MARTIAN CRUSTAL MAGNETIC FIELDS: INFLUENCES ON THE IONOSPHERE

DAVID ANDREWS[1]

LAILA ANDERSSON[2], ROBERT ERGUN[2], ANDERS ERIKSSON[1], MARCIN PILINSKI[2], AND KATERINA STERGIOPOULOU[1]

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david.andrews@irfu.se

1: Swedish Institute of Space Physics (IRF), Uppsala, Sweden

2: Laboratory for Atmospheric and Space Physics (LASP), CU-Boulder, USA

Martian crustal magnetic fields: influences on the ionosphere

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David Andrews, Laila Andersson, Robert Ergun, Anders Eriksson, Marcin Pilinski, and Katerina Stergiopoulou

Recent Mars Express and MAVEN observations have shown the extent to which Mars's crustal fields, though weak in absolute magnitude, nevertheless exert significant control over the structure of the ionosphere over a range of altitudes. However, quantifying this control remains challenging given the generally dynamic nature of the Mars solar wind interaction, and the therefore naturally varying densities and temperatures of the upper ionosphere in particular. In this study we examine MAVEN Langmuir Probe and Waves data, and show for the first time a very clear correspondence between the structure of the crustal fields and both the measured electron temperatures and densities. Electron temperatures are shown to be systematically lower in regions of strong crustal fields over a wide altitude range. We speculate on the origins of this deviation.

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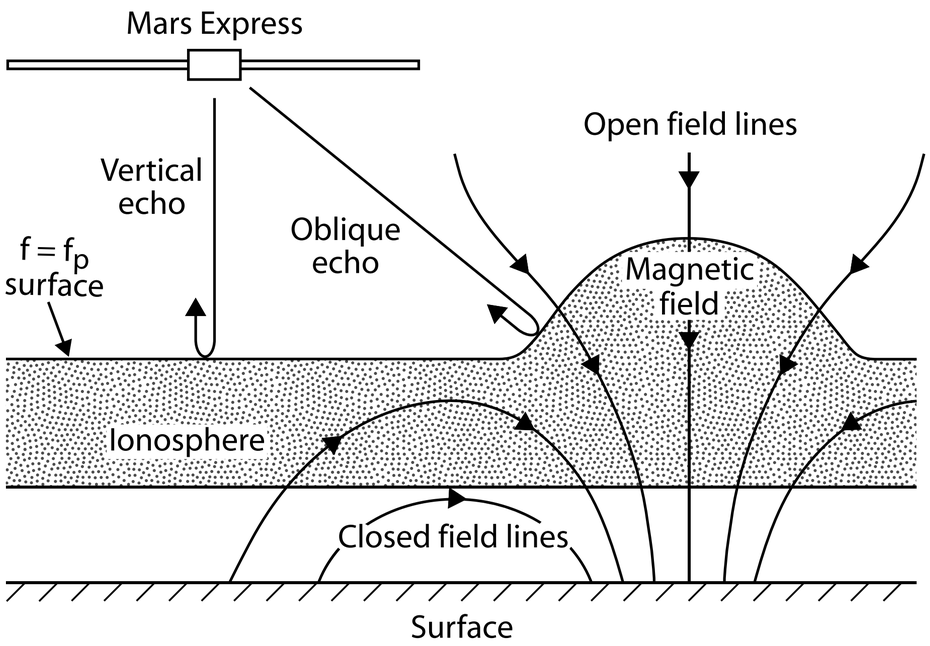
Background (I)



Duru+06 - Ionospheric upwellings

- Mars's relatively weak crustal substantially affect the ionosphere
  - Ionospheric upwellings
  - Plasma & heat transport
  - Atmospheric escape
- Mostly evidenced by location of variation and correlation with areas of stronger crustal fields
- Crustal fields exceed typical draped IMF strength over ~30% of planet's surface

