

Uncertainty in Observations of Sea State from Satellite Altimeters and Moored Wave Buoys in Nearshore Locations

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Summary

ESA Sea State CCI (Advertisement!)

— Phase 2 underway!



Challenges of collocations nearshore

- Methodology to collocate altimeters and buoys in areas of complex sea states
- Application to some sites in the North Pacific
- What altimetry observations tell us about spatial properties of long-term sea state variability
- What this tells us about individual *in situ* platforms

ESA Sea State Climate Change Initiative

ESA Sea State CCI: Phase 2



— Sea State CCI produces re-tracked and consistently calibrated satellite data (nadir altimeter and SAR imagery)

- > Extended Hs data from altimeters (new missions; ERS-1/2; Topex; Sentinel-3A/B; Sentinel-6A)
- > Multivariate sea state data from ERS-1/2; Envisat; Sentinel-1; TerraSAR-X

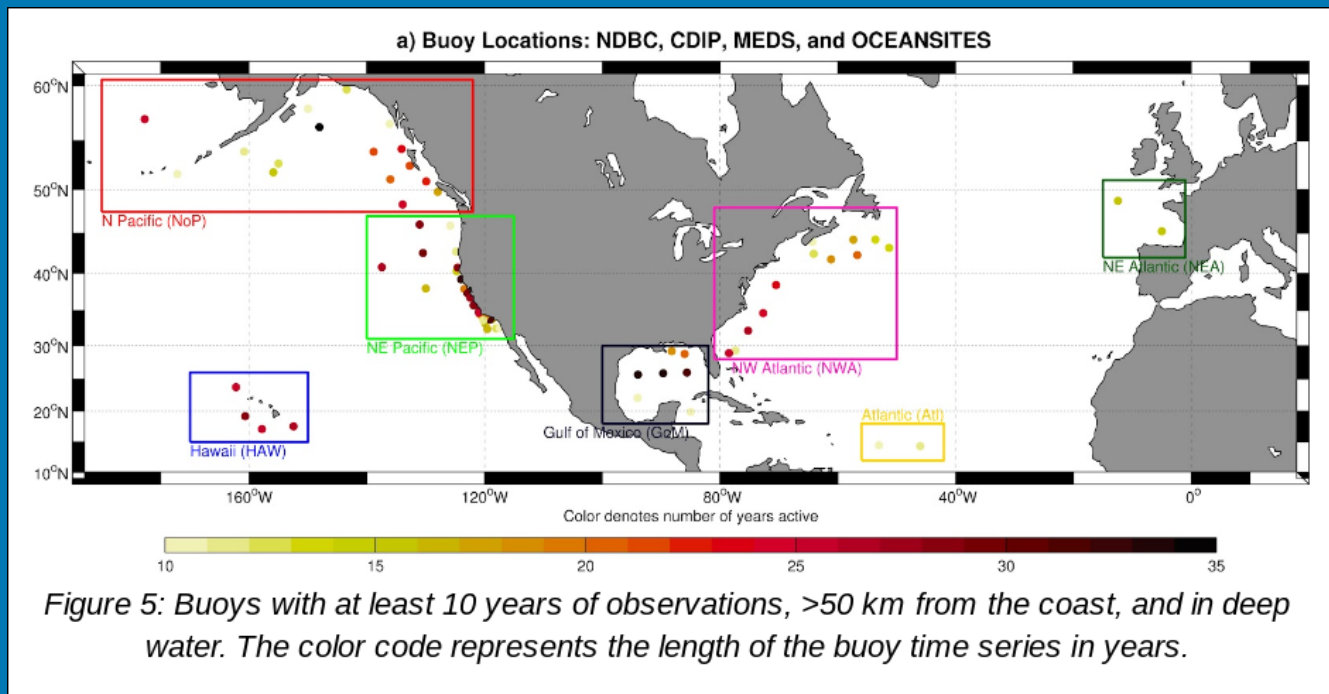
— **User Consultation Meeting: Nov/Dec 2025, NOC Southampton**

— <https://climate.esa.int/en/>



Collocation of sea state data

- Collocation of altimetry data and other sources is hugely important for the long term sea state record (e.g. Sea State CCI, Ribal & Young)
- Historically, “super-observations” used, e.g. 50 km and 30 minutes, assumes homogeneity of local conditions (Campos 2023).
- Coastal sites are neglected due to:
 - > Strong local variability driving spatial gradients
 - > Representativity error

