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 #2,

Thank you for your comments on our work. We will address each of your concerns in the following comments.

This article compares surface gravity wave statistics as measured by GPS and IMU equipped "microSWIFTs", or "mSs" for short (essentially a drifter), to an AWAC (an ADCP). Although this article is informative and should be published, I believe it should only be published after minor to major revision.

I will first comment on a couple "bigger" concerns that I have.

1) The main point of this article is to compare the significant wave height from small drifters equipped with an IMU and GPS to a nearby AWAC. I think the main difficulty with this analysis is that the mS's drift past the depth of the AWAC quite quickly, such that there is relatively few mS observations at the same water depth as the AWAC. The authors are aware of this (eg. line 40) and this is discussed at line 201, 212, 234 etc.

As such only mSs close to the AWAC depth are used in the comparison and there is few mS observations used in the comparison. I believe that the authors might be able to get more mS data to compare as long as the mSs are not within the inner surfzone with active wave breaking. I believe this as Hs should be similar offshore to the break point as it only increases slightly (~10%) as waves shoal to the break point. The critical spot is the break point and not so much the exact same depths. Perhaps the authors could get more data this way?

Thank you for this suggestion. We have adjusted the analysis to include data outside the approximate surf zone for a more complete comparison. This updated comparison between the microSWIFT significant wave height and that from the 4.5 meter AWAC is shown in Figure 9 (see below). Including more data from the measurements outside the surf zone has improved the comparison. In this figure, we also include other fixed sensors, corrected for shoaling, to confirm the measurements from 4.5 meter AWAC. We have also added analysis as to whether the microSWIFT array is within the shadow of the pier, which can lead to an underestimation of the significant wave height. This analysis helps to explain many of the cases where the microSWIFT array underestimates the significant wave height but does not provide an explanation for all points. Other underestimated points could be explained as being far from the sensor and thus seeing different waves than the fixed sensors.

If they can, I would like a more detailed comparison between the spectra of the mSs and AWAC and not just the mSs that have similar depths as the AWAC. Currently the only comparison in the MS is between the AWAC and mS Hs and a_0(f), the SSH spectra. This is a limited comparison. I think the analysis should be extended to compared mean periods, mean directions, and directional spreads. The analysis needs to be expanded to include aspects of the wave field in addition to the significant wave height.

We appreciate this suggestion; however, we have shifted our perspective on the utility of the dataset given the comments of all the reviewers and decided that it is more appropriate to pursue the Level 1 data products further. Therefore, we have kept just a single example comparison of the energy density spectra from the microSWIFTs to the 4.5 meter AWAC, shown in Figure 7. Future studies may look more into other wave statistics that can be computed with the microSWIFTs, including mean periods, mean direction, and directional spread. While we present an example comparison of the energy density spectra to the fixed instruments, we acknowledge that this comparison is not direct since the mircoSWIFTs are not in the same location as the AWAC. Further studies may use a more dedicated verification process for the Level 2 data that could be applied to this dataset. For now, we change the focus of the paper to look at the dataset's ability to investigate surface transport, spatial variability of surface kinematics, and detection of breaking waves and the associated dynamics of the breaking waves. Please see the *Data Use* section of the revised manuscript for a description of how this dataset can be utilized.

I also believe that the authors should calculate Hs as the integral of the spectra over sea-swell frequencies and not from the distribution of wave heights as they should be the same. If possible Hs from AWAC and mSs should be calculated in the exact same manner.

For the example spectra comparison, the significant wave height has been computed from the integral of the spectral energy density in this example, as shown in Figure 7 below. This example comparison has a good qualitative agreement between the calculated significant wave heights, shown in the legend of the figure. However, since the buoys are drifting quickly through the surf zone, there is rarely enough data to compute an energy density spectrum from a single buoy. Instead, we rely on the zero crossing method and aggregating wave realizations (i.e., individual wave heights) across multiple buoys to estimate the significant wave height. This approach also highlights our intention for “coherent” array analysis.

