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GLOBAL RUNOFF DATASET PRODUCED BY GSWP2

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1. INTRODUCTION

The second Global Soil Wetness Project (GSWP-2) is an ongoing scientific activity which is charged with producing global estimates of soil moisture, surface fluxes etc by integrating uncoupled land surface models (LSMs) using surface forcings and standardized soil and vegetation distributions (Dirmeyer et al. 2002). Global runoff is one of the datasets GSWP2 is producing. From global runoff dataset, we can obtain global streamflow using a global river routing model. By comparing calculated and observed streamflow, we can validate GSWP2; both the performance of LSMs outputs and their forcing data (Oki et al., 1999). A global river discharge dataset is requested by various study fields such as global water resources assessment (Oki et al. 2001), terrestrial material circulation (Suga et al. 2004) and climate and ocean study, since rivers pour fresh water to the ocean and have a potential impact to ocean circulation (Oka and Hasumi, 2004).

The runoff dataset produced by the first Global Soil Wetness Project (GSWP1) is evaluated by Oki et al 1999. They pointed out that it tends to underestimate streamflow, especially in northern mid to high latitude. They attributed this to gauge under-catch in strong wind condition. To overcome this problem is one of the motivations of GSWP2. An empirical technique to correct gauge under-catch is proposed (Motoya et al. 2004) and adopted in the process to produce GSWP2 precipitation data. In this paper, we will evaluate the GSWP2 runoff dataset whether the problem is overcome.

2. METHODOLOGY

First, global runoff datasets are collected for both GSWP1 and GSWP2 B0 (baseline run) submitted by all participating institutes. For GSWP1, 11 institutes participated, and for GSWP2, 12 institutes have so far submitted their B0 run (on 31st Oct 2004). Since the simulation period of GSWP1 is two years from 1987 to 1988, we use the same period for GSWP2 runs in order to make all simulation period the same length. Next, inter-model mean for each project is produced (GSWP1-mean and GSWP2-mean respectively). These products can be biased by some extreme values among models. Therefore we produced a different inter-model mean; we remove the maximum and minimum data for each grid box and calculated the average of remaining data (GSWP1-cut and GSWP2-cut respectively). These four global runoff datasets are routed with a global river routing model, namely TRIP (Oki and Sud, 1998). Each calculated streamflow dataset is aggregated to monthly value and evaluated at 269 river gauging stations all over the world with two statistical value; bias and root mean square error (RMSE):

$$Bias = \frac{100}{\bar{O}} \times \frac{\sum_{i=1}^{n}(P_i - O_i)}{n} \qquad (1)$$

$$RMSE = \frac{100}{\bar{O}} \times \sqrt{\frac{\sum_{i=1}^{n}(P_i - O_i)^2}{n}} \qquad (2)$$

where $\bar{O}$ is observation mean for the whole period. P_i is simulated and O_i is observed discharge for the i th record. n is the total number of records (in this time 24). We refer to two earlier studies on global streamflow; WMO, 1997 and Vörösmarty et al 2000.

We also collected precipitation dataset that is forced to LSMs in GSWP1 and GSWP2 since Oki et al. 1999 attributes the underestimation of runoff to the underestimation of precipitation. We refer to a global precipitation dataset "CPC Merged Analysis of Precipitation (CMAP)" for the simulation period (Xie and Arkin, 1997). The characteristics of precipitation datasets (magnitude and spatial distribution) are shown with the difference between CMAP and them.

3. RESULTS

3.1 Precipitation data

Table1 shows the precipitation of GSWP1 and GSWP2 B0 for 1987. Figure1 shows the global distribution of difference between CMAP and GSWP1 annual precipitation. Figure 2 is that for GSWP2.

GSWP1 precipitation agrees well with CMAP globally, during a year. We can see some inconsistencies in Greenland and Northern Africa, but they are not significant.

GSWP2 B0 precipitation is much larger than CMAP in northern mid and high latitude, particularly in Northern Europe and some part in western and northern Siberia. This pattern consists during a year, slightly weakened in the boreal summer. In northern low latitude and southern hemisphere, GSWP2 B0 precipitation agrees well with CMAP. Table1 shows that GSWP2 B0precipitation is larger than CMAP in all continents.

3.2 River discharge

Table2 shows the runoff (before routing) of GSWP1 and GSWP2 B0.

First, we review the simulated global streamflow of GSWP1. Table2 shows that GSWP1 runoff is smaller than average of WMO, 1997 and Vörörsmarty et al. 2000 in all continents. The runoff in Asia and North America is smaller by more than 30%. Figure3a shows the bias of GSWP1 streamflow. It clearly shows the streamflow in northern mid to high latitude is

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underestimated. Exceptionally, the streamflow in central and some part of east Europe is well reproduced. Figure 3b shows the RMSE of GSWP1 streamflow. The dominant range is 40% to 100% in North America, Europe, and Asia, exceeds 100% in central Africa, Australia and some parts of East Siberia.

In GSWP2 B0, the situation changed drastically. Figure4 shows GSWP2 B0 streamflow overestimate at almost all river gauging stations in the northern mid to high latitude. The distribution of overestimated area is identical to where GSWP2 B0 exceeds CMAP precipitation. The RMSE of GSWP1 streamflow increased at almost all river gauging stations. The significant overestimation of streamflow indicates the over-correction of gauge under-catch.

3.3 Comparison of two model-mean products

The difference of two methods to calculate inter model mean is examined. GSWP1-cut runoff is around 5% smaller than GSWP1-mean (SeeTable2). Since GSWP1 tends to underestimate runoff, the performance of GSWP1-cut is worse than GSWP1-mean. GSWP2-cut runoff is around 10% smaller than GSWP2-mean. In contrary, GSWP2 B0 tends to overestimate runoff, the performance of GSWP2-cut is better than GSWP2-mean. Both GSWP1 and GSWP2 B0 has strong overestimation or underestimation in runoff, we cannot conclude which method is better than another.

