Poster Submission

- **Posters A** will present on **Tuesday, Nov19, 4:30 - 5:30 pm**.
- **Posters B** will present on **Wednesday, Nov 20, 5:00 - 6:00 pm**.
- Please **vote for The Best Poster** (simply circle the poster you want to vote on, on the back of the poster layout handout and give it to Angela (2019AllHandsMeetingPosterSessionLayout-ballot_v2.pdf))

Posters/presentations Overview

Title	First Author	Topic	Affiliation
A01. Investigating the human interaction effects on water cycles	Xiaoying Shi	*BGC*	E3SM
A02. Examining the role of phosphorus cycle in land responses to environmental changes	Xiaojuan Yang	*BGC*	E3SM BGC
A03. Machine learning approaches for surrogate modeling	Daniel Ricciuto	BGC, land/energy model development, software tools	BGC, OSCM-SciDAC
A04. Using neural network ensembles as model comparators	Christopher Holder	BGC	Johns Hopkins University
A05. Parameter Calibration and Structural Error in Land Models	Khachik Sargsyan	BGC, land/energy model development, software tools	BGC, SciDAC-OSCM
A06. Nutrient Dynamics Developments in ELM-FATES	Ryan Knox	land/energy model development, BGC	NGEE-Tropics, ELM
A07. Soil-plant hydrodynamics and vegetation demography within ELM-FATES	Jennifer Holm	*BGC, Land/Energy model development, E3SM evaluation*	Land/Energy NGD; ELM-FATES; LBNL
A08. Trends in planting date and growing season for crops	Beth Drewniak	BGC land/energy model development	E3SM, ANL
A09. A tree-level hydrodynamics model for ELM to study competition for water	Gautam Bisht	Land/Energy Model Development	PNNL
A10. TDycore	Gautam Bisht	*land/energy model development*	SciDAC
A11. Model soil erosion under land use change	Zeli Tan	land/energy model development	NGD Land/energy
A12. MOSART-lake-stratification	Hong-Yi Li	*land/energy model development*	land/energy NGD
A13. InteRFACE development for E3SM	Andrew Roberts	BGC, cryosphere, ocean/ice model development, E3SM evaluation, applied E3SM	InteRFACE
A14. Evaluating Sea Ice in E3SM with an Altimetric Satellite Emulator	Andrew Roberts	cryosphere, water cycle	LANL
A15. Better representation of land surface heterogeneity in E3SM	Teklu Tesfa	Water Cycle, BGC	E3SM Land Group
A16. Global to coastal multiscale modeling in the Energy Exascale Earth System Model (E3SM)	Phillip J. Wolfram	ocean/ice model development, land/energy model development, coastal development	ICoM ESMD project, coastal waves mini-NGD
A17. Ice-shelf ocean boundary layer physics and its representation in E3SM	Carolyn Begeman	cryosphere, ocean/ice model development	LANL

A18. ProSPect1	stephen price	Cryosphere	ProSPect (SciDAC)
A19. ProSPect2	stephen price	Cryosphere	ProSPect (SciDAC)
A20. ProSPect3	stephen price	Cryosphere	ProSPect (SciDAC)
A21. CICE Consortium	Elizabeth Hunke	ocean/ice, updates and plans for the CICE Consortium	Los Alamos National Laboratory
A22. Eddy-driven diffusivity using Lagrangian particles in global ocean simulations	Amrapalli Garanaik	*ocean/ice model development*	Los Alamos National Laboratory
A23. Sensitivity of grounding line flux	Tong Zhang	cryosphere	Los Alamos National Laboratory
A24. Effects of optical parameterization on the cooling of the Southern Ocean	Marie-Aude Pradal	ocean/ice model development	Johns Hopkins University,
A25. Implementation of Greenland Ice Sheet Freshwater Fluxes in E3SM Models	Theresa Morrison	*ocean/ice model development*	? RGMA ?
A26. Antarctic and Greenland Continental Shelf Circulation	Julie McClean	ocean/ice, Water cycle	RGCMA
A27. Using Power diagrams to build optimal unstructured meshes for C-grid models	Darren Engwirda	Ocean/ice model development; Software tools	Columbia University
A28. Numerical challenges in representing isopycnal mixing on a regular grid	Anand Gnanadesikan	Ocean/ice model development	Johns Hopkins University
A29. Metrics for evaluation of E3SM atmospheric simulations over the Antarctica and Southern Ocean	Wuyin Lin	Cryosphere, Water Cycle, E3SM evaluation	E3SM Cryosphere Group, BNL
A30. Design and Implementation of the Model Analysis Platform for Energy Systems	Michael Kelleher	*software tools, E3SM evaluation*	NGD Software
A31. E3SM Diagnostics Package v2	Jill Chengzhu Zhang	software tools, E3SM development tool	E3SM Infrasturcture
A32. MAM verification and evaluation using a box model	Jian Sun	software tools, verification	NGD Architecture Software and Algorithm, ACME-SM: A Global Climate Model Software Modernization Surge
A33. ETD for HOMME-NH	Cassidy Krause	computing, atmospheric model development	NGD Software and Algorithms
A34. ETD for the Tracer Equations in Ocean Models	Sara Calandrini	computing, ocean/ice model development	Florida State University
B01. EAMv1 CONUS RRM	Qi Tang	Water cycle	E3SM Water Cycle, LLNL
B02. EAMv1 aquaplanet simulation with CONUS RRM	Xue Zheng	*Water cycle*	E3SM Water Cycle, LLNL
B03. ECS > 5 K; a tale of two models	Chris Golaz	*E3SM evaluation*	E3SM Water Cycle
B04. zstash: HPSS long-term archiving tool	Chris Golaz	*software tools, infrastructure*	E3SM Water Cycle
B05. On the use of nudging in EAMv1	Jian Sun	atmospheric model development, E3SM evaluation, software tools	NGD Architecture Software and Algorithm / Watercycle
B06. Resolution Sensitivity of the simulation	Salil Mahajan	Water cycle	E3SM Water Cycle

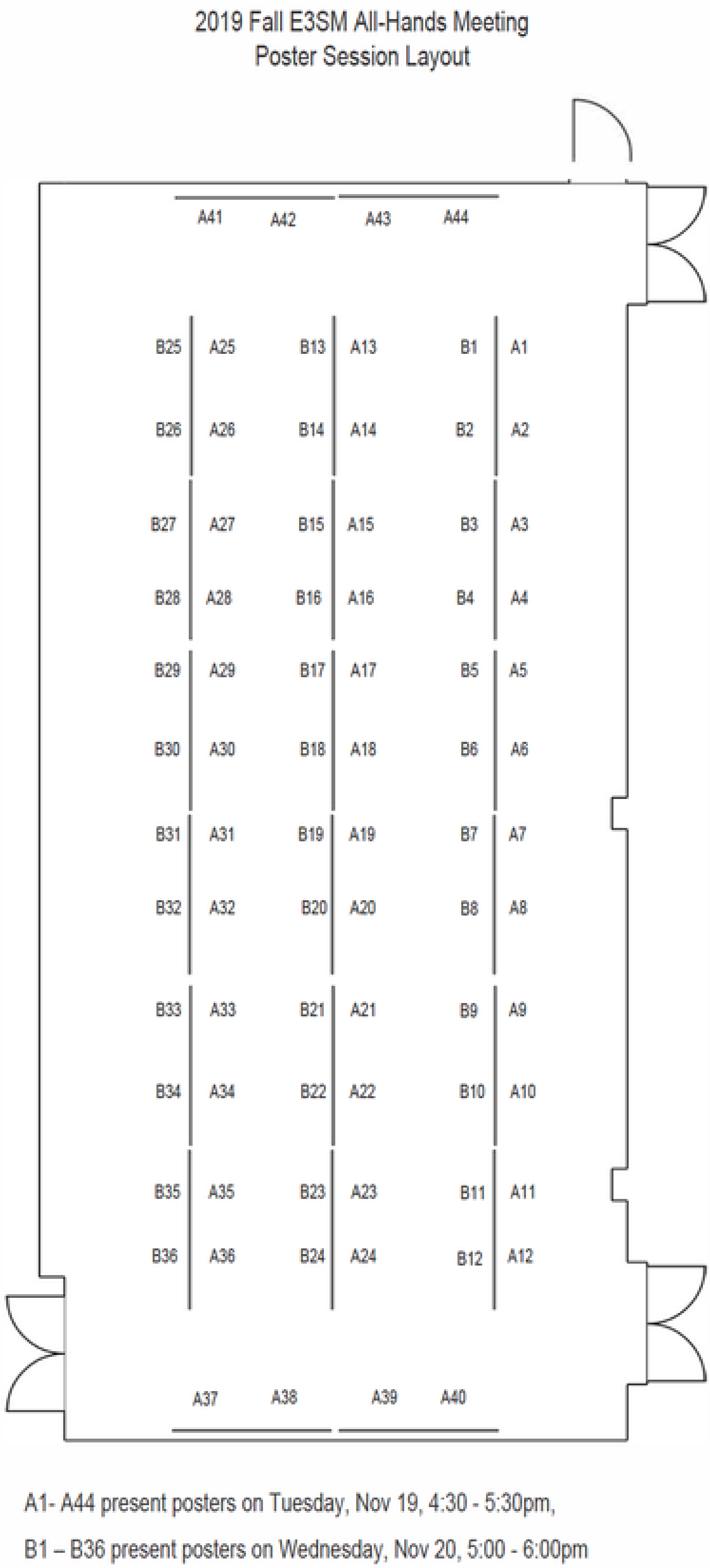
of teleconnections to extremes			
B07. Climate Simulations On Summit	Vince Larson	atmospheric model development	NGD — Atmospheric Physics
B08. Plant Hydraulics Effect	Yilin Fang	Water Cycle	E3SM Water Cycle
B09. Understanding Monsoonal Water Cycle Changes	Bryce Harrop	Water cycle, E3SM evaluation, applied E3SM	E3SM Water Cycle
B10. Upper ocean fresh biases in low-resolution E3SMv1 simulations: diagnostics and possible remedies	Milena Veneziani	water cycle	E3SM Water Cycle, LANL
B11. E3SM-FIVE	Hsiang-He Lee	Atmospheric model development	E3SM Water Cycle, LLNL
B12. Earth System Viz	Lauren Wheeler	Water Cycle	E3SM Visualizations
B13. Cloud Deck Spatial Errors in the EAMv1	Michael Brunke	E3SM evaluation	E3SM University of Arizona project
B14. EAMv1 Cloud Evaluation	Yuying Zhang	E3SM evaluation	NGD-Atmospheric Physics, LLNL
B15. Improving Diurnal Cycle of Precipitation in E3SM	Shaocheng Xie	Atmospheric model development	NGD-Atmospheric Physics
B16. Scale-awareness of ZM Convection Scheme	Guang Zhang	atmospheric model development	NGD Atmosphere
B17. P3 cloud microphysics in E3SM	Kai Zhang	*atmospheric model development*	NGD Physics
B18. P3's Impact in RRM Simulation of MCSs	Jingyu Wang	E3SM evaluation	CMDV
B19. Multi-Plume EDMF Unified Parameterization	Joao Teixeira	atmospheric model development	E3SM NGD-Atmospheric Physics, JIFRESSE, UCLA
B20. Using PPE simulations to understand model physics and parametric sensitivity in EAMv1	Yun Qian	Atmospheric model development	NGD-atmosphere
B21. SOA distributions and radiative forcing from chemistry and photolysis processes in E3SM	Manish Shrivastava	atmospheric model development	NGD atmospheric physics
B22. Investigation of a New Dust Emission Scheme in E3SM	Yan Feng	*atmospheric model development*	NGD atmospheric physics
B23. Nitrate and Stratospheric Aerosol	Hailong Wang	atmospheric model development	NGD - Atmospheric Physics
B24. Atmospheric Chemistry in E3SM	Philip Cameron-Smith	atmospheric model development	NGD-atm
B25. Tropical forest interaction with Hadley cell circulation	Yue Li	*applied E3SM*	RGMA
B26. Convergence-based Solution Correctness Testing	Shixuan Zhang	*atmospheric model development, computing, E3 SM evaluation, software tools*	SciDAC
B27. Solar-J work	Juno Hsu	atmospheric model development	University of California Irvine
B28. Surface-atmosphere longwave coupling in E3SM with M-PACE and	Xianwen Jing	atmospheric model development	the University of Michigan (E3SM University Project)

AWARE observations

B29. Tropical Cyclone Rainfall Structures in CMIP6 HighResMIP Simulations	Yumin Moon	*applied E3SM*	RGMA
B30. Tropical Cyclones in the high-resolution E3SM	Karthik Balaguru	E3SM evaluation	E3SM, RGMA
B31. Influence of Climate Bias on Extreme Events	Ramalingam Saravanan	*atmospheric model development, applied E3SM*	RGMA
B32. US precipitation extremes in E3SM	Akintomide Akinsanola	*atmospheric model development*	RGMA
B33. Mesoscale Parameterization	Chih-Chieh-Jack Chen	Atmospheric Model Development	NGD/NCAR

2019 All Hands Meeting Poster Session Layout

2019AllHandsMeetingPosterSessionLayout-ballot_v2.pdf



A Poster Session: Tuesday, Nov 19, 4:30 - 5:30 pm

- A01. Investigating the human interaction effects on water cycles
- A02. Examining the role of phosphorus cycle in land responses to environmental changes
- A03. Machine learning approaches for surrogate modeling
- A05. Parameter Calibration and Structural Error in Land Models
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- A32. MAM verification and evaluation using a box model
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- A34. ETD for the Tracer Equations in Ocean Models

B Poster Session: Wednesday, Nov 20, 5:00 - 6:00 pm

- B01. EAMv1 CONUS RRM
- B02. EAMv1 aquaplanet simulation with CONUS RRM
- B03. ECS > 5 K; a tale of two models
- B04. zstash: HPSS long-term archiving tool
- B05. On the use of nudging in EAMv1
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- B29. Tropical Cyclone Rainfall Structures in CMIP6 HighResMIP Simulations
- B30. Tropical Cyclones in the high-resolution E3SM
- B31. Influence of Climate Bias on Extreme Events
- B32. US precipitation extremes in E3SM

A01. Investigating the human interaction effects on water cycles

Poster Title	Investigating the human interaction effects on water cyclesInvestigating the human interaction effects on water cycles
First Author	Xiaoying Shi
Topic	*BGC*
Affiliation	E3SM
Link to document	...

Title

Investigating the human interaction effects on water cycles

Authors

Xiaoying Shi Katherine Calvin Andrew D. Jones Ben Bond-Lamberty Peter Thornton Alan Di Vittorio

Abstract

In the traditional asynchronous approach, human system information required as forcing for climate prediction is generated in advance by economic integrated assessment models (IAMs) that include both energy and agricultural sectors. An integrated Earth System Model (iESM), which couples the Global Change Assessment Model, Global Land-use Model, and community Earth System Model together, was recently developed (Collins et al. 2015; Thornton et al., 2017). It provides a tremendous opportunity for modeling experiments to examine interactions between the human and natural systems, which is a synchronous approach for climate change projection. A bundle of experiments was conducted using the iESM under the RCP8.5 scenario to explore the radiative and physiological effects of atmospheric CO_2 concentration and Earth-human interactions in the context of future hydrological projections. We found that CO_2 concentration has significant effects on the hydrological cycle by modulating the evapotranspiration of the plant and soil system. Considering the Earth and human system interactions also has significant impacts on future water cycle through interactive land use and land cover change, greenhouse gas emissions and so on. On the basis of these results, we address the importance of using more integrated modeling system to project the Earth environmental change.

A02. Examining the role of phosphorus cycle in land responses to environmental changes

Poster Title	Examining the role of phosphorus cycle in land responses to environmental changes
First Author	Xiaojuan Yang
Topic	*BGC*
Affiliation	E3SM BGC
Link to document	...

