MARS-SOLAR WIND INTERACTION: COUPLING BETWEEN HYBRID, IONOSPHERIC, THERMOSPHERIC AND EXOSPHERIC MODELS.

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Introduction

The solar wind interaction with the Martian neutral environment is investigated by means of three dimensional hybrid magnetospheric simulations. In such formalism, ions have a kinetic description while electrons are treated as an inertialess fluid, ensuring the neutrality of the plasma and contributing to currents and pressure terms. This model has been successfully used to describe the near ionized environment of Mars [1, 2, 3]. The main drawback of the hybrid formalism is the coarse spatial resolution that a sequential program with a uniform grid description can afford (about 130-150 km), mainly restricted by computational limitation (memory and CPU). In the frame of the HELIOSARES project (PI F. Leblanc) dedicated to the modeling of Mars environment (neutral and charged species) from the surface up to the solar wind, a modeling effort of parallelization has been conducted. In parallel, developments concerning a three-dimensional exospheric model and an ionospheric extension of a Global Circulation Model [10] have been performed. The 3D exospheric model provides a description of the Martian exosphere of CO_2, H, H_2 and O from the exobase level to few Martian radii [4], including thermal and non-thermal (as produced by dissociative recombination and sputtering) contributions to the O component. On the other hand, a 3D multifluid dynamical core describing the dynamic of the Martian ionospheric plasma has been included in the LMD Martian General circulation Model [11, 9] that has been extended up to the exobase.

Methodology

The exospheric 3D model used as inputs the descriptions of the thermosphere and ionosphere provided by the extended Martian General Circulation Model [11]. In a similar approach than [5], simulations outputs of the exospheric model are then used as inputs of the magnetospheric model. A realistic and three dimensional description of the neutral environment is therefore used to constrain the production in the magnetospheric model. This approach is also used for the magnetosphere-ionosphere models coupling, the ionospheric density distribution of the ionospheric model [11] being used as inputs of the magnetospheric model.

The exospheric model

This model provides the description of the thermal exospheric components (H, H_2, O and CO_2) as well as a description of the non-thermal oxygen component. The non-thermal oxygen contribution is estimated by means of a Monte-Carlo approach with a description of the thermosphere determined by the extended general circulation model LMD-MGCM [11]. In this model, hot oxygen atoms are either produced by dissociative recombination of the ${O_2}^+$ as modeled by the extended LMD-GCM model or by sputtering using as inputs the flux of pick-up ions reimpacting Mars' exobase as calculated by the magentospheric model. Hot test-particles are then followed through the extended LMD-GCM thermospheric model. The contribution of the thermal part of the exosphere is obtained by using a Chamberlain approach extended to three-dimension and adapted to include planet's rotation and using the extended LMD-GCM model as bottom conditions. Simulation results of this model are presented in [4].

The ionospheric model

The LMD-GCM [10, 6] describing the Martian thermosphere as been completed with the implementation of photoionization and secondary ionization by X-rays and photo electron impact. These inputs allow describing the Martian ionosphere at low altitudes where the ion transport can be neglected [9]. [11] extended this model by implementing an ambipolar diffusion in the ionosphere. This improvement allows investigating the upper ionosphere and its coupling with the magnetosphere.

The hybrid model

The hybrid model used in this work has been presented in[1], parallelized and completed with a realistic ionospheric description with the implementation of a simplified chemistry model [7]. An updated version of the model with a crustal field description is presented by [8]. This simulation model describes the electromagnetic environment and the dynamic of 6 ion species (H^+_{sw}, He^{++}, H^+_{pl}, O^+, CO_2^+ and O_2^+). Simulations are performed on a meso-scale calculation server CICLAD (http://ciclad-web.ipsl.jussieu.fr) dedicated to Institut Pierre Simon Laplace modeling effort : The project has access to 3 servers of 32-cores and 3 servers of 64-cores with 4Go memory per CPU. Communications are perfomed with infinite-band cables.

Results

In this presentation, we will describe the results of a first coupling between these three models. Simulations are performed at mean solar activity, at Ls=90° and for nominal solar wind conditions (with the crustal field placed at midnight) for all exospheric, ionospheric-thermospheric and magnetospheric models. The potential state of Mars' environment from the solar wind up to the surface will be presented. Starting from the magnetosphere, we will discuss the possible signatures of Mars' season on the main structures in the magnetosphere (Bow Shock and magnetopause), in the exosphere (thermal CO_2, O, H and H_2 exospheric seasonal signatures and non-thermal O densities as induced by both sputtering and dissociative recombination) and in the ionosphere/thermosphere (role of the ionospheric transport).

Conclusion

Future developments are still planned in order to take into account the feedback from the magnetosphere onto the ionosphere/thermosphere and therefore on the exosphere. These will be done during the forthcoming years. All these developments are done in the frame of MAVEN science preparation.

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