A Study on the Effectiveness of GNSS Buoys at Harvest

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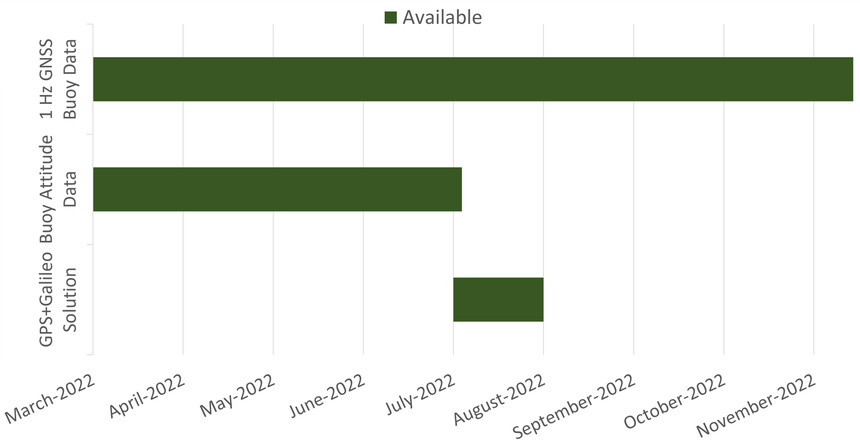
2023 Ocean Surface Topography Science Team Meeting, San Juan, Puerto Rico

Overview

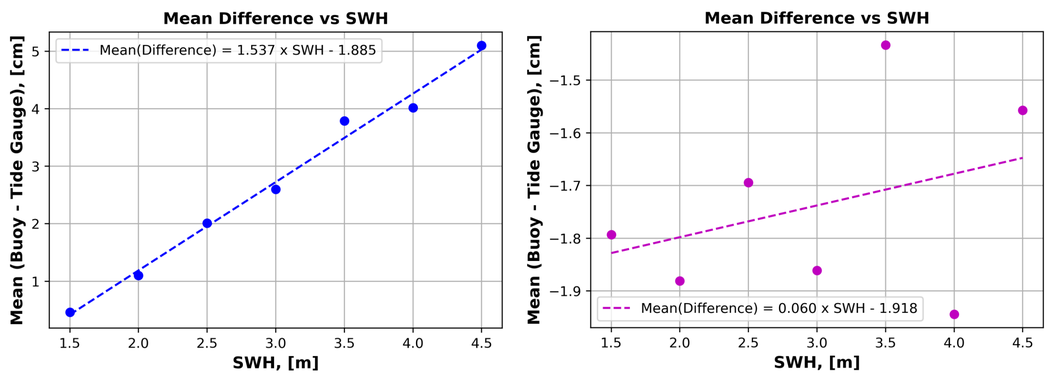
- Tide gauge at the Harvest Platform has been used as an altimetry reference for over three decades
- GNSS buoy was dispatched prior to full decommissioning of the platform to evaluate as potential replacements
- There was an eight month (March 2022 – Nov 2022) overlap between tide gauge and buoy
- Attitude data was available for the buoy from March 2022 – July 2022

Harvest GNSS Buoy



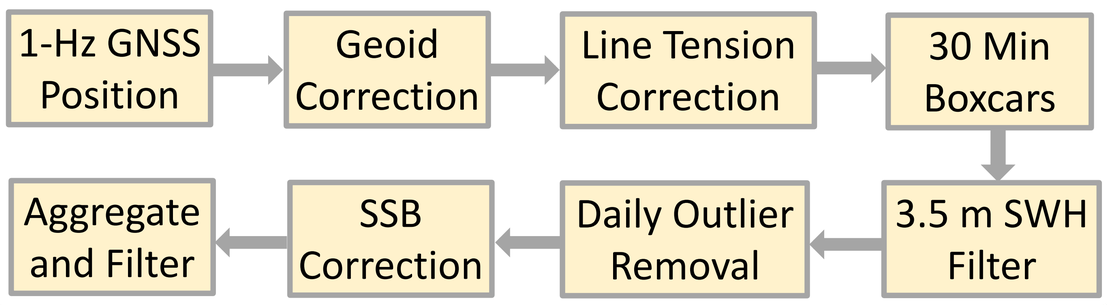
Sea State Bias (SSB) Correction

- Significant wave height (SWH) estimated as 4 x σ(SSH)
- Sea state bias estimated by fitting model to SSH
  - $SSH(t) = \sum_{k=0}^{3} a_k t^k + Ocean\ Tides(t) + cSWH(t)$



- Mean of height differences within 0.5 m SWH bins before SSB correction (L) and after SSB correction (R)
- SSB for buoy and tide gauge estimated independently
  - ➢ Buoy SSB ~ 1.92% SWH, Tide Gauge SSB ~ 0.59% SWH

