Mitigation of Spatial and Temporal Orbit Errors in Satellite Altimeter Sea Surface Height Measurements

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Introduction

- Validate Precise Orbit Ephemeris (POE) on Jason-2 and Jason-3 Geophysical Data Records using GPS-based precise orbit determination.
  - Independent software
  - POE uses combination of GPS and DORIS tracking data.

- Investigate approaches for improving GPS-based precise orbit determination (POD), and evaluating overall performance.

- Results have been presented during each of Precise Orbit Determination (POD) splinter sessions of OSTST from 2017-2020.

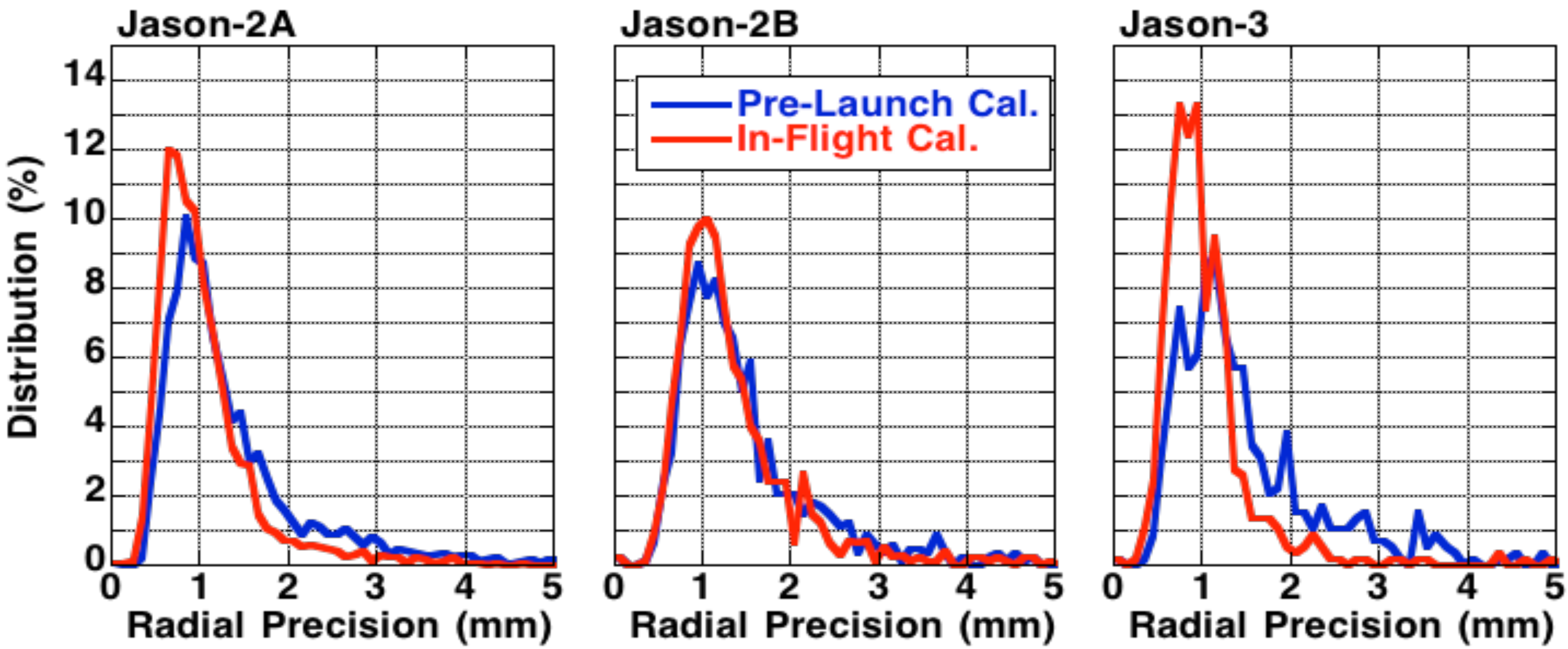
Investigated Impact of Various Approaches to GPS-based POD

- Evaluated impact of:
  - Dynamic force models, e.g.:
    - Time-varying gravity models
    - Models for dynamic atmosphere and oceans (AOD)
  - Antenna calibrations:
    - Pre-launch versus in-flight.
    - Transmitter antenna calibrations.
  - Tracking data resolution:
    - 30-seconds versus 5-minute
  - Elevation-dependent data weighting
  - References frames (IGS08 vs. IGS14)
  - GPS constellation orbit and clock products, e.g.:
    - Fiducial-fixed, no-net-rotation, fiducial-free.