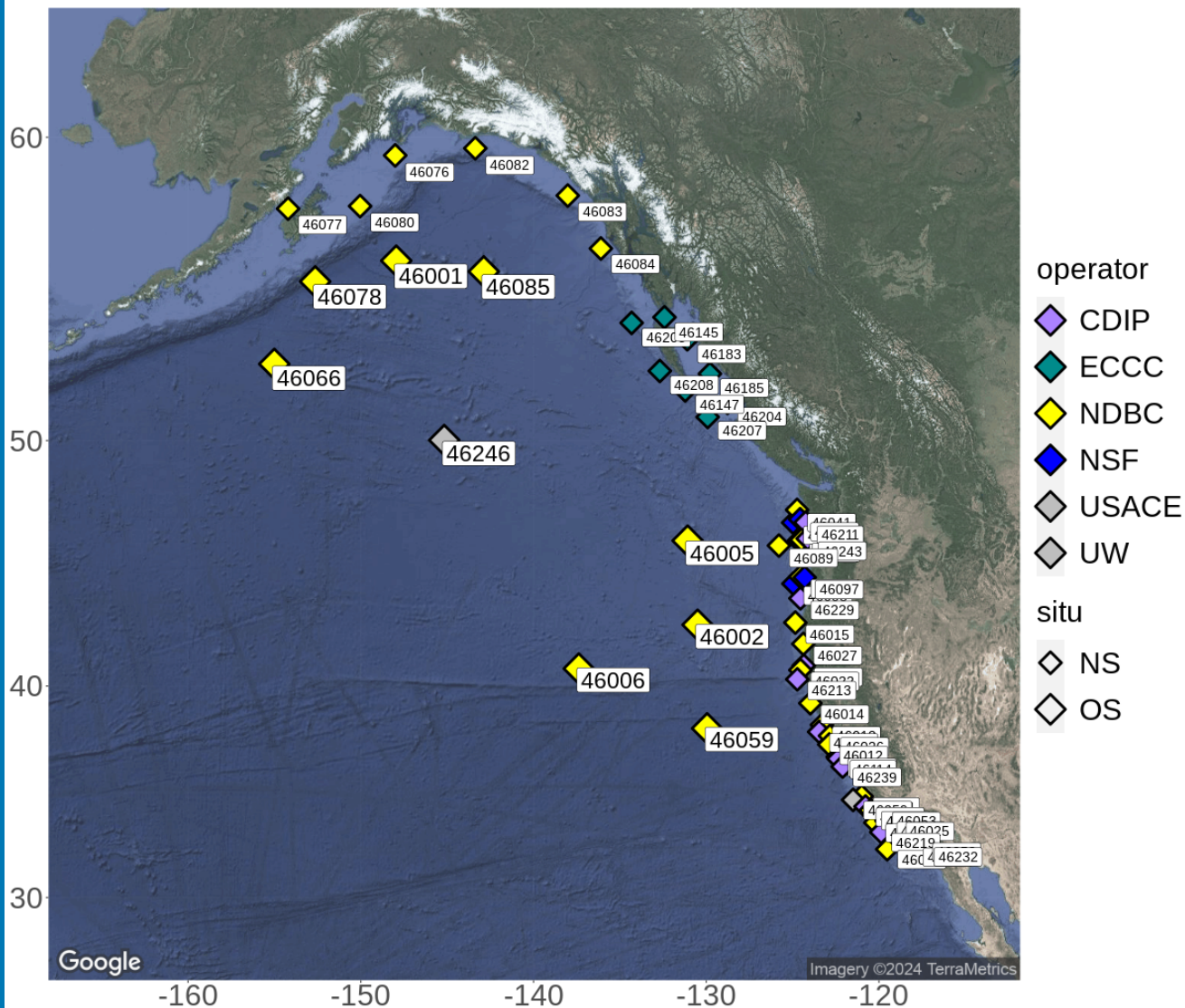


Dodet et al. (2020)

