GPS-Based Precise Orbit Determination of the Sentinel-6 MF Mission

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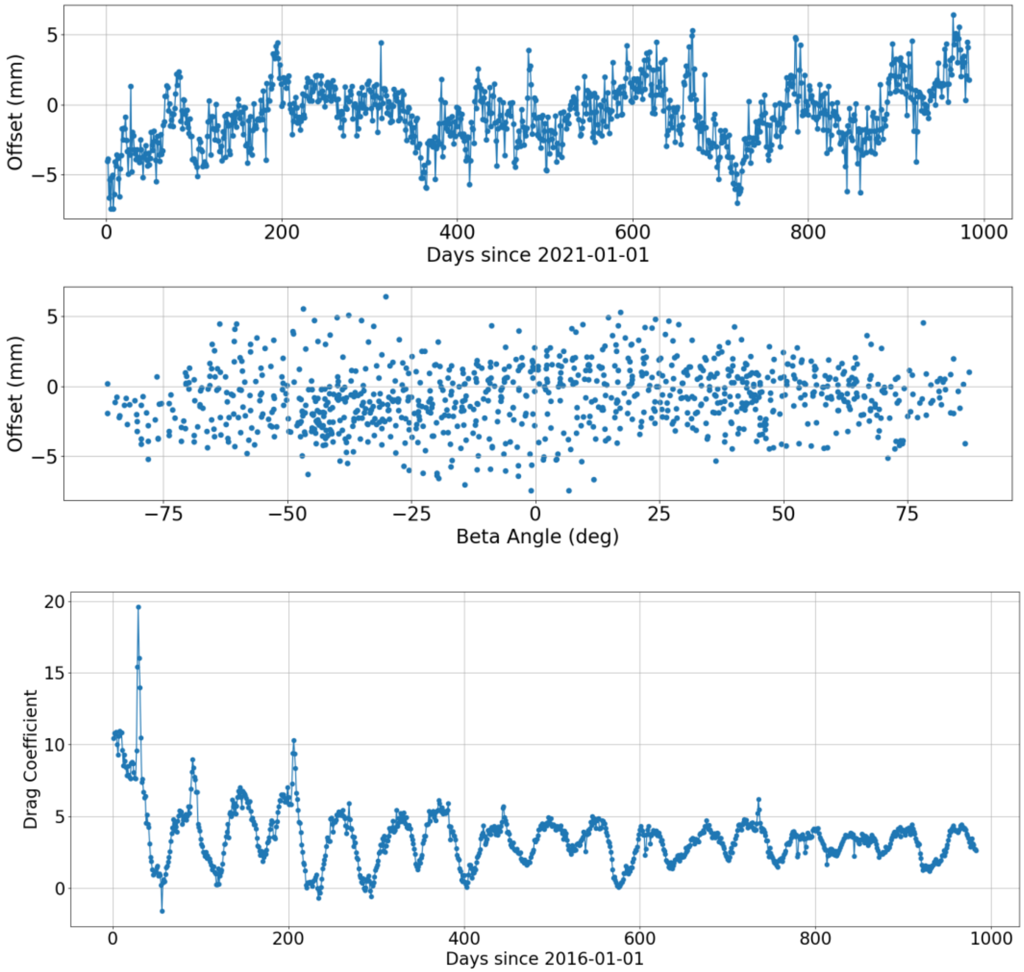
Overview

- Background models
- Orbit overlaps
- Solution Comparisons
  - SLR residuals
  - SSH Crossovers
  - Geographically Correlated Orbit Differences
- Conclusions

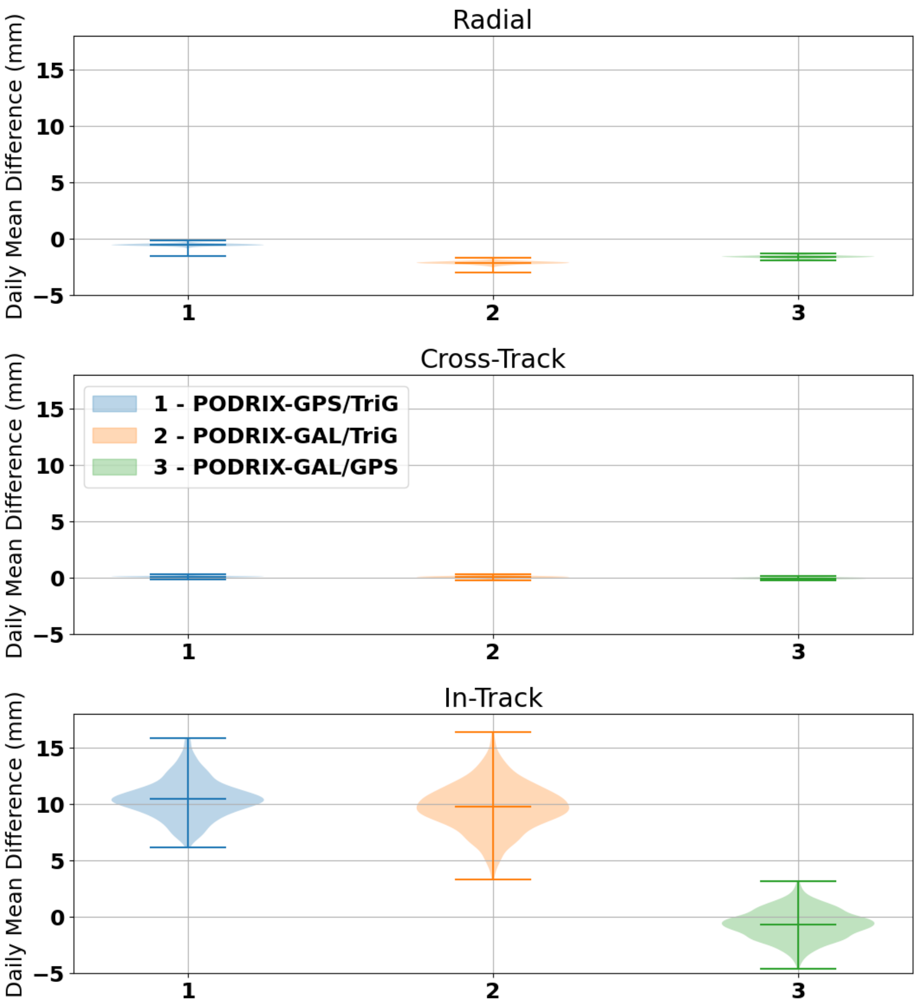
Background Models

- Solar radiation pressure (SRP) table applied
  - Earth radiation pressure uses custom macromodel
- Empirically estimated
- Allows for better modeling of the SRP forces
  - Much more consistent antenna-Y offset estimates across the beta angle cycle
  - More consistent drag coefficient estimates across the yaw-flip



TriG Time-Tag Bias

- TriG and PODRIX solutions show a ~1cm relative in-track bias
- This bias exists regardless of the applied constellation with the PODRIX
- SLR residuals suggest the TriG as the likely source of the bias

