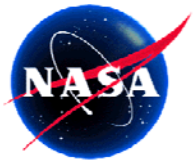


JPL
Jet Propulsion Laboratory
California Institute of Technology

High-Accuracy, Short-Latency Sea Surface Height from the Combined Jason-1 and Jason-2 Missions

Shailen Desai and Bruce Haines

Jet Propulsion Laboratory
California Institute of Technology
October 19, 2010

Background

- Telemetry from Jason-1 and Jason-2/OSTM with altimeter and radiometer measurements available:
  - Approximately every 2 hours
  - Latency < 1 hour
- Measurements provided to users in near-real-time (1-3 hours):
  - Jason-1: Operational Sensor Data Record (OSDR)
    - Intended as a wind/wave product for meteorological applications.
    - Does not provide sea surface height anomaly (SSHA) measurements.
    - Previously used GPS-based orbit determination to create value-added NRT SSHA product.
      - Retired in Nov 2006 with failure of GPS receivers on Jason-1.
  - Jason-2/OSTM: Operational Geophysical Data Record (OGDR)
    - Provides SSHA measurements
- **Objective to provide value-added products with high-accuracy SSHA measurements in NRT.**
  - **Jason-1: OSDR-SSHA (7-9-hour latency)**
    - **Resurrect using inter-satellite crossovers with Jason-2.**
  - **Jason-2: GPS-OGDR-SSHA (3-5-hour latency)**
    - **NRT GPS-based precise orbit determination.**

Motivation

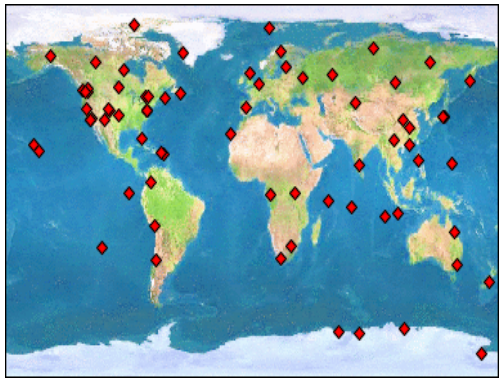
Sea Surface Height Component	Jason-1 OSDR	Jason-2/OSTM OGDR
Altimeter Range Measurements	Yes	Yes
Wet Troposphere Range Correction (Radiometer)	Liquid, Vapor	Yes
Dry Troposphere Range Correction	No	Yes
Ionosphere Range Correction	TEC	Yes
Sea State Bias (SSB) Range Correction	SWH/Wind	Yes
Geophysical Corrections (Tides, Inv. Bar., MSS)	No	Yes
Radial Orbit Accuracy	10-25 cm	3-5 cm

- Ancillary data can be used to derive SSHA for Jason-1, e.g.,:
  - Forecast pressure fields from National Centers for Environmental Prediction (dry troposphere, and inverse barometer correction).
  - Models for SSB and other geophysical corrections.
- **However, orbit accuracy remains a limiting error source for NRT SSHA.**

Jason-2/OSTM NRT GPS-Based Orbit Determination

Jet Propulsion Laboratory
California Institute of Technology

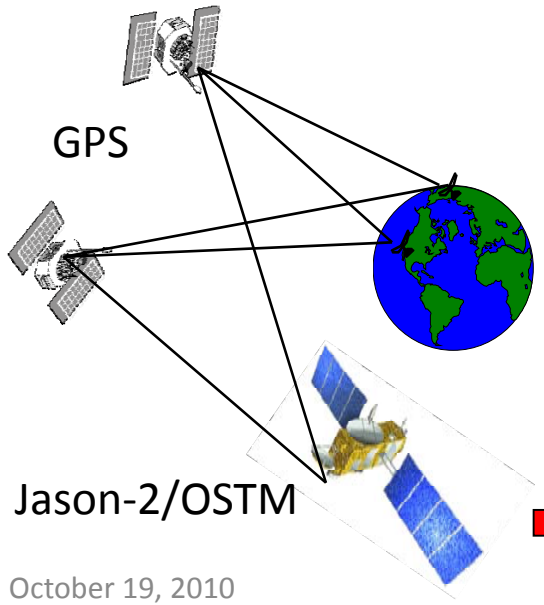
Global GPS Network



Hourly Transfer of Terrestrial GPS Data

GIPSY/OASIS
Computes orbit and clock states of GPS satellites.
Updated hourly.

