Climate Modeling Cloud and Aerosol Activities and Plans

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Climate Modeling Programs

Climate and Environmental Sciences Division

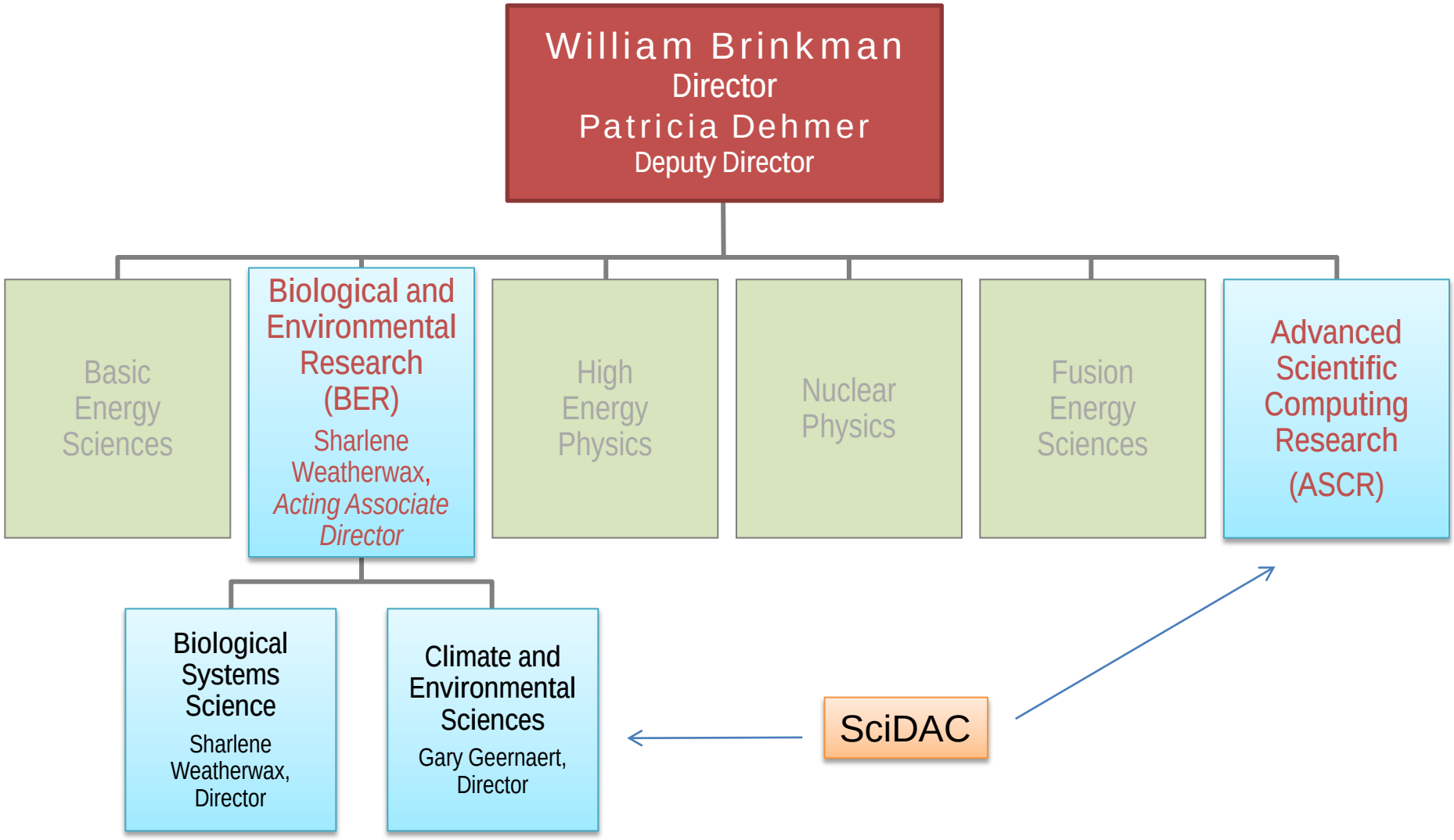
Biological and Environmental Sciences

March, 29, 2011

ASR Science Team Meeting

San Antonio

Department of Energy Office of Science



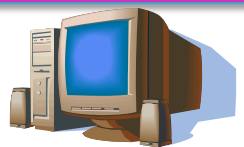
Climate and Environmental Sciences Division

Atmospheric Science

- Atmospheric System Research (Ashley Williamson)
- Atmospheric Radiation Measurement Climate Research Facility (Wanda Ferrell)

Climate and Earth System Modeling

- Regional & Global Climate Modeling (Renu Joseph)
- Earth System Modeling (Dorothy Koch)
- Integrated Assessment (Bob Vallario)

