An Introduction to the GPS-OGDR-SSHA Product for OSTM/Jason-2

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Motivation: OGDR-SSHA vs. IGDR-SSHA

SSHA Parameter		OGDR	IGDR	RMS Difference, IGDR-OGDR (mm)
Orbit Altitude		**DIODE**	**MOE (DORIS/SLR)**	**38**
Ku Range		Retracked	Retracked	22
Dry Troposphere		Predicted	Analyzed	2
Wet Troposphere:	AMR	Uncalibrated	Uncalibrated	< 1
	Model	Not Available	Available	
Ionosphere:	ALT	Dual frequency	Dual frequency	13
	Model	Not Available	Available	
Sea State Bias		Uncalibrated	Uncalibrated	4
Inverse Barometer		Predicted	Analyzed	9
Pole Tide		Predicted	Predicted	0
HF Dealiasing		Not Available	Preliminary	
OGDR-SSHA				**47**

- **Goal: Improve accuracy of OSTM/Jason-2 near-real-time (NRT) OGDR-SSHA product by improving accuracy of NRT orbit for OSTM/Jason-2.**
  - Leverage experience with NRT GPS-based precise orbit determination (POD) for Jason-1 NRT SSHA product.

The GPS-OGDR-SSHA Product

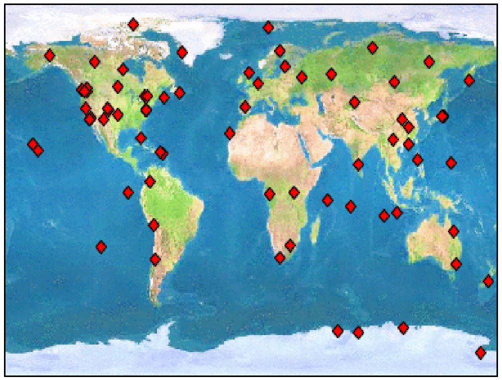
- GPS-OGDR-SSHA product derived by adding two fields to project's OGDR-SSHA product:
  - Orbit altitude derived from new generation NRT GPS-based precise orbit determination of OSTM/Jason-2.
    - **Radial orbit accuracy of < 1 cm (RMS)**
  - Sea surface height anomaly (SSHA) from GPS-based orbit altitude.
    - Identical to SSHA field from OGDR-SSHA except uses GPS-based orbit instead of real-time onboard DORIS-DIODE orbit.
- **Typical latency of 3.5-5 hours (Lag of 1 OGDR).**
  - Compromise between orbit accuracy and latency.
  - Could be reconfigured based on user feedback.
- Also have two higher accuracy, but longer latency, GPS-based orbit products:
  - Next-day and precise orbit ephemeris (POE).
  - Use as reference to evaluate accuracy of NRT orbit.

Near-Real-Time Precise Orbit Determination: OSTM/Jason-2 versus Jason-1

- NRT GPS-based radial orbit accuracy for OSTM/Jason-2 has significant improvement over Jason-1:
  - **< 2.5 cm (RMS) for Jason-1.**
  - **< 1.0 cm (RMS) for OSTM/Jason-2.**
- Primarily due to use of higher accuracy orbit and clock solutions for GPS constellation.
  - NASA's Global Differential GPS system (GDGPS) solutions used for Jason-1 NRT POD (and OSTM/Jason-2 until May 30, 2009).
    - GDGPS GPS orbits: 3-D orbit accuracy of < 20 cm (RMS), 1 second latency.
  - **JPL's Ultra-Rapid GPS solutions used for OSTM/Jason-2 NRT POD.**
    - **Ultra-Rapid GPS orbits: 3-D orbit accuracy of < 5 cm (RMS), 1 hour latency.**
    - **Ultra-Rapid products enable ambiguity resolved precise orbit determination.**
    - Ultra-Rapid is new JPL product developed in 2009.
      - Computed using GIPSY/OASIS software with backward smoothing and ambiguity resolution.
      - Uses optimally distributed 40 out of 140 global terrestrial GPS sites.

