Table S1. Reported basin area, river discharge, and suspended solids (SS) for 65 rivers (Meybeck and Ragu, 2012; Mayorga et al., 2010).

	Meybeck and Ragu (2012)			Global NEWS 2; Mayorga et al. (2010)			
River	Basin Area km^2	Discharge $km^3\ yr^{-1}$	SS Conc $mg\ l^{-1}$	Basin Area km^2	Discharge $km^3\ yr^{-1}$	SS Yields $Mg\ km^{-2}\ yr^{-1}$	SS Loads $Mg\ yr^{-1}$
Amazon	6112000	6590	182.1	5846870	6444.09	74	435355602
Zaire	3698000	1200	19	3694430	1278.28	8	30474848
Ob	2990000	404	40.8	3022320	392.97	11	32408854
Mississippi	2980000	580	862.1	3199170	620.03	16	50447046
Nile	2870000	83.2	1442	3821590	347.84	1	3965538
Parana	2783000	568	139.1	2660890	558.85	13	35825104
Yenisey	2590000	620	9.5	2575660	596.33	12	29934161
Lena	2490000	533	33	2438900	480.54	22	52914080
Amur	1855000	344	72.4	1752600	337.59	14	24698441
Chang Jiang	1808000	928	517	1792120	905.28	92	164644614
Mackenzie	1787000	321.5	134.4	1692900	289.51	24	41025668
Zambezi	1330000	106	188.7	1361960	309.43	12	16721397
Niger	1200000	154.1	259.5	2237360	324.77	11	23939573
Orinoco	1100000	1135	132.2	1038130	1115.14	51	53155946
Murray	1060000	23.6	1271.2	1030290	6.6	9	9558272
Ganges	1050000	493	1055	1626470	1143.76	2029	3299693147
Saint Lawrence	1020000	341	11.7	1052470	354.84	2	2566071
Huang He/Haiho	1009000	133	58997				
Orange	1000000	11.36	7834.5	942459	11.49	6	5450726
Indus	916000	90	2778				
Rio Grande	870000	18	1111.1				
Yukon	849000	201	300	854690	90.3	49	41871742
Danube	817000	203	335	787069	200.19	29	22977561
Mekong	795000	467	321.2	757660	433.3	488	369763372
Tocantins	757000	372	201.6	767705	383.38	6	4320806
Columbia	669000	236	63.6	731105	240.44	39	28487027
Kolyma	660000	128	125.8	664851	104.13	11	7281072
Colorado	639000	18.5	6487	806617	19.03	2	1388732
Sao Francisco	630000	90	66.7	614418	86.59	2	1114044
Brahmaputra	580000	644	1058.8				
Shatt el Arab	541300	47.75	2295				
Dnepr	504000	53.6	42.9	508234	46.94	1	272098
Senegal	441000	24.4	77.9	846269	24.91	4	3706404
Limpopo	440000	26	1269	419839	8.38	18	7682071
Zhujiang	437000	363	190.1	408043	259.51	68	27671181
Irrawaddy	410000	486	535	405481	619.15	1325	537116394
Volta	394000	36.8	516.3	397598	25.66	3	1019136
Khatanga	364000	101	16.8	369915	34.37	18	6831070

Indigirka	362000	53.6	240.7	333729	50.42	14	4707765
N. Dvina	348000	105	42.9	360513	107.83	10	3489082
Pechora	324000	129	50.4	313916	142.41	13	3990446
Godavari/Krishna	572000	135	1733.2	562591	131.59	116	65435724
Neva	282000	78.5	10.4	284166	78.87	3	901953
Uruguay	240000	145	75.9				
Magdalena	235000	237	928.3	251445	236.03	284	71407661
Yana	230800	30.6	114.4	224724	32.45	14	3239635
Rhine	224000	69.4	49.1	164864	72.83	4	698447
Fraser	220000	114	175.4	237222	102.49	52	12372746
Liao	219000	16.2	2531	273728	5.92	7	1821819
Olenek	219000	13.9	32	222924	32.47	15	3308073
Anadyr	200000	63.7	28.3	225578	37.02	9	2029997
Wisla	198000	34.1	73.3	180368	32.83	13	2354478
Rufiji	178000	35.2	483	186538	28.6	157	29244750
Essequibo	164000	178	25.3	150591	140.17	66	9959167
Elbe	146000	23.7	35.4	148353	26.68	7	1000150
Mahanadi	141600	66	909.1	141040	51.73	135	18984547
Albany/Moose	243000	90.2	63.2	243225	74.82	5	1263157
Kuskokwim	123000	59.9	116.9	115670	40.73	32	3689266
Hong (Red)	120000	123	1057	170700	67.96	783	133718671
Brazos/Colorado	221000	7.53	4502	245926	12.75	11	2804187
Mobile	113000	59.9	75				
Odra	112000	18.3	7.1	119703	18.58	5	560380
Chao Phrya	111400	27.8	395.7	141662	17.09	55	7795036
Bandama	105000	11.5	102.6	103965	25.85	32	3309928
Taz	100000	48.5	18.6	170827	42.58	8	1435669

Table S2. Reported basin area, river discharge, and nitrate N (NO_3^-) for 51 rivers (Meybeck and Ragu, 2012).

