ESOC's Multi-GNSS Processing

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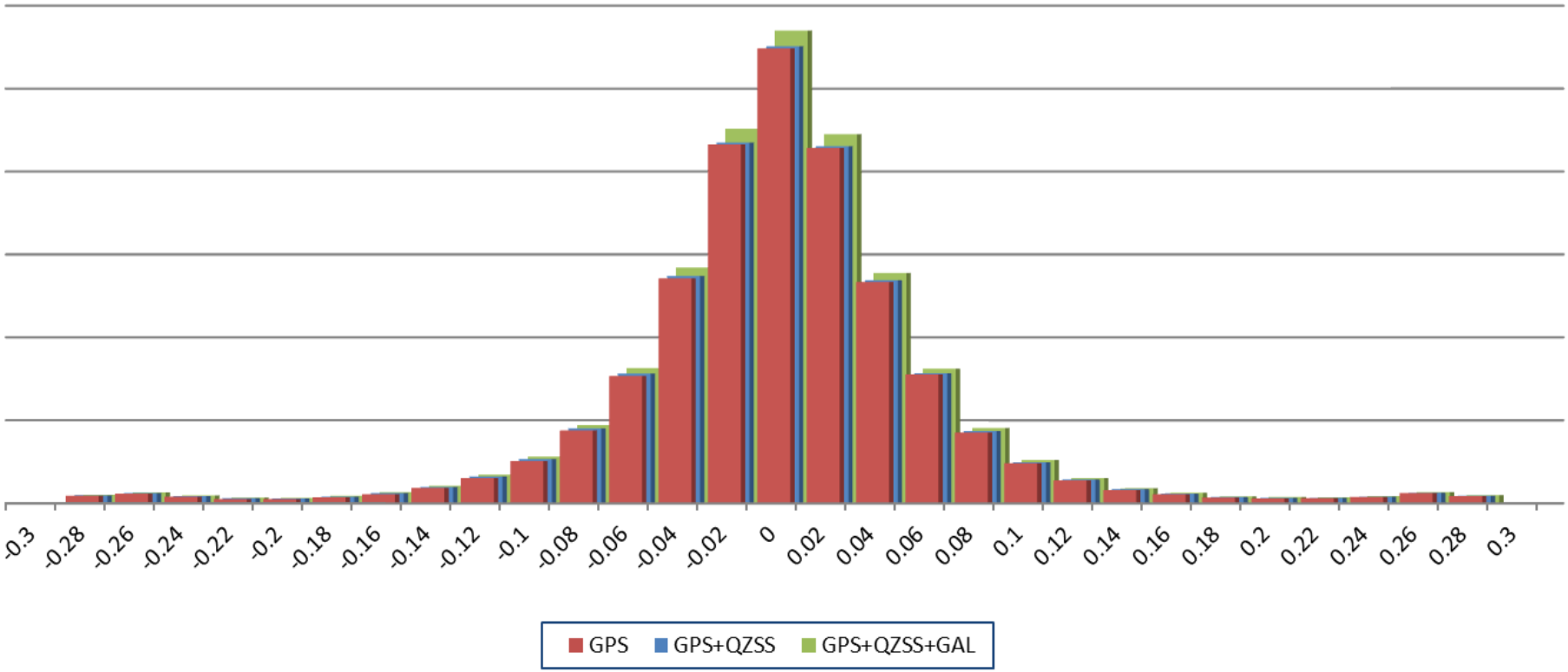
Multi-GNSS Challenges

1. Lots of issues with new and additional frequencies and signals
    a. Will be ignored in this presentation. IGS not ready!?
2. Integer Ambiguity Resolution
    a. GPS L1-L2 P/C understood but how are the other signals
    b. How about the other systems Galileo, GLONASS, BeiDou, QZSS
3. Satellite Attitude
    a. Eclipse phases
    b. Orbit normal mode for BeiDou and QZSS
        – Transition point/epoch from one mode to the other
4. Satellite Radiation Modelling (mainly Solar Radiation)
    a. Simple box-wing
    b. Elaborate satellite models
5. Satellite Transmitter Phase Centre
    a. Location (PCO)
    b. Variation as function of elevation and azimuth (PCV)

