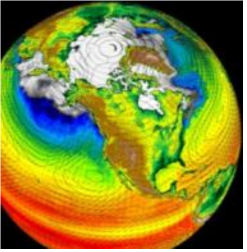
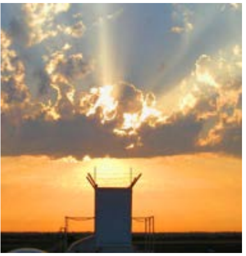
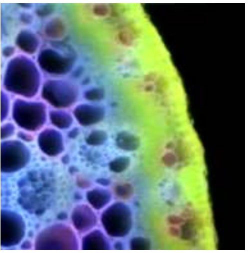
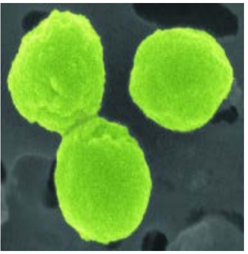



Regional and Global Climate Modeling Program and synergies with the Atmospheric Sciences Research Program

Renu R Joseph
Program Manager, RGCM

Climate and Environmental Sciences Division
Gary Geernaert

Atmospheric Science

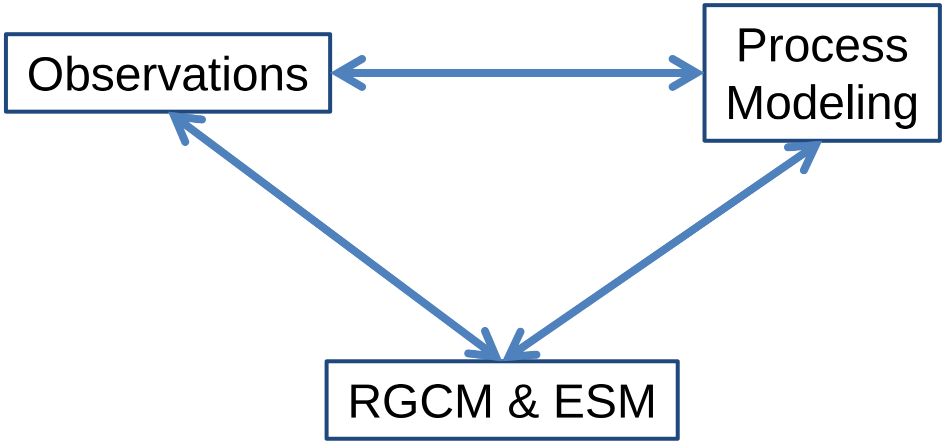
- Atmospheric System Research
- Atmospheric Radiation Measurement Facility

Climate and Earth System Modeling

- Earth System Modeling
- Regional & Global Climate Modeling
- Integrated Assessment

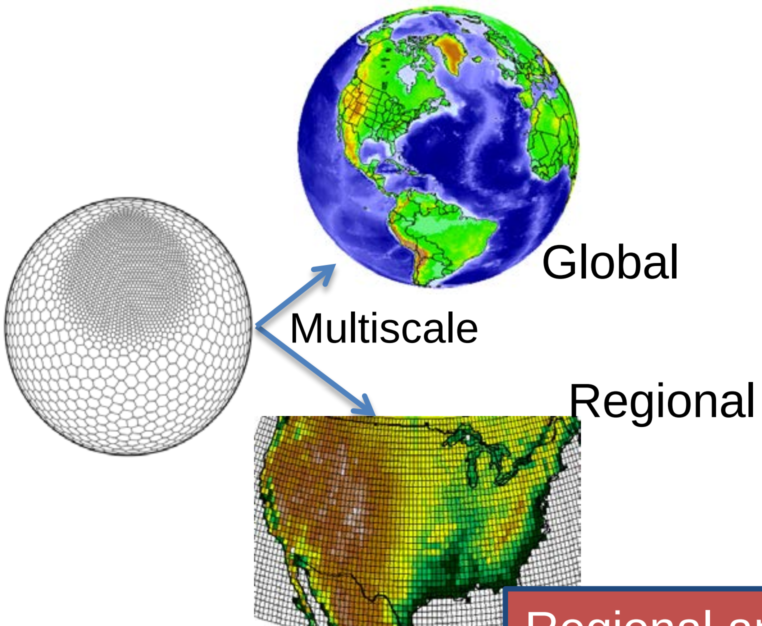
Environmental System Science

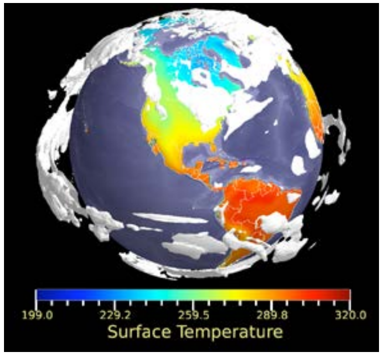
- Terrestrial Ecosystem Sciences
- Subsurface Biogeochemical Research
- Environmental Molecular Sciences Laboratory Facility

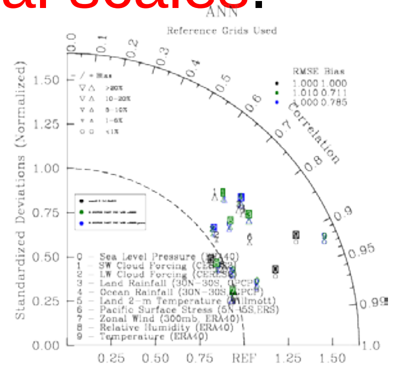


Climate and Earth System Modeling

To advance fundamental understanding of climate variability and climate change by *developing* and *analyzing* Earth System Models and Integrated Assessment at temporal scales ranging from seasons to centuries and spatial scales ranging from global to regional to understand climate and energy impacts at global and regional scales.







