Atmospheric Model Working Group (AMWG)

Agenda

1:30 pm Rich Neale (NCAR) -- Overview of AMWG activities

1:45 pm Cecile Hannay (NCAR) – Results from CAM-SE AMIP and coupled simulations

2:00 pm Sungsu Park (NCAR) – Scale-Adaptive Physics Parameterization

2:15 pm Pete Bogenschutz (NCAR) – A Unified Cloud/Convection Scheme for CAM: Concept and Preliminary results

2:30 pm Xiaohong Liu (PNNL) –Improved ice nucleation in mixed-phased cloud an impact on climate

2:45 pm Brian Mapes (U. Miami) – Multi-analysis nudged CAM-SE runs to evaluate the realism of a convection scheme

3:00 pm Yaga Richter (NCAR) – Higher vertical resolution in CAM – Do we need it?

3:15 pm Kevin Raeder (NCAR) – Data assimilation with CAM-SE and DART

3:30 pm ***Break***

4:00 pm Bill Collins (Berkeley/LBNL) – Nonhydrostatic high-order accurate adaptive mesh dynamics for CAM

4:15 pm David Romps (LBNL) – The forgotten advection in CAM

4:30 pm Discussion (lead Minghua Zhang, Stony Brook)

5:00 pm ***Session Ends***

CAM5 Development Activities

Initial results from physics development

- Cloud physics
- Modal aerosol model
- Numerics sensitivity

Dynamical core and high resolution modeling

- Spectral element (SE) core
- 0.25^{o} global simulations
- Regional refinement simulations
- Vertical resolution

Recently released versions

Key biases

- Tropical precipitation
- Precipitation frequency
- Tropical cyclones

Supported model versions

- Resolution, dynamical core, physics

Planning towards CMIP6/AR6

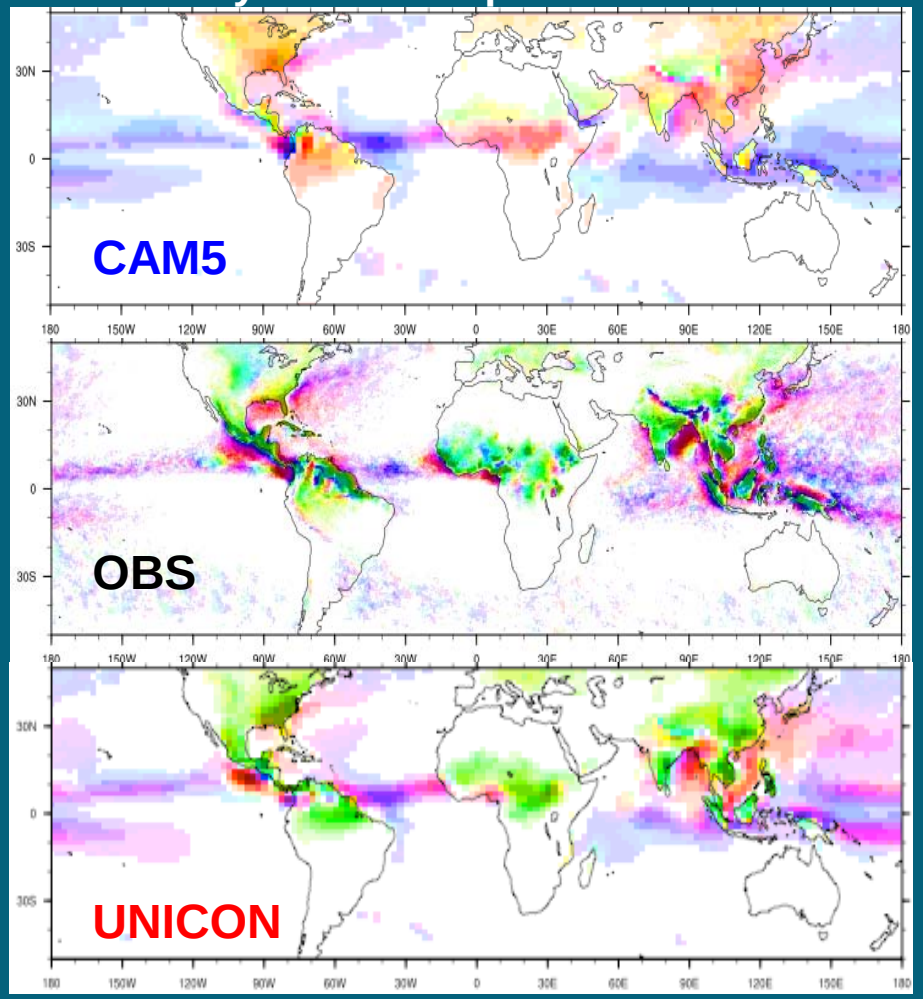
- Timeline
- Current available physics development

UNICON Initial Results

Sungsu Park, NCAR

- **UNICON** – Unified Convection Scheme – is designed to simulate all shallow-deep, dry-moist, and forced-free convection within a single framework in a seamless, consistent and unified way.
- Currently, good results with L30 1-deg resolution with an improved Taylor score (**0.761 in UNICON, 0.784 in CAM5**), climatology
- Much improved variability (e.g., diurnal cycle of precipitation, MJO and ENSO.)
- Extensive test simulations at high horizontal and vertical resolutions will be started soon

Diurnal Cycle of Precipitation

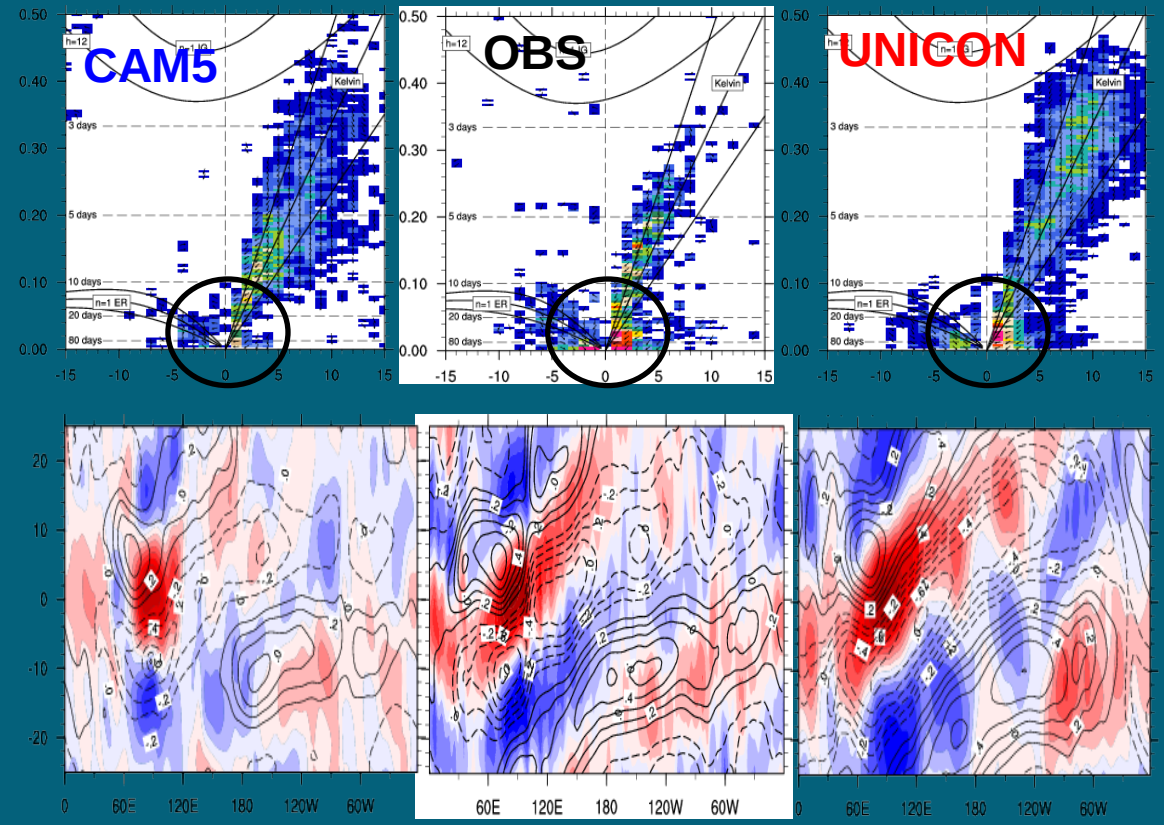


Peak rainfall moves from midday to early evening (JJA)

