

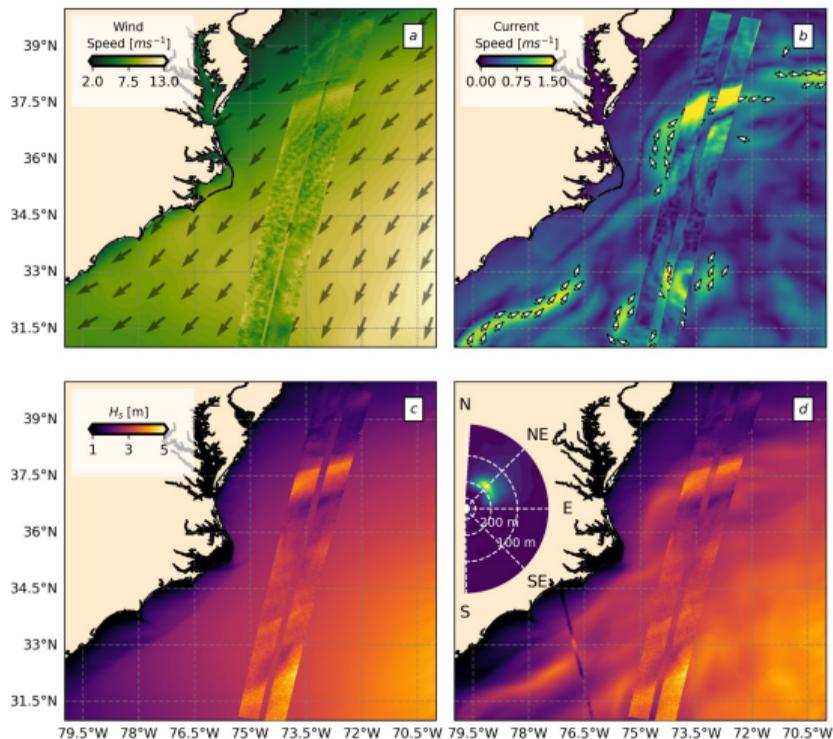
Quantifying wave groups' contributions to variability in surface wave properties

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February 6th, 2026

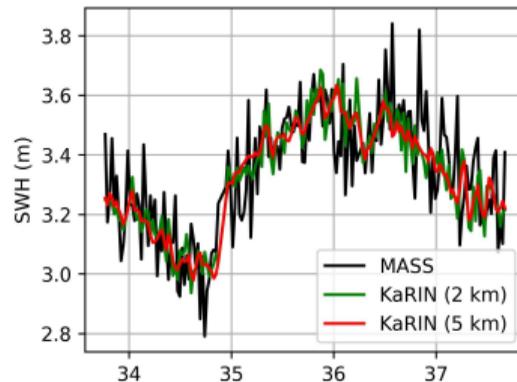
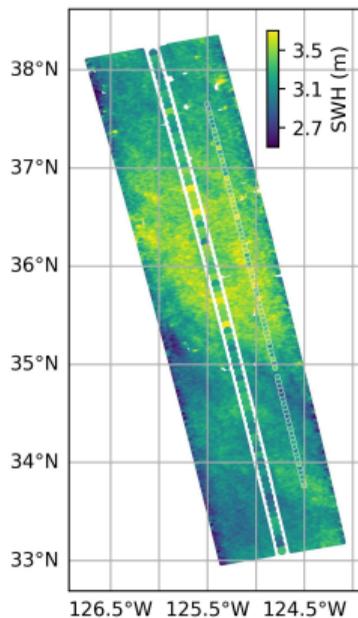
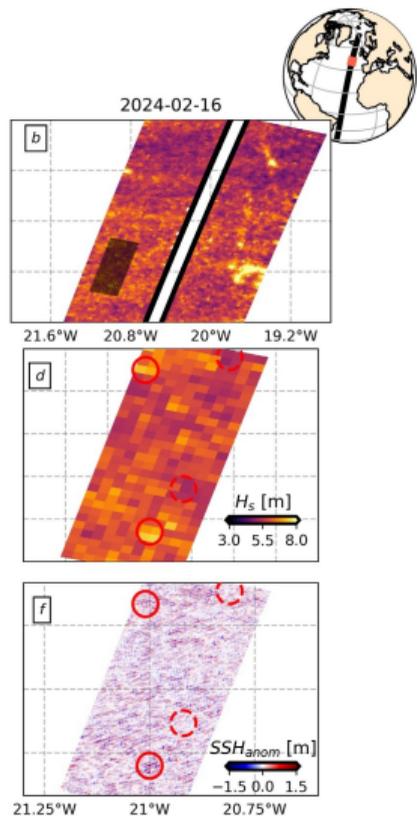
SWOT observe SWH at the submesoscale



