CAM5 and low-resolution CAM

Rich Neale

Climate and Global Dynamics

NCAR, Boulder

Thanks: Julio Bacmeister, Dani Coleman, Cecile Hannay, Peter Lauritzen + many others in AMWG

CESM Chemistry Climate Working Group Meeting
Wednesday, 16 March 2011
National Center for Atmospheric Research – Boulder,

NCAR NATIONAL CENTER FOR ATMOSPHERIC RESEARCH

NESL's Climate & Global Dynamics CGD

U.S. DEPARTMENT OF ENERGY

NSF

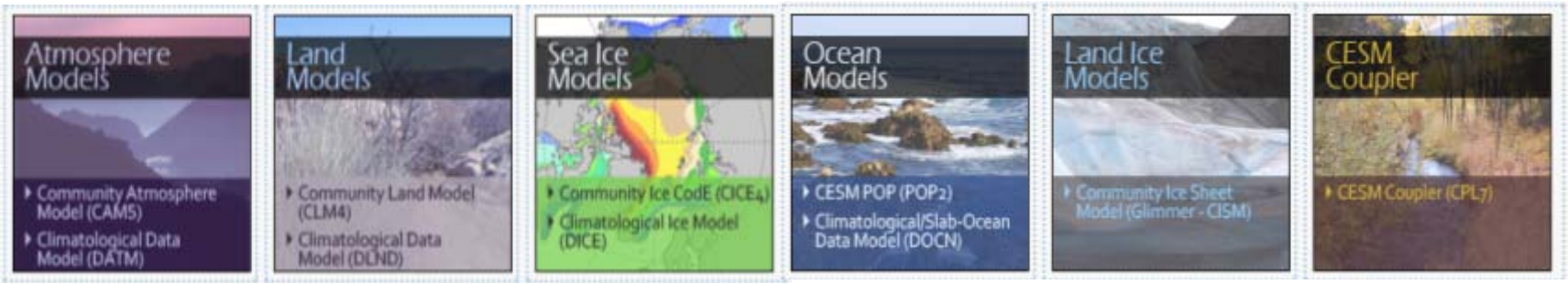
Community Earth System Model CESM

Community Earth System Model

Breckenridge, June 2010

- April 1, 2010: **CCSM4.0 release**
  - ✓ full documentation, including User's Guide, Model Reference Documents, and experimental data

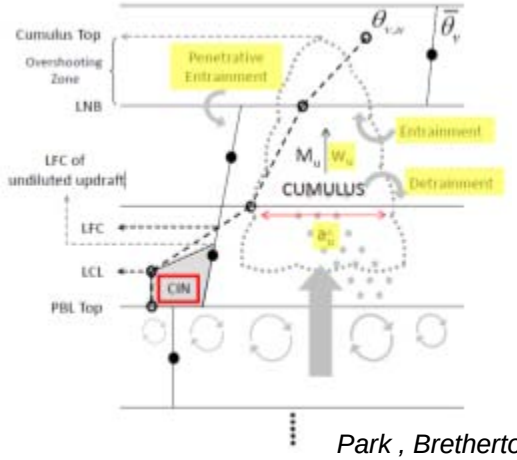
- June 25, 2010: **CESM1.0 release**
  - ✓ ocean ecosystem, interactive chemistry, WACCM, land ice, and CAM5.0 (indirect affects)



http://www.cesm.ucar.edu/models/

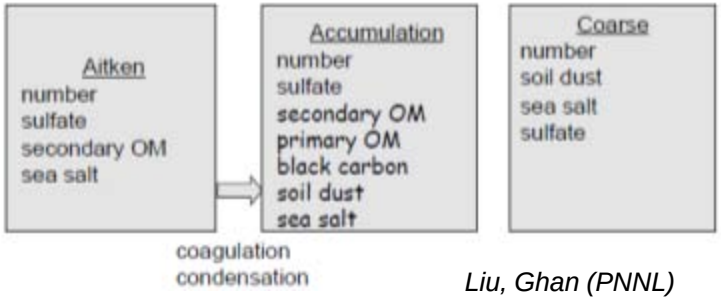
CAM5: Physics Changes
Cloud-aerosol interaction focus

UW PBL and shallow cumulus



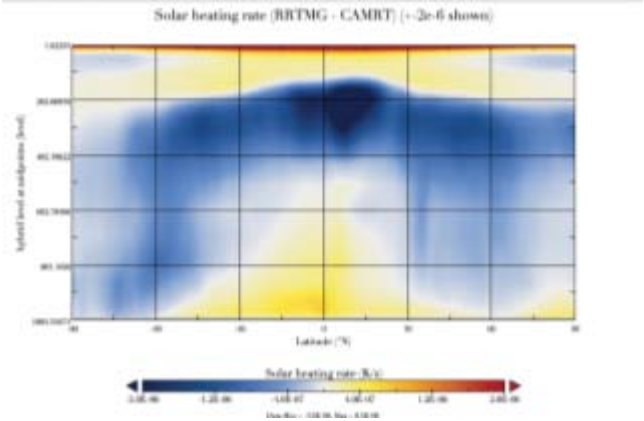
Park , Bretherton (UW)

3-mode Modal Aerosol Model (MAM)



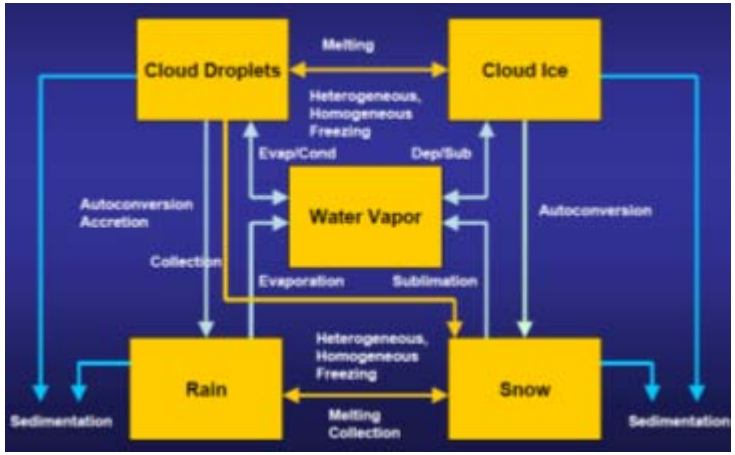
Liu, Ghan (PNNL)

