A Multi-model Analysis for CEOP: Surface Fluxes

Michael Bosilovich, David Mocko
John Roads and Alex Ruane

Data contributions from
BMRC, CPTEC, ECPC, JMA, MSC, NCEP and UKMO
And ECMWF and GMAO

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Phase I Global Analyses

- Coordinated Enhanced Observing Period – EOP 3 and 4, Oct 2002-Dec 2004
- 8 (now 10) global analyses archived at MPI (~5.7TB, native grids/forecst cycles)
- Limited access or use by the science activities in CEOP
- Need to process the data to a more uniform usable format

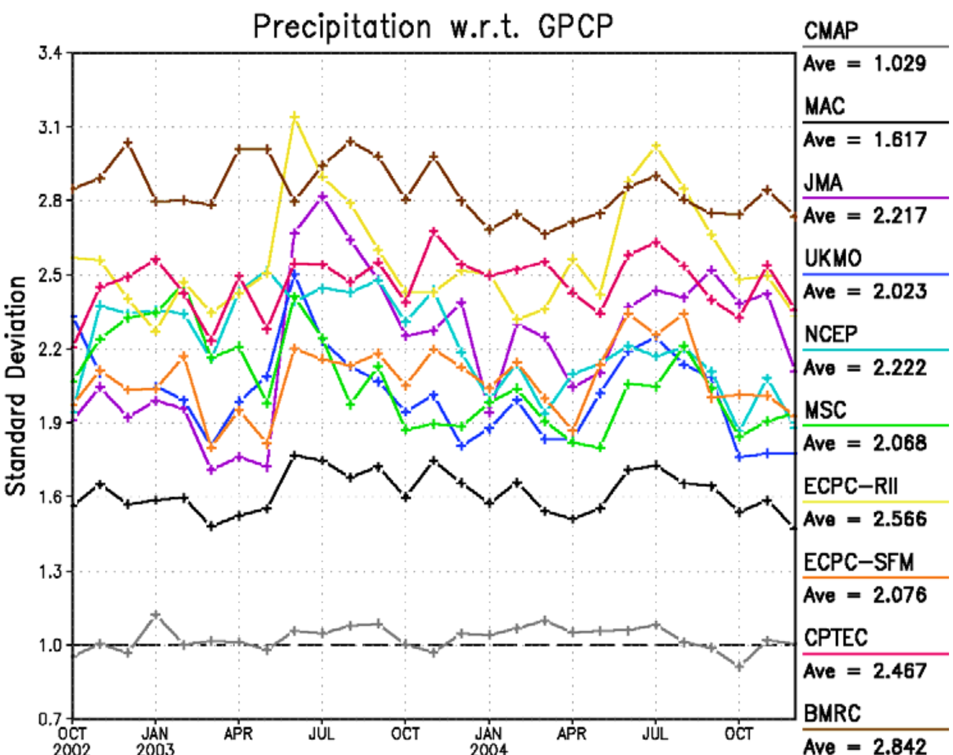
Multi-model Analysis for CEOP (MAC) Objective

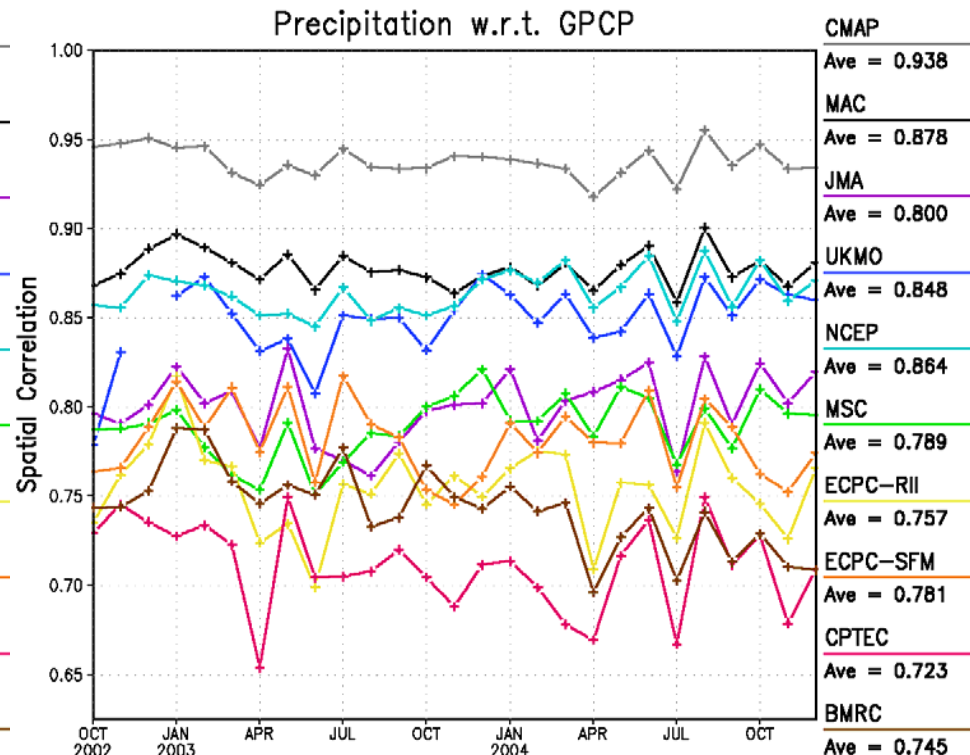
- To homogenize the differences in the data structure, facilitating comparisons and evaluations with independent data
- Focus on the physical processes (especially W&E)
- To produce an ensemble mean and variance data set that may support CEOP science activities
- Hypothesis: Since the input observations are closely related, an ensemble mean should minimize uncorrelated model background error and bias
  - For example: Dirmeyer et al. (2006, GSWP), Philips and Gleckler (2006), Compo et al. (2006)

Multi-model Analysis for CEOP (MAC)

- Each of 8 systems provides 6 hourly analyses, largely the same input observations with different DA methods
  - Some important differences among members
- Unified Dataset
  - 1.25 degree global spatial resolution
  - Monthly, daily, and 6 hourly time series – For all 8 (now 10!) members, ensemble mean and std. dev.
  - NetCDF and Grib online, Binary in archive
- Issues in developing the Ensemble
  - Missing data, spatial resolution, temporal averaging, analysis vs. forecast, occasional bugs, P Surface intersecting the topography, variable names

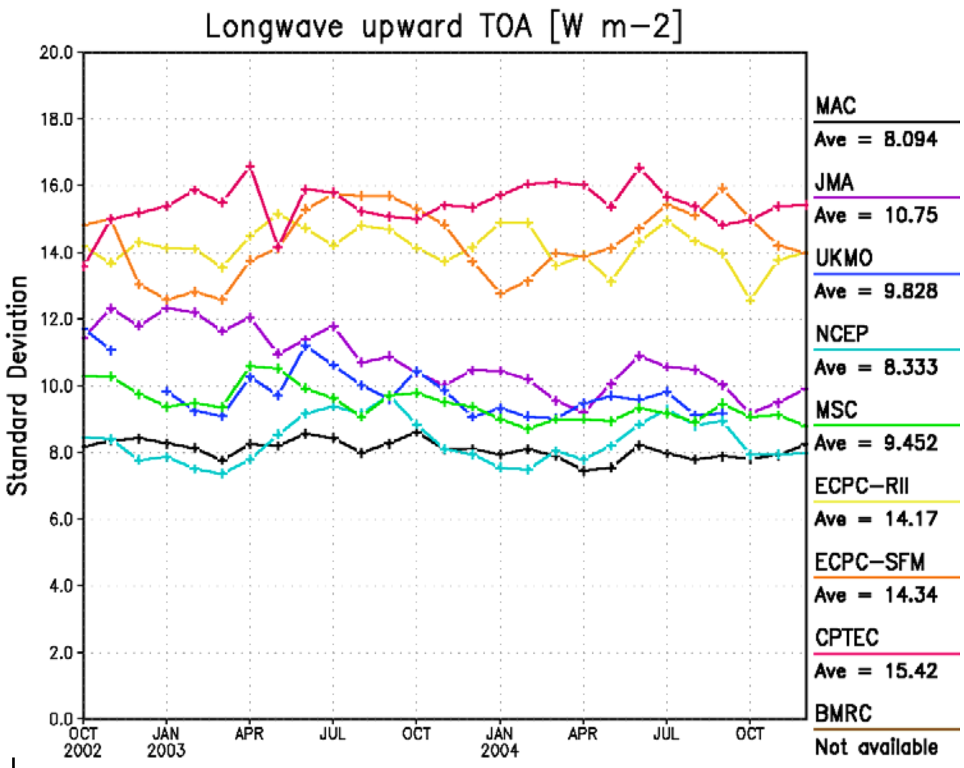
Full EOP 3-4 time series (Monthly)