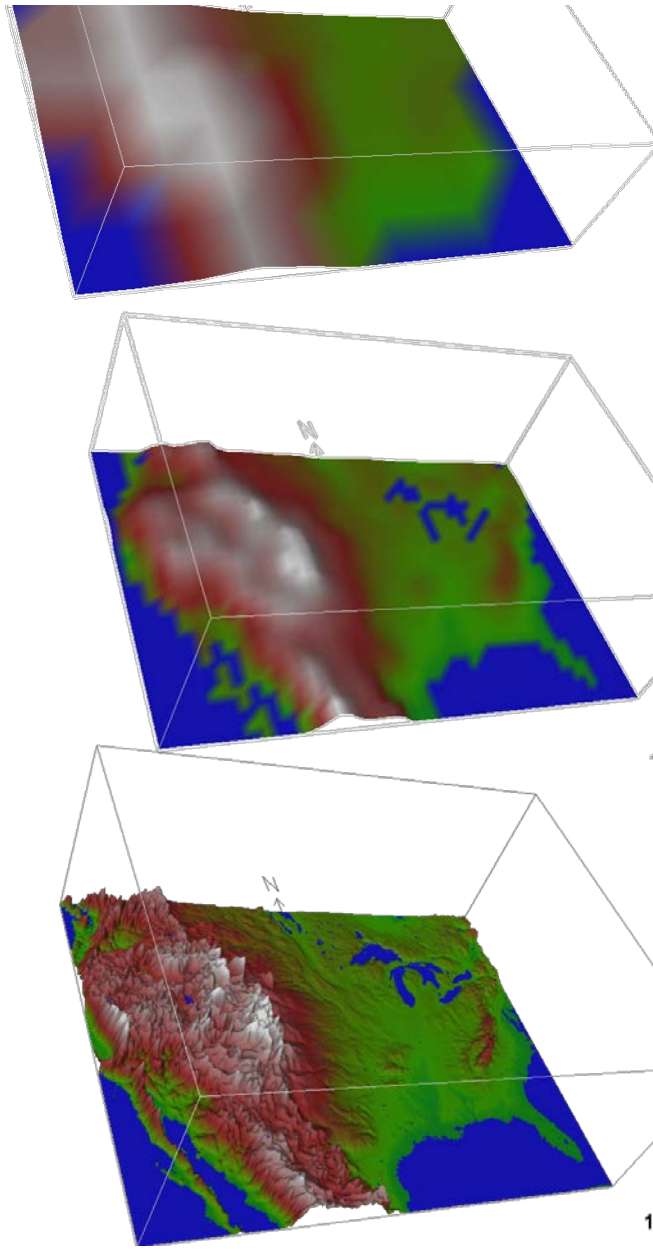


Environmental System Science

- Terrestrial Ecosystem Science
- Terrestrial Carbon Sequestration Research
- Subsurface Biogeochemical Research
- Environmental Molecular Sciences Laboratory

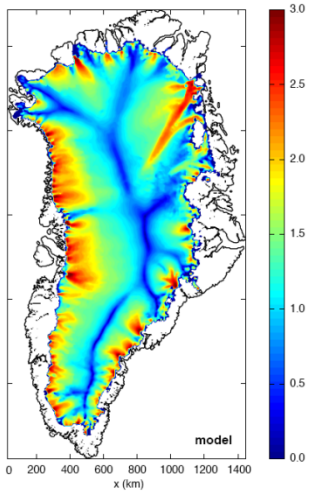
Regional and Global Climate Modeling Program

- Develop and evaluate methods to obtain reliable regional scale climate projections.
- Focus on regions of the globe vital for assessing future climate (e.g., Arctic and Tropics).
- Diagnostic methods and tools; quantify uncertainties and feedbacks in the earth system
- Climate change detection and attribution, modes of variability change with changing climate
- PCMDI



