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*)

	CAM5-default	CAM5-GFS
Deep convection	Zhang and McFarlane (1995); Neale et al. (2008)	Simplified Arakawa-Schubert (Pan and Wu 1995; Han and Pan 2011)
Shallow convection	Park et al. (2009)	Han and Pan (2011)
Turbulence	Bretherton and Park (2009)	Holtslag-Boville (1993) + Lock (2000)

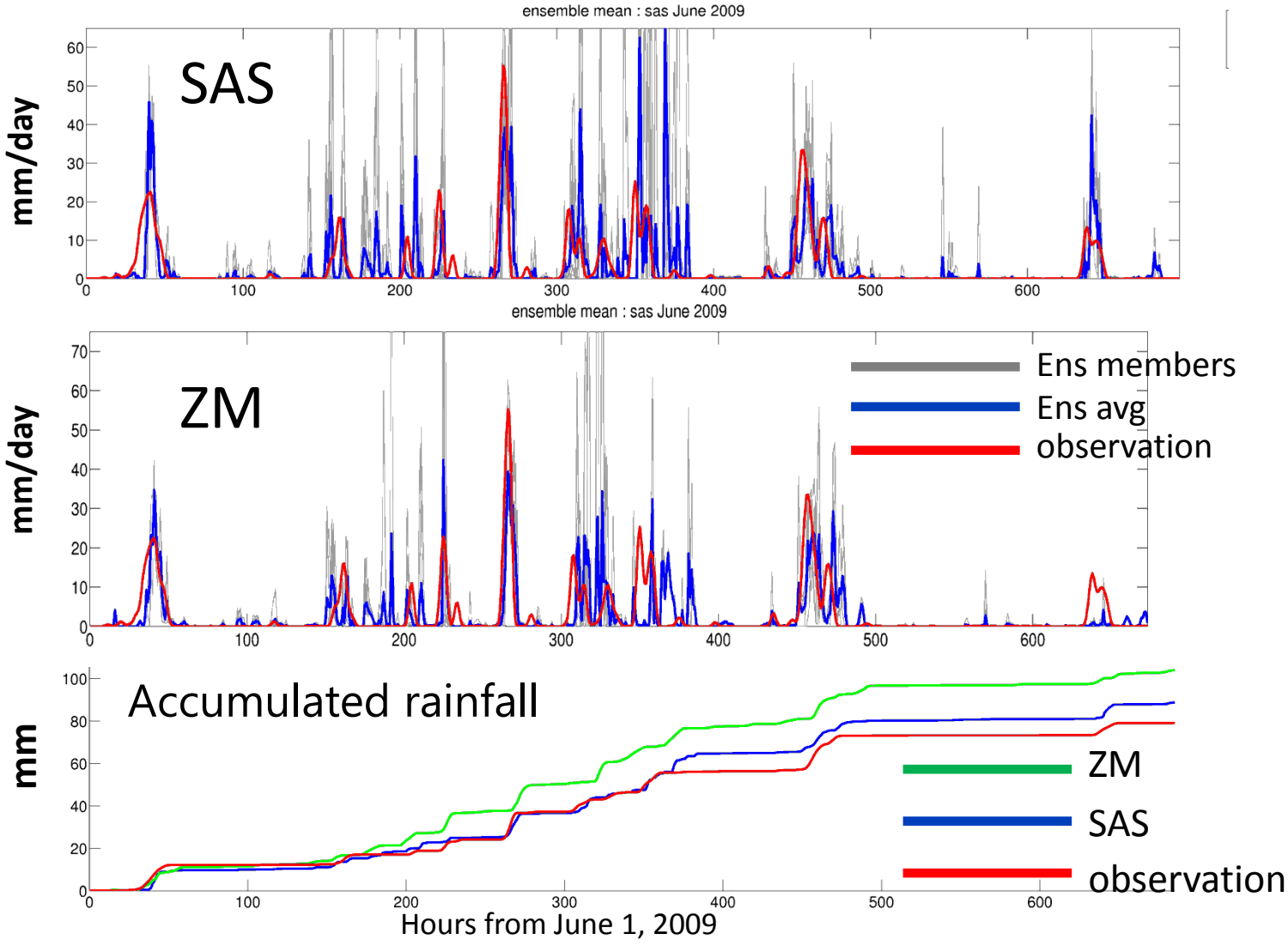
Testing:

- 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

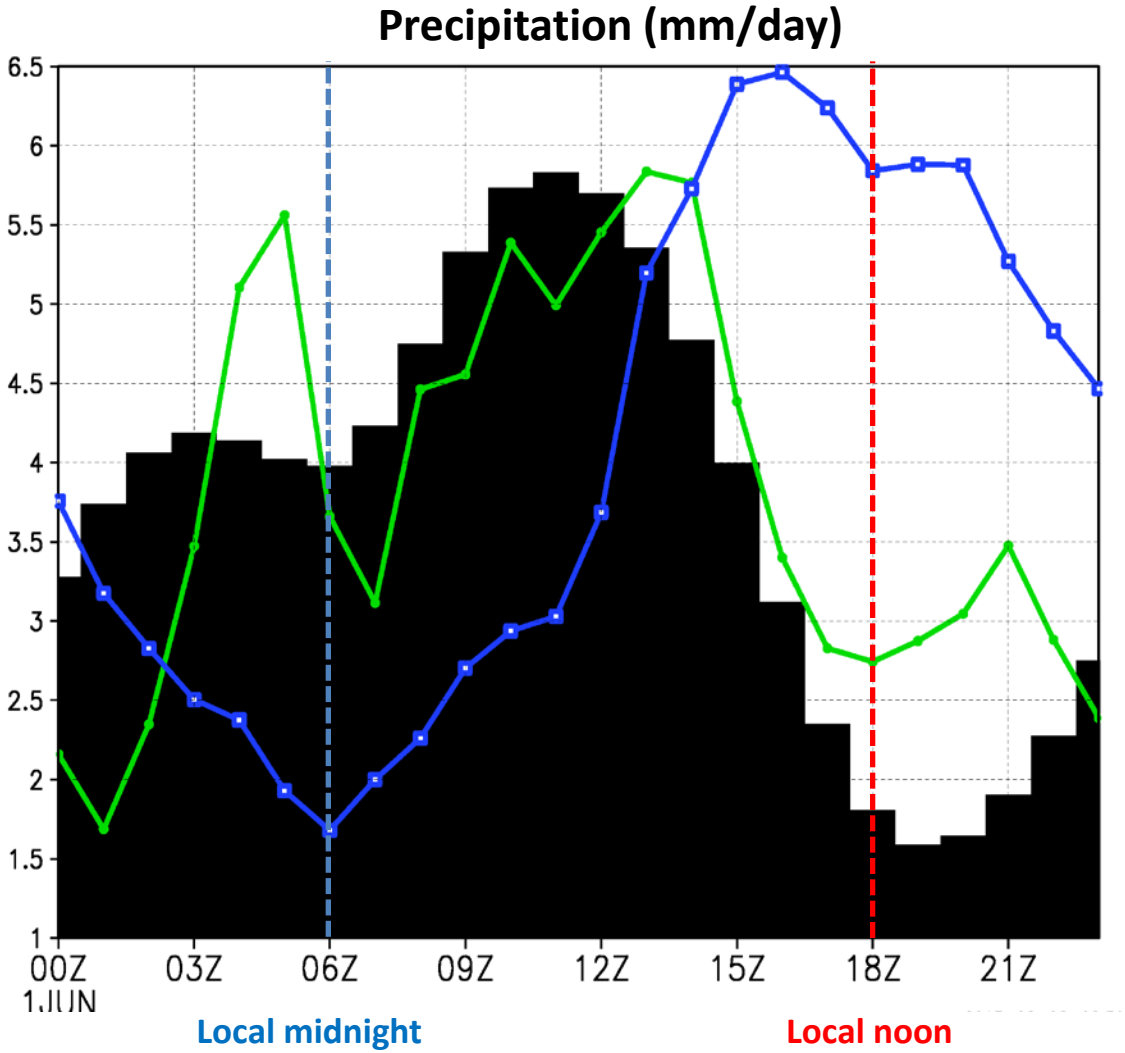
(Single column simulations, hourly output)



Impact of Replacing Deep Convection

Diurnal rainfall cycle during JJA 2009 at ARM SGP site

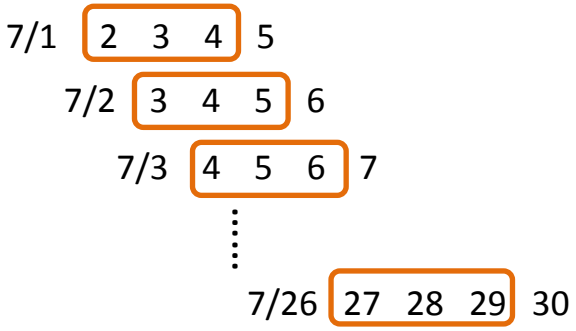
(Single column simulation)



