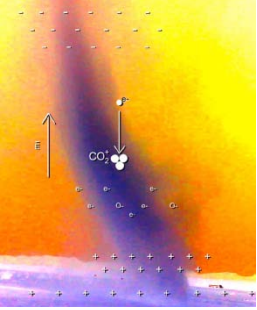


ELECTROSTATIC CHARGING HAZARDS ORIGINATING FROM THE SURFACE (ECHOS) OF MARS WITH APPLICATIONS TO OTHER SURFACE/ATMOSPHERE INTERFACES

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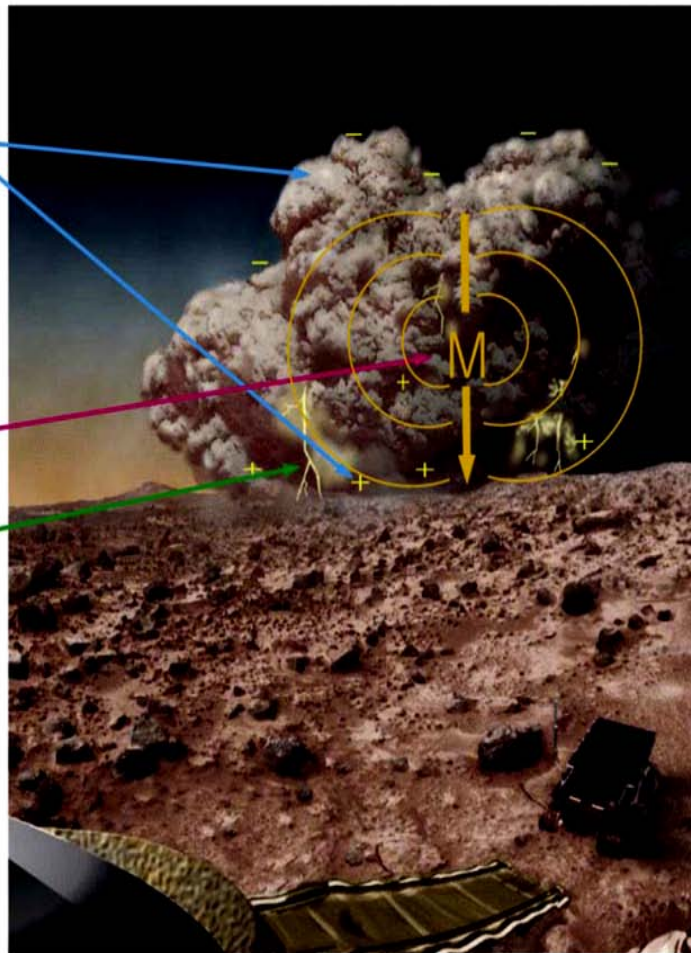


Introduction



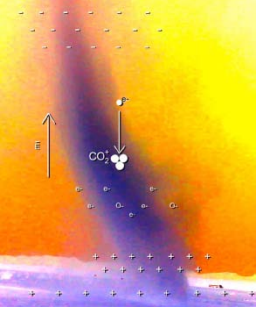
THE ELECTRIC DUST DEVIL

- Triboelectric interactions: Lighter grains (-) charged, Heavy Grains (+) charged [Ette, 1971]
- Light Grains blown upward in convective process - charge separation
- Create Electric Dipole Moment, M , and Dipolar Electric field
- Swirling grains = Change in Moment (dM/dt)
- Terrestrial Devils we see:
 - DC E-fields from M
 - Radio emission from dM/dt
 - Induced Potentials on Surfaces



- Mixing dust will charge due to grain-grain and grain-surface contact electrification
- In tribo-electric process: Smaller grains tend to charge negative [Forward et al., 2009]
- In dust devils and convective features, vertical winds separate to create a large-scale dipole moment

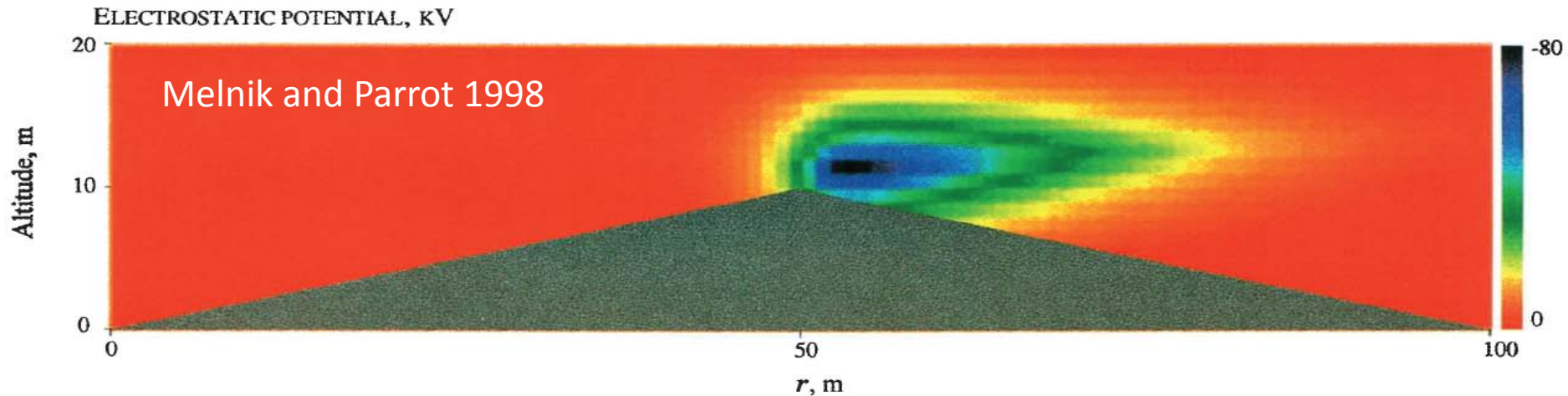
Figure 2. An illustration of the Electric Dust Devil.



