

# STATE OF CESM

THE 26<sup>th</sup> ANNUAL CESM WORKSHOP

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14 JUNE 2021



## Updates on

- Several large / community projects and simulations
- A few new / ongoing science and development efforts

# AGU CESM2 Virtual Special Issue

43 manuscripts published;  
several in review


































Articles available at both the AGU site and at  
<http://www.cesm.ucar.edu/publications/>



**JAMES** | Journal of Advances in  
Modeling Earth Systems

RESEARCH ARTICLE  
10.1029/2019MS001916

## The Community Earth System Model Version 2 (CESM2)

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J. Edwards<sup>1</sup>, L. K. Emmons<sup>2</sup> , J. Fasullo<sup>1</sup> , R. Garcia<sup>2</sup> , A. Gettelman<sup>1,2</sup> , C. Hannay<sup>1</sup> ,  
M. M. Holland<sup>1</sup> , W. G. Large<sup>1</sup>, P. H. Lauritzen<sup>1</sup> , D. M. Lawrence<sup>1</sup> , J. T. M. Lenaerts<sup>3</sup> ,  
K. Lindsay<sup>1</sup>, W. H. Lipscomb<sup>1</sup> , M. J. Mills<sup>2</sup> , R. Neale<sup>1</sup> , K. W. Oleson<sup>1</sup> ,  
B. Otto-Bliesner<sup>1</sup> , A. S. Phillips<sup>1</sup> , W. Sacks<sup>1</sup>, S. Tilmes<sup>2</sup> , L. van Kampenhout<sup>4</sup>,  
M. Vertenstein<sup>1</sup> , A. Bertini<sup>1</sup>, J. Dennis<sup>5</sup> , C. Deser<sup>1</sup> , C. Fischer<sup>1</sup>, B. Fox-Kemper<sup>6</sup> ,  
J. E. Kay<sup>7</sup> , D. Kinnison<sup>2</sup> , P. J. Kushner<sup>8</sup> , V. E. Larson<sup>9</sup> , M. C. Long<sup>1</sup> , S. Mickelson<sup>5</sup> ,  
J. K. Moore<sup>10</sup>, E. Nienhouse<sup>5</sup>, L. Polvani<sup>11</sup> , P. J. Rasch<sup>12</sup> , and W. G. Strand<sup>1</sup> 

**Special Section:**  
Community Earth System  
Model version 2 (CESM2)  
Special Collection

**Key Points:**  
• Community Earth System Model  
Version 2 includes many substantial  
improvements

Eos Science News by AGU

NEWS ▾ OPINIONS ▾ SPECIAL TOPICS NEWS FROM AGU JOURNALS ▾ TOPICS & DISCIPLINES ▾ BLOGS

ATMOSPHERIC SCIENCES Opinion



## Building a Better Model to View Earth's Interacting Processes

Researchers collaborated to produce and evaluate a new version of the Community Earth System Model, and they are documenting their work in the AGU CESM2 virtual special issue.

By Gokhan Danabasoglu and Jean-François Lamarque 15 March 2021

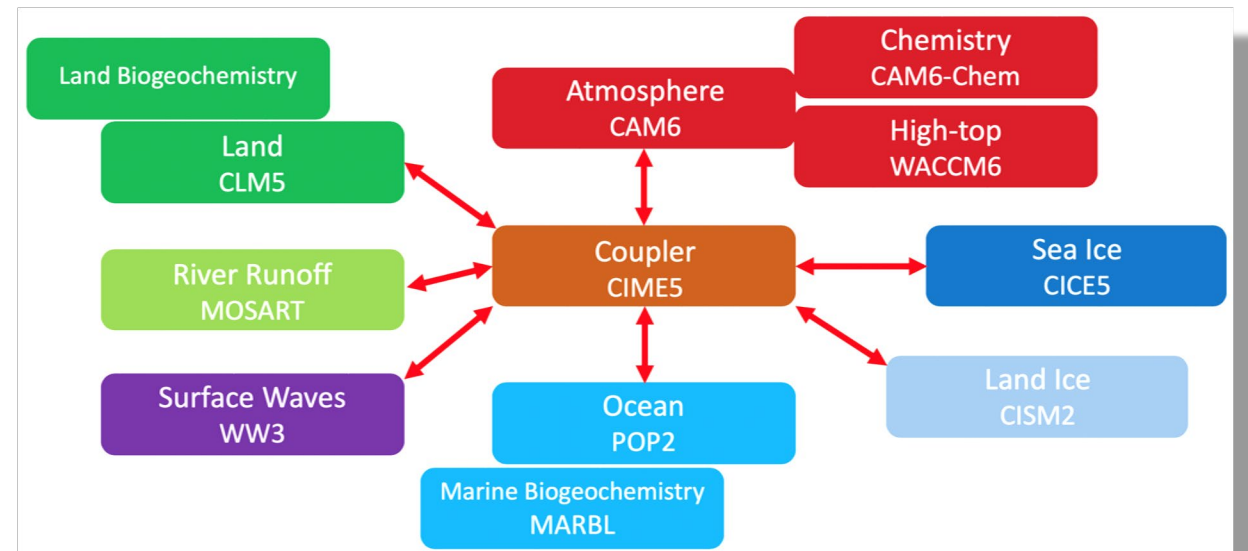
# CESM2 releases

Since December 2018, there have been three incremental releases as CESM2.1.x series.

These releases were non-answer-changing; they further expand the available set of out-of-the-box configurations for readily performing the CMIP DECK, historical, and many MIP Tier 1 simulations for CMIP6.

CESM2.2 was released on 29 September 2020.

This release contains many new developments since 2018, including a functional release of MOM6 ocean model.





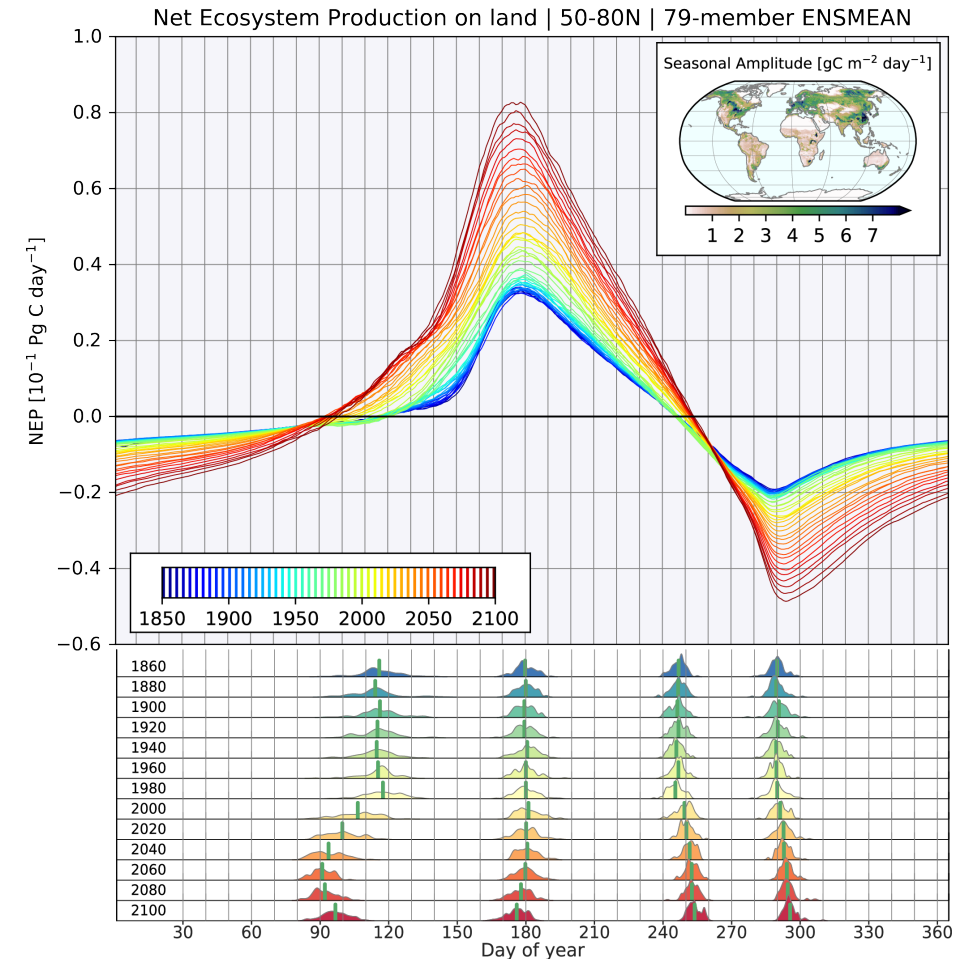
A partnership with the Institute for Basic Science (IBS) Center for Climate Physics (ICCP) in Busan, S. Korea