UNICON Initial Results

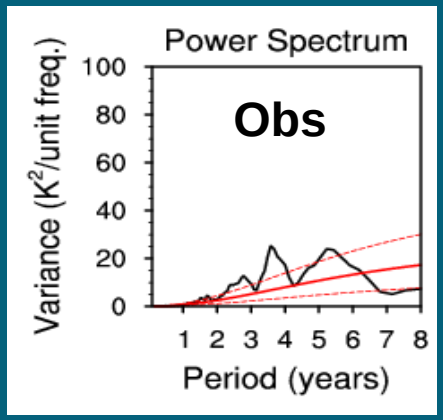
Sungsu Park, NCAR

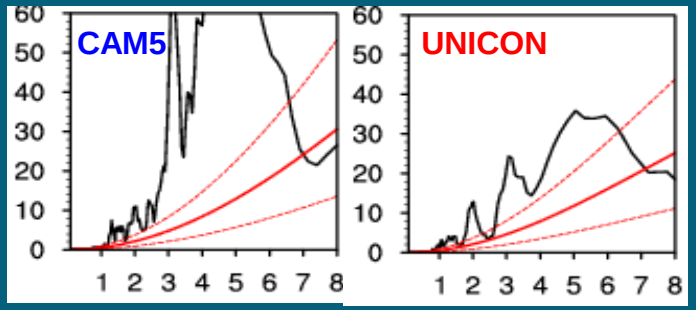
Madden-Julian Oscillation



Improved MJO wave amplitude and propagation

ENSO





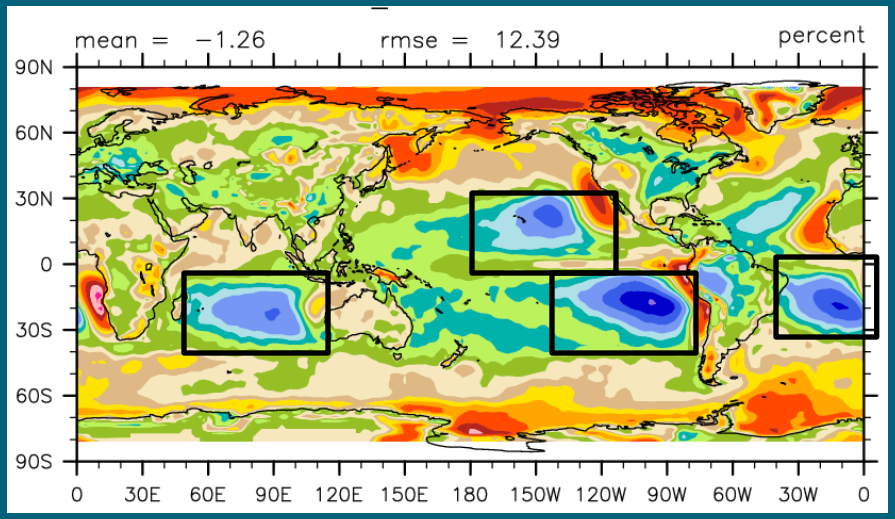
Improved mean El Nino amplitude

CLUBB Cloud Layers Unified by Binormals

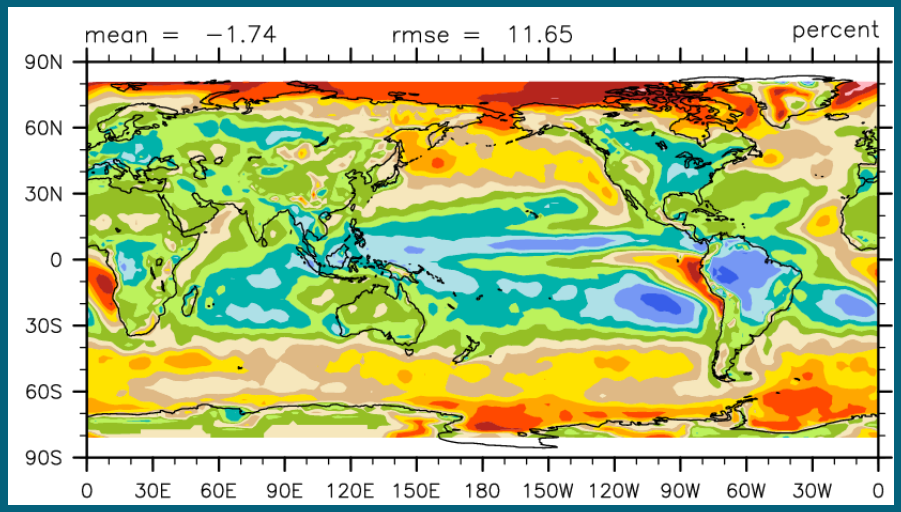
Peter Bogenshutz, NCAR

- ✓Third-order turbulence closure centered around an assumed double Gaussian PDF)
- ✓CLUBB replaces shallow convection, PBL, and cloud macrophysics parameterizations in CAM5 with one equation set
- ✓CAM-CLUBB is in CESM release as an option and is overall competitive with CAM5
- ✓In the next version of CAM-CLUBB, the deep convection scheme will e replaced as well
- ✓(see Bogenschutz talk)

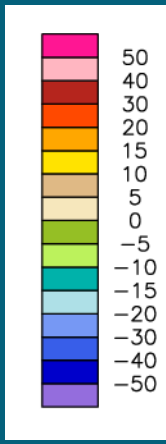
CAM5 minus CLOUDSAT



CAM-CLUBB minus CLOUDSAT



Low Cloud



Fraction

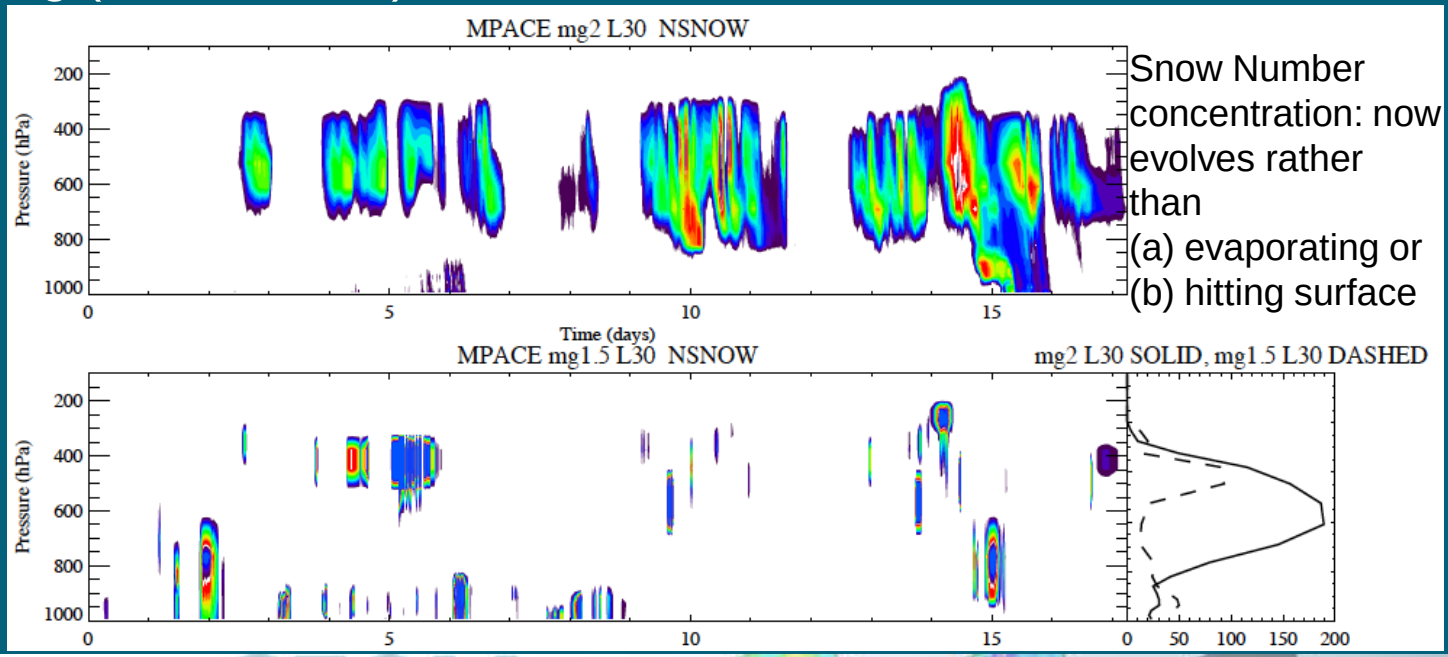
CAM Microphysics Developments

Gettelman, Morrison, Santos, Caldwell, Liu, Chen, Su, NCAR

- Goal: Multi-Scale Clouds
- Refactored MG1.5 code on CAM trunk
  - Includes activation fix
  - Could make this default soon
- New code (MG2) with prognostic precipitation being tested: initial results promising (reduced AIE)

MG2: Prognostic Precip.

