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Extending the GPS IIIA antenna calibration for precise orbit determination of low Earth orbit satellites

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OSTST Meeting

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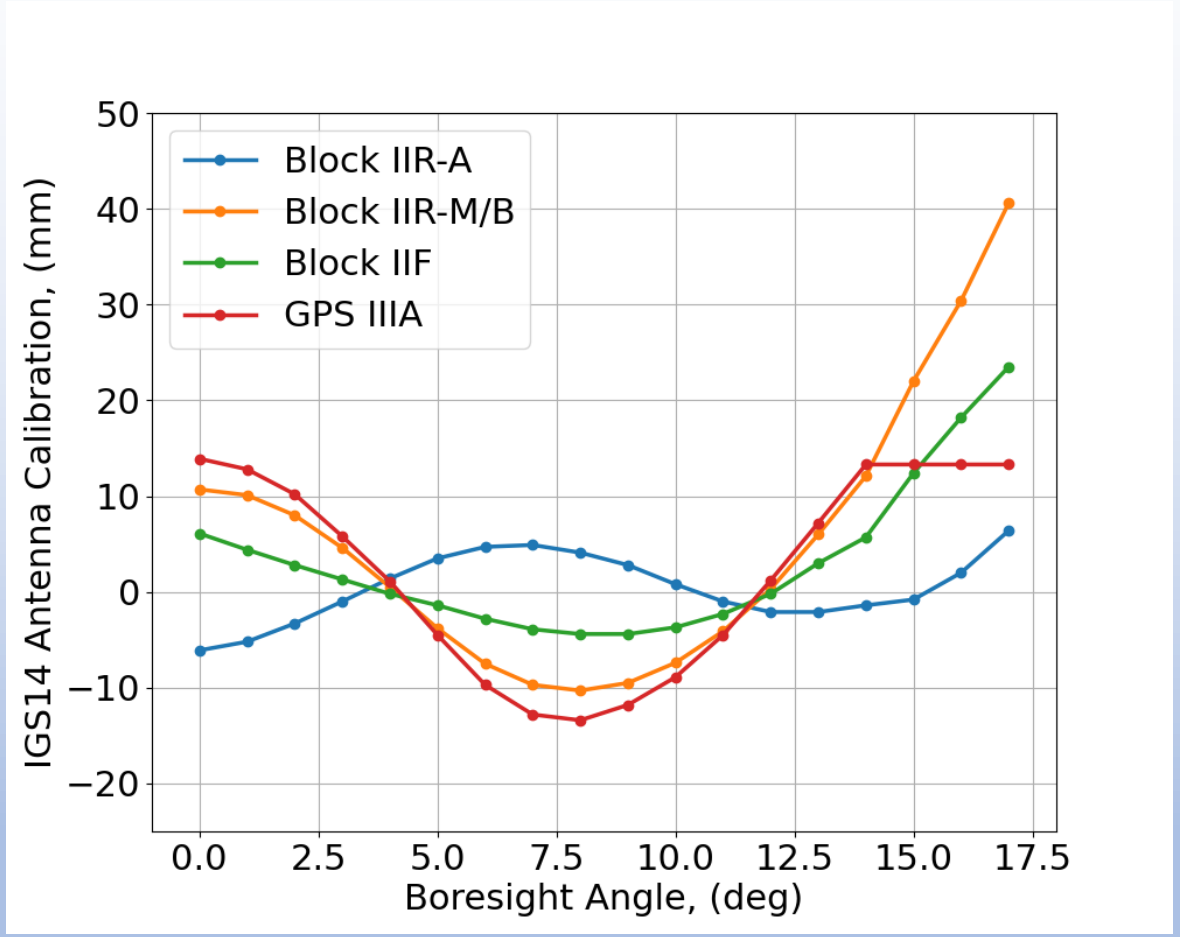
Overview

- Background and motivation
- GPS III antenna calibration extension estimation
- Results
- Conclusions

