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Towards 100% Availability of Wind Measurements

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Abstract

Real-world wind measurements are subjected to some degree of system, environmental, and campaign unpredictability that often manifests as gaps in what would ideally be continuous datasets. Although remote sensors have gained prominence in their utility for wind resource assessment campaigns through supplementation or replacement of traditional meteorological masts, they are not without limitations. One of the main sources of missing data from remote sensors is related to challenging environmental conditions, such as those featuring limited aerosol availability, fog, or periods of intense precipitation – all of which have the potential to impact data availability from Sodar and Lidar-derived observations. In collaboration with Vortex, NRG Systems has explored a unique solution to augment remotely sensed data from direct-detect Lidar with that from a large eddy simulation (LES). The goal of our approach is to identify time periods of measurement uncertainty resulting from challenging environmental conditions or system downtime and reduce said uncertainty through synthesis of Lidar and LES data. Additionally, this investigation has the ability to build a broader foundation for observational network-model interaction to deepen our capacity for more informative insights for wind resource assessment.

Objectives

The goal of this investigation is to introduce the potential utility of GapFill and demonstrate how this product is poised to:

1. Increase project data availability

2. Evaluate whether data gaps are impacting campaign results and enable deployment strategy optimization

Methods

Vortex GapFill **1. ingests in-situ lidar observations** which it uses to correct LES wind distribution at each hour and subsequently evaluate persistency of LES performance as a time series. **2. A calibrated Vortex LES time series is generated** which is used to fill the gaps in the original observational data.

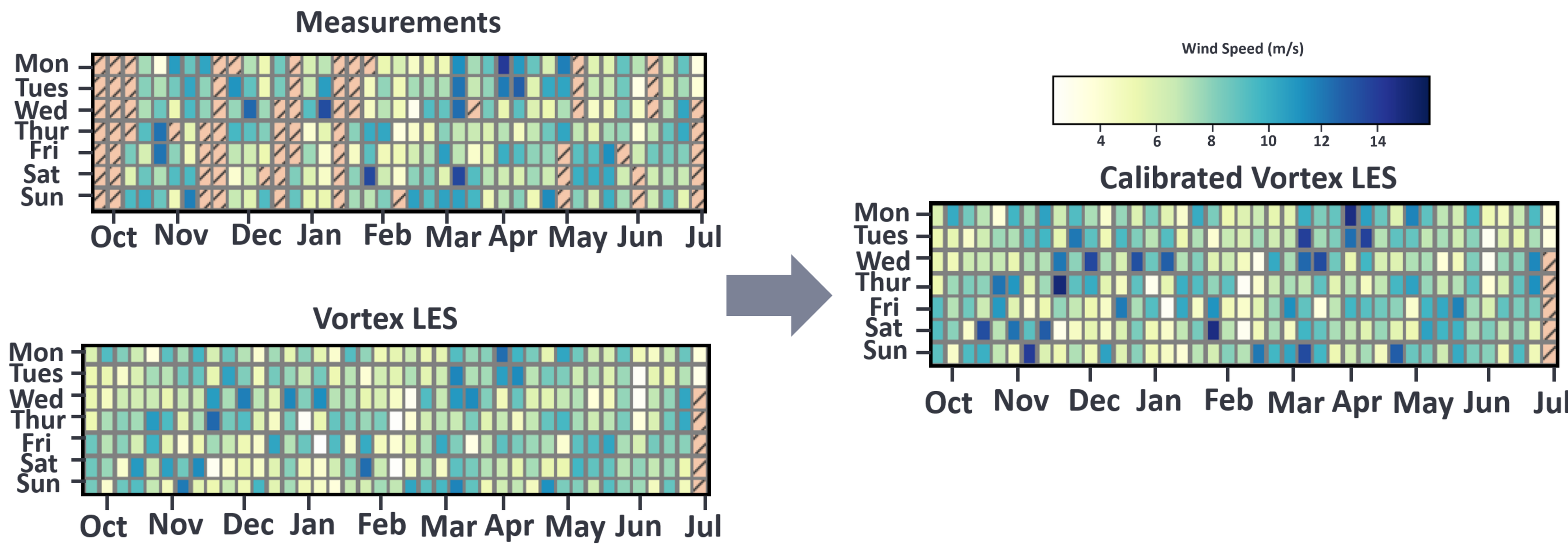

Figure 1. Methods in Vortex GapFill Methodology

3. Vortex GapFill outputs both a gap-filled time series, which combines measurement values at all available campaign timestamps (Figure 2 black) with calibrated LES values for all timestamps with no measurements (Figure 2 magenta) **and a GapFill Report document** which summarizes gap fill performance and characteristics of lidar data gaps.