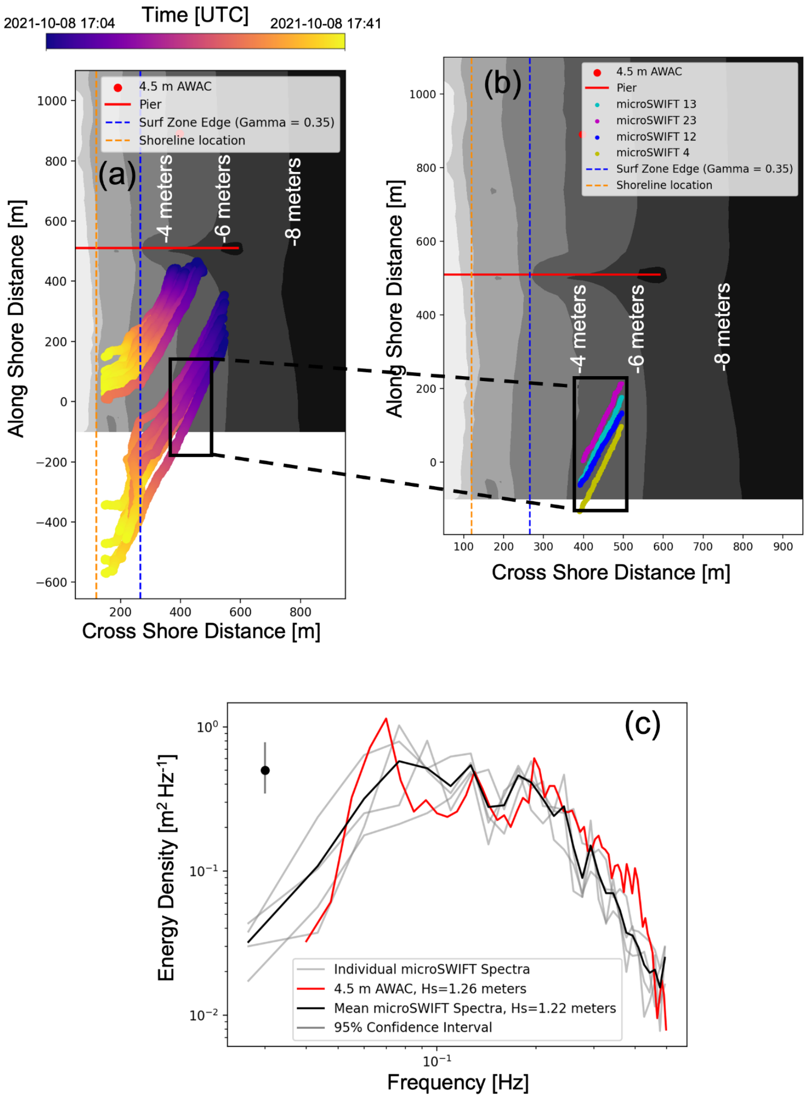

Figure 7. Comparisons of Panel (a) shows the drift tracks of the microSWIFTs from mission 18 plotted over the surveyed bathymetry DEM. Panel (b) shows a subset of the drift tracks where the bathymetry along each track is between -4.3 and -5.3 meters, and each microSWIFT is a different color. Panel (c) 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.

Also, getting the significant wave height as the mean of the top 1/3 wave heights (line 235) isn't as straight forward as

Hs = <H^2>^{1/2)

or

Hs = (8/pi)^(1/2) <H>   (1.6 times the mean of all wave heights)

where H is the random wave heights. Recall, Hs = 4<eta^2>^{1/2} and eta=H/2. As, the distribution of H is Rayleigh distributed, there is only 1 free parameter (Hs). see

https://en.wikipedia.org/wiki/Rayleigh_distribution

it would be more straight forward to calculate Hs this way and it should be more robust than the mean of the top 1/3 waves (which limit the number of waves you use by 1/3!). The mean of top 1/3 merely a consequence of a Rayleigh distribution with only 1 free parameter (and gets rid of the 1.6 factor for all waves). And it would be easier to derive error bars (see link above).
Thank you for suggesting this change; we have revised our approach based on this idea. We now compute the root-mean-square wave height, which uses all measured wave heights and is less sensitive to outliers. The significant wave height is then computed from the RMS wave height as described in Lines 272-273 as follows: "The significant wave height is computed by first computing the root-mean-square of the wave heights and then multiplying by a factor of 1.416 to convert to significant wave height for a Rayleigh distribution (Dean and Dalrymple, 1991)."

2) This article purports to compare wave statistics from mS's and an AWAC. And the article does compare Hs (significant wave height) between the two instruments. The article also compares the SSH (see surface height) frequency spectra between the instruments. I believe this article would be greatly improved if additional statistics were compared such as mean direction and directional spread (like in Raghukumar et al 2019). See also comment above.
Thank you for this comment. Since receiving comments from all the reviewers, we have shifted our perspective on the best use for the dataset and decided that focusing on the Level 1 data is the best use for this dataset. The analysis and comparison to other instruments completed by Raghukumar et al. 2019 is excellent. After our shift in perspective to focus on the Level 1 data, we think that this is a more appropriate use of the data that also differentiates the microSWIFTs from the Spotter buoys. See the general comments above for more detail, and see the *Data Use* section of the revised manuscript. For a full comparison of direntional moments with a Spotter buoy please see *Development and testing of microSWIFT expendable wave buoys* (submitted draft to Coastal Engineering Journal, submitted version is available here: https://github.com/SASlabgroup/SWIFT-codes/blob/master/Documents/microSWIFTs_CEJsubmission_9Jul2023.pdf).

3) I believe that a more detailed exploration of the uncertainty in Hs (for instance) should be explored. What is the 95% CL of the AWAC Hs? What is the 95% CL on the mS estimate. The authors should look at Gemmrich et al 2016 regarding this calculation. Are the differences in Hs between mS and AWAC real or statistical? The article would be greatly improved if the authors can state whether the differences in Hs between the instruments are within expectations. If there are real differences in Hs, reasons for the differences should be explained.

We have now included a more detailed exploration of the uncertainty in the estimates of significant wave height, shown in Figure 9 (see below). We computed 95% confidence intervals using a bootstrap method. We see that some points, especially those that overestimate the significant wave height, have very wide confidence intervals indicating that these points are computed with few data points. We have also included an analysis of when the microSWIFT arrays are within the ‘shadow’ of the pier, which previous authors have shown reduces wave energy significantly. This analysis helps to explain why some points underestimate the significant wave height. We have also added analysis to show when arrays are within a 300 meter radius of the 4.5 meter AWAC, and we see that the remaining points that underestimate the significant wave height, not explained by being within the shadow of the pier, are further away from the AWAC which could also indicate spatial differences in the waves. We now see this analysis as less of a direct comparison between wave heights since they are not measuring the exact location and the estimates are from an aggregate of buoys in different locations.

At Lines 287-296 of the revised manuscript we now state: “The linear regression between the 4.5 m AWAC and microSWIFT array significant wave heights has a slope of 0.61 and an R2 value of 0.74, showing a positive correlation between the two significant wave height estimates. This agreement is reasonable given that the microSWIFTs are measuring at a different alongshore location than the AWAC, although in similar water depths. We also expect that the microSWIFT arrays may under-predict some significant wave heights as the sampling windows are shorter than the AWAC, potentially not measuring the largest and least likely waves in the distribution and times that the microSWIFTs are within the ‘shadow’ of the pier. Being in the pier ‘shadow’ is defined here as missions when the average location of the microSWIFTs during a mission is within 200 meters of the pier, and waves are coming from the other side of the pier based on the mean wave direction from the 8-meter array (furthest offshore sensor). The significant wave height measurements from the 6-meter AWAC and 8-meter array are also adjusted to be in the same depths using linear wave theory and compared to show agreement between multiple sensors for a more robust comparison.”

