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Differential Ablation of meteoric metals in the LMD-Mars-Metals and NCAR WACCM-Metals models

Wuhu Feng et al.

It is evident that a variety of metals are deposited in the Earth's mesosphere and lower thermosphere (MLT, ~70-120 km) through meteoric ablation when the cosmic dust particles enter the atmosphere at high entry velocity (11-72 km/s). However, it is still unclear how much and accurate cosmic dust enters the atmosphere of Mars (though the estimation of global dust input would be a few tons per sol) and what is the difference comparing to Earth's atmosphere (which has a 1-2 order global input range from different estimations).

We have developed global atmospheric meteoric models of Na, Fe, K, Mg, Ni, Ca, Al, Si, P, S etc) into the Whole Atmosphere Community Climate Model (WACCM) and its vertical extensions to 600 km (WACCM-X) from US National Center for Atmospheric Research (NCAR, termed WACCM-metals), which simulate well the metal layers compared with the available lidar/rocket/satellite measurements.

New observations of some metals for the Martian atmosphere (i.e., Mg⁺ observations from IUVS (Imaging UV Spectrometer) and Mg⁺, Na⁺ and Fe⁺ from NGIMS (Neutral Gas Ion Mass Spectrometer)) instruments on NASA's Mars Atmosphere and Volatile Evolution Mission (MAVEN) spacecraft are available from 2014. Therefore, we have incorporated the chemistry of three metals (Mg, Na and Fe) in the Laboratoire de Météorologie Dynamique (LMD) Mars global circulation model (termed as LMD-Mars-Metals), following similar work we have done for the Earth's atmosphere. The model has been developed by combining three components: the state-of-the-art LMD-Mars model covering the whole atmosphere from the surface to the upper thermosphere (up to ~ 2 × 10⁻⁸ Pa or 240 km), a description of the neutral and ion-molecule chemistry of Mg, Fe and Na in the Martian atmosphere (where the high CO₂ abundance produces a rather different chemistry from the terrestrial atmosphere), and a treatment of injection of the metals into the atmosphere from the ablation of cosmic dust particles. The LMD-Mars model contains a detailed treatment of atmospheric physics, dynamics and chemistry from the lower atmosphere to the ionosphere. The model also includes molecular diffusion and considers the chemistry of the C, O, H and N families and major photochemical ion species in the upper atmosphere, as well as improved treatments of the day-to-day variability of the UV solar flux and 15 mm CO₂ cooling under non-local thermodynamic equilibrium conditions.

We have incorporated the chemistries of Mg, Fe and Na into LMD-Mars because these metals have different chemistries which control the characteristic features of their ionized and neutral layers in the Martian atmosphere. The Mg chemistry adds 7 neutral and 8 ionized Mg-containing species, connected by 42 neutral and ion-molecule reactions. The corresponding Fe chemistry has 39 reactions with 14 Fe-containing species. Na chemistry adds 7 neutral and only 2 ionized Na-containing species, with 32 reactions. The injection rate of these metals as a function of latitude, solar longitude at different pressure levels is pre-calculated from the Leeds Chemical Ablation Model (CABMOD) combined with an astronomical model which predicts the dust from Jupiter Family and Long Period comets, as well as the asteroid belt, in the inner solar system. The model has been evaluated against by Mg⁺, Na⁺ and Fe⁺ observations from IUVS and NGIMS measurements.

The comparison of these metal layers between Earth's and Mar's atmospheres will be discussed, which allows us to understand the meteor astronomy, chemistry and transport processes that control the different metal layers in the upper atmosphere on different planets.

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