MG1.5: Diagnostic Precip.



Snow Number concentration: now evolves rather than
(a) evaporating or
(b) hitting surface

Modal Aerosol Model (MAM)

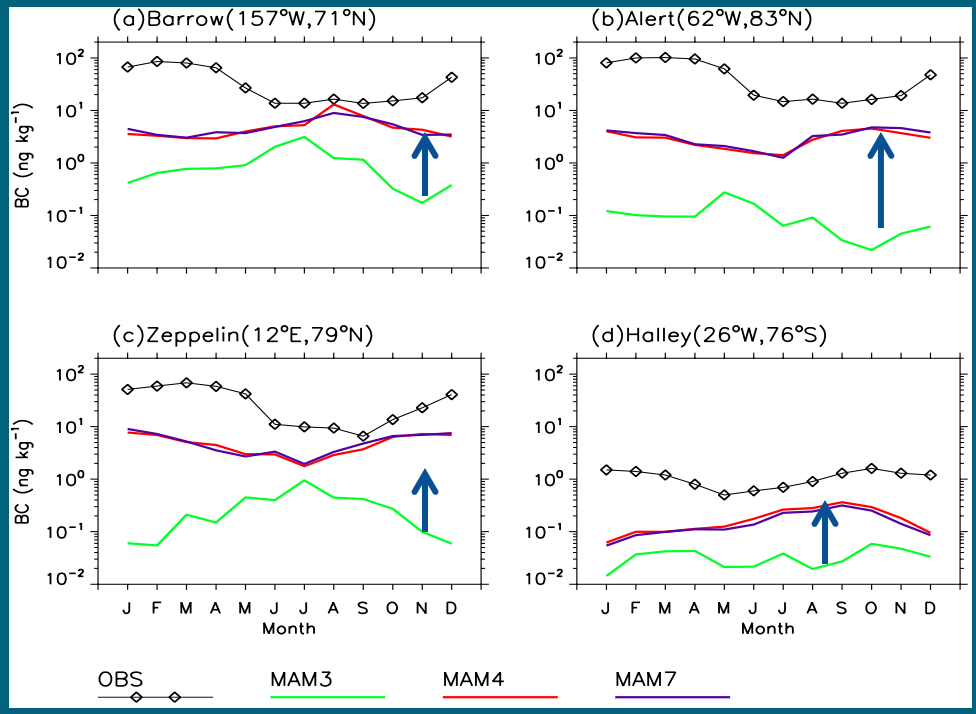
Steve Ghan, Xiaohong Liu, Po-Lun Ma, PNNL

Aitken	Accumulation	Coarse
number	number	number
sulfate	sulfate	soil dust
secondary OM	secondary OM	sea salt
sea salt	primary OM	sulfate
	BC	
	soil dust	
	sea salt	

coagulation
condensation

Primary Carbon
number
primary OM
BC

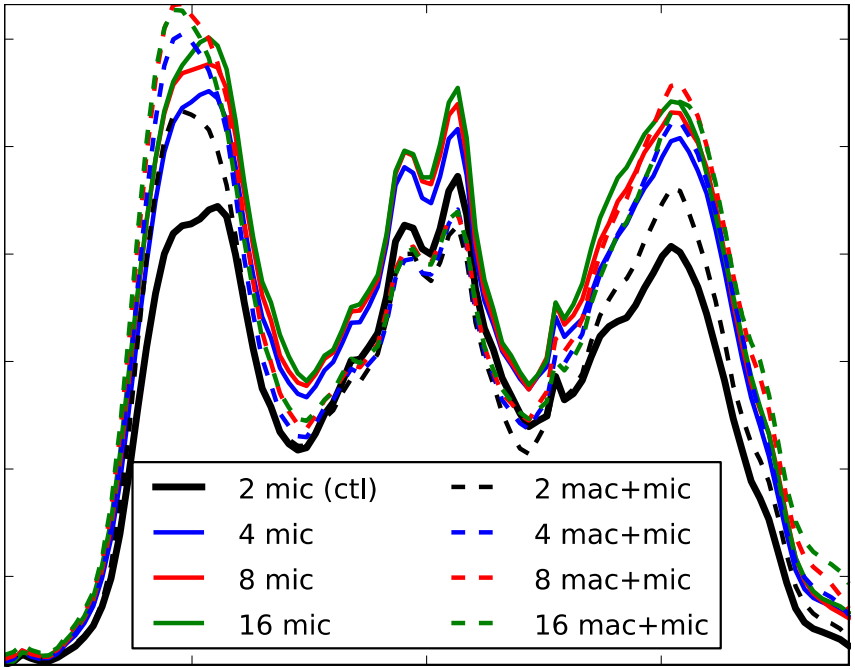
MAM4:
MAM3 with a separate primary carbon mode



- Increases BC and primary OM up to 10-fold in remote regions
- Insignificant changes most places for other species
- Agrees well with MAM7
- 10% additional cost

Numerics of Parameterizations

P. Rasch, H. Wan, P. Caldwell, B. Lebassi Habtezion



Climatological zonal-average liquid water path for simulations with various combinations of macro (mac) +microphysical (mic) substeps.

Goals:

- Fix process coupling issues which have a big effect on CAM5 climate (fig on left)
- Ensure temporal convergence of CAM physics (a prerequisite for high-res skill)

Methods:

- Explore impact of Δt changes
  - Pinpoint source of Δt sensitivity by substepping groups of processes
- Use idealized models to capture pathological problems