Earth System Modeling

Regional and Global Climate Modeling

Integrated Assessment Research Program

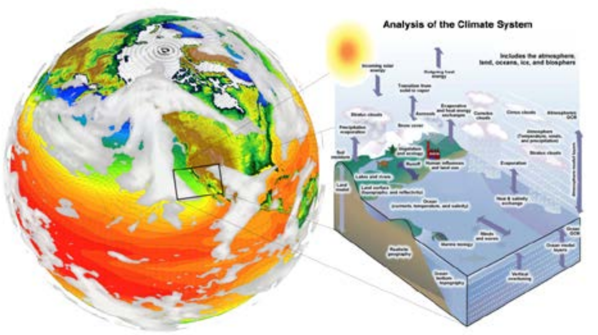
Regional and Global Climate Modeling (RGCM) Program

To develop a predictive understanding of the earth's climate, it's variability and change by focusing on the analysis and analytics of:

i. Regions and processes critical to the Earth's climate;

ii. Methods to obtain reliable information at higher spatial resolution;

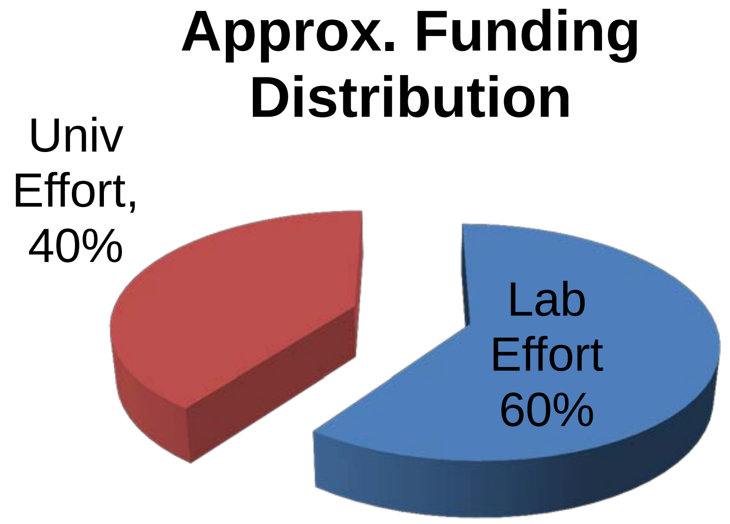
iii. Coupled climate and earth system models to understand climate variability and change



- *Modes of variability*
- *Detection and Attribution of Climate Change*
- *Extremes* event representation and attribution
- *Feedbacks* and interactions between processes within the climate system
- Quantification of the *uncertainties*
- *Biases in ESMs*
- Development of *metrics* to inform model development

RGCM portfolio

- Lab Projects
- Cooperative Agreements
- University Projects



Lab Projects

1. Climate Variability and Change
2. Multiscale analysis, Extreme events, ESM model biases
3. Water Cycle and Climate Extremes
4. Validation and Benchmarking of Biogeochemical Cycles
5. High Latitudes, Decadal Predictions, Sea-level Rise

Cloud-Associated Parameterization Testbed

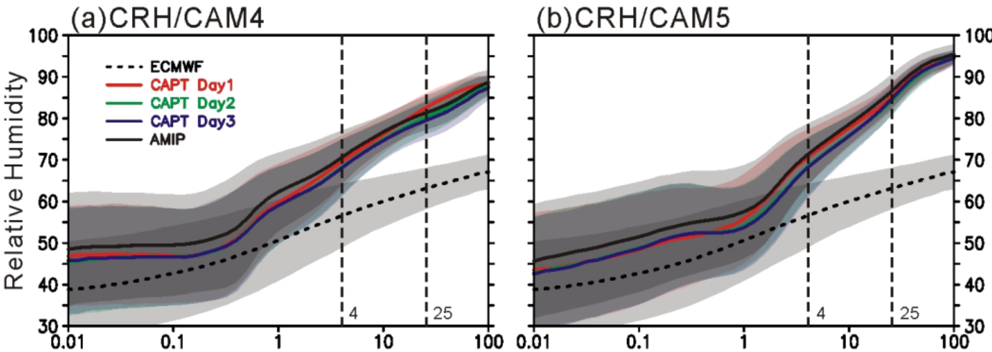
Steve Klein, LLNL

- Integrating climate model cloud schemes in ***weather-forecast mode*** helps with:
  - Comparing climate model simulations to field-campaign data (e.g. ARM sites)
  - Identifying the sources of climate errors
  - Examining MJO sensitivities of CAM5 with perturbed parameter hindcasts
  - Testing new parameterizations in CAPT mode (e.g., Mapes & Neale convective organization parameterization)
  - Developing metrics

Key Accomplishment

- A suitable set of metrics and diagnostics has been proposed and implemented in understanding and linking climate model hindcast errors to their climate errors.
- Many climate errors (e.g., in tropical precipitation) grow fast and are seen in the first few days of the hindcasts.
- Both CAM4 and CAM5 lack intense precipitation events because they require much higher column relative humidity than observations.

Diagnostics help understand why model errors occur

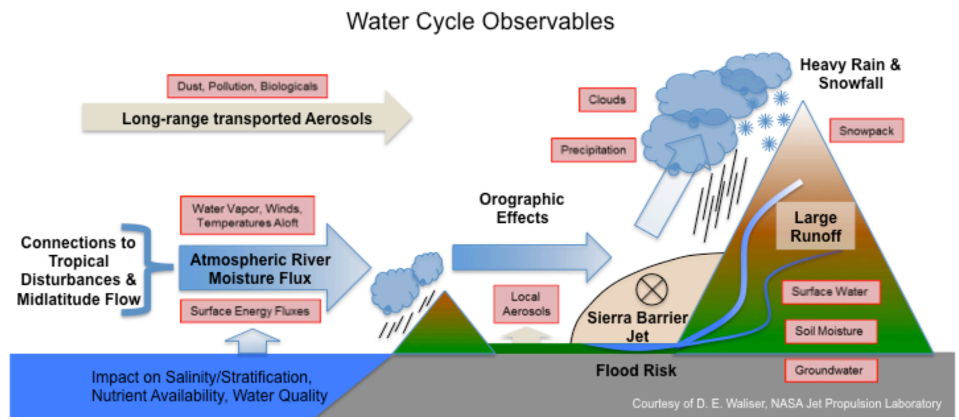


Ma, H., S. Xie, J. S. Boyle, S. A. Klein, and Y. Zhang, 2012: Metrics and diagnostics for precipitation-related processes in climate model short-range hindcasts. J. Climate. In press. doi: http://dx.doi.org/10.1175/JCLI-D-12-00235.1.

Water Cycle and Climate Extremes

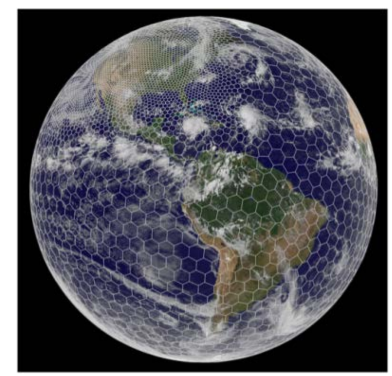
L. Ruby Leung, PNNL

Water cycle extremes in the western U.S.



