Electrical activity and dust lifting on Earth and Mars

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1. Summary

- We study the physics of wind-blown sand and dust lifting on Earth and Mars, with emphasis on the possible role of sand electrification. We developed a physically based model of wind-blown sand, or ‘sailface’ that includes the effects of sand electrification (Kok and Renno, 2008). The model was tested with measurements in terrestrial saltation.

- On Earth, we predict that electric fields sufficient to directly lift sand grains from the surface can be generated. By including sand electrification in the model, we resolved a puzzling discrepancy between measurements of wind-blown sand and classical theory (Kok and Renno, 2008). This is illustrated in Fig. 5.

- We predict that electric discharges may occur in Martian saltation. This is consistent with recent discovery of electric discharges in Martian sand storms by our group (Renu et al., 2008; Ruf et al., 2008).

- Near-surface electric fields on Mars can be much larger than the ~25 kV/m that was assumed in previous studies, and can in fact be large enough to lower the threshold wind stress required to initiate saltation. Large near-surface electric fields also have potentially important implications for atmospheric chemistry.

2. Background

2.1. What is saltation?

Saltation is the main source of dust aerosols on Earth and Mars. Saltation plays a key role in many geological processes on Earth and Mars.

Large electric fields can be generated in saltation. These electric fields affect dust lifting and atmospheric chemistry and may be large enough to cause electric discharges on Mars.

3. Electric fields in saltation

- Charge is transferred during particle collisions in saltation. The smaller particles charge negatively with respect to the larger particle (e.g., Inculet et al., 2006).

- Thus, dust particles hold negative charge, and the surface (an infinitely large particle) holds positive charge. Saltating sand particles can be either positively or negatively charged, depending on the relative frequency of collisions with dust and the surface.

- The predicted charge distribution in saltation, dust storms and dust devils is shown in Fig. 2.

- Sand/dust electrification can generate electric fields in excess of 10 kV/m (Stowe, 1969; Schmidt et al., 1998; Jackson and Farrell, 2006).

4. Physically based numerical model of saltation

- Our model accounts for: Feedback of particle motion on wind profile.

- Particle collisions with surface.

- Lifting of particles from the surface.

- Sand electrification (first physical model to include this).

- Our model is the first physically based model that can reproduce measurements of the particle mass flux in saltation (see Fig. 3).

- The emission and charging of suspended dust and electric field intensity.

- Predicted electric fields are lower estimated.

- Saltation is initiated when the wind shear stress exceeds the threshold to move surface particles. The wind shear velocity u' = (gh)1/2 is an often-used measure of the wind stress (h is air density).

5. Results: Electrification On Earth’s saltation

- A profile of the electric field predicted for Martian saltation is shown in Fig. 6. The breakdown field (blue line) and the Paschen’s law shows that near-surface fields can far exceed the ‘traditional’ breakdown field of ~25 kV/m (dashed line in Fig. 6) assumed in previous studies (e.g., Melnik and Parrott, 1998; Atreya et al., 2006).

- Electric fields in saltation can be strong enough to cause electric discharges (Fig. 7). This is consistent with recent discovery of electric discharges in Martian dust storm (Renno et al., 2008; Ruf et al., 2008).

- The large near-surface electric fields could have important implications for atmospheric chemistry, including the production of large quantities of hydrogen peroxide (Atreya et al., 2006), a powerful oxidant that could make the Martian surface inhospitable to life as we know it.

- The large surface electric fields can facilitate dust lifting by lowering the threshold wind stress required to move surface particles (see inset of Fig. 7 and Fig. 8).

6. Conclusions

Sand electrification has broad implications for Earth and Mars!

- We developed the physically based model of saltation that includes sand electrification and reproduces field measurements of the mass flux of saltating particles.

- We find that the inclusion of sand electrification is necessary to explain measurements of the particle mass flux in saltation. Furthermore, we find that electric fields in saltation on Earth can be strong enough to lift surface particles. This effect approximately doubles the concentration of saltating particles at wind high speeds.

- On Mars, much larger electric fields than previously assumed can be generated. This has potentially important implications for atmospheric chemistry and dust lifting.

Future Work

- We designed and built a miniature sensor to measure electric fields in saltation on Earth and Mars (Fig. 9, Renno et al., 2008).

- We will further test our saltation model against measurements of electric fields with this sensor.

7. References


