CMCC WEBINAR

April 9, 2018 - h. 3 pm CEST

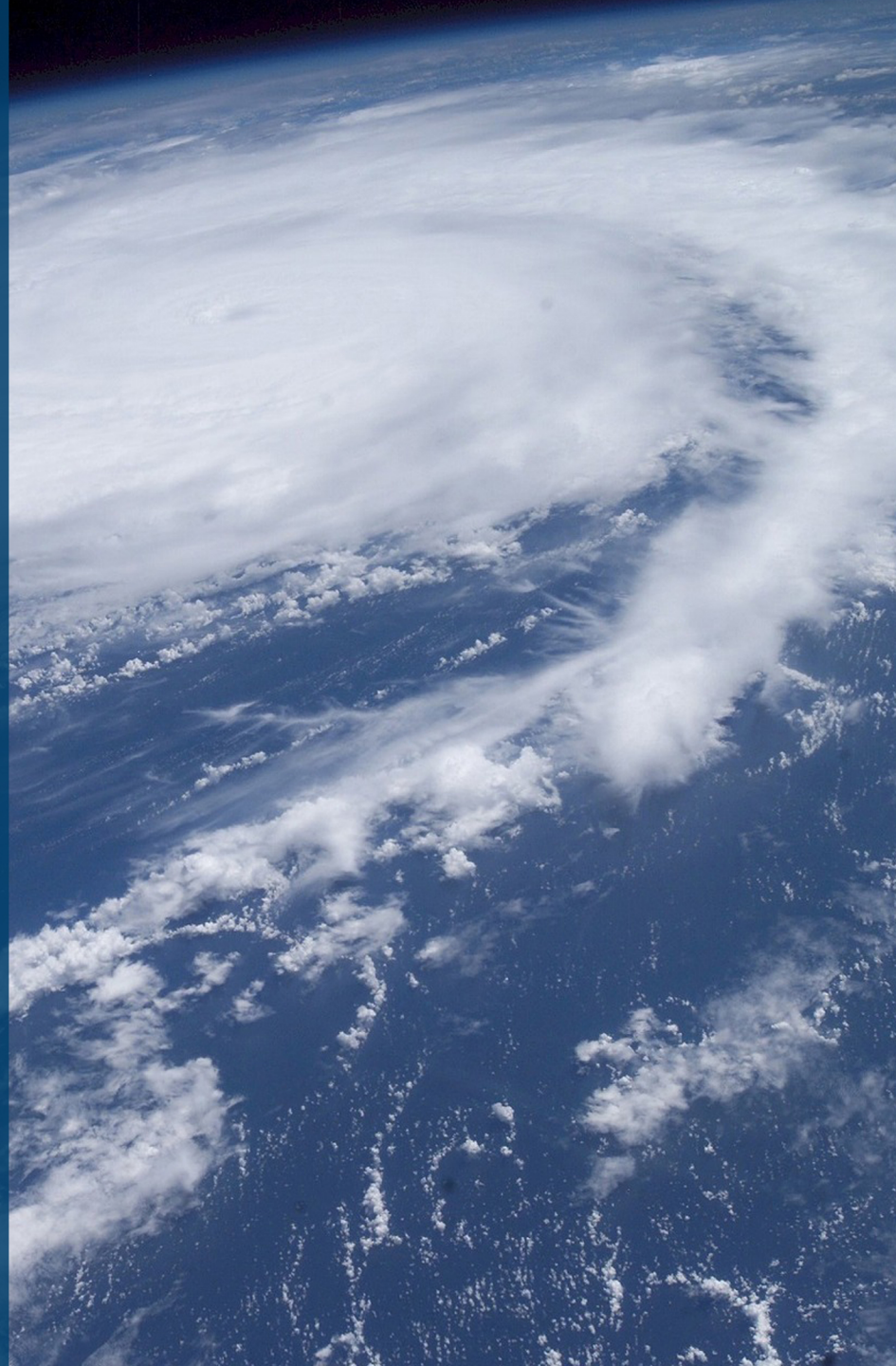
“A History of Bias in the NCAR Community Earth System Model: 20-years of Successes, Tough Choices and Persistent Problems”

Richard Neale

NCAR - National Center for Atmospheric Research

Antonio Navarra - Moderator

Fondazione CMCC – Centro Euro-Mediterraneo sui Cambiamenti Climatici



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To investigate and model our **climate system** and its interactions with **society** to provide reliable, rigorous, and timely **scientific results**, which will in turn stimulate sustainable growth, protect the **environment**, and **develop science driven** adaptation and **mitigation policies** in a **changing climate**

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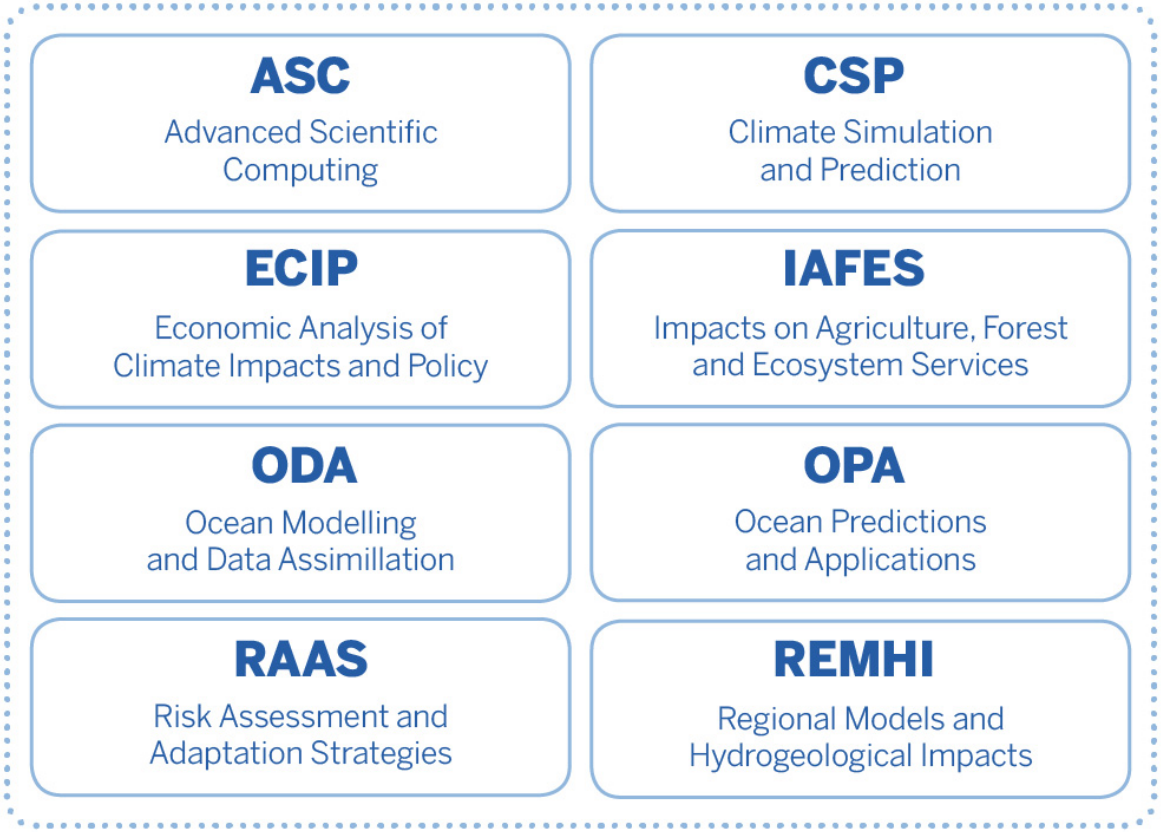

TOPICS


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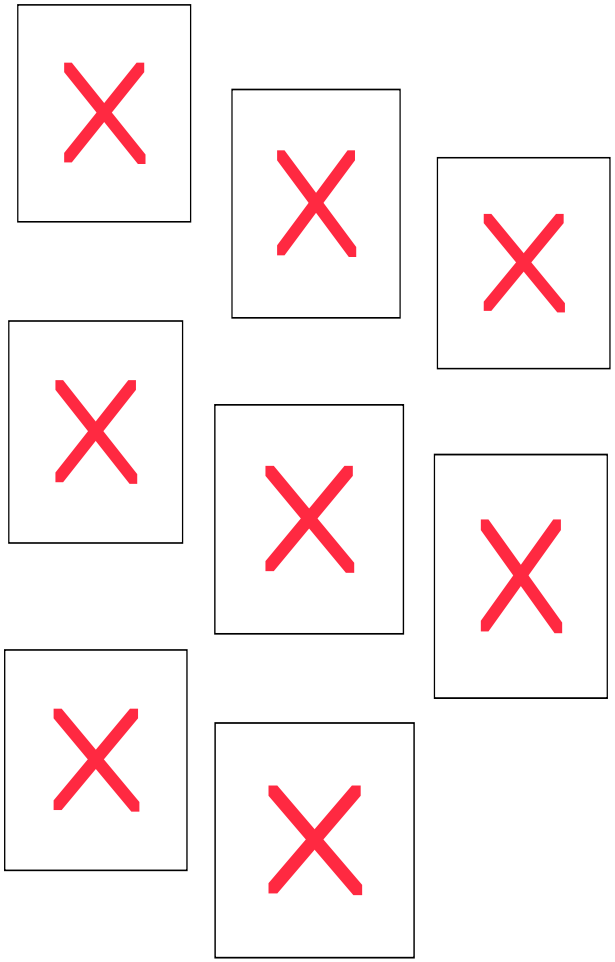
A History of Bias in the NCAR Community Earth System Model (CESM):

20-years of Successes, Tough Choices and Persistent Problems



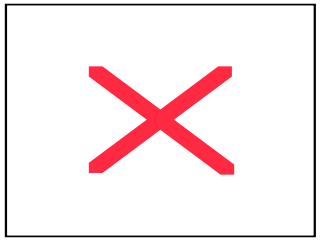
Rich Neale

National Center for Atmospheric Research

Purdue April 2018

with Cecile Hannay, Julio Bacmeister, Andrew Gettelman, Dennis Shea,

and many, many others…!



