Virtual Tower Measurements during AWAKEN

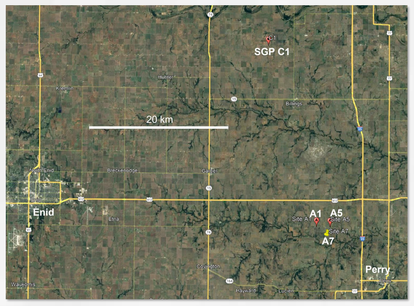
Rob Newsom, Raghu Krishnamurthy, Duli Chand, Mikhail Pekour, Colleen Kaul, Donna Flynn, Lexie Goldberger | *Pacific Northwest National Laboratory, Richland WA*

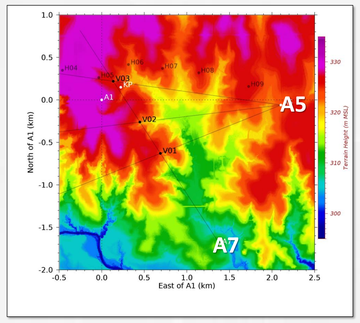
Introduction

The American Wake experimeNt (AWAKEN) is an international, multi-institutional wind energy field campaign which is currently underway in the vicinity of the King Plains wind farm, south of the ARM Southern Great Plains (SGP) Central Facility. The goal of AWAKEN is to provide observations to better understand interactions between wind turbines in a wind farm as well as the overall impact of the wind farm on the lower atmospheric boundary layer.

One component of AWAKEN involves the use of dual-Doppler lidar measurement techniques to observe inflow and outflow (wakes) from individual turbines. In this poster we present preliminary results from the deployment two (ARM) scanning Doppler lidars that were used to measure profiles of wind speed and direction using the so-called virtual tower technique.

Left: The experiment site relative to the SGP C1. Right: Closeup of the experiment site showing terrain elevation and the lidar locations at sites A5 and A7. Also indicated are locations of several wind turbines (H04 through H09)

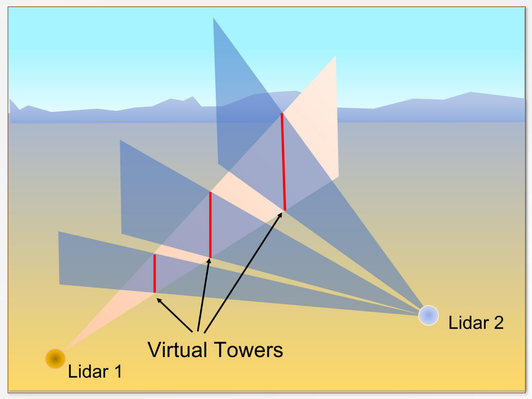




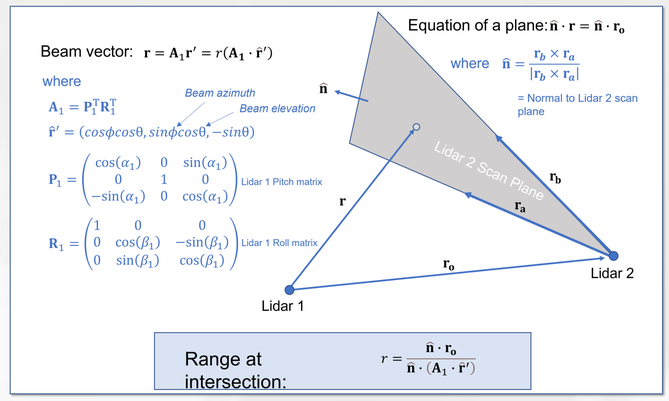
Lidar deployments at sites A5 (left) and A7 (right)

Methods

An asynchronous dual-Doppler scanning method is used to create a linear array of three virtual towers extending southward from the leading row of turbines in the King Plains wind farm. Virtual towers are formed at the intersection of two Range-Height-Indicator (RHI) scans, where radial velocity measurements from both lidars are used to compute profiles of wind speed and direction, as well as estimates of uncertainty.



Above: The lidar at A7 (Lidar 1) performs RHI scans in a single direction, while the lidar at A5 (Lidar 2) performs a sequence of 3 RHI scans towards the west. Both lidars performed shallow RHI scans (elevation angle < 12º), so there is very little sensitivity to vertical velocity. The maximum heights of the virtual towers ranged from 209 to 432 mAGL.