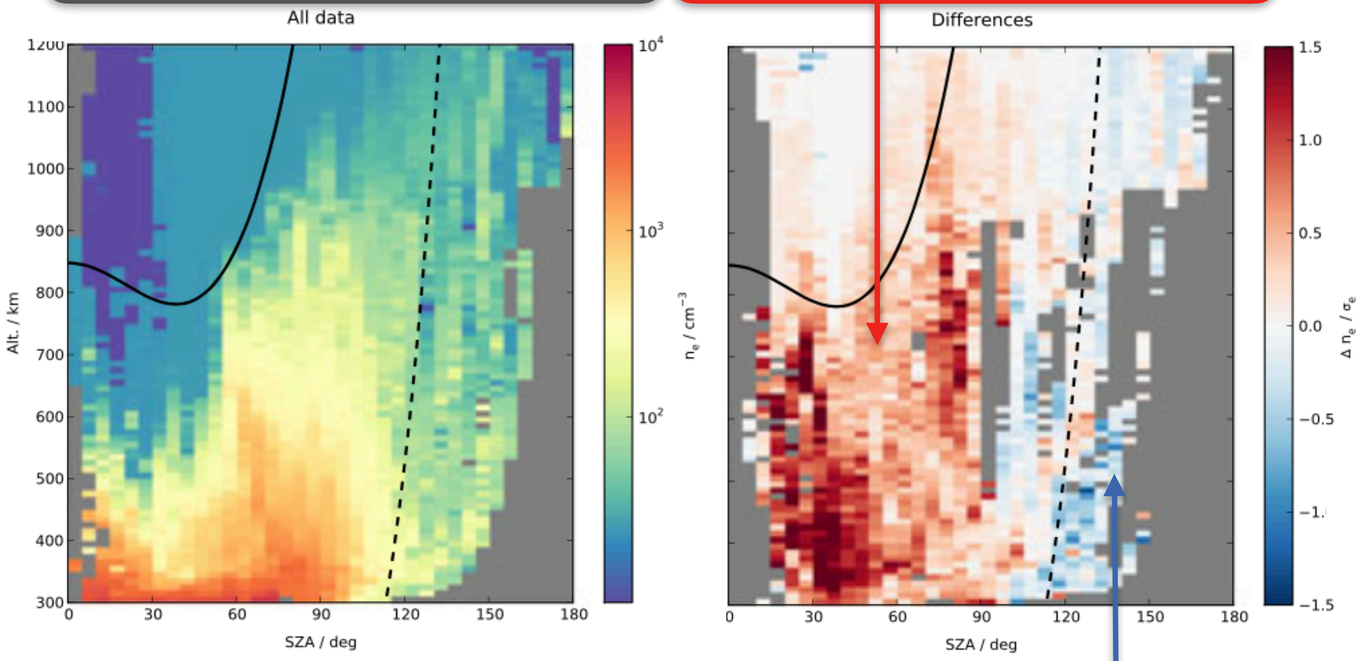
Background (II)

- Studies of ionospheric plasma measured **in-situ** by MARSIS radar on MEX
  - Altitudes > 300 km, transport-dominated regions
  - **Denser plasma on the dayside in regions of strong crustal fields**
  - Opposite behavior on the nightside (?)

- Some evidence for similar effects in MAVEN plasma measurements
  - Improved instrumentation and better sampling at low altitudes and deep into the nightside
  - Effects on electron temperatures previously investigated by Sakai+19: *reduced temperatures in regions of strong crustal fields*

Local electron densities measured by MARSIS (local plasma frequency)