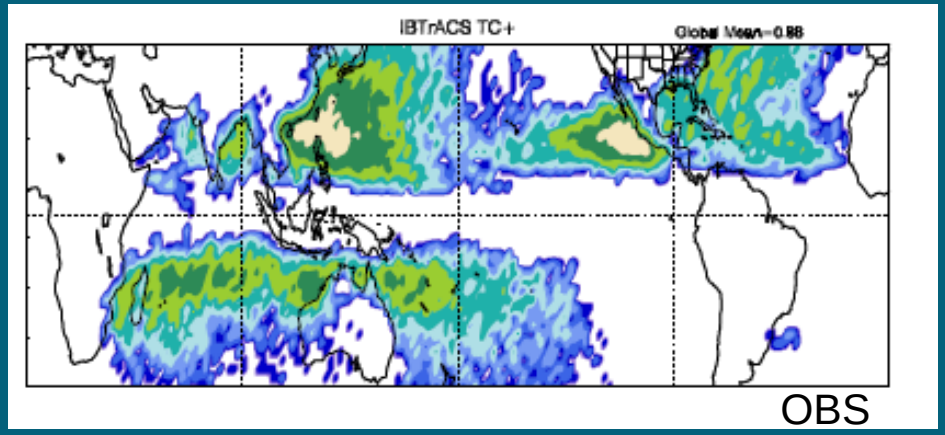
Further CAM developments

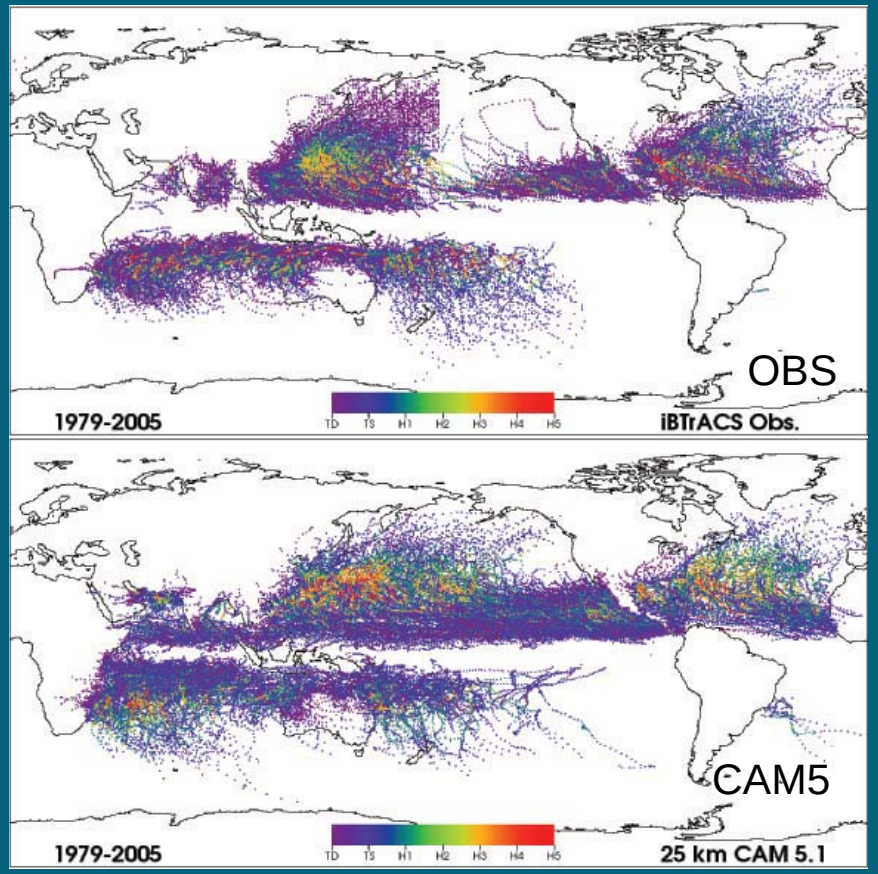
Ongoing model developments and diagnoses (+ many more!)

- ✓ Fix microphysics/activation liquid cloud fraction inconsistency + droplet mass/# inconsistencies – LLNL
- ✓ Implementing PDF-based macro/micro schemes – LLNL/NCAR
- ✓ Further development of 7-mode MAM (MAM7) – PNNL
- ✓ Unified scheme for aerosol vertical transport, activation, and removal in convective clouds – PNNL/LLNL
- ✓ Advanced microphysics in convection - UCSD/NCAR
- ✓ Applying new ice nucleation in mixed phase clouds – PNNL/LLNL/DRI
- ✓ Deriving vertical velocity variance from TKE - NCAR
- ✓ Implementing sub-columns for physics – NCAR/SBU
- ✓ Atmospheric nudging to diagnose biases - NCAR/LLNL/SBU
- ✓ CAPT experiments to diagnose biases - NCAR/LLNL
- ✓ Model for prediction across scales (MPAS) - NCAR/LANL
- ✓ Adaptive mesh refinement – LBNL
- ✓ CAM-SE regional mesh refinement – Sandia
- ✓ CSLAM tracer transport in flux form - NCAR/Sandia
- ✓ Blocked flows and turbulent mountain stress – NCAR
- ✓ Conserved energy changes required in physics - NCAR

High Horizontal Resolution

Julio Bacmeister (NCAR), Michael Wehner (LBNL)





CAM5-SE (ne120, 0.25 deg)

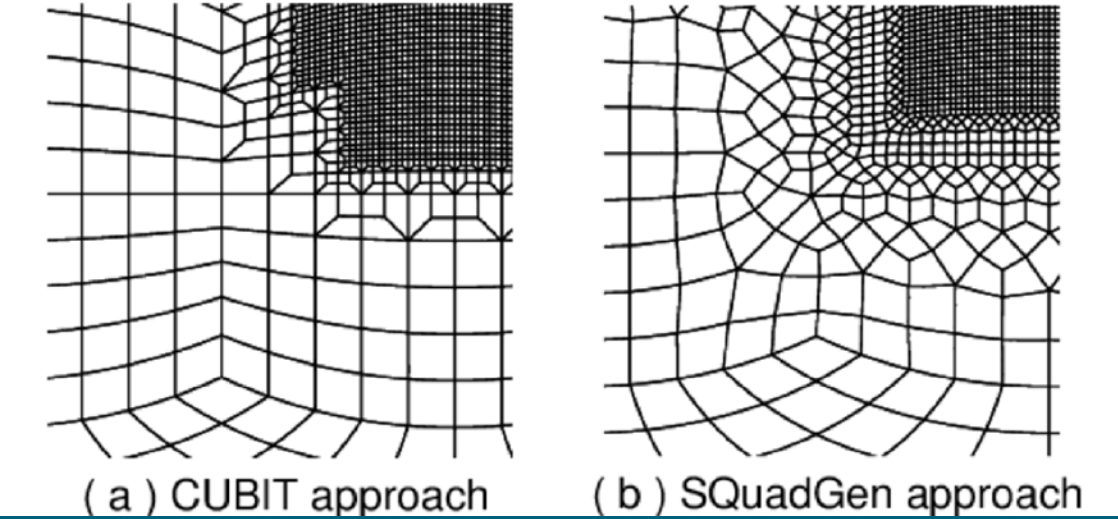
CAM5-FV (0.25 deg)

CAM-SE variable resolution capability

Mark Taylor, O. Guba (Sandia) P. Ullrich (UC Davis)

Sandia National Laboratories

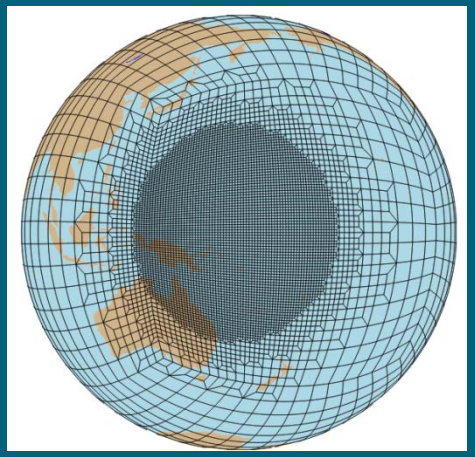
- **Tensor hyperviscosity**
  - Improved CFL condition (faster code due to larger timestep)
  - Robust and scale aware: Single tuning for all grids
  - Reduced error and noise in grid transition regions
- **New grid generation software SQuadGen replaces CUBIT**
  - Low-connectivity mesh transition template: Less distorted elements and improved CFL condition
  - Better smoothing for spherical grids, which further improves CFL condition
  - Source code included with HOMME

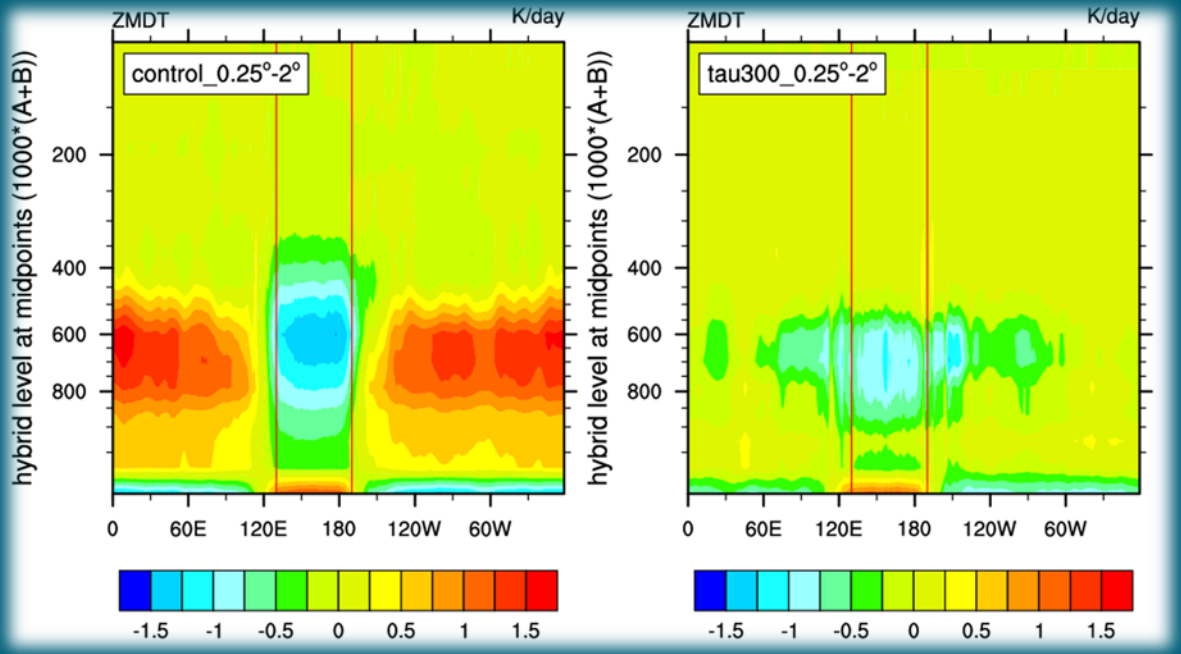


Regional refinement

Substituting global high resolution for a targeted regional focus

Zhuxiao Li, Rich Neale, Mike Levy (NCAR) Mark Taylor (Sandia)