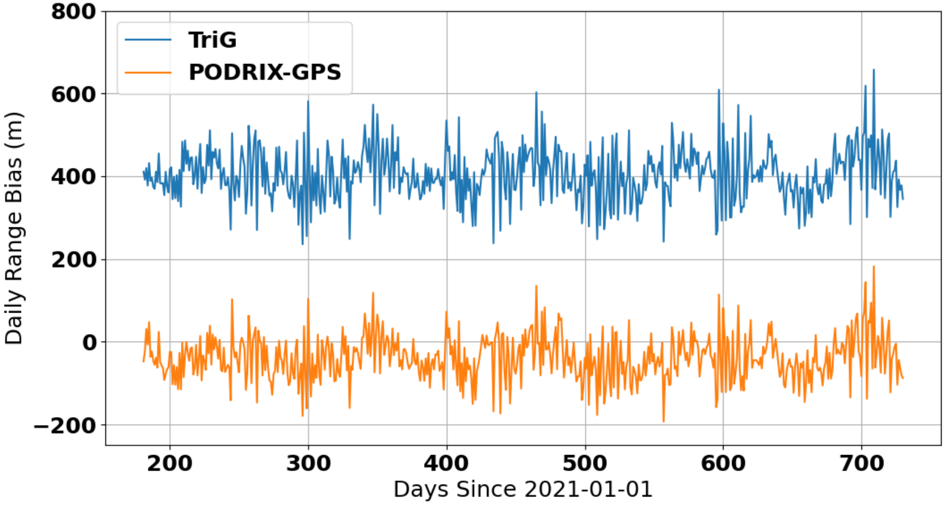


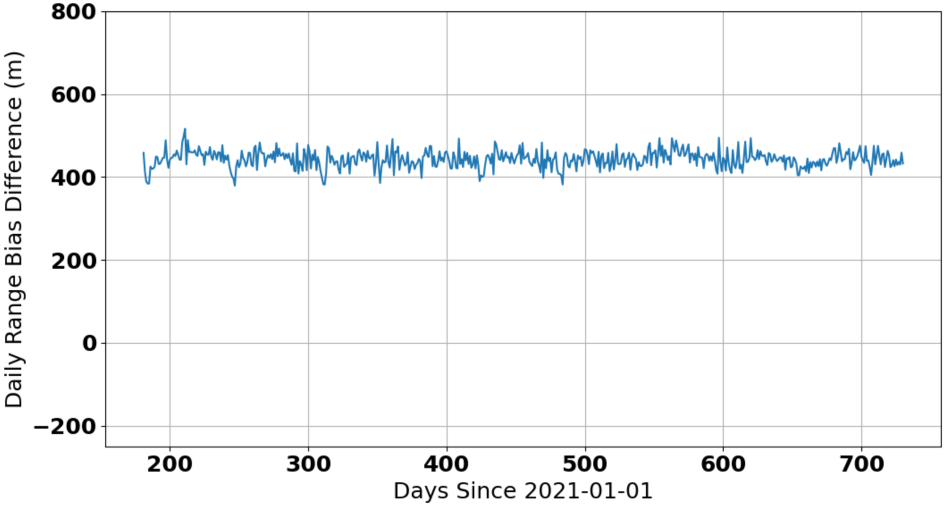
TriG Time-Tag Bias

- The modeled pseudorange incorporates the time-tag effect

$$\rho = r + \delta^{r}_{rx}(c - \dot{\rho}) + \cdots$$

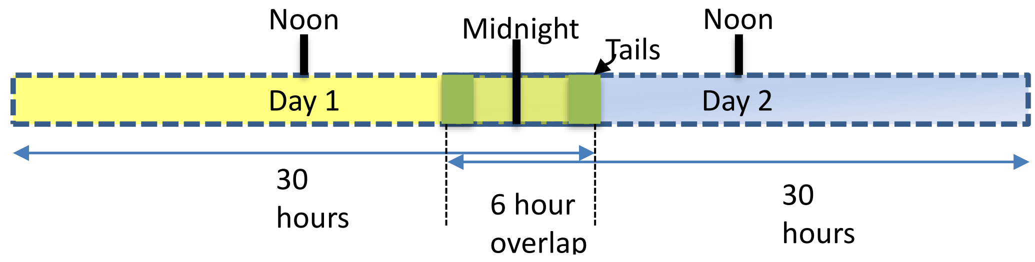
- TriG and PODRIX(GPS + Galileo) observations processed together
  - Range bias estimate for TriG and PODRIX-GPS only
- Resulting TriG range bias of ~400 m
- This is equivalent to a ~1.3 μs time-tag bias

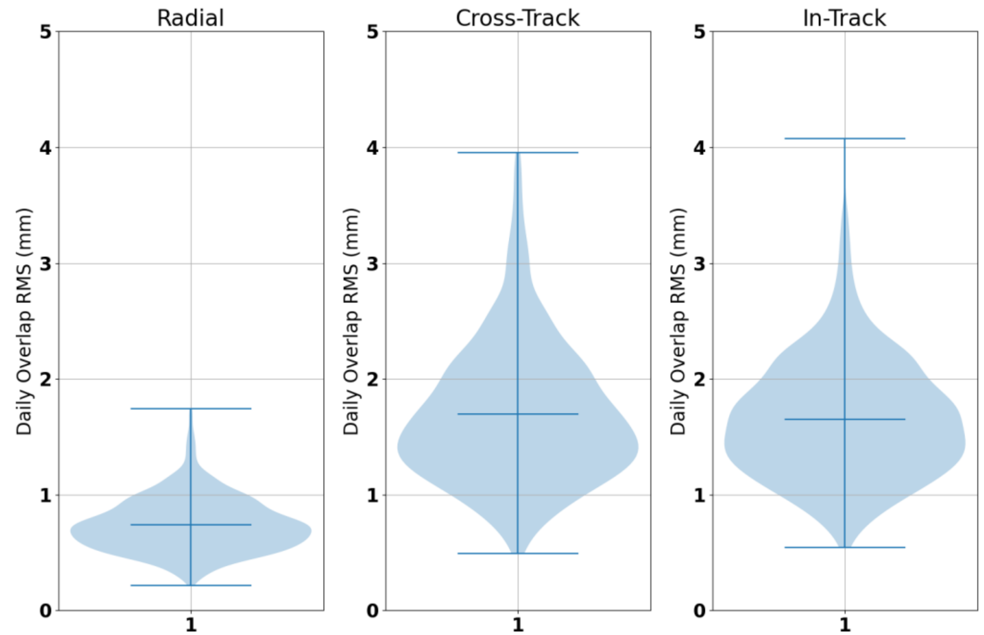




POD Internal Metrics - Overlaps

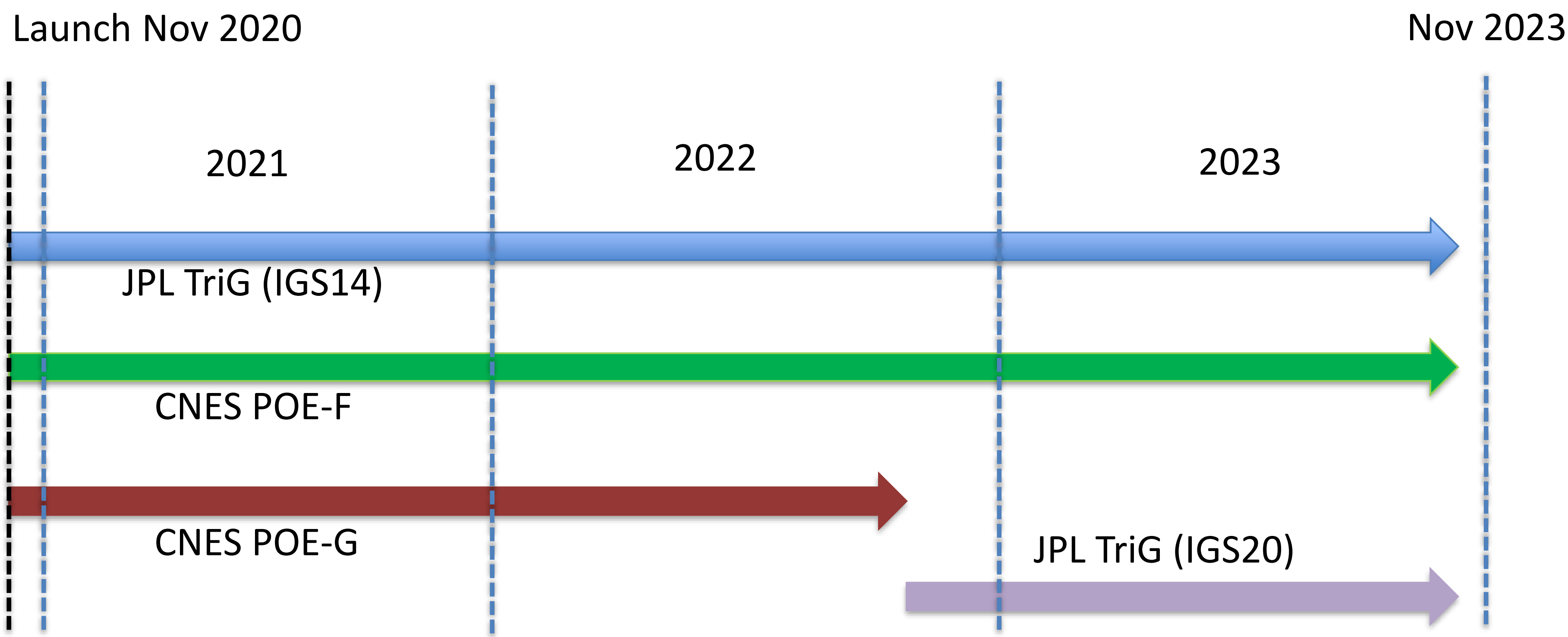
- Orbit Overlaps are a measure of the solution consistency
- Daily RMS computed from central 4 hours of 6-hour overlap period
- Sub-millimeter precision in the radial direction