Community Earth System Model CESM

Climate Modeling Philosophy

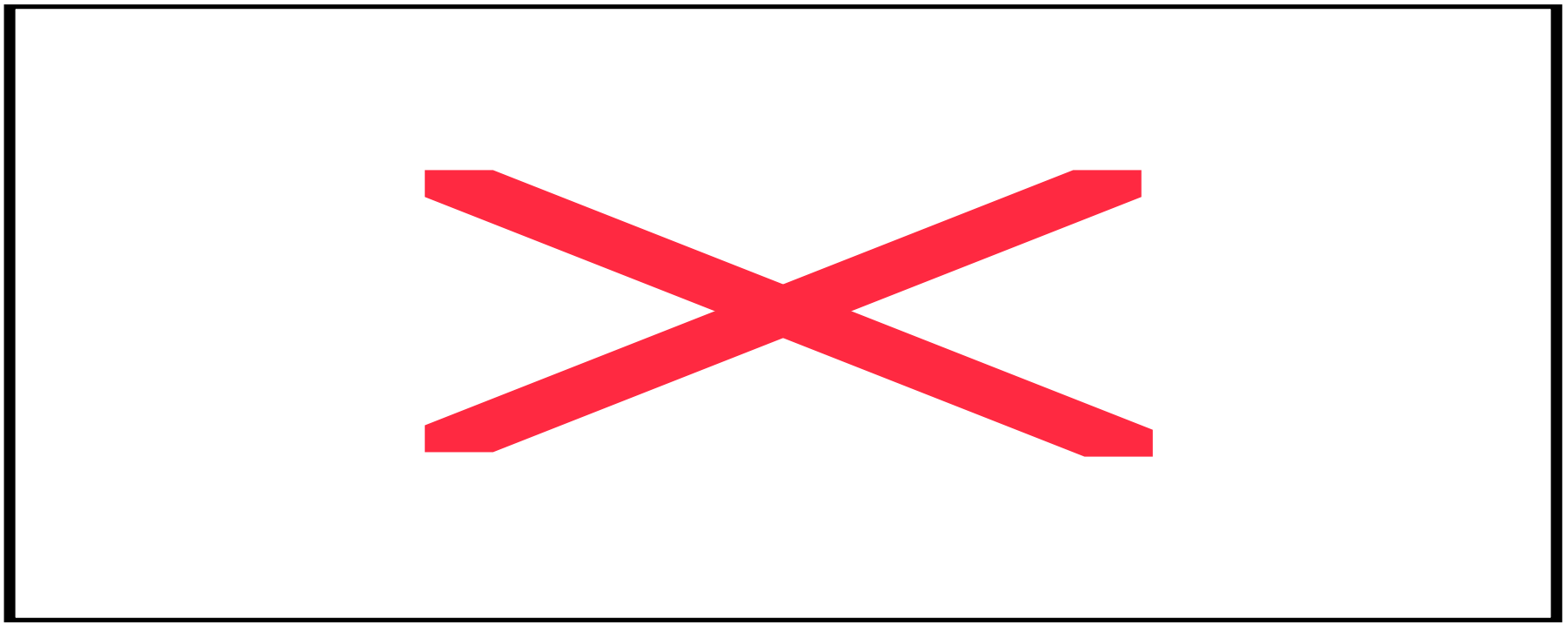
“all models are wrong, but some are useful.”

“Since all models are wrong the scientist cannot obtain a "correct" one by excessive elaboration. On the contrary following William of Occam he should seek an economical description of natural phenomena. Just as the ability to devise simple but evocative models is the signature of the great scientist so overelaboration and overparameterization is often the mark of mediocrity.”

George Box, Statitician

Oh dear…

Climate Modeling Complexity



NCAR Community Earth System Model (CESM)

- CESM complexity has increased dramatically in the last 10 years
- New science, improved/missing processes
- New interactions and new constraints (and old constraints!)
- Previous improvements cannot be lost (got them for the wrong reasons?)
- CESM2 development has encountered problems with most of the above!

Assessing NCAR models

Is CESM2 a better model than CESM1?
Is CESM2 better than all previous models?

- Summarize NCAR atmosphere models over the last 35 years
- How have we improved in the last 20 years
  - **Clear monotonic Improvements**
  - **Persistent biases**
  - **Ups and downs in skill**
  - **Trade-offs**

- Mean climate
- Variability (mostly tropical)
- Compare atmosphere-only and fully coupled configurations
- Development challenges of a complex system **CESM2**

Paleo Climate Model Timeline

NCAR1/2/3

Release	Atmosphere	Coupled
1982	CCM0a	
1983	CCM0b	
1987	CCM1	
1993	CCM2	
1998	CCM3	CSM1/CCSM1
2002	CAM2	CCSM2
2004	CAM3	CCSM3
2010	CAM4	CCSM4
2011	CAM5	CESM1
2018	CAM6	CESM2

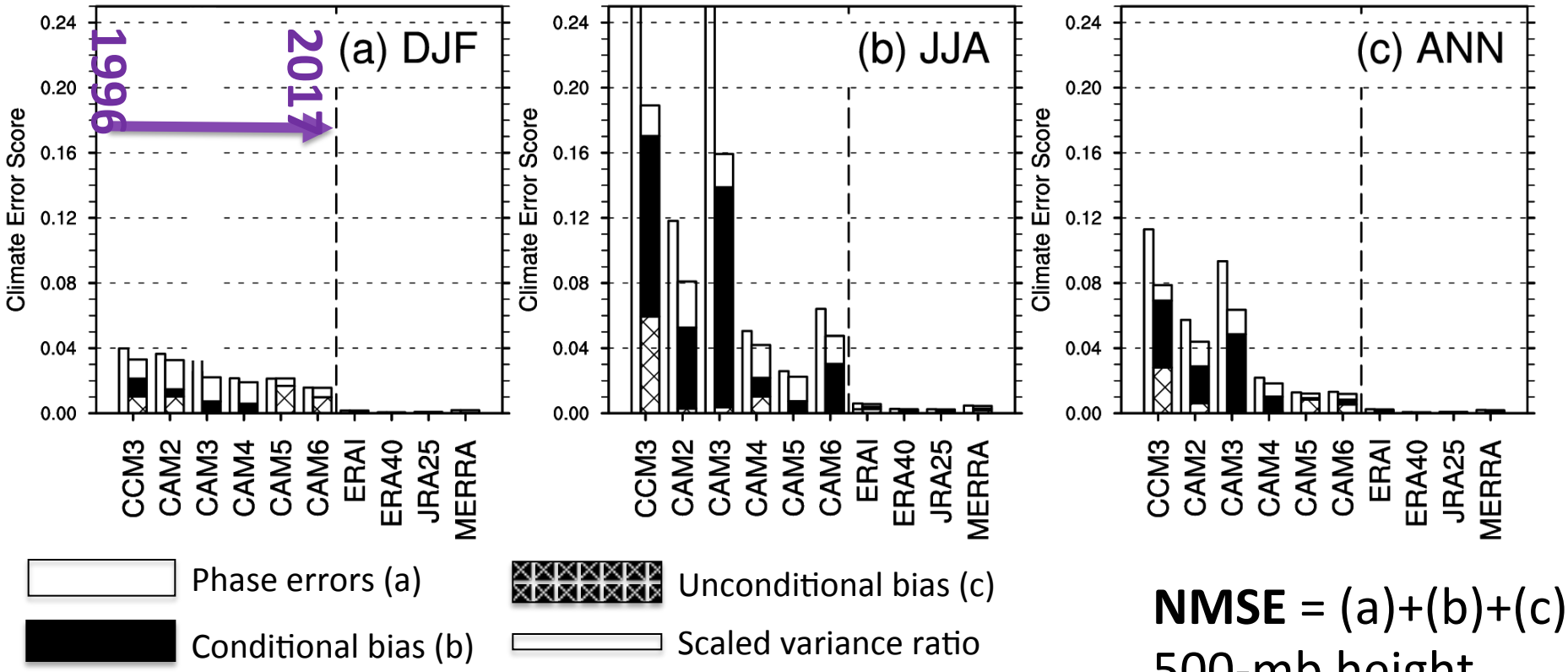
Variability

Simulations

- AMIP: 1979-1999 (*1996)*
- Coupled: 20-30 years 1850 (CCSM2, 1990)
- Annual/DJF/JJA
- Daily output

