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Assessment of nocturnal low-level jets and their implication for wind power from FESST@home measurements

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Nocturnal Low-Level Jets (NLLJ) are maxima in vertical profiles of the horizontal wind speed in the lowest hundreds of meters of the troposphere. NLLJs therefore influence the winds at typical rotor heights. However, due to rare measurements with a sufficient precision and resolution, the occurrence frequency and spatio-temporal characteristics of NLLJs on the mesoscale are still poorly understood. The present work uses new measurements of wind profiles for June to August 2020 from Doppler wind lidars that were installed as a part of the Field Experiment on Submesoscale Spatio-Temporal Variability (FESTVaL) campaign, in Lindenberg and Falkenberg (Germany), at about 6 km of distance from each other. The aim of our NLLJ assessment is to characterize their mesoscale properties and evaluate their potential impacts on wind power production. The vertical profiles of the 10-minute mean winds from the lidar measurements were statistically analysed using automated detection tools for NLLJs. These allowed the determination of the frequency of occurrence, height and wind speed in the core of NLLJs as well as the vertical wind shear with a high temporal resolution. First, we intercompared the results from the two sites in order to analyse the temporal and spatial variability of NLLJs on the mesoscale. Our automatic detection identified NLLJs in about 64% to 74% of the summer nights in 2020, showing that they were a common phenomenon during that summer. About half of the NLLJ events were longer than 3 hours, with Lindenberg having more often shorter events of less than 1 hour. If very long NLLJ events (> 6 hours) occurred, they typically affected both places simultaneously, an indicative of their mesoscale character. Our results further suggest that very long NLLJ events are generated by the classical inertial oscillations, influenced by a large-scale horizontal pressure gradient and intermittent turbulent mixing, while shorter NLLJ events are more strongly dependent on local conditions or are driven by shorter-living density currents. Regarding their potential impact on wind turbines, we simulated wind power production for two different turbine types of different height and capacity. Both simulations indicate that NLLJs clearly increase the power production compared to nights without NLLJs. The quantitative NLLJ impacts on power production strongly depend on the height of the wind turbines: during NLLJ events the average wind production was 80% higher for a hub height of 135 m and only 53% higher for 94 m. At the same time, NLLJs increased the wind shear across the rotor layer. Extreme shear in the rotor layer was often associated with NLLJs, with 37% of all NLLJs leading to extreme shear and 48% of all extreme shear cases being caused by NLLJs. We infer from our assessment that particularly long NLLJ events

strong influence wind power production, while shorter NLLJs can increase the temporal and spatial variability in power production, causing power ramps.