U.S. DEPARTMENT OF ENERGY

Earth and Environmental Systems Modeling

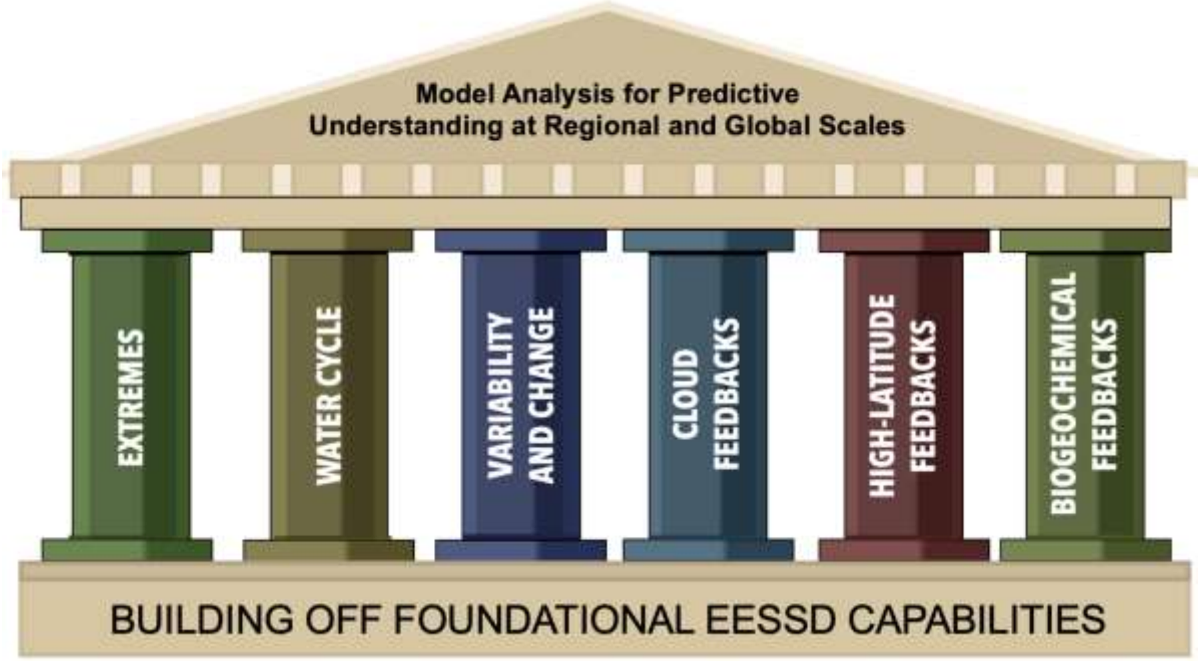
Regional and Global Model Analysis

Program Manager: Renu Joseph

EESM
EARTH & ENVIRONMENTAL SYSTEMS MODELING

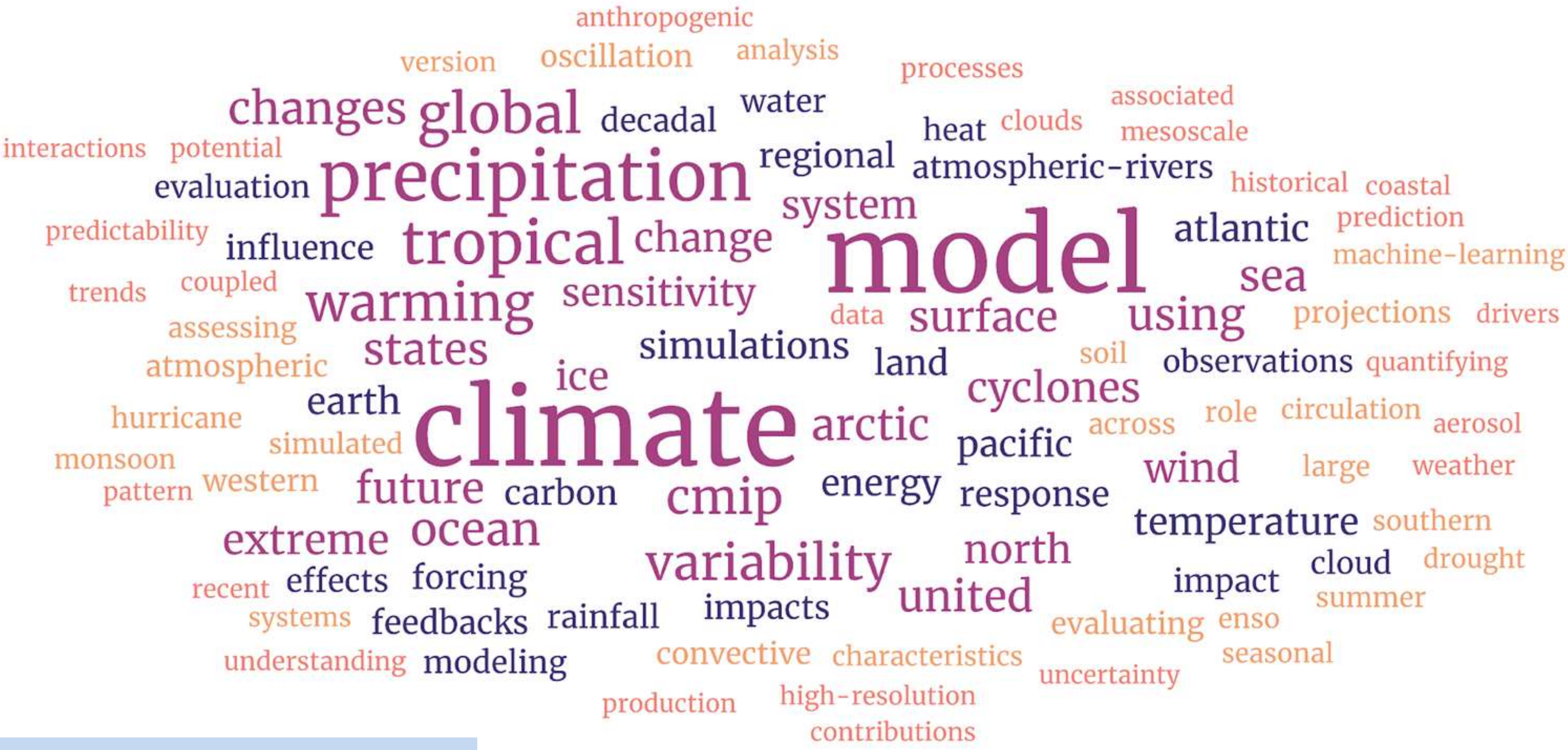
Regional and Global Model Analysis (RGMA)

Goal: To quantify and enhance a predictive, process-level, and decision-relevant understanding of variability and change in the Earth system by advancing capabilities to design, simulate, evaluate, diagnose, and analyze global and regional earth system models informed by observations.



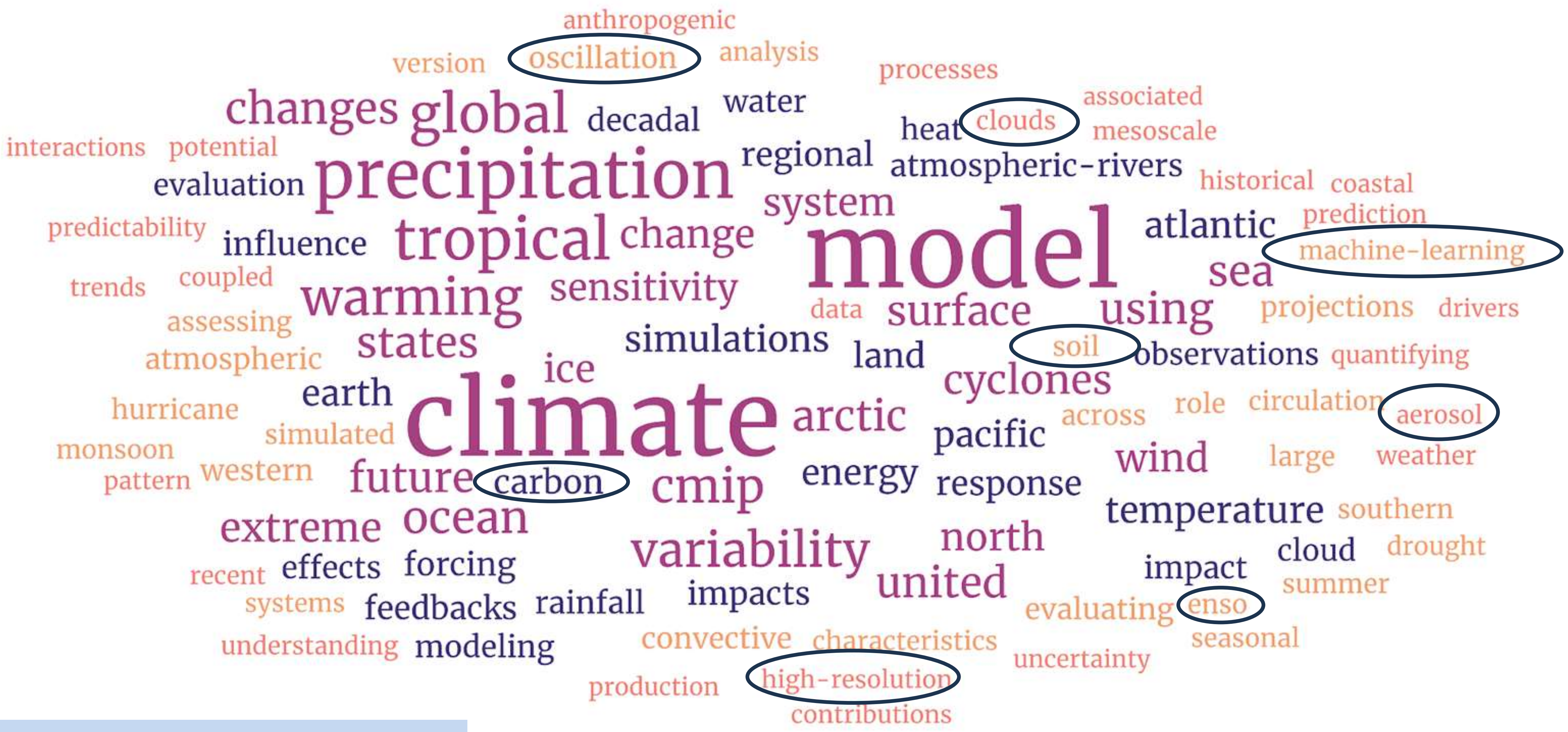
https://climatemodeling.science.energy.gov/program-area/regional-global-model-analysis

Regional and Global Model Analysis (RGMA) Keywords



100 top keywords taken from RGMA funded publications 2020 to present.

Regional and Global Model Analysis (RGMA) Keywords

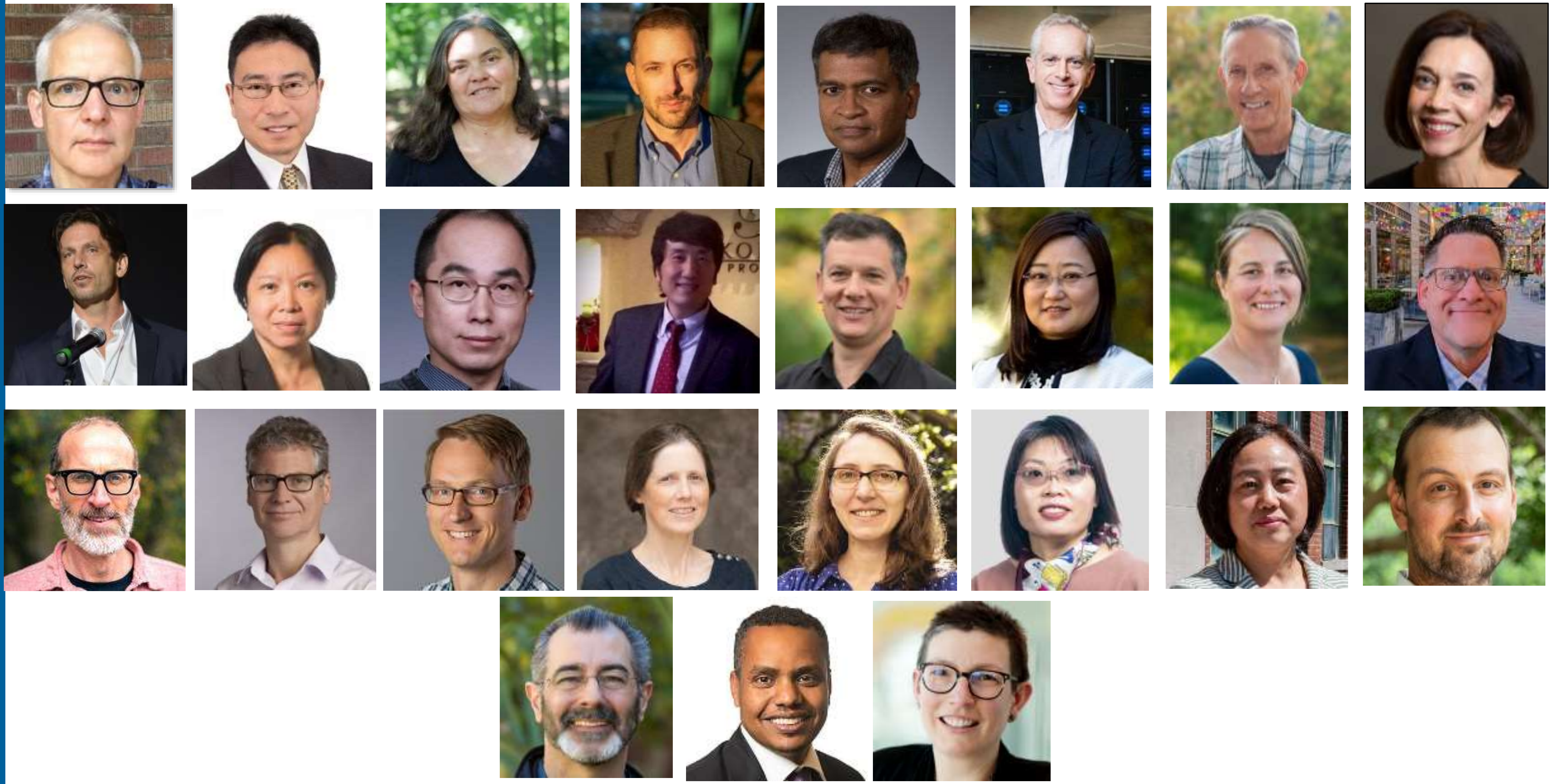


100 top keywords taken from RGMA funded publications 2020 to present.

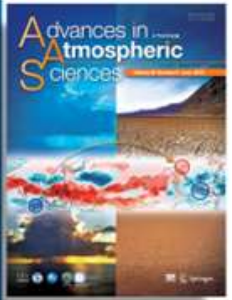
RGMA Scientists Honored (2019-2024)

2023 AGU Fellow	Xiahong Liu, Texas A&M	**2024 AMS Fellow**	William Collins, LBNL
2023 AGU Fellow	Suzana J. Camargo, Columbia U.	**2024 AMS Fellow**	Yun Qian, PNNL
2023 AGU Fellow	Claudia Tebaldi, PNNL	**2024 AMS Fellow**	Jonathan H. Jiang, CalTech
2023 AGU Fellow	Adam H. Sobel, Columbia U.	**2024 AMS Fellow**	Gabe Vecchi, Princeton U.
2023 AGU John Tyndall Lecture Award	Ramalingam Saravanan, Texas A&M	**2024 AMS Banner I. Miller Award**	Hui Su, UCLA
2022 AGU Fellow	Brian Soden, U. of Miami	**2023 AMS Sverdrup Gold Medal**	Gerald Meehl, UCAR
2021 AGU Piers J. Sellers Global Environ. Change Mid-Career Award	Charlie Koven, LBNL	**2024 AMS Julie G. Charney Medal**	Richard Seager, Columbia U.
2021 AGU Edward A. Flynn III Award	Bart Nijssen	**2022 AMS Fellow**	Jiwen Fan, Argonne
2020 AGU Jacob Bjerknes Lecture Award	L. Ruby Leung, PNNL	**2022 AMS Fellow**	Guiling Wang, U. of Connecticut
2020 AGU Fellow	William Collins, LBNL	**2022 AMS Henry G. Houghton Award**	Mark Zelinka, LLNL
2019 AGU John Tyndall Lecture Award	William Collins, LBNL	**2022 AMS Hydrologic Sciences Medal**	L. Ruby Leung, PNNL
2019 AGU Bert Bolin Lecture Award	L. Ruby Leung, PNNL	**2021 AMS Distinguished Sci./Tech. Accomplishment**	Jadwiga Richter, UCAR
2019 AGU Clarence Leroy Meisinger Award	Samson Hagos, PNNL	**2021 AMS Sverdrup Gold Medal**	Sarah T. Gille, UC San Diego
2019 AGU Global Environ. Change Early Career Award	Gretchen Keppel-Aleks, U. of Michigan	**2021 AMS Walter Orr Roberts Lecturer**	Abigail L.S. Swann, U. of Washington
2020 AAAS Fellow	Forrest Hoffman, ORNL	**2019 AMS Julie G. Charney Medal**	J. David Neelin, UCLA
2023 AAAS Fellow	Guiling Wang, U. of Connecticut	**2024 MacArthur Fellow**	Park Williams, UCLA

RGMA Scientists Honored (2019-2024)



RGMA Journal Covers (2019-2024)

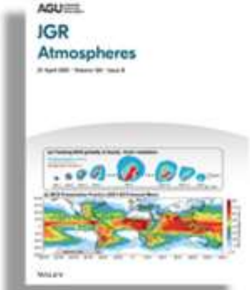


Evidence of specific MJO phase occurrence with summertime California Central Valley extreme hot weather

Lee, Y.Y. and Grotjahn, R. *Advances in Atmospheric Sciences*, 36 (2019). https://doi.org/10.1007/s00376-019-8167-1

Impact of atmospheric rivers on surface hydrological processes in western US watersheds

Chen, X., Leung, L.R., Wigmosta, M. and Richmond, M. *Journal of Geophysical Research: Atmospheres*, 124, 16 (2019). https://doi.org/10.1029/2019JD030468



A Global High-Resolution Mesoscale Convective System Database Using Satellite-Derived Cloud Tops, Surface Precipitation, and Tracking

Feng, Z., Leung, L. R., Liu, N., Wang, J., Houze, R. A., Li, J., et al. (2021). *JGR: Atmos*, 126, e2020JD034202. https://doi.org/10.1029/2020JD034202

Early warm-season mesoscale convective systems dominate soil moisture–precipitation feedback for summer rainfall in central United States

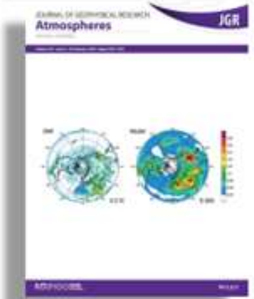
Hu, Huancui, L. Ruby Leung, and Zhe Feng. 2021. *Proceedings Of The National Academy Of Sciences* 118: e2105260118. https://doi.org/10.1073/pnas.2105260118

Urbanization Impact on Regional Climate and Extreme Weather: Current Understanding, Uncertainties, and Future Research Directions

Qian, Y, T. C. Chakraborty, J. Li, D. Li, C. He, C. Sarangi, F. Chen, X. Yang, and L.R. Leung. 2022. *Advances In Atmospheric Sciences* 39 (6). https://doi.org/10.1007/s00376-021-1371-9

Observational constraints on low cloud feedback reduce uncertainty of climate sensitivity.

