Precise Orbit Determination for GNSS satellites

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Outline

- Introduction
- Experimental setup
- Exemplary discussion of results
- Conclusions

General introduction
Motivation

Motivation:

Generation of best GNSS Precise Orbit Determination solution for all GNSS satellites

Difficulties:

- Reference frames (aligned to ITRF with limited accuracy)
- Time scales (aligned to UTC with limited accuracy)
- Different signals/frequencies and combinations (different characteristics, biases)
- Satellite properties and characteristics
- Different orbit characteristics (altitude, inclination, revolution, eccentricities)

Trend in satellite area to mass ratio:

- More signals (requiring and emitting more power)
- Larger solar panels
- Increase of area to mass ratio

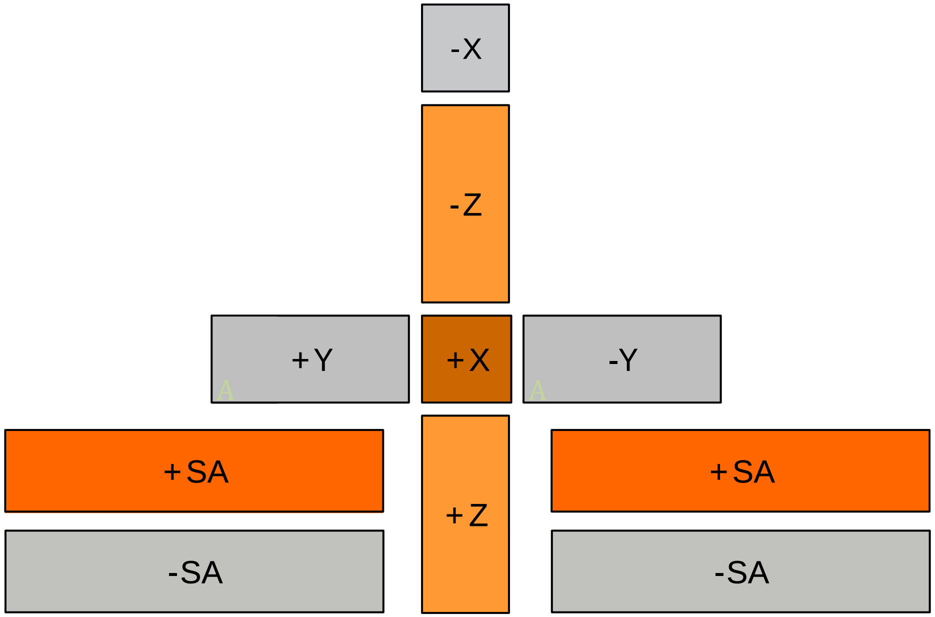
More difficult to model:

- Antenna thrust
- Albedo
- Solar radiation pressure (orbit normal mode needs to be handled properly)

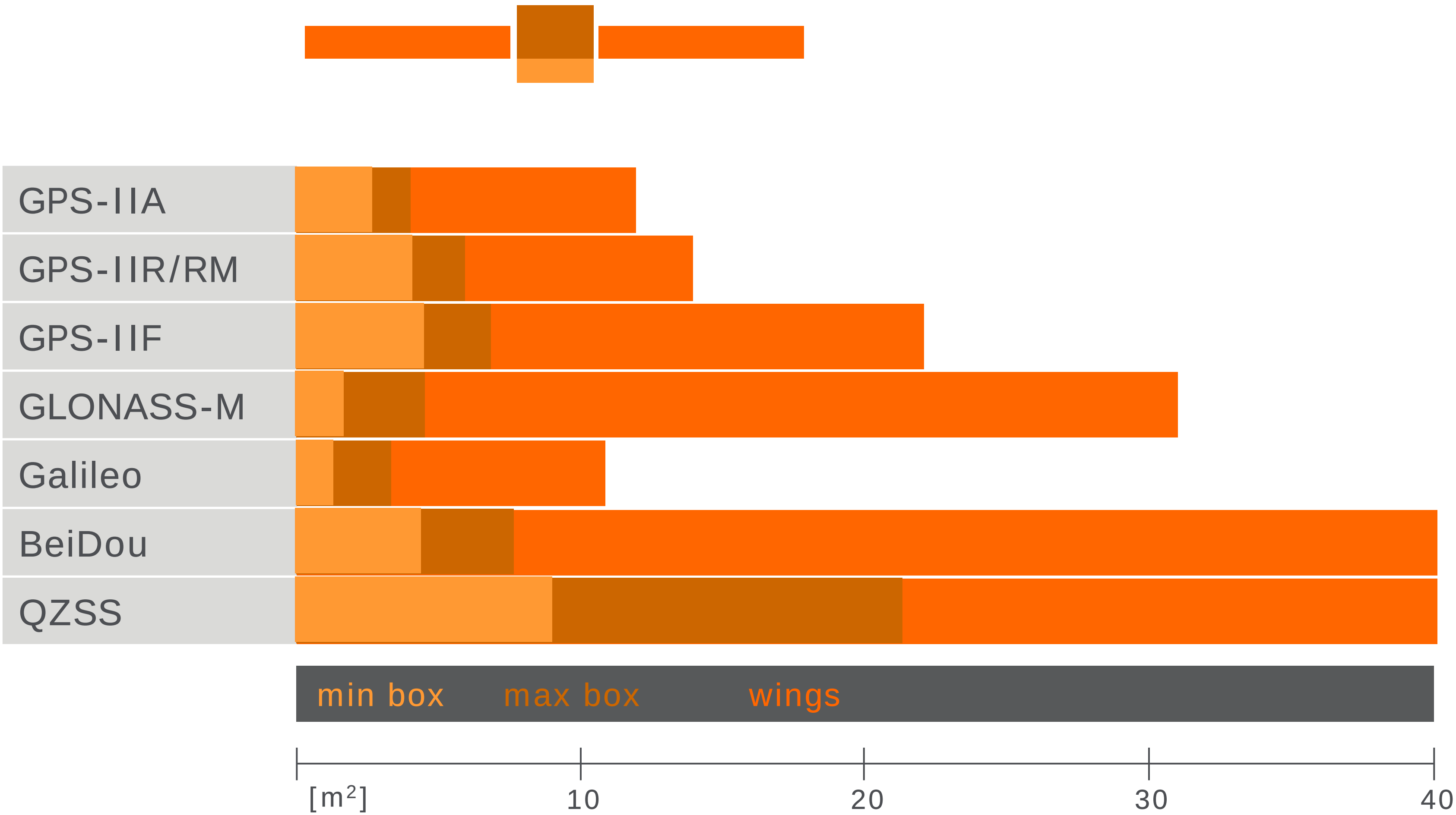
	Approx. Area / mass[1)]	Est. -D0 (Beta 0)
GPS IIA	0.011	~93nm/s^2
GPS IIRM	0.012	~99nm/s^2
GPS IIR	0.012	~102nm/s^2
GPS IIF	0.018	~108nm/s^2
Galileo	0.019	~113nm/s^2
QZSS	0.020	~155nm/s^2

