

# Impact of the SRP model on CODE's 5-system orbit and clock solution for the MGEX

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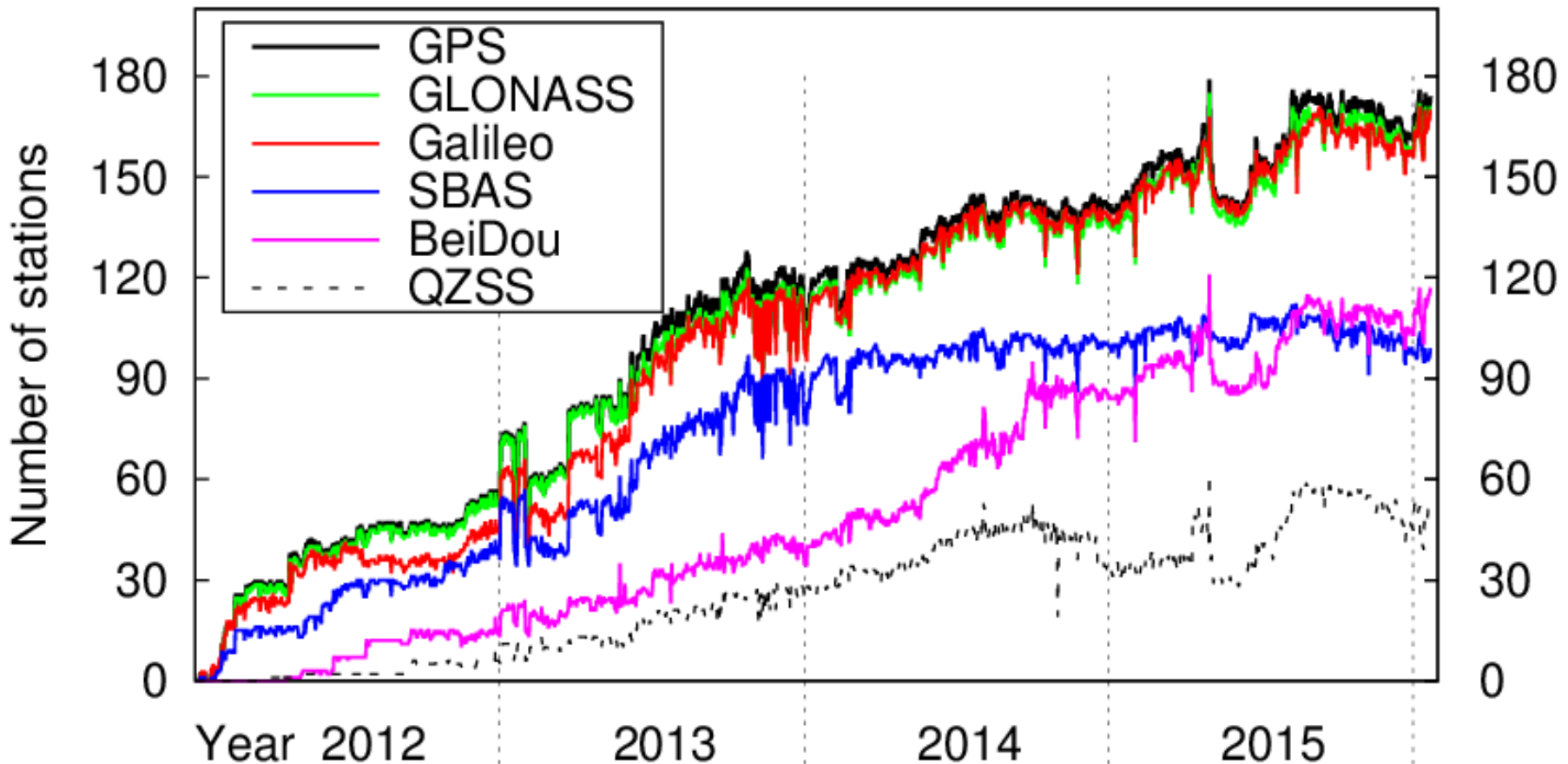
# Contents

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- **Data base and network**
- **CODE MGEX orbit solution**
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- **Impact of CODE's new solar radiation pressure model**
- **Summary and outlook**

# MGEX data monitoring

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



# CODE MGEX orbit solution

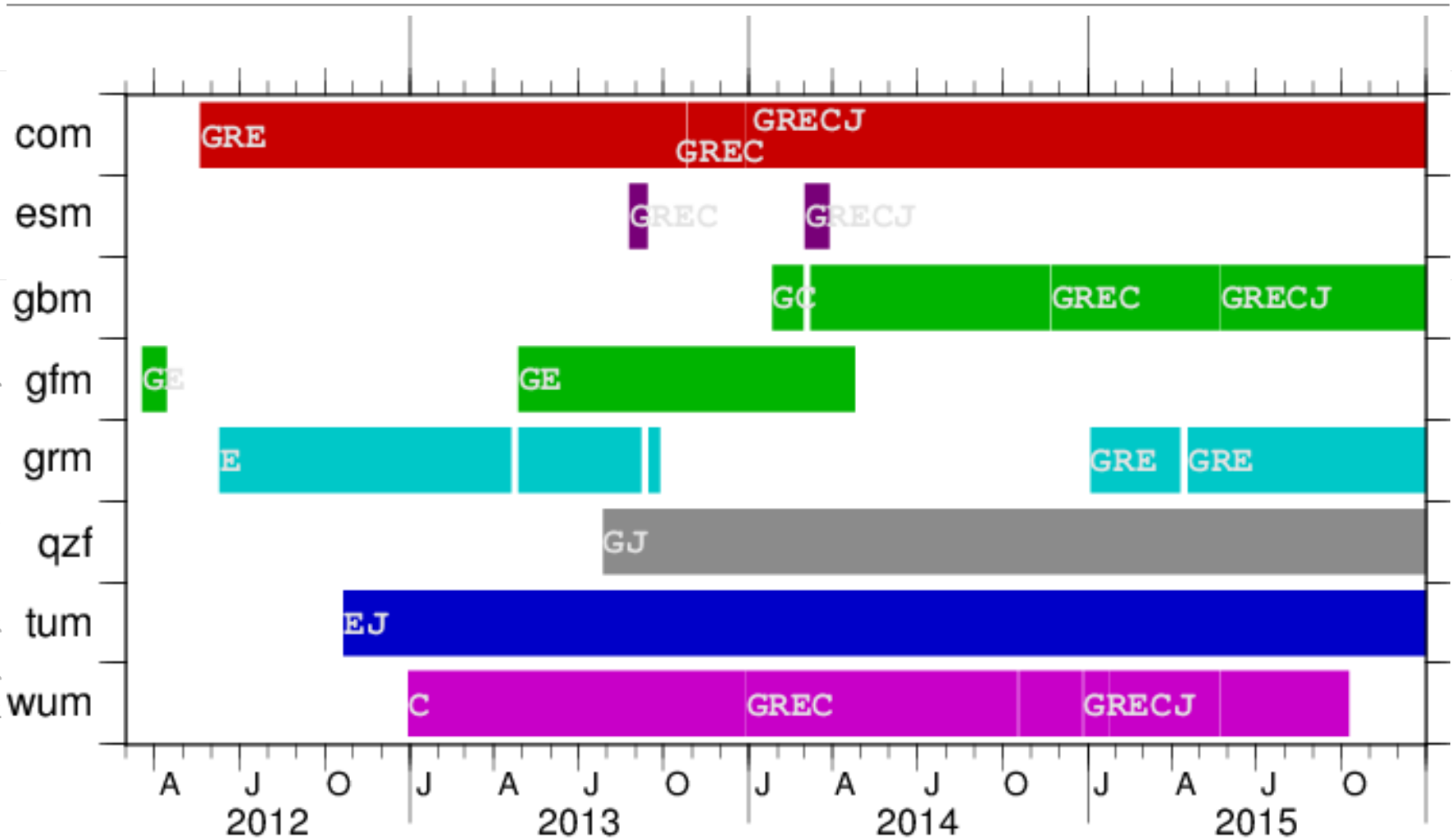
GNSS considered:	GPS + GLONASS + Galileo + BeiDou (MEO+IGSO) + QZSS (≈70 SV)
Processing mode:	Post-processing (≈2 weeks latency)
Timespan covered:	GPS-weeks 1689 - today
Number of stations:	130 (GPS), 110 (GLONASS), 85 (Galileo); 55 (BeiDou); 20 (QZSS)
Processing scheme:	Double-difference network processing (observable: phase double differences)
Signal frequencies:	L1+ L2 (GPS + GLO+ QZSS); E1 (L1) + E5a (L5) Galileo; B1 (L1) + B2 (L7) BeiDou
Orbit characteristic:	3-day long arcs; SRP: 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:	<a href="ftp://cddis.gsfc.nasa.gov/gnss/products/mgex/">ftp://cddis.gsfc.nasa.gov/gnss/products/mgex/</a> and <a href="ftp://ftp.unibe.ch/aiub/CODE_MGEX/">ftp://ftp.unibe.ch/aiub/CODE_MGEX/</a>
Designator:	comwwwwd.???.Z

# CODE MGEX clock solution

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GNSS considered:	GPS + GLONASS + Galileo + BeiDou + QZSS ( $\approx 70$ SV)
Processing mode:	Post-processing ( $\approx 2$ weeks latency)
Timespan covered:	GPS-weeks 1710 - today
Number of stations:	130 (GPS), 35 (GLO), 45 (Galileo); 50 (BeiDou); 20 (QZSS)
Processing scheme:	<b>Zero-difference</b> processing (observable: code+phase undifferenced)
Signal frequencies:	L1+ L2 (GPS + GLO+ QZSS); E1 (L1) + E5a (L5) Galileo; 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 format <a href="ftp://cddis.gsfc.nasa.gov/gnss/products/mgex/">ftp://cddis.gsfc.nasa.gov/gnss/products/mgex/</a> and <a href="ftp://ftp.unibe.ch/aiub/CODE_MGEX/">ftp://ftp.unibe.ch/aiub/CODE_MGEX/</a>
Distribution:	