Science questions

- Can climate models robustly simulate the global and regional water cycle changes?
  - How well can high resolution models simulate water cycle processes?
  - How will water cycle extremes such as floods and droughts change in the future?
  - What are the roles of land-atmosphere and air-sea interactions in modulating the water cycle?



Approach

- Climate models (CAM ,MPAS and HOMME) are used to test hypotheses related to processes of water cycle extremes (e.g., the development and evolution of atmospheric river (AR), role of tropical – extratropical interactions)
- Data including field measurements are used to evaluate climate models and the effects of model resolutions, physics parameterizations, and dynamical cores on simulating floods and droughts (e.g., AR and the associated clouds and precipitation)
- Improve modeling of terrestrial hydrologic processes in the Community Land Model

ARM Cloud Aerosol Precipitation Experiment (ACAPEX)

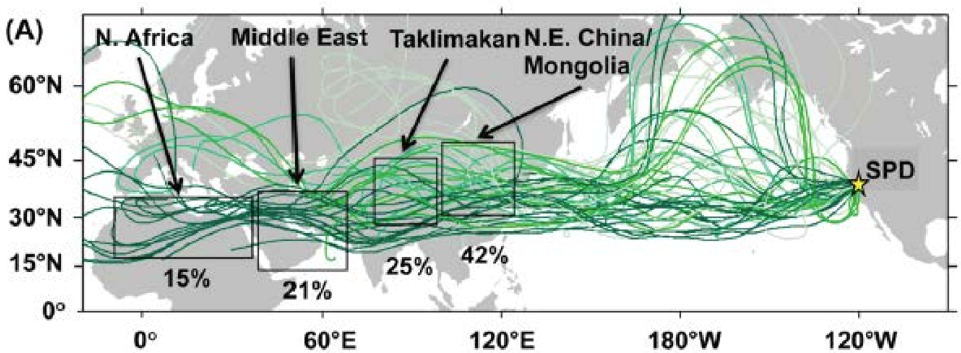
L. Ruby Leung[1], Kim Prather[2], Marty Ralph[3], Danny Rosenfeld[4], Ryan Spackman[3]

[1]PNNL; [2]UCSD; [3]NOAA ESRL;[4]Hebrew University of Jerusalem

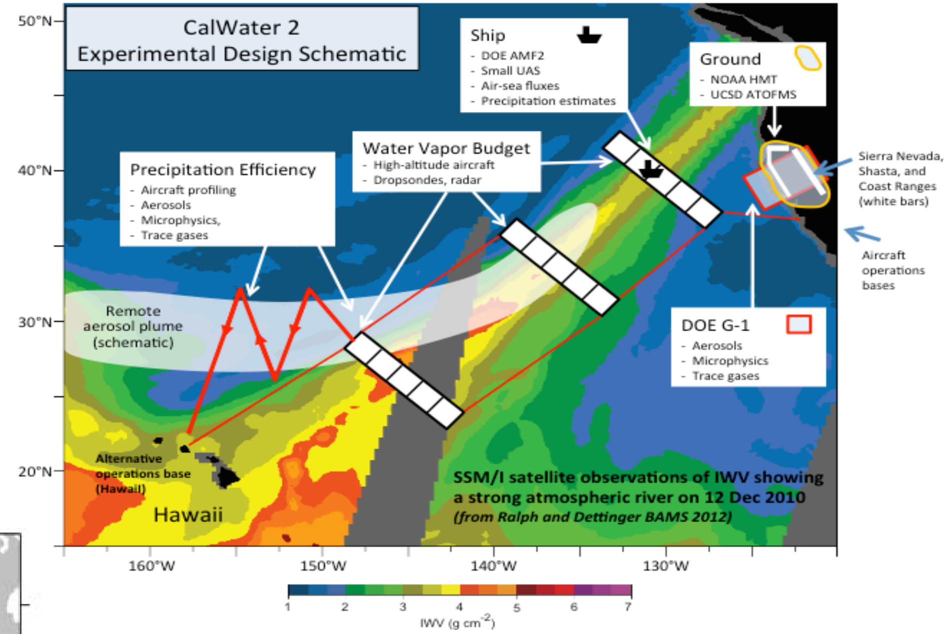
Science questions

- **What influences the evolution and structure of atmospheric river (AR) and its associated cloud and precipitation?**
- **How do aerosols affect the amount and phase of precipitation? How do aerosols influence the development of extratropical cyclones?**

Dust sources from back trajectory analysis over Sugar Pine Dam during storms in 2011 showing trajectories from the Sahara and East Asia (Creamean et al. 2012)



CalWater 2 / ACAPEX observational strategy



Courtesy of F. M. Ralph, NOAA Earth System Research Laboratory

CalWater2 / ACAPEX includes a <u>targeted set of aircraft and ship-based measurements</u> offshore of California and in the central and eastern Pacific for an intensive observing period between <u>December 2014 and March 2015</u>

Creamean, J.M., K.J. Suski, D. Rosenfeld, A. Cazorla, P.J. DeMott, R.C. Sullivan, A.B. White, F.M. Ralph, P. Minnis, J.M. Comstock, J.M. Tomlinson, and K.A. Prather, 2013: Dust and biological aerosols from the Sahara and Asia influence precipitation in the western U.S. Science, DOI: 10.1126/science.1227279

The ASR/RGCM Solicitation – Tropical Biases

- Examine and improve our understanding of **tropical clouds and precipitation** in uniform high or variable resolution global models, global cloud resolving models, and/or regional models, by improving the process representations in the context of tropical Atmospheric Radiation Measurements.

- To foster interactions between atmospheric process and global modelers

  Use observations in the tropics with a particular focus on ARM to identify uncertainties in precipitation and cloud processes in global uniform high or variable resolution models, cloud resolving global models, and/or regional models

  – Develop a modeling framework using a hierarchy of models ranging from single column models to global models to test and improve parameterizations

  – Implement this knowledge into the development or improvement of high resolution global models.

  – Reduce biases in the often identified problems relating to precipitation and clouds in global models.

