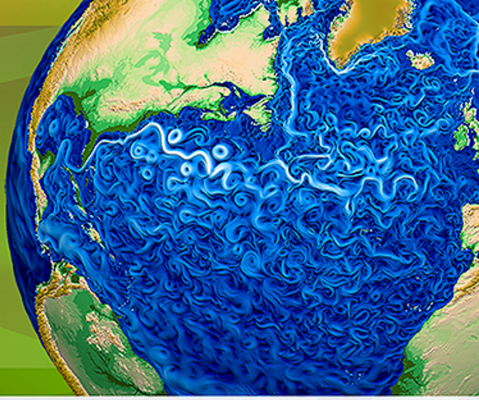
ACME
Accelerated Climate Modeling
for Energy



Choosing a Convection Scheme for ACME: Update and Plan

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S. Klein (RRM)
P. Ma (Vert. Res)
Y. Qian (Short Simulations)
H. Ma (CAPT)

Developer Collaborators
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A. Gettelman (CLUBB, MG2)
P. Bogenschutz (CLUBB)
S. Park (UNICON)
G. Zhang (ZM-TRIMEM)

U.S. DEPARTMENT OF ENERGY

Prepared by LLNL under Contract DE-AC52-07NA27344. LLNL-PRES-667184

ACME
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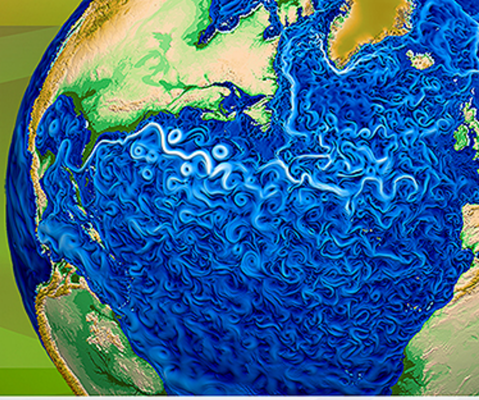


Convection Breakout Session

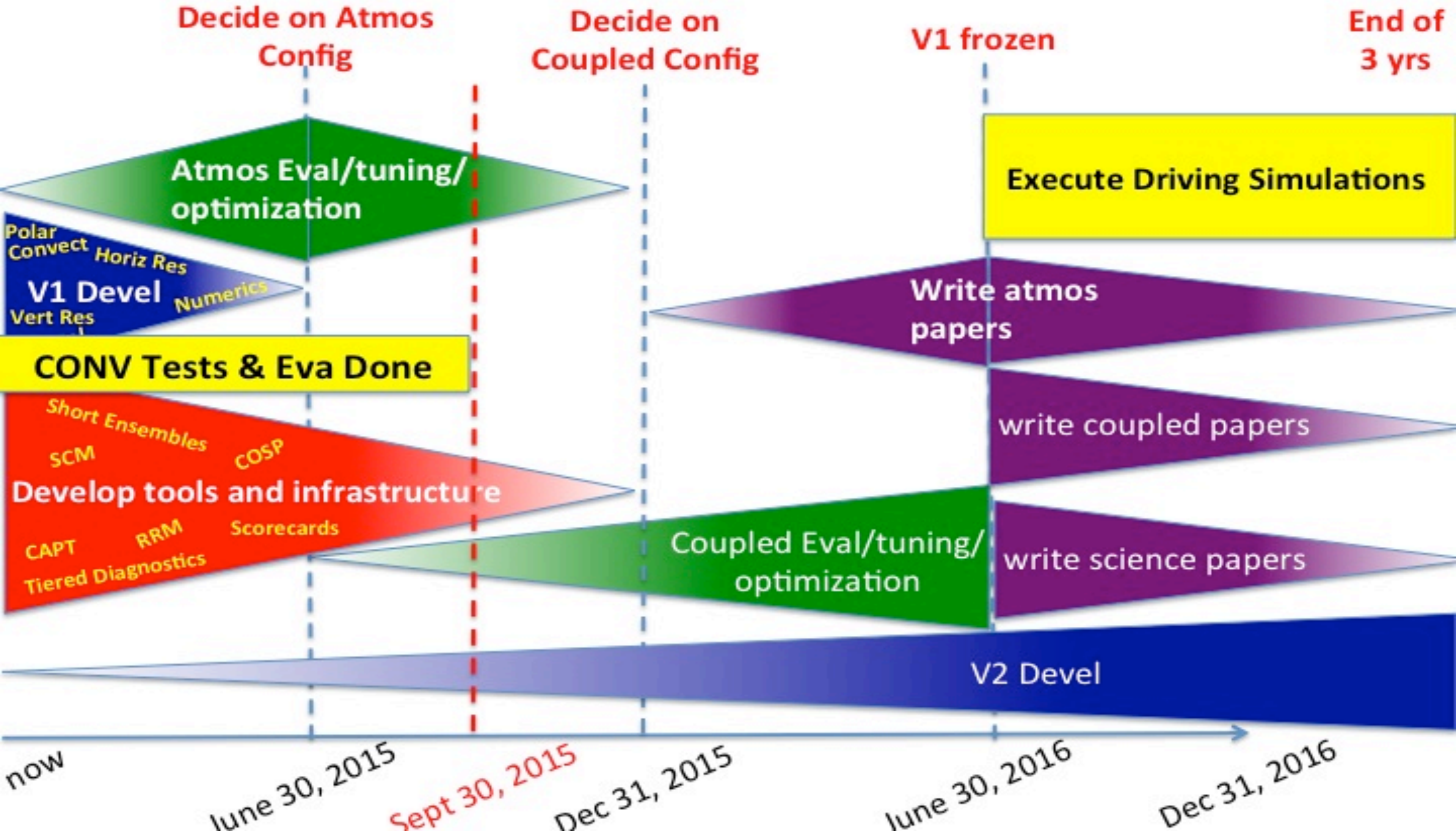
Update and Near Team Plan

Shaocheng Xie & Wuyin Lin (Convection)
Steve Klein (RRM)
Po-lun Ma (High Vert. Res)
Yun Qian (Short Sim)

Prepared by LLNL under Contract DE-AC52-07NA27344. LLNL-PRES-667184

ACME Atmos Timeline

Height of box indicates effort level for given time



Decide on Atmos Config

Decide on Coupled Config

V1 frozen

End of 3 yrs

Atmos Eval/tuning/ optimization

Execute Driving Simulations

Polar Convect

Horiz Res

V1 Devel

Numerics

Vert Res

Write atmos papers

CONV Tests & Eva Done

write coupled papers

Short Ensembles

SCM

COSP

Develop tools and infrastructure

Scorecards

RRM

CAPT

Tiered Diagnostics

Coupled Eval/tuning/ optimization

write science papers

V2 Devel

now

June 30, 2015

Sept 30, 2015

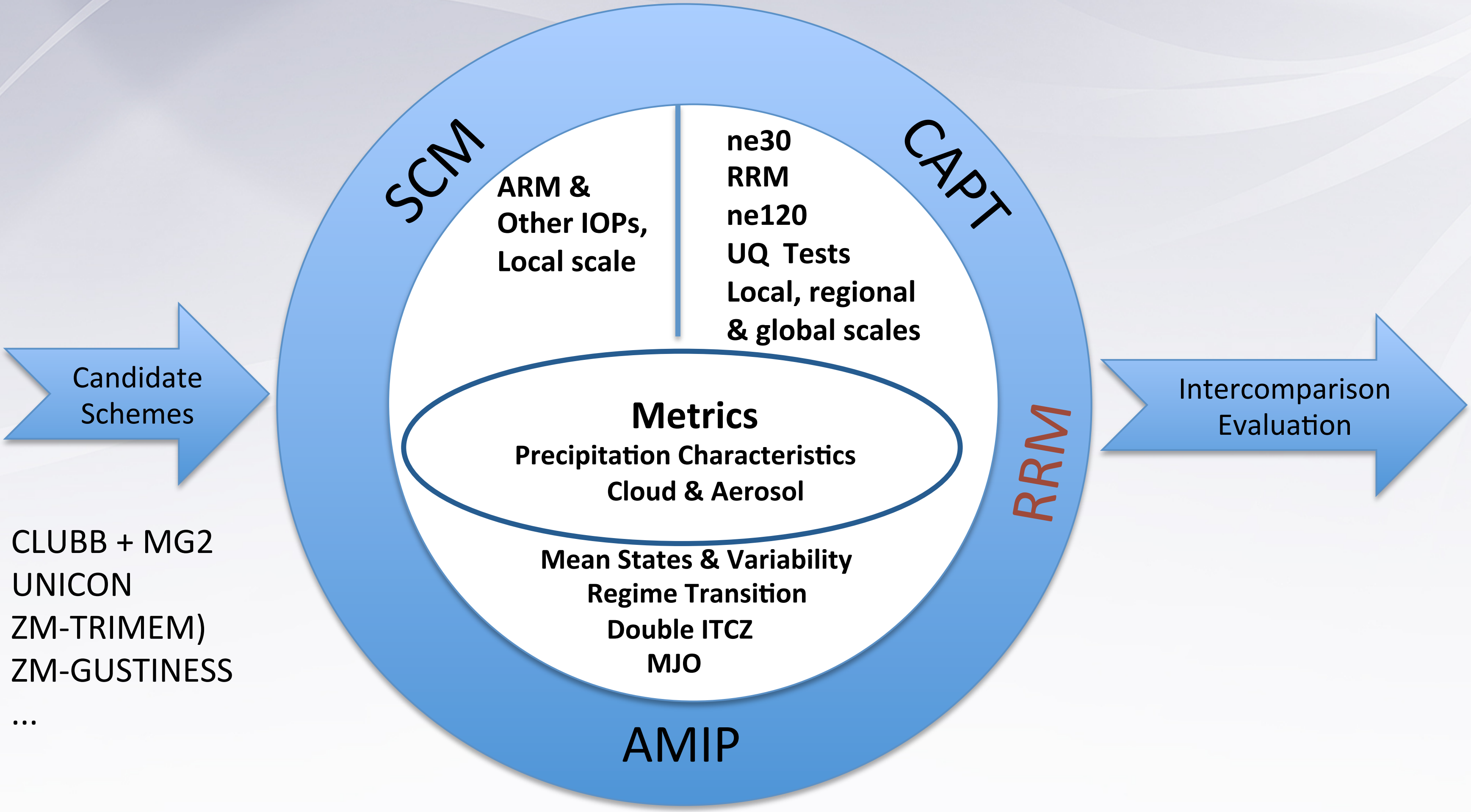
Dec 31, 2015

June 30, 2016

Dec 31, 2016

Slide from Caldwell & Rasch, modified by Xie

Protocol for Convection Tests



Candidate Schemes

SCM

ARM &
Other IOPs,
Local scale

CAPT

ne30
RRM
ne120
UQ Tests
Local, regional
& global scales

Metrics

Precipitation Characteristics
Cloud & Aerosol

Mean States & Variability
Regime Transition
Double ITCZ
MJO

RRM

AMIP

Intercomparison Evaluation

CLUBB + MG2
UNICON
ZM-TRIMEM)
ZM-GUSTINESS
...

