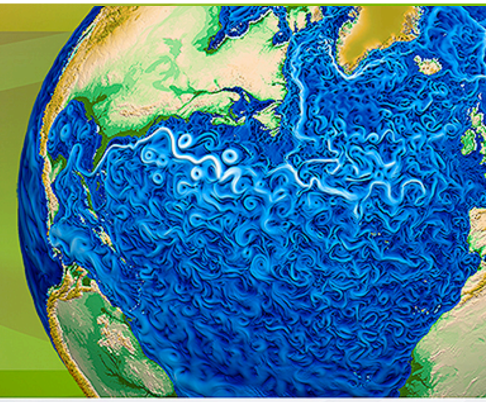


ACME Overview

(Dave Bader)

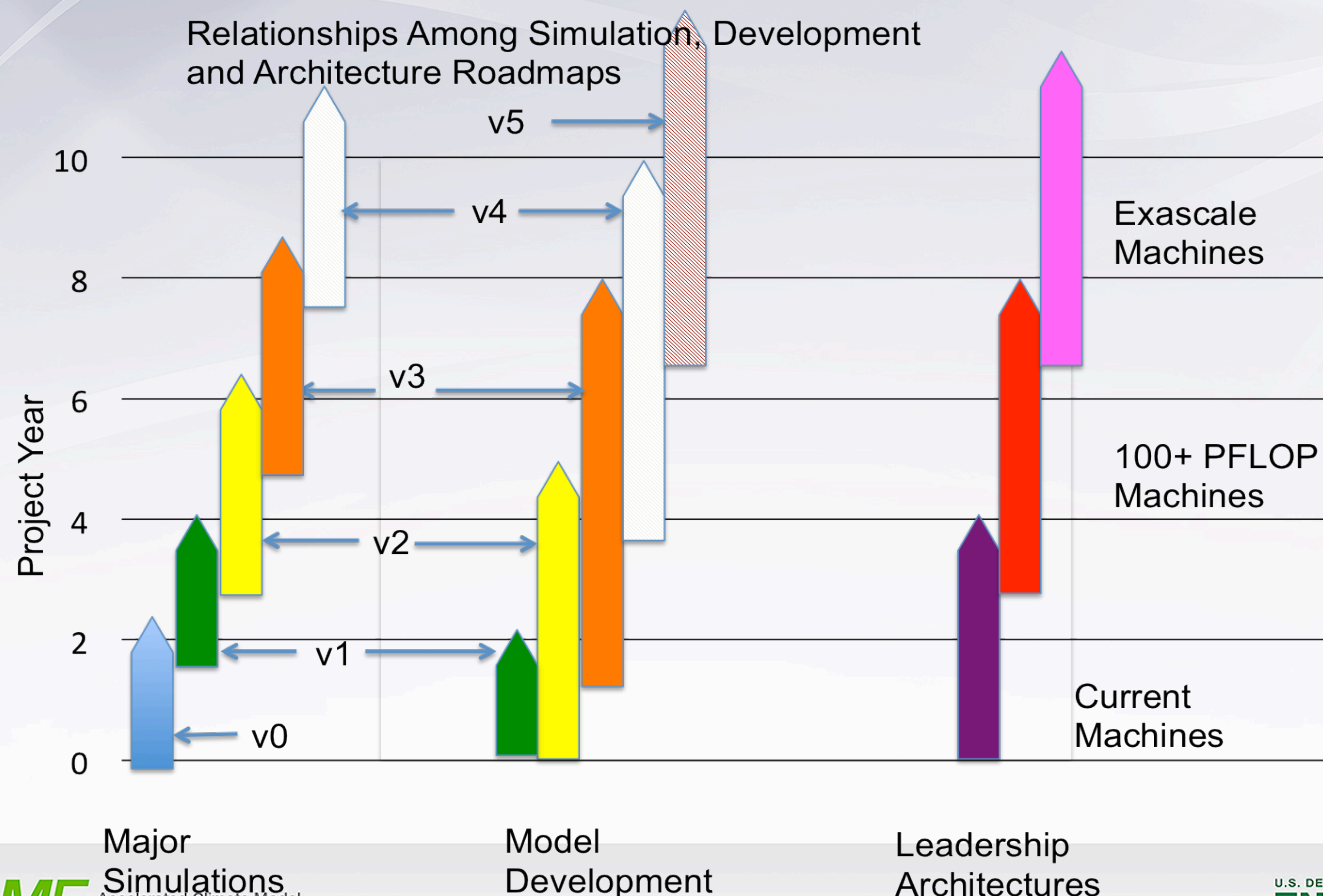
ACME Council Chair and PI

And the ACME SFA Team

ACME Project Elements

- a series of **prediction and simulation experiments** addressing scientific questions and mission needs;
- a well documented and tested, continuously advancing, evolving, and improving **system of model codes that comprise the ACME Earth system model**;
- the ability to use effectively **leading (and "bleeding") edge computational facilities** soon after their deployment at DOE national laboratories; and
- **an infrastructure** to support code development, hypothesis testing, simulation execution, and analysis of results.

ACME Roadmap



ACME Accelerated Climate Model for Energy

U.S. DEPARTMENT OF ENERGY

Management Approach

ACME Council
Dave Bader, Chair
Executive Committee: W. Collins, M. Taylor
R. Jacob, P. Jones, P. Rasch, P. Thornton, D. Williams
Ex Officio: J. Edmonds, J. Hack, W. Large, E. Ng

Executive Committee
Chair: D. Bader
Chief Scientist: William Collins
Chief Computational Scientist: Mark Taylor

