AMWG Overview

Co-chairs: Julio Bacmeister, Peter Caldwell, Christiane Jablonowski

Monday June 15, 2020

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Outline

- Very brief CAM6/CESM2.1 recap

New developments

- CESM 2.2 Release
  - New Dycores
  - Regional Refinement
  - Horizontal Resolution
- Vertical Resolution
- Funded CAM development Activities
  - "CAM7", CPTs
- SIMA
- Summary and Discussion questions

acronyms; e.g. CPT, SIMA, defined where discussed

Recap of CAM6/CESM2.1 (CMIP6 versions)

- CAM6: CLUBB boundary layer-Shallow convection-macrophysics; MG2 microphysics –prognostic rain snow, improved mixed-phase cloud treatment; Beljaars form-drag and updated orographic gravity waves; Modified parameterized deep convective plumes
- Equilibrium climate sensitivity >5.3K (likely connected to aerosol-cloud interactions)
- Many aspects of variability improved over CAM5/CESM1 – Madden-Julian Oscillation, synoptic variability
- Improved cloud radiative forcing
- Some degradation of mean winds, sea-level pressure patterns

partial bibliography attached in "extra slides"

CESM2.2 Release
(expected late summer)

No longer trying to preserve answers from CESM2.1

- CLUBB changes
- Bugfixes

dynamical core developments

- New dycores
- Regional refinement
- High horizontal resolution

Peter Lauritzen, Adam Herrington, Patrick Callaghan, John Truesdale, Brian Eaton

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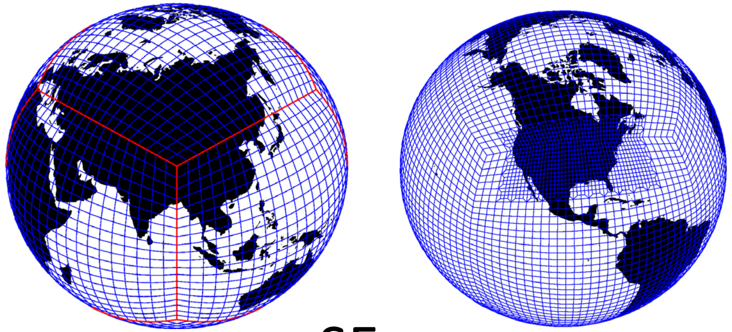
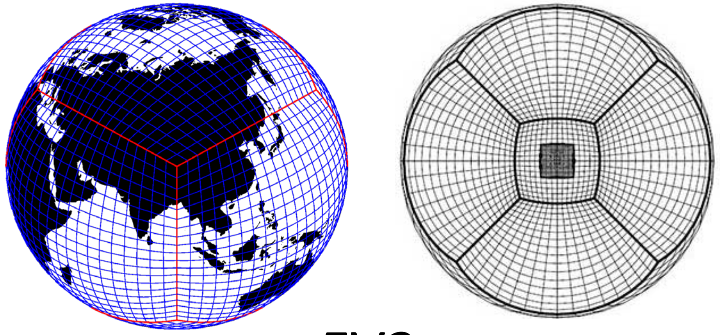
New/revamped dynamical cores released with CESM2.2

- Spectral-Element (**SE**) dynamical core with option for accelerated transport scheme (**CSLAM**)
  - highly scalable hydrostatic dynamical core with flexible mesh-refinement options
  - capability of running physics on a separate (coarser) grid for uniform grid applications
- **FV3**: GFDL's dynamical core used by NCEP for global weather forecasting
  - scalable finite-volume dynamical core (currently using hydrostatic version; non-hydrostatic available)



SE



FV3

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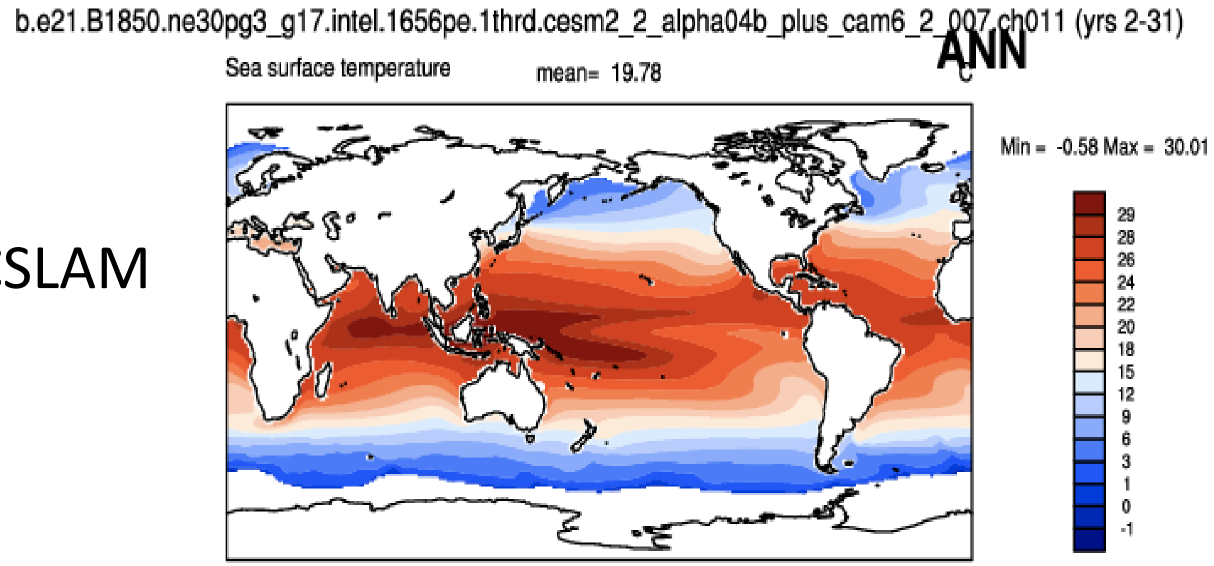
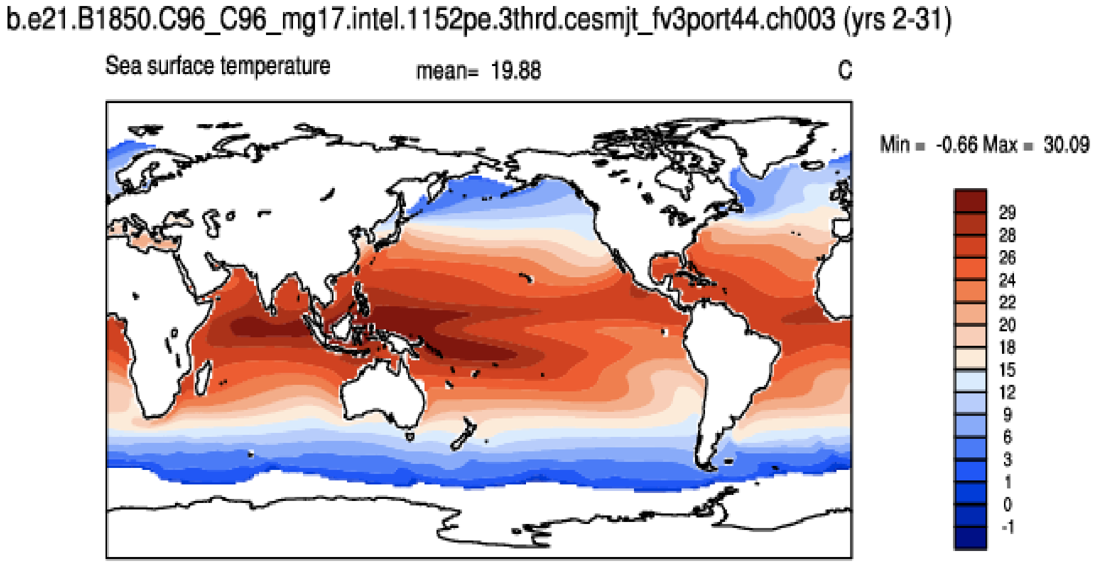
SSTs in fully coupled simulations with FV3 and SE-CSLAM

Dycores

SE-CSLAM



FV3



Coupled simulations with CESM2 , using FV3 and SE-CSLAM dycores have begun. Both yield reasonable SSTs with CAM6 physics.