ESOC is systematically working to address all these issues

Integer Ambiguity Resolution
Histogram of narrow lane fractionals



Integer Ambiguity Resolution

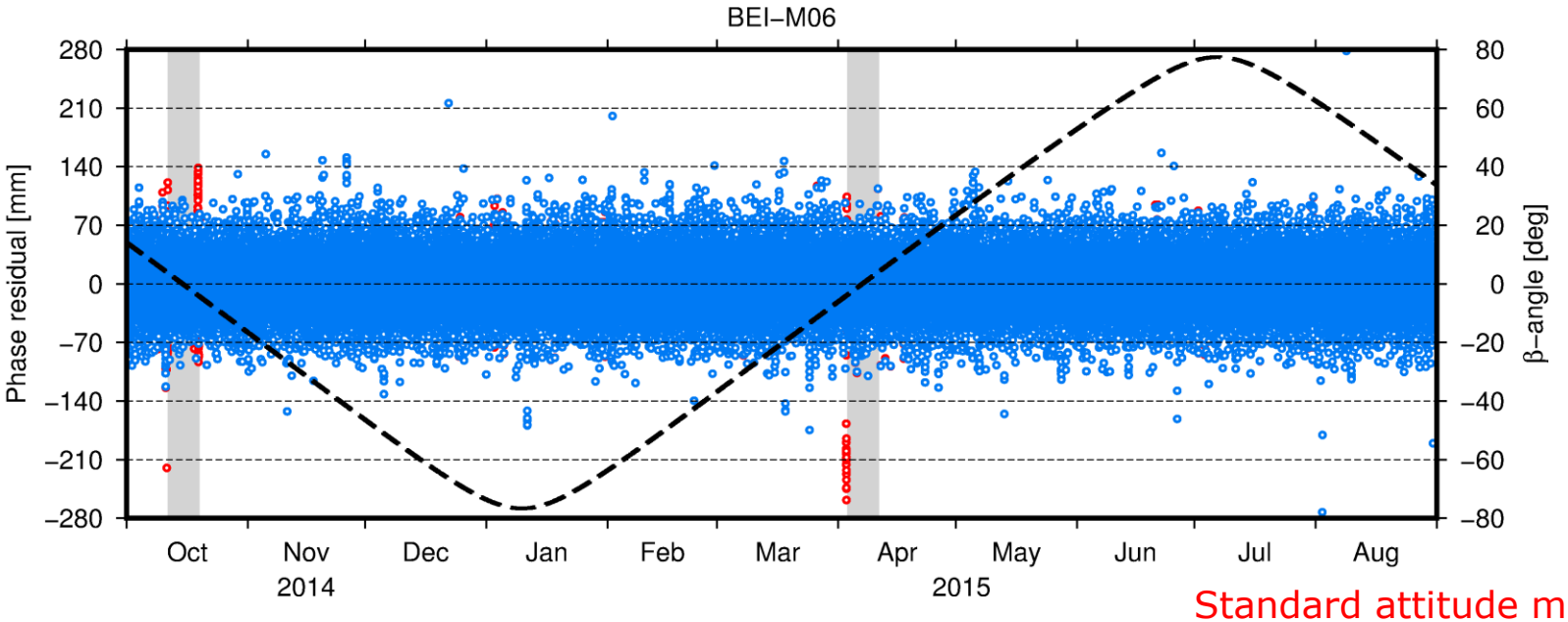
1. GPS L1 C/P – L2 C/P understood
    a. But how about L5C
        - There are issues with compatibility of the L1, L2, and L5 signals
2. How about the other systems
    a. GLONASS
        - Only CODE does ambiguity resolution?
    b. Galileo
        - Looks quite promising
    c. BeiDou
        - Not working for us as MelWub fractionals not very good
        - Elevation dependent code biases part of the reason
    d. QZSS
        - May be treated as a “normal” GPS satellite

