Accelerated Climate Model for Energy Principal Investigator “Most-Hands” November 2-4, 2015 Albuquerque, NM

ACME
Accelerated Climate Modeling for Energy

Dorothy Koch
Earth System Modeling
Climate and Environmental Sciences Division

November 2, 2015

HQ News

ACME and CESD

ACME-ASR-ARM workshop (Oct 21-22, DOE)

- **Improve coordination of Atmospheric facility, program and ACME to solve "grand-challenge" atmospheric research problems**
- **What field campaigns and new atmospheric process research could best contribute to ACME development needs?**

TES: ACME-NGEE coordination workshop (Nov 19)

- **Coordination of science and land model developments (roadmaps) among NGEE-Tropics, NGEE-Arctic and ACME**
- **TES wishes to have NGEE developments contribute to ACME-LM**

ASCR

- **SciDAC Institute call is imminent; partnerships in FY2017**
- **Computation and climate workshop (AXICCS, Jan 26-28, 2016) organized by Evans and Ng, sponsored by BER and ASCR. Seeking frontier directions for computational climate science**

Multi-agency

- **CLIVAR climate process meeting (Oct 15-16, GFDL)**
- **USGCRP Climate Modeling Summit**

ESM (Informal): FOA

ACME management updates

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

Executive Committee
Chair: D. Bader
Chief Scientist: Ruby Leung
Chief Computational Scientist: Mark Taylor

Project Engineer
Renata McCoy

Land Group
Peter Thornton
William Riley

Land Task Leaders

Atmosphere Group
Phil Rasch
Shaocheng Xie

Atmosphere Task Leaders

Software Eng./Coupler Group
Rob Jacob
Andy Salinger

SE/Coupler Task Leaders

Workflow Group
Dean Williams
Val Anantharaj

Workflow Task Leaders

Ocean/Ice Group
Todd Ringler
Steve Price

Ocean/Ice Task Leaders

Coupled Simulation Group

Coupled Sim. Task Leaders

Performance/ Algorithms Group
Phil Jones
Pat Worley

Perf. / Alg. Task Leaders

ACME Updates

"Energy/human" component: Calvin, Jones
- Exercise coupled GCAM-CESM carbon cycle in iESM
- Test importance of water management on water cycle in ACME

Next ACME project review

ACME Laboratory Management Board

NESAP and CAAR postdoctoral opportunities (see Jones, Worley)

Unique elements

Project: Geographically disperse
- 3-year cycle
- Specific scientific goals
- => Organizational overhead

Governance

Community engagement:
- Documented code release
- Direct integration of collaborators

ACME - half-way

ACME
Accelerated Climate Modeling for Energy

What is working, what isn't?

Leadership, teamwork appear solid

Commitment ?

"Collaboration" requirements
Meant to provide clarity across a large project on development, simulation and publication plans:

- Team members need assurance of credit, career advancement
- Not every publication will have every team member, but the each member needs to feel comfortable with the plan

Reporting and documentation requirements – ongoing assessment and adjustment

Are connections and communications (across and within Labs and Teams) working?

Development fatigue.. ?

Other feedback?

ACME successes

Accelerated Climate Modeling for Energy

Posted on ACME public project page

Climate component and coupled system benchmarking
against observations
computational performance
software quality