Next steps for dycores in CESM

- Complete implementation of new non-hydrostatic dynamical core **MPAS** (Model for Prediction Across Scales). Currently testing with CESM simpler models.

- New vertical grid

- Further comparison of dynamical cores using CESM simpler models as well as in fully coupled simulations:

  - conservation properties: mass, total energy, angular momentum, preservation of shape (monotonicity), correlation preservation, ...
  - computational performance in standard CAM, WACCM and CAM-Chem configurations (scalability, cost, ...)
  - mean climate in AMIP-style and coupled configurations

For more details on idealized dycore comparison see AMWG talk by Lauritzen: http://www.cgd.ucar.edu/cms/pel/papers/L2018AMWG.pdf

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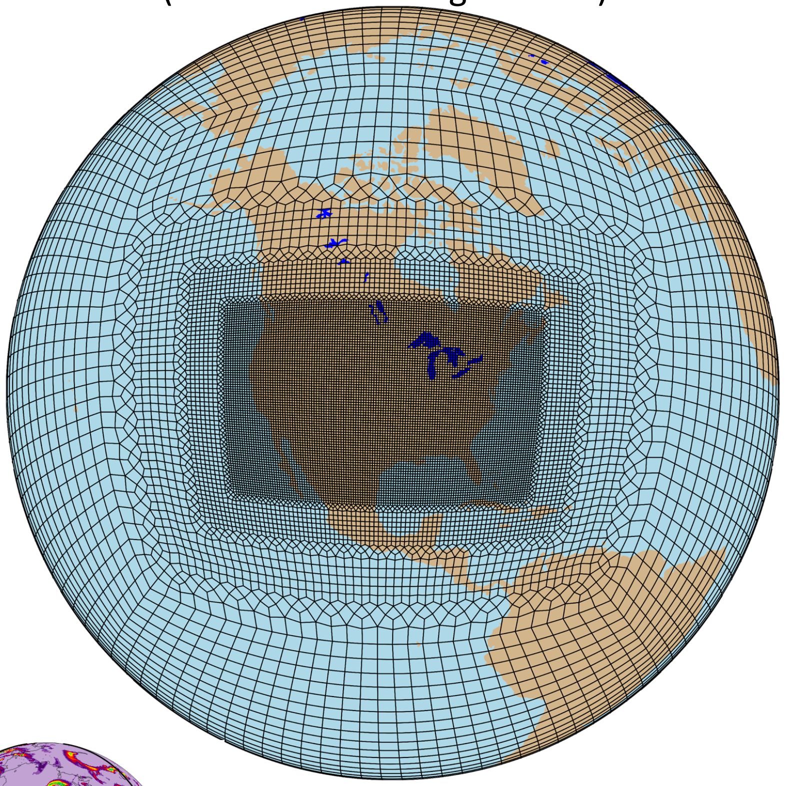
CESM2.2 release: Out-of-the-box support for 3 variable resolution spectral-element configurations

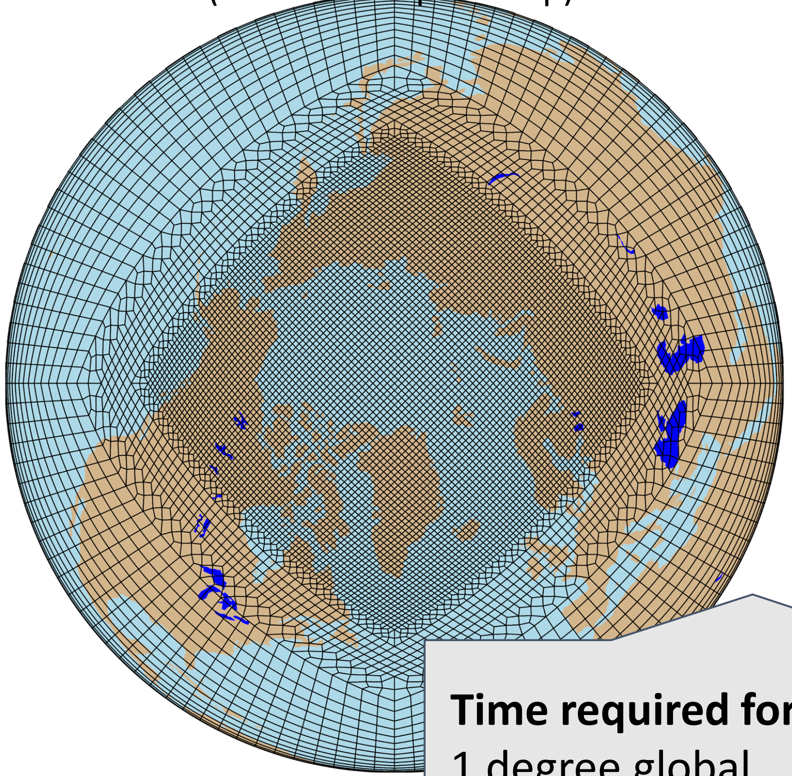
CONUS

(~12km over contiguous US)



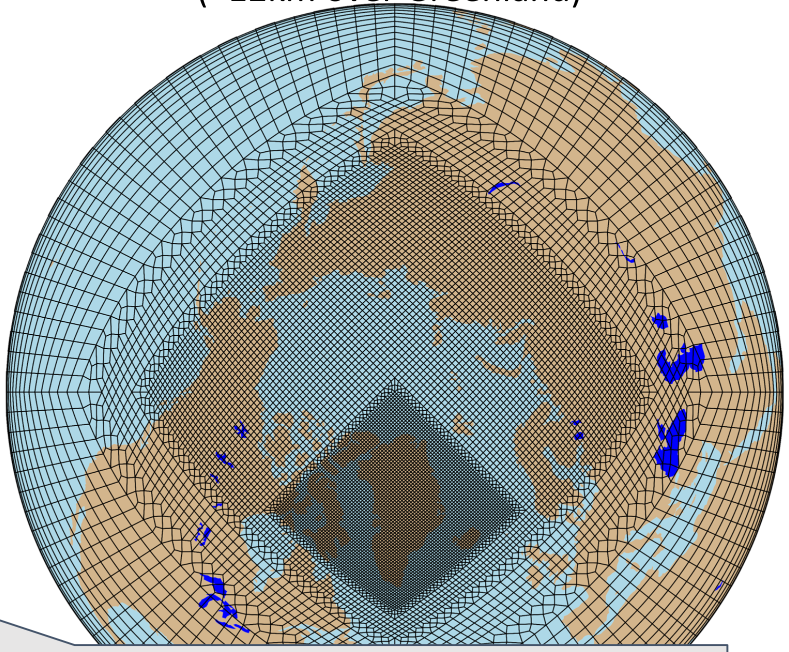
ARCTIC

(~25km over polar cap)



ARCTICGRIS

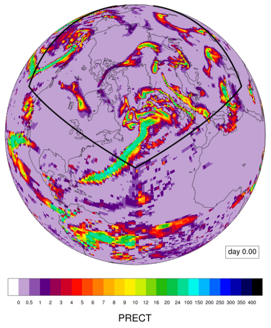
(~12km over Greenland)



Time required for 1 simulated year

1 degree global : 2K CPU hours
¼ degree global : 110K CPU hours
ARCTIC (middle) : 20K CPU hours
ARTICGRIS (right) : 45K CPU hours

