Analysis of finite-volume transport schemes on cubed-sphere grids and an accurate scheme for divergent winds

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Abstract

The cubed-sphere finite-volume dynamical core (FV3), developed by GFDL-NOAA, is widely used as the dynamical core in numerous models around the world. In 2019, it was officially adopted as the dynamical core for the National Weather Service's new Global Forecast System in the USA, succeeding the previous spectral model. The FV3 utilizes a finite-volume approach to solve horizontal dynamics, applying transport finite-volume fluxes for different variables. As a result, the transport scheme is critical to the model's performance. This work aims to revisit the details of the FV3 transport scheme with the goal of introducing enhancements. We propose modifications to the FV3 transport scheme that significantly improve accuracy, especially in the presence of divergent winds, as demonstrated through numerical experiments. Unlike the FV3 scheme, which has first-order accuracy under divergent winds, our proposed scheme achieves second-order accuracy. For divergence-free winds, both schemes are second-order, with our scheme providing slightly greater accuracy. The modified scheme is tested using a transport model on the sphere, and we demonstrate that it can be extended to the shallow-water equations, retaining the favorable properties of the existing FV3 shallow water solver. Additionally, the proposed scheme exhibits slight computational overhead but is easily implemented in the current code. In summary, the proposed scheme offers significant improvements in accuracy, particularly in the presence of divergent winds, which are present in various atmospheric phenomena, while maintaining computational efficiency.

Keywords: Cubed Sphere, Finite Volume, Transport, Advection, Divergent winds

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