A Multi-year Hindcast Experiment for Cloud and Precipitation Studies

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with

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CESM Atmosphere Model Working Group Meeting, Boulder, CO, February 8-10, 2016

LLNL-PRES-678782

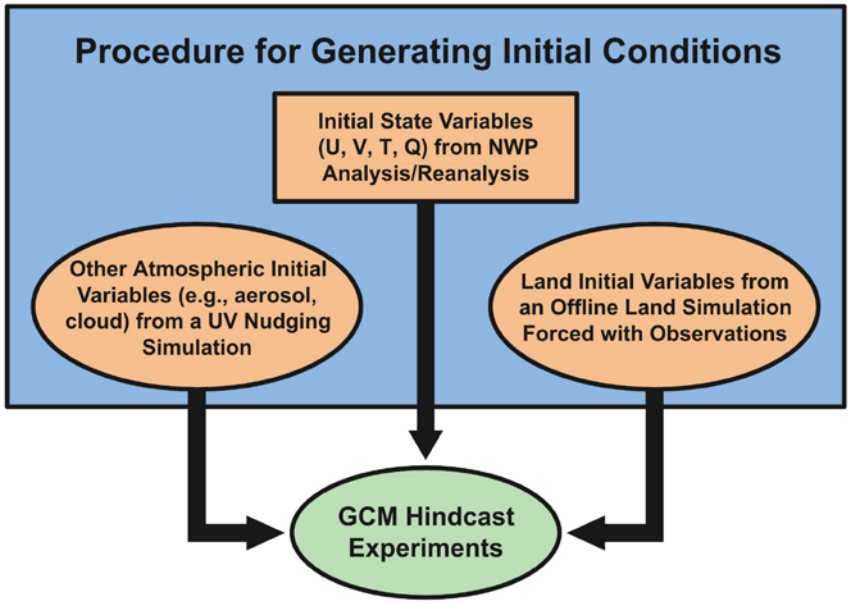
This work was performed under the auspices of the U.S. Department of Energy by Lawrence Livermore National Laboratory under contract DE-AC52-07NA27344. Lawrence Livermore National Security, LLC

Why Multi-year Hindcast Experiment?

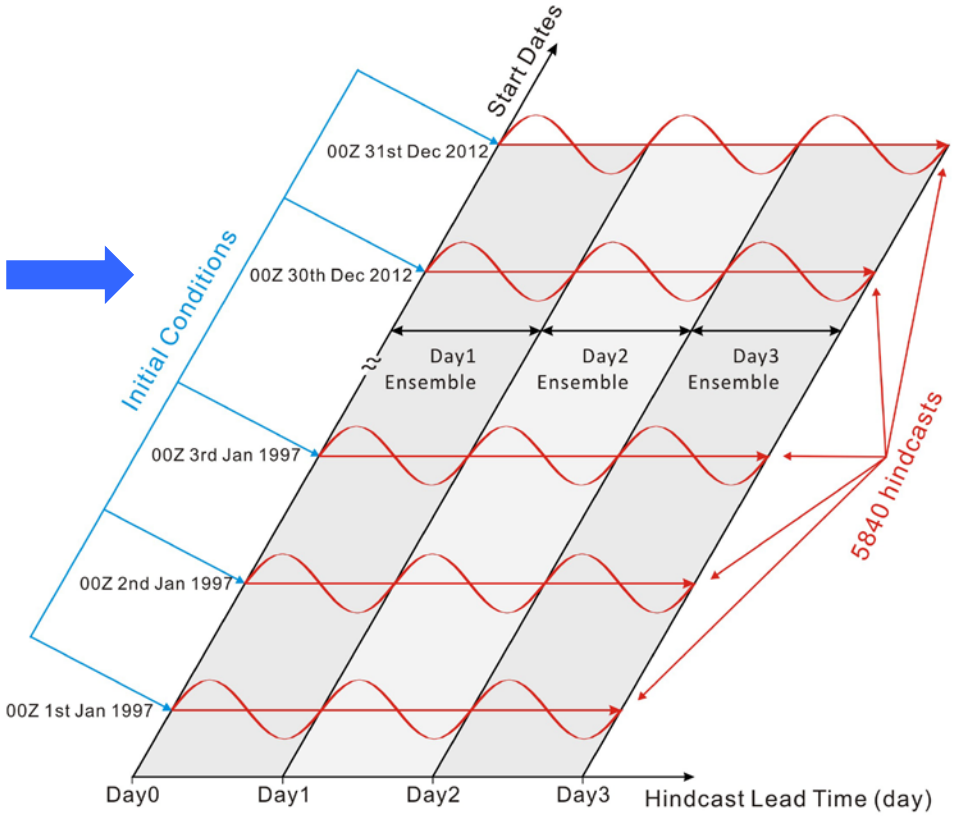
- To compare model simulations (particular moist processes) to ***long-term observations***, such as data collected from the U.S. DOE Atmospheric Radiation Measurement (ARM) sites
- To establish ***robust model systematic biases*** and identify possible causes
- To diagnose how moist processes depend upon the ***imposed large-scale state*** (with a companion AMIP simulation)

Experiment Design

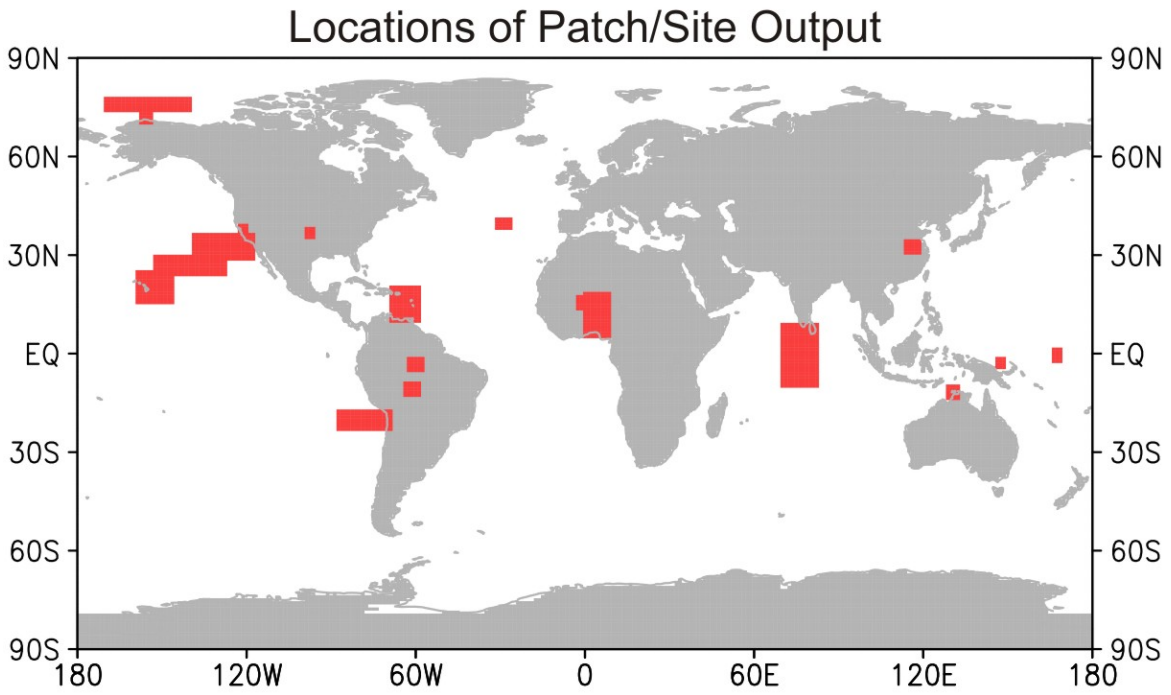
- 3-day long hindcasts starting every data at 00Z for the period of 1997 – 2012 (CAM5.1, 0.9 x 1.25 degree and L30)



