CAM-SE: Regional Resolution Refinement

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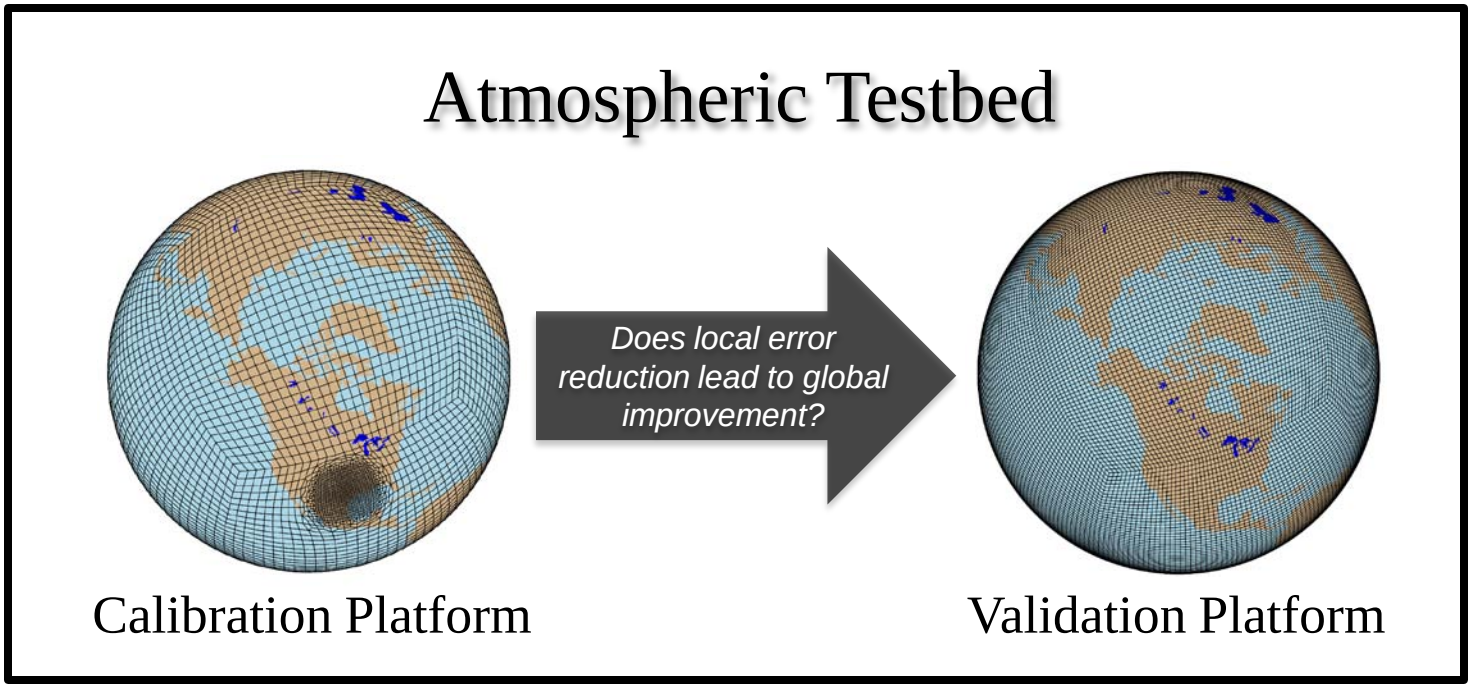
Motivation

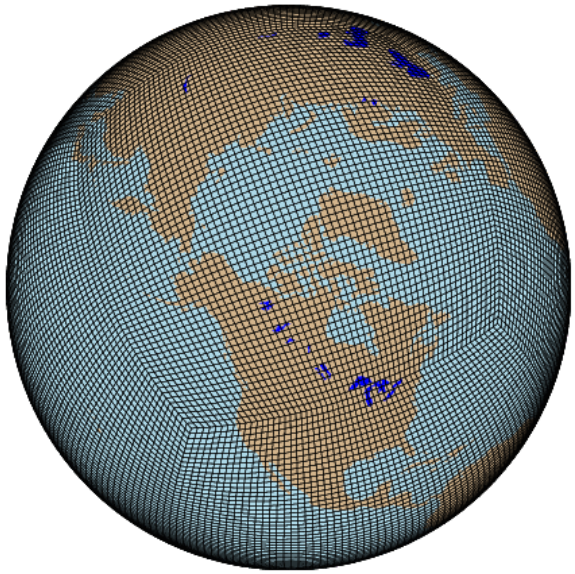


- DOE CSSEF Atmospheric Testbed (PI: D. Bader, Atmosphere team lead: S. Klein)
- Develop a global 1/8° CAM-SE with quantified uncertainty
- Calibration performed with variable resolution grid contains a small region of 1/8° resolution over (e.g.) SGP ARM site

Outline

- **Initial assessment of CAM-SE variable resolution:**
  - CAM4 Aqua Planet Experiments
    - Compare climate produced by CAM4 at 1/4° global resolution with climate in 1/4° region of variable resolution model.
  - CAM5 AMIP simulations
    - Global 1/8° vs. Variable resolution 1° -> 1/8°
    - “sanity check” stage: compare snapshots of precipitable water and precipitation.

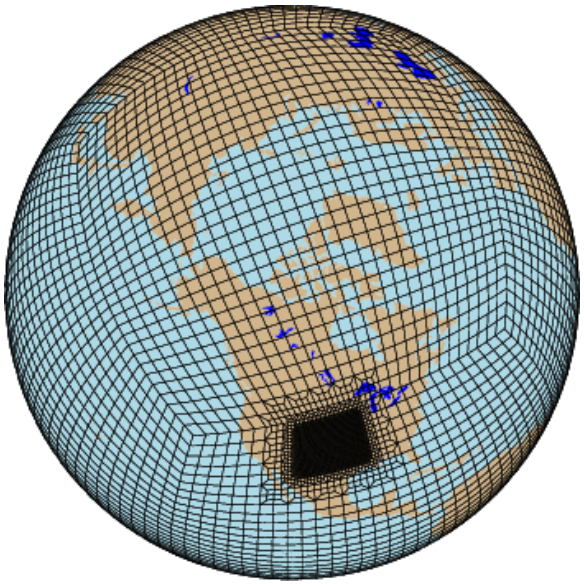
CAM5-SE at 1/8°



Global 1/8°

CAM5-SE has a very efficient, scalable and *expensive* global 1/8° configuration.