- A 100-member ensemble for the 1850-2100 period, using the SSP-3.70 scenario for the future extension;
- Data sets are just being released today!

Expansion of the growing season length

Presentation by Keith Rogers at 16:20 today

*Rodgers et al. (2021, Science Advances, submitted)*



# CESM high-resolution simulations (0.1° ocn; 0.25° atm)

Completed

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

Ongoing

Decadal Predictions (1980 – 2018);  
4xCO<sub>2</sub> to complete DECK;  
Additional members for transient

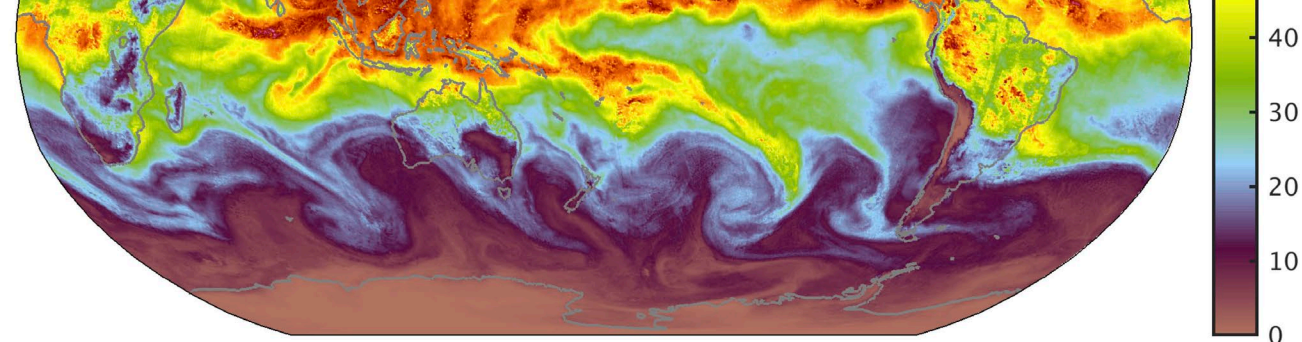
Data Release

12 June 2021!

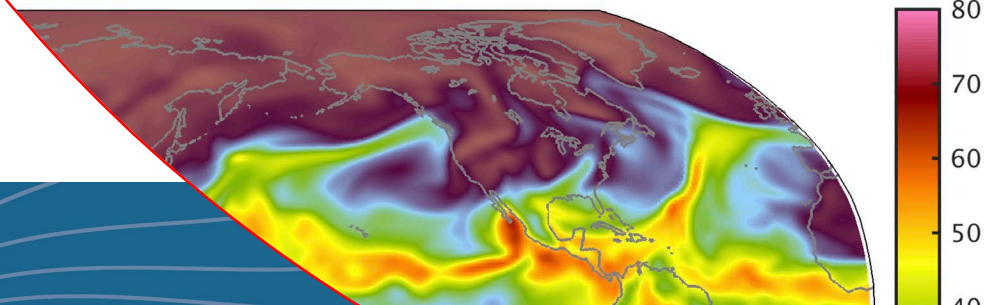
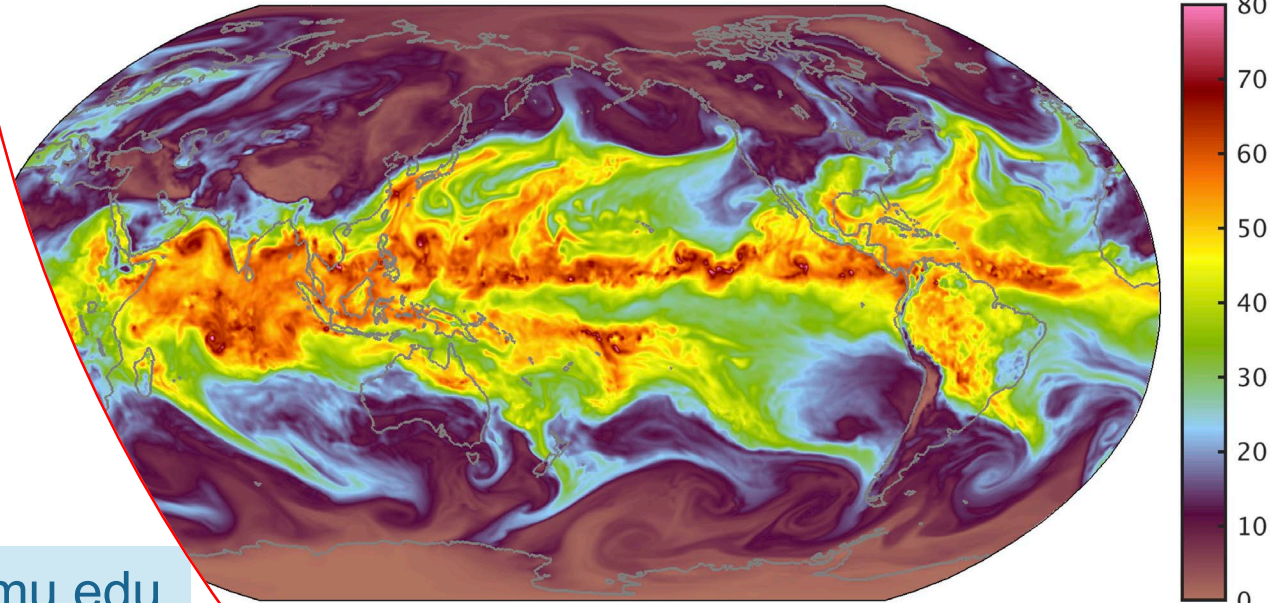
Web site: <https://ihesp.tamu.edu>  
PI Control for years 21-500;  
1 transient member;  
All HighResMIP simulations

