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Evaluating advection/transport schemes using interrelated tracers, scatter plots and numerical mixing diagnostics

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Diagnostics that quantify numerical mixing for a single tracer, two tracers that are nonlinearly related, and three (or more) tracers that are related linearly in that they add up to a constant are proposed. For the two-tracer test the question of how physically reasonable the numerical mixing is can be addressed by using scatter/correlation plots. Truncation errors will,in general, result in scatter points deviating from the preexisting functional curve and thereby introduce numerical mixing between the tracers. The mixing is divided into three categories (real mixing and two types of spurious numerical unmixing), and is quantified in terms of the normalized distances between the preexisting functional curve and scatter points. For the three-tracer test we quantify how nearly a transport scheme can preserve the sum by transporting the individual tracers in terms of standard error norms.

The mixing diagnostics do not require the knowledge of the analytical solution to the transport problem for the individual tracers, however, using an idealized flow field and spatial distributions facilitates the use of the mixing diagnostics in transport scheme development. Hence we propose to exercise the new mixing diagnostics using an idealized but highly deformational analytical flow field. Example results using the recently developed CSLAM (Conservative Semi-LAgrangian Multi-tracer) scheme on the cubed-sphere are presented.