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Variable order mimetic finite elements for shallow water models

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The Gung-Ho project is a 5 year joint research project between the UK academic community, the UK Met Office and the Science and Technology Facilities Council (STFC). It has the goal of developing a prototype dynamical core for the next generation of the Met Office's numerical weather prediction and climate prediction model suitable for use on the envisioned next generation of massively parallel computers. A major goal of the project is to find a suitable numerical discretisation on globally quasi-uniform grids. Mixed finite element methods, where each physical quantity is assigned to a different function space, provide a promising way of achieving a number of desirable properties for an atmospheric dynamical core, such as mimicking certain vector calculus identities, good conservation properties and, as they can be viewed as the finite element extension of the widely used C-grid discretisation, they are expected to extend the good dispersion properties of staggered grids. Here the family of Raviart-Thomas elements on quadrilaterals are investigated in a shallow water model on the sphere. By studying the linearised equations, issues with the dispersion of inertia-gravity waves are found for all but the lowest order elements. These take the form of an increasing number of nonphysical stationary modes. The potential impact of these modes is shown and an efficient method of removing them through modifying the mass matrix is shown and simulations are presented to compare the modified formulation with the unmodified discretisation.