	Radial (mm)	Cross-track (mm)	In-track (mm)
Overall Mean ± Std	0.74 ± 0.23	1.7 ± 0.6	1.7 ± 0.5

Solution Comparisons



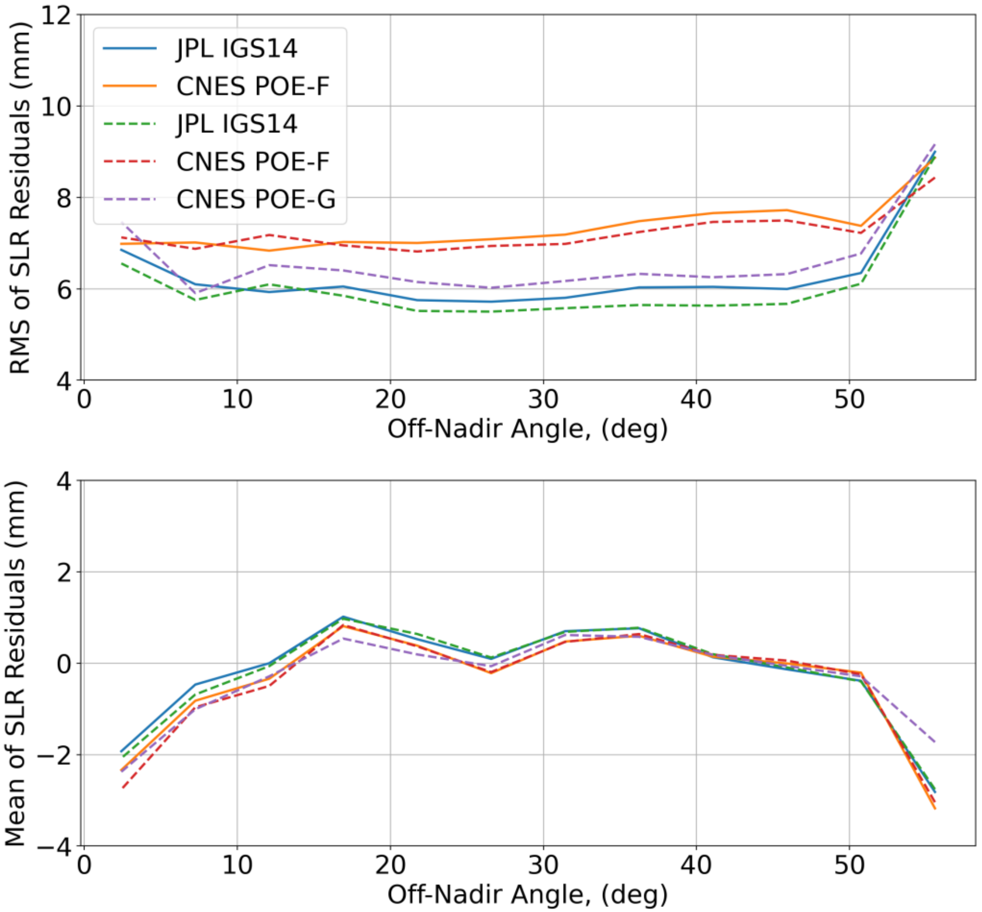
Orbit Validation – SLR

- One-way residuals from 13 best performing stations
- Removed station bias from SLR residuals

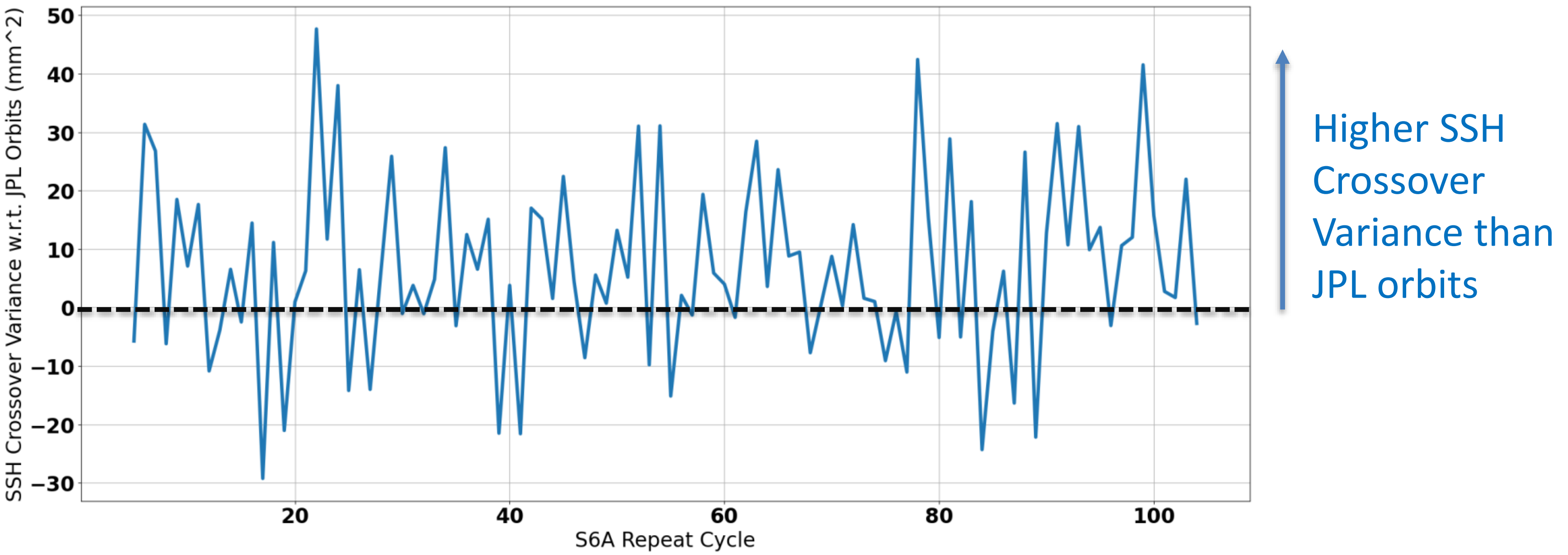
Solid Line	Overall RMS (mm)
JPL IGS14	6.2
CNES POE-F	7.5

