NIM: Nonhydrostatic Icosahedral Model

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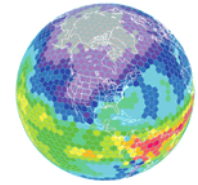


Introduction

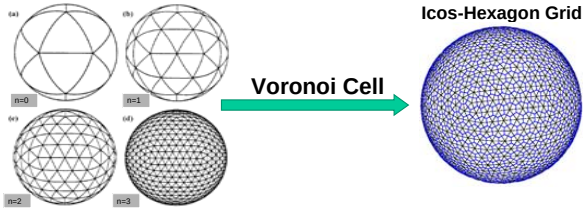
The Earth System Research Laboratory is developing a new global finite-volume **N**on-hydrostatic **I**cosahedral **M**odel, NIM, for earth system modeling and weather and climate prediction. NIM is a multi-scale model designed to improve tropical convective clouds and to extend weather forecasts into intra-seasonal predictions.

Icosahedral Hexagonal Grid

What is Icos-grid?

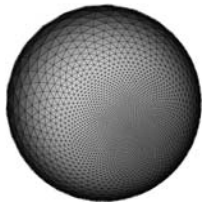
The icos-grid consisting of hexagonal cells with 12 pentagons provides the most uniform coverage of the sphere.

How to Generate Icos-grid



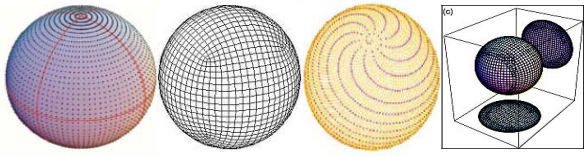
N = ((2ni)**2)*10 + 2; max(d)/min(d) ~ 1.2**
8th division: dx ~ 30km; 11th division: dx ~ 4km

- Grid Optimization available for numerical accuracy and efficiency
- Efficient Indirect addressing
- Variable resolutions Icos-grid



- Uniformity/regularity of existing spherical grids

lat/lon cubed Fibonacci Yin-Yang

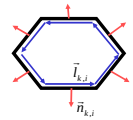


Finite-Volume (f.-v.) Model

What are f.-v. operators?

Stoke's Theorem:

$$\varsigma = \int_A \left(\nabla_h \times \vec{V}_h\right) dA = \oint_s \left(\vec{V}_h \cdot \vec{l}\right) ds$$



Gauss's Theorem:

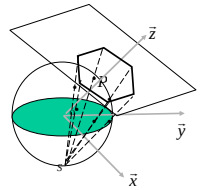
$$\delta = \int_A \left(\nabla_h \cdot \vec{V}_h \phi\right) dA = \oint_s \left(\vec{V}_h \phi \cdot \vec{n}\right) ds$$

Why ?

F.-v. line integration on icos-grid provides excellent conservation with good isotopic property.

Model Characteristics

1. Finite-volume integrations on local coordinate

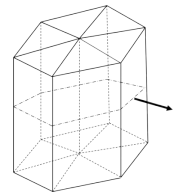


2. Conservative flux formulation suitable for momentum and tracers transports

$$\frac{\partial \chi}{\partial t} + \nabla \cdot \left(\nabla \bullet \vec{V}\chi\right) = F$$

3. Conservative and monotonic AB3-multistep FCT
4. Conservative f.-v. integration on three-dimensional control volume

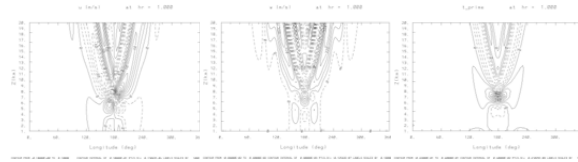
$$\delta = \frac{1}{V}\int_V \left(\nabla \bullet \vec{V}\phi\right) dv = \frac{1}{V}\oint_A \left(\vec{V}\phi \bullet \vec{n}\right) dA$$



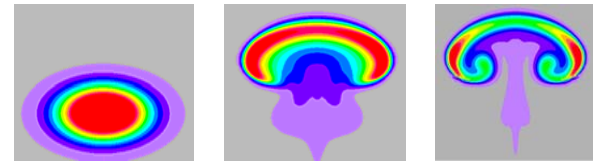
5. Volume-based Z-coordinate w/o terrain terms to improve pressure gradient accuracy.
6. Fast Riemann solver to resolve vertically propagating acoustic waves.
7. Efficient indirect addressing scheme on general grids.
8. Dynamical design to utilize Graphic Processing Unit (GPU) to speed up NIM simulations.
9. Local stencil allows scaling on O(100000) CPU/GPUs.

Numerical Simulations

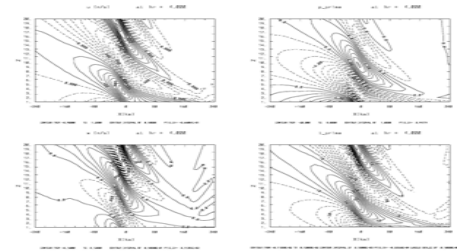
1. Heat-Forced Circulation



2. Buoyant Thermal



3. Mountain Waves



Remarks and Future Directions

- A multi-scale non-hydrostatic finite-volume model, NIM, has been developed and tested with mesoscale cases.
- Medium Range Weather Prediction 0 to 2 weeks, including improve hurricane track and intensity
- Seasonal to intra-seasonal predictions

Relevant to NOAA climate predictions and projections mission: Improving intra-seasonal and inter-annual climate forecasts.