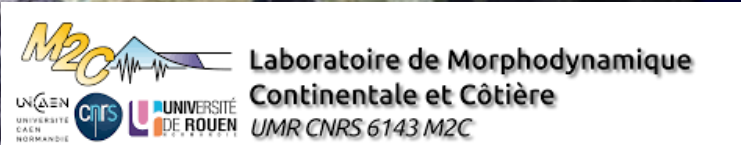
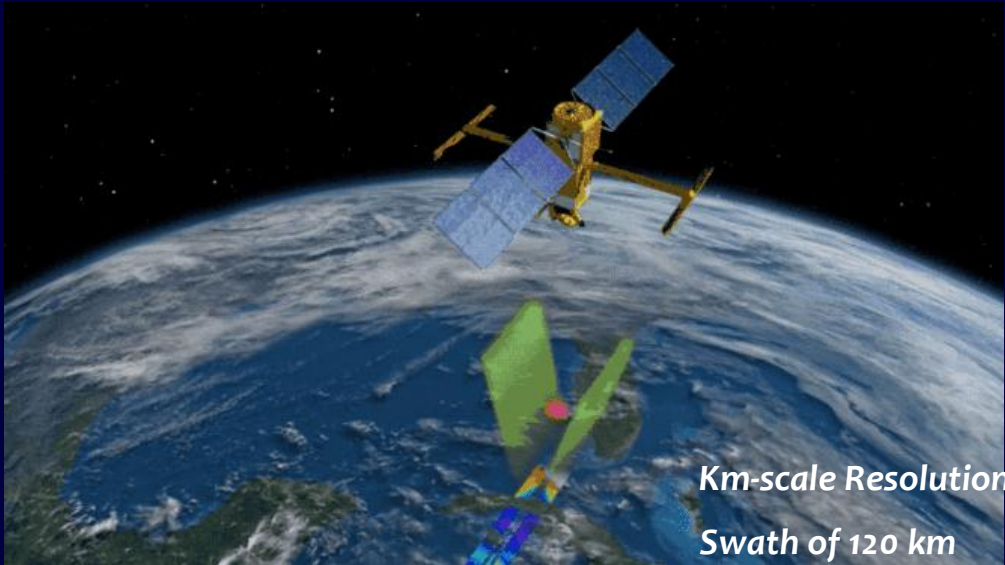


Combination of multi-mission altimetry data for monitoring extreme waves approaching coastal areas

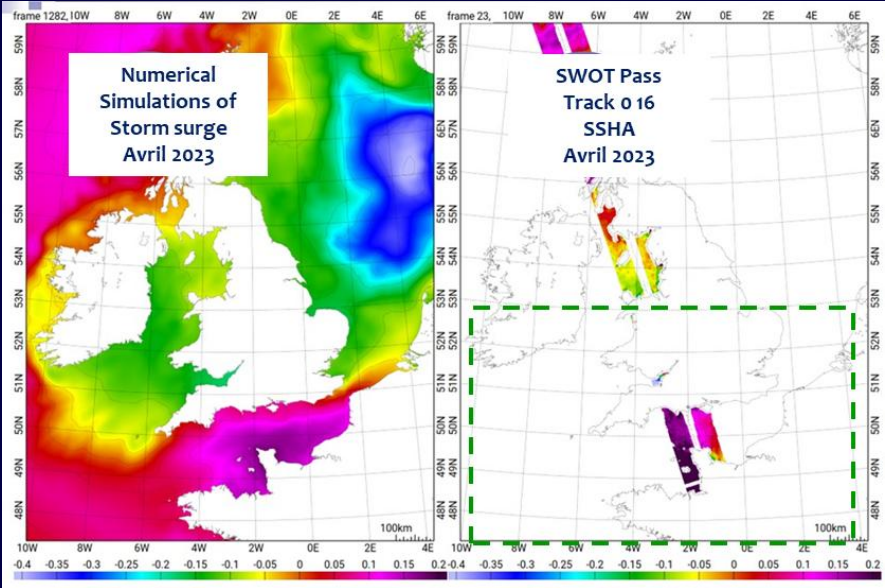
E. Imen Turki, Carlos López Solano, Saiful Islam, Mateo Domingues ,Edward Salameh, Ernesto Mendoza, **Lotfi Aouf**, Frederic Frappart.



