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Large Eddy Simulations of Nocturnal Low-Level Jets over Desert Regions and Implications for Dust Emission

Bernd Heinold (1,2), Peter Knippertz (1), John H. Marsham (1,3)

(1) University of Leeds, School of Earth and Environment, Leeds, United Kingdom, (2) Now at Leibniz Institute for Tropospheric Research, Leipzig, Germany, (3) National Centre for Atmospheric Science, United Kingdom

The breakdown of nocturnal low-level jets (LLJs), which generates peak surface winds usually from morning to midday, is a key meteorological driver of dust emissions. They form at night due to frictional decoupling of air layers above nocturnal inversions. The wind maximum results from an inertial oscillation caused by the perturbed geostrophic-antitriptic balance. For example, the large pressure gradients related to the West African heat low in summer and stable nighttime conditions provide ideal conditions for LLJ formation in the Sahara. The quantification of the spatial-temporal distribution of mineral dust and its various effects are often largely based on model simulations. While global and regional dust models generally match the synoptic-scale dynamics well, the typical peak in surface wind speeds caused by the LLJ erosion is often not reproduced.

Here we present idealized LLJ simulations using the Large Eddy Model (LEM) of the UK Met Office. The model is initialised with observed surface temperatures, and characteristic profiles of potential temperature and wind speed. The high resolution of the LEM allows the computation of probability density functions for surface wind during the jet breakdown period. Sensitivity studies are performed to investigate the influence of surface roughness and latitudinal location/Coriolis force on the LLJ evolution. The model results are used to identify optimal latitude-roughness configurations for maximum LLJ enhancement of winds. Ideal conditions are found in regions between 20°N and 30°N with roughness lengths > 0.01 m providing long oscillation periods and strong ageostrophic winds. Typical LLJ enhancements range from 2 to 3.5 m/s, when geostrophic winds of 10 m/s are assumed. Applying this simple relationship to the Sahara shows a surprisingly good agreement with the location of morning dust source activations observed in satellite imagery. In the future, these findings will be used to develop a LLJ parameterization for global and regional dust models, which allows better assessment of the importance of LLJs for dust emissions.