Metrics for Evaluating Orbit Accuracy

- Internal Metrics:
  - Orbit precision as measured by differences between daily 30-hour POD solutions during 6-hour overlapping period.
  - Data noise as measured by post-fit data residuals
- External Metrics:
  - Sea surface height crossover variance
  - Withheld Satellite Laser Ranging (SLR) tracking data
- Orbit Comparisons:
  - Geophysically correlated orbit errors
  - Temporal variations.

In-Flight GPS Antenna Calibration Improves Orbit Precision (2017 OSTST)

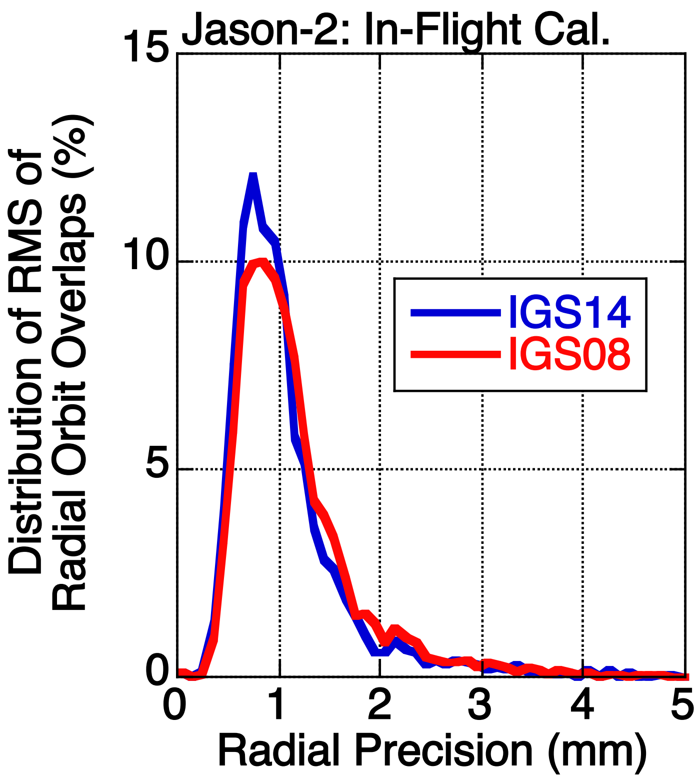


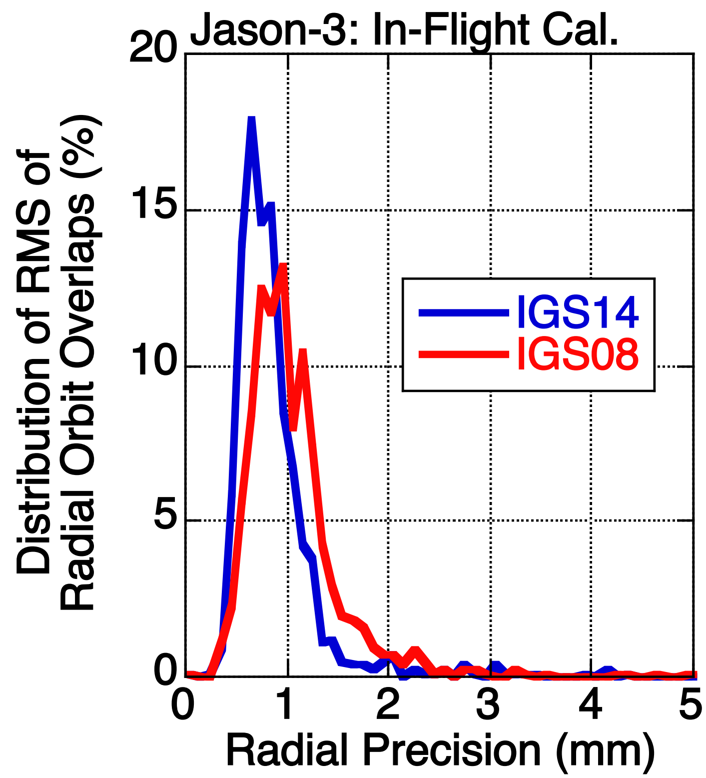
- **Sub-mm radial precision for Jason-2 and Jason-3.**