4. SENSITIVITY STUDIES

The previous section indicated that GSWP2 B0 precipitation is too large and causes the overestimation in runoff in northern mid to high latitude. If we replace the precipitation dataset to better one, can we obtain a better global runoff dataset? In this section we examine the precipitation and runoff datasets of GSWP2 sensitivity studies.

4.1 Precipitation in sensitivity studies

Among various sensitivity studies prepared by GSWP2, we focus on that for precipitation (i.e. suites P1 to PE. See Dirmeyer et al. 2002 for detail) The precipitation in each continents is listed in Table1.

P1 precipitation is a pure ERA-40 reanalysis. Table 1 shows the annual precipitation is larger than CMAP in all continents except Europe. The distribution of precipitation is quite different from that of CMAP. P1 precipitation is larger than CMAP along Rocky, Andes, Himalaya Mountain, eastern part of South America, central Africa and some part of Southeast Asia. P1 Precipitation is smaller in Southern Europe, North Africa, South Asia, and East Asia.

The procedure to produce P2 precipitation is almost same as that of B0, only satellite data was not used in data merging process. The spatial pattern of the difference between P2 and CMAP is almost identical to that of B0, however, the magnitude is increased.

P3 precipitation is a hybrid product of NCEP/DOE and GPCC data, and gauge under-catch correction is not carried out. It agrees well with CMAP and GSWP1 precipitation.

P4 precipitation is pure NCEP/DOE reanalysis. It is larger than CMAP in almost all regions in the world. The only exception is seen in the western part of the Sahara desert.

Finally, PE precipitation is a hybrid product same as B0, only ERA-40 precipitation is used instead of NCEP/DOE. It increases precipitation in northern mid to high latitude same as B0, but the magnitude is smaller. PE precipitation takes an intermediate position between B0 and GSWP1 precipitation.

4.2 Sensitivity of runoff to precipitation

If we replace precipitation dataset, how much does the global runoff and streamflow change? So far, P1, P2, P3 sensitivity runs simulated by four LSMs (NOAH, NSIPP-CATCH, SSiBCOLA and SWAP) have been submitted to GSWP2 InterComparison Center (ICC). Primary sensitivity study is conducted with these runoff datasets.

First we obtained the difference of runoff and precipitation between B0 simulation and each sensitivity run (P1, P2, P3), model (NOAH, NSIPP-CATCH, SSiBCOLA and SWAP) and continent (Asia, Europe, Africa, North America, South America and Oceania). Figure7 shows the scatter gram of difference of precipitation and runoff. It clearly shows the linear relation:

$$R = 0.84P + 0.24 \quad (3)$$

where R is the difference of runoff [mm/year] and P is the difference of precipitation [mm/year]. The coefficient of determination (R^2) is 0.92. Assuming that this relation is applicable to GSW2-mean, GSWP2 PE runoff can be “predicted” even only one institute submitted the result so far. The result is shown in the last line of Table2. Still larger than earlier studies, the runoff in Europe is predicted to be largely reduced. It is predicted to be most close to earlier studies. Of course, the increase or decrease of precipitation changes surface energy and water balance; the further detailed analysis on the sensitivity runs is indispensable.

5. SUMMARY

GSWP2 B0 runoff dataset produced by 12 GSWP2 participating LSMs is larger than earlier studies in almost all continents, especially in the northern mid to high latitude. This is a completely opposite result of GSWP1. It may be attributed to the GSWP2 B0 precipitation dataset that over-correct gauge under-catch. The comparison of precipitation data sets GSWP2 prepared for sensitivity studies, PE precipitation is expected to produce the best global runoff dataset. As 31st Oct 2004, only one institute have submitted the PE run. We strongly encourage all GSWP2 participants to conduct PE run.

Acknowledgement

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References

Dirmeyer, P., Gao, X. and Oki, T., 2002: The Second Global Soil Wetness Project GSWP-2. *IGPO Publication*, **37**

Motoya, K. K. Takata, K. Masuda and T. Oki, 2002: Sensitivity of precipitation gauge correction for the estimation of the global water balance. *J of Hydrometor.*, (submitted)

Oka, A. and H. Hasumi, 2004: Effects of Freshwater Forcing on the Atlantic Deep Circulation: A study with an OGCM Forced by Two Different Surface Freshwater Flux Datasets. *J of Clim*, **17**, 2180-2194

Oki, T., Nishimura, T. and P. Dirmeyer, 1999: Assessment of annual runoff from land surface models using total runoff integrating pathways (TRIP), *J. of Met. Soc. Japan*, **77-1B**, 235–255.

Oki, T. and Sud, Y. C., 1998: Design of total runoff integrating pathways (TRIP) - A global river channel network, *Earth Interactions*, **2**, http://EarthInteractions.org.

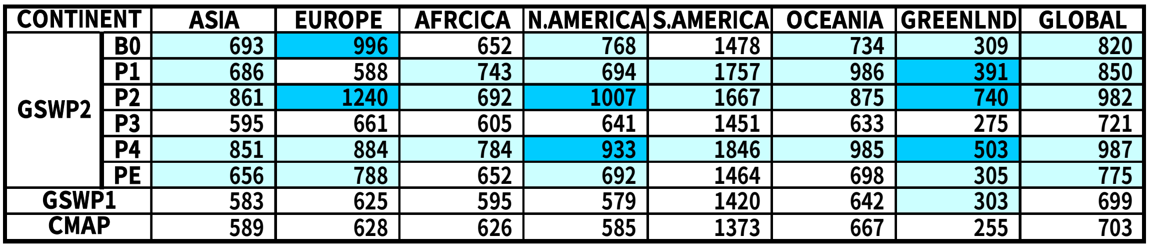
Oki, T., Y. Agata, S. Kanae, T. Saruhashi, D. Yang, and K. Musiake, 2001: Global Assessment of Current Water Resources using Total Runoff Integrating Pathways, *Hydrol. Sci. J.*, **46**, 983-996.

