Modeling the electric field induced by charged dust particles on Mars

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Scientific context/background

Mineral dust is a crucial agent in the Martian environment, and the dust cycle is the main climatic forcing at all time scales. The atmospheric vertical structure, variability, and the transport of aerosols and chemical species are all strongly dependent on the dust spatio-temporal distribution, yet the understanding and modelling of such distribution lacks a comprehensive physical representation, or parameterisation.

In the process of dust lifting from the surface, saltating particles ("sand") and dust electrically charge via triboelectric effects. The electrification occurs even during same-material collisions (Lacks & Levandovsky, 2006). Measurements indicate that, on average, the larger particles (sand) becomes positively charged and tend to be confined closer to the ground with respect to the smaller particles aloft (dust), see e.g. Renno & Kok (2008) and references therein. Airborne dust is vertically transported in the boundary layer, for instance by dusty deep convection, thus the separation of charges can create large electric fields. Among the effects of such electric fields there is the possible positive feedback on the dust lifting, which could be strongly enhanced (Kok & Renno, 2006, 2008). There might also be effects on the sedimentation, which would affect the life cycle of dust storms, but these have not been explored systematically yet. More recently, theoretical research on the lower Martian ionosphere suggests suspended atmospheric dust particles can be charged by photoionization by solar UV radiation and indirect effects of ionization by galactic cosmic rays (Cardnell et al., 2016)

The charging mechanism of Martian dust particles is currently lacking a proper scalable physical parameterisation, which could be used in numerical models at different resolutions. If this mechanism was introduced in Mars Global Climate Models (MGCMs), it could have the potential to significantly improve the capacity to reproduce the spatio-temporal statistics of the observed dust cycle, the dynamics of dust storms, and the distribution of electric charges. Currently, the possibility of electric discharges on Mars, which has been theorized (Renno et al., 2003) and recognized as significant for surface chemistry and exobiology (Atreya et al., 2006), still remains controversial after a series of observational campaigns (Ruf et al., 2009, Anderson et al., 2011).

Despite the current lack of in-situ measurements of the electric field on Mars (ESA's "Schiaparelli" lander was carrying an electric field probe in 2016, but it unfortunately crash-landed), the community of Mars scientists and engineers recognizes that the study of the electrical properties associated to dust is medium to high priority for both Goal II (climate) and Goal IV (human exploration) of the Mars Exploration Program Analysis Group (MEPAG) Goals document (Banfield et al., 2020).

Project objectives

This PhD projects seeks to:

- Review the most recent literature on the distribution of charge associated to triboelectrification of different Mars dust analogue size distributions, including results from laboratory experiments (e.g. Aplin et al., 2012), as well as photoionization by solar UV radiation and indirect effects of ionization by galactic cosmic rays;
- Couple a physical parameterisation of the triboelectric charging of dust particles (and possibly of the charging by direct photoionization/indirect attachment of charges induced by galactic cosmic rays) to a model of dust lifting, transport and sedimentation (i.e. the "dust cycle") in a state-of-the-art Mars GCM. For this project, it is planned that the French Laboratoire de Météorologie Dynamique (LMD) MGCM will be the reference model;
- Carry out a numerical study of the spatio-temporal statistics of neutral and charged dust and electric field distributions;
- Compare the modeled dust statistics to currently available observed statistics and future statistics from the Emirates Mars Mission, in order to understand whether electric effects may have an impact on the dynamics of dust storm (e.g. affecting dust lifting parameters and consequently the ability of the model to reproduce the observed dust distribution);

Candidate profile

For this project, we seek a PhD student who has the following profile:

- MSc in Physics, Mathematics, Space Science, Astronomy, Astrophysics, or similar.
- Strong interest in theoretical and numerical studies applied to Physics. Familiarity with Mars science is not required, but an interest in Mars science is obviously desirable.
- Some familiarity with numerical programming (some knowledge of Fortran language is desirable, as this is the language of the LMD-GCM. Some knowledge of Python language is also desirable, as this is likely the language used for analysis of the numerical results).
- Proficiency in written and oral English.
- Willingness and capacity to work both independently and as part of a small team, even at distance if necessary.
- Availability to travel abroad for possible research collaborations (e.g. to France), and to attend worldwide workshops and conferences.

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