Sea State Uncertainty near the Coast from Recent Satellite Observations from the Sentinel-6 Michael Freilich – Jason-3 Tandem Phase Experiment

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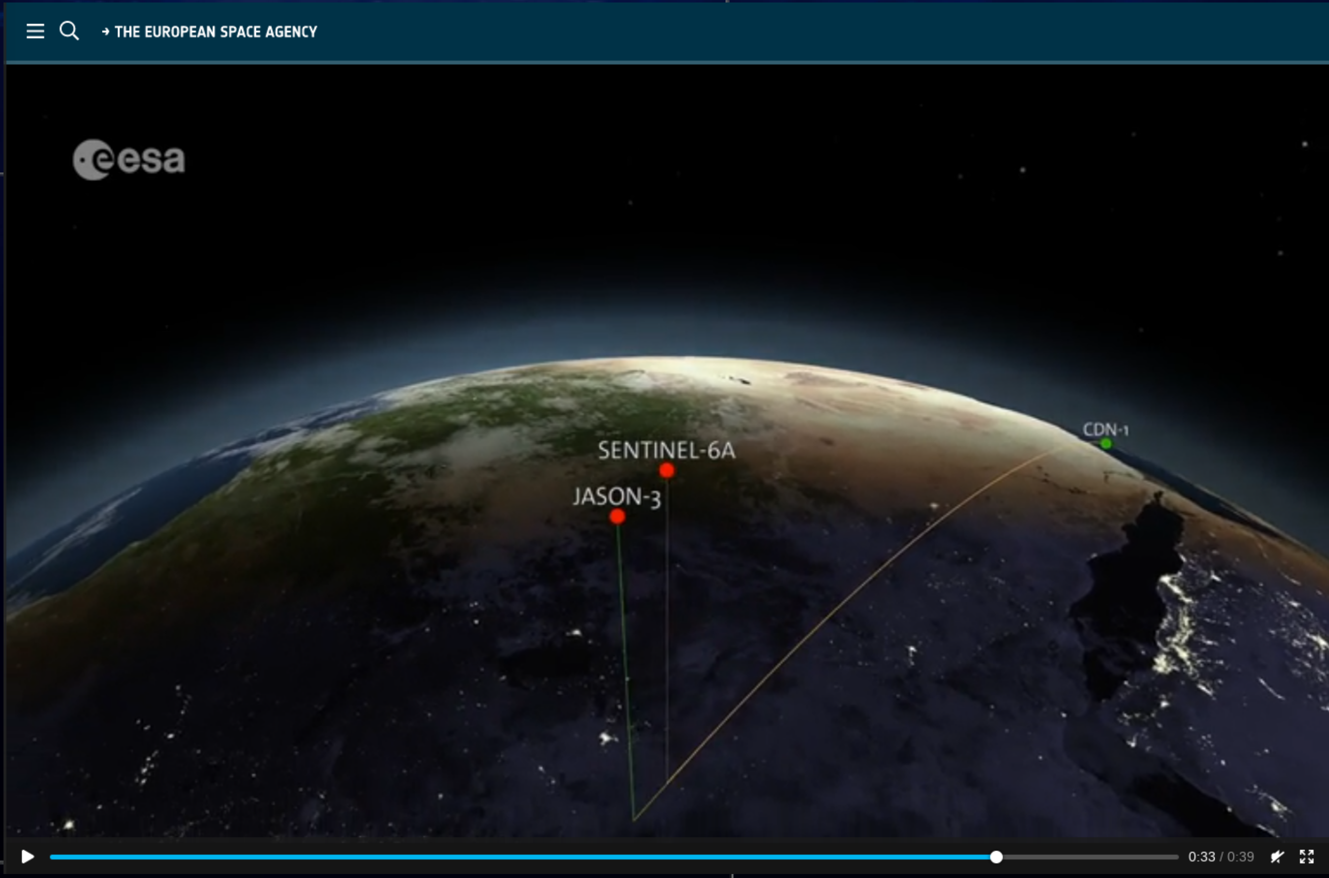
02 Oct 2023

Sentinel-6 / Jason-3 Tandem Experiment (S6-JTEX)

Donlon et al. 2021, The Copernicus Sentinel-6 mission: Enhanced continuity of satellite sea level measurements from space, *Remote Sensing of Environment*

Flight details

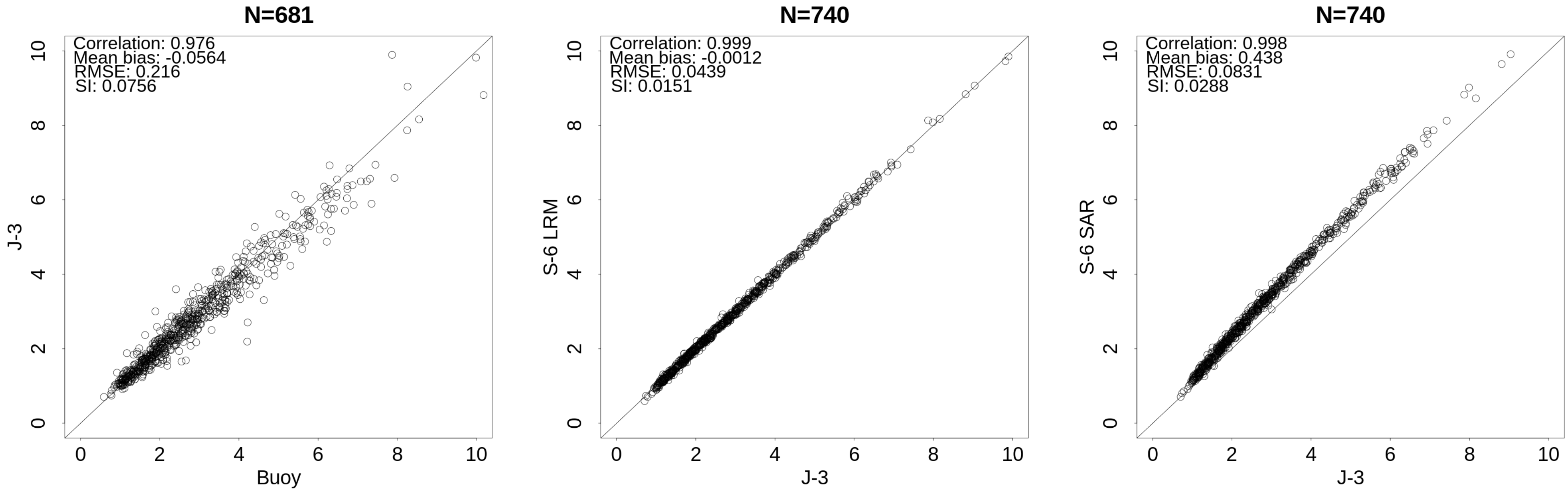
- **Sentinel-6(A) Michael Freilich, launched November 2020**
  - Carries Poseidon 4B altimeter, capable of LRM and SARM retrieval.
  - Fulfils “Jason Continuity of Service” (Jason-CS)
- **Tandem Phase (S6-JTEX)**
  - December 2020 to April 2022 (~15 months)
  - S-6 trailed J-3 by ~30s
  - Jason-3 orbit (~10 day repeat)



https://www.esa.int/ESA_Multimedia/Videos/2021/06/Sentinel-6_and_Jason-3_tandem

Sentinel-6 / Jason-3 Tandem Data (Offshore)

2020/12 - 2021/12 Buoy: 46246,46006,46002,46005,46001



100 km, 30 minutes sampling window
J-3 low bias at high SWH (F00 to F04 reprocessing)
Extremely good agreement between Jason-3 and Sentinel-6 LRM
Strong sea state dependent bias between LRM and SARM acquisition

