Evaluation of NARR and CLM3.5 outputs for surface water and energy fluxes in the Mississippi River Basin

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1. Motivation

Reanalysis outputs are often used for verification of global climate model outputs. The reanalysis outputs are also useful for studying the surface water and energy fluxes at the basin scale, which is important for understanding of hydrologic cycle. However, reanalysis outputs can have biases and uncertainties, which need be analyzed and quantified to improve our confidence in these data. The objective of this study is present a comparative analysis of high resolution reanalysis outputs, coarse resolution global climate model outputs, and observation data.

Data / Model outputs

1. **AmeriFlux:** 16 stations, Average data length: 6 years [Law et al., 2009]
2. **North American Regional Reanalysis (NARR):** High resolution (32 km) regional reanalysis data from 1979 to present [Mesinger et al., 2006]
3. **Community Land Model (CLM3.5)**: Latest version of Community Land Model offline simulation output, spatial resolution T42 (~ 2.4 degree) [Oleson et al., 2008]

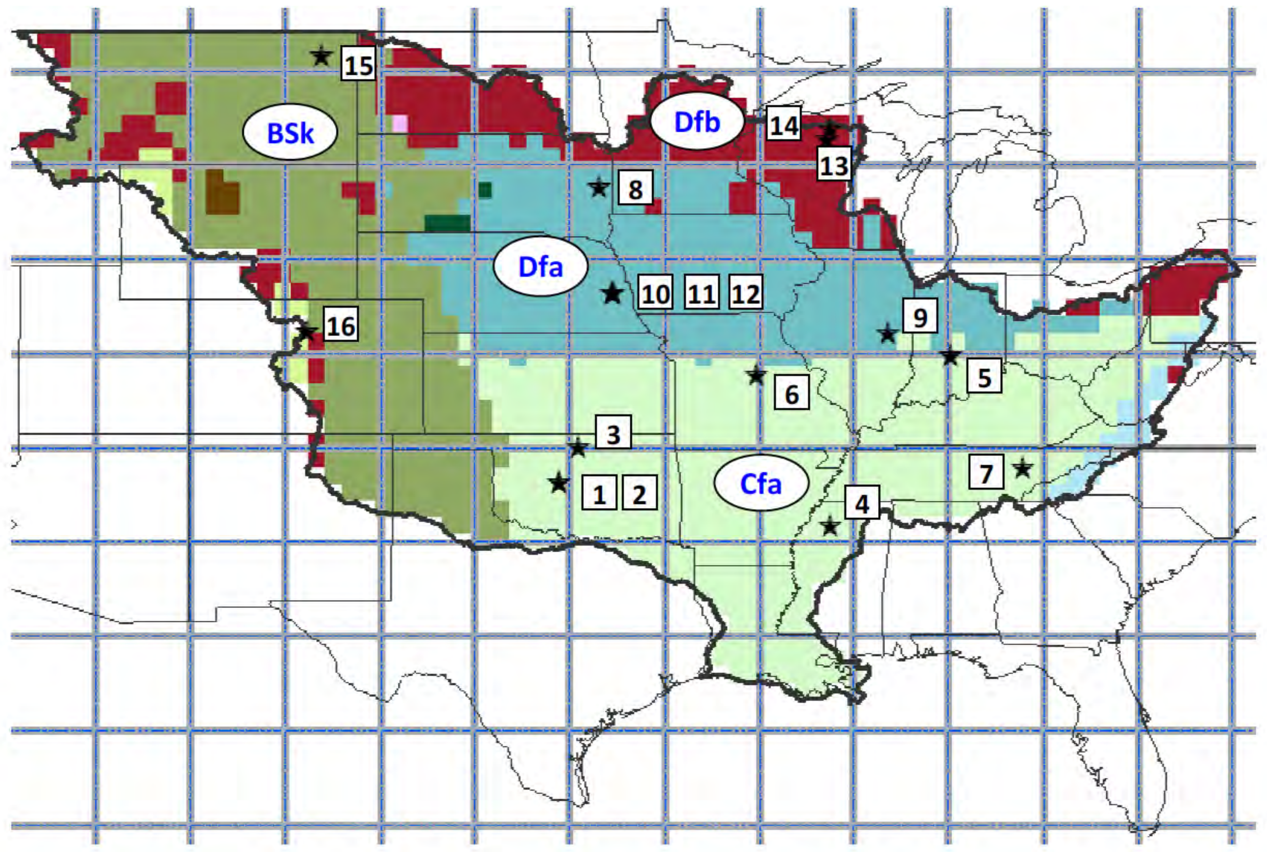


Fig. 1:The major climatic regions (Cfa, Dfa, Dfb, and BSk) and AmeriFlux stations in the Mississippi River Basin with CLM grid (T42 resolution) in the background. Climate classification is based on Köppen-Geiger climate classification map. Each asterisk represents the location of an AmeriFlux station.