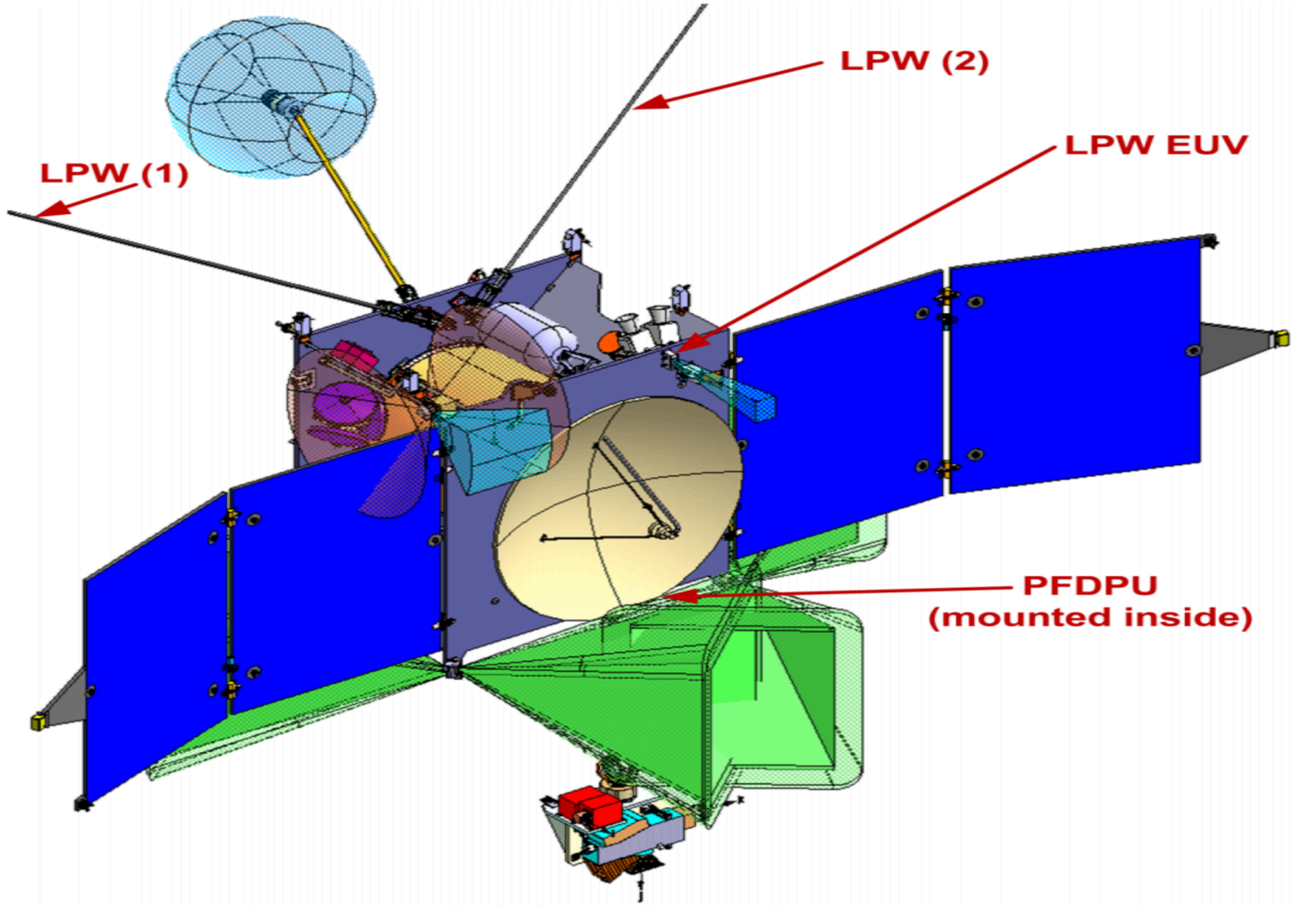
Elevated densities in regions of strong crustal fields



Andrews+13

Reduced densities in regions of strong crustal fields

MAVEN Langmuir Probe & Waves



Study Outline

Motivation: To understand dependencies on crustal fields, primary variations with altitude and SZA must first be removed from the data

Input: MAVEN LPW Electron Densities $\mathbf{N_e}$ & Temperatures $\mathbf{T_e}$ timeseries, derived from Current-Voltage Sweeps

Bin Ne, Te according to altitude **h** and Solar Zenith Angle **SZA**

Compute average Ne or Te in each bin, to define "nominal" value at some h & SZA

Revisit Ne & Te data, now computing deviation from the average binned value at corresponding location

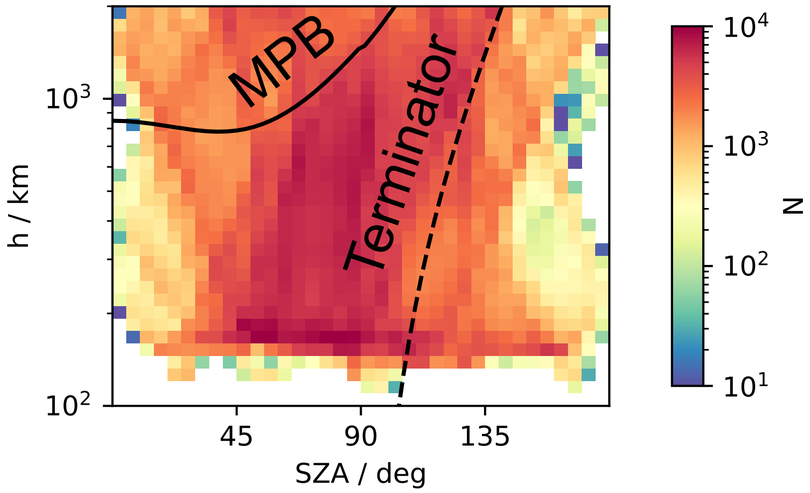
Examine deviations for dependencies on crustal fields, based on latitude & longitude

