State of the Community Earth System Model Project

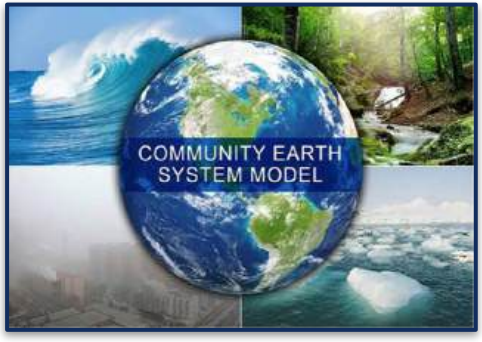
David Lawrence
CESM Chief Scientist

Welcome

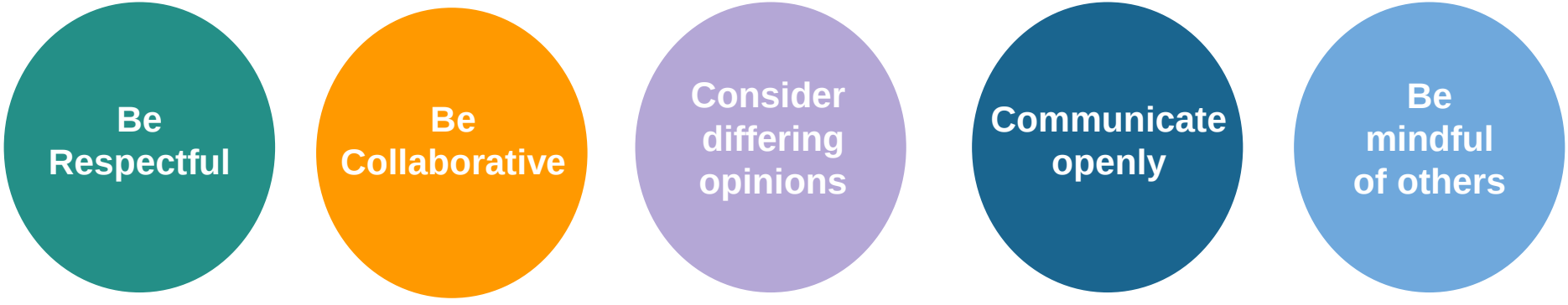
CESM Workshop 2024

29th Annual CESM Workshop

WORKSHOP



Reminder on UCAR Code of Conduct



In-person or Conduct Issues: Reach out to Dave or Elizabeth **or** UCAR Office of Diversity, Equity and Inclusion
Online issues: cesm-workshop-support@ucar.edu

Nursing Room: 2668
All-gender restrooms: 2024, 3048, 3052

Some workshop logistics

In addition to all the oral science sessions

- Group photo (Monday afternoon break, in the lobby)
- Poster session and reception this evening
- Sanitas Brewery (Tuesday evening, drinks and tacos, self pay)

Wed, 4:30-5:30pm summary session
Please submit questions via Slido about the CESM Project that arise from the workshop, from discussions with colleagues, or that you just would like more info about. CESM Leadership will address them during the "end of workshop session"

Quiet Spaces

Outdoor Seating

Walking Path

Thanks!

U.S. National Science Foundation

friends of the national center
A FUND TO ADVANCE EARTH SYSTEM SCIENCE

Supporting participation for 25 ECRs

Workshop organization and support

- Elizabeth Faircloth
- CGD Admin team
- UCAR Multimedia and Events services

Thanks!

Gokhan organized **6 (!)** CESM Workshops during his tenure as Chief Scientist

Forces driving the future of Earth System modeling

- Urgent need for actionable climate change information (climate risks, consequences of intervention/mitigation)
- *Earth System* prediction across timescales (ESPAT), S2S → S2D → 30-yr projections (ideally, seamless)
- Increasing demand for high-resolution (~0.25°) and ultra high-resolution (km-scale) configurations in modeling hierarchy
- Growth and potential of machine learning, hybrid modeling, emulators to transform models
- Changing computing architectures → need for code modernization
- Calls for improved accessibility of ESMs and output (e.g., to global south)

Image: Getty images

These drivers present many opportunities and challenges for the CESM activity

CESM high-resolution (HR) simulations

CESM1.3(HR): 0.25° atm/lnd, 0.1° ocn

500-year PI control

1%CO_2, 4xCO_2

10-member 1850-2100 transient (RCP6, RCP8.5)

All HighResMIP Coupled and AMIP

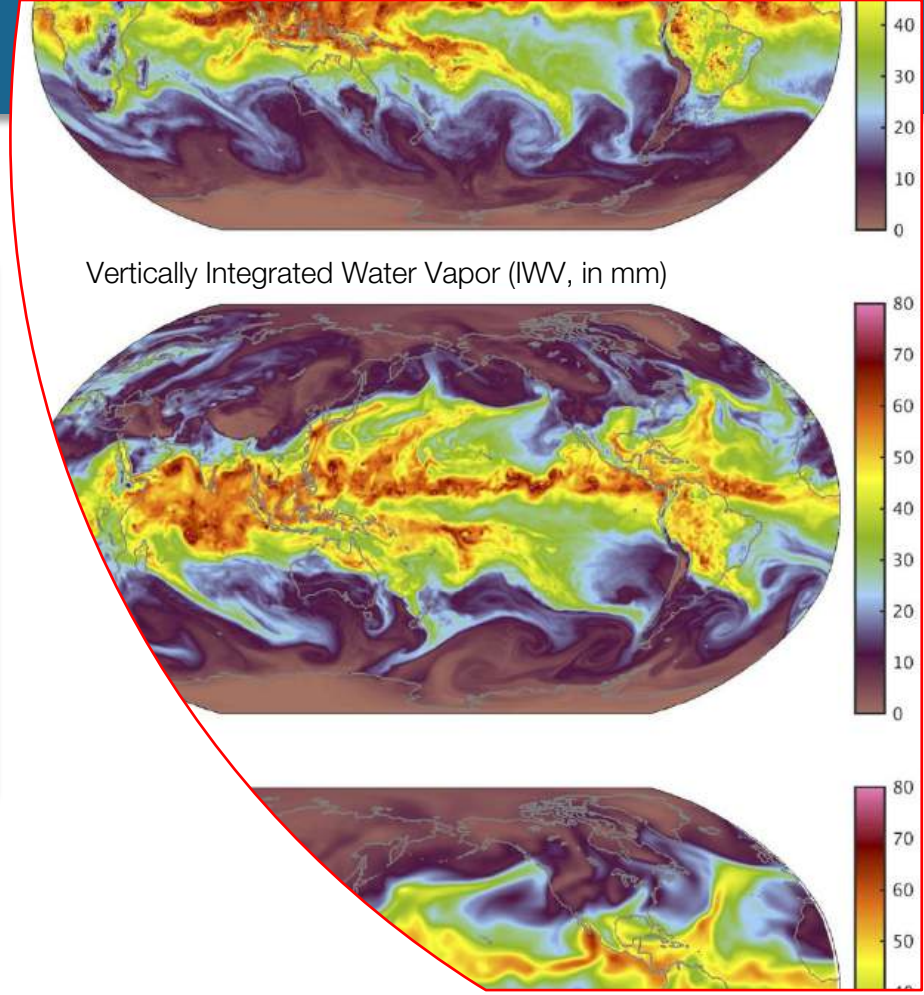
5 cycles of 1958-2018 OMIP (w/ BGC)

3-member 1970-2020 Ozone withholding

3-member 1950-2014 AMIP

Decadal Predictions (1980-2023)

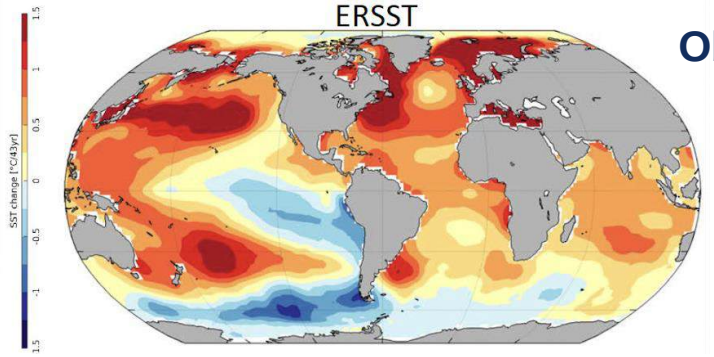
PaleoCWG: 60-year high- and low-CO_2 past periods



Initial simulations were performed by the International Laboratory for High-Resolution Earth System Prediction (iHESP); additional ensemble members supported by NSF MesACLiP project and NAS iPOGS

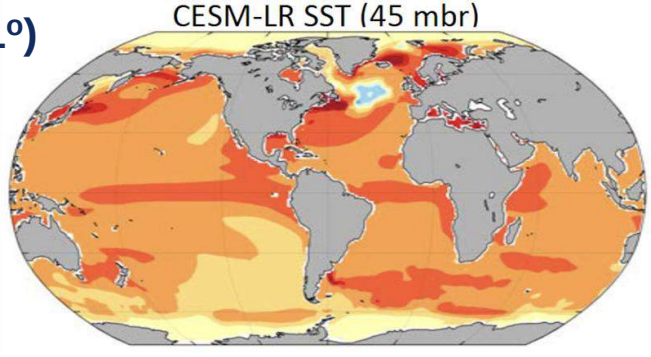
Chang et al. (2020, JAMES)

Linear trend (1980-2022) in SST



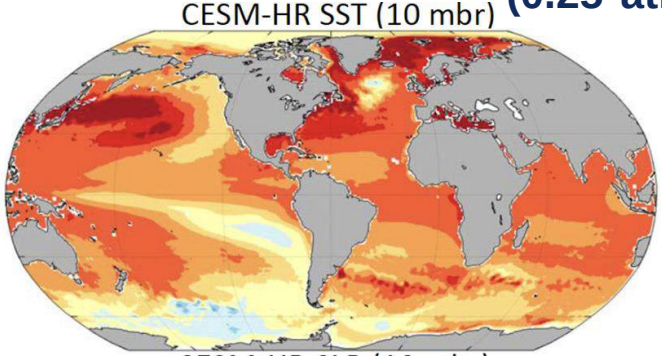
Observed trends

CESM1 (~1°)



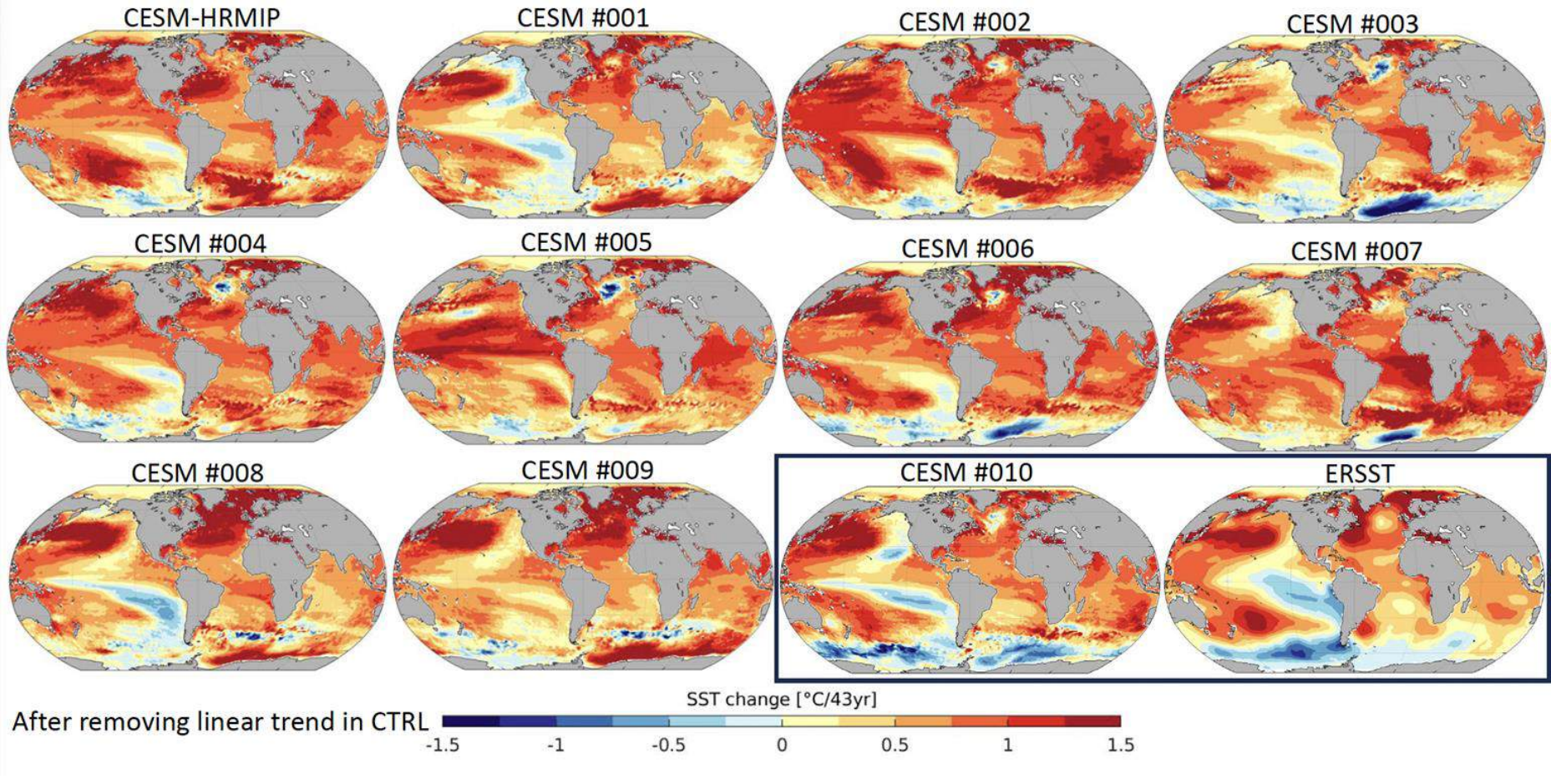
Low res model does not replicate observed SST trends (no CMIP6 low res model does)

CESM1 (0.25°atm, 0.1°ocn)



High resolution model shows just a hint of the observed SST trends

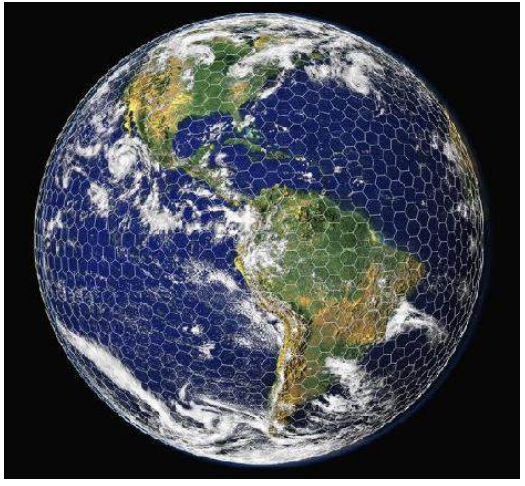
Linear trend (1980-2022) in SST



At least one ensemble member (#10) replicates observed trends pretty well

Slide from Ping Chang

Towards ultra-high resolution (km-scale) capabilities in CESM



Goal

Develop a global coupled CESM configuration with 3.75 km resolution

- Enable research at weather-climate interface
- Understand and resolve deficiencies of lower-resolution versions of CESM
- Create training data sets for machine learning
- Investigate scale interactions
- Develop scale-aware parameterizations that work well for both 3.75 km and ~120 km grids

Collaboration between

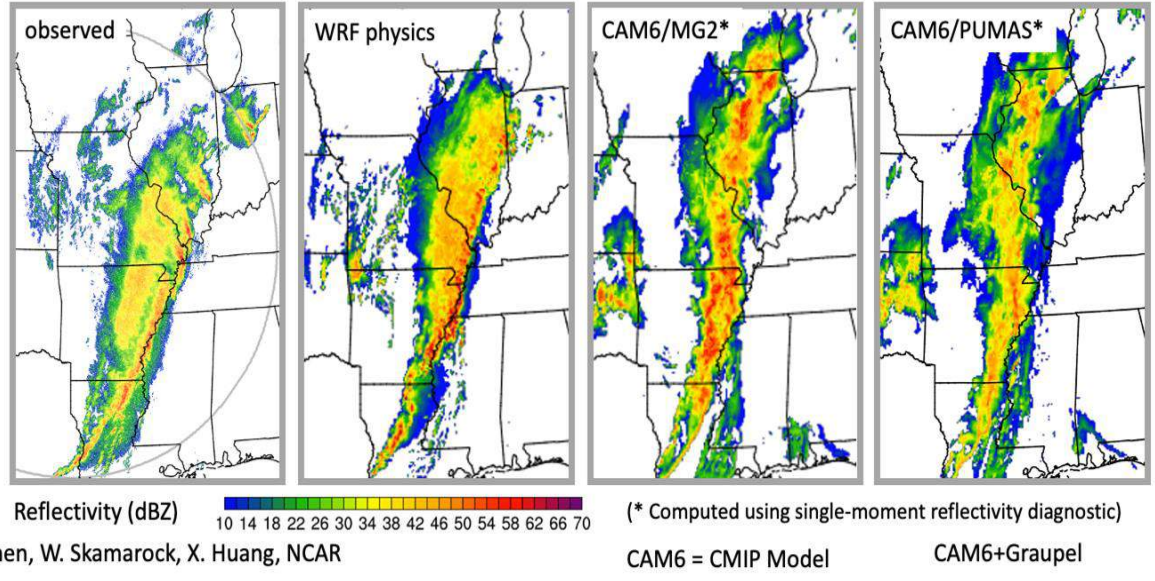
- EarthWorks (CSU)
- StormSPEED (U. Mich, Texas A&M)
- SIMA
- CESM

Towards ultra-high resolution (km-scale) capabilities
EarthWorks, SIMA, CESM collaboration

Progress

- Many technical barriers have been overcome
- MPAS dynamical core is running in CAM and applications using a regionally-refined grid from 60 km to 3 km are running
- Testing and debugging global 3.75km CAM(MPAS)-CLM

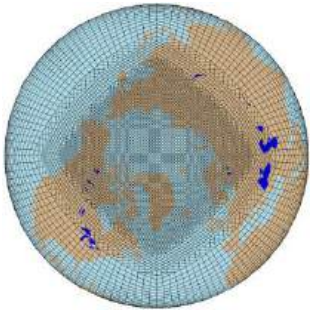
DYAMOND Simulations
40-day summer and winter
(planned for this year)

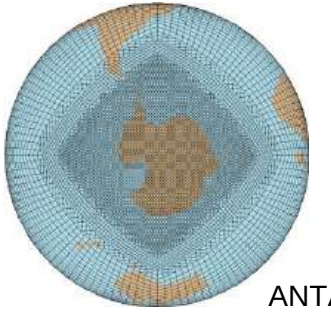


Inclusion of graupel in cloud physics (PUMAS) allows CAM-MPAS simulation to represent the leading line of convection in the squall line; similar to observations and MPAS-A with WRF physics

Variable-resolution spectral element (SE) dycore grids

CESM (w/ university collaborators) has been developing a library of variable-resolution grids for various scientific applications