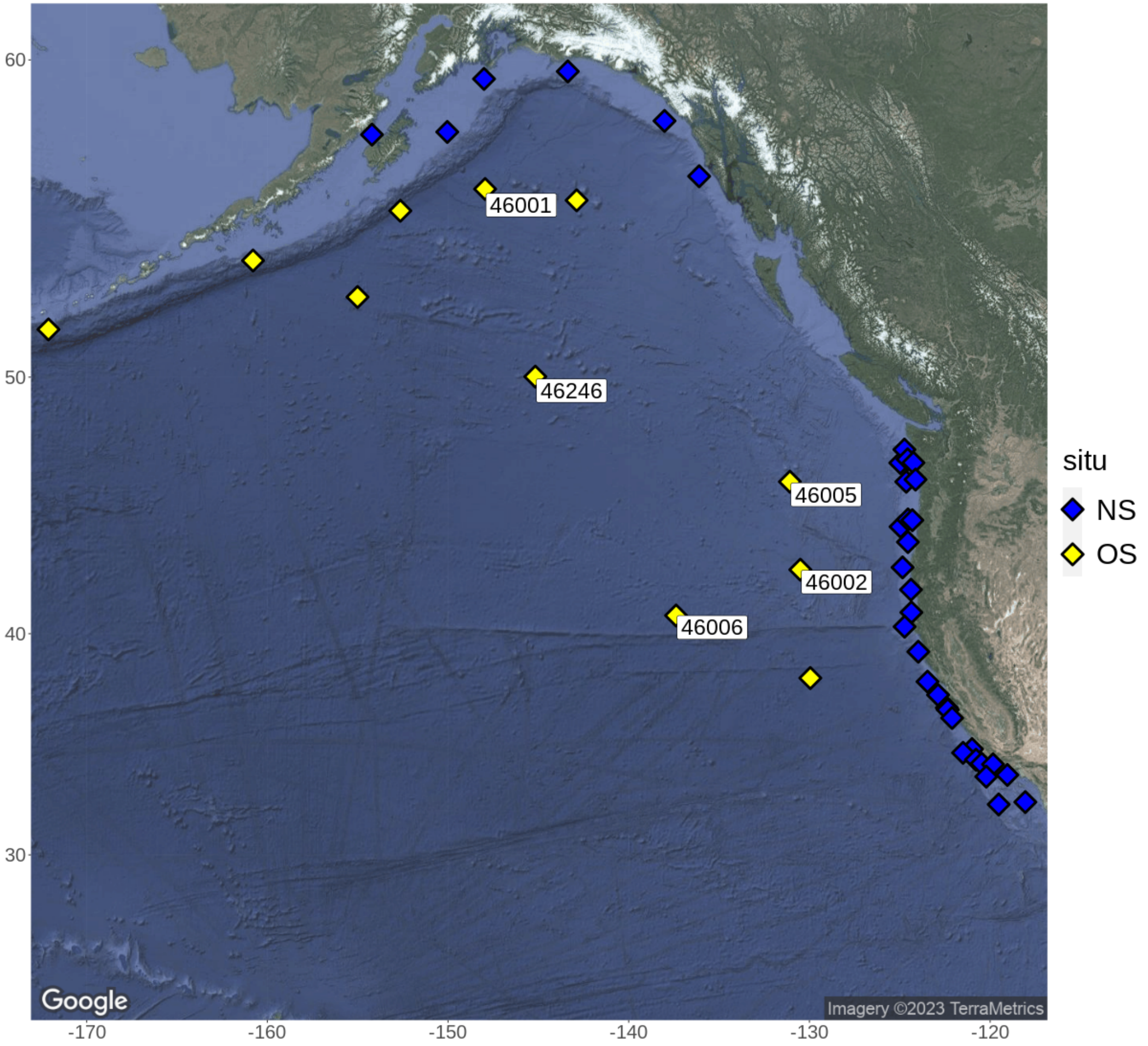
Sentinel-6 / Jason-3 Tandem

Two aspects of this work shown today ...

- With a focus on *in situ* sites closer to the coast, can we use the altimetry to learn more about the spatial distribution of sea state variability?
- Can we use that knowledge to better exploit *in situ* records and better understand how uncertainties affect analyses based on multiple collocations, e.g. through different sampling approaches?

Use of *in situ* moorings

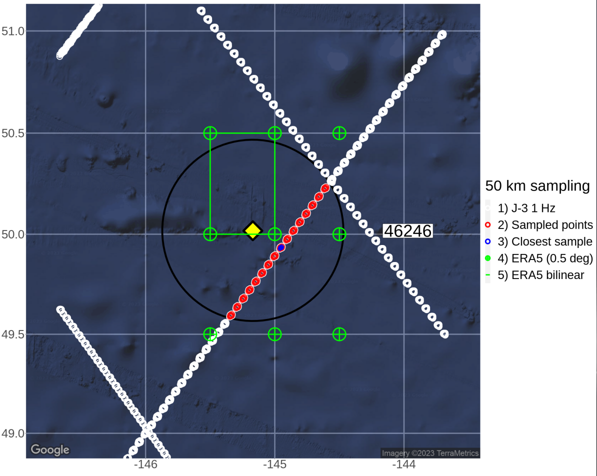
- Sampling, and statistical robustness, can be increased by exploiting larger numbers of sites.
- Coastal sites are relatively abundant compared to deep water sites.

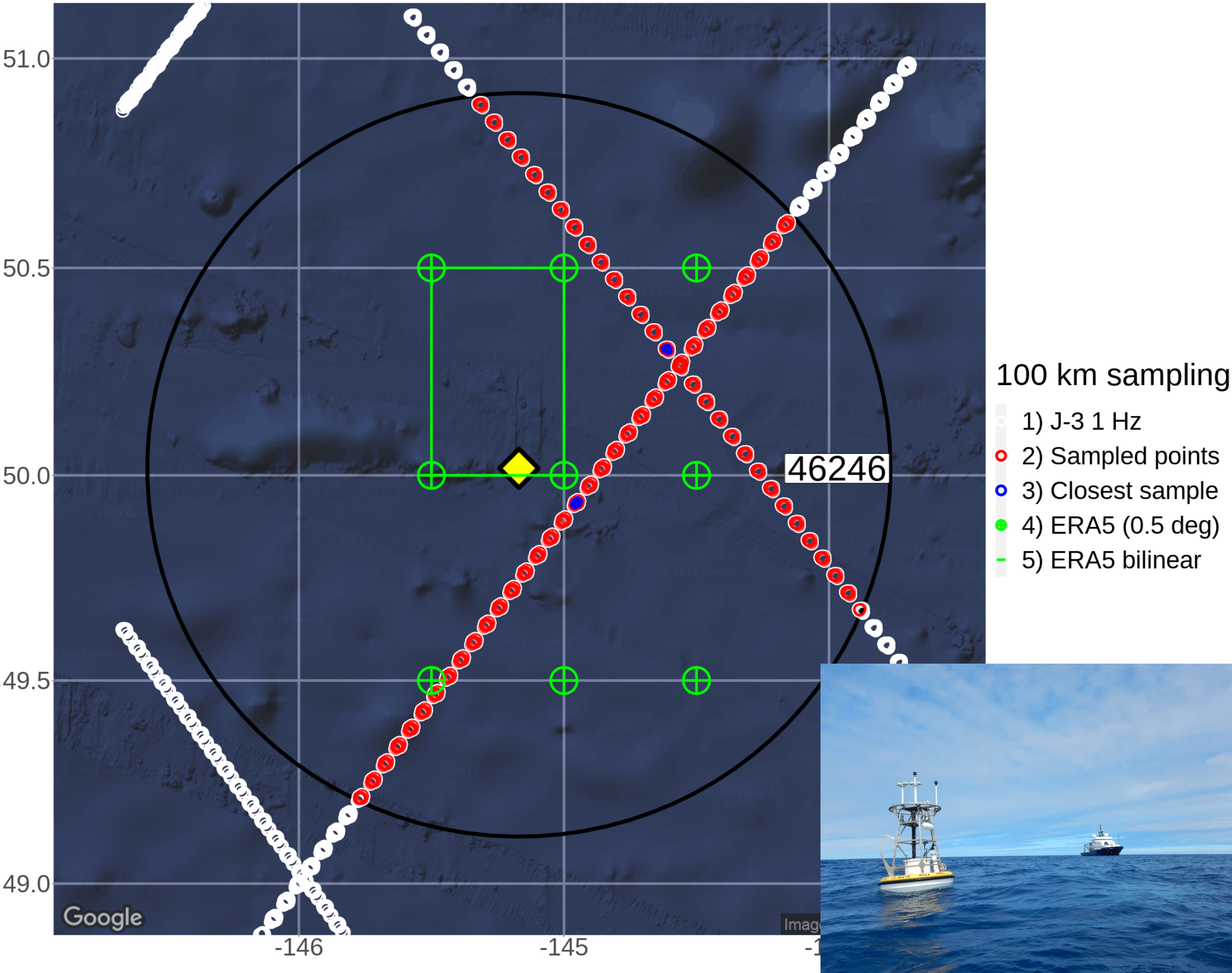


Collocating sea state data

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).
- Is this sampling approach effective in the presence of sea state gradients?