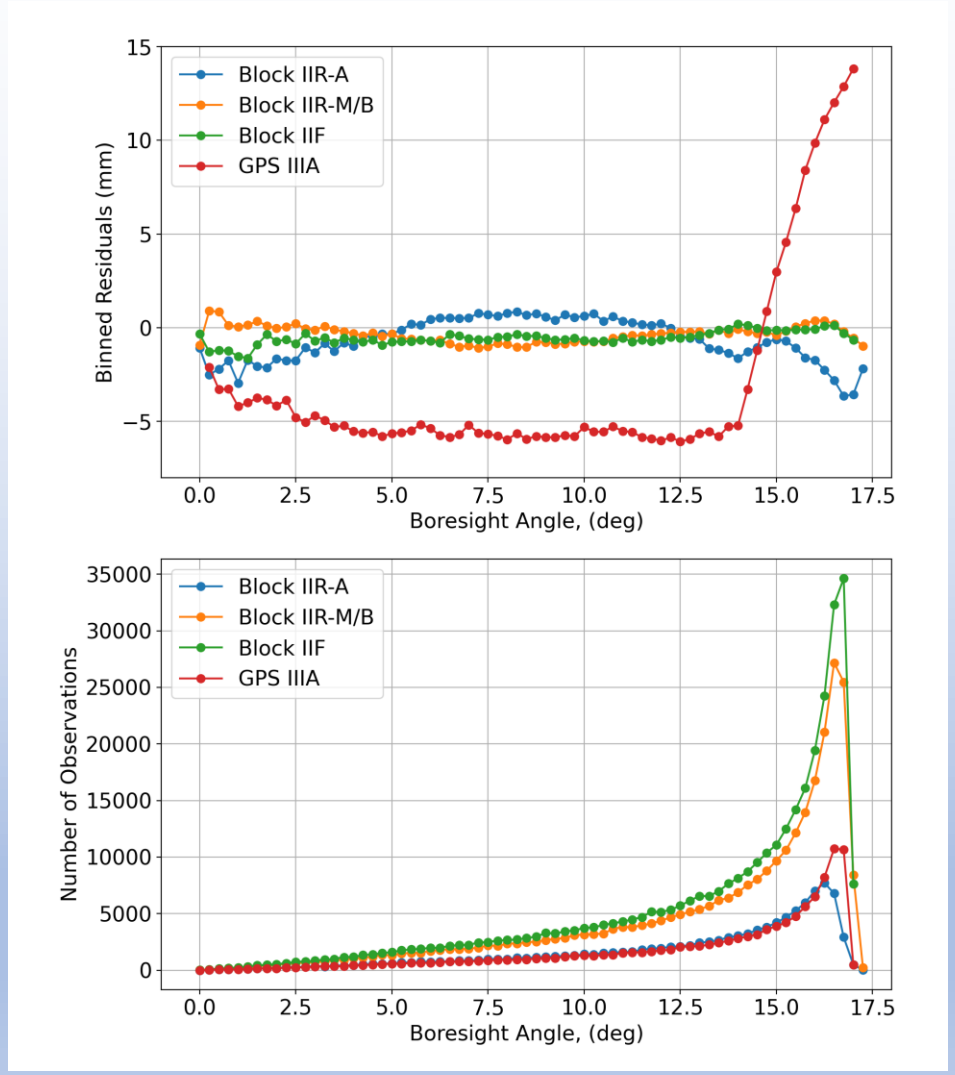
Background/Motivation

- Antenna calibrations consist of a phase center offset (PCO) and line of sight phase variations (PV)
- IGS14 adopts PVs for each transmitter sub-block type that are only dependent on boresight angle
- Current IGS14 PV have been extended to 17-degrees for the Block II satellites
- GPS III are flat above 14-degrees boresight angle – IGS20 adopts this as well



Background/Motivation

- Sentinel-6 MF residuals from applying the IGS14 calibrations result in poor GPS III performance
- For LEO spacecraft (Sentinel-6 MF), significant number of measurements above 14-degrees
- Objective is to derive an extension for the GPS IIIA antenna calibration that is consistent with the current Block II extensions
- GPS III extension derived from the TriG receiver GPS ionosphere free LC observations
    - PODRIX enforces a 10-deg elevation cut-off