Clear dependencies identified…

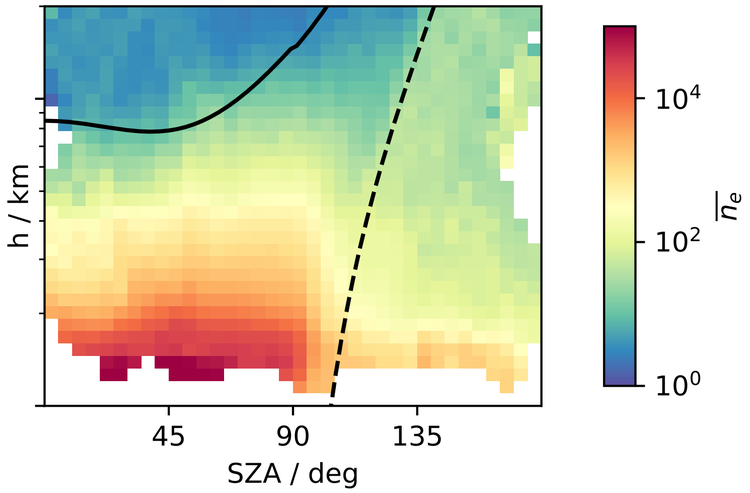
Densities and Temperatures from LPW

Determine mean of Ne and Te with altitude **h** and Solar Zenith Angle (**SZA**), using all available LPW measurements

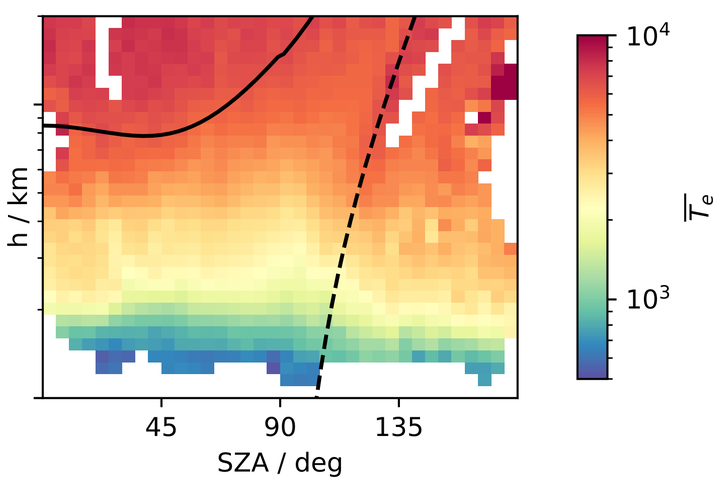
N data points/bin



Electron Densities [cc]



Electron Temperatures [K]



Use these to define empirical "maps" $\langle N_e \rangle$**(h, SZA),** $\langle T_e \rangle$**(h,SZA).**

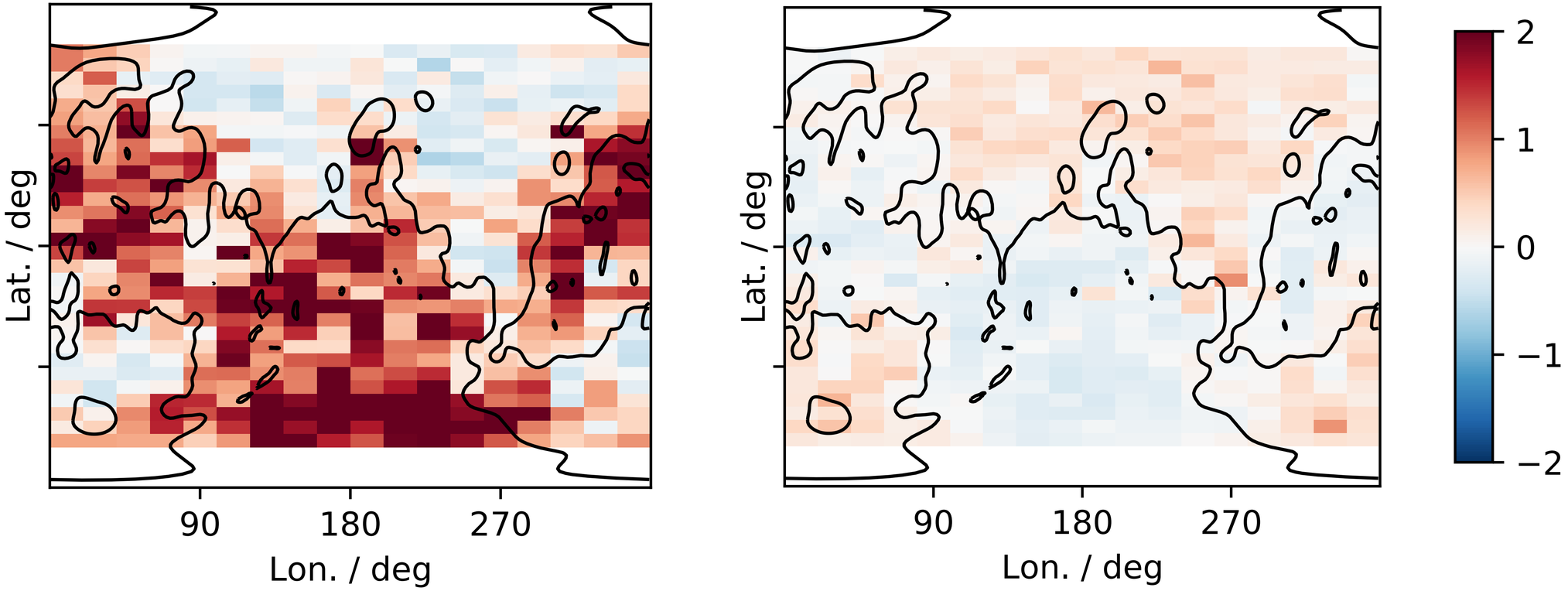
Measurements along a given orbit can then be compared to these averages

