

# THE JOY OF TUNING

## RECIPE BOOK FOR TUNING CAM

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THE 26th CESM ANNUAL WORKSHOP, 15 JUNE 2021



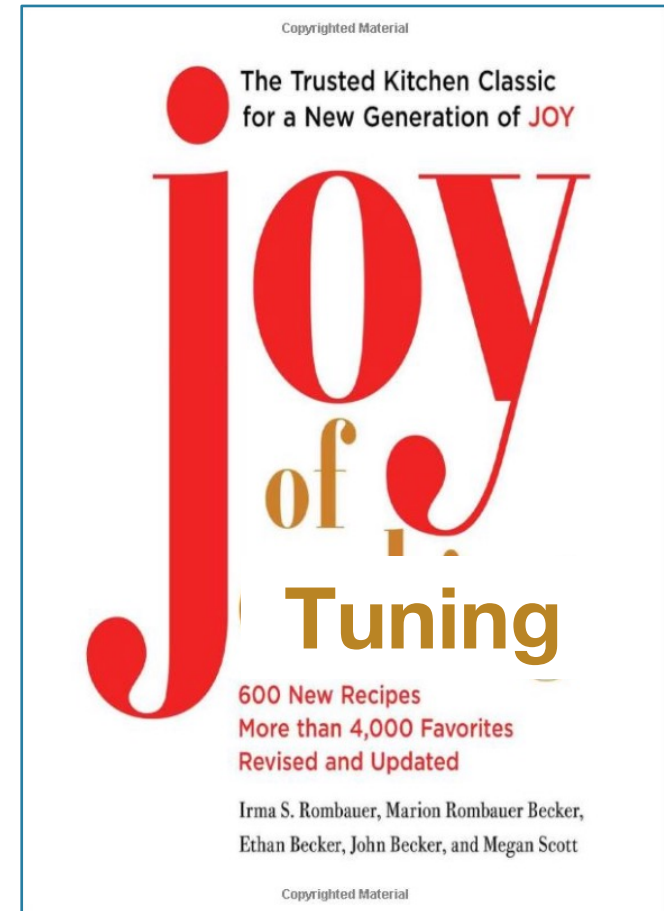
# Motivation

Tuning is a **fundamental step** during model development...

... but **nitty-gritty details** are not fully documented

## “The Joy of Tuning”

- **CAM tuning recipes**
- make CAM tuning process more **explicit** and more **transparent**
- **living** document (feedback welcome)



## Definition of Climate Modeling Tuning

**Tuning = adjusting parameters (“tuning knobs”) to achieve best agreement with observations.**

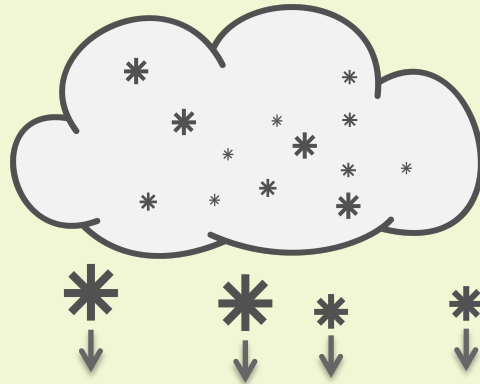
# Definition of Climate Modeling Tuning

Tuning = adjusting parameters (“tuning knobs”) to achieve best agreement with observations.

