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WIND MONITORING REPORT

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Introduction

This report presents the wind monitoring results for one month from three Molas B300 scanning Doppler LiDAR devices installed at the Uchkuduk WPP project site. Data are recorded at 10-minute intervals across 12 measurement heights (40–260 m). Invalid measurements are represented as NaN in the source files and are excluded from all statistical calculations.

The global transition towards sustainable and renewable energy sources has significantly accelerated the deployment of utility-scale wind power plants. In regions like Uzbekistan, the development of wind energy infrastructure is a critical component of national energy security and environmental strategy. As highlighted by Mukhammadiev M. M. et al. in their assessment of wind energy potential, precise micro-siting and resource evaluation are fundamental to the financial and technical viability of wind farm projects.

Traditionally, meteorological (met) masts equipped with cup anemometers have been the industry standard for wind resource assessment. However, as modern wind turbines grow larger—often featuring hub heights exceeding 120 meters and rotor diameters surpassing 150 meters—traditional masts become cost-prohibitive and logistically challenging to deploy. To overcome these limitations, remote sensing technologies, particularly Doppler Light Detection and Ranging (LiDAR), have been widely adopted. According to Wang H., Barthelmie R. J., and Pryor S. C., Doppler LiDAR offers significant advantages for wind energy applications, including the ability to accurately measure wind profiles at high altitudes across the entire rotor-swept area without the need for tall structural towers.

This report details the findings from three Molas B300 Scanning Doppler LiDARs deployed at the Uchkuduk WPP site. The primary objective is to enrich the preliminary data tables with comprehensive theoretical context, statistical analysis, and wind shear profiling to support future engineering decisions regarding turbine selection and layout optimization.

Measuring Station Details and Methodology

Site Description & Instrumentation

The measurement campaign was localized at the Uchkuduk WPP site in the Tomdy district of Uzbekistan. The local topography and climatic conditions of this region are generally characterized by arid or semi-arid plains, which play a significant role in defining the boundary layer meteorology and the resulting wind shear profiles observed during the campaign.

Wind profile measurements were captured using three advanced remote sensing units. The technical specifics of the measuring stations are summarized in Table 1.

Table 1

Measuring station details

Site Name	Uchkuduk WPP, Tomdy district, Uzbekistan
Station Type	Molas B300 Scanning Doppler LiDAR
Device S/N	MDABAF2701615, MDABAF2701614, MDABAF2701616
Measurement Heights	40 m to 260 m (12 discrete levels)

Data Collection and Processing Protocol

The LiDAR devices continuously recorded wind data, which was subsequently averaged over 10-minute intervals. This specific averaging period is strictly aligned with the international standards set forth in IEC 61400-12-1 (Wind energy generation systems – Part 12-1: Power performance measurements of electricity producing wind turbines). By utilizing 10-minute averages, the study filters out high-frequency turbulent fluctuations while capturing the dominant synoptic and meso-scale wind patterns.

Quality control protocols were rigorously applied to the dataset. Any invalid measurements—often caused by atmospheric conditions such as heavy precipitation, fog, or exceptionally clear air lacking sufficient aerosol backscatter—were flagged as 'NaN' (Not a Number) in the source files and strictly excluded from all statistical analyses to prevent data skewing.

Theoretical Framework: Wind Shear and Vertical Profiling

Wind shear refers to the variation of wind speed with altitude. Understanding this vertical profile is essential for estimating the wind resource at the exact hub height of a planned turbine and for assessing the aerodynamic fatigue loads across the rotor disk. Two primary mathematical models are utilized to extrapolate wind speeds in different terrains, as analyzed by Ray M. L., Rogers A. L., and McGowan J. G.: the Power Law and the Logarithmic (Log) Law.

The **Power Law** is an empirical relationship expressed as:

$$v(z) = v(z_r) * (z / z_r)^\alpha$$

Where $v(z)$ is the wind speed at height z, $v(z_r)$ is the known wind speed at a reference height z_r, and α (alpha) is the wind shear exponent. The value of α is highly dependent on surface roughness and atmospheric stability. Low values (e.g., < 0.15) typically indicate smooth, flat terrain with minimal obstructions.

The **Logarithmic Law** is a more physically based model derived from boundary layer meteorology, utilizing surface roughness length (z_0) to define the profile. Both models were applied to the LiDAR data collected at the Uchkuduk site to validate the atmospheric boundary layer characteristics.