4) Only wave statistics are compared in this article but I think the currents could be compared as well. How do mean currents compare? How much of the mean on-off shore velocity can be attributed to Stokes drift? Do the mS's surf broken wave bores?

This is an excellent suggestion and a component we will focus on in future studies. Since the microSWIFT measurements are relatively far away from the fixed instruments, it may not be reasonable to compare the mean currents between the microSWIFTs and the fixed instruments. Further studies may use tracking of foam in video to estimate currents closer to the microSWIFT region. Remote sensing also will be used to track wave crests. These measurements, along with the microSWIFT tracks, can then assess whether the microSWIFT movement is best described by mean currents, Stokes drift, and/or surfing on broken wave bores. The microSWIFTs were visually observed to surf on the broken wave bores. We are interested in investigating this further, but it is outside of the scope of this data paper. Lines 306-318 now note that: “These measurements can investigate buoyant particles’ cross and along-shore transport under various forcing conditions. The microSWIFTs move with both the waves and the currents. They are buoyant, and thus they also tend to ‘surf’ on the broken waves. The buoys’ surfing can enhance the transport of these objects (Pizzo, 2017). This type of motion affects similar objects transported in the surf zone, such as large algae, e.g., Sargassum, a buoyant seaweed affecting coastlines in the south-eastern US (Webster and Linton, 2013). The mean surface currents, Stokes drift, and rip currents are resolved within transport models for surface-constrained particle motion (Moulton et al., 2023). The process of ‘surfing’ is generally unresolved, and this dataset is well suited to investigate this process. Examples of potential buoy surfing events are shown in Mission 18 (Figure 7, panel (a)) and Mission 19 (Figure 8, panel (a)), where all buoys have a sudden change in direction to be nearly directly shoreward within the surf zone. This phenomenon is not observed across all missions. For example, this phenomenon does not occur in Mission 16 (Figure 5, panel (a)). These data can be used to investigate under what conditions this occurs and how it could be further incorporated into models that predict trajectories of buoyant particles. Applications range from scalar transport of plastics to marine search and rescue operations.”

Line by line comments:

Line 41. When discussing wave statistics, the authors state "Fixed sensors generally have robust statistics since they measure continuously for long periods." This feels misleading to me. Most fixed sensors, such as a wave buoy (or ADCP), measures the variance of SSH over a fixed duration, say 30 min, ie. var(eta). Then Hs = 4 * (var(eta))^(1/2). As this is done every 30 min (or 20 min), there is now a time series of Hs. The robustness of a single estimate of Hs doesn't have anything to do with the instrument being fixed as you could get the same estimate from a drifting instrument (see Herbers et al 2012) as long as it sampled for 30 min straight and it samples a statistically stationary wave field. In this article, the issue is that the mS's don't sample a statistically stationary wave field as they drift through the surfzone (see big comment #1 above).

This is a correct interpretation of the differences between the fixed and drifting sensors. There should not be any difference between the two sensors as long as they sample in the same place for at least 30 minutes. However, free drifting platforms do not stay stationary in the surf zone, and therefore never record 30 minutes continuously in the same place as fixed instruments do. In that case, since the fixed instruments sample longer in the same location, they should have more robust statistics than the drifting platform. This is one of the many challenges with the drifting platform.

Line 131. The authors say, "However, when deployed in large numbers as coherent arrays, the mS's can be processed together to explore the spatial variability of the nearshore waves and currents." Is this done here? This article does not explore the spatial variation of the wave field.

We have added some analysis to explore the spatial variability of the surface kinematics. Figure 11 in the revised manuscript now includes an example comparison of cross shore velocity and vertical acceleration inside and outside the surf zone (see Figure 11 below). In this analysis, we look for changes in cross-shore velocities and vertical accelerations, which can both be used to infer properties about the wave field. This analysis uses only Level 1 data. A discussion has been added to the revised manuscript on Lines 320-334: “These data from multiple buoys deployed in a coherent array can be used to investigate the cross and along-shore spatial variability of surface motion. An example of this type of analysis would be comparing the differences in cross-shore velocity and vertical acceleration measured by a buoy inside and outside the surf zone. Figure 11 shows an example of this analysis from Mission 19. In this case, the horizontal velocities are projected into the cross-shore direction, and the vertical acceleration (body frame of reference) is used. These data from all deployed buoys are aggregated and binned into inside and outside the surf zone groups based on the mission’s approximate surf zone edge. The cross-shore velocities have been smoothed with a running 1-second mean, and outliers (points greater than 4 standard deviations away from the mean) have been removed. The cut-off location for inside and outside the surf zone was also extended to 1.5 times the approximate surf zone edge. This buffer is added to further separate the types of motion inside and outside the surf zone since intermittent breaking is expected in the outer surf zone, even under the conservative choice of γs = 0.35. In this case, the distribution of horizontal velocities widens and becomes less Gaussian in the distribution's tails 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.”