GPS NRT Orbit Determination Approach

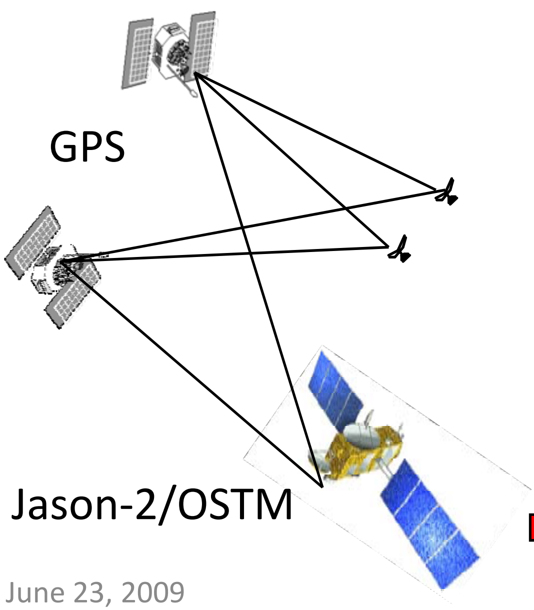
Global GPS Network



Hourly Transfer of Terrestrial GPS Data

GIPSY/OASIS
Computes orbit and clock solutions for GPS constellation.
30-hour orbit solution.
Updated hourly.

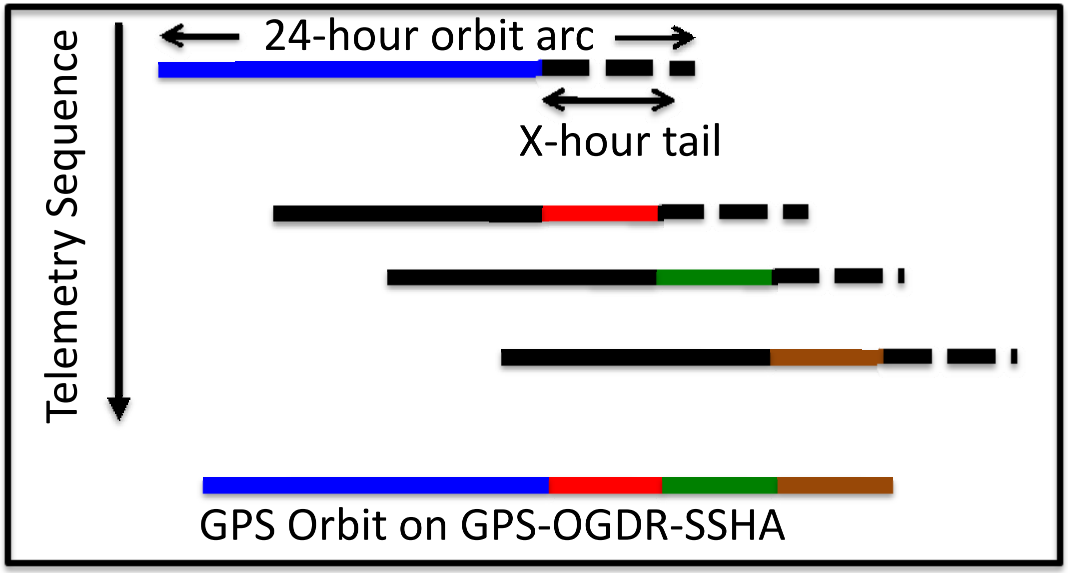
JPL's Ultra-Rapid GPS Orbit and Clock Solutions
3-D Accuracy: <5 cm (RMS)
Latency: 1 hour



Jason-2 GPSP Tracking Data Telemetry
Telemetry received with < 1 hour latency.