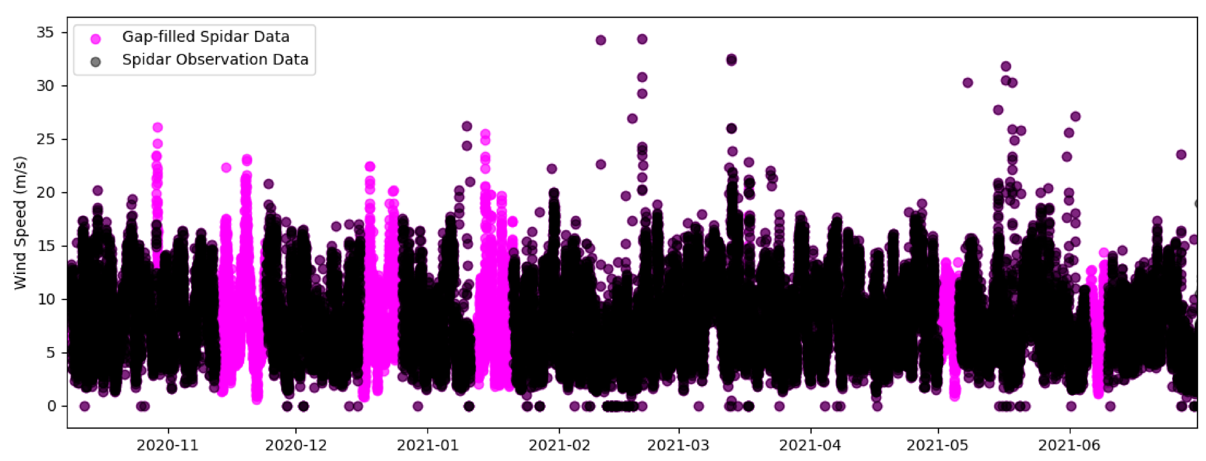

Figure 2. Visualized GapFill output where magenta represents gap-filled data and black represents original observational data from the lidar campaign

Results

To demonstrate a potential validation approach to evaluate this methodology, we chose to implement GapFill for two separate case studies. In both cases, we obtained lidar data from R&D test sites that was not collected with the intention to provide a continuous time series and thus contains natural "system down-time gaps" in which the device was in between a series of sequential tests. For this demonstration, we also obtained a continuous and coincident anemometer wind speed time series that was used as a reference. We were therefore able to compare our understanding of wind resource at each site in three different scenarios: as represented by the reference, as represented by the lidar with system down-time gaps, and as represented by the NRG lidar + Vortex GapFill product.

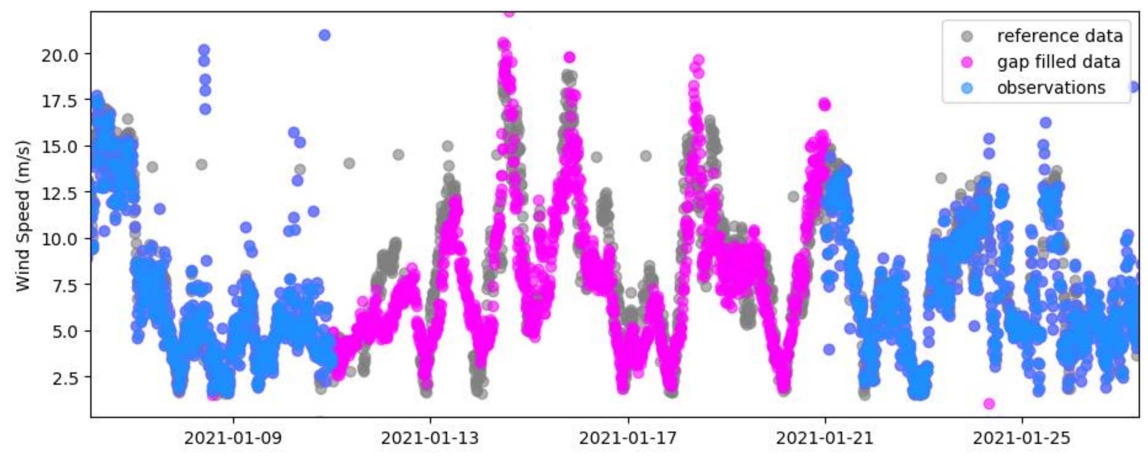

Figure 3. Time series close-up of reference anemometer data (grey), lidar observations (blue) and GapFill data from measurement-calibrated LES (magenta)