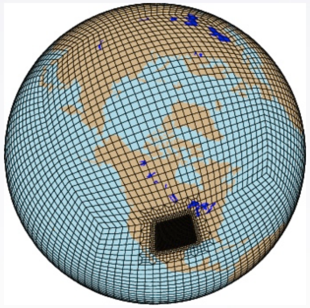
What Have We Done for Convection?

Multi-scale testbeds ready

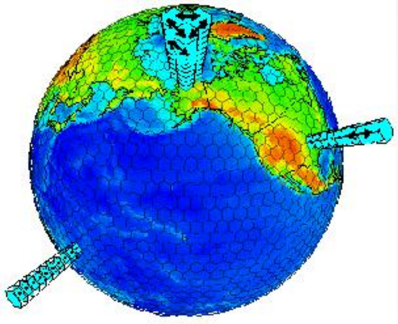
- CAPT – have added the CAPT capability to ACME with the LLNL CAPT team help, 2008-2011 four year initial data from EC-interim (**Wuyin Lin & Hsi-yen Ma**)
- RRM – RRM with the refined region around SGP (**Steve Klein et al**.)
- High Vert Res – Increase of vertical resolution to 60 levels (**Po-lun Ma**)
- SCM – SCM forced by ARM IOP and Continue Forcing datasets (**Kai Zhang and Wuyin Lin**)
- AMIP – Free-running simulation with prescribed SST and sea ice
- UQ techniques – CAPT-like ensemble short simulations with perturbed parameters (**Yun Qian & Hui Wan**)

CAPT
Cloud-Associated Parameterizations Testbed

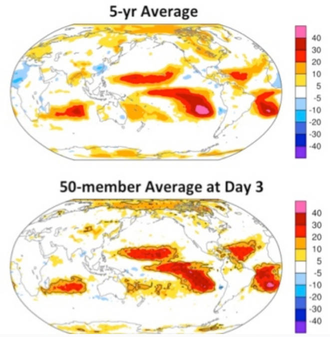
CAPT



RRM



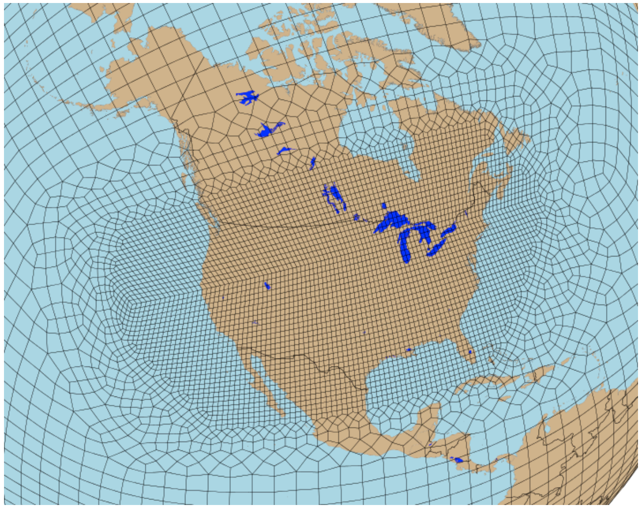
SCM



UQ with CAPT

ACME Regionally-Refined Model (RRM) Status

Erika Roesler, Qi Tang, Wuyin Lin, Mark Taylor, Steve Klein



- **CONUS RRM is Nearly Ready for New Users!**
  - Prototype of regional refined model (RRM) free-running and nudging is ready for rest of Atmosphere team
    - Code merged to ACME master
  - **How to build and run case CONUS from ACME master**:
    - Free-run: https://acme-climate.atlassian.net/wiki/pages/viewpage.action?pageId=20807739
    - Nudging: https://acme-climate.atlassian.net/wiki/pages/viewpage.action?pageId=20153276
- **Major Q4/Q5 activities**
  - Scientific analysis to determine suitability of North-American RRM to study local characteristics of high-resolution climate.
  - Testing alternative model formulations (vertical resolution and physics for V1) with CONUS RRM
- **Major Issue**
  - Creation of new RRM for Asia and Amazon for Water Cycle Experiments require more resources than available in Q4/Q5

How much scientific analysis is needed to be sure of the RRM's utility?

Should we reduce our effort in our planned activities to give us time to create the new RRM for other regions?

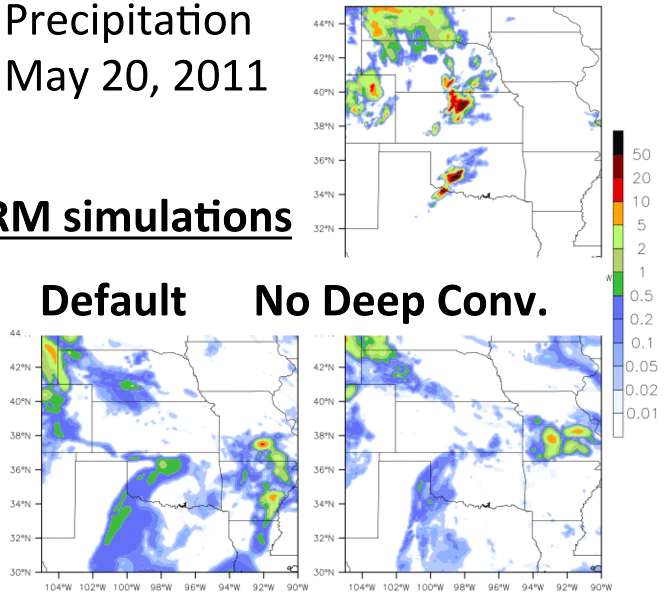
What area coverage and time-periods would be of most interest?

NEXRAD Obs.

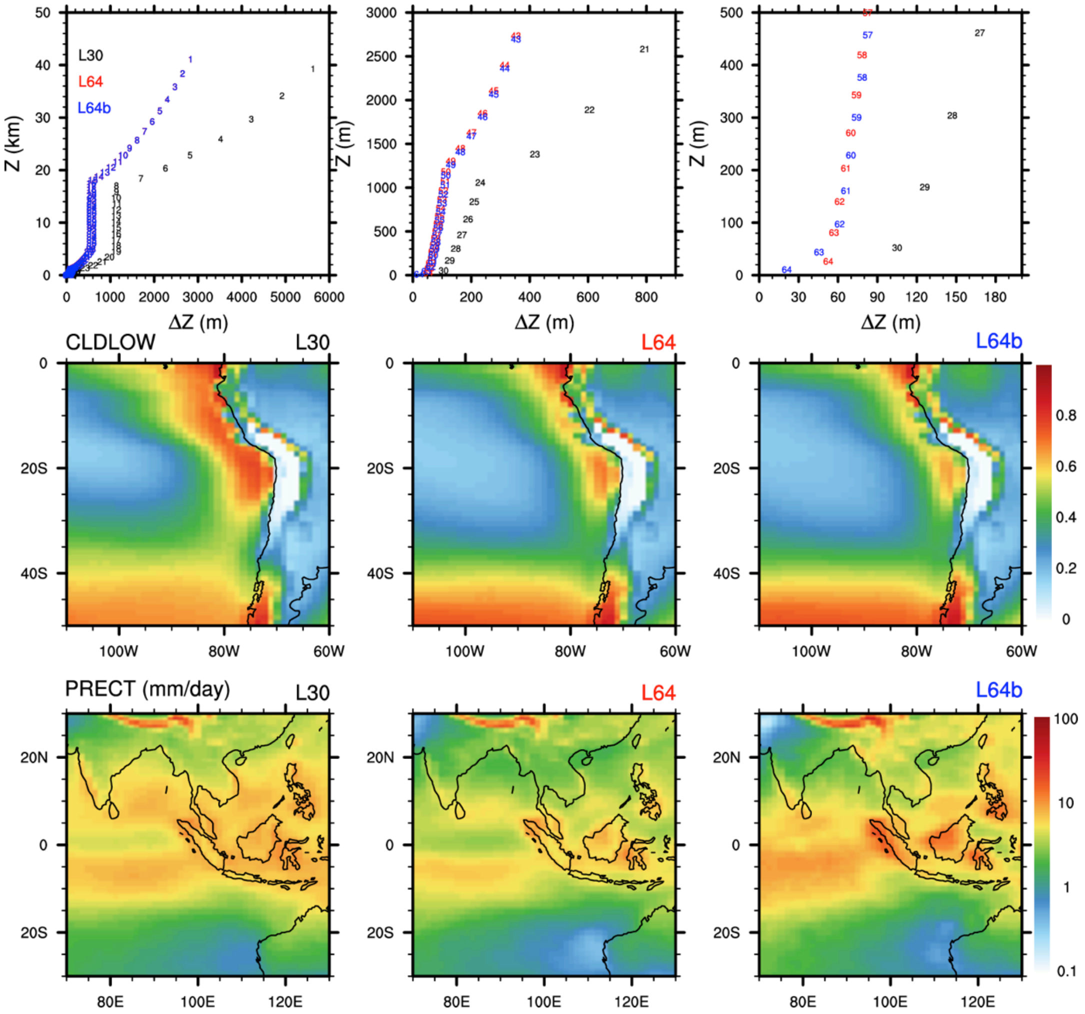
Precipitation
May 20, 2011

RRM simulations

Default **No Deep Conv.**



Vertical resolution sensitivity



Some other vertical grids developed:
L47: doubling resolution above 5km
L50: doubling resolution below 5km
L72: based on L64b, but add 8 more layers above current model top (raise model top to 0.1 hPa)

Top row:
Configurations for the **standard 30-level and two new 64-level** models, for the atmosphere (left), lower troposphere (middle), and near the surface (right).

Middle row:
Reduction of **stratocumulus** clouds with increasing vertical resolution

Bottom row:
Vertical resolution sensitivity of **tropical and monsoonal precipitation**

Next steps:

- Systematically test the vertical resolution sensitivity (L47, L50, L72)
- Test the sensitivity with new model physics (e.g., aerosol, cloud, convection)

Short simulations for efficient model evaluation, tuning and calibration

Yun Qian, Hui Wan, Phil Rasch, Wuyin Lin, and Shaocheng Xie

Objectives:

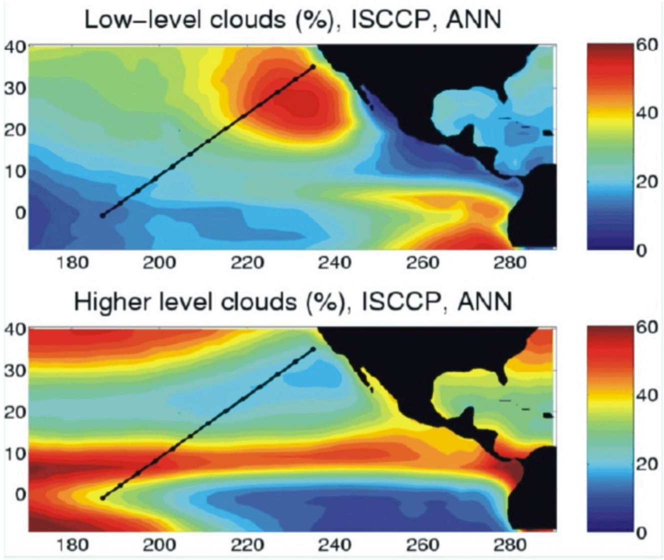
- to explore the feasibility and usefulness of short (2-10 days) simulations for the purpose of efficient and effective testing, tuning and evaluation of high-resolution models.

