Review of "From Shear to Veer: Theory, Statistics and Practical Applications"

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1 Overview

This paper is a very large body of work trying to connect the veer to shear for wind energy applications. This is very relevant for modern and next generation of turbines that will be very large and operating outside the surface layer of the atmospheric boundary layer (ABL). The first part of this paper is highly theoretical followed by comparisons to RANS simulations of the ABL. The latter part of this paper analyzes the experimental data from several wind farms and tries to connect the shear and veer based on the derivations in the theoretical sections. This is very good work and deserves to be published. However, I feel that there's likely a major flaw in Equation 14 that is the basis for Equations 38 and 39 that connect to the theme and the title of the paper. This is outlined in further detail in the next section under "Page 7, Line 165". If the authors could address this and the other specific comments in the next section, this paper should be published and would prove a great addition to the literature.

2 Specific comments

Page 4, Line 88 What is the purpose of Section 2.1.1? I'm not sure where this discussion is used in the rest of the paper. Also, since this paper considers non-zero veer, the balance of terms in the turbulent kinetic energy equation will be

$$\frac{\mathrm{d}e}{\mathrm{d}t} = 0 = -\langle uw \rangle \frac{\mathrm{d}U}{\mathrm{d}z} - \langle vw \rangle \frac{\mathrm{d}V}{\mathrm{d}z} + B + T - \epsilon.$$

Since $\mathrm{d}U/\mathrm{d}z \neq \mathrm{d}|S|/\mathrm{d}z$, I think the expression in Equation 4 of the manuscript will no longer hold.

Page 5, Line 132 I'm not sure of the purpose of the expressions with the complex math as they're not used further in the manuscript. However,

$$d\varphi = \frac{U\,\mathrm{d}V - V\,\mathrm{d}U}{|S|^2} = -i\frac{S^*\mathrm{d}S - S\mathrm{d}S^*}{2|S|^2},$$

where the manuscript uses i instead of $-i$ in the second term.

Page 7, Line 165 The derivative of Equation 13 is taken here after the evaluation at the height of interest to arrive at Equation 14. I don't think this is correct. If you followed the math described at the top of Page 7, it will instead be

$$
\begin{aligned}
\gamma &= \cos^{-1}\left[\frac{|S|}{|G|} + \frac{1}{f|S||G|}\left(U\frac{\partial\langle vw\rangle}{\partial z} - V\frac{\partial\langle uw\rangle}{\partial z}\right)\right], \\
\frac{\partial\gamma}{\partial z} &= \left(-\frac{|S|\alpha}{|G|z} - \left(U\frac{\partial\langle vw\rangle}{\partial z} - V\frac{\partial\langle uw\rangle}{\partial z}\right)\frac{1}{f|S||G|}\frac{\alpha}{z}\right. \\
&\qquad \left. - \frac{1}{f|S||G|}\left(\frac{\partial U}{\partial z}\frac{\partial\langle vw\rangle}{\partial z} - \frac{\partial V}{\partial z}\frac{\partial\langle uw\rangle}{\partial z} + U\frac{\partial^2\langle vw\rangle}{\partial z^2} - V\frac{\partial^2\langle uw\rangle}{\partial z^2}\right)\right) \\
&\qquad \left[1 - \left(\frac{1}{f|G|}\frac{\partial\langle vw\rangle\perp}{\partial z} + \frac{|S|}{|G|}\right)^2\right]^{-1/2}, \\
&= \left(-\frac{|S|\alpha}{|G|z} - \frac{\alpha}{f|G|z}\frac{\partial\langle vw\rangle\perp}{\partial z} - \frac{1}{f|S||G|}\left(\frac{\partial U}{\partial z}\frac{\partial\langle vw\rangle}{\partial z} - \frac{\partial V}{\partial z}\frac{\partial\langle uw\rangle}{\partial z} + U\frac{\partial^2\langle vw\rangle}{\partial z^2}\right)\right) \\
&\qquad \left[1 - \left(\frac{1}{f|G|}\frac{\partial\langle vw\rangle\perp}{\partial z} + \frac{|S|}{|G|}\right)^2\right]^{-1/2}.
\end{aligned}
$$

Out of the 5 terms in the numerator of the last expression, you only have terms 1 and 5 in Equation 15. I'm not sure how the terms 2, 3 and 4 are eliminated. Could you please explain/describe the math here.

Also, what is the connection to Equation 10 of the manuscript here. That appears to be far simpler, albeit lacking any shear exponent!

Page 10, Line 255 Typo in "moreso"? Should be "more so"?

Page 12, Line 294 The velocity profiles based on the shear exponent and the log-law are

$$
\begin{aligned}
|S| &= |S|_{\text{ref}}\left(\frac{z}{z_{\text{ref}}}\right)^{\alpha}, \text{ and} \\
|S| &= \frac{u_*}{\kappa}\ln\left(\frac{z}{z_0}\right)
\end{aligned}
$$

respectively. There is quite a bit of discussion on Page 3 Lines 80-87 describing the invalidity of the log-law above the surface layer and how the shear exponent is better suited for wind energy applications. How do you explain using the log law expression again, especially without the corrections for stability as in M-O law?

Page 12, Lines 296-302 The estimate for the first vertical derivative of the Reynolds stresses seems reasonable as $\partial\langle uw\rangle/\partial z \approx u_*^2/h$, although the sign is likely negative. However, the estimate for the second derivative is not very clear. In addition, considering the mean momentum equation from Equation 7,

$$
\begin{aligned}
\frac{\partial\langle vw\rangle}{\partial z} &= -f(U - U_G), \\
\frac{\partial^2\langle vw\rangle}{\partial z^2} &= -f\frac{\partial U}{\partial z} = -f\alpha\frac{U}{z}.
\end{aligned}
$$

This tells me the sign of this constant c_{vw} must be negative. This might make the numerator of Equation 14 almost zero, suggesting other terms are dominating as expressed in my concerns for Page 7, Line 165. Could you please expand the explanation for your estimate of the second derivative of the stresses?

Page 12, Line 306 Based on the expressions in Equation 31, I got this to be

$$
\sin\varphi_G = \frac{-c_G}{\kappa}\left\{B\cos\varphi_0 - \left[\ln\frac{u_*}{fz_0} - A\right]\sin\varphi_0\right\}. \tag{1}
$$

The multiplication of B by $\cos\varphi_0$ is missing. Could you please check again.

Page 12, Line 315 A summary of the expressions to be evaluated after substitutions listed in Section 2.4 would be extremely helpful before evaluating them in Section 3.1.

Page 14, Line 355 A more thorough overview of how the RANS simulations covers the space of interest would be helpful here.

Page 14, Line 358 How does the expression in Equation 14 compare to Equation 9 in the right plot in Figure 2? Based on my concerns expressed for Page 7, Line 165, I expect the correlation to be not as good as for Equation 9.

Page 15, Line 374 Behavior that is "not inconsistent"? Do you mean consistent? There is no expression derived in Section 2 that gives $Ro_h^1.4$. This is also likely affected by concerns for Page 7, Line 165.

Page 26, Line 583 and Page 28, Line 609 This simplification in Equations 38 and 39 are likely in error. Could you please check my concerns for Page 7, Line 165 before confirming these results.

Page 29, Figure 16 The standard deviation of the veer is almost the same or much larger than the mean from the experiments. It would be hard to consider this as proof of the expressions derived in Equations 38 and 39.