Ma et al. JAMES (2015)



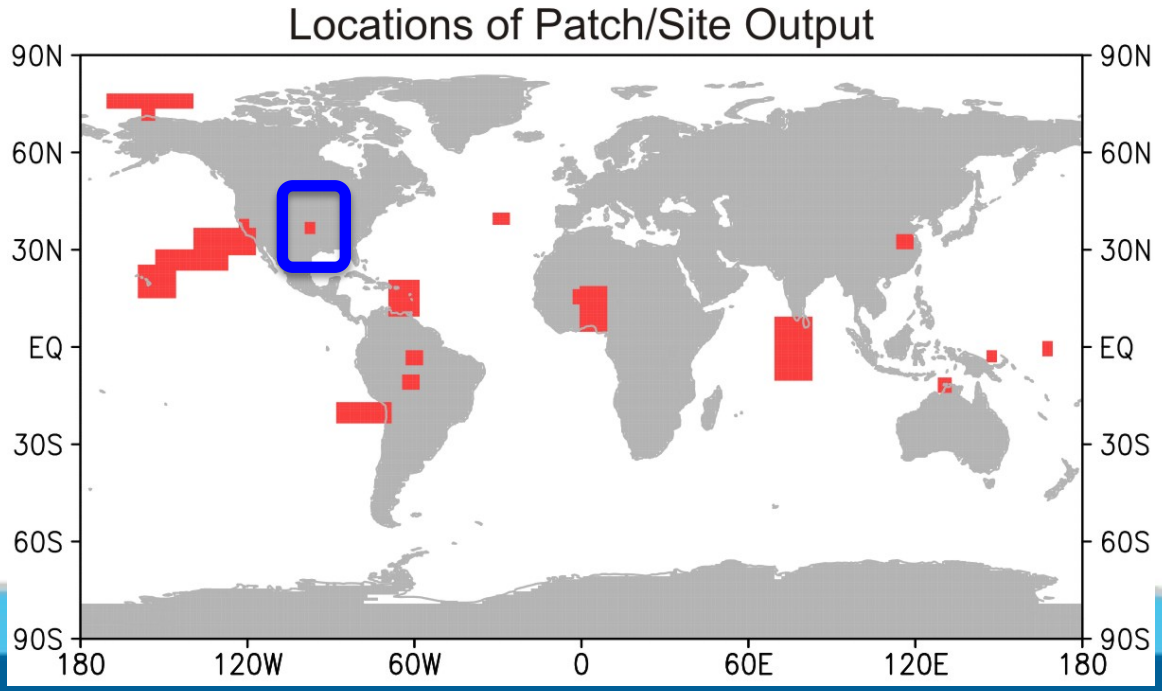
Locations of Patch/Site Output



- **Time-step model output for ARM and major field campaign locations to better study cloud processes at model time step level.**
- **3-hourly global fields including T & Q budgets and selected variables from satellite simulators.**

Studies using ARM observations

- Cloud and precipitation simulations over land (SGP)
- Land-Atmosphere coupling (SGP)
- Marine boundary layer cloud modeling (Azores)