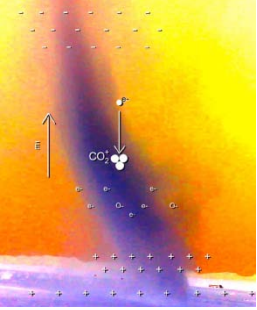
Martian dust electrification

No direct observation but the case developing!

- **Lab Studies:** Eden and Vonnegut [1973] and Mills [1977] saw glow and filament discharges in mixing sand/dust in **low pressure CO₂ gas**
- **Simulation:** High quality Particle in Cell code [Melnik and Parrot [1998]]
- **Analytical models:** Separation of negative small grain currents from surface creates large-scale E-field, E , dE/dt [Farrell et al., 2003; 2006]

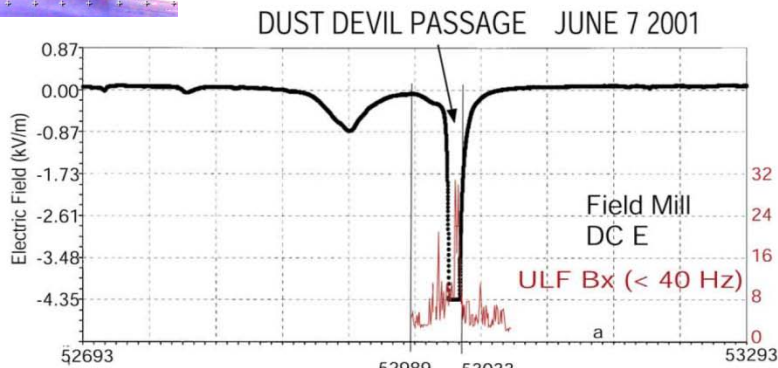


Martian dust electrification (cont)

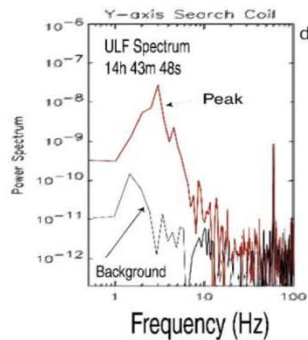
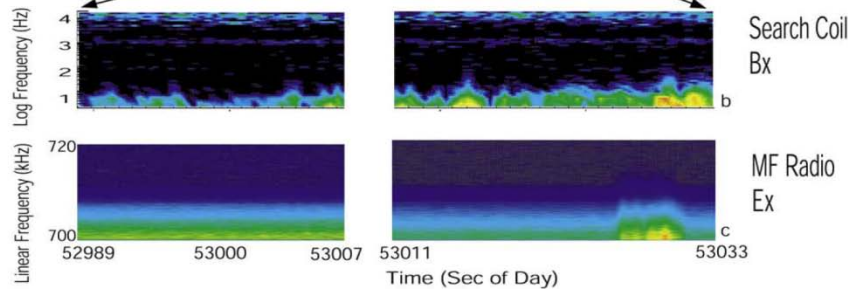


- **Analog Terrestrial Desert Field Tests indicate EM-rich events:**

- Freier [1960] & Crozier [1964]
- In 2000s, coherent study of the electric properties of terrestrial dust devils as analog to Mars (MATADOR)
- 2000 Nevada Outside Boulder City NV
- Arizona 2001, 2002, 2005 Eloy Az....full electro-met
- 2004 Mojave near Edwards AFB
- 2008 Nevada Outside Boulder City NV



ULF Bx (Relative Units (uV))