Accomplishments:

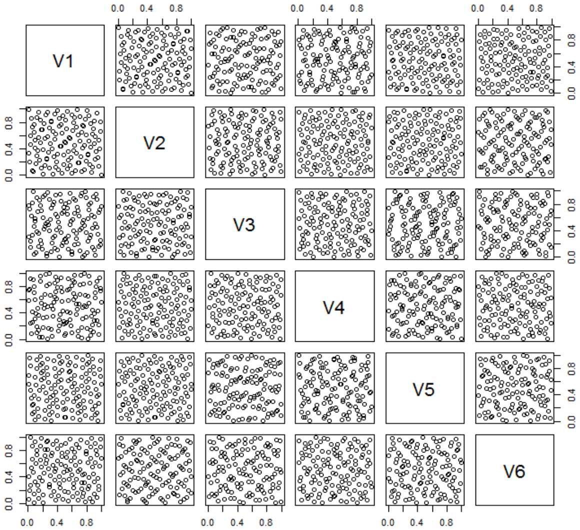
(1) identified a test problem and focus interest region (i.e. GPCI cross-section)

(2) established a complete framework that efficiently conducts simulations and analyzes results for the parametric sensitivity study

(3) completed 31x128 CAPT-based short simulations and preliminarily analyzed the parametric sensitivity by applying a surrogate model



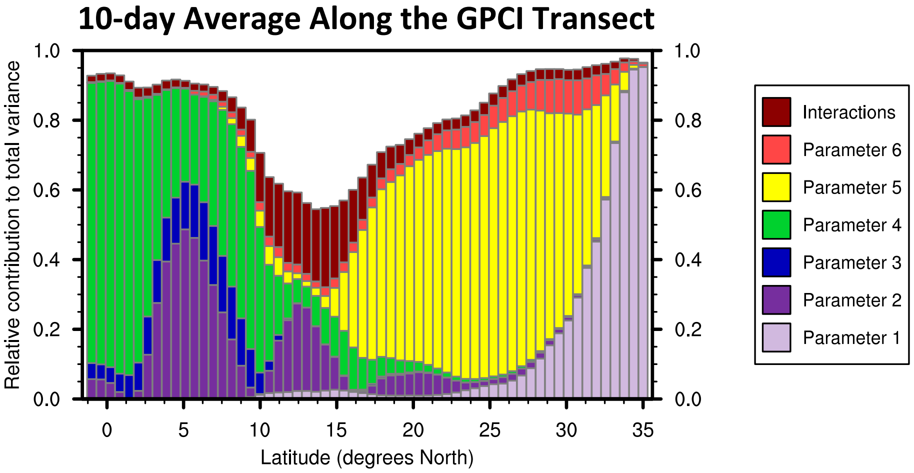
Location of the GPCI cross-section (black lines) and the climatological low- and high-level cloud cover in the surrounding regions



Quasi Monte Carlo sampling of the 6D parameter space. 128 sampling points are shown in the figure

Parametric Sensitivity of Shortwave Cloud Forcing

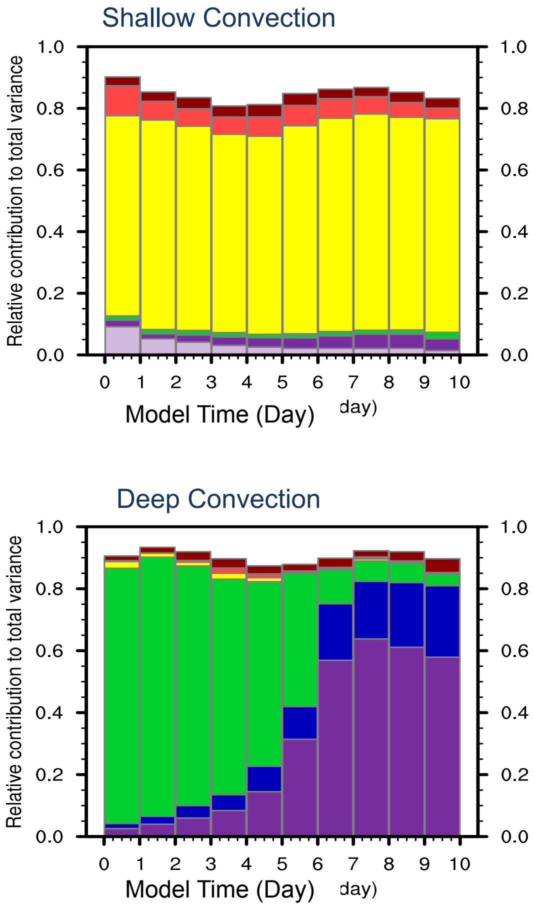
Dependence of Model Sensitivity on Cloud Regime



Impact:

- ➢ Short simulations are effective for the detection of certain model sensitivities.
- ➢ This testing strategy are useful for other tasks, e.g., quantification of the ACME model's resolution sensitivity and evaluation of candidate convection schemes.
- ➢ The experience obtained from short simulations is also helpful in improving our understanding of the model behavior at the process level.

Time Evolution



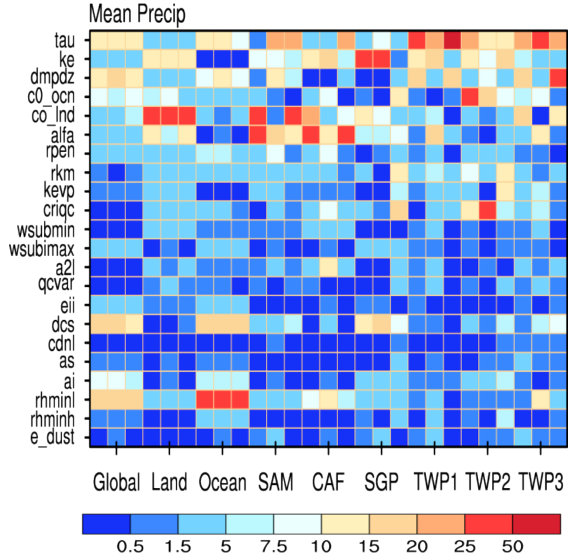
Parametric sensitivity of precipitation at global and local scales in CAM5 (Qian et al., 2015)

Objective

- To identify which parameters are most influential to the behavior of precipitation in CAM5 and how the sensitivity of mean, extreme and diurnal cycle of precipitation to those parameters varies with spatial scale, region and season

Approach

- We adopt both the Latin hypercube and quasi-Monte Carlo sampling approaches to effectively explore the high-dimensional parameter space.
- We conduct two large sets of simulations, one set with 1100 simulations for 22 cloud-related parameters and the other set with 256 simulations for aerosol parameters.
- Generalized linear model is applied to provide quantitative measures of the parametric sensitivity .



Sensitivity of mean precipitation over multiple regions and seasons to each parameter (on y-axis). Three columns for each region (on x-axis) correspond to annual, JJA and DJF mean, respectively. Larger number indicates larger sensitivity.

Impact

- Six parameters having the greatest influences on the global precipitation are identified.
- Precipitation does not always respond monotonically to parameter change.
- Results help to better understand the CAM5 model behavior associated with parameter uncertainties and will guide the next step to reducing model uncertainty in precipitation via calibration of the most uncertain model parameters and/or developing new parameterizations.

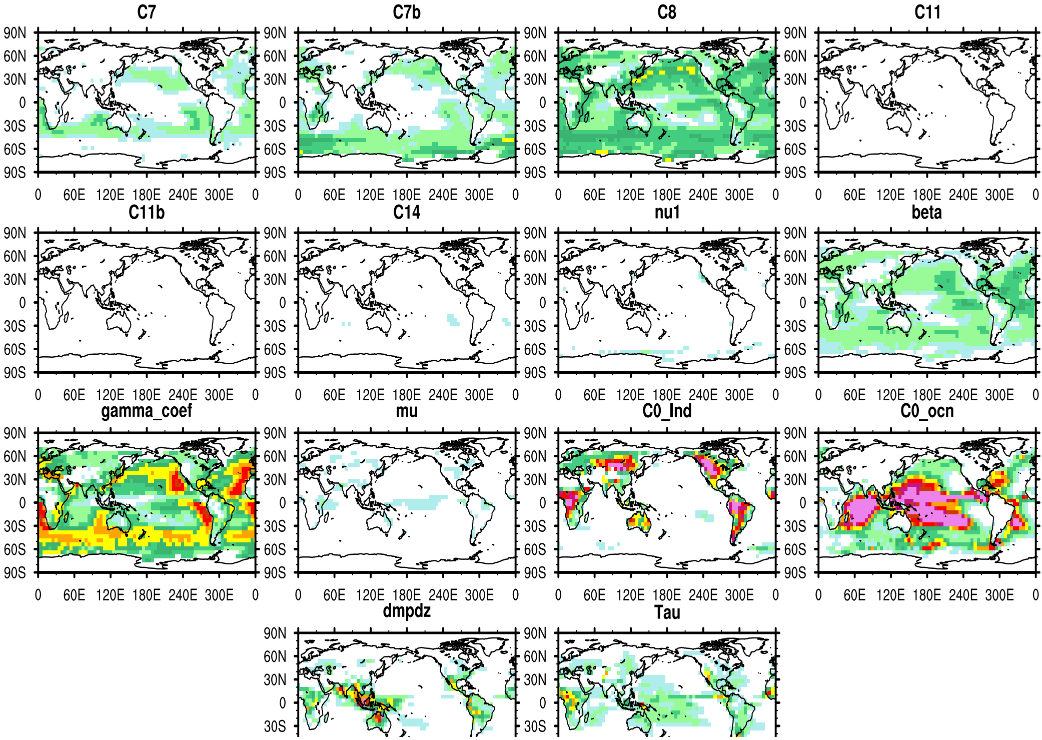
Qian Y, H Yan, Z Hou, G Johannesson, SA Klein, D Lucas, R Neale, PJ Rasch, LP Swiler, J Tannahill, H Wang, M Wang, and C Zhao. 2015. "Parametric Sensitivity Analysis of Precipitation at Global and Local Scales in the Community Atmosphere Model CAM5", J. Adv. Model. Earth Syst., 07, doi:10.1002/2014MS000354.

