NCAR(CESM) Center Report

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NCAR
NATIONAL CENTER FOR ATMOSPHERIC RESEARCH

U.S. DEPARTMENT OF ENERGY

NSF

WGNE-30 Meeting, Greenbelt MD, USA, 24 March 2015

CESM Developments for CMIP6

- Prognostic precipitation (*MG2: snow,rain but no heavy ice-phase*)
- Aerosols
  - Moving from 3-moment MAM3 to 4 moment MAM4
  - Stratospheric/volcanic aerosol will be prognostic
  - Prescribed MAM available
- Isotopes
- Convection/PBL schemes
  - **Config. 1)** UNICON; **Config. 2**) CLUBB+ZM; **Config. 3**) No change
  - Both new configurations **(1,2)** degrade ENSO
  - External panel (re-)evaluation due in June 2015

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Ready to go and approved by NCAR oversight committees

**Gettelman, A., & Morrison, H. (2014). Advanced Two-Moment Bulk Microphysics for Global Models. Part I: Off-Line Tests and Comparison with Other Schemes. Journal of Climate*.

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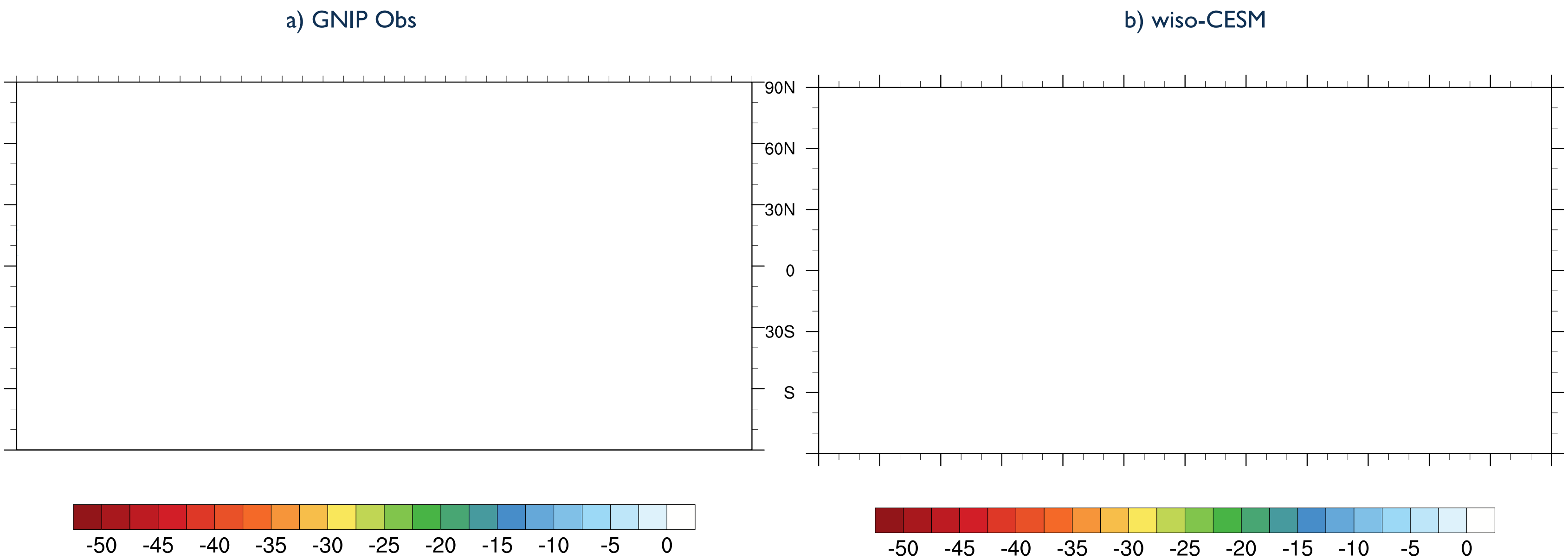
Bette Otto-Bliesner

Water Isotopes in CESM2

- Tracers for following the isotopic content of water have been implemented in CAM5.3, POP2, CLM4, RTM, CICE4, and CPL7.
- The implementations are being readied for merging into the development trunk. We are also currently updating to the newest versions of these models for CESM2.
- Long coupled baseline simulations for Preindustrial and Present using CESM1.2 are being evaluated and show promising results.

Carbon isotopes also implemented

Water Isotopes in CESM1.2



Precipitation δ^{18}O in (a) the observation and (b) the coupled wiso-CESM under present day conditions (year 91-100) (Courtesy *Jiang Zhu*). The coupled model captures the major features of the observation. The model is still undergoing slow spin-up due to the slow evolution in deep ocean.

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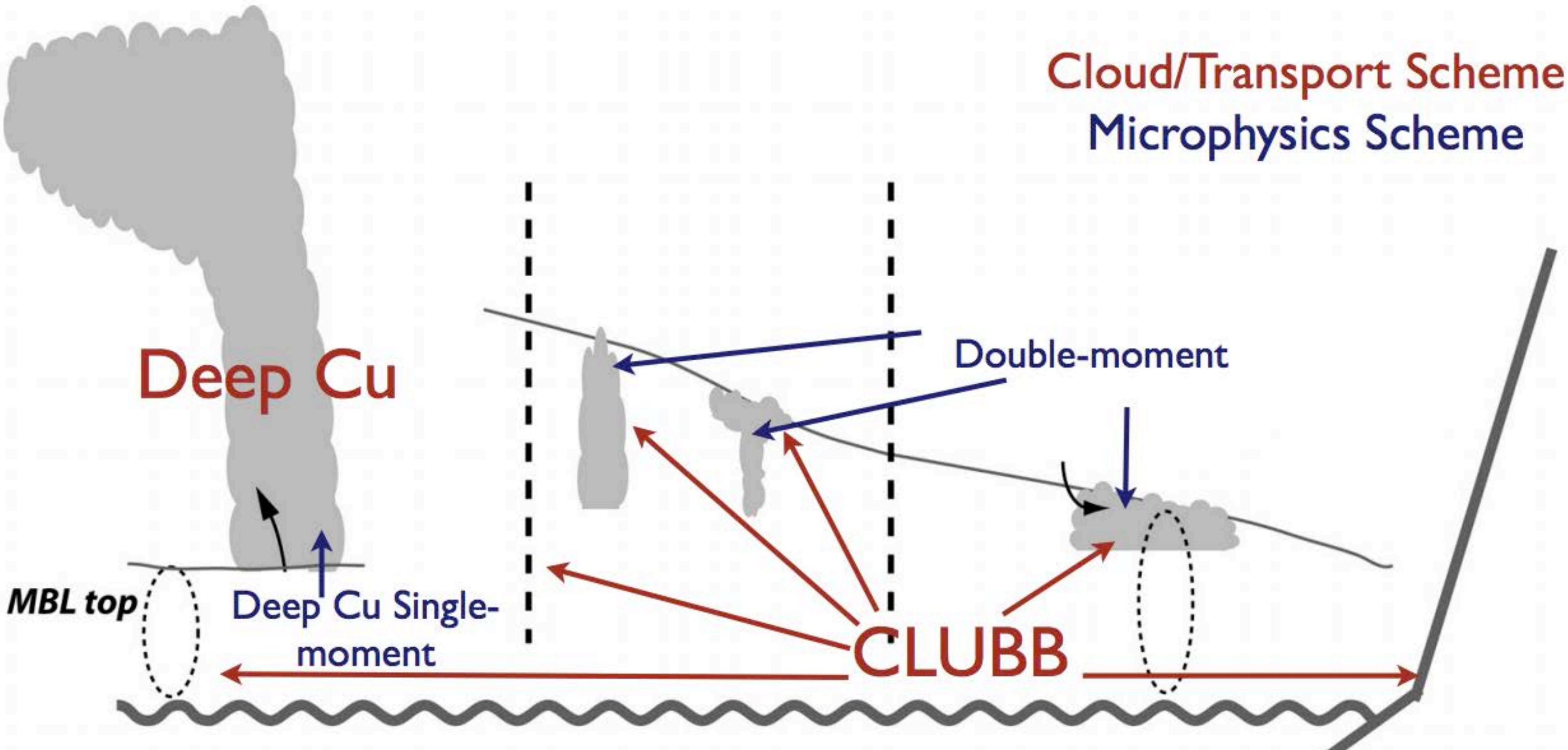
CLUBB: Cloud Layers Unified By Binormals

