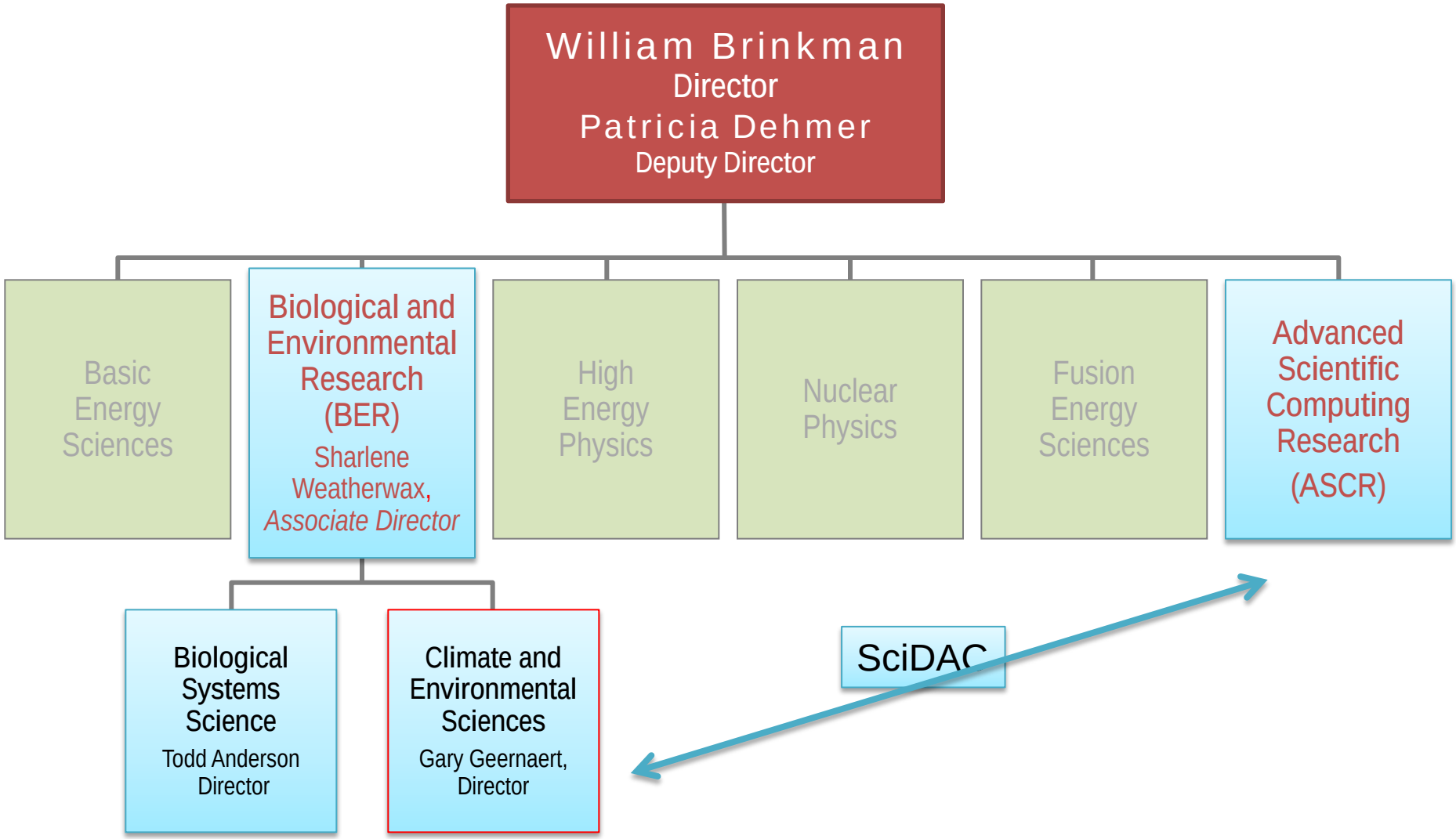
Regional and Global Climate Modeling Program