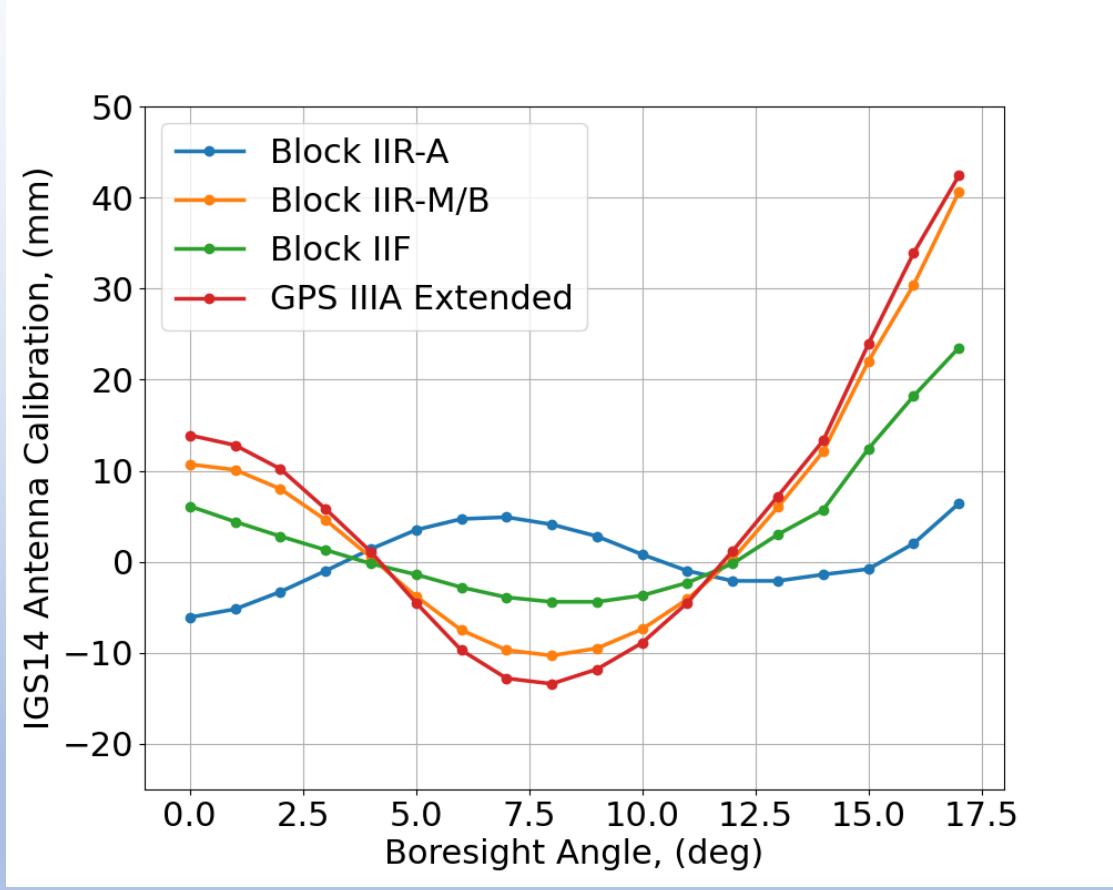


Methods

- JPL's GipsyX software used for all precise orbit determination
- Goal to improve LEO POD without affecting current terrestrial GNSS processing
- Using one year of data (2021), the GPS III extension is derived and validated as follows
    1. An in-flight correction to the Sentinel-6 MF pre-launch TriG receiver antenna calibration from Block II only measurements
    2. GPS III measurements fit to Sentinel-6 MF Block II derived dynamic orbits and receiver clock solutions
    3. GPS III residuals above 14-degrees binned and averaged then added to IGS14 values (iterated)
    4. Assessment and validation (Jason-3) – three scenarios
        a. Block II only measurements - IGS14 PV
        b. Block II and GPS III measurements - IGS14 PV
        c. Block II and GPS III measurements - IGS14 PV for Block II and Extension for GPS III

