Validation of GNSS orbits using SLR observations

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Motivation

SLR observations of GNSS satellites allow for

- Completely independent validation of microwave-based GNSS orbits
- Validation of SLR data (and calibration)

SLR range residuals =

observed ranges (SLR) – computed ranges (relying on orbital information derived from microwave data)

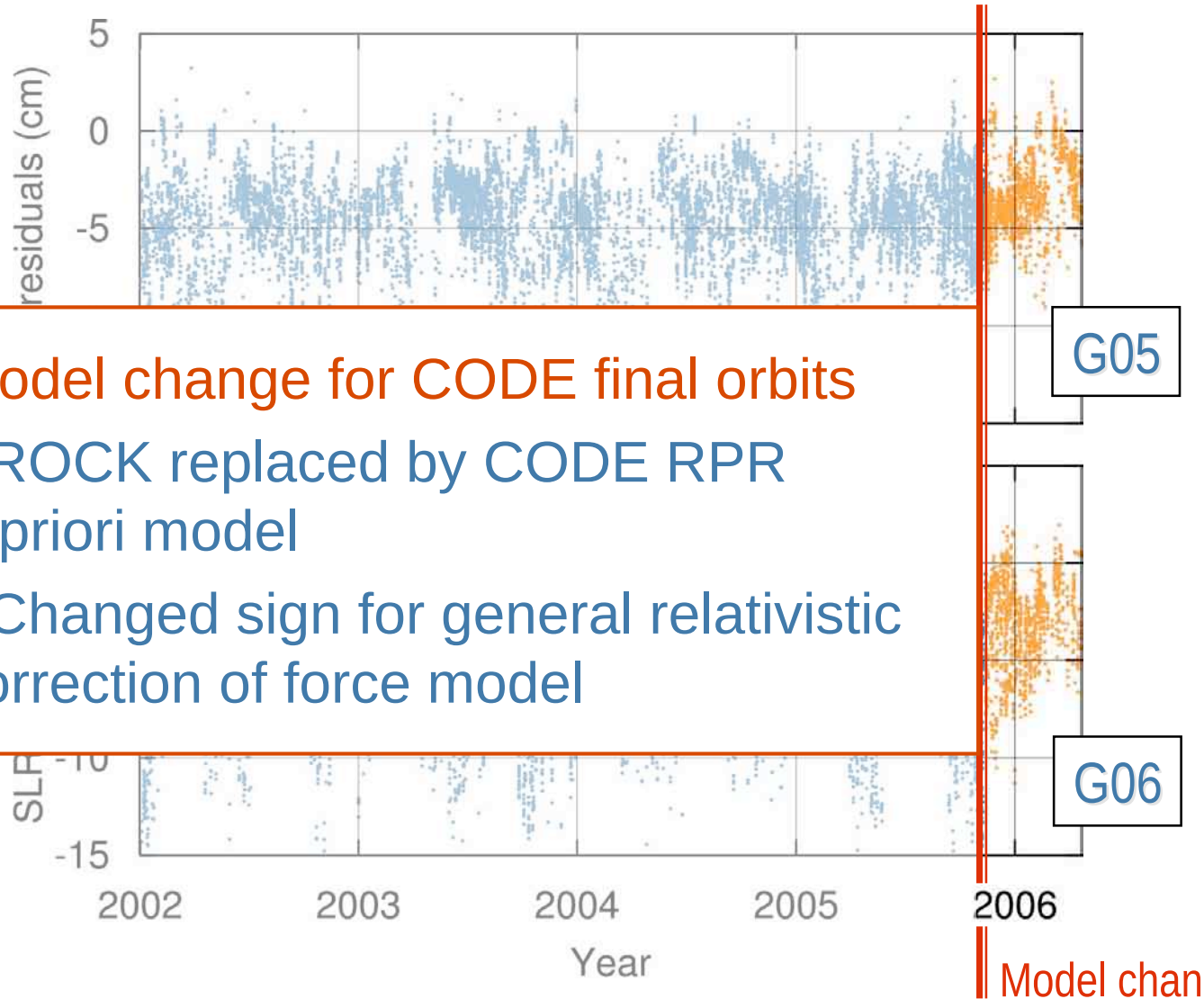
Recent improvements

of validation process

- Changed retro-reflektor offset for GPS satellites of 11 resp. 13 mm
- Latitude dependency introduced in troposphere modeling
- Normal points based on a very small number of data points are rejected

