Comments on "The fence experiment – full-scale lidar-based shelter observations" by Alfredo Peña, Andreas Bechmann, Davide Conti, and Nikolas Angelou.

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As the authors comment, there are relatively few field data on wakes behind fences or indeed behind other surface mounted obstacles, and the study reported by Peña et al (2016) is a valuable addition. They could however have noted the study by Wilson (2004) of flow behind a windbreak of porosity 0.45. One advantage of Wilson's study was a high aspect ratio (fence length (L)/fence height(h)) of 91.2 compared to only 10 in the Peña et al case. In order to consider the flow as approximately 2D for comparison with the Counihan et al (1974) theory it would be desirable to have a much longer fence section. The measurements are relatively close to the fence (x/h <11 or x/L < 1.1) but pressure effects act in an isotropic manner and one might expect some departure from two dimensional behaviour.

The experimental situation is also complicated by the water to land roughness transition at the coastline about 78 m away from the fence. Checking Google Earth (my version of which still shows the fence in place) indicates virtually no step change of elevation at the waters edge. This is good, but there will be some impact from the roughness and possible heat flux changes within the internal boundary layer. The effective roughness lengths listed in Table 4, computed from friction velocity and wind speed measurements via Equations 1 and 2, are mostly of order 0.002 m. There is an error in Equn 2 (exponent 1/2 should be 1/4), which I assume is typographical, but the roughness lengths are lower than normally expected values for a grass covered surface (~0.01m). The flow at the measurement heights 6m and 12m will not have fully adjusted to the land surface change by the time it reaches the fence where the internal boundary layer depth in neutral conditions for flow normal to the shoreline would be ~8m from simple guidelines, Walmsley et al (1989). Certainly the shear stresses at measurement heights will be low - more characteristic of the over water conditions - and lead to the computation of relatively low z_0 values. Impacts on speed-up factors may however be small.

The triple Doppler lidar windscanner approach is an excellent remote sensing addition to in-situ measurements with cups or sonics but there are limitations in terms of sampling volume and turbulence measurements. The flow being measured in this instance would be fully accessible with masts and sonics and these could have provided an alternative or supplementary measurement technique. The direct application to wind turbine siting is rather limited since the measurements are restricted in height (z/h < 3) and downwind extent (x/h < 11). Additional turbulence measurements would have been useful for considerations of potential wear or breakdown for small wind turbines.

A minor suggestion related to Equations (10) and (11) would be that $<ln(z_0)>$ might be a better option than $ln<z_0>$.

The WEMOD and WASP-Shelter models are discussed with the comment that they are based on Counihan et al (1974) and 2-D models. While that is true in part there is also careful consideration of wakes behing surface mounted 3D obstacles in Taylor and Salmon's (1993) WEMOD model and 3D effects may play a role in the present study. A major uncertainty in applications of WEMOD is the estimated value used for the parameters C_h and $C_h$tilde based on the drag and couple on the object. For an infinite 2D fence WEMOD suggests that $C_h$tilde = 0.8 (1-φ) where φ is the porosity (= 0 for the solid fence). However for a finite length fence section there is a suggestion that the coefficient (0.8) should be reduced (0.2 - 0.4) for "long low buidings". We have run both cases (0.8 and 0.4) for the10h length fence and for all flow directions.

Running WEMOD for the Peña et al solid fence and with z/h = 0.46 we get "speed-up" results, $U(x,z)/U_0(z)$, shown in Table I. The Peña et al results were extracted from Figure 9 of their paper, estimating values appropriate to cases I and II for flow normal to the fence, cases III and IV for flow at + 30º and -30º to normal (ignoring the slight asymmetry in the set-up) and case IV for flow at -60º to normal. WEMOD results are averages of calculations at 1º intervals within +/- 15º of the nominal direction. We set z_0 = 0.002m as a representative value. WEMOD is a "far wake" model, intended primarily for x/h>6 but even that range can be optimistic for a solid 2D fence. Comparing estimates with $C_h$tilde = 0.8 with the Peña et al measurements at z/h = 0.46 it is clear that the WEMOD model overestimates the wind speed reductions at all x locations while with $C_h$tilde = 0.4 it generally underestimates them until x/h = 10 where, perhaps fortuitously, they match for all flow direction bins.

The data set for a porous fence (φ = 0.375) is for flow at an angle of -30º to the normal to the fence (Case VII). At z/h = 0.46 we estimate the "speed-up" from Figure 9 in Peña et al to be 0.75 at x/h -= 10 and 0.45 at x/h = 6. The WEMOD model predicts less sheltering, even with $C_h$tilde = 0.8, averaged over +/- 15º for this flow direction (from 30º to left of the upwind normal to the fence) and has corresponding speed-up values of 0.89 and 0.63.

