The SANDEE campaign: Electrical effects during sand transport by aeolian processes in the Negev desert and implications for Mars

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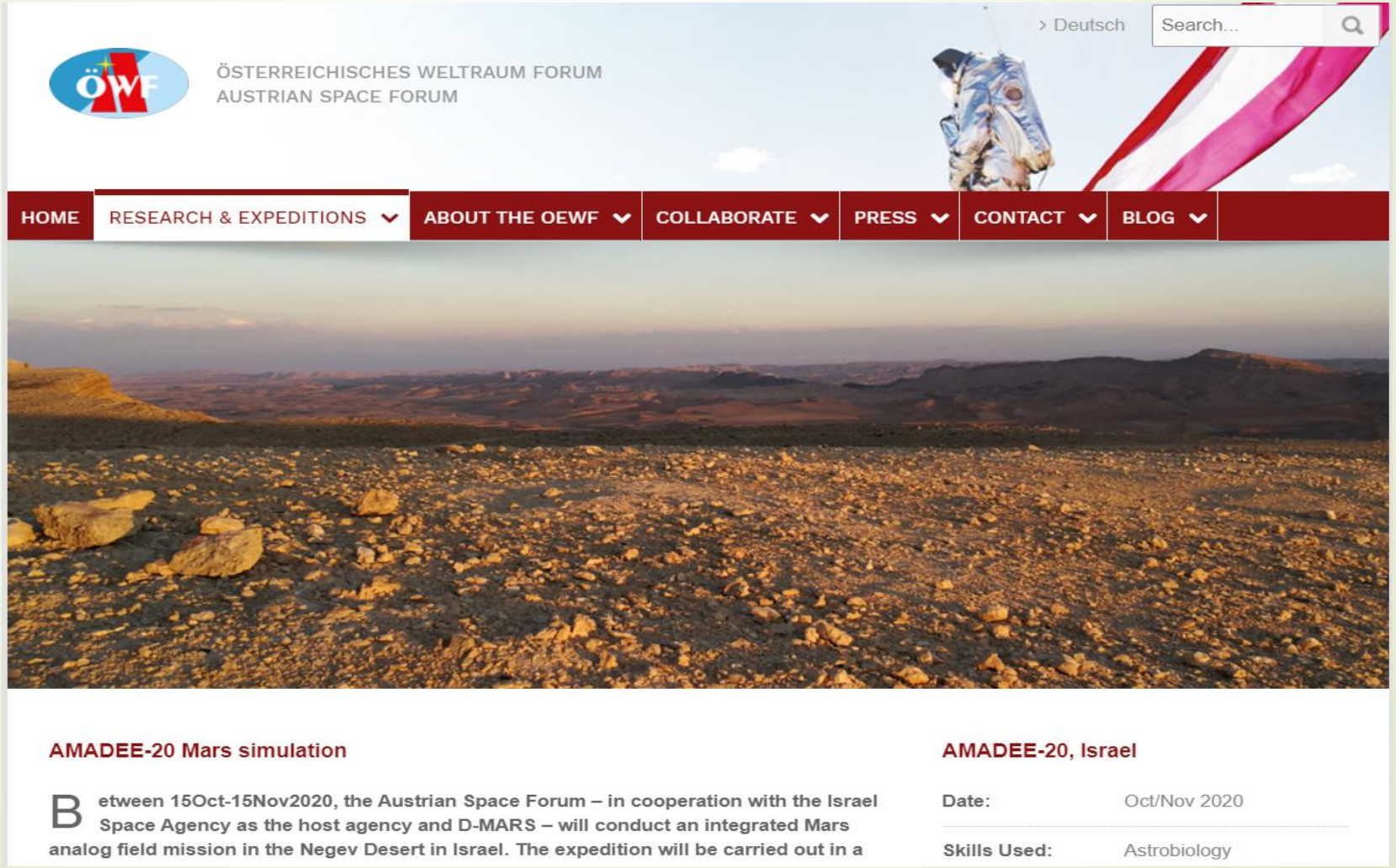
The AMADEE-2020 Analog Mission by OeWF Negev desert, Israel, October-November 2020



Scientific goals of SANDEE

- Explore the effect of dust aerosols on the ambient electric field using a portable wind-tunnel
  - Dependence of E on wind-speed
  - Dependence of E on dust type
- Search for optical signatures of corona discharges (night)