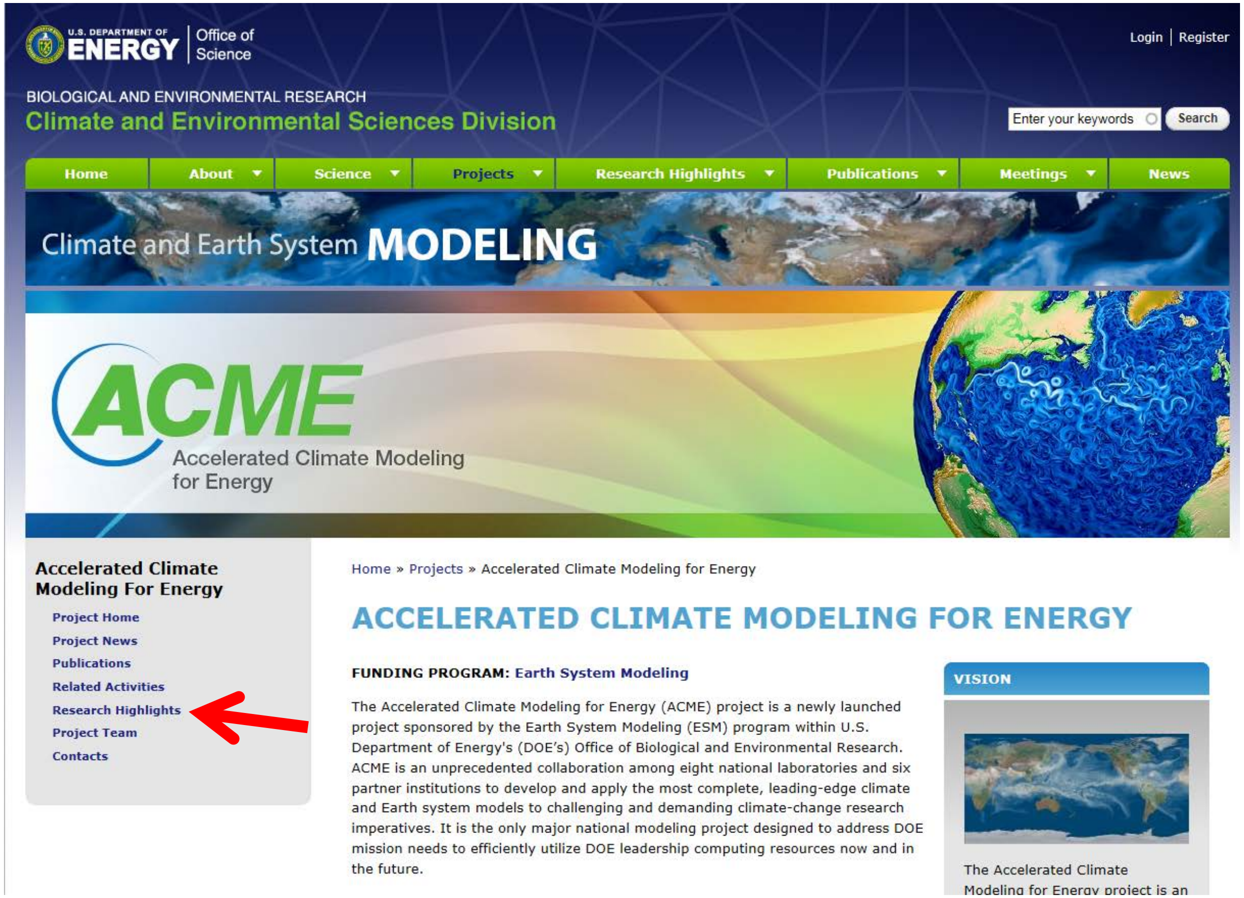
Code – software - tools a) completion, b) release
Highlights for these

ACME team awards

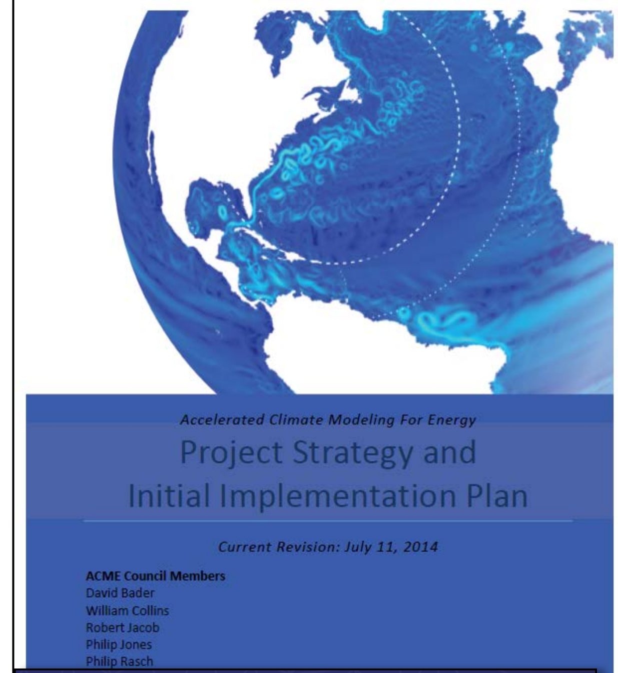
Inform us of awards, press-releases, movies (e.g. MPAS-Ocean)

