Atmospheric Model Working Group(AMWG)

8:30 am Rich Neale (NCAR) -- Introduction and updates

8:45 am Peter Lauritzen/Christoph Erath (NCAR) – Transport and rethinking orography in CAM

9:00 am Julio Bacmeister (NCAR) - High-resolution CAM5-FV and CAM5-SE

9:15 am Dave Williamson (NCAR) - High resolution CAM5-CAPT hindcasts

9:30 am Kevin Reed (U. Mich) -Tropical Cyclone Climatology in High Resolution CAM

9:45 am Peter Caldwell (LLNL) – Improving the consistency of CAM5 physics

10:00 am Chris Bretherton (U. Washington) - Aerosol indirect effects in PBL clouds-LES vs. SCAM5

10:15 am Sungsu Park (NCAR) – UNICON and cumulus stratocumulus transitions

10:30 am ***Break***

11:00 am Steve Ghan (PNNL) – Superparameterized CAM

11:15 am Peter Bogenschutz (NCAR) - Coupling the Community Atmosphere Model with a High-Order Turbulence Closure

11:30 am Discussion (lead Minghua Zhang, Stony Brook)

12:00 pm ***Session Ends***

U.S. DEPARTMENT OF ENERGY | Office of Science

NSF

NCAR

NESL's Climate & Global Dynamics

SciDAC Scientific Discovery through Advanced Computing

DOE Biological and Environmental Research Program

Status of CAM5

Next CAM5 Release

- Release of CAM5 in the fall of 2012
  - Prescribed MAM aerosol (recent success)
  - Default settings for CAM spectral element (CAM-SE) at 1° and 0.25°
  - New settings for the specification of topography datasets (mean, variance)
  - Steps towards making CAM-SE the default

CMIP5 simulations and availability (CESM(CAM5) is best model in CMIP5!)

- Multiple simulations (pre-industrial, 20^{th} C , RCPs , AMIP, SOM, single forcing)
- Most CAM5-CESM simulations complete for 1°
- A suite of simulations at 2° completed (PNNL/NERSC)
- 2° simulations available on Earth System Grid (ESG) @LLNL
- All 1° simulations available on ESG very soon @NCAR
- J. Climate special issue papers accepted, submitted, in prep.

  http://www.cesm.ucar.edu/publications/pub.info.html

Status of CAM5

CESM(CAM5) CMIP5 simulations

- Reduces errors in SST (2° equivalent to CCSM4 1°)
- Cloud optical depth distributions significantly improved
- Improved winter- and summer-time high-pressure blocking
- Reproduces 20^{th} century surface temperature evolution better than CCSM4
- Improved Antarctic sea-ice distribution

High resolution experiments (0.25 deg/25 km and finer)

- Time slices (CAM4-FV, CAM5-FV, CAM5-SE; global spectral)
- Global $1/8^{\circ}$ (12.5 km) simulations using CAM5-SE (2004-2005)
- Regionally refined simulations over US (1° -> $1/8^{\circ}$)
- CAM5 realistic hurricane statistics (number/strength/variability)
- Summer time US orogenic propagating systems, atmospheric rivers

Argonne NATIONAL LABORATORY Leadership Computing Facility

NERSC

20 Years of Excellence in Computational Science OLCF OAK RIDGE LEADERSHIP COMPUTING FACILITY

CAM5 Development Activities

Model Physics

- Microphysics in convection (DOE-ASR) + next generation MG
- Unified Convection (UNICON): combined deep + shallow **Talk**
- Cloud Layers Unified By Binormals (CLUBB) (NSF CPT) **Talk**
- PDF cloud schemes implementation (NSF CPT)
- MMF/SP-CAM (EaSM) **Talk**
- Conservative Semi-LAgrangian Multi-tracer (CSLAM) advection (DOE) **Talk**
- Horizontal resolution dependence -> scale-aware schemes (DOE SciDAC)
- Vertical resolution dependence (L30 -> L60)

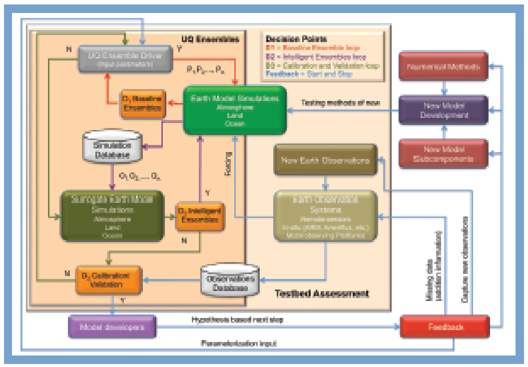
Model climate diagnosis

- Initialized hindcast activities (CAPT) NCAR,LLNL (DOE-CA) **Talk**
- Diagnose fast-physics errors NCAR (DOE-CA)
- Mean climate, variability and numerics sensitivities **2 Talks**
- Uncertainty Quantification (UQ): CAM5 versus CAM4 sensitivities (DOE labs)

Climate Science for a Sustainable Energy Future

CLIMATE SCIENCE FOR A SUSTAINABLE ENERGY FUTURE (CSSEF)

In 2010, the U.S. Department of Energy Office of Science asked its national laboratory system to collectively develop the Climate Science for a Sustainable Energy Future (CSSEF) project to bring together their tremendous scientific assets to meet ongoing and long-term challenges in advancing climate prediction. CSSEF addresses these objectives through an unprecedented collaboration among eight national laboratories* and the National Center for Atmospheric Research.



The CSSEF testbed and development system was designed by the crosscutting Data Infrastructure and Testbed team based on requirements set by CSSEF modelers and observational scientists.

CRITICAL OBJECTIVES

- Accelerate the incorporation of new knowledge, including small-scale process data and observations, into climate models.
- Develop new methods for the rapid validation of improved models including quantifying their uncertainty.
- Develop novel approaches to exploit computing at the level of many tens of petaflops in climate models.

MAJOR RESEARCH THEMES

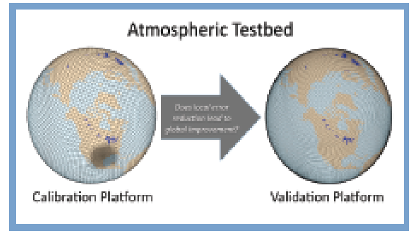
- Accurate simulation of the full hydrological cycle across all scales.
- Development and implementation of variable resolution component models for the global atmosphere and ocean general circulation.
- Quantification and reduction of uncertainty in simulating the terrestrial carbon and other biogeochemical cycles.