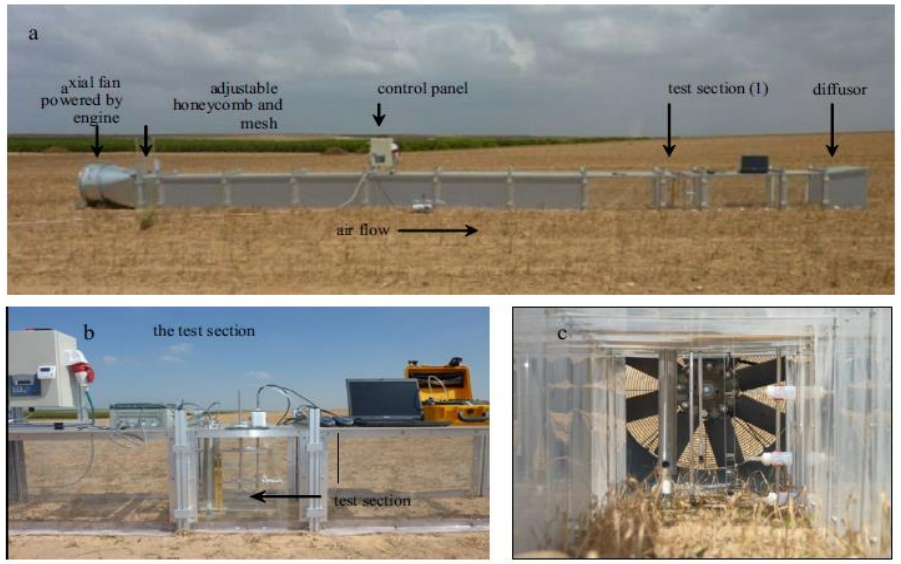


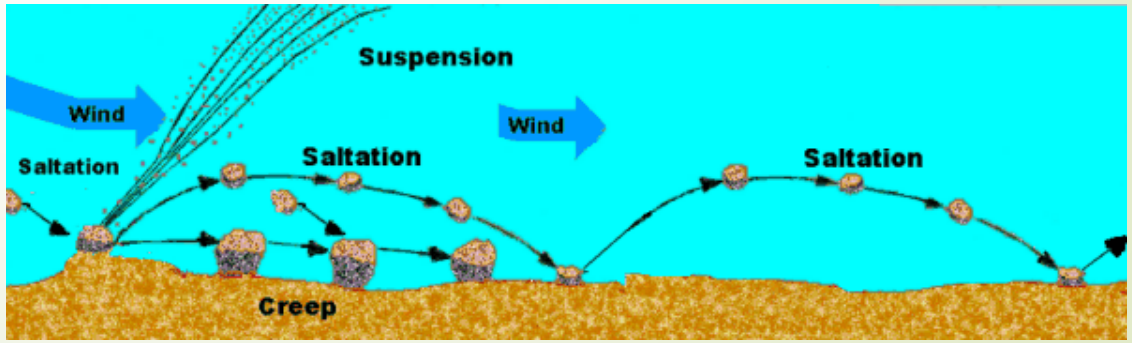
Fig. 3. The portable wind tunnel for field experiments on dust emission processes (Tanner et al., 2016). The tunnel segments are shown in the air-push configuration on a loess agricultural field (a). The cross sectional area is 0.5 × 0.5 m^2 and the test section length is up to 10 m (b). Instruments installed in the test section (c).

Dust electrification is common

- The mass flux of dust increases ~ square of the wind shear velocity (Shao and Lu, 2000)
- Above a certain wind velocity threshold (Ette, 1972) we observe rapid electrification of the lifted aerosols
- The charged dust particles aloft induce strong electric fields below
- The charged aerosols are neutralized through repeated collision–coalescence interactions

Size/Polarity/Humidity issues

- The electric field in wind-blown sand is (mostly) upward-pointing since the small particles saltating in air are usually negatively charged, while the large particles creeping on the soil surface are positively charged
- Compositional dependence – bedrock /aerosol
- Diffusional Charging aloft -> Steady State
- Contact electrification is eliminated at RH=0 % and rises to a maximum at RH=30–40% (ion exchange model, Diaz and Felix-Navarro 2004)

