Update (final word?) on Analysis of High-resolution Climate Simulations using FV-CAM

Many in
AMP/CGD NCAR
Michael F. Wehner
DOE LBNL

AMWG Meeting, Boulder CO, 11 February 2013

Model Runs

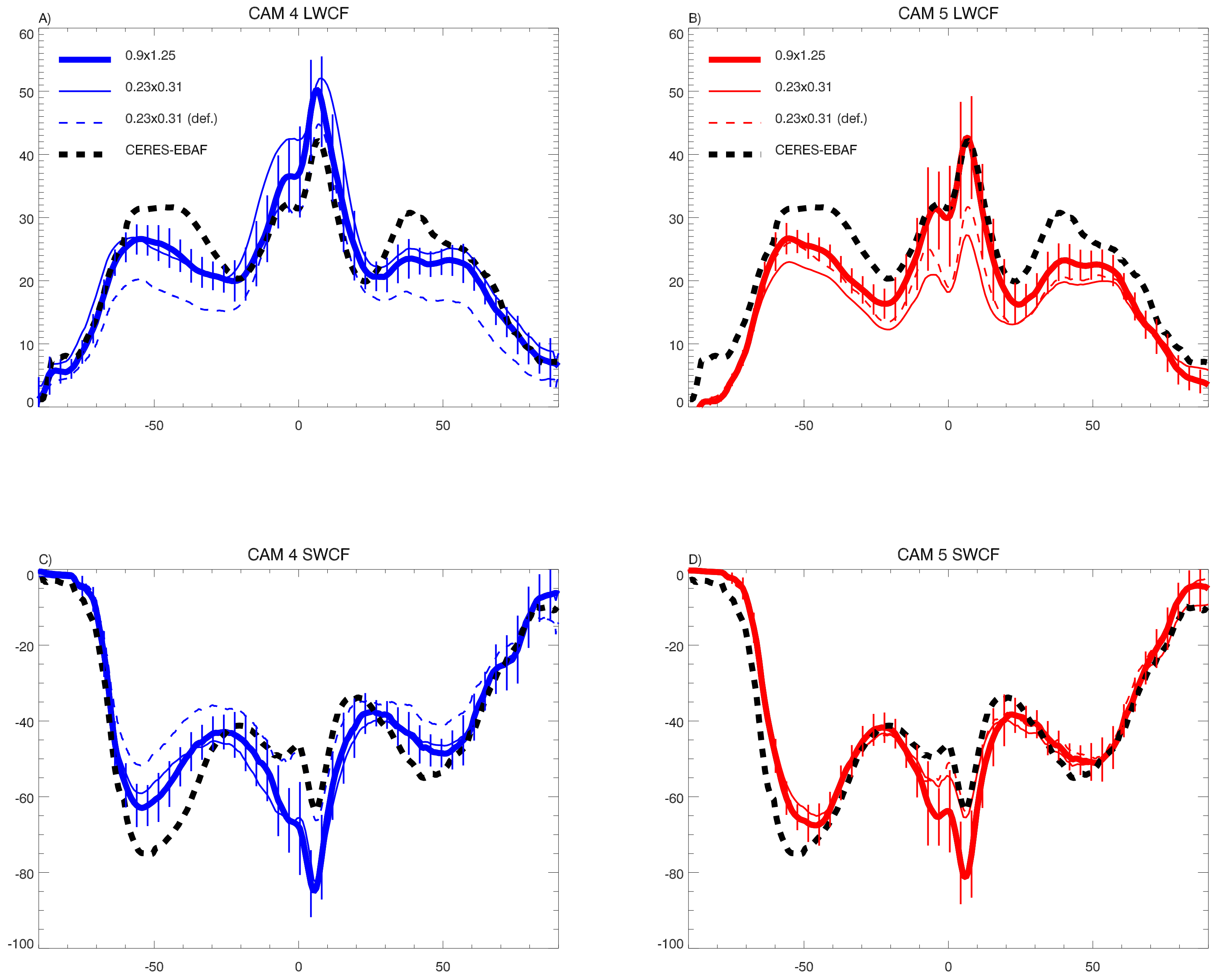
- 4 AMIP-style integrations using observed SSTs 1979-2005, FV dynamical core
  - CAM4: 0.9º*lat* x 1.25º*lon*, and 0.23º*lat* x 0.31º*lon*
  - CAM5: 0.9º*lat* x 1.25º*lon*, and 0.23º*lat* x0.31º*lon*

- A few short integrations (1-2 year) for tuning and development

Modifications for high resolution runs

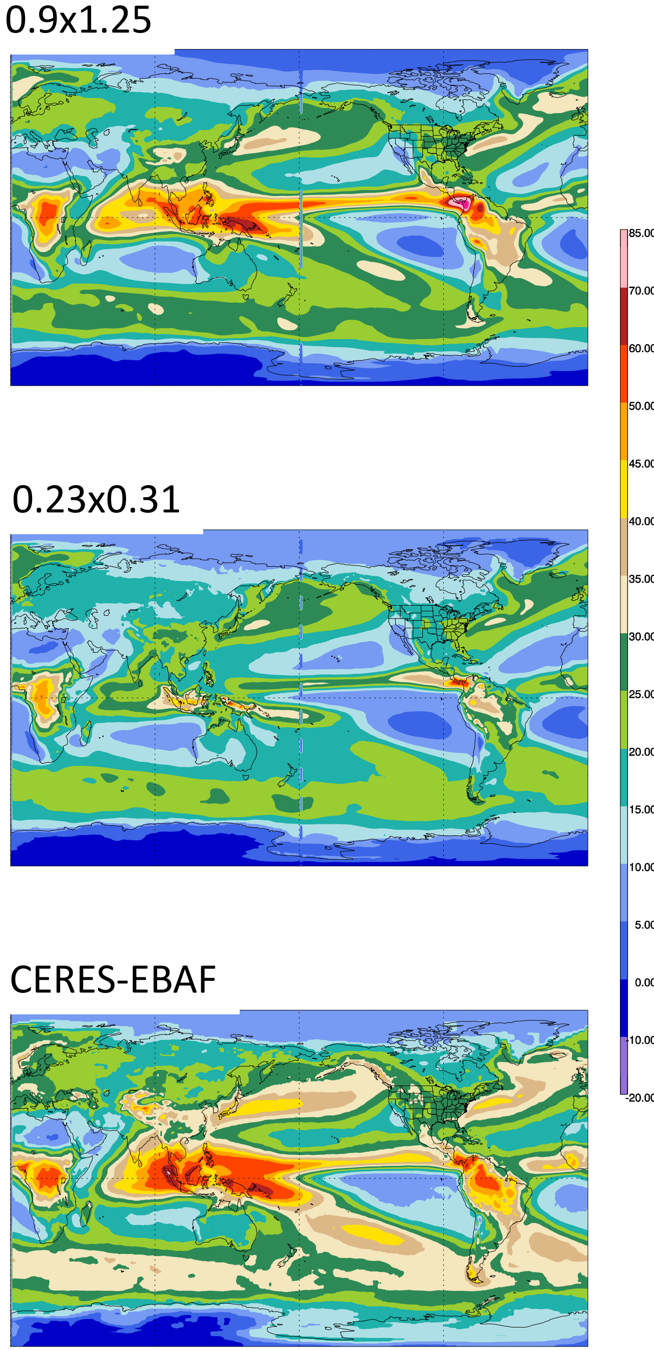
- Ice-cloud radii in CAM4 0.23x0.31 were modified in ad hoc manner to obtain better TOA radiation
- CAM5 0.23x0.31 used interim prescribed BAM aerosol configuration

Clouds and radiation

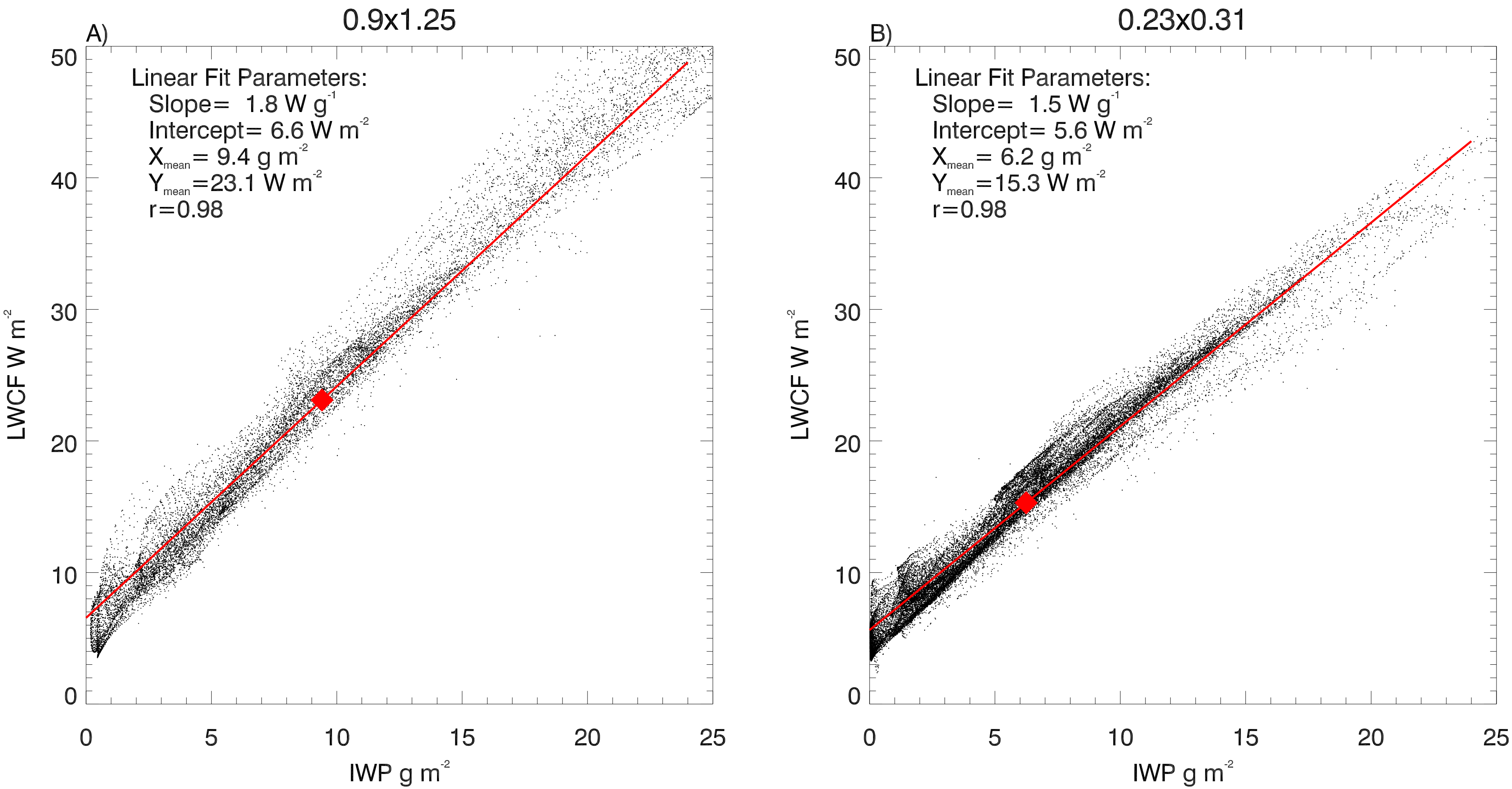


A)
CAM 4 LWCF
0.9x1.25
0.23x0.31
0.23x0.31 (def.)
CERES-EBAF
B)
CAM 5 LWCF
0.9x1.25
0.23x0.31
0.23x0.31 (def.)
CERES-EBAF
C)
CAM 4 SWCF
D)
CAM 5 SWCF

1980-2004 Mean, annually averaged LWCF in **CAM5**

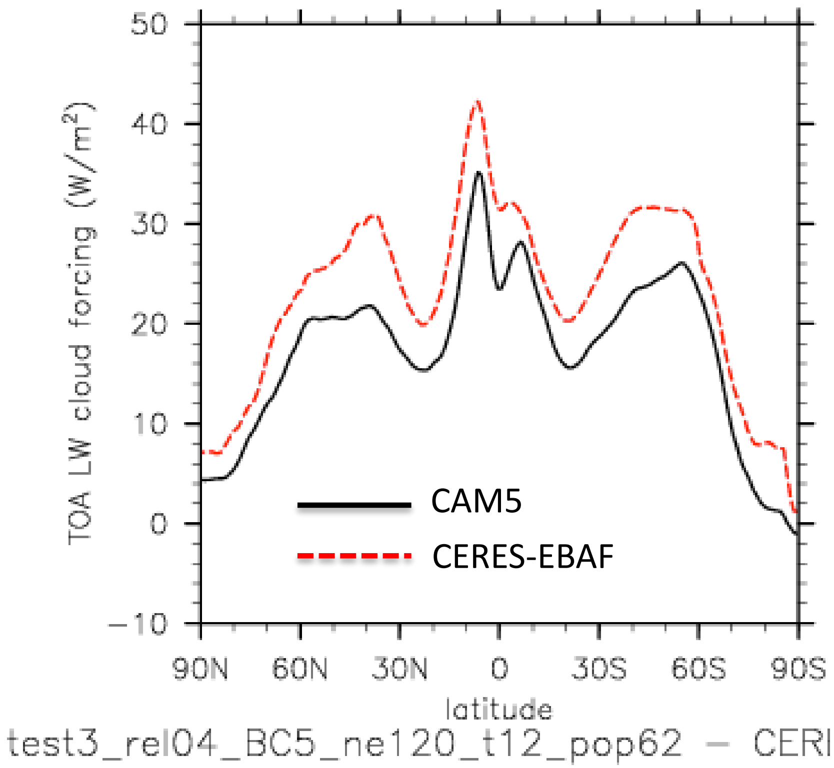


Ice water path vs LWCF (**CAM5** Tropics 30S-30N Annual average)



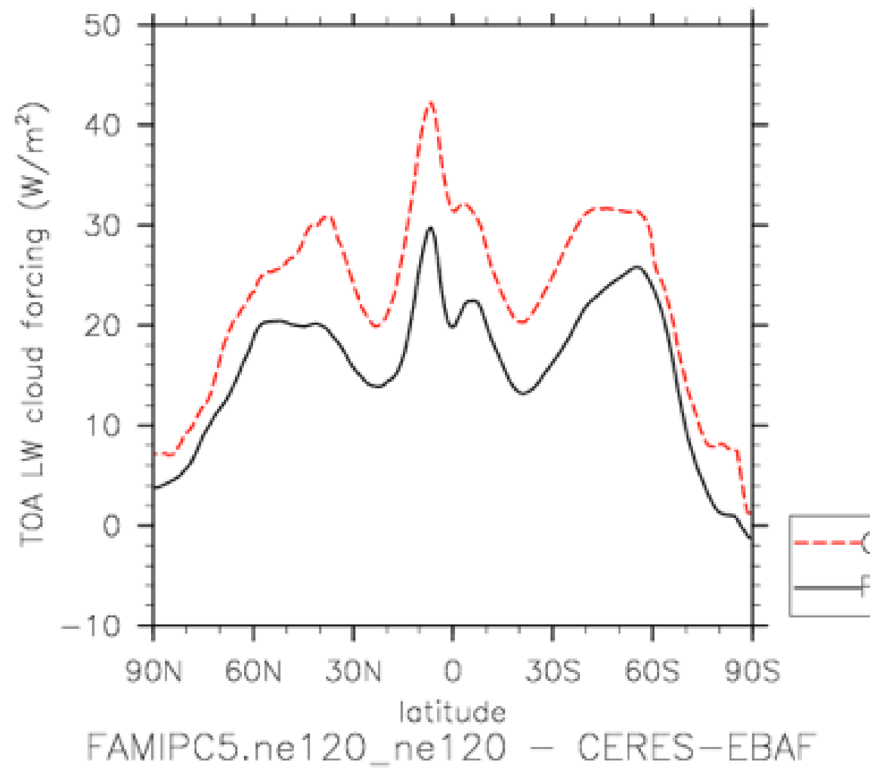
Sensitivity to convective autoconversion rate

zmconv_c0_ocn= 0.0035D0
zmconv_c0_lnd= 0.0035D0



CAM5 defaults

zmconv_c0_lnd = 0.0059D0
zmconv_c0_ocn = 0.0450D0

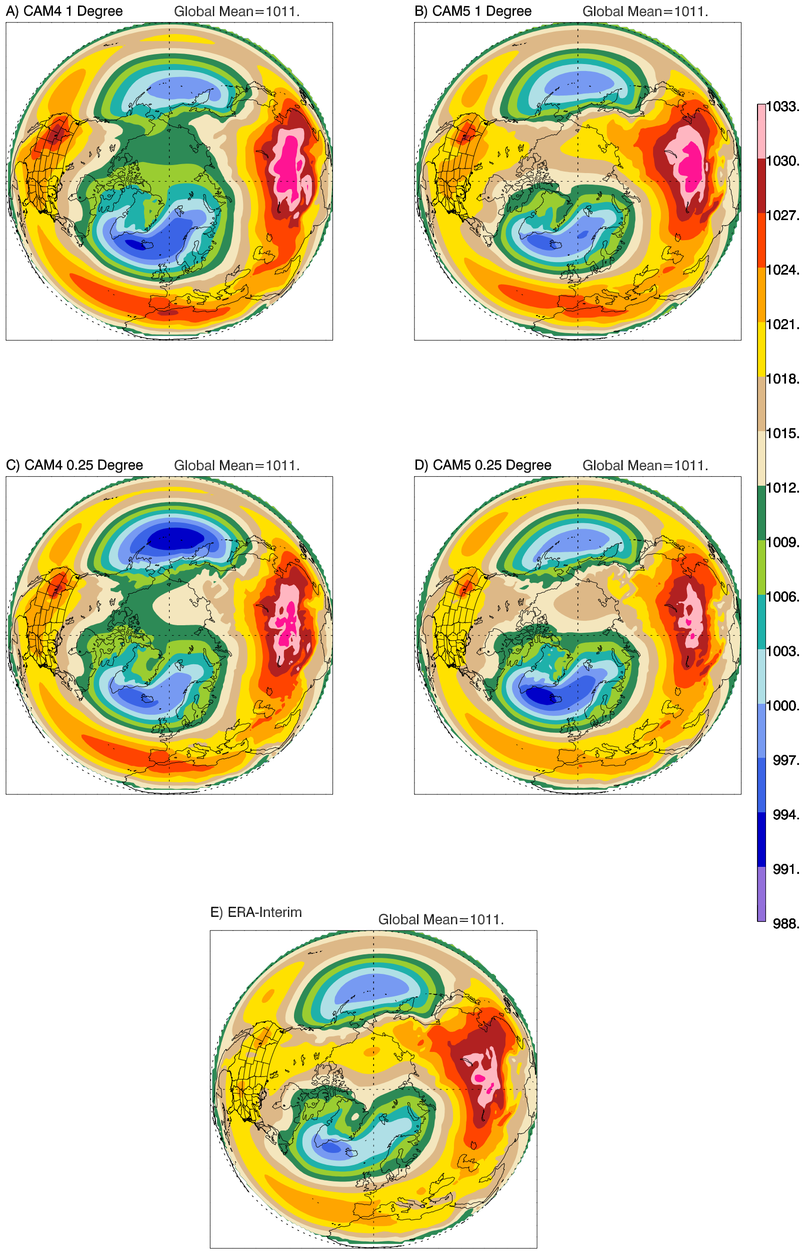


Development runs for Justin Small's Accelerated Scientific Discovery (ASD) project: ***Multi-decadal coupled run using CAM-SE ne120 (~25km) and ~10 km Ocean*** *(currently out to 30+ years)*