Funding ranges:	$250,000 to 500,000/year
Time frame:	3 years

Using ARM Measurements to Understand and Reduce the Double ITCZ Bias in CESM

Minghua Zhang[1], Andrew Vogelmann[2]
[1]SUNY Stony Brook; [2]BNL

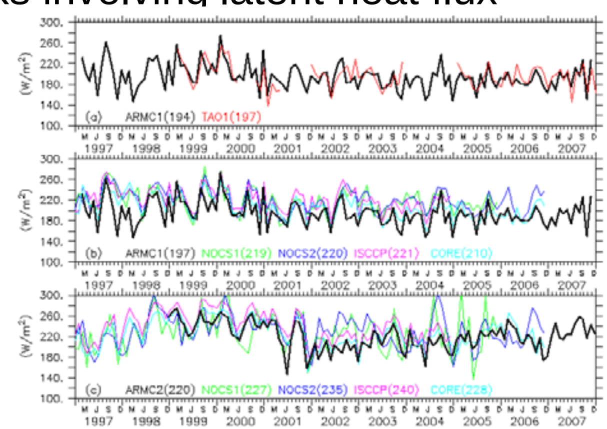
Objectives:

- To better understand the physical cause of the double ITCZ bias in coupled atmosphere-ocean models;
- To use ARM measurements to better constrain the cumulus parameterization and reduce the double ITCZ bias in the Community Atmospheric Model.

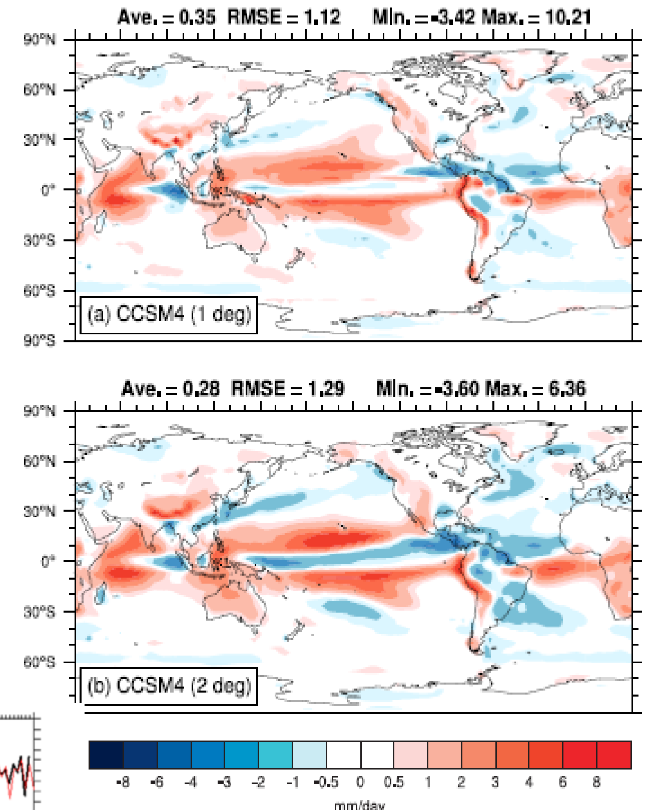
Approach and Results

- Initial-value experiments are used to investigate the trigger and feedback processes of the double ITCZ in CCSM.
    - Identified **excessive surface shortwave radiation** bias in standalone and coupled model.
    - Shortwave bias leads to warm SST biases that amplified through feedbacks involving latent heat flux and oceanic transport

Almost all global datasets overestimate the surface downward radiation relative to ARM data at Naru and Manus



Liu, Hailong, Minghua Zhang, Wuyin Lin, 2012: An Investigation of the Initial Development of the Double-ITCZ Warm SST Biases in the CCSM. *J. Climate*, **25**, 140–155.



Difference of CCSM4-simulated annual mean precipitation from GPCP observational estimates using the CAM component at (a) 1^{0} horizontal resolution, and (b) 2^{0} horizontal resolution (Gent et al , 2011).

Evolution in Cloud Population Statistics of the MJO: From AMIE Field Observations to Global Cloud-Permitting Models

Chidong Zhang[1], Min Deng[2], Jimy Dudhia[3], Samson Hagos[4], Pavlos Kollias[5], Zhiming Kuang[6], Chuck Long[4], Brian Mapes[1], Wei-Kou Tao[7]

[1]University of Miami; [2]University of Wyoming; [3]NCAR; [4]PNNL; [5]McGill University; [6] Harvard University; [7] NASA

Background: The AMIE/DYNAMO field campaign (1 Oct ‘11 – Mar 31 ‘12) observed three MJO events with a variety of instruments, including multiple wavelength radars (Fig. 1). These observations provide unprecedented opportunity to document evolution of cloud population and microphysics for development of cloud permitting models (CPMs).

Objective: Apply AMIE/DYNAMO field observations to the development of CPMs that serve to help reduce biases in tropical cloud and precipitation in climate models

Approach: (a) Combine observations from multiple instruments to build observed statistics of clouds (precipitating and non-precipitating, shallow, deep and stratiform; organized and stochastic), cloud microphysics, and their environment; (b) Validate a hierarchy of CPMs with different domains against the observations; (c) identify the source of biases in tropical cloud and precipitation.

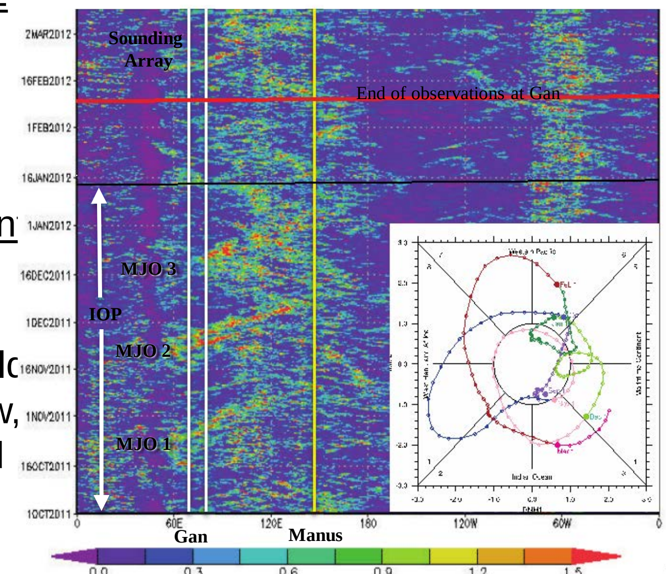
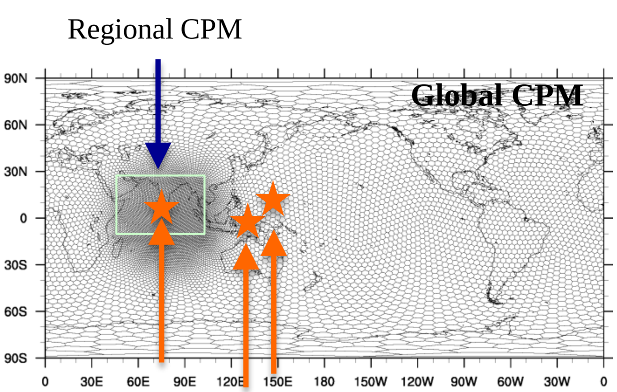
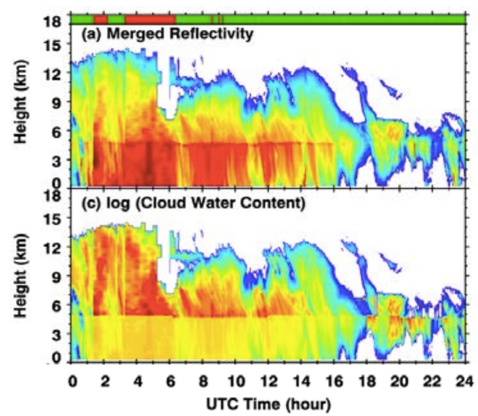