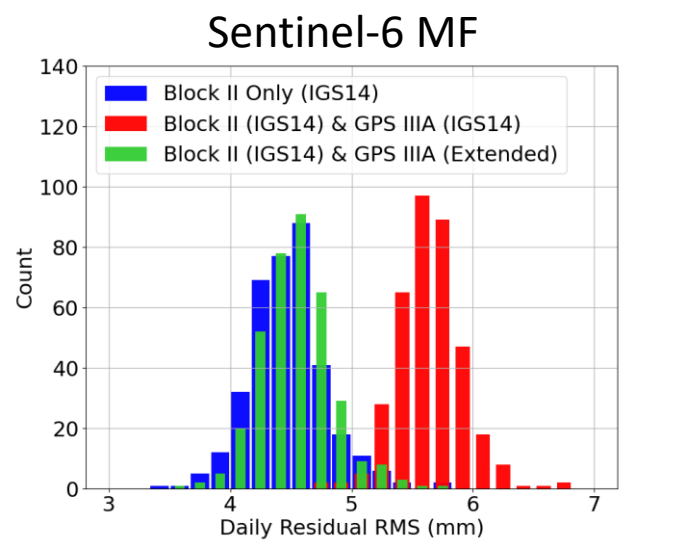
GPS III Extension

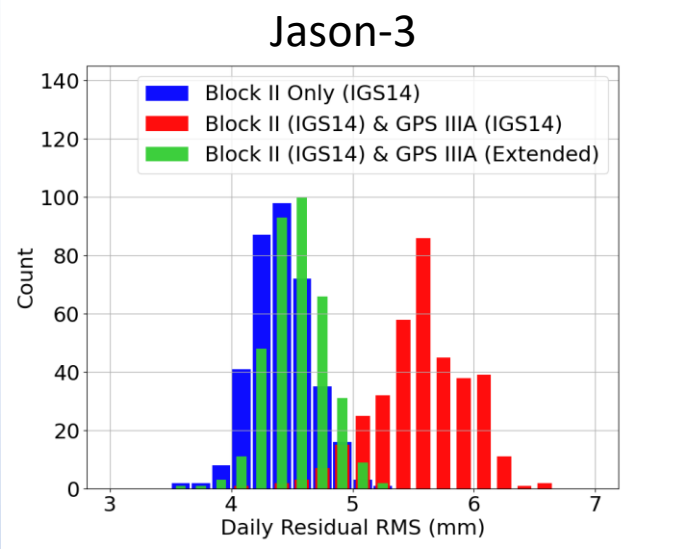
- Estimated from one year of GPS III data (2021) fit to Block II derived orbits
- GPS III extension shows remarkable similarity to the Block IIR-M/B PVs
- Same manufacturer for both
- The Block IIR-M/B values above 14-degrees could be used



Daily Residual RMS

- 30-hour ambiguity resolved reduced dynamic orbits
- Histogram shows daily phase residual RMS from reduced dynamic orbits
- GPS III extension significantly lowers the average daily RMS and is consistent with Block II only solution



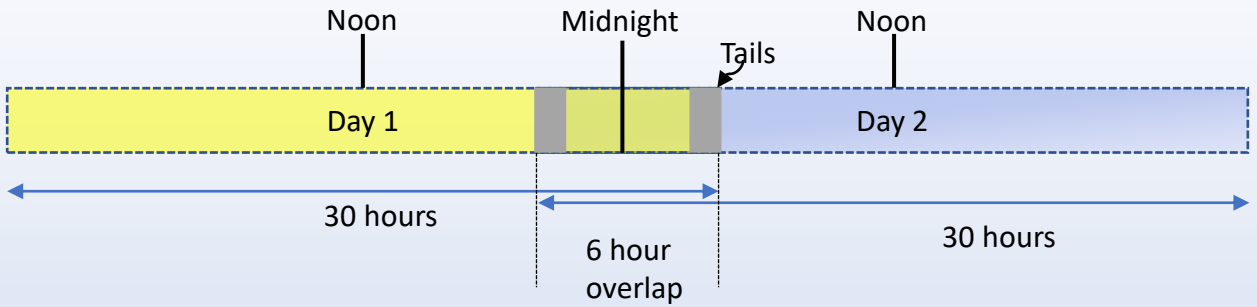


	Sentinel-6 MF		Jason-3	
	LC all (mm)	LC III only (mm)	LC all (mm)	LC III only (mm)
Block II Only	4.5 ± 0.32	--	4.4 ± 0.25	--
Block II and IIIA IGS14	5.6 ± 0.27	9.7 ± 0.45	5.6 ± 0.38	9.3 ± 1.0
Block II and IIIA Extended	4.5 ± 0.30	4.5 ± 0.52	4.5 ± 0.24	4.6 ± 0.40

Mean value ± the standard deviation across all days

Orbit Overlaps

- 30-hour ambiguity resolved reduced dynamic orbits
- Component different RMS from central 4-hours
- Mean ± standard deviation from entire year of overlaps (2021)



