RAM Matrix/Lag-1 Hybrid Wind Speed Data Estimation

Jack Kline
RAM Associates

November 13, 2009

The technique used to estimate missing hourly wind speed data is an expansion of what is commonly referred to as the "matrix method" of wind speed estimation, which has been used by some analysts to estimate wind speeds at one site using data at another. The matrix method begins with the analysis of the wind speed frequency distributions at the target site "B" (the one to be estimated) as a function of the mean wind speeds at the reference site "A" (the one used to make the estimates) in 30-1 m/s wind speed bins for each site. The analysis produces a set of normalized wind speed frequency distributions of site B WS for each of the 1 m/s bins at site A, and the sum of the frequencies in each bin of site A WS is equal to 1.0.

During the estimation process, a random number between 0 and 1 is generated and the random number is taken as a cumulative probability of occurrence of the wind speed at site B in the wind speed bin at site A, as determined by the wind speed is at site A during the hour. The wind speed at site B is estimated by summing the probabilities of occurrence of site B WS associated with the wind speed bin at site A, starting in the 1 m/s wind speed bin. Once the sum of the probabilities exceeds the random number the summing stops and the estimated wind speed at site B is determined to be in the 1 m/s wind speed bin at which the cumulative frequency exceeded the random number.

For example, say the hourly mean speed at site A is 9.7 m/s. This would be in the 10 m/s bin (9.5 m/s <= WS < 10.5 m/s) for site A. Then a random number, say 0.625, is generated. Starting with the 1 m/s bin for site B in the column of 10 m/s frequencies at site A, the probabilities are added and after summing, say the first 10 bins of site B frequency the cumulative frequency is 0.610 and then adding the frequency in the 11 m/s bin the cumulative frequency is 0.700, which exceeds the random number, so the wind speed at site B is determined on this occasion to be in the 11 m/s bin (10.5 m/s <= WS < 11.5 m/s). The exact speed estimate at site B is calculated as the minimum wind speed for the bin (10.5 m/s) plus a portion of the 1 m/s bin width represented by the difference between the random number and the sum of the probabilities through the previous bin divided by the frequency of the current bin. In this example, the cumulative probability through the 10 m/s bin was 0.610 and the probability in the 11 m/s bin was 0.090. The random number was 0.625 so the final wind speed estimate at site B = 10.5 m/s (the minimum WS in the 11 m/s bin) + (0.625 – 0.610)/0.090 = 10.67 m/s.

The matrix method is the first part of the wind estimation model. The second is similar to the matrix method, but the matrix is in this case constructed only from the data at site B (the target site) and uses the wind speed in the current hour as the reference and the wind speed in the next hour (lag-1) as the target. As in the matrix method, wind speed frequency distributions are analyzed in 30-1 m/s bins based on the site B hourly wind speed, but the frequencies represent the probability of the wind speed in the next hour based on the current hour's wind speed. A similar estimation process is followed, using a second random number and the previous hour's estimated wind speed at site B. This produces another estimate of the wind speed at site B, but based not on the wind speed at site A, but the wind speed at site B in the previous hour.

A third estimate of the wind speed at site B is calculated by the application of a simple diurnal wind speed ratio of site B/site A, and the wind speed at site A in the current hour that is being estimated. The diurnal ratios are calculated from the 24-hourly mean wind speeds at the two sites, using only hours when both sites have data to develop the 24 average wind speeds at each site. This estimation method was included to help maintain the mean diurnal wind speed characteristics at site B.

As a secondary factor to force the diurnal shape of the estimated data to conform to the observed diurnal pattern at the target site, a final normalized diurnal ratio (the average of all = 1.0) is applied to the estimated data. This final shaping does not alter the mean speed of the data set but helps to insure a more accurate diurnal wind speed pattern.

In summary, during the period of concurrent data, the wind speeds at the two sites are analyzed, producing two matrices of 30-1 m/s x 1 m/s wind speed frequency distributions; one of which relates the probability of occurrence of site B wind speed to site A wind speed for concurrent hours, the other is the lag-1 frequency distributions at site B, and 24-hourly mean wind speeds at sites A and B, from which 24-hourly wind speed ratios are calculated. Each of these is used to produce an estimate of the wind speed at site B based on the current wind speed at site A (for the matrix and diurnal ratio methods) or the previous hour's estimated WS at site B for the lag-1 method. The three estimates are averaged, using weighting factors that are entered at run time to produce the final estimate. In many cases the weighting factors are all equal to 1, although when estimating higher-level data from low-level data (i.e. estimating the 50 m or 60 m level at a project met tower site from 10 m data at an ASOS site) the diurnal wind speed weighting factor is increased to a value of 2. This has been found to be necessary due to the variance in mean diurnal wind speeds observed at low-level and higher-level measurements.

Comparisons of estimated to observed data show a high level of agreement. This technique has been tested at numerous sites and has proven to be quite effective in estimating wind speeds, particularly for mean speed estimates.

55 Cloverleaf Circle
Brentwood, CA 94513

Ph. 925-240-7855
Fx. 925-240-7881