- SWOT observe SSH, wind speed, and **SWH** (unexpected)
- Meso-submeso variability in SWH due to wave-current interaction
- Extra “pixel-level” variability ??

Villas Bôas, Marechal, and Bohé. 2025. “Observing Interactions Between Waves, Winds, and Currents From SWOT.”

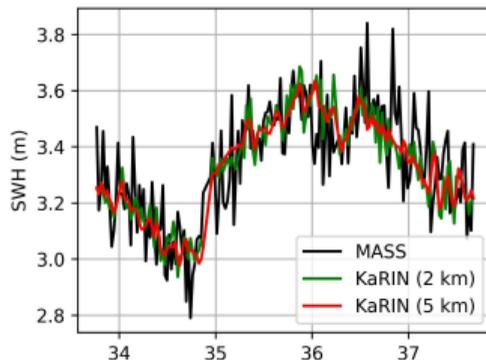
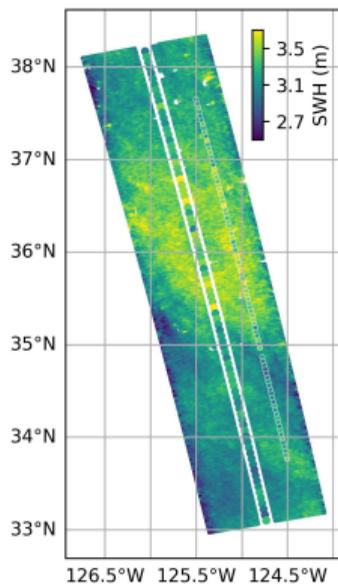
They are wave groups *signal*



Bohé et al. 2025. “Measuring Significant Wave Height Fields in Two Dimensions at Kilometric Scales with SWOT.”

Villas Bôas, Marechal, and Bohé. 2025. “Observing Interactions Between Waves, Winds, and Currents From SWOT.”

Depends on the averaging/observation window

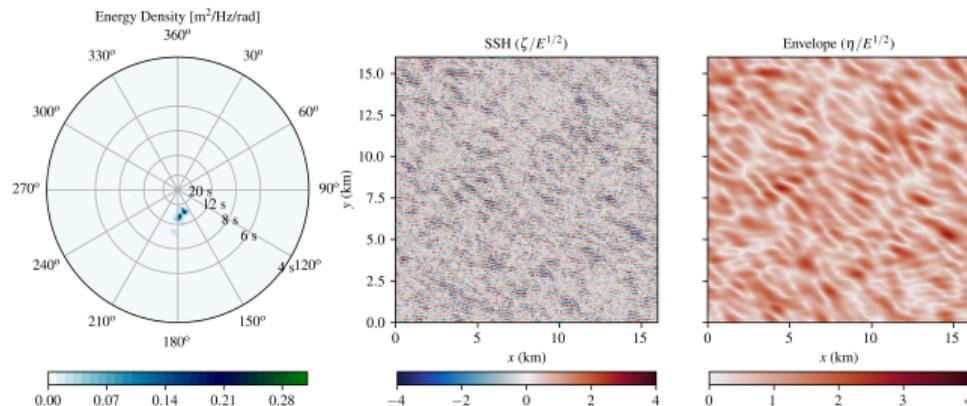


- MASS: 2 km \times 400 m
- SWOT: 2 km \times 2 km or 5 km \times 5 km
- Larger windows average over more wave groups, leading to smaller SWH variability

Bohé et al. 2025. “Measuring Significant Wave Height Fields in Two Dimensions at Kilometric Scales with SWOT.”