Figures courtesy of Adam Herrington



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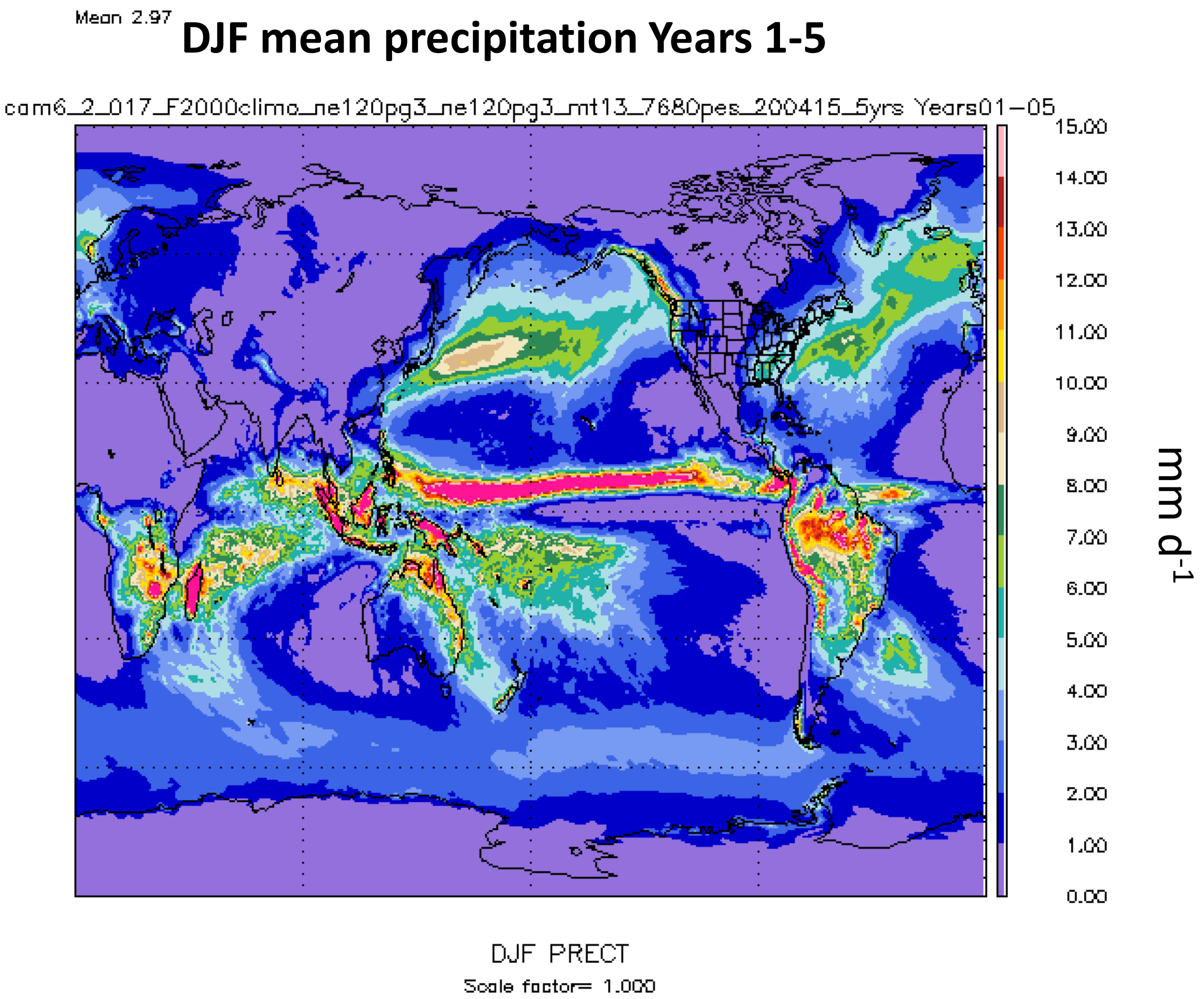
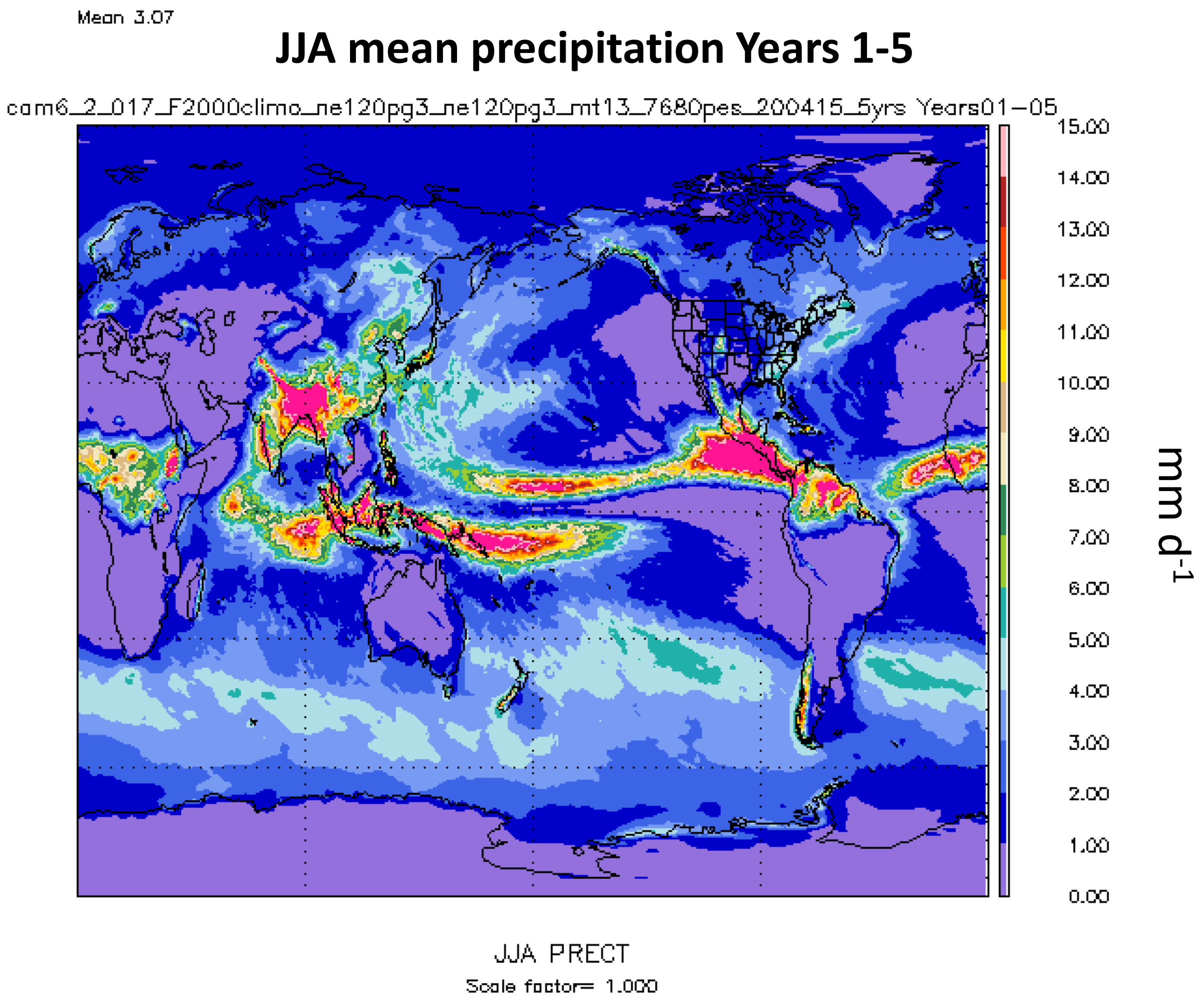
CESM2.2 release: ¼ CAM configuration





(no tuning of CAM6 physics for high resolution)

