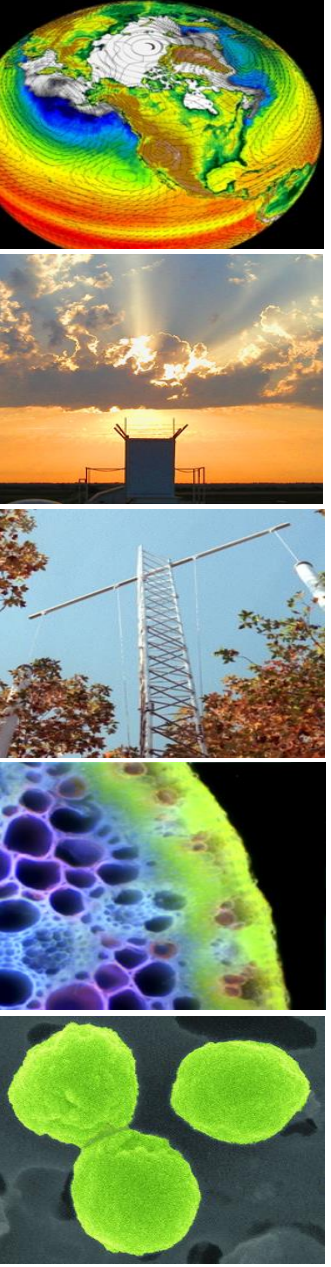


Regional and Global Model Analysis (RGMA) Overview and Earth System Model Development (ESMD)Linkages

2020 ESMD PI Meeting

Renu Joseph, Renu.Joseph@science.doe.gov

U.S. Department of Energy
Office of Science

Office of Biological & Environmental Research

Earth and Environmental Systems Sciences Division

Outline

- **RGMA Overview**
  - *Themes*
  - *SFAs, CAs, Univ Projects*
- **Survey re. use of E3SM in RGMA**
  - **Examples of E3SM simulations**
- **Metrics and Diagnostics –**
  - CMEC
  - ILAMB
- ***Analysis*** – CMIP6

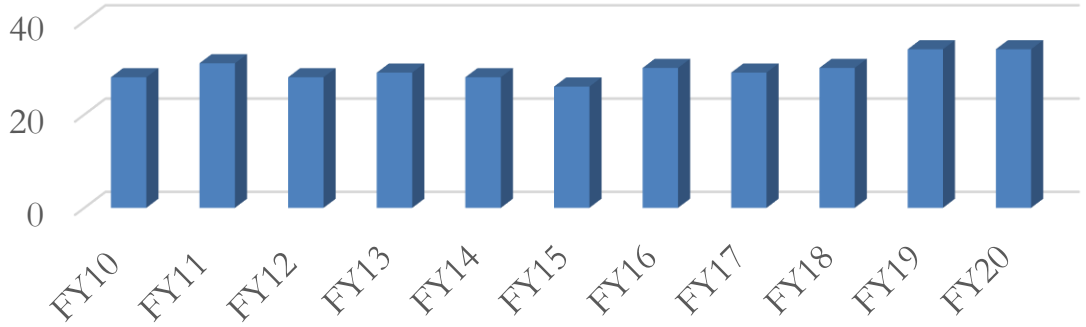
U.S. DEPARTMENT OF ENERGY

Office of Science

Regional and Global Model Analysis (RGMA) Overview

- **Goal**: To enhance predictive and process level understanding of Variability and Change in the Earth system by advancing capabilities to design, evaluate, diagnose, and analyze global and regional earth system models informed by observations
  - Primary Model we focus on is the E3SM – Energy Exascale Earth System Model
  - Multi-Model approaches and also a use of a hierarchy of models of varying levels of varying complexity to address the relevant science questions

FY10	FY11	FY12	FY13	FY14	FY15	FY16	FY17	FY18	FY19	FY20
28M	31M	28M	29M	28M	26M	30M	29M	30M	34M	34M



Roughly 120 publications/year

U.S. DEPARTMENT OF ENERGY

Office of Science

RGMA

Model Analysis to Enhance a Predictive Understanding at Regional and Global Scales

MODES OF VARIABILITY AND CHANGE

CLOUD PROCESSES

HIGH-LATITUDE FEEDBACKS

WATER CYCLE

EXTREMES

BIOGEOCHEMICAL FEEDBACKS

Metrics to Evaluate Models	Test Beds	Uncertainty Characterization	MIPs
	Diagnostic Tools		D&A
Extreme Events & Tipping Points	Climate Feedbacks and Process Interactions	Regional Modeling	Hierarchy of Models

FOUNDATIONAL CAPABILITIES

Model Development

Observations and Process Knowledge

University Projects through FOAs + Jointly funded Interagency Projects

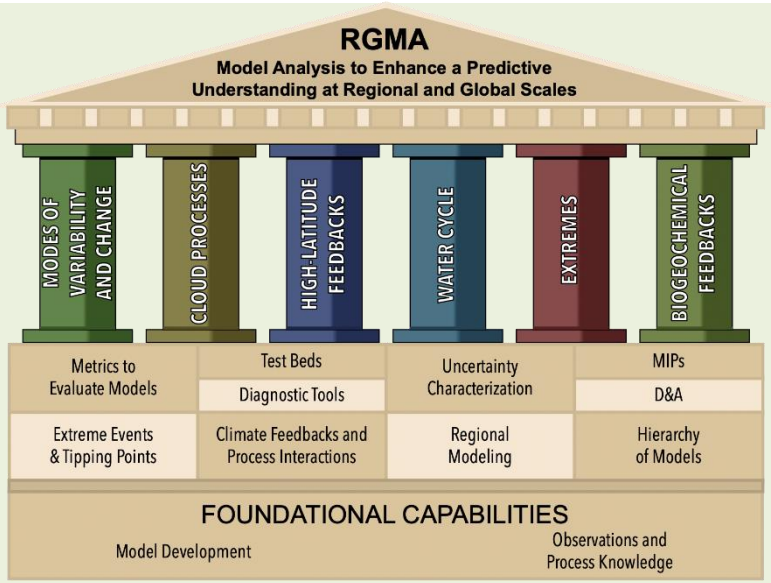
U.S. DEPARTMENT OF ENERGY — Regional and Global Model Analysis: Core Effor

Water Cycle and Climate Extremes Modeling (WACCEM)

Calibrated and Systematic Characterization, Attribution, and Detection of Extremes (CASCADE)

Reducing Uncertainty in Biogeochemical Interactions Through Synthesis and Computation (RUBISCO)

High-Latitude Application and Testing (HiLAT)



Program for Climate Model Diagnosis & Intercomparison

Cooperative Agreement To Analyze variability, change and predictability in the earth SysTem (CATALYST)

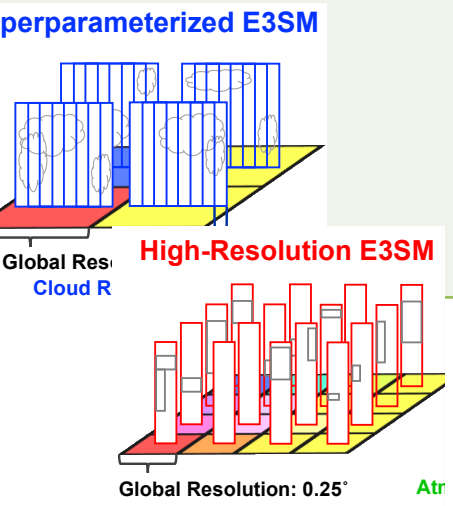
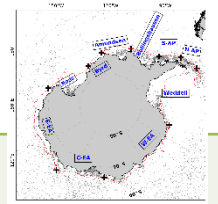
Interdisciplinary Research for Arctic Coastal Environments (InteRFACE)

Integrated Coastal Modeling (ICOM)

U.S. Department of Energy | Office of Science
HYPERFACETS
A Framework for Improving Analysis and Modeling of Earth System and Intersectoral Dynamics at Regional Scales

A Framework for Improving Analysis and Modeling of Earth System and Intersectoral Dynamics at Regional Scales

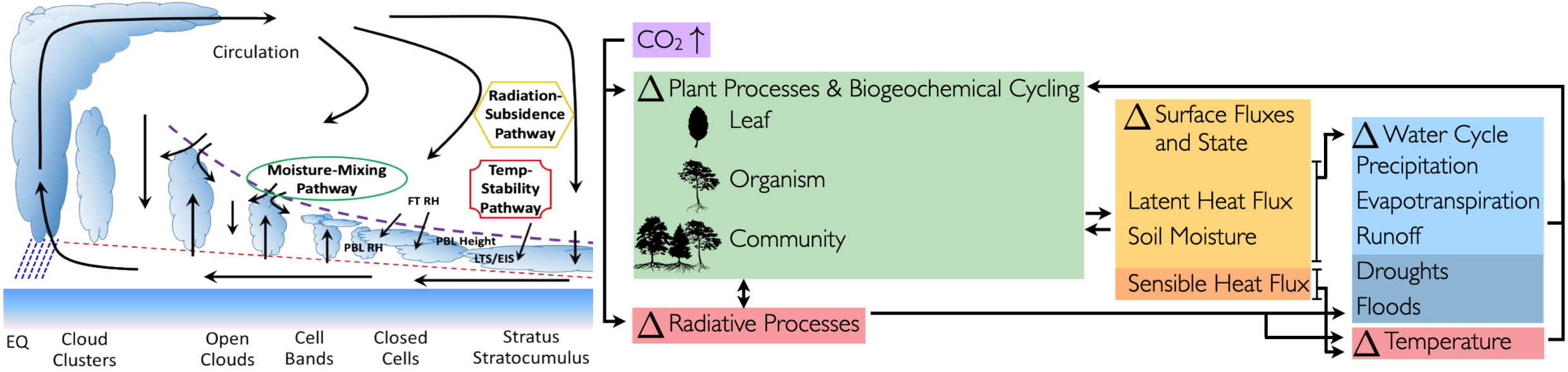
RGMA FY18 & FY19 University Projects from FOA 1862

Science Themes	University Projects
• Water Cycle • Extremes 	• **Boos: Monsoon Extremes: Impacts, Metrics, and Synoptic-Scale Drivers** • **Kooperman: Simulating Extreme Precipitation in the United States in the E3SM: Investigating the Importance of Representing Convective Intensity Versus Dynamic Structure** • **Kim: Madden-Julian Oscillation, Tropical Cyclones, and Precipitation Extremes in E3SM** • **Saravanan: Assessing the influence of background state and climate variability on tropical cyclones using initialized ensembles and mesh refinement in E3SM**
Variability & Change	• **Kirtman: Decadal Prediction and Predictability of Extremes in Ocean Eddy Resolving Coupled Models** • **DiLorenzo: Mechanisms of Pacific Decadal Variability in ESMs: The Roles of Stochastic Forcing, Feedbacks and External Forcing** • **Kwon: The Atlantic Multi-decadal Oscillation – Key drivers and Climate Impacts** • **Cheng: Arctic freshwater pathways and their impact on North Atlantic deep water formation in a hierarchy of models** • **Jin: Understanding Dynamics and Thermodynamics of ENSO and Its Complexity Simulated by E3SM and Other Climate Models** • **DeMott & Klingamon: Understanding air-sea feedbacks to the MJO through process evaluation of observations and E3SM experiments**
 High Latitude Feedbacks	• **Magnusdottir: Reducing Uncertainty of Polar to Mid-latitude Linkages using DOE's E3SM in a Coordinated Model-Experiment Setting** • **McClean: Influence of Antarctic and Greenland continental shelf circulation on high-latitude**