# MGEX products availability

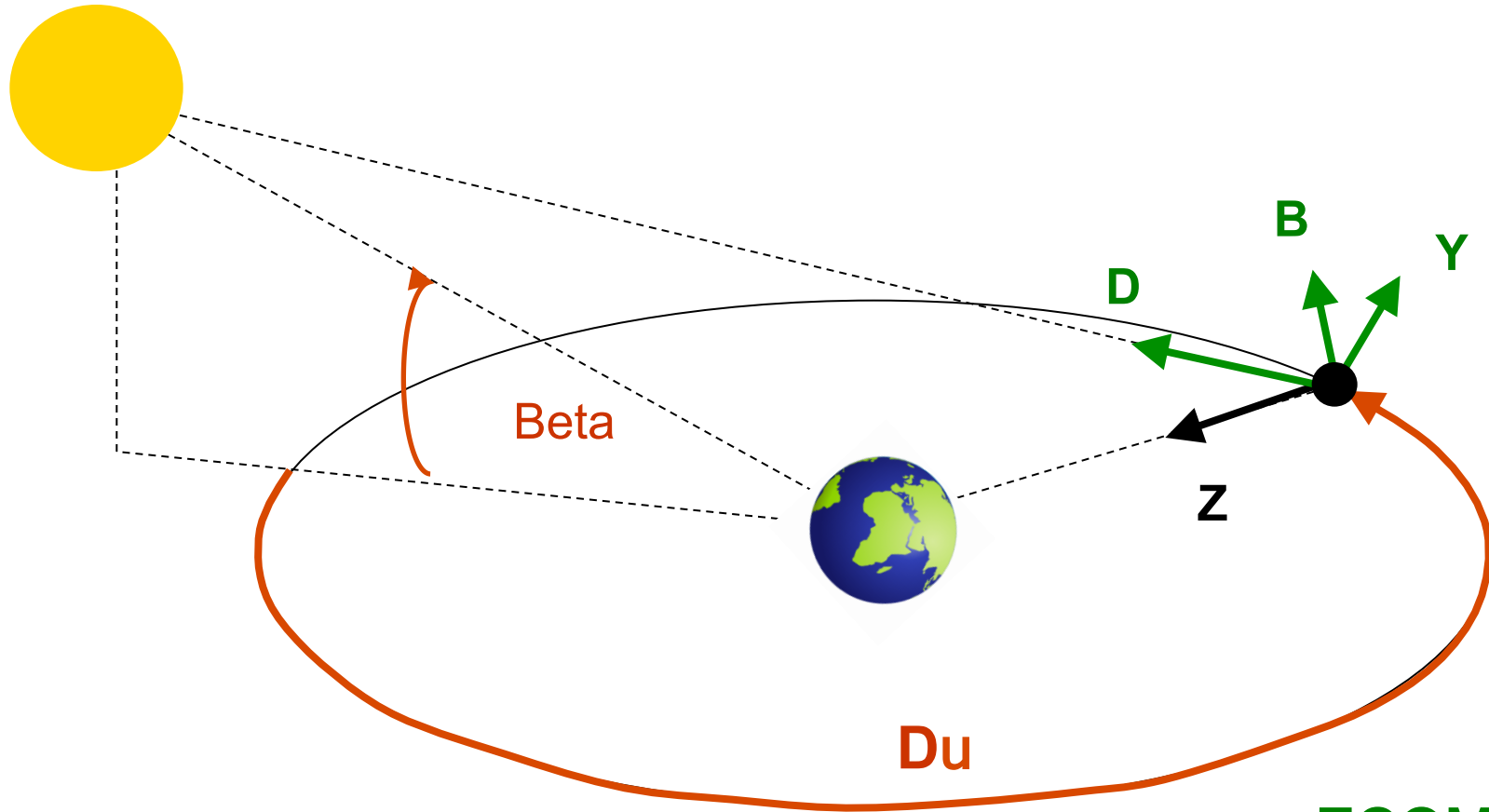


Status: 01-Jan-2016

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

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# Orbit description and Yaw attitude



## Angles and vectors:

**Beta:** Elevation of Sun above orbital plane

**Du:** Argument of latitude

**Z:** Direction satellite -> Earth (antenna direction)

## ECOM axes:

**D:** Direction satellite -> Sun

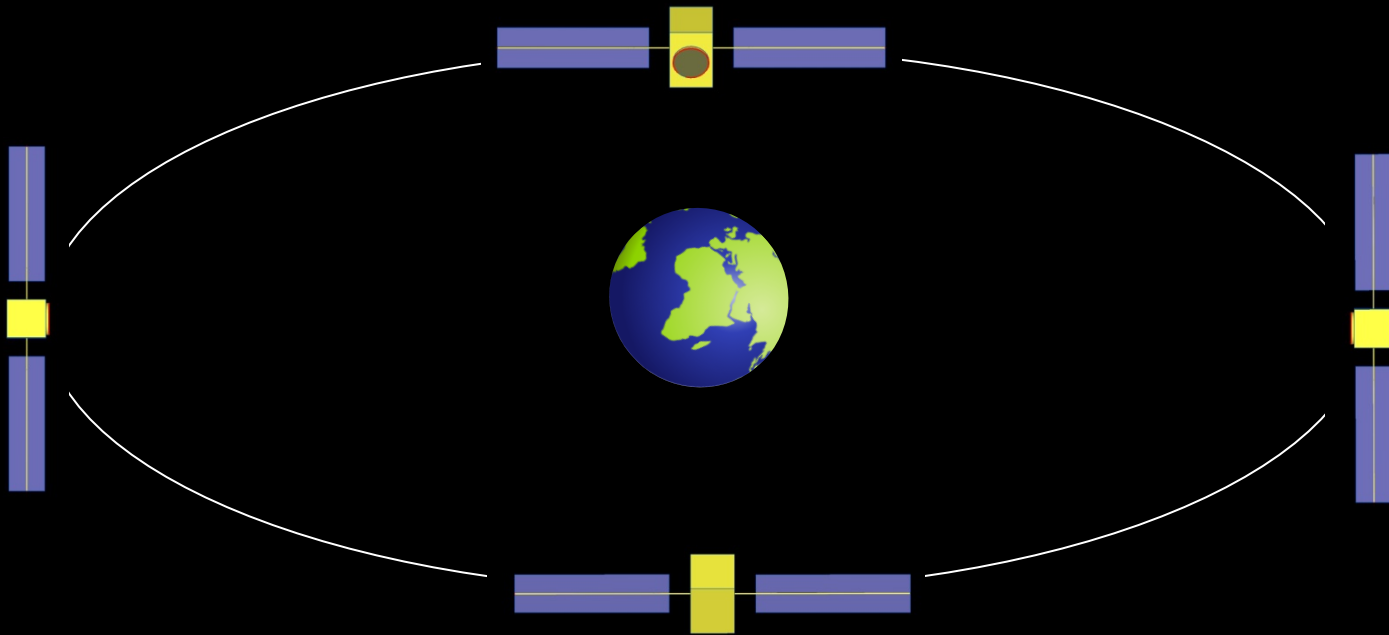
**Y:** Solar panel axis

**B:** Third ECOM axis

# Solar radiation pressure

Satellite cross-section as seen from the Sun (Beta  $\approx 30^\circ$ ) 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.; Beutler et al., 1994, 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 elongated satellite bodies wrt. the Sun
- => Improvements expected for Galileo, GLONASS, QZSS

## ECOM1 (old):

$$D(u) = D_0$$

$$Y(u) = Y_0$$

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

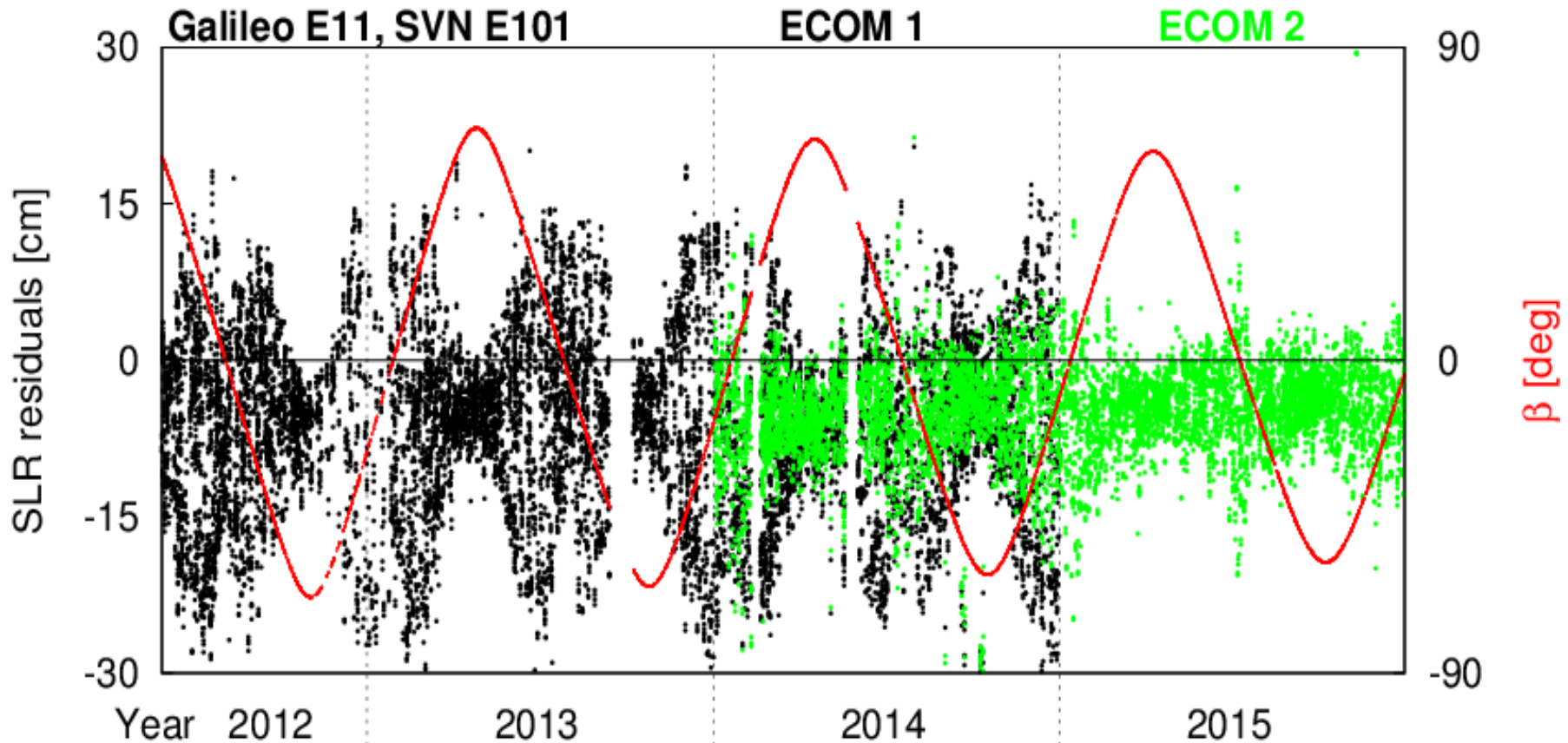
## ECOM2 (new):

