Basin-Scale Assessment of the Land Surface Water Budget Components in NCEP Operational and Research NLDAS-2 Systems

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Outline

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   a. **Mean Annual Comparison**
   b. **Mean seasonal Cycle Comparison**

4. Summary and Conclusion

1. Introduction

NLDAS-2 became part of NCEP product suite in August 2014

Water budget components from either operational or research NLDAS-2 system were not evaluated yet at basin scales

USGS huc8 runoff, FLUXNET-based multiple-tree-ensemble (MTE) products, and GRACE-based data provide a new opportunity to evaluate our products for operational and research NLDAS-2 systems, and even some models from next generation NLDAS system

2. Data and Method

2.1. Data

Masks: Land-sea mask, inland water mask, 12 River Forecast Centers (RFCs) mask

Observations/References: USGS huc8 Q, January1982- December 2008, monthly, hydrologic unit; MTE ET (Jung et al., 2009), January 1982-December 2008, monthly, 0.5 degree resolution; GRACE-based TWSA/TWSC, monthly, 1.0 degree, 2003-2014

Operational NLDAS-2 (Mosaic, Noah, SAC, VIC and their ensemble mean): P, Q, ET, and dw/dt, January 1982 - December 2008, monthly, 0.125 degree

Research NLDAS-2 (Noah-I, SAC-Clim, VIC4.0.5): , Q, ET, and dw/dt , January 1982-December 2008, monthly, 0.125 degree

2.2 Method

In order to use the same mask data, re-grid 1.0/0.5 degree data into 0.125 degree using a water budget method.

Mean annual values, mean seasonal cycles, RMSE, bias, anomaly correlation, and Nash-Sutcliffe Efficiency are used as statistical metrics.

The evaluation is performed based on:

a. Evaluation of NLDAS-2 Precipitation

b. Evaluation of operational NLDAS-2 system

c. Evaluation of research NLDAS-2 system

NLDAS-2 Forcing Evaluation

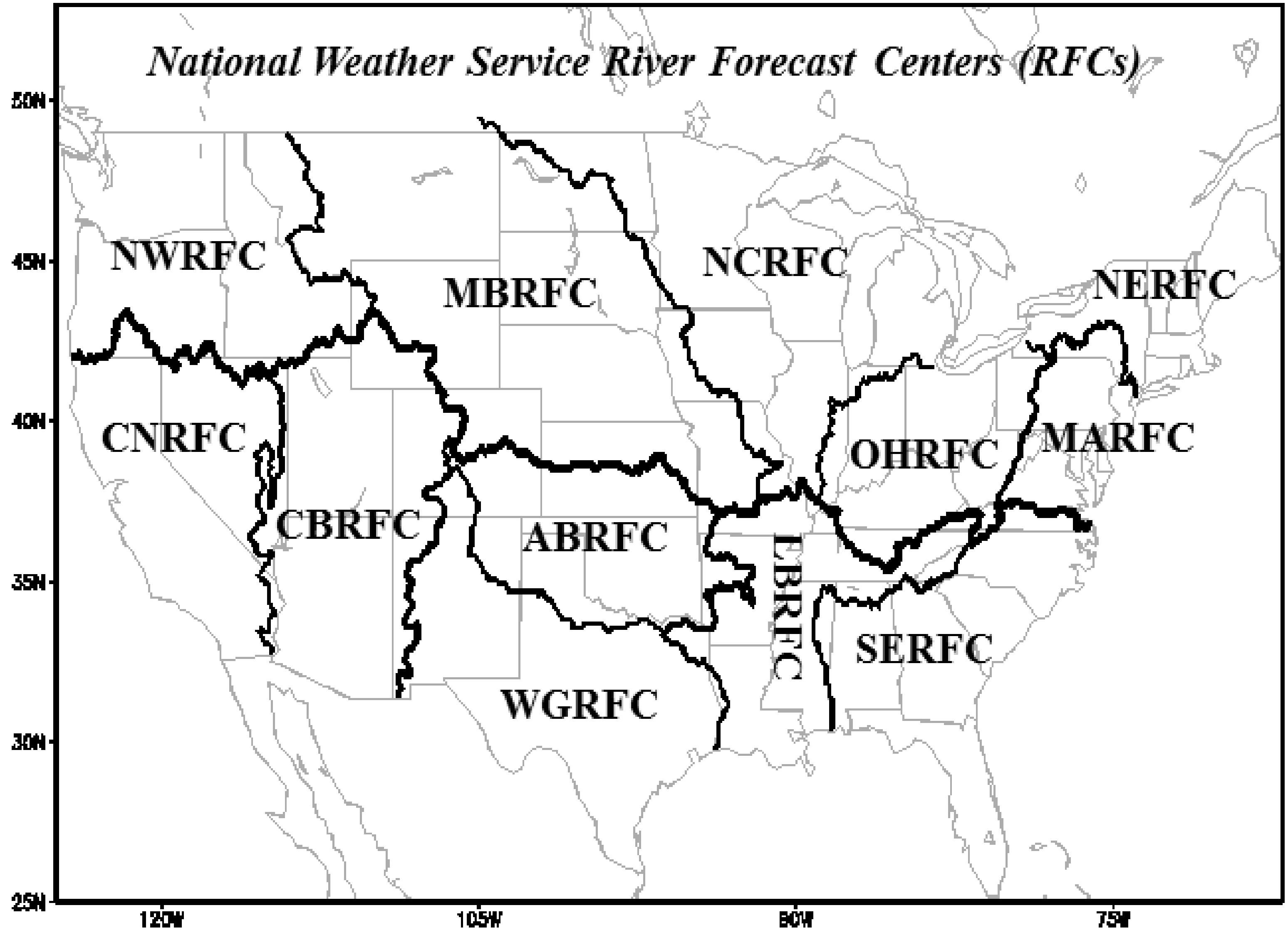


Figure 1: Twelve NWS RFCs

Table 2: RFC names and 27-year (1982-2008) climatology of water budget components (unit: mm/year) calculated from several sources. The RFCs are listed in order of increasing value of P/PE, varying from dry climate to wet climate.

Label	RFC Name	NCDC P (P1) [mm]	NLDAS-2 P (P2) [mm]	USGS Q [mm]	FLUXNET ET [mm]	$\frac{P1}{P2}$ [-]	$\frac{P2}{Q+ET}$ [-]
CBRFC	Colorado	358.2	353.6	53.1	270.5	1.01	1.09
CNRFC	California-Nevada	472.6	459.4	164.3	324.7	1.03	0.94
WGRFC	West Gulf	634.9	627.2	68.3	515.1	1.01	1.08
MBRFC	Missouri	541.7	550.2	73.2	437.4	0.99	1.08
ABRFC	Arkansas	751.6	754.3	105.6	546.8	1.00	1.16
NCRFC	North-Central	804.6	808.5	242.8	517.1	1.00	1.06
NWRFC	Northwest	810.0	804.2	492.1	399.7	1.01	0.90
MARFC	Mid-Atlantic	1103.3	1093.5	468.1	597.8	1.01	1.03
SERFC	Southeast	1291.2	1278.6	392.2	786.6	1.01	1.09
NERFC	Northeast	1137.0	1131.6	637.8	482.0	1.01	1.01
LMRFC	Lower Mississippi	1384.6	1348.5	486.6	777.0	1.03	1.07
OHRFC	Ohio	1128.4	1103.5	466.5	641.3	1.02	1.00

Evaluation of NCEP Operational NLDAS-2

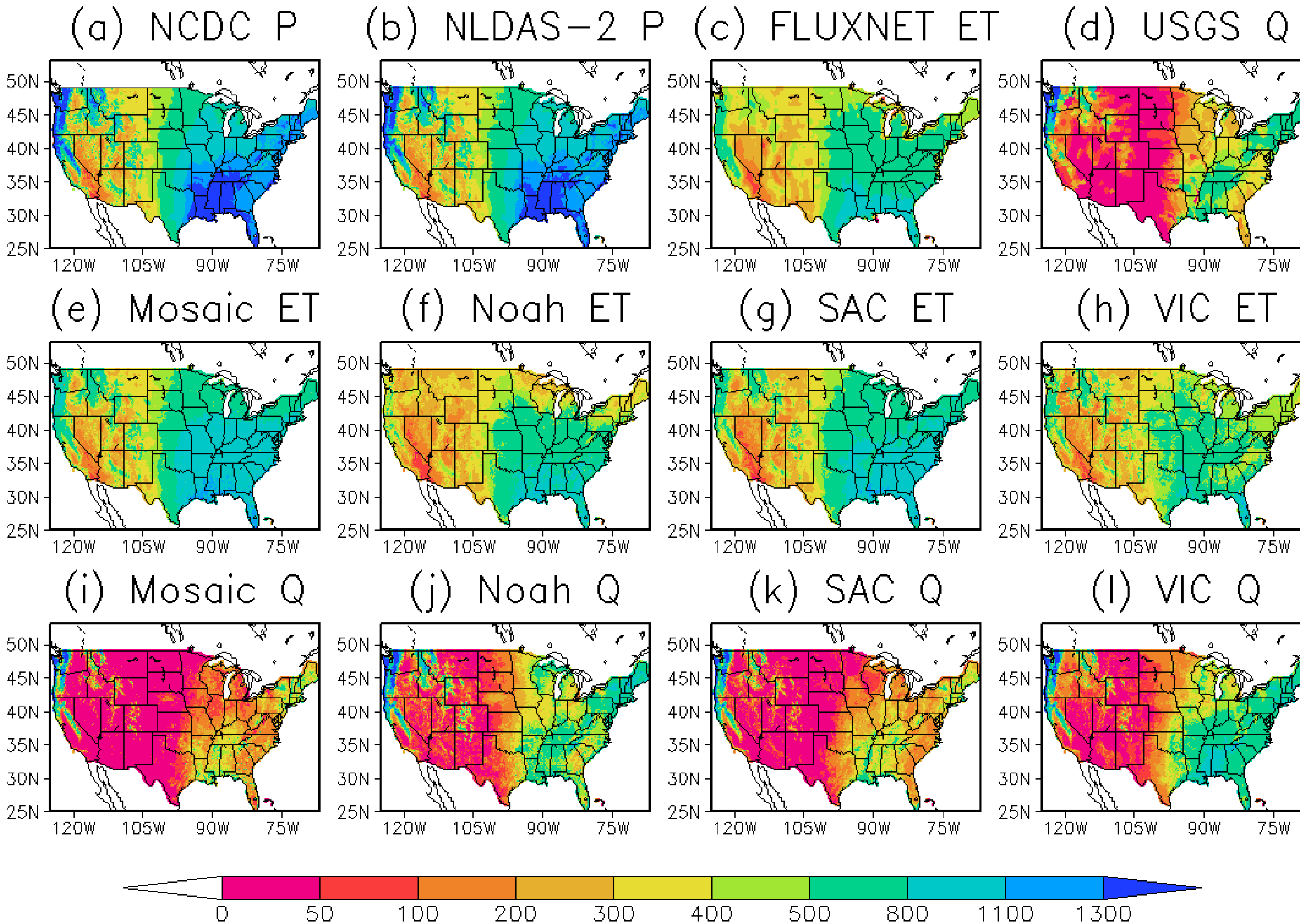


Figure 2: Spatial distribution of mean annual precipitation, evapotranspiration (ET), and total runoff (Q) calculated from USGS, MTE, Mosaic, Noah , SAC, and VIC in NCEP operational NLDAS-2 [unit: mm/year]