Simulations performed by the International Laboratory for High-Resolution Earth System Prediction (iHESP)

Chang et al. (2020, JAMES)



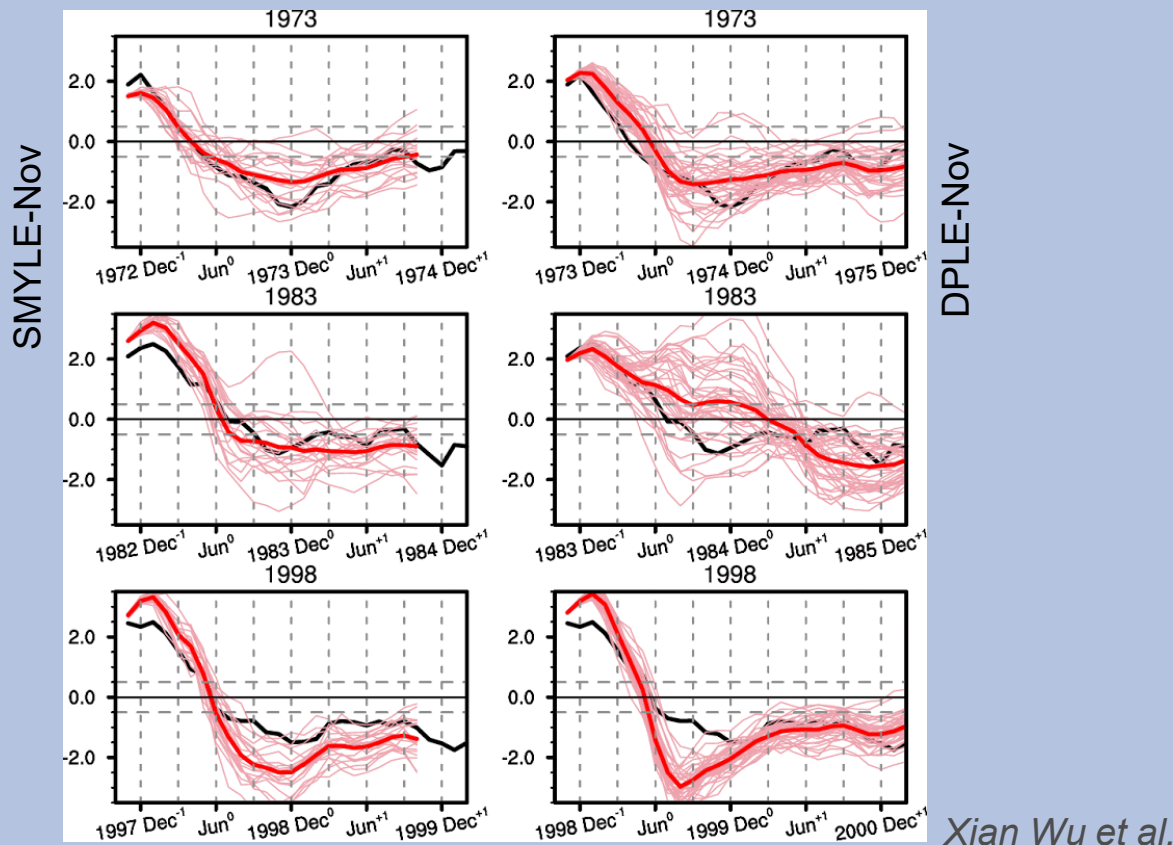
Vertically Integrated Water Vapor (IWV, in mm)





# SMYLE project: Seasonal-to-MultiYear Large Ensemble

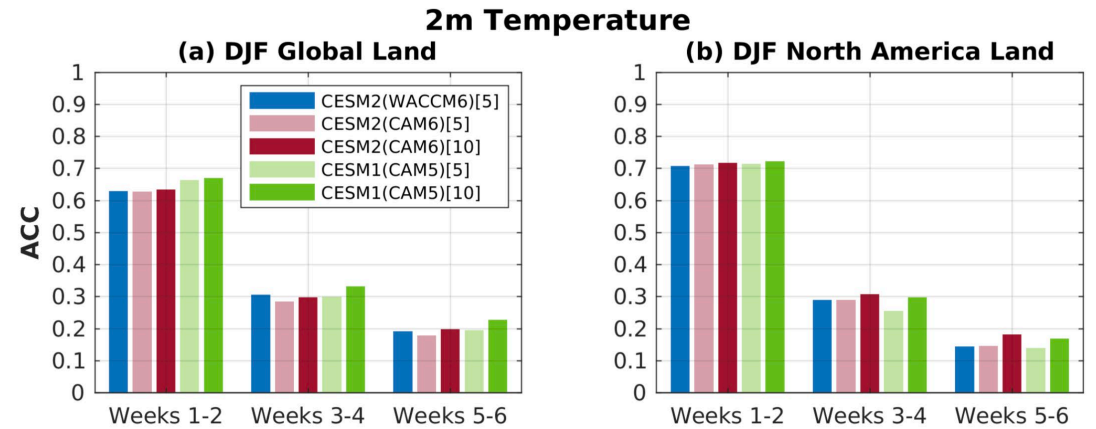
- New initialized hindcast set using CESM2
- 2-year, 20-member ensembles, 4 starts/year, 1970-2018
- Improved 2-year La Niña skill compared to CESM1-DPLE



Xian Wu et al.

# Subseasonal-to-Seasonal (S2S) hindcasts & real-time forecasts

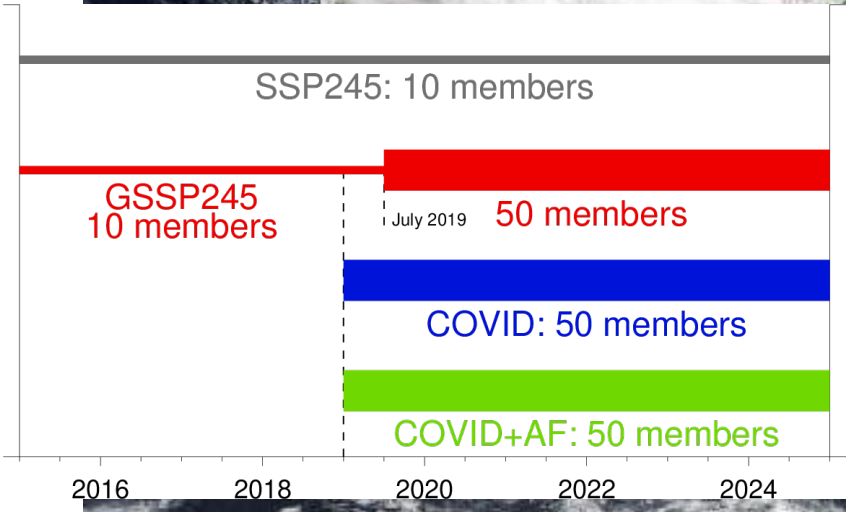
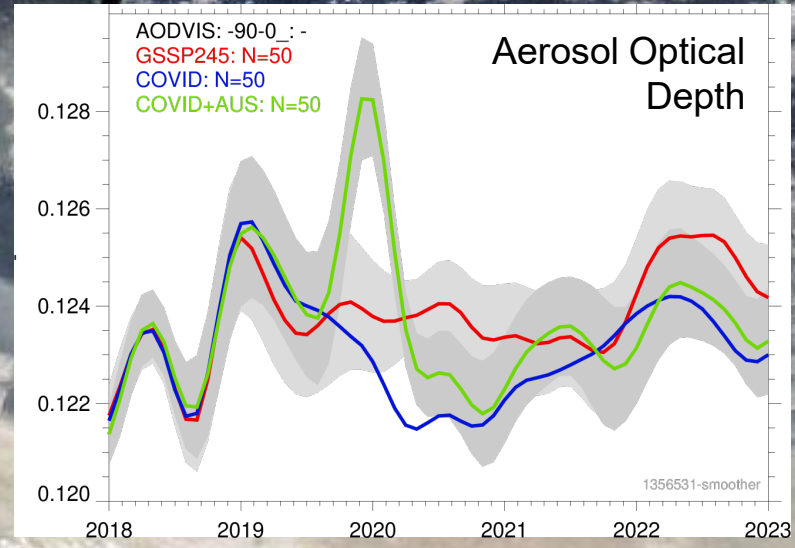
- 11-member hindcast set with CESM2(CAM6), 1999-2020; weekly starts; 45-day long simulations
- Similar 5-member hindcast set with CESM2(WACCM6) for winter season only
- Weekly real-time forecasts: 21-member ensemble: since Sep 2020 with CESM2(WACCM6) since Apr 2020 with CESM2(CAM6) Contributing to the operational NOAA week 3-4 Outlook