**Tuning knob** = parameter weakly constrained by observations

Dcs = Threshold diameter to convert cloud ice particles to snow

Smaller Dcs



Less cloud ice  
Less LWCF

Larger Dcs



More cloud ice  
More LWCF

## Definition of Climate Modeling Tuning

**Tuning = adjusting parameters (“tuning knobs”) to achieve best agreement with observations.**

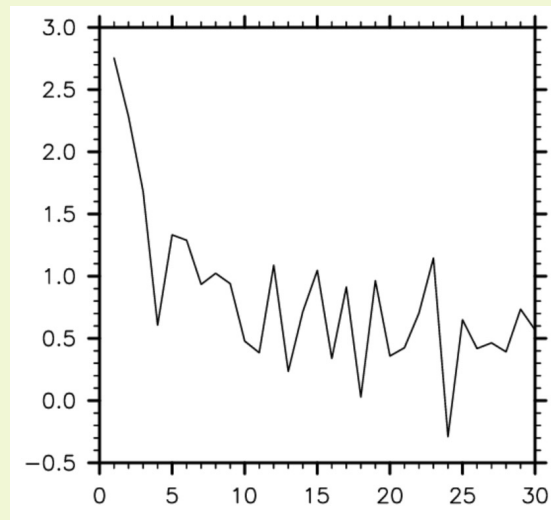
# Definition of Climate Modeling Tuning

Tuning = adjusting parameters (“tuning knobs”) to achieve **best agreement with observations.**

Top of atmosphere radiative balance (**RESTOM should be small**)

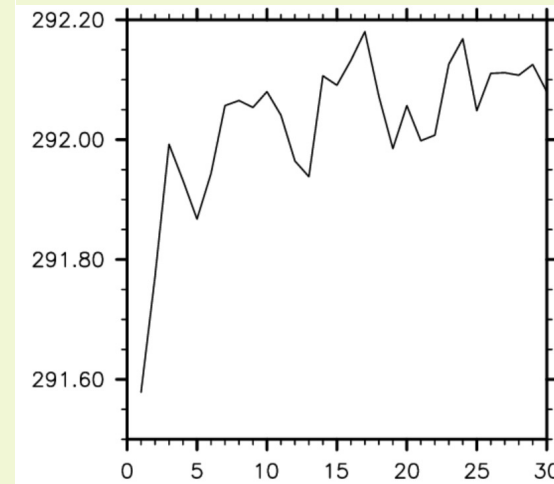
RESTOM in pi-control simulation < 0.1 W/m<sup>2</sup>

RESTOM > 0.1 W/m<sup>2</sup>



=>

SST increases



# Other Key Variables: SST, SWCF, LWCF, PRECT, PSL, TAU

Variables are typically evaluated against observations using the **AMWG diagnostics package**  
Some datasets are being **updated** in the **AMWG Diagnostics Framework (ADF)**

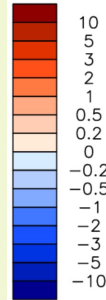
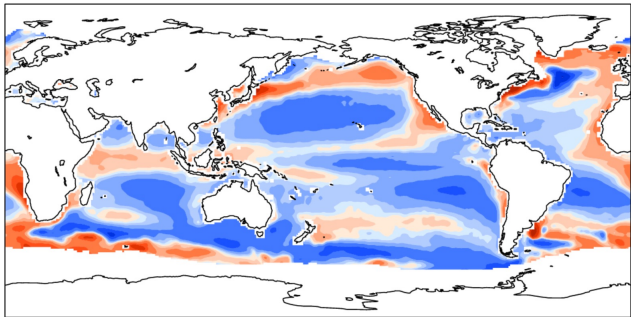
## SST bias

HadISST/OI.v2

Bias < 0.3 K

RMSE < 1.2

mean = -0.32    rmse = 0.98    C



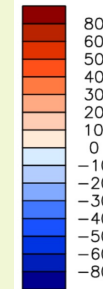
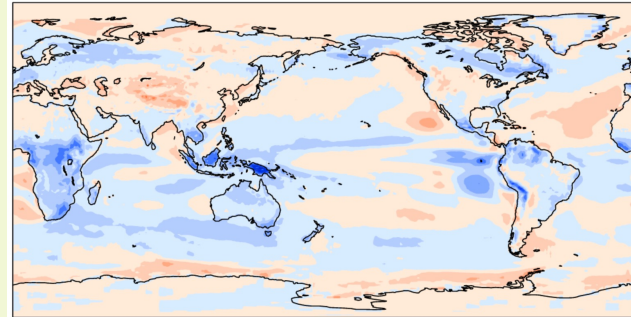
## SWCF bias