- Residual RMS over CNES POE-G Time span

Dashed Line	Overall RMS (mm)
JPL IGS14	5.9
CNES POE-F	7.3
CNES POE-G	6.5



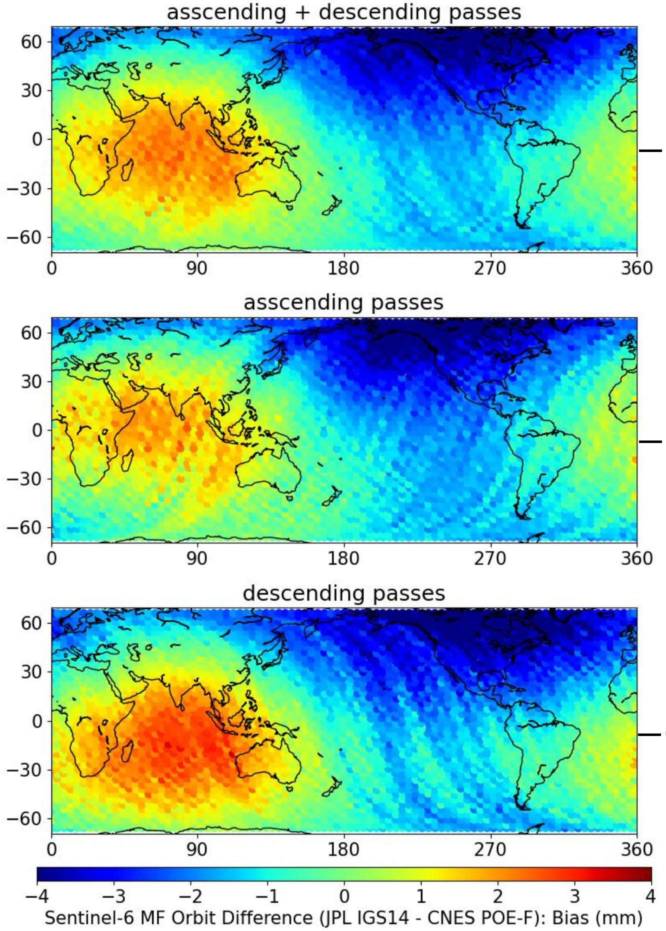
Orbit Validation – SSH Crossover Variance



- JPL's TriG based solutions have slightly lower SSH crossover variance than CNES POE-F solutions
  - Overall mean of SSH crossover variance w.r.t. to JPL-TriG of 7.0 mm^2

Geographically Correlated Radial Orbit Differences: JPL IGS14 vs. CNES POE-F/G (Bias)

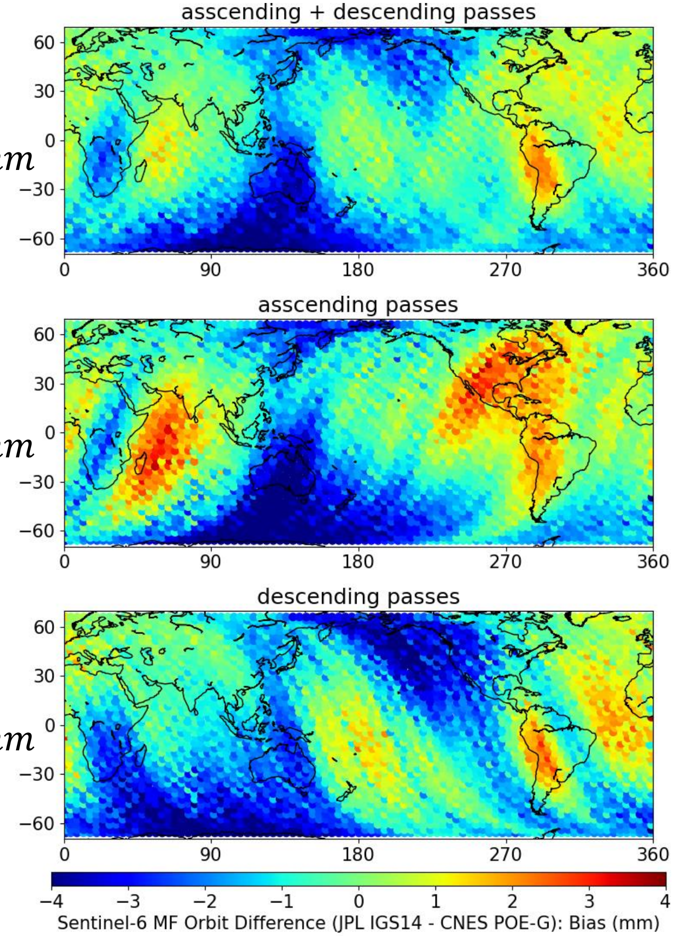
Relative Bias POE-F



Global Bias

POE-F	POE-G
$-0.97\ mm$	$-0.98\ mm$
$-0.96\ mm$	$-0.99\ mm$
$-0.98\ mm$	$-0.94\ mm$

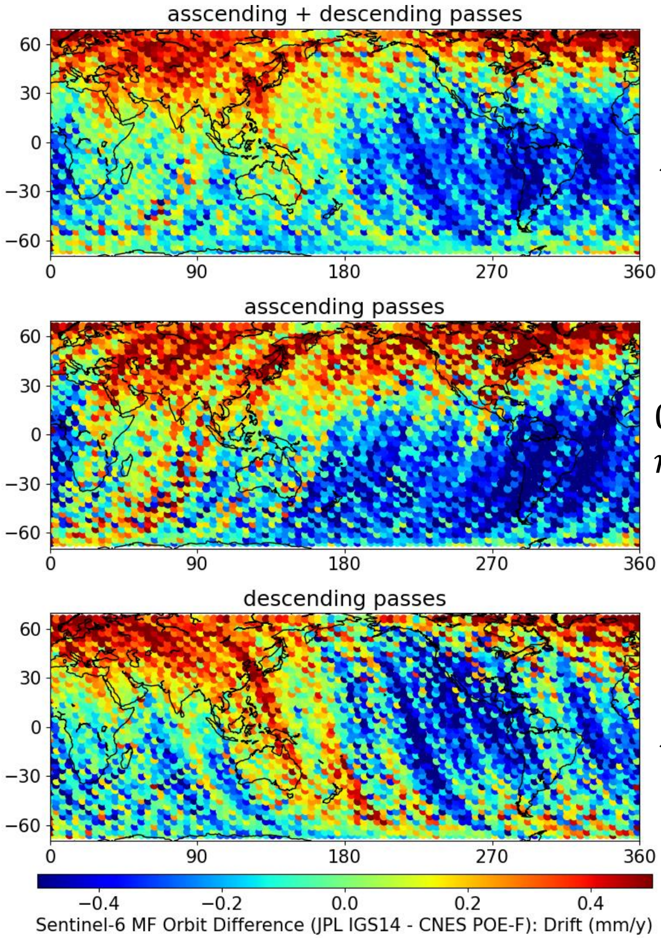
Relative Bias POE-G



- Geographically correlated biases of +/- 4 mm between both solutions
- JPL/POE-G has less consistency between ascending and descending passes

Geographically Correlated Radial Orbit Differences: JPL IGS14 vs. CNES POE-F/G (Drift)