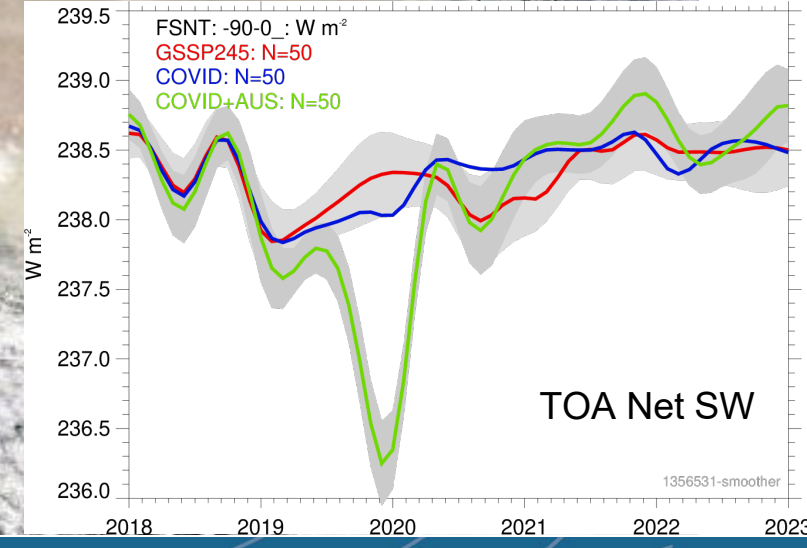
Richter et al. (2021, JAMES)

# Climate responses to COVID-19 and the 2019/20 Australian bushfire season

Jan 6 2020 Australian bushfire emissions  
Image credit NASA



Fasullo et al. (2021, GRL, in revision)





# Coupled land ice simulations

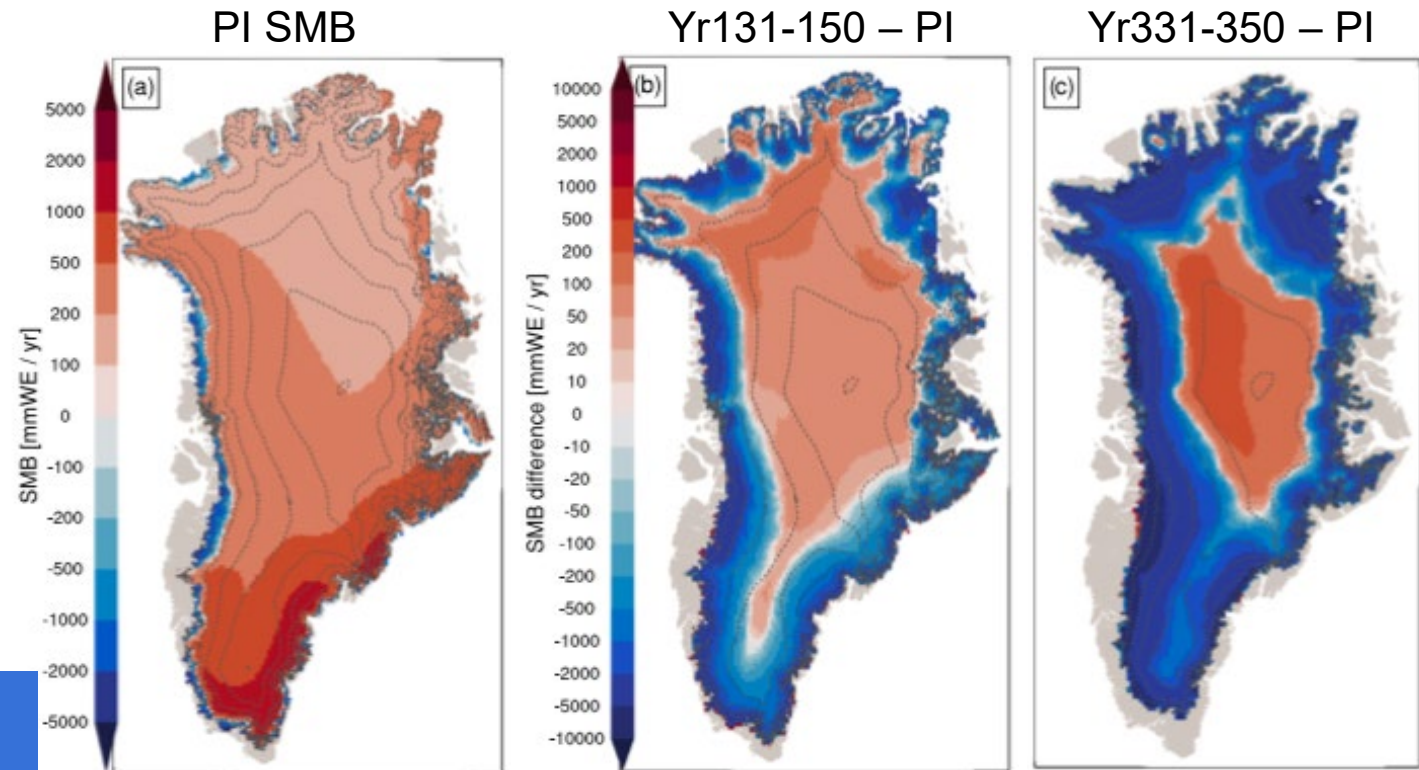
Surface mass balance (SMB) in a 350-year CESM2 simulation with a coupled Greenland ice sheet in which CO<sub>2</sub> concentration increases by 1% per year until quadrupling at year 140 and is then held constant.

