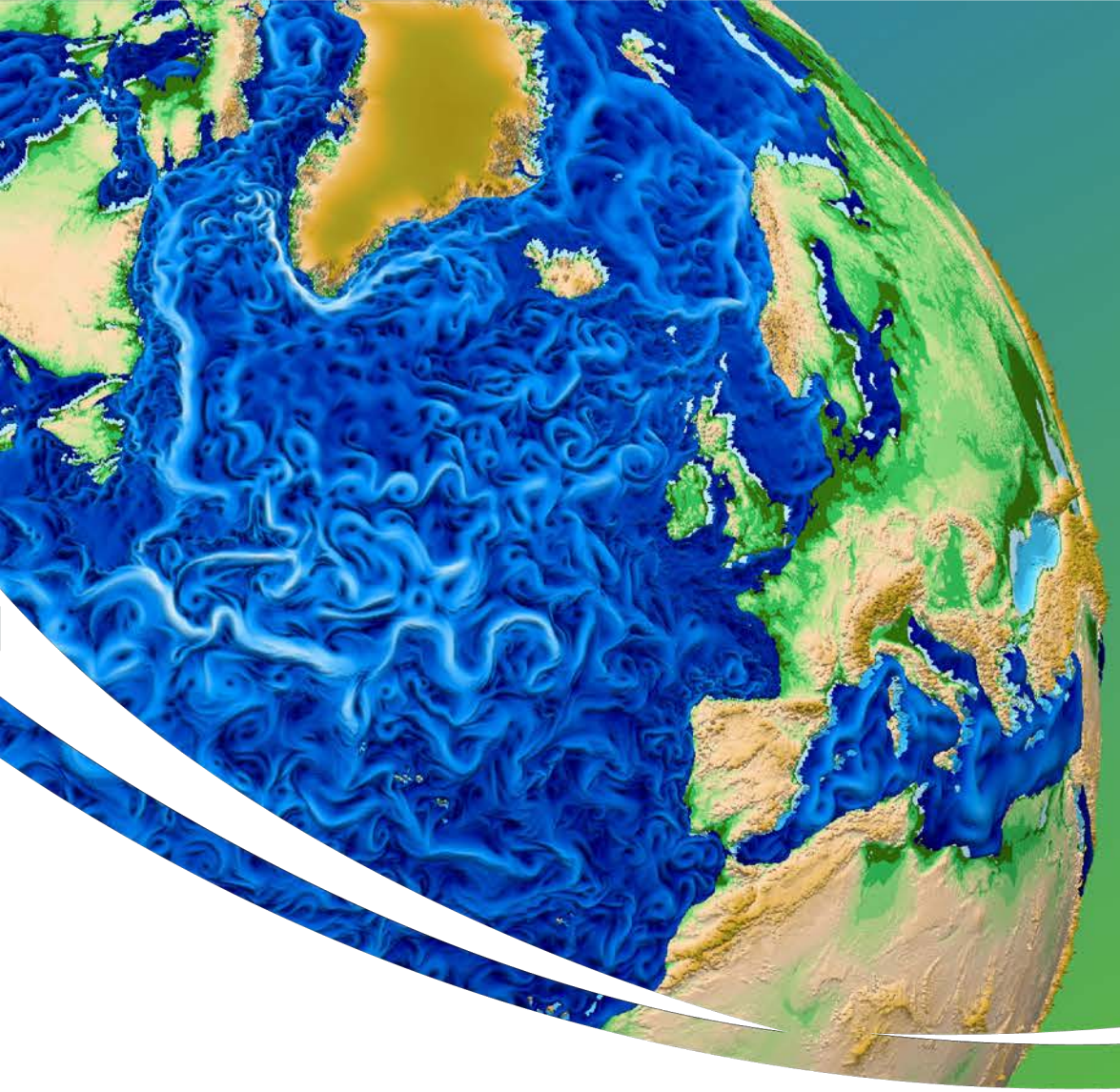
# AGU Town Hall

## E3SM: A Decade of Earth System Modeling Effort at the Department of Energy


Xujing Davis
Asmeret Asefaw Berhe
Gary Geernaert
Dave Bader
Ruby Leung
Mark Taylor
Renata McCoy


E3SM Wins Gordon Bell Prize for Climate Modeling, SC23



# Welcome and Introduction

Xujing Jia Davis
DOE ESMD Program Manager

U.S. DEPARTMENT OF ENERGY

ESMD: Earth System Model Development Program Area

E3SM Energy Exascale Earth System Model

U.S. DEPARTMENT OF ENERGY | Office of Science

*Asmeret Asefaw Berhe*

Basic Energy Sciences

**Biological and Environmental Research (BER)**

*Dorothy Koch*

High Energy Physics

Nuclear Physics

Fusion Energy Sciences

**Advanced Scientific Computing Research (ASCR)**

FY23 Budget: ~$445M

**Earth and Environmental Systems Sciences Division (EESSD)**

*Gary Geernaert*

**Biological System Sciences**

Todd Anderson


Atmospheric Sciences (ASR/ARM)

**Earth and Environmental Systems Modeling (EESM)**

Environmental System Science (ESS/EMSL)

Data Management


**Earth System Model Development (ESMD)**

*Xujing Davis*

**Regional & Global Model Analysis (RGMA)**

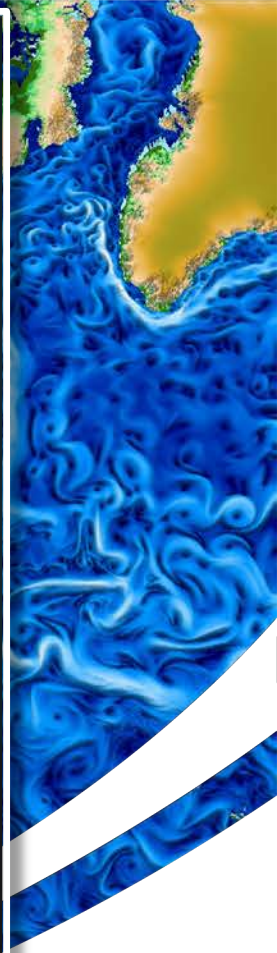
*Renu Joseph*

**MultiSector Dynamics (MSD)**

*Bob Vallario*

# DOE Office of Science Director Perspective: Role of E3SM for DOE Mission and Science

Asmeret Asefaw Berhe
DOE Office of Science Director

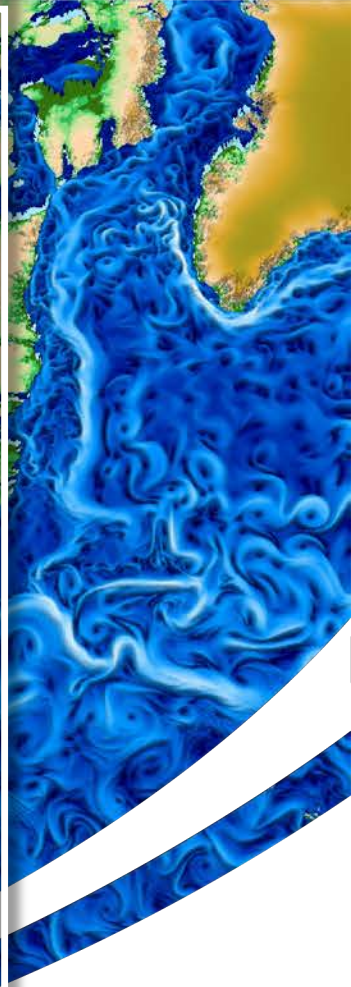


U.S. DEPARTMENT OF ENERGY

E3SM
Energy Exascale Earth System Model

# Earth System Modeling Priorities at DOE and Interagency Landscape

Gary Geernaert
DOE EESSD Director



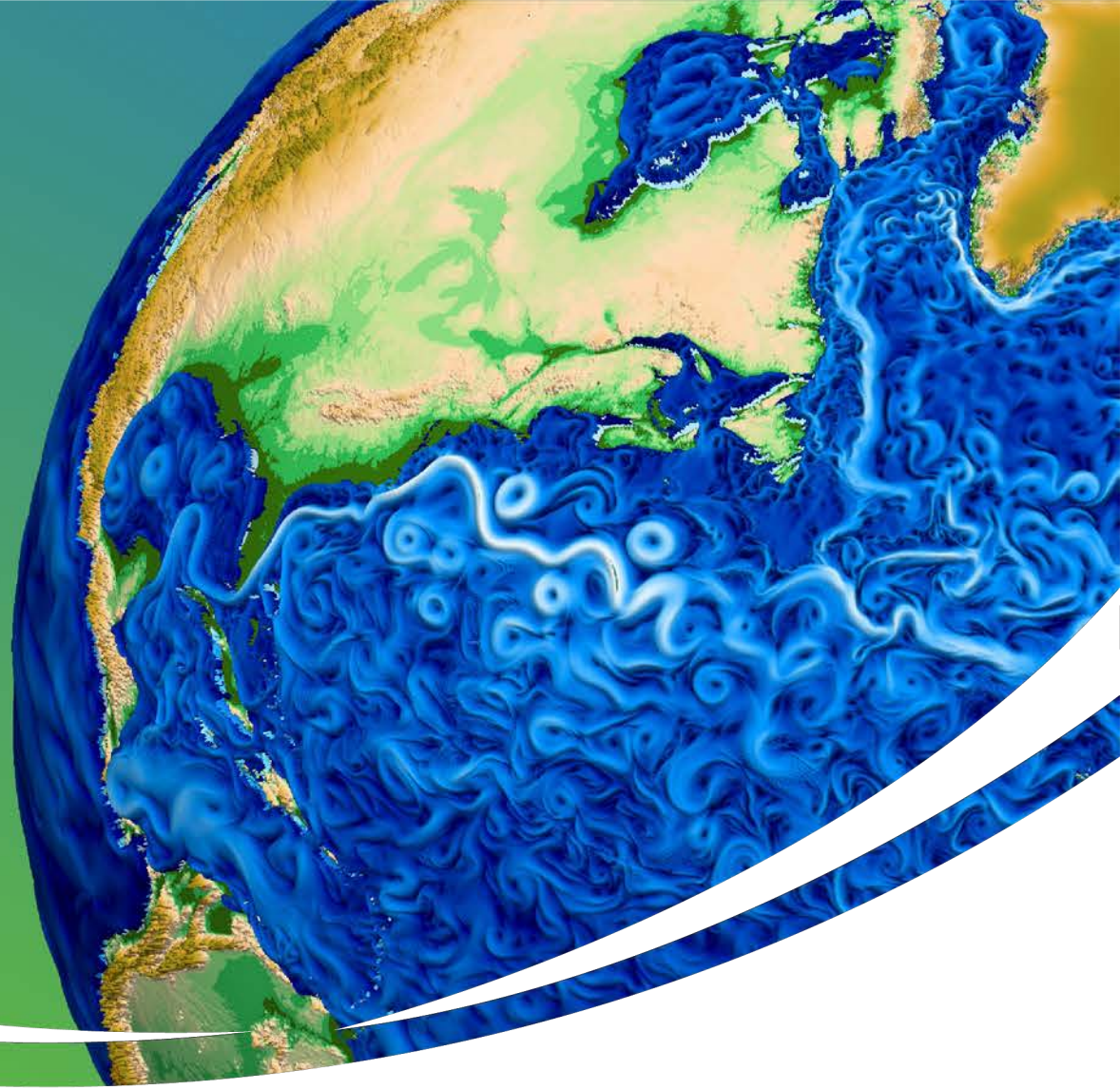
EESSD: Earth and Environmental Systems Sciences Division

U.S. DEPARTMENT OF ENERGY

E3SM
Energy Exascale Earth System Model

# Program Overview

Xujing Jia Davis
DOE ESMD Program Manager



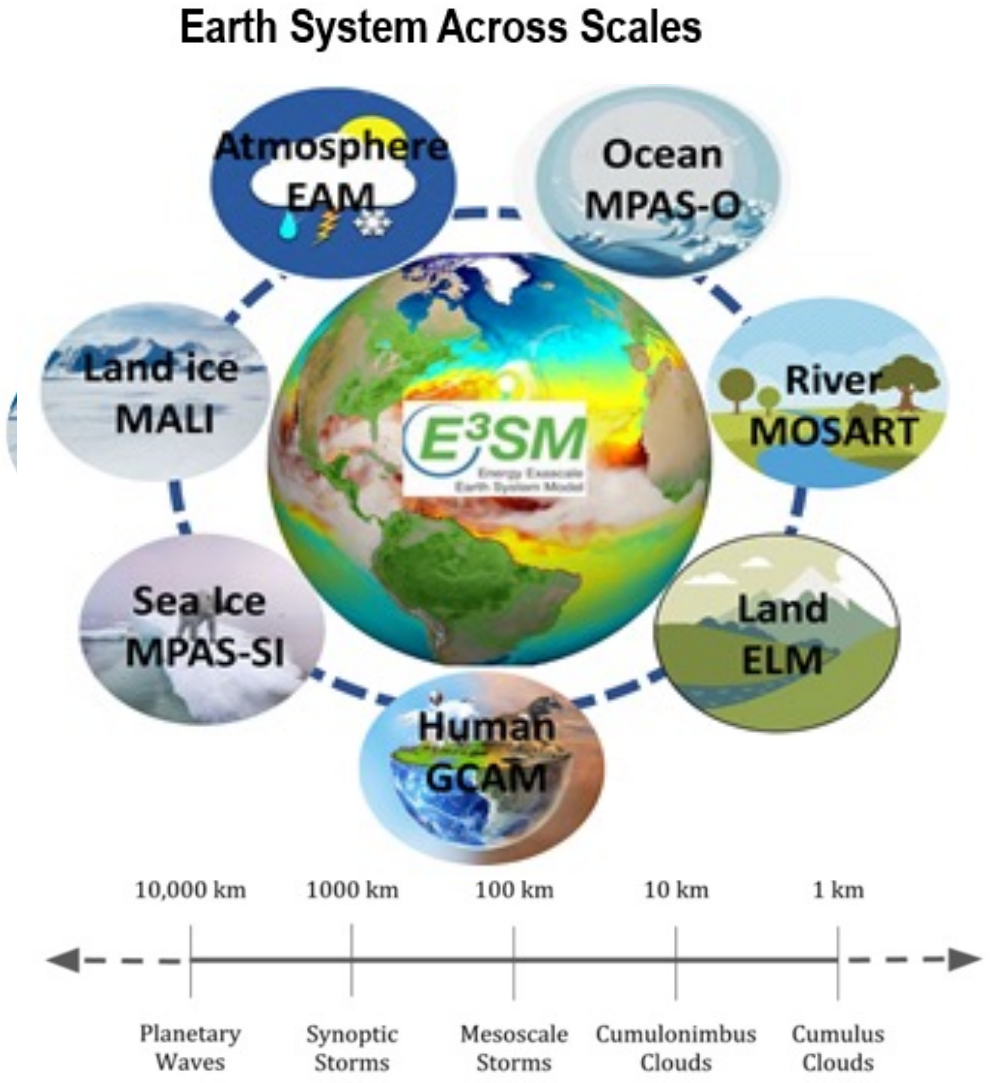
U.S. DEPARTMENT OF ENERGY

ESMD: Earth System Modeling Development Program Area

E3SM
Energy Exascale Earth System Model

# ESMD in Support of E3SM

*Innovative and computationally advanced ESM capabilities, in support of Energy science and mission*