New Mission SWOT (December 2022)



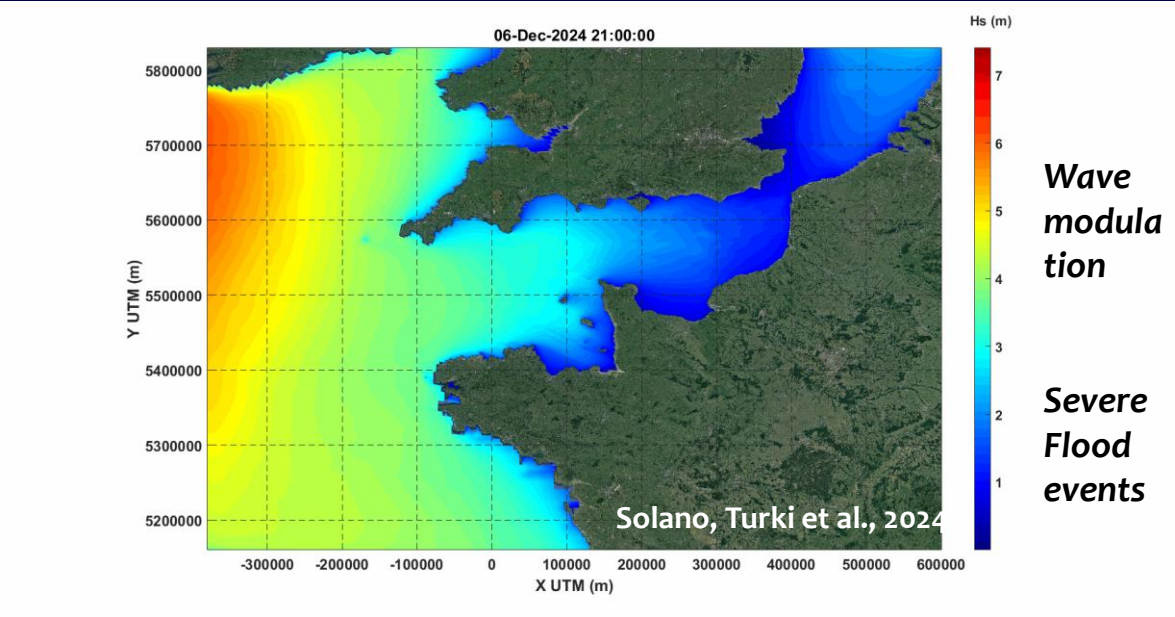
English Channel



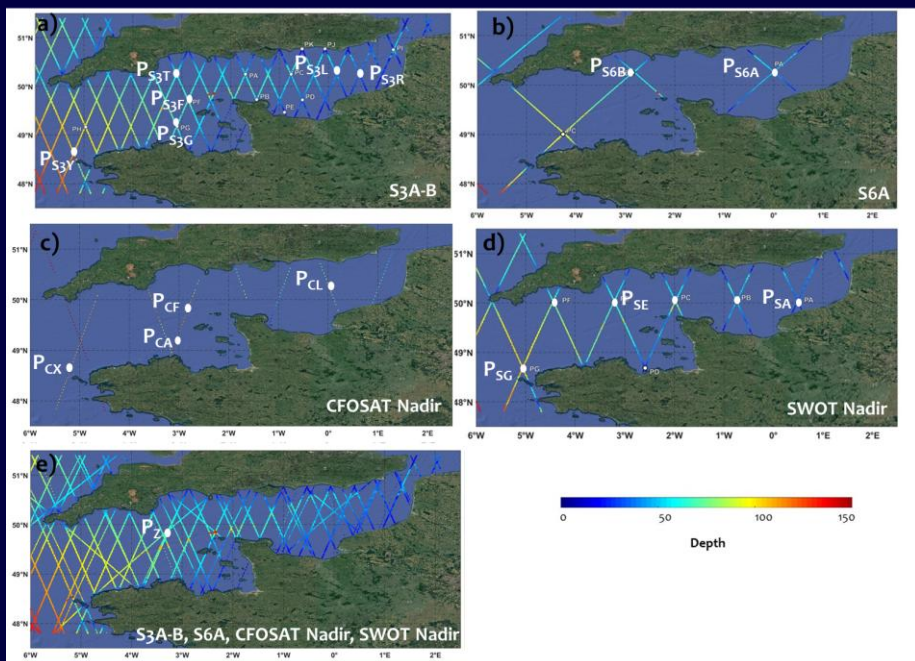
Conventional Altimeters



Wave Modelling; Ciaran Storm (Nov. 2023)