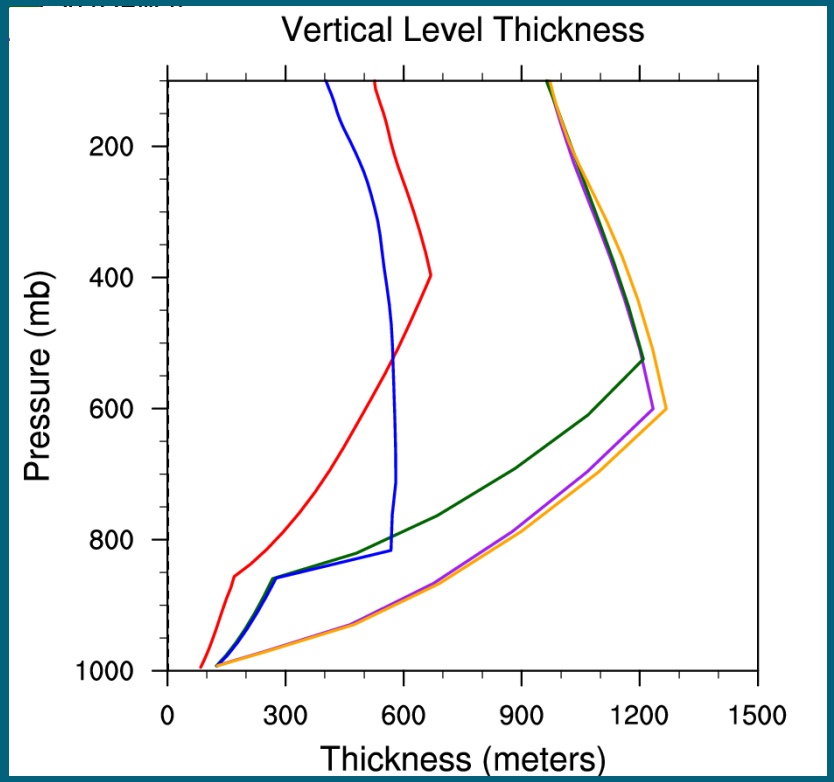


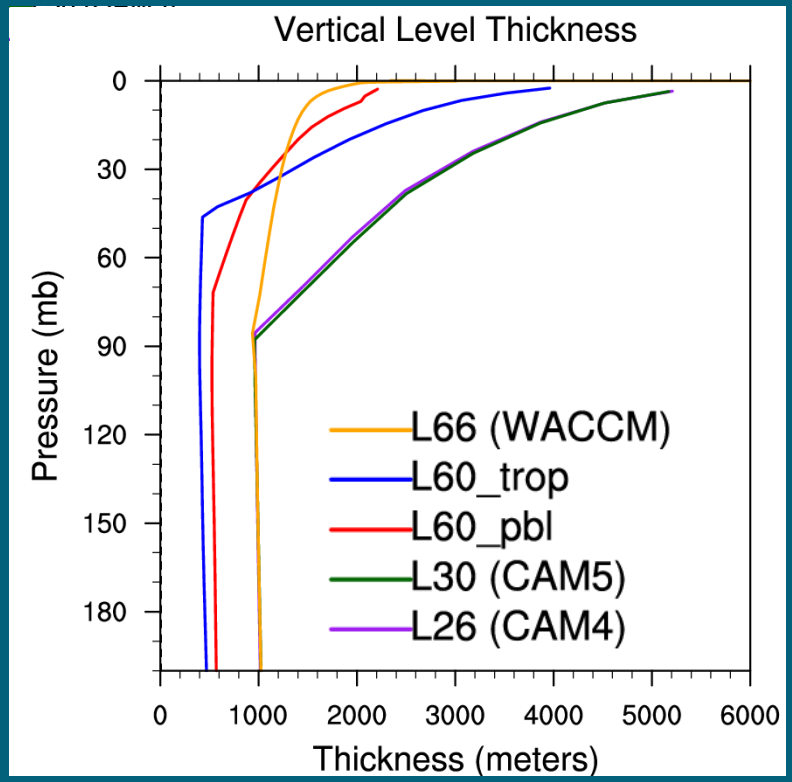
✓Tropical regional refinement ne30->ne120 (2^o to 0.25^o)
✓Aqua-planet CAM5 simulations

✓Deep convective heating is sensitive to region of refinement (between red lines, LEFT)
✓Changing deep convective timescale to 5 minutes reduces sensitivity (RIGHT)

Increased Vertical Resolution

Initial simulations focused on dual strategy





L60_pbl: Increased resolution through whole atmosphere (including PBL)

L60_trop: Increased resolution above boundary layer only

- ✓ Represents realistic biennial oscillation (coupled with WACCM GWD scheme)
- ✓ Significantly reduces cold pole problem

Yaga Richter, Ari Soloman, Julio Bacmeister (NCAR)

Recent CAM5 Releases

CAM5.2 (November 2012, CESM1.1/1.1.1)

- CAM-SE available for users
- Topographic datasets included (consistent sub grid-scale components)
- Diagnostic radiation calculations using MAM

CAM5.3 (last week, CESM1.2)

- CAM-SE
  - Eulerian -> Lagrangian vertical advection
  - Diffusion operator fix
  - Improved low-cloud simulation
  - AMIP and coupled simulations being validated (Cecile Hannay)
- Prescribed aerosols available
- Microphysics updates (MG1.5)
- CLUBB available
- Coupled simulations under way (Cecile Hannay)

