Splitting horizontal and vertical element order in a compatible finite element discretisation

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Abstract

Compatible finite element methods are an attractive choice for modelling geophysical fluids due to good wave dispersion properties and the absence of spurious pressure modes without any reliance on the underlying grid structure. This facilitates non-orthogonal quasi-uniform grids over the sphere, avoiding the clustering grid points at the poles associated with lat-lon grids, which can be a significant computational bottleneck. For this reason, compatible finite element methods are used in the Met Office's next-generation dynamical core, GungHo.
Finite element methods also provide a flexible framework in which the spatial discretisation can be designed to treat vertical and horizontal motion separately. By exploiting the tensor product structure, we can construct a split-order discretisation in which we separately change the order of the model in the horizontal and vertical directions. We carry out a discrete dispersion analysis for these schemes to ensure that the split-order scheme inherits the desirable wave dispersion properties of the uniform-order case.

In addition to the theoretical analysis, we run a suite of test cases at a range of length scales to further justify the validity of a split-order scheme. Altering the order of the model yields a new way to tailor a dynamical core to better resolve motion at specific length scales.

Keywords: Spatial discretisation, compatible finite elements, dynamical core, order, modelling, numerical methods

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