Suga, Y., T. Oki and S. Kanae, 2004: Nitrate-Nitrogen Concentration in Large Rivers of the World, *Hydrol. Proc.* (submitted)

Vörösmarty, C. J., Green, P., Salisbury, J. and Lammers, R. B.,2000: Global water resources: Vulnerability from climate change and population growth, *Science*, **289**, 284–288.

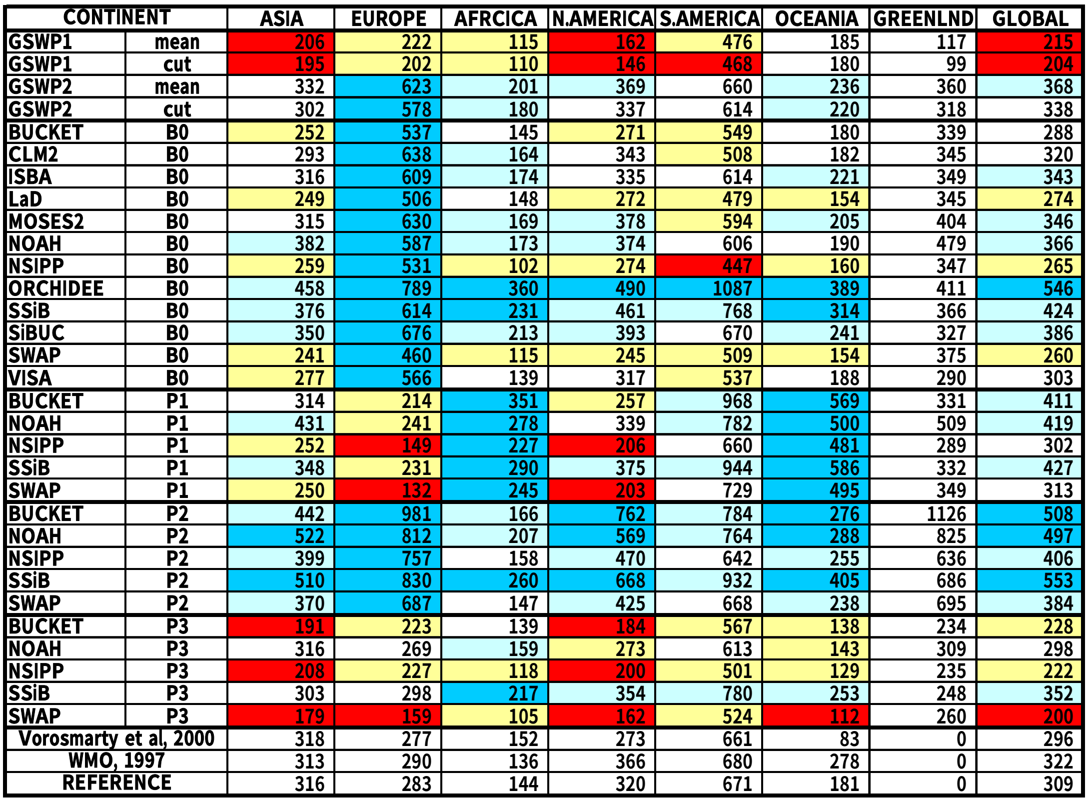
WMO, 1997: Comprehensive assessment of the freshwater resources of the world, *World Meteorological Organization*, Geneva, Switzerland.

Xie, P. and P. A. Arkin: Global Precipitation: A 17-Year Monthly Analysis Based on Gauge Observations, Satellite Estimates and Numerical Model Outputs. *BAMS*, **78**, 2539-2558



CONTINENT		ASIA	EUROPE	AFRCICA	N.AMERICA	S.AMERICA	OCEANIA	GREENLND	GLOBAL
GSWP2	B0	693	996	652	768	1478	734	309	820
	P1	686	588	743	694	1757	986	391	850
	P2	861	1240	692	1007	1667	875	740	982
	P3	595	661	605	641	1451	633	275	721
	P4	851	884	784	933	1846	985	503	987
	PE	656	788	652	692	1464	698	305	775
GSWP1		583	625	595	579	1420	642	303	699
CMAP		589	628	626	585	1373	667	255	703

Table1. The precipitation for each simulation run. Unit: mm/year, area weighted average.
Light blue cell: larger than CMAP more than 10%, thick blue cell: larger than CMAP more than 50%
B0 is used for GSWP2 baseline run, P1, P2, P3, P4, PE for sensitivity runs.



