An Improved Gridded Historical Daily Precipitation Analysis for Brazil

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ABSTRACT

A gauge-only precipitation data quality control and analysis system has been developed for monitoring precipitation at NOAA's Climate Prediction Center (CPC). Over the past 10 yr the system has been used to develop and deliver many different precipitation products over the United States, Mexico, and Central and South America. Here the authors describe how the system has been applied to develop improved gridded daily precipitation analyses over Brazil. Consistent with previous studies, comparisons between the the gridded analyses and station observations reveal fewer dry days, a greater number of low precipitation days, and fewer extreme precipitation events in the gridded analyses. Even though the gridded analysis system reduces the number of dry days and increases the number of wet days, there is still a good correlation between time series of the gridpoint precipitation values and observations.

Retrospective analyses are important for computing basic statistics such as mean daily/monthly rainfall, extremes, and probabilities of wet and dry days. The CPC gridded precipitation analyses can be used in hydrologic and climate variability studies dealing with large spatial-scale anomaly patterns, such as those related to ENSO. The analyses can also be used as a benchmark for evaluating model simulations, serve as a basis for real-time monitoring, and provide statistics on the occurrence of large-scale heavy rainfall events and dry periods.

1. Introduction

Historical and real-time precipitation analyses are needed to support a wide range of scientific research studies and applications, such as improved understanding of the water budget and improved assessments of the state of the climate, which ultimately will lead to improved management of water resources and better emergency planning for extreme events (e.g., droughts and floods). In 2001 a major energy crisis occurred in Brazil, associated with a prolonged (multiyear) period of drought that encompassed the South American monsoon system (SAMS) core region (Silva et al. 2005). As a result, the Brazilian government instituted an energy-rationing program to curb electricity usage in order to avoid extensive blackouts. There is an obvious need for energy resource managers to have a better understanding of intraseasonal-to-interannual variability and trends of precipitation, as an important component of a strategy to understand, simulate, and ultimately predict drought, in order to anticipate possible consequences and mitigate potential societal impacts.

To aid real-time monitoring efforts and studies of climate variability, the Climate Prediction Center (CPC) of the National Oceanic and Atmospheric Administration (NOAA) has undertaken a major effort to improve daily precipitation analyses over the Americas. The CPC routinely produces quality-controlled gauge-based gridded daily precipitation analyses for the United States (Higgins et al. 2000), as part of its effort to monitor conditions in real time, place those conditions in historical context, and provide improved analyses for forecast verification. In 1999 those analyses were expanded to include Mexico and South America.

Recently, station data have been acquired for areas in eastern Brazil that previously had sparse data coverage in the CPC analyses. With these additional data we were able to produce a new version of the historical gridded daily precipitation analyses for Brazil. The primary objective of this paper is to show how this new set of gridded daily analyses compares to station data. A

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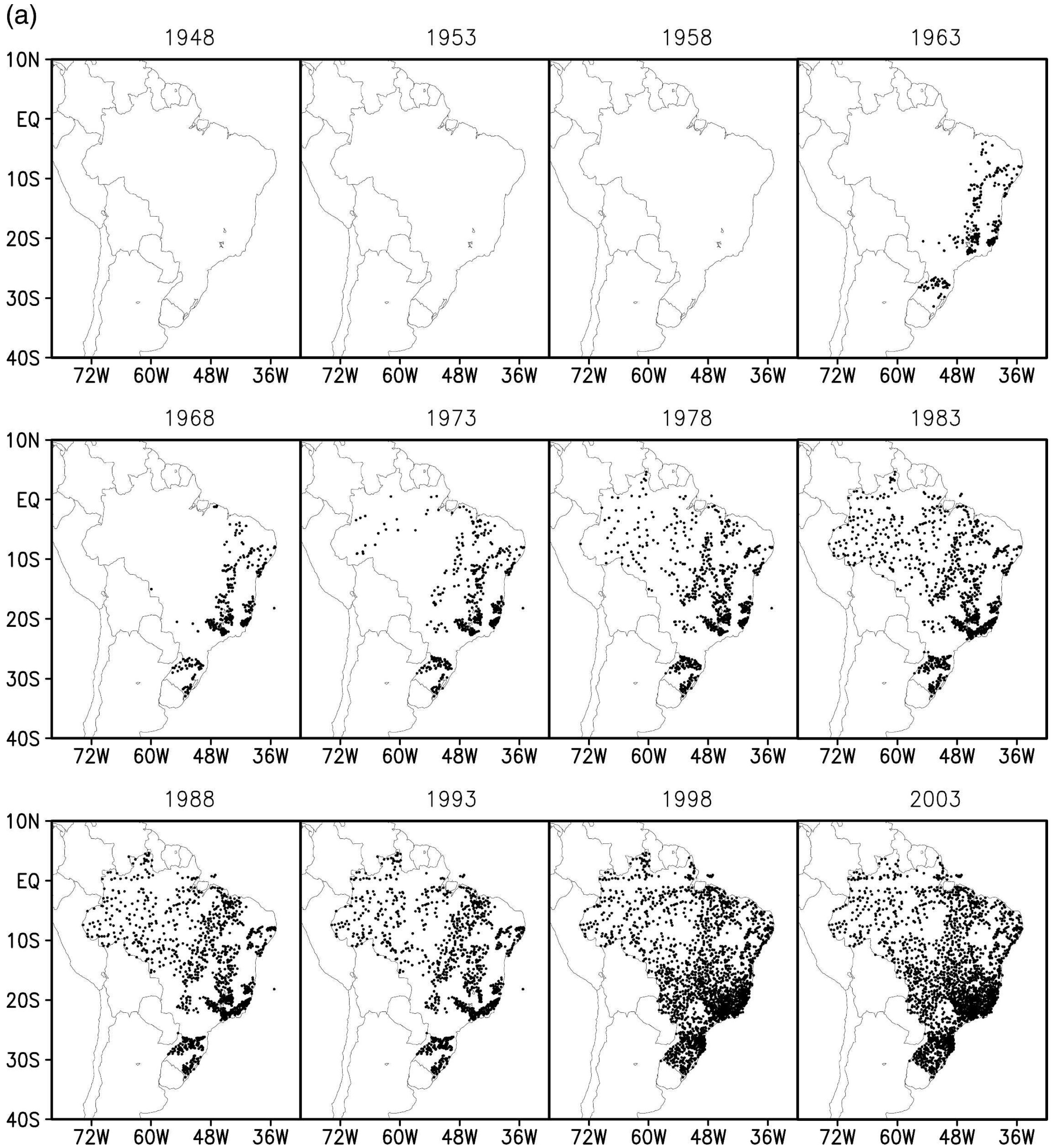

FIG. 1. Snapshot of the station distribution over Brazil for 1 January at 5-yr intervals: (a) version 2000 and (b) version 2005.

description of the analysis technique and diagnostic approach is presented in section 2. Comparisons between station observations and the gridded analyses are presented in section 3. In section 4 we show examples of how the historical gridded daily analysis can be used in studies of climate and climate variability. A brief summary and some concluding remarks are given in section 5.

2. Data and analysis technique

a. Analysis technique

A gauge-only precipitation data quality control and analysis system (Higgins et al. 2000) has been developed and applied to many of CPC's precipitation products. In this system, the daily gauge data are subjected to several types of quality control, including a

