Contribution ID: **32** Type: **Invited Talk**

The construction of a three-dimensional dynamically adaptive finite-element atmospheric model Fluidity-Atmos

Tuesday 8 October 2024 16:15 (30 minutes)

Fluidity-Atmos, representative of a three-dimensional (3D) non-hydrostatic Galerkin compressible atmospheric model, is generated to resolve large-scale and small-scale atmospheric phenomena simultaneously. This achievement is facilitated by the use of non-hydrostatic equations and the adoption of a flexible 3D dynamically adaptive mesh where the mesh is denser in areas with higher gradients of variable solutions and relatively sparser in the rest of the domain while maintaining promising accuracy and reducing computational resource requirements. The dynamic core is formulated based on linear finite-element method and anisotropic tetrahedral meshes in both the horizontal and vertical directions and it incorporates a semi-implicit time-integration scheme. With the design of a virtual structured mesh index system, we achieve the coupling of the adaptive dynamic framework of Fluidity-Atmos with physical parameterisations and an urban-scale shadow computing module.

The performance of the adaptive mesh techniques in Fluidity-Atmos is evaluated by simulating (1) the classic advection, (2) the formation and propagation of a non-hydrostatic mountain wave, (3) the formation and separation of a supercell system and (4) a comparison of radiative fluxes at the top of the atmosphere and the earth surface and heating and cooling rates between Fluidity-Atmos and the high-accuracy results.

The results of idealised test cases (advection and mountain wave) using tetrahedral adaptive mesh are as accurate as those performed by cut-cell / terrain-following fixed mesh and indicates a promising reduction of computing time. Preliminary physics forecast results indicate that the solver formulation is robust and the shortwave radiative fluxes at the earth surface is more accurate than the reference results.

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Session Classification: Numerical Mathematics A