- 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)

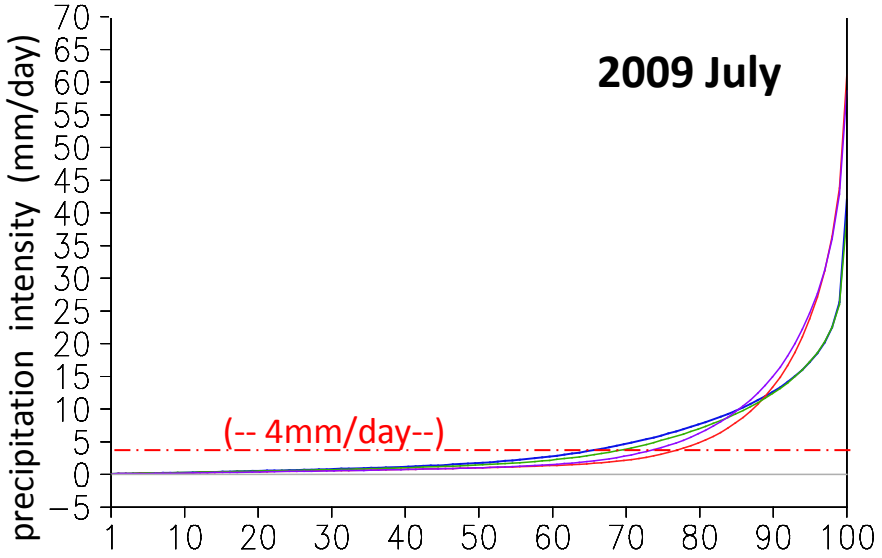
Transpose-AMIP Experiments for CAM-GFS

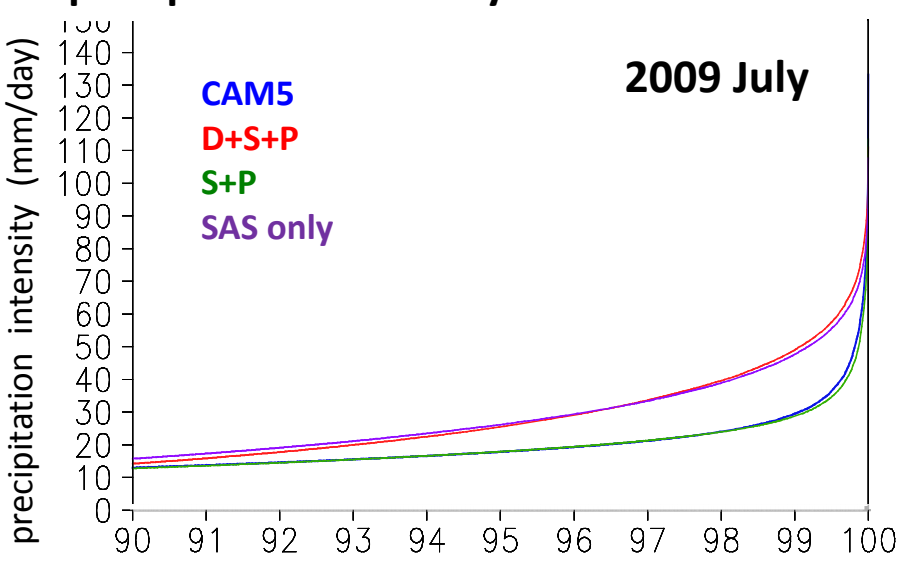
- Run climate models in the weather forecast mode
- Investigate the growth of biases from “fast processes” (e.g., cloud or precipitation).
- Each run performs 5-day simulation and averages of days 2-4 are used.



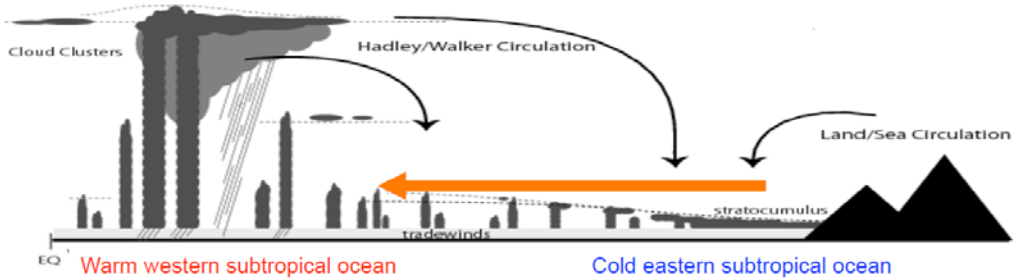
	Deep	Shallow	PBL
CTL (CAM5)	ZM	UW	diagTKE
D+S+P	GFS-SAS	GFS-HP	GFS-PBL
S+P	ZM	GFS-HP	GFS-PBL
SAS only	GFS-SAS	UW	diagTKE

Percentile distribution of precipitation intensity





NE Pacific



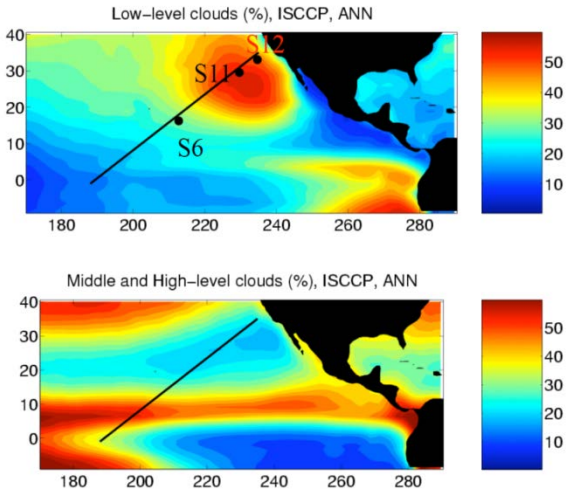
Cloud regimes ranging from stratocumulus in the subtropics, to shallow cumuli and deep convective clouds toward the Equator (Fig. 1 Stevens, 2005b, following Arakawa (1975)).

Max-Planck-Institut für Meteorologie

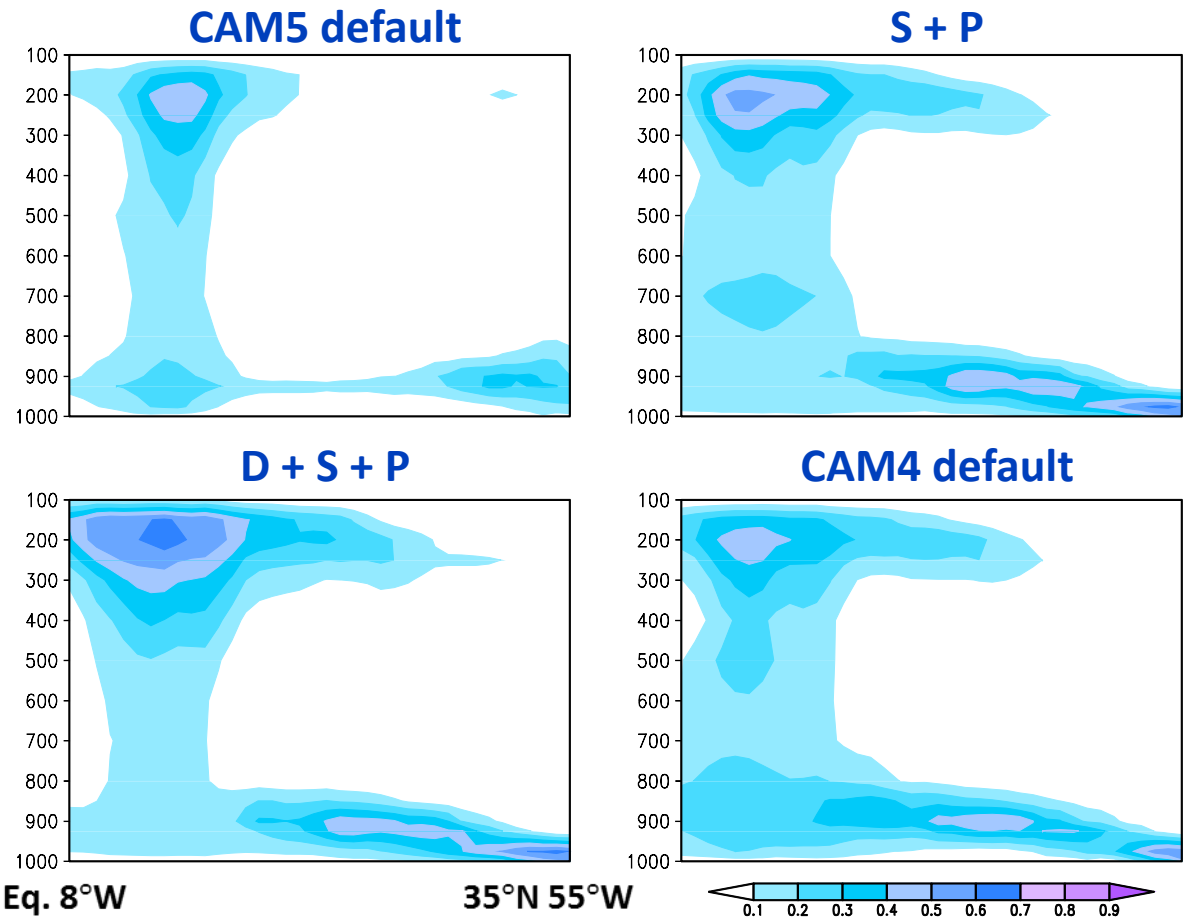
Alexander von Humboldt Stiftung/Foundation