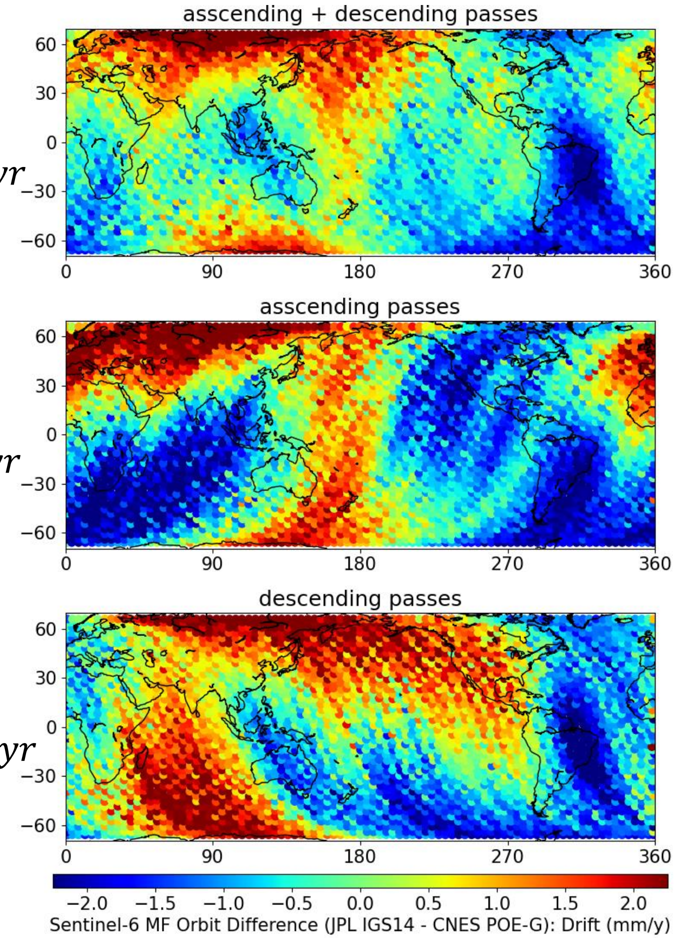
Relative Drift POE-F



Global Drift

POE-F	POE-G
$0.05\ mm/yr$	$0.003\ mm/yr$
$0.01\ mm/yr$	$-0.07\ mm/yr$
$0.08\ mm/yr$	$0.07\ mm/yr$

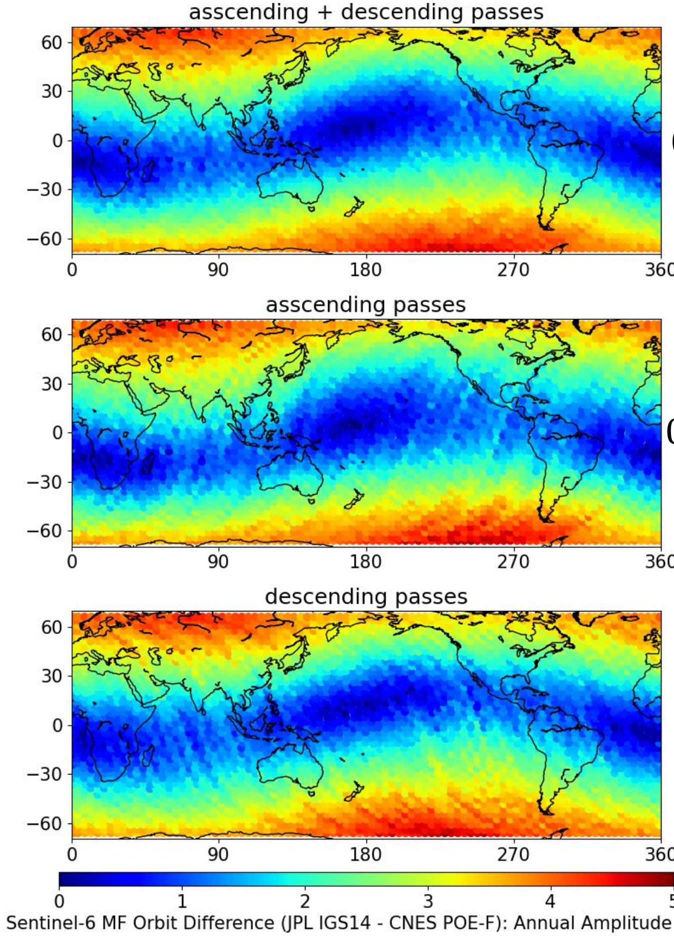
Relative Drift POE-G



- Much larger relative drift between JPL IGS14 and CNES POE-G
- Perhaps related to the age of the IGS14 frame

Geographically Correlated Radial Orbit Differences: JPL IGS14 vs. CNES POE-F/G (Annual)