Central to CSSEF is the ability to thoroughly test and understand the uncertainties in the overall model and its components as they are being developed. CSSEF exploits DOE laboratory expertise in computational science and information technologies to construct advanced testbeds that allow the automated and rapid ingest of observational data together with computer simulation to evaluate model components.

CSSEF AND THE "NEXT +1" GENERATION EARTH SYSTEM MODEL

CSSEF will have a major impact on Earth System Modeling through integration with the core long-term development of the Community Earth System Model (CESM) project. The CESM community collaboration has produced four generations of state-of-the-science global climate models, including the most recent, CESM1. Because aspects of development require 10 to 15 years, the CSSEF project focuses on the long-term development of CESM3, which will complement the

*Argonne, Brookhaven, Lawrence Berkeley, Lawrence Livermore, Los Alamos, Oak Ridge, Pacific Northwest and Sandia National Laboratories



The atmospheric component testbed employs two different versions of the global Community Atmosphere Model (CAM). Calibration of model parameters is performed with a variable and very highly refined grid over the Atmospheric Radiation Measurement Climate Research Facility observational site in the Southern Great Plains. The parameters are validated in a global, uniform resolution model version.

Uncertainty quantification is built-in: A power wall visualization of a Monte Carlo sensitivity study involving 1000 single-point model simulations of the Community Land Model with carbon-nitrogen biogeochemistry (CLM-CN) at the Niwot Ridge flux tower in Colorado is demonstrated.

community effort now dedicated to application of CESM1 and the development of CESM2 (the next generation model), scheduled to be released in the next 4-5 years.

INTERACTIVE TESTBEDS–THE HEART OF CSSEF

CSSEF research is centered on interactive testbeds that enable researchers to rapidly propose, test, and implement improvements to the major CESM components, the Community Land Model, Community Atmosphere Model (CAM), Community Ice Code Sea-Ice Model (CICE) and Model for Prediction Across Scales-Ocean (MPAS-O). The testbeds integrate multiple and diverse observational data sets and model simulations within an interactive environment that utilizes the latest capabilities in information and computer sciences.

Using multiple instrument observational data streams, scientists employ model simulations and data analytics coupled with uncertainty quantification tools to develop and improve model parameterizations of processes, such as cloud formation and precipitation, ocean mixing, and carbon uptake by plants.

FUTURE DIRECTIONS

- Adaptive Grids – CSSEF is developing a dynamically adaptive mesh version of CAM that includes full atmospheric physics and is extending the MPAS formulation to the CICE sea-ice model.
- Full Earth System Model – A "Next+1" generation component coupler for CESM3 is being designed and will be tested so that CESM3 will run efficiently on hybrid computer systems of the type proposed for the DOE Leadership Computing Facilities.
- Uncertainty Quantification – To generate the very large ensembles of simulations needed to thoroughly quantify model uncertainty, computationally efficient surrogate models will be developed for the component codes.

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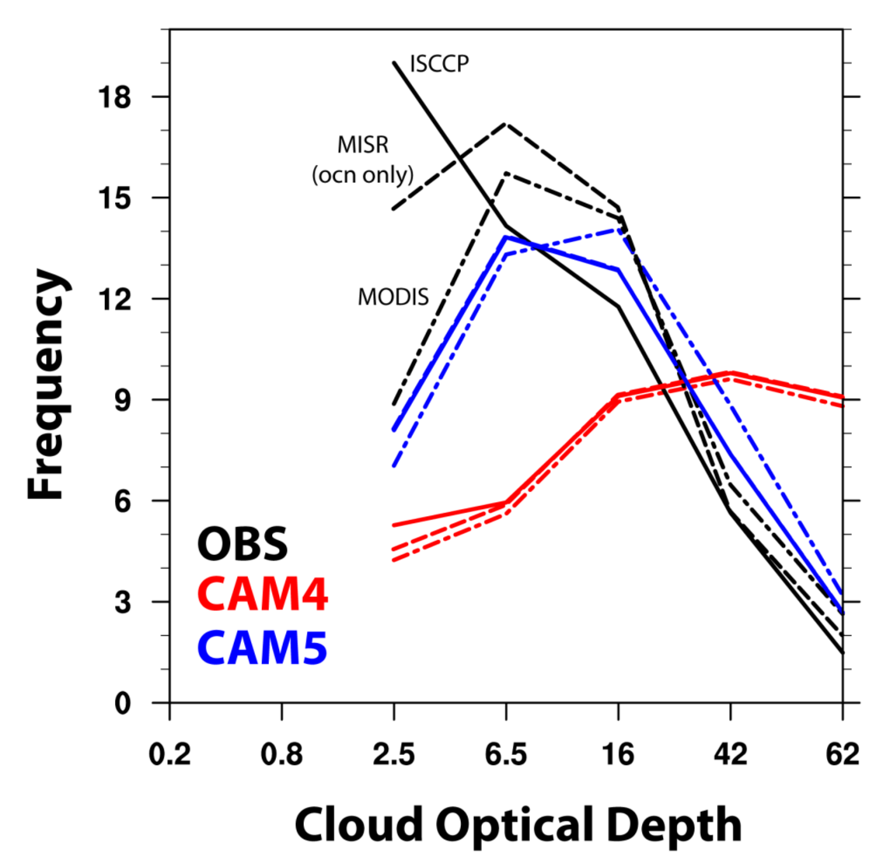
Project Website:
http://climatemodeling.science.energy.gov/projects/cssef-climate-science-sustainable-energy-future