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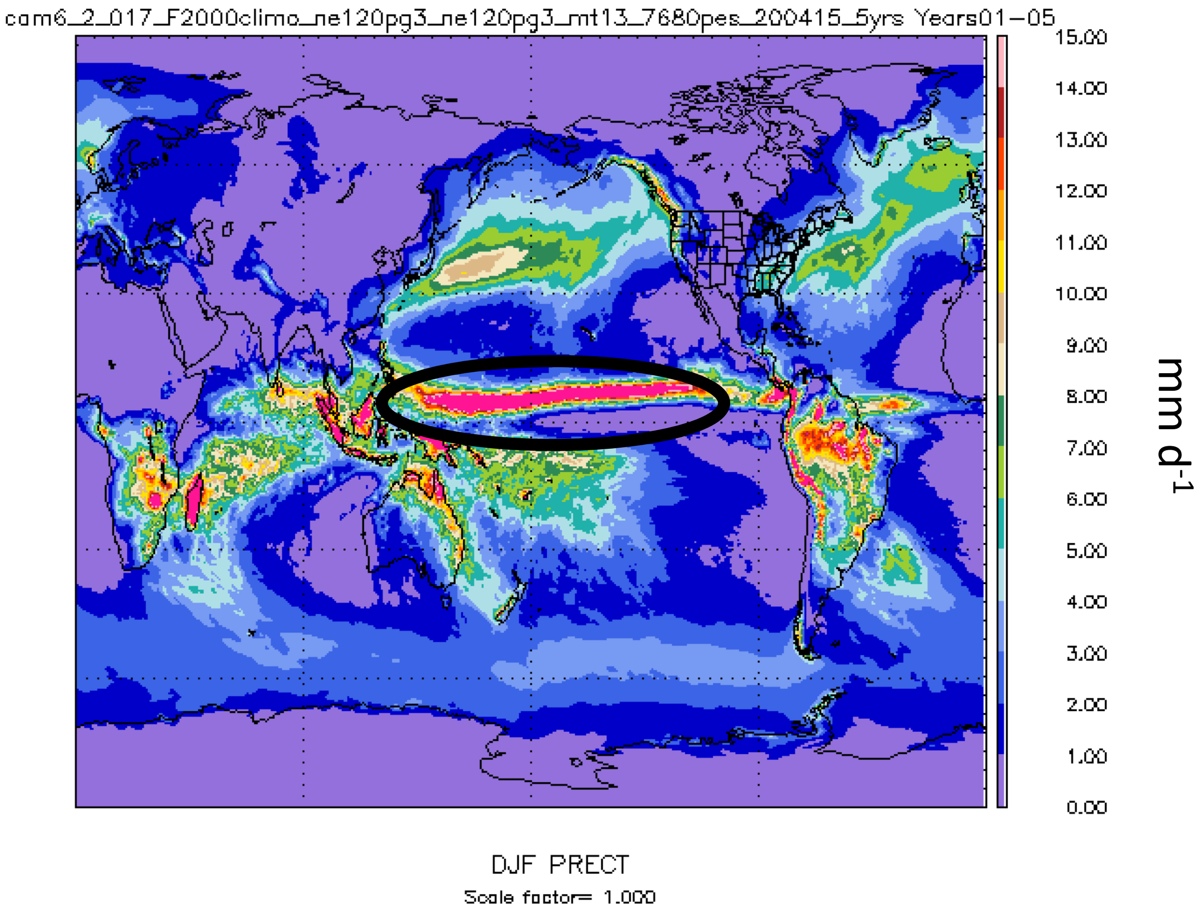
CESM2.2 release: ¼ CAM configuration

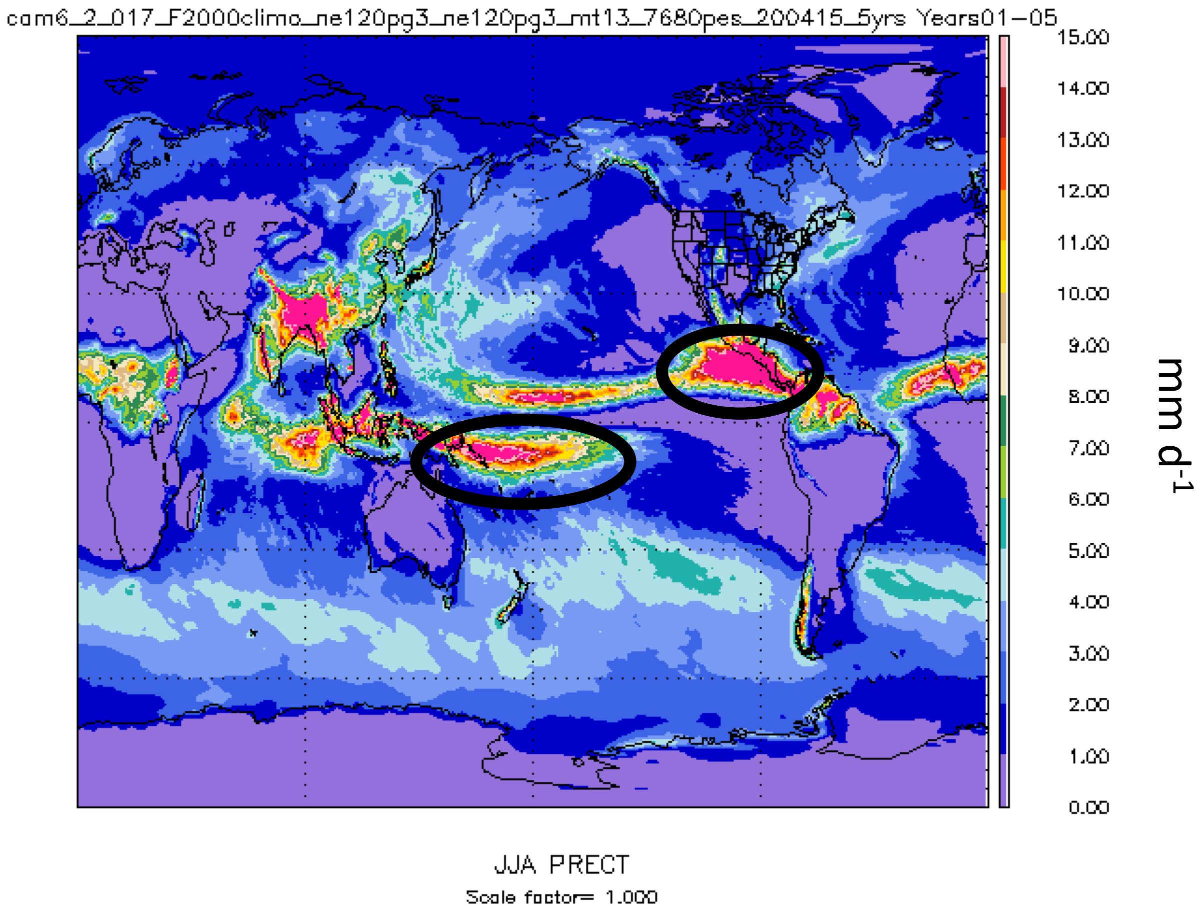
Mean 2.97

DJF mean precipitation Years 1-5



Mean 3.07

JJA mean precipitation Years 1-5



Intensified ITCZ precip (more biased) at high-res. Not shown: problematic wind profiles in TCs

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High horizontal resolution development

- IHESP* effort using CESM1: 25km atm/10km ocn (*finds transient climate response TCR~2.0K similar to 1^{o} model)*

- Is it a good investment of human resources to develop a 25km version of CESM2.1 (CMIP6 model)?

- Is it more sensible to wait for 25km version of CESM2.x with higher vertical resolution?