CONTINENT		ASIA	EUROPE	AFRCICA	N.AMERICA	S.AMERICA	OCEANIA	GREENLND	GLOBAL
GSWP1	mean	206	222	115	162	476	185	117	215
GSWP1	cut	195	202	110	146	468	180	99	204
GSWP2	mean	332	623	201	369	660	236	360	368
GSWP2	cut	302	578	180	337	614	220	318	338
BUCKET	B0	252	537	145	271	549	180	339	288
CLM2	B0	293	638	164	343	508	182	345	320
ISBA	B0	316	609	174	335	614	221	349	343
LaD	B0	249	506	148	272	479	154	345	274
MOSES2	B0	315	630	169	378	594	205	404	346
NOAH	B0	382	587	173	374	606	190	479	366
NSIPP	B0	259	531	102	274	447	160	347	265
ORCHIDEE	B0	458	789	360	490	1087	389	411	546
SSiB	B0	376	614	231	461	768	314	366	424
SiBUC	B0	350	676	213	393	670	241	327	386
SWAP	B0	241	460	115	245	509	154	375	260
VISA	B0	277	566	139	317	537	188	290	303
BUCKET	P1	314	214	351	257	968	569	331	411
NOAH	P1	431	241	278	339	782	500	509	419
NSIPP	P1	252	149	227	206	660	481	289	302
SSiB	P1	348	231	290	375	944	586	332	427
SWAP	P1	250	132	245	203	729	495	349	313
BUCKET	P2	442	981	166	762	784	276	1126	508
NOAH	P2	522	812	207	569	764	288	825	497
NSIPP	P2	399	757	158	470	642	255	636	406
SSiB	P2	510	830	260	668	932	405	686	553
SWAP	P2	370	687	147	425	668	238	695	384
BUCKET	P3	191	223	139	184	567	138	234	228
NOAH	P3	316	269	159	273	613	143	309	298
NSIPP	P3	208	227	118	200	501	129	235	222
SSiB	P3	303	298	217	354	780	253	248	352
SWAP	P3	179	159	105	162	524	112	260	200
Vorosmarty et al, 2000		318	277	152	273	661	83	0	296
WMO, 1997		313	290	136	366	680	278	0	322
REFERENCE		316	283	144	320	671	181	0	309

Table2. Runoff data for each simulation runs. Unit: mm/year, area weighted average. REFERENCE shows average of Vörösmarty et al. 2000 and WMO, 1997. Light blue cell: larger than REFERENCE more than 10%, thick blue cell: larger than REFERENCE more than 50%. Light yellow cell: smaller than REFERENCE more than 10%, red cell: smaller than REFERENCE more than 30%