Project Engineer
Renata McCoy

Land Group
Peter Thornton
William Riley

Land Task Leaders

Atmosphere Group
Philip Rasch
Peter Caldwell

Atmosphere Task Leaders

Software Eng./ Coupler Group
Robert Jacob
Andrew Salinger

SE/Coupler Task Leaders

Workflow Group
Dean Williams
Katherine Evans

Workflow Task Leaders

Ocean/Ice Group
Philip Jones
Todd Ringler

Ocean/Ice Task Leaders

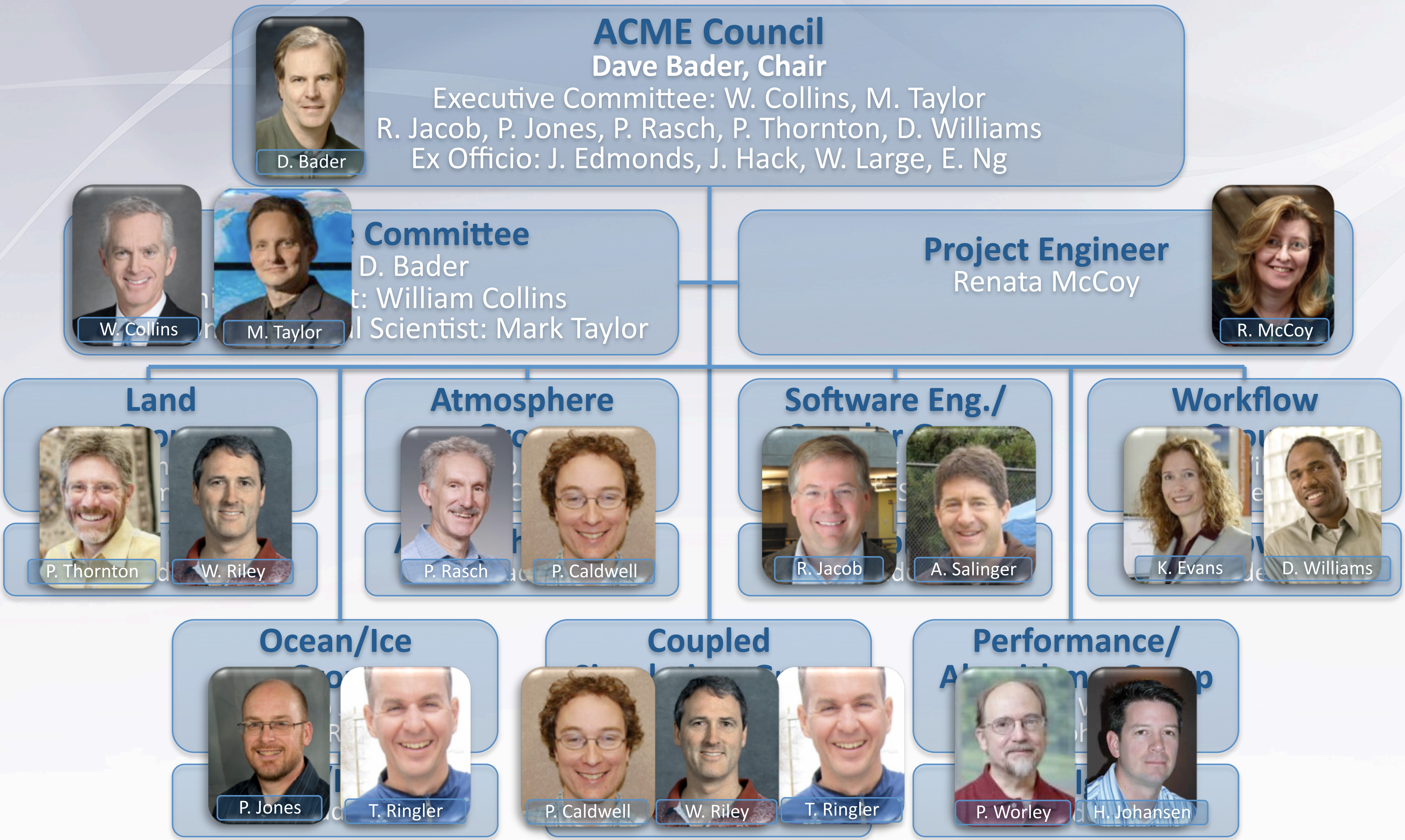
Coupled Simulation Group
Peter Caldwell, William Riley, Todd Ringler

Coupled Sim. Task Leaders

Performance/ Algorithms Group
Patrick Worley
Hans Johansen

Perf. / Alg. Task Leaders

Management Approach



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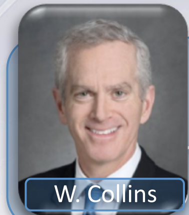

Executive Committee
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Project Engineer
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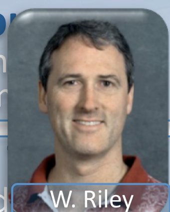
Land



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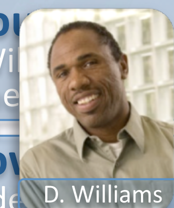

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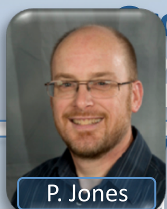

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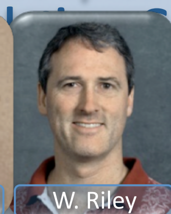


Task

Performance/
Algorithms Group
Patrick Worley
Hans Johansen

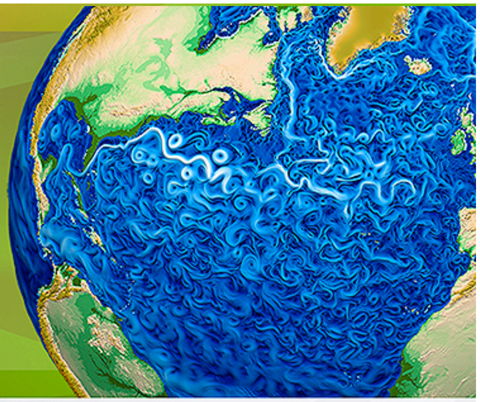
Perf./Alg. Task
Leaders

First Quarter Effort

- 85 researchers working ¼ time or more
- 63 tasks
- Total effort ~43 FTE
- Established ACME software repository and initial code base for v0 model
- Organized tasks among 7 teams
- Completed INCITE and ERCAP proposals
- Engaged NERSC and OLCF centers in pre-Exascale collaborations
- Advisory Committee established

ACME

Accelerated Climate Modeling for Energy



ACME Climate Science

William D. Collins

Lawrence Berkeley Laboratory

ACME Chief Scientist

And the ACME SFA Team

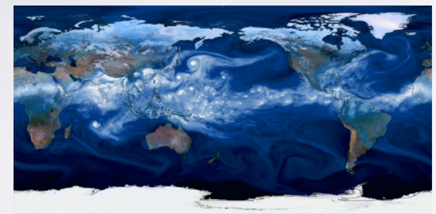
U.S. DEPARTMENT OF ENERGY

Vision and 10-year Goals

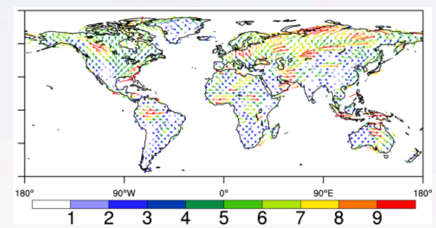
- **Vision:**
  The Accelerated Climate Modeling for Energy Project is an ongoing, state-of-the-science Earth system modeling, simulation and prediction project that optimizes the use of U.S. Department of Energy (DOE) laboratory resources to meet the science needs of the Nation and the mission needs of DOE
  .
- **10-year science goals:**
  – A series of prediction and simulation experiments addressing scientific questions and mission needs
  – A well documented and tested, continuously advancing, evolving and improving system of model codes that comprise the ACME Earth system model

Climate Science Drivers

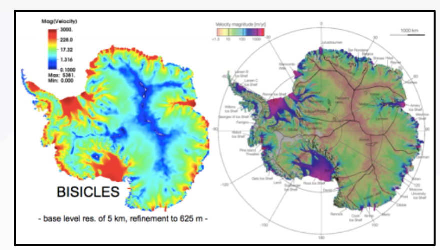
Water cycle: How do the hydrological cycle and water resources interact with the climate system on local to global scales?



Biogeochemistry: How do biogeochemical cycles interact with global climate change?