BeiDou attitude model

Potential attitude model improvement

→ Attitude transition from yaw steering to orbit normal mode

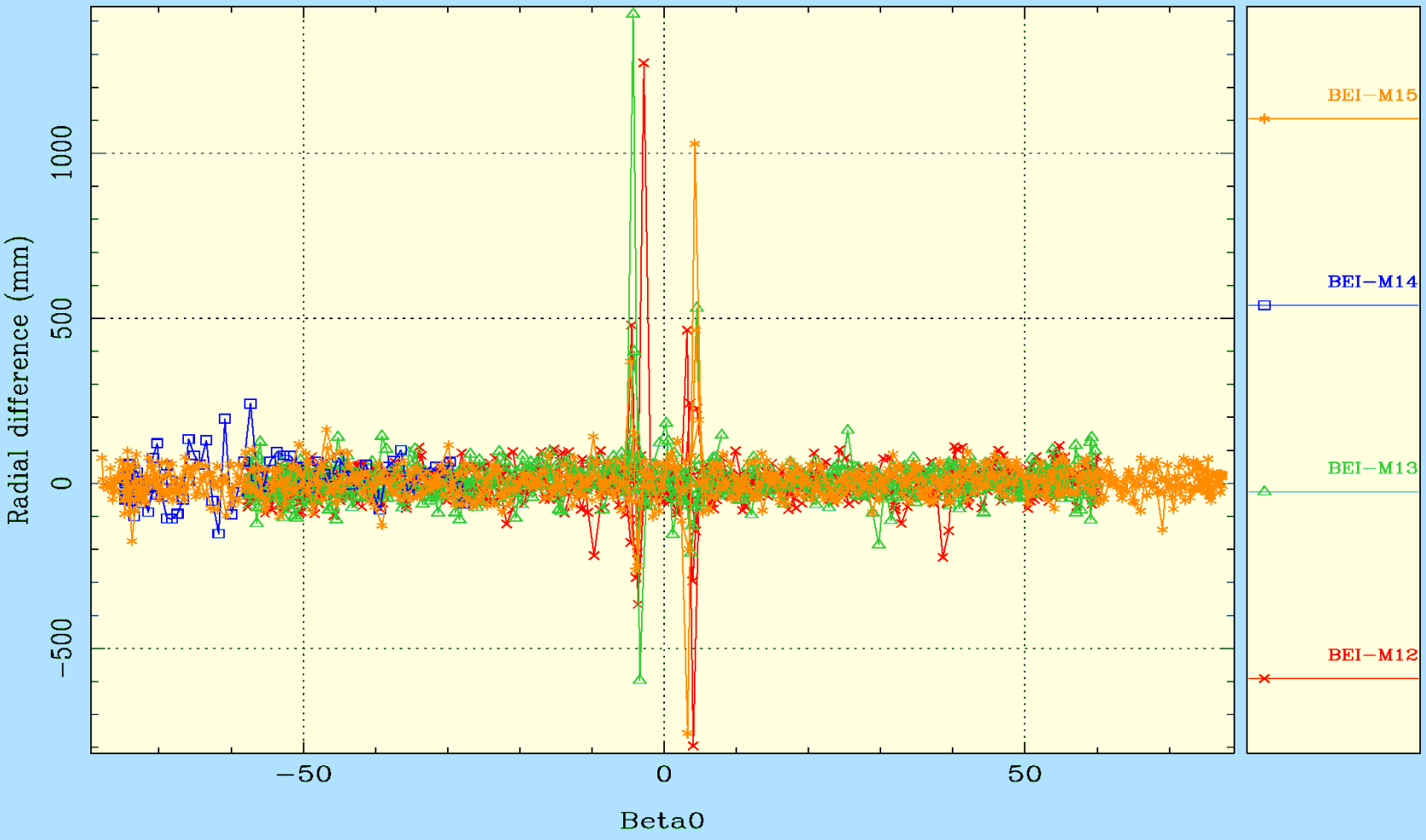
- Phase residuals show improvement
- Dedicated SLR tracking for transition periods could help to validate the attitude model