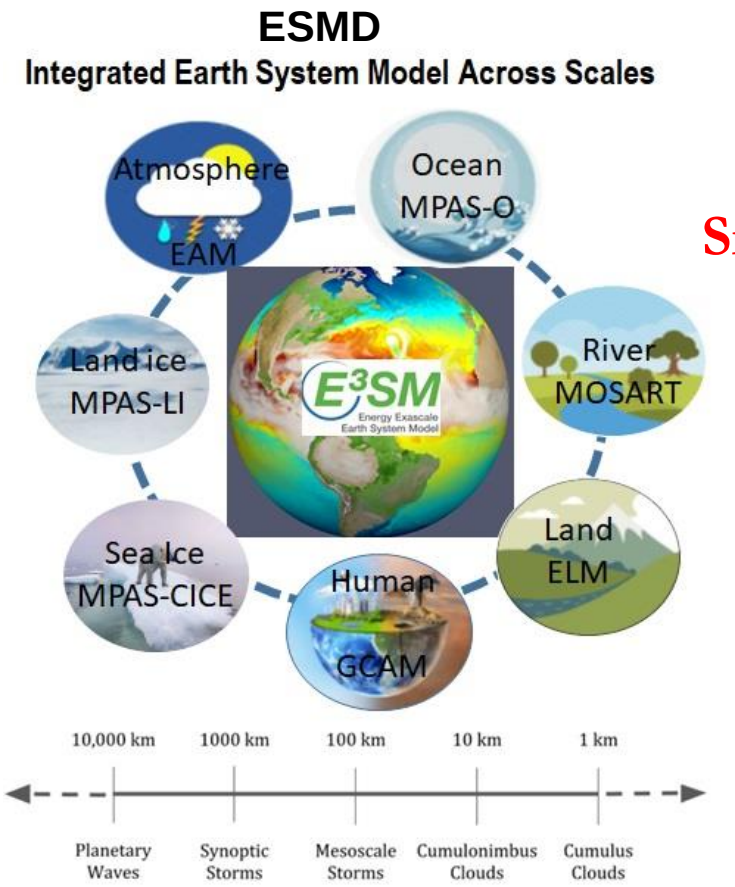
RGMA FY20 University Projects: FOA 2230

Office of Science

Science Themes	University Projects
Cloud Processes	• Soden: Investigating Cloud Feedbacks in Earth System Models • Su: The Role of Deep Convection and Large-scale Circulation in Driving Model Spread in Low Cloud Feedback and Equilibrium Climate Sensitivity
Analysis of BGC Feedbacks	• Swann: Evaluating the influence of plants on hydrologic cycling: Quantifying and validating the role of plant processes and stomatal conductance • Ito: Ocean physical-biogeochemical interactions in the CMIP6 and E3SM Earth System Models

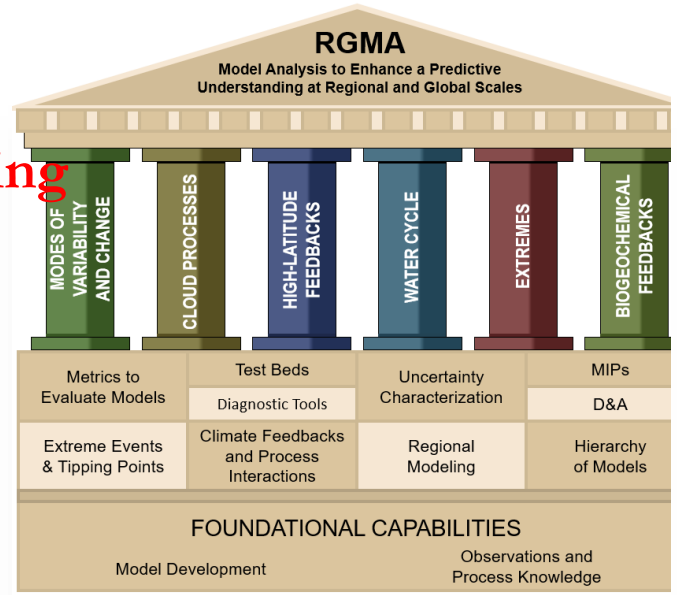


ESMD - RGMA Linkages



Simulations for RGMA to enhance understanding

New RGMA knowledge to benefit E3SM development



EESM Goal: To develop and demonstrate advanced modeling and simulation capabilities, in order to enhance the predictability of the Earth system over multiple temporal and spatial scales.

Science questions (from Survey) from 20 RGMA projects that use E3SM

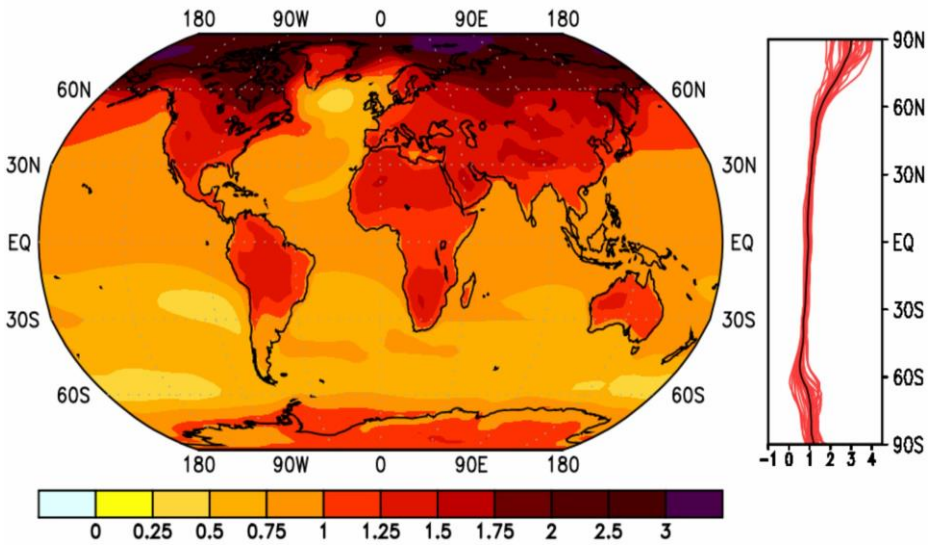
- **Modes of climate variability:**
  - Air-sea interactions and MJO
  - MJO propagation across Maritime Continent
  - ENSO and connections to other modes of variability
  - AMOC and high-latitude connections
- **Arctic and Antarctic:**
  - Heat transport, connections to lower latitudes, polar amplification, sea ice loss and atmospheric response
  - Delivery of warm water to Antarctic and Greenland ice shelves
  - Arctic region storms
  - Permafrost, benthic habitats, wave attenuation in Arctic coastal regions
- **Tropical cyclones:**
  - AEW and Atlantic TC
  - Factors controlling landfalling TC and genesis
  - Effects of air-sea interactions on landfalling TC
- **Extreme precipitation and weather events:**
  - Processes controlling extreme precipitation
  - Impacts of model biases and resolution on simulation of weather extremes
  - Extreme weather events and future changes
- **Cloud and radiation:**
  - ITCZ and cloud-radiative interactions
  - Role of coupling between dynamics and radiation on weather extremes and climate sensitivity
  - Climate sensitivity and cloud feedback
- **Biogeochemistry:**
  - Ocean carbon uptake
  - Carbon cycle feedback, CO2 fertilization effect
  - Impacts of plant biogeochemical responses on water cycle processes

Comparison of E3SM with other models / contribution to model intercomparison

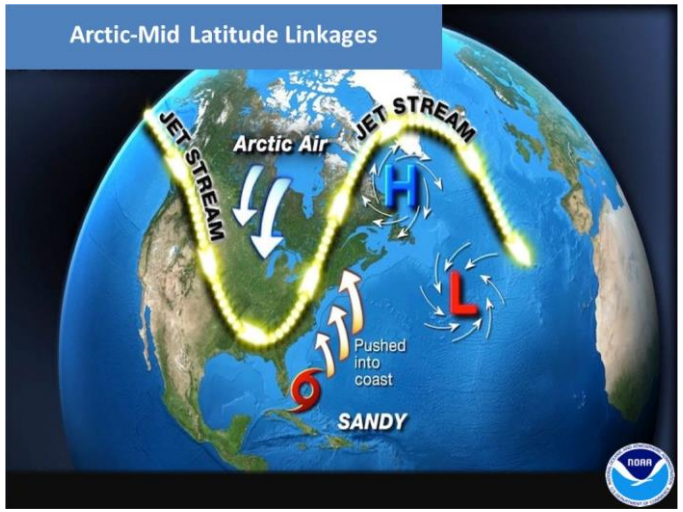
- CMIP6 (e.g., DECK, **C4MIP, CFMIP**, HighResMIP, **PAMIP**)
- WRF-Arctic (Walsh)
- GFDL (Soden)
- CAM (Saravanan)
- CESM (HyperFACETS-Zarzycki; DeMott)
- ATS-MOSART (InteRFACE)
- CAM-MPAS (WACCEM)
- UK Met Office Unified Model (Klingaman)
- RASM (HiLAT)
- UWIN-CM (ICoM)

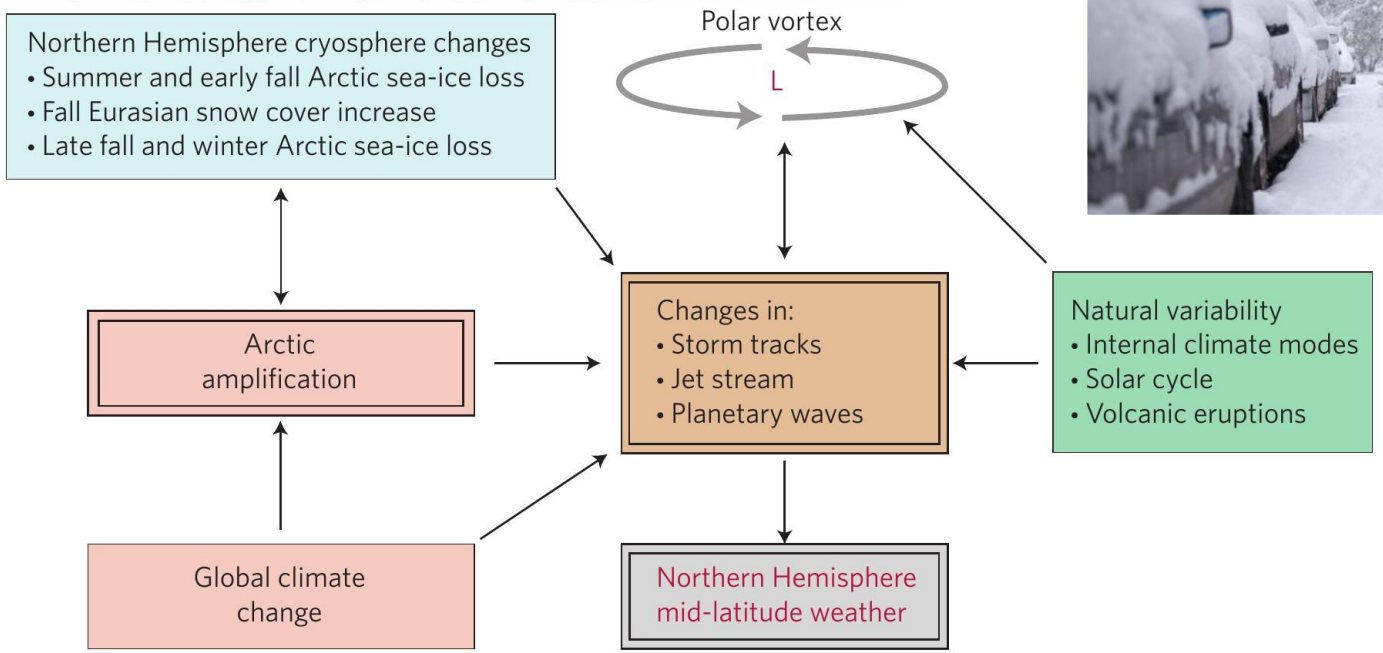
Reducing Uncertainty of Polar to Mid-latitude Linkages Using DOE's E3SM in a Coordinated Model Experiment