ANTARCTIC
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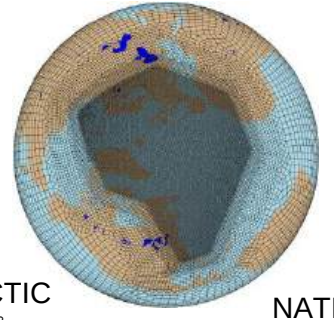

NATL
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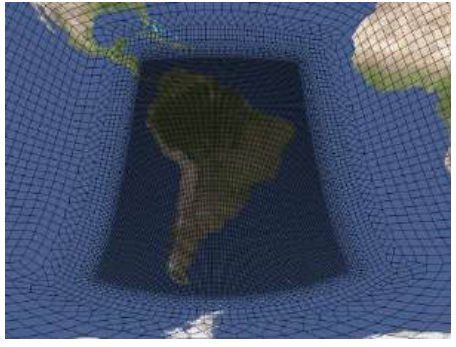
S. AMERICA 1/8˚, 1/16˚



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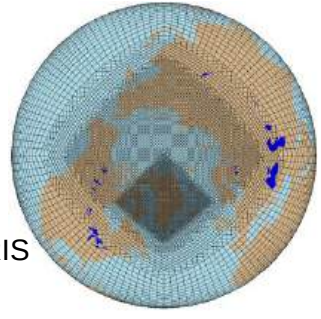

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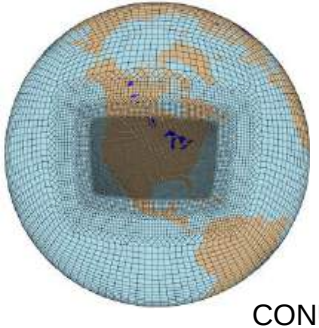

CONUS
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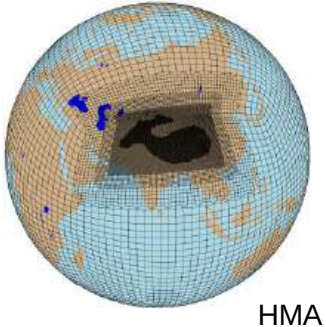

HMA
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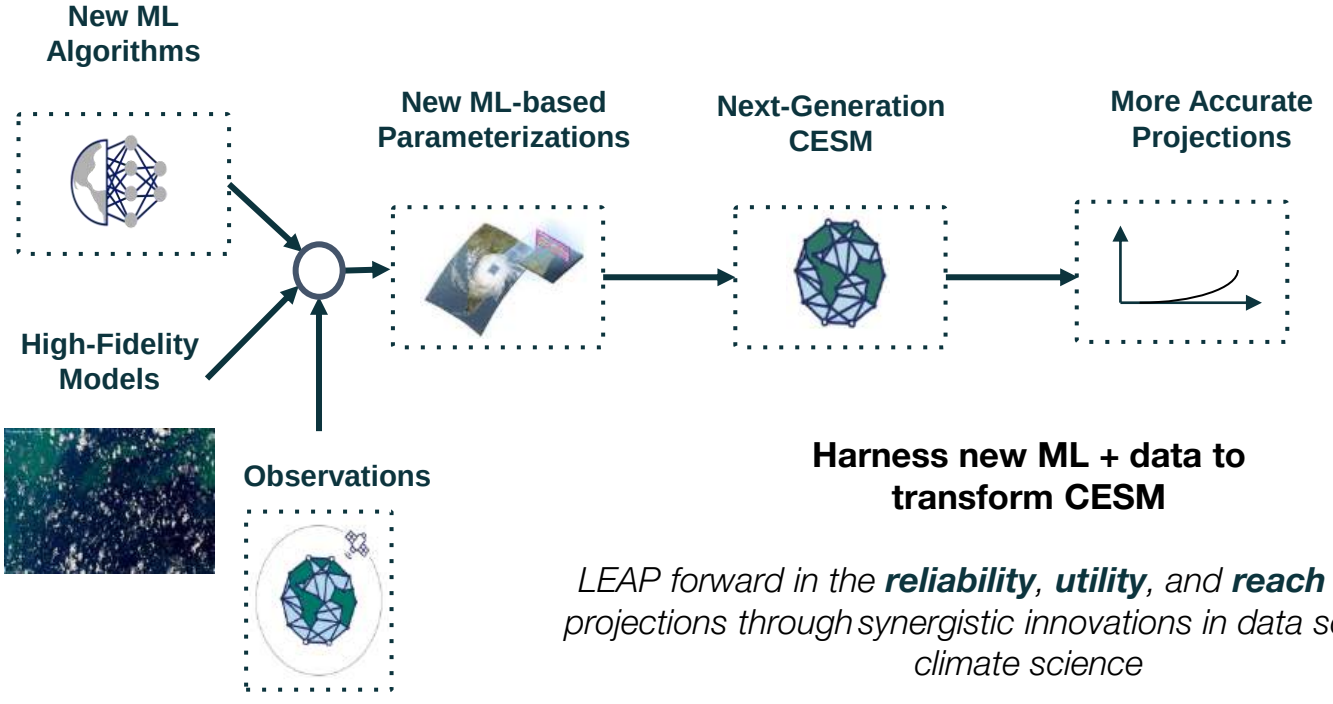
Towards a hybrid (physics + ML) version of CESM (CESM3-MLe)

Learning the Earth with Artificial intelligence and Physics
NSF Science and Technology Center

M²LInES
Schmidt Futures



Harness new ML + data to transform CESM

*LEAP forward in the **reliability**, **utility**, and **reach** of climate projections through synergistic innovations in data science and climate science*

Towards a hybrid (physics + ML) version of CESM

LEAP

Learning the Earth with Artificial intelligence and Physics
NSF Science and Technology Center

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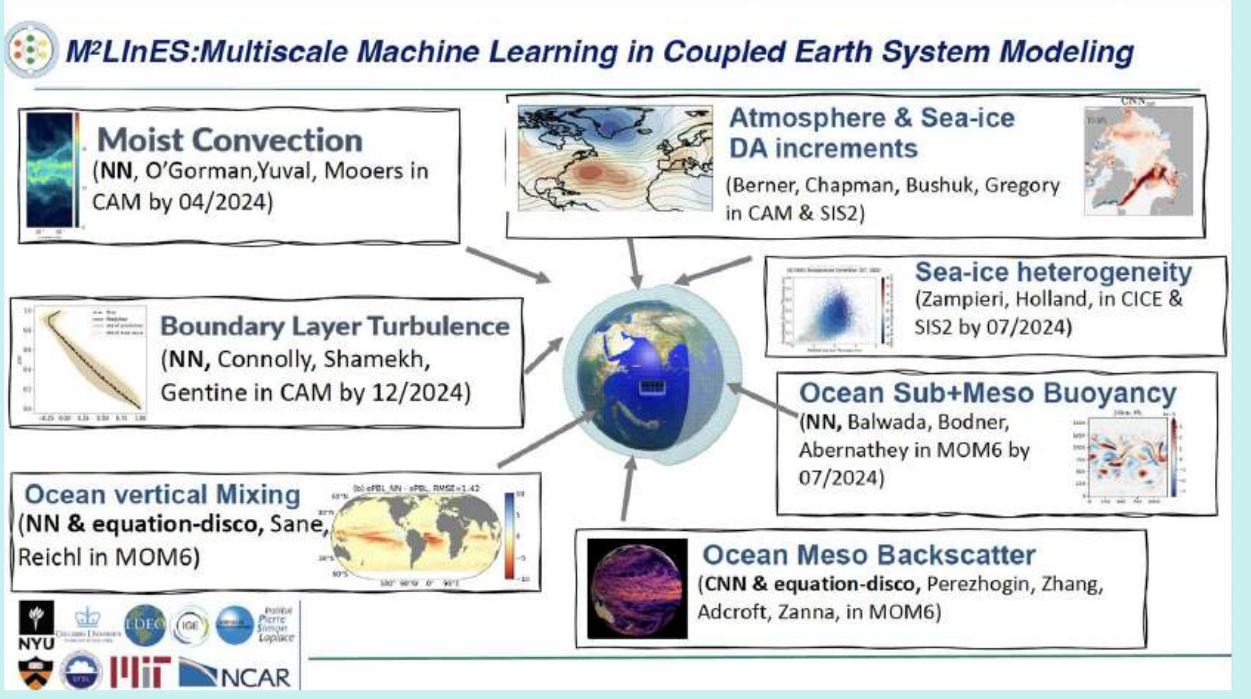
Schmidt Futures



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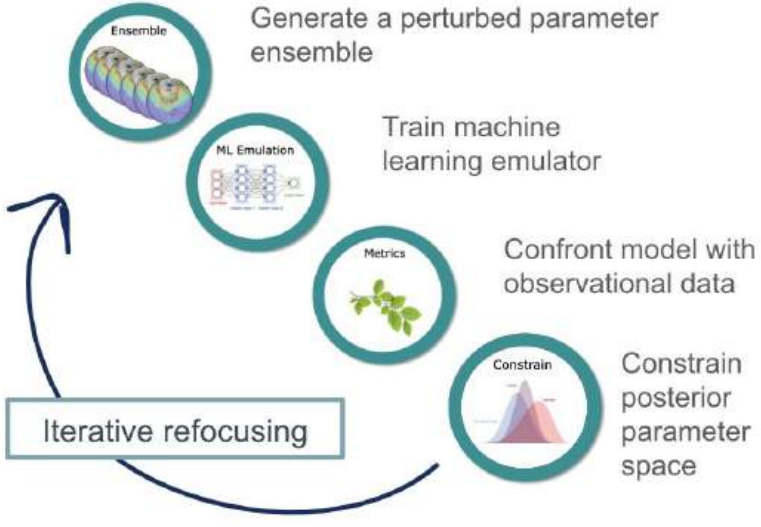
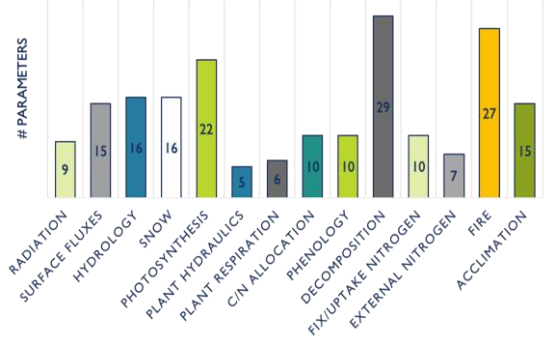


Establish systematic ML-based methodologies for calibration of Earth System Model parameters

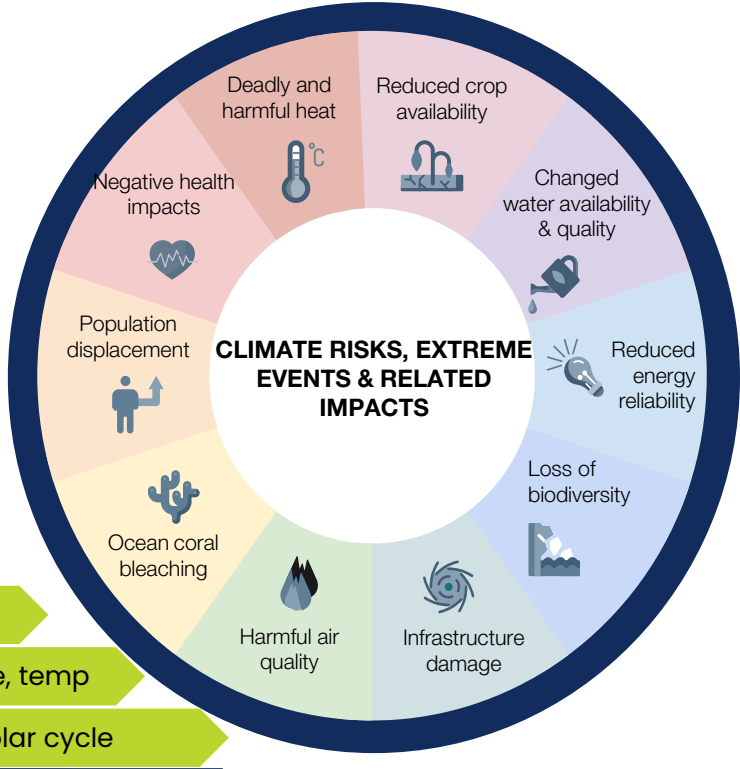


Large CAM and CLM perturbed parameter ensembles are available

NSF NCAR priority: Earth System Predictability Across Timescales (ESPAT)

Guided by societal needs, spanning minutes to centuries

- Tornadoes
- Flooding
- Solar Flares/CME
- Storm Surge
- Wildfires
- Air Quality
- Solar Rossby Waves
- Heat/Cold Waves
- Drought/floods
- Seasonal Temp & Precip
- Sea-ice, land-ice
- Sea-level rise, temp
- Solar cycle

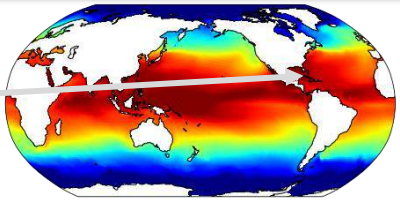


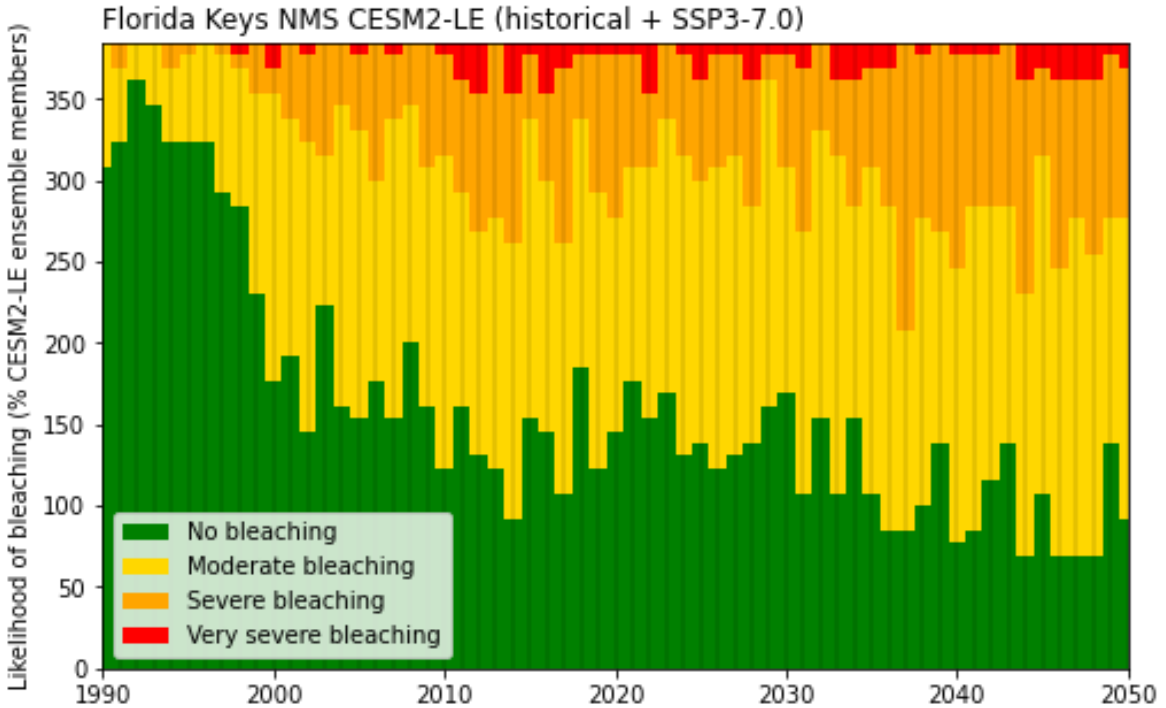
Minutes → **Centuries**

NSF NCAR working with research community to define some near- and long-term priorities

Actionable information
Florida Keys National Marine Sanctuary coral vulnerability assessment

- Monthly sea surface temperature (SST) from the CESM2 large ensemble: historical + SSP3-7.0 future.
- Coral bleaching model, calculates degree heating months, assuming some coral adaptation to warming
- Calculate risk of bleaching in the future using large ensemble statistics





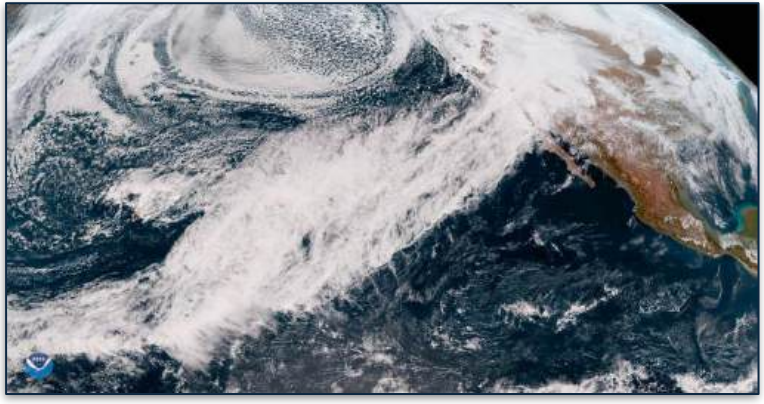
CESM Climate Justice Task Force: Actionable information

Task Force is promoting discussion around

- Documentation and guidance on the purposes, decisions, extended utility, and limitations of model output is needed for responsible accessibility
- Accessibility of modeling products, including data, requires transparency about the origins and development process of the products
- Whose purposes, knowledge, values, and science priorities are represented in the generation process?

Model Simulation and Data Guide?

Mock-up example of a guidance page



Applicability of LENS2 data: Atmospheric Rivers

Christine Shields and Monica Morrison

Model Details: CESM Large Ensemble Community Project (LENS2); 1-degree CESM 2.1.4 ; 100-member ensemble, run period 1850–2100 under CMIP6 historical and SSP3-7.0

Intended Simulation Purpose: Advancing understanding of internal climate variability and climate change; research purposes

Model Documentation/Creators: Rodgers et al. 2021; Gokhan Danabasoglu, Clara Deser, Keith Rodgers, Axel Timmermann

Adequacy-for-Purpose: For models to be adequate for simulating atmospheric rivers they need to represent: 1) synoptic characteristics, i.e., lower and upper level jets, and 2) storm impacts—precipitation location and amount—see AMS Glossary of Meteorology.
Judgment: NOT ADEQUATE.