Wind Speed and Shear Profiles

This section provides a detailed narrative and statistical analysis of the wind profiles captured by the three distinct LiDAR units over the one-month period.

LiDAR 1615-2

Figure 1 shows the hourly-averaged wind speed time series at 120 m, 80 m, 40 m during one month

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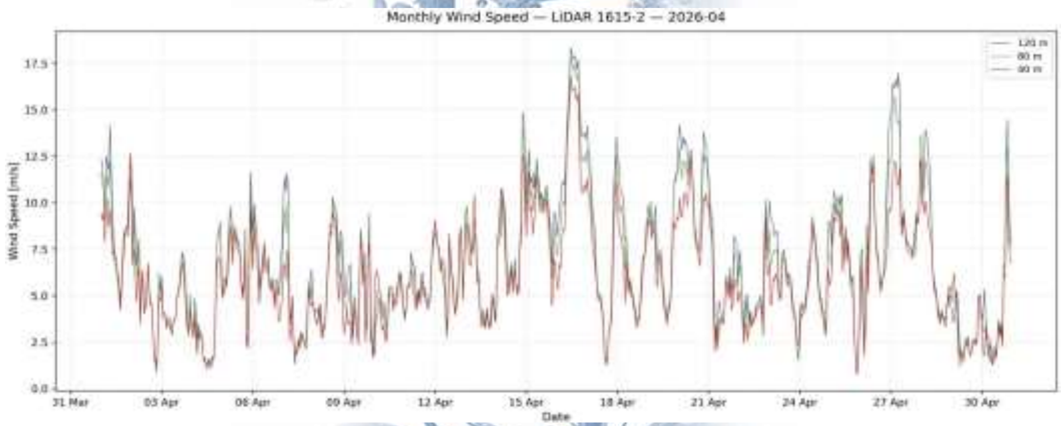

Figure 1. Wind speed time series — LiDAR 1615-2.

