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A climatology of Nocturnal Low-level Jets over North-Africa and implications for simulating mineral dust emission

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Mineral dust plays an important role in the Earth system. It interacts with radiation, affects cloud properties, has impacts on human health, and fertilizes both marine and terrestrial eco-systems. Time, location and amount of dust emissions are a key factor for simulating the mineral dust cycle and its impacts accurately.

The dust emission flux is a non-linear function of surface characteristics, and the momentum transfer from the near-surface wind to the ground. A process that potentially generates a sufficient momentum flux is the Nocturnal Low-level Jet (NLLJ), classically defined as a wind speed maximum in the residual layer that results from an inertial oscillation. The air above a nocturnal surface-inversion accelerates due to reduced dynamical friction, and forms a NLLJ. Momentum of the jet can be mixed downwards by both turbulence induced by vertical wind shear in the course of the night (intermittent turbulence), and by convective eddies during the following morning. Mineral dust is emitted when the increased near-surface wind speed exceeds the soil-dependent threshold velocity. While the breakdown of NLLJs has been suggested as a mechanism for dust emission in various publications, the importance relative to other processes in a statistical sense remains unclear.

This study is part of the European Research Council funded "Desert Storms" project. The work presents the first statistical analysis of the relevance of the NLLJ for dust emission in North Africa, the dominant dust source on Earth. A new objective detection for NLLJs has been developed in order to identify their typical spatio-temporal characteristics and the associated mineral dust emissions. The NLLJ identification algorithm is applied to 30 years (1979-2010) of 6-hourly "European Centre for Medium-Range Weather forecasts" ERA-Interim re-analysis on 60 model levels. Dust emission fluxes are calculated with the Tegen mineral dust model, which is driven by 10m-wind speeds and soil moisture from ERA-interim.

The spatially-averaged NLLJ frequency over North Africa ranges from 22% in Northern Hemisphere summer and 20% in autumn, to 26% in winter and spring. Typical standard deviations are 13-20% per season, reflecting the spatial variance. The areal distribution of the NLLJ highlights their frequent occurrence along the margins of the heat-low in summer, and in regions affected by mountain channelling like the Bodélé Depression, Chad, where NLLJs characterise 40-80% of the nights. Most frequent heights of NLLJs are 300-400m and the median core speed is 10m/s. The results point towards a relative contribution of NLLJ breakdowns to dust emission of 28+/-22% (mean +/- standard deviation) at 06 UTC and 42+/-18% at 00 UTC in the annual-mean over North Africa. The relative importance of NLLJs increases to annual-mean values around 70% in some of the regions, where NLLJs are more frequently occurring. In future work, this first NLLJ climatology for North Africa enables an evaluation of the representation of this phenomenon in state-of-the-art atmosphere models. It thereby holds the potential for improving the diurnal cycle of wind speed and dust emission in numerical weather prediction and climate models.