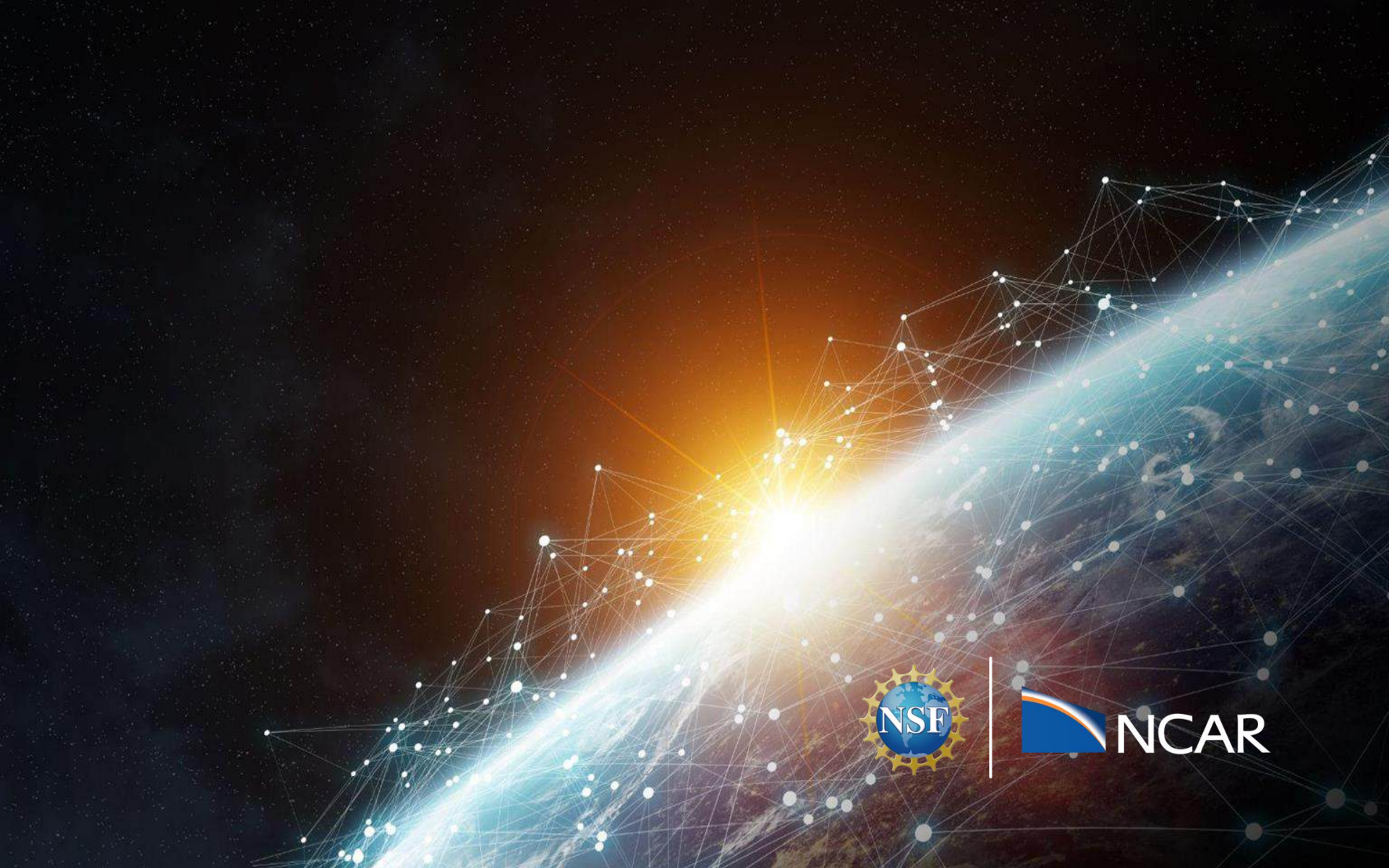
Evaluation Metrics: First-order is evaluating climatology by integrated vapor flux as monthly average; AR tracks metrics include sub-daily values for integrated vapor transport (UIVT and VIVT) or precipitable water (TMQ)

Evaluation Data: ERA5 and MERRA2 (reanalysis)

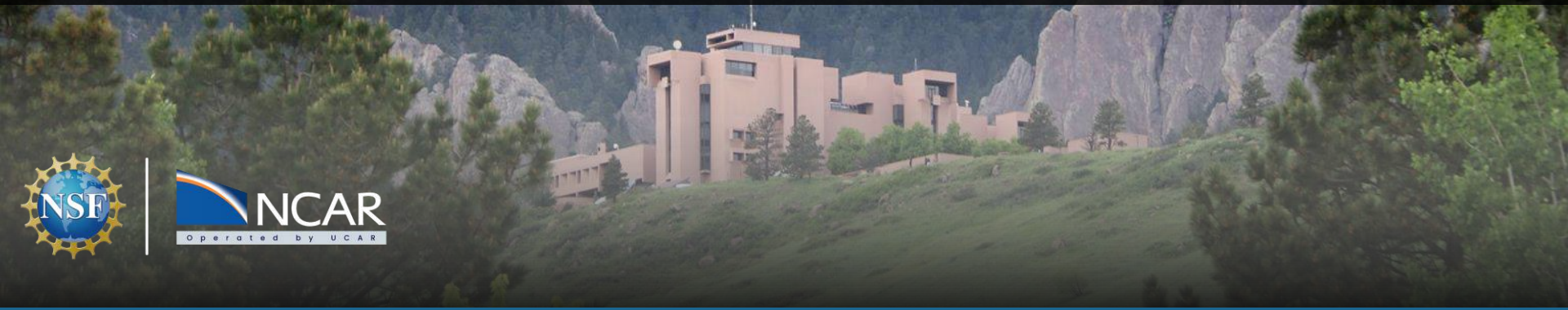
Caveats and limitations: A major source of uncertainty with ARs is methodological associated with differences in detection, stemming from differences in how ARs are characterized (ie., intensity, duration, frequency). See Rutz et al. (2019), O'Brien et al. (2019) and O'Brien et al. 2021. Check for methodological fitness of detection method.

Ethical Hazards: Quality of output from CESM2 and other CMIP6 models does not meet criteria for use outside of research contexts. Potential applied use with postprocessing (downscaling and bias correction, but only if GCM meets (1) and (2) above, and postprocessing is well-validated.


Future
NSF
NCAR


NSF
NCAR

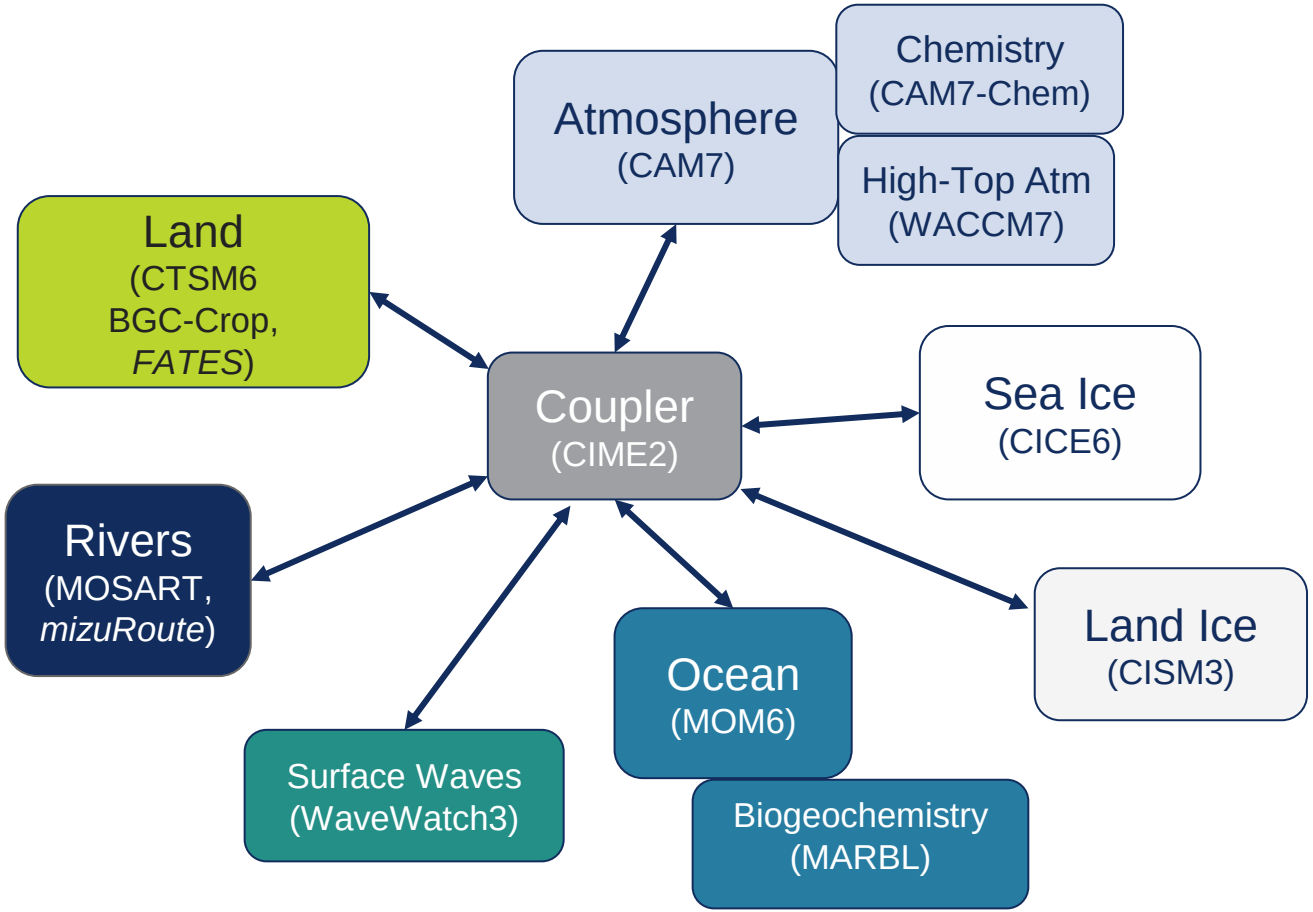
Working towards CESM3



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.

Working towards CESM3

Significant updates to all component models



Community Earth System Model (CESM3)

Atmosphere: SE dycore, enhanced vertical resolution and raised model top, updated CLUBB, PUMAS microphysics, RRTMGP, convective gustiness, ….

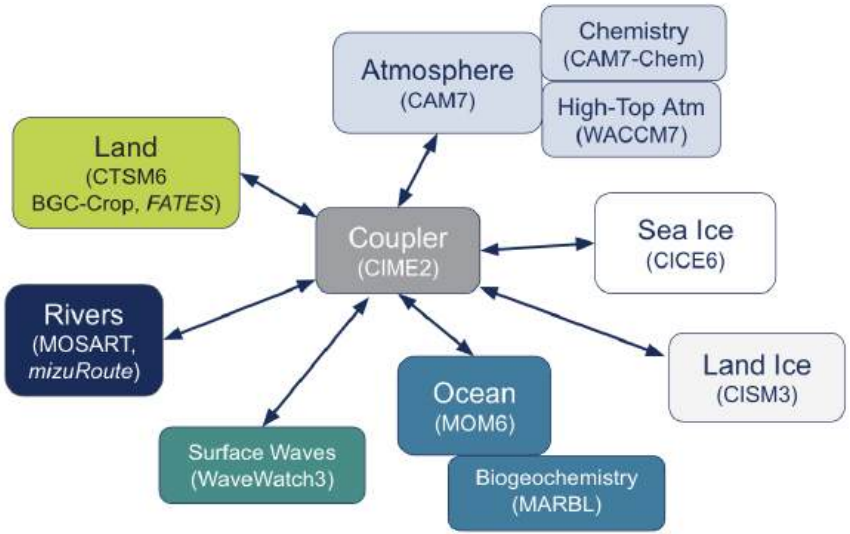
Ocean: MOM6, hybrid coordinate, variable sea level, tracer budgets within the Lab Sea, stochastic GME, isopycnal diffusion (Redi), …

Sea-ice: advanced snow physics, grounded sea ice, and floe size distribution / wave interaction, …

Land: updated high-res surface datasets, biomass heat storage, improved crops (planting calendars, tillage, bioenergy crop types), parameter estimation, hillslopes, …

Land-ice: Dual polar ice sheet capability, ice-ocean interactions, basal sliding and calving schemes

Chemistry: Tropospheric UV radiation, new dust emissions, interactive fire aerosol emissions, …



The CESM Development team is hard at work

Run	Description	Nyrs	Diags / Github	Purpose of the run + comments in red: still running
54	New baseline tag = **cesm2_3_alpha16g**	150	#420	**Baseline** (dust tuning dust_emis_fact = 1.3) **Issue: ENSO amplitude too large + double ITCZ**
64	54 + gustiness	58	#440	Purpose: Convective gust enhancement of U10 Gustiness reduces **ENSO amplitude** => **Lab sea freeze** around yr 50
64e,f,i,j	Start from 64 at yr 43 + perturbation	80	#463	Purpose: How robust is Lab Sea freeze in 64? (Lab sea freeze)
64g,h	Start from 64 at yr 33 + perturbation	80	#463	Purpose: How robust is Lab Sea freeze in 64?
73, 75	Cold branch	18,62	#460	Cold branch = more cam6-like
74, 76	Warm branch	22,41	#471	Warm branch = latest greatest clubb
73b,75b	Same as 73,75 starting from run 54 yr 50	63,38		Start from spunup state (Use ocn/atm spunup state - no ice/lnd spinup)
73c,75c,66c	Same as 73,75 starting from run 54 yr 50	34,34,19		Start from spunup state (Ocn/atm/lnd/ice spunup state)
64intel	Same as 64 but with new intel compiler	50	#464	Purpose: does new intel compile produce same climate ?

64 series: 64 reduced enso amplitude but freeze around year 50
64e,f,g,h: Perturbation of 64 to see to test the **robustness of the Lab sea freeze**.

73b, 75b: Test whether starting from **ocean spinup state** gives the same conclusion

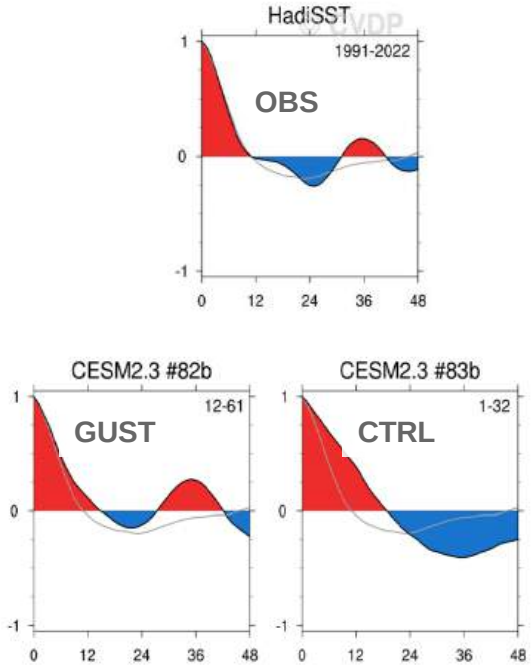
Cold/warm branch: **create new baseline with all the desirable features to reduce ENSO amplitude and double ITCZ**

- Warm branch = latest greatest CLUBB mods
- Cold branch = fallback to a cam6-like configuration

New intel compiler: testing whether the new intel compiler produces the same climate.

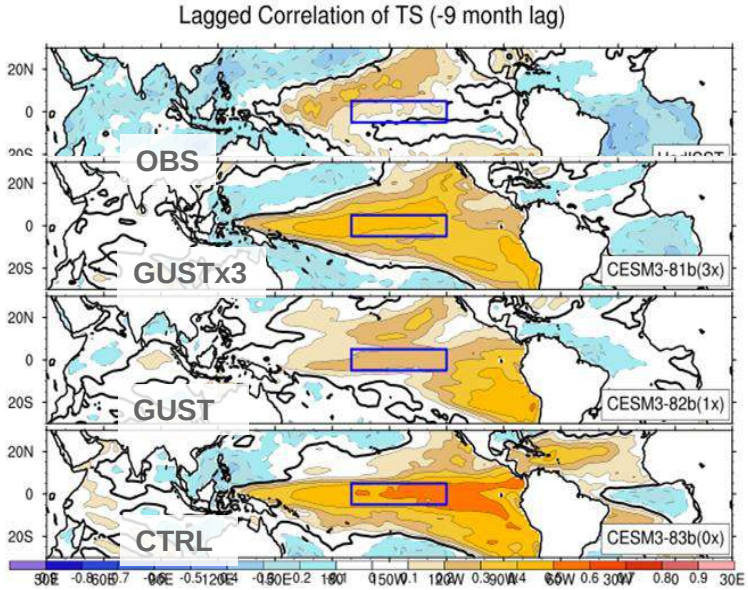
Addition of convective gustiness leads to improvements in ENSO

Meg Fowler



Nino3.4 autocorrelation suggests improved phasing with addition of GUST

Correlation of SST and Nino 3.4



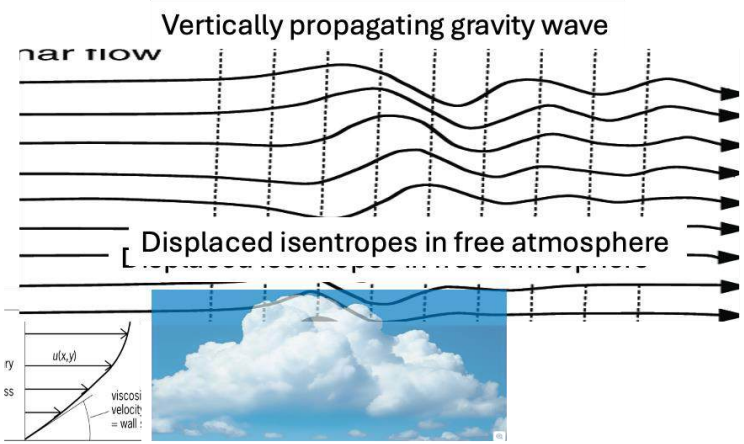
Onset of SST anomalies in Nino3.4 region delayed in GUST, more similar to observations

The driver of these ENSO changes due to gustinesss parameterization, but the result is **better agreement with HadISST observations**

Figures courtesy of R. Neale and A. Phillips

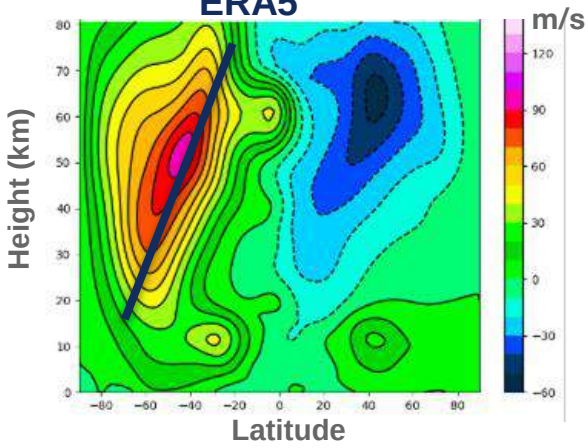
Improvements to stratospheric jets with “moving mountains” GW param

New source of gravity waves
(“moving mountains”)



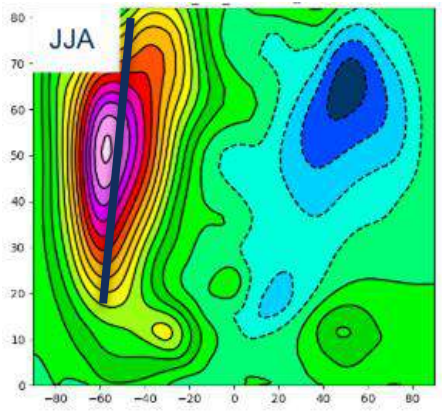
Convection/eddy in sheared PBL flow acts like an obstacle to flow in free atmosphere

ERA5



zonal wind

CAM7 Dev



CAM7 Dev w/ “moving mountains”