Vincent Larson &
Andrew Gettelman

CAM-CLUBB standard

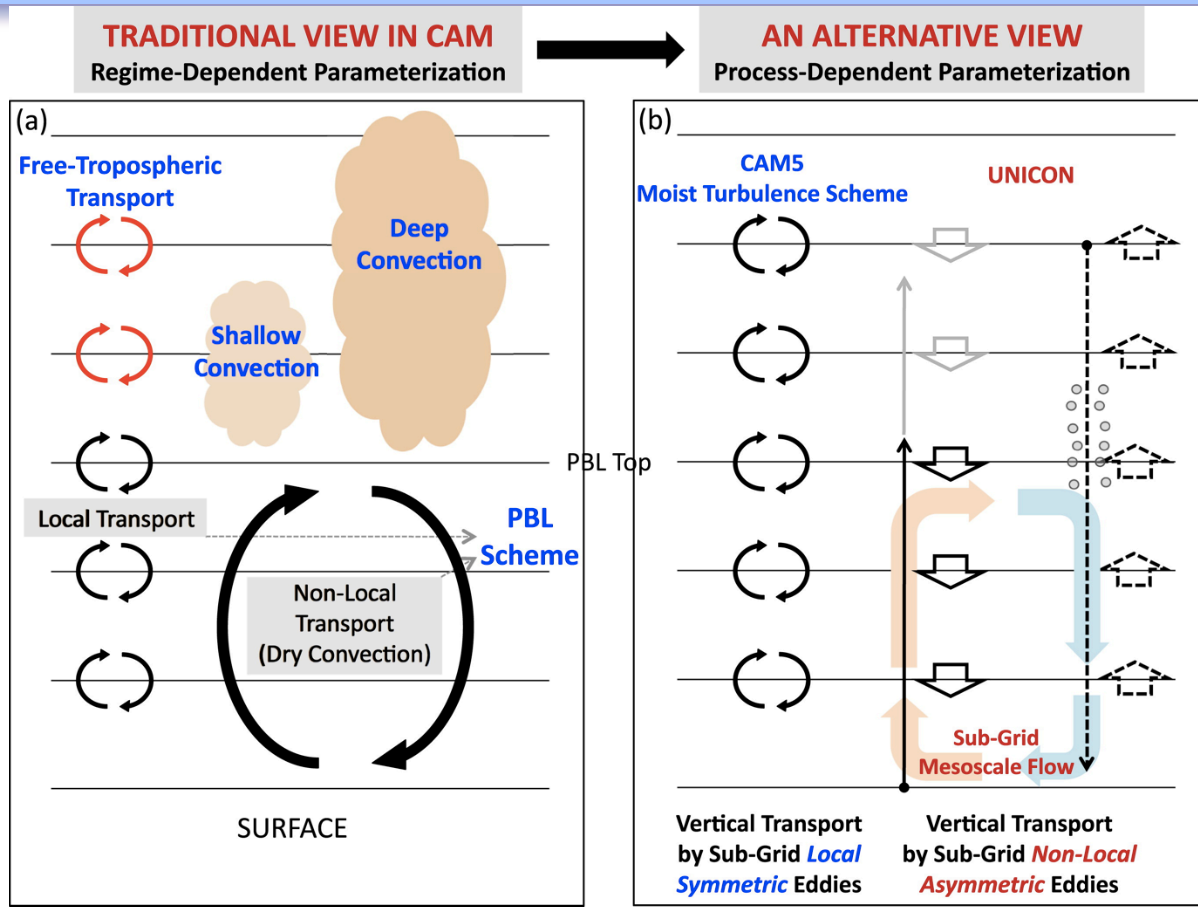


- Prognostic moments w/high order closures (1 third order, 8 second order, *possibly advected*)
- Unifies moist and dry turbulence (except deep convection)
- Uses two Gaussians to describe the sub-grid PDF of each quantity (joint w,q, and θ)

Larson, V. E. and Golaz, J.-C.: Using probability density functions to derive consistent closure relationships among higher-order moments, Mon. Weather Rev., 133, 1023–1042, 2005