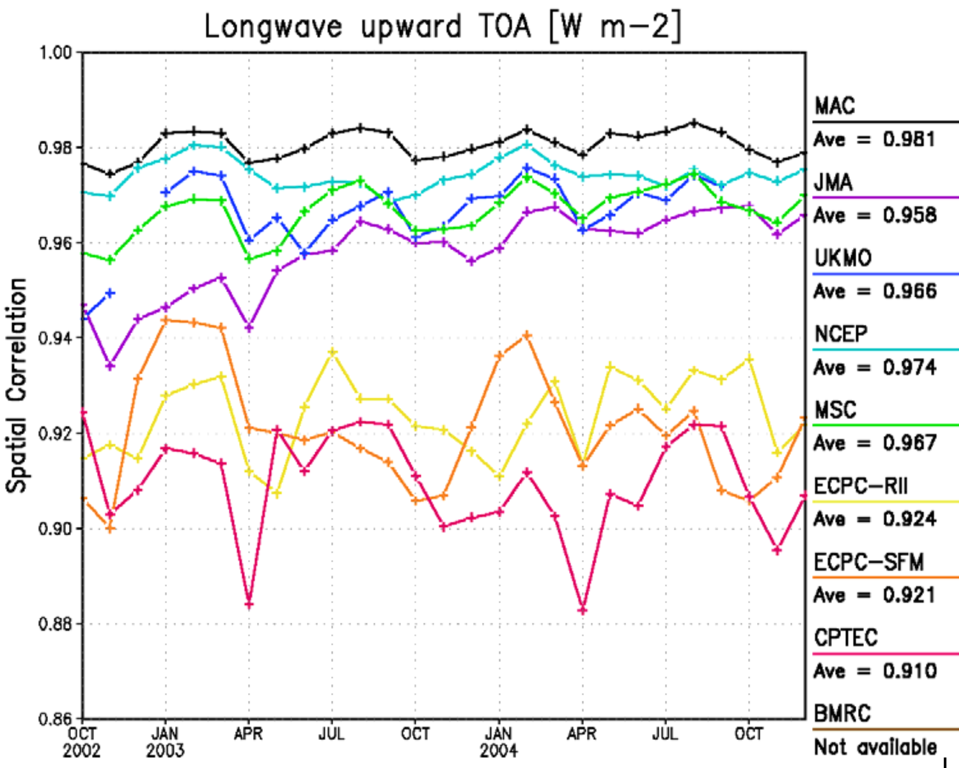




- Global spatial statistics of MAC precipitation compared to GPCP

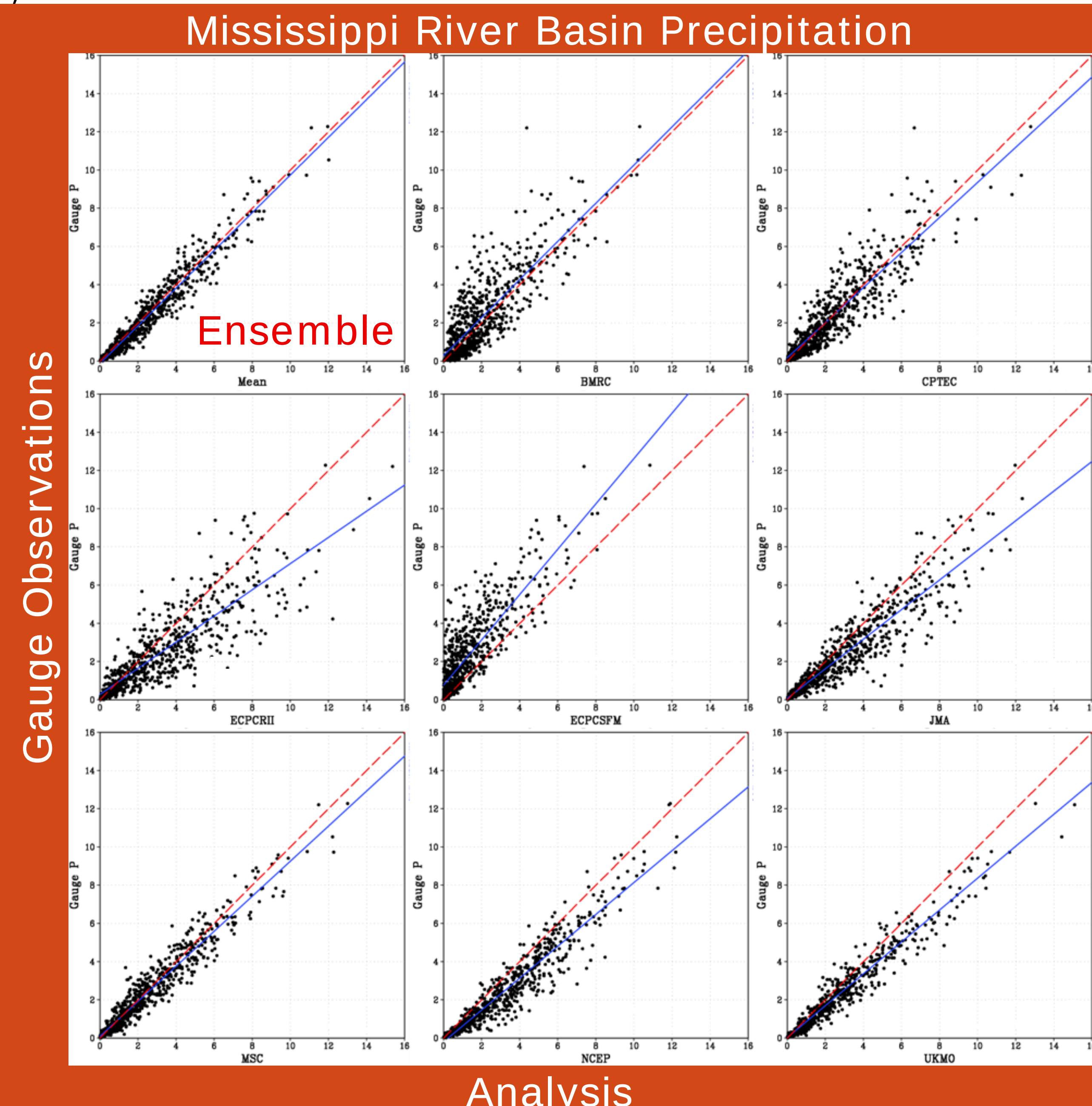
Full EOP 3-4 time series (Monthly)