SLR range residuals

CODE final GPS orbits

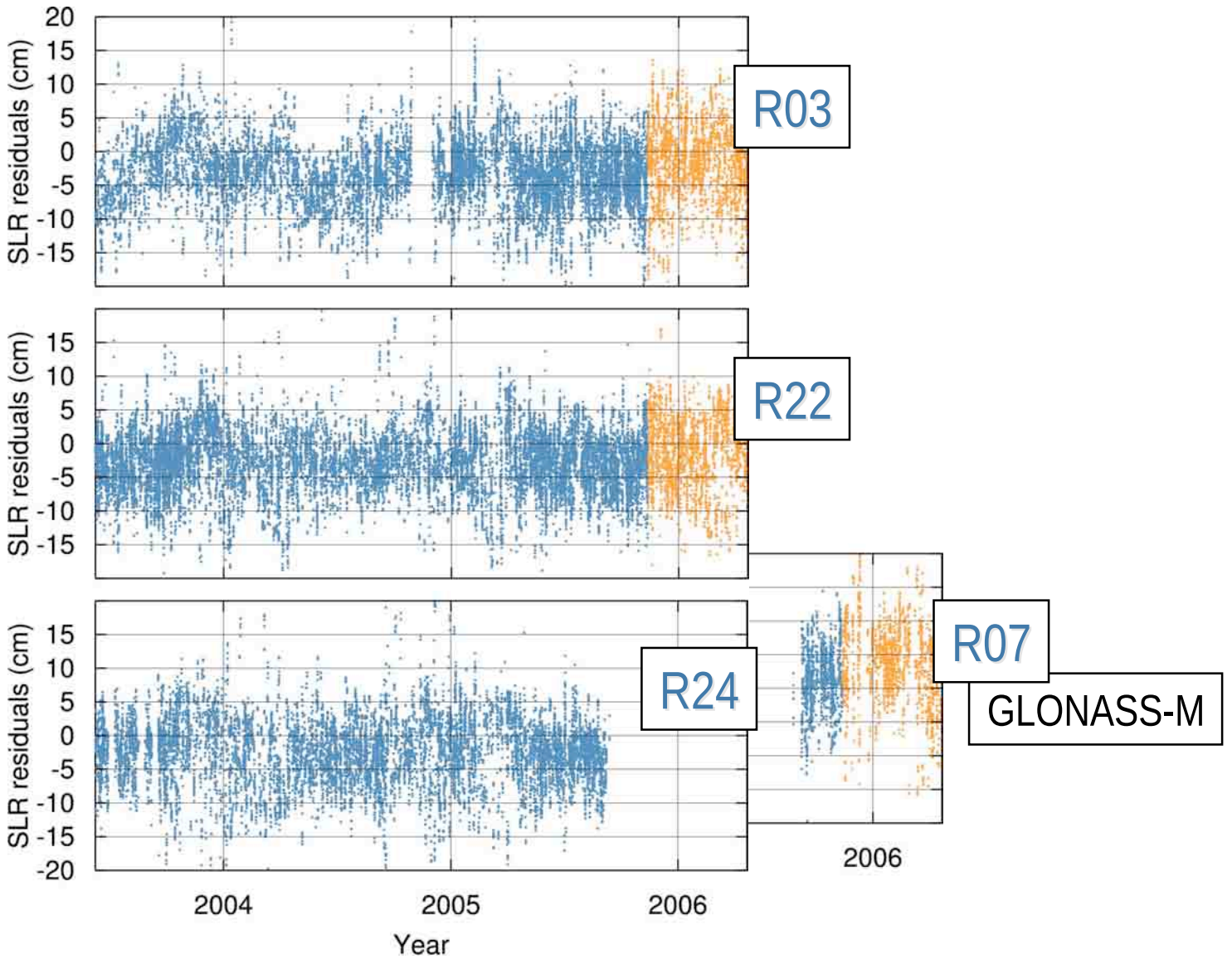


Model change for CODE final orbits

- ROCK replaced by CODE RPR a priori model
- Changed sign for general relativistic correction of force model

SLR range residuals

CODE final GLONASS orbits



STD (cm) of range residuals

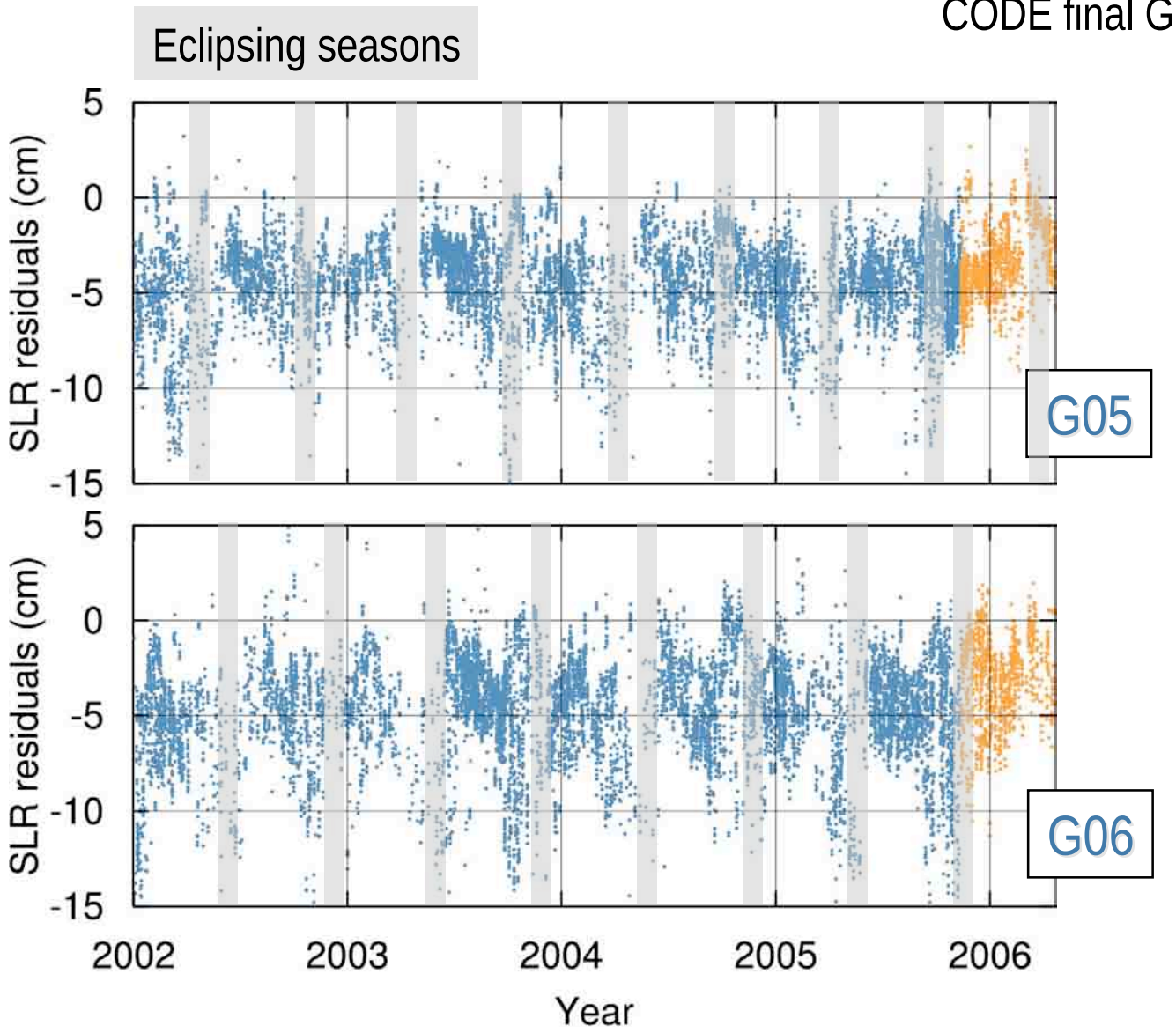
	IGS Final	GFZ Final	JPL Final	COD Final	COD Final
G05	1.9	2.3	2.2	2.2	1.8
G06	2.5	2.7	2.5	2.7	2.2
R03				4.7	5.6
$R07_M$				4.6	5.8
R22				4.4	5.1
R24				5.1	

Observed range biases (cm)

	IGS Final	GFZ Final	JPL Final	COD Final	COD Final
G05	-3.1	-3.6	-2.6	-4.4	-3.5
G06	-2.8	-3.9	-2.8	-4.8	-3.2
R03				-3.3	-1.5
$R07_M$				1.4	3.6
R22				-2.7	-1.3
R24				-2.6	