Standard attitude mode switch

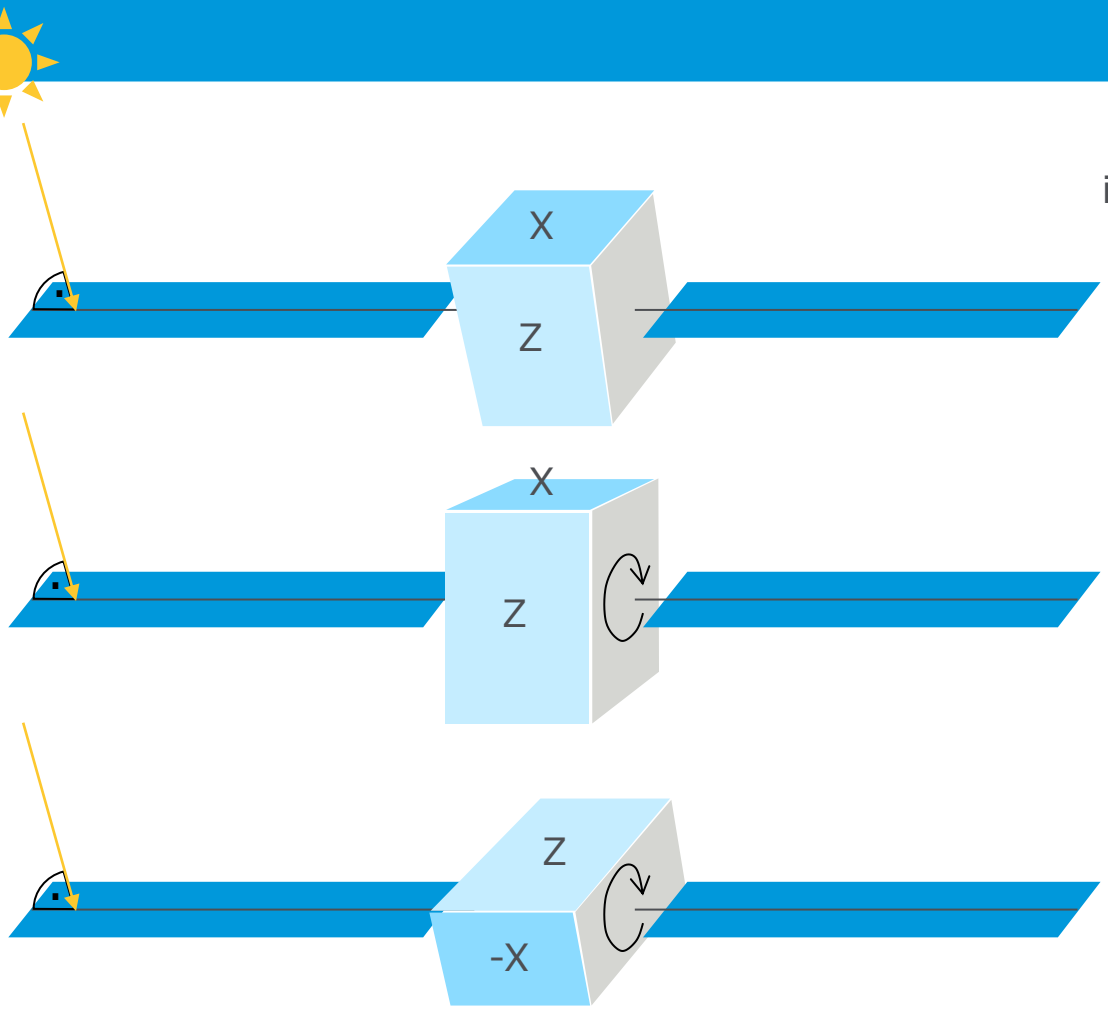
Refined attitude mode switch

BeiDou attitude model
Transition Issues



Solar radiation pressure

Direct SRP force (D)



Projected box area A' in direct Sun direction

X — min area

X' / Z' — max area

Z

Acceleration due to direct SRP is assumed to be:

- constant for the wings (A'_W = const)
- but varying for the box (A'_B = f(t))

