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Towards a Parameterization of Dust Devils for Weather and Climate models

Bradley Jemmett-Smith (1), Peter Knippertz (2), John Marsham (1,3), Carl Gilkeson (4), Siegfried Raasch (5), Maren Weismuller (6), and Fabian Hoffmann (5)

(1) Institute for Climate and Atmospheric Science, University of Leeds, Leeds, United Kingdom (b.jemmett-smith@see.leeds.ac.uk), (2) Institute for Meteorology and Climate Research, Karlsruhe Institute of Technology, Karlsruhe , Germany (peter.knippertz@kit.edu), (3) National Centre for Atmospheric Science, United Kingdom (J.Marsham@leeds.ac.uk), (4) Institute of Thermofluids,University of Leeds, Leeds, United Kingdom (C.A.Gilkeson@leeds.ac.uk), (5) Institute of Meteorology and Climatology, Leibniz University, Hannover (raasch@muk.uni-hannover.de)., (6) Institute of Geophysics and Meteorology, University of Cologne, Cologne (mweis@meteo.uni-koeln.de).

Mineral dust is a key constituent in the climate system. Airborne mineral dust forms the largest component of the global aerosol budget by mass and subsequently affects climate, weather and biogeochemical processes. There remains large uncertainty in the quantitative estimates of the dust cycle.

Dry-convective-vortices and non-rotating plumes of high winds (dust devils and dusty plumes) serve as effective mechanisms for dust uplift. These micro-scale boundary-layer phenomena occur over length scales of several hundred metres or less and are therefore unresolved by current weather and climate models. Their short lifetime and small scale make dust devils and dusty plumes difficult to observe routinely. Subsequently their contribution to the global dust cycle is highly uncertain.

One key contributing factor to this uncertainty is the lack of knowledge regarding the behaviour of dry-convective-vortices under different meteorological conditions and their subsequent impact on dust uplift. Limited observations from field campaigns provide some useful information, but recently our modelling capabilities have increased to a point, where realistic model simulations of dust devils and dusty plumes can be run on a relatively large domain to investigate this problem much more systematically. Here we use data obtained from world-leading high-resolution (2 m horizontal grid spacing over a 4 km^2 domain) large eddy model simulations of numerous dust devil-like vortices performed with the PALM model.

By measuring the effects of dry-convective-vortices on horizontal wind speed distributions, we show that dry-convective-vortices are the main source of dust uplifting winds within the mesoscale domain (when no mean background wind is applied). We then investigate the effects of different meteorological (background wind, surface heat flux) and surface conditions (inhomogeneities) on dry-convective-vortices and the subsequent impacts on horizontal wind speed distributions. These relationships will form the basis to develop a dust devil parameterization for use in weather and climate models.