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

$$Y(u) = Y_0$$

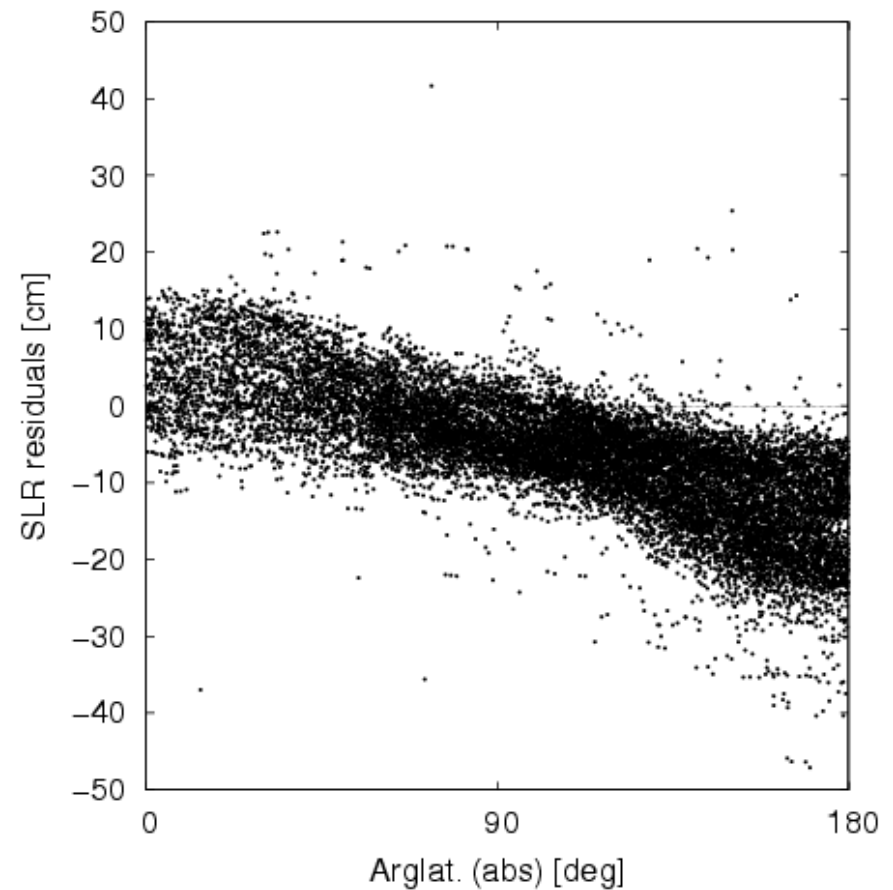
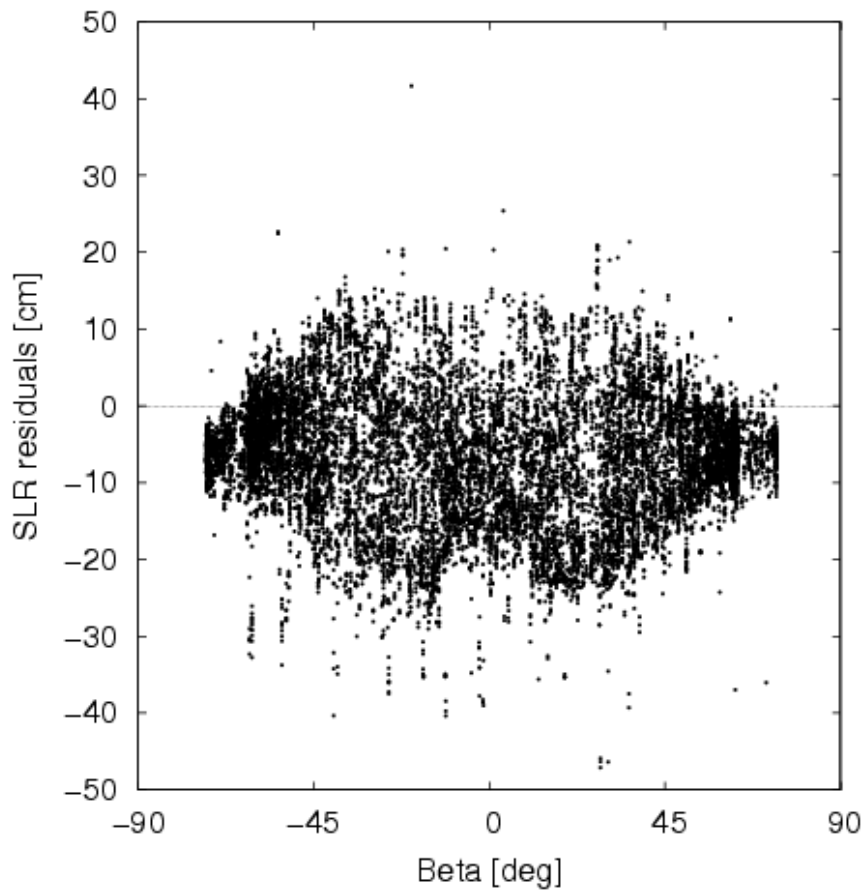
$$B(u) = B_0 + B_C \cos(Du) + B_S \sin(Du)$$

# Impact of new ECOM on Galileo orbits



⇒ Significant reduction of size and dependency of SLR residuals on the Beta-angle

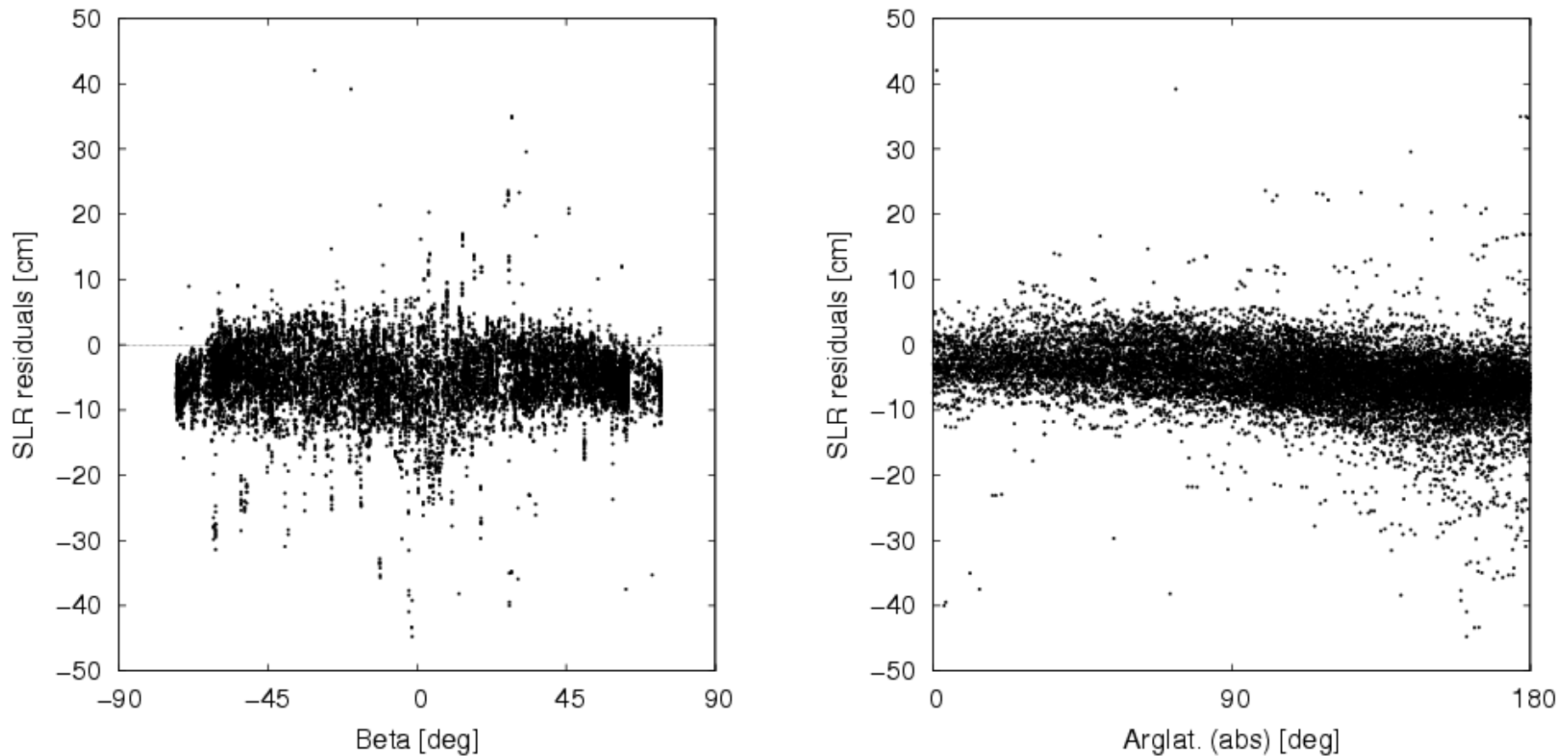
# Impact of new ECOM on Galileo orbits



## ECOM1 (all Galileo satellites):

⇒ SLR residuals of 2014 are large at small and medium Beta angles and with argument of latitude around  $0^\circ$  and  $\pm 180^\circ$