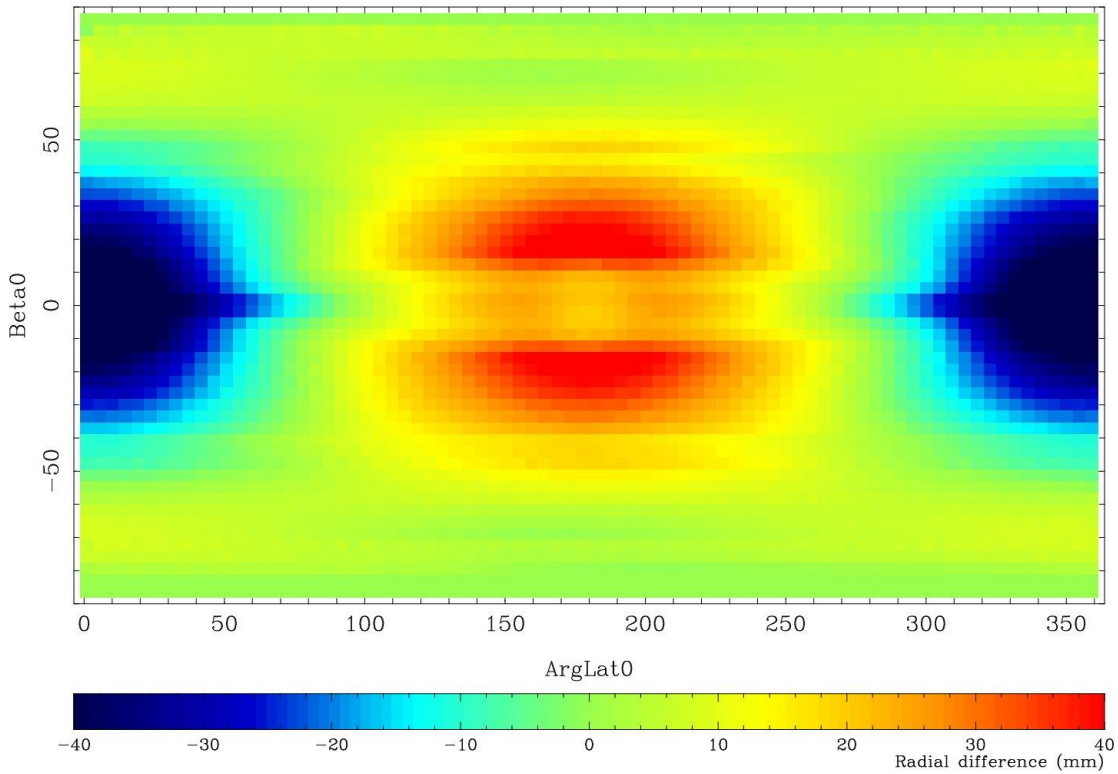
Approx. surface area changes

Not absorbed by ECOM parameters

	max-min [m²]	Mass [kg]	**Impact**	Sensitivity
GPS-IIA	1.3	975	**1.0**	6
GPS-IIR/RM	1.8	1100	**1.3**	4
GPS-IIF	2.3	1450	**1.2**	5
GLONASS-M	2.8	1400	**1.6**	3
Galileo-1 (IOV)	2.0	695	**2.2**	2
BeiDou-M	1.5	2000	**0.7**	7
QZSS	12.2	2000	**4.7**	1

Radial orbit difference – GLONASS-M

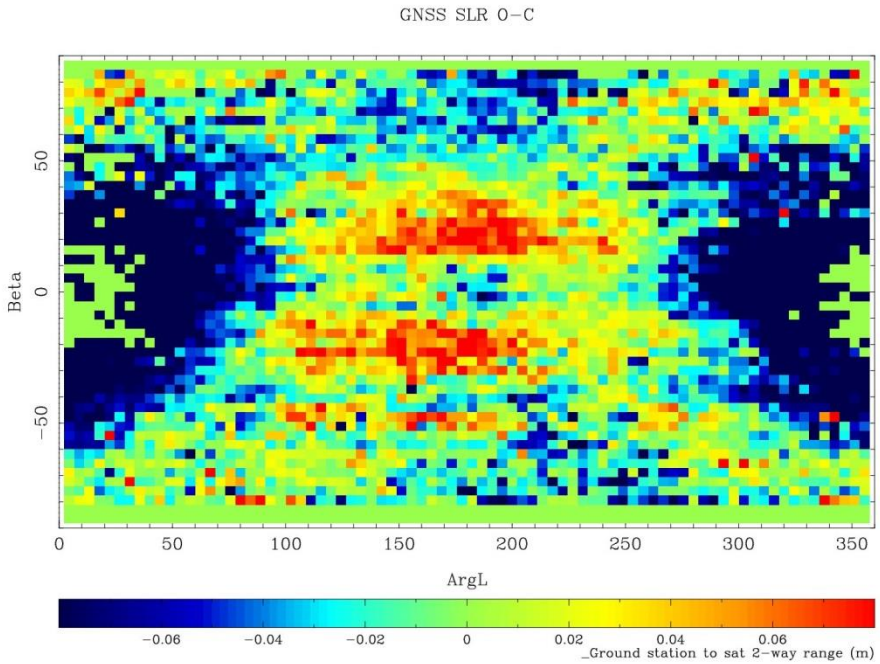
"with box-wing" minus "without box-wing"

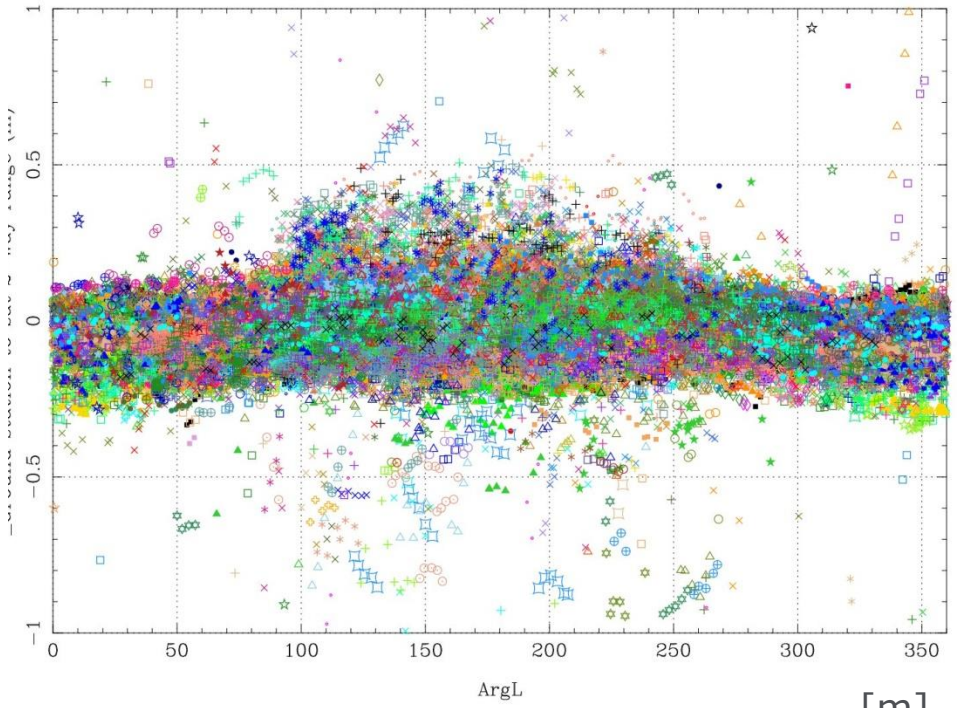


[mm]

