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Mars-Solar wind interaction: coupling between hybrid, ionospheric and exospheric models

R. Modolo (1), F. Leblanc (1), S. Hess (1), J.-Y. Chaufray (1), M. Yagi (2),M. Mancini (3), F. Forget (4), F. Gonzalez-Galindo (5), L. Lorenzato (6), C. Mazelle (6) and G. Chanteur (7)
(1) UVSQ/LATMOS-IPSL/CNRS-INSU, Guyancourt, France, (2) STEL, Nagoya, Japan, (3) LUTH, Obs. de Paris, Meudon, France, (4) LMD-IPSL, Jussieu, France, (5) IAA, Granada, Spain, (6) IRAP, Toulouse, France, (7) LPP, Palaiseau, France

Abstract

Solar wind interacts efficiently with Mars, it contributes to the erosion of the gazeous envelope and concurs to the atmospheric dynamic. The electromagnetic coupling with the neutral environment takes place through ionization processes which act as a catalyzer. A three-dimensional hybrid model has been developped to describe the solar wind and planetary plasma dynamic. Parallelization of the model has been accomplished and enable us to reach a grid resolution of 50/60 km , which are slightly more than plasma scale height in the ionophere. An attempt of coupling between this hybrid model, a three dimensional ionospheric-thermospheric model and a three-dimensional exospheric model is made and presented.

1. Introduction

The solar wind interaction with the Martian neutral environment is investigated by means of three dimensional hybrid 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 providies a description of the Martian exosphere of CO_2 and O from the exobase level to few Martian radii [4]. On the other hand, a 3D multifluid dynamical core describing the dynamic of the Martian ionospheric plasma has been included in a Martian General circulation Model [11, 9].

2. Methodology

In a similar approach than [5], simulations outputs of the exospheric model have been used as inputs of the hybrid model. A realistic and three dimensional description of the neutral environment is therefore used to constrain the production in the hybrid model. This approach is also used for the hybrid-ionospheric model coupling, the ionospheric density distribution of the ionospheric model [11] is used as inputs of the hybrid model.

2.1 The exospheric model

This model provides the description of thermal exospheric components (O, CO, CO_2 and O_2) as well as a description of 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 general circulation model LMD-MGCM [6]. 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. Simulation results of this model are presented in [4].

2.2 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.

2.3 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.

3. Simulations

Simulations are performed at mean solar activity for all exospheric, ionospheric-thermospheric and hybrid models. The description of CO_2 thermal component is used in the hybrid model while the description of the oxygen corona takes into account both thermal and non-thermal components. Density profiles of O^+, O^+_2 and CO^+_2 extracted from the ionospheric model are used as input for the hybrid model. High resolution hybrid simulation results are presented.

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