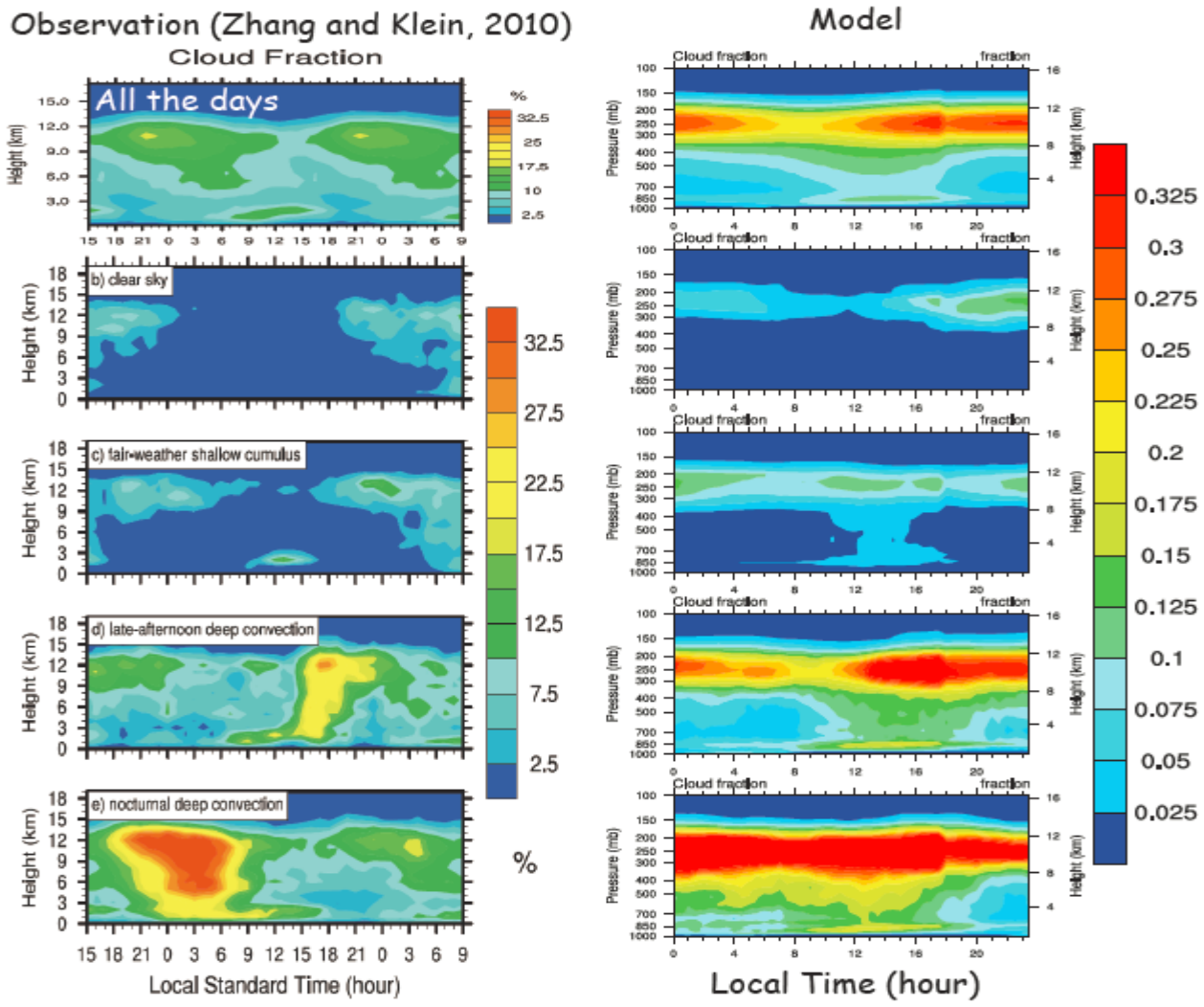


Cloud and precipitation simulations over Land

- What is the performance of CAM5 under well-imposed meteorological conditions and land-surface conditions in simulating diurnal and interannual variability during summertime at SGP?
- Will such evaluation provides any working direction for future LES/SCAM runs given reasonable large-scale forcing and boundary conditions?

(Courtesy of Y. Zhang)

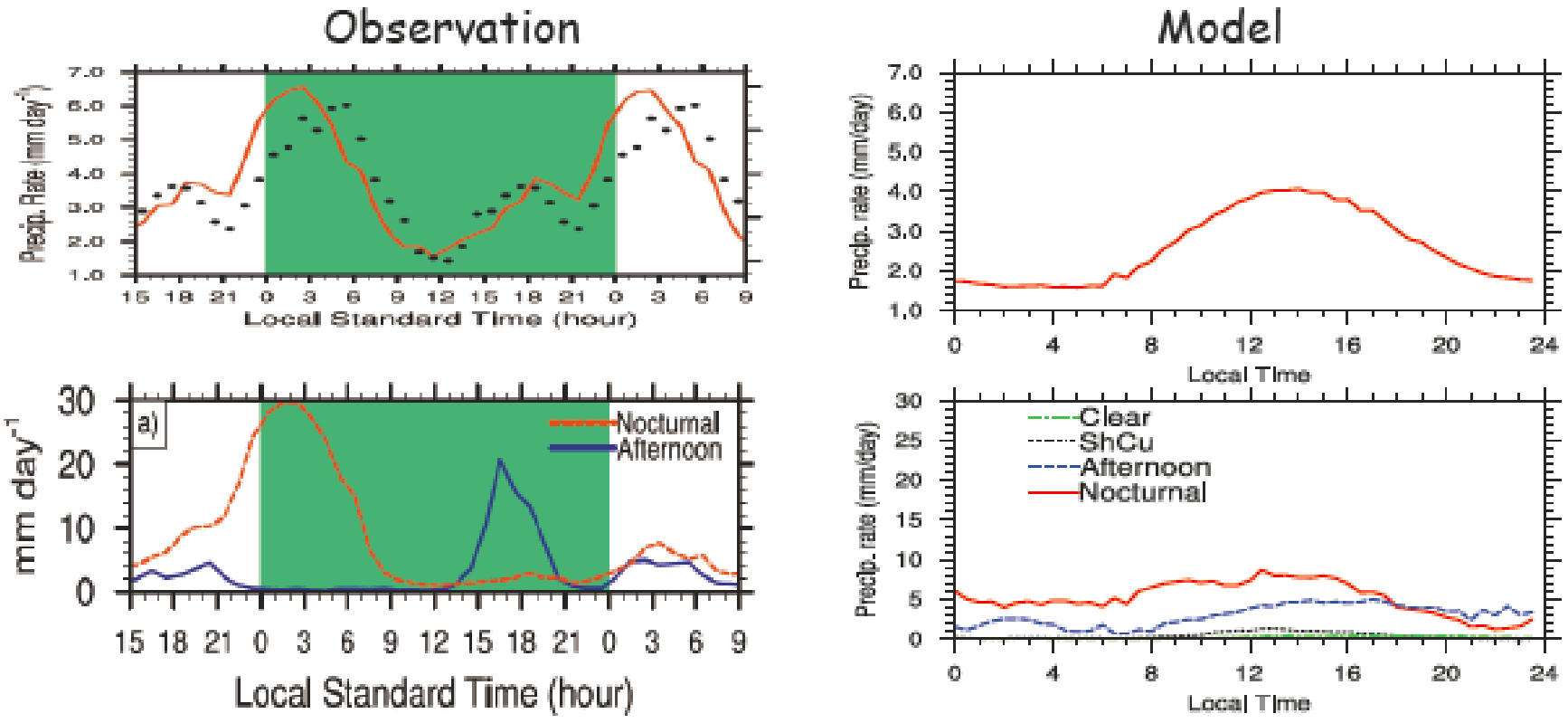
Diurnal Cycle of Clouds at SGP



- An prevailing overestimate of high clouds between 200 and 300 mb.
- On local-surface forced convection days, CAM5 tends to generate shallow convection and late-afternoon deep convection with comparable cloud onset time.

(Courtesy of Y. Zhang)