Title

Examining the role of phosphorus cycle in land responses to environmental changes

Authors

Xiaojuan Yang, Peter Thornton, Daniel Ricciuto

Abstract

One of the major developments in the E3SM Land Model (ELM v1) is the introduction of a prognostic P cycle and C-N-P cycle interactions. In this study, we perform a series of single factor global scale simulations with and without P cycle on. The objective is to examine the role of phosphorus cycle dynamics on land carbon fluxes under different environmental changes. We show that the inclusion of P dynamics and C-N-P interactions leads to different land responses to changes in atmospheric CO2, climate, land use change and nitrogen deposition. Our results suggest that previous modelling effort without considering P cycle dynamics likely overestimate the land's capacity to uptake carbon from the atmosphere. We conclude that the explicit, prognostic representation of P cycle in ESMs is essential for the prediction of future terrestrial carbon uptake and atmospheric CO2 concentration.

A03. Machine learning approaches for surrogate modeling

Poster Title	Machine learning approaches for surrogate modeling in the E3SM land model
First Author	Daniel Ricciuto
Topic	BGC, land/energy model development, software tools
Affiliation	BGC, OSCM-SciDAC
Link to document	...

Title

Machine learning approaches for surrogate modeling in the E3SM land model

Authors

Daniel Ricciuto, Dan Lu, Khachik Sargsyan, Vishagan Ratnaswamy, Cosmin Safta

Abstract

There are a variety of different methods in machine learning that can be applied to create surrogate models. Traditional feed-forward neural networks or a multilayer perceptron (MLP) can be used to build approximations to quantities of interest (QoI) for complex physical models, for example, carbon fluxes in the E3SM land model. A single model output variable (e.g. the gross primary productivity GPP) is spatially gridded and therefore contains a large number of QoIs for a surrogate model to reproduce. Here we demonstrate this high-dimensional GPP output can be accurately represented with a small number of singular values when singular value decomposition (SVD) is applied. An accurate surrogate model can then be trained using a MLP with a relatively small ensemble. Temporal variations in model outputs present additional challenges for creating accurate surrogate models. Thus, the use of a recurrent neural network (RNN) is also suited for the land model. Using a vanilla RNN comes with its own set of issues such as exploding and vanishing gradients; however, those issues can be mitigated with gradient clipping or commonly gates. One common gated method is long short-term memory (LSTM). While the gated-RNN can handle temporal data, it is typically done in a sequential fashion, i.e. it ignores the connected (hierarchical) nature of the QOIs. To make a more physics-based model, we employ a hierarchical NN, specifically a Tree-LSTM that incorporates the hierarchical nature of the land model. We compare how well the Tree-LSTM RNN predicted the QOIs of the land model in one representative grid cell, namely for carbon cycle variables compared with LSTM-RNN and MLP. We find that the Tree-LSTM outperforms MLP and LSTM-RNN, confirming the intuition that physics-based neural network architecture improves the predictive accuracy compared to vanilla methods.

A05. Parameter Calibration and Structural Error in Land Models

Poster Title	Surrogate-enabled Parameter Calibration and Structural Error Estimation in Land Models
First Author	Khachik Sargsyan
Topic	BGC, land/energy model development, software tools
Affiliation	BGC, SciDAC-OSCM
Link to document	...

Title

Surrogate-enabled Parameter Calibration and Structural Error Estimation in Land Models

Authors

Khachik Sargsyan, Daniel Ricciuto, Jennifer Holm

Abstract

Tuning model parameters for complex climate codes is a challenging task due to the expense of a single simulation and a large number of uncertain input parameters. Bayesian calibration typically requires infeasibly many model evaluations on-the-fly. To accelerate Bayesian inference, we rely on polynomial chaos (PC) surrogates that approximate model input-output maps efficiently. Furthermore, the calibration procedure is enhanced to incorporate model structural errors, often the dominant component of predictive uncertainty. Namely, we develop a general framework for a probabilistic representation of the structural error inside the model, followed by a simultaneous calibration of physical inputs and parameters representing the structural error. The resulting embedded model-error strategy conserves physical constraints, allows meaningful predictions of a full set of output quantities of interest (QoIs), disambiguates model error from data noise, and leads to predictions with attributable uncertainties. The developed workflow is implemented in UQ Toolkit (www.sandia.gov/uqtoolkit). Surrogate-enabled sensitivity analysis and parameter inference are demonstrated for ELM FATES given observations, as well as for a simplified land model within the OSCM SciDAC project.

A04. Using neural network ensembles as model comparators

Poster Title	Using neural network ensembles as model comparators
First Author	Christopher Holder
Topic	BGC
Affiliation	Johns Hopkins University
Link to document	...

Title

Using neural network ensembles as model comparators

Authors

Christopher Holder ; Anand Gnanadesikan

Abstract

Biogeochemical simulations can differ across models either because the physical climate is different or because the intrinsic relationships between physical forcing and biogeochemical output are different. For example, models of ocean ecosystems may yield different distributions of chlorophyll because the location of the subpolar front is offset due to winds being offset or because the level of macronutrient required to have high biomass is different. We demonstrate that one can distinguish between these drivers of model difference using neural network ensembles (NNEs) to capture "apparent relationships" between physical forcing and biomass. Under changes in either subgridscale parameterization or greenhouse gas levels, NNEs can recover the fact that the different solutions are produced by the same underlying relationships between light, nutrient and biomass and thus that physical forcing is responsible for the difference. NNEs may also be used to distinguish biological models with different parameterizations of biology from each other. We propose that such tools may be useful in identifying the fundamental drivers explaining why different Earth System Models produce different distributions of biomass under both modern and climate change conditions.

A08. Trends in planting date and growing season for crops

Poster Title	Trends in planting date and growing season for crops
First Author	Beth Drewniak
Topic	BGC land/energy model development
Affiliation	E3SM, ANL
Link to document	...

Title

Trends in planting date and growing season for crops

Authors

Beth Drewniak Argonne National Laboratory

Abstract

The seasonal cycle of crops is strongly influenced by climate. For example, planting date is determined by thresholds of temperature and precipitation, thus allowing the day of planting to change from year to year. Crop productivity and yield are affected by temperature and precipitation during the growing season. The length of the growing season is driven by temperature, since crops phenological development is determined by heat accumulation. Crops have optimum temperature thresholds that limit growth during periods of excessive heat or cold. Because the total number of heat units needed for maturity is semi-fixed for crops, warmer years result in shorter growing cycles, and therefore lower yields as less time is spent during grain development. Furthermore, lack of adequate moisture can have dire consequences on yield. Understanding how changes in climate lead to changes in the seasonal cycle of crops is critical for crop yield estimation. In this study, the new planting date calculator in ELM is tested with global crops to identify possible trends in planting date and the length of the growing season over the historical period. Furthermore, correlations between these, and other variables such as temperature and precipitation over the growing season, and yield are evaluated.

In addition, in the current ELM, growing season for crops is capped by a maximum number of heat units, which is not ideal for all regions. This is particularly true in low latitudes where ideal conditions exist for longer growing seasons but tend toward earlier harvest in the model. Therefore, a sensitivity study is included to look at the impacts of loosening the cap on heat units, to examine the impact of longer growing season on yields. This is a simplistic proxy for representing different cultivars to exist in different regions.

A07. Soil-plant hydrodynamics and vegetation demography within ELM-FATES

Poster Title	**Exploring interactions between soil-plant hydrodynamics and vegetation demography within ELM-FATES**
First Author	Jennifer Holm
Topic	*BGC, Land/Energy model development, E3SM evaluation*
Affiliation	Land/Energy NGD; ELM-FATES; LBNL
Link to document	

Title

Exploring interactions between soil-plant hydrodynamics and vegetation demography within ELM-FATES

Authors

Jennifer Holm (LBNL), William Riley (LBNL), Ryan Knox (LBNL), Daniel Ricciuto (ORNL), Khachik Sargsyan (Sandia)

Abstract

High-latitude forests are known to be vulnerable to permafrost thawing, increased disturbances, and shift in forest cover type to potentially more deciduous as a result of climatic warming. These forest changes can have strong feedbacks to regional and global climate, water and carbon cycling, and carbon sink strengths. For example, soil inundation with thawing can lead to decreases in ecosystem productivity in boreal forests, and strongly influences the vegetation composition via plant competition and survival during wetland expansion, shifting ecosystems into carbon sinks. To be able to accurately predict and model these complex ecological processes we are using a new demographic vegetation model (FATES; Functionally-Assembled Terrestrial Ecosystem Simulator) that is coupled to ELMv1, the land surface model in the global Earth System Model - E3SM. A new continuous soil-root-plant plant hydraulic scheme has been included within FATES, allowing dynamic plant mortality and growth from water stress and changes in subsurface drainage. We use FATES-Hydro to quantify the impacts on water cycling (e.g., water use efficiency, latent heat, soil water storage) and carbon fluxes (NEE) under transitions between boreal evergreen and deciduous trees, and upland and wetland habitats.

As a first step to evaluate climate warming-vegetation interactions, we performed a parameter sensitivity analysis using a Latin hypercube approach to sample the parameter space of 15 main vegetation parameters, over a 100-member ensemble run. In addition, leaf and wood allometry parameters for boreal plants have been updated based on observational data from the BAAD Database. Initial tests of FATES at a boreal Alaska site found strong biomass and plant mortality sensitivity to soil moisture availability in deciduous trees and shrubs, but not evergreen (i.e., spruce) trees. Further testing of the newly developed plant hydraulic scheme (FATES-Hydro) allows us to simulate the impacts of warming and soil moisture changes on boreal evergreen and deciduous tree cover, and ultimately shifts in carbon source vs. sink.

A09. A tree-level hydrodynamics model for ELM to study competition for water

Poster Title	Development of a tree-level hydrodynamics model for ELM to study competition for water
First Author	Gautam Bisht
Topic	Land/Energy Model Development
Affiliation	PNNL
Link to document	

Title

Development of a tree-level hydrodynamics model for ELM to study competition of water

Authors

Gautam Bisht (PNNL), William Riley (LBNL), Gil Bohrer (The Ohio State University), and Ashley Matheny (The University of Texas at Austin)

Abstract

Water availability impacts transpiration which in turn modifies water, energy, carbon, and nutrient cycling in vegetation, and ultimately growth and survival. Plants dynamically regulate their water availability through active controls in their roots, xylem, and leaves. Yet, most current generation global land surface models, including the E3SM Land Model (ELM), do not explicitly resolve water transport through the root and xylem of a plant. Furthermore, ELM allows each plant functional type (PFT) within a grid cell to extract soil water without concurrently accounting for competition from other PFTs in the same grid cell within a given timestep. In this work, we report on our Next Generation Development effort to apply E3SM's terrestrial Multi-Physics Problem (MPP) library to resolve water transport across the soil-plant continuum and explicitly account for water competition among plants. The plant hydrodynamics model is based on the variably saturated Richards equation and accounts for water storage within plant roots and xylem. We apply our model to the US-UMB Ameriflux site and simulate tree-level hydrodynamics for four PFTs within a grid cell. Our model results agree well with soil moisture observations at multiple depths and observed sapflow. Diurnal profiles of simulated transpiration stress within the plant canopy are also analyzed. Lastly, our results show the importance of model structure (i.e., inclusion or exclusion of water storage within a plant) on simulated plant water stress.

A10. TDycore

Poster Title	The development of the Terrestrial Dynamical core (TDycore) library and it’s coupling with E3SM
First Author	Gautam Bisht
Topic	*land/energy model development*
Affiliation	SciDAC
Link to document	...

Title

The development of the Terrestrial Dynamical core (TDycore) library and it’s coupling with E3SM

Authors

Gautam Bisht (PNNL), Jed Brown (Univ. of Colorado, Boulder), Nathan Collier (ORNL), Jennifer Fredrick (SNL), Glenn Hammond (SNL), Satish Karra (LANL), Mathew Knepley (Univ. at Buffalo), Richard Mills (ANL)

Abstract

Developing a predictive understanding of the terrestrial water cycle at local to global scale is essential for accurate assessment of water resources, agricultural production, and energy generation given current climate variability. Higher spatial resolution in the land component of the Energy Exascale Earth System Model (E3SM) project alone is insufficient to meet the U.S. Department of Energy’s 10-year vision for the Earth System Modeling program. Next generation hyperresolution terrestrial models need to not only move beyond one-dimensional systems by including scale appropriate 2D and 3D physics formulations, but also use numerical discretization schemes that are appropriate for terrain-following, non-orthogonal 3D grids.

In this project, we are developing a standalone, scalable numerical library, named TDycore, which solves the three-dimensional transport of water in the subsurface for non-orthogonal grids. The TDycore library is being built on top of the Portable, Extensible Toolkit for Scientific Computation (PETSc) library. The TDycore library will support the following two spatial discretization schemes that support non-orthogonal grids: (i) mixed finite element, and (ii) multi point flux approximation. The temporal discretization is provided by via PETSc’s time stepping methods. The TDycore library will be coupled the E3SM Land Model (ELM) to resolve 3D subsurface flow. We will present results for a range of problems that demonstrate verification of the TDycore library and preliminary results from the ELM-TDycore coupling. The enhanced modeling capabilities provided by the TDycore library will lead to a more mechanistic representation of hydrological cycle in the E3SM.

A11. Model soil erosion under land use change

Poster Title	Improve soil erosion modeling in ELM by considering the effects of land use change and cropland management
First Author	Zeli Tan
Topic	land/energy model development
Affiliation	NGD Land/energy
Link to document	...

Title

Improve soil erosion modeling in ELM by considering the effects of land use change and cropland management

Authors

Zeli Tan[1], L. Ruby Leung[1], Hong-Yi Li[2], Teklu Tesfa[1], Qing Zhu[3], Min Chen[1]

[1]Pacific Northwest National Laboratory, USA

[2]University of Houston, USA

[3]Lawrence Berkeley National Laboratory, USA

Abstract

Soil erosion is an important land surface process that transports enormous amounts of sediment, carbon and nutrients from land to rivers and oceans. Previously, we have developed a soil erosion model in ELM that can simulate soil erosion and erosion induced sediment, C, N and P fluxes under the change of climate. However, this soil erosion model has not considered the impacts of land use change (especially the expansion and abandonment of cropland) and cropland management (such as tillage reduction, plant residual management and irrigation) on soil erosion. As a result, the model cannot make realistic predictions of lateral sediment, carbon and nutrient fluxes. To fill this gap, we will improve the soil erosion model in ELM by turning on the crop model and the irrigation model and the dynamic land use of the cropland land units. We will also add the irrigation water as another force for rainfall-driven erosion, use the modeled plant residual as inputs to calculate the ground cover factor of erosion and integrate the RUSLE tillage factor. In the talk, we will present the data sources for the model improvement and give a preliminary result about how land use change and irrigation could affect the simulation of soil erosion in the recent decades.

A12. MOSART-lake-stratification

Poster Title	MOSART-lake-stratification
First Author	Hong-Yi Li
Topic	*land/energy model development*
Affiliation	land/energy NGD
Link to document	...

Title

A Multilayer Lake/Reservoir Thermal Stratification Module for Earth System Models

Authors

Hong-Yi Li; Wondmagegn, Yigzaw (U of Houston); Ruby Leung

Abstract

Thermal stratification in reservoirs is a critical process that regulates downstream riverine energy and biogeochemical cycling. Current stratification models either simplify vertical energy process, reservoir geometry or neglecting the effects of reservoir operation. Here we present a new multilayer reservoir stratification model that can be applied for reservoir and stream temperature simulation at regional or global scale. With a multilayer vertical discretization, we introduce a newly developed storageareadepth dataset to improve parameterization of advection processes in and out of the reservoir. The new model better represents vertical temperature gradient and subsequently temperature of water released to downstream. The stratification model is applied to 1400 reservoirs over the contiguous US and validated against observed surface, profile, and outflow temperature data over 130 reservoirs subjected to various levels of regulation. The NashSutcliffe values are higher than 0.5 for about 77% of the validated reservoirs using surface temperature while the average values of root mean square error and bias are 3.6^{o}C and 1.1^{o}C, respectively. Using the new reservoir storageareadepth dataset improves the simulation of surface temperature at over 69% of the validated reservoirs compared to using simplified reservoir geometry. The reservoir stratification model contributes to improving predictive understanding of anthropogenic impact on terrestrial hydrological, ecological and biogeochemical cycles.