* A partnership between Qingdao National Laboratory for Marine Science and Technology (QNLM), Texas A&M University (TAMU), National Center for Atmospheric Research (NCAR)

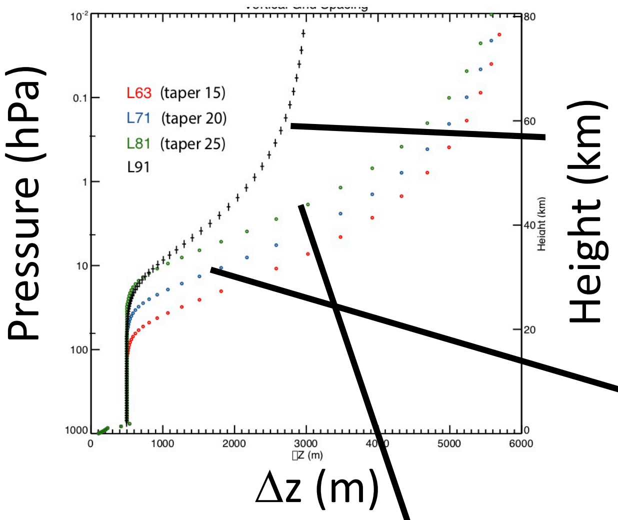
Vertical resolution development
(Isla Simpson leading)

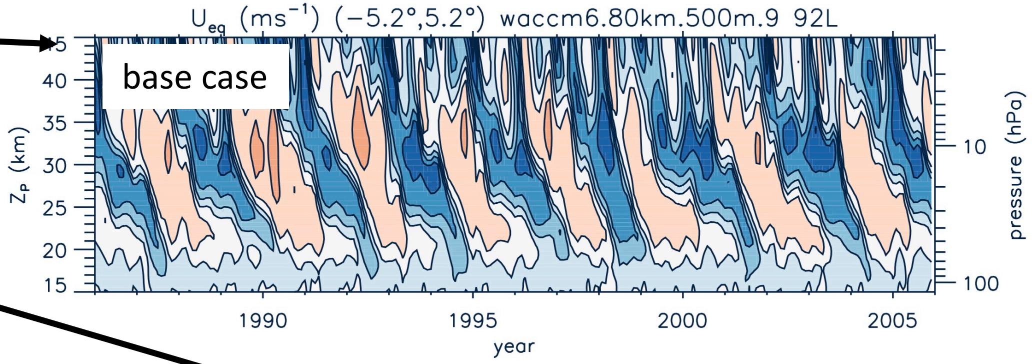
- Multiple phases:
  I. Rough cut of free tropo-stratospheric resolution for next "work horse" CMIP class model *(no more separate CAM vs WACCM CMIP activity)*
  II. Increase PBL vertical resolution
  III. Develop "half-top" version for efficient tropospheric physics development
- Phase I targeted QBO simulation and is largely complete (talk tomorrow by Isla): Δz~500m up to around z=25km, top near 80km
- Phases II and III beginning in earnest over the summer
- Aiming for total of 80-85 levels

U_{eq} (t, z) ±5° latitude average

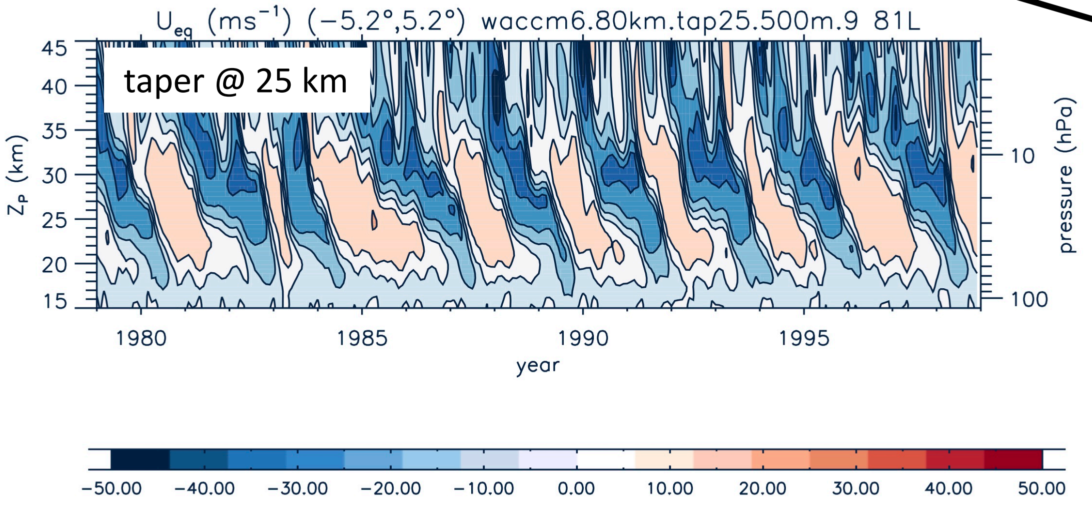
(thanks Rolando Garcia)

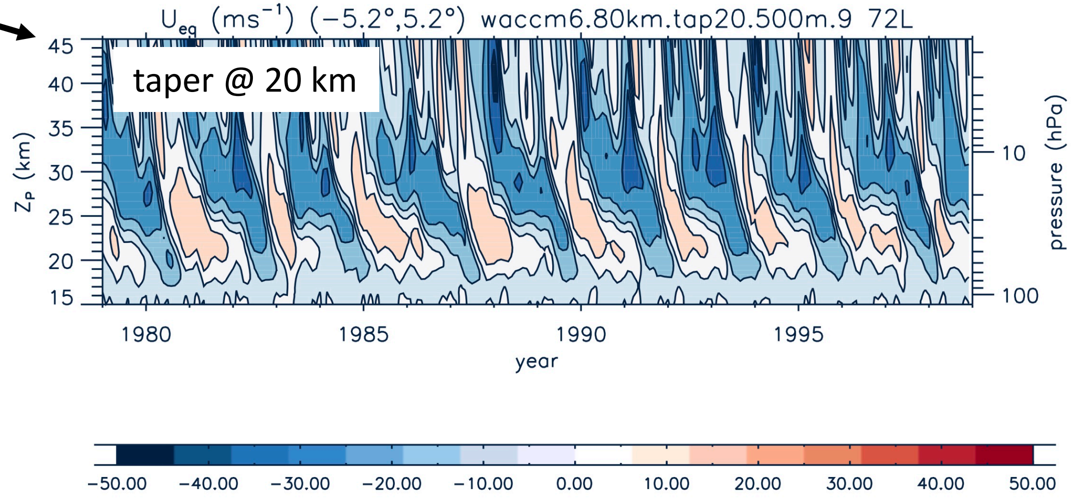
Candidate vertical grids





base case tapers from ~ 25 km, but to Δz = 3 km at the top





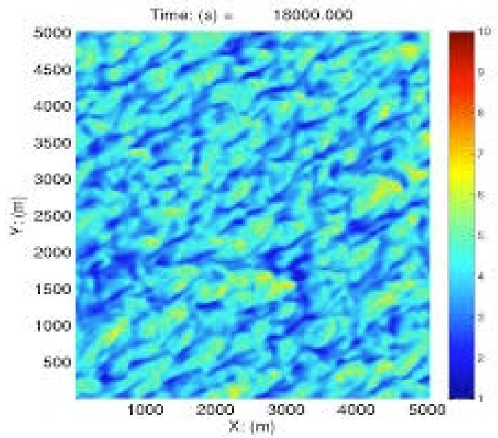
- decrease of QBO amplitude above about 10 hPa can be seen in the runs tapered to Δz = 6 km from 20 and 25 km
- the decrease is substantial in the run tapered from 20 km above ~ 20 hPa
- ***Much more in Isla Simpson's talk tomorrow (11:30am MDT)***

New Funded Efforts in CAM development

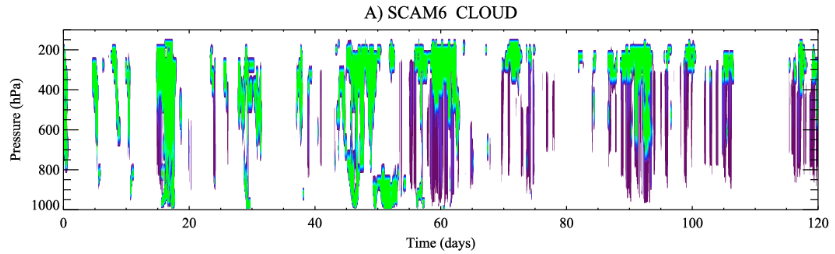
Supplemental NSF Funding for CESM Atmospheric Modeling

(Rich Neale)

- Atmospheric Modeling Priorities
  - Framework for understanding cloud-aerosol and climate sensitivities in CAM6
  - Multi-scale (LES➔GCM) approach for developing and validating new (and existing) physics
  - Consistent workflow to support a model hierarchy
  - Infrastructure for improving accessibility and participation
- Funded proposal, 6 positions for 3 years
  - 1 Lad. Track/ 2 Project Scientists/ 2 Software Engineers/ 1 Associate Sci.. *2 Proj. Sci, 1 S. Eng. already hired.*

