Synergy between in situ and high resolution model data to validate SWIM nadir significant wave height in the coastal zone

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Motivation

- Sea states present strong spatial gradients over the inner shelf of the coastal zone. Radar altimeter have been measuring a wealth of coastal sea states data over decades still under-exploited.

- There is a growing interest for exploiting altimeter data in the coastal zone, paticularly with the advents of new radar technologies, such as Delay-Doppler altimeter (S-6 MF) and radar interferometer (SWOT).

- In situ wave buoys represent the gold standard for assessing the performance of radar altimeters, a large majority of wave buoys are located within 50 km from the coast.

- Data pairing methods, originally developped for deep water comparison, require adaptation to account for the strong sea state variability in the coastal zone.

Context

- Comparisons of altimeter data against in situ data are often based on conventional data pairing method considering all altimeter records located within a fixed distance from the buoy location (e.g. Queffeulou et al. 2004). Coastal buoys are often rejected from analysis.

- Attemps to exploit coastal buoys for altimeter validation have considered lower spatial thresholds to account for spatial SWH variability (e.g. Hithin et al. 2015).

- Nencioli and Quartly, (2019) defined areas of correlation around UK coastal buoys from model hindcast to improve consistancy between S3 and buoy records.

- Janssen et al (2007) used the difference between model outputs at the buoy location and at the altimeter record location in order to quantify the spatial SWH variability and reject matchups if necessary.

Objectives

- Characterizing SWH spatial variability in the coastal zone from HR wave model hindcast
- Compare data pairing method between in situ and altimeter data in the coastal zone
- Investigate sensitivity of SWIM 5Hz SWH uncertainty in the coastal zone to data pairing methods
- Estimate performance of SWIM 5Hz SWH measurements from coastal buoys and HR wave model

Outline

Method

- Datasets
- SWH representative areas in the coastal zone
- Data pairing methods

Results

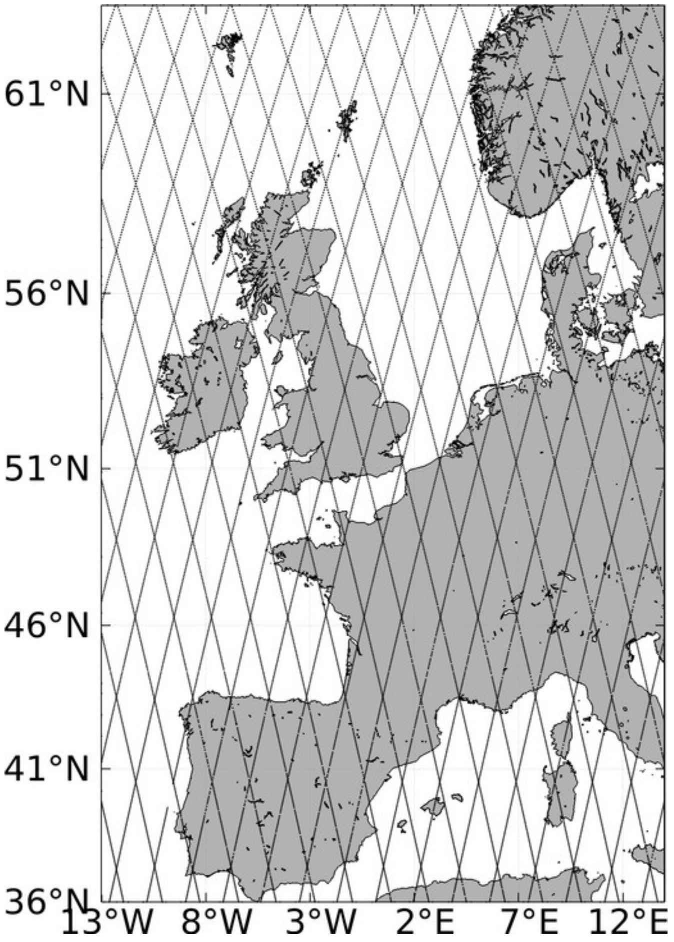
- SWH variability around coastal buoys
- Sensitivity to data pairing methods
- Coastal SWIM Nadir 5Hz performance

Conclusions and Perspectives

Method : Datasets

Altimeter : CFOSAT SWIM L2P Nadir 5Hz NTC

- Available from 03/11/2018 to 06/12/2021 (https://www.aviso.altimetry.fr/)
- SWH estimated from the adaptive waveform retracking (Tourain et al., 2021)
- Data editing based on SWH/σ_0 thresholds + iterative outlier filtering method



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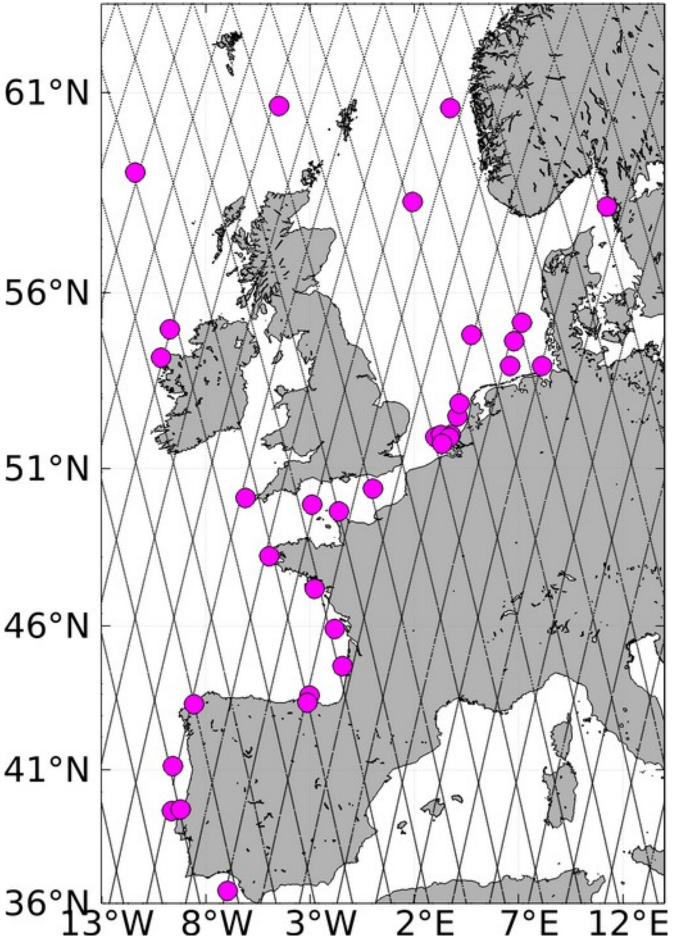
In Situ : CMEMS In Situ Thematic Assembly Center

- Near Real Time hourly SWH observations (http://www.marineinsitu.eu/)
- Buoy selection : distance to nearest CFOSAT track < 20km
- 40 buoys with distance to the coast between 2-200km



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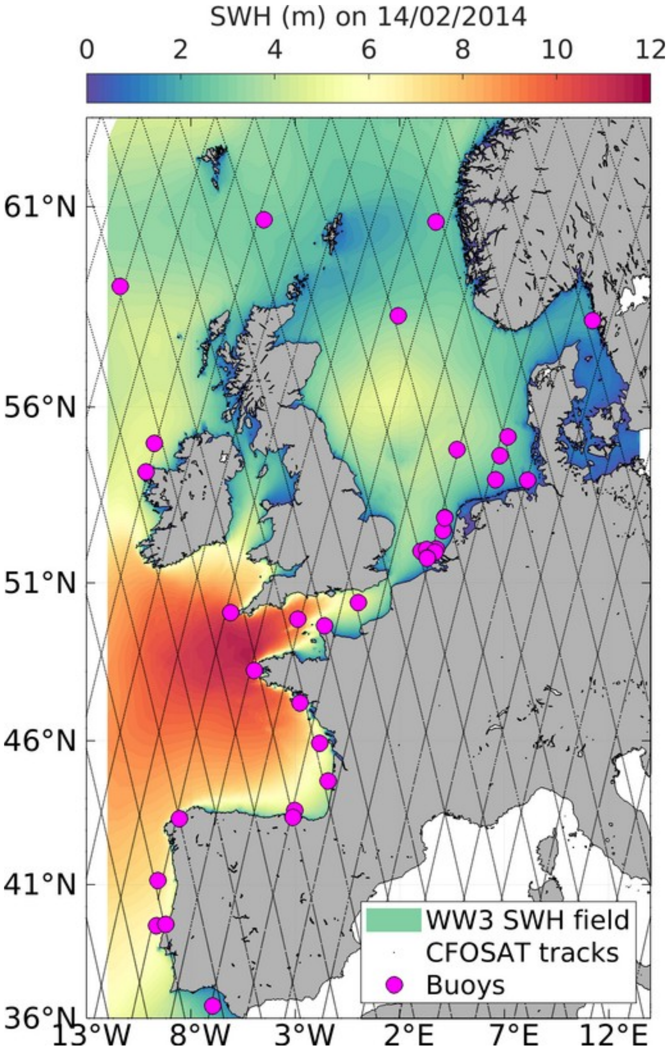
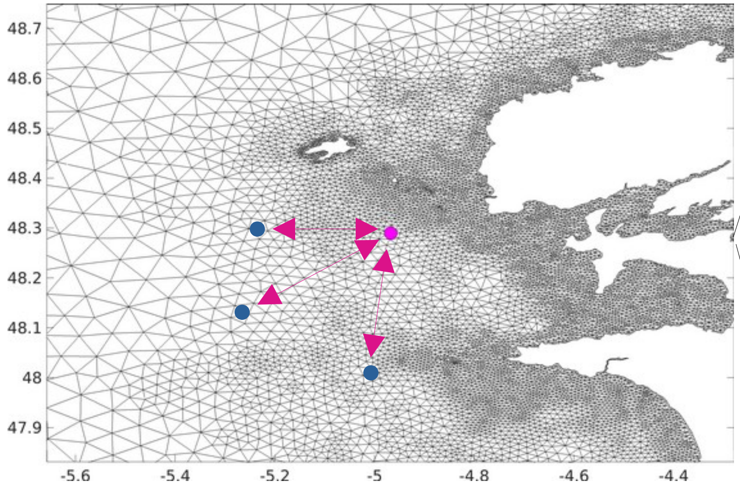
Model : WW3 ResourceCODE hindcast (1992-2021)

- European coastal extent: 36°N - 63°N / 12°W - 14°E
- Unstructured mesh : from 10km to 200m (330,000 nodes)
- T475 parameterization (Ardhuin et al, 2010 ; Alday et al. 2021)
- Wind : ERA-5 + bias correction
- Currents : FES2014 / MARS2D tidal harmonics
- Bathymetry : EMODnet + HOMONIM (Shom)
- Roughness : EMODnet seabed substrate
- More details in Accensi et al. (2021)