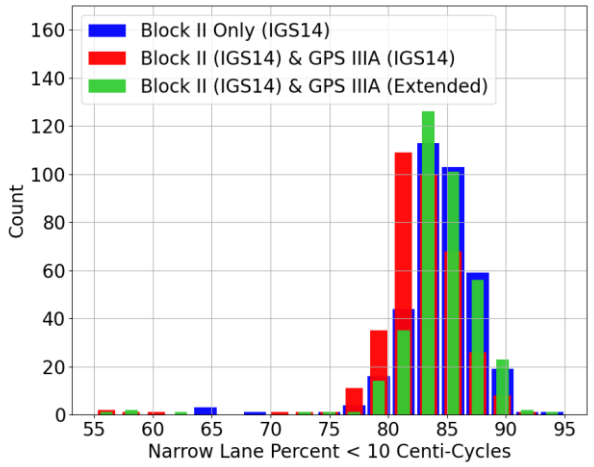
	Sentinel-6 MF			Jason-3		
	Radial (mm)	Cross-track (mm)	In-track (mm)	Radial (mm)	Cross-track (mm)	In-track (mm)
Block II Only	0.78 ± 0.33	1.7 ± 0.57	1.8 ± 1.0	0.80 ± 0.29	1.7 ± 0.61	1.8 ± 0.72
Block II and IIIA IGS14	0.77 ± 0.31	1.7 ± 0.56	1.8 ± 0.90	0.79 ± 0.26	1.7 ± 0.58	1.8 ± 0.62
Block II and IIIA Extended	0.73 ± 0.28	1.6 ± 0.54	1.7 ± 0.83	0.76 ± 0.26	1.7 ± 0.55	1.7 ± 0.62

Mean value ± the standard deviation across all days

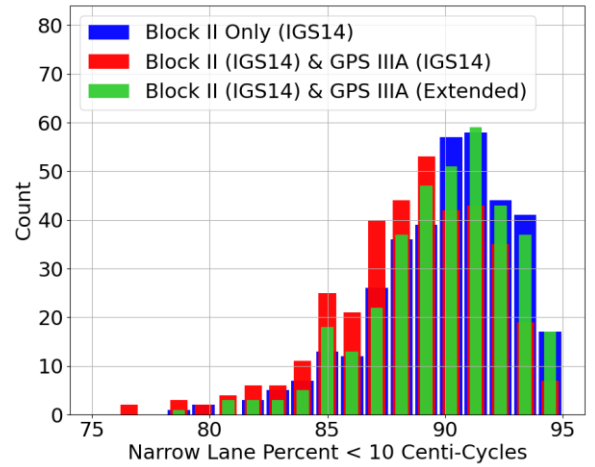
Ambiguity Resolution

- Single receiver ambiguity resolution applied with a soft constraint in filter smoother (iterated)
- Percentage of passes fixed to within 10% of a cycle
- GPS III extension is consistent with Block II only

Sentinel-6 MF



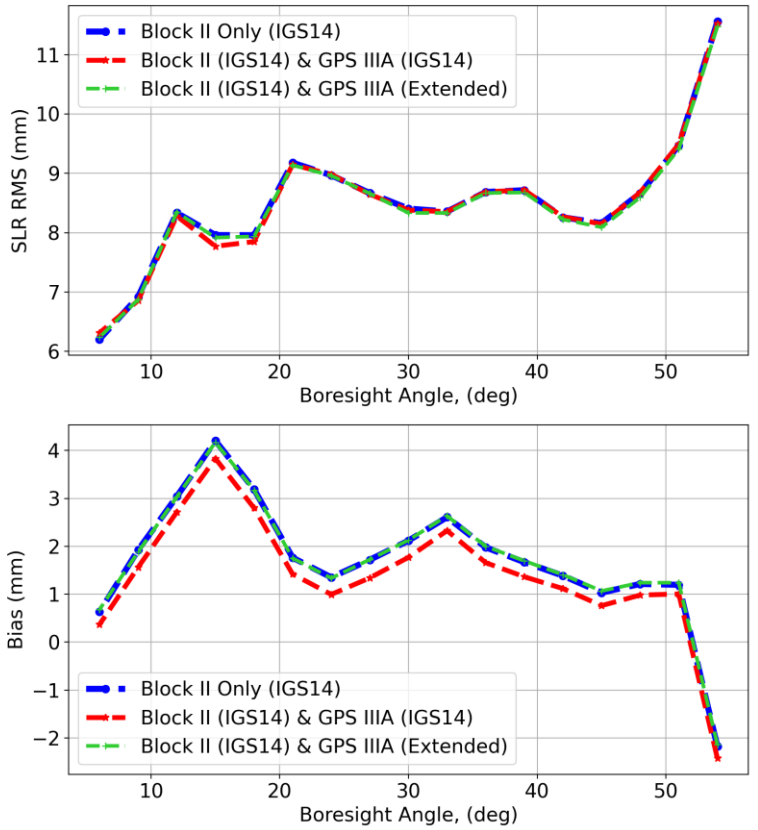
Jason-3



	Sentinel-6 MF	Jason-3
	Median Amb Res (%)	Median Amb Res (%)
Block II Only	84.5	90.3
Block II and IIIA IGS14	82.7	89.0
Block II and IIIA Extended	84.5	90.4