UNICON: Unified Convection Scheme

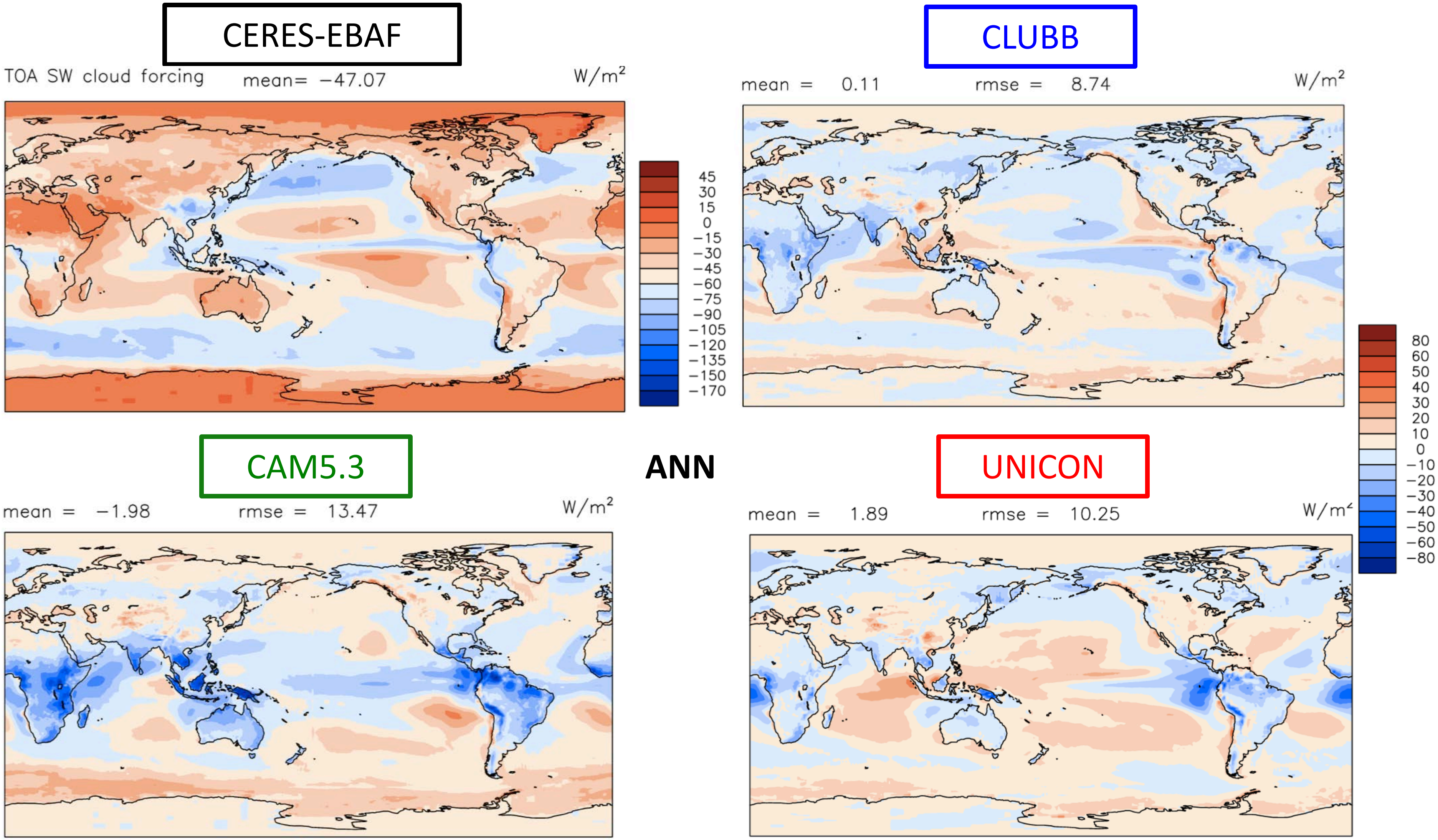
Sungsu Park



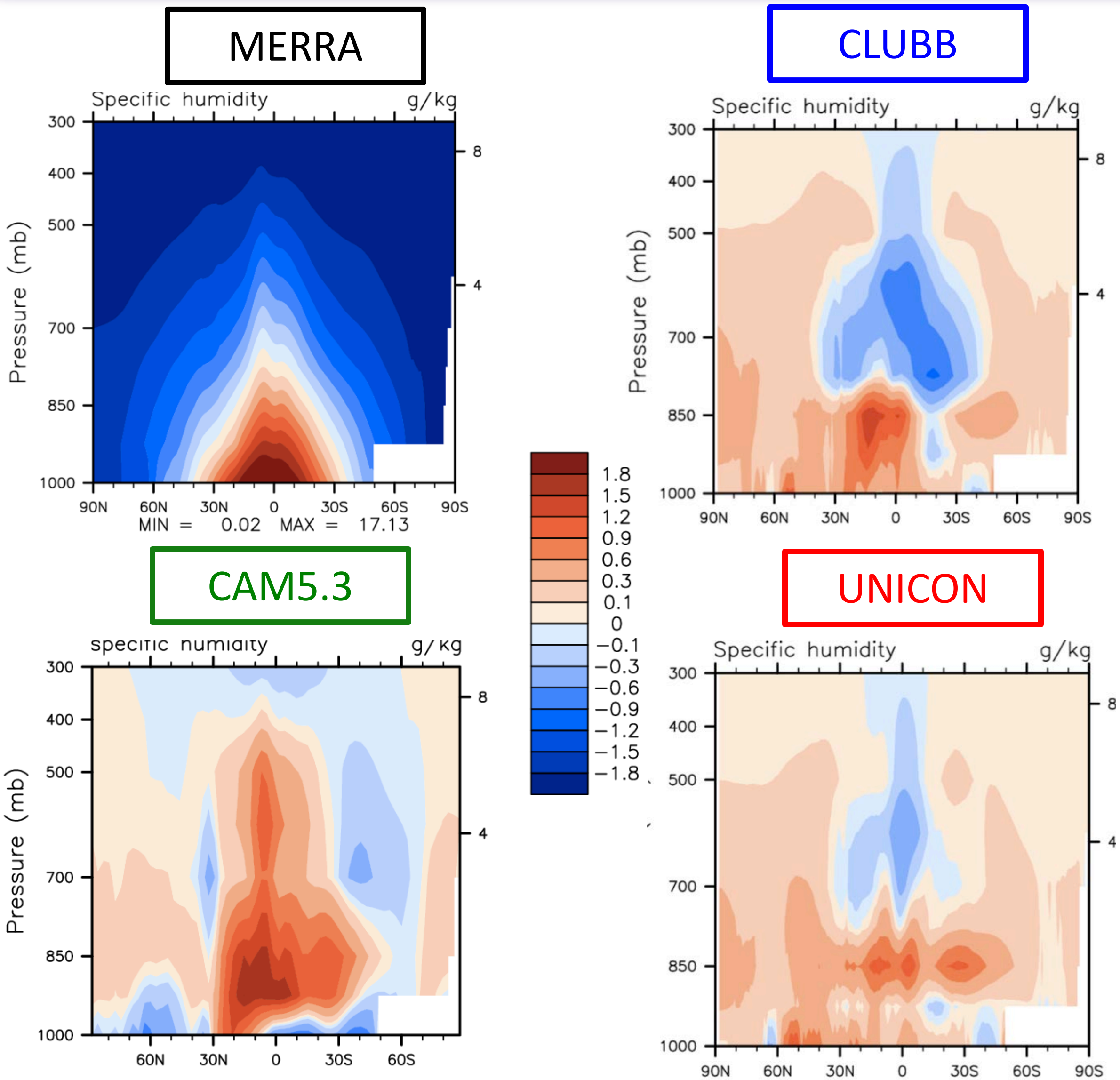
- Unifies deep and shallow convection schemes
- Generates forced/free/dry shallow convection + deep convection
- Accounts for sub-grid mesoscale flows (prognostic representations of subgrid variability)

  Park, S. (2014). A unified convection scheme (UNICON). Part I: Formulation. Journal of the Atmospheric Sciences, 71(11), 3902-3930.

Clouds: Short-wave cloud forcing (AMIP)