- 6M core hours per year (ANL Intrepid)
- Yellowstone: 2M core hours?
- 3.1M physics columns
- dtime=600, dynamics dt=9.2

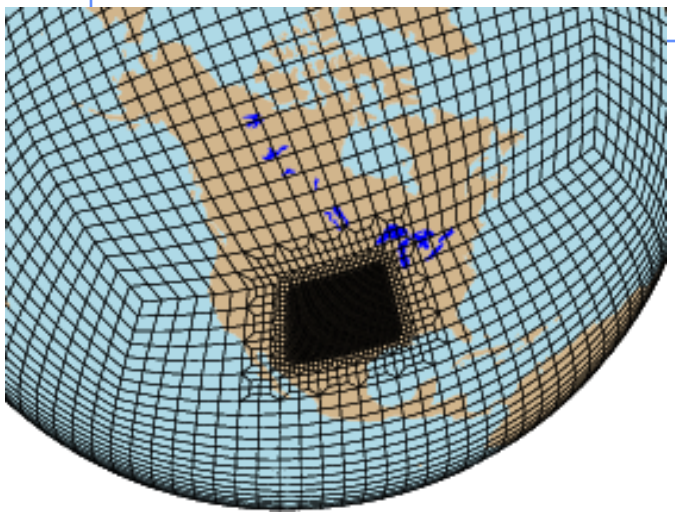


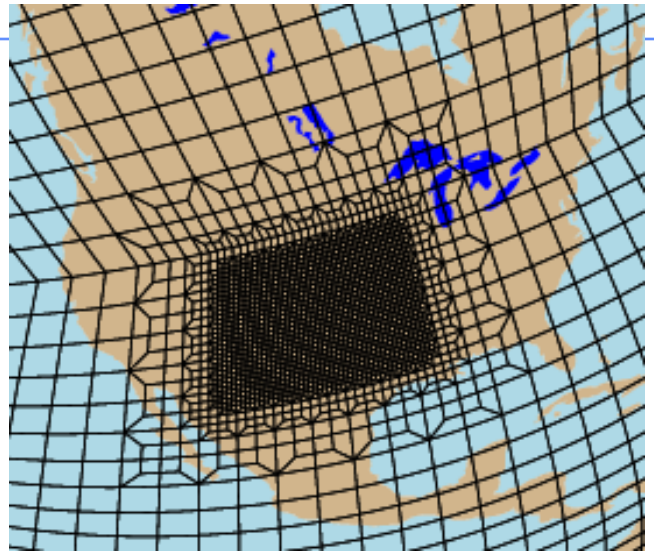
SGP 8x Regionally Refined

1° global resolution, refined to 1/8° continental sized region centered over SGP ARM site.

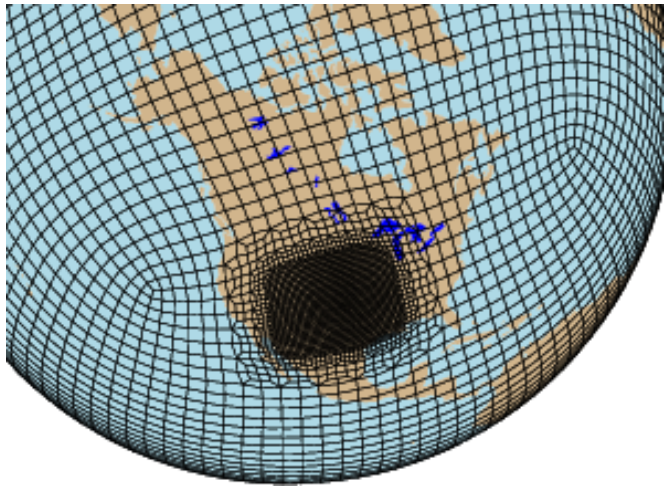
- 0.12 M core hours per year (Sandia Linux cluster).
- 67K columns.
- dtime=600, dynamics dt=7.9

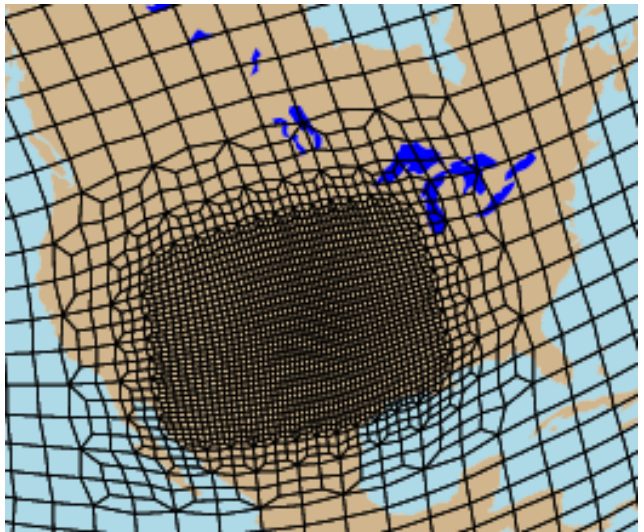
“SGP 8x” Variable Resolution Grid
1° global -> 1/8° regional





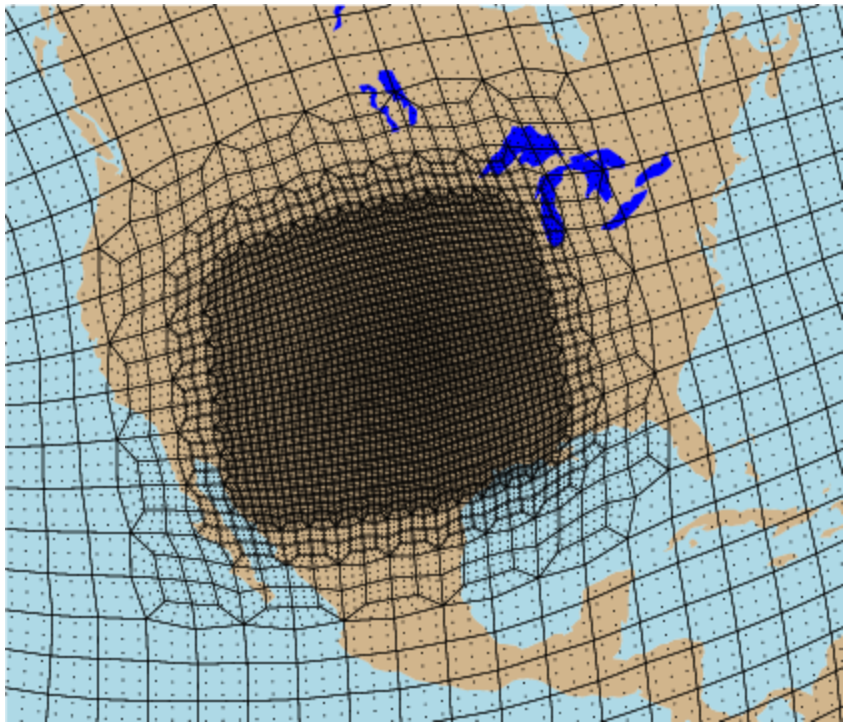
Unsmoothed
Grid generated with CUBIT GUI-based meshing tool. Starting with global grid, apply refinement in selected regions.