G. Magnusdottir[1], A. Audette[2], R. Fajber[2], T.-Y. Hsu[1], Z. Labe[1], P. Kushner[2], Y. Peings[1], F. Primeau[1]



Contributed to E3SM in PAMIP simulations



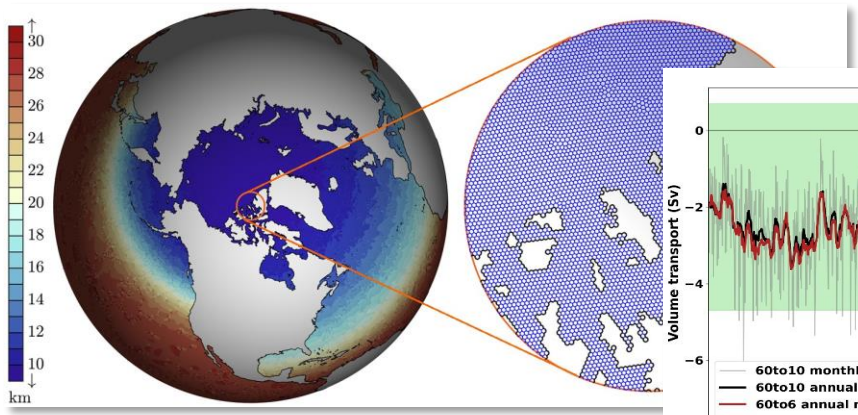


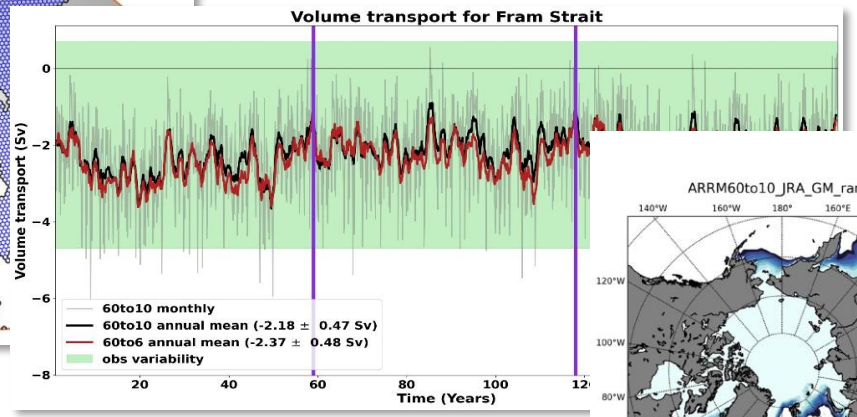
Schematic of ways to influence Northern Hemisphere mid-latitude weather (Cohen et al. 2014)

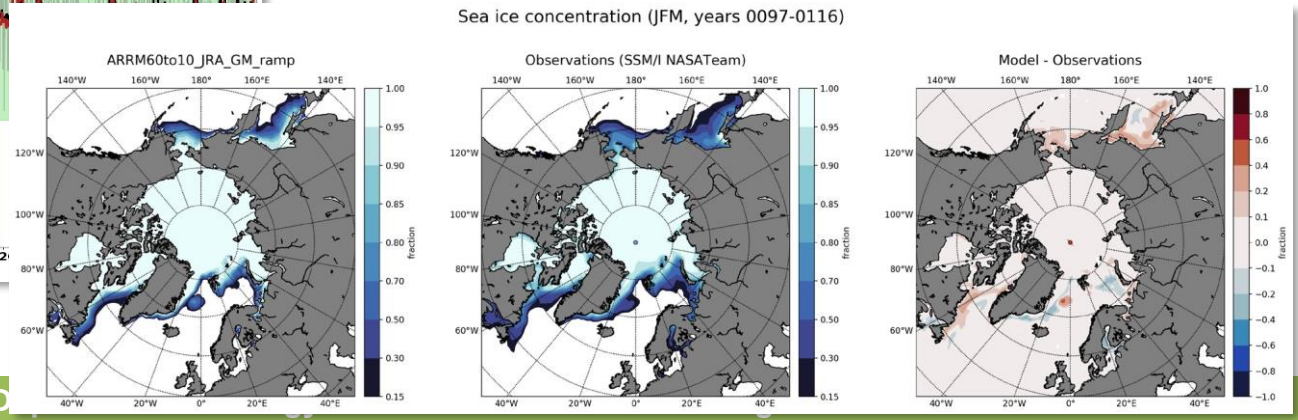
Variable Resolution E3SM-Arctic

- The HiLAT-RASM team is working on Arctic-refined configurations of E3SM: *E3SM-Arctic*
  - Ocean-sea ice configuration (JRA55-forced)
  - Two grids: *60-to-10* and *60-to-6*
  - Key metrics are well represented
    - Veneziani et al. (in review)
  - Currently working on a fully-coupled configuration

High-Resolution modeling of Arctic cyclones – John Walsh, Xiangdong Zhang, Erika Roesler and Ben Hillman







Veneziani et al. (in review)

Multi-Year Predictability and Prediction in Ocean Eddy Resolving Coupled Models

catalyst

Cooperative Agreement to Advance variability, change and predictability in the earth System

Ben Kirtman, Leo Siqueira, Lucas Laurindo
Kathy Pegion Robert Burgman

CESM & E3SM

- Predictability
  - Extended Simulations
  - Homogeneous (Identical Twin) Experiments
- Initialized Prediction
  - Brute Force (Operational NOAA Analysis)
  - Ocean-Only (CORE Forcing) Derived

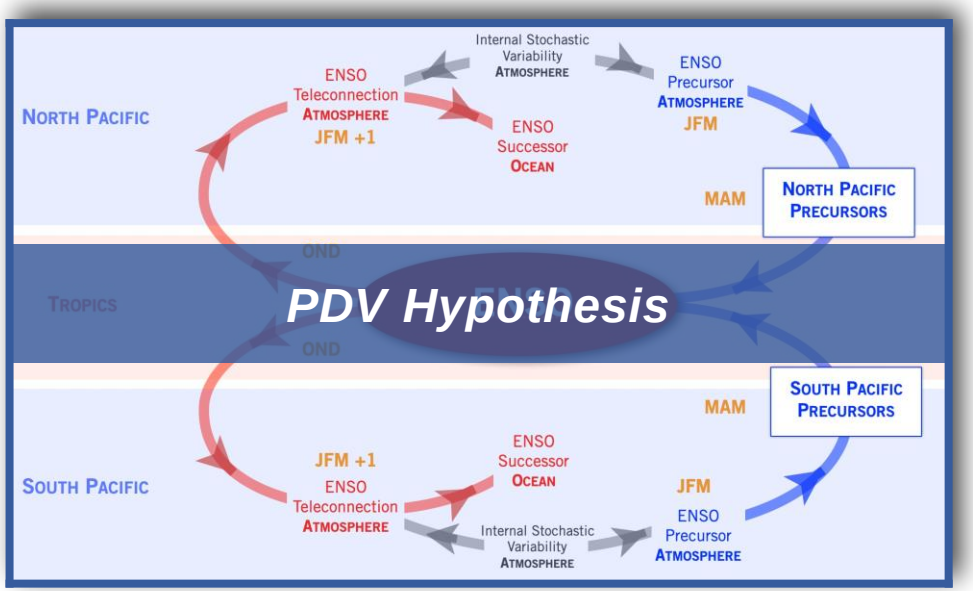
CESM-LR (Ocean Eddy Parameterized)	CESM-HR (Ocean Eddy Resolving)
E3SM-LR (Ocean Eddy Parameterized)	E3SM-HR (Ocean Eddy Resolving)

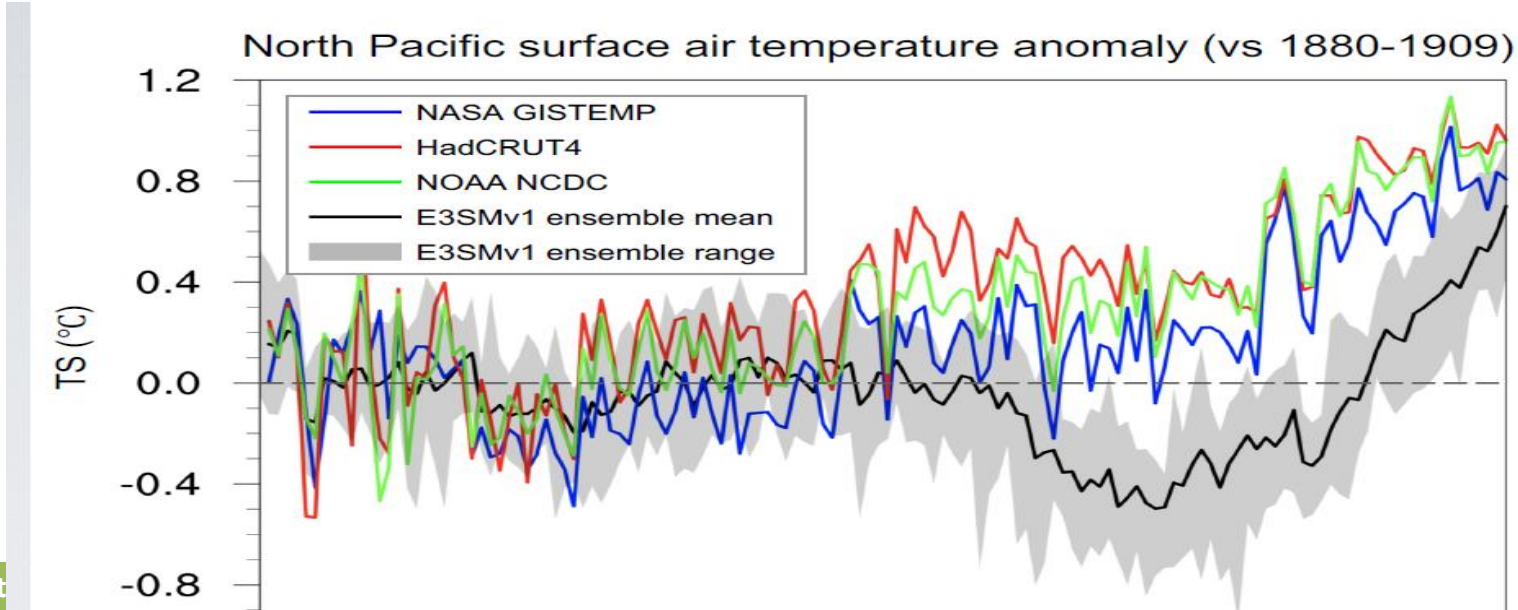
Mechanisms of Pacific Decadal Variability in ESMs

Emanuele Di Lorenzo, Matt Newman, Sam Stevenson, Luke Van Roekel, Sang-Ik Shin and Antonietta Capotondi

Develop fundamental understanding and synthesis of the **mechanisms that energize Pacific decadal variability (PDV)** in Earth System Models (ESMs)

Contributing E3SMv1 Large Ensemble: unique initialization strategy





Collaboration on E3SM Simulations

- RUBISCO and the E3SM Coupled Biogeochemistry Group collaborating in CMIP6 simulations
- RUBISCO is also applying different versions of the modeling system to address specific science questions, like deforestation/afforestation, AMIP-style ENSO simulations, etc.
- Completed CMIP6 simulations with E3SMv1.1 and land/ocean BGC include:
  - LS3MIP offline land simulations with multiple atmospheric reanalysis and factorial forcings (Contact Jiafu Mao)
  - 1pctCO2 (rad, bgc, full) for CTC-CNP, ECA-CNP, and CTC-CN (Recently completed)
  - abrupt4xCO2 (rad, bgc, full) for CTC-CNP and CTC-CN (Recently completed)
- Planned CMIP6 simulations with E3SMv1.1 and land/ocean BGC include:
  - 1pctCO2Ndep (bgc, full) for CTC-CNP, ECA-CNP
  - ssp5-85-ext (extension to 2300)
  - SSP1.2, SSP2-4.5, SSP3-7.0, SSP5-3.4os and LUMIP simulations swapping land use
- Planned CMIP6 simulations with E3SMv2 and land/ocean BGC include:
  - esm-historical, esm-ssp5-85, esm-ssp5-85 extension

Investigating Cloud Feedbacks in Earth System Models

Brian Soden & Gabe Vecchi

Questions:

i) Is convective aggregation important in the presence of *realistic boundary conditions*?
ii) How do cloud-circulation feedbacks influence *weather extremes*?
iii) How do cloud-circulation feedbacks influence *climate and climate sensitivity*?
iv) How can observations be used to *evaluate the representation* of these feedbacks?