Publication Highlights…

ACME public website, fact-sheet



http://climatemodeling.science.energy.gov/projects/accelerated-climate-modeling-energy



The Accelerated Climate Modeling for Energy (ACME) project is sponsored by the U.S. Department of Energy's (DOE's) Office of Biological and Environmental Research (BER) to develop and apply a computationally advanced climate and Earth system model to investigate the challenges posed by the interactions of climate change and societal energy requirements.

The ACME model simulates the fully coupled climate system at high-resolution (15-25km) and will include coupling with energy systems, with focus on a near-term hindcast (1970-2015) for model validation and a near-term projection (2015-2050) most relevant to societal planning. The model further employs regional-refinement using advanced adaptive mesh methodologies in order to provide ultra-high-resolution to resolve critical physics and meteorological phenomena. The ACME model branched from the Community Earth System Model (CESM), and increasingly, its code will be designed to optimize performance on current and future DOE Leadership Class computers.

ACME's initial scientific goals address three areas of importance to both climate research and society:

1. **Water cycle:** How do the hydrological cycle and water resources interact with the climate system on local to global scales?
2. **Biogeochemistry:** How do biogeochemical cycles interact with global climate change?
3. **Cryosphere-ocean system:** How do rapid changes in cryosphere-ocean systems interact with the climate system?

The ACME project was constructed from existing DOE climate modeling resources and is distributed across eight DOE national laboratories and six partner institutions.

Climate Science Objectives

WATER CYCLE

Understanding and developing the capability to project the evolution of water in the Earth's system is of fundamental importance both to climate-science and to societal and many energy-related processes, including coal-, nuclear-, biofuel-, and hydro-power potentials.

Using river flow as a key indicator of hydrological changes from natural and human systems, ACME is testing the hypothesis that changes in river flow have been dominated by land management, water management, and climate change associated with aerosol forcing but will be increasingly dominated by greenhouse gas changes.

The initial phase of the project focuses on simulation of precipitation and surface water in orographically complex regions, including the western United States and the headwaters of the Amazon. Improved resolution and parameterizations of clouds, aerosols, and their interactions, should produce a more realistic portrayal of the precipitation location, frequency and intensity, as well as aerosol deposits on snow and surface ice—all factors that influence runoff, snowpack, and snowmelt. ACME explores the role of these various physical processes in influencing river flow and fresh water supply, with a goal of simulating an accurate portrayal of present-day river flow for major river basins on the planet.

The longer-term water cycle goal is to understand how the hydrological cycle in the fully coupled climate system will evolve with climate change and the expected effect on local, regional, and national supplies of fresh water.

ACME will further examine whether during the next 40 years, the additional forcing from increasing greenhouse gas concentrations will come to dominate river flow changes.

1

ACME News

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- Project Home
- Project News
- Publications
- Research Highlights
- 2015 PI Meeting
- Related Activities
- Project Team
- Contacts

Home »

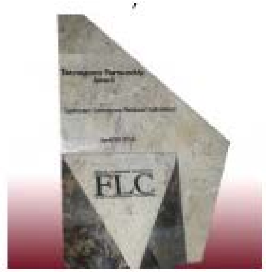
ACCELERATED CLIMATE MODELING FOR ENERGY NEWS