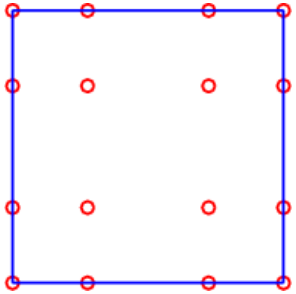




Smoothed
CUBIT’s Winslow smoothing option uses metric appropriate for spectral elements. But also *smooths the cube corners* – Need option to apply smoothing in limited region.

CAM-SE: CAM with HOMME's Spectral Element Method

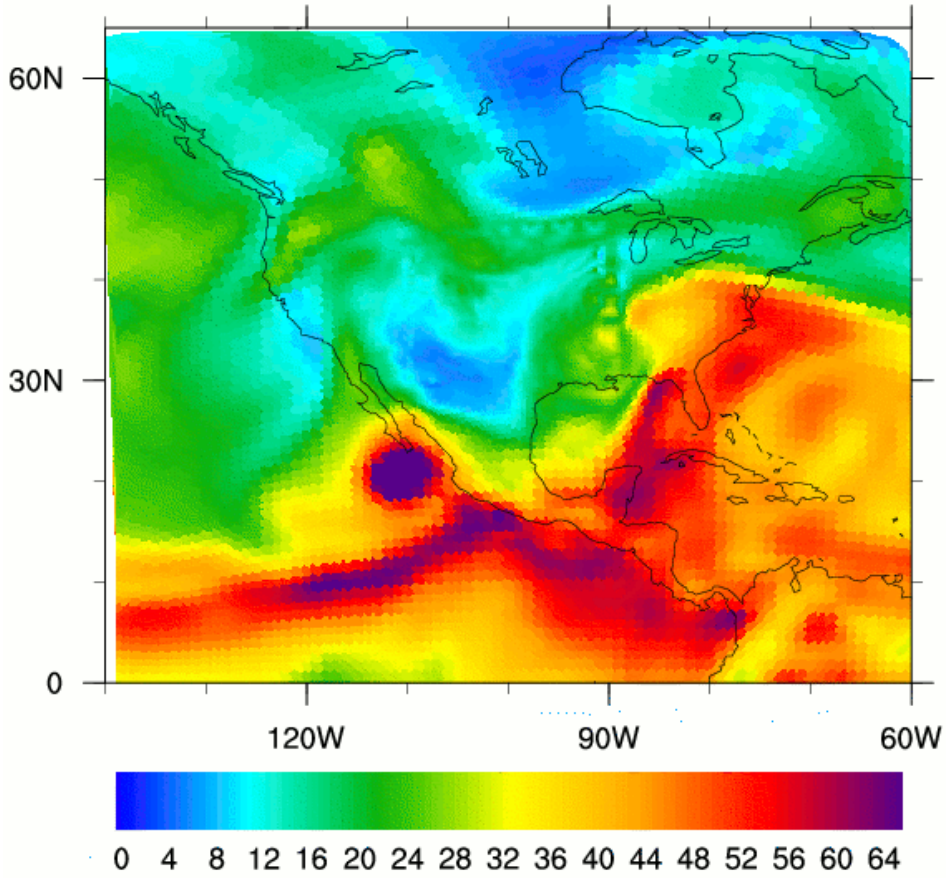




- Each element uses a 4x4 GLL collocation grid (forming a 3x3 array of subcells)
- This plot (unlike others) shows the additional degrees of freedom within each element

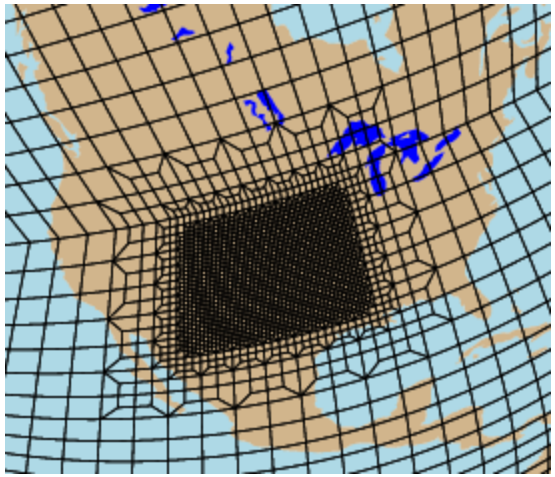
CAM5 AMIP on SGP 8x grid

Precipitable Water (kg/m^2)



3h snapshots

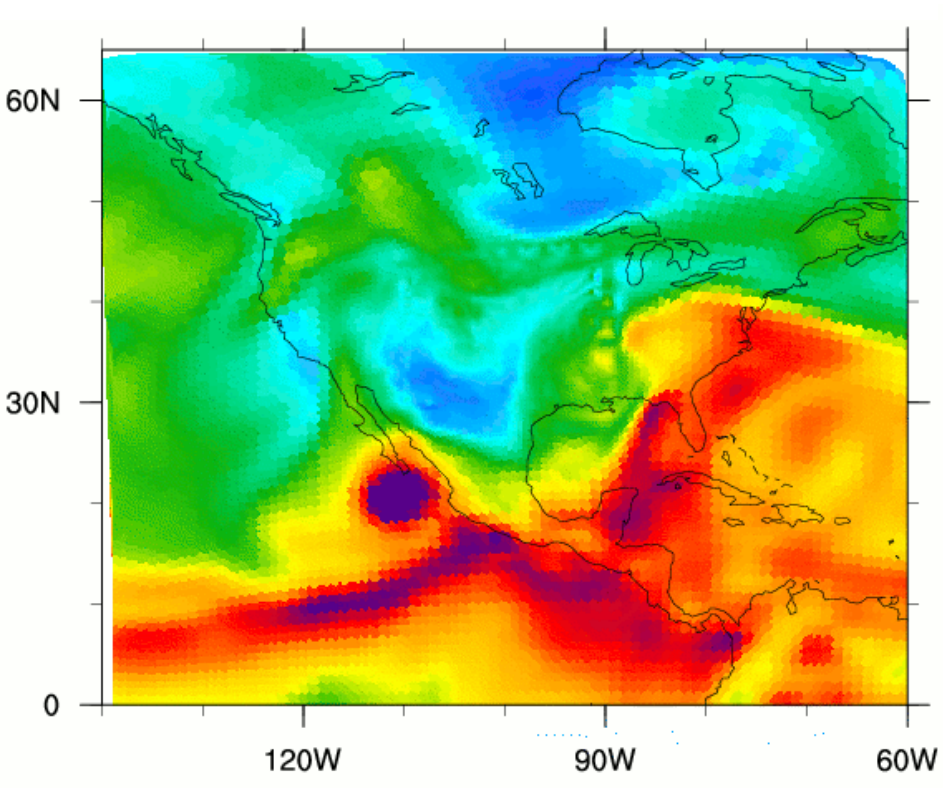
Initial results showed ugly stationary grid artifacts at transition boundaries