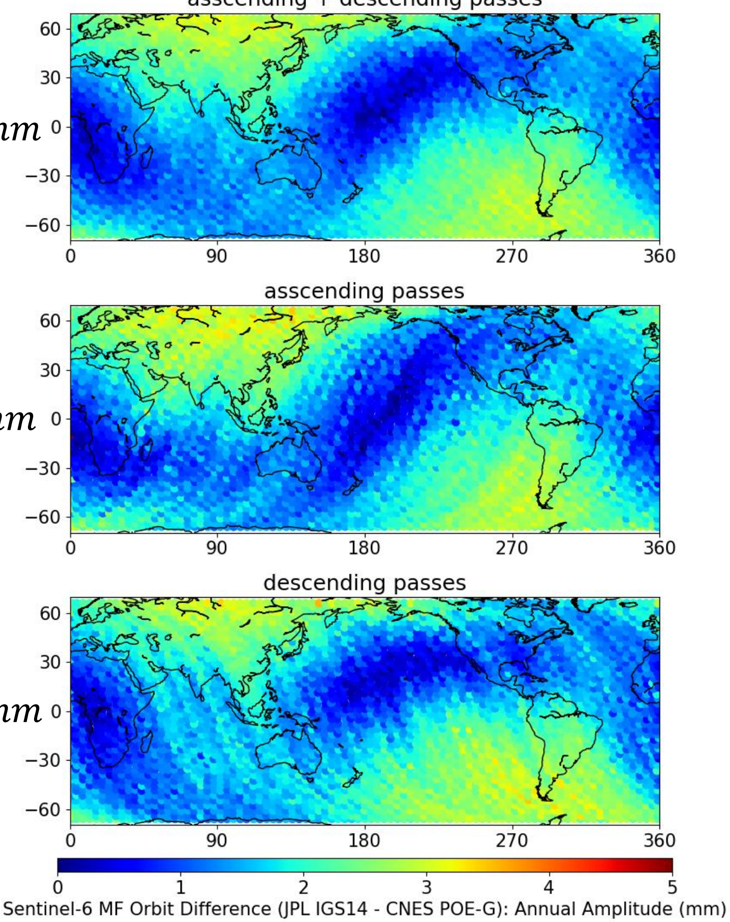
Annual POE-F



Global Amplitude

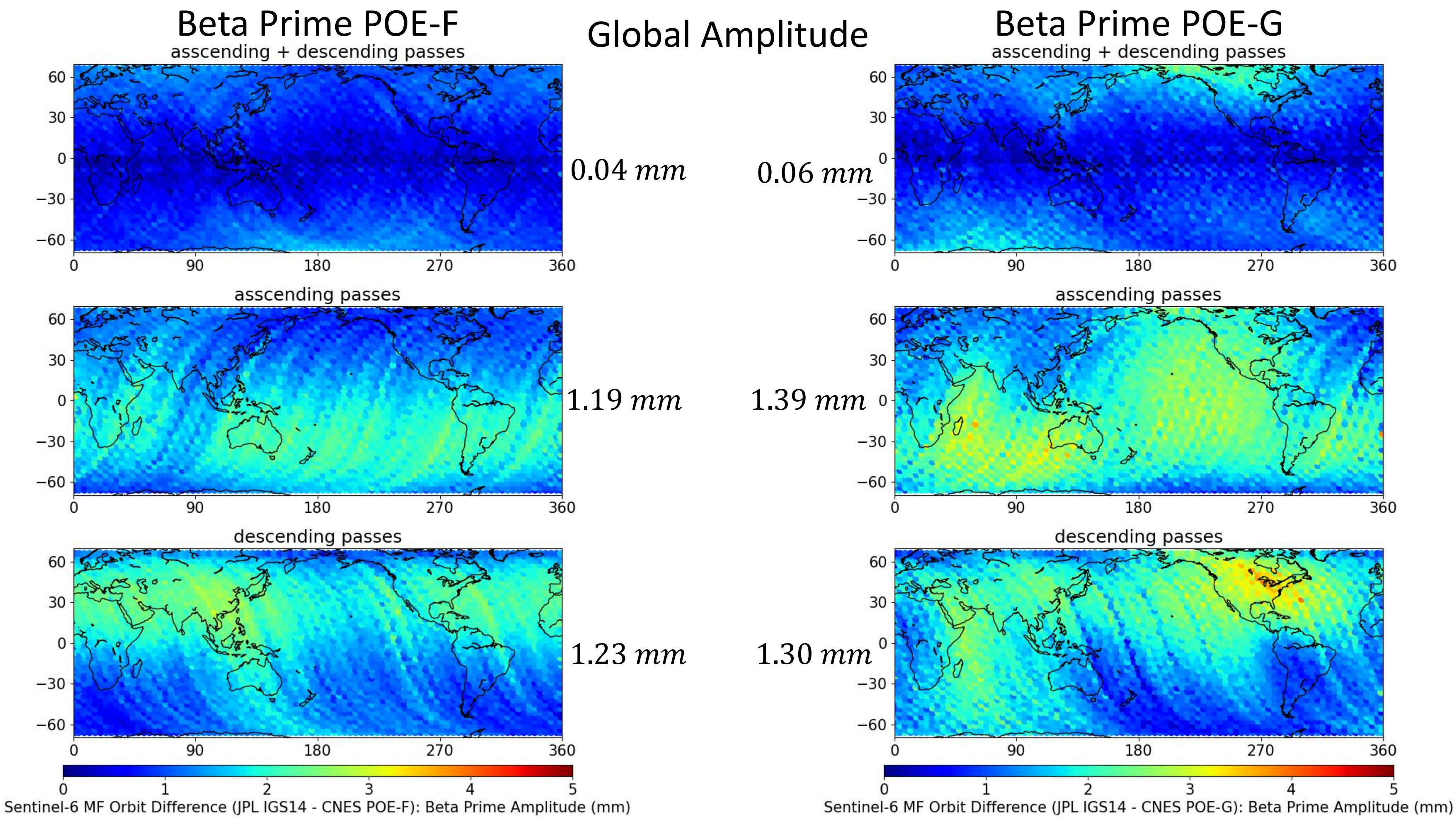
	POE-F	POE-G
ascending + descending	$0.07\ mm$	$0.08\ mm$
ascending	$0.04\ mm$	$0.05\ mm$
descending	$0.18 mm$	$0.20 mm$

Annual POE-G



- Fairly strong annual signal in JPL vs POE-F
- Greatly reduced in the JPL vs POE-G
  - Remaining signal potentially related to IGS14 products

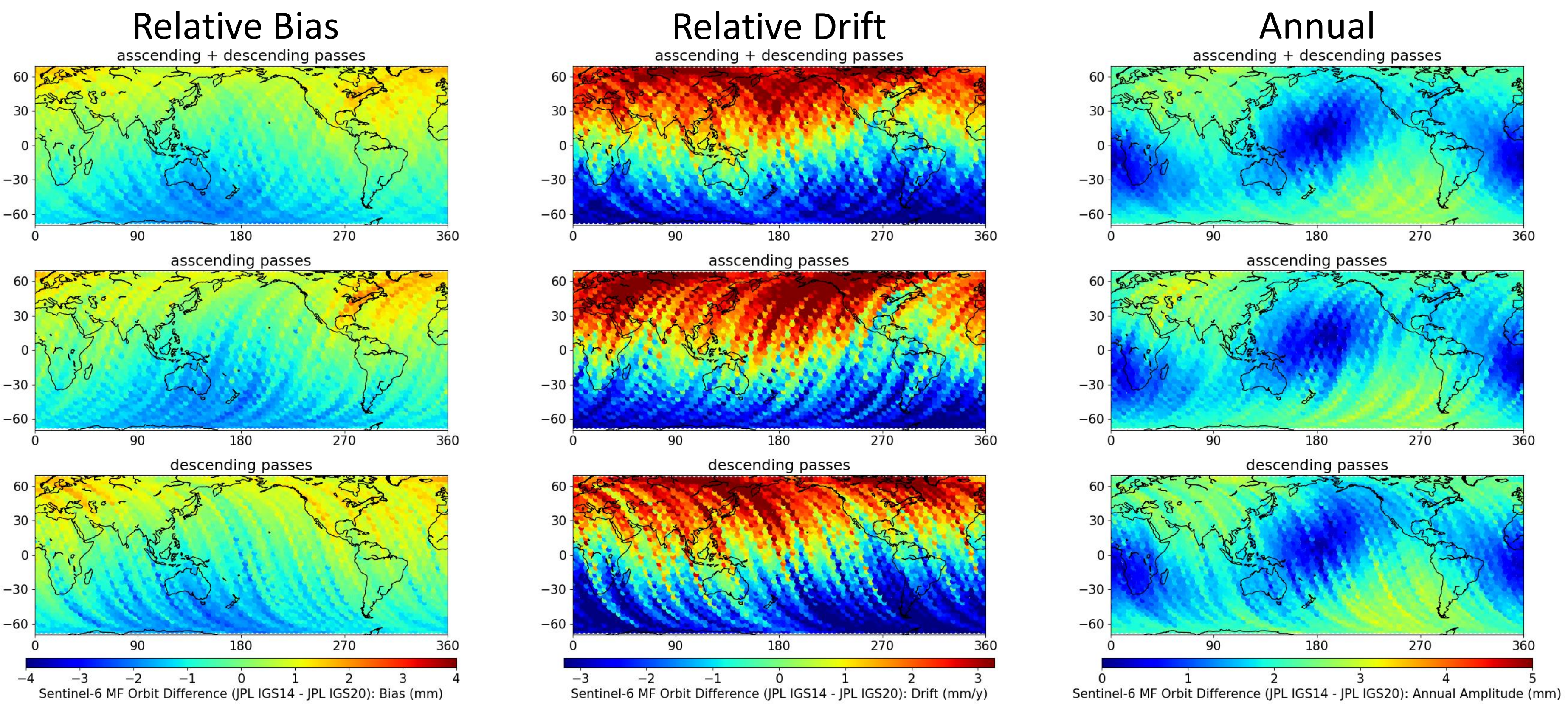
Geographically Correlated Radial Orbit Differences: JPL IGS14 vs. CNES POE-G/F (Beta Prime)



- Very small total signal, but larger on ascending and descending passes
- Beta prime signal similar between POE-F/POE-G

Geographically Correlated Radial Orbit Differences: JPL IGS14 vs. JPL IGS20 Rapid

Only 11 months of IGS20 Rapid solutions



- North/south bias of +/- 2.5 mm
- Much larger drift, also north south
- Same structure in annual amplitude as JPL IGS14 vs POE-F

Conclusions

- JPL-TriG based solutions show good precision and accuracy as inferred by orbit overlaps, and SLR residuals
- Similar SSH crossover variance performance from JPL-TriG and CNES POE-F.
- Geographically correlated errors exist between the JPL-TriG and CNES POE solutions
  - Strong annual signal between JPL/POE-F is much smaller in JPL/POE-G and has geographically correlated structure similar to the JPL IGS14/20 differences
  - Relative differences are dependent on the orbit and clock product (IGS14/IGS20)

List of SLR Stations Used in This Study

Station ID	Station Name	Station ID	Station Name
7105	Greenbelt, Maryland	7841	Potsdam, Germany
7839	Graz, Austria	7827	Wettzell, Germany
7119	Haleakala, Hawaii	7825	Mt Stromlo, Australia
7501	Hartebeesthoek, South Africa	7501	Hartebeesthoek, South Africa
7840	Herstmonceux, United Kingdom	7124	Tahiti, French Polynesia
7701	Izaña (Tenerife), Spain	8834	Wettzell, Germany (WLRS)
7941	Matera, Italy (MLRO)		