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



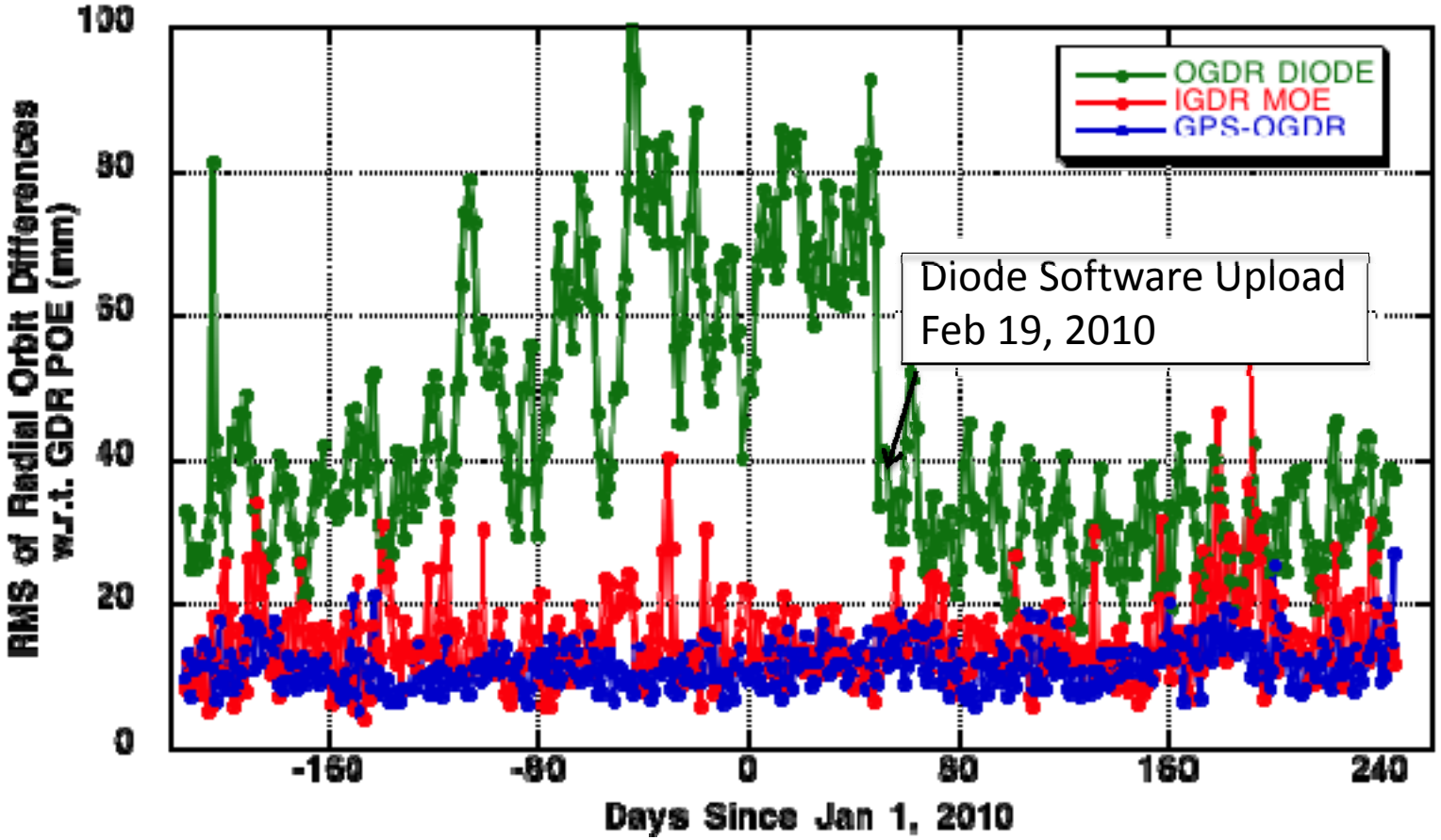
Jason-2 GPSP Tracking Data Telemetry
Telemetry received with < 1 hour latency.

Near-Real-Time Jason-2/OSTM Precise Orbit Determination
Triggered by arrival of:
GPSP Telemetry
Ultra-Rapid GPS Products
Radial Accuracy
1.0 cm (RMS)
3-5 hour latency.

Orbit Differences with GDR Precise Orbit Ephemeris (POE): Jason-2/OSTM

Median of Daily RMS of Orbit Differences

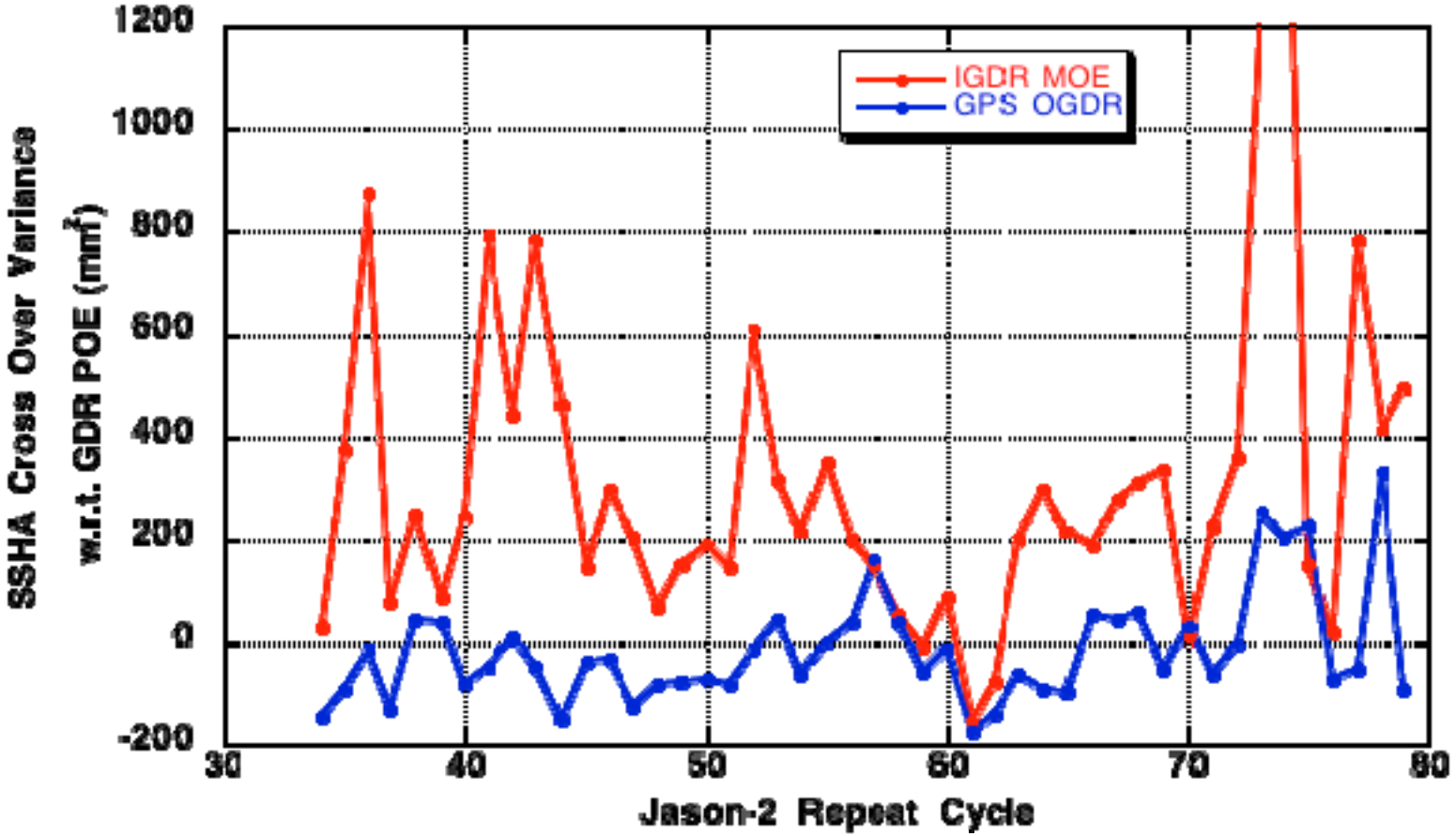
OGDR DIODE	IGDR MOE	GPS-OGDR
38.0 (30.5) mm	14.1 mm	11.2 mm



