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# Modeling Electric Fields Generated by Martian Dust Devils

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## Abstract

The particles present in Martian dust devils are subject to triboelectric charging and likely contribute to electric field generation in Martian dust devils. Electric fields in excess of 100 kV/m have been measured in terrestrial dust devils, but no such measurements have yet been made on Mars. Triboelectric dust charging physics via the Macroscopic Triboelectric Simulation (MTS) code has been coupled to the Mars Regional Atmospheric Modeling System (MRAMS) in order to simulate the electrodynamics of dust devils on Mars. Using this model, we explore how macroscopic electric fields are generated within dust disturbances and attempt to quantify the time evolution of the electrodynamical system. This research was supported by the Mars Fundamental Research Program, NASA Grant NX07AR69G.

## 1. Introduction

Dust charging studies with Mars soil simulant [1,2] suggest triboelectric charging of dust is very possible on Mars. A typical terrestrial dust devil has been found to generate macroscopic electric field perturbations in excess of 100 kV/m [3]. Once charged, some of these grains are injected further into the air where they are transported upward by atmospheric currents. Differential transport and gravitational sedimentation sorts the dust devil aerosols so that the lighter and predominantly negatively charged particles populate the higher portion of the disturbance while the heavier, positively charged particles fall to the ground or remain in the lower portion of the vortex.

## 2. Modeling

MRAMS is a nonhydrostatic model which permits the simulation of atmospheric flows of large vertical accelerations, such as dust devils. Dust particles are represented by discrete mass bins; each bin is carried in the model as a scalar species that can be advected and diffused. The dust lifting scheme includes multi-size dust transport capability. The dust surface source is parameterized based on the work of [4,5]. Laminar wind and dust devil lifting are implicitly included in this single scheme. Dust devils occupy the tail end of the Weibull distribution in unstable (Ri<0) conditions. MTS quantifies charging associated with swirling, mixing dust grains. Grains of pre-defined sizes and compositions are placed in a simulation box and allowed to move under the influence of winds and gravity. The model tracks the movement of grains in prevailing winds and charge exchange upon grain-grain collision. The composition of the grains is also a predefined variable and we impose a compositional mix to maximize the triboelectric surface potential difference between larger and smaller grains. Specifically, we apply the grain/grain contact electrification algorithm presented in [6]. Information describing each MTS dust particle (i.e., charge, radius, and mass) are fed into the MRAMS dust lifting scheme for each MRAMS model grid-point. The coupled model enables the ability to simulate charging with a fully dynamic model in a manner that allows the wind field, dust distribution, and charging to be physically consistent.

## 3. Dust Devil Simulation Results

The coupled model is run over a 15 km x 15 km domain up to a height of about 8 km. Once dust devils begin to form, a subsection of the model domain is run with grid nesting allowing for 33 m resolution in the xy-plane. This makes our results most sensitive to dust devils which are a few 100 m in diameter. The dust particle population (as defined by the MTS simulations) is composed of smaller, negatively charged particles ranging in radius from 0.5 – 2 $\mu$m, with most particles having a radius of 1 $\mu$m; and larger, positively charged particles of 2 – 100 $\mu$m in radius, with the peak of the size distribution at 4 $\mu$m. Simulations with these size distributions shifted up by a factor of 10 are also considered. The charge on individual particles ranges from about $10^{-18}$ to $10^{-13}$ C. The negatively charged particles outnumber the positively charged particles at a ratio of 3:1, but the entire population of the surface dust reservoir is net neutral. The atmosphere is initialized using temperature and wind profiles from a Viking 1 landing site LES model at approximately 10:00 LMST. Dust devils are observed about 1.5 hours into the simulations.

A number of simulations have shown that the electric fields generated within the dust devils vary in strength due to three main factors: size of the dust particles, the average charge density, and the number of dust particles in the atmosphere (controlled by the lifting efficiency of the dust particles). Depending on these factors, dust devils can create short-lived electric fields ranging from millivolts per meter to a few kilovolts per meter. A dust devil with one of the strongest electric fields generated is shown in Figures 1 and 2.

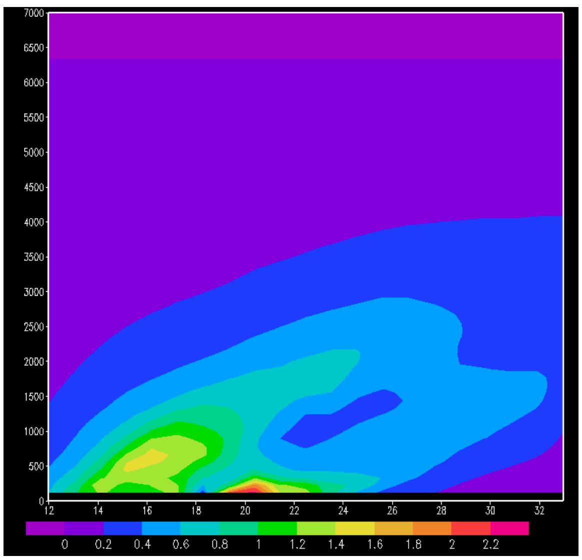


Figure 1: Electric field in a vertical slice tracking the dust devil core. Colored contours are magnitude of the E-field in kV/m. The E-field values shown are what an observer moving within the dust devil at the minimum pressure point would see over the lifetime of the dust devil. Altitude values are in meters. The x-axis indicates time at 30 second output frequency (10.5 minutes shown).

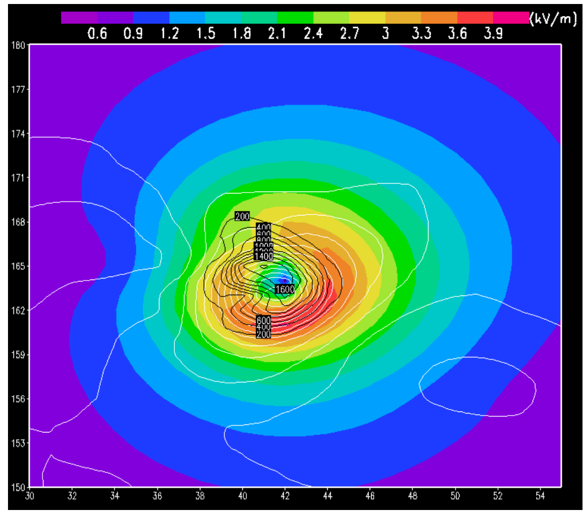


Figure 2: A horizontal slice (approx 1 km by 1 km area) near the surface showing the electric field (kV/m) magnitude corresponding to time= 20 in the previous figure. The white (pressure) contours show the location of the dust devil center (x=42,y=163).

# References


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