CCSM-HOMME Update

Mark Taylor (Sandia)

Jim Edwards (NCAR/IBM)

Kate Evans (ORNL)

Peter Lauritzen (NCAR)

Saroj Mishra (CU/NCAR)

Amik St.Cyr (NCAR)

CCSM Workshop SEWG session, Breckenridge, June 2009

U.S. Department of Energy

Office of Science

CCPP

SciDAC
Scientific Discovery through Advanced Computing

Sandia National Laboratories

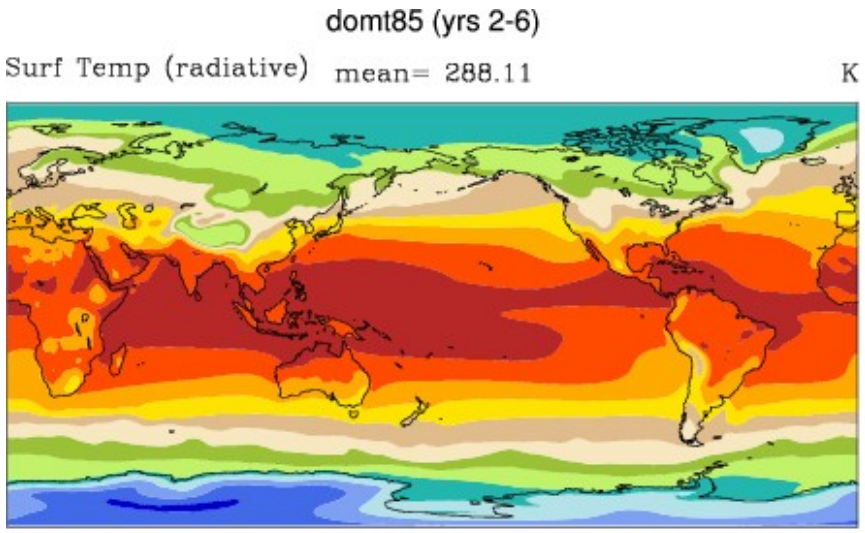
Outline

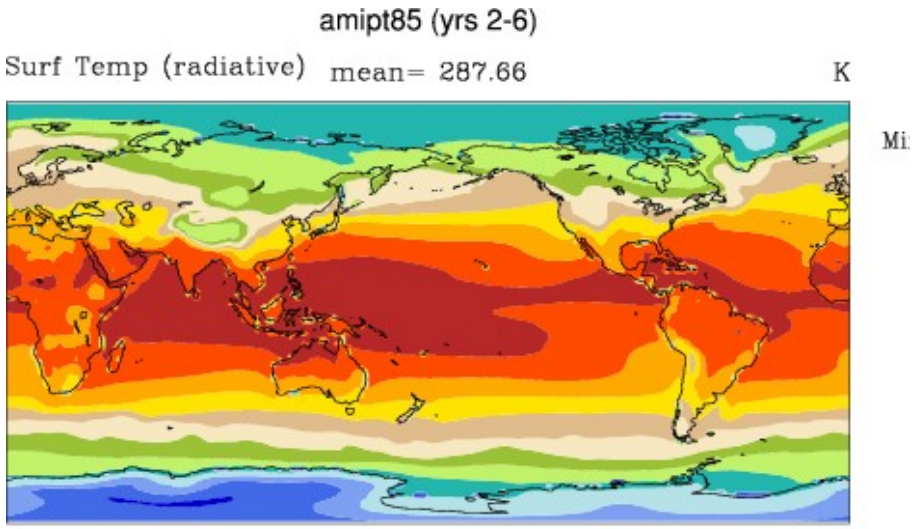
- **Experiments with CCSM tri-grid infrastructure**
  - Tested with CAM-Eul in addition to HOMME
- **Recent updates to CCSM-HOMME**
  - Conservative, non-oscillatory advection
- **AMIP Simulations (cyclical 2000)**
  - CAM-HOMME / CLM / Data ocean/ice
- **High-resolution Simulations**
  - CAM-HOMME at 1/8 degree
  - CLM on FV 0.23x0.31 grid
  - Data ocean/ice on gx1v5
  - Running at 0.5 SYPD on BG/P

