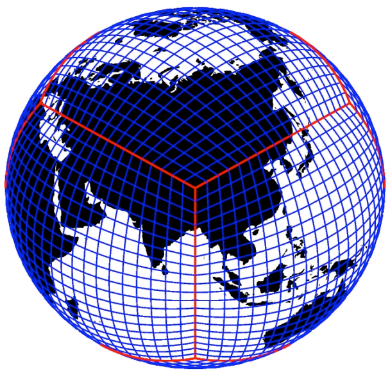
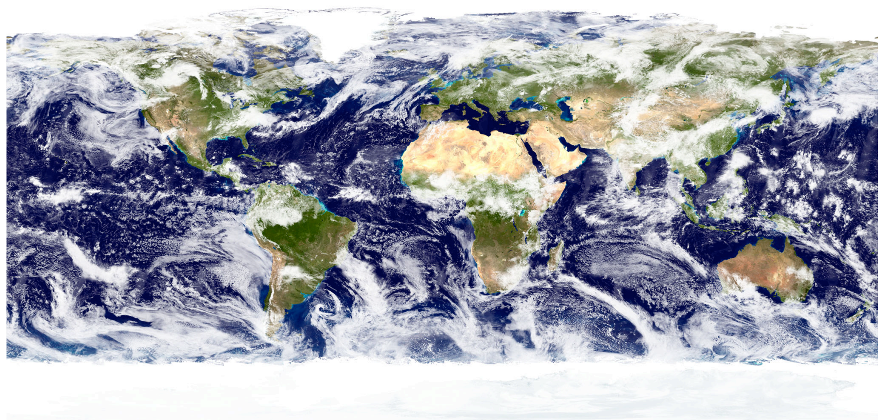
Dynamical core development





Peter Hjort Lauritzen & David Williamson

Atmospheric Modeling & Predictability Section

Requirements

1. **Scalable** O(100k+) cores
2. **Conservation** of energy and tracer masses (locally)
3. **Consistent** and **shape-preserving** tracer transport
4. **Reasonable spectra** of kinetic energy, temperature and tracers
5. **Economical**, i.e. no more expensive than current methods of choice for comparable quality solution
6. **Static mesh-refinement capability** to allow regional climate studies in contrast to or complementary to nested modeling
   (*at this stage probably not a requirement but we think the modeling community is moving in that direction*!)
7. It is highly desirable that **developers collaborate** with staff and remain **responsive** when problems appear

Note: Since frictional heating occurs on scales well below the truncation limit, 2) and 4) imply a fixer will most certainly be needed.

Some dynamical core efforts

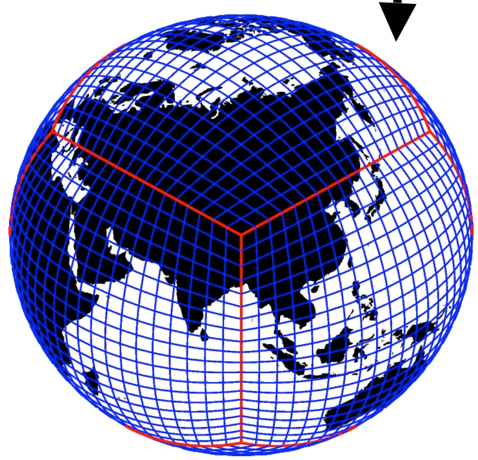
(in random order)

- MIT General Circulation Model (**MITgcm**)
- High-Order Modeling Environment (**HOMME**), NCAR & DOE.
- GFDL's Climate Model (**CM3**)
- NASA's cubed-sphere version of Goddard Earth Observing System (**GEOS**)

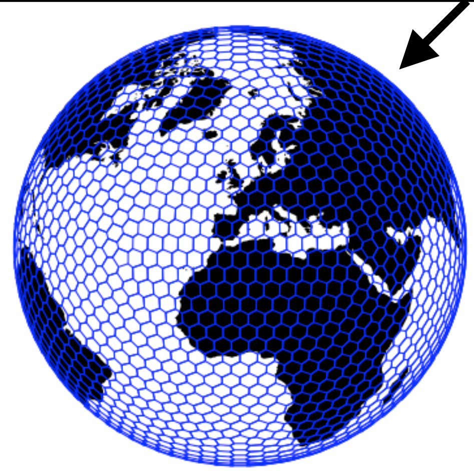
- EULerian and LAGrangian framework (EULAG) on a "stretched lat-lon grid" with static mesh-refinement capability coupled to CAM3 physics (**CAM-EULAG**), Iowa State University.