Diagnosing CAM5 climate

CFMIP Observation Simulator Package (COSP): in CAM5.1 release

Global cloud optical depth distributions
from ISCCP, MODIS and MISR using COSP



✓COSP:
•Allows a more direct comparison between the satellite retrievals

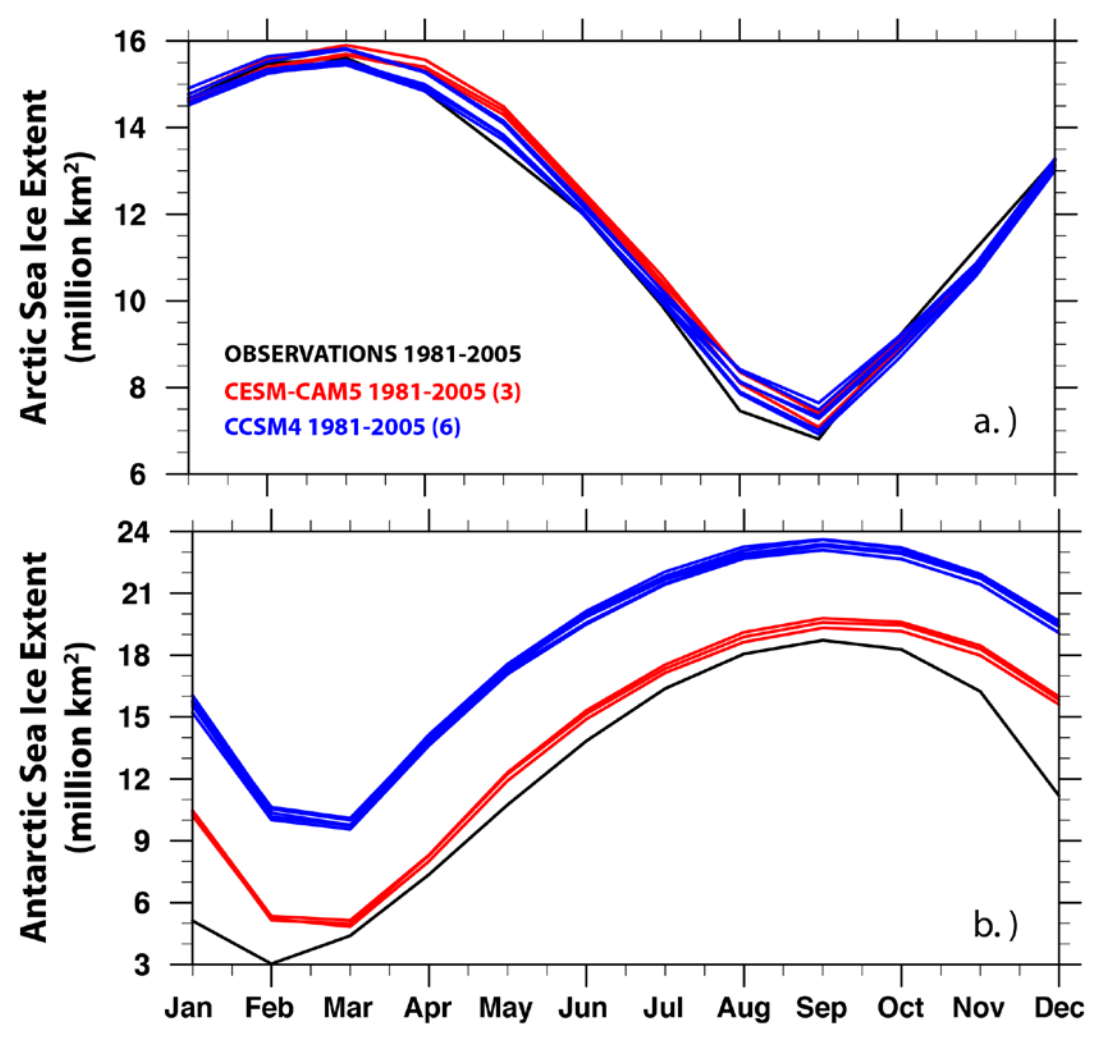
✓CAM4:
•Too many optically thick clouds

✓CAM5:
• Improved frequency of clouds at all optical depths

Kay et al. (2012) J. Climate

Polar Sea-Ice

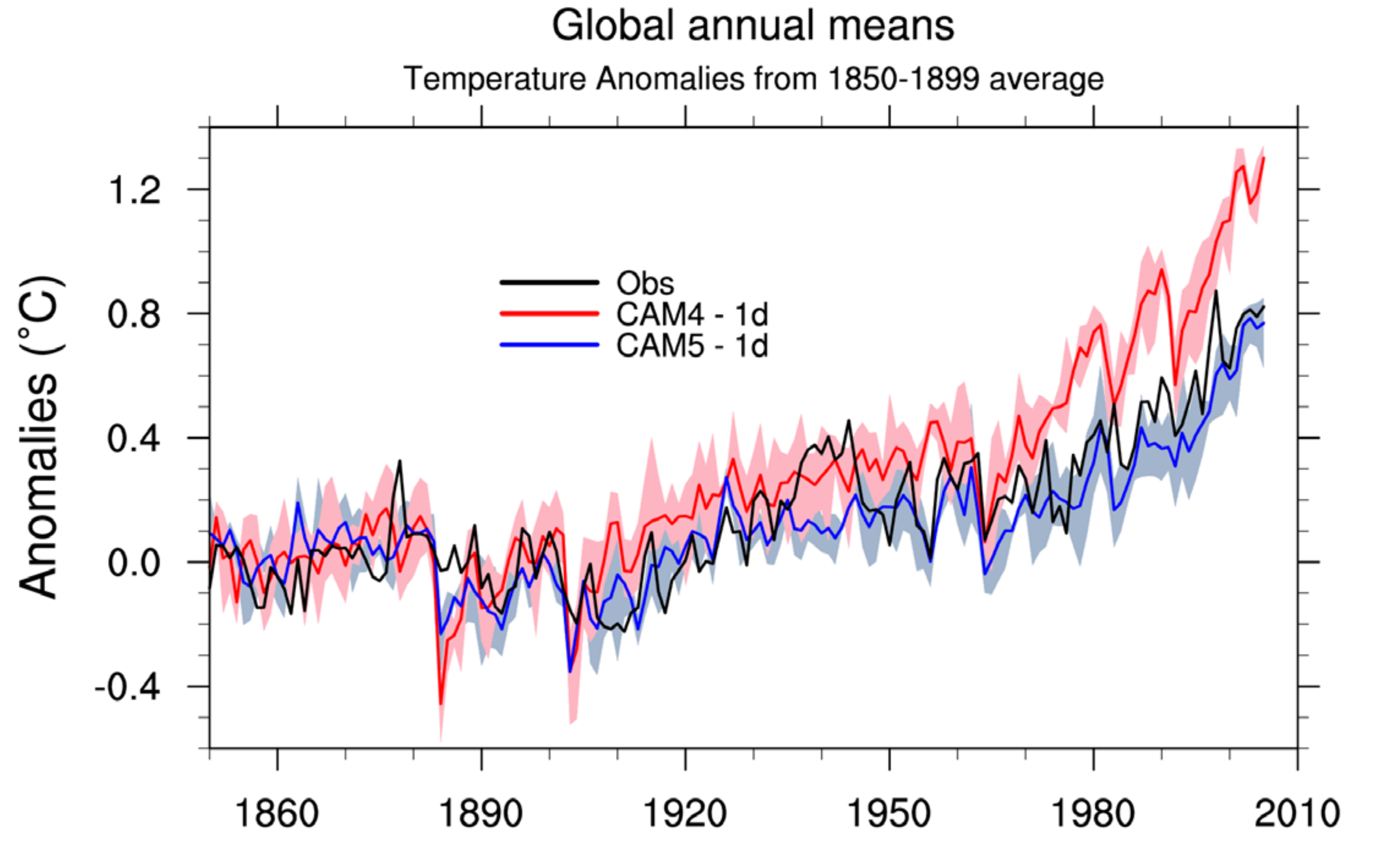