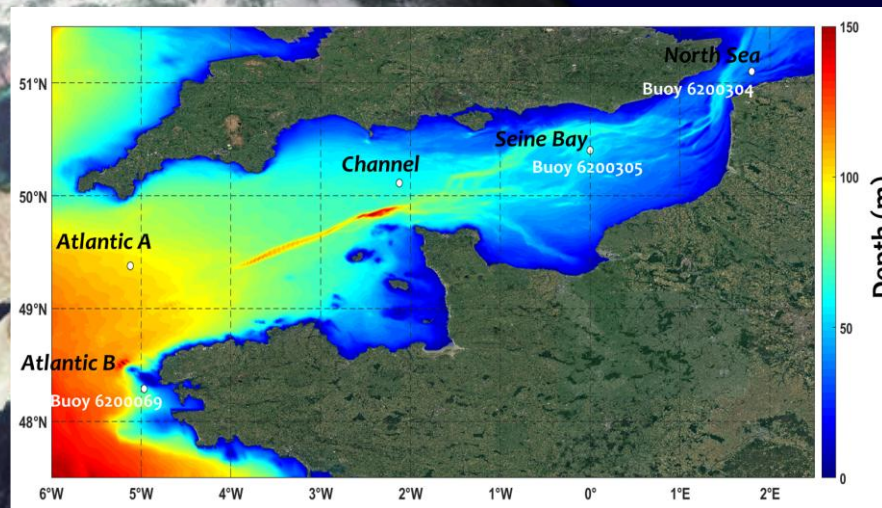


SWOT with 9 conventional missions

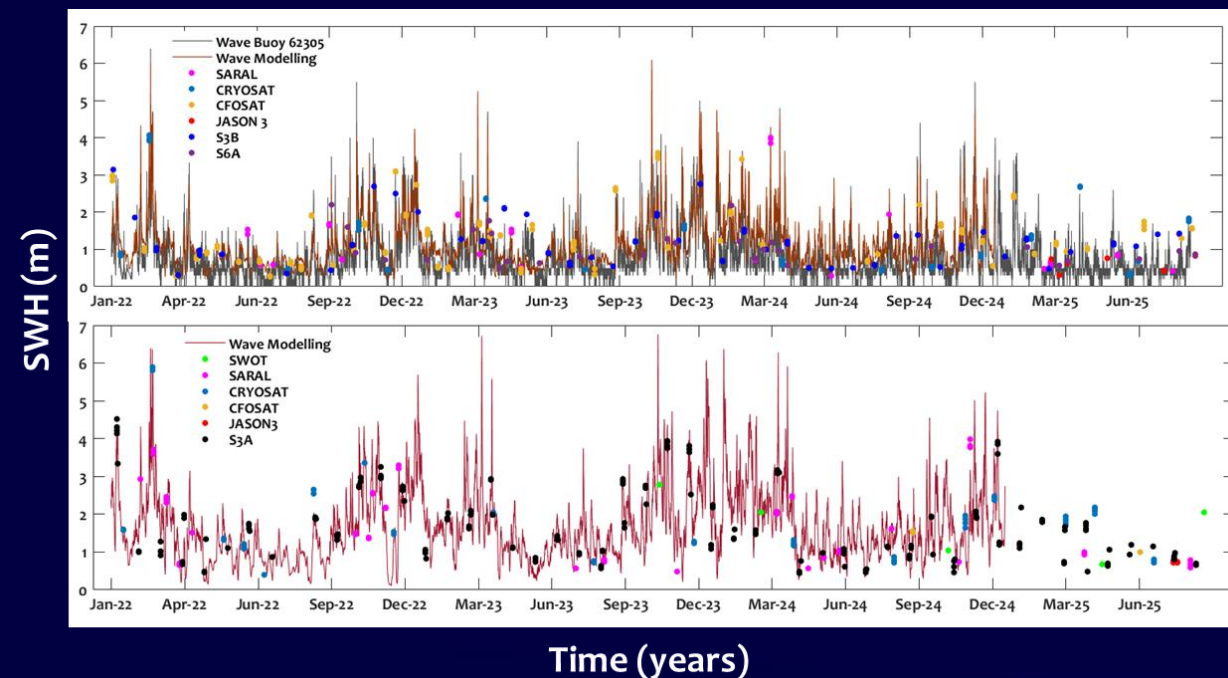


SWOT
 CFOSAT
 CRYOSAT-2
 SARAL
 Jason-3
 Hai Yang-2B
 Hai Yang-2C
 Sentinel-3A
 Sentinel-3B
 Sentinel-6

