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An orthogonal terrain-following coordinate and its preliminary tests using 2-D idealized advection experiments

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Abstract. We have designed an orthogonal curvilinear terrain-following coordinate (the orthogonal σ coordinate, or the OS coordinate) to reduce the advection errors in the classic σ coordinate. First, we rotate the basis vectors of the *z* coordinate in a specific way in order to obtain the orthogonal, terrain-following basis vectors of the OS coordinate, and then add a rotation parameter *b* to each rotation angle to create the smoother vertical levels of the OS coordinate with increasing height. Second, we solve the corresponding definition of each OS coordinate through its basis vectors; and then solve the 3-D coordinate surfaces of the OS coordinate numerically, therefore the computational grids created by the OS coordinate are not exactly orthogonal and its orthogonality is dependent on the accuracy of a numerical method. Third, through choosing a proper *b*, we can significantly smooth the vertical levels of the OS coordinate over a steep terrain, and, more importantly, we can create the orthogonal, terrain-following computational grids in the vertical through the orthogonal basis vectors of the OS coordinate, which can reduce the advection errors better than the corresponding hybrid σ coordinate. However, the convergence of the grid lines in the OS coordinate over orography restricts the time step and increases the numerical errors. We demonstrate the advantages and the drawbacks of the OS coordinate relative to the hybrid σ coordinate using two sets of 2-D linear advection experiments.

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