Reply to comment by Cristina Archer and Mark Jacobson on "Evaluation of a wind power parameterization using tower observations"

Steven Lazarus[1] and Jennifer Bewley[1]

Received 21 June 2005; revised 21 December 2005; accepted 25 January 2006; published 24 May 2006.

Citation: Lazarus, S., and J. Bewley (2006), Reply to comment by Cristina Archer and Mark Jacobson on ''Evaluation of a wind power parameterization using tower observations,'' *J. Geophys. Res.*, *111*, D10104, doi:10.1029/2005JD006396.

1. Introduction

[1] The *Lazarus and Bewley* [2005] (hereinafter referred to as LB05) evaluation of the *Archer and Jacobson* [2003] (hereinafter referred to as AJ03) methodology was designed to examine various sensitivities of a wind power parameterization that was applied globally to estimate 80-m wind power. AJ03 has since been updated in a sequence of papers which has, in part, resulted in a reduction of their original power estimates due to some changes in their basic equations. The motivation for the LB05 work can be found in AJ03's Figure 3 which indicates annual wind power estimates of class 6 and 7 effectively collocated with class 1 and 2 along the Florida east coast. Note that there were several relevant findings associated with our detailed analysis of the AJ03 parameterization (as we applied it), which are clearly stated in the conclusions of LB05. (Figure 1).

2. Method

[2] 1. We agree with *Archer and Jacobson* [2006] (hereinafter referred to as AJ) that it is indeed difficult, even when desirable, to replicate all aspects of a given study. The work presented by LB05 reflects an effort to examine various sensitivities and assumptions of the AJ03 parameterization. As such, great care was taken to emulate, when possible, the method presented by AJ03 which includes both quality control measures and experimental design. The specific nature of these issues is discussed in more detail below.

[3] 2. LB05 was first submitted in April 2004, well in advance of *Archer and Jacobson* [2005] (hereinafter referred to as AJ05) and the latest of their modifications such as the ''forced power law.'' LB05 reflects all of the significant corrections in the AJ03 equations.

[4] 3. There are four towers with redundant sensors in the KSC network. Tower 313 does have multiple sensors (3131 and 3132) mounted on the northeast and southwest sides, respectively. The other three towers, with redundant sensors (towers 2, 36, and 110), do not have data that extends above 62 m. Because of this, and our desire to evaluate the AJ03 80-m wind estimates, we purposely chose to use data from tower 313 only.

[5] The 90-m data from tower 3131 was paired with 9-m data from towers 511, 512, and 513 independently (i.e., data from 511, 512, and 513 were never combined during the pairing). The independent pairings were meant to illustrate that the results were consistent among towers, which they were.

[6] LB agree that it was unnecessary to combine data from tower 3131 and tower 511, prior to the least squares fit. However, it should be fairly evident in LB05 Figure 10 that a fit using a reference height (z_r) of either 4 m or 16 m for tower 3131 would essentially yield the same results. The same issues and sensitivities (as discussed by LB05) manifest themselves in either scenario. To illustrate this point, we show an analog to the LB05 Figure 11 but instead use z_r = 4 m and remove the 10-m winds from tower 511. Note that while we now use a 4-m reference height for the 0000 UTC fit, we continue to use the daily averaged 10-m wind (from tower 511) as the AJ03 input as it is the latter that AJ03 use globally to produce their Figure 3. In LB05 the tower winds are the sonde surrogate, while the 10-m winds, obtained from the nearby tower 511, are likely more representative than the AJ03 methodology in which surface stations are paired with upper air data that is as much as 200–300 km away.

[7] The use of different sensors does not invalidate a study. There are small differences in the manufacturer specifications of accuracy for the two instruments (R.M. Young 5305-18/AQ and Met One TG1564D); however, as discussed by LB05, the 7-year KSC tower wind data had undergone a fairly rigorous quality control regimen. Furthermore, it is common to integrate and/or assimilate observations from multiple platforms as was done by AJ03 (i.e., sonde and surface data). While in the context of data assimilation observation errors are directly taken into account, this is not the case for AJ03 as both the least squares fit and inverse square interpolation assumes perfect observations. One could compare the residuals from the LS fit for the various towers (with different instruments) in an attempt to estimate the relative errors.