2. Study Area

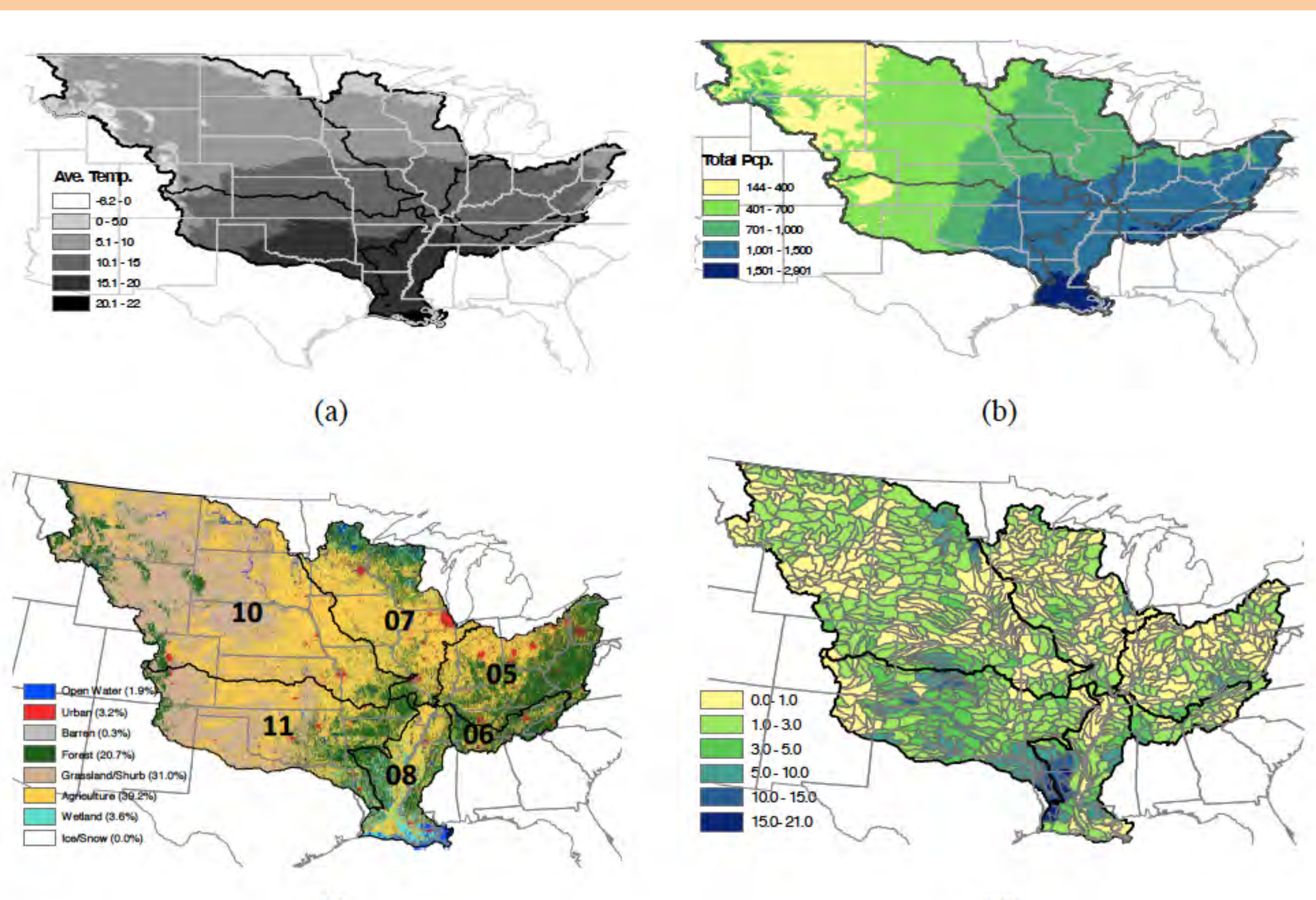