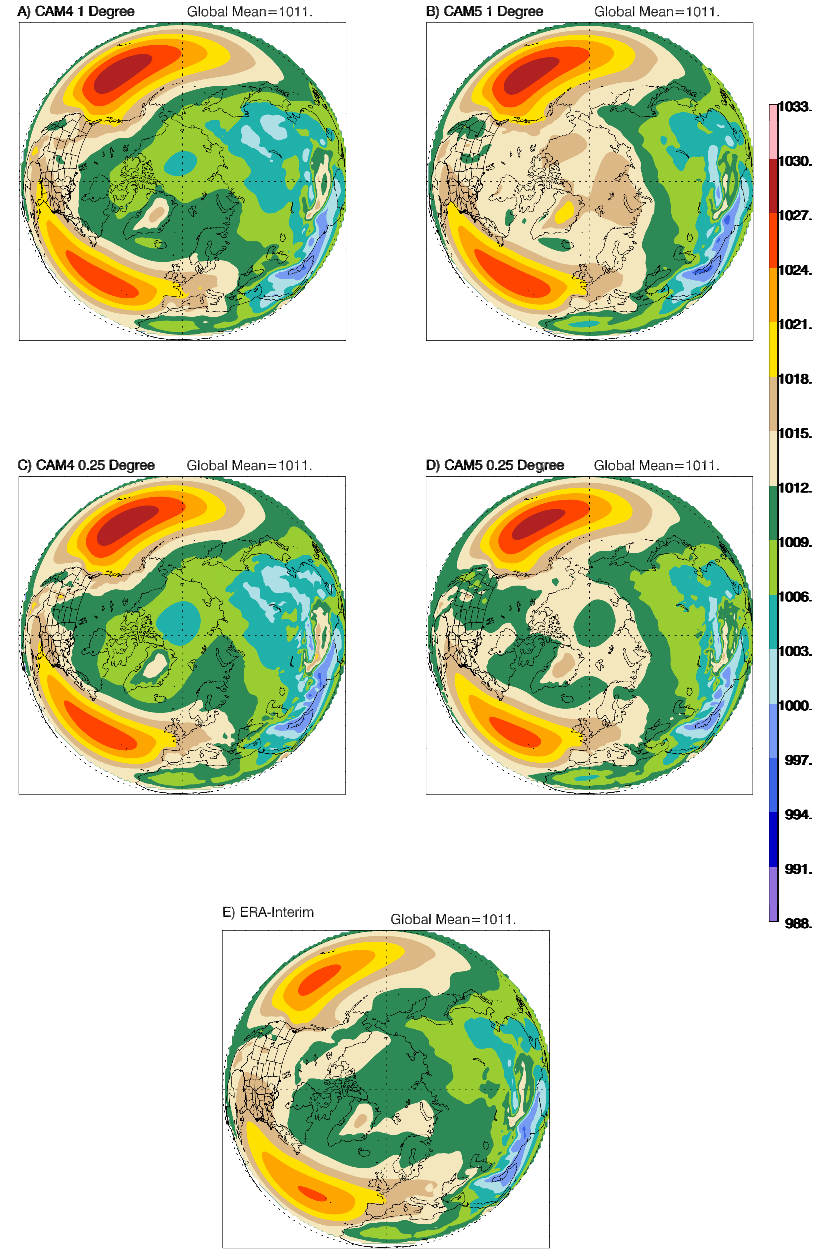
Seasonal Means

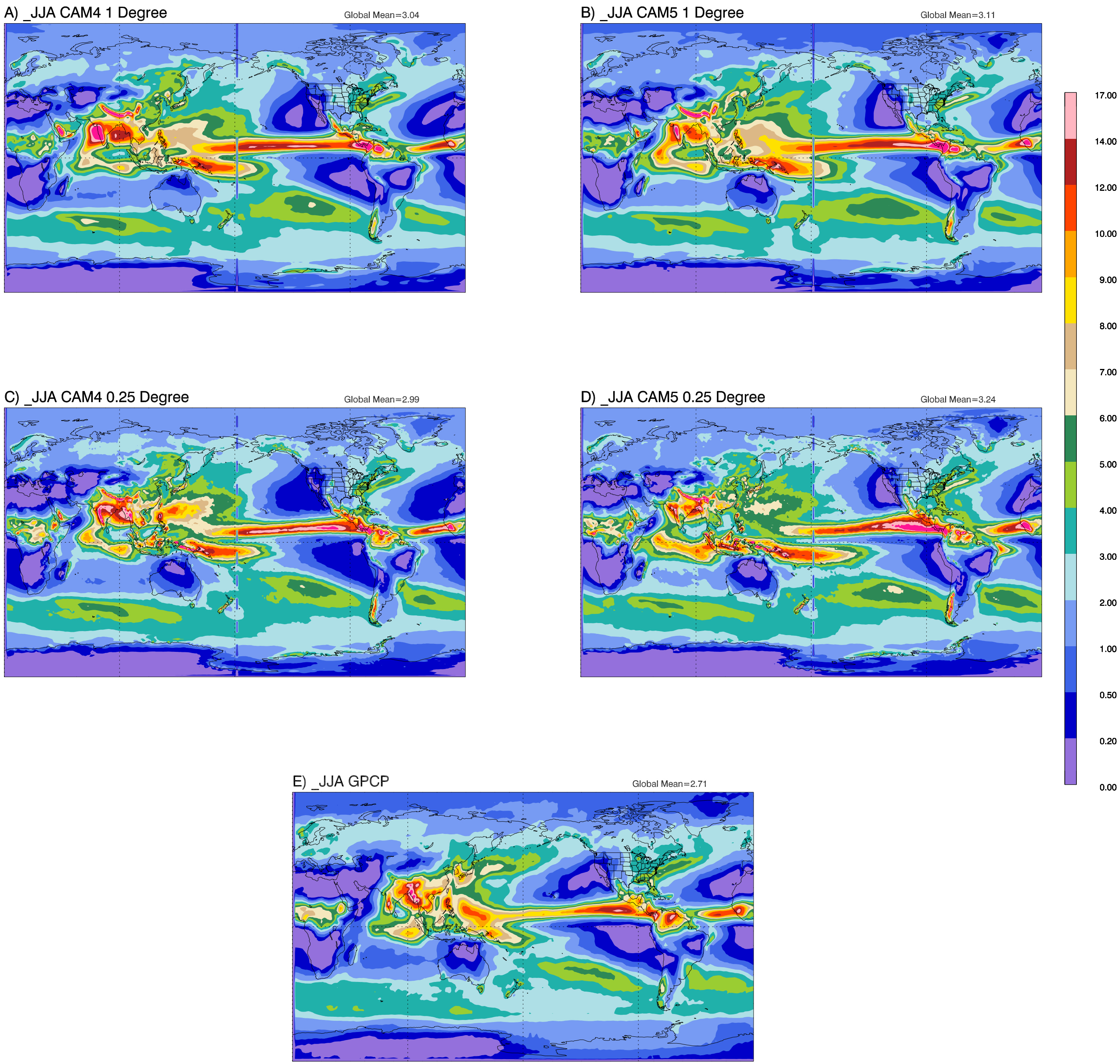
Sea-level Pressure

DJF



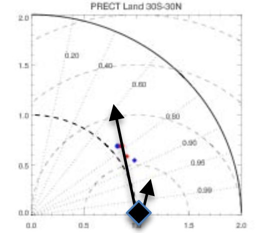
JJA

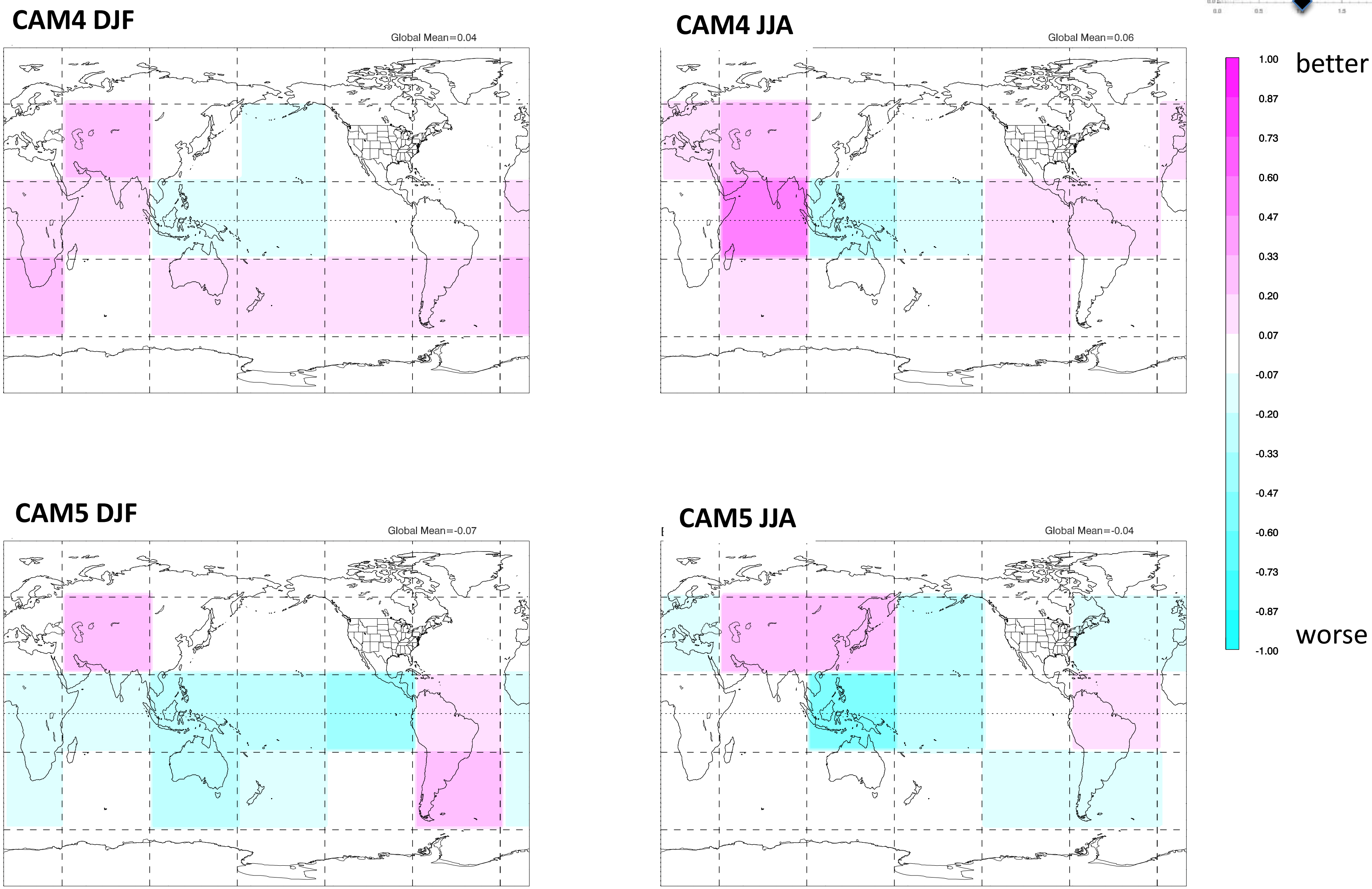




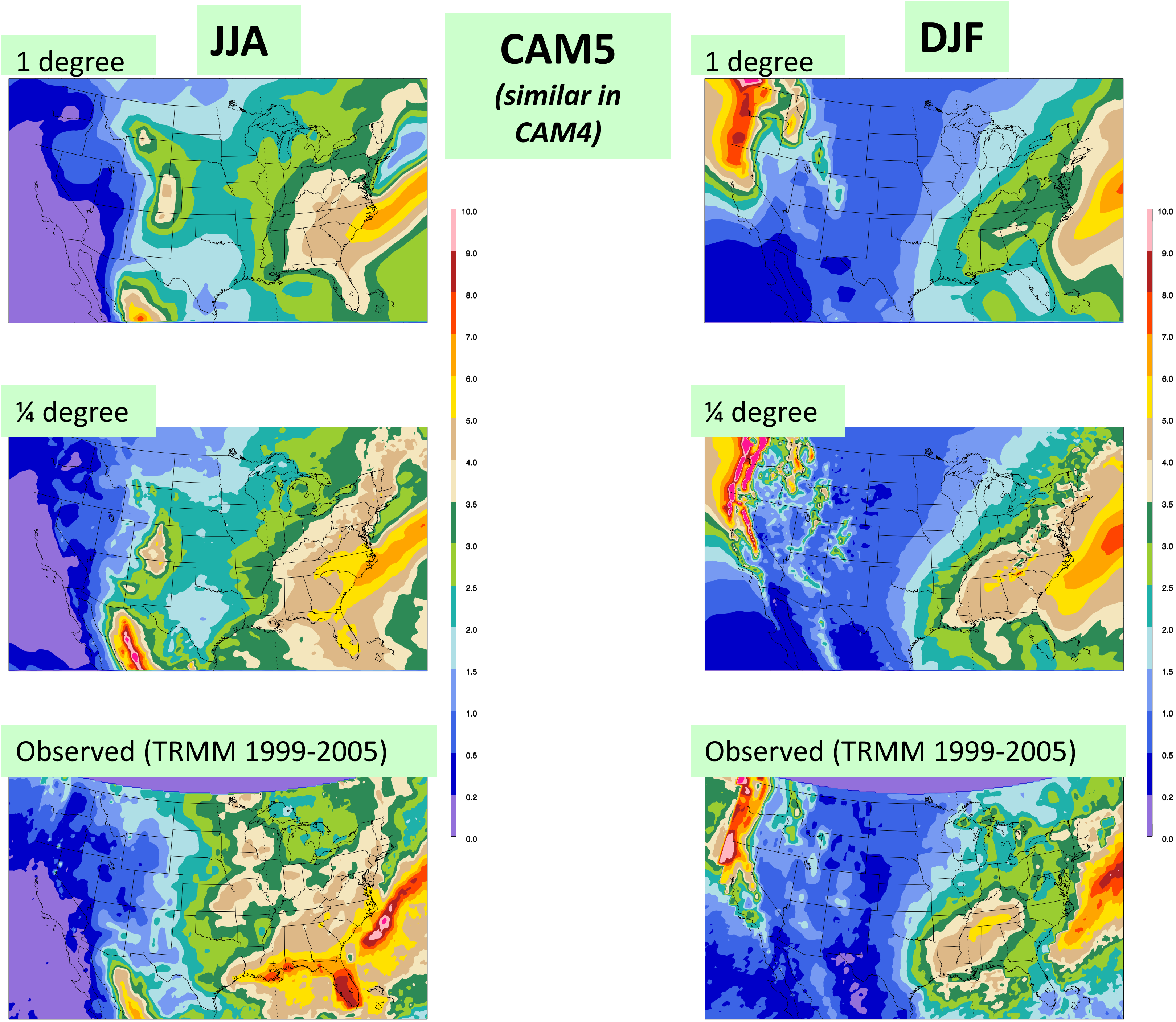
A) _JJA CAM4 1 Degree
Global Mean=3.04
B) _JJA CAM5 1 Degree
Global Mean=3.11
C) _JJA CAM4 0.25 Degree
Global Mean=2.99
D) _JJA CAM5 0.25 Degree
Global Mean=3.24
E) _JJA GPCP
Global Mean=2.71
17.00
14.00
12.00
10.00
9.00
8.00
7.00
6.00
5.00
4.00
3.00
2.00
1.00
0.50
0.20
0.00

