

# Activities of US Modeling Groups

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08 NOVEMBER 2022



This material is based upon work supported by the National Center for Atmospheric Research, which is a major facility sponsored by the National Science Foundation under Cooperative Agreement No. 1852977.



# GFDL's Seamless Modeling System



	<b>SHiELD</b> System for High-resolution prediction on Earth-to-Local Domains	<b>SPEAR</b> Seamless System for Prediction and EArth System Research	<b>CM4</b> Coupled Physical Model Version 4	<b>ESM4</b> Earth System Model Version 4
<b>MODELS:</b>				
<b>TIMESCALE:</b>	Weather; Subseasonal to Seasonal (S2S)	Seasonal-to-Decadal (S2D)	Decades to Centuries Climate processes	Decades to Centuries Climate & Composition
<b>USED FOR:</b>	Research Applications Predictions	Research Applications Predictions Projections	Research Applications Projections	Research Applications Projections

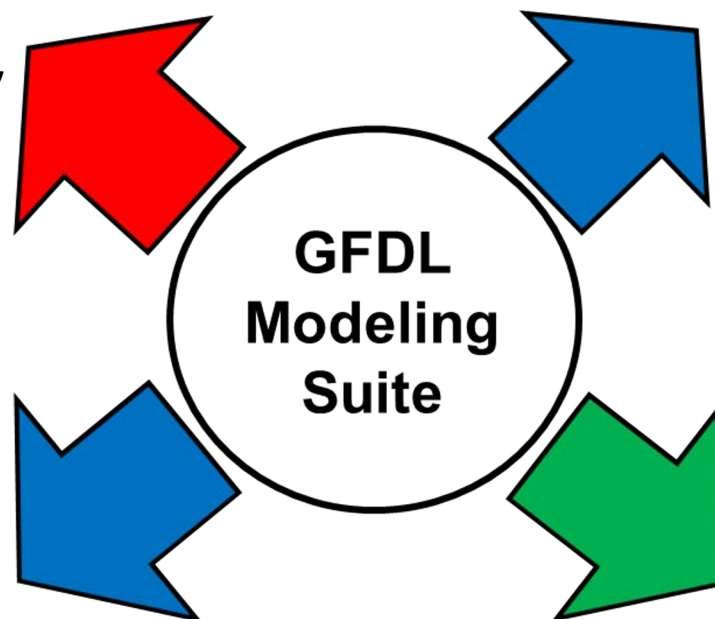


# Users of GFDL Models, Data, and Information



**World Meteorological Organization, Climate Projections, Assessments, peer-reviewed publications, and Quarterly Bulletins**

**National Weather Service, National Marine Fisheries Service, National Environmental Satellite, Data, and Information Service, National Ocean Service, Oceanic and Atmospheric Research**



**Experimental Predictions:**  
Weather → NWS/EMC  
Seasonal → NWS/NMME  
Hurricane → NWS/NHC  
Arctic summer sea ice → NSIDC  
Annual → IRI/Columbia  
Decadal → UKMO/WMO