CERES-EBAF

Globally:  $\pm 2$  W/m<sup>2</sup>

+ Local biases

mean = -1.43    rmse = 8.97    W/m<sup>2</sup>



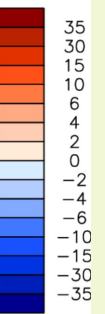
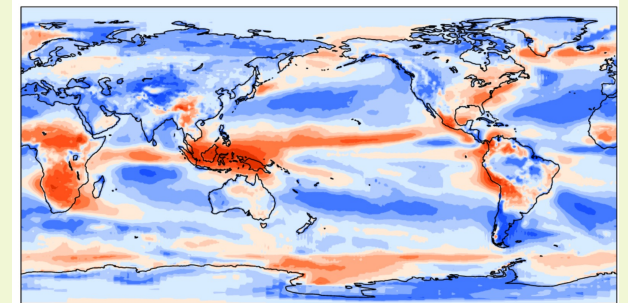
## LWCF bias

CERES-EBAF

Globally:  $\pm 2$  W/m<sup>2</sup>

+ Local biases

mean = -1.13    rmse = 4.87    W/m<sup>2</sup>



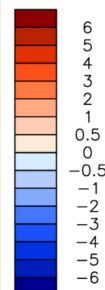
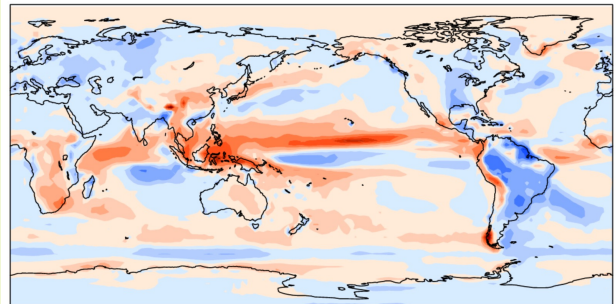
## PRECT bias

GPCP

Bias < 20%

RMSE < 1.2

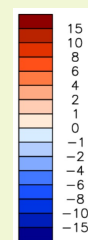
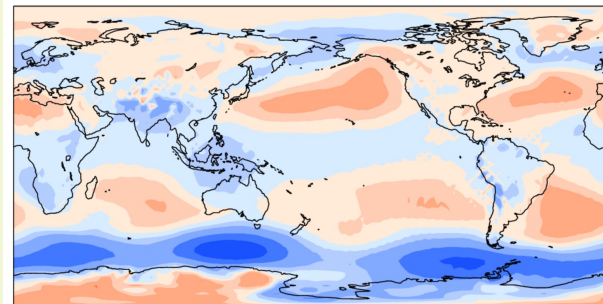
mean = 0.18    rmse = 0.89    mm/day



## PSL bias

JRA25

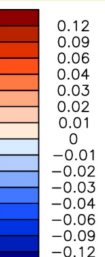
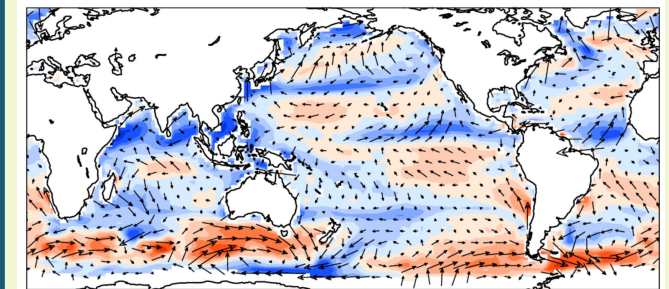
mean = -0.14    rmse = 1.62    millibars