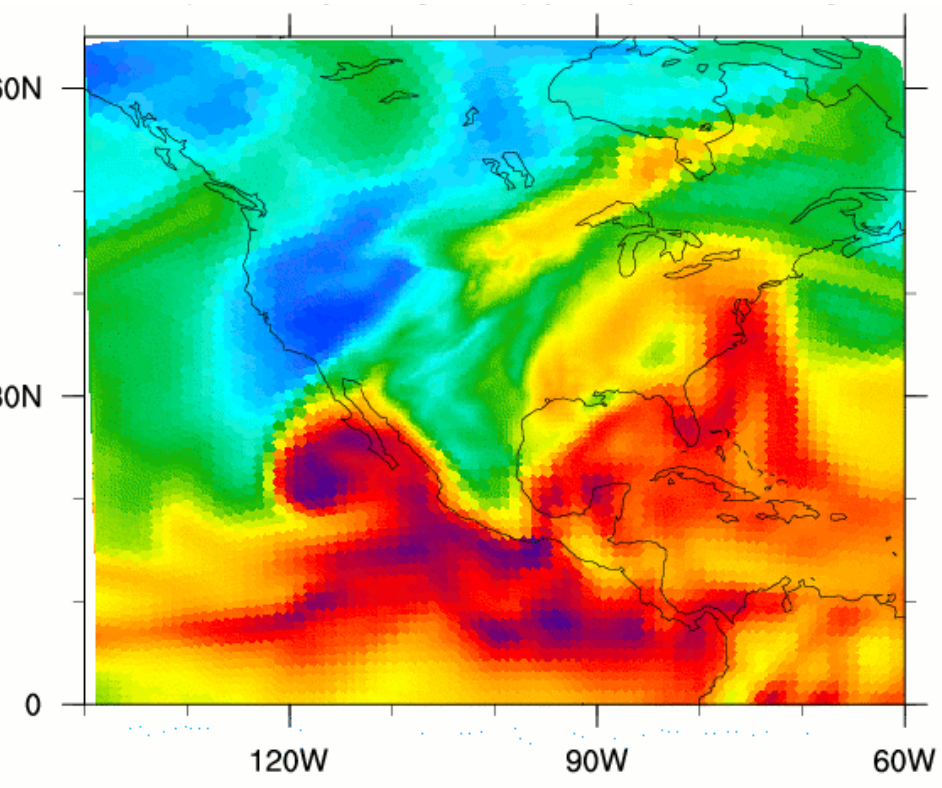


CAM5 AMIP, SGP 8x Unsmoothed Grid

Initial simulation with stationary artifacts in grid transition region

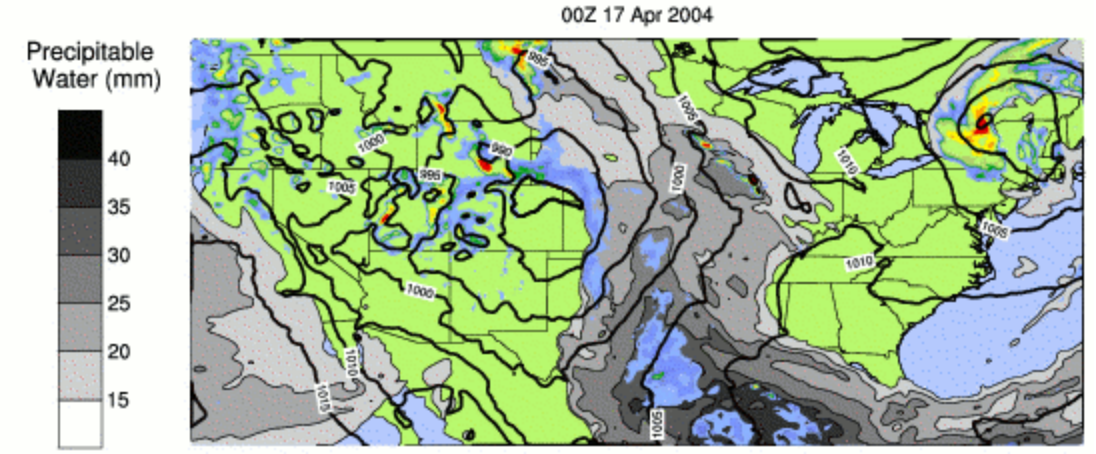
Artifacts eliminated with improved variable-coefficient hyperviscosity operator.