Significant Antarctic Improvements



Neale et al. (2012)
J. Climate, *in prep*

20^{th} Century Climate Change

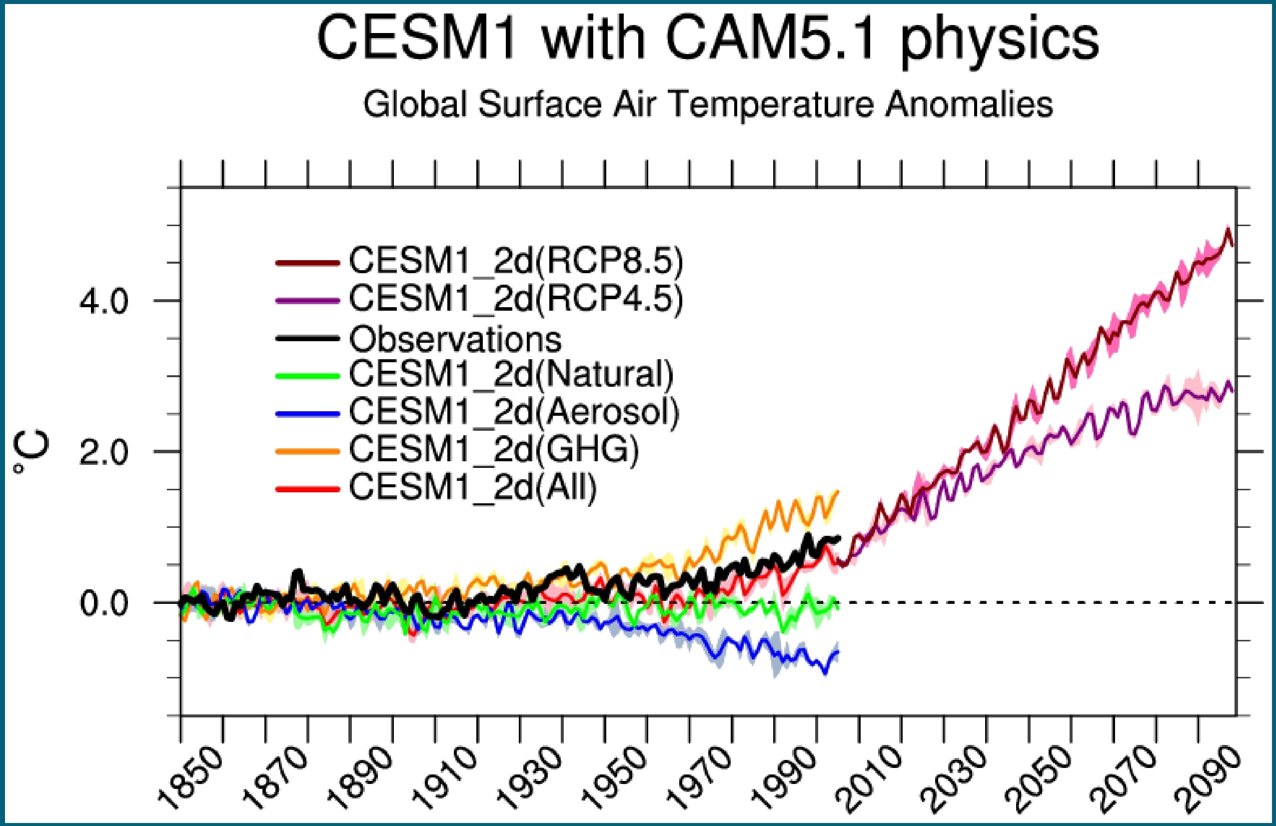
CESM1(CAM5) CMIP version vs. CCSM4(CAM4)



Neale et al. (2012)
J. Climate, *in prep*

Global-mean surface temperature change

Suite of 2 degree experiments

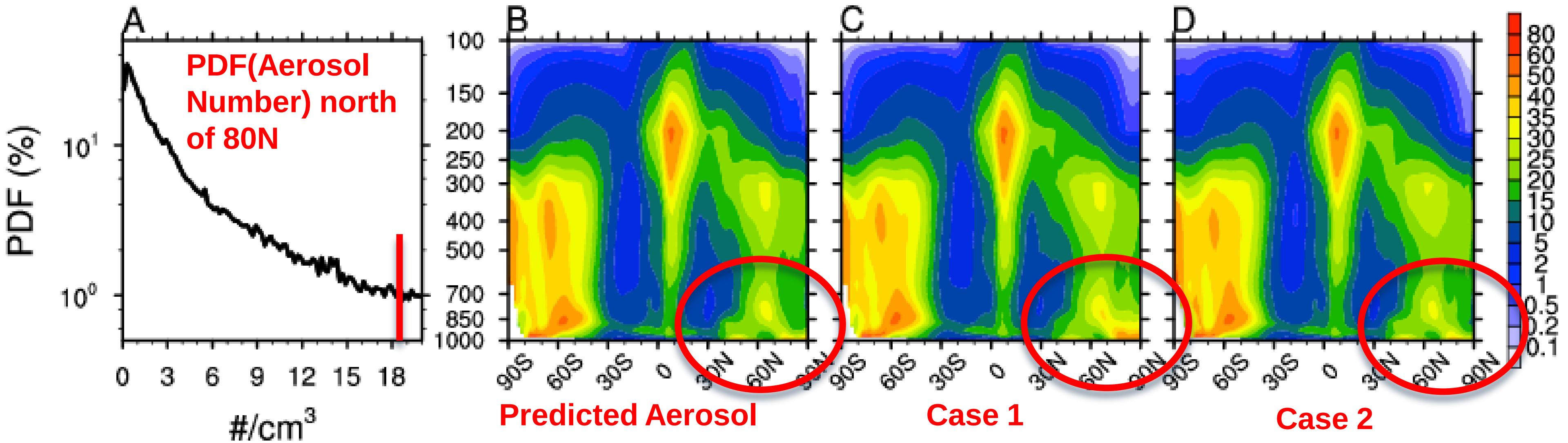


- Recently CESM1-2deg runs are published through ESG/PCMDI.
- This is in collaboration with NCAR and PNNL.
- Thanks to NERSC/PCMDI/NCAR.