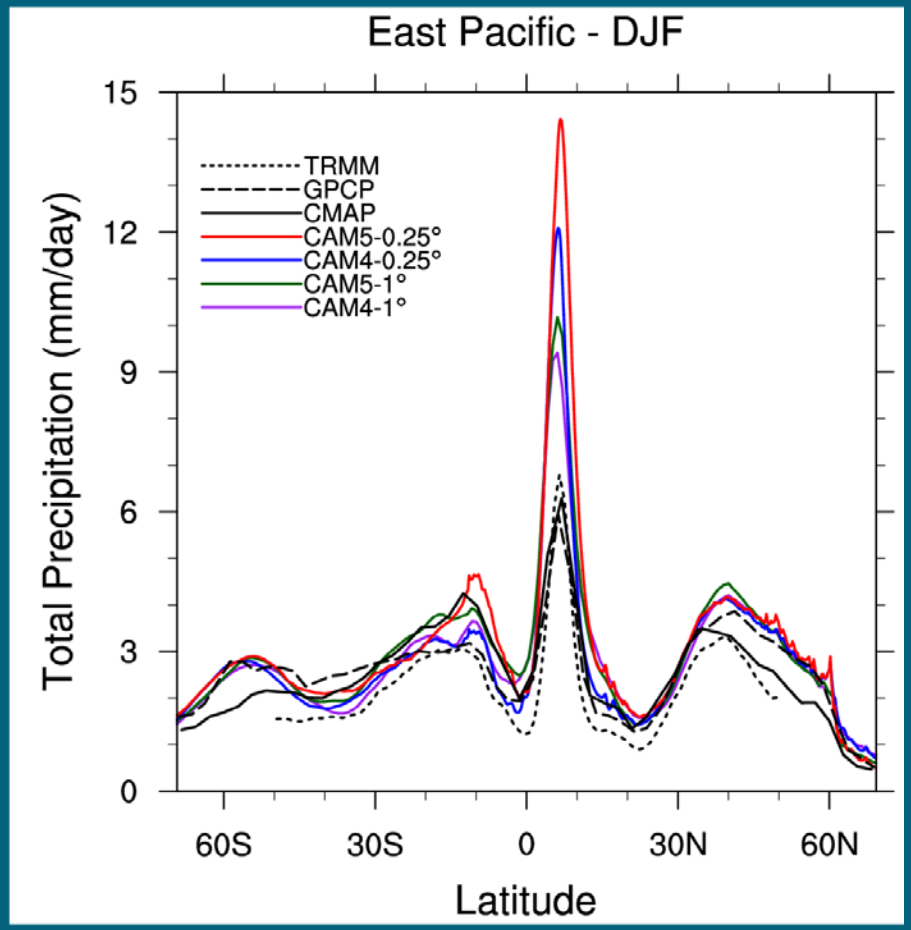
Discussion Slides

Discussion

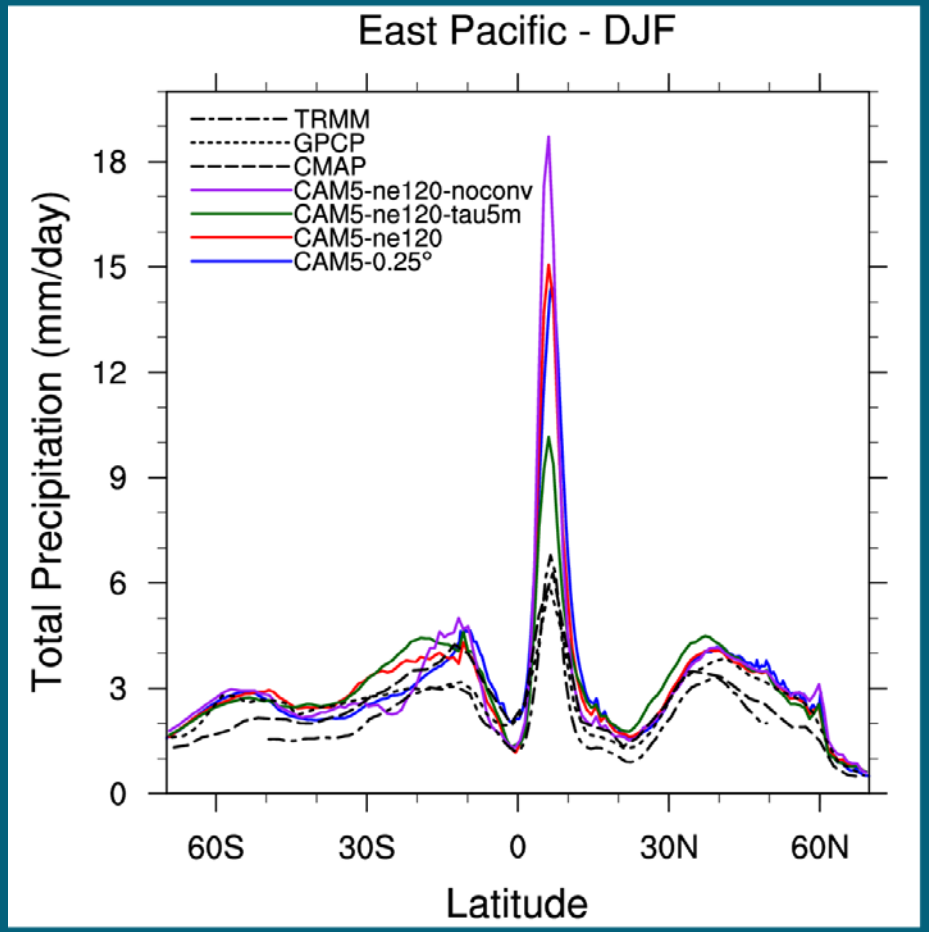
1. Addressing systematic errors; what are the priorities?
   - Tropical precipitation, high cloud LWCF, mid-west rainfall, mixed phase clouds
2. How do we move towards a supported high-res model (horizontal and vertical)?
3. How do we maintain a university available model?
4. How can we better entrain non-NCAR developers?
5. Supported model versions
6. Path(s) forward on model development (esp. physics)
7. Timeline of model development for CMIP6
8. AMWG draft development documents (developments, metrics and protocols)
9. What will be the ‘new science opportunities’ for CESM2 (~2016)
   - Regional climate modeling