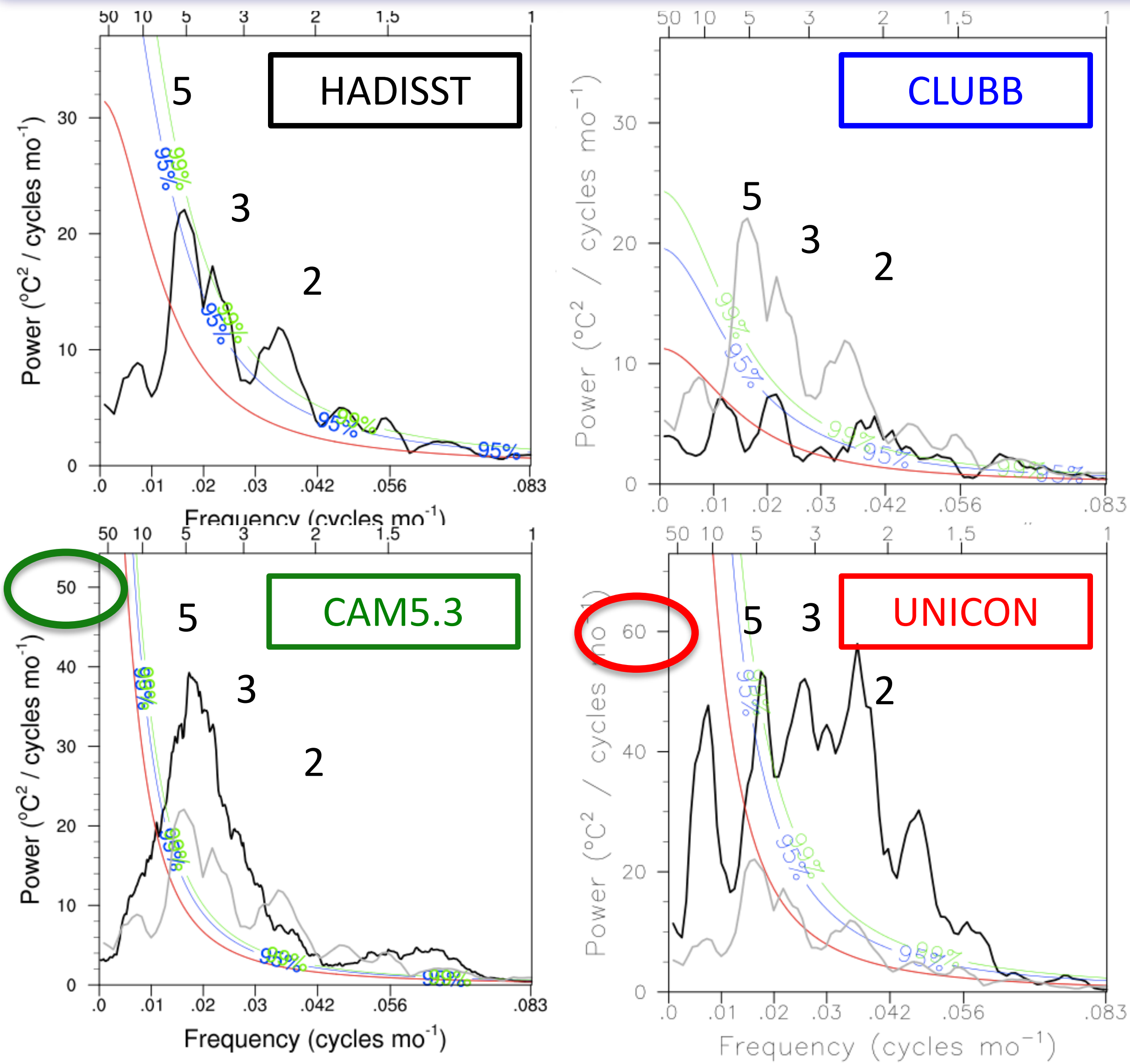


Atmospheric humidity: Reduced moist bias



- CAM5.3 persistent wet bias
- CLUBB/UNICON dryer
- PBL water too high
- Mid-latitude moisture increased

ENSO: Cause for concern



- ENSO not well simulated
- UNICON too strong amplitude at two wide a frequency
- CLUBB has very weak amplitude and no preferred frequency

Other significant simulations/results

- AMIP runs at 100 km
  - SE/FV* climates are close
- Coupled runs 100km atmos/1^{o} ocean
  - SE leads to cooler ocean than FV. SE rejected for bulk of CMIP6 work (at 1^{o})
- AMIP runs and time-slice runs at 25 km
  - High-resolution calculations will continue to use SE
  - 25 km FV and SE AMIPs are close, a few more TCs/year globally in SE

*SE = Spectral Element dynamical core, FV=finite volume dycore (latlon)

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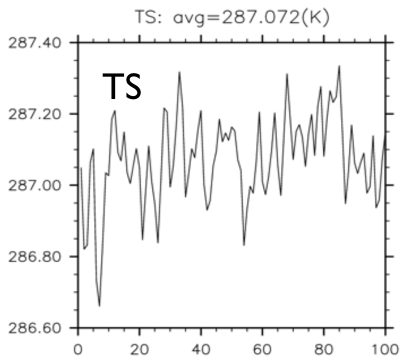
Coupled run spin-up

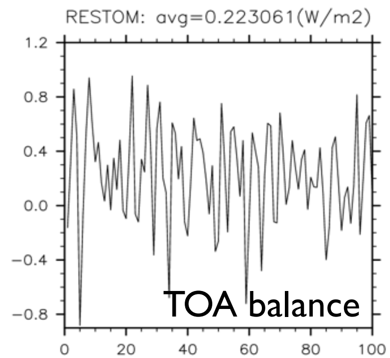
(Cecile Hannay)

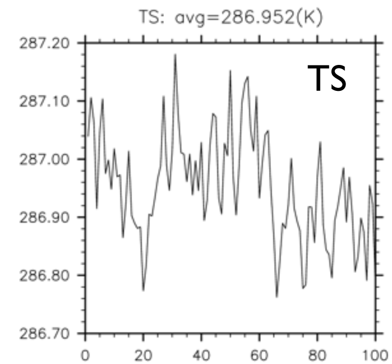
CESM1.1: Finite volume (FV)

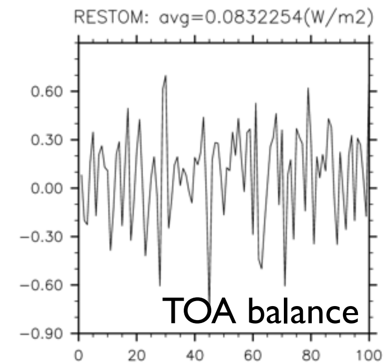
CESM1.2: Spectral element (SE)

Spunup ocean





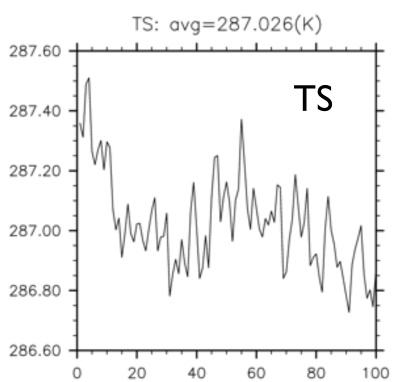


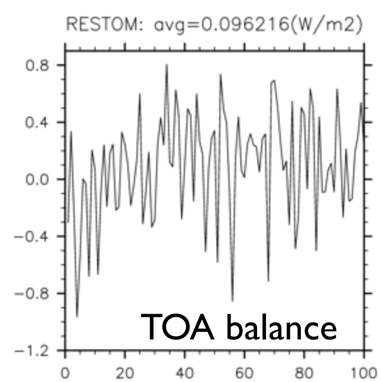


When starting from spunup ocean,
model quickly adjusts (20 years)