Prescribed Aerosol in CAM5

- Case 1: $X = X_{cs} * f_{lcloud} + X_{ucs} * (1 - f_{lcloud})$ ➔ excessive Arctic low cloud during summer.
  - X_{cs}(X_{ucs}): Conditionally (unconditionally) sampled aerosol properties (mass and numbers)
  - This is due to ***unrealistically low aerosol numbers and mass***. Adding a primary carbon mode to MAM3 for improved aging of black carbon. Now a 4 mode version of MAM (MAM4). 5-10% increase run-timecompared to standard CAM5.1 with MAM3

- Case 2: X = Randomly selected based on log-normal distribution of X_{ucs}.
  - To overcome this excessive low cloud, we introduce '***stochastic aerosol distribution***'
  - Based on mean and variance of log(X_{ucs}). We can construct PDF(X_{ucs}) at each grid point.

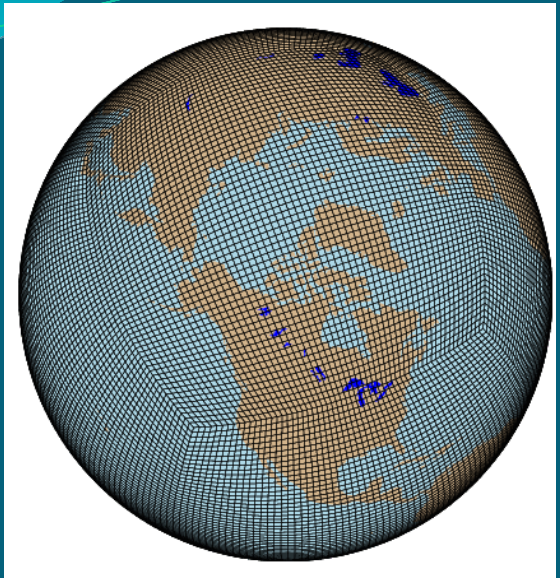


CAM5 Regionally Refined

1° global resolution, refined to 1/8°

Sandia National Laboratories

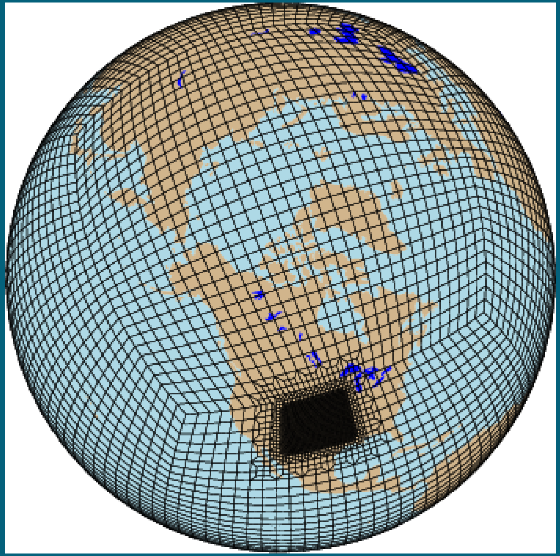
Argonne National Laboratory — Leadership Computing Facility



Global 1/8°

CAM5-SE has a very efficient, scalable and *expensive* global 1/8° configuration.

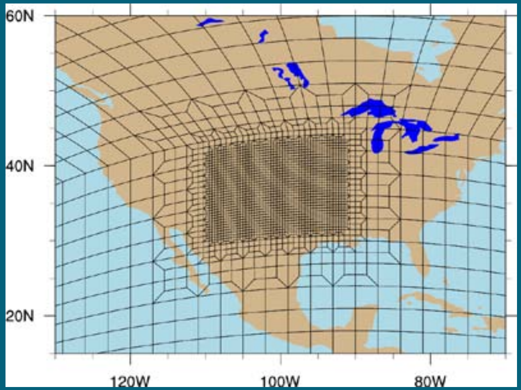
- 6M core hours per year (ANL Intrepid)
- Yellowstone: 1-2M core hours?
- 3.1M physics columns
- dtime=600, dynamics dt=9.2



SGP 8x Regionally Refined

1° global resolution, refined to 1/8° continental sized region centered over SGP ARM site.

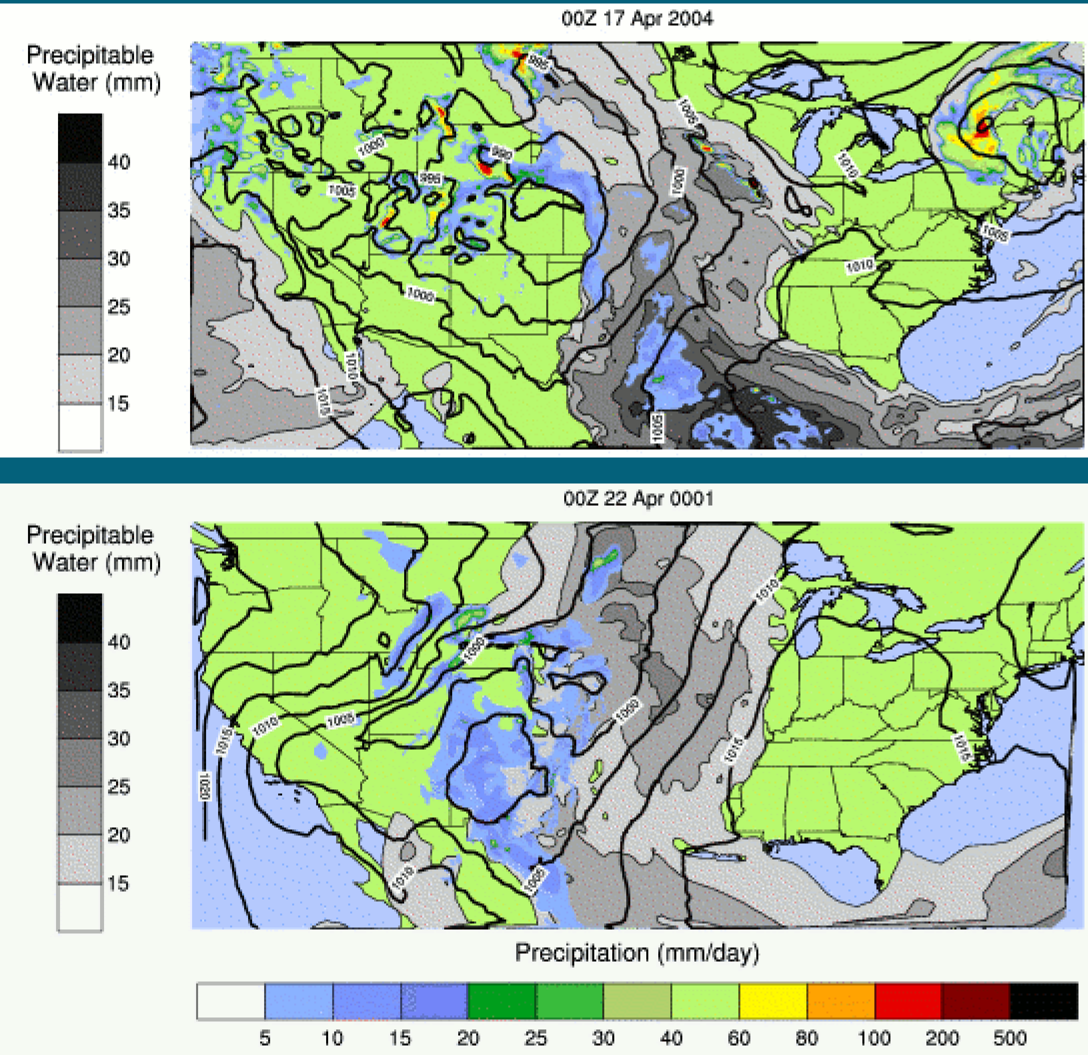
- 0.12 M core hours per year (Sandia Linux cluster).
- 67K columns.
- dtime=600, dynamics dt=7.9