Rapid Radiative Transfer Model (RRTM)



Iacono (AER), Conley (NCAR), Collins (UCB)

2-moment microphysics + ice cloud



Morrison, Gettleman (NCAR)

Current status of CAM5

(Since Breckenridge)

Physics

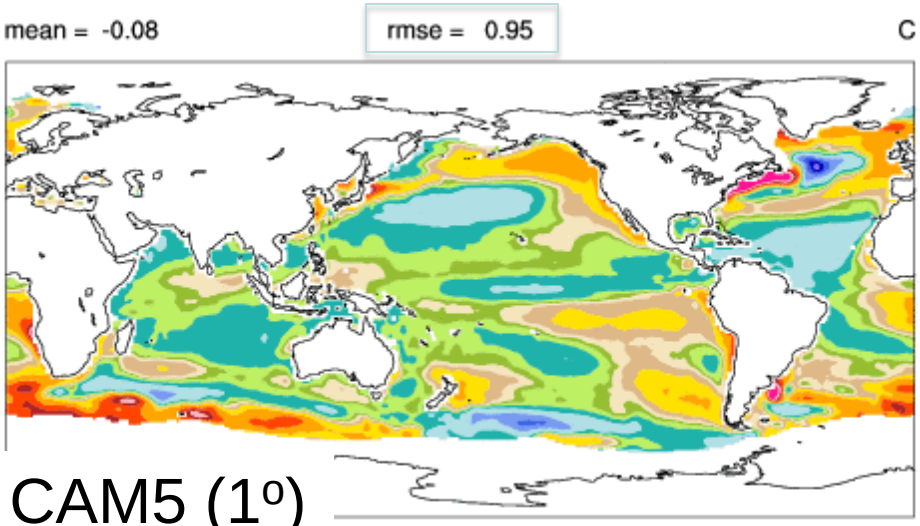
- Some answer changing bugs found since CAM5 release in June ‘10
- Snow (large-ice) effective radius for radiation too large
- Some retuning was required (SW cloud-forcing at high latitudes)
- CN (carbon-nitrogen cycle) turned on in the land (as in CCSM4) requires spin-up

Experiments

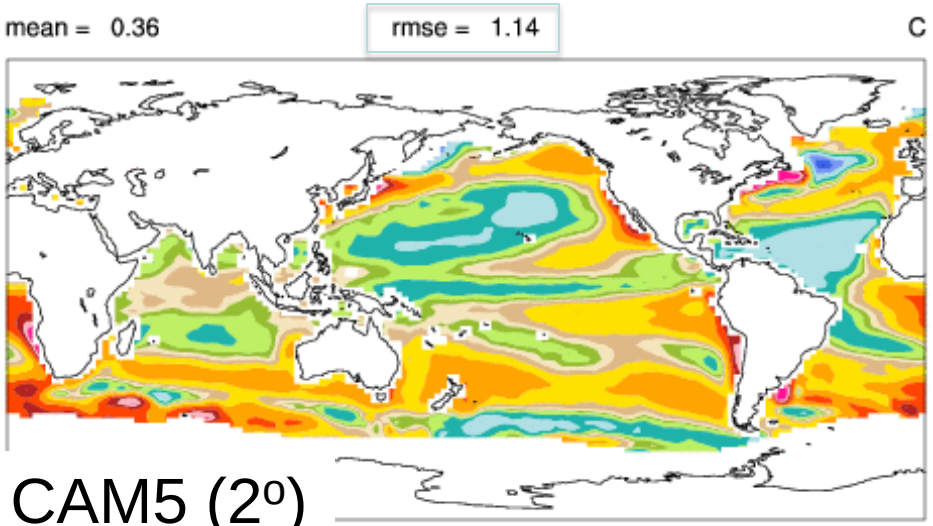
- Time devoted to 1^{o} coupled runs on DOE-ORNL resources
- Aim to perform a significant number of CMIP5 integrations (2^{o} also)
- Currently have +200-year control (1850)
- Running 20^{th} century + SOM experiments ($2XCO_{2,}$ +aerosols)
- This configuration will constitute CAM5.1

HOMME

- HOMME is now fully compatible with CAM5 physics (5-yr, 1^{o} expt.)
- Capability for on-the-fly re-gridding to a lat, lon grid



CAM5 (1º)

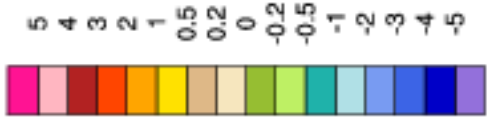


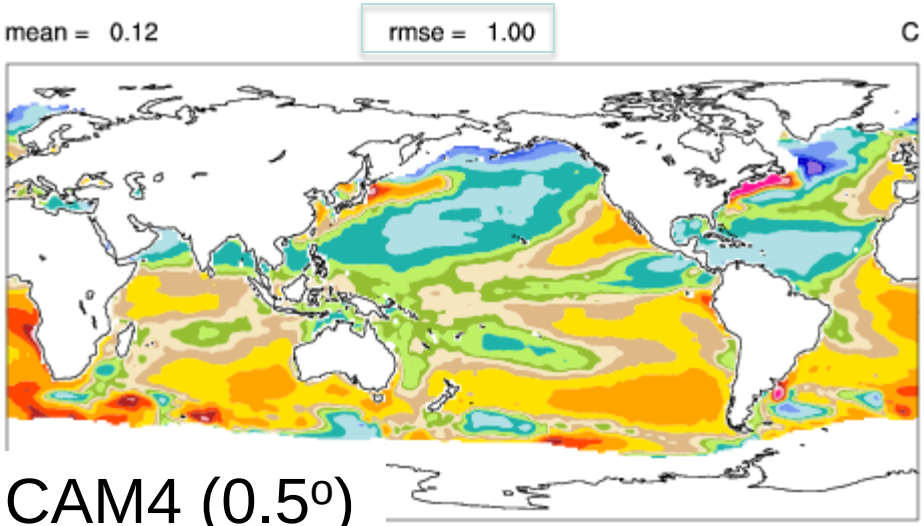
CAM5 (2º)

