Comparison of Precipitation Datasets over the Tropical South American and African Continents

ROBINSON I. NEGRÓN JUÁREZ, WENHONG LI, RONG FU, AND KATIA FERNANDES

School of Earth and Atmospheric Sciences, Georgia Institute of Technology, Atlanta, Georgia

ANDREA DE OLIVEIRA CARDOSO

Universidade de Campinas, Campinas, Sao Paulo, Brazil

(Manuscript received 19 March 2008, in final form 13 August 2008)

ABSTRACT

Six rainfall datasets are compared over the Amazon basin, Northeast Brazil, and the Congo basin. These datasets include three gauge-only precipitation products from the Climate Prediction Center (CPC), Global Precipitation Climatology Center (GPCC), and Brazilian Weather Forecast and Climate Studies Center (CLMNLS), and three combined gauge and satellite precipitation datasets from the CPC Merged Analysis of Precipitation (CMAP), Global Precipitation Climatology Project (GPCP), and Tropical Rainfall Measuring Mission (TRMM) product. The pattern of the annual precipitation is consistently represented by these data, despite the differences in methods and periods of averaging. Quantitatively, the differences in annual precipitation among these datasets are 5% more than the Amazon domain (0°–15°S, 50°–70°W), 22% more than Northeast Brazil (5°–10°S, 35°–45°W), and 11% more than the Congo domain (5°N–10°S, 15°–30°E). Over the Amazon domain the rainfall variation is well correlated between CPC, TRMM, GPCP, and GPCC ($r^2 > 0.9$) except for the northwestern Amazon, whereas CMAP and CLMNLS were different from these four datasets. Over the Congo basin, the coefficient of determination between these rainfall datasets is generally below 0.7. The empirical orthogonal functions analysis suggests large discrepancies in interannual and decadal variations of rainfall among these datasets, especially for the Congo basin and for the South American region after 1998. In general, CMAP, GPCC, TRMM, and GPCP significantly agree over the tropical areas in South America.

1. Introduction

Tropical rain forests cover 12% of global land area (Mayaux et al. 2005) and represent the world largest terrestrial biome and rainfall centers (e.g., Valdoire and Royer 2004; Probst et al. 1994; Ometto et al. 2005; Justice et al. 2001). Of that total, 35% are located in the Amazon basin (Eva et al. 2004) and 11% in the Congo basin (Mayaux et al. 2005; Justice et al. 2001), constituting the two largest contiguous continental tropical forests. However, accuracy of the rainfall estimates, including rainfall amount and spatial and temporal variations, is considerably lower than that over tropical oceans and middle latitude land regions as a result of sparse in situ observations. Consequently, substantial differences exist among different rainfall datasets. Costa and Foley (1998) have provided the first comparative analysis of precipitation datasets over the Amazon basin. Since then the methods of estimating rainfall have been updated, and satellite-based precipitation radar measurements have become available. Recently, Fernandes et al. (2008) have suggested that the Climate Prediction Center (CPC) rainfall data appears to provide the best closure for surface water budget over the Amazon rainfall basin based on streamflow data near the mouth of the Amazon river and the surface evapotranspiration measurements scaled up to basin scale. However, this agreement does not offer any information as to whether the spatial pattern and seasonal variation of the rainfall is reasonable. Thus neither the temporal and spatial domain nor the climate variability have been compared and evaluated with the focus exclusively on the tropical land areas.
In this work we compared three gauge-only and three combined (merged gauge and satellite data) precipitation datasets widely used in climate studies with available data extending at least until December 2005 at the time of this study. Our objectives are as follows: (i) to perform comparative analyses among precipitation datasets over the Amazon basin, Northeast Brazil, and the Congo basin and (ii) to evaluate their capability to represent the precipitation variability.

2. Study area and datasets

Our study areas include the Amazon and Congo basins, covered primarily by tropical rain forest, and Northeast Brazil, dominated by savannah. The annual precipitation over the Amazon and the Congo basins has been estimated to be 2124 mm (Willmott and Johnson 2005) and 1506 mm (Todd and Washington 2004), respectively. In Northeast Brazil, which undergoes recurrent drought events (Hastenrath and Heller 1977; Kousky and Chu 1978; Negrón Juárez and Liu 2001), the annual precipitation varies from 1800 mm in the coastal regions to less than 400 mm in the semiarid regions (Silva 2004). In our analysis, the Amazon basin (A1) is defined by the area within 0°–15°S and 50°–70°W, Northeast Brazil (A2) by the area of 5°–10°S, 35°–45°W, and the Congo basin (A3) by the area of 5°N–10°S and 15°–30°E, as shown in Fig. 1a.
Table 1. Datasets used in this study and their main characteristics.