William Leads Team to Federal Laboratory Consortium Award

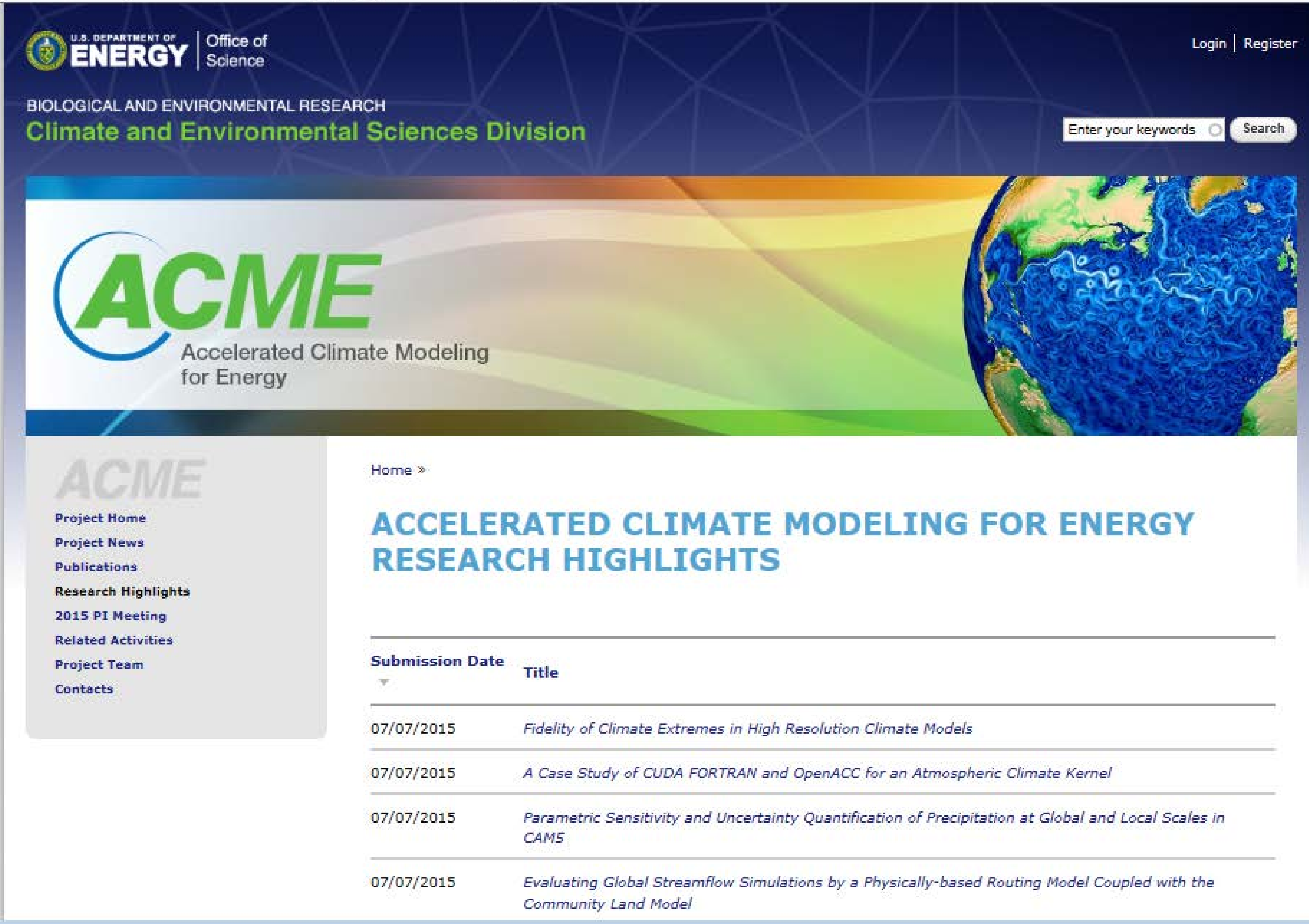
Posted: 10/07/2015

A novel system developed by Lawrence Livermore National Laboratory (LLNL) and nine partners that enables climate researchers to solve their most complex data analysis and visualization challenges has netted the team a Federal Laboratory Consortium (FLC) award. The partnership that brought the...

