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A new 3D parallel multi-species hybrid model for Solar Wind – Mars interaction

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Abstract

In the frame of the HELIOSARES project (PI F. Leblanc) dedicated to the modeling of Mars environment (neutral and charged species) from the lower atmosphere to the solar wind, a modeling effort of parallelization has been conducted. Such model allows having a kinetic description of the ions with a rather improved spatial resolution (smaller than the ion inertial less). The latest progresses are reported and simulations results with a uniform spatial resolution of 75 km are presented.

1. Introduction

Due to the absence of strong intrinsic magnetic field, the Martian atmosphere/exosphere is directly in contact with the Solar Wind (SW), exchanging part of its momentum and energy. This coupling occurs via ionization processes and contributes to the erosion of the neutral environment of the planet. Several space missions (past, active and future), such as Phobos-2, MGS, Mars-Express and soon MAVEN, are dedicated to reveal the Martian neutral and ionized environment properties. Many *in situ* observations are available and characterize the plasma (and neutral) environment in the near vicinity of the spacecraft but these observations are highly localized in space and time. With a single spacecraft it is difficult to separate spatial from temporal structures and we often resort to global simulation to set back the observation in a global context. In this scope we have developed a new version of an existing simulation model [1].

1.1 Modelling effort

MHD and hybrid models are largely used to investigate the properties of the SW interaction with Mars [2]. Both of these approaches have their own advantages and limitations: an excellent spatial resolution for MHD models [3] and a well-adapted fluid approximation in the ionosphere while hybrid models include finite Larmor radii effects, which are emphasized in several space observations, but with a coarse spatial resolution [1,4,5,6]. Our approach is to use hybrid formalism and to improve the spatial resolution such that we try to reach the plasma scale height in the upper ionosphere (about 35-50 km), allowing a consistent coupling between general circulation model describing the Martian atmosphere/thermosphere [7], exospheric model [8] and this hybrid model.

In the frame of the HELIOSARES project (granted by the French National Agency), we have parallelized our previous hybrid model [1]. This study presents the first simulation results with an improved spatial resolution from a 3-dimensional parallel multi-species hybrid model of the Martian interaction with the SW.

2. A parallelized hybrid model dedicated to Mars

2.1 The hybrid formalism

In the hybrid frame, only kinetic effects related to ions are taken into account. Ions are considered as macro-particles and electrons are treated as an inertia-less fluid ensuring the neutrality of the plasma and contribute to the total current and electronic pressure. The model solves the Maxwell equations to provide the temporal evolution of the electromagnetic field.

2.2 Specificities of the parallelized simulation model

The hybrid model that we developed previously [1,9] has been parallelized with the Message Passing Interface (MPI) protocol. Such developments allow us to perform simulation on a meso-scale computational center dedicated to this project.

First simulations have been performed on a 160x300x300 grid with a spatial resolution of $\Delta x \sim 100$ km. This model includes neutral coronae of atomic oxygen and hydrogen as well as a corona of carbon dioxide. This neutral environment is partly ionized by solar photons, electronic impact and charges exchanges between SW and planetary ions and neutrals. In addition a simplified ionospheric chemistry description is also implemented in this model. The set of chemical equations solved in the model is consistent with the one used in the ISSI SWIM challenge [2].

3. Simulation results

Simulation results with an improved spatial resolution (below 100km) will be presented. Magnetic field draping and the dynamic of the planetary and SW plasma will be described. Plasma escape rate will be discussed.

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