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Effects of Global and Regional Dust Storms on the Martian Hot O Corona and Photochemical Loss

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Abstract

We examine here for the first time the effects of both global and regional dust storms on the formation of the Martian hot O corona and subsequent photochemical loss process. Our study is conducted by utilizing our integrated model framework, which couples our Martian hot O corona model with a Mars multifluid magnetohydrodynamic model for the non-dusty and dusty cases. The main effect of dust storms on the ionosphere is the upward shift of the ionosphere on the dayside, which results in an increase in production of hot O at all altitudes above the ionospheric peak. However, the inflation of the neutral atmosphere quickly suppresses the enhanced nascent hot O, reducing the photochemical loss rate by ~28%. The density structure of the hot O corona does not show any significant changes, while the magnitude of the density decreases for all altitudes.

1. Introduction

Coupling between the lower and upper atmosphere at Mars allows the lower atmospheric processes to drive forcings in the upper atmosphere. In particular, dust enhancement in the lower atmosphere of Mars has prominent effects on the dynamics, energy balance, and structure of the upper thermosphere and ionosphere [1]. Typical regional dust storms always occur when Mars is near its perihelion, but global dust storms are rare. These large dust storms can engulf the entire planet and have planet-wide impacts on the atmosphere for several months. Global dust storms can lead to the cooling on the surface, dust aerosol radiative heating, inflation of the lower atmosphere and modification of the atmospheric circulation, which in turn influence the chemistry and climate of Mars [2]. However, the physical mechanisms and effects of the global dust storms in the upper atmosphere are not yet sufficiently investigated. Here, we present our modeling study to better understand the effects of dust storms on the upper atmosphere and ionosphere. This study focuses particularly on the dust storm effects on the hot O corona and resulting photochemical loss process from Mars.

2. Dust Storm Effect Simulations

The simulations in this study are carried out by utilizing an integrated model framework, which couples our 3D Adaptive Mesh Particle Simulator (AMPS) [3,4] with a 3-D multifluid magnetohydrodynamic (MF-MHD) model [5]. The model integration is achieved in one-way, such that our AMPS code incorporates pre-simulated results by the MF-MHD model without transferring the feedback for updating the computation. We simulated the non-dusty and dusty cases for 1971-1972 global and 2017 regional dust storms [6].

2.1 Hot O Corona and Photochemical Loss

The dust storm effects are described through the one-way model integration method. For the purpose of this study, we employ the 3D MF-MHD model to incorporate the disturbed ionospheric condition by dust storms. The MF-MHD model describes the ionosphere self-consistently based on the neutral atmosphere adopted for the non-dusty and dusty conditions. The response of the ionosphere is much stronger to the global dust storm than to the regional dust storm. The modeled electron density for the global dust storm shows the altitude shift of the ionosphere, which results in an increase in the production of hot O at all altitudes (Figure 1). The simulated ionospheres for the cases considered in the study are used as inputs to our hot O coronal model.

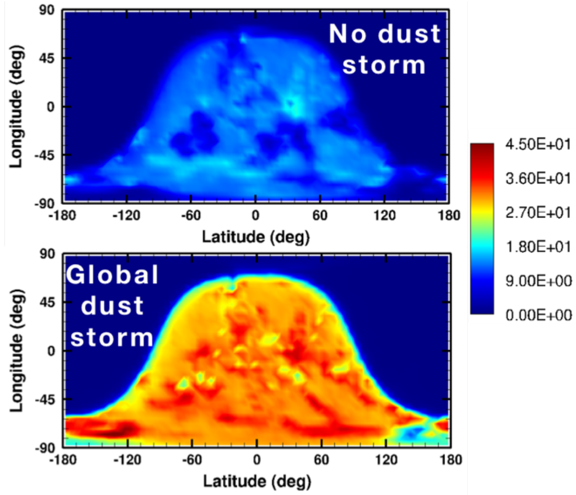

Figure 1: Dissociative recombination of O_2^+ rate at an altitude of ~ 200 km for the (top) non-dusty and (bottom) dusty cases (global dust storm).

3. Results

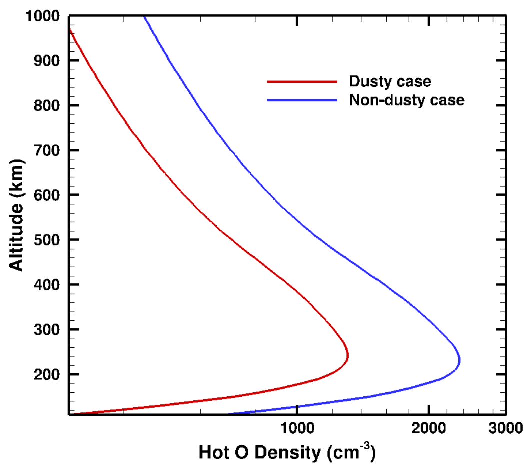

Figure 2: Simulated hot O density for the non-dusty and dusty cases (global dust storm).

As shown in Figure 2, regardless of the lifted source region in altitude, the structure of the resulting hot O density does not show any significant changes when the global dust storm occurs, whereas the magnitude of the hot O density decreased for all altitude levels. As nascent hot O collides with the ambient thermal species, the enhancement of hot O gets quickly thermalized by increased thermospheric densities. Consequently, the overall photochemical loss rate decreases by ~28% for the strong dust storm case.

References

[1] Bougher, S. W., Murphy, J., and Haberle, R. M.: Dust storm impacts on the Mars upper atmosphere, *Adv. Space Res.*, 19, 8. pp. 1255-1260.

[2] Vandaele, A. C., et al.: Martian dust storm impact on atmospheric H_2O and D/H observed by ExoMars Trace Gas Orbiter, *Nature Letter*, 568, pp. 521-525.

[3] Tenishev, V., et al.: A Global Kinetic Model for Cometary Comae: The Evolution of the Coma of the Rosetta Target Comet Churyumov-Gerasimenko throughout the Mission, *The Astrophysical Journal*, 685(1), pp. 659-677.

[4] Lee, Y., et al.: Hot oxygen corona at Mars and the photochemical escape of oxygen: Improved description of the thermosphere, ionosphere, and exosphere, *Journal of Geophysical Research: Planets,* 120, pp. 1880–1892.

[5] Najib, D., et al. (2011), Three-dimensional, multi-fluid, high spatial resolution MHD model studies of the solar wind interaction with Mars, *J. Geophys. Res.*, 116, A05204.

[6] Fang, X., et al. (2019), Mars Dust Storm Effects in the Ionosphere and Magnetosphere and Implications for Atmospheric Carbon Loss, *J. Geophys. Res. Space Phys.* 2019JA026838.