Update on CAM and the AMWG: Recent activities and near-term priorities.

by the AMWG

OMWG meeting 21 January 2013

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

What's in CAM5.2 ?

- New dynamical core (Spectral Element: SE)

- New topography for CAM-SE

- 6 bug fixes
  - Fix for the land scaling of dust
  - Fix to wet radius calculation in the modal_aero_wateruptake module.
  - Fix for the value for the Obukhov length used in dry deposition calculations.
  - Fix in zm_conv to fix some inconsistency in the initialization of moist static energy.
  - Fix in uw_shallow for the unreasonable concentration of some species in WACCM.
  - Mods in MAM to generalize the method for calculating pH value of cloud water.

  => Very little impact (25-year coupled run at FV-1deg)

- Tuning for CAM-SE (dust and stratocumulus)

Coupled simulations

CESM-CAM-FV 1 degree: 25 years

CESM-CAM-FV 2 degree: 25 years

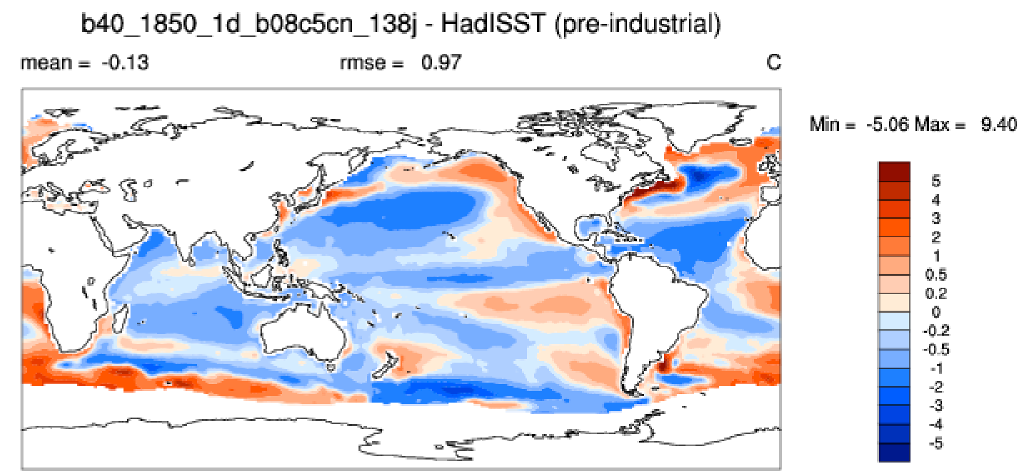
similar to CESM1.0
⇒bugfixes have small impact

CESM-CAM-SE ne30 (~1 deg): 25 years

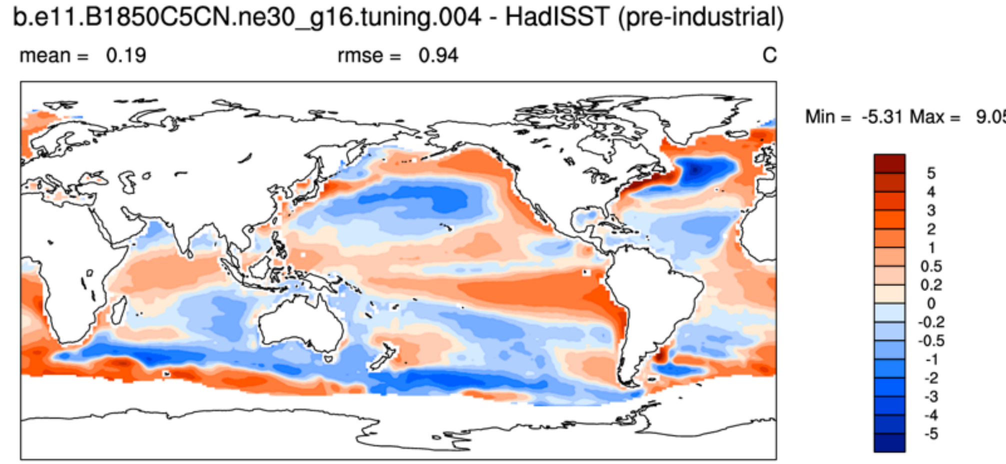
Competitive with FV except for stratocumulus