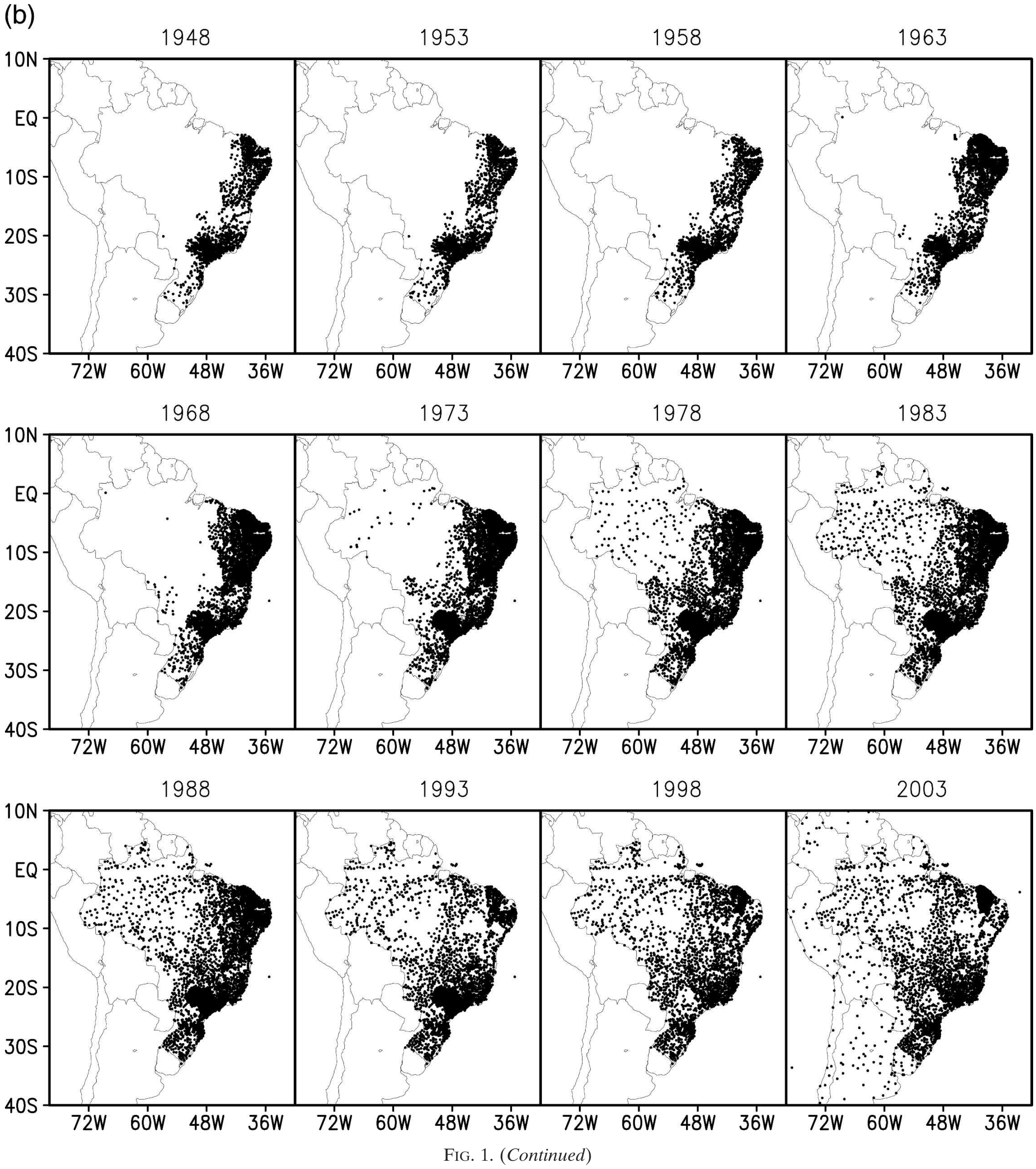

FIG. 1. (*Continued*)

duplicate station check, a buddy check (nearby stations), and a standard deviation check. The daily gauge data are gridded at a specified resolution (1° × 1° latitude–longitude for Brazil) over the domain of interest, using a modified Cressman (1959) scheme (Glahn et al. 1985; Charba et al. 1992). The day 1 analysis is valid for the window from 1200 UTC on day 0 to 1200 UTC on day 1.

The modified Cressman scheme is an interpolation method that corrects the background gridpoint value by a linear combination of residuals (corrections) between calculated and observed values. In the current analysis, the scheme begins with a background field of zero precipitation at all grid points. The background value at each grid point is then successively adjusted on the basis of nearby observations within the radius of influence

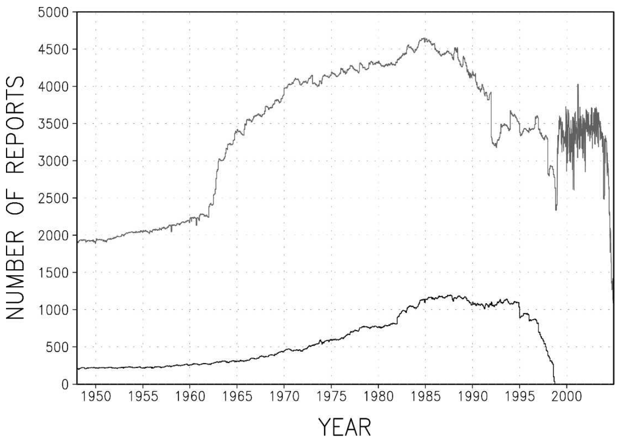

FIG. 2. Number of Brazil daily reports after quality control for version 2000 (dark gray line) and version 2005 (light gray line).

in a series of four scans through the data. The radius of influence is not fixed in the modified Cressman scheme, but rather changes with average station separation for each day, since the number of reporting stations shows daily variations. In this analysis, the initial value of the radius of influence is about 200 km on average. The radius of influence is then reduced on successive scans in order to increase precision. For each station, an error is defined as the difference between the station value and the value obtained by interpolation from the grid to that station location. A weighting factor W_j , which depends only on the radius of influence (R) and the distance between the grid point and station j (r_j), is then applied to all such errors within the radius of influence of the grid point to arrive at a correction value for that grid point:

$$W_j = \frac{R^2 - r_j^2}{R^2 + r_j^2}. \tag{1}$$

The analysis value at each grid point (G_{i+1}) is calculated as the value from the previous pass (G_i) added to the sum of the products of the calculated weights (W_j) and the difference between the actual station value (P_j) and the interpolated background value at the station (P_j^e), divided by the sum of the weights:

$$G_{i+1} = G_i + \frac{\sum_{j=1}^{N} W_j(P_j - P_j^e)}{\sum_{j=1}^{N} W_j}, \tag{2}$$

where i denotes the ith pass and j represents station j.

Other interpolation methods were tested and the results compared. The analyses produced by Cressman (1959), Barnes (1964), and Shepard (1968), and optimal interpolation (Gandin 1963) schemes, revealed only minor differences in the analyses over areas having sufficient gauge density.

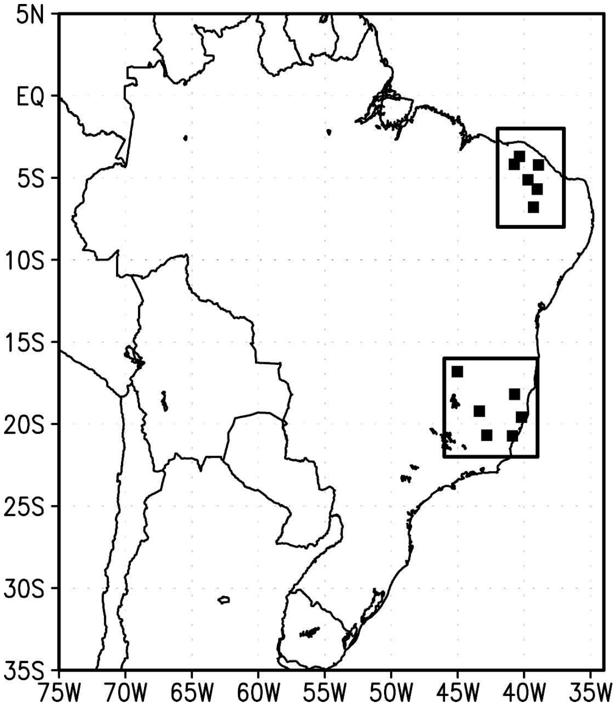

FIG. 3. Selected stations over NEBR and SEBR.

b. Data sources and methodology

The primary sources and period of record of daily precipitation data for Brazil used in the historical gridded precipitation analyses (2005 version) are (a) Agência Nacional de Energia Eléctrica (ANEEL; National Agency for Electrical Energy; 1960–97), (b) Agência Nacional de Águas (ANA; National Water Agency; 1948–2004), (c) Fundação Cearense de Meteorologia e Recursos Hídricos (FUNCEME; Meteorology and Hydrologic Resources Foundation of Ceará; 1973–2004), (d) Superintendência do Desenvolvimento do Nordeste (SUDENE; Superintendence for Development of the Northeast; 1948–98), (e) Departamento de Águas e Energia Elétrica do Estado de São Paulo (DAEE; Department of Water and Electrical Energy for the State of São Paulo; 1948–97), in collaboration with the Centro de Previsão de Tempo e Estudos Climáticos (CPTEC; Brazilian Weather Forecast and Climate Studies Center), and (f) Technological Institute of Paraná (SIMEPAR, 1997–2004).

c. Data improvement

Snapshots of the typical station distribution, used as the basis for the gridded precipitation analysis over Brazil—version 2000 (Shi et al. 2000) and version 2005—are shown in Figs. 1a,b, respectively. It is evident that the station coverage has improved over eastern and southern Brazil in the newest version of the

