Geophysical Fluid Dynamics Laboratory Review

June 30 - July 2, 2009

Dynamical Core and Seamless Regional-Global Model Developments

Presented by

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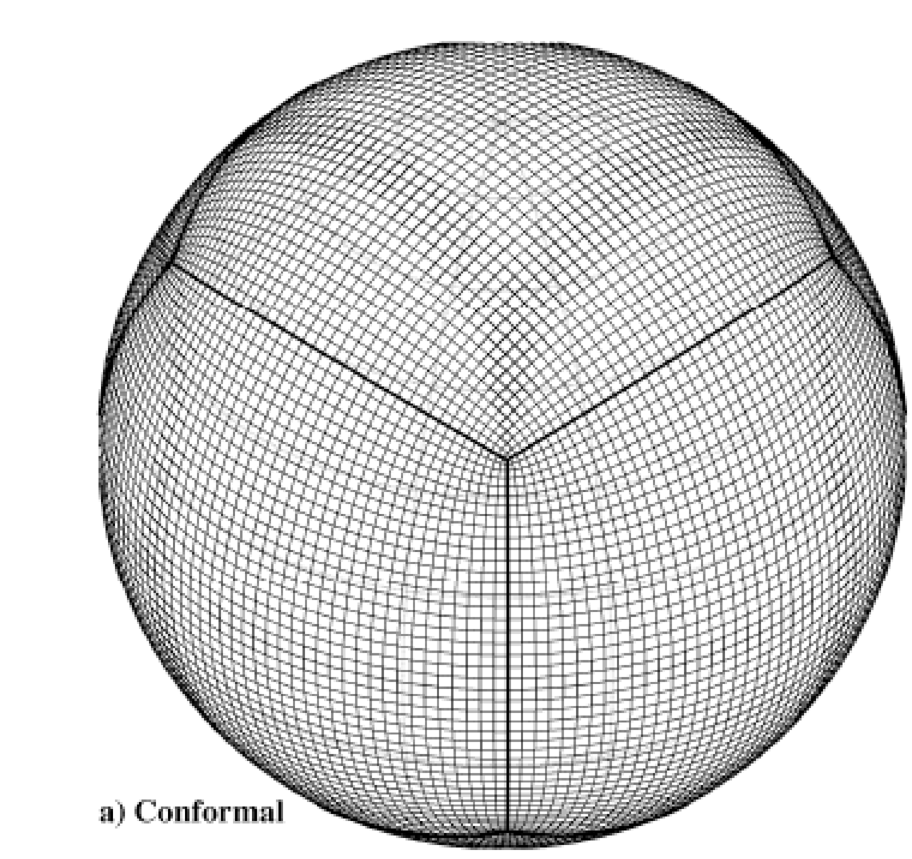
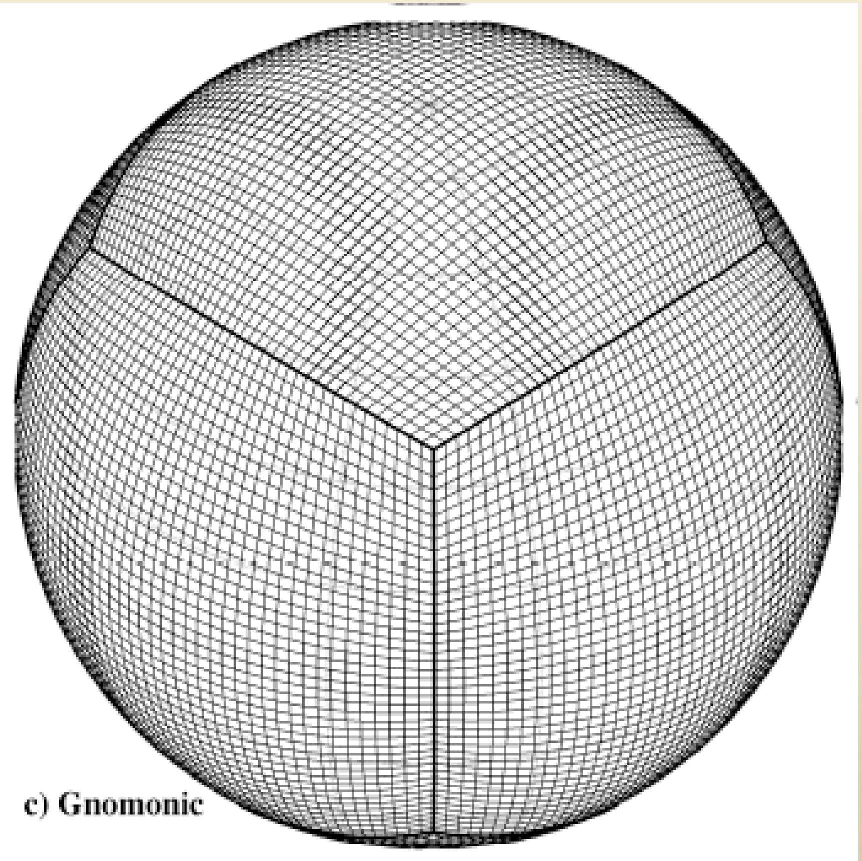