[8] 4. Figure 7 is an evaluation of the AJ03 temporal (not LS/spatial) methodology. In light of this, LB05 attempt to apply a method analogous to that used by AJ03 to calculate

[1]Department of Marine and Environmental Systems, Florida Institute of Technology, Melbourne, Florida, USA.

0148-0227/06/2005JD006396

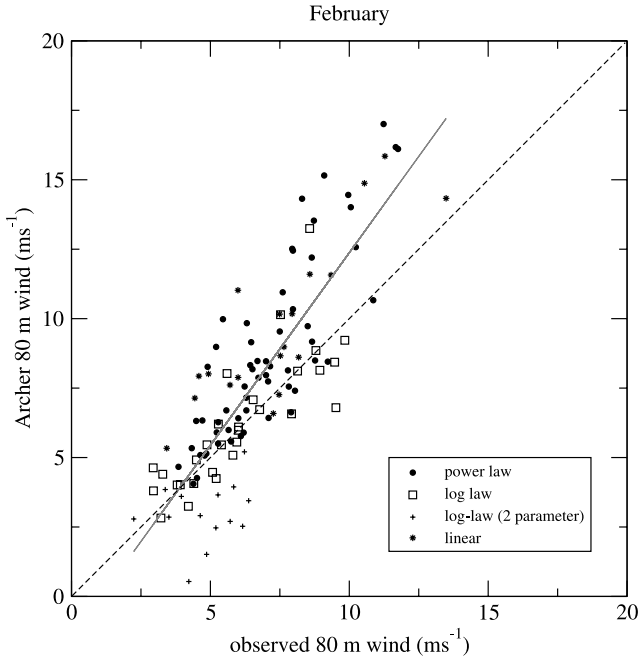

Figure 1. Observed versus AJ04 80-m LS winds for 1995–2001 February 0000 UTC profiles. Symbols represent lowest residual producing method: power law (circles), log law (squares), two-parameter log law (pluses), and linear (asterisks).

their amplitude but instead use the 0000 and 1200 UTC tower data in lieu of sonde data. While we agree with AJ concerning the fickle nature of a value of ρ estimated from 5-min average winds, our application of the tower data in this fashion was meant to emulate their procedure whereby the hourly trend in the 80-m wind is estimated using the LS extrapolated values of ρ at 0000 and 1200 UTC. Indeed, an alternative would have been to use a longer time average for the 10-m wind, but this would have been somewhat inconsistent with the 80-m wind that AJ03 use to estimate ρ_{00} and ρ_{12} which is only available at the sonde times (and is thus not an hourly average). LB05 does not attempt to address what the appropriate scale (i.e., averaging period) is for the 10-m wind in this case. However, for the case shown by LB05's Figure 7a (and Figure 7b), taking an hourly average does not change our results with respect to the potentially problematic nature of assigning a negative amplitude (for example, Figure 7a $\overline{\rho}_{12}(\sim 2.27) < \overline{\rho}_{00}(\sim 2.66)$, where in this case the overbar denotes an hourly average.) However, we do show that a negative amplitude may lead to a large overestimate of the actual power, even with an extended averaging period for the input 10-m wind (LB05's Figure 9).

3. Accuracy

[9] 1. Because LB05 focused on various detailed aspects of the AJ03 parameterization (e.g., isolation of the daily AJ03 80-m wind estimates for 0000 and 1200 UTC tower profiles, identification of the lowest producing residual method, daily estimates of A, etc.) we deliberately tried to avoid averaging our findings over an extended period (e.g., a year). The results shown in AJ05's Figures 1 and 2 are not likely substantially different from our results. However, to fully appreciate the application of the AJ03 parameterization, we feel that it was important to present as much in the way of detail as possible, especially at a location where the estimate can be directly verified. Had we also not stratified our results by day, month, sounding time, etc., our results may have indeed been quite similar. It is also worth pointing out that AJ05's Figure 1 is an LS estimate of the 54 m wind, not 80 m (a result of using multiple towers none of which extend above 54 m with the exception of tower 313).