Ablation areas expand; sea-level rise > 1 m by year 350 with 4xCO<sub>2</sub>

## Antarctic Ice Sheet

CESM2 and CISM have been modified to support **multiple ice sheets**, including Antarctica

Testing underway with ice-ocean coupling



**Red** = net accumulation, **blue** = net ablation

*Muntjewerf et al. (2020, JAMES; 2020, GRL)*

# Actionable polar science

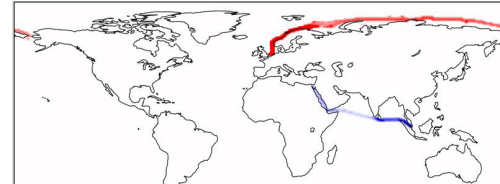
Co-producing Understanding of Drivers and Consequences of Environmental Arctic Change



A collaboration between scientists, indigenous people, and decision-making experts to produce and share actionable knowledge

Holland, DuVivier, Bailey, & Landrum

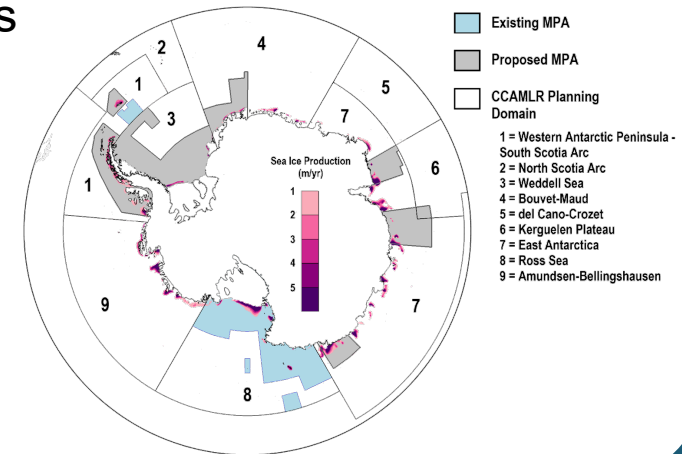
## Arctic Shipping



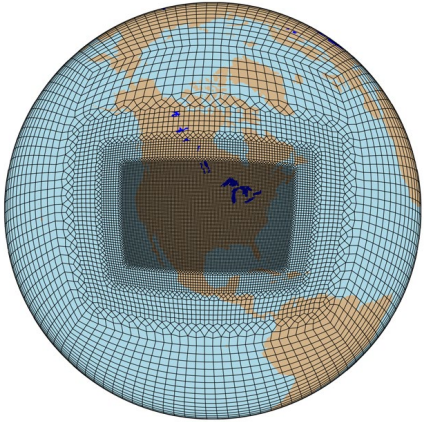
- Impacts of ship emissions
- Economic considerations
- Risk indices
- Transportation policy
- Likelihood of potential ship paths and assessment of maritime risk

## Antarctic Marine Protected Areas

- Identification of biological hotspots
- Forecasting locations of highest ecological value for protection
- Work in collaboration with the Scientific Committee on Antarctic Research, the Southern Ocean Coalition, the Pew Charitable Trusts, and Sea Legacy



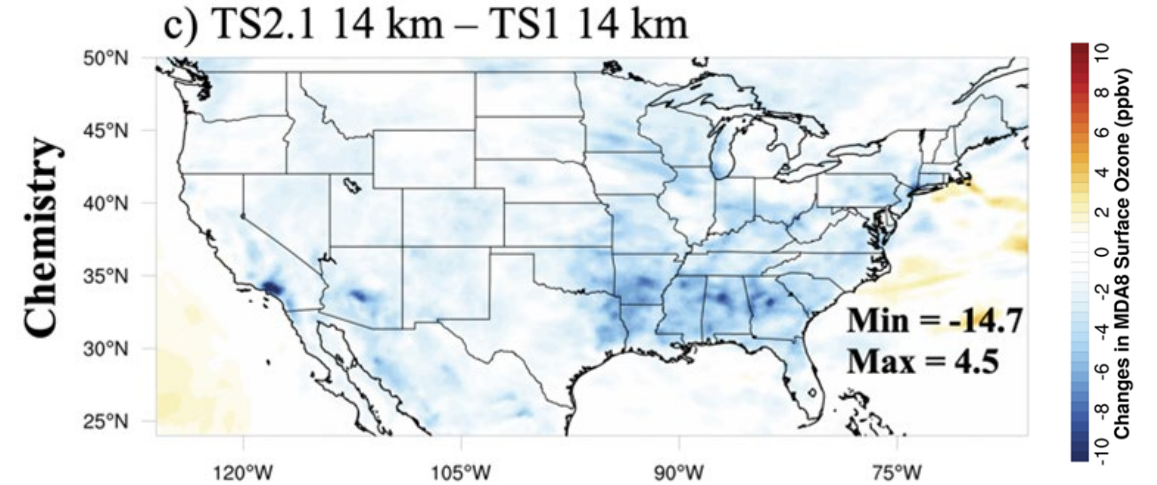
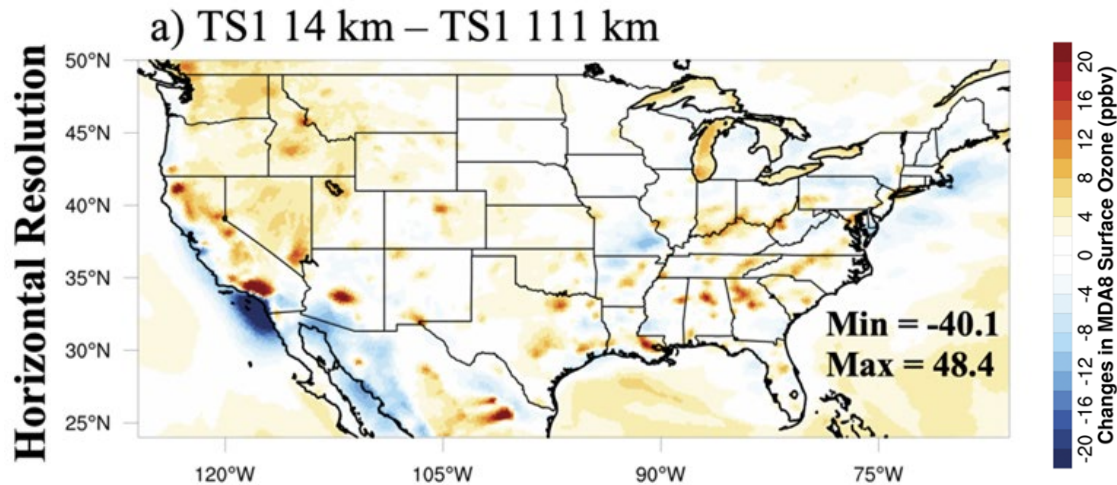
# MUSICA-V0: Impacts of horizontal resolution and chemical complexity



- MUSICA-V0 = CAM-chem, Spectral Element with regional refinement
- Default grid: 14 km over US, 1° rest of globe
- Providing capability for regional-scale air quality analyses in a global model
- Improving estimates of human health impacts from PM2.5 [Lacey]
- Improving simulation of surface ozone [Schwantes]

Finer resolution more accurately represents emissions and chemistry of cities and fires

Increased chemical complexity has more impact at higher resolution, improving ozone over southeast U.S.