SSHA Crossover Variance Comparison

Average SSHA Crossover Variance w.r.t. POE

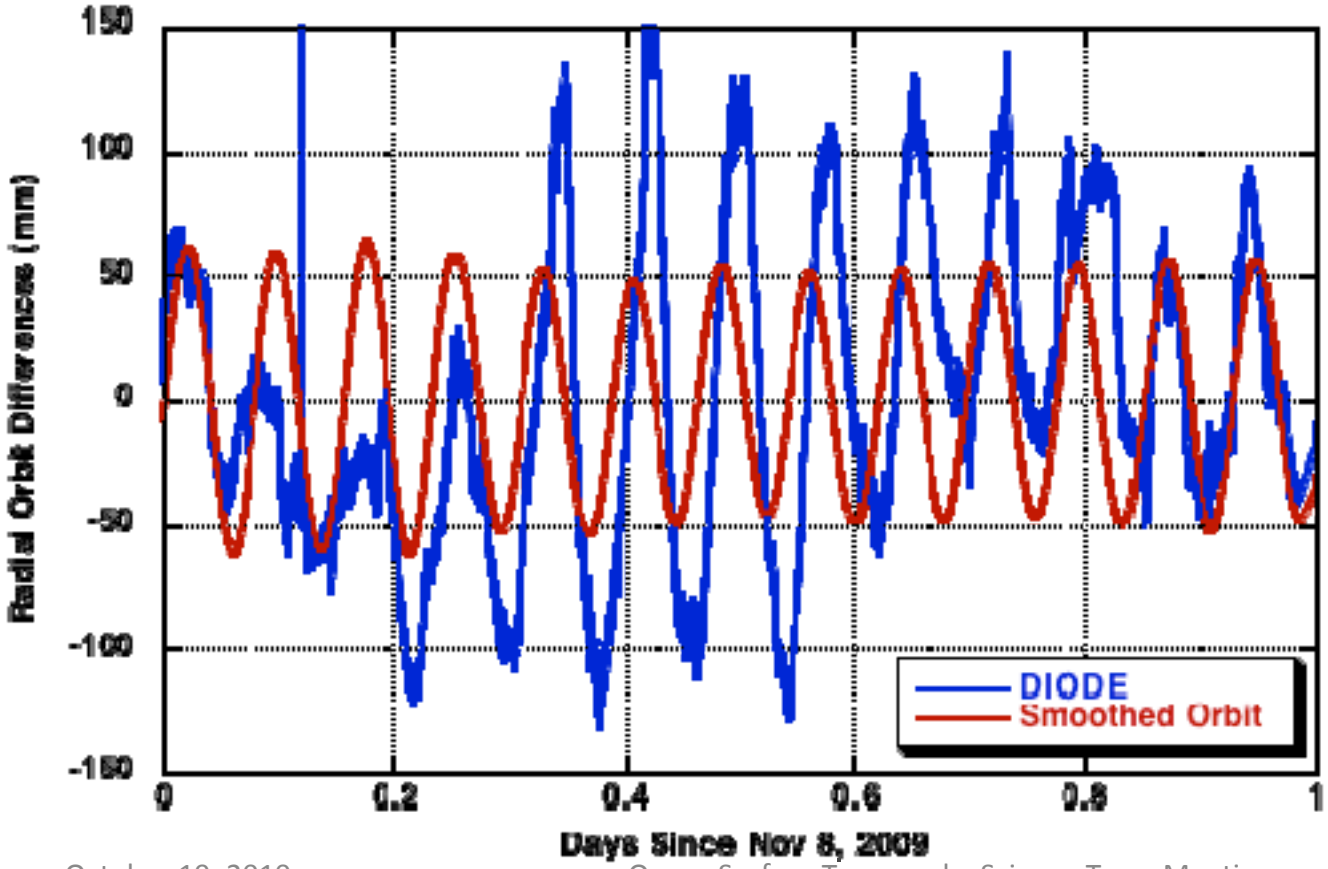
IGDR MOE	GPS-OGDR
+319 mm^2	-16 mm^2



Dynamic, Filtered, Backward-Smoothed Jason-1 Orbit Solution

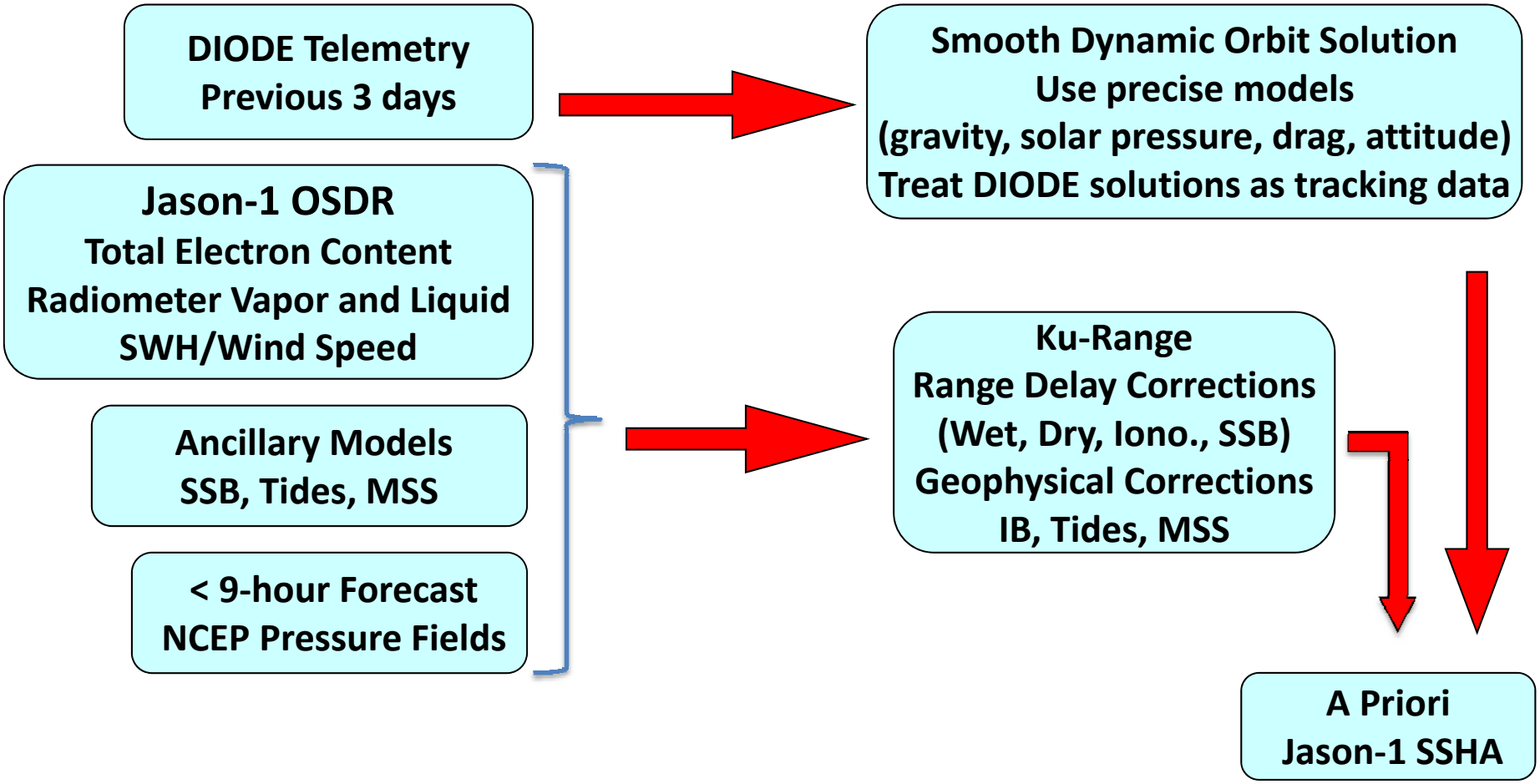
DIODE Telemetry
Previous 3 days

Smooth Dynamic Orbit Solution
Use precise models
(gravity, solar pressure, drag, attitude)
Treat DIODE solutions as tracking data