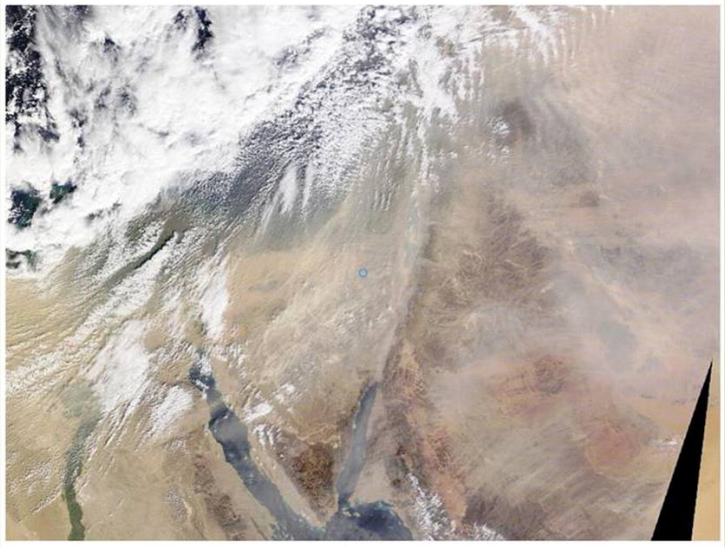


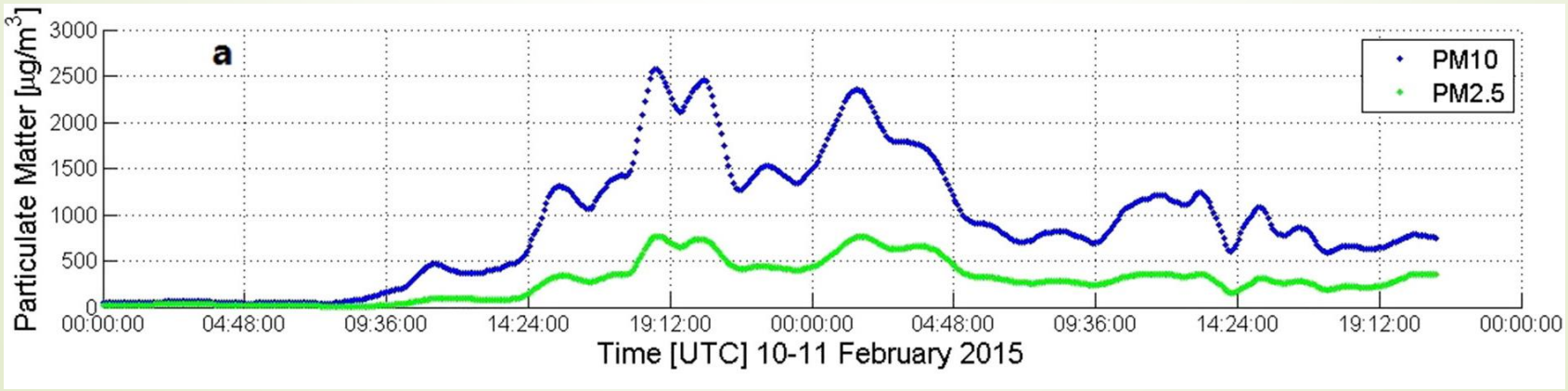
Haboob and Dust Devils

Dust Devils are turbulent vertical small-scale storms caused by sharp local instabilities (*like funnel clouds in tornado).

Negev desert and Mt. Hermon Stations

2 m CM10 Tripod Configuration[2]			
Accuracy	±5% of reading + 8 V m^{-1} offset[1]		
Measurement Range[3] (V m^{-1})	Resolution (V m^{-1})	Sensitivity (µV/V m^{-1})	Noise (V m^{-1} RMS)
±(0 to 2,200)	0.32	1.2	0.42
±(2,200 to 22,300)	3.2	13	1.9

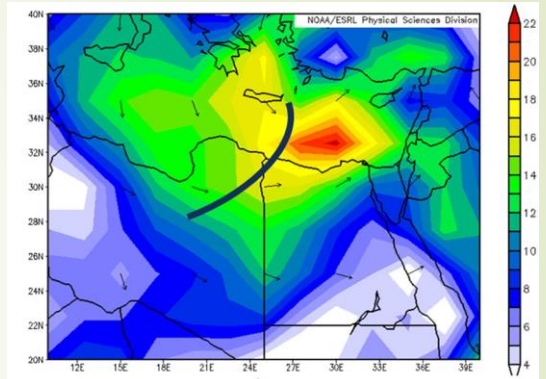




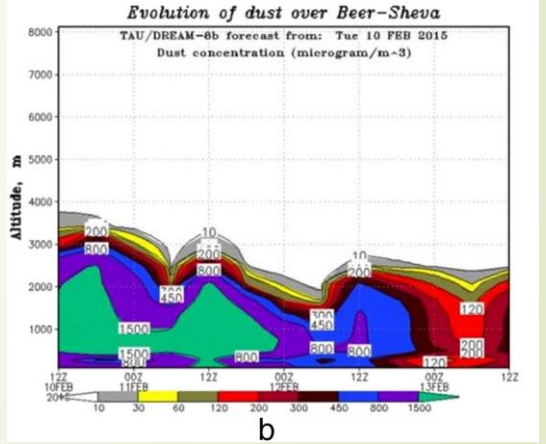
Dust storm 10-11 February 2015 (Yair et al., 2016)

Back-trajectory analysis for the air-masses that reached the Sde-Boker AERONET station on February 10th–11th 2015. (HYSPLIT to February 6th, 2015). Deep purple is for 950 hPa, light purple is 850 hPa and light blue is at 700 hPa