<table>
<thead>
<tr>
<th>Dataset</th>
<th>Main characteristics</th>
</tr>
</thead>
<tbody>
<tr>
<td>CLMNLS</td>
<td>Climanálise (No available reference yet. Data available by request). Spatial resolution: $0.25^\circ \times 0.25^\circ$. Area: Brazil. Series: 1961–present. Data source: rain gauge. CLMNLS data are composed of surface synoptic observations as well as rain gauge station data belonging to the Data Collection Center (CMCD) of INPE, Brazil. The data are collected on a daily basis and interpolated to a regular grid interval of $0.25^\circ \times 0.25^\circ$ using the Kriging method (Krig 1951). On average, data from 1000 stations are collected daily over South America.</td>
</tr>
<tr>
<td>TRMM</td>
<td>Tropical Rainfall Measuring Mission (Huffman et al. 2007). TRMM merged with other satellite data and rain gauge estimates (3B43-V6). Resolution: $0.25^\circ \times 0.25^\circ$. Area: $180^\circ$W–$180^\circ$E, 50$^\circ$N–50$^\circ$S. Series: 1998–present. [Available online at <a href="http://daac.gsfc.nasa.gov/data/datapool/TRMM/">http://daac.gsfc.nasa.gov/data/datapool/TRMM/</a>]. Data source: Microwave/TRMM satellite, Special Sensor Microwave Imager (SSM/I), Advanced Microwave Scanning Radiometer for Earth Observing System (AMSR-E), Advanced Microwave Scanning Unit-B (AMSU-B); Infrared (IR): window-channel ($\sim 10.7\mu m$) IR data from the international constellation of geosynchronous earth orbit (GEO) satellites; gauge: GPCC. Climate Assessment and Monitoring System (CAMS; Xie et al. 1996). Microwave and IR data are merged into a calendar month and then combined with gauge data, as in Huffman (1997).</td>
</tr>
</tbody>
</table>

Climatology (1961–90) datasets

| INMET          | Brazilian National Weather Service (Instituto Nacional de Meteorologia 1992). Resolution: $0.25^\circ \times 0.25^\circ$. Area: Brazil. |
| CRU            | Climatic Research Unit (New et al. 1999). Resolution: $0.5^\circ \times 0.5^\circ$. Area: Global. |
| eGPCC          | Global Precipitation Climatology Project (Rudolf and Schneider 2005). Resolution: $1^\circ \times 1^\circ$. Area: Global. |

the order of $10^5$ over the Amazon basin and Northeast Brazil but with higher density over the northeast (Rudolf and Schneider 2005; Silva et al. 2007; C. Cunning 2008, personal communication). Over the Congo basin (A3), the number of stations reported by GPCC is around 10, and they located in the extreme north and west. Over this area Nicholson (1993) presented a denser gauge station distribution. The three combined precipitation datasets are as follows: (i) the CPC Merged Analysis of Precipitation (CMAP), (ii) the Global Precipitation Climatology Project (GPCC) precipitation, and (iii) the Tropical Rainfall Measuring Mission (TRMM) 3B43 product. We also discuss the climatology for the period 1961–90 produced by the Brazilian National Weather Service (Instituto Nacional de Meteorologia, or INMET), the Climatic Research Unit (CRU), and the GPCC (GPCC). The datasets are different in spatial resolution, temporal coverage, and methodologies. To deal with the spatial resolution, an aggregation process was performed to homogenize the spatial resolution when it was needed. It consists of calculating the weighted average of all pixels from high resolution that...
spatially overlap the lower resolution. The temporal periods were chosen when datasets (or most of them) overlap.

