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New wave-solutions of the shallow water equations over a sphere and their application to global scale models

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Recent theoretical advances have yielded explicit expressions of zonally propagating wave solutions of the Shallow Water Equations over a sphere. These newly found wave solutions are accurately approximated by Hermite Functions in baroclinic modes and by Gegenbauer Functions (i.e. Gegenbauer polynomials multiplied by some high power of cosine(latitude)) in barotropic modes. The theory also yields highly accurate explicit expressions for the dispersion relations of these waves. A natural application of these theoretical advances is the construction of new bases for spectral global scale general circulation models. Preliminary results from this application demonstrate that when a model is initialized by an exact wave solution the Hermite based Shallow Water solver reproduces the exact solution for 100 days with no noticeable error in either the phase speed or the amplitude while with the Spherical Harmonics based solver the exact wave solution was completely destroyed within 4 days. On close examination of the numerical calculations one can detect the generation of errors near the poles followed by their growth and propagation to lower latitudes where they modify the initial signal appreciably. Our results suggest that although Spherical harmonics are the eigenfunctions of the Laplacian in spherical coordinates they are not the most fitting basis for solving the Shallow Water equations on a rotating sphere. Another future application of the theoretical advances is the construction of test cases that will allow a quantitative comparison between the performance (e.g. accuracy, convergence, speed, etc.) of various global scale General Circulation Models. Towards this, the new spectral solvers have to be extended to include nonlinear terms, various types of forcing and dissipation while currently the solver is limited to linear dynamics only.