Physics-dynamics coupling with element based high-order Galerkin methods: quasi equal-area physics grid

Advanced Study Program
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Finite Element vs. Grid Cell

Element - a part or aspect of something abstract, especially one that is essential or characteristic

CAM-SE has 16 nodes (9 degrees of freedom), in each element!
Conventionally, the physics and dynamics are computed on the same grid (b/c, why not?)

Physics-Dynamics Coupling: Convention
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PDF of upward vertical motion +/- 10°, and at all levels, in a CAM6 aqua-planet run
Math makes us put them there

Nodal locations are chosen to satisfy quadrature rules…

Degree three Lagrange basis set (puts the ‘spectral’ in ‘spectral-element’)

Consider transect through 3 elements

Smooth Initial Conditions
Consider transect through 3 elements

Advance all nodes one Runge-Kutta time-step
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Compute boundary exchange – (a numerical flux that results in an averaging of the two nodal states)
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The physics forms a cloud on a boundary node
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Which the dynamical core interprets to be -
Consider transect through 3 elements.

Let's say the cloud instead forms at an interior node...
Consider transect through 3 elements

Which the dynamical core interprets as -
The irregular physical distance between nodes seems to have less bearing on the solution, compared with whether one is, or is not on an element boundary.
Element based Galerkin methods are susceptible to Grid Imprinting, for non-smooth problems. The conventional method of evaluating the physics at the nodal points, exacerbates the problem.
Introducing an \textit{\textasciitilde} equal area physgrid

Grid Imprinting may be reduced through mapping the state to an approximately isotropic physics grid

\[ np = 4 \quad \quad pg = 3 \]

The \textit{\textasciitilde}isotropic finite-volume grid, pulls the solution away from the boundary nodes
Results – Aqua-planets

State the physics ‘see’ is now independent of location within element!
Results – Aqua-Planets

…and so the physics forcing is now independent of location within the element!
Results – Held-Suarez w/ topo
(& passive moisture transport)
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Questions?