Myers, T.A., Scott, R.C., Zelinka, M.D., et al. *Nature Climate Change. 11, 6* (2021). https://doi.org/10.1038/s41558-021-01039-0



Sulfate Aerosol in the Arctic: Source Attribution and Radiative Forcing

Yang, Y., Wang, H., Smith, S. J., Easter, R. C., & Rasch, P. J. (2018). *Journal of Geophysical Research: Atmospheres*, 123. https://doi.org/10.1002/2017JD027298

Human influence on joint changes in temperature, rainfall and continental aridity

Bonfils, C.J., Santer, B.D., Fyfe, J.C., et al. *Nature Climate Change. 10, 8* (2020). https://doi.org/10.1038/s41558-020-0821-1

Boreal–Arctic wetland methane emissions modulated by warming and vegetation activity

Yuan, K., Li, F., McNicol, G. et al. *Nat. Clim. Chang.* 14, 282–288 (2024). https://doi.org/10.1038/s41558-024-01933-3

Calibration, measurement, and characterization of soil moisture dynamics in a central Amazonian tropical forest

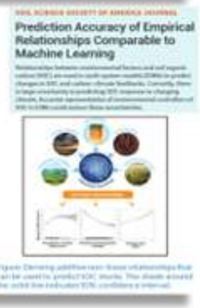
Negrón-Juárez et al. Vadose Zone Journal. 19, 1 (2020). https://doi.org/10.1002/vzj2.20070

Evidence of human influence on Northern Hemisphere snow loss

Gottlieb, A., & J. S. Mankin (2024), Nature (2024). https://doi.org/10.1038/s41586-023-06794-y

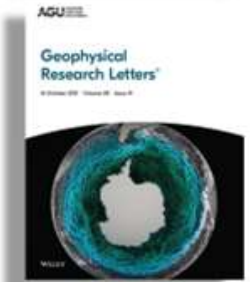
Human-induced salinity changes impact marine organisms and ecosystems

Röthig, T., Trevathan-Tackett, S.M., Voolstra,, et al. *Global Change Biology*. 29, 17 (2023). https://doi.org/10.1111/gcb.16859



Empirical relationships between environmental factors and soil organic carbon produce comparable prediction accuracy as the machine learning

Mishra, U., K. Yeo, A. Adhikari, et al. *Soil Science Society of America Journal*, 86 (2022). https://doi.org/10.1002/saj2.20453

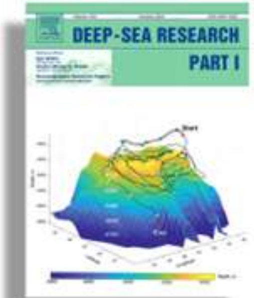


The Influence of Ocean Topography on the Upwelling of Carbon in the Southern Ocean

Brady, R.X., Maltrud, M.E., Wolfram, P.J. et al. *Geo. Research Letters*. 48, 19 (2021). https://doi.org/10.1029/2021GL095088

Robustness and uncertainties in global multivariate wind-wave climate projections

Joao Morim, Ben Timmermans, Michael Wehner, et al. Nature Climate Change. 9 (2019). https://doi.org/10.1038/s41558-019-0542-5



The Zapiola Anticyclone: A Lagrangian Study of its Kinematics in an Eddy-Permitting Ocean Model

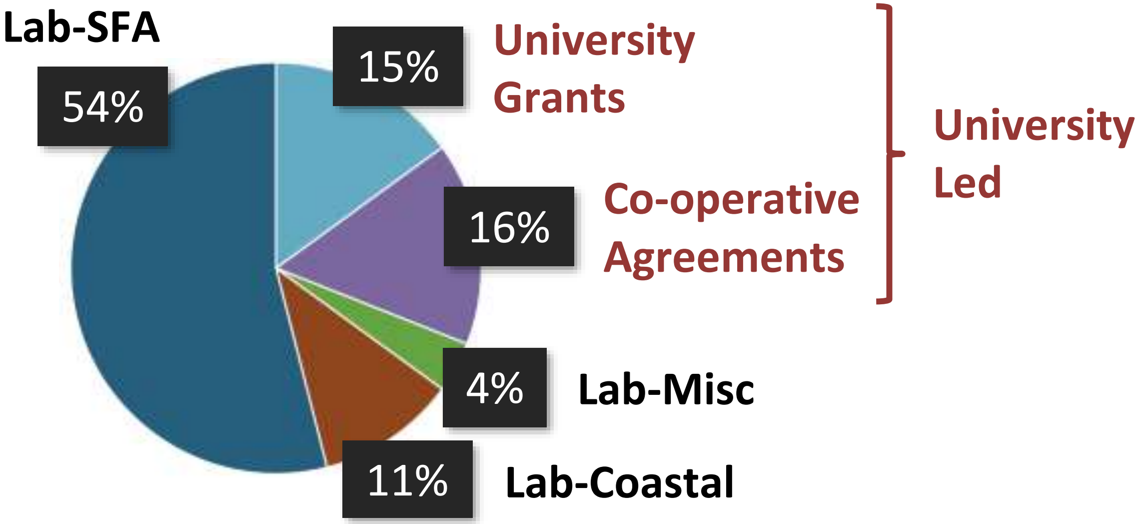
Weijer, Wilbert, Alice Barthel, Milena Veneziani, and Hannah Steiner. 2020. *Deep Sea Research Part I: Oceanographic Research Papers* 164. https://doi.org/10.1016/j.dsr.2020.103308

A mixture of core efforts (laboratory and cooperative agreements) and university projects

Core RGMA Projects

- **Water Cycle** and Climate Extremes Modeling (WACCEM)
- Calibrated and Systematic Characterization, Attribution and Detection of **Extremes** (CASCADE)
- Reducing Uncertainty in **Biogeochemical Interactions** Through Synthesis and Computation (RUBISCO)
- **High-Latitude** Application and Testing (HiLAT)
- Cooperative Agreement to Analyze **variability, change and predictability** in the earth SysTem (CATALYST)
- PCMDI: Earth System Model **Evaluation** Project
- A Framework for Improving Analysis and Modeling of Earth System and Intersectoral Dynamics at Regional Scales (HyperFACETS)
- Integrated Coastal Modeling (ICoM)
- Interdisciplinary Research for Arctic Coastal Environments (InteRFACE)
- COMPASS-Great Lakes Modeling
- Coastal Work Puget Sound

FY23 Funding ~$38M



RGMA Funded Projects

New University Projects: FOA 3228

Investigator	Title	Topic
McCoy, Daniel	Linking **aerosol forcing** and **cloud feedback** to **atmospheric moisture processing**	Clouds + Aerosol
Huang, Xianglei	Understanding the **polar cloud longwave feedback** and its confounding factors through a spectral lens	Clouds
Schiro, Kathleen	Evaluating mean state relationships to **high cloud feedbacks** and **climate sensitivity** in CMIP model ensembles and E3SM	Clouds
Larson, Vincent	Overfitting and **uncertainty** in the presence of **model structural error**	Clouds + UQ
Pu, Zhaoxia	Coupled Land-Atmosphere-Ocean **Data Assimilation for E3SM with DART** for Understanding **Subseasonal-to-Seasonal Predictability** of Extreme Events	Initialization
Gnanadesikan, Anand	Using apparent relationships derived from **machine learning methods** to improve the simulation of **marine organisms** within the Energy Exascale Earth System Model	Marine BGC
Lovenduski, Nicole	SOS-Carbon: **Southern Ocean Storminess** and the **Carbon Cycle**	Marine BGC
Chen, Min	Understand And Reduce Uncertainty In E3SM's **Land-Atmosphere Feedbacks On Carbon, Water, and Energy** In Response To **Wildfire Disturbance**	Terrestrial BGC
Shi, Zheng	Experimental-data-informed, **machine-learning**-enabled benchmarking and development of **land carbon cycle** in Earth system models	Terrestrial BGC
Song, Yang	An integrated **artificial intelligence** and E3SM hierarchal modeling framework for elucidating environmental responses of **soil carbon and nutrients dynamics** and its implications for **land carbon-climate**	Terrestrial BGC
Sun, Ying	Amazon vs Congo: Understanding the Intercontinental Differences of **Tropical Rainforests**' Responses to **Climate Variability**	Terrestrial BGC

Enhancing scientific understanding of the Earth System via...

SCIENCE THEMES

- Water cycle
- Biogeochemical cycles, processes, and feedbacks
- High-latitude processes and feedbacks (e.g., Arctic Amplification)
- Modes of Variability, Trends, and Change
- Extreme events and Tipping points (e.g., floods, droughts, fires)
- Cloud, aerosol, precipitation processes, feedbacks
- Process-level understanding informed by stakeholder needs

SOFTWARE AND TOOLS

E3SM to emulators
Regional and global models
Model hierarchies
Multi-model approaches
Streamlining analysis
Machine learning

MODEL SIMULATIONS

Storyline capabilities
Initialized predictions
Hypothesis-driven science
Revealing insights

DIAGNOSTICS AND METRICS

Coordinated Model Evaluation Capabilities (CMEC)
Flagship packages (PMP, ILAMB)

COMMUNITY CONNECTIONS

External contributions
Intra-agency, inter-agency
National and international
Stakeholder co-production

Balancing high-risk high-reward efforts and incremental science

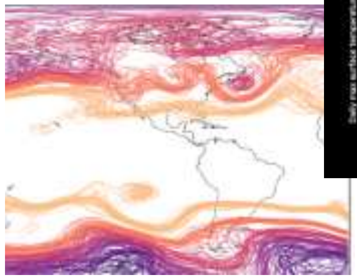
Monthly Extreme Weather Telecon

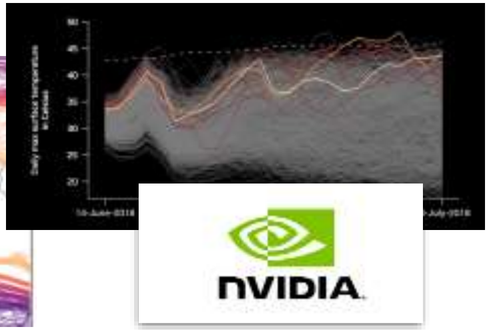
Tue, Plenary **PI: Bill Collins, LBNL**

Goal: To advance understanding of singular climate extremes known as **low-likelihood, high-impact events (LLHIs)**, the drivers that cause them, and the evolution of these drivers in warmer climates

Approach:

- Machine learning methods, including FourCastNet collaboration with NVIDIA and generation of huge ensemble (HENS)
- High-performance feature tracking (TECA)
- Statistical methods (extreme and Bayesian)
- Model and observational data



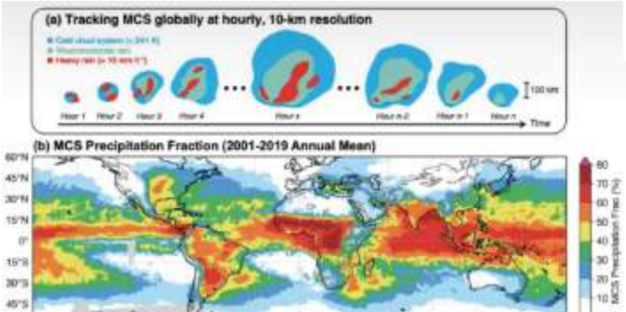


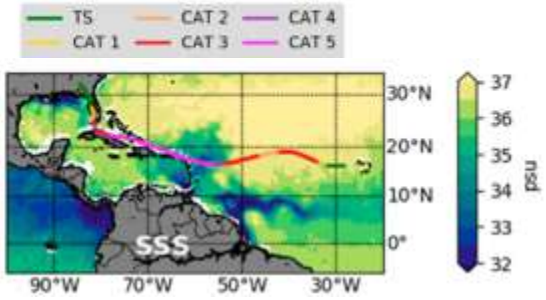
Tue, Plenary **PI: Ruby Leung, PNNL**

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

Approach:

- Understanding large-scale circulation, mesoscale convection, boreal summer intraseasonal oscillation (BSISO), and surface-atmosphere interactions.
- Development of new tools and datasets.
- New capabilities and frameworks for E3SM.
- Seasonal to Subseasonal predictability of hydrologic extremes.

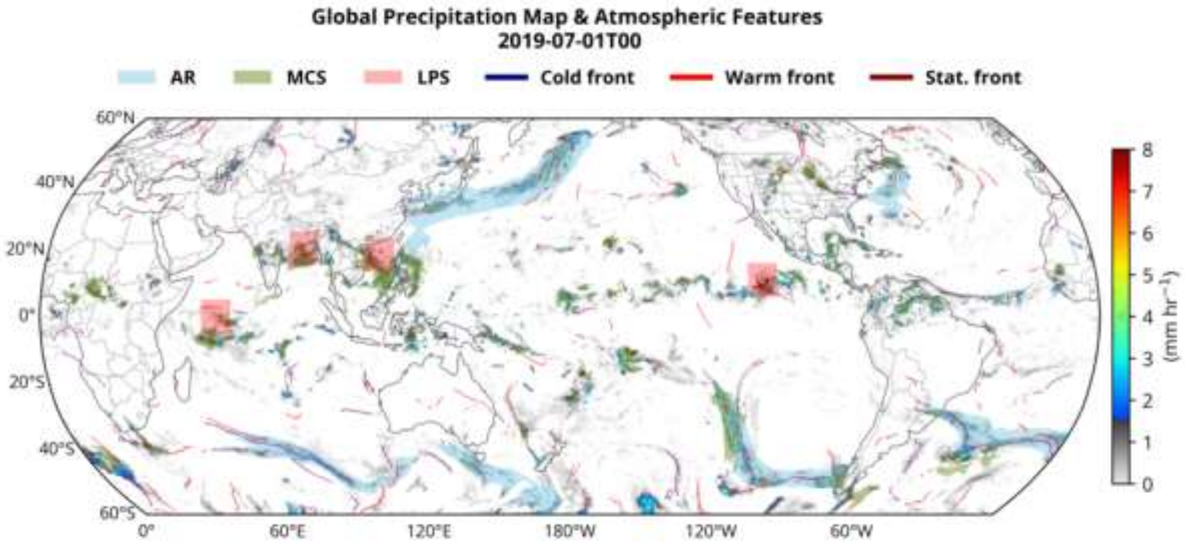




DE-SC0023244: *Extreme precipitation features and their large-scale environments (UCLA lead JD Neelin)*
DE-SC0023519: *Investigating the Effects of Co-Occurring Weather Phenomena on Extreme Precipitation in Reanalysis, E3SM, and CMIP6 (IU lead O'Brien) + UCB, LBNL, UCD, LLNL, PNNL, U Exeter*

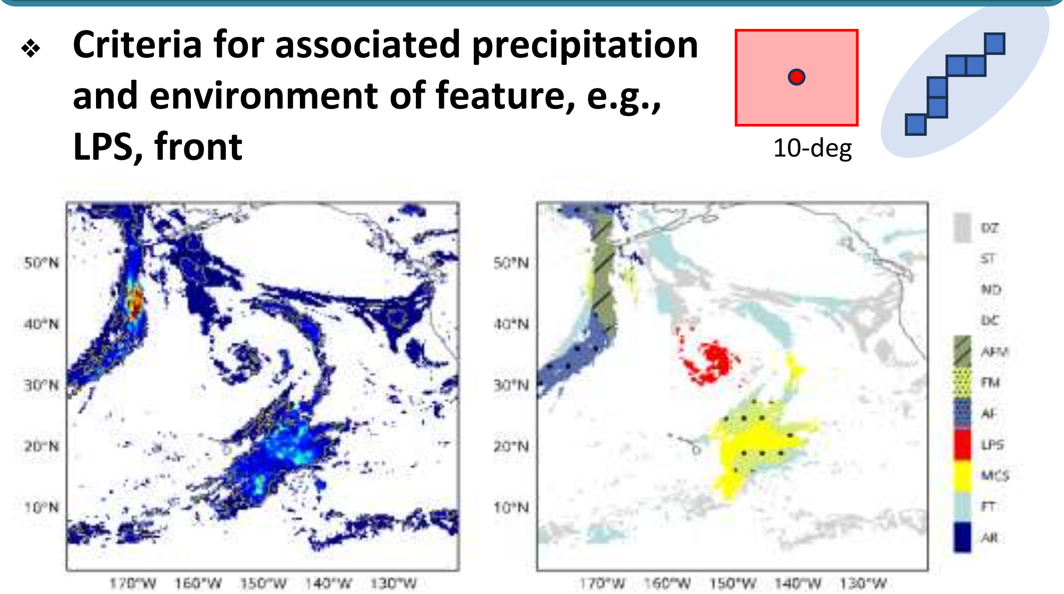
Task I: identify leading features in observation and climate models

- **Atmospheric features, their co-occurrences, and precipitation**



Task II: toward process-level diagnostics of leading features and rainfall

- **Criteria for associated precipitation and environment of feature, e.g., LPS, front**



Extract environmental variables in vicinity of feature

- **Coordinating published feature identification algorithms for: fronts, atmospheric rivers, mesoscale convective systems, and low-pressure systems (FT, AR, MCS, LPS)**
- **Identify precipitation associated with combinations of feature cooccurrence and evaluate implications for precipitation extremes**

A dataset for precipitation associated with fronts, AR, MCS, LPS and their cooccurrence will be publicly available on Dryad:

Tsai, Wei-Ming et al. (Forthcoming 2024). Precipitation identifiers for meteorological features combining global GPM-IMERG retrievals and ERA5 reanalysis [Dataset]. Dryad. https://doi.org/10.5061/dryad.v9s4mw73g

Monthly Joint Metrics, Clouds & Variability Telecon

catalyst

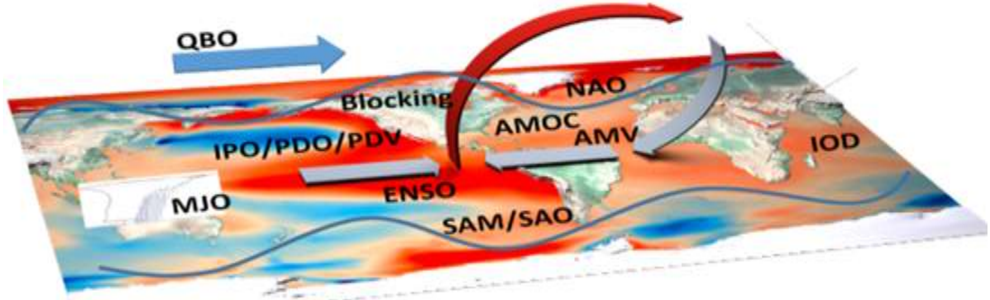
Wed, Plenary

PI: Jerry Meehl, NCAR

Goal: Focus on modes of Earth system variability and change to explore the limits of predictability, identify fundamental underlying mechanisms, quantify interactions among modes of variability and associated high impact events, and discover tipping points in the Earth system.

