Simulations of the effects of extreme solar flares on technological systems at Mars

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Florida Institute of Technology, Melbourne, Florida

Summary

- Extreme space weather events modify the ionosphere of Mars, affecting the performance of existing and future navigations/communications systems
- Effects
  - Range error in GPS-like systems
  - D-region absorption reduces signal strength
  - Others? Scintillation?
- Events
  - Nominal conditions
  - Meteors
  - Cosmic rays (plasma at very low altitudes?)
  - Energetic particle events (plasma at low altitudes?)
  - Solar flares

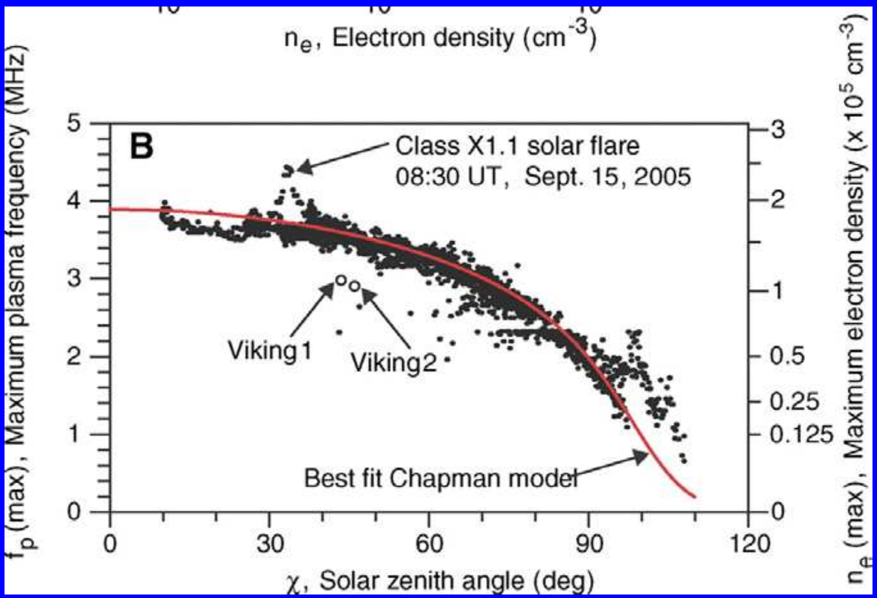
Method

- Obtain vertical profiles of plasma density (data and models)
- Calculate range error, D-region absorption and anything else relevant using that profile
- Examine how effects on nav/comm systems vary with type and intensity of space weather forcing, radio frequency, and other possible factors

Recent Progress

- Undergraduate student started in January, was making excellent progress, then vanished
- His results vanished too
- So progress has been slower than desired

Solar Flares (1)