Location of study

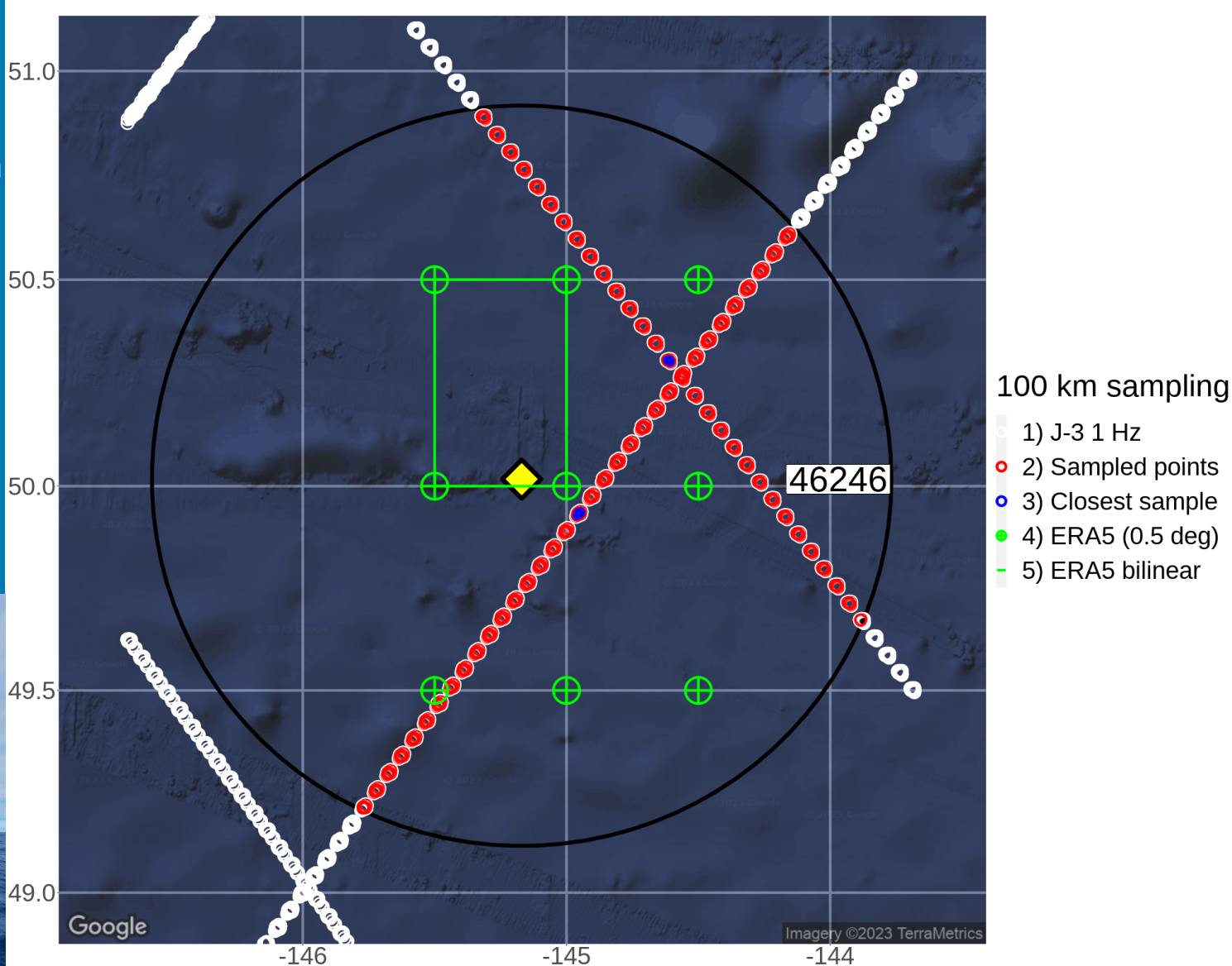
“Offshore” vs “Nearshore”

- Offshore assumed unaffected by land and steep sea state gradients.
- Nearshore important to coastal science, coastal industry and impacts.
- How about altimetry performance nearshore?
- Many nearshore buoys providing *in situ* measurements available.



Collocation introduces sources of uncertainty:

- Maps show collocation of three data sources; Jason-3 altimetry; in situ mooring; reanalysis grid.
- Average of 1 Hz “**Super-observations**” used for collocation (assume homogeneity of local conditions).
- Probably justifiable offshore, but how about nearshore?