Finite Volume Dynamical Cores

- **Past** **users of the latitude-longitude FV core[1]: a community resource**
  - GFDL CM2.1, NASA GEOS-5, NCAR/CCSM, and ECHAM-5 (for tracer transport)
  - Univ of Maryland (Kalnay), Univ of Michigan (Penner), ICTP (Italy), National Central Univ (Taiwan), Seoul National Univ (Korea), and …
- **Present** **Cubed-sphere FV core: improved accuracy & parallelism[2]**
  - GFDL CM3 for IPCC AR5
  - NASA/GSFC and GISS are developing their next generation climate model based on the cubed-sphere FV core
- **Future** **Non-hydrostatic option and various algorithmic improvements:**
  - Adaptive Mesh Refinement and a limited area configuration with self consistent nesting for improved regional resolution
  - Global cloud-resolving weather-climate applications

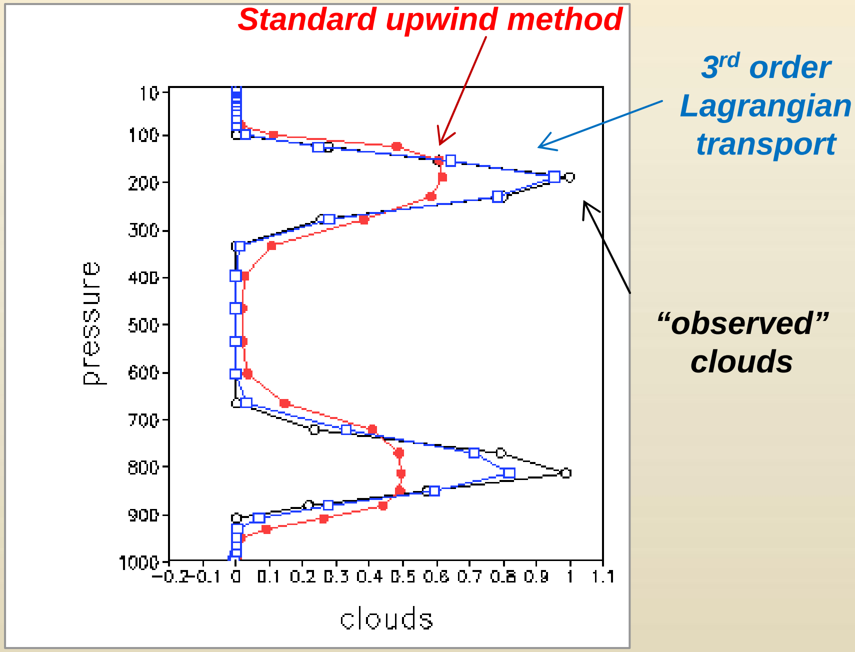
1 Lin 2004, Mon. Wea. Rev.
2 Putman and Lin 2007, J. Comp. Phys.