**Computational & Infrastructural Support, Community Collaborations, other Federal Agencies, and Private sector**

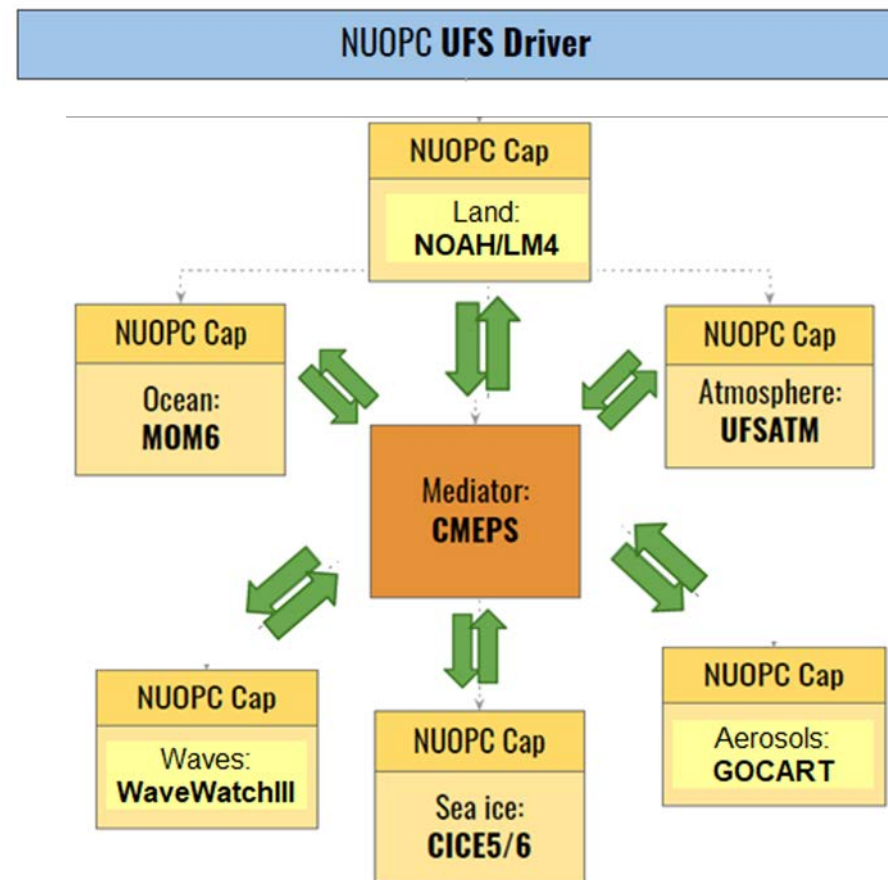
# NWS Operational Targets for UFS-based Global Coupled Applications

## *GFS v17/GEFS v13: Fully coupled system for MRW and Subseasonal predictions*

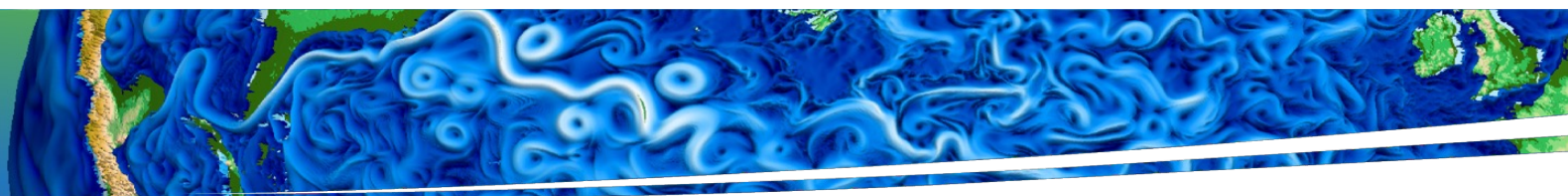
- FV3+MOM6+CICE6+WW3+NOAH-MP+GOCART Coupled Model
- Advanced Physics, Weakly Coupled DA
- **FY24: Implement GFS v17 & GEFS v13**

## *Seasonal Forecast System (SFS v1.0)*

- Fully coupled Unified Forecast System
- Seasonal ensemble forecasts with reanalysis and reforecasts
- Advanced coupled DA
- **FY27+: Implement SFS v1.0**





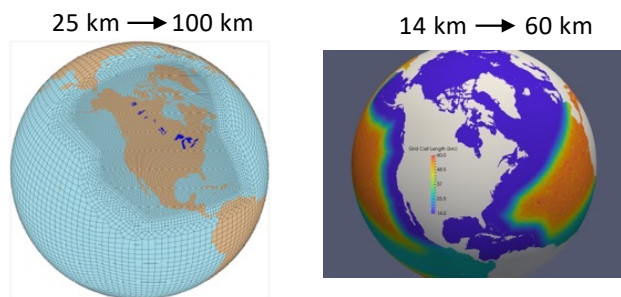


## Overarching goal: advance actionable science in support of DOE's energy mission

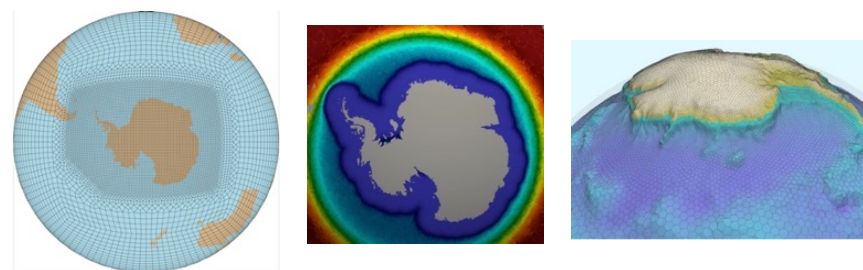
High resolution modeling, representing human-Earth system interactions, and quantifying uncertainty