Median of Radial Precision (mm)

	JA2-A	JA2-B	JA3
Pre-Launch Cal.	1.1	1.3	1.2
In-Flight Cal.	0.9	1.2	0.9

Modern Reference Frames Improves Orbit Precision (2018 OSTST)

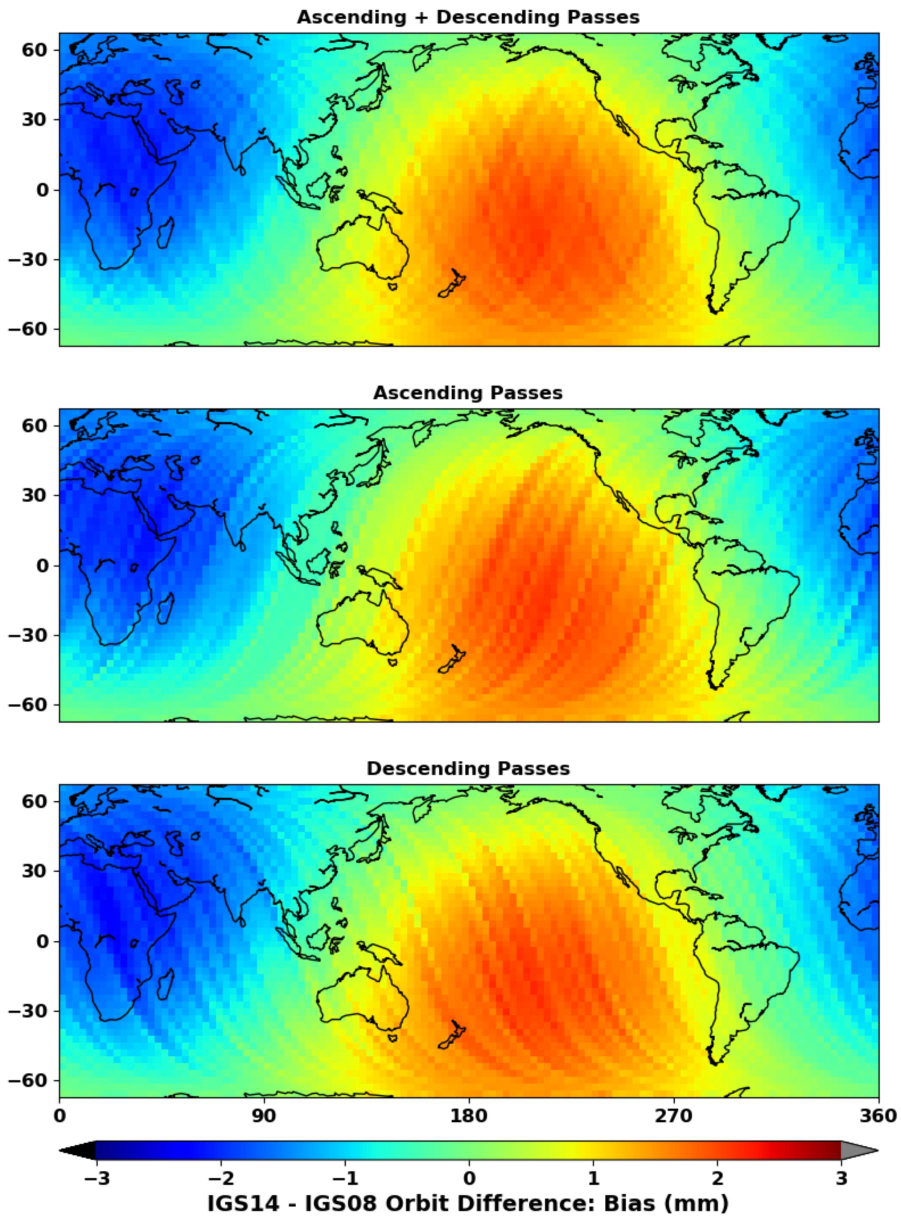