CCM – Community Climate Model
CAM – Community Atmosphere Model
CCSM – Community Climate System Model
CESM – Community Earth System Model

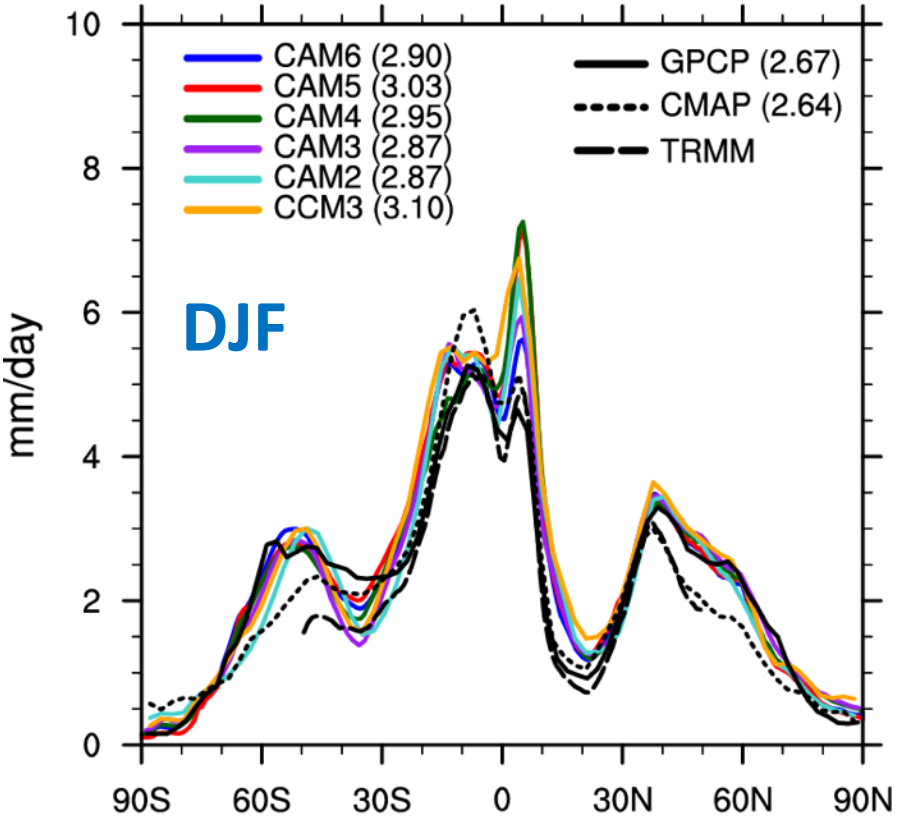
Have we Improved? – AMIP

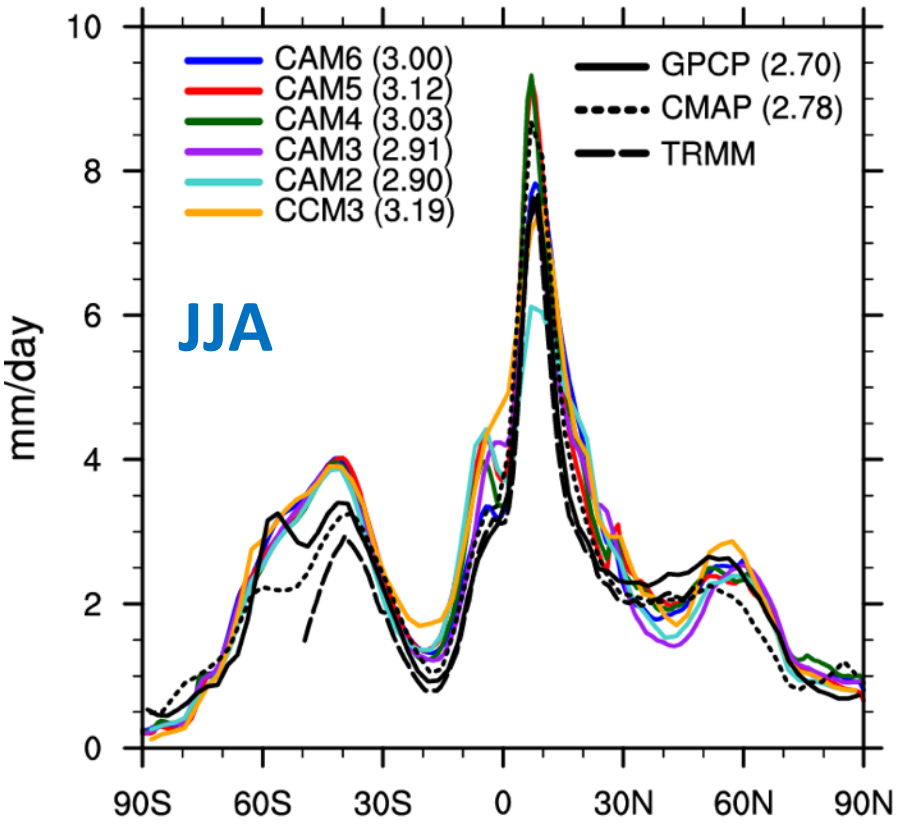


NMSE = (a)+(b)+(c)
500-mb height
Nhem (30-80 deg)

- Winter: Well simulated (baroclinic activity) with monotonic improvement
- Summer: Larger biases (unconditional, lag-regression), land dependencies

Precipitation – Seasonal - AMIP

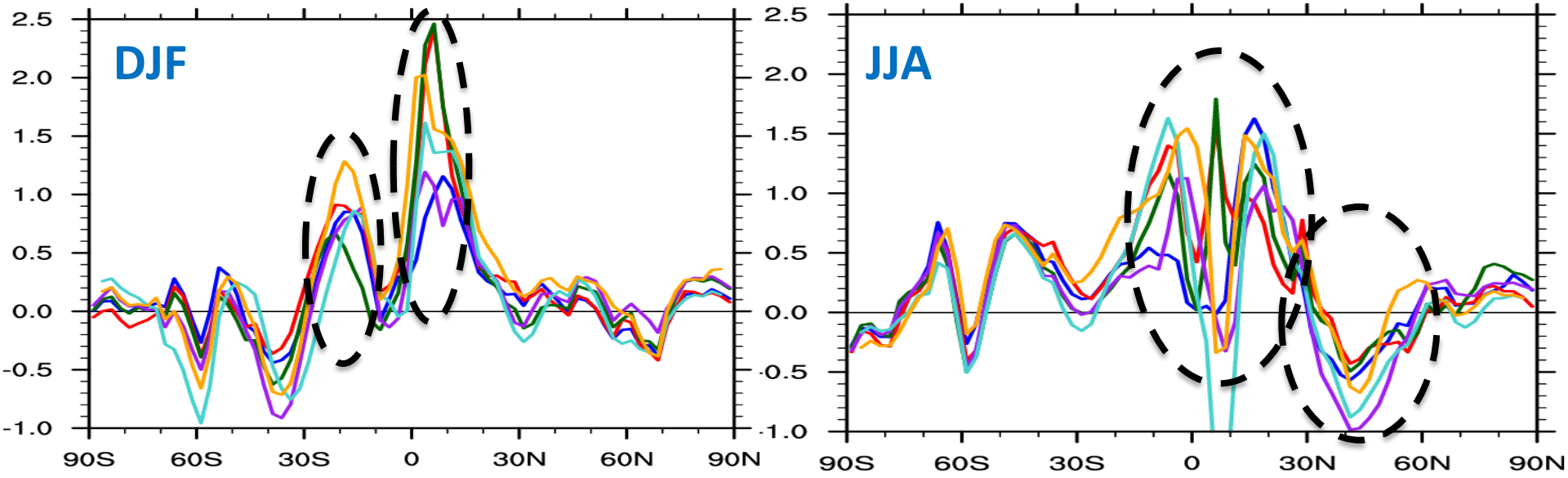




CAM6
CAM5
CAM4
CAM3
CAM2
CCM3

- Mean precipitation () is always too large
- Distributions have always been *reasonable*
- Good, long-term, global observations remain a challenge (and they change!)

