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Article

The wake of a wind turbine and its influence on sound propagation

DIETRICH HEIMANN[1]*, YVONNE KÄSLER[1] and GÜNTER GROSS[2]

[1]Deutsches Zentrum für Luft- und Raumfahrt (DLR), Institut für Physik der Atmosphäre, Oberpfaffenhofen, Weßling, Germany
[2]Leibniz Universität Hannover, Institut für Meteorologie und Klimatologie, Hannover, Germany

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Abstract

The wake of a single wind turbine was measured with a Doppler wind lidar system during a night with a well developed low-level jet. Two meteorological microscale models with different model assumptions were applied to the same situation to generate consistent three-dimensional fields of wind components, turbulent kinetic energy and temperature. A three-dimensional ray-based sound particle model was used to simulate the propagation of the wind turbine noise into the downwind area. Two-dimensional sound propagation simulations were performed on the basis of the lidar measurements and three-dimensional simulations were based on the results of the meteorological models. Both meteorological models are capable of reproducing the main features of the measured wake flow. However, the results differ in many details from each other as well as from the lidar measurements. The acoustical model results show that the wake flow favours the sound propagation from the upper sources (aerodynamic noise at the wing tips near the crest of the rotor plane) towards the ground. The acoustical simulations also suggest a high sensitivity of the noise impact near the ground to differences between the simulated meteorological fields.

Zusammenfassung

Die Nachlaufströmung einer Windenergieanlage während einer Nacht mit einem ausgeprägten Grenzschichtstrahlstrom wurde mit einem Wind-Lidarsystems vermessen. Zwei meteorologische Mikroskalenmodelle mit unterschiedlichen Modellannahmen wurden auf die entsprechende Situation angewandt um konsistente dreidimensionale Felder der Windkomponenten, der turbulenten kinetischen Energie und der Temperatur zu erzeugen. Ein dreidimensionales, strahlenbasiertes Schallpartikelmodell wurde verwendet, um die Ausbreitung von Lärm des Windrades in den Nachlaufbereich zu simulieren. Zweidimensionale Schallausbreitungssimulationen wurden auf der Basis der Lidarmessungen und dreidimensionale Simulationen auf der Basis der meteorologischen Modellergebnisse durchgeführt. Beide meteorologischen Modelle waren in der Lage die Hauptmerkmale der gemessenen Nachlaufströmung wiederzugeben. Jedoch unterscheiden sich die Ergebnisse in vielen Details untereinander wie auch von den Lidarmessungen. Die akustischen Modellergebnisse zeigen, dass die Nachlaufströmung die Schallausbreitung von den höheren Quellen (aerodynamische Geräusche der Blattspitzen nahe des Scheitelpunkts der Rotorebene) hin zum Boden begünstigt. Die akustischen Simulationen deuten zudem auf eine hohe Sensibilität der bodennahen Schallimmission bezüglich von Unterschieden in den simulierten meteorologischen Feldern hin.

1 Introduction

Wind energy is a quickly growing business. According to WWEA (2009) the worldwide annual growth rate of the installed capacity is 31.7 percent with increasing tendency. Environmental problems associated with wind energy converters are mainly acoustical and optical nuisances. The wind reduction in the wake of wind turbines and the generation of turbulence impairs the energy yield of downwind turbines and has to be considered in the planning of wind parks. Moreover, larger wind parks may have an impact on the local climate. Therefore, many studies have investigated the wake flow of wind turbines by field measurements, scale-model measurements and numerical simulation.

An overview of wind turbine wake aerodynamics is given by VERMEER et al. (2003). Lidar measurements of the wake structure have been performed by BINGÖL et al. (2010), TRUJILLO et al. (2010) and KÄSLER et al. (2010). A survey on wind turbine wake simulation methods is provided by CRESPO et al. (1999). More recently, numerical large-eddy simulations (LES) have been published e.g. by WUSSOW et al. (2007), JIMENEZ et al. (2007) or TROLDBORG et al. (2010). LARSEN et al. (2008) have developed a dynamic wake meandering model (DWM), which can handle power and load aspects simultaneously. EMEIS (2010) has derived a simple analytical tool to assess the wake effects in wind parks as a function of ambient roughness and atmospheric stability. The impact of atmospheric stratification on the extension of wind turbine wakes and the associated turbulence intensity has been investigated by GROSS (2010) with a meteorological microscale model

*Corresponding author: Dietrich Heimann, Deutsches Zentrum für Luft- und Raumfahrt (DLR), Institut für Physik der Atmosphäre, Oberpfaffenhofen, 82234 Weßling, Germany, email: dietrich.heimann@dlr.de

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