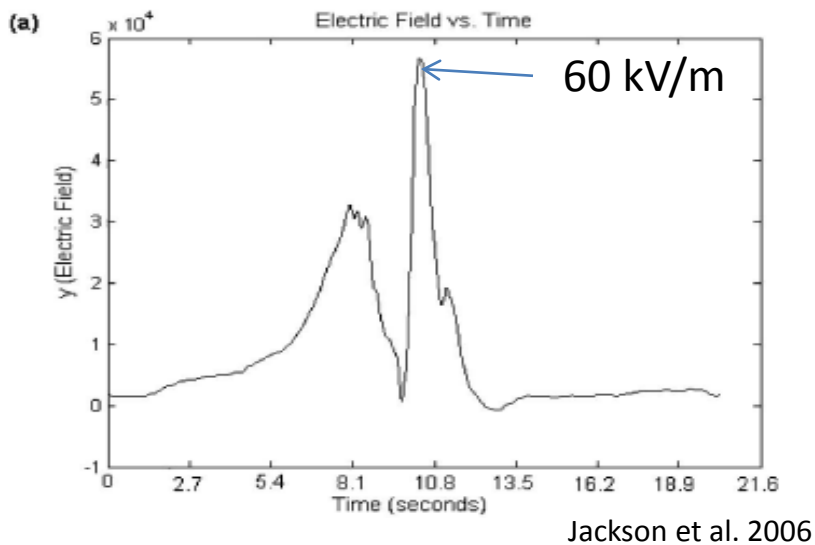
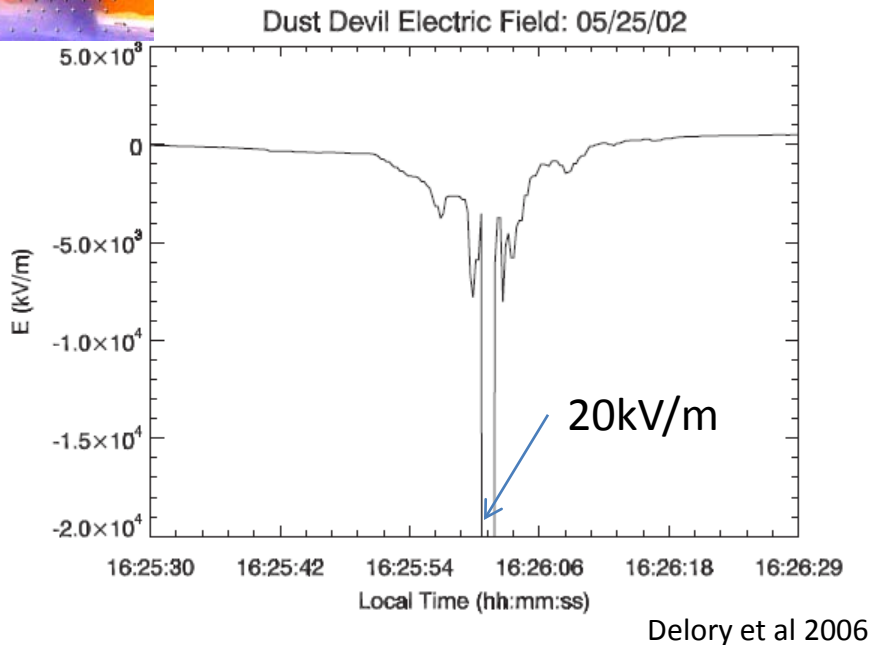


- Large DC E fields saturates Field Mill near -4.3 kV/m
- ULF Magnetic signals detected as devil approached and receded
- MF Radio contamination as charged grains impact antenna

Farrell et al., 2004

2001 Eloy Az Base Observations

Big E-fields: Saturation!



- Delory et al [2006] Eloy, Az in 2002; field mill - saturated
- Jackson et al. [2006]; Mojave Desert in 2004; electrometer, not saturate
- In Mojave, sensor on top of SUV, pass through DD