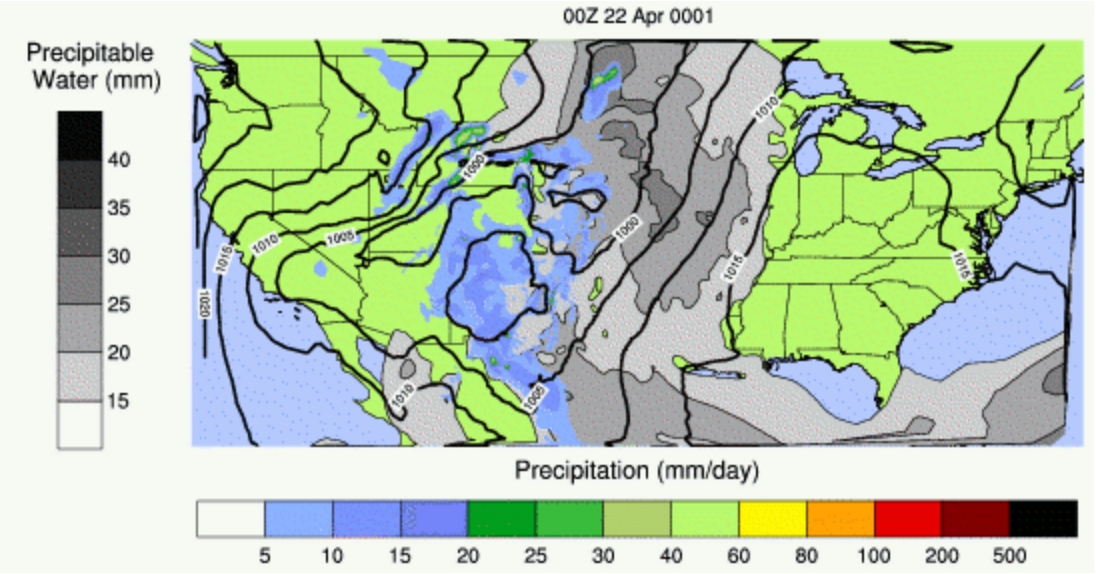
CAM5 AMIP

Precipitable water (gray), precip rate (color), sea level pressure (contours)



Global 1/8° Simulation

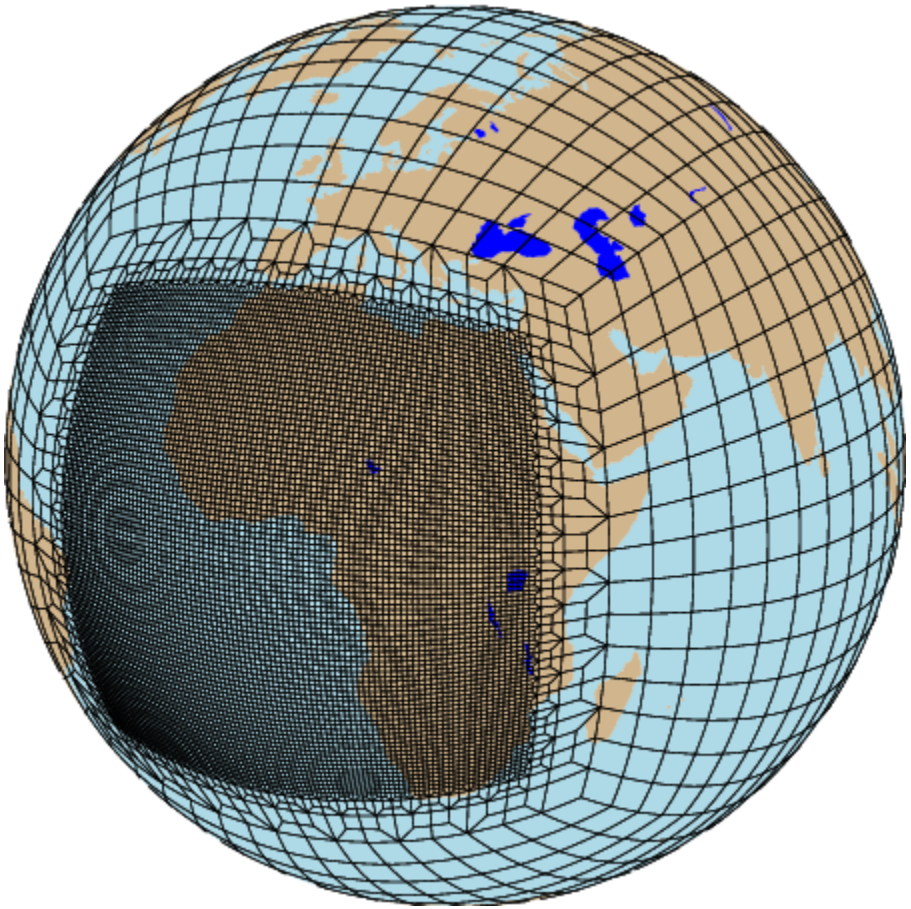
Snapshots show propagating convective system not seen at lower resolutions. Detailed frontal structure and tapping of moisture



Regionally Refined Simulation

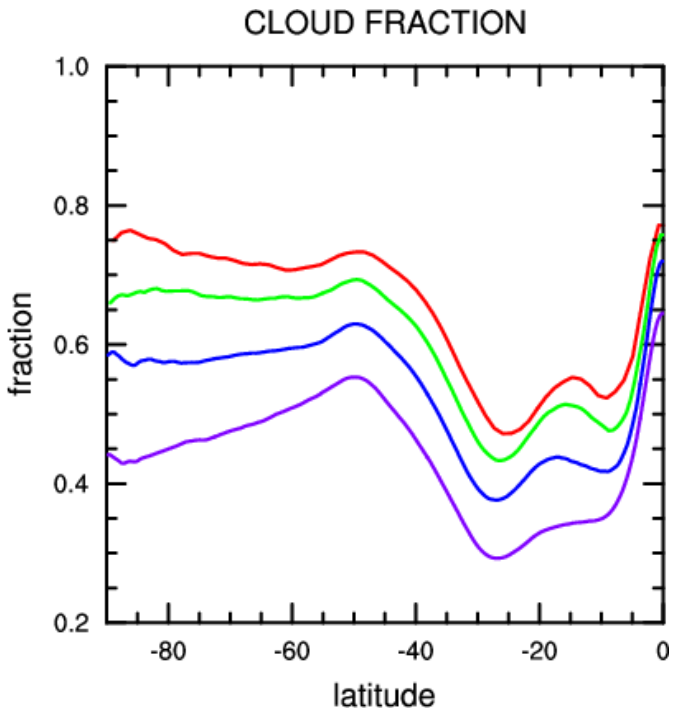
Similar convective systems form in the 1/8° region, strongly dissipated as it propagates into the 1° region