3. Comparison of rainfall climatology and seasonal cycle among the datasets

The long-term mean monthly total precipitation values for A1, A2, and A3 are shown in Figs. 1b–d, respectively. The periods range from 1986 to 2005 except for TRMM (1998 to 2005). Although with the shorter time series, TRMM data have been calibrated and validated over the Amazon basin (Negri et al. 2002) during the TRMM–Large-scale Biosphere–Atmosphere Experiment in Amazonia (LBA) field campaign (Silva Dias et al. 2002). The climatological values and their uncertainties [standard deviations (SD)] are also shown. Datasets showed very similar seasonal cycles over the three study areas despite the differences in methodology and analysis periods. Climatologically (INMET, CRU, and GPCC), the Amazon basin (A1) was characterized by a rainy season from November to April and a dry season (precipitation < 100 mm) from June to September. A1 showed maximum monthly total rainfall (mean ± SD) of 319 ± 90 mm in March and minimum of 42 ± 2 mm in July. In Northeast Brazil (A2) the maximum value was 173 ± 4 mm in March, and the minimum was 23 ± 4 mm in September. Over the Congo basin (A3), the seasonal cycle showed a bimodal pattern with maximum values in March (163 ± 3 mm) and November (171 ± 11 mm) and the minimum value in July (62 ± 4 mm). The annual climatological precipitation over A1, A2, and A3 was 2081 ± 36, 933 ± 35, and 1508 ± 52 mm, respectively.

Over A1 (Fig. 1b) the largest difference among datasets was ~24 mm or 8% relative difference, which occurred during the peak of the wet season (December–March) with the highest values reported by TRMM and the lowest by CLMNLS and CPC. During the dry season, the maximum difference in monthly total rainfall was ~10 mm or 17%. CMAP showed higher values than all the other datasets during the dry season. The annual precipitation varied ~5% among datasets, with the lowest value reported by CPC (1890 mm) and the highest by GPCP and TRMM (2003 and 2048 mm, respectively). Over the A2 region, the maximum difference in wet season rainfall among these datasets occurred between February and April was ~30 mm or

![Fig. 2. Precipitation dataset intercomparison using the coefficient of determination ($r^2$) over tropical areas used in this study. Monthly data ranges for the period January 1998–December 2005 at 1° of horizontal resolution except for CMAP and GPCP (2.5°).](image)
18%. During the dry season, the difference in monthly total rainfall was ~20 mm or 38% (Fig. 1c), with the lowest values in CPC and the highest in CPCP. The annual total rainfall varied from 778 for CPC to 1003 mm for GPCP, a difference of 22%. Over A3 (Fig. 1d), the difference among datasets was about 25 mm year-round. During the wet season, the lowest and highest values were reported by TRMM and GPCP, respectively. During the dry season, CMAP reported the highest values. This translated into a difference of 18% in the wet season and 26% in the dry season. The annual precipitation varied from a minimum of 1327 (GPCC) and a maximum of 1488 mm (CMAP), for a difference of 11%.

The monthly-mean values for the six datasets shown in Fig. 1 were significant (95% confidence interval) as estimated by the bootstrap approach (Wilks 2006). Ten thousand bootstrap estimates for a given month for all available years were performed for this calculation. The highest uncertainties were observed during the rainy season over the three study areas.

In summary, the three climatological products were similar, and their patterns were well represented by the long-term average of all the datasets except in the center of the Amazon basin (not shown). The pattern of annual cycle was well represented by all the datasets. However, the monthly total rainfall differences were as high as 24 and 25 mm for the Amazon and Congo areas, respectively, and 30 mm for Northeast Brazil. The maximum relative differences occurred during dry seasons for up to 17% over the Amazon area and 38% and 26% for the Northeast Brazil and Congo areas, respectively.

### 4. Precipitation datasets intercomparison

Figure 2 shows spatial distributions of the coefficient of determination ($r^2$) for monthly rainfall among all datasets for the period 1998–2005. Assuming a maximum discrepancy of 10% ($r^2 = 0.9$), the figure shows that most of the datasets were consistent over the southern portion of Amazon basin and Northeast Brazil. The highest discrepancies were observed over the northwest portion of the Amazon basin and across the Congo basin.

Temporally, a detailed analysis was conducted over A1, A2, and A3 (Fig. 3). First, we describe the main differences among gauge-only datasets. Over A1, CLMNLS showed higher values with respect to CPC and GPCC until 1999, and then the pattern of the bias was reversed. This behavior may be related to changes in data processing or changes in both gauge station network density and location (Willmott and Legates 1991; Silva et al. 2007). The smallest discrepancies were observed between CPC and GPCC ($r^2 = 0.96$, root-mean-square difference (RMSD) = 20.3 mm) and the highest observed between CLMNLS and CPC ($r^2 = 0.94$, RMSD = 18.5 mm).