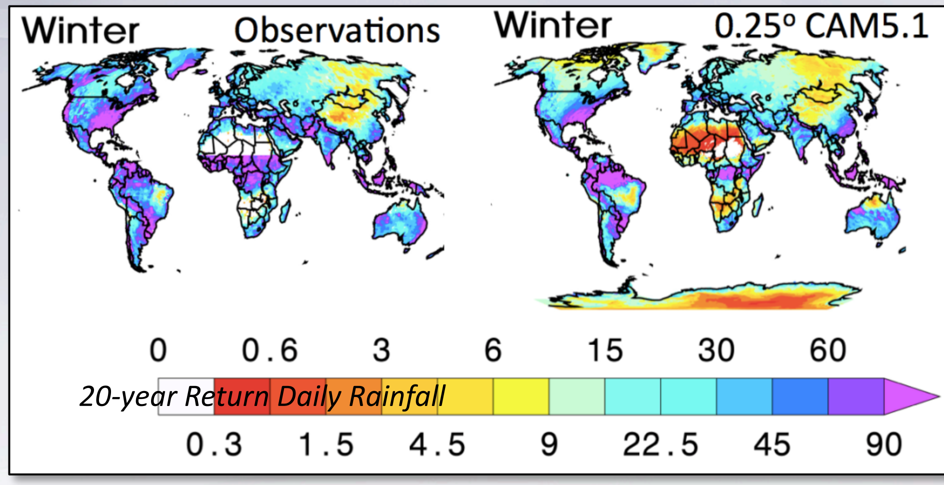
Cryosphere: How do rapid changes in cryospheric systems interact with the climate system?



Science Questions

- *Water cycle:*
  - What are the processes and factors governing precipitation and the water cycle today and how will precipitation evolve over the next 40 years?
- *Biogeochemistry:*
  - What are the contributions and feedbacks from natural and managed systems to current greenhouse gas fluxes, and how will those factors and associated fluxes evolve in the future?
- *Cryosphere:*
  - What will be the long-term, committed Antarctic Ice Sheet contribution to sea level rise (SLR) from climate change during1970–2050?

Water Cycle Experiments

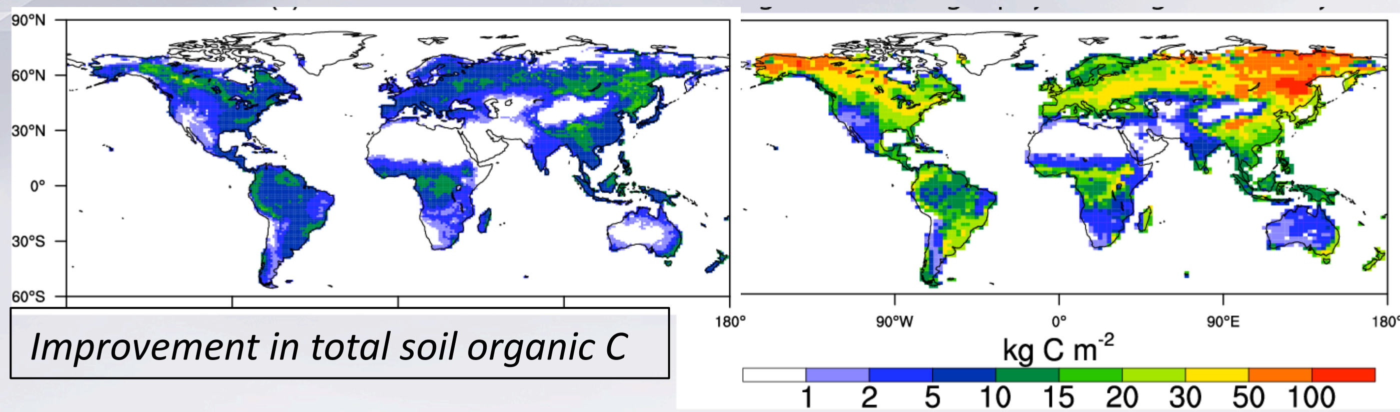


Near-term: How will more realistic portrayals of features in the water cycle (resolution, clouds, aerosols, snowpack, river routing, land use) affect river flow and associated freshwater supplies at the watershed scale?

Simulations: Preliminary simulation plan includes:

1. Prescribed SST experiments to quantify resolution effects.
2. Fully coupled experiments to examine feedbacks = f(resolution)
3. Conduct simulations under RCP hypothesis to test hypothesis.

Biogeochemical Experiments



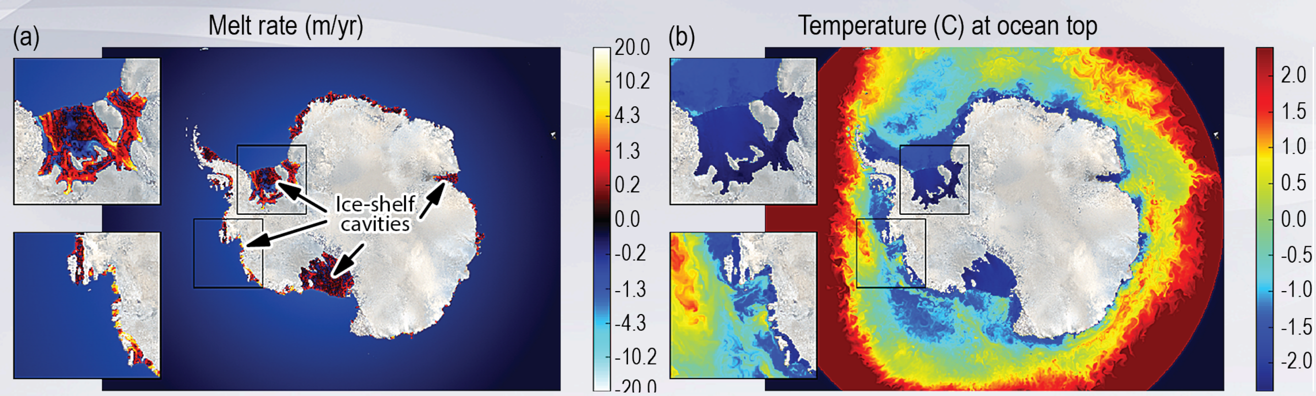
Improvement in total soil organic C

Near-term: How do carbon, nitrogen, and phosphorus cycles regulate climate system feedbacks, and how sensitive are these feedbacks to model structural uncertainty?