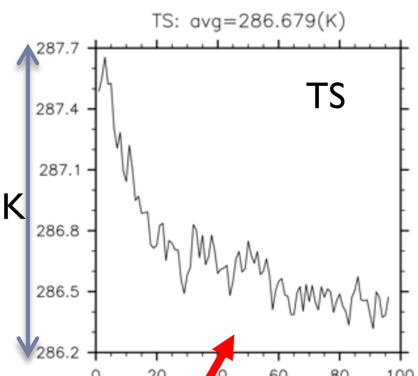
1.0K

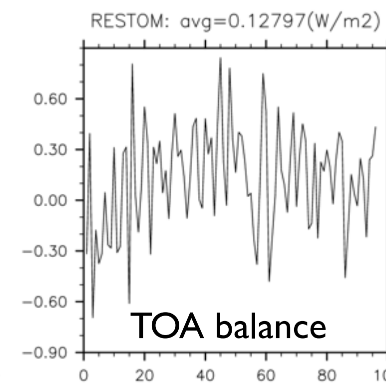
Levitus





1.5K





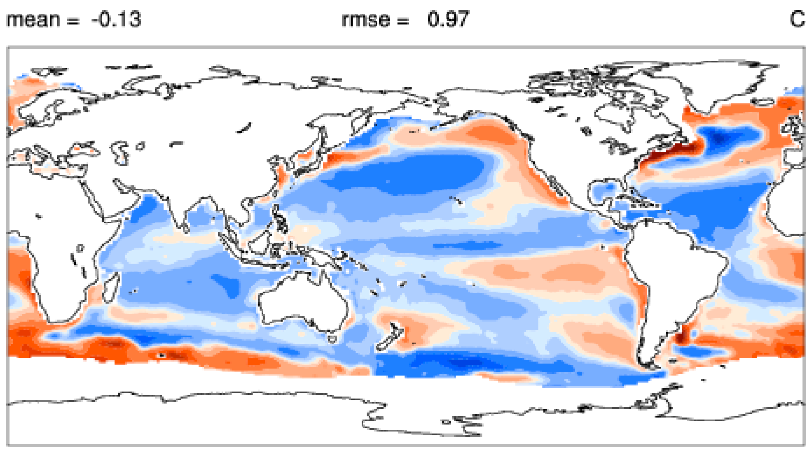
When starting from Levitus,
model spinups longer (100 years).

Cooling despite mostly positive TOA radiation balance!

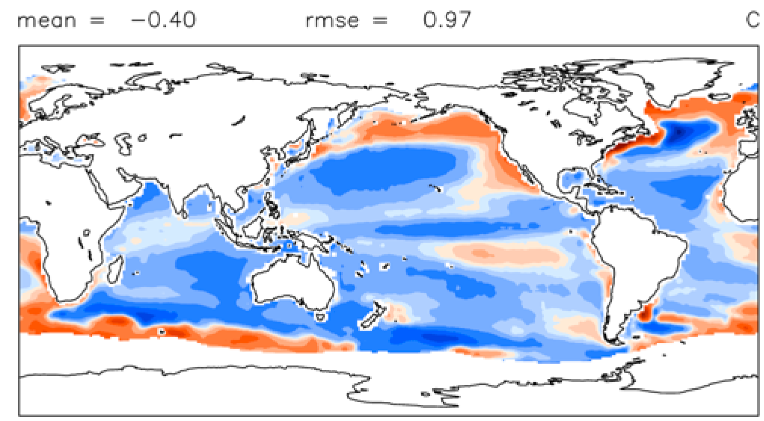
SST biases

Compared to HadISST/OI.v2 (pre-industrial)

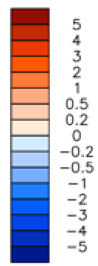
Finite Volume: Spunup ocean



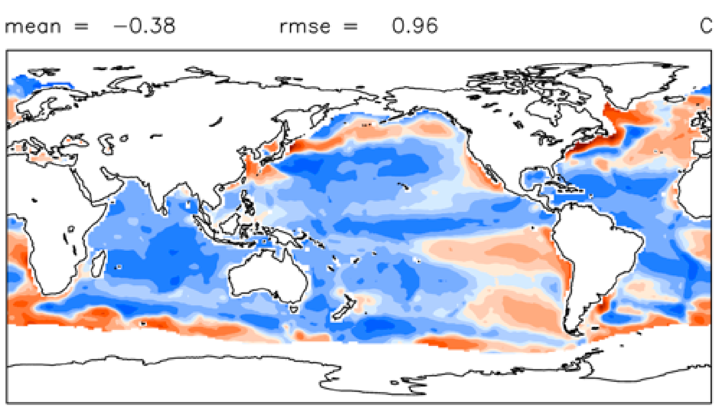
Spectral Element: Spunup ocean



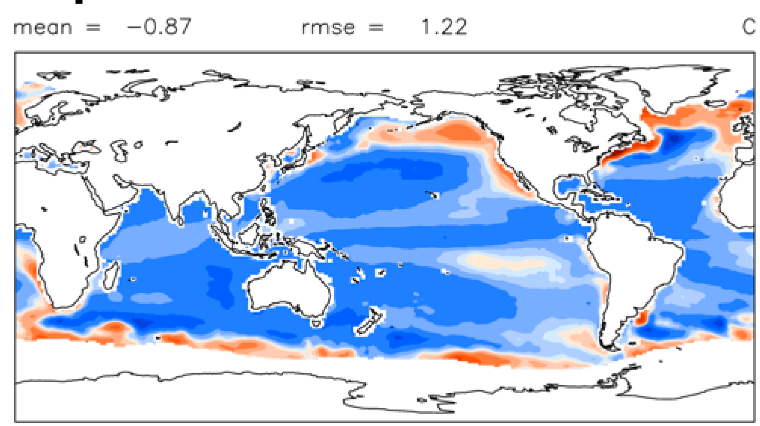
SST Bias similar to FV except SE Pacific.