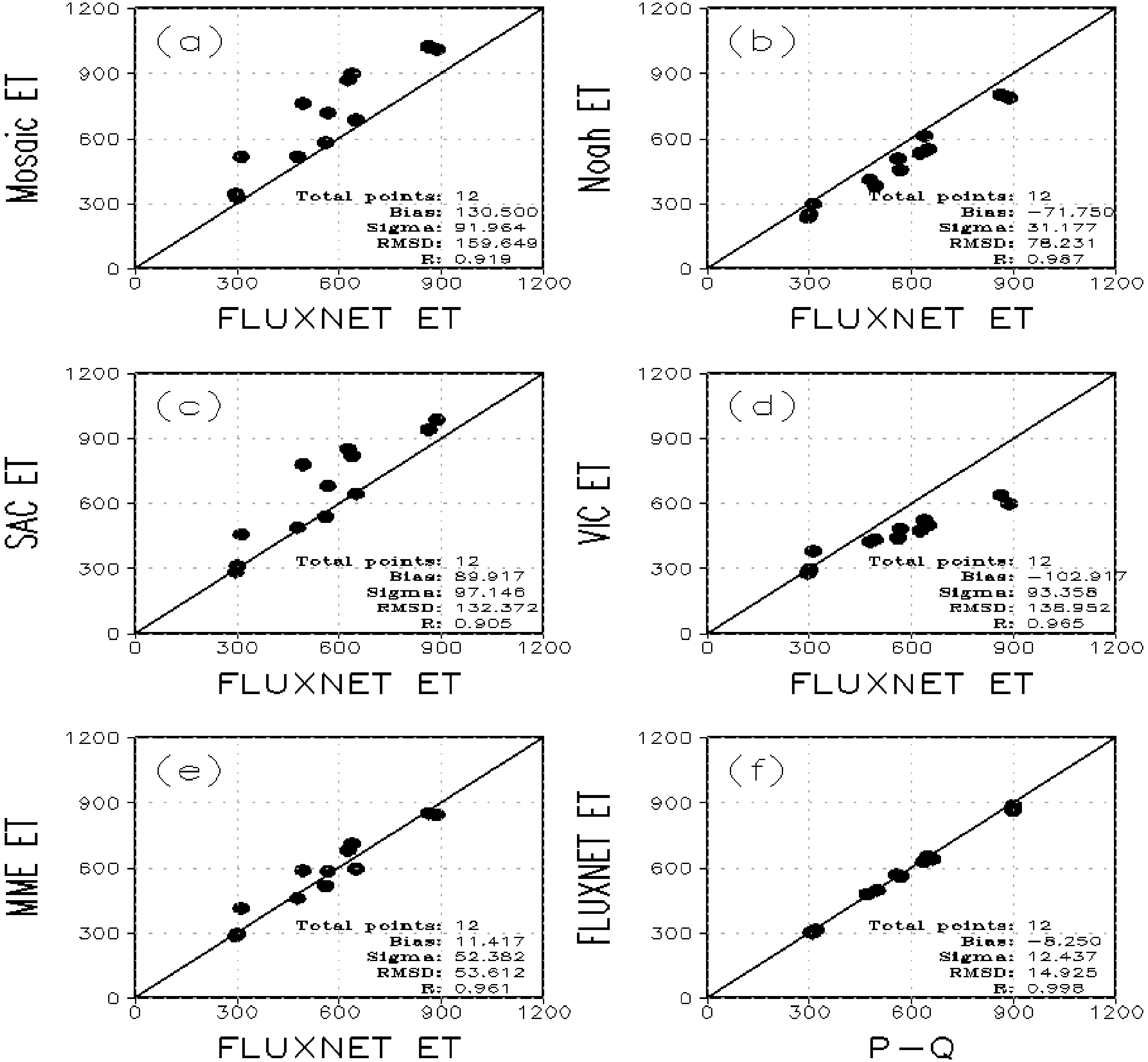


Figure 3: Scatter plots and statistical metrics for MTE and NLDAS-2 ET

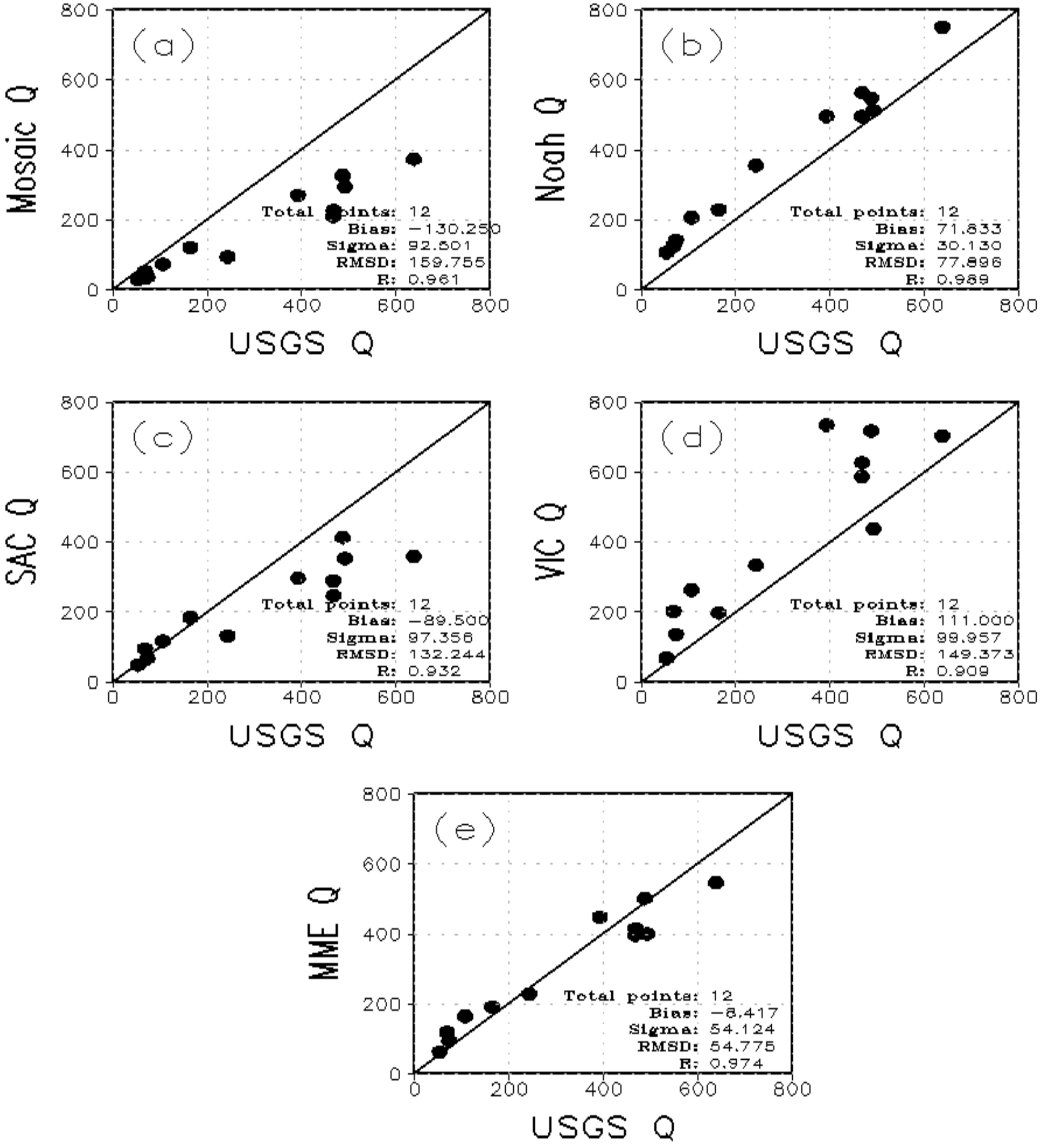
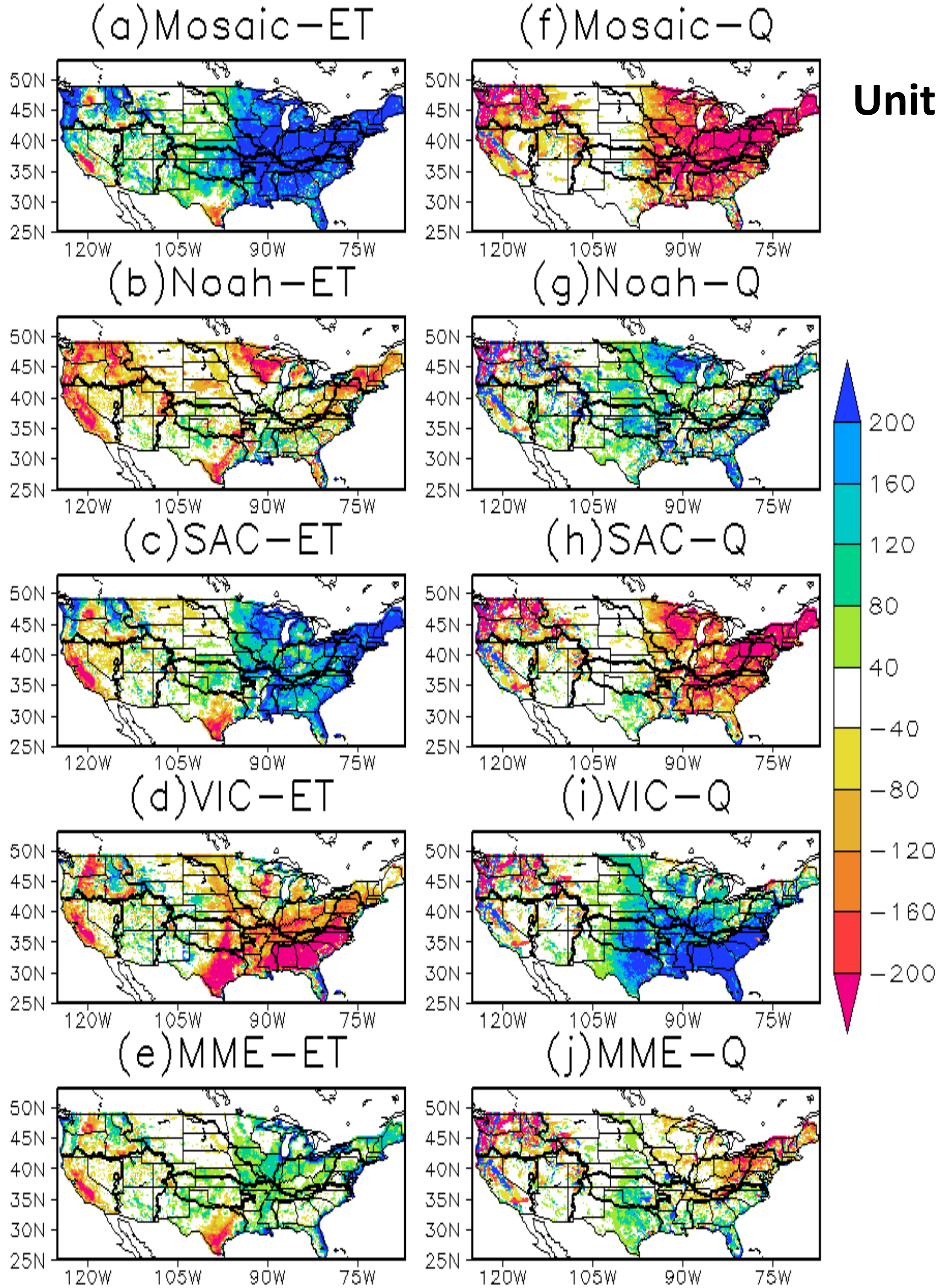