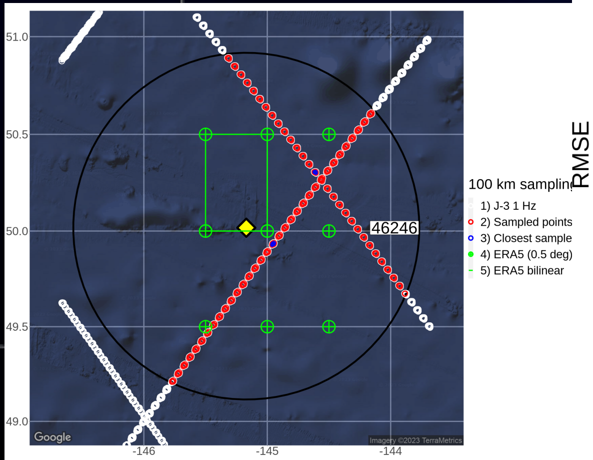


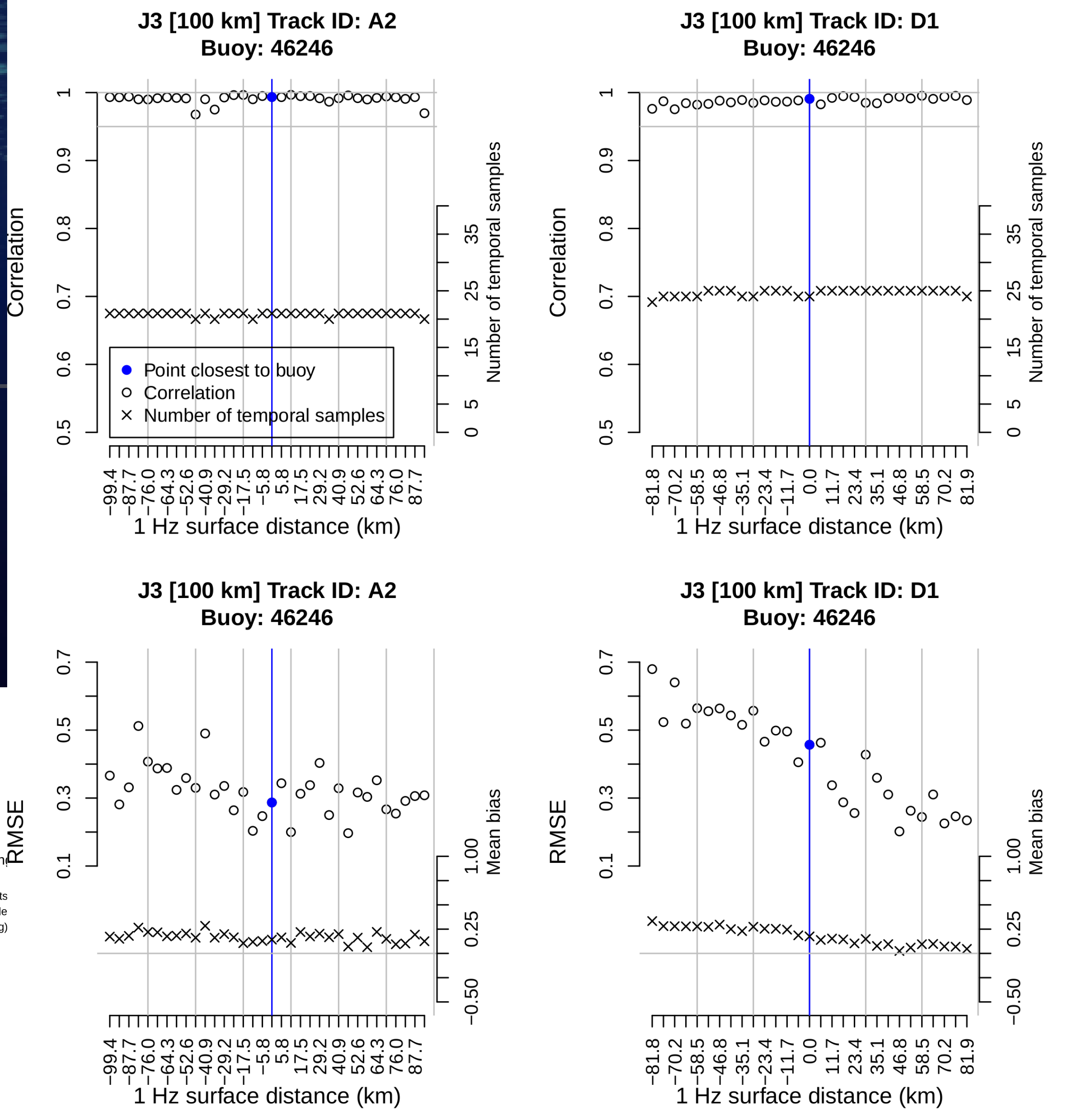


Sampling sea state at 46246

We can look explicitly at longer term statistics between “1 Hz locations” and e.g. in situ or reanalysis.

- The ascending track (A2) and descending track (D1) exhibit different characteristics.
- Figures (top) show correlations and number of temporal samples for ~12 months J-3 data (~38 orbital repeats):
  - Number of temporal samples (crosses)
  - Correlation for each 1 Hz repeat location (circles) with buoy data.
- Figures (bottom) show RMSE (circles) and mean bias (crosses).
- Note the spatial variability of RMSE and bias for track D1.





Offshore Locations

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North East Pacific

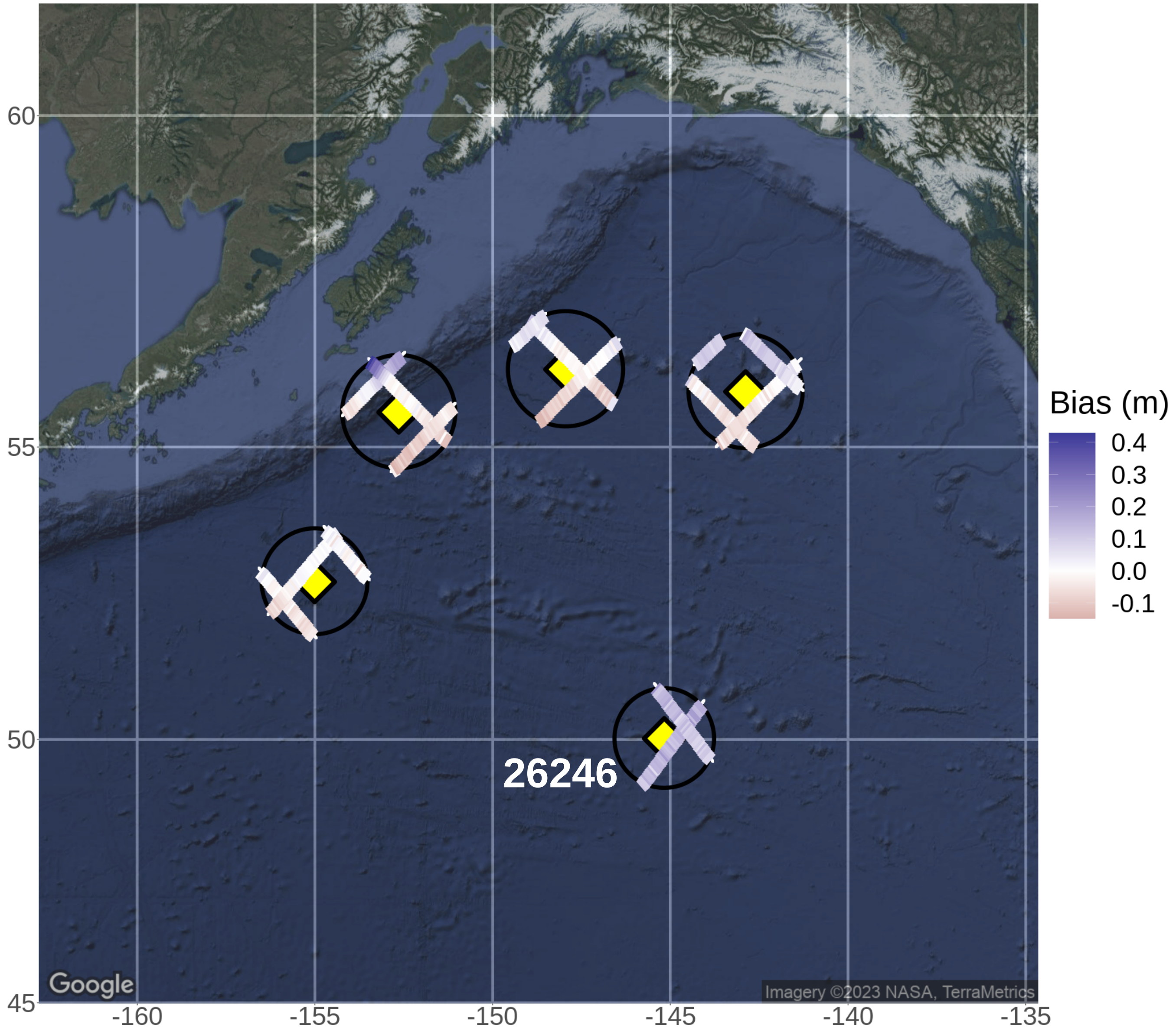
Jason-3 (2017-2021)

Sampling at 100 km radius

Mean bias between buoys and Jason-3

Note the site dependent gradients:

- Sheltering and shelf-sea likely linked to large changes in bias.
- Anomalous bias at 46246??