Renu R Joseph
Program Manager, RGCM

Department of Energy Office of Science



Climate and Environmental Sciences Division

Gary Geernaert

Atmospheric Science

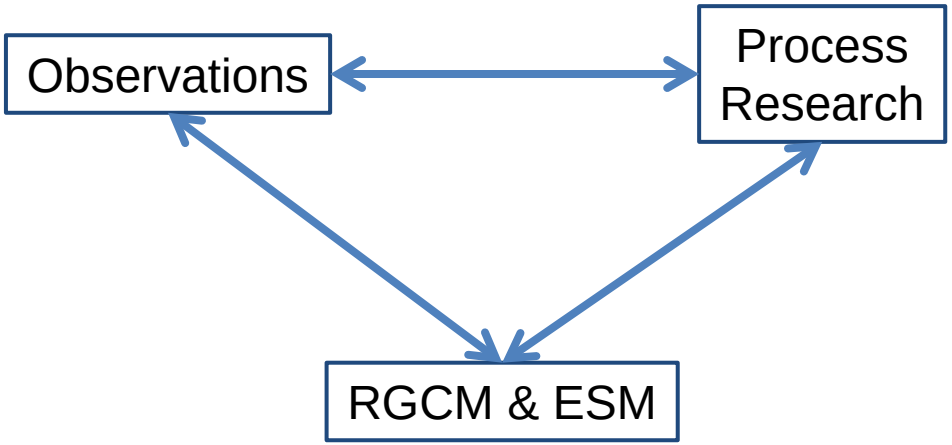
- Atmospheric System Research
- Atmospheric Radiation Measurement Facility

Climate and Earth System Modeling

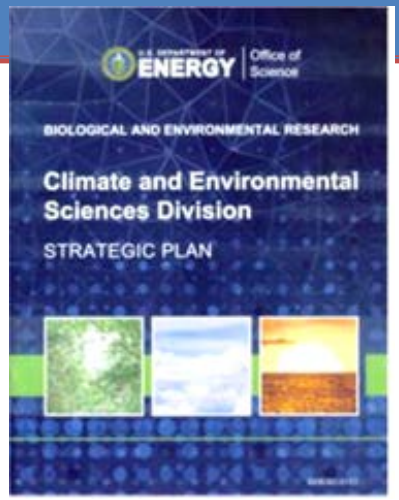
- Earth System Modeling
- Regional & Global Climate Modeling
- Integrated Assessment

Environmental System Science

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



Climate and Environmental Sciences Division: Strategic Plan



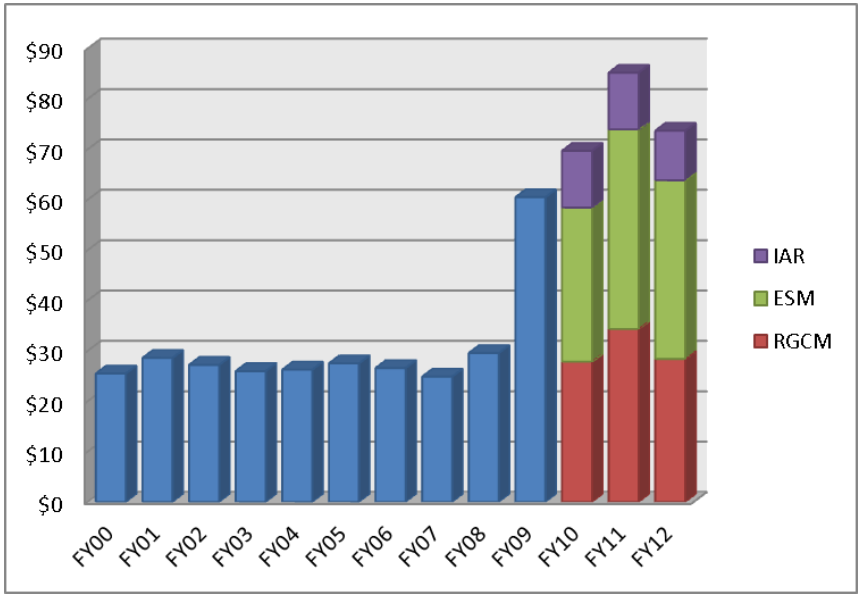
Mission: To advance a robust predictive understanding of Earth's climate and environmental systems and to inform the development of sustainable solutions to the Nation's energy and environmental challenges.