In contrast to these examples of poor results from WEMOD, Table II presents comparisons with the measurements reported by Wilson (2003). As with Table I there is averaging of WEMOD calculations over 1º values within +/-15º of the wind directions indicated. There are sometimes a range of values extracted from Wilson's plots because of stability differences and the values in the table are intended to span neutral conditions. In general WEMOD values (with $C_h$tilde = 0.8(1-φ) since the Wilson fence has L/h = 91.2 and we are looking at distances x/h < 20) are within or close to the range reported by Wilson. An exception is for x/h = 4 with flow normal and at 30º to the upwind normal to the fence but this is close to the fence and not in the far wake for which WEMOD application is anticipated.

There are differences between the plastic windbreak fencing used by Wilson and the porous wooden structure used in the Peña et al study, and in the different lengths of the two fences but porosities were similar. A comparison of speed-up values for three flow directions (normal, +/- 30º, +/-60º) at x/h = 10, z/h ≈ 0.5 shows 0.73, 0.78, 0.89 with porosity 0.45 from Wilson and 0.75, 0.9, 1.0 with porosity 0.375 from Peña et al. For flow normal to the fence these are compatible but for 30º and 60º angles the relatively short fence in the Peña et al study may allow flow around the ends which increases the speed-up.

In the near wake region there is relatively strong reverse flow (u < 0) but it is not clear to what extent the wind speed change is affected by the v component, especially for flow at 60º to the fence normal (Case IV, Fig 9, z/h = 0.21) where it appears that a vortex parallel to the fence may exist. Separate plots of u and v components, perhaps normalised by $U_0(h)$, in addition to Figure 9 could provide additional information.

p14 I am puzzled by the $<\sim>_{ws}$ combination since (p10) the ~ symbol appears to indcate a sonic measurement over a time interval corresponding to a full WS scan. Also I assume U(z) should be U(x,z) in this context.

References

Counihan, J., Hunt, J. C. R., and Jackson, P. S., 1974, Wakes behind two-dimensional surface obstacles in turbulent boundary layers, J. Fluid Mech., 64, 529–563.

Peña, A., Bechmann, A., Conti, D. and Angelou, N., 2016, The fence experiment – full-scale lidar-based shelter observations, Wind Energ. Sci. Discuss., doi:10.5194/wes-2016-8

Taylor, P.A. and Salmon, J.R., 1993, A model for the correction of surface wind data for sheltering by upwind obstacles, J. Appl. Meteorol., 32, 1683–1694

Walmsley, J.L., Taylor, P.A. and Salmon, J.R., 1989: Simple Guidelines for Estimating Wind Speed Variations due to Small-Scale Topographic Features - An Update, Climatological Bulletin, 23(1), 3-14.

Wilson. J, 2004, Oblique, Stratified Winds about a Shelter Fence. Part I: Measurements, J. Appl. Meteorol., 43, 1149-1167.

Table I SHELCOR Comparisons with Peña et al (2016) measurements; Short fence; z/h = 0.46; z_0 = 0.002m; h = 3m; Porosity 0.

		Peña et al Obs			SHELCOR 0.8			SHELCOR 0.4		
x(m)	x/h	0º	30º	60º	0º	30º	60º	0º	30º	60º
12	4	-0.30	0.20	1.10	-0.37	-0.13	0.75	0.32	0.44	0.87
18	6	0.30	0.80	1.00	0.09	0.38	0.96	0.54	0.69	0.98
24	8	0.60	0.87	1.00	0.34	0.66	0.99	0.67	0.83	1.00
30	10	0.75	0.90	1.00	0.50	0.81	1.00	0.75	0.90	1.00

Table II SHELCOR Comparisons with Wilson (2003) measurements; Long fence; z/h = 0.50; z_0 = 0.019m; h - 1.25m; Porosity 0.45.

		Wilson Obs			SHELCOR 0.8(1-φ)		
x(m)	x/h	0º	30º	60º	0º	30º	60º
5	4	0.44-0.52	0.50	0.63-0.67	0.19	0.30	0.63
7.5	6	0.46-0.58	0.60	0.75-0.79	0.49	0.57	0.78
12.5	10	0.64-0.74	0.73	0.84-0.87	0.73	0.78	0.89
18.75	15	0.80-0.86	0.83	0.91-0.93	0.84	0.87	0.91
26	20	0.87-0.94	0.88	0.90-0.92	0.89	0.91	0.96