Courtesy: Mark Taylor, Sandia

Precipitable water (gray), precip rate (color), sea level pressure (contours)

Sandia National Laboratories



Global 1/8° Simulation

Snapshots show propagating convective system not seen at lower resolutions. Detailed frontal structure and tapping of moisture

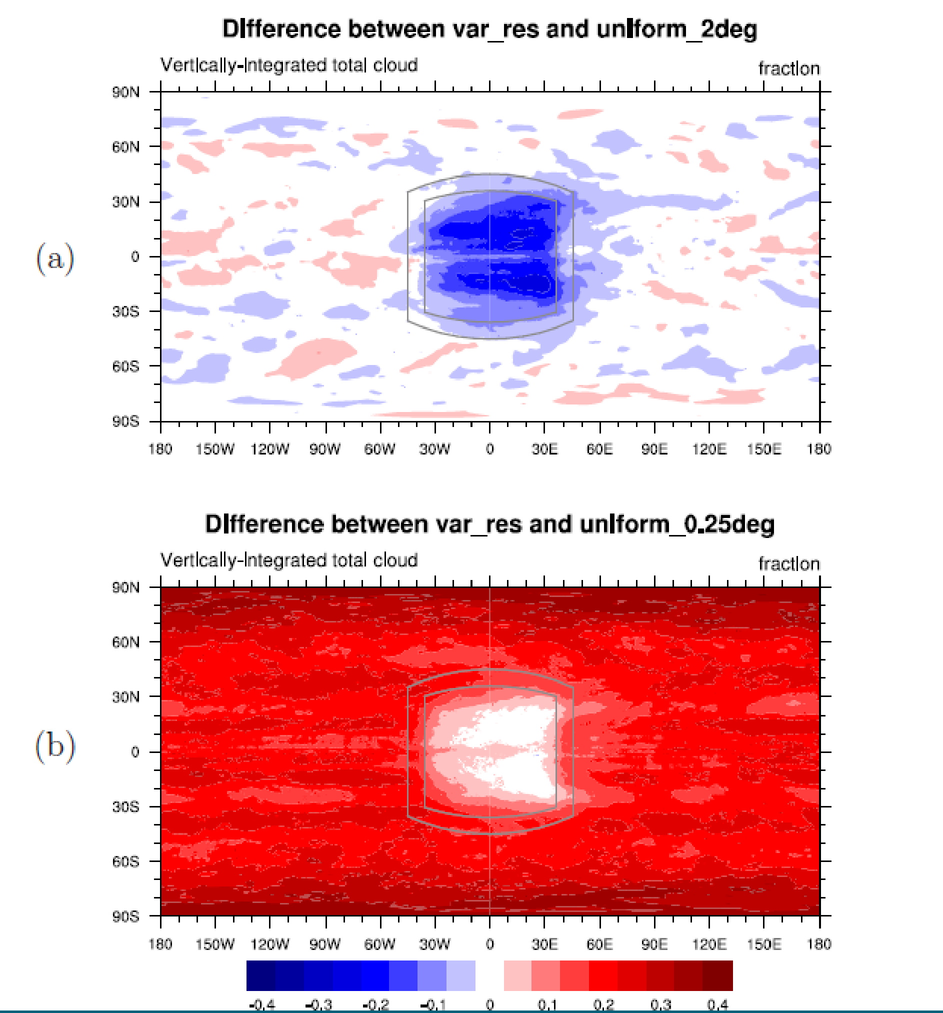
Regionally Refined Simulation

Similar convective systems form in the 1/8° region, strongly dissipated as it propagates into the 1° region

Courtesy: Mark Taylor, Sandia

Regional Grid Refinement

Significant dependence of cloud on resolution



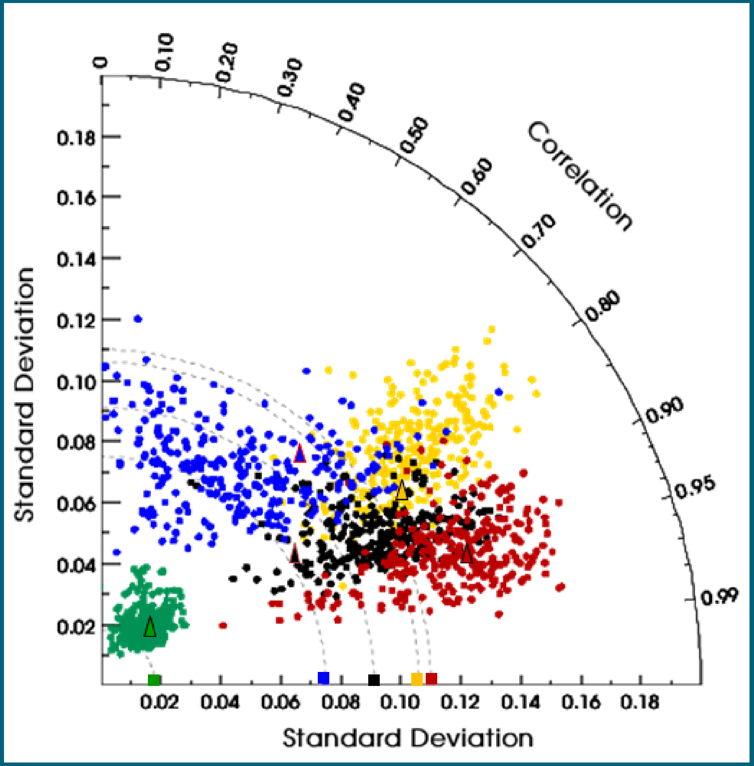
- ✓Aqua-planet experiments
  - ✓Uniform 2 deg and 0.25 deg
  - ✓Regionally refined 2 deg to 0.25 deg in tropics

