Evaluation of Regional Water and Energy Balance in Contemporary Reanalyses

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Motivation

Roads et al. (2002) evaluated GEWEX regional water and energy budgets using observations and NCEP Reanalyses, where the residual term was interpreted as the result of the observational analysis. Here, we revisit this method adding the latest generation of reanalyses, including JRA3Q, ERA5 and MERRA-2. When possible, we include an estimate of the analysis increment in the water and energy budgets, so that the residual terms can be expanded to:

1) $RSQ = QANA + RSQ'$ and 2) $RST = HANA + RST'$

3) $\frac{\partial Q}{\partial t} = E + MC - P + RSQ$

4) $Cp\frac{\partial T}{\partial t} = QRT - QRS + LP + SH + HC + RST$

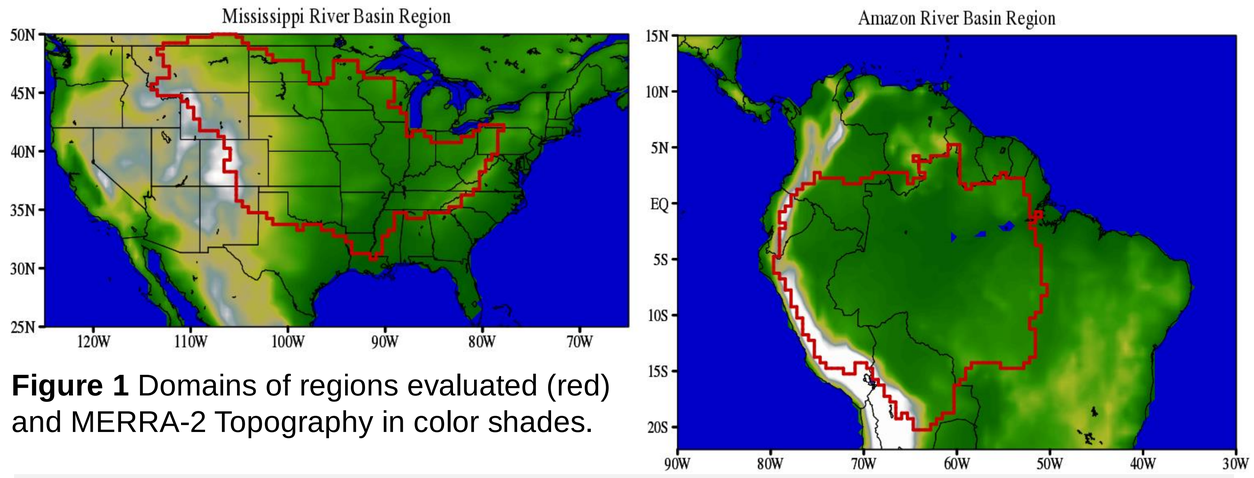


Figure 1 Domains of regions evaluated (red) and MERRA-2 Topography in color shades.

Analysis

The regions of focus are the Mississippi and Amazon River Basins. While both are important water systems, these represent different climates owing to the mean latitude, but also, different density of observations.