Goals:

- **Process knowledge and innovative computational methods advancing next-generation, integrated models of the human-Earth system.**
- Process-level understanding of atmospheric systems and terrestrial ecosystems, extending from bedrock to the top of the vegetative canopy.
- Coupled biogeochemical processes in complex subsurface environments to enable systems-level environmental prediction and decision support.
- Enhance the unique capabilities and impacts of the ARM and EMSL scientific user facilities and other BER community resources to advance the frontiers of climate and environmental science.
- **Address science gaps that lead to solutions for DOE's most pressing energy and environmental challenges.**

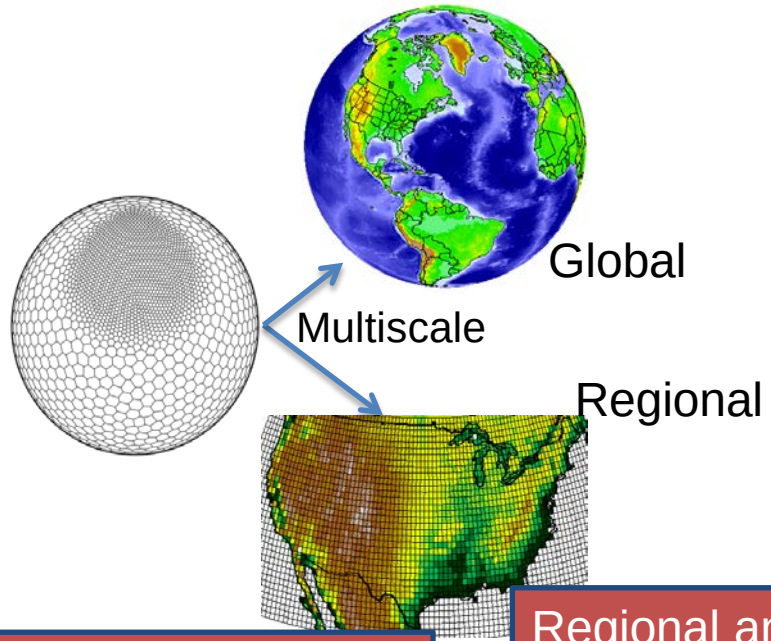
Background:

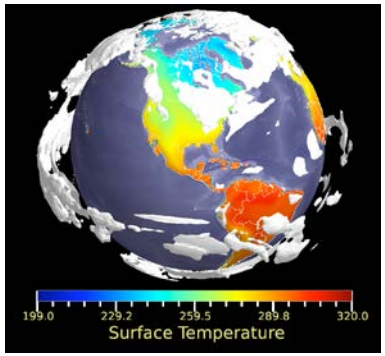
- RGCM program formed in 2010 due to an increase in funding in the Climate Change Prediction Program managed by Anjuli Bamzai.
- Contained a mixture of development and analysis projects.
- As a result of the strategic plan, the focus is transitioning to analysis of the earth system
  - facilitated by solicitations to Universities
  - Will be reflected in the new direction for SFAs.

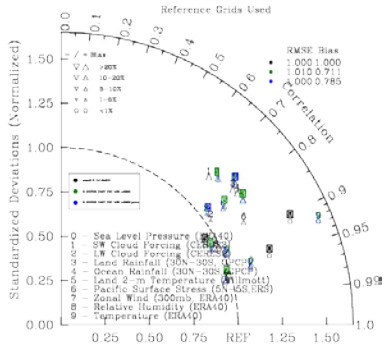


Climate and Earth System Modeling

To advance a predictive understanding of the Earth System by *developing* and *analyzing* Regional and Global Earth System Models and Integrated Assessment Models 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.







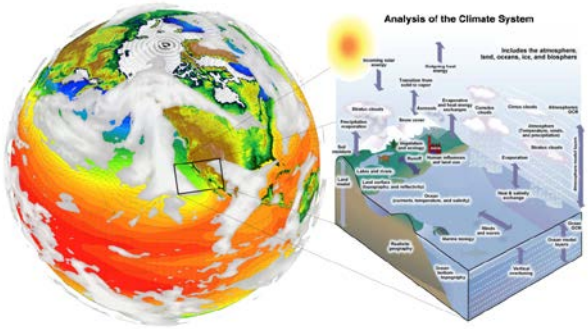
Earth System Modeling

Regional and Global Climate Modeling

Integrated Assessment Research Program

Regional and Global Climate Modeling

Strategic Goal: To advance understanding and predictability of climate and earth system models through analysis of model simulations at regional and global scales