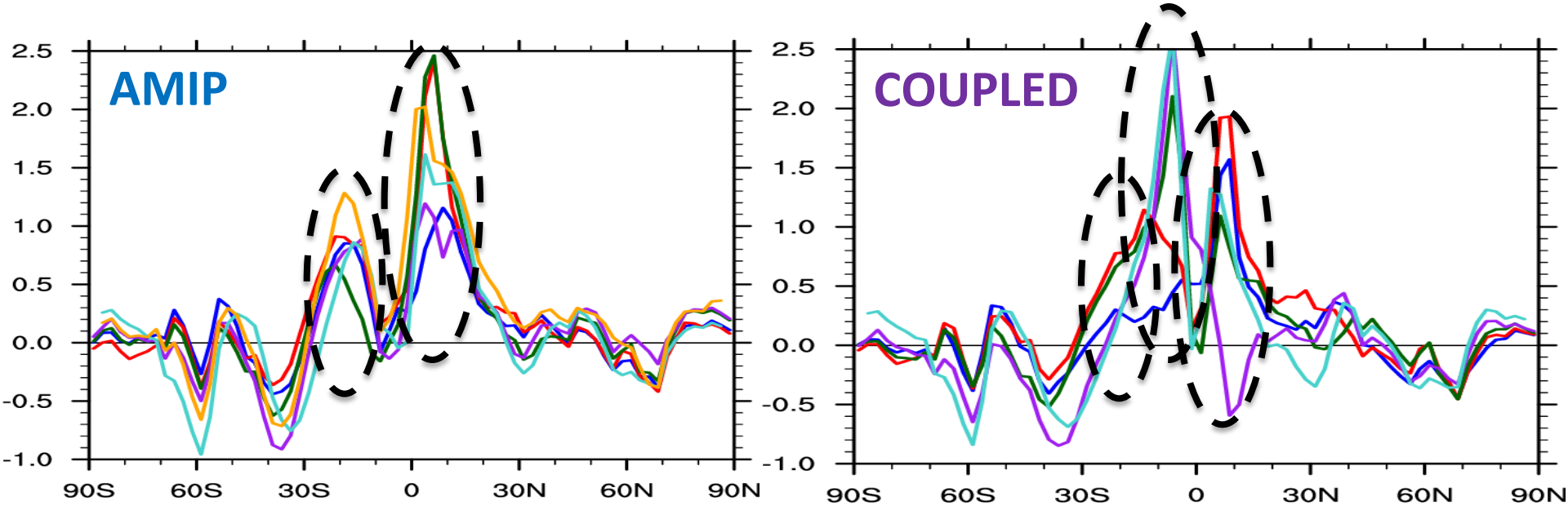
Precipitation – Seasonal - AMIP



CAM6
CAM5
CAM4
CAM3
CAM2
CCM3

- DJF N. Hem ITCZ bias came, went, came, went
- S. Hem barely improved (SPCZ/Australia)
- JJA heterogeneous (monsoons)
- ITCZ width bias
- NH Extra-trop. Storm-track dry bias

Precipitation – Seasonal - DJF



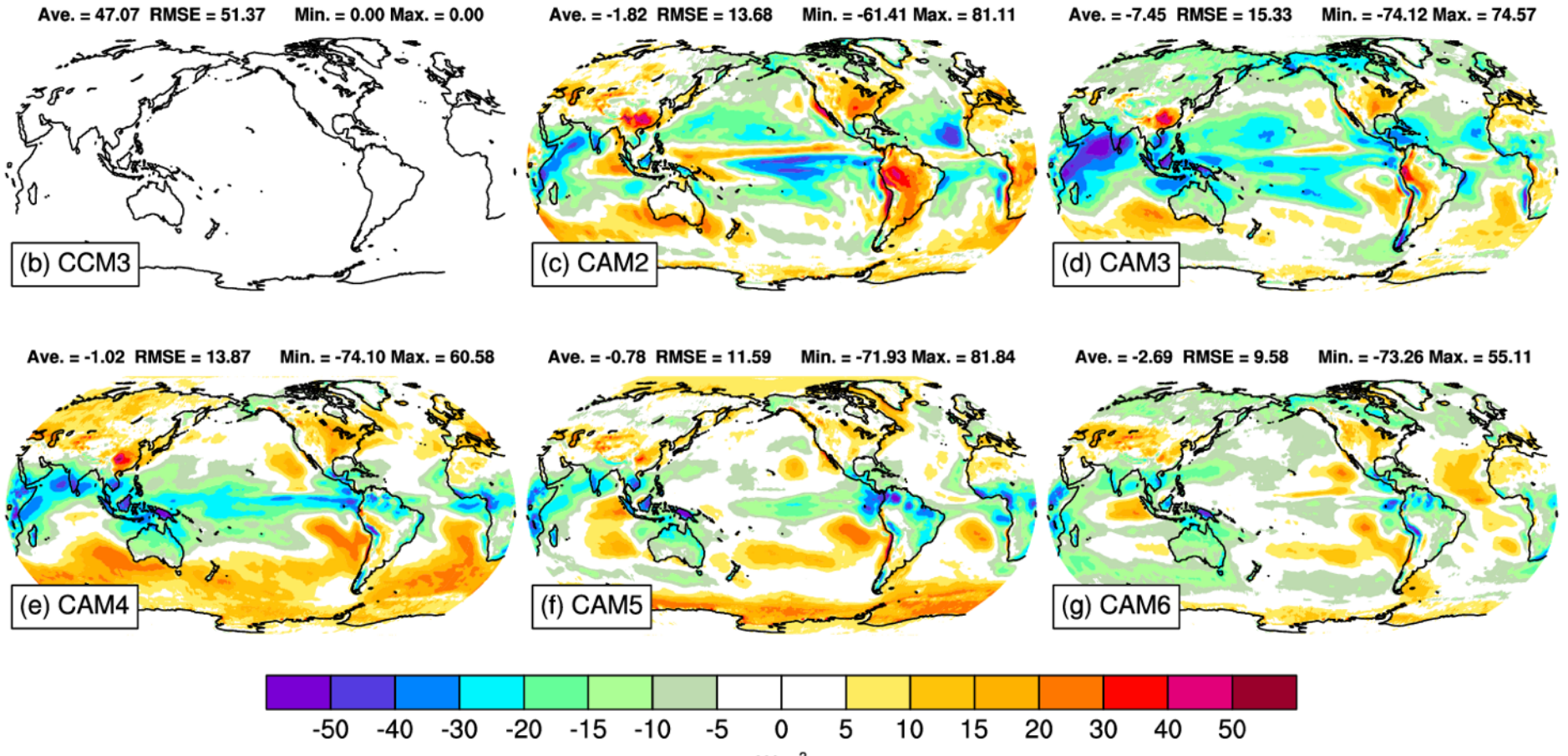
CAM6
CAM5
CAM4
CAM3
CAM2
CCM3

- 'Equivalent' biases at different latitude in coupled models
- SPCZ a coupled bias. CESM2 much improved
- Different N. Hem ITCZ Skill evolution
- High latitude biases very similar

CESM2
CESM1
CCSM4
CCSM3
CCSM2

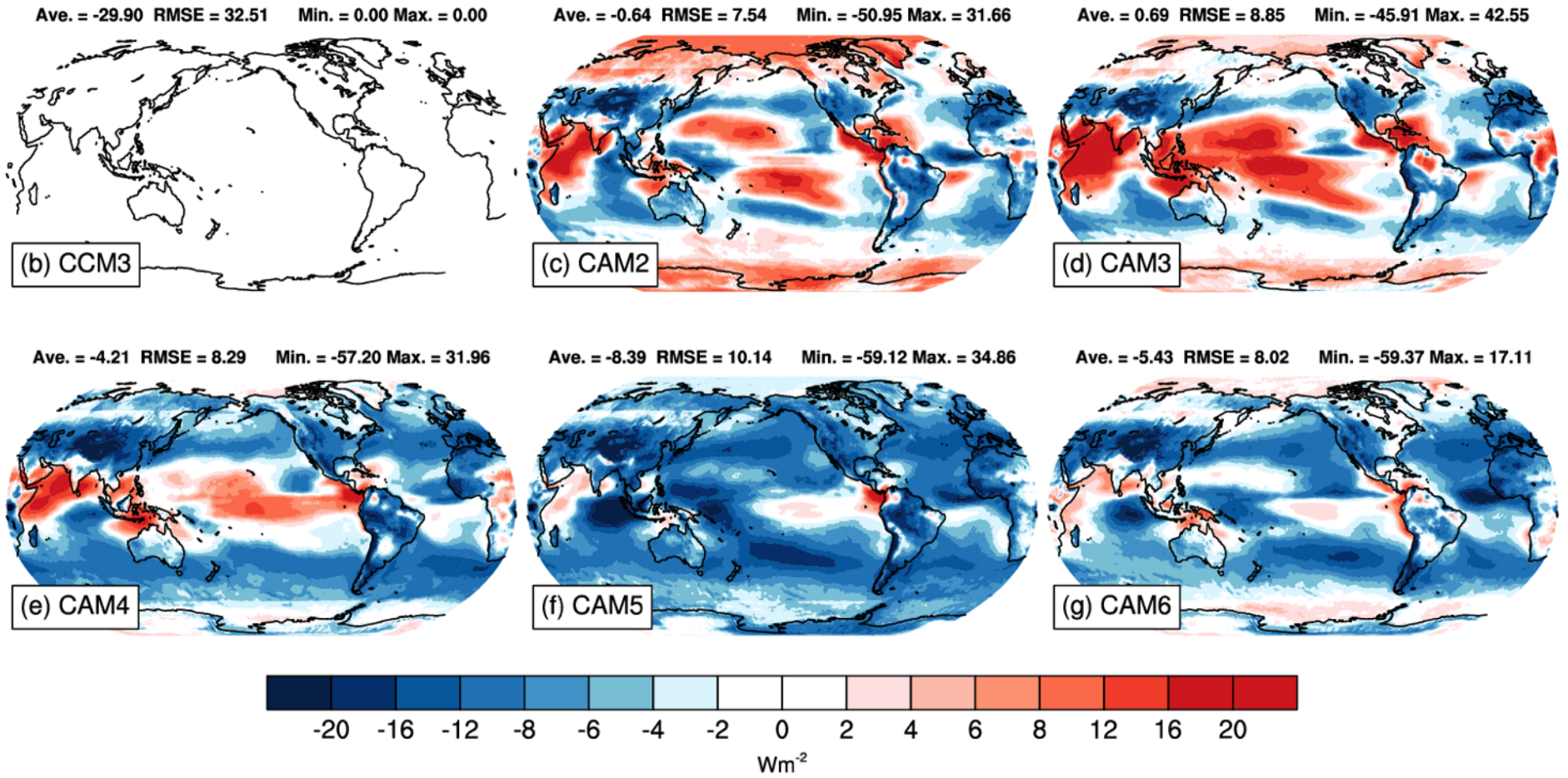
Short Wave Cloud Forcing (Annual) - AMIP