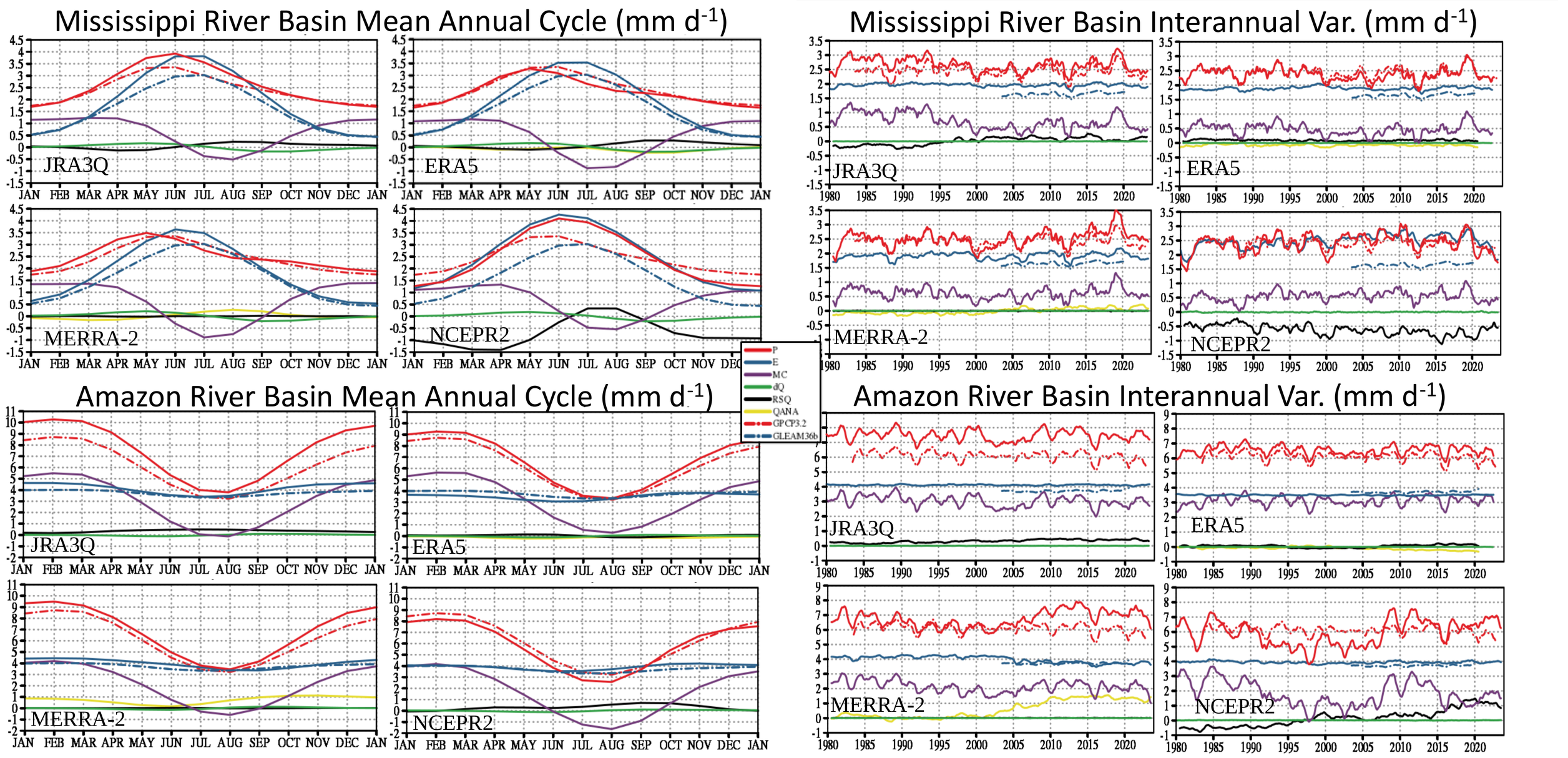


Figure 2 Mean annual cycle (1991-2020) of the water cycle quantities. Reference observations are included as dashed lines. Residuals are in black and yellow.

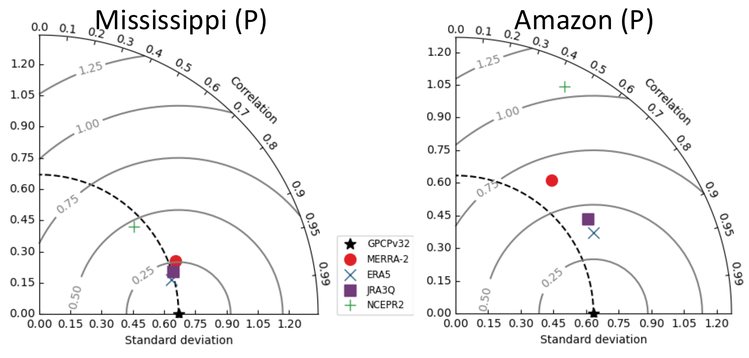
Figure 3 Interannual variability of the water cycle terms (12 month running mean applied to remove the annual cycle). Reference observations are included as dashed lines. Residuals are in black and yellow.

