



# Using SLR for GNSS orbit model validation

Claudia Flohrer, Tim Springer, Michiel Otten, Cristina Garcia Serrano, Florian Dilssner, Erik Schönemann, Werner Enderle

ESOC - Navigation Support Office, Darmstadt, Germany

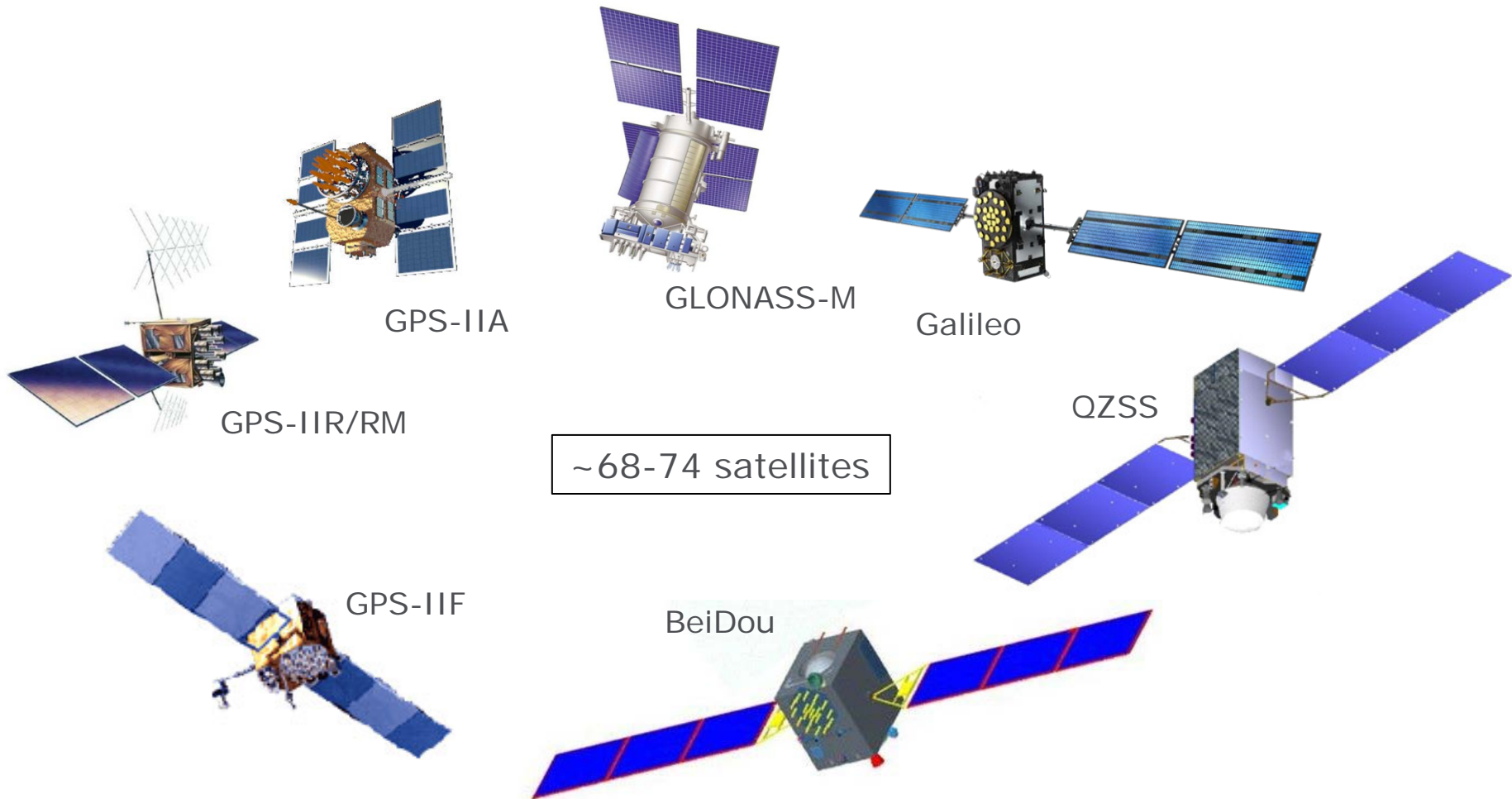
ILRS Technical Workshop 2015 | Matera | Italy  
26/10/2015



- We are official IGS, ILRS and IDS analysis center
- We process data of all GNSS constellations for Precise Orbit Determination (POD)
- For **POD** we need detailed models (satellite dynamics), but not all of the data needed for detailed modelling is available
- SLR provides an independent source for validating GNSS satellite orbits and the underlying models
- Within this presentation we focus on the use of SLR for the validation of Box-Wing models to account for Solar Radiation Pressure (SRP) forces acting on the GNSS satellites

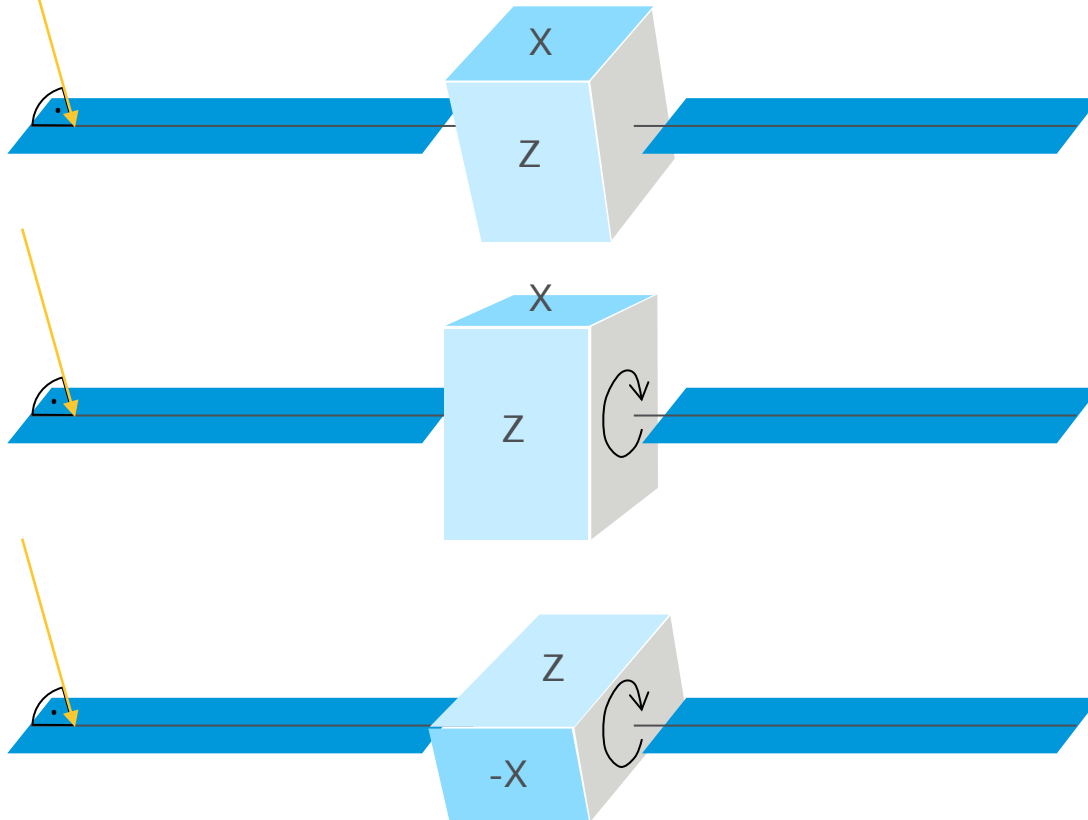
# Multi-GNSS data processing (2014)