North East Pacific

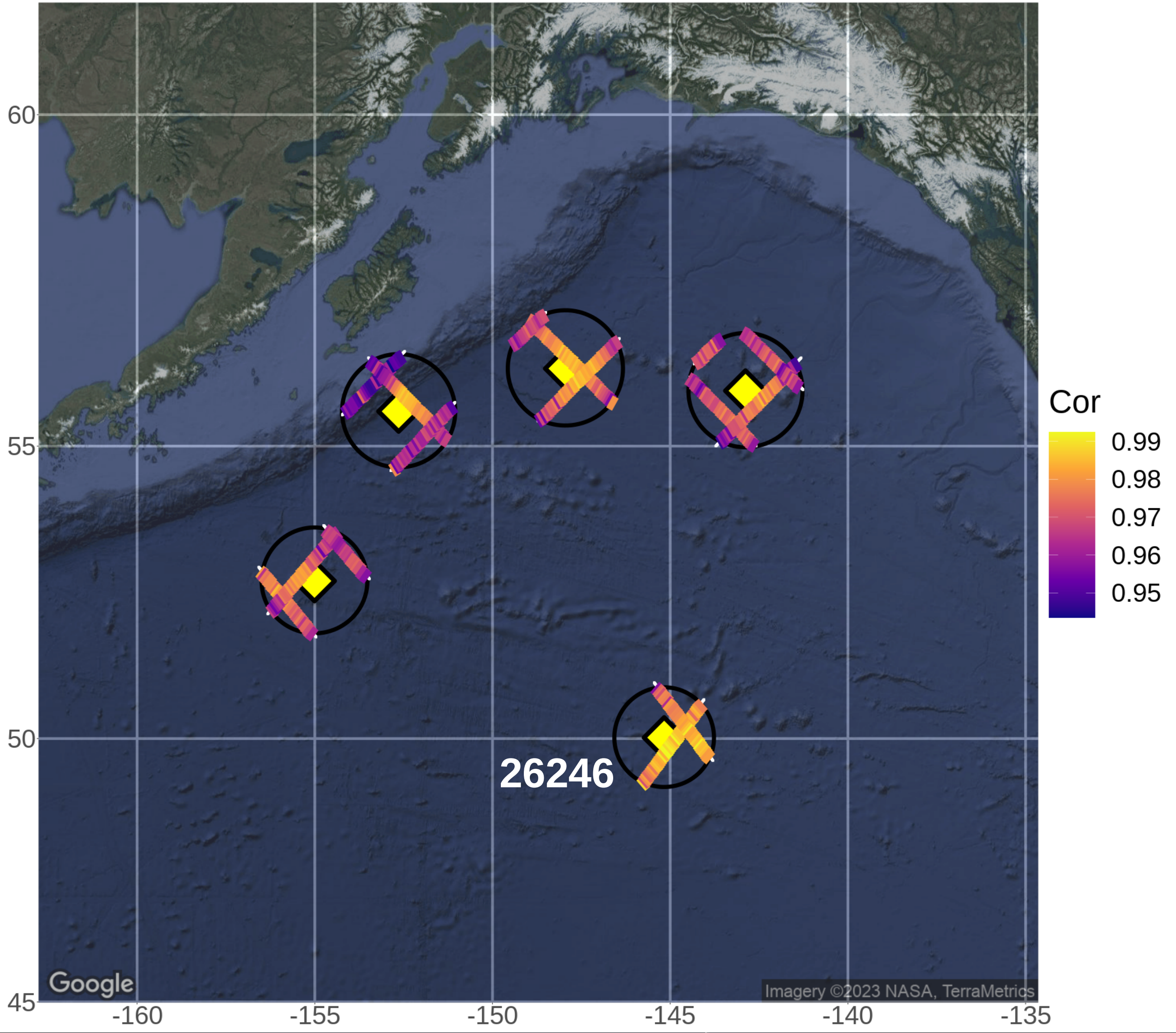
Jason-3 (2017-2021)

Sampling at 100 km radius

Correlation between buoys and Jason-3

Note the site dependent gradients:

- Highest correlations furthest offshore (46246).
- Correlation more variable closer to coast.



Nearshore Locations

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Nearshore sites

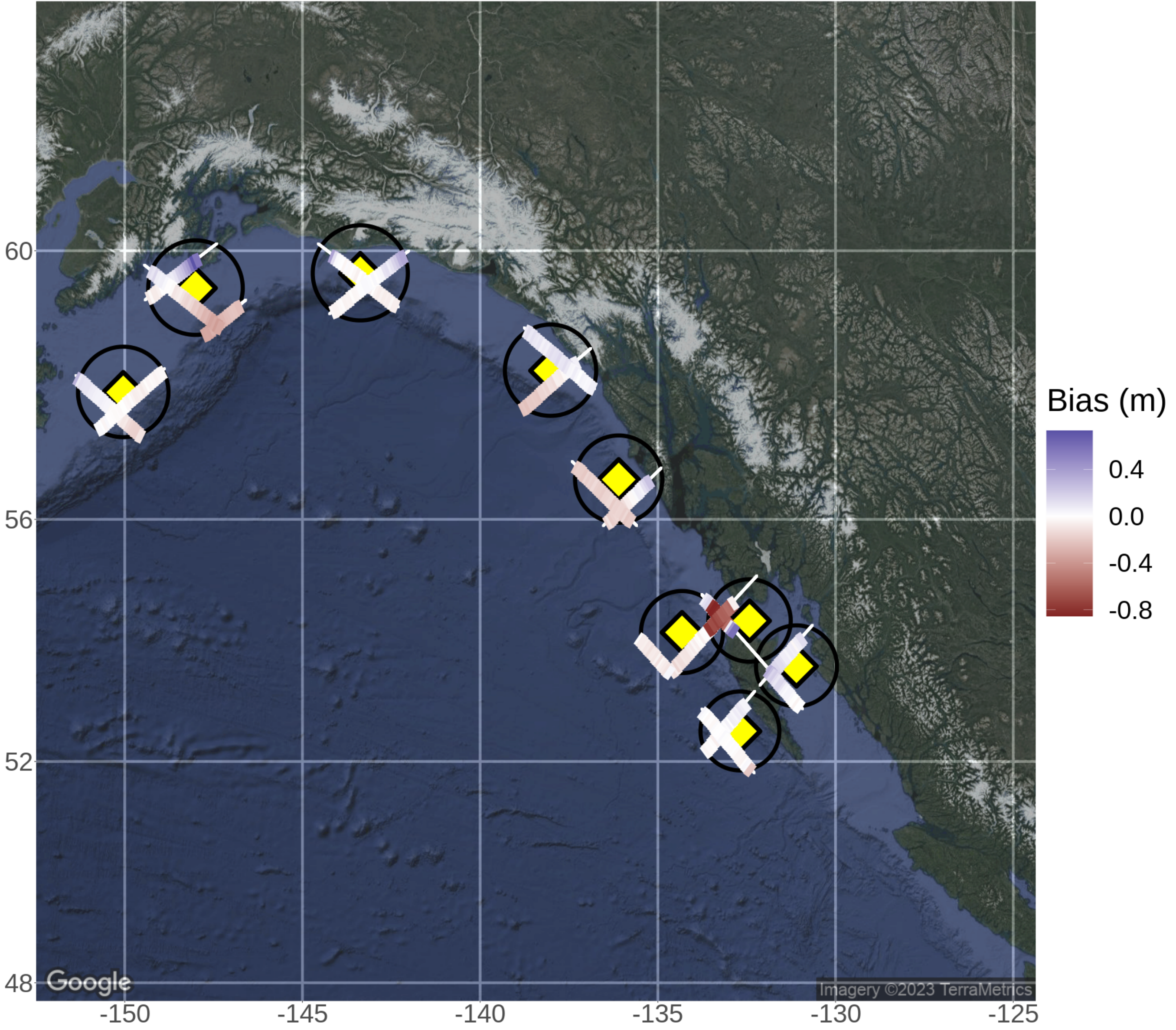
Jason-3 (2017-2021)

Sampling at 75 km radius

Mean bias between buoys and Jason-3

Note the site dependent gradients:

- Stronger gradients than seen offshore.
- Increased variability between sites.