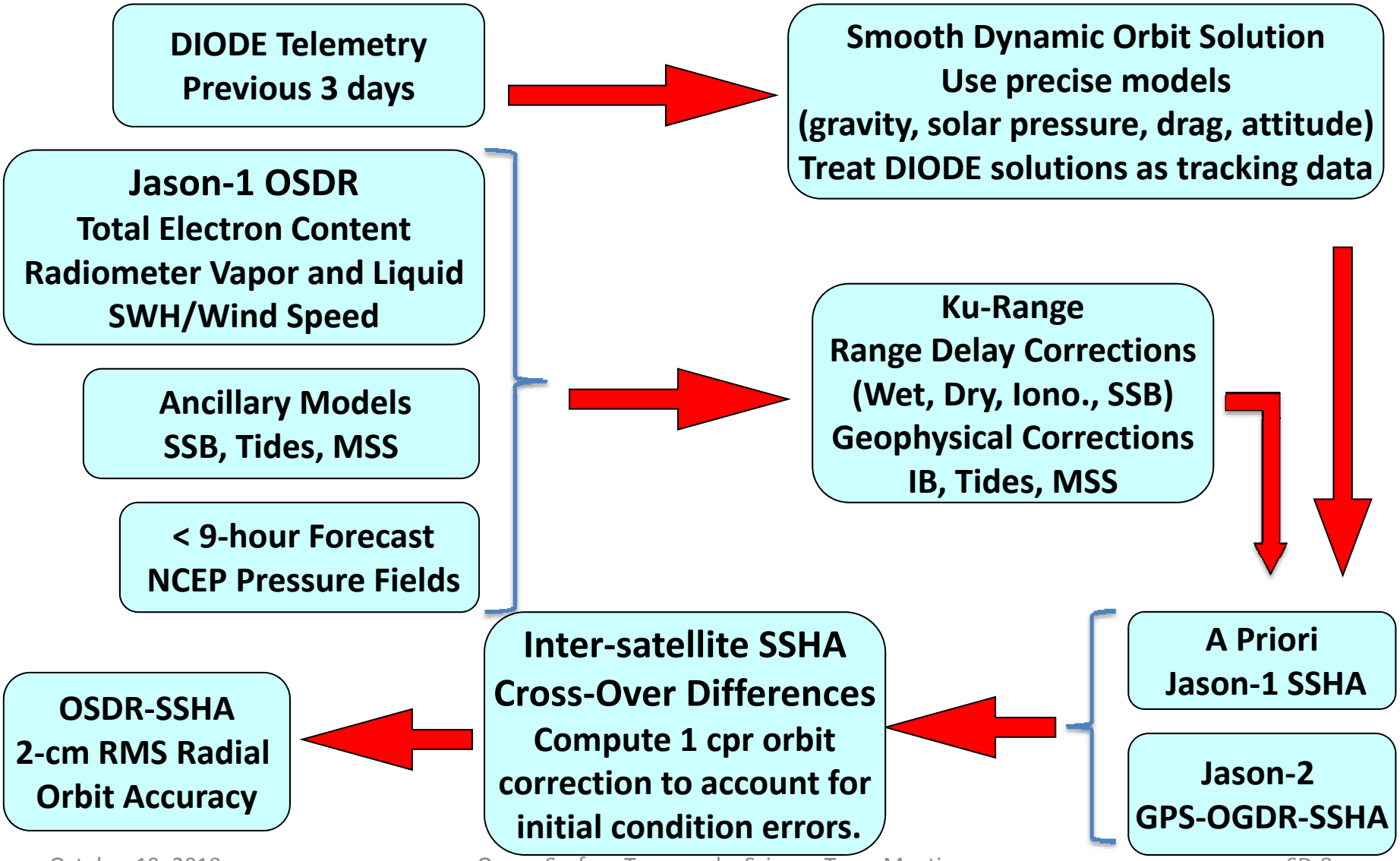


- Serves as low-pass filter to create smooth orbit solution.
- Enables use of rigorous force models.
- Remaining errors are mainly initial condition errors that manifest at 1 cpr.