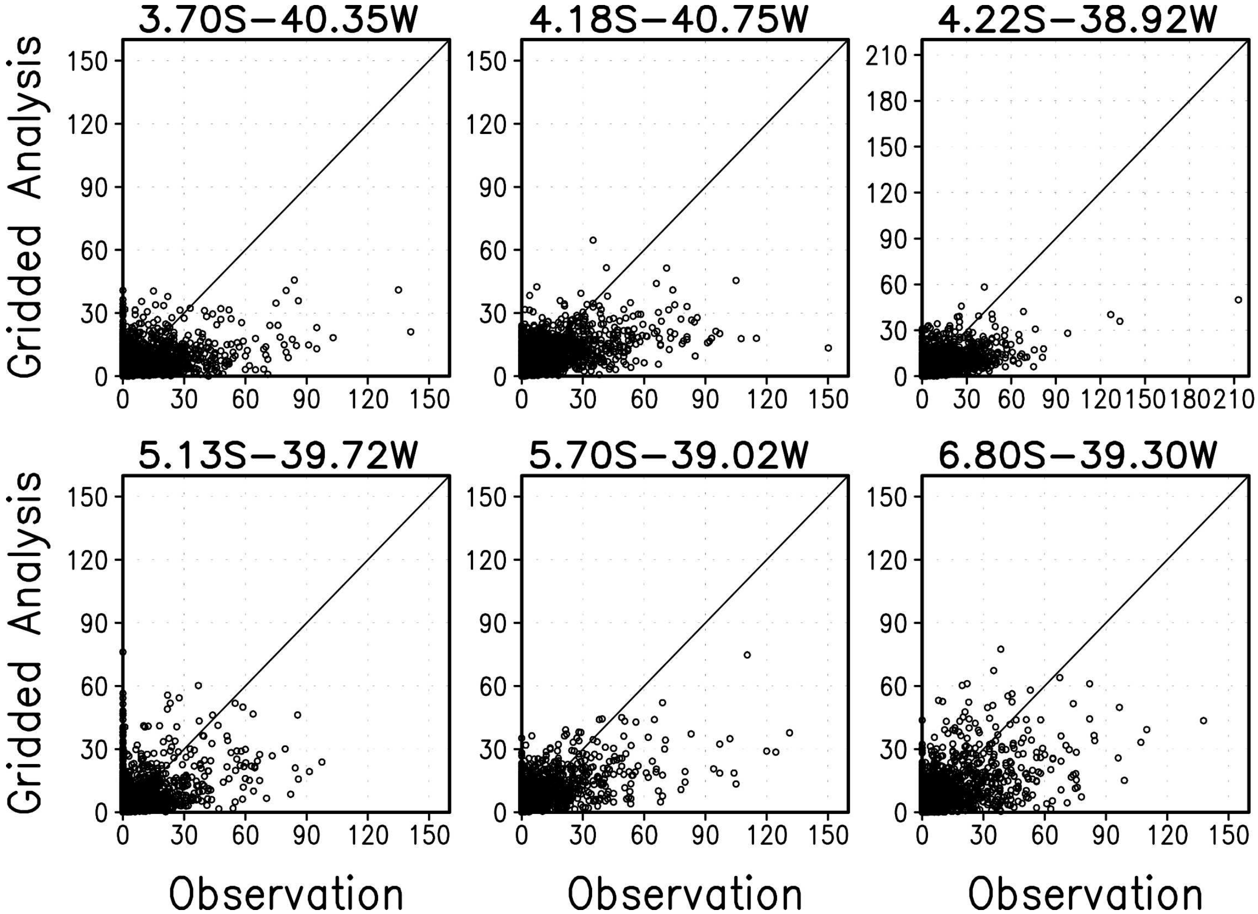

FIG. 4. Single station and gridded analyses comparison for NEBR. February to April (FMA) (1977–2004).

gridded analysis (cf. Figs. 1a,b). The total number of daily reports used in the two versions of the gridded analyses [version 2000 (1948–2000) and version 2005 (1948–2005)], after passing through our quality control system, is shown in Fig. 2. The number of stations passing the quality control is more than 4 times greater in the version 2005.

The increase in the number of reporting stations during the 1960s is probably due to efforts to digitize historical data. The quantity of station observations prior to 1965 will likely increase in the future, as data-mining and digitizing efforts extend back in time. New versions of the historical analyses are planned as additional data become available. The period 1965–2004 has the greatest number of reporting stations. However, some of those stations do not report in real time, which is the reason for the sudden drop in the number of stations used in the real-time analyses for 2005. This reduction in the number of observations has an adverse effect on the quality of the real-time analyses of mean and anomalous precipitation. CPC is exploring the possibility of using a subset of the historical observations to produce a climatology that is consistent with the real-time station distribution; we will report on the outcome of these tests in a future study.

d. *Gridded daily analysis products available*

Real-time precipitation analyses for South America (1999–present) are available online at ftp://ftp.cpc.ncep.noaa.gov/precip/wd52ws/SA/. They are updated, maintained, archived, and distributed on a daily basis, and are routinely used for operational real-time monitoring, assessment, and verification activities at CPC. The historical reanalysis for Brazil is also available online (see http://www.cpc.ncep.noaa.gov/products/precip/realtime/GIS/retro.shtml).

3. Comparison between station observations and the gridded analyses

a. *Grid point versus single station*

To verify how the CPC precipitation analyses relate to a single station observation, a comparison was made

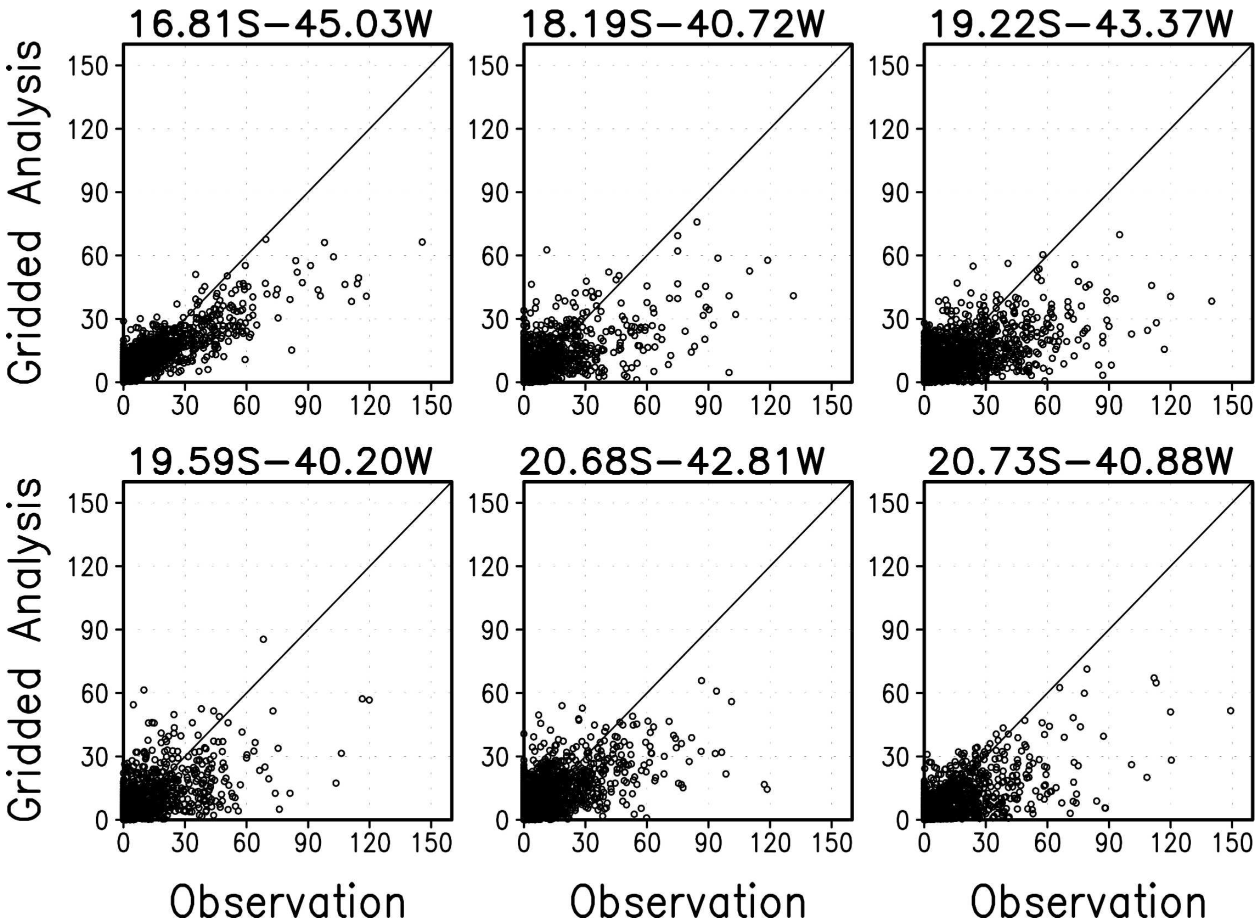

FIG. 5. Single station and gridded analyses comparison for SEBR. December to February (1977–2004).

between the gridpoint rainfall values and observations at 12 stations: six in northeast Brazil (NEBR) and six in southeast Brazil (SEBR) for the period 1977–2004 (see Fig. 3 for the station locations). The selected stations have less than 1% missing reports during that period. Figures 4 and 5 (scatterplots) show the correspondence between the observed precipitation for each selected station and the analyzed precipitation at the nearest

TABLE 1. Comparison between individual stations and the nearest grid points for the period 1977–2004.