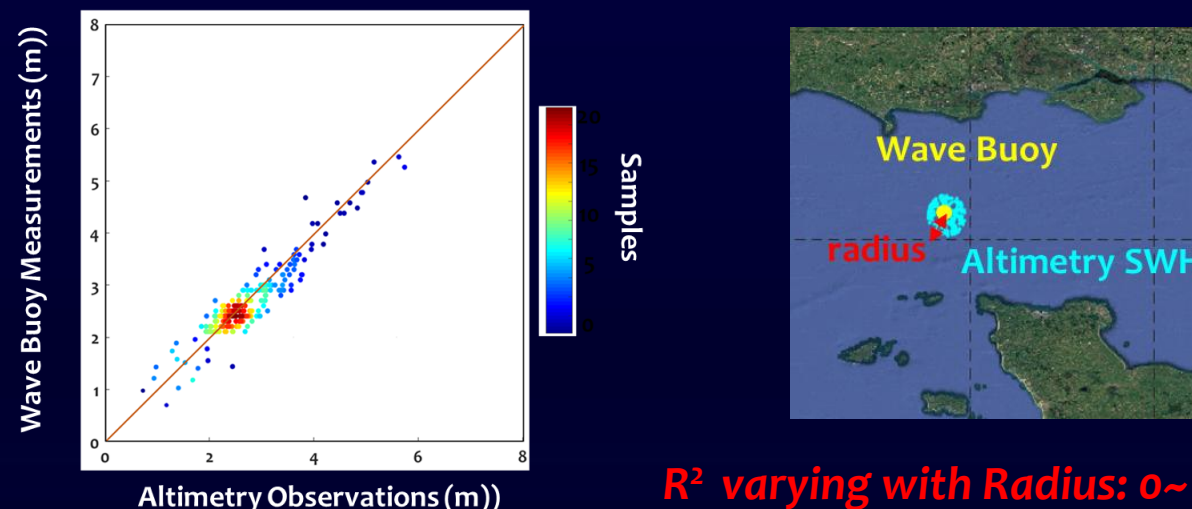
English Channel



SWH altimetry observations vs Measurements and Models