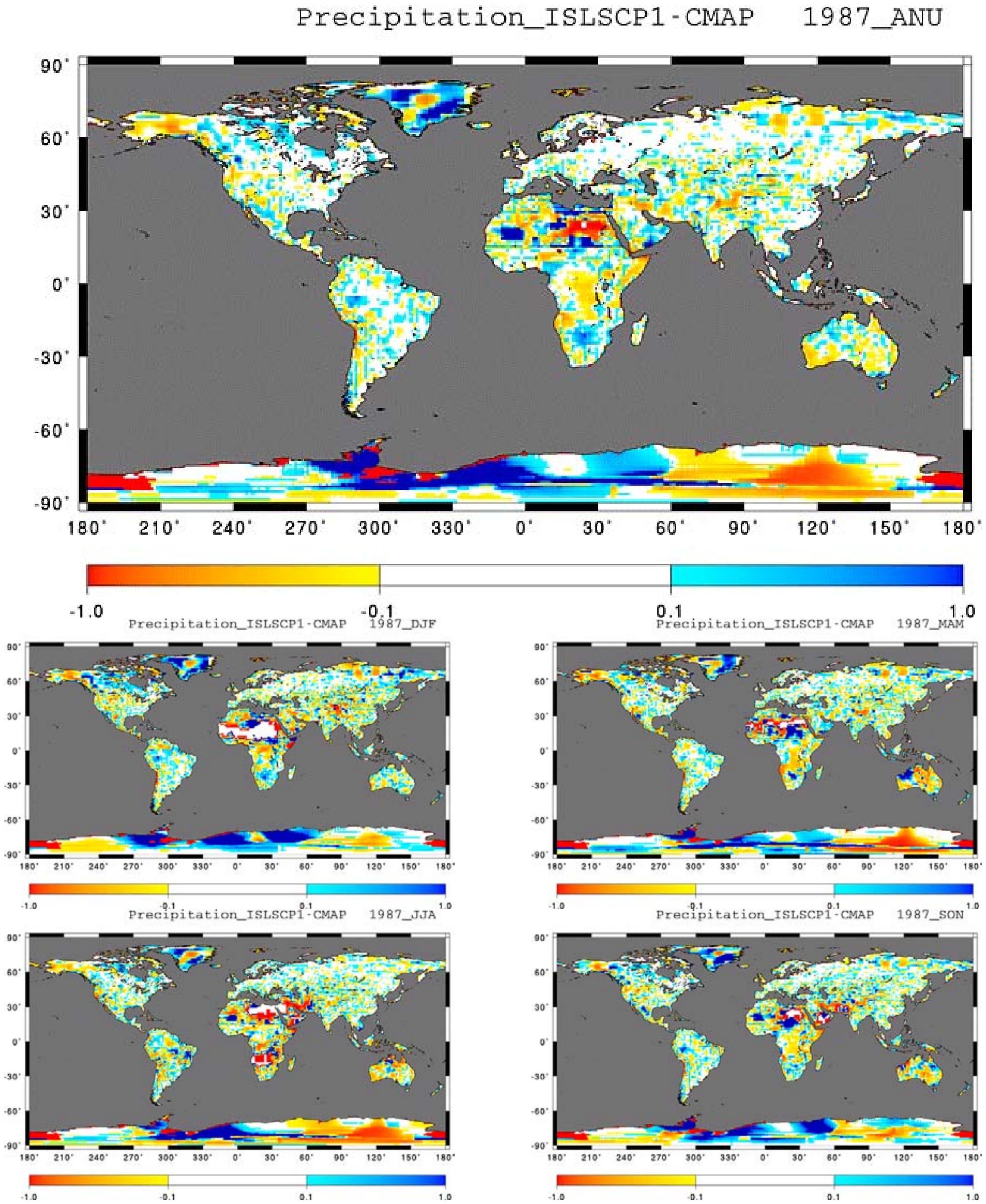


Figure1. The difference between GSWP1 and CMAP precipitation for 1987

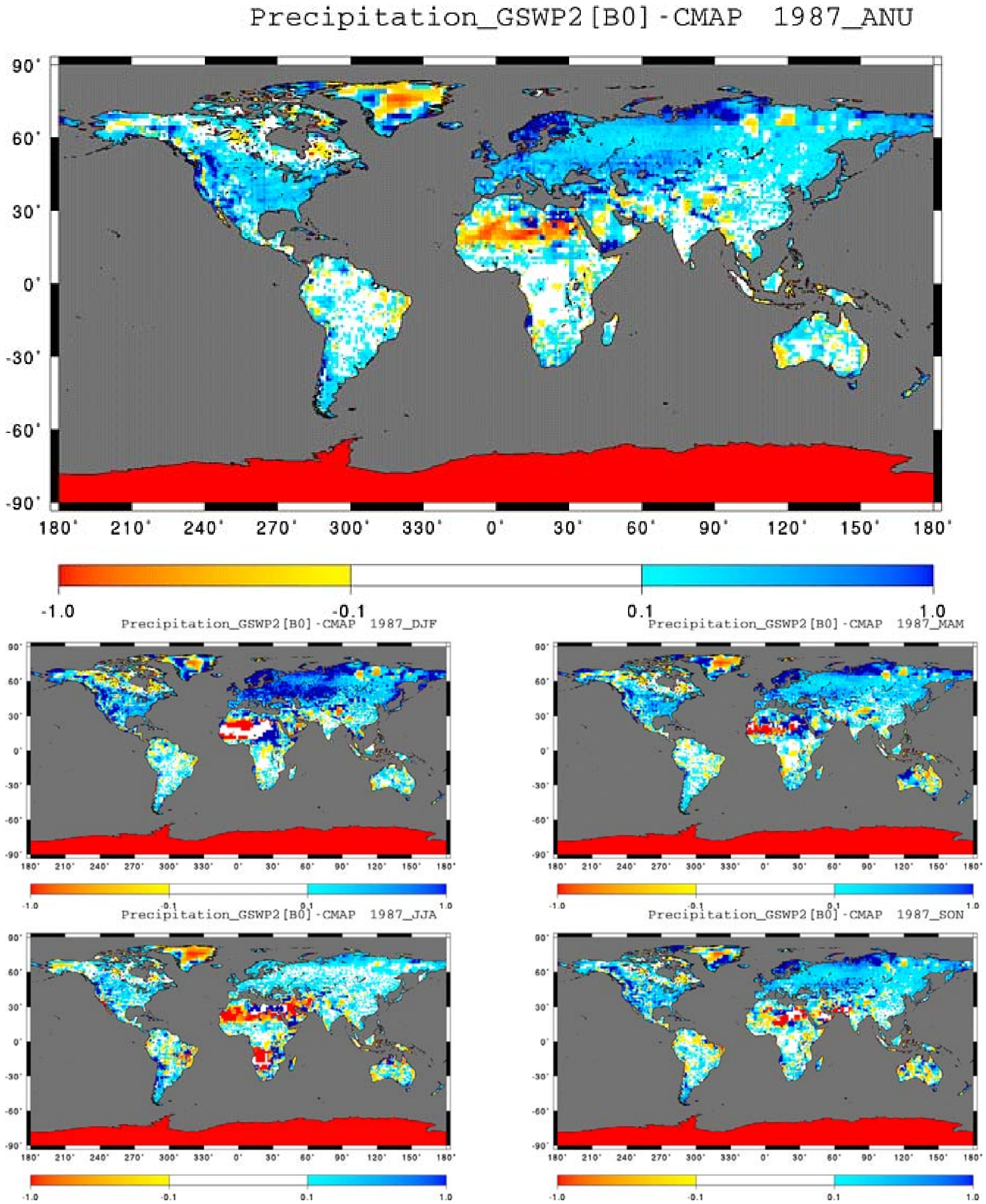