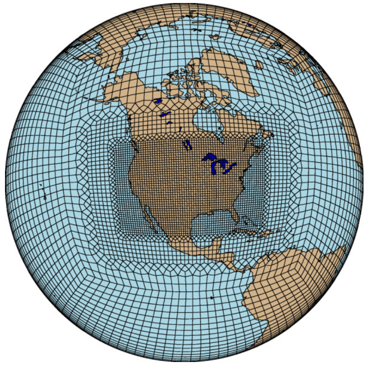


Large Eddy Simulation (LES)



Simpler Models

Accessibility



Regional Modeling Infrastructure

Contact Rich Neale (rneale@ucar.edu) if interested or look out for the announcements on cesm-jobs@cgd.ucar.edu

Climate process teams (CPTs, NOAA/NSF funded)

- Momentum transport in CLUBB (P.I. Colin Zarcycki, PSU): Targeted at alleviating momentum related biases in CAM –PSL, low-level jets, TC wind profiles, Southern ocean wind stress
  - NCAR/CGD Project Scientist (Chris Kruse) started (4/6/2020)

- Eddy-Diffusivity/Mass-Flux (EDMF) unified convection and turbulence. (P. I. Joao Teixeira, UCLA/JPL): Targeted at improved representation deep and shallow convection
  - NCAR/CGD Project Scientist (Adam Herrington) starting (7/6/2020)
  - *2 Talks by UCLA team tomorrow*

(Google 'ncar sima wiki')

Future of CAM and SIMA*: We need your input!

(Andrew Gettelman)

- CAM will be supported as part of SIMA
  - SIMA is just new framework/infrastructure
  - AMWG/CESM determines CAM configurations

Please provide your input:

- All CAM users should take the 'User Experience Survey'
  - https://forms.gle/Qug9gi2tUNZ4694e9 (link on wiki page)
  - Input on workflows, usability, needs: use to design future CAM infrastructure
- Also a 'SIMA Community Survey'
  - https://forms.gle/HwUXG3HpRReK7nZ39 (link on wiki page)
  - Community survey used to prioritize development of future applications

* System for Integrated Modeling of the Atmosphere

SIMA Community Workshop June 29-July 1

System for Integrated Modeling of the Atmosphere

SIMA = next generation infrastructure for 'CAM7'

- https://wiki.ucar.edu/display/SIMA. (Google 'ncar sima wiki')

Community workshop to define vision and goals of SIMA

- Also critical to get input for future CAM infrastructure

Virtual Workshop information/application:

https://cpaess.ucar.edu/meetings/sima-2020

Apply TODAY if you want to come!
Deadline has passed

Summary and Discussion Points

- Vertical resolution/model top will be changing
- CAM-SE-CSLAM and FV3 dycores in next release
- Regional refinement grids for SE in next release
- How do we approach high horizontal resolution development?
  - Skip CESM2.1 focus on next model?
- Research questions related to COVID driven emission changes
- Did not get to cover today:
  - Common Community Physics Package (CCPP) Framework (S. Goldhaber, NCAR)
  - Development of updated diagnostics package (C. Hannay, NCAR)

EXTRA SLIDES

Partial Bibliography

- CESM2 description and summary of results – Danabasoglu et al 2019 JAMES (https://doi.org/10.1029/2019MS001916)
- ECS in CESM2 - Gettelman et al 2019 GRL (https://doi.org/10.1029/2019GL083978)
- Variability in CAM6 - Simpson et al 2020 JGR (in press)
- ECS, TCR 4xCO2 runs - Bacmeister et al 2020 JAMES (in review)
- CAM description - Neale et al 2020 (in prep)

See also talks by Isla Simpson, Brian Medeiros and Rich Neale in AMWG March 2020 meeting (to be posted at http://www.cesm.ucar.edu/events/wg-meetings/2020/atmos.html

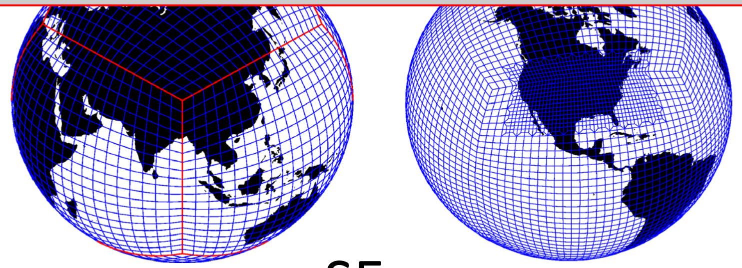
New/revamped dynamical cores released with CESM2.2

We have worked through many details of physics-dynamics coupling and verified that the new dynamical cores have been coupled to CAM physics correctly (mass conservation, thermodynamic consistency, etc.)

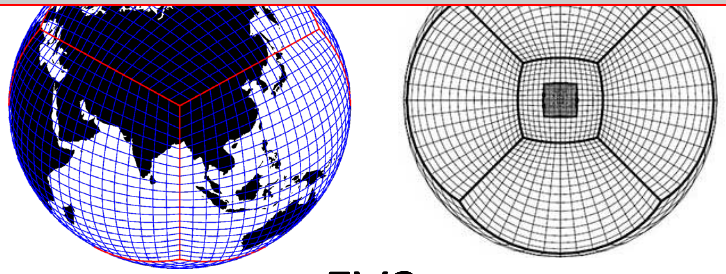
New dynamical cores are not imported as black boxes!

Implementing various diagnostics in the dynamical cores has increased our understanding of the details of the algorithms used in FV3 and SE-CSLAM.

We are still doing dynamical core research and, without exception, changes are necessary in the dynamical core for accuracy and stability for certain applications(in particular high top modeling)



SE



FV3

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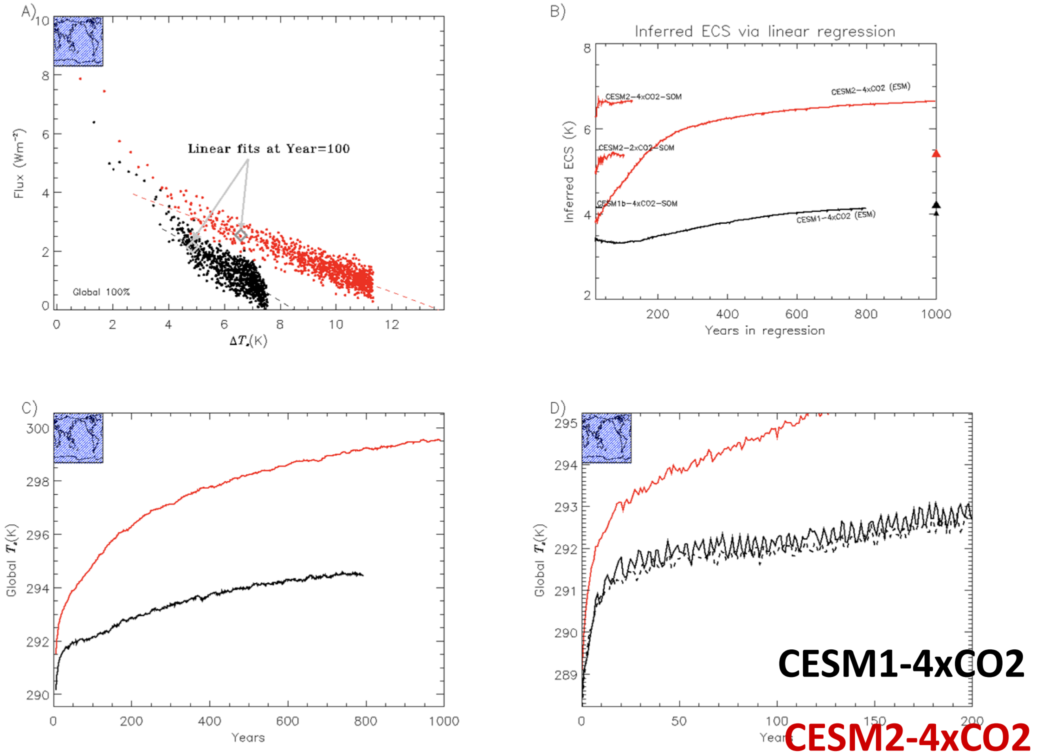
(CCPP) Common Community Physics Package Framework