Will use E3SM and GFDL models

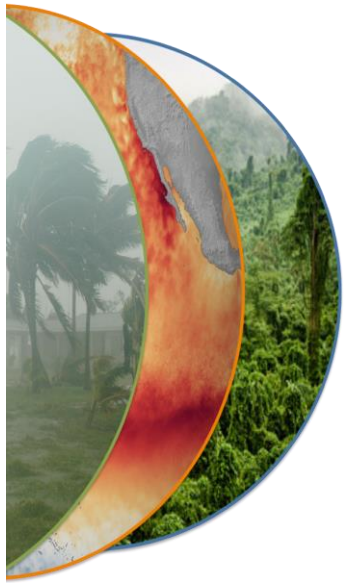
PCMDI

- Modified Cloud Feedbacks (PCMDI) - CFMIP
- Various ways to suppress cloud-radiation feedback (each 11 years), and with 4K warming and 4xCO2 forcing and 4xCO2 SST pattern (WACCEM)

CMEC - Coordinated Model Evaluation Capabilities

Integrated Tools and Science for Event Analysis

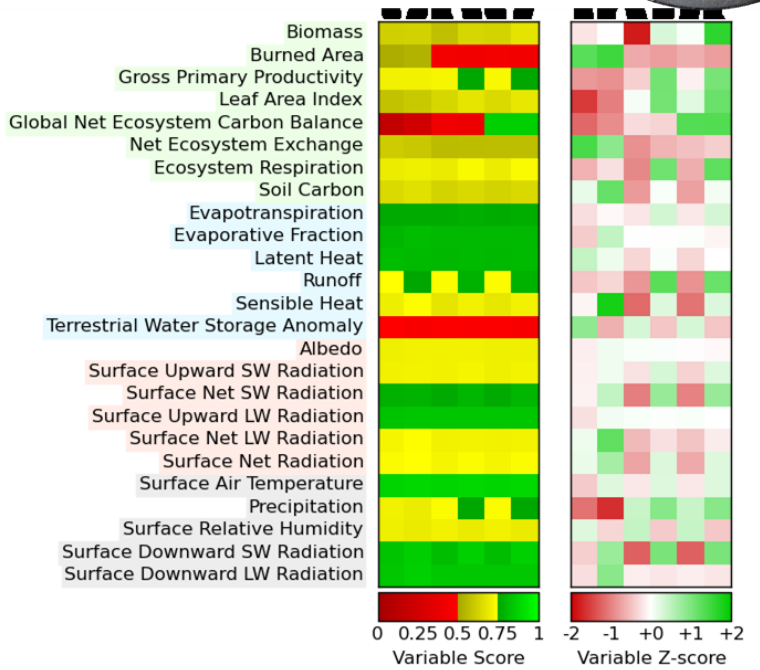
CMEC



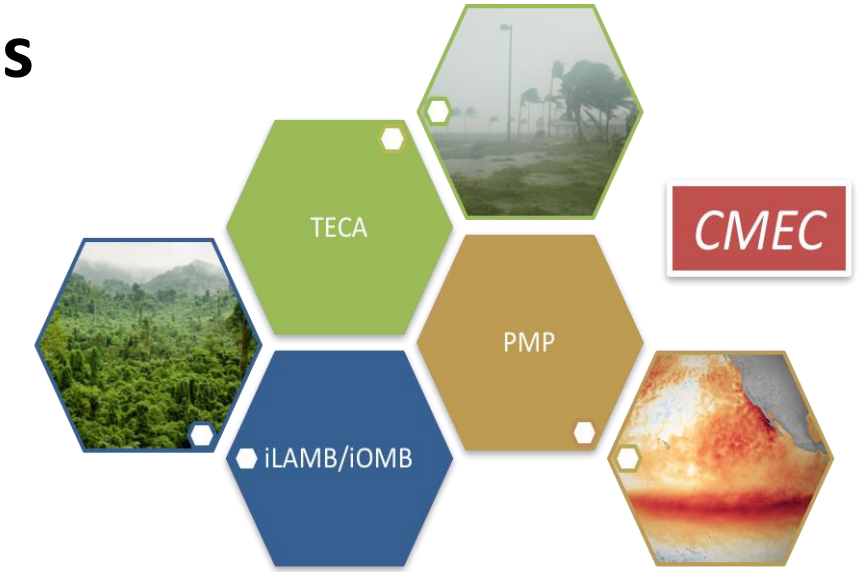
TECA

TempestExtremes

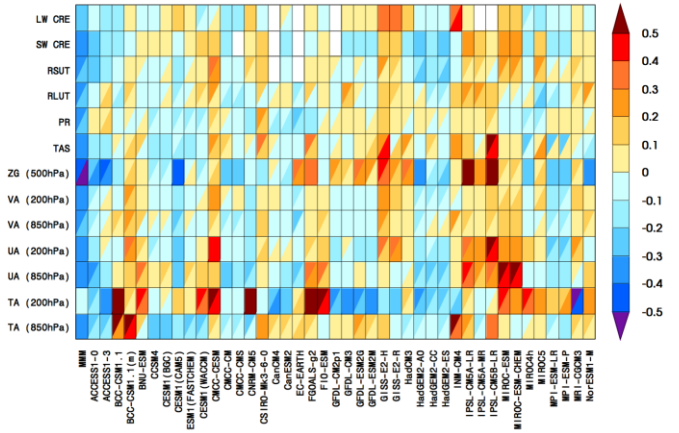
ILAMB



CMEC



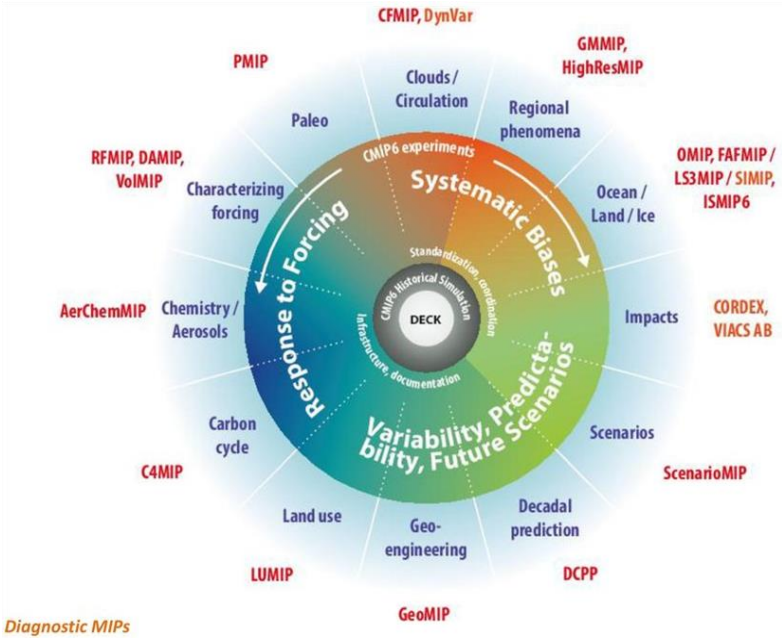
PMP



RGMA CMIP6 Analysis and Hackathon

Office of Science

Wilbert Weijer
Forrest Hoffman
Paul Ullrich
Mike Wehner

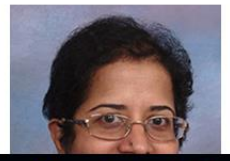


Data is available on NERSC
More Data is being added

For RGMA news check out

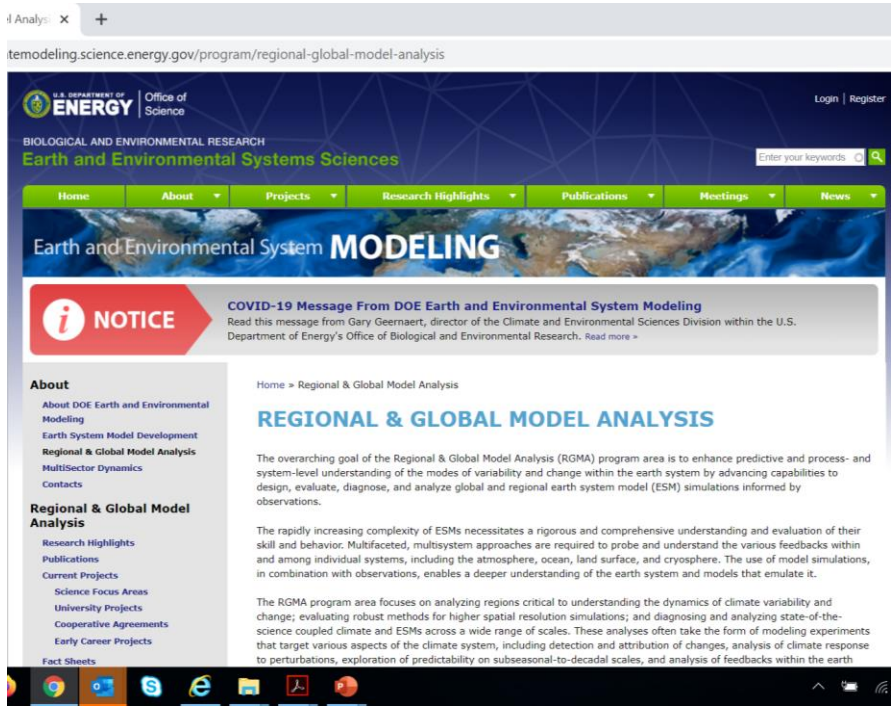
https://climatemodeling.science.energy.gov/program/regional-global-model-analysis

FROM THE PROGRAM MANAGER



Welcome to *RGMAgram!*

Welcome to the first edition of *RGMAgram*. This quarterly newsletter will deliver important news and information while



Thank You

RGMA Survey regarding use of E3SM

- Questions:
  - What science questions will your projects address using E3SM?
  - What is your simulation plan? (e.g., model version, model configurations, major code changes, resolution, simulation period and length)
  - What computational resources are needed for your simulations and how will you obtain the resources?
  - Will you develop a modeling hierarchy using E3SM?
  - Will you produce or need any spun-up states for initializing your simulations?
  - Will you compare E3SM simulations with those from other models?
- PIs of 20 projects responded
  - SFAs (HiLAT, WACCEM, PCMDI, RUBISCO, ICoM, InteRFACE)
  - 14 university projects

Simulation plan

- Low resolution coupled:
  - Modified cloud feedbacks (PCMDI)
  - 100 members of 14-month runs with prescribed Arctic/Antarctica sea ice loss (Magnusdottir)
  - Hypothesis-testing simulations: changing insolation or parameters in ZM scheme; nudged atmosphere (Kim)
- RRM simulations coupled:
  - E3SM v2: Arctic coupled (ARRM and WC14) (HiLAT; Walsh-Roesler)
  - E3SM v2 WC14 mesh - HighResMIP type simulations with 10 ensemble members (1950-2015) (InteRFACE)
- Biogeochemistry simulations (LR):
  - Require long spinup (e.g., 200 years)
  - Long simulations (e.g., 140 years)
  - Partially coupled with ELM and ELM-FATES hypothesis testing (Swann; RUBISCO)
  - DECK type simulations with land and ocean BGC and different scenarios (e.g., various SSPs) (RUBISCO)