Tropical Biases

Many biases worsen, e.g., ITCZ



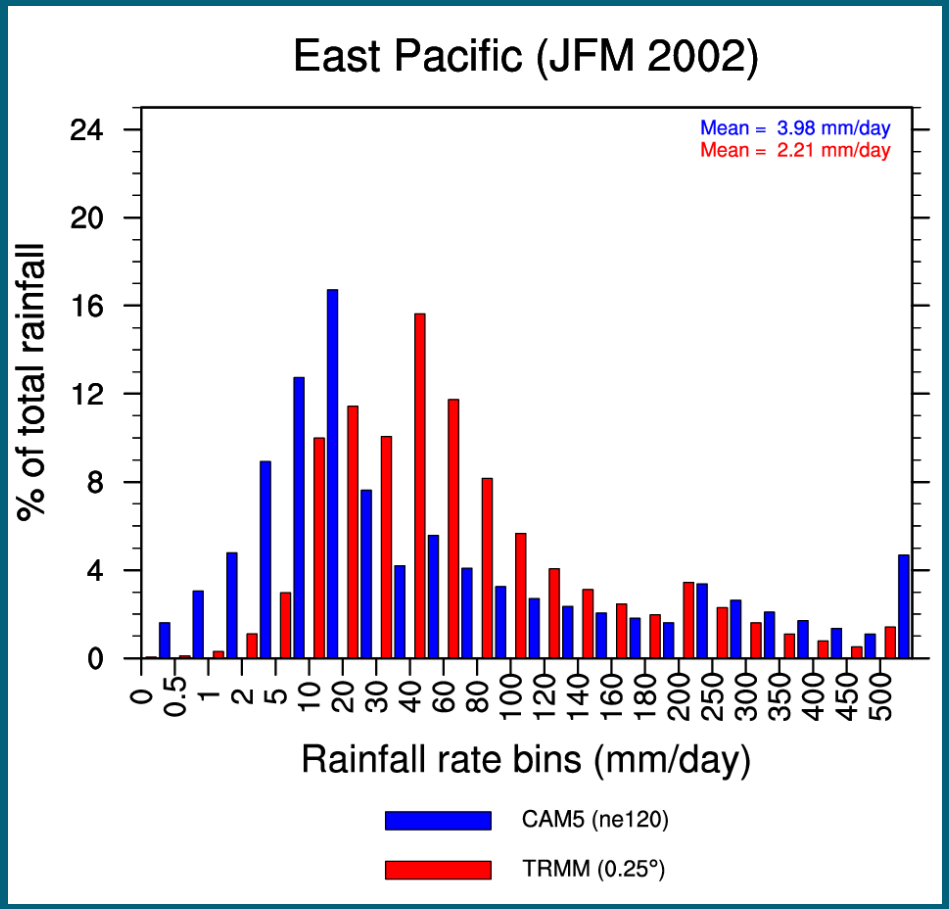
CAM4/CAM5 similar resolution dependence

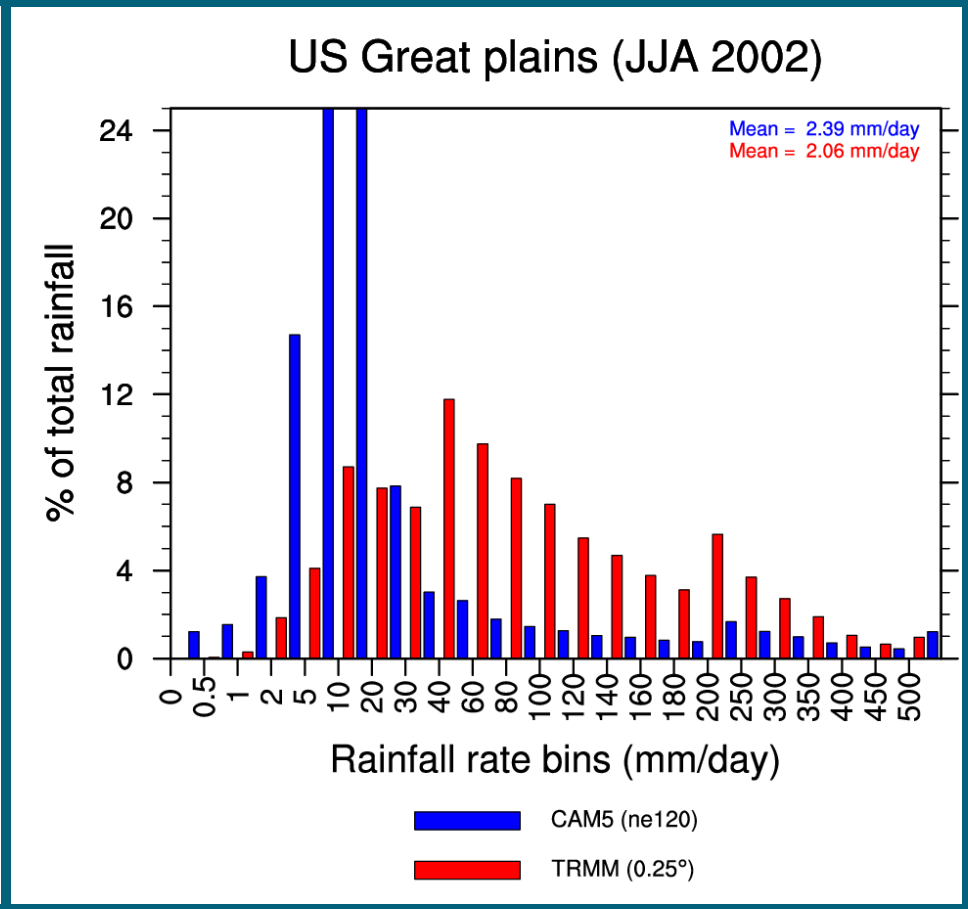


Errors linked to deep convection

Rainfall frequency

Common bias for many regions: Too much light rainfall, not enough heavy

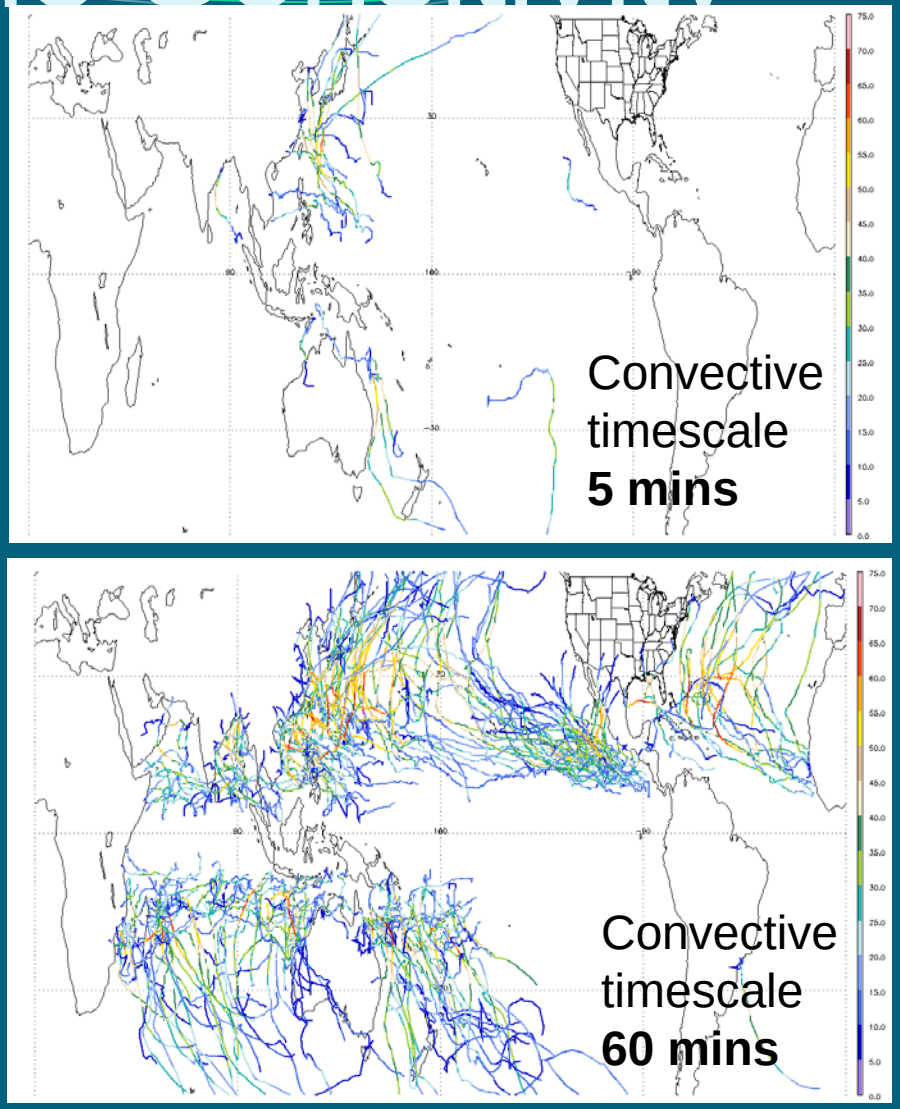




Tropical Cyclone Sensitivity

Julio Bacmeister, John Truesdale (NCAR)

- CAM5 has realistic tropical cyclone climatology
- Sensitive to deep convection settings
- With 5 minute timescale reduced cyclone count
- Rapid response of deep convection shuts of cyclone development
- Emphasizes sensitivities in the high resolution model that need to understood



Cyclone track climatology colored by windspeed

Feedback on AMWG documents

Draft documents

- CAM development protocols
- Simulation metrics
- Near term developments

http://www2.cesm.ucar.edu/working-groups/amwg

Supporting CAM configurations

Varying resolution, dynamical core and physics packages

Supported
CAM5-SE ne30 (1º)
General climate applications
CAM5-FV 2º
Paleo, chemistry and biogeochemistry applications
+ university users

In Development
CAM5-SE ne120 (0.25º)
High resolution simulations
CAM5-SE ne30_r_ne120
Regional climate applications

Functional
CAM5-FV 0.25º and 1º
CAM4-FV 1º and 2º
CAM5-SE ne16 (2º)
CAM5-SE ne240 (0.125º)
CAM4-EUL (T180,T360)

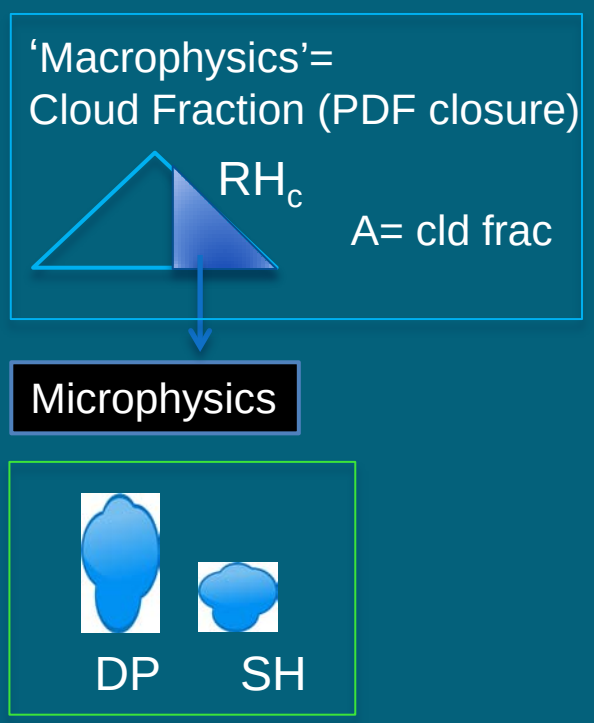
Other Applications
CAM5-EUL T31
CESM Tutorial configuration
CAM5-FV 4º
WACCM university users

Ocean
Mostly x1
x3 (university users)
x0.1 (experimental)