- Colorado State University General Circulation Model (**CSUgcm**)
- Model for Prediction Across Scales (**MPAS**), NCAR & DOE
- Flow-following finite-volume Icosahedral Model (**FIM**), NOAA
- Ocean-Land-Atmosphere-Model (**OLAM**), Duke University
- Non-hydrostatic ICosahedral Atmospheric Model (NICAM), JAMSTEC, Japan
- ICOsahedral Nonhydrostatic general circulation model, (**ICON-GCM**), MPI-M, Germany

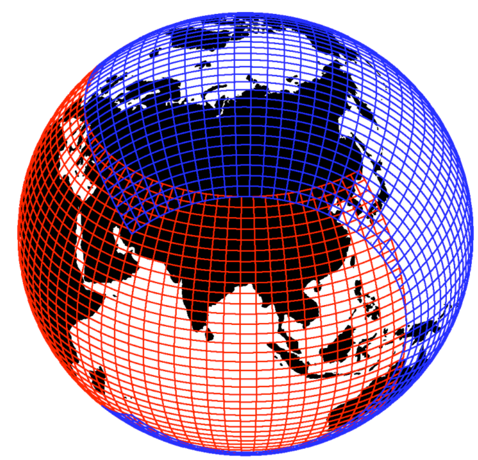
Lat-lon



Cubed-sphere



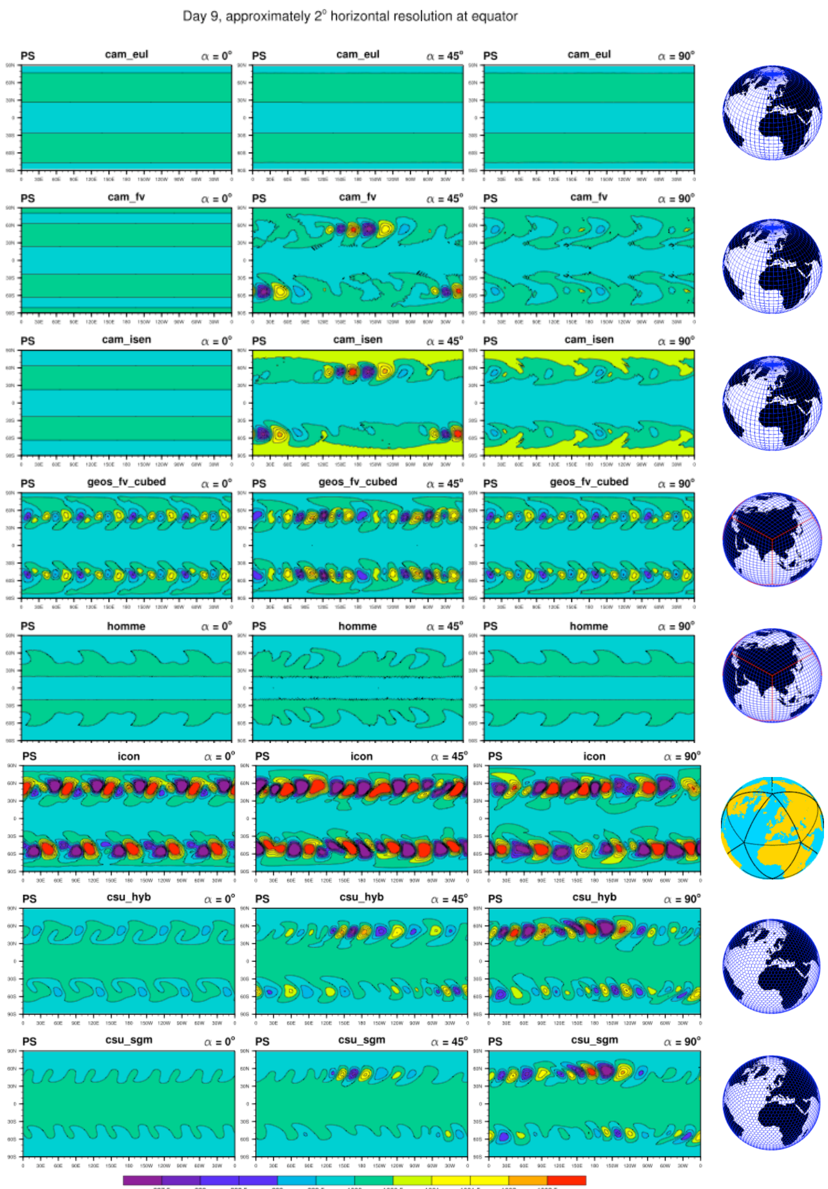
Icosahedral



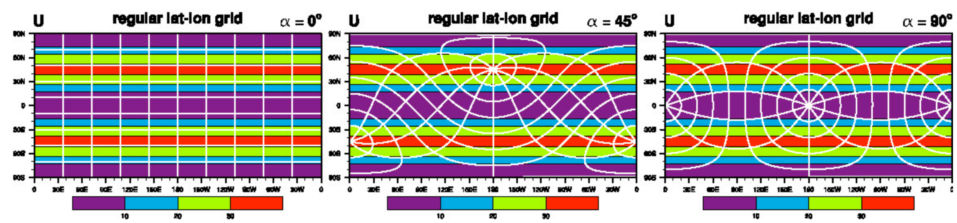
Yin-Yang

2008 NCAR Summer Colloquium on Dynamical Cores

Adiabatic rotated steady-state test case (Lauritzen et al., 2010, Journal of Advances in Modeling Earth Systems)



Rotate computational grid
(physical flow stays the same)



CAM_EUL (NCAR)	: Spectral transform
CAM_FV (NCAR)	: Finite-volume
CAM_ISEN (NCAR)	: CAM_FV with isentropic vertical coordinates