		NEBR (FMA)			
Station location	Obs mean daily (mm)	Grid mean daily (mm)	Mean bias (mm)	RMS difference	Correlation
3.70°S, 40.35°W	6.7	5.9	−1.44	13.89	0.34
4.18°S, 40.75°W	8.6	7.2	−1.64	13.43	0.54
4.22°S, 38.92°W	8.2	5.9	−2.78	12.66	0.51
5.13°S, 39.72°W	4.5	5.1	0.78	12.50	0.40
5.70°S, 39.02°W	5.2	5.4	0.22	12.11	0.58
6.80°S, 39.30°W	6.6	5.8	−1.22	13.76	0.55
		SEBR (DJF)			
Station location	Obs mean daily (mm)	Grid mean daily (mm)	Mean bias (mm)	RMS difference	Correlation
16.81°S, 45.03°W	7.0	6.7	−0.65	10.23	0.84
18.19°S, 40.72°W	5.3	5.2	−0.35	12.61	0.65
19.22°S, 43.37°W	9.3	7.2	−3.22	15.51	0.60
19.59°S, 40.20°W	5.2	5.1	−0.12	11.95	0.59
20.68°S, 42.81°W	6.8	7.6	1.10	11.46	0.64
20.73°S, 40.88°W	6.2	4.7	−2.53	12.80	0.67

TABLE 2. Mean annual number of days per water year (July–June) falling in specified categories of precipitation (mm) for the period (July 1977–June 2004).

	NEBR											
	3.70°S, 40.35°W		4.18°S, 40.75°W		4.22°S, 38.92°W		5.13°S, 39.72°W		5.70°S, 39.02°W		6.80°S, 39.30°W	
	Obs	Grid	Obs	Grid	Obs	Grid	Obs	Grid	Obs	Grid	Obs	Grid
$P < 1$	304.6	250.1	275.1	228.1	230.5	238.6	319.7	265.4	317.0	255.7	305.2	265.6
$1 \leq P < 5$	16.1	64.5	29.5	68.5	55.6	69.7	12.5	60.4	13.1	62.7	15.7	53.2
$5 \leq P < 10$	14.4	28.4	19.5	34.1	31.0	31.5	10.2	20.3	11.0	24.4	13.0	21.8
$10 \leq P < 25$	19.2	19.8	25.1	31.3	33.4	22.9	14.6	14.7	14.9	18.9	17.9	17.9
$25 \leq P < 50$	8.6	2.0	12.1	3.1	12.1	2.5	6.1	4.0	6.5	3.5	9.9	5.8
$P \geq 50$	2.5	0.04	3.7	0.15	2.5	0.07	2.1	0.4	2.8	0.07	3.4	0.9
	SEBR											
	16.81°S, 45.03°W		18.19°S, 40.72°W		19.22°S, 43.37°W		19.59°S, 40.20°W		20.68°S, 42.81°W		20.73°S, 40.88°W	
	Obs	Grid	Obs	Grid	Obs	Grid	Obs	Grid	Obs	Grid	Obs	Grid
$P < 1$	294.0	238.8	277.0	218	263.8	231.6	259.1	193.2	277.4	202.5	249.0	206.3
$1 \leq P < 5$	21.9	61.0	37.1	84.1	33.8	58.7	48.8	102.0	28.9	78.0	41.5	92.9
$5 \leq P < 10$	14.5	28.9	18.6	31.1	18.8	29.4	21.5	36.2	20.0	36.8	25.7	32.5
$10 \leq P < 25$	19.6	28.7	20.0	25.2	26.8	36.2	22.7	26.7	24.6	40.4	30.3	27.1
$25 \leq P < 50$	10.9	7.4	8.5	6.4	15.7	8.9	10.4	6.3	11.2	7.2	13.6	6.0
$P \geq 50$	4.2	0.5	3.9	0.6	6.2	0.4	2.7	0.7	3.1	0.3	5.1	0.3

corresponding grid point. The scatterplots for both regions (NEBR and SEBR) show a tendency for the values to be shifted to the right of the diagonal lines, which means that the station values are higher than the gridded values. The seasonal mean, mean bias, root-mean-square difference (RMSD), and correlation between the two datasets were calculated for both regions (see Table 1). In NEBR the correlations vary from 0.34 to 0.58, the mean bias varies between −2.78 and 0.78 mm, and the RMSD for wet days (rainfall greater than or equal to 1 mm) varies between 12.11 and 13.89 mm. The station-to-station variability in the mean bias may be related to the individual station locations with respect to local orographic features. For SEBR the correlation is higher than over NEBR, which implies a higher station-to-station correlation around a grid point [i.e., rainfall is organized by large-scale dynamics, as discussed by Liebmann et al. (1999)]. Taking into consideration the way the analysis is done, it is almost impossible to have a gridded value be exactly the same as the station observation, unless the station and the grid point have exactly the same latitude and longitude and there are no other stations in the vicinity. (If this were true for every station, then one would question the need to produce a gridded analysis.)

Table 2 shows the mean number of days during the water year (here defined as July–June) for which $P < 1$ mm (dry days), $1 \leq P < 5$ mm, $5 \leq P < 10$ mm, $10 \leq P < 25$ mm, $25 \leq P < 50$ mm, and $P \geq 50$ mm (July 1977–June 2004) at the 12 selected stations and nearest corresponding grid points. The number of dry days ($P < 1$ mm) at the grid points is less than at the stations, except for the station at 4.22°S, 38.92°W (in NEBR). This difference is undoubtedly due to the station averaging performed in deriving the gridded analyses. For rainfall amounts between 1 and 10 mm, the gridded analyses have more cases than do the individual sta-

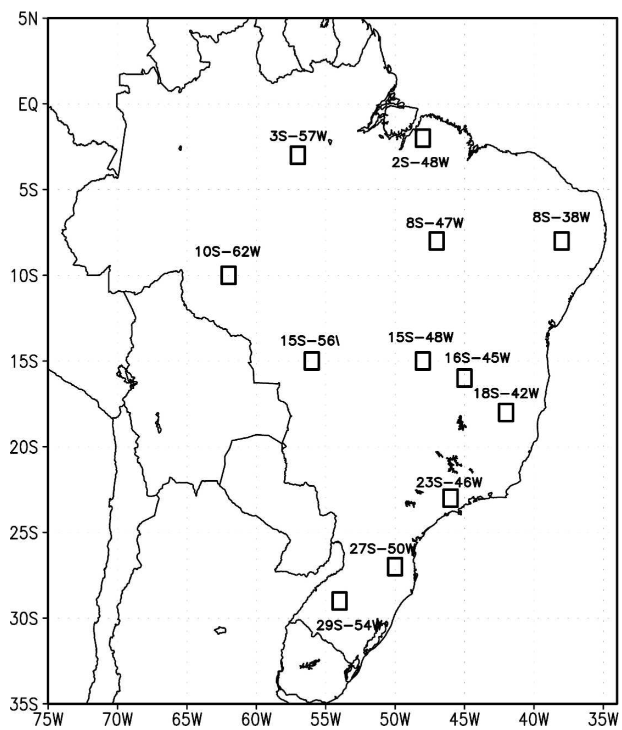

FIG. 6. Selected areas over Brazil.