# Lossy compression of CESM data

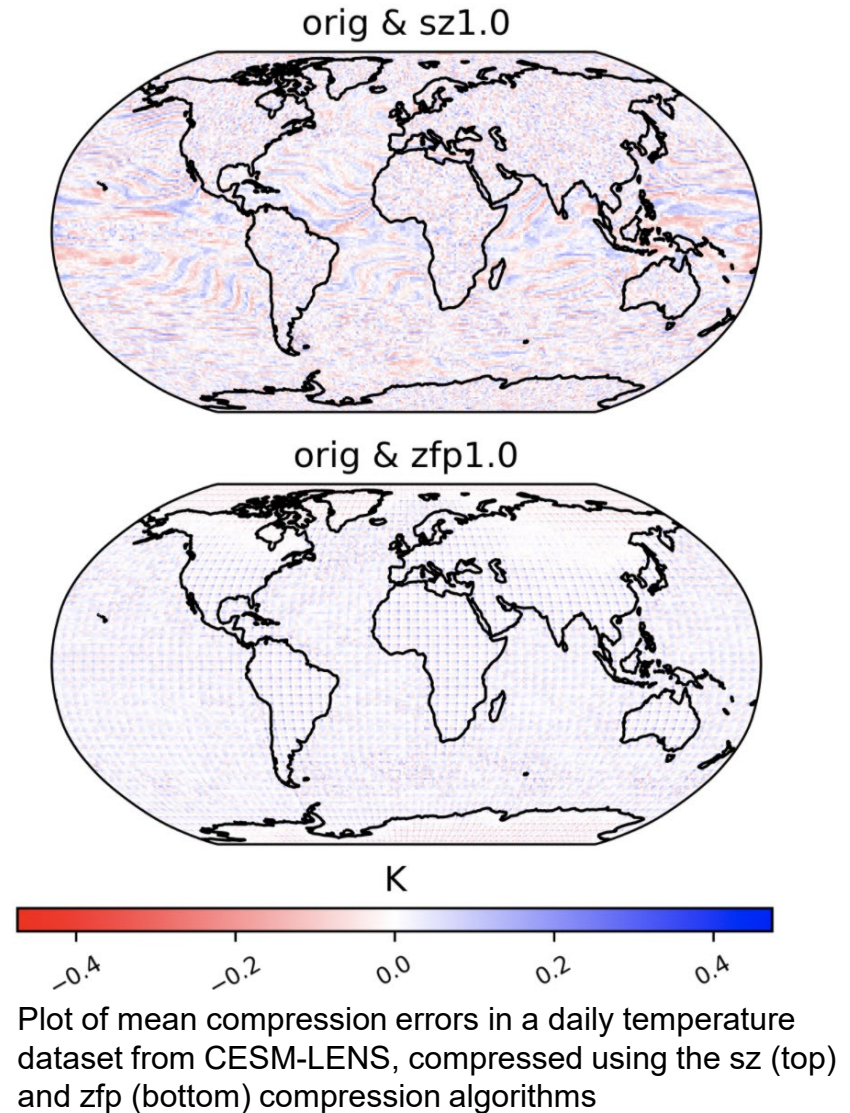
Application of lossy compression applied to climate datasets can result in a large amount of data reduction with minimal drawbacks – ***IF*** it can be applied carefully.

Optimal compression settings are determined for several test datasets using a metric called the Data Structural Similarity Index Measure (SSIM)...

Available for testing by users – **you can be one of them!**

A new Python package *ldcpy* can assist users in analyzing potential compression effects visually and through budgets and more.

*Hammerling, Baker, & Pinard*



# Streamlining coupled, simplified modelling within CESM

Ocean bathymetry tool  
CESM configuration query tool

Prototype CESM configuration query tool

Next steps:

Tools for generation of idealized  
land surface conditions

Completion of coupled simpler  
models tool chain

*Bachman, Simpson, Danabasoglu, Vertenstein, Sacks,  
Altuntas, & Dobbins*

Step 1: Preliminaries

Step 2: Create Case

Initialization Time: 1850 2000 HIST

Components:

ATM	LND	ICE	OCN	ROF	GLC	WAV
<input checked="" type="checkbox"/> datm	<input checked="" type="checkbox"/> clm	<input checked="" type="checkbox"/> cice	<input checked="" type="checkbox"/> pop	<input checked="" type="checkbox"/> rtm	<input checked="" type="checkbox"/> cism	<input checked="" type="checkbox"/> ww3
<input checked="" type="checkbox"/> satm	<input checked="" type="checkbox"/> dlnd	<input checked="" type="checkbox"/> dice	<input checked="" type="checkbox"/> mom	<input checked="" type="checkbox"/> mosart	<input checked="" type="checkbox"/> sglc	<input checked="" type="checkbox"/> dwav
<input checked="" type="checkbox"/> cam	<input checked="" type="checkbox"/> slnd	<input checked="" type="checkbox"/> sice	<input checked="" type="checkbox"/> docn	<input checked="" type="checkbox"/> drof		<input checked="" type="checkbox"/> swav
			<input checked="" type="checkbox"/> socn	<input checked="" type="checkbox"/> srof		

Component Physics:

<input checked="" type="checkbox"/> CAM60	<input checked="" type="checkbox"/> CLM45	<input checked="" type="checkbox"/> CICE	<input checked="" type="checkbox"/> MOM6	<input checked="" type="checkbox"/> DROF	<input checked="" type="checkbox"/> SGLC	<input checked="" type="checkbox"/> WW3
<input checked="" type="checkbox"/> CAM50	<input checked="" type="checkbox"/> CLM50					
<input checked="" type="checkbox"/> CAM40						
<input checked="" type="checkbox"/> CAM30						

Component Options:

<input checked="" type="checkbox"/> (none)	<input checked="" type="checkbox"/> (none)	<input checked="" type="checkbox"/> (none)	<input checked="" type="checkbox"/> (none)	<input checked="" type="checkbox"/> (none)	<input checked="" type="checkbox"/> (none)	<input checked="" type="checkbox"/> (none)
<input checked="" type="checkbox"/> 1PCT	<input checked="" type="checkbox"/> SP	<input checked="" type="checkbox"/> PRES		<input checked="" type="checkbox"/> NYF		
<input checked="" type="checkbox"/> 4xCO2	<input checked="" type="checkbox"/> SP-VIC	<input checked="" type="checkbox"/> CMIP6		<input checked="" type="checkbox"/> IAF		
<input checked="" type="checkbox"/> CCTS1	<input checked="" type="checkbox"/> CN	<input checked="" type="checkbox"/> CICE1		<input checked="" type="checkbox"/> IAFNIS00		

compset: 2000\_CAM60\_CLM45\_CICE\_MOM6\_DROF%NYF\_SGLC\_WW3

Grids:

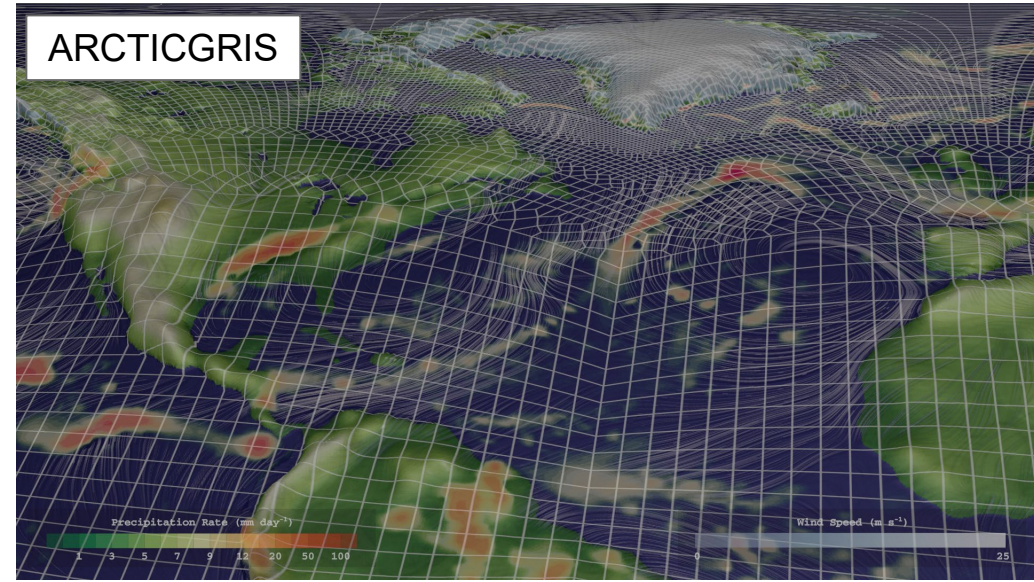
Compatible Grids: Select from 17 compatible grids

Case name:   Create new case

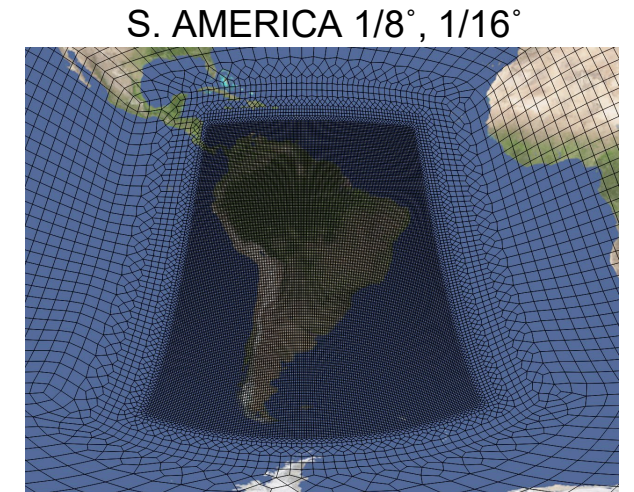
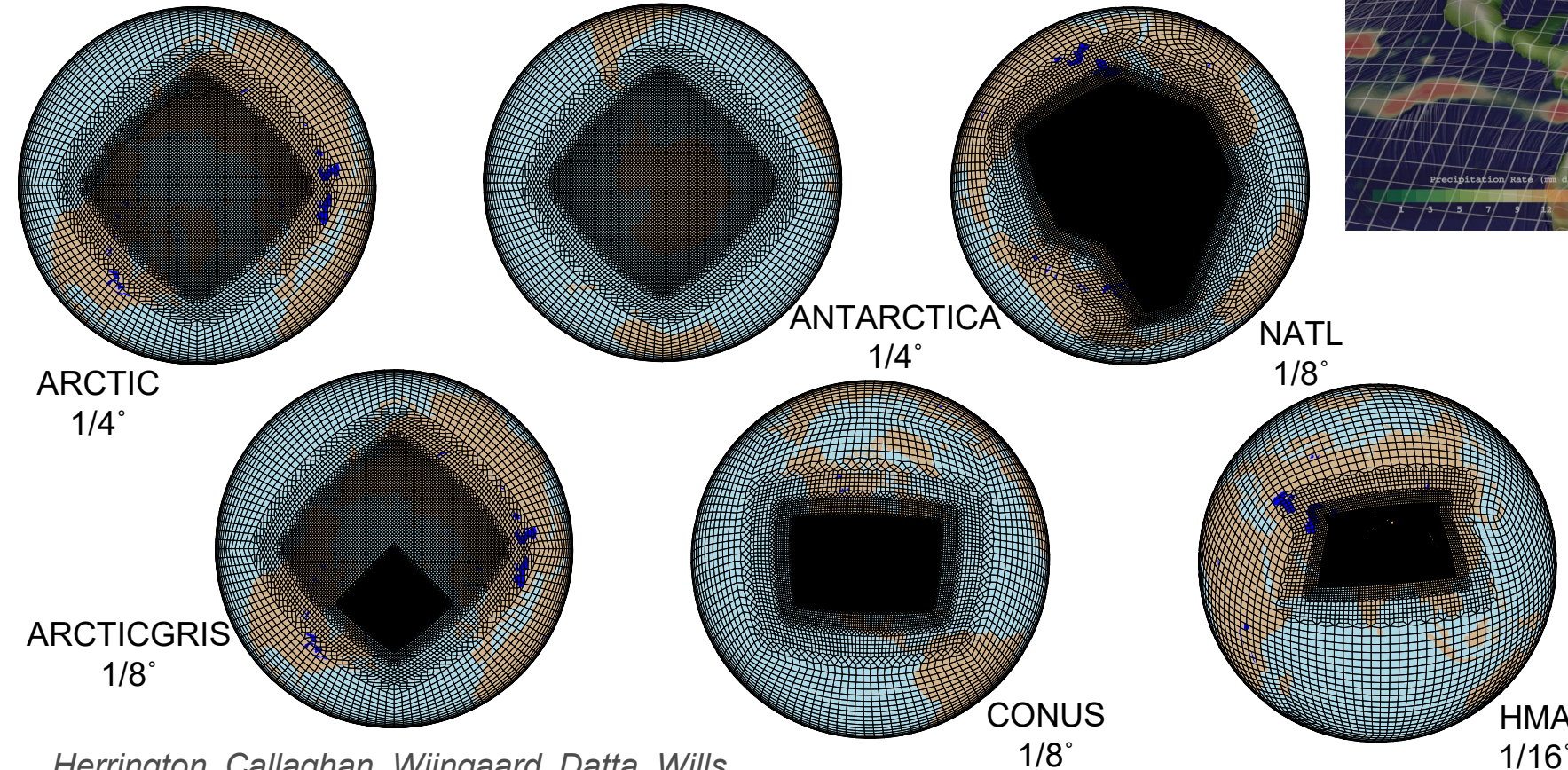


