Investigations of profiling lidar measurements in complex terrain using high-fidelity numerical modeling

Mithu Debnath, Eliot Quon and Patrick Moriarty
National Renewable Energy Laboratory. Contact: mithu.debnath@nrel.gov

Motivation and workflow

- Current wind Light Detection and Ranging (lidar) technology uses retrieval algorithm that considers **horizontal homogeneity** (wind speed is constant within the considered circle) which **creates bias in wind speed measurements in complex terrain** due to the higher fluctuation, curvature and vortex-recirculation of wind flows.
- A **correction algorithm is needed** to remove the bias.
- Before a correction algorithm is developed, a better understanding of lidar measurements in complex terrain is needed. The framework for this approach is:

*1) **Lidar measurements pointing at a sonic anemometer** mounted on a meteorological tower (in **simple terrain**) to understand the lidar technology itself*

↓

*2) **Profiling lidar measurements** with a co-located meteorological tower in a complex terrain*

↓

*3) **Large eddy simulation (LES)** to model the wind flow over the complex terrain*

↓

*4) **Virtual lidar modeling** within the LES platform*

↓

*5) **Error investigation** with the **virtual lidar***

↓

*6) **Comparison** between **virtual and real lidar** in complex terrain*

1) How is the lidar technology doing?

- Mean line-of-sight (LOS) wind speed has good agreement with R^2 and slope (linear regression parameters) close to 1.0. Overall under-estimation in standard deviation is 13.1%. However, predicted under-estimation is 7.9 % (Ref. 1).

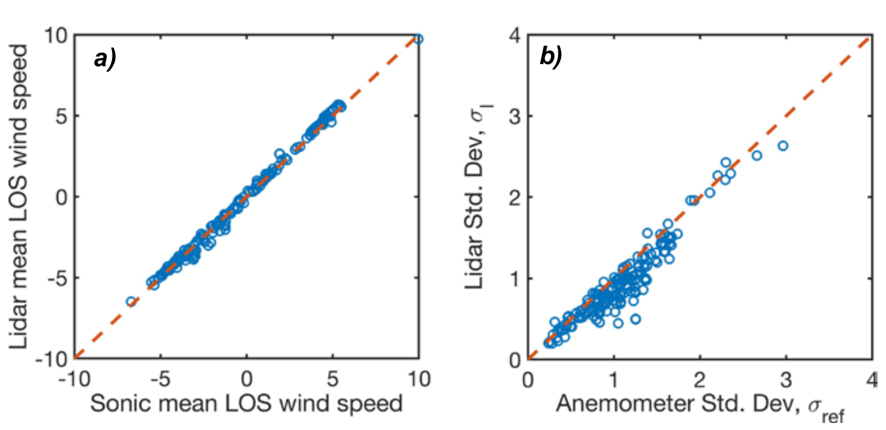


***Figure-1:** A scanning lidar is stared at a sonic anemometer mounted at 41 m height AGL. a) mean LOS wind speed; b) standard deviation of LOS wind speed.*

2) How is the profiling lidar doing?

- The profiling lidar has bias of 1.81% in mean wind speed compared to sonic anemometer
- Lidar over-estimates the turbulence intensity of 1.98%