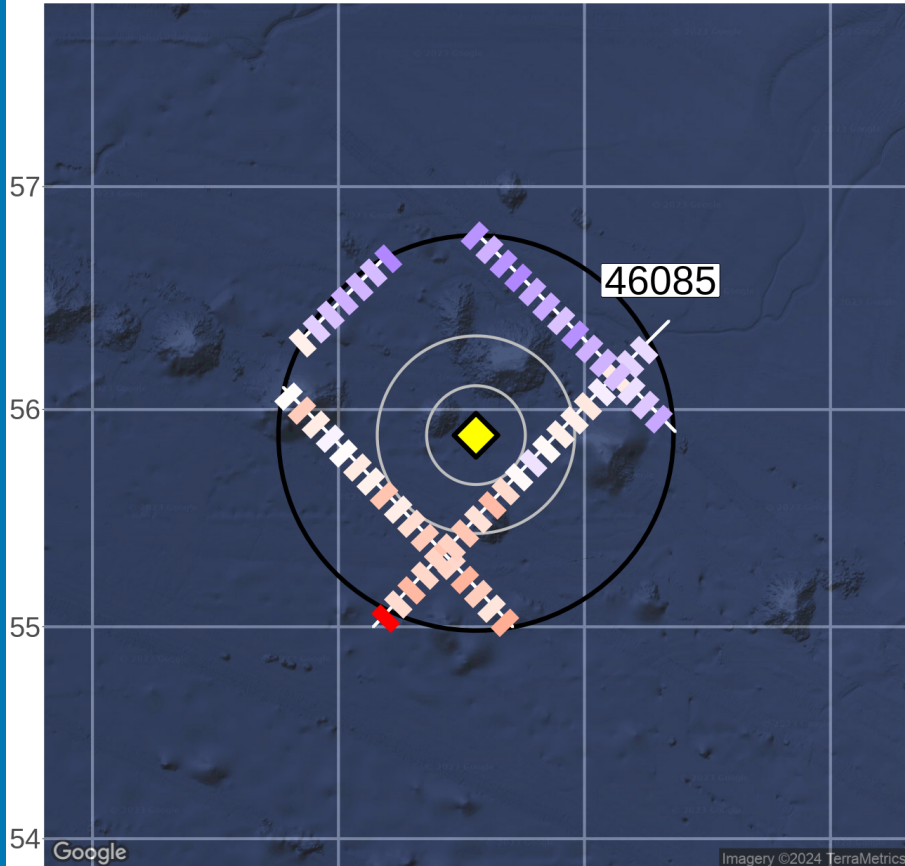


Methodology for altimetry collocation

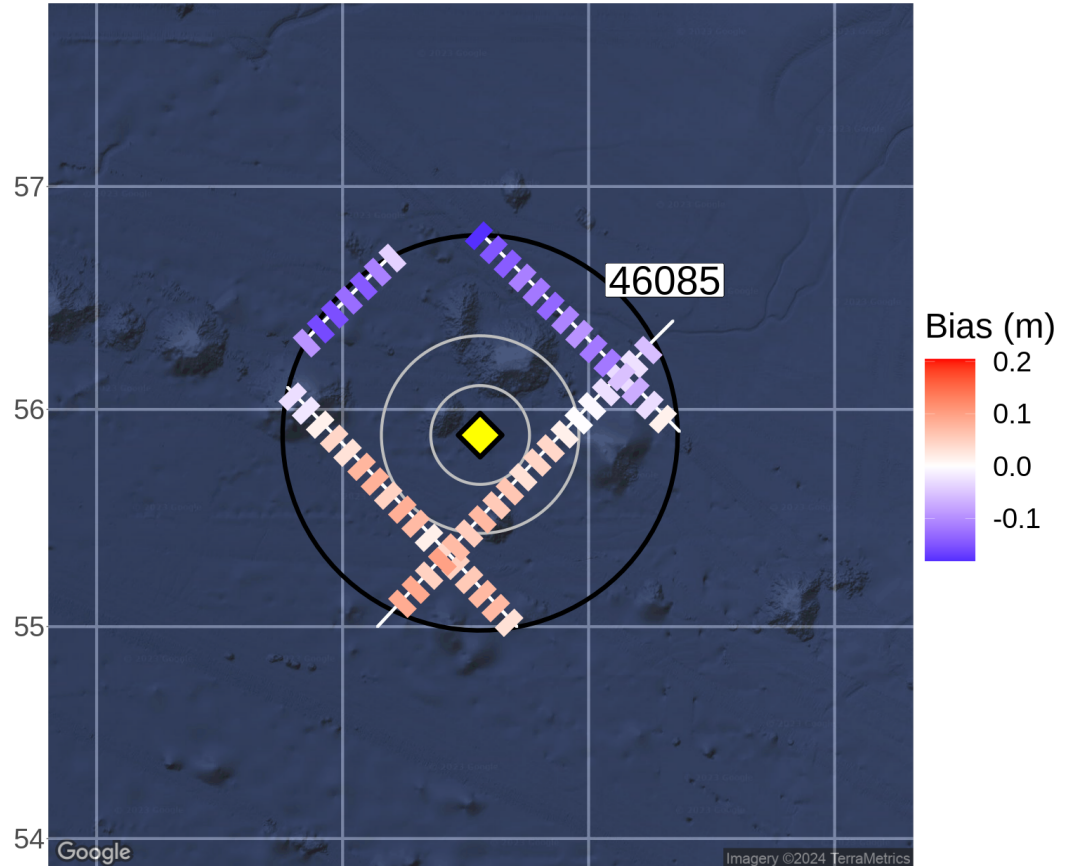
- Binned 1 Hz data from altimeter on Jason-3 [2017-2021]; 10-day repeat
- Seasonal [AMJJAS; ONDJFM] Hs mean bias