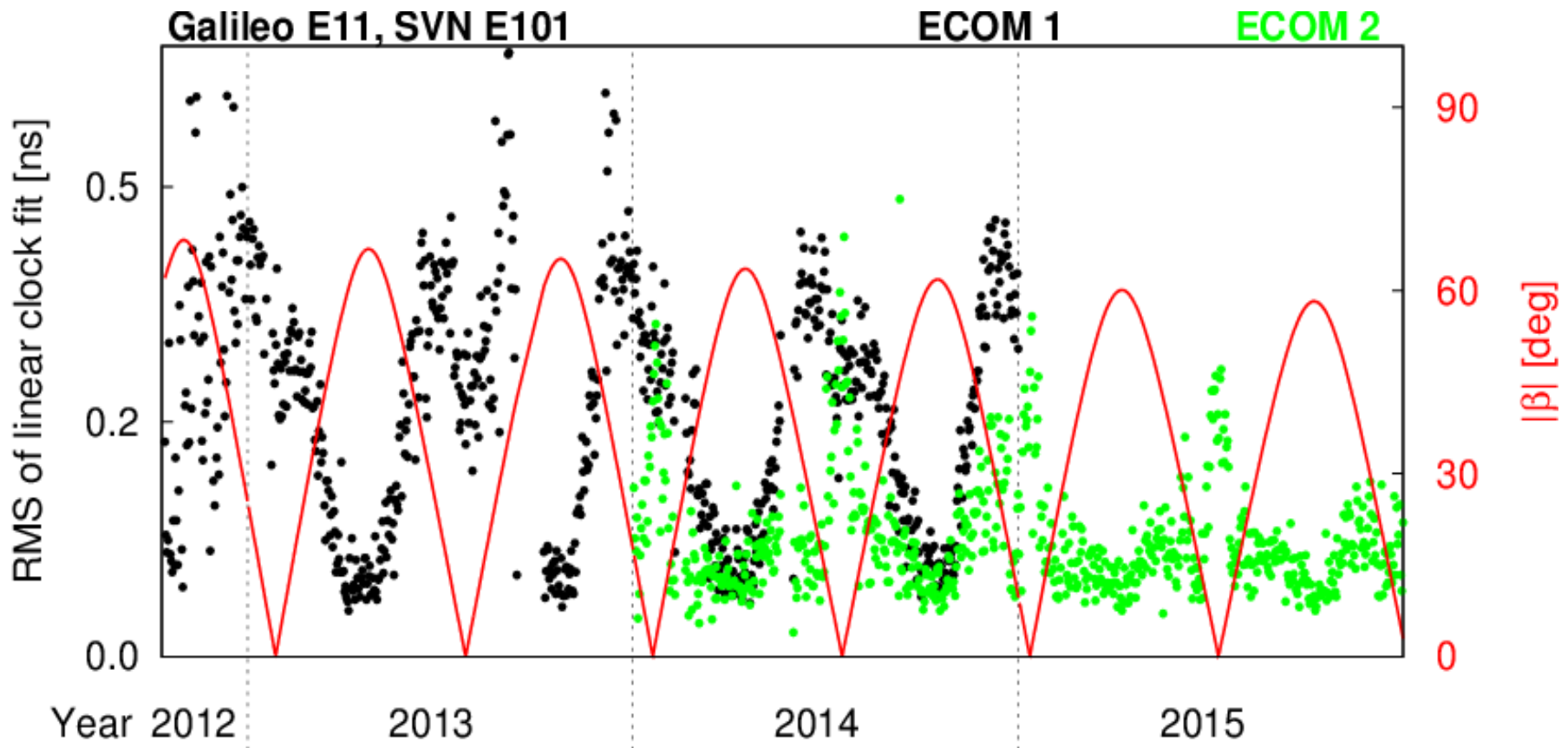
# Impact of new ECOM on Galileo orbits



## ECOM2 (all Galileo satellites):

- ⇒ Systematics in the SLR residuals are significantly reduced
- ⇒ Significant SLR offset remains

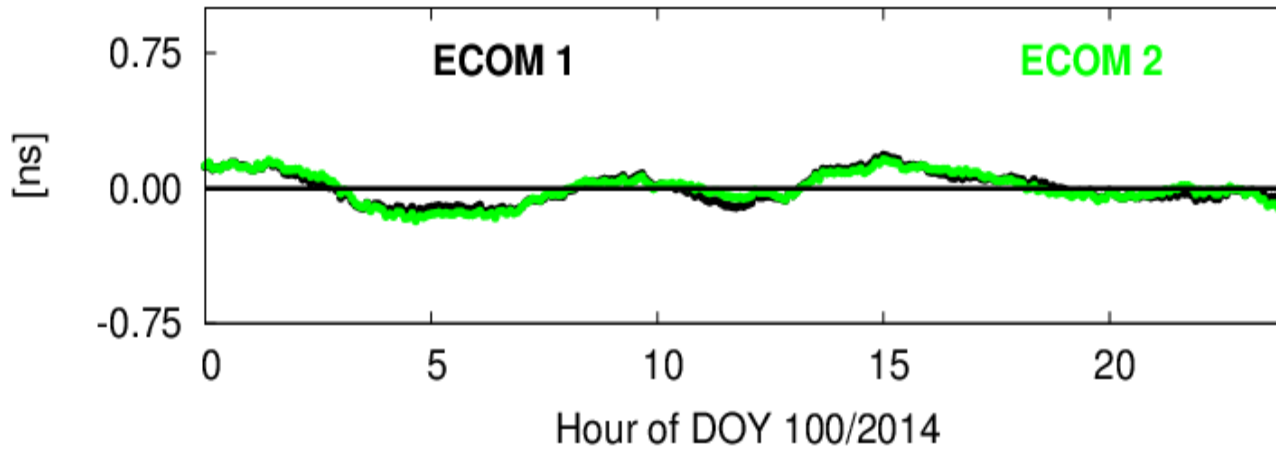
# Impact of new ECOM on Galileo clock corrections



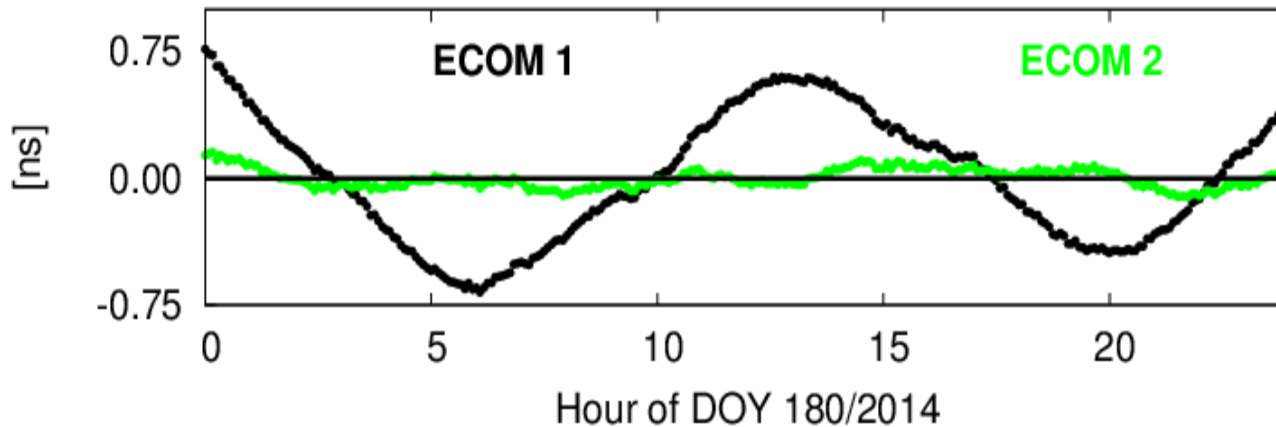
- ⇒ Significant reduction of Beta angle dependency
- ⇒ Pronounced signal remains during eclipse season or close-by (impact of mis-modelled attitude?)

# Impact of new ECOM on Galileo clock corrections

Clock corrections of Galileo E11, SVN E101



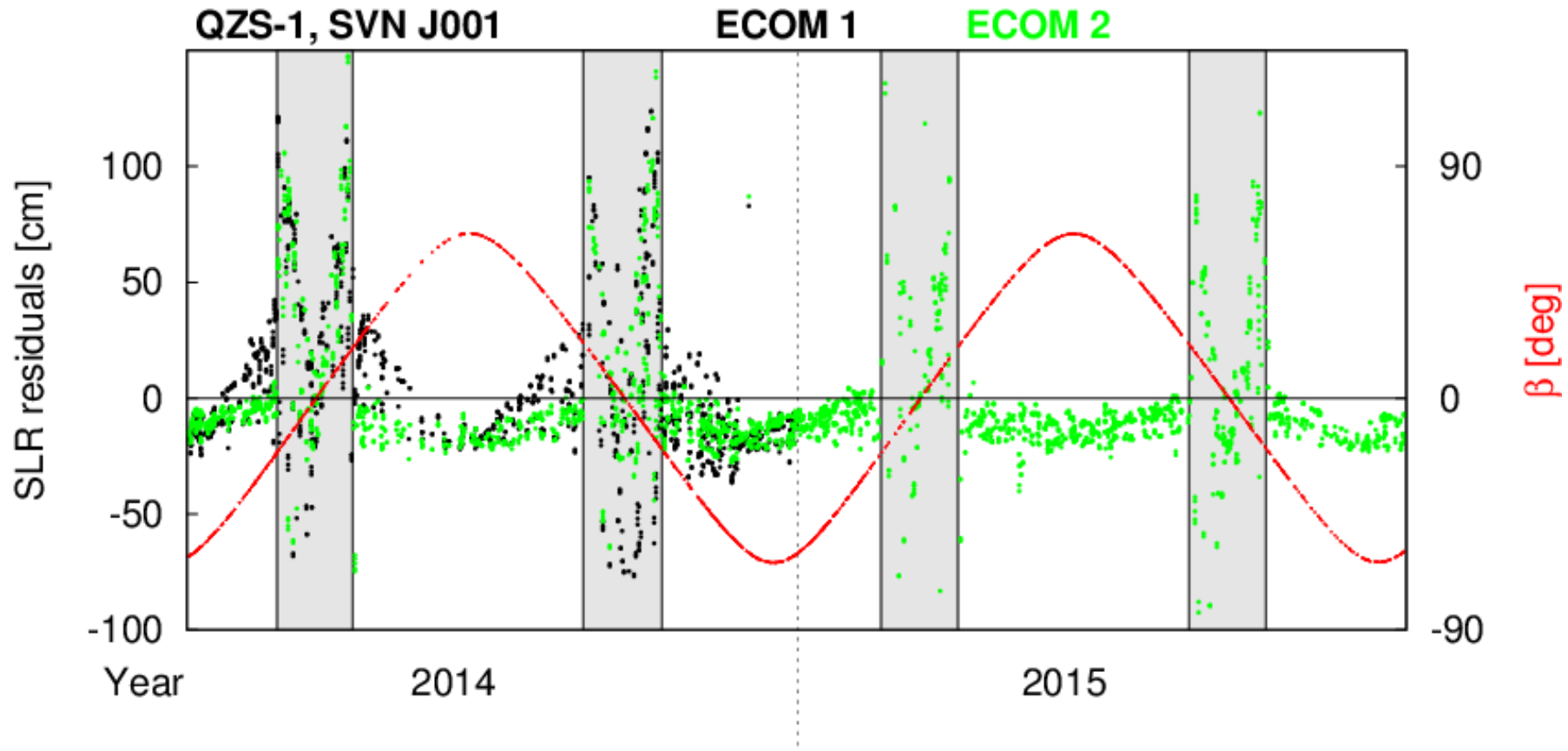
Large beta-angle:  
=> Clock signal has  
small amplitude  
(about  $\pm 0.15$  ns)