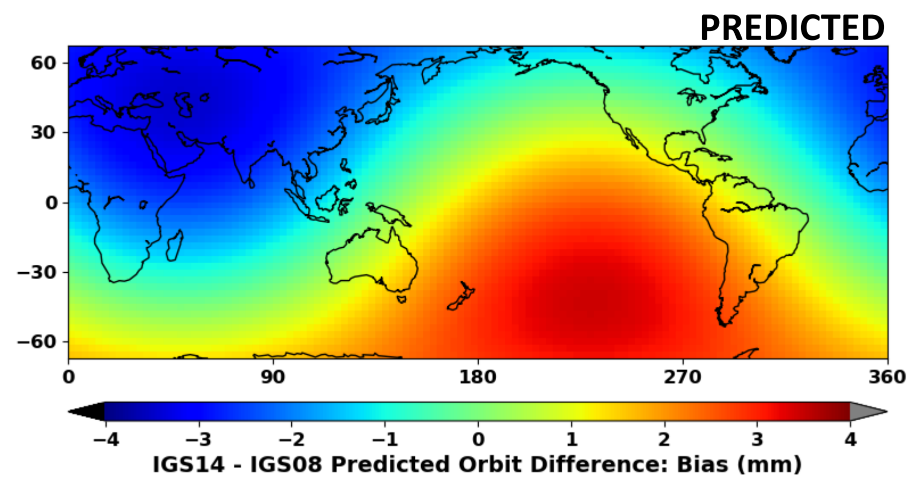
Median of Radial Precision (mm)

	IGS08	IGS14
Jason-2	1.0	0.9
Jason-3	1.0	0.8

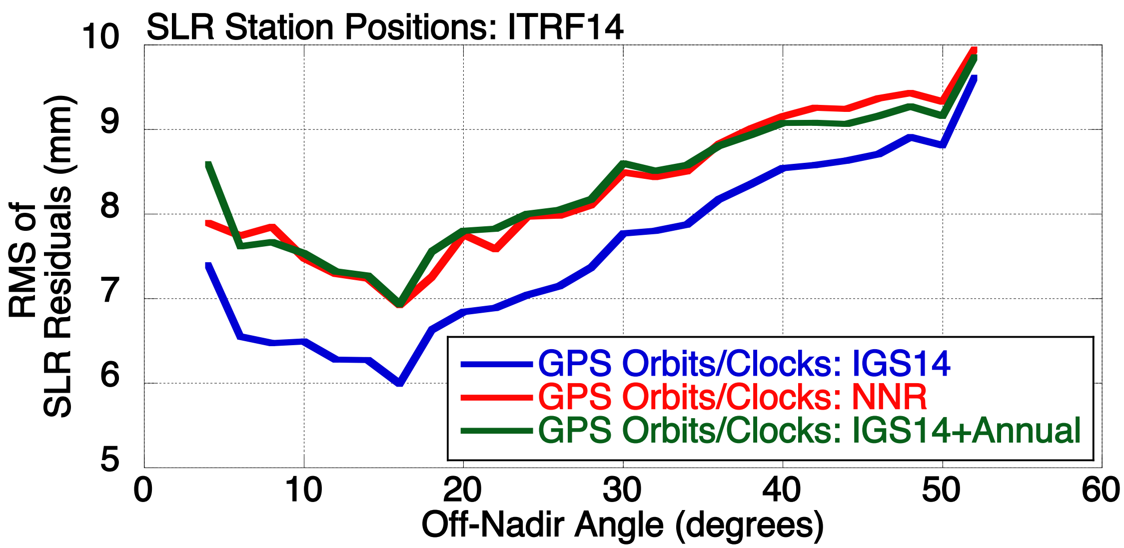
References Frames Impact Orbit Centering (2018 OSTST)