NRG-Vortex GapFill Scenario 1: Simple terrain at 50m; Jan 2020 – May 2021 NRG R&D Test Site | TX, USA

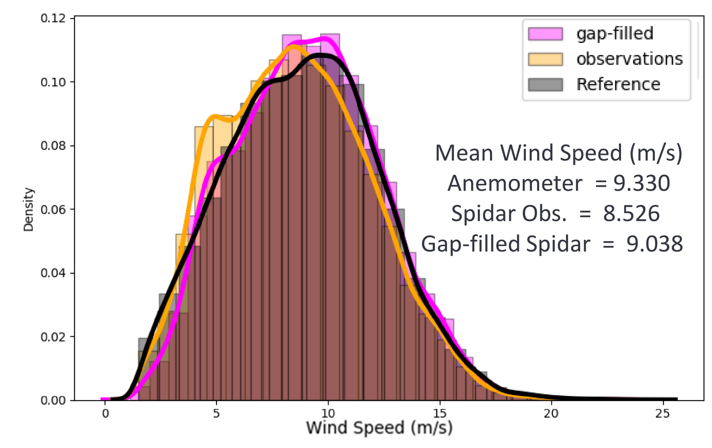

Figure 4. Results for comparing observations and GapFill to reference data. System availability is boosted to 100% in GapFill data. The representative mean wind speed is closer to the reference using gap-filled spidar data.

NRG-Vortex GapFill Scenario 2: Complex terrain at 100m; Jan 2020 – Dec 2021 NRG R&D Test Site | VT, USA

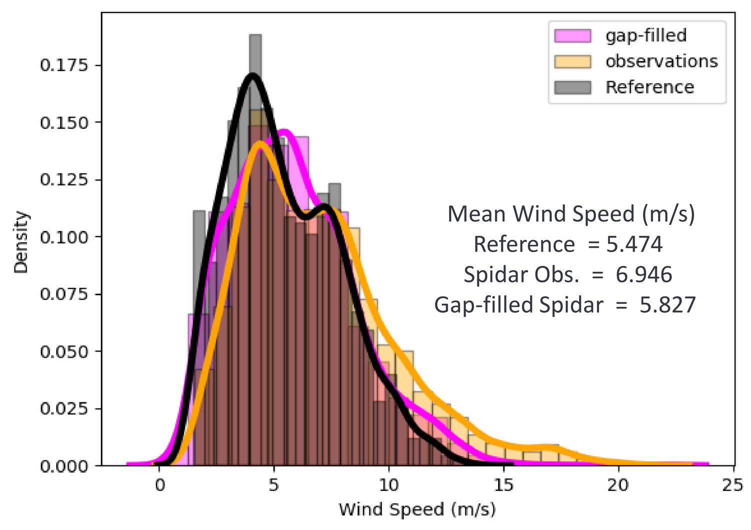

Figure 5. Results for comparing observations and GapFill to reference data. System availability is boosted by 25% in GapFill data. The representative mean wind speed is closer to the reference using gap-filled spidar data. Regression statistics, as expected, decline when incorporating calibrated model data.

Data Set	Sys. Avail.	Slope	R2	MSE (m/s)	RMSE (m/s)	Mean Bias, Available Data (m/s)	Mean Bias, Full Campaign (m/s)
Spidar Data	75%	1.020	0.980	0.111	0.333	0.151	1.472
Gaps Filled	100%	1.067	0.808	1.452	1.205	0.353	0.353
Δ	+ 25%	+ 0.047	- 0.172	+ 1.341	+ 0.872	+ 0.202	- 1.119

Table 1. Regression statistics for Spidar Data and for GapFill scenario 2.

Conclusions

GapFill shows promise as a check for whether missed measurement periods are skewing the overall distribution of measurements at a site.

The effect on mean bias of 10-minute averages appears manageable by keeping the share of synthetic wind data relatively low: Vortex recommends using < 20% GapFilled data.

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