Finite Volume: Levitus



Spectral Element: Levitus

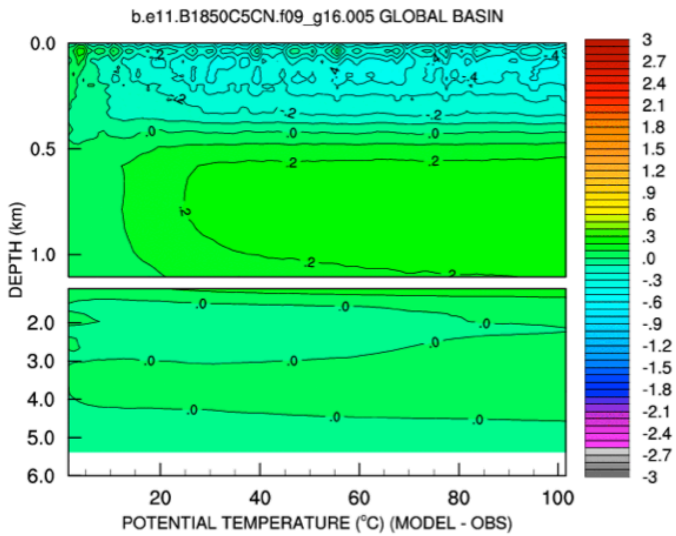


SSTs stabilize but too cold compared to obs
SST: 0.5K colder than FV

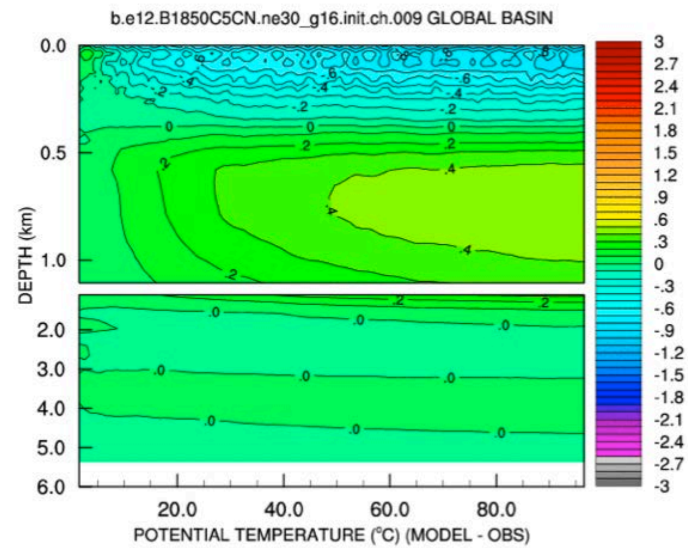
Ocean temperature bias

T bias = Tocn - Levitus

Finite Volume: Levitus



Spectral Element : Levitus

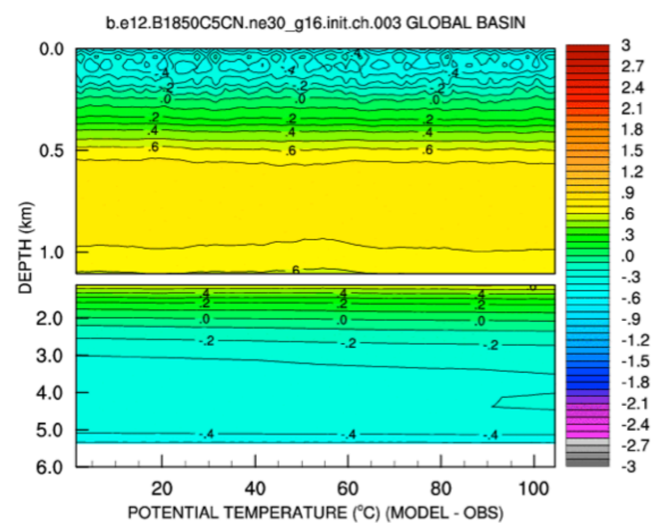


When starting from Levitus:
- cools near the surface
- warms around 750 meter
- exacerbated in SE

When starting from long spunup ocean:
- the 750-meter warm layer is present at initialization

750-meter warm layer is a signature of Spectral Element (present in every run)

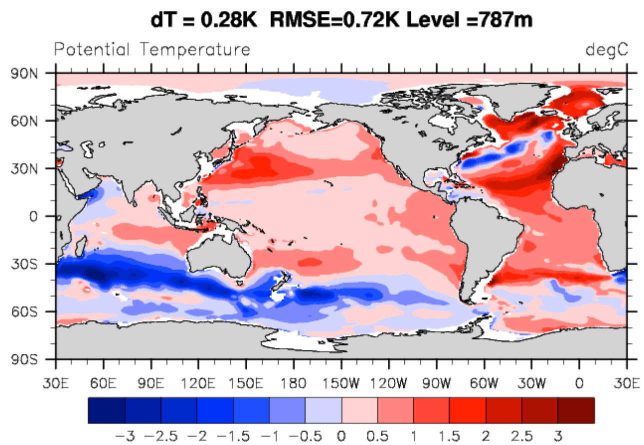
Spectral Element: Spunup ocean



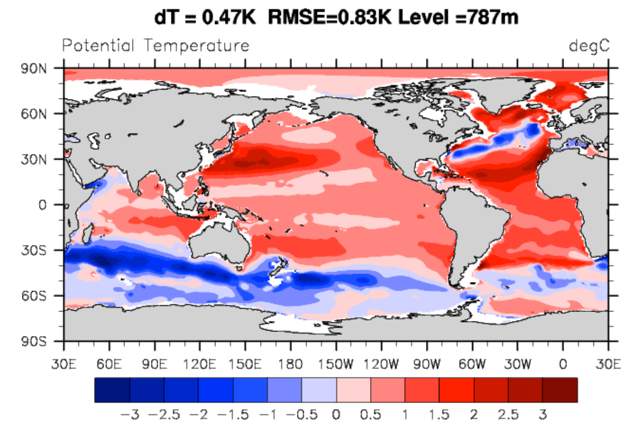
Is 750-meter warming uniform over ocean ?

Bias at 750m = T 750-m - Levitus

Finite Volume (yrs 70-89)



Spectral Element (yrs 70-89)



Warming is not uniform: areas of warming and cooling

Warming also exists in Finite Volume but cooling compensates warming globally.

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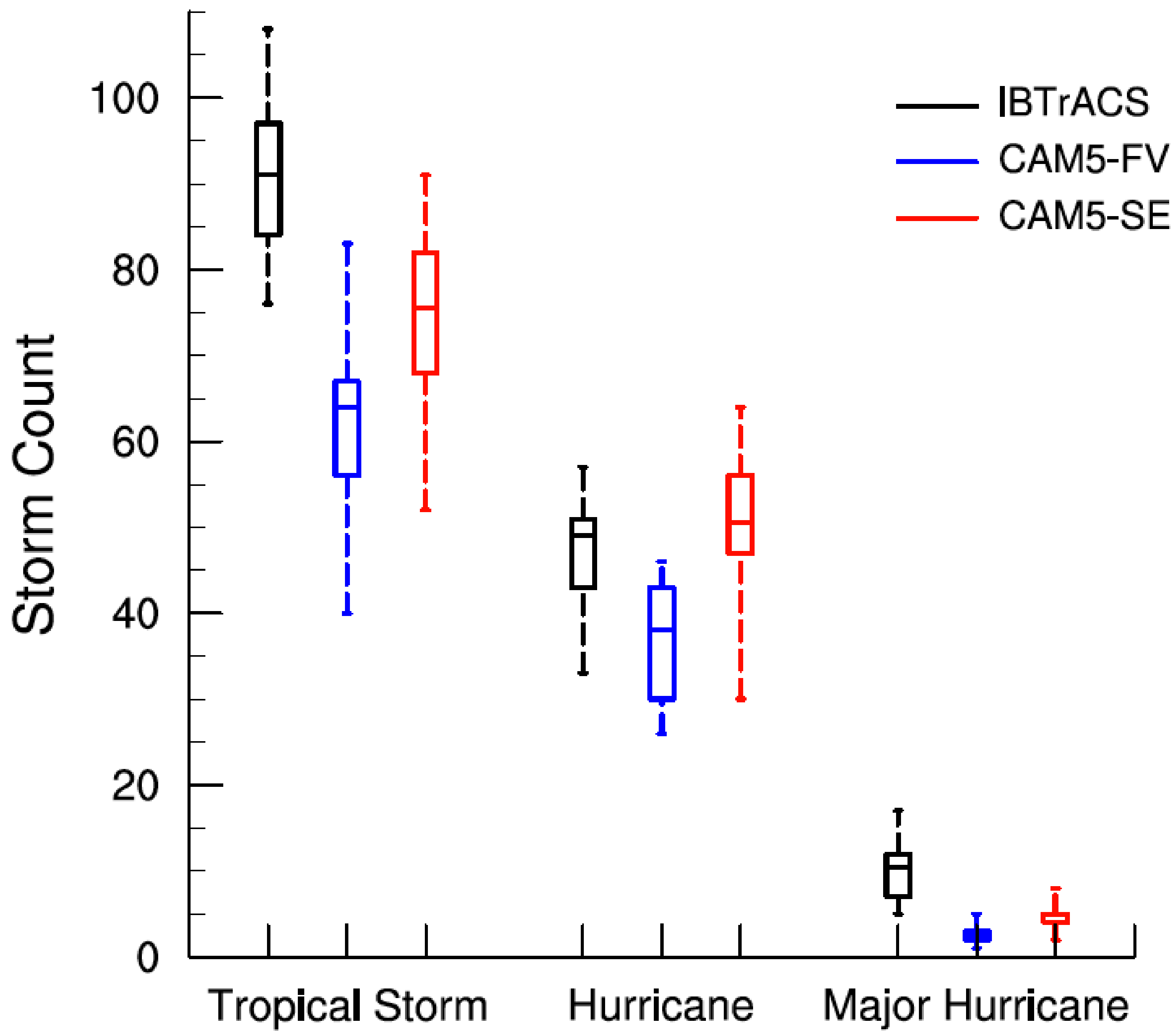
AMIP runs and time-slice runs at 25 km