- Shift of biases from tropics to higher-latitudes.
- Microphysics has large impact
- Sub-tropical strato-Cu recent bias



Long Wave Cloud Forcing (Annual) - AMIP

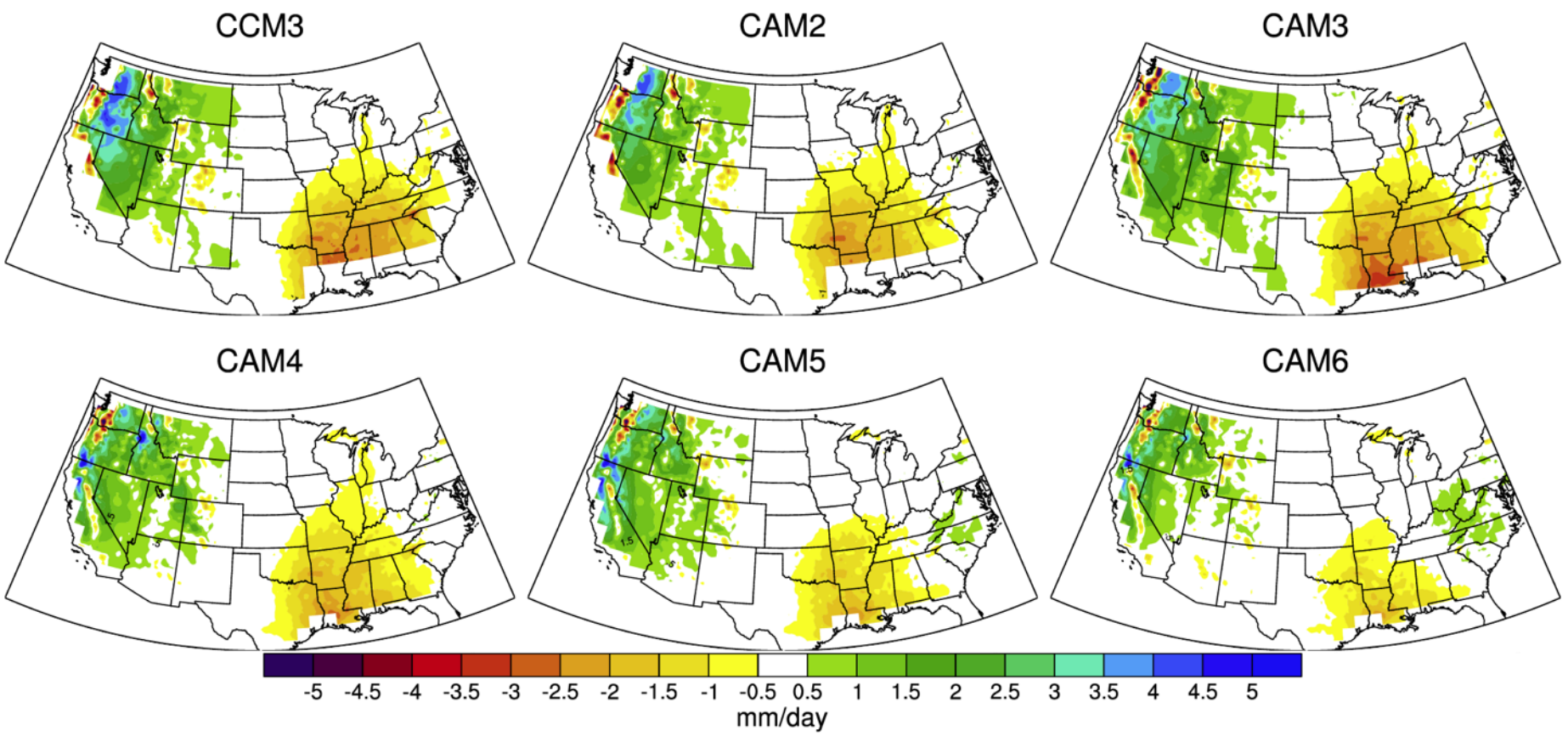
- No significant improvement with time
- Shift of sign, and excessive values from low to higher latitudes
- More ambitious microphysics



RMSE Skill Scores (Annual) - AMIP

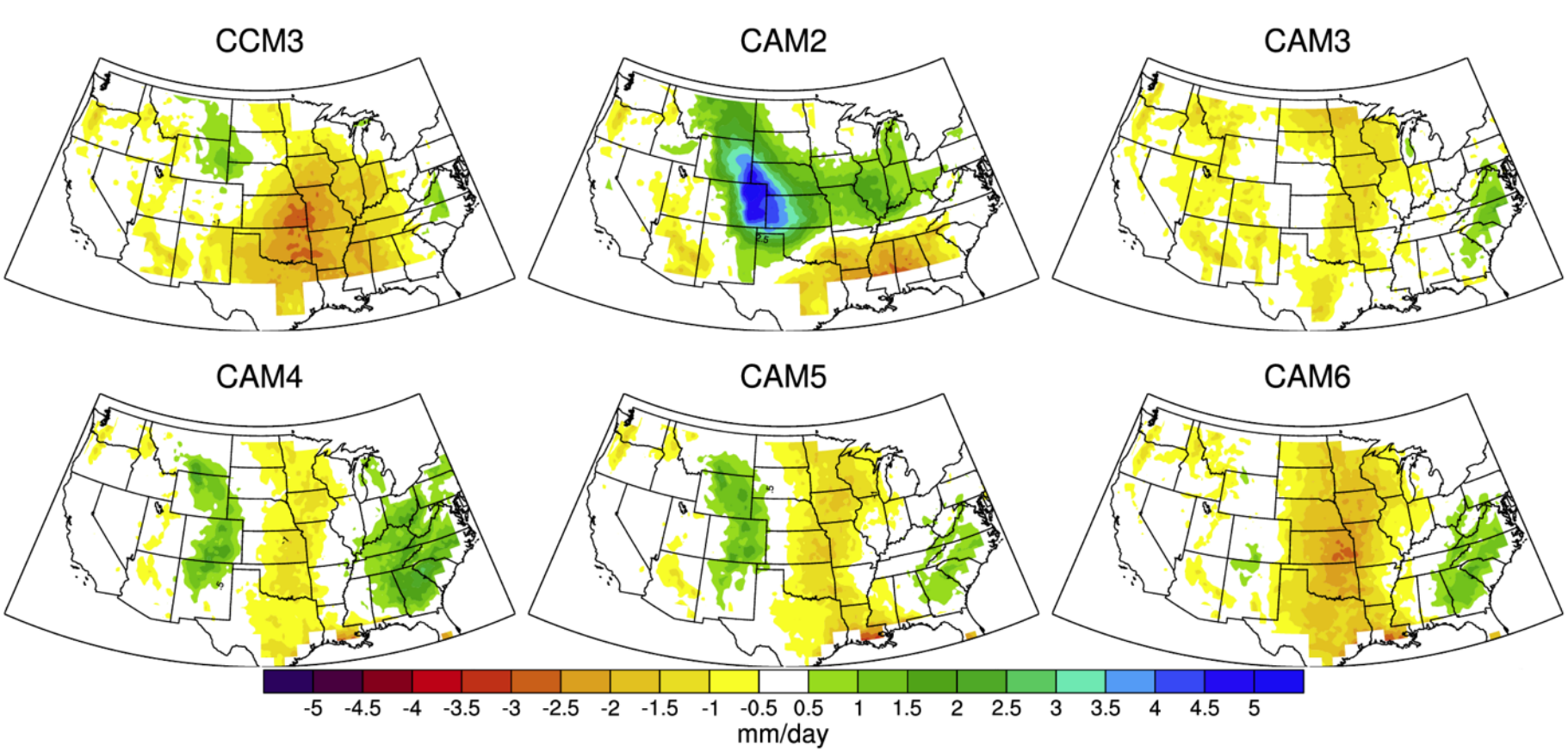
Variable	CCM3	CAM2	CAM3	CAM4	CAM5	CAM6
Precipitation	1.33	1.17	1.17	1.09	1.06	0.87
500-mb Temperature	1.72	1.61	1.12	0.59	0.90	1.03
850-mb Temperature	1.73	1.19	1.03	1.02	1.04	1.36
200-mb Temperature	4.16	4.92	3.63	3.08	3.34	2.14
200-mb Zonal Wind	3.81	4.31	3.68	2.14	1.64	2.52
850-mb Zonal Wind	1.79	2.27	1.99	1.55	0.95	1.37
500-mb Height	38.80	27.67	31.64	15.14	14.06	23.60
Surface Zonal Stress	0.033	0.038	0.031	0.021	0.020	0.019
SW cloud forcing	-	13.68	15.33	13.87	11.59	9.58
LW cloud forcing	-	7.54	8.85	8.29	10.14	8.02