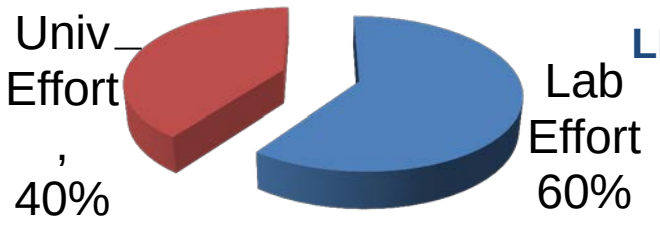
Program Description: Through hypothesis-driven research based on model simulations, enhance our understanding of the Earth System by:

- Focusing on multiscale interactions of Earth System processes
- Understanding climate variability and change
- Detection and attribution of climate change
- Investigating climate feedbacks
- Characterizing uncertainties in climate simulations
- Exploring methods to reduce model biases
- Evaluating approaches to robust modeling at higher resolution
- Diagnosing, evaluating, and analyzing state-of-the-science coupled climate and Earth system model simulations
- Developing metrics and analysis/visualization tools to quantify model skill and analyze model simulations
- Supporting core modeling infrastructure: PCMDI

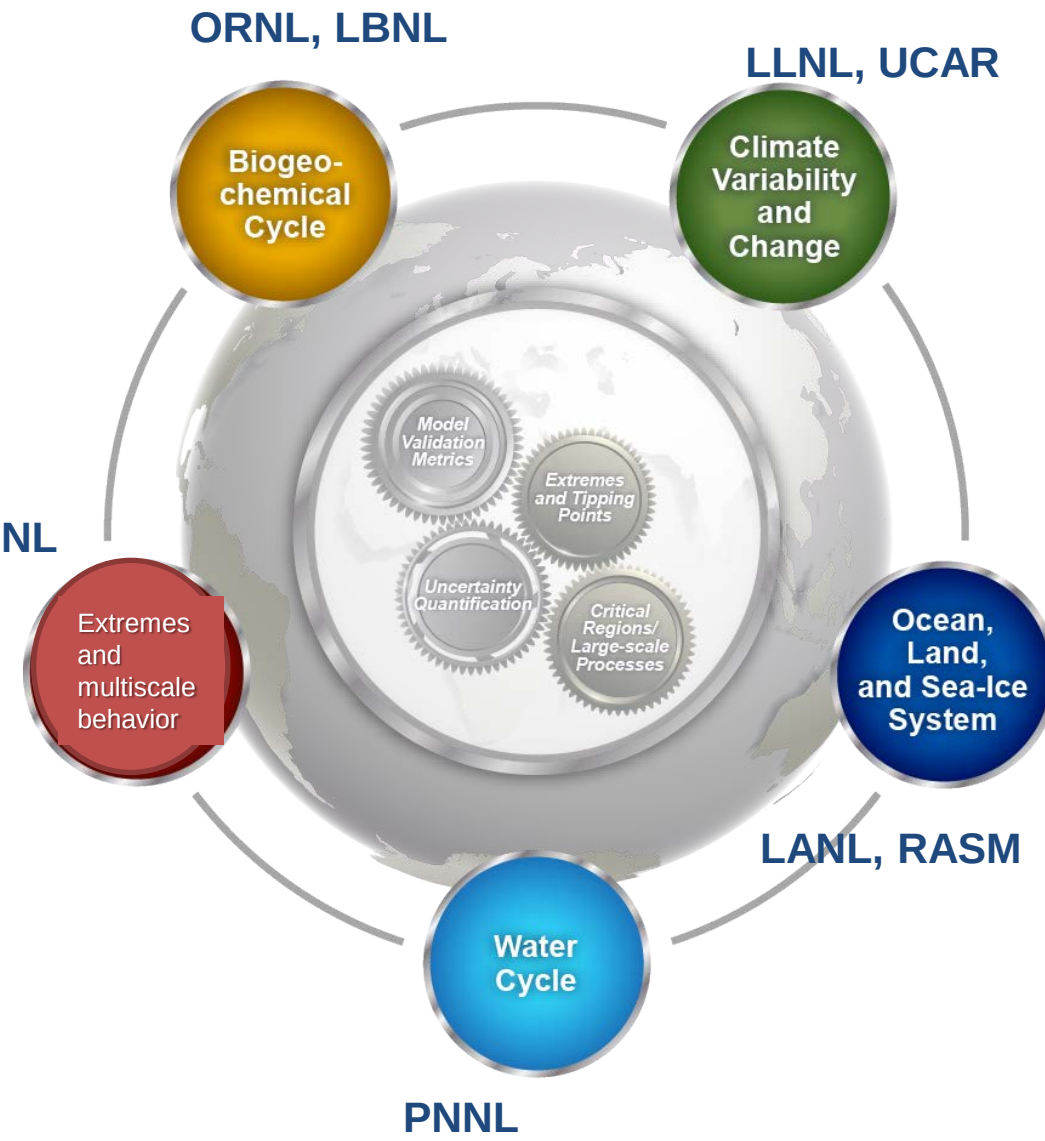
RGCM Portfolio

- Lab Projects
- Cooperative Agreements
- University Projects

Approx. Funding Distribution

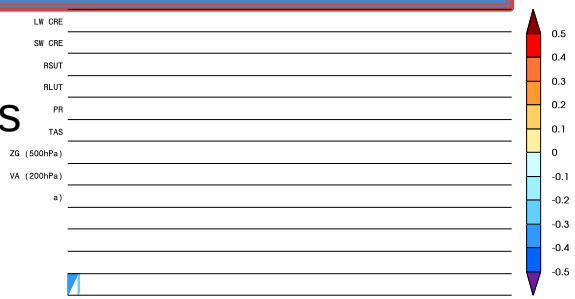


FY10	FY11	FY12	FY13
28M	31M	28M	28M



LLNL focuses on providing a multi-model perspective and understanding of climate and climate change.

(POCS: Bader,Taylor, Klein)

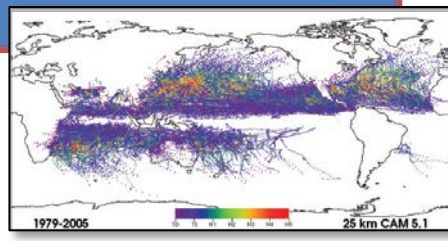


- **PCMDI**
  - Coordination of CMIP enables community-wide analysis and diagnosis of climate models.
  - Climate variability and Change
    - Builds on in-house expertise in, e.g., detection and attribution, MJO, ENSO and monsoon variability, ocean heat content changes, and skill scores.