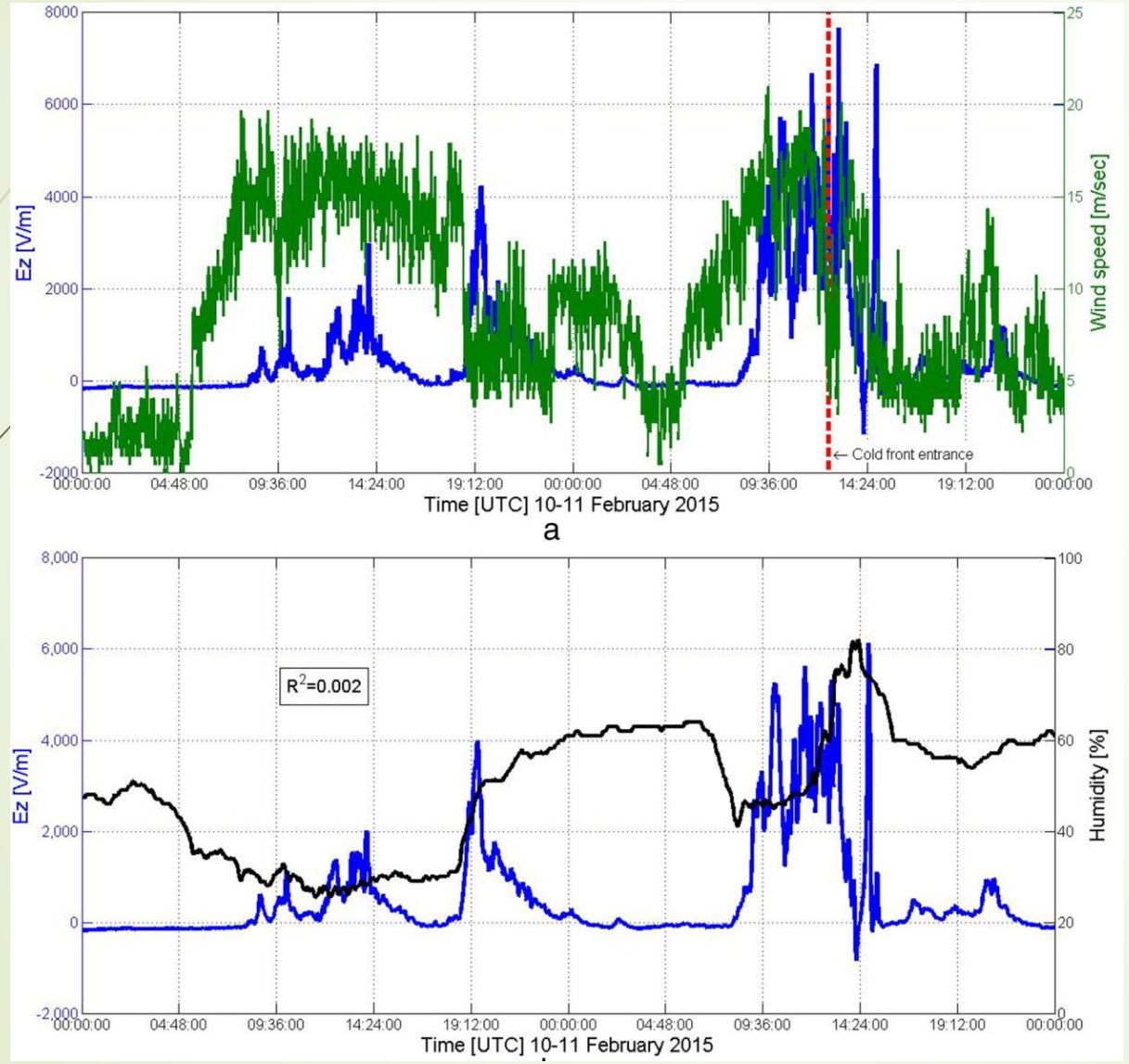
Wind velocity field at the surface for February 10th, 12 UTC.



Dust forecast over the city of Be'er Sheba from the TAU/Dream model



(Top) The vertical electric field (V m^{-1}) and wind speed (m s^{-1}) for the 48 h starting at February 10th 00 UT. (bottom) The vertical electric field (Ez) vs. the relative humidity.



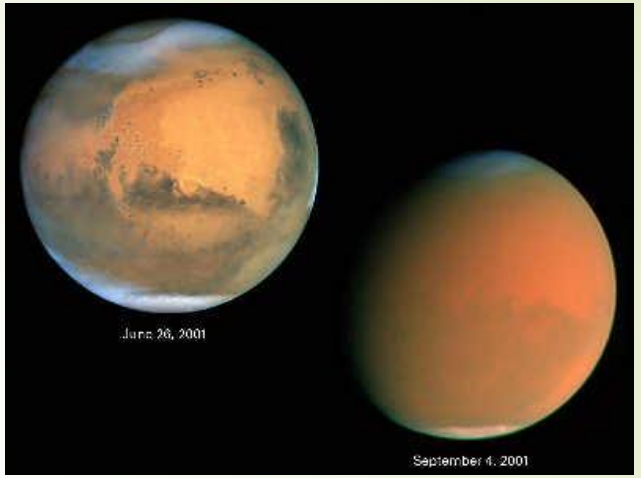
Passage of cold front – wind intensification and strong electric fields