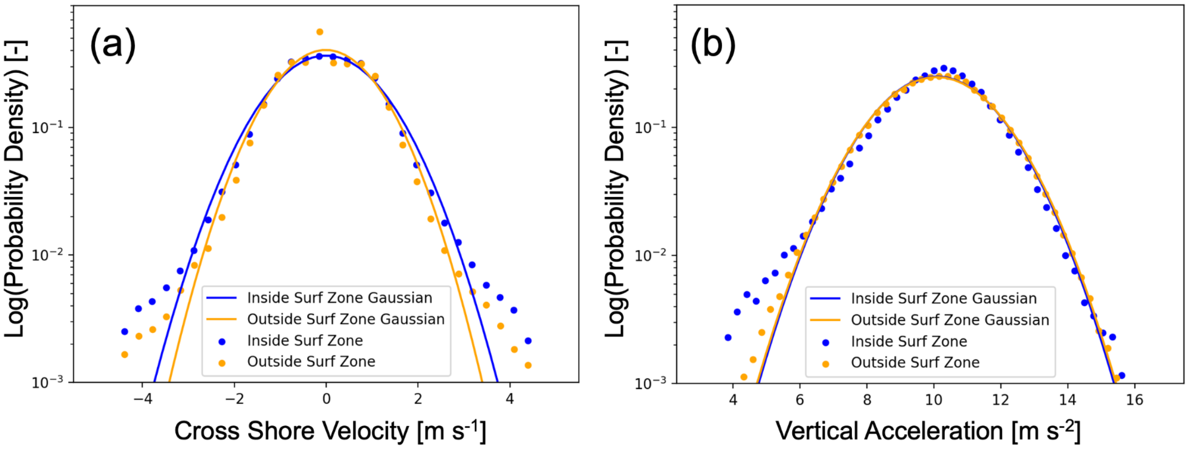

Figure 11. Histograms of cross-shore velocity (a) and vertical acceleration (b) from Mission 19. The velocity and acceleration are sorted into inside and outside the surf zone based on the approximate surf zone edge for this mission.

I believe that it should and show that Hs decreases shoreward consistent with expectations.
Inside the surf zone and in the outer surf zone, the microSWIFTs are exposed to breaking waves which manifest as high-intensity accelerations. We take as many precautions as we can to reduce these events in the acceleration signals through digital filtering described in Lines 213-217: “We then use a first-order Butterworth band-pass filter to remove low (f < 0.05 Hz) and high (f > 0.5 Hz) frequency noise outside of the gravity wave band from the signals. We then integrate the filtered acceleration signals via a time domain cumulative trapezoid method to velocities. The velocities are filtered again with the same filter to eliminate any spurious integration errors, then integrated to estimate positions, and finally filtered one last time to eliminate integration errors. The corrected and filtered accelerations, velocities, and positions are the Level 2 data.” However, within the surf zone where breaking is prevalent and the wave height is expected to decrease, the buoys have the most high-intensity acceleration events, which leads to spurious large waves. Therefore, within the surf zone, we do not see a reduction in Hs, and we restrict our analysis to outside the surf zone where these events are more intermittent, following your previous suggestion. This is further discussed in the revised manuscript on Lines 223-227: “We also expect measurements outside the surf zone to be more reliable for estimating wave properties since they are exposed to fewer breaking waves. Breaking waves tend to manifest as short bursts of high frequency and amplitude accelerations (Sinclair, 2014; Brown et al., 2019; Feddersen et al., 2023). Integrating these acceleration bursts can lead to spuriously large or nonphysical sea surface elevations; therefore, we expect the best agreement of wave measurements when the buoys are outside the surf zone or in the outer surf zone where breaking is more intermittent.”

Line 192. When discussing the AWAC wave statistics, the authors should describe the statistics in much better detail. I suppose that the AWAC gives: a_0(f), the SSH spectra, a_1(f), a_2(f), b_1(f), b_2(f). From these the AWAC estimates: Theta(f), the mean direction at each frequency; and sigma_Theta(f), the directional spread at each frequency. These statistics should be listed in a methods section. In that section, how the AWAC computes these statistics should be stated. ie., How long is the record for which a_0(f) is calculated? The number of degrees of freedom is stated at 48, where does this number come from? Also, the authors state at line 206 that there are 51 degrees of freedom for the mS a_0(f). How does one get an odd number of degrees of freedom for a spectra? I calculate the DOF as 2x3x5=30: 2 for each periodogram, 3 for 3 separate 5 minute chunks of data (these are not completely independent, and 5 for averaging 5 independent frequencies.
The AWAC is a fixed instrument the FRF maintains, and its staff completes all data processing. Since we are not computing the other statistics from the microSWIFT arrays, it may not be helpful to show these statistics. A comparison of directional moments between the microSWIFTs and a Spotter buoy is shown in full detail in *Development and testing of microSWIFT expendable wave buoys* (submitted draft to Coastal Engineering Journal, submitted version is available here: https://github.com/SASlabgroup/SWIFT-codes/blob/master/Documents/microSWIFTs_CEJsubmission_9Jul2023.pdf).

A more detailed explanation of how the degrees of freedom for the microSWIFT and AWAC spectra are computed is described in Lines 241-251. The discussion follows: “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).

$$DOF = (8/3)\frac{N}{M}$$

(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 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).”

Line 216. "... some of the mS's will be measuring the same wave as it propagates ... which improves the robustness of the statistics by sampling many realizations." I don't think this is correct. In order to increase the robustness (ie. get an estimate closer to the true value), it is necessary to sample different regions (or times) of the wave field (eg Gemmrich et al 2016). If two mS's have the exact same 10 min z(t), the 2 estimates of Hs are the same and I would argue less robust. In this case, having mS's far from each other, so they are not coherent, would increase the robustness of the estimate. Fig 9 in Raghukumar et al 2019 suggests that 50 m is the length scale over which waves decorrelate. This suggests a thorough investigation of the errors in estimating Hs.

Thank you for correcting this phrasing. While measuring multiple realizations does not necessarily improve the robustness of the estimate, it can improve the confidence in the estimate. Further discussion on this idea is given in Lines 262-268, and the discussion is the following: “Since the microSWIFTs are spatially distributed in the nearshore and sampling simultaneously, some microSWIFTs will measure the same wave as it propagates past multiple buoys. We treat this like a physical ‘sampling with replacement’ method similar to Monte Carlo or Bootstrap simulation methods known as re-sampling techniques. These types of re-sampling techniques are used to improve the confidence in a statistical estimate from a finite amount of data (Thomson and Emery, 2014). In this case, the finite data is the short period that the buoys sample an area, but multiple datasets from different microSWIFTs, occasionally containing measurements of the same wave, can help improve confidence in the statistics.”