River	Basin Area, km^2	River Discharge, $km^3\ yr^{-1}$	NO_3^-, $mg\ l^{-1}$
Amazon	6112000	6590	0.14
Zaire	3698000	1283	0.08
Ob	2990000	404	0.06
Mississippi	2980000	580	1.4
Parana	2783000	568	0.165
Yenisey	2590000	620	0.02
Lena	2490000	533	0.03
Amur	1855000	344	0.02
Chang Jiang	1808000	928	0.319
Mackenzie	1787000	321.5	0.053
Zambezi	1330000	106	0.13
Nelson	1132000	83.3	0.012
Orinoco	1100000	1135	0.08
Murray	1060000	23.6	0.11
Saint Lawrence	1020000	341	0.16
Orange	1000000	11.36	0.72
Indus	916000	90	2
Rio Grande	870000	18	0.15
Yukon	849000	201	0.1
Danube	817000	203	1.8
Tocantins	757000	372	0.015
Huang He	752000	41	2.2
Columbia	669000	236	0.2
Kolyma	660000	128	0.04
Colorado	639000	18.5	0.35
Godavari/Krishna	572000	135	0.17
Dnepr	504000	53.6	0.21
Zhujiang	437000	363	0.62
Volta	394000	36.8	0.15
Khatanga	364000	101	0.03
Indigirka	362000	53.6	0.024
N. Dvina	348000	105	0.02
Churchill	298000	40	0.01
Neva	282000	78.5	0.23
Pechora	248000	110	0.07
Magdalena	240900	214.5	0.22
Uruguay	240000	145	0.226
Yana	230800	30.6	0.01
Rhine	224000	69.4	3.9
Brazos/Colorado	221000	7.53	0.42
Fraser	220000	114	0.099

Liao	219000	16.2	0.105
Olenek	219000	13.9	0.03
Wisla	198000	34.1	1.83
Rufiji	178000	35.2	1.3
Elbe	146000	23.7	3.6
Mobile	113000	59.9	0.26
Balsas	112000	14	0.19
Loire	112000	28.4	1.7
Odra	112000	18.3	2.42
Chao Phrya	111400	27.8	0.14

Table S3. Reported basin area, river discharge, and ammonium N (NH_4^+) for 37 rivers (Meybeck and Ragu, 2012).

River	Basin Area, km^2	River Discharge, $km^3\,yr^{-1}$	NH_4^+, mg l^{-1}
Amazon	6112000	6590	0.02
Zaire	3698000	1200	0.007
Ob	2990000	404	0.6
Mississippi	2980000	580	0.04
Parana	2783000	568	0.05
Yenisey	2590000	620	0.28
Lena	2490000	533	0.08
Amur	1855000	344	0.43
Chang Jiang	1808000	928	0.319
Zambezi	1200000	223	0.014
Orinoco	1100000	1135	0.035
Murray	1060000	23.6	0.036
Saint Lawrence	1020000	341	0.08
Indus	916000	90	0.2
Rio Grande	870000	18	0.03
Yukon	849000	201	0.03
Huang He	752000	41	0.01
Columbia	669000	236	0.01
Kolyma	660000	128	0.05
Zhujiang	437000	363	0.01
Khatanga	364000	101	0.04
Indigirka	362000	53.6	0.004
N. Dvina	348000	105	0.12
Pechora	324000	129	0.22
Churchill	298000	40	0.1
Neva	282000	78.5	0.03
Uruguay	240000	145	0.05
Yana	230800	30.6	0.17
Rhine	224000	69.4	0.9
Liao	219000	16.2	0.175
Olenek	219000	13.9	0.05
Wisla	198000	34.1	0.435
Rufiji	178000	35.2	0.095
Elbe	146000	23.7	1.3
Balsas	112000	14	0.395
Odra	112000	18.3	0.21
Chao Phrya	111400	27.8	0.1

Table S4. Reported basin area, river discharge, and dissolved organic nitrogen (DON) for 18 rivers (Meybeck and Ragu, 2012; Mayorga et al., 2010).

	Meybeck and Ragu (2012)			Global NEWS 2; Mayorga et al. (2010)			
River	Basin Area km^2	Discharge $km^3\ yr^{-1}$	DON Conc $mg\ l^{-1}$	Basin Area km^2	Discharge $km^3\ yr^{-1}$	DON Yields $kg\ km^{-2}\ yr^{-1}$	DON Loads $Mg\ yr^{-1}$
Amazon	6112000	6590	0.162	5846870	6444	7061	306.4
Zaire	3698000	1200	0.18	3694430	1278	1278	102.2
Nile	2870000	83.2	0.01	3821590	348	356	0.1
Parana	2783000	568	0.08	2660890	559	559	71.9
Lena	2490000	533	0.46	2438900	481	485	58.9
Mackenzie	1787000	321.5	0.1	1692900	290	270	47.6
Niger	1200000	154.1	0.13	2237360	325	332	46.2
Orinoco	1100000	1135	0.16	1038130	1115	1116	303.6
Ganges	1050000	493	0.063	1626470	1144	1396	230.0
Saint Lawrence	1020000	341	0.03	1052470	355	355	117.3
Orange	1000000	11.36	0.15	942459	11	12	6.2
Danube	817000	203	0.6	787069	200	211	106.4
Kolyma	660000	128	0.35	664851	104	104	48.1
Brahmaputra	580000	510	0.042				
Khatanga	364000	101	0.41	369915	34	34	24.6
Indigirka	362000	53.6	0.35	333729	50	50	46.4
Yana	230800	30.6	0.4	224724	32	32	44.2
Olenek	219000	13.9	0.41	222924	32	33	44.8

Table S5. Reported basin area, river discharge, and total Kjeldahl N (TKN, the sum of NH_4^+, DON, and PON) concentration for 12 rivers (Meybeck and Ragu, 2012).

