Lidar Technology for Improvements in Wind Resource Assessment and Power Forecasts.

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Abstract

The paper presents the wind flow variability from Doppler lidar measurements and NWP operational models at two sites in Columbia River Gorge during the second Wind Forecast Improvement Project (WFIP-2).

Keywords: Scanning D*oppler lidar, wind forecasting, wind variability, the Second Wind Forecast Improvement Project (WFIP-2)*

Introduction

Accurate wind forecasts are required for optimal grid management and effective balancing between electricity consumption and wind power generation. Wind generation is a direct function of wind speed so wind forecasts from the operational weather prediction (NWP) models are used by grid operators to account for day-ahead fluctuations in wind power production when making decisions in unit commitment and economic dispatch. To improve model physics and short-term weather forecasts of wind flow over complex terrain, and to increase understanding of physical phenomena that affect model accuracy, the Second Wind Forecast Improvement Project (WFIP-2), led by DOE and NOAA, was held in the Columbia River Gorge region. A variety of in-situ and remote-sensing instruments, including two NOAA scanning Doppler lidars, were deployed by participating organizations to the study area.

NOAA scanning Doppler lidars in WFIP-2

NOAA scanning, pulsed Doppler lidar systems were deployed to sites near the Wasco and Arlington, Oregon airports about 40 km apart, providing real-time measurements from September 2015 to April 2017. These systems provided accurate line-of-sight (LOS) velocity measurements with a precision of 20 cm/s at high frequency (2 Hz). The LOS velocity measurements were processed in real-time to obtain vertical profiles of the mean wind flow variables (wind speed, direction, and vertical velocity variance) from near the surface up to 3.5 km. The high vertical (10-15 m), and temporal (15 min) resolution of these profiles is well suited to understanding physical processes within the boundary layer.

High-resolution lidar data allow capturing wind variability at hub-height or through the rotor layer at different time scales: from minutes and hours to daily cycles, which may be substantial due to various factors such as daily temperature changes; and from seasonal to yearly variations, which may be due to variability in pressure gradients and large-scale synoptic systems. In addition to quantifying the temporal and vertical variability of wind flow at both sites, measurements from two identical scanning lidars separated by ~40 km provide a unique opportunity to understand the horizontal variability between the two sites due to the complex terrain. Analysis of monthly, seasonal, annual, and experiment-long distributions of hub-height and rotor-layer wind directions show two prevailing modes of winds at both sites; more frequent westerlies for summer months and almost equal occurrence of westerly and easterly winds in winter. Observed wind speeds at both sites range between 0-20 m/s with stronger winds during summer months compared to winter months. Distributions of wind speed and wind direction for the duration of the experiment is shown in Figure 1.

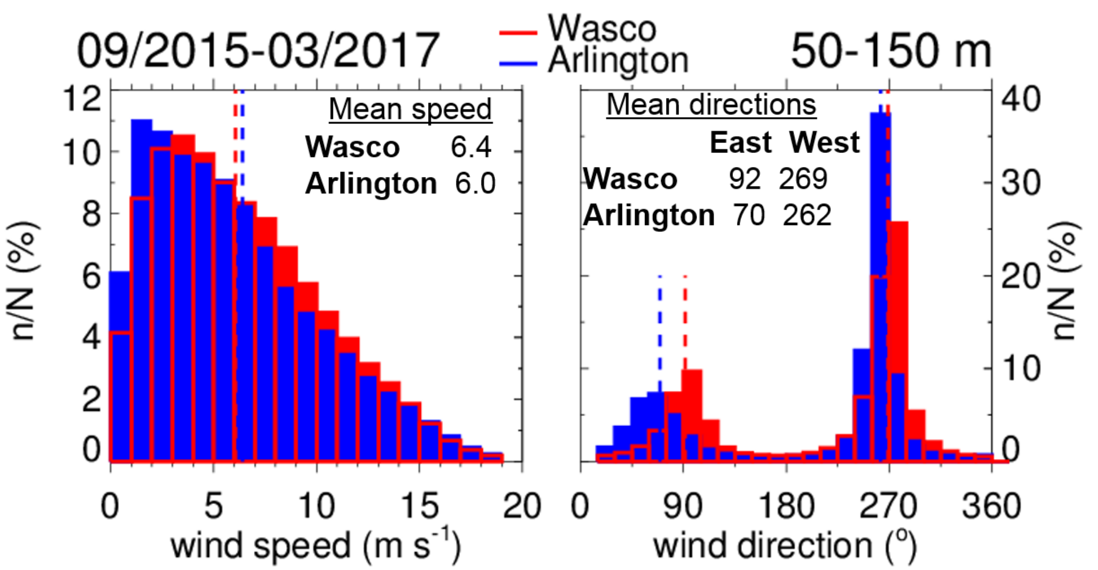

Figure 1. Frequency distributions (%) of rotor-layer (50-150 m) wind speed and wind direction at the (red) Wasco and (blue) Arlington sites. Dashed lines show mean values of each distribution.

Lidar measurements provide a comprehensive dataset to validate NWP model wind forecasts and evaluate model accuracy over days, months and seasons, as well as for periods of interesting meteorological events observed in the study area. Verification metrics such as bias, RMSE, MAE, and the correlation coefficient between observed and modeled wind variables, analyzed as a function of height, time, and forecast lead hour provide insight to potential model improvements. A discussion will be provided on validation uncertainty, which includes the combined effects of lidar measurements errors, data averaging techniques, and extrapolation of modeled variables to the location of instruments.

Deployment of two identical scanning lidars to separated sites presents an opportunity to obtain data upstream and downstream of the local wind farms and analyze turbine wakes and the overall impact of wind farms on wind flow at two sites. A properly sited lidar upstream of the wind farms measures wind speed that is strongly correlated with total wind power generated, as reported by the Bonneville Power Administration (BPA). Some examples of measured and modeled wind speed trends compared to the BPA power will be shown for different time scales.

Conclusions

Measurements from two scanning Doppler lidars at Wasco and Arlington sites are used to analyze temporal, vertical and site-to-site wind flow variability, to better understand physical processes related to the terrain effects, seasonality, or diurnal cycle and to capture cases of unusual wind flow such as wind speed and direction ramps, cold fronts, or marine pushes. Statistical metrics between lidar-observed and NCEP HRRR, ESRL HRRR modeled hub-height and rotor-layer winds, obtained for selected cases, as well as for monthly and seasonal averages, provide insight on model accuracy during such events.

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