Figure2. The difference between GSWP2 B0 and CMAP precipitation for 1987

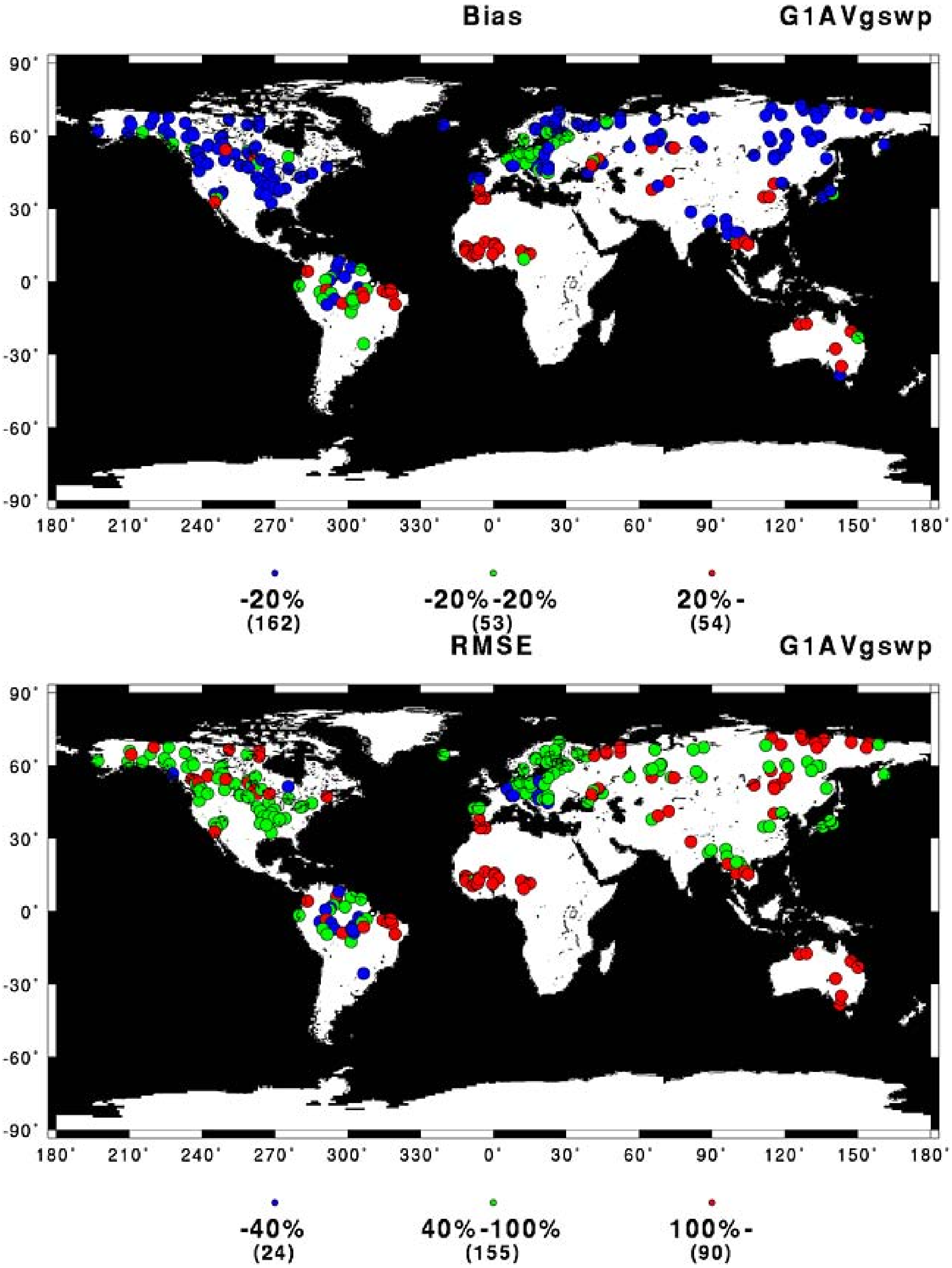


Figure3. Bias and RMSE of GSWP1-mean streamflow

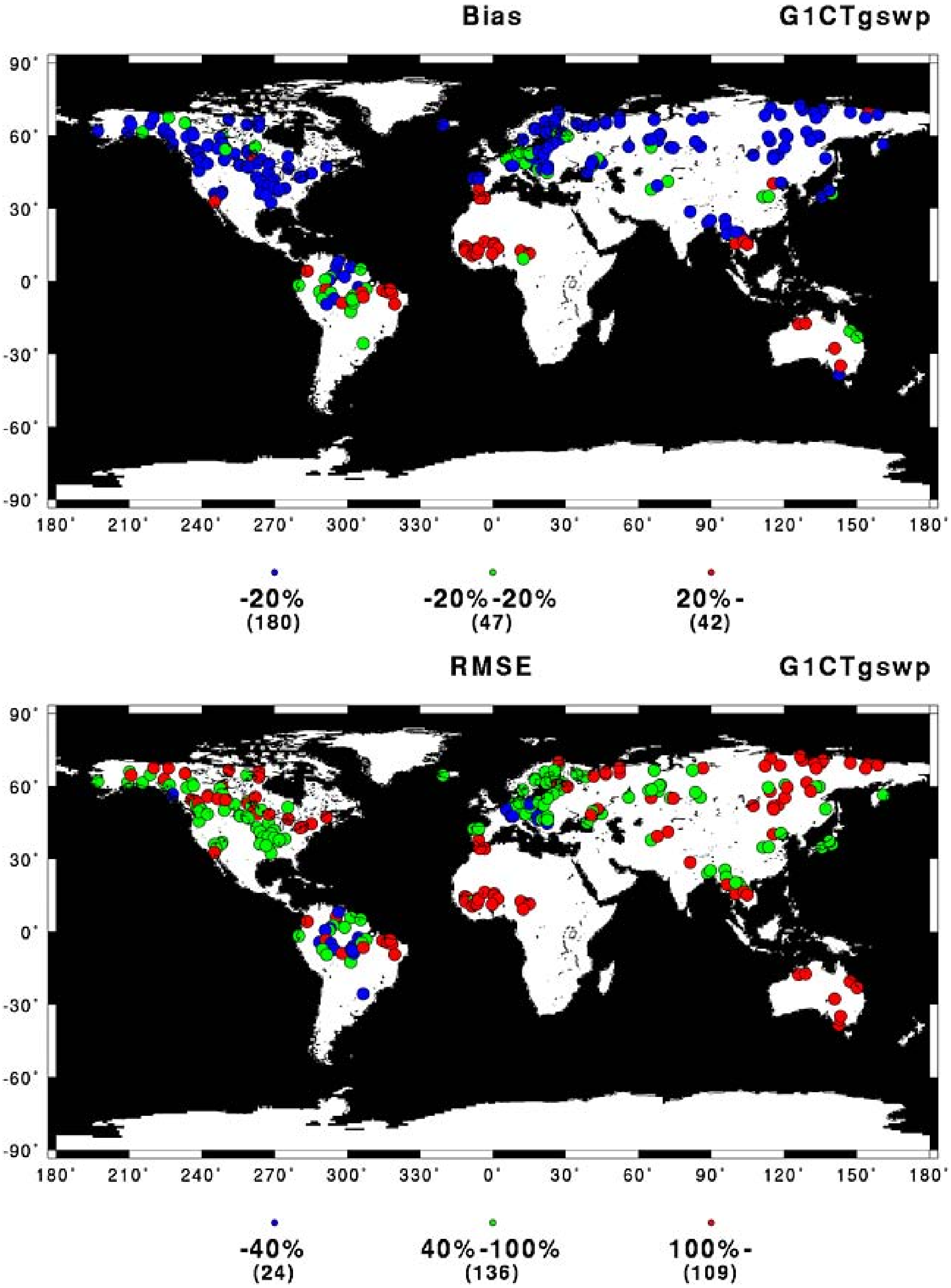