Fig 1. Add LLW and HHW levels to Fig 1c for reference.

These changes have been added to Figure 1, shown below.

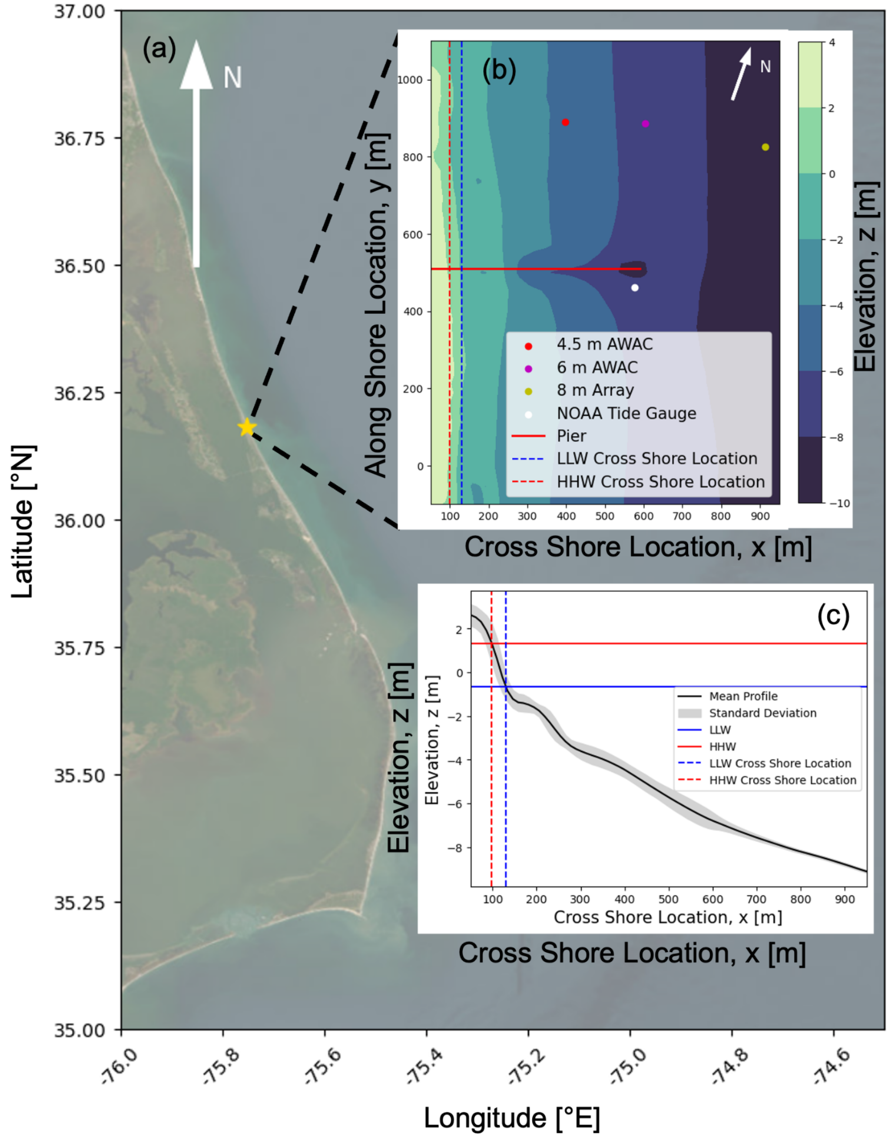

Figure 1. (a) Aerial imagery of the Outer Banks of North Carolina, US, where the gold star is the location of the US Army Corps of Engineers - Field Research Facility (FRF) (© Source: Esri, Maxar, Earthstar Geographics, and the GIS User Community). Panel (b) shows the bathymetry contours at the field site from October 21st, 2021, relative to the NAVD88 datum and locations of fixed instrumentation (Data provided by USACE, Field Research Facility, https://frfdataportal.erdc.dren.mil/). Panel (c) shows the average cross-shore profile of the bathymetry with one standard deviation above and below the average. The higher high water (HHW) and lower low water(LLW) levels measured during the experiment are also shown.

Fig 5a,b. Add a dashed line where wave breaking starts. Do the mSs sample a region of broken waves? Where is the shoreline. How wide is the surfzone?
A dashed line for the shoreline location based on an average bathymetry profile and the water level from the nearby NOAA water level gauge. A blue dashed line has also been added to show the location where we expect the surf zone edge to be based on the ratio of offshore significant wave height (from the FRF's 8-meter array of pressure sensors) to water depth. A discussion of how the surf zone edge is estimated is added on Lines 153-167, and the discussion is the following: "For each mission, the mean water level during the deployment is added to the alongshore bathymetry profile to give a cross shore depth profile during the mission. The shoreline is then estimated as the cross shore location where the depth during the mission equals zero on the along shore averaged profile. Waves are expected to begin breaking when the ratio of wave height Hs to water depth d,

$\gamma s = Hs/d$, (1)

reaches a certain threshold. Using this definition of γs, the variable Hs represents the offshore significant wave height (will use measurements from the 8-meter pressure gauge array, location in Figure 1, panel (c)), and the variable d represents the water depth during the mission. Values of γs from the Duck, NC field site have been observed to be between 0.4 and 0.8 (Sallenger Jr and Holman, 1985). Further studies have shown that within the inner surf zone at the Duck, NC field site γs can reach as low as approximately 0.275 and as high as 0.375 at depths greater than 0.8 meters (Raubenheimer et al., 1996). Smaller values of γs drive the breaking depth to deeper water, and larger values drive the breaking depth to shallower waters. From these observed values, we chose γs = 0.35 to provide a representative estimate of the surf zone edge location. These estimates are shown in both panels of Figure 5, and the same estimation method is used to add context to the analysis later on. The choice of γs = 0.35 is a traditionally low value but is used as a conservative estimate to include the outer surf zone where intermittent breaking is prevalent."