A14. Evaluating Sea Ice in E3SM with an Altimetric Satellite Emulator

Poster Title	Evaluating Sea Ice in E3SM with an Altimetric Satellite Emulator
First Author	Andrew Roberts
Topic	cryosphere, water cycle
Affiliation	LANL
Link to document	...

Title

Evaluating Sea Ice in E3SM with an Altimetric Satellite Emulator

Authors

Andrew Roberts, Jonathan Wolfe, Adrian Turner, Elizabeth Hunke (Los Alamos National Laboratory), Alice DuVivier (National Center for Atmospheric Research), Wieslaw Maslowski (Naval Postgraduate School), Ron Kwok (Jet Propulsion Laboratory), Sinéad Farrell (University of Maryland)

Abstract

We address a key deficiency in the evaluation of sea ice in the Energy Exascale Earth System Model (E3SM) using a freeboard satellite emulator that compares simulated sea ice height above sea level with that of polar ocean retrievals by space-borne altimeters. Late winter, spring and autumnal measurements of surface topography of the Arctic Ocean by the Geoscience Laser Altimeter System (GLAS) instrument aboard the Ice, Cloud, and land Elevation Satellite (ICESat) are used to evaluate E3SM. Sea ice freeboard is retrieved from model grid cells in close spatiotemporal proximity to GLAS samples, and used to generate basin-wide skill and bias statistics of model simulations. We compare E3SM results with the Community Earth System Model (CESM) Version 2 using both the CAM and WACCM models, and also different datasets of ice freeboard and thickness derived from ICESat. A key outcome of this work is that none of the fully coupled CMIP6 DECK simulations from E3SM nor CESM perform particularly well, whereas the observationally-guided Regional Arctic System Model (RASM) does a much better job in creating the spatial pattern commonly seen in sea ice thickness in the central Arctic. In all models, ice freeboard bias is as much as a full standard deviation removed from observations and this is unaffected by the snow cover on the ice. However, what sets E3SM apart from CESM is its large variability across the DECK ensembles, suggesting problems with E3SM's standard-resolution polar atmosphere, ocean or sea ice physics. Critically, we are able to assign precise skill scores to characterize the E3SM's and CESM's limitations, and thus set a benchmark by which the E3SM V2 polar climate may be judged in future publications.

A13. InteRFACE development for E3SM

Poster Title	InteRFACE development for E3SM
First Author	Andrew Roberts
Topic	BGC, cryosphere, ocean/ice model development, E3SM evaluation, applied E3SM
Affiliation	InteRFACE
Link to document	...

Title

InteRFACE development for E3SM

Authors

Andrew Roberts, Luke Van Roekel, Nicole Jeffery, Mathew Maltrud, Joel Rowland, Phillip Wolfram, Elizabeth Hunke (Los Alamos National Laboratory), Ethan Coon (Oak Ridge National Laboratory), Stephanie Waldhoff (Pacific Northwest National Laboratory)

Abstract

InteRFACE (Interdisciplinary Research for Arctic Coastal Environments) is a new Department of Energy (DOE) project to understand and predict coupled physical, biological and human-system changes occurring at the margins of the Arctic Ocean, including Alaska's North Slope. The project is novel because it spans the Regional and Global Model Analysis (RGMA), Earth System Model Development (ESMD), Multisector Dynamics (MSD) and Data Management (DM) programs of the DOE Office of Biological and Environmental Research, along with its sister project, Integrated Coastal Modeling (ICoM) of the North American Atlantic coast. InteRFACE Phase 1 is a close collaboration between polar oceanographers, cryospheric scientists, hydrologists, biogeochemists, economists and social scientists. Phase 1 began in October 2019 and over the next three years, we plan several key developments in E3SM, tested and benchmarked on a regionally refined oceanic mesh designed to inform navigability for Arctic shipping, and better represent coastal biogeochemistry and river outflow. We will be introducing landfast sea ice, wave-sea ice coupling, higher-order-closure-type oceanic mixing, benthic biogeochemistry and a nested permafrost hydrology model to branched versions of E3SM. These new developments will undergo strident testing and analysis within InteRFACE using fully coupled E3SM simulations, and developments demonstrated to be robust will be committed to the core E3SM project code. Our model development, analysis, and testing is being backed up by a simulation campaign focused on quantifying the spread of moderately-sized ensembles and offers the potential of significant improvements to the polar physics and biogeochemistry of E3SM.

A06. Nutrient Dynamics Developments in ELM-FATES

Poster Title	Nutrient Dynamics Developments in ELM-FATES
First Author	Ryan Knox
Topic	land/energy model development, BGC
Affiliation	NGEE-Tropics, ELM
Link to document	...

Title

Nutrient Dynamics Developments in ELM-FATES

Authors

Ryan Knox, Charles Koven, William Riley, Jennifer Holm, Xiaojuan Yang, Qing Zhu, Jinyun Tang, Anthony Walker, Gregory Lemieux, Peter Thornton, Benjamin Sulman and Gautam Bisht

Abstract

Here we present a model system that enables the dynamics, transport and competitive acquisition of nutrients between demographic vegetation, soil mineral surfaces and microbial decomposers in the Energy Exascale Earth System Model (E3SM). This system is achieved through the coupling of nutrient dynamics in the Functionally Assembled Terrestrial Ecosystem Simulator (FATES) with the E3SM Land Model. Nutrient dynamics in FATES is d esigned with an emphasis on modularity and extensibility to facilitate the addition and comparison of new hypotheses. FATES can also be coupled with different soil biogeochemical models in ELM. The work reported here is an explanation of how FATES-ELM is coupled, as well as a demonstration of its current status.

A16. Global to coastal multiscale modeling in the Energy Exascale Earth System Model (E3SM)

Poster Title	Global to coastal multiscale modeling in the Energy Exascale Earth System Model (E3SM)
First Author	Phillip J. Wolfram
Topic	ocean/ice model development, land/energy model development, coastal development
Affiliation	ICoM ESMD project, coastal waves mini-NGD
Link to document	... DRAFT ICoMPoster.pdf

Title

Global to coastal multiscale modeling in the Energy Exascale Earth System Model (E3SM)

Authors

Phillip J. Wolfram, Tian Zhou, Gautam Bisht, Zeli Tan, Hong-Yi Li, Chang Liao, Andrew Roberts, Jon Wolfe, Mark Petersen, Brian Arbic, Darren Engwirda, Steven Brus, Zhendong Cao, Mathew Maltrud, Xylar Asay-Davis, Ruby Leung, Ian Kraucunas

Abstract

Existing Earth System Model coastal modeling approaches typically neglect an explicit, continuous representation of coastal processes that seamlessly transfer from global to coastal scales. The consequences of this historical design decision is that coupled processes at the terrestrial aquatic interface are unable to be directly represented in terms of interacting, coupled processes. Use of unstructured meshes in the U.S. Department of Energy's Energy Exascale Earth System Model (E3SM) provides an unparalleled capability to resolve the terrestrial aquatic interface, leveraging new Model for Prediction Across Scales Ocean (MPAS-O) flooding capabilities and improved representation of the land-river-ocean interface via dynamic coupling with the E3SM Land Model (ELM) and the Model for Scale Adaptive River Transport (MOSART). Use of a single unified multiscale mesh across the land-river-ocean interface will enable seamless coastal modeling and cross-shore exchanges will be enabled by this scale-consistent coupling to facilitate transport of sediment, nutrients, and salinity fluxes across the entire coastal zone. We present plans and initial results towards development of this broad E3SM coastal capability that focuses on inundation, first steps toward coastal biogeochemistry, and land-river-ocean estuarine exchanges at high climate model resolution scales.

A17. Ice-shelf ocean boundary layer physics and its representation in E3SM

Poster Title	Ice-shelf ocean boundary layer physics and its representation in E3SM
First Author	Carolyn Begeman
Topic	cryosphere, ocean/ice model development
Affiliation	LANL
Link to document	...

Title

Ice-shelf ocean boundary layer physics and its representation in E3SM

Authors

Carolyn Begeman (LANL), Xylar Asay-Davis (LANL), Luke Van Roekel (LANL)

Abstract

A key cryosphere focus within E3SM is the impacts of ocean-ice shelf interactions on Antarctic ice loss and sea level rise. However, a poor representation of ice-shelf ocean boundary layer physics hinders our assessment of these impacts. We undertake very high resolution ocean modeling (large-eddy simulation) to illuminate this boundary layer physics and develop parameterizations of scalar and momentum transport suitable for ice-shelf melt prediction in MPAS-Ocean and other global ocean models. Here we present early results from this work, which show the development of a buoyant boundary layer near the ice shelf base that modulates ice shelf melt rates.

A18. ProSPect1

Poster Title	Probabilistic Sea-Level Projections from Ice Sheet and Earth System Models 1: New Model Physics
First Author	stephen price
Topic	Cryosphere
Affiliation	ProSPect (SciDAC)
Link to document	ProSPect-poster1-2019b.pdf

Title

Probabilistic Sea-Level Projections from Ice Sheet and Earth System Models 1: New Model Physics

Authors

Stephen Price (PI; LANL), Esmond Ng (PI; LBNL), Xylar Asay-Davis (LANL), Jeremy Bassis (UM), L. Bertagna (SNL), C. Book (LANL), Darin Comeau (LANL), Matt Dunlop (NYU), Katherine Evans (ORNL), Matthew Hoffman (LANL), John Jakeman (SNL), Sam Kachuck (UM), Joseph Kennedy (ORNL), Dan Martin (LBNL), Mauro Perego (SNL), Mark Petersen (LANL), Andrew Salinger (SNL), Adam Schneider (UCI), Chad Sockwell (SNL), Georg Stadler (NYU), Irina Tezaur (SNL), Raymond Tuminaro (SNL), Brian Van Straalen (LBNL), Jerry Watkins (SNL), Tong Zhang (LANL)

Abstract

Changes to the Greenland and Antarctic ice sheet over recent decades have contributed to sea-level rise at an accelerating rate and present the largest potential for future changes in sea-level. Accurate sea-level projections require simulations of ice sheet evolution using next-generation ice sheet models coupled to Earth-System Models (ESMs), but current limitations prohibit such projections. SciDAC's *ProSPect* focuses on ice sheet and ESM improvements in three main areas: 1) ice-sheet model physics and coupling, 2) initialization and uncertainty analysis, and 3) ice-sheet model performance on next-generation, high-performance computing (HPC) architectures. In this poster, we present recent advancements under ProSPect in the area of ice sheet model physics.

A19. ProSPect2

Poster Title	Probabilistic Sea-Level Projections from Ice Sheet and Earth System Models 2: Ice Sheet and Earth System Model Coupling
First Author	stephen price
Topic	Cryosphere
Affiliation	ProSPect (SciDAC)
Link to document	ProSPect-poster2-2019b.pdf

Title

Probabilistic Sea-Level Projections from Ice Sheet and Earth System Models 2: Ice Sheet and Earth System Model Coupling

Authors

Stephen Price (PI; LANL), Esmond Ng (PI; LBNL), Xylar Asay-Davis (LANL), Jeremy Bassis (UM), L. Bertagna (SNL), C. Book (LANL), Darin Comeau (LANL), Matt Dunlop (NYU), Katherine Evans (ORNL), Matthew Hoffman (LANL), John Jakeman (SNL), Sam Kachuck (UM), Joseph Kennedy (ORNL), Dan Martin (LBNL), Mauro Perego (SNL), Mark Petersen (LANL), Andrew Salinger (SNL), Adam Schneider (UCI), Chad Sockwell (SNL), Georg Stadler (NYU), Irina Tezaur (SNL), Raymond Tuminaro (SNL), Brian Van Straalen (LBNL), Jerry Watkins (SNL), Tong Zhang (LANL)

Abstract

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A20. ProSPect3

Poster Title	Probabilistic Sea-Level Projections from Ice Sheet and Earth System Models 3: Performance, Optimization and Uncertainty Quantification
First Author	stephen price
Topic	Cryosphere
Affiliation	ProSPect (SciDAC)
Link to document	ProSPect-poster3-2019b.pdf

Title

Probabilistic Sea-Level Projections from Ice Sheet and Earth System Models 3: Performance, Optimization and Uncertainty Quantification

Authors

Stephen Price (PI; LANL), Esmond Ng (PI; LBNL), Xylar Asay-Davis (LANL), Jeremy Bassis (UM), L. Bertagna (SNL), C. Book (LANL), Darin Comeau (LANL), Matt Dunlop (NYU), Katherine Evans (ORNL), Matthew Hoffman (LANL), John Jakeman (SNL), Sam Kachuck (UM), Joseph Kennedy (ORNL), Dan Martin (LBNL), Mauro Perego (SNL), Mark Petersen (LANL), Andrew Salinger (SNL), Adam Schneider (UCI), Chad Sockwell (SNL), Georg Stadler (NYU), Irina Tezaur (SNL), Raymond Tuminaro (SNL), Brian Van Straalen (LBNL), Jerry Watkins (SNL), Tong Zhang (LANL)

Abstract

Changes to the Greenland and Antarctic ice sheet over recent decades have contributed to sea-level rise at an accelerating rate and present the largest potential for future changes in sea-level. Accurate sea-level projections require simulations of ice sheet evolution using next-generation ice sheet models coupled to Earth-System Models (ESMs), but current limitations prohibit such projections. SciDAC's *ProSPect* focuses on ice sheet and ESM improvements in three main areas: 1) ice-sheet model physics and coupling, 2) initialization and uncertainty analysis, and 3) ice-sheet model performance on next-generation, high-performance computing (HPC) architectures. In this poster, we present recent advancements under ProSPect in the area of performance, optimization, and uncertainty quantification.

A21. CICE Consortium

Poster Title	CICE Consortium
First Author	Elizabeth Hunke
Topic	ocean/ice, updates and plans for the CICE Consortium
Affiliation	Los Alamos National Laboratory
Link to document	...

Title

Progress and Plans for Sea Ice Column Physics from the CICE Consortium

Authors

Elizabeth Hunke, Los Alamos National Laboratory

Richard Allard, Naval Research Laboratory Stennis Space Center

David A. Bailey, National Center for Atmospheric Research

Philippe Blain, Environment and Climate Change Canada

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Marika Holland, National Center for Atmospheric Research

Nicole Jeffery, Los Alamos National Laboratory

Jean-Francois Lemieux, Environment and Climate Change Canada

Till Rasmussen, Danish Meterological Institute

Mads Ribergaard, Danish Meterological Institute

Andrew Roberts, Los Alamos National Laboratory

Matt Turner, Los Alamos National Laboratory

Michael Winton, NOAA Geophysical Fluid Dynamics Laboratory

Abstract

The CICE Consortium is a group of stakeholders and primary developers of the Los Alamos sea ice model (CICE), formed to maintain the current CICE model for existing and new users, to incorporate and maintain new research and development, and to accelerate scientific sea ice model development and its transfer into operational use. The CICE model was originally developed and maintained by the Department of Energy as a computationally efficient sea ice component for use in fully coupled, atmosphere-ice-ocean-land global circulation models. Over the past two decades, a broad community of climate and weather forecasting groups have adopted and enhanced the code. The CICE Consortium was formed as a vehicle for collaboration in sea ice model support and development as the community continues to use and improve sea ice models. The Consortium is set up as a framework able to evolve with general sea ice model future contributions, in order to fulfill the desire to continue our collaborations in the longer term. Since DOE moved to the MPAS framework for the sea ice component in E3SM and is also supporting development of a new, discrete element sea ice model, the Consortium provides the sea ice column physics, now referred to as Icepack, for these DOE models. Here we provide an update of new sea ice modeling capabilities incorporated into the Consortium's CICE and Icepack repositories with particular relevance to DOE, and outline expected future developments.