ECMWF

2009 July

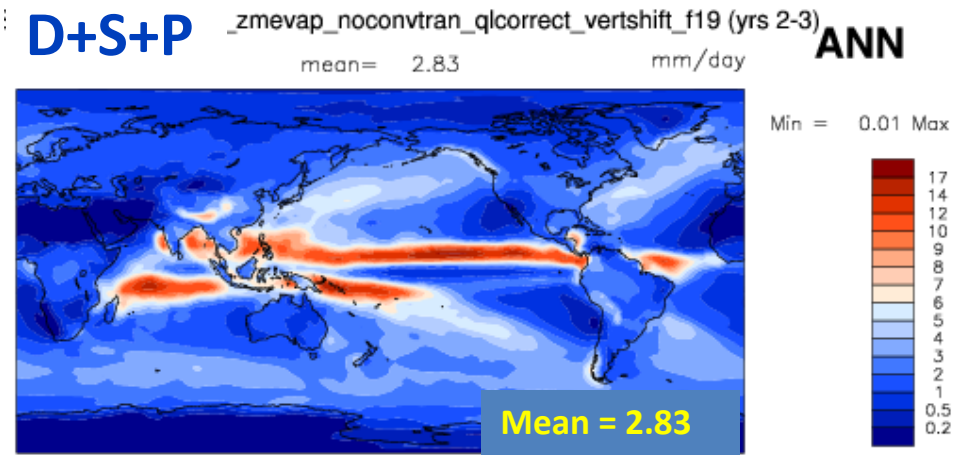


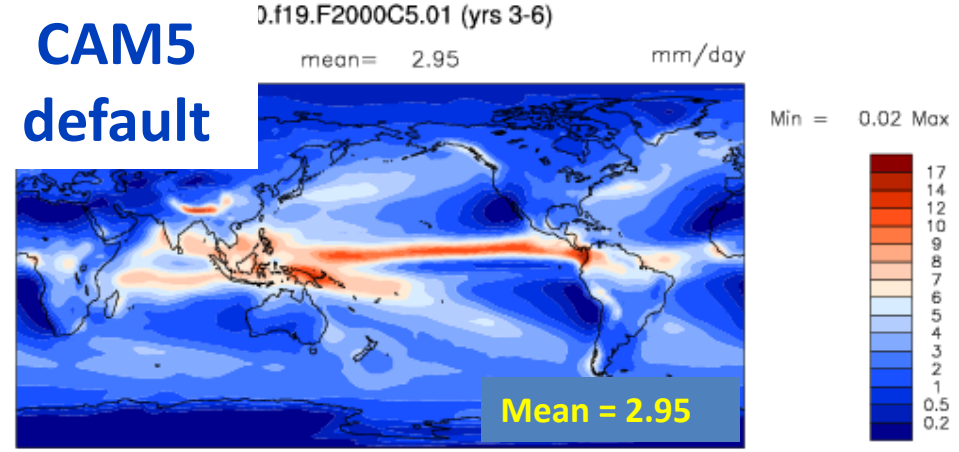
(Zhang et al.)

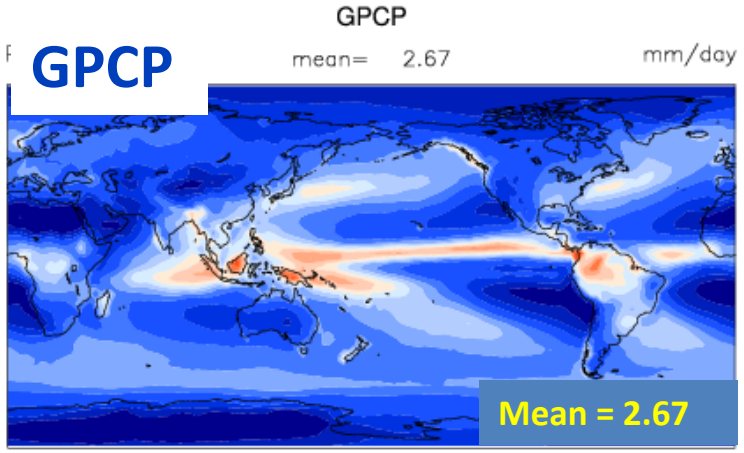


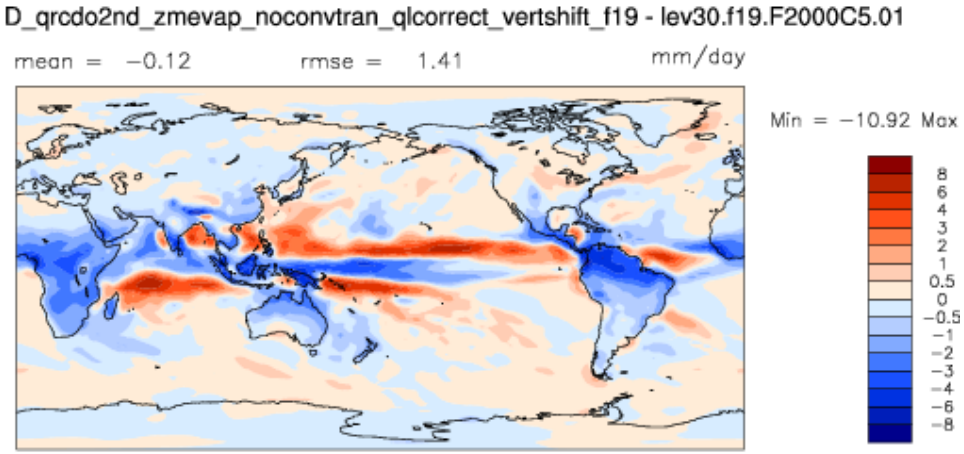
Annual Mean of Total Precipitation (2 degree)

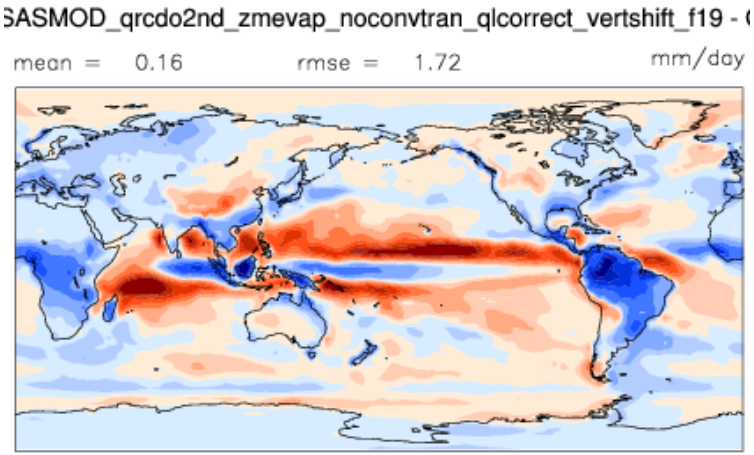
 # Too strong ITCZ
 # Too weak precipitation over land