Approach:

- Multi-model and initial condition large ensemble simulations (E3SM and CESM)
- Initialized prediction experiments
- Detection and attribution



PCMDI

Earth System Model Evaluation Project

Wed, Plenary

PI: Paul Ullrich, LLNL

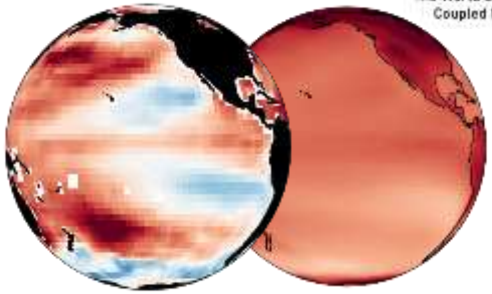
Goal: To quantify & reduce uncertainties in the variability, forcing & response of Earth System Models

Approach:

- Observational analysis, single model experimentation, and multi-model analyses
- Benchmark model performance, including key features and processes, using novel metrics
- Coordination and facilitation of climate research to leverage latest model- and observational-based insights

CMIP

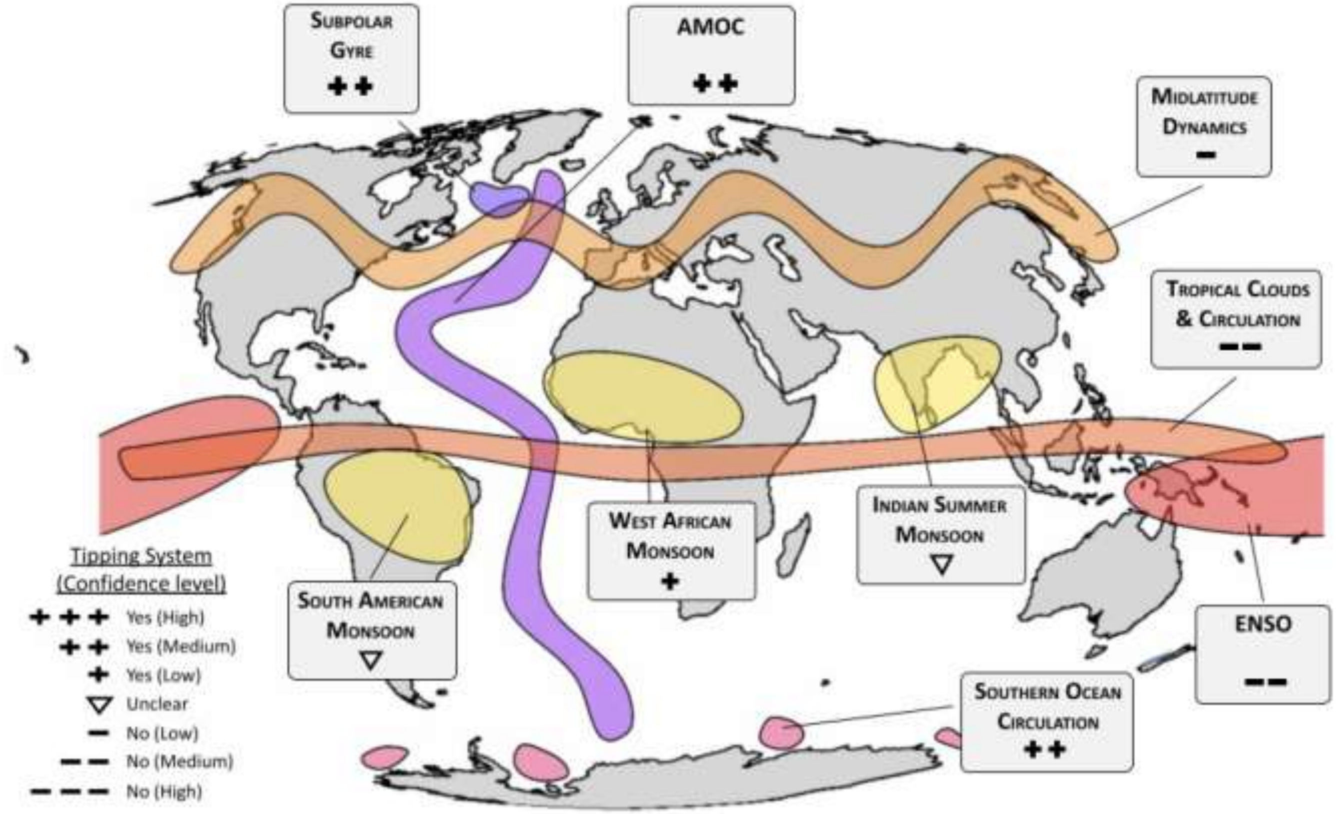
The World Climate Research Programme's Coupled Model Intercomparison Project



https://doi.org/10.5194/egusphere-2023-2589
Preprint. Discussion started: 11 December 2023

Tipping points in ocean and atmosphere circulations

Sina Loriani[1], Yevgeny Aksenov[2], David Armstrong McKay[3,4], Govindasamy Bala[5], Andreas Born[6], Cristiano Mazur Chiessi[7], Henk Dijkstra[8], Jonathan F. Donges[1,4], Sybren Drijfhout[9,10,11], Matthew H. England[12,13], Alexey V. Fedorov[14,15], Laura Jackson[16], Kai Kornhuber[1,17,18,19], Gabriele Messori[20,21,22], Francesco Pausata[23], Stefanie Rynders[2], Jean-Baptiste Sallée[24], Bablu Sinha[2], Steven Sherwood[25], Didier Swingedouw[26], Thejna Tharammal[27]



A broad review of potentially tipping systems in ocean and atmosphere circulations

Cross-programmatic with

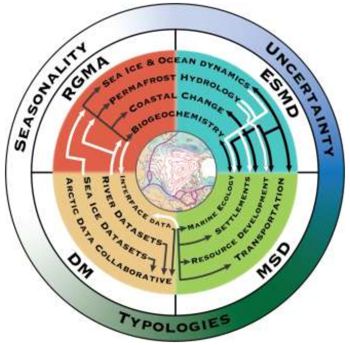
Thu, Plenary

PI: Nicole Jeffrey, LANL

Goal: Evaluate and improve the predictive skill of Earth and human system modeling to identify and understand trajectories of change for which the Arctic coastal system, both human built and natural, is most vulnerable

Approach:

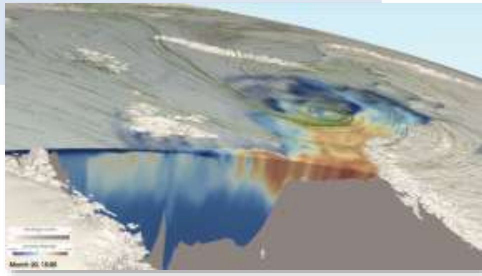
- Model the coupled natural-human system
- Cyberinfrastructure for Arctic data
- Model across scales



Thu, Plenary

PI: Wilbert Weijer, LANL

Goal: Improve our ability to project future Arctic changes by developing a unifying framework to understand, quantify, and compare complex Earth system feedbacks that modulate Arctic warming, and to improve the model representation of such feedbacks.



Approach:

- Regionally refined E3SM-Arctic
- Community engagement
- Reduced-order models
- Metrics and diagnostics for high-latitude regions
- Leverage observations and model simulations

Co-operative Agreement

Cross-programmatic with MSD

RUBISCO

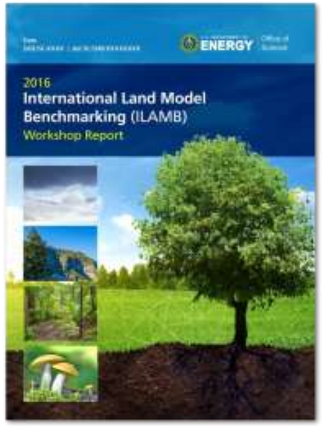
Thu, Plenary

PI: Forrest Hoffman, ORNL

Goal: Identify and quantify interactions between biogeochemical and hydrological cycles and the earth system, and to quantify and reduce uncertainties in ESMs associated with those interactions.

Approach:

- Benchmarking and uncertainty quantification
- Global data synthesis
- Model-data integration
- Machine learning methods
- Topical working groups



HYPERFACETS

U.S. Department of Energy | Office of Science

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

Tue, Plenary

PI: Erwan Monier, UCDavis

Goal: Understand how much can we trust given climate information for actionable climate science and how we can ensure its saliency.

Approach:

- Direct stakeholder engagement
- Storyline simulations
- Use-informed metrics and diagnostics
- Understanding climate data products
- Process-level understanding informed by stakeholder needs

Cross-programmatic with

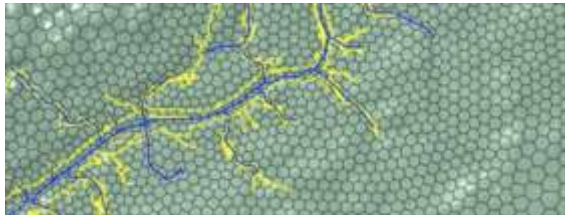
Tue, Plenary

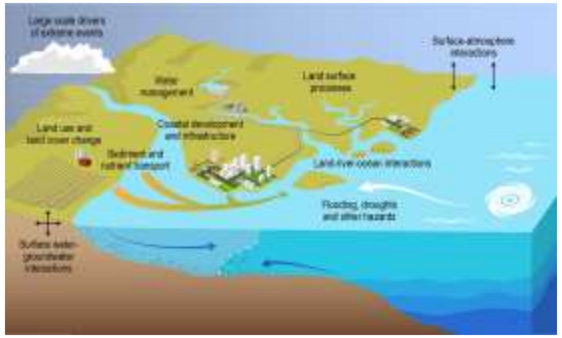
PI: Ian Kraucunas, PNNL

Goal: Improve scientific understanding of coastal regions and populations across the country and around the world, including vulnerabilities to the physical and natural system.

Approach:

- Coupled modeling of ocean, atmosphere, land-surface and human system processes
- Characterization of surface and subsurface hydrologic response
- Understanding of extreme weather events in the coastal environment.





Wed, Plenary

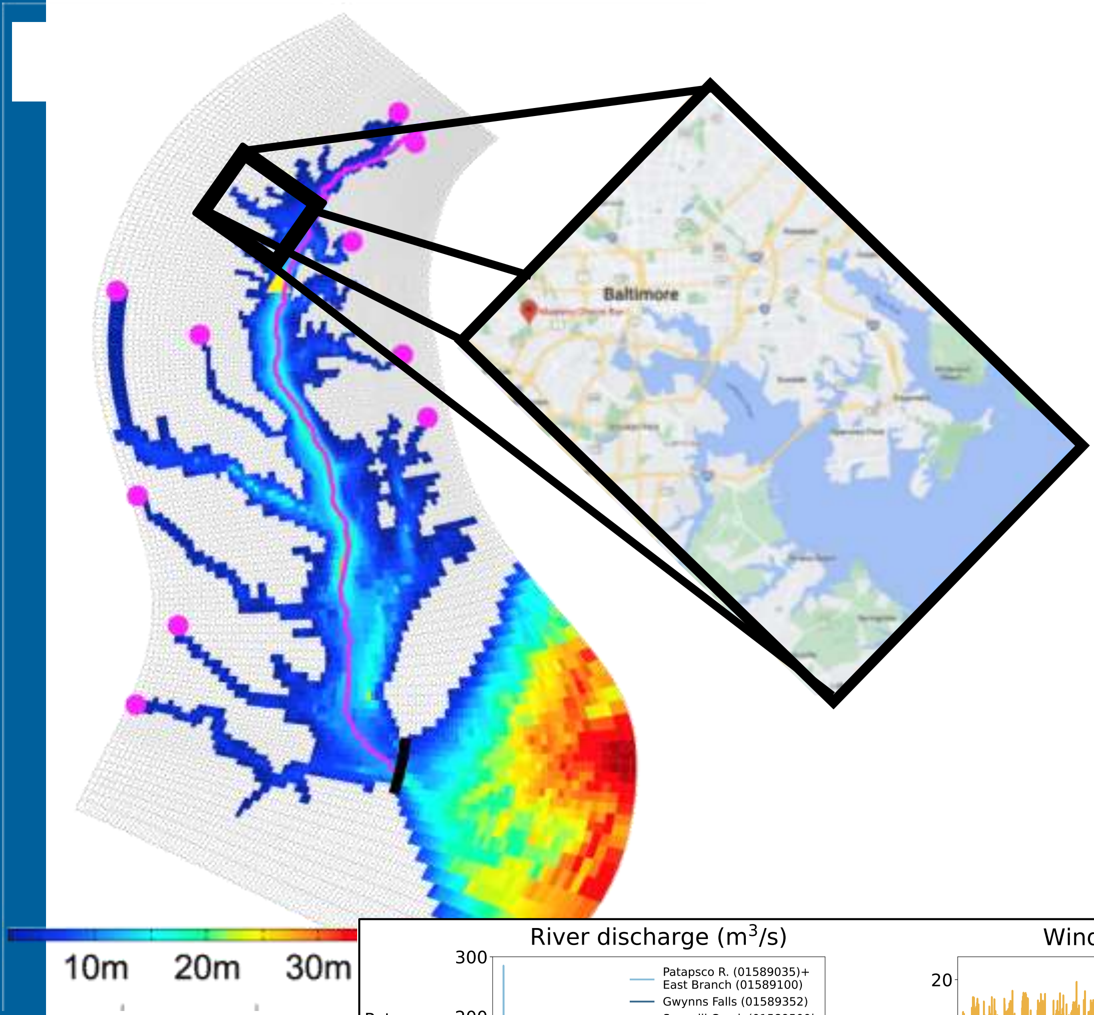
PI: Rob Hetland, PNNL

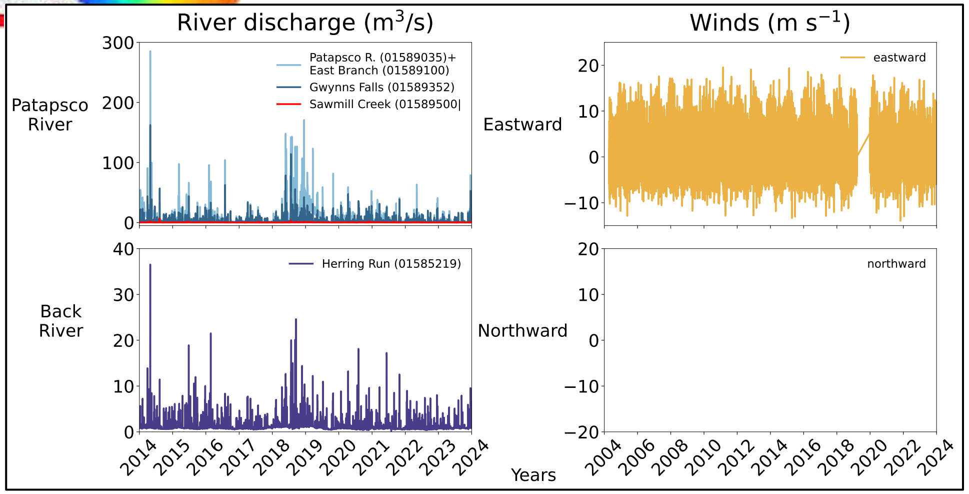
Goal: Improving predictive understanding of coastal systems by coupling Earth system components, each with application-appropriate detail, to understand the co-evolution and interdependencies of coastal regional processes and human systems, using the Great Lakes Region as a test bed.

Approach:

- Regional and cross-scale modeling, including extremely high-resolution land surface modeling
- Understanding interplay between agriculture and natural systems
- Agent-based models
- Understanding of lake processes

Early Career Award:
Toward a Predictive Understanding of Estuarine Biogeochemistry During Coastal Urban Floods in a Changing Climate





1. When cities flood, when and where are contaminants and nutrients from rivers, flooded sewers, and other sources transported, and how do they impact estuarine biogeochemistry?

2. How do changes in storm characteristics, water temperatures, and other aspects of climate change impact the results?

3. What aspects of this are predictable (or not) in different climates and locations?

Moriarty and Geller (in prep)

Upcoming Community Simulations

Emissions Driven Ensemble

RUBISCO will continue to develop simulation protocols for community simulations for CMIP7 and conduct new **emissions-driven ensemble** simulations **with E3SM and CESM out to year 2300 in which atmospheric CO_2** is allowed to freely evolve to address project research questions.

Simulations will include high, moderate, and stabilization emissions trajectories as well as a large net negative and zero emissions scenarios.

(ORNL, LBNL, NCAR)

RUBISCO

CESM & E3SM Comparisons

Two-model analysis of modes of variability with E3SM and CESM; COSP satellite simulators for E3SMv1 and CESM CAM6 for cloud amount biases; Initialized Earth system prediction with E3SM and CESM

Initialized S2D hindcasts with E3SM and CESM: E3SMv1 and CESM1 initialized for a limited set of start years with two different initialization methods - comparable skill for predicting the IPO using the historical large ensembles in both models with both initialization schemes (Meehl et al.,2023); https://project.cgd.ucar.edu/projects/CATALYSTInitialized Earth system prediction, SMYLE: CESM has been run - E3SMv2.1 SMYLE is currently being run

catalyst

catalyst

DYAMOND3 Leadership

Do models that explicitly resolve cloud-scale motions have different climate sensitivities than their coarse resolution predecessors? If so, why?

PCMDI and **E3SM/SCREAM** are jointly developing the experimental protocol for DYAMOND3 (one-year control simulation and one-year +4°C warming experiment):

- PCMDI (POC Mark Zelinka) is leading the scientific campaign and coordinating the international intercomparison.
- E3SM/SCREAM (POC Chris Terai) is developing and contributing the initial E3SM simulations.

