Connecting Jason-3 to the Long-Term Sea Level Record: Results from Harvest and New Regional Campaigns

Bruce Haines, Shailen Desai and Rashmi Shah
Jet Propulsion Laboratory, California Institute of Technology, Pasadena USA
Adam Dodge, Bob Leben, Dallas Masters and Steve Nerem
Colorado Center for Astrodynamics Research, University of Colorado, Boulder USA
Christian Meinig and Scott Stalin
NOAA Pacific Marine Environmental Laboratory, Seattle USA

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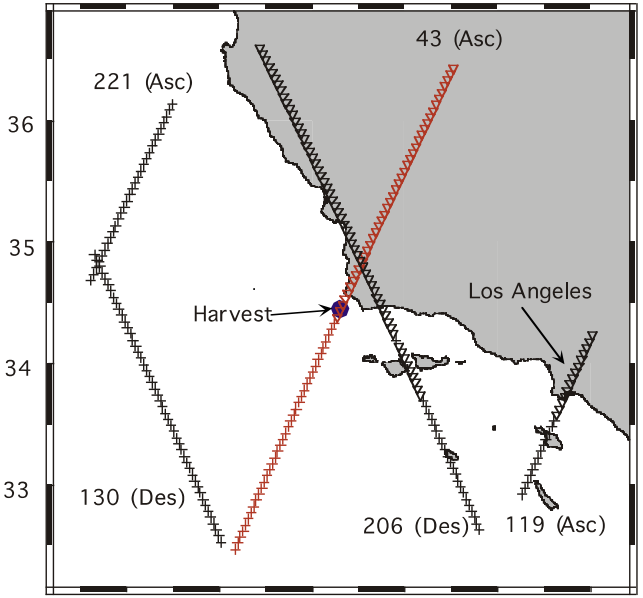
Harvest Platform

- **NASA Prime Verification Site for High-Accuracy (Jason-class) Altimetry**
  - Open-ocean location along 10-d repeat track
  - 10-km off coast of central California
- **Provides independent measure of local geocentric sea level**
  - Precise GPS receivers
  - Redundant tide gauges (Bubbler, radar, lidar)
  - Local survey
- **Yields absolute SSH bias**
  - Also provides for monitoring of ancillary parameters (e.g., wet troposphere delay)
- **Rich in-situ data set representing over 25 years of continuous monitoring**
  - 365 T/P overflights spanning 10 years (1992–2002)
  - 259 Jason-1 overflights spanning 7 years (2002–2009)
  - 303 Jason-2 overflights spanning 8 years (2008–2016)
  - 62 Jason-3 overflights and counting (2016–)
    - In formation 80 seconds after Jason-2 until 10/2/16.
    - 23 dual J2/J3 overflights before J2 orbit shifted.
- **Platform production still on hold**
  - Future of platform not assured



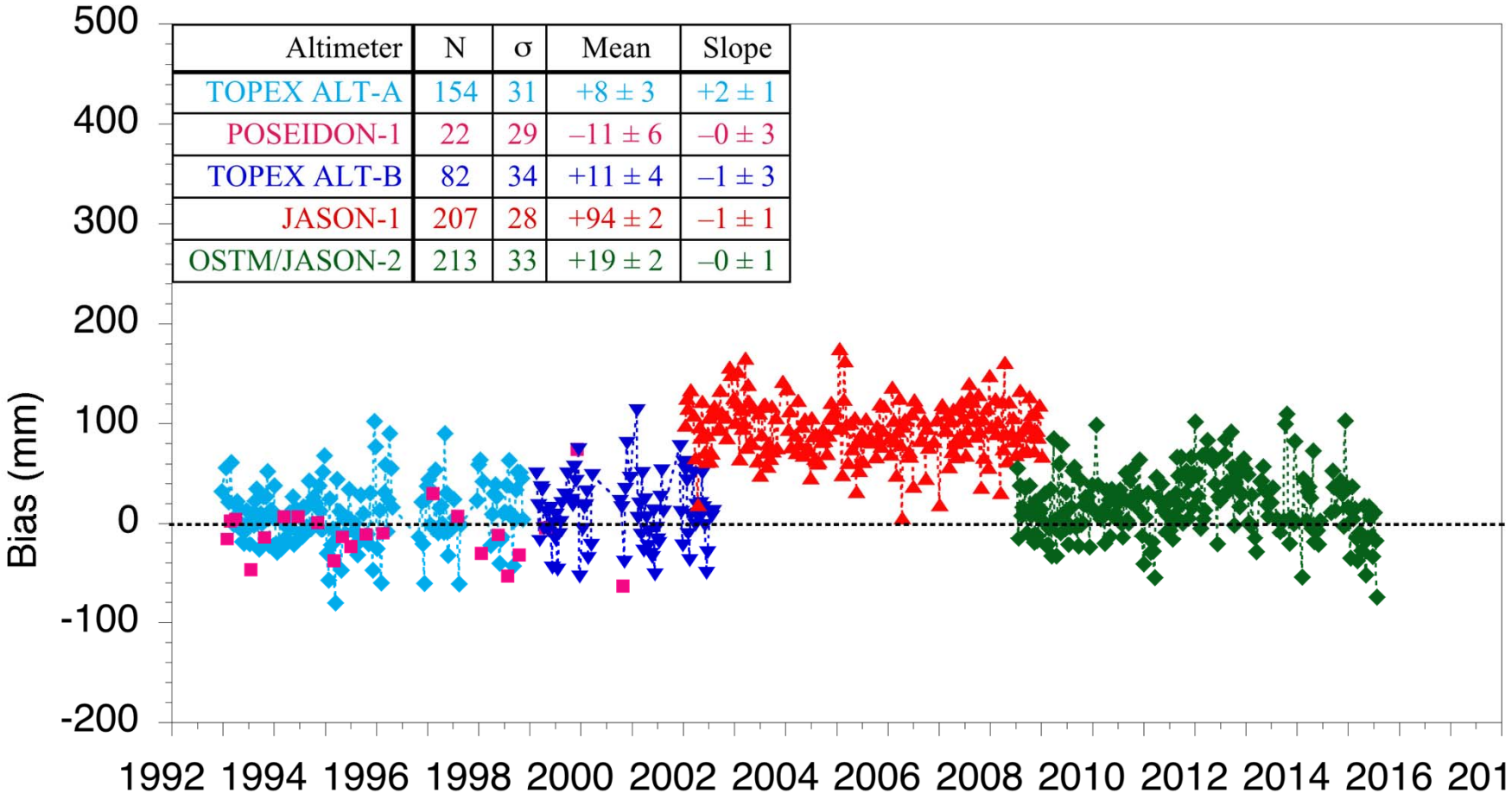
Harvest Long-Term SSH Calibration Record

On Eve of Jason-3 Launch

Nominal Time Series:

T/P: MGDR + reprocessed orbits (*Lemoine et al.*, 2010) and wet trop. (*Brown et al.*, 2009); **Jason-1:** GDR-C; **Jason-2**: GDR-D

Altimeter	N	σ	Mean	Slope
TOPEX ALT-A	154	31	+8 ± 3	+2 ± 1
POSEIDON-1	22	29	–11 ± 6	–0 ± 3
TOPEX ALT-B	82	34	+11 ± 4	–1 ± 3
JASON-1	207	28	+94 ± 2	–1 ± 1
OSTM/JASON-2	213	33	+19 ± 2	–0 ± 1

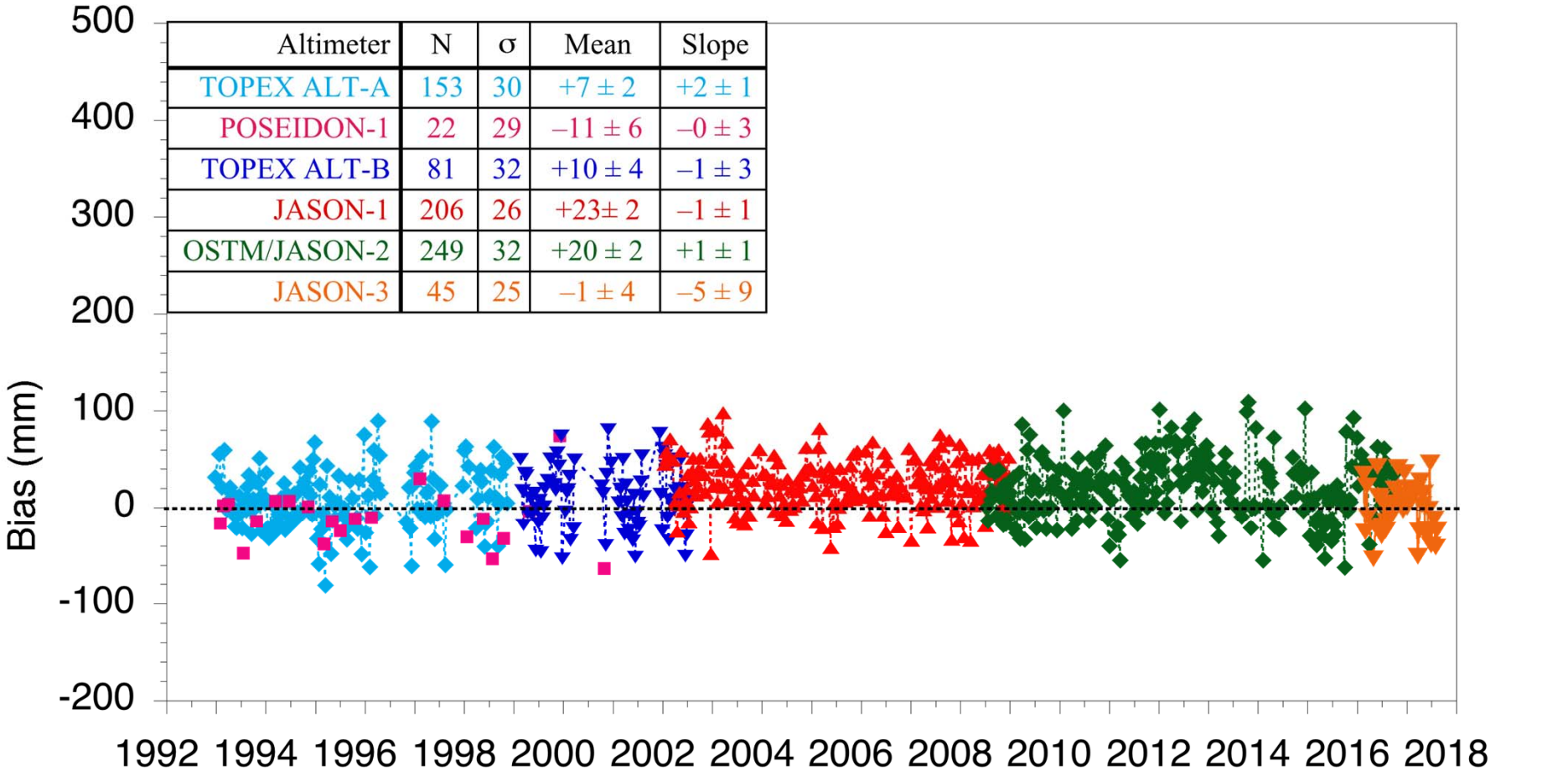


Harvest Long-Term SSH Calibration Record

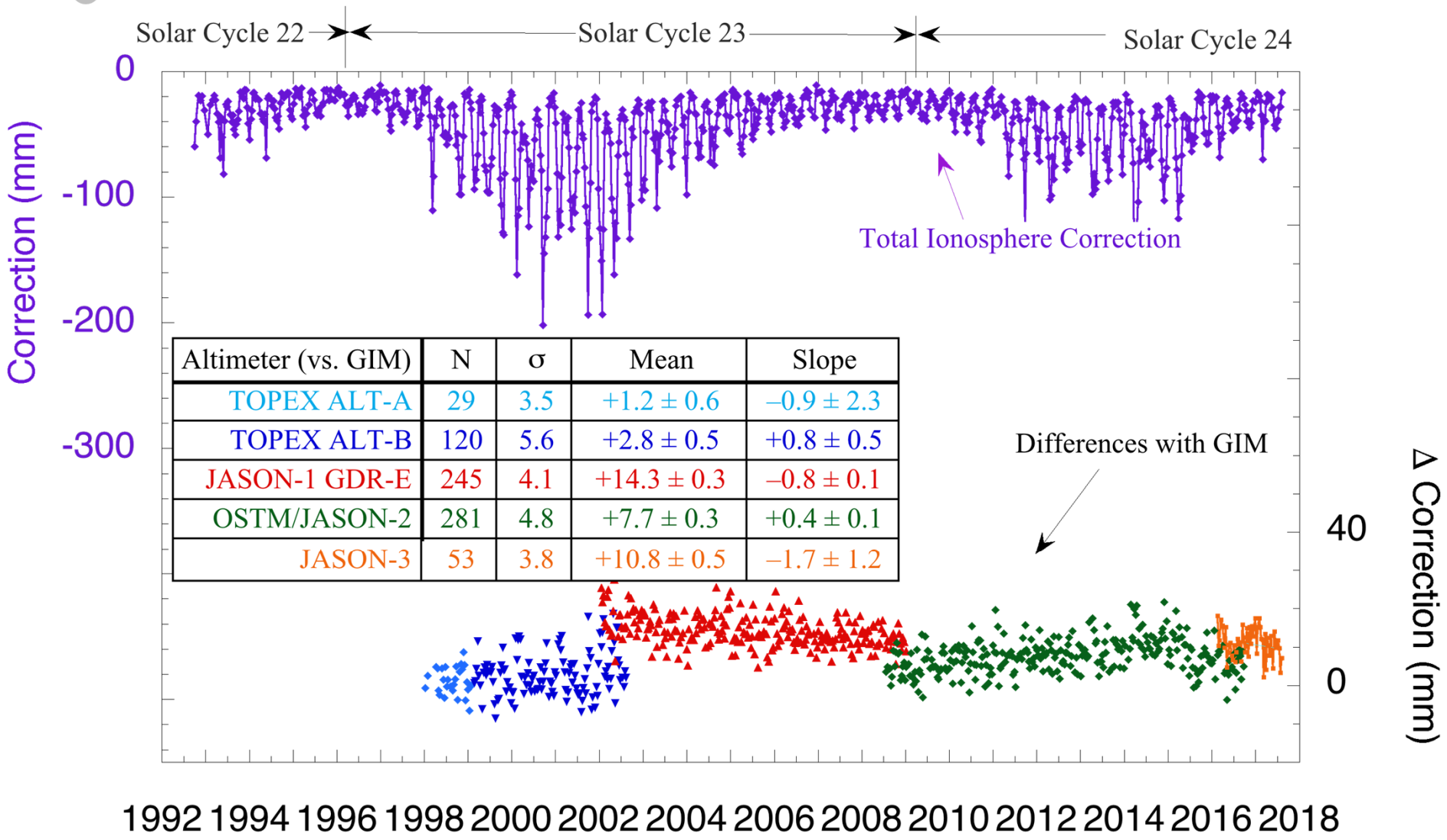
Current Best Estimate

Nominal Time Series:

T/P: MGDR + reprocessed orbits (*Lemoine et al.*, 2010) and wet trop. (*Brown et al.*, 2009); **Jason-1:** GDR-E; **Jason-2**: GDR-D; **Jason-3**: GDR-D