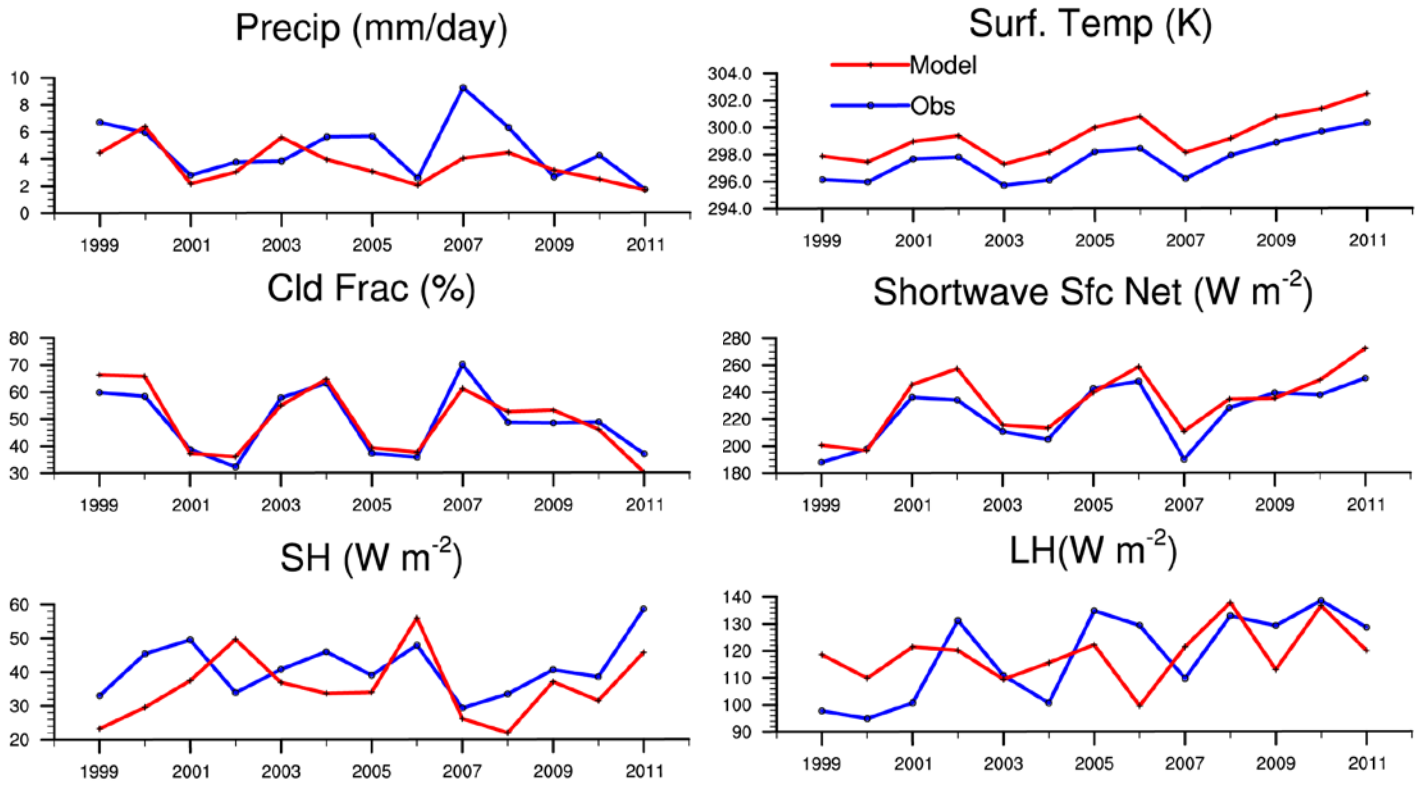
Diurnal Cycle of Precipitation at SGP



- Model still simulates poor diurnal cycle of precipitation over land even with the well-constrained large-scale state.

(Courtesy of Y. Zhang)

Interannual variability



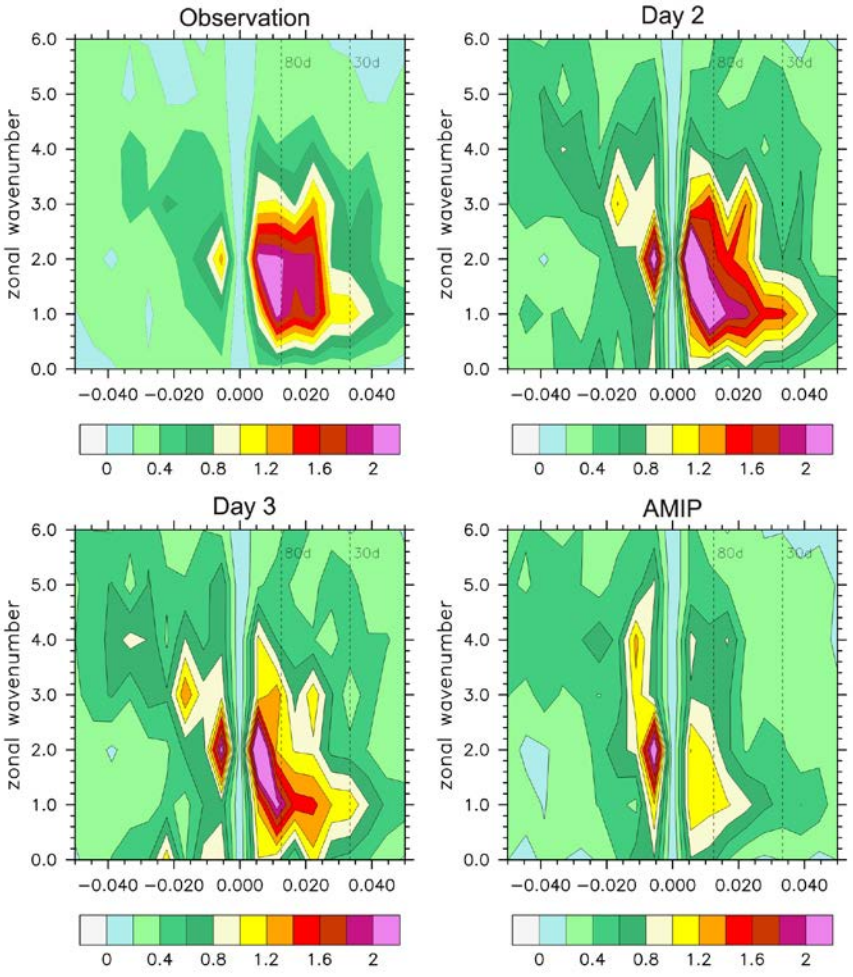
- Note the interannual variability of the simulated fields (Day 2) at ARM SGP site.

(Courtesy of Y. Zhang)

Regional and Global Studies

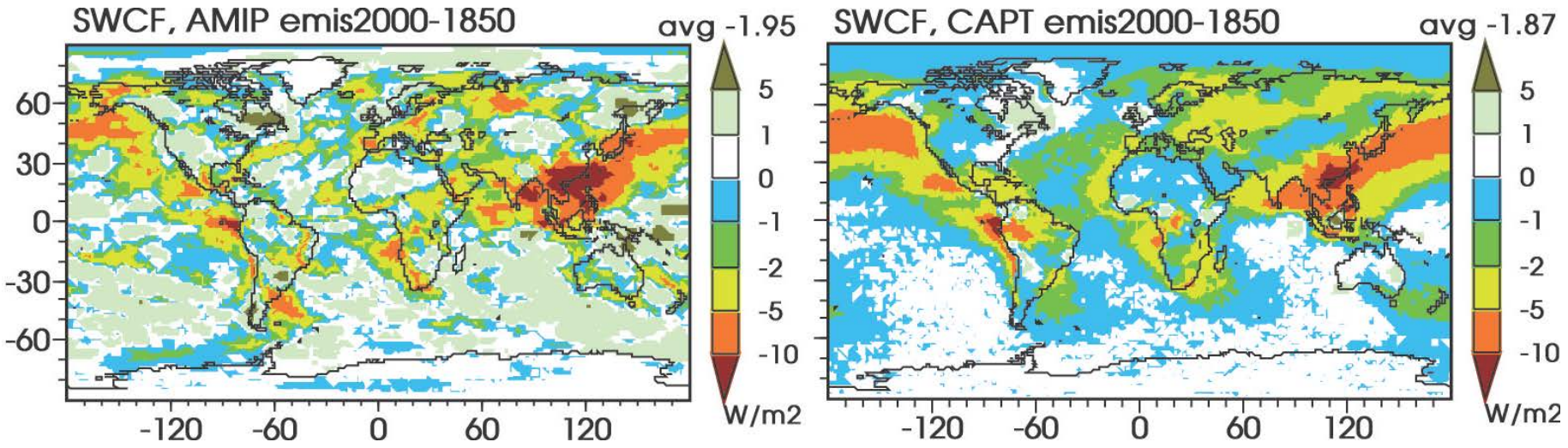
- Intraseasonal variability in the tropics
- Aerosol cloud interactions
- Interannual variability of cloud radiative effect and feedbacks
- Monsoons
- Warm bias over the U.S. Midwest
- Droughts in the U.S. or other regions
- Atmospheric river
- Clouds and precipitation response to ENSO