1) Properties from public available data

General introduction
Simplified satellite shape



General introduction
Satellite shapes (relationship between box and wing)



Difficult to model SRP, if attitude is not accurately known.

GNSS attitude modes

GNSS	
GPS	Yaw steering
GLONASS	Yaw steering
Galileo	Yaw steering
BeiDou (MEO)	Yaw steering / orbit normal
BeiDou (IGSO)	Yaw steering / orbit normal
BeiDou (GEO)	Orbit normal
QZSS	Yaw steering / orbit normal

Difficulty to use estimated solar radiation pressure parameters (empirical models such as CODE, ECOM2) in orbit normal mode.

ESOC decided to use analytical a-priori models (in this case box-wing).

Reprocessing

Approach:

Reprocessing of multi-GNSS observation data to analyse data and resulting products and to develop, optimise and test different satellite models.

Time period:

- 01. January 2014 – 29 June 2015

Observation data:

- ESOC + JAXA + MGEX tracking network

GNSS:

- All available GNSS (GPS, Glonass, Galileo, BeiDou, QZSS)

Processing setup:

- Aligned to ESOC IGS processing, but adjusted for multi-GNSS

Approach:

- Iterative process, introducing/improving the models step by step

Reprocessing
Extract of list of runs performed

First run (as ESOC IGS run (box-wing for GPS+GLONASS))**:**

- + All GNSS (Galileo, BeiDou, QZSS)

Second run (as previous run):

- + Attitude modelling for BeiDou and QZSS

Third run (as previous run)**:**

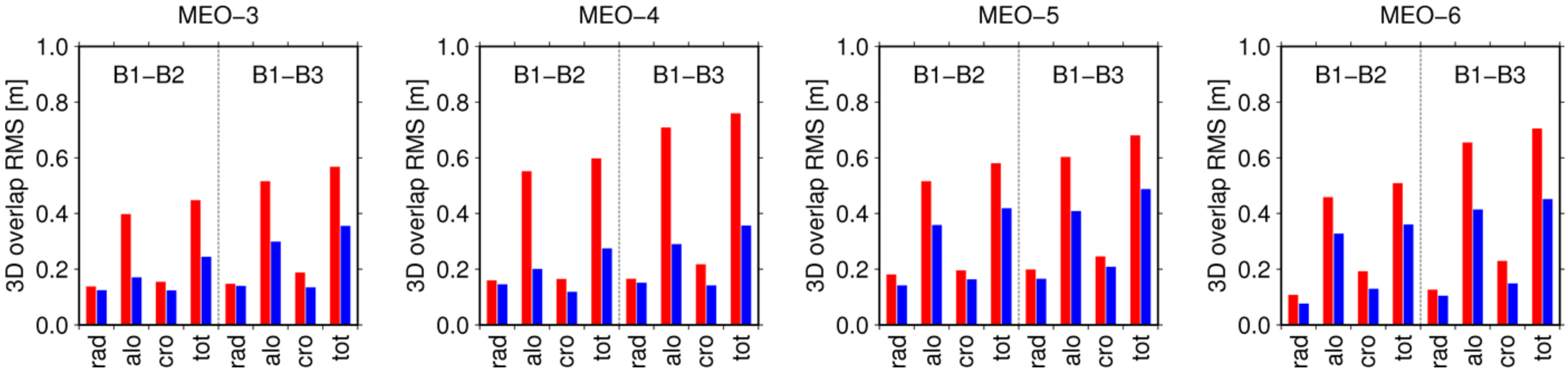
- + Box-wing model for all constellations (+CODE parameter)

