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A simple model of a dust devil vortex with thermodynamically active dust

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The dust devil exhibits an interesting though sometimes potentially hazardous atmospheric phenomenon. On Mars, dust devils are much bigger and stronger than on Earth and they serve as one of the principal mechanisms of dust transporting into the Martian atmosphere, thus influencing the general circulation and climate on that planet. In this communication, we report on a steady generalized Rankine vortex model of a dust devil, which takes into account the sunlight absorption by airborne dust particles and diabatic heating of the rotating dust column. For 'swirl ratios' S (the maximum swirl velocity divided by the mean updraft velocity) exceeding 3 the model admits significant simplifications, which allow for its complete analytical treatment in terms of standard functions of mathematical physics. The competitive effects of (i) surface heat fluxes and (ii) suspended-dust-caused diabatic heating on the vortex constitution (strength, height and shape) are analyzed. The second factor is found to be more influential for the strongest vortices, at least when $S>3$. It is hypothesized that for such strong vortices the surface heat fluxes predominantly specify a larger thermal, in which the dust devil is embedded, whereas the sunlight absorption by dust is more important for the specification of the dust devil vortex per se. The vortex radius near the ground does not explicitly enter the model results but remains a free parameter whose value in nature is specified by a set of external random factors, e.g. by the environmental vorticity. General arguments from mathematical information theory are invoked to introduce a negative-exponential distribution of dust devil vortices with respect to their radius (visible diameter), which proves to fit satisfactorily well the observational data on dust devils in Arizona and southern California (USA) and also agrees with some preliminary observational statistical results on Martian dust devils.