(Steve Goldhaber)

- **What is it?**
  - State of the art code generation software using metadata parsing and analysis to support development and use of portable atmospheric physics.
  - Jointly developed by NCAR and NOAA.
  - Key part of SIMA atmospheric infrastructure
- **Why?**
  - Currently atmospheric physics schemes and suites are not interoperable because they contain host atmosphere specific code and data structures
  - The CCPP Framework auto-generates interfaces from metadata – removing this obstacle
- **NCAR Status:**
  - **New CAM/CCPP physics testbed** enables functional development and testing of new or existing physics schemes and suites.
  - **New process created for porting CAM physics to the CCPP**
    - Kessler physics suite has been ported.
    - Work started on porting the CAM6 physics suite.
  - MPAS in process of implementing a CCPP interface

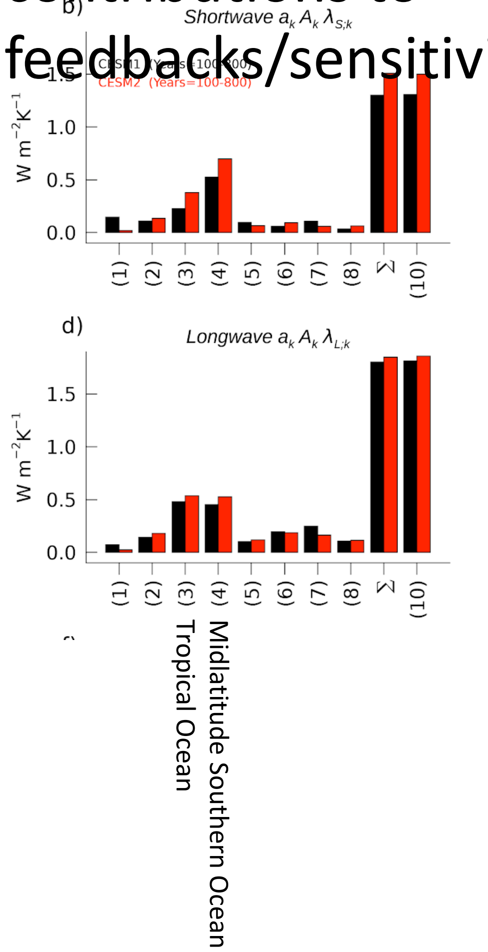
Equilibrium Climate Sensitivity (4xCO2 simulations)

Gregory plots, ECS, timeseries etc.

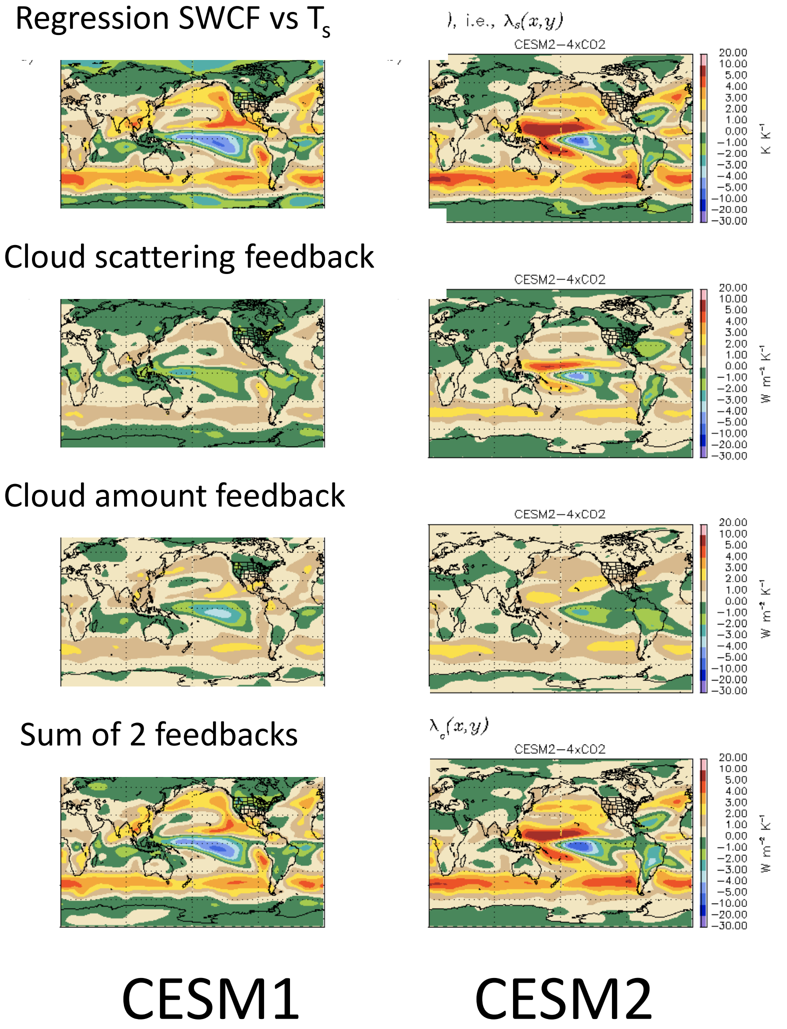


Bacmeister et al. (2020, in prep)
Gettelman et al. (2019) GRL

Regional contributions to feedbacks/sensitivity



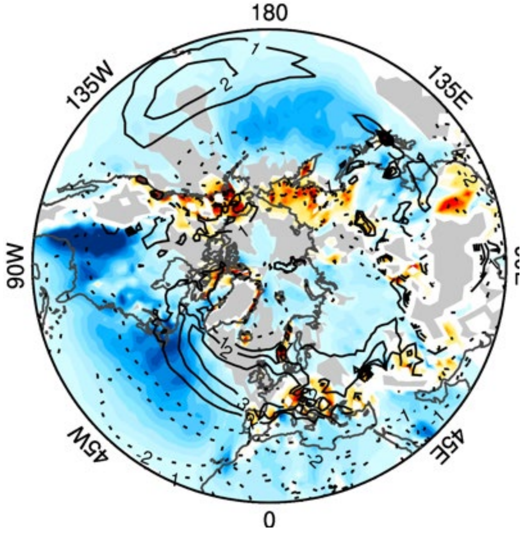
APRP analysis



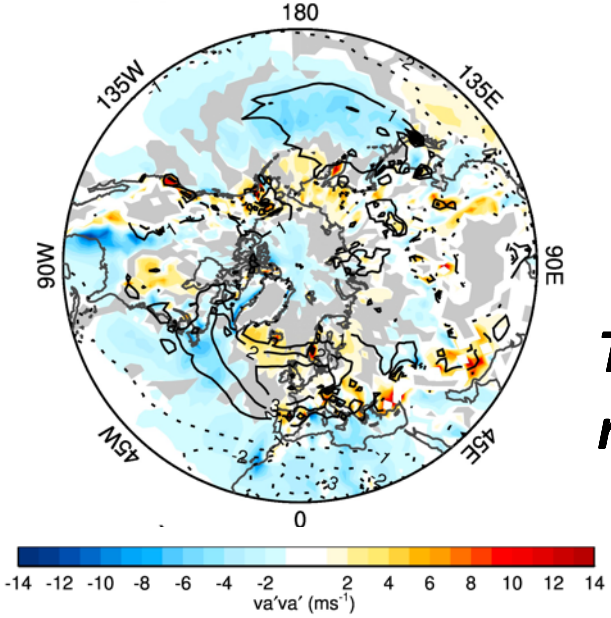
ECS has increased between CESM1 and CESM2. Shortwave feedbacks in the tropics and Southern Ocean are responsible. Increased cloud scattering feedbacks dominate