1850 Coupled Experiments (1º ocean)

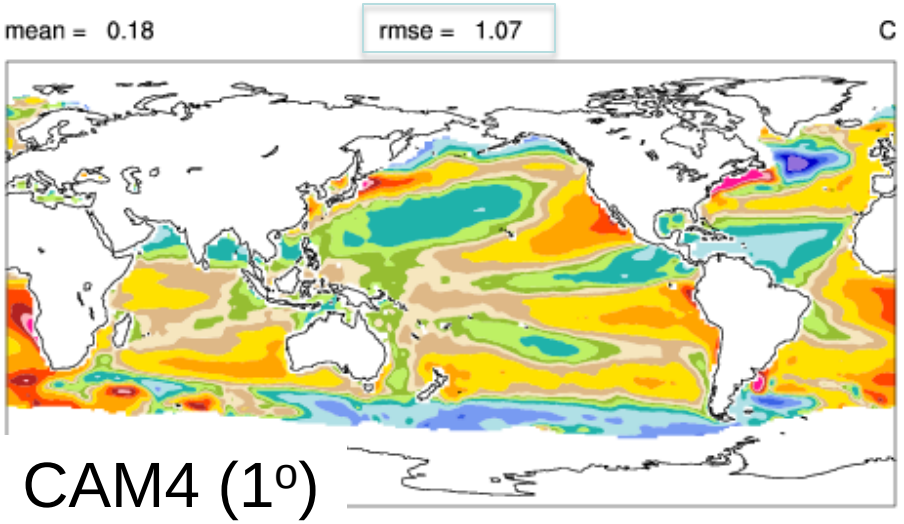
SST-bias (K)

20-year means



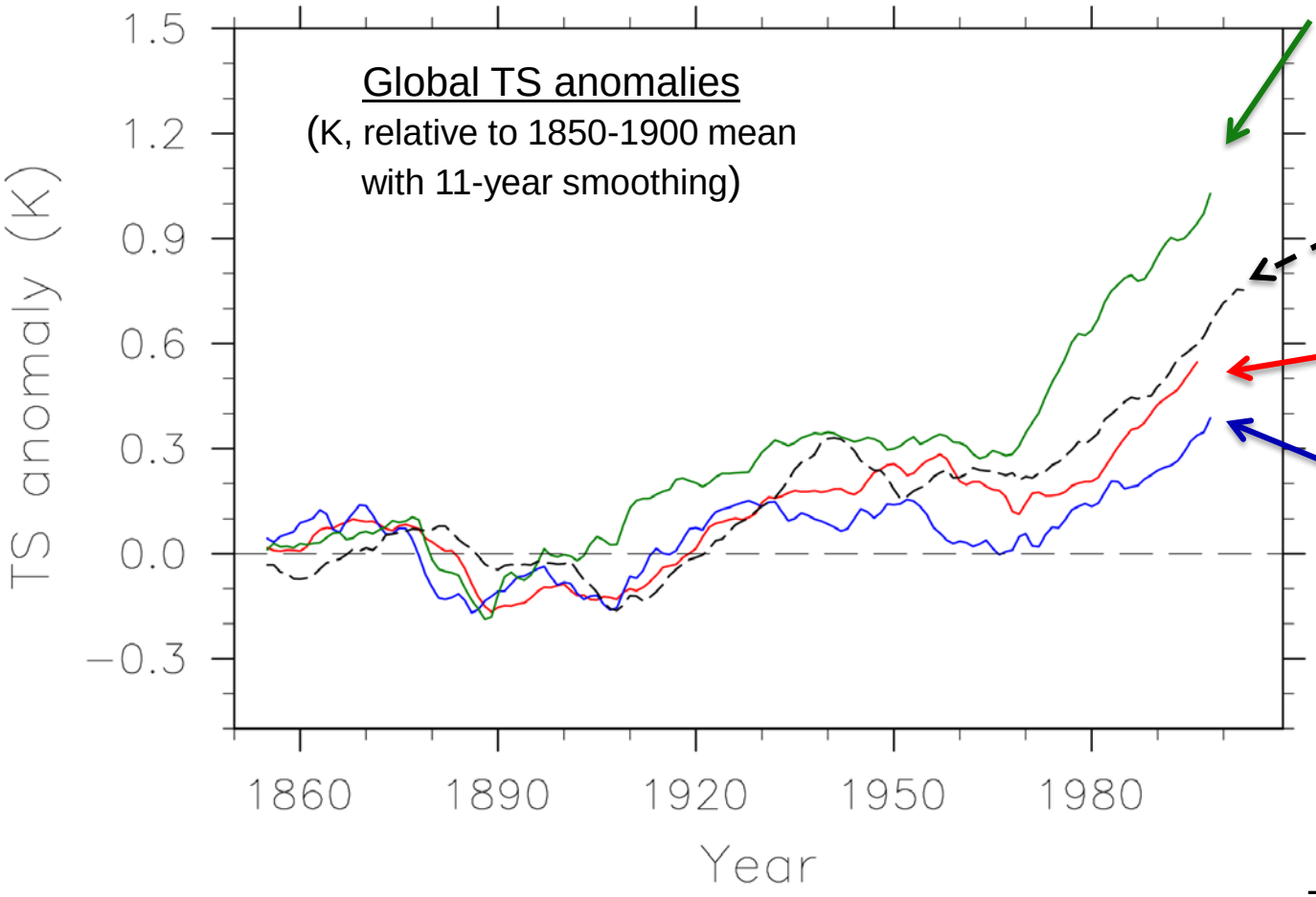


CAM4 (0.5º)



CAM4 (1º)

20th Century Coupled Experiments (1° ocean)



CAM4 (1°)

HadCRU (Obs.)

