Flow curvature bias remains the leading impendence to widespread adoption of remote sensing for wind resource assessment in complex terrain. Previous studies have shown that the flow pattern can be predicted with CFD modeling, yielding a correction to compensate for the flow-induced bias in horizontal wind speed measurements\(^1\). This paper demonstrates a systematic approach to correcting this bias and introduces a new method for assessing uncertainty in the computed corrections.

Twenty sites were selected, spanning a wide range of terrain complexity, and with concurrent remote sensor / tower data. The windSim CFD modeling software was used to predict 3D wind flow at the lower location and in the vicinity of the remote sensing device (RSD). Model results were analyzed to predict flow curvature above the remote sensor, and from the curvature, compute RSD bias as a function of wind direction and measurement height. The mean wind-speed site-calibration between the RSD and tower was also computed from the model results and applied to the data, so the remaining discrepancy in the measured data could be compared to the predicted RSD bias.

### Methods

#### CFD Simulations

WindSim CFD model computes flow curvature information by solving the Reynolds-averaged Navier-Stokes Equations for 3D wind directions. The wind flow is represented as 3D velocity vectors for each grid point around and above the RSD. The innermost, highest resolution part of the grid is 400 m x 400 m. It has a grid spacing of 5 m in the horizontal plane, and is centered on the RSD location. In the height dimension, the lower part of the grid (comprising the measurement height range of the remote sensor) has 20 m vertical grid spacing.

### Results

#### Bias by Direction

The following example shows the comparison predicted and measured biases from one site in the study. Plots show site calibration, flow curvature bias, and the total bias, as predicted by the CFD-based method. These are compared to the observed differences, expressed as a percentage, between the Triton and met tower measurements for all anemometer heights, and for all wind direction sectors with sufficient data (minimum 60 data points per wind direction bias).

### Conclusions

On a site-by-site basis, the CFD-predicted bias combining both flow curvature and site calibration effects generally captured the correct sign of the observed difference between the Triton and met-measured wind speeds. It captured the magnitude in most cases. Capturing the pattern of the bias with wind direction was more challenging, although in some cases was captured very well. Unfortunately, the site calibration and flow curvature biases cannot be separated in the comparison data. The CFD methodology was used to compute both correction biases, and the results we see reflect the combined improvement. It is not possible to evaluate the improvement from flow curvature bias by itself.

Overall, application of the correction factors [by height and direction] to the time series of Triton-measured winds resulted in an improvement in bias across all measurement pairs, from ~0% to ~0.1%. The root mean square, across all 57 Triton met/tower pairs, of mean wind speed difference, was reduced from 3.2% to 2.3%. These results indicate that correction factors derived from a relatively simply configured CFD model can significantly reduce the flow-induced errors inherent in wind speed measurements from divergent beam-based remote sensing devices. The uncertainty metric provides an indication of how site specific flow curvature limits accuracy in the computed corrections.

### References