Simulations: Simulation plan includes

1. Fixed-forcing control simulations, using pre-industrial (circa 1850 AD) boundary conditions
2. Transient-forcing control simulations, using historical forcings
3. Fixed-forcing C-N-P simulations
4. Transient-forcing C-N-P simulations

Cryospheric Experiments

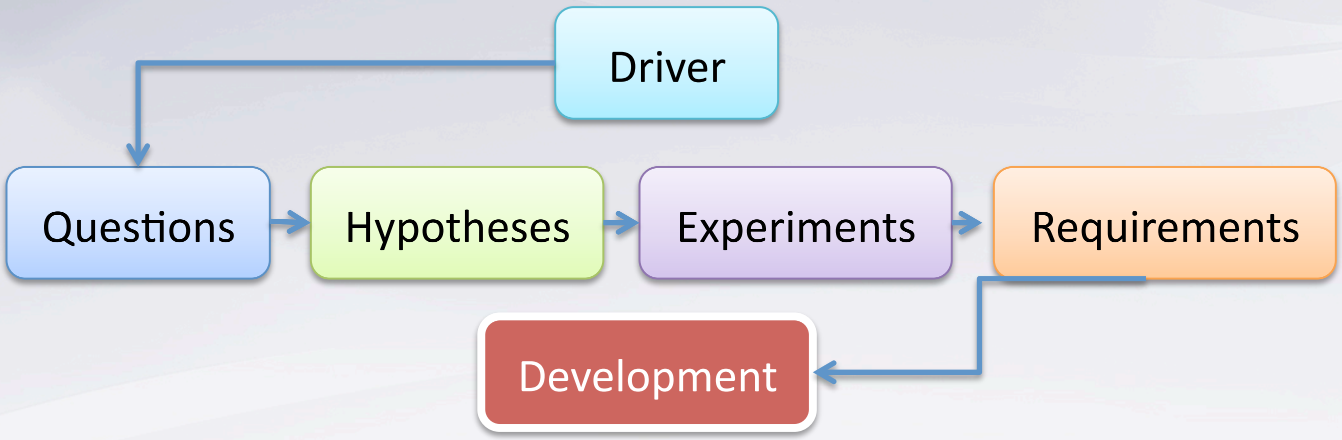


Near-term: Could a dynamical instability in the Antarctic Ice Sheet be triggered within the next 40 years?

Simulations: Simulation plan focuses on

1. Rigorous testing of the ice sheet and its interactions with the atmosphere, underlying continent, ocean, and sea ice
2. Transient fully coupled simulation from 1970 to 2050.

Drivers guide Development



The Science Drivers Determine our Development Path

Energy/Climate: Ability to assess the connection and co-evolution of human and physical Earth systems

Atmosphere: More accurate simulation of aerosols, clouds, wind, and precipitation

Land: More accurate simulation of terrestrial feedbacks from enhanced carbon, nutrient and water cycles

Ocean: Introduction of multi-resolution dynamics to more accurately simulate ocean heat uptake and water masses

Sea ice: Recast numerics to focus resolution in polar regions, and add icebergs, sea ice strength, and snow physics