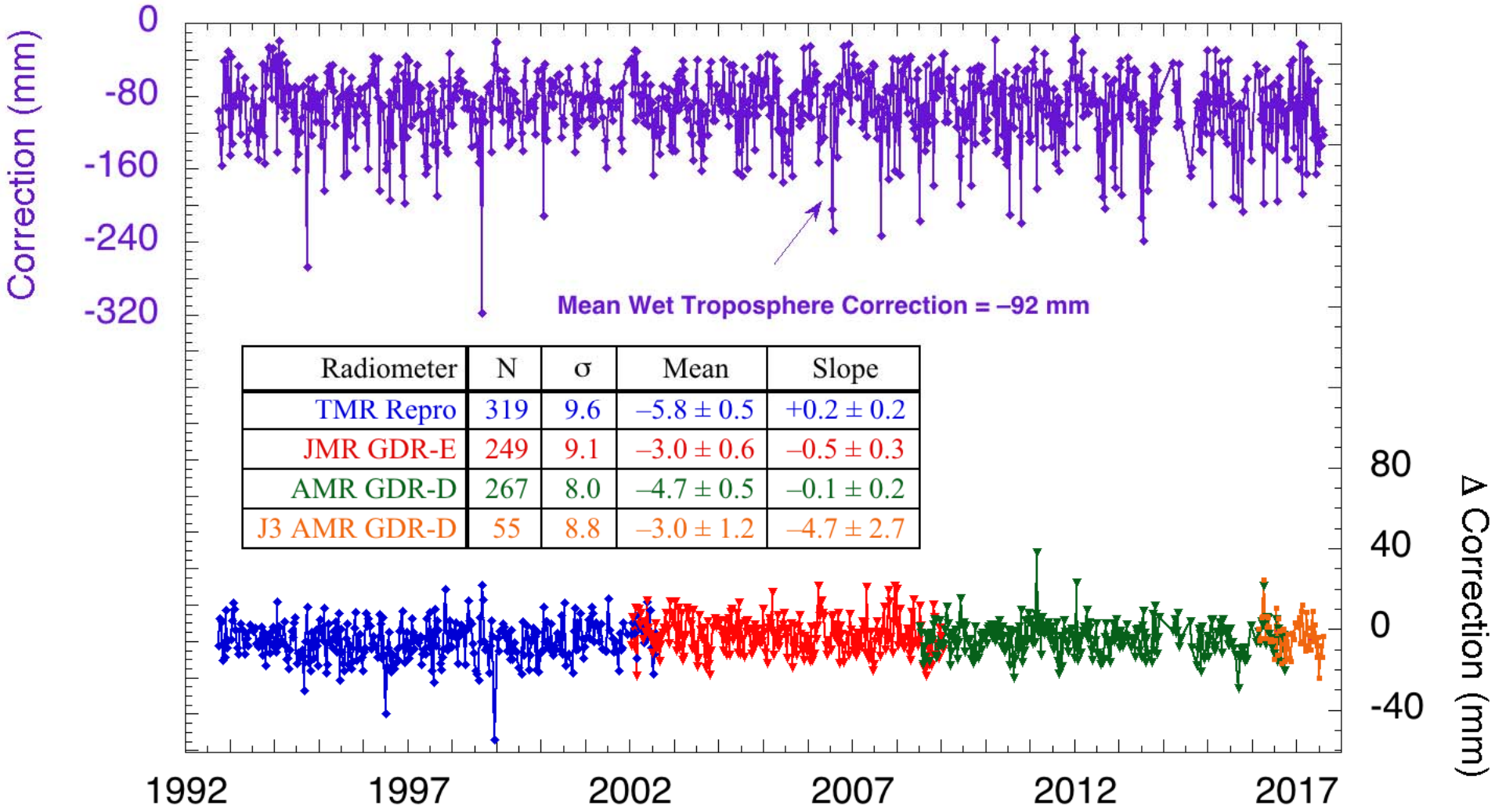


Ionosphere: Ku-Band Altimeter vs. GPS



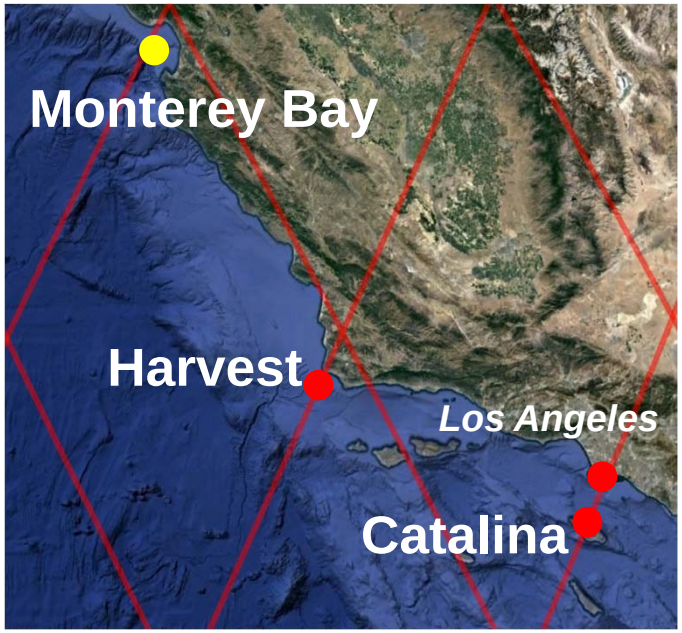
Altimeter (vs. GIM)	N	σ	Mean	Slope
TOPEX ALT-A	29	3.5	+1.2 ± 0.6	–0.9 ± 2.3
TOPEX ALT-B	120	5.6	+2.8 ± 0.5	+0.8 ± 0.5
JASON-1 GDR-E	245	4.1	+14.3 ± 0.3	–0.8 ± 0.1
OSTM/JASON-2	281	4.8	+7.7 ± 0.3	+0.4 ± 0.1
JASON-3	53	3.8	+10.8 ± 0.5	–1.7 ± 1.2

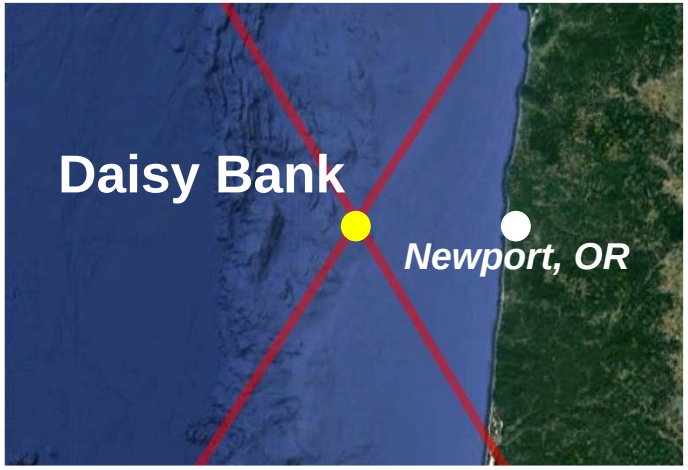
Wet Troposphere: Radiometer vs. GPS

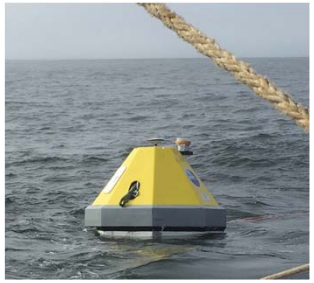


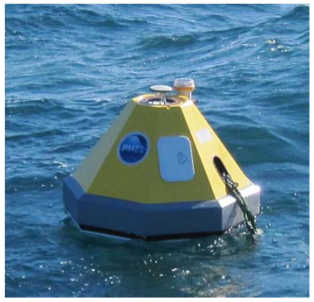
Radiometer	N	σ	Mean	Slope
TMR Repro	319	9.6	–5.8 ± 0.5	+0.2 ± 0.2
JMR GDR-E	249	9.1	–3.0 ± 0.6	–0.5 ± 0.3
AMR GDR-D	267	8.0	–4.7 ± 0.5	–0.1 ± 0.2
J3 AMR GDR-D	55	8.8	–3.0 ± 1.2	–4.7 ± 2.7

Regional Campaigns: Expanding the Calibration Footprint









Monterey Bay

Summer 2017 GPS Buoy Campaign for SWOT (but also near Jason pass).

Harvest

NASA Prime Verification Site for High-Accuracy (Jason-class) Altimetry.

Stable and Accurate Calibration Record Spanning 25 Years.

Catalina Island

Provisional calibration site est. 6/17 (lidar tide gauge + existing GPS).

Daisy Bank

Summer 2016 GPS Buoy Campaign at Jason Crossover Location

GPS Buoy Project

- Joint NASA JPL, NOAA PMEL and U. Washington project funded through NASA ROSES call (Physical Oceanography)*

OBJECTIVES:

- Design, build and test a modular, low-power, robust, high-accuracy GNSS measurement system for long-term, continuous and autonomous operations on ocean- and cryosphere-observing platforms.
- Probe the limits of new kinematic precise-point positioning (PPP) techniques for accurately determining sea-surface height, and recovering neutral and charged atmosphere characteristics.
- Explore potential scientific benefits—in the fields of physical oceanography, weather and space weather—of accurate GNSS observations from a global ocean network of floating platforms.

**Extending the Reach of the Global GNSS Network to the World's Oceans: A Prototype Buoy for Monitoring Sea Surface Height, Troposphere and Space Weather*, B. Haines, S. Brown, S. Desai, A. Komjathy, R. Kwok, D. Stowers, C. Meinig and J. Morison.

Prototype Precision GPS Buoy

FEATURES

- Integrated low-power (~1 W), dual-frequency GPS system (Septentrio)
- Miniaturized digital compass/accelerometer.
- Iridium communications (presently used for basic heartbeat information).
- Adaptable to multiple floating platforms (e.g., buoys, wave gliders).
- Enables geodetic quality solutions without nearby reference stations.

DEVELOPMENT AND TESTING

- Buoy tested successfully under progressively more challenging conditions:

✓ *Lake Washington (Aug. 7–12, 2015).*

✓ *Puget Sound (Nov. 10 to Dec. 14, 2015).*

✓ *Daisy Bank: open ocean Jason crossover location (May 11 to Sep. 8, 2016).*

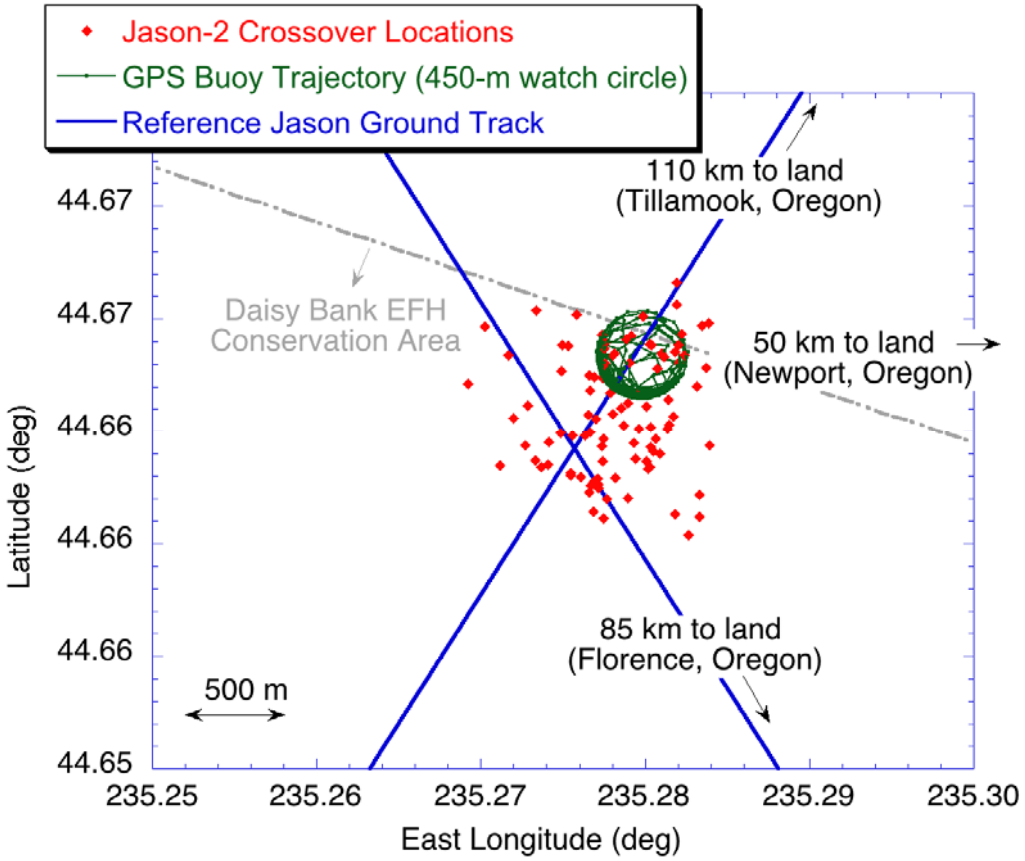
✓ *Monterey Bay: SWOT Pilot Experiment (June 22 to September 7, 2017).*

⇨ **Total of 236 days in the water** (20 days of data from Monterey Bay data lost due to failed USB drive).