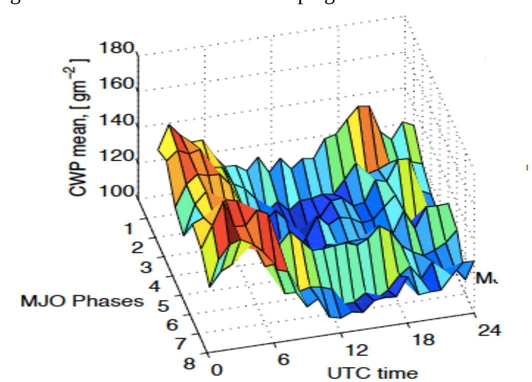
Figure 1 Time-longitude diagram of TRMM precipitation (mm/hr) during the AMIE/DYNAMO field campaign



Observations and local CPMs



KASR/S-Polka merged reflectivity and cloud water content at Gan



Composite of the diurnal cycle in cloud water content in different MJO phases at Manus.

Impacts of Aerosols and Air-Sea Interaction on Community Earth System Model (CESM) Biases in the Western Pacific Warm Pool Region

R. Saravanan[1], S. Mahajan[2], and P. Chang[1]
[1]Texas A&M University; [2]Oak Ridge National Laboratory

Motivation:

- Air-sea interaction plays an important role in determining the climate of the tropical Pacific.
- The Western Pacific Warm Pool region bears a significant influx of aerosols (Fig. 1).
- Uncoupled atmospheric models ignore the possible role of coupled climate feedbacks.
- Fully coupled ocean-atmosphere model can capture the feedbacks, but are more complex to analyze.
- A hierarchy of intermediate coupled models can help us better understand the impact of air-sea feedbacks on aerosol-climate interaction.

Methodology:

- Carry out a high-resolution control integration of CESM1.0
- Carry out uncoupled atmospheric model integrations
- Carry out CAM5+SOM (slab ocean model) integrations. This will capture the thermodynamic aspects of air-sea interaction.
- Carry out integrations using CAM+RGOM (reduced gravity ocean model). This can capture upper ocean feedbacks, including the role of El Nino-Southern oscillation (ENSO)
- Compare simulations to ARM datasets

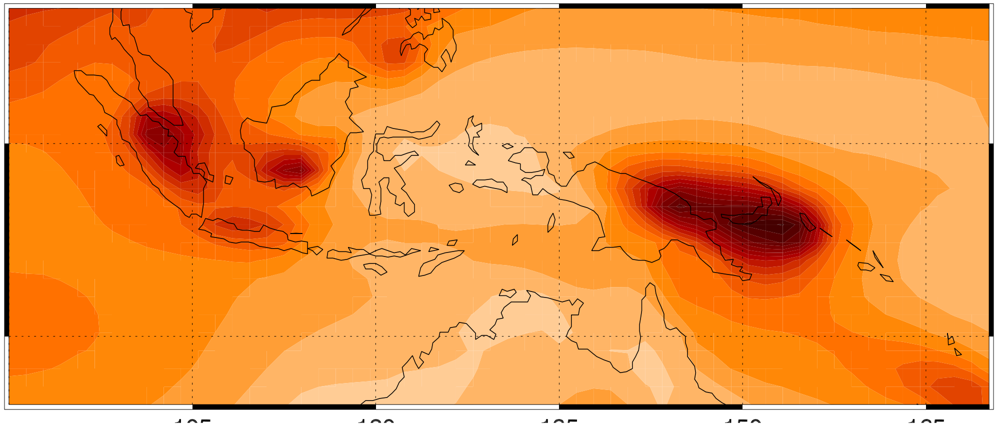


Fig. 1: Aerosol Optical Depth for the period 1991-2000 over the WPWP averaged over the months of September-November derived from an ensemble of stand-alone CAM4 experiments prescribed with a high-resolution (1x1) tropospheric aerosol dataset with monthly resolution.

Department of Energy, Office of Science

Reducing tropical precipitation biases in CESM —Tests of unified parameterizations with ARM observations

V. Larson, A. Gettelman, H. Morrison, J. Bacmeister, G. Feingold, S.-S. Lee, C. Williams

Main problem that our project addresses:

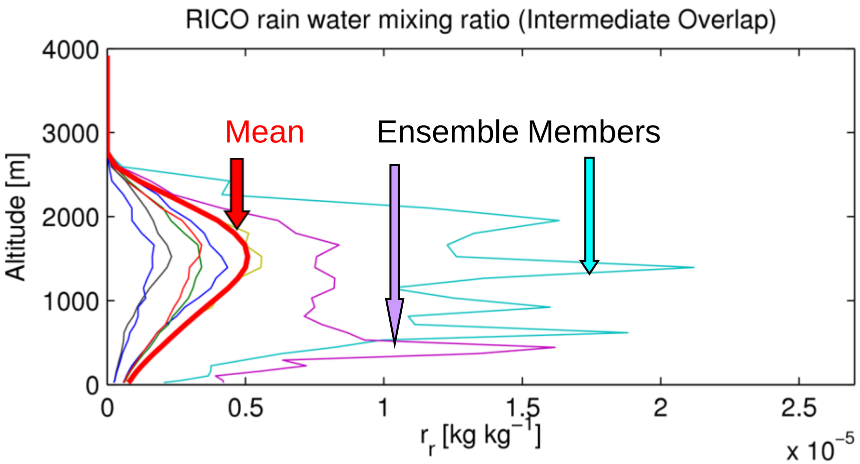
Climate models use **3 different microphysical parameterizations:** 1 for stratiform cloud, 1 for shallow cumulus, and 1 for deep cumulus. The use of 3 schemes leads to undue complexity and inconsistency.