All runs untuned, i.e., 100km physics settings used at 25km

Experiment	period
Present day AMIP runs (ne120_ne120)	
f.e13.FAMIPC5.ne120_ne120.1979_2012.001	1979-2010
f.e13.FAMIPC5.ne120_ne120.1979_2012.002	1979-2010
f.e13.FAMIPC5.ne120_ne120.1979_2012.003	1979-2010
Future Time-slice runs	
f.e13.FAMIPC5.ne120_ne120.RCP85_2070_2099.001	2070-2100
f.e13.FAMIPC5.ne120_ne120.RCP85_2070_2099.002	2070-2100
f.e13.FAMIPC5.ne120_ne120.RCP85_2070_2099.003	2070-2100
Alternate SST runs	
f.e13.FAMIPC5.ne120_ne120.RCP85_2070_2099_sst2.001	2070-2087 (continuing)
f.e13.FAMIPC5.ne120_ne120.RCP85_2070_2099_sst3.001	2070-2100
ne120_g16 runs	
FAMIPC5_ne120_79to05_03_omp2	1979-2010
f.e12.FAMIPC5.ne120_g16.amip.001	1979-1990 (continuing)
f.e12.FAMIPC5.ne120_g16.rcp4.5.001 ***(RCP4.5)***	2070-2100
FAMIPC5_ne120_2070to2100_03_omp2 ***(RCP8.5)***	2070-2100
0.23x0.31 FV runs	
cam5_amip_run1 *(prescribed BAM aerosols)*	1979-2008
f.e13.FAMIPC5.02_02. .... *(fully prognostic MAM3)*	1979-2010

~300 years of prescribed SST simulation at 25km resolution + 50 years coupled (0.1^{o} ocean)



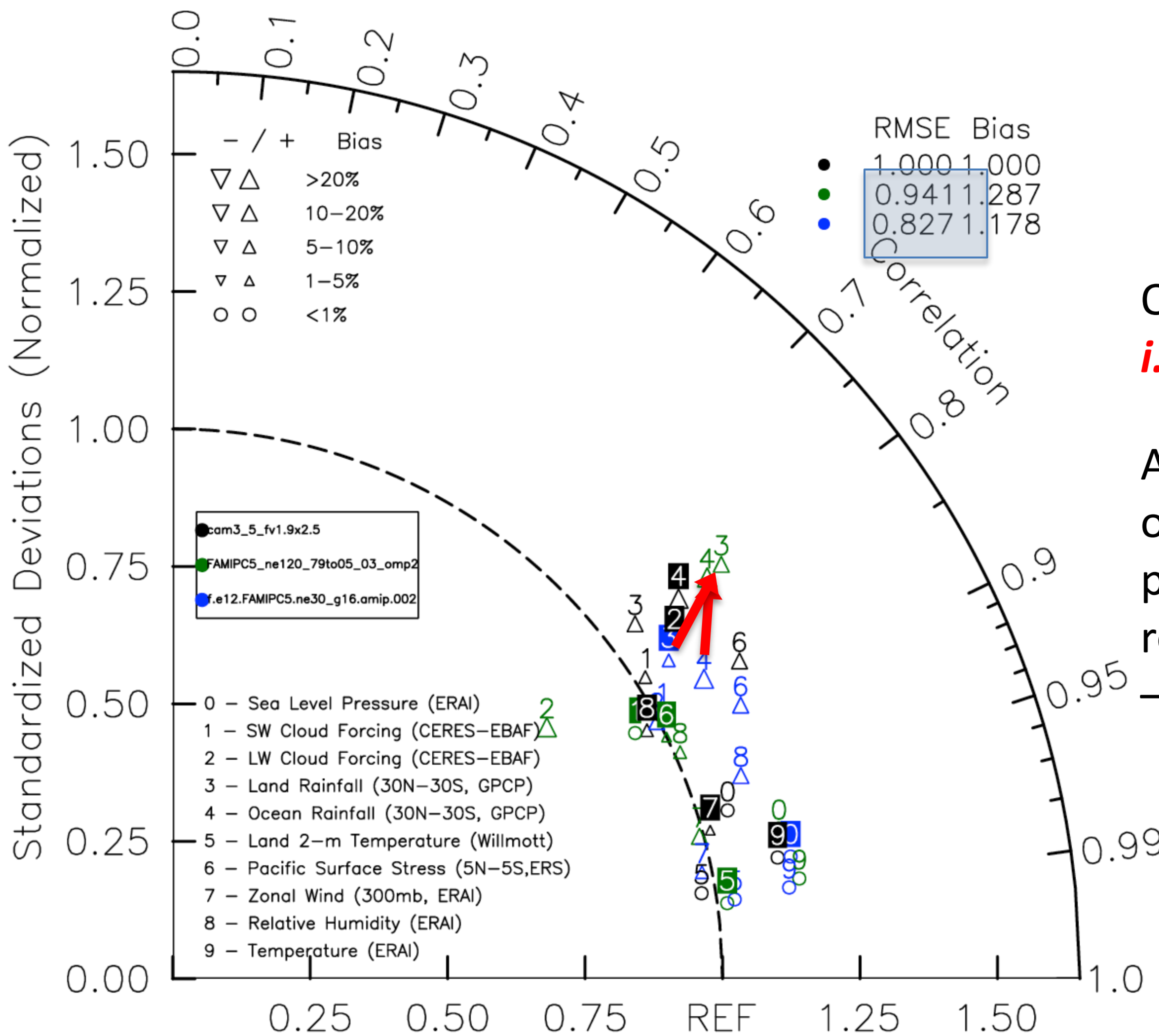
Storm Count
100
80
60
40
20
0
IBTrACS
CAM5-FV
CAM5-SE
Tropical Storm
Hurricane
Major Hurricane

Summary Taylor diagram for 1980-2005 AMIP runs

Black – CAM3 FV 1 Deg

Blue – CAM5 ne30 (100 km)

Green – CAM5 ne120 (25 km)