CAM5 (1°)

CAM5 (2°)

Thanks: Cecile Hannay

Status of CAM5

Aerosols

- CAM5 physics order 4-5X CAM4 -> Advecting 20+ aerosol species
- Prescribed MAM aerosol version of CAM5 imminent (2.5X CAM4)
- Version of CAM5 with prescribed aerosols from BAM (Andrew)

High Resolution

- CAM5 high resolution (0.25º) experiments; credible hurricanes
- Starting to examine how physics-dynamics interactions behave
- CAM4 time-slice experiments (DOE-ORNL): 20 years
- Prescribed AMIP SST: Present Day + future scenario (2080-2100, RCP8.5)
- HOMME activities continue for a scalable, high resolution climate runs

Low Resolution

- Committed to FV 2.5x3.33 version CAM4 and CAM5 (high-cost, long-time)
- AMIP runs for CAM4 and in near-future CAM5

Plans for the coming year

1. CAM5.1 (May)
   - ✓ Perform suite of CMIP5 experiments at 1^{o} with CN (RCPs, single forcings)
   - ✓ Finalize 2^{o} versions and identify resources for CMIP5 experiments
   - ✓ Release updated code to the community
2. CAM5.2 (July/August)
   - ✓ Provide version of CAM for future, other-component development
   - ✓ Prescribed aerosol capability with CN
   - ✓ Include HOMME/CAM-SE as default for 1^{o} and 2^{o} (FV equivalence)
   - ✓ HOMME transport (CSLAM, Peter Lauritzen) implemented
3. Understanding CAM5
   - ✓ Cloud-aerosol-radiation interactions
   - ✓ Robustness of climate sensitivity
   - ✓ Coupled simulation fidelity
4. Global High Resolution (0.25^{o})
   - ✓ Improve mean simulation degradations with resolution
   - ✓ Cloud and cloud forcing at higher latitudes (+6K TS over USA)
   - ✓ Dynamical core dependencies (hopefully few)
   - ✓ Dynamics-physics interactions (CAM4 and CAM5)

Ongoing

1. Systematic Errors
   - ✓ Tropical: Double ITCZ, intra-seasonal variability
   - ✓ USA summer climate: Rainfall, diurnal cycle, orogenic waves
   - ✓ Mid-latitude cloud forcing (ice cloud, long-wave CRF), N Pacific Psurf.
   - ✓ Do we need focused efforts?
2. Parameterization Development
   - ✓ Traditional (UNICON, convective microphysics, GWD, TMS)
   - ✓ Sub-grid descriptions, PDF-based, higher order (sub-columns, SP-CAM, CLUBB)
   - ✓ Common framework collaboration required now
   - ✓ Conceptually how should these methods work across resolution?
3. Regional Climate Problems
   - ✓ Regional grid refinement (where?, when?, how,? if?)
   - ✓ Scale-aware parameterization

A Compromise Low Resolution Version of FV-CAM

Peter Lauritzen, Rich Neale, Dani Coleman

- *Compromise low-resolution version of CAM4 and CAM5*
- *Applications that require good conservative transport properties*
- *Applications that require complex (and more) physics*
- *Applications that require long-integrations*

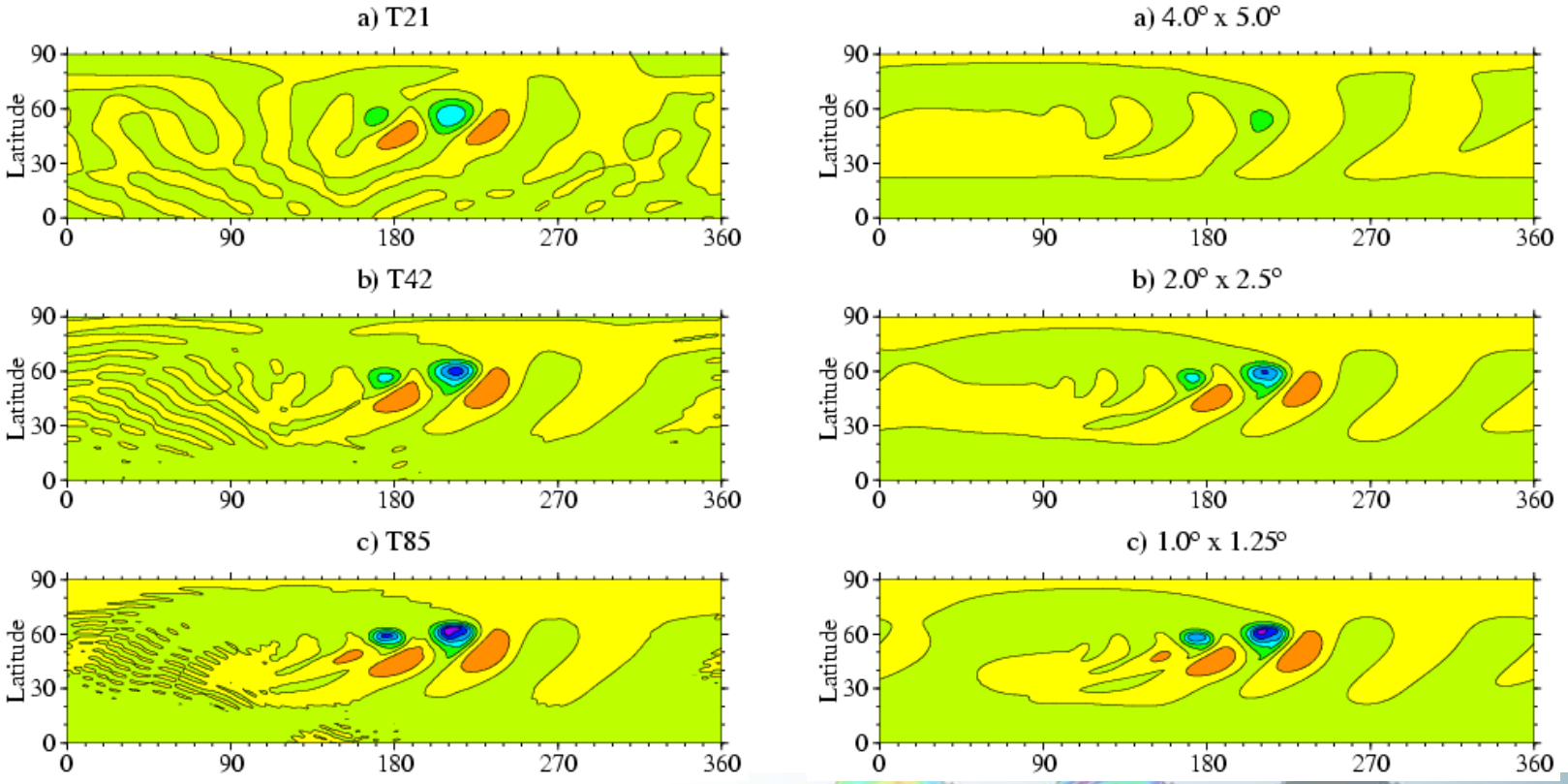
- *WACCM, CAM-chem, paleo, BGC (CAM4 and CAM5)*