In MRB, apparent issues in NCEPR2 residual (identified by Roads et al. 2002) are significantly improved for all the contemporary reanalyses. While residuals have decreased, they do have annual variations. Amazon is less clear as MERRA-2 and JRA3Q overestimates P with a noticeable analysis increment. All reanalyses are estimating the E in MRB, perhaps owing to a regional bias present in GLEAM.

An example where knowing the analysis increment helps understand the budgets. MERRA-2 analysis increases in the 2000's, and seems linked to increases in precipitation. ERA5 has very stable interannual variations with only small analysis increments. JRA3Q trends in MRB residual seems related to trends in both precipitation and moisture flux convergence.

Q(mm d-1)	Mississippi						Amazon					
	MRB	MERRA2	ERA5	JRA3Q	NCEPR2	OBS	Amazon	MERRA2	ERA5	JRA3Q	NCEPR2	OBS
	TPW	17.5	17.0	16.4	17.3	16.9 (AIRS)	TPW	46.7	45.8	44.0	43.5	45.4 AIRS
	P	2.57	2.32	2.61	2.52	2.43 (GPCP3.2)	P	6.90	6.51	7.38	6.05	6.06 GPCP3.2
	E	1.92	1.89	1.95	2.64	1.65 (GLEAM)	E	3.86	3.49	4.12	3.93	3.72 GLEAM
	MC	0.60	0.42	0.56	0.61		MC	2.02	3.12	2.87	1.63	
	RSQ	0.00	0.08	0.10	-0.73		RSQ	0.01	0.06	0.40	0.49	
	QANA	0.06	-0.08				QANA	1.02	-0.17			

H(W m-2)	MRB	MERRA2	ERA5	JRA3Q	NCEPR2	OBS	Amazon	MERRA2	ERA5	JRA3Q	NCEPR2	OBS
	Ts	284.1	284.2	284.9	283.9	285.6 AIRS	Ts	297.9	297.4	296.8	297.0	297.3 AIRS
	T2m	284.0	284.2	284.0	284.0	284.0 CRU	T2m	297.9	297.7	297.5	296.9	298.5 CRU
	QRS	88.7	81.6	84.3	87.6	85.9 CERES	QRS	137.8	131.3	147.2	128.6	138.6 CERES
	QRT	-8.2	-12.1	-13.2	-9.7	-15.7 CERES	QRT	50.5	41.2	41.0	22.7	47.6 CERES
	Hs	33.1	24.9	26.4	3.6	23.6 ERA5L	Hs	27.6	30.1	27.4	12.4	28.0 ERA5L
	LP	75.1	67.0	75.5	73.0	70.4 GPCP3.2	LP	197.9	188.4	213.7	175.1	175.4 GPCP3.2
	HC	-9.9	8.3				HC	-124.4	-136.4			
	RST	-2.3	-3.4				RST	-14.9	8.1			
	ANA	1.05	-3.16				ANA	1.12	-0.08			



Energy balancing has some challenges. Residuals cannot be computed with a lack of energy convergence. Numerical truncation and residuals makes clear closure more challenging. Differences of large values.

Summary

In many respects, there has been notable improvements in the contemporary reanalyses regarding the representation and closures of regional water balances. Smaller increments in the MRB are clear, compared to NCEPR2 (and the Roads et al. results). The increments also provide a diagnostic to characterize the impact of observing system variations on the closure. For energy, some difficulties remain. While ERA5 and MERRA-2 demonstrate some small values of increments in a climatological sense, the physical energy terms are large and differing signs, making it difficult to assess the closure. The lack of energy convergence terms in JRA3Q and NCEPR2 do not permit residual calculation. Differences can be easily seen in different regions, and the density of observations plays a significant role. It is important for reanalyses to produce the physical terms of the budgets, as well as a representation of the increments that allows for closure.

Bosilovich, M.G., J.B. Roberts, M. Mayer, and F.R. Robertson, 2024: Regional Evaluation of Water and Energy Cycles in Contemporary Reanalyses. *GEWEX Quarterly*, **34**, 2, pp 12-16.

Roads, J., M. Kanamitsu, and R. Stewart, 2002: CSE Water and Energy Budgets in the NCEP–DOE Reanalysis II. *J. Hydrometeor.*, **3**, 227–248, 10.1175/1525-7541(2002)003<0227:CWAEBI>2.0.CO;2.

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