46085; 100 km sampling; 10 km bin size

AMJJAS



ONDJFM

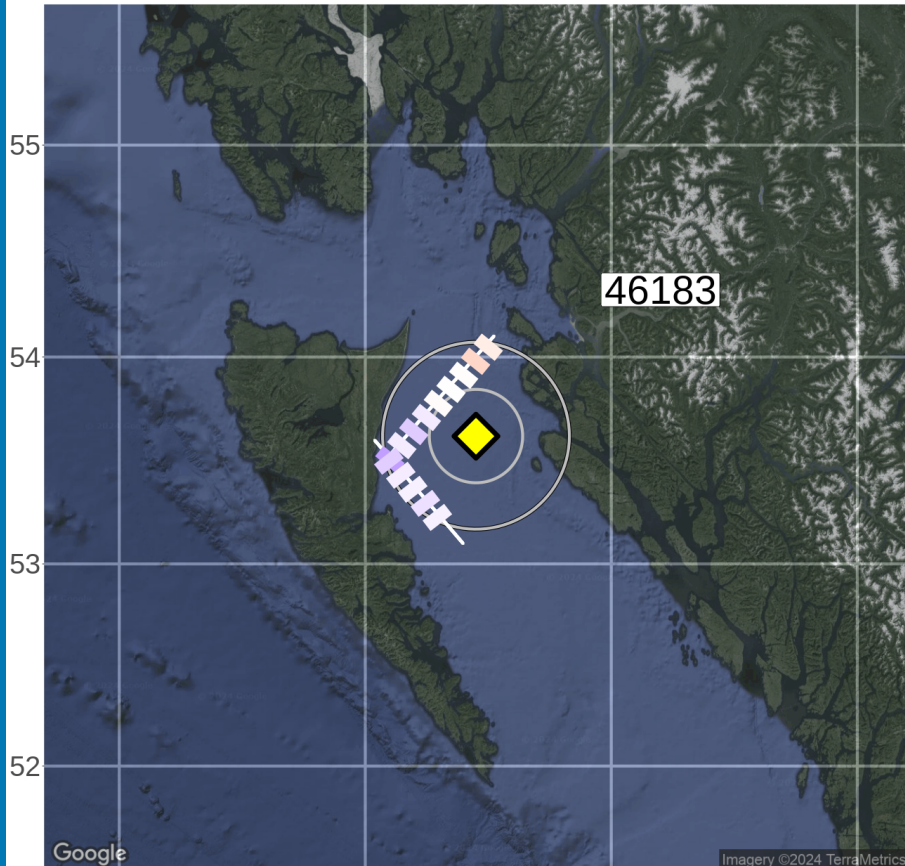


Methodology for altimetry collocation

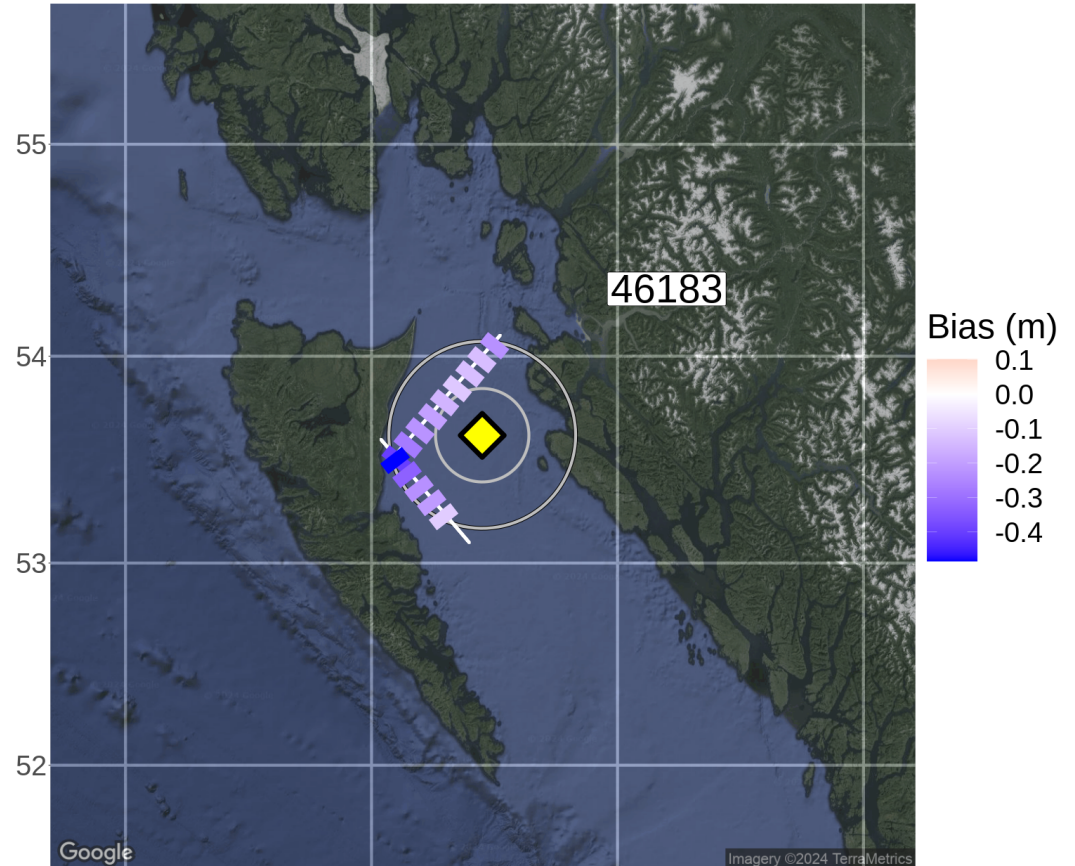
- Binned 1 Hz data from altimeter on Jason-3 [2017-2021]; 10-day repeat
- Seasonal [AMJJAS; ONDJFM] Hs mean bias