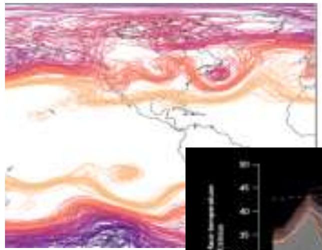
PCMDI
Earth System Model Evaluation Project

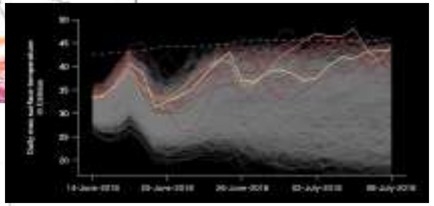
Low Likelihood High Impact (LLHI) Events

Huge Ensemble HENS (10,000's): Using FourCastNet and same ensembling techniques as operational weather centers

Validating HENS: Examine extremes using the same techniques as NWP

LLHIs in HENS: Study and quantify near-miss LLHIs in ultra-large counterfactuals of recent extremes (e.g., heat waves).



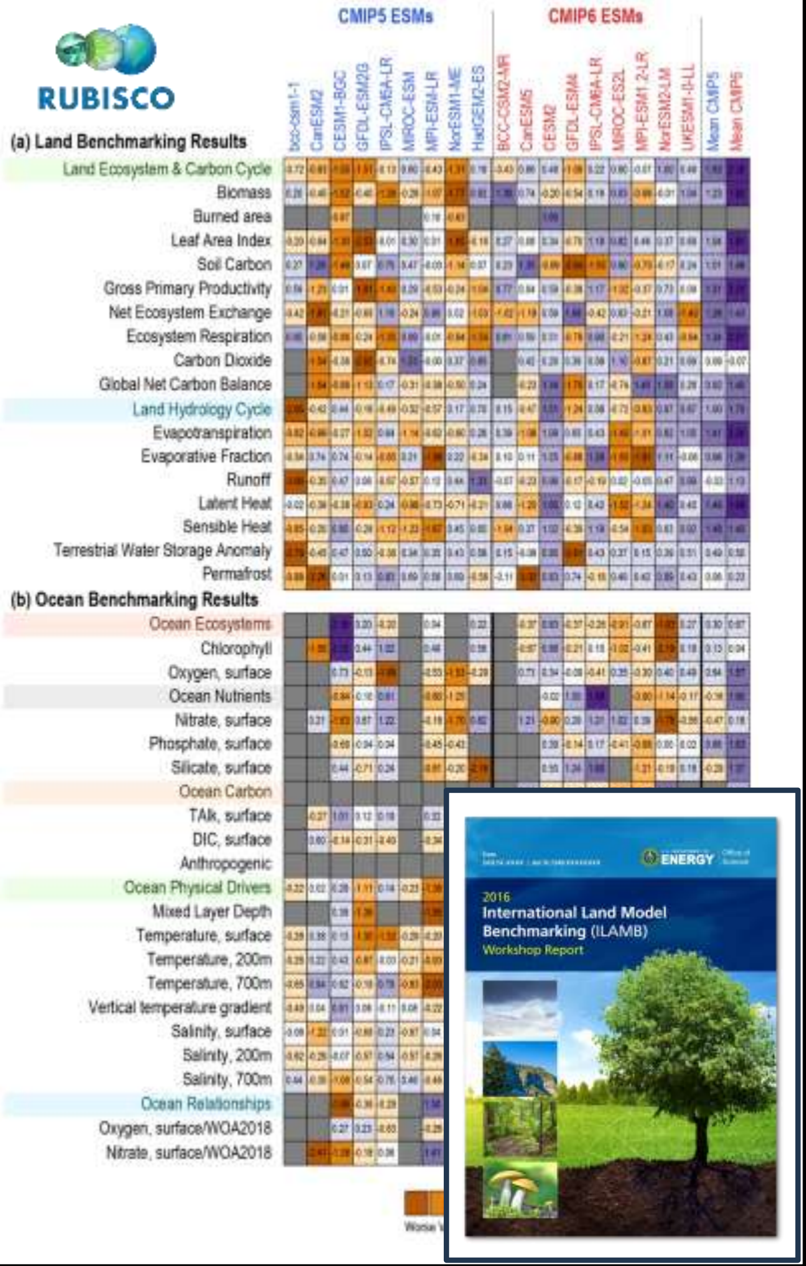


NVIDIA

CASCADE

Metrics

ILAMB/IOMB



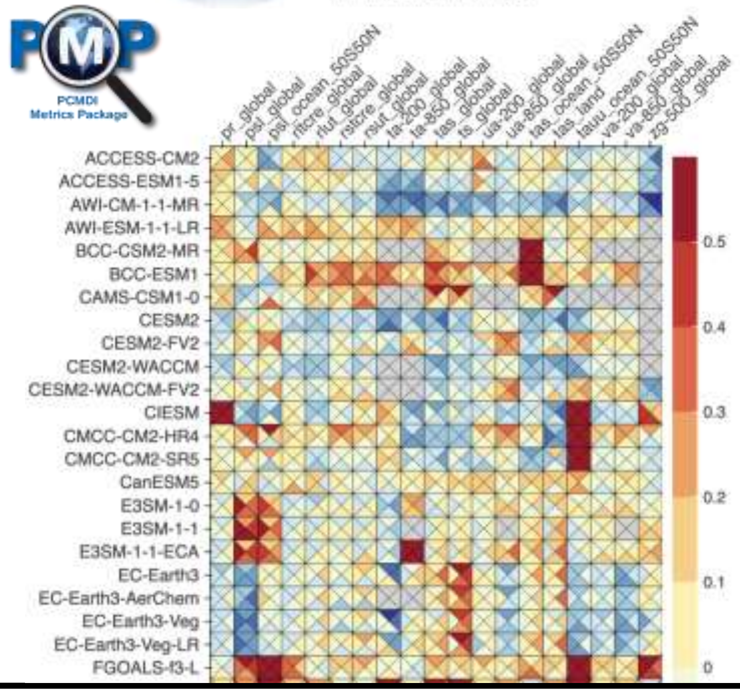
PCMDI Metrics Package

- Mean climate
- Simulated precipitation benchmarks
- El Niño Southern Oscillation (ENSO)
- Extratropical Modes of Variability
- Madden-Julian Oscillation (MJO)
- Monsoon characteristics
- Temperature and precip. extremes
- QBO-MJO Connections
- High-latitude metrics

CASCADE

catalyst

HiLAT



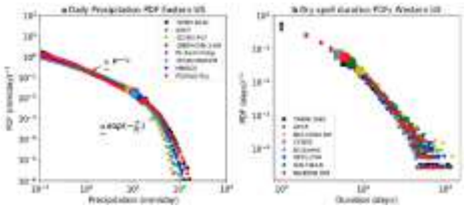
Coordinated Model Evaluation Capabilities (CMEC)

CMEC

A community framework for interoperable model evaluation packages and toolsets.

- Coastal metrics
- Drought metrics
- Connections to the Model Diagnostics Task Force

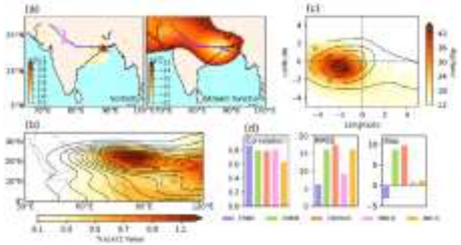
Exploratory Precipitation Metrics



WACCEM

WATER CYCLE AND CLIMATE EXTREMES MODELING

(Leung et al.. 2022 JCLIM)



Feature Tracking and Analysis Tools

TempestExtremes

A highly extensible and multifaceted framework for rapid feature detection, tracking, and scientific analysis of regional or global Earth system datasets supporting native grid systems.

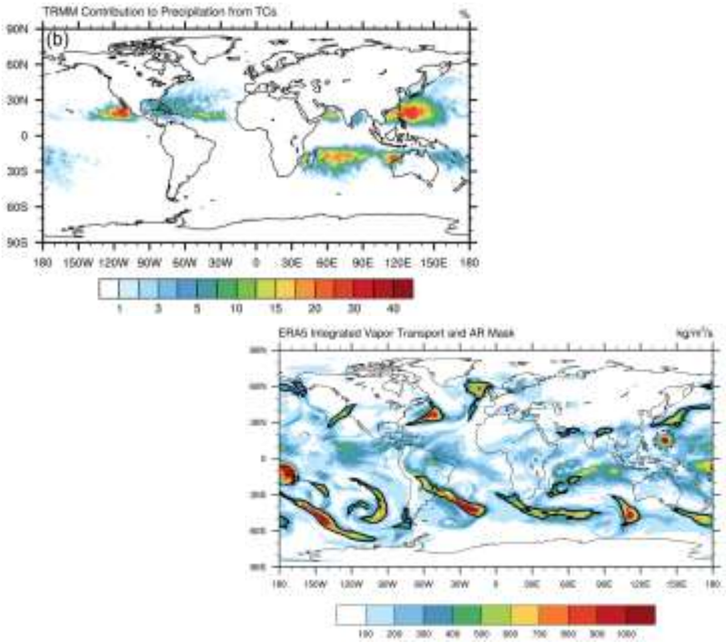


Figure: TempestExtremes TC precipitation and atmospheric river detection.

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

Toolkit for Extreme Climate Analysis (TECA)

A general-purpose, high-performance tool for detecting discrete events in climate model output. It leverages a map-reduce framework for efficient parallelization at large scales (order 10K+ cores).

Figure: TECA allows researchers to examine many distinct weather events—hurricanes, in this case—in an automated way.

CASCADE

PyFLEXTRKR

A powerful tool for tracking mesoscale convective systems (MCSs) and other features

Used to develop US (4 km, hourly) and global (10 km, hourly) **MCS tracking datasets** used by > 40 groups worldwide

WACCEM
WATER CYCLE AND CLIMATE EXTREMES MODELING

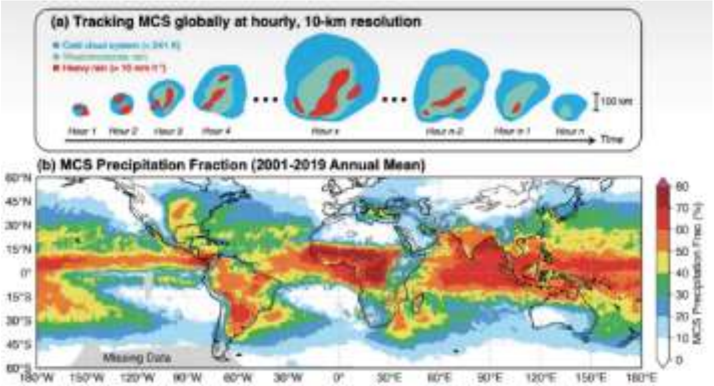


Figure: PyFLEXTRKR tracking algorithm and MCS tracking dataset.

Potential Role at CMIP7: Metrics and Benchmarking- Collaborations and Leadership

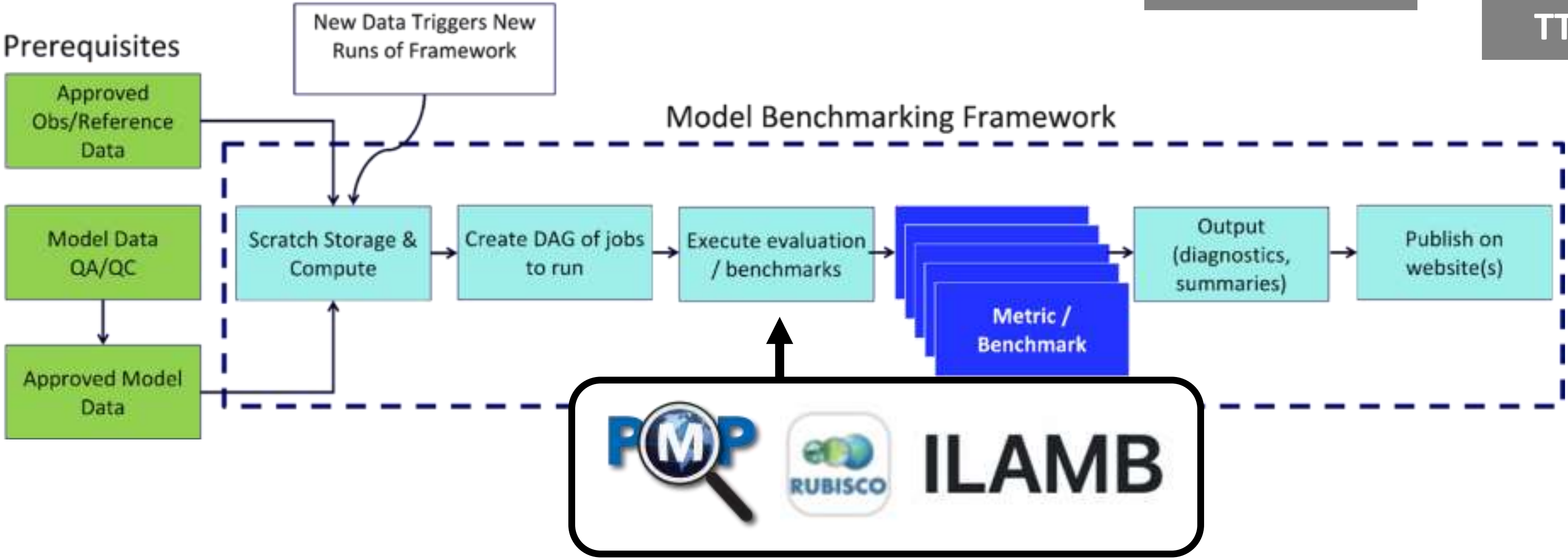
DOE EESM personnel are guiding model evaluation activities through the World Climate Research Programme (WCRP)

Birgit Hassler
TT Co-Lead

Forrest Hoffman
TT Co-Lead

Jiwoo Lee
TT Member

Proposal for **CMIP7 Rapid Evaluation Framework**



CMIP Model Benchmarking

Task Team Meeting @Germany, DLR (2024 May)

Workshops and Working Groups

CAMAS: Consortium for the Advancement of Marine Arctic Science

- Enhance international collaboration on Arctic marine science
- Develop and implement Arctic metrics
- Engage early-career scientists in Arctic marine research

CAMAS

RGMA Metrics Packages Tutorial Workshop Series

- Increase user base of RGMA-supported metrics packages
- Improve software, documentation, tutorial materials
- Encourage community contribution of new metrics
- https://climatemodeling.science.energy.gov/meetings/rgma-metrics-packages-tutorial-series

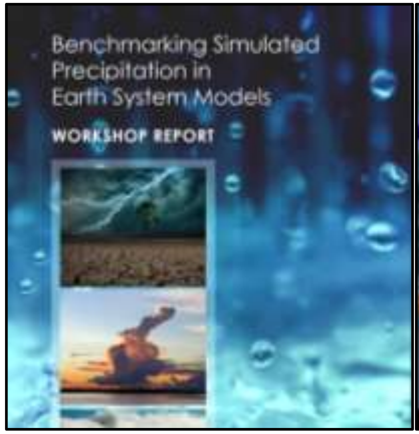
Featuring ILAMB/IOMB, PMP, CMEC, TempestExtremes, TECA, xCDAT and others

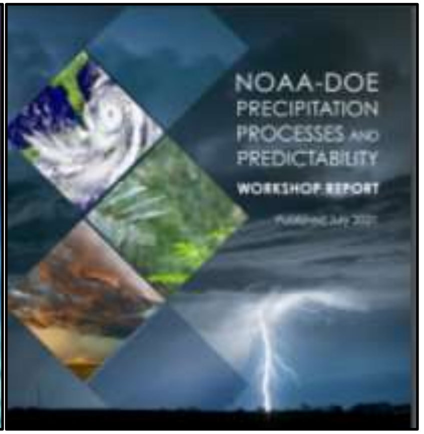
Understanding Decision-Relevant Climate Data Workshop

A meeting of scientists from DOE/PCMDI and DOD/SERDP, together with researchers, data producers, end-users and agency representatives to understand the state of the nation's decision-relevant regional climate datasets and projections.

PCMDI

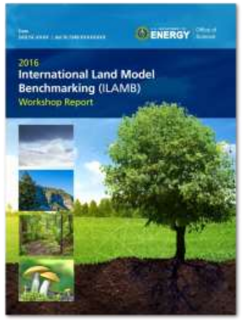
United States Global Change Research Program





Rubisco Community Working Groups

RUBISCO



Coming soon: A third international workshop to develop community priorities for model metrics and observational data in ILAMB

Connection to DOE BSSD

RGMA Leadership: Local to Global
Contributes to the EESM Integrated Modeling Framework

International

Metrics: ILAMB, PMP and CMEC highlighted along with ESMValTool
CMIP: Leadership on metrics panel; C4MIP leadership and contribution; Input4MIPs. 9 RGMA funded scientists on WCRP committees.
IPCC: Four lead authors for AR6; many contributors
HighResMIP & DYAMOND: CASCADE, WACCEM, PCMDI leadership
Software: TempestExtremes, TECA, CMOR, xCDAT
Global leaders in D&A of extremes, production of C20C simulations,

National

NCA5: 8 RGMA-funded chapter leads
Metrics: Ongoing collaboration with Model Diagnostics Task Force
Models: FOAs support E3SM and other models (GFDL, CESM, MPAS)
USCMS: Cofunded activities
MIPs: ARTMIP (atmospheric rivers), MCSMIP (mesoscale conv. syst.)
Workshops: Precipitation metrics (2019), precip. Predictability (2021), Upcoming RGMA Metrics Workshop + Tutorial

BER Connections

RUBISCO: Soil BGC WG emphasizes understanding of metagenomics
PCMDI: Providing credible decision-relevant data

EESSD Connections

ASR: Via THREAD SFA, PINACLES LES, and upcoming FOAs,
ESS: NGEE Tropics and NGEE Arctic (many joint science highlights)

Summary of Capabilities of Core Projects

E3SM: Use of the Big Iron (tackling the complex problems)
Multimodel & Hierarchical framework: Offers agility and adaptability
CATALYST: S2S Predictability, SMYLE for E3SM
CASCADE: Digital Earth and NVIDIA connections via FourCastNet
HyperFACETS: Expert guidance on climate data and co-production for stakeholders; bridge between E3SM and social needs
PCMDI: Credibility of big data; metrics and diagnostics frameworks; understanding cloud SST connections; ECS
WACCEM: Capabilities towards a Digital Earth, Leadership in MCS
HiLAT: Leadership in the high-latitude community

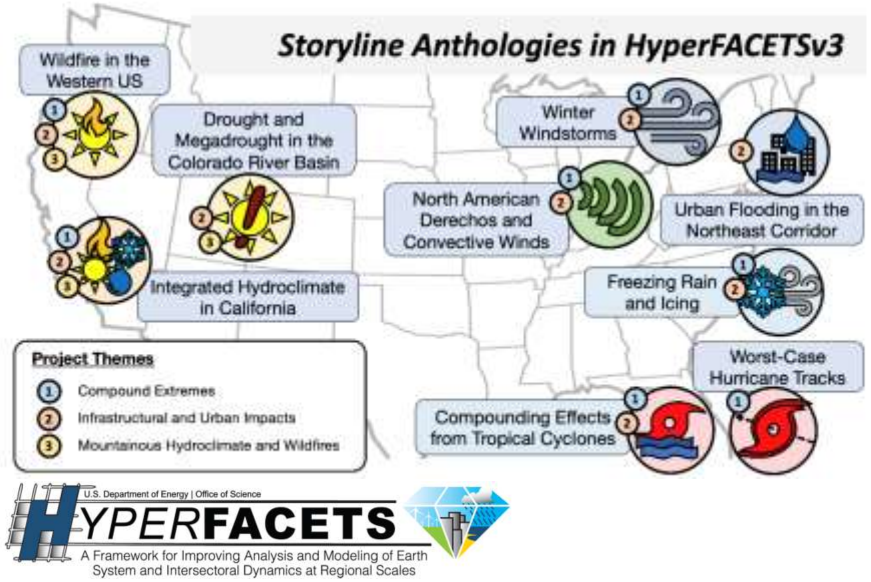
RGMA Weblinks: A resource for program and project information and connections

- DOE Regional and Global Model Analysis (RGMA) program area portal
- RGMA Overview and Status Report
- Information on over 30 current university grants (past and current)
- RGMA Scientific Focus Areas
- RGMA Tools and Datasets
- RGMA Co-operative Agreements and Federated Projects

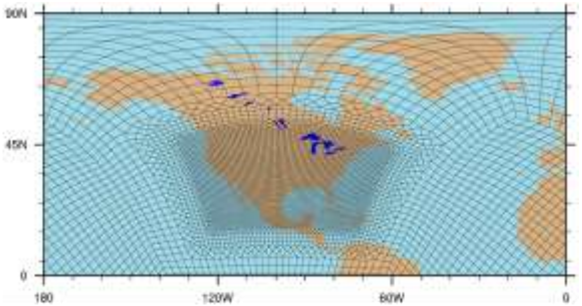
RGMA Web Links

Questions?