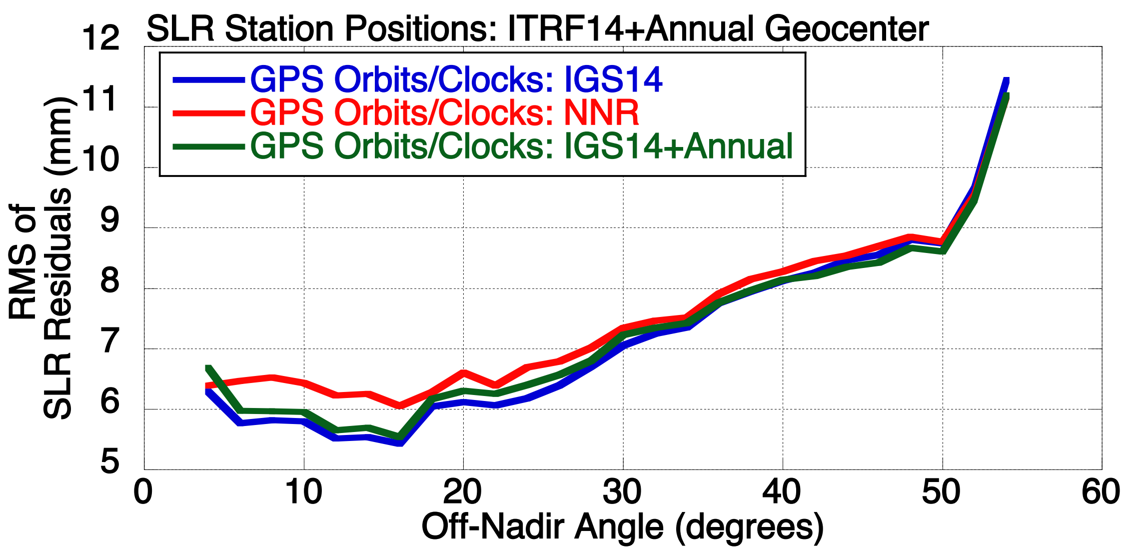


- Map radial orbit differences from Jason-3 cycles 1-84.
  - Simultaneously fit bias, drift, beta prime (118 days) period, annual period.
  - Epoch for bias is cycle 1.
- Primary impact is on orbit centering.
  - Smaller than predicted by ITRF14/ITRF08 translation and slightly shifted north/west:
    - (X, Y, Z)=(1.6, 1.9, 2.4) mm
- Also considered:
  - Drift: < 0.5 mm/yr
  - Beta-prime period: < 0.5 mm
  - Annual period: < 0.5 mm.



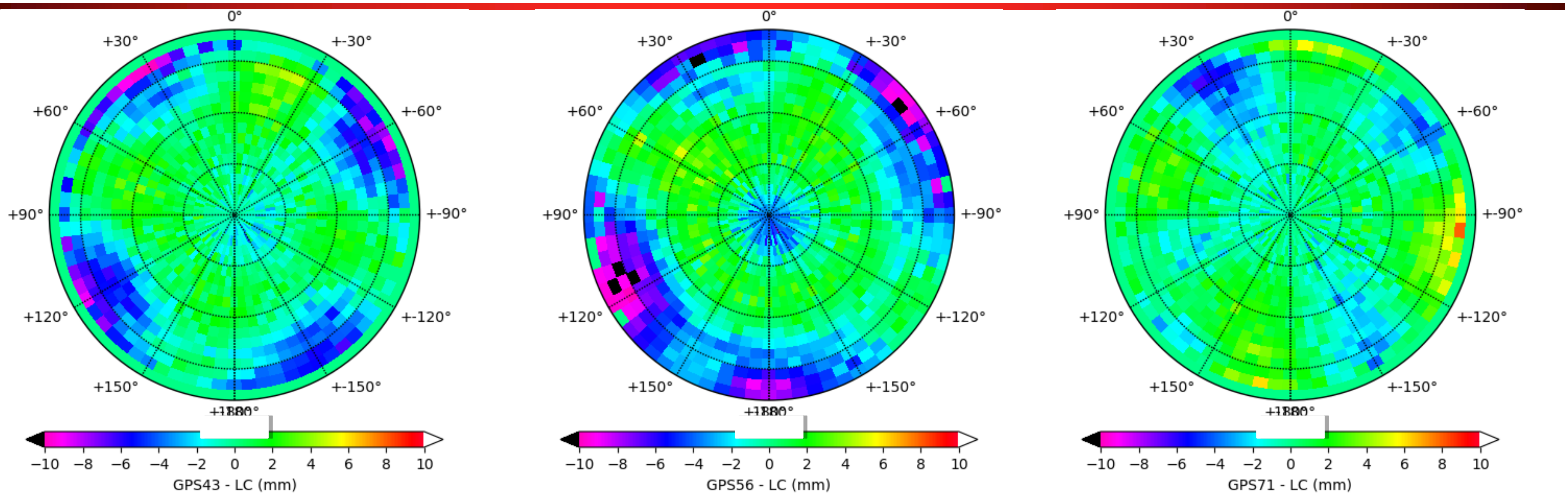
GPS Orbit and Clock Products Impact Orbit Accuracy (2019 OSTST)