River	Basin Area, km^2	River Discharge, $km^3\ yr^{-1}$	TKN, mg l^{-1}
Mississippi	2980000	580	1
Nelson	1132000	83.3	1
Murray	1060000	23.6	0.83
Saint Lawrence	1020000	341	0.24
Rio Grande	870000	18	1
Yukon	849000	201	0.5
Columbia	669000	236	0.4
Churchill	298000	40	0.6
Uruguay	240000	145	0.45
Rhine	224000	69.4	1.6
Balsas	112000	14	0.89
Chao Phrya	111400	27.8	0.28

Table S6. Reported basin area, river discharge, and phosphate P (PO_4^{3-}) for 47 rivers (Meybeck and Ragu, 2012; Mayorga et al., 2010).

	Meybeck and Ragu (2012)			Global NEWS 2; Mayorga et al. (2010)			
River	Basin Area km^2	Discharge $km^3\ yr^{-1}$	PO_4 Conc $mg\ l^{-1}$	Basin Area km^2	Discharge $km^3\ yr^{-1}$	PO_4^{3-} Yields $kg\ km^{-2}\ yr^{-1}$	PO_4 Loads $Mg\ yr^{-1}$
Amazon	6112000	6590	0.022	5846870	6444	19.404	113451
Zaire	3698000	1200	0.024	3694430	1278	2.250	8314
Ob	2990000	404	0.065	3199170	620	8.563	27396
Mississippi	2980000	580	0.07	3022320	393	4.687	14164
Parana	2783000	568	0.045	2660890	559	2.364	6291
Yenisey	2590000	620	0.008	2575660	596	0.633	1631
Lena	2490000	533	0.004	2438900	481	1.445	3524
Amur	1855000	344	0.021	1752600	338	7.090	12426
Chang Jiang	1808000	928	0.2	1792120	905	51.316	91964
Mackenzie	1787000	321.5	0.004	1692900	290	0.762	1290
Zambezi	1330000	106	0.01	1361960	309	1.115	1519
Murray	1060000	23.6	0.024	1030290	7	0.319	328
Nelson	1132000	83.3	0.004	1138420	87	0.331	376
Orinoco	1100000	1135	0.01	1038130	1115	7.959	8263
Ganges	1050000	493	0.075	1626470	1144	101.905	165745
Indus	916000	90	0.52	1141750	52	1.110	1267
Rio Grande	870000	18	0.03	803837	3	0.056	45
Yukon	849000	201	0.01	854690	90	0.231	198
Danube	817000	203	0.18	787069	200	32.083	25251
Tocantins	757000	372	0.003	767705	383	3.144	2414
Huang He	752000	41	0.02	892570	31	2.367	2113
Columbia	669000	236	0.014	731105	240	1.258	920
Kolyma	660000	128	0.009	664851	104	0.852	566
Colorado	639000	18.5	0.1	806617	19	0.004	3
Brahmaputra	580000	510	0.06				
Dnepr	504000	53.6	0.036	508234	47	3.125	1588
Zhujiang	437000	363	0.003	408043	260	60.149	24543
Khatanga	364000	101	0.006	369915	34	0.256	95
Indigirka	362000	53.6	0.006	333729	50	0.794	265
N. Dvina	348000	105	0.039	360513	108	4.576	1650
Pechora	324000	129	0.008	313916	142	6.152	1931
Churchill	298000	40	0.006	303135	40	0.385	117
Neva	282000	78.5	0.03	284166	79	8.142	2314
Uruguay	240000	145	0.037				
Magdalena	235000	237	0.12	251445	236	104.207	26202
Yana	230800	30.6	0.001	224724	32	0.719	161
Rhine	224000	69.4	0.4	164864	73	23.289	3839
Fraser	220000	114	0.05	237222	102	3.274	777

Liao	219000	16.2	0.053	273728	6	11.272	3085
Olenek	219000	13.9	0.003	222924	32	0.739	165
Wisla	198000	34.1	0.21	180368	33	53.180	9592
Rufiji	178000	35.2	0.01	186538	29	2.566	479
Elbe	146000	23.7	0.39	148353	27	30.332	4500
Balsas	112000	14	0.095	122842	28	21.418	2631
Loire	112000	28.4	0.09	118141	29	36.059	4260
Odra	112000	18.3	0.37	119703	19	40.555	4855
Chao Phrya	111400	27.8	0.026	141662	17	1.893	268

Table S7. Reported basin area, river discharge, and dissolved organic P (DOP) for 9 rivers (Meybeck and Ragu, 2012; Mayorga et al., 2010).

	Meybeck and Ragu (2012)			Global NEWS 2; Mayorga et al. (2010)			
River	Basin Area km^2	Discharge $km^3\ yr^{-1}$	DOP Conc $mg\ l^{-1}$	Basin Area km^2	Discharge $km^3\ yr^{-1}$	DOP Yields $kg\ km^{-2}\ yr^{-1}$	DOP Loads $Mg\ yr^{-1}$
Amazon	6112000	6590	0.015	5846870	6444.1	16.6	96798.0
Lena	2490000	533	0.022	2438900	480.5	3.1	7679.5
Orinoco	1100000	1135	0.01	1038130	1115.1	16.5	17170.4
Danube	817000	203	0.035	787069	200.2	4.7	3672.0
Kolyma	660000	128	0.015	664851	104.1	2.6	1711.7
Khatanga	364000	101	0.006	369915	34.4	1.3	487.0
Indigirka	362000	53.6	0.009	333729	50.4	2.5	830.3
Yana	230800	30.6	0.01	224724	32.5	2.4	532.3
Olenek	219000	13.9	0.006	222924	32.5	2.4	535.2

Table S8. Reported basin area, river discharge, and total P (TP) for 5 rivers (Meybeck and Ragu, 2012; Mayorga et al., 2010).