***Goal:*** *Support the development of E3SM including its subcomponents, to address the grand challenge of actionable predictions of the changing Earth system, emphasizing on the most critical scientific questions facing the nation and DOE*

## Strategies:

- Science driver for model development
- Earth system across scales (high-resolution frontier, bridge gaps, quantify uncertainty via LE)
- Prepare for and overcome the disruptive transition to next era of computing, leverage ASCR HPC capabilities
- Innovative mathematical, computational methods, tools, algorithms (e.g., ML/AI)

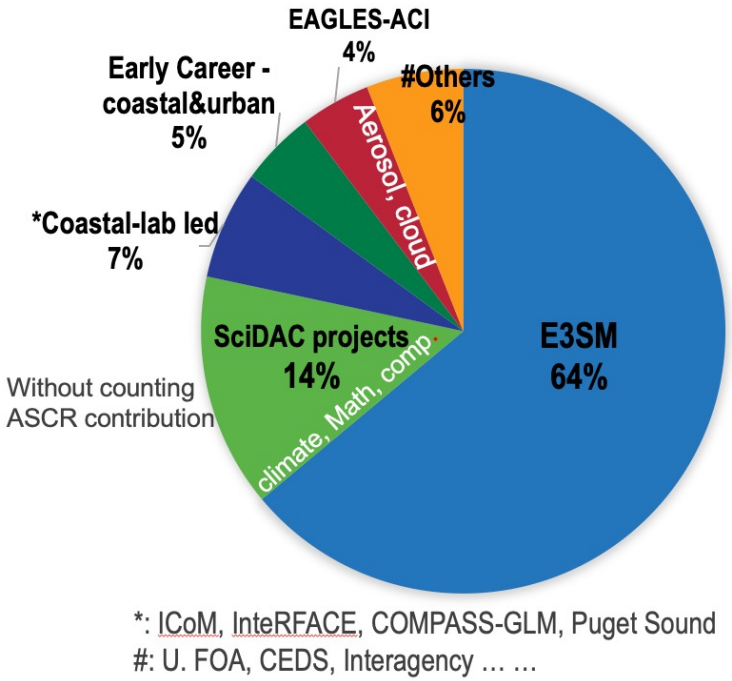
**EAM:** E3SM Atmosphere Model; **ELM:** E3SM Land Model **; GCAM:** Global Change Assessment Model; **MOSART:** Model for Scale Adaptive River Transport; **MPAS-SI:** Model for Prediction Across Scales (MPAS) – Sea Ice; **MPAS-O:** MPAS – Ocean; **MALI:** MPAS-Albany Land Ice Model.

***More E3SM Acronyms: https://e3sm.org/resources/help/acronyms/***

# ESMD Portfolio & Ecosystem in Support of E3SM

***E3SM:*** *An integrator of DOE earth, environmental, mathematical and computational sciences, in advancing ESM capability for DOE science mission.*

## FY 23 Budget Distribution




*: ICoM, InteRFACE, COMPASS-GLM, Puget Sound
#: U. FOA, CEDS, Interagency … …

***Note: Univ. scientists across ESMD projects***

See detail about ESMD Projects

**FY 23: $49 M**

**ESMD supported Projects:**

- **Funding instruments:**
- **1. Lab-led projects** including Scientific Focus Area (**SFAs**, e.g., **E3SM**); **2.** Scientific Discovery through Advanced Computing (**SciDAC**) Awards; **3. Early Career Awards** and **4.** Other projects: e.g., **U. FOA**, Interagency activities (e.g, USGCRP/IGIM, CICE Consortium…)
- **E3SM SFA is the central driver** of the E3SM development with focused scientific questions, well defined time frames, goals and strategies
- **Other projects contribute to E3SM** development in various ways on different time frames

**E3SM in DOE ecosystem**

**EESSD:**

- *RGMA*: PCMDI, RUBISCO, HYPERFACETS, WACCEM, HiLAT-RASM, CATALYST, CASCADE…
- *MSD*: GCIMS (GCAM), HYPERFACETS, IM3 …
- *ARM/ASR*: Field Campaigns, THREADS, LASSO …
- *ESS*: NGEE-Arctic, NGEE-Tropics, SPRUCE, COMPASS-FME, Urban IFL …

**ASCR:** *SciDAC*, Exascale Computing Project (*ECP*) ...

**Office of Science:** Energy Earthshot, RENEW, FAIR, RDPP, CRC …

# Science Community Leadership and Service

## National

- **USGCRP**: **IGIM** US Climate Modeling Summit (USCMS), **GEWEX**: *D. Bader, R. Leung*
- **NASEM Digital Twin** Workshop: *R. Leung, M. Taylor*
- **NCA5:** *R. Leung, P. Thornton, C. Tebaldi, P. Ullrich*
- **US CLIVAR** : *R. Leung*
- **OSTP ICAMS** Subcommittee on Earth System Modeling and Prediction(ESM&P) Implementation Teams: *M. Taylor, R. Jacob, C. Golaz, P. Jones, A. Donahue, O. Guba*
- CESM Advisory Committee: *E. Hunke, M. Taylor*

## International

- **CICE Consortium**: *E. Hunke, A. Roberts*
- **International CLIVAR**: *L. Van Roekel*
- **International Workshop on Coupling Technologies for ESMs**: *R. Jacob*
- **WCRP GEWEX** Global Atmospheric System Studies Panel (GASS) annual meeting: *S. Xie*
- Association for **Computing Machinery (ACM) and the Swiss National Supercomputing** Centre: *O. Guba*


*E3SM contributes to national and global endeavor in advancing Earth System Predictability while addressing the DOE mission*

# E3SM Timeline and Major Achievements

*Approaching its 10th year*

**Realizing Exascale vision**

**Oct 2014**
Project begins

**Apr 2018**
E3SMv1 Release, open development project

**Sep 2021**
E3SMv2 release, better, faster, RRM; SCREAMv0 developed

**Feb 2023**
SCREAMv1
EAMxx on GPU
Frontier

**Dec 2023, Now**
E3SMv3 under testing, expected exciting advancements

**2026**
E3SMv4, GPU enabled, fully coupled, foundation for Digital Twins

Phase 1 → Phase 2 → Phase 3 → Phase 4

SCREAM: Simple Cloud Resolving E3SM Atmosphere Model

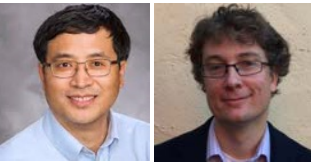
***E3SM wins Inaugural Gordon Bell - Climate Modeling Prize!***

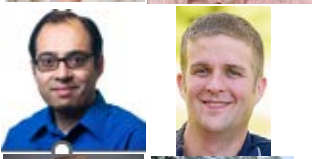

## E3SM Unique Capabilities for Actionable Science:

- **Exascale Readiness**: developed the 1st benchmark of its kind by running ~3km global simulation SCREAM on Frontier with record setting performance, i.e., the 1st global cloud-resolving model (~3km) to simulate a world's year of climate in a day
- **RRM** – 1st ESM running fully coupled global simulations with RRM in all components (except river), completed climate production simulations
- **Coupled Earth-Human Feedback**: coupling with GCAM

# E3SM Leadership Team: Cross Laboratory Initiative

Speakers today →



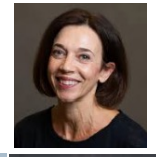
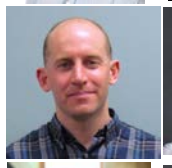
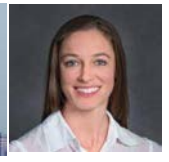


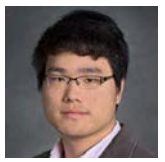
LLNL
PNNL
Sandia
LANL
LBNL
BNL
ANL
ORNL

E3SM Executive Committee

■ **David Bader**, Chair ■ **Ruby Leung**, Chief Scientist ■ **Mark Taylor**, Chief Computational Scientist ■ **Renata McCoy**, Project Engineer





## COMPONENT DEVELOPMENT

■ S. Xie
■ S. Burrows

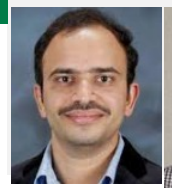
Atmosphere | Land | OMEGA* | Sea Ice & Land Ice

EAMxx

■ P. Thornton
■ G. Bisht
■ L. Van Roekel
■ S. Brus
■ M. Petersen
■ P. Jones
■ E. Hunke
■ D. Comeau

*OMEGA: Ocean Model for E3SM Global Applications

■ P. Caldwell
■ S. Burrows




## INTEGRATION

*Requirements* ←

■ C. Golaz
■ W. Lin

Coupled System

Infrastructure, Performance & Data

■ R. Jacob ■ J. Zhang

■ S. Sreepathi

*Performance Coordinator* →

*ML/AI Coordinator* →

■ A. Salinger

*Capabilities* →

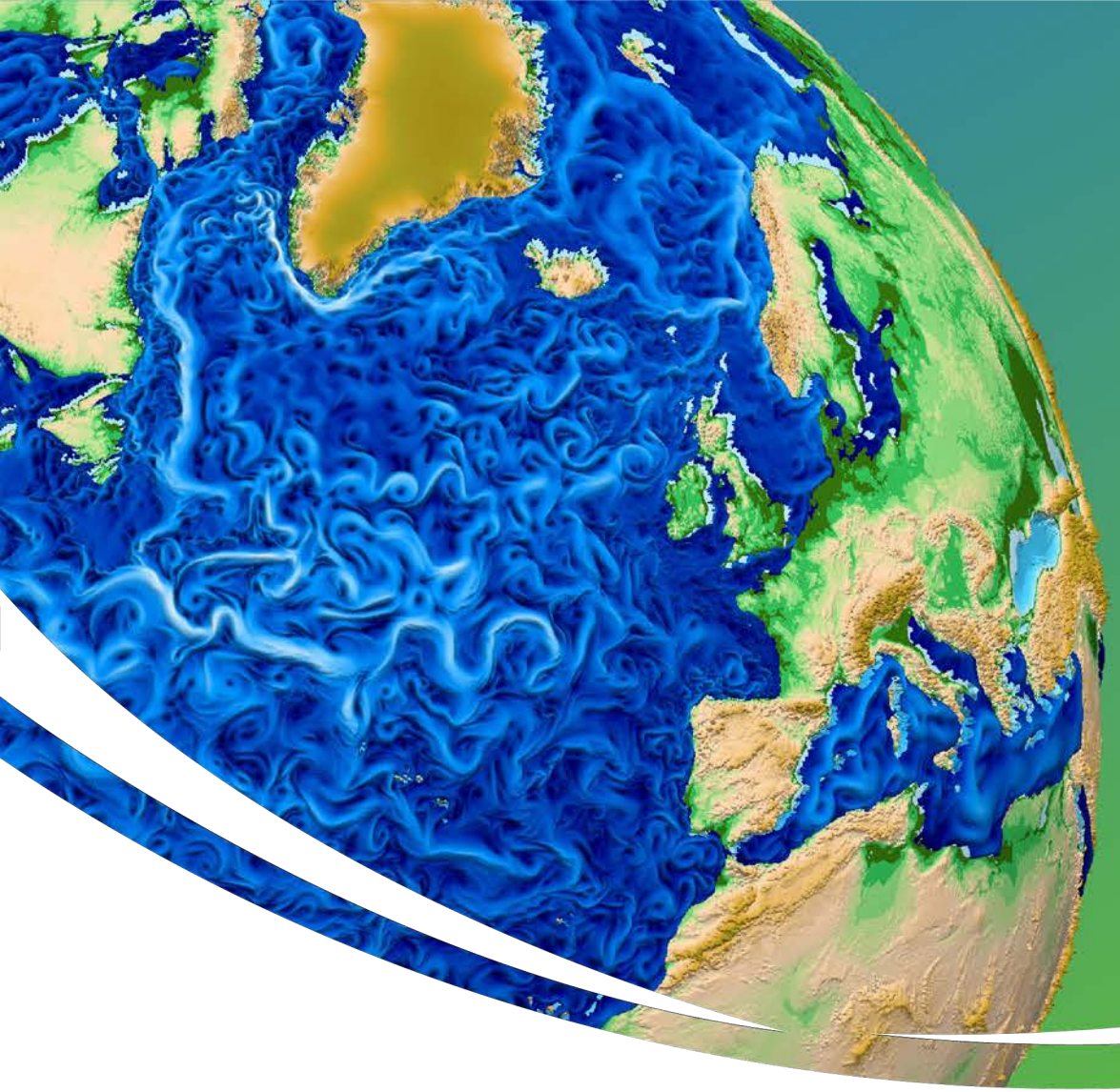
## SCIENCE SIMULATION CAMPAIGNS

Water Cycle Changes and Impacts

Human-Earth System Feedbacks

Polar Processes, Sea-Level Rise and Coastal Impacts

■ B. Harrop
■ C. Tebaldi
■ B. Bond-Lamberty
■ J. Holm
■ N. Jeffery
■ Q. Zhu
■ Stephen Price
■ Andrew Roberts