Temperature biases

CESM1.0 FV 1deg
mean = -0.13
RMSE = 0.97

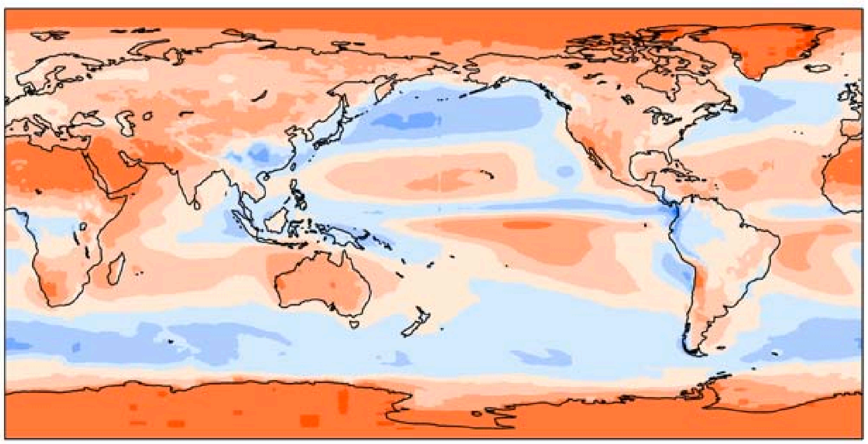


CESM1.1 SE ne30
mean = 0.19
RMSE = 0.94

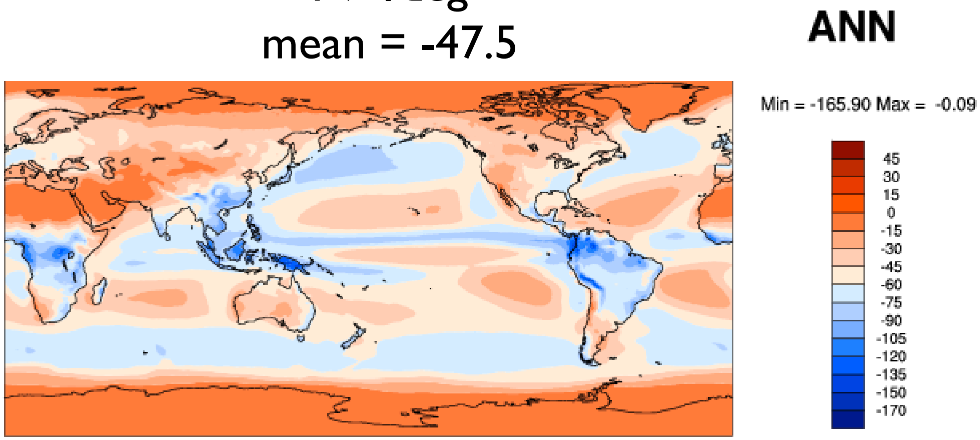


SWCF

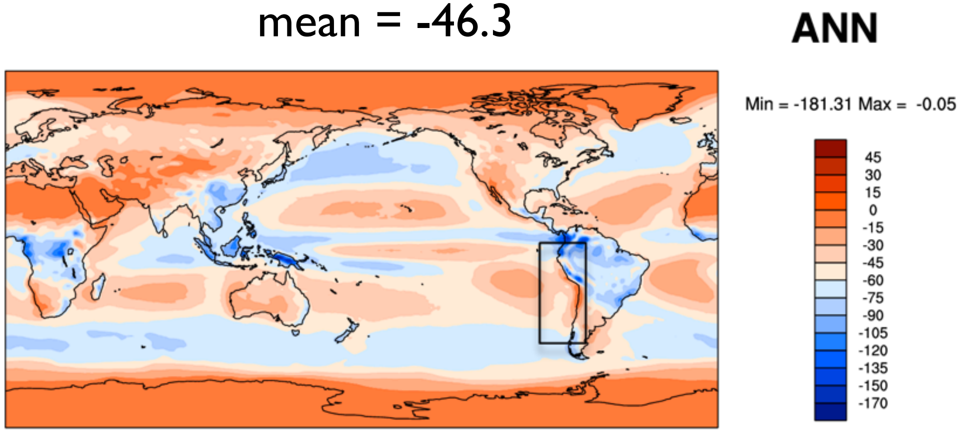
CERES-EBAF
mean = -47.1



FV 1deg
mean = -47.5



SE ne30
mean = -46.3



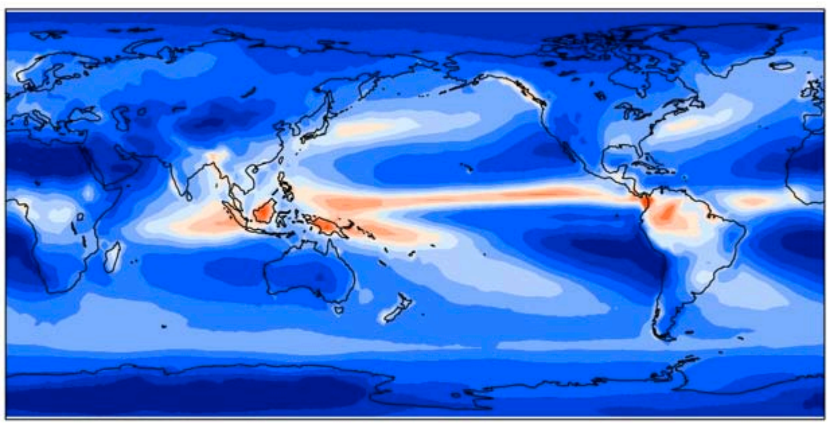
Future development:

Change in vertical advection of T

Precipitation

GPCP
mean = 2.67

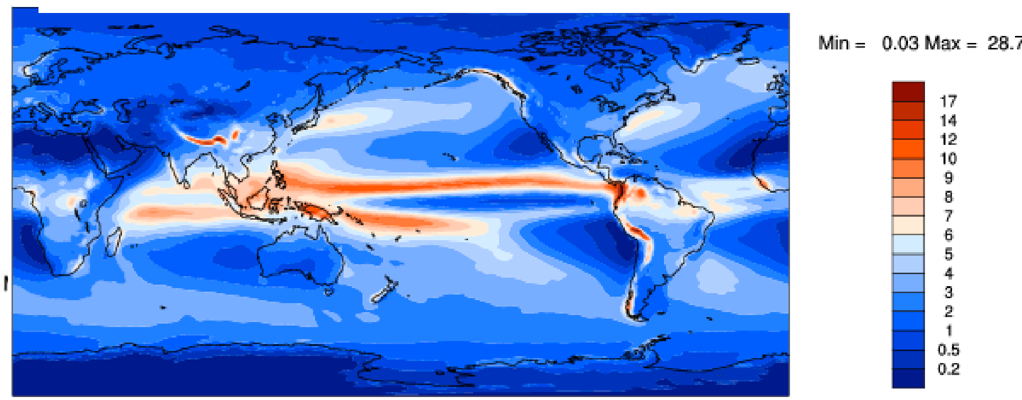
day



FV 1 deg
mean = 3.06

Pre

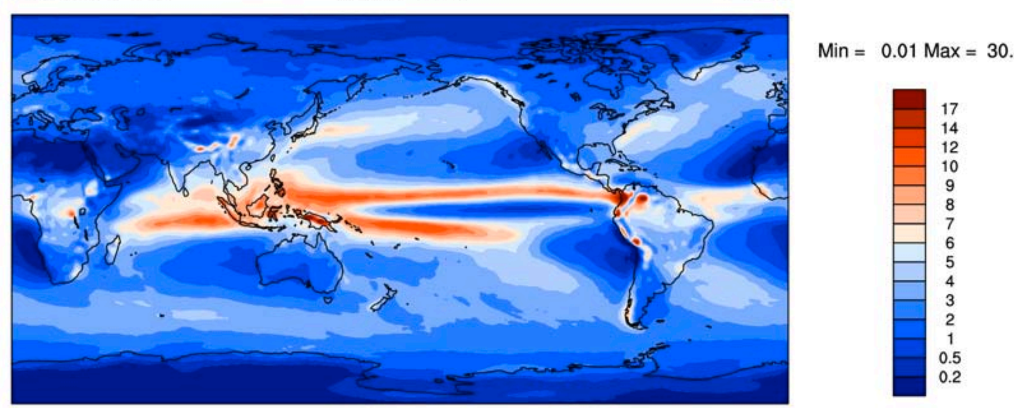
ANN

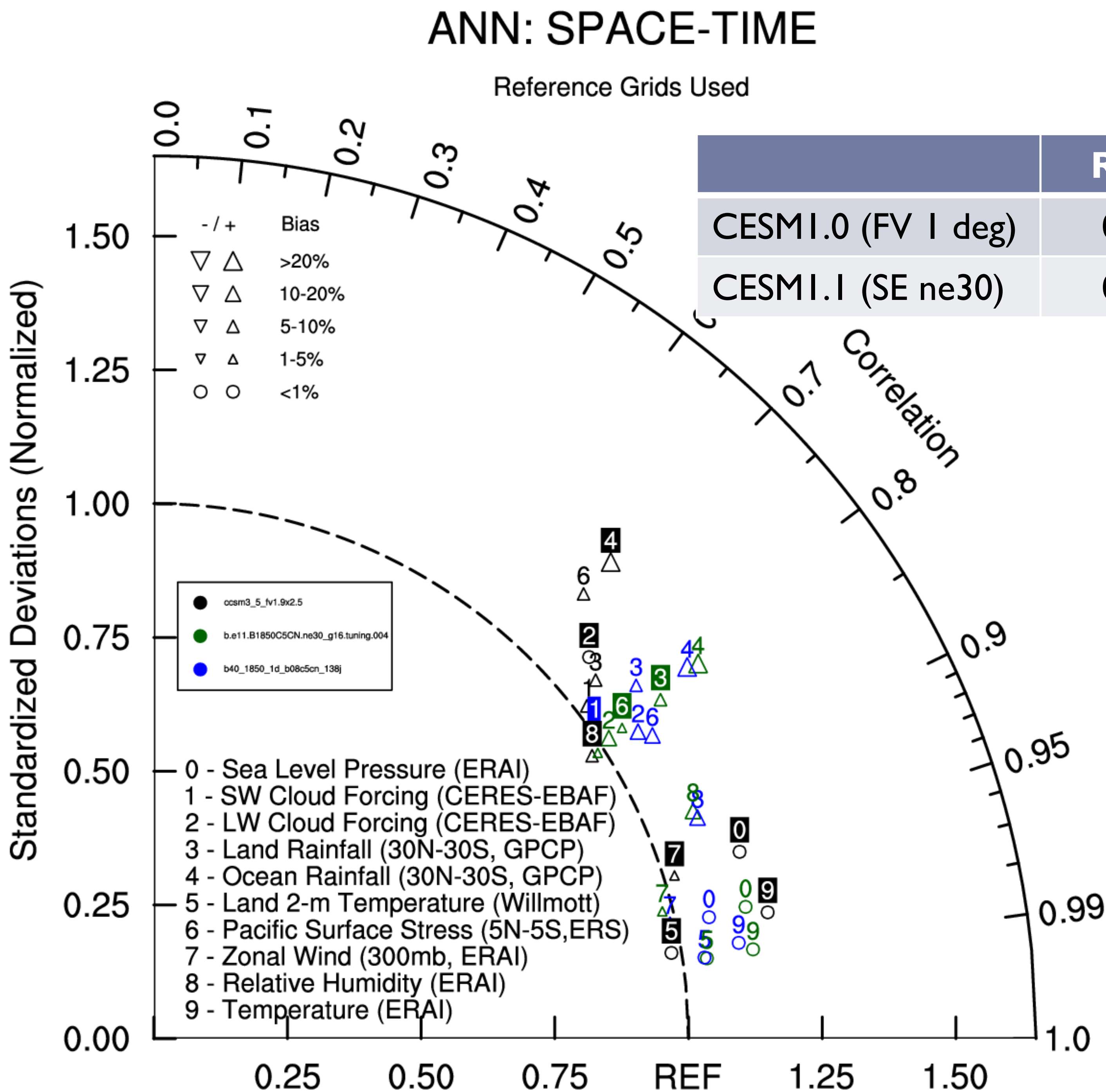


SE ne30
mean = 3.10

Pr

ANN





	RMSE	Bias
CESM1.0 (FV 1 deg)	0.788	1.483
CESM1.1 (SE ne30)	0.794	1.319

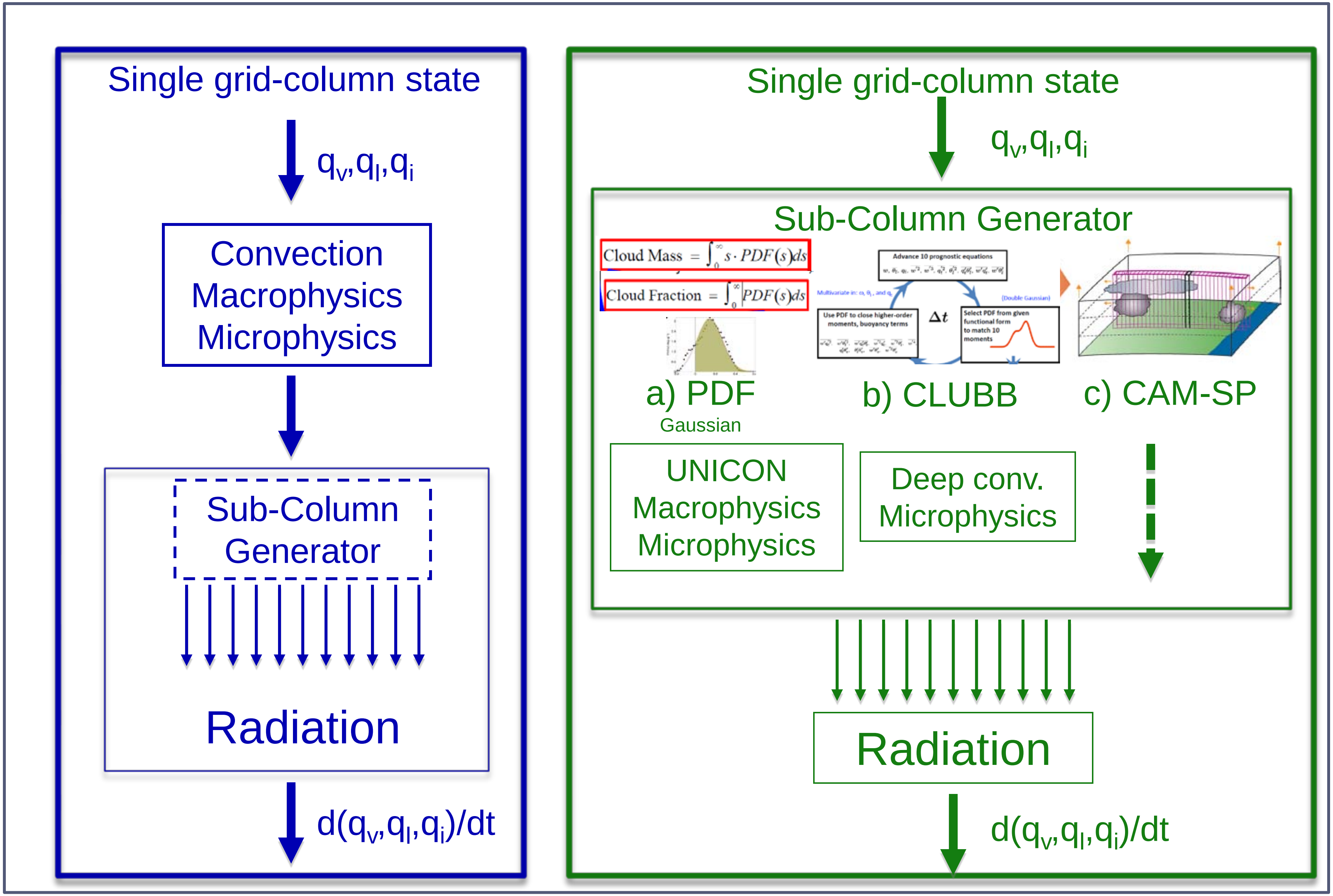
Current/near-term model development

- Dynamics
  - Lagrangian vertical transport (all variables)
  - Conservative Semi-LAgrangian Multi-tracer (CSLAM) advection
  - MPAS dycore and regional mesh refinement in CAM-SE
- Resolution
  - High resolution runs (0.25 and finer). Horizontal resolution dependence (climate change response).
  - Vertical resolution dependence (L30 -> L31, L60)
- Diagnostics
  - COSP cloud phase diagnostics
  - Refactored diagnostics package
- Address systematic precipitation biases (see next slide)
  - double ITCZ, Asian monsoon, summertime US rainfall
  - CAPT framework, high-resolution, UNICON, …
- Documentation (CESMwide)
  - Moving from latex file to web-based documentation

Near-term model development (moist physics/radiation)

- Unified Convection (UNICON)
  - unifies treatment deep + shallow
- Cloud Layers Unified By Binormals (CLUBB):
  - third-order turbulence closure centered around an assumed double Gaussian PDF
  - treatment for shallow+PBL+macrophysics
- Consistent PDF-based macrophysics
- SP-CAM: super-parameterization on branch
- Next generation MG microphysics
  - prognostic precipitation, mixed phase ice nucleation and convective microphysics
- Aerosol scheme
  - Prescribed Aerosol (BAM /MAM)
  - MAM4
- Sub-columns infrastructure
  - all schemes see the same sub-columns: consistency among processes

Physics framework in CAM5+



Slide courtesy: Rich Neale

(More grid resolution/scale tolerant)