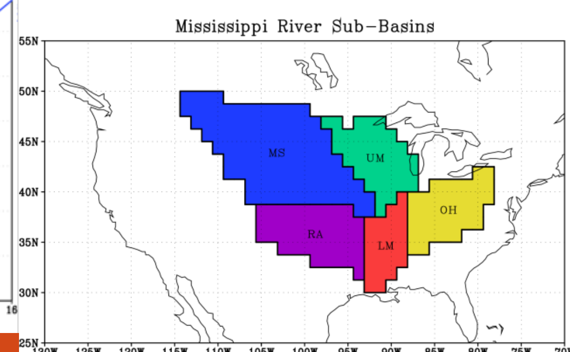


- Global spatial statistics of MAC TOA OLR compared to SRB

CEOP EOP 3-4 Daily MRB Precipitation

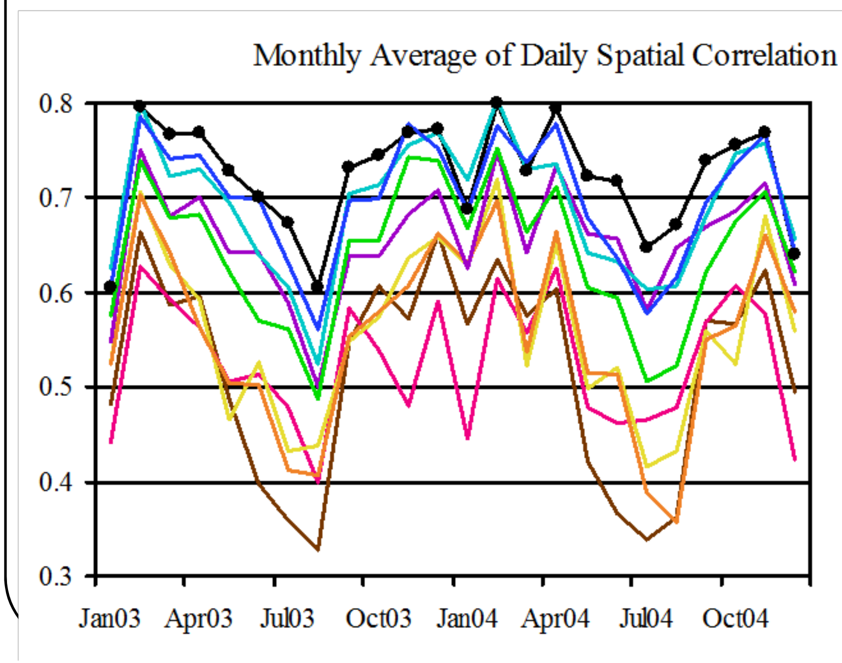


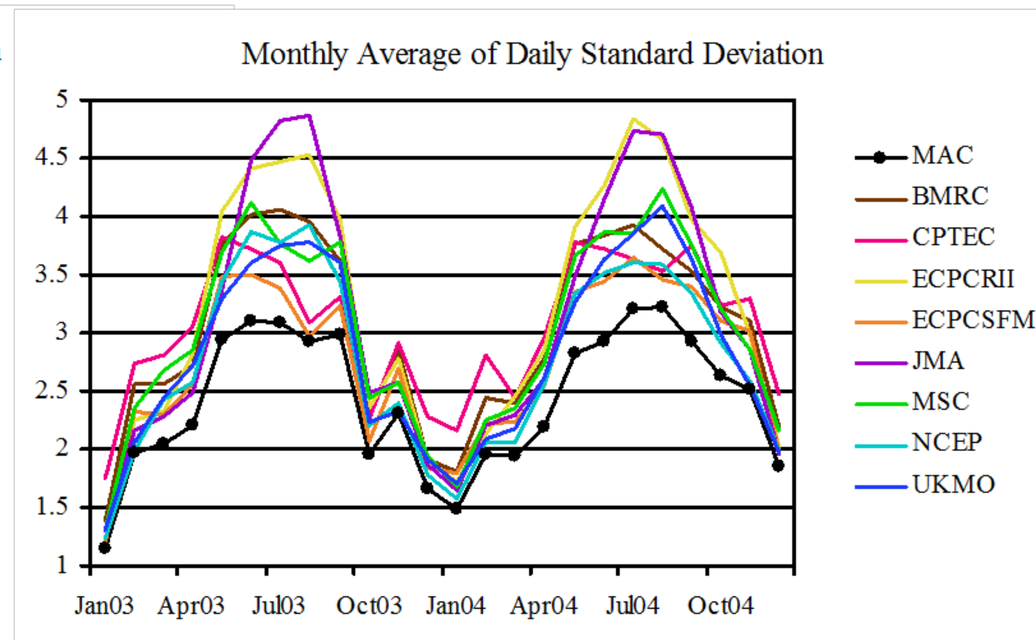
- Precipitation is independent (not assimilated)
- In general, Models have different characters
- Most overestimate high rain events
- Daily spatial correlations highest in the ensemble



Daily Spatial Statistics of MRB Precip

- Each day calculate the spatial correl. and Std. Dev for the MRB
- Time average the daily statistics for presentation
- The daily spatial distribution of the MAC Ensemble Precip has more skill than any single member

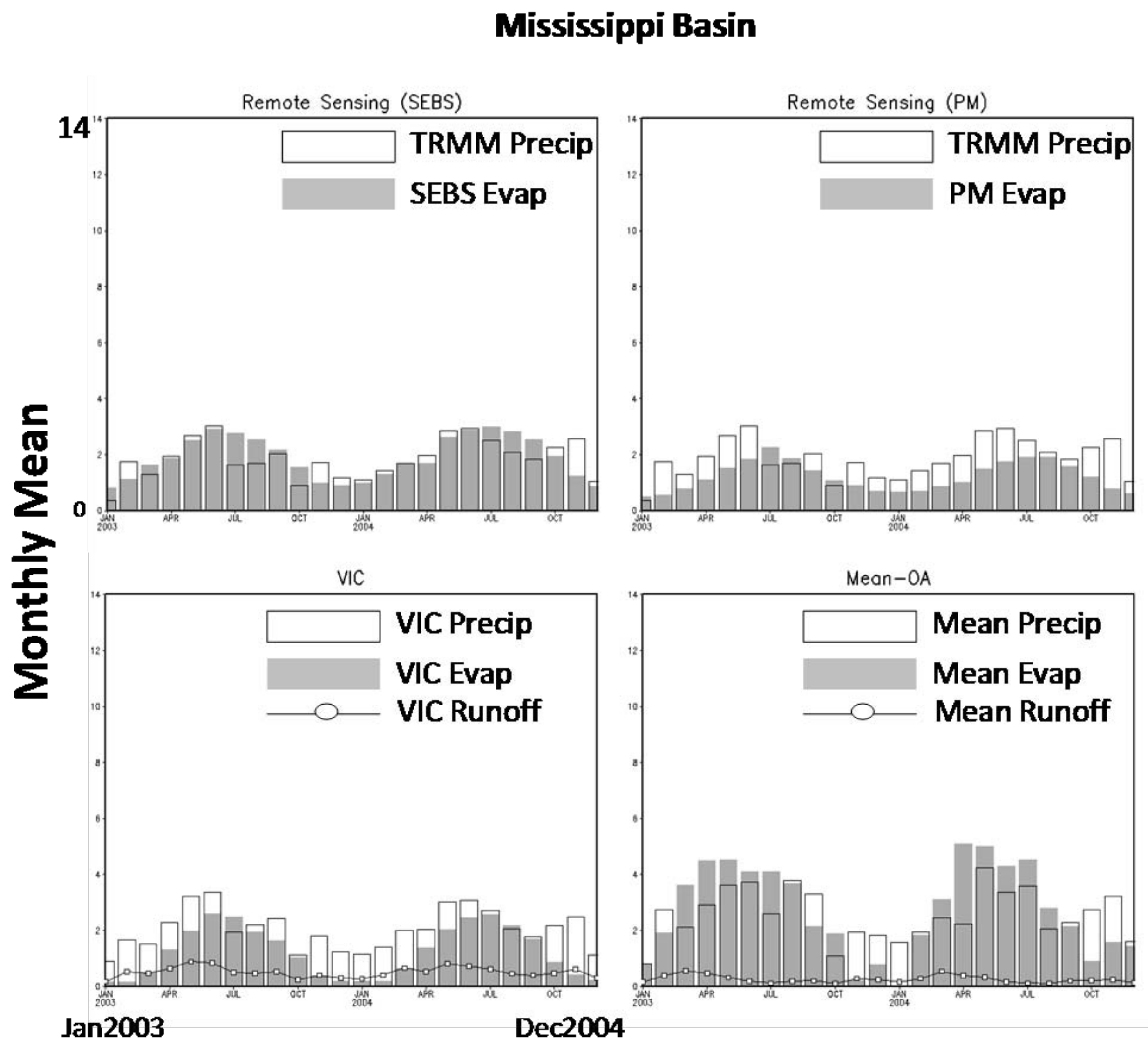




Comparison with SEBS ET

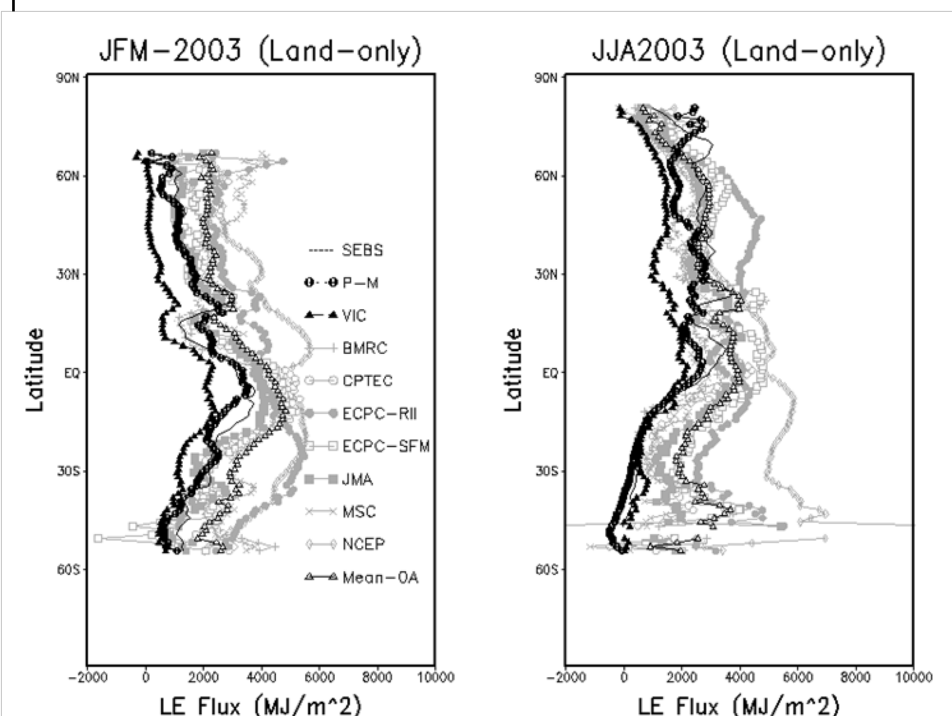
Vinukollu and Wood

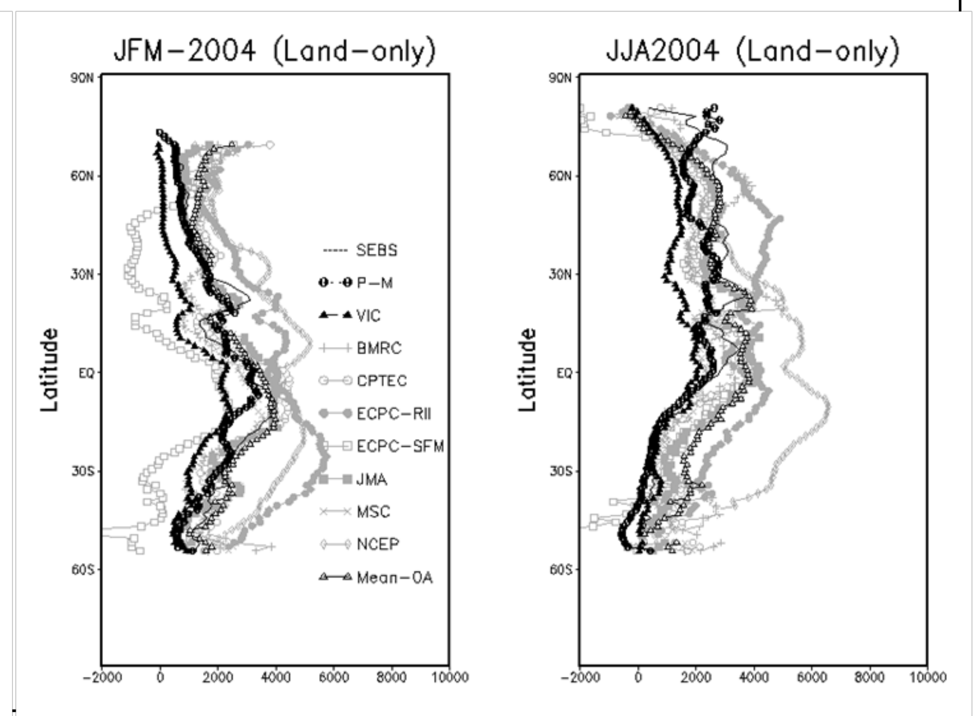
- SEBS – Multi-sensor (CERES AIRS, MODIS) derived land surface evaporation