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	-	variable

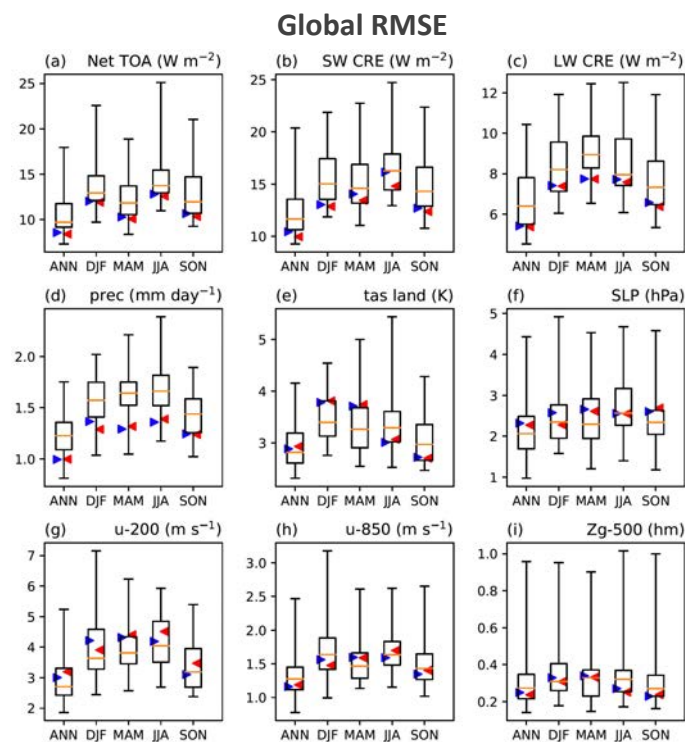
North American Regional Refined Model (NARRM)



Southern Ocean Regional Refined Model (SORRM)

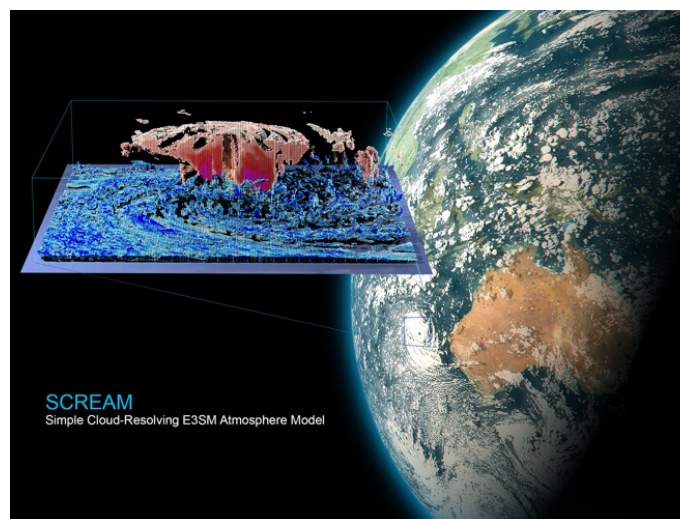


E3SMv2 (ECS = 4.0K) is better and faster than E3SMv1  
DECK and historical simulations completed using LR  
(red) and NARRM (blue) configurations