Small beta-angle:  
=> Periodic signal  
caused by mis-  
modelled orbit  
(ECOM1)  
=> Significant reduction  
of signal amplitude  
from  $\pm 0.75$  ns to  
 $\pm 0.15$  ns (ECOM2)



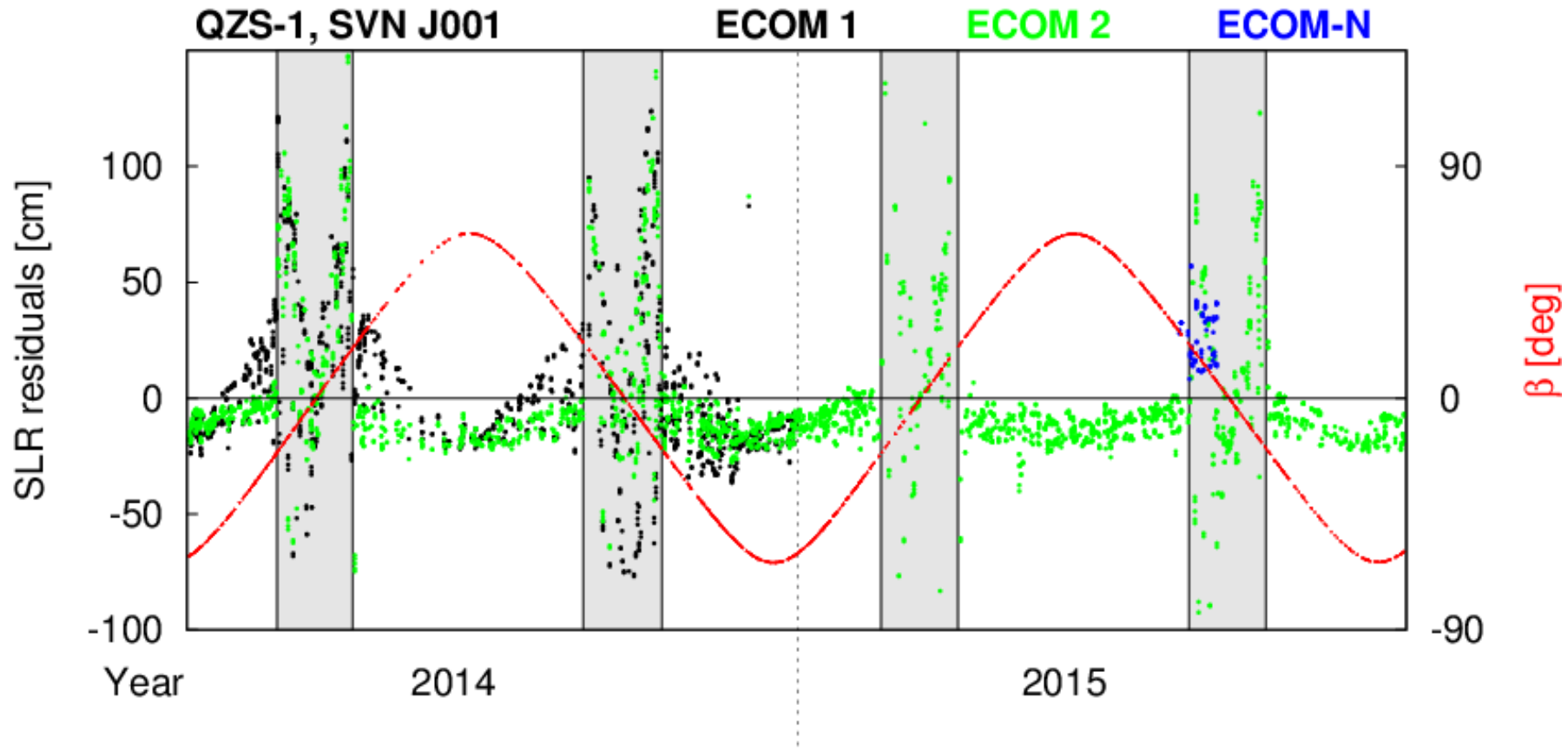
# Impact of new ECOM on QZSS orbits



- ⇒ ECOM2 reduces dependency on Beta angle
- ⇒ Significant SLR offset remains

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# Impact of new ECOM on QZSS orbits

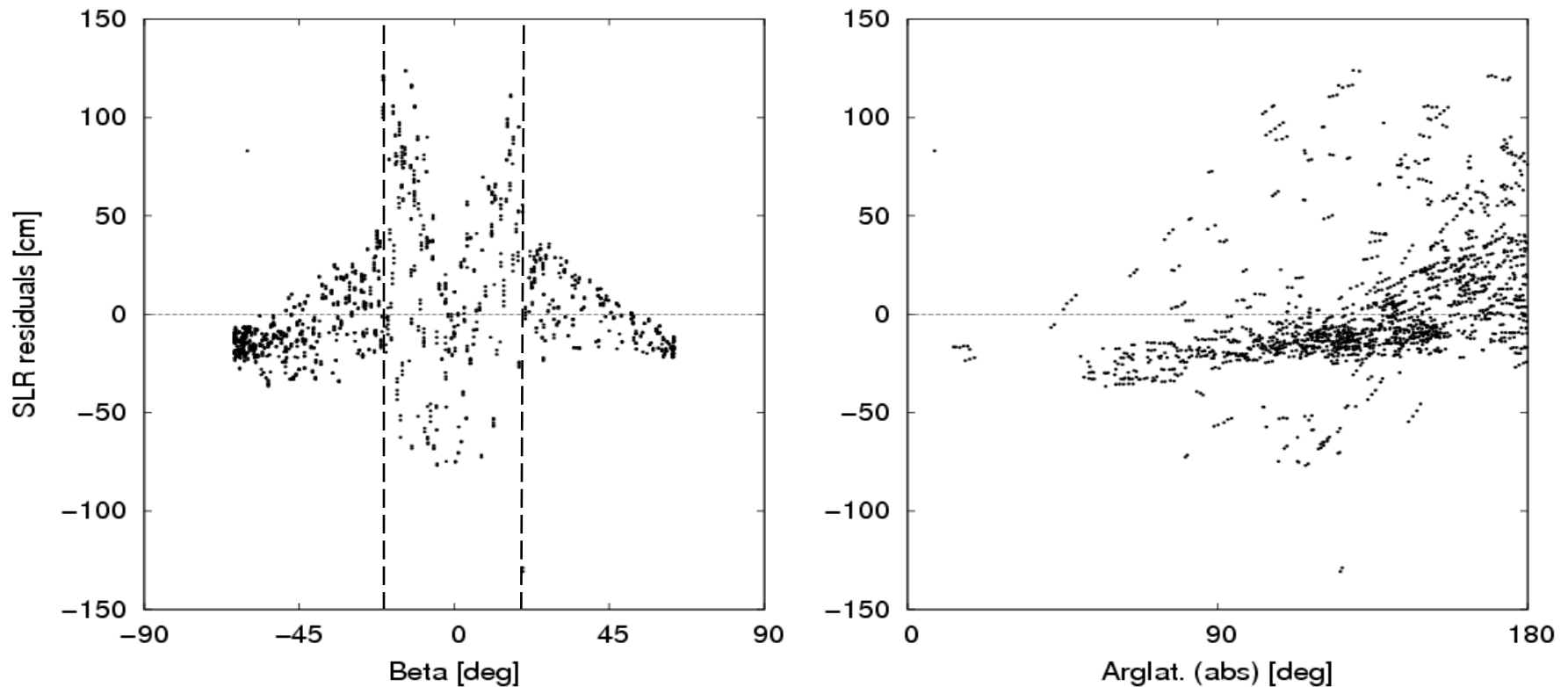


- ⇒ Large orbit errors occur at  $|\beta| < 20^\circ$  (marked grey)
- ⇒ Test of new ECOM version suited for orbit normal attitude mode