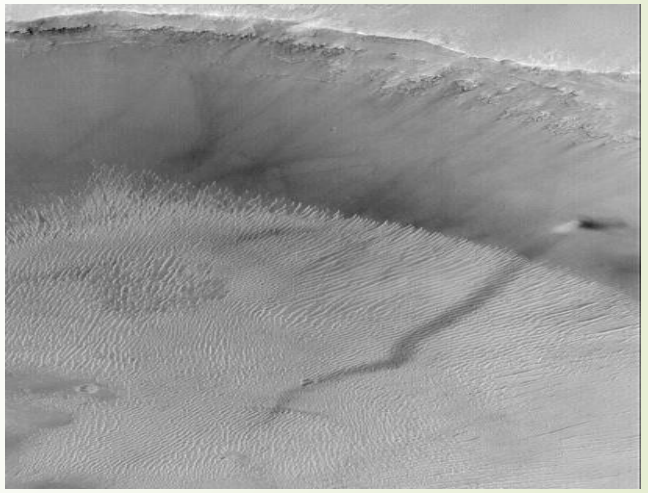
Positive Field (Ez) =negative charge aloft

Episodes of strong electrification coincide with low values of the relative humidity

Mars dust storms & devils

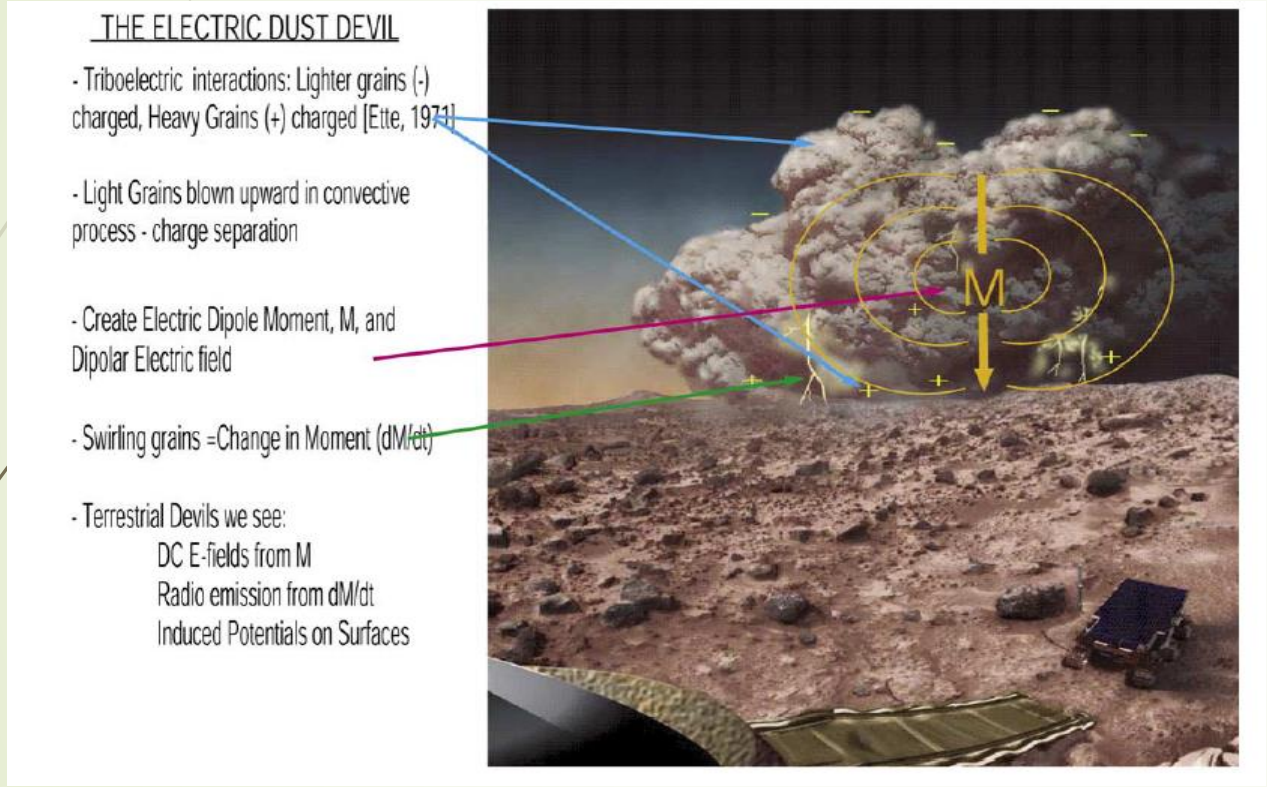
- Dust storms occur mainly by aeolian processes, stronger in regions of slopes and near the polar caps.
- Dust particles suspended in air acquire charge by tribolelectric interaction with other particles (friction charging).
- Triboelectrric charging depends on:
  - Size and composition of interacting particles
  - Frequency of collisions