SLR residuals (2-way) – GLONASS-M

without box-wing





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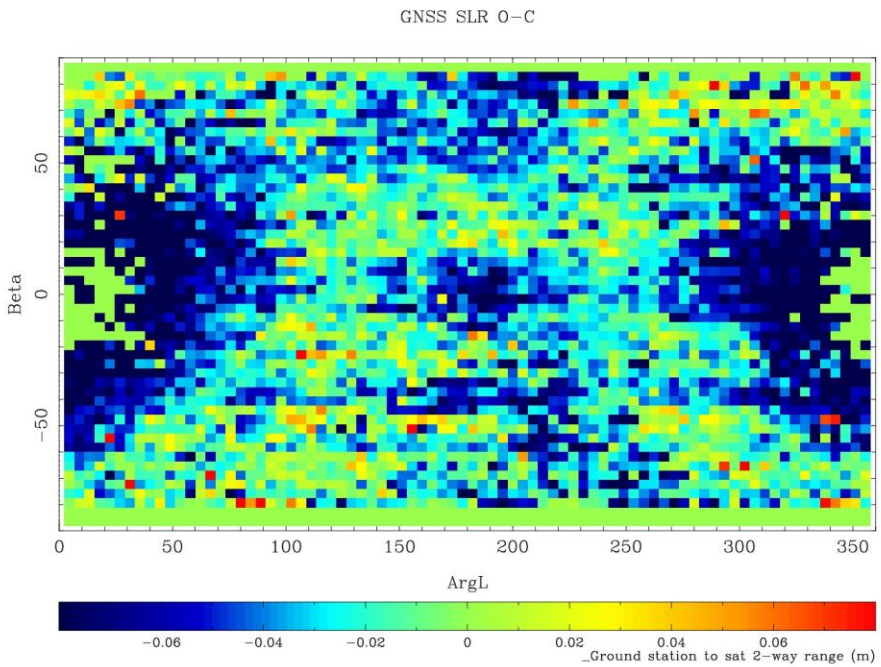
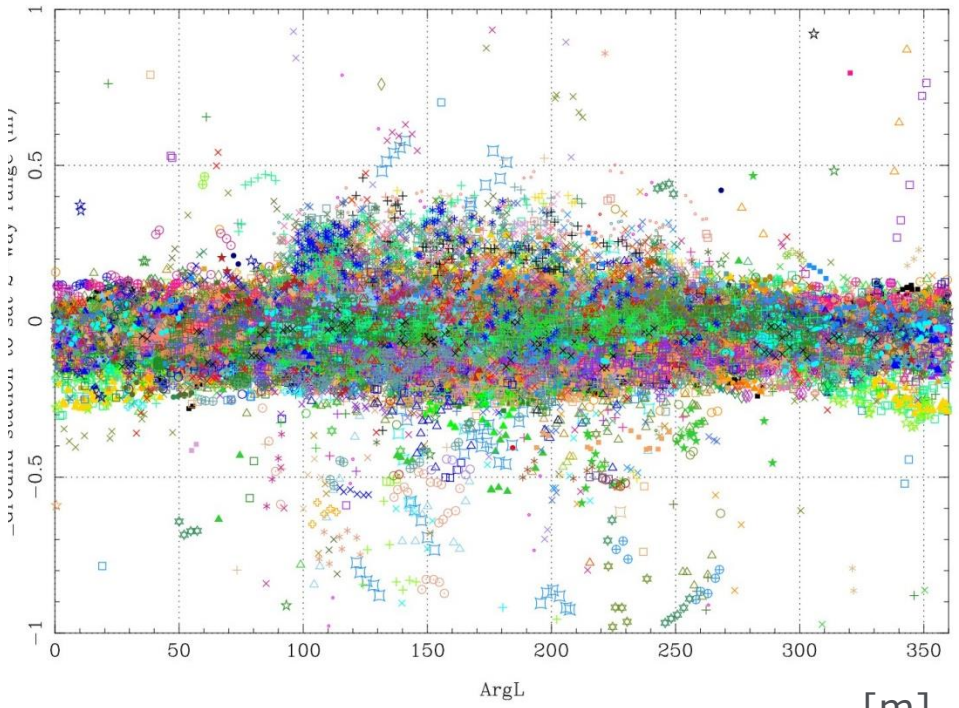
SLR residuals (2-way) – GLONASS-M