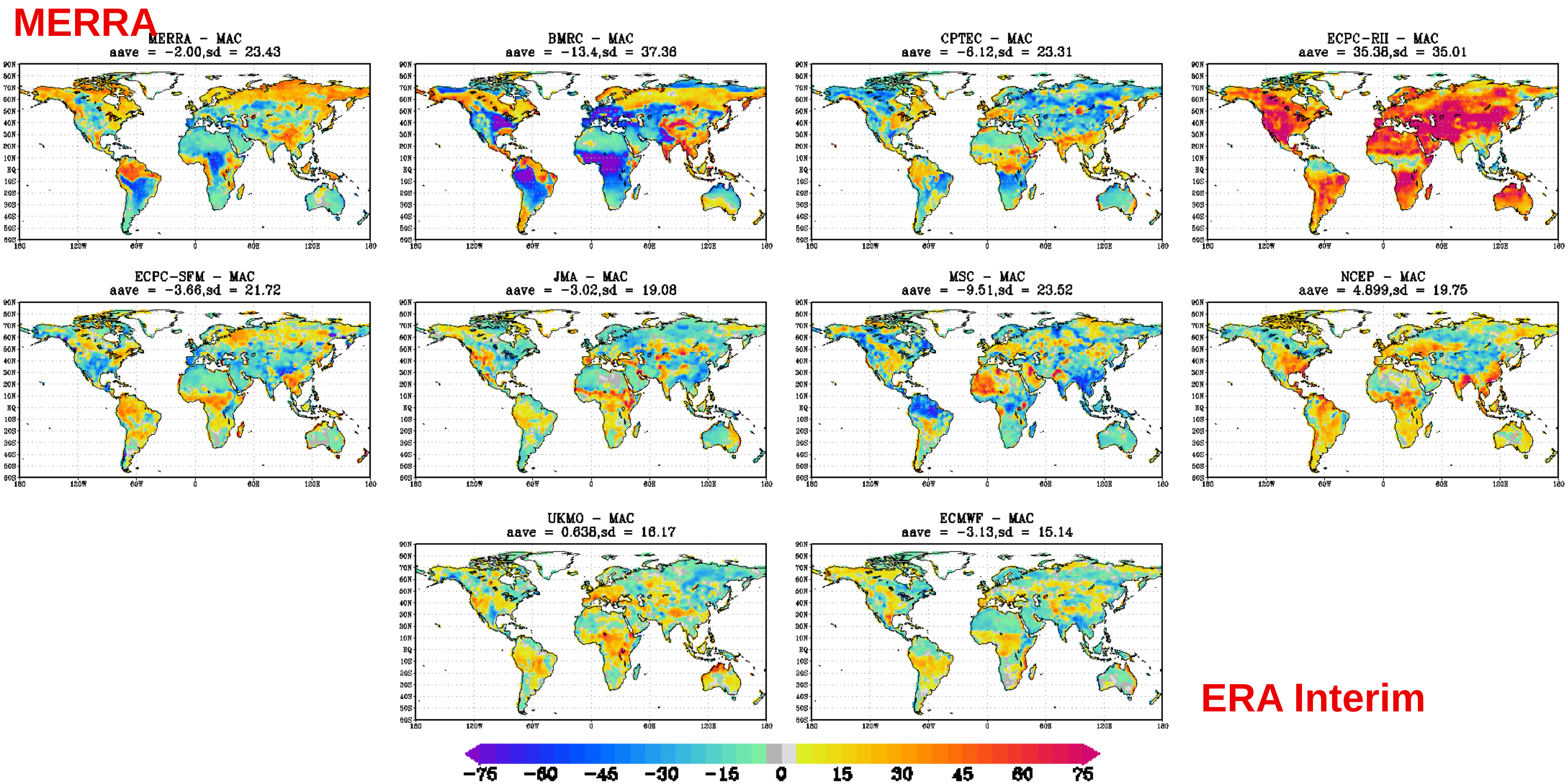
Zonal and Seasonal SEBS LE

- Multi-model mean compares well in summer seasons, and less so in winter seasons (high bias)
- Still undergoing statistical comparisons





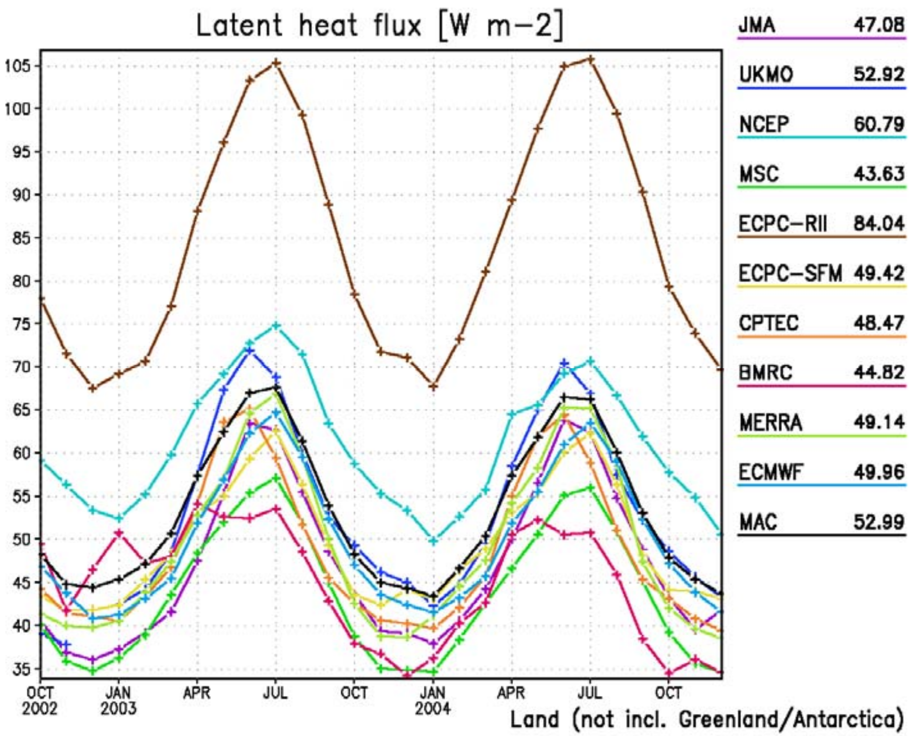
200407 Latent heat flux (W/m^2)



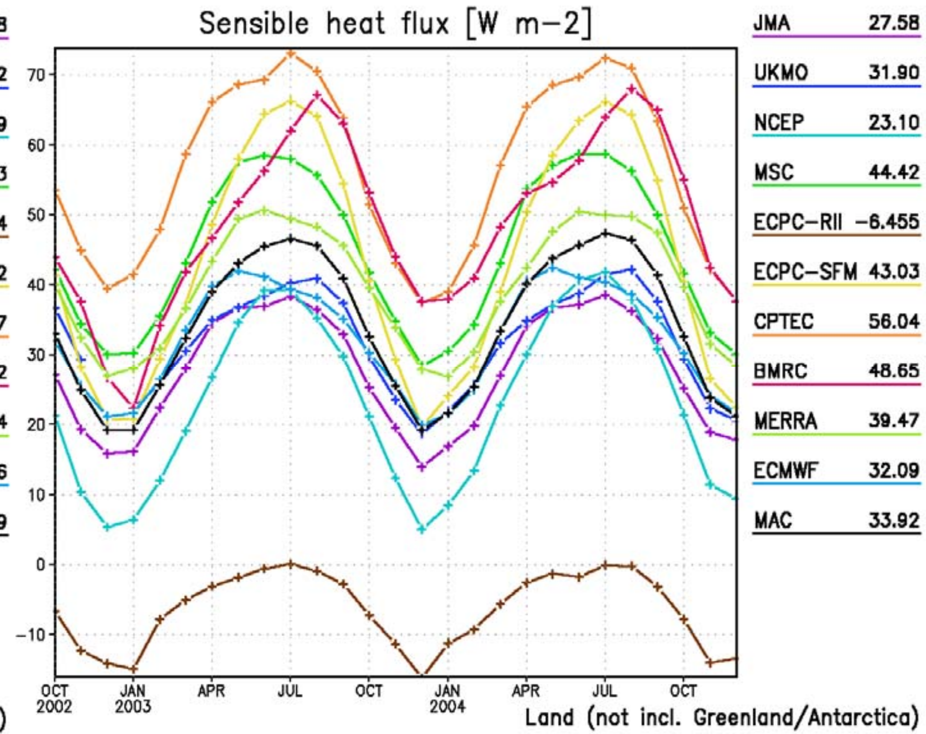
- Just starting to work with Version 2 – 10 member data set
- Differences from the 10 member ensemble average
- Range of +/- 75 Wm^{-2} in the monthly mean difference
- ERA Interim is the closest to the ensemble mean