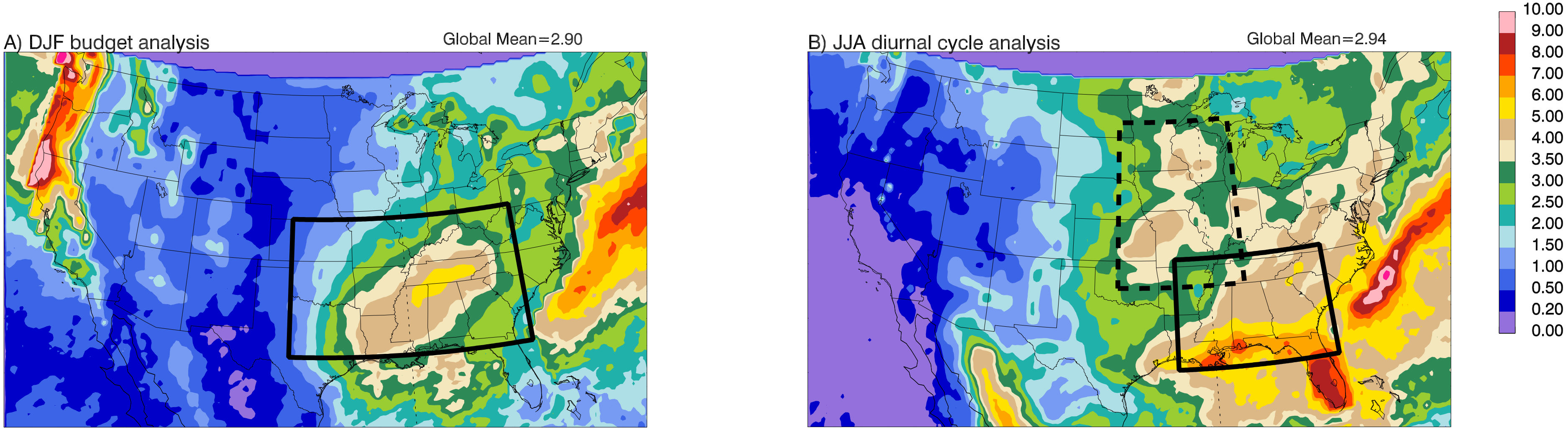
Regional change in precipitation Taylor metric (distance from [1,0]) with increasing resolution



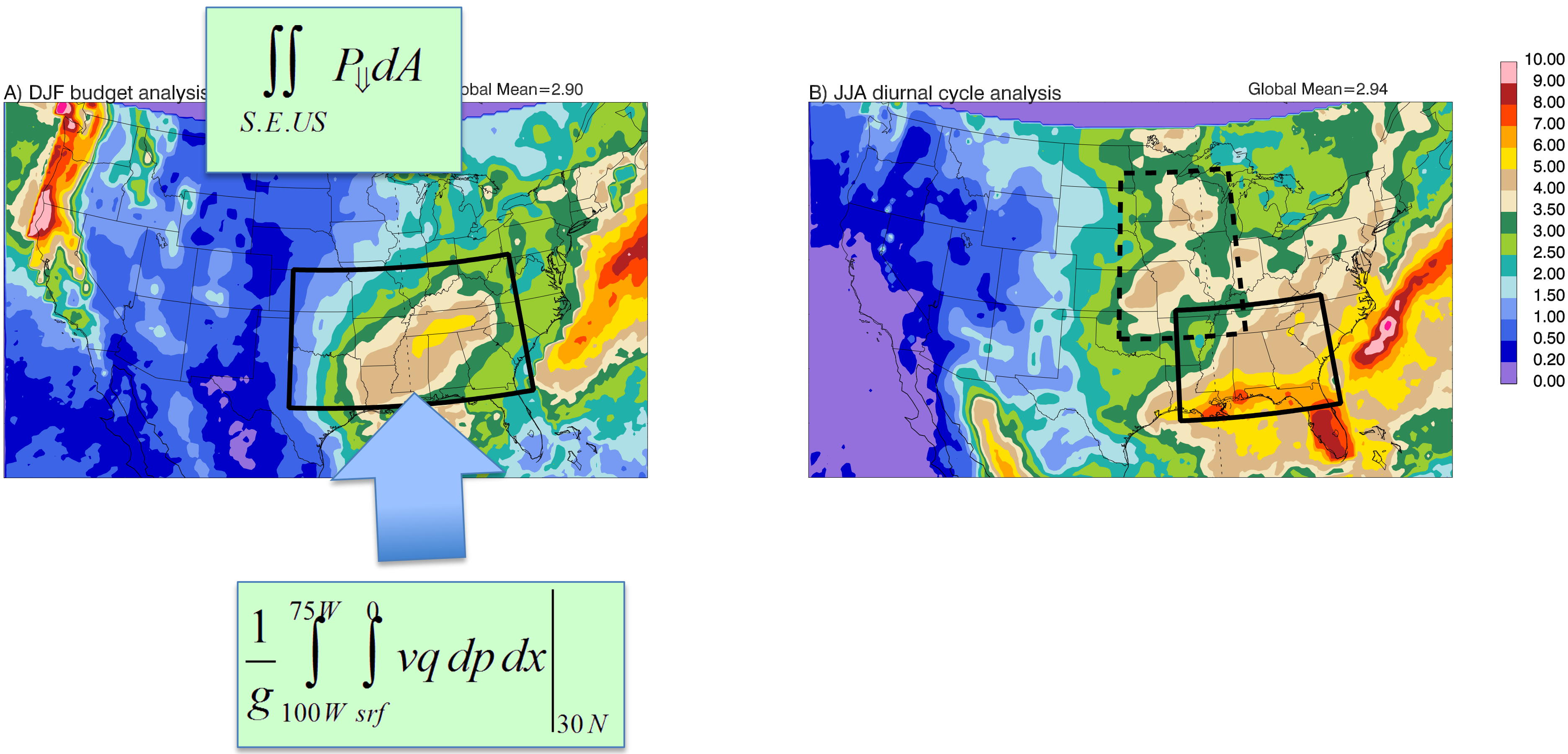


Regional Impact of Increased Resolution in US


JJA
CAM5
(similar in CAM4)
DJF
1 degree
1 degree
¼ degree
¼ degree
Observed (TRMM 1999-2005)
Observed (TRMM 1999-2005)
10.0
9.0
8.0
7.0
6.0
5.0
4.0
3.5
3.0
2.5
2.0
1.5
1.0
0.5
0.2
0.0

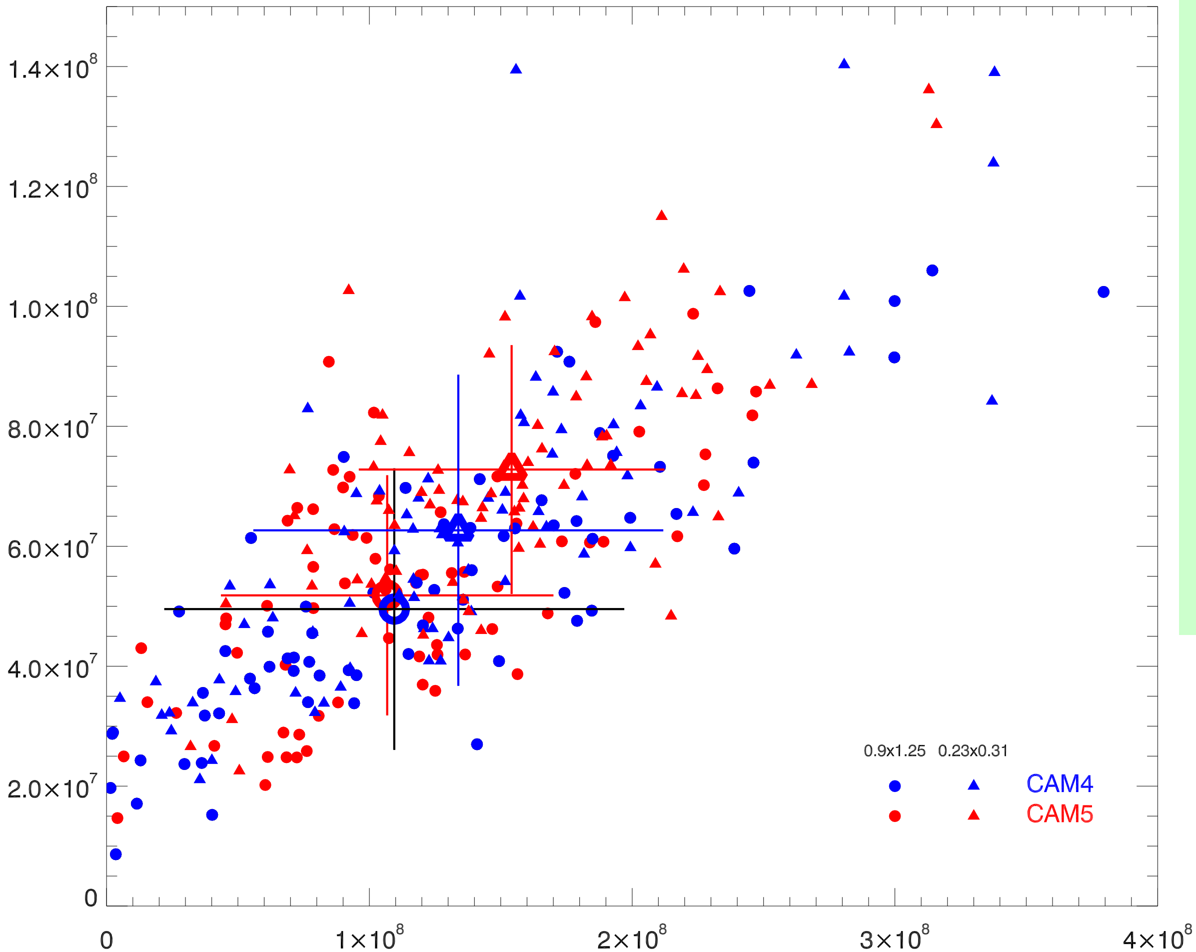


A) DJF budget analysis
Global Mean=2.90
B) JJA diurnal cycle analysis
Global Mean=2.94
10.00
9.00
8.00
7.00
6.00
5.00
4.00
3.50
3.00
2.50
2.00
1.50
1.00
0.50
0.20
0.00



A) DJF budget analysis
Global Mean=2.90
$\iint_{S.E.US} P_{\Downarrow} dA$
$\frac{1}{g} \int_{100W}^{75W} \int_{srf}^{0} vq \, dp \, dx \Big|_{30N}$
B) JJA diurnal cycle analysis
Global Mean=2.94
10.00
9.00
8.00
7.00
6.00
5.00
4.00
3.50
3.00
2.50
2.00
1.50
1.00
0.50
0.20
0.00

DJF Northward moisture transport into SE US vs. area integrated precipitation



$$\iint_{S.E.US} P_{\Downarrow} dA$$

$$\frac{1}{g} \int_{100W}^{75W} \int_{srf}^{0} vq \, dp \, dx \Bigg|_{30N}$$

r~0.7 for all cases

"Regional Efficiency" ~0.3-0.4

Precip means

CAM5

7.3e7 kg/s (1/4 deg)

5.2e7 (1 deg)

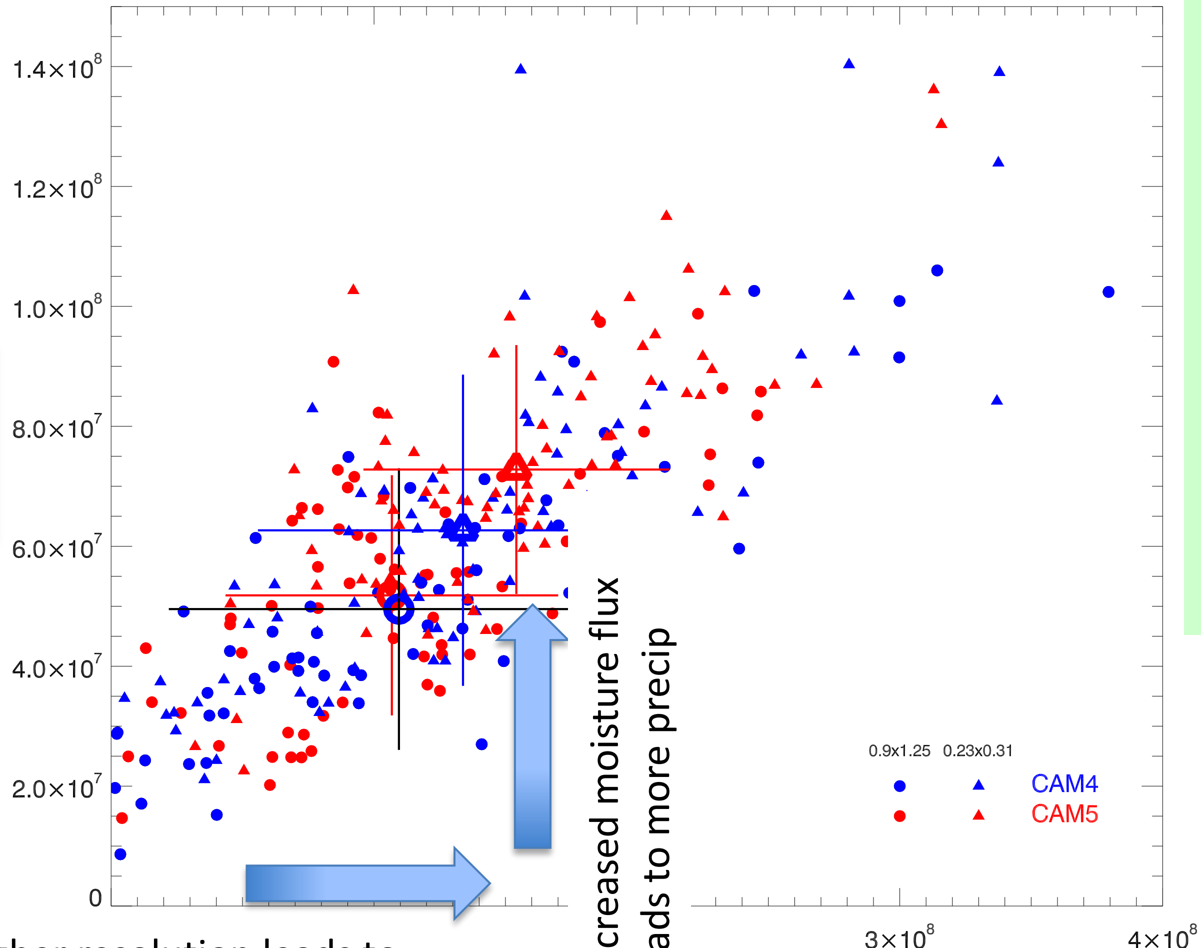
CAM4

6.2e7 (1/4 deg)

4.9e7 (1 deg)

DJF Northward moisture transport into SE US vs. area integrated precipitation

$$\iint_{S.E.US} P_{\Downarrow} dA$$



Increased moisture flux leads to more precip

Higher resolution leads to increased moisture flux

$$\frac{1}{g}\int_{100W}^{75W}\int_{srf}^{0} vq\,dp\,dx\Big|_{30N}$$

r~0.7 for all cases

“Regional Efficiency” ~0.3-0.4

Precip means

CAM5

7.3e7 kg/s (1/4 deg)

5.2e7 (1 deg)