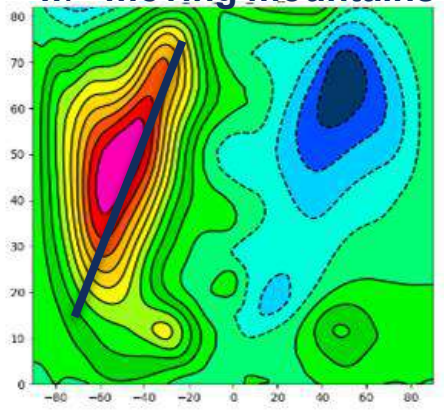


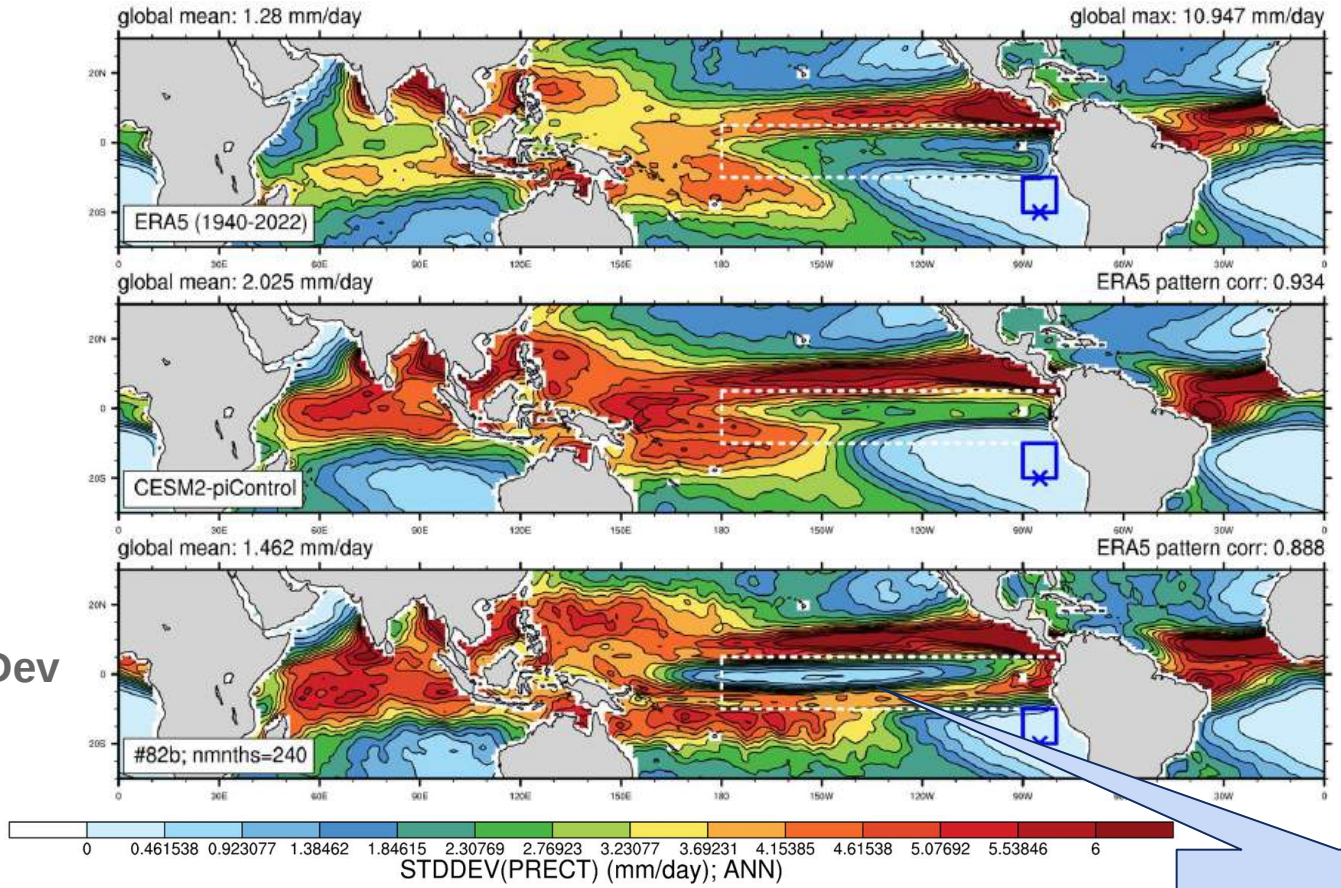
Figure courtesy of Julio Bacmeister

Issues: Tropical precipitation

Obs

CESM2

CESM3 Dev

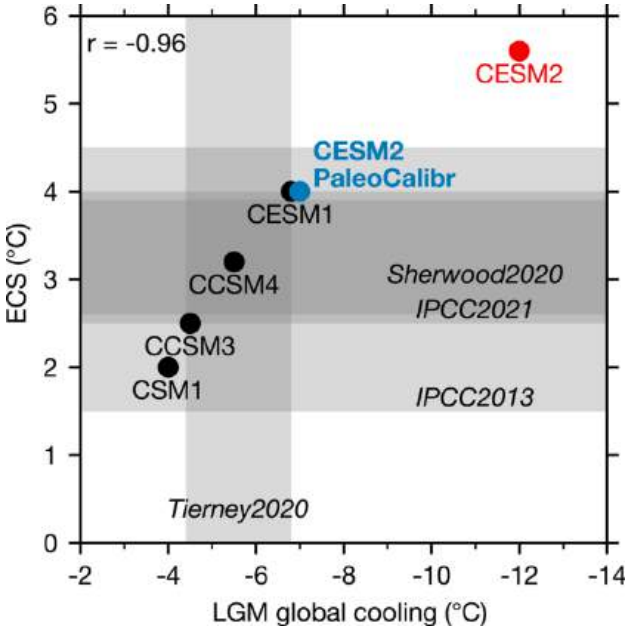


"Weird" dry patch!

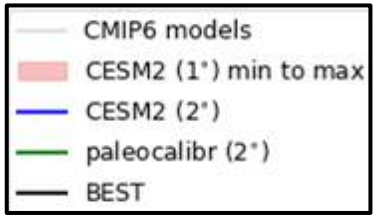
Figure from Adam Herrington

CESM2 microphysics and Equilibrium Climate Sensitivity (ECS)

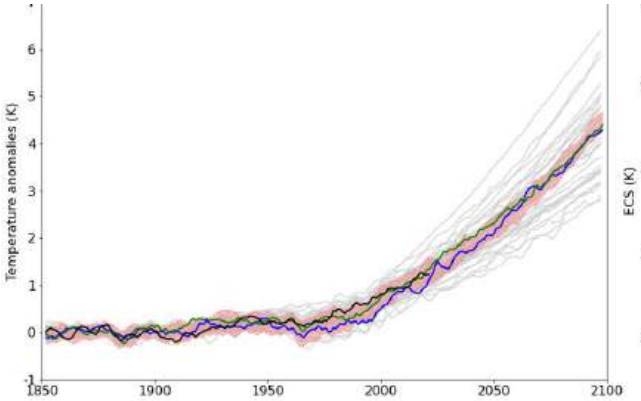
- CESM2 has high ECS
- CESM2 also scores at or near the top across a wide range of metrics among CMIP6 models
- But, CESM2 is far too cold in LGM (Zhu et al, 2021)
- With preliminary corrections to (1) inappropriate limiter on cloud ice number, (2) timestep dependence of cloud microphysical processes
  - CESM2 PaleoCalibr LGM cooling is within proxy estimates
  - ECS is reduced from 5.2K to 4.0K



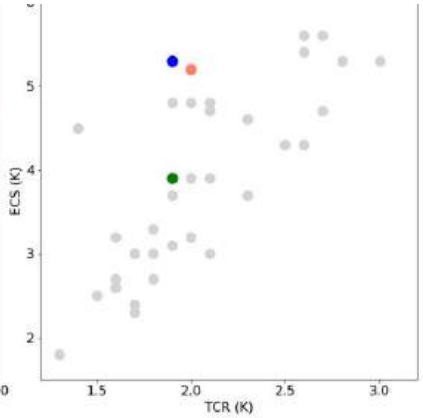
CESM2 microphysics and Equilibrium Climate Sensitivity (ECS)



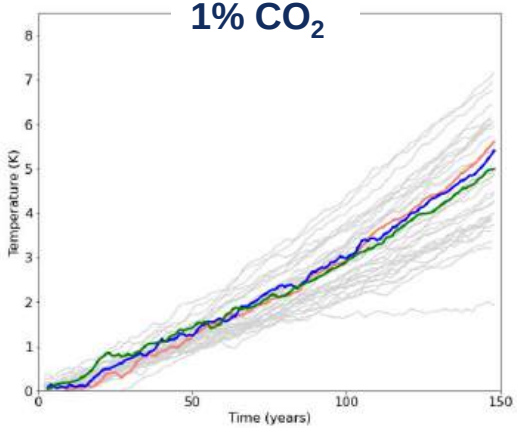
Global mean T_s



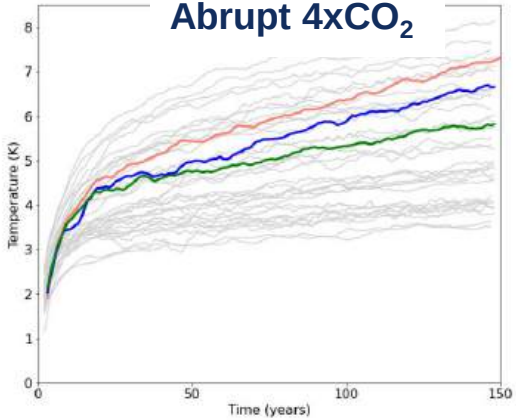
ECS vs TCR



1% CO_2



Abrupt 4xCO_2



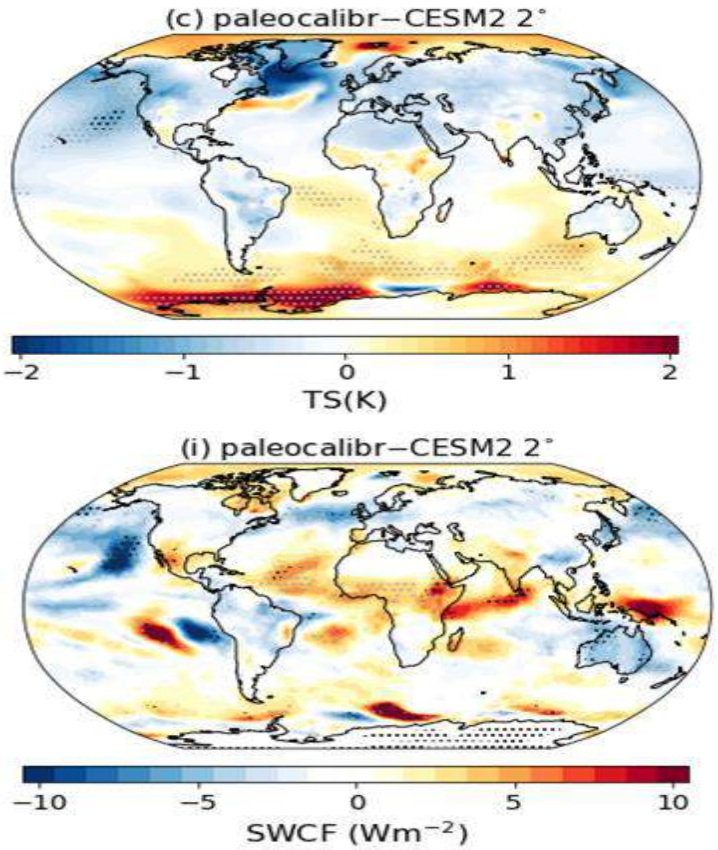
Margaret Duffy, Isla Simpson, Christina McCluskey, Jiang Zhu, and many others

CESM2 microphysics and Equilibrium Climate Sensitivity (ECS)

Perspectives manuscript in prep

- CESM2 has a high ECS and simulates too-cold ice age climates and too-hot warm paleoclimates
- Representation of microphysical processes in CESM is rapidly evolving and the simulated climate is sensitive to state-of-art representation of microphysics
- CESM2 has a moderate transient climate response and is appropriate for simulations of the modern climate and up to 4K warming
- Global climate models should not be evaluated exclusively according to their climate sensitivities, which are extremely uncertain and do not reflect a model's complexity

2050-2100 minus 1950-2000

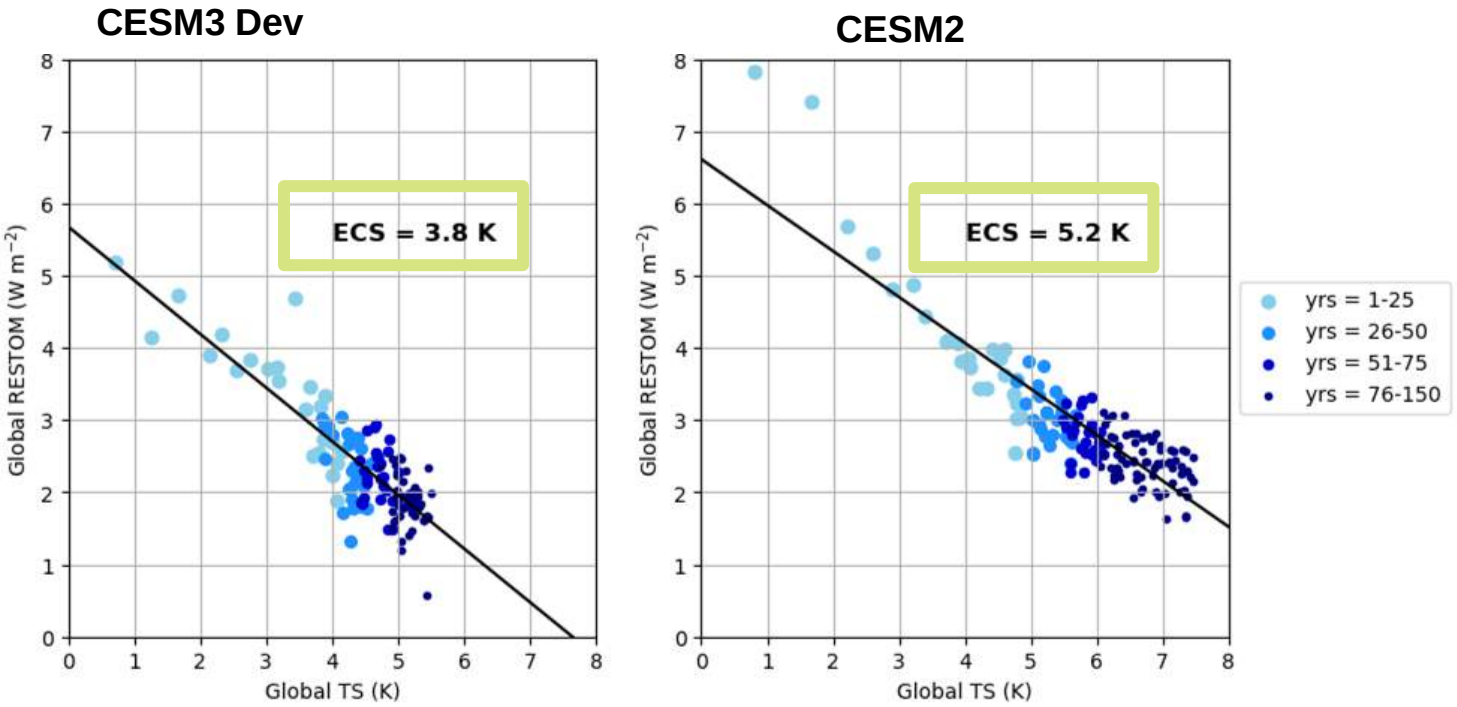


Margaret Duffy, Isla Simpson, Christina McCluskey, Jiang Zhu, and many others

grey stippling: diff > than CESM2 LE range

black stippling: diff > 1σ of CMIP6 diffs

Reduced ECS in CESM3 development versions

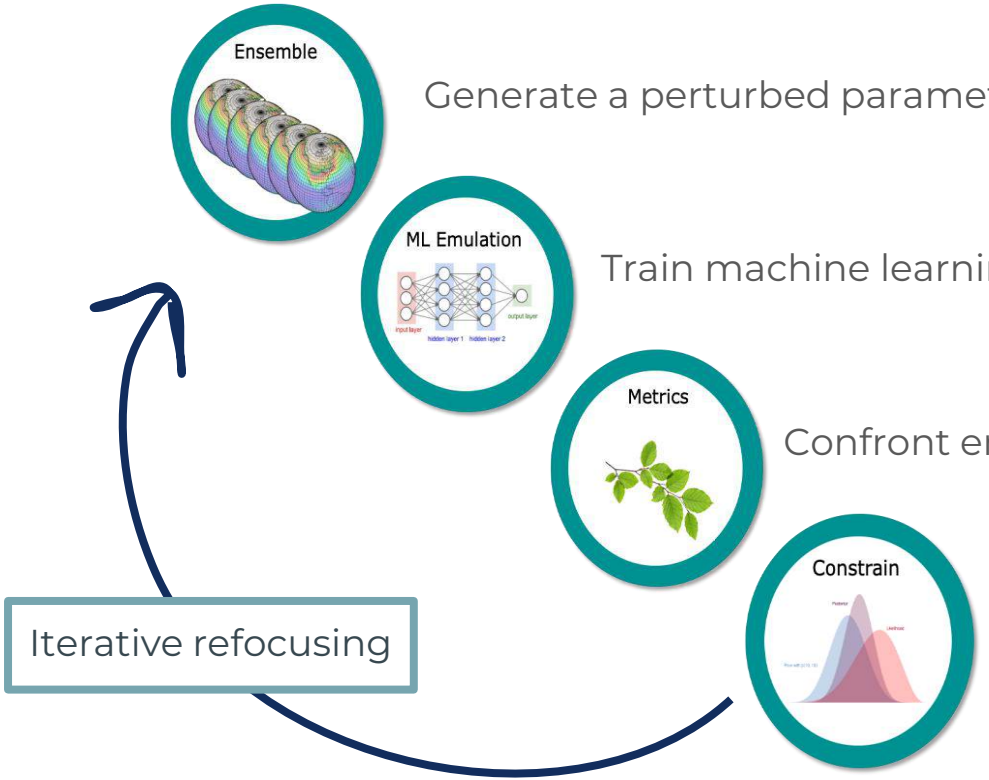


… and early Last Glacial Maximum test implies reasonable cooling. :)

Figure Cecile Hannay

Parameter Estimation: Methodology

Establish systematic ML-based methodology for calibration of Earth System Model parameters



Generate a perturbed parameter ensemble

Train machine learning emulator

Confront emulator with observational data

Constrain posterior parameter space

Land model parameter estimation: Challenges & Results

Challenges unique to land modeling

- Long simulations, slowly varying C cycle (1850-2014)
- Over 200 parameters
- Parameters have a plant species dimension
- Spatially explicit