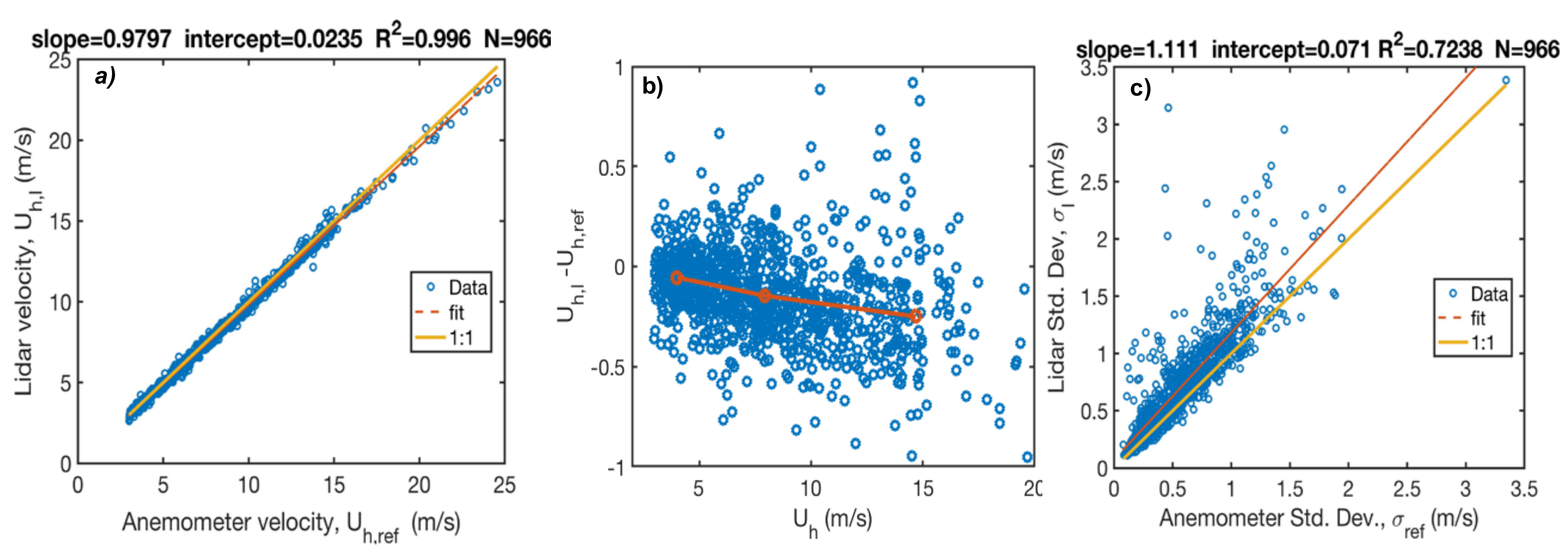
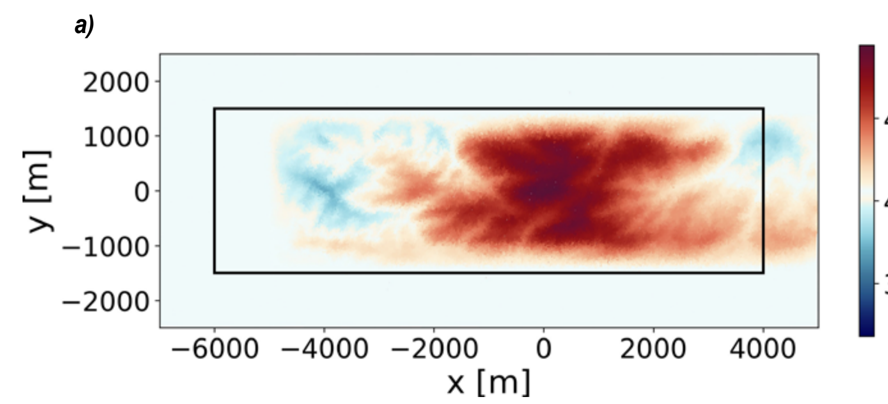