	Meybeck and Ragu (2012)			Global NEWS 2; Mayorga et al. (2010)			
River	Basin Area km^2	Discharge $km^3\ yr^{-1}$	TP Conc $mg\ l^{-1}$	Basin Area km^2	Discharge $km^3\ yr^{-1}$	TP Yields $kg\ km^{-2}\ yr^{-1}$	TP Loads $Mg\ yr^{-1}$
Amazon	6112000	6590	0.24	5846870	6444	180	1052369
Parana	2783000	568	1.1	2660890	559	21	55942
Nelson	1132000	83.3	0.19	1138420	87	3	3897
Orinoco	1100000	1135	0.06	1038130	1115	77	80187
Elbe	146000	23.7	0.65	148353	27	50	7468

Table S9. Reported basin area, river discharge, and dissolved inorganic N (DIN) for 37 rivers (Meybeck and Ragu, 2012; Mayorga et al., 2010).

	Meybeck and Ragu (2012)			Global NEWS 2; Mayorga et al. (2010)			
River	Basin Area km^2	Discharge $km^3\ yr^{-1}$	DIN Conc $mg\ l^{-1}$	Basin Area km^2	Discharge $km^3\ yr^{-1}$	DIN Yields $kg\ km^{-2}\ yr^{-1}$	DIN Loads $Mg\ yr^{-1}$
Amazon	6112000	6590	0.16	5846870	6444	161	938617
Zaire	3698000	1200	0.097	3694430	1278	56	208185
Ob	2990000	404	0.66	3022320	393	40	119941
Mississippi	2980000	580	1.44	3199170	620	213	680176
Parana	2783000	568	0.215	2660890	559	119	317108
Yenisey	2590000	620	0.3	2575660	596	28	71285
Lena	2490000	533	0.11	2438900	481	21	52053
Amur	1855000	344	0.45	1752600	338	101	176420
Chang Jiang	1808000	928	0.638	1792120	905	1067	1912999
Zambezi	1330000	106	0.17	1361960	309	141	191808
Orinoco	1100000	1135	0.115	1038130	1115	277	287166
Murray	1060000	23.6	0.146	1030290	7	2	2148
Saint Lawrence	1020000	341	0.24	1052470	355	249	262331
Indus	916000	90	2.2	1141750	52	73	83605
Rio Grande	870000	18	0.18	803837	3	0	17
Yukon	849000	201	0.13	854690	90	11	9227
Huang He	752000	41	2.21	892570	31	29	26219
Columbia	669000	236	0.21	731105	240	106	77857
Kolyma	660000	128	0.09	664851	104	22	14822
Zhujiang	437000	363	0.63	408043	260	1347	549488
Khatanga	364000	101	0.07	369915	34	11	4187
Indigirka	362000	53.6	0.028	333729	50	25	8348
N. Dvina	348000	105	0.14	360513	108	205	73897
Pechora	324000	129	0.22	313916	142	94	29664
Churchill	298000	40	0.11	303135	40	10	3043
Neva	282000	78.5	0.26	284166	79	169	47898
Uruguay	240000	145	0.276				
Yana	230800	30.6	0.18	224724	32	21	4690
Rhine	224000	69.4	4.8	164864	73	913	150533
Liao	219000	16.2	0.28	273728	6	40	10830
Olenek	219000	13.9	0.08	222924	32	11	2518
Wisla	198000	34.1	2.265	180368	33	281	50685
Rufiji	178000	35.2	1.395	186538	29	52	9627
Elbe	146000	23.7	4.9	148353	27	385	57153
Balsas	112000	14	0.585	122842	28	175	21504
Odra	112000	18.3	2.63	119703	19	244	29176
Chao Phrya	111400	27.8	0.24	141662	17	71	10102

Table S10. Model sensitivities to the fractions of dividing TN and TP inputs into different N and P species (Table 3), examined based on the percentage (%) difference in global river loads between the sensitivity and baseline simulations for the year 1990.

	SS	TN	DIN	DON	PON	TP	DIP	PIP	DOP	POP
Agricultural surface runoff (surficial runoff)	0	1	0	0	3	0	-4	-8	9	8
Agricultural surface runoff (soil loss)	0	-1	0	0	-7	0	7	11	-13	-10
Agricultural surface runoff (40% surficial runoff, 60% soil loss)	0	0	0	0	-2	0	1	3	-3	-3
Agricultural surface runoff (60% surficial runoff, 40% soil loss)	0	0	0	0	0	0	-1	-1	1	1
Agricultural surface runoff (20% surficial runoff, 80% soil loss)	0	-1	0	0	-4	0	4	6	-8	-6
Agricultural surface runoff (80% surficial runoff, 20% soil loss)	0	0	0	0	2	0	-3	-5	5	5
Wastewater (untreated)	0	0	-3	1	7	0	-9	-1	6	6
Wastewater (secondary/tertiary treated)	0	0	-1	0	0	0	0	0	0	0
Wastewater (80% untreated, 10% primary treated, 10% secondary/tertiary treated)	0	0	-3	1	5	0	-7	-1	4	5
Wastewater (40% untreated, 40% primary treated, 20% secondary/tertiary treated)	0	0	-1	0	3	0	-3	-1	2	2