In idealized tests (adiabatic baroclinic wave and aquaplanet with physics)

-EUL-T85 is equivalent to FV-1.0x1.25
-EUL-T42 is equivalent to FV-2.0x2.50
-EUL-T21 is NOT equivalent to FV-4.0x5.0

Williamson (2008)

Day 9 baroclinic wave test case

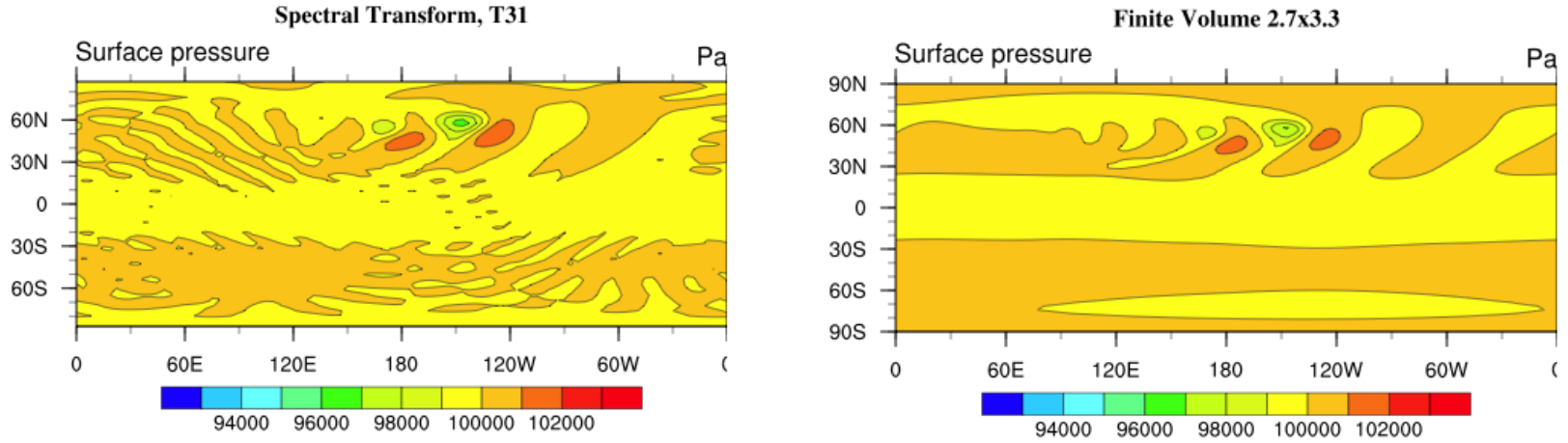


Jablonowski and Williamson, *Q. J. R. Meteorol. Soc.* (2006)

NCAR

EUL-T31 dynamical core is currently used for low resolution CCSM applications

Is there a FV resolution that is equivalent to EUL-T31?

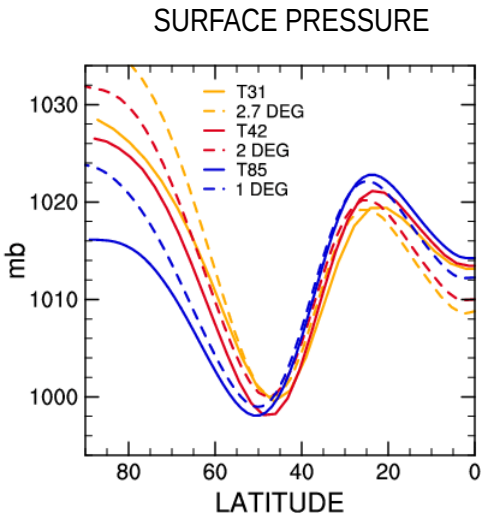


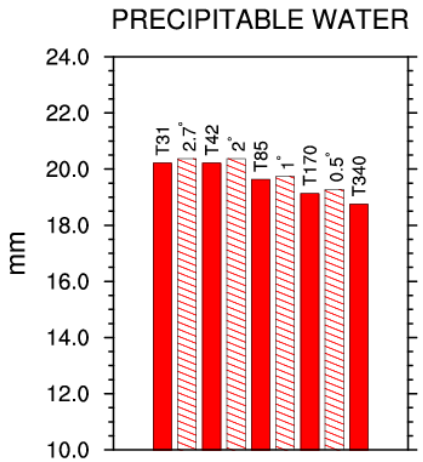
Day 9 baroclinic wave test case

Aqua-planet simulations (Neale & Hoskins, 2000)