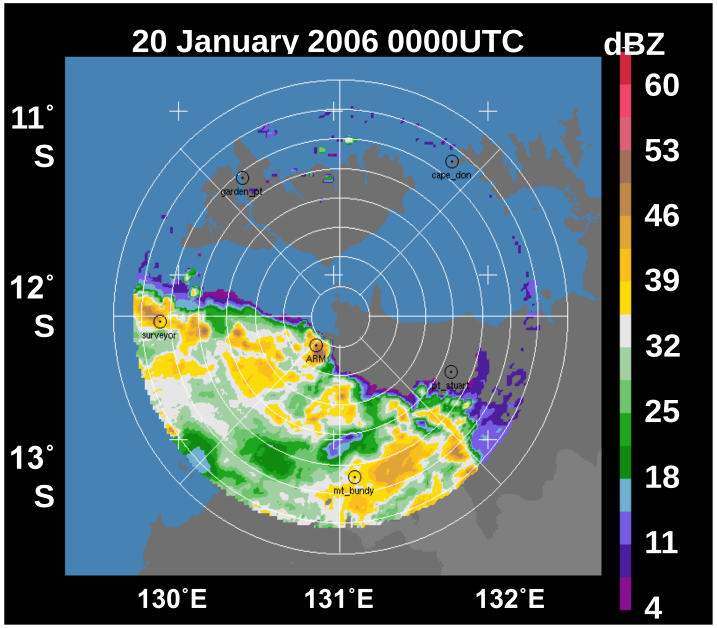
Proposed Solution:

Unify convective parameterizations and unify microphysics parameterizations.

Accomplishments to date

Constructed a climate model with unified microphysics and completed year-long global test simulations.





C-Pol radar obs from Darwin (TWP-ICE) illustrate the small-scale variability in deep convection that ought to be parameterized in climate models.

Rain profiles drawn from climate model distribution provide a more apple-to-apple comparison with ARM "point" profiles from radars.

Larson and Schanen (2013): "The Subgrid Importance Latin Hypercube Sampler (SILHS): a multivariate subcolumn generator." Geosci. Model Dev. Discuss., 6, 1–39, www.geosci-model-dev-discuss.net/6/1/2013/

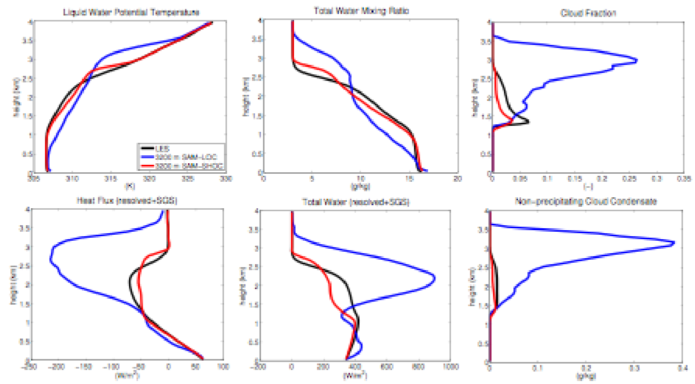
High-resolution global modeling of the effects of subgrid-scale clouds and turbulence on precipitating cloud systems
The TuRbulence Intercomparison Project (TRIP)

David Randall, Peter Bogenschutz, Anning Cheng, Grant Firl, Steven Ghan, Marat Khairoutdinov, Steven Krueger, Vincent Larson, and Chin-Hoh Moeng

Objectives: To implement, test, and evaluate four recently developed turbulence parameterizations, using a wide variety of methods and modeling frameworks together with observations including ARM data. The turbulence schemes considered are:

- Cloud Layers Unified by Binormals (CLUBB)
- Diagnostic Higher-Order Closure (DHOC)
- Intermediately-Prognostic Higher-Order Turbulence Closure (IPHOC)
- Two-and-a-Half ORder closure (THOR)

ARM Southern Great Plains data, June 21, 1997



Horizontally and temporally averaged profiles of liquid water potential temperature, total water mixing ratio, cloud fraction, the fluxes of moist static energy and total water, and cloud water mixing ratio. The new model (SAM-SHOC) agrees with LES much better than the old model (SAM-LOC).

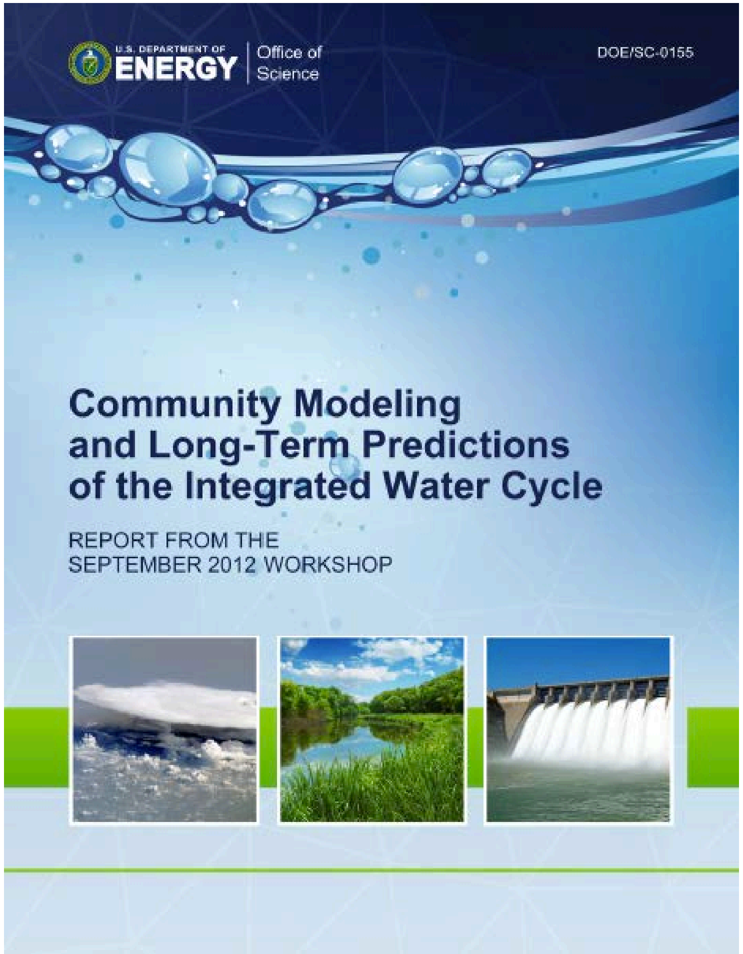
Approach:

- Compare and evaluate parameterizations on the basis of:
  - a priori conceptual merits, including closure assumptions;
  - the realism of the results obtained in tests, including tests with global models; and
  - their computational speeds.
- Some modest development work will be done to take advantage of what is learnt from the test results.

