits



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

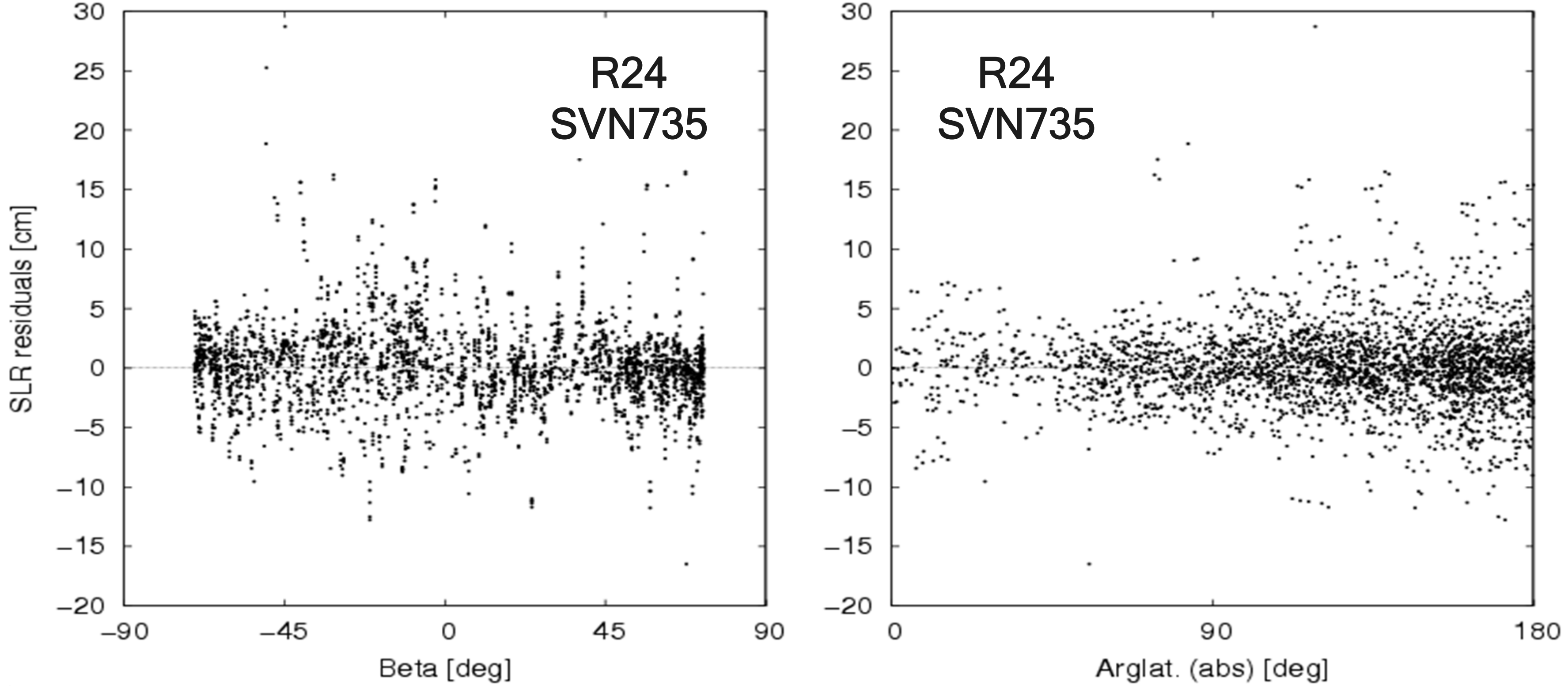
Impact of new ECOM on GLONASS orbits



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

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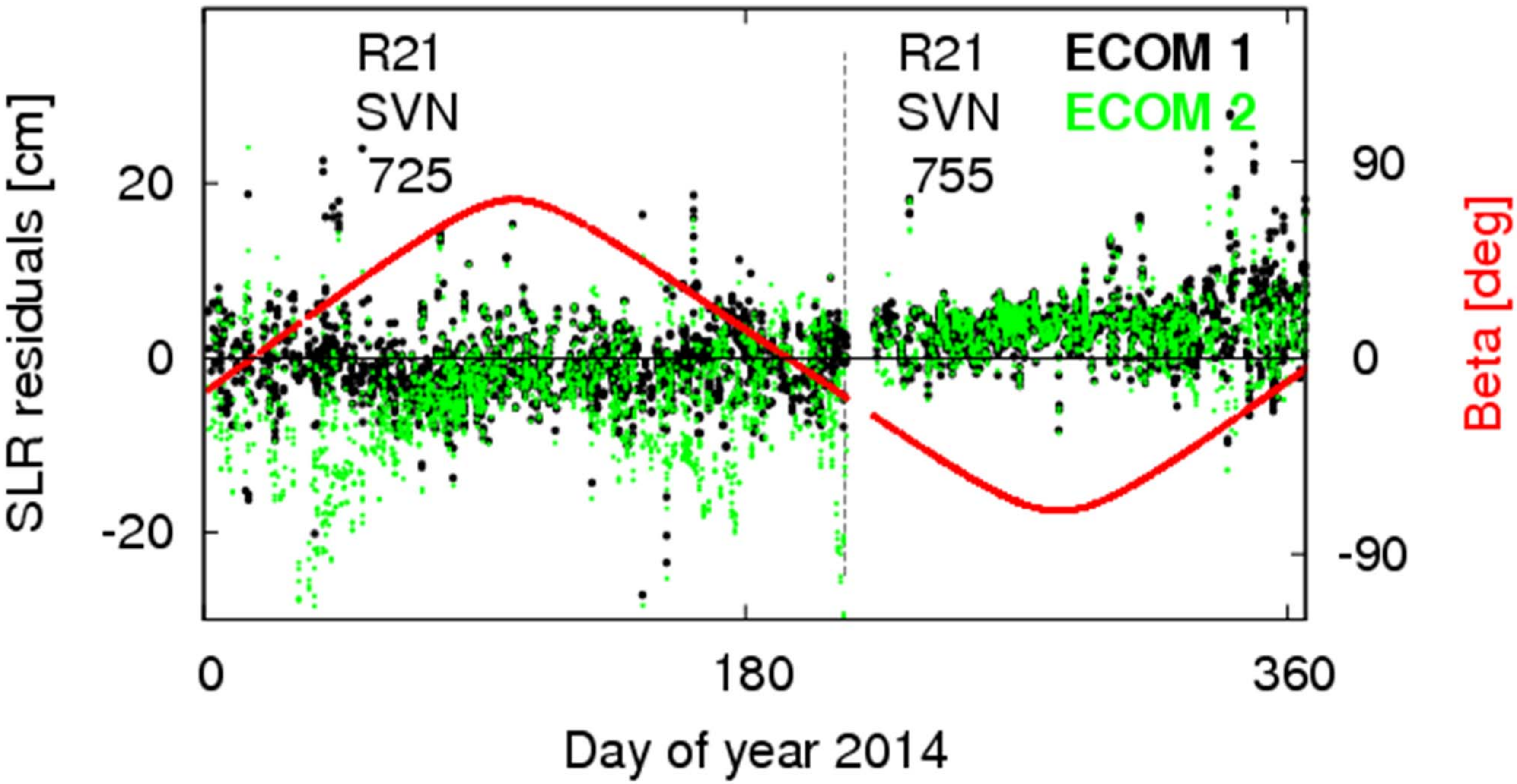

=> ECOM2 does not work well for all GLONASS satellites

Orbit modeling: Summary

- Galileo: clear benefit from ECOM2
- QZSS: significant benefit from ECOM2 when in yaw attitude mode
- GLONASS: moderate benefit from ECOM2 for the majority of satellites; degradation for some satellites
- ECOM2 seems to be more sensitive to attitude mis-modellings
- Normal attitude steering mode at low beta-angles causes very large orbit errors if not correctly considered
- Stable satellite clocks (GPS IIF, Galileo, QZSS) are suited for orbit validation

Thank you

for

your interest!