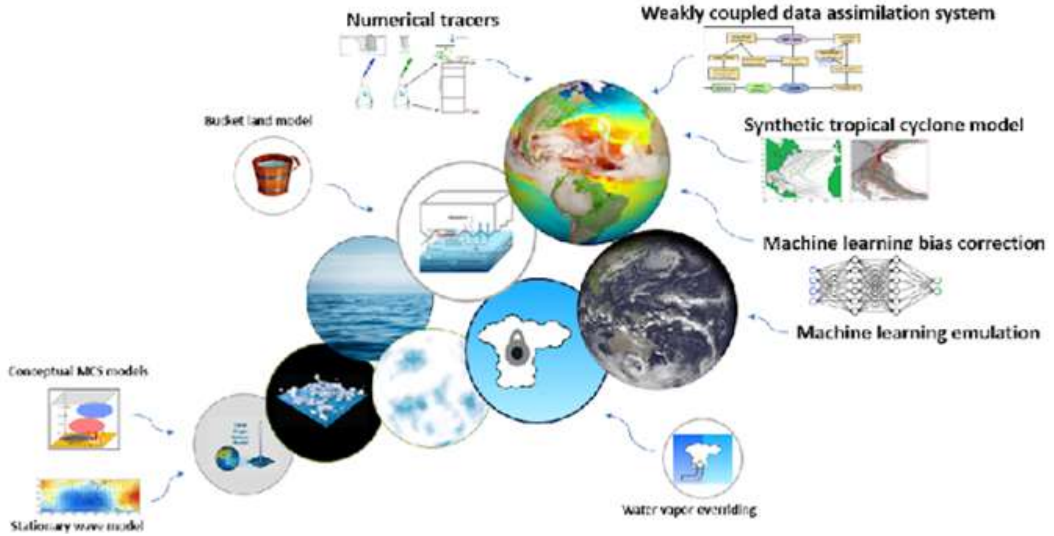
Storyline Simulations in HyperFACETS



Weather forecasts and hindcasts conducted using ***E3SM-RRM*** or ***WRF***. Rapid initialization on arbitrary grids using ***Betacast.***



E3SM Model Hierarchy and New Capabilities



WACCEM
WATER CYCLE AND CLIMATE EXTREMES MODELING

E3SM
Energy Exascale Earth System Model

Unique Capabilities

E3SM Arctic

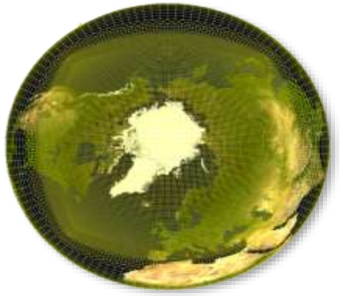
Arctic Amplification+ First Fully coupled RR Arctic simulations

- 10 km ocean/sea ice
- 25 km atmosphere/land

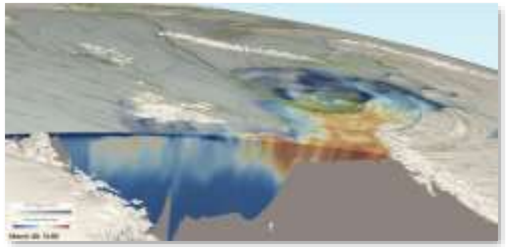
Simulations

- 1950-control
- Historical forcing (1950-2014) ensemble

HiLAT RASM

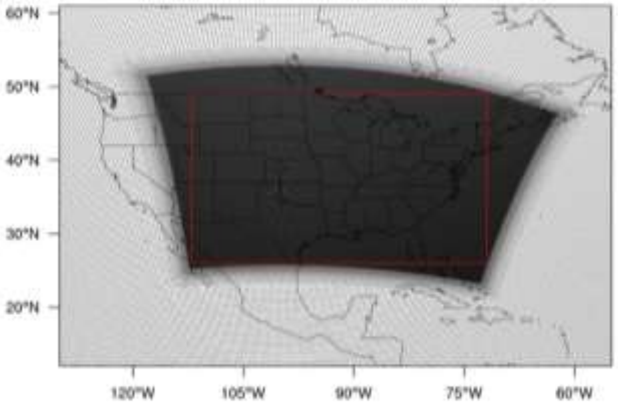


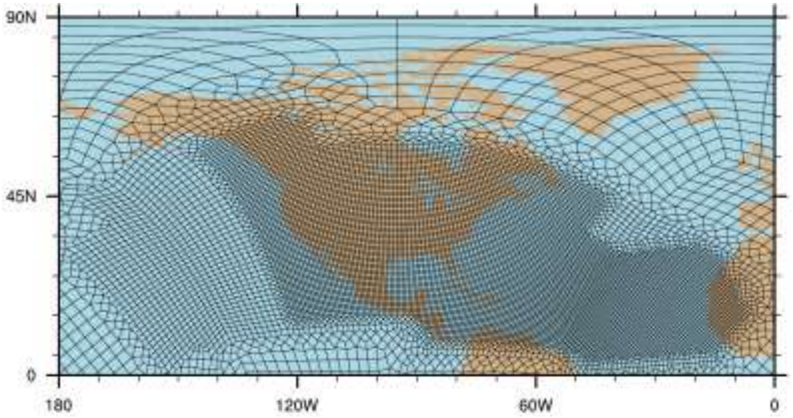
E3SM-Arctic atmospheric grid

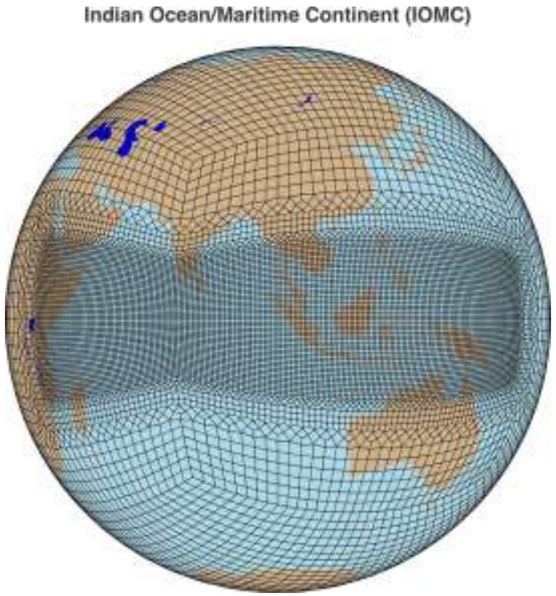


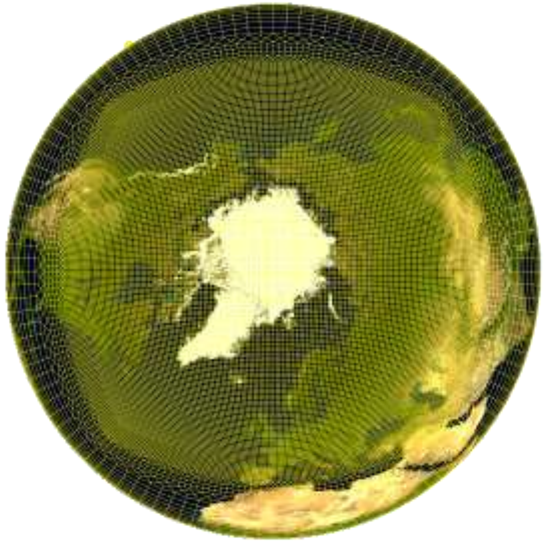
E3SM-Arctic: Cyclone in Barents Sea

Examples of Configurations of Regionally Refined E3SM being used in RGMA Projects

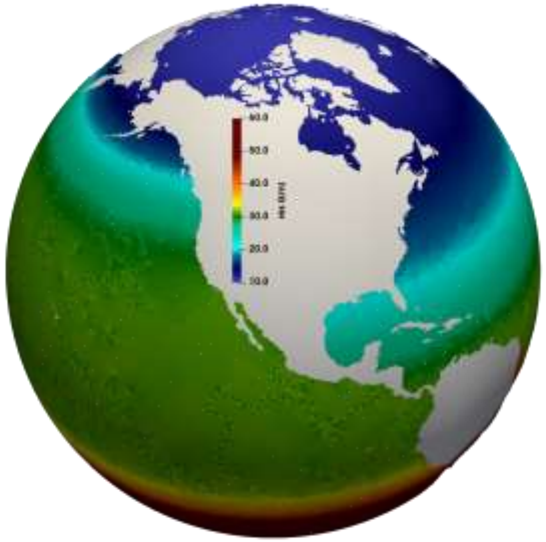








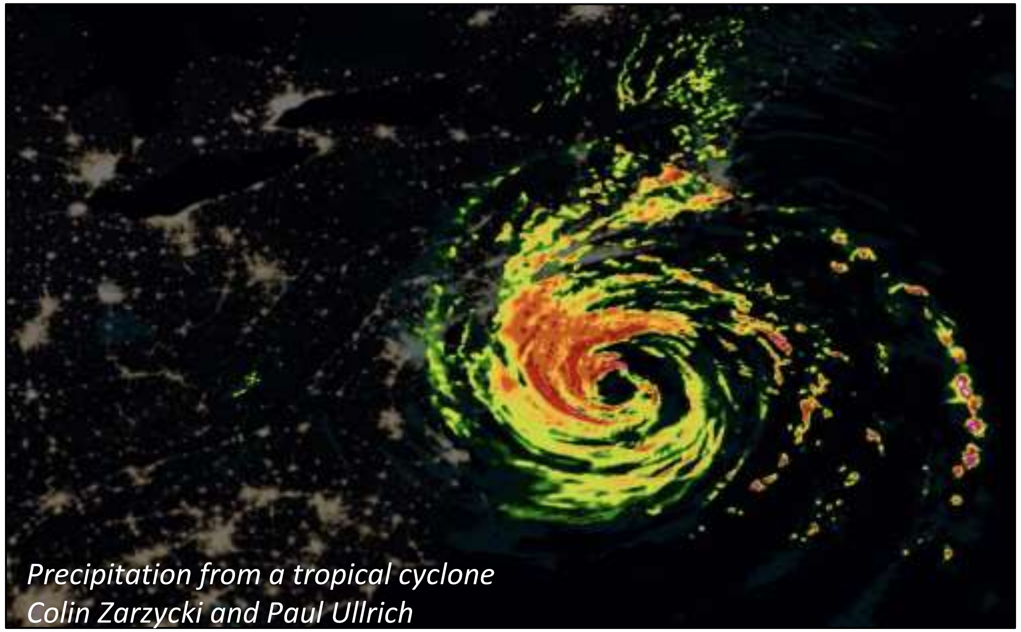
E3SM-Arctic atmosphere grid



E3SM-Arctic ocean grid

RGMA Towards EESM Integrated Modeling Framework


Heat wave over Los Angeles
Andrew Jones and Pouya Vahmani


Precipitation from a tropical cyclone
Colin Zarzycki and Paul Ullrich

RGMA contributes to the **EESM Framework** consisting of E3SM, and a broad suite of multi-models, and hierarchical, multiscale, and multi-sectoral models leads to unparalleled, often-sought, capabilities both nationally and internationally for scientifically and societally relevant questions.

EESM Websites, Newsletters, Weblinks, Youtube

Websites

https://climatemodeling.science.energy.gov (and ESMD,RGMA, MSD sites within)

https://e3sm.org/(exclusively E3SM)

https://multisectordynamics.org/

Newsletters and updates

- E3SM newsletter quarterly
- RGMA newsletter quasi-annual but EESM website is often updated
- MSD Community of Practice Newsletter

Blogs and YouTube

E3SM YouTube

RGMA YouTube

MSD Community of Practice Blog

Join Webinars and Working Groups

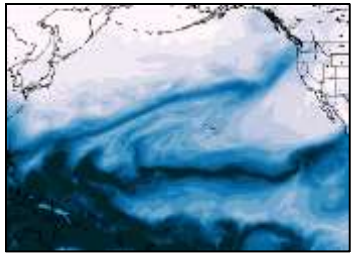
- E3SM All Hands Webinar
  - https://acme-climate.atlassian.net/wiki/spaces/ECM/pages/155287565/All-Hands+Presentations
- RGMA Communities Monthly webinars
  - On Extreme events (WACCEM & CASCADE) –Ruby Leung, PNNL
  - On Modes of Variability and Cloud Feedbacks (CATALYST & PCMDI) – Paul Ullrich, LLNL
  - On Biogeochemical Feedbacks (RUBISCO) – Forrest Hoffman
    - RUBISCO has 3 working groups: Soil Carbon, RUBISCO-Ameriflux, Soil Moisture
  - High Latitude Feedbacks (HiLAT-RASM)- Wilbert Weijer, LANL
    - CAMAS – Annual Consortium
- MSD Working Groups
- Open Science and FAIR Data
  - Human Systems Modeling Urban Systems
  - Uncertainty Quantification and Scenario Development
  - Multisector Impacts of Energy Transitions
  - Professional Development and Education for Early Career Scientists

CAlibrated and Systematic Characterization, Attribution, and Detection of Extremes (CASCADE) SFA (PI: Bill Collins, LBNL)

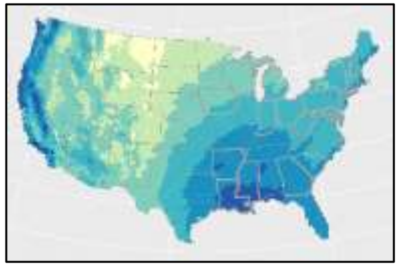
Goal: To advance understanding of singular climate extremes known as **low-likelihood, high-impact events (LLHIs)**, the drivers that cause them, and the evolution of these drivers in warmer climates

Extremes in the Observational Record
- Method and dataset development: tools for analysis of extremes at impact-relevant scales
- Characterization, detection, and attribution of extremes using in situ observations
- Evaluation of extremes in climate model simulations

Subseasonal to Multidecadal Variability in Extremes
- Forced responses in extremes versus responses to natural variability
- Multiscale interactions between extremes and their precursors
- Physical mechanisms driving variability and change in extremes



Observing and Modeling Extremes at Their Native Scales
- Multiscale processes and feedbacks required for hydroclimate extremes in climate simulations
- Toward theory-based understanding of multiscale extremes
- Multiscale convective processes and teleconnections

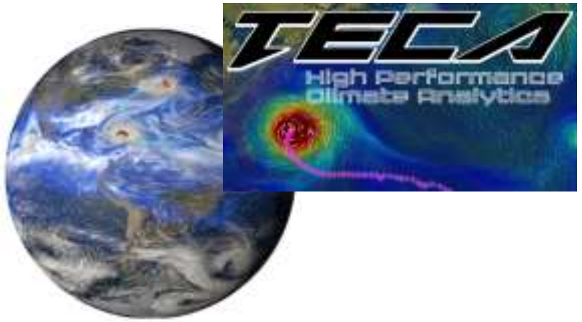


CAlibrated and Systematic Characterization, Attribution, and Detection of Extremes (CASCADE) SFA (PI: Bill Collins, LBNL)

Goal: To advance understanding of singular climate extremes known as **low-likelihood, high-impact events (LLHIs)**, the drivers that cause them, and the evolution of these drivers in warmer climates

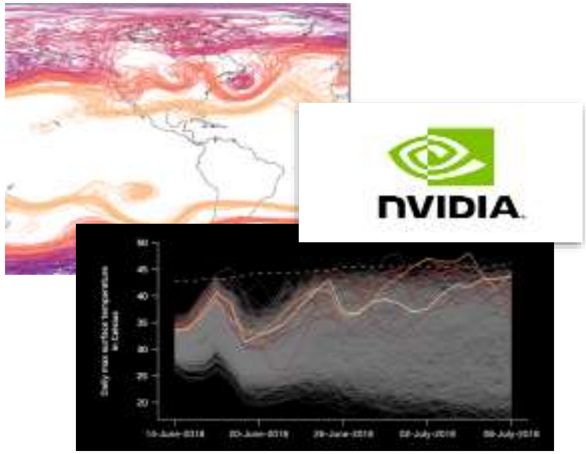
Toolkit for Extreme Climate Analysis (TECA)

TECA is a general-purpose, high-performance tool for detecting discrete events in climate model output. It leverages a map-reduce framework for efficient parallelization at large scales (order 10K+ cores). It incorporates ML layers in TECA pipelines (e.g., FourCastNet).



Huge Ensembles of NN Simulations

Huge ensembles of hindcast simulations, with complementary large ensembles from CATALYST. Allows for greater statistical significance and more opportunity for producing LLHIs in models.



Capabilities and Tools

20th Century Plus Project (C20C+) simulations for detection and attribution.