Figure 4: Same as Figure 3 but for Q.



Unit: mm/year

Figure 5: Left column: difference between mean annual simulated ET of the operational NLDAS-2 from (a) Mosaic, (b) Noah, (c) SAC, (d) VIC, and (e) their ensemble mean (MME) and MTE FLUXNET ET. Right column: difference between mean annual simulated Q of the operational NLDAS-2 from (f) Mosaic, (g) Noah, (h) SAC, (i) VIC, and (j) their ensemble mean (MME) and USGS Q.

Table 2: Anomaly correlation (AC) for runoff Q (top section), evapotranspiration ET (middle section), and total water storage change dS/dt (bottom section) between observed and modeled water budget components in the NCEP operational NLDAS-2 for the 27-year period of 1982 to 2008. The bold-font value in each column of each section denotes the maximum value for the given RFC (An AC value >*0.12* is significant at the 5% significance level).

RFC	CBRFC	CNRFC	WGRFC	MBRFC	ABRFC	NCRFC	NWRFC	MARFC	SERFC	NERFC	LMRFC	OHRFC
Q												
Mosaic	0.59	0.94	0.87	0.83	0.85	0.81	0.87	0.86	0.94	0.85	0.90	0.79
Noah	0.68	**0.95**	0.87	0.89	0.91	0.87	0.92	0.91	0.95	0.83	**0.97**	0.87
SAC	0.57	0.89	0.88	0.86	0.92	0.90	0.89	0.91	0.91	0.83	0.93	0.90
VIC	**0.76**	**0.95**	**0.90**	0.85	0.92	0.94	**0.93**	0.92	0.93	**0.94**	**0.97**	**0.95**
MME	0.69	0.94	**0.90**	**0.90**	**0.94**	**0.95**	**0.93**	**0.95**	**0.96**	**0.94**	**0.97**	0.94
ET												
Mosaic	**0.83**	0.80	0.85	0.74	0.77	0.42	0.58	0.29	0.04	0.36	0.16	0.41
Noah	0.81	**0.81**	0.87	0.79	**0.81**	0.48	0.60	**0.41**	**0.36**	0.21	**0.36**	**0.52**
SAC	0.72	0.69	0.85	0.79	0.76	0.21	0.58	0.06	0.03	0.10	0.05	0.09
VIC	0.75	0.65	0.83	0.82	0.73	**0.59**	0.59	0.15	0.16	**0.48**	0.20	0.38
MME	0.82	0.80	**0.88**	**0.84**	**0.81**	0.49	**0.67**	0.22	0.12	0.36	0.19	0.39
dW/dt												
Mosaic	0.90	**0.97**	0.92	0.93	0.95	0.93	0.93	0.93	**0.96**	0.91	0.94	0.86
Noah	0.93	0.95	**0.96**	**0.97**	**0.97**	0.94	0.94	0.92	0.94	0.86	0.96	0.91
SAC	0.90	0.93	0.91	0.93	0.95	0.94	0.93	0.93	0.95	0.93	0.96	0.92
VIC	**0.96**	0.94	0.94	0.93	0.95	**0.96**	**0.96**	0.89	0.88	0.94	0.93	0.93
MME	0.94	0.96	0.94	0.96	**0.97**	**0.96**	**0.96**	**0.95**	**0.96**	**0.96**	**0.97**	**0.94**

Table 5: Anomaly correlation (AC) coefficient between GRACE-observed and NLDAS-2 simulated total water storage anomaly (TWSA) is calculated for 12 RFCs from January 2003 to December 2014. The bold font denotes the maximum AC values from Mosaic, Noah, SAC, VIC, and MME for each RFC (An AC value > |0.12| is significant at the 5% significance level).

RFC Name	Mosaic	Noah	SAC	VIC	MME
CBRFC	0.78	0.75	0.77	**0.83**	0.80
CNRFC	0.89	0.89	0.81	**0.90**	0.89
WGRFC	0.88	**0.92**	0.87	0.86	0.90
MBRFC	0.82	**0.86**	0.66	0.84	0.83
ABRFC	0.83	**0.90**	0.80	0.81	0.86
NCRFC	**0.83**	**0.83**	0.56	0.75	0.77
NWRFC	0.89	0.91	0.81	**0.96**	0.92
MARFC	0.77	**0.79**	0.60	0.65	0.74
SERFC	0.79	**0.83**	0.53	0.62	0.77
NERFC	0.74	**0.76**	0.63	0.68	0.73
LMRFC	**0.90**	0.86	0.78	0.79	0.88
OHRFC	0.87	**0.88**	0.75	0.83	0.87
Mean	0.83	**0.85**	0.71	0.79	0.83

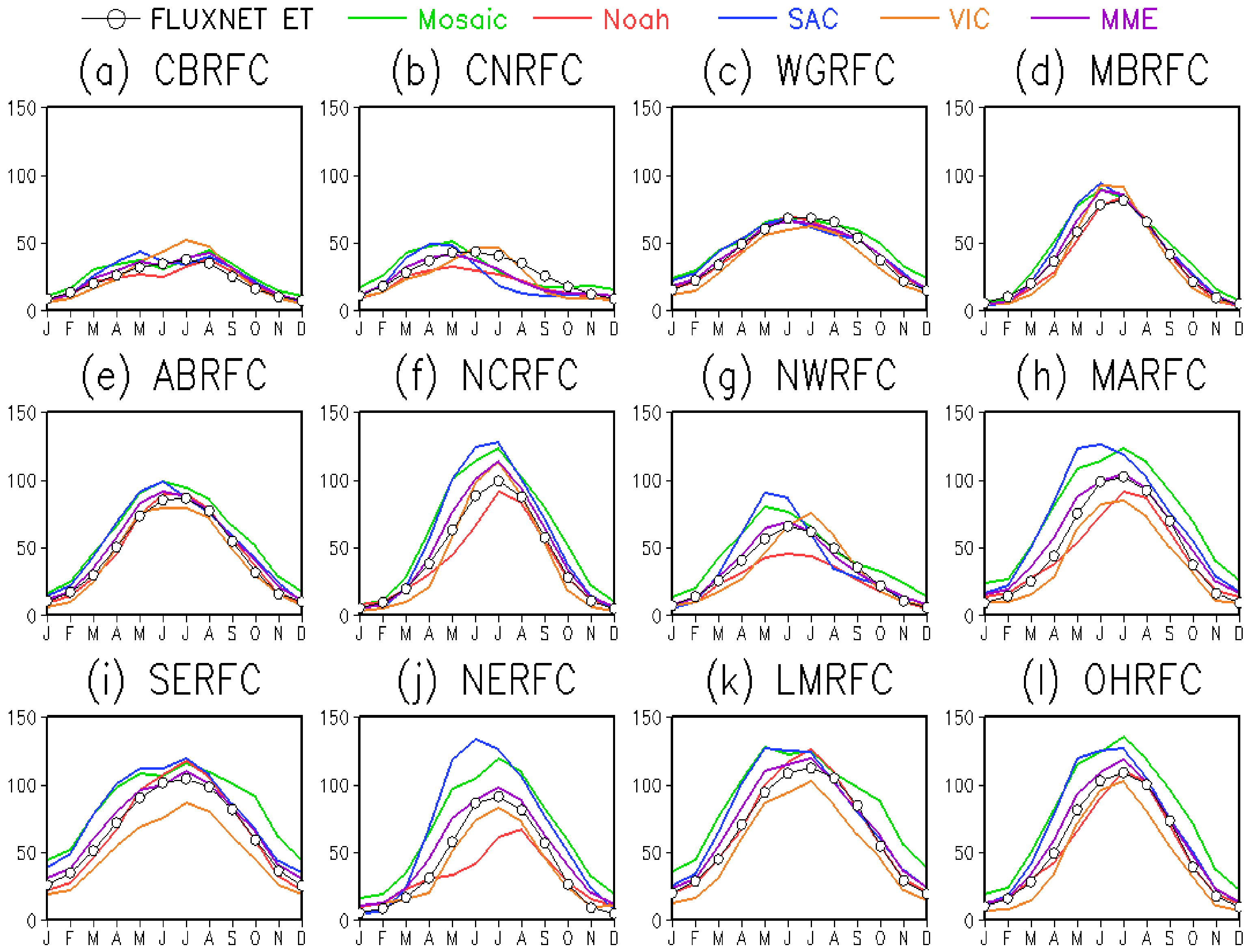


Figure 6: Mean annual cycle for ET calculated from MTE and operational NLDAS-2 system (unit: mm/month).