CAM4

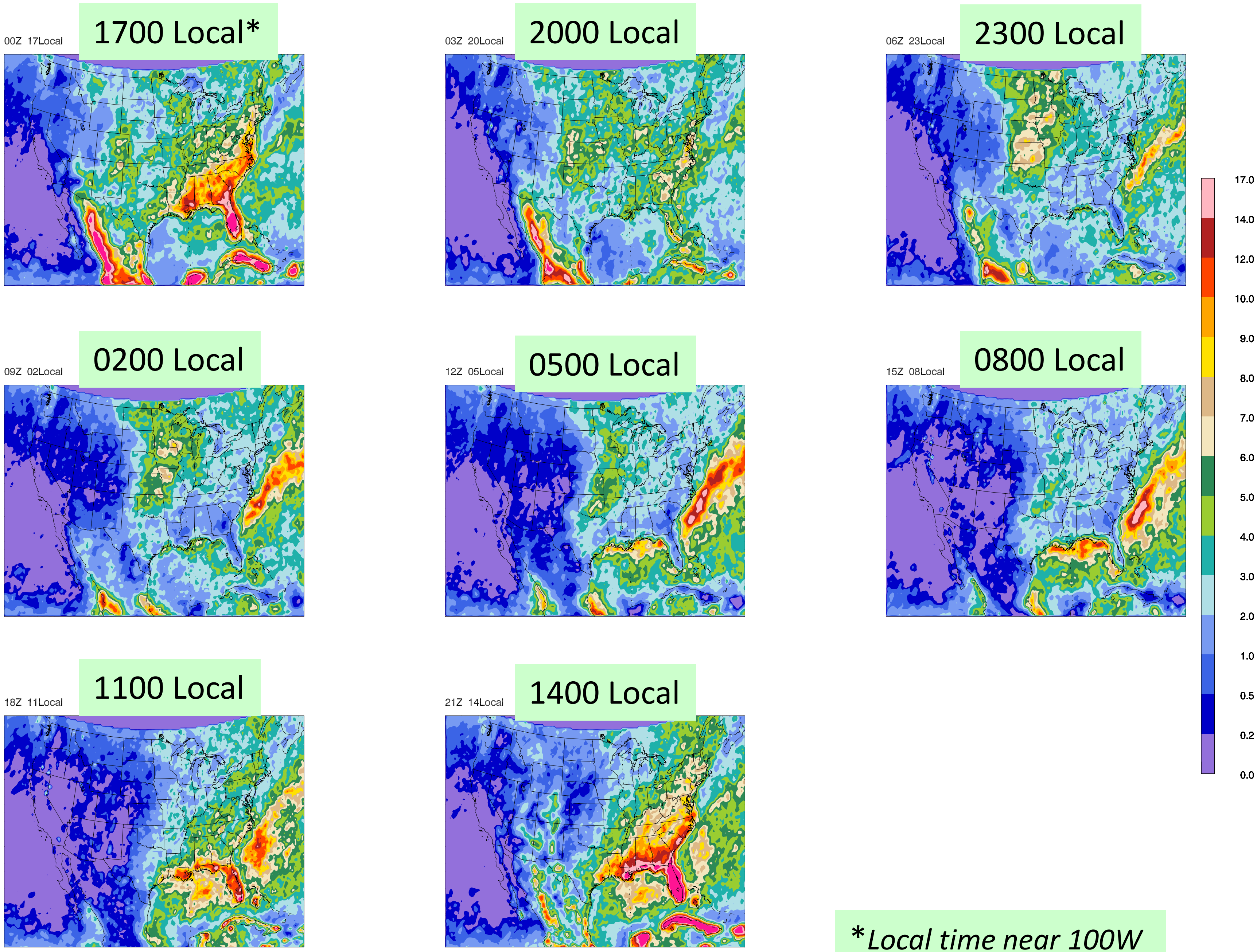
6.2e7 (1/4 deg)

4.9e7 (1 deg)

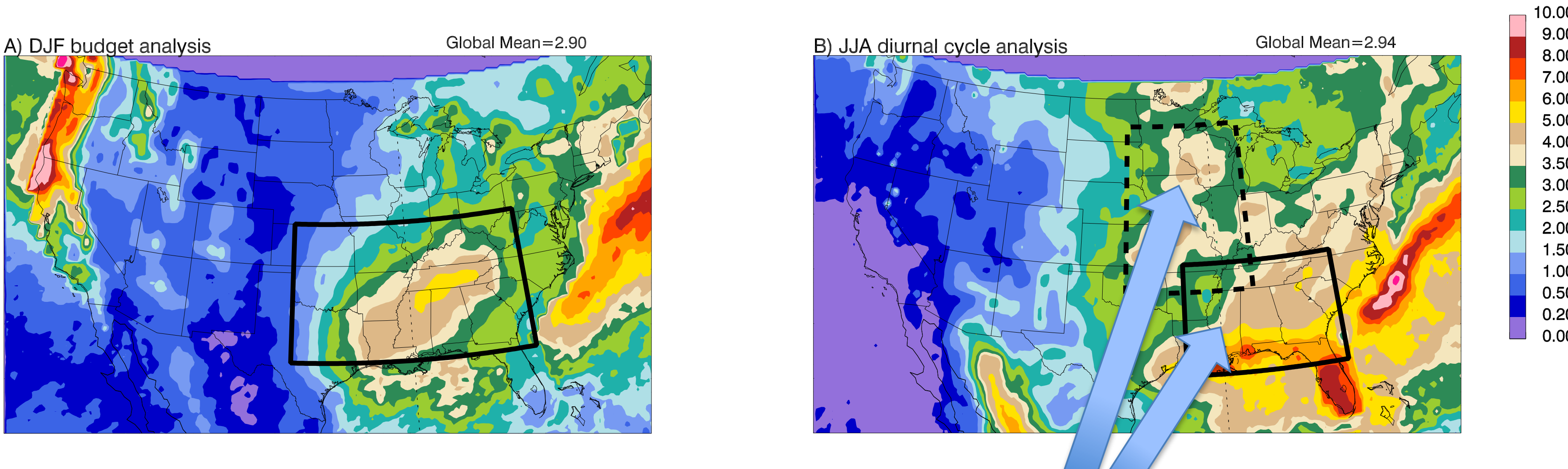
NOTE:

Increased moisture flux may be related to rougher topography, not resolution itself. High-resolution runs with smoothed topography exhibit weaker precipitation increase in SE US.

Mean diurnal cycle of precipitation in JJA 2000-2005 TRMM



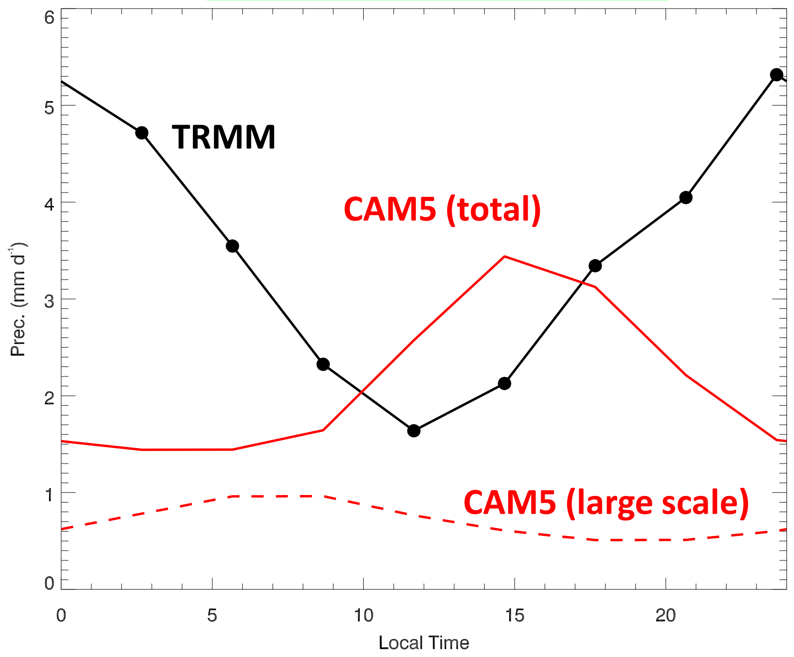
**Local time near 100W*



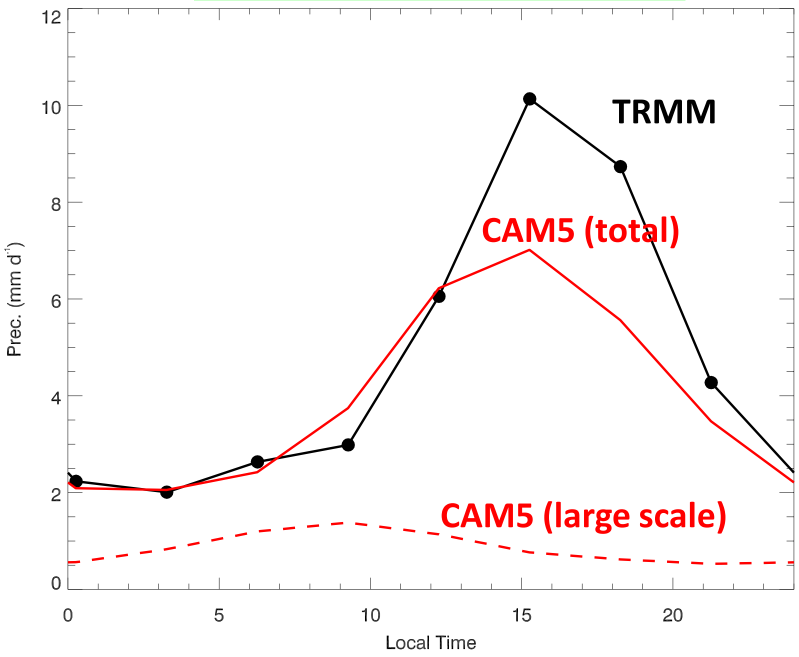
Average diurnal cycles of precipitation JJA 2000-2005

Mean diurnal cycle of precipitation in JJA 2000-2005 CAM5

90W-100W, 35N-45N
(Upper Midwest)



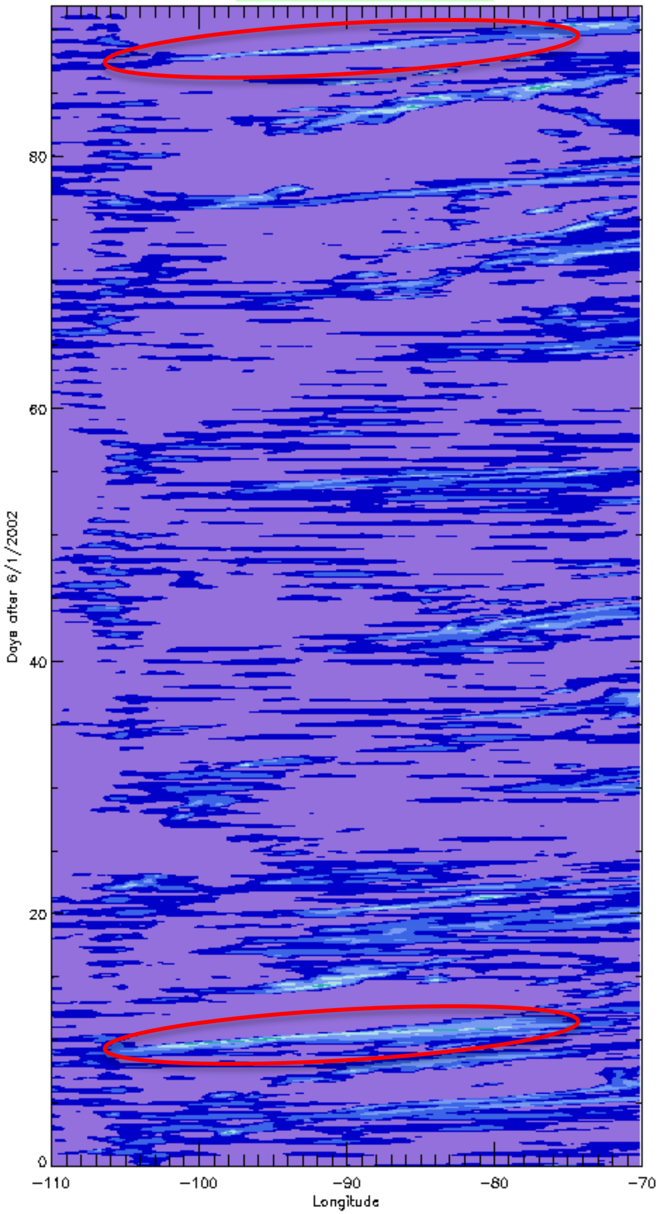
81W-91W, 30N-40N
(Southeast, Gulf Coast)



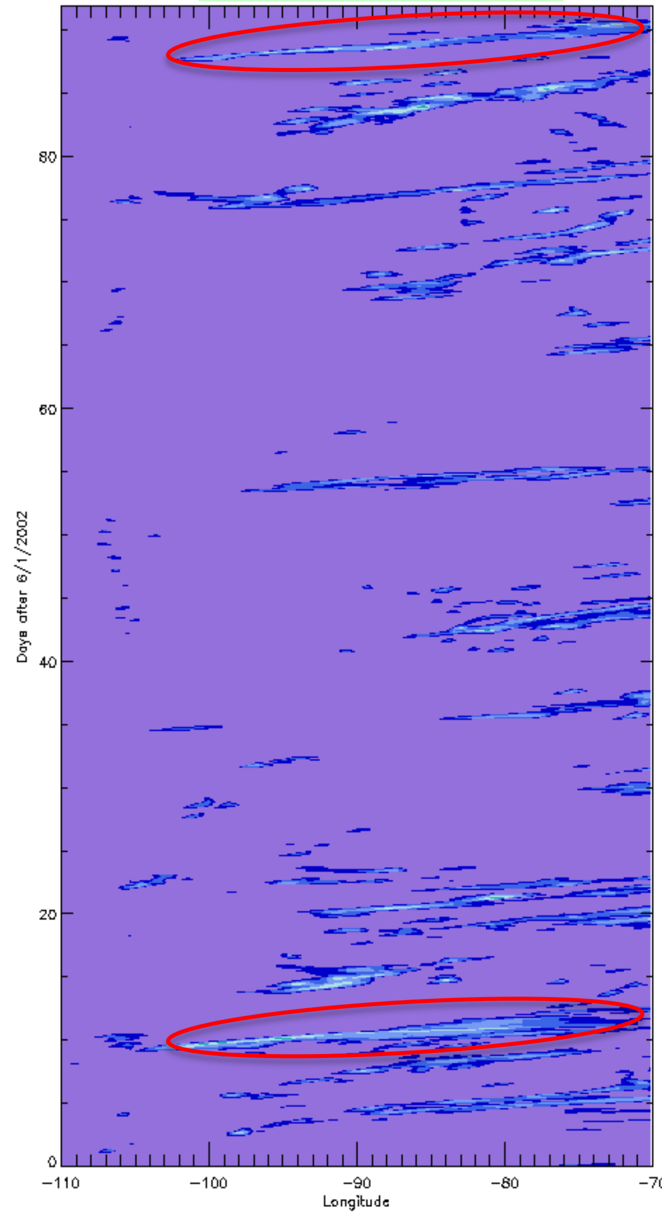
Precipitation Hovmuller diagrams June 1- Aug 31 2002 CAM5

Averaged 35N-45N

Total Precip.



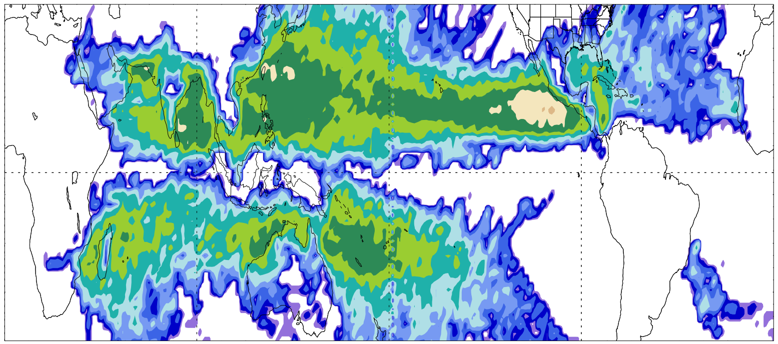
Large Scale Precip.



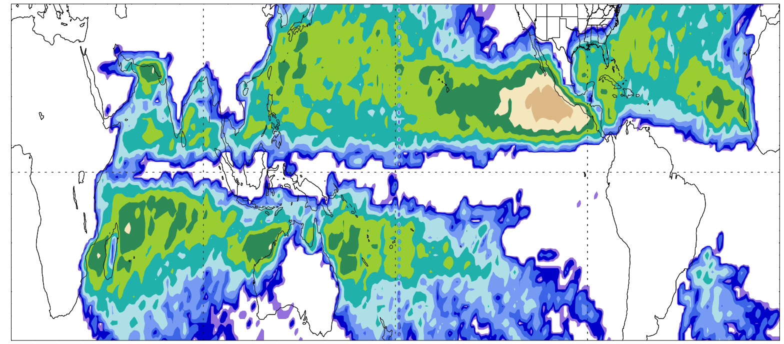
Tropical Cyclone Statistics

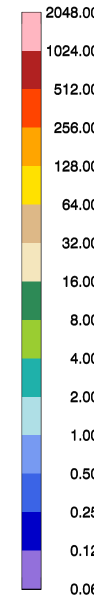
Hours per year per 1° gridbox with TS-Cat 5. 1980-2004 avg