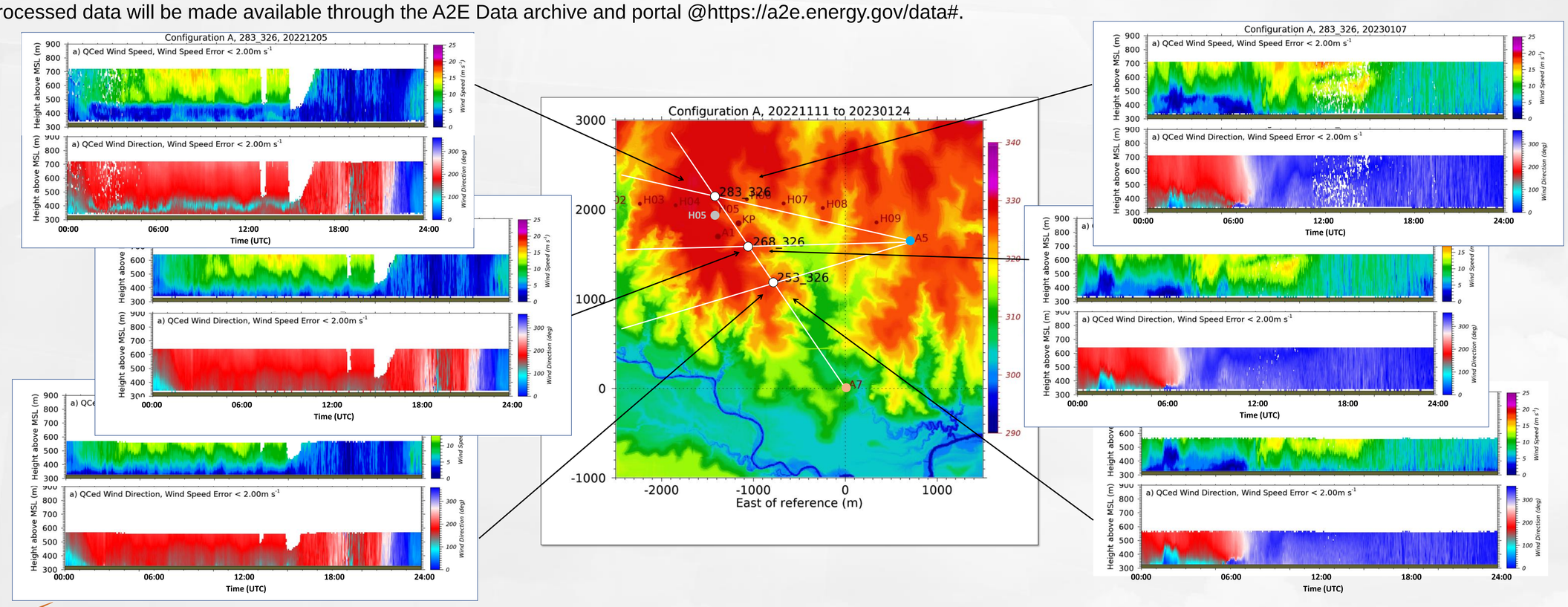
Above: The method interpolates each beam from Lidar 1 to the scan plane of Lidar 2 and vice versa. The lidars' tilt (pitch and roll) are accounted for in the analysis. Estimates of uncertainty are computed using the four range bins nearest the intersection point. The scan angular resolution was 0.2º, which enabled post-processing using a vertical grid resolution of 10 m.

Below: Data availability for processed virtual tower profiles (to date). Green indicates that data are available.

Results

In contrast to traditional single-Doppler ground-based wind profiling, the virtual tower method 1) makes no assumption of horizontal homogeneity, 2) enables much finer vertical resolution, and 3) enables profiling very close to the surface. The examples below show time-height displays of wind speed and direction retrieved from three virtual towers for December 5, 2022 (left) , and January 7, 2023 (right). Comparing winds from three virtual towers on a given day reveals the impact of the H05 turbine on "283_326" tower. In the examples below, the wake from the H05 turbine significantly reduces the the wind speeds at "283_326". The example on the left (5 Dec 2022) also shows a strong deflection of the winds in the wake of the turbine.

Raw and processed data will be made available through the A2E Data archive and portal @https://a2e.energy.gov/data#.



Acknowledgments: This research was supported by the Atmospheric Radiation Measurement (ARM) user facility, and by the U.S. Department Of Energy's (DOE) Office of Energy Efficiency and Renewable Energy. The ARM user facility managed by the Biological and Environmental Research (BER) program. Pacific Northwest National Laboratory (PNNL) is operated by DOE by the Battelle Memorial Institute under Contract DE-A06-76.

Contact Information: Rob Newsom, rob.Newsom@pnnl.gov; Raghu Krishnamurthy, raghu.krishnamurthy@pnnl.gov