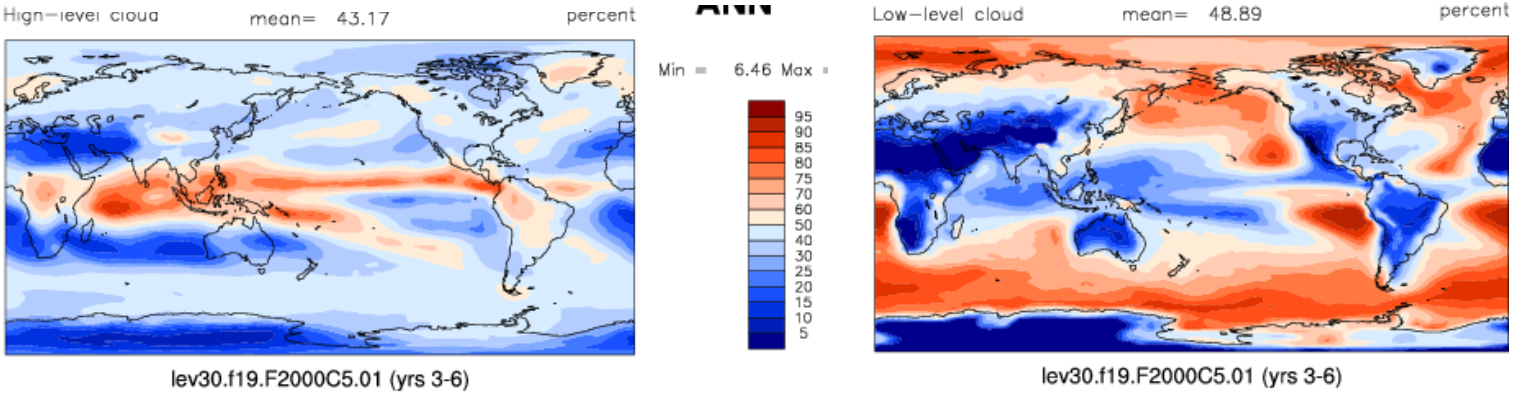
Annual Mean Clouds

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

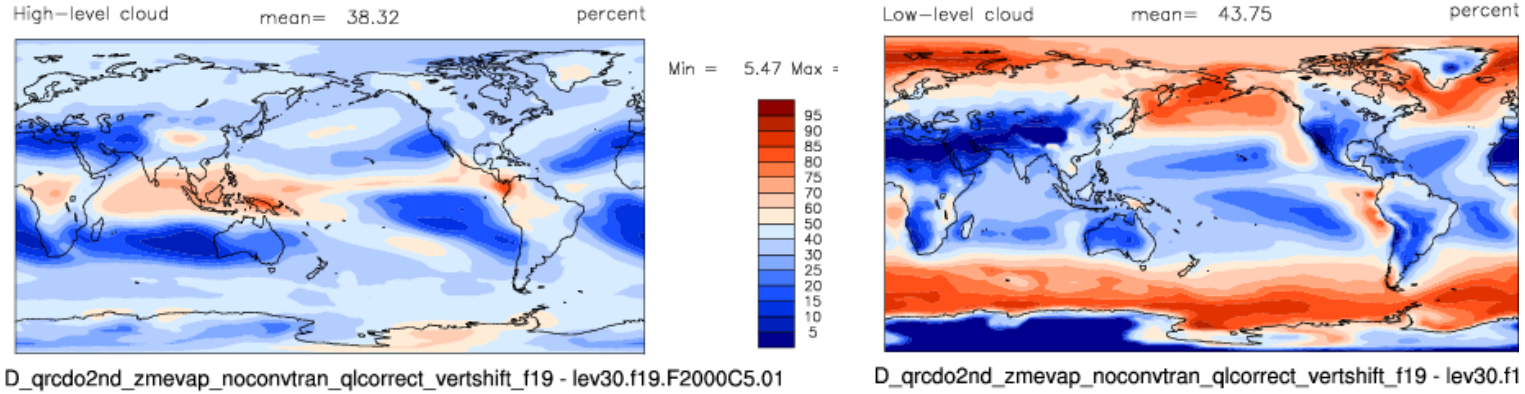
High Cloud

Low Cloud

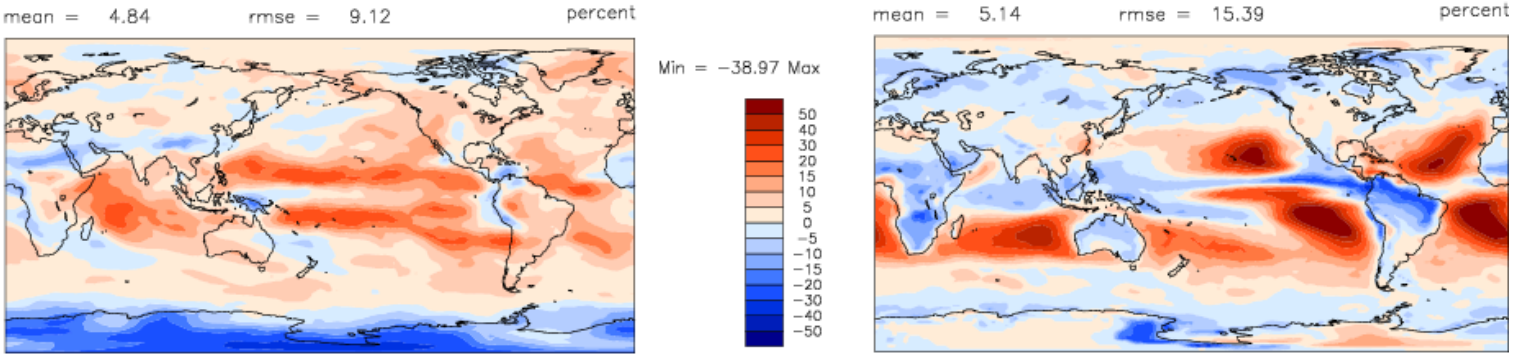
D+S+P



CAM5 default



Difference

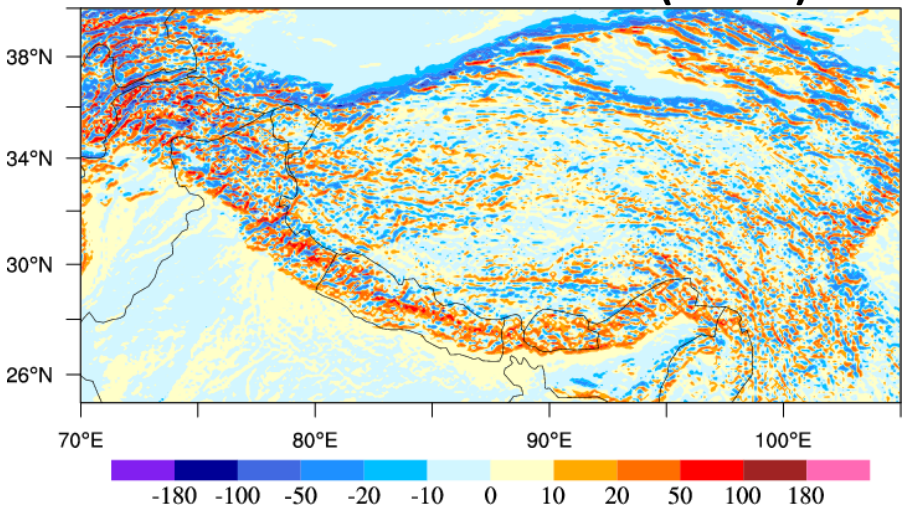


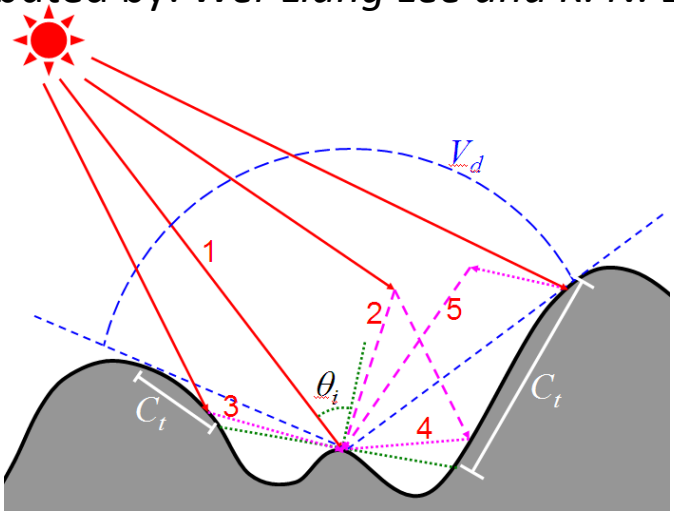
Topography Effect on Surface Solar Radiation

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.