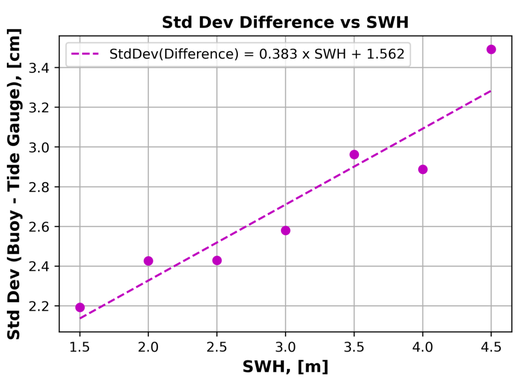
Data Processing Flow



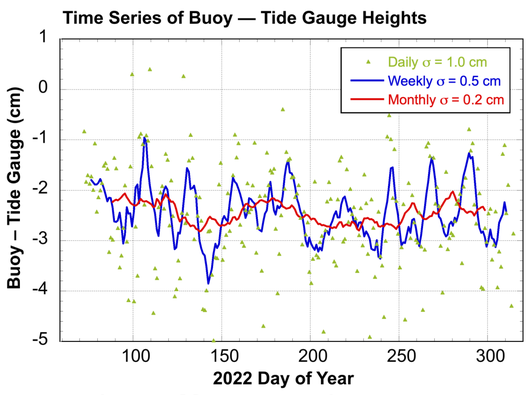
March – November, Baseline Case

- No attitude or antenna map, GPS-only

Case σ (Buoy – Tide Gauge) [cm]	Nominal	Geoid	Geoid + Line Tension	Geoid + Line Tension + SSB	3-σ Outliers Removed
Linear Line Tension	2.619	2.607	2.560	**2.394**	0%
Load Cell Correction	2.619	2.607	2.591	**2.508**	0%
Linear Line Tension 3-σ outlier removal	2.245	2.282	2.246	**2.060**	2.14%
Load Cell Correction 3-σ outlier removal	2.245	2.282	2.271	**2.197**	1.75%



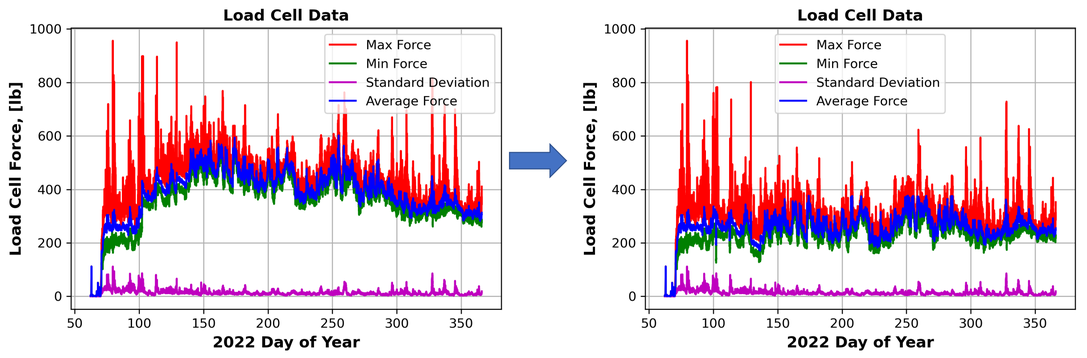
- Data binned to 0.5 m SWH
- Agreement depends on SWH cutoff
- 3.5 m SWH threshold retained > 97% data



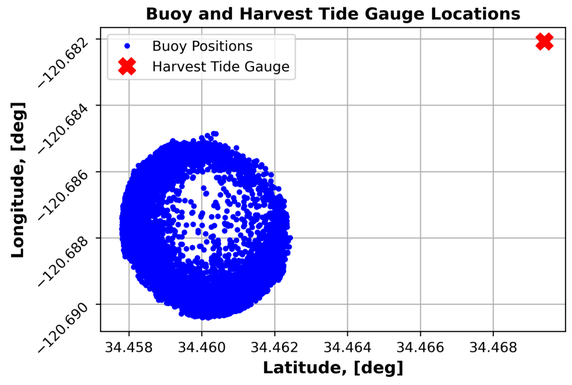
- Daily Difference between tide gauge and buoy heights
- Linear fit through data:
  - ➢ Mean: -2.5 ± 0.1 cm
  - ➢ StdDev: 1 cm
  - ➢ Trend: -5 ± 3 mm/year

Buoy Line Tension

- Two models – load cell (sensor) and linear fit (estimated)
- **Load Cell Model –** 0.0254 m/105 lb-f correction based on the load cell measurement
  - ➢ Data was leveled by removing three piecewise biases and a linear term to make it consistent with other buoy campaigns



- **Linear Line Tension Model** – correction based on the distance from the center of the buoy watch circle with an estimated slope:
  - ➢ 0 – 3.3 cm from center to edge of circle



July, Combined GPS + Galileo Solution

- No attitude or antenna map, linear line tension model

Case σ (Buoy – Tide Gauge) [cm]	Nominal	Geoid	Geoid + Line Tension	Geoid + Line Tension + SSB	3-σ Outliers Removed
Baseline	2.127	2.065	1.986	**1.942**	0%
Combined G+E Solution	1.874	1.810	1.729	**1.665**	0%
Baseline 3-σ outlier removal	1.978	1.865	1.853	**1.816**	1.33%
Combined G+E Solution 3-σ outlier removal	1.665	1.598	1.653	**1.611**	0.67%

Observations and Conclusions

- A combined GPS + Galileo solution is a significant improvement (>2.5 mm) over the nominal GPS-only solution
- The SSB correction can improve agreement by up to 2 mm
  - ➢ Potentially refine using Lagrangian Mean Height
- 3-σ outlier removal on the difference removed ~2% of data, but improved agreement by up to 2.5 mm
  - ➢ Additional research is required to eliminate these outliers without relying on both sensors
- 5 mm/year drift needs further investigation
- Adding attitude data/calibration map did not significantly change results from baseline case
- GNSS buoys show promise as a method for measuring water level in areas without dedicated tide gauges

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This research was carried out at the Jet Propulsion Laboratory and the California Institute of Technology under a contract with the National Aeronautics and Space Administration.

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