## Data from ESA and MGEX GNSS Sensor Stations

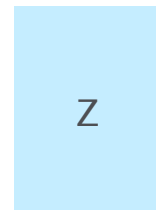
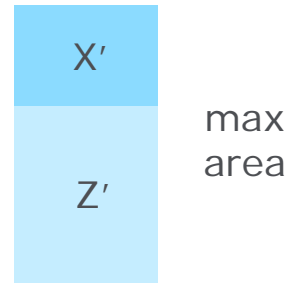
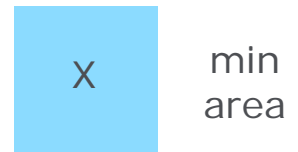


# Solar radiation pressure

Direct SRP force (D)



Projected box area  $A'$  in direct Sun direction



Acceleration due to direct SRP is assumed to be:

- constant for the wings ( $A'_W = \text{const}$ )
- but varying for the box ( $A'_B = f(t)$ )

# Box-Wing model

Surface areas used in NAPEOS

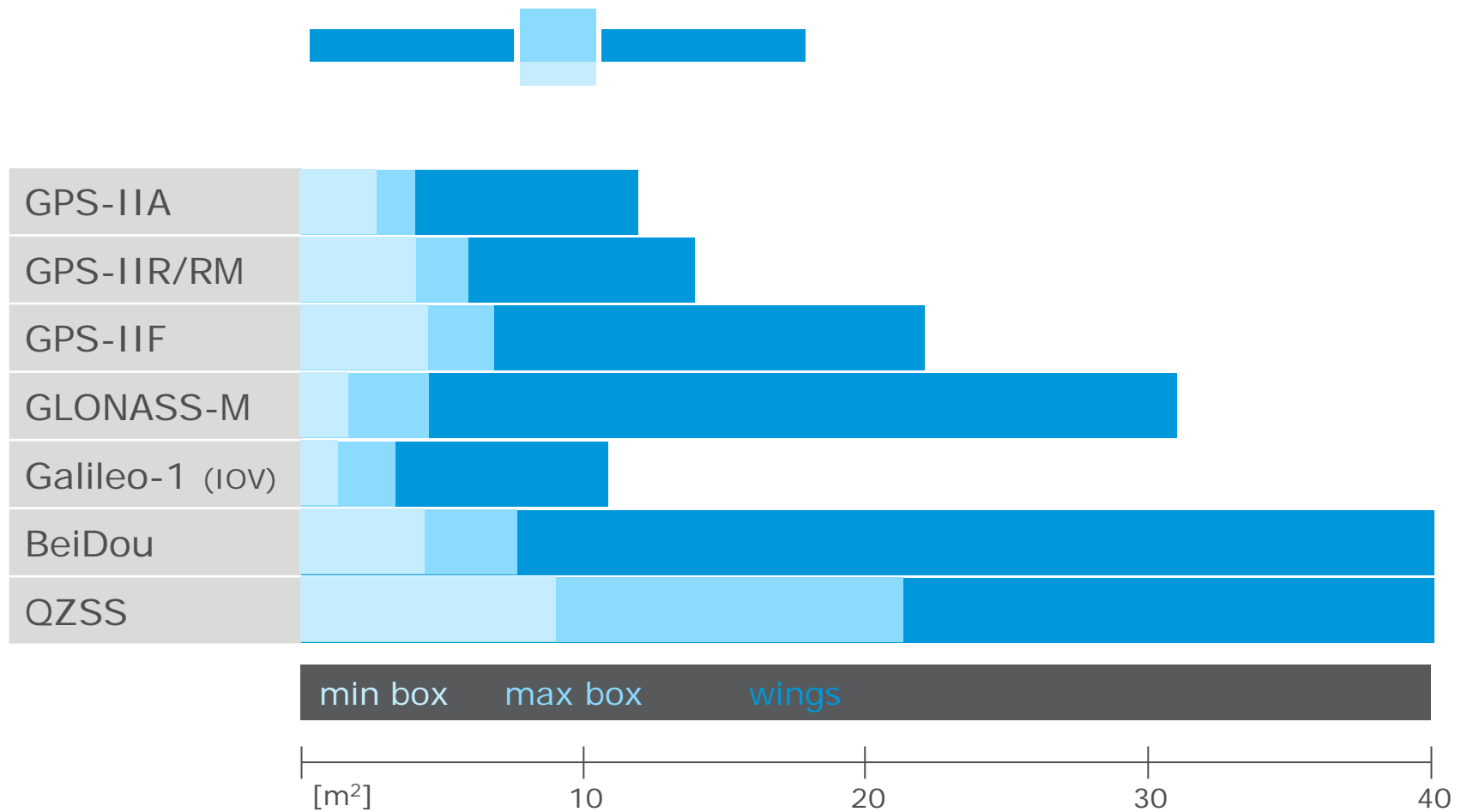


	Box [m <sup>2</sup> ]			Wing [m <sup>2</sup> ]
	X	Y	Z	
GPS-IIA <sup>1)</sup>	2.7		2.9	11.9
GPS-IIR/RM <sup>1)</sup>	4.1		4.3	13.9
GPS-IIF <sup>1)</sup>	4.5		5.1	22.0
GLONASS-M <sup>2)</sup>	4.2		1.7	30.9
Galileo-1 (IOV) <sup>1)</sup>	1.3		3.0	10.8
BeiDou <sup>2)</sup>	6.2	6.8	4.4	40.0
QZSS <sup>1)</sup>	19.2	18.0	9.0	40.0

<sup>1)</sup> data publicly available

<sup>2)</sup> ESOC tuned public data

# Surface areas



# Approx. surface area changes

Not absorbed by D0 parameter



	max-min [m <sup>2</sup> ]	Rank	Mass [kg]	Area/Mass	Rank
GPS-IIA	1.3	7	975	0.0013	7
GPS-IIR/RM	1.8	6	1100	0.0017	4
GPS-IIF	2.3	4	1450	0.0016	5
GLONASS-M	2.8	3	1400	0.0020	3
Galileo-1 (IOV)	2.0	5	695	0.0028	2
BeiDou	3.2	2	2000	0.0016	5
QZSS	12.2	1	2000	0.0061	1

# Validating orbit models with SLR

without box-wing

with box-wing

Orbit difference

Which orbit is better?