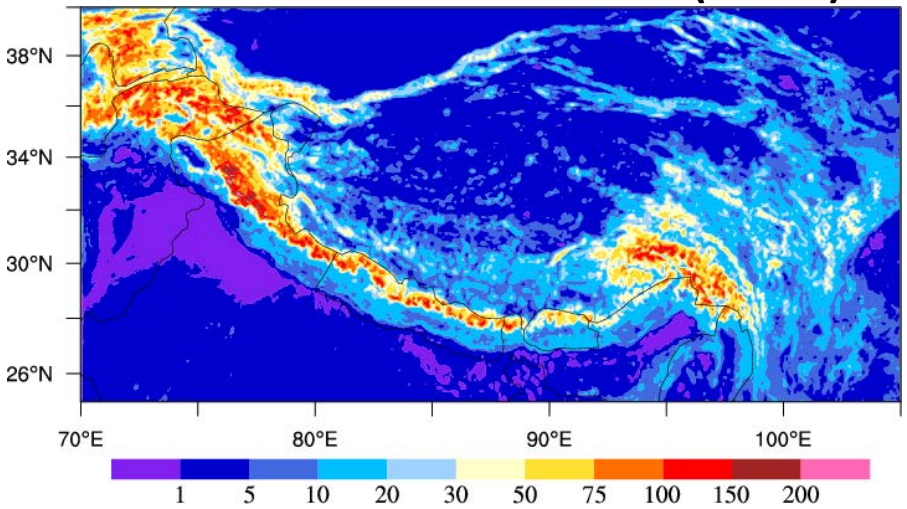
(Contributed by: *Wei-Liang Lee and K. N. Liou*)

Difference in Direct Fluxes (10 km)

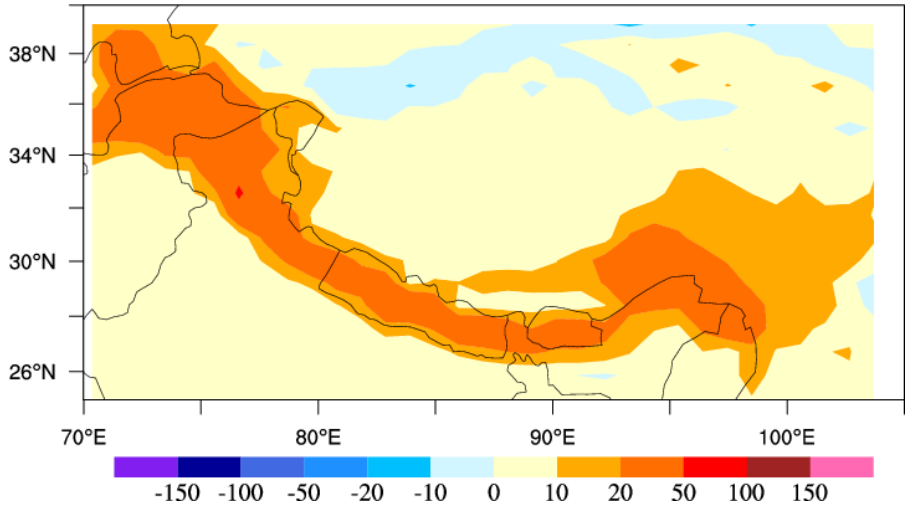




Difference in Reflected Fluxes (10 km)



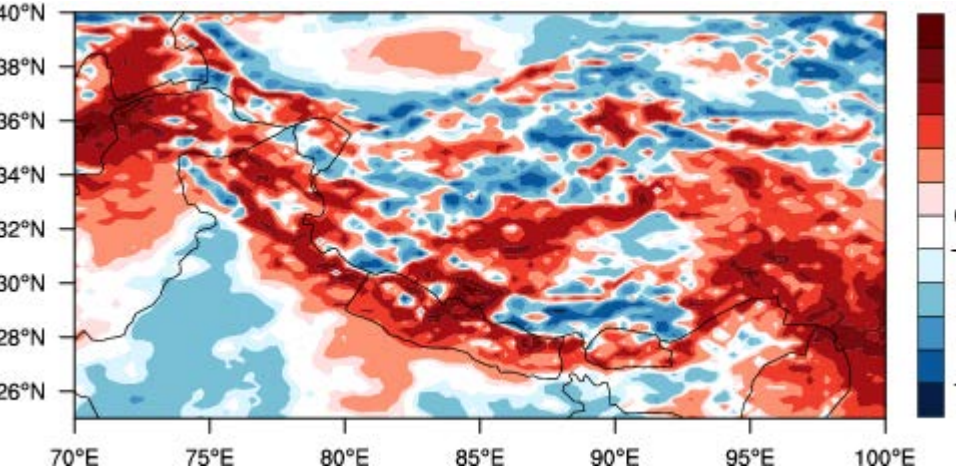
Net Difference at 100 km resolution



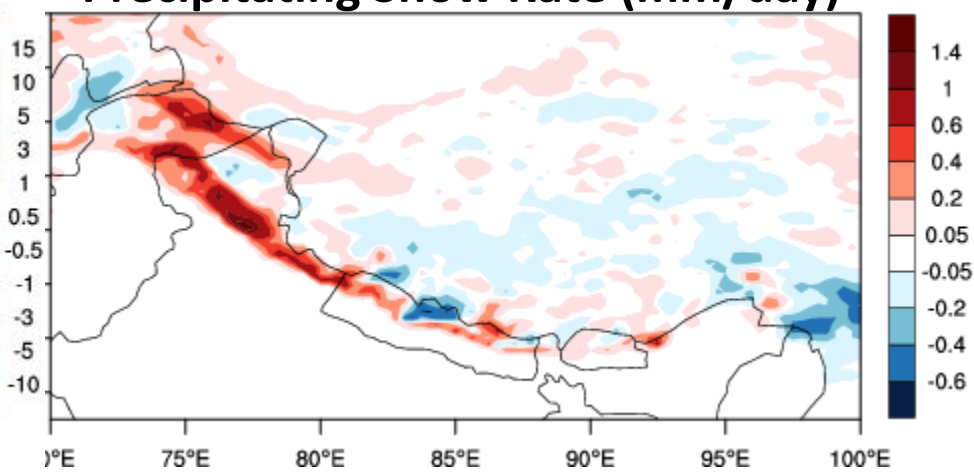
Topography Effect on Solar Radiation

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

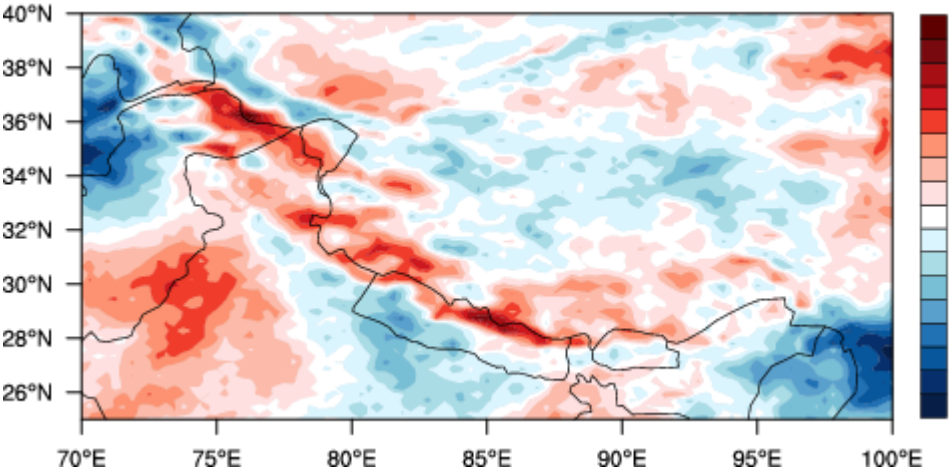
Surface Net Solar Flux



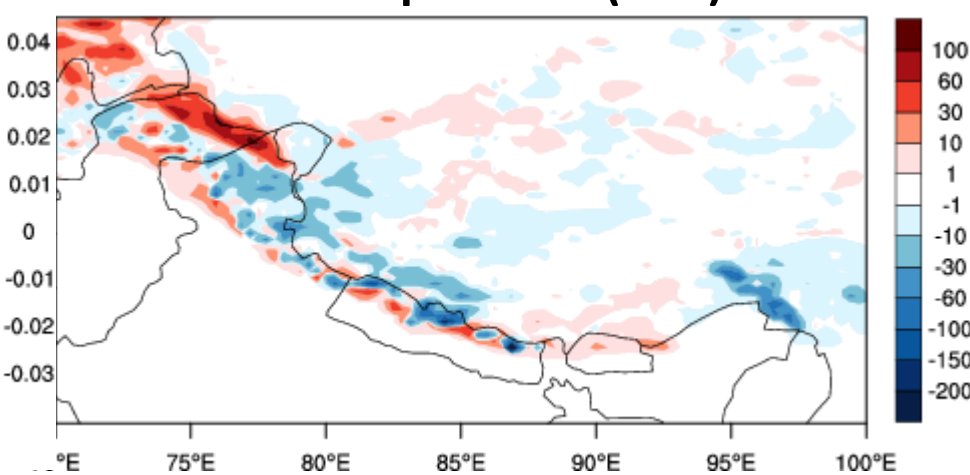
Precipitating Snow Rate (mm/day)



Total Cloud Fraction



Snow Water Equivalent (mm)