Second, we describe the main biases of the combined datasets (TRMM, GPCP, and CMAP) relative to GPCC (Fig. 4 and Table 2). Over A1 CMAP had the strongest low bias during the wet season (October–April) and high bias during the dry season (May–September); therefore, it had the highest RMSD (12.8 mm). Over A2 the CMAP rainfall was higher by ~25 mm from January to July and lower by ~15 mm during

![Fig. 3. Monthly differences (mm) among gauge-only precipitation datasets over A1 and A2.](image)

<table>
<thead>
<tr>
<th>A1</th>
<th>A2</th>
<th>A3</th>
</tr>
</thead>
<tbody>
<tr>
<td>$r^2$</td>
<td>RMSD</td>
<td>$r^2$</td>
</tr>
<tr>
<td>CLMNLS vs CPC</td>
<td>0.94</td>
<td>23.3</td>
</tr>
<tr>
<td>CLMNLS vs GPCC</td>
<td>0.91</td>
<td>27.7</td>
</tr>
<tr>
<td>CPC vs GPCC</td>
<td>0.96</td>
<td>20.3</td>
</tr>
<tr>
<td>GPCC vs TRMM</td>
<td>0.99</td>
<td>8.3</td>
</tr>
<tr>
<td>GPCC vs GPCP</td>
<td>0.99</td>
<td>8.4</td>
</tr>
<tr>
<td>GPCC vs CMAP</td>
<td>0.98</td>
<td>12.8</td>
</tr>
<tr>
<td>TRMM vs GPCP</td>
<td>0.99</td>
<td>5.3</td>
</tr>
<tr>
<td>TRMM vs CMAP</td>
<td>0.98</td>
<td>12.5</td>
</tr>
<tr>
<td>GPCP vs CMAP</td>
<td>0.98</td>
<td>12.2</td>
</tr>
</tbody>
</table>
the rest of the year compared to those of the GPCC. In A1 and A2, TRMM and GPCP showed higher rainfall compared to GPCC especially from April to September, whereas over A3, TRMM, GPCP, and CMAP showed higher rainfall than GPCC. Over A3 the CMAP has exhibited different variability since 1998, which may be related to an artificial downward trend for the period after 1996, although its effects are expected to appear over ocean (Yin et al. 2004). Overall, CMAP showed the higher discrepancies over all the study areas (Table 2).

5. Interannual and decadal variations as assessed by the EOF analysis

Precipitation over tropical lands is strongly influenced by local and random high temporal frequency changes. To evaluate the large-scale coherence among different datasets, we applied empirical orthogonal functions (EOF; Wilks 2006). The analysis was performed for the austral summer [December–February (DJF)] from 1986 to 2005 over two areas in our domain: South America (10°N–18°S, 80°–33°W) and Africa (10°N–18°S, 16°W–40°E). Previous works using EOF were presented by Zhou and Lau (2001) for CMAP during the austral summer (DJF) in South America and by Yin et al. (2004) for GPCP and CMAP on a global scale. Our results for CMAP agreed with those reported by Zhou and Lau (2001). We compared only the first two modes because they contain most of the variance. EOF analysis is sensitive in the spatial domain; the results for the CLMLS dataset are, therefore, more likely to be affected by this characteristic when compared with the other datasets.

a. South American modes

Differences were observed between the spatial and temporal structures of the main modes for each dataset; however, spatially they resembled the climatological pattern extensively discussed in Sombroek (2001). The first mode (EOF1) showed interannual variability (frequency of 4–6 yr) with opposite behavior during the El Niño and La Niña events (Fig. 5a). All datasets captured the impact of the 1996 La Niña on Amazon rainfall. The first mode of GPCC explained 19% of the total variance, whereas the first mode of the other datasets explained 25% of the total variance. Spatially (Fig. 6), the first mode was characterized by a northwest–southwest dipole over the Amazon in all the datasets. The dipole was strongest in CPC and GPCP and weakest in CLIMNLS. Overall, the first EOF mode of CMAP, GPCP, and GPCC were similar (Fig. 5a). CLIMNLS agreed with these datasets until mid-2000, and CPC showed opposite interannual changes before the late 1980s with respect to the other datasets.