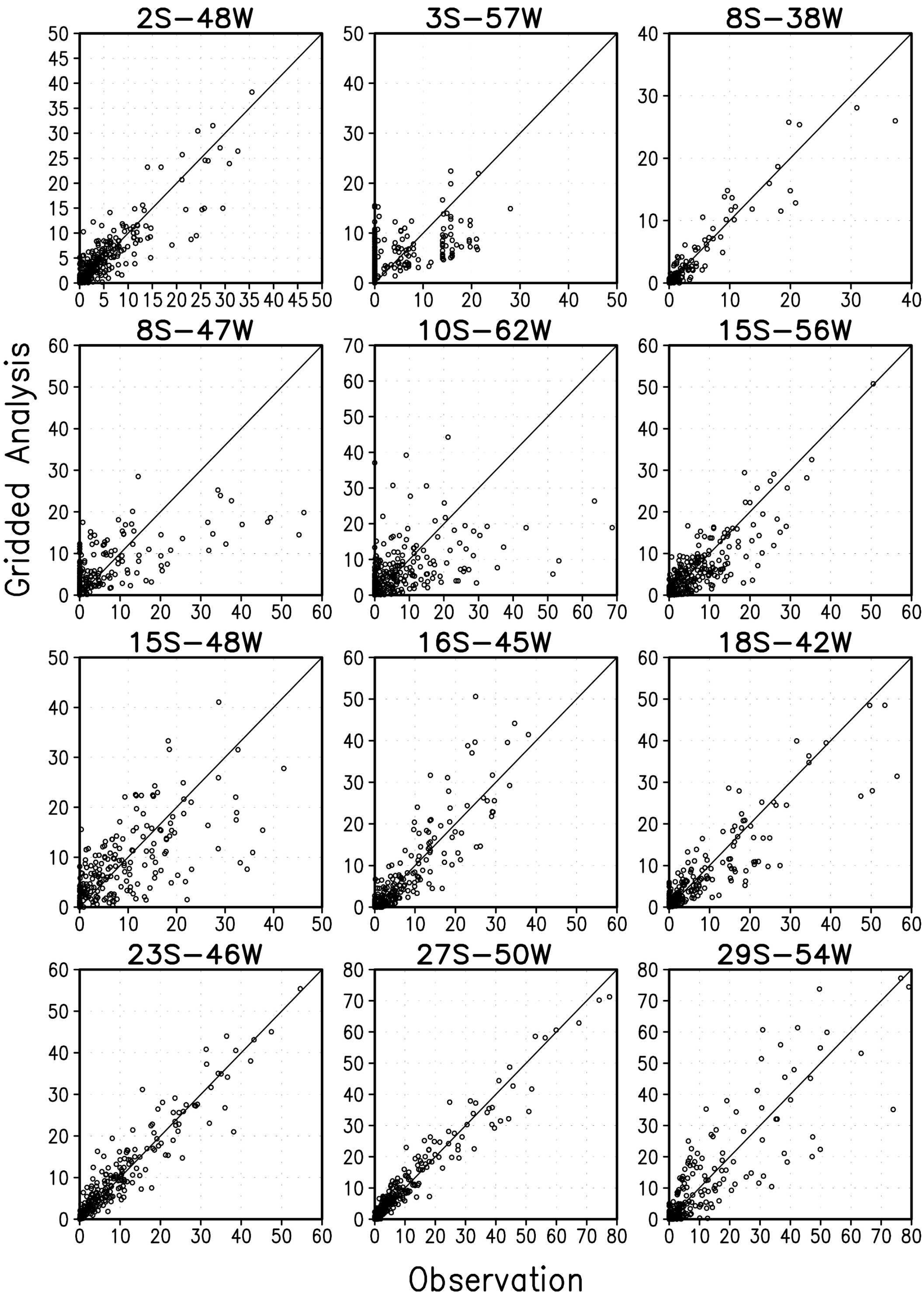

FIG. 7. All-station average and gridded analyses comparison (1983).

TABLE 3. Comparison between grid point and all-station average for the periods 1983 (El Niño) and 1989 (La Niña).

El Niño 1983

Grid point	All-station mean daily (mm)	Grid mean daily (mm)	Mean bias (mm)	RMS difference (Pg − Ps) mm	Correlation
		Amazon Basin			
2°S, 48°W	3.96	4.07	0.17	3.45	0.86
3°S, 57°W	2.73	3.78	1.35	5.51	0.54
8°S, 47°W	3.30	3.42	0.16	8.24	0.65
10°S, 62°W	5.13	4.68	−0.61	10.28	0.40
		Northeast Brazil			
8°S, 38°W	1.37	1.35	0.04	2.69	0.93
		Central Brazil			
15°S, 56°W	4.12	−0.85	4.74	0.80	
4.68					
15°S, 48°W	4.89	4.76	−0.24	7.24	0.62
		Southeastern Brazil			
16°S, 45°W	4.42	4.44	0.34	5.33	0.85
18°S, 42°W	4.37	4.09	−0.7	5.45	0.88
23°S, 46°W	6.06	6.48	0.63	3.67	0.94
		Southern Brazil			
27°S, 50°W	6.90	7.24	0.53	3.59	0.97
29°S, 54°W	6.14	6.42	0.77	9.24	0.84

La Niña 1989

Grid point	All-station mean daily (mm)	Grid mean daily (mm)	Mean bias (mm)	RMS difference (Pg − Ps) mm	Correlation
		Amazon Basin			
2°S, 48°W	7.33	7.11	−0.26	4.89	0.88
3°S, 57°W	8.35	7.49	−1.1	10.96	0.74
8°S, 47°W	4.76	4.43	−0.57	8.48	0.68
10°S, 62°W	11.81	6.00	−1.61	10.32	0.65
		Northeast Brazil			
8°S, 38°W	2.56	2.45	−0.13	2.57	0.90
		Central Brazil			
15°S, 56°W	4.97	4.93	−0.13	4.8	0.84
15°S, 48°W	4.25	4.14	−0.29	4.65	0.83
		Southeastern Brazil			
16°S, 45°W	3.15	3.71	1.67	5.39	0.88
18°S, 42°W	3.18	2.86	−0.81	6.09	0.80
23°S, 46W	4.39	4.99	1.15	4.09	0.88
		Southern Brazil			
27°S, 50°W	4.23	4.30	0.1	2.93	0.95
29°S, 54°W	4.38	4.40	0.22	7.88	0.87

tions. For $10 \leq P < 25$ mm, the number of cases in the gridded analyses is closer to the observed number of cases at the individual stations. For the extreme rainfall categories ($P \geq 25$ mm), the number of observed cases exceeds the number of cases in the gridded analyses. Thus, the gridded analyses tend to have fewer cases of high precipitation ($25 \leq P < 50$ mm and $P \geq 50$ mm) and a greater number of cases with low precipitation ($1 \leq P < 10$ mm), relative to station observations.

b. Grid point versus all-station average

A comparison was also made between the gridpoint rainfall values and the mean rainfall for all stations located within 1° of the 12 selected grid points (see Fig. 6). The years 1983 (El Niño) and 1989 (La Niña) were selected for the comparison. Over the northern portion of Brazil, five grid points were selected: four of them in the Amazon basin (2°S, 48°W; 3°S, 57°W; 10°S, 62°W; 8°S, 47°W) and one in the northeast (8°S, 38°W). For the Amazon basin (1983, El Niño) there are cases in which the all-station average observation is zero, while the gridded analysis indicates nonzero values (e.g., see the scatterplot, Fig. 7, for the grid point 3°S, 57°W). In these cases the gridpoint value is influenced by station observations outside the 1° box, which is a result of the relatively sparse observing network in the region (see Fig. 1). Similar results were found for 1989 (La Niña; not shown).