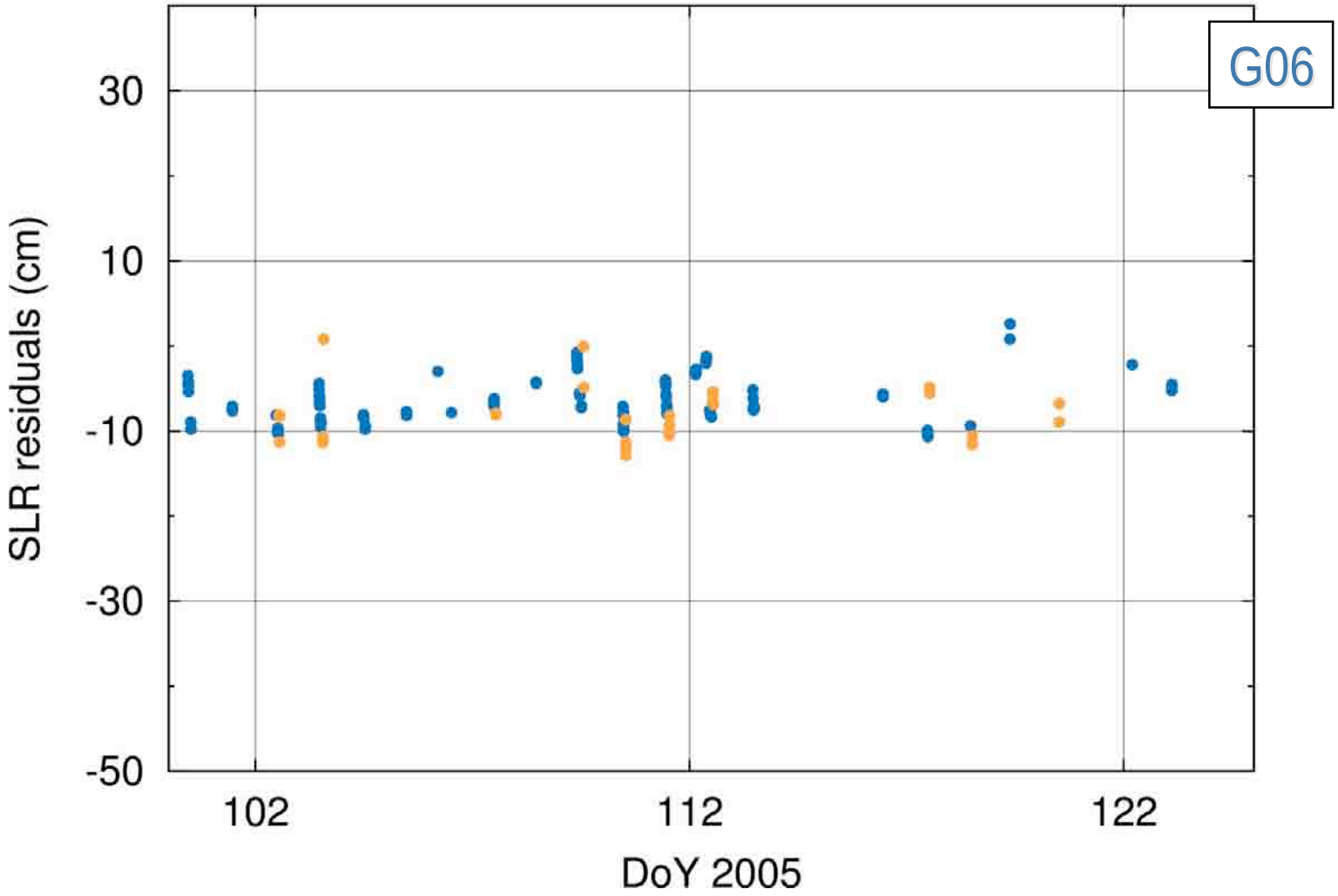
SLR range residuals

CODE final GPS orbits



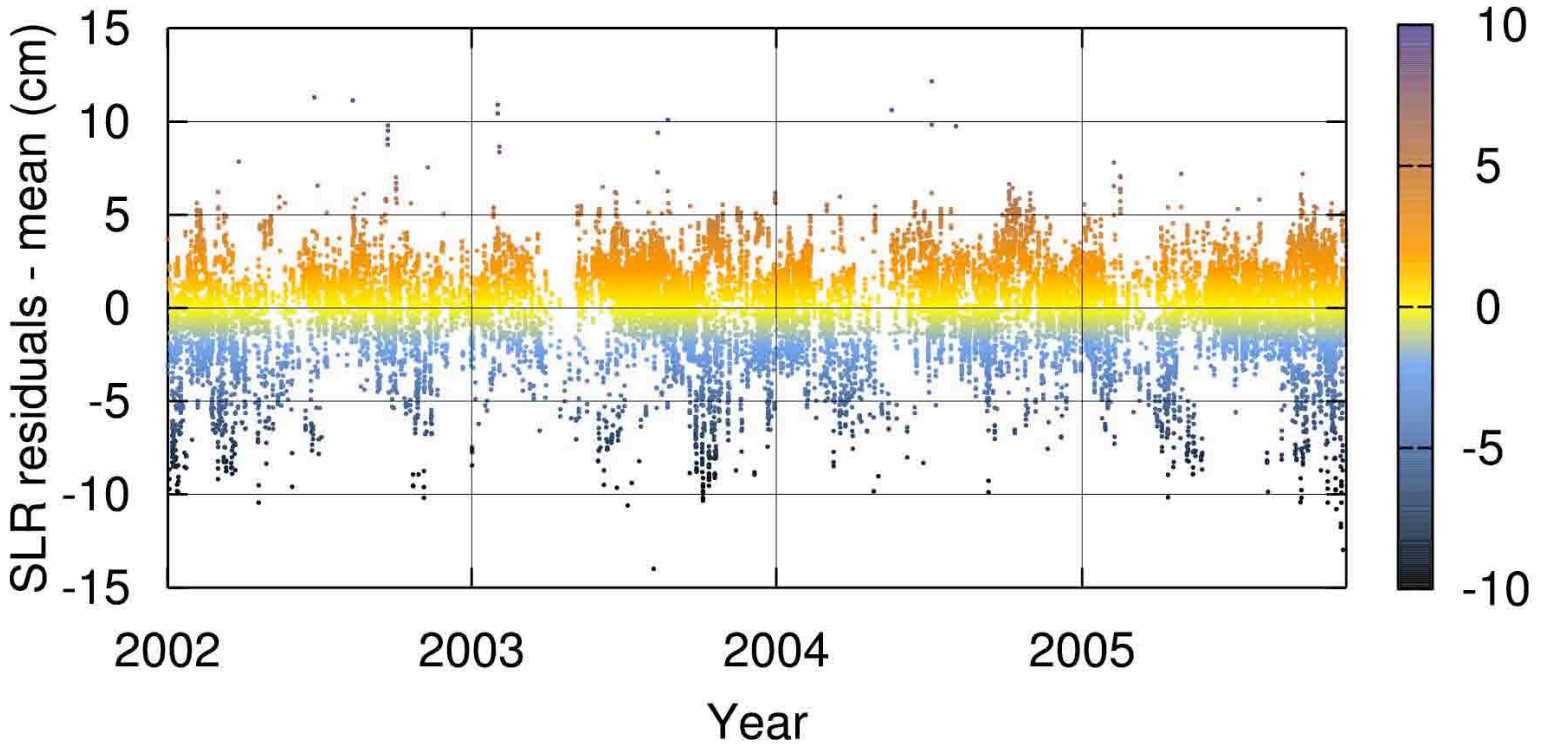
Applying yaw rates during eclipse

CODE final GPS orbits



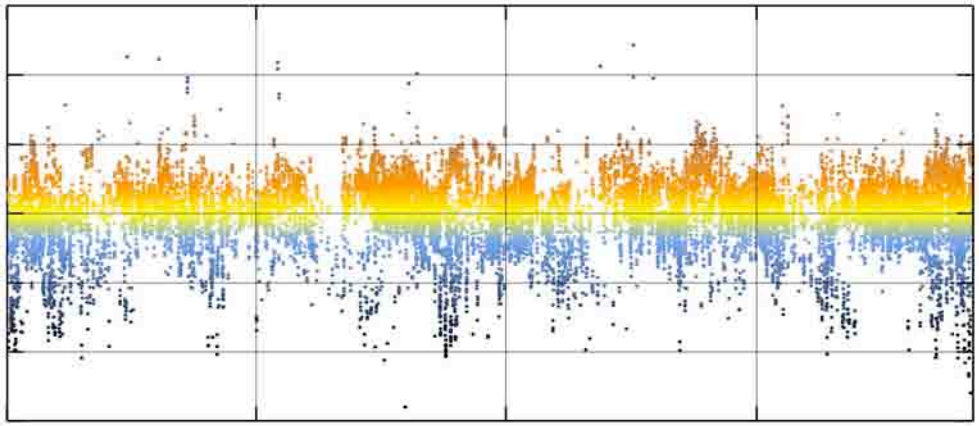
Investigation of periodic signature

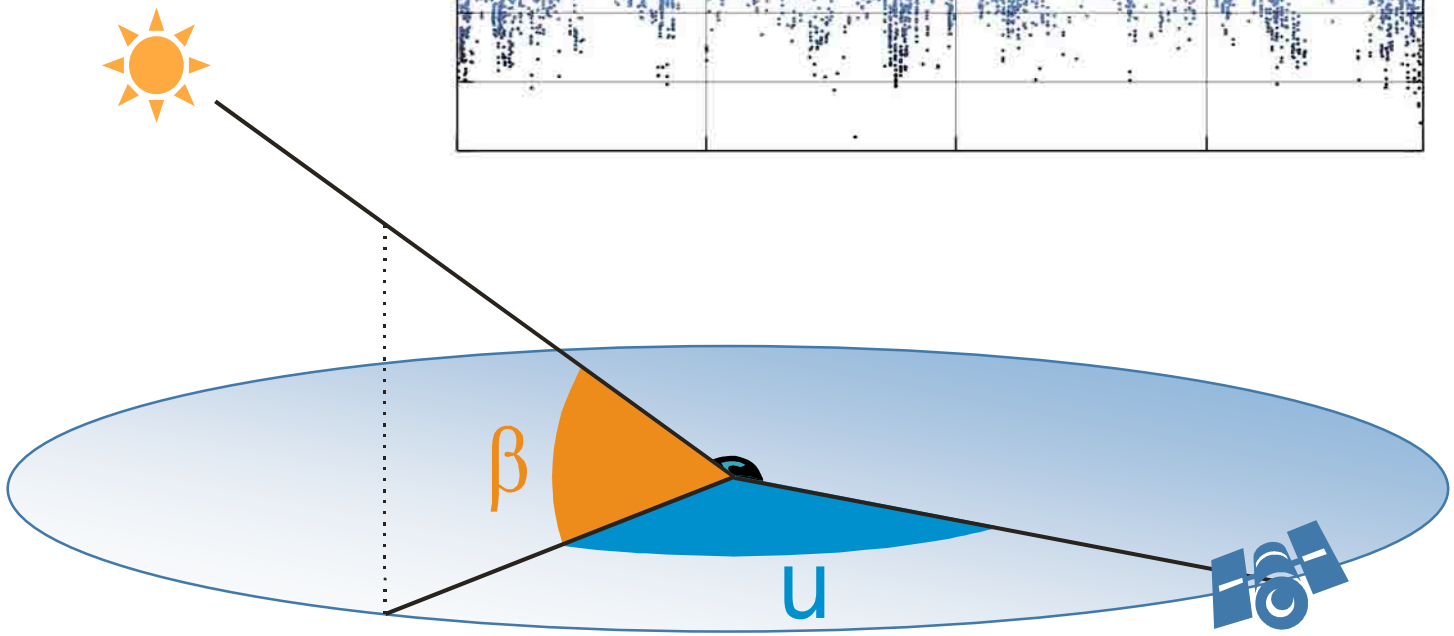
CODE final GPS orbits



Coordinate system β-u

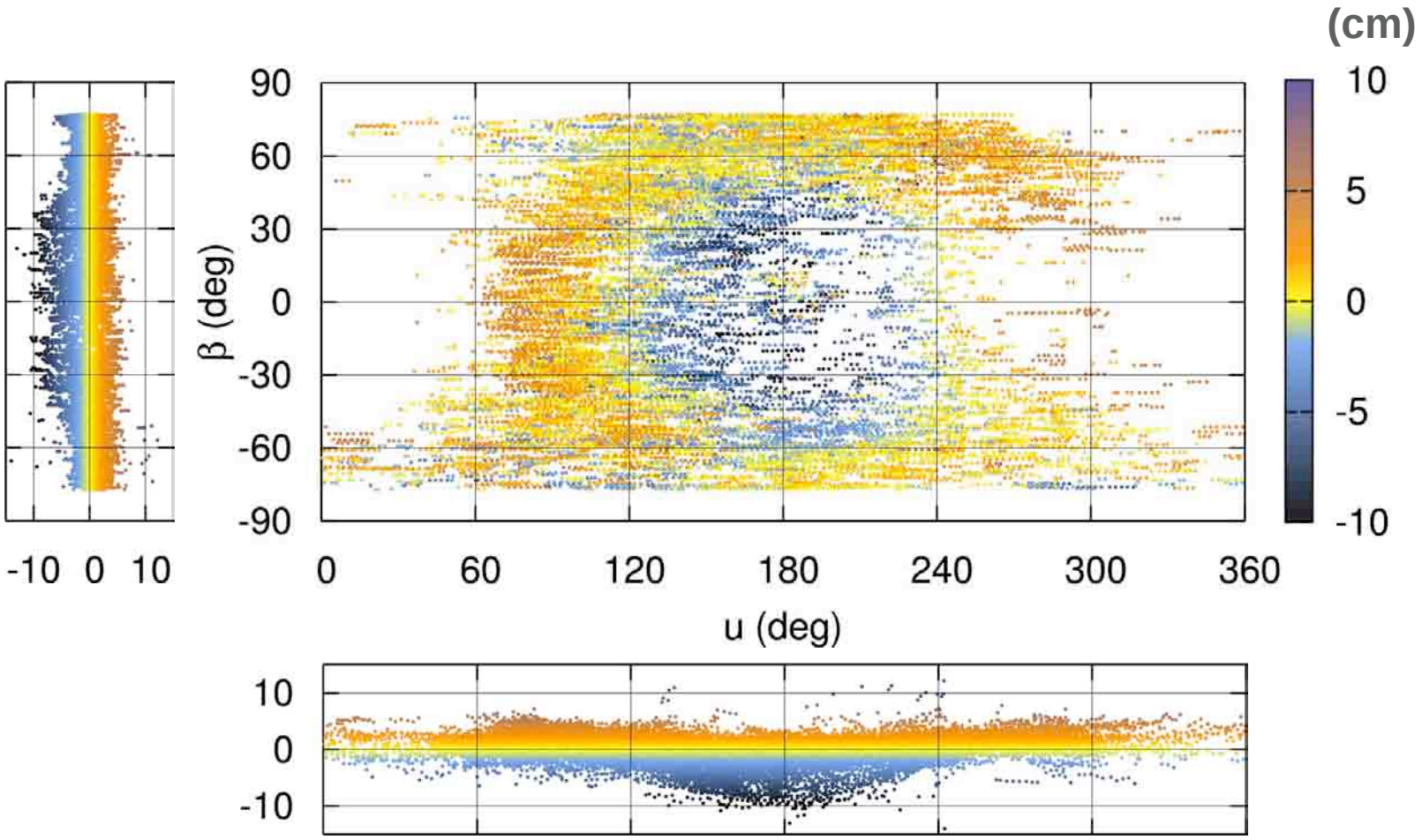
Satellite‘s position w.r.t. the Sun