Parametric Behaviors of CLUBB in CAM5

(Guo et al., 2014, 2015)

Table 1. Tunable parameters of CLUBB and ZM

Parameter	Description	Default Value	Investigated Range
C1	Constant associated with $\overline{w'^2}$ dissipation	2.5	1.25~5
C2rt	Constant associated with $\overline{r_t'^2}$ dissipation	1.0	0.5~2
C6rt	Low skewness of Newtonian damping of water flux	4.0	3.0~8.0
C6rtb	High skewness of Newtonian damping of water flux	4.0	3.0~8.0
C7	Low skewness of buoyancy damping of water flux	0.5	0.25~1.0
C7b	High skewness of buoyancy damping of water flux	0.5	0.25~1.0
C8	Constant associated with Newtonian damping of $\overline{w'^3}$	3.0	1.5~6.0
C11	Low skewness of buoyancy damping of $\overline{w'^3}$	0.8	0.0~1.0
C11b	High skewness of buoyancy damping of $\overline{w'^3}$	0.65	0.0~1.0
C14	Constant of Newtonian damping of $\overline{u'^2}$ and $\overline{v'^2}$	1.0	0.5~2.0
$\boldsymbol{\nu}$(nu)	Background coefficient of eddy diffusion	20.0	10.0~40.0
$\boldsymbol{\beta}$(beta)	Constant related to skewness of θ_l and r_t	1.75	0.0~3.0
$\boldsymbol{\gamma}$(gamma_coef)	Constant of the width of PDF in w-coordinate ($\tilde{\sigma}_w^2$)	0.32	0.1~0.6
$\boldsymbol{\mu}$(mu)	Parcel entrainment rate [1/m]	0.001	0.5~2.0e-3
C0_lnd	ZM precipitation efficiency over land	0.0059	0.003~0.09
C0_ocn	ZM precipitation efficiency over ocean	0.045	0.003~0.09
dmpdz	Entrainment rate of ZM	-10^{-3}	$-0.2\sim-2x10^{-3}$
tau	CAPE consumption time scale (s)	3600s	1800~10800

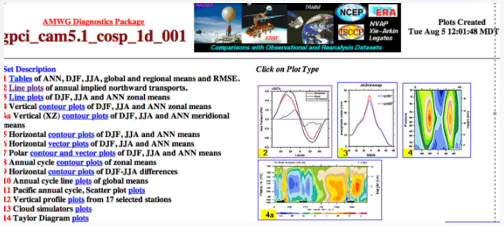


Contributions (%) of the 18 parameters (14 CLUBB and 4 ZM) to the GLM estimated total variance of annual mean SWCF

What Have We Done for Convection?

Initial metrics and diagnostics developed

- **Convection characteristics** at global and regional scales and over the ARM sites – PDF, diurnal variation, diabatic heating
- Focus on **systematic errors**
  - Double ITCZ, weak MJO, wrong diurnal cycle, too much weak precipitation and too few intense events, no clear transition from shallow to deep convection, wrong partition between stratiform and convective precipitation
- ACME, CSSEF, CAPT, and AMWG metrics package and satellite and ARM simulators



AMWG Diagnostics Package

gpci_cam5.1_cosp_1d_001

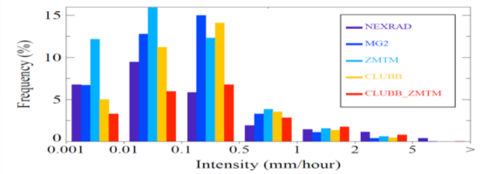
Plots Created
Tue Aug 5 12:01:48 MDT

Set Description

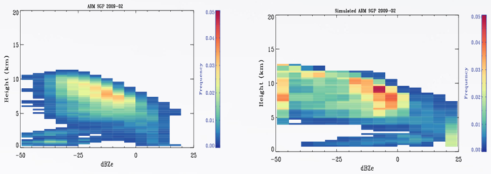
1 Tables of ANN, DJF, JJA, global and regional means and RMSE.
2 Line plots of annual implied northward transports.
3 Line plots of DJF, JJA and ANN zonal means
4 Vertical contour plots of DJF, JJA and ANN zonal means
4a Vertical (XZ) contour plots of DJF, JJA and ANN meridional means
5 Horizontal contour plots of DJF, JJA and ANN means
6 Horizontal vector plots of DJF, JJA and ANN means
7 Polar contour and vector plots of DJF, JJA and ANN means
8 Annual cycle contour plots of zonal means
9 Horizontal contour plots of DJF-JJA differences
10 Annual cycle line plots of global means
11 Pacific annual cycle, Scatter plot plots
12 Vertical profile plots from 17 selected stations
13 Cloud simulators plots
14 Taylor Diagram plots

Click on Plot Type

AMWG-like metrics for Mean State and variability



Precipitation Characteristics



Satellite and ARM Cloud Simulators

Utilize ACME Diagnostics/Metrics

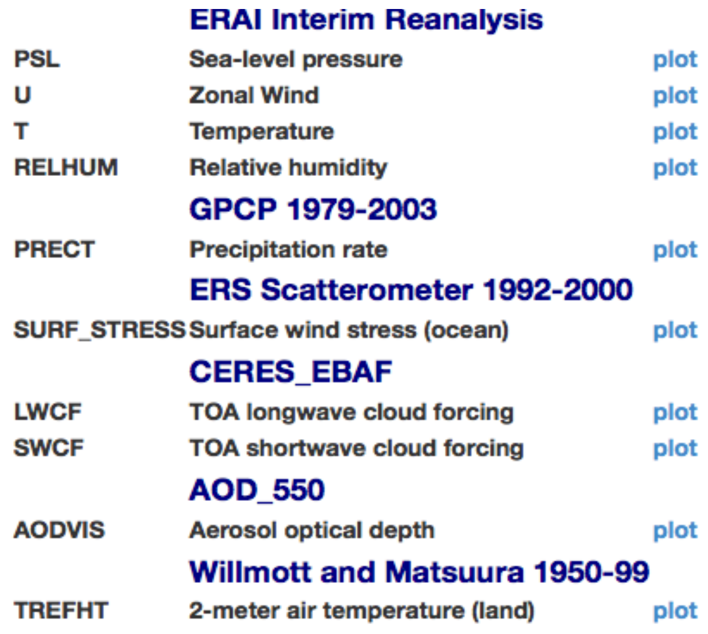
Diagnostics being developed in Atmos. to tailor for ACME science

Diagnostics organized into overlapping groups centered around science questions:

- *Tier 1a = 'top 10' that we always try to optimize*
- *Tier 1b = collections of fields relevant to ACME regions or phenomena:*
  - *{Amazon, US, Asia} Hydrologic Cycle*
  - *S. Ocean/Antarctic meteorology,*
  - *Tropical/Extratropical modes of variability with strong influence on water cycle,*
  - *Global clouds and the water cycle*
- Tier 2 = other diagnostics (e.g. everything in AMWG diagnostics)

- ACME is developing diagnostics in the UV-CDAT framework

Tier 1a Diags (from Classic Viewer)



	ERAI Interim Reanalysis	
PSL	Sea-level pressure	plot
U	Zonal Wind	plot
T	Temperature	plot
RELHUM	Relative humidity	plot
	GPCP 1979-2003	
PRECT	Precipitation rate	plot
	ERS Scatterometer 1992-2000	
SURF_STRESS	Surface wind stress (ocean)	plot
	CERES_EBAF	
LWCF	TOA longwave cloud forcing	plot
SWCF	TOA shortwave cloud forcing	plot
	AOD_550	
AODVIS	Aerosol optical depth	plot
	Willmott and Matsuura 1950-99	
TREFHT	2-meter air temperature (land)	plot

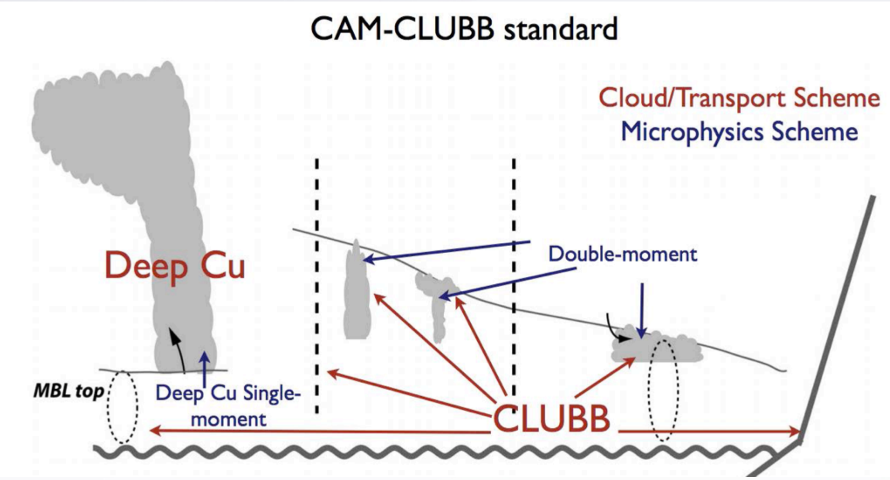
Slide from Caldwell & Rasch

What Have We Done for Convection?

Candidate schemes implemented in ACME v0.2

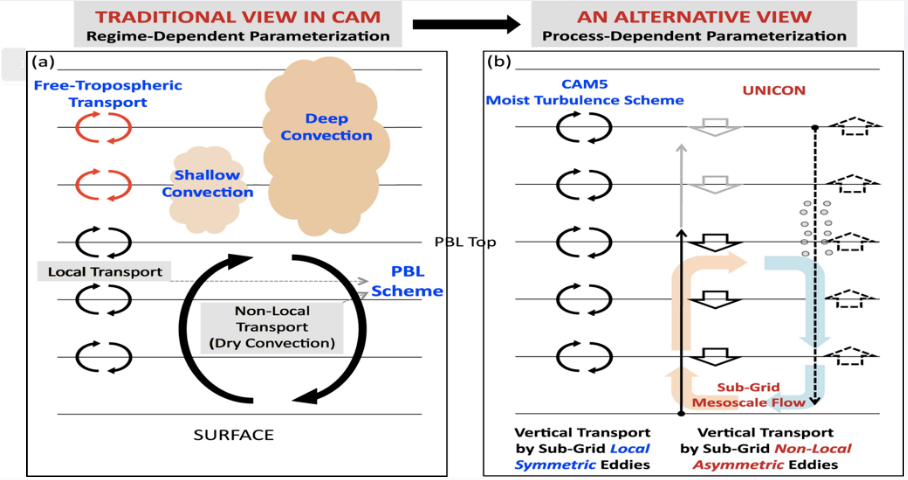
- CLUBB + MG2 (Wuyin Lin, Andrew Gettelman, Pete Bogenshutz, Vince Larson)
- UNICON (Jin-ho Yoon, Sungsu Park)
- ZM-TRIMEM (Steve Ghan, Guang Zhang)
- ZM-GUSTINESS (Rich Neale)