HOMME
Cubed-sphere grid

CCSM Tri-Grid

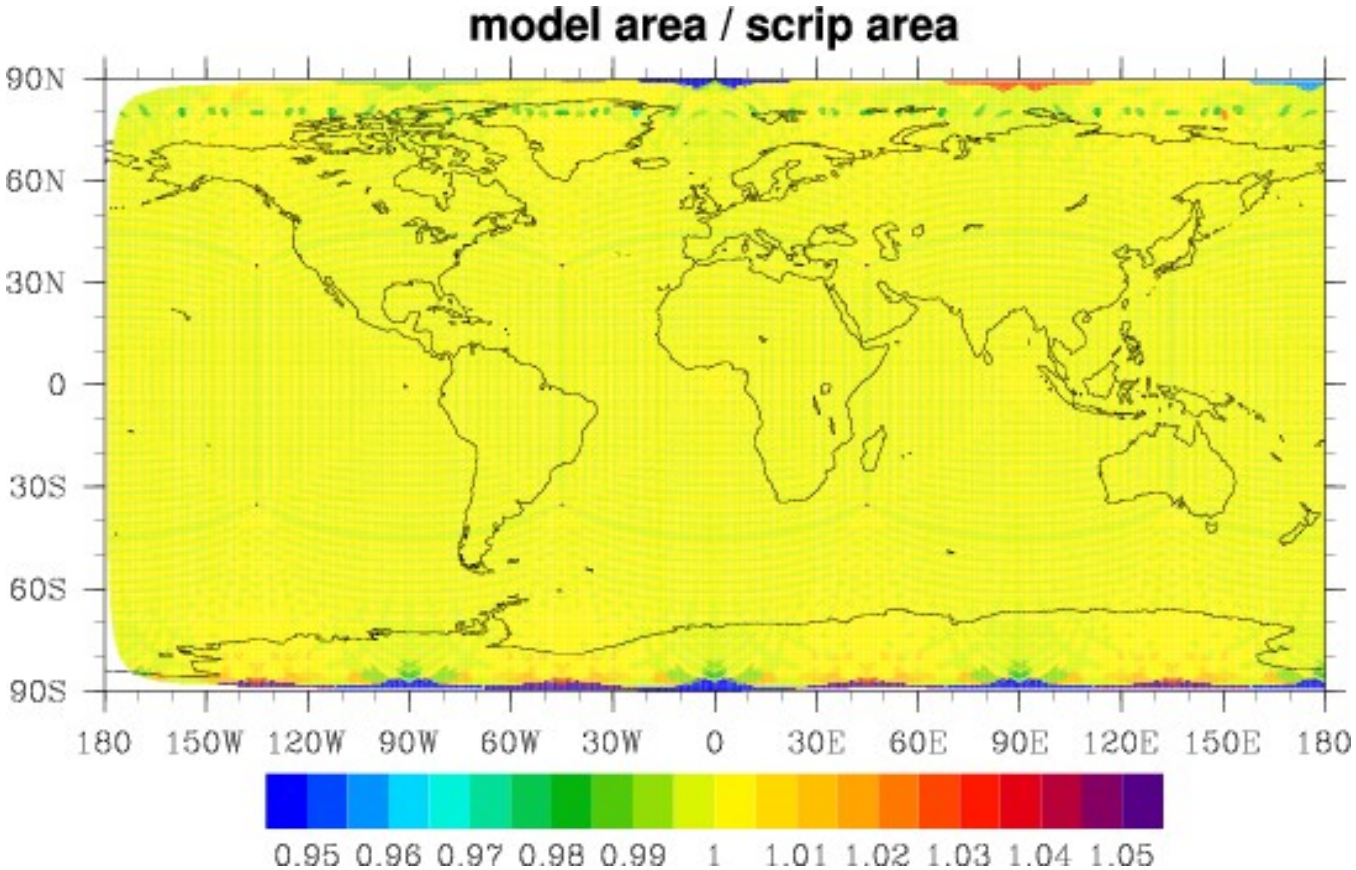
- **Standalone CAM-Eul (T85) vs. T85 / FV1.9 / gx1v4**
  - Results from AMWG diagnostics: http://users.nccs.gov/~taylorm
  - First look: almost identical
  - One minor issue: land fraction from land<->atmosphere mapping vs. ocean<->atmosphere mapping.