Forth run (as previous run)**:**

- + Tuned Box-wing models QZSS and BeiDou (+CODE parameter)
- + ESOC ANTEX (IGS GPS only + ESOC corrections Galileo, BeiDou, QZSS)

Phase centre offsets / variations
Impact of incorrect PCO offset on POD (BeiDou)

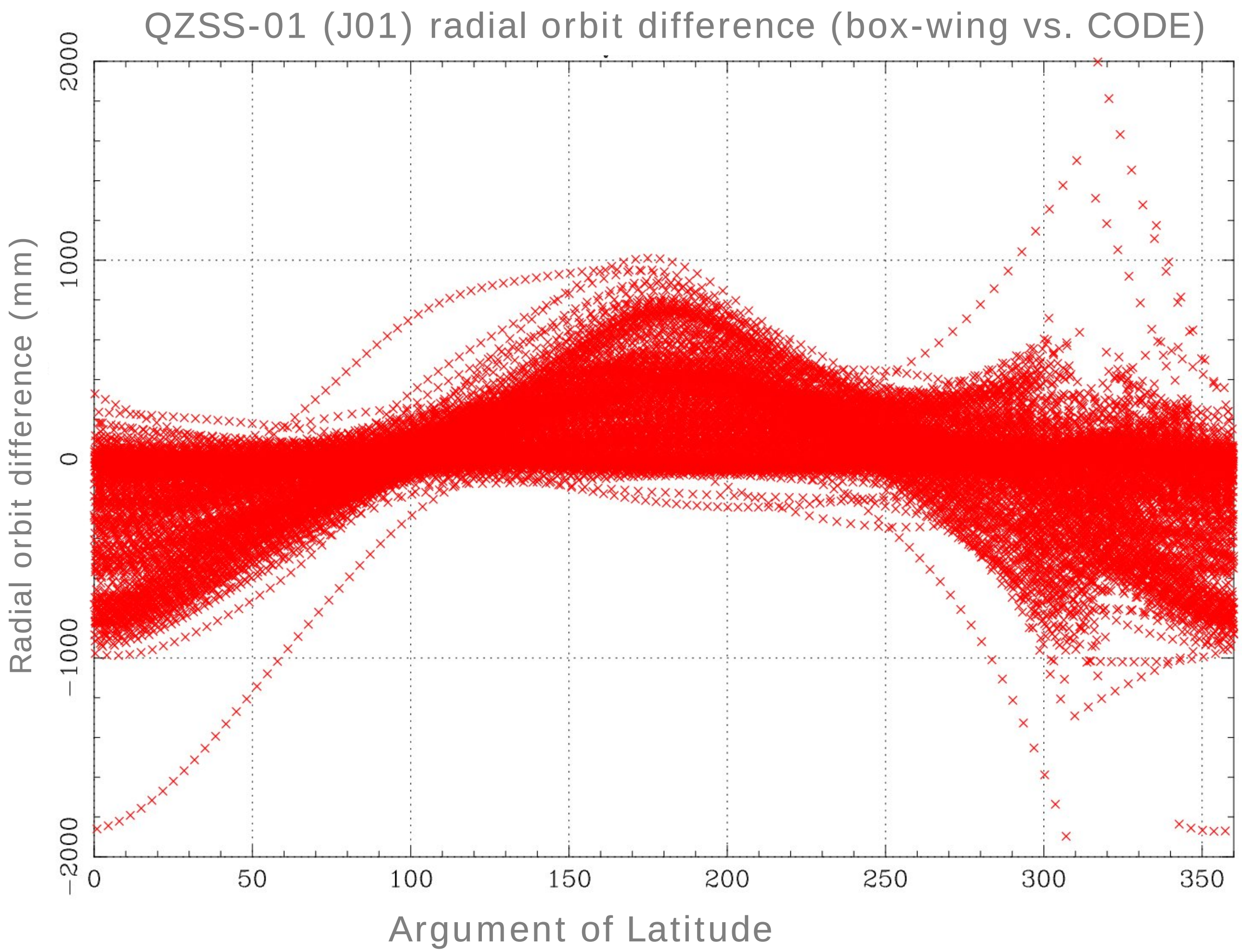
RMS of orbit overlap differences (3D)
Ionosphere free linear combination (B1-B2 & B1-B3)



Dilßner, F. et al.: Estimation of Satellite Antenna Phase Center Corrections for BeiDou. IGS workshop 2014, June 23-27, Pasadena, USA