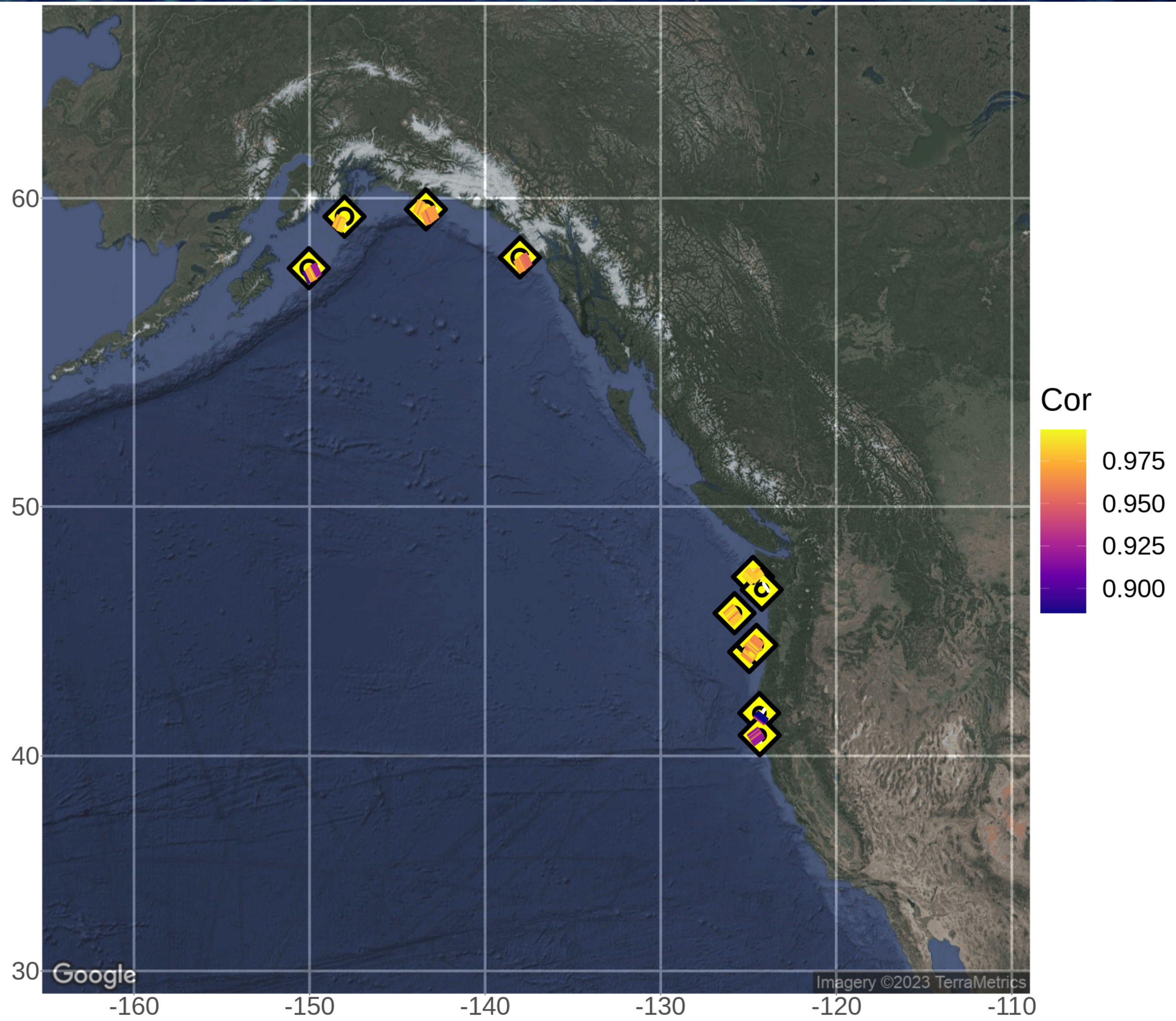


To perform an analysis across many sites, the impact of representativity errors from sea state gradients can be mitigated by constraining collocations:

25 km sampling

11 buoys

Samples become very limited!

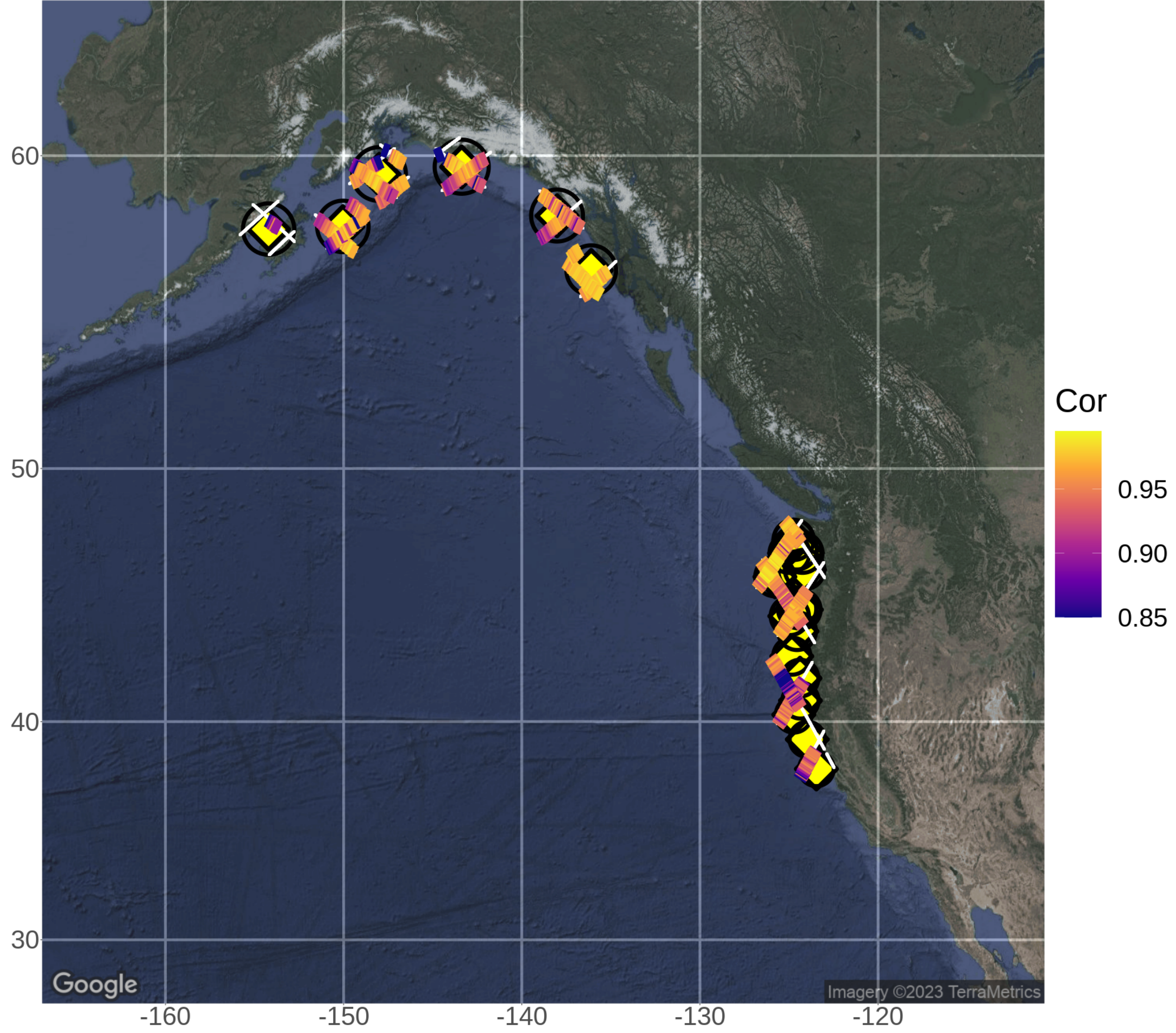


Perhaps we can sample over larger area but “adaptively” filter by matching the long term variability (e.g. using a correlation threshold?):

85 km sampling

23 buoys

Samples increased by >100%!



