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Pressure Gradient Error of Spectral Element Dynamical Core associated with Topographic Forcing: Comparison with the Spherical Harmonics Dynamical Core

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Response characteristics of the spectral element hydrostatic dynamical core on the cubed sphere to the global topographic forcing are investigated in terms of pressure gradient error, and it is compared with the spherical harmonics hydrostatic dynamical core. The vertical hybrid-pressure coordinate and finite difference method are introduced to both dynamical cores, and explicit and implicit hyper-diffusion schemes are applied to spectral element dynamical core and spherical harmonics dynamical core, respectively. The model atmosphere at initial time is set to the quiescent environment so that the term affecting on the time tendency of the momentum equation at the first time step is the pressure gradient term only which is influenced by the observed surface topography. During 6 days of time integration, the spurious flow is generated due to inaccurate numerical approximations of pressure gradient term for each dynamical core. High zonal wind speed which can be regarded as numerical error is occurred commonly in two dynamical cores around steep topography (e.g., the Tibetan Plateau, the Rocky Mountains, and the Andes Mountains), but the maximum zonal wind speed at day 6 of spectral element dynamical core is 8-9 times larger than that of spherical harmonics dynamical core. The vertically averaged kinetic energy spectrum at day 6 shows very different trend between two dynamical cores. By performing the experiments with the scale-separated topography, it turns out that these kinetic energy spectrum trends are mainly caused by the small-scale topography. A simple change of pressure gradient term into log-pressure form is found to significantly reduce numerical error (up to 63% of maximum wind speed in case of spectral element dynamical core) and noise-like small-scale phenomena.