# Overview of the E3SM Project

David C. Bader, LLNL

E3SM Council Chair and Lead Principal Investigator

U.S. DEPARTMENT OF ENERGY

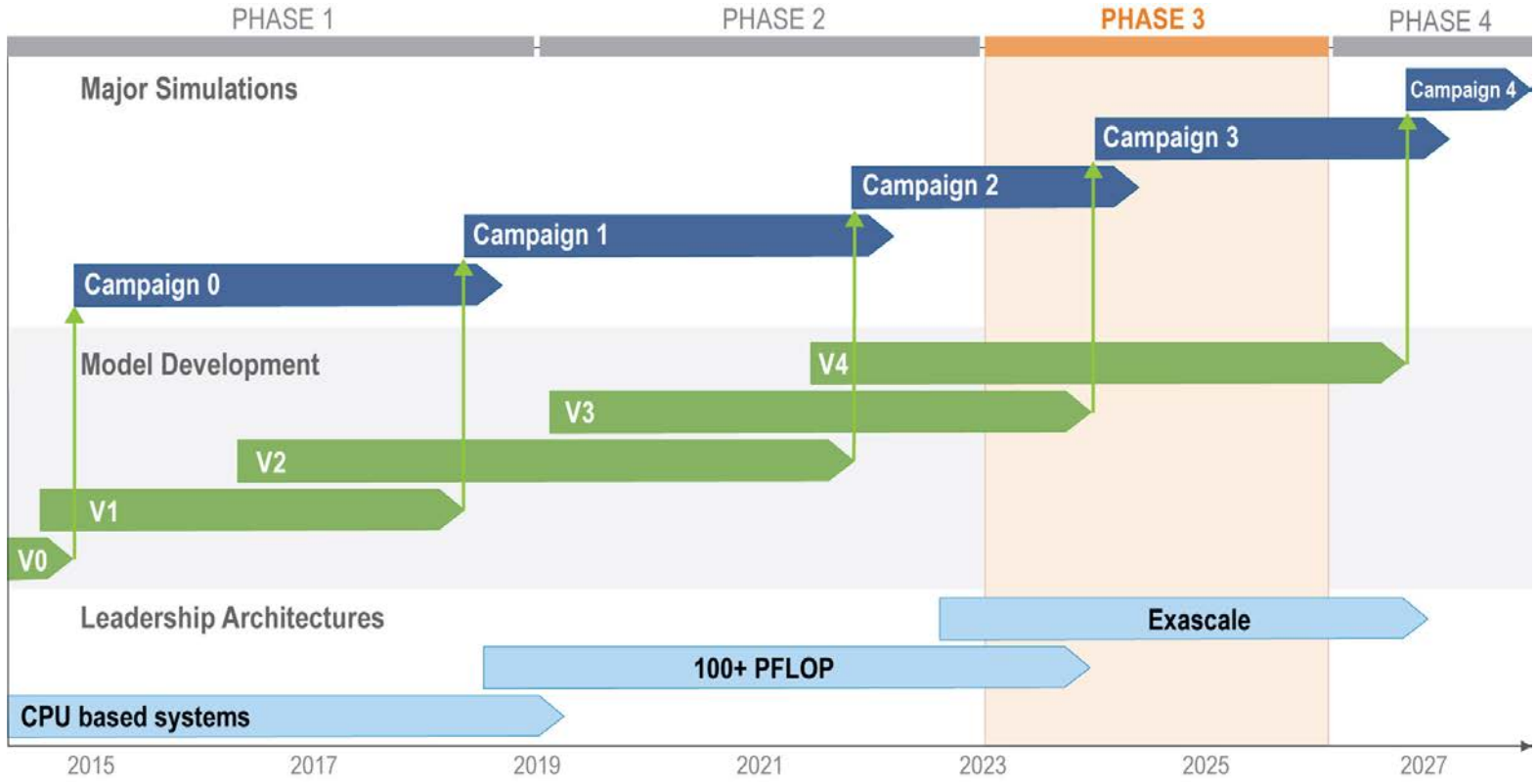
E3SM Energy Exascale Earth System Model

*The E3SM Mission: Use exascale computing to carry out high-resolution Earth system modeling of natural, managed and man-made systems, to answer pressing problems for the DOE*.*


"A DOE Model for DOE's Mission on DOE Computers"

***The E3SM project's long-term goal is to assert and maintain international scientific leadership in the development of Earth system models that address the grand challenge of actionable modeling and projections of Earth system variability and change, with an emphasis on addressing the most critical challenges facing the nation and DOE.**

# E3SM Approach




- **Major simulations.** A series of simulation-and-projection experiments addressing mission needs with actionable scientific results.
- **Model development.** A well-documented, tested, continuously improving system of model codes that comprise the E3SM Earth system model.
- **Leadership architectures.** The ability to use effectively leading (and "bleeding") edge computational facilities soon after their deployment at DOE national laboratories.
- **Infrastructure.** An infrastructure to support code development, hypothesis testing, simulation execution, and analysis of results.

# E3SM Phase 2 Highlights

- **E3SM is possible because of a strong culture of "project before lab," and the commitment of talented and dedicated scientists, computational scientists and software engineers.**
- Completion of v1 Simulation Campaign
- Over 12,000 simulated years of simulations using v2 E3SM
- v2 RRM with consistent model tuning with v2 standard resolution
- Atmosphere algorithmic improvements doubled model throughput
- Demonstrated templated C++ programming model for hybrid CPU/GPU (Exascale) machines that requires little support from compiler vendors
- Established a more rigorous Code Review/Testing process to enable more predictable integration of new developments, both internal and external, eg EAGLES.
- Installed and maintained E3SM system on NERSC and COMPY computers for use by other BER/EESSD programs

# The Simple Cloud-Resolving E3SM Atmosphere Model (SCREAM)

- DOE has the fastest computers in the world, but they use NVIDIA, AMD, and Intel GPUs
  - Weather/climate models require major modification to run on GPUs
  - No single programming strategy works for all 3 GPU vendors

⇒ "Performance portability" was needed for E3SM to achieve its exascale ambitions

- This was achieved by writing a new atmosphere model in C++/Kokkos
- SCREAM won the 2023 Gordon Bell Climate Prize for breaking 1 simulated year per day at Δx=3.25 km

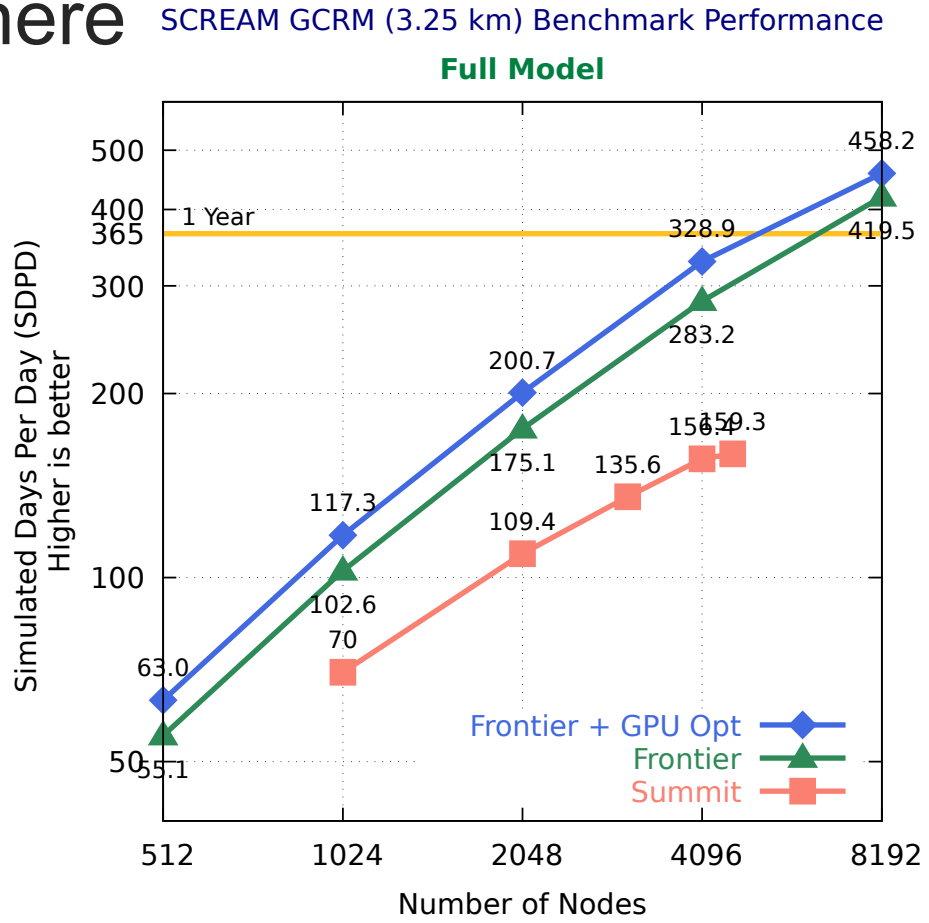
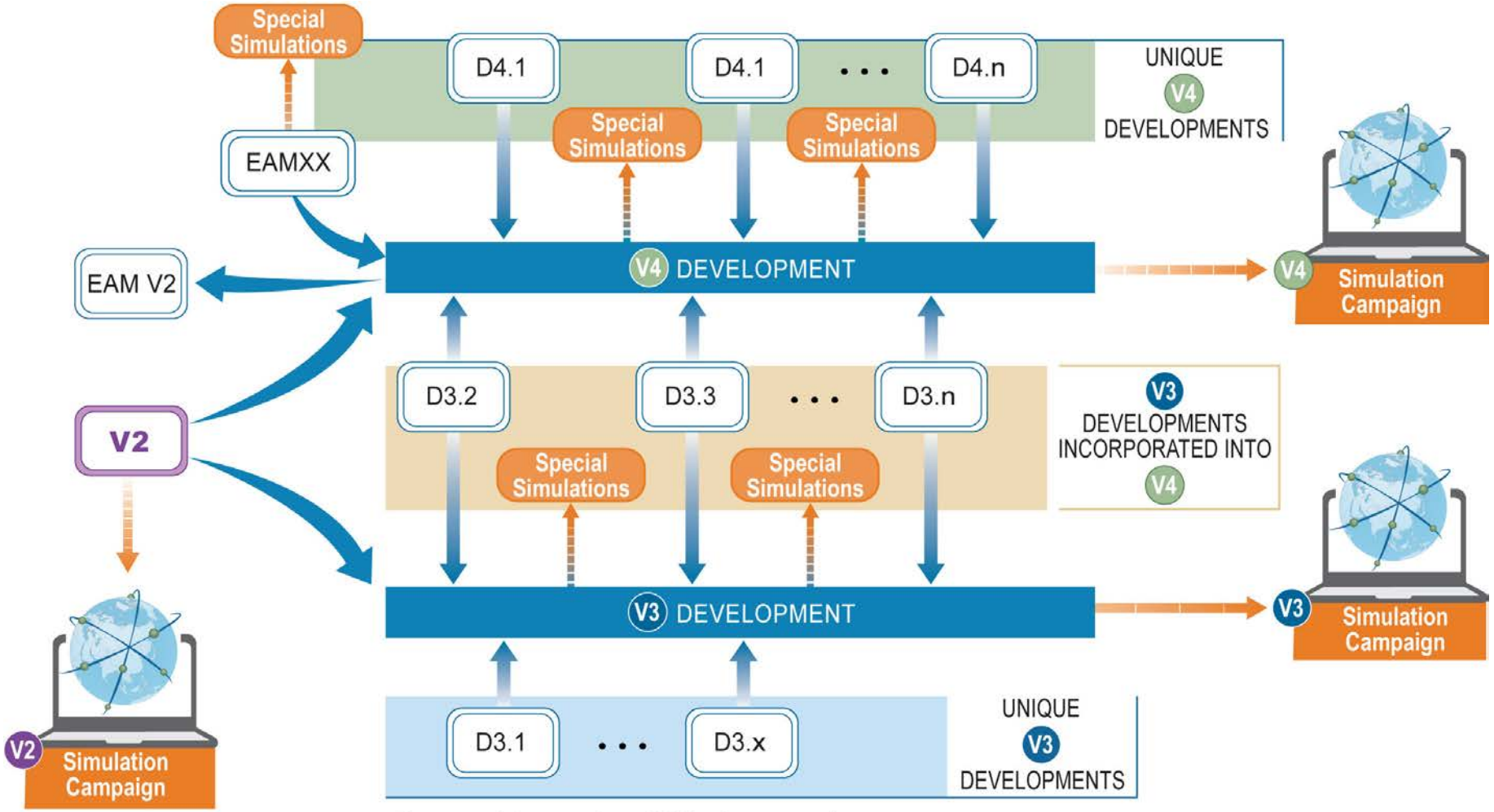