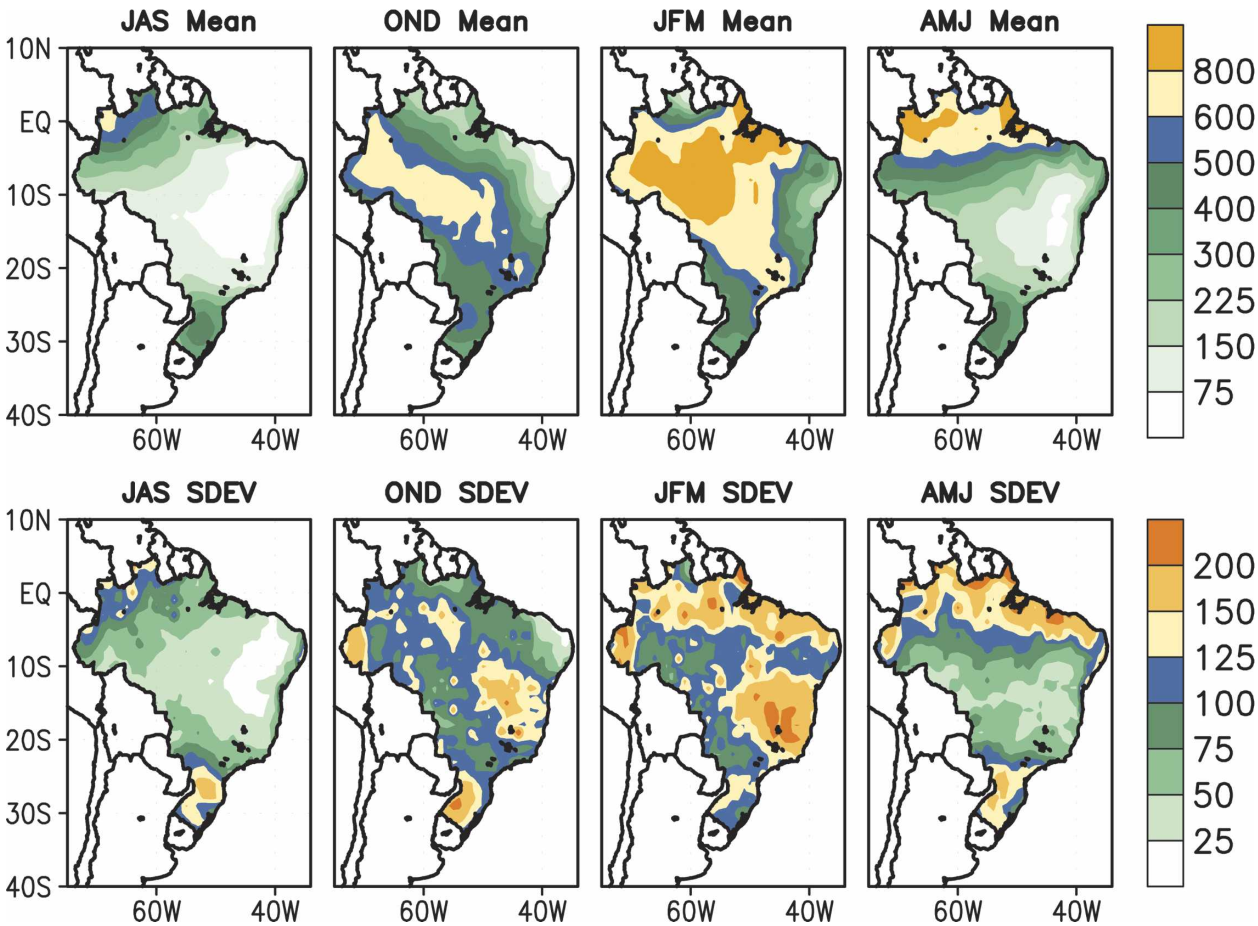

FIG. 8. Mean (1977–2004) precipitation and standard deviation for JAS, OND, JFM, and AMJ. Units are in mm.

The average bias in the Amazon region is positive (gridded analyses overestimate precipitation) during the El Niño 1983 (dry year) and negative (gridded analyses underestimate precipitation) during the La Niña 1989 (wet year) (see Table 3). In spite of these biases, there is a good correlation between the grid-point values and the all-station average over that region (Table 3). Over northeastern Brazil the gridded analyses are very close to observations (correlation 0.93 for 1983 and 0.90 for 1989). Over the central portion of Brazil, two grid points were selected (15°S, 56°W and 15°S, 48°W). For 15°S, 48°W, it seems that half of the time the gridded analyses underestimate precipitation and the other half the gridded analyses overestimate it (Fig. 7). However, there is a good correlation between the two datasets (Table 3). Over southeastern and southern Brazil, in general, the gridded analysis is highly correlated with the all-station average (see Table 3).

For this comparison we stress the fact that a single station does not properly represent the rainfall over a region. However, a comparison between the gridded precipitation and averages of nearby station observations of precipitation showed better agreement. Thus, the gridded precipitation analyses are likely to be useful in hydrological studies and applications over river basins, such as the La Plata Basin in South America, as well as in research studies on large-scale patterns of anomalous precipitation linked to the major modes of climate variability.

4. Climatology and variability

Retrospective analyses are important for computing basic statistics such as mean daily/monthly rainfall, extremes, probabilities of wet and dry days, etc. In this section we present examples of how the version 2005 historical gridded daily analyses for Brazil (for the period 1977–2004) can be used in studies of climate and climate variability. The period 1977–2004 was selected because adequate station coverage for the Amazon basin is restricted to that period.

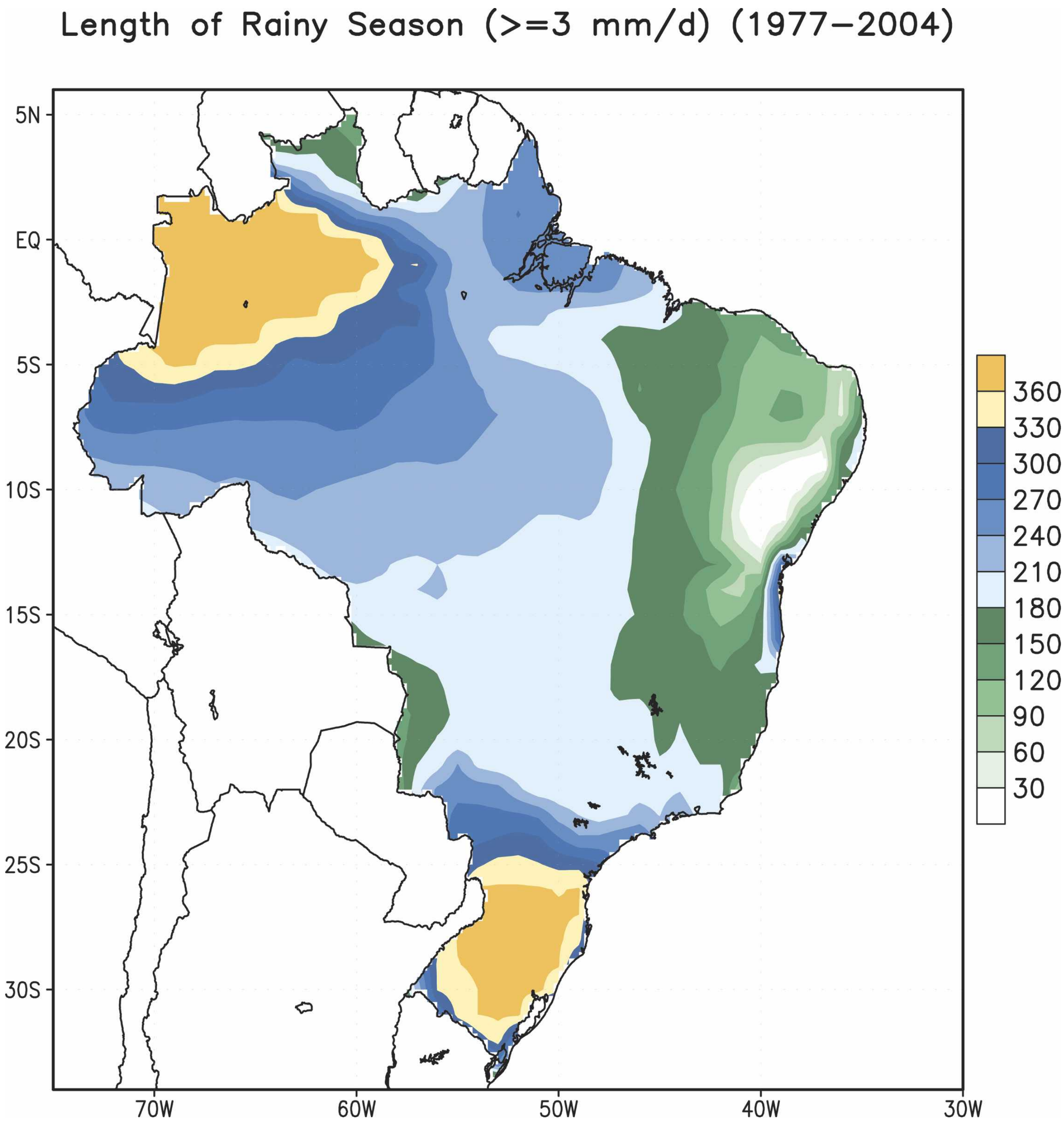

FIG. 9. Mean (1977–2004) length of rainy season (days) based on a rainfall threshold of 3 mm day^{-1}.

a. Seasonal mean precipitation and standard deviation

The mean precipitation and standard deviation for the seasons July–September (JAS), October–December (OND), January–March (JFM), and April–June (AMJ) are shown in Fig. 8. The peak of the rainy season over central and western Brazil occurs during JFM, while over southern Brazil rainfall occurs throughout the year (no distinct wet and dry seasons). Extreme northern Brazil has a rainfall peak during AMJ and a minimum during JFM. A pronounced dry season is evident across central Brazil during JAS and over northeast Brazil during JAS and OND. The standard deviation of seasonal precipitation is large in southern Brazil throughout the year, while over southeastern and central Brazil there is marked seasonality in the rainfall variability, with a maximum during OND and JFM and a minimum during JAS. Previous studies have shown