Land ice: Addition of the first realistic, dynamic coupled ice-sheet model

ACME

Accelerated Climate Modeling for Energy

ACME Computational Science

Robert Jacob

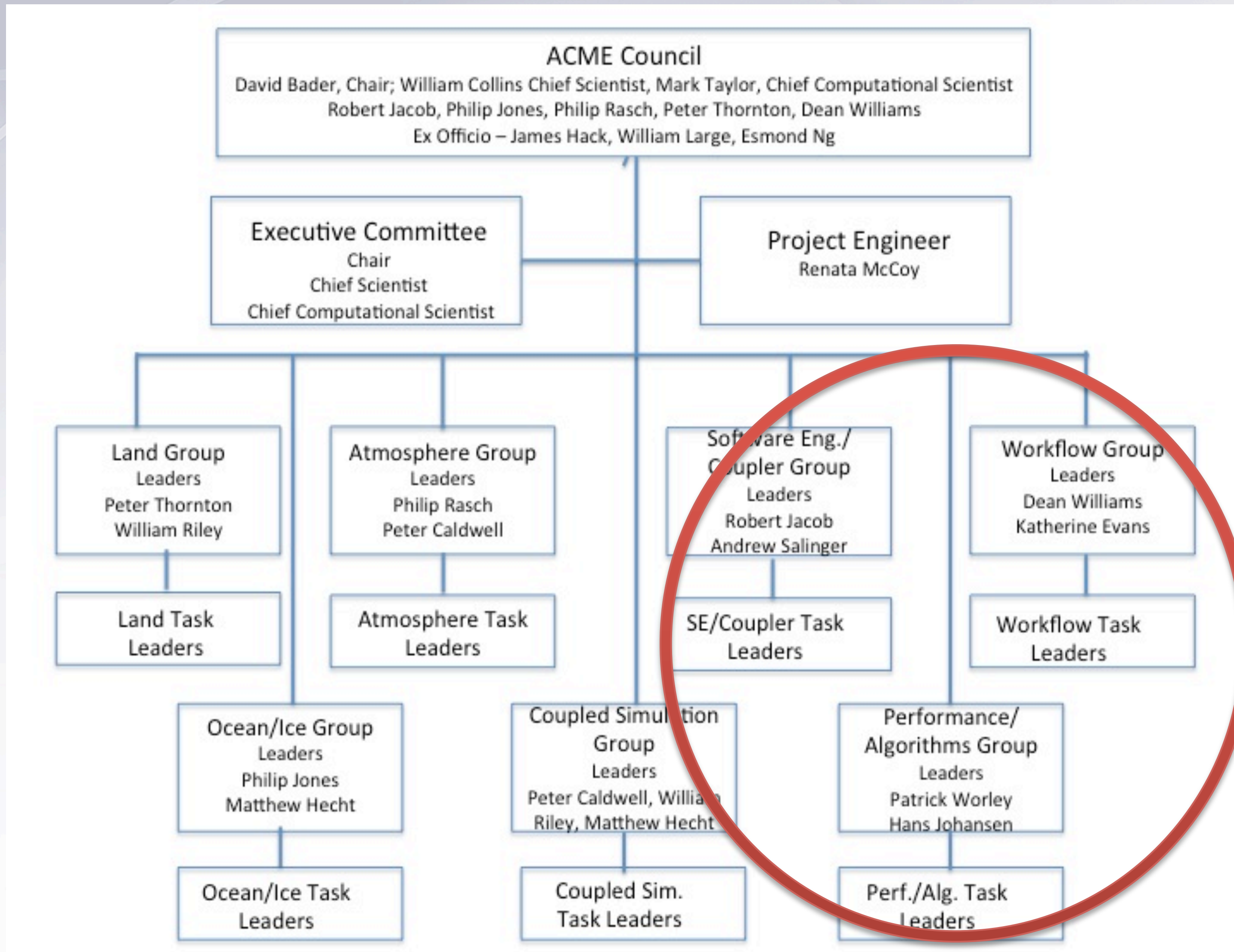
Argonne National Laboratory

ACME Council, Software Engineering and Coupling

And the ACME SFA Team

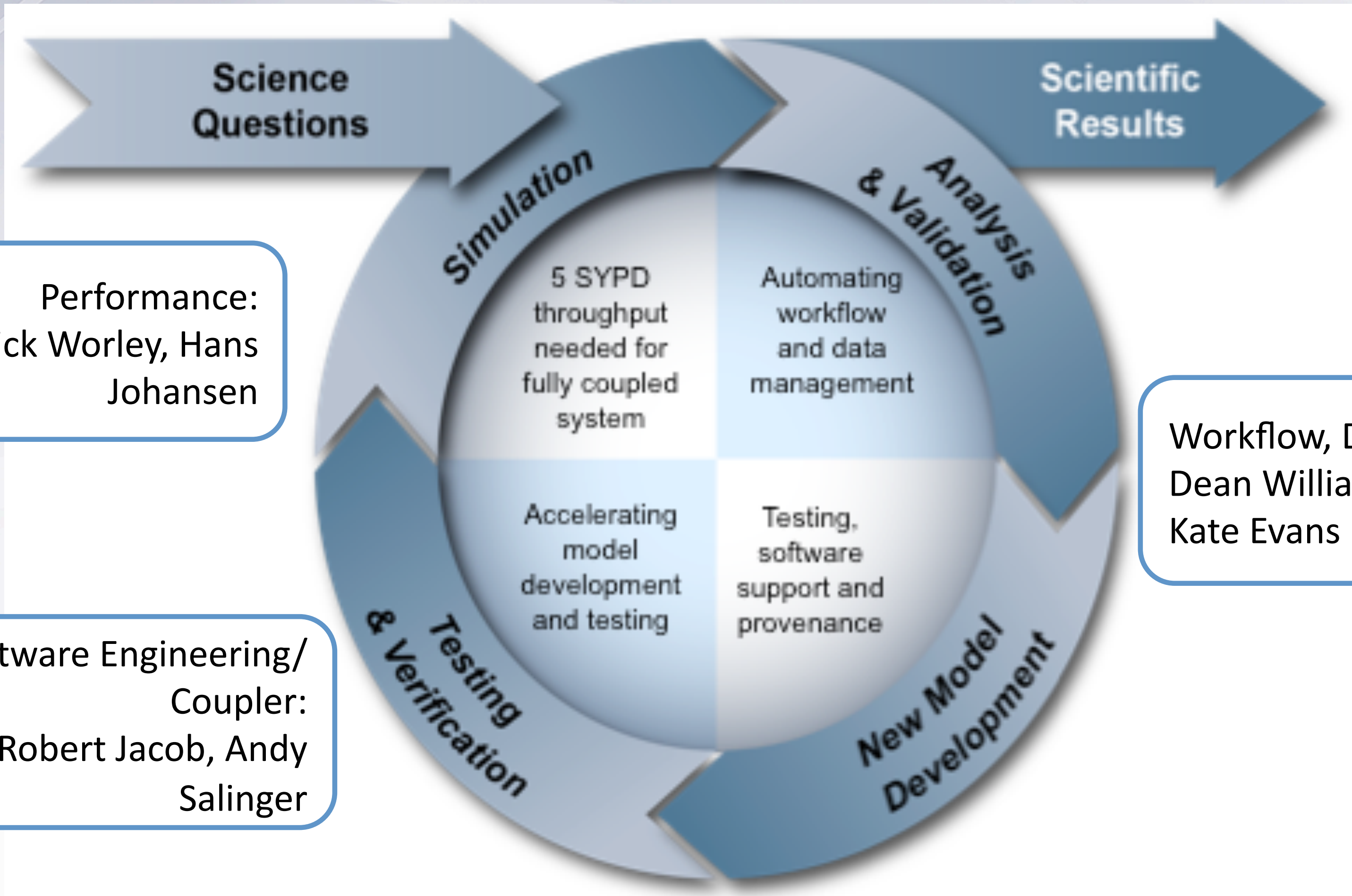
U.S. DEPARTMENT OF ENERGY

Computational Science Groups



Computational Goal: Accelerate delivery of science results from ACME fully coupled climate model