## Surface stress bias

Large-Yeager

Surface stress    mean = -0.00    N/m<sup>2</sup>



# Tuning steps

## Step 1 CAM-only simulations

F2000climo: 5-10 yrs  
FHIST: 10-30 yrs



**Key variables:**  
SWCF, LWCF,  
PRECT, PSL, ...

Initialization  
spunup state

## Step 2 Fully coupled pre-industrial

B1850: 10-20 yrs



**RESTOM <math>< 0.1 \text{ W/m}^2</math>**  
+ Key variables

B1850: 50-100 yrs

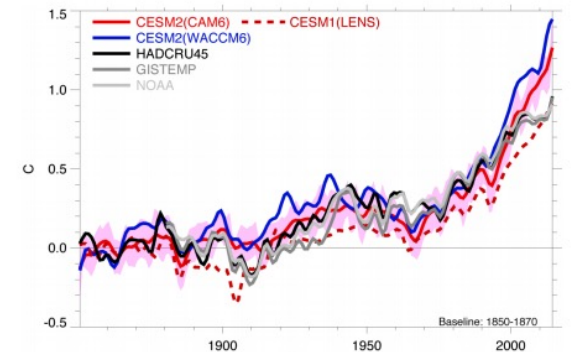


**RESTOM and TS drift**  
+ Key variables  
+ ENSO, AMOC, sea-ice

## Step 3 Fully coupled historical runs

BHIST: 1850-2014

**Historical warning**



No Tuning



# Dilemmas while tuning

- **Subjectivity of tuning targets**

Tuning involves choices and compromises  
Overall, tuning has limited effect on model skills

- **Tuning for pre-industrial ↔ Tuning for present day**

Pre-industrial: Radiative equilibrium  
Present day: Available observations

- **Tuning individual components ↔ Tuning coupled model**

Tuning individual components is fast  
But no guarantee that results transfer to coupled model

- **Tuning exercise is very educative**

We learn a lot about the model during the tuning phase.

# Where does “The Joy of Tuning” live?

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**UCAR | CESM®**

PUBLICATIONS ABOUT HELP SEARCH ...

ADMINISTRATION WORKING GROUPS MODELS EVENTS

CESM Working Groups / Atmosphere Model Working Group

## Atmosphere Model Working Group **AMWG**

The Atmosphere Model Working Group (AMWG) is a broad collection of researchers across university and federal institutions engaged in atmospheric science research using the Community Earth System Model (CESM). The overarching goal is to continually develop the Community Atmosphere Model (CAM) in order to periodically provide new versions for use by the wider CESM community.

We set short and long term development targets to guide community research. Ultimately, we aim to deliver the best representation of the atmosphere to be used in multiple applications for climate, climate variability and climate change research.

**ATMOSPHERE MODEL WORKING GROUP**

- Overview
- Featured Highlights
- Contact Info

**CAM DEVELOPMENT**

- Dycores & Resolution
- Parameterizations
- Simulations

**MODELS AND TOOLS**

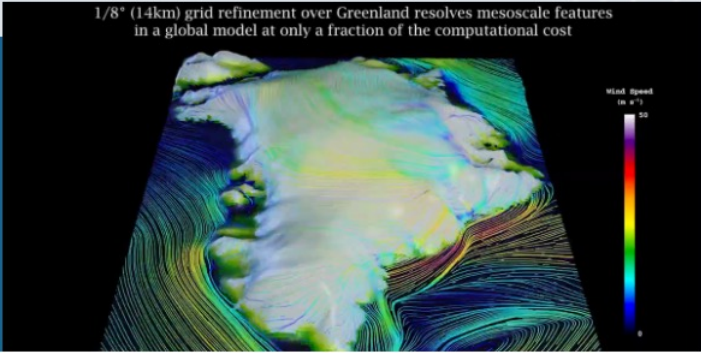
- Atmosphere Models
- Diagnostics Packages
- Developer's corner

## Featured Highlights

05/28/2021

### New visualization illustrating the benefits of variable-resolution grids for use in ice sheet research

1/8° (14km) grid refinement over Greenland resolves mesoscale features in a global model at only a fraction of the computational cost



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CESM Working Groups / Atmosphere Model Working Group / Developer's corner

## Developer's Corner

Information and tools for developers of the Community Atmosphere Model

## Community Atmosphere Model

The CAM source code (including both release and development code) is located in a [Github repository](#). See the [README](#) file in the CAM Github repository for instructions on downloading the correct version of CAM and view the [CAM documentation](#) which includes the user's guide.