46183; 50 km sampling; 10 km bin size

AMJJAS



ONDJFM

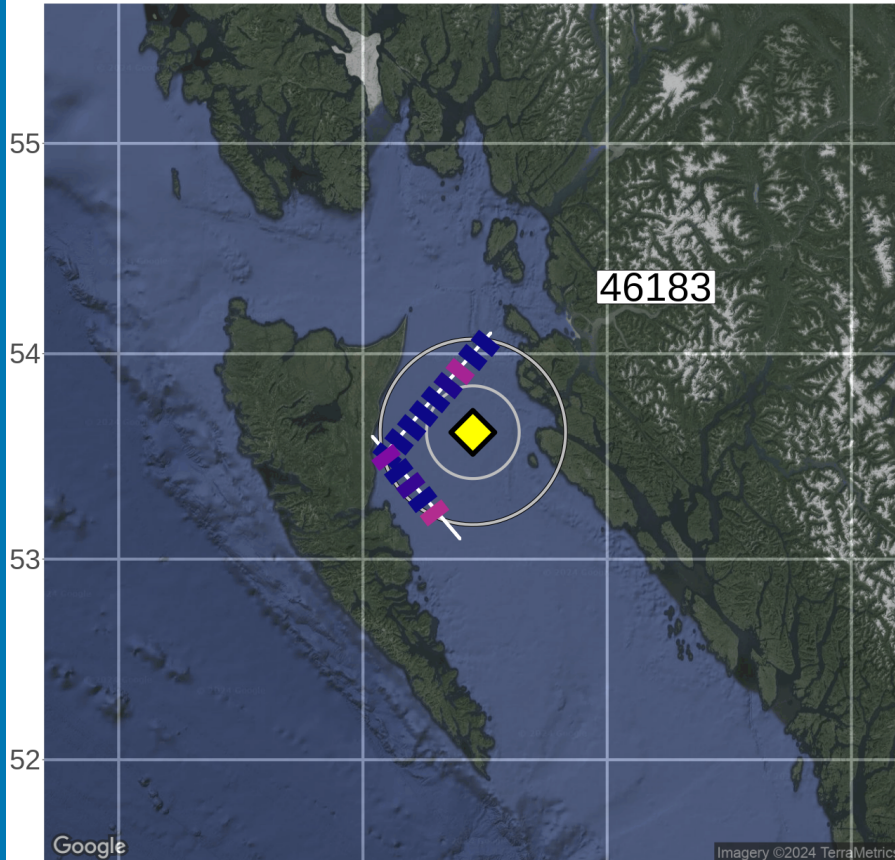


Methodology for altimetry collocation

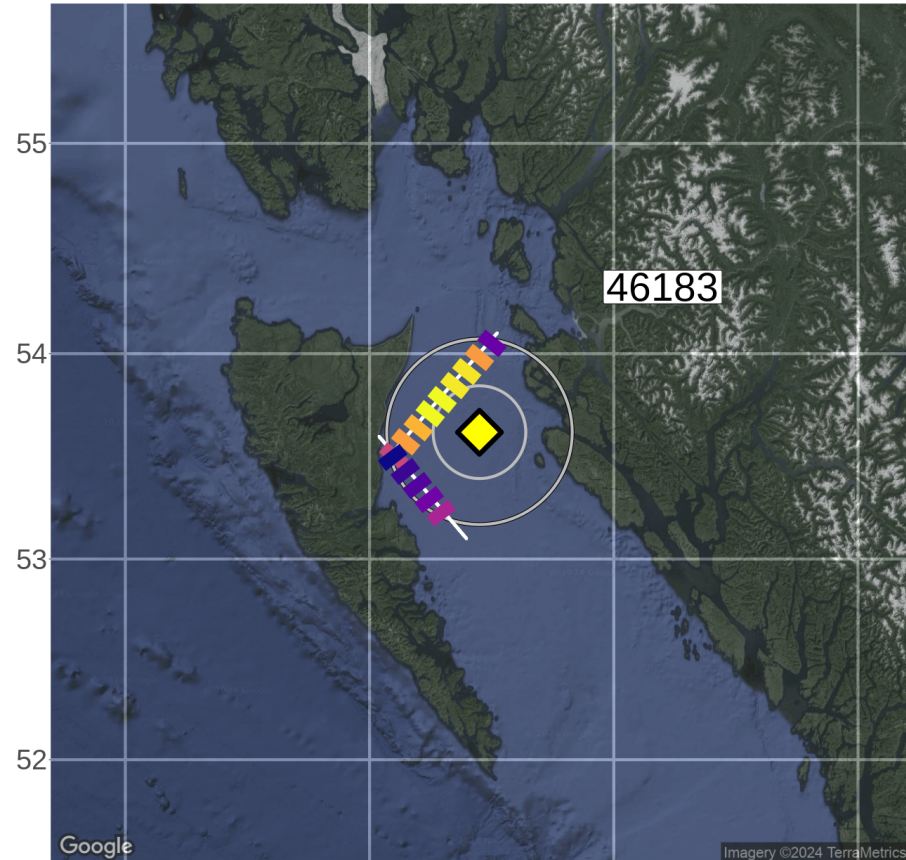
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AMJJAS