The changes to the figure are shown in Figure 5 below. Panel (a) has measurements both inside and outside of the breakers, while Panel (b) just has measurements inside where we expect breaking to be occurring.

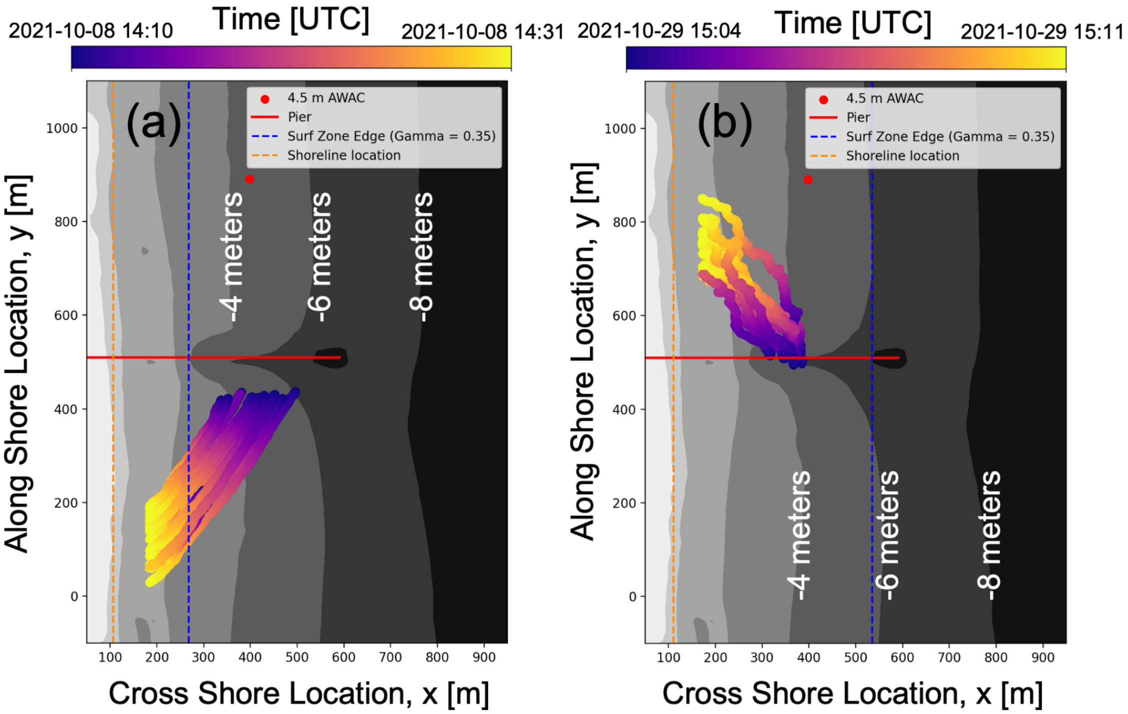

Figure 5. Example drift tracks(location of microSWIFTs over time) of microSWIFT arrays during a mission plotted over of the bathymetry digital elevation model shown in Figure 1 Panel (b). Panel (a) shows the drift tracks from mission 16, which has 19 microSWIFTs deployed, and Panel (b) shows the drift tracks from mission 79, which has 13 microSWIFTs deployed. Approximate shoreline and surf zone edges are shown for each mission.

Fig 7a,b. Add a dashed line where wave breaking starts. Do the mSs sample a region of broken waves? Where is the shoreline. How wide is the surfzone?
Fig 7c. The lines are very hard to tell apart. Choose better colors, especially for the AWAC (thick black?). Also choose some different thicknesses. Hs for each should also be stated in the caption. Maybe also show the mean of all mSs? Then the individual mSs could be thin gray.
This figure has been adjusted with your suggestions. Panels (a) and (b) now include a dashed line for the shoreline and the location we expect breaking to occur, as shown in Figure 7 above. Panel (c) of Figure 7 (shown above) now shows each individual microSWIFT as a thin gray line and the mean value as a dark black line. The significant wave heights computed from integrating the two spectra over the frequency domain are shown in the legend.

Fig 8a,b. Add a dashed line where wave breaking starts. Do the mSs sample a region of broken waves? Where is the shoreline. How wide is the surfzone?
Dashed lines for the shoreline and the surf zone edge have been added to both panels (a) and (b) of Figure 8, as shown below.

