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Interaction of Venus-like solar system bodies with the solar wind in spherical hybrid model.

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Abstract

We are developing spherical hybrid model, using the HYB hybrid model for planetary plasma interactions, to study how the Venus-like solar system bodies interact with the solar wind. The globally unmagnetized planets are under the influence of the super-alfvenic and super-sonic solar wind from the Sun. The ionospheres of such objects form an obstacle to the magnetized solar wind flow, and, as a result, an induced magnetosphere is formed around these objects.

In this brief report we illustrate the latest achievements of the spherical grid development and illustrate the usage of the new spherical HYB hybrid model (HYBs) by showing the result of Venus interaction with the solar wind.

1. Introduction

A hybrid approach provides an efficient way to model how the cosmic plasma interacts with non-magnetized and weakly magnetized planetary objects. In a hybrid model ions are treated as particles, while electrons form a massless, charge neutralizing fluid. The basic properties of the HYB hybrid model are described in [1]. The HYB hybrid model family is being developed at the Finnish Meteorological Institute (FMI) during the last decade.

The model has been used successfully to describe how the flowing plasma interacts with various solar system bodies such as Mercury, Venus, the Moon, Mars, Saturnian moon Titan and asteroids.

One geometrical limitation of the HYB model is, however, that it assumes cube shaped grid cells. In order to expand the usage of the HYB model we have initialized a project aiming to develop a spherical coordinate version of the model (HYBs).

2. Spherical grid in a hybrid model

In this section we briefly describe main advantages and challenges of the spherical grid when it is used in a hybrid model.

2.1 Advantages

1. Grid resolution. In spherical coordinates there is "natural" grid refinement: the closer the cells are to the obstacle the smaller grid cells become. This property could be used for the introducing of a self-consistent ionosphere into the hybrid model, where we need to decrease the cell size at low altitudes.
2. Obstacle boundary condition. Another "natural" property of spherical coordinates is the geometrical interpretation of the obstacle. Planetary surface is covered by the r = constant surface of the spherical grid, which simplifies the implementation of the boundary condition.

2.2 Challenges

1. Interpolations. Hybrid approach implies a number of vector and scalar value interpolations between different grid elements. As the curvilinear grids are not homogeneous, the realization of interpolation methods is not as straightforward as in the Cartesian coordinates.
2. Pole-regions. Spherical grid includes two singular points, poles, where the numerical values are not defined.

3. Venus – solar wind interaction.

Here we illustrate the first realistic results of the HYBs model: simulation of the solar wind flowing around Venus.

Input parameters of simulation:

Initial Magnetic Field:
$B_x = 0$, $B_y = 10nT$, $B_z = 0$

Particle populations: (Similar as in Jarvinen at al, 2009 [2])

1 .Solar Wind Population

H+, $n = 14 \cdot 10^{6}$ m^{-3}, $T = 10^{5}$ K, $V_z = 4.3 \cdot 10^{5}$ m/s

2. Ionospheric Population

O+, Emission rate = $2.0 \cdot 10^{25}$ s^{-1}, T = 2000 K

3. Exospheric Populations

H+, Emission rate = $2.0 \cdot 10^{23}$ s^{-1}, T = 6000 K

O+, Emission rate = $4.0 \cdot 10^{24}$ s^{-1}, T = 5600 K

H+, Emission rate = $6.2 \cdot 10^{24}$ s^{-1}, T = 200 K

MacroParticles: ~ $2 \cdot 10^{6}$ macroparticles, particles/cell=30

Grid stucture: Spherical

dr = 302 km, $d\theta = 4.53^{o}$, $d\varphi = 9.00^{o}$

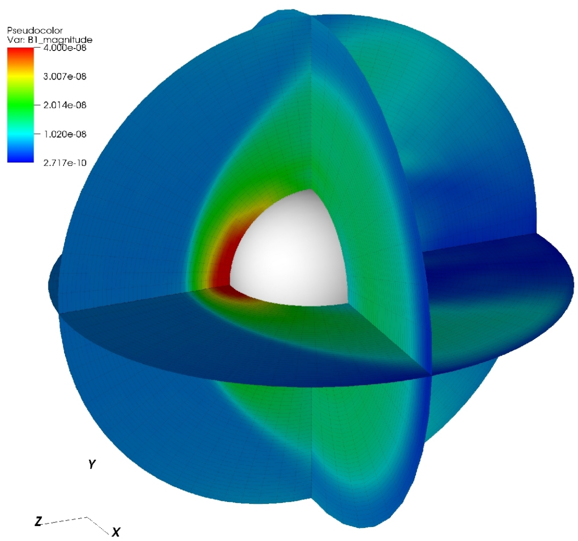

Figure 1: Solar wind – Venus interaction. Magnetic field.

The figures demonstrate steady state regime and represent the total magnetic field and the total velocity of solar protons (H+). The results are very similar to the results, which were obtained by the Cartesian version of HYB model with the same input parameters [2].

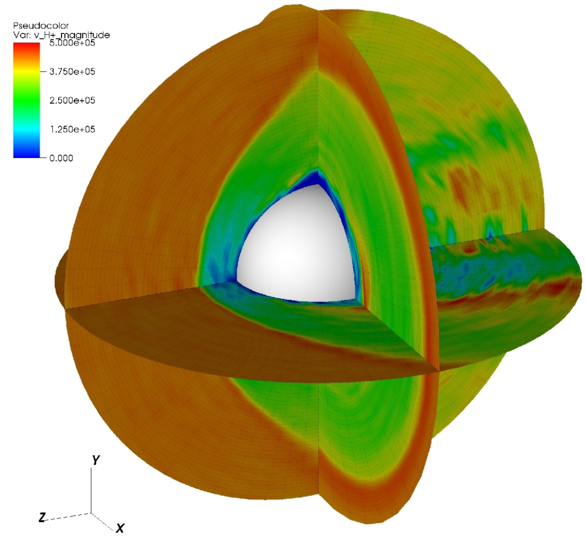

Figure 2: Solar wind – Venus interaction. Total solar wind velocity (H+).

4. Conclusions

A developing of HYBs model is anticipated to provide a powerful tool for the modeling of self-consistent cosmic plasma interactions with various solar system bodies and exoplanets, it is also can be applied to another astrophysical phenomena e.g. magnetodisk formation [3]. Developing of such a model is, however, a challenging task, because of the complexity of the interpolation, the polar region of the grid and appropriate boundary conditions.

Reference

[1] Kallio, E., and Janhunen P.: Annales Geophysicae, Vol. 21, p. 2133, 2003

[2] Jarvinen, E., Kallio, E., Janhunen, P., Barabash, S., Zhang, T.L., Pohjola, V., Sillampää, I.: Annales Geophysicae, Volume 27, Issue 11, 2009, pp.4333-4348

[3] M.L. Khodachenko, N.S. Erkaev, S.Dyadechkin, I. Shaykhislamov, Z.Vörös, I.Alexeev, E.Belenkaya, T.Zaqarashvili, E.Kallio, H.Lammer: Abstract to EPSC2012