*Fig: throughput vs node count at Δx=3.25 km on Frontier (AMD GPUs) and Summit (NVIDIA GPUs)*

# The Phase 3 Concept



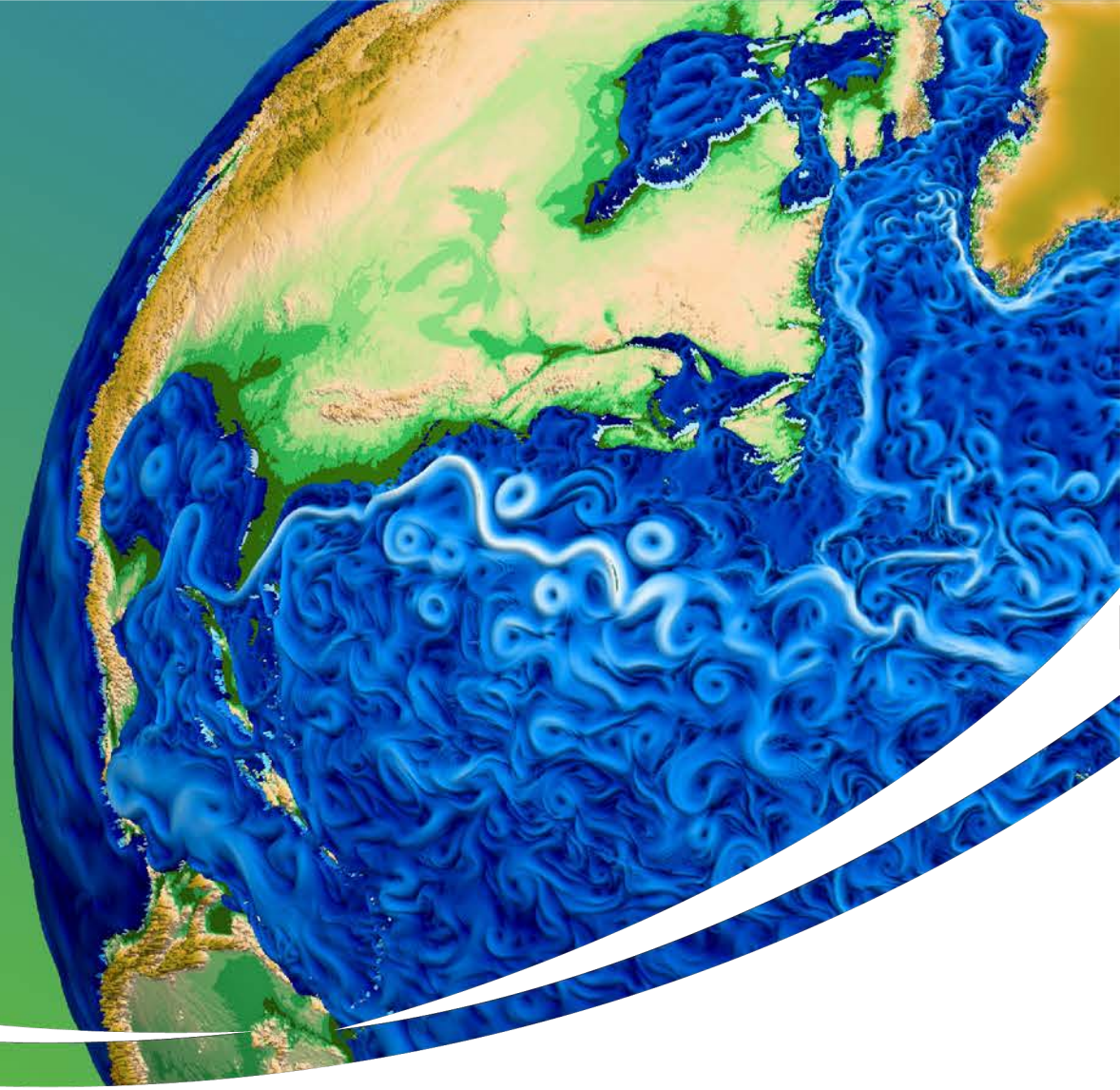

Conceptual diagram of parallel development paths

# E3SM is on the verge of delivering an Exascale modeling system. What's next?

- Pushing past past exascale will require ever-more ***disruptive approaches*** such as edge computing, machine learning (ML), and next-generation artificial intelligence (AI) to accelerate the fusion of observations and measurements with computing.
- The E3SM project will ***continuously integrate advanced technologies*** and Earth system science to deliver capabilities for multi-resolution modeling of the coupled human–Earth system.
- E3SMv4 will be at the center of a connected scientific ecosystem for understanding and modeling the Earth system, and will be ***the foundation for digital twins of the system and its components.***
- DOE will lead in actionable projections of human–Earth system evolution across a broad range of time and spatial scales to ***support multisectoral decision making and DOE's energy mission***.

# E3SM Science

Ruby Leung, PNNL
E3SM Chief Scientist

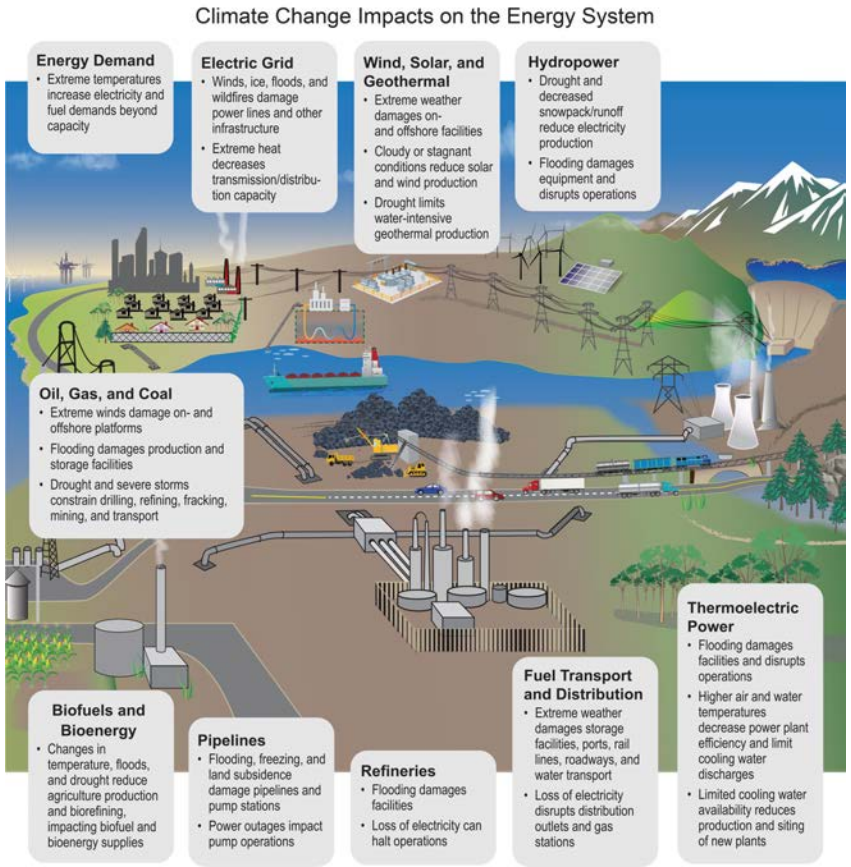


U.S. DEPARTMENT OF ENERGY

E3SM
Energy Exascale Earth System Model

# Overarching goal: advance actionable science in support of DOE's energy mission

Climate change impacts on energy supply, delivery, and demand




(NCA5 Chapter 5)

## Science drivers:

- Water cycle changes and impacts
- Human-Earth system feedbacks
- Polar processes, sea-level rise, and coastal impacts

# E3SM actionable science goals

- High-resolution modeling of extreme weather events in a changing climate
- Represent natural, managed and manmade systems and their interactions to project future outcomes
- Ensemble modeling to quantify uncertainty

Earth system science  Computational science

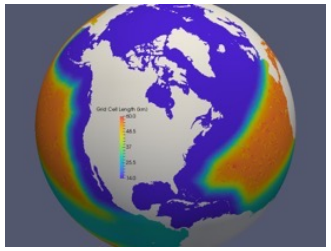
# Modeling across scales

| Model component | Lower resolution (LR) | High resolution (HR) | Cloud-resolving (SCREAM) | Regional refined model (RRM) |
|---|---|---|---|---|
| Atmosphere & Land | 100 km | 25 km | 3 km | variable |
| Ocean & Ice | 30-60 km | 6-18 km | prescribed | variable |
| River | 50 km | 12 km | 3 – 12 km | variable |
| | **CMIP6 DECK, C4MIP** | **HighResMIP** | **DYAMOND** | **CMIP6 DECK (NARRM)** |

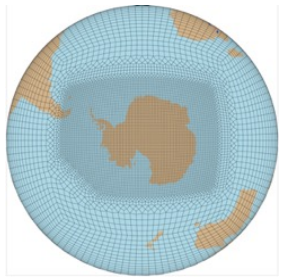
**North America RRM**

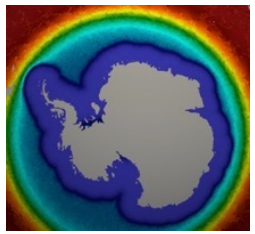
25 km → 100 km

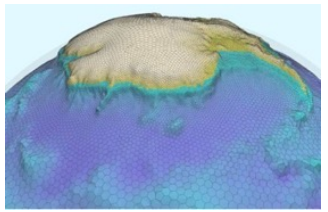
14 km → 60 km



**Southern Ocean RRM**







**Delaware Bay RRM**

4 km → 240 km

# Regional refinement: NARRM

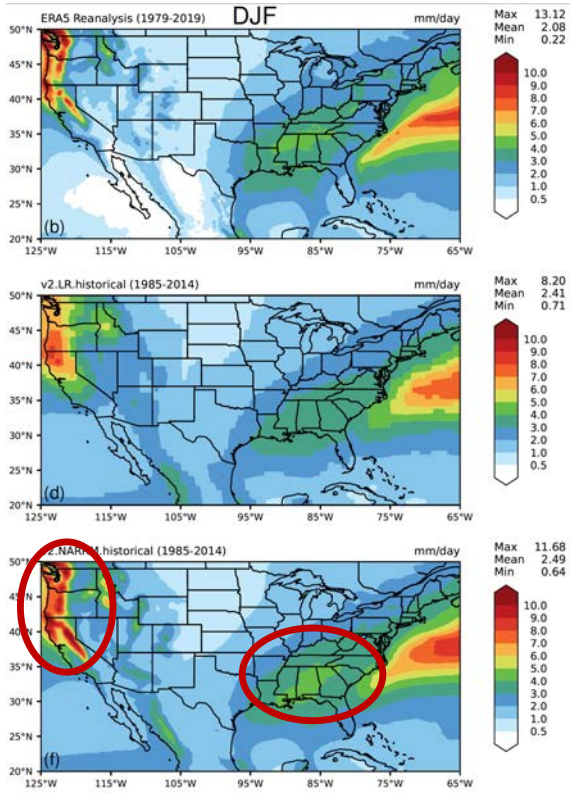
NARRM has similar climate sensitivity as LR, simplifying model calibration

**Improved orographic precipitation**

ERA5

LR

NARRM

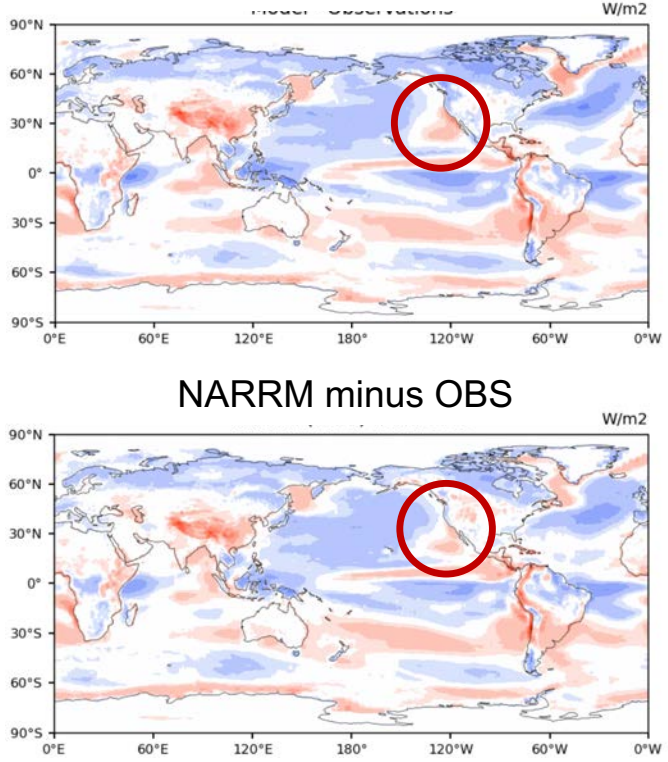



(Tang et al. 2023 GMD)