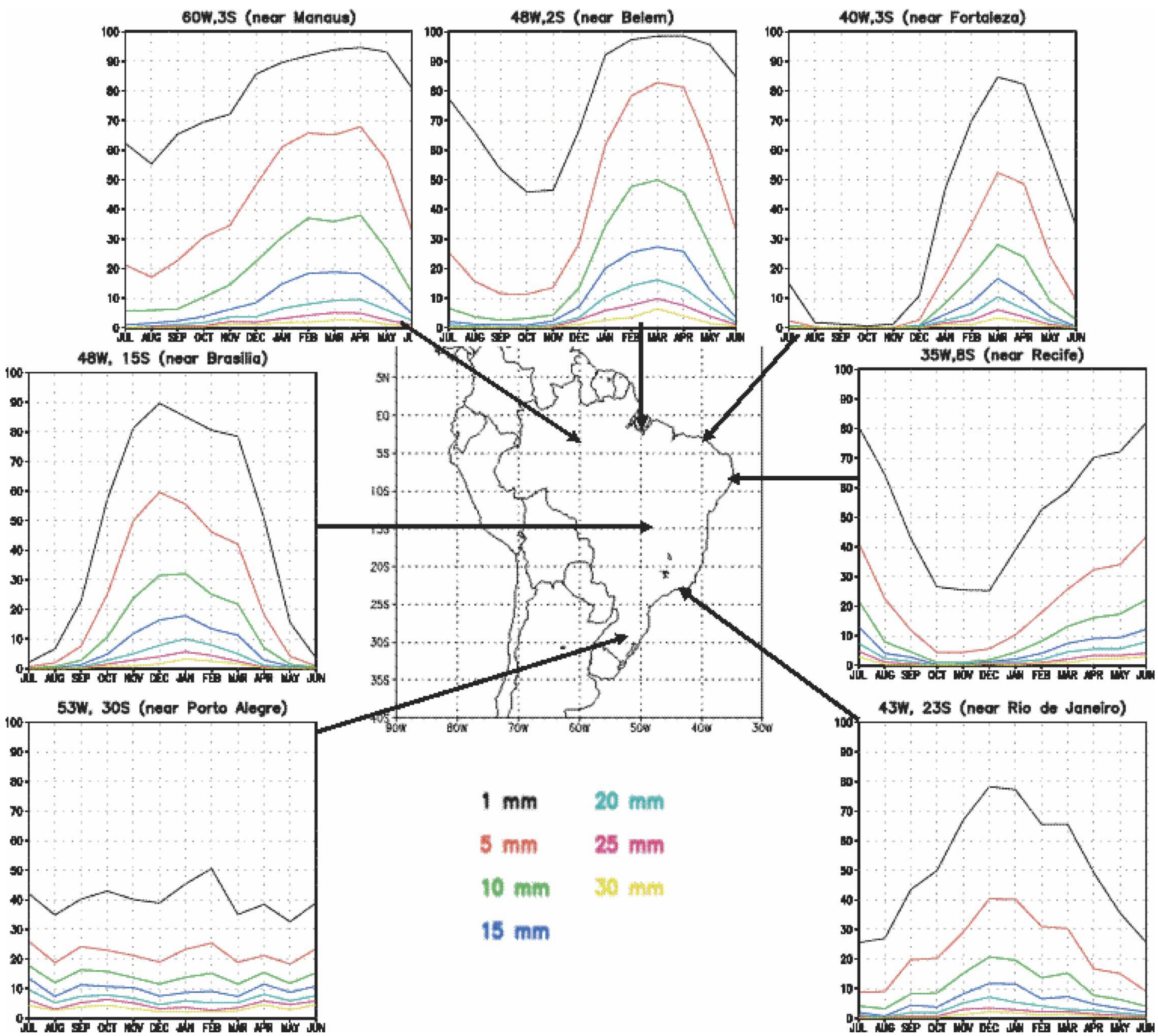

FIG. 10. Seasonal cycle of probability (%) that daily precipitation exceeds selected threshold amounts (indicated on the plot).

that the high variability over southeastern Brazil during OND and JFM is associated with the variability in the position and intensity of the South Atlantic convergence zone (SACZ) (e.g., Casarin and Kousky 1986; Kousky and Cavalcanti 1988; Nogues-Paegle and Mo 1997; Liebmann et al. 1999; Paegle et al. 2000; Silva and Kousky 2001). The standard deviation of seasonal precipitation is large over northern Brazil during JFM and AMJ, during the time of the year when rainfall is a maximum in that region.

b. Length of rainy season

Previous studies (e.g., Kousky 1988; Marengo et al. 2001; Gan et al. 2004) used arbitrary threshold values of either outgoing longwave radiation (OLR) or precipitation to define the onset and demise dates of the rainy season over Brazil. Here we choose a threshold of 3 mm day^{-1} as the basis for determining the length of the rainy season (number of consecutive days exceeding that threshold; Fig. 9). Northwestern Brazil and southern Brazil have rainy seasons exceeding 360 days, which is equivalent to no dry season. Northeastern Brazil has the shortest rainy season, with some interior sections experiencing a rainy season lasting between 30 and 90 days or less. A marked contrast exists in the length of the rainy season between the semiarid interior and coastal areas of the northeast, where the rainy season exceeds 180 days. A large portion of central Brazil, west of 45°W, experiences a rainy season of between 180 and 210 days.

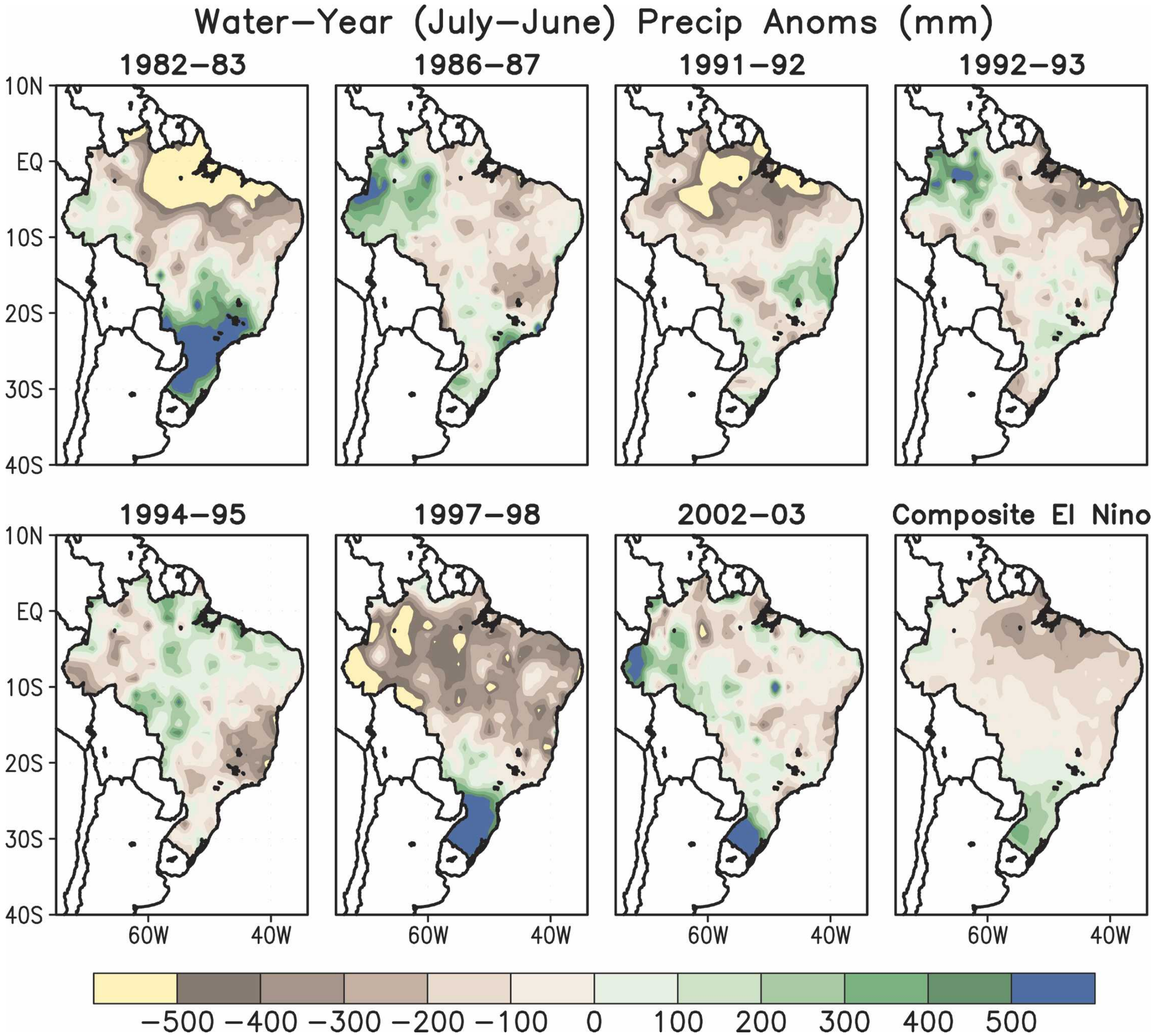

FIG. 11. Precipitation anomalies for water years (July–June) during El Niño episodes. The composite for the seven episodes is shown in the lower right-hand panel. Anomalies (mm) are computed with respect to the July 1977–June 2004 base period means.