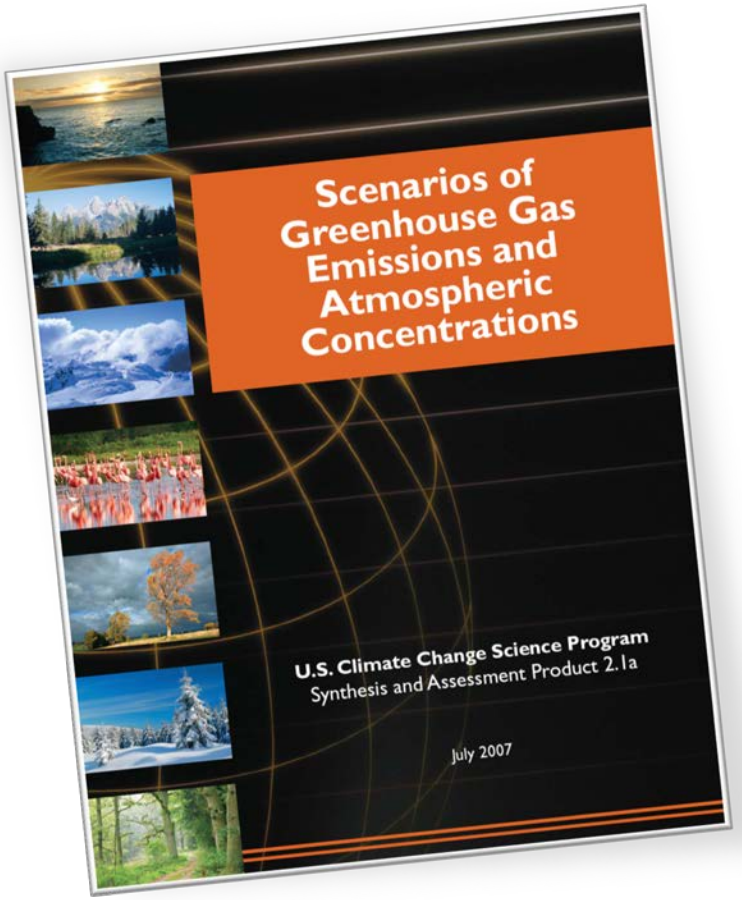
Earth System Modeling Program

- **Develop** model physics of system components
- **Optimize** computationally intensive processes and codes
- **Test** and improve components using observations (“Test-bed”)
- **Couple** individual components
- **Evaluate** process feedbacks and potential for abrupt climate change
- **SciDAC** partnership with Advanced Scientific Computing (ASCR)