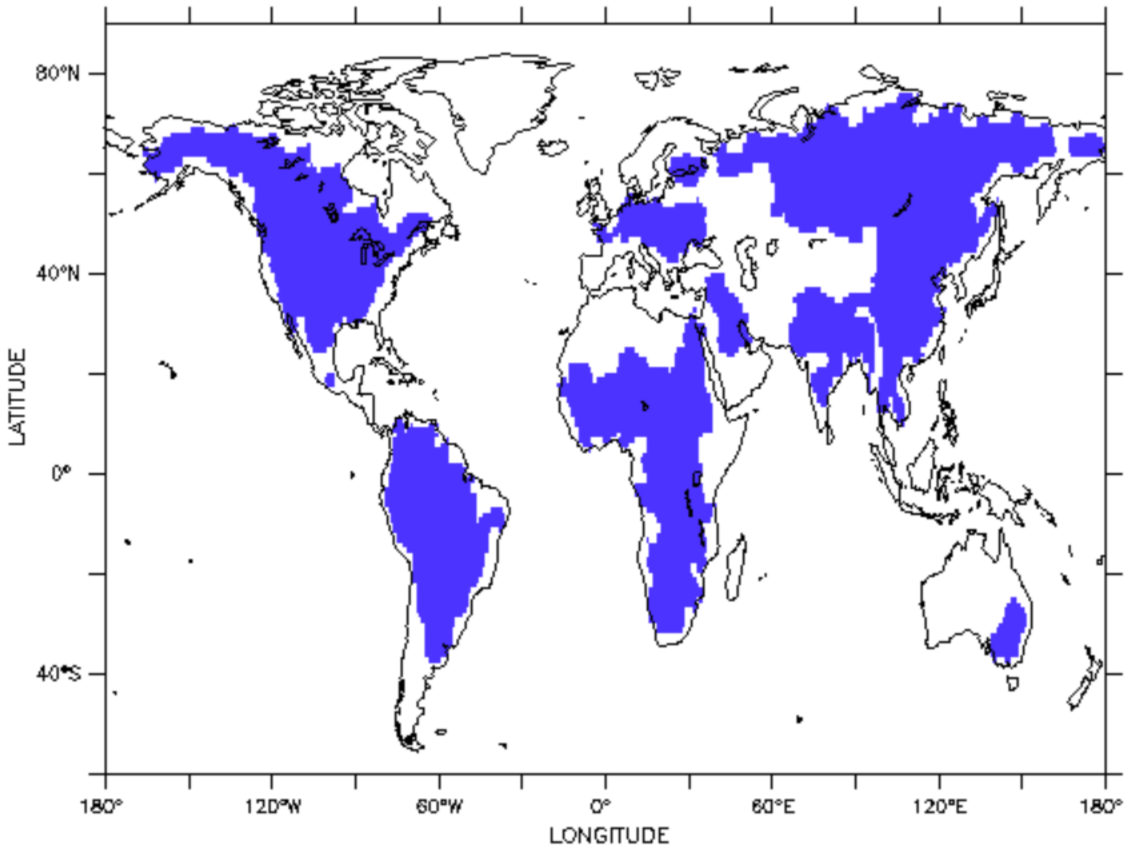

Figure S1. The 70 rivers considered for analyses are distributed broadly covering various climate and land use. The basin area of the 70 rivers covers 55% of global land area (excluding the Antarctic).