Dust devils are bigger and stronger than on earth: reach up to 7 km and have diameters 100m -1 km.
Martian dust devils are 700 times more dense in dust particles than the ambient atmosphere

Evidence for Martian Dust Electrification? (Farrel et al., JGR, 2004)



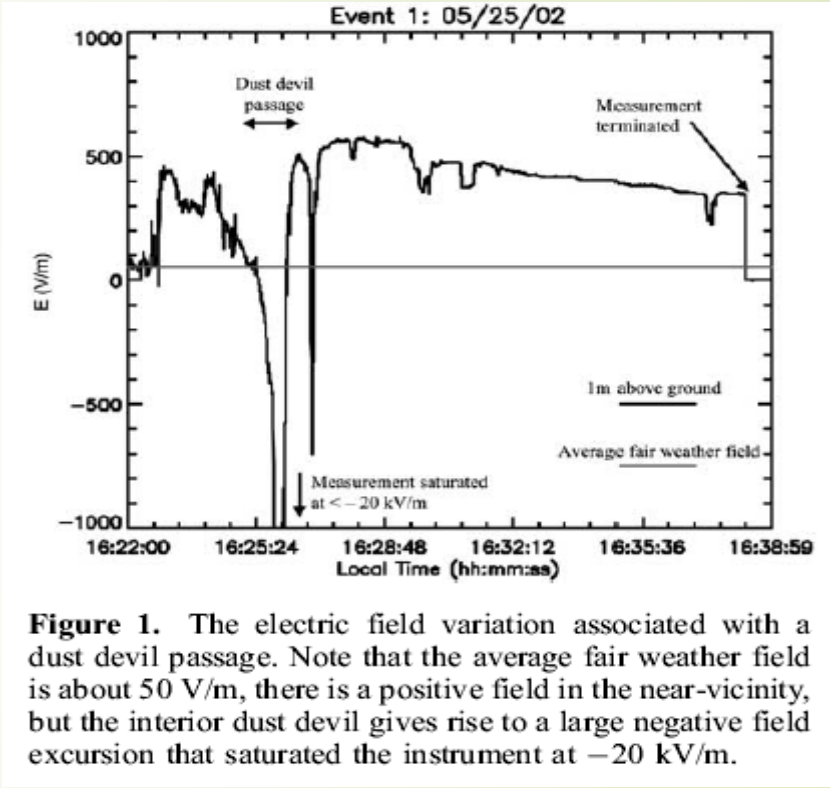
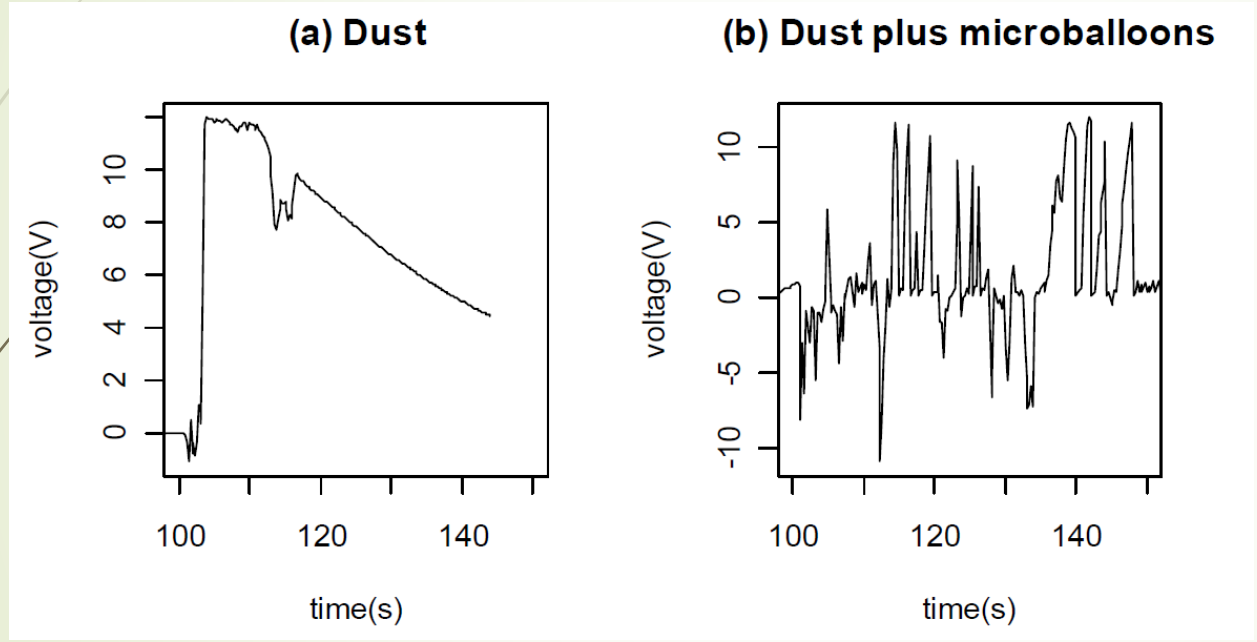
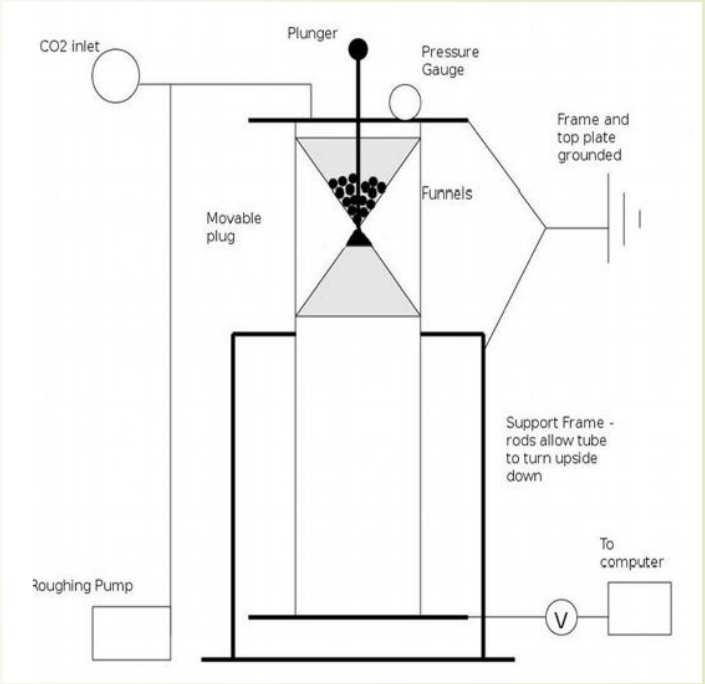