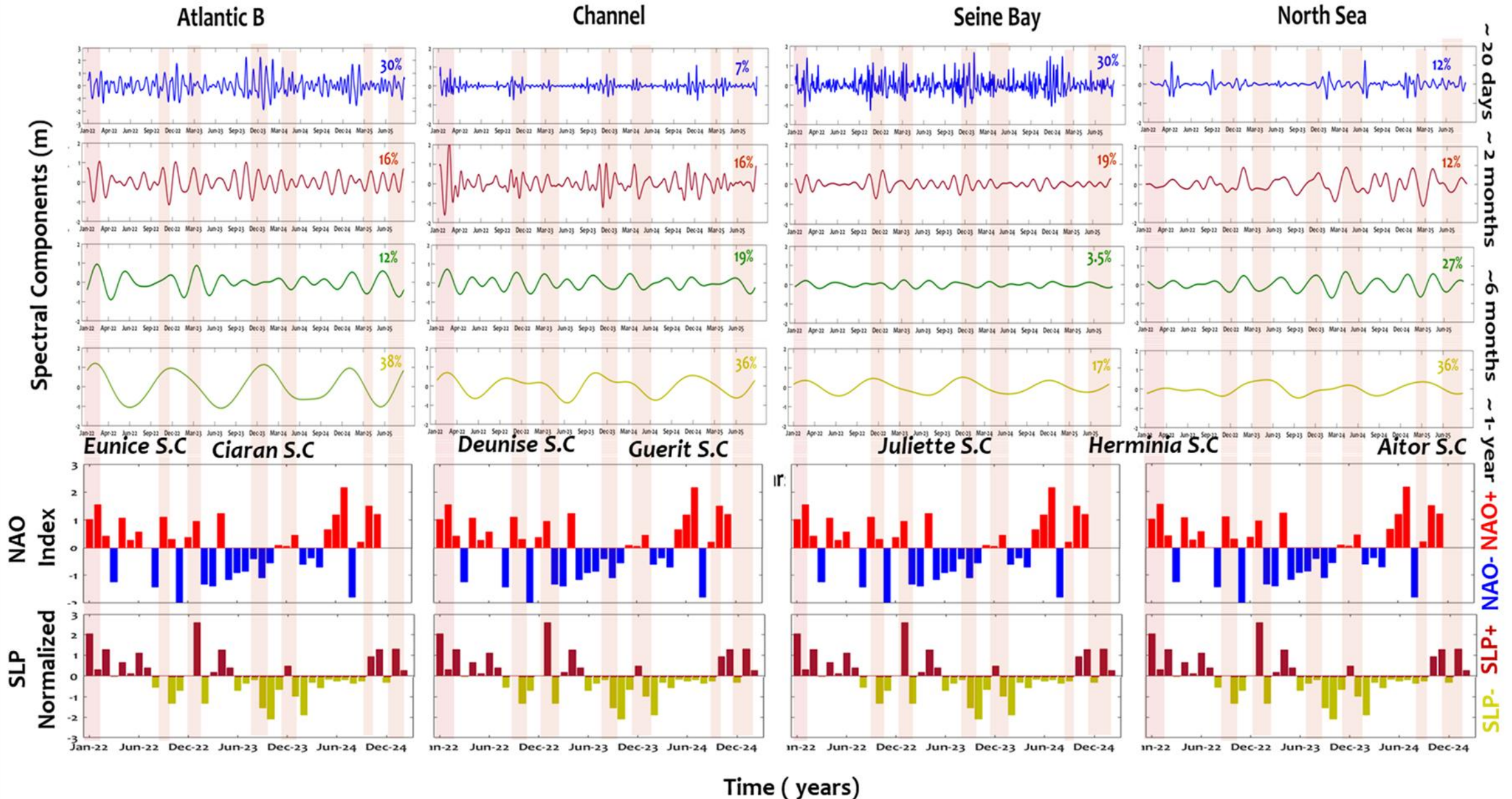


Consistency of Multi-source Altimetry Observations