Atmospheric River Tracking Method Intercomparison Project (**w/ CATALYST, HyperFACETS & WACCEM**)

HighResMIP Data Lake @ NERSC

Bayesian approach for PCA and SVD with **ensemble gridded datasets of temperature and precipitation**

Community scientific software products (TECA, climextRemes, fastKDE, and others available from https://cascade.lbl.gov/software-products)

Water Cycle and Climate Extremes Modeling (WACCEM) SFA

(PI: Ruby Leung, PNNL)

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

WACCEM
WATER CYCLE AND CLIMATE EXTREMES MODELING

RE1. Large-Scale Circulation

1A. Midlatitude stationary waves and extremes

1B. Tropical circulation and intraseasonal variability

RE2. Mesoscale Convection

2A. Mesoscale convective organization over tropical ocean

2B. Extreme mesoscale convective systems over land

RE3. Surface-Atmosphere Interactions

3A. Local and remote land-atmosphere interactions

3B. Land-atmosphere-ocean interactions

Extreme events: heatwaves, storms and extreme precipitation, floods, droughts

Pacific Northwest NATIONAL LABORATORY

PennState

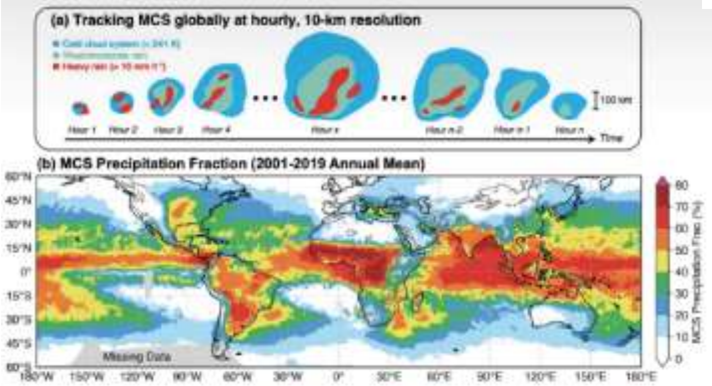
COLUMBIA UNIVERSITY

Water Cycle and Climate Extremes Modeling (WACCEM) SFA

(PI: Ruby Leung, PNNL)

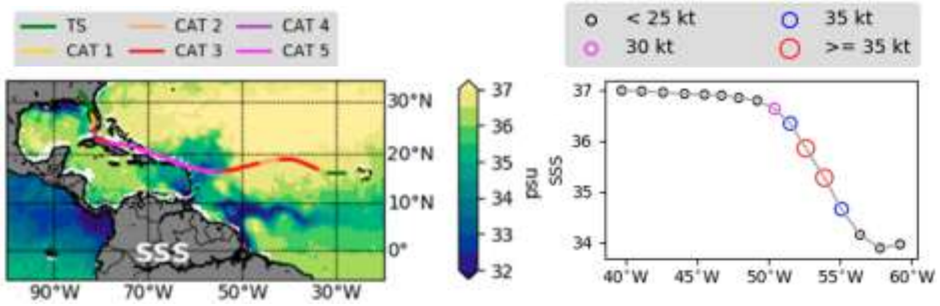
- **PyFLEXTRKR** for tracking mesoscale convective systems (MCSs) and other features.
- Developed US (4 km, hourly) and global (10 km, hourly) **MCS tracking datasets** used by > 40 groups worldwide.
- Developed **a high-resolution (9 km) MCS regional reanalysis (TMeCSR)** to accelerate tropical MCS research.
- **A statistical rapid intensification (RI) prediction scheme** including surface salinity as predictor, which significantly improves RI detection skill and is being tested at NOAA AOML for operational RI forecasting
- **Exploratory precipitation metrics** including spatiotemporal characteristics, process-oriented, and phenomena-based metrics.

PyFLEXTRKR and global MCS tracking data



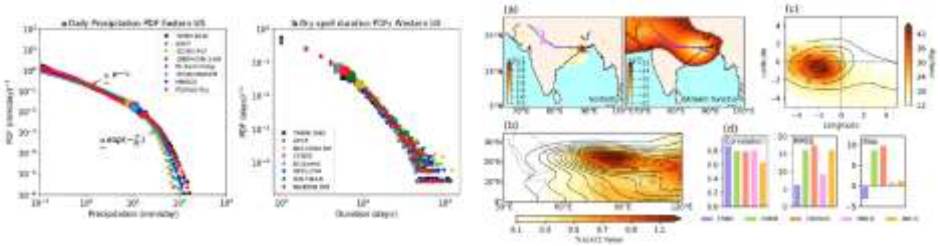
(Feng et al. 2021 JGRA)

Surface salinity effect on hurricane intensification



(Balaguru et al. 2020 BAMS)

Exploratory precipitation metrics



(Leung et al.. 2022 JCLIM)

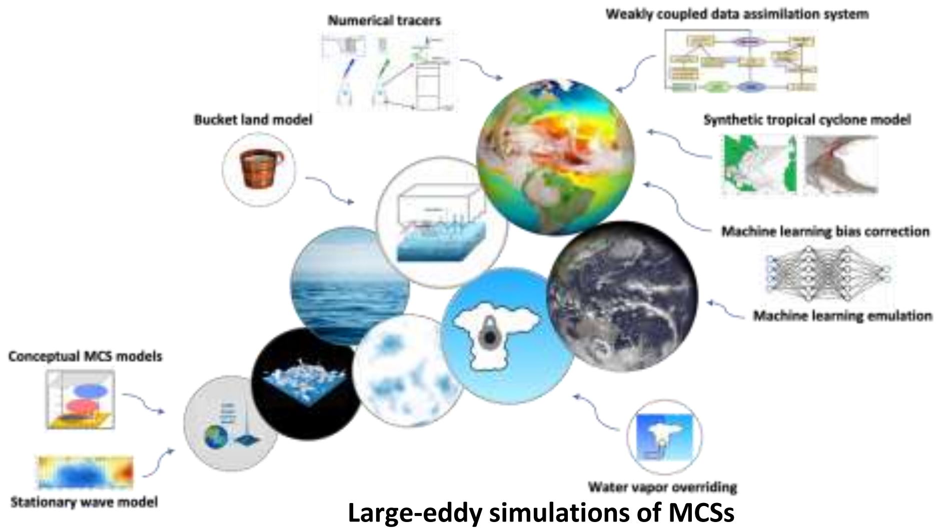
Water Cycle and Climate Extremes Modeling (WACCEM) SFA

(PI: Ruby Leung, PNNL)

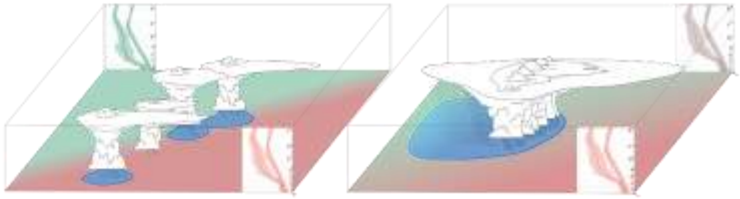
WACCEM enhances E3SM as a "digital Earth" for scientific discovery

- A **E3SM model hierarchy** with different complexity levels and mechanisms denial for hypothesis testing
- A **weakly coupled data assimilation system** in E3SM for predictability studies (will complement with **CATALYST SMYLE**)
- A **tracer-enabled E3SM (WT-E3SM)** for studying land-atmosphere interactions and moisture recycling (**work with EC PI and Univ PI**)
- A library of convection permitting and large-eddy simulations of MCS to study and contrast convective self-aggregation and MCSs
- Response of the boreal summer intraseasonal oscillation (BSISO) and associated extremes to future warming
- Local and remote land-atmosphere interactions on S2S predictability of hydrological extremes

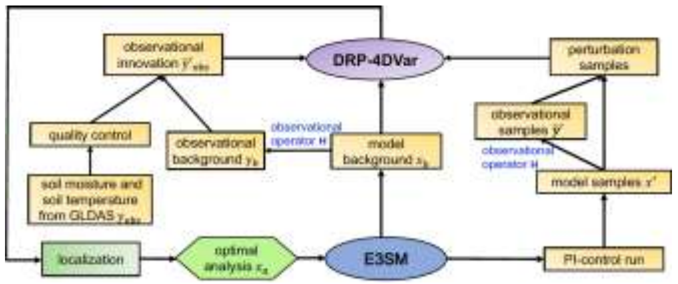
A E3SM model hierarchy and new capabilities



Large-eddy simulations of MCSs



A weakly coupled land data assimilation system in E3SM



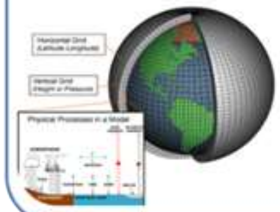
(Shi et al. in review GMD)

catalyst

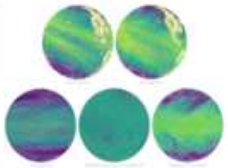
Cooperative agreement to analyze variability, change and predictability in the earth system

Focus on **modes of Earth system variability and change** to explore the limits to predictability, identify fundamental underlying mechanisms, quantify interactions among modes of variability and associated high impact events, and discover tipping points in the Earth system

PI: Gerald Meehl co-PI: Jadwiga (Yaga) Richter project manager: Nan Rosenbloom



Research Objective 1 (Lead: Aixue Hu)
Use a combination of Earth system models and machine learning methods to understand modes of variability and their limits of predictability on subseasonal to decadal timescales



Research Objective 2 (Lead: Brian Medeiros)
Use a hierarchy of models to understand relevant processes and feedbacks related to how modes of variability interact with each other

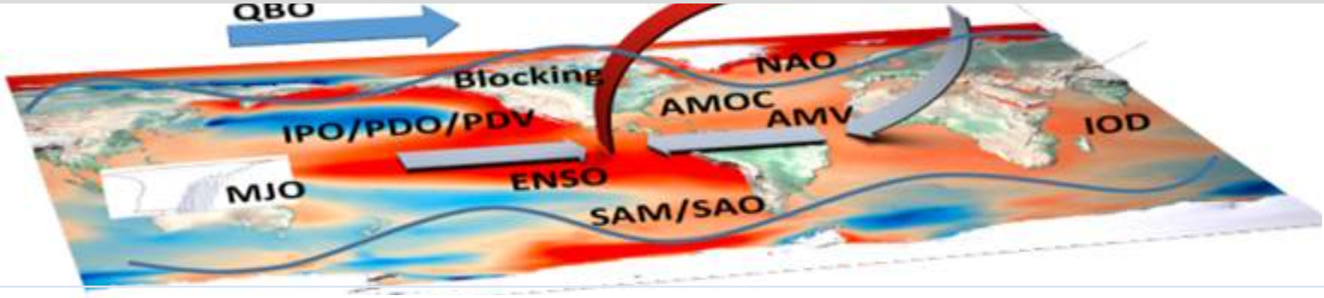
Research Objective 3 (Lead: John Fasullo)
Examine the simulation of internal modes of variability, tipping points, and connections between them in a changing climate

Research Objective 4 (Lead: Christine Shields)
Use high resolution ESMs, RRMs, and ML methods to investigate the relationships between high impact events, the synoptic systems that produce them, and their interactions with modes of variability

Research themes across CATALYST:

- Two-model analysis of modes of variability with E3SM and CESM
- Initialized Earth system prediction with E3SM and CESM
- Machine learning analysis and prediction of modes of variability
- Antarctic atmospheric river analysis of observations, E3SM and CESM using ML methods

CATALYST scientific and capability priorities



- **E3SM large ensembles & CESM-E3SM comparisons:** 20-member E3SMv2 future climate (SSP3.70) ensemble, building on a collaboration with Chris Golaz (LLNL) to produce a 20-member historical+future large ensemble with E3SMv2. Additionally, CATALYST scientists, in collaboration with university scientist Samantha Stevenson (UCSB), contributed to the completion of the ensemble members making up the E3SMv1-LE (Fasullo et al., Earth Sys. Dyn., 2023). Other E3SM-CESM papers in the notes below
- **Initialized Earth system prediction, E3SM SMYLE:** addresses seasonal to multiyear timescales (E3SM v2) are currently underway. When completed, this effort will produce 20-member ensemble hindcasts, initialized quarterly between 1970-2019 (four start dates per year) and integrated for 24 months and will be comparable to the CESM2 SMYLE simulations. https://project.cgd.ucar.edu/projects/CATALYST/E3SM/E3SMv21-SMYLE/
- **Initialized Earth system prediction, E3SMv2.1 S2S-control:** These E3SMv2.1 simulations will be a subseasonal reforecast initialized with observed and analysis-based atmospheric, ocean and sea ice, and land ICs with weekly starts between October and March from 1999 to 2022, simulation length of 45 days, and an 11-member ensemble. `
- **Earth system prediction and projection:** E3SM and CESM simulations will be run with large ensembles of 20 year projections using historical model simulations for initial states, compared to 10 year simulations initialized from comparable observed initial states

Quantify the predictability of time-evolving regional climate through hypothesis-driven research focused on modes of variability

- **Explore the role of tropical Pacific, Atlantic, and Indian Ocean SSTs in the predictability (**MJO, NAO, south Asian monsoon) across S2S timescales; and on the predictability of PDV, AMV, and related AMOC variability on ***seasonal-to-decadal*** (**S2D**) timescales. **Evaluation of processes is essential to understanding sources of skill for initialized Earth system predictions in E3SM and CESM.**

- **Explore time scale interactions in initialized Earth system predictions with E3SM and CESM** to address the hypothesis that longer and shorter term processes alternately assert an influence on each other; (e.g. ENSO-IPO; MJO-ENSO); **Understanding time scale interactions will provide vital insights into relevant processes that provide skill in initialized Earth system predictions with E3SM and CESM.**

- Use **ML methods** to provide insight into, and to complement, initialized predictions with Earth system models & Contribute to Metrics

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

PI: Forrest M. Hoffman (ORNL), Sr. Science Co-Lead: William J. Riley (LBNL), and Chief Scientist: James T. Randerson (UC Irvine)

Overarching Phase 3 Science Questions

1. How can observational constraints and models be used to identify and reduce uncertainties in terrestrial and oceanic carbon sinks?
2. How can advances in machine learning be leveraged to improve understanding of biospheric processes and their representation in Earth System Models?
3. What is the contribution of the carbon–climate feedback to future climate and biospheric variability on interannual to multi-decadal timescales?
4. What are the key pathways and strengths of global ecological teleconnections?

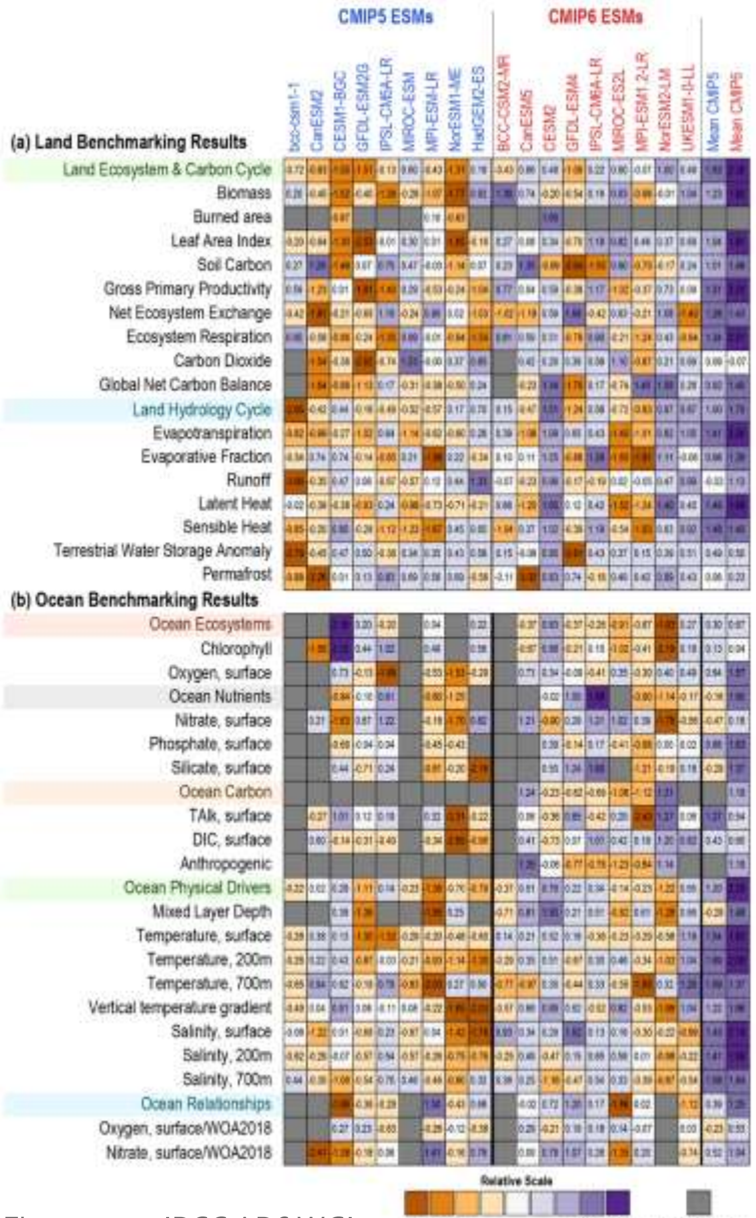
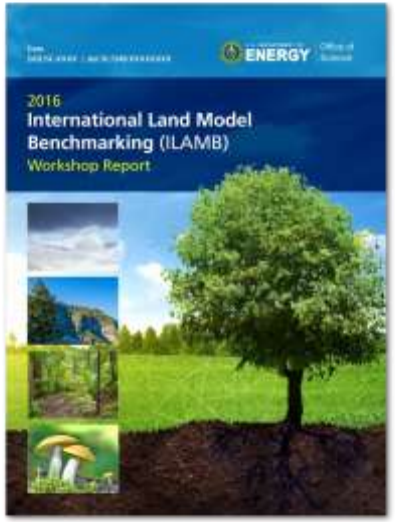


Figure 5.22, IPCC AR6 WGI

RUBISCO leads the development of the International Land Model Benchmarking (ILAMB) and International Ocean Model Benchmarking (IOMB) packages for community multi-model evaluation.

We used ILAMB and IOMB to compare CMIP5 vs. CMIP6 models (IPCC AR6).