Fractional Density & Temperature Variations

How do Ne and Te depart from the averaged values at a given latitude & longitude?

Example: On the dayside, and in the 300 - 500 km altitude range…

$(N_e - \overline{N_e})/\overline{N_e}$ $(T_e - \overline{T_e})/\overline{T_e}$

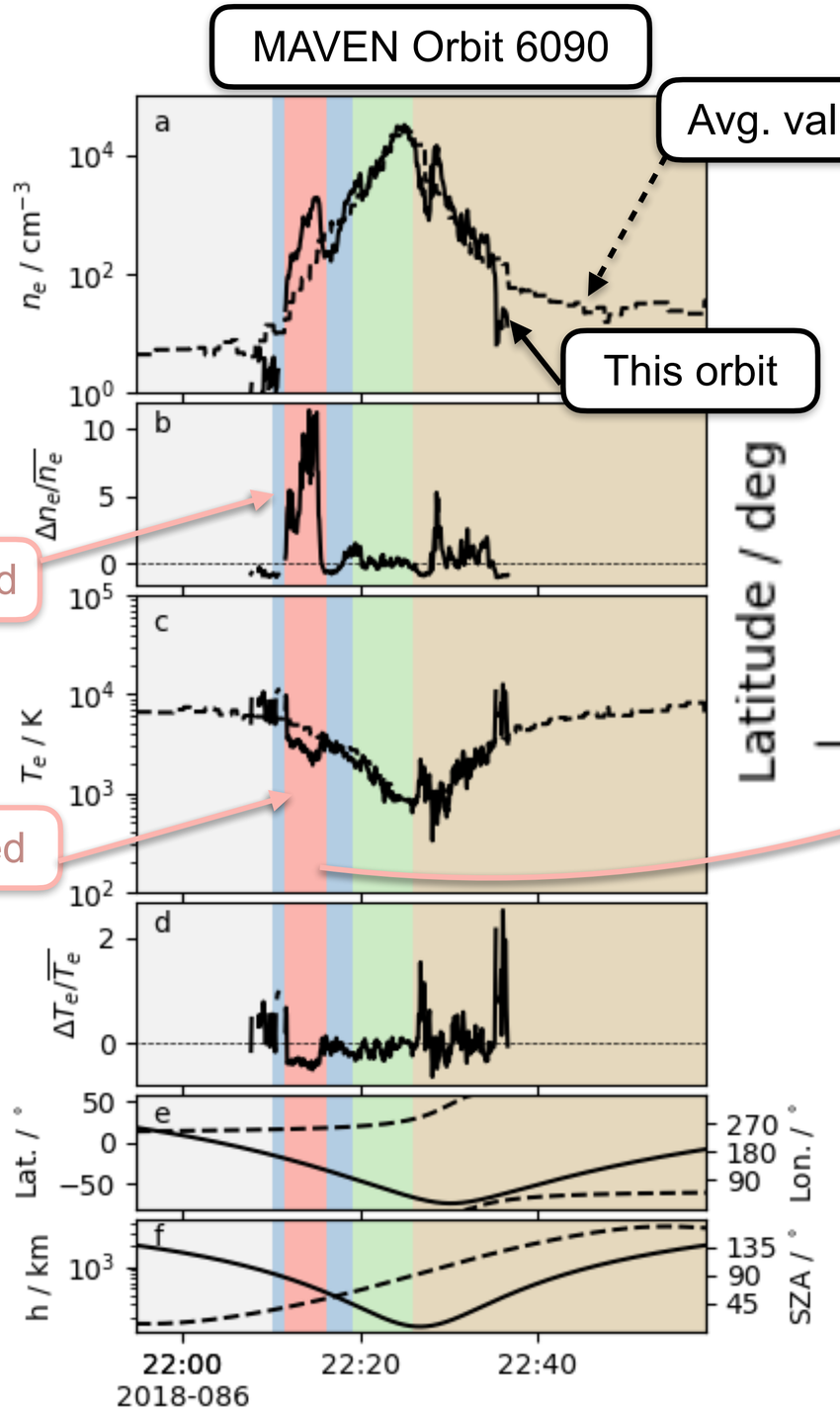


Structure correlates nicely with crustal fields

Consistent with previous reported results [Andrews+13,15, Sakai+19]