Global Land-only Monthly Series

Latent Heat Flux

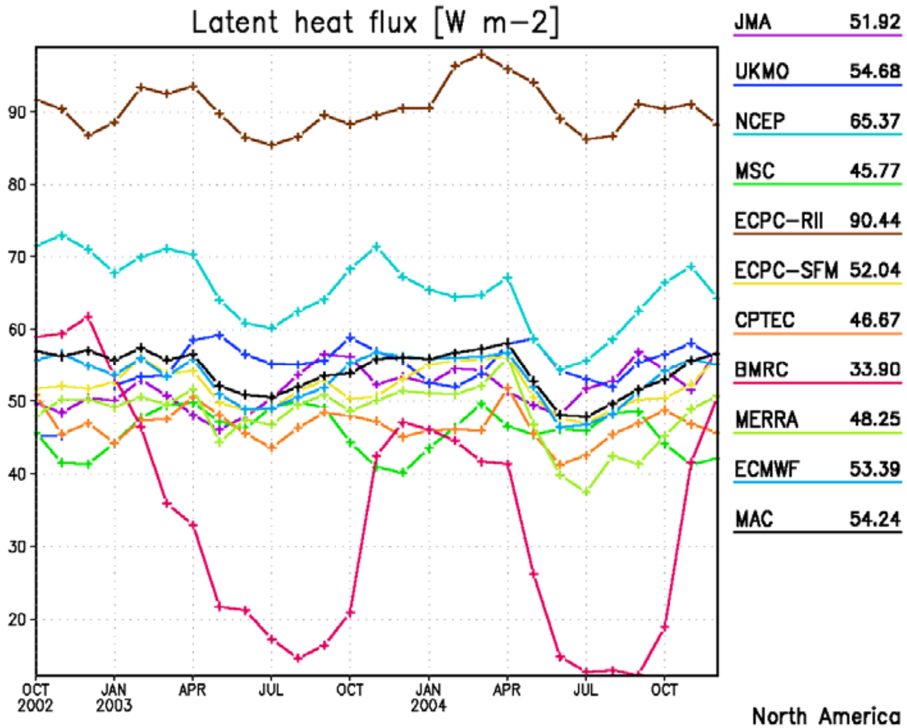


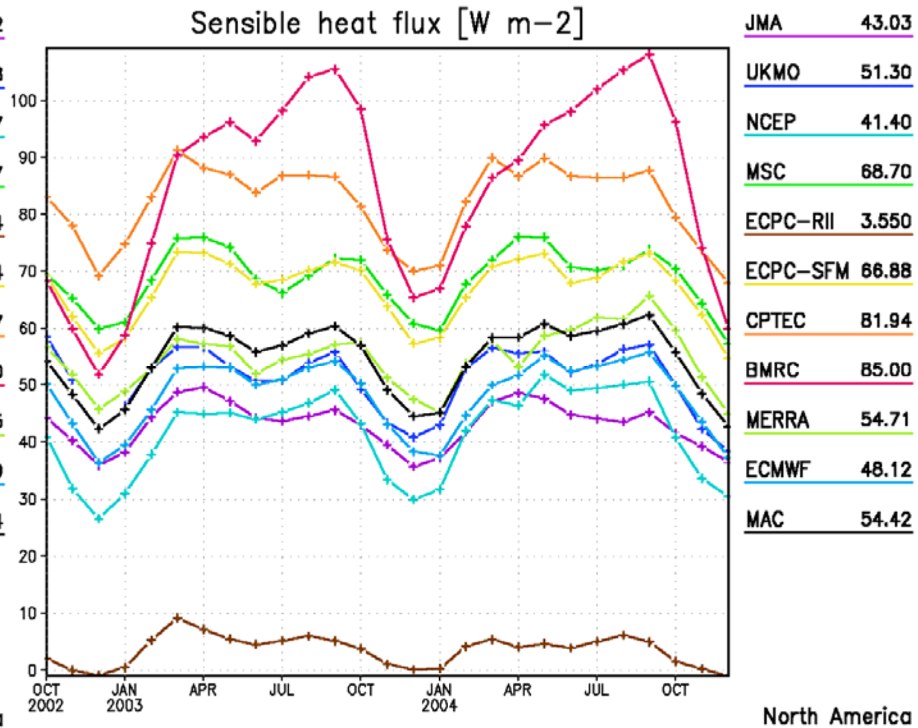
Sensible Heat Flux



- The spread of values allows calculation of the uncertainties
- Greenland/Antarctica excluded from land integration

North American Land Fluxes





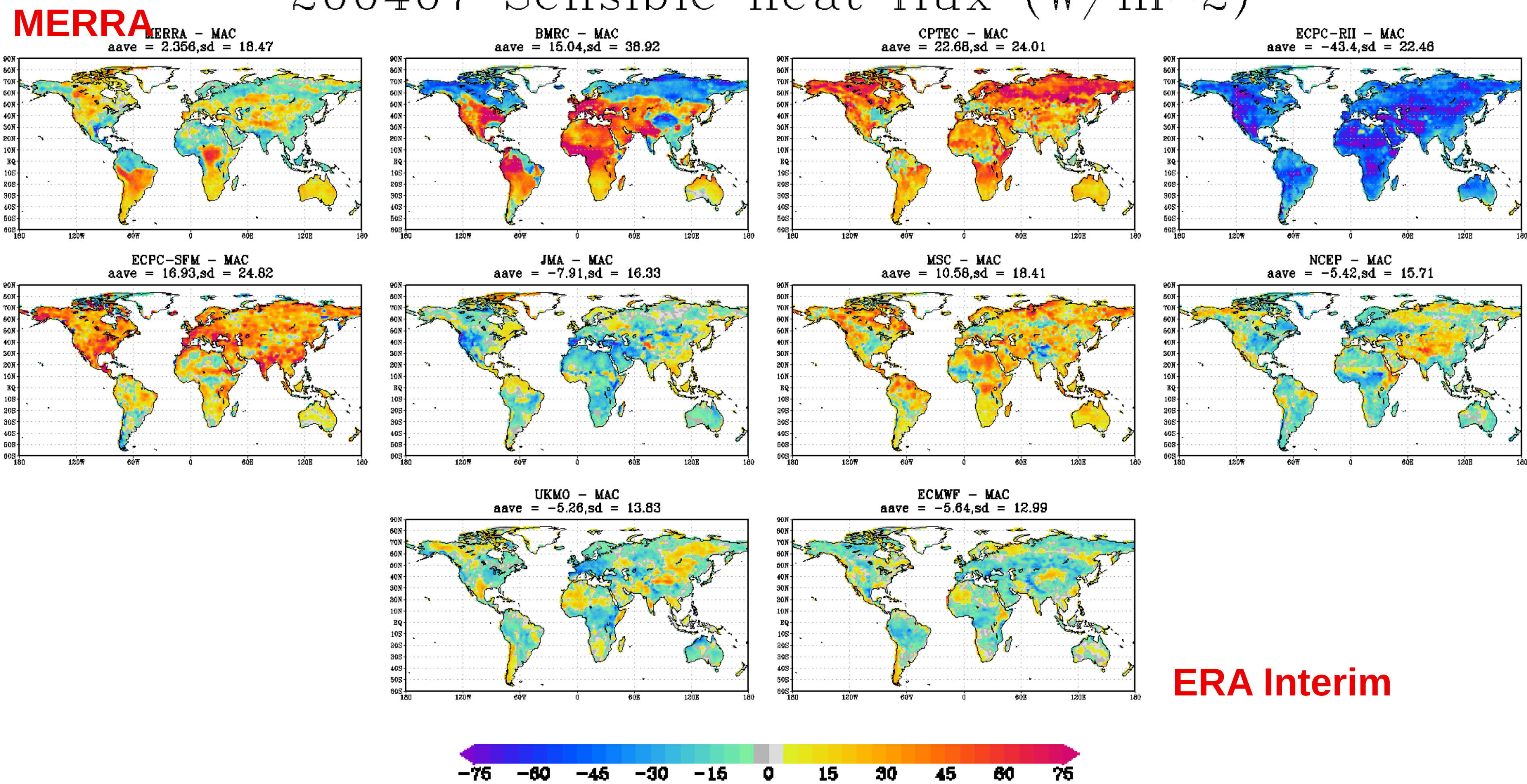
- For NA, most centers fluxes have similar cycles and patterns in the time series, with a with range of means