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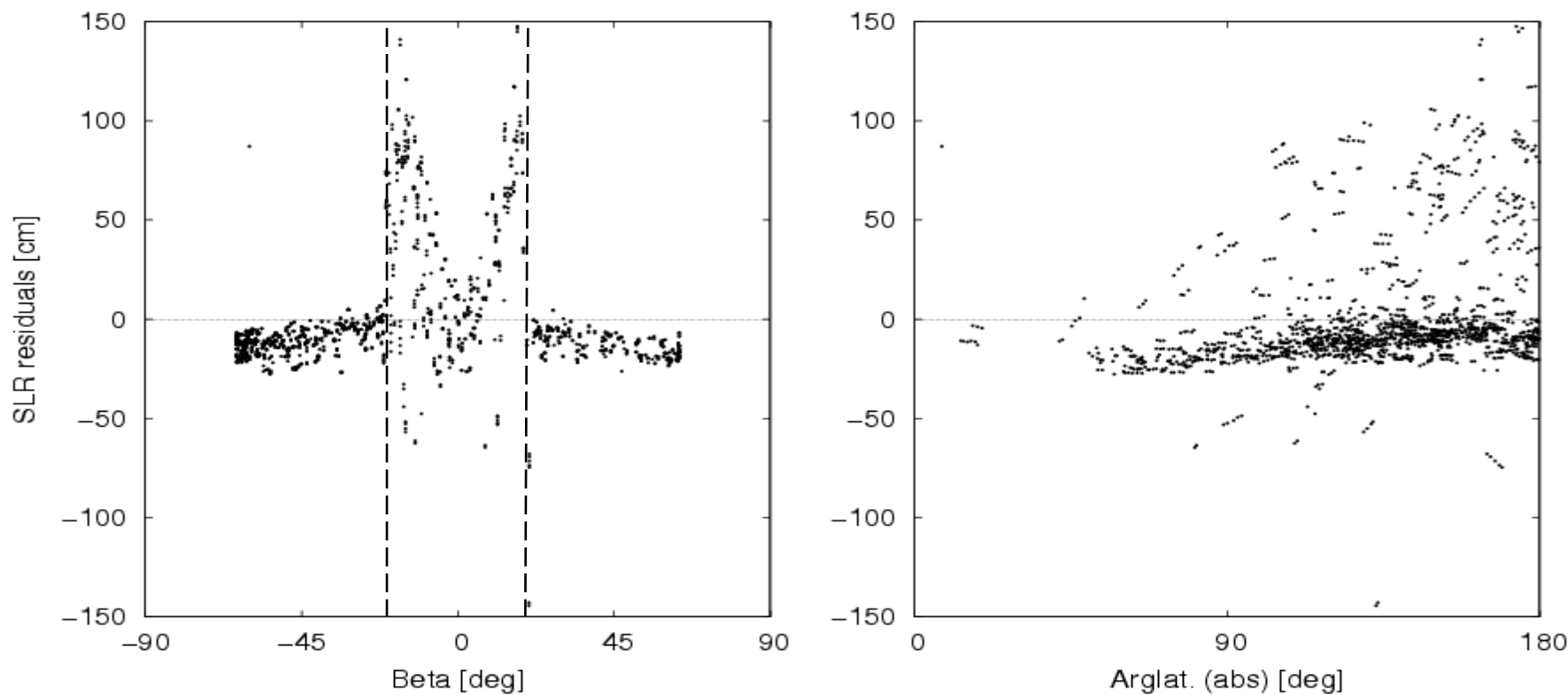
# Impact of new ECOM on QZSS orbits



## ECOM1:

- ⇒  $|\beta| < 20^\circ$ : SLR residuals of 2014 are dominated by not correctly considered orbit normal attitude mode
- ⇒  $|\beta| > 20^\circ$ : correlation with Beta angle and argument of latitude

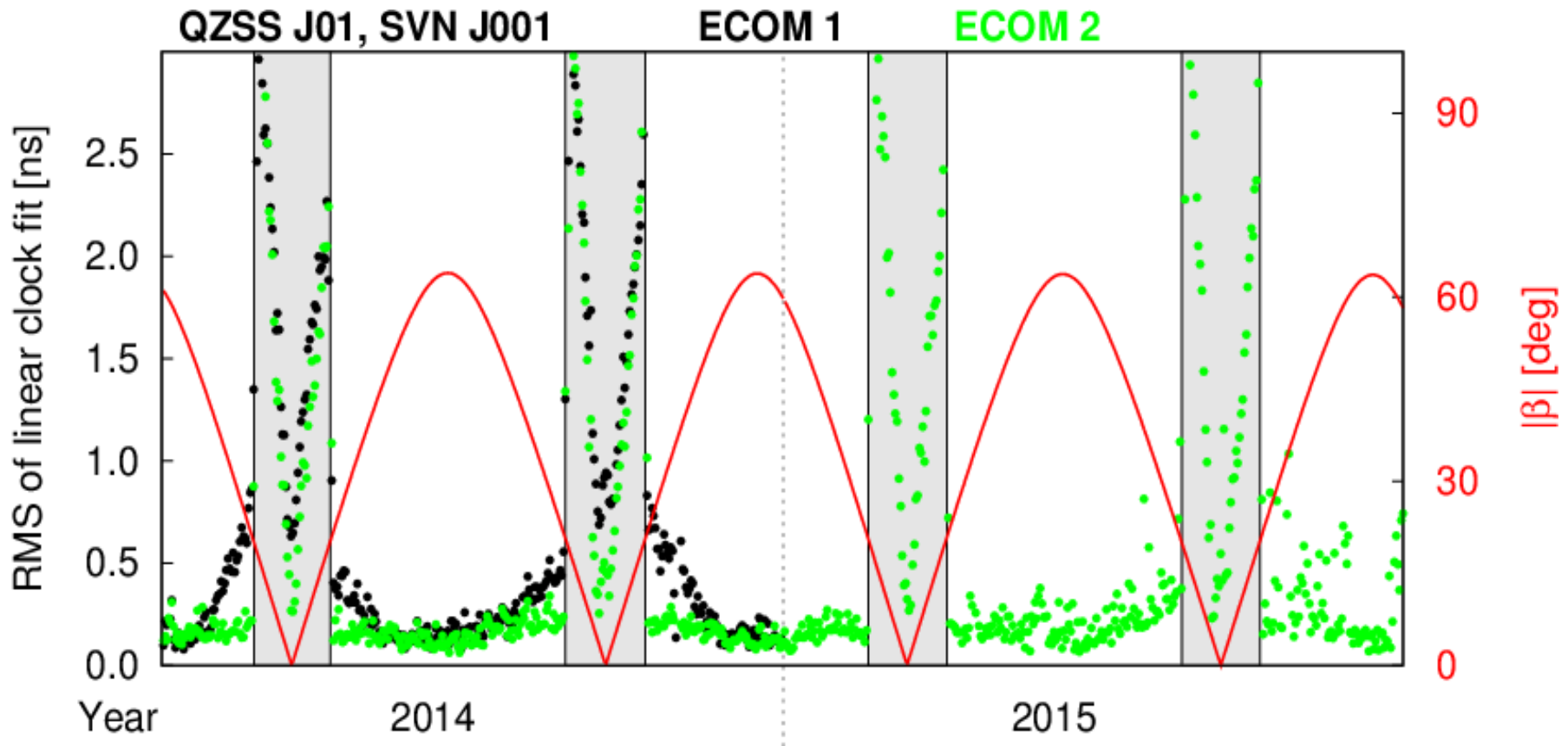
# Impact of new ECOM on QZSS orbits



## ECOM2:

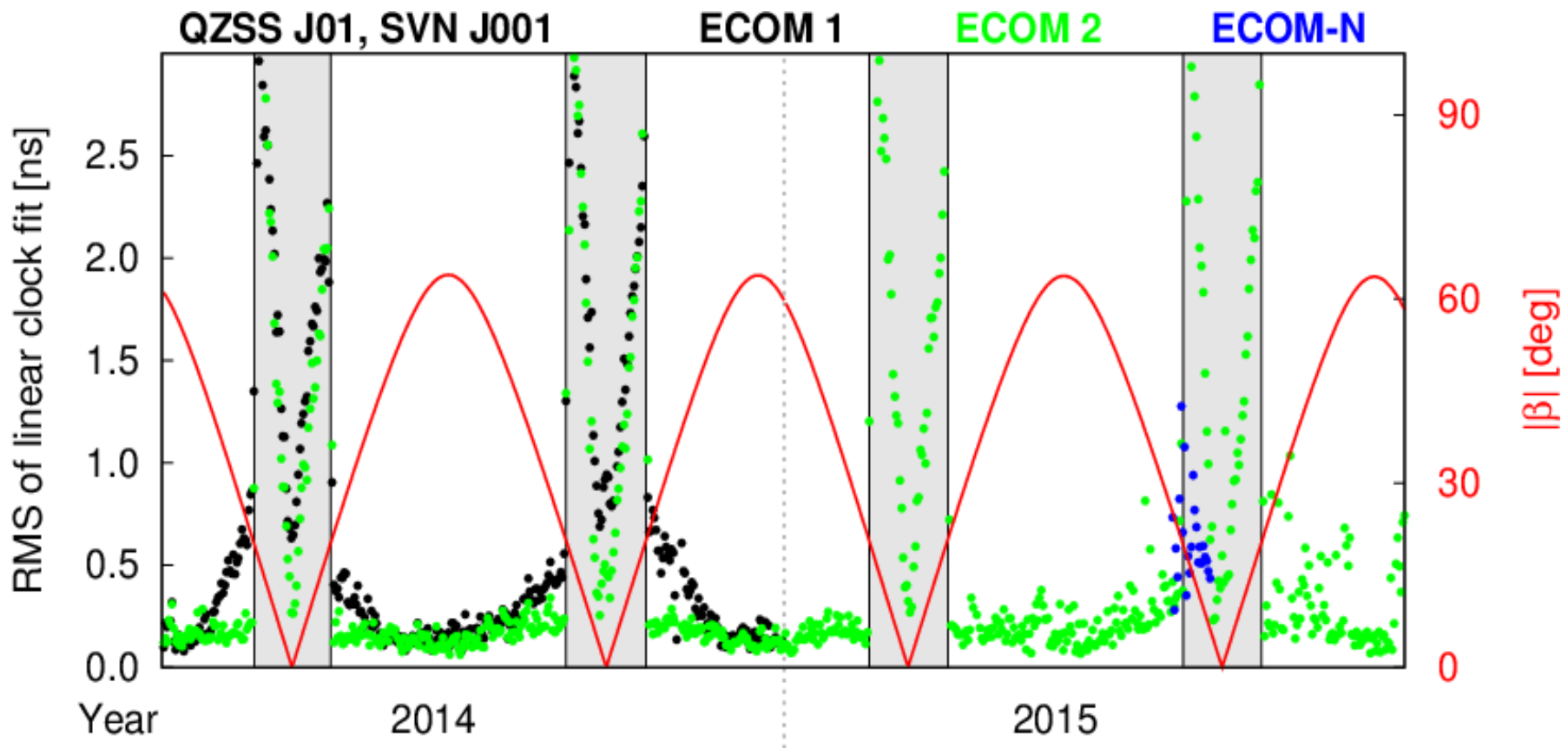
- ⇒  $|\beta| < 20^\circ$ : SLR residuals remain large
- ⇒  $|\beta| > 20^\circ$ : systematics in the SLR residuals are reduced
- ⇒ SLR offset remains

# Impact of new ECOM on QZSS clock corrections



- ⇒ Significant reduction of Beta angle dependency at Yaw attitude thanks to ECOM2
- ⇒ Large errors remain at orbit normal attitude

