

Low-Level Jet Climatology and Evaluation of Jet Induced Turbulence and Topographic Interactions Using Observations and High Resolution Modeling

The decoupling of the lower troposphere from the friction governed surface layer leading to the formation of a distinct maximum in the vertical profile of the horizontal wind speed, called low-level jet (LLJ), is one of the dominant nocturnal atmospheric boundary-layer processes over land areas. LLJs are also responsible for local transport of aerosols and water vapor, controlling the evolution of clouds and precipitation. Moreover, the associated high wind speeds and turbulent motions of LLJs are crucial to understand for wind energy applications.

In this study, LLJ periods are evaluated by exploiting long-term observations of a ground-based Doppler wind lidar supported by tower observations at the Jülich ObservatorY for Cloud Evolution (JOYCE), a mid-latitude site in western Germany. The continuous observations of over four years reveal LLJ presence in 13 % of the time. The LLJ climatology shows a clear diurnal cycle of LLJ occurrence and a prevailing nighttime appearance of the jets, with a median height of 375 m and a median wind speed of 8.8 m/s at the jet nose.

The Doppler wind lidar measurements can also be used to assess turbulent motions connected to the LLJs. Significant turbulence below the jet nose only occurs for high bulk wind shear, which is found to be an important parameter for describing the turbulent characteristics of the jets. The numerous LLJs (16 % of all jets) in the range of wind turbine rotor heights below 200 m demonstrates the importance of LLJs and the associated intermittent turbulence for the impact on wind turbines. Also, with additional eddy-covariance measurements, a decrease in surface fluxes and an accumulation of carbon dioxide are observed if LLJs are present, supporting the hypothesis of a decoupling between the surface layer and the lower troposphere.

For a comprehensive analysis of a single LLJ case the remote sensing measurements are complimented with high resolution large-eddy simulations (LES). The surrounding heterogeneous topography is dominated by an open pit mine and a 200 m high hill close to the site and the evaluation of the wind field indicates the presence of an orographic flow depending on the wind direction. This causes a high variability of the vertical velocity in the LES model field but also in the long-term measurements of the Doppler wind lidar.