## Contributing to CAM

If you have already developed a solution for a particular bug, or if you are working with an NCAR scientist or engineer to bring in new science or a new model feature, then first create a fork of the CAM repo, and add/test your code changes there. Instructions for how to do this properly can be found [here](#).

Once you have your own personal version with all of the working code modifications, then open a pull request to the main CAM repo. Instructions for how to do this properly (including how to push to the correct CAM branch) can be found [here](#).

Finally, CAM coding standards for Python and Fortran (the two main programming languages used in CAM) can be found [here](#).

## Tuning CAM

Model tuning is a necessary part of climate models development. We provide [here](#) a living document that describe the tuning process of CAM.

## Debugging CAM

Helpful techniques which are useful when the model is crashing can be found [here](#).

## Reporting Bugs & Issues

If you are having trouble with CAM, or if you believe there is a bug or problem with the model, then please make a post on the [CAM forum](#).

If the problem is indeed a real bug, then you will be notified by an NCAR scientist or engineer, and an official Github issue will be created and added to the work list.

## Git & Github

If you need any help with either Git or Github, or would like to know some possibly helpful tips, you can view them [here](#).

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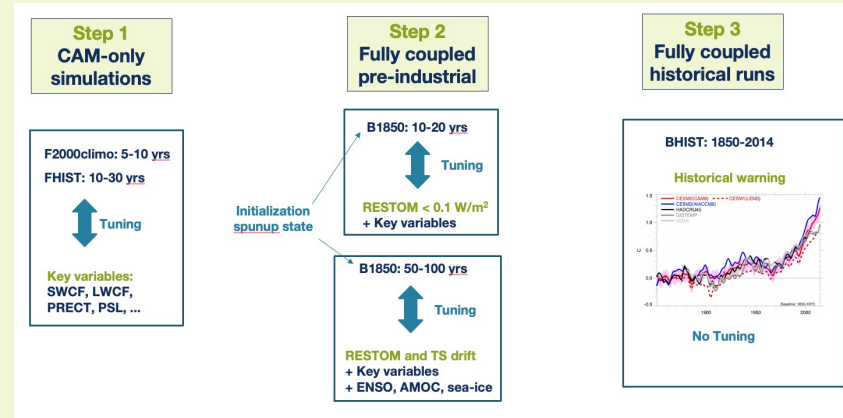
[https://www.cesm.ucar.edu/working\\_groups/Atmosphere/](https://www.cesm.ucar.edu/working_groups/Atmosphere/)

# What does “The Joy of Tuning” provide?

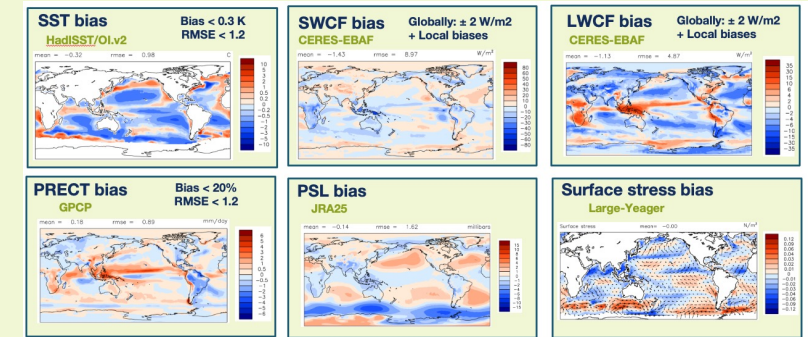
CAM tuning recipe  
in living document



## Overall process



## Key variables



Coming soon: Stratosphere tuning document

## Tuning parameters

Parameters	Description	Default value and range	Diags
micro_mg_dcs	Threshold diameter to convert cloud ice particles to snow	Default = 500.D-6 Range = [300.,600.] D-6	N/A
clubb_gamma_coef	Controls the skewness of vertical velocity (larger values produce larger skewness)	Default = 0.308 Range = [0.25, 0.35]	N/A
clubb_c_K10	Ratio of eddy diffusivity of wind to heat	Default = 0.5 Range = [0.2, 0.6]	N/A