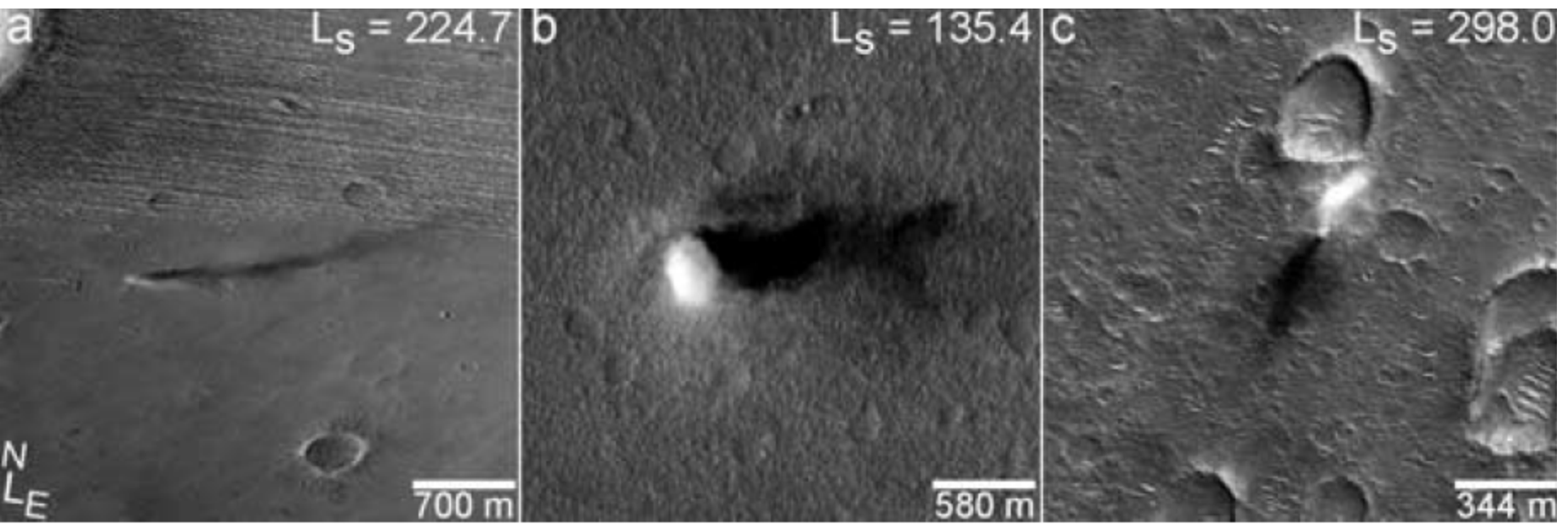
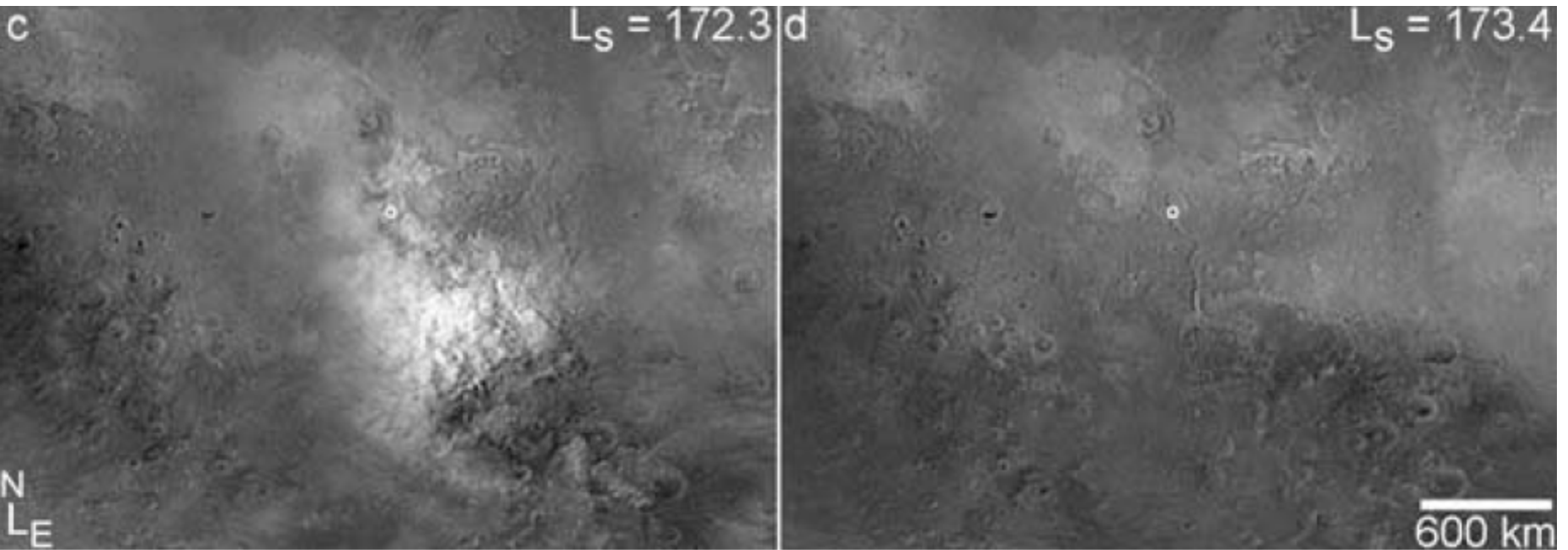


Fig. 3. Electrometer fixed to the vehicle.

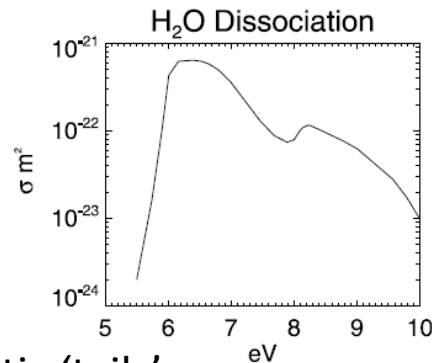
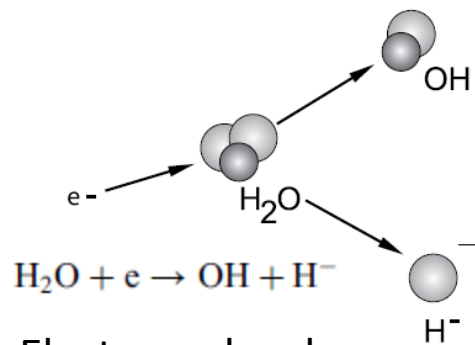
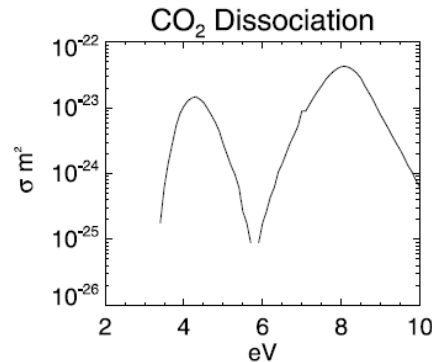
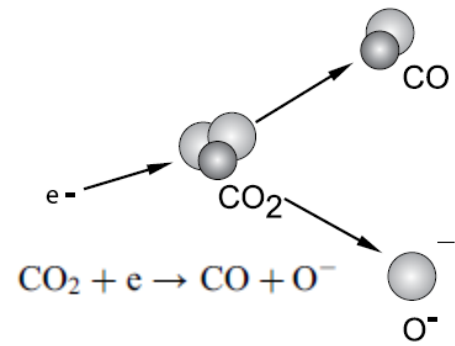
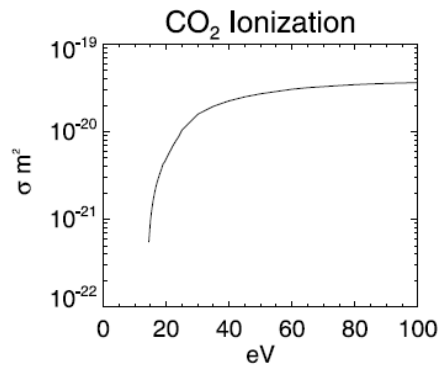
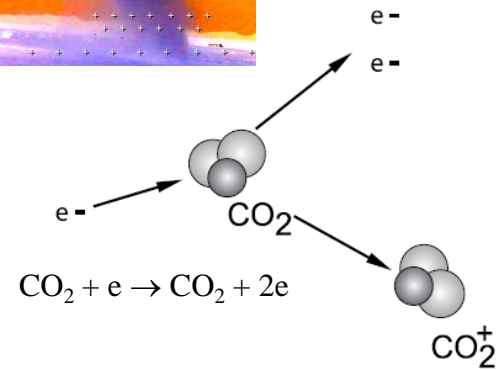
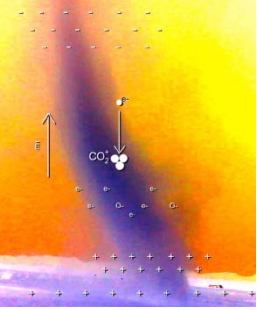
Mars Dust Devils & Storms – Mars Global Surveyor Rogues