**Reduced SWCF bias from stratocumulus**

LR minus OBS

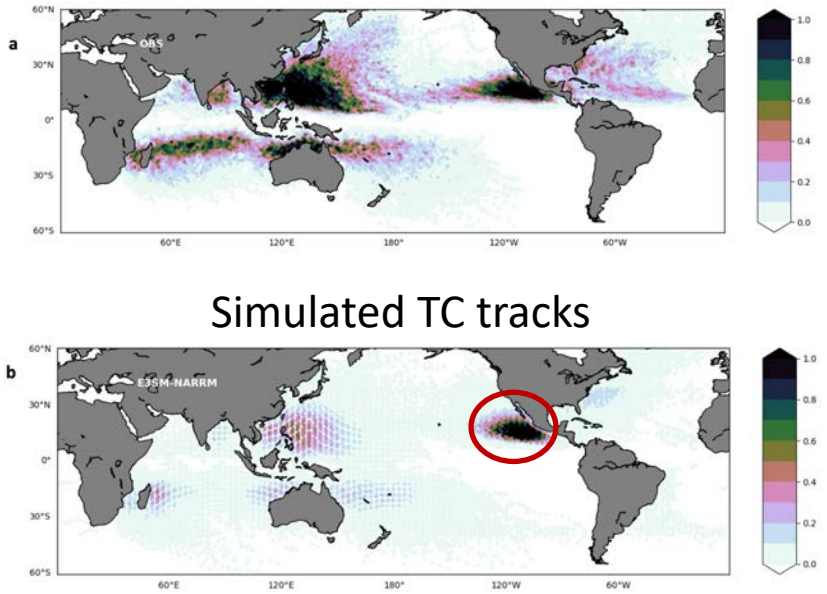
NARRM minus OBS




**More realistic tropical cyclone tracks**

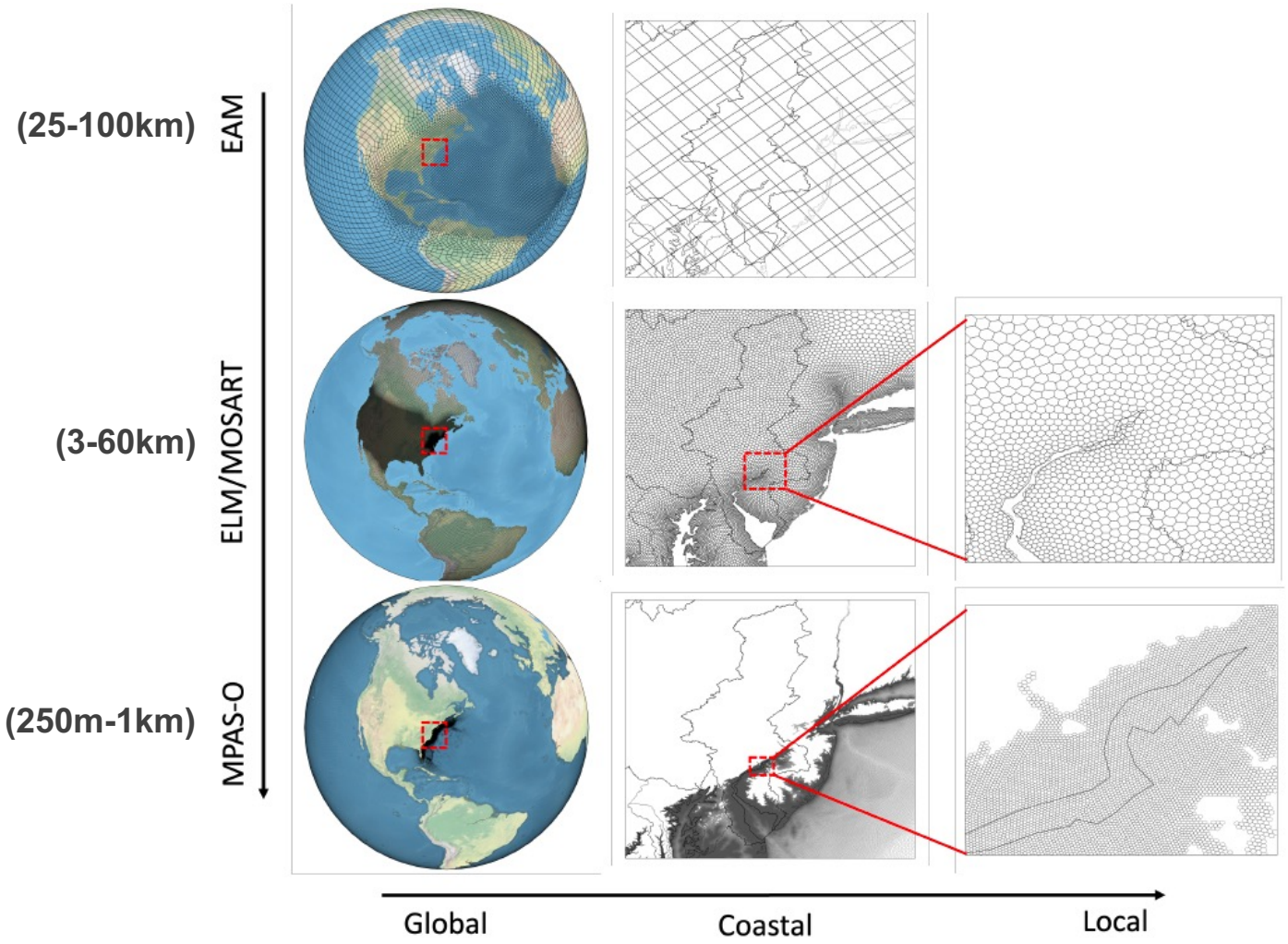
Observed TC tracks

Simulated TC tracks




(Balaguru et al. in prep)

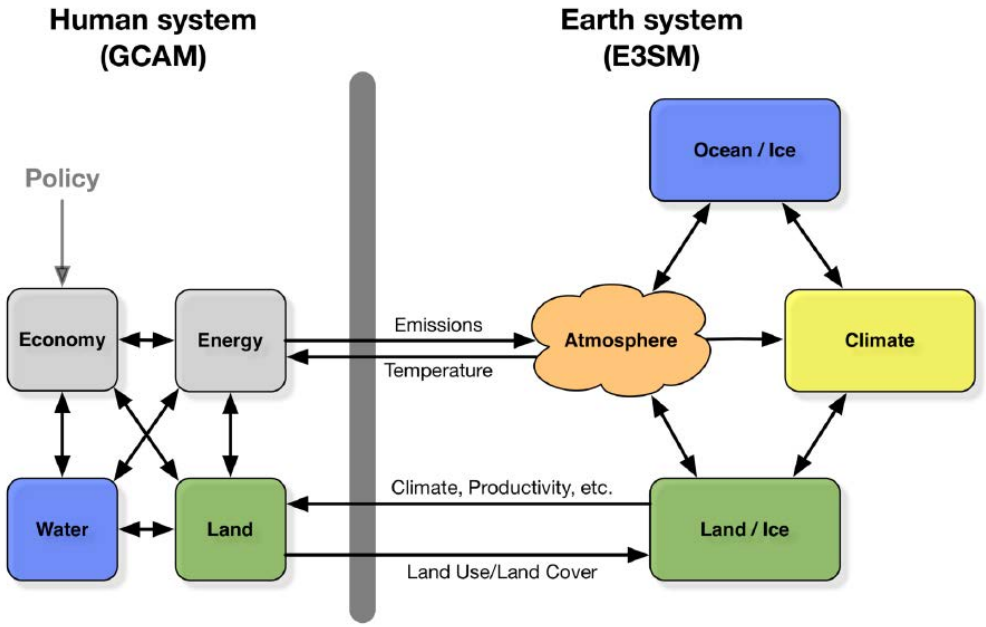
# A new unified surface mesh over land, river, and ocean



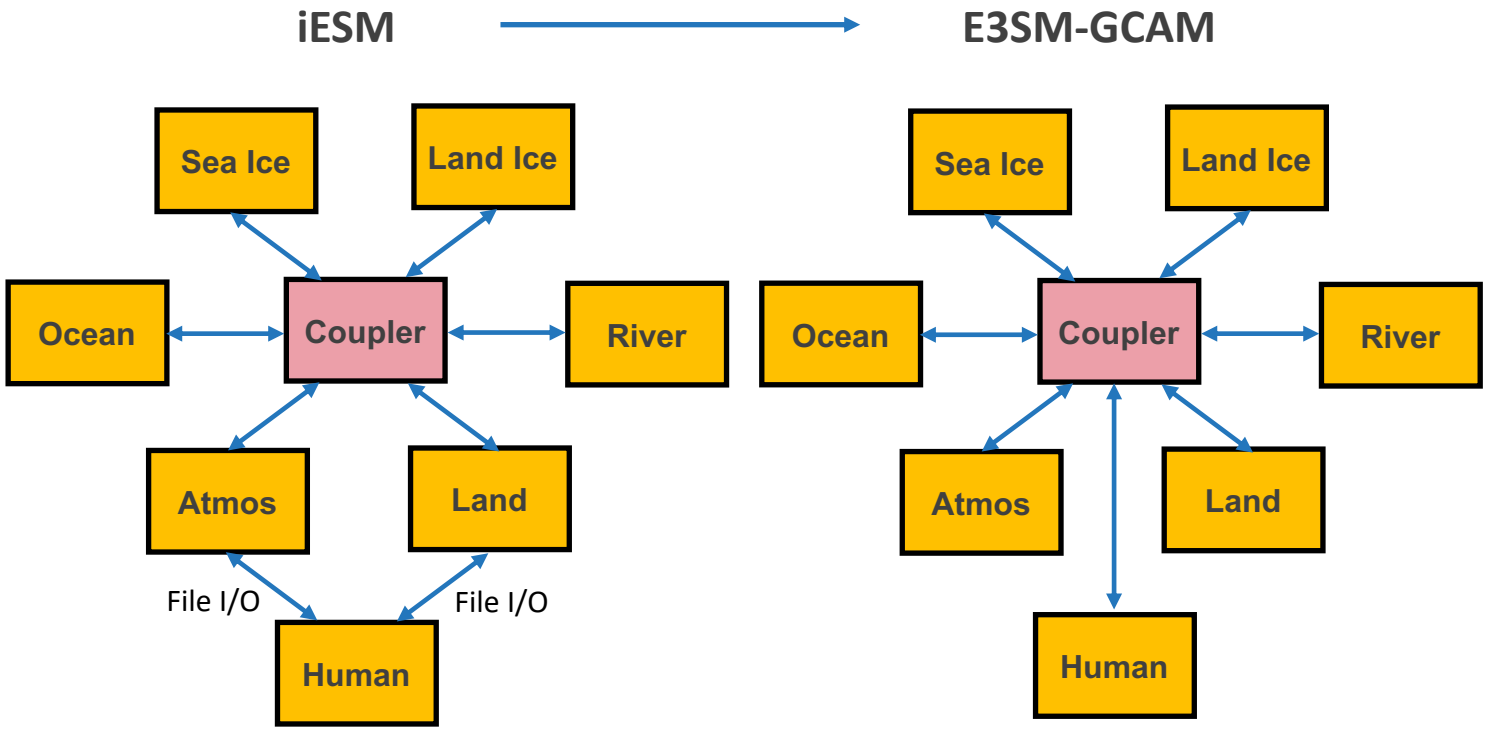

Use of tri-grid and unstructured mesh in all model components provides flexibility for telescoping to the grid spacing needed to **model multiple flood drivers and their interactions in coastal regions**

# Modeling human-Earth system feedbacks

## Coupling E3SM-GCAM



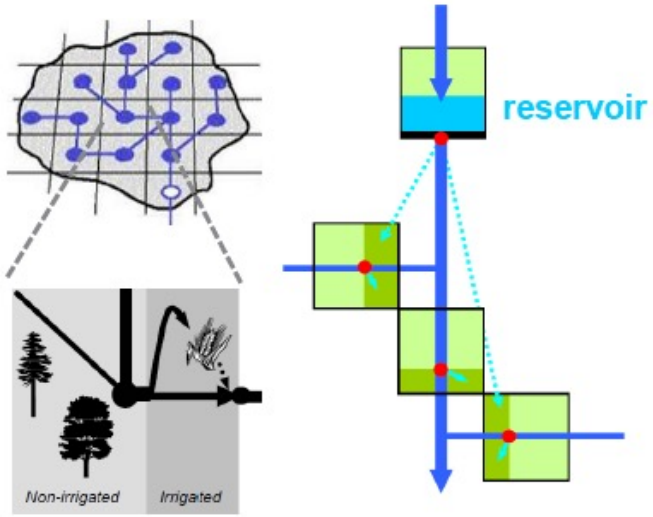

**Online coupling** using the coupler enables more dynamic representation of human-Earth system processes




(Di Vittorio, Calvin, Sinha, et al., in prep )