Coming soon: Results from CAM-PPE

## Datasets

Quantities	Datasets	Guidance
SST	HadISST	We use HadISST/OI.v2 (Pre-Industrial) 1870-1900 A mean SST bias compared to pre-industrial HadISST of between [-0.3, 0.3] K A RMSE below 1.2 is acceptable, below 1.0 is ideal to be comparable with CESM release versions.
SWCF	CERES-EBAF Ed4.1 (2001-2020)	The present day global annual mean SWCF in the CERES-EBAF Ed4.1 dataset is -45.3 W/m <sup>2</sup> For B1850, we target a global SWCF between -44.5 and -47.5 W/m <sup>2</sup>
LWCF	CERES-EBAF Ed4.1 (2001-2020)	The present day global annual mean LWCF in the CERES-EBAF Ed4.1 dataset is 25.8 W/m <sup>2</sup> . The LWCF is typically underestimated in CAM. For B1850, we target a global annual LWCF > 24 W/m <sup>2</sup>

Coming soon: Some datasets are updated

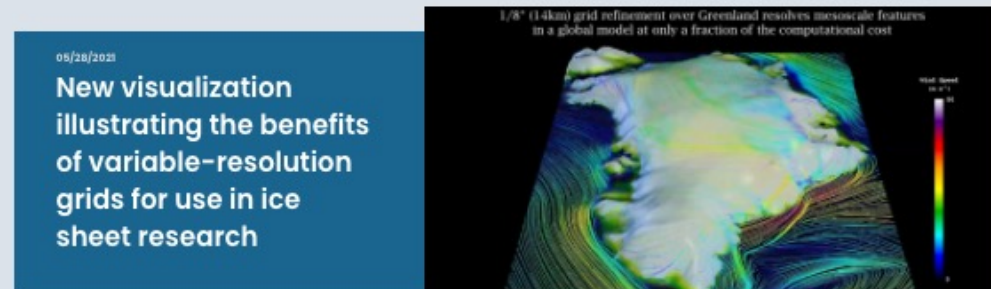
# And while you are there...

Take a tour of the AMWG website: [https://www.cesm.ucar.edu/working\\_groups/Atmosphere/](https://www.cesm.ucar.edu/working_groups/Atmosphere/)



The screenshot shows the top navigation bar with logos for NCAR, UCAR, and the Community Earth System Model (CESM). The main heading is "Atmosphere Model Working Group" with a sub-label "AMWG". Below this is an "Overview" section with a paragraph describing the group's mission. To the right is a dark sidebar menu with categories: "ATMOSPHERE MODEL WORKING GROUP", "CAM DEVELOPMENT", and "MODELS AND TOOLS".

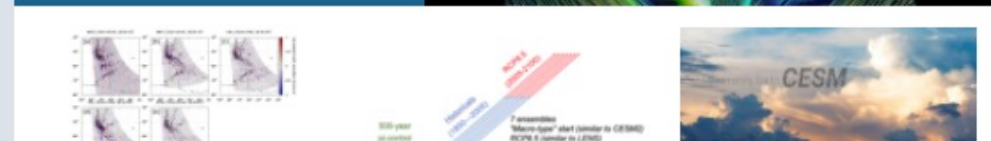
## Featured Highlights



**05/28/2022**  
**New visualization illustrating the benefits of variable-resolution grids for use in ice sheet research**

1/8° (14km) grid refinement over Greenland resolves mesoscale features in a global model at only a fraction of the computational cost

The image shows a 3D visualization of Greenland's ice sheet with a color-coded elevation scale on the right. The terrain is rendered with high detail, showing mountain ranges and valleys.