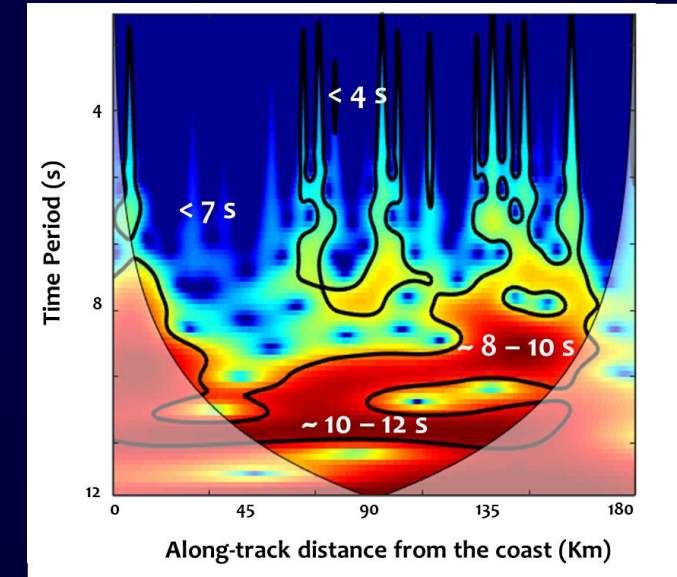
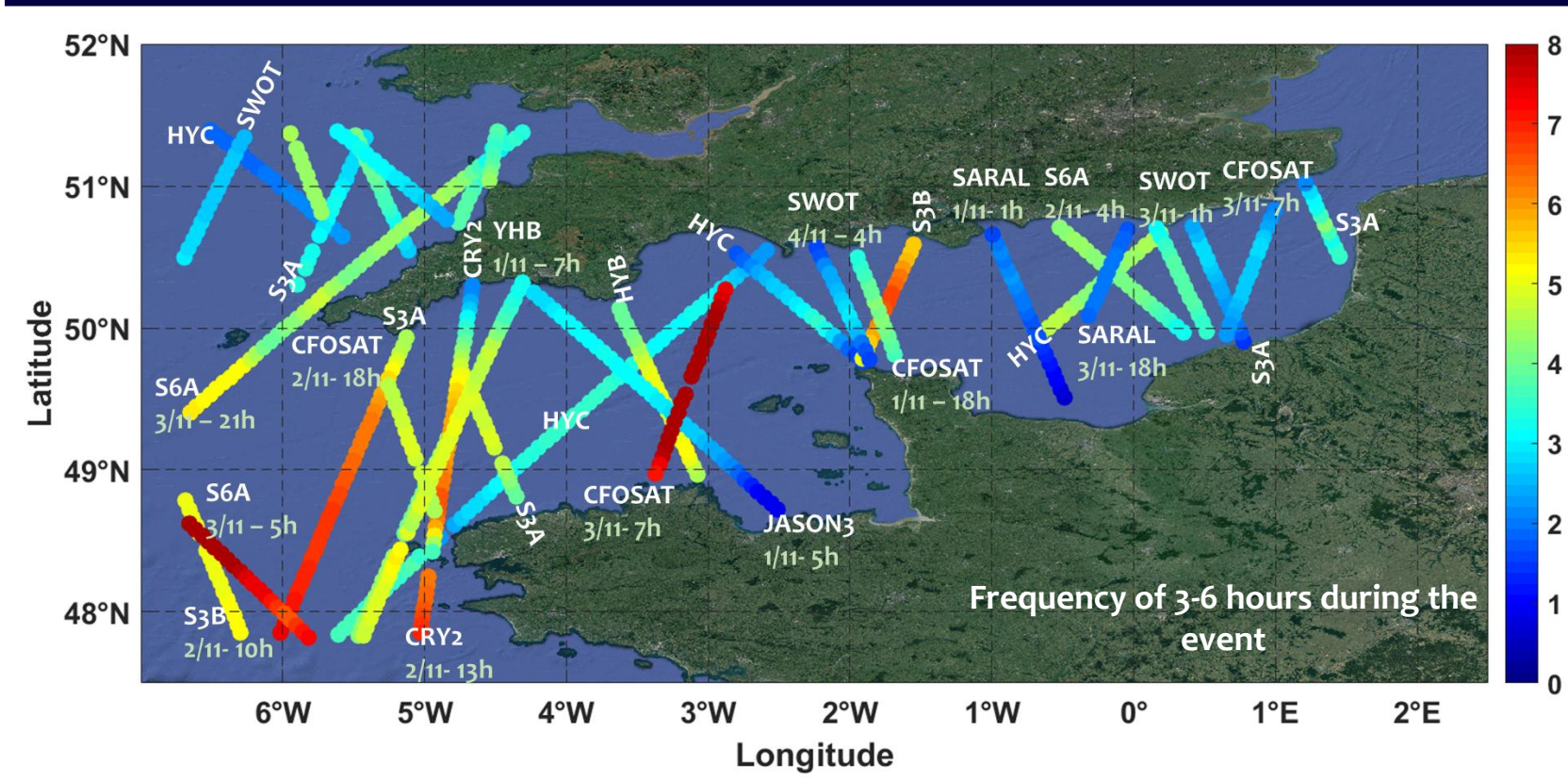
R² varying with Radius: 0~50 km