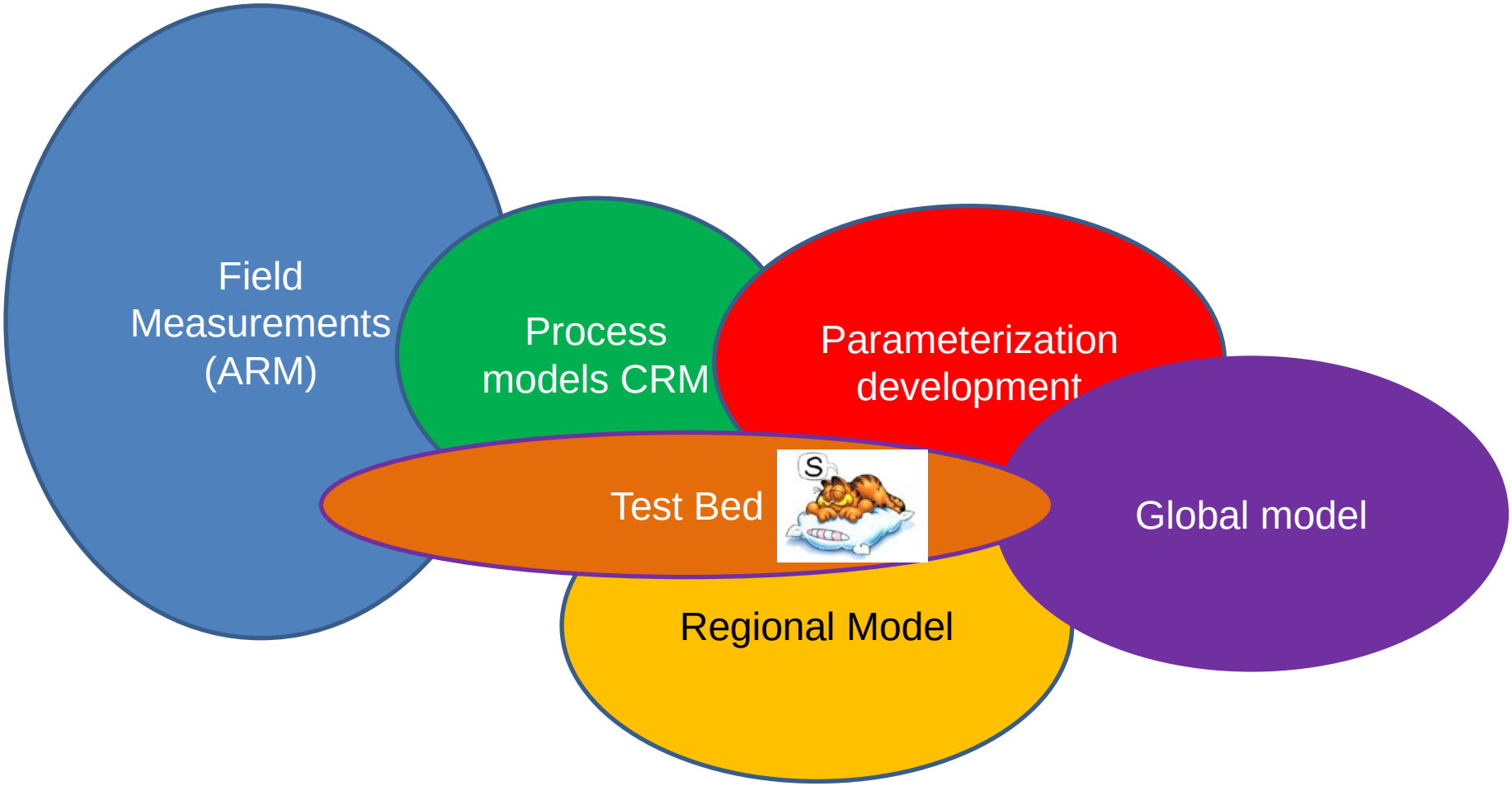


Integrated Assessment Research Program

- Understand and model interactions of human and natural systems
- Developmental pathways, emissions, the role of energy innovations, and mitigation strategies
- Climate change impacts, adaptations, and the effects of combined, multiple stressors
- Global, national, and regional perspectives within economic and other policy-relevant frameworks



Aerosols and clouds: Field to the global model



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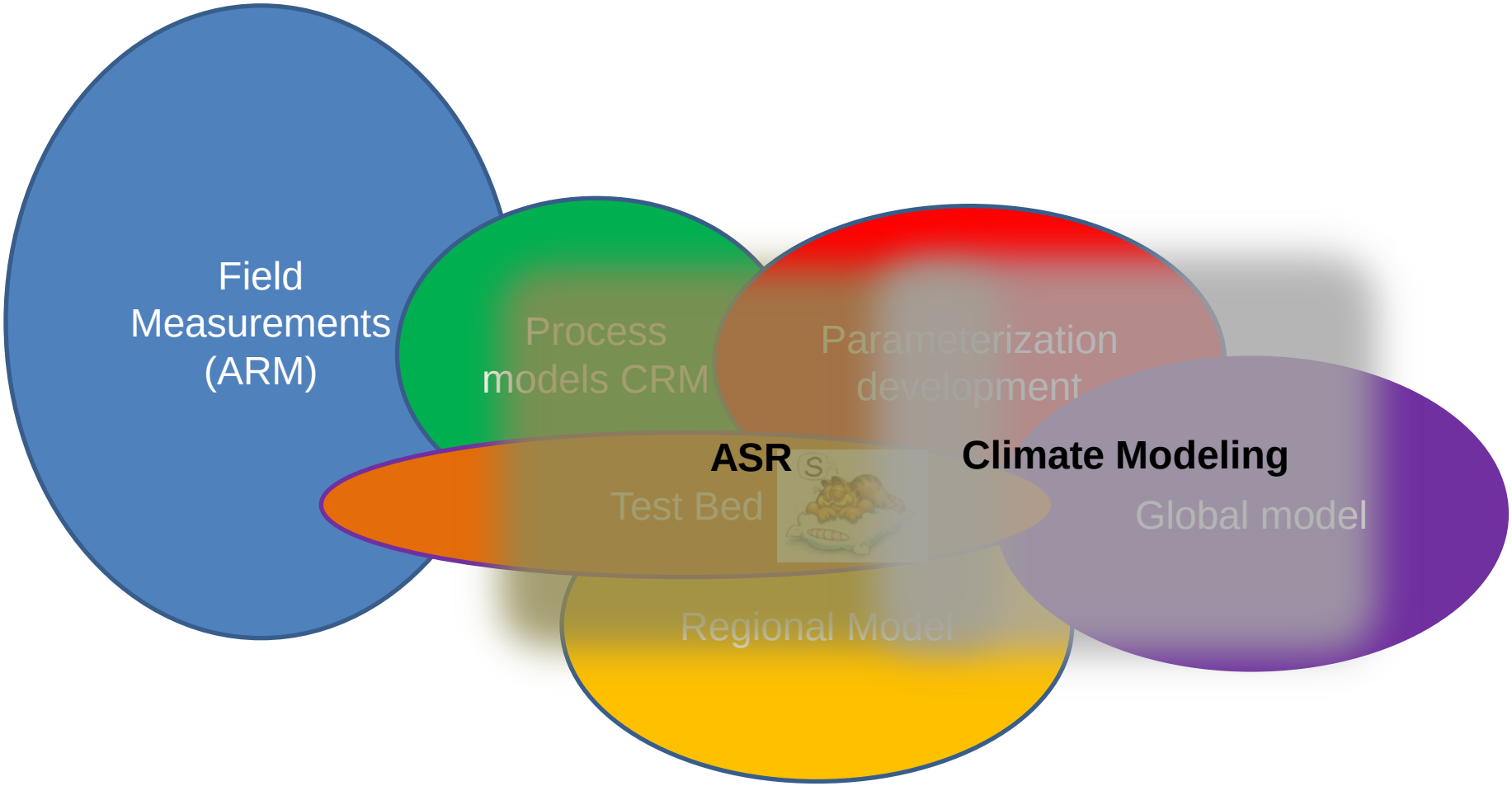
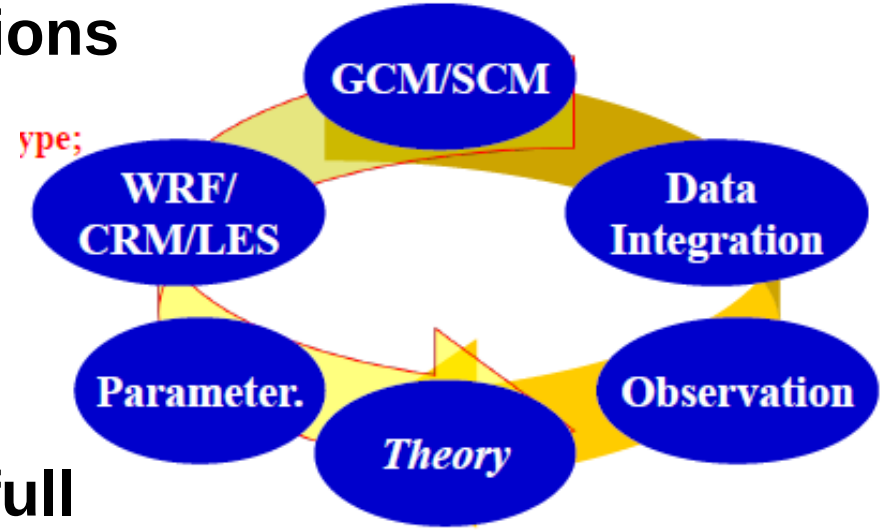