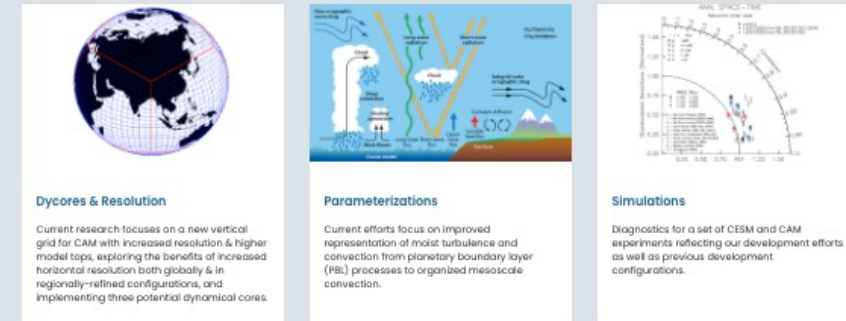


**70th Anniversary**  
**"Micro-Open" Start (partner to CESM)**  
2021 year of discovery

The image features a collage of scientific plots and a central image of a cloudy sky with the text "CESM" overlaid.

## CAM Development

Development focuses on research into new and existing physical parameterizations, dynamical cores and added functionality for CAM.

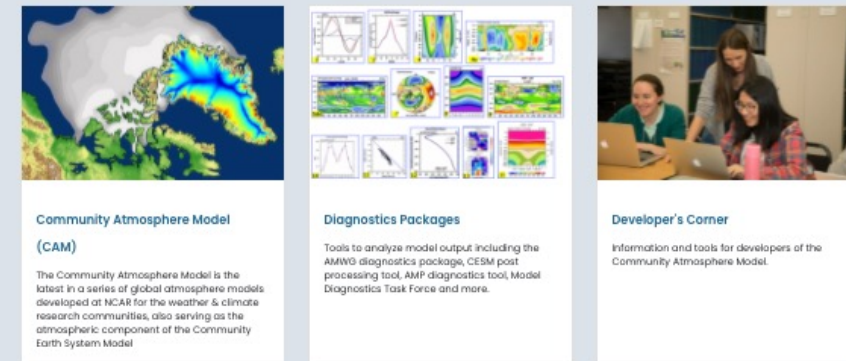


This section contains three sub-sections, each with a title, a representative image, and a brief description of current research efforts.

- Dycores & Resolution**: Image of a globe showing a grid. Description: Current research focuses on a new vertical grid for CAM with increased resolution & higher model tops, exploring the benefits of increased horizontal resolution both globally & in regionally-refined configurations, and implementing three potential dynamical cores.
- Parameterizations**: Image of a vertical cross-section of the atmosphere showing clouds and convection. Description: Current efforts focus on improved representation of moist turbulence and convection from planetary boundary layer (PBL) processes to organized mesoscale convection.
- Simulations**: Image of a plot showing model output. Description: Diagnostics for a set of CESM and CAM experiments reflecting our development efforts as well as previous development configurations.

## Featured Tools

Providing information about the Community Atmosphere Model as well as tools to analyze the model output.



This section contains three sub-sections, each with a title, a representative image, and a brief description of the tool or resource.

- Community Atmosphere Model (CAM)**: Image of a map of North America. Description: The Community Atmosphere Model is the latest in a series of global atmosphere models developed at NCAR for the weather & climate research communities, also serving as the atmospheric component of the Community Earth System Model.
- Diagnostics Packages**: Image of a grid of various diagnostic plots. Description: Tools to analyze model output including the AMWG diagnostics package, CESM post processing tool, AMP diagnostics tool, Model Diagnostics Task Force and more.
- Developer's Corner**: Image of three people working on laptops. Description: Information and tools for developers of the Community Atmosphere Model.

## Atmosphere Model Co-Chairs

Dr. Julia Bacmeister  
3/1/2017 - 2/28/2023  
NCAR-CGD, P.O. Box 3000, Boulder, CO 80307-3000  
303.497.1340



Thank You!