CLUBB



Thanks Pete Bogenschutz

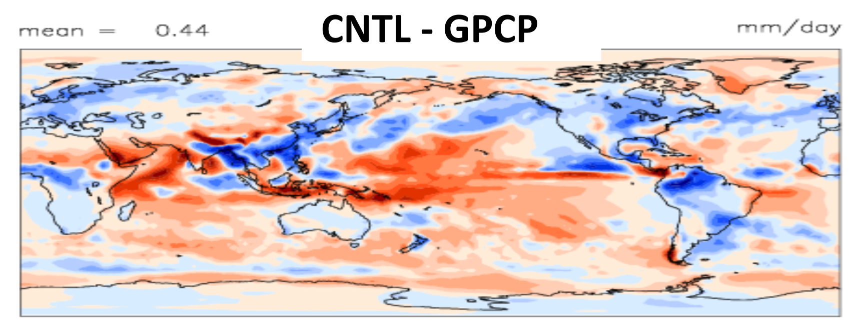
UNICON

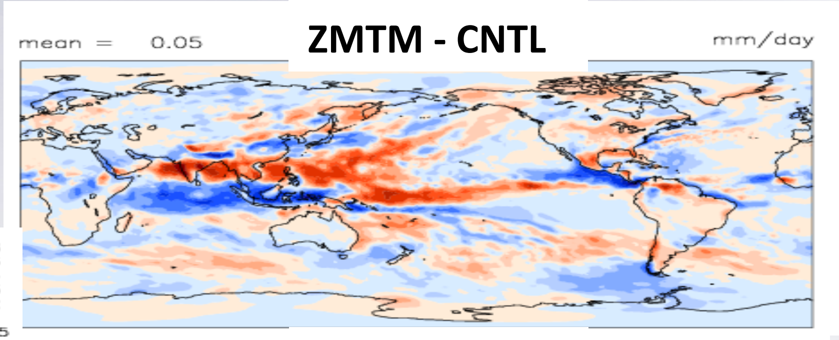


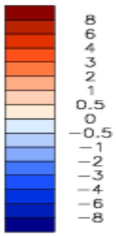
Thanks Sungsu Park

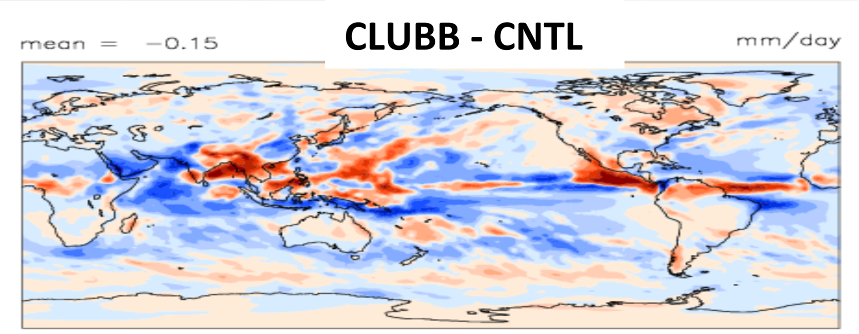
Preliminary Results with ACME v0.2

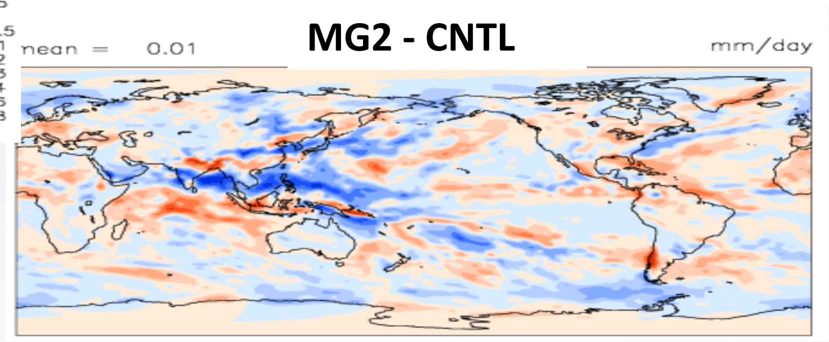
AMIP 2008-2009, JJA Total Precipitation

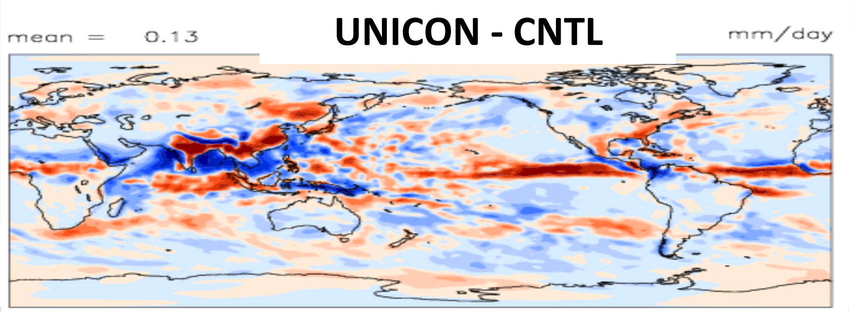

CNTL - GPCP


ZMTM - CNTL




CLUBB - CNTL

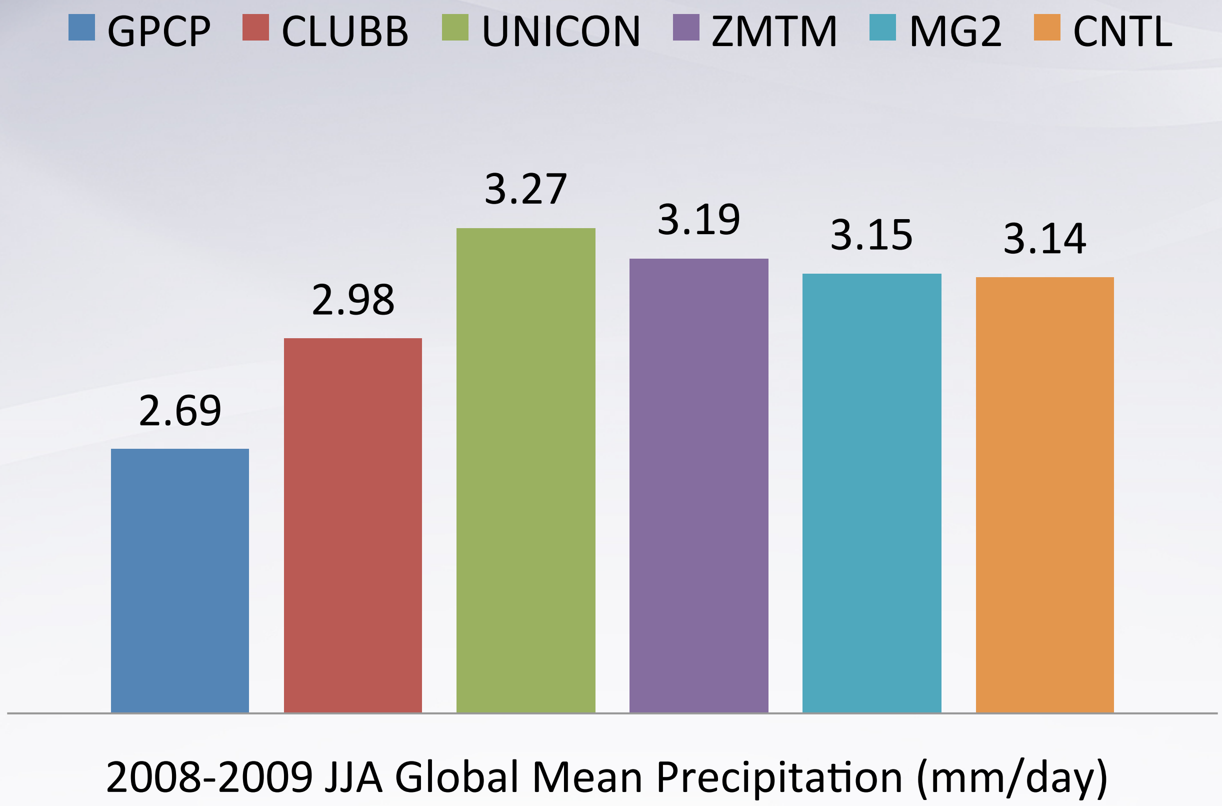

MG2 - CNTL


UNICON - CNTL

CLUBB appears to broadly improve the precipitation pattern. UNICON and ZMTM's performances are mixed.

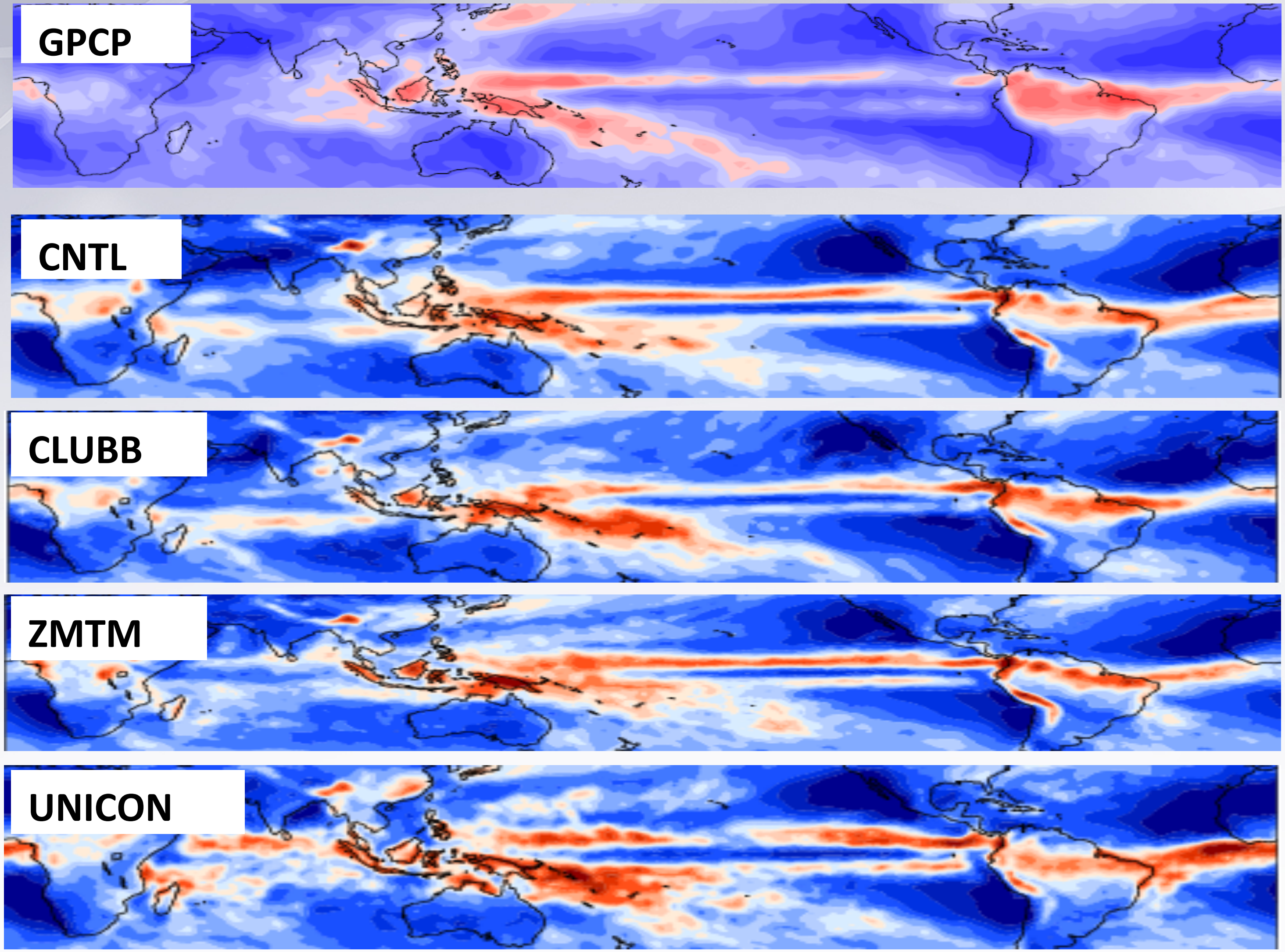
Slide from Wuyin Lin

Preliminary Results with ACME v0.2



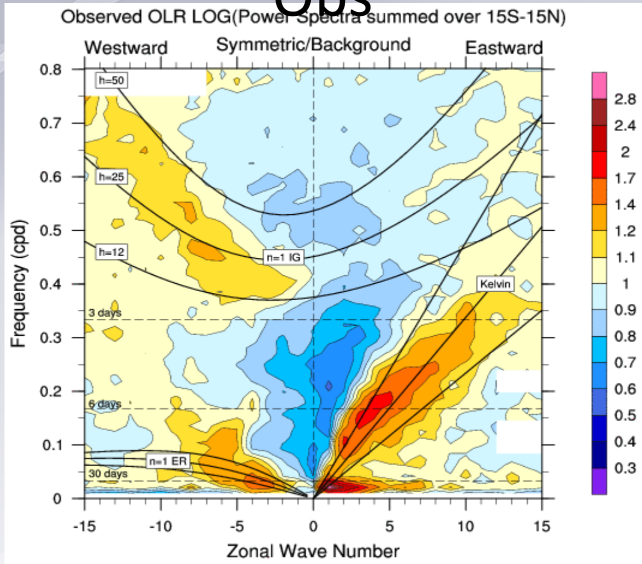
All schemes over produce global mean precipitation, but improvement is clear with CLUBB