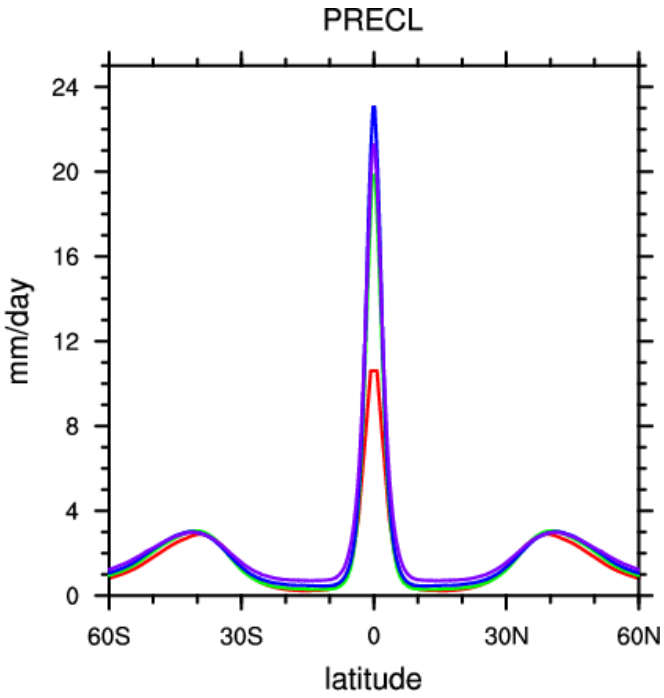
CAM4 Variable Resolution
Aqua Planet Climate



APE 8x grid

- Compare ¼° global uniform resolution climate with the climate in the ¼° region from a variable resolution simulation
- APE 8x grid: 2° transitioning to ¼° in large equatorial region
- Following DOE Robust Regional Modeling Project evaluation strategy (CAM4 physics, dtime=600)

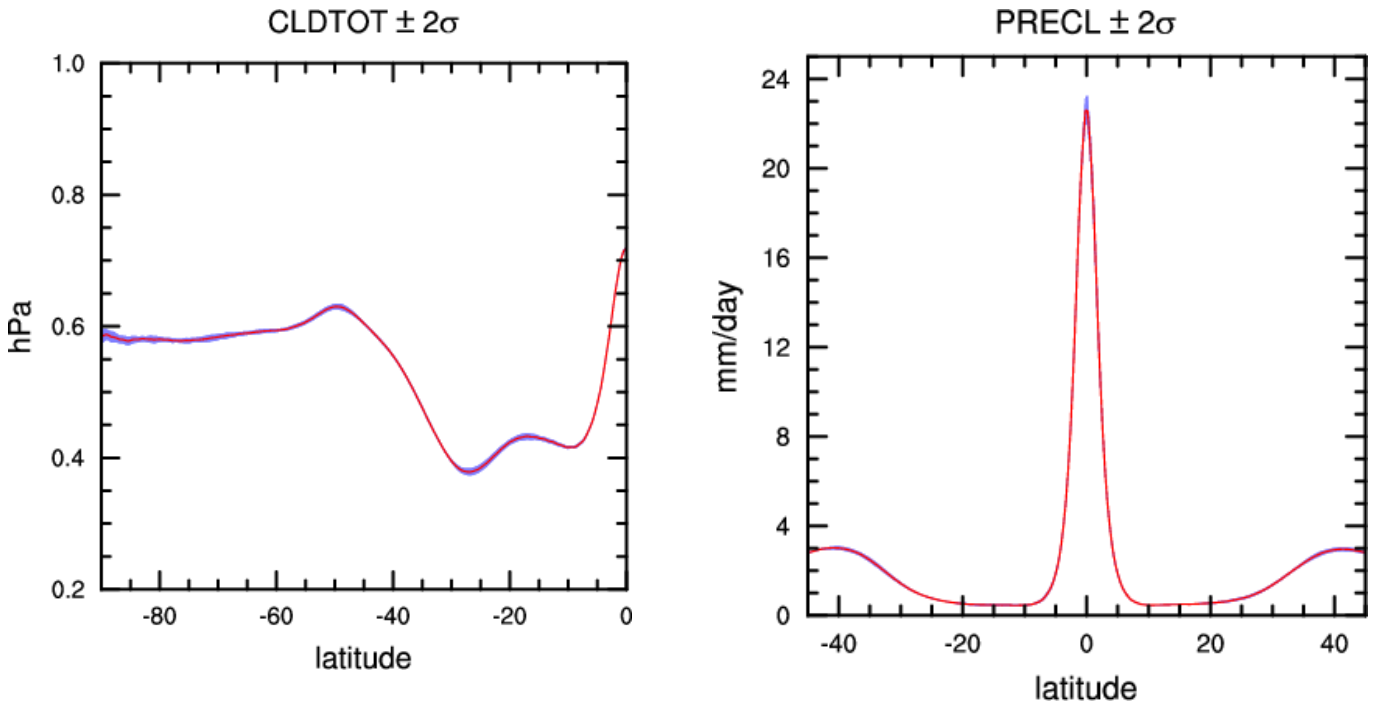




2° red
1° green
0.5° blue
0.25° purple

- CAM4 APE shows strong signal under mesh refinement, mimicking that seen in CAM3.1 APE (Williamson, Tellus 2007)
- Focus on two quantities examined in Williamson 2007 with some of the largest resolution sensitivity: cloud fraction and large scale precipitation.