FASTER: FAst-physics System TEstbed and Research

(Liu, BNL +10 institutions that use 3 different GCMs)

Goal: Use ARM measurements to evaluate/improve parameterizations of cloud-related fast processes in Numerical Weather Prediction, WRF and Cloud Resolving Models.

- **Construct testbed from SCM-testbed, NWP-testbed, and WRF**
- **Execute WRF/CRM/LES simulations**
- **Construct multiscale data assimilation system**
- **Evaluate model performance**
- **Develop parameterizations, evaluation metrics**
- **Incorporate knowledge into the full GCMs**



CAPT: Cloud-Associated Parameterizations Testbed (LLNL)

Integration of climate model cloud schemes (into CAM), driven in "weather-forecast" mode to:

- Compare to (e.g. ARM) observations
- Evaluate parameterizations apart from model-specific feedbacks

Example: Ice-cloud microphysics for CAM5, tested against ARM MPACE observations

Global simulations of ice nucleation and ice supersaturation with an improved cloud scheme in the Community Atmosphere Model

A. Gettelman,[1] X. Liu,[2] S. J. Ghan,[2] H. Morrison,[1] S. Park,[1] A. J. Conley,[1] S. A. Klein,[3] J. Boyle,[3] D. L. Mitchell,[4] and J.-L. F. Li[5]