Spectral Analysis of the non-stationary SWH ; Timescale Variability: inter-daily to inter-monthly scales



Monitoring of marine storms along the English Channel and the French/UK
coasts through the coupling of SWOT with conventional mission .
Case of Ciaran Storm , 1-3 November 2023

Wave features and their changes
from the nearshore to the coast,



Example, CFOSAT 5 Hz

Valuable insight of **Merging multi-source altimeter SWH datasets** for monitoring storms and strengthen the reliability of models.

The potential of **SWOT's 2D wide-swath capability** to enhance the spatial and temporal monitoring of storms and observe wave features with short wavelengths.



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Multi-Source Satellite Altimetry for Monitoring Storm Wave Footprints in the English Channel's Coastal Areas

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Multi-Mission Satellite Altimetry for Monitoring Extreme Coastal Waves

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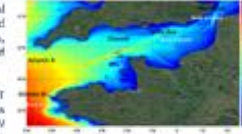
Email Address: imen.turki@univ-rouen.fr

General Context and Motivation

Satellite altimetry has greatly improved monitoring of coastal hydrodynamics, but single missions remain limited in spatial and temporal coverage. Combining multiple datasets helps fill these gaps, particularly for short-lived events such as storms, yet the accuracy of this approach in complex coastal settings is not fully understood.

This work evaluates multi-source altimetry—integrating the SWOT with nine conventional altimeters—for monitoring storm surges over three winter seasons in the unpopulated English Channel (EN France), a region prone to intensified wave energy and flooding. Within the framework of the SWOT mission (launched in December 2022), we assess the potential of enhanced satellite observations, including SAR and InSAR, to improve understanding of storm-driven wave evolution and coastal impacts (Turki et al., 2025a, 2025b).

The Channel exhibits complex variations in seabed structure and shallow-water topography, which modulate energy transmission and generate strong reflections between the UK and French coasts.



New SWOT Altimetry mission for providing 2D patterns of Sea surface features

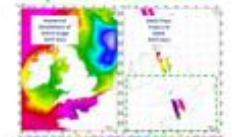


Fig. 3. Mapping of storm surges in Northern Europe, including the Channel where surges reach their maximum values (April 2022, left). The position of the SWOT track during the CalNal phase crossing Rue Blanchard in France is also shown (right). Both CalNal and Science orbits are considered. The boundary of the numerical scheme used in DELFT3D is indicated by the green rectangle.

Multi-Source Altimetry for Assessing Multi-timescale Waves from storm effects to Climate Connections

The three-year multi-source altimetry SWH record has been compared with in-situ measurements and numerical simulations to assess consistency from oceanic to coastal areas (Figs. 4 and 5). The temporal variability of SWH has been examined using spectral analysis (continuous and discrete wavelets). Particular attention is given to seven storm clusters during 2022–2023, their connection with climate oscillations, North Atlantic Oscillations (NAO) and Sea Level Pressure (SLP), are displayed in Figs. 6 and 7; and their spatial evolution derived from the combination of different altimeters (Figs. 8 and 9) is also shown.

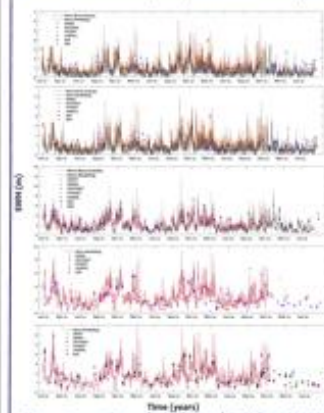


Fig. 4. Comparative analysis of Hs and SWH from GOSAT, SWOT, Sentinel-6A, Sentinel-6, Jason-3, Cryosat-2, and GOSAT. The figure shows time series plots for Hs and SWH from 2022 to 2023, with a color scale for SWH ranging from 0 to 12 m.