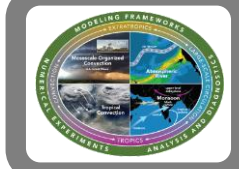
Simulation plan

- Atmosphere-only runs:
  - 10-year AMIP runs at LR and HR (Saravanan)
  - ~ 100 seasonal-to-annual simulations at HR (Patricola)
  - Radiation feedback suppression at HR (Soden)
  - Various ways to suppress cloud-radiation feedback (each 11 years), and with 4K warming and 4xCO2 forcing and 4xCO2 SST pattern (WACCEM)
  - Cloud feedback experiments with prescribed SST (e.g., AMIP-p4K, AMIP-p4xCO2, etc) (PCMDI)
  - 100 members of 14-month runs with PI/future Antarctic sea ice at LR (Magnusdottir)
  - WC14; comparison with WRF-Arctic (Walsh-Roesler)
- Ocean-ice only runs:
  - Arctic with marine BGC (HiLAT)
  - Freshwater flux release in Greenland and Antarctica (McClean)
- E3SM coupled to a 1D mixed layer ocean: several 30-year simulations (DeMott; Klingaman; HiLAT)

Simulation plan

- Shorter simulations (atmosphere-only):
  - Storyline simulations (multiple < 10 days): large ensemble (O(100)) atmosphere-only at multiple resolutions (110km, 28km, 14km) (Zarzycki-Reed)
  - Short-term (2-4 week) forecast ensemble equivalent to 10 years at LR and HR (Saravanan)
  - Multi-year, short-range (5-day long) hindcasts initialized every day at 00Z from Jan 1, 2010 to Dec 31, 2018, with EAM v1 and v2 (ne30) (PCMDI)
- Comparison of coupled simulations at LR (1.5 deg), HR (0.3 deg), and MMF (1.5 deg) 5 years each (Kooperman and Hannah)
- Repeat E3SM v1 LR / HR simulations for higher frequency / special outputs (DeMott; Ito; Jin; ICoM)

Water Cycle and Climate Extremes Modeling (WACCEM) SFA (Leung, PNNL; Skamarock, NCAR; Chen PSU)



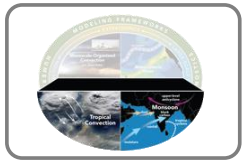
To advance robust predictive understanding of water cycle processes and hydrologic extremes and their multi-decadal changes

Large-scale circulation

- Predictability of atmospheric rivers and extreme precipitation
- Monsoon-ITCZ from an energetic perspective
- Baroclinic annular mode and subseasonal precipitation variability

Mesoscale convection

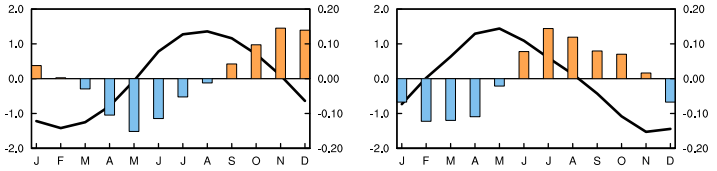
- Global characteristics of mesoscale convective systems (MCSs)
- Large-scale environments of MCSs and future changes
- MCSs and hydrologic floods in the U.S.



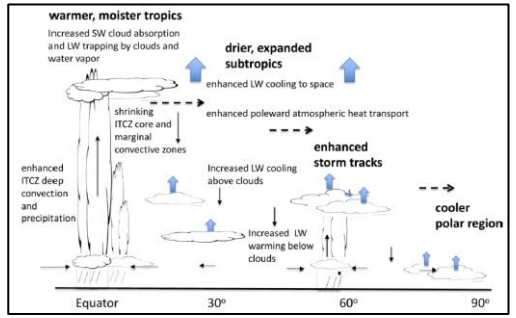
Multiscale convection-circulation interactions

- Role of convection in tropical overturning circulation
- Subseasonal variability of convection and influence on extremes
- MJO and tropical cyclones

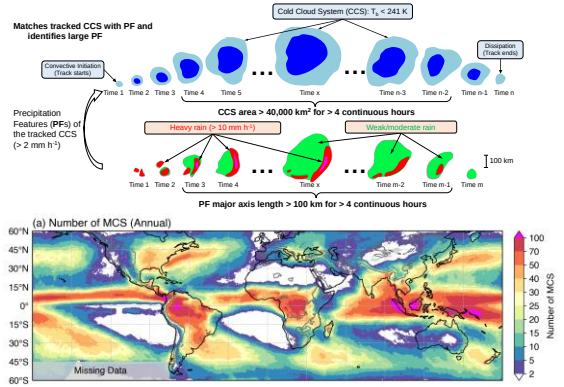
Contrasting precipitation seasonal cycle phase changes over land and ocean under warming



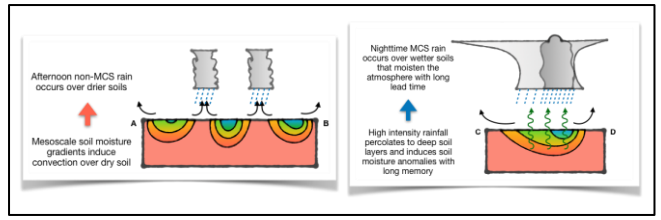
Radiation-cloud-convection-circulation induced changes in ITCZ from MMF experiments



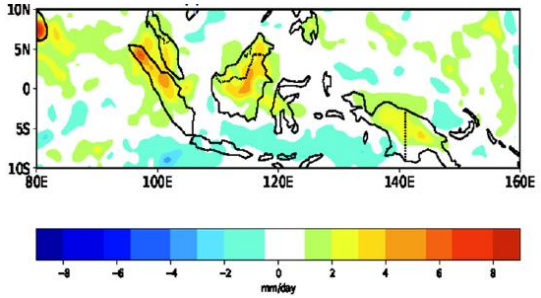
A new global MCS dataset



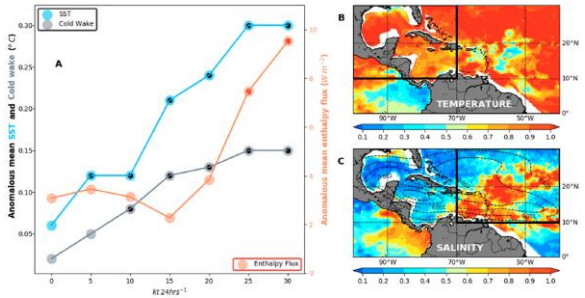
MCS plays a larger role than non-MCS in soil moisture-precipitation feedback in the central US



Solar insolation and soil moisture affect how the MJO interacts with the Maritime Continent



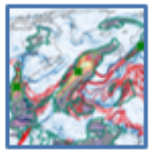
Salinity has pronounced impact on rapid intensification of tropical cyclones



CAlibrated and Systematic Characterization, Attribution, and Detection of Extremes (CASCADE) SFA – Collins (LBNL)

To advance understanding of natural and anthropogenic influences on multi-scale climate extremes in observations and models

ML & Infrastructure Crosscut

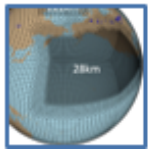


TECA3

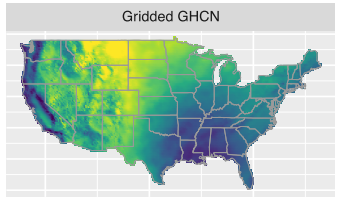
Statistical Analysis Software

Preparing for Exascale

Ad hoc Tool Development

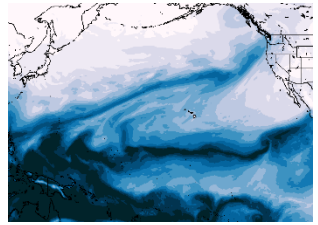


Extremes in Observations



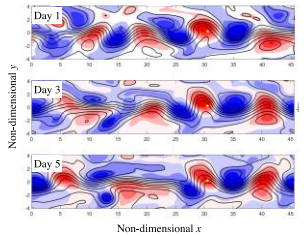
- Statistical modeling to interpret trends in the observational record
- Innovative geostatistical approaches for reducing signal-to-noise

Variability in Extremes



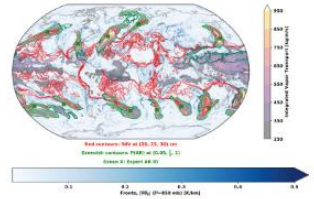
- Investigation of response of extremes to thresholds & non-linearities in the coupled system
- Emphasis on mountain hydroclimate

Extremes @ Native Scales



- High-resolution model & observational analysis of multiscale extremes
- Focus on MJO, blocking, teleconnections and model fidelity

Detection of Extremes & UQ



- Develop machine-learning approaches for detecting weather phenomena: ARs, TCs, ETCs, fronts,…
- Uses statistical and NN-based ML approaches

Reducing Uncertainties in Biogeochemical Interactions through Synthesis and Computation (RUBISCO)

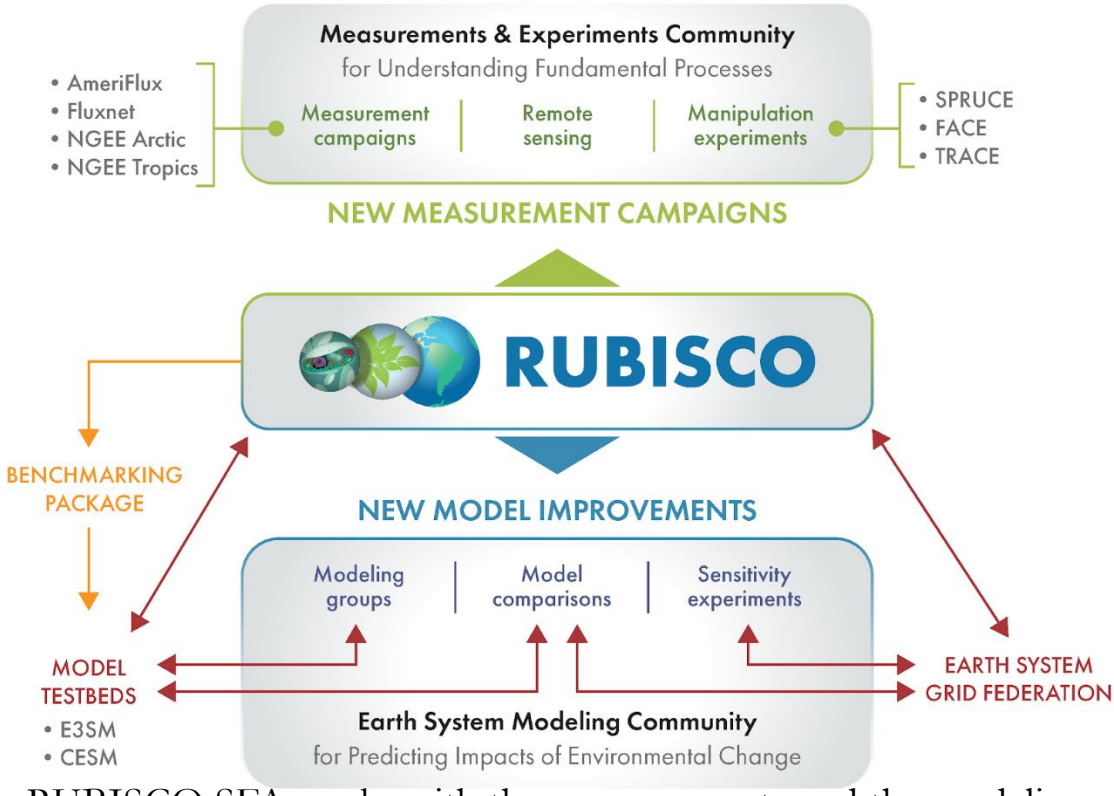
Forrest M. Hoffman (Laboratory Research Manager), William J. Riley (Senior Science Co-Lead), and James T. Randerson (Chief Scientist)

Research Goals

- Identify and quantify interactions between biogeochemical cycles and the Earth system
- Quantify and reduce uncertainties in Earth system models (ESMs) associated with interactions

Research Objectives

- Perform hypothesis-driven analysis of biogeochemical & hydrological processes and feedbacks in ESMs
- Synthesize in situ and remote sensing data and design metrics for assessing ESM performance
- Design, develop, and release the International Land Model Benchmarking (ILAMB) and International Ocean Model Benchmarking (IOMB) tools for systematic evaluation of model fidelity
- Conduct and evaluate CMIP6 experiments with ESMs



The RUBISCO SFA works with the measurements and the modeling communities to use best-available data to evaluate the fidelity of ESMs. RUBISCO identifies model gaps and weaknesses, informs new model development efforts, and suggests new measurements and field campaigns.

