Geoscientific Model Development Discussions

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Comment on gmd-2021-122

Anonymous Referee #3

Referee comment on "UBER v1.0: a universal kinetic equation solver for radiation belts" by Liheng Zheng et al., Geosci. Model Dev. Discuss., https://doi.org/10.5194/gmd-2021-122-RC3, 2021

The paper presents a new numerical solver, UBER, which can solve the general form of radiation belt Fokker-Planck equation and Boltzmann equation in arbitrarily provided coordinate systems, and with user-specified boundary geometry, boundary conditions, and equation terms. The mathematical theory and numerical techniques of UBER are clearly described, and three example problems are presented which well demonstrates the capability and reliability of the solver. Overall, this is a nicely written paper with convincing results showing that UBER could make important contribution to radiation belt modeling. The reviewer only has a few minor comments before recommending the paper for publication in GMD.

- Could the authors clarify or discuss further if the UBER solver can handle boundary conditions at varying locations or not? If we look at the radial diffusion model as a simple example, in the traditional solvers based on finite different method, it is often driven by data-driven outer boundary conditions at a fixed L*. However, the L* location of the satellite data providing the outer boundary is actually varying in time, which could lead to data gaps in the outer boundary condition and uncertainties in the model results. Discussions on if and how this type of boundary conditions can be implemented in UBER will further increase the significance of the work.
- The reviewer is also curious how the coordinate conversion between adiabatic invariants and energy and pitch angle can be implemented in UBER. As discussed in Subbotin and Shprits [JGR, 2012], several 3D diffusion radiation belt models "utilized two grids to solve the Fokker-Planck equation; one grid, which keeps the first and second adiabatic invariants constant, was used for the computation of the radial diffusion, and the other grid, orthogonal in energy and pitch angle at each fixed radial distance, was used for the computation of energy diffusion, pitch angle diffusion, and mixed energy and pitch angle diffusion." At each time step, the results were converted and interpolated between the two grids, which could lead to uncertainties in the model results depending on how the conversion and interpolation are performed. Is this coordinate conversion still needed in UBER? If not, why?
- It will greatly enhance the significance of the paper if discussions are included in comparing the efficiency, stability, and accuracy between the UBER code and traditional finite difference codes. It is demonstrated the UBER is more efficient than previous SDE

codes, but how does it compare with the traditional solvers based on the finite difference method? Is it still much less efficient if global distributions of radiation belt electrons in L, energy, and pitch angle are targeted? How about if we only need to solve for the distribution locally at certain L, energy, and pitch angle? The authors could perhaps use example problem 3 to compare the efficiency, stability, and the accuracy between the two different types of solvers and then expand the discussion to higher-dimension models such as 3D diffusion models.