Some performance statistics for Jason-3 at 85 km sampling.

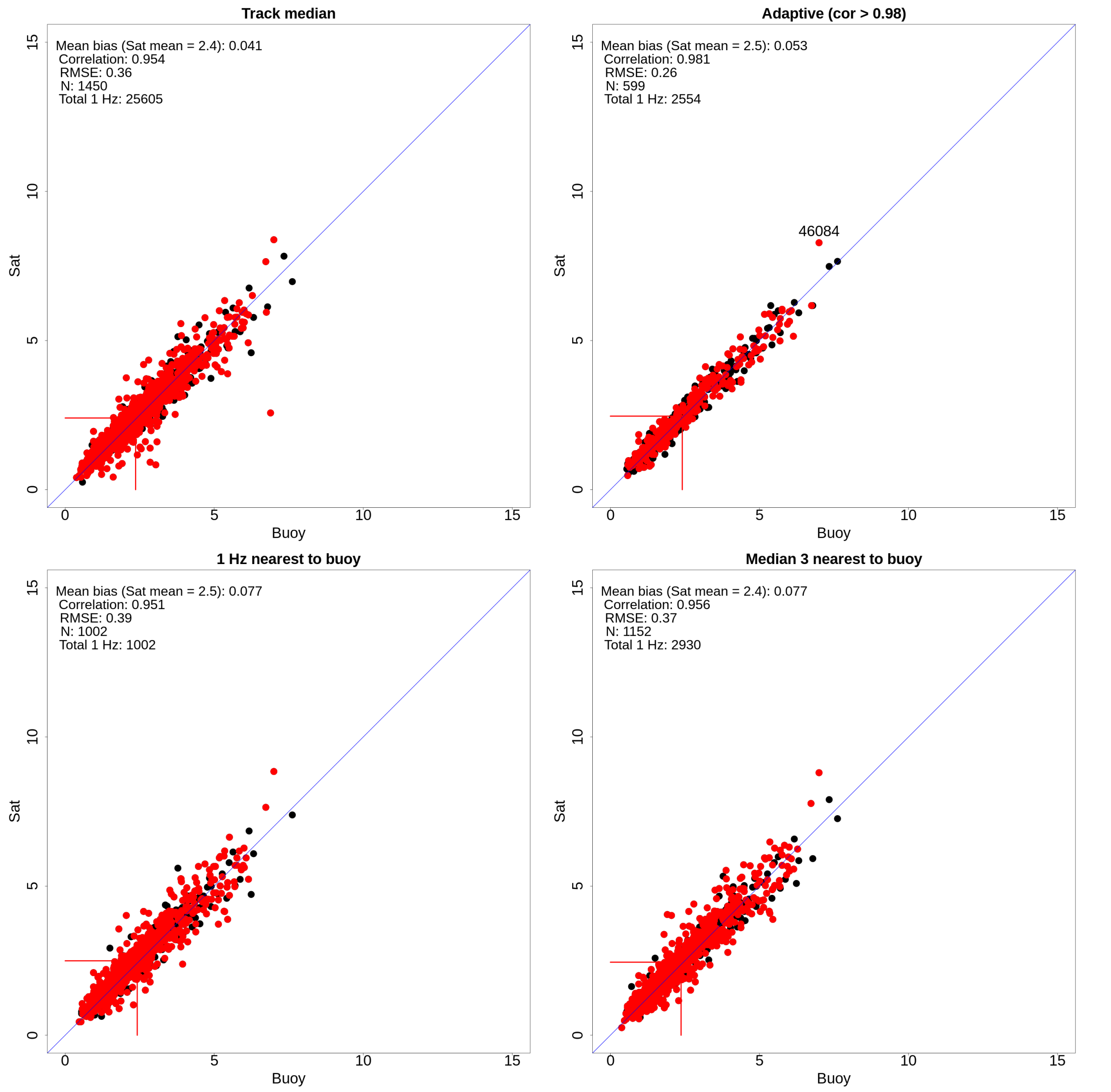
Four sampling methods:
1) Top left: full track median
2) Top right: “adaptive”, cor > 0.98
3) Bottom left: single nearest 1 Hz
4) Bottom right: median 3 nearest 1 Hz

23 buoys available

Red dots: > 25 km
Black dots: < 25 km

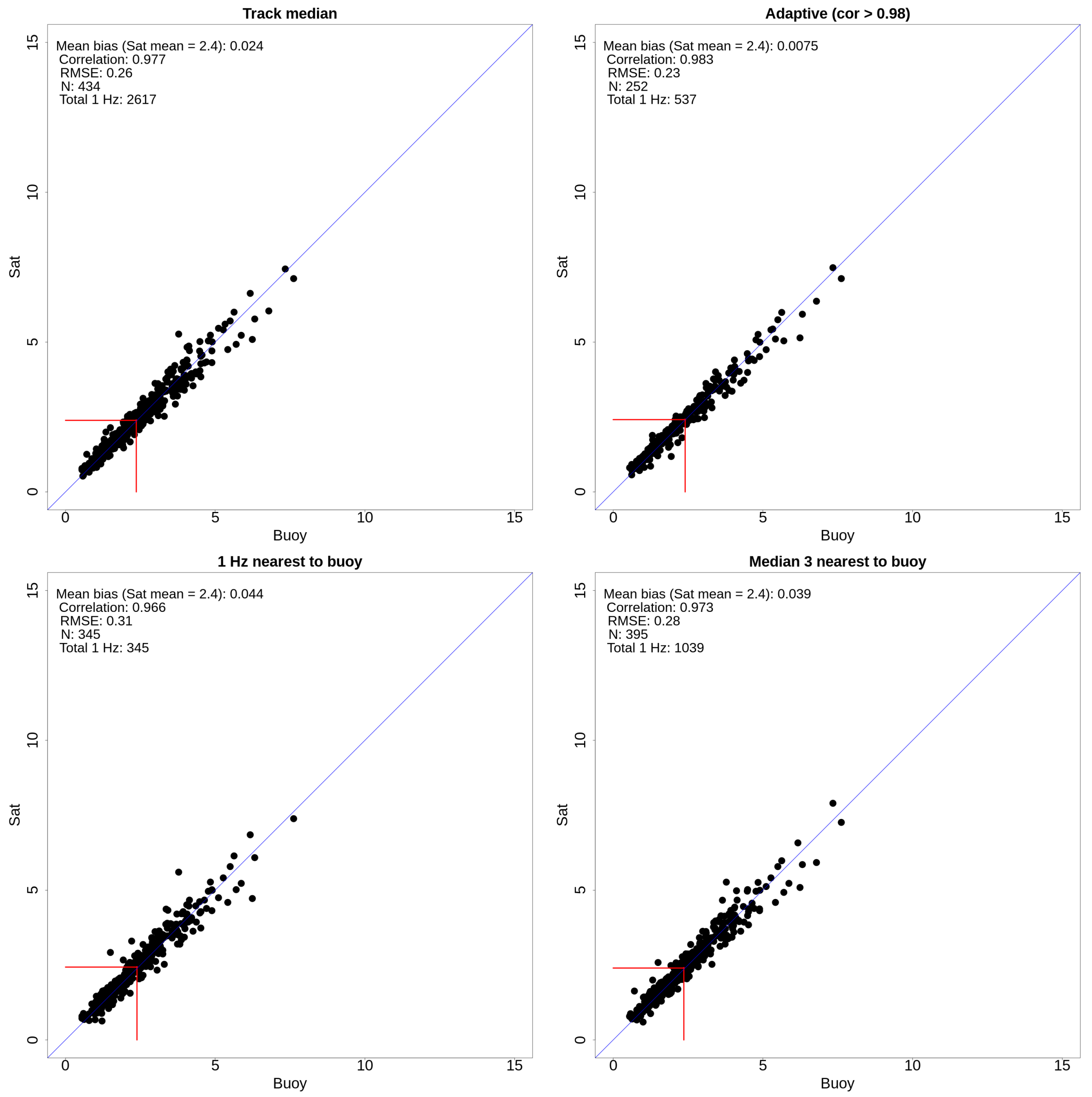
Performance statistics close to the coast are comparable to those offshore.