Gallery [Cantor et al 2006]

Gusev Crater



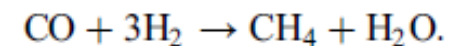
Implications: Science



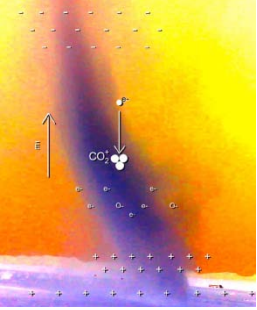
- New atmospheric chemistry
- In the **low pressure Martian CO₂** atmosphere, if get $E > 15 \text{ kV/m}$, initiate electron impact ionization of the gas [Delory et al., 2006; Kok and Renno, 2009; Jackson et al., 2010]
- Form a mildly ionized gas: a corona
- Create anomalous component of CO_2^+ , CO , OH , O^- , H^-
- Recombine into H_2O_2 [Atreya et al., 2006]
- Destroy methane [Farrell et al., 2006]
- Create Methane? [Robledo-Martinez et al., 2012]

Electrons develop energetic 'tails'

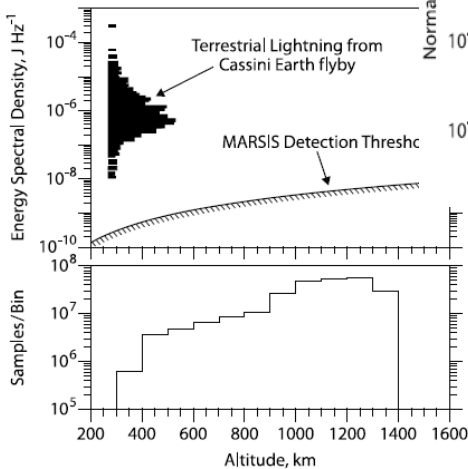
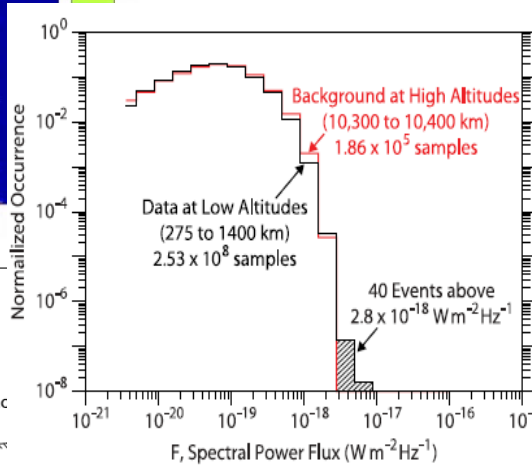
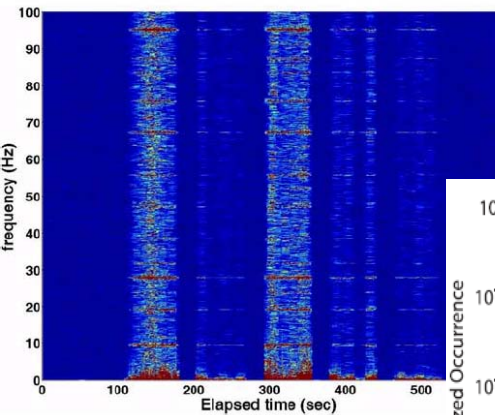
Delory et al., 2006