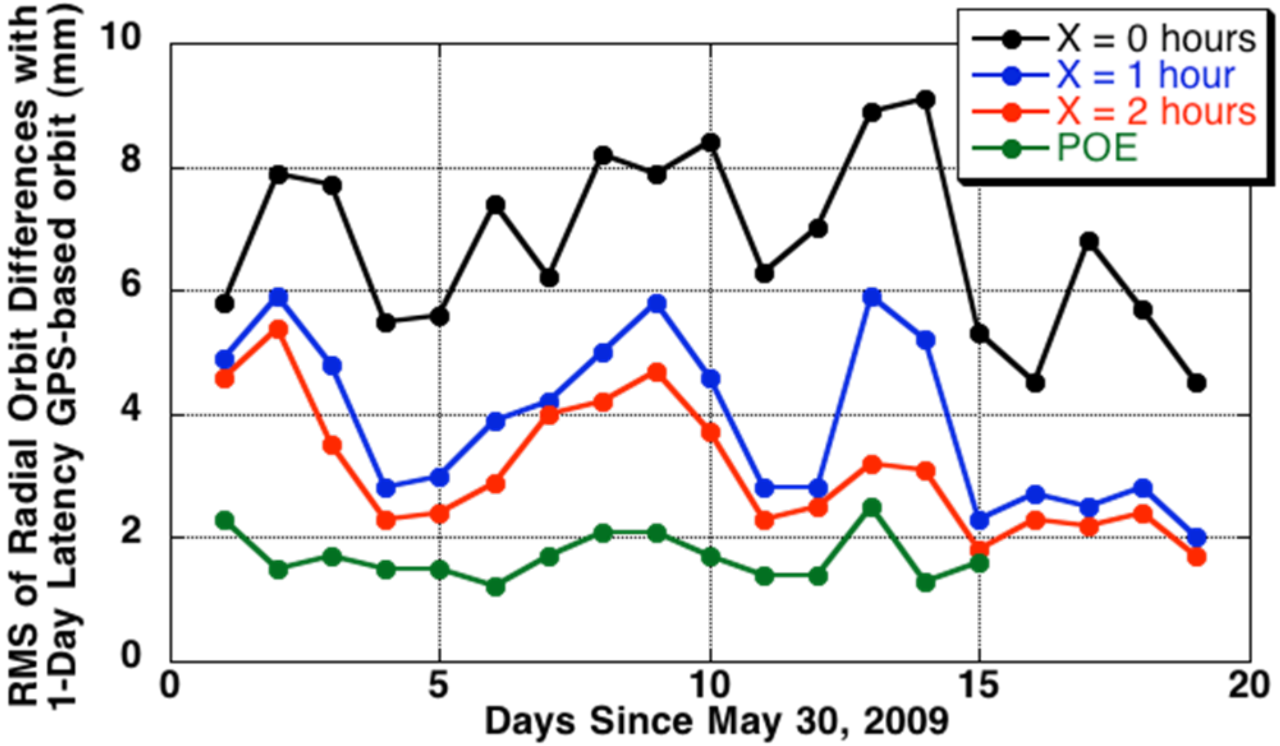
Near-Real-Time Jason-2/OSTM Precise Orbit Determination
Triggered by arrival of:
GPSP Telemetry
Ultra-Rapid GPS Products
<u>**Radial Accuracy**</u>
<u>**< 1.0 cm (RMS)**</u>
<u>**3.5-5 hour latency.**</u>

GPS-based Orbits for GPS-OGDR-SSHA



- 24-hour POD solution arcs ending with each new telemetry dump.
- Ignore X-hours of tail of orbit solution.
  - Compensates for “bow-tie effect”, where orbit errors larger at edges of orbit determination arcs.
  - Tested X = 0, 1, and 2 hours.
- Append orbit solutions where not already defined.
- X = 1 hour presently adopted in GPS-OGDR-SSHA product.
  - Largest gain in accuracy versus increased latency.