Figure 1. The electric field variation associated with a dust devil passage. Note that the average fair weather field is about 50 V/m, there is a positive field in the near-vicinity, but the interior dust devil gives rise to a large negative field excursion that saturated the instrument at −20 kV/m.

- To date, there are no direct measurements of electrical activity on Mars. Laboratory experiments show that dust grains in a Martian-like chamber acquire significant charge

Laboratory experiments in Mars dust analogues (Aplin et al., 2011)

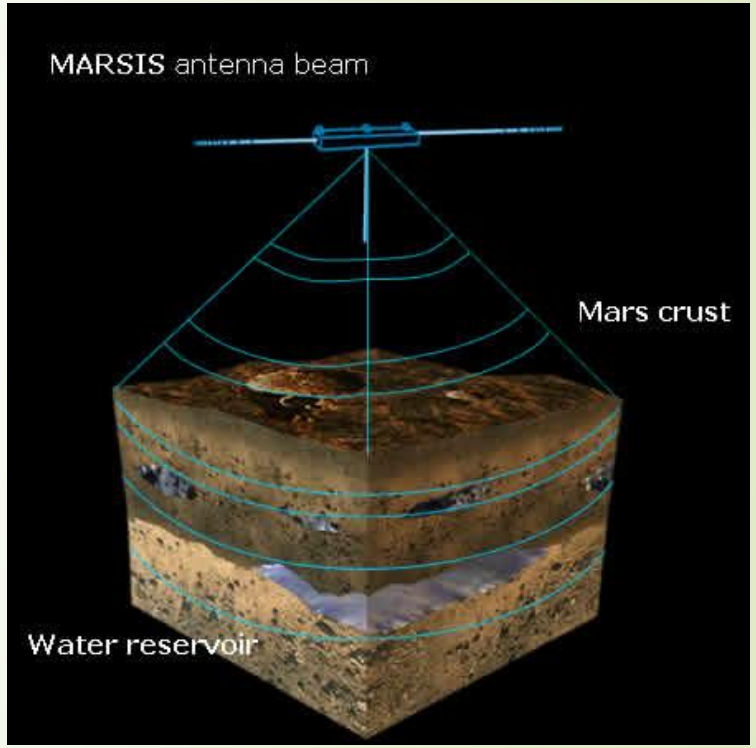




- Simulated triboelectric charging in dust collisions with Mars soil composition occurring in 9 mb of CO_2. Though charging is evident, wall effects cannot be excluded