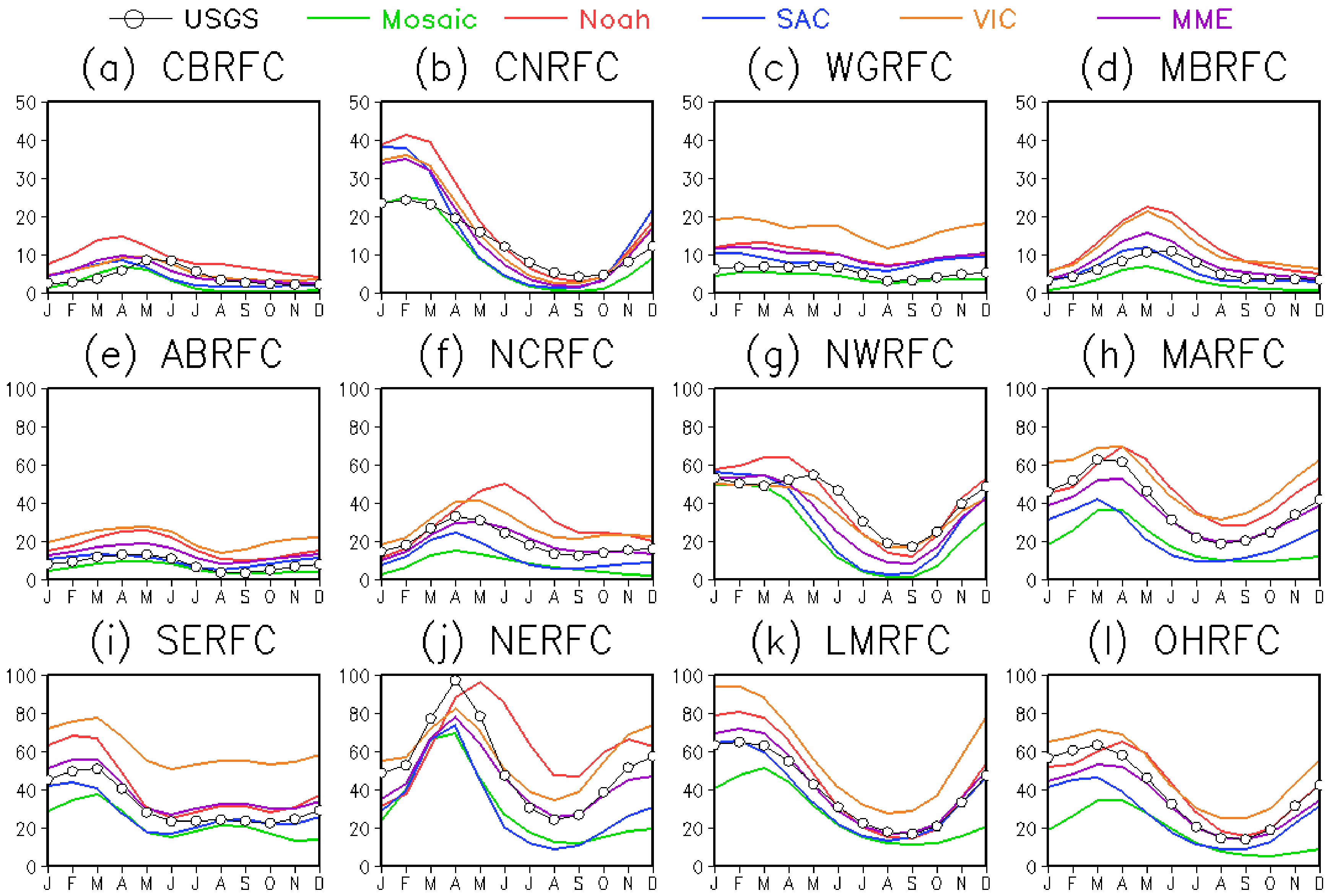


Figure 7: Same as Figure 6 but for Q (unit: mm/month).

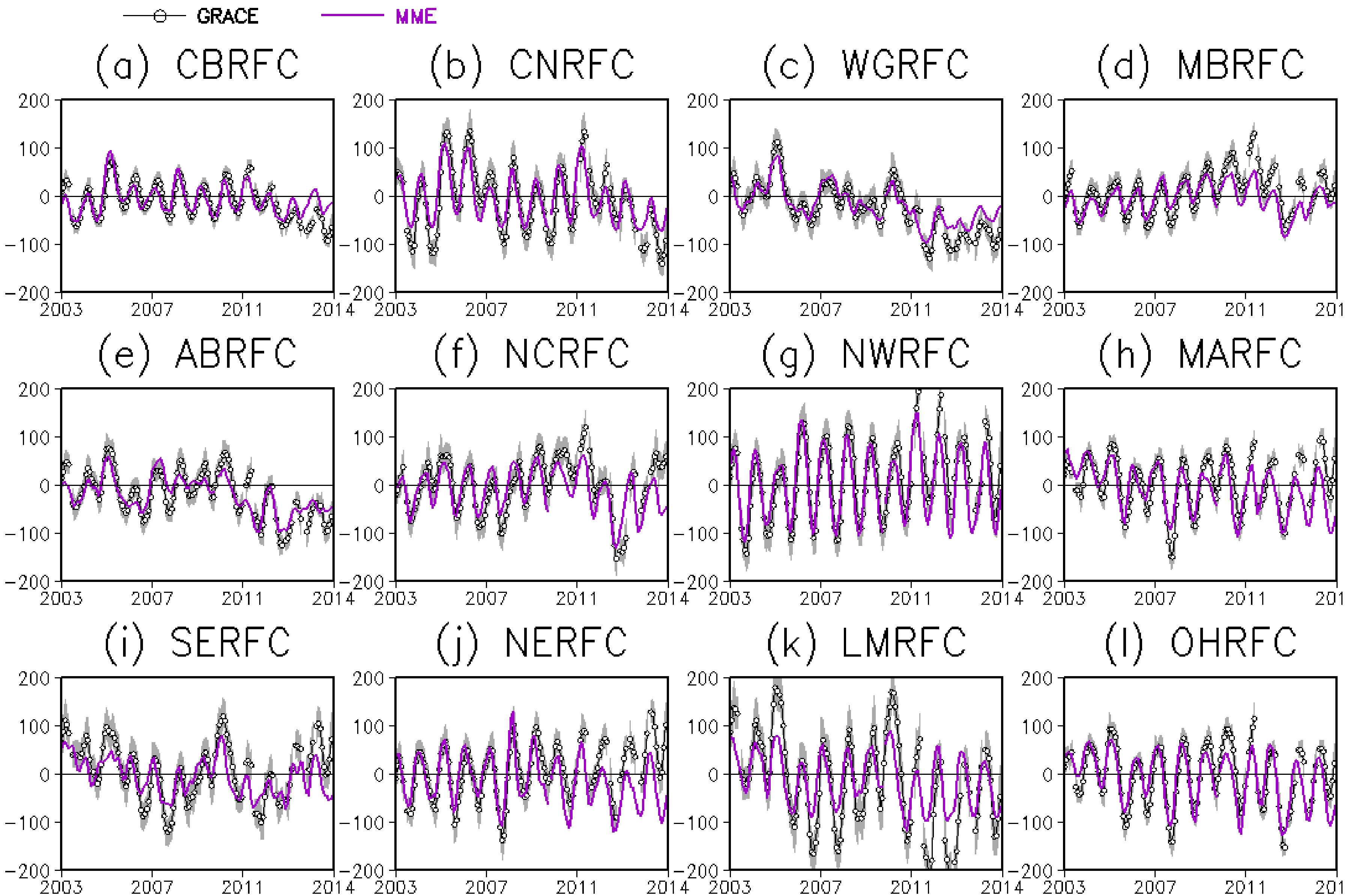


Figure 8: Total water storage anomaly calculated from GRACE satellites and operational NLDAS-2 system [unit: mm]. Gray area is one standard deviation.