[10] 2. The data from LB05 Table 2 were provided (via e-mail) by C. Archer between paper updates. However, the latest AJ power estimates for the region continue to show both power class 6 and 7 along the Florida east coast (http://www.stanford.edu/group/efmh/winds/us_winds.html).

4. Objectivity

[11] LB05 recognize a number of favorable aspects of the AJ03 work including their estimate of $\overline{\rho}$, the relative success of the 12 UTC fit and clearly acknowledge in the conclusions the months in which the AJ parameterization performs well. As stated previously LB05 avoided, as much as possible, long-term averaging (e.g., yearly composites), preferring instead to focus on the day-to-day (and monthly) variations in the parameterization inputs and output. Regardless, there are "positive" results in the LB05 manuscript, including aspects of Figures 4, 5, and Figure 11 and Tables 4, 5, and 6, the latter of which, in part, indicates why AJ03 (as applied by LB05) performed well for some months and not well for others. Nonetheless, detailed statistics are shown for all months, are not presented exclusively for any 1 month, and nothing is hidden from the reader. Furthermore, the winter months are the only potentially interesting months in terms of nominal (i.e., possibly low-end commercial) wind energy in Florida and thus demonstrate the greatest variability with respect to the AJ03 methodology.

5. Summary

[12] A thorough examination of a parameterization and its potential biases is both very relevant and important. There are numerous examples in the meteorological literature that address the global application issue. (For example, GCMs often parameterize their subgrid-scale stratiform clouds based on a simple relative humidity relationship whereby the creation/removal of the subgrid stratus are governed by an arbitrary relative humidity threshold that is often assumed to be the same everywhere, despite observational evidence otherwise.). Regardless, AJ continue to show fast wind speeds (power class 6 or greater) both on and offshore of the Florida east coast (see http://www.stanford.edu/group/efmh/winds/us_winds.html). LB05 believe the relevant question to be whether or not we are looking at real variability in the 80-m wind estimates presented in AJ03 and AJ04 or some artifact of the parameterization. One can essentially ask the reverse question, i.e., what would the 10-m wind be, given an 80-m wind (an issue that obviously depends on surface roughness, stability, etc.).

Ultimately, it might be interesting (and instructive) to present a follow-up study that illustrates, in more detail, the true AJ method as it applies to the nearly collocated but disparate power classes along the Florida east coast.

References

Archer, C. L., and M. Z. Jacobson (2003), Spatial and temporal distributions of U.S. winds and wind power at 80 m derived from measurements, *J. Geophys. Res.*, *108*(D9), 4289, doi:10.1029/2002JD002076. (Correction to "Spatial and temporal distributions of U.S. winds and wind power at 80 m derived from measurements," *J. Geophys. Res.*, *109*, D20116, doi:10.1029/2004JD005099, 2004.).

Archer, C. L., and M. Z. Jacobson (2005), Evaluation of global wind power, *J. Geophys. Res.*, *110*, D12110, doi:10.1029/2004JD005462.

Archer, C., and M. Z. Jacobson (2006), Comment on "Evaluation of a wind power parameterization using tower observations" by Steven M. Lazarus and Jennifer Bewley, *J. Geophys. Res.*, doi:10.1029/2005JD006098, in press.

Lazarus, S. M., and J. Bewley (2005), Evaluation of a wind power parameterization using tower observations, *J. Geophys. Res.*, *110*, D07102, doi:10.1029/2004JD005614.

J. Bewley and S. M. Lazarus, Department of Marine and Environmental Systems, Florida Institute of Technology, 150 West University Boulevard, Melbourne, FL 32901, USA. (slazarus@fit.edu)