Read More



ACME highlights



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- Project Home
- Project News
- Publications
- Research Highlights
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- Project Team
- Contacts

Home »

ACCELERATED CLIMATE MODELING FOR ENERGY RESEARCH HIGHLIGHTS

Submission Date	Title
07/07/2015	*Fidelity of Climate Extremes in High Resolution Climate Models*
07/07/2015	*A Case Study of CUDA FORTRAN and OpenACC for an Atmospheric Climate Kernel*
07/07/2015	*Parametric Sensitivity and Uncertainty Quantification of Precipitation at Global and Local Scales in CAM5*
07/07/2015	*Evaluating Global Streamflow Simulations by a Physically-based Routing Model Coupled with the Community Land Model*

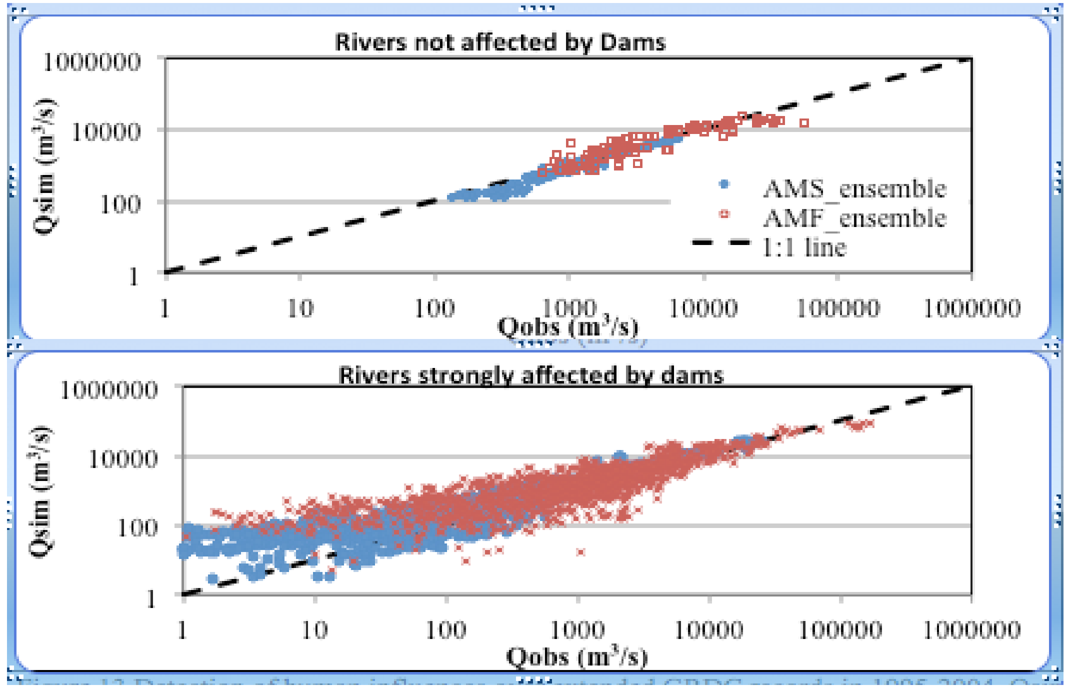
Evaluating Global Streamflow Simulations by a Physically-based Routing Model Coupled with the Community Land Model

Objective

- Evaluate the capacity of global streamflow prediction by Model for Scale Adaptive River Transport (MOSART) coupled with Community Land Model (CLM)
- Quantify the uncertainty sources from forcing, model structure and human influences

Approach

- Develop a comprehensive global hydrography dataset to support MOSART application over multiple resolutions
- Evaluate the model simulations against global streamflow observations
- Quantify modeling uncertainty using four different atmospheric forcing datasets, stepwise reduction of model complexity, and a global classification of the level of flow regulation by dams



Human influences on streamflow are detected by comparing the simulated natural flows (Qsim) with observed streamflow (Qobs) in 1995-2004. Larger differences between Qsim and Qobs are found in both annual mean streamflow (AMS) and annual maximum flood (AMF) in rivers strongly affected by dams.

Impact

- The newly developed river routing model, MOSART, has been coupled with CLM and evaluated globally with satisfactory performance
- MOSART provides a global framework for modeling riverine water, energy and biogeochemistry.