Implications: Exploration

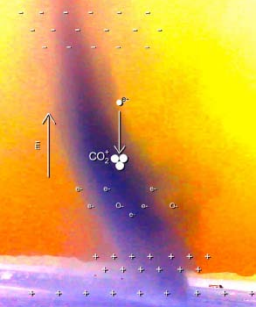


Ruf et al. 2009



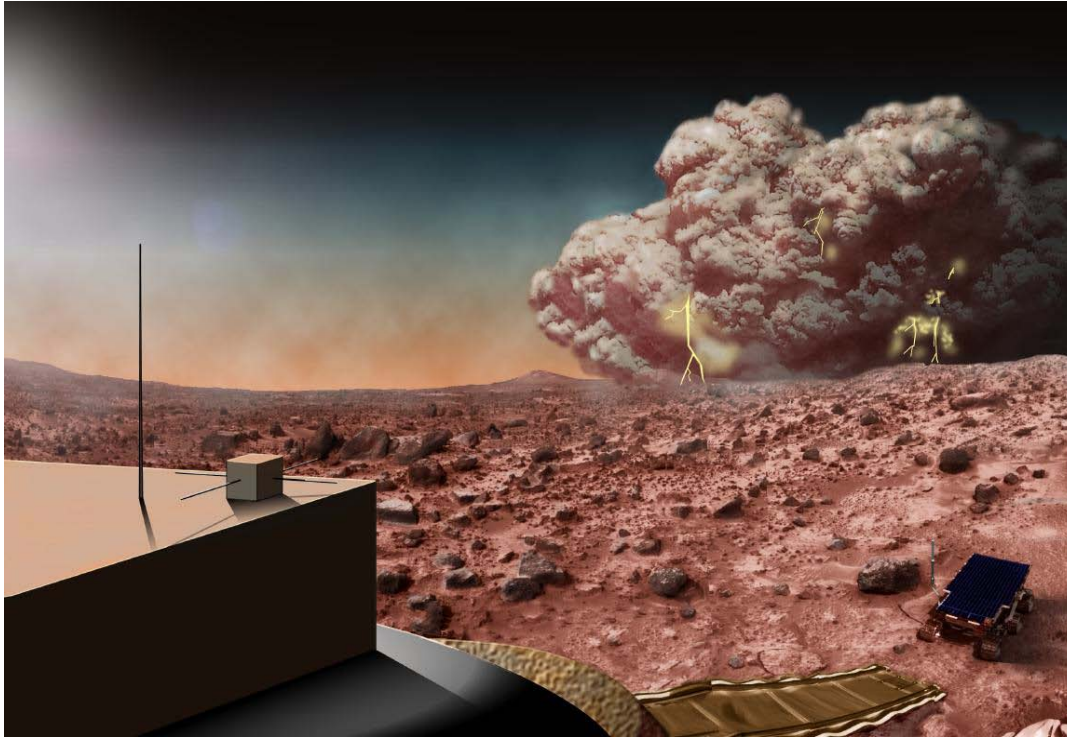
MEX/MARSIS
Gurnett et al 2010

- MEPAG Goal 4: Human Exploration
- Electricity as a hazard
- **Is the discharge manifested as a low energy quasi-constant glow or are there times when there is a catastrophic breakdown?**
- Not observe lightning at Mars, but then not really investigated dusty cores, storms, and big DDs
- Eden and Vonnegut [1973]
- Lightning at Mars? RF detections?
 - Ruf et al. [2009] radio telescope; 8.5 GHz observation (Yes)
 - Gurnett et al [2010] MEX/MARSIS; 4 MHz observations (No)
 - Anderson et al [2012] radio telescope; 3 and 8 GHz observations (No)



Landed Electro-meteorology Instrument: Ideal Suite

- Instrument Suite
 - Met V, T, P
 - DC E-field
 - AC E-field
 - Camera-photometer
 - Atmospheric Chemistry
 - Electrometer Chain
 - Paschen Breakdown experiment
 - IDPU

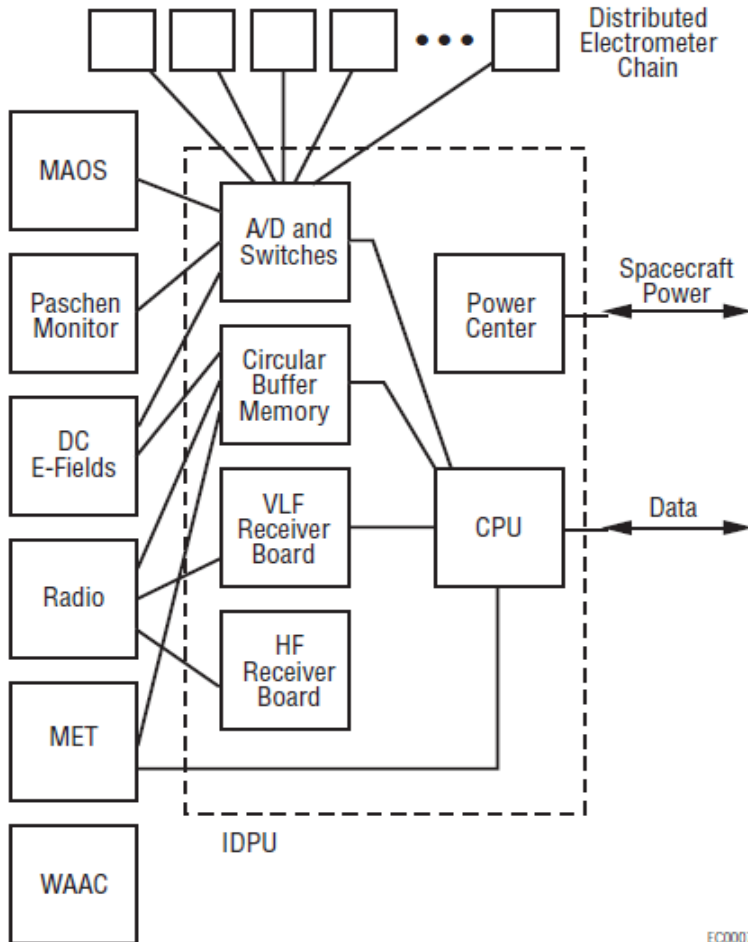


Objectives:

- Correlate E-field with local aeolian and met features (vortices)
- Monitor for lightning generated 'sferic' emissions
- Determine if new chemistry really results from aeolian electrical structures

ELECTROSTATIC CHARGING HAZARDS ORIGINATING FROM THE SURFACE

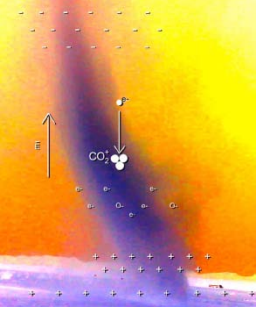
(ECHOS)



- Selected for Mars03 Surveyor mission (Original MSR)
- Partners: GSFC, SETI, ARC, UC Berkeley, GRC, JPL, U of Iowa, Ariz St.
- ECHOS a **Human Exploration and Development of Space (HEDS)** package
- Merged with UArizona camera into a new MATADOR (Mars ATmosphere And Dust in the Optical and Radio) instrument, PI: P. Smith, Ariz.
- Selected late 1999, mission cancelled 2001
- So it never flew!
- Funded comprehensive terrestrial analog studies!

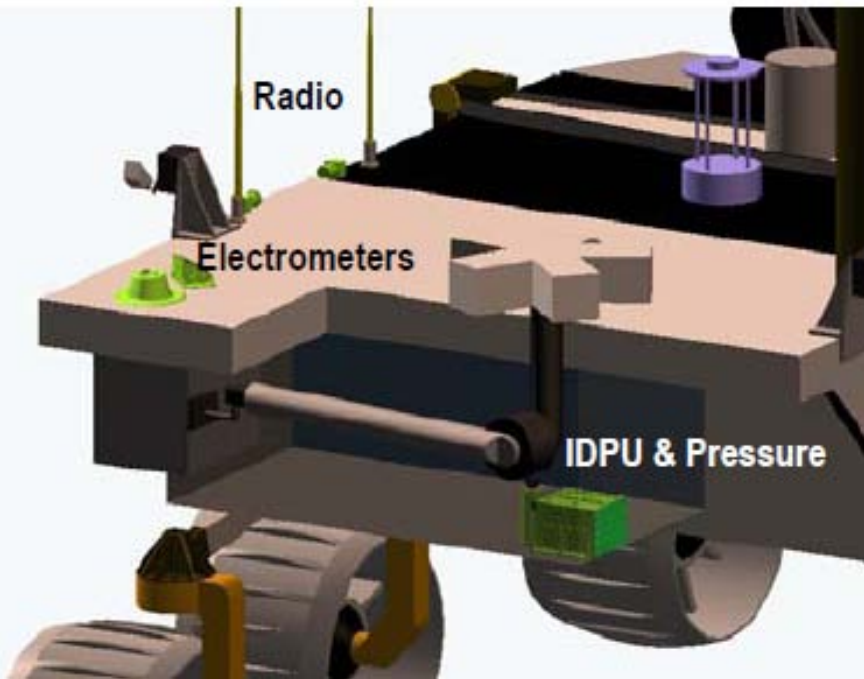
EC0007

Figure 1.3.1: Schematic Diagram of the ECHOS Suite



Mars ATmospheric Chemistry in Electrical Storms (MATCHES)

MATCHES Instruments

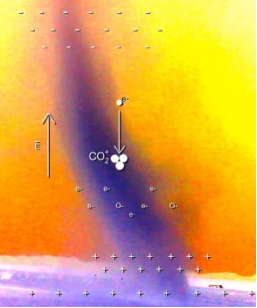


Also had a MET- option

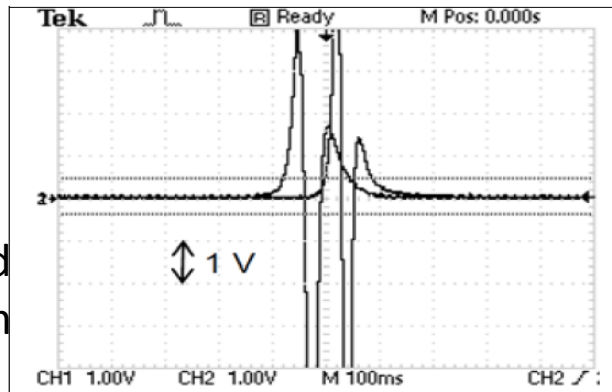
- Proposed to MSL solicitation in 2004
- PI: Delory at UCB
- Provided electrostatic environmental info
- MATCHES DPU connect with SAM DPU
- Ensures SAM captures atmo chem sample in large E environment
- Targets: peroxides, methane change, more COs, Os, OHs
- Got great reviews: Cat 2

