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Neutral and Plasma Wave Activity in the Martian Thermosphere-Ionosphere System

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Abstract

The NASA Mars Atmosphere and Volatiles EvolutioN (MAVEN) spacecraft has been collecting data in the Martian atmosphere since November 2014. Using ~4 years of neutral (Neutral Gas and Ion Mass Spectrometer) and plasma density data (Langmuir Probe), we analyze the statistical trends of density perturbations with wavelengths of 20-300 km. The results include gravity waves and are investigated as a function of local time and altitude. We find that a significant portion of plasma variability in the ion-demagnetization region can be explained by fluctuations in the neutral atmosphere.

1. Introduction

Gravity waves have been analyzed previously using data from Mars [1,2,3]. The focus is generally on "apparent wavelengths" which are wavelengths observed along the elliptical satellite track. Recently, Mayyasi et al. [4] has looked at the existence of coupling between the ions and thermospheric species and found regions of coupling concentrated near the dawn terminator as well as 12LST. Note that ions are demagnetized below ~200km making them more susceptible to neutral motions than plasma forces. The ionosphere in this region responds quickly (<<1hr) to perturbations on the order of few 10s of percent. A completely depleted ionosphere, on the other hand, may take up to several hours to reach photochemical equilibrium.

2. Data Analysis

In our study, a polynomial is fit to the plasma and neutral densities and a residual density is computed by subtracting the fit from the data and dividing by the fit. A periodogram is then computed in a sliding window along each orbit. Information from each window is indexed to local solar time and altitude bins. This information includes wavelengths, amplitudes, and the number of "wave occurrences" beyond the threshold for statistical significance.

3. Results

Figure 1 depicts the probability of occurrence of plasma (left column) and neutral (right column) waves as a function of local time and altitude. Each of the three rows represents a different apparent wavelength range noted on the left of the figure. Note that CO_2 wave activity for short wavelengths is concentrated at lower altitudes/pressure-levels (panel b) and for medium wavelengths at mid altitudes/pressure-levels (panel d) For the longest apparent wavelengths observed in CO_2, wave activity clusters at the highest altitudes/pressure levels. Electron density fluctuations show no clear trends with wavelength, altitude, nor local time, in terms of relative probability of occurrence.

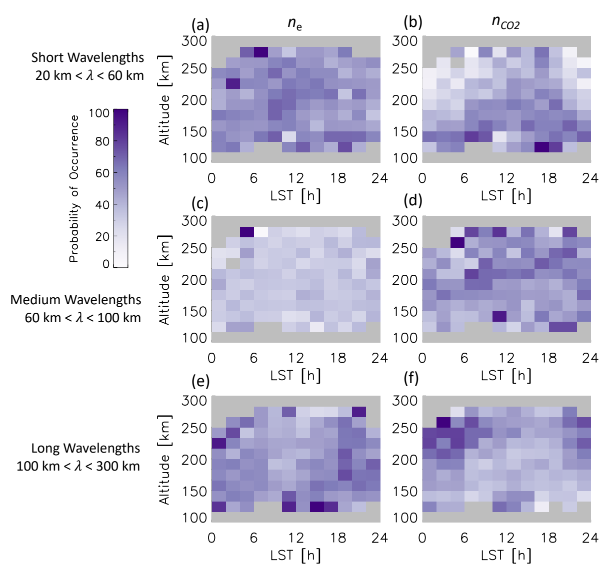

Figure 1: Relative probability of wave occurrence as a function of LST, altitude, and apparent wavelength. Results are shown for n_e (a,c,e) and n_{CO2} (b,d,f).

This suggest that the ionospheric-thermospheric coupling might not be as strong as recently thought across all regions of the ionosphere-thermosphere system. It could also suggest that while coupling is strong at some wavelengths, there also exist ionospheric perturbations on timescales shorter than the neutral fluctuations.

There is some apparent correlation of where long wavelength features tend to occur in both neutral and plasma observations (panels e and f) with wave occurrence concentrations appearing during night above 150 km and near 12LST below 150 km. Meanwhile wave power tends to be concentrated within a few hours after the dawn and dusk terminators for both plasma and neutral perturbations having apparent wavelengths greater than ~50 km. Note that the observed correlation in wave occurrence and amplitude statistics does not prove a relationship between neutral drivers and plasma fluctuations. A better indication of ion-neutral coupling can be inferred by examining specific cases when plasma and neutral waves are seen to occur together at the same time, place, and location. Conversely, we can see in panels (a) through (d) that there are many places where neutral wave occurrence *does not* correspond to plasma fluctuations with similar wavelengths. For apparent wavelengths less than 60 km, this is lack of statistical co-location traces the low-pressure regions of the thermosphere indicating that non-neutral drivers can masquerade as gravity-wave signatures especially at night. There, horizontal features such as ion-precipitation events can result in apparent spectral signatures similar to those of gravity waves. The influence of precipitating plasma is especially significant on the night hemisphere where the dominant plasma production results from precipitation rather than solar EUV.

4. Summary and Conclusions

Our findings indicate that short wavelength neutral density waves are most likely to occur below 180 km altitudes while longer wavelengths are more likely at higher altitudes. In other words, the shorter wavelength waves dissipate above 180 km while the longer wavelengths are not as efficiently damped. Furthermore, there are significant differences in the local time behavior of waves below and above 180 km altitude. At lower altitudes wave power in the neutral species peaks after the dawn and dusk terminators. This behavior is reflected in the plasma fluctuations and is consistent with the close coupling between plasma and neutral densities at these altitudes. Above 180 km, wave power in both the neutrals and plasma peaks ~15 LST, the location of highest neutral densities. Therefore, plasma in the demagnetized regions of the ionosphere tends to be strongly driven by neutral wave behavior. This is because ion-neutral collision frequencies are relatively high and the ionosphere photochemical response timescale is less than the period of the gravity waves below 180 km altitude.

Acknowledgements

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