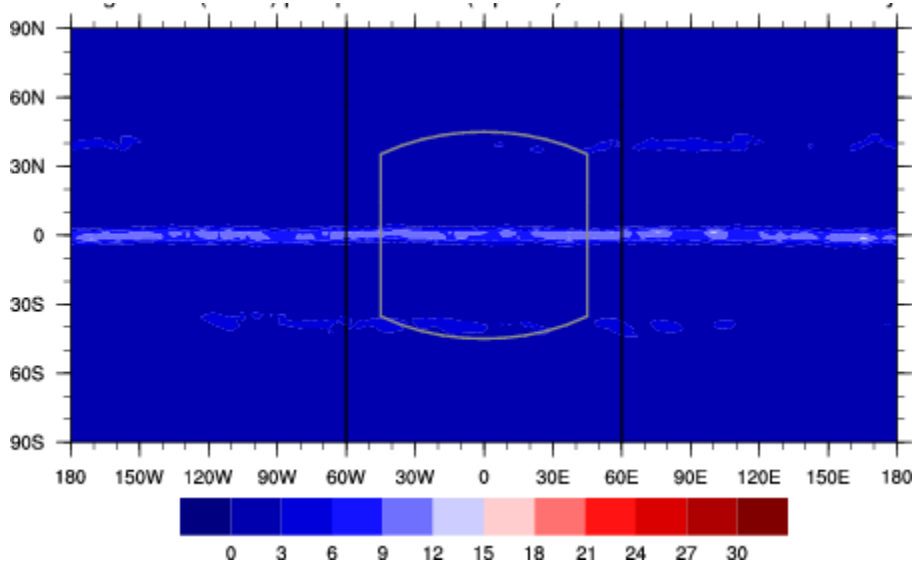
STD of 1 year means



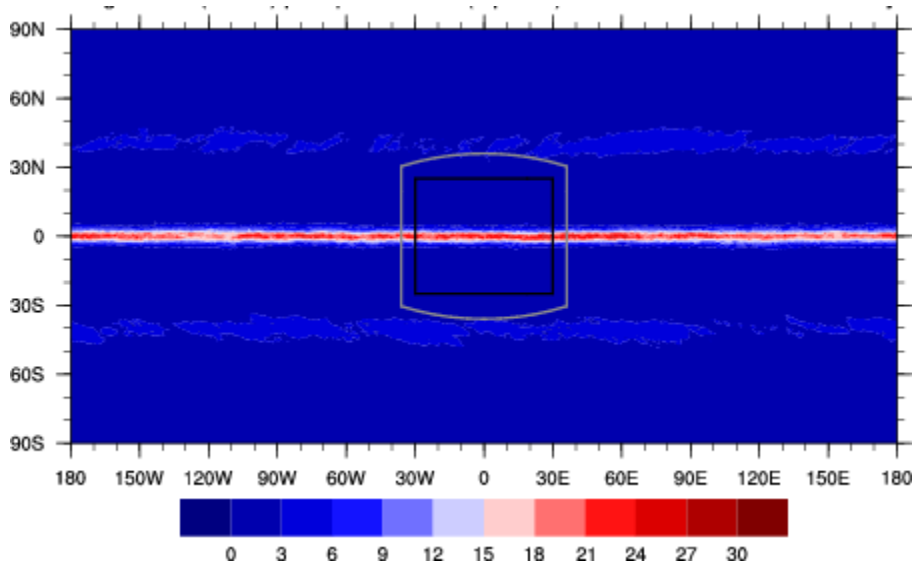
20 (10?) year average (red) of zonal mean PS and cloud fraction. Purple: standard deviation of 1 year means. (from ½ degree data)