Changes / Improvements Since IPCC AR4

- Generalization to non-orthogonal curvilinear coordinate
- Horizontal transport scheme
  - fully monotonic with reduced numerical dissipation
- 4th order pressure gradient and remapping of the winds from D to C grid
- The vertical remapping (Lagrangian ↔ Eulerian)
  - one-sided extrapolation at the top/ bottom using cubic polynomials that is coupled with the interior PPM sub-grid reconstruction scheme (1D tri-diagonal solver)
- More scale-selective 4th , 6th, and 8th order divergence damping
- Non-hydrostatic dynamics with model top "open" to sound waves (solving a 1-D Rieman-invariant problem)
- Mesh refinement and two-way self consistent nesting (work in progress)

Reducing numerical dissipation - avoiding compensating tuning in physical parameterizations

- Small amount of cloud ice transported into lower stratosphere beyond the freeze-dry point can lead to anomalously high water vapor concentration
- Commonly used low-order numerical methods in cloud micro-physics, and/or cumulus parameterizations can introduce large errors that is compensated by unphysical tuning
- It is important that the basic numerics be accurate enough before physical tuning is performed. The FV core provides a solid foundation for physics development

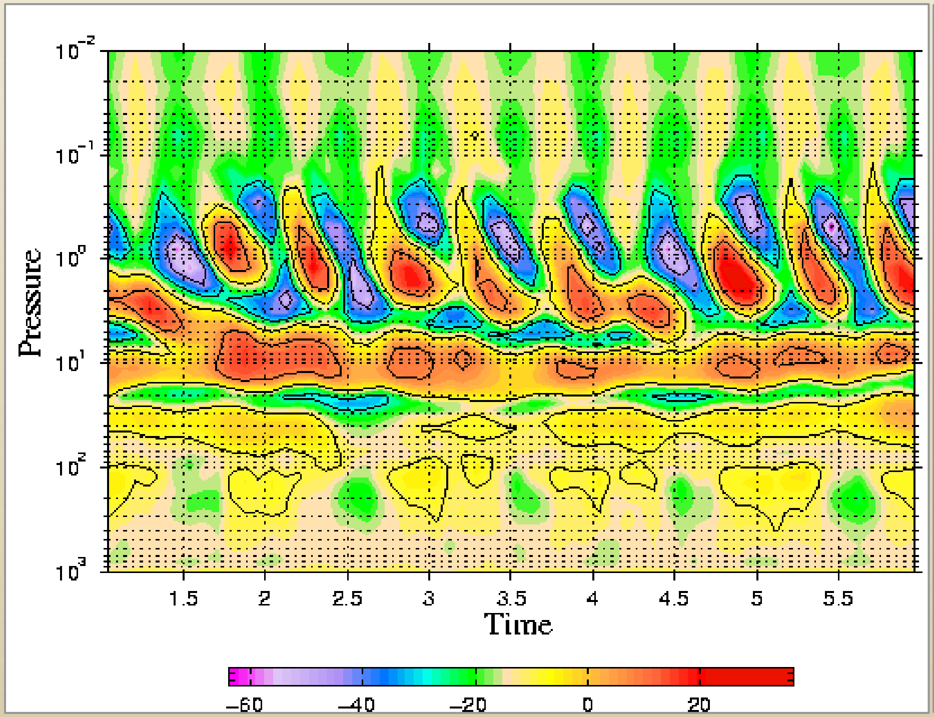


1D (L48) experiment set up:

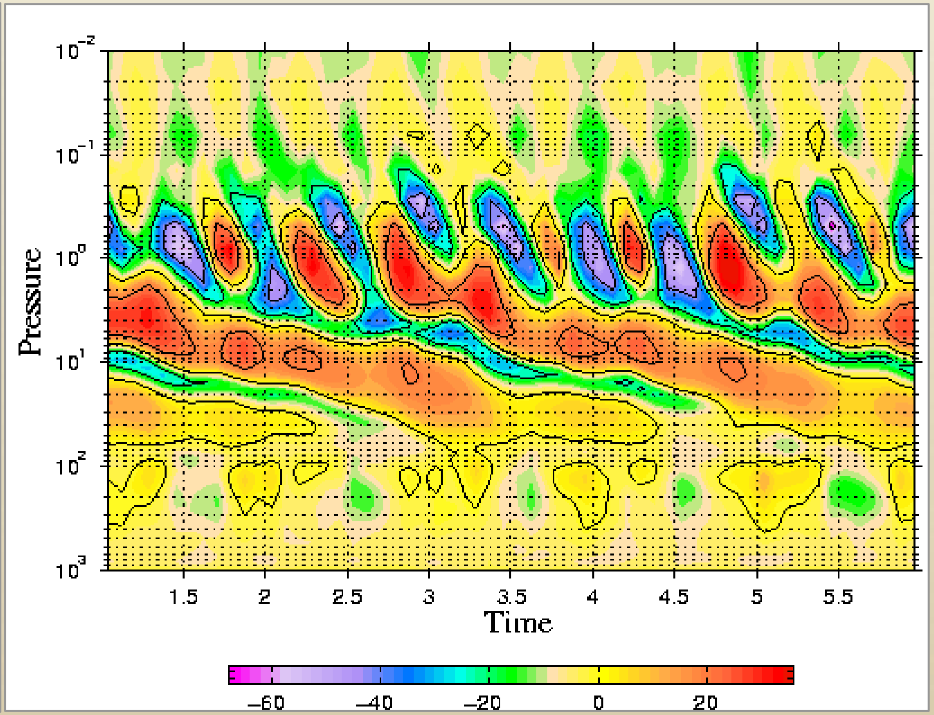
- Cloud condensates in 3-way equilibrium (terminal fall, large-scale transport, and production by convection and micro-physics)
- Net (zero) transport emulated by random movements of the layer interfaces development

Reducing numerical dissipation → improved QBO

Old FV model with del-2 divergence damping

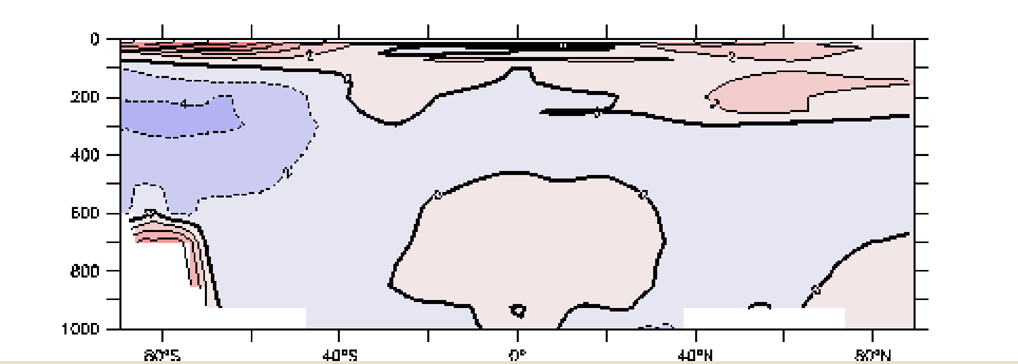


New FV model with higher order divergence damping

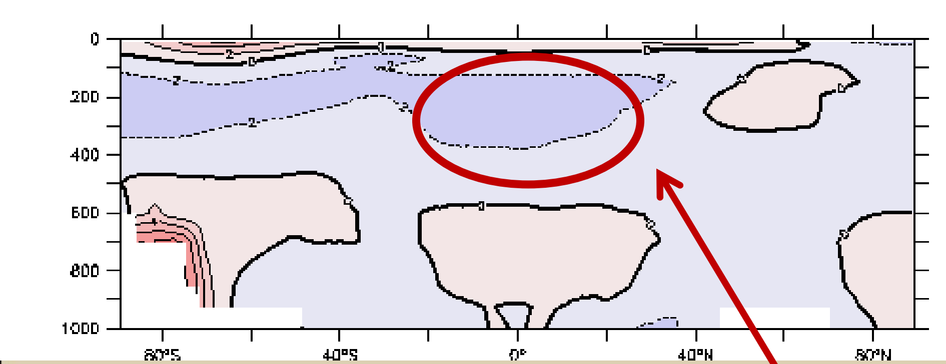


Can the tropical cold bias be avoided without deep convective parameterization?