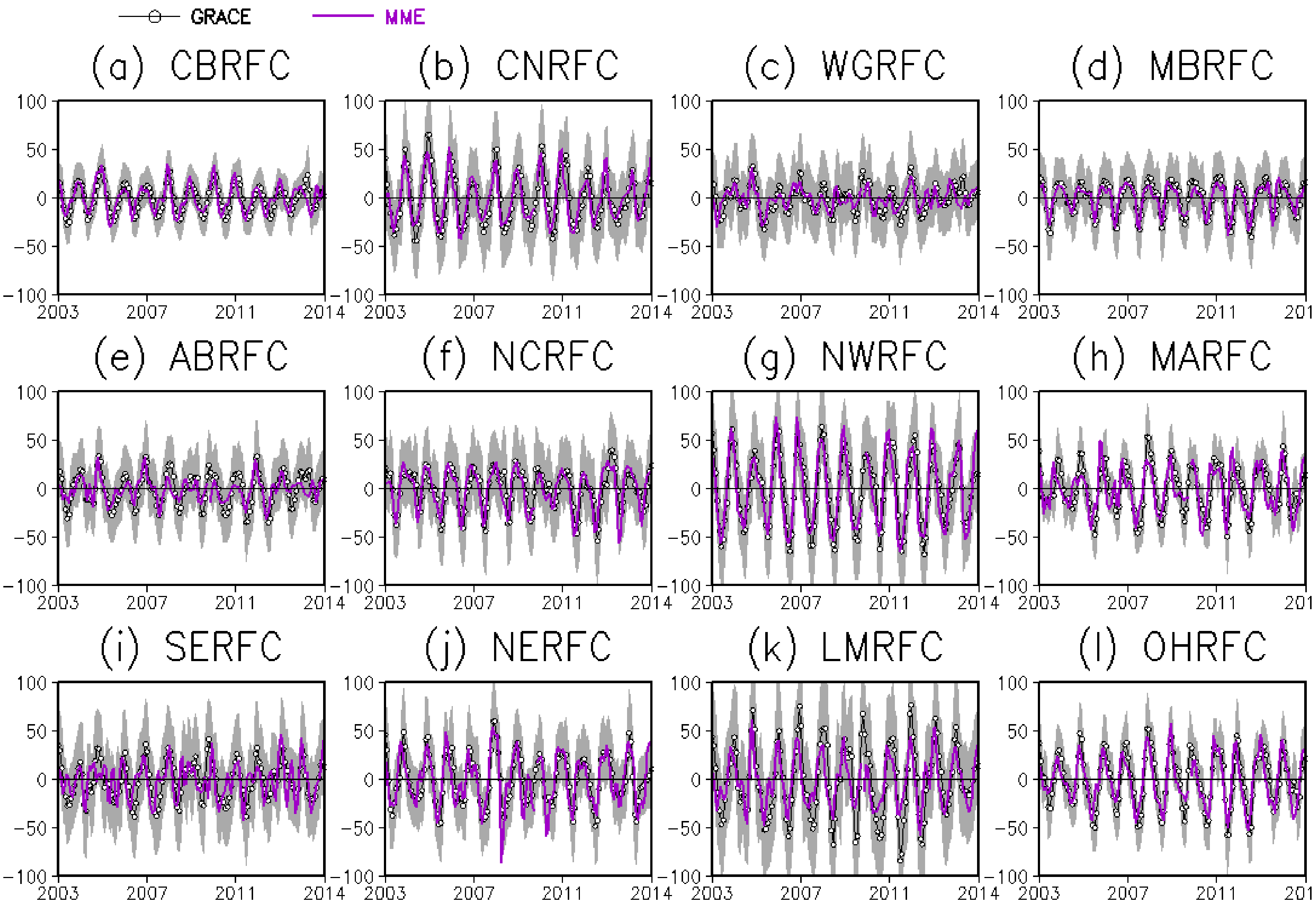


Figure 9: Same as Figure 8 but for total water storage change (mm).

Evaluation of NCEP Research NLDAS-2

Difference between operational and research version

- **Noah vs Noah-I: To constrain surface exchange coefficient for boundary stable case only for snow surface (Xia et al. 2015) rather than everywhere (Livneh et al. 2010)**

- **SAC vs SAC-Clim: SAC uses bias-corrected Noah PE and SAC-Clim uses Pan-derived monthly ET data**

- **VIC4.0.3 vs VIC4.0.5: Soil and hydrological parameters were tuned by Troy et al. (2008)**

References

Livneh, B., Y. Xia, K. E. Mitchell, M. B. Ek, and D. P. Lettenmaier (2010), Noah LSM Snow Model Diagnostics and Enhancements, *J. Hydrometeor*, *11*, 721–738.

Troy, T. J., E. F. Wood, and J. Sheffield (2008), An efficient calibration method for continental-scale land surface modeling, *Water Resour. Res.*, *44*, W09411, http://dx.doi.org/10.1029/2007WR006513.

Xia, Y., Peter-Lidard C. D., Huang M., Wei H., and Ek M. (2015), Improved NLDAS-2 Noah-simulated hydrometeorological products with an interim run, *Hydrol. Process*., 29, 780–792.

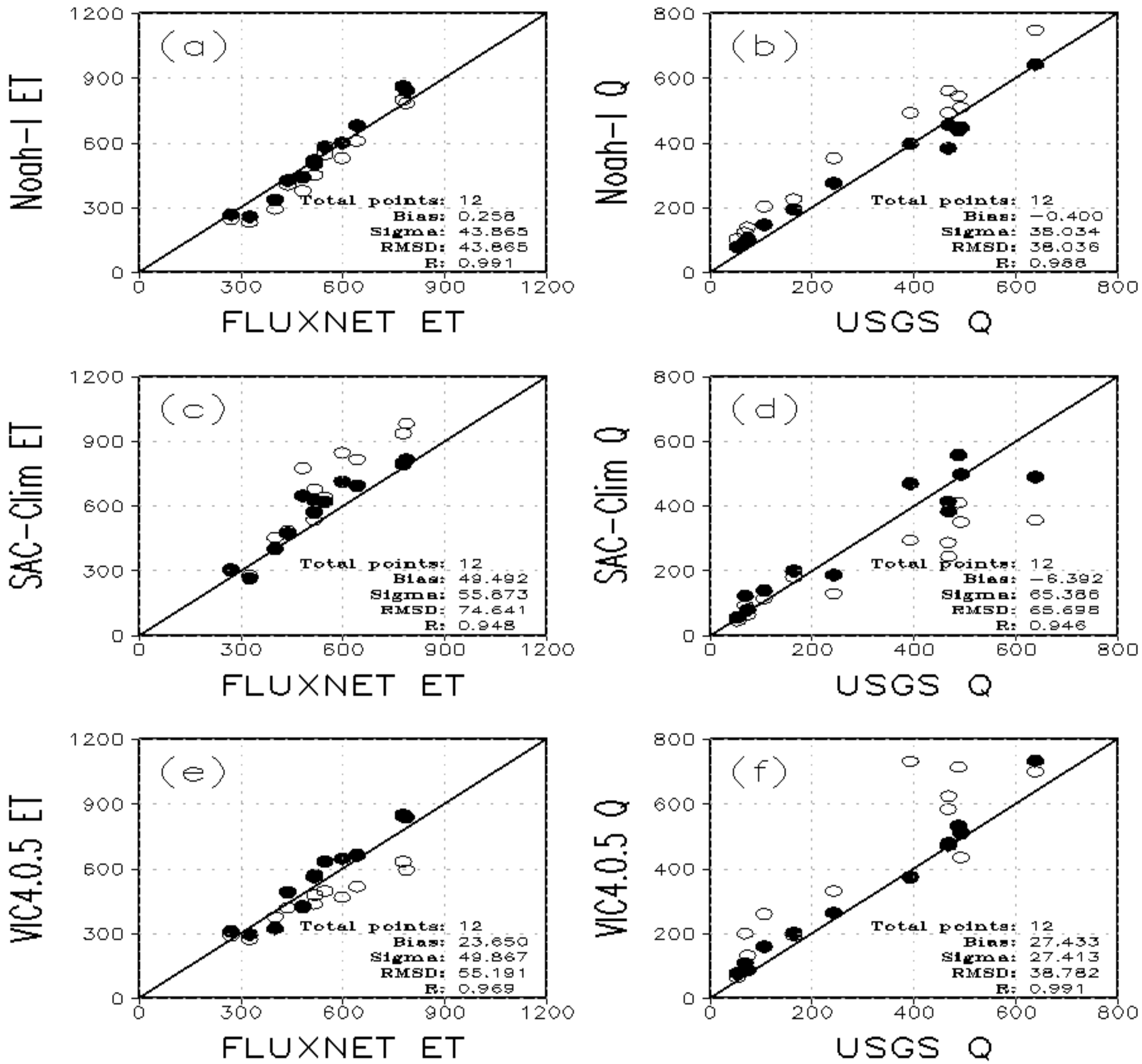


Figure 10: Scatter plots and their statistical metrics for operational (open circle) and research (closed circle) NLDAS-2 systems