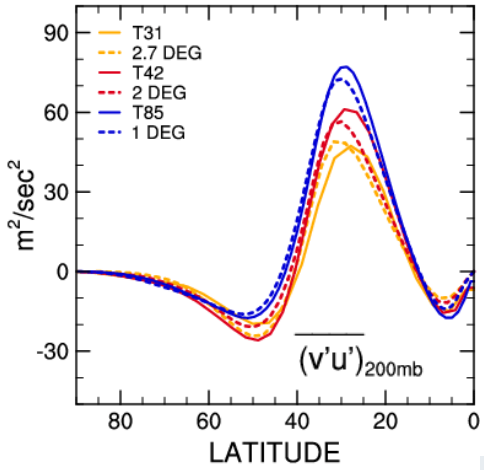
Time average, zonal average

Time average, global average





Zonal average meridional eddy statistics



Meridional eddy momentum flux

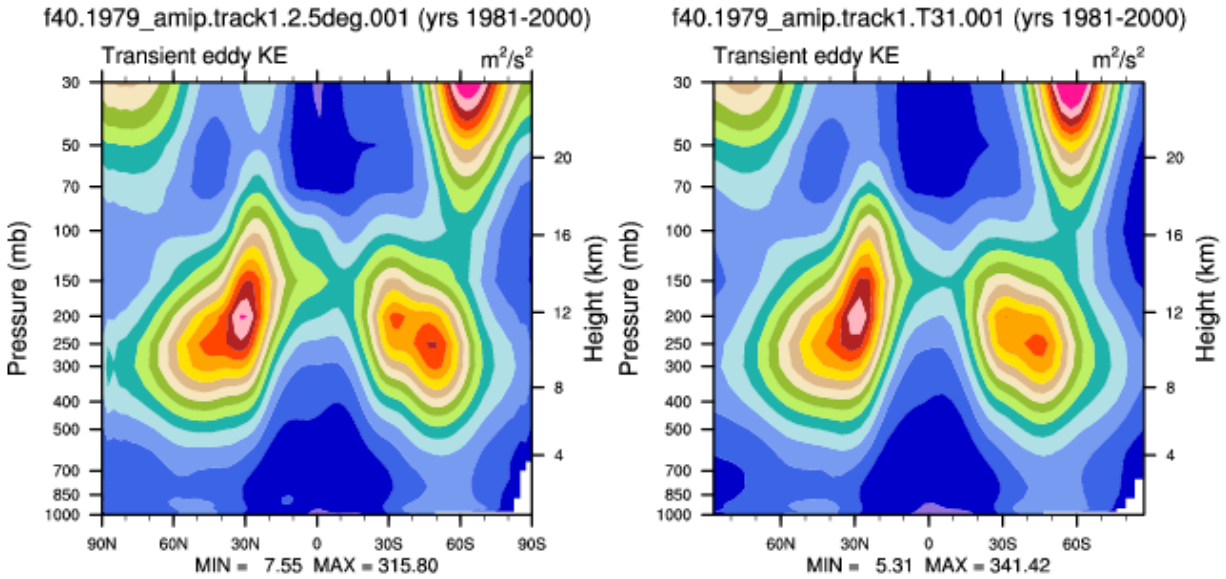
Variation with Resolution

20 year CAM4-AMIP (1981-2000) L26

NAME	CAM4 res.	YRS/DAY	#grid points	RMSE	Bias
1^{o}	FV 0.9x1.25	3	55296	0.937	0.905
2^{o}	FV 1.9x2.5	12	13824	1.023	1.175
2.5^{o}	FV 2.5x3.33	25	7776	1.028	1.231
T31	T31 (3.75^{o})	47	4608	1.051	0.938

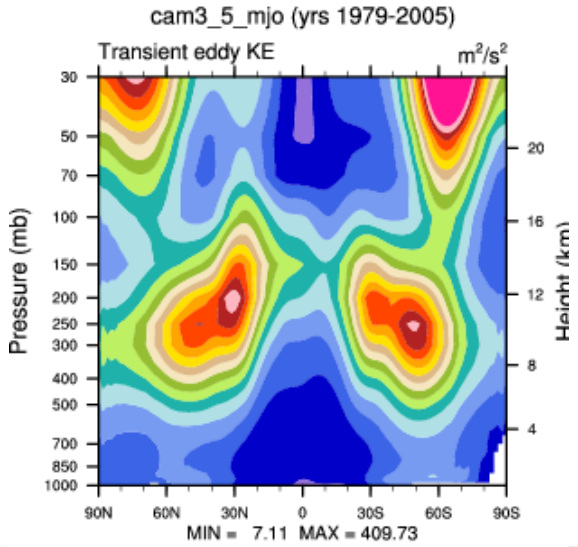
Eddy Kinetic Energy Errors (ERA40)

T31



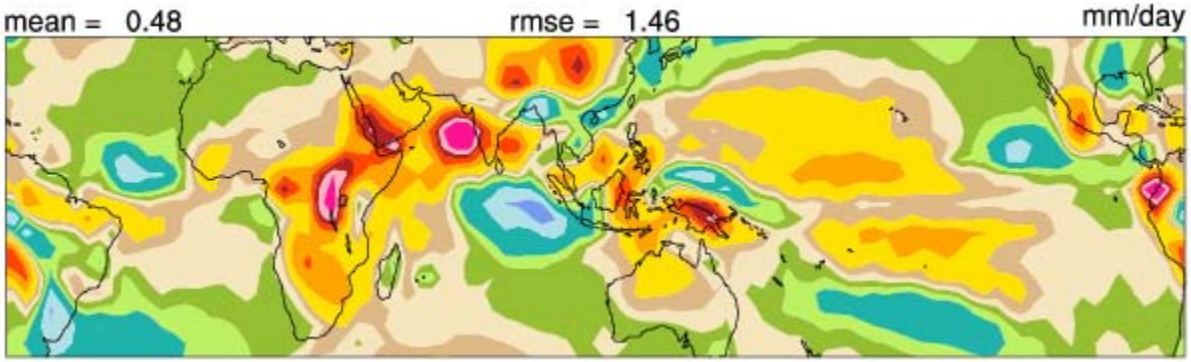
2.5º

2º

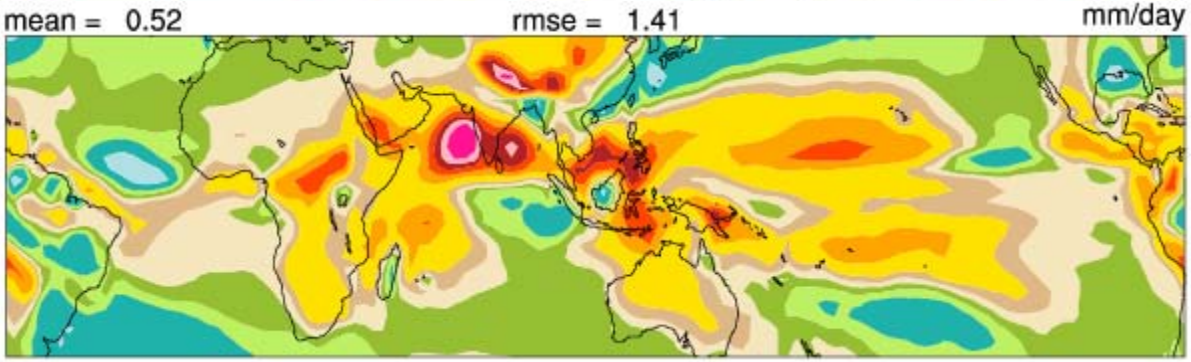


Annual Precipitation Errors (GPCP)