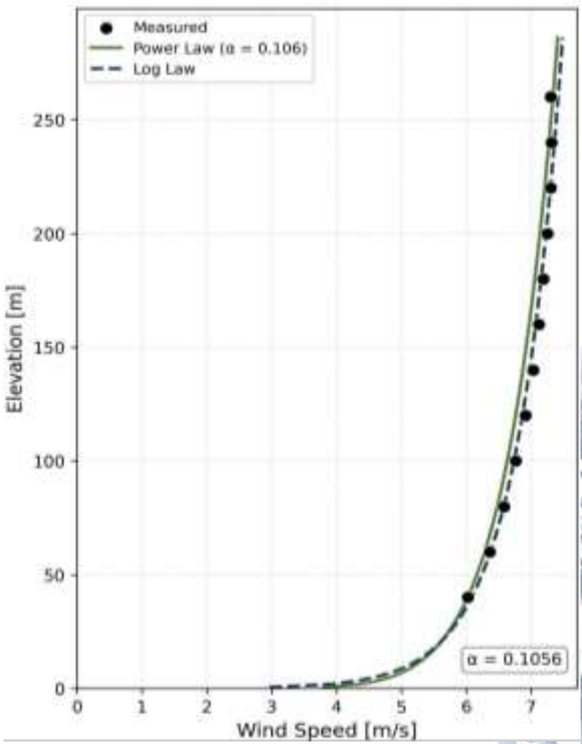

Figure 2. Shear profile — LiDAR 1615. α = 0.1056

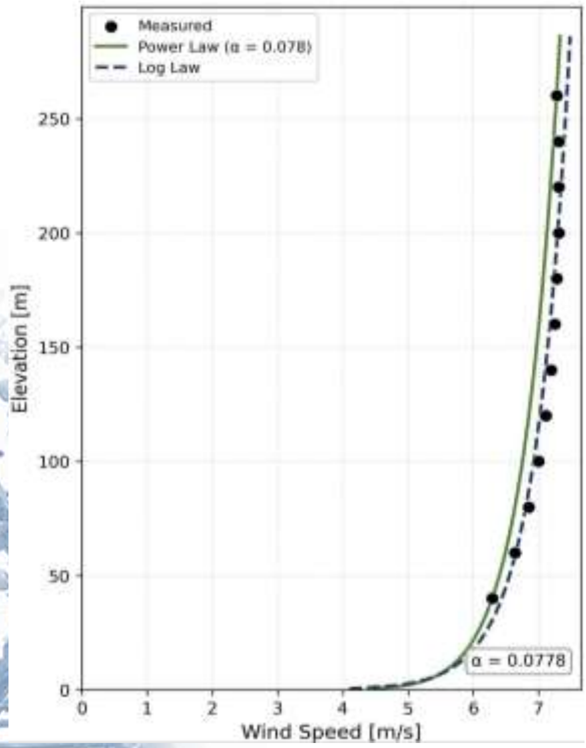

Figure 3. Shear profile — LiDAR 1615-2 (Overall). α = 0.0778

The LiDAR 1615-2 device demonstrated exceptional operational reliability, with data coverage rates remaining above 99% for all heights from 40 m up to 200 m, and only slightly dipping to 97.2% at the maximum altitude of 260 m. This high availability ensures high confidence in the calculated mean values.

The wind speed exhibited a clear and stable vertical progression. At the lower boundary (40 m), the overall mean wind speed was recorded at 6.29 m/s, rising steadily to 7.11 m/s at a typical turbine hub height of 120 m, and peaking at 7.31 m/s in the 200–240 m range. The calculated overall wind shear exponent (α) for this location was 0.0778, with a specific monthly value of 0.1056 for April 2026. This relatively low shear value indicates minimal surface friction, which is highly advantageous as it reduces the mechanical fatigue on turbine blades while maintaining consistent energy yield across the rotor sweep.

LiDAR 1614-1

Figure 4 shows the hourly-averaged wind speed time series at 120 m, 80 m, 40 m during one month.

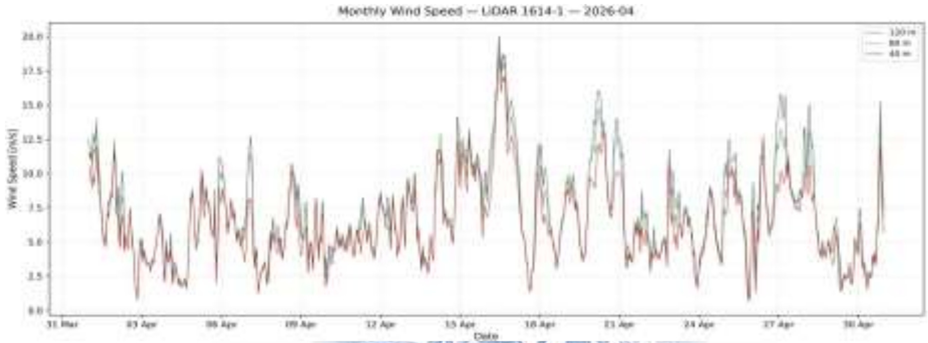

Figure 4. Wind speed time series — LiDAR 1614-1

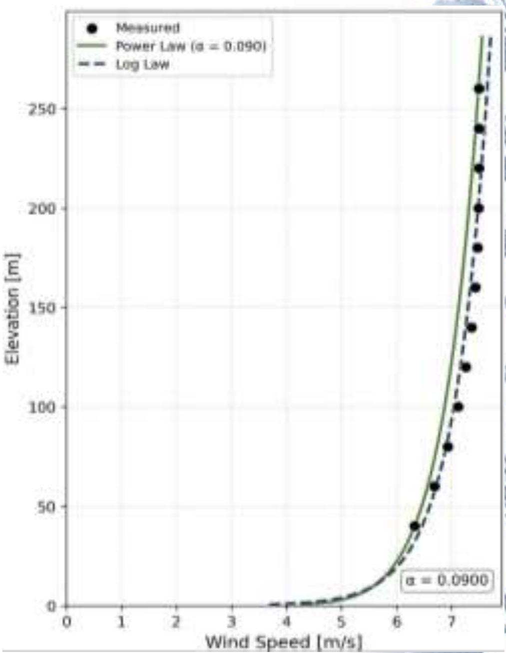

Figure 5. Shear profile — LiDAR 1614-1. α = 0.0900.