Intraseasonal variability in the tropics (OLR)



- Models tend to simulate poor intraseasonal variability in the tropics.
- The Day 2 hindcasts can capture the intraseasonal signals relative well.
- However, the power spectrum of OLR starts to decay on the intraseasonal band at Day 3.

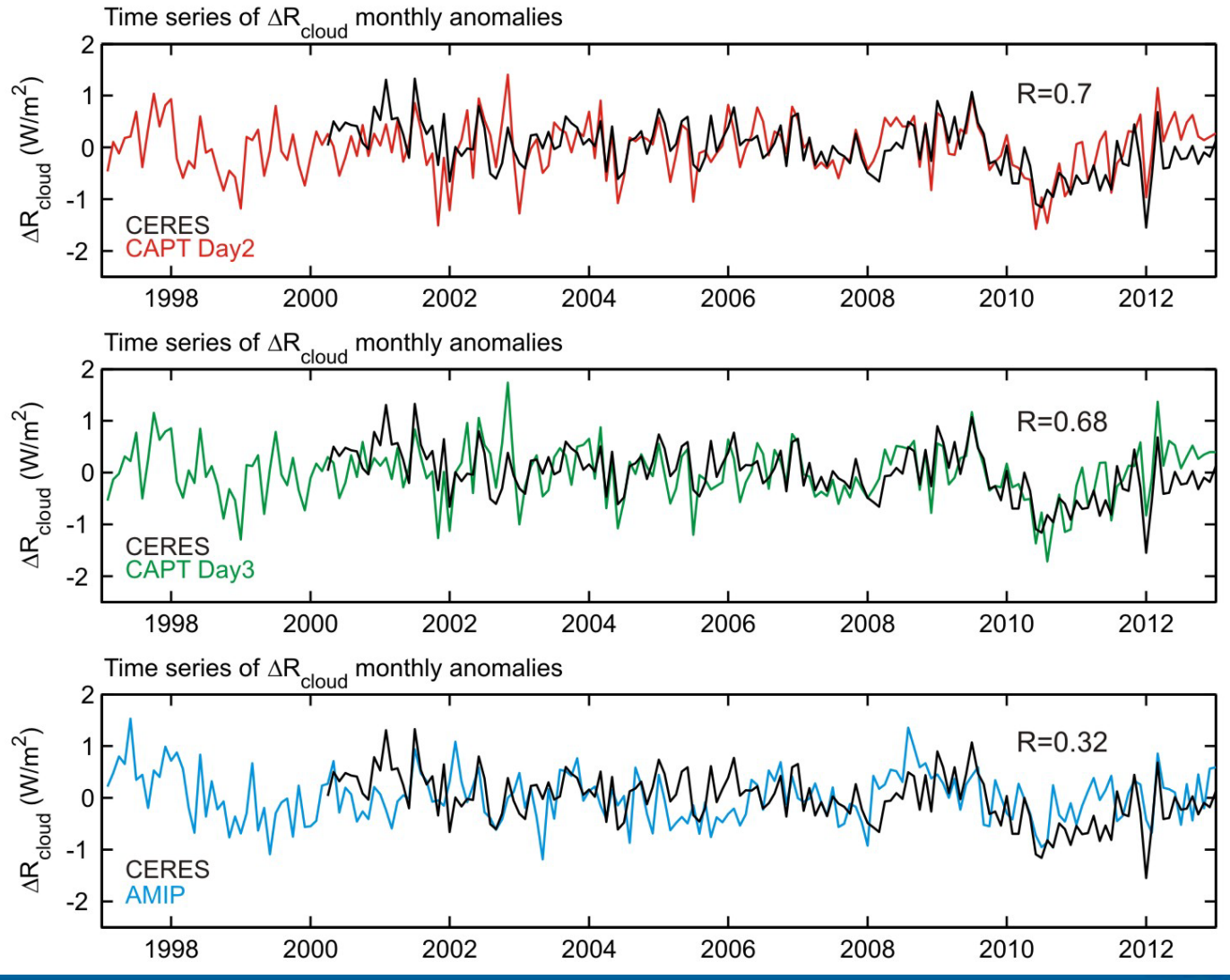
Cloud-Aerosol Interactions



- The average effects of aerosols on clouds as simulated in CAM free-evolving climate integrations (left) are well replicated with many short-term hindcasts (right), but with less noise due to constrained dynamics in CAPT hindcasts
- CAPT hindcasts with varying aerosol emissions can be used to diagnose the impact of aerosols on clouds.