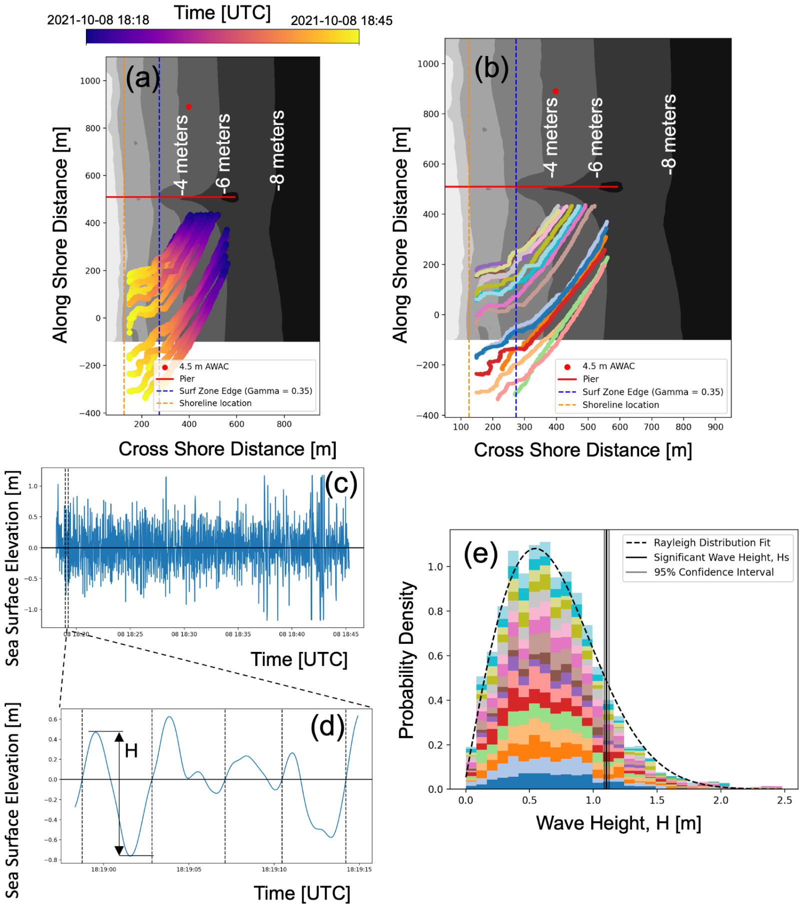

Figure 8. Example of steps in processing each mission. Panel (a) shows the drift tracks of the microSWIFTs from mission 19 plotted over the surveyed bathymetry DEM. Panel (b) shows the same drift tracks as Panel (a) but shows each microSWIFT as a different color. Panel (c) show the time series of computed sea surface elevation, with one-time series being highlighted as an example. Panel (d) is a zoomed-in portion of the overall time series showing the locations of zero crossings and how we define the height of an individual wave in a time series. Panel (e) is the probability density of all wave heights from the entire time series, where the colors show the contribution from each microSWIFT with the corresponding color. The probability density distribution fits a Rayleigh distribution. The vertical line shows the computed significant wave height for this distribution and the 95% confidence interval of the estimate.

Fig 9. Not sure if this figure needs to be included. It could be improved too. Use contour rather than contourf for the the bathy.

We have adjusted the original Figure 9, which showed the location of wave realizations, to now show the spatial density of Level 1 data from the microSWIFTs. This shows the spatial range of measurements and where those measurements are concentrated. We primarily sampled on the pier's south side due to logistic restraints but did sample some of the north side of the pier, especially in the inner surf zone. The figure has been improved with your suggestions, as shown in Figure 10 below (it has been changed to Figure 10 in the revised manuscript).

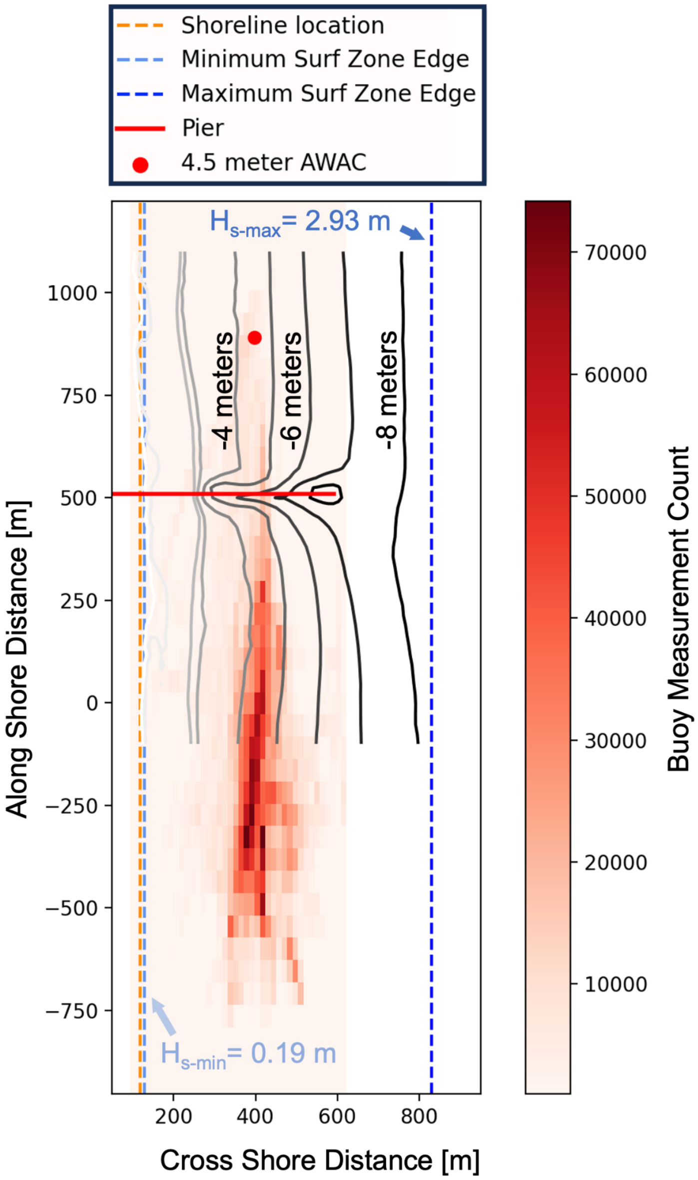

Figure 10. Density of Level 1 buoy measurements over the entire experiment from October 3rd to October 30th, 2021, plotted over the bathymetry contours. Most measurements were made on the pier's south side between -2 and -6 meters in bottom elevation. The bin spacing for this histogram is 13.2-meter bins in the cross-shore direction and 54.3-meter bins in the along-shore direction. The average shoreline over the experiment is shown along with the approximate surf zone edges based on the smallest and largest offshore significant wave height during the experiment.