Model: E3SM v1.1	CTC		ECA
BGC configuration	CN	CNP	CNP
CMIP (total: 1050 yrs)			
piControl	x	x	
1pctCO2	x	x	x
abrupt-4xCO2		x	
C4MIP (total: 900 yrs)			
1pctCO2-bgc	x	x	x
1pctCO2-rad	x	x	x
LS3MIP (total: 1440 yrs)			
land-hist	x	x	
land-hist-cruNcep	x	x	
land-hist-princeton	x	x	
Factorial experiments (total: 480 yrs)			
climate only		x	
CO2 only		x	
nitrogen deposition only		x	
land use and land cover change only		x	
CMIP with new surfdata and LU (total: 300 yrs)			
piControl		x	
Historical		x	
ScenarioMIP (total: 319 yrs)			
SSP5-8.5		x	
SSP3-7.0		x	
SSP1-2.6		x	
SSP5-3.4OS		x	

We conduct CMIP and related simulations of E3SM and CESM for our science and community research

Community Leadership

RUBISCO

RUBISCO organizes topical working groups for the research community aimed at synthesizing observational data and developing metrics for constraining models

Berkeley Lab · NCAR National Center for Atmospheric Research · Oak Ridge National Laboratory · Sandia National Laboratories · University of California Irvine · Michigan

RUBISCO SOC working group

BSSD Connection..

RUBISCO

- **Global Data Synthesis** – spatial and vertical distribution
- **Model–Data Integration** – benchmarking and UQ

- 51 participants from 25 institutions globally.
- Conference calls monthly
- Annual meeting at participating institutions.

nature communications

Article

Global soil profiles indicate depth-dependent soil carbon losses under a warmer climate

Soil Science Society of America Journal

PEDOLOGY

Empirical relationships between environmental factors and soil organic carbon produce comparable prediction accuracy to machine learning

Umakant Mishra | Kyongmin Yeo | Kabindra Adhikari | William J. Riley | Forrest M. Hoffman | Corey Hudson | Sagar Gautam

https://doi.org/10.5194/essd-2022-232
Preprint. Discussion started: 25 July 2022
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Earth System Science Data

On the magnitude and uncertainties of global and regional soil organic carbon: A comparative analysis using multiple estimates

RESEARCH ARTICLE

WILEY

Continental United States may lose 1.8 petagrams of soil organic carbon under climate change by 2100

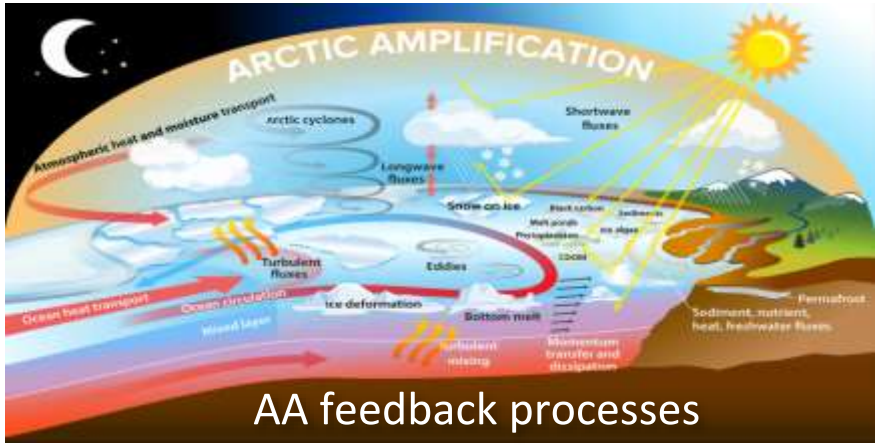
Sagar Gautam | Umakant Mishra | Corinne D. Scown | Skye A. Wills | Kabindra Adhikari | Beth A. Drewniak

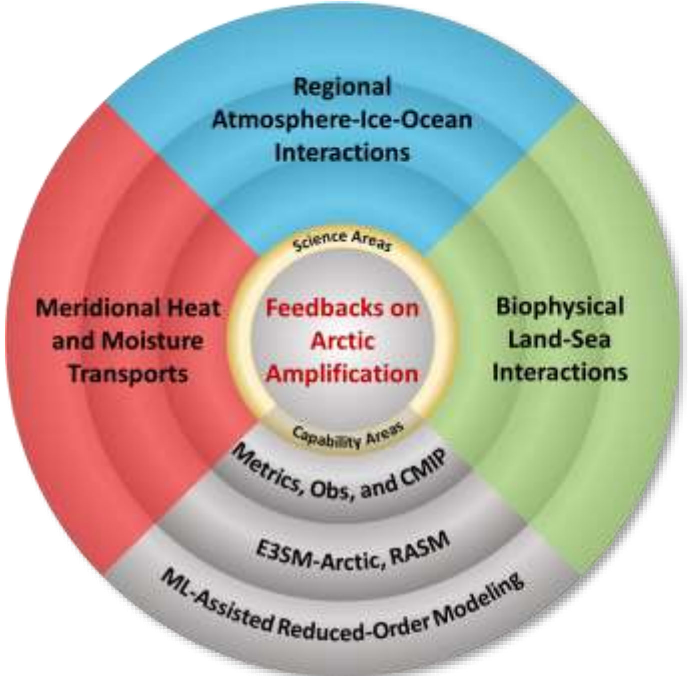
High-Latitude Application and Testing of Earth System Models (HiLAT-RASM) (PI – Wilbert Weijer, LANL)

Focus: Feedbacks on Arctic Amplification

Addressing three science areas

- Meridional Heat and Moisture Transports
- Arctic Atmosphere-Ice-Ocean Interactions
- Biophysical Land-Sea Interactions





Building three cross-cutting capabilities

- E3SM-Arctic and RASM modeling tools
- Reduced-Order Modeling tools assisted by Machine Learning
- CMIP5/6 data, Reanalysis Products, Observations, and Metrics

Current HiLAT-RASM Science (in notes) & Capabilities

E3SM-Arctic

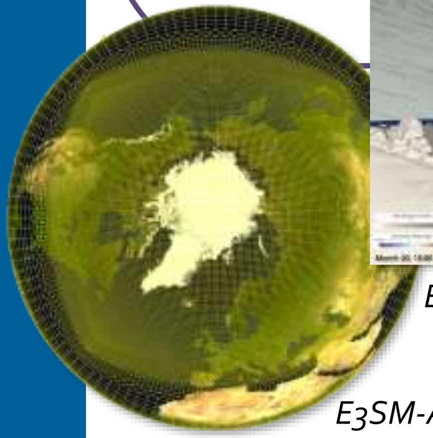
- Configuration of Energy Exascale Earth System Model with grid refinement in the Arctic in all model components (with E3SM)
  - 10 km ocean/sea ice
  - 25 km atmosphere/land
- Designed for investigating processes and feedbacks contributing to Arctic Amplification
- Simulations
  - 1950-control
  - historical forcing (1950-2014) ensemble

RASM

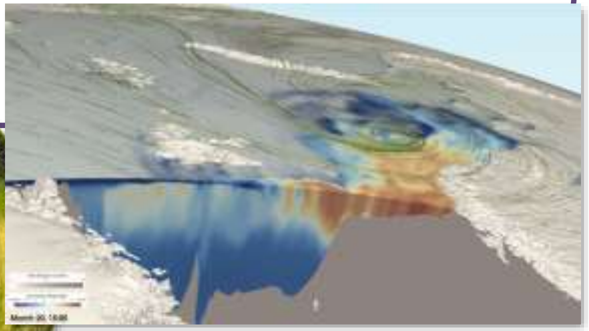
- Regional Arctic Earth System Model
  - 9 km ocean/sea ice/BGC (1/12°)
  - 50 km atmosphere/land
- Dynamical downscaling of
  - Reanalyses (ERA-I, CFS)
  - ESMs (E3SM, CESM)
- Optimization experiments with varying parameter space
- Recent simulations w/ ocean/sea ice at ~2 km (1/48°)

E3SM Slab Ocean Model

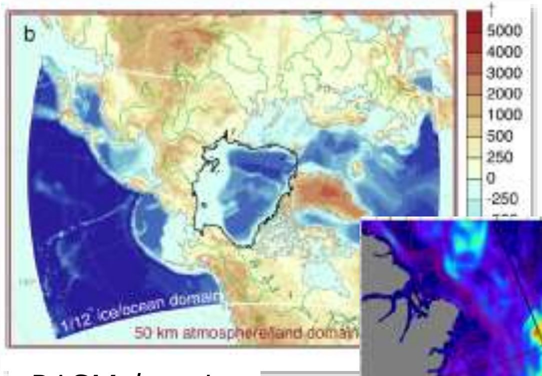
- SOM replaces MPAS dynamic ocean to simulate SST and sea ice based on climatology of ocean mixed-layer depth and heat transports (from E3SM or CESM)
- SOM reproduces baseline climate and ECS in fully coupled E3SMv2
- Invaluable tool for hierarchical modeling and E3SM tuning



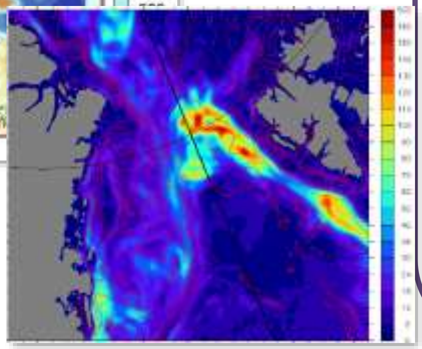
E3SM-Arctic atmospheric grid



E3SM-Arctic: Cyclone in Barents Sea



RASM domain



RASM: Kinetic energy in Fram Strait

Metrics

- Metrics to evaluate the model spatial representation of sea ice and quantify biases in ESMs
- Various Arctic Amplification quantification metrics applicable to observations, reanalysis, and models

HiLAT-RASM Science & Capabilities

Community Activities

We will organize community activities to strengthen the science commu

- CAMAS: Consortium for the Advancement of Marine Arctic Science
  - Enhance international collaboration on Arctic marine science
  - Develop and implement Arctic metrics
  - Engage Early-Career scientists in Arctic marine research
- RGMA Metrics Packages Tutorial Series (with PCMDI, RUBISCO,CASCADE)
  - Increase user base of RGMA-supported metrics packages
  - Improve software, documentation, tutorial materials
  - Encourage community contribution of new metrics

- Quantify of Arctic Amplification (AA) feedbacks
  - Impact of Meridional Heat and Moisture Transports on AA
  - Impact of Atmosphere/Ice/Ocean Interactions on AA
  - Impact of Biophysical Processes on AA
- Get impact of high-res Arctic
- Understand tipping points in the Arctic system
- Understand the causes of and reduce persistent Arctic model biases in the response to internal variability and forcings

Arctic Metrics

- We will develop Arctic-relevant metrics for process understanding and model evaluation
- We will contribute sea ice/ocean metrics to RGMA-funded metrics packages (collaboration with PCMDI)

Reduced-Order Models

We will develop Reduced-Order Models of the Arctic Earth System using the latest advances in Dynamical Systems Theory and Machine-Learning

- Hierarchy of ROMs for capturing range of complexities in feedbacks
- Data driven causal inference
- Public facing code package

High-Resolution Arctic Modeling

We will continue to push the boundaries of high-resolution Arctic modeling. Developments:

- E3SM-Arctic with 2.5 km ocean/sea ice
- RASM with 2.4 km ocean/sea ice, and 25 km atmosphere

PCMDI
Earth System Model Evaluation Project

Goal

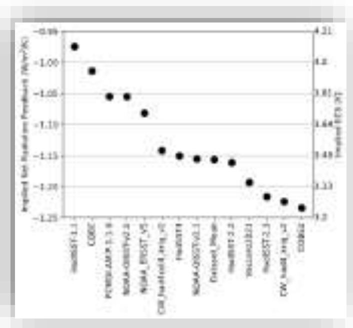
To quantify & reduce uncertainties in Earth System variability, forcing & response

Research

Interpreting Earth System Changes
Improving understanding of human and natural effects on the climate system

Constraining Cloud and Precipitation Processes
Reducing uncertainties in future projections from the response of clouds, precipitation and other feedbacks

Performance Metrics & Novel Diagnostic Capabilities
Objective benchmarks for Earth System Models

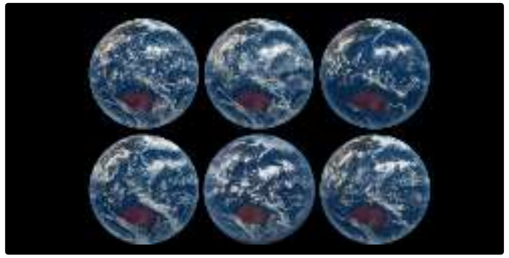


UNDERSTANDING SST PATTERN SENSITIVITIES

Observed SST datasets differ significantly in their pattern of change; these differences could be responsible for up to a degree of spread in ECS. Using E3SM we are examining the regional consequences of these differences.

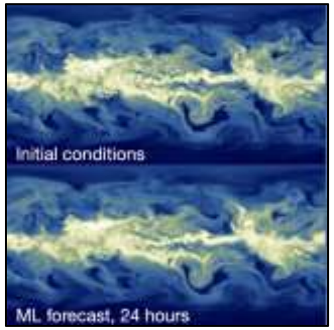
EVALUATING AI/ML GENERATED DATA

AI/ML generated weather and climate data is rapidly coming online. PCMDI seeks to develop new evaluation capabilities suitable for these emerging datasets.



DYAMOND3

Do models that explicitly resolve cloud-scale motions have different climate sensitivities than their coarse resolution predecessors? If so, why? In collaboration with E3SM and international partners seeks to deepen our understanding of these models.



UNDERSTANDING DECISION-RELEVANT CLIMATE DATA

Leverage deep PCMDI global climate data experience to (a) understand the current state of national decision-relevant climate data products, (b) develop a coordinated national climate data strategy, (c) develop metrics and diagnostics that are applicable to decision-relevant climate data.

A collaboration w/ SERDP

PCMDI
Earth System Model Evaluation Project

Leadership & Service

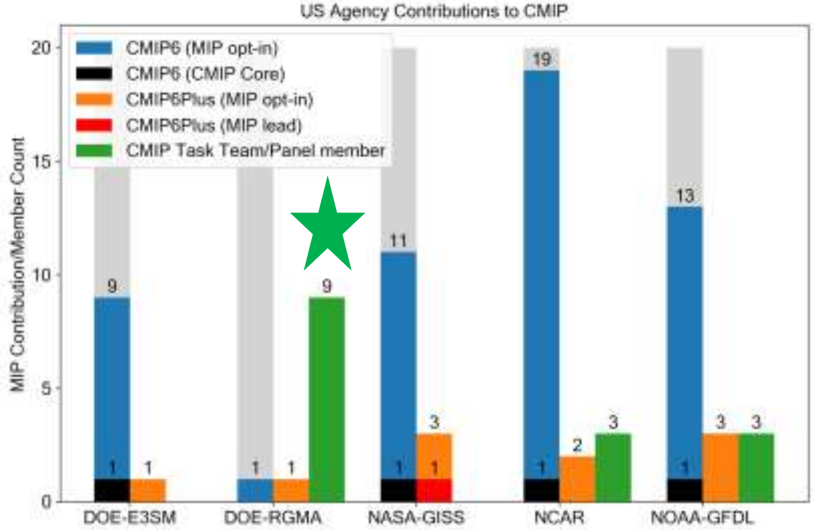
Model Intercomparison Project Science
Leading the science, design, implementation, and delivery of international MIP activities since 1989

Software Development and Data Provisioning
Forging a tighter bond between observationalists, model diagnosticians and model developers, accelerating the development of Earth System Models.

UXARRAY

New user-friendly functionality for seamlessly analyzing unstructured and native grid data. In collaboration with SEATS and CESM Community.

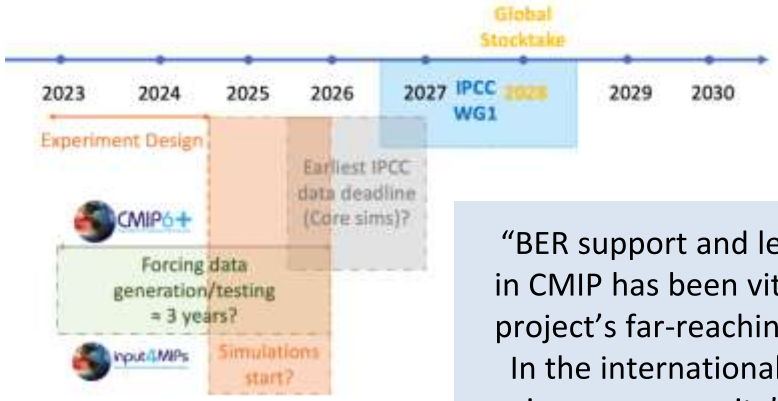
SUPPORTING CMIP ENGAGEMENT



CMEC
Coordinated Model Evaluation Capabilities

Standards and software to enhance interoperability of climate data evaluation packages from throughout the climate community. In collaboration with the Model Diagnostics Task Force (NOAA).

BUILDING THE CMIP7 TIMELINE



"BER support and leadership in CMIP has been vital for the project's far-reaching success In the international climate science community" (BERAC)

obs4MIPs
Observations for Model Intercomparison Projects

Development and provision of observational data product conforming to community-accepted standards.

PMP
PCMDI Metrics Package

Powerful, world-class global and regional climate model evaluation capabilities.

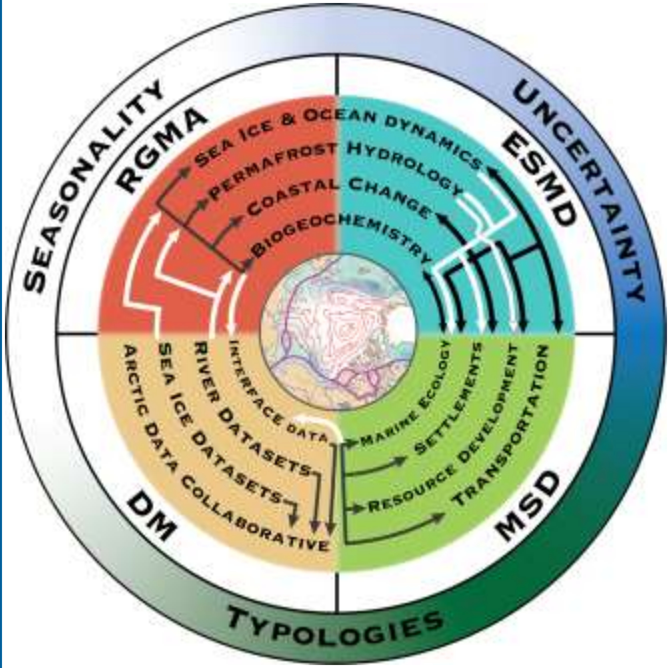
xCDAT

CMOR
Climate Model Output Rewriter

Supporting climate data analysis, standardization and evaluation throughout the international community.