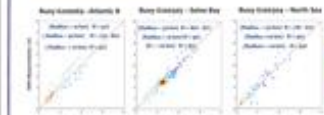


Fig. 5. Scatter-point density plots comparing SWH observations from five altimeters with wave buoy measurements. Correlation coefficients R2 between SWH observations from five altimeters, wave buoy measurements. The radius range, distance between the altimetry track and the wave buoy, is specified.

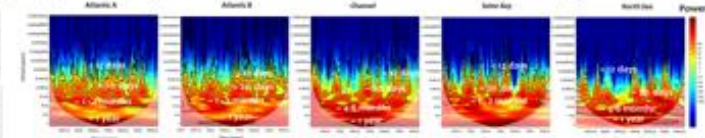


Fig. 6. CWT of multi-source altimetry SWH along the Channel. The different frequency and variability modes are highlighted, revealing SWH timescales from inter-daily to inter-monthly. Changes in SWH frequency content from the Channel entrance to the central and coastal areas are also shown.

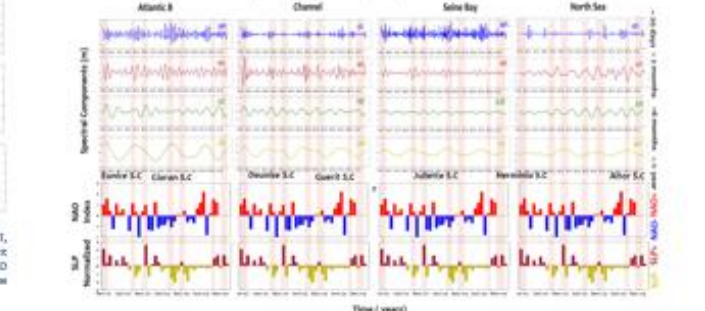


Fig. 7. Spectral analysis of SWH at different sites within the Channel. Storm clusters (SC), along with variations in NAO and SLP, are also shown, revealing a strong connection that depends on storm severity, frequency, and geographical impacts (e.g., induced storm surges). The combined effects of negative NAO and SLP are associated with a southward shift of wave tracks, particularly affecting French coasts.

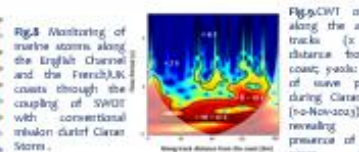
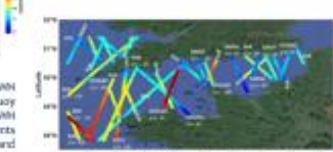
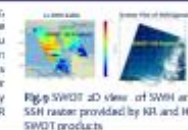


Fig. 8. Monitoring of marine storms along the English Channel and the French coast through the coupling of SWOT with conventional mission during storm clusters. The figure shows a map of the English Channel with a color scale for SWH ranging from 0 to 12 m.

Fig. 9. CWT of SWH along the altimetry tracks. The figure shows a map of the English Channel with a color scale for SWH ranging from 0 to 12 m.

Perspectives

This study demonstrates the potential of multi-source altimetry, including SWOT, to monitor storm waves in the English Channel. The approach captured ~75% of storms with strong agreement to in-situ data and revealed significant wave modulation and dissipation across coastal areas. SWOT's high-resolution 2D observations enhance spatial and temporal coverage, offering valuable input for improving numerical models, though further work is needed to fully exploit its KaRin sensor, by combining different products HR FMC/Reuter and LR products.



Acknowledgments

This work was supported by CNRS (TOSCA program SWOT4COST) and INRAE (EONIS-SWOT), led by E.I. Turki. We thank CNRS staff for providing the SWOT products, and SHOM and the Mercator for providing the wave buoy dataset.

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