**Title:** Wind Resource Measurement and Analysis for Wind Energy Application using Scanning Doppler Lidar  

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**Abstract**  
The scanning Doppler Lidar-based wind field measurements and analysis techniques are evaluated for wind energy application. The Lidar measurements are first validated against measurements from existing V1 Lidar, showing good agreement even for the availability limit of 20%. Vertical profiles of wind blowing from land and that from sea, measured using DBS configuration show that later is significantly higher. A method is proposed to retrieve velocity vector field from the measured radial wind speed using RHI and PPI scans and is employed to investigate near-shore velocity fields and wind turbine wake. An internal boundary layer develops from the shore and persists up to 2000 m offshore. Flow field around wind turbine shows the characteristic velocity deficit in wind turbine wakes. Lidar measurements data are also used to validate mesoscale simulation and a wake model.

**Objectives**  
- Evaluate the performance of Lidar technology in measurement of wind field and propose methods for processing of measured data  
- Characterize near-shore marine atmospheric boundary layer (ABL)  
- Measure and characterize wind turbine wake  
- Use Lidar measurement to validate mesoscale and wake models.

**Measurement Techniques and their Validation**

**Doppler beam swinging (DBS) configuration**  

- Retrieval of velocity vector:  
  \[ u = \frac{u_{eg} - u_{eg'}}{2 \cos \phi}, \quad v = \frac{u_{eg'} - u_{eg}}{2 \cos \phi}, \quad w = u_{eg} \]  

**Terrain effect**  
- RHI scan towards the northern coast  
- Internal boundary layer develops and persists until 2000 m

**Results**

- Vertical profiles of wind from land & from sea  
  - Wind blowing from sea is significantly higher (35% high at hub height)  
  - Good agreement between measurement & mesoscale simulations up to 300 m.

- Simulations agree well with measurement  

**Measurement of wind turbine wake**  
- Horizontal profiles of mean wind speed at hub height  
  - Maximum velocity deficit at x/D = 3  
  - Characteristic double peak observed in the measurements  
  - Wake model agrees with the measurements

**Summary**  
- Validated Lidar measurement and proposed a method for retrieval of velocity vector from RHI PPI scans  
- ABL profiles showed that wind from land is slower than that from sea  
- IBL could be observed for wind blowing from the shore  
- Measured and characterized wind turbine wake

**References**

1. Ishihara T, Yamaguchi A, Goit JP and Tanemoto J 2017 Annual Meeting JAWE pp 87-88  

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**Plan-position indicator (PPI)**  
- Retrieval of velocity vector:  
  \[ u_x = V \cdot u_x = u \cos \phi \sin \theta + v \cos \phi \cos \theta \]  
- \( V \) from wind vane on nacelle or met tower is used

**Range height indicator (RHI)**  
- Wind direction (\( \phi \)) from wind vane on nacelle or met tower is used

**Test Site and Measurement Setup**

- Measurement data collected from Choshi offshore wind energy test facility  
- Meteorological tower equipped with two Lidars on the platform, other sensors at multiple heights

**Terrain effect**  
- Close to coast  
- 1950 m from coast  
- 2950 m from coast

**Plan-view indicator (PPI)**  
- Single PPI elevation scan

**Windcube 100S**

**Lidar**  
- Vertical profile of mean wind speed at hub height

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Acknowledgements: The study was carried out as a part of Offshore wind condition observation research program, funded by The New Energy and Industrial Technology Development Organization (NEDO).