Linnia Hawkins,
Daniel Kennedy,
Katie Dagon, +

Default

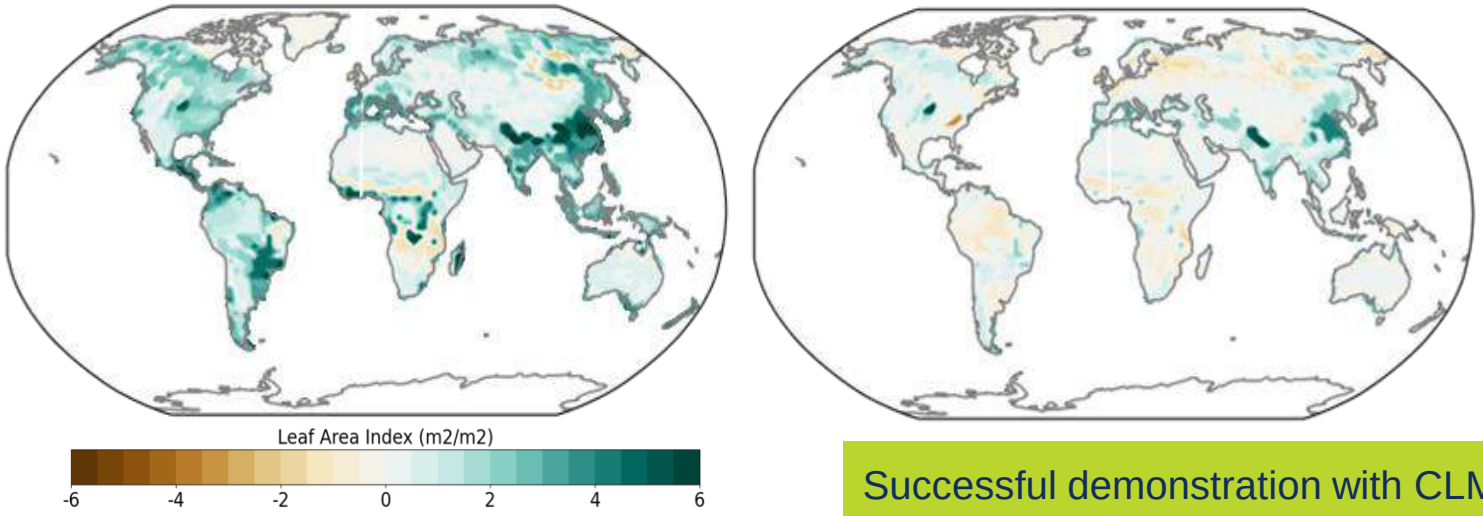
Leaf Area Bias

Mean absolute error = **1.36**

Calibrated

Leaf Area Bias

Mean absolute error = **0.60**



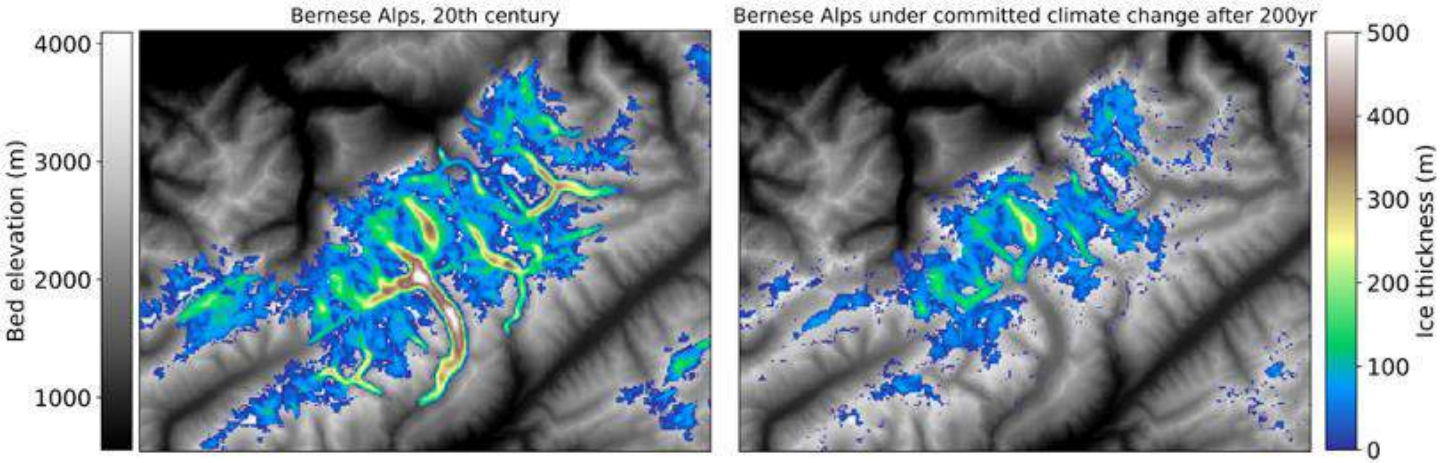
Successful demonstration with CLM5.1, will apply to CLM6 when finalized for inclusion in CESM3

Simulating Alpine glaciers with the Community Ice Sheet Model

Goal

Use the Community Ice Sheet Model (CISM) to simulate mountain glaciers and study freshwater availability and security on decadal time scales.

Figs: (Top left) Bernese Alps region of Switzerland. (Bottom) Simulated glacier ice thickness (m) in the Bernese Alps. (Left) Initial state based on forcing from the 1980s, when glaciers were roughly in balance with the climate. (Right) Retreated state after a 200-year simulation with recent climate forcing (2000–2019).



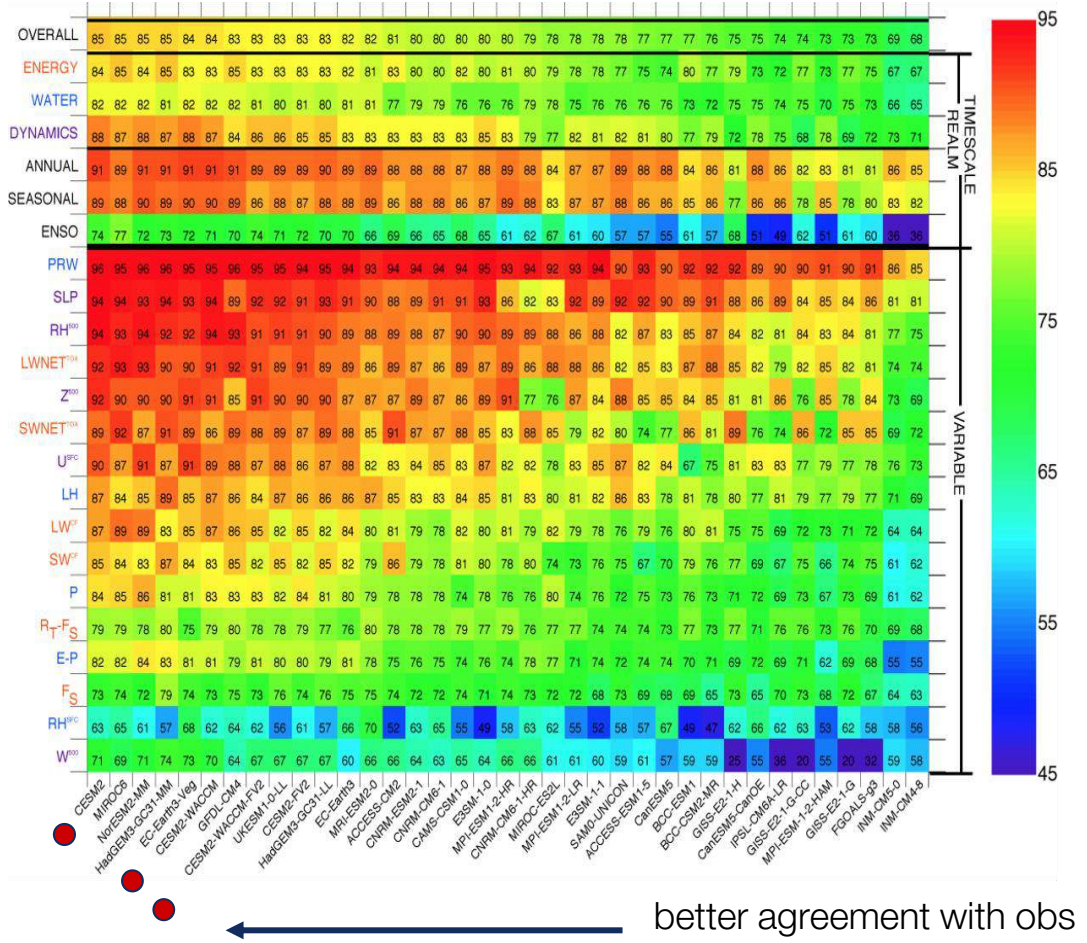
Capability available in the next CISM release (Fall 2024)

Samar Minallah, Bill Lipscomb, Gunter Leguy, Kate Thayer-Calder

CESM3 assessment, tuning, and simulations

As we finalize the CESM3 science configuration (soon), we will be working to resolve issues, tune the model, and run control simulations

… but, CESM2 was/is a pretty good model, so … we'll see



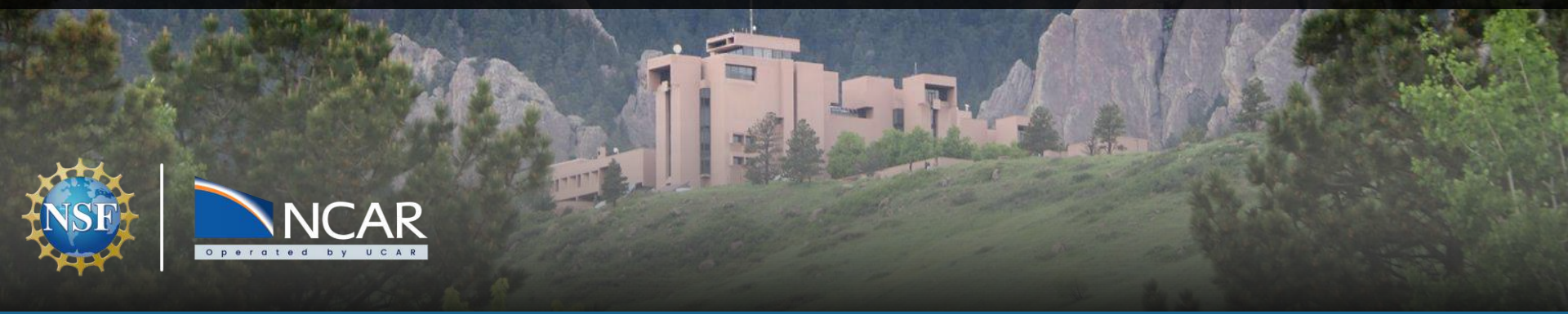
Scores for pattern correlations, seasonal contrasts, and ENSO teleconnections

CESM2 versions

better agreement with obs

CMAT analysis, Fasullo et al., 2020

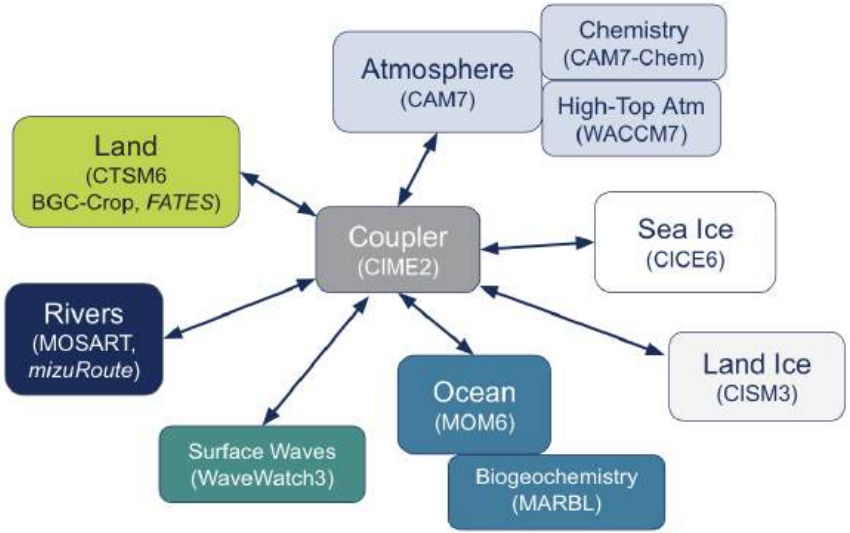
CESM3 Timelines and CMIP7 Fast Track



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.

CESM3 CMIP7 plans

- CMIP7 DECK + FastTrack runs due by end of 2026
- Aiming to start CMIP7 DECK / FastTrack runs in early 2025, when forcings become available
- … which means CESM3 needs to be ready by late 2024, ideally

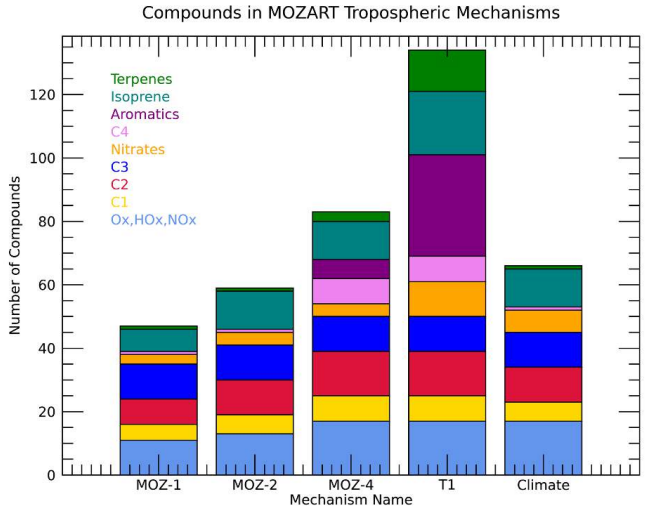


CESM3 CMIP7 plans

- CMIP7 DECK + FastTrack runs due by end of 2026
- Aiming to start CMIP7 DECK / FastTrack runs in early 2025, when forcings become available
- … which means CESM3 needs to be ready by late 2024, ideally

Aiming for the Mid-Top (93L to 80km) with simplified chemistry for climate as default configuration

Cost and throughput (TBD) will be important factors in CMIP7 DECK and Fast Track … and other MIPs participation

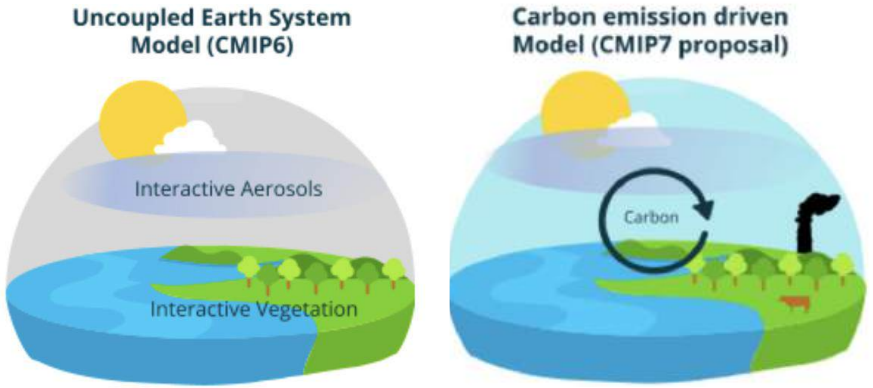


CESM3 CMIP7 plans

- CMIP7 DECK + FastTrack runs due by end of 2026
- Aiming to start CMIP7 DECK / FastTrack runs to start in early 2025
- … which means CESM3 needs to be ready by late 2024, ideally

Open questions around inclusion of several ‘Earth system’ aspects for CMIP7 version of CESM3

- **Emissions-driven** (yes, if CO_2 trajectory is ok)
- **Interactive fire emissions** (possibly, recent new init method makes it more possible)
- **Interactive ice sheets** (if surface mass balance is ‘good enough’)



Sanderson et al, in review

Image: BC Wildfire Service/Handout

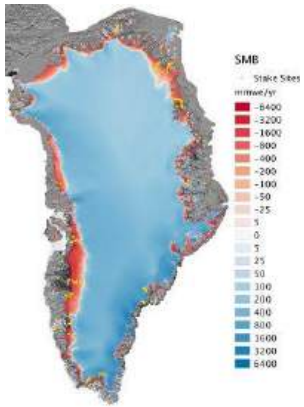
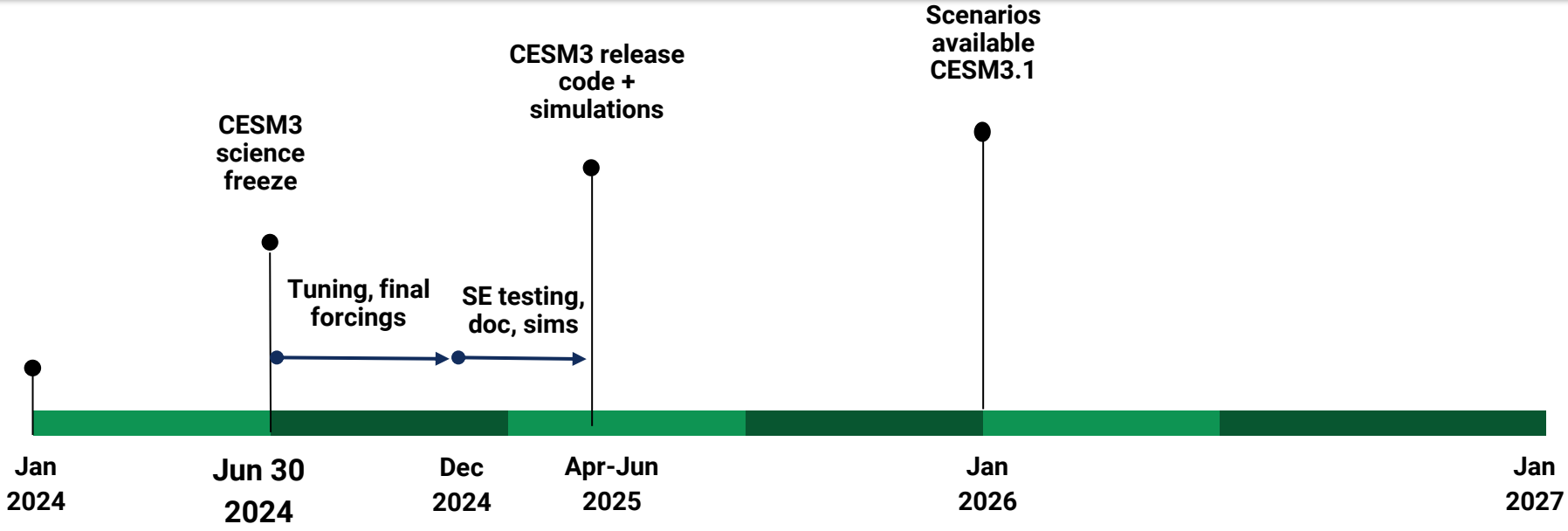