GPS Buoy Campaigns

DAISY BANK CLOSEUP

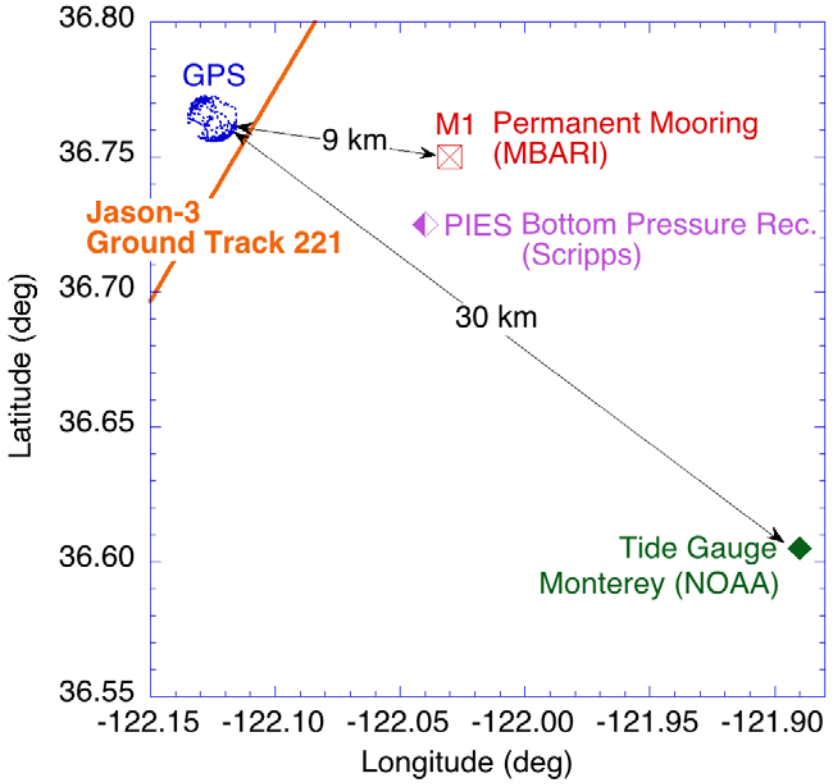
~200-m depth



Deployment spanned 24 dual Jason-2/3 overflights

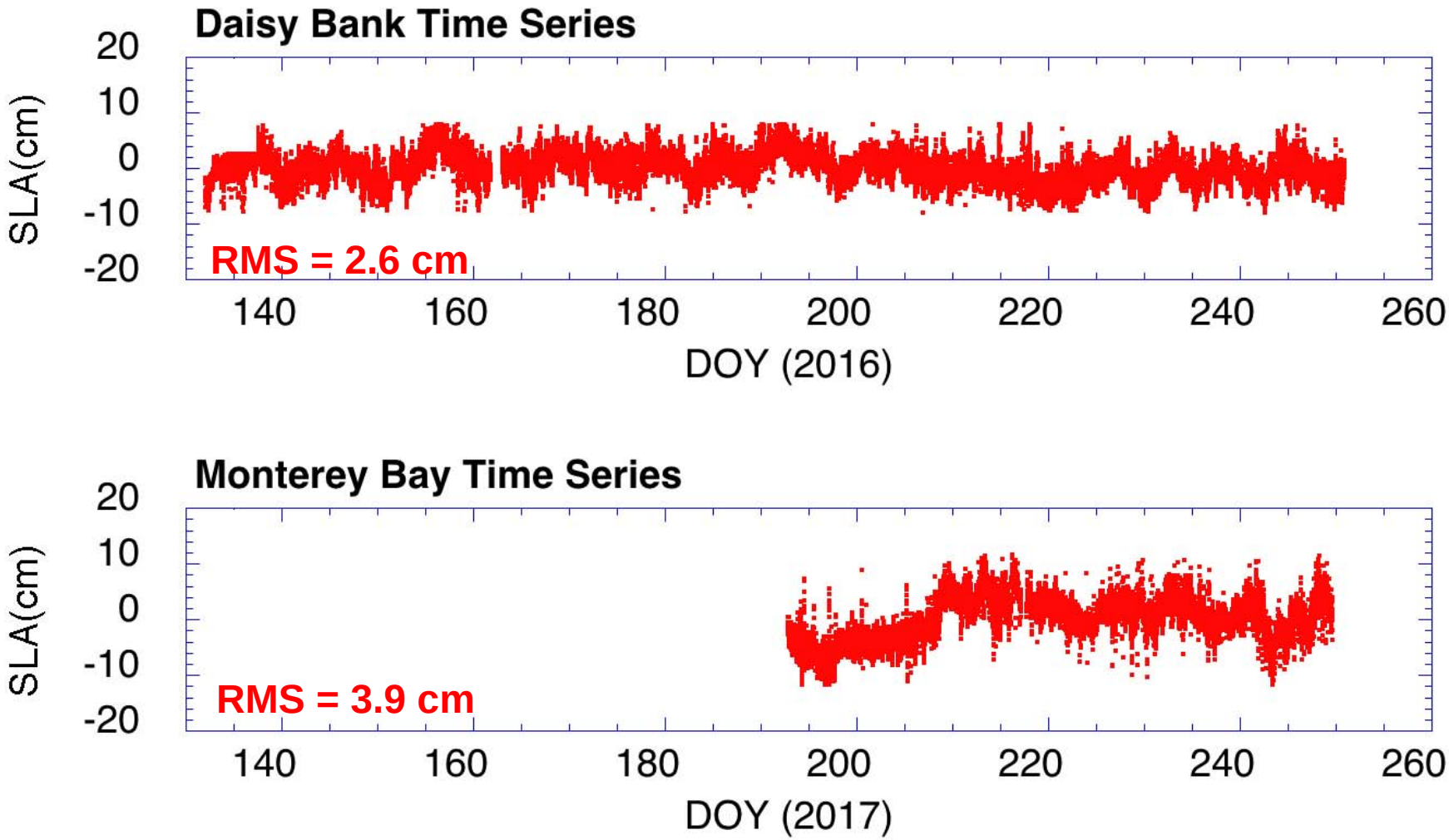
MONTEREY BAY CLOSEUP

~1000-m depth



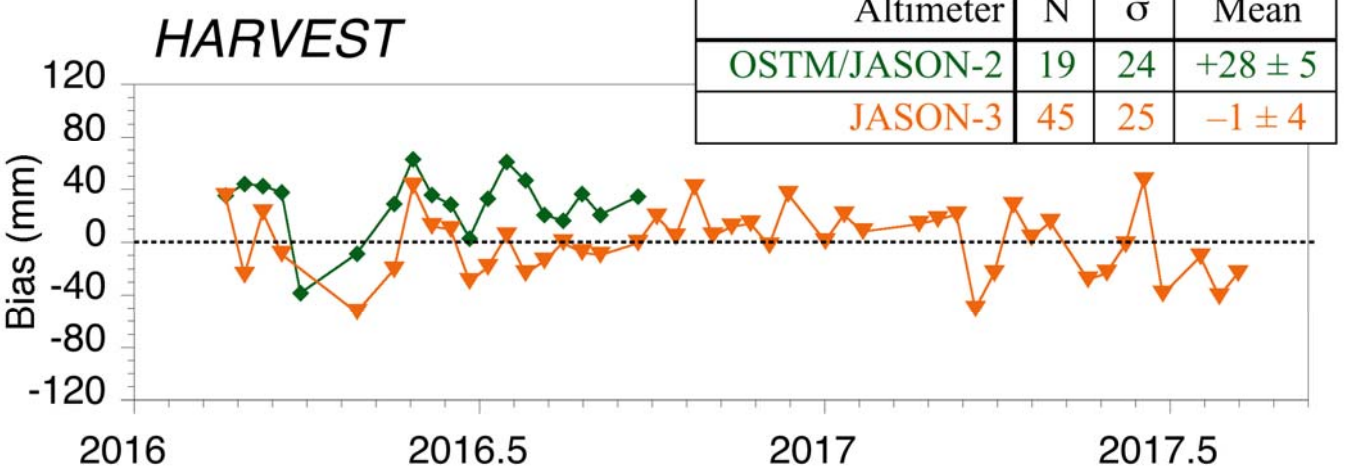
Deployment spanned 6 Jason-3 overflights

SLA from 6-min. GPS Buoy Data Averages
Daisy Bank (2016) vs. Monterey Bay (2017)