with box-wing





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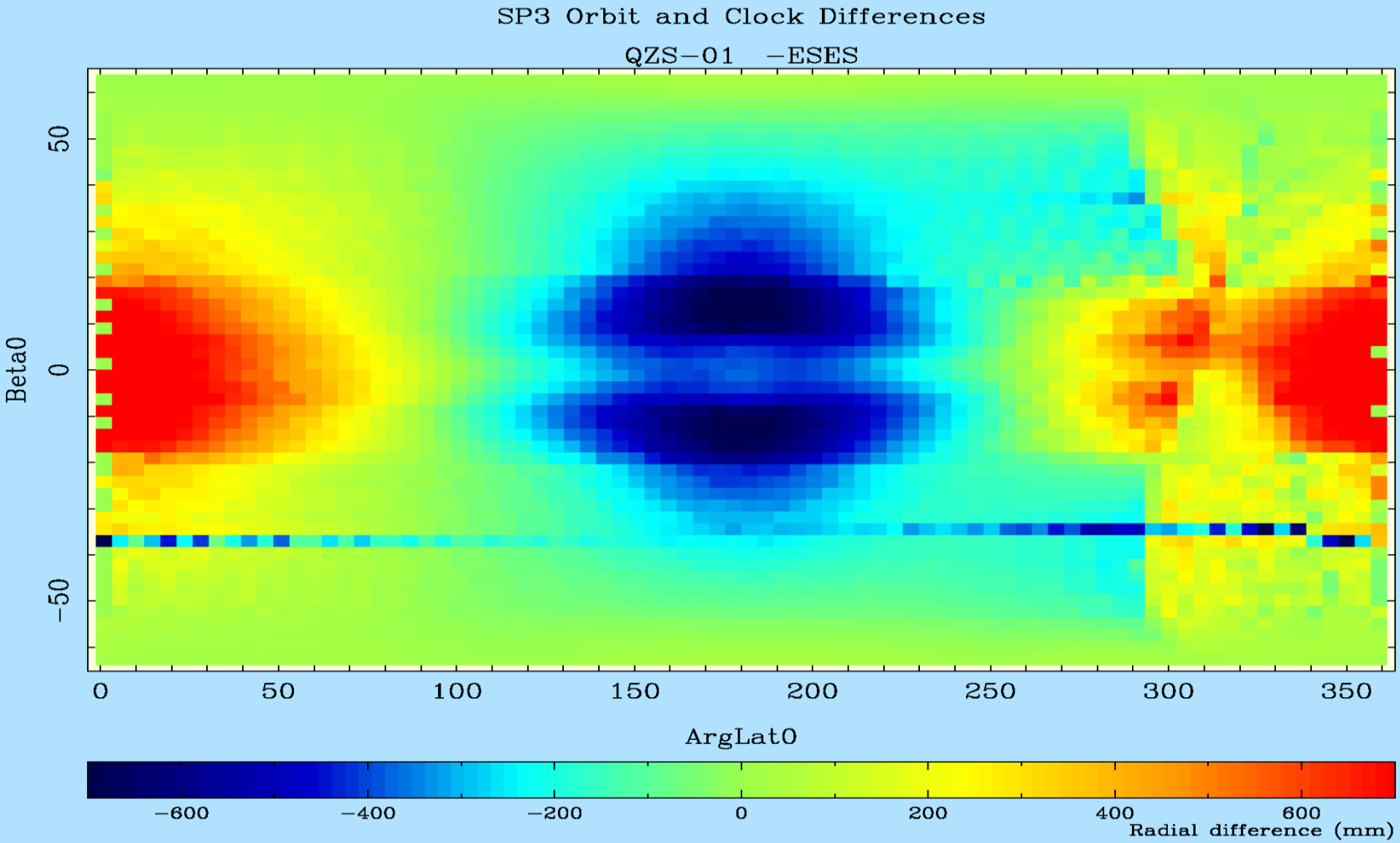
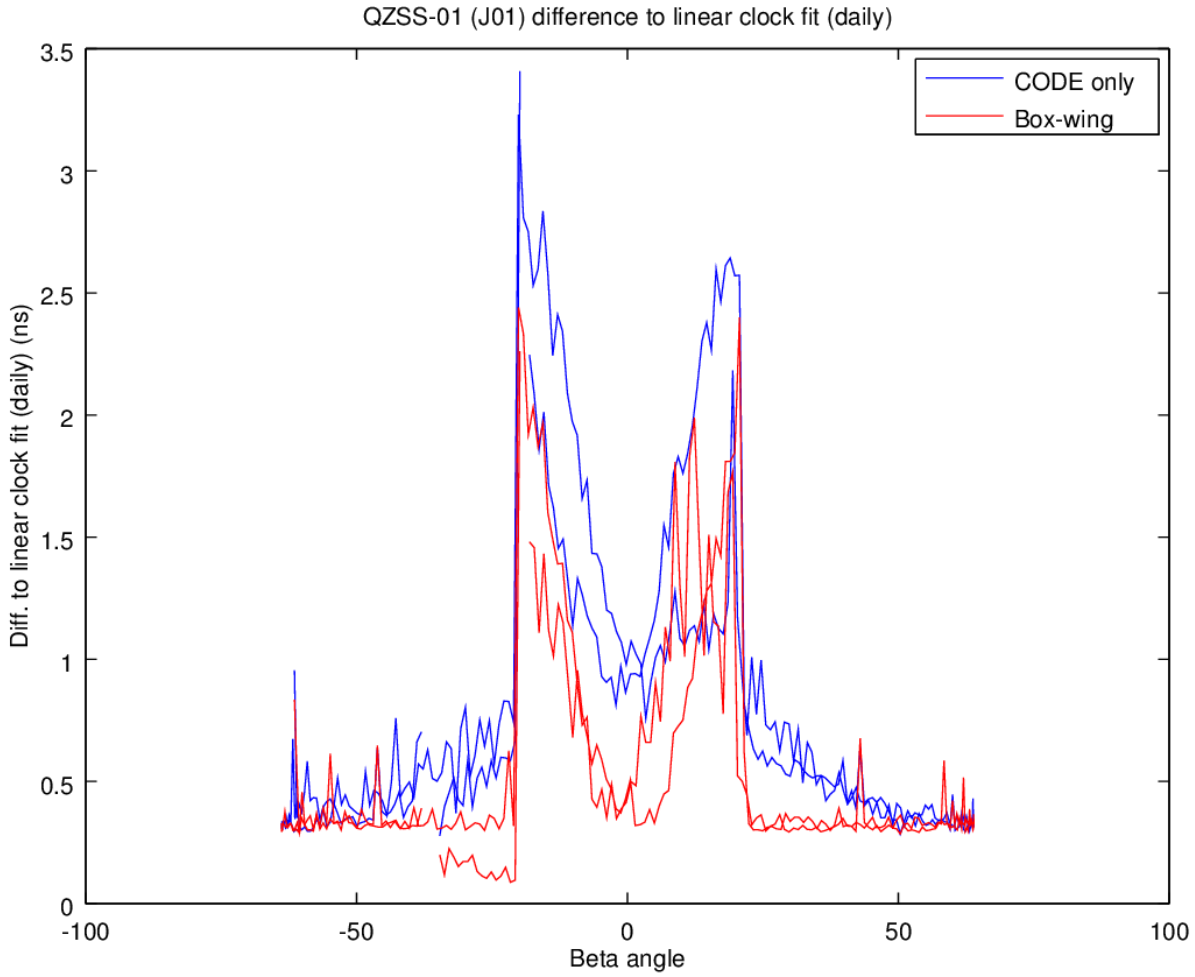
QZSS Radial Orbit Differences
No Box-Wing versus Box-Wing