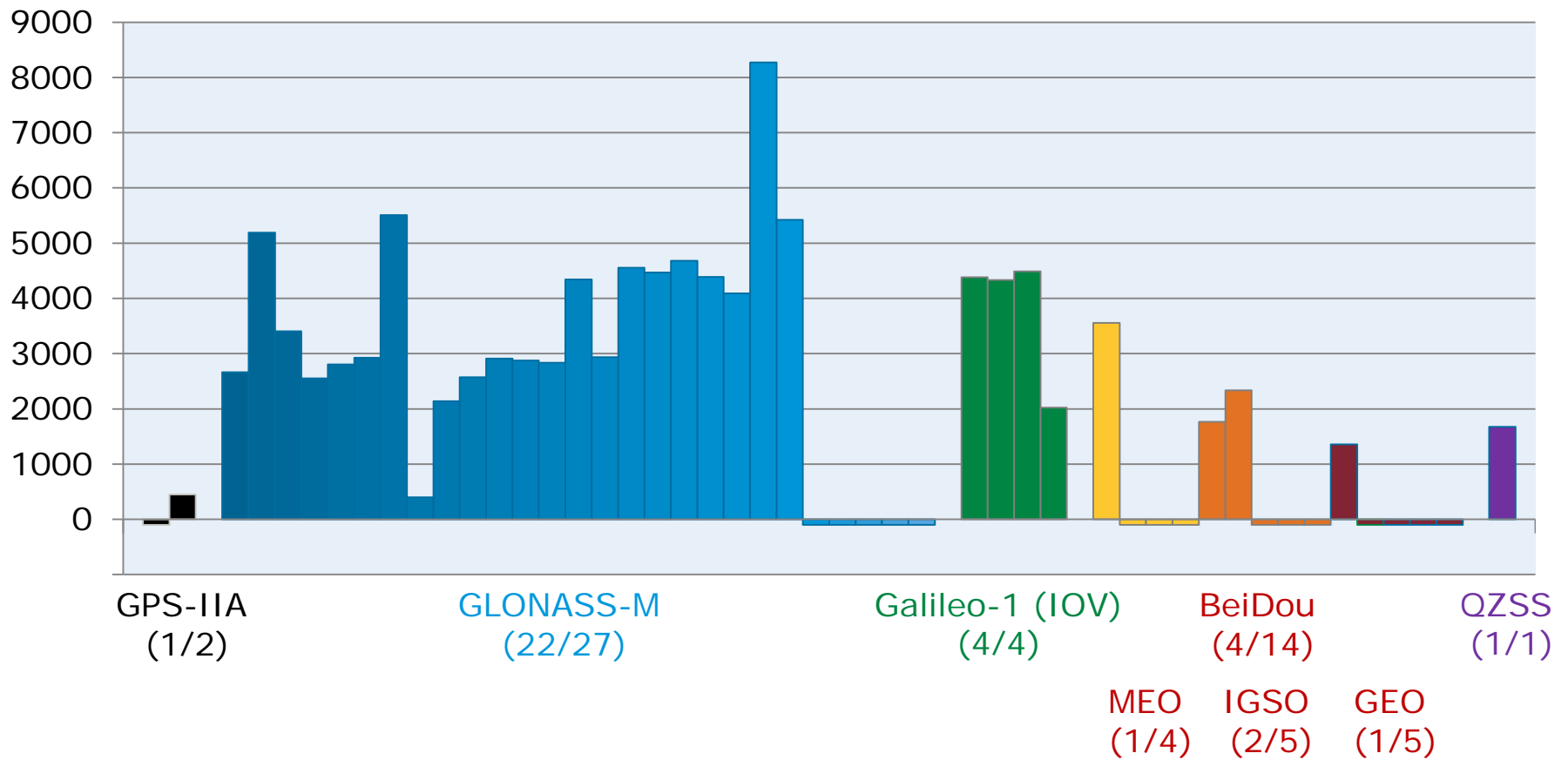


SLR can tell! (mainly in radial direction)



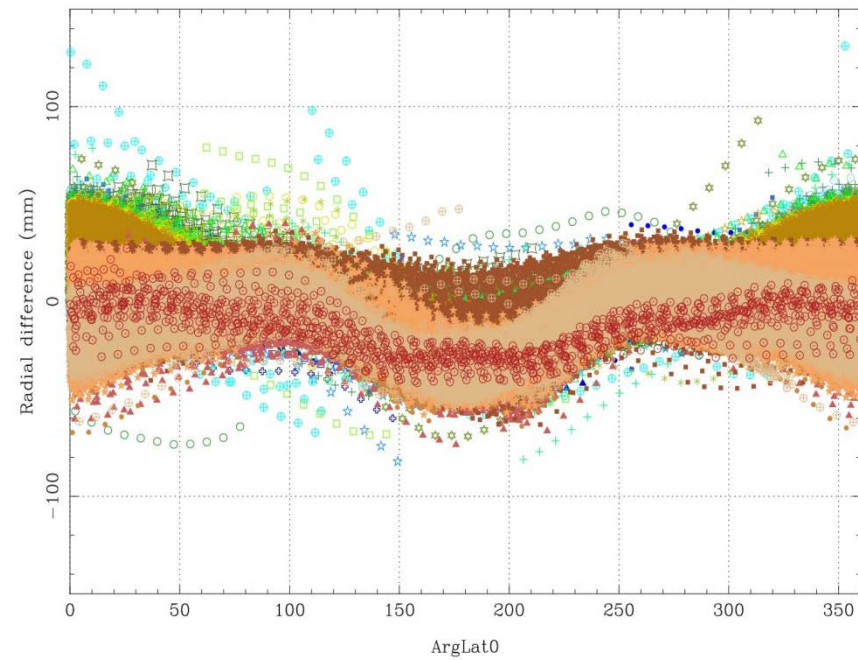
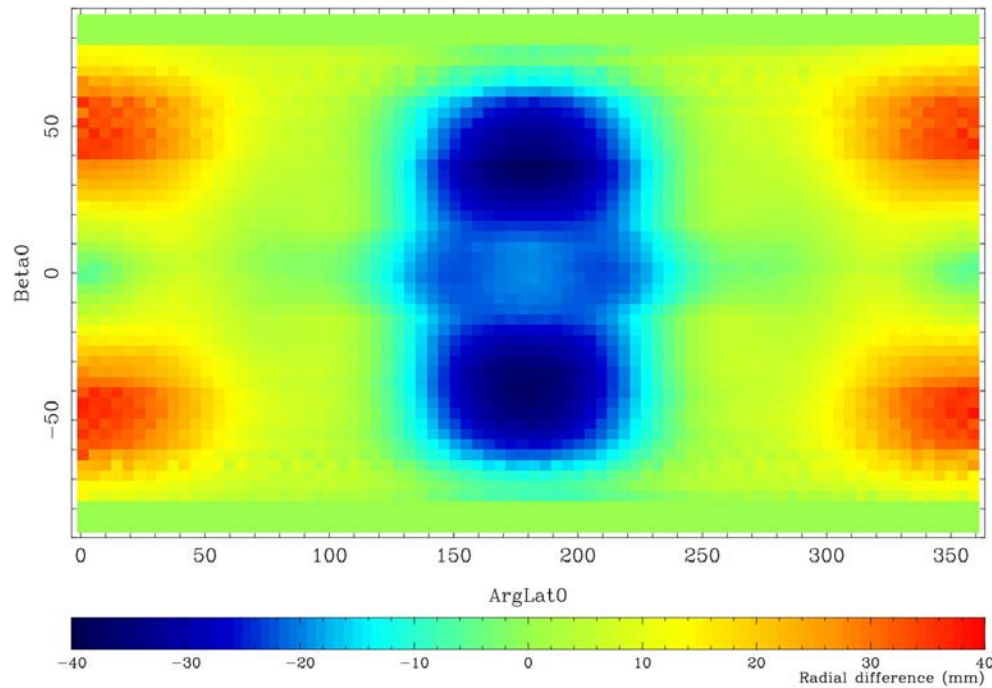