    - Attempts to promote more systematic and comprehensive summaries of model performance
  - Performance metrics and promotion of systematic quantitative analysis of climate models
- **CAPT**
  - To identify error sources in CAM's simulation of clouds and aerosols (e.g., YOTC; Correspondence of forecast errors to climate errors)
- **Cloud Feedbacks component to narrow climate projection uncertainties**
  - Quantifying and identify sources of inter-model spread in cloud feedbacks

CAPT
Cloud-Associated Parameterizations Testbed

LBNL : CAlibrated and Systematic Characterization, Attribution, and Detection of Extremes (CASCADE)

(POC: Collins)



- **Extremes attribution / projection with robust UQ**
  - Probabilistic attribution of individual and multiple climate extremes
  - Falsifiable short-range projections of extreme frequency and number
  - Risks of changing scale / coincidence / duration / frequency
- **High-performance pipelines for UQ and metrics of extremes**
  - UQ system for extremes combining UQ and visualization frameworks
  - Statistical analysis of PPE and perturbed IC/BC ensembles for UQ
  - Analysis of CMIP5 & C20C archives for structural UQ, Type I/II errors
- **From model formulation to skillful attribution and projection**
  - Experiments to quantify roles of new scale-aware physics in extremes
  - Capabilities and limitations of new refinable dycores for extremes
  - Process-oriented tests to explore upper limits on model fidelity