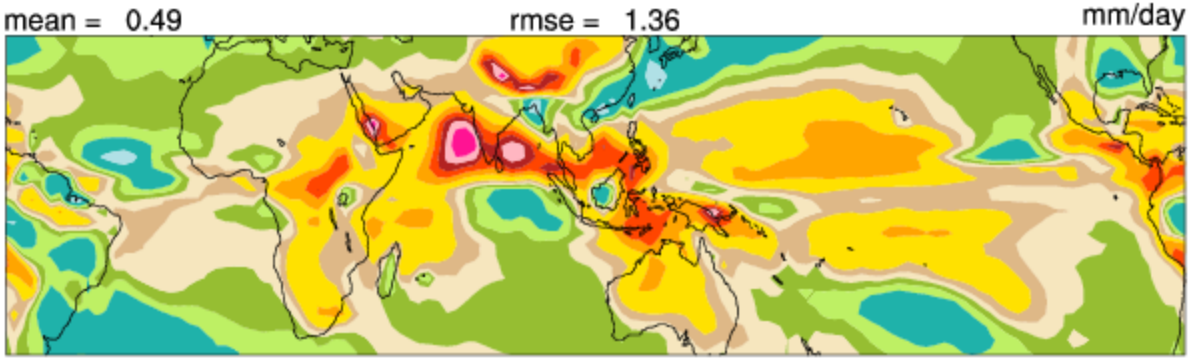
T31

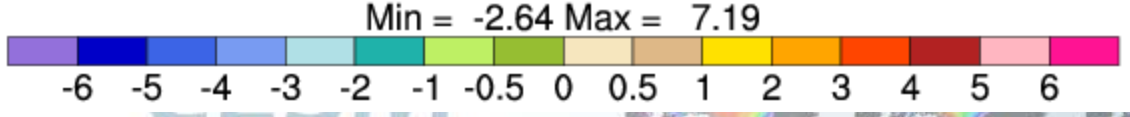


2º



2.5º

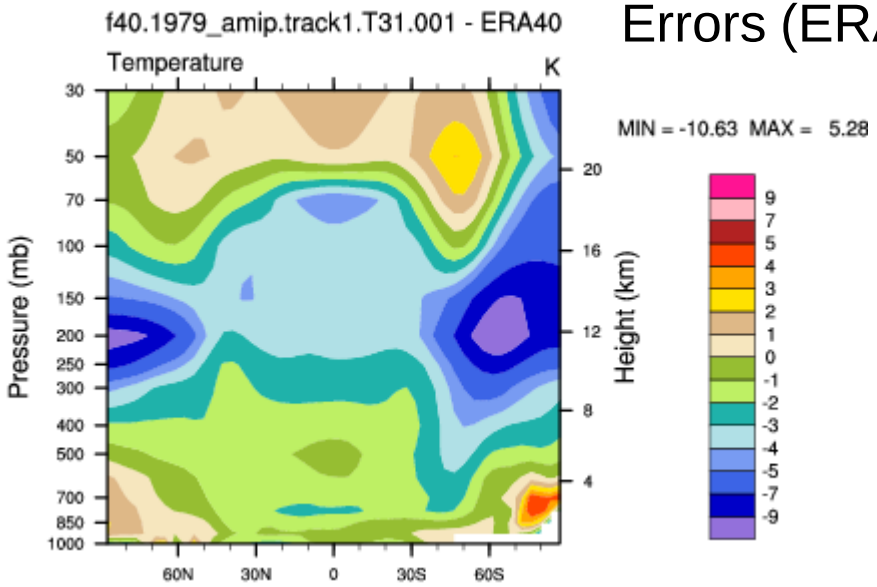




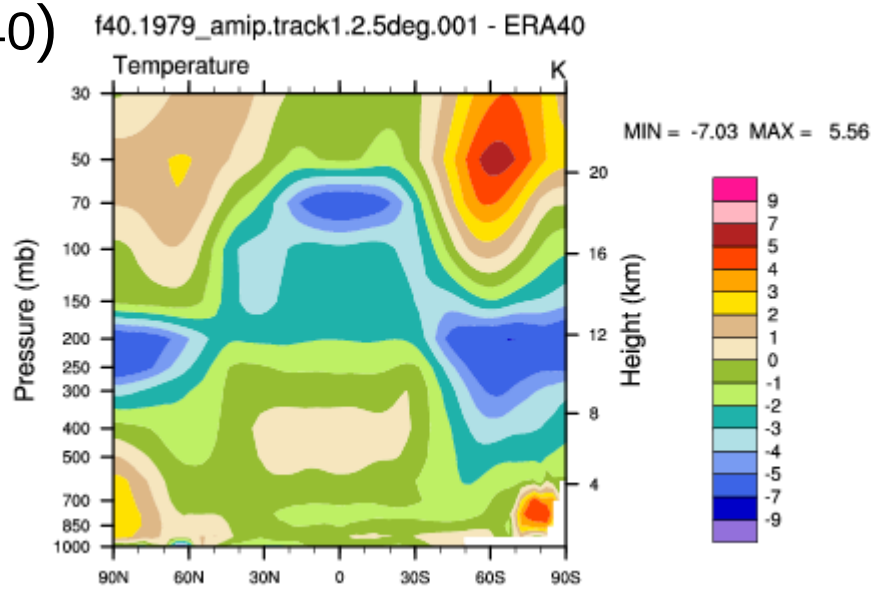
Community E

Annual Temperature Errors (ERA40)