A22. Eddy-driven diffusivity using Lagrangian particles in global ocean simulations

Poster Title	Eddy-driven diffusivity using Lagrangian particles in global ocean simulations
First Author	Amrapalli Garanaik
Topic	*ocean/ice model development*
Affiliation	Los Alamos National Laboratory
Link to document	...

Title

Eddy-driven diffusivity using Lagrangian particles in global ocean simulations

Authors

Amrapalli Garanaik, Mark R. Petersen and Phillip J. Wolfram

Abstract

The understanding and accurate representation of tracer transport and mixing due to eddies is still an outstanding problem in the field of large-scale ocean dynamics. Lagrangian particles provide a unique and powerful tool to characterize turbulent mixing and dispersion, as well as track the sources, pathways, and sinks of heat and water masses in global ocean models. In this study, the Energy Exascale Earth System Model (E3SM) is used in conjunction with Lagrangian in Situ Global High-Performance Particle Tracking (LIGHT) module for analyzing turbulence statistics in high-resolution ocean models. The focus of the work is to develop a better parameterization of isopycnal diffusivity using LIGHT data and evaluate improved nonlinear closure models that are based on the relationship between mixing lengths and nonlinear eddy parameters.

A23. Sensitivity of grounding line flux

Diagnosing the sensitivity of grounding line flux to changes in sub-ice shelf melting

Poster Title	Diagnosing the sensitivity of grounding line flux to changes in sub-ice shelf melting
First Author	Tong Zhang
Topic	cryosphere
Affiliation	Los Alamos National Laboratory
Link to document	...

Title

Diagnosing the sensitivity of grounding line flux to changes in sub-ice shelf melting

Authors

Tong Zhang, stephen price, Matt Hoffman, Mauro Perego, Xylar Asay-Davis

Abstract

We seek to understand causal connections between changes in sub-ice shelf melting, ice shelf buttressing, and grounding line flux. We study changes in ice shelf buttressing and grounding line flux as a function of localized ice thickness perturbations -- a proxy for changes in sub-ice shelf melting -- applied to both idealized (MISMIP+) and realistic (Larsen C) model domains. From this, we identify a strongly direction-dependent ``buttressing number'' that links local changes in ice shelf thickness and ice dynamics to changes in the integrated grounding line flux. We find that a buttressing number calculated along the first principal stress direction or the ice flow direction correlates better with changes in grounding line flux than one calculated along the second principal stress direction. We also present an adjoint-based method for calculating the sensitivity of the integrated grounding line flux to local changes in ice shelf geometry. The adjoint-based sensitivity is nearly identical to that deduced from pointwise, forward model perturbation experiments except very near to the grounding line where the dependence of ice flux on the ice thickness is highly nonlinear. Because of the significant computational savings afforded by the adjoint-based sensitivity calculation and because it is accurate over the majority of the ice shelf, we propose that it is ideally suited for assessing grounding line flux sensitivity to changes in sub-ice shelf melting.

A24. Effects of optical parameterization on the cooling of the Southern Ocean

Effects of optical parameterization on the cooling of the Southern Ocean under doubled forcing in a coupled ESM

Poster Title	Effects of optical parameterization on the cooling of the Southern Ocean under doubled forcing in a coupled ESM
First Author	Marie-Aude Pradal
Topic	ocean/ice model development
Affiliation	Johns Hopkins University,
Link to document	...

Title

Effects of optical parameterization on the cooling of the Southern Ocean under doubled forcing in a coupled ESM

Authors

Mrie-Aude Pradal (mpradal1@jhu.edu), Anand Gnanadesikan and Grace Kim

Abstract

The dynamics of the mixed layer are sensitive to the optical parameterization used in an ESM. Historically, the GFDL ESM2Mc model calculates the absorption of light by chlorophyl only, following a formulation by Manizza. We show how introducing a representation of the absorption by CDOM separately from chlorophyl affects the penetration of light, resulting in an effect on the SAT, the SST, the depth of the mixed layer, the area of the ice cover and the transport of heat. Recently, observational measurements have shown a cooling of the SST in the Southern Ocean which is rarely captured by ESMs but is enhanced in our simulations under doubled CO_2 conditions.

A25. Implementation of Greenland Ice Sheet Freshwater Fluxes in E3SM Models

Poster Title	Implementation of Greenland Ice Sheet Freshwater Fluxes in E3SM Models
First Author	Theresa Morrison
Topic	*ocean/ice model development*
Affiliation	? RGMA ?
Link to document	...

Title

Implementation of Greenland Ice Sheet Freshwater Fluxes in E3SM Models

Authors

Theresa Morrison (1), Julie McClean (1), Sarah Gille (1), Mathew Maltrud (2), Frank Bryan (3), Gustavo Marques (3), Detelina Ivanova (1); 1. Scripps Institution of Oceanography, 2. Los Alamos National Laboratory 3. National Center for Atmospheric Research

Abstract

Mass loss from the Greenland Ice Sheet has increased in recent decades adding a source of freshwater to the Subpolar North Atlantic. Freshwater perturbation experiments have shown that deepwater formation is sensitive to the magnitude and distribution of excess freshwater. However, these experiments have often not accounted for the vertical dilution of freshwater that occurs in narrow fjords along the ice sheet margin. The dilution and vertical structure of ice sheet melt water modify stratification and therefore are critical for understanding downstream impacts. Fully resolving the dynamics within glacial fjords is beyond the capabilities of high resolution Earth System Models and coupling between ice sheet and ocean models remains limited.

We are implementing two methods for representing this dilution: a uniform vertical distribution and a fjord box model. We present results from global 0.1 degree E3SMv0 (POP2-CICE5, COREII forcing) hindcast simulations with freshwater added in a uniform vertical distribution over the top 200m of the ocean. We compare the salinity properties in the Subpolar North Atlantic during the first 5 years of the freshwater perturbation period to a control simulation. In addition we present the theory of the fjord box model that we are implementing in E3SMv1. The box model uses the conservation of salt and potential energy to estimate the dilution of ice sheet meltwater within a fjord. This box model is aimed at contributing to improved coupling of ice sheet and ocean models within E3SM.

A26. Antarctic and Greenland Continental Shelf Circulation

Poster Title	Influence of Antarctic and Greenland Continental Shelf Circulation on High-latitude Oceans in E3SM
First Author	Julie McClean
Topic	ocean/ice, Water cycle
Affiliation	RGCMA
Link to document	

Title

Influence of Antarctic and Greenland Continental Shelf Circulation on High-latitude Oceans in E3SM

Authors

Julie L. McClean, Sarah. T. Gille, Fiamma Straneo, Mathew E. Maltrud, Detelina P. Ivanova, Theresa Morrison, André Palóczy, Peter Gleckler, and Elizabeth C. Hunke

Abstract

Melting along the ice sheet margins of Antarctica and Greenland has accelerated over past decades releasing freshwater into the ocean. Water properties and stratification are subsequently altered and, in turn, ocean circulation patterns and sea-ice distributions along with mesoscale structures and mixing via density changes, and ultimately the meridional overturning circulation. Our objective is to evaluate the impact of freshwater input caused by ice melt within global Energy Exascale Earth System Model (E3SM) and Coupled Model Intercomparison Project6 (CMIP6) “HighResMIP” simulations, with goals both to advance understanding of the critical processes and also to identify the most useful metrics for cross-comparing meltwater input within multiple models. Two generations of E3SM, forced with reanalysis atmospheric fluxes, are used in the first instance to study melt effects on the Greenland and Antarctic continental shelves/slopes as well as property exchanges with adjacent interior basins. E3SMv0 and v1 simulations that are eddy-permitting in the study regions and have no freshwater surplus representations are compared with a counterpart E3SMv0 simulation with freshwater surpluses and a mesoscale eddy-resolving configuration, also with surpluses. These comparisons will shed light on the importance of including freshwater surpluses and resolving mesoscale eddies when modeling change and variability over the past decades in high latitudes. Fully-coupled HighResMIP simulations and fully-coupled E3SMv1 run under the HighResMIP protocol, although without surpluses, will also be evaluated to understand feedbacks among the ocean, sea-ice, and atmospheric model components, providing a broader context to interpret the importance of the freshwater releases.

A27. Using Power diagrams to build optimal unstructured meshes for C-grid models

Poster Title	Using Power diagrams to build optimal unstructured meshes for C-grid models
First Author	Darren Engwirda
Topic	Ocean/ice model development; Software tools
Affiliation	Columbia University
Link to document	...

Title

Using Power diagrams to build optimal unstructured meshes for C-grid models

Authors

Darren Engwirda, Columbia University

Xylar Asay-Davis, LANL

Mark Petersen, LANL

Phillip J. Wolfram, LANL

Steven Brus, LANL

Kristin Hoch, LANL

Mike Herzfeld, CSIRO

Farhan Rizwi, CSIRO

Abstract

Can we do better than Voronoi diagrams when building unstructured meshes for C-grid GCMs? By exploring the relationship between discretisation error and mesh layout, a new unstructured meshing kernel is proposed for the generation of 'weighted', 'Voronoi-like' configurations known as 'Power diagrams'. Seeking to minimise errors in the discrete numerical operators, a 'primal-dual' optimisation strategy is derived to compute the vertex positions, weights and cell topology of a given variable-resolution mesh. These optimised 'Power' meshes are shown to improve grid geometry and reduce staggering errors. These improvements are especially useful for difficult cases incorporating aggressive changes in resolution and user-defined constraints such as coastlines.

A28. Numerical challenges in representing isopycnal mixing on a regular grid

Poster Title	Numerical challenges in representing isopycnal mixing on a regular grid
First Author	Anand Gnanadesikan
Topic	Ocean/ice model development
Affiliation	Johns Hopkins University
Link to document	...

Title

Numerical challenges in representing isopycnal mixing on a regular grid

Authors

Anand Gnanadesikan (gnandes@jhu.edu) and Marie-Aude Pradal

Abstract

Mixing along isopycnals in the ocean is much stronger than mixing across these surfaces- with tracer spreading hundreds of km laterally while moving only 20-30 m vertically. However, there is a fundamental challenge in enforcing this constraint on regular Cartesian grids, where fluxes are either in the vertical or horizontal directions. In order to ensure that the net flux across an isopycnal is zero, downgradient fluxes in one direction are always balanced with upgradient fluxes in another. Such upgradient fluxes can result in the creation of spurious minima and maxima and even (in some idealized cases when combined with biological cycling) in the generation of instabilities. In this poster we explore whether allowing mixing between different levels of adjacent columns can improve this problem and under what conditions it does so.

A29. Metrics for evaluation of E3SM atmospheric simulations over the Antarctica and Southern Ocean

Poster Title	Metrics for evaluation of E3SM atmospheric simulations over the Antarctica and Southern Ocean
First Author	Wuyin Lin
Topic	Cryosphere, Water Cycle, E3SM evaluation
Affiliation	E3SM Cryosphere Group, BNL
Link to document	...

Title

Metrics for evaluation of E3SM atmospheric simulations over the Antarctica and Southern Ocean

Authors

Wuyin Lin, Shaocheng Xie, Qi Tang, Yuying Zhang, Xianglei Huang

Abstract

This work establishes metrics for comprehensive assessment of the E3SM atmospheric simulations over the Southern Oceans and Antarctica. Large changes in atmospheric conditions over Antarctica and the surrounding oceans could have tremendous impact on the cryosphere system and the cascading effect on the Earth's climate system could have important implications for the societies. Surface conditions exert direct influence on the cryosphere system as atmospheric forcing. Upper air conditions serve to portray the overall climate in the region Model performance in simulating the surface and upper air conditions must be evaluated and well understood in order to be used for climate changes due to anthropogenic activities. Key metrics need to be established to facilitate such evaluation and track the progress of the model development in simulating the climate over this region. Southern Hemisphere can potentially have a tremendous impact on the environment and society globally. Global climate system in turn can exert influences on the cryosphere system around the Antarctica partly via the atmospheric forcing. The metrics for evaluating the linkage between polar climate and large-scale systems in lower latitudes will also be included. The atmosphere model simulations used here are part of the E3SMv1 DECK (Diagnostic, Evaluation and Characterization of Klima) experiments, with prescribed observational sea surface temperature and ice coverage. Preliminary analysis shows that the simulated cloud, precipitation, and radiation fields, in comparison with limited available observations, exhibits large discrepancies that are with strong seasonality and sharp contrast over ice sheets, on the periphery of the ice sheets and over the circumpolar southern oceans. These are clear indications that issues in cloud physics, surface-air interactions and the ability to reproduce synoptic scale weather systems over the region may all have a large influence on the model results. The outcome of this work will be used to guide the improvement of the simulations of the atmospheric forcing important to modeling the cryosphere system.

A30. Design and Implementation of the Model Analysis Platform for Energy Systems

Poster Title	Design and Implementation of the Model Analysis Platform for Energy Systems
First Author	Michael Kelleher
Topic	*software tools, E3SM evaluation*
Affiliation	NGD Software
Link to document	...

Title

Design and Implementation of the Model Analysis Platform for Energy Systems

Authors

Michael E. Kelleher, Moetasim Ashfaq, Katherine J Evans

Abstract

The US Energy system is a multifaceted, complex network of interconnected systems which depend on data from a variety of sources in order for decisions relevant to their interests to be made. The purpose of the Model Analysis Platform for Energy Systems (MAPES) is to facilitate access to this data to scientists and decision makers outside the climate science domain. The software, developed in Python, depends on a number of packages including xarray, numpy, pandas, geopandas, hvplot, bokeh, and flask web framework.

The design requirements for this software are for it to be expandable to aid in future development, interactive, easy to use for non-climate scientists, and flexible to accommodate different data sets and user domains. Given that the tool is meant for non-domain scientists, the interface must be designed in a way that enables the translation of climate models' outputs to stakeholders relevant, easy to understand metrics without overwhelming the users with the complex technical needs of data manipulation and processing.

Presented will be the initial, unreleased version of the MAPES software, a description of the problems which needed to be solved, the technologies involved in processing and visualizing the data, and a look at future plans for the software.

A31. E3SM Diagnostics Package v2

Poster Title	E3SM Diagnostics Package v2
First Author	Jill Chengzhu Zhang
Topic	software tools, E3SM development tool
Affiliation	E3SM Infrasturcture
Link to document	...

Title

E3SM Diagnostics Package v2

Authors

Jill Chengzhu Zhang, Chris Golaz, Ryan Forsyth: LLNL

Zeshawn Shaheen

Abstract

E3SM diagnostics package is a modern, Python-based diagnostics package for evaluating earth system models. The goal of this work is to build a comprehensive diagnostics software package as an essential E3SM tool to facilitate the diagnosis of the next generation earth system models.

E3sm_diags has evolved to version 2. In the new version, a more flexible frame is built for accommodating more types of diagnostics. Time series for annual trends are included as a new set. In this poster, new user cases and user guides will be presented to guide our users to get familiar with the new version

A32. MAM verification and evaluation using a box model

Poster Title	Verification and evaluation of the aerosol microphysics parameterization in E3SM using a box model
First Author	Jian Sun
Topic	software tools, verification
Affiliation	NGD Architecture Software and Algorithm, ACME-SM: A Global Climate Model Software Modernization Surge
Link to document	...