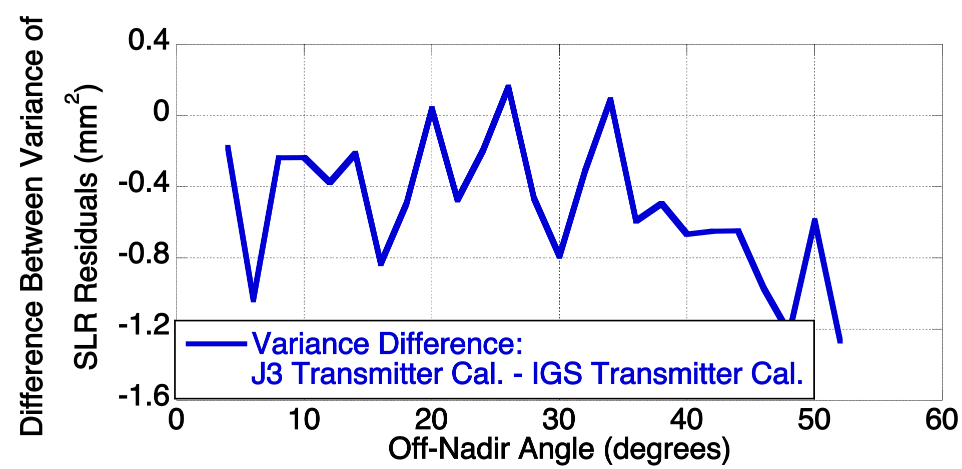


- Best radial orbit accuracy achieved when using IGS14 fiducial-fixed GPS satellite orbit and clock products (IGS14), as compared to:
  - NNR = No-Net Rotation
- SLR performance improves significantly when modeling annual geocenter motion in the SLR station positions.

“Signals of Opportunity” in Jason-3 Post-fit Residuals (2019 OSTST)