# Number of SLR data (NP) in 2014



# Radial orbit difference – GPS-11A

“with box-wing” minus “without box-wing”



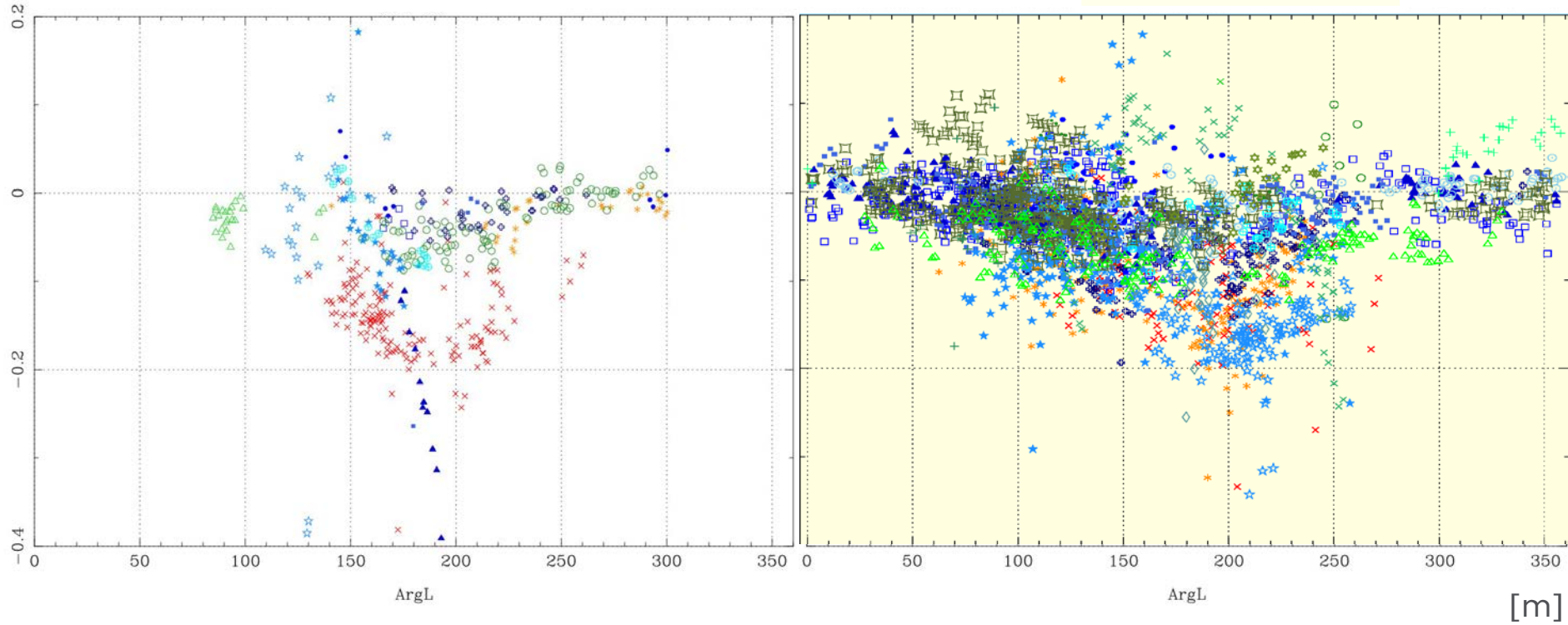
[mm]

# SLR residuals (2-way) – GPS-IIA

without box-wing

2014 (GPS-36)

2012 (GPS-35/36)

