Choosing a Convection Scheme for ACME: Update and Plan

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Y. Qian (Short Simulations)
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S. Park (UNICON)
G. Zhang (ZM-TRIMEM)

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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)
ACME Atmos Timeline

Height of box indicates effort level for given time

- Decide on Atmos Config
  - Atmos Eval/tuning/optimization
    - Polar Convect Horiz Res Numerics
    - V1 Devel Vert Res
  - CONV Tests & Eva Done
    - Short Ensembles SCM COSP
    - CAPT RRM Scorecards
    - Tiered Diagnostics
- Decide on Coupled Config
  - Coupled Eval/tuning/optimization
    - V2 Devel
- V1 frozen
  - Execute Driving Simulations
  - Write atmos papers
  - Write coupled papers
  - Write science papers
- End of 3 yrs

Slide from Caldwell & Rasch, modified by Xie
Protocol for Convection Tests

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

RRM

AMIP

SCM

CAPT

Metrics
Precipitation Characteristics
Cloud & Aerosol
Mean States & Variability
Regime Transition
Double ITCZ
MJO

ne30
RRM
e120
UQ Tests
Local, regional & global scales

ARM & Other IOPs, Local scale
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)
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?*
Vertical resolution sensitivity

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)

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)
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
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.
**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.

**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.

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Table 1. Tunable parameters of CLUBB and ZM

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Description</th>
<th>Default Value</th>
<th>Investigated Range</th>
</tr>
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<tbody>
<tr>
<td>C1</td>
<td>Constant associated with $w'^2$ dissipation</td>
<td>2.5</td>
<td>1.25-5</td>
</tr>
<tr>
<td>C2rt</td>
<td>Constant associated with $T'^2$ dissipation</td>
<td>1.0</td>
<td>0.5-2</td>
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<tr>
<td>C6rt</td>
<td>Low skewness of Newtonian damping of water flux</td>
<td>4.0</td>
<td>3.0-8.0</td>
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<tr>
<td>C6rtb</td>
<td>High skewness of Newtonian damping of water flux</td>
<td>4.0</td>
<td>3.0-8.0</td>
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<tr>
<td>C7</td>
<td>Low skewness of buoyancy damping of water flux</td>
<td>0.5</td>
<td>0.25-1.0</td>
</tr>
<tr>
<td>C7b</td>
<td>High skewness of buoyancy damping of water flux</td>
<td>0.5</td>
<td>0.25-1.0</td>
</tr>
<tr>
<td>C8</td>
<td>Constant associated with Newtonian damping of $w'^2$</td>
<td>3.0</td>
<td>1.5-6.0</td>
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<tr>
<td>C11</td>
<td>Low skewness of buoyancy damping of $w'^2$</td>
<td>0.8</td>
<td>0.0-1.0</td>
</tr>
<tr>
<td>C11b</td>
<td>High skewness of buoyancy damping of $w'^2$</td>
<td>0.65</td>
<td>0.0-1.0</td>
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<tr>
<td>C14</td>
<td>Constant of Newtonian damping of $u'^2$ and $v'^2$</td>
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<td>0.5-2.0</td>
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<tr>
<td>$\nu$</td>
<td>Background coefficient of eddy diffusion</td>
<td>20.0</td>
<td>10.0-40.0</td>
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<tr>
<td>$\beta$</td>
<td>Constant related to skewness of $\theta_1$ and $r_1$</td>
<td>1.75</td>
<td>0.0-3.0</td>
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<tr>
<td>$\gamma$</td>
<td>Constant of the width of PDF in w-coordinate ($\sigma_2^w$)</td>
<td>0.32</td>
<td>0.1-0.6</td>
</tr>
<tr>
<td>$\mu$</td>
<td>Parcel entrainment rate [1/m]</td>
<td>0.001</td>
<td>0.5-2.0e-3</td>
</tr>
<tr>
<td>C0_ind</td>
<td>ZM precipitation efficiency over land</td>
<td>0.0059</td>
<td>0.003-0.09</td>
</tr>
<tr>
<td>C0_ocn</td>
<td>ZM precipitation efficiency over ocean</td>
<td>0.045</td>
<td>0.003-0.09</td>
</tr>
<tr>
<td>$dmpdz$</td>
<td>Entrainment rate of ZM</td>
<td>$10^{-3}$</td>
<td>-0.2-2x$10^{-3}$</td>
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<tr>
<td>$\tau$</td>
<td>CAPE consumption time scale (s)</td>
<td>3600s</td>
<td>1800-10800</td>
</tr>
</tbody>
</table>

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-like metrics for Mean State and variability

Precipitation Characteristics

Satellite and ARM Cloud Simulators
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

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### Tier 1a Diags (from Classic Viewer)

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

Thanks Pete Bogenschutz

Thanks Sungsu Park
Preliminary Results with ACME v0.2

AMIP 2008-2009, JJA Total Precipitation

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 becomes even less than CNTL

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

Slide from Wuyin Lin
Preliminary Results with ACME v0.2

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

- 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.

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

(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**
- SCM tests
- 5-yr AMIP 1° L30
- CAPT 1° 2009
- 5-yr AMIP 1° L60
- RRM-CAPT MC3E
- CAPT 0.25° MC3E

**Scheme Updates**
- Evaluation, make choice on vertical res, and select two candidate schemes for further tests
- SCM tests
- 5-yr AMIP 1° L60

**Simulation Done**
- CAPT 0.25° L60 2009, ini. every mon
- Short Sim UQ

**Evaluation Done**
- Evaluation, Tuning, and choose an improved scheme for ACME

**Timeline**
- June 15, 2015
- July 15, 2015
- Aug 31, 2015
- Sept 30, 2015