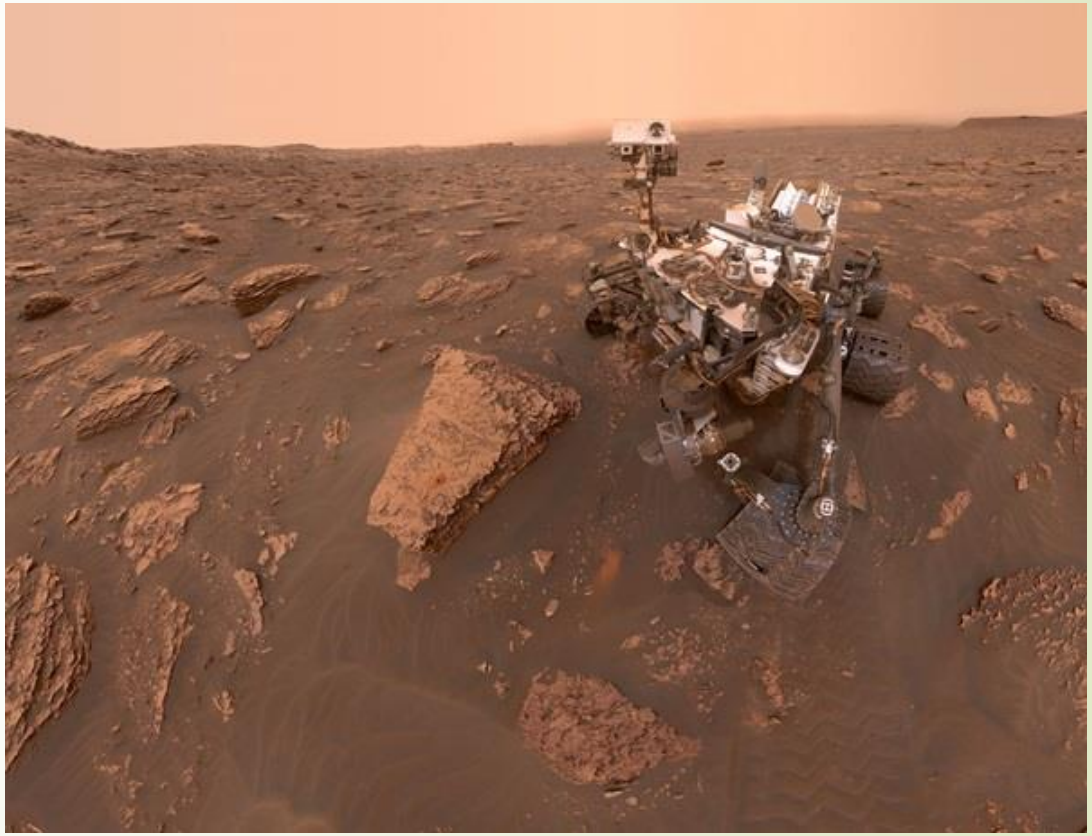
Detection of impulsive radio signals from Mars (Granroth et al., AGU, 2018)

- Mars Express MARSIS looked for impulsive radio signals from electrical discharges within Martian dust storms.
- The search covered ~ 8 years of data and spanned altitudes from 275 km to 1400 km and frequencies from 4.0 to 5.5 MHz, with a time resolution of 91.4 μs and a detection threshold of 2.8×10^{-18} Watts m^{-2} Hz^{-1}.
- Only 25 single-pixel events were found that exceeded the detection threshold. This is out of a total of 1.01×10^{9} single-pixel measurement.
- **Electrical activity maybe rare, or weak (or none-existent).** [Fischer et al., 2016]



Implication of (electrified) dust storms on Mars to spacecraft and lander operations

- Astronaut Health
- Communication
  - Space-ground
  - [Future] Habitat-crew
- Visibility limitations
  - Maneuverability
  - Mobility and navigation
- Command and control
  - EVA
  - Robotics
- Solar energy
  - Coating
  - Diminished output
- Ablation of lander surfaces



Credits: JPL/NASA

Measured quantities by analog astronauts

- Wind profile
- Saltation flux
- Dust concentrations [PM10 and PM2.5]
- Electric Field
- Optical emissions (night)

Image credit OSF

Wind tunnel construction & operation

- Easy construction/dismantling – 30 minutes (5 meters)
- Several sessions – each at a different speed, 5 minutes each
- With / without dust
- Total duration – 1.25 hours (in darkness, probably longer)

Expected significance

- In-situ outdoor measurements of dust effects on electrical parameters
- Wind velocity thresholds for electrification for earth and Mars soils
- Nocturnal detection of corona discharges (First!!)

Problems and Fallbacks

- Tunnel operation / malfunctions
- Suit operations - E-field data collection on EVAs
- Sample collection -> manual options

Present Status of SANDEE

1. Data acquisition chain – proven
2. Full configuration – To be tested as soon as university campus is opened
3. Mars soil sample – 9 kg arrived, 9 held by customs
4. Night time sensor – in development
5. Readiness for Dress Rehearsal 1 – estimated ~80%

Thank You! Any questions?

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