Fig 10a,b. std bars are on mSs Hs in 10a but on AWAC Hs in 10b. Shouldn't the error bars in 10b be on mSs as they are the same as in 10a? In 10b, error bars on should be on the AWAC and mS estimates. Also, these should be 95% confidence limits, not stds as the reader will be interested in how good your estimate is and not how much scatter there is in the estimate. Please calculate correct 95% confidence limits based on the number of wave heights used.
Fig 10b. Although overall the scatter is OK (R^2 = .67), for AWAC Hs>2, there is little to no relationship between AWAC and mS Hs. This should be commented on in the Ms. Perhaps including all mSs that are not in the surfzone will make the relationship better? Perhaps, correct 95% confidence limits will help to explain when the relationship isn't so great?
We have implemented your suggestions for the original Figure 10, shown below from the revised manuscript, now as Figure 9. The axes have been flipped to show the 4.5 meter AWAC significant wave height on the horizontal axis and the other significant wave height estimates on the vertical axis. The error bars have been corrected to be 95% confidence intervals estimated using a bootstrap method. We have also removed the original Figure 10a, which did not add information beyond the current Figure 9. Measurements from the 6 meter AWAC and 8 meter array of pressure sensors have been corrected for shoaling and added to this analysis to show how other instruments compare with the measurements from the 4.5 meter AWAC. The microSWIFT array estimates of significant wave height also now use all data outside of the surf zone, which includes many more measurements.

Further analysis to determine when the microSWIFT arrays are within the shadow of the pier has been added and to show when the microSWIFTs are within a radius of 300 meters of the 4.5 meter AWAC. These additional analyses help to explain the discrepancies between the 4.5 meter AWAC measurements and those from the microSWIFTs. Discussion of these additional analyses is included in the revised manuscript on Lines 287-297 and is the following: “The linear regression between the 4.5 m AWAC and microSWIFT array significant wave heights has a slope of 0.61 and an R2 value of 0.74, showing a positive correlation between the two significant wave height estimates. This agreement is reasonable given that the microSWIFTs are measuring at a different alongshore location than the AWAC, although in similar water depths. We also expect that the microSWIFT arrays may under-predict some significant wave heights as the sampling windows are shorter than the AWAC, potentially not measuring the largest and least likely waves in the distribution and times that the microSWIFTs are within the ‘shadow’ of the pier. Being in the pier ‘shadow’ is defined here as missions when the average location of the microSWIFTs during a mission is within 200 meters of the pier, and waves are coming from the other side of the pier based on the mean wave direction from the 8-meter array (furthest offshore sensor). The significant wave height measurements from the 6-meter AWAC and 8-meter array are also adjusted to be in the same depths using linear wave theory and compared to show agreement between multiple sensors for a more robust comparison. The agreement in significant wave height and scalar energy density spectra supports that the Level 2 data are useful for investigating wave spectra and statistics.”

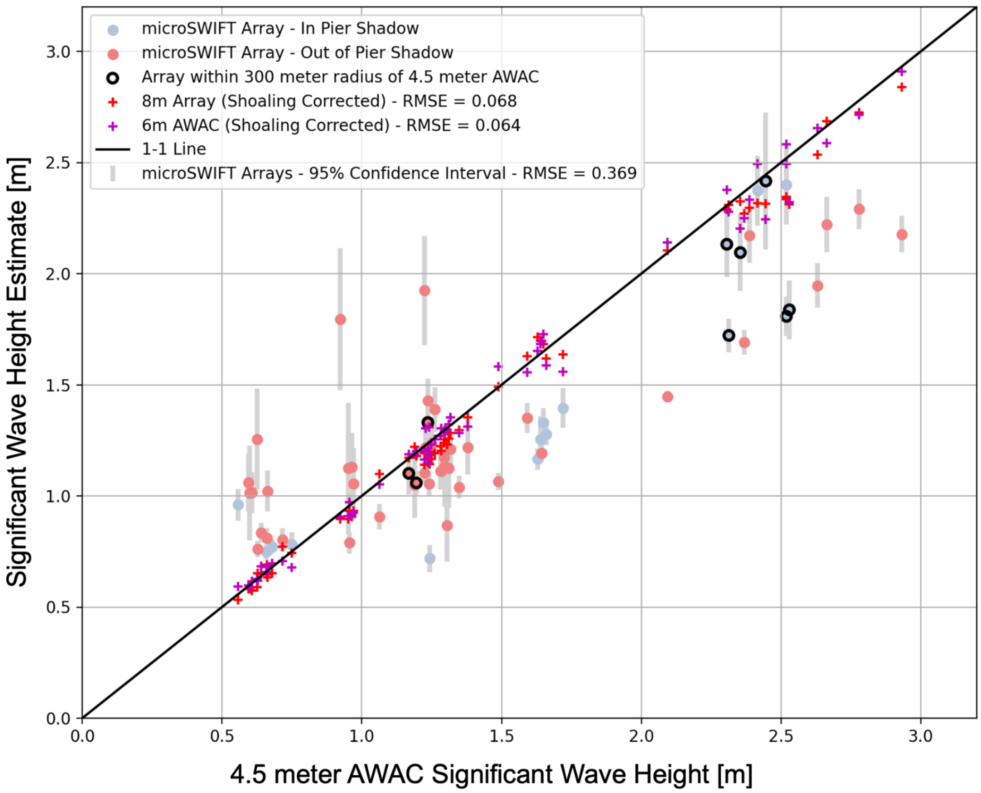

Figure 9. Comparison of the estimated significant wave heights from the microSWIFT arrays, 6-meter AWAC, and 8-meter pressure sensor array (6-meter AWAC and 8-meter array have been corrected for shoaling) to the estimates from the 4.5 m AWAC. While the microSWIFT arrays are not in the same water depth as the 4.5 m AWAC, we see that the microSWIFT arrays characterize the size of the waves with good comparison to the 4.5 m AWAC. The gray bars indicate 95% confidence intervals around each of the significant wave height estimates, computed using a bootstrap method from the distributions of wave heights. The colors of the estimates depict if the microSWIFT array is in the 'shadow' of the pier where we expect a reduction in wave energy.

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