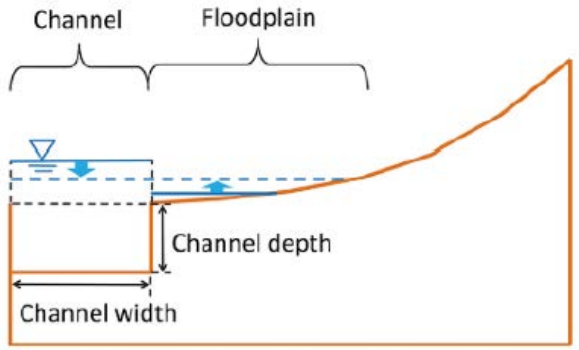
# Modeling human-Earth system feedbacks

Water supply and dam regulation schemes



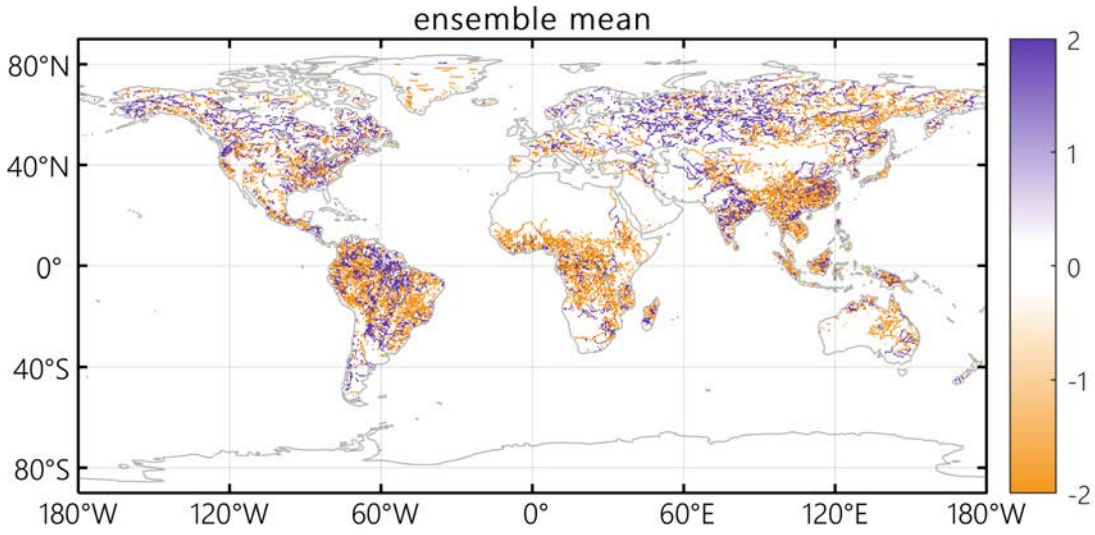

(Zhou et al. 2020 JAMES)

Floodplain inundation scheme




(Luo et al. 2017 GMD)

Where does water management alleviate future flood



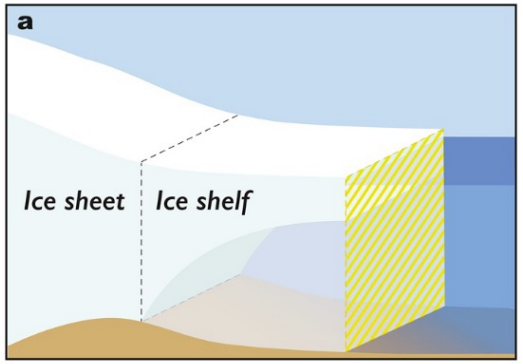

Water management does not alleviate future flood

Water management alleviates future flood

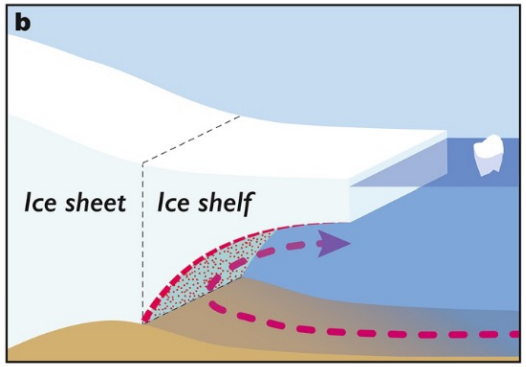
(Zhou, Leung, et al. in prep)

# Modeling polar processes: ice shelf melt fluxes

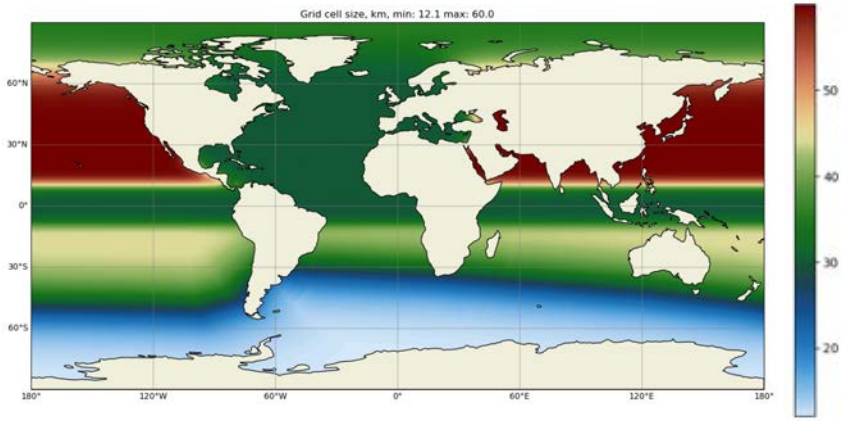
**Most climate models**




**E3SM**




**Southern Ocean Regionally Refined Mesh (SORRM) resolution (km)**

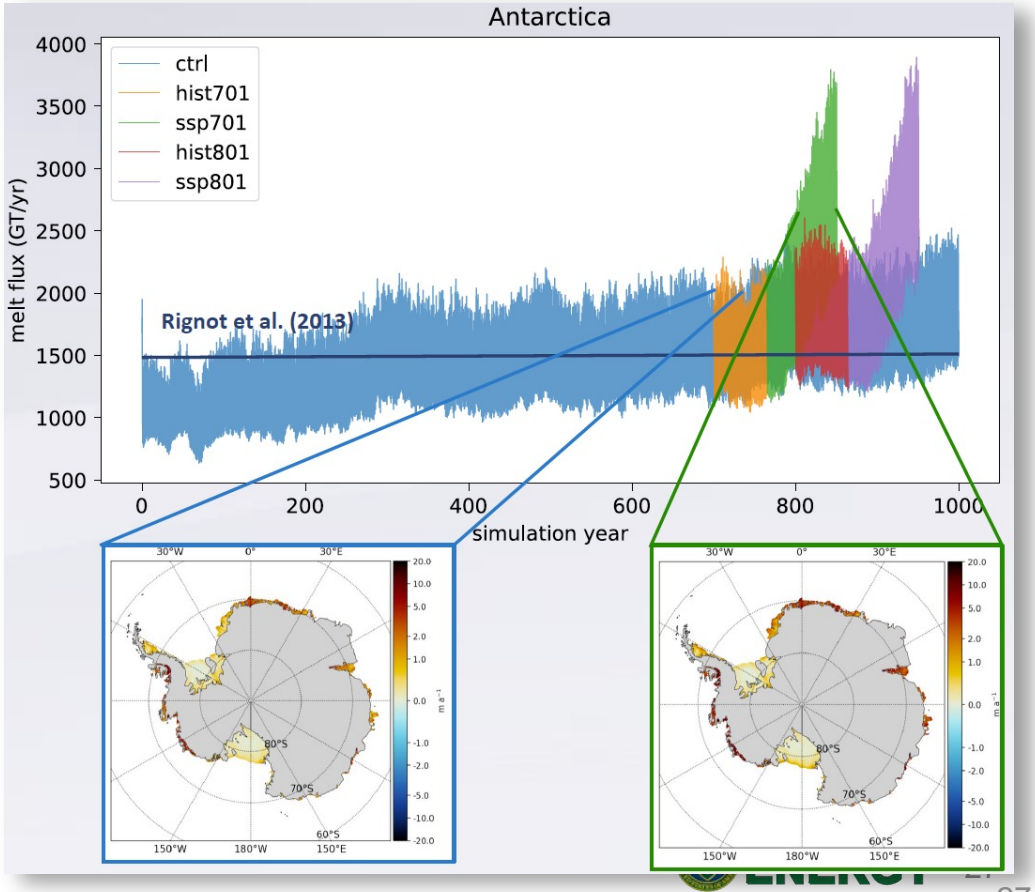



**Configuration:**

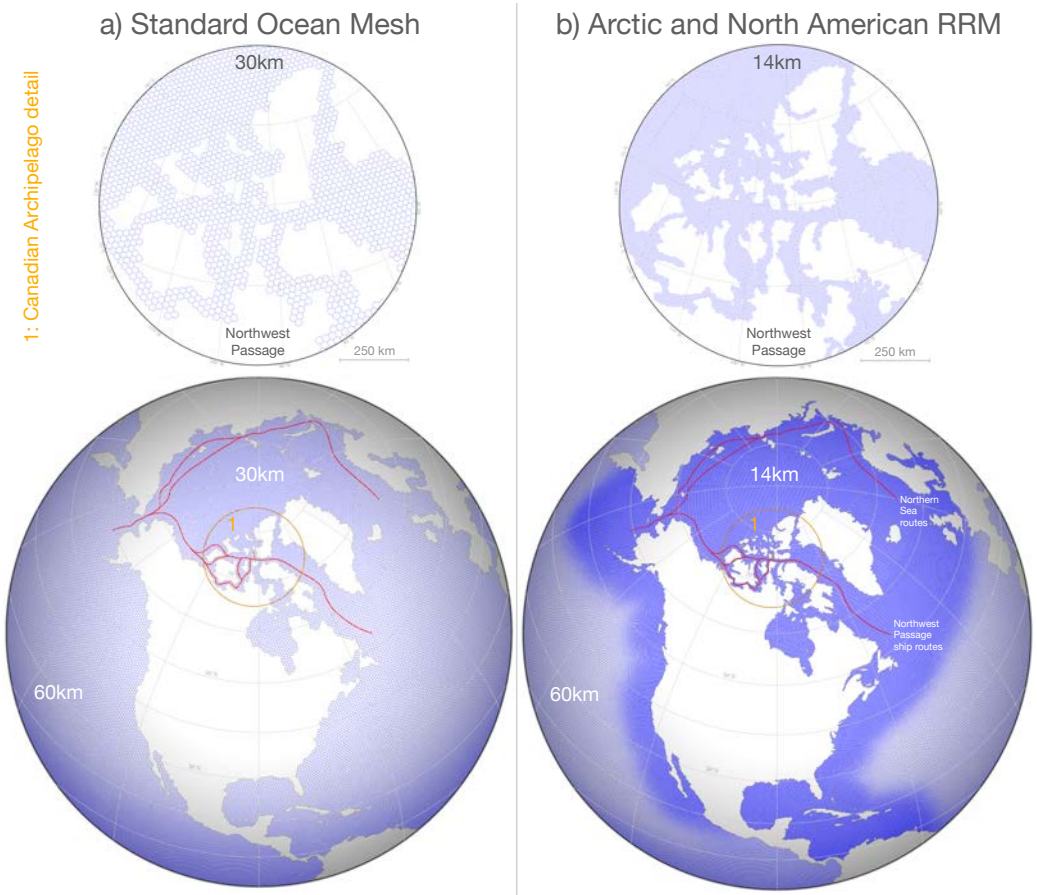
- Resolution of 12 km in the Antarctic, ~30-60 km elsewhere
- Prognostic ice shelf melt fluxes, data iceberg melt climatology

*C21D-1262* (Asay-Davis et al.) on Tuesday, 9:30am – 1:30pm

**Melt fluxes in control, two ensemble members of historical and future (SSP370) simulations**



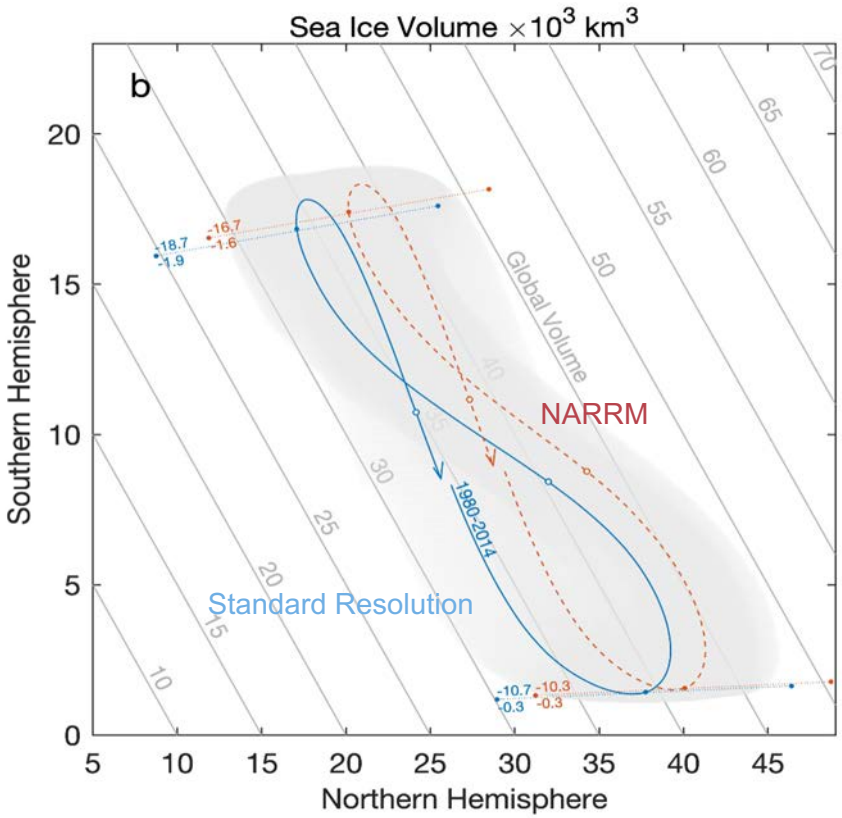
# Modeling polar processes: Arctic sea ice