PNNL: Water Cycle and Climate Extremes Modeling

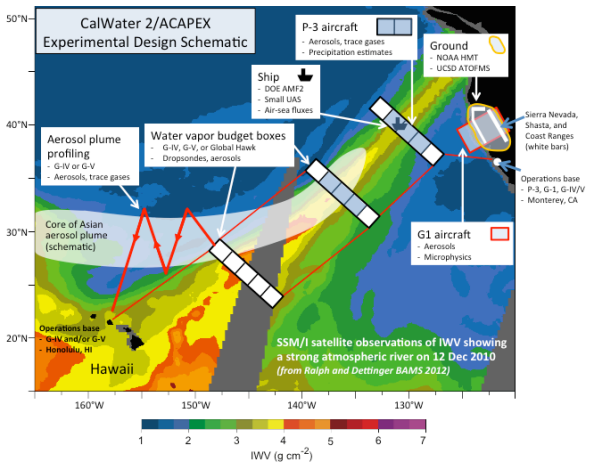
(POC: Leung)

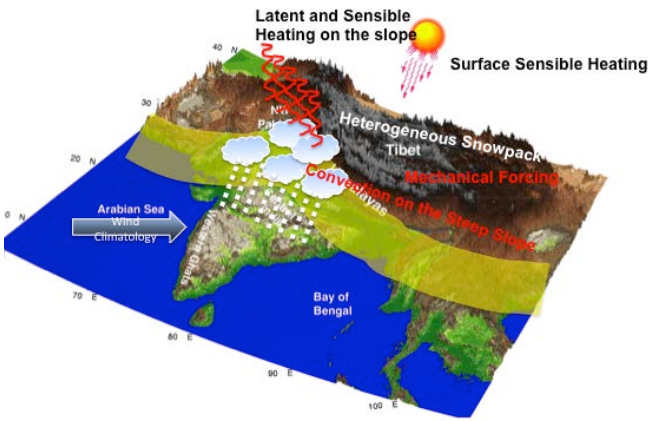
Objectives

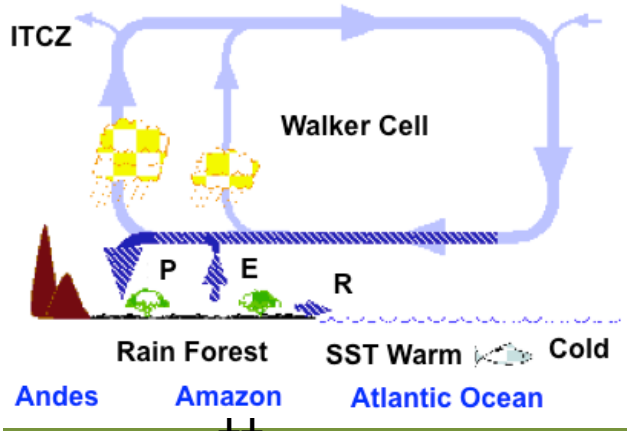
- To improve and evaluate methodologies for high resolution modeling of water cycle and climate extremes governed by multi-scale processes
- To advance understanding of processes and feedback mechanisms associated with water cycle and climate extremes

Approach

- Use a hierarchical evaluation framework to assess how dynamical framework and physics parameterizations interact at multiple time/space scales
- Apply models to test hypotheses on process feedbacks that influence climate extremes associated with the atmospheric rivers, South American monsoon, and Asian monsoon