Performance:
Patrick Worley, Hans Johansen

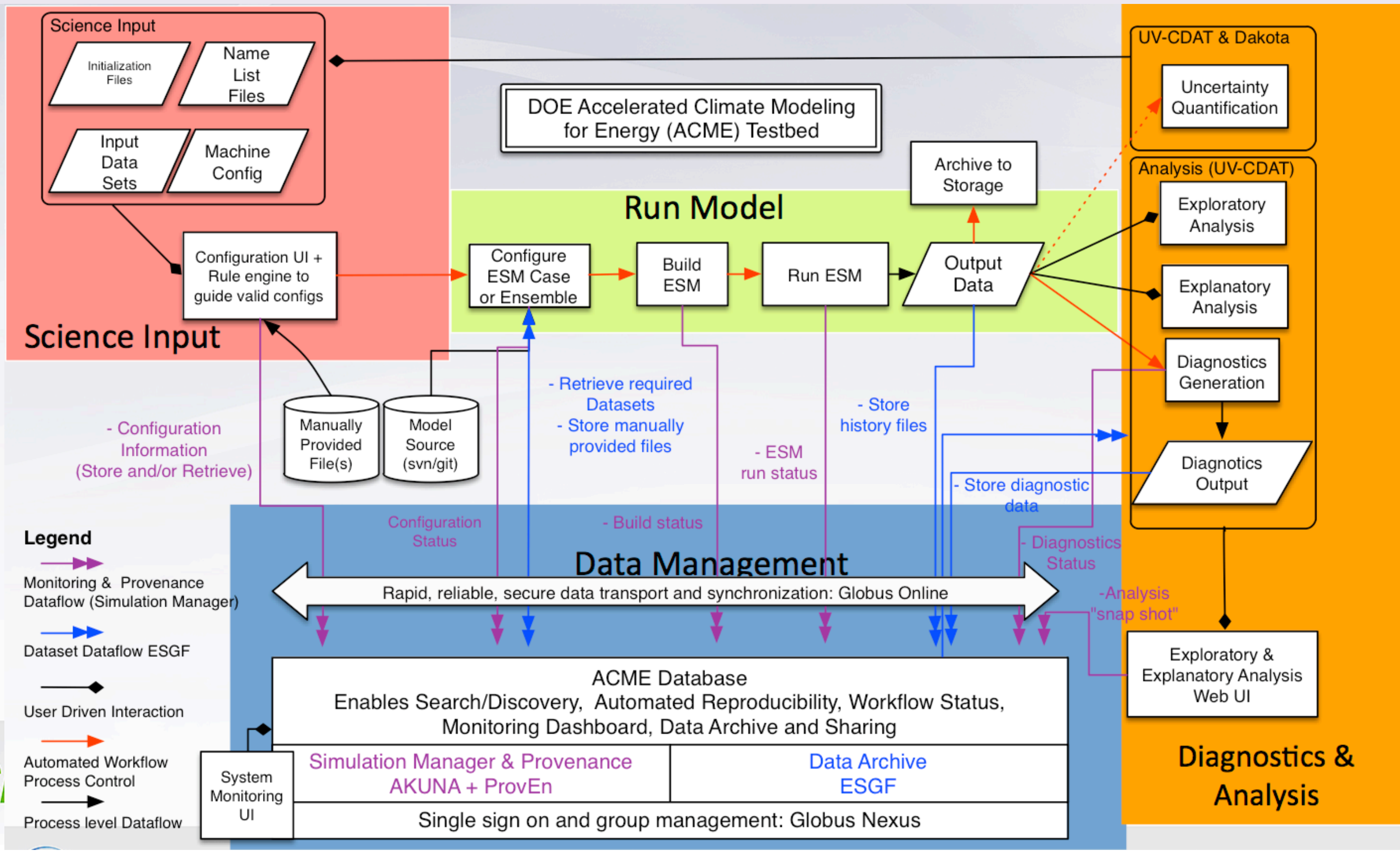


Workflow, Diagnostics:
Dean Williams,
Kate Evans

Software Engineering/ Coupler:
Robert Jacob, Andy Salinger

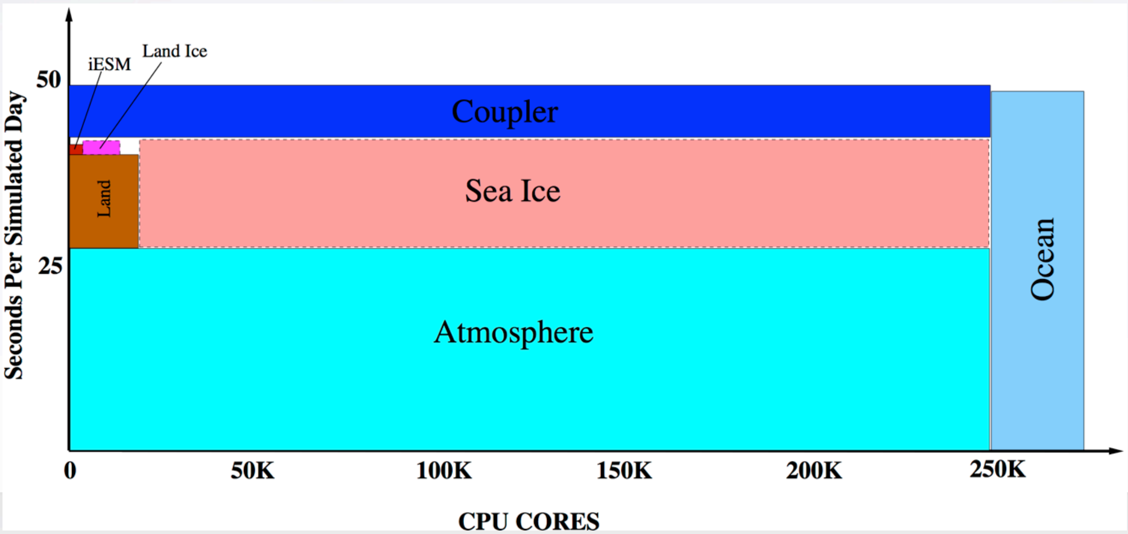
Workflow/Diagnostics: A comprehensive approach to better enable large scale climate science

The end-to-end workflow integrates a model run simulation manager (AKUNA), a data publishing/sharing/archiving infrastructure (ESGF), a secure data transport (Globus), analysis/diagnostics/visualization tools (UV-CDAT), and a provenance capture framework (ProvEn) to improve reproducibility and tracking



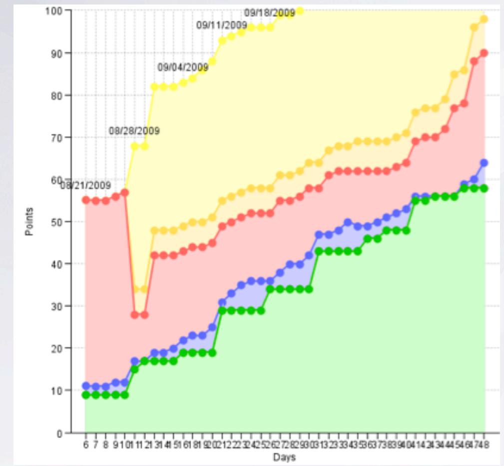
Performance Group: Simulation Throughput is Crucial

- Performance of the global high-resolution coupled system on DOE Leadership Computing Systems
- Tasks:
  - Performance Monitoring and Analysis
  - Internode and I/O: Load balancing, communication algorithm optimization, computation/communication overlap, exploiting additional concurrency
  - On-node: Accelerators, threading, memory management, programming models
  - Next Generation Architectures: NERSC NESAP, OLCF-4 CAAR, ALCF-3 ESP
- Work with SciDAC SUPER Institute (e.g. MPAS threading) and SciDAC ACES4BGC (efficient multi-tracer transport), SciDAC Multiscale (GPU and implicit solvers)



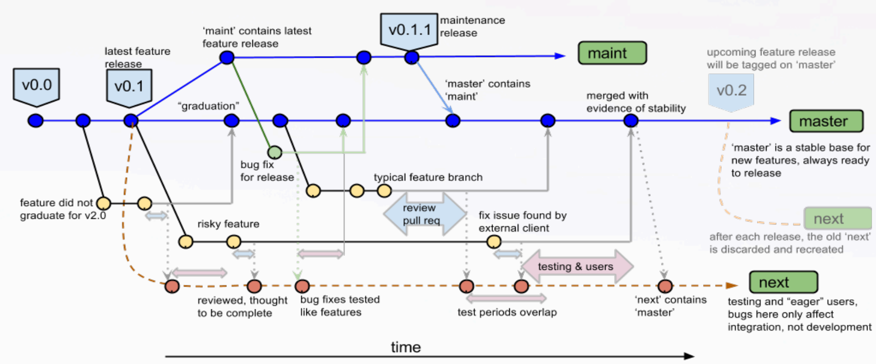
Software Engineering/Coupler: Productivity Improvements

- Best Practices: Common tools, methodologies adopted across ACME science/tech teams.
  - Rapid "Developers" test suite
  - Continuous Integration
  - Unit Testing
- I/O: Parallel I/O at ACME model scales, increased use of in-situ diagnostics.
- Modularity and configurability: Modular interfaces for all new components, improved runtime configurability
- Coupling: Coupler performance, on-line interpolation, discretization-aware remap.