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



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

Satellite Attitude and Radiation Model

1. Orbit normal mode for BeiDou and QZSS:
   a. BeiDou MEO and IGSO when |beta|< 4 degrees
   b. QZSS when |beta|< 20 degrees
   c. BeiDou GEO always

Neither ECOM nor ECOM2 model works very well for this mode

1. Transition point/epoch from one mode to the other needed to be understood and modelled properly
2. Good radiation pressure models for these satellites are needed

2. Every satellite type handles the eclipse phase differently:
   a. Block II/IIA/IIR
   b. Block IIF (which have also unexpected behaviour even outside eclipse)
   c. GLONASS and Galileo rather similar
      – Some older GLONASS satellites have issues

Multi-GNSS Conclusions

Significant Efforts Needed for:

1. Integer Ambiguity Resolution Concepts
    a. BeiDou and GLONASS
    b. How about inter-system ambiguity resolution?
2. Satellite Attitude
    a. GPS IIF issues
    b. BeiDou and QZSS attitude transition
3. Satellite Radiation Modelling
    a. Very important for QZSS and Galileo
    b. Crucial for BeiDou and QZSS when in orbit normal mode
4. Transmit Antenna PCO/PCV
    a. Estimates needed from different ACs
    b. Also need to start worrying because of more than 2 freq's

THANK YOU

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