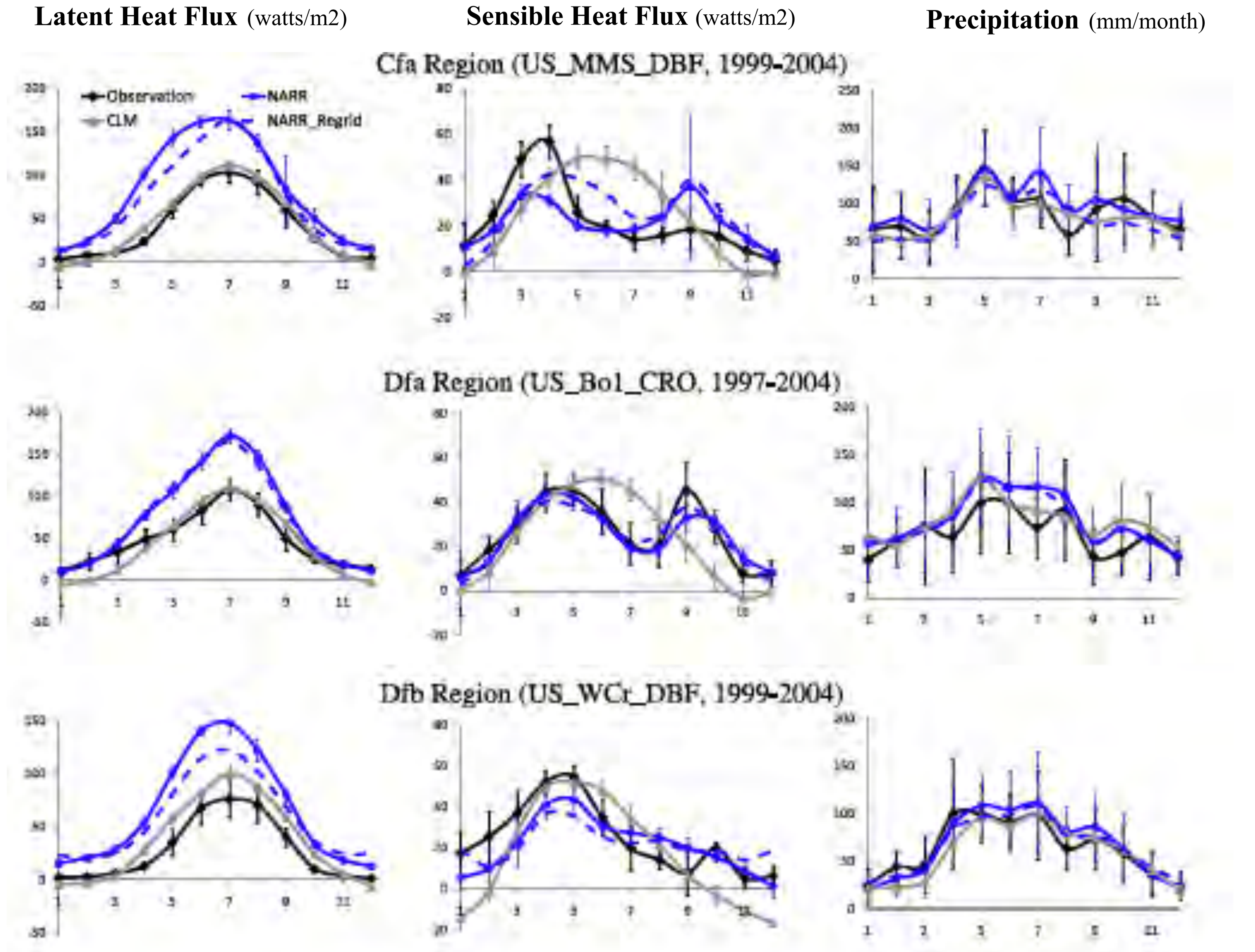