A Priori Jason-1 SSHA



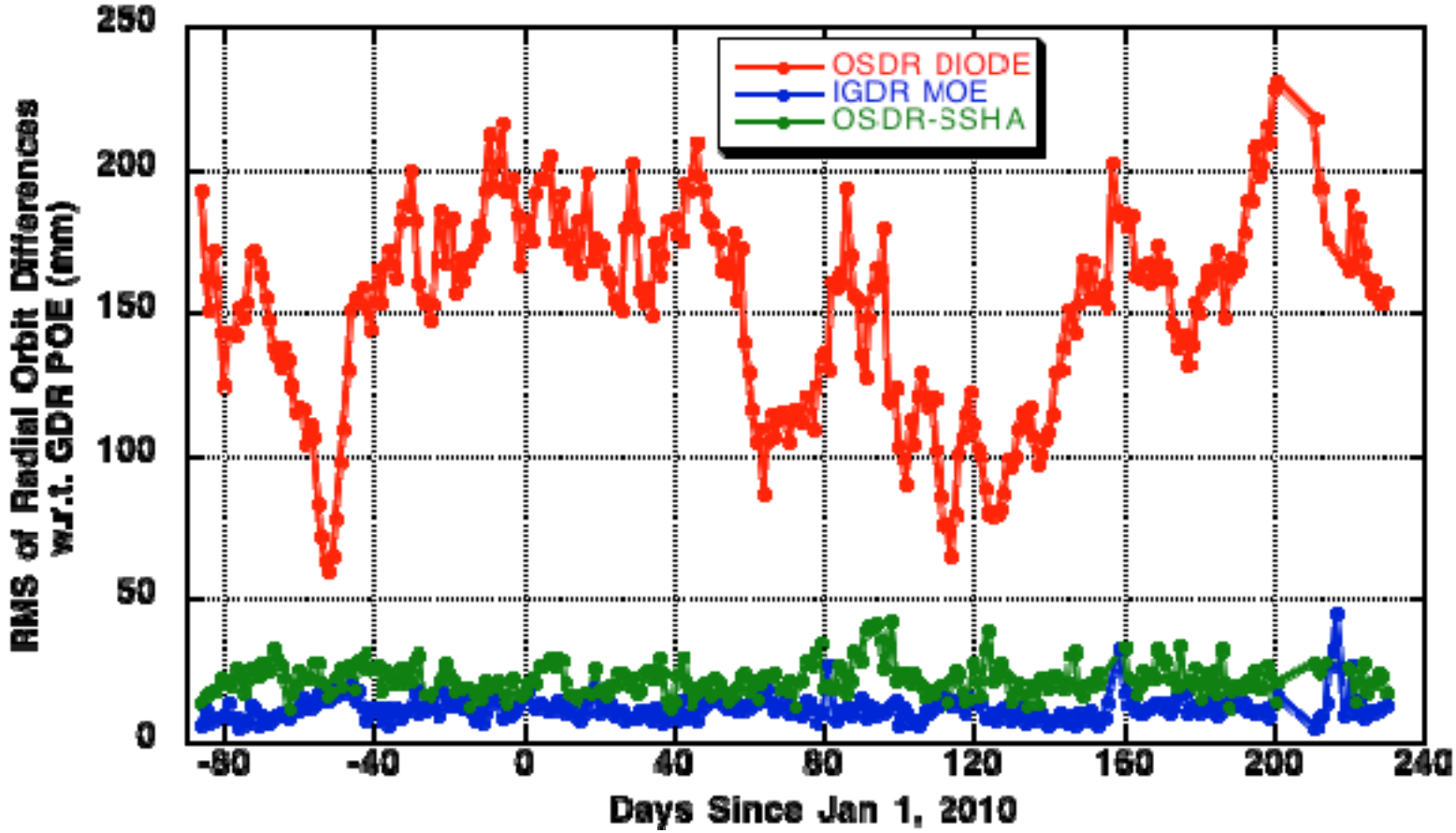
Jason-1 OSDR-SSHA



Orbit Differences with GDR Precise Orbit Ephemeris: Jason-1

Median of Daily RMS of Orbit Differences

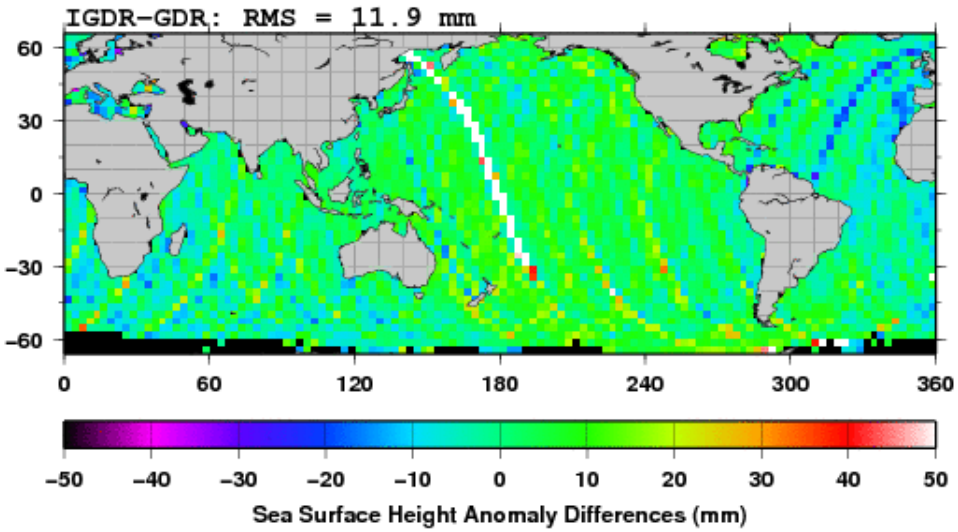
OSDR DIODE	IGDR MOE	OSDR-SSHA
159.0 mm	11.8 mm	21.3 mm

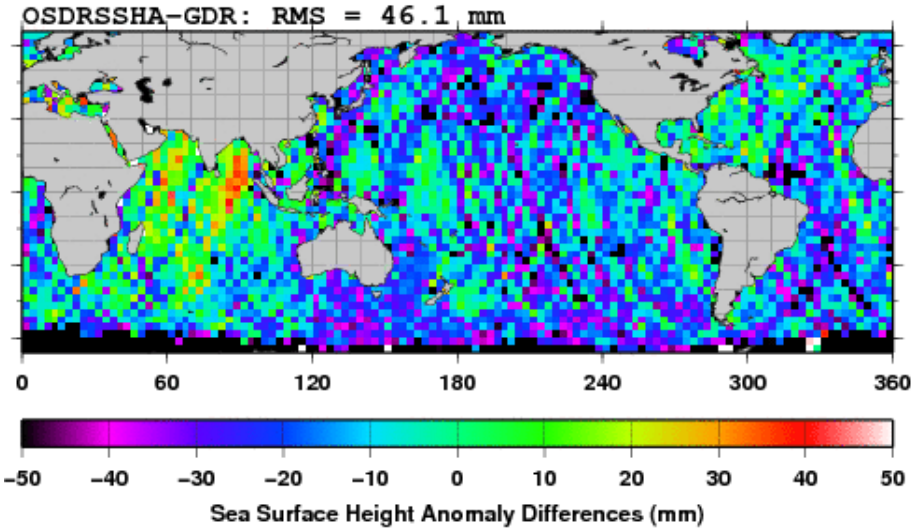


Standard Deviation of Differences with GDR
Units: mm

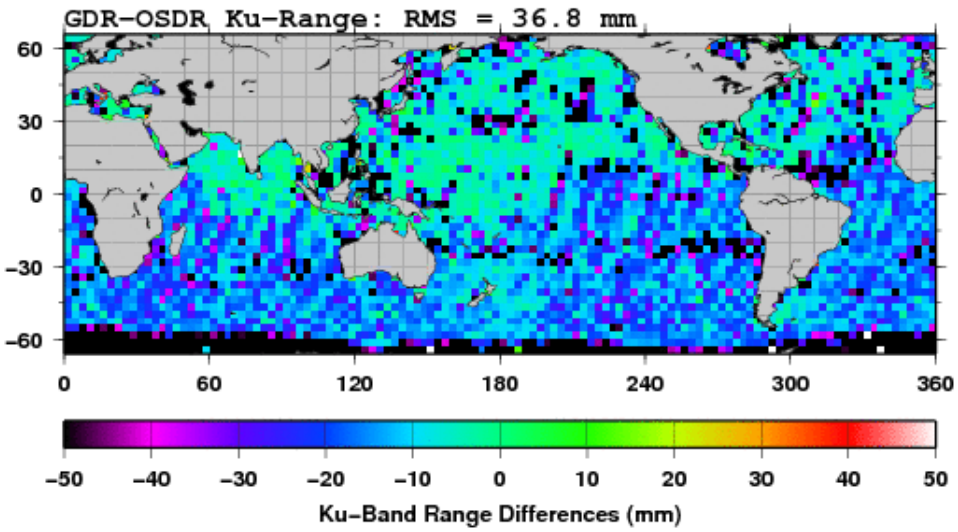
Parameter	Jason-1 OSDR-SSHA	Jason-2 GPS-OGDR-SSHA
Orbit Altitude	21	14
Ku-Band Range (2-m SWH)	37 (26)	2 (1)
Sea State Bias (2-m SWH)	8 (7)	0 (0)
Ionosphere Delay	11	1
Wet Troposphere Delay	0	0
Dry Troposphere Delay	2	2
Mean Sea Surface	0	0
Inverse Barometer	9	7
Solid Earth Tide	0	0
Ocean Tide	3	0
Pole Tide	0	0
SSHA – RSS (2-m SWH)	46 (37)	16 (16)
SSHA Accuracy	< 4.0 cm (RMS)	< 3.5 cm (RMS)

