Investigating the 2007 global scale dust storm at Mars with ASPERA-3

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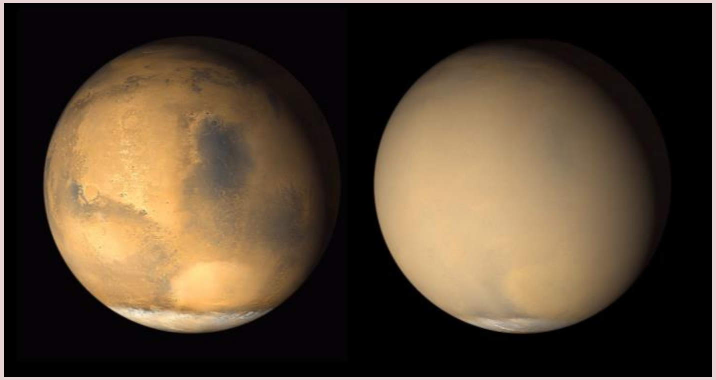
(1) Introduction

Mars' atmosphere is exposed to the solar wind due to the lack of a global magnetic field, allowing the contents of the atmosphere to be stripped away and lost into space.

Dust transportation plays an important role in the Martian climate system. As dust content increases, atmospheric and thermospheric heating increases which increases ionospheric densities causing expansion. Dust storms may merge and create a planet-wide dust event. The last two global scale storms occurred in 2007 and 2018 (Mars Years 28-29 and 34).



2001 Global dust storm at Mars as observed by Mars Global Surveyor. Image credit: NASA

(2) Research Aims

- Identify if the bow shock, induced magnetospheric boundary (IMB) and ionopause position are significantly altered due to the dust storm
- Assess if the southern hemispheric crustal fields also change the conditions during the storm
- Look for any geographical variations in the magnetic environment

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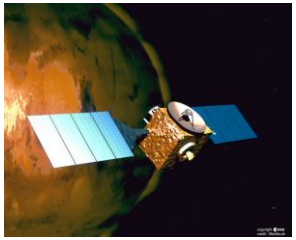
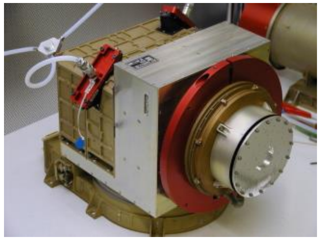
(3) Mars Express ASPERA-3 ELS





Mars Express artists impression (left) and ASPERA-3 instrument (right). Image credit: ESA

- Launched 2003, began science operations in 2004
- ASPERA-3: Analyser of Space Plasma and EneRgetic Atoms. Contains two energetic neutral atom sensors, an electron spectrometer (ELS) and an ion spectrometer[1]
- ELS is a top-hat electrostatic analyser covering electron energies 0.001 – 20 keV

(4) 2007 Global Scale Dust Storm

- Dust began lifting to 35 – 40 km altitudes at solar longitude (Ls) 265°
- H_2O concentration increases by an order of magnitude at 60 – 70 km altitude[2]
- Storm became global at Ls = 275°
- Temperatures up to 240 °K at high latitudes[3]
- High temperatures due to adiabatic heating in downwelling meridional circulation[3]
- CO_2 particles dominate at larger altitude range[4]
- Ionisation due to dust and aerosols reaches higher in the atmosphere as mixing of dust aerosols increases[5]
- Enhancement of plasma density and increased peak altitude over magnetic field regions due to net upward motion[5]
- Decay phase begins at Ls = 285, increased H_2O concentration ends[2,3]