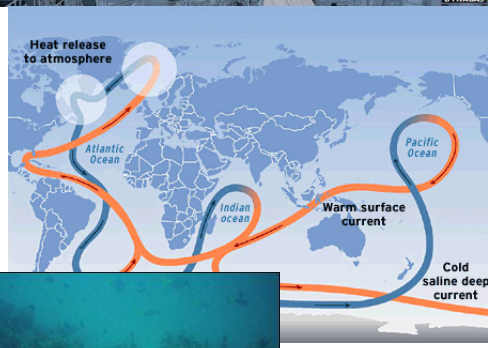


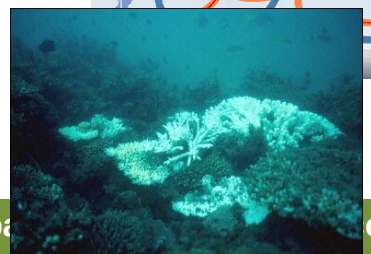


Adapted from Ning Zeng

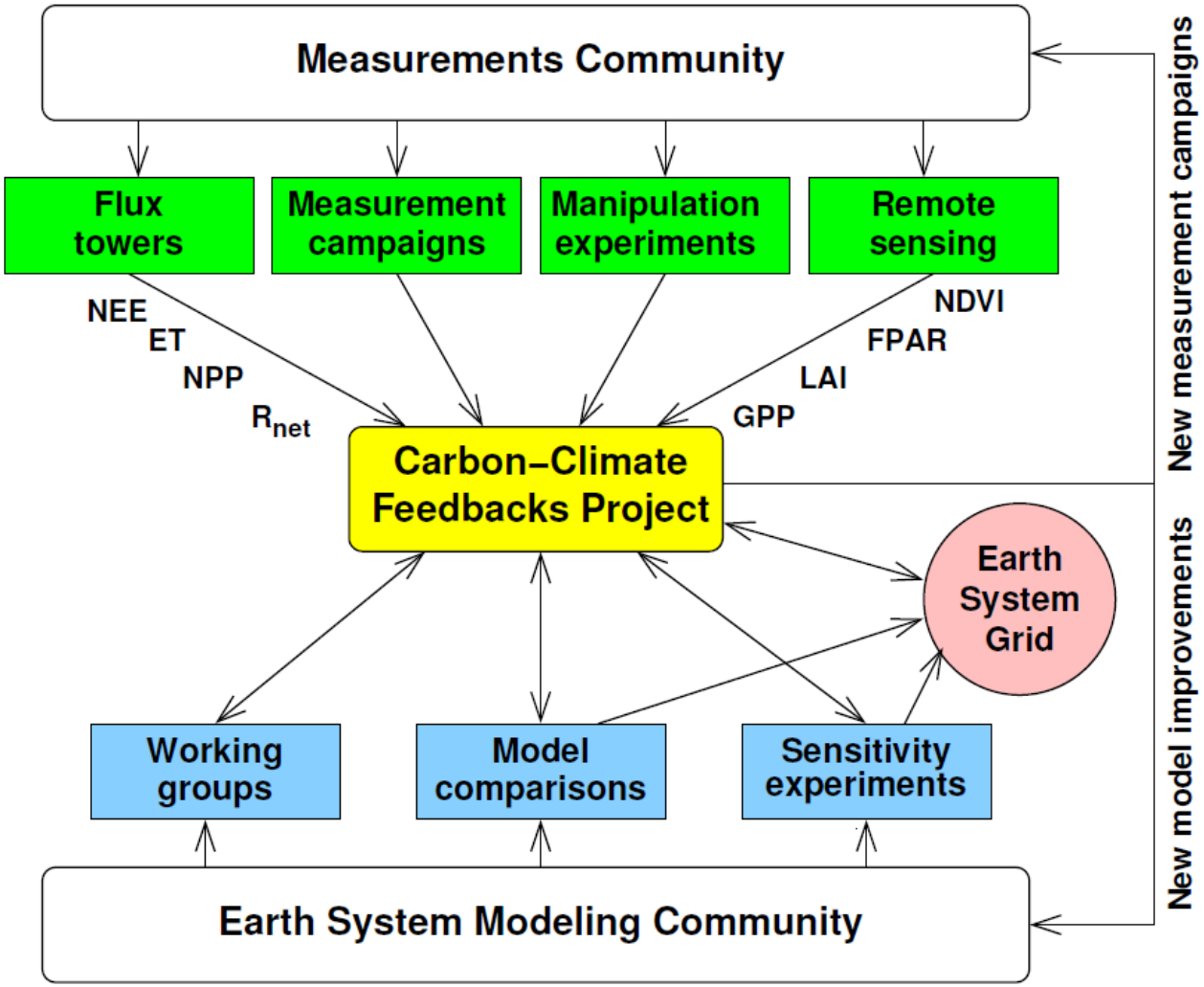
LANL: COSIM-RGCM Project – Applications and Analysis (POC: Jones)