Understanding linear wave groups

CDIP buoy 191 (POINT LOMA SOUTH, CA) 2025-07-18 22:00

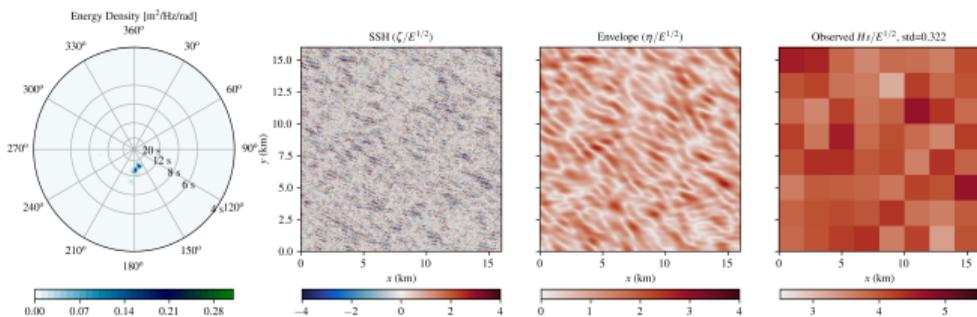


- Model SSH as a Gaussian random field from the wave spectra
- Linear superposition of waves form wave groups
- 2D wave envelope using the Riesz transform (extending Hilbert transform)

$$\eta^2 = \zeta^2 + \mathcal{R}_x[\zeta]^2 + \mathcal{R}_y[\zeta]^2$$

Scale of wave groups vs. spectral peakedness

CDIP buoy 191 (POINT LOMA SOUTH, CA) 2025-07-18 22:00



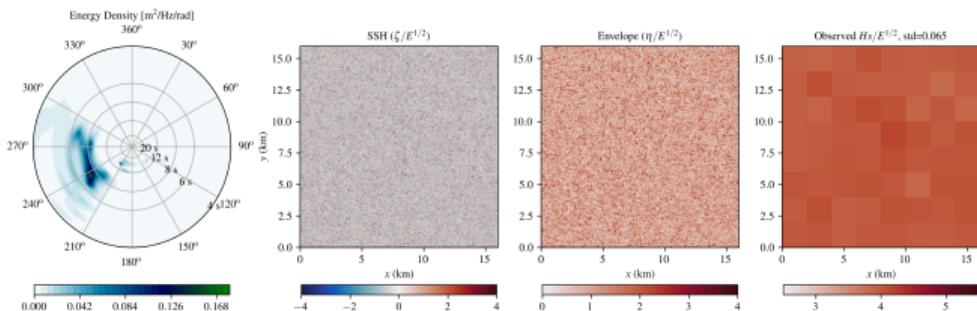
Heisenberg's inequality:

$$\left(\int x^2 C^{\eta^2}(x) dx \right) \left(\int k^2 F^{\eta^2}(k) dk \right) \geq 1$$

C is the autocorrelation function

F is the spectrum

CDIP buoy 166 (OCEAN STATION PAPA) 2025-08-14 12:00



- “The peakier the spectrum, the bigger the wave group”
- In 2D, this works for each angle