Example: dashboard for JIRA issue tracking

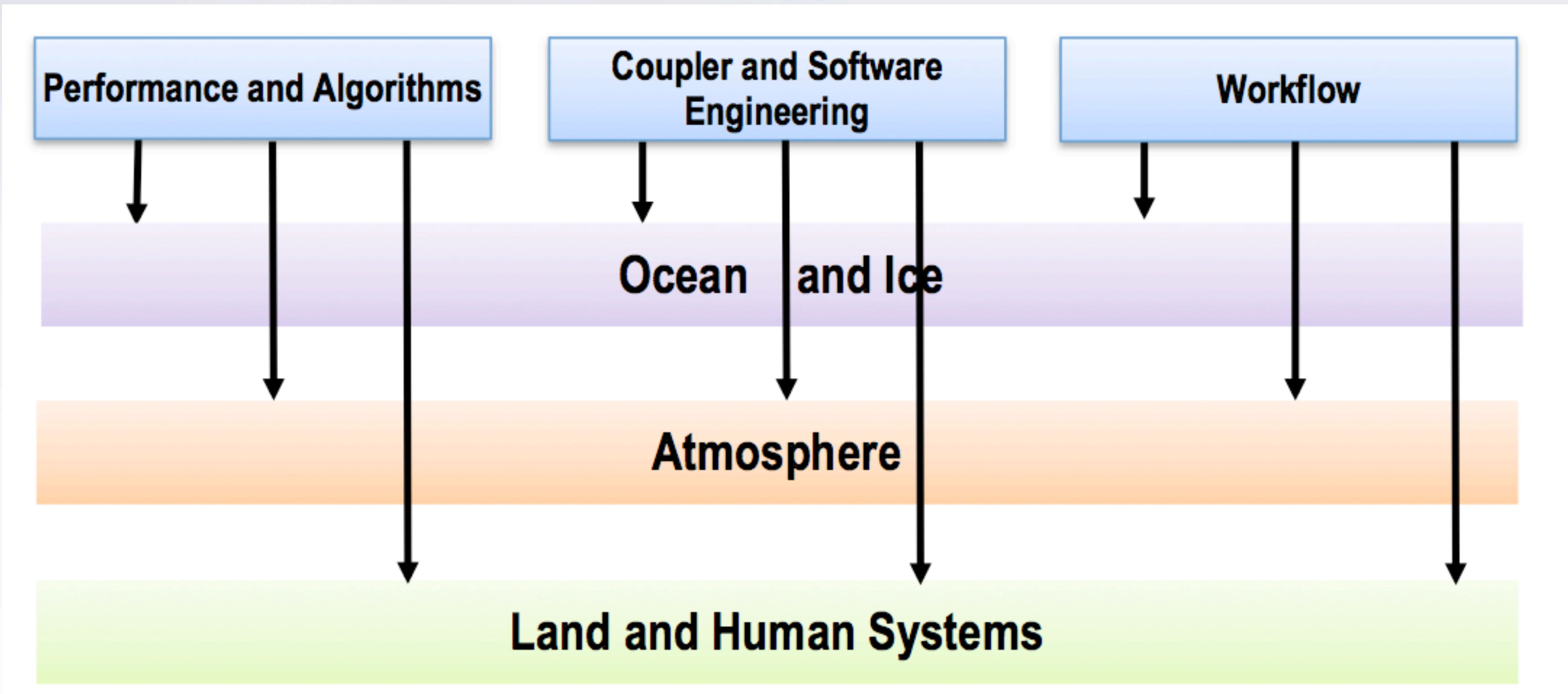
HPC programming models will continue to evolve; best defense is flexibility, testing



ACME git workflow

Computational Groups Hub-Spoke Structure

- **Touchpoints across labs and science teams, for adoption ("spokes"), but also need resource critical mass in infrastructure-focused teams ("hubs").**



ACME Computational Roadmap – Evolve while doing science

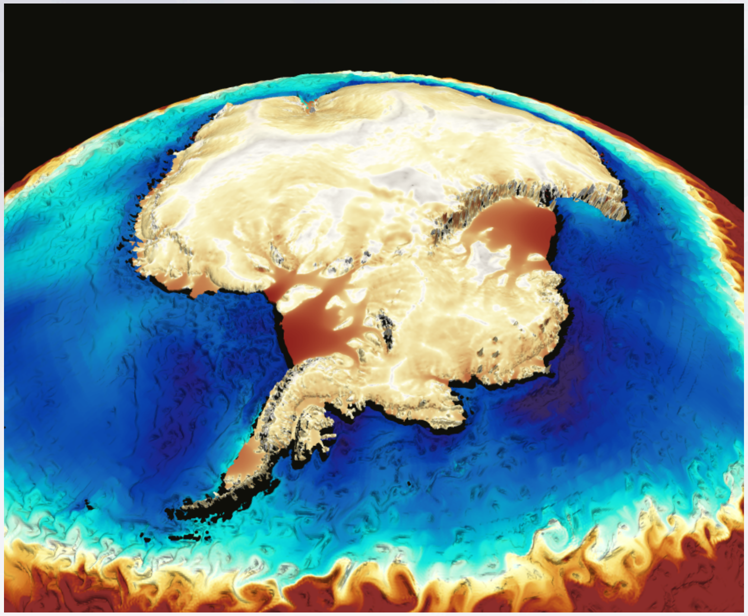
	ACME v1 (0-2 years)	*ACME v2 (2-4 years)*	*ACME v3+ (4-7 years)*
Modern SW Engineering *(e.g. sw design)*	Baseline testing and automation	Modular components, coupling	Transform code for exascale
Preparing for Exascale *(e.g. parallelism)*	Many-core threading, libraries	Architecture-optimized performance	Language-enabled performance
"Big data" for Climate *(e.g. validation)*	Workflow, in-situ diagnostics	Automated analysis, data management	Online data assimilation
Transformative Algorithms *(e.g. time integrators)*	1D implicit integrators	2D implicit-explicit	Adaptive, stochastic

ACME Early Results Highlights

ACME Group Leads

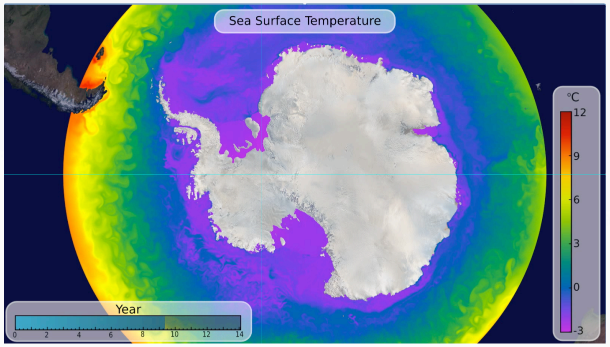
ACME Ocean/Ice Group

- MPAS Ocean v3 released
  - Validation in Coordinated Ocean Reference Experiment (CORE) under way
- Significant progress in
  - MPAS-CICE
  - MPAS ice sheet
  - Biogeochemical components
  - On track for ACME v1 release
- Initial coupled configuration and testing for ocean-ice sheet interactions