Sentinel-6 MF SLR Residuals

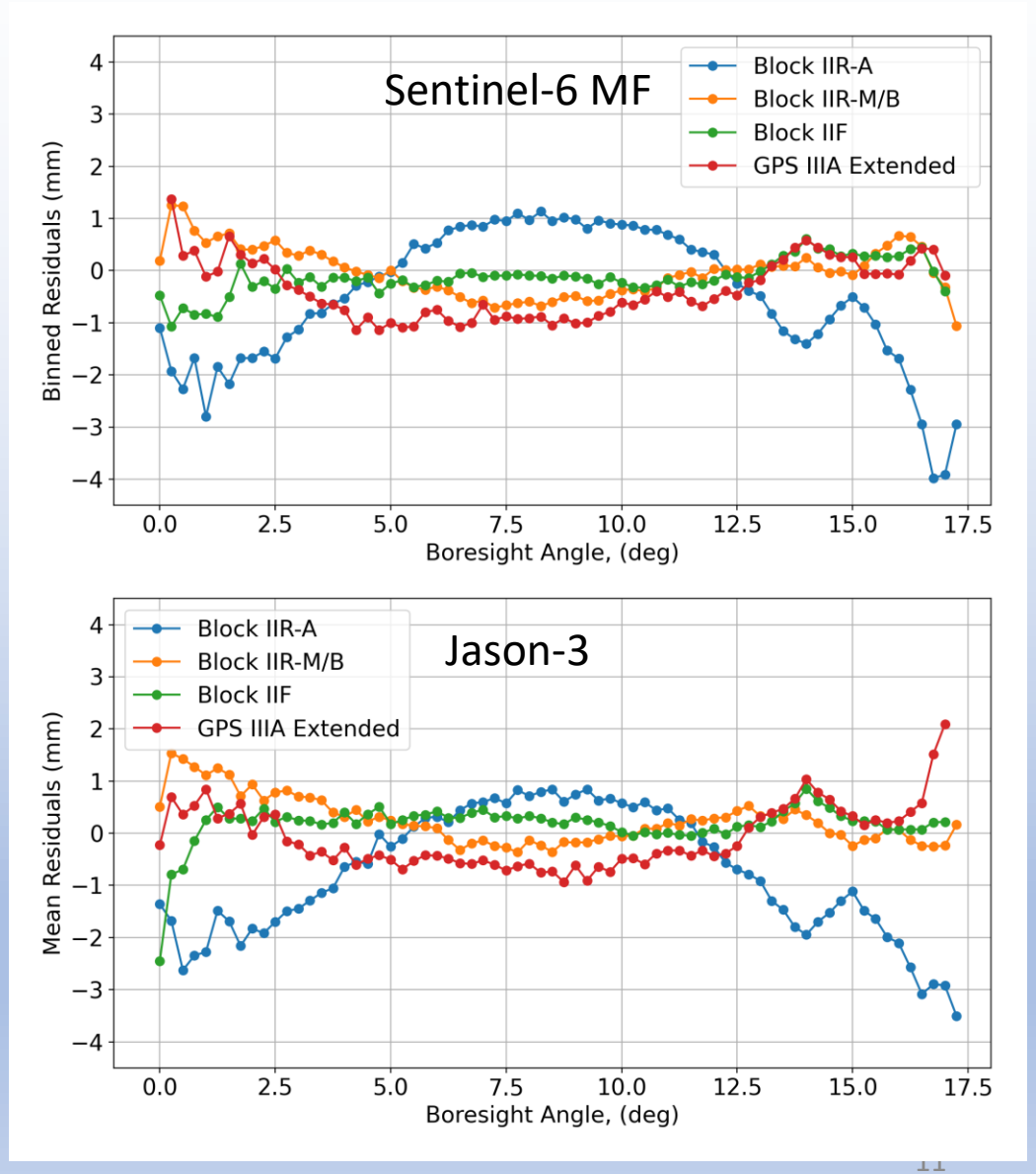
- SLR one-way measurement residuals from stations with biases below 5 mm
  - Eight Stations: GODL, GRZL, HARL, HERL, STL3, YARL, WETL, ZIML
- GPS III extension shows a small improvement in overall RMS
- Similar performance likely due to the strength of the Block II ambiguity resolution (> 85% of observations)
- Indicates better than 1 cm radial RMS accuracy



	RMS (mm)	Bias (mm)
Block II Only	8.9	1.26
Block II and IIIA IGS14	8.9	0.99
Block II and IIIA Extended	8.8	1.28