Figure4. Bias and RMSE of GSWP1-cut streamflow

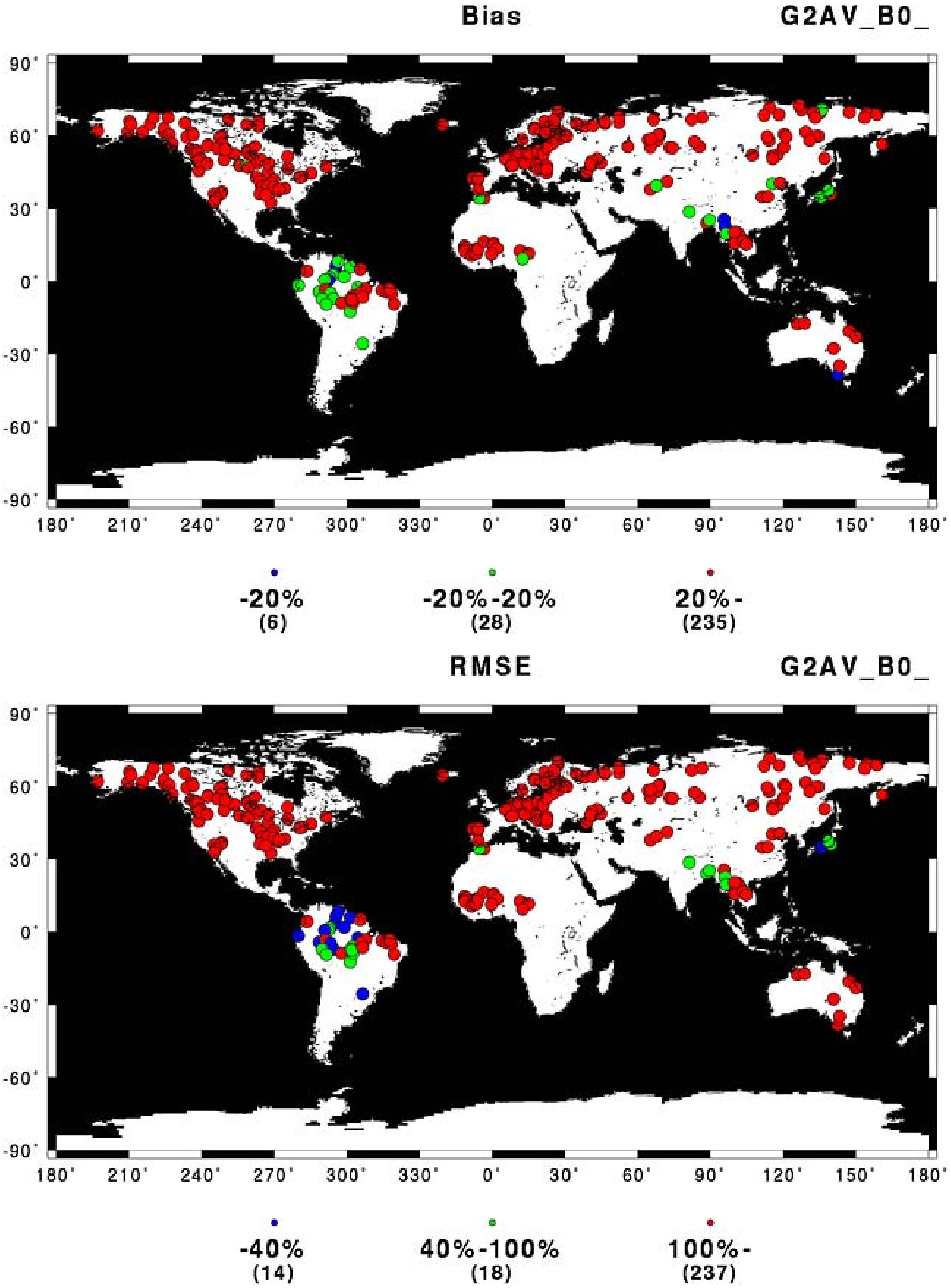


Figure5. Bias and RMSE of GSWP2-mean streamflow