Fig. 2: Map of Mississippi River Basin showing: (a) annual average temperature (0C); (b) annual total precipitation (mm/year) [data source: PRISM climate -normal 1971-2000]; (c) major land cover types (NLCD 2001); and (d) land cover change % (eight digit HUC watershed average, 1992 to 2001). Numbers in the (c) correspond to major river basins/ water resource region in the MRB; 05: Ohio, 06: Tennessee, 07: Upper Mississippi, 08: Lower Mississippi, 10: Missouri, 11: Arkansas-White-Red.

3. Comparison with AmeriFlux Data

Latent Heat Flux (watts/m2) **Sensible Heat Flux** (watts/m2) **Precipitation** (mm/month)



- Compared to average values at 11 AmeriFlux sites in MRB, NARR show higher biases (compared to CLM) in incoming solar radiation (24%), sensible heat flux (27%), and latent heat flux (59%); whereas, CLM show smaller biases (compared to NARR) in incoming solar radiation (0.5%), sensible heat flux (-2%), and latent heat flux (11%).
- Seasonal cycle of observed sensible heat flux in the crop region show two peaks (bimodal pattern), which is captured by NARR, but CLM do not show any bimodal pattern.

4. Point Scale Versus Climate Model Grid Cell

- Seventy one USHCN (United States Historical Climatology Network) stations in Indiana, and Illinois (Menne et al. 2009)
- Monthly precipitation and temperature data for 113 years (1896 to 2008)
- **How different are these observations?**

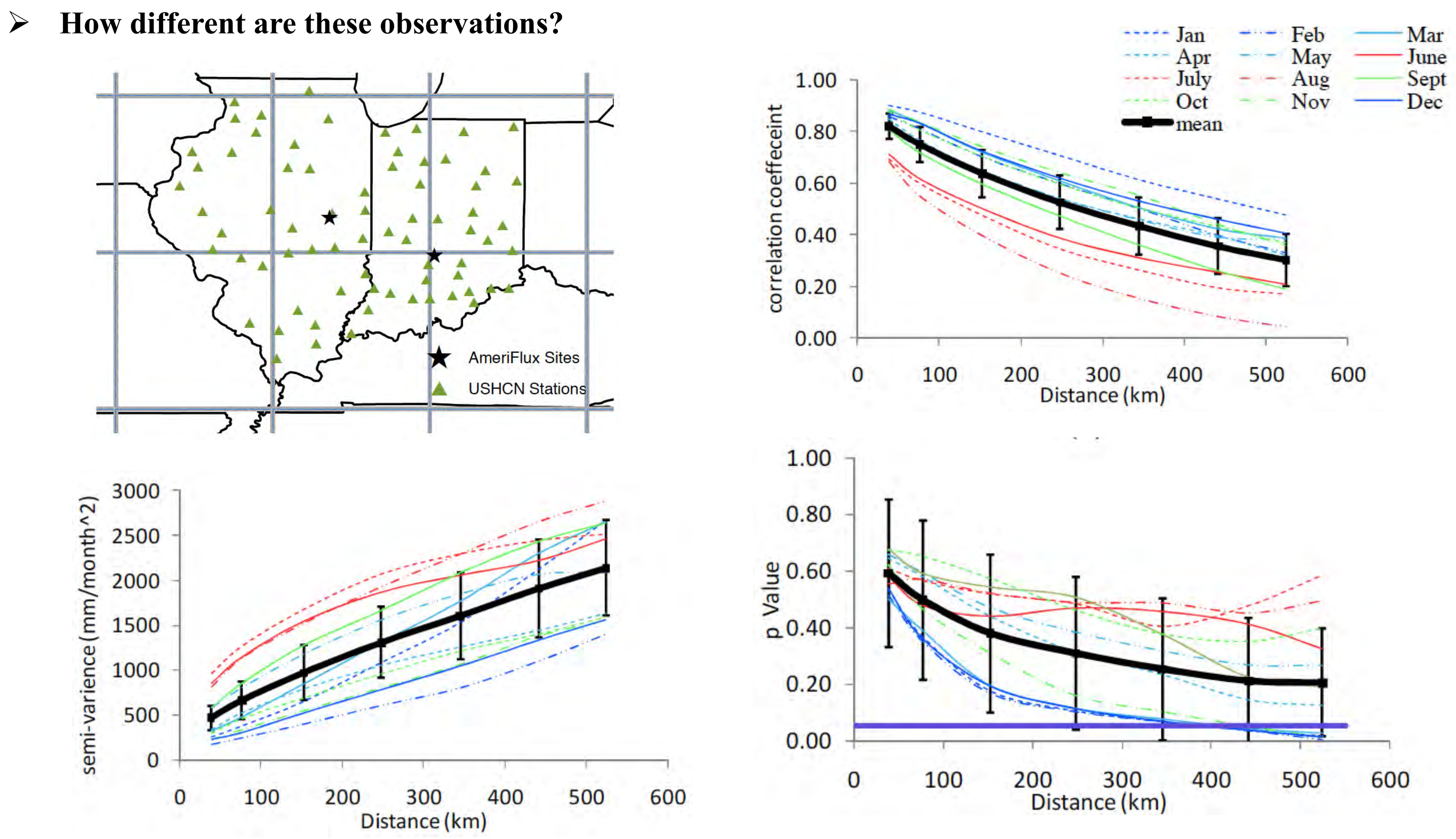


Fig. 4: Spatial variability analysis for monthly precipitation [Thin line represent the mean value for each month (Jan. to Dec.), black thick line represent average of 12 monthly values, Error bar represent mean of monthly standard deviation. For p Values, the H0 is monthly mean value are same.