US Precipitation (DJF minus CPC) - AMIP



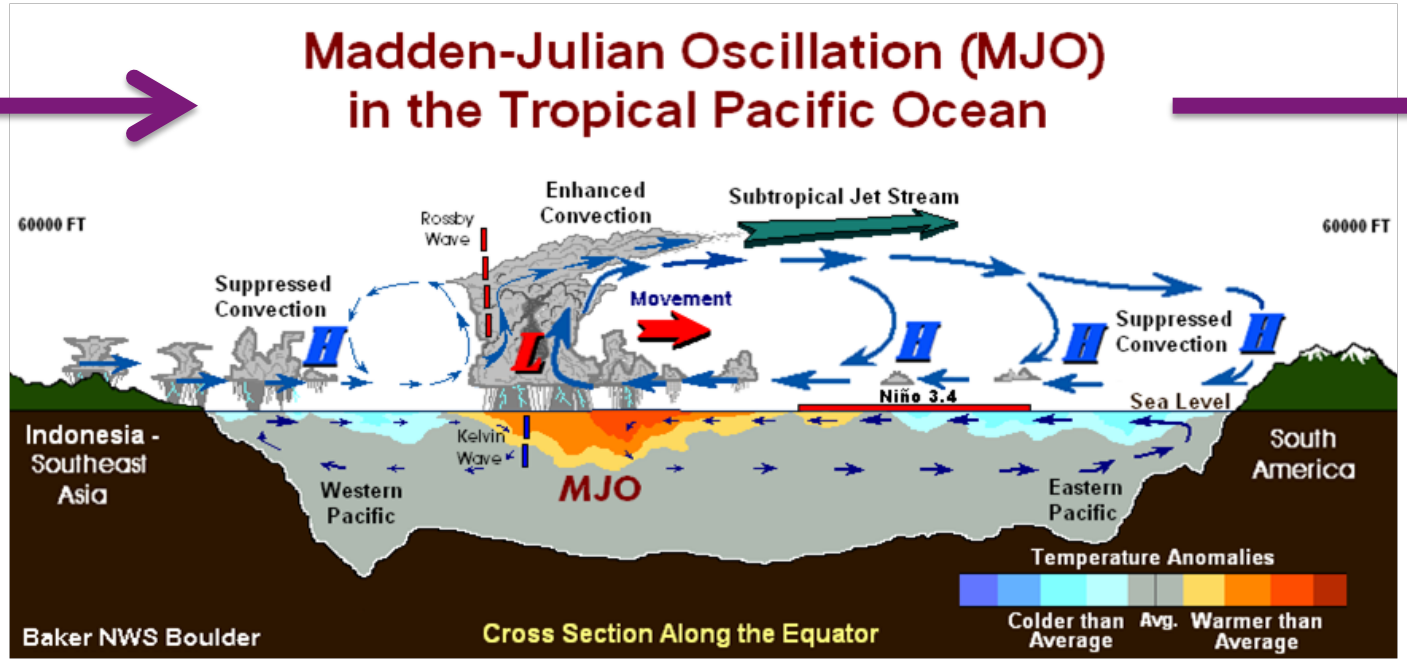
- Persistent biases across USA
- Bias halved in South-East and North West
- Reflects DJF improvements in general

US Precipitation (JJA minus CPC) - AMIP



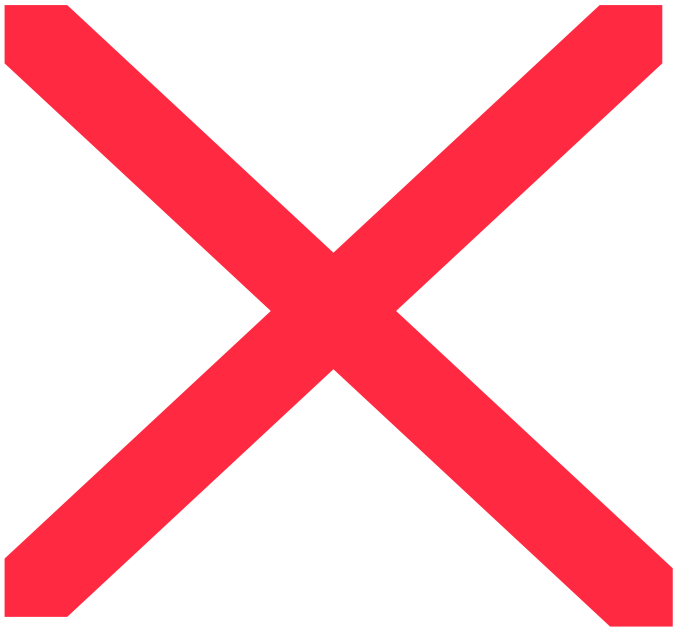
- Mid-west biases/Colorado have changed over time (JJA in general)
- Recent persistent biases over mid-west have worsened
- Deficient deep convection
- Lack of organization representation (resolution)

The Madden Julian Oscillation (MJO)



- Dominant large-scale east-ward mode of variability on intraseasonal (20-100 day) timescales in the tropics – strongest in winter-time
- Convection organizes in Indian Ocean propagates into the Pacific
- Multiple interactions: ENSO, Monsoons, North Pacific wave propagation, NAO
- Potential to extend predictability to multiple weeks
- **Emergent phenomenon**

Summary of CAM MJO performance



Combined EOF (OLR, u850, u200, daily BP filtered 20-100d)

CAM3

Low convective entrainment

CAM4

High entrainment = moisture sensitivity

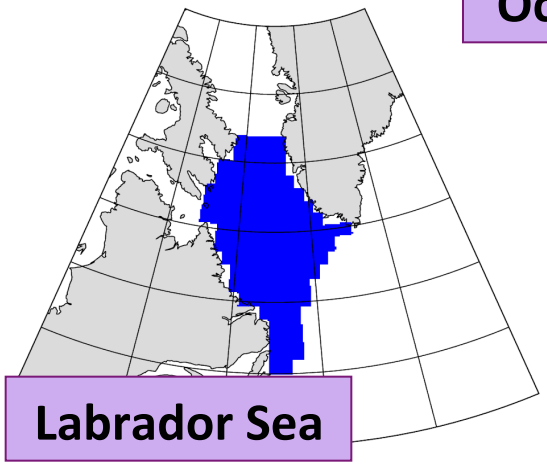
CAM5

Convective retuning + changed params.