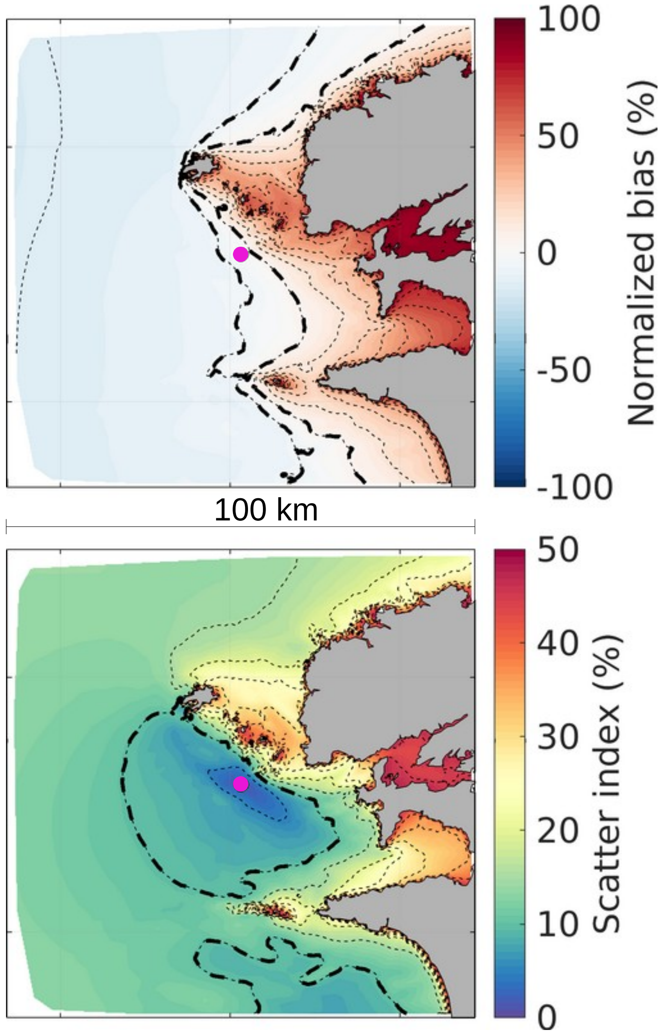


Method : Sea state representative areas in the coastal zone

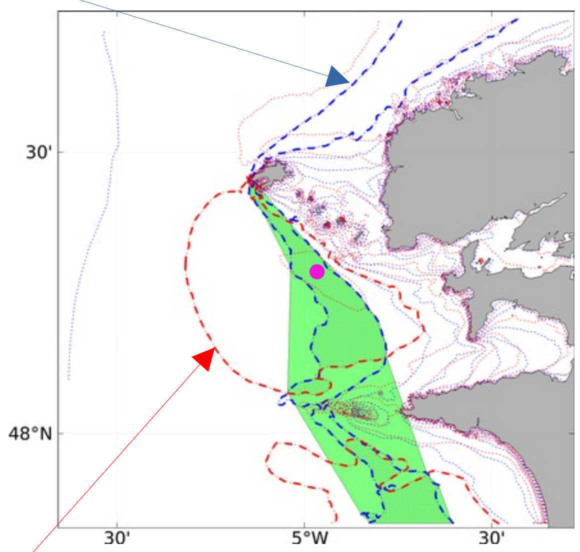
Step 1 : WW3 SWH differences between buoy and surrounding nodes are computed over the full hindcast duration



Step 2 : Maps of normalized bias and SI are interpolated over 100kmx100km grid (with 200m resolution)



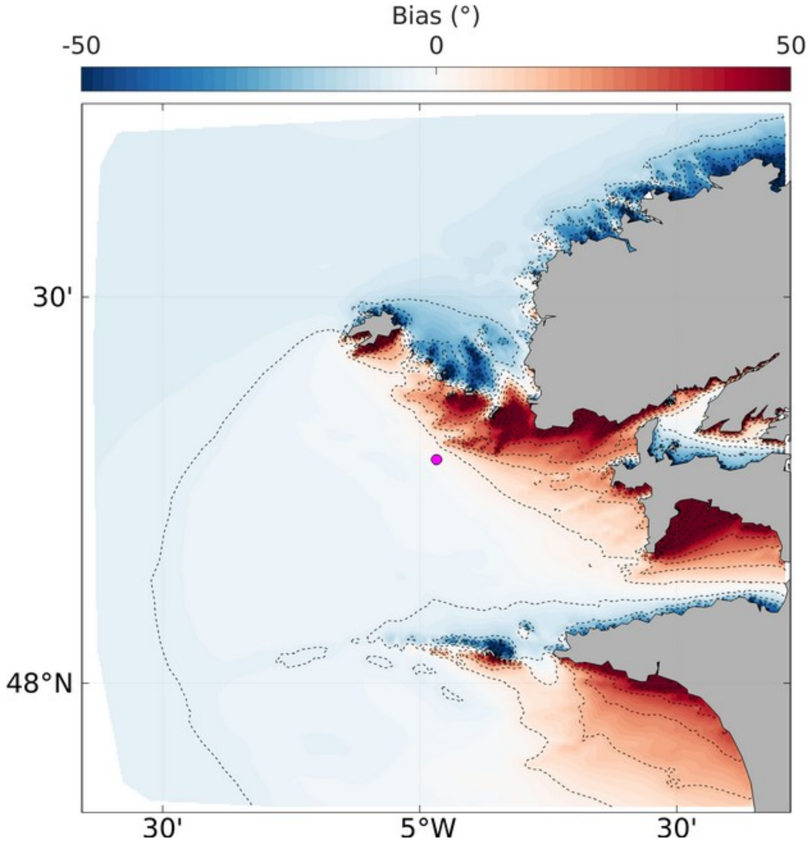
Step 3 : Intersection between areas with |nbias|<5 % and SI<10 % is extracted

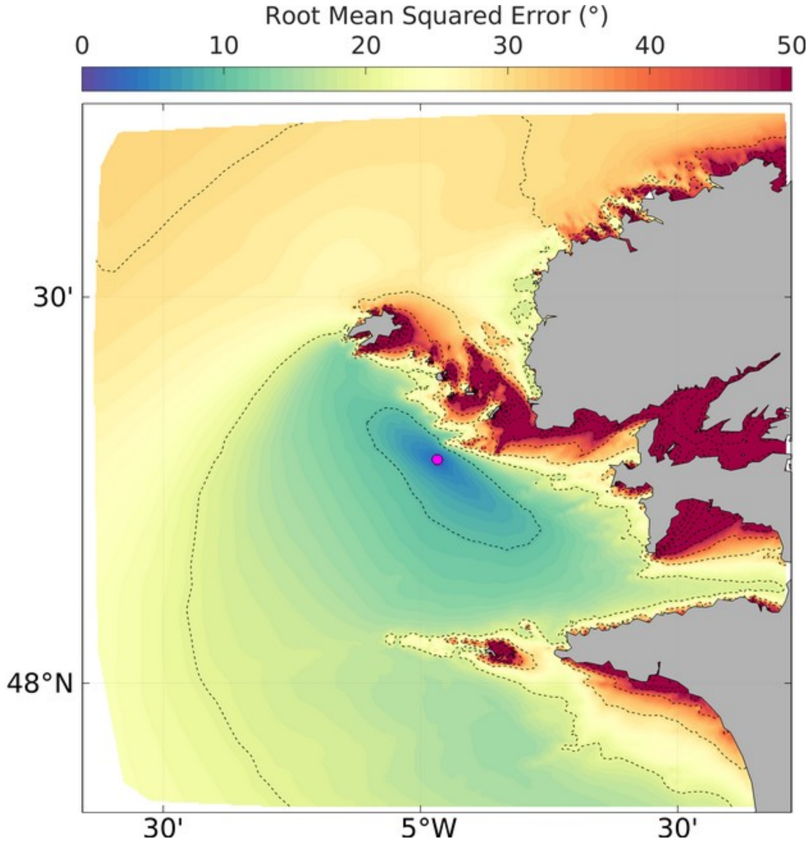


Step 4 : A **polygon** is fitted to cast the surface of low SWH variability

Method : Sea state representative areas in the coastal zone

Same method can be applied to characterize the variability of other sea state parameters (**here for the peak wave direction**). See Mureau et al. (2022) for more details





Method : Data pairing methods

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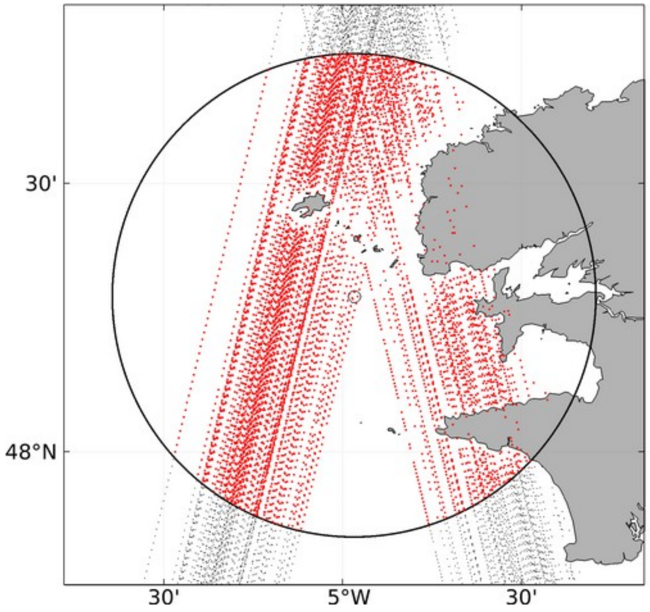
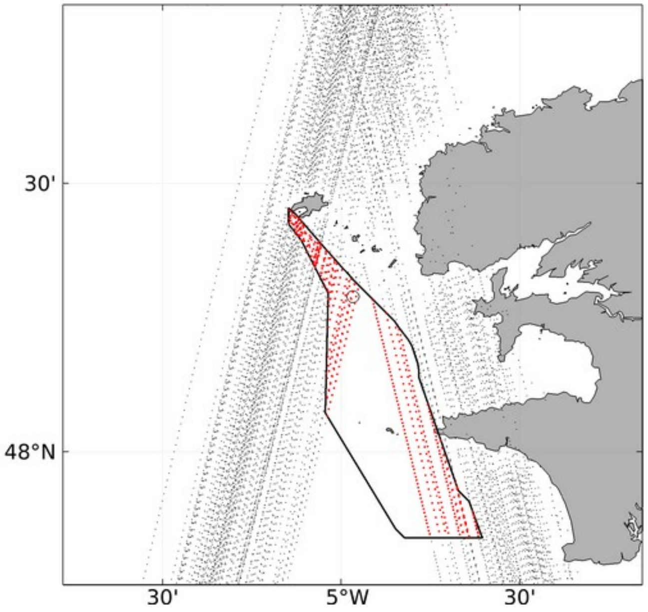


