Development of Taiwan Earth System Model on the Basis of CESM

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Motivation and Goals

- Improve GCM simulations of atmospheric variability in smaller spatial and temporal scales.
  1. Replacing deep convection, shallow convection, and PBL schemes with NCEP/GFS physical packages
  2. Adding the 3-D topography effect on surface solar radiation
  3. Coupling a high-vertical-resolution mixed layer model to CAM

- Develop a coherent cloud-aerosol-precipitation microphysics scheme.
  1. Adding microphysical scheme to the deep convection
  2. Replacing the aerosol scheme in CAM5
# Replacing CAM5 Physics by GFS

(Contributed by: Yi-Chi Wang, Chao-An Chen, Chein-Jung Shiu, and Hua-Lu Pan)

<table>
<thead>
<tr>
<th></th>
<th>CAM5-default</th>
<th>CAM5-GFS</th>
</tr>
</thead>
<tbody>
<tr>
<td>Shallow convection</td>
<td>Park et al. (2009)</td>
<td>Han and Pan (2011)</td>
</tr>
</tbody>
</table>

**Testing:**
- Single-column CAM5 (SCAM; Xie et al. 2004, Zhang et al. 2011)
- Transpose AMIP (Xie et al. 2012)
- Prescribed SST simulations
Impact of Replacing Deep Convection

Rainfall time series in June 2009 over ARM SGP site
(Single column simulations, hourly output)
Impact of Replacing Deep Convection

Diurnal rainfall cycle during JJA 2009 at ARM SGP site
(Single column simulation)

- SGP Central Facility, Lamont, Oklahoma 36° 36’ N, 97° 29’ W
- SCAM driven by RUC-based advective forcing (Xie et al., 2004; Zhang et al., 2001)
**Transpose-AMIP Experiments for CAM-GFS**

- Run climate models in the weather forecast mode
- Investigate the growth of biases from “fast processes” (e.g., cloud or precipitation).
- Each run performs 5-day simulation and averages of days 2-4 are used.

### Percentile distribution of precipitation intensity

<table>
<thead>
<tr>
<th>Date</th>
<th>Deep</th>
<th>Shallow</th>
<th>PBL</th>
</tr>
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<tbody>
<tr>
<td>7/1</td>
<td>ZM</td>
<td>UW</td>
<td>diagTKE</td>
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<tr>
<td>7/2</td>
<td>GFS-SAS</td>
<td>GFS-HP</td>
<td>GFS-PBL</td>
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<tr>
<td>7/3</td>
<td>ZM</td>
<td>GFS-HP</td>
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<td>7/26</td>
<td>GFS-SAS</td>
<td>UW</td>
<td>diagTKE</td>
</tr>
</tbody>
</table>

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**2009 July**

- CAM5
- D+S+P
- S+P
- SAS only

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(--- 4mm/day---)
Cloud regimes ranging from stratocumulus in the subtropics, to shallow cumuli and deep convective clouds toward the Equator (Fig. 1 Stevens, 2005b, following Arakawa (1975)).
Mean = 2.83

**Annual Mean of Total Precipitation (2 degree)**

# Too strong ITCZ
# Too weak precipitation over land
Annual Mean Clouds

High Cloud

- Too much high clouds in convective zone
- Too much low clouds in Sc and trade Cu

Low Cloud

D+S+P

CAM5 default

Difference

lev30.f19.F2000C5.01 (yrs 3-6)

lev30.f19.F2000C5.01 (yrs 3-6)

D_qrodo2nd_zmevap_noconvtran_qicorrect_vartshift_f19 - lev30.f19.F2000C5.01

D_qrodo2nd_zmevap_noconvtran_qicorrect_vartshift_f19 - lev30.f19.F2000C5.01

Min = 5.14  Max = 15.39
On the basis of simulations from a ray-tracing Monte Carlo approach, we developed a parameterization for 3-D radiative transfer in complex topography to account for the impact of shadow and reflection on surface solar radiation.

(Contributed by: Wei-Liang Lee and K. N. Liou)
Topography Effect on Solar Radiation

The impact of the topography effect in 3-year prescribed SST simulations at 0.25 degree resolution

Surface Net Solar Flux

Precipitating Snow Rate (mm/day)

Total Cloud Fraction

Snow Water Equivalent (mm)
Coupling Mixed Layer Model (SIT) to CAM

SIT is a mixed layer ocean model with a vertical resolution of 1 m. Coupling SIT with ECHAM5 significantly improves MJO simulations.

(Contributed by: Wan-Ling Tseng, Yung-Yao Lan, Ben-Jei Tsuang, and Noel Keenlyside)

U850 anomalies in May-Oct
Sensitivity Tests of SIT with ECHAM5

Obs.

T62, $\Delta z = 1$ m

T213, $\Delta z = 1$ m

T62, $\Delta z = 10$ m

T62, $\Delta z = 50$ m
Implementation of warm cloud microphysics to deep convection

A two-moment warm cloud parameterization (Chen and Liu 2004) is implemented into the deep convection scheme of CAM5 for treatment of conversion of cloud liquid to rain. (Chein-Jung Shiu and Jen-Ping Chen)

Cloud liquid water path

- **Model**
  - CAM5.2 Ctrl
  - CAM5.2+JP2M

- **Observation**
  - UWisc 1988-2008
  - AMSR-E v7 (2003-2010)
Non-precipitating ice water

Precipitating ice water
Adding warm cloud parameterization for convective clouds will increase stratiform precipitation fraction and total precipitation only change a little bit.
### Statistical-Numerical Aerosol Parameterization (SNAP)

(Jen-Ping Chen and I-Chun Tsai)

<table>
<thead>
<tr>
<th></th>
<th>MAM3</th>
<th>SNAP</th>
</tr>
</thead>
<tbody>
<tr>
<td>size distribution</td>
<td>modal 2</td>
<td>modal 2</td>
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<tr>
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<td>Num, Area, Mass</td>
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<td>S, C, BC, SS, D</td>
<td>S, C, BC, SS, D</td>
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<td>external + internal</td>
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<td>nucl, cond, coag, d+w dep, ice nucl</td>
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<td>eq size, CC, modal ext/abs coefficient</td>
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<td>diagnostic eqs</td>
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</tbody>
</table>

**SNAP-MAM3 aerosol number**

**SNAP-MAM3 aerosol mass**
Summary

1. On the basis of CESM1, we are working on improving weather-scale variability in climate simulations.

2. We are also developing a coherent aerosol-cloud-precipitation microphysics scheme.

3. Related ongoing works include:
   # Ground water and irrigation in CLM;
   # Surface wave-induced vertical mixing in POP;
   # Parallel Domain-Decomposed Taiwan Muti-Scale Community Ocean Model (PD-TIMCOM).

4. Diagnostic studies focus on East Asian monsoon, typhoon variability, MJO, ITCZ, and etc.