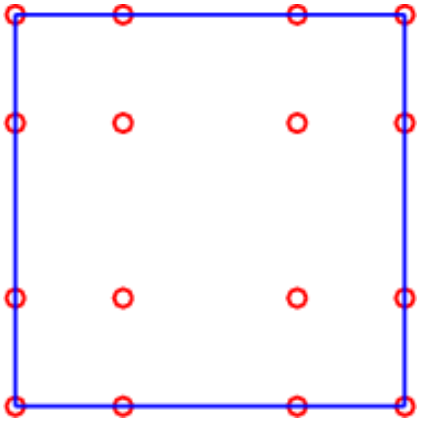
CCSM Tri-Grid

- **SCRIP weights for cubed-sphere mapping**
  - SCRIP areas computed in Mercator projection, HOMME areas computed via great circle arcs. (See: Lauritzen & Nair MWR 2008)
  - Conservative mapping requires multiplying by the ratio, leading to some grid noise



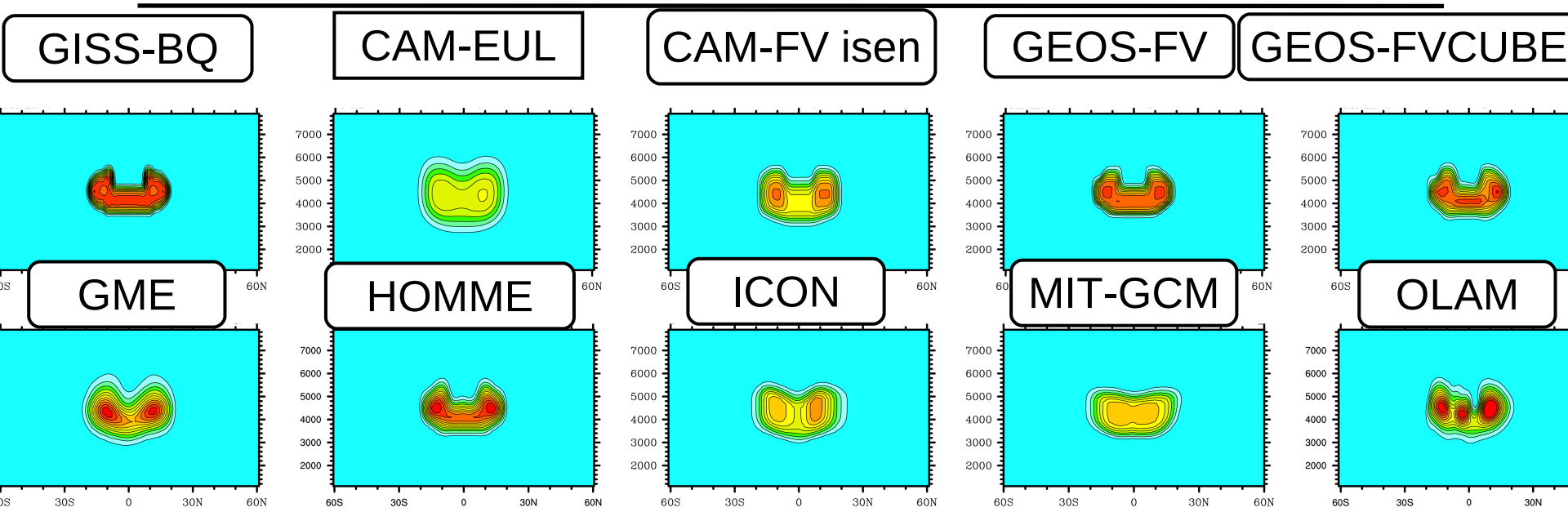
CCSM-HOMME

- A continuous-Galerkin, polynomial-based *hp* finite element method. Cubed-sphere grid with p=3
- Dynamics: 4th order accurate compatible discretization on arbitrary conforming unstructured grids in curvilinear coordinates:
  - Local conservation of mass (exact)
  - Local conservation (2D) of PV (exact)
  - Semi-discrete conservation of moist total energy
- Tracer advection:
  - Horizontal: sign-preserving, 3rd order accurate
  - Vertical: Lagrange+Remap (SJ Lin 2004) w/monotone reconstruction (Zerroukat QJRMS 2005)
  - RK2 SSP
- TODO:
  - Subcycle tracers (3x faster)
  - Upgrade dynamics to RK2 so we can obtain mass/tracer mass consistency