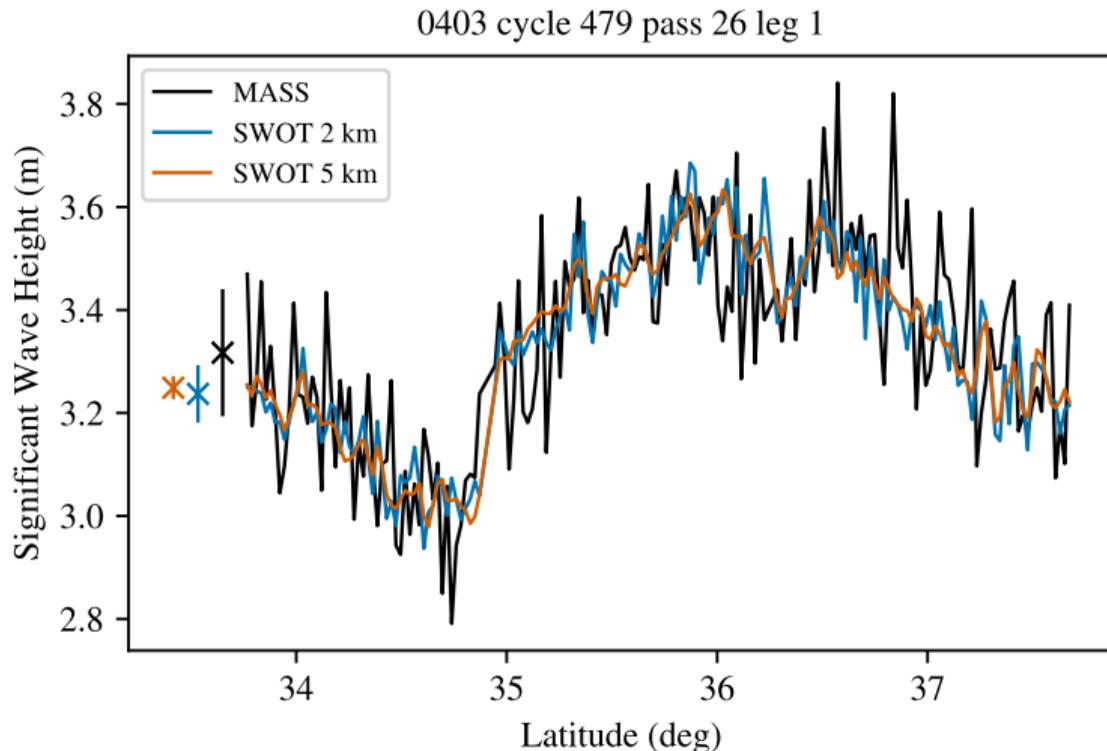
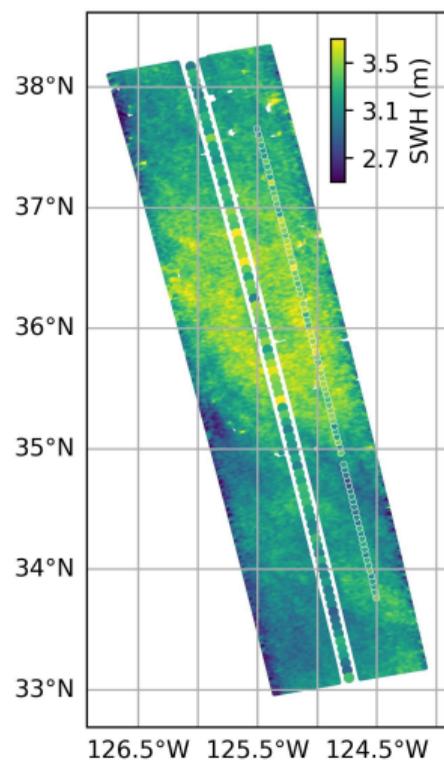
Skeleton of the model