***Figure-2:** a) Horizontal wind speed; b) Error in horizontal wind speed; c) Standard deviation.*

3) LES simulation over complex terrain



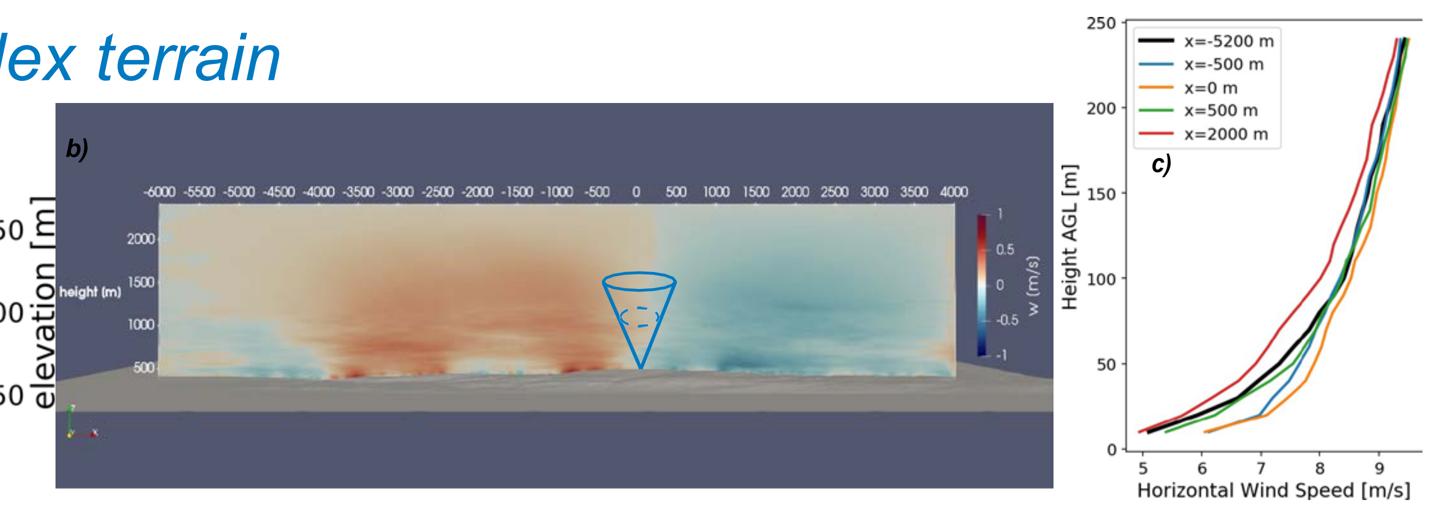
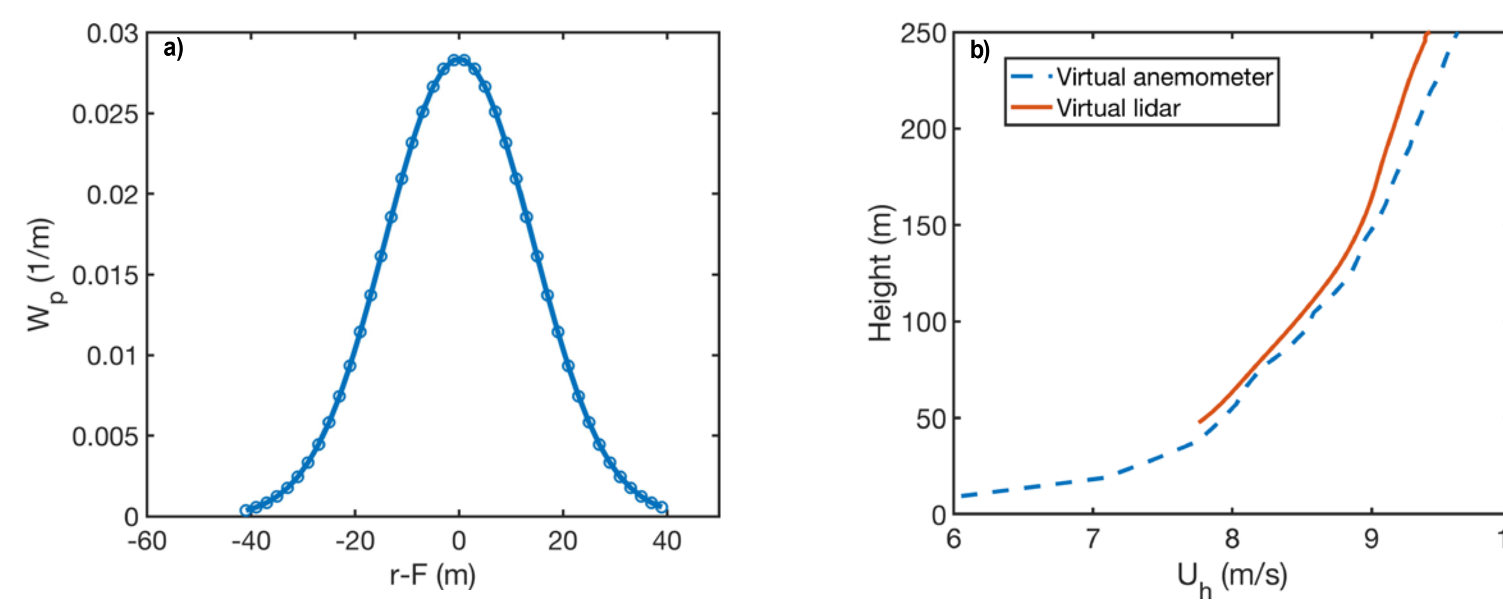