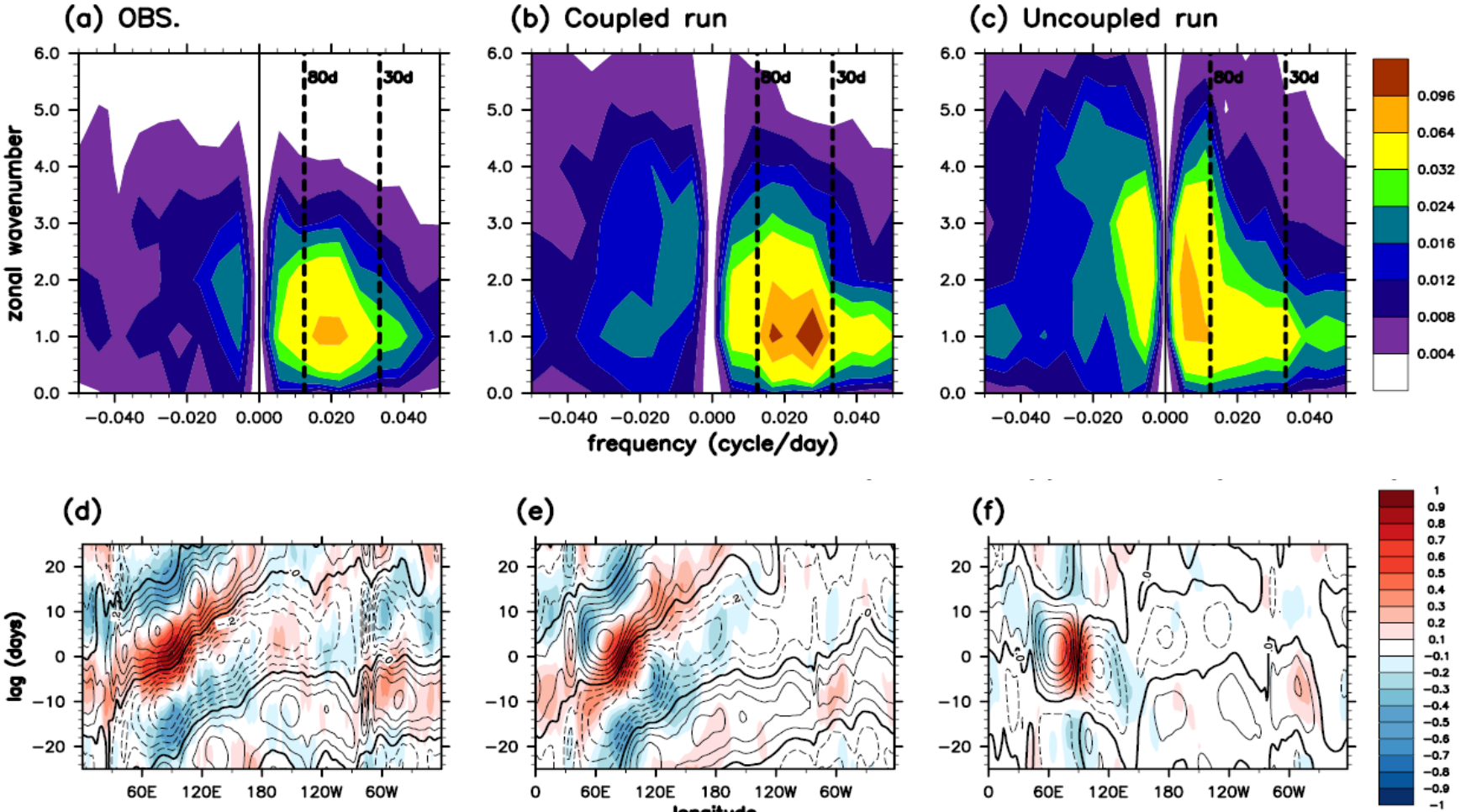


Coupling Mixed Layer Model (SIT) to CAM

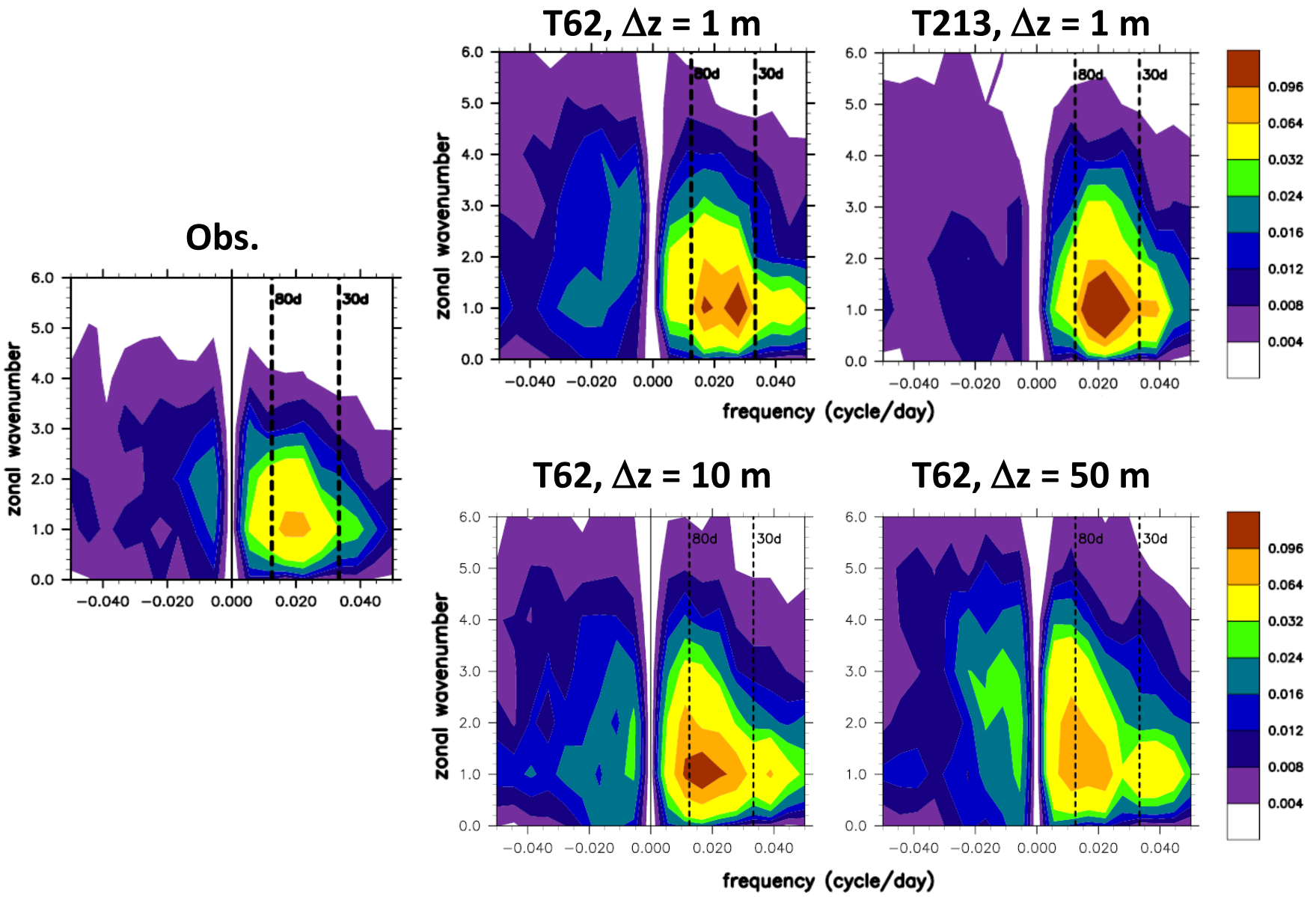
SIT is a mixed layer ocean model with a vertical resolution of 1 m.
Coupling SIT with ECHAM5 significantly improves MJO simulations.