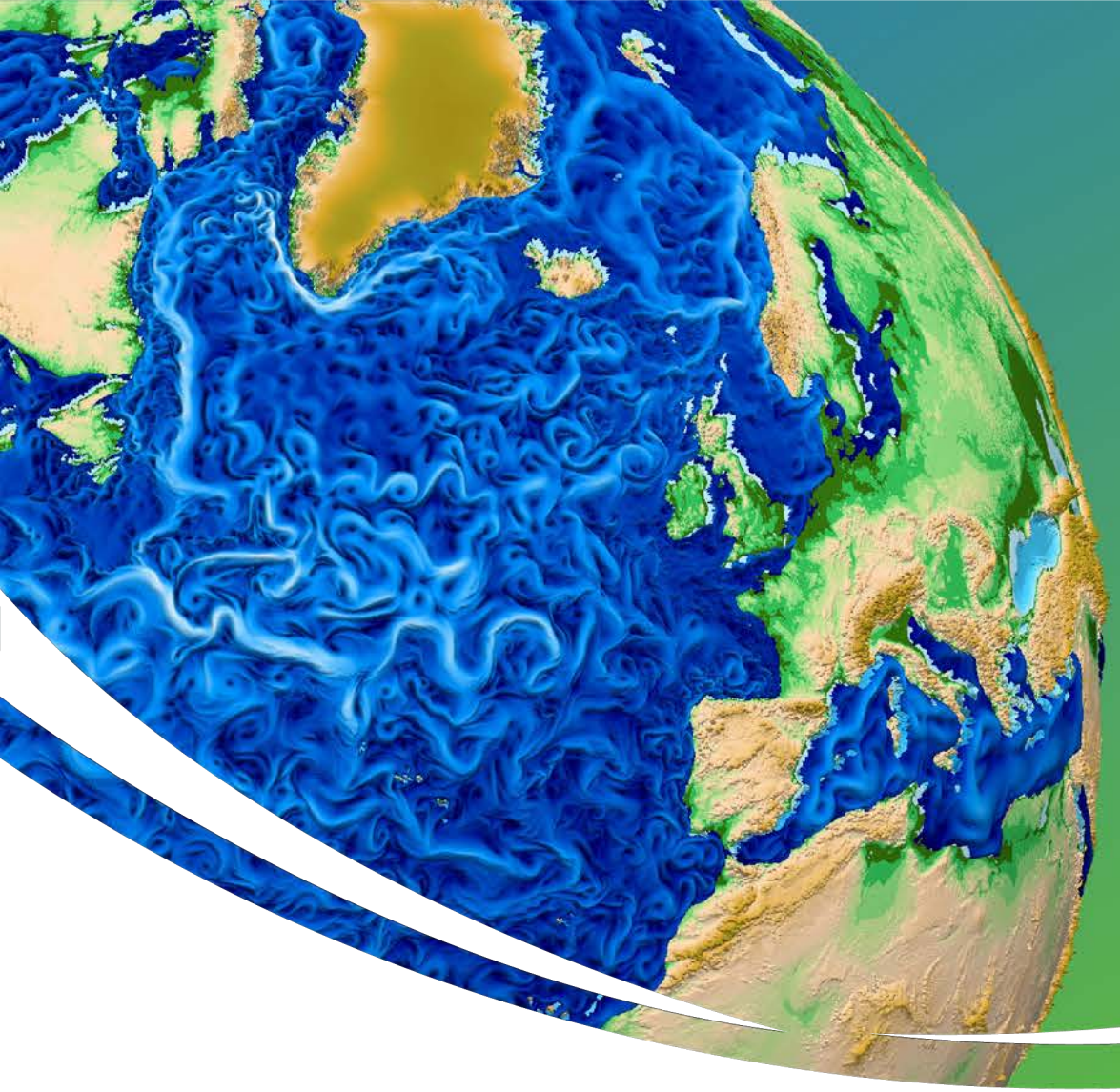



Standard Resolution

Eddy Permitting in the Arctic

## Regional Refinement Increases Arctic Sea Ice Volume





# E3SM Exascale Readiness

Mark Taylor, SNL

E3SM Chief Computational Scientist

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U.S. DEPARTMENT OF ENERGY

EXASCALE COMPUTING PROJECT

E3SM Energy Exascale Earth System Model

# DOE Computing Landscape

- DOE: Large investments in Exascale computing
  - E3SM mission to run on these computers
  - DOE SC machines ranked #1, #2, #7, #12 in the Top500 list of the world's fastest computers
  - Most of the compute power, power consumption and purchase cost comes from the GPUs
- E3SM Exascale mission = run efficiently on GPUs
- Challenge: GPUs can provide large acceleration of many kernels, but what about the full model, including all the time spent in communication?
  - E3SM's global cloud resolving atmosphere (SCREAM)
  - 5.8x faster (AMD 2x64 core CPU node vs. 4xA100 GPU node)
  - 3.5x faster per Watt (based on measured power consumption)

**https://www.top500.org/**

| Rank | System | Cores | Rmax (PFlop/s) | Rpeak (PFlop/s) | Power (kW) |
|---|---|---|---|---|---|
| 1 | **Frontier** - HPE Cray EX235a, AMD Optimized 3rd Generation EPYC 64C 2GHz, AMD Instinct MI250X, Slingshot-11, **HPE**<br>DOE/SC/Oak Ridge National Laboratory<br>United States | 8,699,904 | 1,194.00 | 1,679.82 | 22,703 |
| 2 | **Aurora** - HPE Cray EX - Intel Exascale Compute Blade, Xeon CPU Max 9470 52C 2.4GHz, Intel Data Center GPU Max, Slingshot-11, **Intel**<br>DOE/SC/Argonne National Laboratory<br>United States | 4,742,808 | 585.34 | 1,059.33 | 24,687 |
| 3 | **Eagle** - Microsoft NDv5, Xeon Platinum 8480C 48C 2GHz, NVIDIA H100, NVIDIA Infiniband NDR, **Microsoft**<br>Microsoft Azure<br>United States | 1,123,200 | 561.20 | 846.84 | |
| 4 | **Supercomputer Fugaku** - Supercomputer Fugaku, A64FX 48C 2.2GHz, Tofu interconnect D, **Fujitsu**<br>RIKEN Center for Computational Science<br>Japan | 7,630,848 | 442.01 | 537.21 | 29,899 |
| 5 | **LUMI** - HPE Cray EX235a, AMD Optimized 3rd Generation EPYC 64C 2GHz, AMD Instinct MI250X, Slingshot-11, **HPE**<br>EuroHPC/CSC<br>Finland | 2,752,704 | 379.70 | 531.51 | 7,107 |
| 6 | **Leonardo** - BullSequana XH2000, Xeon Platinum 8358 32C 2.6GHz, NVIDIA A100 SXM4 64 GB, Quad-rail NVIDIA HDR100 Infiniband, **EVIDEN**<br>EuroHPC/CINECA<br>Italy | 1,824,768 | 238.70 | 304.47 | 7,404 |
| 7 | **Summit** - IBM Power System AC922, IBM POWER9 22C 3.07GHz, NVIDIA Volta GV100, Dual-rail Mellanox EDR Infiniband, **IBM**<br>DOE/SC/Oak Ridge National Laboratory<br>United States | 2,414,592 | 148.60 | 200.79 | 10,096 |
| 8 | **MareNostrum 5 ACC** - BullSequana XH3000, Xeon Platinum 8460Y+ 40C 2.3GHz, NVIDIA H100 64GB, Infiniband NDR200, **EVIDEN**<br>EuroHPC/BSC<br>Spain | 680,960 | 138.20 | 265.57 | 2,560 |
| 9 | **Eos NVIDIA DGX SuperPOD** - NVIDIA DGX H100, Xeon Platinum 8480C 56C 3.8GHz, NVIDIA H100, Infiniband NDR400, **Nvidia**<br>NVIDIA Corporation<br>United States | 485,888 | 121.40 | 188.65 | |
| 10 | **Sierra** - IBM Power System AC922, IBM POWER9 22C 3.1GHz, NVIDIA Volta GV100, Dual-rail Mellanox EDR Infiniband, **IBM / NVIDIA / Mellanox**<br>DOE/NNSA/LLNL<br>United States | 1,572,480 | 94.64 | 125.71 | 7,438 |
| 11 | **Sunway TaihuLight** - Sunway MPP, Sunway SW26010 260C 1.45GHz, Sunway, **NRCPC**<br>National Supercomputing Center in Wuxi<br>China | 10,649,600 | 93.01 | 125.44 | 15,371 |
| 12 | **Perlmutter** - HPE Cray EX 235n, AMD EPYC 7763 64C 2.45GHz, NVIDIA A100 SXM4 40 GB, Slingshot-11, **HPE**<br>DOE/SC/LBNL/NERSC<br>United States | 888,832 | 79.23 | 113.00 | 2,945 |

# Programming Models for GPU systems


- **Fortran + Directives**
  - Relies heavily on (lagging) vendor compiler support
  - Remains immature w.r.t. advanced Fortran features
  - Good performance still requires major code refactoring

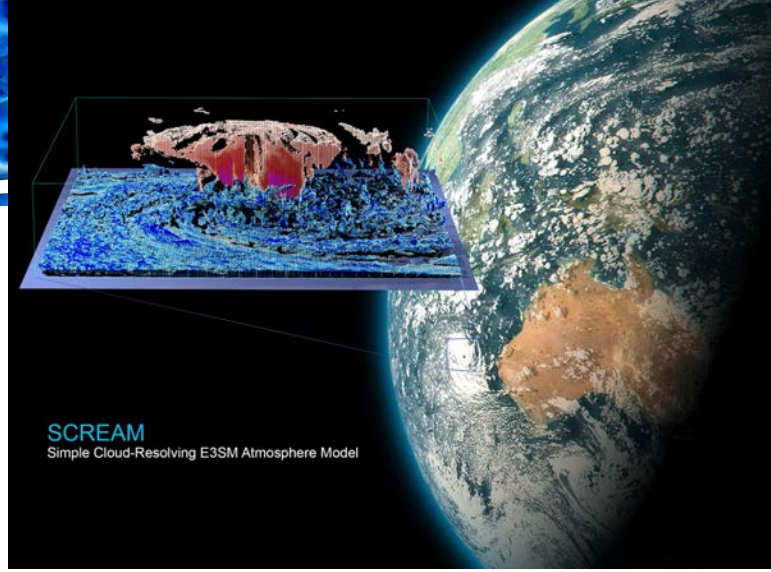

- **C++ / on-node Parallel array abstractions ( Kokkos and YAKL)**
  - C++ has robust vendor support across NVIDIA, AMD and Intel
  - Kokkos and YAKL backends quickly adapt to each vendor's preferred technology (CUDA, HIP, SYCL, pthreads, etc…)
  - Kokkos and YAKL rely on standard C++ methodology and work together seamlessly


- **DSL: Domain Specific Language**
  - Promising approach being explored by several modeling centers ( e.g. GT4Py, GridTools, PSyclone)
  - Most HPC experience within DOE labs is with C++

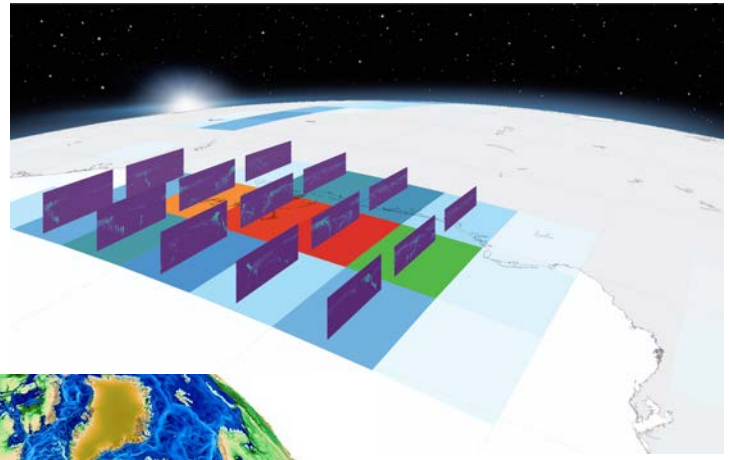
```
Kokkos::parallel_reduce(
  Kokkos::TeamThreadRange(team, kmax-kmin+1), [&] (int pk_, Scalar& lmax) {
    const int pk = kmin + pk_;
    const auto range_pack = scream::pack::range<IntSmallPack>(pk*Spack::n);
    const auto range_mask = range_pack >= kmin_scalar && range_pack <= kmax_scalar;
    const auto qc_gt_small = range_mask && qc_incld(pk) > qsmall;
    if (qc_gt_small.any()) {
      // compute Vq, Vn
      Spack nu, cdist, cdist1, dum;
      get_cloud_dsd2<false>(qc_gt_small, qc_incld(pk), nc_incld(pk), mu_c(pk), rho(pk), nu, dnu, lamc(pk), cdist,
      nc(pk).set(qc_gt_small, nc_incld(pk)*lcldm(pk));
      dum = 1 / (pack::pow(lamc(pk), bcn));
      V_qc(pk).set(qc_gt_small, acn(pk)*pack::tgamma(4 + bcn + mu_c(pk)) * dum / (pack::tgamma(mu_c(pk)+4)));
      if (log_predictNc) {
        V_nc(pk).set(qc_gt_small, acn(pk)*pack::tgamma(1 + bcn + mu_c(pk)) * dum / (pack::tgamma(mu_c(pk)+1)));
      }

      const auto Co_max_local = max(qc_gt_small, -1,
                                    V_qc(pk) * dt_left * inv_dzq(pk));
      if (Co_max_local > lmax)
        lmax = Co_max_local;
    }
}, Kokkos::Max<Scalar>(Co_max));
team.team_barrier();
```