Orbit Differences with Next-Day Precise GPS-based Orbit

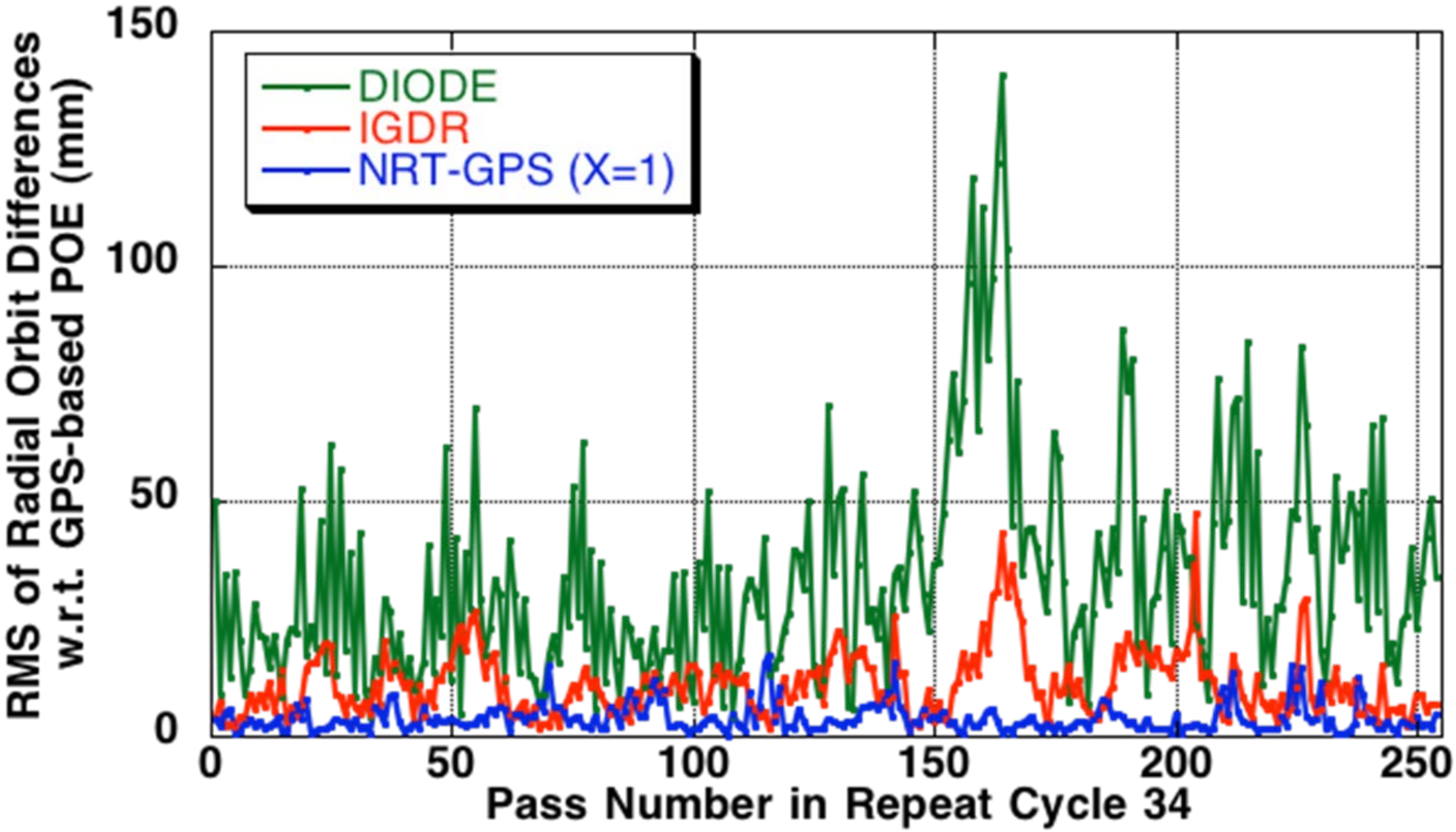


Average of Daily Radial RMS of Orbit Differences w.r.t. Next-day Orbit.