Title

Verification and evaluation of the aerosol microphysics parameterization in E3SM using a box model

Authors

Jian Sun, Richard Easter, Hui Wan Kai Zhang

Abstract

Atmospheric aerosol particles play an important role in the climate system, but the representation of aerosol processes in Earth system models still needs to be improved. The Modal Aerosol Module (MAM) used in E3SM provides a simplified but rather complete treatment of the aerosol processes. Based on assumptions on the size and composition of aerosols, the model solves different kinds of equations, including algebraic equations (e.g. for aerosol water uptake), ordinary differential equations (e.g. for trace-gas condensation), and/or partial differential equations (e.g. for sedimentation). Since many processes are involved and some of them are tightly coupled, we need to make sure that these equations are correctly formulated and accurately solved. Using the terminology from other computational sciences, we distinguish two types of testing: (1) verification, which checks whether the numerical methods and code implementation correctly solve the equations the model developer intended to formulate and solve, and (2) validation, which checks if the results reasonably represent the physical phenomena in the real world. However, testing MAM in the full E3SM is challenging, since the aerosol processes and other physical/dynamical processes have strong interactions.

In this effort, we use a box model to test MAM and its components in isolation from the resolved atmospheric dynamics and other parameterized processes (e.g., clouds and radiation). The box model is updated to the MAM version used in the current E3SM (i.e., they share the same code and data structure), so that we can verify the same code and merge any code improvements to E3SM more easily. We have developed offline drivers for aerosol microphysical processes including water uptake, nucleation, condensation, coagulation, aging, and redistribution of particles among modes of different size ranges. In addition to performing unit tests for individual aerosol processes, the box model is also used to test numerical convergence for time integration of multiple processes and the impact of operator splitting. We show two examples in this presentation: 1) verification of the numerical solution for trace-gas condensation in terms of time step convergence; and 2) evaluation of the aerosol water uptake parameterization in MAM by varying the ceiling values of relative humidity.

A33. ETD for HOMME-NH

Poster Title	Exponential Integrators for the HOMME-NH Nonhydrostatic Atmosphere Model
First Author	Cassidy Krause
Topic	computing, atmospheric model development
Affiliation	NGD Software and Algorithms
Link to document	...

Title

Exponential Integrators for the HOMME-NH Nonhydrostatic Atmosphere Model

Authors

Cassidy Krause, Sandia National Laboratories

Andrew Steyer, Sandia National Laboratories

Abstract

Time-stepping in the HOMME-NH nonhydrostatic atmosphere model requires integration of a stiff initial value problem. The current standard is to solve these equations using implicit-explicit (IMEX) Runge-Kutta (RK) methods with a horizontally explicit - vertically implicit (HEVI) partitioning. We introduce a n exponential time differencing (ETD) scheme as an alternative to solving these stiff equations. The main drawback to exponential methods is the cost of forming the matrix exponential. Here, we show that we can mitigate this cost by taking advantage of the tridiagonal-like form of our Jacobian and parallelizing our computations, making this solver an attractive option for HOMME-NH.

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SAND2019-9005 A

A34. ETD for the Tracer Equations in Ocean Models

Poster Title	Exponential Integrators for the Solution of the Tracer Equations appearing in Primitive Equation Ocean Models
First Author	Sara Calandrini
Topic	computing, ocean/ice model development
Affiliation	Florida State University
Link to document	...

Title

Exponential Integrators for the Solution of the Tracer Equations appearing in Primitive Equation Ocean Models

Authors

Sara Calandrini (Florida State University), Konstantin Pieper (Oak Ridge National Laboratory), Max Gunzburger (Florida State University)

Abstract

Exponential time differencing (ETD) methods, also known as exponential integrators, constitute a class of numerical methods for the time integration of stiff systems of differential equations. The main idea behind exponential integrators is a splitting of the right-hand side term of an equation into a linear part and a remainder, with an appropriate choice of the linear operator A. Exponential integrators have recently gained attention in the ocean modeling community due to their stability properties that allow time steps considerably larger than those dictated by the CFL condition. We present is an ETD scheme for the tracer equations appearing in the primitive equation ocean models, where the vertical terms (transport and diffusion) are treated with a matrix exponential, whereas the horizontal terms are dealt with in an explicit way. By treating exponentially terms related to fast time-scales, bigger time steps can be taken, and so computational speed-ups can be obtained over explicit methods. Compared to semi-implicit methods, higher accuracy is expected due to an exact treatment of the fast scales. We investigate numerically the computational speed-ups that can be obtained over other semi-implicit methods, and analyze the advantages of the method in the case of multiple tracers.

B01. EAMv1 CONUS RRM

Poster Title	Regionally refined test bed in E3SM atmosphere model version 1 (EAMv1) and applications for high-resolution modeling
First Author	Qi Tang
Topic	Water cycle
Affiliation	E3SM Water Cycle, LLNL
Link to document	...

Title

Regionally refined test bed in E3SM atmosphere model version 1 (EAMv1) and applications for high-resolution modeling

Authors

Qi Tang[1], Stephen A. Klein[1], Shaocheng Xie[1], Wuyin Lin[2], Jean-Christophe Golaz[1], Erika L. Roesler[3], Mark A. Taylor[3], Philip J. Rasch[4], David C. Bader [1], Larry K. Berg[4], Peter Caldwell[1], Scott E. Giangrande[2], Richard B. Neale[5], Yun Qian[4], Laura D. Riihimaki[4], Charles S. Zender[6], Yuying Zhang[1], and Xue Zheng[1]

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Abstract

Climate simulations with more accurate process-level representation at finer resolutions (<100km) are a pressing need in order to provide more detailed actionable information to policy makers regarding extreme events in a changing climate. Computational limitation is a major obstacle for building and running high-resolution (HR, here 0.25 average grid spacing at the Equator) models (HRMs). A more affordable path to HRMs is to use a global regionally refined model (RRM), which only simulates a portion of the globe at HR while the remaining is at low resolution (LR, 1). In this study, we compare the Energy Exascale Earth System Model (E3SM) atmosphere model version 1 (EAMv1) RRM with the HR mesh over the contiguous United States (CONUS) to its corresponding globally uniform LR and HR configurations as well as to observations and reanalysis data. The RRM has a significantly reduced computational cost (roughly proportional to the HR mesh size) relative to the globally uniform HRM. Over the CONUS, we evaluate the simulation of important dynamical and physical quantities as well as various precipitation measures. Differences between the RRM and HRM over the HR region are predominantly small, demonstrating that the RRM reproduces the precipitation metrics of the HRM over the CONUS. Further analysis based on RRM simulations with the LR vs. HR model parameters reveals that RRM performance is greatly influenced by the different parameter choices used in the LR and HR EAMv1. This is a result of the poor scale-aware behavior of physical parameterizations, especially for variables influencing sub-grid-scale physical processes. RRMs can serve as a useful framework to test physics schemes across a range of scales, leading to improved consistency in future E3SM versions. Applying nudging-to-observations techniques within the RRM framework also demonstrates significant advantages over a free-running configuration for use as a test bed and as such represents an efficient and more robust physics test bed capability. Our results provide additional confirmatory evidence that the RRM is an efficient and effective test bed for HRM development.

B02. EAMv1 aquaplanet simulation with CONUS RRM

Poster Title	EAMv1 aquaplanet simulation with CONUS RRM
First Author	Xue Zheng
Topic	*Water cycle*
Affiliation	E3SM Water Cycle, LLNL
Link to document	...

Title

EAMv1 aquaplanet simulation with CONUS RRM

Authors

Xue Zheng (LLNL), Chris Golaz (LLNL), and Walter Hannah (LLNL)

Abstract

RRM will be an important part of E3SM Phase 2 simulation campaign. The main known challenges for atmospheric RRM simulations include the poor scale awareness of the cloud parameterizations and optimum orography smoothing within the RRM domain. We plan to improve the scale awareness of the cloud parameterizations in aqua-planet simulations, in which the effects of the land and topography are excluded. We will first evaluate the model sensitivity to spatial resolution in the aqua-planet simulation with CONUS RRM. And then we will test different ways to minimize the undesirable discontinuities inside and outside of the RRM domain.

B03. ECS > 5 K; a tale of two models

Poster Title	**ECS > 5 K; a tale of two models**
First Author	Chris Golaz
Topic	*E3SM evaluation*
Affiliation	E3SM Water Cycle
Link to document	...

Title

ECS > 5 K; a tale of two models

Authors

Chris Golaz, LLNL

Abstract

E3SMv1 and CESM2 are close cousins. Perhaps not surprisingly, both models share a high climate sensitivity (ECS > 5 K). Despite this similarity, these two models behave differently in idealized CO2 forcing simulations (abrupt-4xCO2, 1pctCO2) as well as historical simulations. In particular, we explore possible reasons why one model (CESM2) simulates the evolution of the global mean surface temperature over the historical record significantly more accurately than the other (E3SMv1).

B04. zstash: HPSS long-term archiving tool

Poster Title	**zstash: HPSS long-term archiving tool**
First Author	Chris Golaz
Topic	*software tools, infrastructure*
Affiliation	E3SM Water Cycle
Link to document	...

Title

zstash: HPSS long-term archiving tool

Authors

Chris Golaz, LLNL

Abstract

E3SM simulations generate large amount of data that need be archived on HPSS (High Performance Storage System). For optimal performance, storage on HPSS should consist of a relatively small number of large files. Therefore, it is not possible to directly archive individual E3SM model output files on HPSS.

Zstash is a python command line utility developed to serve E3SM long-term archiving needs. With zstash, files are archived into standard tar files with a user specified maximum size. Tar files are created locally, then transferred to HPSS. For improved performance, md5 checksums of input files are computed *on-the-fly* during archiving. Checksums and additional metadata is stored in a database. File integrity is verified by computing checksums on-the-fly during extraction.

B05. On the use of nudging in EAMv1

Poster Title	Impact of nudging strategy on the climate representativeness and hindcast skill of constrained EAMv1 simulations
First Author	Jian Sun
Topic	atmospheric model development, E3SM evaluation, software tools
Affiliation	NGD Architecture Software and Algorithm / Watercycle
Link to document	...

Title

Impact of nudging strategy on the climate representativeness and hindcast skill of constrained EAMv1 simulations

Authors

Jian Sun, Kai Zhang, Hui Wan, Po-Lun Ma, Qi Tang, Shixuan Zhang

Abstract

Nudging is a simulation technique widely used in sensitivity studies and in the evaluation of atmosphere models. Care is needed in the experimental setup in order to achieve the desired constraint on the simulated atmospheric processes without introducing undue intervention. In this study, we revised the nudging implementation in E3SM Atmosphere Model version 1 (EAMv1) and conducted sensitivity experiments to identify setups that can give results representative of the climate simulated by the unnudged model and meanwhile reasonably capture characteristics of the observed meteorological conditions to facilitate the comparison of model results with measurements.

B06. Resolution Sensitivity of the simulation of teleconnections to extremes

Poster Title	Model resolution sensitivity of the simulation of NAO and ENSO teleconnections to precipitation extremes
First Author	Salil Mahajan
Topic	Water cycle
Affiliation	E3SM Water Cycle
Link to document	...

Title

Model resolution sensitivity of the simulation of NAO and ENSO teleconnections to precipitation extremes

Authors

Salil Mahajan (ORNL)

Abstract

We evaluate the impact of model resolution on the simulation of teleconnections of low frequency climate modes of variability on precipitation extremes in E3SMv1 and v0. We quantify the linear dependence of precipitation extremes over US and Europe on North Atlantic Oscillation (NAO) and ENSO using Generalized Extreme Value (GEV) theory in ensembles of coupled (and uncoupled) production E3SM nominal 1-degree and 0.25-degree resolution simulations. In general, the high-res model improves the simulation of these teleconnections both in magnitude and spatial pattern. For example, as compared to the low-resolution model the high-res model simulates a stronger impact of NAO on daily precipitation extremes over the western slopes of mountain ranges South-western Norway, North-western UK and the Western Balkan states, but underperforms the low-res model over South-western Iberian peninsula. And, the high-res model better simulates the ENSO-dependence of precipitation extremes over Southeastern US, but underperforms the low-res model over Western US. These improvements are largely due to an improved simulation of vertical moisture flux from the boundary layer and enhanced stable condensation in the high-res model. However, that effect is offset by the poor simulation of the teleconnections to extra-tropical cyclone activity and moisture availability in the high-res model.

A15. Better representation of land surface heterogeneity in E3SM

Improving land surface heterogeneity in E3SM

Poster Title	Efforts towards better representation of land surface heterogeneity in the Energy Exascale Earth System Model
First Author	Teklu Tesfa
Topic	Water Cycle, BGC
Affiliation	E3SM Land Group
Link to document	...

Title

Efforts towards better representation of land surface heterogeneity in the Energy Exascale Earth System Model

Authors

Teklu Tesfa, Ruby Leung, Peter Thornton, Michael Brunke, Steve Ghan

Abstract

Land surface heterogeneity exerts major control on land surface processes. Consequently, better representations of surface heterogeneity may contribute to more accurate climate and land surface simulations in Earth System Models. Recently, new topography-based landunits (also called topounits) have been implemented within a hierarchical subgrid spatial structure to improve representation of land surface processes in the Energy Exascale Earth System Model (E3SM) with minimal increase in computational demand, while improving the ability to capture the spatial heterogeneity of atmospheric forcing and land cover influenced by topography. Recognizing the importance of the effects of subgrid topography on atmospheric processes, methods of downscaling atmospheric forcing from grid cell mean to the subgrid topography-based topounits have also been implemented in the E3SM Land Model (ELM). In this presentation we will discuss overall progress in the implementation of the topography-based subgrid structure in ELM.

B08. Plant Hydraulics Effect

Poster Title	Plant hydraulics on response of soil water and ET to environmental conditions
First Author	Yilin Fang
Topic	Water Cycle
Affiliation	E3SM Water Cycle
Link to document	...

Title

Plant hydraulics on response of soil water and ET to environmental conditions

Authors

Yilin Fang and Ruby Leung

Pacific Northwest National Laboratory

Abstract

A simple plant hydraulics model assuming steady state condition and ignoring plant tissue water storage has been implemented in ELM. One degree global simulation using GPCC atmospheric forcing shows that there is a good correlation between the simulated and MOD16 ET in America and Europe in the drought year of 2002 and 2003, respectively. However, simulated ET in Amazon exhibits narrower range compared to MOD16 ET, thus lower correlation. In general, ET simulated with default plant hydraulics (PHS) parameters is higher than that without PHS. PHS parameters can be tuned to match the observation, but they could be spatially and PFT dependent. The difference in ET between the models with and without PHS are not significant when ambient CO2 is doubled, but both models simulate decreased ET compared to the control run.

B09. Understanding Monsoonal Water Cycle Changes

Poster Title	Understanding Monsoonal Water Cycle Changes in a Warmer Climate in E3SMv1 Using a Normalized Gross Moist Stability Framework
First Author	Bryce Harrop
Topic	Water cycle, E3SM evaluation, applied E3SM
Affiliation	E3SM Water Cycle
Link to document	...

Title

Understanding Monsoonal Water Cycle Changes in a Warmer Climate in E3SMv1 Using a Normalized Gross Moist Stability Framework

Authors

Bryce Harrop Po-Lun Ma, Phil Rasch, Yun Qian, Guangxing Lin, Cecile Hannay

Abstract

One of the grand challenges of climate science is understanding the changes of the tropical rain belts and monsoon systems owing to CO2-induced warming. A promising path forward links the fluxes of energy and moisture to tropical circulation features. To this end, we make use of the Energy Exascale Earth System Model version 1, where the divergence of moist static energy and moisture have been calculated online, and employ a normalized gross moist stability (NGMS) diagnostic framework to understand the linkages between changes in the flow of energy and moisture within the monsoons. We focus on the Asian Summer Monsoon system and utilize a series of atmosphere-land and atmosphere-land-ocean simulations to understand the connection between fluxes and monsoons. Uncoupled simulations with prescribed sea surface temperatures indicate that decreases in NGMS over land are important in explaining precipitation increases in response to both sea surface temperature and CO2 increases. In fully coupled experiments, NGMS decreases remain an important contributor to the increase in P-E, but the coupled simulations highlight the importance of consistent ocean and land responses in interpreting the monsoon changes. This study indicates that transient eddy fluxes play an important role in NGMS decreases and that a time-mean view of the monsoon circulations is insufficient to quantify the link between future changes in the fluxes of energy and moisture. Compensation between dynamic and thermodynamic components of vertical moist static energy advection occurs, with the thermodynamic contribution dominating. The compensation is shown to be sensitive to relative humidity, with higher relative humidity leading to a stronger thermodynamic component.