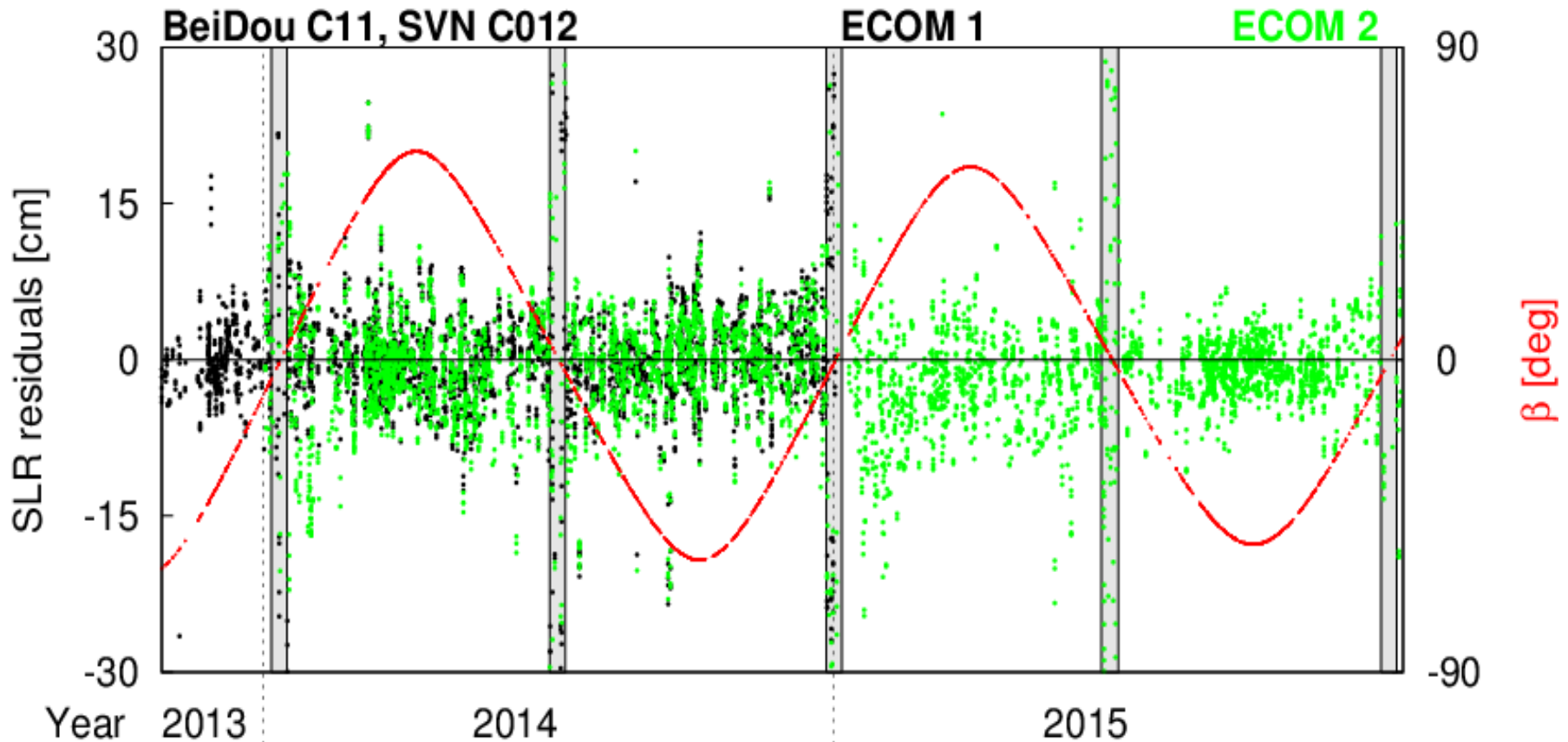
# Impact of new ECOM on QZSS clock corrections



⇒ Significant reduction of Beta angle dependency at Yaw attitude thanks to ECOM2

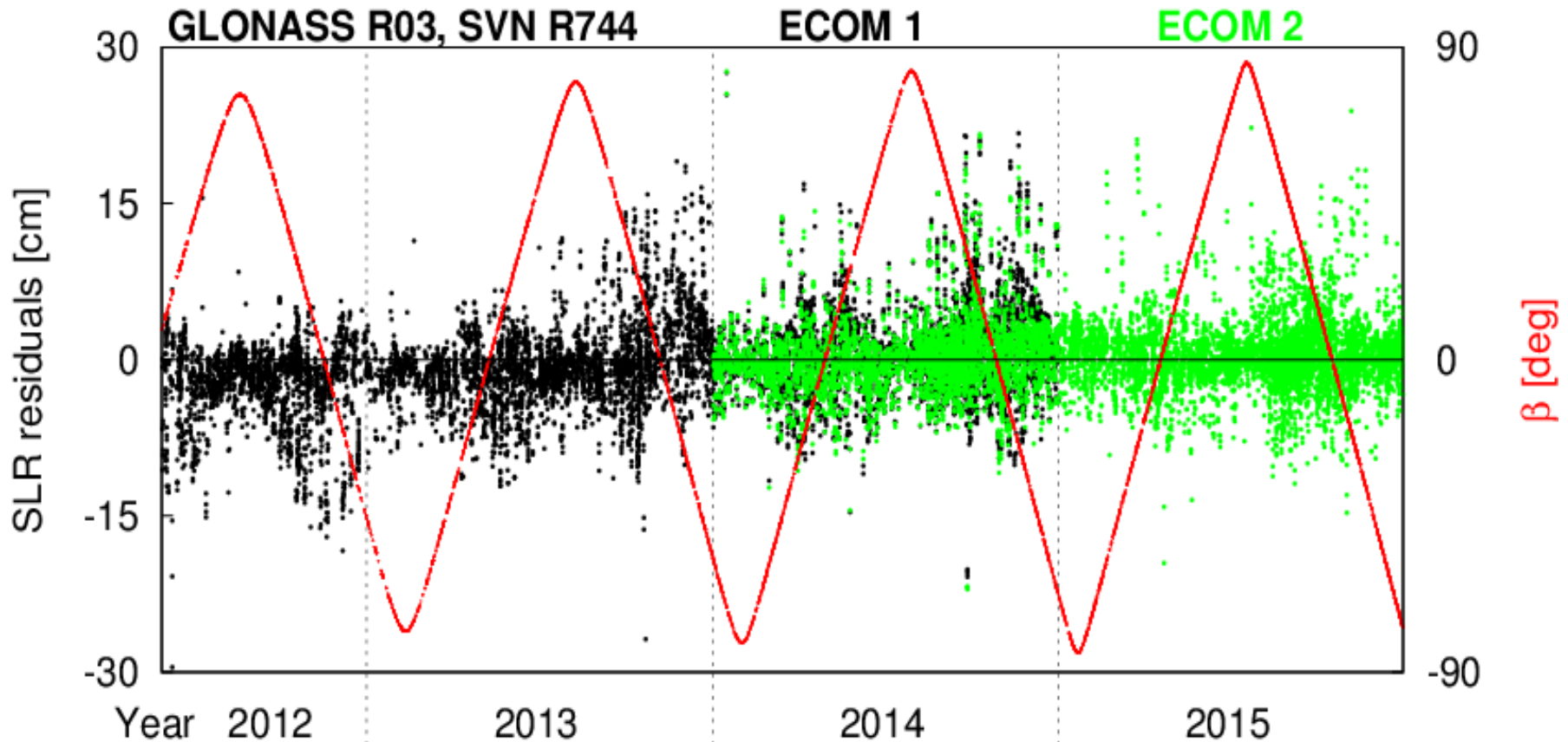
⇒ Experiments with ECOM version suited for normal attitude mode

# Impact of new ECOM on BeiDou orbits



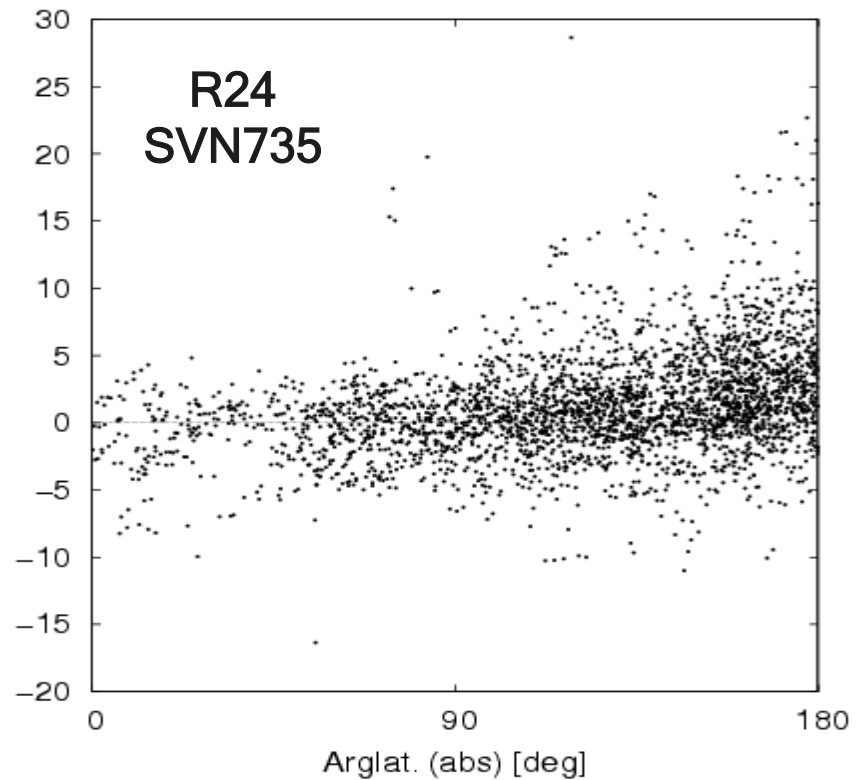
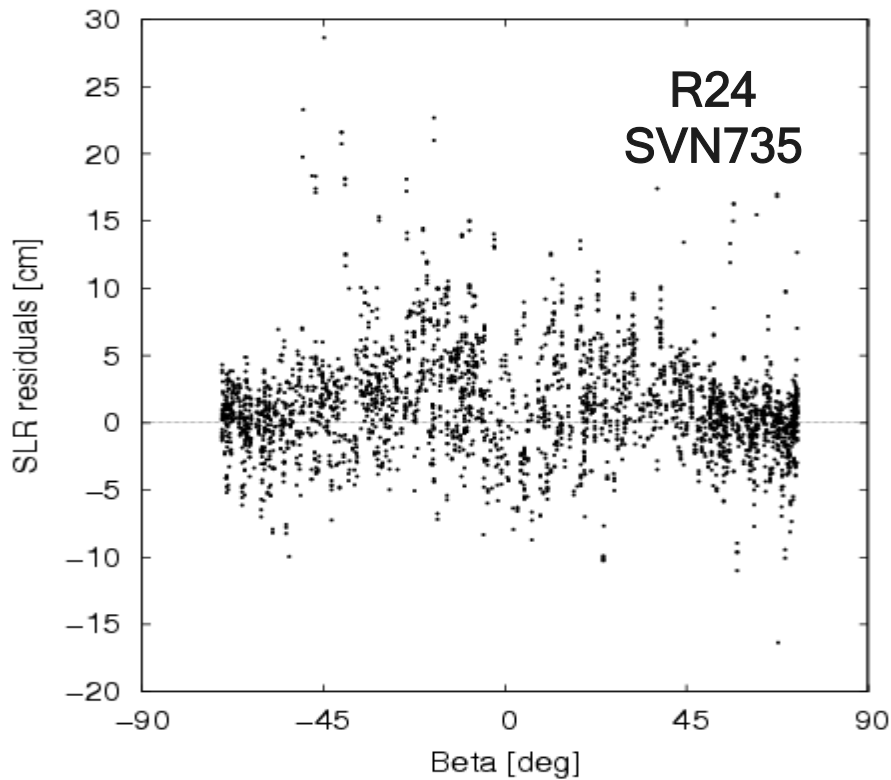
- ⇒ No significant impact of new ECOM on BeiDou orbits
- ⇒ Large residuals for  $|\beta| < 4^\circ$  (marked grey), because orbit normal attitude not yet correctly considered