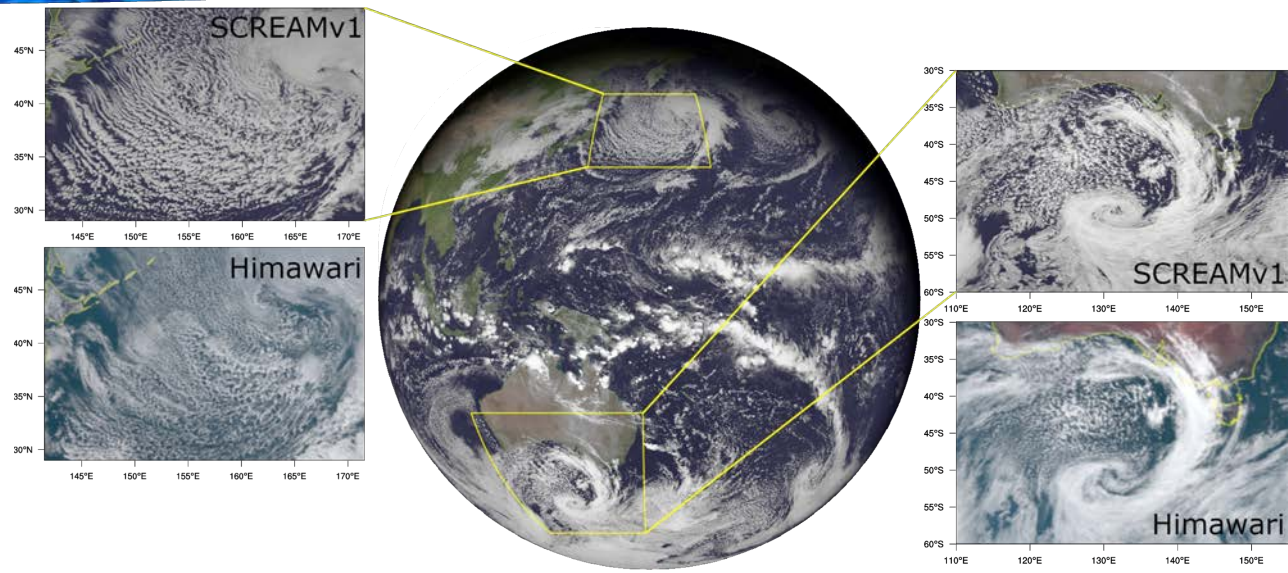
# E3SM GPU Capabilities




- SCREAM: Simple Cloud Resolving E3SM Atmosphere Model
  - New nonhydrostatic atmosphere model, rewritten from scratch in C++
  - Designed for cloud resolving resolutions (prescribed aerosols, no deep convection parameterizations)
  - Competitive with Fortran version on CPUs, and running well on NVIDIA, AMD (and hopefully soon Intel) GPUs
  - 2023 Gordon Bell Prize for Climate Modeling!
- E3SM-MMF (superparameterized-E3SM)
  - E3SM fully coupled simulations at typical climate resolution, running with most atmosphere parameterizations replaced by a local cloud resolving model
  - GPU acceleration allows MMF approach to obtain similar throughput as a conventional model
- In Progress:
  - Omega: Port of MPAS-Ocean into C++/YAKL
  - ELM: GPU acceleration via Fortran/OpenACC (transitioning to OpenMP to support AMD and Intel GPUs)



# GPU enabled simulations Roadmap

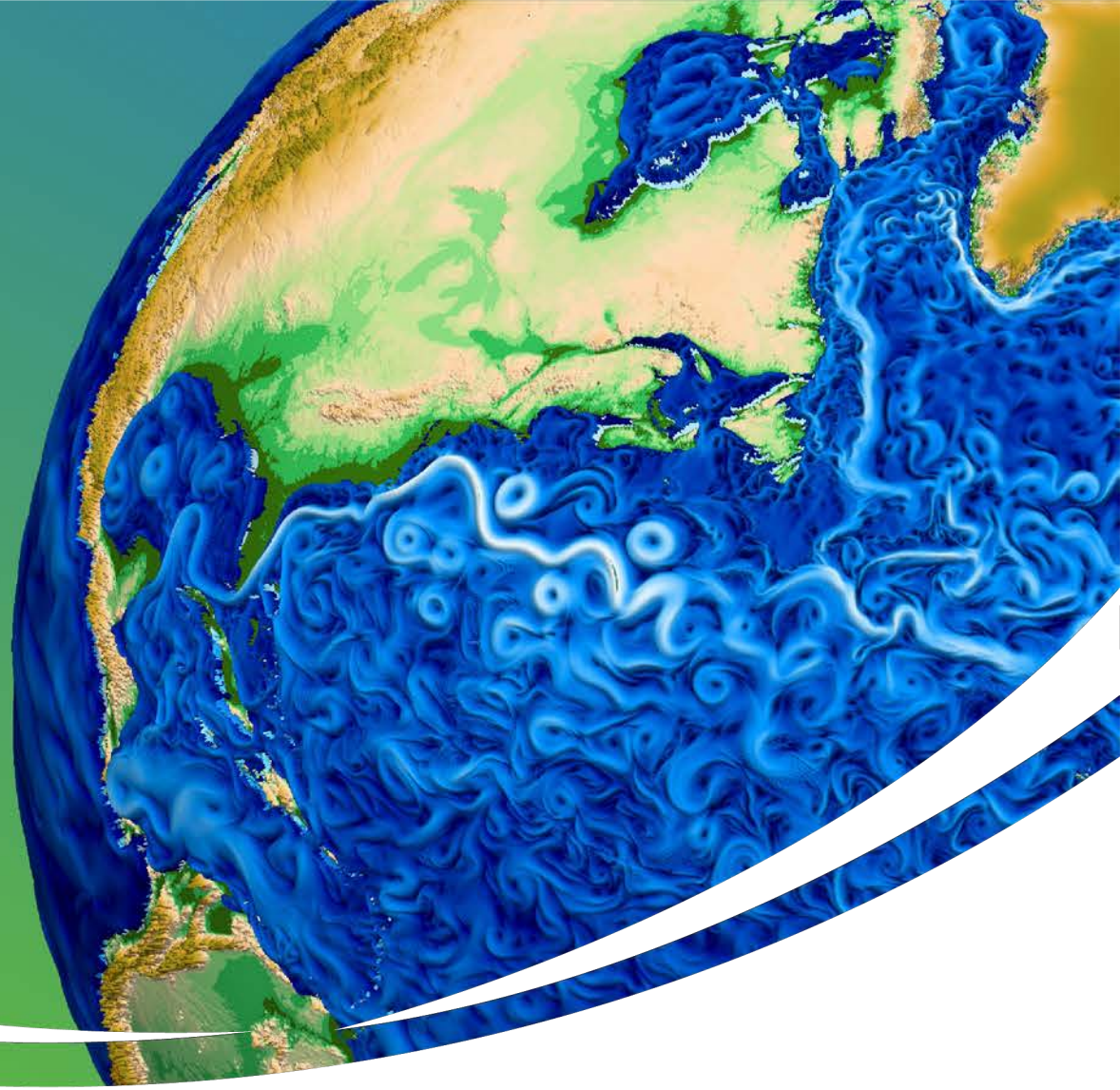



- Cloud resolving atmosphere simulations
  - 2023: Multi-year simulations for Cess-Potter climate sensitivity
  - 2024: Multi-decadal AMIP simulations
- E3SM-MMF
  - 2023: Century long full coupled climate simulations with cloud resolving deep convection “super-parameterization”
- E3SMv4: 2026
  - Full Earth System Model running efficiently on GPUs
  - Atmosphere: based on SCREAM, with additional support for non-cloud resolving resolutions, prognostic aerosols and some chemistry
  - Ocean: Omega eddy resolving ocean
  - Less expensive components (land, Ice): use idle CPU cores of the GPU node, or run on GPUs depending on readiness

# E3SM as an Open Science Model Development Project

Renata McCoy, LLNL

E3SM Chief Operating Office & Project Engineer



U.S. DEPARTMENT OF ENERGY

E3SM Energy Exascale Earth System Model

# Open Science Development Model

- E3SM is **Open Development Code**!!
  - As of the first data release (Apr 2018), E3SM is freely available on GitHub
- All in **E3SM tools** are **open-source** development tools
  - https://e3sm.org/resources/tools/
- **Data** from all major, campaign simulations are **available to all**, **published on ESGF** *
  - Few months delay between the production and publication to ESGF to publish an overview paper
- Support for code and data (limited)
  - Support for **"scientifically validated" compsets / configuration** used in simulation campaigns
  - Supported versions:
    - maint-v1.0, maint-v1.1, maint-v1.2, maint-v2.0, maint-v2.1,
  - Guaranteed to run on the **E3SM-supported DOE LC centers**

* ESGF – Earth System Grid Federation

# External project's early access to data or internal documentation

Projects can submit a **collaboration request** specifying:

- What data/simulation/early access information they need
- What research are they planning to do
- Specify an E3SM Point of Contact (POC)
- Agree to collaborate and include the E3SM POC in your publication

- **Fill in the doc at**
  - https://e3sm.org/about/collaboration/collaboration_request/

# Documentation, Webinars, Online Tutorials

- Extensive documentation on the **Confluence public site**
  - https://acme-climate.atlassian.net/wiki/spaces/DOC
- Diagnostics and analysis tools
  - https://e3sm.org/resources/tools/
- Documentation and online tutorials
  - https://e3sm.org/about/events/e3sm-tutorials/
- Webinars and presentations
  - https://e3sm.org/about/events/all-hands-presentations/

# First In-person Hands-on Tutorial Workshop @ NERSC

- May 7-10, 2024
- At NERSC
  - National Energy Research Scientific Computing Center (NERSC)
    Lawrence Berkeley National Lab in Berkeley, CA.
- Applications
  - Announce via E3SM and EESSD-related email lists in December
  - Priority to DOE projects
  - https://e3sm.org/announcing-the-e3sm-tutorial-workshop-at-nersc
- The tutorial will encompass:
  1. Lectures on earth system simulation and the model components of E3SM.
  2. Practical sessions on running E3SM, modifying components, and analyzing data.
  3. Best practices for utilizing the model and potentially contributing to its development.
- Will be **recorded** and available on **E3SM YouTube**
  - Lectures, examples, class notes

# E3SM Communication

- **E3SM Website** http://e3sm.org

- Public **Confluence** for
  - Developer's documentation: https://acme-climate.atlassian.net/wiki/spaces/DOC
  - E3SM Conferences: https://acme-climate.atlassian.net/wiki/spaces/ECM

- **E3SM quarterly "*Floating* Points" Newsletter** provides:
  - Latest news
  - Research Highlights
  - Project vision and Roadmaps
  - Self subscribe:
    - email listserv@listserv.llnl.gov with the email body: 'subscribe E3SM-news'

- **E3SM YouTube Channel** with seminars, webinars, and tutorials
  - https://www.youtube.com/@e3sm-project


November 30, 2023 View in Browser

E3SM Floating Points, Nov '23: E3SM Wins Gordon Bell Prize for Climate Modeling.

E3SM Energy Exascale Earth System Model

FLOATING POINTS

*News from DOE's state-of-the-science Earth system model development project.*

Editor in Chief: Renata McCoy

*From the Program Manager*

Welcome to the Winter issue of E3SM newsletter ... On November 16th, at the Supercomputing Conference (SC23), it was announced that E3SM wins the inaugural Gordon Bell Prize for Climate Modeling. It is an incredible honor for E3SM to receive such a prestigious prize among our well-accomplished national and international peers ... Read more of Dr. Davis' message.

*Project News*

**E3SM Wins the Gordon Bell Prize for Climate Modeling**

We are pround to announce that in November 2023, at the Supercomputing Conference (SC23) in Denver, E3SM was awarded the Gordon Bell Prize... Read more.

**Data Releases: v2.0 NARRM and Large Ensembles and More**

Three data categories were added: E3SMv2 North America Regionally Refined Model (NARRM), E3SMv1.0 high resolution data, and the Large Ensembles (LENS) simulation ecosystem data. ... Read more.

**Summary of the E3SM Leadership Meeting**

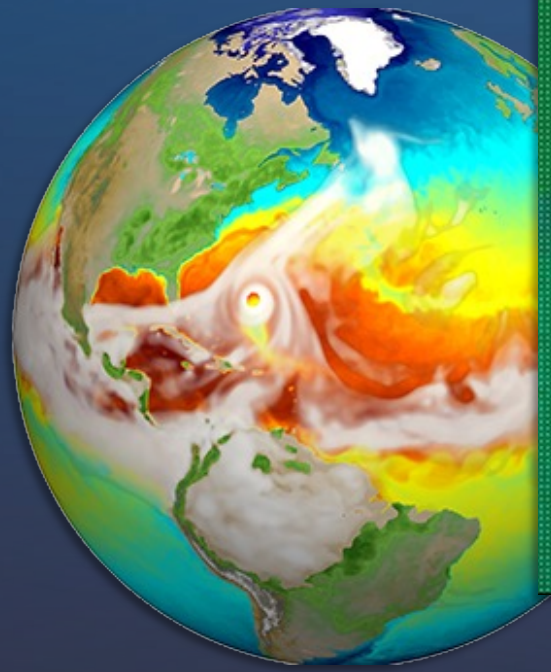
E3SM Leadership Team held an in-person meeting in Bethesda, MD, focusing on long-term strategy and project support including: communication, documentation, tutorials, code review, and best practice standards. ... Read more.

**Announcing the E3SM Tutorial Workshop at NERSC**

The first ever in-person E3SM Tutorial Workshop will be held during May 7-10 at the National Energy Research Scientific Computing Center (NERSC) at Lawrence Berkeley National Lab in Berkeley, CA. ... Read more.

# Thank You!

e3sm.org




E3SM-related sessions on AGU: https://tinyurl.com/a8yvy958