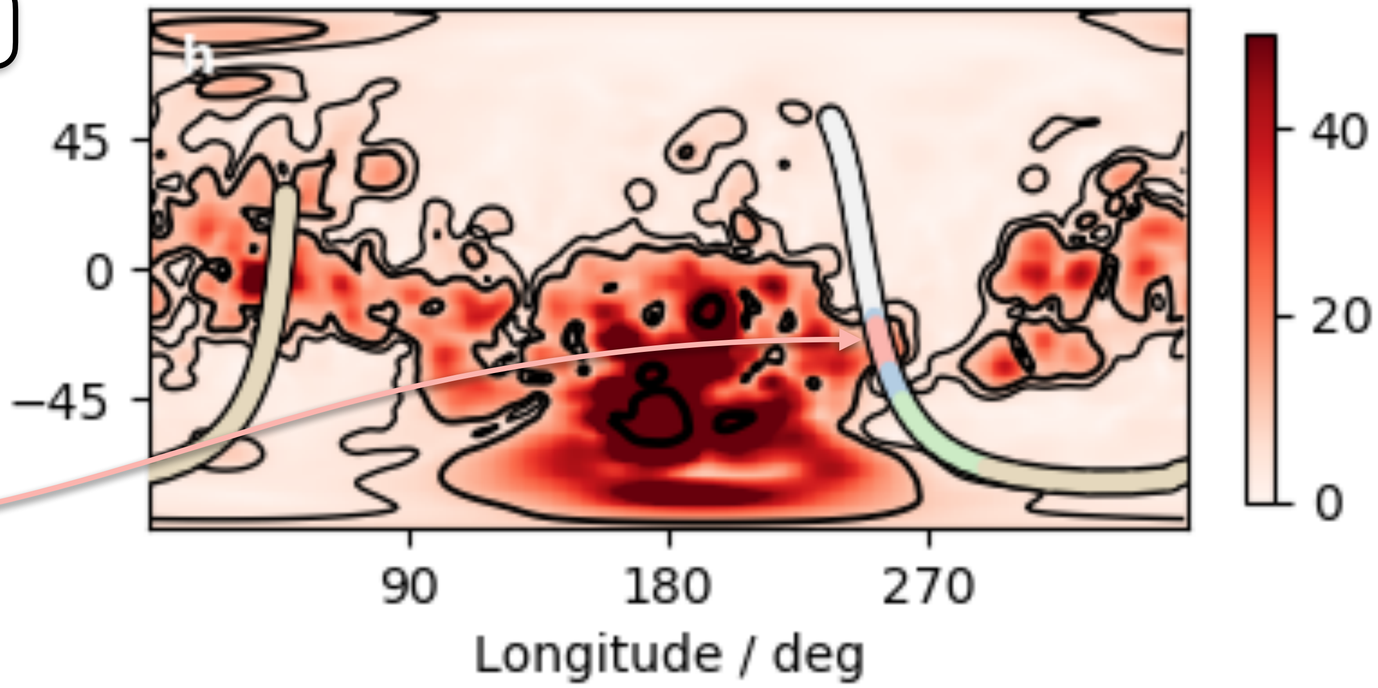
Examples in data

Q: Is the dependence on crustal fields evident in the underlying timeseries data? A: Yep:



n_e increased

T_e decreased



Dayside, strong crustal fields (B_{400} > 10nT), 300-500km

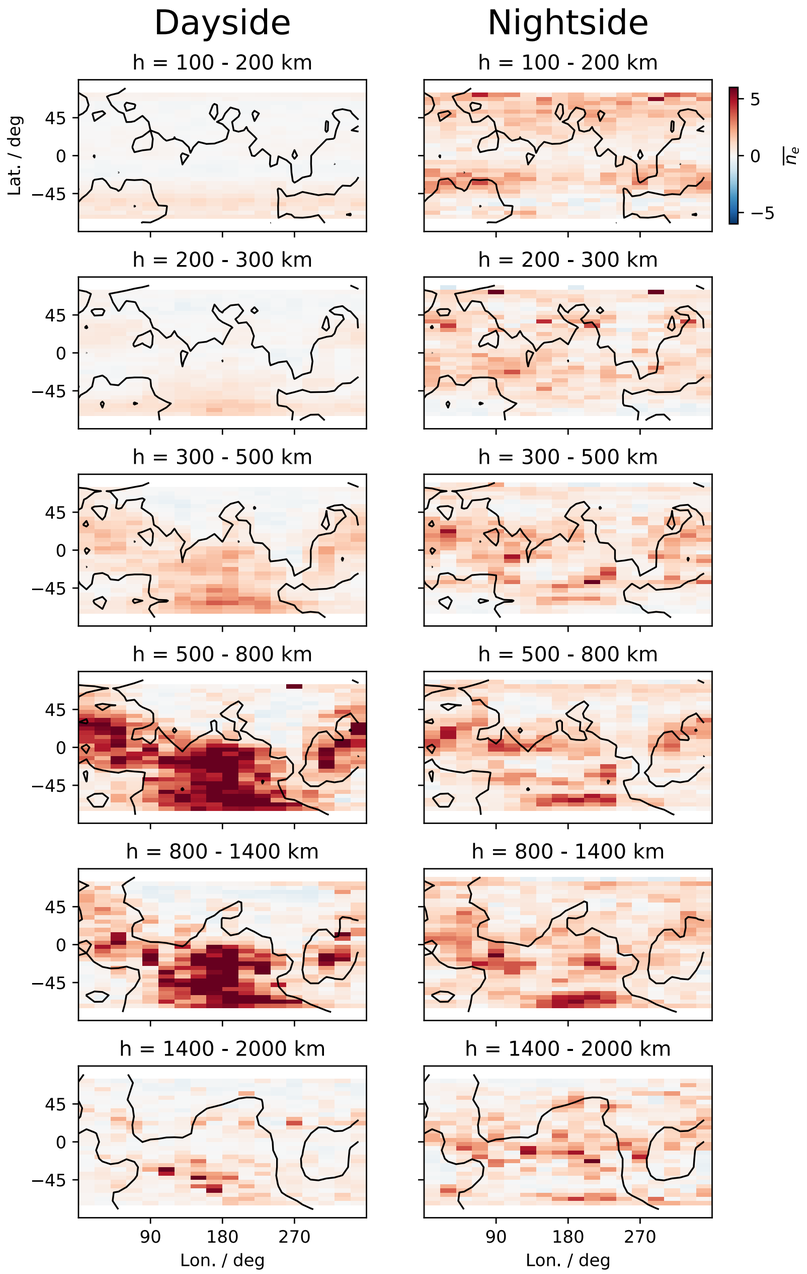
Dayside, weak crustal fields(B_{400} < 10nT), 300-500km