Global Land Energy

b) Land	LH	SH	RLd_{sfc}	RLu_{sfc}	RSd_{sfc}	RSu_{sfc}	RLu_{toa}	RSd_{toa}	RSu_{toa}	Net_{sfc}	Net_{toa}	Precip
BMRC	51	46	326	401	212	40	-	-	-	0.1	-	2.40
CPTEC	55	54	333	401	224	44	253	-	106	2.3	-15.3	2.46
ECPC-RII	87	-3	322	393	208	42	246	343.2	105	12.4	-7.5	2.81
ECPC-SFM	54	42	313	396	232	45	255	343.2	89	7.4	-0.6	1.95
JMA	53	27	301	391	219	46	260	343.1	95	1.7	-11.9	2.45
MSC	49	43	319	392	206	43	250	342.0	103	-2.6	-10.5	2.34
NCEP	65	23	322	392	208	44	249	-	101	5.8	-7.2	2.84
UKMO	58	31	328	396	196	38	240	343.4	104	1.2	-0.9	2.64
MAC	59	33	320	395	214	43	250	343.0	100	3.5	-7.8	2.48
Sdev	12.2	18.0	9.9	3.9	11.3	2.7	6.3	0.5	6.1	4.8	5.5	0.28
TFK	39	27	304	383	185	40	232	330.2	113	0.0	-15.6	-
SRB/GPCP	-	-	329	402	192	35	243	343.1	-	-	-	2.30

- **Model data are for Jan 2003-Dec 2004**
- **MAC ensemble average based on 6 hourly means (not the average of global values)**
- **Sdev is the standard deviation of the models global values**
- **TFK - Trenberth, Fasullo and Keihl (2009, BAMS)**
- **P in mm/day, others W/m2**
- **SRB/GPCP 2003-2004, as in the models, TFK for Mar00-May04, GRFA due soon**

200407 Sensible heat flux (W/m^2)



- Similar wide range of sensible heat fluxes

Results

- *Monthly comparisons to precipitation and TOA OLR show the variance of the analyses and that the ensemble generally compares the closest*
- Also, noticeable improvements to any individual member has only slight effect on the ensemble
- Selecting only the best skill systems only improve the ensemble results marginally
- *Daily precipitation in the MRB is very well represented by the ensemble*
- This extends to sub-basins and also daily spatial distribution of precipitation

Surface Fluxes

- Sensible and Latent heat vary greatly from system to system
- May also expose serious deficiencies, but care must be taken in determining outliers (something that is an outlier, may actually be more realistic)
- Further comparisons among surface flux data sets (satellite based and LDAS based)
- Ensemble average may be representative, but still requires validation and improvements
- An ensemble approach allows estimates of uncertainty

Summary

- Comparing models to a single analysis is clearly inadequate
- The variance in the ensemble appears to be unacceptably high; should be monitored, allowing feedback to centers
  - Still Selective Ensembles have only small improvement
- GMAO and ECMWF contributions have been added to Version 2
- http://gmao.gsfc.nasa.gov/research/modeling/validation/ceop.php

Data info and download:

http://gmao.gsfc.nasa.gov/research/modeling/validation/ceop.php

Thank you for your time!

Implications of this Work

- GEWEX Objectives 1 & 2: A data set that can be used to better understand W&E cycles and contributes to the RHPs and focus studies
- Ken Mitchell (NCEP) and Paul Earnshaw (UKMO) have copied the data and is using it in their system evaluations
- Kun Yang (WEBS) and W. Guo (S-A) have copied the data for use in their contributions to CEOP

Next Steps

- Provides impetus to continue or expand the efforts tested in the CEOP Global modeling group
- Un-Acronymed Project in 2013: An effort to collect and synthesize a multitude of international operational analyses for weather and ultimately climate model development (e.g. AMIP or IPCC)
  - Need commitments from NWP centers, not just data, but formatting, and documentation
  - Can or will TIGGE data be augmented to include physical process data used in GEWEX studies?
  - Can we enhance the archive site to handle the reformatting of the model analyses and forecasts? Probably with input from the contributing centers (PCMDI utilities?)

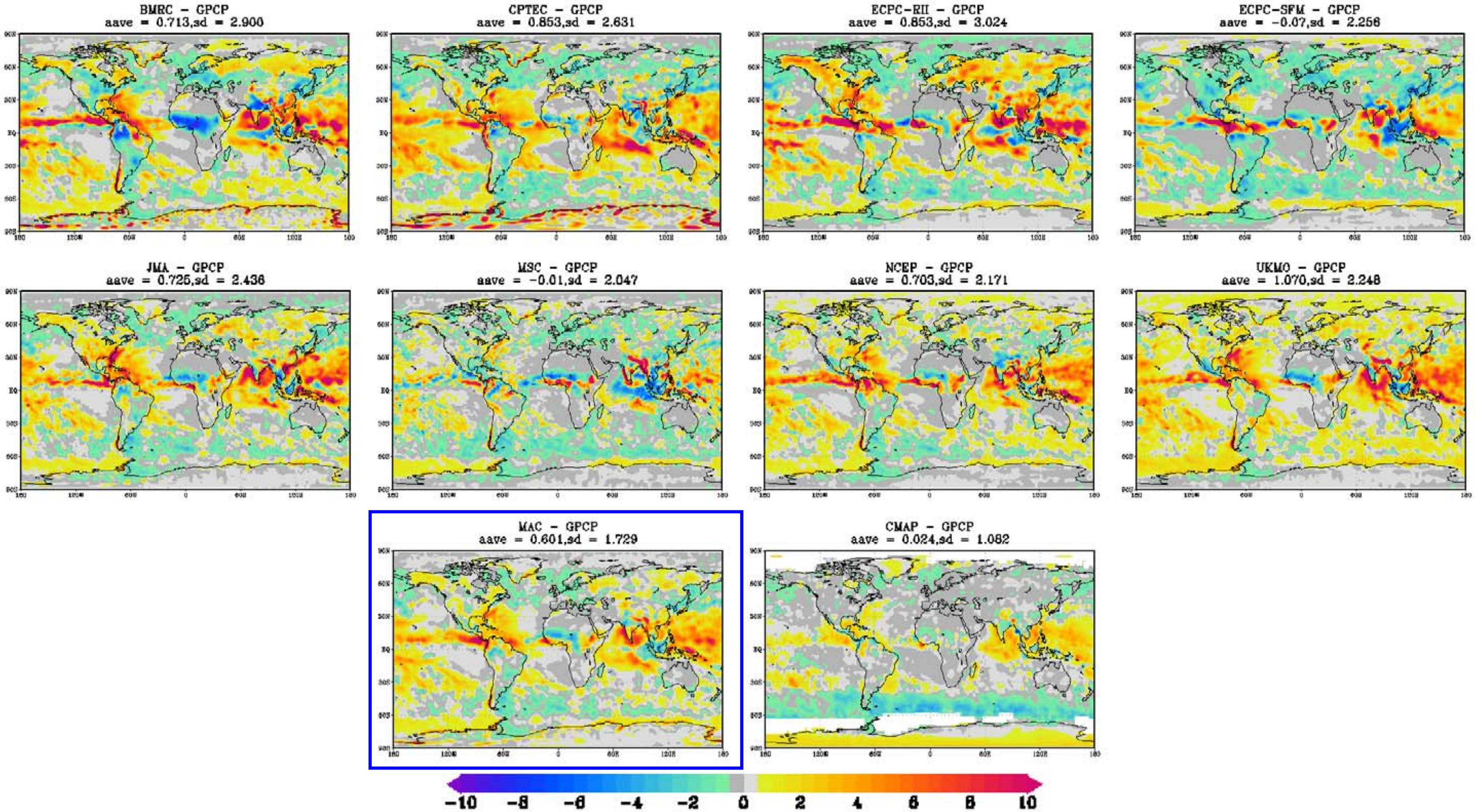
Benefits for Weather and Climate

- About the quality of current reanalyses, plus uncertainty estimates (useful for metrics)
- Community would have access to centralized analyses of weather data for research
- NWP centers would gain valuable information regarding the multitude of output diagnostics from external research/validation
- Would allow operational centers that cannot produce a reanalysis to contribute to a climate record (in time)