Plain Language Summary

One of the challenges of climate science is understanding how warming will change monsoon rainfall. A promising path forward links the transport of energy to the transport of water vapor. This link, termed the normalized gross moist stability (NGMS), can be used to fingerprint monsoon rainfall changes coming from different energy sources as well as changes to NGMS itself. A fingerprint of the Asian Summer Monsoon rainfall response to warming is made for a general circulation model, which highlights the importance of the NGMS term for understanding the monsoon rainfall response to warming. By examining this NGMS term more carefully, evidence is shown for the importance of the ocean circulation toward explaining the monsoon rainfall response to warming. Further analysis of the NGMS term also suggests that the traditional time-mean view of the monsoon is insufficient to explain its response to warming. The response of NGMS to warming is shown to be sensitive to the relative humidity of the atmosphere.

B10. Upper ocean fresh biases in low-resolution E3SMv1 simulations: diagnostics and possible remedies

Poster Title	Upper ocean fresh biases in low-resolution E3SMv1 simulations: diagnostics and possible remedies
First Author	Milena Veneziani
Topic	water cycle
Affiliation	E3SM Water Cycle, LANL
Link to document	...

Title

Upper ocean fresh biases in low-resolution E3SMv1 simulations: diagnostics and possible remedies

Authors

Milena Veneziani, Luke Van Roekel, Jon Wolfe, Mark Petersen, Darin Comeau, Hyein Jeong, Mat Maltrud, Xylar Asay-Davis, Matt Hoffman, Steve Price (all at LANL), Chris Golaz (LLNL)

Abstract

A common problem of low-resolution E3SMv1 simulations is the occurrence of high upper ocean salinity biases. These fresh biases develop relatively quickly (over the first 10-20 years in fully-coupled simulations) and have reached maxima of up to 5 psu over the last 50 years of the DECK control simulation, for example. They manifest themselves almost globally, but they are particularly evident in the North Atlantic, especially in the subpolar gyre, and in the southern hemisphere, both in the mid-latitudes and in the Southern Ocean. Fresh biases of this magnitude are concerning at all latitudes, but they can substantially change the ocean stratification and circulation at high-latitudes, where salinity often plays a more important role than temperature on density. Here, we first diagnose the problem considering the sources of freshwater in the upper 100 m of the water column, through atmosphere-ocean, land-ocean, and sea-ice formation and melting processes. We then report on various remedies being considered, mostly in MPAS-ocean, to allow the ocean model component to better represent the upper ocean stratification at low-resolution. This investigation has helped identifying improvements in the eddy parameterization and vertical mixing schemes, which will be helpful for the next phase of E3SM.

B11. E3SM-FIVE

Poster Title	Higher Vertical Resolution for Select Physical Processes in the Energy Exascale Earth System Model (E3SM)
First Author	Hsiang-He Lee
Topic	Atmospheric model development
Affiliation	E3SM Water Cycle, LLNL
Link to document	

Title

Higher Vertical Resolution for Select Physical Processes in the Energy Exascale Earth System Model (E3SM)

Authors

Hsiang-He Lee . Peter Bogenschutz . Takanobu Yamaguchi

Abstract

The low cloud bias in atmospheric models for climate and weather remains an unsolved problem. Coarse vertical resolution in the current global climate models (GCM) may be a significant cause of low cloud bias because planetary boundary layer (PBL) parameterizations, including higher-order turbulence closure (HOC), cannot resolve sharp temperature and moisture gradients often found at the top of subtropical stratocumulus layers. The aim of this work is to implement a new computational method, the Framework for Improvement by Vertical Enhancement (FIVE) into the Energy Exascale Earth System Model (E3SM) and its single column model. Three physics schemes are interfaced to vertically enhanced physics (VEP), which allows for these schemes to be computed on a higher vertical resolution grid compared to rest of the E3SM model. In this presentation we use VEP for turbulence, microphysics, and radiation parameterizations and demonstrate better representation of subtropical boundary layer clouds while limiting additional computational cost from the increased number of levels. We will also briefly discuss future plans for an adaptive vertical grid for VEP, which will allow for additional layers to be added only when/where they are needed.

B12. Earth System Viz

Poster Title	*Earth System Viz: Enabling Discovery of Science at Scale*
First Author	Lauren Wheeler
Topic	Water Cycle
Affiliation	E3SM Visualizations
Link to document	...

Title

Earth System Viz: Enabling Discovery of Science at Scale

Authors

Lauren Wheeler, Erika Roesler, and Mark Bolstad

Abstract

This project is working to develop reproducible and inspiring images and animations from the E3SM Water Cycle simulations using open source software. As part of the development of the project deliverables, using Paraview, we explore colormaps that are proven to be intuitive and lend themselves to better scientific interpretations. Additionally, we explore atmospheric variables associated with the Water Cycle and the different features (e.g., hurricanes, atmospheric rivers, orographic precipitation) visible within these fields. Presented here are images from a single time-step of regridded monthly output of the the E3SM v1 High Resolution Water Cycle Simulations (theta.20180906.branch_noCNT.A_WCYCL1950S_CMIP6_HR.ne120_oRRS18v3_ICG simulation). We request that the community provide feedback on the visualizations.

B13. Cloud Deck Spatial Errors in the EAMv1

Poster Title	Subtropical Marine Stratocumulus Cloud Deck Spatial Errors in the E3SMv1 Atmosphere Model
First Author	Michael Brunke
Topic	E3SM evaluation
Affiliation	E3SM University of Arizona project
Link to document	...

Title

Subtropical Marine Stratocumulus Cloud Deck Spatial Errors in the E3SMv1 Atmosphere Model

Authors

Michael A. Brunke (The University of Arizona), Po-Lun Ma (Pacific Northwest National Laboratory), J. E. Jack Reeves Eyre (The University of Arizona), Philip J. Rasch (Pacific Northwest National Laboratory), Armin Sorooshian (The University of Arizona), Xubin Zeng (The University of Arizona)

Abstract

Subtropical marine low-level clouds continue to be poorly simulated in models despite many studies and field experiments devoted to their improvement. Many of these previous studies have noted the lack of simulated clouds in the regions where the subtropical marine stratocumulus cloud decks should be, implying amplitude errors, but it is also recognized that these decks have spatial errors. Here we focus on the spatial errors in the Atmospheric Model Intercomparison Project (AMIP) run of version 1 of the Energy Exascale Earth System Model (E3SMv1) developed by the Department of Energy relative to the Cloud-Aerosol Lidar and Infrared Pathfinder (CALIPSO) climatology. Location errors of the cloud decks are characterized by centroid distances, while size errors are quantified by area ratios. The combined effects of location, size, and shape errors are measured by overlap ratios. E3SMv1's spatial errors are compared to those of three other U.S. climate and Earth system models.

Model dynamics is better simulated than clouds in E3SMv1. Therefore, the spatial errors in the AMIP run are attributed primarily to model physics. To gain additional insight, we performed a sensitivity run in which model winds were nudged to those of MERRA-2. This results in a large change (but not necessarily an improvement) in the simulated cloud decks that are mainly due to the interactions between model dynamics and physics, since the same physical parameterizations are used in both runs. These results suggest that both model physics (widely recognized) and its interaction with dynamics (less recognized) are important to model improvement in simulating these low-level clouds.

B14. EAMv1 Cloud Evaluation

Poster Title	Evaluation of Clouds in the E3SM Atmosphere Model Version 1 with Satellite and Ground-Based Simulators
First Author	Yuying Zhang
Topic	E3SM evaluation
Affiliation	NGD-Atmospheric Physics, LLNL
Link to document	...

Title

Evaluation of Clouds in the E3SM Atmosphere Model Version 1 with Satellite and Ground-Based Simulators

Authors

Yuying Zhang, Shaocheng Xie, Wuyin Lin, Stephen A. Klein, Mark Zelinka, Po-Lun Ma, Philip J. Rasch, Yun Qian, Qi Tang, Hsi-Yen Ma

Abstract

This study systematically evaluates clouds simulated by the Energy Exascale Earth System Model (E3SM) Atmosphere Model version one (EAMv1) against satellite cloud observations. The simulator package, COSP, is used to facilitate a meaningful “apples-to-apples” comparison between model and observation by considering the different definitions of geophysical quantities among models and observations and the limitations/features of the observing process. EAMv1 is configured at two horizontal resolutions (1º and 0.25º) and one vertical resolution of 72 layers for different scientific applications. To provide a more complete picture of the model performance in simulating clouds and insights into modeled cloud biases, the evaluation is performed by utilizing unique features of individual instrument contained in COSP in observing different aspects of clouds.

Both low (1°) and high (0.25°) resolution EAMv1 configurations generally underestimate clouds in low and midlatitudes and overestimate clouds in the Arctic although the error is smaller in the high-resolution model. The underestimate of clouds is due to the underestimate of optically thin to intermediate clouds, as EAMv1 generally overestimates optically intermediate to thick clouds. Other model errors include the largely under-predicted marine stratocumulus along the coasts and high clouds over the tropical deep convection regions. The underestimate of thin clouds results in too much LW radiation being emitted to space and too little SW radiation being reflected back to space while the overestimate of optically intermediate and thick clouds leads to too little LW radiation being emitted to space and too much SW radiation being reflected back to space. EAMv1 shows better skill in reproducing the observed distribution of clouds and their properties and has smaller radiatively relevant errors in the distribution of clouds than most of the CFMIP1 and CFMIP2 models. It produces more supercooled liquid cloud fraction than CAM5 and most CMIP5 models primarily due to a new ice nucleation scheme and secondarily due to a reduction of the ice deposition growth rate.

B15. Improving Diurnal Cycle of Precipitation in E3SM

Poster Title	Improved Diurnal Cycle of Precipitation in E3SM with a Revised Convective Trigger
First Author	Shaocheng Xie
Topic	Atmospheric model development
Affiliation	NGD-Atmospheric Physics
Link to document	...

Title

Improved Diurnal Cycle of Precipitation in E3SM with a Revised Convective Trigger

Authors

Shaocheng Xie (LLNL), Yi-Chi Wang (Academia Sinica/Taiwan), Wuyin Lin (BNL), Hsi-Yen Ma (LLNL), Qi Tang (LLNL), Shuaiqi Tang (LLNL), Xue Zheng (LLNL), Chris Golaz (LLNL), Guang Zhang (UCSD), and Minghua Zhang (SBU)

Abstract

General Circulation Models (GCMs) for weather forecasts and climate simulations continue having difficulties in modeling the diurnal precipitation, particularly over land. Most models tend to rain too early after sunrise with a rainfall maximum around the local noon rather than the observed late afternoon peak and fail to capture the observed nocturnal peak. In general, GCMs often rain too frequently at reduced intensity. Increasing model horizontal resolution seems to have little impact on the simulated phase of the diurnal cycle of precipitation. In this study, we proposed a new convective triggering function for weather and climate models by introducing a simple dynamic constraint on the initiation of convection that emulates the collective effects of the large-scale forcing to prevent convection from being triggered too frequently, as well as allowing air parcel launching above boundary layer to capture nocturnal elevated convection which is often decoupled from the surface. The proposed triggering mechanisms have been strongly supported by both field observations and NWP re-analysis in several examined climate regimes. Implementation of the new trigger to the DOE’s Energy Exascale Earth System Model (E3SM) Atmosphere Model version 1 has led to a substantial improvement in the simulated diurnal cycle of precipitation over both midlatitude and tropical lands. The nocturnal peak of precipitation over the central Great Plains and the eastward propagation of convection over the downstream of the Rockies and the adjacent Great Plains are much better captured. The proposed trigger also results in a considerable reduction of convective precipitation over subtropical regions and the frequency of light precipitation occurrence. The overall impact of the mean precipitation with the new trigger is minor with some notable improvements seen over the Indo-Western Pacific, subtropical Pacific and Atlantic, CONUS, and South America. The respective contributions from the individual changes in the convective trigger are discussed.

B16. Scale-awareness of ZM Convection Scheme

Poster Title	Evaluation of Scale-awareness of dCAPE-based Closure in Zhang-McFarlane Convection Scheme
First Author	Guang Zhang
Topic	atmospheric model development
Affiliation	NGD Atmosphere
Link to document	...

Title

Evaluation of Scale-awareness of dCAPE-based Closure in Zhang-McFarlane Convection Scheme

Authors

Guang J. Zhang, Xu Wang, Scripps Institution of Oceanography, La Jolla, CA

Shaocheng Xie, Lawrence Livermore National Laboratory, Livermore, CA

Abstract

Convective parameterization is one of the major factors responsible for biases in global climate model (GCM) simulations. At spatial scales of ~100 km or larger, there exists a quasi-equilibrium between convection and large-scale forcing. At grey zone scales (e.g., ~10 km or smaller), many important assumptions in convective parameterization break down. Therefore, for high-resolution E3SM development, a scale-aware convection scheme is needed. The existing approaches to making a convective scheme scale-ware is by incorporating a cloud fraction factor as proposed by Arakawa. However, trigger functions and closures for convective parameterization can also affect the scale-awareness of convection schemes. Here we examine a dCAPE-based closure in the Zhang-McFarlane (ZM) scheme using cloud-resolving model simulation output for both tropical and midlatitude convection. To generate GCM grid-scale variables, the CRM output is averaged over subdomains of sizes equivalent to GCM resolutions. The GCM-scale fields are then used to compute dCAPE (CAPE generation by the GCM-grid scale circulation). The relationships between dCAPE so computed and CRM-simulated convection within the corresponding averaging subdomain are examined. It is found that convection (both in terms of precipitation and convective mass flux) is well correlated with dCAPE for GCM resolutions even into grey scale. However, the dependence of convective mass flux on dCAPE becomes nonlinear as the averaging subdomain size decreases to grey zone. The similarities and differences in the relationships between organized and unorganized convection will be presented and discussed.

B17. P3 cloud microphysics in E3SM

Poster Title	Implementation and performance of the P3 cloud microphysics in the E3SM atmosphere model
First Author	Kai Zhang
Topic	*atmospheric model development*
Affiliation	NGD Physics
Link to document	...

Title

Implementation and performance of the P3 cloud microphysics in the E3SM atmosphere model

Authors

Kai Zhang (PNNL), Jiwen Fan* (PNNL), Jingyu Wang (PNNL), Marco Paukert (PNNL), Hui Wan (PNNL), Phil Rasch (PNNL), Xiaohong Liu (Texas A&M)

*Presenting author

Abstract

The representation of cloud microphysical processes in a global climate model has large impacts on the simulated Earth's radiative budget and hydrological cycle. Our previous work has shown that: a) the artificial treatment of the ice-to-snow conversion process has a large impact on the net radiative balance at the top-of-the-atmosphere; b) less careful treatment of the numerical coupling of competing and compensating processes, such as the ice nucleation, ice depositional growth/sublimation, and source/sink of water vapor, can lead to inaccurate solutions. To address these problems and improve the atmosphere component of E3SM, we have implemented the single-ice-category Predicted Particle Properties (P3) scheme in the model. The scheme has been revised for use at coarser resolutions (e.g. cloud fraction treatment and consideration of subgrid variability) and to better represent the interaction between processes. We performed global nudged simulations using both P3 and MG2 (the original microphysics scheme) in E3SM and evaluated the simulated cloud, precipitation, and radiative properties. Results show that E3SM-P3 performs well in simulating macrophysical and microphysical properties of both liquid and ice clouds. We find large differences between P3 and MG2 in simulating the microphysical process rates and associated heating, which affect the simulated frequency distribution of precipitation. We further examined the reasons responsible for the improved simulation results with P3 compared to MG2. The revised P3 scheme has also been tested in at high-resolutions, which will be presented in a companion poster.