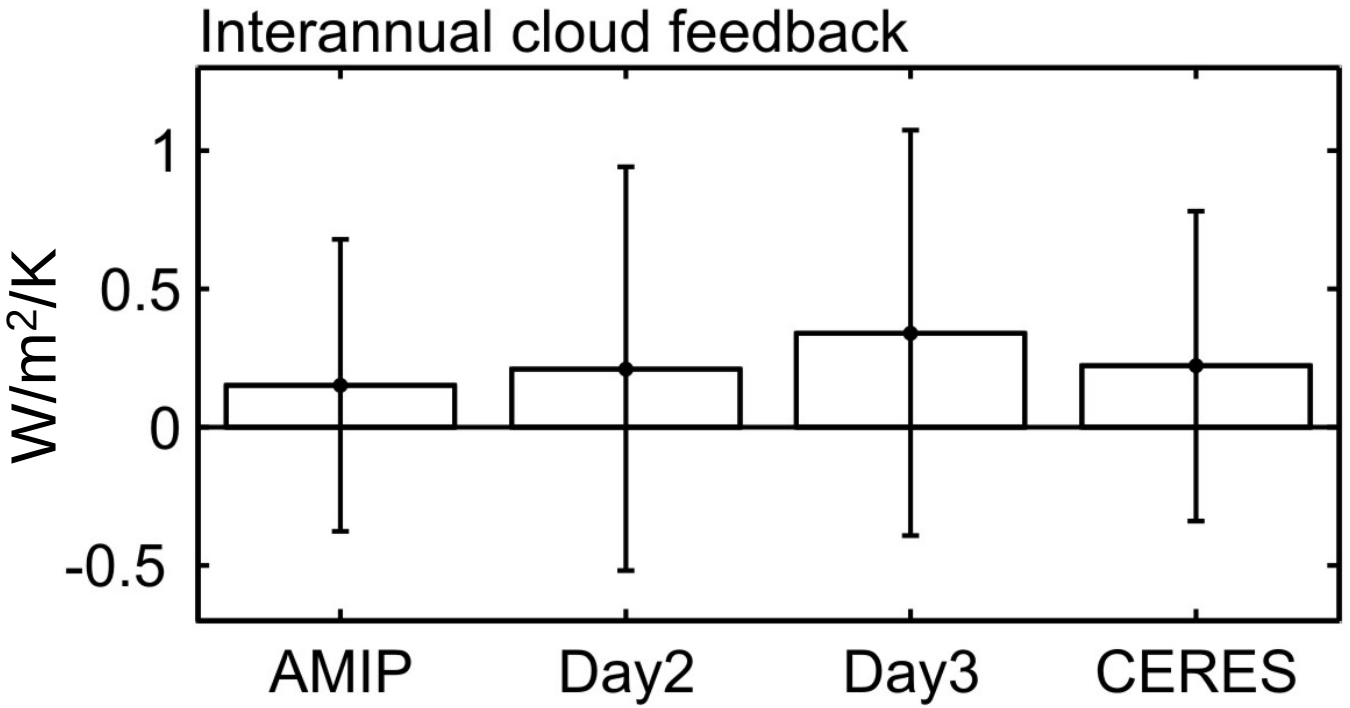
(Courtesy of C. Chuang)

Interannual Cloud Radiative Effect



Courtesy of C. Zhou and M. Zelinka

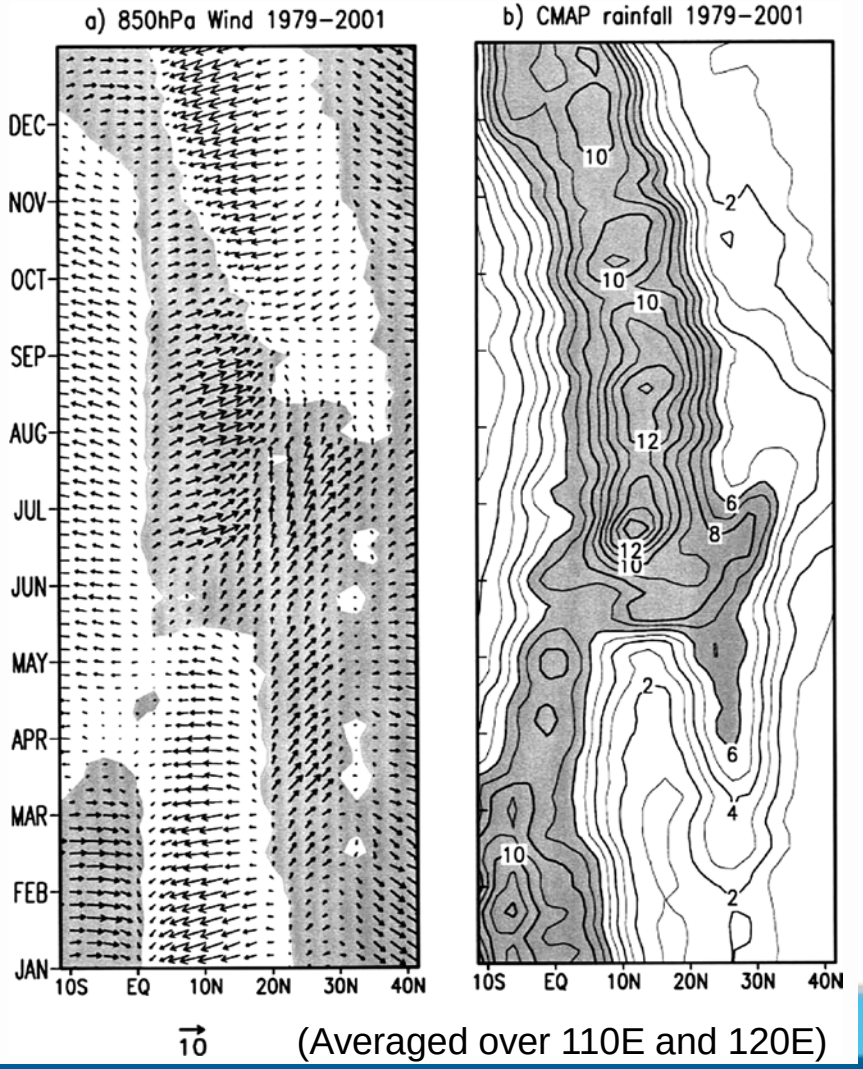
Short-term Cloud Feedback



- Difference between interannual cloud feedback in AMIP and CAPT is not statistically significant.
- Whether model dynamical fields are close to obs or not has little contribution to the magnitude of interannual cloud feedback, at least for CAM5

