

A Spectral Element Atmospheric Model for Multi-Resolution Climate Modeling

Research Objectives

- Couple SEAM with CAM Physics & CLM: CAM-SEM
- Apply CAM_SEM for long-term global climate simulations
- Apply CAM_SEM with LMR for both global and regional climate simulations

Previous Work

- 2-D shallow water model (Taylor *et al*, 1997)
 - Mapping sphere to cube
 - Standard shallow water tests
 - Local Mesh Refinement (LMR) over Andes
- 3-D atmospheric dynamical model (σ -coordinates)
 - Held-Suarez experiments (Taylor)
 - Polar vortex experiments (Taylor, Fournier)

Recent Development

- Converted to Fortran 90
- Finished implementation of η -coordinates
- Implemented a semi-Lagrangian scheme for moisture transport
- Implemented a RK4 scheme for time integration
- Coupled with CAM physics & CLM

Spectral Element Method

- Spectral element method
 - Grid-flexibility of finite element method
 - High-order accuracy of spectral method
- Application in SEAM
 - Mapping sphere to cube (Taylor *et al*, 1997)

Semi-Lagrangian Transport

- Divided into horizontal & vertical transport
- Horizontal transport on spectral element nodes
 - Use RK2 for trajectory calculations
 - Use local spectral element base for interpolation
 - Impose max/min limiter on moisture
- Vertical transport in η coordinates, similar to CAM-EUL (Collins *et al*, 2003)
 - Use RK2 for trajectory calculations
 - Use Hermitian cubic interpolation
 - Impose a sufficient condition for monotonicity

RK4 Scheme

- A 4th-order Runge-Kutta scheme
 - A 1-step scheme
 - Equivalence to the semi-Lagrangian scheme
- Sub-cycling for dynamics
 - Use four $\Delta t/4$ -steps for dynamics and one Δt -step for physics

Houjun Wang, Univ. of Maryland

Joe Tribbia, CGD/NCAR

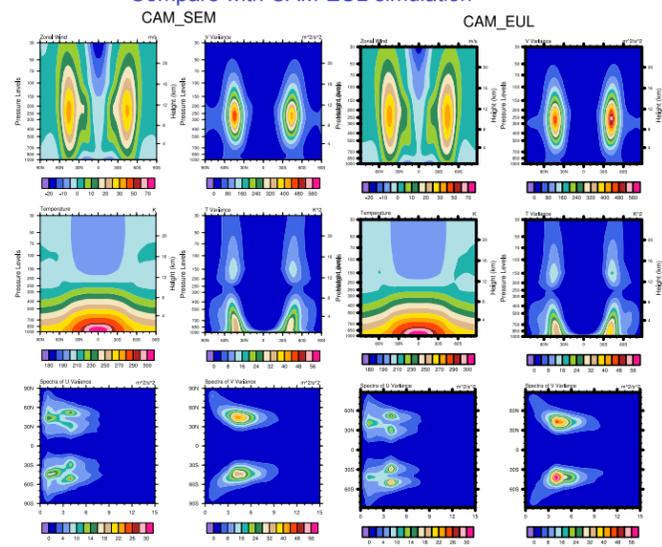
Ferdinand Baer, Univ. of Maryland

Aimé Fournier, Univ. of Maryland | NCAR

Mark Taylor, Sandia National Lab

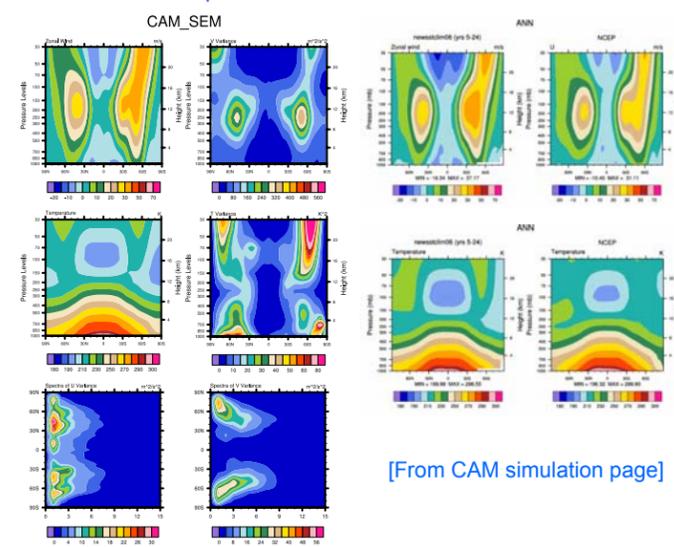
Held-Suarez Experiment

- Use CAM-SEM dynamical core (η -version)
- Integrate 1200 days with $\Delta t=450s$
- Compare with CAM-EUL simulation



