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Topographic flow test problems for nonhydrostatic models

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Two nonhydrostatic dynamical cores from the Coupled Ocean/Atmosphere Mesoscale Prediction System (COAMPS) and the Weather Research and Forecasting-Advanced Research (WRF-AR) model are compared and evaluated for a series of test problems for flow over and around topography. These tests are performed for a number of steady-state topographic flows for which analytic or semi-analytic solutions are obtained. Two- and three-dimensional COAMPS and WRF-AR simulations of linear hydrostatic and nonhydrostatic mountain waves are considered. The model results for the horizontal and vertical velocity, as well as momentum and energy flux have been quantitatively evaluated using the analytic solutions for flow over smooth bell shaped and multi-scale terrain. Simulations were also performed on a limited number of nonlinear mountain wave flows for which the characteristics of the solutions are well known from theory and previous numerical simulations, such as mountain waves, wakes, eddy shedding, and wave breaking. For example, simulations of a strongly forced wave breaking event 11 January 1972 Boulder, CO windstorm, which was the subject of a previous model intercomparison among 11 nonhydrostatic models, are compared and evaluated for COAMPS and WRF-AR. These tests have identified several deficiencies in the dynamical cores. The results also highlight the advantages of higher-order accurate numerical techniques for topographically forced-mountain waves, particularly for more complex terrain geometries that excite a spectrum of waves. The simulations also underscore the necessity for a well-posed non-reflective upper boundary condition in order to achieve accurate simulations.