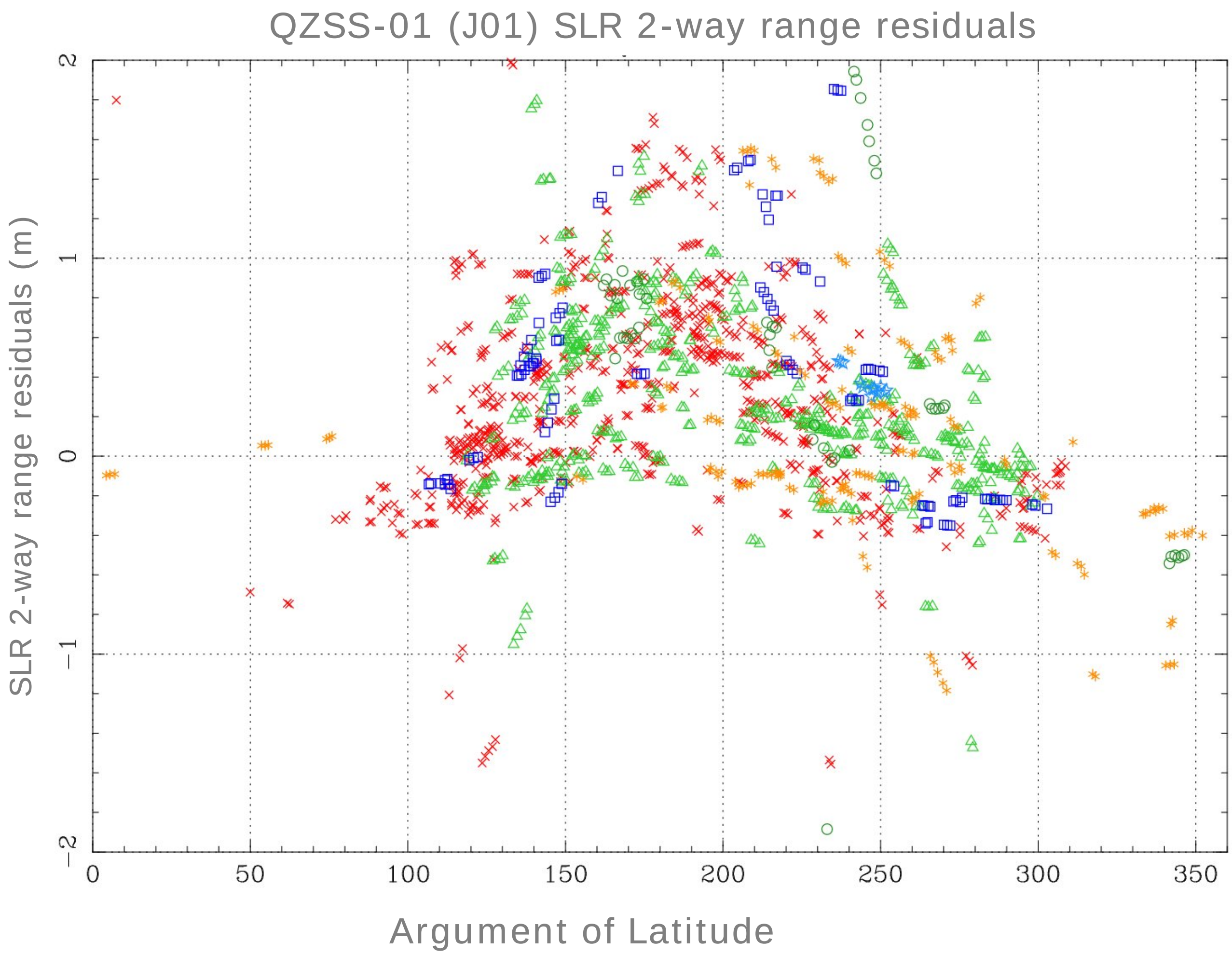
- PCO correction as recommended by MGEX in 2014 (in red)
- ESOC estimated PCO/PCV-based solution (in blue)

Impact of analytical SRP models (box-wing)
QZSS-01 radial orbit difference (box-wing + CODE vs. CODE)



Box-wing model generated empirically.