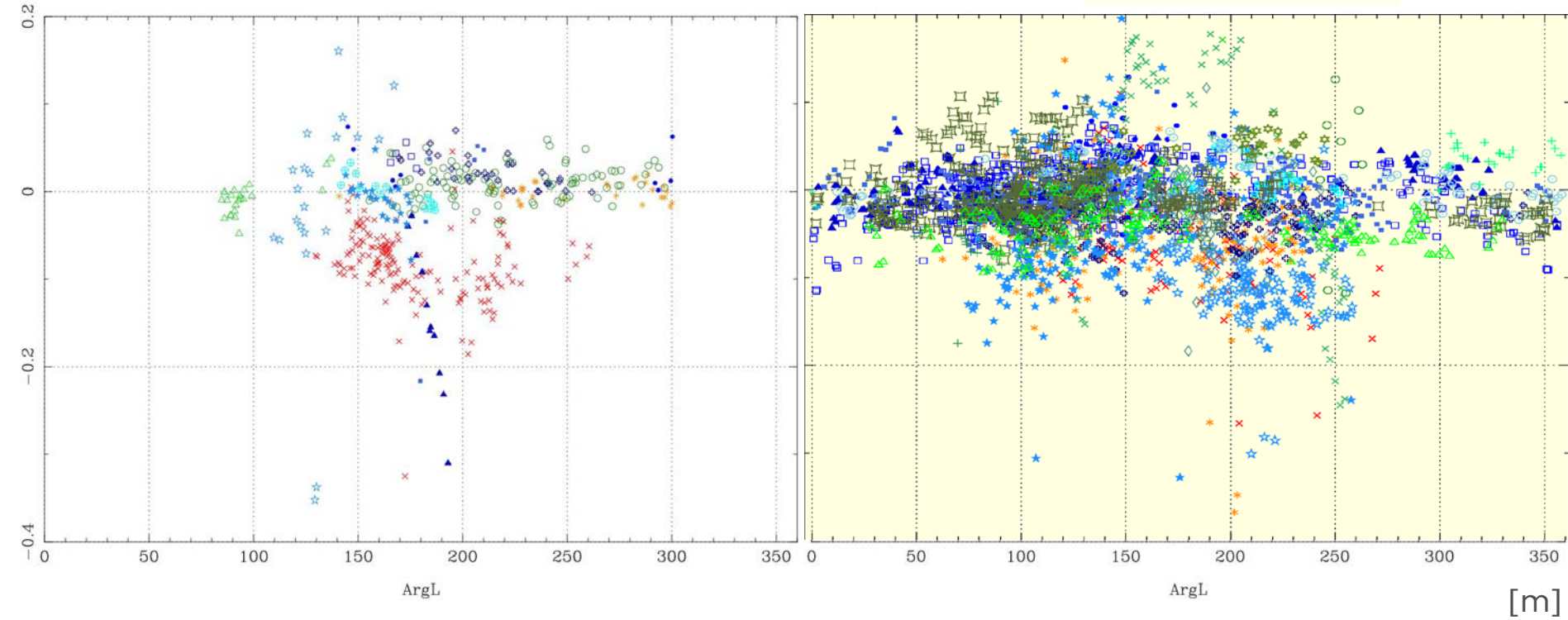


# SLR residuals (2-way) – GPS-IIA

with box-wing

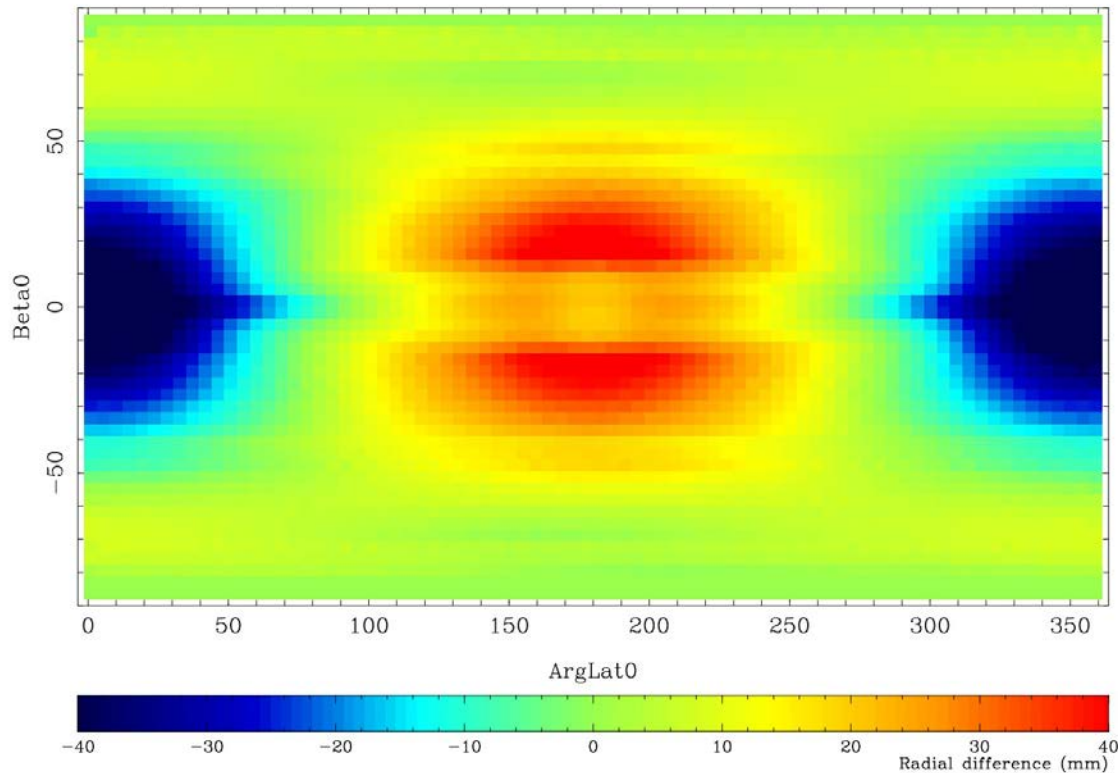
2014 (GPS-36)

2012 (GPS-35/36)



# Radial orbit difference – GLONASS-M

“with box-wing” minus “without box-wing”

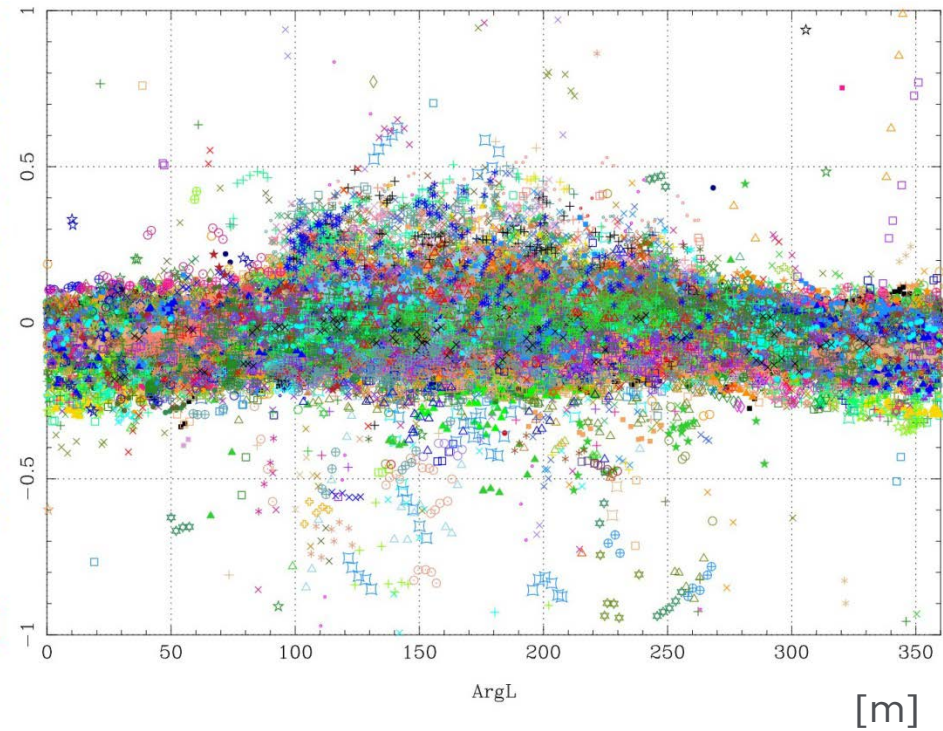
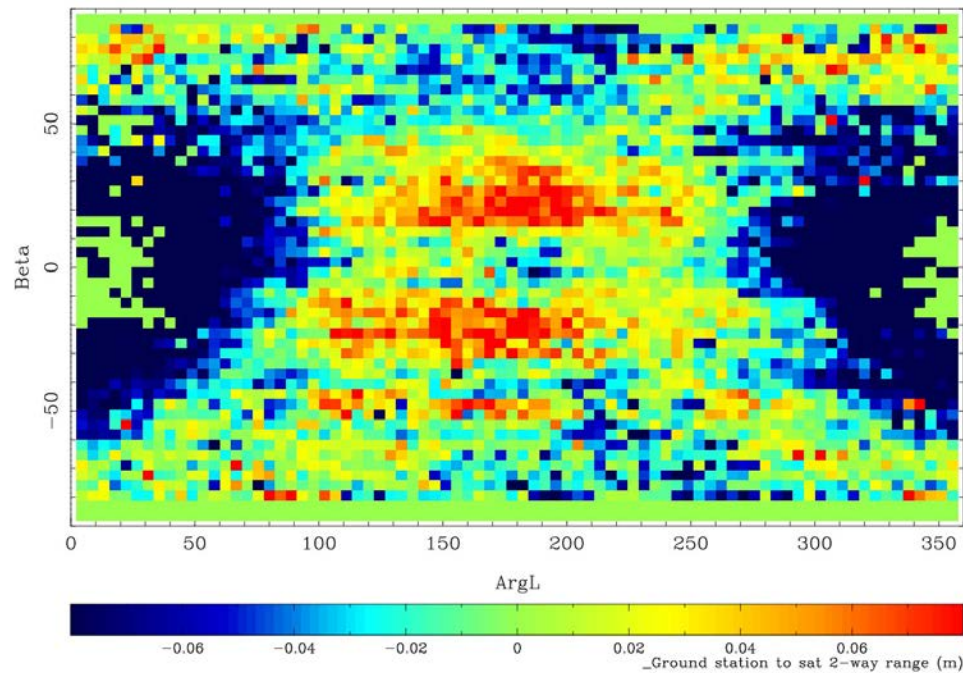