HiLAT-RASM: High-Latitude Application and Testing of Earth System Models - Phase II

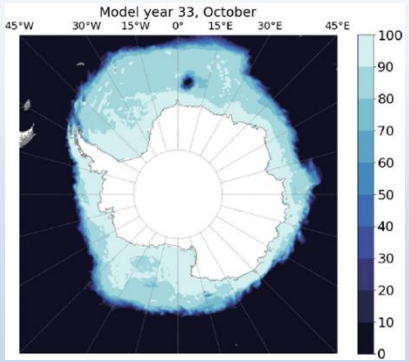
(Weijer, LANL; Wang, PNNL, Maslowski NPS)

- ***Integrative Earth System Science*** to reduce uncertainties in modeling and enhance predictive understanding of high-latitude environmental change and its global consequences

Theme 1: Role of sea ice in mediating meridional heat transports in the ocean and atmosphere

We are studying:

Relationships between sea ice and meridional heat transports in the ocean and atmosphere

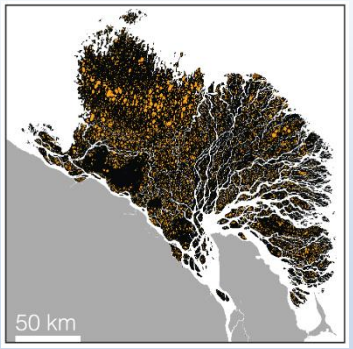


Maud Rise Polynya in E3SMv0-HR (Kurtakoti et al. 2018)

Theme 2: Role of fine-scale and transboundary transport processes in Arctic change

We are studying:

- ***Impact of small-scale processes on AA***
- ***Impact of riverine fluxes on Arctic warming***

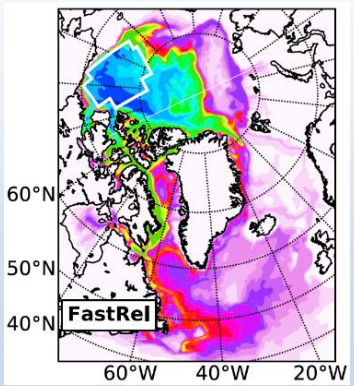


Lakes of the Lena River Delta (Pilioura & Rowland 2020)

Theme 3: Extra-polar impacts of Arctic change

We are studying:

- ***Impact of sea ice loss on extra-polar climate and weather***
- ***Impact of Beaufort Gyre variability on the AMOC, and global climate***

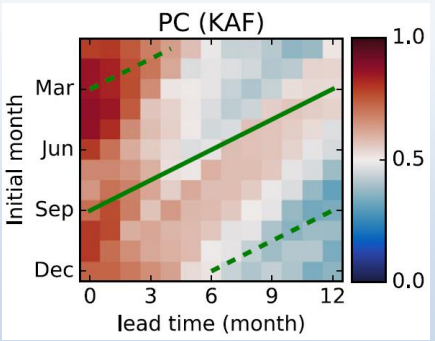


Distribution of Beaufort Gyre freshwater 13 years after release (Zhang et al. 2020)

Theme 4: Decadal predictability of high-latitude environmental change

We are studying if predictability can be improved by:

- ***combining dynamical and statistical models***
- ***explicitly resolving mesoscale processes (downscaling)***



Predictive skill of Kernel Analog Forecasting for Arctic sea ice (Comeau et al. 2019)

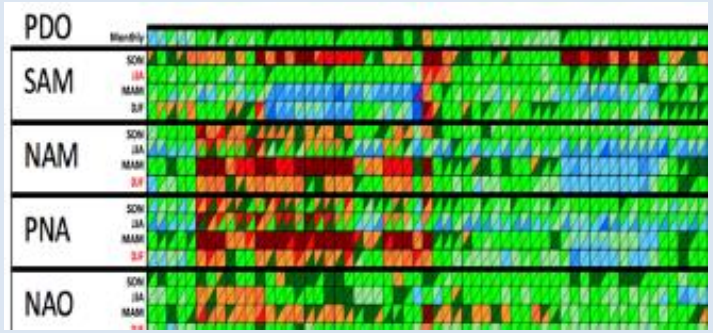
PCMDI – An Earth System Model Evaluation Project

PI: Steve Klein

PCMDI Earth System Model Evaluation Project

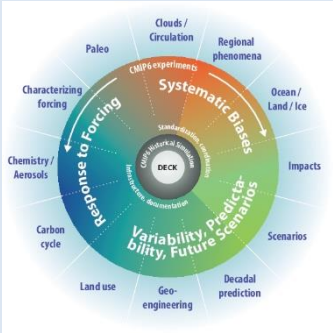
Using model ensembles of today and tomorrow to measure model performance, reduce uncertainties in their predictions, and determine the pathways for their improvement

Measuring Model Performance and Facilitating Community Involvement

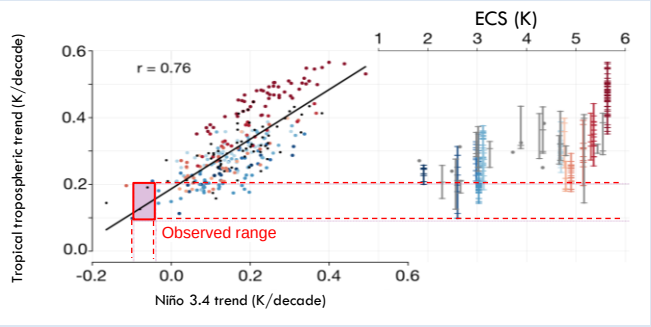


Supporting Ensembles of Earth System Models

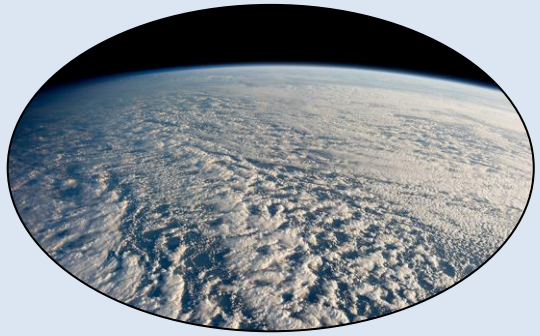
CMIP6



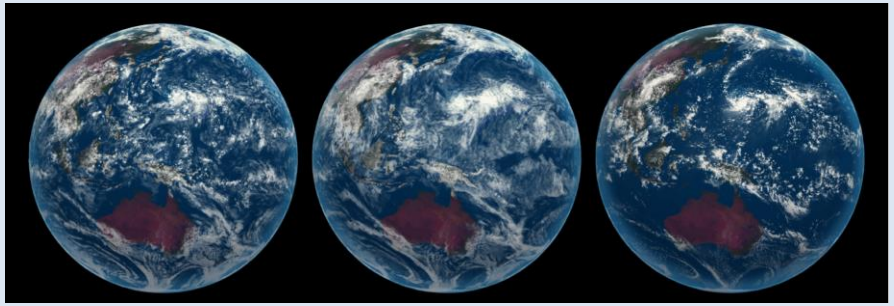
Interpreting Recent Changes in Climate to Inform Predictability



Reducing Uncertainties in Cloud Feedbacks & Climate Sensitivity



Engaging with the Convection Permitting Models of Tomorrow



U.S. DEPARTMENT OF ENERGY

Office of Science

Cooperative Agreement To Analyze variabiLity, change and predictabilitY in the earth SysTem (CATALYST) (Meehl, UCAR)

catalyst
Cooperative Agreement To Analyze variabiLity, change and predictabilitY in the earth SysTem

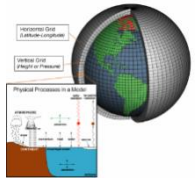
Perform foundational research toward advancing a robust understanding of modes of variability and change using models, observations and process studies

External forcing, internal variability, and predictability

- Interplay between external forcing and internal variability
- Earth system simulation capability to study variability and predictability
- Changes of variability on multi-decadal timescales

High impact events

- Processes and mechanisms that produce high impact extremes
- Possible future changes to high impact events
- Global and regional sea level rise



Parametric and structural uncertainty

- Quantify uncertainties and feedbacks; machine learning
- Evaluate model improvements using a hierarchy of models
- Optimization and calibration at the development timescale

HyperFACETS- A joint RGMA, MSD Effort
PI: Paul Ullrich (UCD)

How are stakeholders using climate data? What are stakeholder needs for climate data?

Use-Inspired Metrics

How well do Earth-system models, integrated human-Earth system models, and available datasets perform for relevant quantities?

Stakeholder Engagement

U.S. Department of Energy | Office of Science

HYPERFACETS

A Framework for Improving Analysis and Modeling of Earth System and Intersectoral Dynamics at Regional Scales

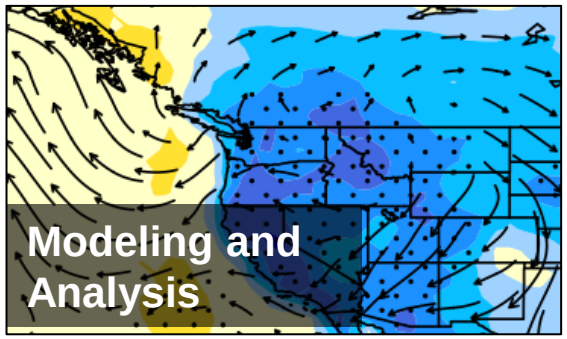
Process Understanding

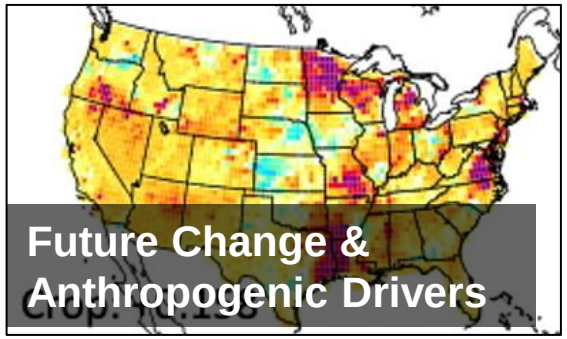
What are the drivers and processes that are most important for ensuring model performance?

What role does human activity (GHG vs. land-use) play in affecting these quantities?

How credible and salient are Earth-system models and available datasets for stakeholder need?