Impact on double ITCZ, MAM 2008-2009

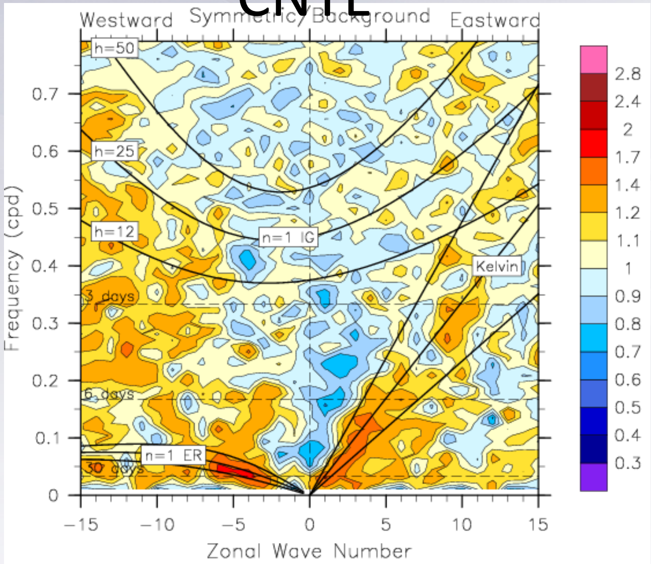


Tropical Waves

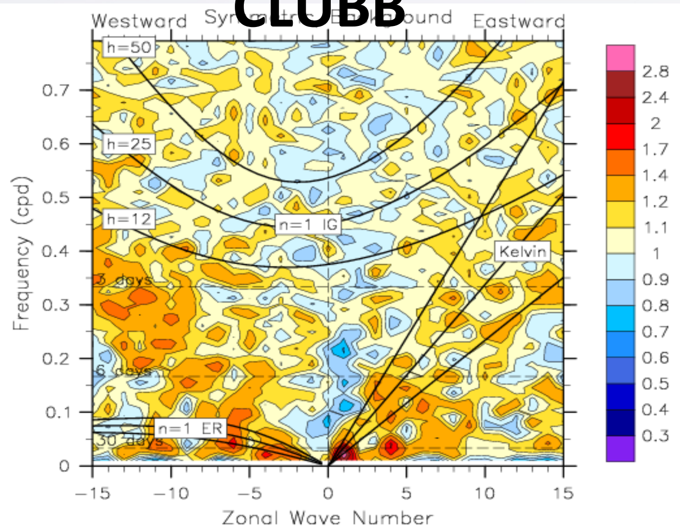
Obs



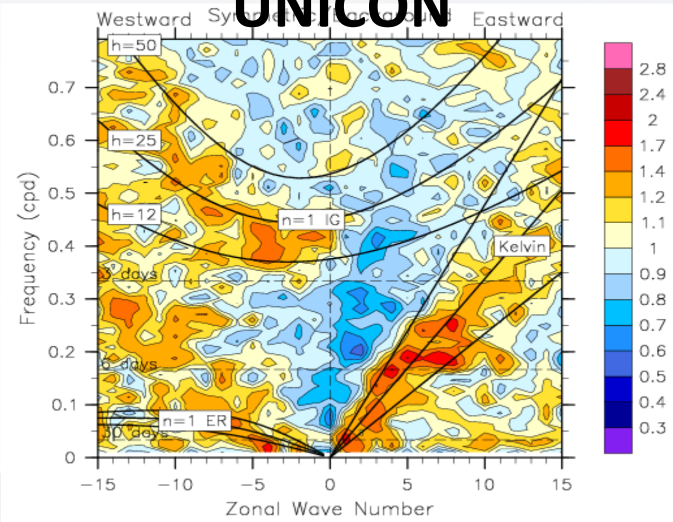
CNTL



CLUBB

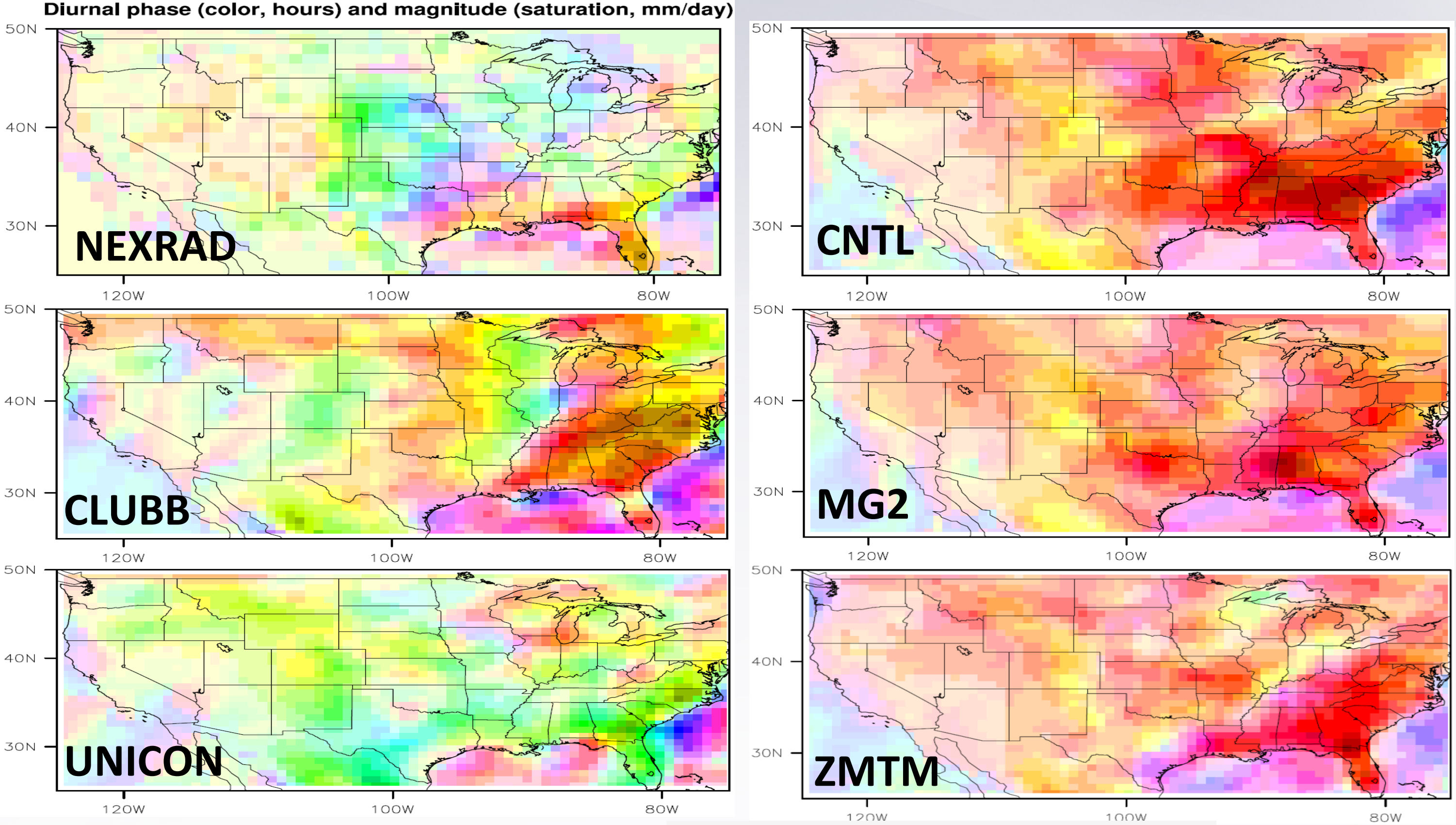


UNICON



Preliminary Results with ACME v0.2

April-July 2009 AMIP Precip 1st



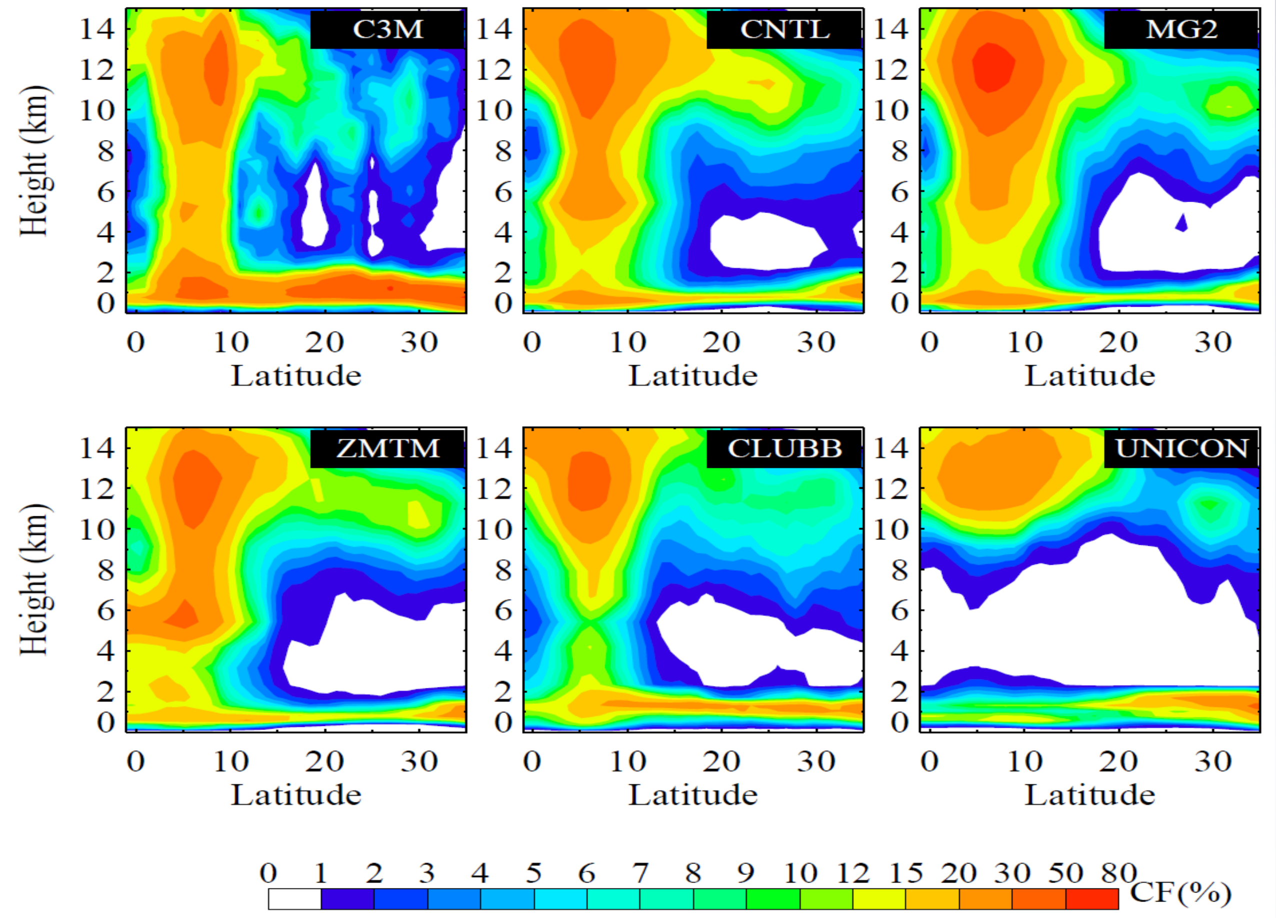
CLUBB & UNICON have improved skill in capturing warm season continental propagating convection.