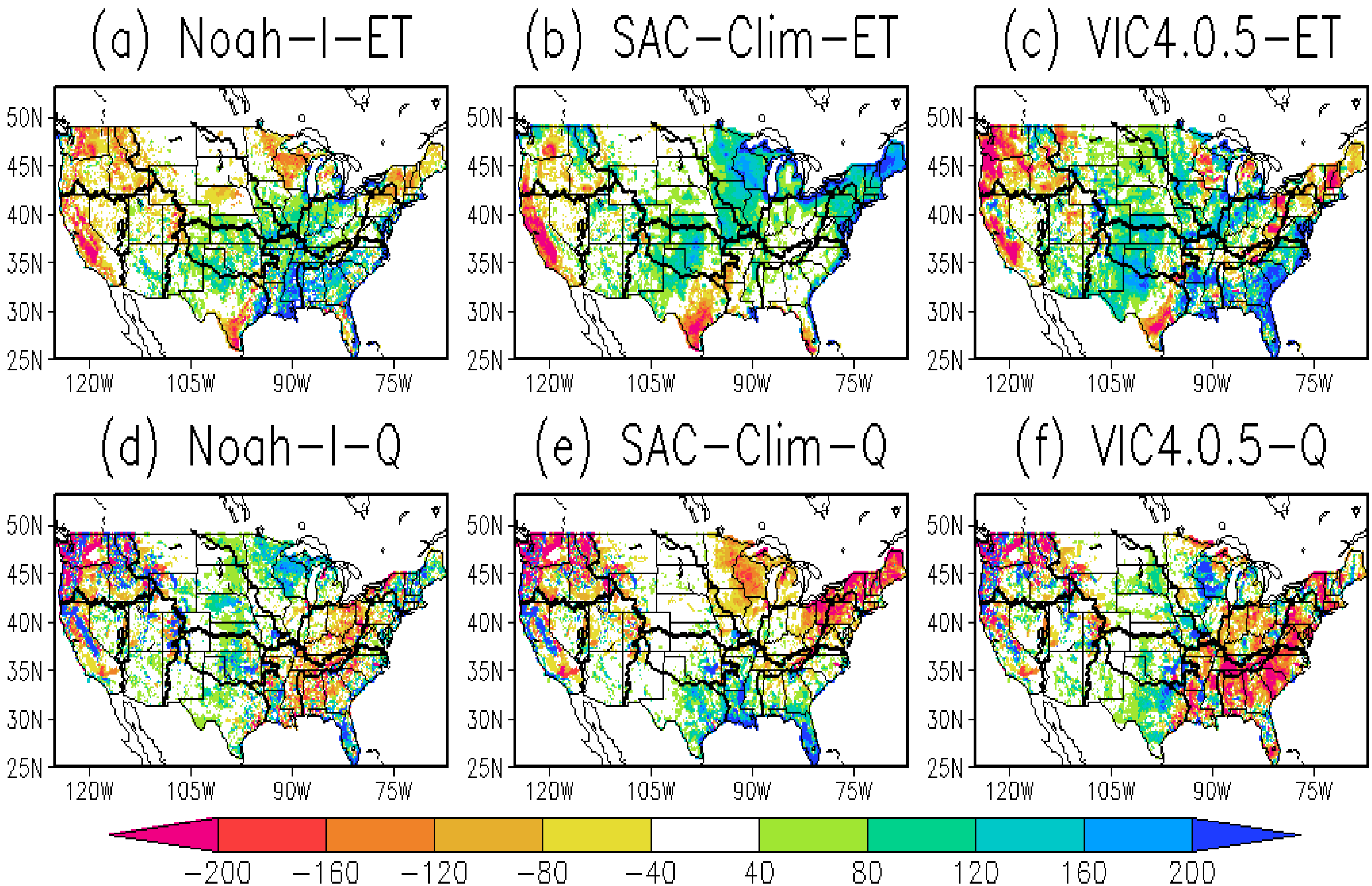


Figure 11: Difference between mean annual ET (mm/year) and Q simulated in the research NLDAS-2 system.

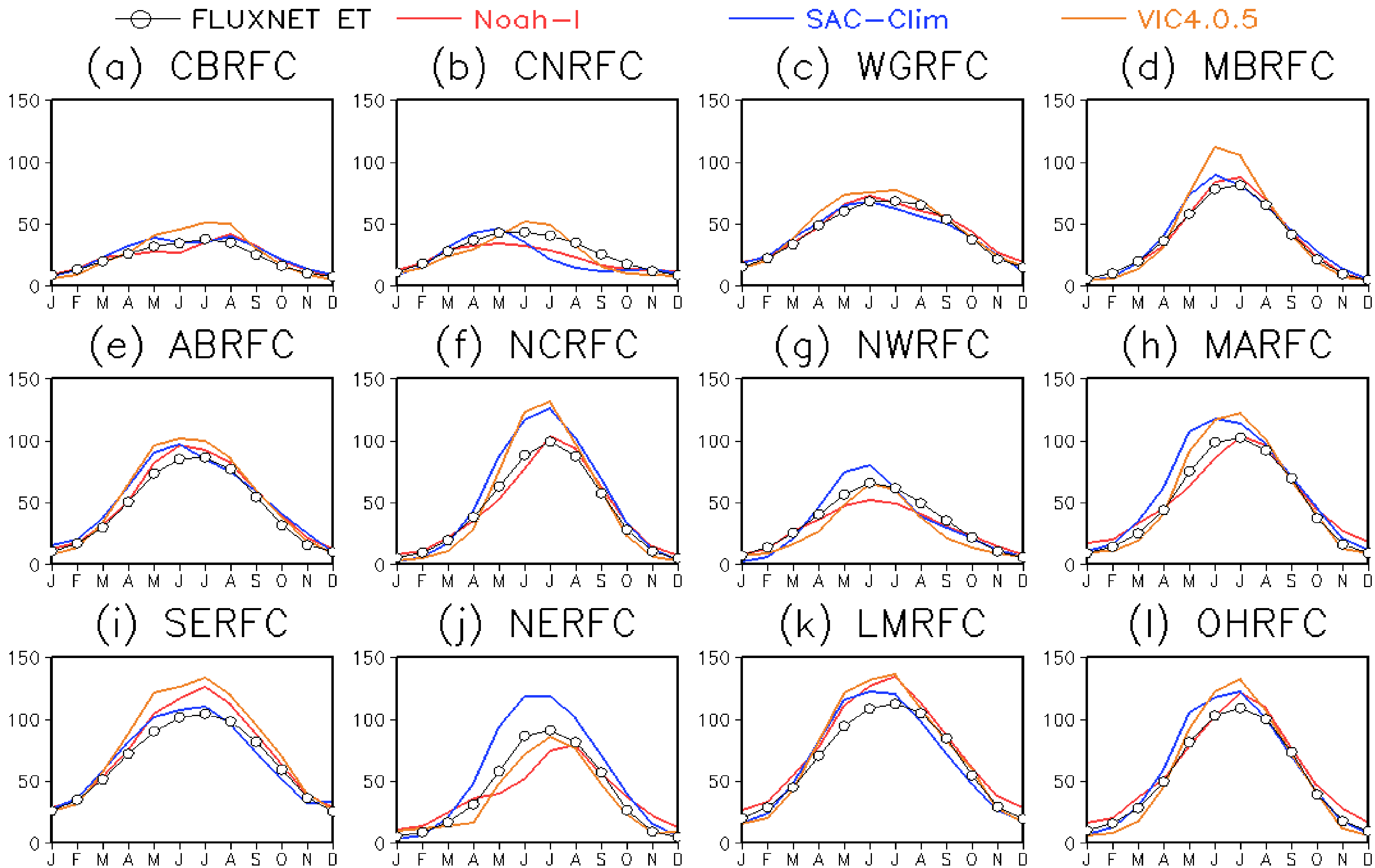


Figure 12: For each of the 12 RFCs, comparison of the 27-year (1982-2008) mean annual cycle of monthly mean ET (unit: mm/month) of the observation-based MTE FLUXNET reference (black line with open circles) with that simulated in the research NLDAS-2 system.

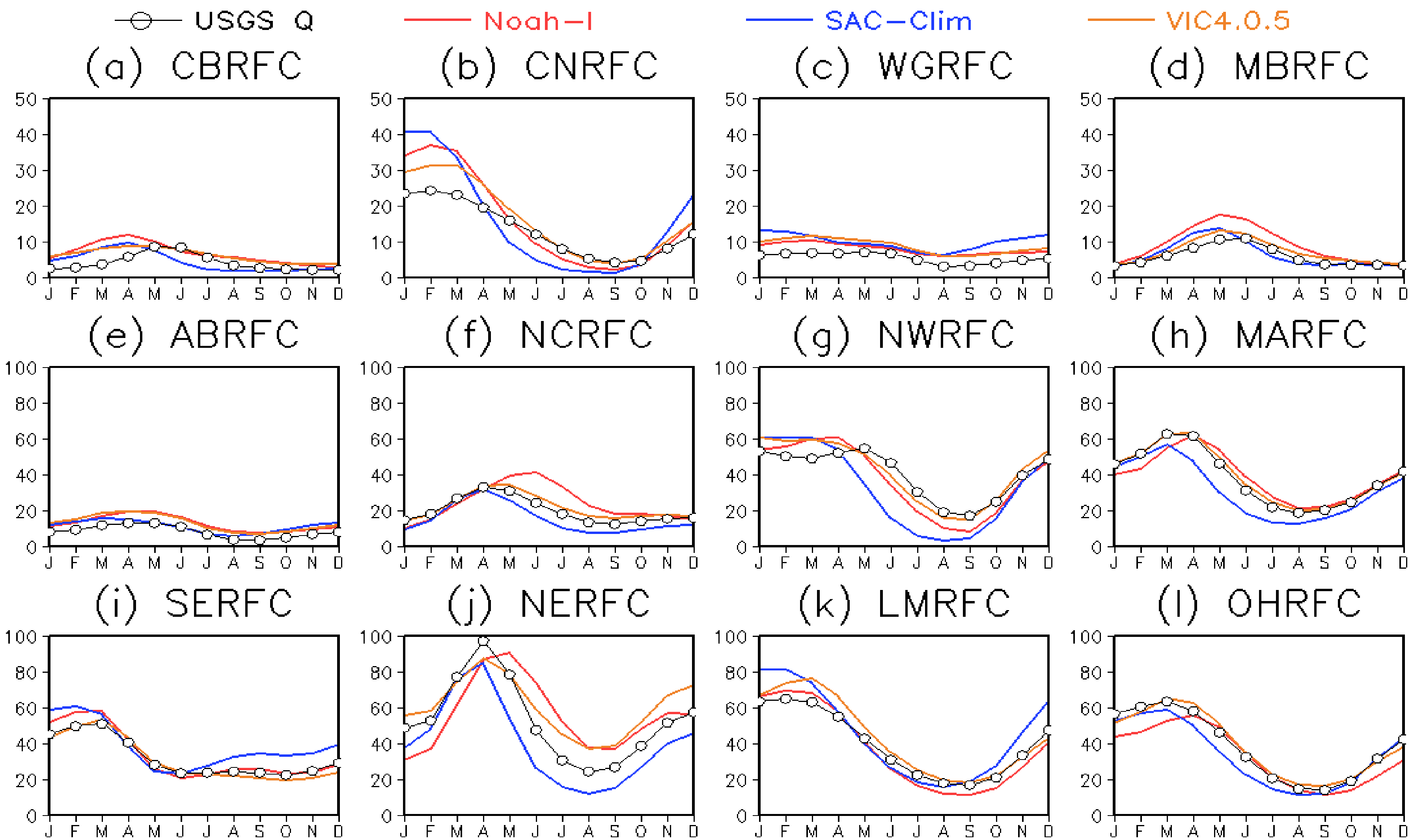


Figure 13: As in Figure 12, except for Q. The observation-based reference values (black line with open circles) are from USGS Q.