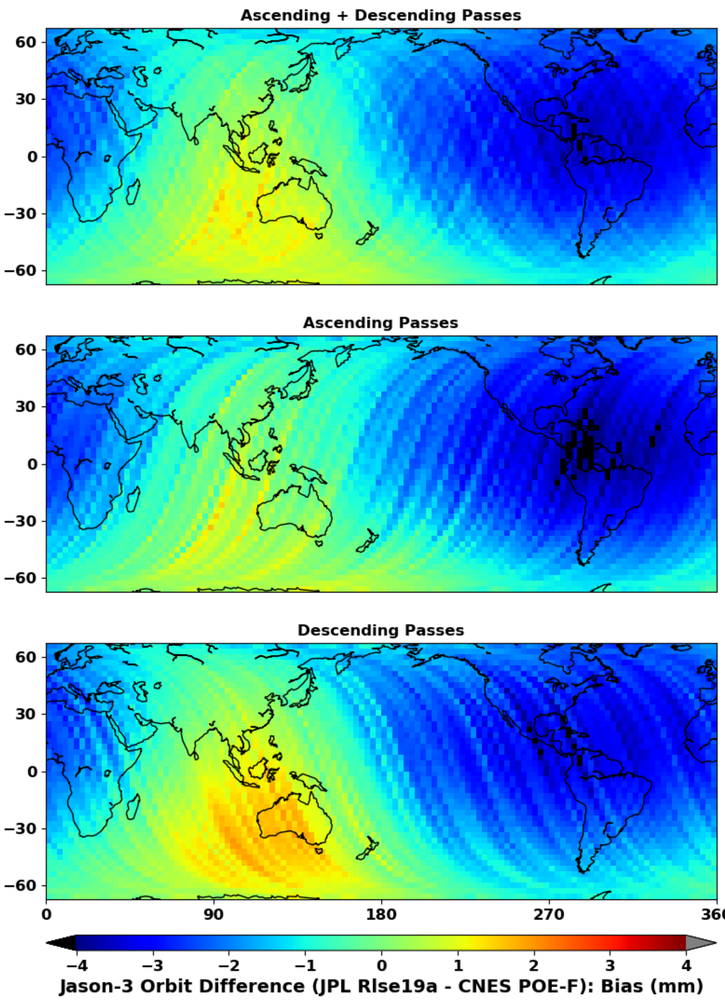


- IGS GPS transmitter calibrations do not contain any azimuthal variations.
- Accumulating JPL Release 19a post-fit residuals reveal strong (up to 10 mm) azimuthal variations for many GPS satellites.
  - Corresponds to transmitter antenna elements.
- **Improved GPS-based POD accuracy achieved by accounting for azimuthal variations in GPS transmitter calibrations.**
  - **Evidenced by lower SLR residuals.**

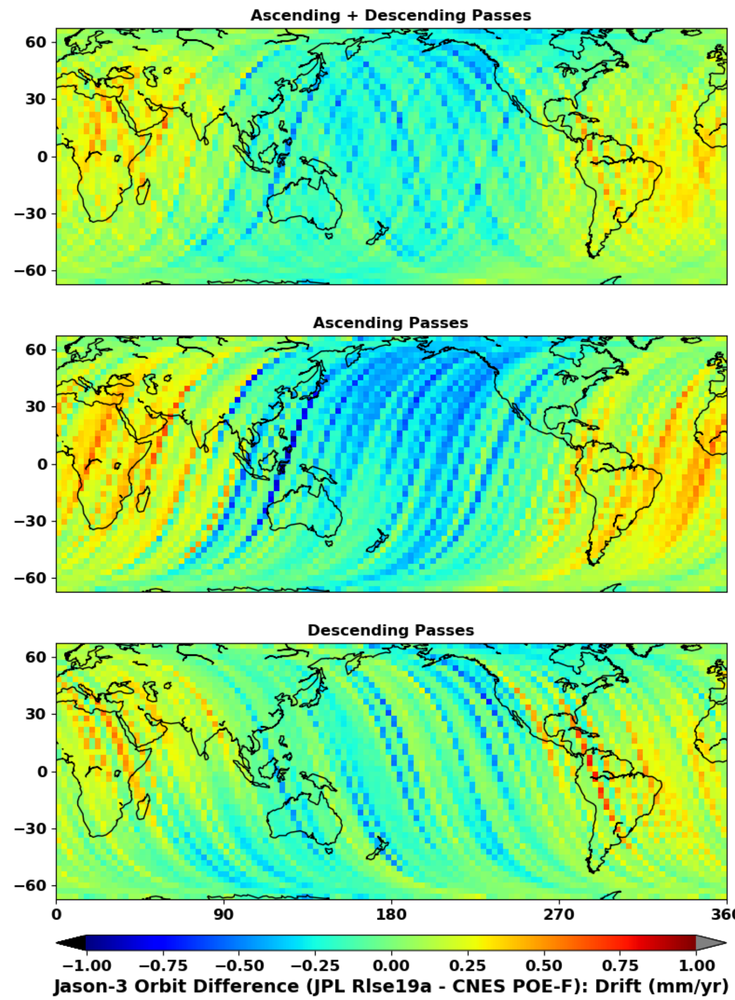


Geographically Correlated Orbit Differences with POE-F (2019 OSTST)