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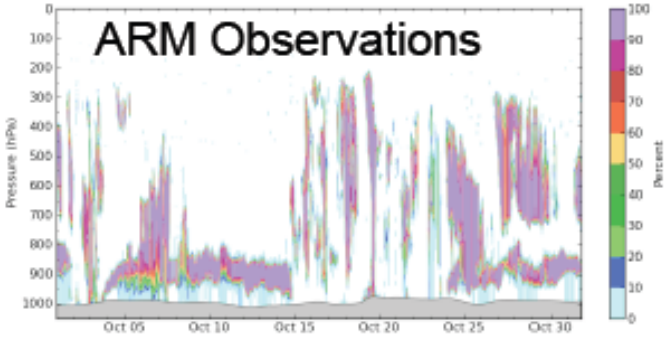
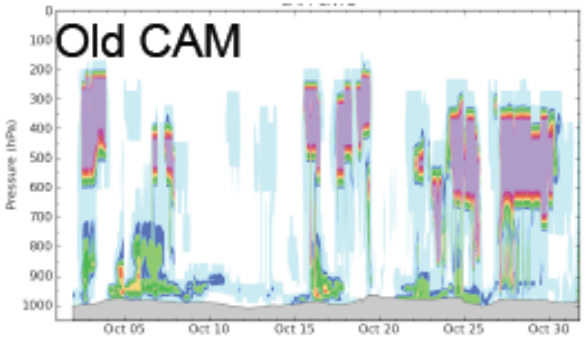
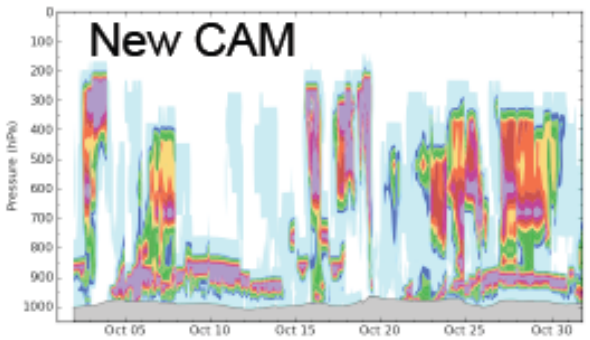


Cloud Fraction as a function of height and time over Barrow in October 2004





Cloud Feedback Analysis for CMIP5 models (LLNL, UCLA)

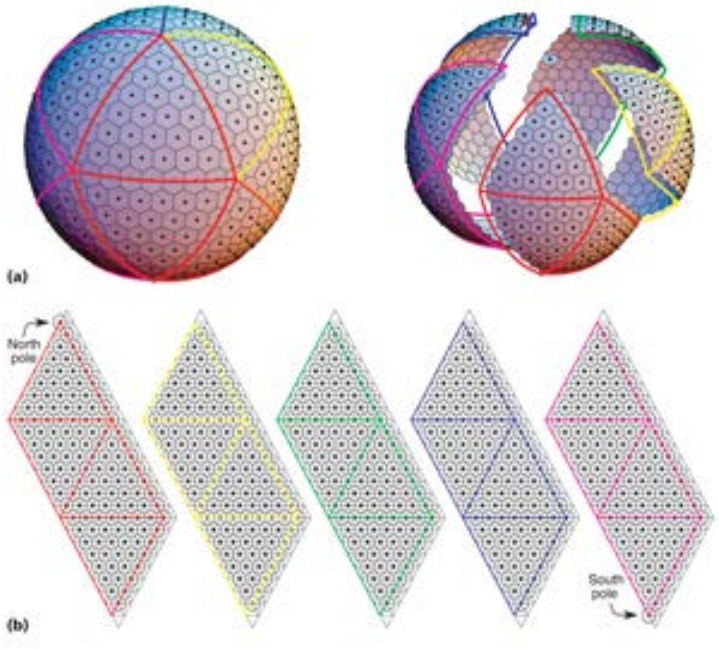
- Identify time-scale invariance in feedbacks for stratocumulus, high clouds, extra-tropical stratiform clouds; seek observations to constrain feedbacks.
- Apply stratocumulus mixed-layer model to CMIP output, diagnose robust changes
- Analyze CMIP5 and CloudFeedbackMIP, including diagnostics from a satellite simulator (COSP)

Global Cloud Resolving Model (Randall, Col. State Univ.)