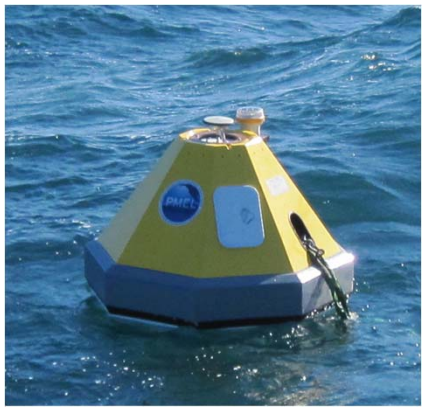


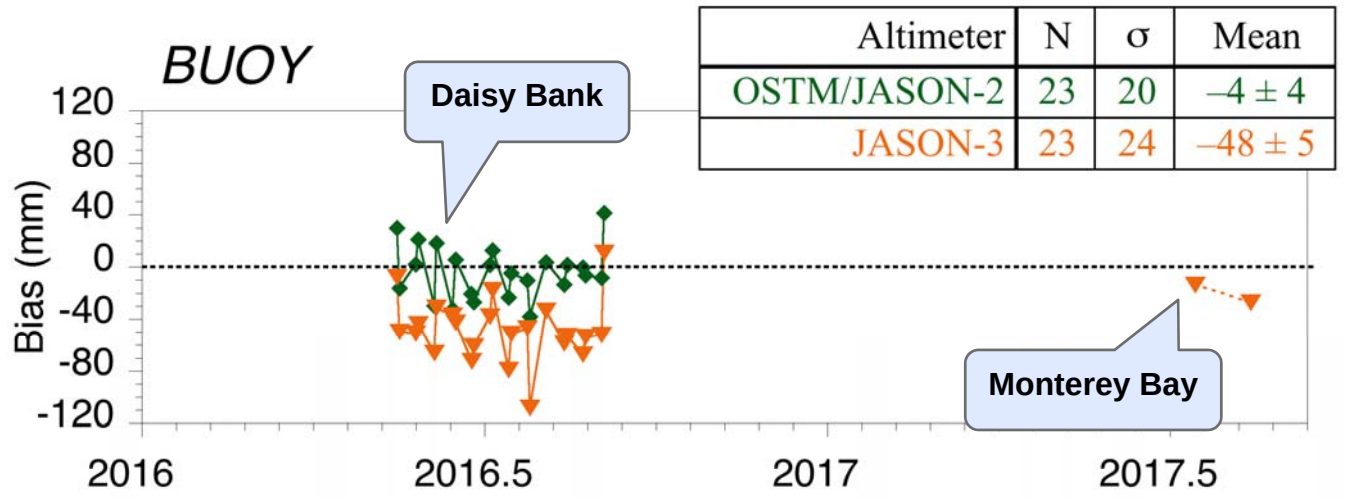
SSH Bias: Harvest vs. Buoy

Comparable Results for the Jason-3 Era



Altimeter	N	σ	Mean
OSTM/JASON-2	19	24	+28 ± 5
JASON-3	45	25	–1 ± 4

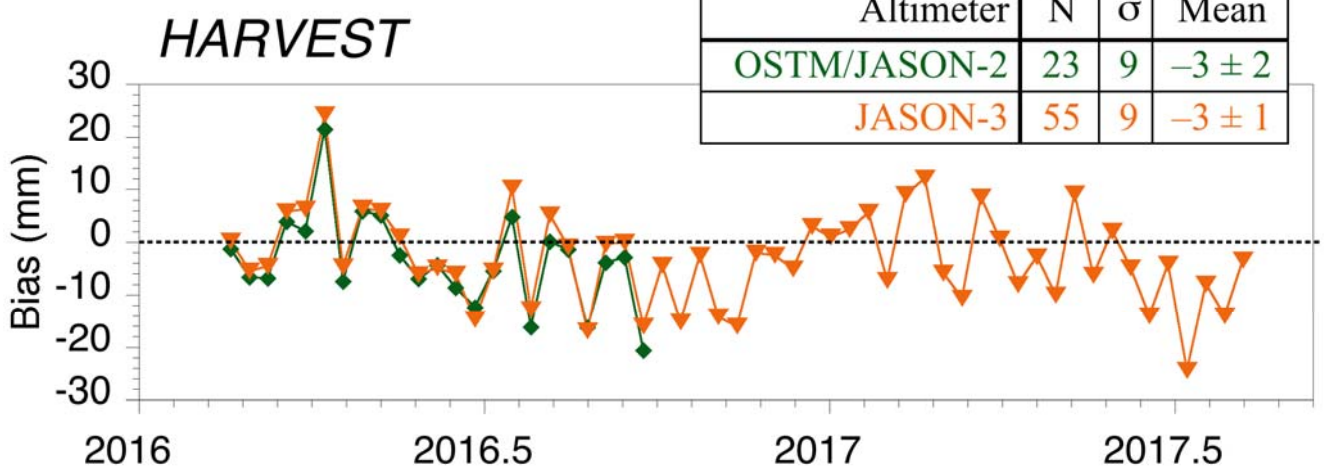


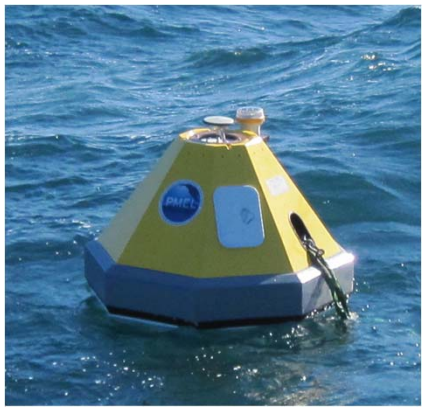


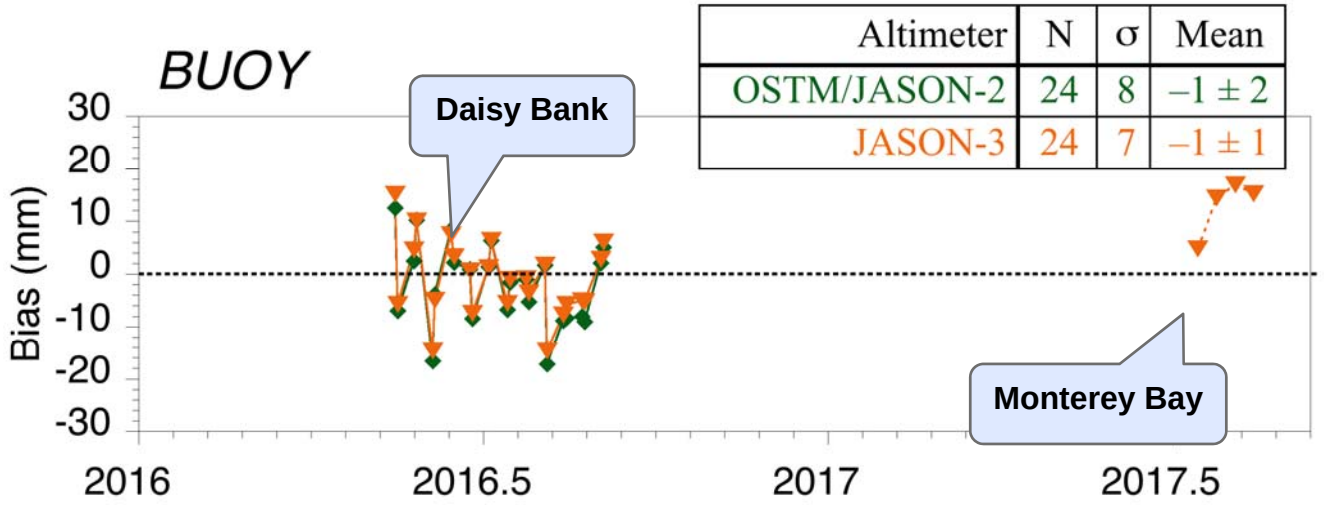
Altimeter	N	σ	Mean
OSTM/JASON-2	23	20	–4 ± 4
JASON-3	23	24	–48 ± 5

GPS Wet Path Delay Calibration: Harvest vs. Buoy

Comparable Results for the Jason-3 Era

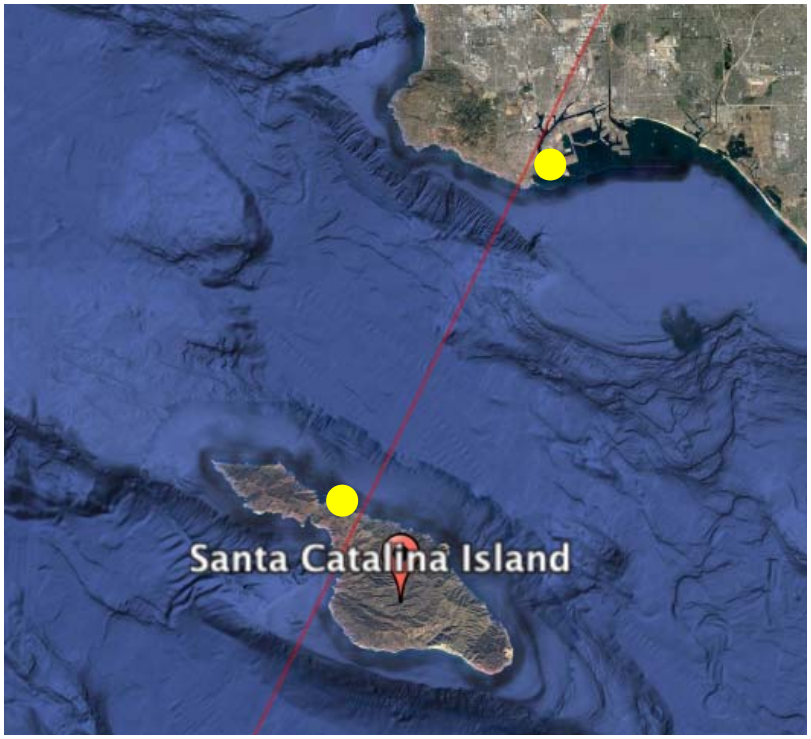






Extending the Reach of Harvest:
Provisional Site on Santa Catalina Island
(see Masters et al. poster for additional information)

- **Lidar-based tide gauge installed June 2017**
  - Wrigley Institute for Environmental Studies (U. of Southern California) near Two Harbors.
  - 100 m from permanent GPS site (est. 1995)
  - ~2 km from Jason-3 ground track (Pass 119, adjacent to and west of Harvest Pass 43).
  - ~20 km (along Jason pass 119) to center of San Pedro Channel.
  - ~40 km (along Jason pass 119) to historical Los Angeles tide gauge (est. 1923 in San Pedro).
- **Preliminary Altimeter (GDR) vs. Tide Gauge (lidar) comparisons are promising.**
  - ~15 mm repeatability (N = 5 Jason-3 overflights)**.**
- **Next steps?** Make absolute tie of lidar to GPS station (CAT3) and deploy transponder.