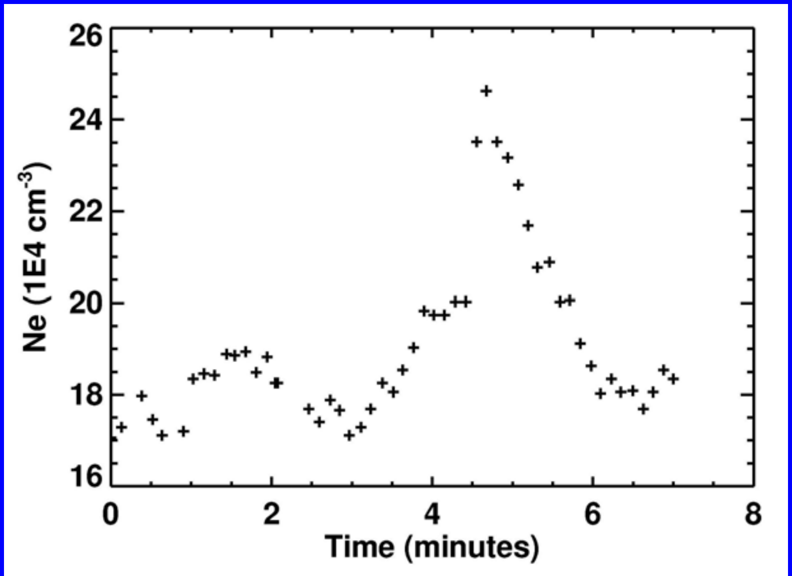
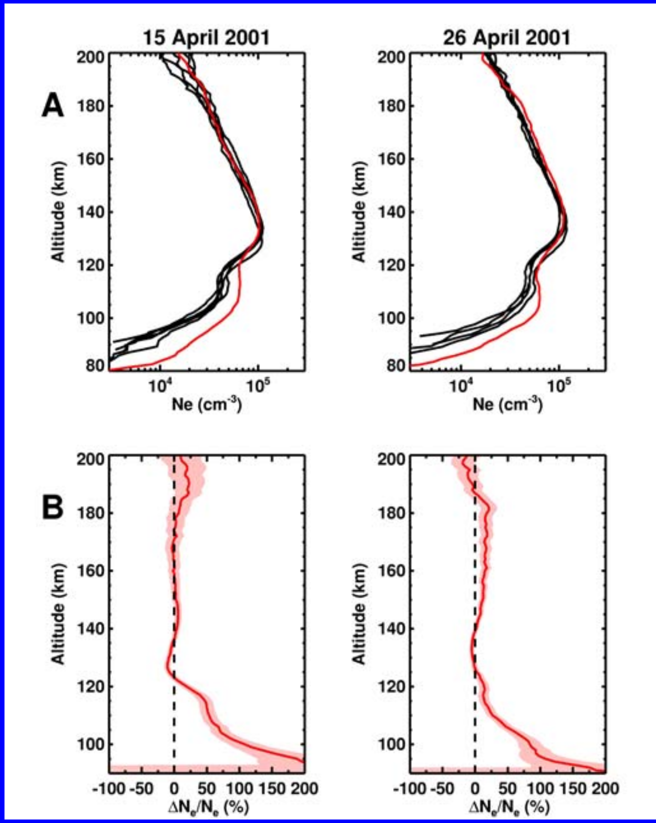


Fig 3. Seven minutes of MARSIS topside radar sounder data at constant solar zenith angle from 15 Sep 2005. Peak Ne increased from 1.8 x 10^5 cm^{-3} to 2.4 x 10^5 cm^{-3} during an X1.1 solar flare (Gurnett et al., 2005; Nielsen et al., 2006).

- Peak plasma densities increases by tens of percent during X-class solar flare
- MARSIS topside radar sounder measures peak plasma density >1/minute, but can't observe below the peak
- N(z) profiles not yet determined from ionograms



Solar Flares (2)