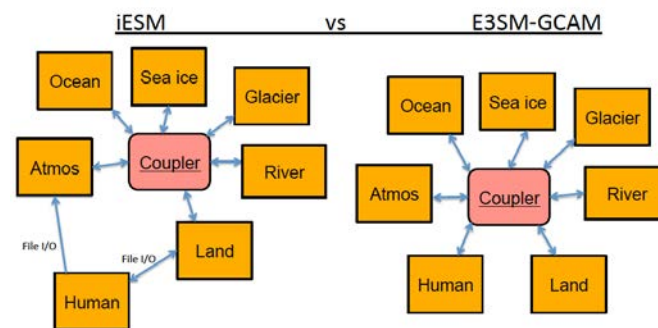
(Golaz et al. 2022 JAMES; Tang et al. JAMES submitted)

Global cloud resolving simulation at 3.25 km resolution  
GPU-enabled version fully functional



(Caldwell et al. 2021 JAMES)

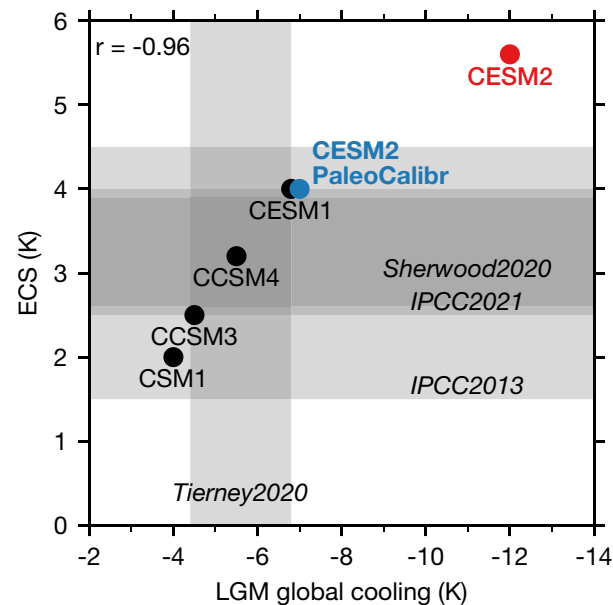
Coupled GCAM with E3SM as a component  
model allows more dynamic representation  
of human-Earth interactions



# Community Earth System Model (CESM)

Overarching Goal: Advance science and understanding of the Earth system and provide actionable information for societal use in strong collaboration with the **community**

Many applications, including contributions to CMIP DECK and MIPs, use the nominal  $1^\circ$  resolution version of the model



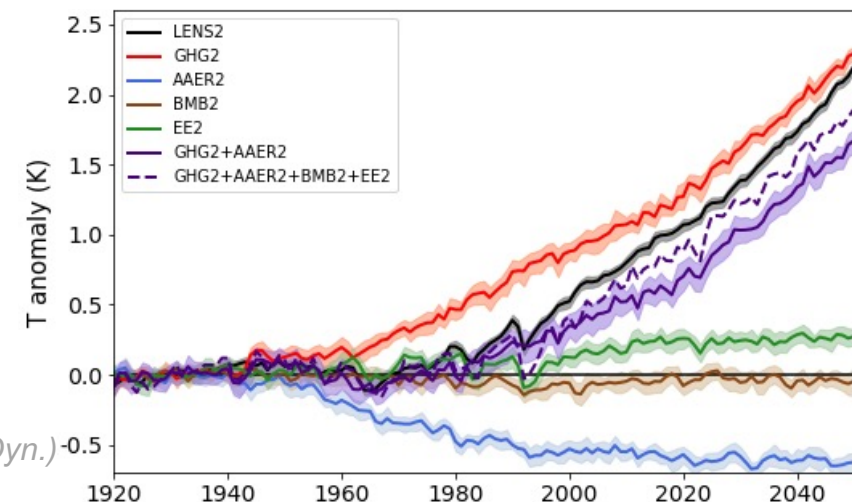
Zhu et al. (2022, JAMES)

## CESM2 Large Ensembles

A 100-member ensemble for the 1850-2100 period with SSP-3.70;

**Single forcing:** 15 members each for greenhouse gases only; anthropogenic aerosols only; biomass burning aerosols only; and everything else

Rodgers et al. (2021, Earth Syst. Dyn.)  
Simpson et al. (2022, J. Climate)