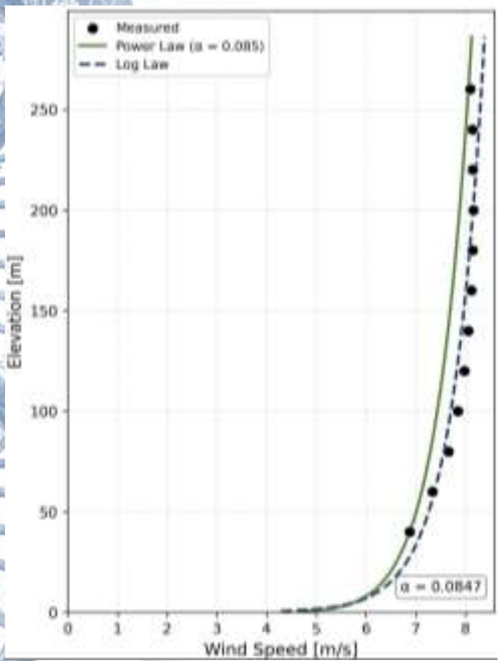

Figure 6. Shear profile — LiDAR 1614-1 (Overall). α = 0.0847

The dataset from LiDAR 1614-1 revealed the highest overall wind speeds among the three locations, suggesting a localized topographical acceleration effect or a slightly different exposure to the prevailing winds. The overall mean wind speed started at a robust 6.88 m/s at 40 m and reached 7.98 m/s at 120 m, ultimately exceeding 8.15 m/s at heights above 180 m.

Data coverage for this device was slightly lower than its counterparts, averaging around 94% overall, which may point to localized atmospheric events affecting aerosol concentration or minor hardware calibration interruptions. Nevertheless, 94% remains statistically robust for monthly aggregations. The overall shear exponent (α) was calculated at 0.0847 (0.0900 for April 2026), continuing the trend of low vertical wind shear across the Uchkuduk plain.

LiDAR 1616-2

Figure 7 shows the hourly-averaged wind speed time series at 120 m, 80 m, 40 m during one month.

