Reviewer 1:

Thank you for a close reading of the manuscript and many valuable suggestions to clarify the presentation of the material. In this response, I focus on the technical points and questions you raised.

In the following, the reviewer's comments are italicized.

RC1: *Figures 20 and 21 shows larger diffusion for shorter time steps. Could you elaborate on this? Is the traditional SL property that longer time steps reduce diffusion (while the solution can degrade in other metrics)? How would one choose the right time step in practice?*

Yes, generally in SL methods, longer time steps reduce dissipation. It is simplest to understand this in remap-form methods. In remap-form methods, the only source of dissipation is in the remap step, which occurs once per time step. Thus, as the time step is decreased, the dissipation increases. One sees this, for example, in the SL methods in [3] that provide data for two different time steps: CSLAM and FARSIGHT.

Semi-Lagrangian passive tracer transport is simpler than semi-Lagrangian dynamical cores. Importantly, long trajectories are possible because the velocity data are provided by the dynamics. Thus, the relatively inexpensive transport trajectory algorithm can be substepped, if necessary, relative to the expensive tracer transport remap step. In this case, the advection algorithm can be robust over a large range of time steps.

When using a method that is robust over a large range of time steps, the practical time step limit is determined by the simulator in which the transport method is embedded. For example, the transport step cannot exceed the maximum permitted physics parameterization time step, since updated tracer values must be provided to the physics parameterizations. In addition, details of the dynamical core may require additional transport-dynamical-core coupling computations, e.g., to exceed a dynamical core's vertically Lagrangian vertical remap time step. Finally, selecting multiple subcomponents' time steps while satisfying substepping divisibility constraints influences final time step selection. Practical experience in E3SMv2 and SCREAM [2] with a method very close to the $n_p^{\mathrm{t}} = n_p^{\mathrm{v}} = 4$, $n_f = 2$ Islet method shows that a time step 5–8 times longer than the dynamics time step satisfies the various constraints. For example, in the E3SMv2 standard and Regionally Refined Model (RRM) resolutions, the factor is 6; it is 8 in [2]; and it is 5 in some other SCREAM simulations due to divisibility constraints and balancing other time steps. The Islet method with other parameter values will maintain this range of factors.

RC1: *l631: why can you not use the dynamical core to compute the density? the chosen approach seems rather ad-hoc; can you guarantee that density values are realistic?*

Thank you for this clarifying question. I should have provided more details in the manuscript. The density factor is described in the text surrounding equation 32 of reference [1]. In the manuscript, its discretization follows from approximation of the integrals in that equation by $n_p = 4$ GLL quadrature (since $n_p = 4$ is used for the total mass density field ρ); with this quadrature scheme, the basis function nodal values are 0 except at one quadrature point. The resulting discretization has order of accuracy 2. The experiments are run with a standalone program that is not part of the dynamical core. In addition, to run many long experiments, we need a fast method to compute density; thus, an interpolation semi-Lagrangian method makes sense.

Thanks,
Andrew Bradley

References

[1] P. A. Bosler, A. M. Bradley, and M. A. Taylor. Conservative multimoment transport along characteristics for discontinuous galerkin methods. *SIAM J. on Sci. Comput.*, 41(4):B870–B902, 2019.

[2] P. M. Caldwell, C. R. Terai, B. R. Hillman, N. D. Keen, P. A Bogenschutz, W. Lin, H. Beydoun, M. A. Taylor, L. Bertagna, A. M. Bradley, et al. Convection-permitting simulations with the e3sm global atmosphere model. *J. Adv. Model Earth Sy.*, page e2021MS002544, 2021.

[3] P. H. Lauritzen, P. A. Ullrich, C. Jablonowski, P. A. Bosler, D. Calhoun, A. J. Conley, T. Enomoto, L. Dong, S. Dubey, O. Guba, et al. A standard test case suite for two-dimensional linear transport on the sphere: results from a collection of state-of-the-art schemes. *Geosci. Model Dev.*, 7(1):105–145, 2014.