Bogenschutz, P., and S. K. Krueger, 2013: A Simplified PDF Parameterization of Subgrid-scale Clouds and Turbulence for Cloud-Resolving Models. Accepted by *J. Geophys. Res.*

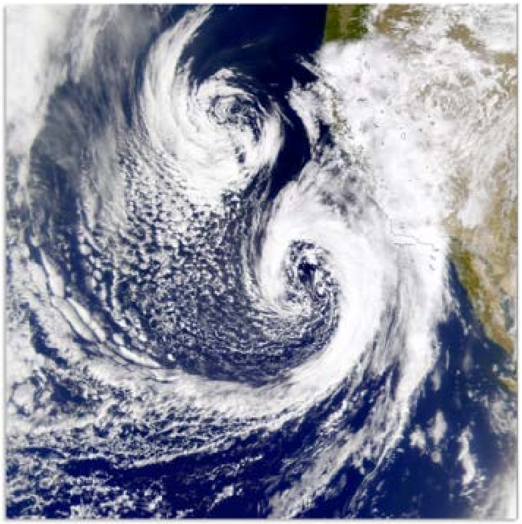
Community Modeling and Long-Term Predictions of the Integrated Water Cycle

- Goal: Identify challenges of next generation human-earth system models for improving long-term predictions of the **regional-scale integrated water cycle**
- Co-chairs:
  - L. Ruby Leung, PNNL
  - Bill Collins, LBNL
  - Jay Famiglietti, UC Irvine
- September 24 – 26, 2012 Washington DC
- ~ 80 invited participants including representatives from 8 agencies
- Culminated in an interagency panel discussion



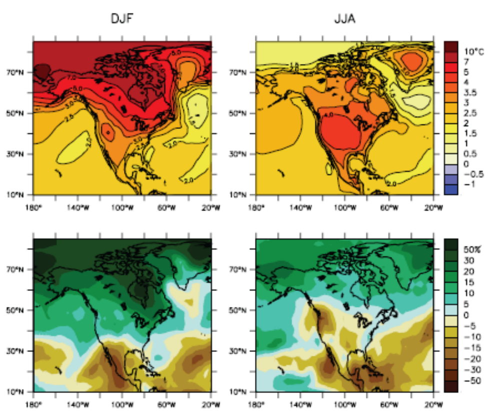
Science Grand Challenge 1

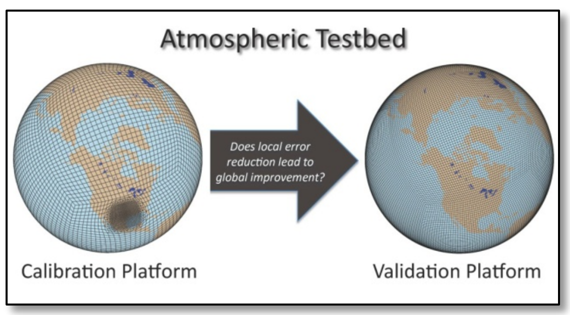
- Modeling the multi-scale atmospheric and terrestrial processes and their interactions
  - Understanding the scaling and scale interactions of atmospheric and terrestrial processes
  - Representing the multi-scale processes and the interactions across systems in earth system models
  - Model testbed, evaluation, and data needs

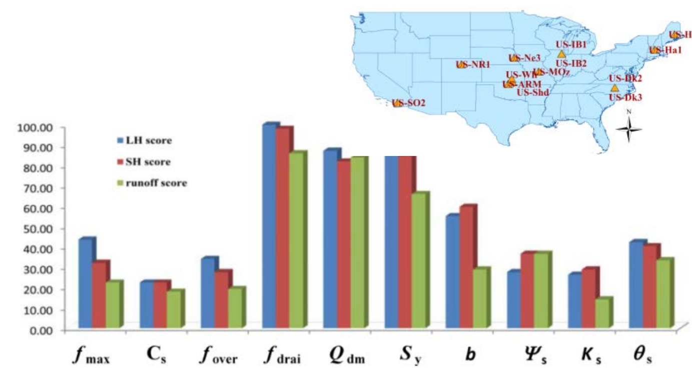


Science Grand Challenge 3

- Advancing prediction and uncertainty quantification for decision support and mission-oriented objectives
  - Advancing model predictions
  - Developing uncertainty quantification, metrics, and observations
  - Developing a team approach to use-inspired research







Priorities of ASR-RGCM Collaborations
(focus on development of "community" models)

- Identify and test methods of reducing biases in Regional and Global climate and Earth System Models
- Identify and prioritize processes/features that need attention
- Identify and prioritize regions to focus on
- Develop metrics to evaluate the veracity of models
- Quantify sources of uncertainty as means to guide development (e.g., what complexities and resolutions are needed to represent aerosol direct and indirect effects)




http://www.climatemodeling.science.energy.gov/

FY11 Solicitation - Decadal and Regional Climate Prediction using Earth System Models (EaSM)

Joint Effort by NSF, USDA and DOE (totaling ~50M)

Overall focus: Achieve comprehensive, reliable global and regional predictions of decadal climate variability and change through advanced understanding of the coupled interactive physical, chemical, biological and human processes that drive the climate system.