GPS-based Orbit	Average (mm)
NRT, X=0	6.8
NRT, X=1	3.9
NRT, X=2	3.1
GPS POE	1.7

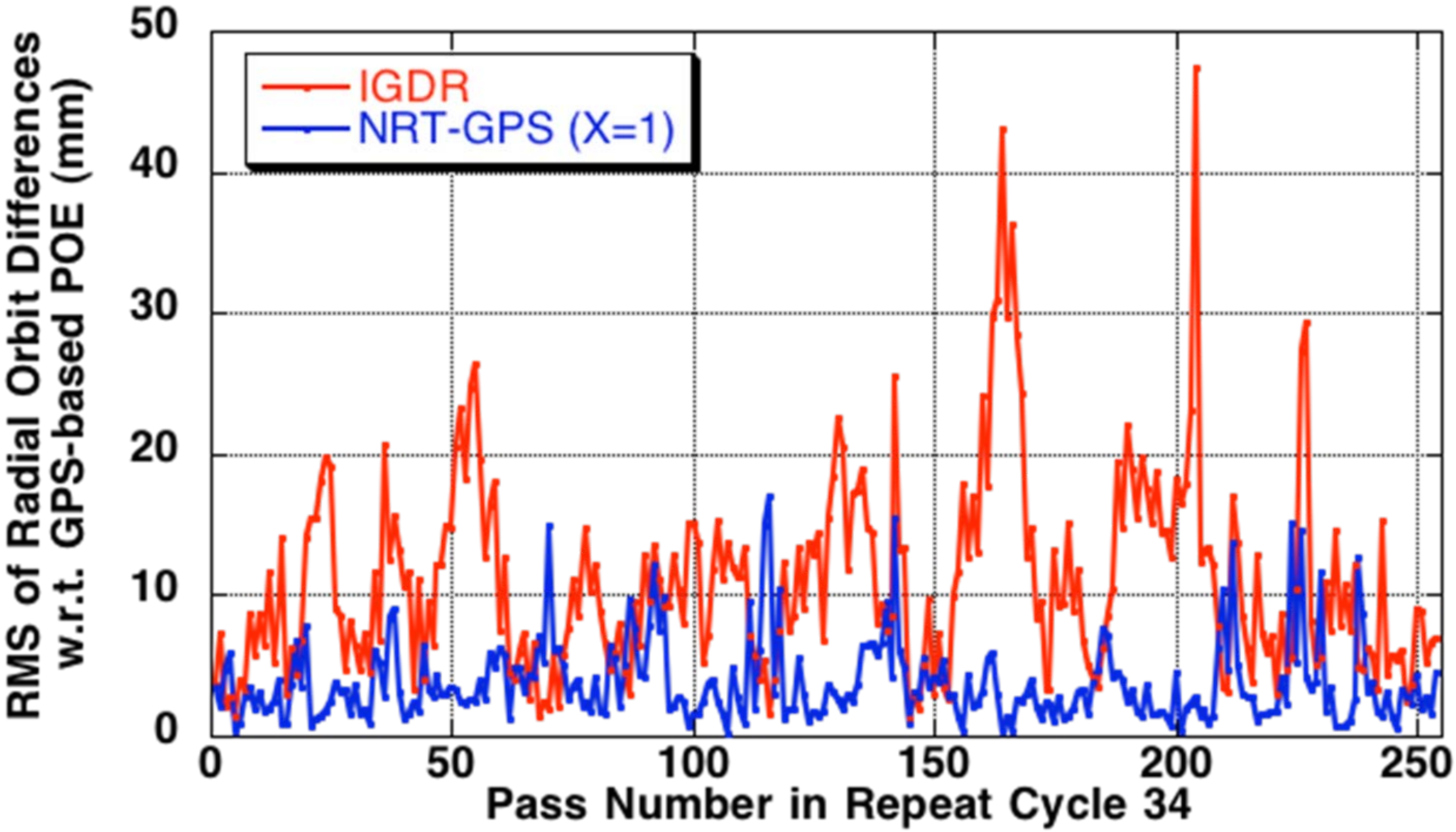
- GPS-based next-day and GPS-based POE agree to < 2 mm (RMS).
- 1 hour orbit cutoff requires latency of 1 OGDR lag, but provides significant (2.9 mm RMS) gain in radial orbit accuracy.
- 2 hour orbit cutoff provides additional 0.8 mm (RMS) improvement in radial orbit accuracy, but requires lag of 2 OGDRs.

Orbit Differences with GPS-based POE: Cycle 34



- RMS of difference over complete cycle 34:
  - DIODE: 40.9 mm   IGDR: 12.9 mm   NRT-GPS: 4.8 mm

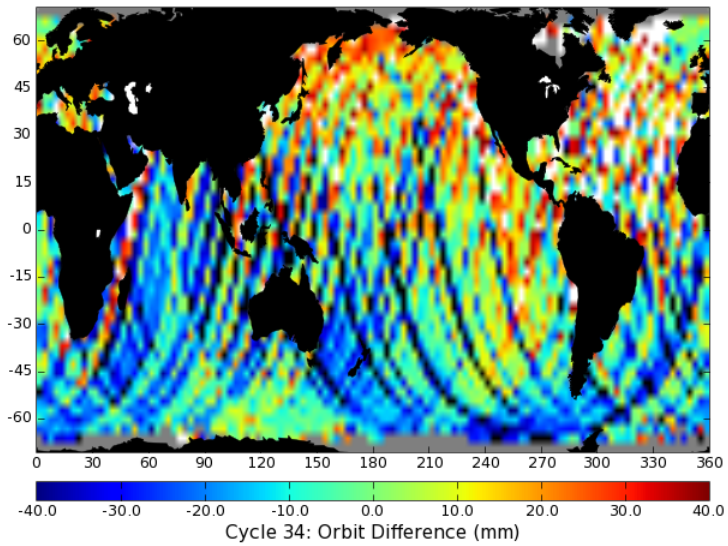
Orbit Differences with GPS-based POE: Cycle 34