ONDJFM



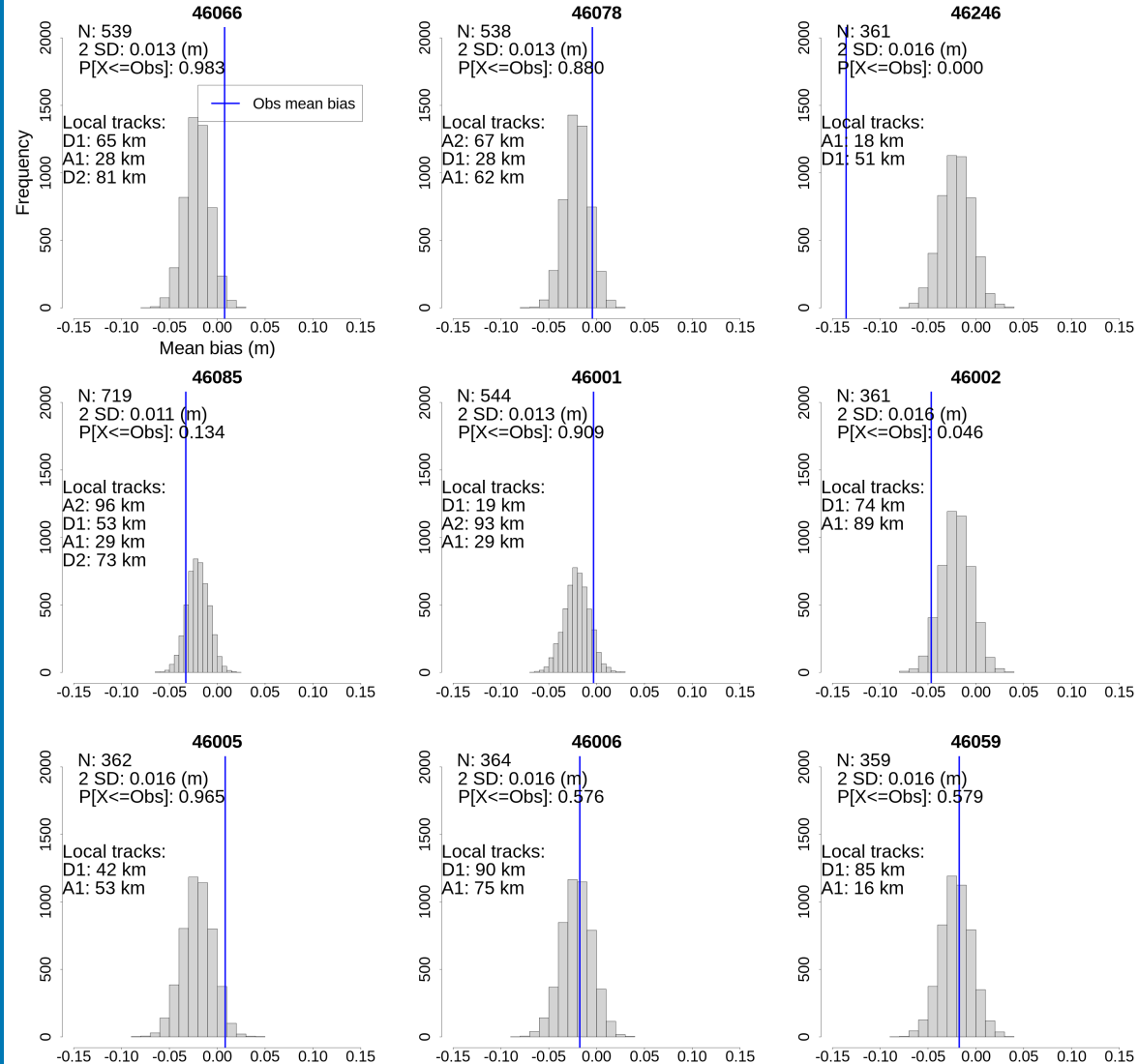
Disagreement between altimeters and buoys

— Here we have used resampling to examine uncertainty in mean bias between Jason-3 (GDR) and buoys.

— **46246 (top right panel) suffers an anomalous bias:**

- > Blue lines show observed mean bias;
- > Mean bias lies well beyond any meaningful confidence limit.

OS J3[M60] 100km Bootstrap sampling distribution for mean bias



Conclusions

— **Methodology to collocate altimeters and buoys in areas of complex sea states has been developed:**

- > Sea state gradients evaluated using along-track altimetry ~10 km
- > “Informed” sampling methodology for aggregate (many buoys) analysis may be developed...
- > “Problematic” buoys rigorously identified.

— Do you have coastal applications that might benefit from sea state observations from satellite?

