Responses to Reviewers on *Measurements of Nearshore Waves through Coherent Arrays of Free-Drifting Wave Buoys*

The Reviewer Comments are in red.
The Author's responses are in black.

General Response:

The initial version of this paper focused on estimating wave height statistics from the buoy dataset. Further reflection and the reviewer comments have prompted us to shift our focus to the utility of the Level 1 motion data, including the quality-controlled GPS locations and velocities of the buoys and the body-reference-frame accelerations and rotation rates. These data contain rich information on the kinematics of the ocean surface, how buoyant particles move in the nearshore, and the wave-breaking process. Wave height statistics and other Level 2 data are still a worthwhile avenue to pursue with this dataset; however, we have more clearly stated the caveats and challenges in estimating wave statistics from arrays of buoys rapidly transiting the nearshore region, which are sometimes moving with mean flows and sometimes with breaking waves and bores. In addition to text and figure changes reflecting this shift in focus, we have made a small change to the title: "Measurements of Nearshore Ocean-Surface Kinematics through Coherent Arrays of Free-Drifting Buoys." We have also added a section in the paper to discuss how these data can be used in further studies to address a few of the reviewers' concerns regarding applications. We have also expanded the analysis of the differences in significant wave height between the microSWIFT arrays and the 4.5-meter AWAC. Two other fixed instruments, the 6-meter AWAC and 8-meter array, have been added to the comparison to corroborate the measurements from the 4.5-meter AWAC. More specific comments are addressed below.

Dear Reviewer #1,

Thank you for your thoughtful review. We will address each comment you had in the following response.

Last sentence in abstract: "These data will be used as a validation dataset for wave-averaged and wave-resolving models and will be used to investigate nearshore wave dynamics. " The authors see a robust instrument, "suitable for investigating dynamics of nearshore waves in both a statistical and wave-by-wave framework." I see an instrument not ready for prime wavetime. Given fig 10, I cannot conjure a nearshore wave dynamics question that could be investigated confidently with SWIFT buoys. The authors should include a plausible example dynamics investigation. "Beauty is in the eye of the beholder" certainly holds here.
The first version of this manuscript focuses on the water surface elevation estimates and associated statistics as the key observations provided by the buoys. Taking a step back and considering your review, we reframed the paper to focus on the Level 1 motion data, including horizontal GPS velocities and positions, body frame accelerations, and rotation rates. These are all robust measurements from previously well-established sensors. The Level 2 data products

(i.e., water surface elevation estimates and earth-frame statistics) are still included in the revised paper, with an appropriate description of uncertainties. We have also modified the paper to give specific examples of how these Level 1 data (i.e., direct motion measurements) can be used to investigate nearshore dynamics.

The buoys' velocities, accelerations, and rotation rates contain information about how buoyant objects move in the nearshore under varying forcings. For example, what is the range of accelerations and thus forces that are experienced by a floating object in a nearshore breaking wavefield? How does this change with different offshore conditions? How do the distributions of accelerations and velocities experienced by a buoyant particle change with location in the nearshore? What is the resulting cross-shore transport?

In another example, the Level 1 motion data provide indicators about the onset and strength of breaking, which may be used to investigate breaking parameterizations. Here we can extend ideas from previous work, including 1) breaking onset as a critical ratio of particle speed to wave speed (Derakhti et al, 2020), and 2) breaking strength as the instantaneous acceleration at breaker impact (Brown et al, 2018).

We plan to investigate these questions in future papers. Thank you for helping reframe the potential of this dataset. Please see the *Data Use* section of the revised manuscript for multiple examples of questions that we can answer using this dataset.

The single ground truth in 4.5m depth is inadequate SWIFT performance for H in the surfzone is not addressed.
You are correct in that many assumptions go into comparing the wave heights from microSWIFT arrays with the significant wave height at the 4.5 meter AWAC. To expand the comparison, we now include significant wave heights from the nearby 6 meter AWAC and 8 meter pressure sensor array. We adjust the measurements from these fixed instruments using linear wave theory to “shoal” the significant wave height measurements to the depth of microSWIFT measurements.

In addition to shoaling, the true wave heights at the microSWIFT array locations might differ from these fixed measurements because of alongshore variations, including refraction and shadowing near the pier. The fixed instruments are on the north side of the FRF pier, and the microSWIFT arrays were (mostly) on the pier's south side. The bathymetry around the pier is scoured, and refraction away from this deep feature can reduce the total wave energy arriving at the south side (when waves are arriving from the north). These effects are now considered in the wave height comparison.

