CAM/HOMME: Parallel Scalability and Aqua Planet Results for CAM on the cubed-sphere grid

Mark Taylor (Sandia)
Jim Edwards (NCAR/IBM)
Amik St.Cyr (NCAR)

Joe Tribbia and members of the cubed-sphere dycore integration meetings
Dave Williamson

CCSM Workshop SEWG session, Breckenridge, June 2008
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Outline

• Integration of NCAR's HOMME into CAM
  – Process-split physics/dynamics interface (Williamson MWR 2002)
  – Physics/dynamics splitting infrastructure (Worley & Drake, IJHPCA 2005)

• Motivation: Petascale-ready version of CAM
  – BG/L and BG/P benchmark results on up to 86,200 processors

• Evaluation using Aqua Planet Experiments
CAM/HOMME
Spectral Element Dynamical Core

- $h-p$ Finite element method on a cubed-sphere grid
- Exactly conserves dry mass
- Energy conservation is semi-discrete: (exact with exact timestepping)
- KE dissipation added via hyper-viscosity
- Tracer advection: consistent with mass equation, positive preserving, but not monotone
- No pole problem allows for full 2D domain decomposition
Aqua Planet Experiments

- Follow Williamson equivalent resolution methodology
- CAM 3.1 Physics
- 14 month simulations
- 5min physics timestep used for model comparisons
- 30min physics timestep used for benchmarks
- Eulerian T85 physics tuning (all models)
- Eulerian and FV results taken from Williamson, Tellus 2008a, 2008b
- Additional results: http://swiki.ucar.edu/ccsm/86
• Good scalability down to 1 element per processor (86,200 processors at 0.25 degree resolution). Higher resolutions will easily scale to even more processors

• BG/L achieves integration rates better than 5 simulated years/day at resolutions down to 0.25 degree

Fixed Mesh Scalability on LLNL BG/L
Fixed Mesh Scalability on ANL BG/P

Each core is about 2x faster

BG/P results use 4 processor cores per node. BG/L used 1 processor per node due to memory constraints.

Thus each BG/P node is effectively 8x faster than a BG/L node.
Minimal cubed-sphere grid imprinting

Pressure vertical velocity contoured on the 4'th eta-level. Noise characteristics quite similar to the near perfectly isotropic Eulerian model.

This field is one of the most sensitive to grid imprinting. See for example Wyman et al. (SEWG 2007 presentation) from GFDL FV cubed-sphere aqua planet simulations.
# Aqua Planet Global Mean Quantities

<table>
<thead>
<tr>
<th>Resolution</th>
<th>Physics dt</th>
<th>Viscosity</th>
<th>PRECC</th>
<th>PRECL</th>
<th>CLDTOT</th>
<th>TMQ</th>
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<tbody>
<tr>
<td>EUL T42</td>
<td>5m</td>
<td>1.0E+16</td>
<td>1.71</td>
<td>1.11</td>
<td>0.64</td>
<td>20.21</td>
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<td>1.14</td>
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<td>1.36</td>
<td>1.75</td>
<td>0.50</td>
<td>18.75</td>
</tr>
</tbody>
</table>

Compared to the size of the resolution signal, there is a remarkable agreement between CAM/HOMME and CAM/Eulerian.
Aqua Planet Experiment: Zonal Data
Comparison with FV & Eulerian Dycore

HOMME

FV & Eulerian
**Precipitation PDFs**

**1mm bin-size**

**PRECISSION PDF**

- Red: HOMME 1.9° v=1e16
- Green: HOMME 1.0° v=1e15
- Blue: HOMME 0.5° v=1.5e14

**mm/day**

**a**

- Red: T42
- Orange: 2 DEG
- Green: T85
- Black: 1 DEG
- Blue: T170
- Light blue: 0.5 DEG

**b**

- Red: T42
- Orange: 2 DEG
- Green: T85
- Black: 1 DEG
- Blue: T170
- Light blue: 0.5 DEG

**10mm bin-size**

**PRECISSION PDF**

- Red: HOMME 1.9° v=1e16
- Green: HOMME 1.0° v=1e15
- Blue: HOMME 0.5° v=1.5e14

**mm/day**
High Resolution Aqua Planet Experiments

- CAM 3.5 Physics
- 14 month simulations
- 5min physics timestep
- Eulerian T85 physics tunings
- Simulations on LLNL BG/L system
  - 0.250 degree: 43200 processors  ~1 day per simulation
  - 0.125 degree: 57600 processors  ~3 days per simulation  (done with no restart!)
High Resolution Results - CAM 3.4 Physics

CLIMATOLOGY
CAM3.1/HOMME APE 250mb

- Blue line: EUL T340 $\nu=1.5e13$
- Green line: $0.25^\circ \nu = 1.5e13$
- Orange line: $0.25^\circ \nu = 5e12$
- Red line: $0.125^\circ \nu = 2e12$

Kinetic Energy

spherical wavenumber

$10^{-6}$ $10^{-5}$ $10^{-4}$ $10^{-3}$ $10^{-2}$ $10^{-1}$ $10^0$ $10^1$ $10^2$ $10^3$
High Resolution Results - CAM 3.4 Physics

CLIMATOLOGY
CAM3.1/HOMME APE 250mb

-3
-5/3

Compensated Kinetic Energy

spherical wavenumber
Summary

• CAM
  – Infrastructure can handle non-lat/lon grids
  – With a scalable dycore, CAM is petascale ready

• CAM/HOMME
  – Very reasonable aqua planet experiments
  – Low dissipation dynamics and high resolution captures Nastrom-Gage type transition at 0.125 degree

• Current Work
  – CCSM coupling with land, ocean and ice (Mariana Vertenstein, Tony Craig, Kate Evans)
  – Better advection schemes for HOMME (Ram Nair, Amik St.Cyr)
Aqua Planet Experiment: Comparison with FV & Eulerian Dycore

**EULERIAN**

**HOMME**

**FV**

![Graphs comparing energy spectra in different models](image-url)
Aqua Planet Experiment: Comparison with FV & Eulerian Dycore