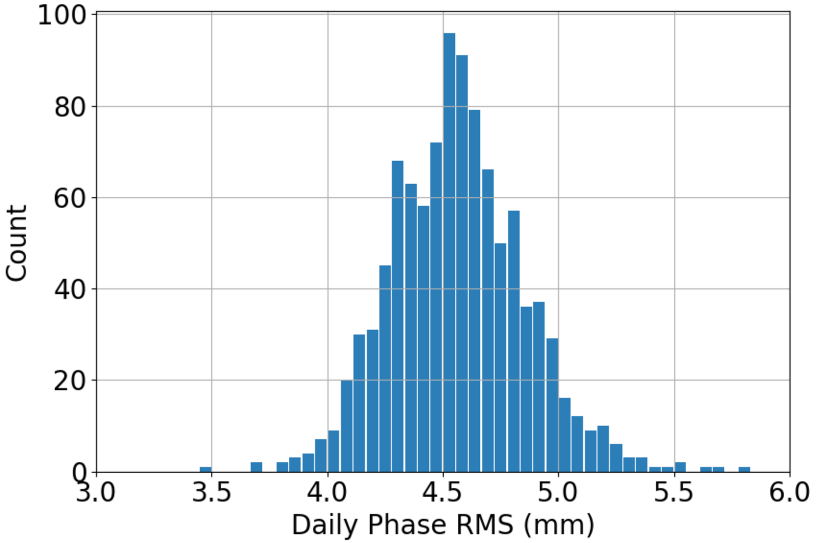
- Single station bias removed over entire time-span

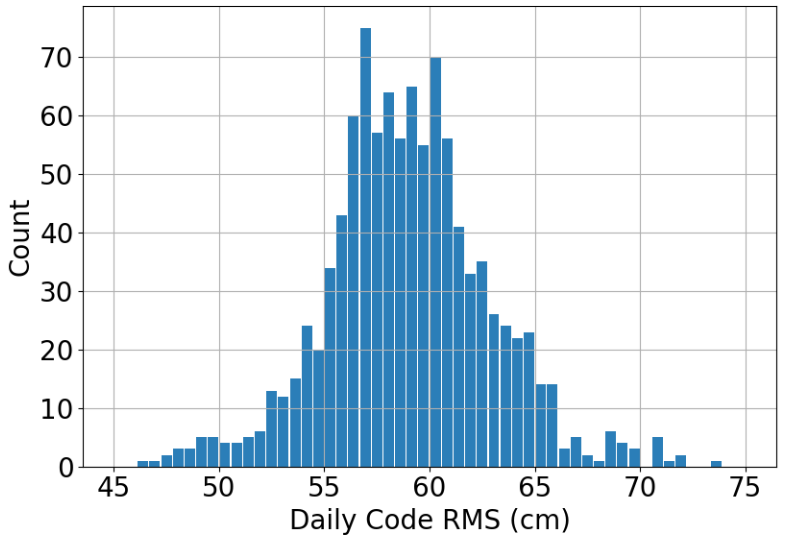
POD Internal Metrics - RMS

- Solutions derived only from TriG observations
- Daily post-fit residual RMS for phase and pseudorange
- Very consistent phase residuals
- Pseudorange residuals larger than those observed for Jason-3
  - Contains significant transmitter dependent biases (see backup)
  - May be contributing to lower than expected TriG wide-lane ambiguity resolution

	Overall RMS (mm)
Phase (L1W/L2W)	4.6 ± 0.3
Code (C1W/C2W)	570 ± 40

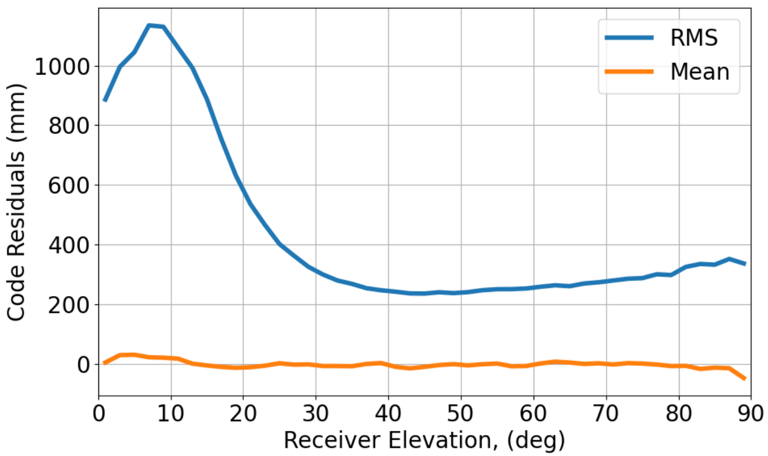
Mean +/- std

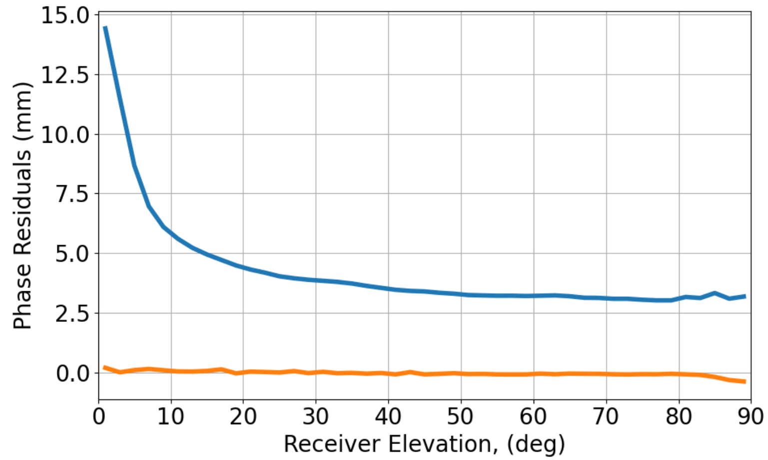




Backup

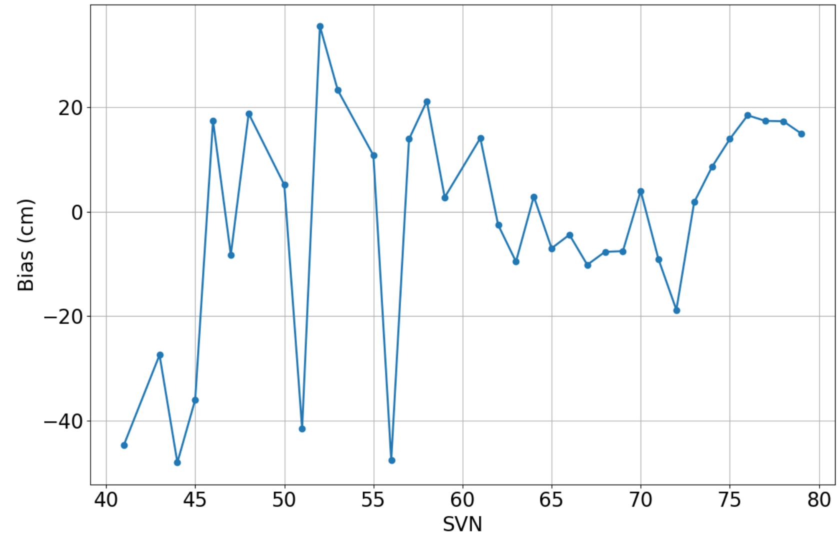
- Code and phase residuals in the receiver frame
- Increase in code residual RMS occurs around 30 degrees, but for phase is relatively flat until about 10-15 degrees

