Reply to reviewer: for “**Brief communication: Impact of swell waves on atmospheric surface turbulence: A wave-turbulence decomposition method”**

Reviewer comments are presented in black text using the "Calibri" font format with a size of 12. My responses are displayed in blue text using the "Calibri" font format with a size of 13.

Reviewer 2

Wave-Turbulence Decomposition holds significance for both the wave and atmospheric communities. However, it is a considerable challenge for the decompositon. Within this study, the author introduces a method for decomposing wave and turbulence fluctuations. The concept is intriguing and certainly warrants publication. Prior to the manuscript's publication, I have outlined several comments that the author may wish to consider addressing.

Thank for your thoughtful feedback. I'm committed to addressing these invaluable comments to enhance the clarity and quality of the manuscript. In particular, the brief definition of the wave boundary layer is provided to clarify how wave-induced orbital velocities influence velocity fluctuations in the lower marine atmospheric boundary layer, especially in stable conditions. The suggested decomposition method is compared to three wave-turbulence decomposition methods that rely solely on the spectral information of the timeseries. I will elaborate on the observational coherence by available sonic data at two different heights (with separation distance of 5m – I specifically use our sonic data at 20m for this purpose). This study also introduces a theoretical coherence method crucial for generating the cross-spectral density matrix to simulate fluctuating wind velocity and wave height. These contributions emphasize the model's importance and its effectiveness in analyzing aerodynamic and structural loads on offshore wind turbines.

Specific comments

1. Several established methods for wave-turbulence decomposition have been utilized in previous studies. To provide context, I recommend that the author furnish an overview of these methods in the introduction. This should encompass the work conducted by Hristov et al. (2003, 2014), the spectral method outlined by Veron et al. (2008) and Grare et al. (2013), as well as the interpolation method described by Rieder and Smith (1998) and Högström et al. (2015).

   I appreciate this feedback. Your suggestion to include references to established wave-turbulence decomposition methods such as those by Hristov et al. (2003, 2014), the spectral method by Veron et al. (2008) and Grare et al. (2013), as well as the interpolation method outlined by Rieder and Smith (1998) and Högström et al. (2015) will enhance the context and comprehensiveness of the manuscript. In response to another reviewer's comment regarding this manuscript's suitability for being considered as a regular manuscript, I have room for further elaborations and will improve the introduction section to provide a more detailed overview and background on the methods (by including references and background). Additionally, I'll include an appendix to explain a few decomposition methods with a figure to compare them with the suggested spectral method of this manuscript, ensuring a more thorough description of the methodology and its effectiveness.

2. In light of these established techniques, it would be beneficial for the author to address whether their proposed method has been compared to these prior approaches. Specifically, have the results obtained using the author's method demonstrated good agreement with those generated by the aforementioned methods?

   In my research, such processing tool, and its application, has evolved over several years, involving the application of various decomposition methods to high-frequency oceanic and atmospheric sensor data, such as shear probes data and ADVs for oceanic studies and sonic anemometer data for atmospheric studies. Notably, these decomposition methods differ, with some relying also on high-frequency surface wave elevation data (beside to wind and current time series) and others solely on high-frequency wind (current) velocity time series. I have conducted thorough comparisons between the suggested spectral method and a couple of established approaches. These comparisons consistently demonstrated promising agreement, with the spectral method standing out as robust and efficient, acting as a statistical physics-informed gap-filling technique.

It is noted that selecting the appropriate decomposition method can be a complex task, depending on factors such as data characteristics, the nature of wind-wave interaction (like misalignment, stability conditions, etc), advection of wave orbital velocities across a broad frequency range, and more [1]. I've found that the spectral method and its associated technique for deriving wave and corrected turbulence time series from wind speed (ocean current) frequency data are robust and valuable for various atmospheric flux studies over and under the wavy air-sea interface.

I will clearly present and discuss in the manuscript, affirming the effectiveness of the approaches, by comparing the technique with few other ones I made using solely the spectral information, specifically I add an appendix and detail them there.

3. Furthermore, it would be pertinent to explore the strengths and limitations of the author's method in comparison to the existing alternatives. Within the scope of this study, a comparison has been made between the method developed by Hristov and the approach outlined by Veron et al. in 2008. It is noted that the results obtained from these two methods show an acceptable level of agreement, as previously established by Wu et al. in 2008. This comparison adds credibility to the validity of the author's method. Incorporating this comparative analysis would provide a more comprehensive understanding of the novelty and effectiveness of the author's proposed approach in relation to the existing methodologies.