Deep Ionosphere, h < 300 km

Nightside

Many similar examples can be found where the dependency is clear

Vertical Variations

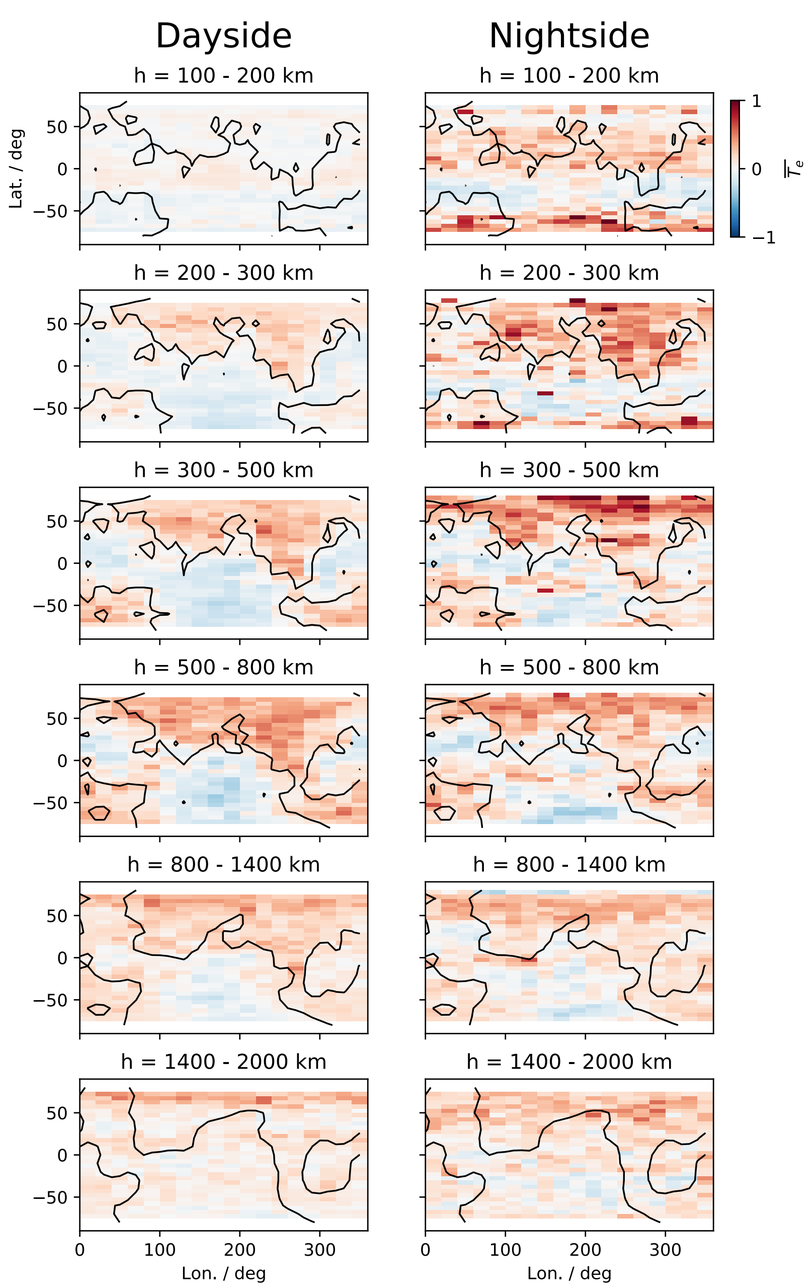


Over what altitude range is the influence of the crustal fields exerted?

Poor statistics below ~200km, but no evidence of organization: Dominance of photochemical equilibrium < 200km

Clear dayside control in the range ~200 - 1400 km

Organization by crustal fields on the nightside much less evident



Summary & Conclusions

- Rigorous statistical study of plasma densities and temperatures
- **Mars's crustal significantly affect the bulk parameters (density, temperature) of the plasma in the altitude range ~200 - 1400 km on the dayside**
- *This correspond to the region where plasma transport dominates over photochemical processes*
- **A less significant effect is present on the nightside** (some previous could have been due to seasonal biases, despite large ~4 Mars year data set studied by Andrews+13)
- Effects are evident also when examining along-orbit measurements

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Mars's crustal fields clearly control a substantial fraction of the variability of electron densities and temperatures

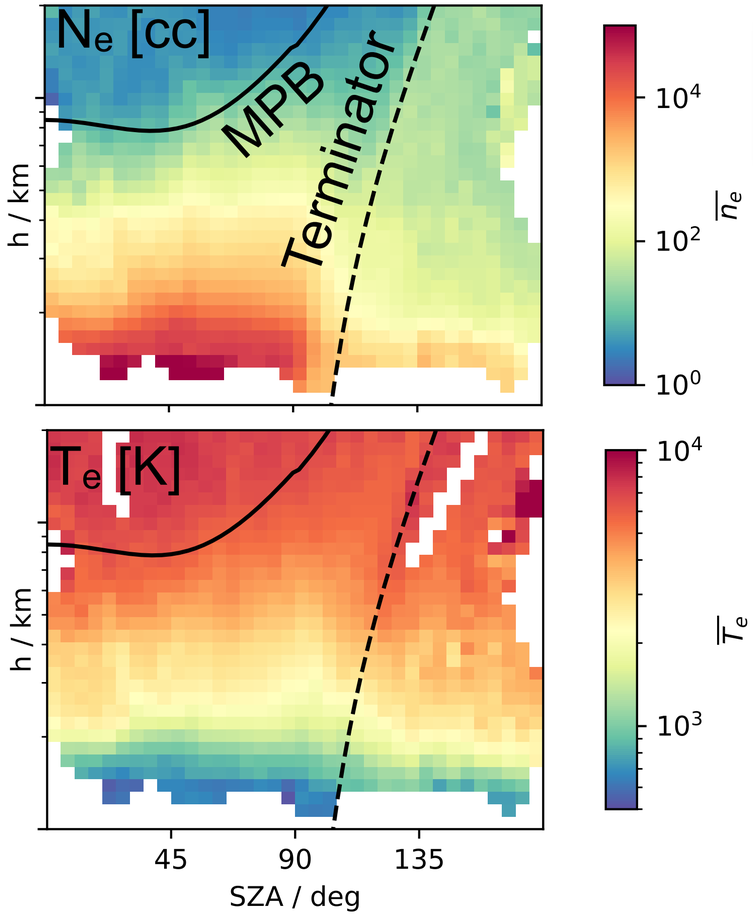
1. MAVEN LPW Data used to determine mean of N_e and T_e with altitude h and Solar Zenith Angle (SZA)

2. Calculate deviations from these average behaviors at different altitudes

3. Clear relationship between crustal fields and enhanced densities + reduced temperatures

See expanded presentation for more!

Mean values



Dayside Results: Departures from average values