DOE’s focus

- Decadal Modes of Climate Variability
- Extremes
- Indirect Effect of Aerosols

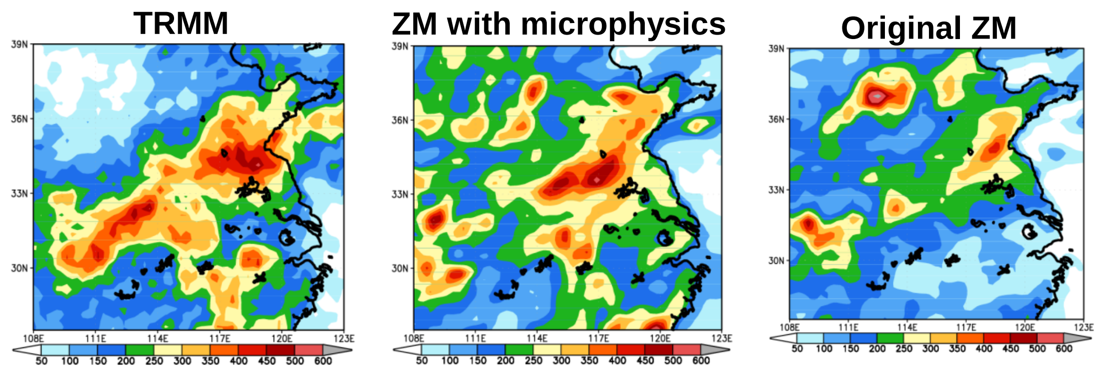
Simulating Aerosol Indirect Effects with Improved Aerosol-Cloud-Precipitation Representations in a Coupled Regional Climate Model

Yang Zhang[1], L. Ruby Leung[2], and Jiwen Fan[2]
[1]North Caroline State University; [2]Pacific Northwest National Laboratory

Objectives

- Develop and improve representations of aerosol effects on convective cloud and precipitation in climate models
- Evaluate models using surface, aircraft, satellite and reanalyses data
- Simulate aerosol indirect effects on hydrological cycle in East Asia

Observed and simulated precipitation (July 2009)



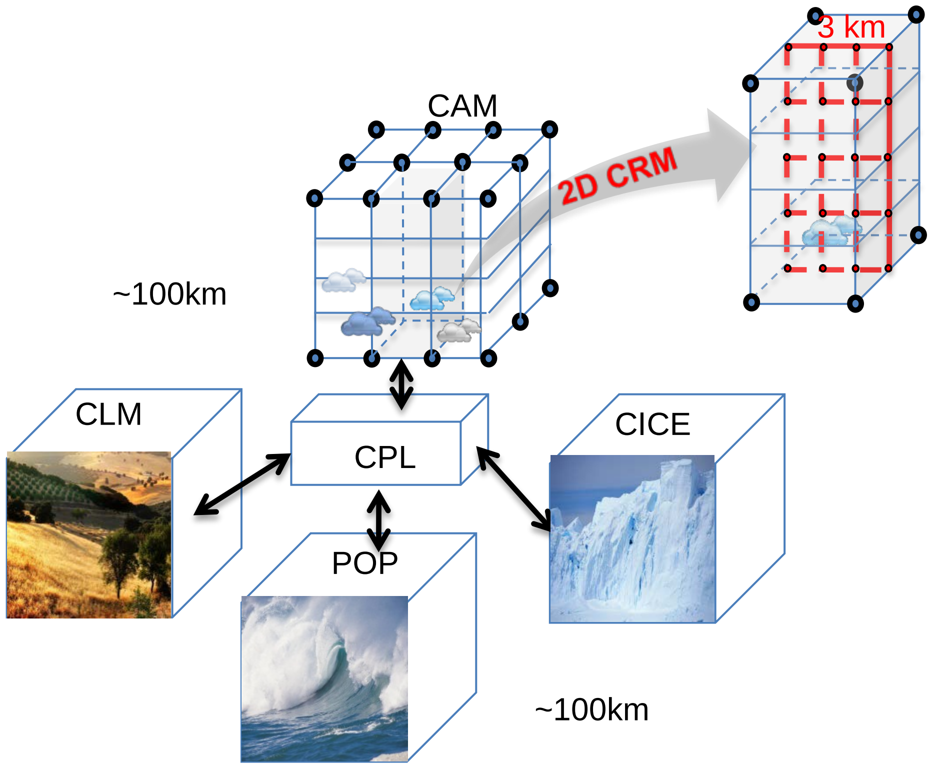
Recent Accomplishments and Activities

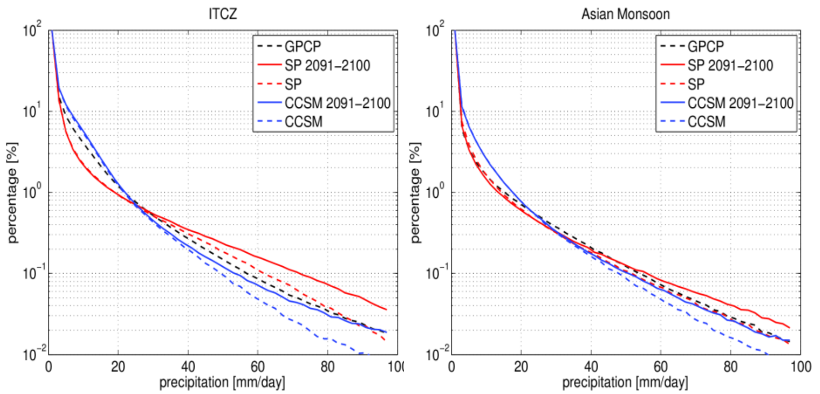
- Implemented Zhang and McFarlane (ZM) convective parameterization with a two moment microphysics scheme implemented by Song and Zhang (2011) to WRF, together with the CAM5 physics package
  - Evaluated simulations using satellite and AMF-China data showing improved performance with the new ZM scheme with microphysics – enhanced detrained cloud liquid and ice
  - ZM with microphysics showed aerosol invigoration of convection leading to TOA radiative warming
- Performed WRF-Chem simulations over East Asia to investigate aerosol effects
  - The Zender et al. (2003) dust emission module largely improved predictions of PM_{10} and AOD
  - Aerosols have large impacts on radiation, cloud properties, and other boundary layer processes

Reducing Uncertainty of Climate Simulations Using the Super-parameterized CESM

Science Questions

- What is the cloud representation impact on the simulation of precipitation extremes in the current climate and in future climate change scenarios?
- What is the cloud representation impact on the projection of droughts in future climate change scenarios?





Probability distribution function of daily precipitation over the Intertropical Convergence Zone (ITCZ) and Asian Monsoon region. Dotted lines correspond to current climate conditions and solid lines to the last decade of the 21th century.

Recent Accomplishments

- Completed a control simulation of 100 years
- Completed RCP8.5 simulation – 3 ensemble members

Available to the community through the NCAR ESG

Stan, C. and L. Xu, 2013: Climate simulations and projections with the super-parameterized version of CCSM4. *JAMES* (submitted).