Multiscale Simulations of Space Plasmas at Ataptive Block Grids and Related Numerical Scheme Issues

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Simulation of the space plasmas flows is a key point in the problem of the so called "space weather forecast". The eruptive processes near the Sun cause the complicated plasma motions which are responsible for a lot of practically important processes around the Earth, among them being the magnetic storms, dangerous radiation at the spacecraft orbits and the scintillations in the upper atmosphere irradiated by the solar energetic particles.

To simulate these processes the multiscale MHD codes are under development, which allows to simulate the coronal mass ejections in the Sun atmosphere (spatial scale of order of 10^6 km), the shock wave propagation up to the Earth through the distance 10^8 km and the Earth magnetosphere restructuring with the scales of 10^3-10^4 km. To cover this wide range, we use the adaptive block grid, which fills the computational domain with the blocks, each of the block being the chunk of a uniform cartesian (or spherical) grid [1]. Choosing the different spatial resolution for a different regions in the computational domain one can achieve the higher resolution where it is needed and only there. At the same time near the interfaces between the blocks of different resolutions the numerical schemes and algorithms should be properly modified. The present paper descirbes the means we use to mantian the high-order resolution and shock-capturing properties of the MHD simulation at the adaptive block grids. The particular issues are following.

The Earth magnetic field at lower altitudes and its pressure is so strong comparing to the space plasma pressure that even a minor imperfection in this field approximation can result in a physically absurd numerical solution with wrongly distributed or even negative plasma pressure. We constructed a positive conservative numerical scheme which eleminates this effect.

For more complicated MHD models, such as semi-relativistic [2] and relativistic models we found a general way to derive the source terms which allow to deal with the numerical solutions, which involve a small but finite portion of divergent magnetic field resulting from truncation errors and their accumulation. On the other hand we develop a powerful means to clean up the numerical solution from this divergent magnetic field which are intentionally suited for block grids with jump-like changes in a resolution.

We also suggest a way to smooth the numerical solution by smoothing the grid near the resolution changes. The larger of the two neighboring control volumes shares its exsessive volume with his finer neighbor, what results in a specific form of the control volume (not completely closed and may be self-intersecting) looking like a maltese cross or a latin cross. The improvement in the results quality is demonstrated.

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[1] Powell K. et al, J.Comput.Phys., **154**, 284, 1999
[2] Gombosi T.I. et al J.Comput.Phys., **177**, 176, 2002