Only records located within a circle of radius R

4 radius values considered :
100 km / 50 km / 20 km / 5 km

Method 2

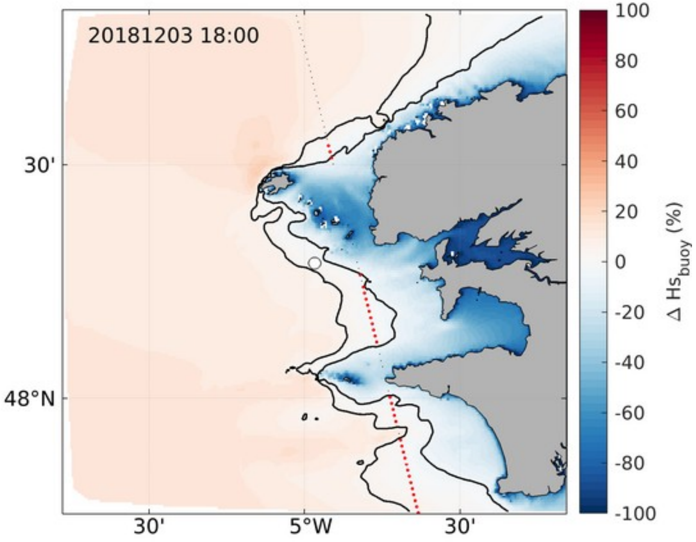


Only records located within polygons of low SWH variability

Based on model hindcast analysis

Adapted from Nencioli and Quartly (2019)

Method 3



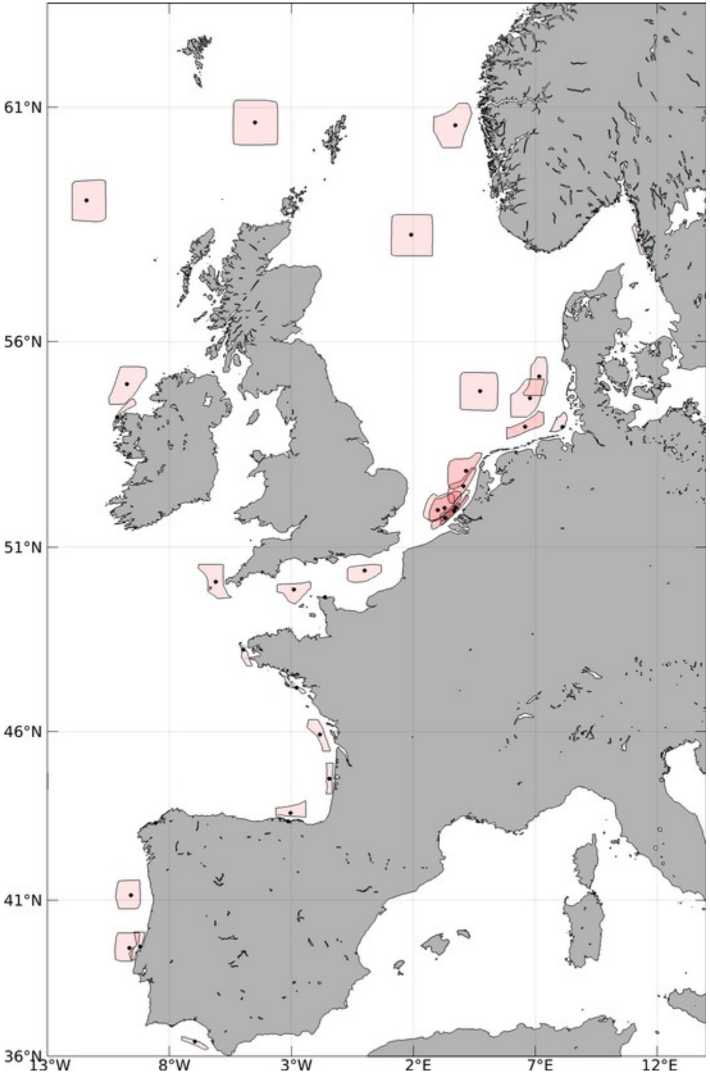
Only records for which modelled $\Delta Hs_{buoy/alti} < 5$ %

Additional criteria : $\Delta\theta_{buoy/alti} < 45°$

Adapted from Janssen et al. (2007)
Abdalla et al. (2011)

Results : SWH variability around coastal buoys

- Areas of low SWH variability (ALSV) present a strong heterogenity in size and shape



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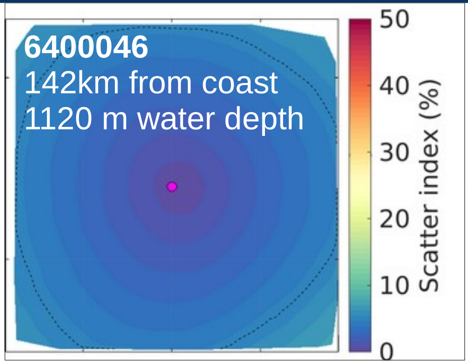
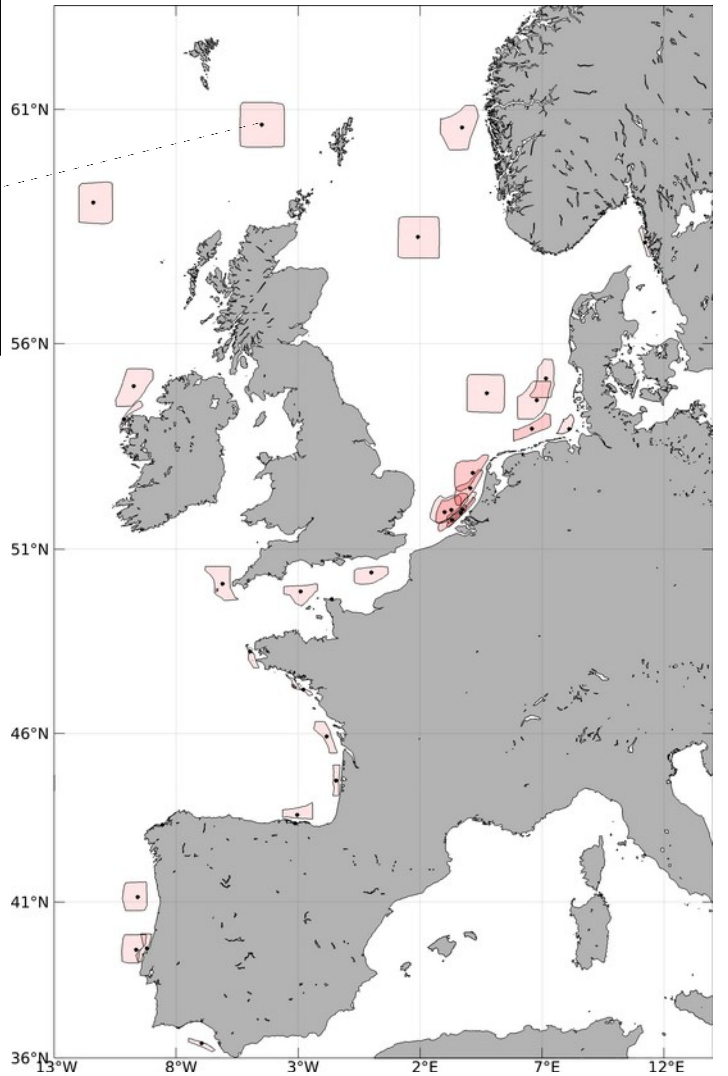
- Offshore buoys present low isotropic SWH variability resulting in large ALSV





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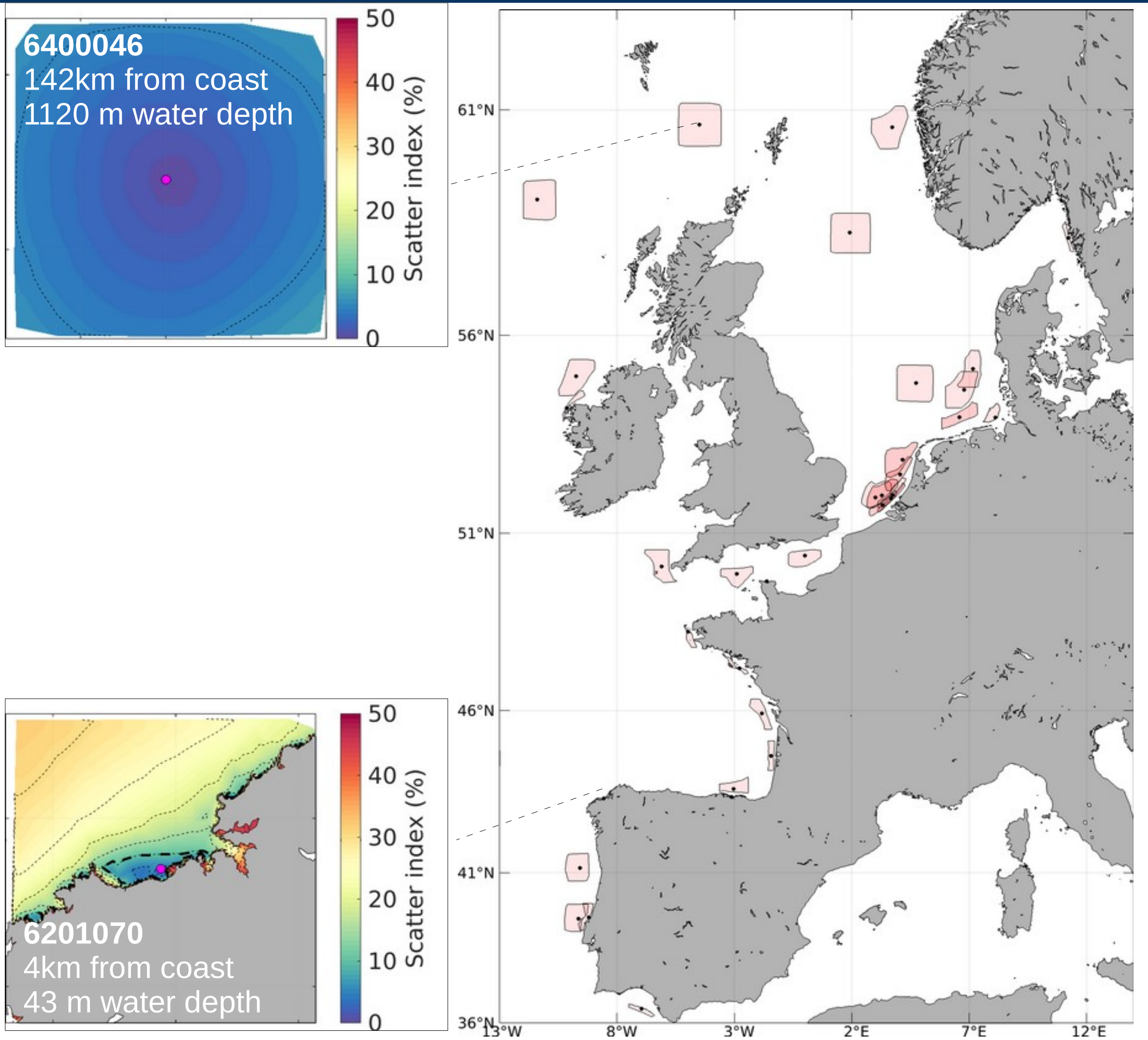
- Nearshore buoys present very local error gradients resulting in reduced ALSV