- Focus on high latitude climate change and its impacts (MPAS)
  - Ice sheets and sea level rise, especially longer term implications
  - Long-term sea ice thinning, sea ice predictability and new sea ice intercomparisons
  - Ocean circulation and stability with a focus on meridional overturning and role of eddies in ocean circulation
- Development of new metrics and diagnostics
  - Eddy diagnostics
  - Long-term tracers and proxies for mode water and AMOC studies
  - Ocean, ice metrics for intercomparison and prediction
  - UQ/assimilation approaches for data comparison
- Single (or few)-component sims for science questions, process studies, and model evaluation



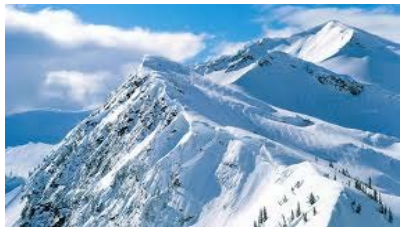


Employing best-available observational data, the Carbon-Climate Feedbacks Project develops metrics and diagnostics for systematic assessment of Earth System Models- (POCs: Forrest @ ORNL; Riley @ LBNL)



Expected Priorities/Outcomes of Efforts in RGCM

- Identify and test methods of reducing biases in Regional and Global climate and Earth System Models => informs model development
- "Analyze climate feedbacks and multiscale process interactions in climate sensitive regions => inform process research and observational needs
- Develop metrics and diagnostics to evaluate the veracity of a hierarchy of models
- Ensure that the analysis contributes to a larger goal
  - The analysis effort accelerates the development of metrics and diagnostics
  - The analysis packages (when useful) are contributed to a repository
  - The visualization tools that are developed are shared with the community
- This requires more interaction between
  - The larger thrusts (SFA, CA)
  - Lab and university efforts
  - Interagency coordination

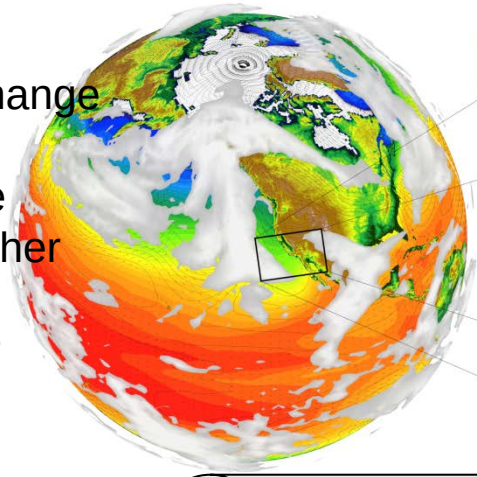



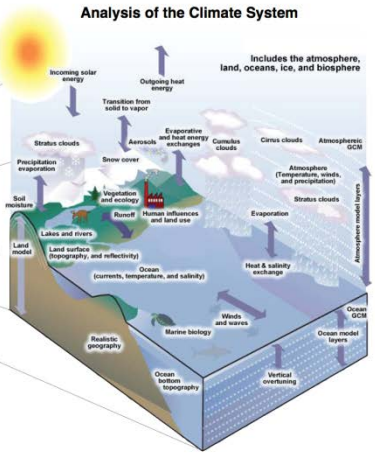
Regional and Global Climate Modeling

FY10	FY11	FY12
28M	31M	28M

Goal of the program is to advance the predictive understanding of Earth's climate, its variability, and change by:

1) Focusing processes and regions critical to climate
2) Evaluating methods to obtain robust results at higher resolution
3) Diagnosing and analyzing state-of-the-science for coupled climate and Earth system models





Science we focus enhances understanding in :

- **Climate Variability and Change**
- **Extremes, Thresholds and Tipping points***
- **Feedbacks within the climate system***
- **Detection and Attribution of climate**
- **Decadal predictability and Sea-level Rise***
- **Cross-cutting topics like the Water and Biogeochemical cycles***

Tools include:

- **Advanced (multivariate) model metrics***
- **Observation-based diagnostics***
- **Uncertainty quantification methods to guide model development, gauge model improvement, and establish confidence in model projections***
- **Visualization tools to facilitate analysis of model output**

Three Recent Successes:

1) PCMDI and the RGCM funded scientist community played a significant **leadership role in the latest IPCC process**
2) The UCAR CA **performed** and the funded scientist community **analyzed the CESM/CCSM simulations**
3) The Carbon-Cycle Feedbacks project **contributed to the latest version of the CLM4.5 upgrade**

Thanks