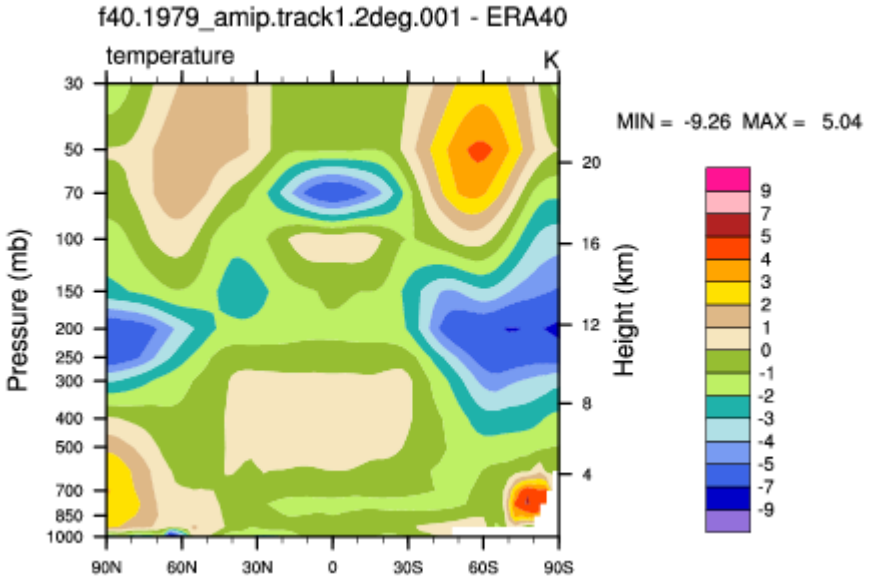
T31



2.5º



2º

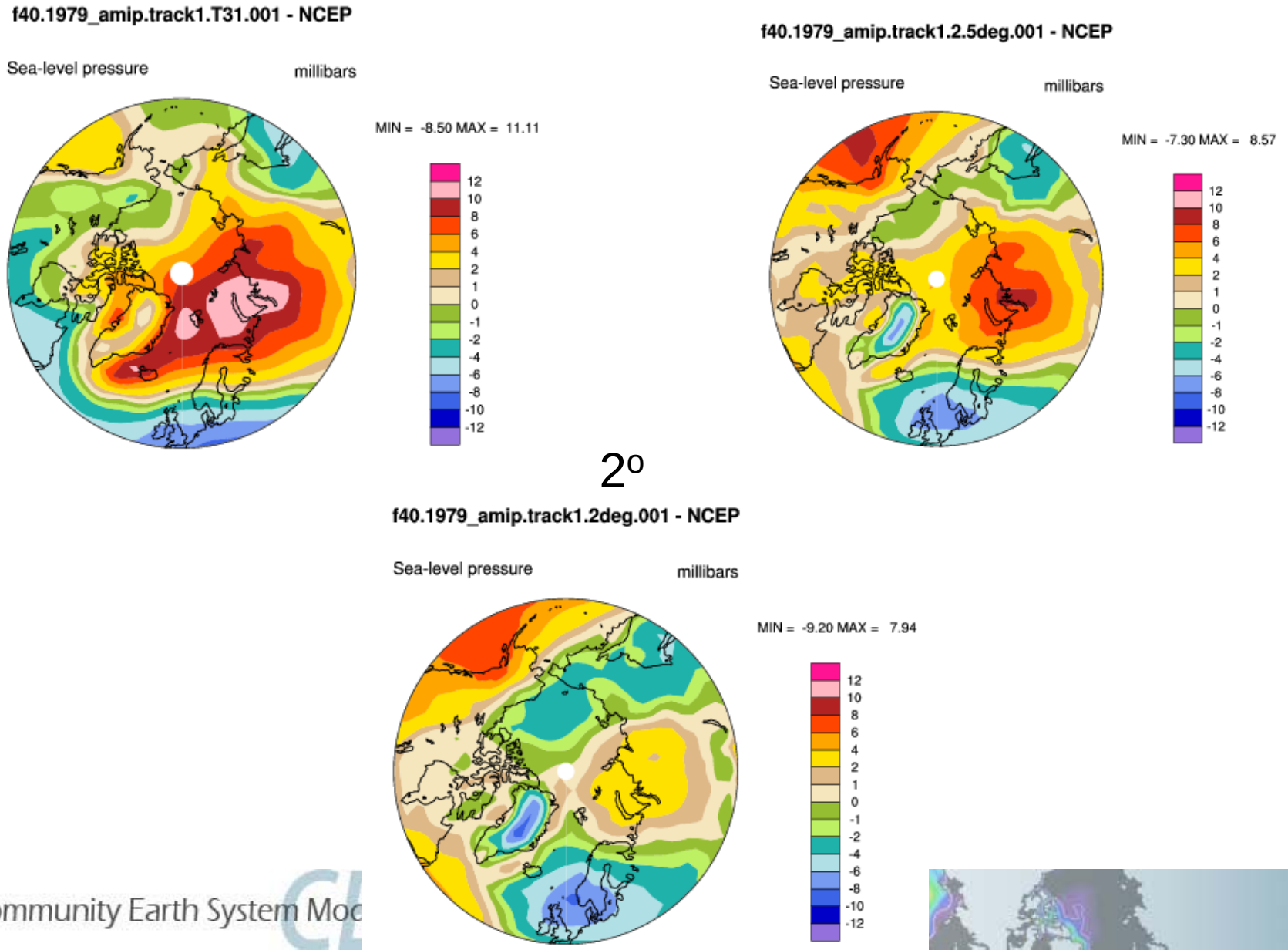


DJF SLP Errors (NCEP)

T31

2.5º

2º



SUMMARY

- ✓Build lower resolution FV model
- ✓Useful for resource-intensive research (WACCM, Chem, length)
- ✓Lowest resolution with T31 equivalent baroclinic eddies
- ✓2X faster than FV 2^{o} similar climate (RMSEs)
- ✓2X slower than T31: similar climate (RMSEs)
- ✓Effects of coupling?
- ✓Some benefit for polar climate; upper troposphere
- ✓Need to examine CAM5 2.5^{o}