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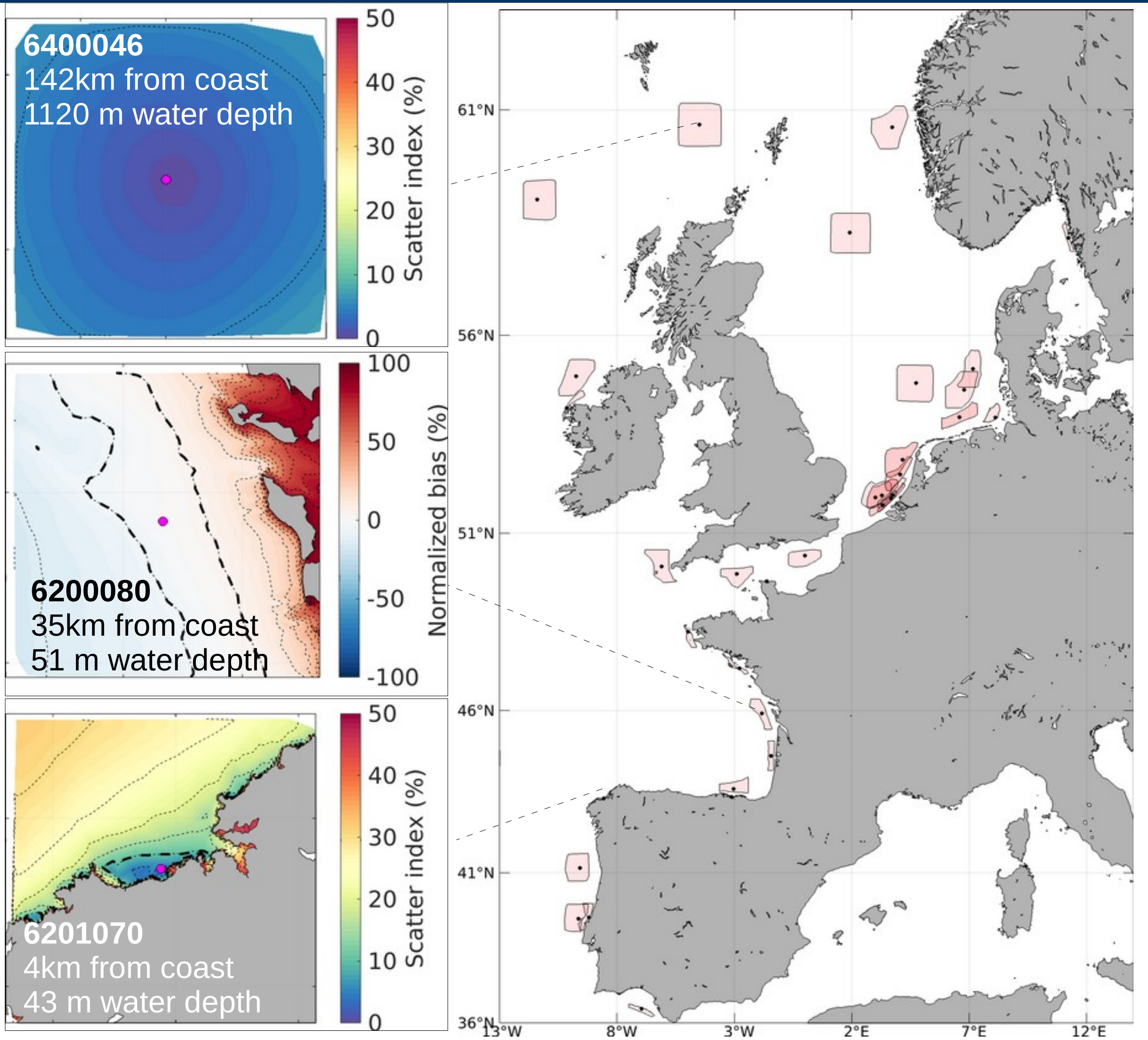

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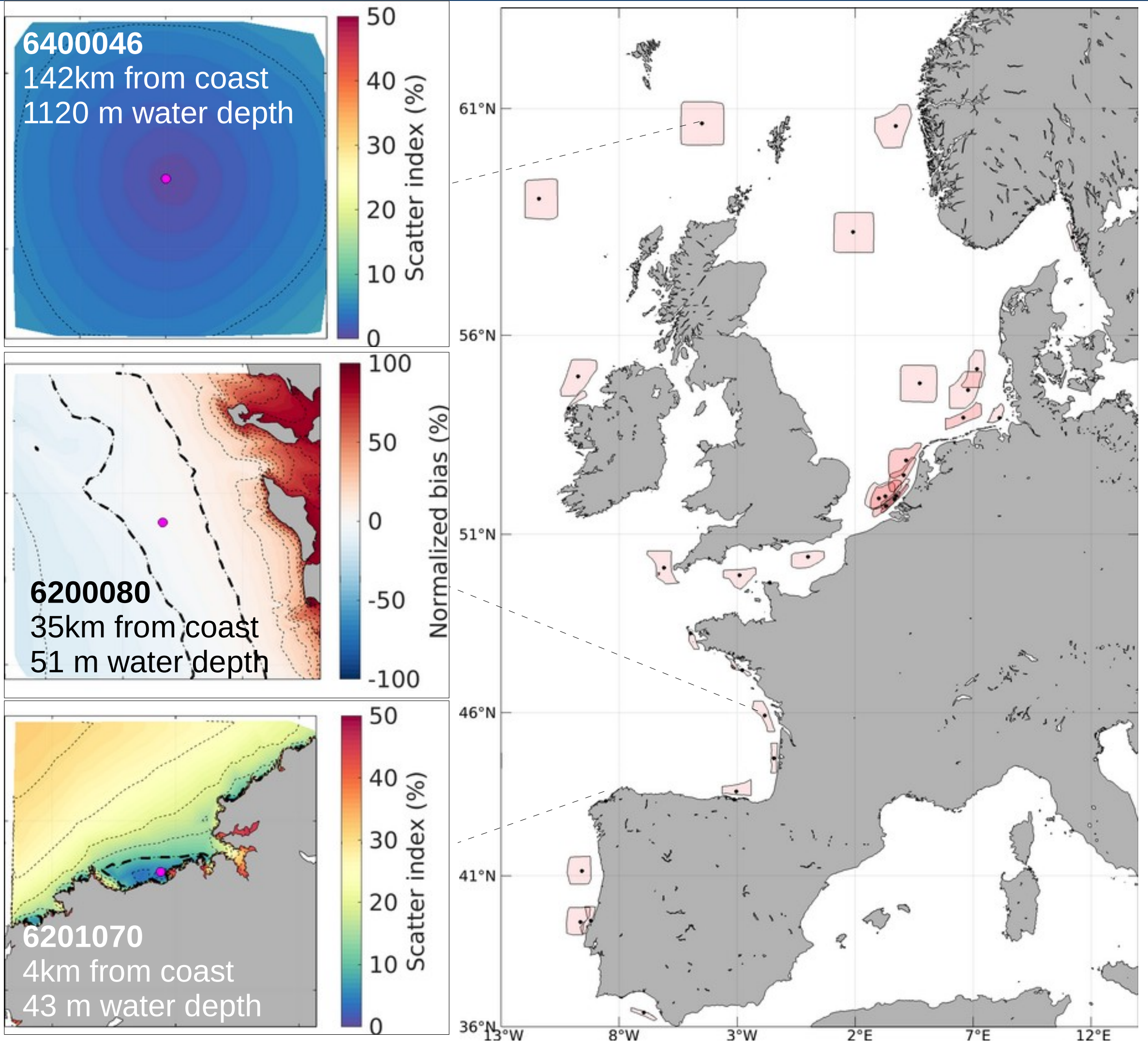
- Buoys at intermediae distance present significant cross-shore error gradients resulting in elongated (along-shore) ALSV
- Overall, the surface areas of low SWH variability vary over 3 order of magnitudes (from 10km^2 to ~10,000km^2)
- The main factors driving coastal sea state variability are : water depth, coastline geometry, bathymetry gradients, tidal currents, and wind gradient/direction (!).