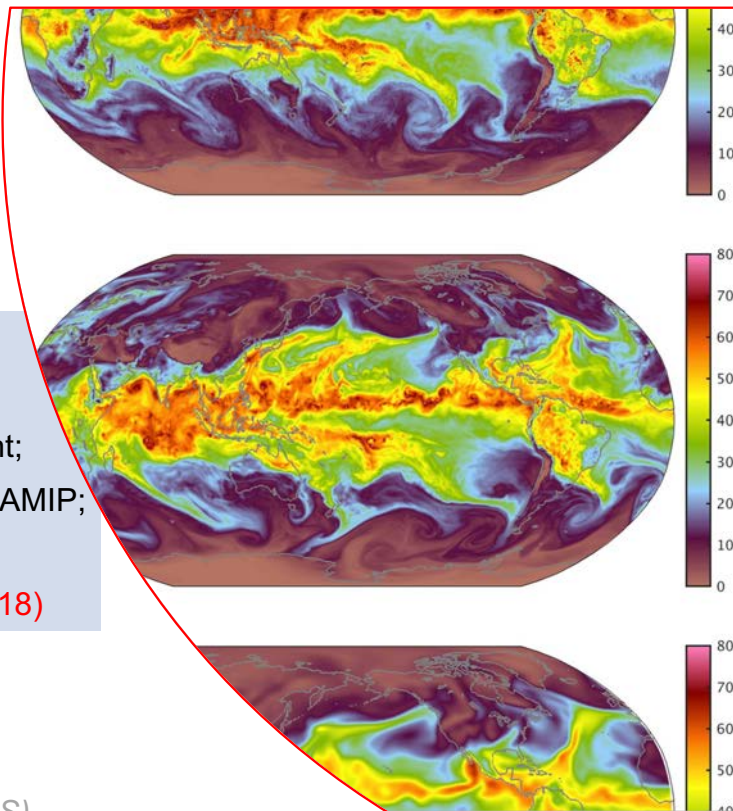


# Community Earth System Model (CESM)

CESM high-resolution with  $0.25^\circ$  atmosphere / land  
and  $0.1^\circ$  ocean / sea-ice

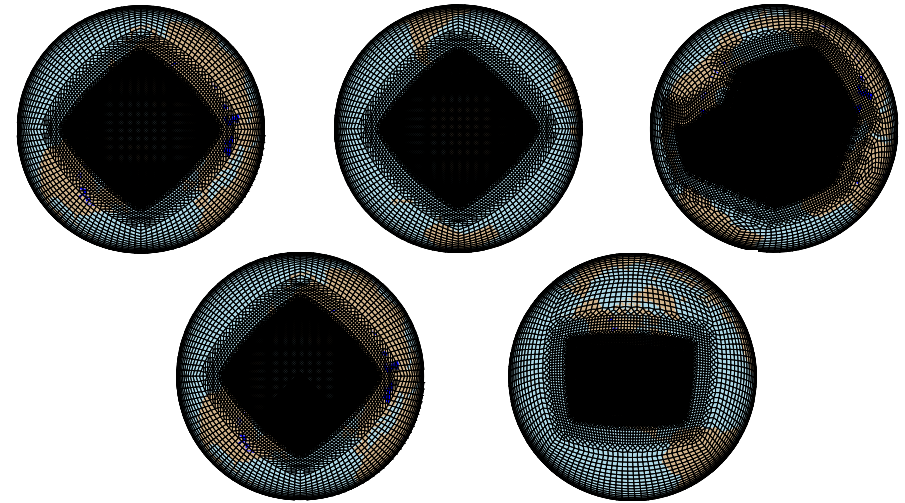
650-year PI control;  
80-year 1%CO<sub>2</sub>;  
3-member 1850-2100 transient;  
All HighResMIP Coupled and AMIP;  
5 cycles of 1958-2018 OMIP;

Decadal Predictions (1980-2018)



Chang et al. (2020, JAMES)