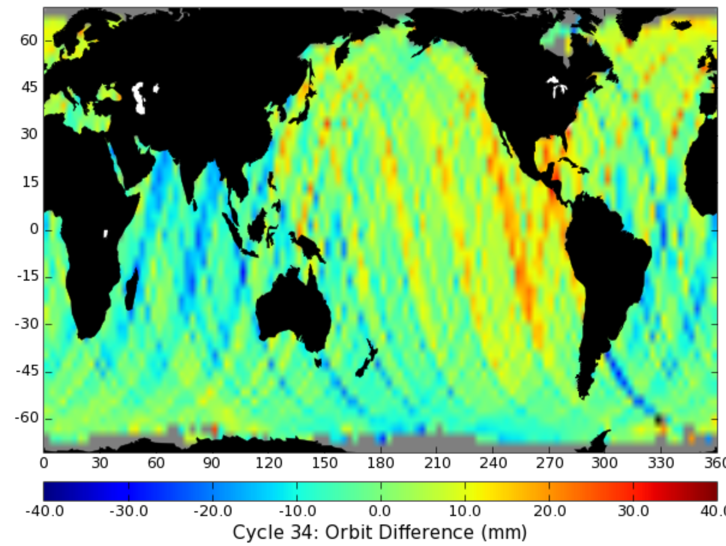
- Over entire cycle, NRT-GPS orbit has better agreement with GPS-based POE than IGDR orbit by 8.1 mm (RMS).
- Some passes where IGDR orbit has better agreement with GPS-based POE.

Geographically Correlated Differences

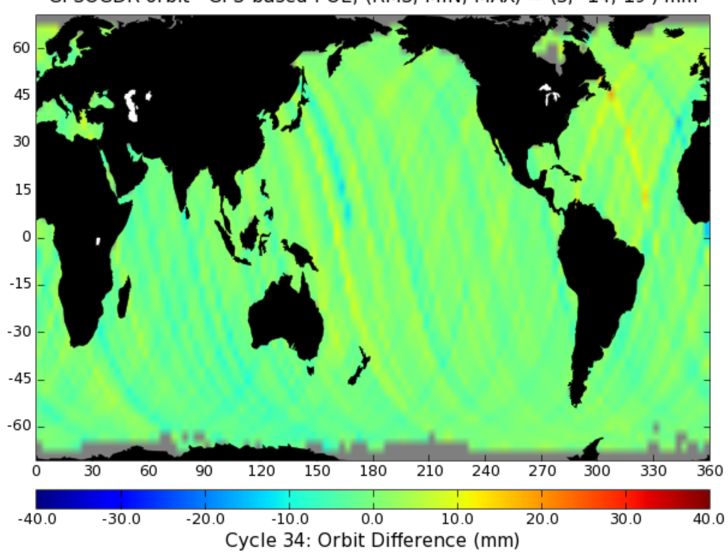
OGDR orbit - GPS-based POE, (RMS, MIN, MAX) = (27, -118, 165) mm