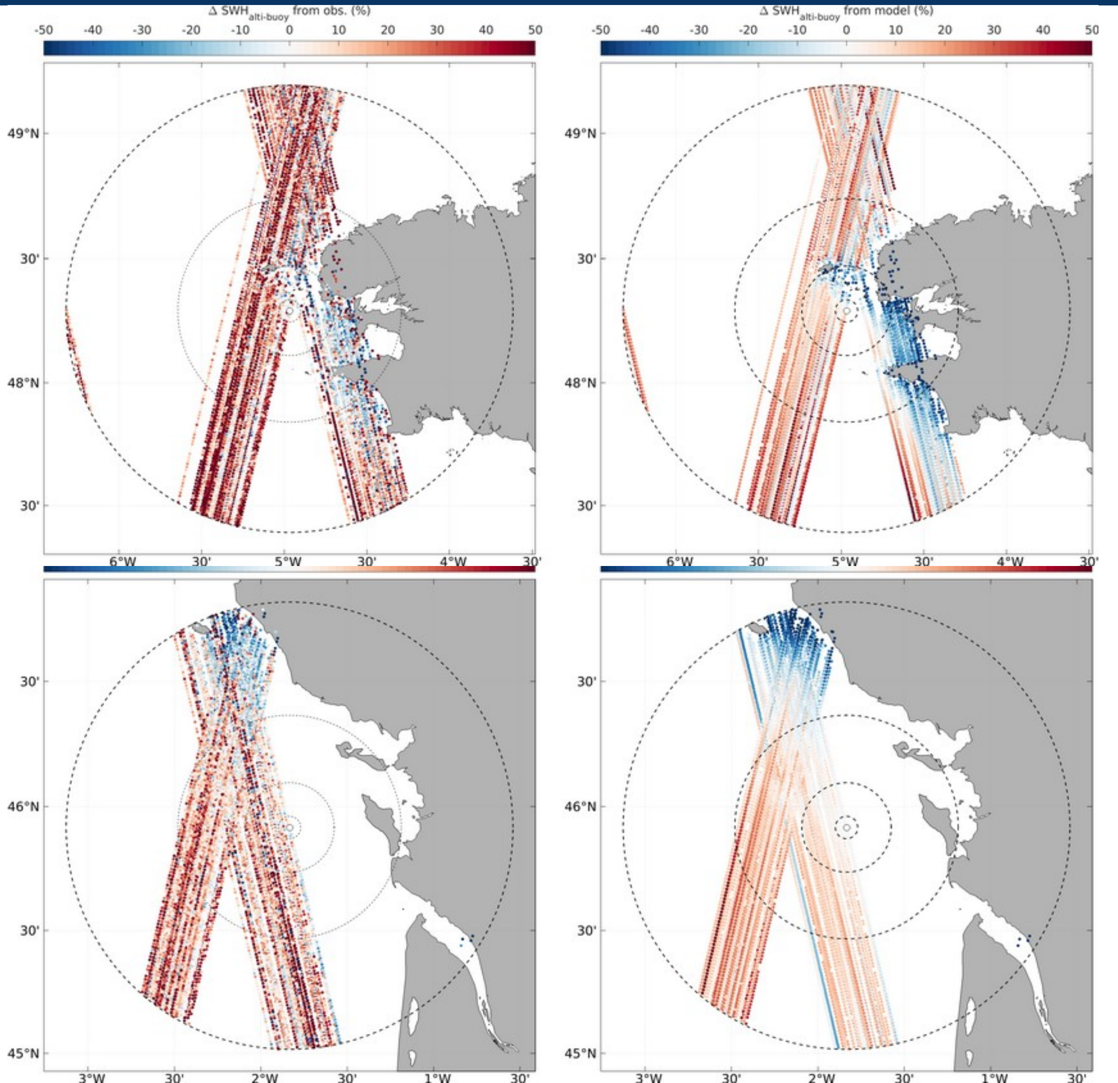


Results : SWH variability around coastal buoys

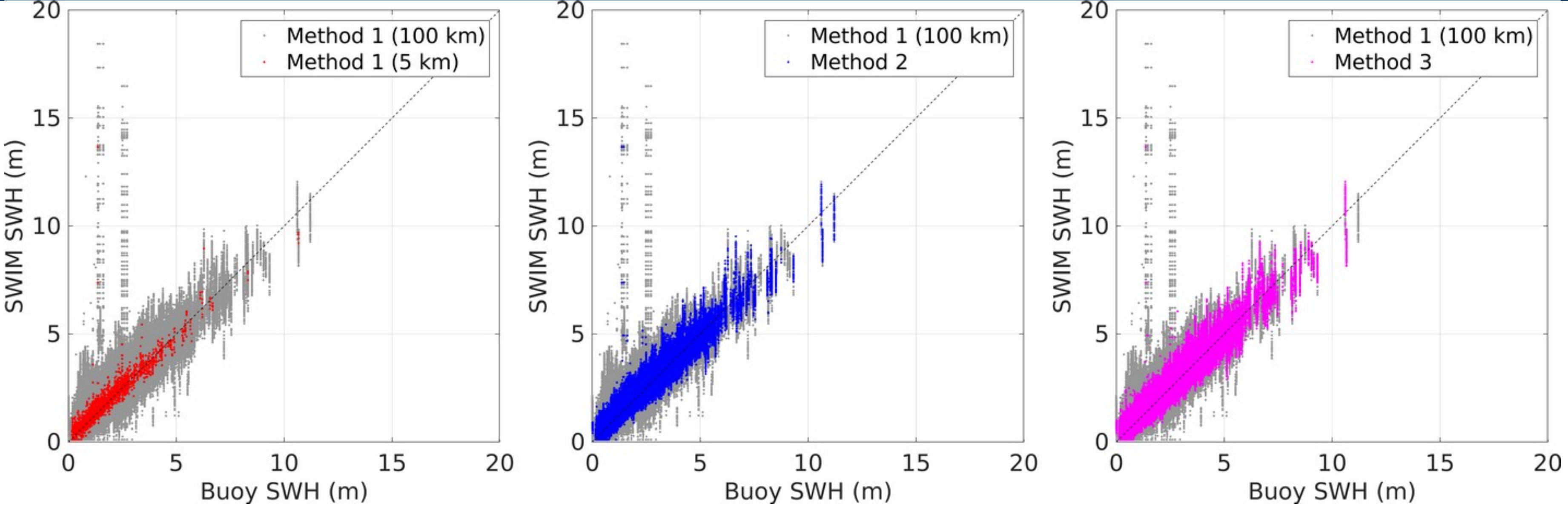
Is SWIM nadir altimeter able to capture SWH variability in the coastal zone ?

Here we compare the normalized difference between SWH at the buoy location and along SWIM ground track (left panels)

Coherent structures of over / under estimation are observed, comparable to WW3 simulations (right panels) but much more noisy.



Results : Sensitivity to data pairing methods



Method	Method 1 Fixed radius				Method 2 Polynom	Method 3 ΔSWH (& ΔDIR)	
Criteria	100	50	20	5	N/A	ΔSWH<5%	& ΔDIR<45°
Nval abs	1586388	585300	137726	7491	320452	472741	454542
Nval rel (%)	100.00	36.90	8.68	0.47	20.20	29.80	28.65
Bias (m)	0.19	0.14	0.13	0.11	0.11	0.11	0.11
NBias (%)	11.10	8.38	7.49	6.32	6.05	5.36	5.15
RMSE (m)	0.52	0.41	0.34	0.38	0.34	0.35	0.35
NRMSE (%)	24.24	19.54	16.09	17.96	14.85	14.41	14.27
SI (%)	22.52	18.33	14.93	17.23	14.02	13.70	13.61

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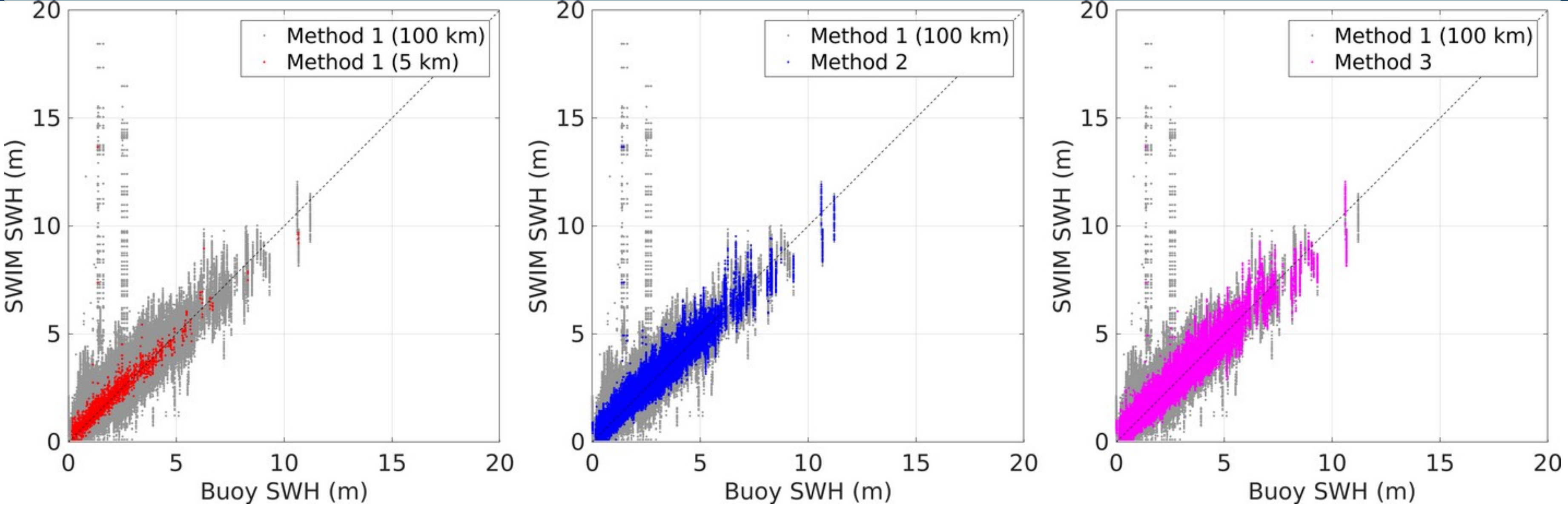

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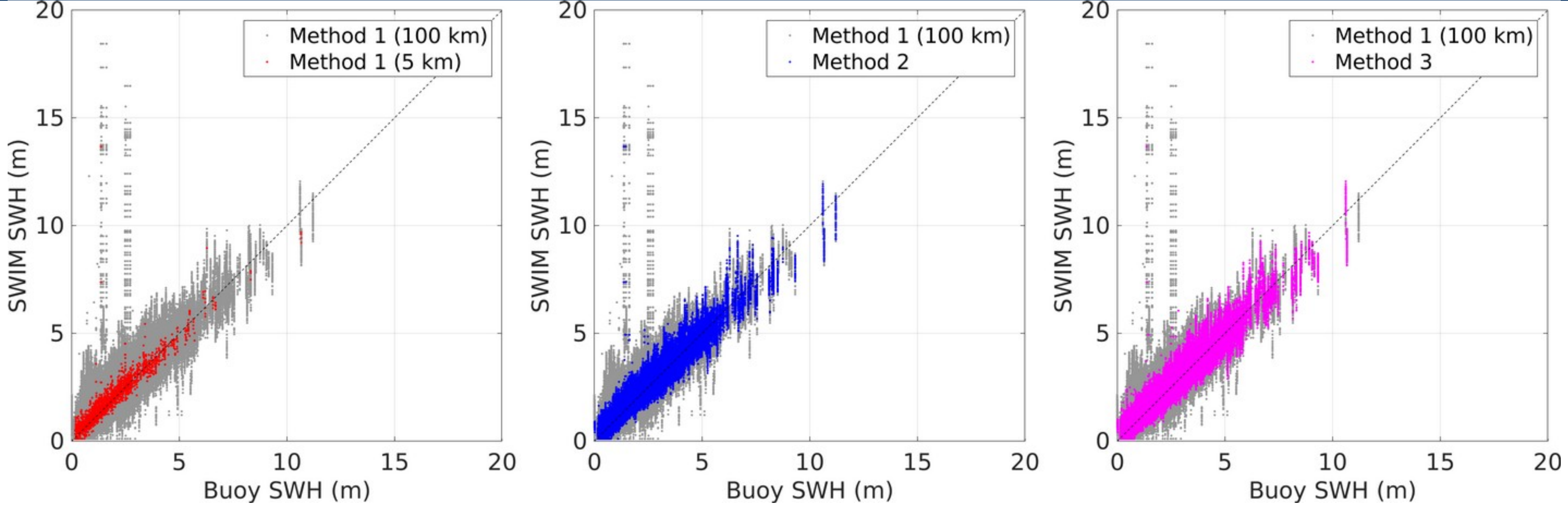