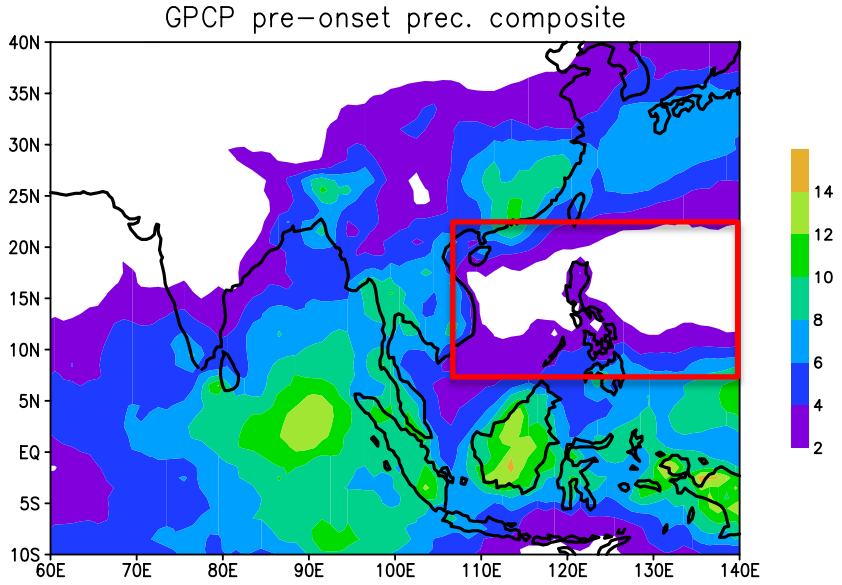
Courtesy of C. Zhou and M. Zelinka

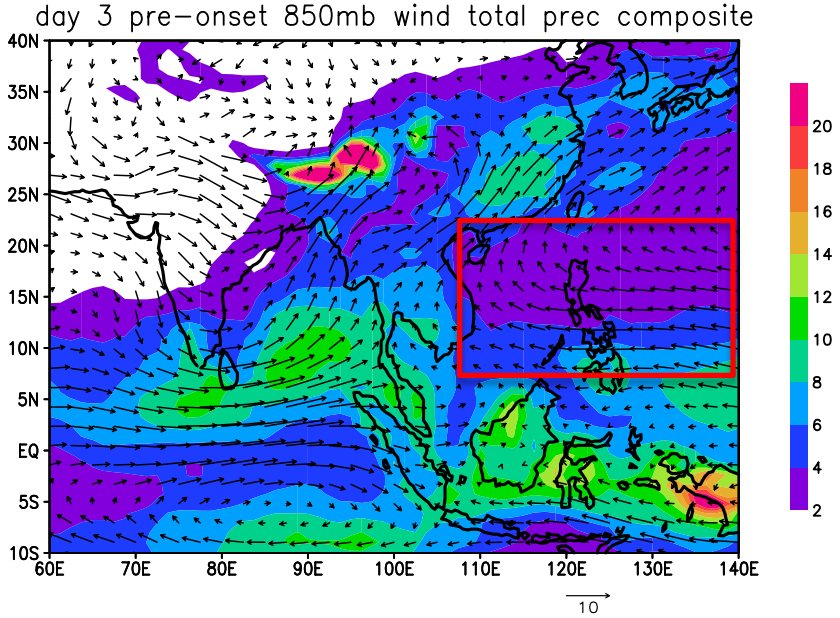
Onset of East Asian summer monsoon

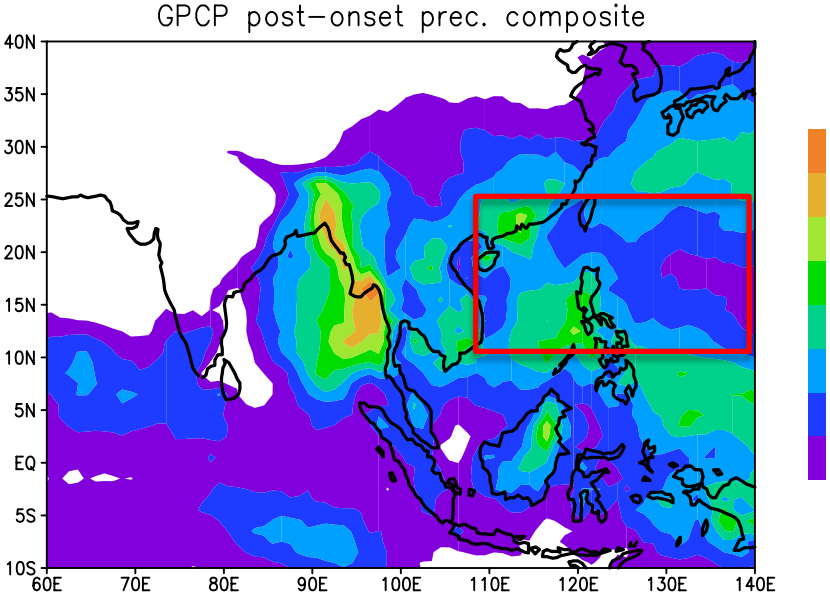


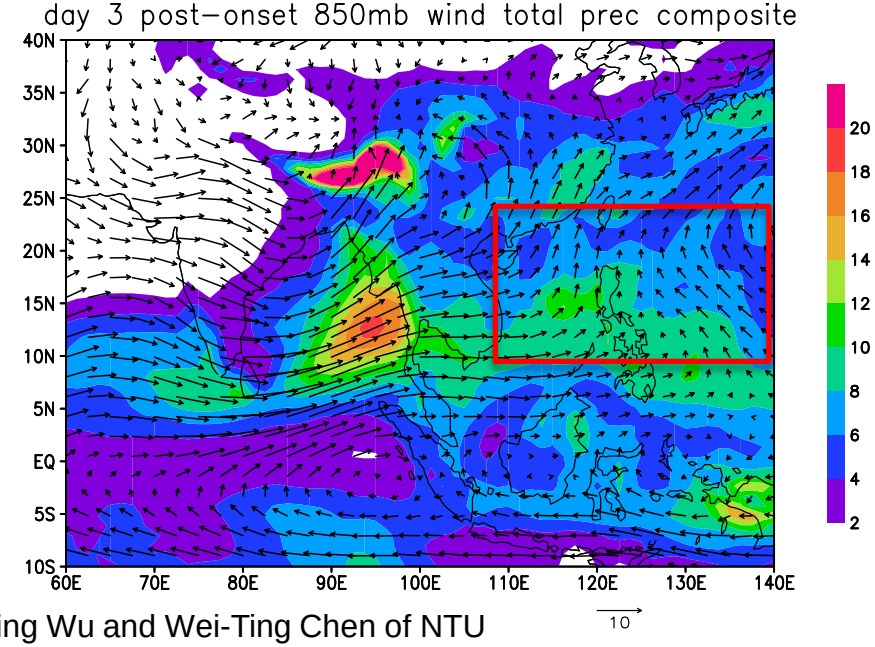
- A unique feature of the summer monsoon is the simultaneous commencement across its large latitudinal range from 3 to 22N.
- U_{scs} (5-15N, 110-120E) to determine the monsoon onset date
  - In the onset pentad $U_{scs} > 0$ m/s
  - In the subsequent four pentads, U_{scs} must be positive in at least three pentads and the accumulative four pentad mean $U_{scs} > 1$ m/s