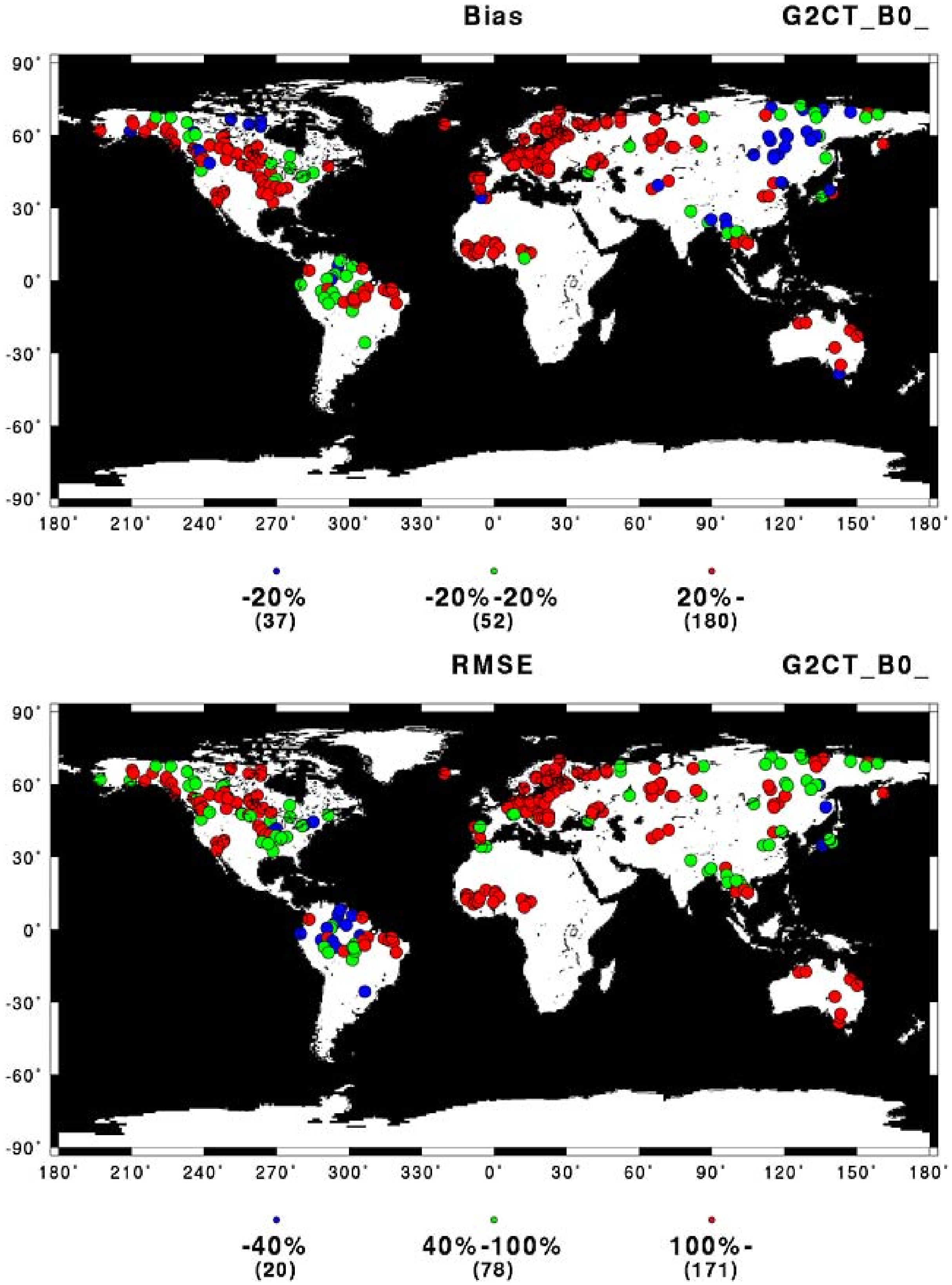


Figure6. Bias and RMSE of GSWP2-cut streamflow

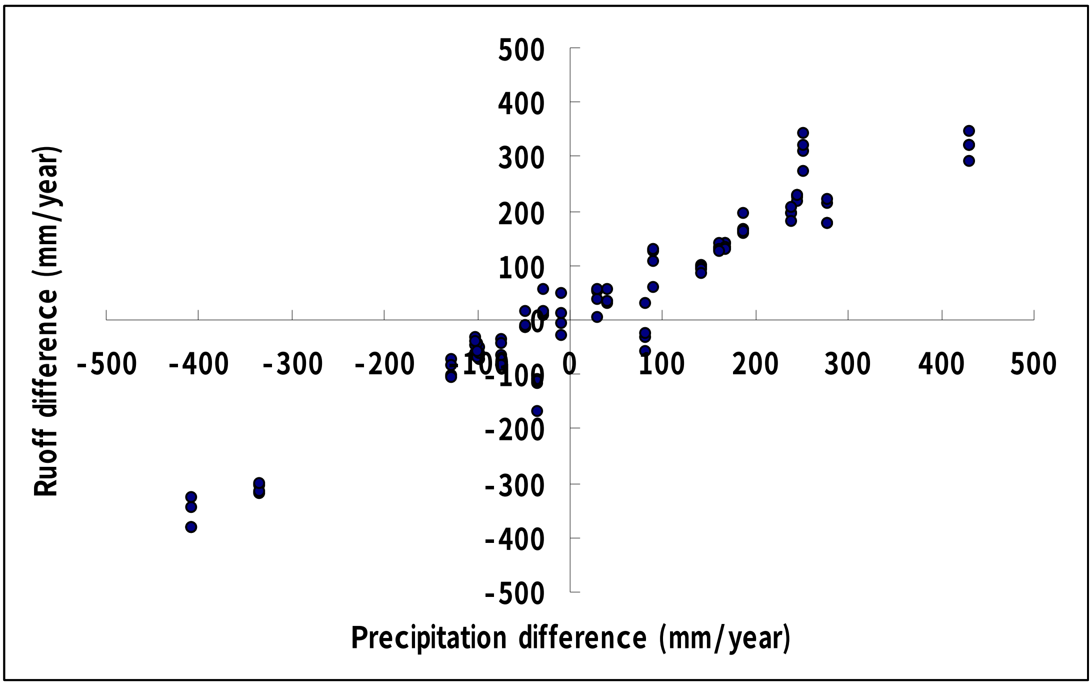


Figure 7. Precipitation difference and Runoff difference