CAM6

Increased stability sens. + coupling + new params

Challenges of Development: Labrador Sea

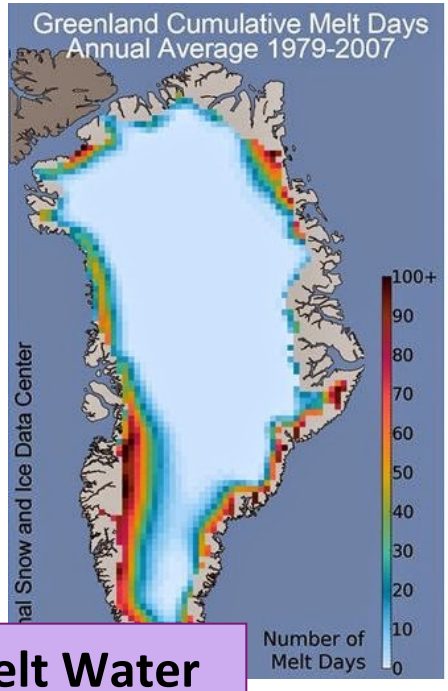


Labrador Sea

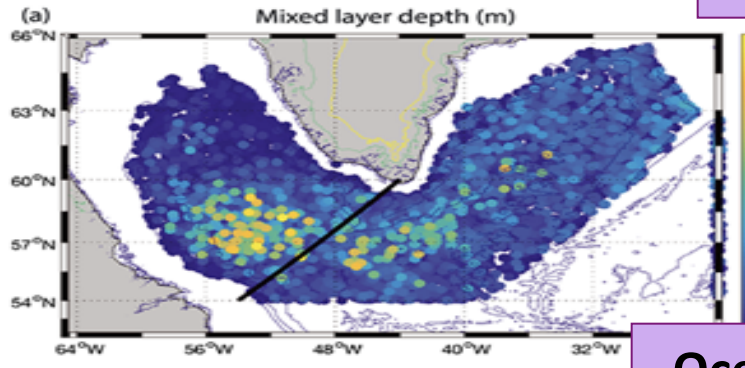
Ocean Currents

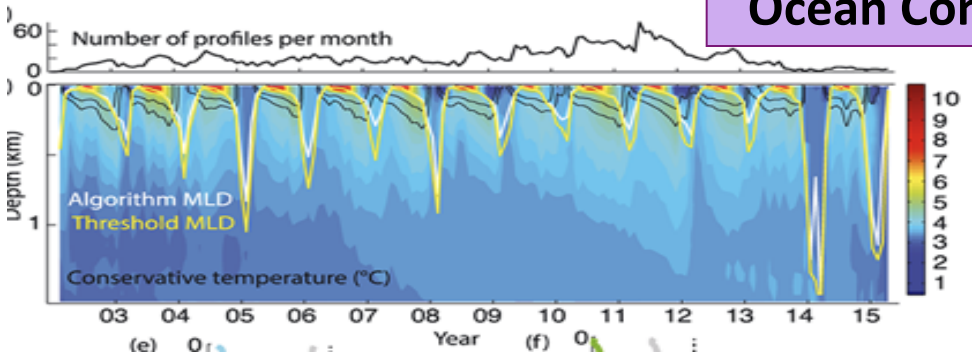
Sea Ice

Atmos. Circulation



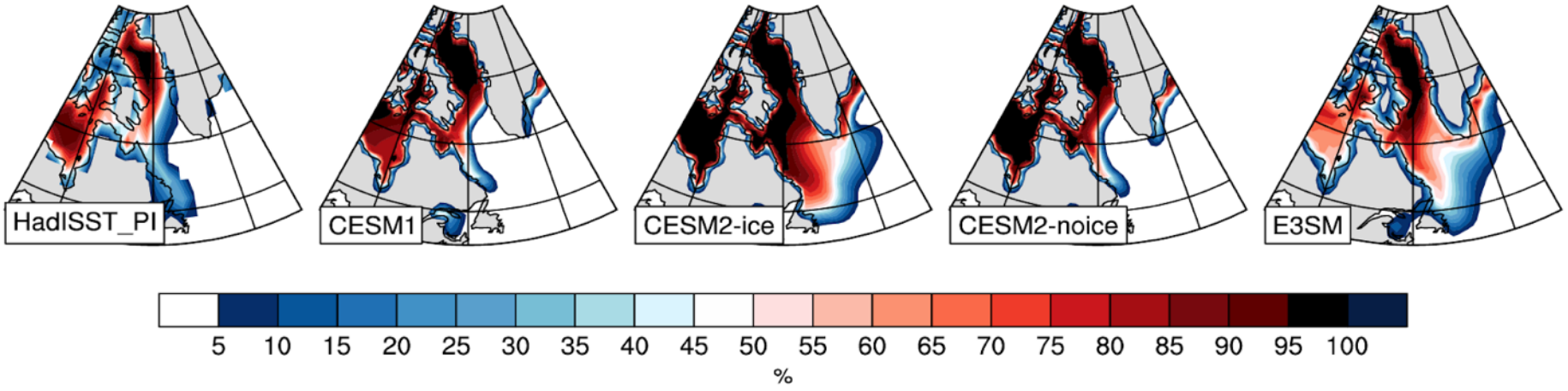
Melt Water

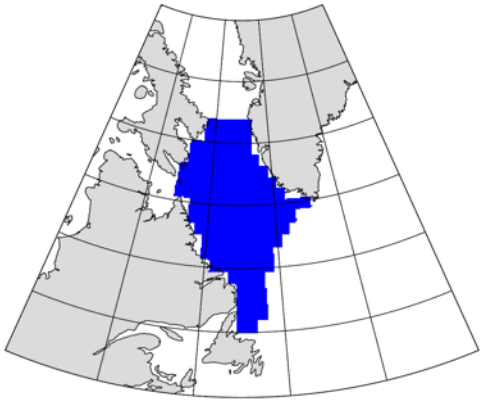


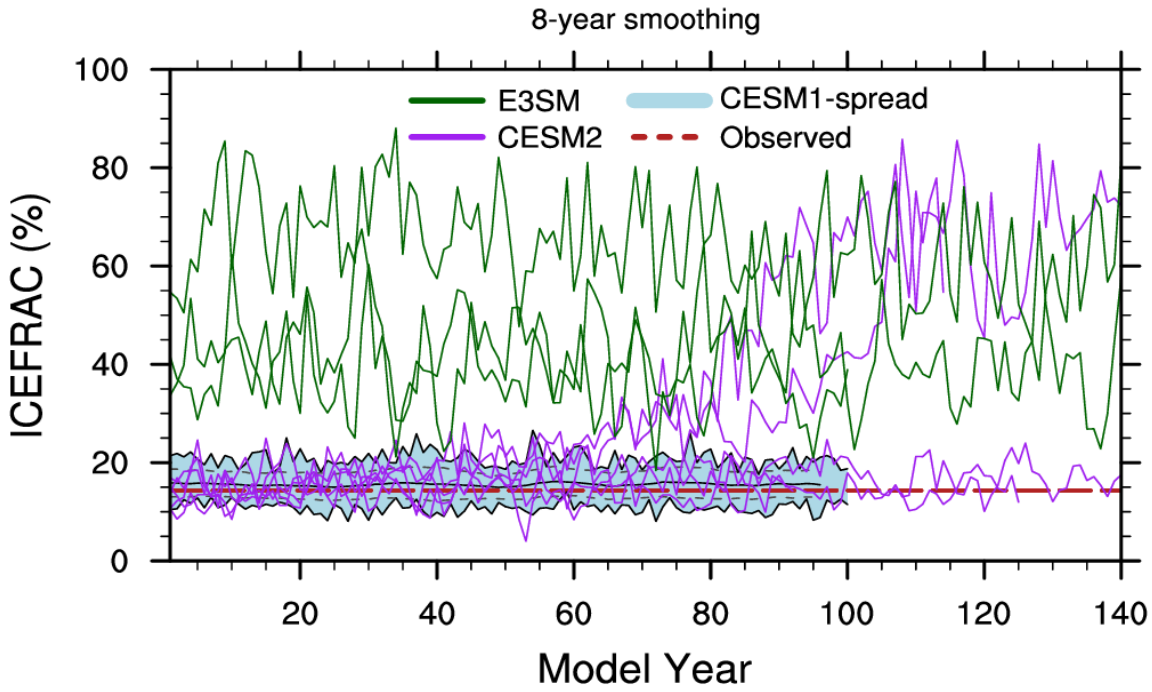


Ocean Convection

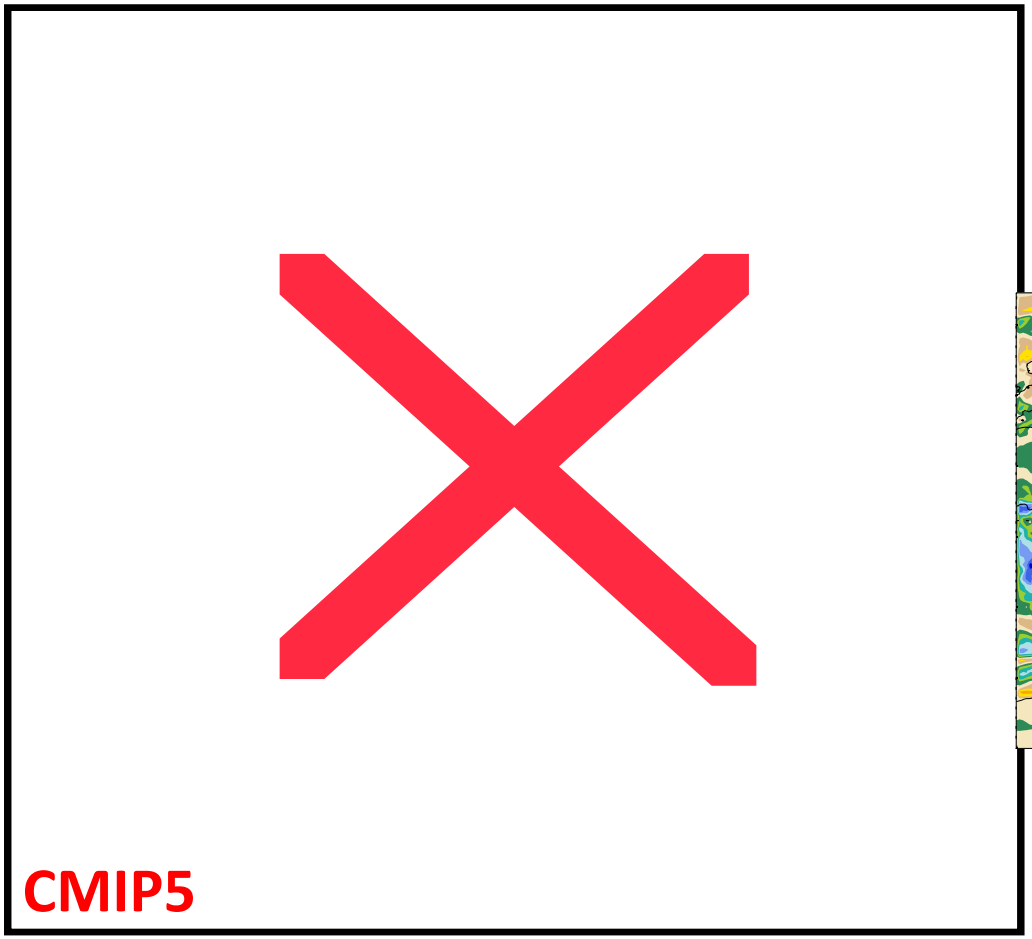
Challenges of Development: Labrador Sea





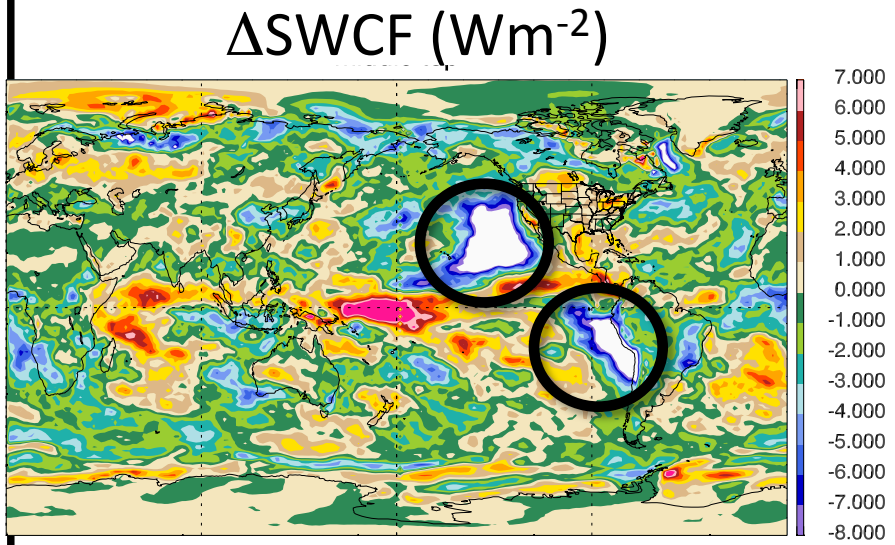


Challenges of Development: Forcing Datasets



CMIP5

CMIP6/CMIP6

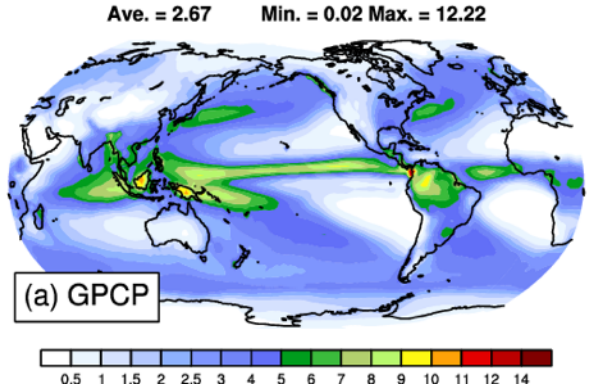


- Competing cloud forcings and feedbacks
- Cloud sensitivities (accretion/Bergeron/autoconversion)
- Emission peculiarities in CMIP6

Thanks:
Andrew

35 years of improvements?

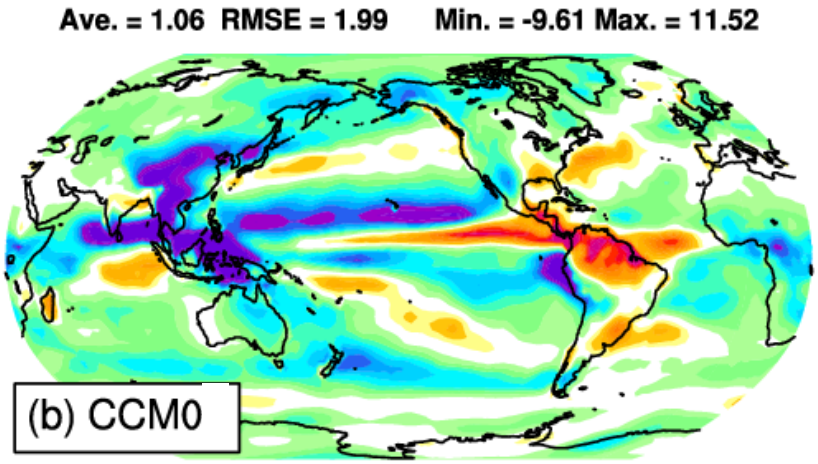
Total Precipitation Difference (ANN)

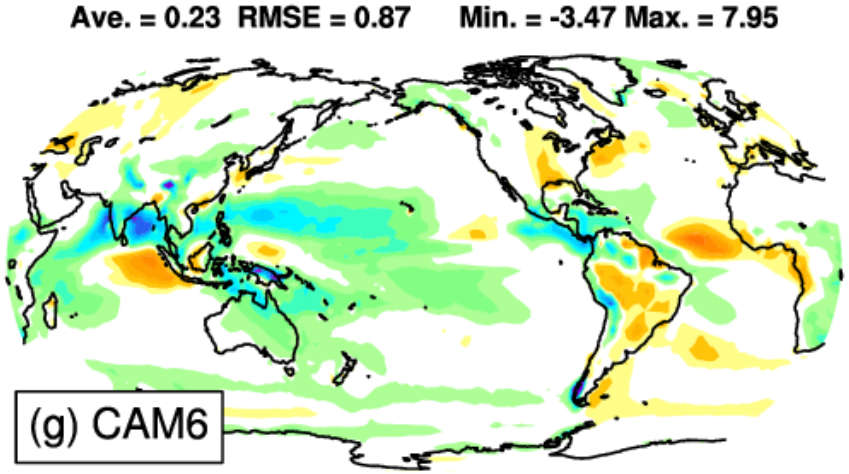