New Addition: 'Slow' Dust Detector

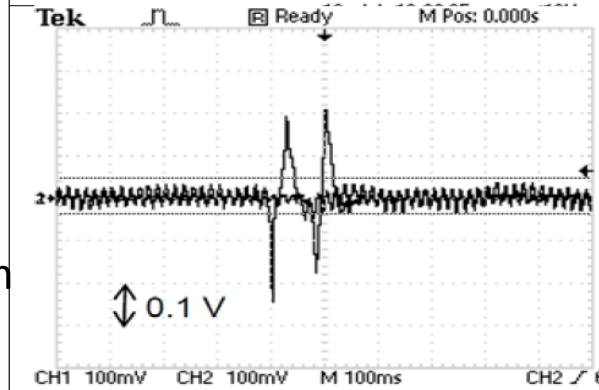
GSFC IRAD Program Development



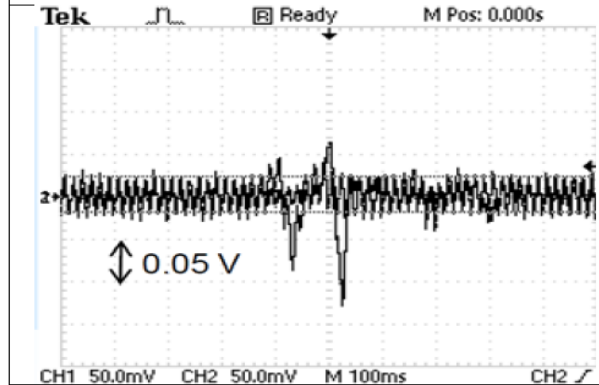
Coffee Ground
0.5 mm



Salt
100 μm



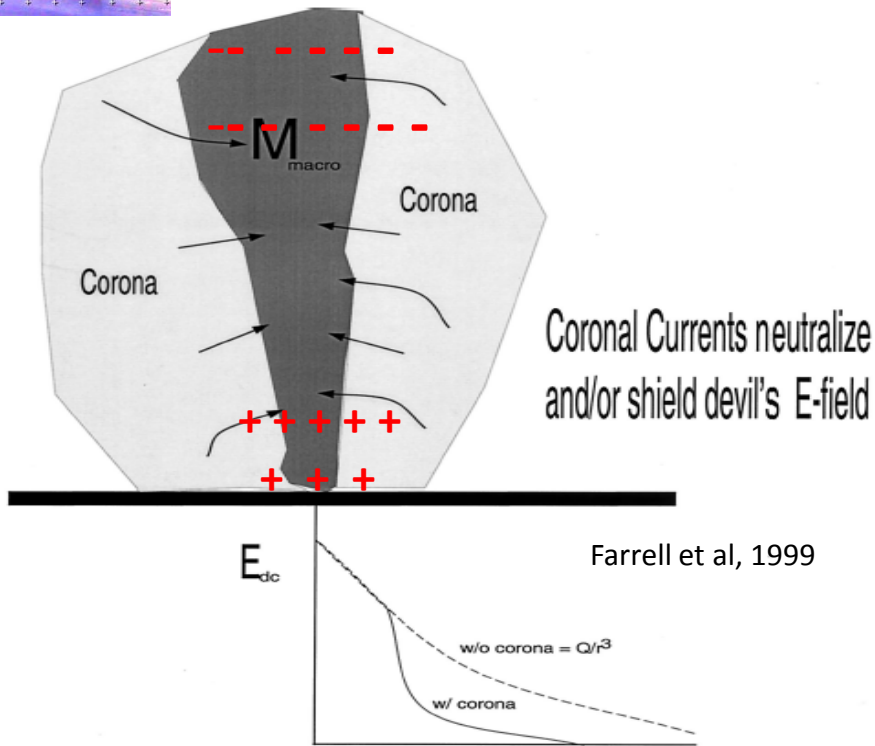
Talc
10 μm



- Can use dust grain incidence with radio antenna to detect dust
- Have now developed a slow dust detector via capacitive coupling

Moving at
~1.5 m/s

Charging vs. Dissipation Time Scales

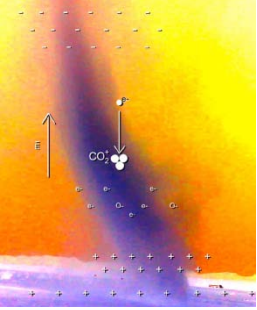


Farrell et al, 1999

$$\epsilon \frac{\partial E}{\partial t} \sim J_{\text{dust}} - \sigma E$$

Vertical dust current
Dissipation current

- If charging time scales in dust devil/storm greatly exceed dissipation time scales
 - Build up big charge centers
 - Potential for lightning!
- But if charging time is comparable to dissipation times, then can quench the charge centers
- Corona (glow discharge) can form to aid in dissipation process...its a leakage current from atmosphere to dissipate charge center
- Hazard tied to the physics of dust charging in CO₂ gas, surface, and secondary electron sources (GCRs?)



Conclusions



- Science: Dust electrostatics and charged dust storms is an energy source for new harsh chemistry (MEPAG Goal 1, 2)
- Exploration: The lightning story – is it really a hazard? (MEPAG Goal 4)
- **Take-away:** We don't really know the extremes in the meteorologically-driven electrical environment
- **Recommend:** ECHOS should be flown once to buy down the risk - once flown and observation set obtained, reasonable conclusions can be drawn
- ExoMars EDM/DREAMS will have an E-field system to examine the dust-created electrical environment
- Packages sizes can vary: ECHOS , MATCHES, or even an electric augmentation to MET package
- Package for Titan? Venus? Question of lightning and particulate charging at these bodies as well....