Hong-Yi L, LR Leung, A Getirana, M Huang, H Wu, Y Xu, J Guo, and N Voisin. 2015. “Evaluating Global Streamflow Simulations by a Physically Based Routing Model Coupled with the Community Land Model.” *Journal of Hydrometeorology*, 16: 948–971. DOI: 10.1175/JHM-D-14-0079.1

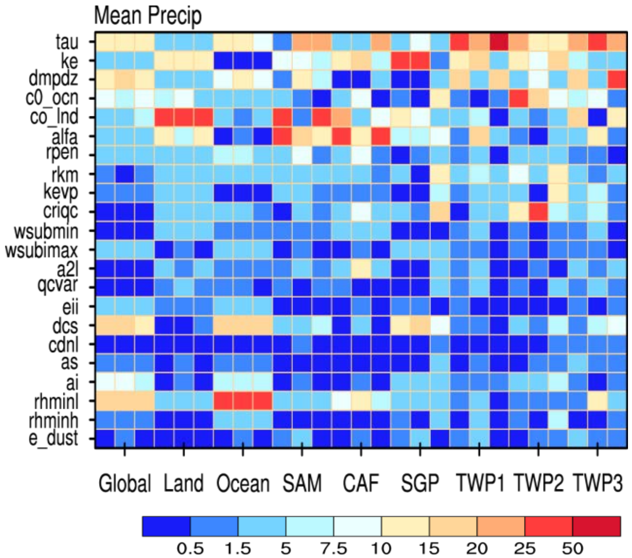
Parametric Sensitivity and Uncertainty Quantification of Precipitation at Global and Local Scales in CAM5

Objective

- Identify which CAM5 parameters are most influential on precipitation. Find the sensitivity of precipitation mean, extreme, and diurnal cycle and how the parameters vary by spatial scale, region and season.

Approach

- Use two sampling approaches (the Latin hypercube and quasi-Monte Carlo) to effectively explore the high-dimensional parameter space
- Conduct two large simulation sets: one set with 1100 simulations for 22 cloud-related parameters and the other set with 256 simulations for aerosol parameters.
- Apply a generalized linear model to quantify parametric sensitivity.



Sensitivity of mean precipitation over multiple regions and seasons to each parameter (on y-axis). Three columns for each region (on x-axis) correspond to annual, JJA and DJF mean, respectively. Larger number indicates larger sensitivity.

Impact

- Identified six parameters having the greatest influences on global precipitation
- Precipitation does not always respond monotonically to parameter change.
- Better understanding of CAM5 model behavior associated with parameter uncertainties to guide the next step to reducing model uncertainty in precipitation and developing new parameterizations.

Qian Y, H Yan, Z Hou, G Johannesson, SA Klein, D Lucas, R Neale, PJ Rasch, LP Swiler, J Tannahill, H Wang, M Wang, and C Zhao. 2015. "Parametric Sensitivity Analysis of Precipitation at Global and Local Scales in the Community Atmosphere Model CAM5." *Journal of Advances in Modeling Earth Systems* 07. DOI:10.1002/2014MS000354

A Case Study of CUDA FORTRAN and OpenACC for an Atmospheric Climate Kernel

Objectives

- Determine the maturity of OpenACC (OACC) compiler implementations for a representative climate kernel compared to CPU and CUDA implementations in terms of (1) bugs and (2) cost.
- Determine whether OACC is a viable option for porting ACME to GPUs.

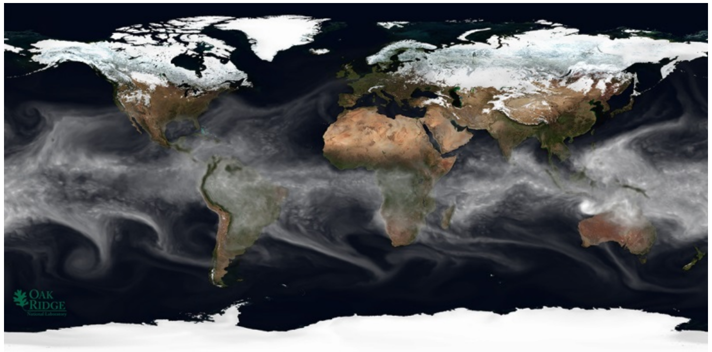
Impact

- Significant portions of ACME must be ported to accelerators, requiring a directives-based approach. But can directives compete with CUDA in terms of runtime cost?
- We now have a quantitative view of OACC's speed in PGI and Cray implementations, better informing our approach to porting ACME.