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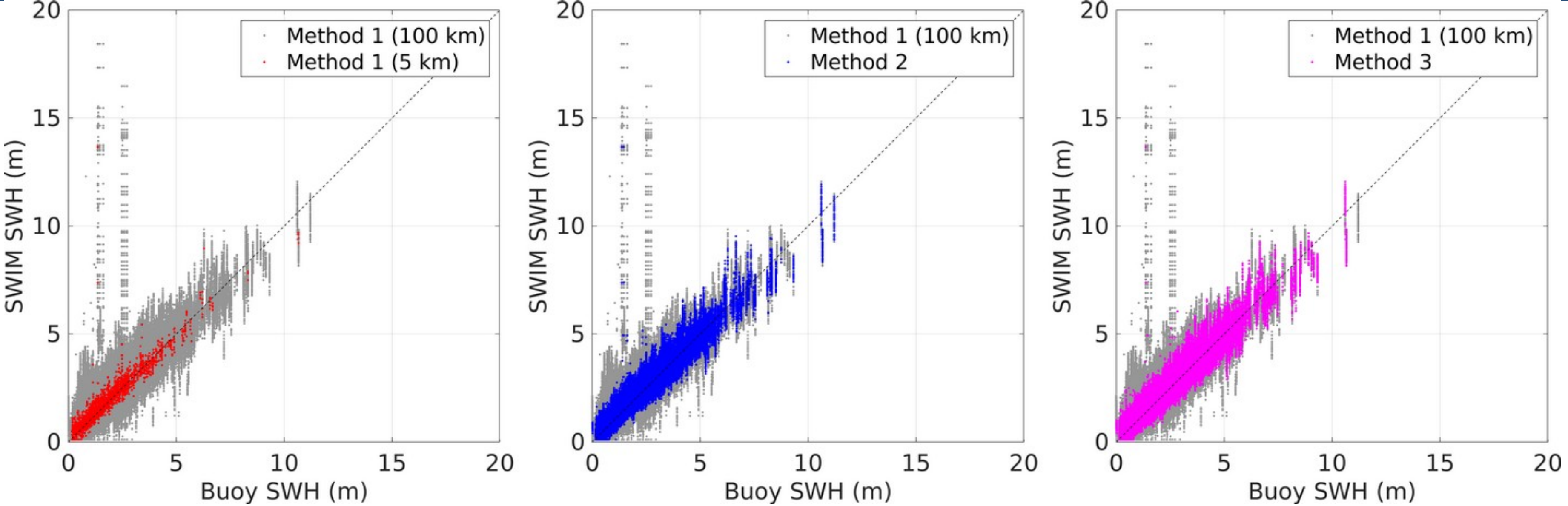

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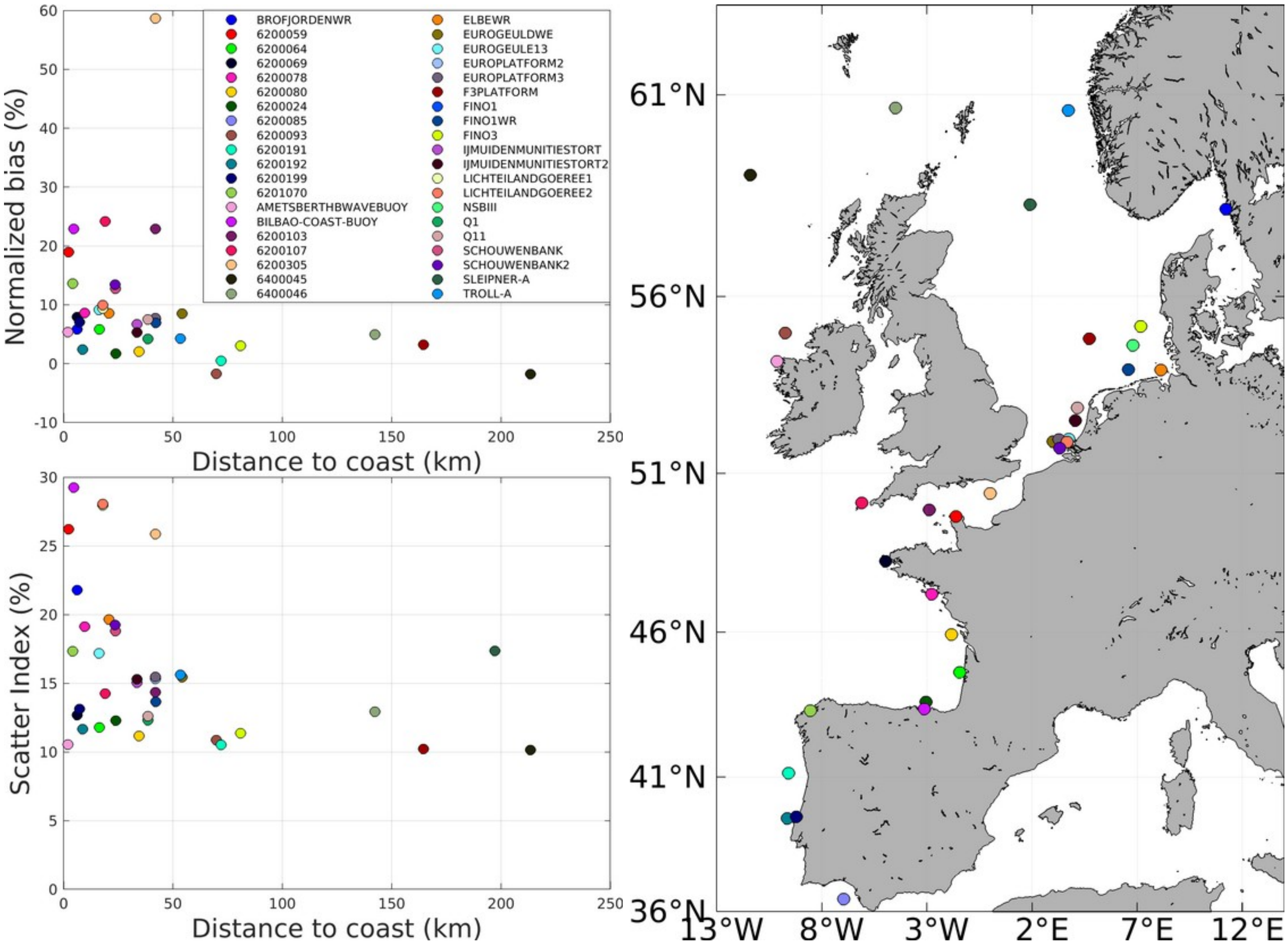
Results : Coastal SWIM 5Hz performance

Error metrics obtained with Method 3 are binned with respect to distance to the coast.



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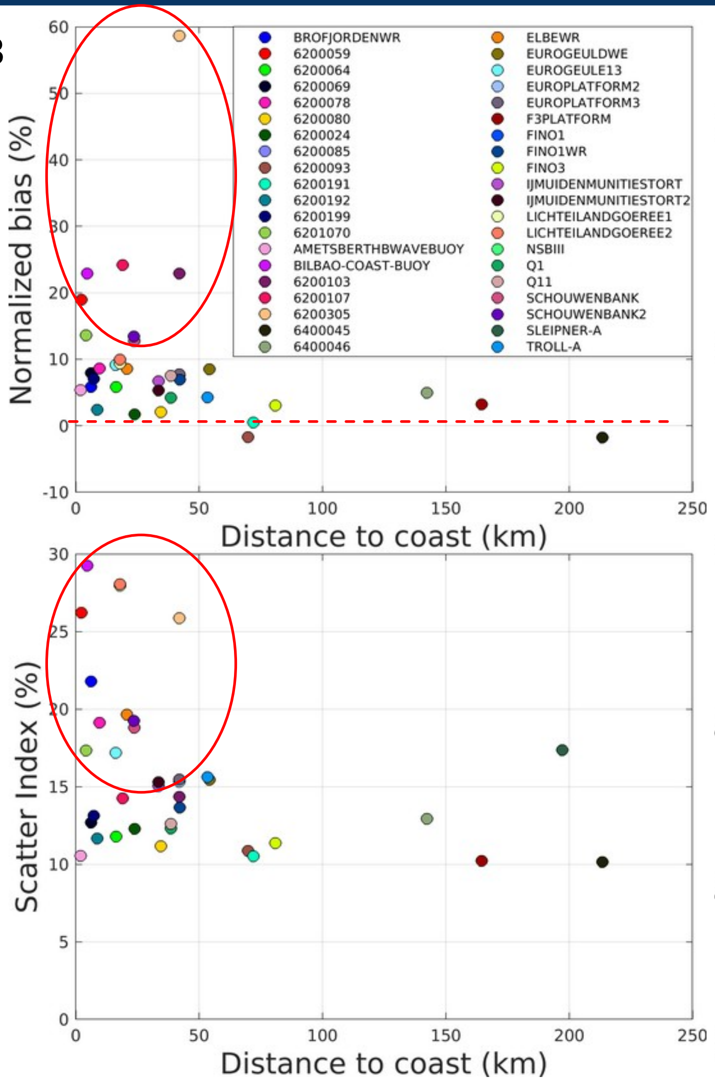
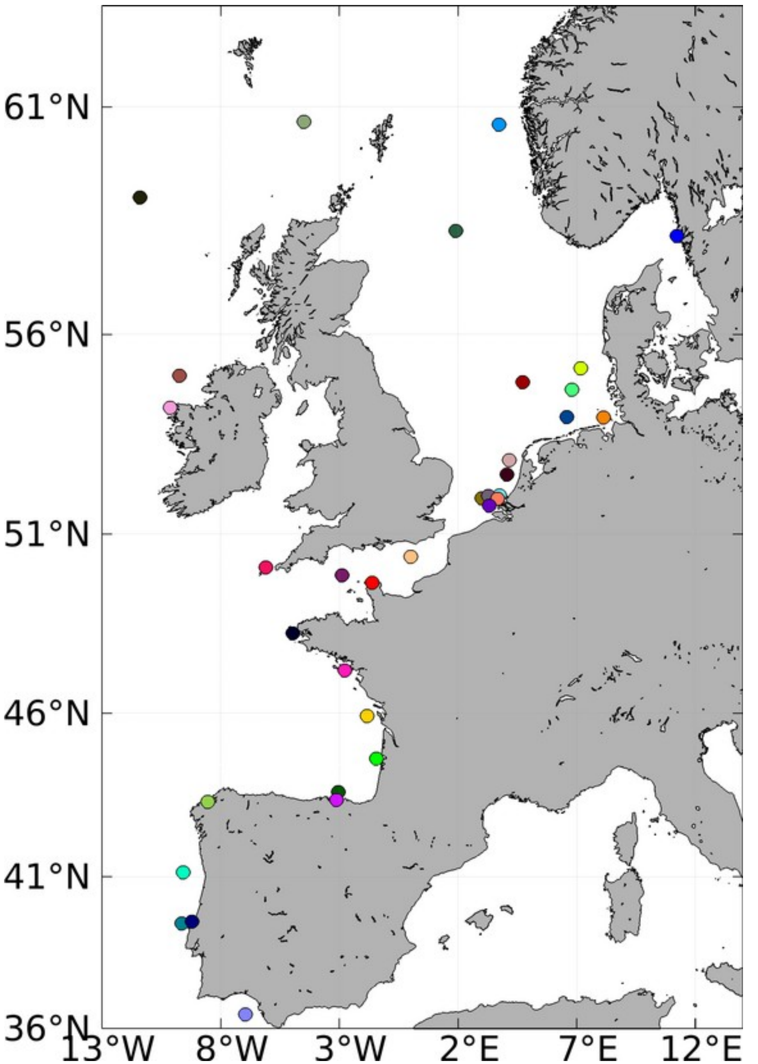
Error metrics obtained with Method 3 are binned with respect to distance to the coast.

