

Review of ‘A computationally efficient TVD-FFSL hybrid tracer transport scheme on spherical centroidal Voronoi tessellations in iAMAS (v2.6.3)’ by Li et al.

Summary: This manuscript presents the development and evaluation of a TVD-FFSL hybrid tracer transport scheme for the iAMAS model on spherical centroidal Voronoi tessellation (SCVT) meshes. The scheme combines a horizontal TVD flux operator with the KOREN limiter, a vertical FFSL operator based on PPM reconstruction, and second-order TVD Runge-Kutta time integration. The authors first evaluated the numerical reliability of the scheme through idealized 2D tests (solid body rotation and deformational flow) and realistic 3D dust simulations. Idealized 2D tests demonstrate that TVD-FFSL achieves robust shape preservation. Realistic 3D dust simulations on a 16–60 km variable-resolution grid confirm its long-term stability and accuracy comparable to 2H1FCT. Then, performance benchmarks show that TVD-FFSL achieves over $2\times$ speedup in standalone transport tests and exceeds $3.75\times$ speedup in long-term atmospheric dust simulations, significantly reducing the computational overhead of numerous tracer transport.

The topic is well suited to GMD. Tracer transport is a critical computational bottleneck in high-resolution atmospheric chemistry models with tens to hundreds of species, and therefore, developing a more efficient scheme that maintains stability and monotonicity is a valuable contribution. The manuscript is generally well organized and clearly written.

However, I have several concerns that should be addressed before publication. My main concerns: 1) the lack of a rigorous mathematical monotonicity guarantee, which the authors acknowledge but do not fully quantify; 2) the need for more detail on the vectorization implementation and its portability; and 3) the need to spell out many abbreviations for clarity (e.g., ATTILA, CLaMS, FLEXPART). Below are my specific comments.

Specific comments:

1. The authors rightly note that the hybrid TVD-FFSL scheme lacks the strict mathematical monotonicity guarantee of FCT-type schemes, especially on unstructured meshes. However, the manuscript does not quantify how often or how severely monotonicity is violated in practice. The statement that "no unphysical

instabilities or mass accumulations are observed" is reassuring but qualitative. I would encourage the authors provide quantitative evidence where feasible. This would help readers assess the practical reliability of the scheme.

2. The authors emphasize that the PPM reconstruction is highly vectorized in this TVD-FFSL implementation, and the PPM reconstruction is implemented in an array-oriented, branch-free programming paradigm, as outlined in Algorithm 1. However, the manuscript does not discuss its portability. Is the vectorized implementation specific to the Sunway architecture, or is it portable to other platforms (e.g., Intel, AMD, ARM)? Some discussion of portability would be helpful. Moreover, how much of the speedup is due to vectorization versus algorithmic differences?
3. Page 3, Line 65: 'semi-Lagrangian methods and Eulerian methods' → 'semi-Lagrangian and Eulerian methods'
4. Page 5, Lines 135-140: the density of dry air is usually denoted by ρ_d .
5. Page 6, Line 177: 'gradients, whose exact definition is' → 'gradients, defined exactly as'
6. Page 7, Line 191: What exactly do "MINMOD and SUPERBEE" refer to? A brief clarification might be helpful.
7. Page 8, Line 216: 'Consequently, then FFSL scheme', 'then' → 'the'.
8. Page 8, Line 236: 'the PPM reconstruction are highly vectorized', 'are' → 'is'.
9. Page 13, Line 374: 'concentrationsagainst' → 'concentrations against'.
10. Page 13, Section Efficiency and scalability: It should first be clarified how the wall-clock time per dynamical time step is measured, e.g., whether it is averaged over multiple time steps.