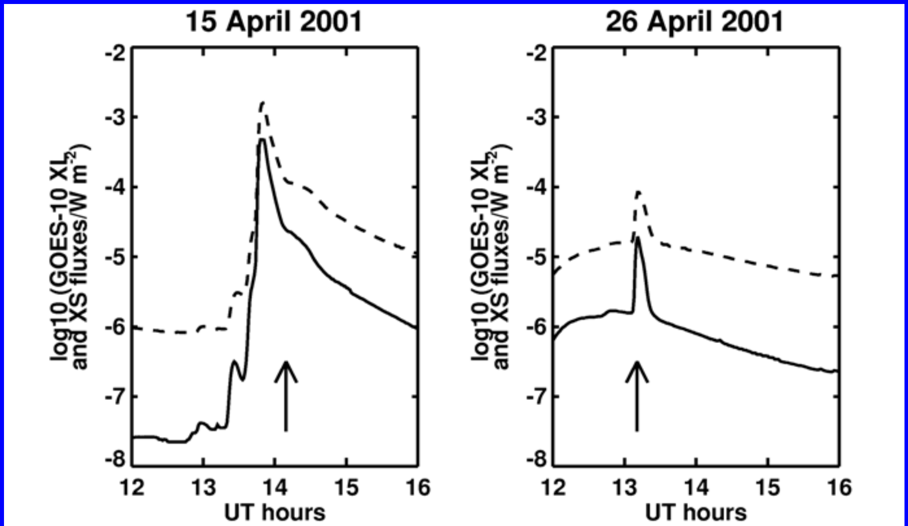


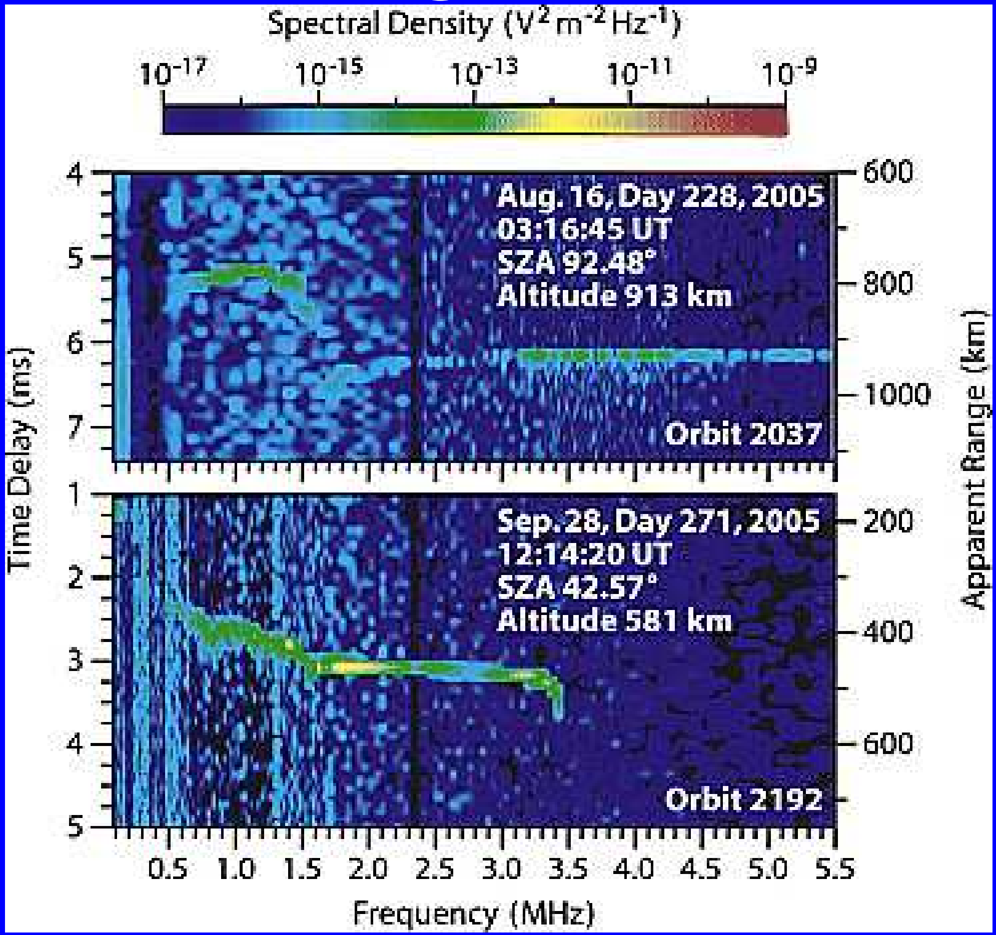
Fig 5. Solar X-ray flux at Earth. GOES XS (solid line, 0.05-0.3 nm) and XL (dashed line, 0.1-0.8 nm) data. Times of MGS Ne(z) are arrowed.

- About 10 MGS Ne(z) profiles show enhancements in bottomside plasma densities consistent with solar flares
- Excellent vertical range and resolution, but measurements made at 2 hour intervals