Positive bias are obtained for almost all stations.

Many buoys within 50 km from the coast show increased systematic and random errors.





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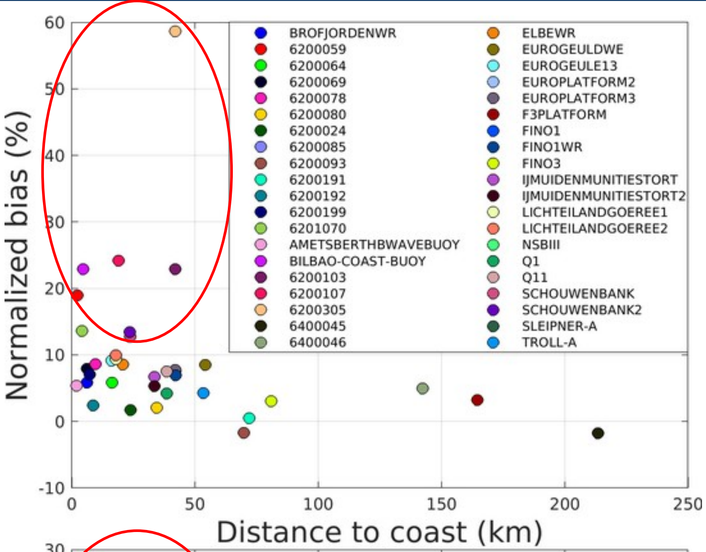
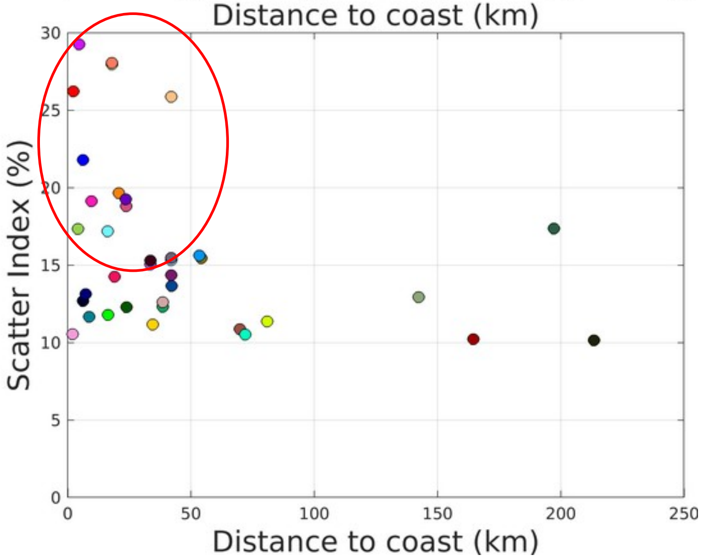
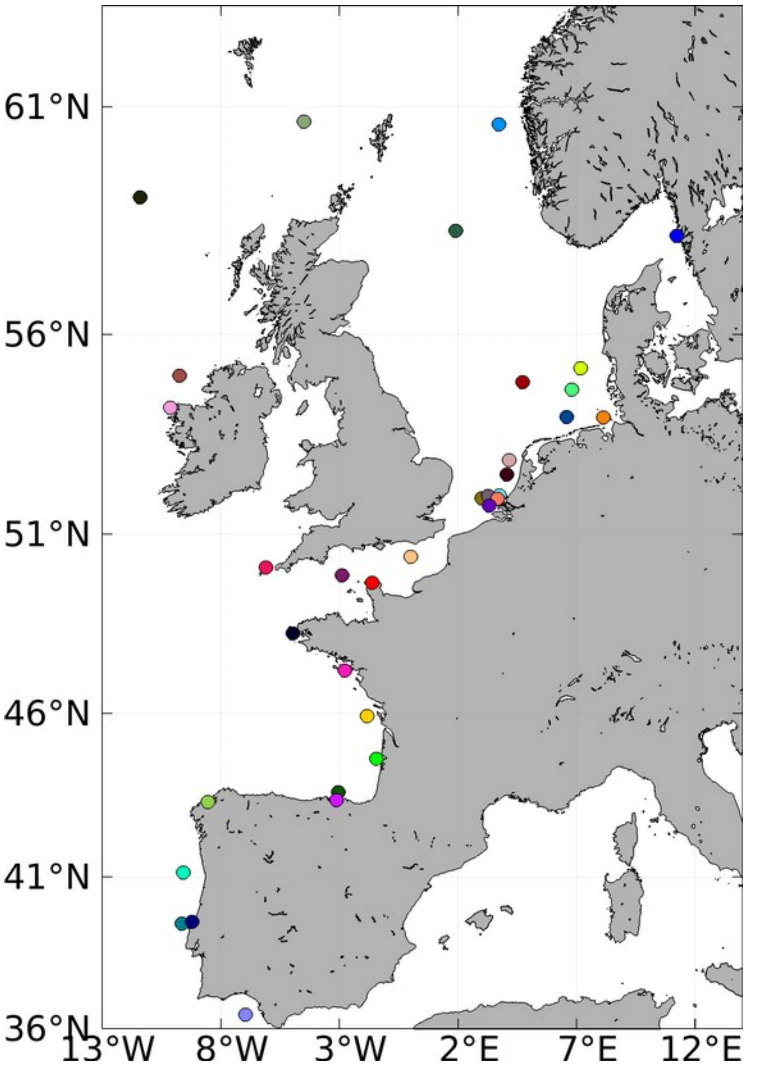
- asymetry in the spatial distribution of altimeter records ?

- higher number of low SWH values for these buoys ?







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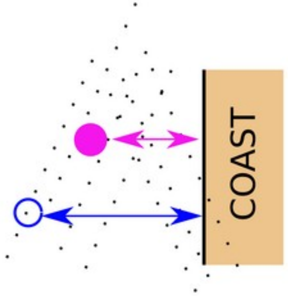

