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Vertical finite element discretization on staggered grids used in a cubed sphere spectral element model

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In this presentation, we introduce our experience to implement the vertical finite element (VFE) discretization on Lorenz staggering in a non-hydrostatic numerical weather prediction model known as KIM (Korean Integrated Model). The system is originally designed with a horizontally spectral element and vertically finite difference method by the flux-form Euler equations on a cubed sphere and Lorenz grid structure.
At the first time, the VFE scheme was constructed by using an unstaggered grid to evaluate the vertical integral and derivatives. With this scheme, the experiment shows some instability especially on a mountain region, which is caused by the lack of the invertible property of the integral and derivative operation for representing hydrostatic balance and the difficulty on specifying the bottom/top boundary conditions in a system. The invertibility was one of the important properties to be satisfied in such models which use mass-coupled flux-form equation. For the other option, the VFE scheme on a staggered grid is built by using general order of b-splines, since it is able to handle directly the basis functions with various boundary conditions. In addition, some calculations to evaluate the vertical mass flux are manipulated to alleviate the invertibility constraint, in which the vertical pressure velocity gained by the integral operator is not performed through the derivative operator.
This talk will mainly focus on the procedure of the constructed VFE operators with b-splines on a staggered grid implemented in dynamical core of the system. The behavior of the VFE scheme will be discussed with some idealized simulations and compared with vertical finite difference method.