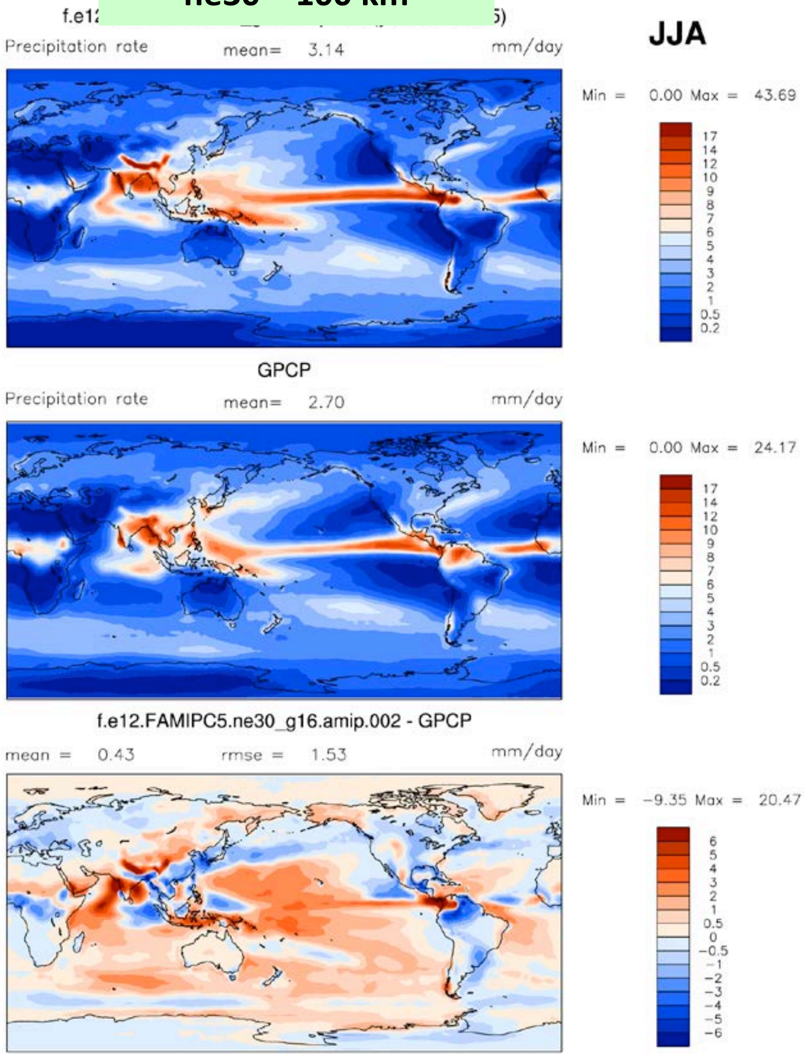


Overall RMSE ***lower, i.e. better, for ne30***

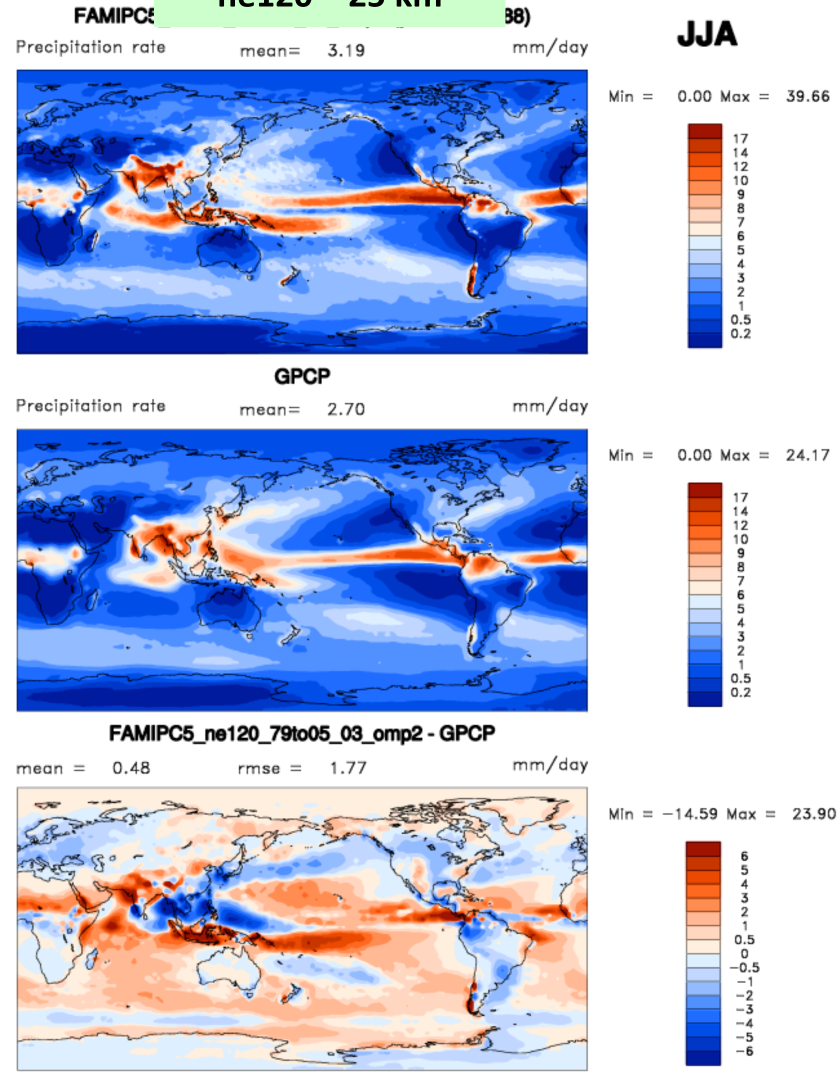
Arrows show change of land and ocean precipitation as resolution increases –***both degrade***

JJA Seasonal-mean precipitation (1980-2005)

ne30 – 100 km



ne120 – 25 km



Have also looked at:

- SST generation for future time-slices
- Coupling of atmosphere to ocean surface
- Aerosols

Possible implications for HighResMIP?
-On Thursday

Summary

- CMIP6 version of CESM may look very much like CMIP5 version
  - No increase in horizontal or vertical resolution
  - No change in dycore
  - Possible changes to convection/PBL schemes still under evaluation
- Extensive work with current version at high-resolution ($\Delta x \sim 25$km)
  - Mean climate not optimal
  - Some dycore impact on TC statistics
  - Interesting climate change impacts on TCs emerging

Thank You

EXTRA SLIDES

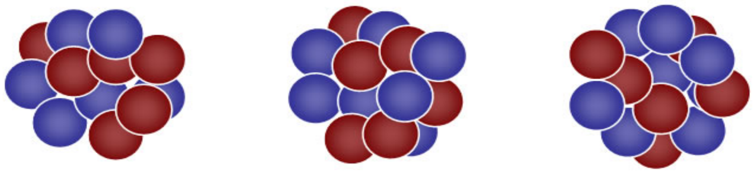
Carbon isotopes in CESM2

- Carbon isotopes (^{13}C and ^{14}C) have been added to the land model (CLM4.5, released with CESM1.2, A. Bozbiyik et al., U. Bern) and ocean model (POP2, to be released with CESM1.3, A. Jahn et al. 2015, under revision for GMD)

- Ocean ^{13}C use for scientific applications depends on the availability of a fast spin-up technique for ocean ecosystem tracers (currently under development, K. Lindsay, NCAR)

- Carbon isotopes are planned to be added to the atmosphere (CAM5.5/6) to allow for coupled carbon isotope simulations

Carbon isotopes



^{12}C	^{13}C	^{14}C
6 protons	6 protons	6 protons
6 neutrons	7 neutrons	8 neutrons
(stable)	(stable)	(radioactive)