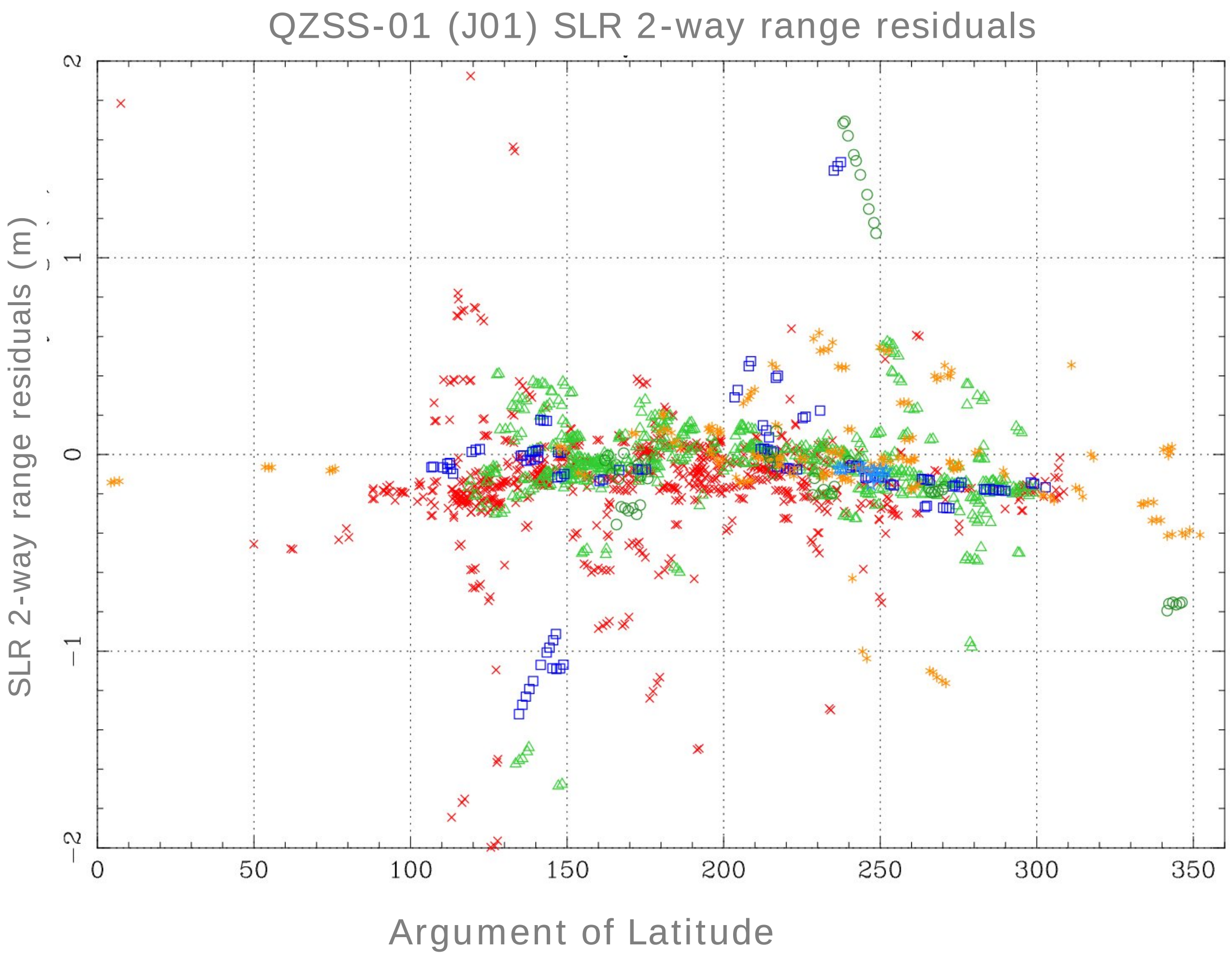
Impact of analytical SRP models (box-wing)
QZSS-01 SLR 2-way range residuals (Empirical SRP mod.)



Note: Figure shows 2-way SLR residuals!

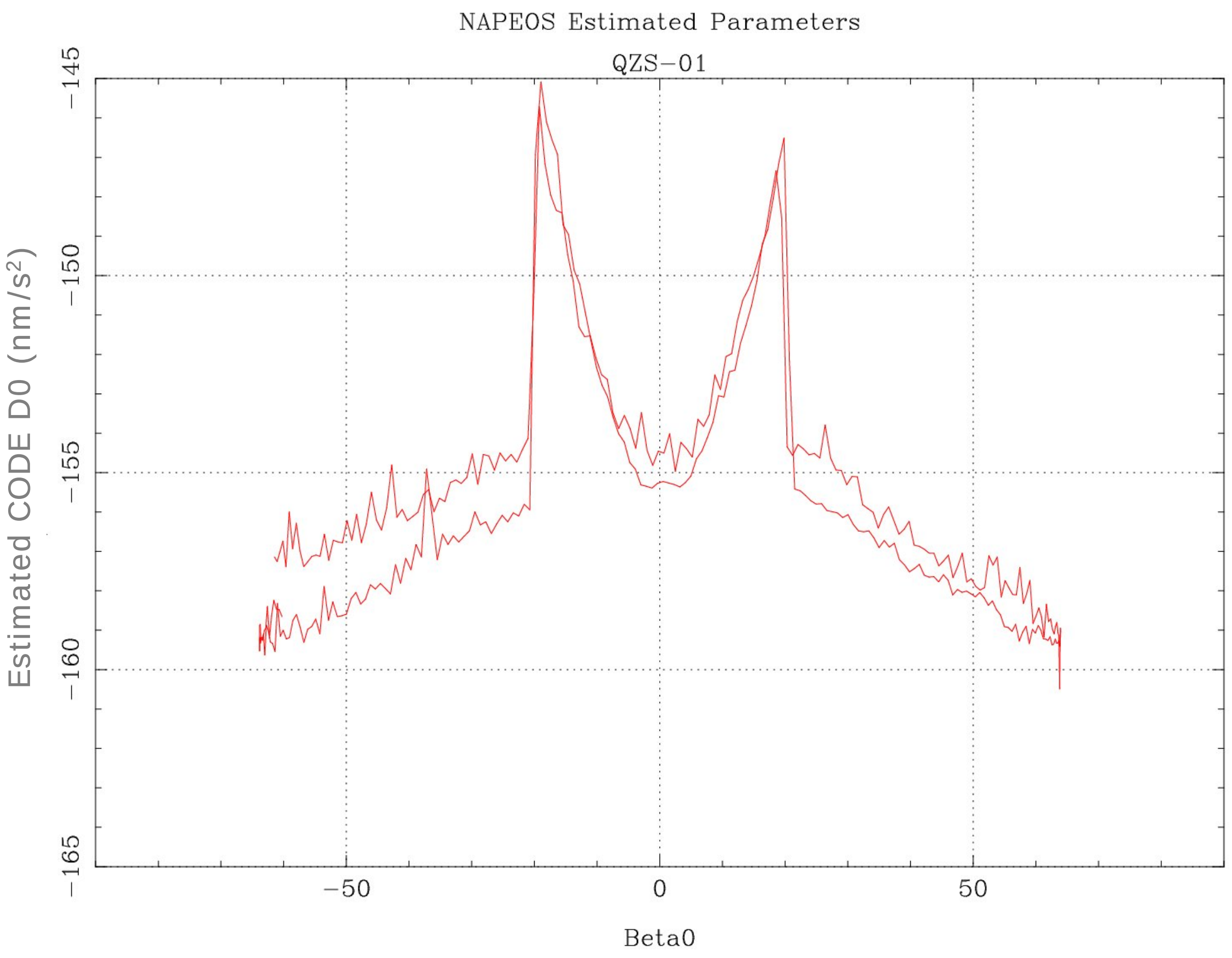
Impact of analytical SRP models (box-wing)