- Challenge: non-hydrostatic fluid solutions that can run on global scale models

- Resolution <4km (100 million cells), 128 levels

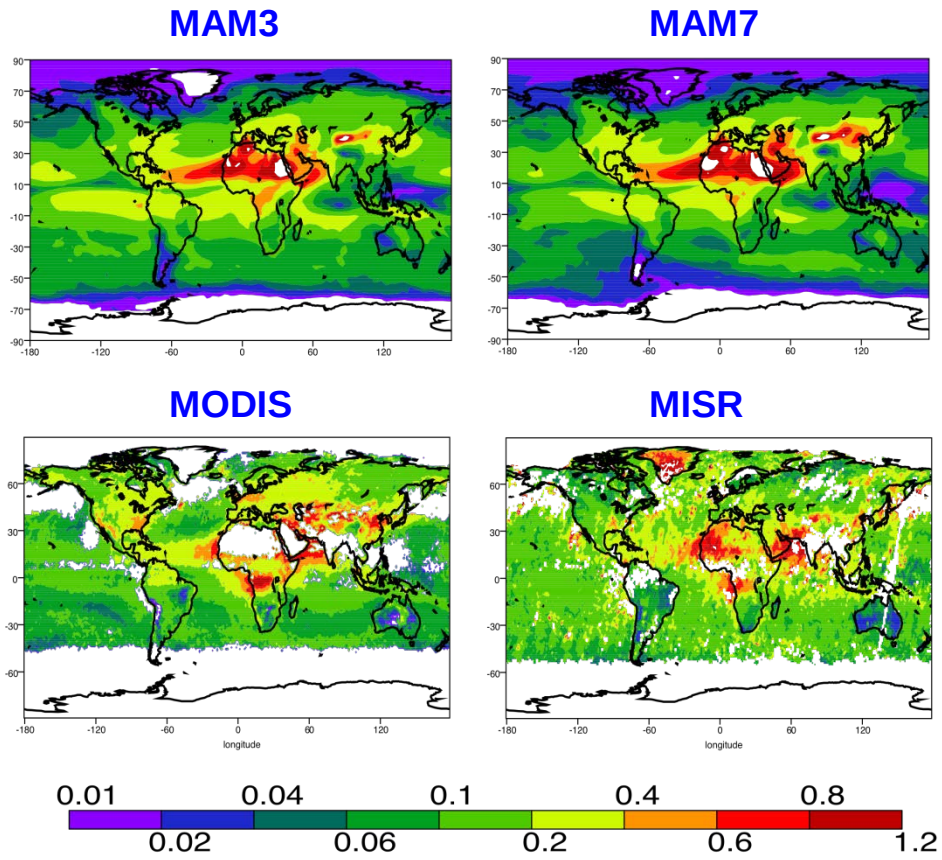
- Developed 2 competing dynamical cores to run on aqua-planet model



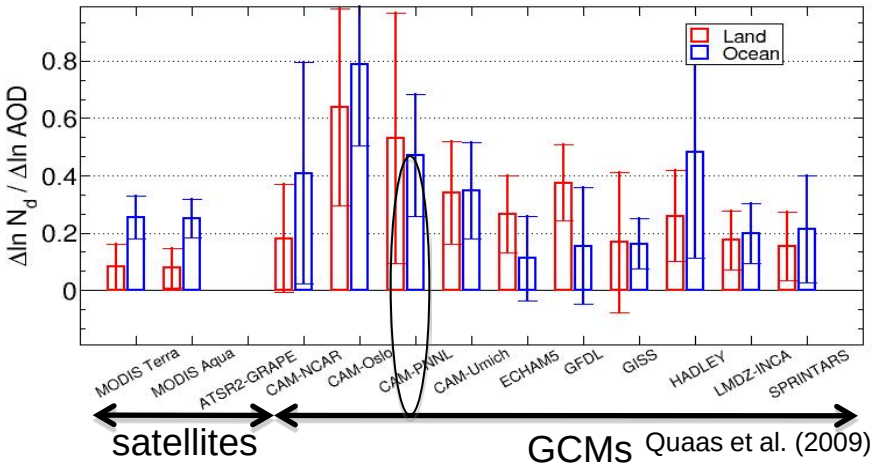
A Scalable and Extensible Earth System Model for Climate Change Science

Anthropogenic Aerosols, chemistry for CAM5

(PNNL)



A modal aerosol module (MAM) with 2 versions (3- and 7-modes) for CAM5 with aerosol internal/external mixing, predicts both aerosol mass and number concentrations. Interface with cloud microphysics, to study aerosol indirect effects.



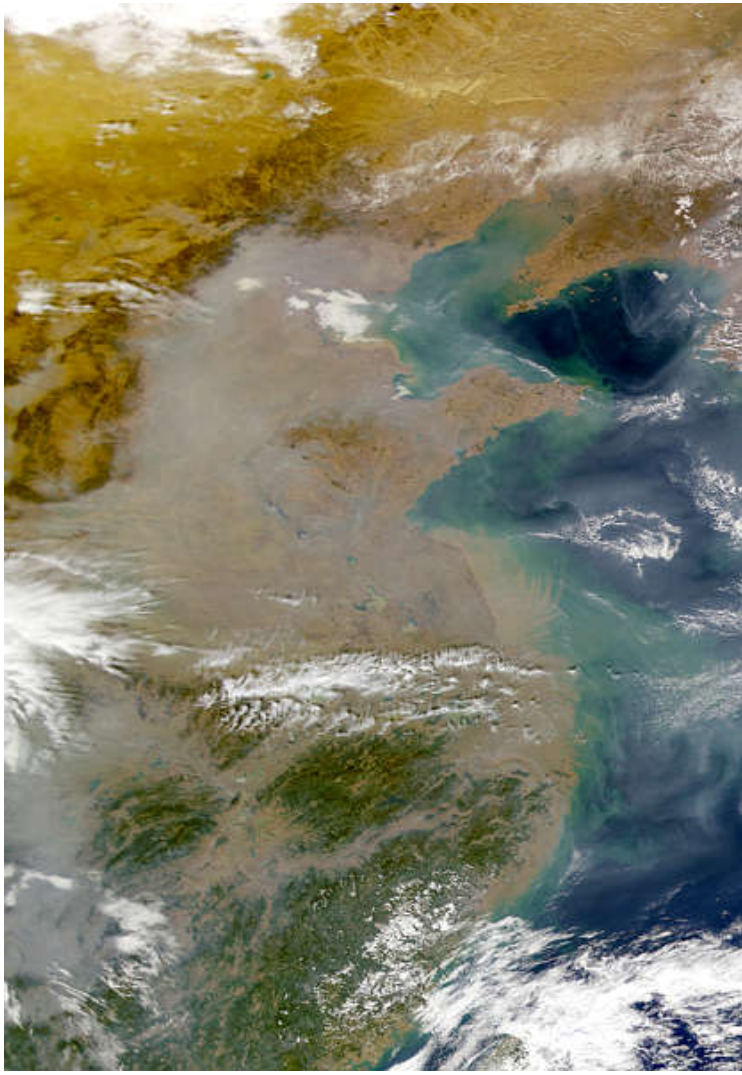
Aerosol-cloud-radiation interactions: GCMs tend to overestimate cloud droplet number response to anthropogenic aerosol compared to satellite