Timings on Yellowstone for CESM1.0.5

http://www.cesm.ucar.edu/models/cesm1.0/timing_cesm_1_0_5/

NOTE:
FV_2° 1850CN pe-hrs/yr=237
T31 pe-hrs/yr=56

FV_2° for Paleo and WACCM

Low-res option

Machine	Resolution	Compset	Total PEs	Cost pe-hrs/yr	ThruPut yrs/day	cpl pes	lnd pes	ice pes	atm pes	glc pes	ocn pes	Version Date	Comment
yellowstone	0.9x1.25_0.9x1.25	FMOZ	512	1778.25	6.92	512 512x1 0	512 512x1 0	512 512x1 0	512 512x1 0	1 1x1 0	512 512x1 0	cesm1_0_5_rel01 2013-01-12	
yellowstone	0.9x1.25_gx1v6	B1850BDRD	576	836.85	16.52	160 160x1 0	160 160x1 160	160 160x1 0	320 320x1 0	1 1x1 0	256 256x1 320	cesm1_0_5_rel02 2013-01-16	
yellowstone	0.9x1.25_gx1v6	B1850BPRP	576	717.33	19.27	160 160x1 0	160 160x1 160	160 160x1 0	320 320x1 0	1 1x1 0	256 256x1 320	cesm1_0_5_rel01 2013-01-14	
yellowstone	0.9x1.25_gx1v6	B1850C5CN	1008	1795.48	13.47	320 320x1 640	320 320x1 320	320 320x1 0	960 960x1 0	1 1x1 0	48 48x1 960	cesm1_0_5_rel01 2013-01-15	
yellowstone	0.9x1.25_gx1v6	B1850CN	352	431.84	19.56	160 160x1 0	128 128x1 160	160 160x1 0	288 288x1 0	1 1x1 0	64 64x1 288	cesm1_0_5_rel02 2013-01-17	
yellowstone	0.9x1.25_gx1v6	B1850CNCHM	352	573.44	14.73	160 160x1 0	128 128x1 160	160 160x1 0	288 288x1 0	1 1x1 0	64 64x1 288	cesm1_0_5_rel01 2013-01-17	
yellowstone	0.9x1.25_gx1v6	B20TRCN	352	433.06	19.51	160 160x1 0	128 128x1 160	160 160x1 0	288 288x1 0	1 1x1 0	64 64x1 288	cesm1_0_5_rel02 2013-01-17	
yellowstone	0.9x1.25_gx1v6	BRCP45CN	352	429.85	19.65	160 160x1 0	128 128x1 160	160 160x1 0	288 288x1 0	1 1x1 0	64 64x1 288	cesm1_0_5_rel02 2013-01-17	
yellowstone	0.9x1.25_gx1v6	ICN	256	33.77	181.92	256 256x1 0	256 256x1 0	256 256x1 0	256 256x1 0	256 256x1 0	256 256x1 0	cesm1_0_5_rel01 2013-01-17	
yellowstone	1.9x2.5_1.9x2.5	FMOZ	352	450.89	18.73	352 352x1 0	352 352x1 0	352 352x1 0	352 352x1 0	1 1x1 0	352 352x1 0	cesm1_0_5_rel01 2013-01-12	
yellowstone	1.9x2.5_1.9x2.5	FWX	512	9244.85	1.33	512 512x1 0	512 512x1 0	512 512x1 0	512 512x1 0	512 512x1 0	512 512x1 0	cesm1_0_5_rel02 2013-01-17	
yellowstone	1.9x2.5_gx1v6	B1850C5CN	384	517.11	17.82	240 240x1	64 64x1	240 240x1	320 320x1	1 1x1	64 64x1	cesm1_0_5_rel01 2013-01-12	

01/18/2013 04:

Timings on Yellowstone for CESM1.1

http://www.cesm.ucar.edu/models/cesm1.1/timing/

NOTE:
FV_1° 1850C5CN
pe-hrs/yr=1650
ne30 pe-hrs/yr=2657

Spectral core no longer supported SCIENTIFICALLY (will be functionally)

Machine	Resolution	Compset	Total PEs	Cost pe-hrs/yr	ThruPut yrs/day	cpl pes	lnd pes	rof pes	ice pes	atm pes	glc pes	ocn pes	Version Date	Comment
yellowstone	0.9x1.25_gx1v6	B1850BPRP	780	657.39	18.69	600 300x2 0	240 120x2 0	240 120x2 0	360 180x2 120	600 300x2 0	2 1x2 0	180 180x1 300	cesm1_1_0_rel06 20121015	
yellowstone	0.9x1.25_gx1v6	B1850C5CN	1024	1648.26	14.92	976 976x1 0	336 336x1 0	336 336x1 0	640 640x1 336	976 976x1 0	1 1x1 0	48 48x1 976	cesm1_2_alpha01b 20121218	
yellowstone	0.9x1.25_gx1v6	B1850C5CN	1920	1599.28	15.37	1800 900x2 0	600 300x2 0	600 300x2 0	1200 600x2 300	1800 900x2 0	2 1x2 0	120 60x2 900	cesm1_2_alpha01e 20121012	
yellowstone	0.9x1.25_gx1v6	B1850CN	1024	628.24	38.63	928 928x1 0	288 288x1 0	288 288x1 0	640 640x1 288	928 928x1 0	1 1x1 0	96 96x1 928	cesm1_2_alpha01b 20121217	
yellowstone	0.9x1.25_gx1v6	B1850CN	720	425.87	21.64	600 300x2 0	180 90x2 0	180 90x2 0	420 210x2 90	600 300x2 0	2 1x2 0	120 60x2 300	cesm1_1_1_alpha01c 20121016	
yellowstone	ne30np4_gx1v6	B1850BPRP	1280	1016.96	30.21	896 896x1 0	256 256x1 0	256 256x1 0	640 640x1 256	896 896x1 0	1 1x1 0	384 384x1 896	cesm1_2_alpha01b 20121218	
yellowstone	ne30np4_gx1v6	B1850C5CN	2048	2657.39	18.50	1984 1984x1 0	512 512x1 0	512 512x1 0	1472 1472x1 512	1984 1984x1 0	1 1x1 0	64 64x1 1984	cesm1_2_alpha01b 20121218	
yellowstone	ne30np4_gx1v6	B1850C5CN	928	2155.69	10.33	896 896x1 0	256 256x1 0	256 256x1 0	640 640x1 256	896 896x1 0	1 1x1 0	32 32x1 896	cesm1_2_alpha01b 20121218	
yellowstone	T62_gx1v6	C	120	46.62	31.59	120 60x2 0	120 60x2 0	120 60x2 0	120 60x2 0	120 60x2 0	120 60x2 0	120 60x2 0	cesm1_1_1_alpha01c 20121015	
yellowstone	T62_gx1v6	C	240	61.56	49.90	240 120x2 0	240 120x2 0	240 120x2 0	240 120x2 0	240 120x2 0	240 120x2 0	240 120x2 0	cesm1_1_1_alpha01c 20121015	