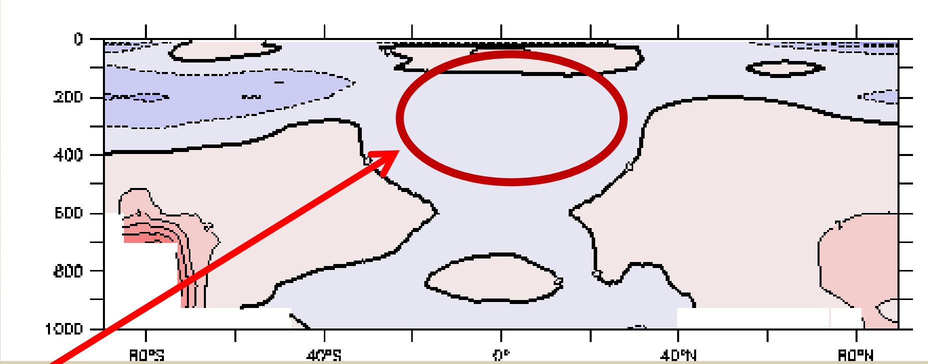
AM2.1 (2x2.5 deg.)



C90 cloud-resolving prototype



C360 cloud-resolving prototype

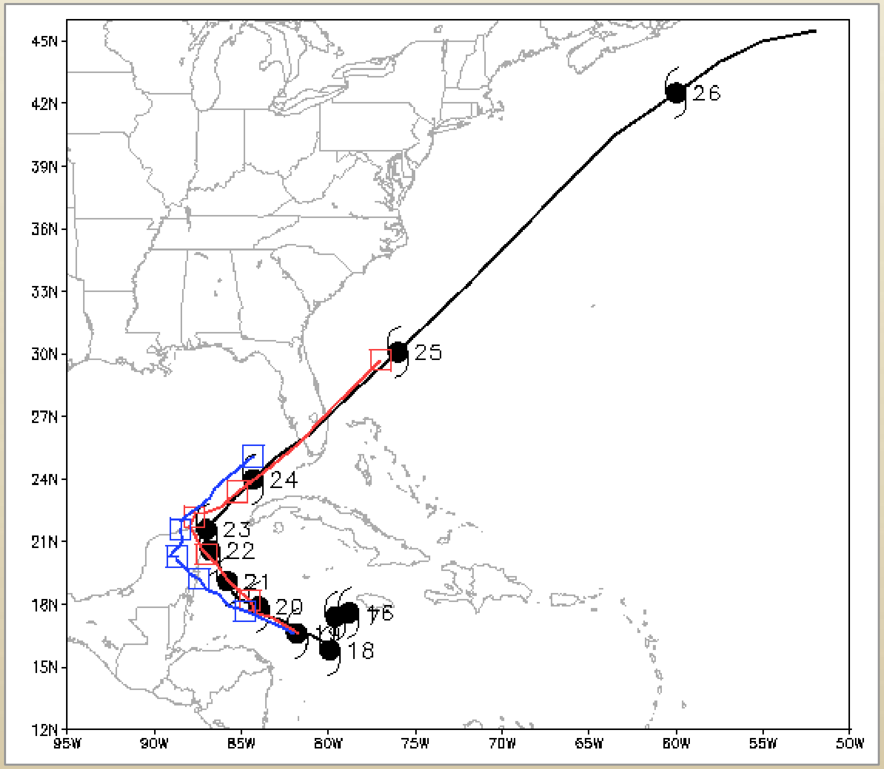


Cold bias disappears as resolution increases

Global cloud-resolving prototype model development

- Finite-Volume dynamical core starting from C90 (~100 km) to C2000 (~ 5km), reducing the need for sub-grid parameterizations
- Non-precipitating shallow convection
- Cloud microphysics with cloud water, ice, snow, rain, and graupel as prognostic variables. Conservative and highly accurate Lagrangian terminal fall of all condensates
- Binary cloud cover (0/1)

HFIP: 5-day forecast experiments (2005 hurricane Wilma)
C360 (25km) *vs.* C720 (13 km)



Global cloud-resolving prototype model (C720): 5-day forecast of Wilma (18 Oct 2005)

Summary

- The latitude-longitude grid finite-volume dynamical core has become a community resource (*e.g.*, NCAR CCSM and NASA GEOS-5)
- The finite-volume algorithms have been extended to the cubed-sphere geometry with quasi-uniform resolution over the whole globe – improving both the scalability and numerical accuracy
- The non-hydrostatic extension of the cubed-sphere FV core provides a development path towards higher horizontal resolution - reducing the need for sub-grid parameterizations with increasing realism

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