Table 4: Anomaly correlation (AC) coefficients between references and the models used in the research NLDAS-2 (The AC value > |0.12| is significant at the 5% significance level for a student t-test. The bold values represent improvements and bold italic values represent deteriorations at the 5% significance level for a two-tailed test when compared with the AC values calculated from the corresponding operational model version listed in Table 2).

	Q			ET			dS/dt		
RFC	Noah-I	SAC-Clim	VIC4.0.5	Noah-I	SAC-Clim	VIC4.0.5	Noah-I	SAC-Clim	VIC4.0.5
CBRFC	**0.70**	0.58	0.65	**0.82**	**0.75**	***0.68***	**0.96**	**0.94**	0.97
CNRFC	**0.96**	***0.88***	**0.96**	**0.82**	**0.74**	***0.60***	0.94	**0.96**	***0.95***
WGRFC	***0.85***	***0.87***	***0.87***	***0.85***	0.86	***0.81***	0.97	**0.95**	**0.97**
MBRFC	0.89	***0.84***	**0.91**	**0.83**	***0.69***	0.82	0.97	**0.95**	0.93
ABRFC	***0.90***	***0.91***	**0.95**	0.80	***0.72***	0.75	**0.94**	0.93	***0.93***
NCRFC	**0.88**	0.90	0.93	**0.54**	-0.08	***0.45***	**0.95**	**0.95**	***0.95***
NWRFC	**0.93**	0.89	***0.91***	**0.63**	***0.44***	0.63	**0.95**	**0.94**	***0.95***
MARFC	**0.92**	0.96	**0.96**	0.44	-0.12	0.34	0.90	0.93	**0.95**
SERFC	0.95	**0.93**	**0.96**	***0.26***	-0.04	0.24	**0.97**	0.96	**0.96**
NERFC	**0.86**	**0.90**	***0.93***	**0.26**	-0.20	**0.62**	**0.92**	**0.95**	0.94
LMRFC	***0.96***	0.93	***0.95***	***0.32***	-0.08	**0.28**	0.96	**0.93**	**0.95**
OHRFC	0.87	**0.94**	0.95	0.53	-0.12	**0.49**	**0.92**	**0.95**	**0.94**

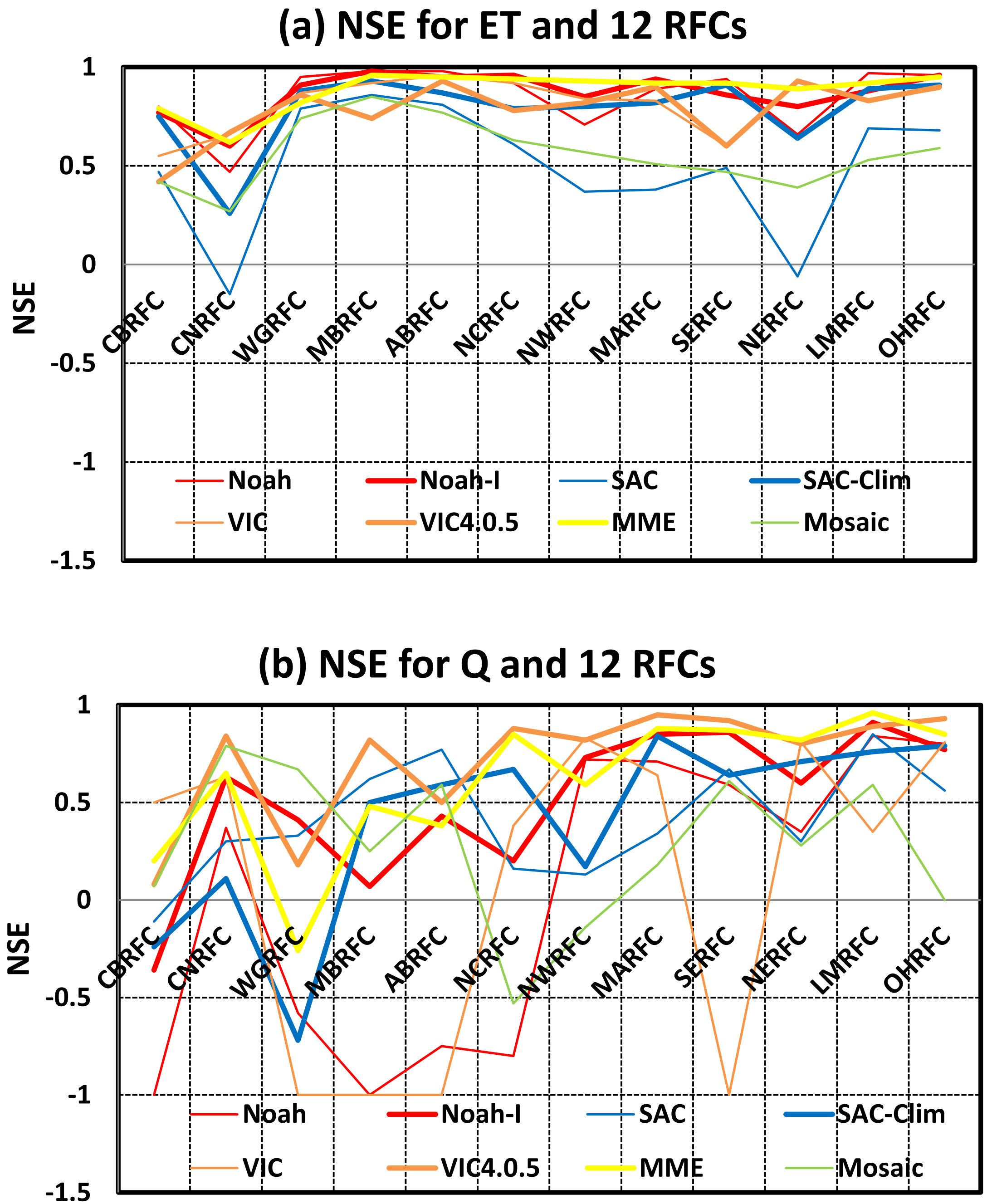


Figure 14: (a) Comparison of Nash-Sutcliffe Efficiency (NSE) calculated from the observation-based MTE FLUXNET reference ET and the simulated ET from the operational and the research NLDAS-2 systems. (b) Same as (a), except for Q, with the observation-based reference Q from the USGS.

Evaluation of Next-Generation NLDAS system

(NoahMP3.6, CLSMF2.5)

Preliminary Results

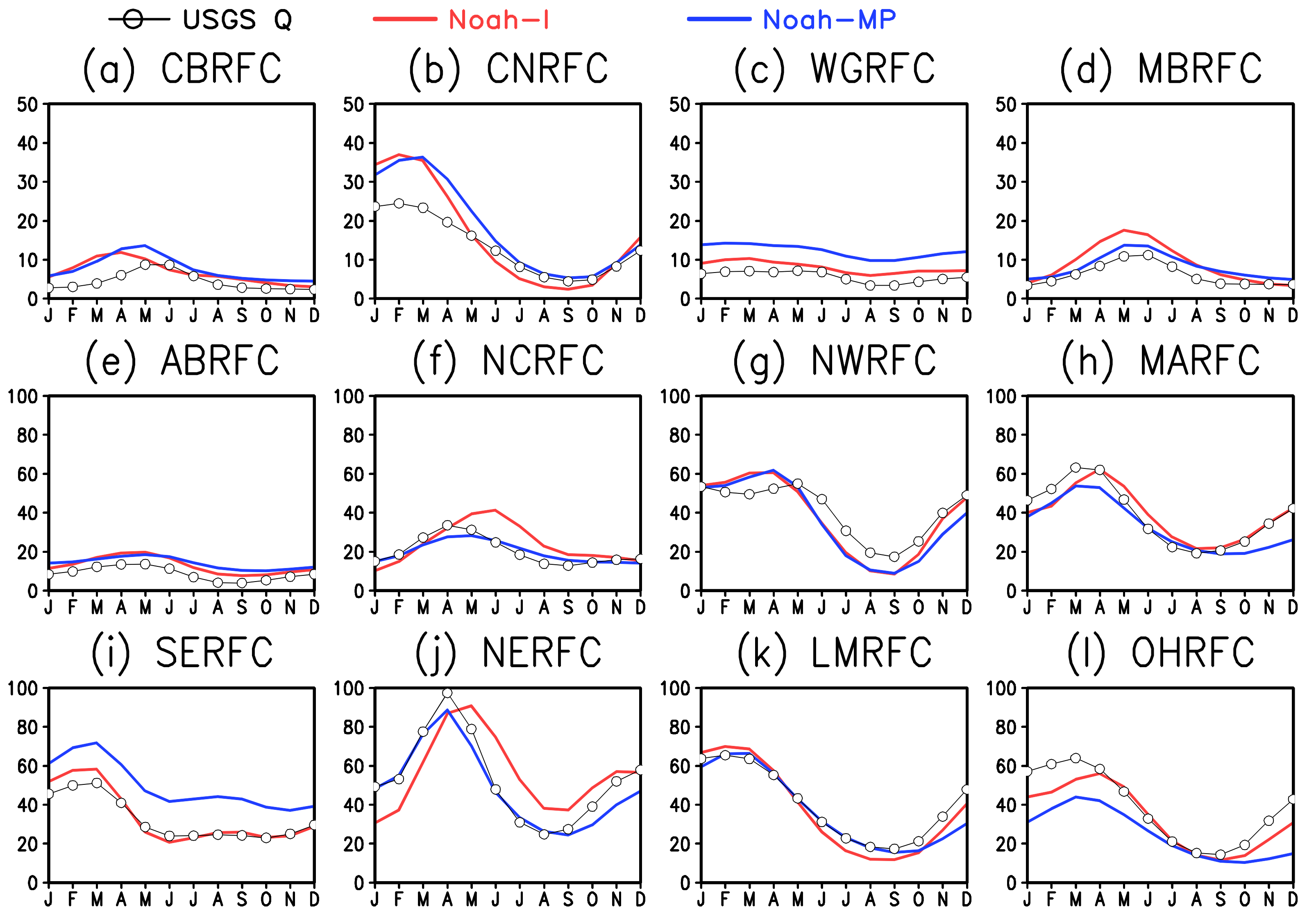


Figure 15: For each of the 12 RFCs, comparison of the 27-year (1982-2008) mean annual cycle of monthly mean Q (unit: mm/month) of the observation-based USGS reference (black line with open circles) with that simulated in the research NLDAS-2 by Noah-I (red) and Noah-MP (blue).