Relative Bias

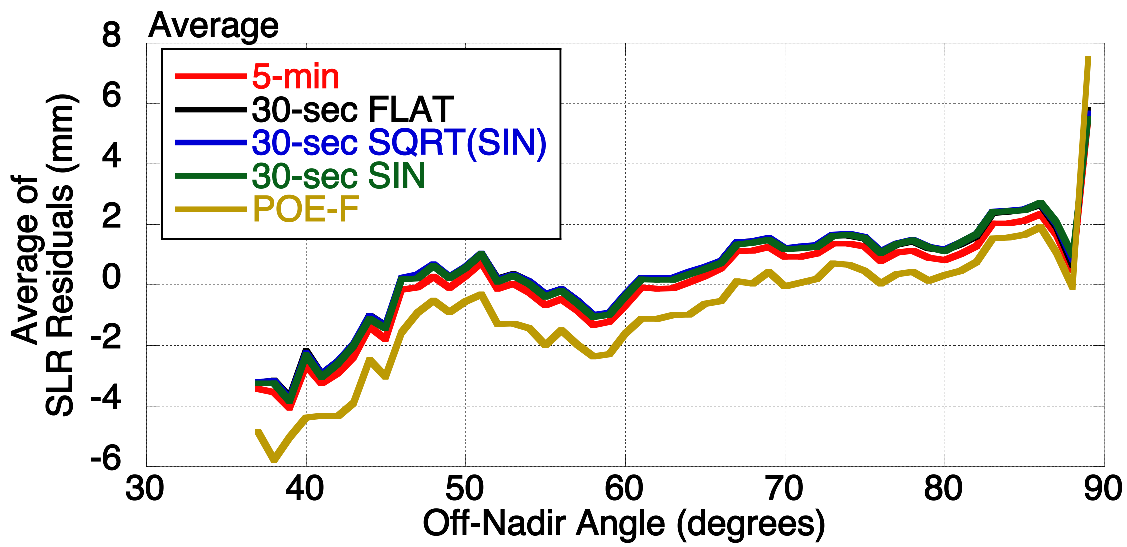


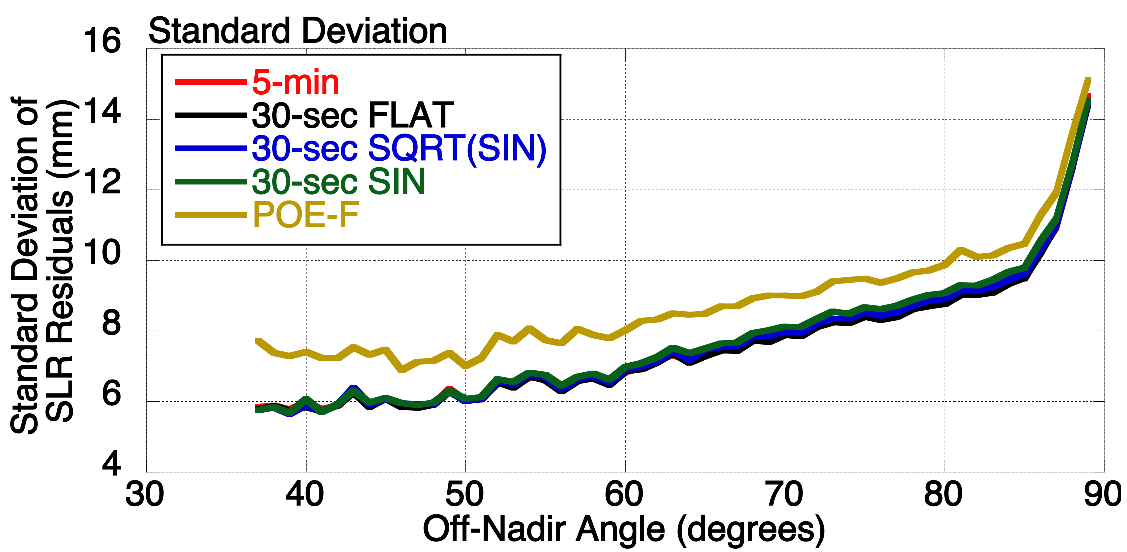
Relative Drift



- Relative bias of +/- 4 mm, and relative drift of +/- 0.5 mm/year between GPS-only orbit solutions and POE-F.

Small Impact from Using 30-sec Instead of 5-minute GPS Tracking Data (2020 OSTST)





- Similar performance of all GPS-only solutions.
  - 30-sec solutions biased higher than 5-min solutions by ~0.3 mm.
    - Consistent with orbit differences.
- GPS-only solutions biased higher than POE-F by 0.9 mm.
- GPS-only solutions have lower standard deviation than POE-F at all elevations.

Conclusions

- **Improvements to GPS-based precise orbit determination have been achieved using:**
  - **In-flight antenna calibrations.**
  - **Modern reference frames.**
  - **Observation-based models for azimuthal variations in GPS constellation transmitter calibrations.**

- **Independent assessment using withheld SLR tracking data improves when accounting for:**
  - **Annual geocenter motion at SLR tracking stations**
  - **Calibration for Laser Retroreflector Array instrument.**