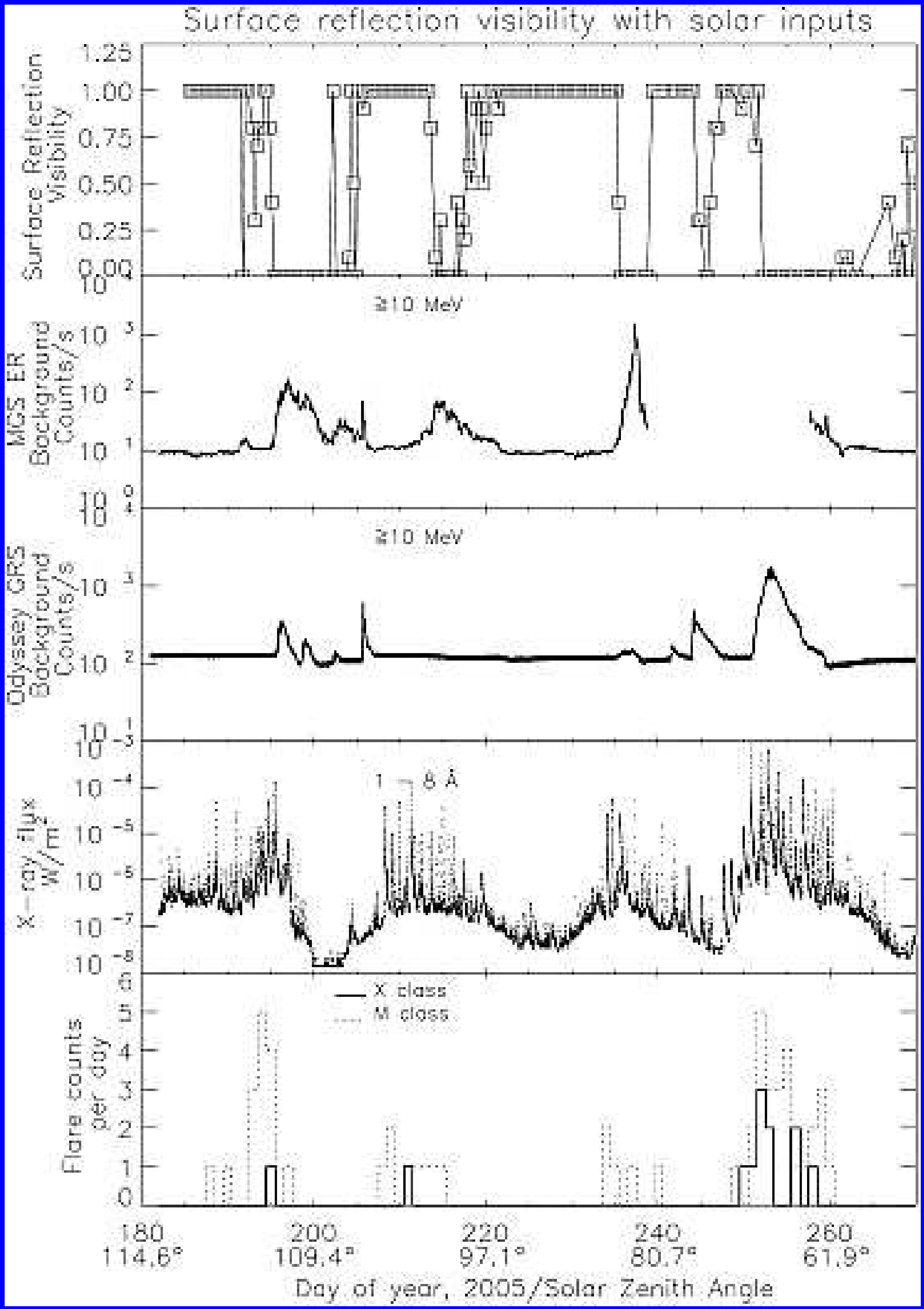
Relevant dates for solar flares

- 15 September 2005 (X1.1, MARSIS)
- 15 April 2001 (X14.4, MGS)
- 26 April 2001 (M7.8, MGS)
- Other possible MGS detections of solar flares are:
  - 24 November 2000
  - 19 December 2000
  - 02 April 2001
  - 18 April 2001
  - 02 December 2002
  - 28 January 2003
  - 04 May 2003
  - 18 May 2003
  - 17 January 2005
  - 15 March 2005
  - 11 April 2005
  - 13 May 2005
  - 14 May 2005
  - 25 May 2005

Solar energetic particles



- MARSIS topside radar sounder does not detect signal reflected from martian surface during solar energetic particle events
- Analogous to terrestrial polar cap absorption events (PCAs)