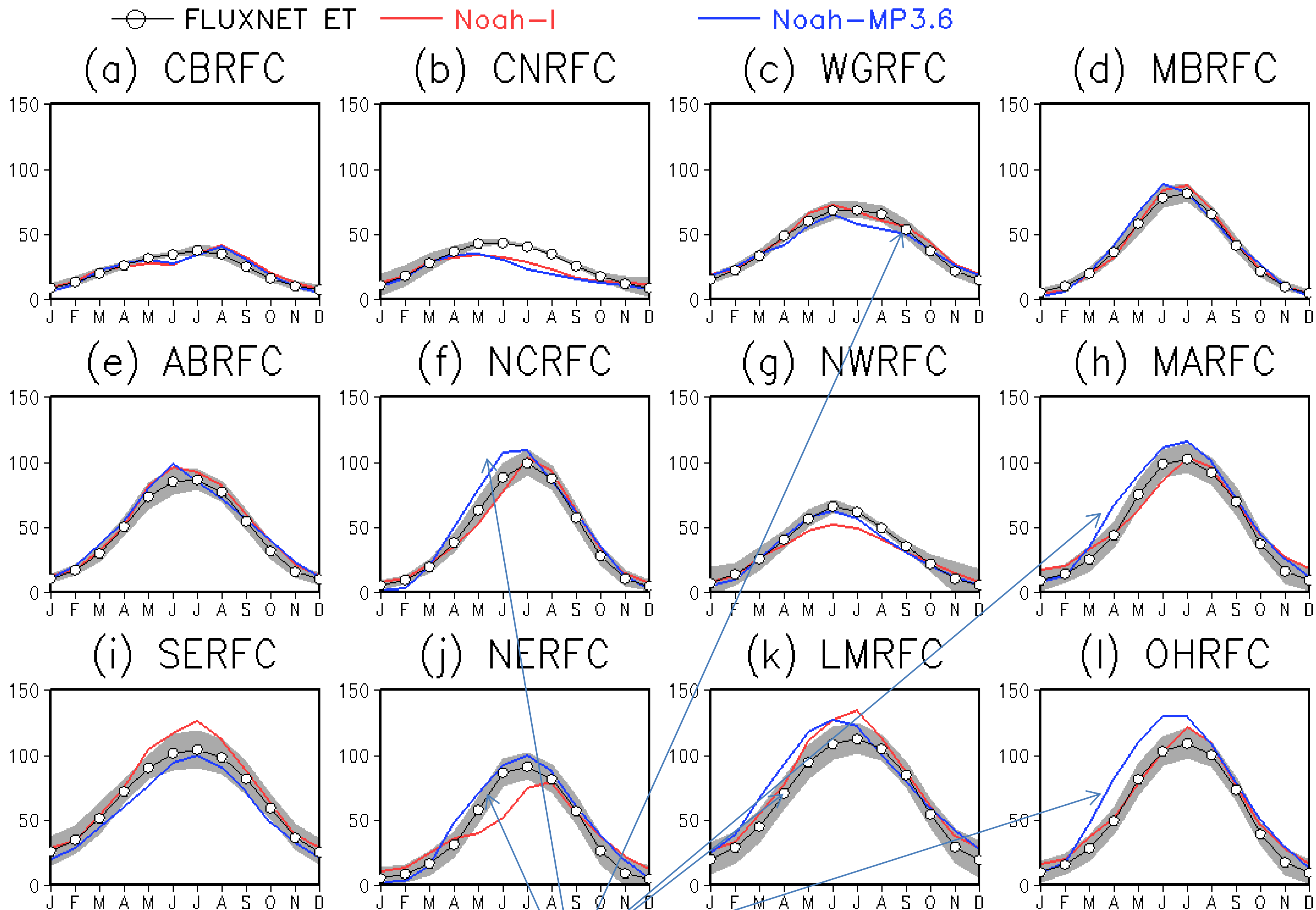


Figure 16

(1) Impact of dynamic vegetation, (2) Impact of CH

Shading area: ±10%P – water balance error

Mosaic high ET and low Q:

(1) shallow root zone (1m), (2) small water holding capacity, and (3) small albedo

CLSM-F2.5

Adding shallow ground water leads higher ET and lower Q

As these issues are not fixed, adding shallow groundwater will increase lower soil layer soil water and leads to more ET (less Q). This addition may desegregate water component simulation.

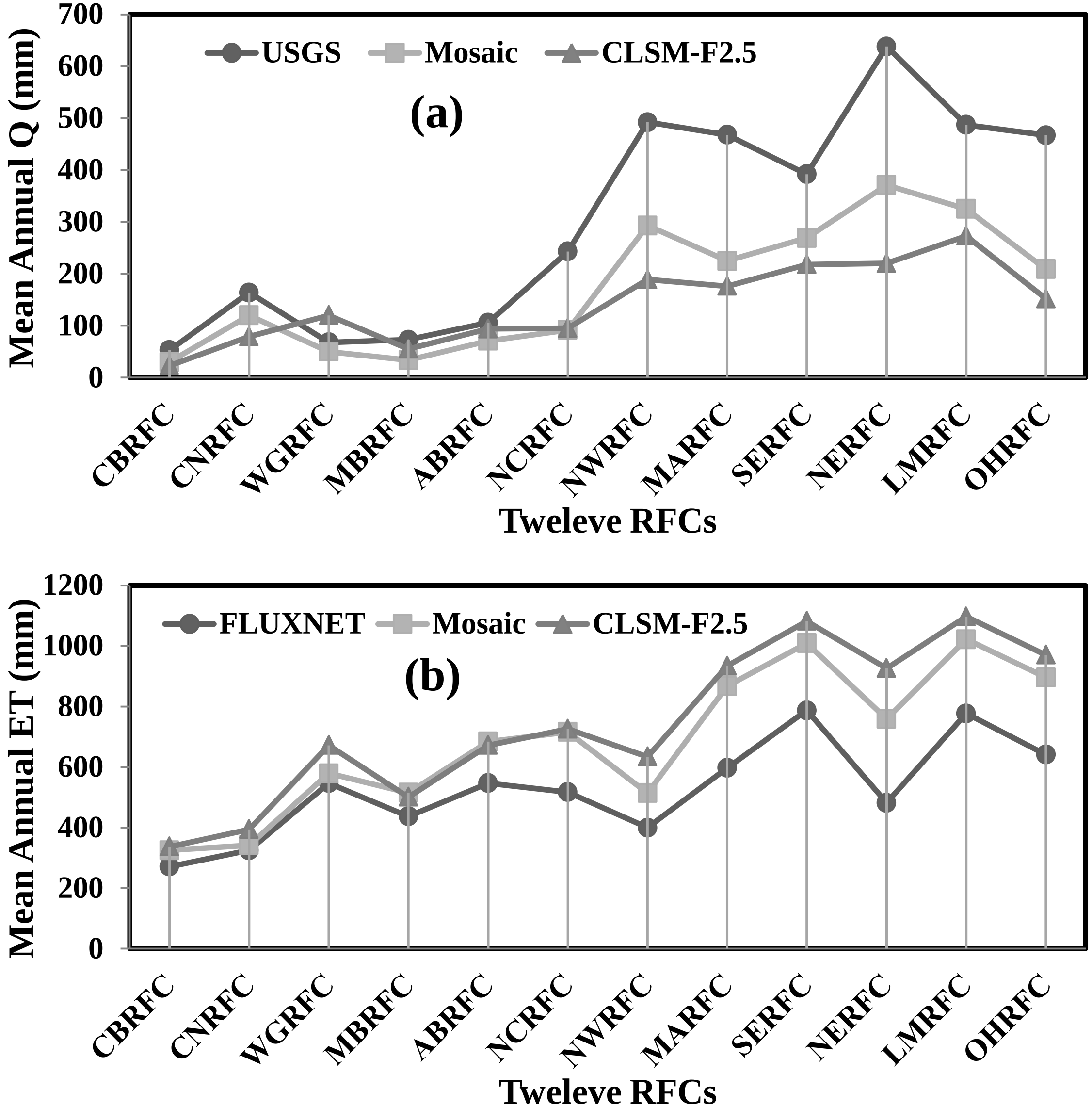


Figure 17: Comparison of mean annual Q and ET: Mosaic vs CLSMF2.5

Take away message

NCDC gauge-based precipitation, GRACE satellite-based TWSA/TWSC, USGS- runoff observations, and FLUXNET-based flux reference data are used to evaluate NLDAS-2 forcing, NCEP operational and research NLDAS-2 surface water budget components for monthly and yearly time scales. Major conclusions are below:

a. **NLDAS-2 precipitation are comparable with NCDC new precipitation dataset. The precipitation is very reasonable.**

b. **Operational NLDAS-2 system has large anomaly correlation for Q and dw/dt when compared to the observations/references although there are large inter-model differences and RMSE and bias .**

c. **Research NLDAS-2 system shows moderate-to-large improvement when compared to operational NLDAS-2 system for ET and Q when compared to the observations and references.**

d. **Next generation NLDAS-2 models produce a mixed result: ET and Q are improved in some basins and degraded at other basins for Noah-MP. Compared to Mosaic model, CLSM-F2.5 has large deterioration when compared to the observations and references. Some further investigations including science understanding of model physical processes and reasonability of model parameters are needed.**

Xia, Y., B. A. Cosgrove, K. E. Mitchell, C. D. Peters-Lidard, M. B. Ek, M. Brewer, D. Mocko, S. Kumar, H. Wei, J. Meng, and L. Luo, 2016: Basin-Scale Assessment of the land surface water budget components in NCEP operational and research NLDAS-2 Systems. *J. Geophys. Res. Atmos.*, doi:10.1029/2015JD023733 (accepted on 7 March 2016)

See full article from http://onlinelibrary.wiley.com/doi/10.1002/2015JD023733/abstract.

Questions/Comments/Suggestions ??