SLR range residuals

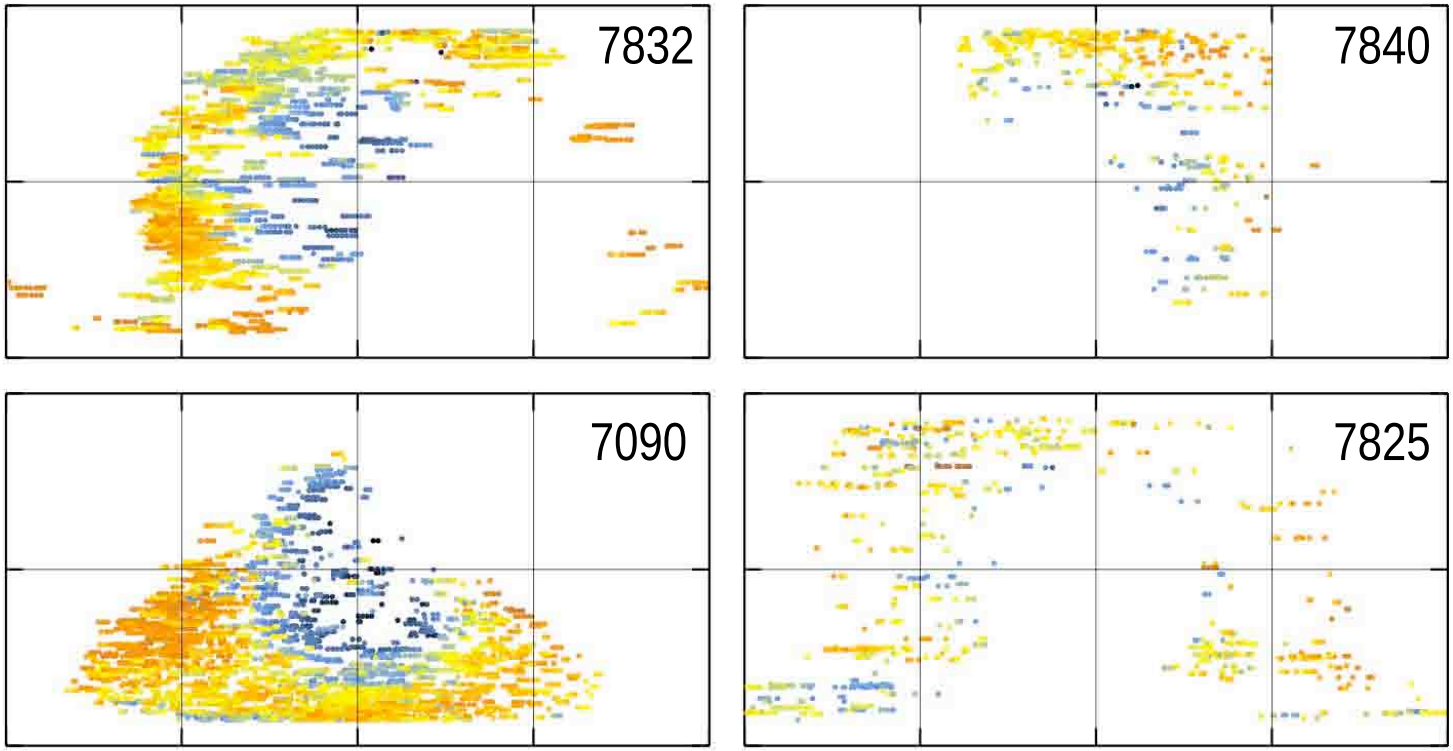
CODE final GPS orbits



SLR range residuals

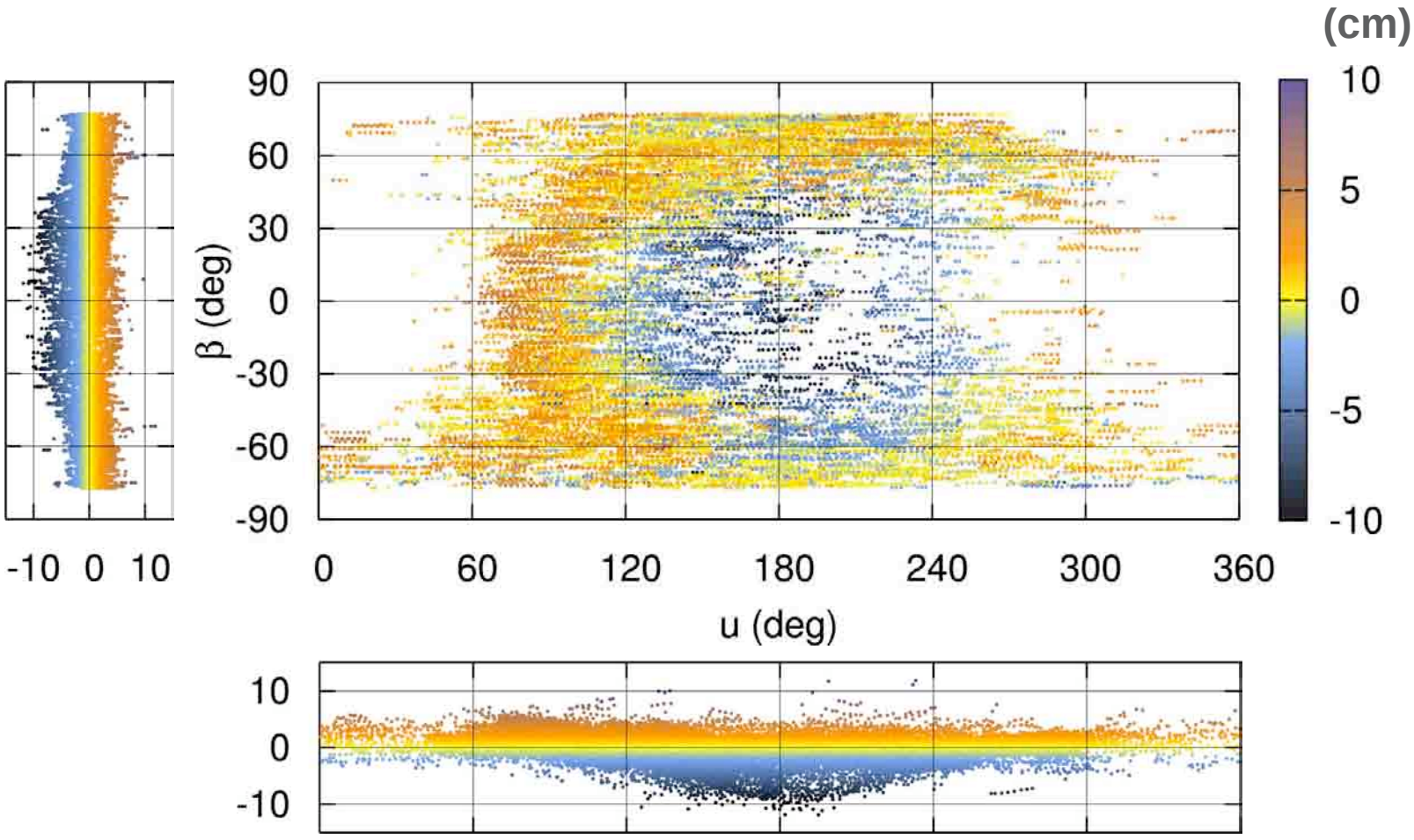
CODE final GPS orbits

station-independent signature



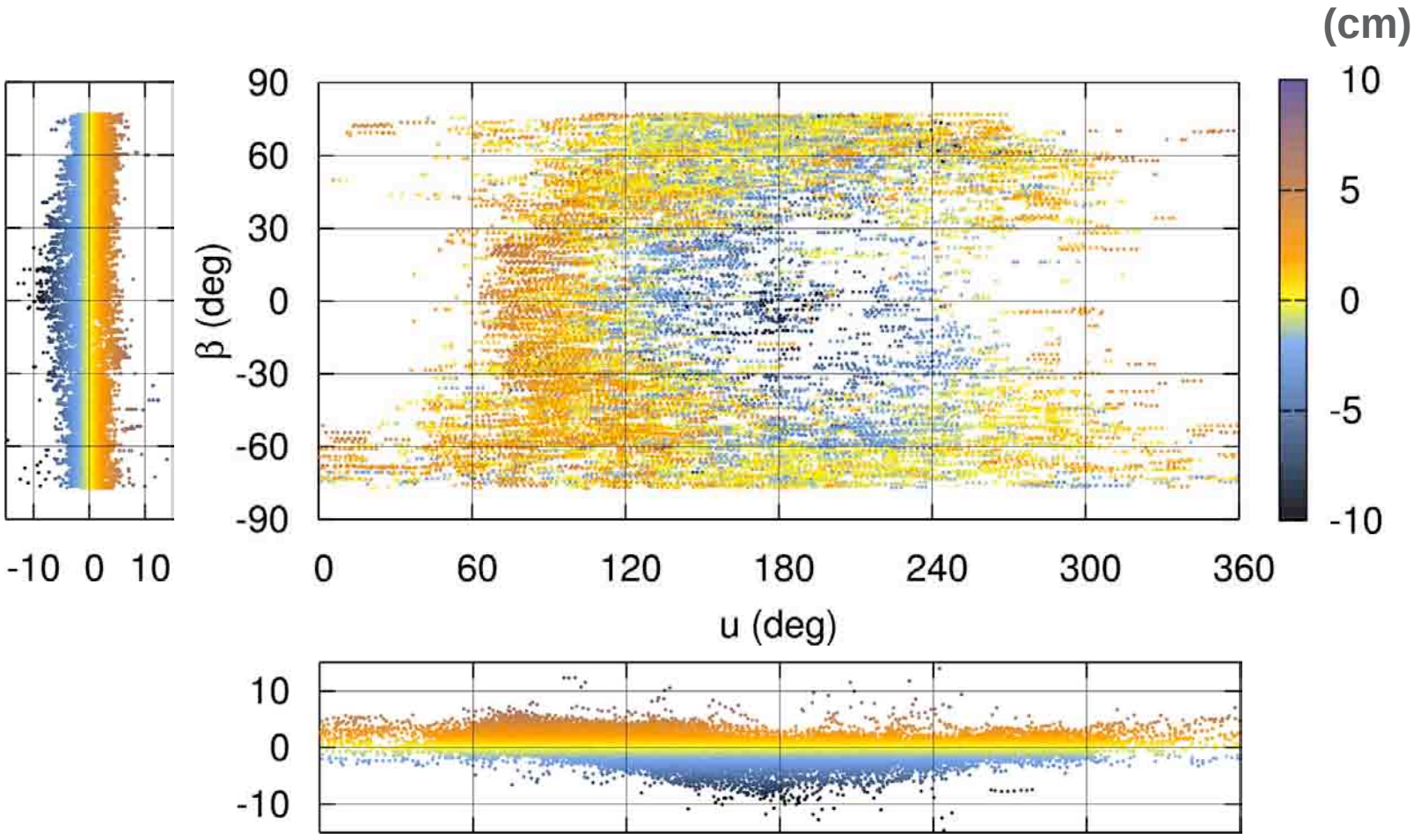
SLR range residuals

GFZ final GPS orbits



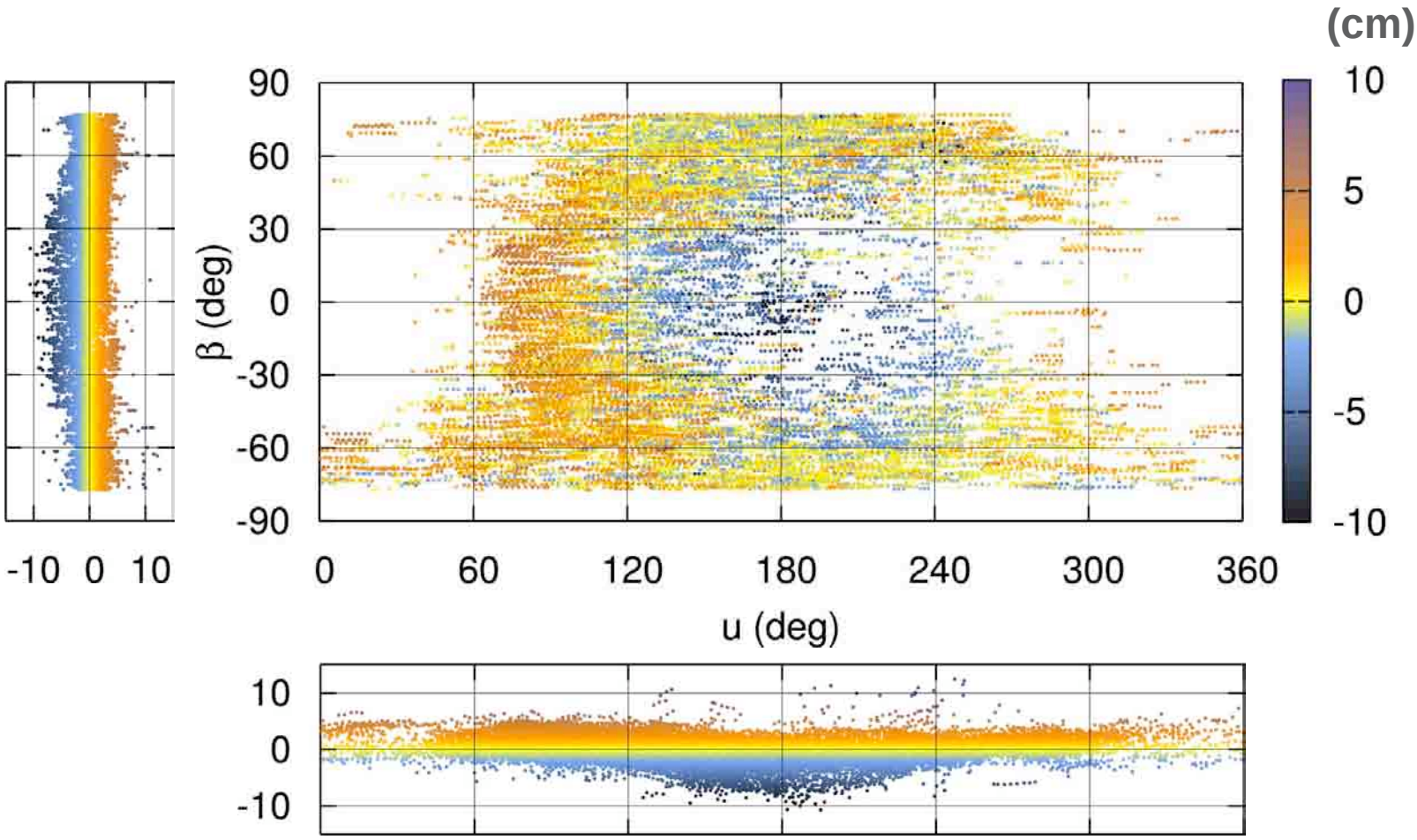
SLR range residuals

JPL final GPS orbits



SLR range residuals

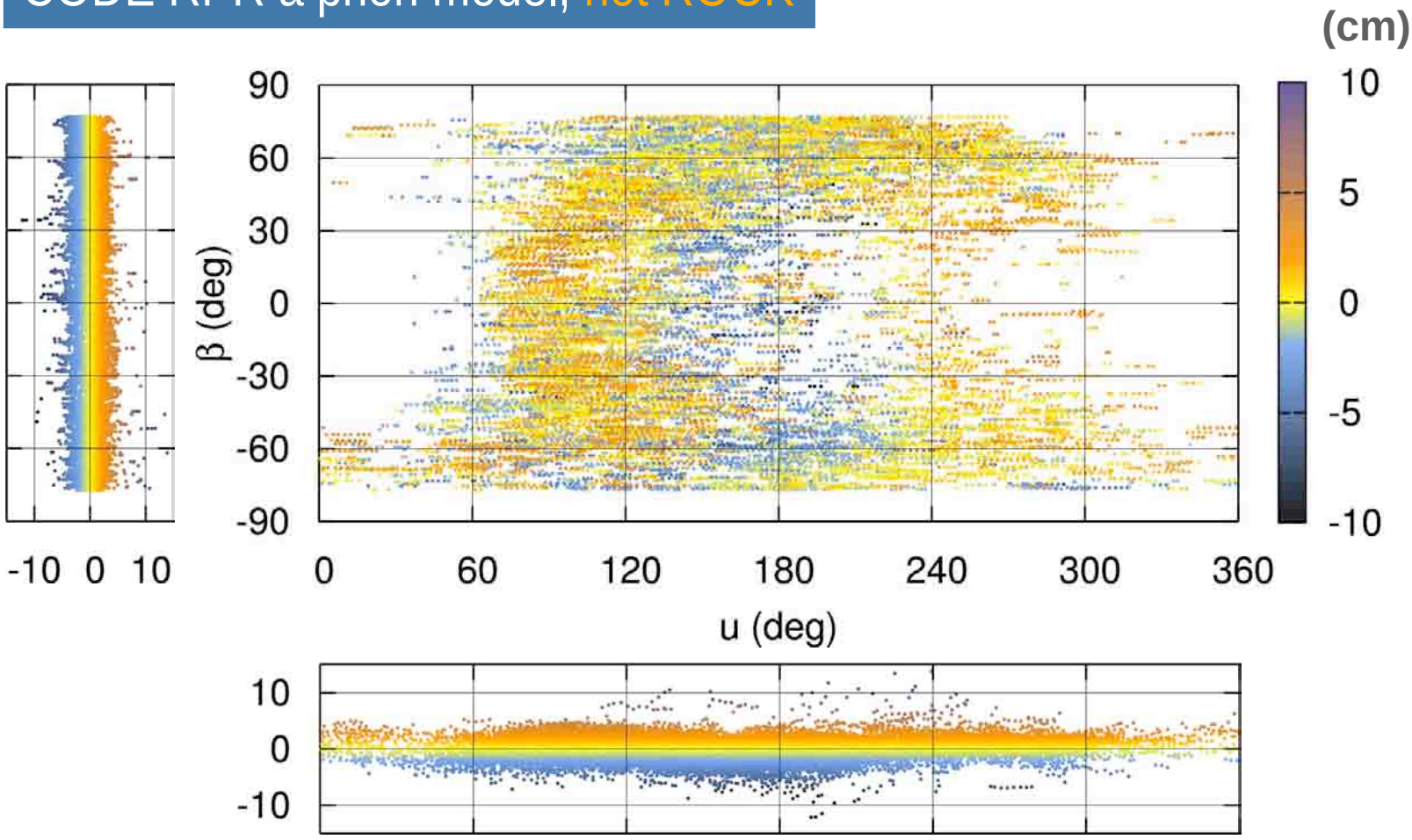