Input: wave spectra, window size and shape

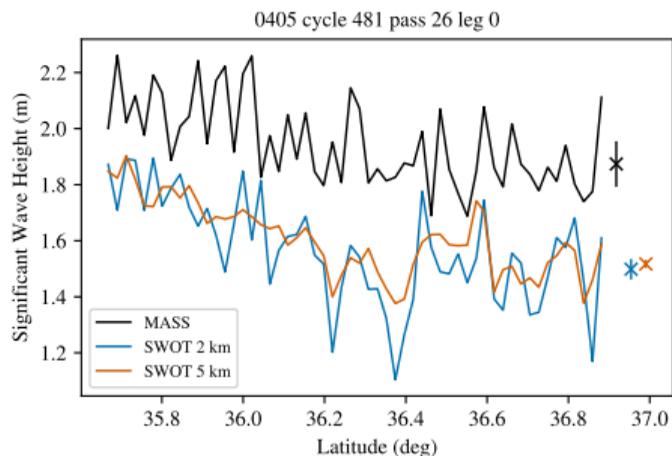
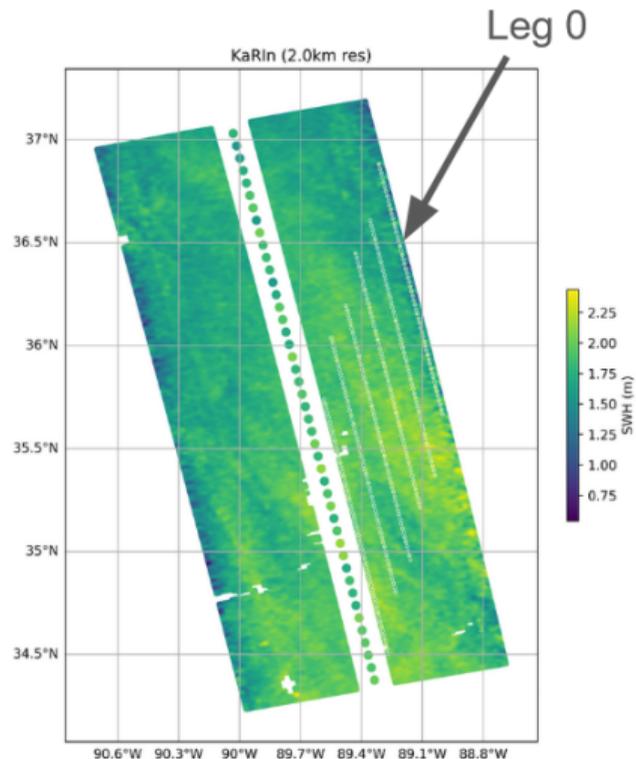
- Approximate both as 2D Gaussians
 - Shape information is captured in the second moment matrix of the Gaussian
- Observing the envelope using a window
 - == convolution in real space
 - == multiplication in Fourier space (explicit formula for Gaussians)

Output: Variance of observed H_s == Integral of the H_s spectra (Parseval's identity)

Apply to SWOT and MASS

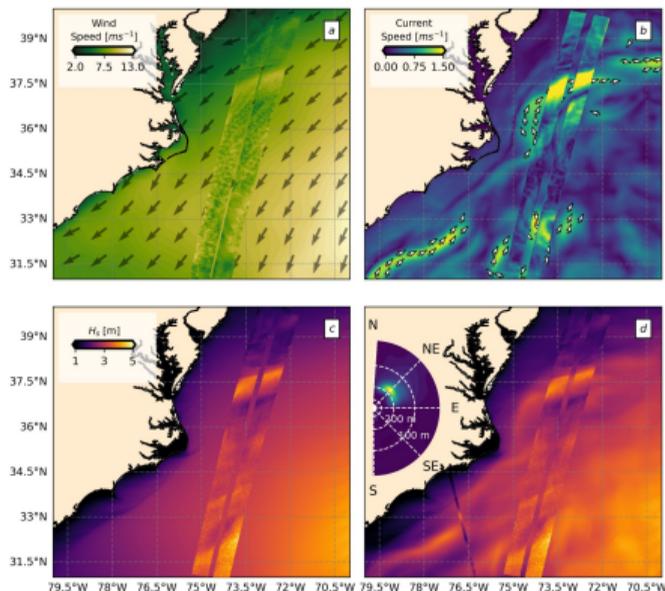


Can wave groups be the only cause?



- Bias in the mean: there is an existing fix
 - Too much variability: now clear after modeling the wave group contribution.
- Expected in SWOT data, hard to get SWH at swath edge.

Broader implications



- Wave groups contribute to submesoscale variability in wave properties (SWH, Stokes drift, wave spectra)
- This work is a model of the *error bars*
- Till what scale is SWH dominated by currents?
- WWIII does not model wave groups. Important to consider when run at submeso resolution.
- Useful for model-data and data-data comparison
- Error bar when using surface wave properties in parametrization? Surface mixing scheme? Air-sea interaction? Wave-ice?

Can wave groups be the only cause?

Sum the wave group induced variability of MASS and SWOT as an upper bound of the “allowed” difference