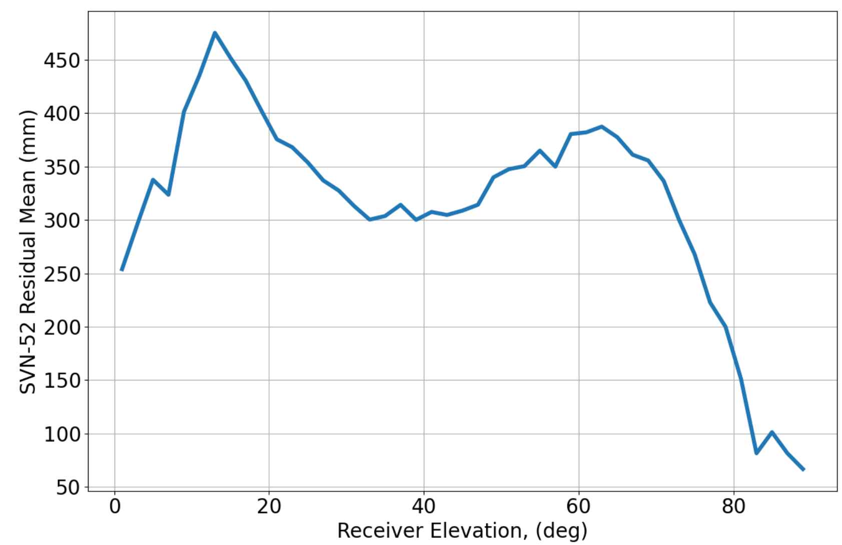




Transmitter Dependent Biases

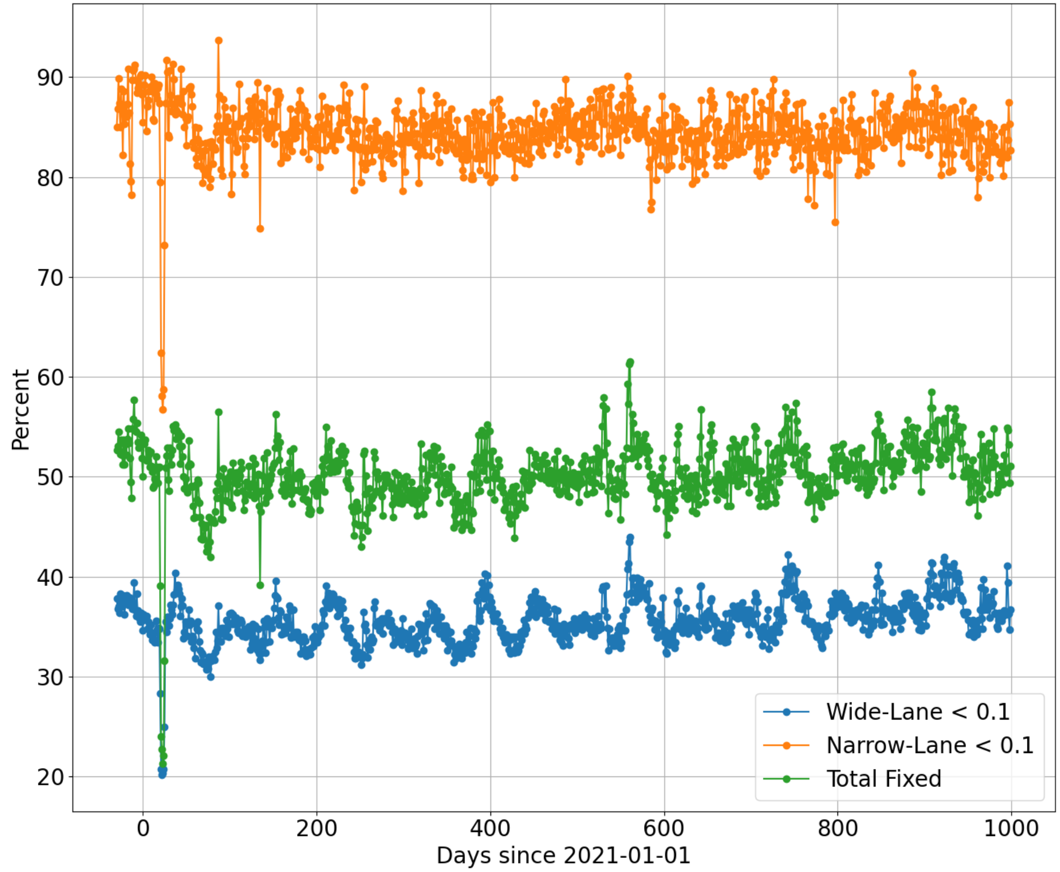
- The larger code residual RMS is due primarily to significant transmitter dependent biases
- These are largest in the older transmitters
- This could be related to the poor wide-lane resolution of the TriG





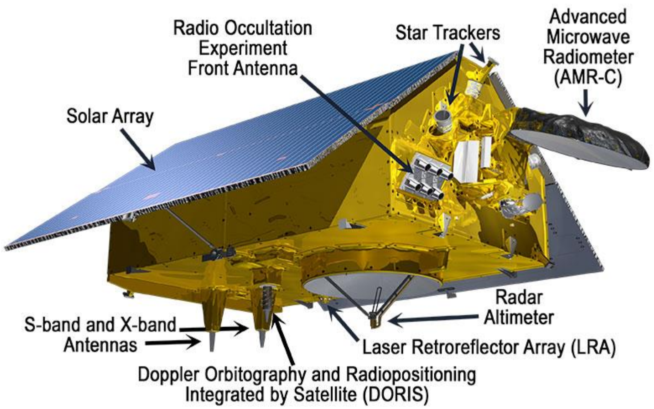
POD Internal Metrics - AmbRes

- Narrow-lane resolution performance is quite good
- Wide-lane resolution is very low
- This results in only about 50% of possible double difference combinations being constrained



Introduction

- Sentinel-6 MF is the current reference ocean altimeter mission
  - Altitude 1336 km
  - Inclination of 66 degrees
  - 9.92-day ground track repeat period
- Altimetry requires precise orbit determination (POD)
- Four independent tracking systems
  - DORIS, LRA, multi-GNSS PODRIX receiver, GPS TriG receiver (RO)
- Focus on JPL POD performance with TriG receiver and comparisons to CNES-POE



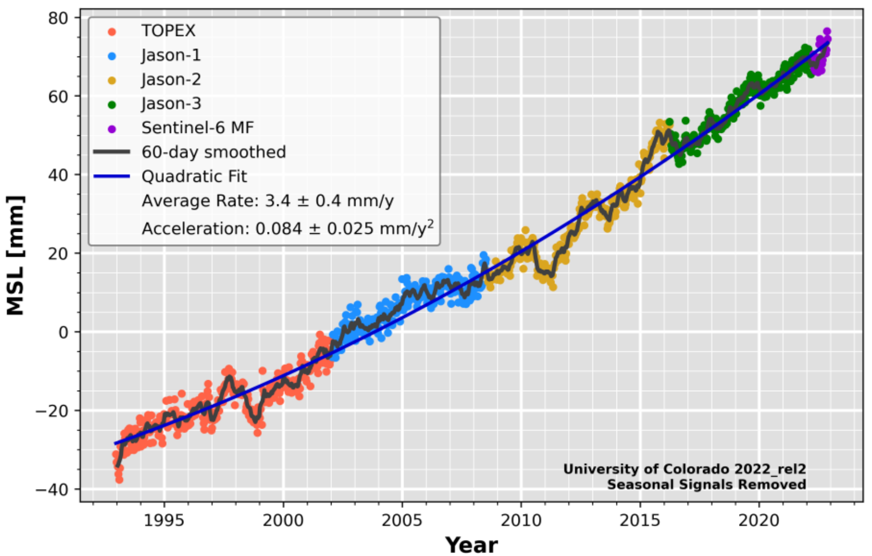


Image Credit: Sea Level Research Group, CU, *Nerem et. al.*