[mm]



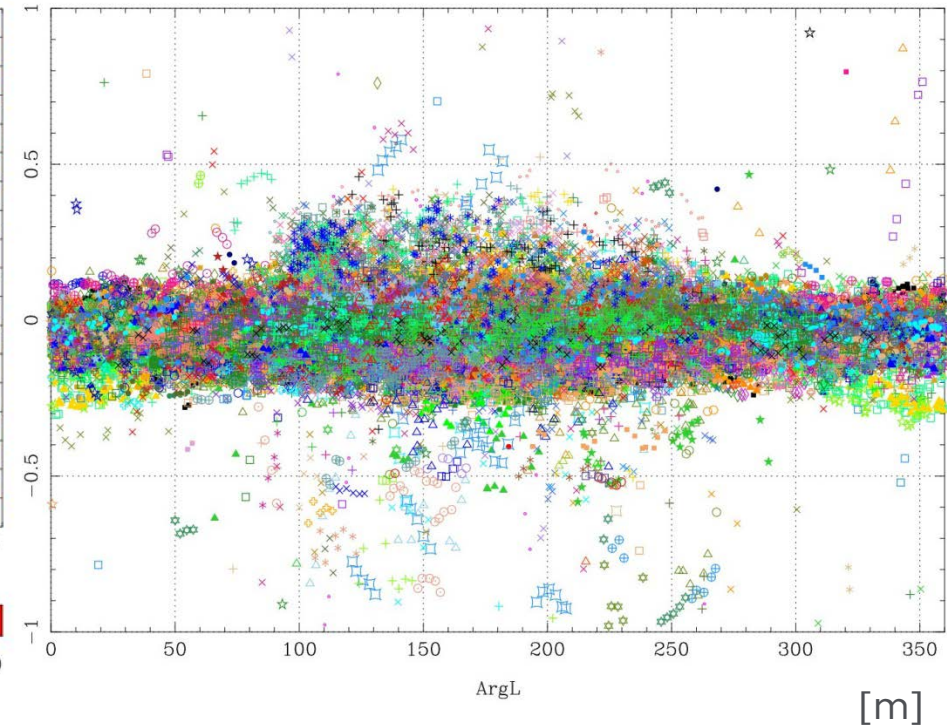
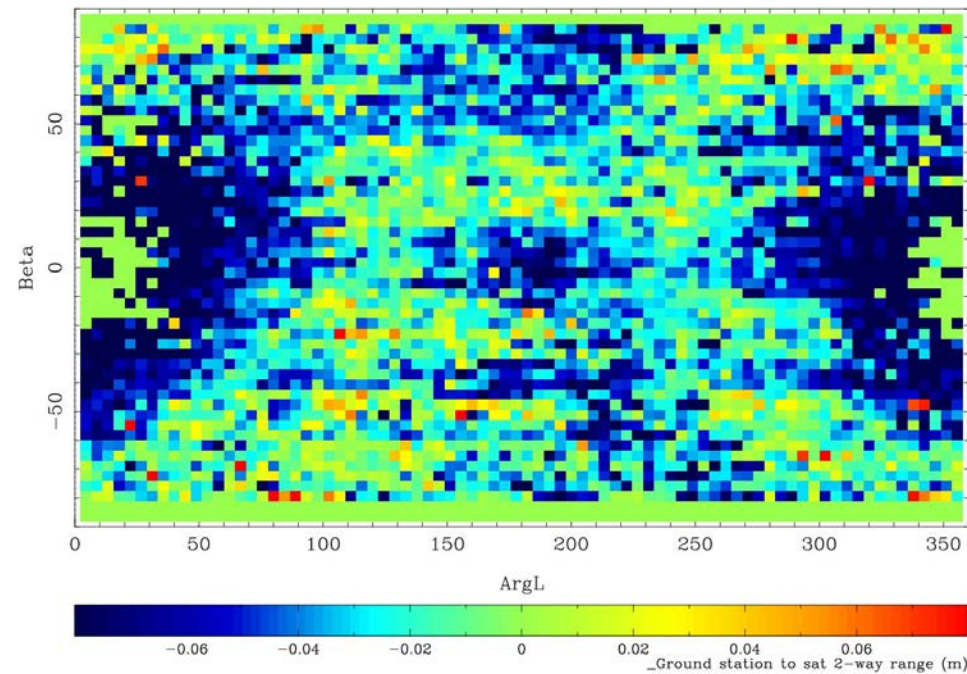
# SLR residuals (2-way) – GLONASS-M