Multi-scale cloud evolution in CAM

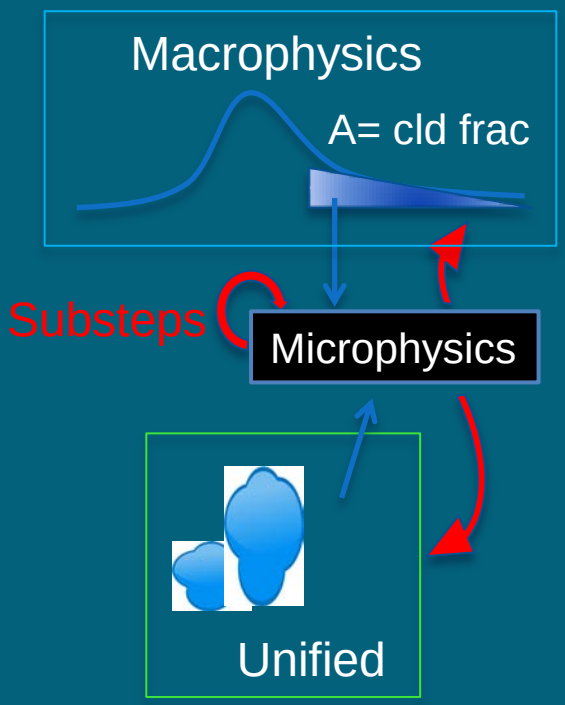
Address biases in tropics & precipitation (convection) and radiation (stratiform)

Scale Dependent → Minimal Scale Dependence



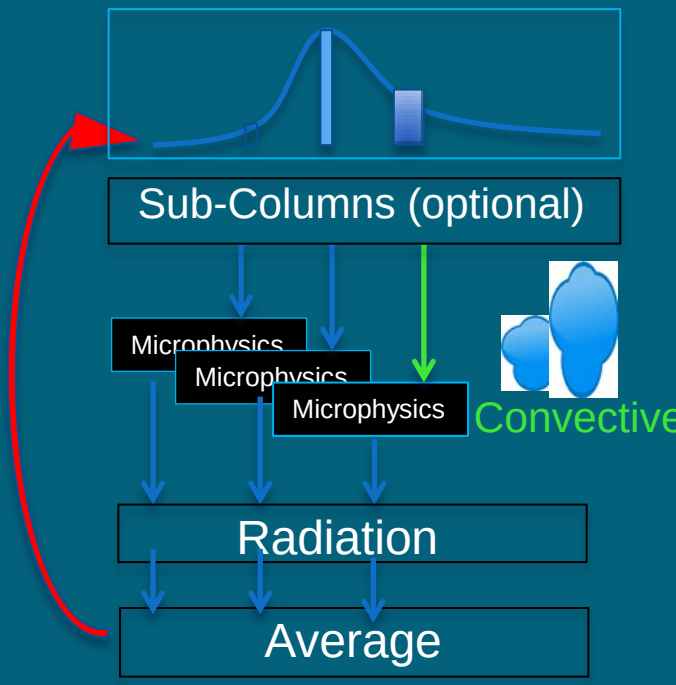
Stratiform threshold RH (RH_c) is resolution dependent. Coupling is time dependent.
Convection separate.

2013 (CESM1.2)



Complex, multivariate PDF
Unified convection with microphysics.
Substeps improve processes

2014



Predicted PDF Variance
As scale → small
variance → small
Can couple to radiation

2016 (CMIP6)

Community Earth System Model

Big effort: DOE Labs (LBL,LLNL,PNNL),
CPT (NSF, NOAA), Universities (UW, UWM, UCB) and NCAR

CAM Development Timelines

The path towards CMIP6

Physics

- Replace GWD with WACCM scheme
- Testing alternative cloud physics (UNICON,CLUBB)
- MG2 implementation
- MAM4 implementation
- Test TMS and replace scheme with EC scheme
- RRTM radiation update
- MAM7 implementation
- Physics decisions for CAM6
- Control simulations with CAM6 physics
- **CAM6 model in CESM2 for CMIP6**

High Res.

- CAM5 0.25 deg tuning Vertical resolution testing (L60)? With CAM5 physics
- Decision for vertical resolution increase
- CAM5 0.25 deg tuning Vertical resolution testing With new physics options
- **0.25 deg CAM6 model**

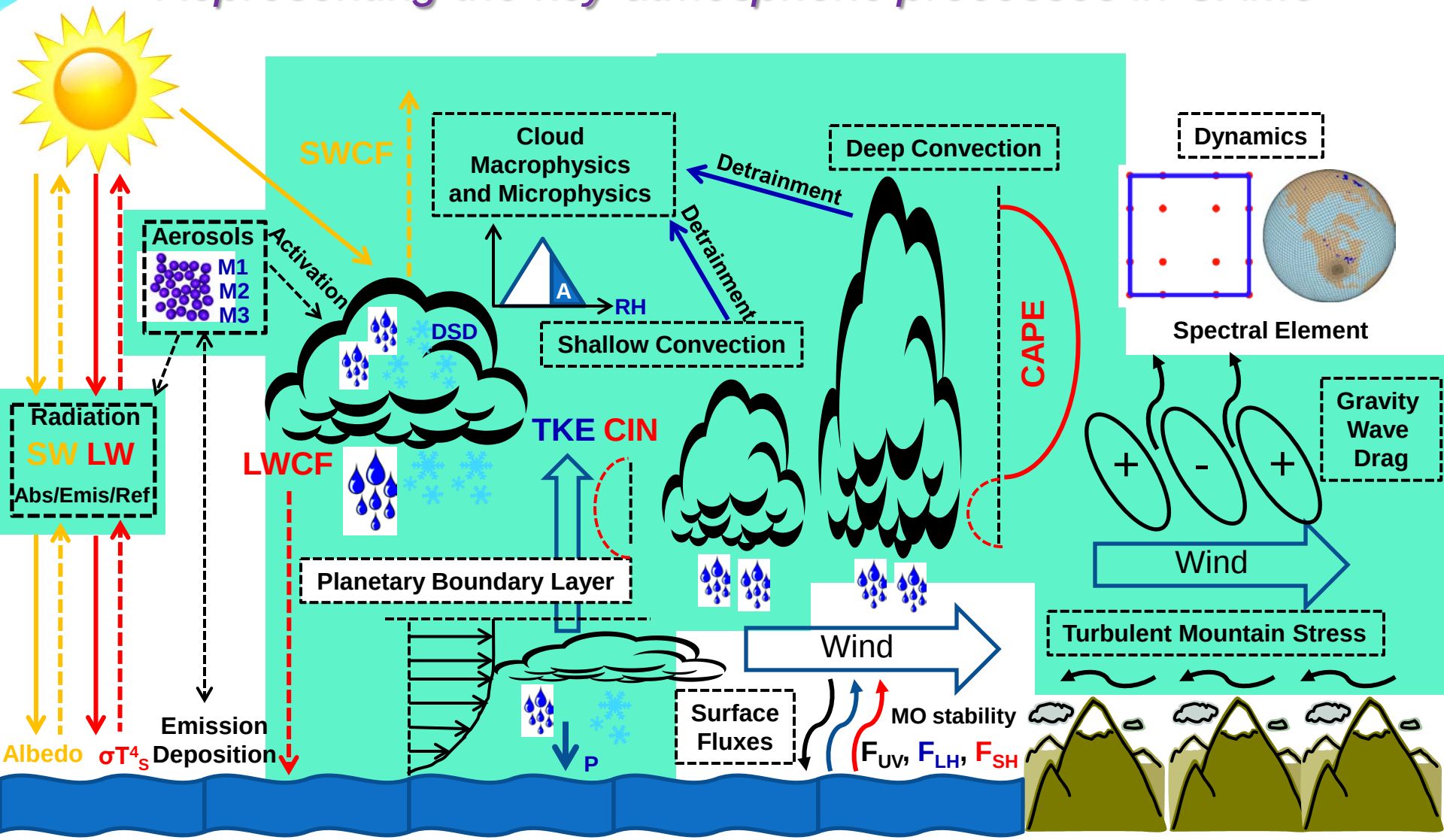
Low Res.

- Prescribed MAM implementation
- Prescribed MAM testing
- Consistent sub-grid orography
- Efficiency improvements for 2deg CAM5
- Physics decisions for low-res CAM6
- **CAM6 low resolution model**

2013 (CESM1.2) — 2014 (CESM1.3) — 2015 (CESM1.4) — 2016 (CESM2)

Community Atmosphere Model

Representing the key atmospheric processes in CAM5



Community Earth System Model

CESM