Available Variables

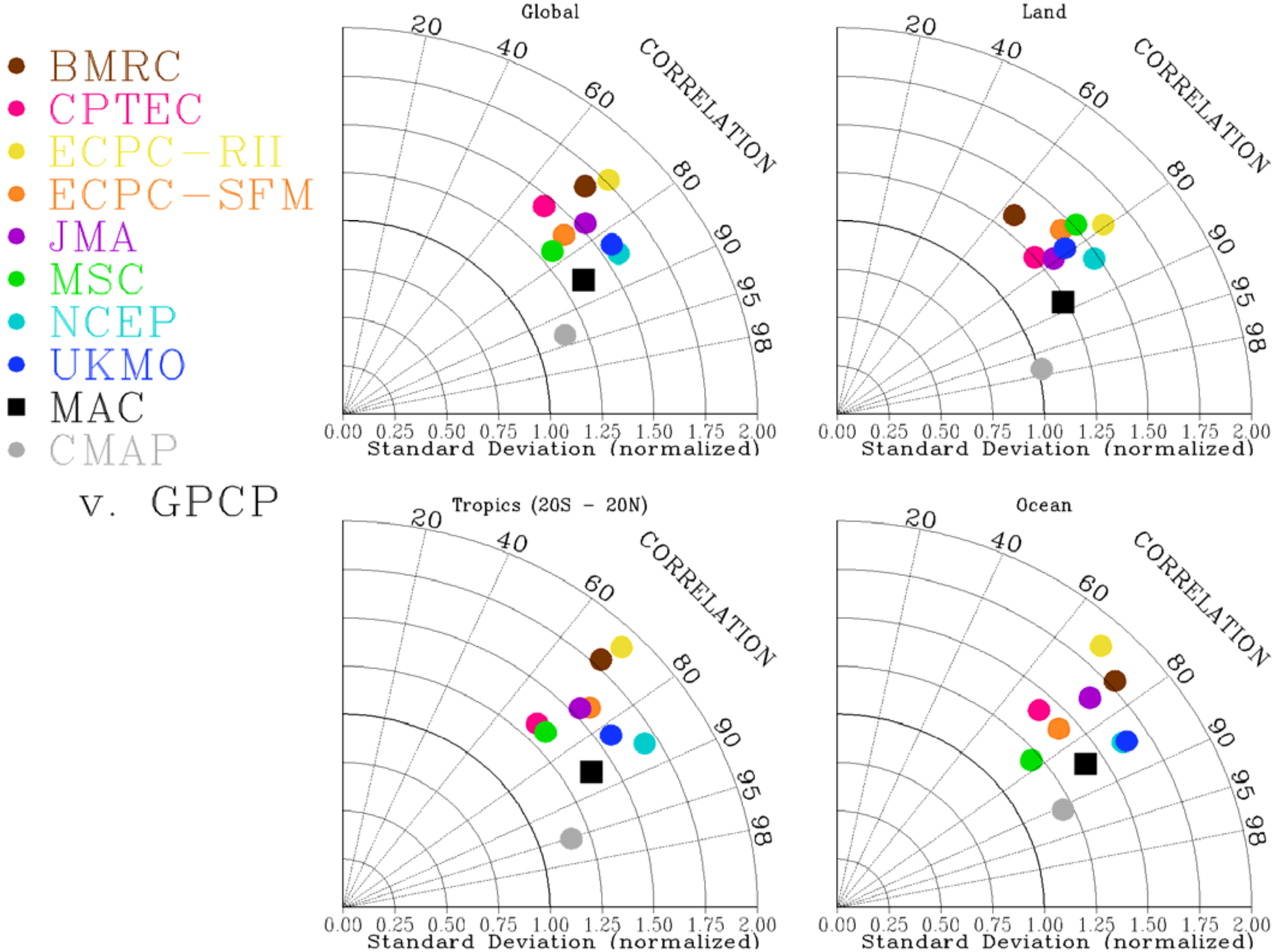
		Centers							
Description	**Units**	**BMRC**	**CPTEC**	**ECPCRII**	**ECPCSFM**	**JMA**	**MSC**	**NCEP**	**UKMO**
Surface Pressure	Pa	SURFPsfc	PRESsfc	PRESsfc	PRESsfc	PRESsfc	SURFPsfc	PRESsfc	SURFPsfc
Mean Sea Level Pressure	Pa	MSLPsfc		PRMSLmsl	PRESmsl				PRMSLmsl
Surface Air Temperature	K	TMP2m	TMP2m	TMP2m	TMP2m	TMP2m	TTSUsfc	TMP2m	LOWT2m
Surface Skin Temperature	K	SURFTsfc	SURFTsfc	TMPsfc	TMPsfc		SURFTsfc	TMPsfc	SURFTsfc
Surface Air Moisture	$kg\ kg^{-1}$	SPFH2m	RH2m	SPFH2m	SPFH2m	SPFHhbl	HUSUsfc	SPFH2m	LOWSH2m
Surface Eastward Wind	$m\ s^{-1}$	UGRD10m	UGRD10m	UGRD10m	UGRD10m	UGRD10m	UUSUsfc	UGRD10m	TENUS10m
Surface Northward Wind	$m\ s^{-1}$	VGRD10m	VGRD10m	VGRD10m	VGRD10m	VGRD10m	VVSUsfc	VGRD10m	TENVS10m
Precipitation	$kg\ m^{-2}\ s^{-1}$	APCPsfc	APCPsfc	PRATEsfc	PRATEsfc	PRATEsfc	PRsfc	PRATEsfc	APCPsfc
Convective Precipitation	$kg\ m^{-2}\ s^{-1}$			CPRATsfc	CPRATsfc				ACPCPsfc
Surface Runoff	$kg\ m^{-2}$		WATRsfc	WATRsfc	WATRsfc		N0sfc	WATRsfc	WATRsfc
Liquid equivalent snow depth	$kg\ m^{-2}$	SNODsfc		WEASDsfc	WEASDsfc		I5sfc	WEASDsfc	
Latent Heat Flux	$W\ m^{-2}$	LHTFLsfc	LHTFLsfc	LHTFLsfc	LHTFLsfc	LHTFLsfc	AVsfc	LHTFLsfc	LHTFLsfc
Sensible Heat Flux	$W\ m^{-2}$	SHTFLsfc	SHTFLsfc	SHTFLsfc	SHTFLsfc	SHTFLsfc	AHsfc	SHTFLsfc	SHTFLsfc
Surface Incoming Shortwave	$W\ m^{-2}$	DSWRFsfc	DSWRFsfc	DSWRFsfc	DSWRFsfc	DSWRFsfc	N4sfc	DSWRFsfc	TDSWSsfc
Surface Incoming Longwave	$W\ m^{-2}$	DLWRFsfc	DLWRFsfc	DLWRFsfc	DLWRFsfc	DLWRFsfc	ADsfc	DLWRFsfc	TDLWSsfc
Surface Reflected Shortwave	$W\ m^{-2}$	USWRFsfc	USWRFsfc	USWRFsfc	USWRFsfc	USWRFsfc	N4sfc-ASsfc	USWRFsfc	TUSWSsfc
Surface Outgoing Longwave	$W\ m^{-2}$	ULWRFsfc	ULWRFsfc	ULWRFsfc	ULWRFsfc	ULWRFsfc	ADsfc-AIsfc	ULWRFsfc	TULWSsfc
TOA Longwave Outgoing	$W\ m^{-2}$		ULWRFtoa	ULWRFtoa	ULWRFtoa	ULWRFtoa	ARsfc	ULWRFtoa	TULWTtoa
TOA Shortwave Incoming	$W\ m^{-2}$			DSWRFtoa	DSWRFtoa	DSWRFtoa	ABsfc		TDSWTtoa
TOA Shortwave Outgoing	$W\ m^{-2}$		USWRFtoa	USWRFtoa	USWRFtoa	USWRFtoa	AUsfc	USWRFtoa	TUSWTtoa
Total Cloud Cover	(0-1)		TCDCclm	TCDCclm	TCDCclm	TCDCsfc	TCDCsfc	TCDCclm	TCDCsfc
Total Column Water Vapor	$kg\ m^{-2}$	PWATclm	PWATclm	PWATclm	PWATclm		IHsfc	PWATclm	
Total Column Condensed Water	$kg\ m^{-2}$					CWATprs	IEsfc	CWATclm	
Q850	$kg\ kg^{-1}$	SPFHprs	SPFHprs	SPFHprs	SPFHprs		SPFHprs	RHprs	RHprs
T850	K	TMPprs	TMPprs	TMPprs	TMPprs	TMPprs	TMPprs	TMPprs	TMPprs
U850	$m\ s^{-1}$	UGRDprs	UGRDprs	UGRDprs	UGRDprs	UGRDprs	UGRDprs	UGRDprs	UGRDprs
V850	$m\ s^{-1}$	VGRDprs	VGRDprs	VGRDprs	VGRDprs	VGRDprs	VGRDprs	VGRDprs	VGRDprs
H850	m	HGTprs	HGTprs	HGTprs	HGTprs	GPprs	HGTprs	HGTprs	GPprs
Q700	$kg\ kg^{-1}$	SPFHprs	SPFHprs	SPFHprs	SPFHprs		SPFHprs	RHprs	RHprs
T700	K	TMPprs	TMPprs	TMPprs	TMPprs	TMPprs	TMPprs	TMPprs	TMPprs
U700	$m\ s^{-1}$	UGRDprs	UGRDprs	UGRDprs	UGRDprs	UGRDprs	UGRDprs	UGRDprs	UGRDprs
V700	$m\ s^{-1}$	VGRDprs	VGRDprs	VGRDprs	VGRDprs	VGRDprs	VGRDprs	VGRDprs	VGRDprs

