Methods for Correcting Lidar Measurements in Complex Flow Conditions

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Background

Inhomogeneous flow can bias remote sensing measurements
- Remote sensing measurements rely on the assumption that the flow in the measurement volume is homogenous (not changing over space)
- At some measurement locations steep slopes or changes in forest canopy can cause inhomogeneous flow above the lidar or sodar measurement area
- Changes in wind characteristics between the lidar or sodar beams cause an error in the estimated wind speed
- This error may exist or under predict the wind speed by as much as 7%
- Predicting wind characteristics using flow modeling potentially offers a means for correcting the error

Scope of the Project
- Collected lidar data using a WINDCUBEv2 Lidar Remote Sensor at a flat site and moderately complex terrain site
- Evaluated three wind flow methods used to predict and correct any bias
- Verified methods against a WindSensor P2546A (Formerly Risø) anemometer measurements

Correction Methods

Flow modeling methods can potentially be used to correct bias
Three methods were evaluated in this project:
1. Linear Model
   - WAsP Engineering, developed by Risø DTU9
   - Linearized flow model, considers terrain and roughness
2. Linear Model based on Lidar Measurements
   - Linear mapping of flow field using lidar measurements, developed by DNV
   - Considers variation in horizontal and vertical wind speed over the lidar measurements heights
3. CFD Model
   - MeteodynWT, developed by Meteodyn
   - CFD model, considers terrain, roughness, and stability

Baseline Measurements at Flat Site

Flat Site
- **Purpose:** Develop a baseline relationship between met mast and lidar
- **Site characteristics:** Gentle slope of 40-m elevation over 2 km, Farmland with areas of trees in the distance. Measured inflow angle is between 0° and 90° for all wind directions. TI is approximately 8% for northwest winds and 10% to 15% for other wind directions.
- **Data Collection Period:** 1-month data period; 430 hours of measurements after filtering
- **Lidar to Cup Comparison:** Lidar wind speed was 1% higher compared the WindSensor P2546A and NRG #40C anemometers

Develop a baseline relationship between met mast and lidar

Complex Site
- **Purpose:** Quantify potential lidar bias at moderately complex site and evaluate bias for different wind directions
- **Site Characteristics:** Farmland with a ravine of approximately 100-m depth to the west; smaller ravine to the east. Average TI approximately 10% for all wind directions.
- **Data Collection Period:** 2-month data period; 510 hours of measurements after filtering
- **Lidar to Cup Comparison:** Lidar wind speed was 2% lower compared the WindSensor and 1% lower compared to the NRG #40C

Results for Complex Site

Cup Anemometer Comparison
- NRG #40C to WindSensor ratio
- Ratio exhibits TI and inflow dependencies seen in other studies2
- Ratio is lower for low TI conditions; low TI conditions exist at this site
- Ratio is higher for upslope wind flow; for this site upslope conditions exist in west winds

WAsP Engineering Correction
- Lidar correction with WAsP Engineering compared to WindSensor
- Reduced the lidar to cup difference from 2% to 0% across all wind directions
- Resulted in 1% to 2% overestimate of cup measurements in some direction sectors

Measured Flow Extrapolation Correction
- Lidar correction based on linear extrapolation of measured flow compared to WindSensor
- Resulted in no significant adjustment to lidar data at this site
- Lidar to cup difference remains at -2%

CFD Lidar Correction
- Lidar correction with CFD compared to WindSensor
- Reduced the lidar to cup difference from -2% to 0% across all wind directions
- Large variation in the individual data points (scatter)

Conclusions

Small difference in lidar and cup measurements observed at a complex site
- The lidar wind speed was 2% lower than the WindSensor and 1% lower than the NRG #40C
- Difference between cup and lidar measurements is on the order of the uncertainty of cup anemometers in field inflow and turbulence conditions

Proposed correction methods for lidar in inhomogeneous flow resulted in reasonable adjustments to average wind speeds
- The magnitude of the correction is within the uncertainty of the modeling
- DNV concludes that an adjustment to the lidar data will not reduced uncertainty for this data set

Result will vary for different sites and flow conditions
- DNV recommends careful consideration of lidar measurements and correction methods for complex flow sites
- More studies are needed to better understand the potential lidar error and correction methods

References


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