Expert Guidance



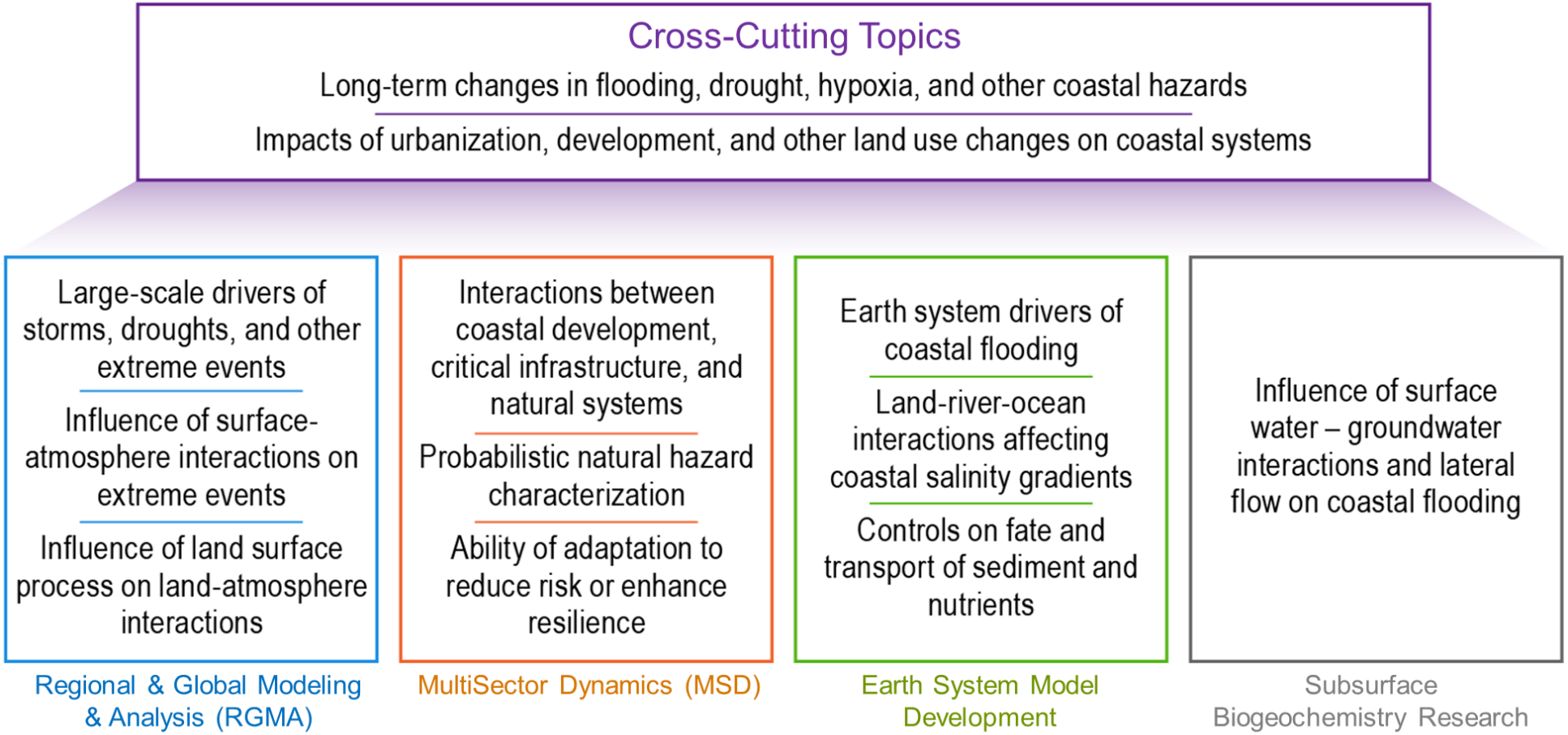


U.S. DEPARTMENT OF ENERGY

Office of Science

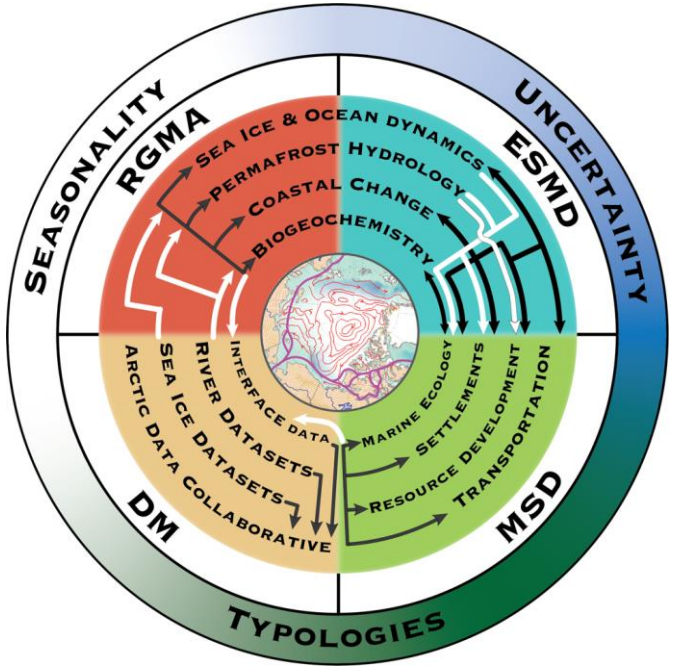
DOE's Integrated Coastal Modeling (ICoM) Project (Kraucunas, PNNL)

ICoM Research Topics for FY 2020–2022



Interdisciplinary Research for Arctic Coastal Environments (InteRFACE): A joint EESM and DM Project- (J. Rowland, LANL)

The INTERFACE project focuses on how the coupled, multi-scale feedbacks among land processes, sea ice, ocean dynamics, coastal change biogeochemistry, atmospheric processes, and human systems will control the trajectory and rate of change across the Arctic coastal interface.



Earth System focus on:

- Sea ice and ocean dynamics
- Coastal Change
- Permafrost Hydrology
- Marine Biogeochemistry

Multi-sector dynamics focus on:

- Shipping
- Settlements
- Resource development

INTERFACE

Los Alamos NATIONAL LABORATORY

OAK RIDGE National Laboratory

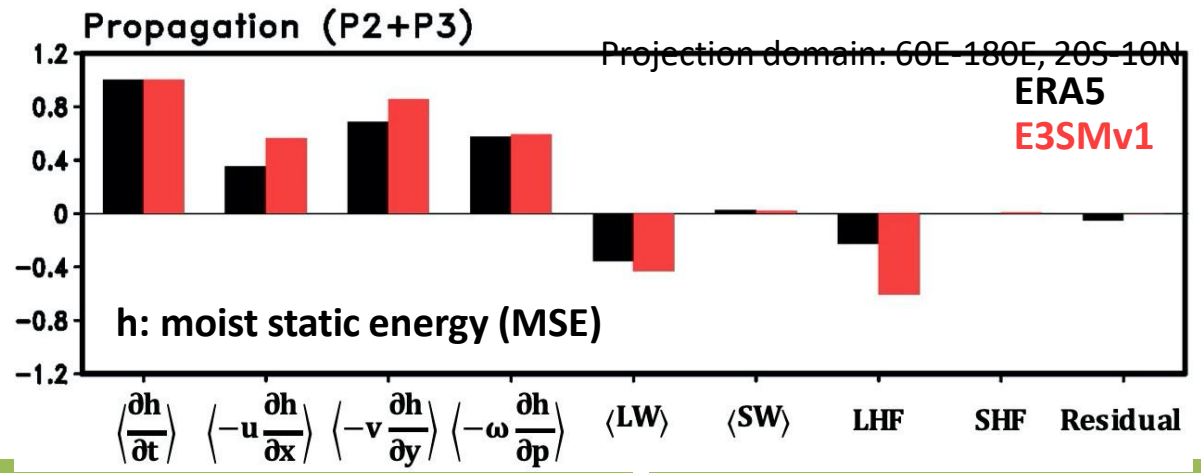
Pacific Northwest NATIONAL LABORATORY

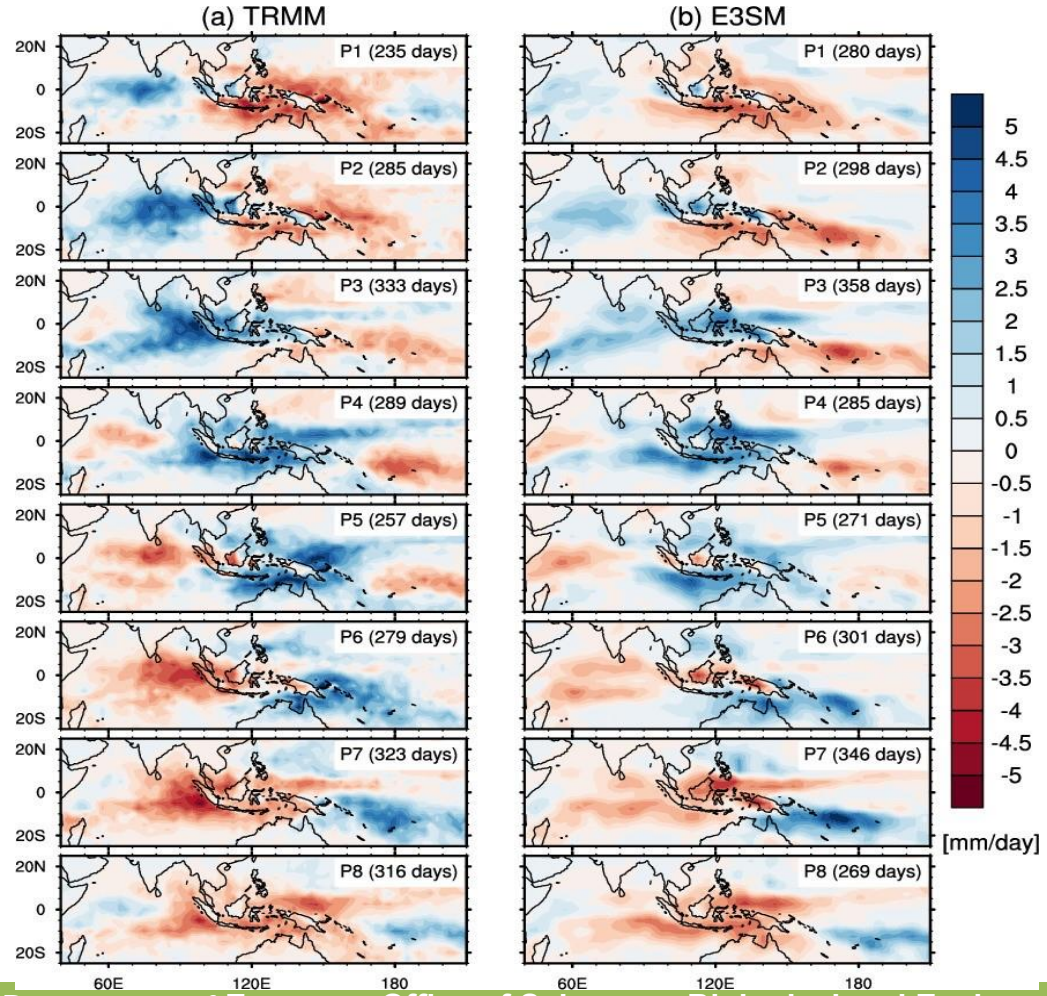
Sandia National Laboratories

UAF UNIVERSITY OF ALASKA FAIRBANKS

MJO in E3SMv1 – Multiple projects: CATALYST CA, University Projects [Kim (UW), DeMott (ColoState)]

- E3SMv1 realistically simulates MJO's eastward propagation, including the spatial pattern of precipitation anomalies around the Maritime Continent (phases 4 and 5)
- MJO MSE budget shows that horizontal and vertical advection terms are responsible for the eastward propagation, as in observations and consistent with the moisture mode framework





Role of AMOC in Transient Climate Response to increasing CO2 in E3SMv1 and CESM2

Objective: We focus on the Atlantic Meridional Overturning Circulation (AMOC) and its role in determining equilibrium climate sensitivity (ECS) and transient climate response (TCR) to increasing CO2.

Approach: The models used here are the Community Earth System Model version 2 (CESM2) and the Energy Exascale Earth System Model version 1 (E3SM1) and the experiments include preindustrial control, historical and 1% CO_2 runs.

Results/Impacts: While CESM2 and E3SM1 have very similar ECS, our analysis suggests that a weaker AMOC contributes in part to the higher TCR in E3SM1 by permitting a faster warming of the upper ocean and a concomitant slower warming of the subsurface ocean. Likewise the stronger AMOC in CESM2 with a slower warming of the upper ocean leads in part to a smaller TCR. Thus, while the mean strength of AMOC does not affect the ECS, it is likely to play an important role in determining the TCR on the centennial time scale.