A library of regionally-refined grids



## New Earth System Prediction Efforts

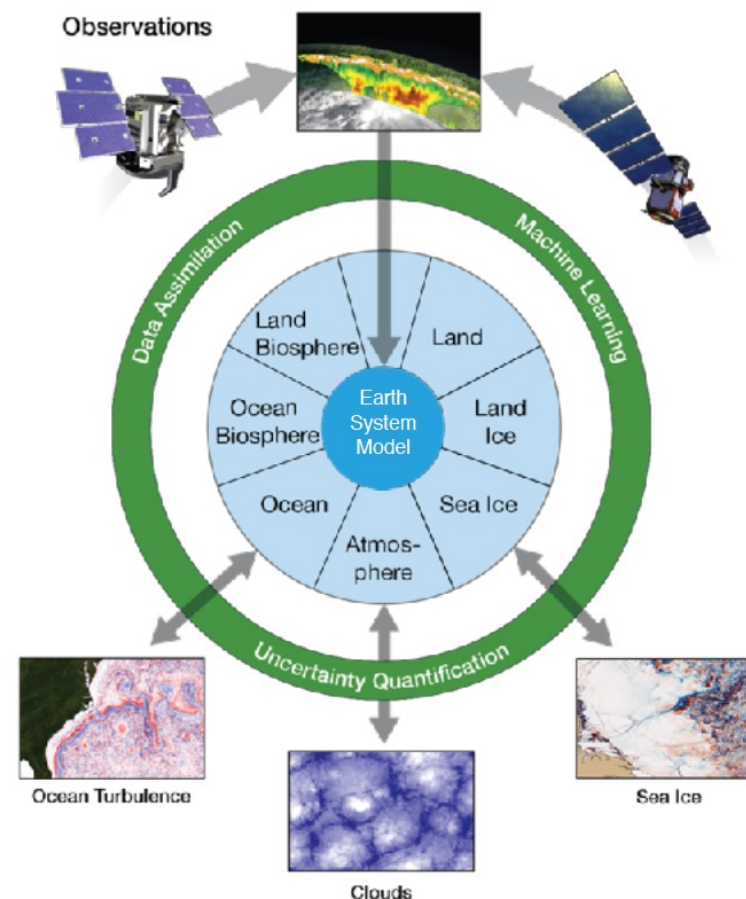
- Subseasonal, including high-top atmosphere (*Richter et al. 2022 WAF*)
- Seasonal-to-MultiYear Large Ensemble (SMYLE) prediction system (*Yeager et al. 2022 GMD*)
- High-res decadal predictions (*Yeager et al. 2022, GRL, submitted*)



# Climate Modeling Alliance (Caltech, MIT, JPL)

- Unique project worldwide developing an **all-new Earth system model** (and the only university-based project)
- Uses **physics/AI hybrid methods** to inform ESM with data from observations and high-resolution simulations
- **Calibration and uncertainty quantification** of ESM through **ML-accelerated Bayesian learning**
- Software architecture emphasizes **performance portability** (CPUs/GPUs) and **ease-of-use** (everything is written in high-level Julia language)
- Broad involvement of **students** and **early-career researchers** in science leading to model development
- **Training next-generation of scientists** to be not only model users but also developers

[clima.caltech.edu](https://clima.caltech.edu), [github.com/CLiMA](https://github.com/CLiMA)



Targeted High-Resolution Simulations



# EarthWorks

(CSU Lead, funded by NSF CSSI. NCAR and LANL Collaborators)



## Science Drivers

- Climate projections are essential for guiding adaptation.
- Extreme weather & climate events are costly for societies and ecosystems.
- High resolution is needed to resolve storms, mountains, and cities.
- Kilometer-scale grids simulate extreme weather events directly.
- Analysis of high-resolution simulations leads to better understanding of parameterized processes.

## Model design:

- A global coupled model configuration of CESM.
- 3.75 km global grid for the atmosphere, ocean, and land (440 Million columns)
- Uses CESM components and infrastructure, including the CMEPS Coupler.
- Non-hydrostatic MPAS Atmosphere with MPAS Ocean and MPAS CICE.
- Enables CESM community exploration of this new science.
- GPU-enabled.
- 2025 Performance goal is ~1 SYPD.

## Status as of November 2022:

- Port of MPAS-O and MPAS-CICE to CESM (via CMEPS) completed.
- Coupled simulations working with 30-km grid spacing on Cheyenne.
- Dynamical cores and most of the atmospheric physics running on GPUs, testing at NERSC & TACC.
- Tests with 15-km grid spacing under way.