Binned Observations

- 30-hour reduced dynamic ambiguity resolved orbits
- Comparison between Sentinel-6 MF and Jason-3 binned residuals as a function of transmitter boresight angle
- Similar structure for both with a deviation of a few mm
- Block IIR-A has the most structure in the binned observations and may benefit from additional tuning of PVs

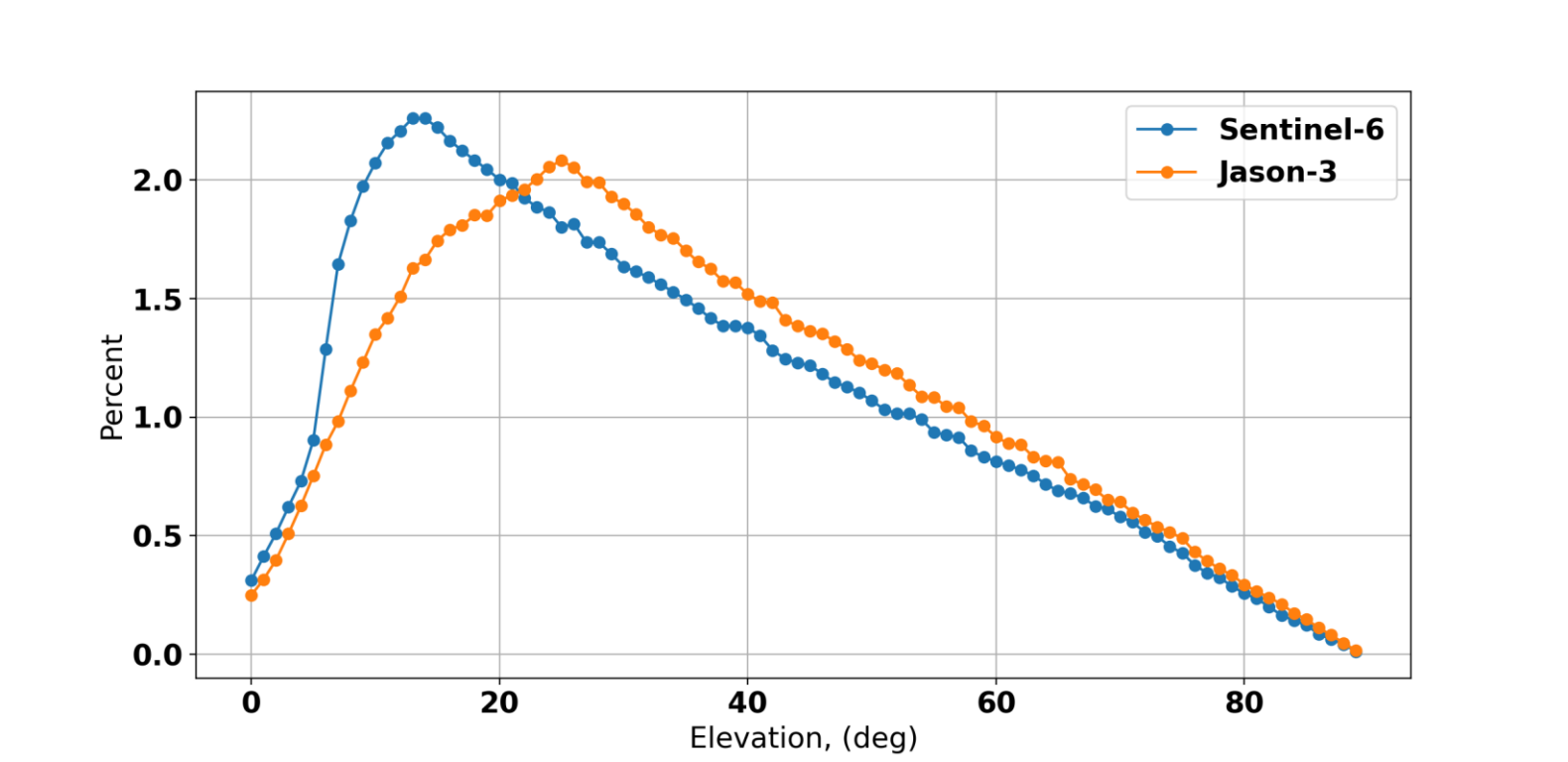


Summary

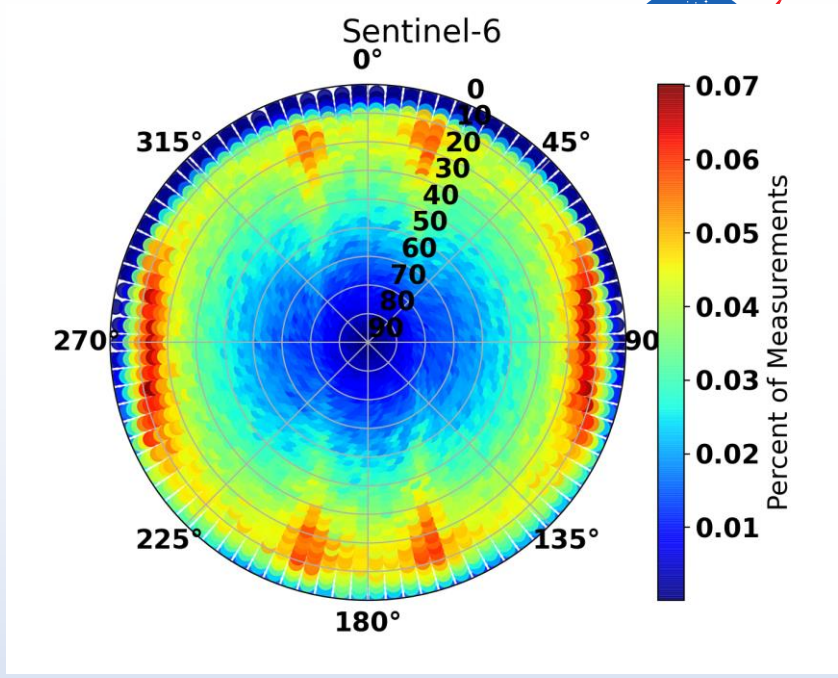
- The estimated GPS III extension produces orbits that are more consistent with the Block II only results
  - Daily residual RMS
  - Ambiguity resolution