IGS final GPS orbits



SLR range residuals

CODE rapid GPS orbits

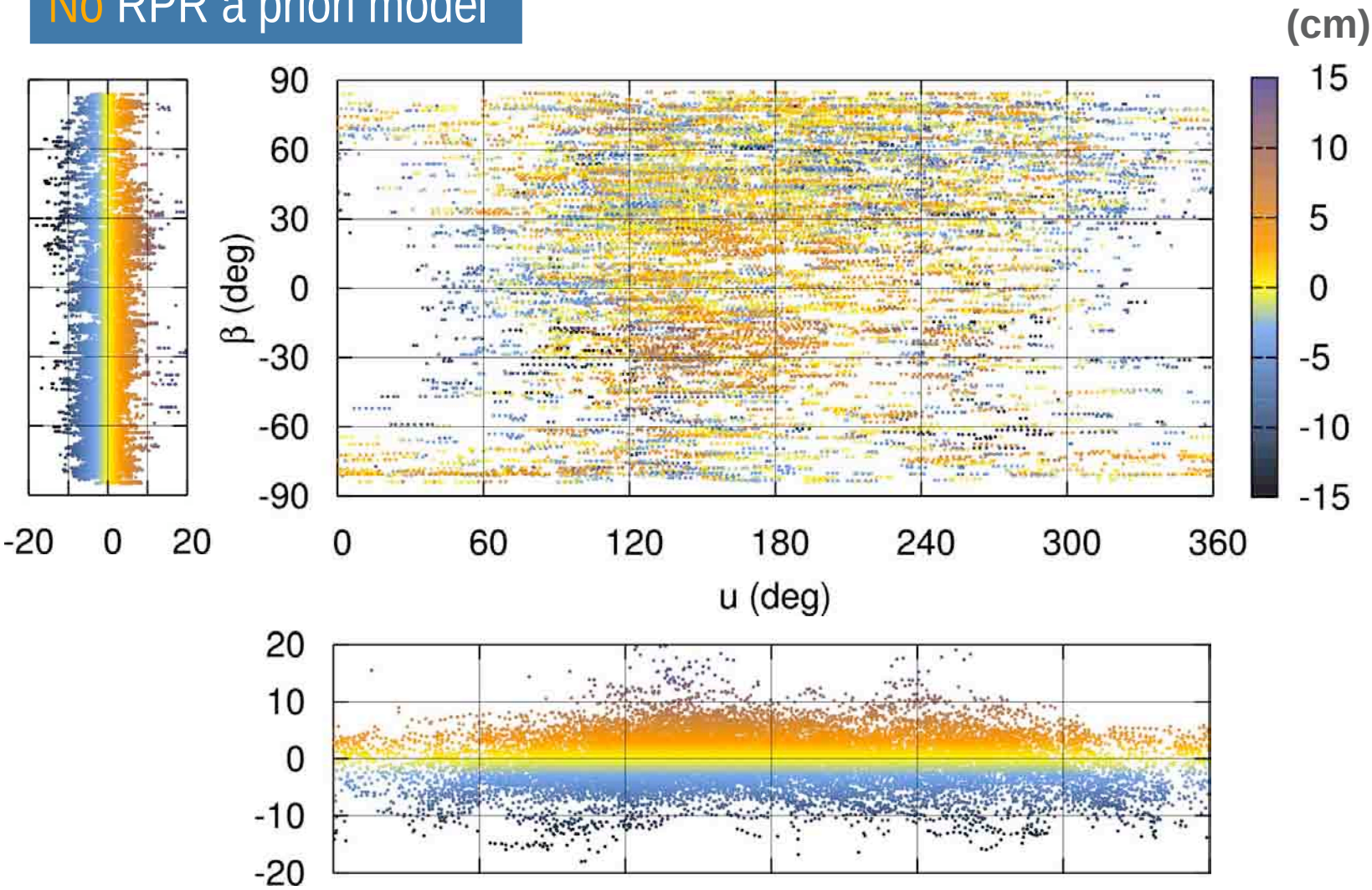
CODE RPR a priori model, not ROCK



SLR range residuals

CODE final GLONASS orbits

No RPR a priori model



Possible explanations

... for the periodic signature in the range residuals of the GPS satellites

	Behavior	Suspect
SLR	station-independent	no
Attitude	once-per-rev	yes
Solar RPR	once-per-rev	yes
Earth albedo	once-per-rev	yes