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(5) Methodology

Mars Express ASPERA-3 ELS data from June – September

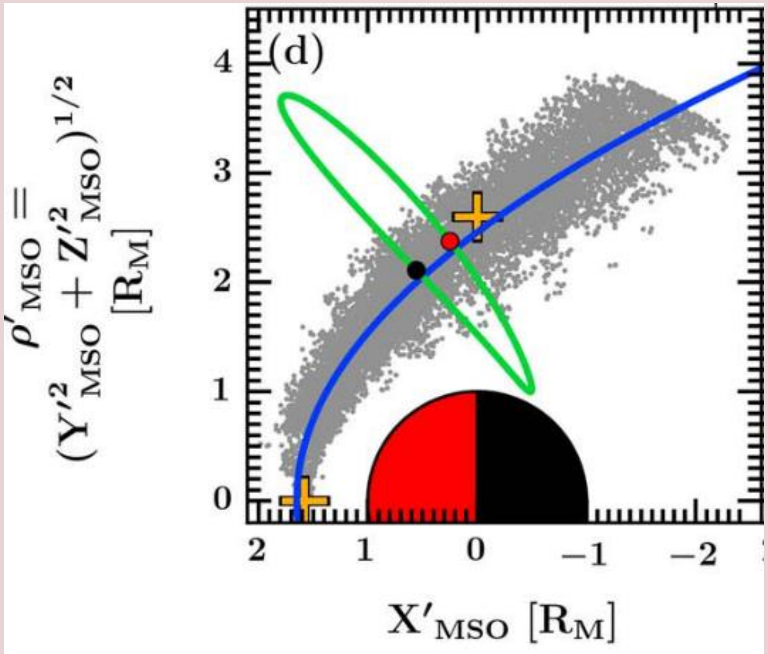
- Hall *et al.*, 2016 bow shock model to identify bow shock crossings
- Magnetic models in addition to ELS data to identify IMB crossings
- Visual identification of ionopause, IMB and MPB crossings

Removal of other influencing factors

- Solar zenith angle (SZA)
- Solar wind variations
- Southern hemispheric crustal fields

Statistical Analysis

- Compare average locations of the boundaries over the duration of the storm



Scatterplot of bow shock crossings, January 2004 – May 2015 from Hall et al., 2016 model. Blue curve is their best fit, orange crosses are positions from previous models. Example MEx orbit shown in green, with egress and ingress as black and red dots (respectively)

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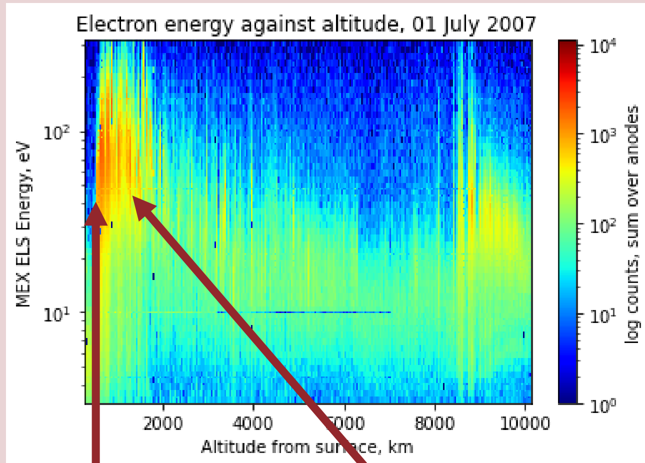
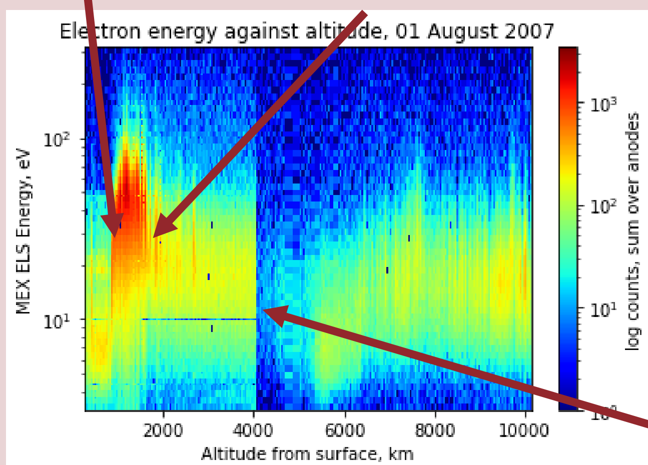
(6) Preliminary Results