UNICON more systematically alter the simulated diurnal phase (mostly for the better)

Slide from Wuyin Lin

Preliminary Results with ACME v0.2

Cloud Transition Along the GPCI Transect JJA 2008-2009



CNTL:
Overproduces high cloud over the whole GPCI. Underproduces low cloud over Cu and Dc zone; Cu depth too shallow.

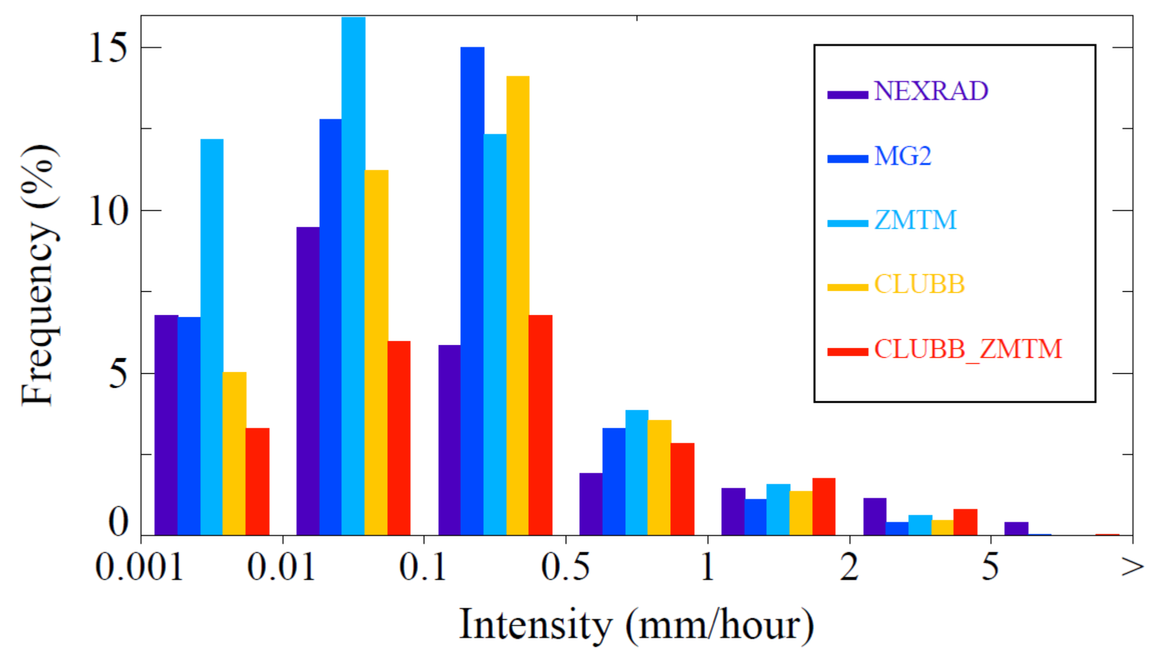
ZMTM:
Slight improvement in high cloud; low cloud gets worse

CLUBB:
More substantial improvement in high clouds along the GPCI, low clouds over Dc zone beomes even less than CNTL

UNICON:
Improves high clouds over Sc regime; Cloud biases over Cu and Dc regimes much morse, esp. mid-clouds; possibly related to over-precipitating.

Slide from Wuyin Lin

Preliminary Results with ACME v0.2



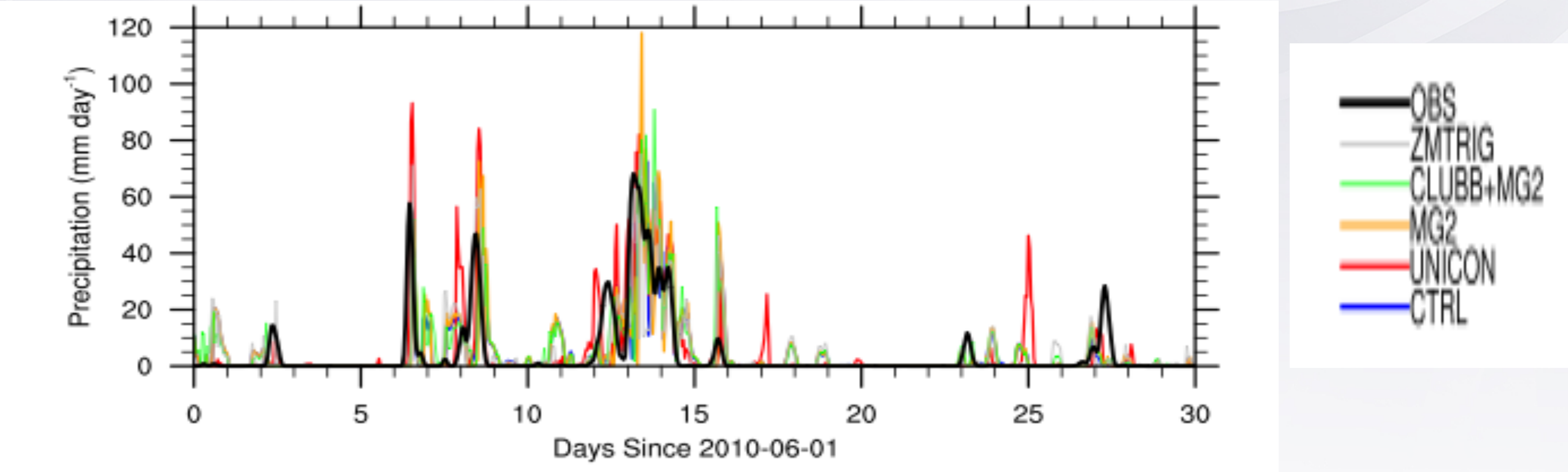
- CLUBB less biased in producing weak precipitation
- ZMTM has excessive weak precipitation.
- All schemes tend to miss strong precipitation
- CLUBB+ZMTM produces less weak precipitation and slightly more strong precipitation, but also overly drier.

Hourly Precipitation Distribution Over South and Central USA (30N – 45N, 110W – 85W) from NEXRAD & CAPT Day 2 Forecast For April – July 2011

Slide from Wuyin Lin

Preliminary Results with ACME v0.2

SCM Simulated Summer Precip at SGP



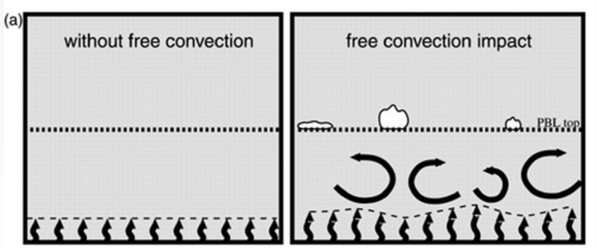
UNICON precipitation too strong

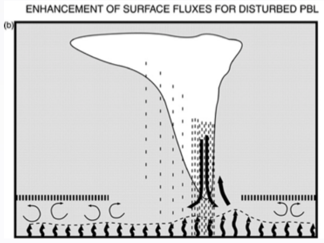
Slide from Kai Zhang

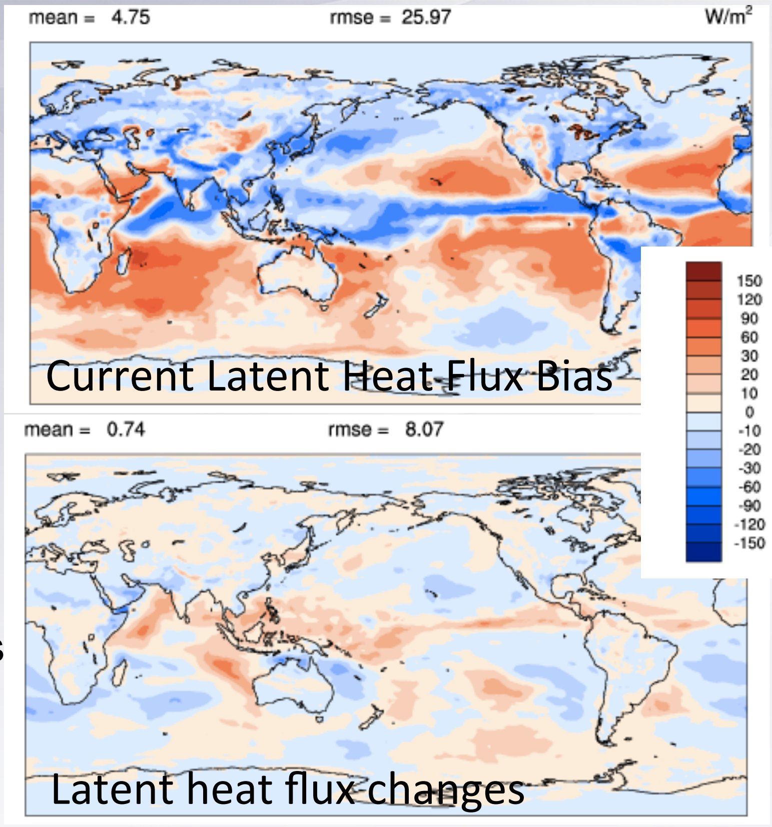
Convective Gustiness

Rich Neale, Cecile Hannay and Julio Bacmeister

- CAM does not currently parameterize sub-grid scale downdraft effects at the surface including ***sub-grid scale convective gustiness*** and the impact on surface fluxes
- Fluxes are enhanced following a simple empirical relationship between convective precipitation and surface gustiness (derived from the TOGA-COARE experiment in Redelsperger et al., 2000)
- JJA has largest response, where enhanced fluxes shifts the Monsoon precipitation center of action to the East. This improves existing biases
- JJA precipitation biases are amplified in the high-resolution model configuration; gustiness should help
- This modification can be added to the model regardless of the choice of convection parameterization