Levy et al. (2012) MWR, *submitted*

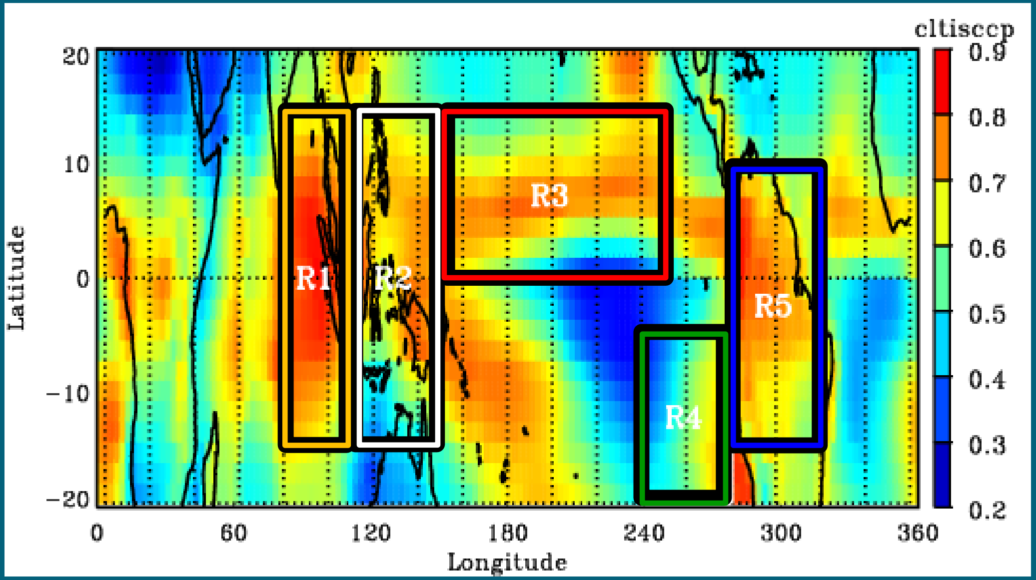
Regional Assessment of the Parameter-Dependent Performance of CAM4 in Simulating Tropical Clouds

Lawrence Livermore National Laboratory

Taylor Diagram of high cloud fraction



Selected High Cloud Regions

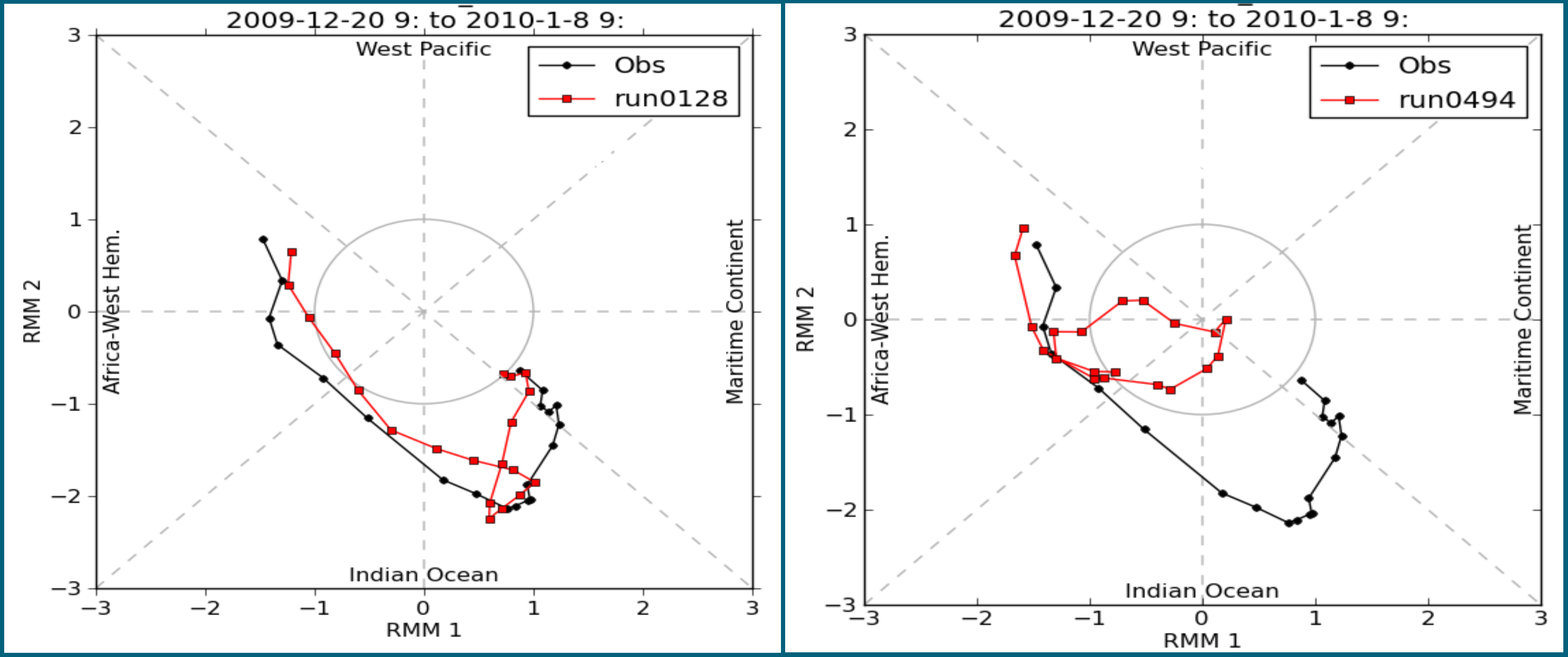


Zhang, Y., S. Xie, C. Covey, D. Lucas, P. Gleckler, S. A. Klein, J. Tannahill, C. Doutriaux, and R. Klein. GRL, in Revision.

