On forward in time differencing: an unstructured mesh framework

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A rigid connectivity of Cartesian grid routinely used in the simulation of stratified rotating flows imposes severe limitations on mesh adaptivity to flow features and/or the complex geometry of physical domains. In contrast, for many problems, a wide range of scales in atmospheric flows, heterogeneous distribution of regions of interest, and/or complex geometry can be accommodated efficiently with fully-unstructured mesh technology. The realization of limitations of structured-grids, and of a need for flexible mesh adaptivity, has stimulated recent interest within the atmospheric/oceanic science community in the development of unstructured-mesh solvers. However, such solvers are still in their infancy compared to both established structured-grid codes and state-of-the-art engineering advancements with unstructured meshes. In order to prove the competence and competitiveness of unstructured-mesh technology for simulating all-scale flows in the atmosphere and oceans, there is a need for developing an advanced fully non-hydrostatic model for simulating accurately rotating stratified flows in a broad range of the Rossby-, Froude-, and Reynolds-number regimes. The presentation will report on recent developments towards an unstructured mesh ”clone” of EULAG, aiming at this goal.

The key of the present development is the derivation of an approach which provides an equivalence between the structured grid methodologies used in EULAG and the edge-based framework. Consequently, the proven elements of the EULAGs non-hydrostatic model are adopted to unstructured meshes. This not only provides a particularly efficient numerical development path, but also facilitates a meaningful comparison between the performance of structured and unstructured meshes. The essential steps leading towards a fully non-hydrostatic model such as a development of an accurate advection scheme and a class of non-oscillatory forward in time solvers will be described. A generalization to algorithms operating on a sphere will follow.

The resulting, non-oscillatory forward in time solvers are applicable to both incompressible and compressible flows including problems with complex geometries for which unstructured meshes and mesh adaptivity are desirable. Theoretical considerations will be supported with numerical examples from standard benchmarks, idealized atmospheric flows and multidisciplinary applications illustrating flexibility and robustness of the approach.