GEOS_FV_CUBED (NASA/GFDL)	: Finite-volume
HOMME (NCAR/Sandia)	: Spectral elements
ICON (MPI-M)	: Finite difference/volume
CSU_SGM (Colorado State University)	: Finite-difference
CSU_HYB	: CSU_SGM with isentropic vertical coordinate

ome relevant dynamical core efforts

Available in CAM now!
(is being tested in "AMIP mode")
- see Taylor's talk

Effort to integrate hydrostatic version of cubed-sphere dynamical core into CAM

- M... ...eral Circula... ...)
- High... ...der Modelin... (**HOMME**), NCAR & DOE.
- GFDL's Climate Model (**C...**
- NASA's cubed-sphere versio... of Goddard Earth Observing System (**GEOS**)

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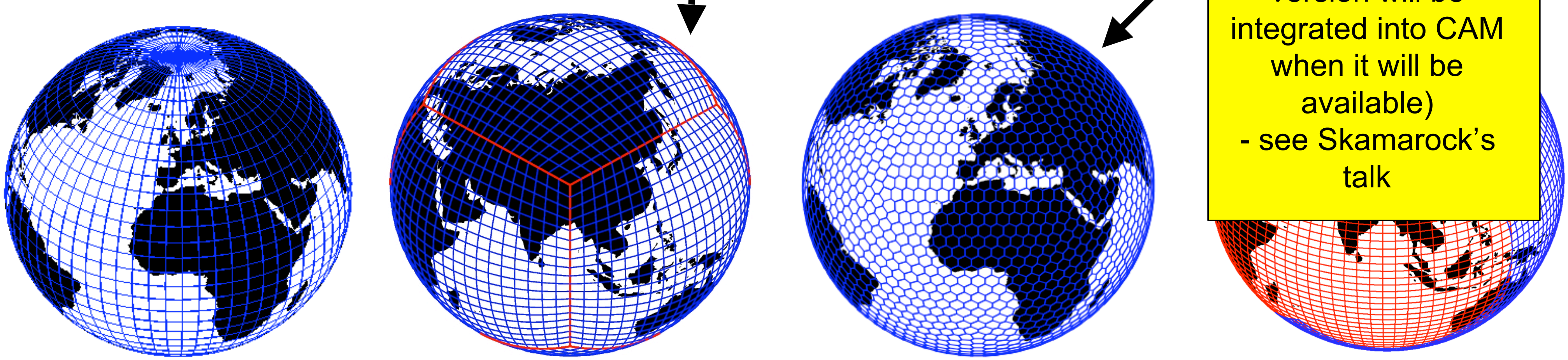
Hydrostatic version of MPAS is being integrated into CAM (unknown if non-hydrostatic and mesh-refinement version will be integrated into CAM when it will be available)
- see Skamarock's talk