CAM4

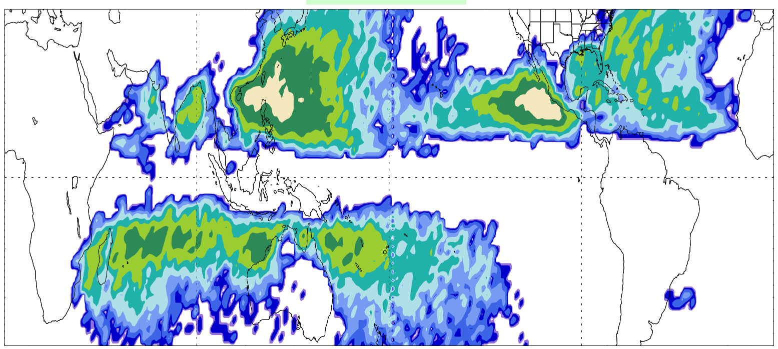


CAM5

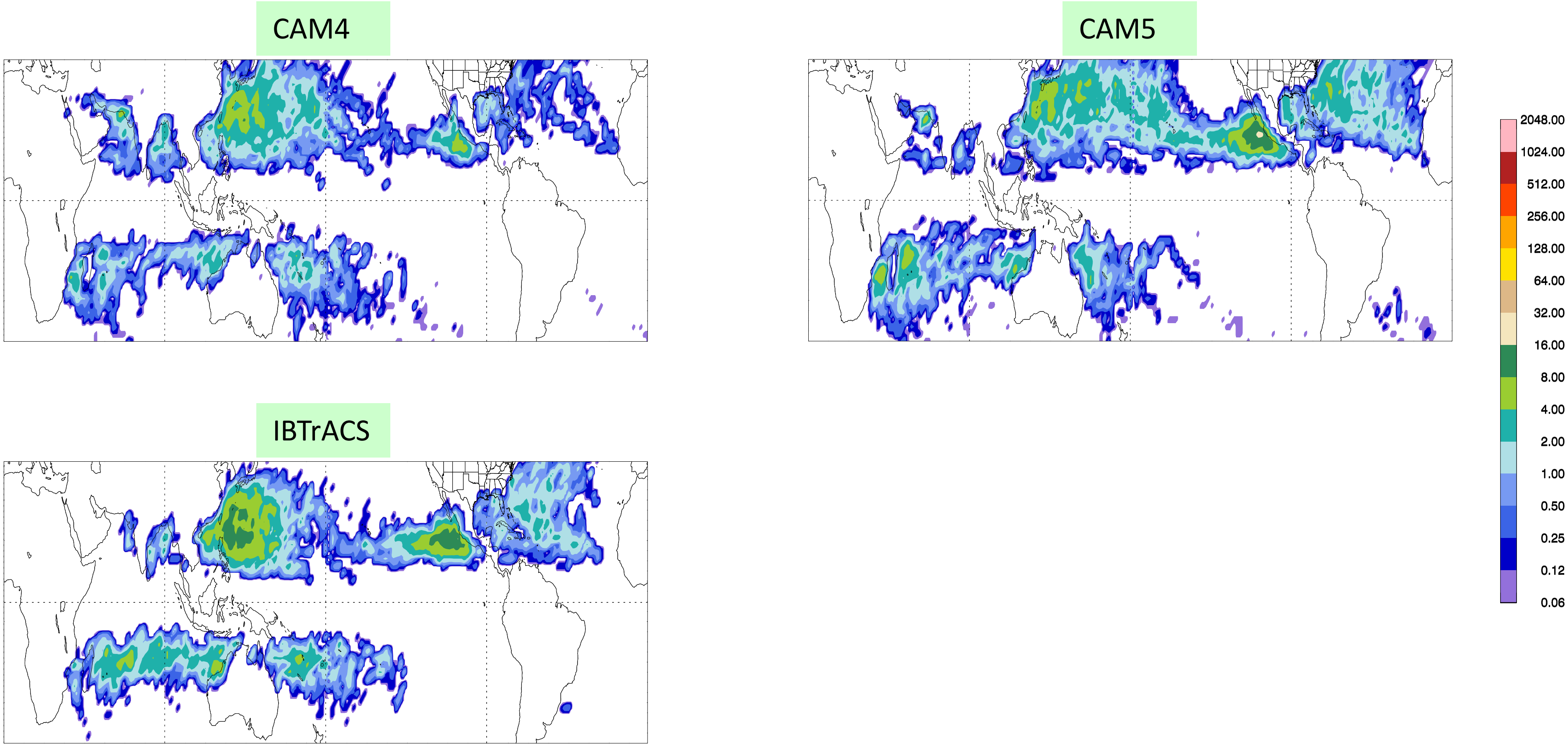




IBTrACS

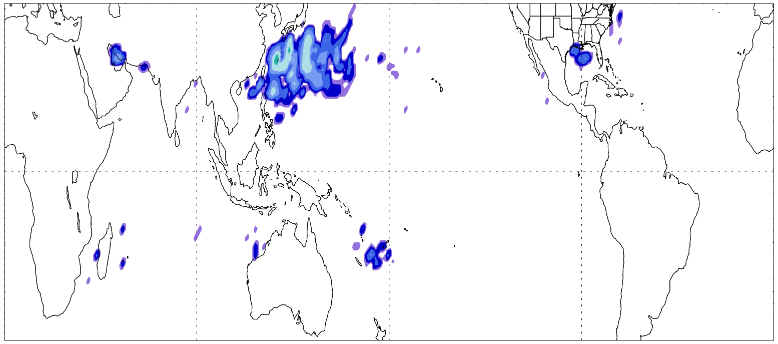


Hours per year per 1° gridbox with Cat 1-Cat 5. 1980-2004 avg

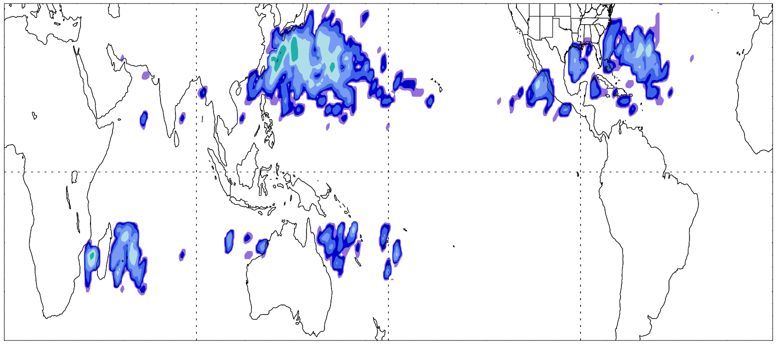


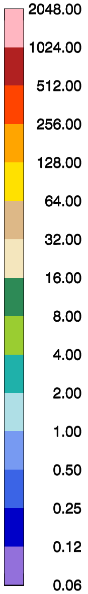
Hours per year per 1° gridbox with Cat 3-Cat 5. 1980-2004 avg

CAM4

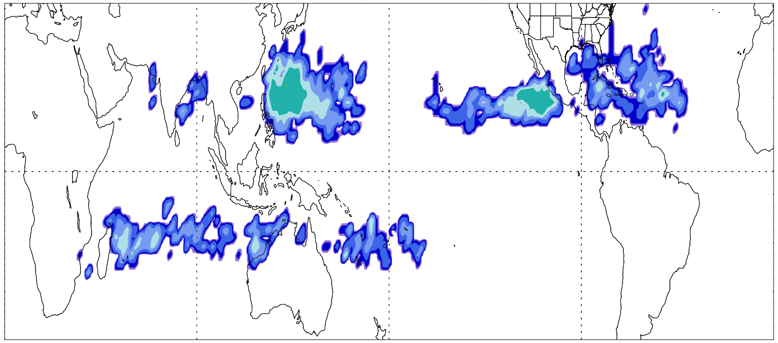


CAM5

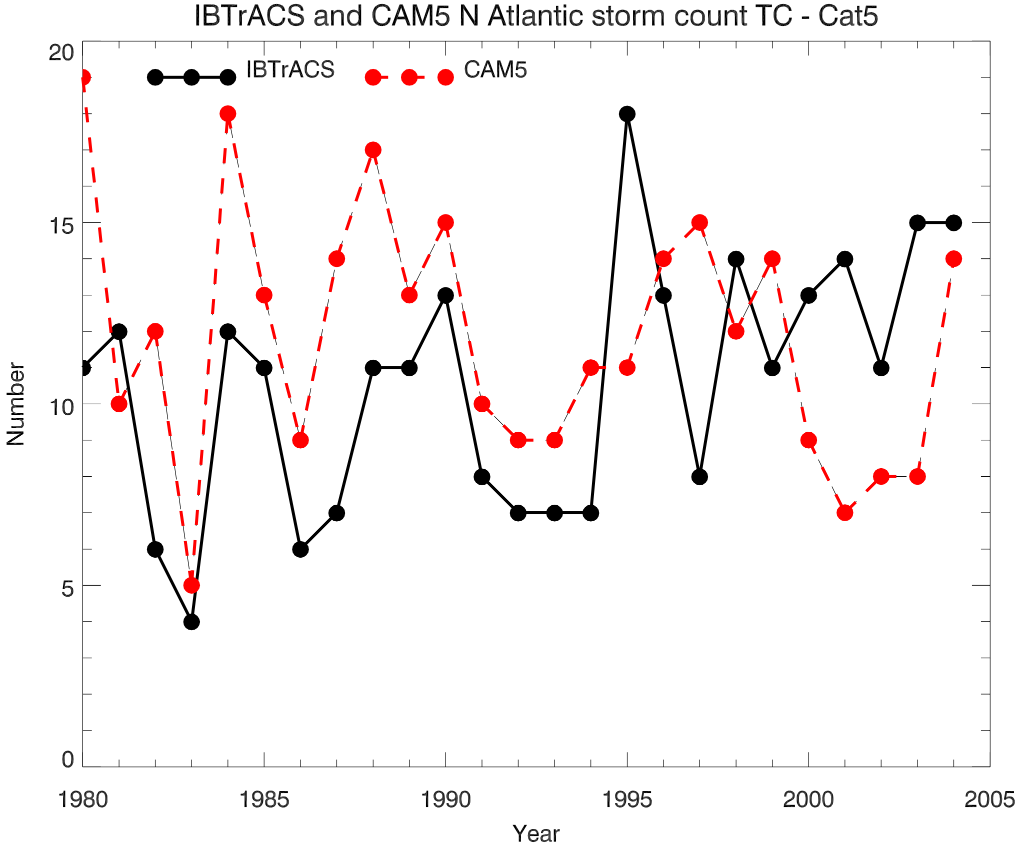




IBTrACS



N Atlantic Tropical Cyclone number (TS-Cat 5)

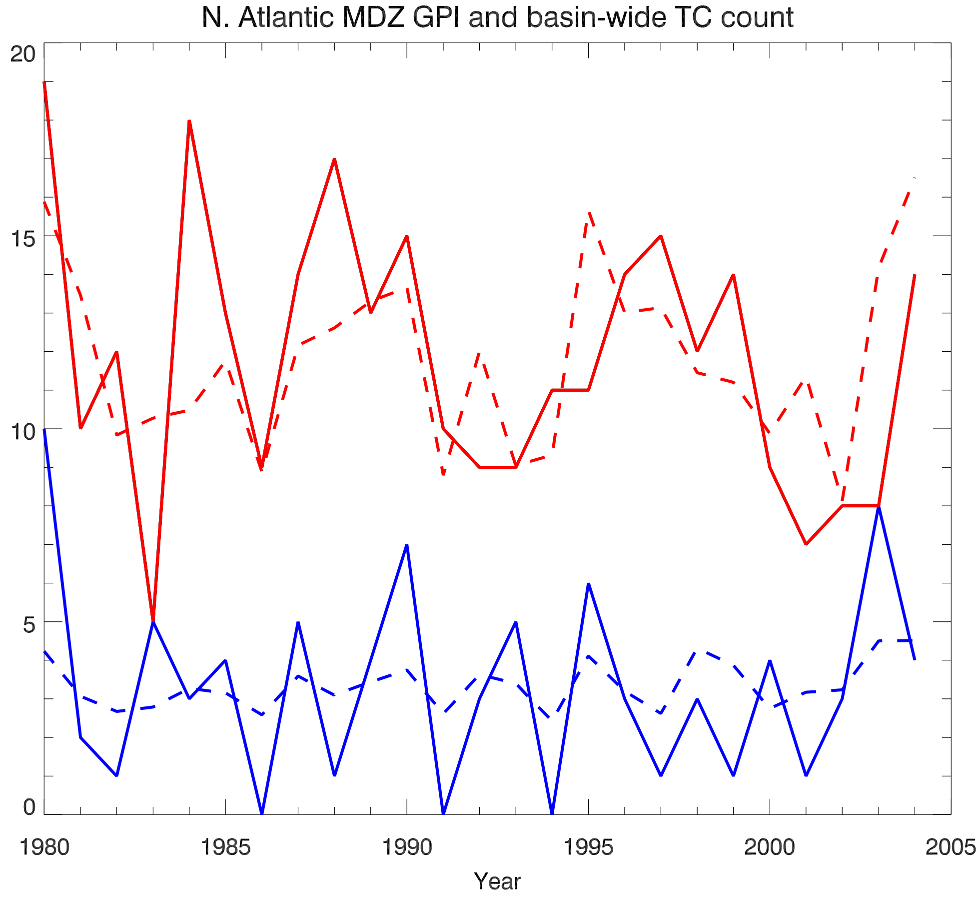


Years 1980-1994: r= 0.72
Years 1980-2004: r= 0.20

GPI vs N Atlantic Tropical Cyclone number (TS-Cat 5)

CAM5 r= 0.45

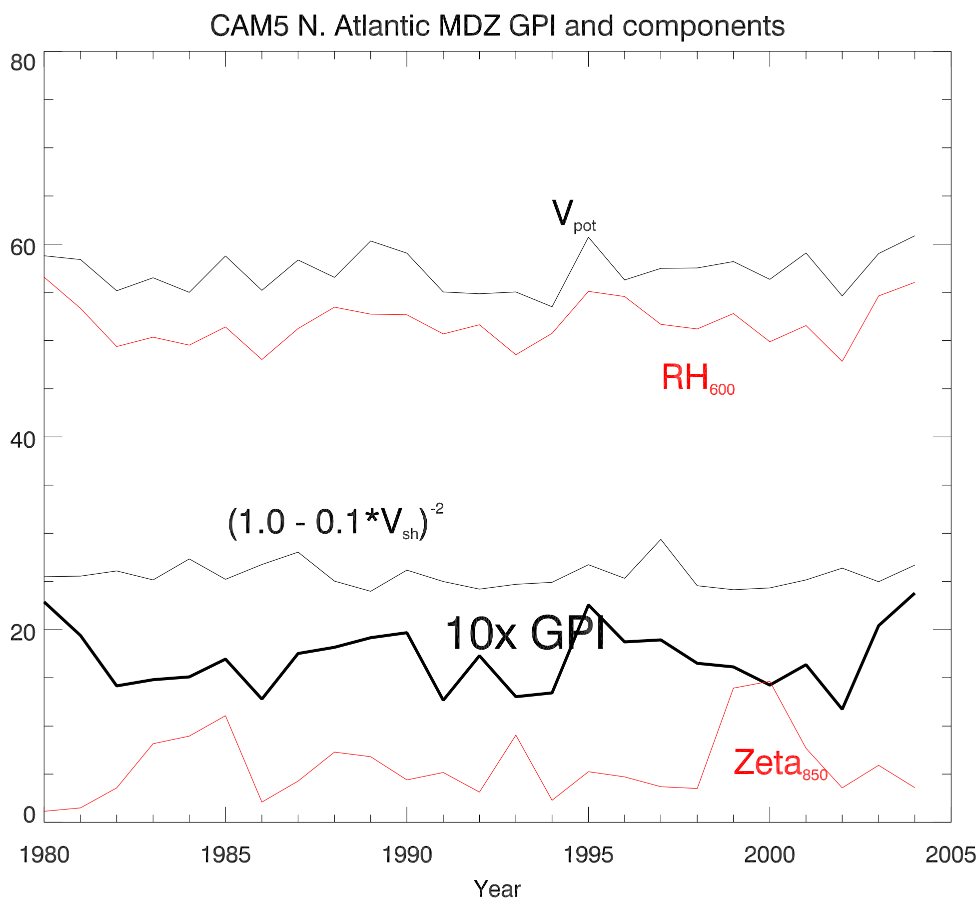
CAM4 r= 0.67



GPI is areally-averaged in N Atlantic “max. development zone” then scaled

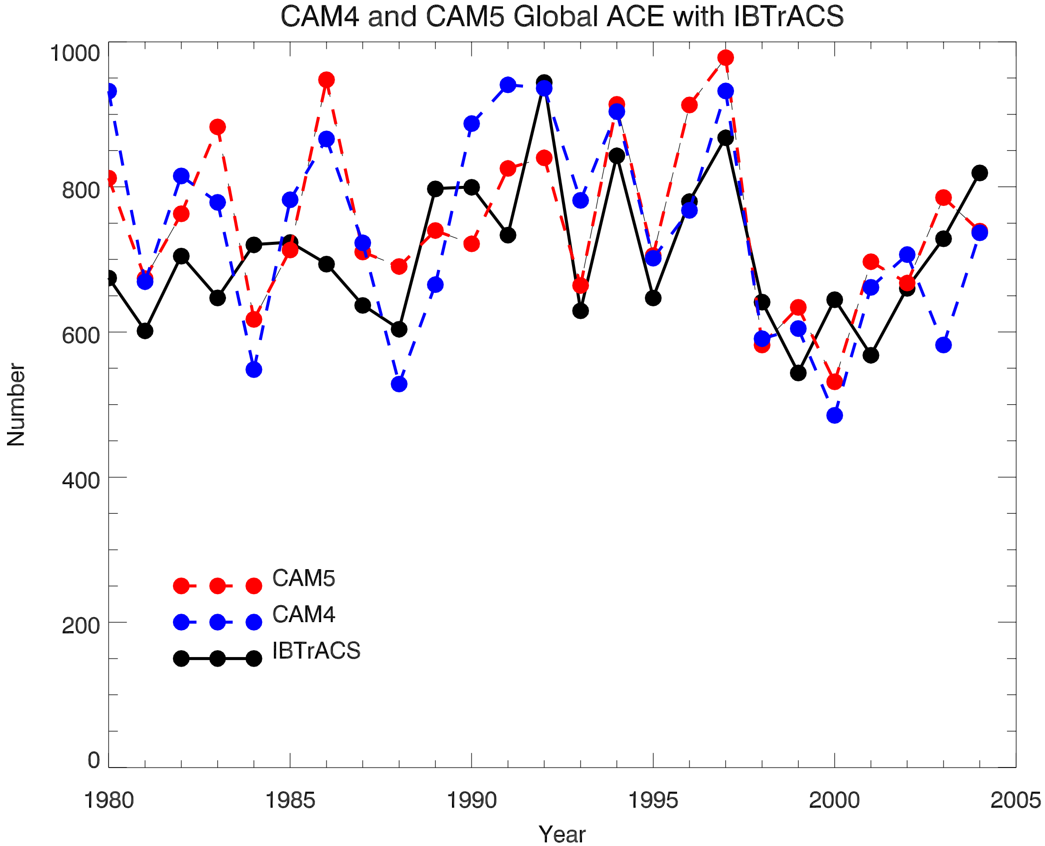
Components of GPI in N Atlantic

$$\mathrm{GP} = |10^5\eta|^{3/2}\left(\frac{\mathcal{H}}{50}\right)^3\left(\frac{V_{\mathrm{pot}}}{70}\right)^3(1 + 0.1V_{\mathrm{shear}})^{-2},$$



Global Accumulated Cyclone Energy (ACE)

$$ACE = 10^{-4} \sum_i V_i^2$$ *(Bell et al 2000)*



Years 1980-2004 CAM4/IBTrACS: r= 0.57
Years 1980-2004 CAM5/IBTrACS: r= 0.57
Years 1980-2004 CAM4/CAM5 : r= 0.75

Basinwide, global ACE are not as sensitive to tracking algorithms as number

Summary of Tropical Cyclone Statistics

- Climatological geographic distribution is reasonable
- CAM4 and CAM5 differ strongly in N Atlantic
- Interannual variability has some positive aspects, but still needs improvement.
- Global ACE agrees with obs. and across models (??!!)
- ***Not shown:*** *TC-cores dominated by large-scale precip*

Caveats:

- **ONE ensemble member for each model.**
- **Track algorithms influence statistics, especially number of weak storms *(but not ACE)***

Looking Ahead

CAM5-SE is ready for work

- Climate of SE ne30 (~100km) now close to FV 0.9x1.25 –coupled as well as uncoupled
- Tropical ice-cloud issues in 0.23x0.31 persist in ne120
- CAM5-SE ne120 (~25km) AMIP run underway soon

How to proceed?