Wave shape (skewness/asym) is not discussed.
The true geometric wave shape, including skewness and asymmetry, is challenging for the buoys to measure accurately. A discussion of these challenges is presented in Lines 67-69: “While buoys have inherent challenges in measuring nearshore waves, including distortion of surface elevation from accelerometer measurements (Magnusson et al., 1999) and inability to

resolve second-order non-linearity (Forristall, 2000), they are the only tool that can be used to obtain direct measurements of the kinematics of the surface.”

Though we cannot use the sea surface elevation time series to investigate wave shape directly, we can explore kinematics. We now include a statistical exploration of the velocities and accelerations for buoys inside and outside the surf zone, and we show non-Gaussian motion within the surf zone. This example is in Figure 11 (shown below), and the discussion surrounding this example analysis is on Lines 330-334 and reads: “In this case, the distribution of horizontal velocities widens and becomes less Gaussian in the tails of the distribution inside the surf zone compared to outside, which could indicate the waves are more asymmetric and could also indicate breaking. The distribution of vertical acceleration also becomes less Gaussian inside the surf zone. There is an excess of low acceleration values, consistent with buoys approaching free-fall during active wave breaking (Brown et al., 2019). Future work will extend this analysis to investigate the along-shore variability of these types of surface motion under different wave conditions.”

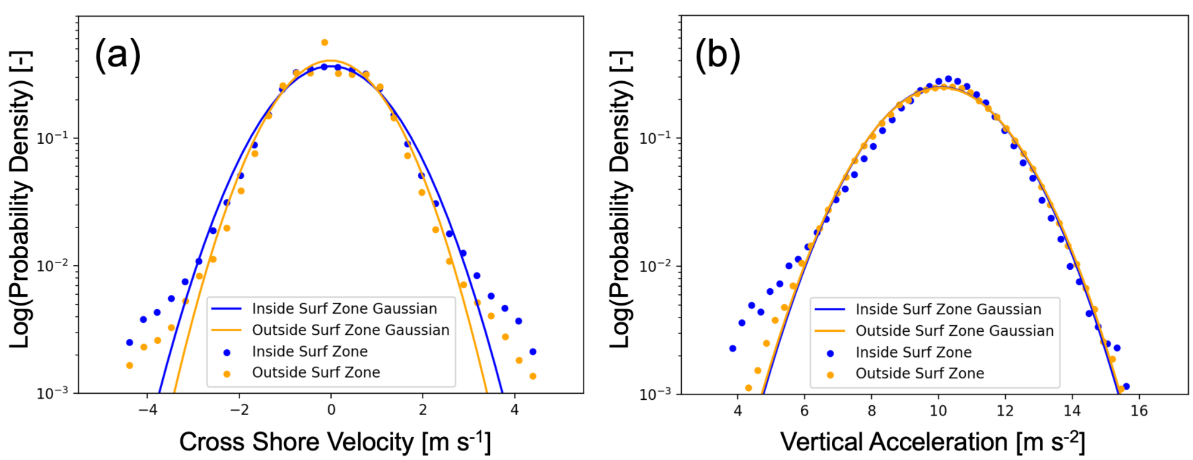

Figure 11. Histograms of cross-shore velocity (a) and vertical acceleration (b) from Mission 19. The velocity and acceleration are sorted into inside and outside the surf zone based on the approximate surf zone edge for this mission.

The comparison shown (Fig 10b) suggests SWIFT errors might be larger than the errors expected from modern numerical wave models.

The error bars originally shown showed the range of one standard deviation of the wave height distribution. We have since changed these error bars using a bootstrap method to estimate the 95% confidence interval of the significant wave height. This drastically reduces the error bars for missions with sufficient data, and missions with less data now have much larger error bars, as expected. Using the missions with sufficient data will allow us to compare the microSWIFT measurements to models with similar errors.

This 2022 reference is incomplete. Rainville, E. J., Thomson, J., Moulton, M., and Derakhti, M.: Measurements of Nearshore Waves through Coherent Arrays of Small-Scale, Free-Drifting Wave Buoys, 2022.
This citation was corrected.