Accomplishments

- OACC performance about 1.5x slower than CUDA
- PGI implementation significantly less mature than Cray
  - Cannot use FORTRAN derived types, other bugs as well
- PGI needs more code transformations to perform well
- OACC porting significantly easier and more readable
- OACC (particularly Cray) should be suitable for porting

M. Norman, J. Larkin, A. Vose, K. Evans. "A Case Study of CUDA FORTRAN and OpenACC for an Atmospheric Climate Kernel", In *Journal of Computational Science*, 2015; 9:1-6..



CAM simulation of integrated water vapor, one of many passive tracers transported globally (courtesy, J. Daniel)

Fidelity of Climate Extremes in High Resolution Climate Models

Objectives

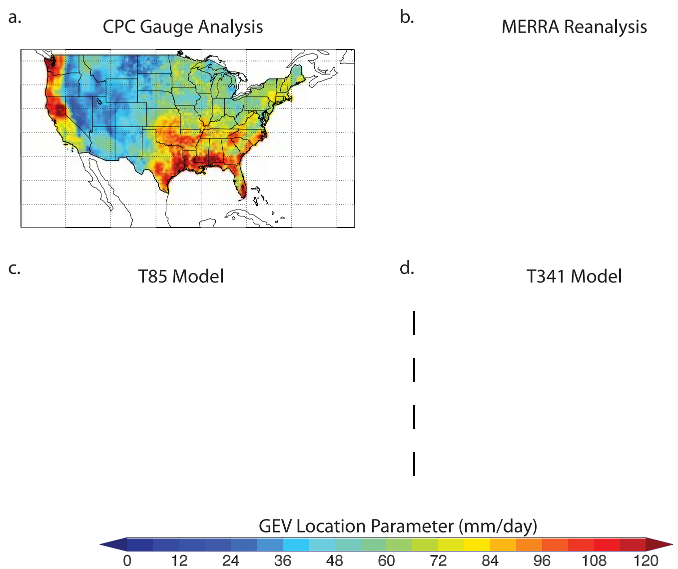
- Develop a regionalization framework to improve sampling of extreme events
- Assess the simulations of stationary and non-stationary climate extremes in ultra high-resolution global climate model simulations

Impact

Demonstrated that high resolution climate models better capture stationary as well as non-stationary precipitation extremes as compared to low resolution simulations.

Accomplishments

- Developed a regionalization framework to quantify climate extremes
- Implemented the framework in a parallel algorithm allowing a speed up of the analysis of extremes in global high resolution simulations by several orders of magnitude.

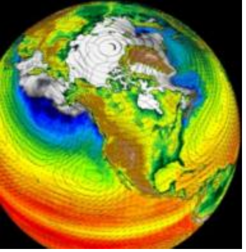


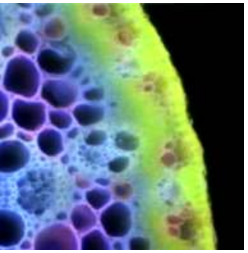
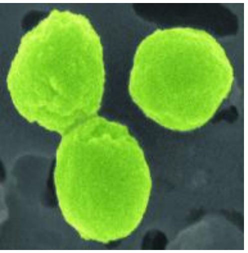
Location parameters of Generalized Extreme Value Distribution are better represented in high resolution model (T341) as compared to low resolution model (T85)

Mahajan S., K. J. Evans, M. Branstetter, V. Anantharaj and J. K. Leifeld (2015): Fidelity of precipitation extremes in high resolution global climate simulations, *Procedia Computer Science*, 51:2178-2187.

Thanks!

- Renata McCoy
- Mark Taylor
- Marie Asher, ORAU



Dorothy.Koch@science.doe.gov

ACME:
http://climatemodeling.science.energy.gov/projects/accelerated-climate-modeling-energy

Earth System Modeling:
http://science.energy.gov/ber/research/cesd/earth-system-modeling-program/