without box-wing



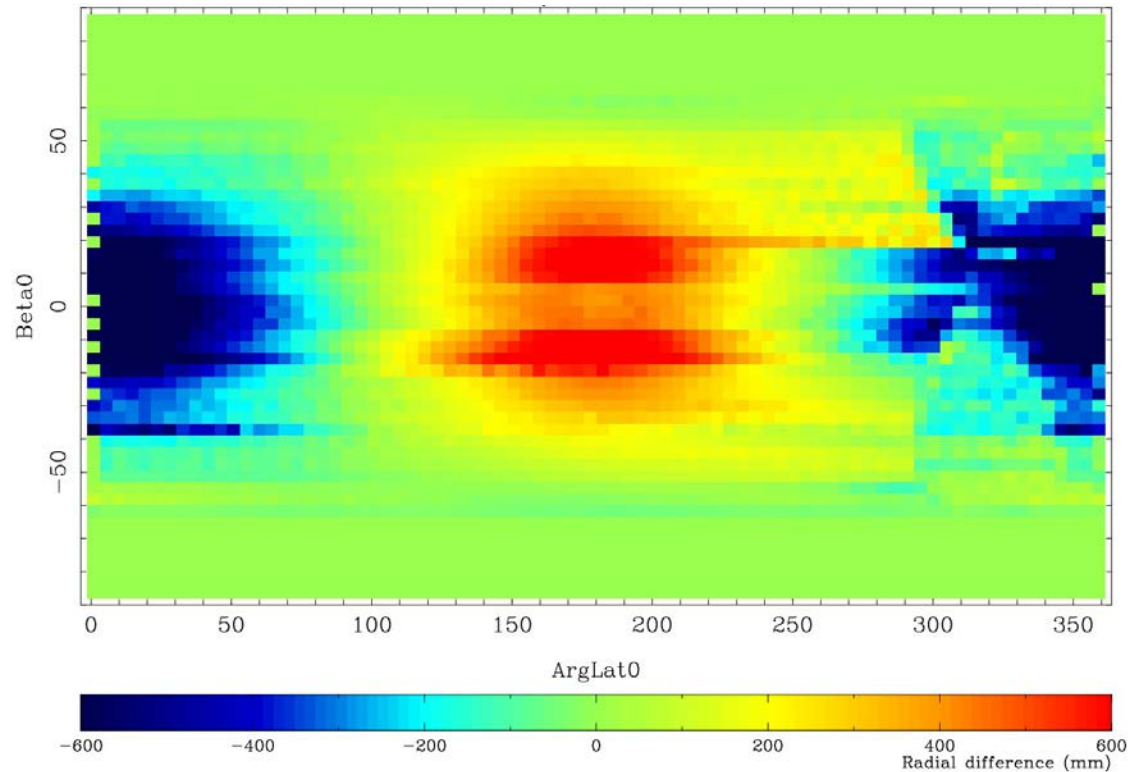
# SLR residuals (2-way) – GLONASS-M

with box-wing



# Radial orbit difference – QZS-1

“with box-wing” minus “without box-wing”

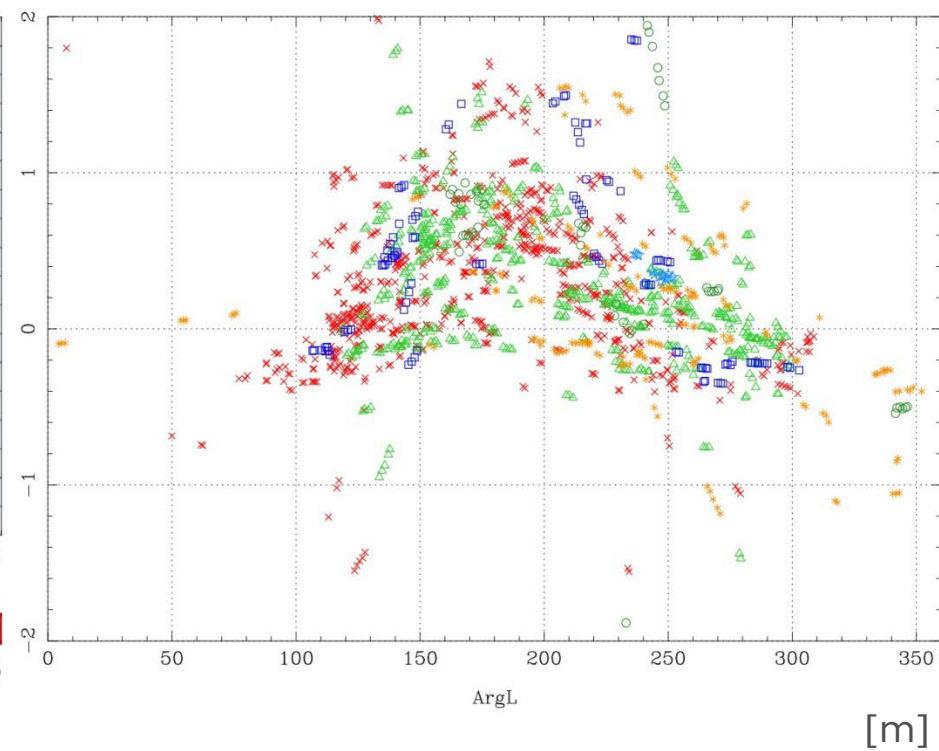
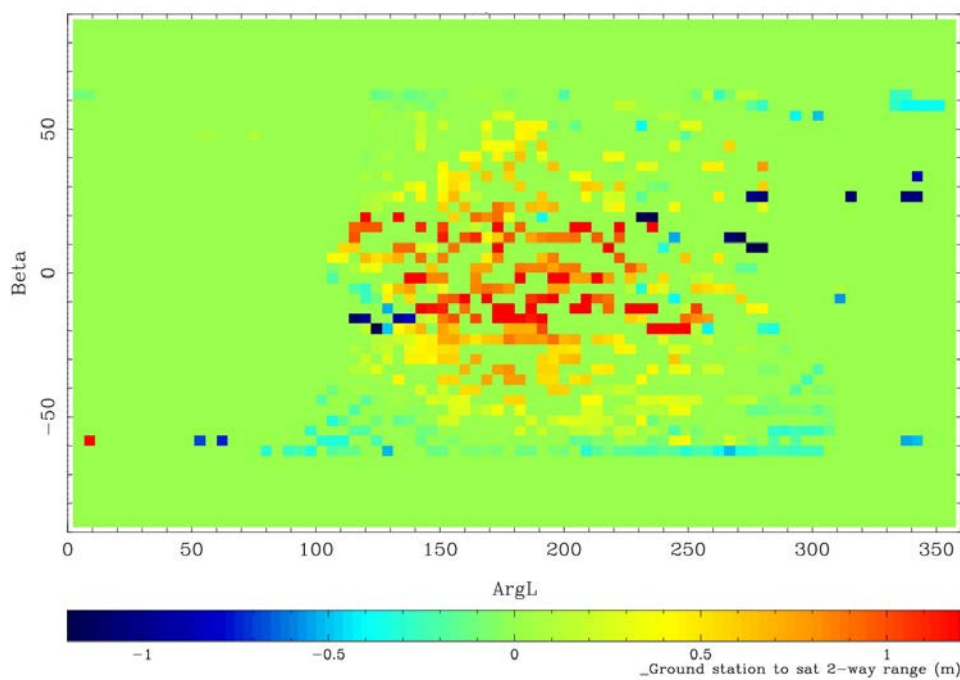


[mm]