Simulating Aerosol Indirect Effects with Improved Aerosol-Cloud-Precipitation Representation in WRF-CHEM (Zhang, N Carolina)

Nucleation: Improve parameterizations for particle formation, SOA

Convection: Improve and evaluate convective param (Zhang and McFarlane), including effects of aerosols, cloud microphysics, ice nucleation, precipitation

China: compare model with measurements



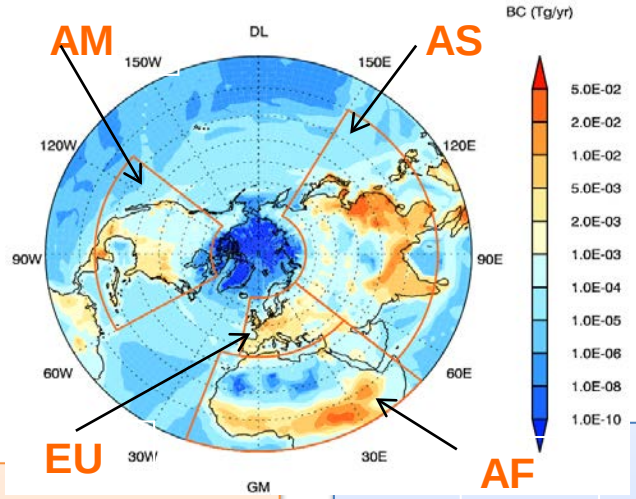
Indirect effects in CAM, CESM
(Nenes, GA Tech; Liu, PNNL; Park, NCAR)

Aerosol indirect effect sensitivity to:

- Organic aerosol hygroscopicity
- CCN activation kinetics
- Giant CCN
- Cloud-scale entrainment
- Ice nucleation in mixed/cirrus clouds
- Subgrid variability of vertical velocity
- Fall speed
- Cloud particle collection and aggregation
- Cloud-radiation-turbulence interactions

Improving the Characterization of Clouds, Aerosols and the Cryosphere in Climate Models

(LANL, PNNL, LBL, LLNL)



Aerosols

- **Source attribution**
- **Transport: Sensitivity to model parameters, circulation, Dome**
- **Formation: Nucleation, Secondary aerosol formation**
- **Transformation: Aging, coagulation and condensation**
- **Removal: Clouds, cloud scavenging**

Clouds

- **Cloud-aerosol interactions**
  - **Crystal nucleation**
  - **Dust mineralogy**
- **Cloud occurrence, extent**
  - **Winter low-level clouds**
- **Subgrid-scale cloud generator: Total water PDF; Improved treatment of radiative effects; Improved cloud overlap; Microphysical process rates; ice supersaturation**

Compare with ARM, MPACE

Aerosol, Cloud Global Modeling Future Priorities?
(focus on development of "community" models)

- **Quantify sources of uncertainty as means to guide development; how much complexity is optimal?**
- **Cloud parameterization improvements, scale-aware parameterizations; Non-hydrostatic cloud modeling**
- **Aerosol-cloud interactions: Ice/mixed phase, convection**
- **Test-bed development (Earth System Grid); aerosol microphysics**
- **Cloud feedbacks, cloud-aerosol feedbacks**
- **Organic aerosols: impacts on indirect, direct effects**

Most of these benefit from ASR-modeling program coordination