- Tune existing CAM5 physics in ne120?
  - Autoconversion
  - Convective time scale
  - TMS
- UNICON
- CLUBB
- Vertical resolution
- New/WACCM GW drag scheme
  - Non-zero phase speeds
  - Anisotropic mountain wave drag

Coupled high-res ocean/atmosphere project in the NCAR Accelerated Scientific Discovery program

- J. Small, F. Bryan, J. Tribbia, R. Tomas, D. Bailey, J. Dennis, A. Baker, J. Edwards, J. Caron, M. Vertenstein, T. Scheitlin, J. Bacmeister
- Aims: investigate the role of small scales in the ocean and ice on climate
- Machine: Yellowstone, using up to 22000 cores
- Coupled CAM5-SE ne120/pop 1/10$^{th:}$ present day
  - 40+ years
- Atmosphere-only simulations
  - with high resolution SST, 14 years
- Atmosphere-only sensitivity tests
  - Surface roughness, convection, topography
- Ocean-ice-only sensitivity
  - High-frequency ice-ocean coupling
  - Ocean viscosity (Gulf Stream separation)

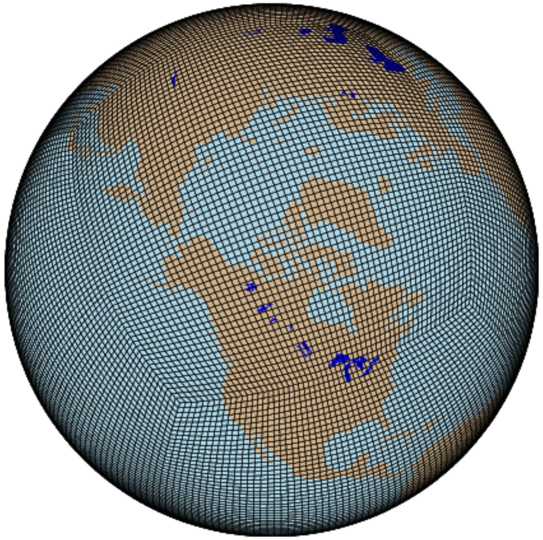
NCAR

SciDAC
Scientific Discovery through Advanced Computing

Thank You

CAM5 Regionally Refined

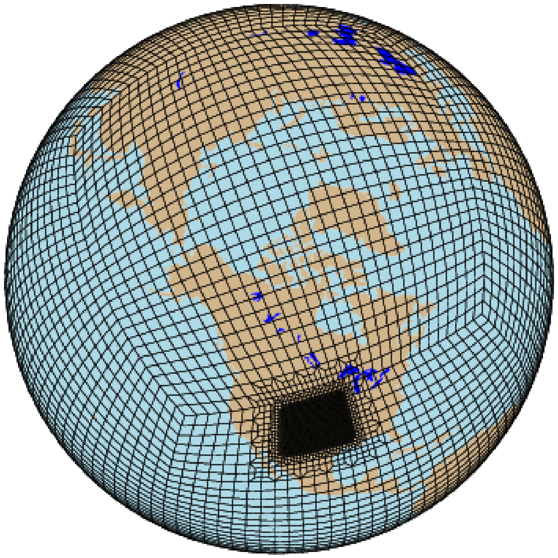
1° global resolution, refined to 1/8°



Global 1/8°

CAM5-SE has a very efficient, scalable and *expensive* global 1/8° configuration.

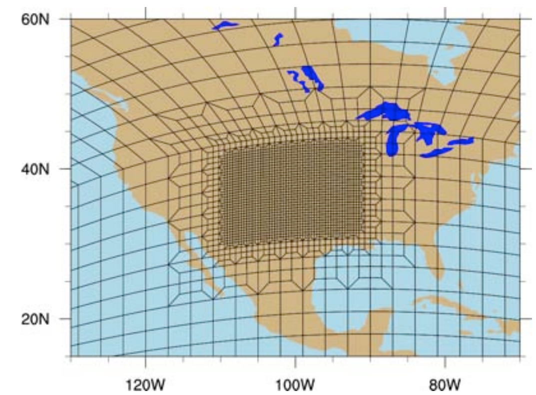
- 6M core hours per year (ANL Intrepid)
- Yellowstone: 1-2M core hours?
- 3.1M physics columns



SGP 8x Regionally Refined

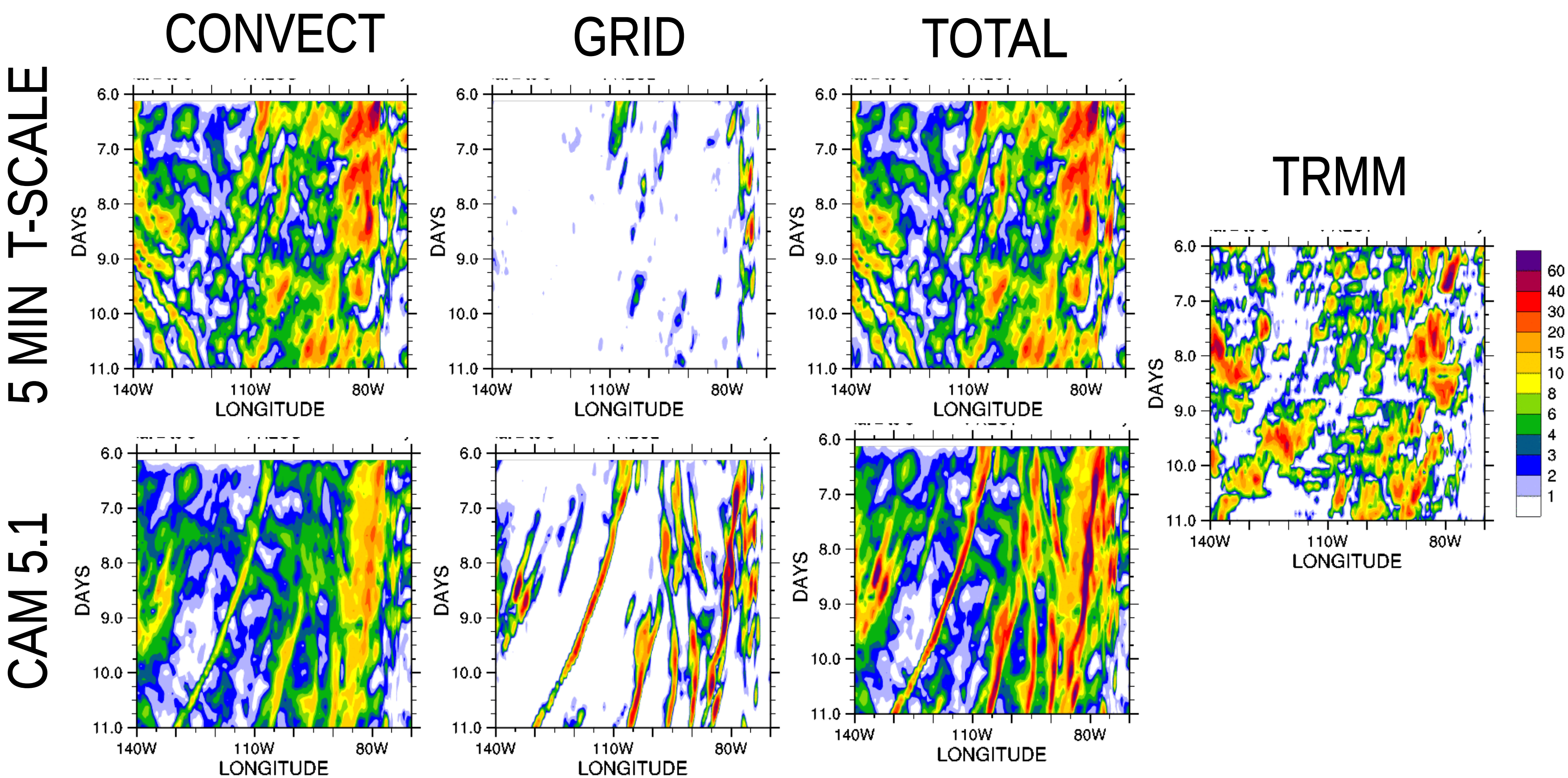
1° global resolution, refined to 1/8° continental sized region centered over SGP ARM site.

- 0.12 M core hours per year (Sandia Linux cluster).
- 67K columns.



Courtesy: Mark Taylor, DOE Sandia Labs

INDIVIDUAL FORECAST IC = 6 JAN

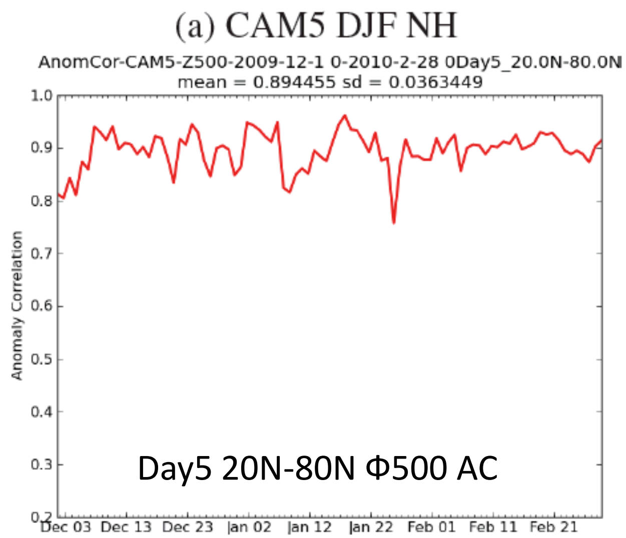


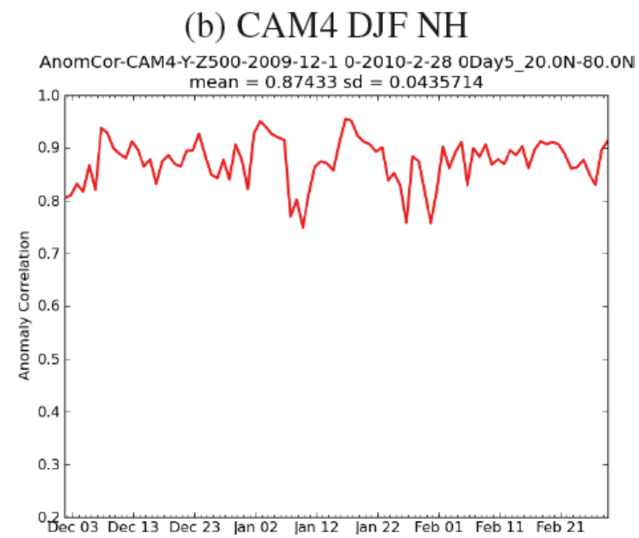
from Dave Williamson

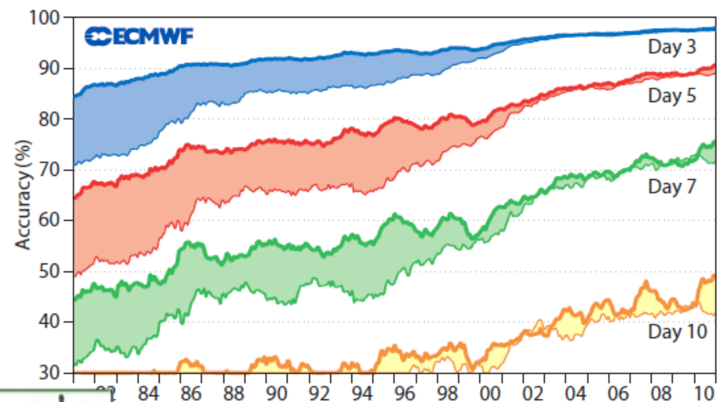
Model Skill for Hindcast Experiments

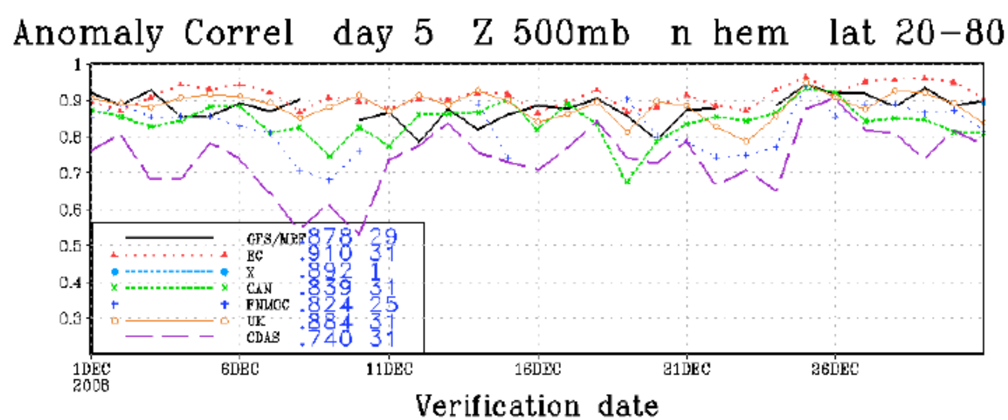
The values are comparable to those achieved by the major forecast centers.