Various methods exist for decomposing wind-wave interactions, including phase averaging, linear transformation, and orthogonal projection of the wind onto the Hilbert space to estimate the wind-wave coherence signal, etc. Many of these techniques rely on complex cross-spectra between horizontal u and v fluctuating air velocities and vertical w fluctuating air velocities, along with sea surface elevation, to isolate the direct wave influence.

The choice of decomposition method in this manuscript, as outlined in the methodology section, is based on specific considerations related to the research objectives and the nature of the data I am working with (i.e. sonic anemometer data at 15m height above the mean sea level). I plan further to add a figure comparing between the suggested method in this manuscript with one or 2 other decomposition methods. My approach differs in the following ways that I will clarify in the manuscript:

- the approach solely utilizes sonic wind velocity data, omitting the need for concurrent high-frequency wave measurements in the decomposition process. It neglects velocity fluctuations within the wave band, assuming turbulence field stability during transformation into wavenumber space.
- Additionally, the method stands out as a physics-informed statistical approach that employs a turbulence spectrum model to effectively bridge the gap between high- and low-frequency sections in the observed spectra. This enables us to estimate the variance attributed to turbulent velocity fluctuations within the wave frequency band by learning solely from the energy spectrum of the corresponding wind component.
- Notably, this method uniquely provides wind-corrected and wave time series, a critical data component for structural analysis that is not accessible through other known methods in my knowledge.

In summary, the decision to employ this decomposition method is rooted in the specific nature of the datasets I am working with, and my extensive experience in motion compensation of moving sensors in both atmospheric and oceanic environments in the presence of a wavy air-sea interface. Through this experience, I have found that filling spectral gaps using a well-established spectrum is an effective approach across a broad spectrum of atmospheric stability and sea state conditions, on both sides of the sea surface.

To address this comment, I've added an appendix comparing three methods for isolating wave motions from the vertical wind velocity data. These methods, the stopband filter, the intrinsic mode function, and linear interpolation in frequency domain don't rely on wave elevation time series but solely on sonic data. The stopband filter is employed by knowing the wave peak frequency or dominant wave frequency band. I use an estimation for the frequency band as 0.6fp to fp+0.1. The SB filter method significantly reduces energy within the wave-dominant frequencies, resulting in an associated underestimation of turbulent energy; this is approximately the same for the intrinsic mode functions that can be further improved while the method alone may not completely eliminate the wave velocities. The linear interpolation in the spectral domain may be sensitive to the choice of the wave frequency band.

4. The presence of multiple layers of sonic sensors introduces an intriguing opportunity for validation. It would be highly compelling to ascertain whether the wave coherence contribution as discussed in Section 2.2 aligns with the findings derived from the methods detailed in Section 2.1 across the various sensor layers. This comparative analysis could yield valuable insights into the consistency and reliability of the outcomes.

Thank you for this insightful comment. The idea of a comparative analysis across the various sensor layers is indeed intriguing. In the revised version, I explore the possibility of aligning the wave coherence contribution discussed in Section 2.2 with the findings derived from the methods detailed in Section 2.1 across these multiple sensor layers. This analysis has the potential to provide valuable insights into the consistency and reliability of method outcomes. Furthermore, I will incorporate time series data from another sonic anemometer operating at a 20-meter height. This addition will allow to estimate the observational coherence between the 15-meter and 20-meter sonic anemometers, bridging the gap between the theoretical coherence function proposed and real-world coherence data.

The following figure illustrates coherent structures at two different heights (15m and 20m). In Fig. 1a, a 20-minute sonic data time series at these heights is displayed, while Fig. 1c shows the observed coherence and the theoretical model results. This also sheds light on why the theoretical coherence formula incorporates the wave-induced bump. To address this concept and establish a connection between the observed coherence and my proposed theoretical formula, I will include the fitting of the theoretical coherence to this data. A more detailed explanation will be provided in the methodology and results sections.

