Discussion: "LiDAR Measurements of Wind Shear Exponents and Turbulence Intensity Offshore the Northeast United States" (Viselli, A., Faessler, N., and Filippelli, M., 2022, ASME J. Offshore Mech. Arct. Eng., 144(4), p. 042001)

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*The work by Viselli et al. (Viselli, A., Faessler, N., and Filippelli, M., 2022, "LiDAR Measurements of Wind Shear Exponents and Turbulence Intensity Offshore the Northeast United States," ASME J. Offshore Mech. Arct. Eng., **144**(4), p. 042001) presents results on wind shear exponents and turbulence intensity obtained from the analysis of field data collected offshore the Northeast United States. This discussion is focused on the wind shear exponent that is obtained by combining the logarithmic mean wind speed profile and the power law mean wind speed profile, containing the sea surface roughness as a parameter. Here, the sea surface roughness is specified using three formulae given in terms of significant wave height and spectral wave steepness. The discussion points out how the sea surface roughness can be included in future applications of the authors' analysis method.*
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First, the discusser wishes to compliment the authors, Viselli et al. [1] (hereafter referred to as VFF22), on their results presenting wind speed shear exponents and turbulence intensity collected from their LiDAR measurements offshore the Northeast United States. This discussion focuses on the wind shear exponent and points out how the sea surface roughness given in terms of significant wave height and spectral wave steepness can be included in future applications of the authors' analysis method.

VFF22 used the sea surface parameter in the power law wind shear exponent α, where Eq. (3) in VFF22 should read as follows:

$$\alpha = \frac{ln\,[ln\,(z/z_0)/ln\,(H/z_0)]}{ln\,(z/H)} \tag{1}$$

where z is the height above the sea surface and positive upward with $z = 0$ at the sea surface, H is the reference height above the sea surface, and z_0 is the sea surface roughness. This equation is a result of combining the logarithmic mean wind speed profile and the power law mean wind speed profile (see VFF22 and DNV-RP-C205 [2] for more details).

The sea surface roughness is difficult to estimate; it depends on air–sea interaction mechanisms, which generally should cover the range from small to big waves including wind waves, swell waves, and combined wind waves and swell. Currently, no consistent theory exists covering this wide range of wave conditions. The pioneering work of Charnock [3] was based on a dimensional argument giving the sea surface roughness as $z_0 = \beta u_*^2/g$ with the original Charnock parameter $\beta = 0.012$, u_* is the friction velocity and g is the acceleration due to gravity. Then, other values of β as well as z_0-formulae have been suggested, also including the mean wind speed and the wave age as parameters: see, e.g., the studies by Jones and Toba [4] and Zhao and Li [5]. Zhao and Li [5] provided a review of the literature up to that date together with own analysis of both laboratory and field data investigating the influence of wind waves on wind stress in terms of the sea surface roughness and drag coefficient. As presented in the study by Powell et al. [6], they found that the drag coefficient reaches a peak for strong winds exceeding about 30–40 m/s. Zhao and Li [5] also suggested to estimate wind stress from low to high winds using a roughness formula in terms of the spectral wave steepness and the significant wave height (see subsequent discussion). Recently, Myrhaug [7] applied this formula to estimate the sea surface roughness based on wind and wave statistics. Other formulations of the sea surface roughness in terms of the spectral wave steepness and the significant wave height have been provided by, e.g., Taylor and Yelland [8] and Takagaki et al. [9] (see subsequent discussion). Myrhaug et al. [10] presented some statistical features of the sea surface roughness using the Taylor and Yelland [8] formula together with joint statistics of significant wave height and spectral wave steepness.

Here, the sea surface roughness is taken as follows:

$$\frac{z_0}{H_s} = c s_p^d \tag{2}$$

where H_s is the significant wave height, $s_p = H_s/((g/2\pi)T_p^2)$ is the spectral wave steepness, T_p is the spectral peak period, and c and d are dimensionless coefficients. Here, the three following (c, d) values are taken as proposed by Taylor and Yelland [8], Takagaki et al. [9], and Zhao and Li [5], respectively:

$$(c,\, d) = (1200,\, 4.5),\ TY01 \tag{3}$$

$$(c,\, d) = (10.94,\, 3.0),\ T12 \tag{4}$$

$$(c,\, d) = (2.79,\ 2.77),\ ZL19 \tag{5}$$

The Taylor and Yelland [8] formula was found to be the best to use for mixed wind sea and swell and for swell-dominant situations for which the spectral wave steepness exceeds 0.02 (but not good for swell-dominant conditions with the spectral wave steepness smaller than 0.02). This was concluded by Drennan et al. [11], resulting from performing a comprehensive intercomparison of different parameterizations of the sea surface roughness using field data from eight locations ranging from lakes (two locations in Lake Ontario) to deep water sea (six locations). The Takagaki et al. [9] formula was obtained as a best-fit curve to laboratory and field data for wind speeds ranging up to about 35 m/s and 70 m/s for field and laboratory data, respectively. The Zhao and Li [5] formula was a result of the comprehensive analysis of the influence of wind waves on wind stress based on both laboratory and field data. They also provided two other formulae in terms of spectral wave steepness and wave age, which shows less scatter than Eq. (5). They found, however, that z_0/H_s as a function of the spectral wave steepness is more suitable than the wave age, and that the relationship in Eq. (5) can be used to estimate wind stress covering low to high wind conditions. More details are provided in the respective references.

Now, the power law wind shear exponent α is calculated using $H = 40$ m and $z = 100$ m as in VFF22 and the three z_0 formulae in Eqs. (3)–(5).

First, results are exemplified using $H_s = 1.04$ m and $T_p = 9.5$ s, representing the average wave conditions during approximately 7 months. The data were collected by the offshore LiDAR buoy located offshore southwest of Monhegan Island, Maine, at a water depth of 95 m (see VFF22 for more details). These values of H_s

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and T_p give the spectral wave steepness $s_p = 0.0074$, which substituted in Eq. (2) using the coefficients in Eqs. (3)–(5) yields $z_0 = 3.2 \cdot 10^{-7}$ m (TY01), $4.6 \cdot 10^{-6}$ m (T12), and $3.6 \cdot 10^{-6}$ m (ZL19), respectively. Then, substitution in Eq. (1) with $z = 100$ m and $H = 40$ m yields $\alpha = 0.053$ (TY01), 0.061 (T12), and 0.060 (ZL19), respectively. It should be noted that this value of s_p is smaller than 0.02, i.e., it is not good for using the Taylor and Yelland formula in Eq. (3) as referred to. However, taking this as an example, it appears that both z_0 and α are largest for T12 followed by ZL19 and TY01, but there are small differences among the values of z_0 and α, which differs from the significant differences among the three pairs of values of c and d in Eqs. (3)–(5).

Second, results are compared with the APR RP 2MET [12] results given in Table 12 in VFF22 corresponding to a mean wind speed of 20 m/s at 10 m above the sea surface, i.e., $U_{10} = 20$ m/s, with $z_0 = 4 \cdot 10^{-4}$ m and $\alpha = 0.08$. Here, the results are estimated by using the Pierson–Moskowitz wave amplitude spectrum, which is valid for fully developed wind waves, for which $H_s = 0.0246 U_{10}^2$ and $T_p = 0.785\, U_{10}$ (see Ch. 5.5 in the study by Tucker and Pitt [13]). Thus, this gives $H_s = 9.84$ m, $T_p = 15.7$ s, and $s_p = 0.0256$ (i.e., s_p exceeds 0.02, which was the recommended range for the Taylor and Yelland formula in Eq. (5)). Substitution of this in Eq. (2) using the coefficients in Eqs. (3)–(5) yields $z_0 = 8.1 \cdot 10^{-4}$ m (TY01), $1.8 \cdot 10^{-3}$ m (T12), and $1.1 \cdot 10^{-3}$ m (ZL19), respectively. Then, substitution in Eq. (1) with $z = 100$ m and $H = 40$ m yields $\alpha = 0.089$ (TY01), 0.096 (T12), and 0.092 (ZL19), respectively. It appears that these values of z_0 are larger than $z_0 = 4 \cdot 10^{-4}$ m, and the values of α are larger than $\alpha = 0.08$. It is noted, however, that the results corresponding to the Taylor and Yelland formula yield the best agreement with $z_0 = 4 \cdot 10^{-4}$ m and $\alpha = 0.08$.

One should notice that the comparison with more data is required to obtain a firm conclusion regarding which sea surface roughness formula is the most appropriate to use. However, as suggested by Zhao and Li [5], the sea surface roughness in terms of the wave steepness and the significant wave height can be used in covering low to high wind conditions, which should be useful in future applications of the authors' analysis method.

Conflict of Interest

There are no conflicts of interest.

Data Availability Statement

No data, models, or code were generated or used for this paper.

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