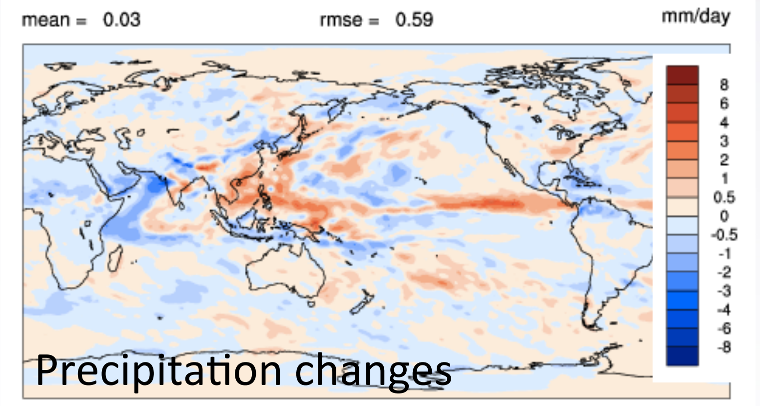






Current Latent Heat Flux Bias

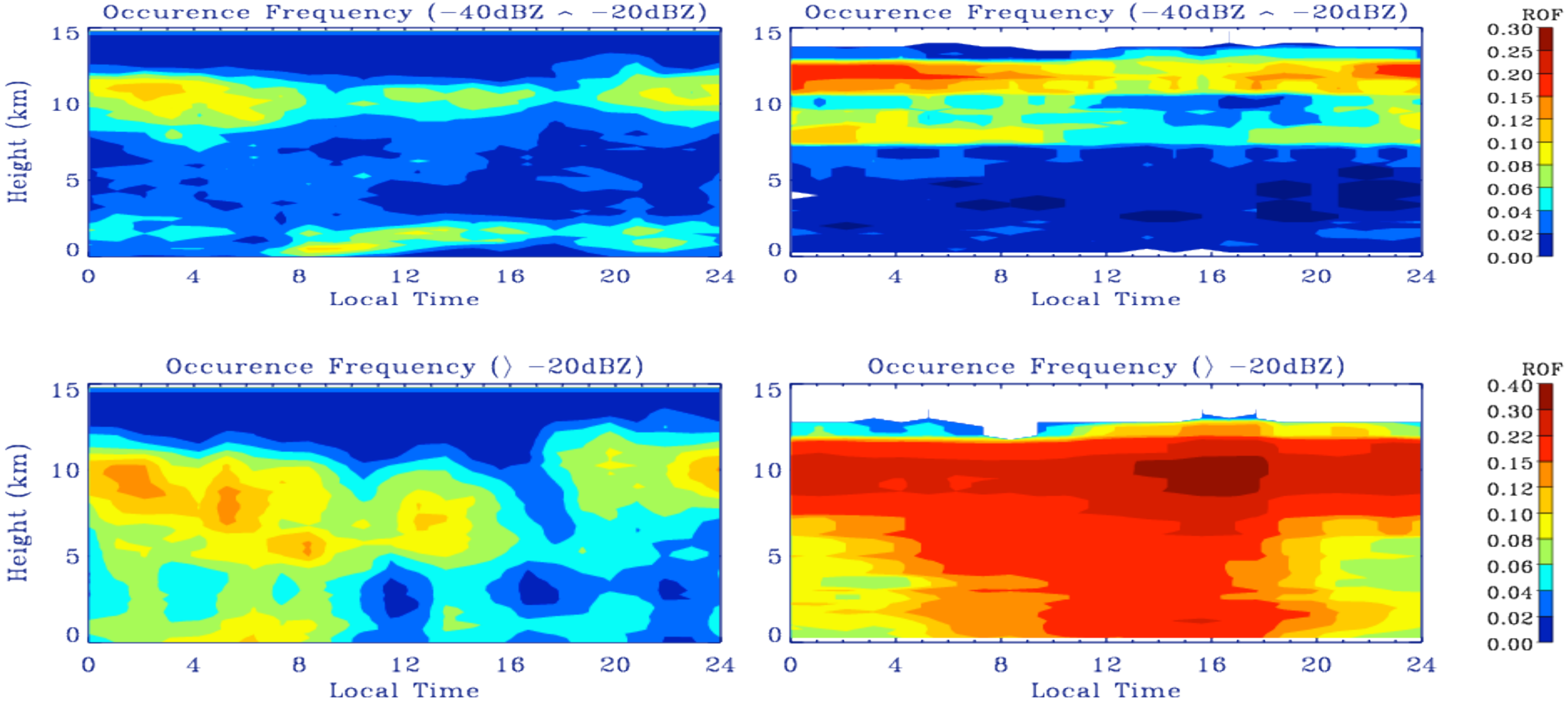
Latent heat flux changes



Precipitation changes

ARM Radar Simulator

Summer Diurnal Precipitation at SGP (2009)



Not enough shallow convection, too much cirrus, bad timing to the diurnal cycle of precip

Slide from Yuying Zhang

Summary of Preliminary Results

CLUBB appears clearly reduces JJA precipitation biases (spatial distribution and global mean), other schemes less clear or even further degrade performance (identified also via ARM cloud simulators)

CLUBB and UNICON improve the continental precipitation diurnal cycle, with UNICON having more systematic improvement.

CLUBB and UNICON improve the Sc-Cu transition along the GPCI transect, but UNICON has very large biases over the deep convective regime.

CLUBB appears to less likely produce double ITCZ biases, compared to all other schemes.

CLUBB has somewhat improved skill on MJO, but Kevlin wave spectrum more diffusive, which has implication, for example, on atmos response to El Nino. UNICON and ZMTM outperform in capturing tropical waves except for MJO.

UNICON appears to have too strong precipitation in an SCM test over SGP

Q4/Q5 Plan

Tests will be managed by testbeds rather than convection schemes

- AMIP – 1^0, forced by monthly (or weekly?) time varying SST 2008-2012 (**Wuyin Lin**)
- CAPT – 1^0, 0.25^0 (**Wuyin Lin**)
- RRM-SGP – AMIP and nudging (CAPT) runs to 0.25^0 (**Qi Tang and Wuyin Lin**)
- High Vert Res – 60 levels (**Po-lun Ma**)
- SCM – 30L and 60L (**Kai Zhang**)
- UQ techniques – 1^0, 0.25^0 CAPT-like ensemble short simulations with perturbed parameters (**Yun Qian & Hui Wan**)

(Convection team members will join each testbed team)

Results will be shared on Confluence

- Metrics/diagnostics plots
- Data

Evaluation will involve all collaborators and those who are interested

Q4/Q5 Plan

Task leads need to create a confluence page for their respective task for data and results sharing

- AMIP – 1^0, forced by monthly (or weekly?) time varying SST 2008-2012 (**Wuyin Lin**)
- CAPT – 1^0, 0.25^0 (**Wuyin Lin**)
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(Convection team members will join each testbed team, sign on the task pages)

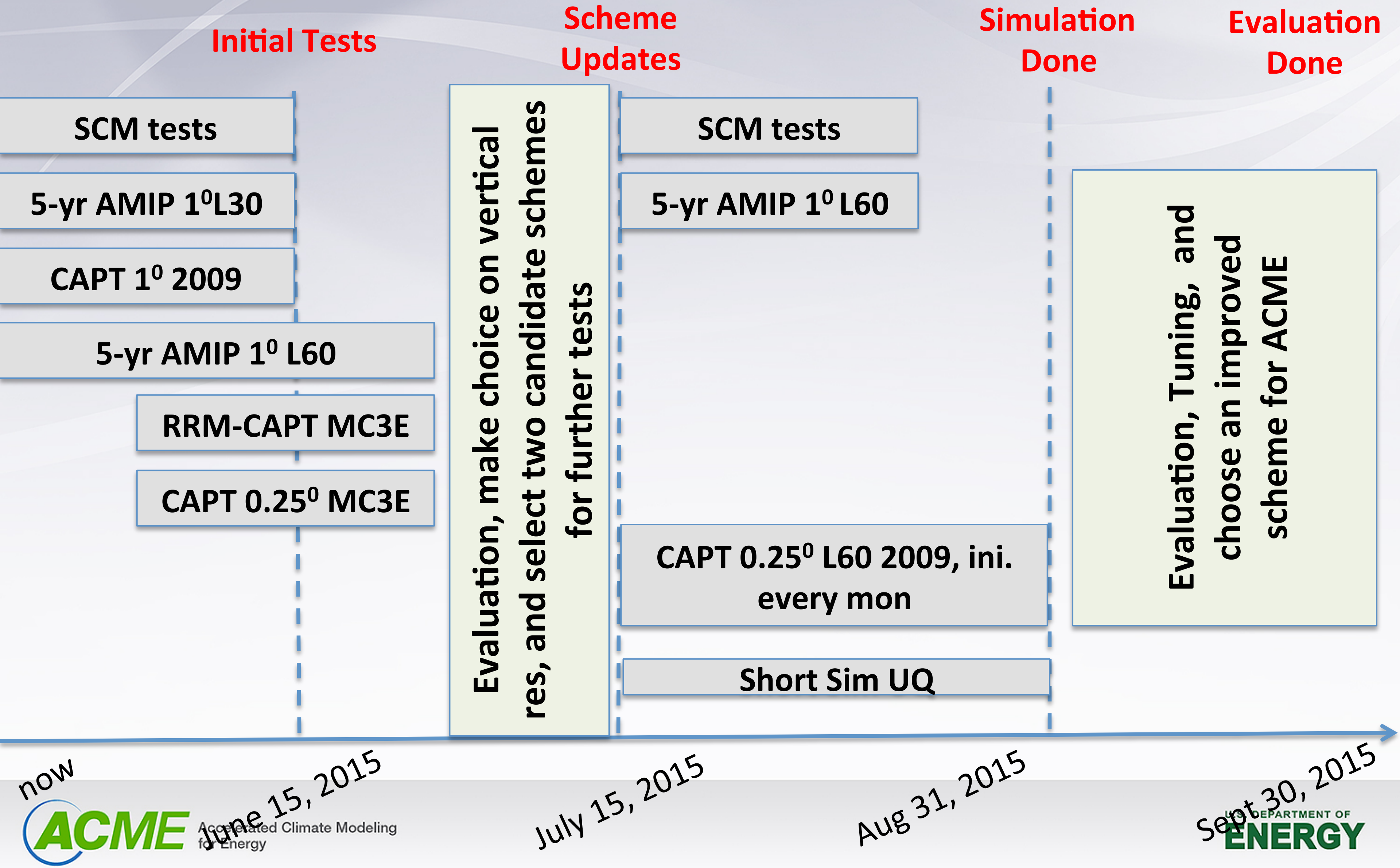
Detailed plan (two-week subtasks) needs to be developed before May 15, 2015

Most tests will start on May 18, 2015

Issues with Convection

- CLUBB and UNICON actively tuned and tested for improving ENSO
    - CLUBB with improved ENSO is ready for us to test
    - UNICON won't take a long time, but no exact date set
- Coordination with other task teams (RRM, High Vert. Res., Short Simulations, R1- metrics and evaluation)
- Coupled runs?
- Merge the convection parameterization with the aerosol and cloud modifications and the sub-grid orography (Hailong Wang, Steve Ghan)
- Utilize current staff resources

ACME Convection Timeline



Initial Tests

Scheme Updates

Simulation Done

Evaluation Done

SCM tests

5-yr AMIP 1^0L30

CAPT 1^0 2009

5-yr AMIP 1^0 L60

RRM-CAPT MC3E

CAPT 0.25^0 MC3E

Evaluation, make choice on vertical res, and select two candidate schemes for further tests

SCM tests

5-yr AMIP 1^0 L60

CAPT 0.25^0 L60 2009, ini. every mon

Short Sim UQ

Evaluation, Tuning, and choose an improved scheme for ACME

now

June 15, 2015

July 15, 2015

Aug 31, 2015

Sept 30, 2015