Large scale precip

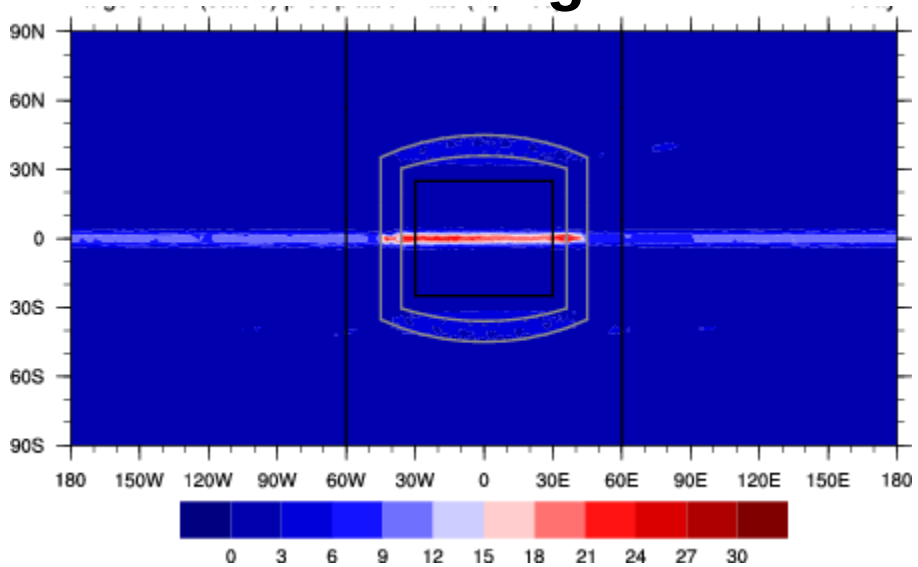
2° Global



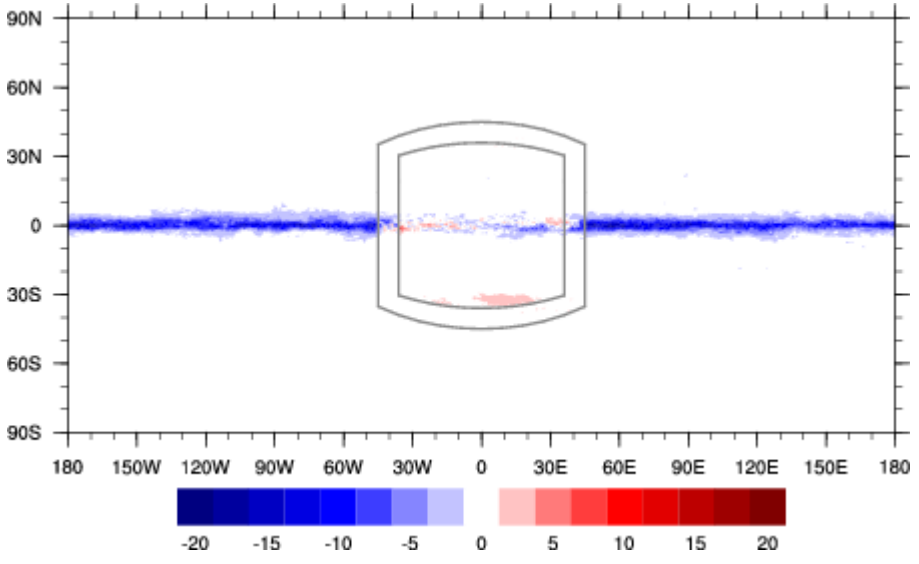
1/4° Global



APE 8x grid

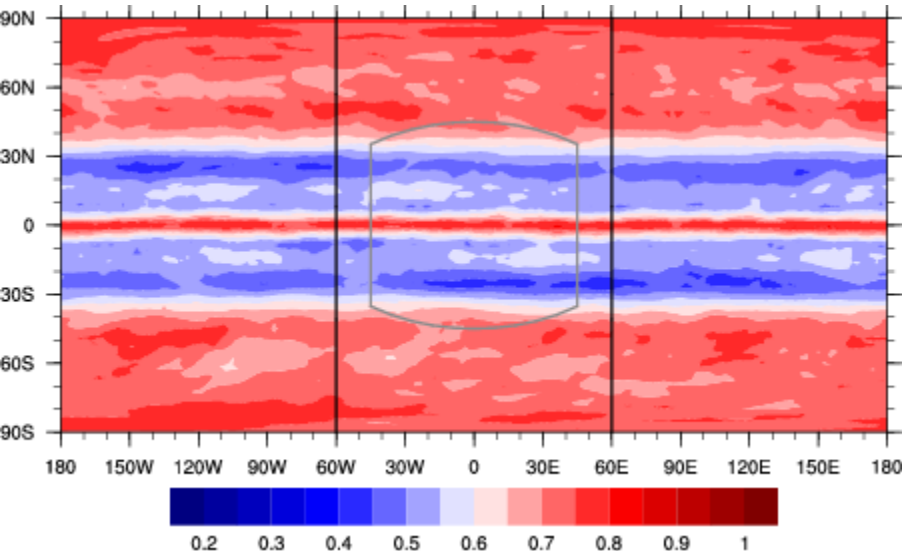


APE 8x - 1/4° Global

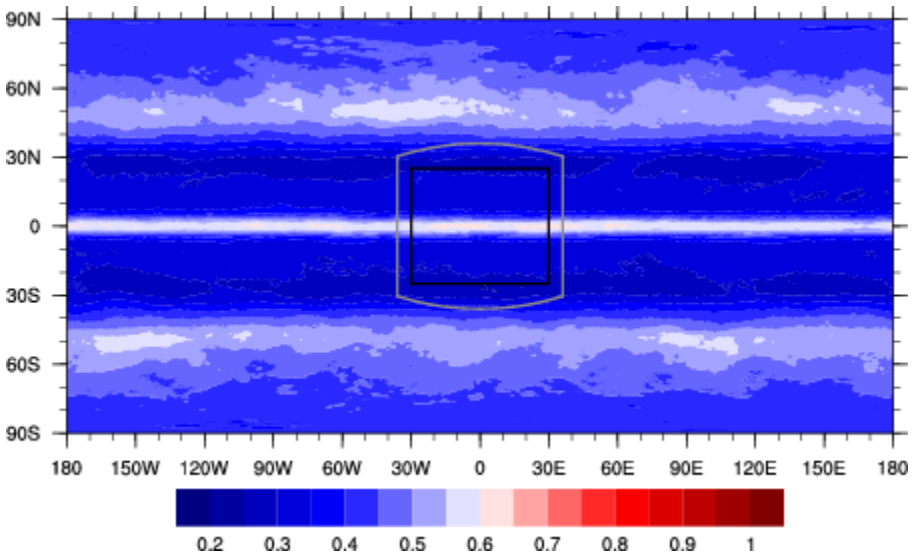


Cloud Fraction

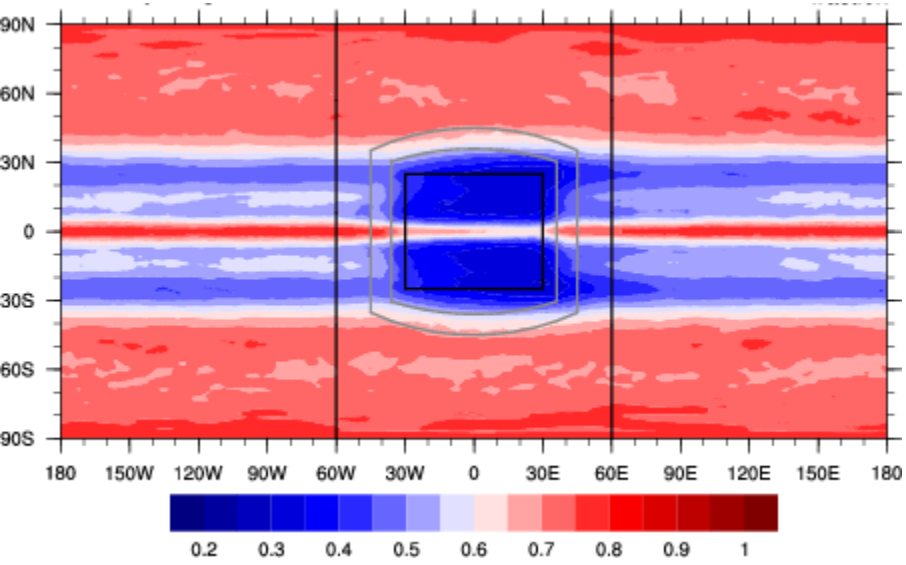
2° Global



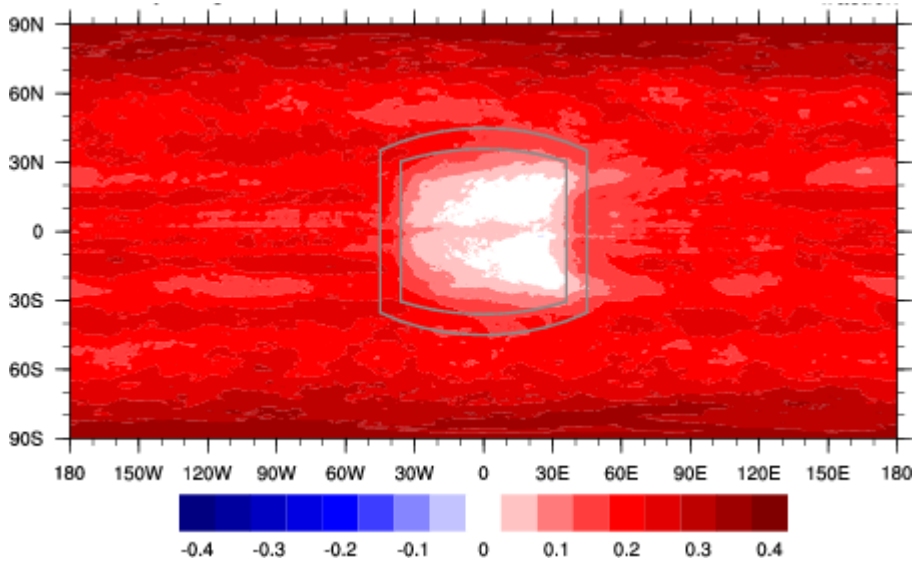
1/4° Global



APE 8x grid



APE 8x - 1/4° Global



Conclusions

- CAM4 Aqua Planet Experiments
  - Large resolution signal seen in cloud fraction and large scale precip is captured in the variable resolution grid.
- CAM5 AMIP simulations
  - “eyeball norm” suggests 1/8° precip features are similar in the 1/8° region of the variable resolution simulation.
- Other work: Colin Zarzycki (Michigan)
  - CAM5 physics, variable resolution grids can develop/maintain TCs that do not appear to suffer significant numerical errors when moving through grid transition regions
- Variable resolution can be used for efficient evaluation of the high-res behavior of parameterizations