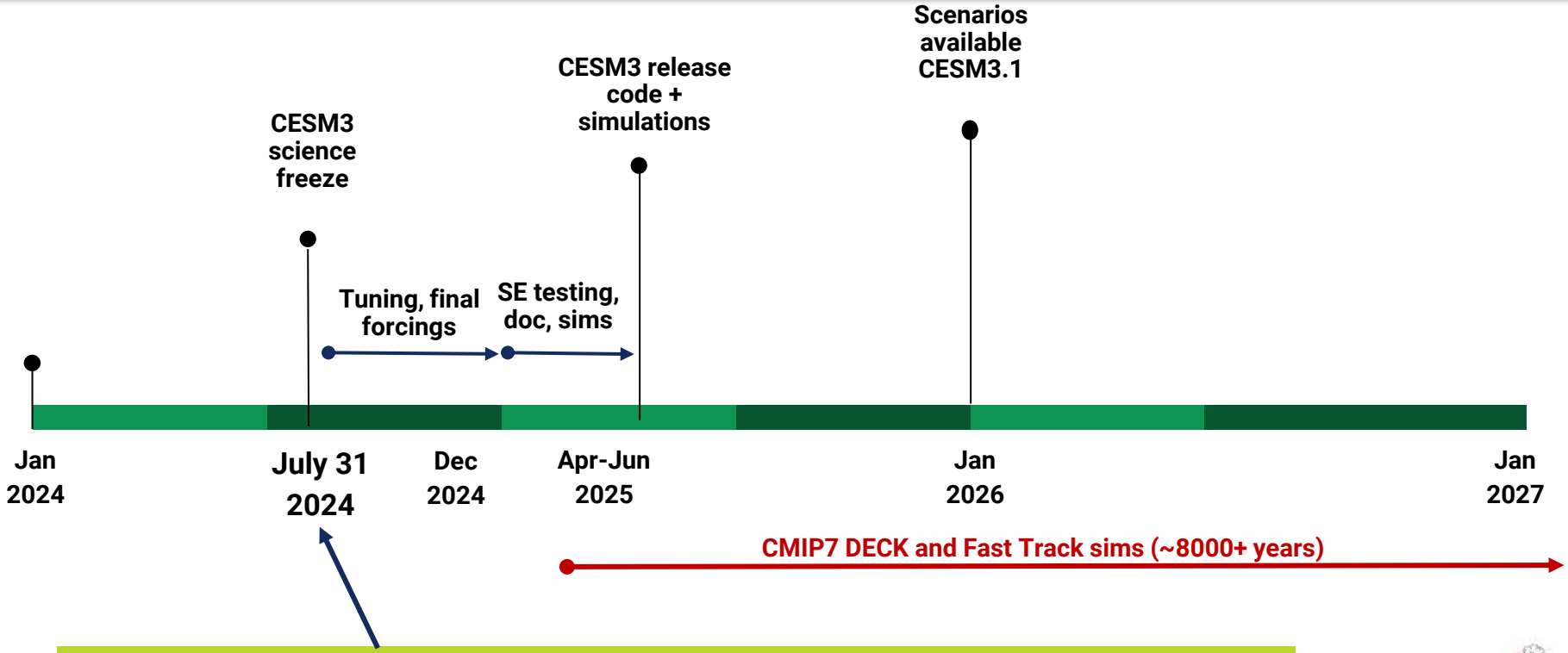
Image: Brice Noël

Proposed CESM Timelines



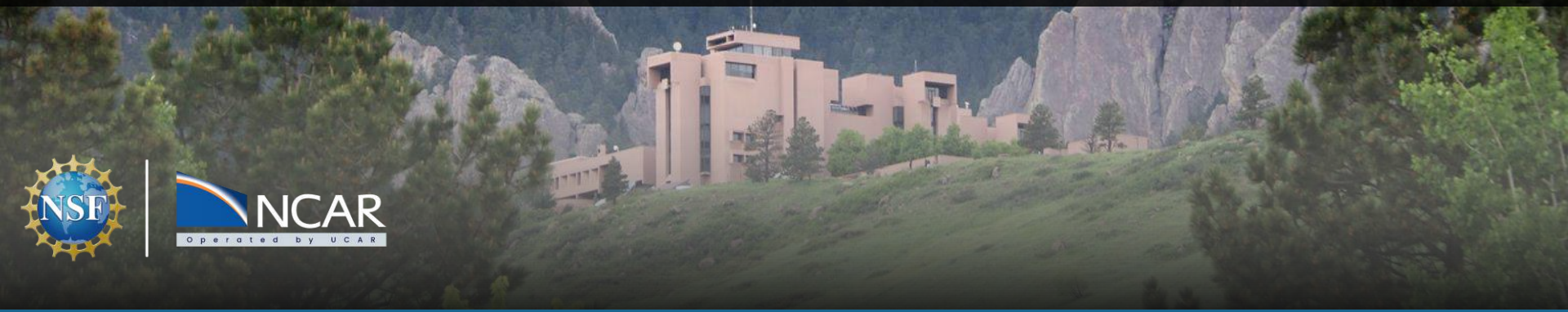
Don't want a Douglas Adams type of perspective on deadlines:
"I love deadlines. I like the whooshing sound they make as they fly by."

Proposed CESM Timelines



Don't want a Douglas Adams type of perspective on deadlines:
"I love deadlines. I like the whooshing sound they make as they fly by."

A few recent CESM science highlights



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.

Tropical Cyclones in the North Atlantic – Past to Future

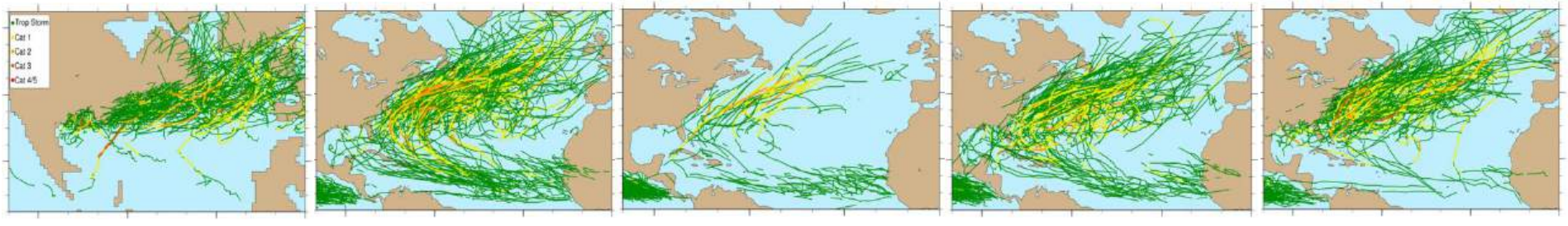
Simulating precipitation and heat extremes for past hothouse and icehouse climates with CESM1.3 HR *(0.25^{o} atm/lnd, 0.1^{o} ocn/ice)*

Tropical cyclones extend farther poleward at CO_2 levels higher than PI

Deep tropics become more hostile for tropical cyclone development at high CO_2 (*Eocene & RCP8.5)*

More CAT3 and stronger hurricanes (*red, orange*) in warm climates

High CO_2 → **Low CO_2** → **High CO_2**

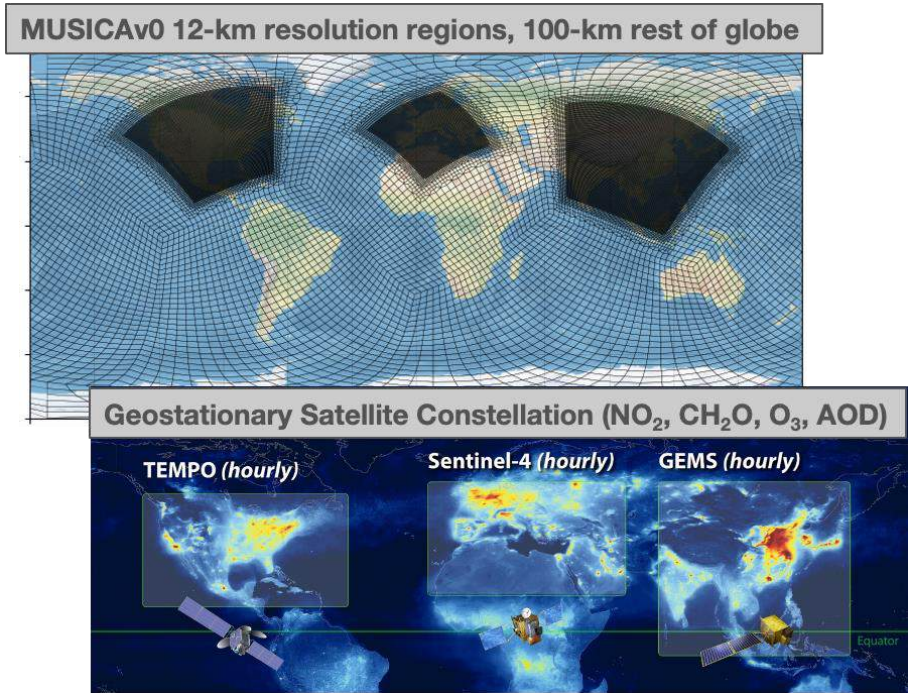


Eocene ***Pliocene*** ***LGM*** ***Preindustrial*** ***RCP8.5 (@2100)***

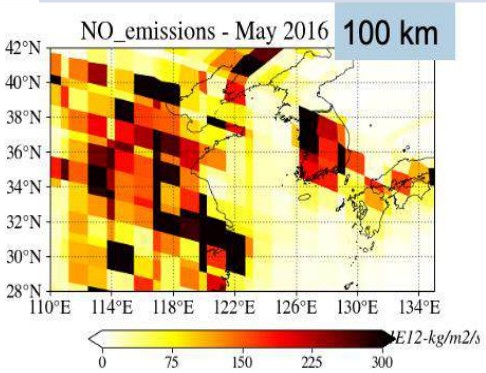
Otto-Bliesner et al., 2024, in prep.

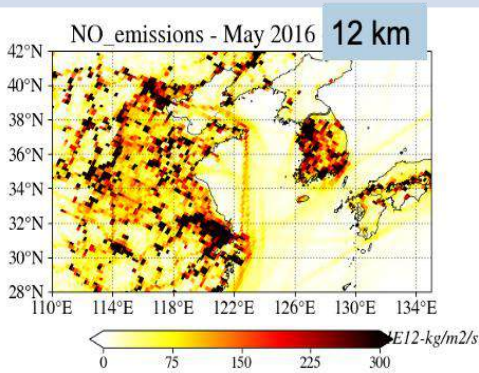
MUSICAv0: Refined regions to match geostationary satellite constellation

Grid created to replicate Geo Constellation matching resolution of observations
Comprehensive tropospheric & stratospheric chemistry with 458,000 grid points, 250 transported tracers, ~2M core-hrs/sim-year



- Emissions at higher resolution in source regions
- More realistic chemical regimes (NOx / VOCs)
- Pollution plumes more finely resolved
- Improve simulation of intercontinental transport



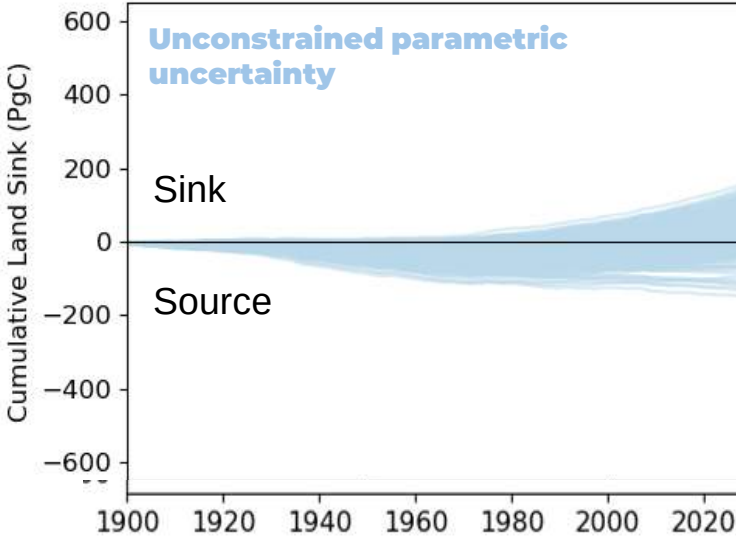


Simulations some of first on new NCAR HPC "Derecho", assisted by J. Edwards and A. Herrington (NCAR/CGD)

Louisa Emmons, NCAR/ACOM
emmons@ucar.edu

Constraining parametric uncertainty in Land Carbon Sink

32 parameters in the Community Land Model
500 member perturbed parameter ensemble



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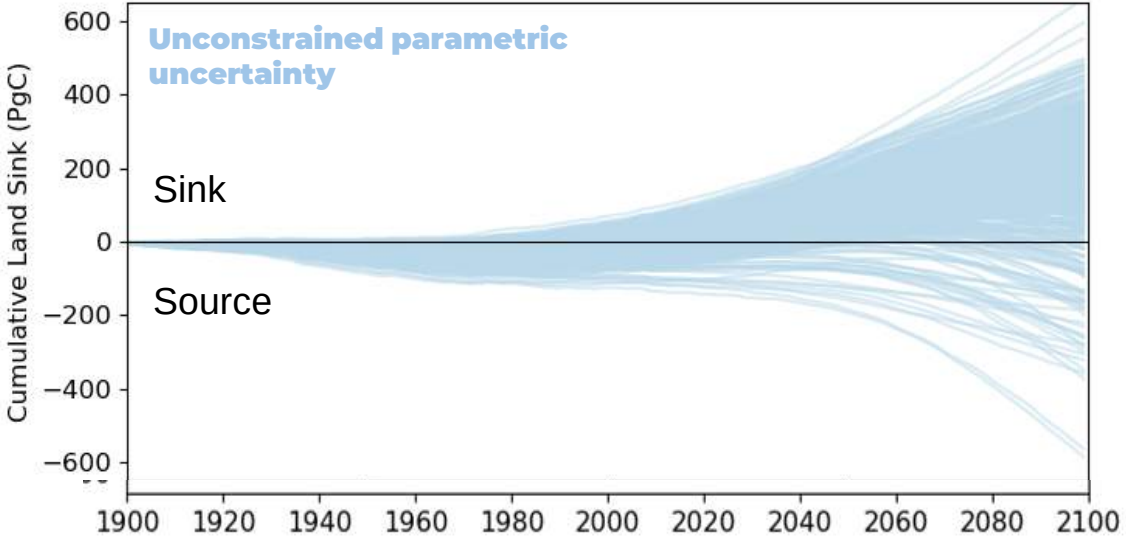
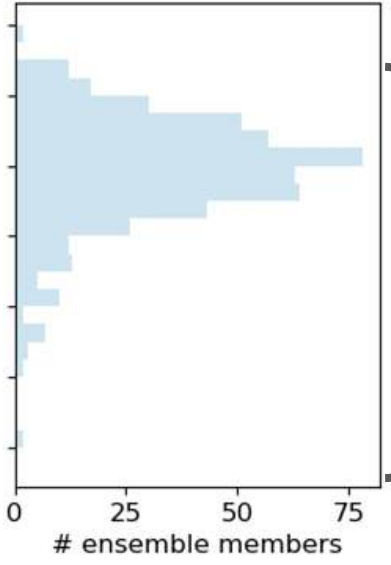
Uncertainty in CMIP6 ensemble ~1000 PgC





~1000 PgC

~100 years of fossil fuel emissions

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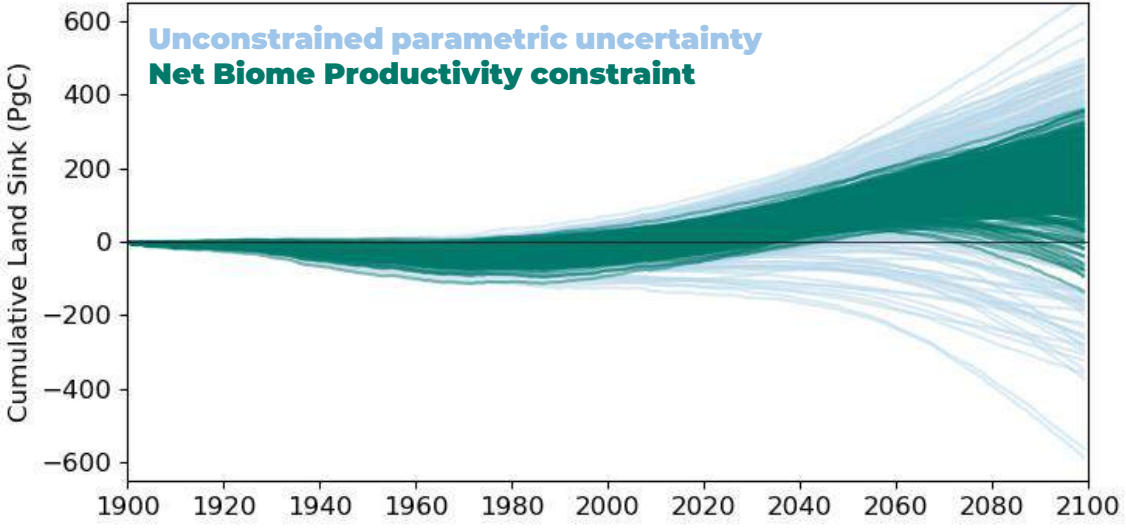

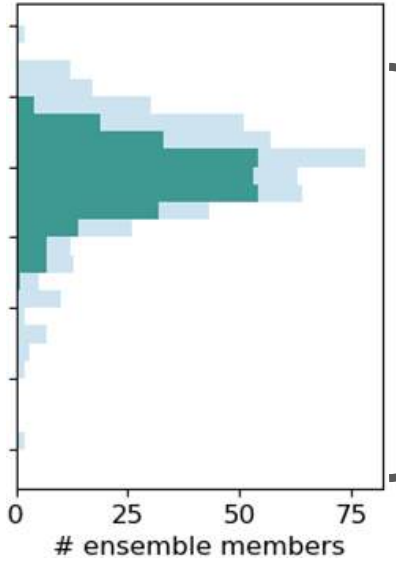

~1000 PgC

~100 years of fossil fuel emissions

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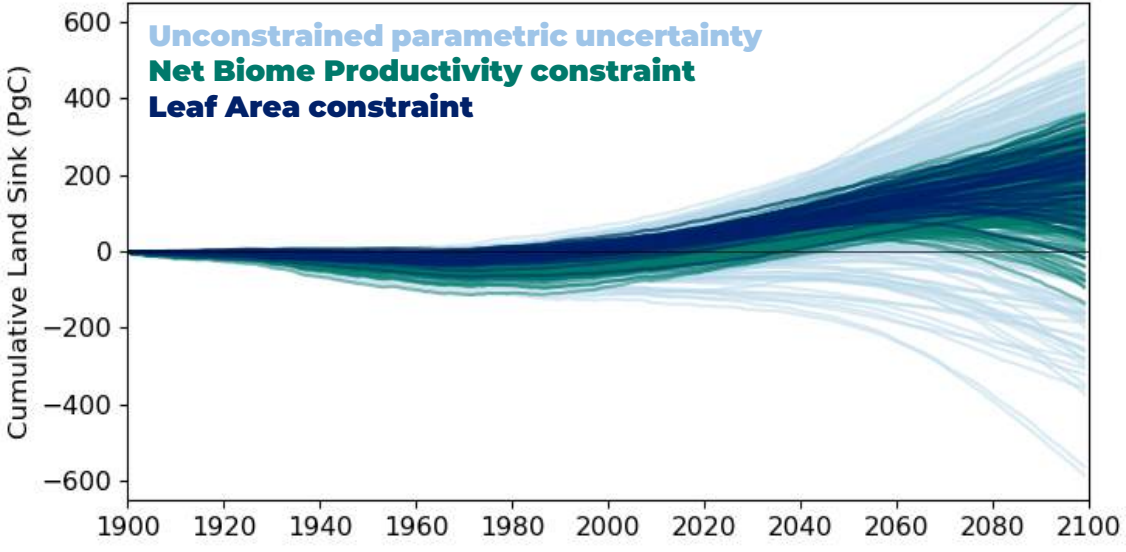
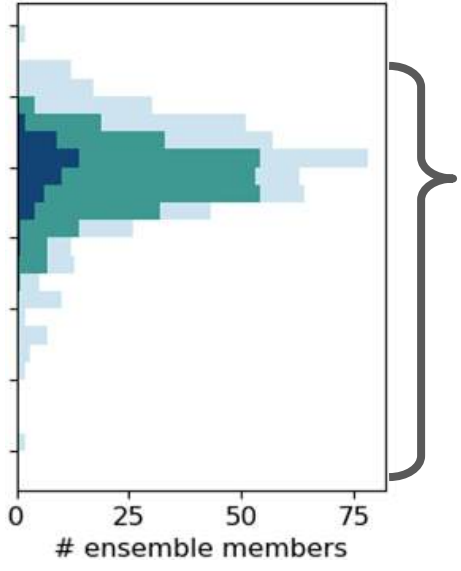
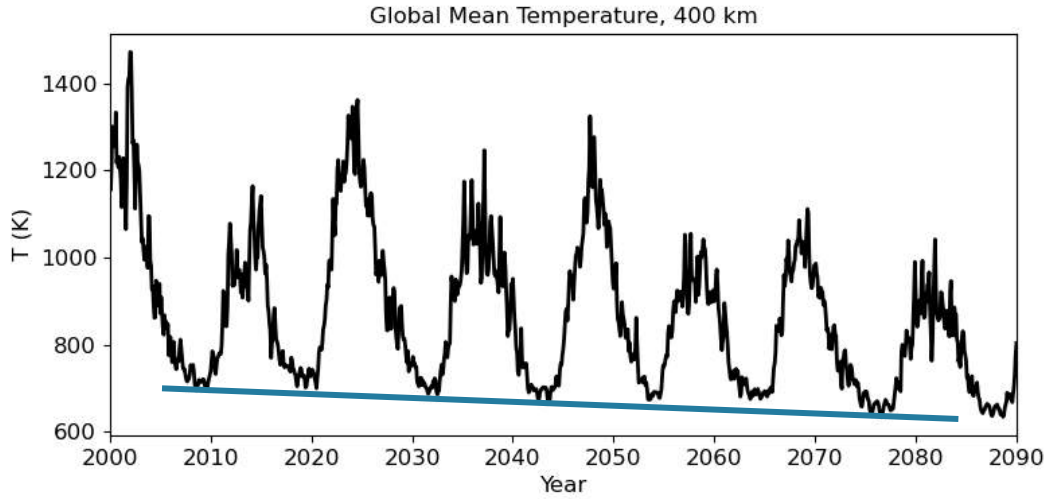