c. Probability of daily rainfall exceeding given thresholds

The daily gridded analyses can be used to compute the mean probability that daily rainfall for any month will exceed given threshold amounts, where the probability is defined as the number of cases for which the observed precipitation exceeds a given threshold in the entire record divided by the total number of days in the record (28 yr × 31 days = 868 for January). The seasonal cycle in probabilities for grid points near major cities for a range of thresholds is shown in Fig. 10. Remarkable seasonal variability is evident at most of the selected grid points, with the exception of the one at 30°S, 53°W (Porto Alegre) where rainfall occurs throughout the year. The greatest seasonality in the probabilities occurs near the cities of Brasilia and Fortaleza, where the probability of experiencing daily rainfall greater than 1 mm exceeds 80% during the rainy season and falls to near zero during the dry season. During the rainy season most of the selected areas have a relatively high probability (5%–10% or 1–3 days per month) that daily rainfall will exceed 25 mm.

d. Interannual variability related to El Niño and La Niña

The ENSO cycle has been shown to have pronounced effects on precipitation in certain areas in Brazil (e.g., Hastenrath and Heller 1977; Kousky et al.

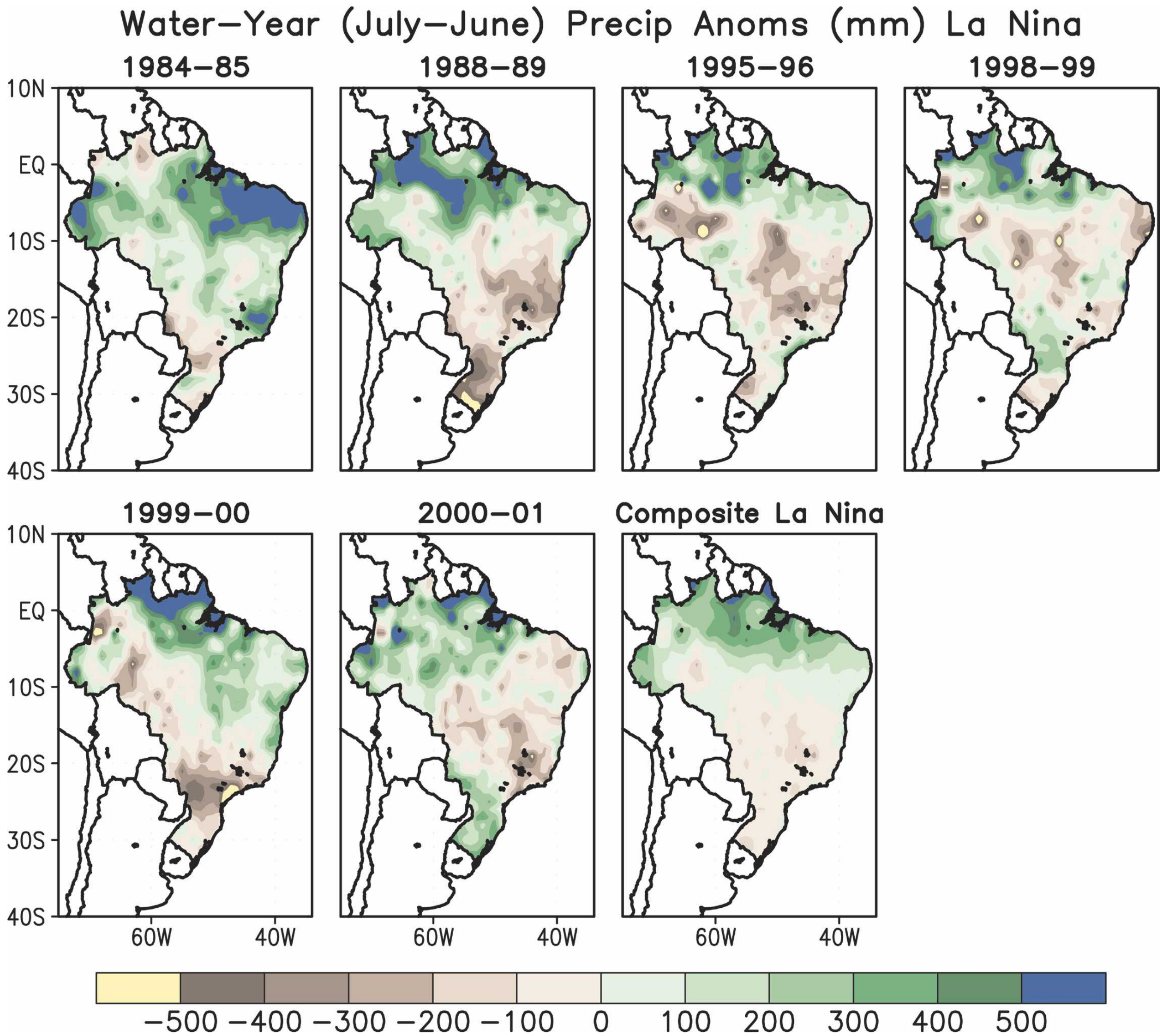

FIG. 12. Precipitation anomalies for water years (July–June) during La Niña episodes. The composite for the six episodes is shown in the lower right-hand panel. Anomalies (mm) are computed with respect to the July 1977–June 2004 base period means.

1984; Ropelewski and Halpert 1987, 1989; Grimm et al. 1998). Since the extreme phases of the ENSO cycle tend to peak during the austral summer, we elected to use water-year (July–June) precipitation anomalies to illustrate the utility of the gridded analyses for studying interannual rainfall variability.

The pattern of anomalous precipitation during El Niño episodes (Fig. 11) shows considerable event-to-event variability, especially in the magnitude of the departures. The strongest El Niño episodes (1982/83, 1991/92, and 1997/98) feature large precipitation deficits over the Amazon basin. The weaker events tend to have weaker precipitation anomalies. Most of the events also feature excess precipitation in southern Brazil, a region that sometimes experiences disastrous flooding related to strong El Niño episodes such as 1982/83 (Kousky et al. 1984). The composite for the seven El Niño episodes yields a pattern (precipitation deficits in the central and eastern Amazon, and over northeast Brazil; precipitation surpluses in southern Brazil) that is consistent with previous studies on ENSO cycle impacts (e.g., Ropelewski and Halpert 1987, 1989; Grimm et al. 1998).

The precipitation anomaly patterns during La Niña episodes (Fig. 12) show more event-to-event consistency compared to the patterns for El Niño. Above-average precipitation was observed over the northern part of Brazil in all six La Niña episodes. There is also a tendency for wetter-than-average conditions (four out of six cases) to occur over northeast Brazil. The composite pattern for the water-year precipitation anomalies during La Niña episodes does not reflect dryness in southern Brazil, which is a feature associated with La Niña at certain times of the year (e.g., Ropelewski and Halpert 1989; Grimm et al. 1998).

5. Summary and conclusions

A new version (2005) of a gridded daily precipitation analysis system for Brazil is available at CPC. Here we have described the basic characteristics of the analysis, which is entirely gauge based and has been subjected to an advanced QC system developed at CPC.

The retrospective analyses are probably best suited for use in hydrologic and climate variability studies dealing with large spatial scale anomaly patterns, such as those related to ENSO. The analyses can also be used as a benchmark for evaluating model simulations, serve as a basis for real-time monitoring, and provide statistics on the occurrence of large-scale heavy rainfall events and dry periods. The user should keep in mind that the analyses for eastern Brazil can be used from 1948 until the present. However, for the Amazon basin region, adequate station coverage is restricted to the period 1977–present.

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