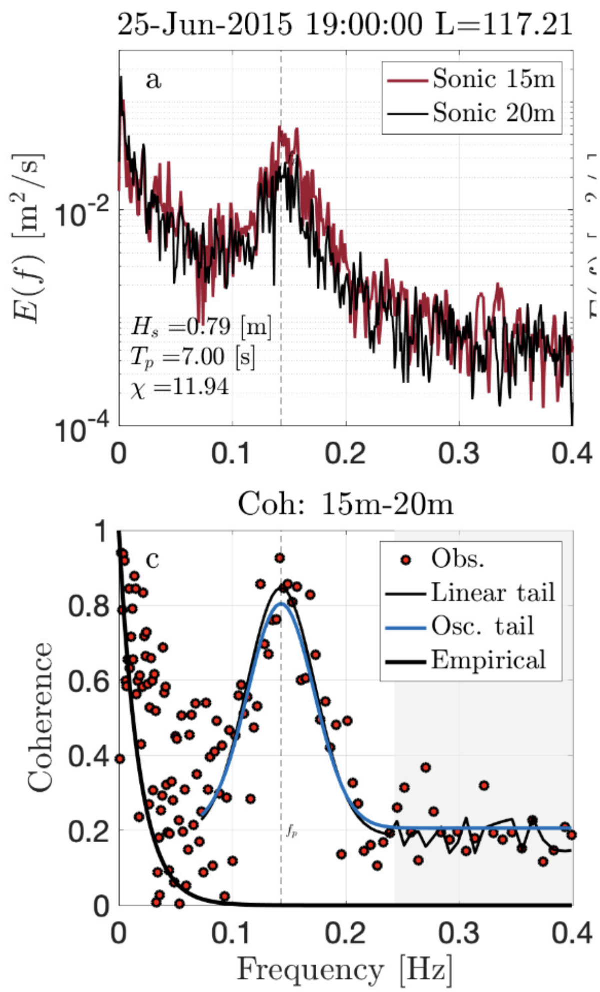

Figure 1. The observational and theoretical coherence representations for two sonic anemometers at 15m and 20m heights.

5. It is not easy to follow the connection between sections 2.1, 2.2, and 2.3. Please consider restructuring it.

Thank you for your suggestion regarding the restructuring of methodology section/subsections. I will improve and enhance the clarity and comprehensiveness of both the introduction and methodology sections of the paper.

In response to restructuring, I will undertake the following steps to address your comments:

Introduction section: I will restructure the introduction to provide a more comprehensive overview of the established methods for wave-turbulence decomposition. This will include references to the work by Hristov et al. (2003, 2014), the spectral method by Veron et al. (2008) and Grare et al. (2013), as well as the interpolation method outlined by Rieder and Smith (1998) and Högström et al. (2015). By enhancing this section, I will offer readers a stronger foundation for understanding the context of this research.

Methodology section: I will revise the methodology section to explicitly address the comparison between the proposed methods and the established approaches (I use specifically three wave-turbulence decomposition methods as explained in reply to comment 3). This comparison will be presented in a more structured and detailed manner, highlighting the consistency and agreement observed in the evaluations, by emphasizing on the robustness and efficiency of the suggested spectral method as a statistical physics-informed gap-filling technique.

Result section: I will correspondingly revise the result section by adding two new figures (Figure 1 is a sample plot).

I believe that these changes will significantly enhance the quality and clarity of the work.

6. For section 2.3: Eq. 11 is only valid for the surface. Thus, it should not have the dependent on z which is confused the readers.

   I agree and the text is enhanced by defining the wave boundary layer as the region where the non-static pressure distribution on the surface layer becomes apparent, with a height of impact corresponding to several significant wave heights (Hs). For medium waves, the typical WBL height is a few meters, while for larger waves, it can extend up to say 20 meters. The WBL interacts with the wave surface below and merges with the Monin-Obukhov stratified boundary layer above. Within the WBL, surface wave movements influence the structure, which is shaped by the specific characteristics of the wave field.

7. In the manuscript, you use many “we”. Since there is only one author, it should be “I” instead.

   Thank you for your feedback. The use of “we” in my manuscript is my impression that this is a common convention in academic writing, even when there is a single author. It can make the writing more formal and objective. However, I can certainly make the change to use “I” instead if it is the preferred style.

References:

[1] Bakhoday Paskyabi, Mostafa. A wavelet-entropy based segmentation of turbulence measurements from a moored shear probe near the wavy sea surface. *Springer Nature Applied Sciences* 2019.