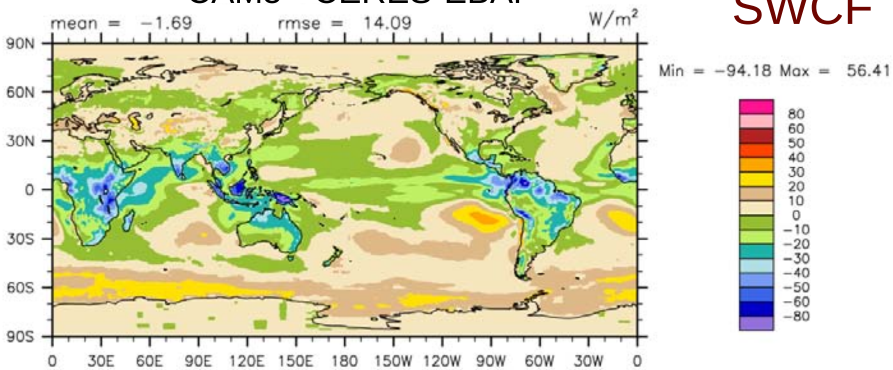
Thanks

Extra slides

CAM-CLUBB

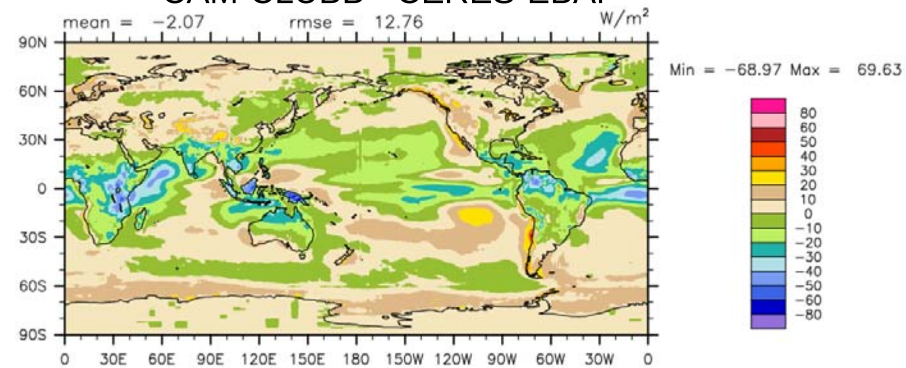
- CLUBB = Cloud Layers Unified by Bi-normals (third-order turbulence closure centered around an assumed double Gaussian PDF)
- Prognostic moments of the PDF: allows testing of physics ‘across scales’ and a way to drive sub-columns.
- CLUBB unifies treatment of shallow convection, PBL, and cloud macrophysics parameterizations
- CAM-CLUBB is a developmental release in CAM5.2
- Simulations currently equal metrics for CAM5. Some aspects are better, some are slightly worse (e.g.: SW Cloud Radiative Effects below). Still testing and exploring. Computational cost similar to CAM5.2
- Exciting new foundation for further experimentation

CAM5 - CERES-EBAF



SWCF

CAM-CLUBB - CERES-EBAF



Slide courtesy: Peter Bogenschutz, Andrew Gettelman, Hugh Morrison, Vincent Larson, and Cheryl Craig