# Impact of new ECOM on GLONASS orbits



⇒ Moderate reduction of SLR residuals at low Beta angles for majority of GLONASS satellites

# Impact of new ECOM on GLONASS orbits

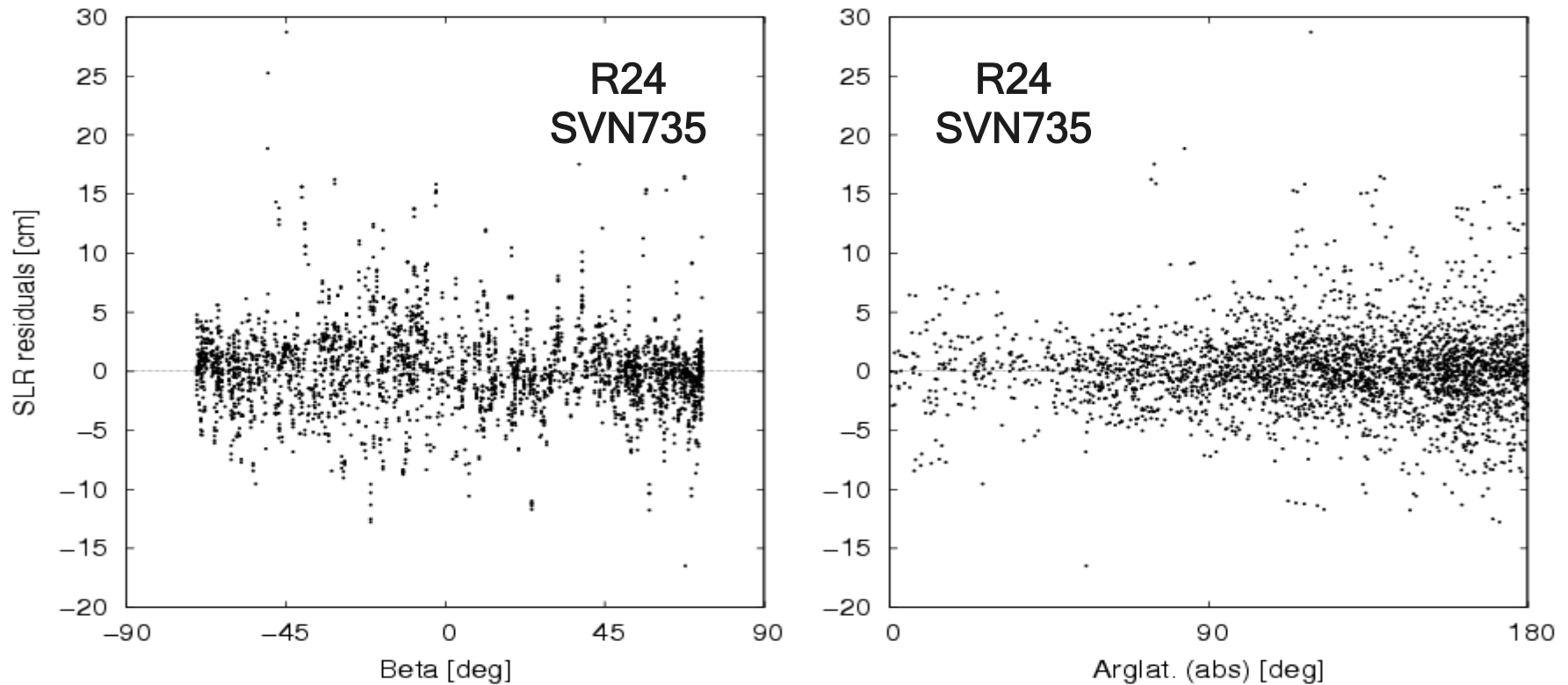


## ECOM1:

⇒ Moderate correlation of SLR residuals from 2014 with Beta angle and argument of latitude



# Impact of new ECOM on GLONASS orbits

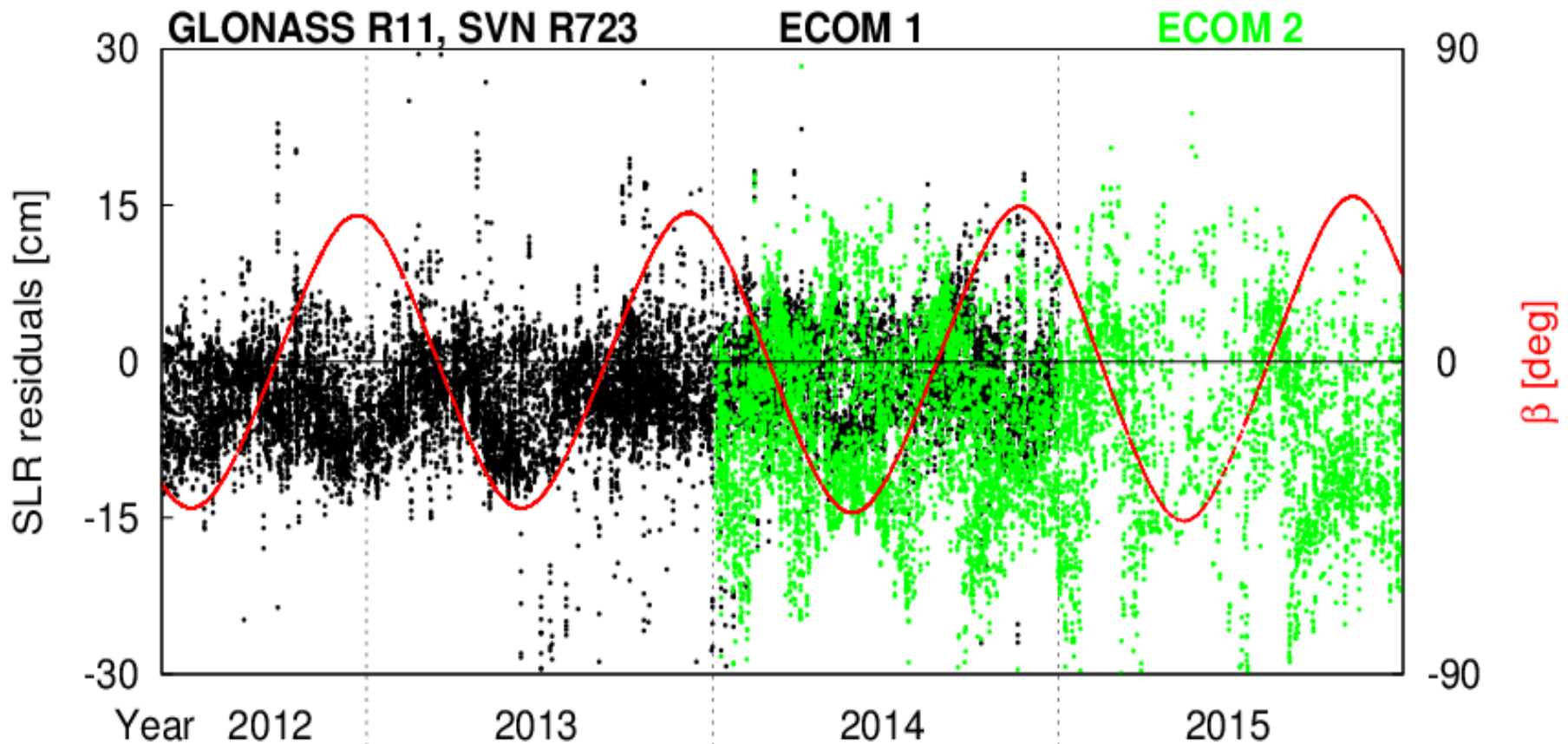


## ECOM2:

⇒ Systematics in the SLR residuals are reduced for most GLONASS satellites



# Impact of new ECOM on GLONASS - exceptions



**But:** ECOM2 does not work well for all GLONASS satellites  
(related to attitude issues?)

# Summary

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- Galileo, QZSS: significant improvement of orbits and clocks with ECOM2, when in yaw-attitude
- GLONASS: moderate orbit improvement with ECOM2 for the majority of satellites; degradation for some satellites
- ECOM2 is possibly more sensitive to attitude mis-modellings (compared to ECOM1)
- Normal attitude steering mode at low beta-angles causes very large orbit errors if not correctly considered
- Stable satellite clocks (GPS IIF, Galileo PHM, QZSS) are well suited for orbit validation
- Reprocessing of data from 2015 planned

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Thank you  
for  
your interest!