Components
Atmosphere

Components

Atmosphere	Chemistry
Land	Bio-geo-chem
Ocean	Land-ice
Sea-ice	Paleo
WACCM	*Maintenance*





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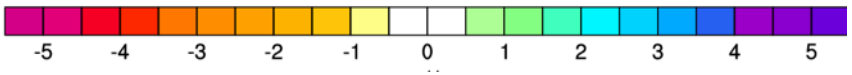


2017

Assessing NCAR Atmosphere Models

How have we improved in the last 20 years? Next 20 years?

- Clear monotonic improvements (DJF)
- Persistent biases
- New biases begin and old biases return
- Ups and downs in skill (JJA)

- Trade-offs (within and across components)
- Human bias, value judgements (I like tropical clouds, other people like stress)

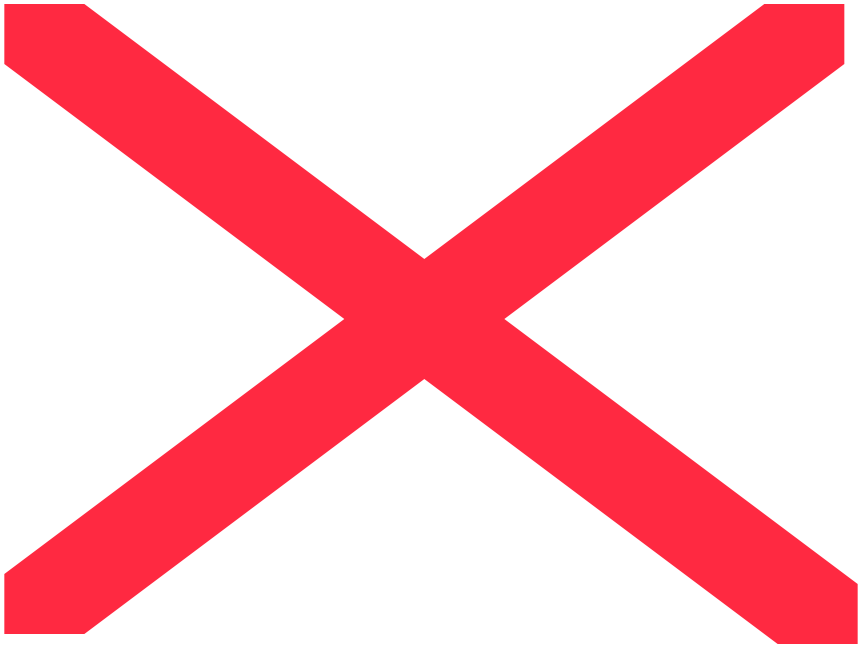
- Future looks challenging
- Mounting requirements and constraints
- Making sure things don't get worse!

Climate Modeling Climate

“all models are wrong, but some are useful.”

“some models are more wrong than others, but some are more useful than others”

Questions?



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