(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

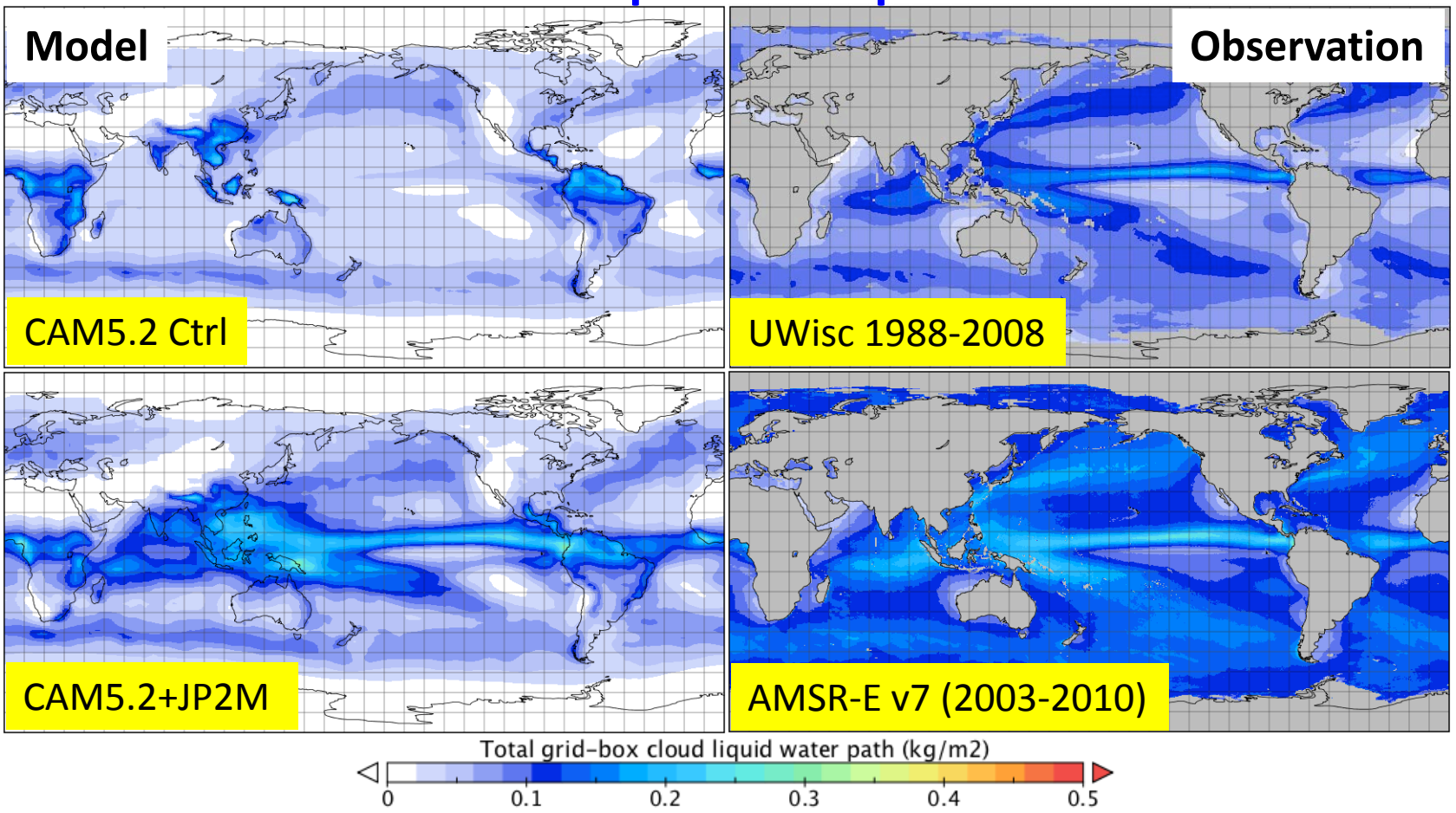


Implementation of warm cloud microphysics to deep convection

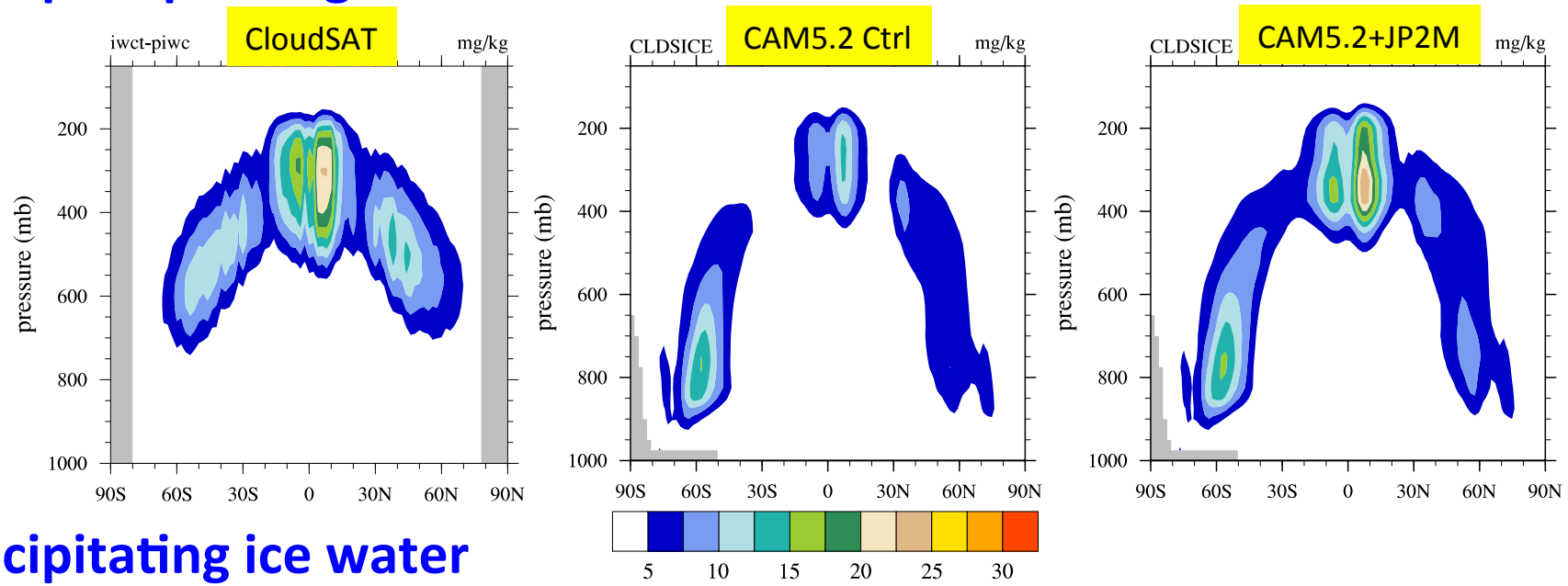
A two-moment warm cloud parameterization (Chen and Liu 2004) is implemented into the deep convection scheme of CAM5 for treatment of conversion of cloud liquid to rain.

(*Chein-Jung Shiu and Jen-Ping Chen*)