MARSIS AIS mode surface reflection visibility

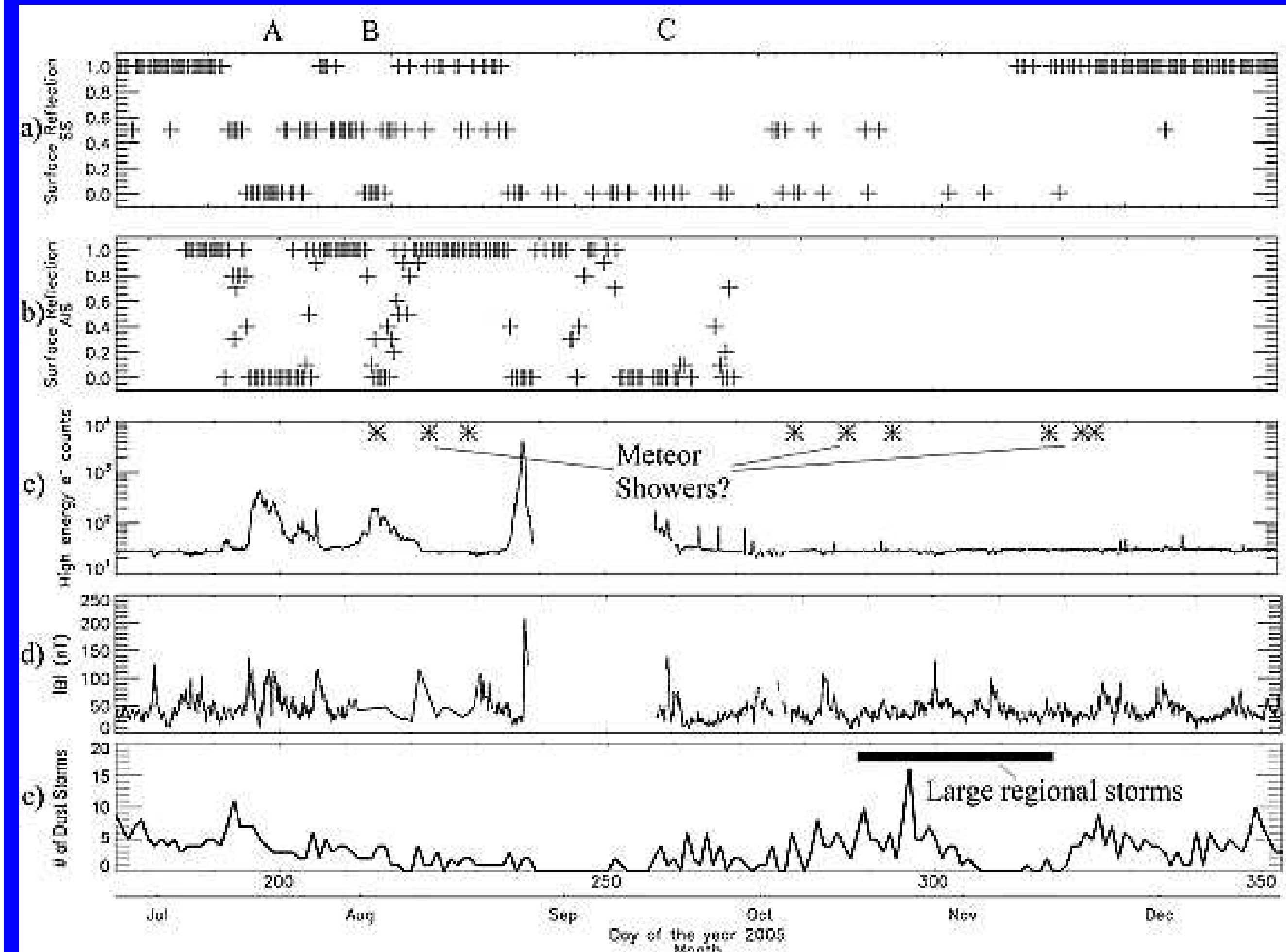
MGS ER background count

ODY GRS background count

GOES X-ray flux at Earth

NOAA daily flare counts

1 July 2005 to 30 September 2005



MARSIS SS mode surface reflection visibility

MARSIS AIS mode surface reflection visibility

MGS ER bgd count

Subsolar magnitude field at 400 km at Mars

Number of dust storms

1 July to 31 Dec 2005

Subsurface mode of MARSIS instrument also fails to get surface reflections

No simulations of how N(z) varies due to solar energetic particle events

Relevant dates for solar energetic particles

- MARSIS AIS mode
- 10-25 July 2005
- 01-08 August 2005
- 23-27 August 2005
- 01-23 September 2005

- MARSIS SS mode
- 14-24 July 2005
- 1-4 August 2005
- 23 August – early November 2005

- Dates effectively the same for both analyses

Summary

- Consider these dates for targeted studies
- If you simulate changes in N(z) in the martian atmosphere due to solar energetic particle events, I would like to use N(z)