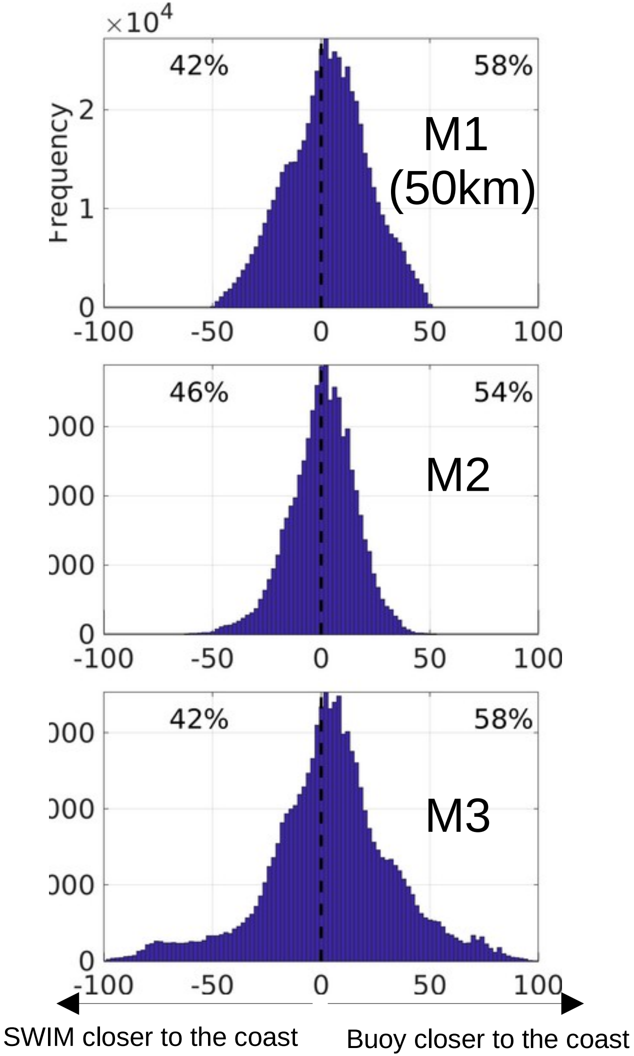

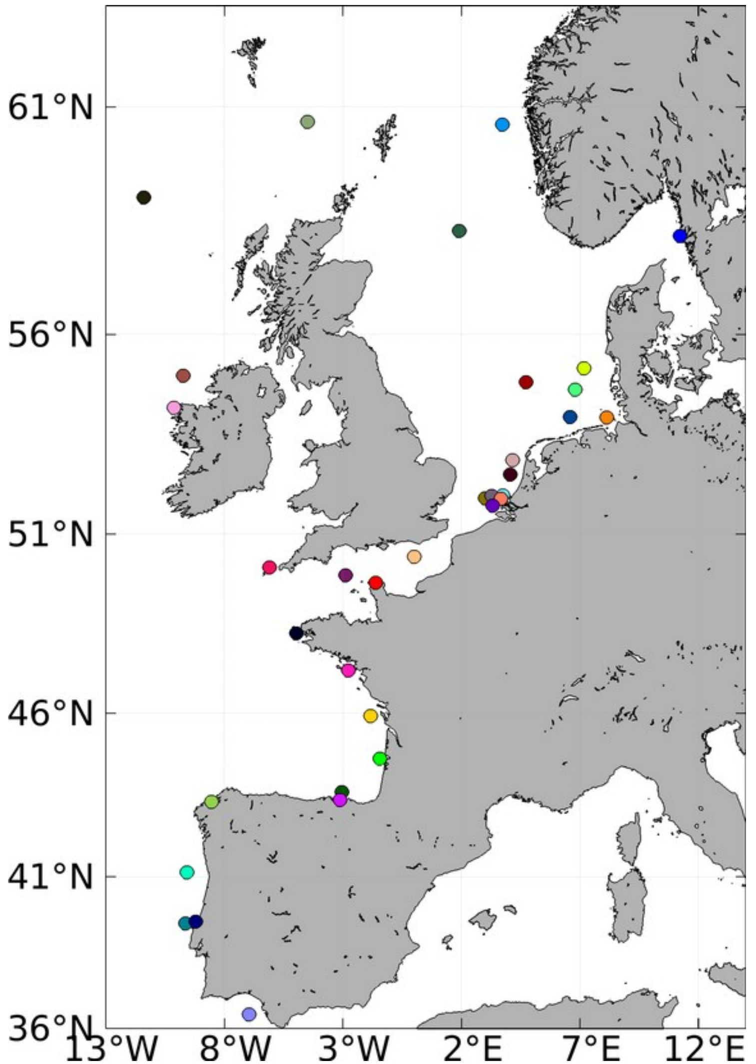

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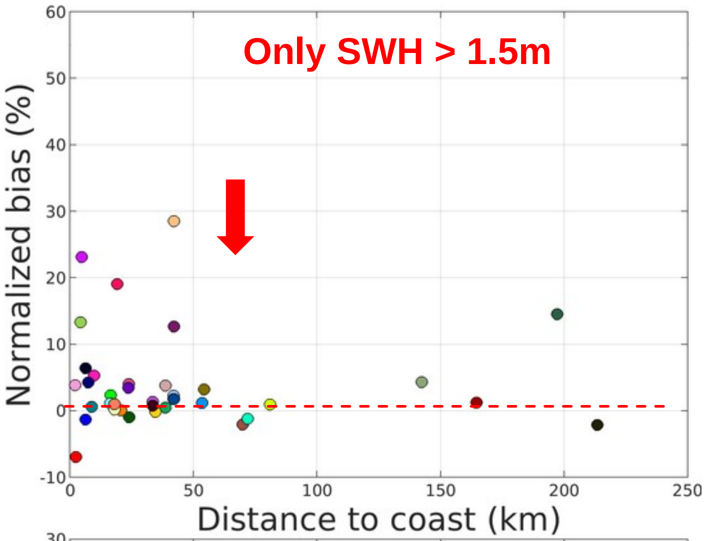

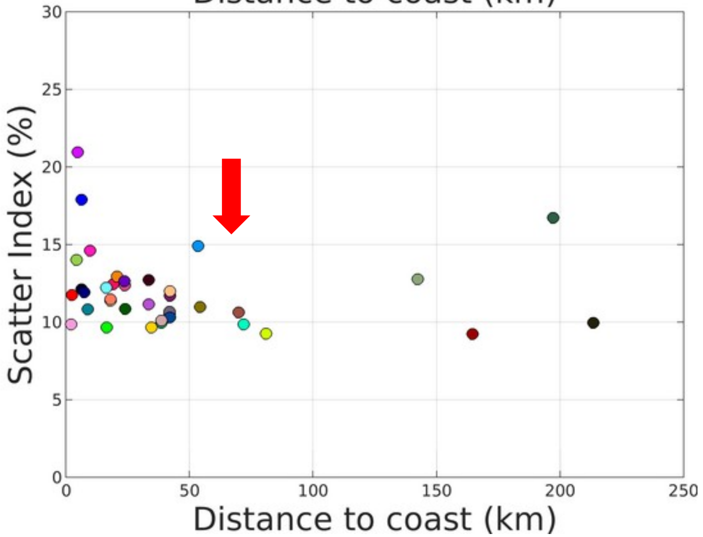

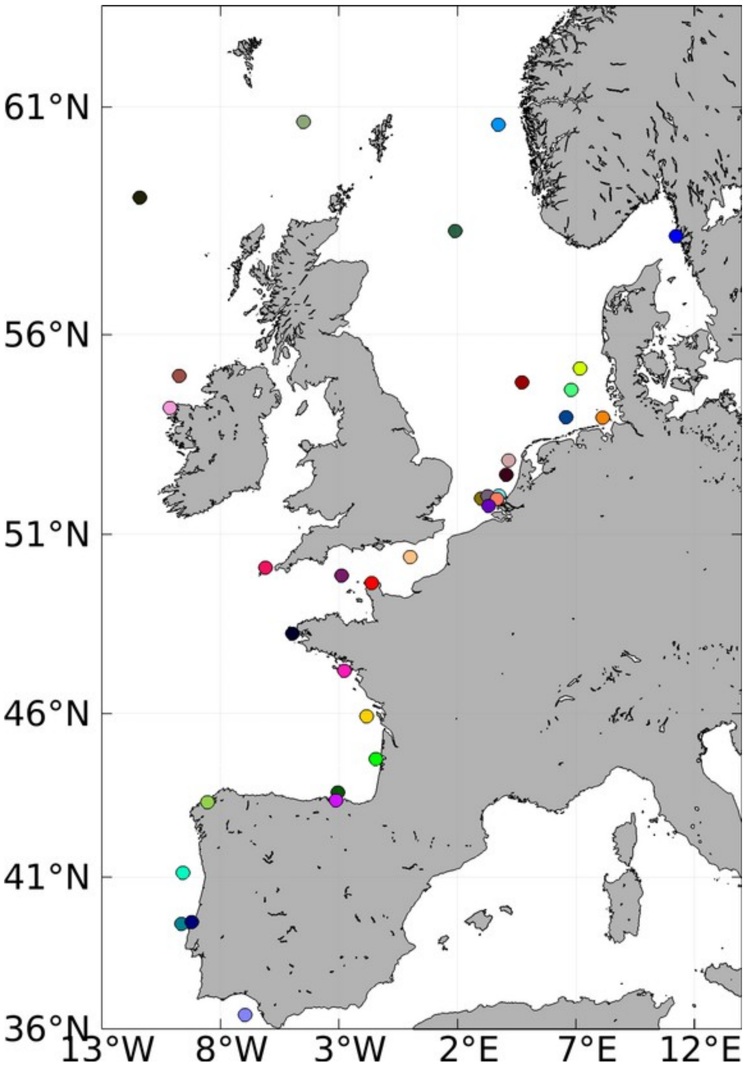

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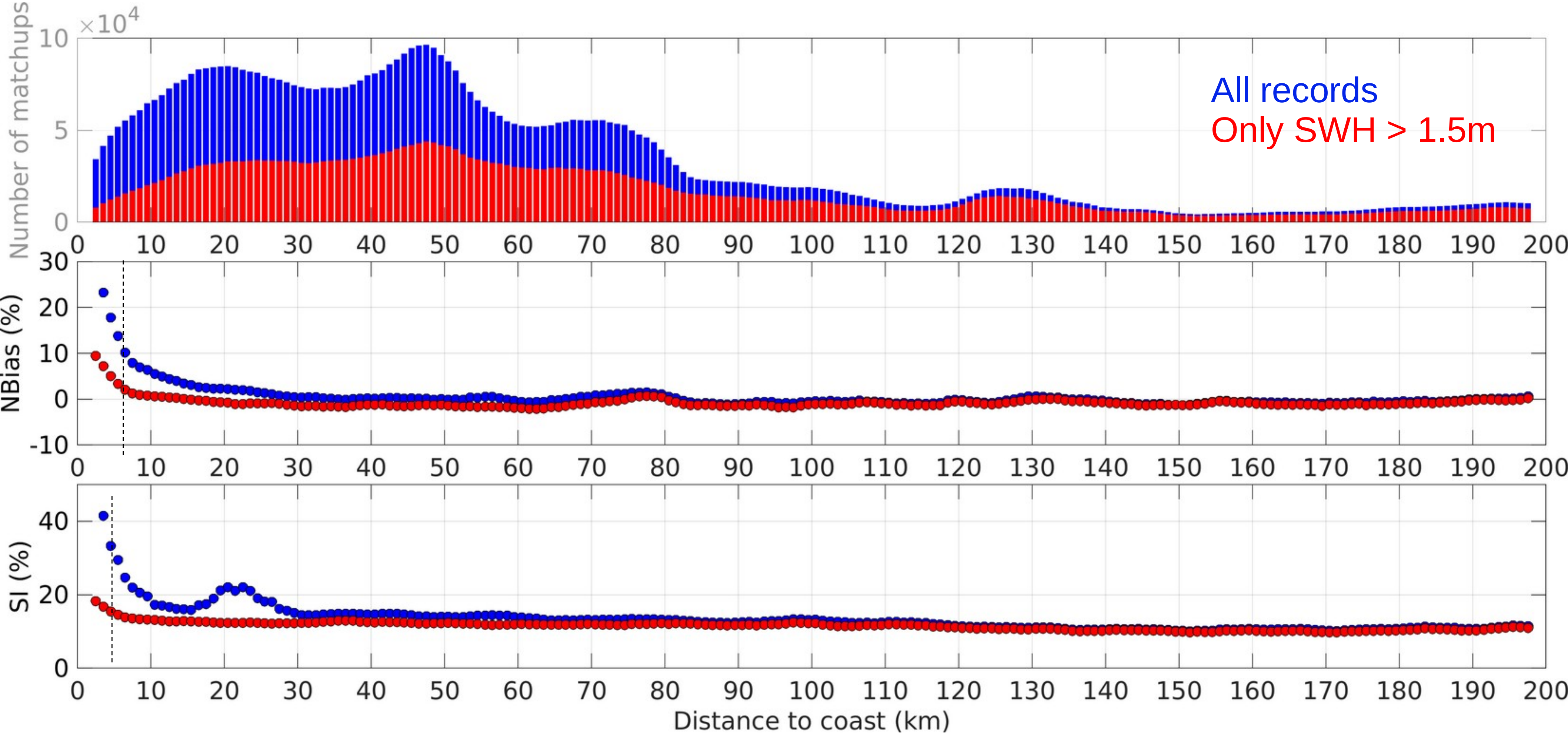
Comparaisons to HR model



Conclusion and Perspectives

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- Large SWH gradients in the coastal zone significantly impact comparisons between altimeter and in situ data
- Pairing methods enhanced with model results improve the robustness of validation in the coastal zone
- Cross-shore asymetry in the distribution of altimeter matchups, and higher number of low sea state events near the coast cause increased systematic (postive) and random errors
- SWIM Nadir 5Hz measurement show very good performance in the coastal zone, particularly when low sea states are ignored from the analysis

Perspectives

- Compare missions' performance for measuring sea states in the coastal zone thanks to coastal buoys and HR model
- Investigate coastal sea state gradients from altimeter and model data

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THANK YOU FOR YOUR ATTENTION !

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