# Variable-resolution grids

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



Snapshot from NCAR VisLab



Herrington, Callaghan, Wijngaard, Datta, Wills

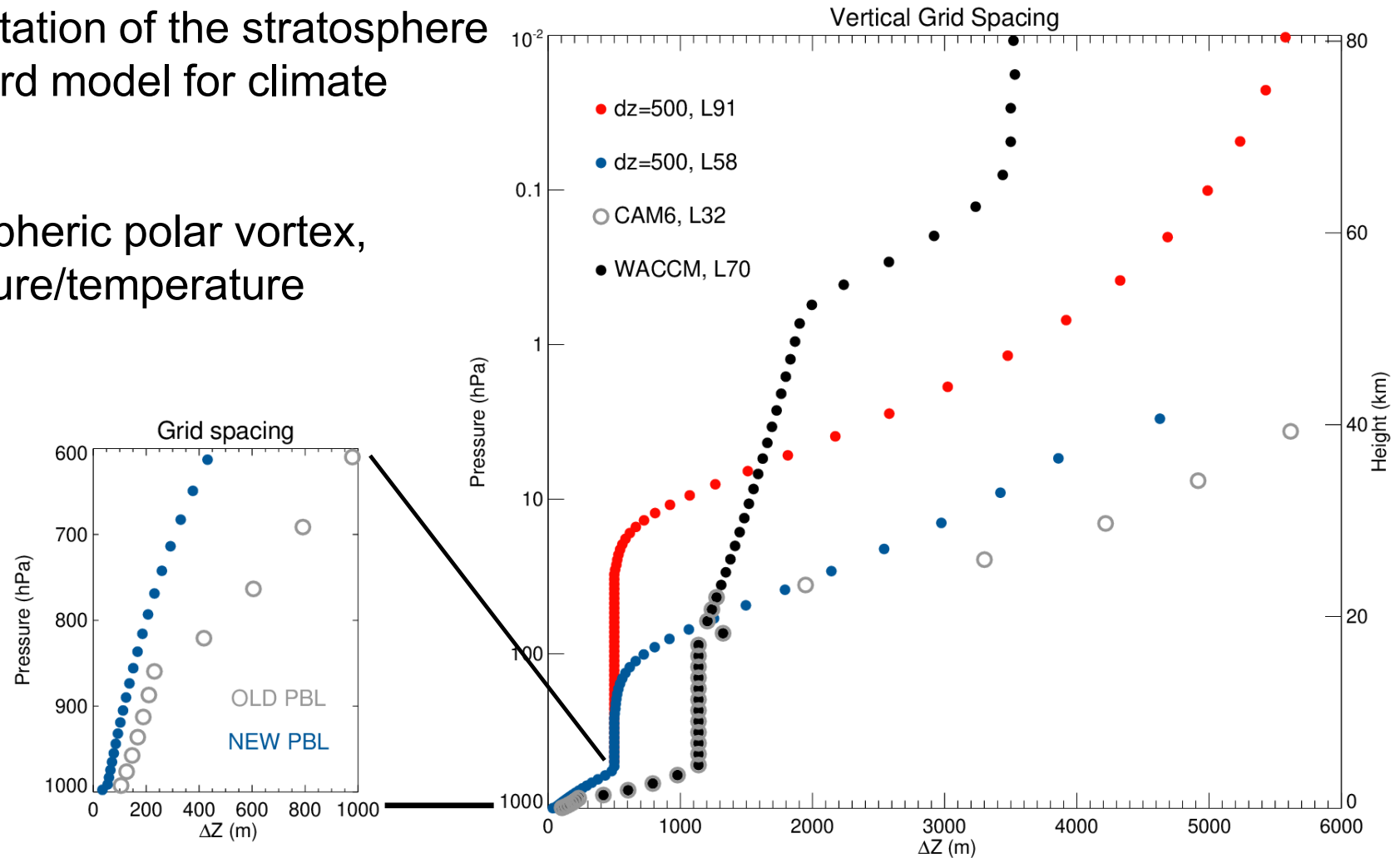


# Vertical resolution evaluation for the next *workhorse* version of CESM

Motivation: Improve the representation of the stratosphere and boundary layer in our standard model for climate applications.

Improve/represent: QBO, stratospheric polar vortex, boundary layer clouds and moisture/temperature profiles, surface fluxes.....

- ~80 km top (91L) or ~40 km top (58L)
- 500 m grid spacing in the free troposphere and lower stratosphere
- 10 additional levels in the boundary layer
- New PBL resolution currently being tuned in CAM-SE with 40 km top.



Isla Simpson & Task Team

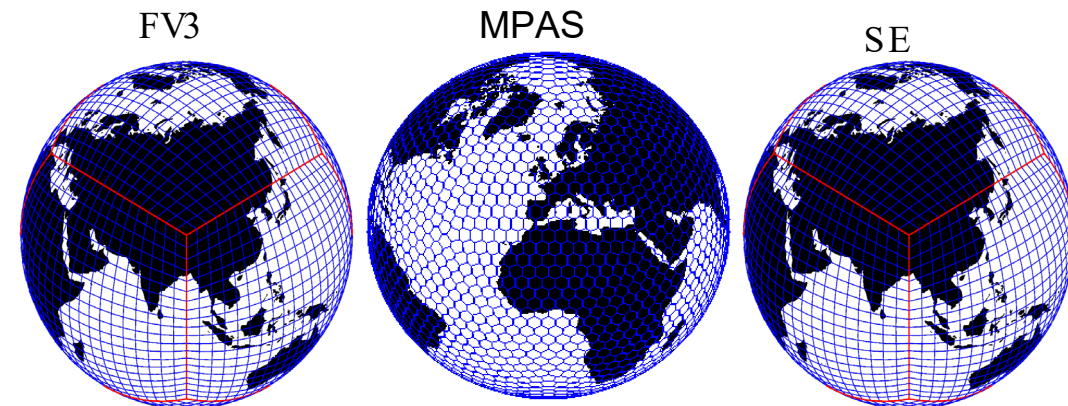
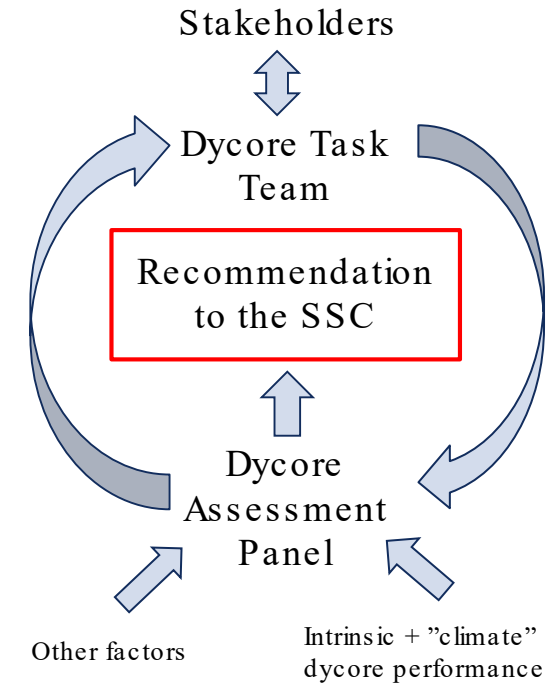
# Dycore evaluation for the next *workhorse* version of CESM

Three dynamical cores are under consideration for the next generation of  $\sim 1^\circ$  CESM that will be used for climate applications.

Although one dycore will be chosen for this application, all dycores will remain within CESM and will be available for use for other applications.

Multiple facets of dycore performance to be considered:

- **Phase 1:** Inherent properties of the dycore, e.g., computational performance, tracer transport characteristics, energy and momentum conservation (**near completion**)
- **Phase 2:** General performance under comprehensive AMIP simulation mode (**about to start**)
- **Phase 3,4,5,.....:** Coupled, chemistry-climate, ... (**to be defined**)



*Peter Lauritzen & Isla Simpson*



Thank You!





# CESM Distinguished Achievement Award



Jerry Meehl  
NCAR



# CESM Graduate Student Award

Patricia DeRepentigny  
University of Colorado Boulder