Geographic SSHA Differences with GDR
Jason-1 Cycle 317



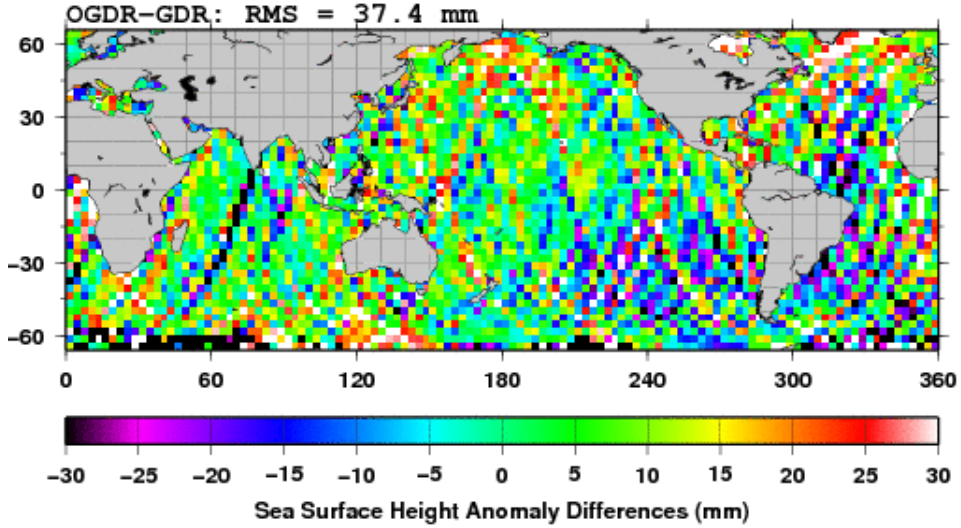


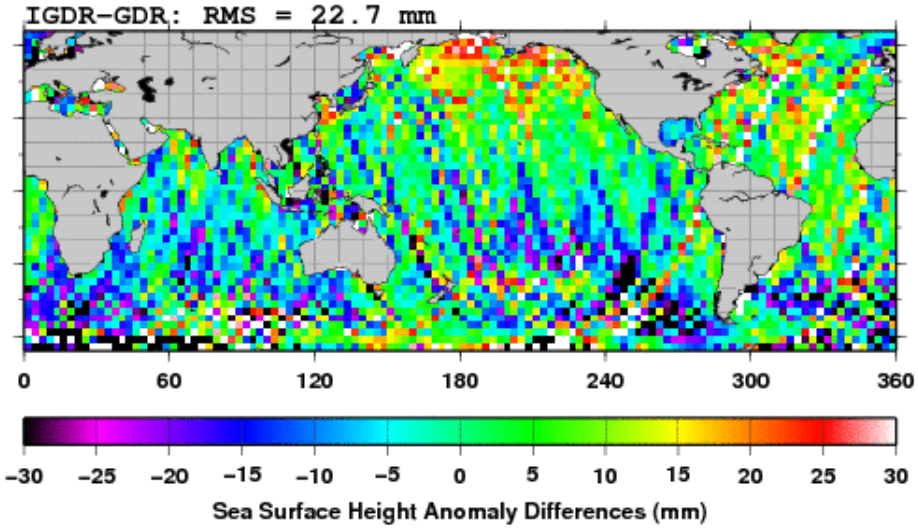
- ~65% of variance in SSHA differences between OSDR and GDR are due to differences in Ku-band range.
  - OSDR uses onboard retracking.
  - IGDR uses MLE4 ground retracking.
  - Ku-band range differences are consistent with uncorrelated errors, e.g.
    - OSDR and IGDR range error quoted as 18 and 16 mm.