B18. P3's Impact in RRM Simulation of MCSs

Poster Title	Impact of a New Cloud Microphysics Parameterization to Simulations of Mesoscale Convective Systems in E3SM Regionally Refined Model (RRM) Framework
First Author	Jingyu Wang
Topic	E3SM evaluation
Affiliation	CMDV
Link to document	...

Title

Impact of a New Cloud Microphysics Parameterization to Simulations of Mesoscale Convective Systems in E3SM Regionally Refined Model (RRM) Framework

Authors

Jingyu Wang* (PNNL), Jiwen Fan (PNNL), Zhe Feng (PNNL), Kai Zhang (PNNL), Erika Roesler (SNL), and Benjamin Hillman (SNL)

Abstract

Mesoscale convective systems (MCSs) play important roles in the hydrological cycle and general circulation because they are the largest in the family of deep convective clouds and have a major contribution to global precipitation. Traditional global climate models (GCMs) with coarse horizontal resolution (~100 km) fail to simulate MCSs. The pursuit of more accurate and detailed representations of climate processes promotes the need for finer model resolution, thereby establishing the possibility of simulating MCSs in GCMs. Besides resolution, cloud microphysics used in the GCMs generally do not consider convective microphysics (e.g., rimed particles), which is an important precipitation process in mixed-phase and deep convective clouds. In this study, we (1) use a regionally refined mesh with 0.25° grid spacing for the atmosphere and land components within the Energy Exascale Earth System Model (E3SM) atmosphere model to perform regional high-resolution simulations over the contiguous United States, and (2) explore the impact of using a newly developed Predicted Particle Properties (P3) cloud microphysics scheme for E3SM, which is physically more appropriate for simulating deep convective cloud microphysics than the original scheme (MG2, Morrison and Gettelman, 2015). To examine the MCS properties, an observationally-based tracking algorithm is applied to the 0.25° simulations and observations for intercomparison during the period of March-April-May 2011. Results show that despite reasonable agreement in total precipitation, the model simulates insufficient MCS precipitation and excessive non-MCS precipitation compared to the observations. Additionally, the diurnal cycle of MCSs is out of phase. We find that the underestimation of MCSs by the model is a result of much smaller predicted area of convective systems and lower precipitation rates. The simulation with P3 predicts higher hourly rain rates and larger area of convective systems, resulting in more MCSs and a higher total MCS precipitation compared to MG2, agreeing better with the observations. The larger rain rates predicted by P3 is mainly a result of the melting rimed particles. We show that the larger convective system areas by P3 are associated with much more cloud ice produced and much stronger updraft motion, which is possibly a result of stronger microphysics feedback to the dynamics. The impact of the microphysics parameterization is expected to be larger at higher resolution such as 3 km, which will be examined in our future work.

B19. Multi-Plume EDMF Unified Parameterization

Poster Title	The Multi-Plume Eddy-Diffusivity/Mass-Flux (EDMF) Unified Parameterization: Stratocumulus and the Transition to Cumulus Boundary Layers
First Author	Joao Teixeira
Topic	atmospheric model development
Affiliation	E3SM NGD-Atmospheric Physics, JIFRESSE, UCLA
Link to document	...

Title

The Multi-Plume Eddy-Diffusivity/Mass-Flux (EDMF) Unified Parameterization: Stratocumulus and the Transition to Cumulus Boundary Layers

Authors

Joao Teixeira (Joao.Teixeira@jpl.nasa.gov), Marcin J. Kurowski, Mikael K. Witte; JIFRESSE, UCLA

Abstract

The key goal of this project is to reduce the subtropical boundary layer cloud deficiencies and biases in oceanic upwelling regions by implementing, and evaluating, into the E3SM model, a new unified boundary layer and convection parameterization based on the multiplume EddyDiffusivity/MassFlux (EDMF) approach. This is a turbulence and convection parameterization that can be considered fully unified, in the sense that it is able to represent convective processes from boundary layer convection (dry and cloudy) to deep moist convection with one single parameterization. In this presentation we will discuss the implementation of the new multiplume EDMF parameterization in an independent Single Column Model (SCM) and in the E3SM SCM, and the evaluation against LES casestudies.

B20. Using PPE simulations to understand model physics and parametric sensitivity in EAMv1

Poster Title	Using PPE simulations to better understand model physics and parametric sensitivity in EAMv1 over different cloud regimes
First Author	Yun Qian
Topic	Atmospheric model development
Affiliation	NGD-atmosphere
Link to document	

Title

Using PPE simulations to better understand model physics and parametric sensitivity in EAMv1 over different cloud regimes

Authors

Yun Qian, Vincent E. Larson, Ruby Leung, Wuyin Lin, Ying Liu, Po-Lun Ma, Qi Tang, Hui Wan, Hailong Wang, Heng Xiao, Shaocheng Xie, Guang Zhang, Kai Zhang, Tao Zhang, Shixuan Zhang, and Yuying Zhang

Abstract

The atmospheric component of Energy Exascale Earth System Model (E3SM) version 1 has included many new features in the physics parameterizations compared to its predecessors. Potential complex nonlinear interactions among the physical processes create a signicant challenge for understanding the model behaviors and physics, especially at regional scale and process level. To better understand the E3SM atmosphere model behaviors and physics, we conducted a large number of short simulations in which 18 parameters carefully selected from parameterizations of deep convection, shallow convection, and cloud macrophysics and microphysics were perturbed simultaneously using the Latin hyper cube sampling method. Based on those PPE simulations, we identied the different sensitive parameters corresponded to multiple selected interest variables and quantied how the model responds to changes of the parameters over different regions and cloud regimes. We found the cloud forcing has opposite response to some parameters over mid-latitude vs. tropical land. We analyzed how parametric sensitivity changes from stratocumulus to deep convection system over ocean along GPCI cross section. We also investigated how parametric sensitivity evolved with prediction lengthy. The difculty in simultaneously reducing biases in different regions and cloud regimes highlights the need of characterizing model structural uncertainty (so-called embedded errors) to inform future development efforts.

B21. SOA distributions and radiative forcing from chemistry and photolysis processes in E3SM

Poster Title	Insights in global SOA distributions and radiative forcing from multigenerational chemistry and photolysis processes using the Energy Exascale Earth System Model
First Author	Manish Shrivastava
Topic	atmospheric model development
Affiliation	NGD atmospheric physics
Link to document	...

Title

Insights in global SOA distributions and radiative forcing from multigenerational chemistry and photolysis processes using the Energy Exascale Earth System Model

Authors

Manish Shrivastava (PNNL), Sijia Lou (PNNL), Richard Easter (PNNL), Hailong Wang (PNNL), Philip Rasch (PNNL), Po-Lun Ma (PNNL), Alla Zelenyuk (PNNL), Yang Yang (PNNL), John Shilling (PNNL), Johannes Schneider (Max Planck), Christiane Schulz (Max Planck), Pedro Campuzano-Jost (CU Boulder), Jose Jimenez (CU Boulder), Qi Zhang (UC Davis), Scot Martin (Harvard), Virendra Ghate (ANL), Manvendra Dubey (LANL), Philip Cameron Smith (LLNL)

Abstract

Secondary organic aerosols (SOA) are large contributors to fine particle mass loadings and number concentrations, and interact with clouds and radiation. Several processes affect the formation, chemical transformation and removal of SOA in the atmosphere. These processes govern the horizontal, vertical and temporal distributions of fine particles and their ability to act as cloud condensation nuclei (CCN). Global models that use simplified treatments of SOA often do not capture the dynamics of SOA formation. Here, we conduct simulations using the Energy Exascale EarthSystem Model (E3SM) global model with a detailed treatment of SOA to investigate how SOA distributions respond to some of the important but uncertain processes. Our primary findings are as follows:

(1) The branching ratio between fragmentation and functionalization that governs the multigenerational aging of gas-phase SOA precursors greatly impacts SOA formation and its long-range transport. Decreasing fragmentation with an increase in functionalization reactions results in a stronger source of SOA.

(2) Both a strong source (i.e. strong functionalization) and a strong sink of SOA (i.e. particle-phase photolysis) are needed to explain vertical organic aerosol (OA) profiles measured by aircraft during several field campaigns (DOE Green Ocean Amazon (GoAmazon2014/5), Atmospheric Tomography Mission (Atom) 2016, and the NASA Arctic Research of the composition of the Troposphere from Aircraft and Satellite (ARCTAS) 2008). While SOA treatments that do not include photolysis also agree with surface-based OA measurements e.g. with Aerosol Mass Spectrometer (AMS) and IMPROVE network at several locations, these treatments overpredict SOA at middle and upper troposphere. A strong sink of SOA, like photolysis, is needed to explain OA loadings at higher altitudes where wet removal sinks are small.

(3) To account for recent field studies that suggest no increase in net OA formation over and downwind biomass burning regions, we also test a simple SOA treatment that increases primary organic aerosol (POA) from biomass burning and anthropogenic emissions near source region and converts POA to SOA with an aging timescale of 1 day. This simple treatment without explicit multigenerational aging of SOA precursors performs surprisingly well in simulating OA loadings near the surface as measured by AMS and IMPROVE network. However, the simple treatment also overestimates OA loadings in middle and upper troposphere compared to aircraft measurements, especially during the dry biomass burning season of GoAmazon2014/5, and the wintertime Atom2 field campaign flights over equatorial ocean and North America. The model configuration that includes moderate 50% fragmentation and photolysis performs much better than the simple treatment in these regions, and performs as well as the simple treatment in other regions.

(4) Differences in SOA treatments greatly affect the direct radiative forcing of aerosols ranging from -0.67 W m^{-2} (50% fragmentation and photolysis) to -2.1 W m^{-2} (50% fragmentation without photolysis). Notably, most SOA formulations predict similar global indirect forcing of SOA calculated as the difference in cloud forcing between present-day and pre-industrial simulations likely due to cancellations of errors in SOA formulations. However, the simple treatment is an anomaly and predicts 20% differences in global indirect forcing compared to explicit SOA formulations.

Compared to the default E3SMv1 model, our explicit SOA treatment with fragmentation and photolysis agrees much better with oxygenated organic aerosol (OOA) and IMPROVE OC measurements at multiple surface locations. In addition, our new formulation agrees much better with aircraft-based OA measurements in the middle and upper troposphere compared to E3SMv1, which likely overestimated OA concentrations at high altitudes.

Our results provide important insights about how different SOA processes likely impact aerosol distributions and radiative forcing.

B22. Investigation of a New Dust Emission Scheme in E3SM

Poster Title	Investigation of a New Dust Emission Scheme in E3SM
First Author	Yan Feng
Topic	*atmospheric model development*
Affiliation	NGD atmospheric physics
Link to document	...

Title

Investigation of a New Dust Emission Scheme in E3SM: High Latitude Dust

Authors

Yan Feng, Argonne National Laboratory; Douglas Hamilton and Natalie Mahowald, Cornell University

Abstract

One of the main improvements for dust physics in V3/V4 is to enable a close coupling between land and atmosphere for dust generation. In V1, dust emission is modelled based on the Dust Entrainment And Deposition model (DEAD), which requires a fixed soil erodibility map. We have recently updated it to include the brittle fragmentation theory of vertical dust flux on mineral size fractions during the V2 integration. In addition, dust aerosol absorption in the shortwave is improved by using observationally-based optical properties, resulting in a more negative aerosol forcing at TOA.

In the present study, emissions of dust are further improved to follow a physically based vertical flux theory, which calculates soil erodibility online based on the predicted soil moisture and other properties. This emission scheme has been shown to significantly improve dust emissions with CAM4 and CAM5. It allows for the removal of the soil erodibility map approach previously employed by the DEAD scheme in V1. Global dust emissions are tuned such that a global annual mean dust AOD of ~0.03 is still retained, but yield better simulation of regional dust concentrations with the new emission scheme implemented. In the high latitudes (>50º N), there are evident increases of dust emissions. Emissions of dust from >50º N are about 1~2% of the global dust total, while in V1 the high latitude dust sources were very little near the polar regions. In general, the high latitude dust concentrations peak closest to coast lines and in the summer. A few recent studies have shown that the inclusion of high latitude dust results in dust concentrations and seasonality more consistent with recent observations in the Arctic related to glacial processes. However, we found that the magnitude of the new dust emissions strongly depends on the soil moisture and surface wind predictions by the model, which have large uncertainties. As the high-latitude dust sources have the potential to significantly influence glaciation of Arctic low-level clouds, this warrants further investigation of the fidelity of the new dust emissions.

B23. Nitrate and Stratospheric Aerosol

Poster Title	Nitrate, Stratospheric Aerosol, and their Coupling to Atmospheric Chemistry for E3SMv3
First Author	Hailong Wang
Topic	atmospheric model development
Affiliation	NGD - Atmospheric Physics
Link to document	...

Title

Nitrate, Stratospheric Aerosol, and their Coupling to Atmospheric Chemistry for E3SMv3

Authors

Hailong Wang, Xiaohong Liu, Ziming Ke, Zheng Lu, Balwinder Singh, Mingxuan Wu, Rudong Zhang

Abstract

Several science-driven model developments, including the new treatments of nitrate aerosol and stratospheric sulfate, are currently being implemented in E3SM to better capture their role in the Earth's water cycle and biogeochemistry, and cryosphere system. E3SMv1 simulates the major aerosol species but neglects a few important aerosol components (e.g., nitrate) that will be increasingly important in future climate. Nitrate aerosol is projected to become a significant aerosol component as sulfur and carbonaceous emissions are reduced while NO_x and ammonia emissions continue to increase. Stratospheric aerosols from volcanic eruptions are crudely treated in E3SMv1 by prescribing stratospheric aerosol optical properties from CESM simulations, which is inconsistent with the prognostic treatment of tropospheric aerosols. The new treatment of prognostic stratospheric sulfate will add a new capability for geoengineering simulations as well.

One major difficulty in treating nitrate and stratospheric sulfate is that it requires comprehensive atmospheric chemistry to represent the formation of nitrate and the destruction of oxidants after volcanic eruptions. Additionally, the treatment of nitrate is highly sensitive to gas-particle transfer of semi-volatile nitric acid gas, which can be simulated by the advanced scheme MOSAIC. MOSAIC consists of accurate yet computationally efficient treatments for aerosol thermodynamics, phase state, and gas-particle mass transfer (Zaveri et al., 2008). Nitrate aerosol and MOSAIC have recently been tested and evaluated in two versions of the CESM model (Zaveri et al. and Lu et al., in preparation). For the prognostic stratospheric sulfate with a longer lifetime, it can be aged to the coarse particle mode that has a mode width significantly narrower than that in the troposphere. Therefore, additional aerosol modes are needed for representing stratospheric sulfate. We have started implementing the MOSAIC and developed a new stratospheric MAM7_s aerosol module (i.e., the default MAM4 plus three new stratospheric sulfate modes) in E3SMv1. Both nitrate and stratospheric sulfate aerosols are interactively coupled to a more comprehensive gas-phase chemistry than what the E3SMv1 currently has. The implementations and initial sensitivity test results will be presented and discussed at the meeting.

B24. Atmospheric Chemistry in E3SM

Poster Title	Atmospheric Chemistry in E3SM
First Author	Philip Cameron-Smith
Topic	atmospheric model development
Affiliation	NGD-atm
Link to document	...