An Intercomparison of 10 Atmospheric Model Dynamical Cores

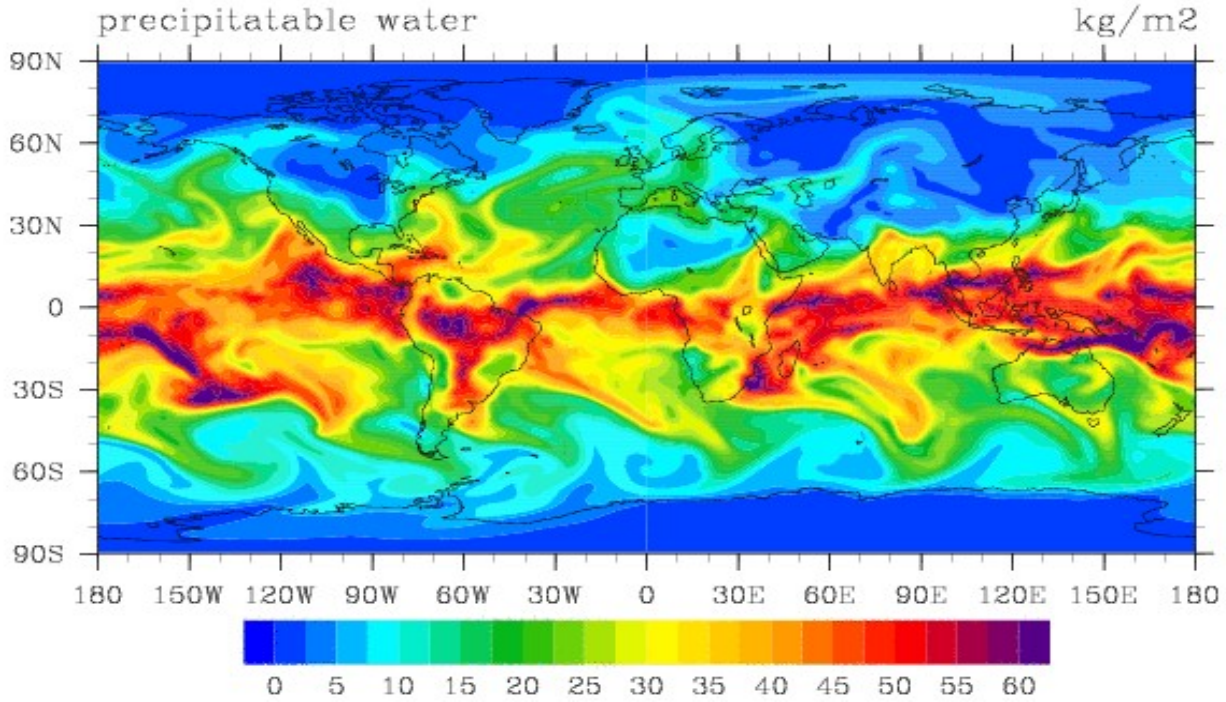
Christiane Jablonowski, Peter H. Lauritzen, Mark A. Taylor, Ram D. Nair



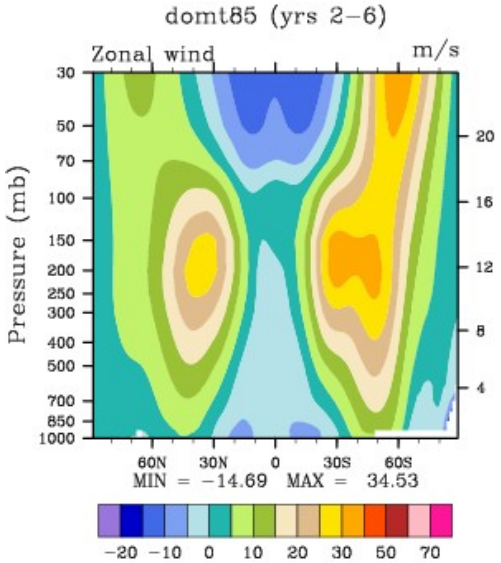
Test 3: Pure Advection. Latitude-height cross section of a 3D slotted ellipse tracer distribution after one revolution (45 degree angle) around the sphere (day 12). The 3D winds are prescribed. The slotted ellipse has followed a trajectory path with three wave cycles in the vertical direction. The test evaluates the diffusion characteristics of the advection algorithm.