Hu, A., L. V. Roekel, W. Weijer, O. A. Garuba, W. Cheng, B. T. Nadiga, 2020, Role of AMOC in transient climate response to greenhouse gas forcing in two coupled models, *J. Climate*, 33, 5845-5859, doi: 10.1175/JCLI-D-19-1027-1.

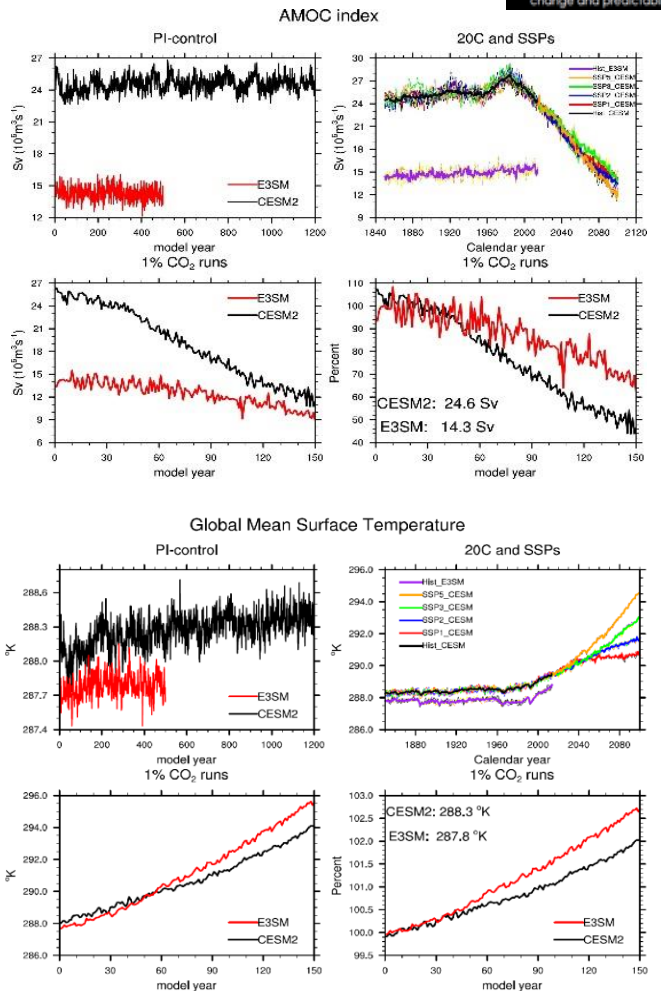
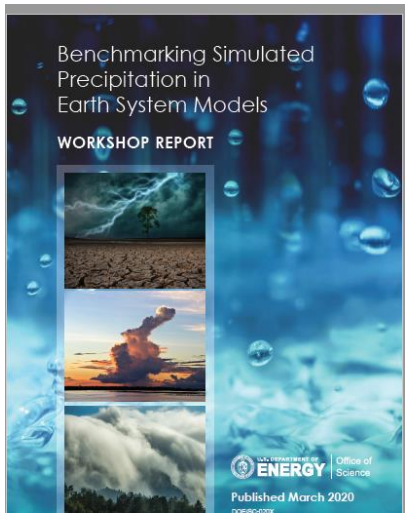


Figure 1. Time evolution of the AMOC index (top 4 panels) and global mean temperature (bottom 4 panels) in the (top left) preindustrial control run, (top right) twentieth century and future SSP runs, (bottom left) 1% CO2 runs, and (bottom right) the percentage changes relative to the control run mean in 1% CO2 runs

RGMA Collaborative Activities

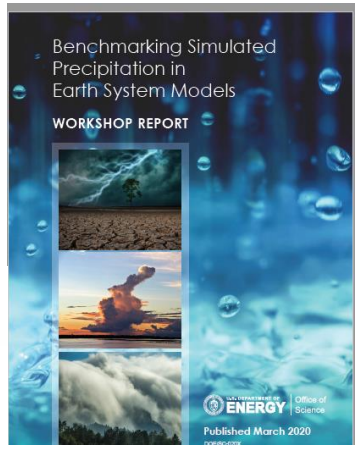
- DOE Precipitation Metrics Workshop
  - Develop Baseline and Exploratory Metrics
- NOAA-DOE Workshop on Precipitation Predictability
  - Nov 30-Dec 2
  - DOE funded scientists involved
- 3rd ARTMIP Workshop
  - Enabled tracking of ARs
- Two BGC Working Groups led by RUBISCO
  - Soil BGC & RUBISCO-Ameriflux – produced many publications

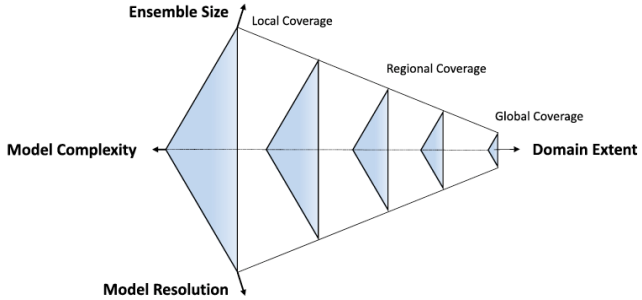


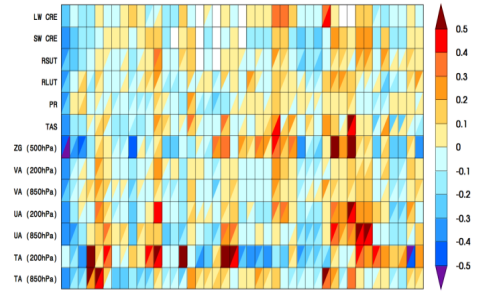
RGMA Collaborative Activities

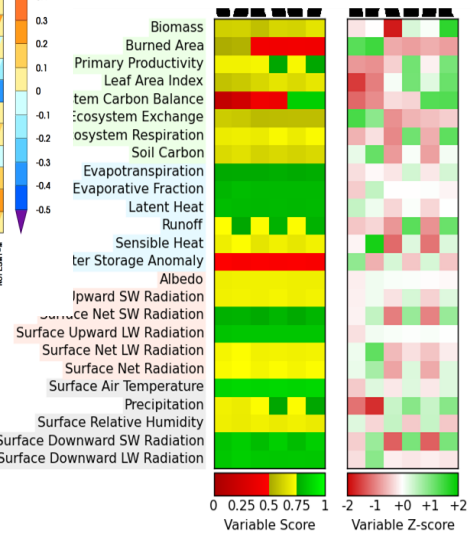
Office of Science

- The Ongoing Need for High-Resolution Regional Climate Models
  - BAMS Publication -(An outcome of the last PI meeting)
- DOE Precipitation Metrics Workshop
  - Develop Baseline and Exploratory Metrics
- NOAA-DOE Workshop on Precipitation Predictability
  - Nov 30-Dec 2
  - DOE funded scientists involved
- 3rd ARTMIP Workshop
  - Enabled tracking of ARs
- CMIP6 Hackathon –
  - Data for the DOE Community - NERSC
- Two BGC Working Groups led by RUBISCO
  - Soil BGC & RUBISCO-Ameriflux – produced many publications
- Community Model Evaluation Capabilities









Precipitation Metrics Workshop

PCMDI · Pacific Northwest NATIONAL LABORATORY · NCAR NATIONAL CENTER FOR ATMOSPHERIC RESEARCH

- Inspired by the lack of objective and systematic benchmarking of simulated precipitation
- Community input via DOE 2018 AGU Town Hall and international modeling working groups
- Date/venue: July 1-2, 2019 in Rockville, Md

Identify targets for improvement

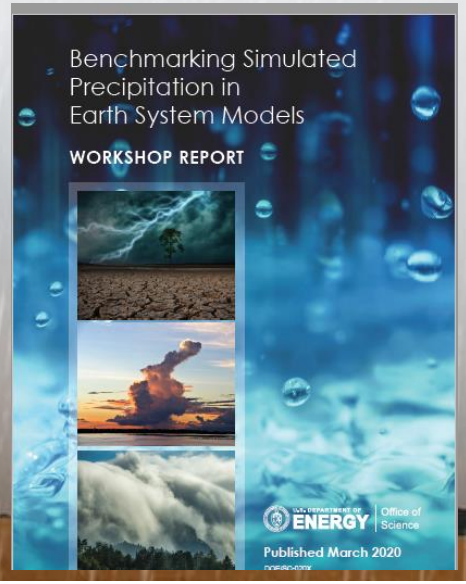
Team of experts identifies useful measures for gauging how well models simulate precipitation

Develop capability to gauge model quality

Baseline metrics incorporated into a model evaluation capability and used to assess current

Improve simulated Precipitation

Modelers provided with metrics capability to serve as a target for improving newer model versions



Establishing a pathway to help guide modelers

- Select a limited set of established benchmarks and develop a strategy for implementing them in a model evaluation capability
- Define how to use this capability for baseline evaluation
- Address the multiscale nature of precipitation, including the existence of model errors at all scales scales
- Identify key research areas where exploratory work can yield more in-depth and informative metrics to include
- Challenge the modeling community to use the expert groups' evaluation metrics as a guide to improve their models; quantify improvement in the next generation of models

NOAA - DOE
Precipitation Processes and Predictability Workshop

Nov. 30 – Dec. 2, 2020

A **community workshop** jointly organized by NOAA and DOE in partnership with USGCRP and USCLIVAR

Scope and focus of the workshop:

- Contiguous U.S. in the context of global models
- Subseasonal to multi-decadal timescales

Major Themes:

1. Sources and limits of predictability
2. Key processes critical to precipitation biases
3. Interdisciplinary Processes
4. Regions

RGMA participating scientists

- Samson Hagos
- Ben Kirtman
- Hsi Yen Ma
- Angeline Pendergrass

RUBISCO-AmeriFlux Working Group

- Formed after community recommendation from the 2016 International Land Model Benchmarking (ILAMB) Workshop Report
- Objective is to use AmeriFlux data to improve process understanding and to develop, parameterize, and test models
- Multiple conference calls led up to a meeting at the UC Berkeley Botanical Garden (outside LBNL) on October 15–17, 2019

Four key areas of research emerged from the Working Group Meeting:

- **Ecosystem trend spotting** - employing long ecosystem carbon and water flux records to detect trends in ecosystem metabolism and to disentangle responses of ecosystems to elevated CO_2, climate change, and human disturbances
- **Ecosystem responses to extreme events** - use long-running AmeriFlux measurements, which include ecosystem responses to extreme weather conditions, to evaluate models
- **Untangling contributions to carbon exchange** - use complementary measurements of respiration fluxes and satellite-derived vegetation indices to improve partitioning methods for eddy covariance estimates of GPP and R_{eco}
- **Scaling up from sites to ecosystems** - combine bottom-up and top-down approaches for scaling fluxes across spatial scales

For more information, see Measuring, Monitoring, and Modeling Ecosystem Cycling in *Eos Trans. AGU* (August 5, 2020)

Soil Carbon Dynamics Working Group

Office of Science

- Formed after community recommendation from the 2016 International Land Model Benchmarking (ILAMB) Workshop Report
- Objective is to apply data and models to improve predictive understanding
- June and September conference calls led to meeting at ORNL in October

Data to Knowledge
Synthesize existing data from collaborative networks, archives, and publications

Knowledge to Data
Perform simulations to test hypotheses and characterize model structural uncertainties

Predictive Understanding
Design functional relationship metrics to confront models and apply data-driven approaches to model formulation

Global Data Synthesis Theme

- Combine field observations from collaborative sampling networks and databases, including International Soil Carbon Network (ISCN) and published literature
- Quantify vertical distribution of SOM and responses to controlling mechanisms

Model–Data Integration Theme

- Develop consistent datasets for initializing, forcing, and benchmarking microbially explicit soil carbon models
- Characterize model structural uncertainty through software frameworks to understand controlling mechanisms

For more information, contact Forrest M. Hoffman <forrest@climatemodeling.org> or Umakant Mishra <umishra@anl.gov>