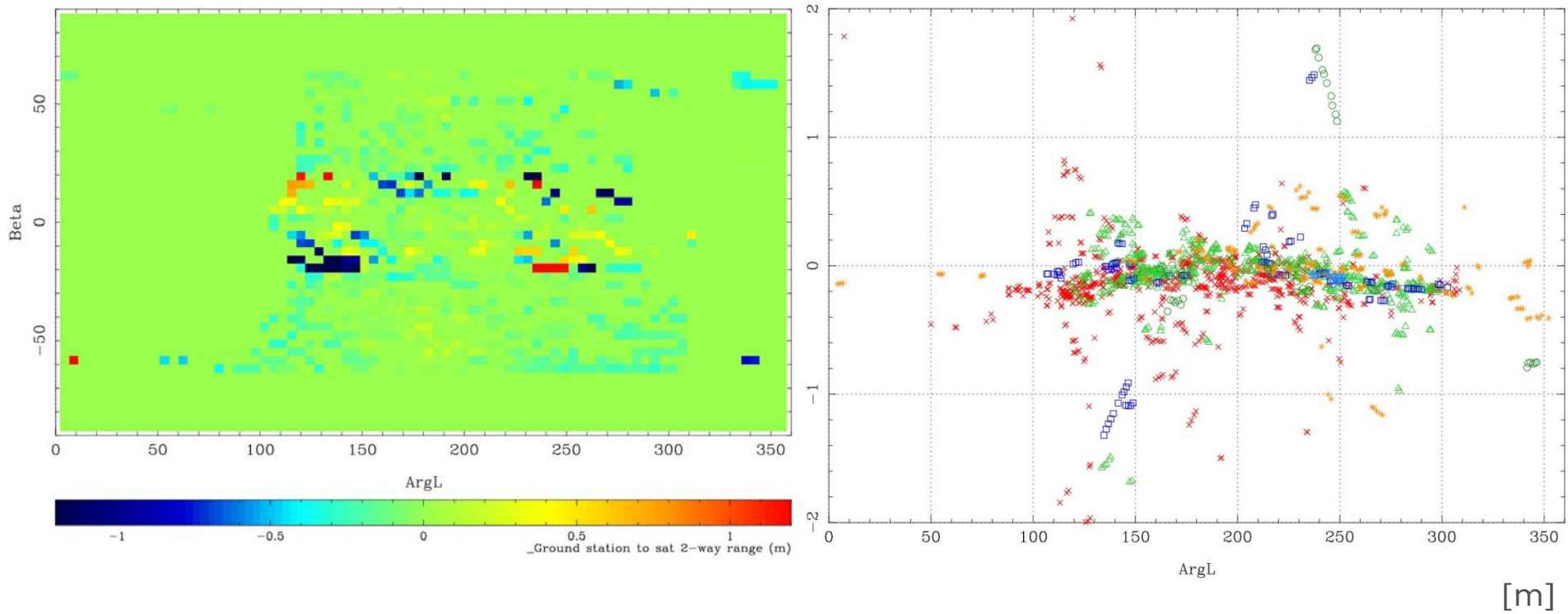
# SLR residuals (2-way) – QZS-1

without box-wing



# SLR residuals (2-way) – QZS-1

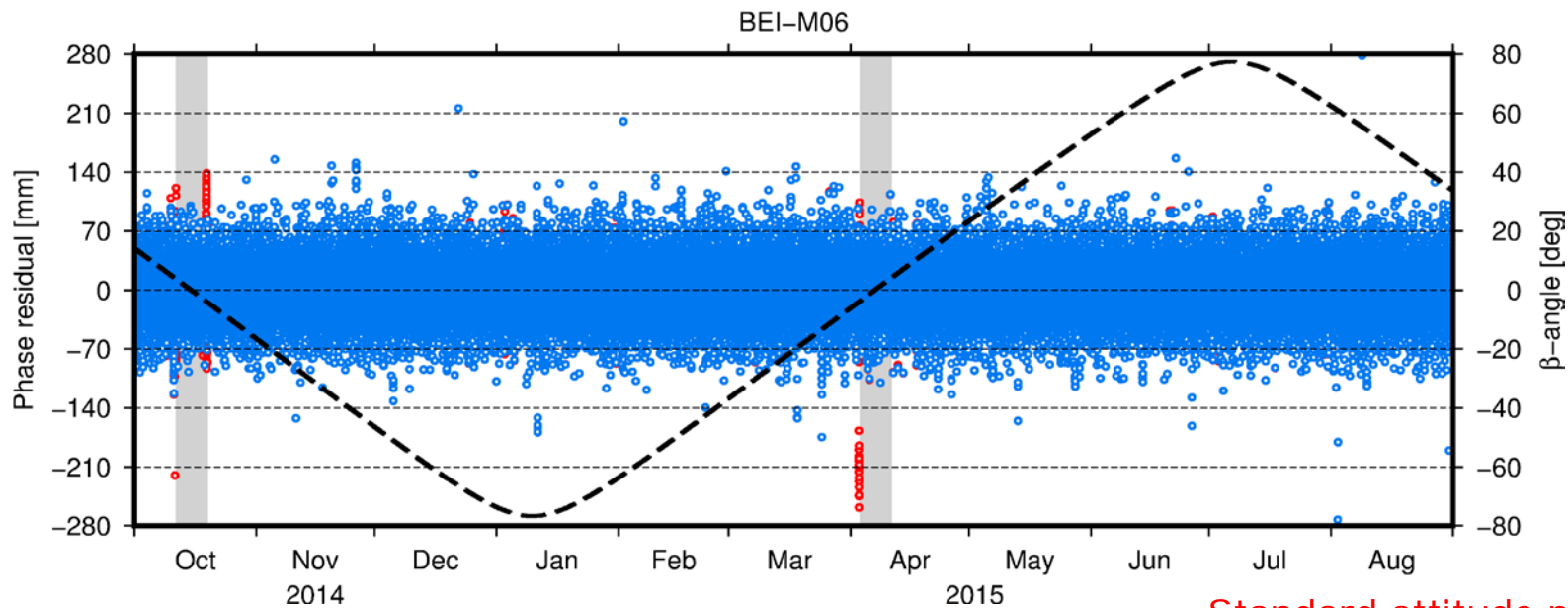
with box-wing



## Potential attitude model improvement

→ Attitude transition from yaw steering to orbit normal mode

- Phase residuals show improvement
- Dedicated SLR tracking for transition periods could help to validate the attitude model



Standard attitude mode switch  
Refined attitude mode switch

- Significant impact of Box-Wing model to account for SRP acceleration has been demonstrated
- Validation of Box-Wing model could be performed using SLR data
- SLR data provide the **only independent check of GNSS orbit accuracy** (radial component) → SLR data is an important mean to validate GNSS orbits and underlying models
- **No SLR for GPS (IIR, IIF)** → Sensitivity of incorrect SRP modelling is expected to be larger than for IIA
- **Many SLR observations for GLONASS** allow for more specific analysis (e.g. dependencies on orbital plane)
- **More SLR observations are desirable** especially for upcoming new GNSS systems (in particular Galileo with larger area/mass), as **GNSS orbit modelling issues will increase** → **SLR gets even more important!**
- **Dedicated SLR tracking campaigns** could also help to improve attitude models (e.g. understanding of attitude transition modes)

**THANK YOU**

Claudia Flohrer

[claudia.flohrer@esa.int](mailto:claudia.flohrer@esa.int)

<http://navigation-office.esa.int/>