Bin Wang et al. 2004 JCLI







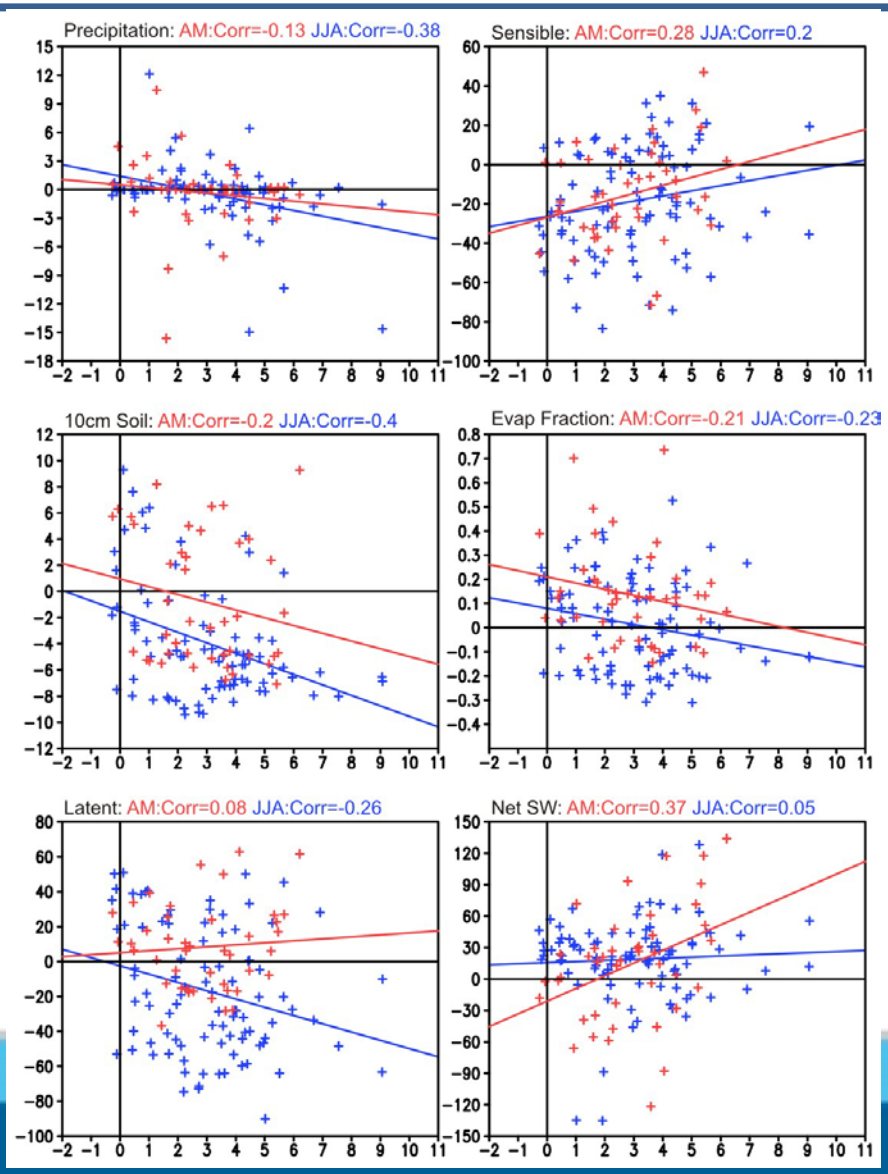


Courtesy of Profs. Chien-Ming Wu and Wei-Ting Chen of NTU

Summary

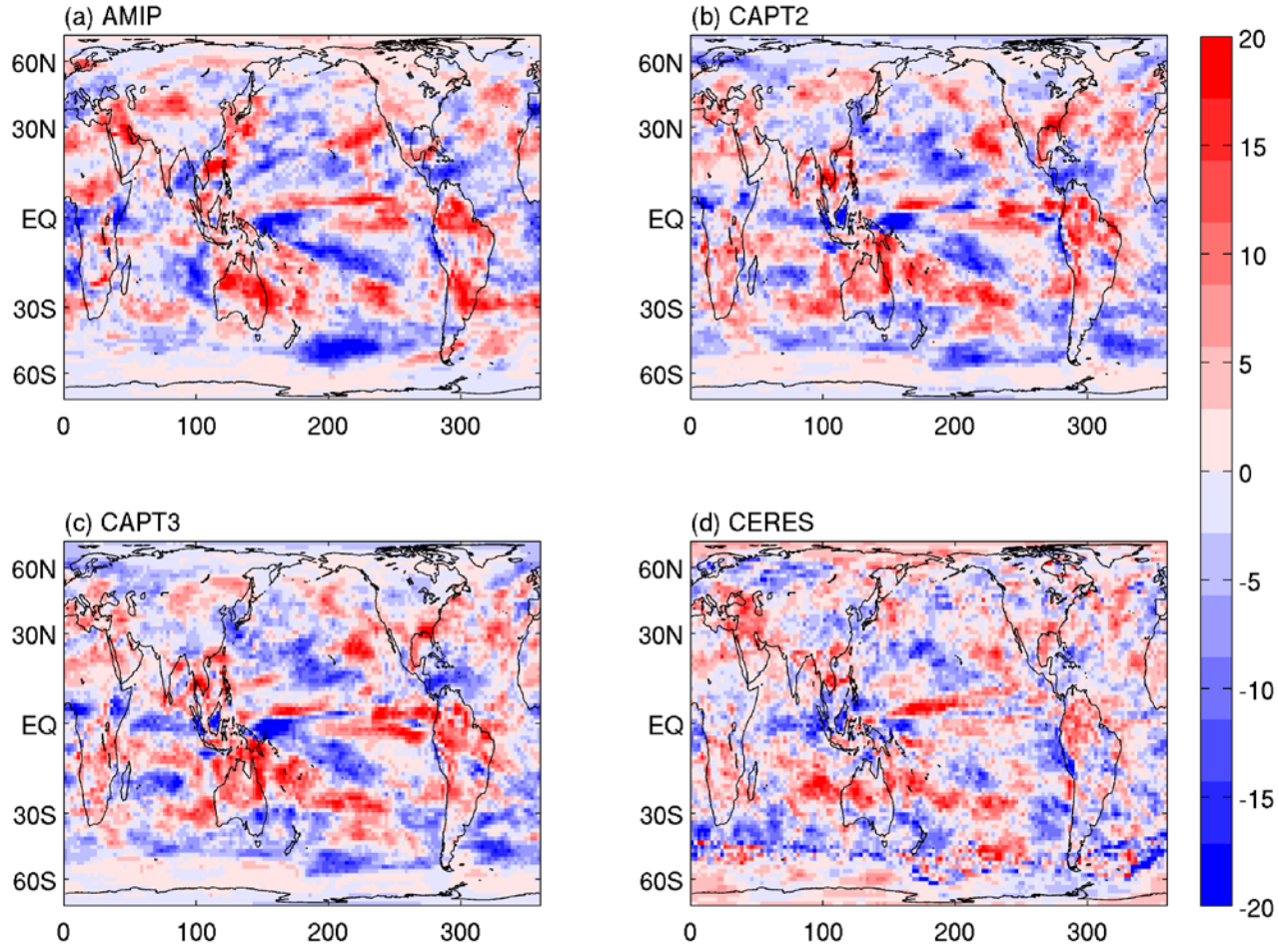
- Multi-year hindcast experiments allow us to conduct detail process-level studies of cloud and precipitations compared to long-term observations (e.g., DOE ARM observations)
- We can identify robust systematic model biases through multi-year analysis.
- A corresponding AMIP simulation with the same output allows one to diagnose how cloud processes depend upon the imposed large-scale state.

What causes a warm bias in surface air temperature over land? (CAUSES project)



- Cloud and net surface radiation biases seems to play important role in T2m bias in April and May (AM)
- However, precipitation and soil moisture biases contribute more the T2m bias in June-August (JJA).
- Are these features robust beyond 2011?

Interannual Cloud Feedback



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