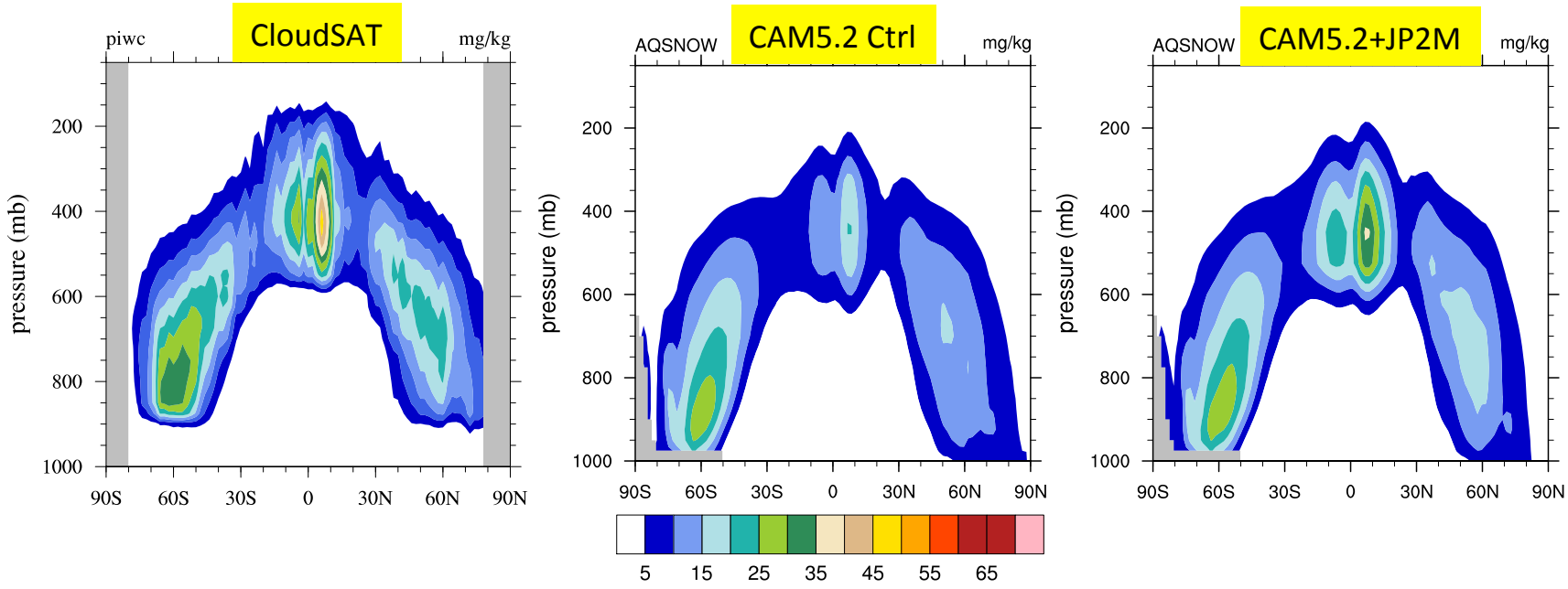
Cloud liquid water path



Non-precipitating ice water

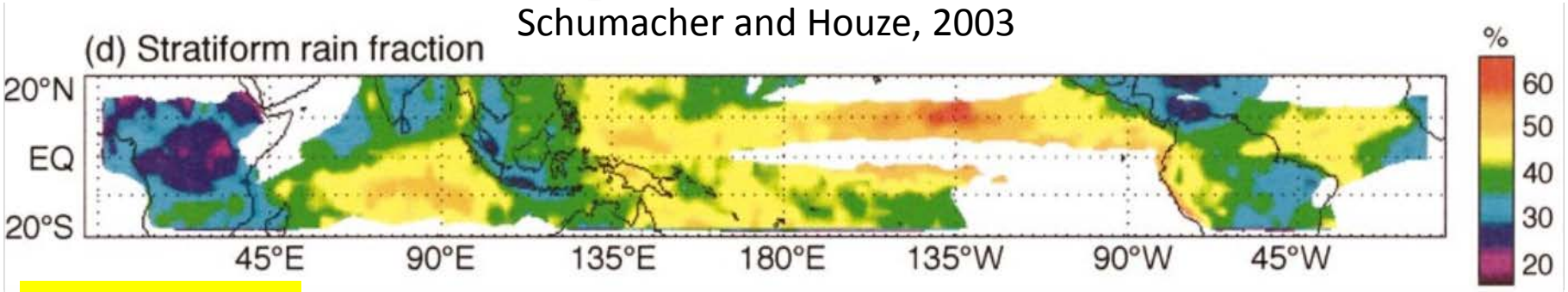


Precipitating ice water

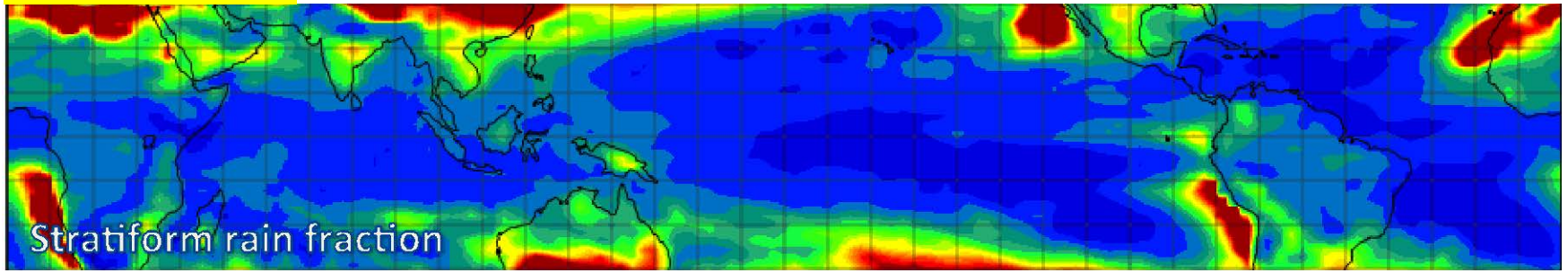


Stratiform Precipitation Fraction

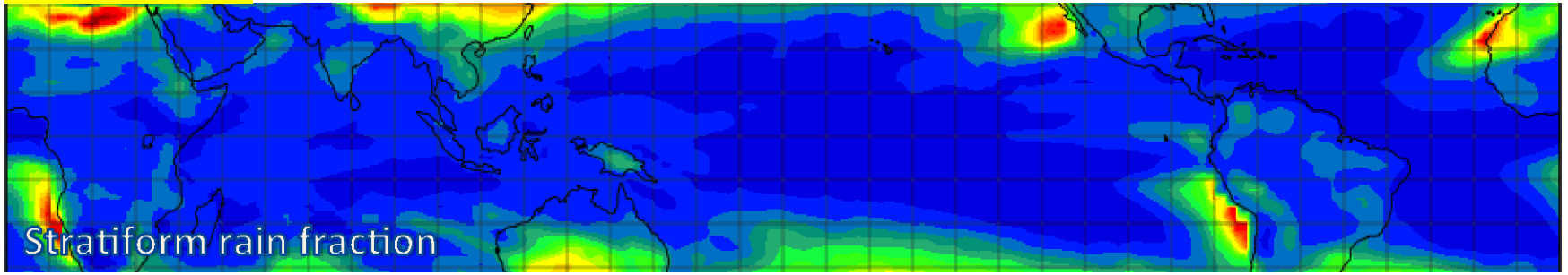
Schumacher and Houze, 2003



CAM5.2+JP2M



CAM5.2 Ctrl



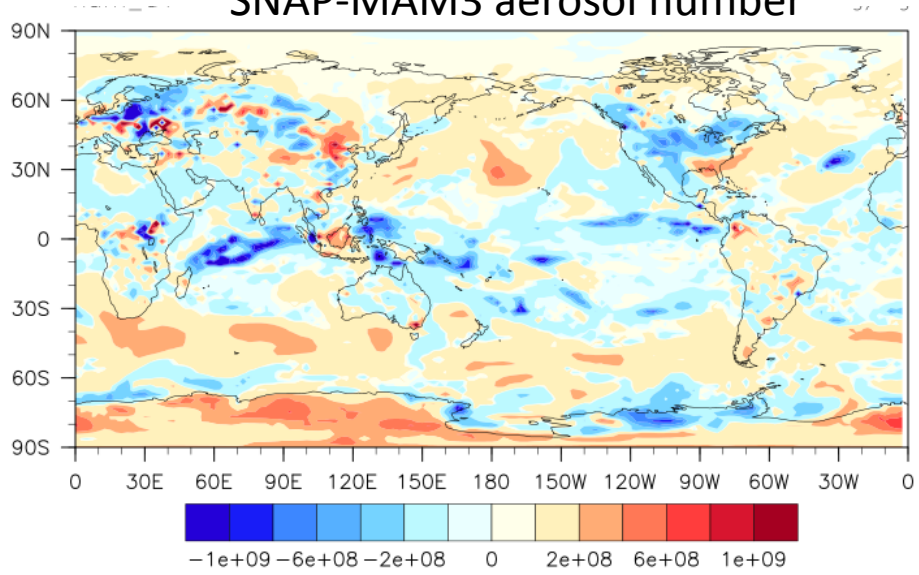
Adding warm cloud parameterization for convective clouds will increase stratiform precipitation fraction and total precipitation only change a little bit.

Statistical-Numerical Aerosol Parameterization (SNAP)

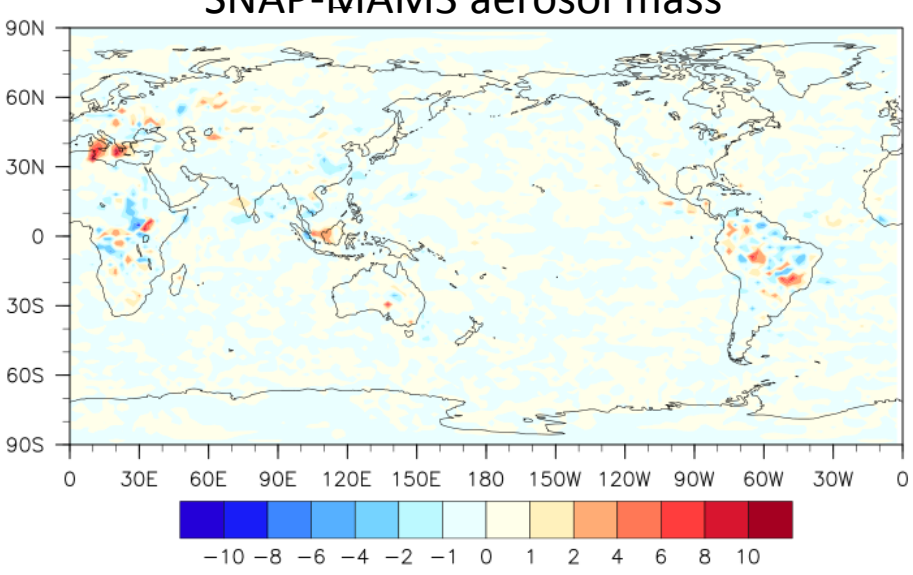
(*Jen-Ping Chen and I-Chun Tsai*)

	MAM3	SNAP
size distribution	modal	modal
# of modes	2	2
prognostic variables	Num, Mass	Num, Area, Mass
aerosol species	S, C, BC, SS, D	S, C, BC, SS, D
aerosol mixture	internal	external+internal
microphysical processes	nucl, cond, coag, d+w dep	nucl, cond, coag, d+w dep, ice nucl
activation	Abdul-Razzak and Ghan (2002)	Chen and Liu (2004)
diagnostic eqs		eq size, CC, modal ext/abs coefficient

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.