Anomaly Correlation





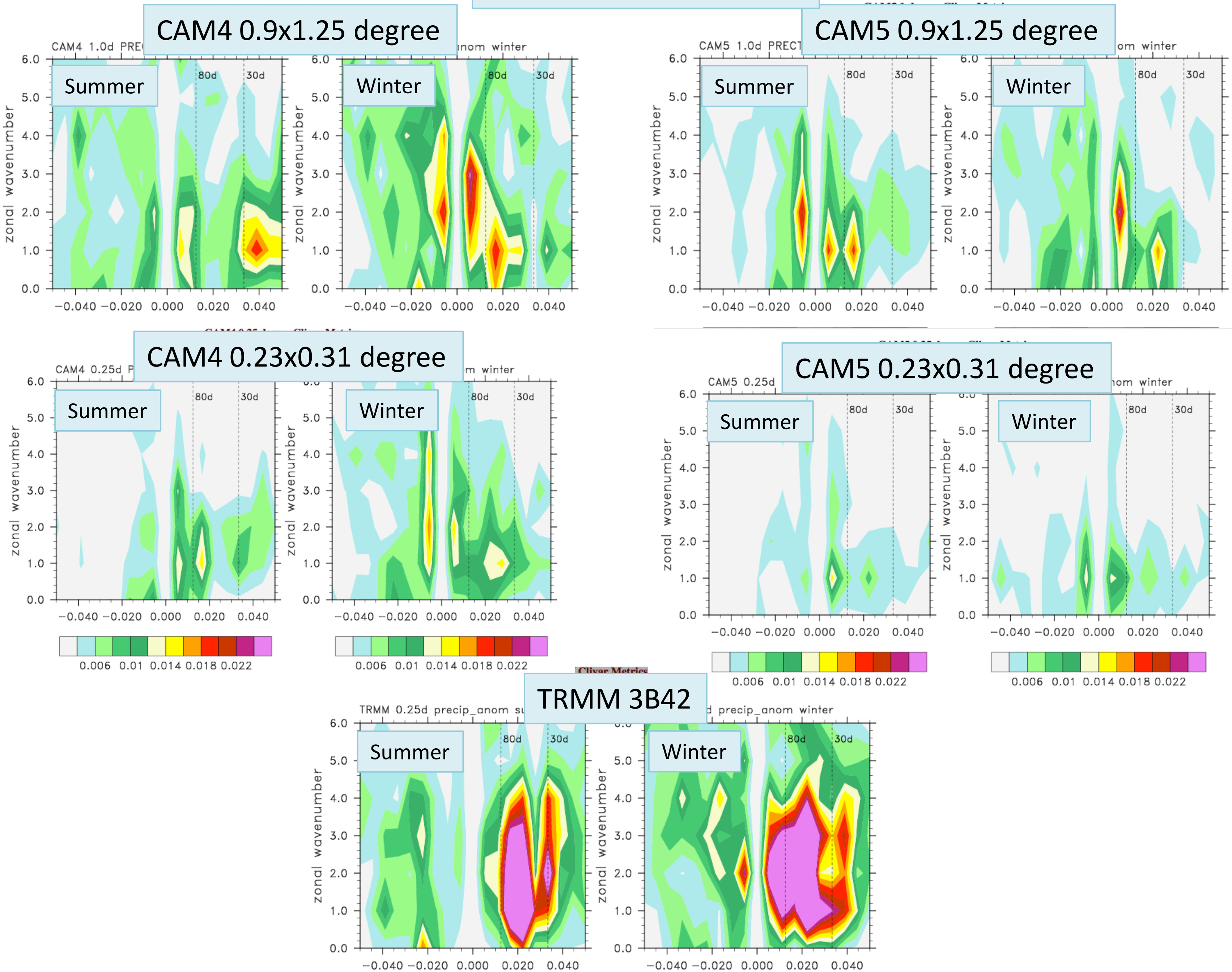


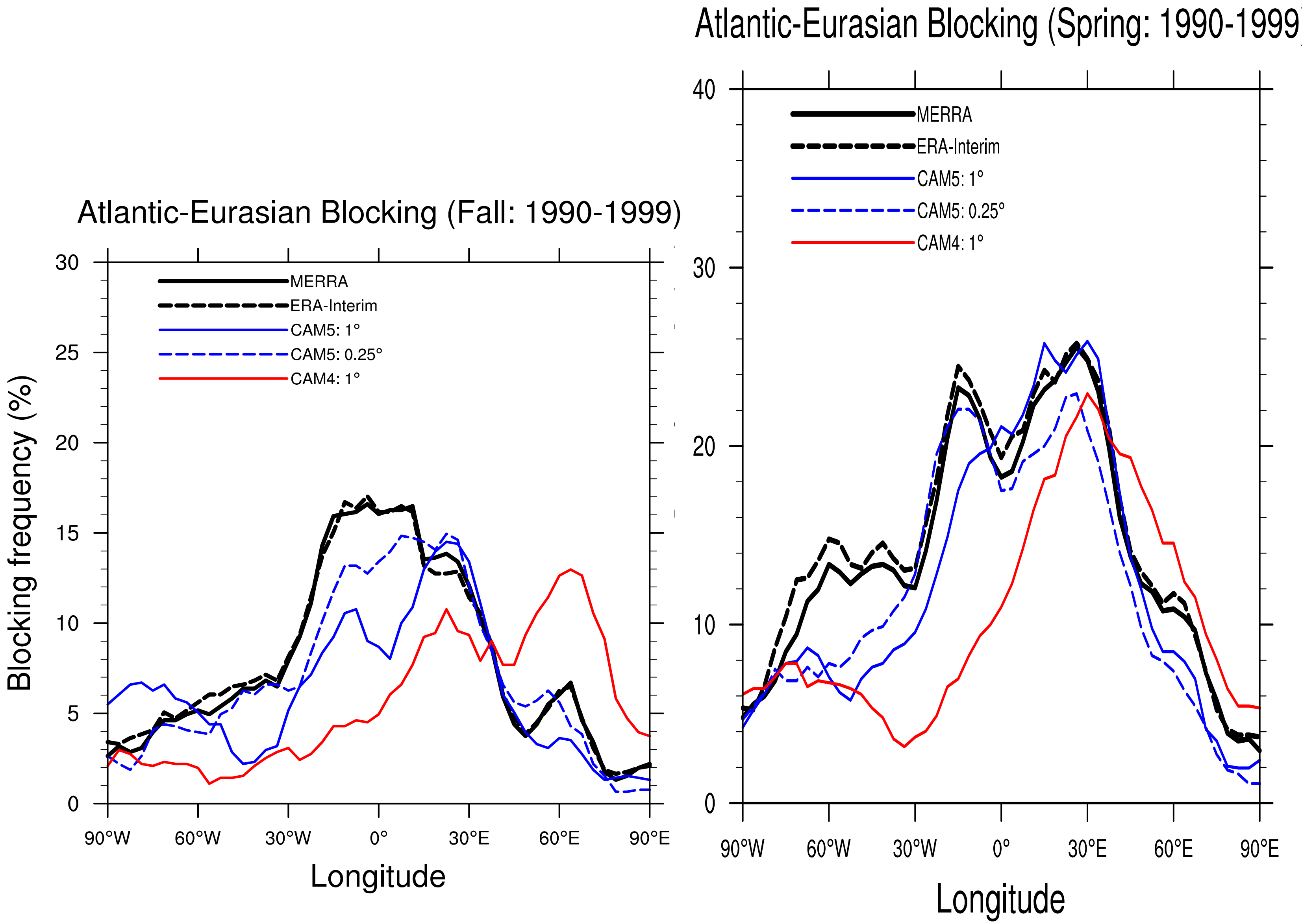


CAPT Cloud-Associated Parameterizations Testbed

Thanks: Steve Klein and Jim Boyle, LLNL

MJO CLIVAR Spectra





Tibaldi-Molteni index, courtesy *Rich Neale*

What is the impact of resolution for future projections ?

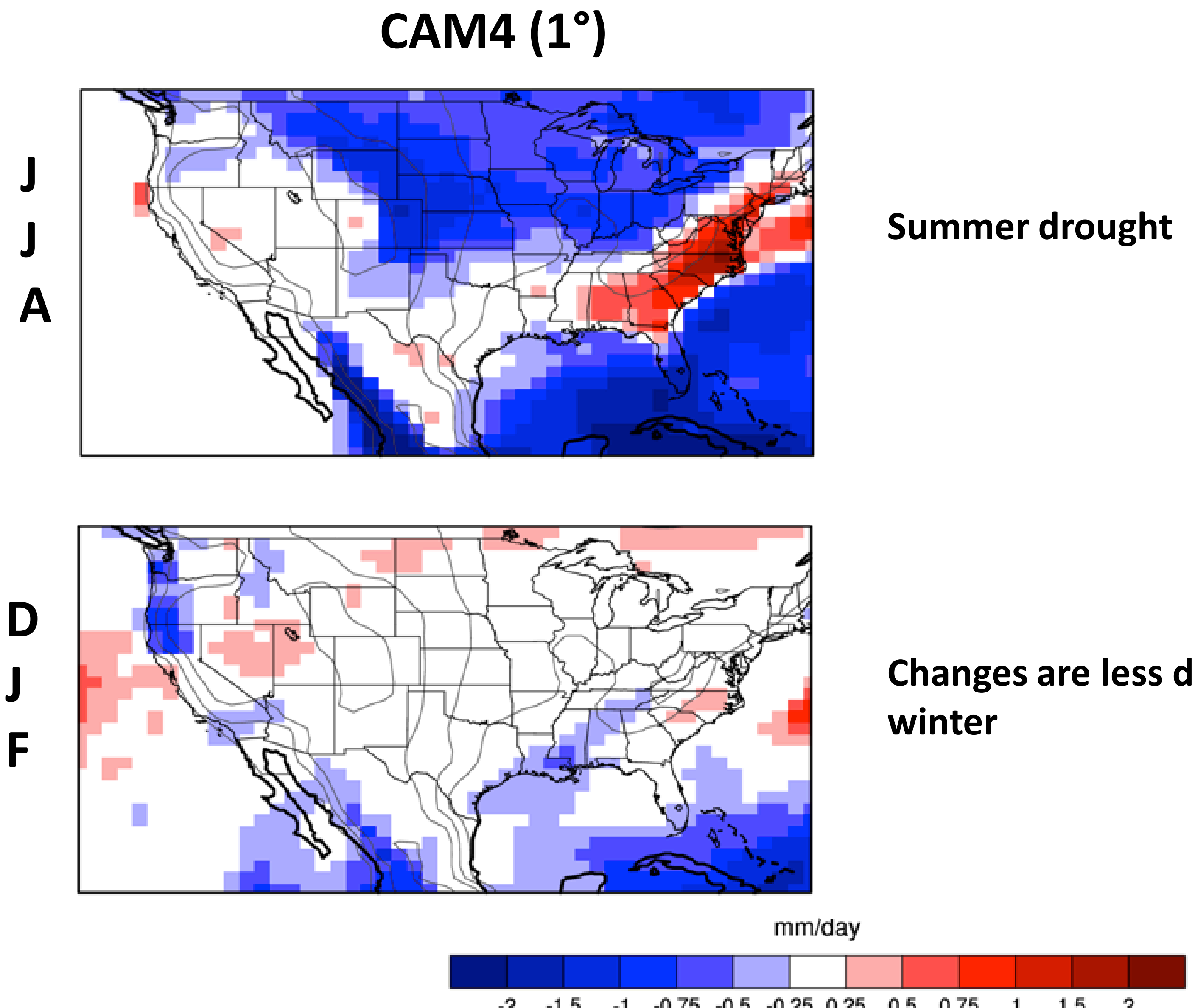
- **Present-day time-slice: Observed SSTs**

- **Future time-slice: SSTs from RCP8.5**
  + use correction for CESM SST bias
  + use correction for sea-ice cover (Hurrell *et al*, 2008)