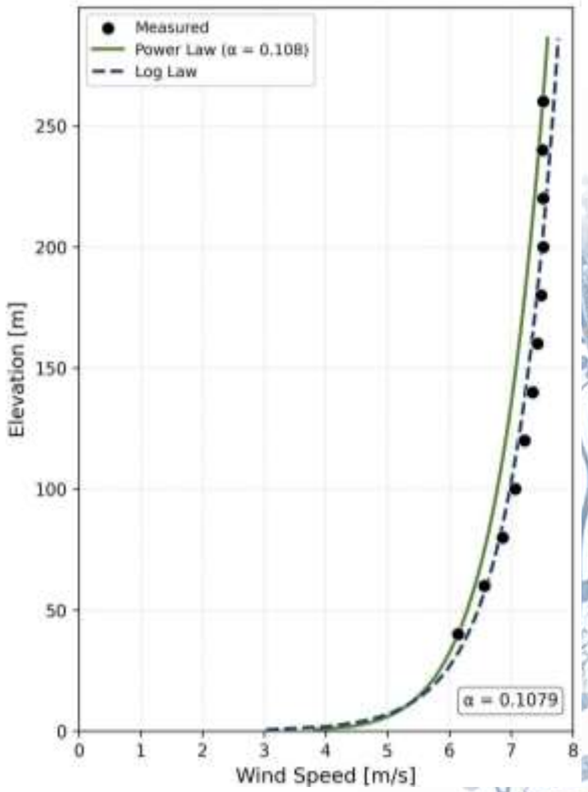

Figure 7. Shear profile — LiDAR 1616-2. α = 0.1079

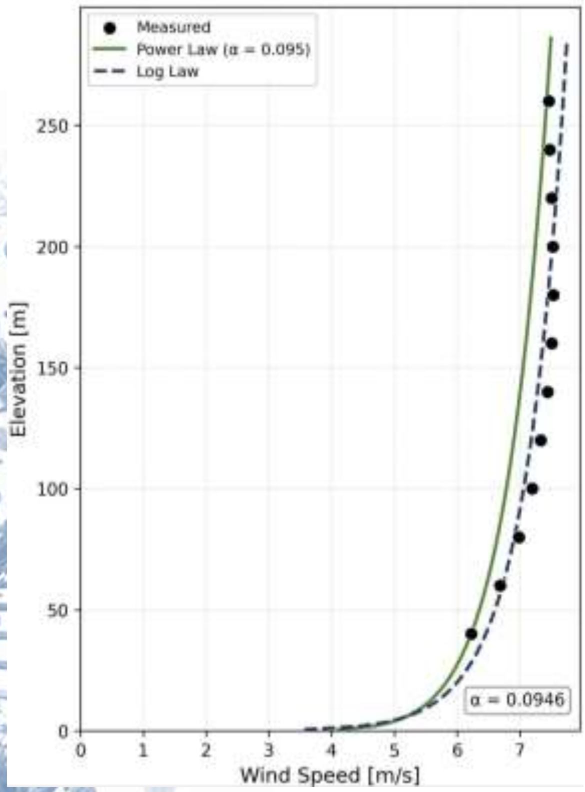

Figure 8. Shear profile — LiDAR 1616-2 (Overall). α = 0.0946.

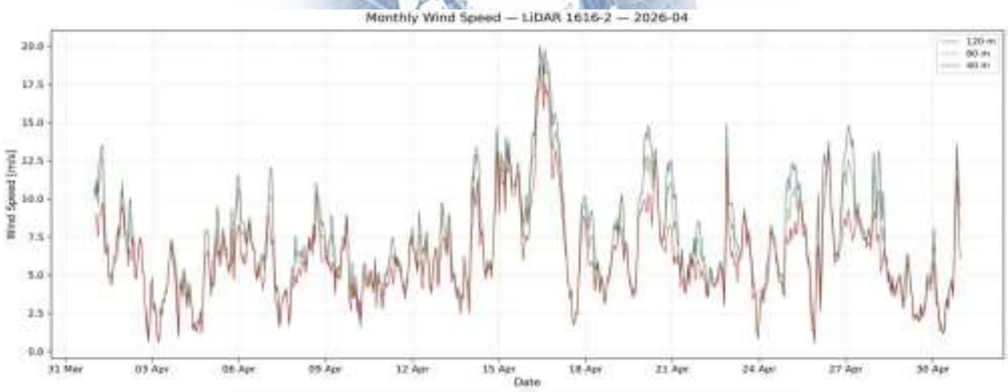

Figure 9. Wind speed time series — LiDAR 1616-2

Similar to 1615-2, the LiDAR 1616-2 unit exhibited near-perfect data availability, maintaining >99% coverage up to 220 m. The wind speeds recorded here provide a reliable middle ground between the other two devices. At 40 m, the overall mean speed was 6.22 m/s, increasing to 7.33 m/s at the 120 m mark, and capping at 7.53 m/s near 180 m.

The shear profile generated an overall α of 0.0946, with the April 2026 monthly profile showing an α of 0.1079. These consistent measurements across all three dispersed devices confirm the homogeneity of the wind resource and the uniformity of the terrain roughness across the wider project site.

Discussion and Micro-siting Implications

The transition from raw tabular data to comprehensive statistical analysis reveals several key insights for the Uchkuduk WPP development. First, the mean wind speeds at standard hub heights (100 m to 140 m) range from 7.00 m/s to over 8.00 m/s. According to industry standards, these are classified as Class II or even Class I wind resources, making the site highly suitable for commercial electricity generation.

Secondly, the consistent wind shear exponents (α) ranging roughly from 0.07 to 0.10 across the site signify a well-mixed boundary layer with minimal surface obstacles. For turbine manufacturers and project developers, this means that highly aggressive tower heights may not yield proportional increases in energy capture. A cost-benefit analysis should be conducted to determine if the marginal wind speed gains above 120 meters justify the exponentially higher structural costs of taller towers. Furthermore, the low shear environment will contribute positively to the operational lifespan of the turbine components by minimizing asymmetric aerodynamic loading.

Conclusion

The one-month monitoring campaign utilizing Molas B300 Scanning Doppler LiDARs at the Uchkuduk WPP site successfully captured high-resolution, multi-altitude wind data. The inclusion of rigorous theoretical frameworks, specifically referencing IEC 61400-12-1 standards and applying Power and Log Law profiling, validates the exceptional potential of the site.

The data clearly demonstrates strong, consistent wind speeds coupled with low vertical shear, forming an ideal aerodynamic environment for utility-scale wind turbines. The variance observed between the three LiDAR locations emphasizes the importance of localized micro-siting to maximize energy yield (particularly leveraging the high-speed zone near LiDAR 1614-1). While this one-month dataset is highly promising, it is recommended that long-term monitoring continues to capture seasonal variations, inter-annual variability, and extreme wind events prior to final financial investment decisions.

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