- The IIR-M/B PVs above 14-deg could be a simpler approach to use for III extensions
- The GPS IIIA extension could be used with the IGS20 antenna calibrations

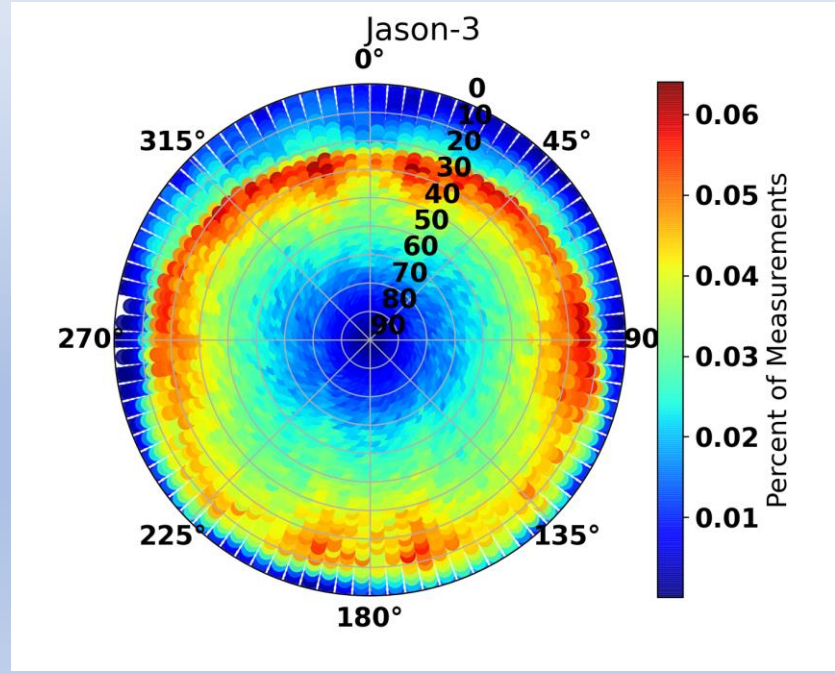
Image Credit: NASA

- S6 vs Jason-3


Sentinel-6
Jason-3
Percent
2.0
1.5
1.0
0.5
0.0
0
20
40
60
80
Elevation, (deg)

- S6 vs Jason-3


Sentinel-6
0°
45°
90
135°
180°
225°
270
315°
0
10
20
30
40
50
60
70
80
90
0.07
0.06
0.05
0.04
0.03
0.02
0.01
Percent of Measurements


Jason-3
0°
45°
90
135°
180°
225°
270
315°
0
10
20
30
40
50
60
70
80
90
0.06
0.05
0.04
0.03
0.02
0.01
Percent of Measurements