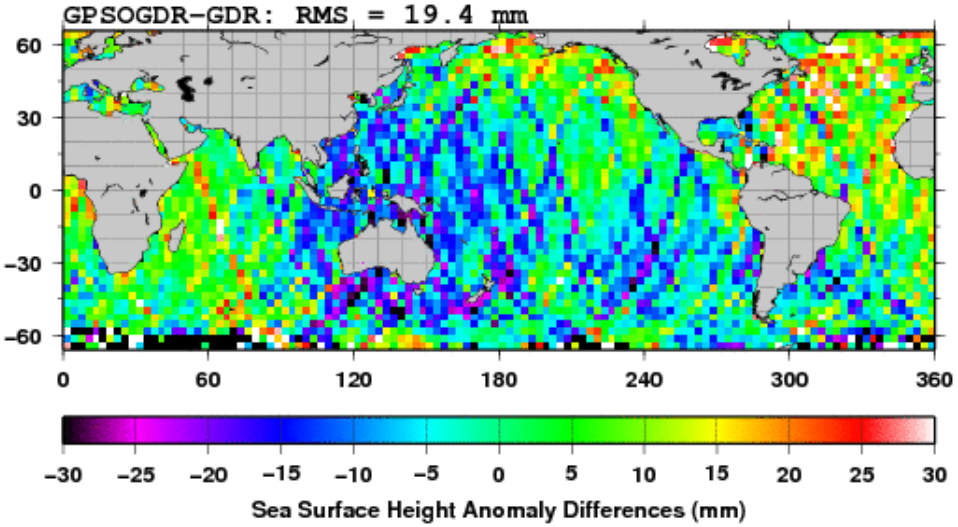


Geographic SSHA Differences with GDR
Jason-2/OSTM Cycle 79

Jet Propulsion Laboratory
California Institute of Technology





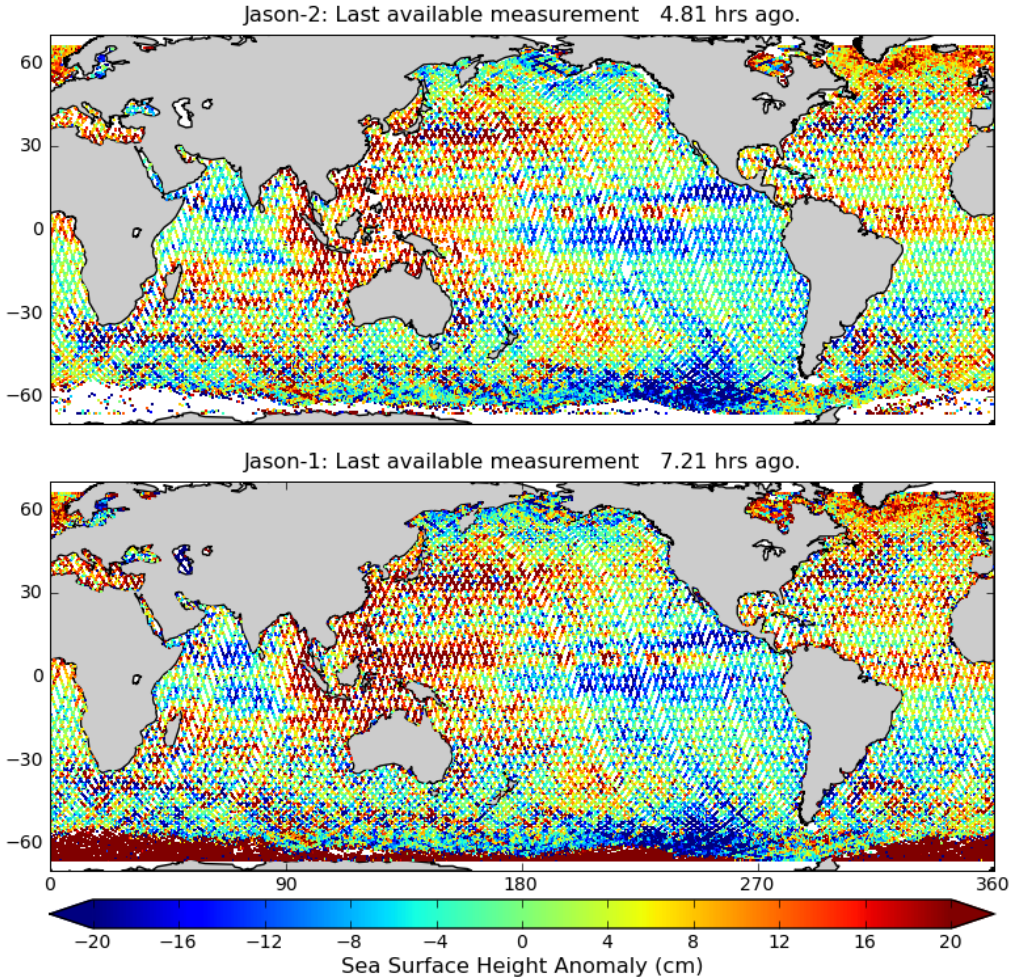


- Jason-2 SSHA differences with GDR are factor of 2 smaller when using NRT GPS orbit instead of DIODE orbit.
- Smaller SSHA differences with GDR when using GPS-OGDR instead of IGDR.

Conclusion

- NRT radial orbit accuracy:
  - Jason-1: 2 cm (RMS)
    - Similar or slightly worse then IGDR MOE.
  - Jason-2: 1 cm (RMS)
    - Similar accuracy as GDR POE, and better than IGDR MOE.
- SSHA accuracy (at 2-m SWH):
  - Jason-1: < 4.0 cm
    - Simialr to IGDR error budget.
  - Jason-2: < 3.5 cm
    - Conservatively add environmental range delay differences to GDR error budget.
- NRT SSHA products should not be considered as definitive climate records:
  - Susceptible to calibration shifts in radiometers.
  - Use predicted pole locations, and forecast pressure fields.
  - Do not contain high-frequency response to wind and pressure (e.g. Mog2D).
  - On Jason-1, do not use ground-retracking of altimeter waveforms.
  - Research grade products generated on best-efforts basis.
- Available at Physical Oceanography Distributed Active Archive Center: ftp://podaac.jpl.nasa.gov/pub/sea_surface_height/

Last 10 days of NRT SSHA Measurements from Jason-1 and Jason-2/OSTM



Impact of Two Missions with High-Accuracy NRT SSHA Measurements