IGDR orbit - GPS-based POE, (RMS, MIN, MAX) = (9, -44, 44) mm

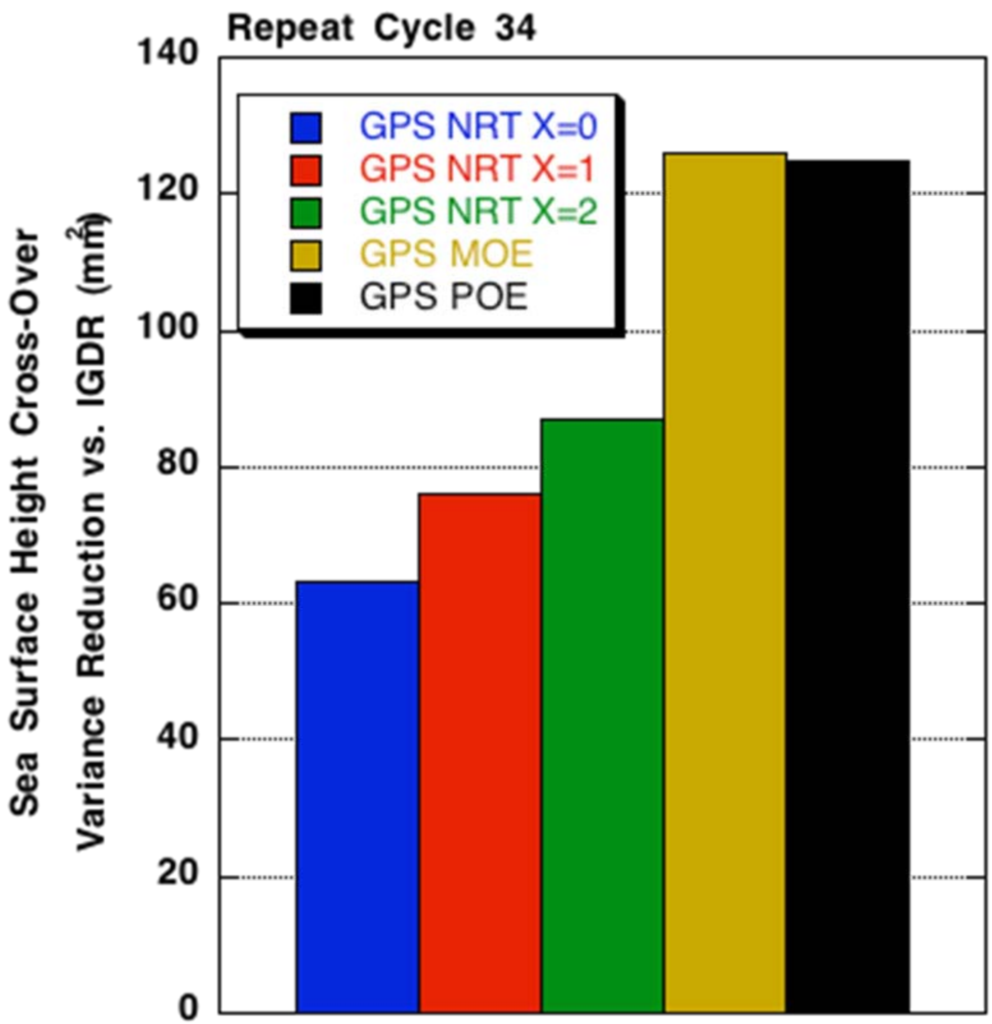


GPSOGDR orbit - GPS-based POE, (RMS, MIN, MAX) = (3, -14, 19) mm



- GPS-OGDR orbit provides order of magnitude reduction of geographically correlated errors compared to OGDR orbit.

Sea Surface Height Cross-Over Variance Reduction w.r.t IGDR Orbit



- All GPS-based orbits provide smaller SSH X-over residual variance than IGDR orbit.
- GPS-based POE and next-day orbits statistically identical.
- Residual variance with GPS POE smaller than with GPS-OGDR orbit by 49 mm^2
- **GPS-OGDR orbit has radial orbit accuracy of < 1 cm(RMS).**
  - E.g. Difference between GPS POE and GSFC POE (DORIS/SLR) is 7 mm (RMS).

Conclusion

- GPS-based NRT-POD for OSTM/Jason-2 demonstrating < 1 cm (RMS) radial orbit accuracy.
  - At least for cycle 34, better accuracy than DIODE and IGDR orbits.
  - Will continue to monitor, e.g. comparisons to other POEs, withheld SLR residuals.
- NRT GPS-based orbit provided on value-added GPS-OGDR-SSHA product.
  - Available at Physical Oceanography Distributed Active Archive Center: ftp://podaac.jpl.nasa.gov/pub/sea_surface_height/ostm/preview/GPS-OGDR/
  - Research grade product generated on best efforts basis.
    - GPSP instrument not considered mission critical.
    - Impacts design of NRT GPS-based POD system.
- Feedback on user value of orbit of < 1 cm (RMS) radial accuracy for operational NRT altimetry useful.
  - Is DIODE orbit accuracy sufficient?
  - Response might be used to affect development of future missions.
    - E.g. Does GPS instrument need to be defined as mission critical so that NRT GPS-based orbit can be provided on formal project products?
- Investigating techniques to reduce orbit errors from DIODE orbit on Jason-1 OSDRs to resurrect NRT-SSHA product for Jason-1.
  - Capitalize on accuracy of NRT OSTM/Jason-2 GPS-OGDR-SSHA product.