— Sea State CCI User Consultation Meeting: **Nov/Dec 2025, NOC Southampton**



References

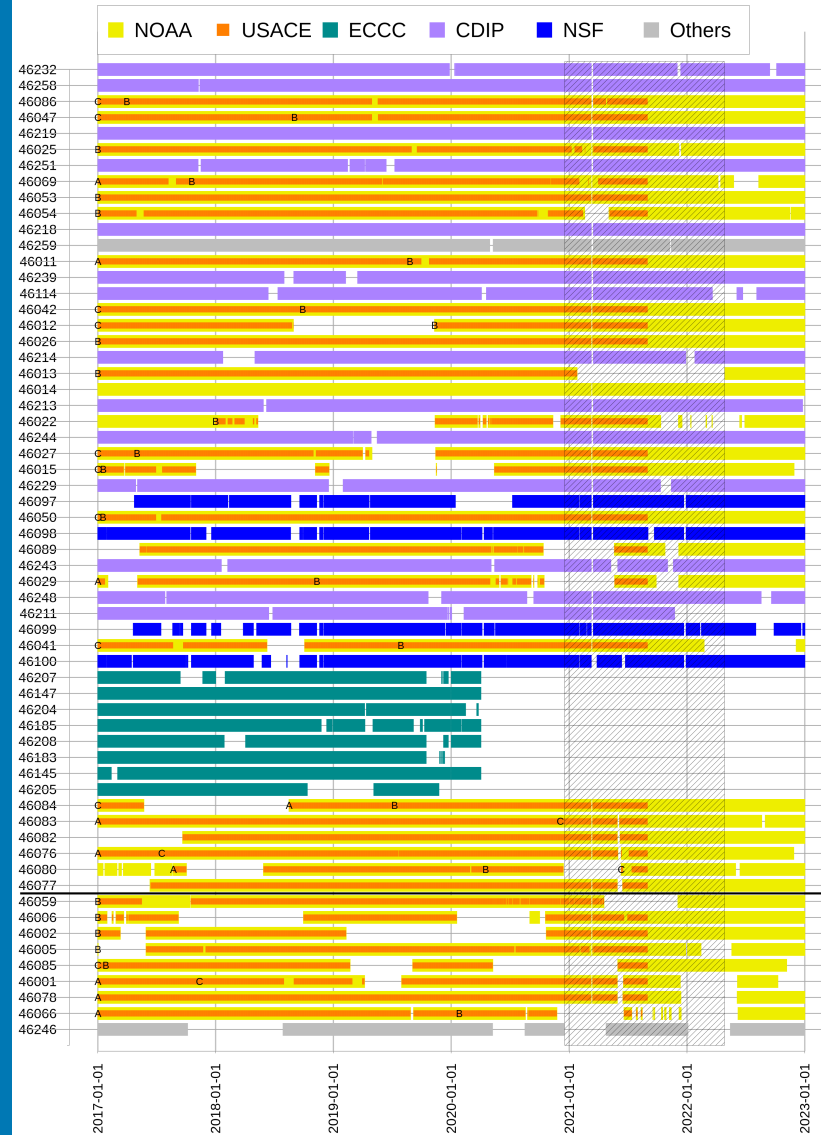
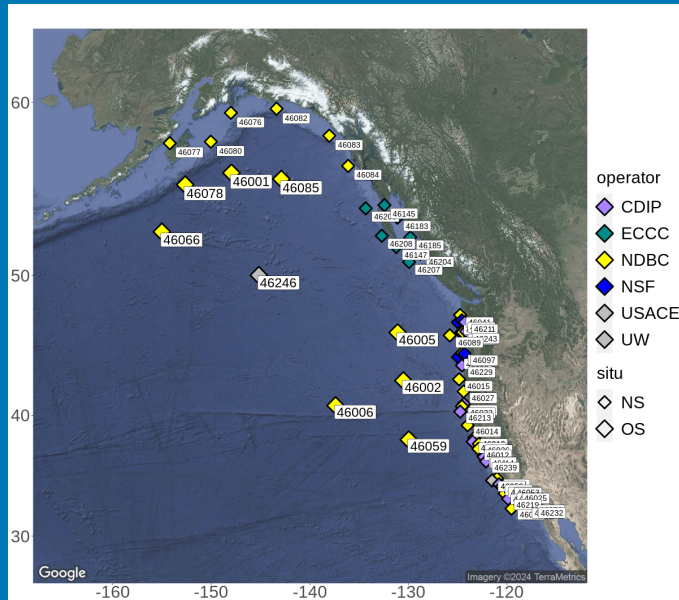
- > Ribal, A. & Young, I. 2019, 33 years of globally calibrated wave height and wind speed data based on altimeter observations, *Scientific Data*, 6, <https://doi.org/10.1038/s41597-019-0083-9>
- > Candice Hall & Robert E. Jensen (2022) USACE Coastal and Hydraulics Laboratory Quality Controlled Consistent Measurement Archive *Scientific Data* 9:248 | <https://doi.org/10.1038/s41597-022-01344-z>
- > Dodet, G. et al. (2022), Error Characterization of Significant Wave Heights in Multidecadal Satellite Altimeter Product, Model Hindcast, and In Situ Measurements Using the Triple Collocation Technique, *J.Tech*, 39, <https://doi.org/10.1175/JTECH-D-21-0179.s1>
- > Ricardo M. Campos (2023) Analysis of Spatial and Temporal Criteria for Altimeter Collocation of Significant Wave Height and Wind Speed Data in Deep Waters *Remote Sensing* 15, <https://doi.org/10.3390/rs15082203>

Validation updates: *In situ* data

Variability across platforms

— Comparison of coverage and platform variability for Northeast Pacific *in situ* data

— Note, payload denoted by (small!) black letters



Validation updates: *In situ* data

Disagreement between sources

— For NOAA buoys, data can be acquired from at least three different sources:

- > NDBC archive (web portal)
- > USACE dataset (Hall & Jensen)
- > CMEMS In-Situ TAC (web portal)

— **46001 [1987 – 2000]**

- > USACE appears to disagree with NDBC and CMEMS