Full-Physics Experiment

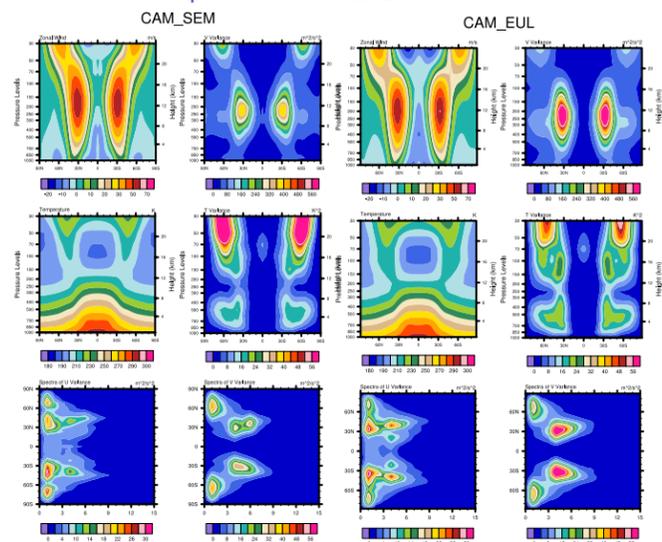
- Use CAM-SEM with CAM physics & CLM
- Integrate 1200 days with $\Delta t=1200s$
- Compared with CAM2.0.1



[From CAM simulation page]

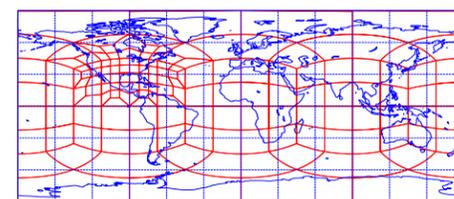
Aqua-Planet Experiment

- Use CAM-SEM with CAM physics
- Integrate 1200 days with $\Delta t=1200s$
- Compared with CAM-EUL simulation

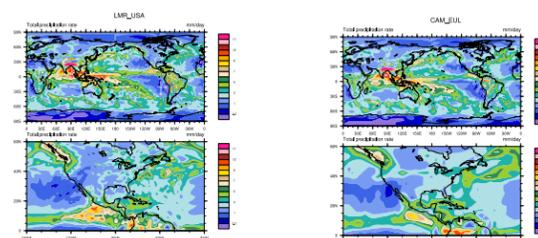


Local Mesh Refinement

- Conforming h -refinement
- Example: 3xLMR over the continental USA

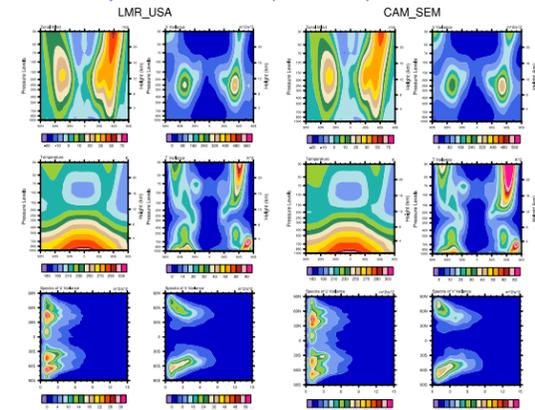


Precipitation Rate

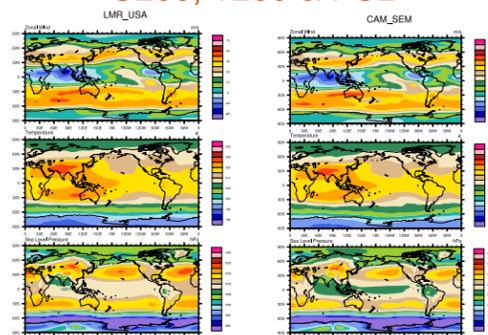


LMR Experiment

- Use CAM-SEM with CAM physics & CLM
- Use 3xLMR over the continental USA
- Integrate 1200 days with $\Delta t=600s$
- Compared with base (non-LMR) simulation



U200, T200 & PSL



Summary

- SEAM is successfully coupled with CAM physics & CLM
- A semi-Lagrangian scheme for moisture transport and a RK4 scheme for time integration were implemented in CAM-SEM
- Held-Suarez, aqua-planet, full physics, and LMR experiments were performed for 1200 days with CAM-SEM

Future Work

- Use *SCRIP* to prepare the surface boundary data for CLM
- Refine coupling procedure: e.g. eliminate the redundant computation in *physkg* on overlapping elemental boundary points
- Investigate the dependence of model simulations on physics and resolutions
- Apply CAM-SEM with LMR for both global and regional climate simulations

Acknowledgements & References

- *Acknowledgements*
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- *References*
 - Collins *et al*: Description of the NCAR Community Atmosphere Model (CAM2) (2003).
 - Fournier *et al*: The spectral element atmosphere model (SEAM). *Mon. Wea. Rev.* **132**, 726-748 (2004).
 - Taylor *et al*: The spectral element method for the shallow water equations on the sphere. *J. Comput. Phys.*, **130**, 92-108 (1997).