Very little difference between Jason-3 and Sentinel-6 LRM (see additional slides).



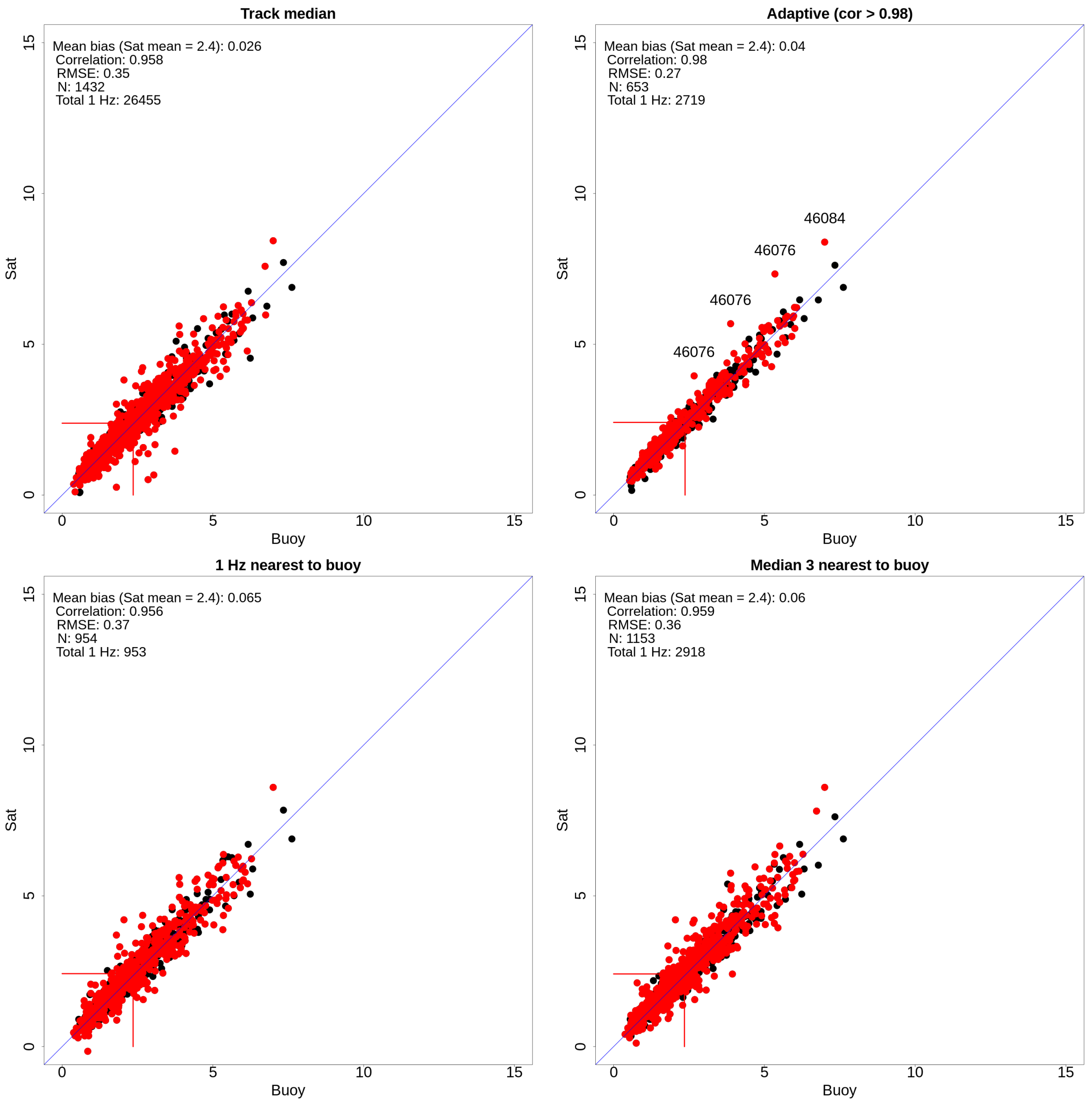
For reference, some performance statistics for Jason-3 at 25 km sampling (same as previous slide but with red dots removed).

11 buoys available



For reference, some performance statistics for Sentinel-6 LRM at 85 km sampling.

Statistics are comparable to Jason-3 (see earlier slides).



Summary

- **The Jason-3 Sentinel-6 Michael Freilich tandem experiment offers a unique experimental setup to explore uncertainty in SWH observations from altimetry.**
  - Stability of long-term SWH LRM record appears to be maintained at sites both offshore and closer to the coast.
  - SARM altimetry suffers sea state dependent bias;
  - Tandem data itself (J-3, S-6 LRM and S-6 SAR) appear problematic for mutual collocation due to correlated errors;
  - “Observation-informed” collocation methodology provides a deeper understanding of local sea state conditions, and may facilitate collocation in more complex sea states (e.g. nearshore).
- **Paper in prep.**

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ESA Sea State CCI ***Phase 2*** is forthcoming...

Look out for:

- *Periodic community calls,*
- *User Consultation Meeting (NOC, Southampton) ~end 2025...!*