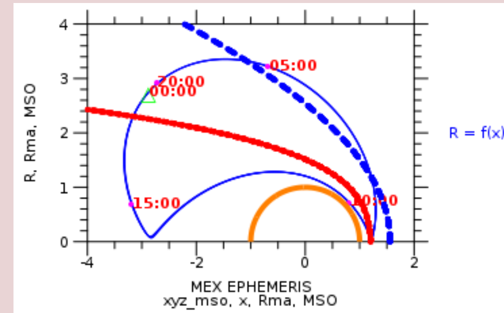
- Induced magnetospheric boundary (IMB) and bow shock located further from the surface during the global storm
- Density of electrons within the induced magnetosphere increases
- Ionisation increases due to increased heating of particles in atmosphere and ionosphere
- Pressure on boundaries increases, pushing them further from the surface



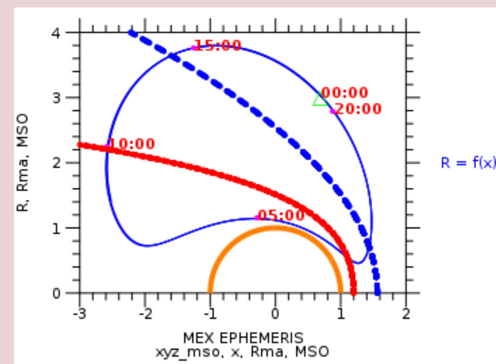
IMB

Bow Shock





Electron energy and counts against MEx altitude for 01 July (top) and 01 August (bottom) 2007, in addition to the orbit. Conditions pre-global storm (top), and during global storm (bottom). 0 km altitude represents the surface of Mars.



Sharp boundary here due to differences in MEx position w.r.t. Mars

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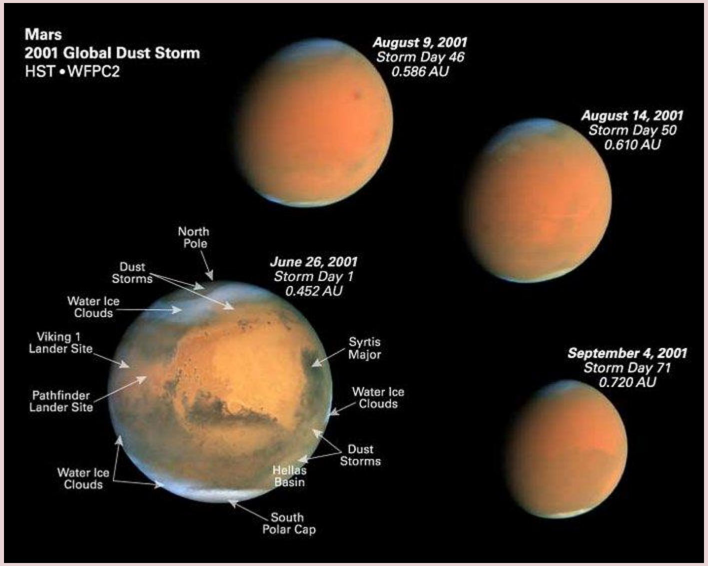
(7) Next Steps

- Identify IMB and ionopause in MEx ELS dataset
- Access bow shock crossings in Hall et al., 2016 model
- Remove influences of SZA, solar wind and crustal fields to leave the effects of the dust storm
- Perform statistical analysis on resulting boundary locations, to look at evolution over the onset, peak and decay of the 2007 storm

(8) Conclusion

- IMB and bow shock appear further from the surface during the storm (compared to models)
- Pressure on the boundaries increases as ionisation increases
- Other factors need to be considered to understand how the system is responding



2001 Global scale storm as observed by the Hubble Space Telescope. Image credit: Zolt Levay (STScI)

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(9) Acknowledgements

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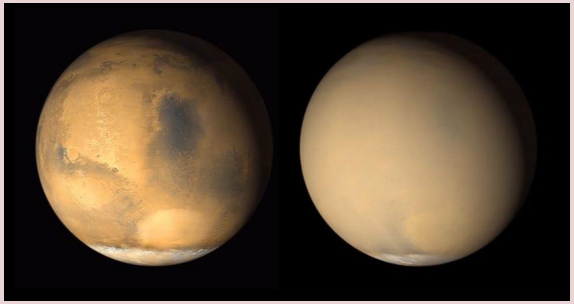

2001 Global dust storm at Mars as observed by Mars Global Surveyor. Image credit: NASA

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