Improvements in stormtracks, NH winter, 850hPa 10-day high pass filtered eddy meridional wind variance

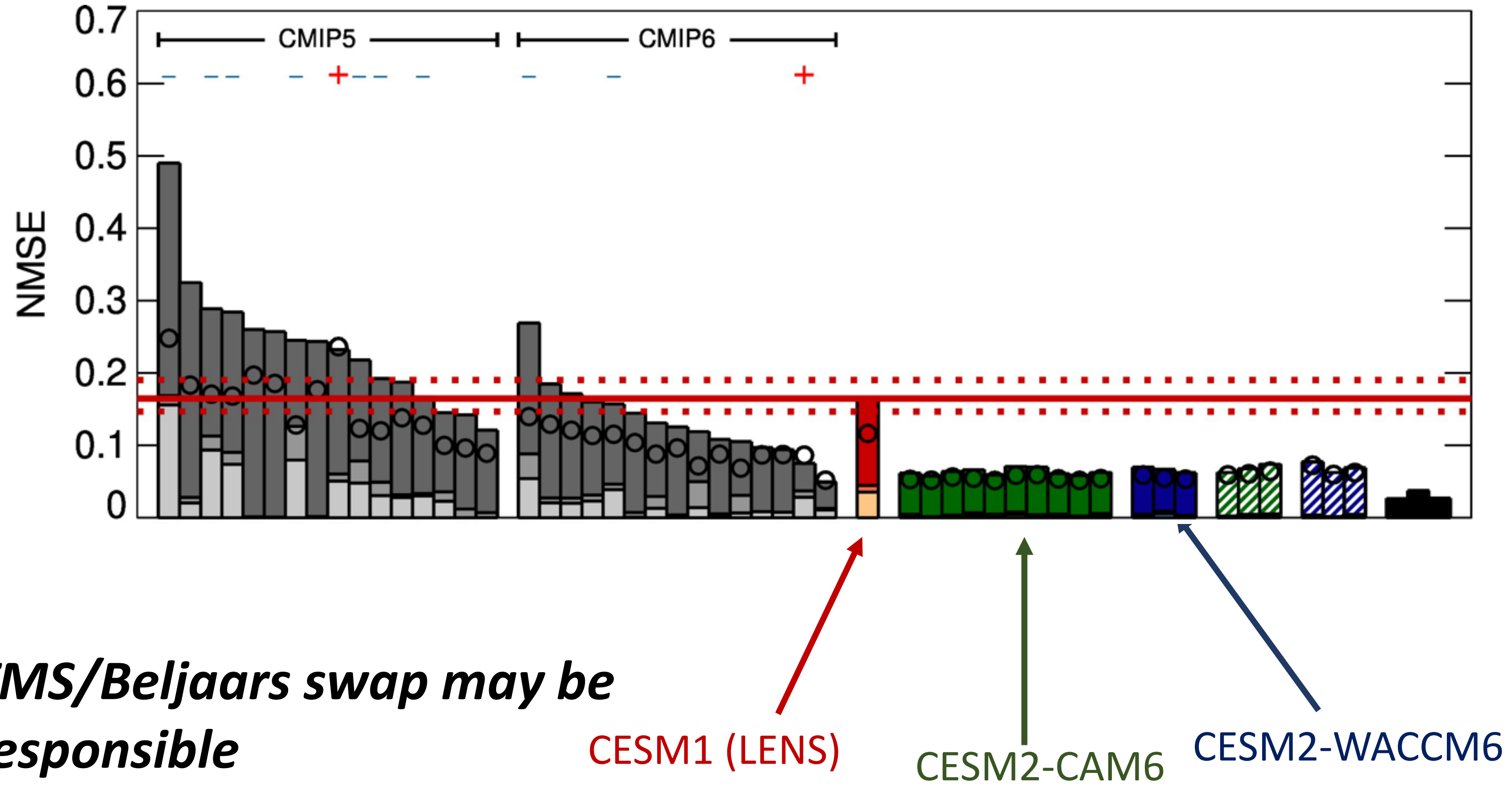
CESM1 – ERA5



CESM2 – ERA5



Normalized mean squared error relative to ERA5, 850hPa v'v', Equator-90N



TMS/Beljaars swap may be responsible

Isla Simpson (Simpson et al 2020 JGR, in review)

F-case runs

Extensive suite of runs

- revert to cam5 parameterizations

- revert to cam5 tuning parameters

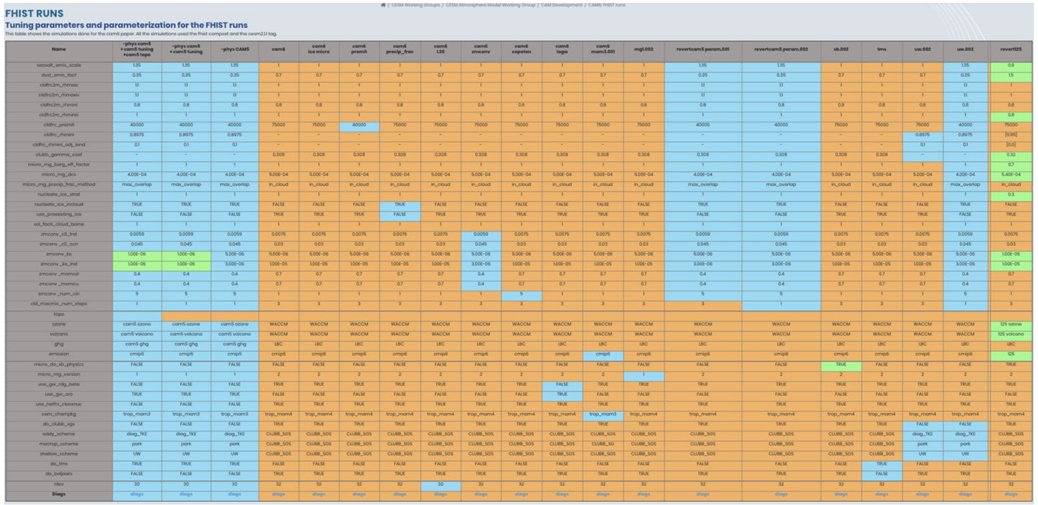
- impact of SSTs

All these runs are 1979-2005 with monthly and high frequency data.

Contact Cecile or Rich to get the data.

Impact of parameterizations and tuning parameters

cam5 *cam6* *other*



Impact of SSTs datasets

SST datasets

This table shows the simulations done with different SSTs. All the simulations used the fhist compset and the cesm2.1.1 tag.

Name	SST	Physics	Diagnostics
f.e20.FHIST.f09_f09.cesm2_1.001	Hadley monthly SST	CAM6	diags
f.e20.FHIST.f09_f09.cesm2_1_reynolds_daily_sst.006	Reynolds daily SST	CAM6	diags
f.e20.FHIST.f09_f09.cesm2_1_coupled-sst-amip.001	Coupled CAM6 SST Monthly historical	CAM6	diags
f.e20.FHIST.f09_f09.cesm2_1_coupled-sst-amip_daily.001	Coupled CAM6 SST Daily historical	CAM6	diags
f.e20.FHIST.f09_f09.cesm2_1_coupled-sst-climo.001	Coupled CAM6 SST Monthly Climatological	CAM6	diags
f.e20.FHIST.f09_f09.cam5-with-cam6_coupled-sst-amip.001	Coupled CAM6 SST Monthly historical	CAM5 (-phys cam5)	diags
f.e20.FHIST.f09_f09.cesm2_1_coupled_cam5_sst.001	Coupled CAM5 SST Monthly historical	CAM6	diags
f.e20.FHIST.f09_f09.cam5_with_coupled_cam5_sst.001	Coupled CAM5 SST Monthly historical	CAM5 (-phys cam5)	diags

HadSSTs, Reynolds,
CESM1 vs CESM2 SSTs
daily vs monthly SSTs