Misorientation of z-axis? < 6 deg

Same influence for GLONASS?

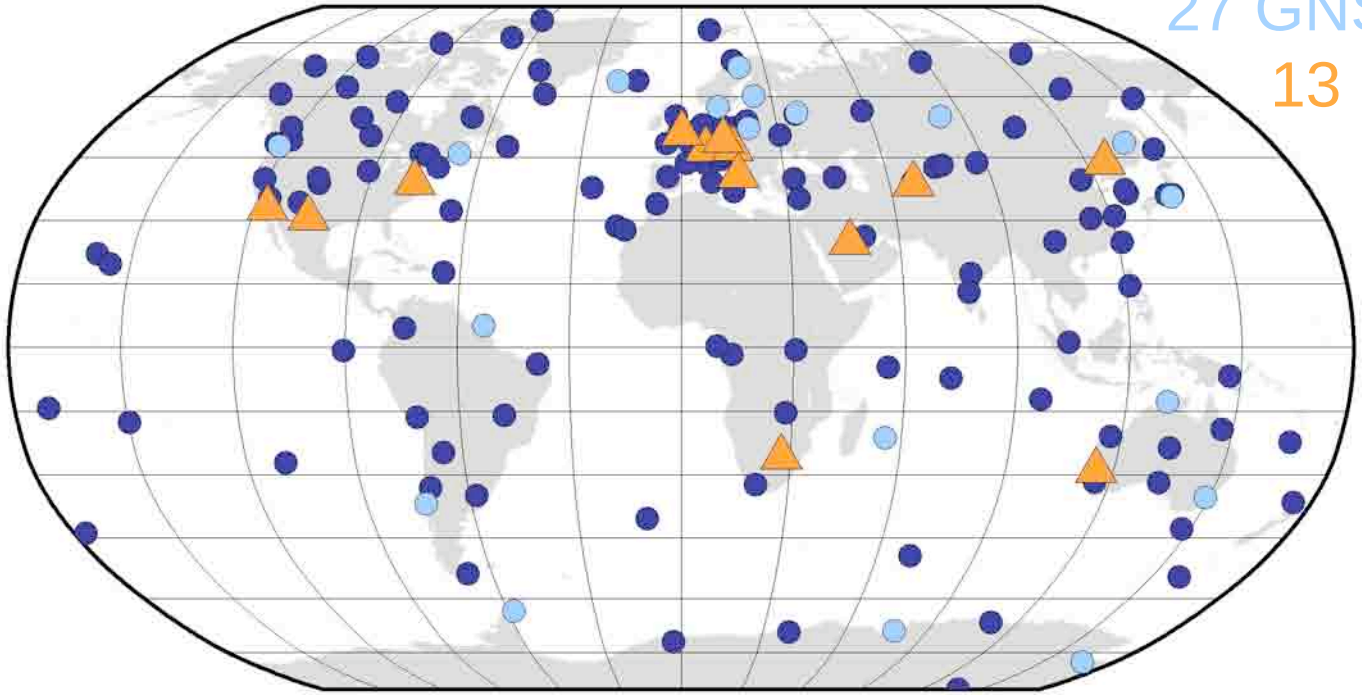
Conclusions

- SLR observations are very useful for independent validation of microwave orbits
- Reveal orbit (or attitude) modeling deficiencies
- SLR retro-reflectors are considered as a must for new GNSS satellites (at least one reflector array for each satellite type)

  → Co-location at satellites

GNSS tracking network

130 GPS-only