Lat-lon | Cubed-sphere | Icosahedral | Yin-Yang

Remapping (conservative interpolation)

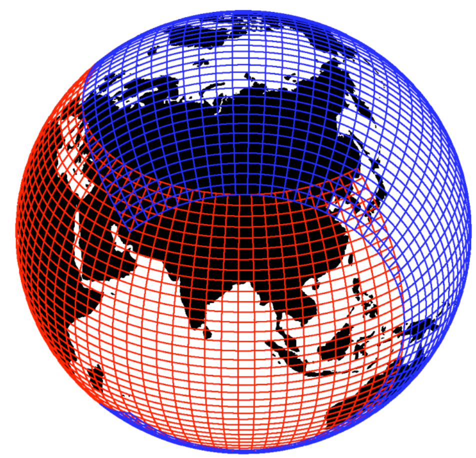
Note: To couple dynamical cores defined on non-traditional grids to other component models (land, ocean, …) might need more robust (and perhaps more accurate) remapping software and support for regional grids.

Could become a show-stopper if new software is not developed or if existing software is not "upgraded"!

Lat-lon

Cubed-sphere

Icosahedral



Yin-Yang

Some suggestions for idealized testing of dynamical cores

Passive advection: 2D and 3D translational, divergent and deformational flows on the sphere

- tests advective operator in settings where the analytic solution is usually known (Williamson et al., 1992, Nair and Machenhauer 2002, Nair and Jablonowski 2008, Nair and Lauritzen 2010, etc.)

Adiabatic : Baroclinic wave (non-rotated and rotated)

- analytic solution not known but reference solutions and the uncertainty of the reference solutions “known” => test can be used to determine at what resolution the dynamical core has converged (Jablonowski and Williamson, 2006)
- rotated version: Is the solution method isotropic? (Lauritzen et al. 2010)

Idealized physics: Held-Suarez

- simplified physics (Held and Suarez, 1994)

Aqua-planet using the same physics package

- Simplified surface but full physics (Neale and Hoskins, 2001)

- More global idealized tests are (probably) needed! Suggestions?

- We find fora where models are tested against each other using the same test suite useful (e.g., 2008 NCAR ASP Colloquium)

A dynamical core intercomparison workshop is planned in 2012 (Jablonowski, Lauritzen, Taylor, Nair)

Physics-dynamics interface/coupling

- Total energy is not treated consistently in CAM
- Should we add the infrastructure to CAM so that the physics can be run on a different grid (both in the vertical and horizontal)?
- Other?

Coupling the dynamical core to physics and the impact of how that is done is still an underexplored, yet important, area of research

Multiple dynamical cores?

- Should we support multiple dynamical cores?
- Should we use the same dynamical core at all resolutions (coarse paleo-climate to high regional climate resolutions)?
  (remember that user base extends from linux-cluster users to massively parallel system users)
- Should we keep supporting "old" dynamical cores (CAM-EUL, CAM-SL, CAM-FV)?

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Functionality?

- Should we require the dynamical core to be non-hydrostatic in this development cycle?
- Should we require functionality to run in a doubly-periodic-plane-mode for idealized testing of parameterizations?