CAM Hindcasts

Cloud-Associated Parameterization Testbed (CAPT)

MJO Phase Plots (RMM)

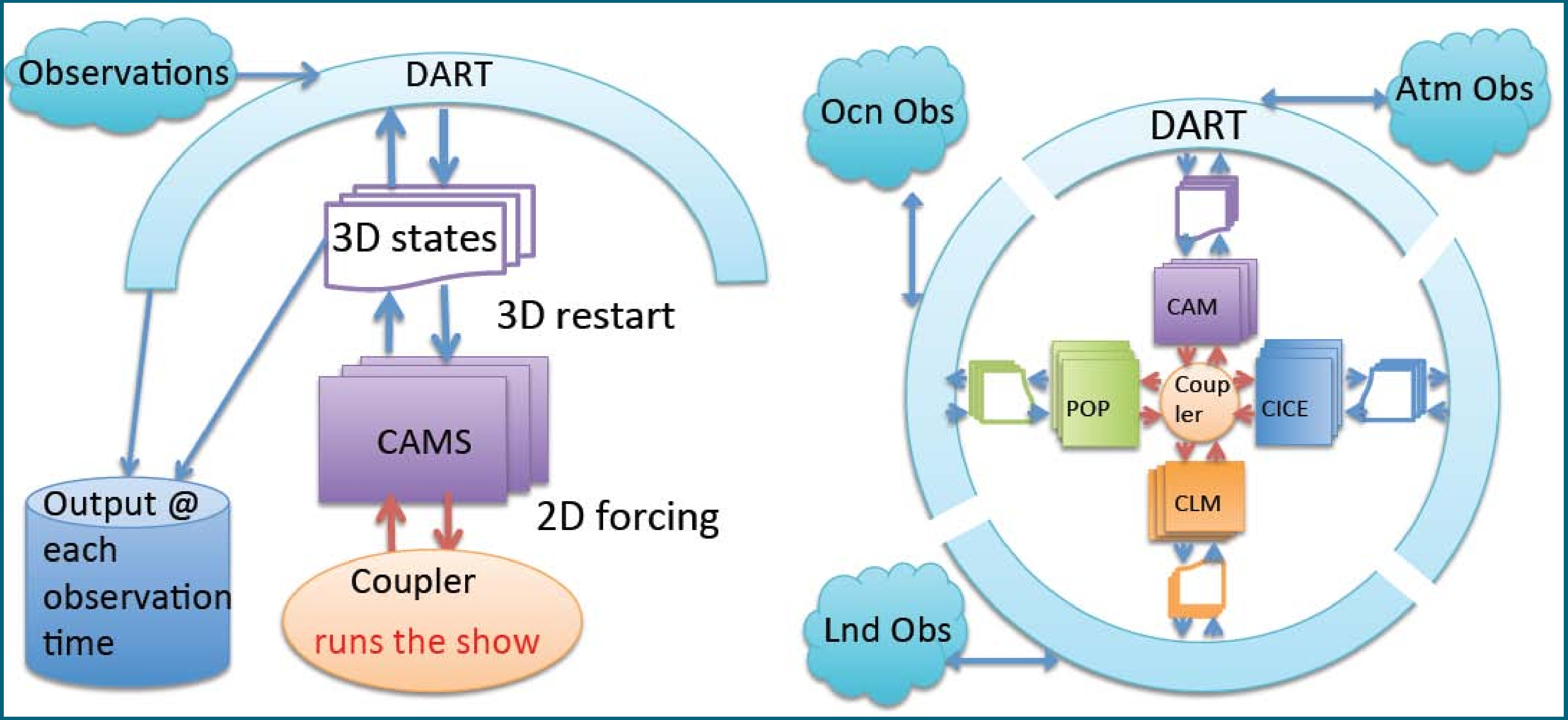


- Using CAM5, a large perturbed parameter ensemble of 20-day hindcasts for a strong MJO event during YOTC have been generated

S. A. Klein, J. Boyle, J. Tannahill, D. Lucas, S. Xie, K. Sperber, and R. Neale, 2012: Perturbed parameter hindcasts of the MJO with CAM5. In preparation.

CESM multi-instance model simulation

Data Assimilation Research Testbed (DART) capability



Development Experiments

Climate Simulation Lab (CSL) on yellowstone

http://www.cesm.ucar.edu/management/CSL/CSL12-14ProposalCESMFinal.pdf

D1. Maintain and improve scalability of CAM at high resolution

D2. Support separate isotropic grids for physics and transport computations

D3. Implementing the Conservative Semi-LAgrangian Multi-tracer (CSLAM) transport scheme

D4. Test increases to CAM vertical resolution

D5: Testing regional resolution refinement of global grids in CAM-SE

D6. CAM-MPAS validation

D7. Finalize a prescribed aerosol version of CAM5

D8. Validating high resolution impactful phenomena

D9. Advancing scale-aware physics: UNICON, CLUBB, boundary layers and cloud PDFs

D10. Advancing cloud microphysics

D11. Implementing the multi model framework (MMF) into CESM

D12. Investigating physics, dynamics and numerics interactions using initialized and idealized simulations

Development Experiments

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D9. Advancing scale-aware physics: UNICON, CLUBB, boundary layers and cloud PDFs

D10. Advancing cloud microphysics

D11. Implementing the multi model framework (MMF) into CESM

D12. Investigating physics, dynamics and numerics interactions using initialized and idealized simulations

D13. Understanding the role of coupled errors in initialized simulations

D14. Diagnosing climate uncertainty in the CESM Cloud-Radiation-Aerosol ensemble system (CAR)

D15. Advancing applications research (aircraft jet contrails)

D16. Next generation algorithm preparation for GPU utilization (RRTMG)

Totals

9.8M core hours

296 Tb

Production Experiments

Climate Simulation Lab (CSL) on yellowstone

http://www.cesm.ucar.edu/management/CSL/CSL12-14ProposalCESMFinal.pdf

P1. Validation of CAM-SE coupled climate

P2. Validation of CAM-SE high-resolution

P3. Validation of CAM5 prescribed aerosols

P4. Validation of physical parameterizations in long AMIP and coupled simulations

P5. National Multi-Model Ensemble (NMME) Project

<u>Totals</u>

5.3M core hours

203 Tb

<u>Awarded around 85% of requested resources</u>