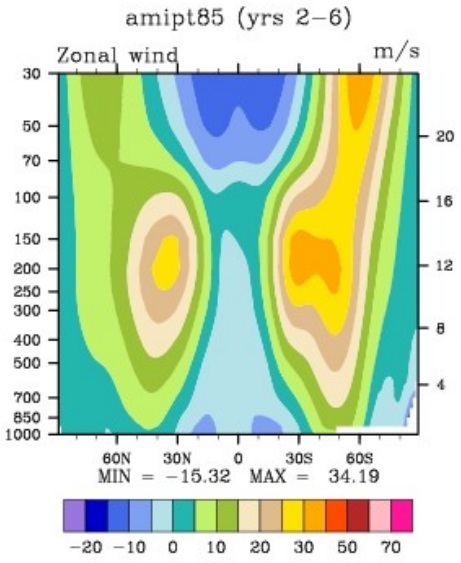
Real Planet Simulations

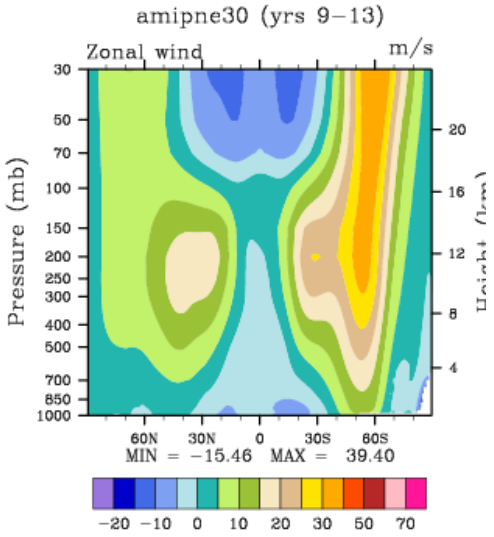
- CCSM beta 10, "-phys cam3_5", cyclical year 2000
  - 5 and 10 year simulations
  - CAM-HOMME on cubed-sphere grid (1 degree)
  - CLM2 on FV 1.9x2.5
  - Data ocean/ice on gx1v4



- AMWG diagnostics: http://users.nccs.gov/~taylorm
- Precipitation: very reasonable – see Saroj Mishra's poster
- Energy balance with no energy "fixer"
  - Dycore conserves total moist energy to ~ 0.01 W/m^2
  - RESTOM-RESSURF: -0.4 W/m^2
- Energy balance if dycore fixes *dry total energy* (not conserved by the moist primitive equations used by CAM)
  - RESTOM-RESSURF = 0.02 W/m^2
  - Impact of the fixer: -0.4 W/m^2
  - Conclusion: moist contribution to total energy is very small, but moist contribution to dE/dt is at the level of 0.4 W/m^2
- Zonal Winds are too week (10m/s)







1/8 Degree Simulations

- CCSM beta 10, Track 1 “-phys cam3_5_1” configuration
  - Cyclical year 2000 data sets
  - CAM-HOMME 1/8 degree, 56,000 cores
  - CLM2 on FV ¼ degree, 1024 cores
  - Data ocean/ice, gx1v5, 512 cores
  - Coupler, 512 cores
- LLNL BG/P Simulations:
  - 0.5 SYPD
  - Full history, plus 2h snapshots of some flow variables
  - PIO/PNETCDF: history & restart ~700 MB/s
  - 3 months completed Monday, 2 year simulation should finish this week

Conclusions

- CCSM tri-grid infrastructure works great
  - Some minor mapping issues still to be addressed
- CCSM-HOMME
  - Realistic simulations running
  - Some tuning issues remain before running true AMIP simulations
- Scalable CCSM:
  - Scalability of dycore is preserved by CAM
  - Scalability of CAM is preserved by CCSM
  - CCSM-HOMME 1/8 degree running at 0.5 SYPD
  - Should scale to O(300K) cores (2.5 SYPD)
  - Subcycling tracers: > 5 SYPD