UNICON

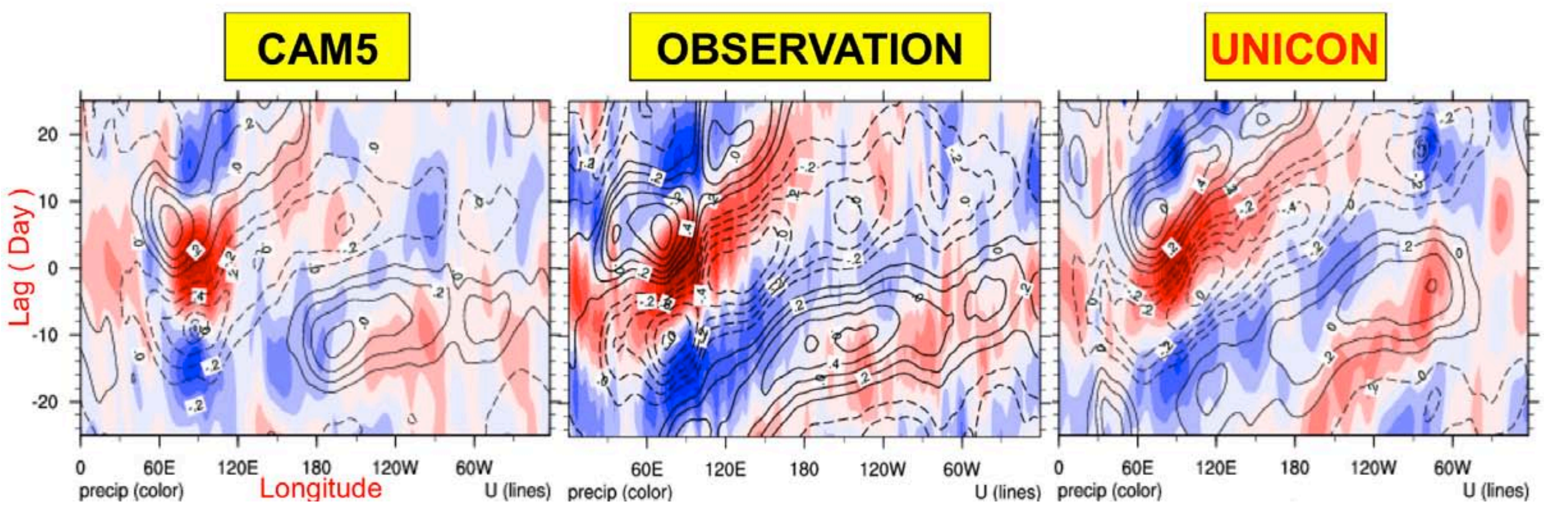
• UNICON is a sub-grid vertical transport scheme by non-local asymmetric turbulent eddies and a scale-aware parameterization well harmonized with CAM5 moist turbulence scheme without double-counted transport.

• UNICON simulates all shallow-deep, dry-moist, and forced-free convections within a single framework in a seamless, consistent and unified way.

• UNICON simulates MJO and diurnal cycle of precipitation with improved climatologies.

• UNICON ***knows how to turn on-and-off*** MJO ***and*** diurnal cycle of precipitation. The key process controlling MJO and diurnal cycle of precip is the feedback among convective updraft, convective downdraft and meso-scale flows.

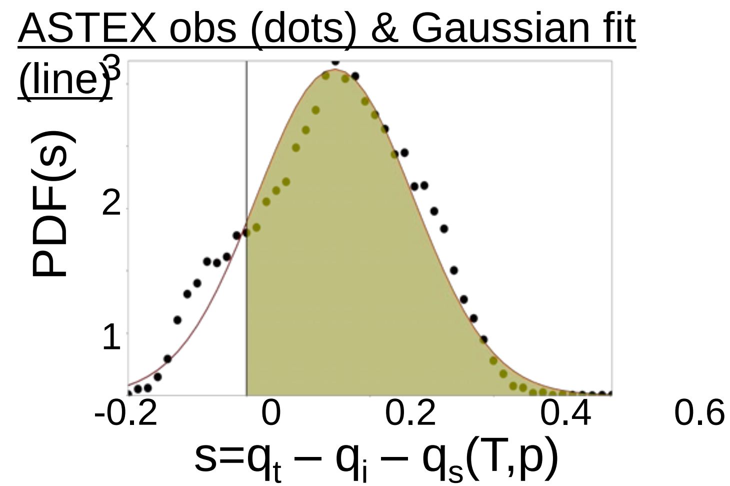
Madden-Julian Oscillation. Summer. Indian Ocean.
Lag-Correlation of PRECT (Color) and U850 (Line).



Slide courtesy: Sungsu Park

PDF-Based Stratiform Cloud Physics

- In *stratiform* regions, subgrid moisture variability typically follows a Gaussian



- Consistent cloud fraction and mass can be computed via:

$$\text{Cloud Fraction} = \int_0^{\infty} PDF(s)\,ds$$

$$\text{Cloud Mass} = \int_0^{\infty} s \cdot PDF(s)\,ds$$

Led by Peter Caldwell (LLNL). Funded by DOE "Polar Project" with support from Teixeira CPT

Microphysics Development: MG2

- Refactored code (Model independent code)

- Prognostic precipitation
  - Why? Improvements in process rates (like accretion) that impact cloud lifetime

- Activation fix from Caldwell

- Hail/Graupel (mixed) phase hydrometeors

- Use in convective clouds (strong updraft)
  - Probably means additional transport code

- Resulting MG2 code will 'unify' scheme with Morrison et al 2005 WRF code: maintain a single code for WRF and CESM

Slide courtesy: Andrew Gettelman

Sub-columns

- Sub-columns are a key conceptual method for physics 'across scales': as scale gets smaller, sources of variance decrease, and PDF narrows
- We prognose a PDF ('macrophysics')
- Total water and vertical velocity PDFs critical
- Sample the PDF generate consistent sub-columns ('sub-column generator')
- Use sub-columns for determining microphysics and radiation
- Some doubts remain: need to test the ideas
- Infrastructure also used for SP-CESM (embedded cloud model)

Slide courtesy: Andrew Gettelman