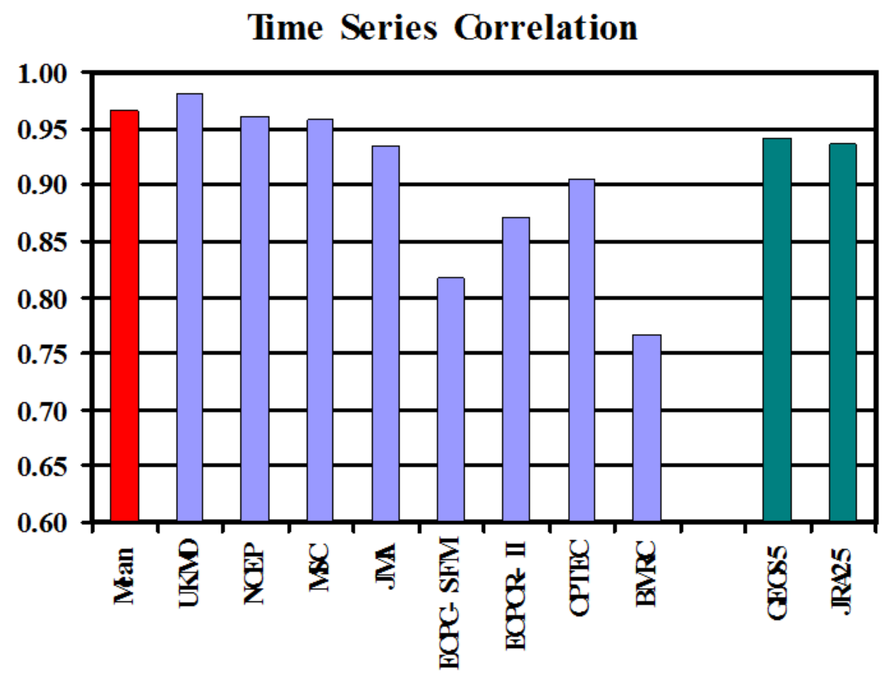
July 2004 Comparison to GPCP



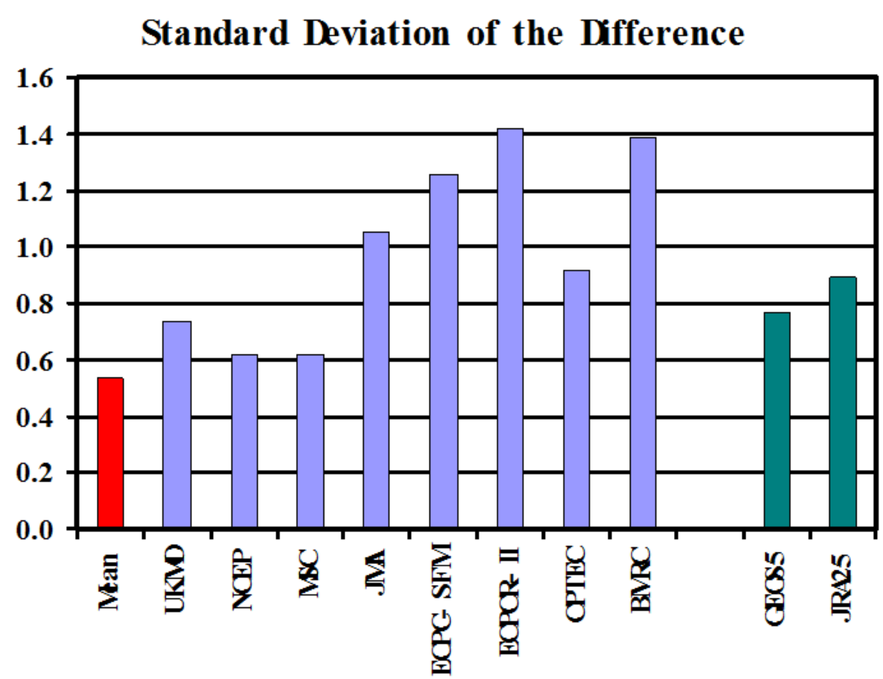
- MAC most closely comparable to spatial pattern of GPCP

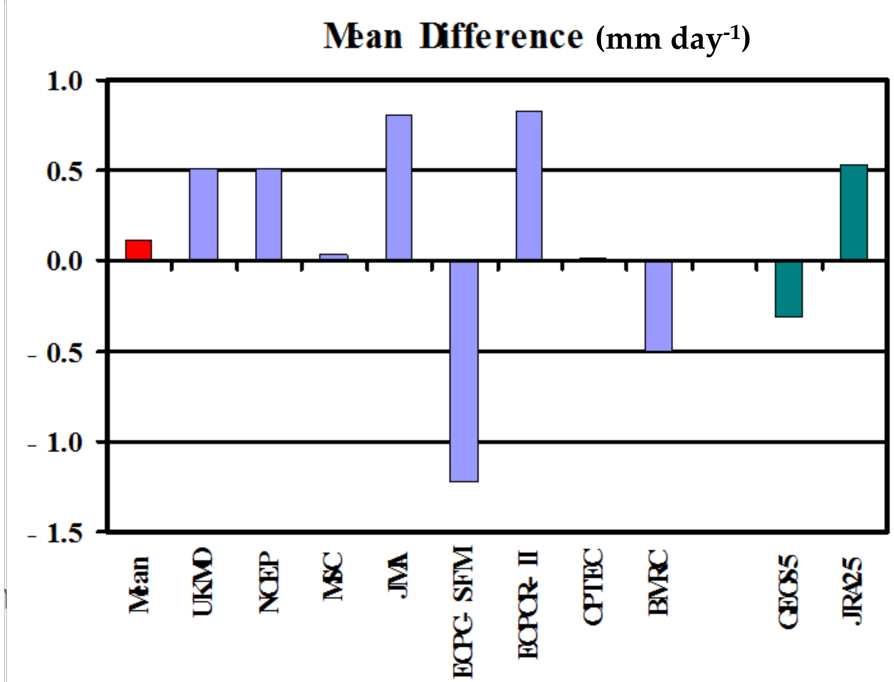
July 2004 Precipitation: Taylor Diagram

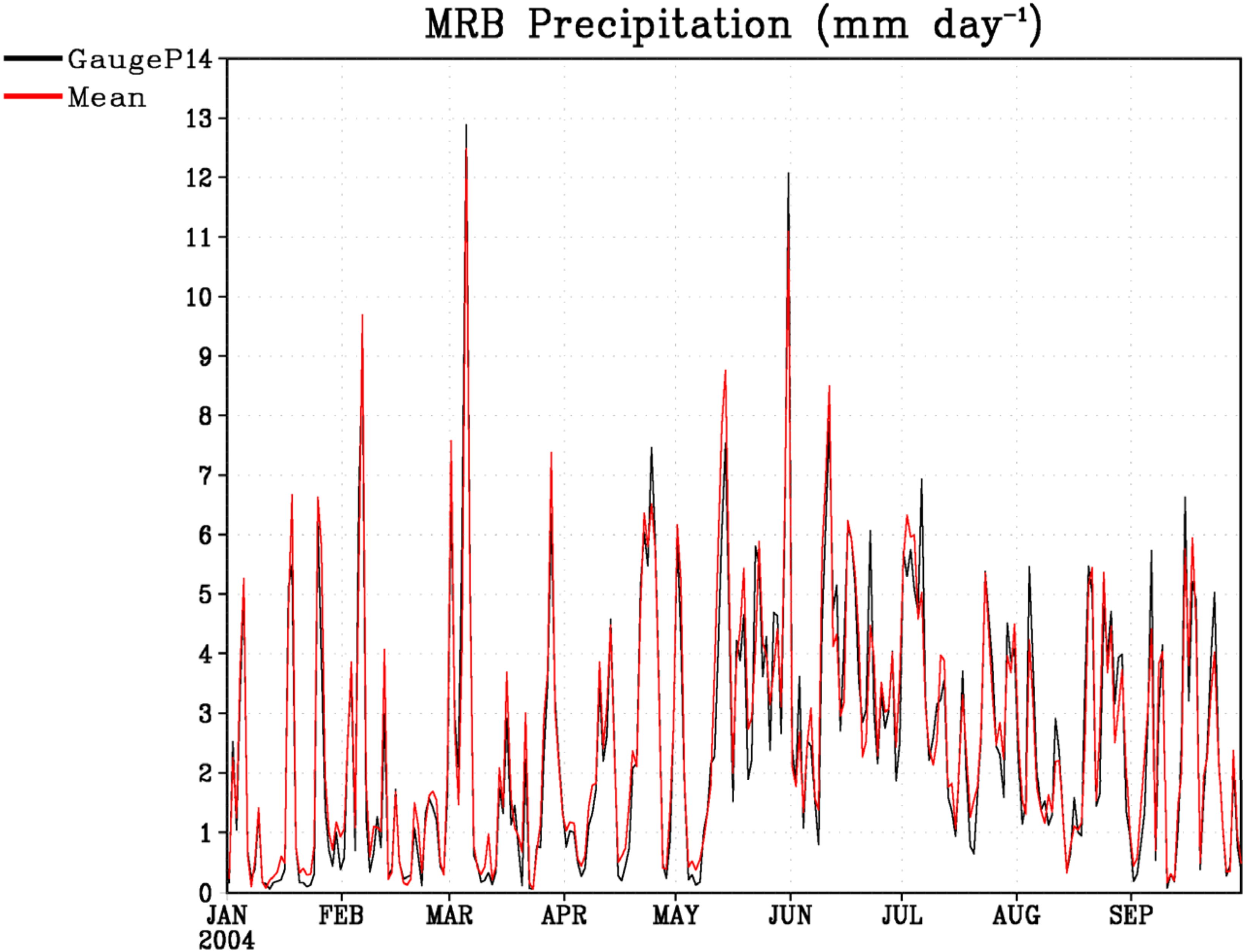




- GEOS5 not up to the highest oper. analyses, but still in range
- Biases happen to balance in the ensemble







MRB Precipitation (mm day⁻¹)
GaugeP14
Mean
0
1
2
3
4
5
6
7
8
9
10
11
12
13
14
JAN
2004
FEB
MAR
APR
MAY
JUN
JUL
AUG
SEP