Fig 7 : One error bar is shown for the largest confidence interval of the spectra with 51 degrees of freedom. What does "Largest" mean? All confidence limits are the same on a log plot?
Confidence limits on a log plot are the same size for spectra computed with the same number of degrees-of-freedom (DOF). In Figure 7, each spectrum has a slightly different number DOF, due to different lengths of the time records (all approximately 10 minutes). We show the confidence interval for the spectrum with the lowest number of DOF (=53). The text has been revised to describe how the degrees of freedom are computed for the wave spectra on Lines 236-246. The text discusses the following: "The microSWIFT spectra are computed using Welch's method, with Hanning windows and 50% overlap between adjacent windows. The energy in each five adjacent frequencies is band-averaged to improve the statistical robustness of each estimate. The equivalent degrees of freedom for each spectrum is computed using the formulation in equation 2 for Hanning windows from Thomson and Emery (2014).

$$DOF = (8/3)\frac{N}{M} \quad \text{(Equation 2)}$$

Here, N is the number of data points in the time series, and M is the half-width of the window in the time domain. For these spectra, N = 7200, which is 10 minutes (600 seconds) sampling at 12 Hz frequency, and M = 1800, which is the half-width of a single window. After band-averaging the five adjacent estimates, this results in approximately 53 degrees of freedom (rounded to the closest integer). The AWAC measurements consist of a 34-minute record with a sample rate of 2 Hz, and spectra are 250 computed with 13 50%-overlapping windows (512 points per window) leading to approximately 42 degrees, comparable to that of the microSWIFTs (Christou et al., 2011)."

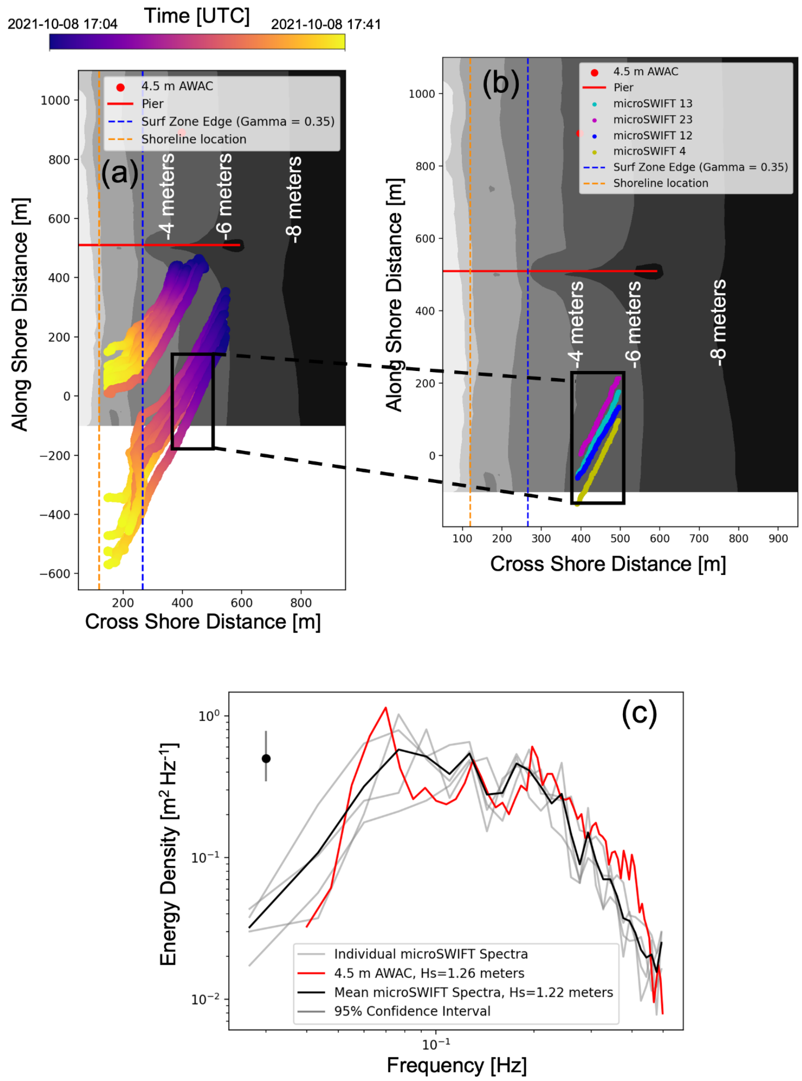

Figure 7. Comparisons of Panel (a) shows the drift tracks of the microSWIFTs from mission 18 plotted over the surveyed bathymetry DEM. Panel (b) shows a subset of the drift tracks where the bathymetry along each track is between -4.3 and -5.3 meters, and each microSWIFT is a different color. Panel (c) shows the spectra computed from a subset of the sea surface elevation time series for each microSWIFT. One error bar is shown for a confidence interval of the spectra with 53 degrees of freedom. Significant wave heights are computed by numerically integrating the AWAC and averaged microSWIFT spectra.