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Vertical grain size distribution in dust devils: Analyses of in situ samples from southern Morocco

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1. Introduction

Dust devils are vertical convective vortices occurring on Earth and Mars [1]. Entrained particle sizes such as dust and sand lifted by dust devils make them visible [1]. On Earth, finer particles (<~50 µm) can be entrained in the boundary layer and transported over long distances [e.g., 2]. The lifetime of entrained particles in the atmosphere depends on their size, where smaller particles maintain longer into the atmosphere [3]. Mineral aerosols such as desert dust are important for human health, weather, climate, and biogeochemistry [4]. The entrainment of dust particles by dust devil and its vertical grain size distribution is not well constrained. In situ grain size samples from active dust devils were so far derived by [5,6,7] in three different continents: Africa, Australia, and North America, respectively. In this study we report about in situ samples directly derived from active dust devils in the Sahara Desert (Erg Chegaga) in southern Morocco in 2012 to characterize the vertical grain size distribution within dust devils.

2. Data and Methods

For our analysis two different dust devils on April 22 in 2012 were sampled. Dust devil #1 was relatively strong and had a diameter of ~15 m. Dust devil #2 was weaker with a diameter of ~4-5 m. The investigated dust devils were manually sampled vertical in heights up to 4 m, in intervals every 50 and 25 cm, respectively. We used screwable aluminium pipes prepared with sticky tape on one side. This sticky side was held in wind direction into the dust devil. After the passage of the dust devil, the sticky tape (pasted with grains) of different sample heights were directly prepared on glass object holder, avoiding the sample from disruptions. These in situ samples were analysed in the laboratory with an optical microscope (200x magnification). All particles within a sample area of 1 cm^2 were measured with the software package "Analysis". Grains sizes were classified after the grain size classification of Wentworth [8]. The following results are only referred to samples of dust devil #1.

3. Results

Fig. 1 shows the sampling of the dust devil #1. Notice the person (author) for scale, who is sampling the dust devil. Fig. 2a shows the number of grains (n) versus height (m) of the samples. The largest amount of grains (~37%) was sampled within the first 50 cm, which represent the sand skirt of the dust devil. The sand skirt consists mainly of grains with the largest diameter (Fig. 2b), which cannot lifted in upper heights.

Fig. 1: Photo of the sampling of the investigated dust devil.

This behaviour is also visible in Fig. 3d, where sand grains in heights above 1 m are only minor components (~33%). In heights between 1 and 4 m the number of grains (between ~1000 and ~1500 µm, ~10% of total grains per sample height, Fig. 2a) and maximum diameter (between ~300 and ~500 µm, Fig. 2b) is relatively constant. Fig. 2c represents the relative weight (%) of all measured grains within the sample area (one cm^2) versus the height. It is obvious that most material was lifted only into heights of 10 cm (~42%) and less into upper heights. Fig. 2d represents the mean value and median of grain sizes versus height. Also these results show that the mean value of diameter of grains decreases with height. The median values give a more representative information. At about 2 m height the median grain size is around 10 µm.

Fig. 3 shows the distribution of grain sizes in different heights in detail, grouped in clay (<4 µm), silt (4-<63 µm), and sand (63-<500 µm) after [8]. Notice the decrease of sand grains with height. Fig. 3b shows the distribution of clay, which is very irregular and shows no clear trend. The distribution of silt is also irregular, but with more medium and coarse silt within the first meter of sampling (Fig. 3c). Sand (Fig. 3d) decreases with height in all grain size classes. Most sand grains (primarily the largest measured sand sizes) are lifted only into heights of approximately 1m.

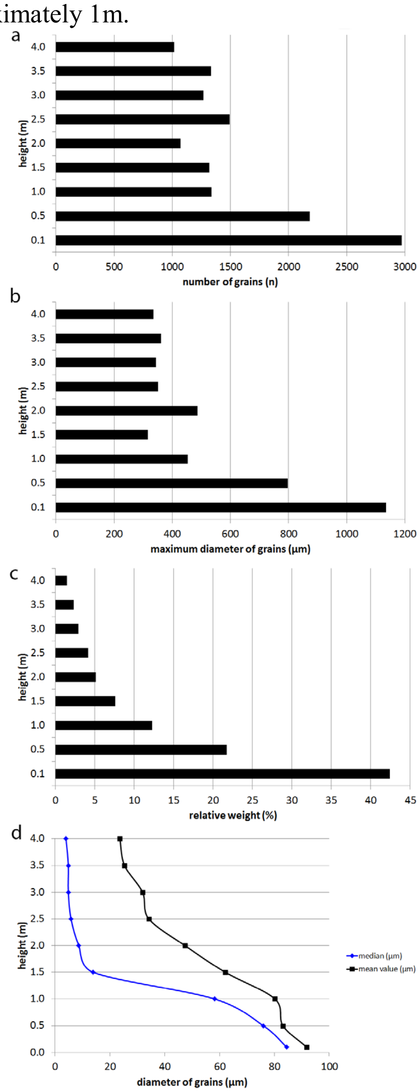

Fig. 2: All measurements were conducted on one cm² of the sample sticky tape. (a) Number of grains versus height. (b) Maximum diameter of grains versus height. (c) Relative weight of grain sizes versus height. (d) Mean and median value versus height.

4. Discussion

In situ measurements presented in this work show that most of the material were only transported into heights of approximately 1.5 m. Sand grain measurements imply the presence of a sand skirt with a height up to 0.5 m. Fine material under 10 µm (PM10) can be suspended into the atmosphere [7], also indicated by high values of clay and silt in heights up to 4 m. The results presented here are comparable to the measured dust devil #2, which is not presented in this abstract. Our measurements are also comparable to in situ samples derived by [6]. Methods to sample material in situ of a dust devil are very similar, but [6] classified the samples into different particle sizes (they use the standard Australia classification), which made a direct comparison difficult.

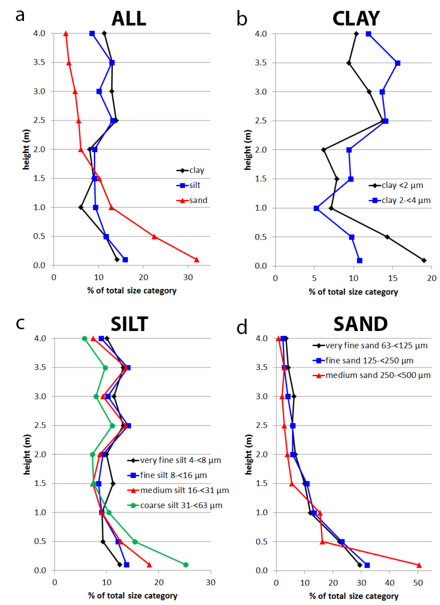

Fig. 3: Detailed analysis of distributions of different grain size categories (classified after [8]).

[6] sampled particles with a diameter >6 µm into heights up to 1.6 m. Coarser material (medium sand) in this work has the same behaviour as in [6] (Fig. 3d). Finer material (silt and fine sand) [6] are comparable to results of our work (Fig. 3c and d). Results from [6] as well show that most of the lifted material was sampled in the first decimetres from the surface, indicating the presence of a sand skirt. Variations in silt distribution between 2 and 4 m of silt (Fig. 3c) probably represent turbulences within dust devils.

5. Acknowledgements

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6. References

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