~1000 PgC

~100 years of fossil fuel emissions

WACCM-X simulations of historical and future space climate



- Temperature and densities in the thermosphere are critical for understanding the space climate, including the lifetime of orbital satellites and debris
- SSP5.85 projection simulations using WACCM-X show a **significant cooling of the thermosphere related to increasing greenhouse gases**
- WACCM-X enables a unique capability to study the evolution of the space climate

McInerney et al., 2024

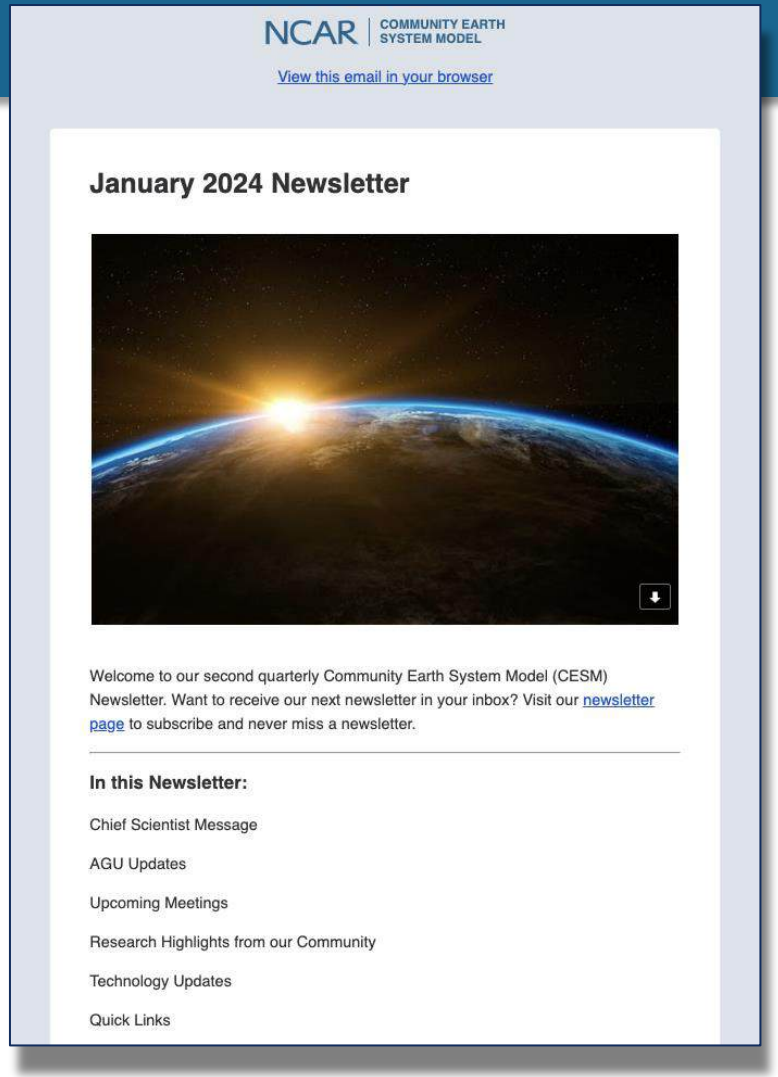
Community engagement and user support

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.

The CESM Newsletter

- Additional way to communicate with CESM research community
- Updates on events
- Point users to new or under-advertised features of CESM
- Research highlights from across community
- Quick links to common pages (CGD Youtube, User support forum, Release pages, etc)

Scan QR code to sign up or visit cesm.ucar.edu



NCAR | COMMUNITY EARTH SYSTEM MODEL

View this email in your browser

January 2024 Newsletter

Welcome to our second quarterly Community Earth System Model (CESM) Newsletter. Want to receive our next newsletter in your inbox? Visit our newsletter page to subscribe and never miss a newsletter.

In this Newsletter:

Chief Scientist Message

AGU Updates

Upcoming Meetings

Research Highlights from our Community

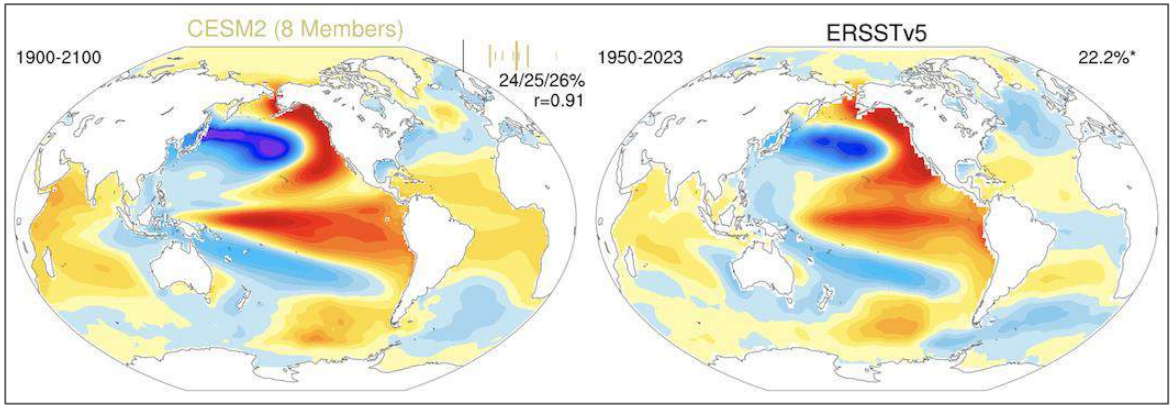
Technology Updates

Quick Links

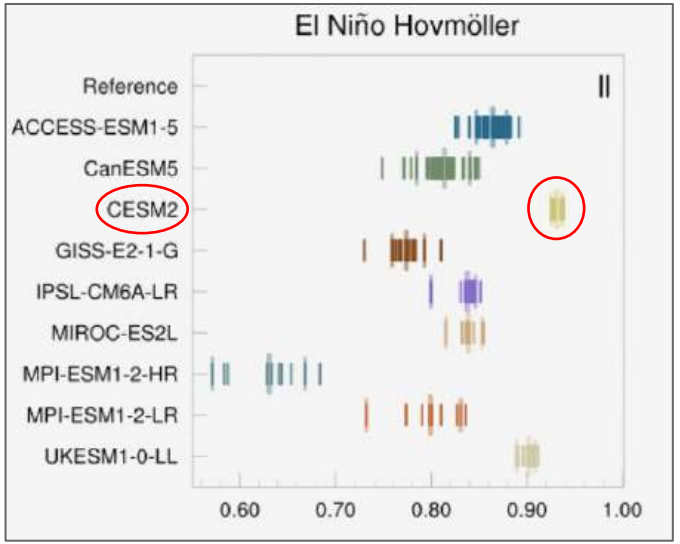
NEW Climate Variability Diagnostics Package (version 6 release)

Automated analysis tool and data repository for assessing modes of variability and trends.

EOF1 Pacific Decadal Variability (quadratic detrending)



Pattern Correlation w/ Obs

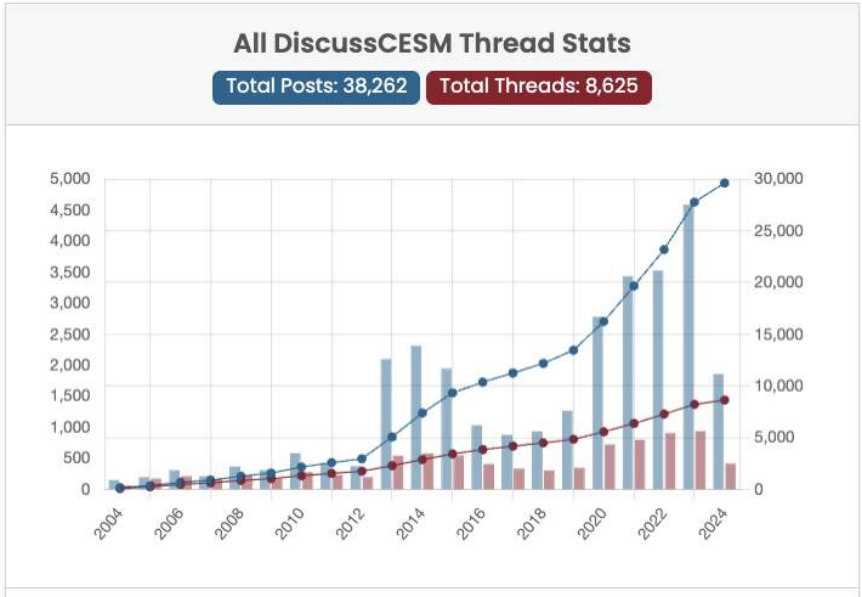


- Combines capabilities of CVDP and CVDP for Large Ensembles (CVDP-LE).
- New detrending options: linear and quadratic, 30-year high-pass filter, remove ensemble mean.
- Reference data can be either observations or model simulations.
- CAM-SE data is regridded automatically.

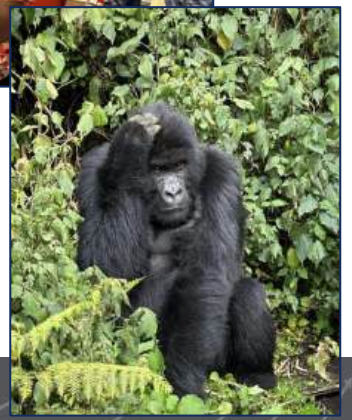
Contact: Adam Phillips and Clara Deser (Climate Analysis Section)

Tutorials and support

- Tutorials, annual CESM, component tutorials, and fully cloud-based tutorials at AGU, AMS, and WCRP in Kigali
- DiscussCESM (user support)
  - Trying to direct all support requests to DiscussCESM for greater collective benefit
  - Implement ‘best answer’ flag (?)



Tutorial on tour in Kigali!



CESM Unified Postprocessing and Diagnostics (CUPiD)

Project Vision

A grassroots collaborative effort to unify CESM component postprocessing and diagnostics

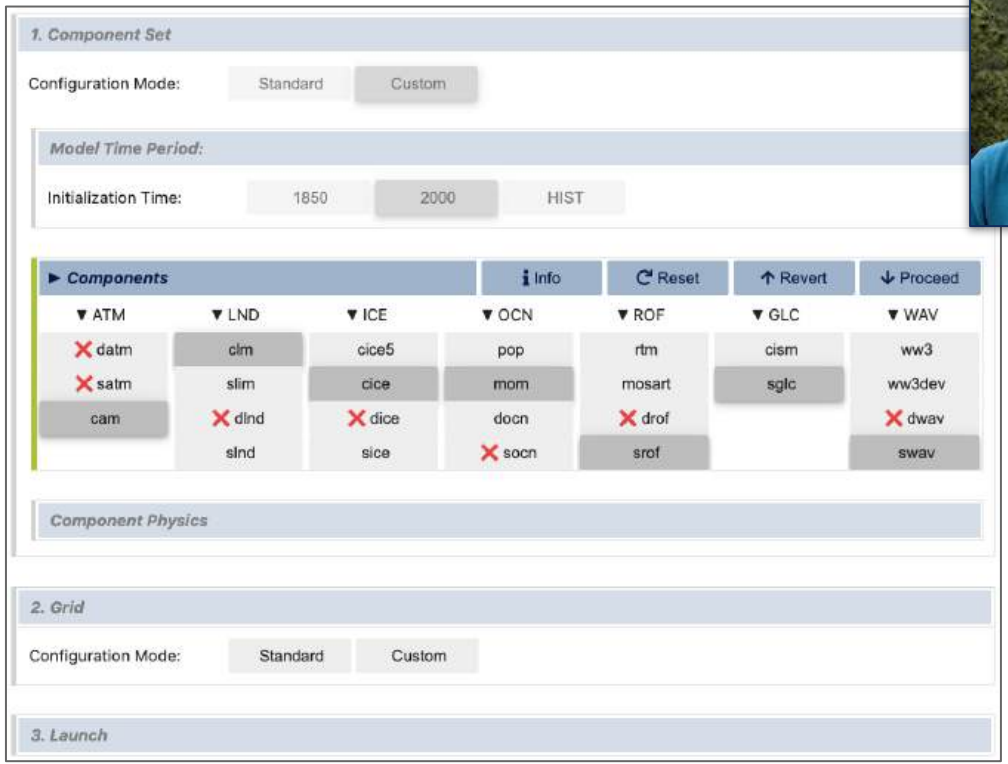
- Python code that
  i. runs in an easy-to-generate conda environment
  ii. can be launched via CIME workflow or independently
- Diagnostics for single/multiple runs and single/multiple components
- Unified post-processing tools (incl. timeseries gen, CMORization)
- An API that makes it easy to include user code
- Ongoing support and software maintenance
- https://github.com/NCAR/CUPiD

Ease-of-use: visualCaseGen

A user-friendly graphical interface (GUI) to assist users in creating CESM experiments

Key features:

- Easy exploration and setup of CESM configuration options
- Rapid generation of custom configurations:
  - Mix and match settings in a compatible manner
  - Create or interactively modify model grids



Alper Altuntas

A typical visualCaseGen Workflow

Alper Altuntas

1. Choose Components and Settings

Model Time Period:

Initialization Time: 1850 2000

▸ Components

▾ ATM	▾ LND	▾ ICE
✕ datm	clm	cice5
✕ satm	slim	cice
cam	✕ dlnd	✕ dice
	slnd	sice

Component Physics

Component Options

2.a Choose/Create Model Grids

▸ Custom Ocean Grid

Grid Extent: Global ✕ Regional

Zonally Reentrant: True ✕ False

Number of Cells in X direction:

Number of Cells in Y direction:

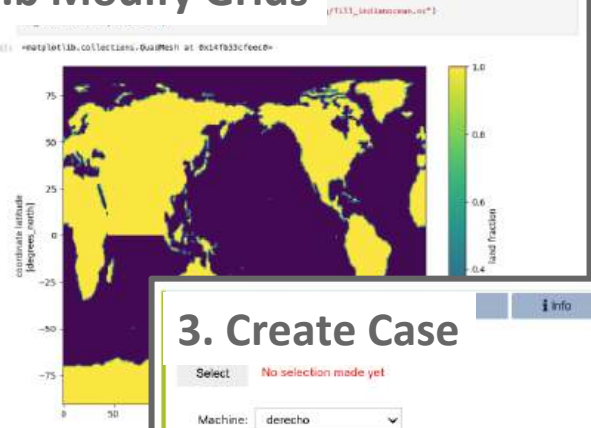
Grid Length in X direction (degrees):

Grid Length in Y direction (degrees):

Custom Ocean Grid Name:

Launch mom6

2.b Modify Grids



apply the existing land

3. Create Case

ℹ Info ⟲ Reset ↑ Revert ↓ Proceed

Select No selection made yet

Machine: derecho

Project ID:

Create Case Show Commands

Thank you!

- Urgent need for actionable climate change information (climate risks, consequences of intervention/mitigation)
- *Earth System* prediction across timescales (ESPAT), S2S → S2D → 30-yr projections (ideally, seamless)
- Increasing demand for high-resolution (~0.25°) and ultra high-resolution (km-scale) configurations in modeling hierarchy
- Growth and potential of machine learning, hybrid modeling, emulators to transform models
- Changing computing architectures → need for code modernization
- Calls for improved accessibility of ESMs and output (e.g., to global south)

BONUS SLIDES

2024 CESM Distinguished Achievement Award

Jim Edwards

For his foundational contributions to the CESM software framework

2024 CESM Graduate Student Award

Samuel Mogen

University of Colorado **Boulder**

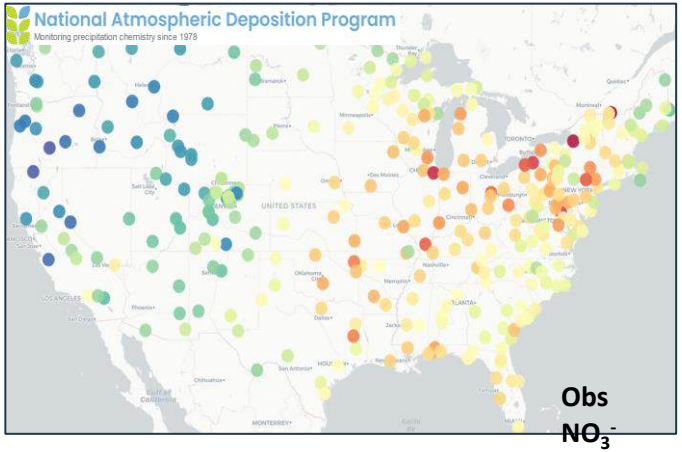
For his outstanding contributions to ocean biogeochemical prediction research

Validating modeled atmospheric deposition timeseries with observed long-term records across the U.S.