5. Water and Energy Balance in MRB

Runoff in the MRB

ID	mean mm/year	Correlation coefficient	RMSE mm/year
ML_2001	237		
UNH-GRDC	187		
VIC	242	0.94	13
NARR	89	0.57	151
CLM3.5	281	0.91	47

Note: Observation is naturalized runoff from Maurer and Lettenmaier (2001), UNH-GRDC is runoff output from Fekete et al. (2002), VIC outputs is from Maurer et al. (2002)

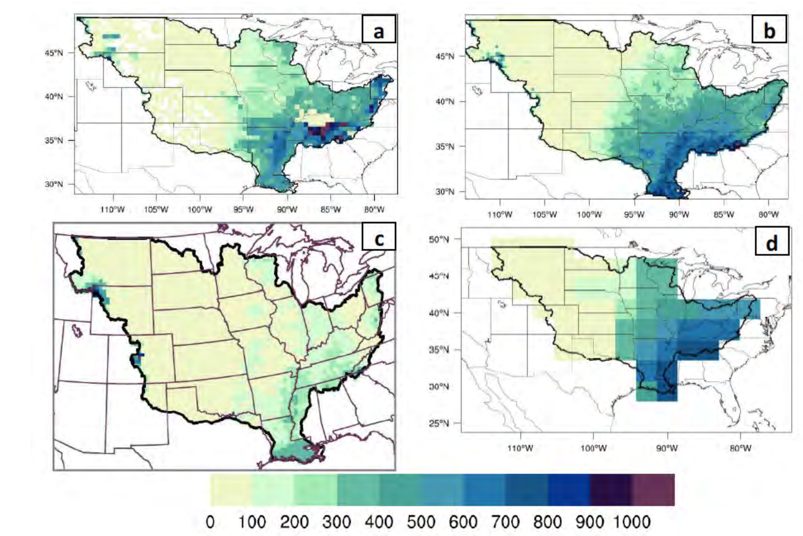


Fig. 5: Total Runoff (mm/year) 1988-1999 (a) UNH-GRDC (climatological mean), (b) VIC, (c) NARR, (d) CLM

Comparison with other reanalysis, and models

Comparison with the WEBS study. The WEBS climatology is for 1996 to 1999, NARR and CLM (This study) is for 1980 – 2004, and the observation (OBS) is for 1988 to 1999. Observed ET is estimated as difference between average PRISM precipitation and average naturalized runoff for 1988 to 1999. Details of the WEBS study are given in Roads et al. (2003). ET – Evapotranspiration, P – Precipitation, N – Total Runoff, Lht – Latent Heat Flux, Sht- Sensible Heat Flux, Rn – Net Rdiation

	The WEBS Study						This Study		
	REAN1	REAN2	GSM	RSM	ETA	VIC	NARR	CLM	OBS
ET/P	1.02	1.05	0.89	0.88	0.94	0.71	1.00	0.66	0.71
N/P		0.06	0.15	0.09	0.17	0.29	0.12	0.34	0.29
Lht/Rn	0.77	0.85	0.75	0.75	0.64	0.63	0.70	0.59	
Sht/Rn	0.13	0.10	0.17	0.28	0.34	0.33	0.40	0.39	

6. Concluding Remarks

- Hydro-climatic variables for which observations are not assimilated in the reanalysis products (e.g. ET and runoff in NARR) should be used with caution for evaluation of climate model outputs. CLM 3.5 outputs provide better characterization of surface water and energy fluxes in the MRB, compared to NARR.
- Availability of AmeriFlux observations in recent years has proved to be an important data source to improve our understanding of land surface and atmospheric interaction. Issue of spatial scale, and its integration with other data e.g. runoff requires further investigations.
- NARR data show significantly lower (62%) total runoff in MRB. This finding is consistent with other studies related to hydrologic validation of reanalysis data (Hagemann et al., 2005; Lucarini et al., 2007), as well as the WEBS study. Availability of runoff observation makes it a candidate variable for indirect assimilation in the Reanalysis data.

Reference

1. Kumar, S., and V. Merwade (2011), Evaluation of NARR and CLM3.5 outputs for surface water and energy budgets in the Mississippi River Basin, *J. Geophys. Res.*, 116, D08115, doi: 10.1029/2010JD014909
2. Roads et al. (2003), GCIP water and energy budget synthesis (WEBS). *J. Geophys. Res.*, 108 (D16), 8609,doi:10.1029/2002JD002583