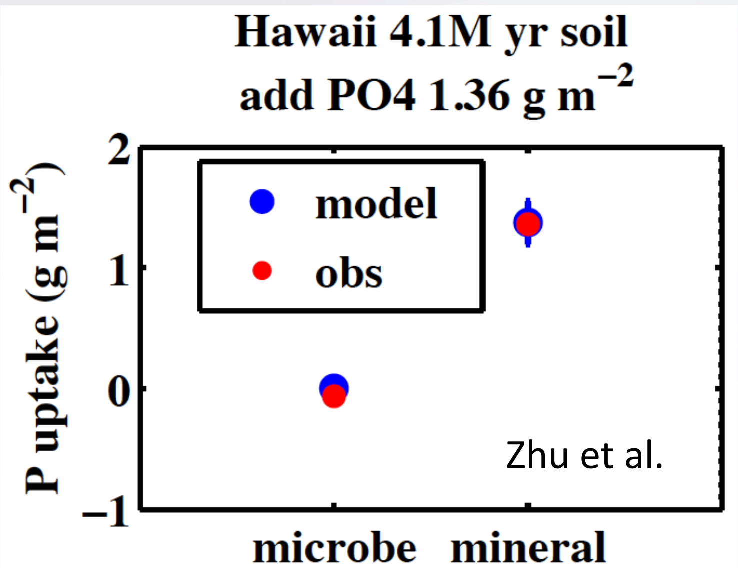
Southern Ocean SST from MPAS simulation

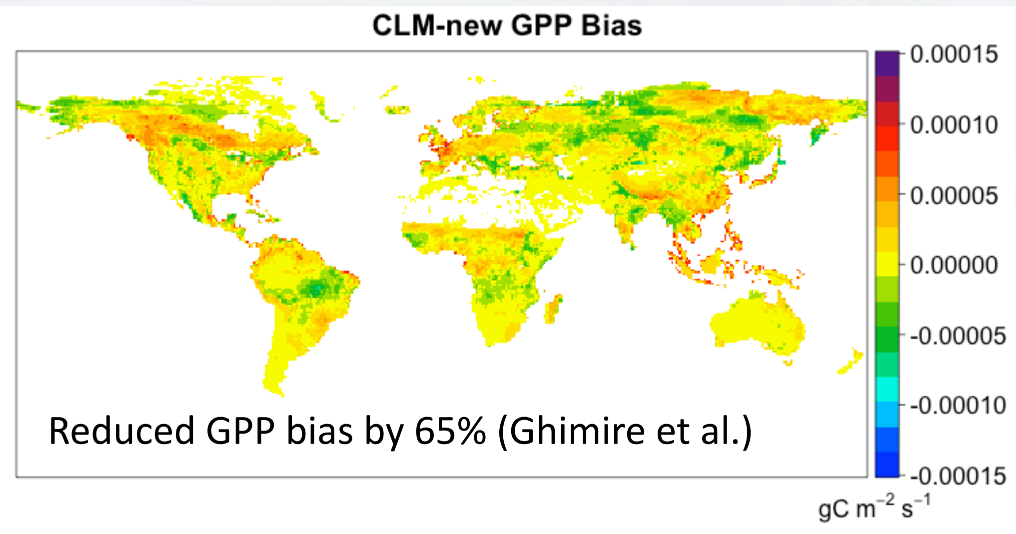
Ocean flow in extended domain under ice shelves



Improvements in ACME Carbon Cycle Predictions from New Nutrient Competition Methods

- We integrated the Equilibrium Chemistry Approximation (Tang and Riley 2013) to represent plant-microbe nutrient competition
- We integrated a prognostic carbon-nitrogen-phosphorus model (CLM-CNP: Yang et al., 2014) and crucial global phosphorus datasets (Yang et al., 2013)
- Preliminary results indicate these changes improved **site-level** perturbation responses and **global** carbon cycle metrics





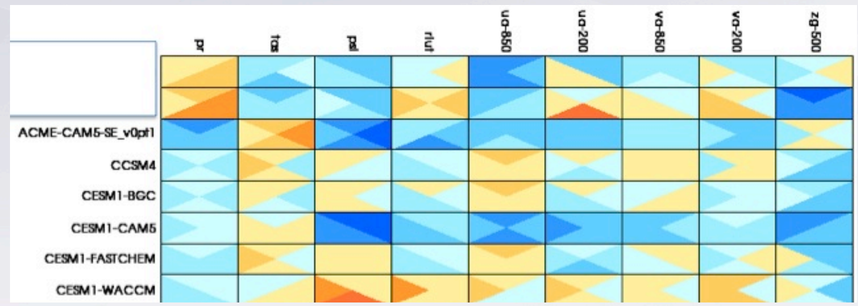
ACME Diagnostics and Analysis

- Diagnostics
  - Used to quickly evaluate models and validate their results
  - Python scripts from UV-CDAT produce climatology files and static HTML and plots (gif, jpg, etc.)

  - Scalable, dynamic and intuitive diagnostics package produce results that help ascertain and evaluate model output quickly
  - 1, 2, and 3D visualization component are easily integrated into the ACME workflow

Coupled Highlight: Initial Version (V0) Runs

- Based on CESM 1 as ported August 2014 (CAM5-SE, POP2, CLM4, CICE)
- As expected, model looks very much like CESM parent
- Uses independent GIT repository
- Two resolutions
  - 1° atm/land, 1 ° ocean/ice
  - ¼ atm/land/0.1° ocean/ice (Small et a.l, 2014 JAMES) configuration
- Baseline simulations
  - Initialized from mid-20th century CORE forced POP-CICE
  - PI atmospheric GHG and aerosol concentrations
  - Tuned for energy balance only
  - These runs will be the baseline against which future improvements will be measured



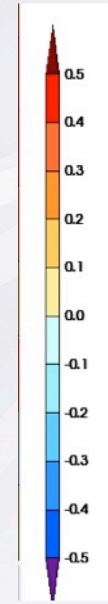


Fig: PCMDI metrics for 1^{O} V0 run

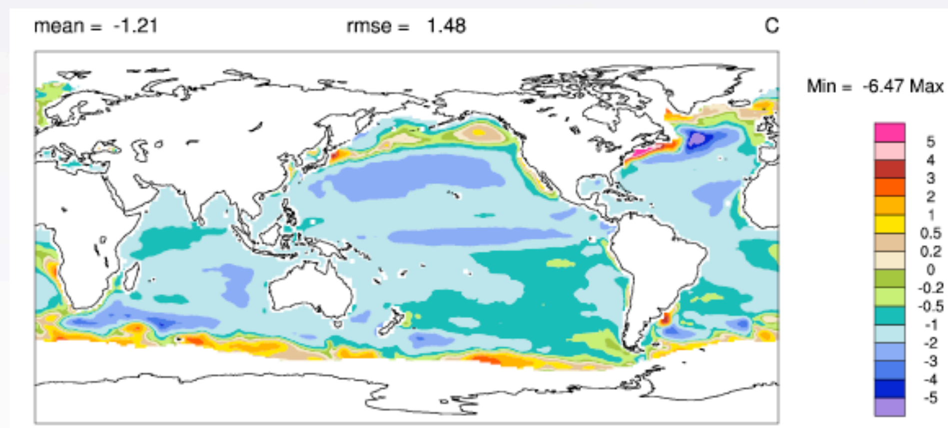


Fig: Pre-industrial SST bias for high-resolution run

Questions?

ACME community engagement

DOE

ACME is used by other programs (parameterization development and analysis)

Computing office supports with the SciDAC program and facilities.

CESM

ACME is within the CESM family of models and has ongoing coordination

Direct engagement (and future partnerships) with NCAR and other community collaborators

Codes to be made available to CESM

Climate modeling and High Performance Computing

Regular release of codes

Develop methods to deploy climate codes on Leadership-class architectures, maximize portability;

Tools to process and analyze large datasets

Energy-mission

Direct engagement with other model groups/types (IA, IAV) and stakeholders

Questions?