Data “denoising” from Sea State CCI

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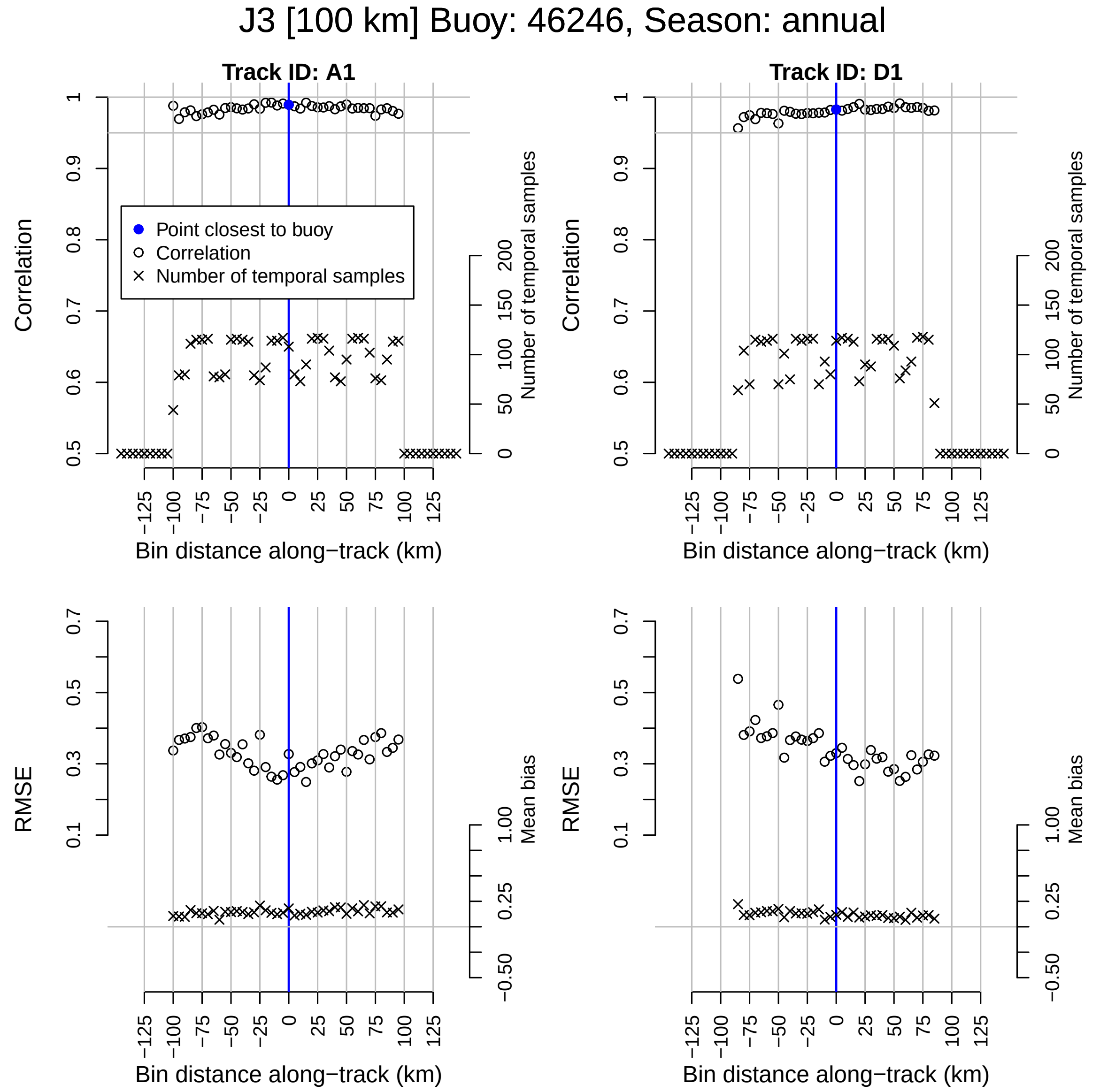
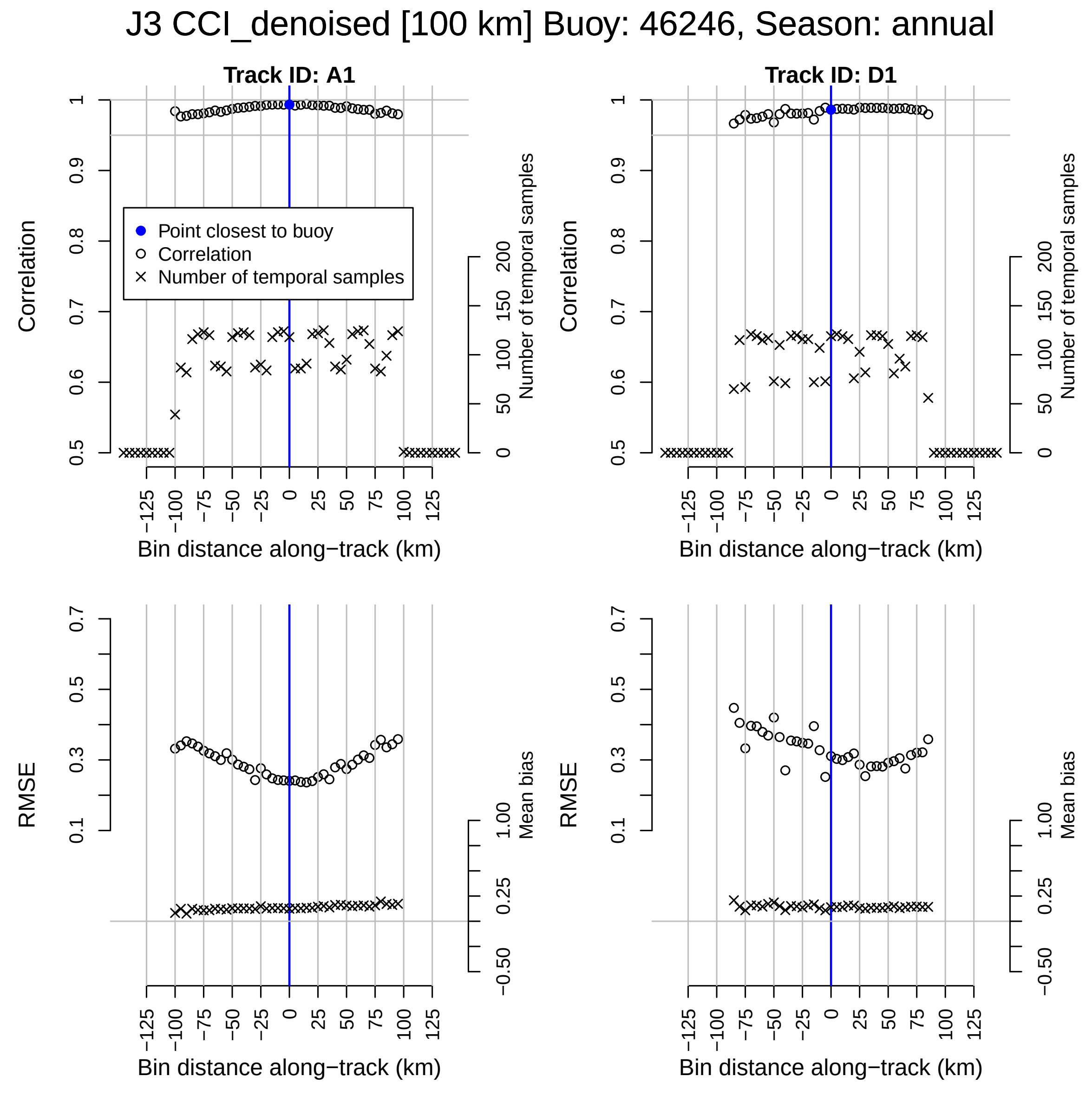
Along track statistics using Jason-3 S-GDR (2017-2021)



Along track statistics using Jason-3 Sea State CCI V3 "denoised" data (2017-2021)



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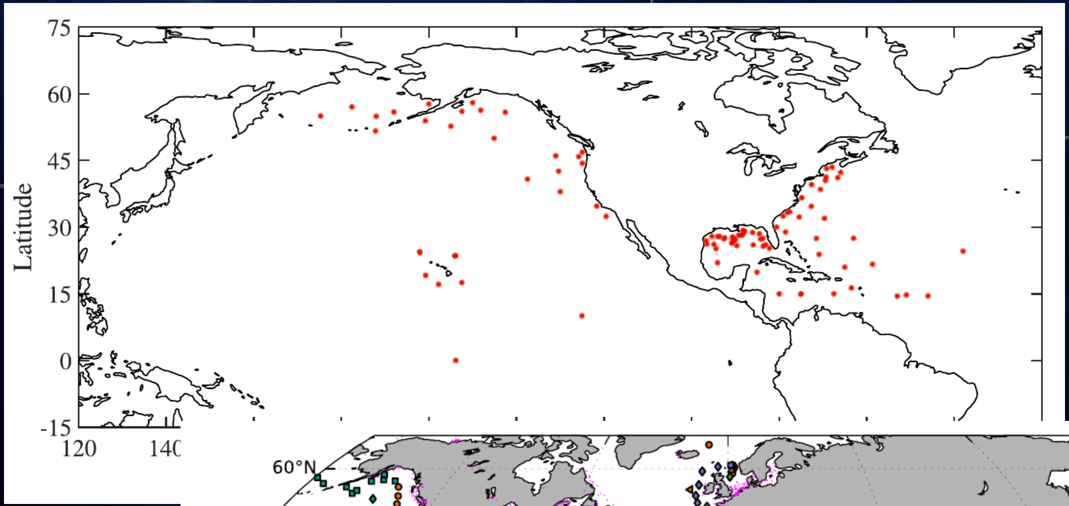
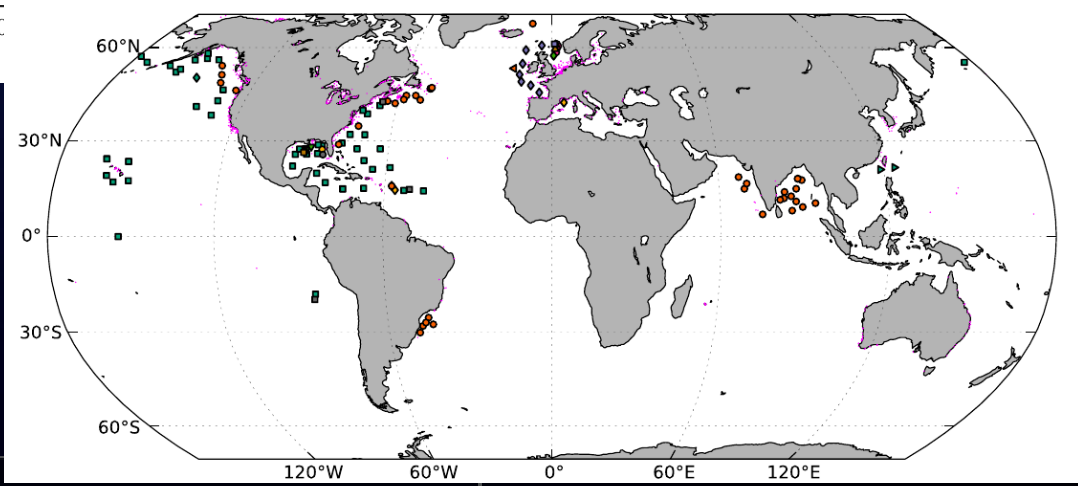
Collocation: challenges for long term data

- **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.
- **Coastal sites are neglected due to strong local variability.**
  - Match-up data may be strongly affected by;
    - Local sea state gradients
    - Representativity error
    - Coarse resolution (numerical data)

Ribal & Young (2019)





Dodet et al. (2022)