Title

Atmospheric Chemistry in E3SM

Authors

Philip Cameron-Smith, Michael J. Prather, Qi Tang

Abstract

Atmospheric chemistry is the dominant process controlling the stratospheric temperature profile and setting the concentrations and distributions of most of the GHGs [including methane (CH_4), ozone (O_3), nitrous oxide (N_2O), and halogenated species (eg, CFCs)]. Interactive stratospheric ozone was incorporated into E3SMv1, but tropospheric species and all other stratospheric species we specified by monthly-mean input files (so E3SM had to depend on other modeling centers to calculate GHG and oxidant concentrations from emission scenarios). Hence, we are implementing the UC Irvine chemistry mechanism (32 species) to address the known limitations of our super-fast mechanism in E3SM. In the stratosphere, this chemistry will include the new Linoz v3, which simulates the stratospheric species O_3, N_2O, NO_Y and CH_4. This will provide E3SM with: (1) the capability to simulate CH_4, (2) improved simulation of oxidants for production of aerosols (sulfate, nitrate, and SOAs), (3) improved O_3 concentrations, especially in polluted regions, (4) simulation of important GHGs in the stratosphere (CH_4 & N_2O), which is critical to simulating the climate impact of their changing emissions, and (5) tracer-based diagnostics of the tropopause, ITCZ, and stratosphere-troposphere airmass exchange.

We will present the behavior of stratospheric ozone in the E3SMv1 simulations, the capabilities of the new chemistry mechanism we are adding, and the value of the diagnostic tracers we are adding.

B25. Tropical forest interaction with Hadley cell circulation

Poster Title	Tropical forest interaction with Hadley Cell and their impacts on nutrient transport
First Author	Yue Li
Topic	*applied E3SM*
Affiliation	RGMA
Link to document	...

Title

Tropical forest interaction with Hadley Cell and their impacts on nutrient transport

Authors

Yue Li, University of California, Irvine

Abstract

Limited knowledge of the interactions across biosphere, atmosphere and nutrient cycles restricts our understanding on the complex relationship within the Earth system. Previous studies mostly focus on the interaction between any two of them such as the land-atmosphere coupling, nutrient limitation on ecosystem and atmospheric transport of the nutrient elements. This issue is expected to be solved under the Earth System framework of the E3SM. A typical case would be the interaction of tropical forest dynamics with Hadley circulation and their linkage to nutrient transport from Sahel to Amazon region. We aim to address specific science question such as would Hadley Cell feed itself via enhancing nutrient transport that increases tropical canopy greenness.

B26. Convergence-based Solution Correctness Testing

Poster Title	Convergence-based Solution Correctness Testing
First Author	Shixuan Zhang
Topic	*atmospheric model development, computing, E3SM evaluation, software tools*
Affiliation	SciDAC
Link to document	...

Title

Convergence-based Solution Correctness Testing

Authors

Shixuan Zhang, Hui Wan, Phil Rasch, Balwinder Singh, Vince Larson, Carol S. Woodward

Abstract

E3SM solves a large set of equations in millions of grid cells. A typical comparison of two solutions involves comparing “climate statistics” of tens to hundreds of physical quantities. Multiple years of simulations are needed to produce data to derive such statistics, costing a lot of computer time. Simpler, cheaper, and more objective methods are needed for the testing of solution correctness, especially for high-resolution simulations. We have developed a simple, quantitative and objective testing method using the concept of time step convergence and used it to assess solution correctness in new software and hardware environments and for simulations using reduced floating-point precision. Results from short convergence tests are found to be good predictors of E3SM’s long-term behavior related to fast physics, making the test computationally very efficient. The method is expected to be applicable to other models that solve time evolution equations.

B07. Climate Simulations On Summit

Poster Title	A proposal for running long-duration climate simulations on Summit
First Author	Vince Larson
Topic	atmospheric model development
Affiliation	NGD — Atmospheric Physics
Link to document	...

Title

A proposal for running long-duration climate simulations on Summit

Authors

Vincent Larson, Gunther Huebler, Brian Griffin, Zhun Guo, John Dennis

Abstract

It would be desirable to take advantage of GPU-based supercomputers, such as Summit, not only to run short-term science simulations, but also to run long-duration climate simulations that include aerosol effects, e.g., a hindcast of 20th-century climate. However, to parallelize code efficiently on GPUs, the GPU threads must be given a substantial amount of computational work to do. Furthermore, in order to run simulations of long duration, the throughput must be high and hence the time step must be long.

To meet both these requirements, we propose the following variant of E3SM. In order to give the GPU threads lots of work, we propose to use subcolumns (i.e., to call the physics parameterizations many times per grid column). If the subcolumns call microphysics (and possibly radiation), the GPU threads will be given lots of work to do. Moreover, subcolumns are highly parallel to each other. To allow high throughput, we propose to use low resolution (100 km), which enables long time steps.

This poster outlines our early steps to develop such a variant of E3SM.

B33. Mesoscale Parameterization

Poster Title	**E3SM with first implementation of mesoscale convective system parameterization**
First Author	Chih-Chieh-Jack Chen
Topic	Atmospheric Model Development
Affiliation	NGD/NCAR
Link to document	...

Title

E3SM with first implementation of mesoscale convective system parameterization

Authors

Chih-Chieh-Jack Chen, Jadwiga H. Richter, Changhai Liu, Mitchell Moncrieff

Abstract

Transport of momentum throughout the atmosphere in large part controls the global circulation, and hence moisture and precipitation patterns. However, several momentum transport processes occur on scales much smaller than a global circulation model (GCM) grid box, and hence have to be parameterized. E3SMv1 currently employs a parameterization of subgrid momentum transport within convection, however it is completely missing the effects of convective organization on the global circulation. Mesoscale convective systems, such as squall lines and mesoscale convective systems can alter the momentum, heat and moisture budgets. We implemented a multiscale coherant structure parameterization (MCSP) into E3SMv1. In this first implementation, we only consider changes to the convective heating profile by organized mesoscale convection. We show the effects of the MCSP on the simulation of mean precipitation and variability in E3SMv1.

B27. Solar-J work

Poster Title	On the errors incurred by solar radiation calculations in Earth System models
First Author	Juno Hsu
Topic	atmospheric model development
Affiliation	University of California Irvine
Link to document	

Title

On the errors incurred by solar radiation calculations in Earth System models

Authors

Michael Prather and Juno Hsu (junoh@uci.edu)

Abstract

Sunlight drives the Earth's weather, climate, chemistry, and biosphere. Recent efforts to improve solar heating codes in climate models focused on more accurate treatment of the absorption spectrum or fractional clouds. A mostly forgotten assumption in climate models is that of a flat Earth atmosphere. Spherical atmospheres intercept 2.5 Wm2 more sunlight and heat the climate by an additional 1.5 Wm2 globally. Such a systematic shift, being comparable to the radiative forcing change from preindustrial to present, is likely to produce a discernible climate shift that would alter a model's skill in simulating current climate. Regional heating errors, particularly at high latitudes, are several times larger. Unlike flat atmospheres, constituents in a spherical atmosphere, such as clouds and aerosols, alter the total amount of energy received by the Earth. To calculate the net cooling of aerosols in a spherical framework, one must count the increases in both incident and reflected sunlight, thus reducing the aerosol effect by 10 to 14% relative to using just the increase in reflected. Simple fixes to the current flat Earth climate models can correct much of this oversight, although some inconsistencies will remain.

In addition to the errors caused by ignoring the spherical geometry, different classes of errors from various approximations used in radiative transfer code of the climate models (CLIRAD, RRTMG, LLNL) are also quantified. This includes the use of broad wavelength bins to integrate over spectral features; multiple-scattering approximations that alter the scattering phase function for clouds, aerosols, and gases; treatment of fractional cloud cover including cloud overlap; and the approximation of ocean surface albedo by a constant. These approximations, coded as options in the Solar-J code can be further tested in E3SM to investigate how they impact long climate simulations.

B28. Surface-atmosphere longwave coupling in E3SM with M-PACE and AWARE observations

Poster Title	Assessing the improved treatments of surface-atmosphere longwave coupling in the E3SM with M-PACE and AWARE observations
First Author	Xianwen Jing
Topic	atmospheric model development
Affiliation	the University of Michigan (E3SM University Project)
Link to document	...

Title

Assessing the improved treatments of surface-atmosphere longwave coupling in the E3SM with M-PACE and AWARE observations

Authors

Xianwen Jing, Yi-Hsuan Chen, Xianglei Huang (University of Michigan), Ping Yang (Texas A&M), Wuyin Lin (BNL)

Abstract

Previous studies have identified surface spectral emissivity and cloud longwave scattering as key missing processes in the surface-atmosphere longwave coupling in the polar climate simulation. We have implemented a new ice-cloud radiation scheme into the E3SM and modified the RRTMG_LW to take longwave scattering into account. As a parallel effort to our assessment of the new schemes for coupled simulations, here we study the impact of the new schemes on the single-column model (SCM) simulations for two sub-polar campaigns by the ARM project, i.e., the M-PACE in October 2004 and AWARE in January 2016. Large-scale forcing is prescribed using the ARM observations for the M-PACE period and ERA-interim reanalysis tendency fields for the AWARE period, at a frequency of every three and one hours, respectively. The evolution of atmospheric temperature and water vapor are subject to physical tendencies in addition to the prescribed forcing, while the surface quantities (e.g., temperature, latent heat, and sensible heat) are entirely determined by the forcing. The SCMs from standard E3SM v1 and modified E3SM are both used in the simulation. The results are compared with each other as well as against the observations. Other sub-grid atmospheric physical processes are unchanged from the standard E3SM. Consistent with our findings from the fully coupled simulations, the new schemes that we implemented affect the downward longwave flux the most and have little impact on cloud and precipitation fields. The simulated changes of total water vapors and surface longwave fluxes due to the inclusion of both mechanisms are comparable to the counterparts from AMIP-type simulations. These findings suggest that the inclusion of cloud longwave scattering can improve the fidelity of the simulated energy budget but does not deteriorate other aspects of simulated climate in the high latitudes. Such an impact on the surface energy budget will be manifested through the atmosphere-surface longwave coupling, a mechanism not included in the SCM simulations.

B29. Tropical Cyclone Rainfall Structures in CMIP6 HighResMIP Simulations

Poster Title	Evaluation of tropical cyclone rainfall structures in CMIP6 HighResMIP simulations
First Author	Yumin Moon
Topic	*applied E3SM*
Affiliation	RGMA
Link to document	...

Title

Evaluation of tropical cyclone rainfall structures in CMIP6 HighResMIP simulations

Authors

Yumin Moon, University of Washington

Abstract

This study examines tropical cyclones (TCs) that are simulated by CMIP6 HighResMIP global climate models (GCMs). Previous studies have examined GCM-simulated TC structures, often focusing on wind structures and upper-level warm-core anomalies. However, not many studies have evaluated TC rainfall structures in GCM simulations. In this work, we perform an observation-based evaluation of GCM-simulated TCs by comparing against the multiple satellite-based rainfall retrievals. This process-oriented diagnosis can help determine which GCMs produce more realistic TCs than others in terms of key TC processes. Preliminary results indicate that GCM-simulated TCs in CMIP6 HighResMIP simulations tend to overestimate the inner-core rainfall in comparison to the satellite-derived rainfall at comparable intensity.

B30. Tropical Cyclones in the high-resolution E3SM

Poster Title	Tropical Cyclone activity in the high resolution E3SM v1
First Author	Karthik Balaguru
Topic	E3SM evaluation
Affiliation	E3SM, RGMA
Link to document	

Title

Tropical Cyclone activity in the high resolution E3SM v1

Authors

Karthik Balaguru, PNNL

Abstract

Here we present an overview of simulated Tropical Cyclones (TCs) in the high and low resolution versions of the fully coupled Energy Exascale Earth System Model (E3SM) v1. In the high resolution version of the model, the simulation of TCs is reasonable when compared to observations. An average of 65 TCs are simulated globally per year, which is lower than the observed value of around 90. Also, the TC intensity distribution in various basins is in reasonable agreement with observations, except that the model slightly under produces major TCs and over produces weaker TCs. An analysis of the Genesis Potential Index, based on thermodynamic Potential Intensity and Vertical Wind Shear, is performed to understand the relative distribution of TC production in different basins with respect to observations. On the other hand at low resolution, only 15 TC-like vortices are simulated globally. Despite the bias, this value is comparable to the CMIP5 multi-model mean, where spatial resolution is also around 1 degree. Further, in the low-resolution version, E3SM relatively underproduces TC-like vortices in the Atlantic basin, behavior that is consistent with many CMIP5 models and is possibly related to biases in the simulation of African Easterly Waves at that resolution.

B31. Influence of Climate Bias on Extreme Events

Poster Title	Isolating the Influence of Climate Bias on Extreme Events Using Initialized Ensembles
First Author	Ramalingam Saravanan
Topic	*atmospheric model development, applied E3SM*
Affiliation	RGMA
Link to document	...

Title

Isolating the Influence of Climate Bias on Extreme Events Using Initialized Ensembles

Authors

Ramalingam Saravanan, Texas A&M

Abstract

One of the important applications of global climate models is to predict anticipated changes in the statistical properties of extreme events. Tropical cyclones (TCs) are among the extreme events with the greatest socioeconomic impacts in the United States and other regions of the world. Although coarse-resolution global climate models are not capable of simulating individual TCs accurately, they do exhibit significant skill in simulating the interannual and decadal variations in the aggregate statistics of TCs. We propose to analyze and simulated extremes in E3SM, with a focus on TC activity on the Northern Hemisphere.

One of the challenges in simulating the spatial distribution of TCs and other extreme events is the impact of climate bias. Since these biases can develop within a few weeks from the start of a simulation, it becomes difficult to distinguish between the flow bias effect and other possible deficiencies in the climate model, such as errors in the representation of clouds or poor spatial resolution. To address this problem, we propose to use an initialized ensemble approach, where a series of short (14-day) weather forecasts is carried out using the high resolution (0.25-degree) EAM, the atmospheric component of E3SM, for the Northern Hemisphere TC season. The background flow in the ensemble-average of the forecasts will be close to the observed flow, by construction, whereas long EAM control runs will exhibit fully developed biases. The integrations will be performed for the 10-year period 2000-2009, initialized from atmospheric analyses and using observed sea-surface temperature and sea-ice during this period as the surface boundary condition. Comparing the statistics of TC simulations in the initialized forecast ensemble to those in the control run of EAM will allow us to isolate the impact of mean flow biases.

B32. US precipitation extremes in E3SM

Poster Title	Evaluation of precipitation extremes over the United States in E3SM compared to observations and CMIP6 simulations
First Author	Akintomide Akinsanola
Topic	*atmospheric model development*
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Link to document	...

Title

Evaluation of precipitation extremes over the United States in E3SM compared to observations and CMIP6 simulations

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Abstract

Realistically representing the present-day characteristics of extreme precipitation has been challenging for both gridded observations and Earth system model (ESM) simulations. In this project, we use a range of gridded observation datasets to assess simulations from Coupled Model Intercomparison Project Phase 6 (CMIP6) and Energy Exascale Earth System Model (E3SM) – including low-resolution, high-resolution, and super-parameterized versions. We evaluate precipitation over the United States with a comprehensive set of extreme precipitation indices and storm-specific statistics, including an assessment of magnitude, intensity, timing, and spatial structure across observations and ESMs. In addition to conventional ESMs, we assess the potential for high-resolution and super-parameterization, also known as a multi-scale modelling framework, implemented in E3SM, to improve key aspects of simulated precipitation compared to the standard version. Our preliminary results highlight common biases in CMIP6 ESMs and differences compared with E3SM, which are critical for understanding reliability of future projections of extreme precipitation.