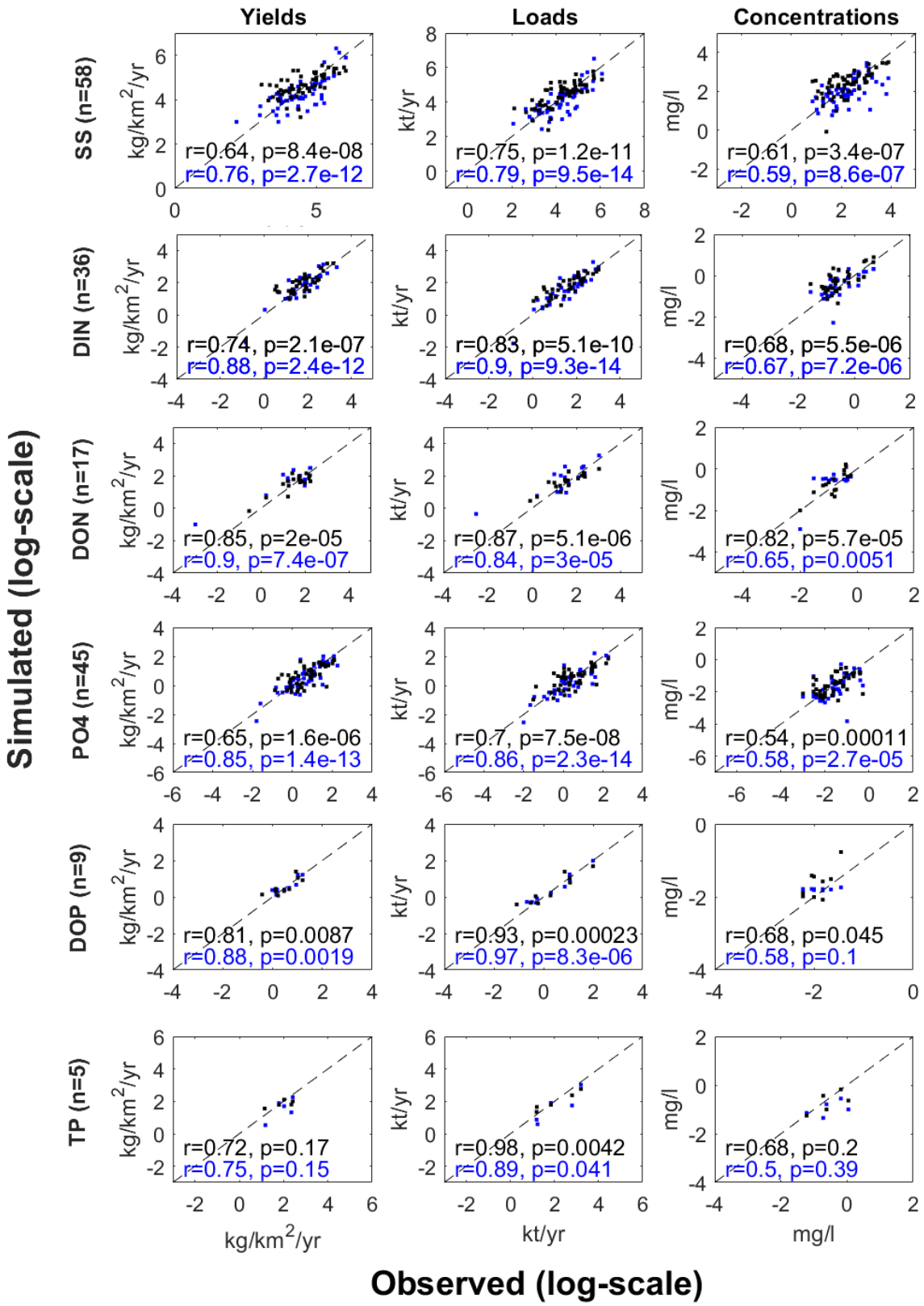

Figure S2. Pearson correlation coefficients (r) and p values (p) between log-transformed measurement-based vs. simulated SS, DIN, DON, PO_4^{3-}, DOP, and TP yields, loads, and concentrations for the year 1990. The color represents LM3-FANSY (black) and Global NEWS 2 (blue).

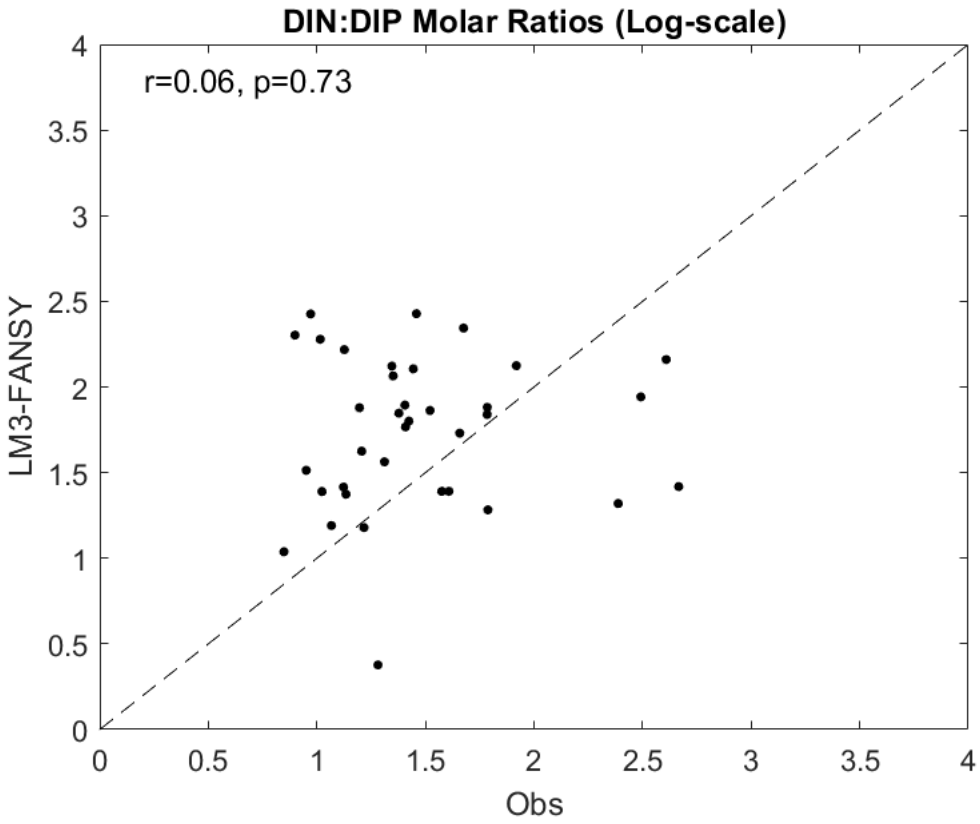

Figure S3. Pearson correlation coefficient (r) and p value (p) between the log-transformed measurement-based vs. simulated DIN:DIP molar ratios across 36 rivers for the year 1990.