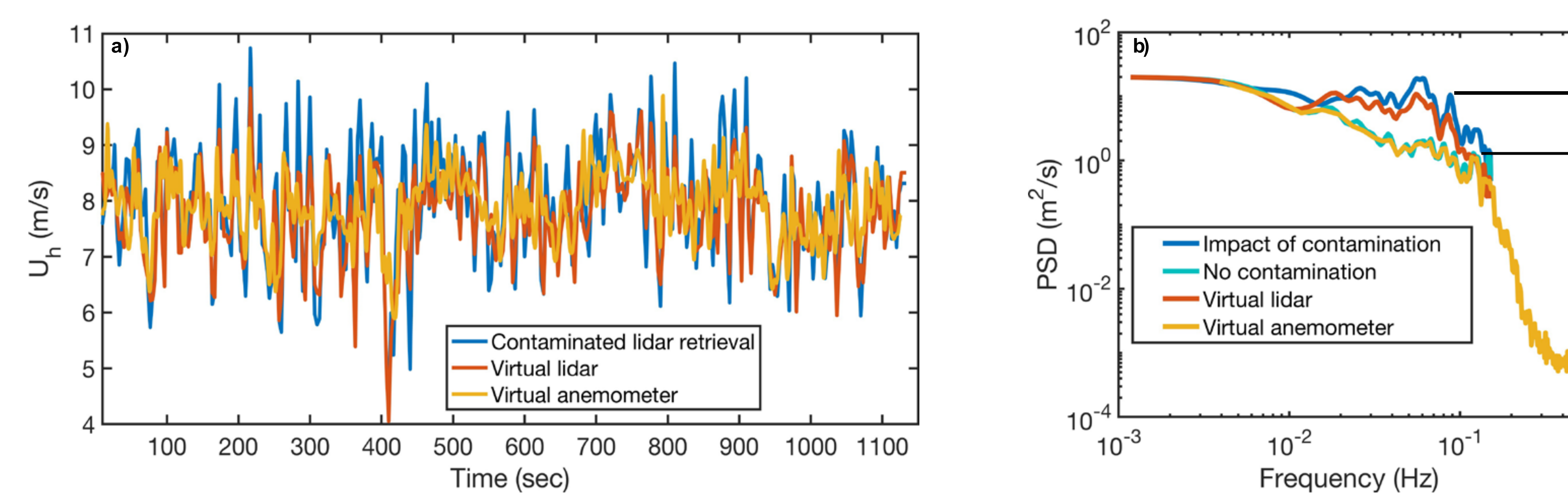
***Figure-3:** a) Terrain elevation of the site (lidar at x=0, y=0); b) Vertical velocity (xz plane at y=0); c) Wind speed profiles at different streamwise locations.*

4 & 5) Virtual lidar and error investigation



Difference between the wind speed profiles provides bias in mean wind speed

***Figure-4:** a) Lidar weighting function used in the numerical simulation; b) wind speed profile with height.*



Noise due to contamination in retrieval process

***Figure-5:** a) Wind speed signals at 50 m height from different instruments modeled in the simulation; b) Power spectral density of the the signals.*

6) Comparison:

	Mean error in wind speed (m/s)	Mean percentage error in wind speed (%)	Error in standard deviation (%)
Real lidar	-0.16	-1.81	26.0
Virtual lidar	-0.14	-1.76	29.1

Conclusions:

- The numerical model is able to reproduce the lidar error in mean wind speed and turbulence intensity
- Mean wind speed error: increases with height (up to 200 m), gradient of vertical velocity along streamwise direction is a good representation of the bias
- TI error: contamination on the lidar retrieved data due to the horizontal homogeneity assumption

Future work & collaborations:

- Develop a robust correction algorithm to correct the lidar measurements in complex terrain
- Evaluate correction method based on mass conservation model (Ref. 2) and compare with LES framework
- The lidar campaign was not in fully complex terrain. If you have lidar data in complex terrain, please raise your hand!

References:

1. Cheynet et al. (2017), Remote Sensing.
2. Nabi et al. (2019), US patent, US20190293836A1.

*This work was authored by the National Renewable Energy Laboratory, operated by Alliance for Sustainable Energy, LLC, for the U.S. Department of Energy (DOE) under Contract No. **DE-AC36-08GO28308**. Funding was provided by the U.S. Department of Energy, Office of Energy Efficiency and Renewable Energy. The views expressed in the article do not necessarily represent the views of the DOE or the U.S. Government. The views expressed in the article do not necessarily represent the views of the DOE or the U.S. Government.*

NAWEA/WindTech 2019 Conference
Amherst, MA
October 14-16, 2019