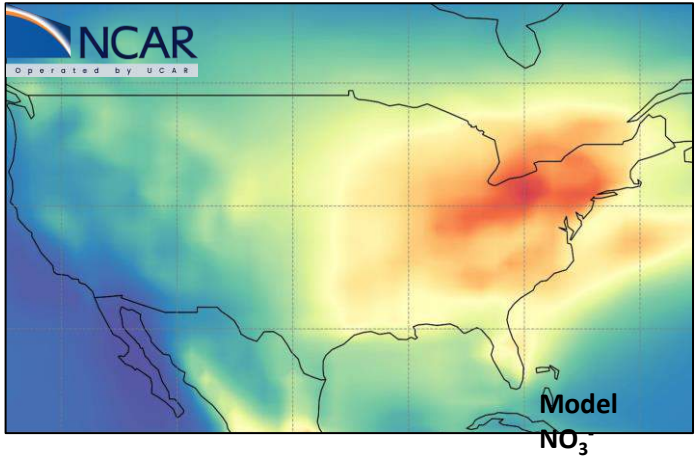
Desneiges (Deni) Murray[1], Rebecca Buchholz[2], Louisa Emmons[2], Shawn Honomichl[2], Wenfu Tang[2], Simone Tilmes[2], and Adam S. Wymore[1]

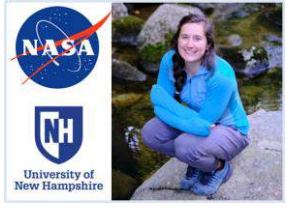
[1] University of New Hampshire, Department of Natural Resources and the Environment, Durham, NH USA

[2] Atmospheric Chemistry Observations & Modeling Laboratory, National Center for Atmospheric Research, Boulder, CO, USA



Talk:
Chemistry Climate Working Group
Wed June 12th
2 pm





Objective: assess CAM6 modeled wet deposition over CONUS

Approach: evaluate SO_4^{2-}, NO_3^-, NH_4^+

Global model run: CESM2.2 (1°, 32L, CAM-chem, TS1, 2002-2022)

Main outcome: SO_4^{2-}, NO_3^- are better represented by the model than NH_4^+

Next steps: perform sensitivity study for wildfire impacts on deposition

Next-generation Earth System modeling to address urgent mitigation and adaptation needs

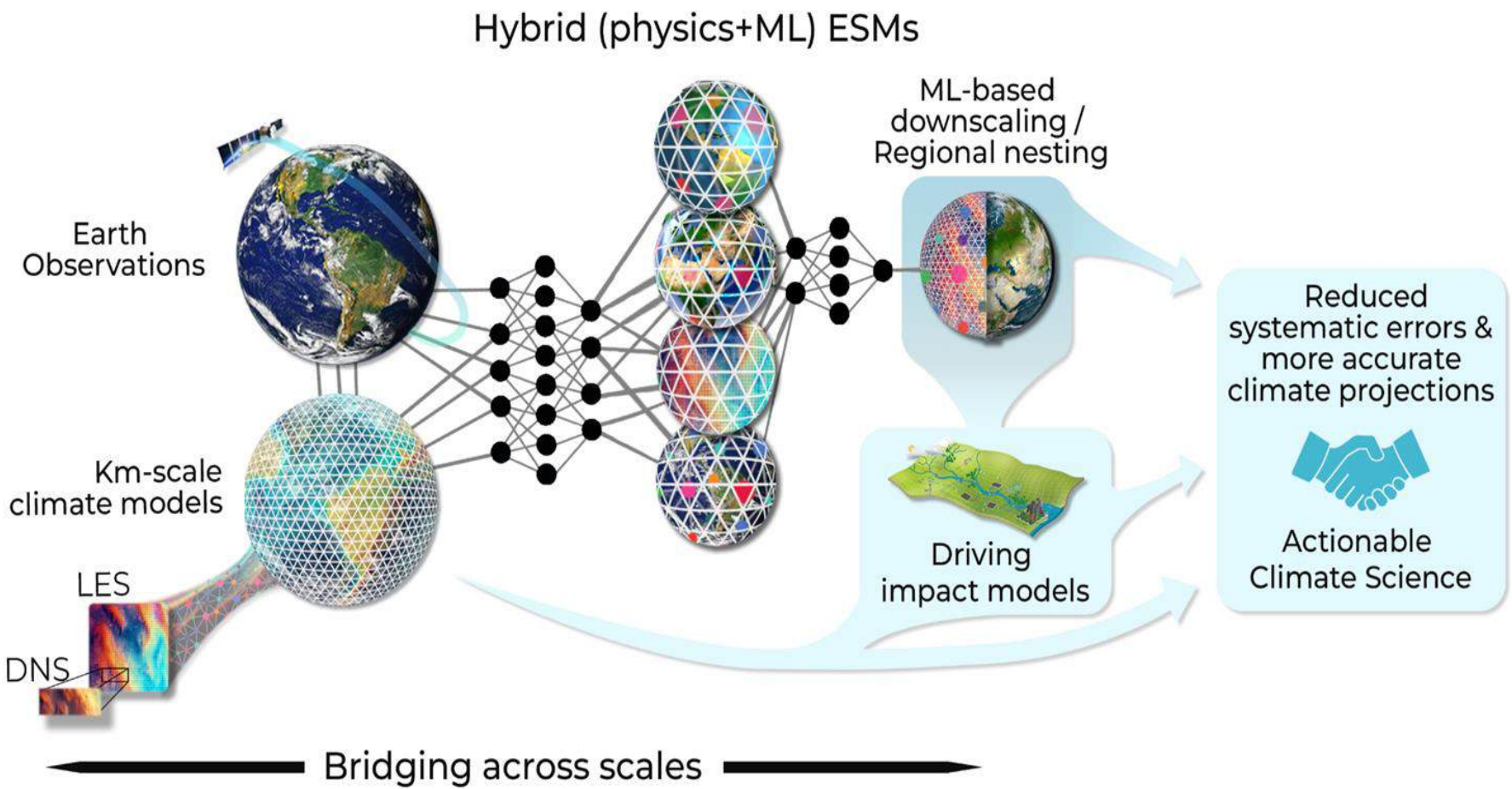
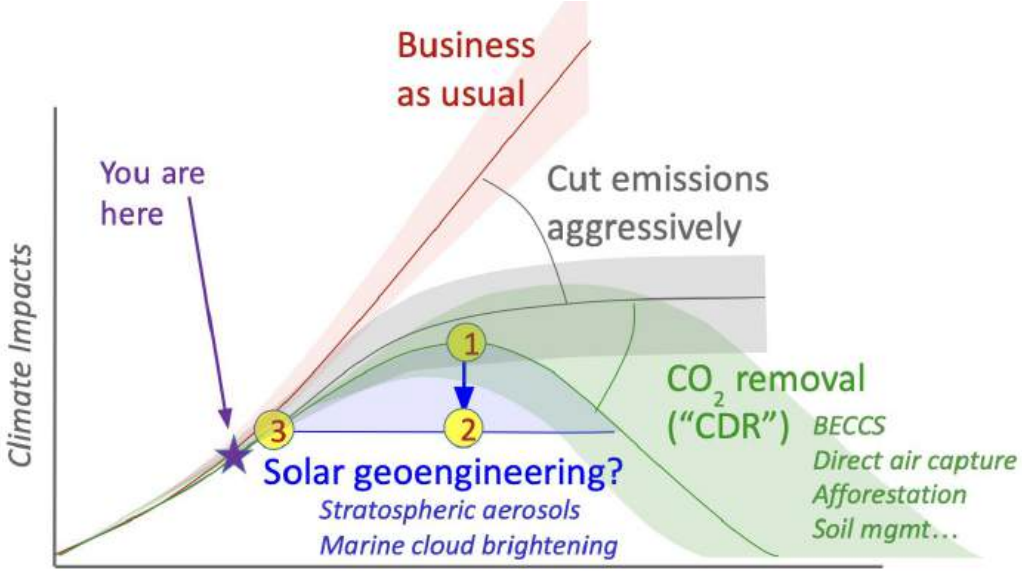


Figure from Eyring, Gentine, Camps-Valls, Lawrence (in review)

Climate intervention research

How to protect lives and environment?

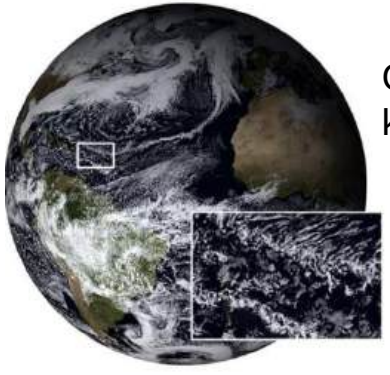


Solar Radiation Management & CDR

- **Whole Earth System Modeling:** Key to predicting consequences & effectiveness of strategies
- Requires collaboration with **broad research community** for understanding, **impacts assessment** & uncertainty communication

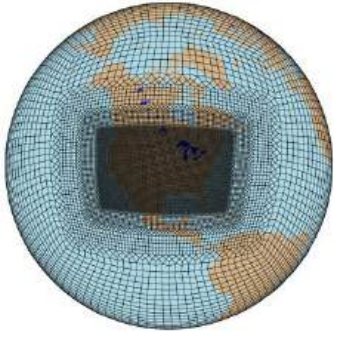
CGD goal?: Research innovation at the climate-weather interface

High resolution modeling
Accurate simulation weather phenomena



Global
km-scale

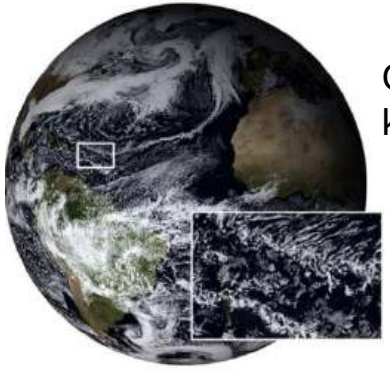
Regionally-
refined



CGD goal?: Research innovation at the climate-weather interface

High resolution modeling
Accurate simulation weather phenomena

Large ensembles
climate change uncertainty



Global
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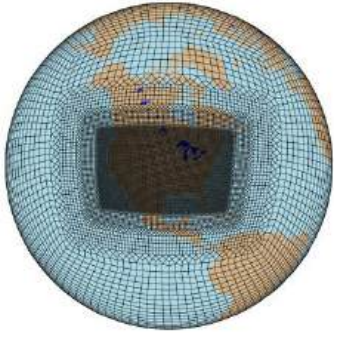
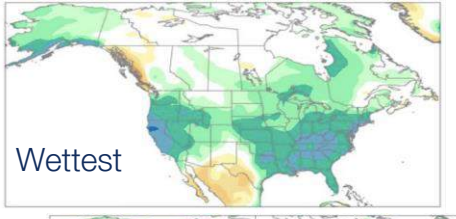
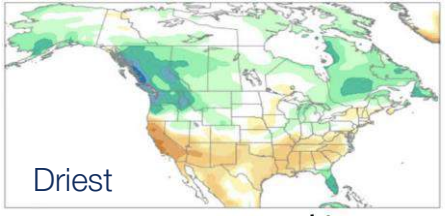


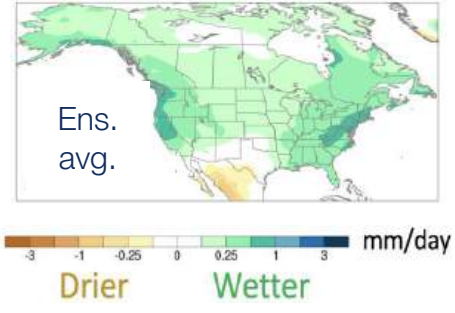
Regionally-
refined

Internal vs Forced



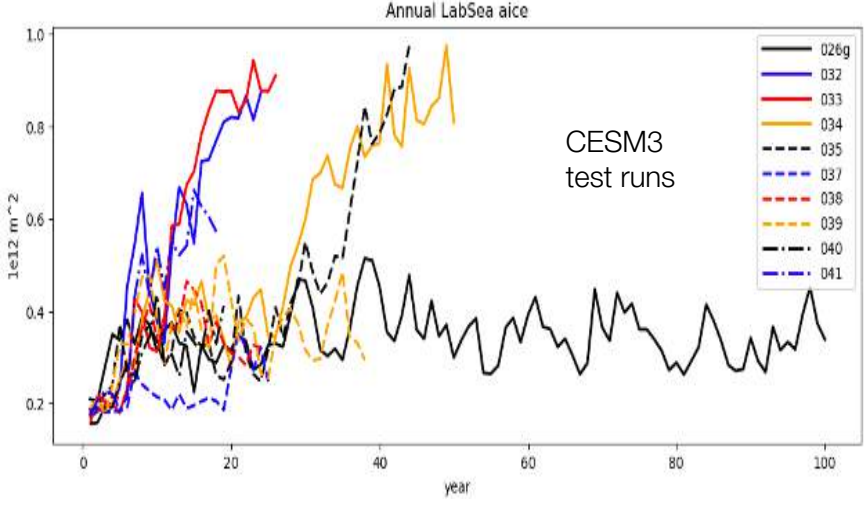


Winter Precipitation Trend
(2010-2060)



CESM longer-term opportunities are plentiful, … but ESM development is hard

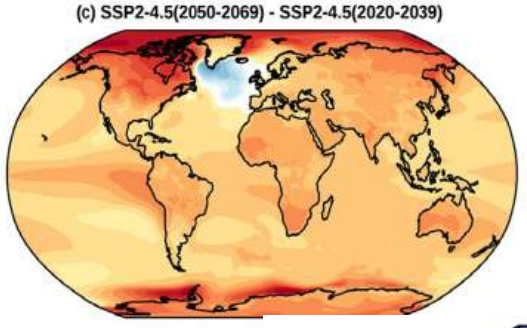
- Complexity of CESM framework continually increasing
- CESM user base continues to grow
- Expanding range of model applications is driving diverse model development priorities
- CESM/CGD advisory bodies recognize the challenge, but recommend “both-and” approach
- **Updated procedures for prioritization are needed**



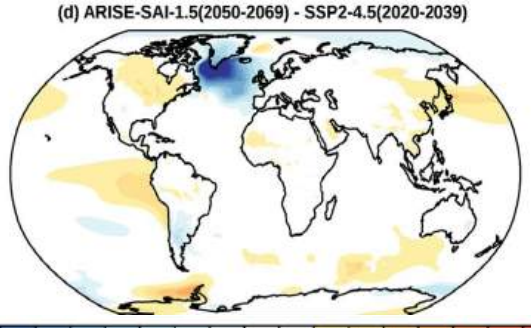
Earth System Model development is hard

Climate intervention research

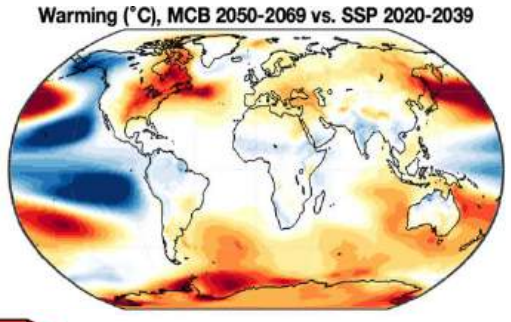
No Intervention

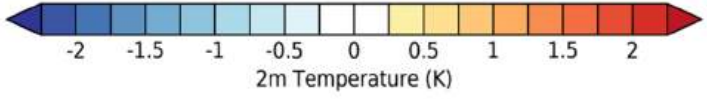


Stratospheric Aerosol Injection

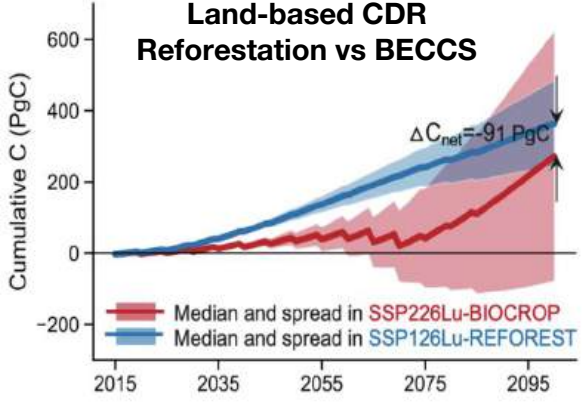


Marine Cloud Brightening





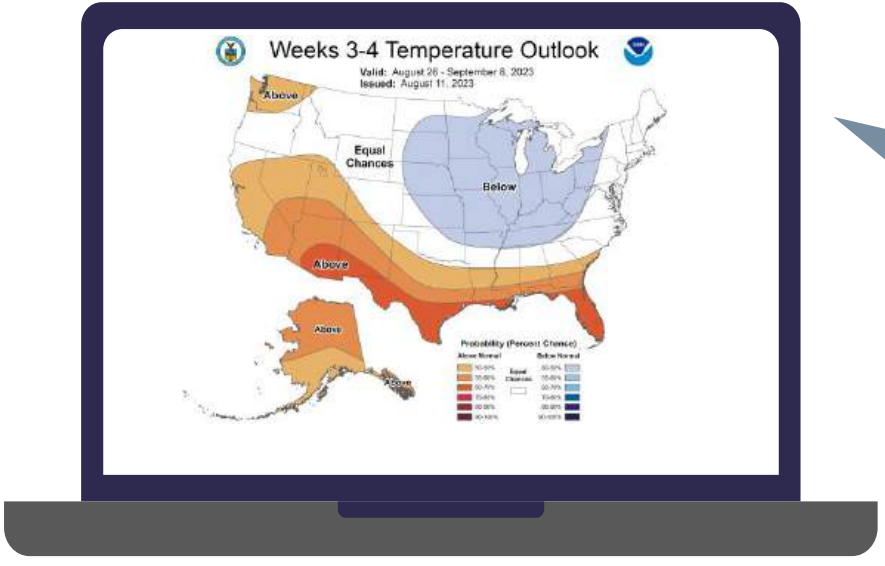
Land-based CDR
Reforestation vs BECCS

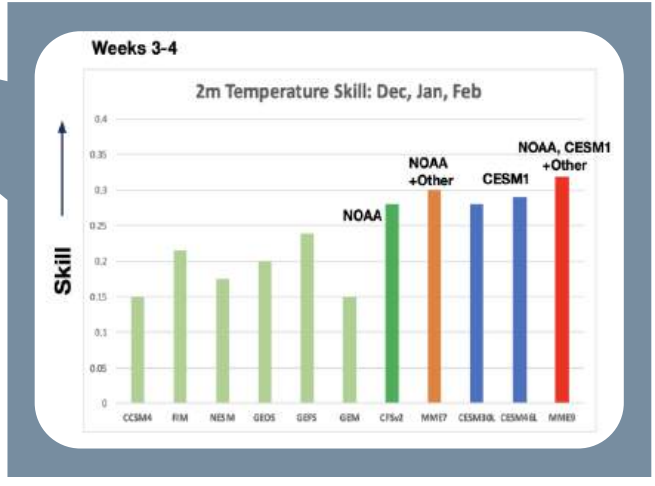


Growing set of climate intervention simulations are available for community use under broad auspices of Community Climate Intervention Strategies (CCIS) group, e.g., ARISE, NSF Growing Convergence

Subseasonal to decadal prediction system with CESM

Significant prediction skill on subseasonal to decadal timescales





SMYLE: Seasonal-to-MultiYear Large Ensemble (*Yeager et al. 2022, Geosci. Model Dev.*)