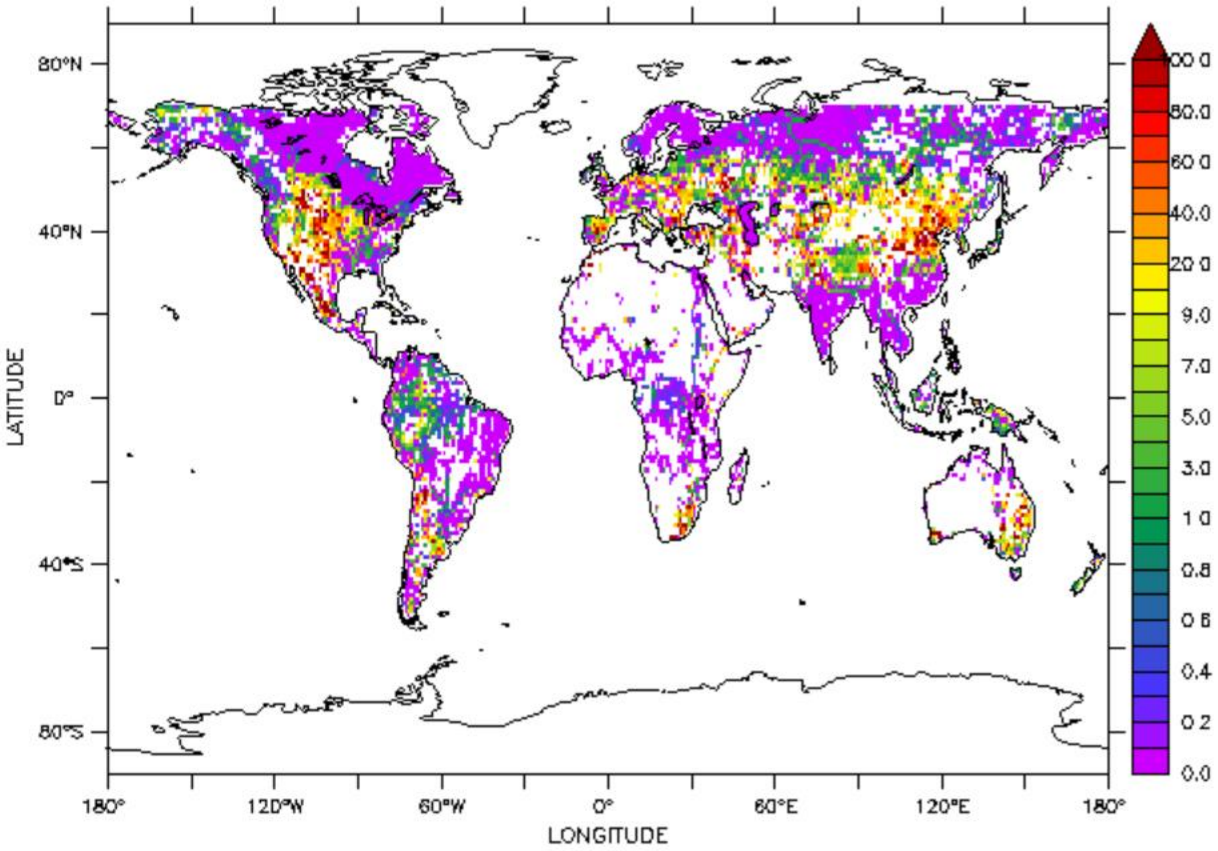

Figure S4. Chlorophyll-a concentrations (mg m^{-3}) in lakes for the year 1990.