27 GNSS
13 SLR



1 GPS: 20,000 MW 10 SLR (NP)
1 GLONASS: 3,000 MW 15 SLR (NP)

STD (cm) of range residuals

Different RPR a priori models

	IGS Final	GFZ Final	JPL Final	ROCK COD Final	CODE COD Rapid
G05	1.9	2.3	2.2	2.2	1.9
G06	2.5	2.7	2.5	2.7	2.1
R03				4.7	5.1
$R07_M$				4.6	4.8
R22				4.4	5.0
R24				5.1	6.1

None

STD (cm) of range residuals

	IGS Final	GFZ Final	JPL Final	COD Final	ROCK COD Final	COD Rapid	COD Rapid
G05	1.9	2.3	2.2	2.2	1.8	1.9	2.0
G06	2.5	2.7	2.5	2.7	2.2	2.1	2.4
R03				4.7	5.6	5.1	5.7
$R07_M$				4.6	5.8	4.8	5.9
R22				4.4	5.1	5.0	5.0
R24				5.1		6.1	

Observed range biases (cm)

	IGS Final	GFZ Final	JPL Final	ROCK COD Final	CODE COD Final	CODE COD Rapid	CODE COD Rapid
G05	-3.1	-3.6	-2.6	-4.4	-3.5	-4.1	-3.6
G06	-2.8	-3.9	-2.8	-4.8	-3.2	-3.9	-3.4
R03				-3.3	-1.5	-2.8	-1.0
$R07_M$				1.4	3.6	2.3	4.5
R22				-2.7	-1.3	-2.1	-0.8
R24				-2.6		-1.6	