QZSS-01 SLR 2-way range residuals (Box-wing mod.)

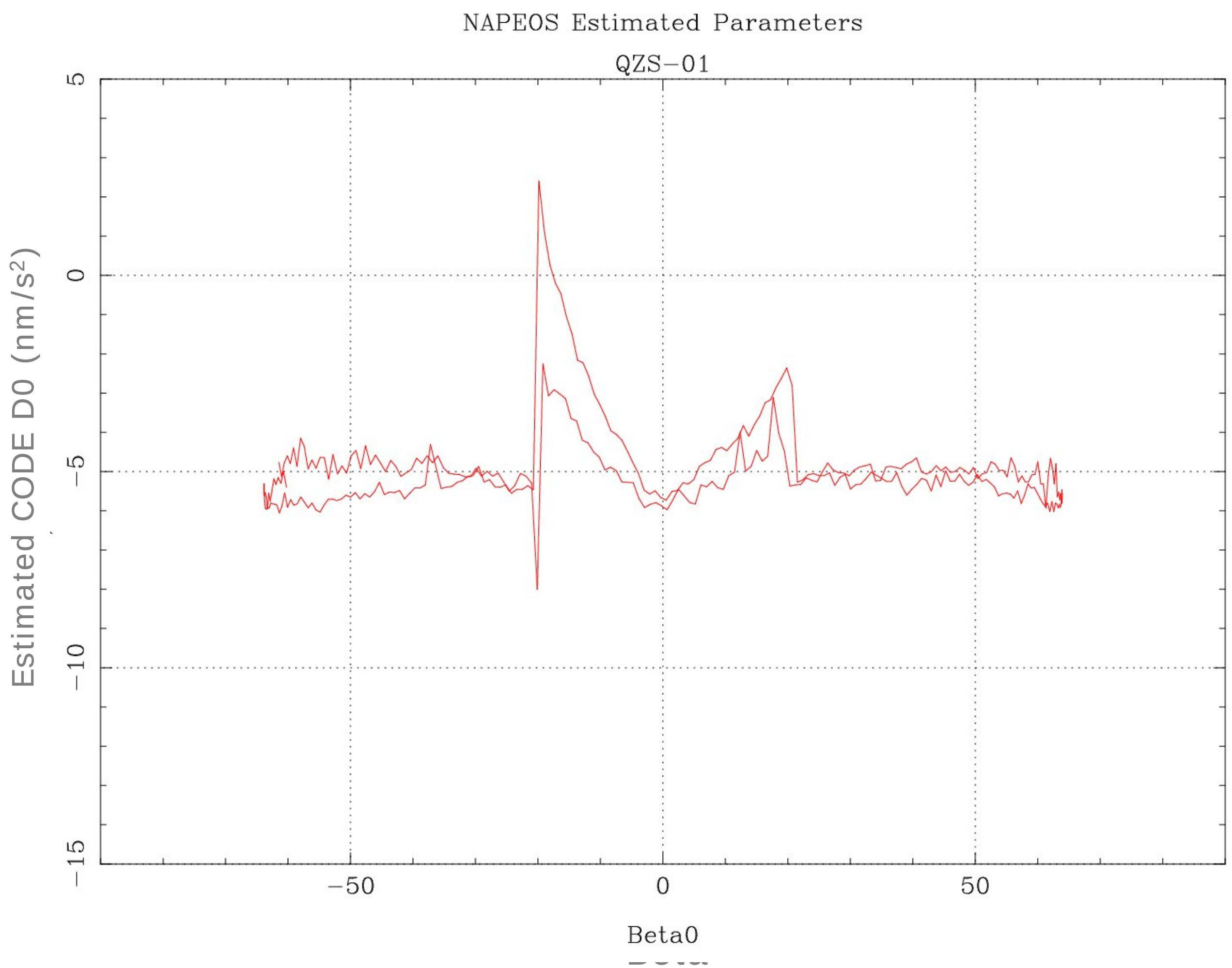


Note: Figure shows 2-way SLR residuals!