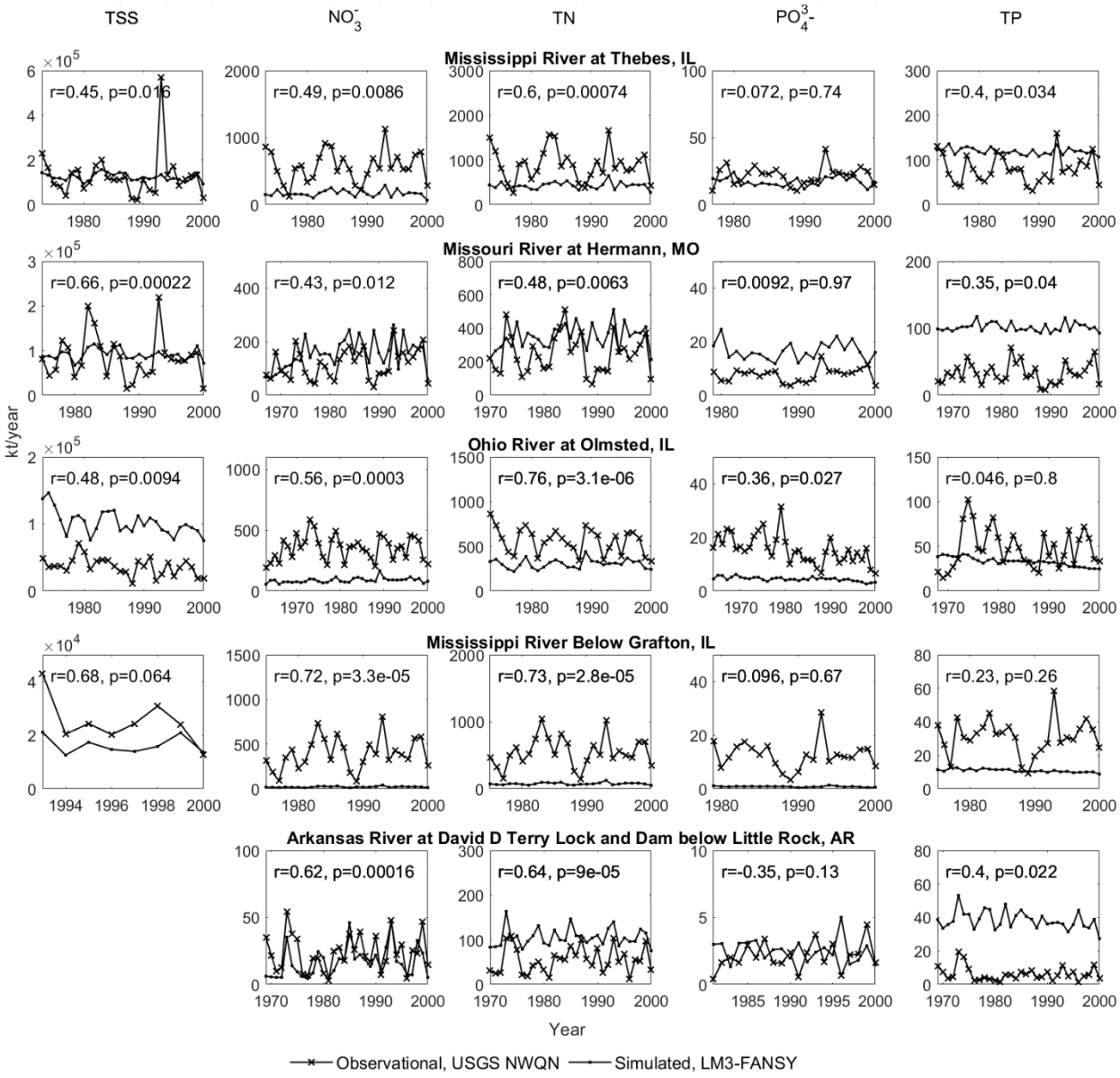

Figure S5: Pearson correlation coefficients (r) and p values (p) between the measurement-based vs. simulated annual loads across 5 stations in the Mississippi River Basin for the periods ~1963-2000.

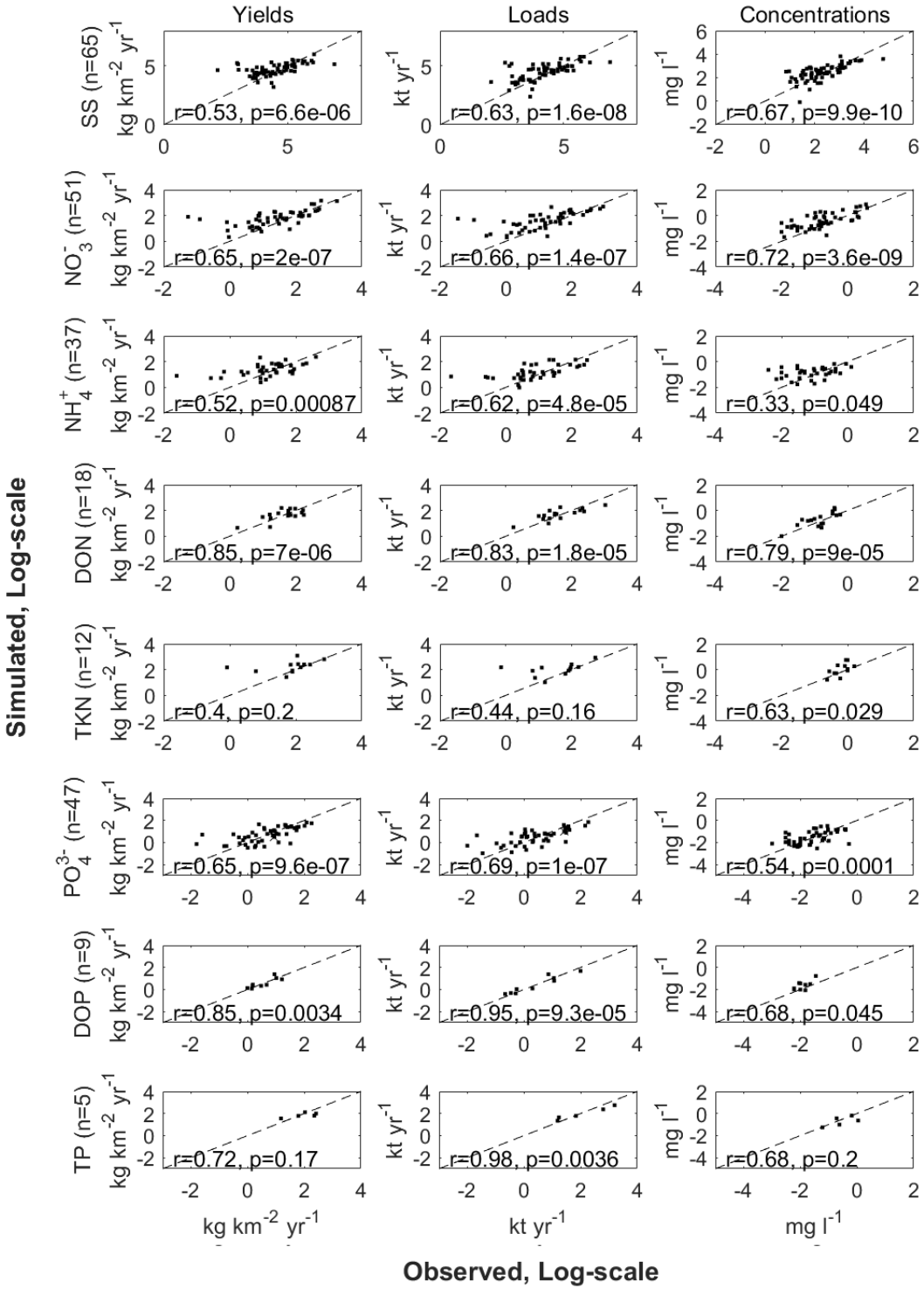

Figure S6: Pearson correlation coefficients (r) and p values (p) between the log-transformed measurement-based vs. simulated SS, N, and P yields, loads, and concentrations in different forms across the world major rivers for the year 1990. Here the actual water discharges of GEMS-GLORI were used when calculating loads and yields from the GEMS-GLORI's concentrations.

References

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Meybeck, M. and Ragu, A.: GEMS-GLORI world river discharge database, https://doi.org/10.1594/PANGAEA.804574, 2012.