- **Precipitation change = Prec[2081-2100] – Prec[1981-2000]**

From Cécile Hannay

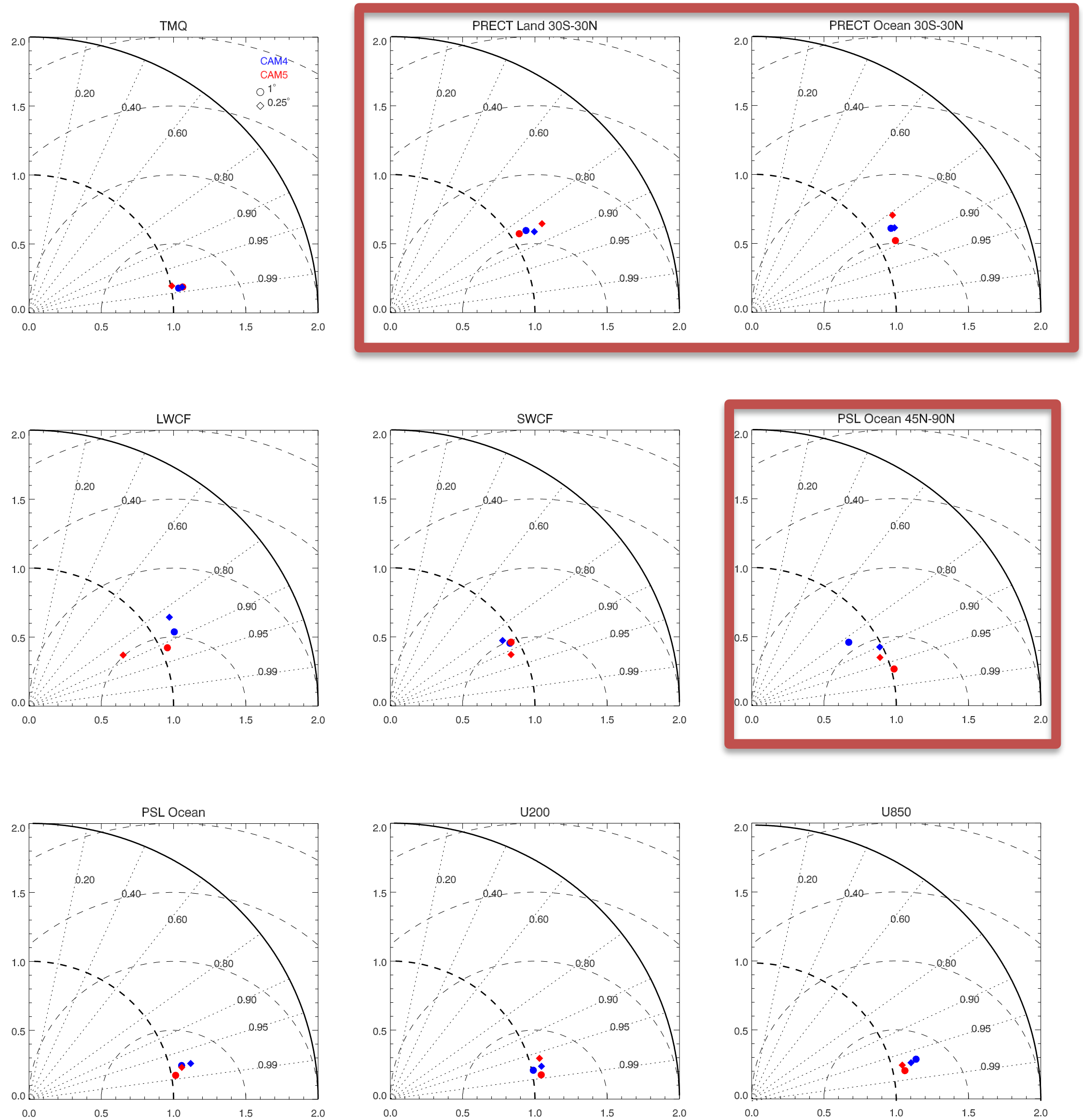
Change in precipitation over the US



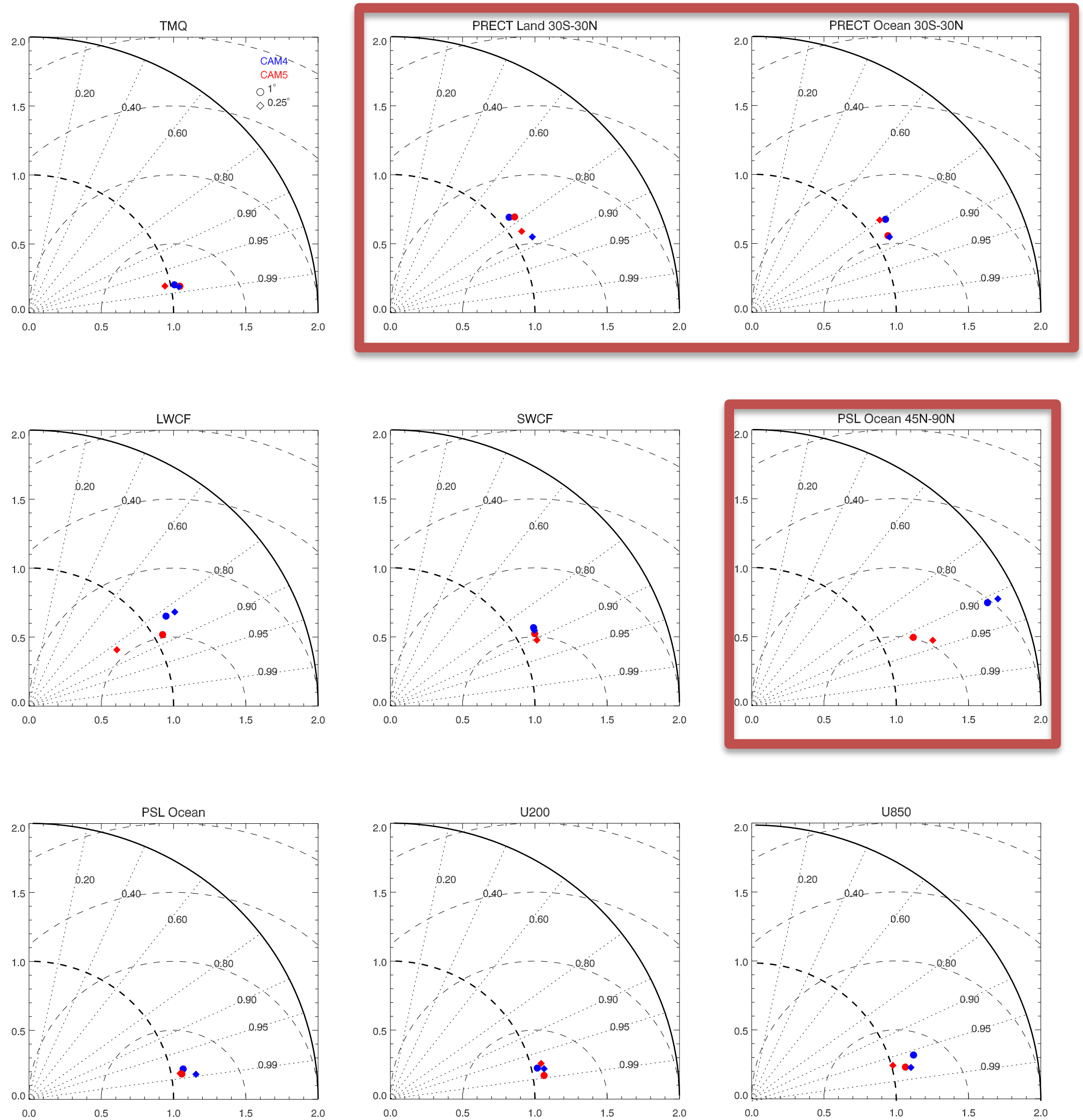
Summer drought

Changes are less dramatic in winter

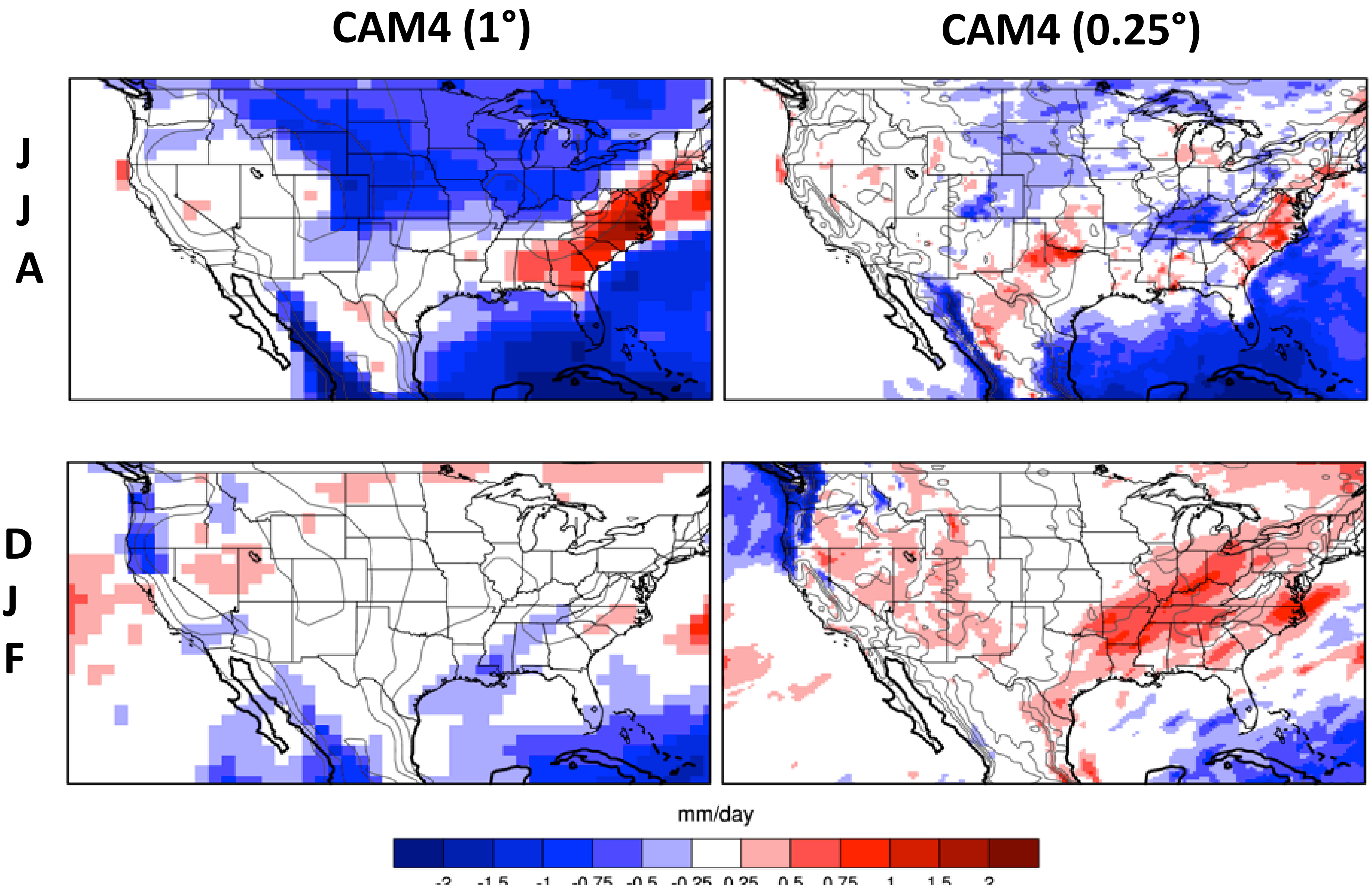
Taylor Diagrams (DJF)



Taylor Diagrams (JJA)



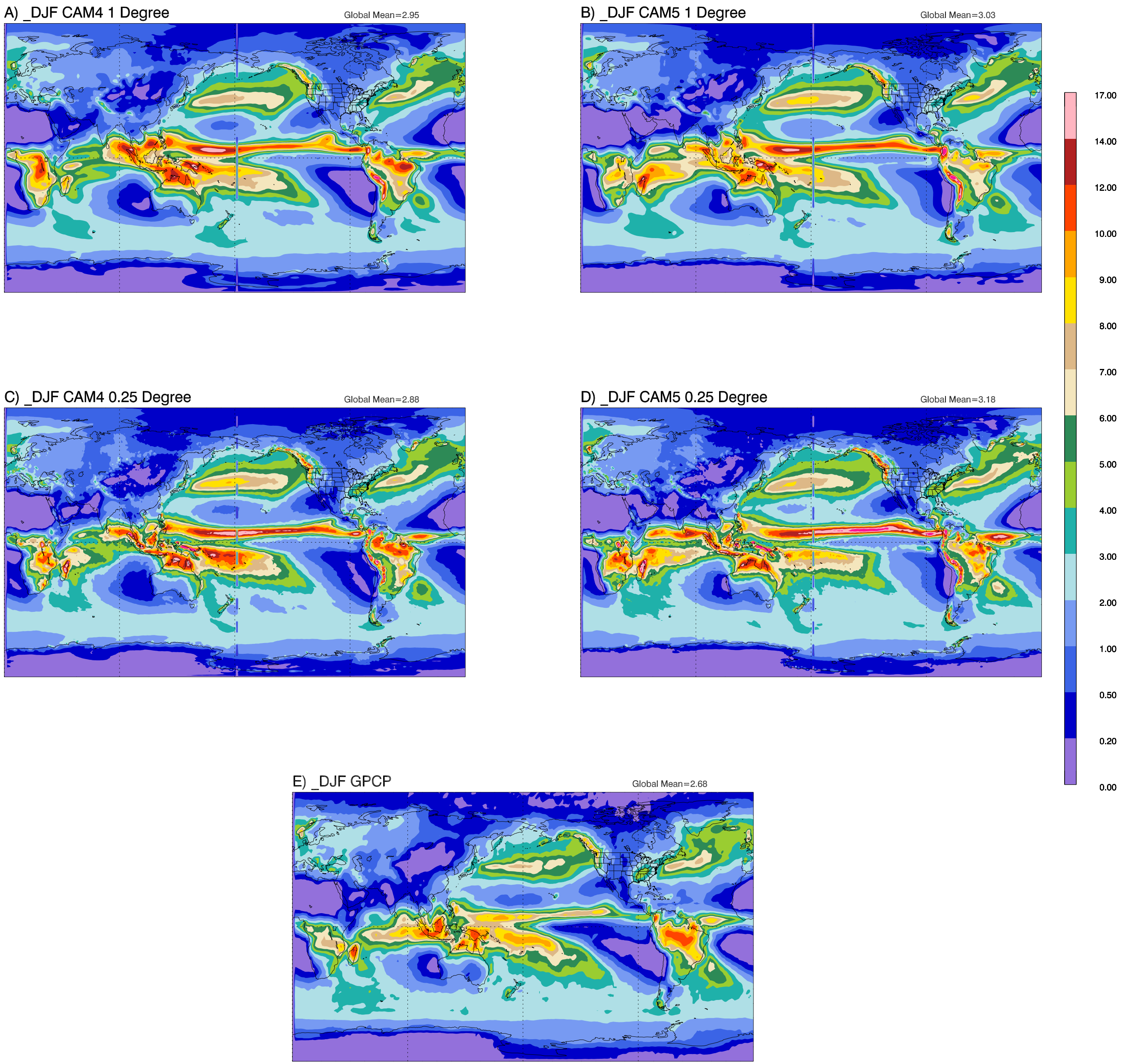
Change in precipitation over the US



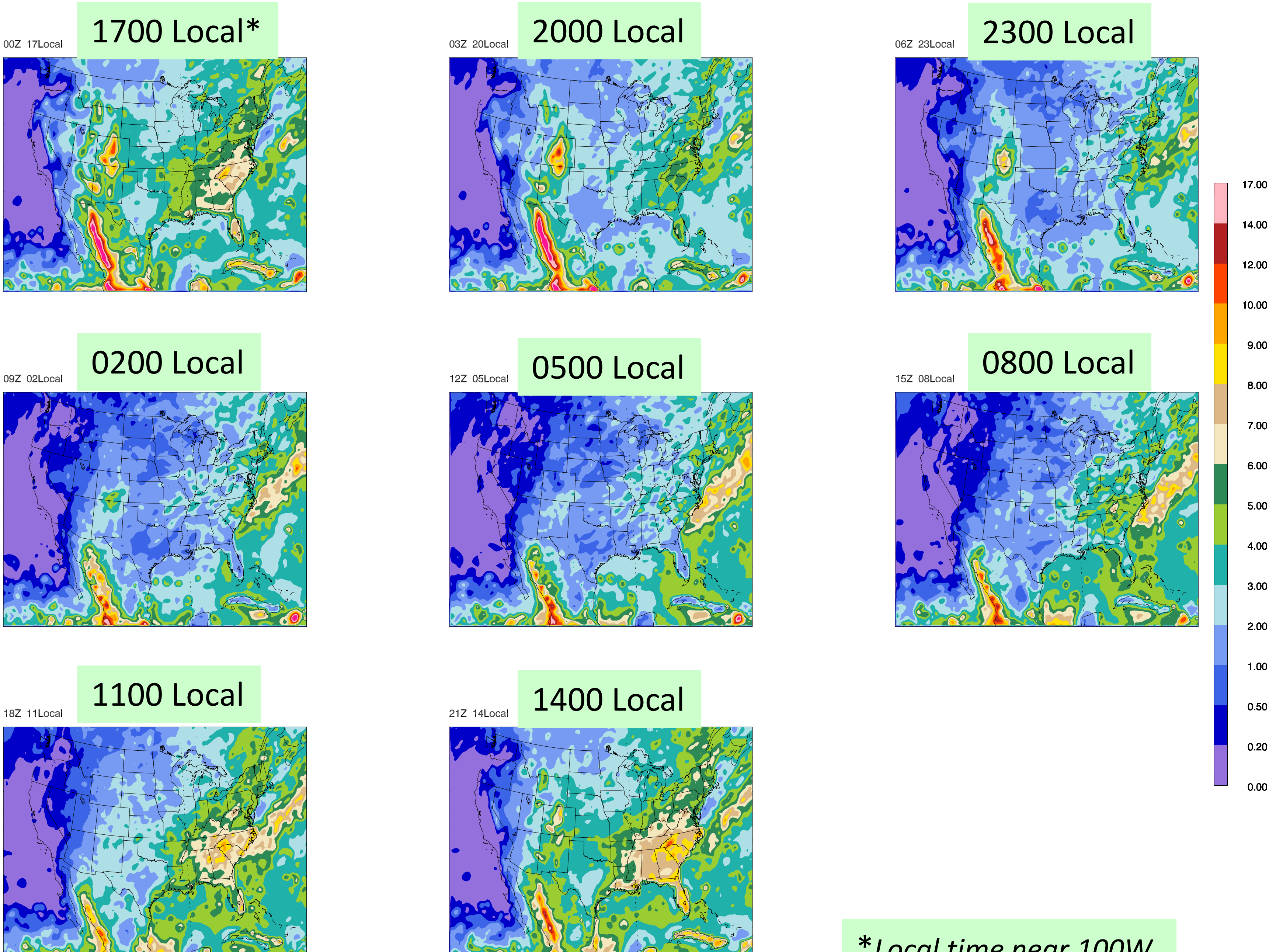
The CAM family

Model	CAM3 CCSM3	CAM4 CCSM4	CAM5 (CAM5.1) CESM1.0 (CESM1.0.3)	CAM5.2 CESM1.1
Release	**Jun 2004**	**Apr 2010**	**Jun 2010 (June 2011)**	**Nov 2012**
PBL	Holtslag-Boville (1993)	Bretherton et al (2009)	Bretherton et al (2009)	Bretherton et al (2009)
Shallow Convection	Hack (1994)	Hack (1994)	Park et al. (2009)	Park et al. (2009)
Deep Convection	Zhang-McFarlane (1995)	Neale et al. (2008)	Neale et al. (2008)	Neale et al. (2008)
Microphysics	Rasch-Kristjansson (1998)	Rasch-Kristjansson (1998)	Morrison-Gettelman (2008)	Morrison-Gettelman (2008)
Macrophysics	Rasch-Kristjansson (1998)	Rasch-Kristjansson (1998)	Park et al. (2011)	Park et al. (2011)
Radiation	Collins et al. (2001)	Collins et al. (2001)	Iacono et al. (2008)	Iacono et al. (2008)
Aerosols	Bulk Aerosol Model	Bulk Aerosol Model BAM	Modal Aerosol Model Ghan et al. (2011)	Modal Aerosol Model Ghan et al. (2011)
Dynamics	Spectral	Finite Volume	Finite Volume	Spectral element

= New parameterization/dynamics

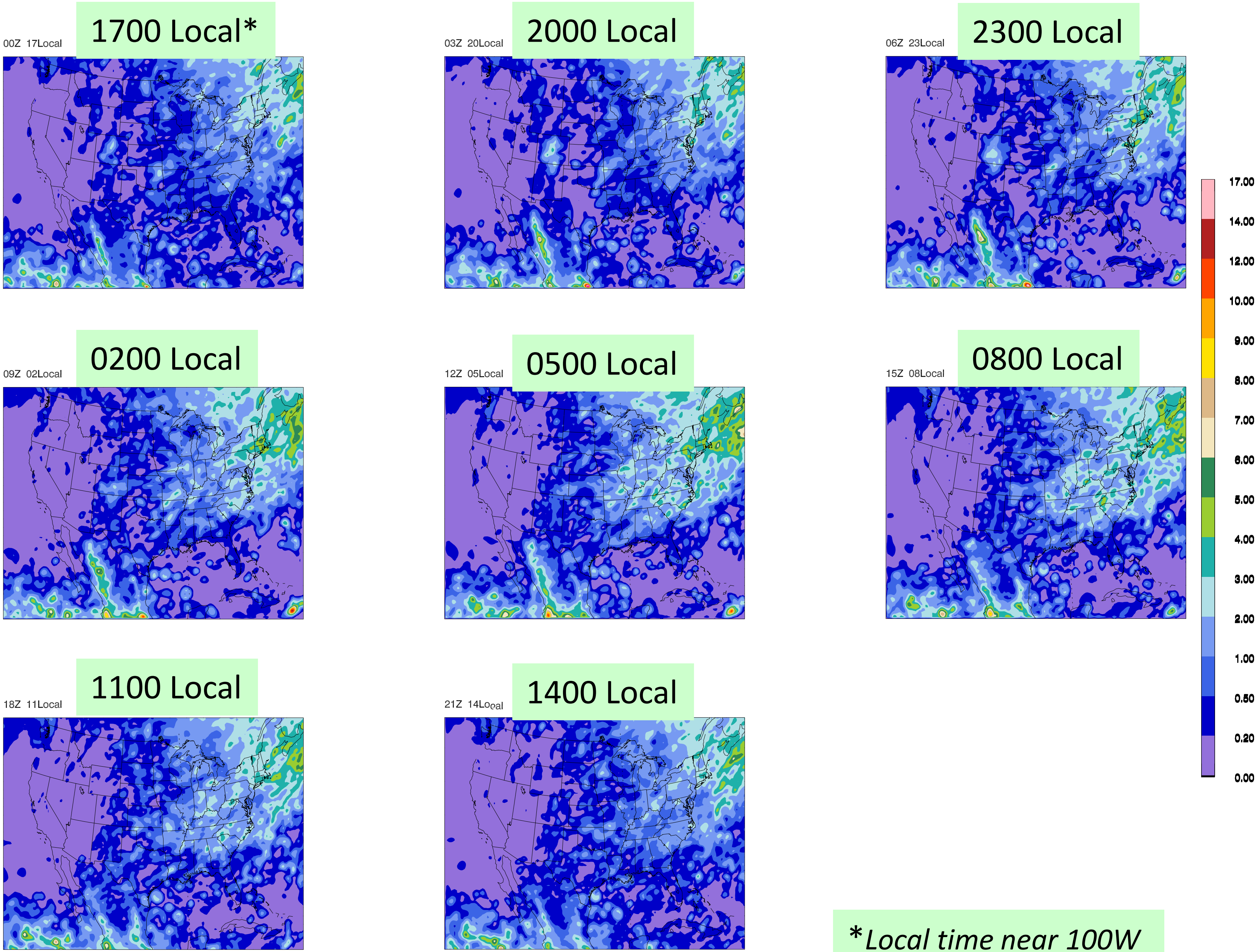

A) _DJF CAM4 1 Degree
Global Mean=2.95
B) _DJF CAM5 1 Degree
Global Mean=3.03
C) _DJF CAM4 0.25 Degree
Global Mean=2.88
D) _DJF CAM5 0.25 Degree
Global Mean=3.18
E) _DJF GPCP
Global Mean=2.68
17.00
14.00
12.00
10.00
9.00
8.00
7.00
6.00
5.00
4.00
3.00
2.00
1.00
0.50
0.20
0.00

Mean diurnal cycle of precipitation in JJA 2000-2005 CAM5



**Local time near 100W*

Mean diurnal cycle of ***large-scale*** precipitation in JJA 2000-2005 CAM5



**Local time near 100W*