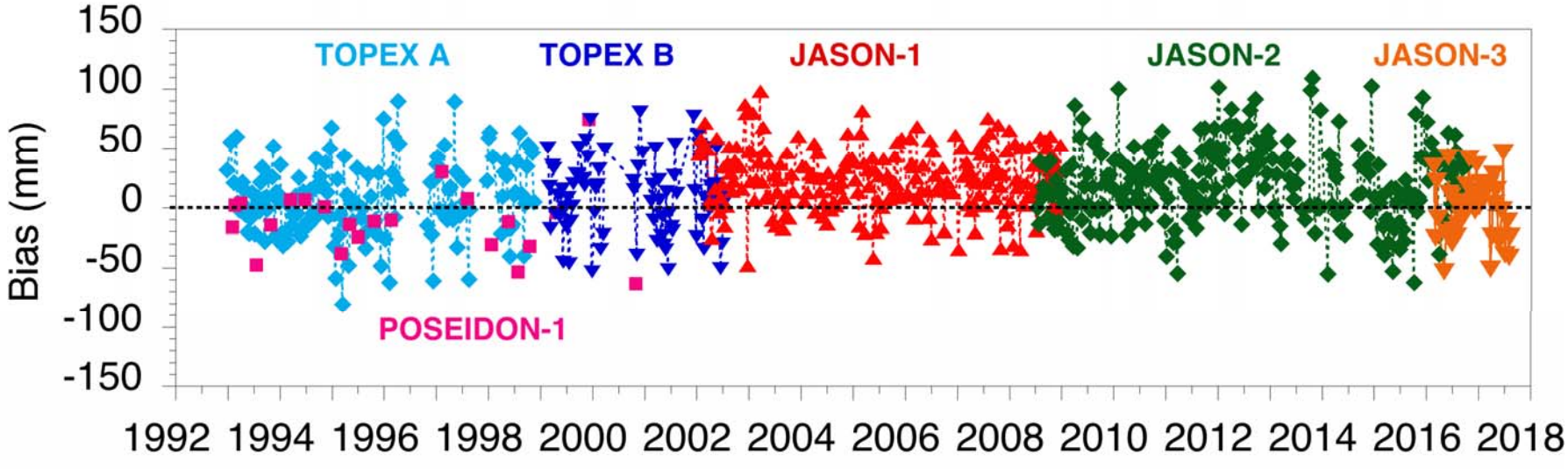


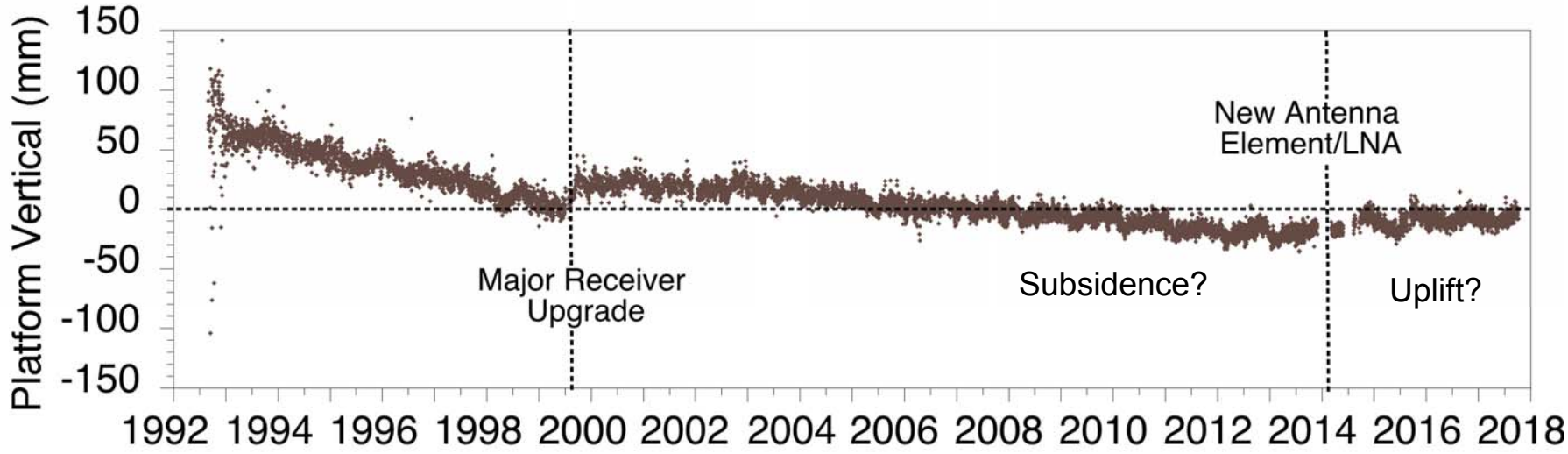
Summary

- **Absolute SSH bias from Harvest***
  - Jason-3: –1 ± 15 mm for GDR-T (Cycles 1 to 55 with N = 45)
  - Jason-2: +20 ± 15 mm for GDR-D (Cycles 1 to 303 with N = 249)
  - Jason-1: +23 ± 10 mm for GDR-E (Cycles 1 to 259 with N = 206)
- **Relative Jason-2 vs. Jason-3 SSH bias *from dual Harvest overflights*:**
  - Jason-3 SSH lower (by 39 ± 4 mm) than Jason-2 SSH.
  - Comparisons with "orbit-range" suggest SSH bias comes mainly from range.
  - Smaller Jason-3 ionosphere delay (~5 mm).
- **SSH drift at Harvest indistinguishable from zero for all legacy systems**
  - ≤ 1 mm/yr for all systems except TOPEX (Side A). Jason-3 time series too short.
- **Preliminary results from GPS buoy very promising**
  - Returned continuous, high accuracy data for Daisy Bank and Monterey Bay
  - Supported accurate retrievals of SSH, SWH, wet path delay and ionosphere.
  - Competitive with Harvest for all altimeter calibration metrics.
  - Next planned deployment: Summer 2018 at Harvest (TBC) with two buoys.

** Error includes uncertainty in platform vertical*

Vertical Land Motion Model for Harvest:
Important Update Coming?





Monterey Bay GPS vs. Tide Gauge