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

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



Earth System focus on:
- Sea ice and ocean dynamics
- Coastal Change
- Permafrost Hydrology
- Marine Biogeochemistry

Multi-sector dynamics focus on:
- Shipping
- Settlements
- Resource development

INTERFACE · Los Alamos National Laboratory · Oak Ridge National Laboratory · Pacific Northwest National Laboratory · Sandia National Laboratories · UAF University of Alaska Fairbanks

InteRFACE - Interdisciplinary Research for Arctic Coastal Environments

seeks to evaluate and improve the predictive skill of Earth and human system modeling to identify and understand trajectories of change for which the Arctic coastal system, both human built and natural, is most vulnerable

Phase 1 Science Focus Areas:

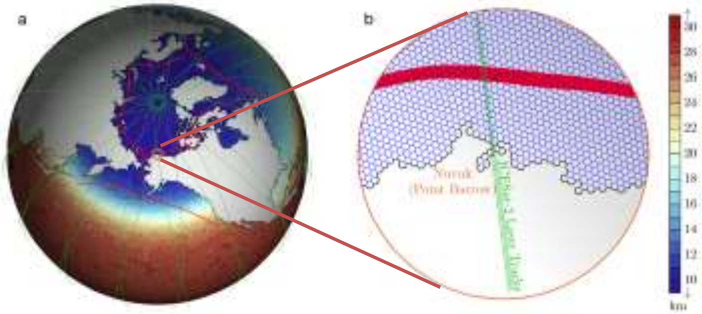
Natural Systems - Marine Biogeochemistry, Sea Ice and Ocean Dynamics, Coastal Change, Permafrost Hydrology
Multisector Dynamics - Alaskan Community Impacts, Shipping, Infrastructure

(RGMA, ESMD, MSD, DM)

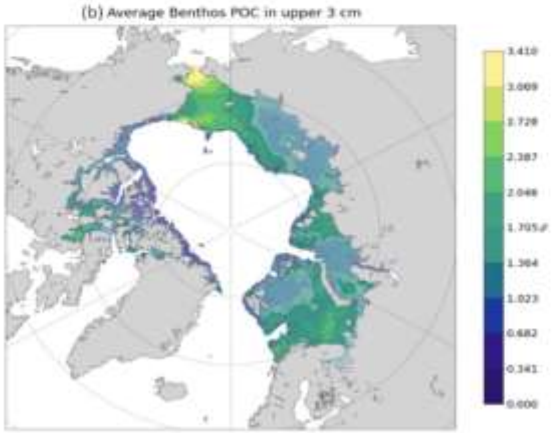
Phase 1 Tools and Capabilities:

Wave-Sea Ice Modeling

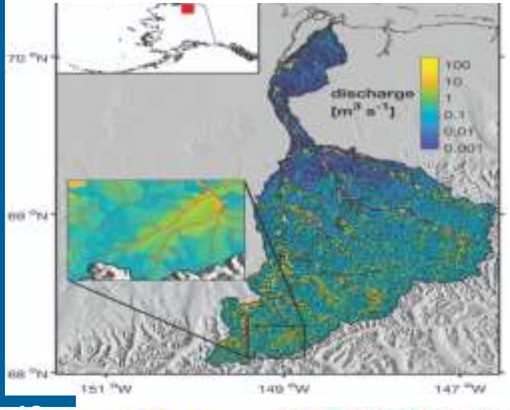
SM – Arctic Refined Mesh



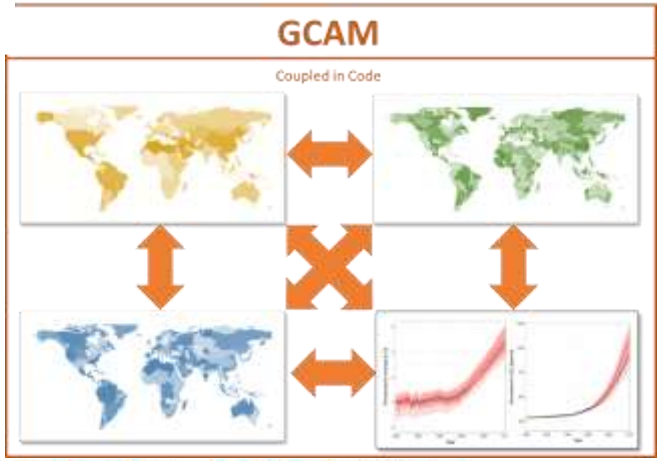
Ocean-Bottom Shelf Biogeochemical Model



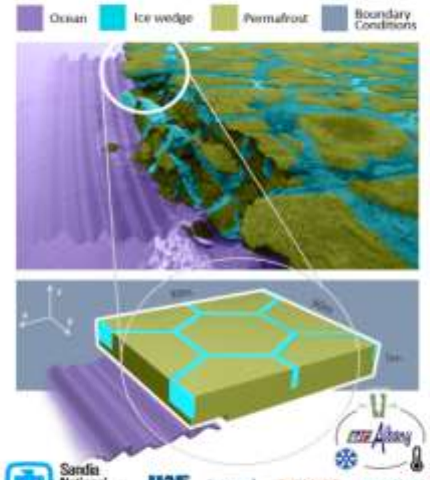
Multi-scale Watershed – MOSART Coupling



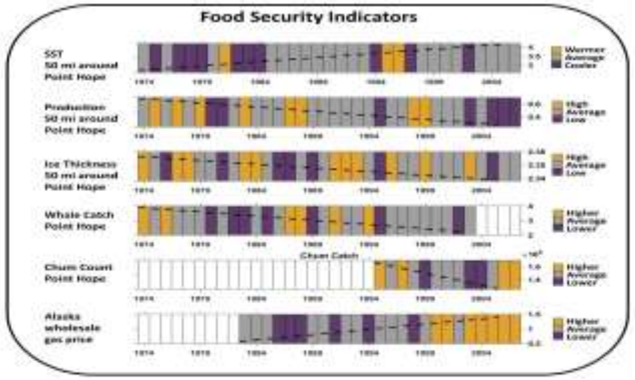
GCAM - Human Dimension



High-Resolution Arctic Coastal Erosion Model

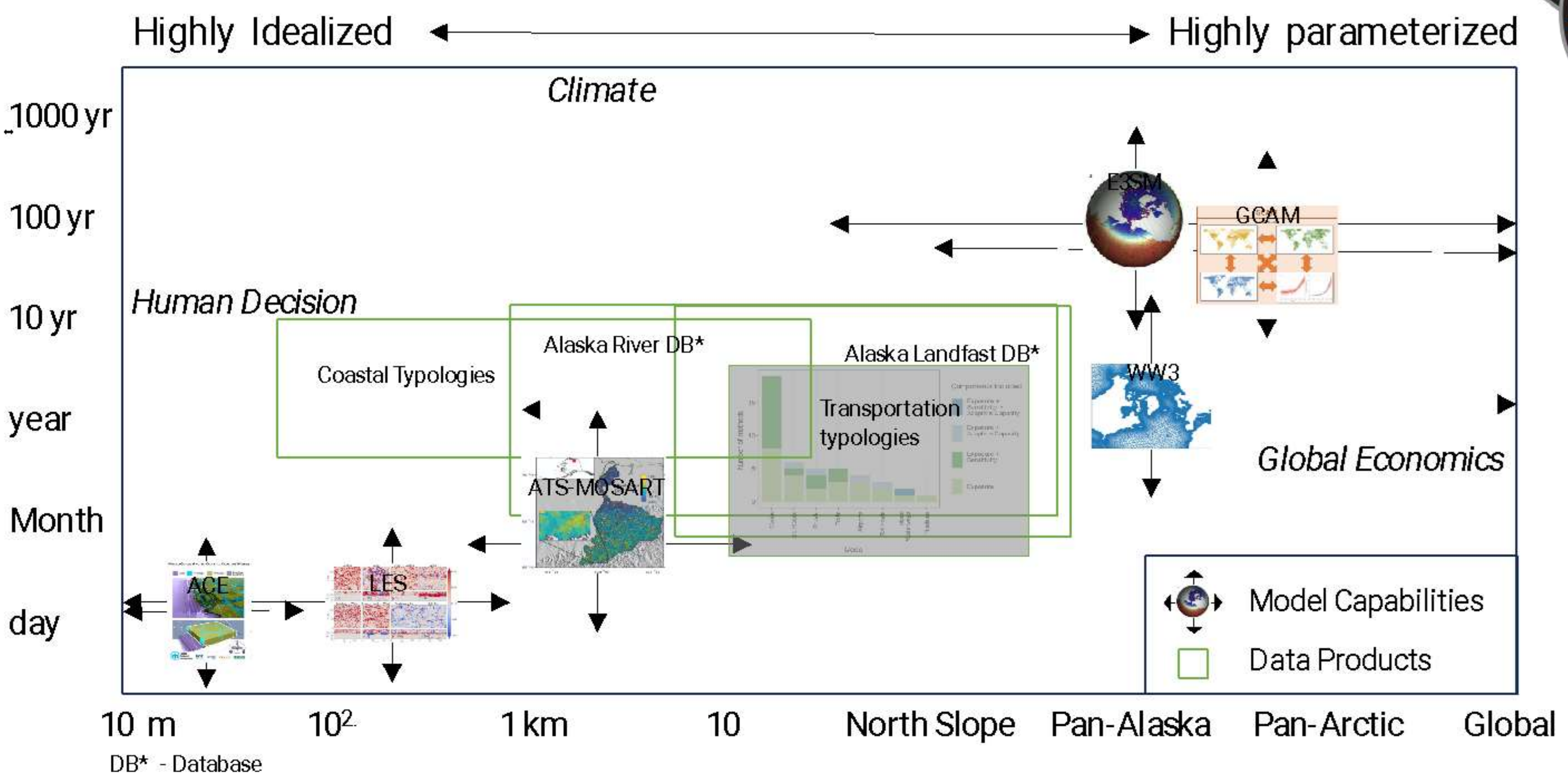


Arctic Food Security Metrics



Los Alamos NATIONAL LABORATORY | Oak Ridge National Laboratory | Pacific Northwest | Sandia National Laboratories | UAF UNIVERSITY OF ALASKA FAIRBANKS

InteRFACE Capabilities – Scales of Prediction for Arctic Coastal Environments



Spatial and temporal scales of prediction for the modeling capabilities developed and exploited in InteRFACE. Shaded regions correspond roughly to the scales of "human decision", "global economics" and "climate". Also shown are the major data base curations and data-products contributed by the project. Not shown are the Statistical Learning algorithms and models which serve a critical role in bridging scales and integrating information.

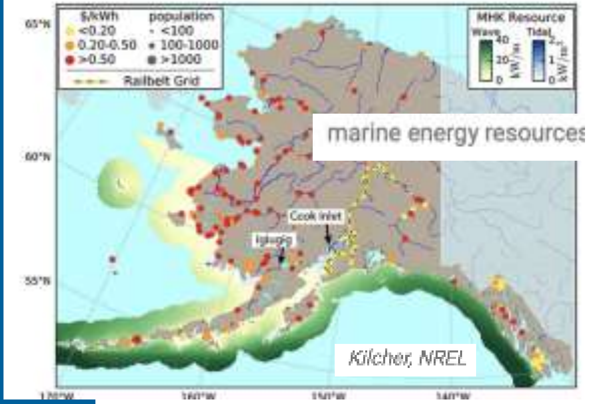
Research Themes - Towards Phase 2

Coastal Change Under Energy Transitions

Threats to Coastal Infrastructure

Biological Resource Vulnerabilities and Change

Transportation Challenges



NASA

Collaboration network

E3SM Energy Exascale Earth System Model · IARPC COLLABORATIONS · RUBISCO · ICOM · IDEAS Watersheds · NCAR NATIONAL CENTER FOR ATMOSPHERIC RESEARCH · HiLAT RASM · Oregon State University · Arctic - COLORS Coastal Land Ocean Interactions

AGU 2023 Presentations

C33F-1462 Forecasting River Ice Breakup in Alaska USA Using a Long Short Term Memory Model **Russell Limber**, Jitendra Kumar, and Forrest M Hoffman,

C41F-1580 Wave – Sea Ice Interactions in Global Climate Simulations of the Energy Exascale Earth System Model (E3SM) **Erin Thomas,** Andrew Roberts, Elizabeth Clare Hunke, Adrian K Turner, Olawale James Ikuyajolu, Steven R Brus and Luke Van Roekel

C32C-07 Improving the Application of a Novel Model Conceptualization for Permafrost Simulation at Full-river Basin **Bo Gao,** Ethan Coon, Matthew G Cooper, Jonathon P Schwenk, and Tian Zhou

C33F-1457 Characterization of Arctic Hydrologic Dynamics Using Remote Sensing **Kavya Sivaraj**, Dana Nossov Brown, Kurt Solander, and Jonathon P Schwenk

GC41B-05 Collapse of the Sea Ice Lemnisc **Andrew Roberts**, Luke Van Roekel, Darin Comeau, Qi Tang, Jean-Christophe Golaz, Xue Zheng, Erin Thomas, Elizabeth Clare Hunke, Stephen Price, Xylar Asay-Davis

U.S. Department of Energy | Office of Science

HYPERFACETS

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

Overview

Overarching Questions

How much can we trust given climate information for actionable climate science?
How can we ensure its saliency?

Project Goals

1. Advance our **understanding** of processes at the atmosphere-water-energy-land interface.

2. Fundamentally **understand and evaluate** our ability to perform **credible climate modeling** of particular regions and their associated processes, especially in the **extreme**.

3. To **strengthen stakeholder engagement** in model development, evaluation and application. Engage effectively in **co-production**: Together enforcing the science and meeting real needs.

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

Stakeholder Engagement

HyperFACETS represents the division's first foray into the direct stakeholder engagement process.

- Regular iterative co-production activities: From co-developing our research proposal to joint publications
- Engaging a large number of scientists and stakeholders: ~ 60 participants including regional water managers (CA, CO, SQ, FL, UT, DEL), energy & land management agencies, and HyperFACETS scientists
- Long-term co-production: ~ 7+ years
- Reflective co-production: Improve on engagement processes, based on a reflection of what worked or not within our groups
- Engagements include: Annual in-person meetings, monthly spotlight telecons, bi-monthly working group meetings

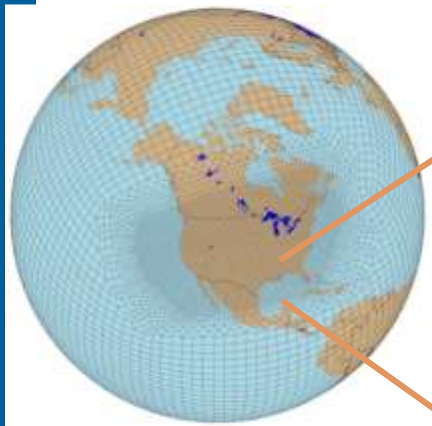

ELSEVIER
Global Environmental Change
Volume 82, September 2023, 102732

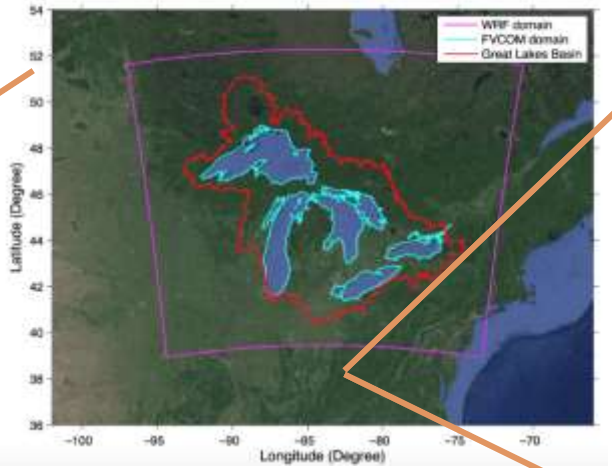
Typologies of actionable climate information and its use

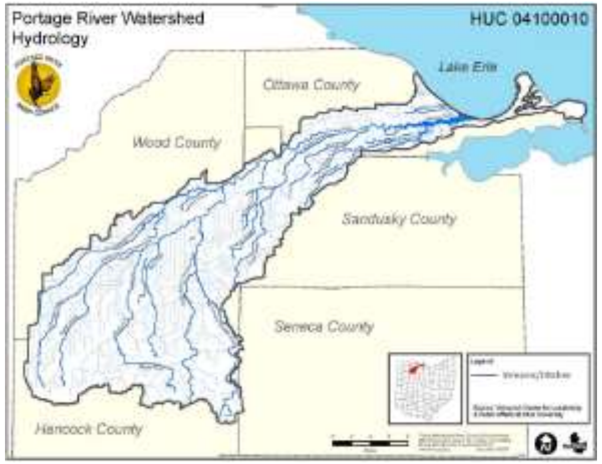
Kripa Jagannathan[a], Smitha Buddhavarapu[a], Paul A Ullrich[b], Andrew D Jones[a], the HyperFACETS Project Team

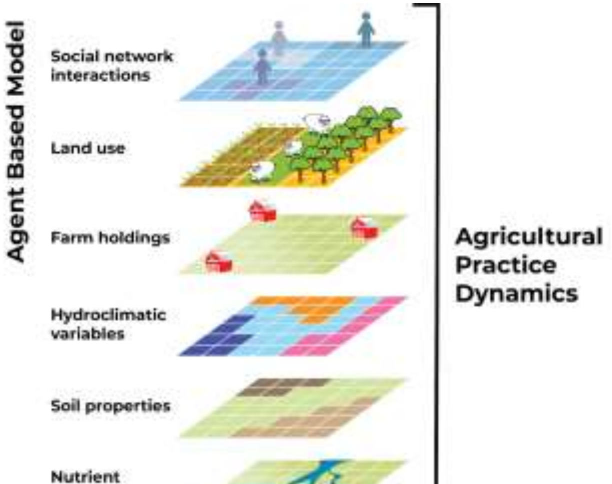
COMPASS Great Lakes Modeling (GLM) Project – PI: Rob Hetland, PNNL

Focuses on natural processes and human interactions within and between a variety of regional domain scales









Global E3SM: Provides information on variability and long term changes in a future climate to inform downscaling, for example, through pseudo-global warming experiments

Regional Coupled Modeling Domain: How do precipitation, runoff, and air temperature in the GRL interact with lake water balance, thermal structure, lake ice, and circulation to influence regional climate changes and extremes?

High-resolution Watershed Modeling Domain: How do hydrologic intensification and watershed characteristics interact to control event-scale nutrient exports from Great Lakes watersheds?

Human systems: How have agricultural communities historically adapted their practices based on human and natural system drivers, and how will this change in a future climate?

COMPASS | GREAT LAKES MODELING

Coastal Observations, Mechanisms, and Predictions Across Systems and Scales

GLM Long-term goal:

Improving predictive understanding of coastal systems by coupling Earth system components, each with application-appropriate detail, to understand the co-evolution and interdependencies of coastal regional processes and human systems, using the Great Lakes Region as a test bed.