Impact of analytical SRP models (box-wing)
QZSS-01 est. CODE D0 parameter (without box-wing mod.)



Impact of analytical SRP models (box-wing)
QZSS-01 est. CODE D0 parameter (box-wing mod.)

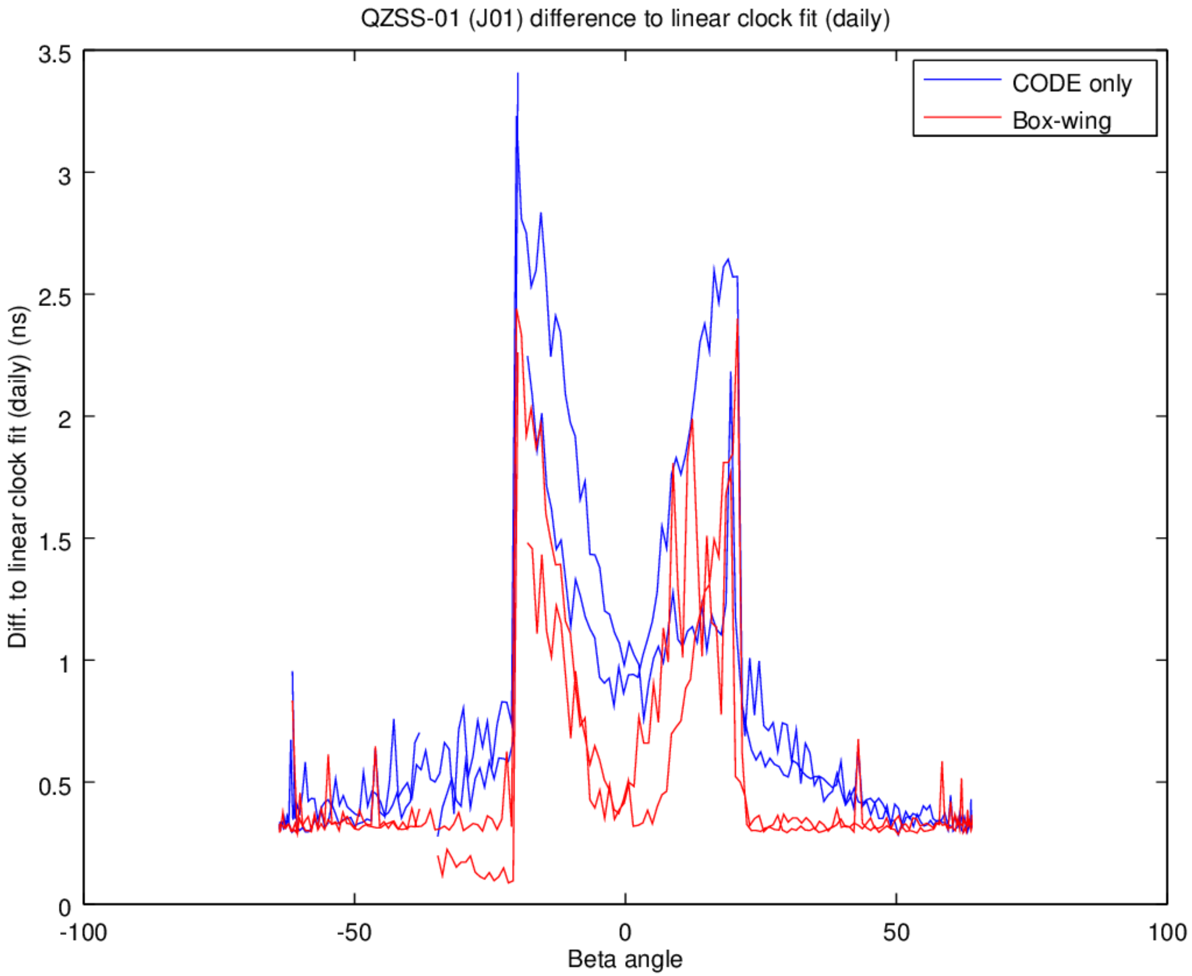


D0 reduced by 97%

Still not zero, but pattern reduced significantly

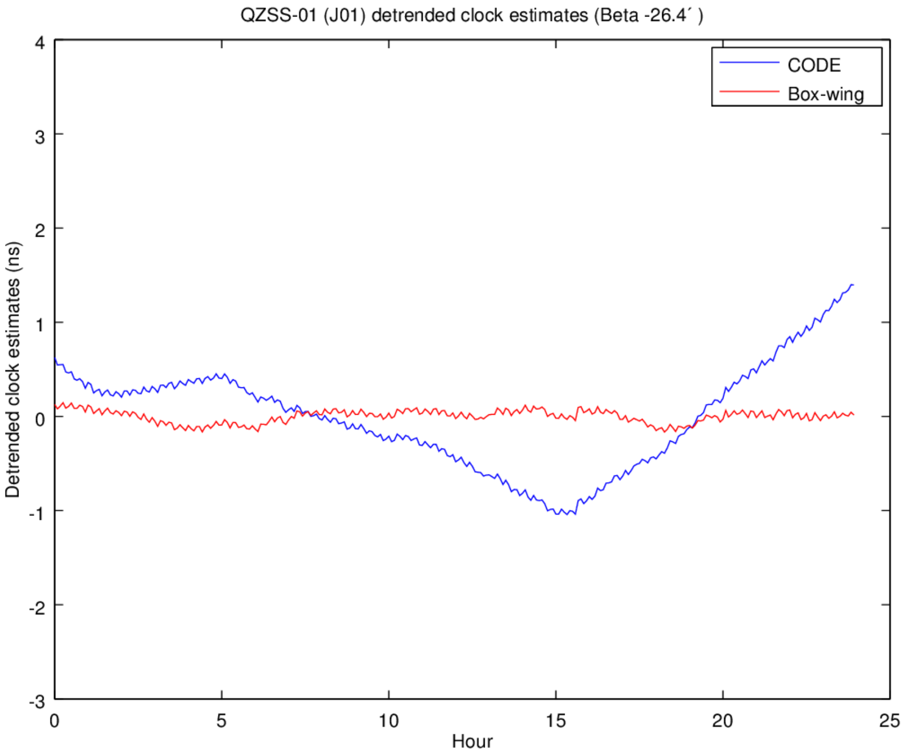
Still problems in transition phase and in orbit normal mode

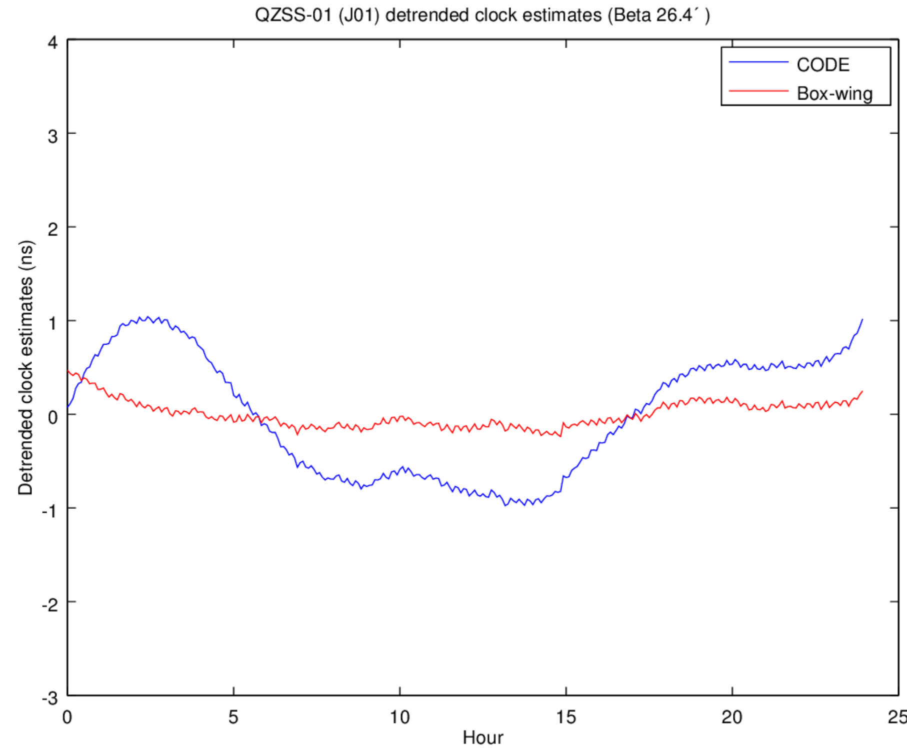
Impact of analytical SRP models (box-wing)
QZSS-01 difference of est. clock to linear fit (daily)



- Orbit error mapped to clock
- Still problems in transition phase and in orbit normal mode

Impact of analytical SRP models (box-wing)
QZSS-01 epoch wise clock estimates (CODE vs. box-wing)





Difference to linear fit:

CODE 0.64ns
Box-wing 0.30ns

Difference to linear fit:

CODE 0.71ns
Box-wing 0.32ns

Conclusions

- The evolutions in the GNSS space segments introduce challenges for modelling of spacecraft dynamics (new satellites with different characteristics, shapes weights, etc.)

- This presentation highlights the importance of GNSS satellite dynamics modelling for GNSS POD on the example of SRP impact on QZSS

- Additional evaluation of the results for GNSS satellite dynamic models can be obtained by the characterisation of the highly accurate on-board clocks

- Independent evaluation of the GNSS satellite dynamic models can be performed via processing of SLR

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