The second precipitation mode (EOF2; Fig. 5b) explained 18% of the total variance (but 22% for CPC and GPCP) and appears to be dominated by interdecadal and quasi-biennial fluctuations (two to three years). For lower frequency fluctuations, there was a good agreement among all the datasets. Until 1995, CLMNLS, CMAP, GPCP, and GPCC were similar in terms of temporal variation and amplitude. Spatially (Fig. 6), the second mode showed an off-phase rainfall change between the northwest corner and the rest of the tropical and subtropical regions. The intercomparison of principal components (PCs) time series showed the lowest coefficient of determination values, with
Fig. 5. PC time series over South America for (a) mode 1 and (b) mode 2. (c),(d) Same as (a),(b) over Africa. Boxes represent approximately the extent of El Niño (black) and La Niña (white) events (available online at http://www.cpc.noaa.gov).

Fig. 6. EOF analysis over (left) South America and (right) Congo basin areas during the austral summer (DJF) for the period 1986–2005.
CLMNLS for the first mode and CMAP for the second mode.

b. African modes

In this region no similarity was observed in the spatial pattern of the first precipitation mode for GPCC, CPCP, and CMAP, although the time series of this mode (Fig. 5c) showed variation in the low frequency (two to six years). The variance explained for the first mode was ~25% for GPCC and GPCP but 19% for CMAP, and the second mode explained ~18% of the total variance for GPCC and CMAP but 20% for GPCP. For the GPCC and GPCP, the main variation was observed in the ENSO-like time scale. The variations for GPCP and CMAP were opposite in the 2-yr scale before 1995, but a better agreement was observed after this year in the lower frequency (~6 yr). The spatial pattern (Fig. 6) of this mode for GPCC showed a homogeneous change across the domain. But CMAP and GPCP had a pattern with three meridional belts with opposite signs of their coefficients. The time series of the second mode showed an interdecadal, an interannual, and a 2-yr fluctuation since 1997. This mode showed a better agreement among the datasets, especially CPCP and CMAP. The similarity between these datasets was also observed in the spatial domain (Fig. 6). Notice that the time series of the GPCC’s first mode looks similar to the GPCP’s second mode. Therefore, the precipitation modes over Africa were not similarly characterized by the datasets. The figure also shows a similarity between EOF1 and EOF2 for GPCC over the Congo basin that may be a consequence of the merging procedure. If there are too few (or zero) gauges, GPCP does not perform analyses for large-scale adjustments which is different from CMAP, which uses the gauge analysis without considering the gauge number (Yin et al. 2004). Thus, insufficient rain gauge data may reproduce unreliable precipitation spatial structures (Adler et al. 2003) in GPCC. The result for the first mode was different for all datasets, and despite showing fluctuation in similar scales, the variability of the main peaks did not coincide. The intercomparison of principal component time series showed that the lowest coefficients of determination were related to CMAP.

Our analysis of the first two EOF modes revealed a better consistency among all the datasets over South America (except for CMAP and CLMNLS) than those over Africa. However, the three sets of merged analyses (TRMM, GPCP, and CMAP) are defined over land using GPCC as their main input. Over gauge-sparse areas, the merged analysis should provide coverage with better quality as a result of the usage of satellite observations. Differences among the merged analyses were from those in the satellite data used and in the merging algorithms. It is difficult to determine which one is better than the others by intercomparisons among the datasets. Rather, differences among the merged analyses should be a measure of the uncertainties of the analyses. From that point of view, substantial differences in the EOF analysis over tropical Africa implies that caution is needed when explaining the variability as seen from the individual precipitation datasets over the region.

6. Sensitivity of dataset to climate events

The annual precipitation anomalies for the period 2000–05 were used to evaluate the spatial and temporal sensitivity of the datasets to climate events. The anomaly was calculated as the difference of the annual precipitation minus the annual climatology for a given dataset. In section 3 it was observed that CRU and GPCC climatologies were very similar; therefore the baseline climatology used to calculate the annual anomalies was arbitrarily taken as that of GPCC. The horizontal resolution was reset to 1° except for GPCP and CMAP (2.5° × 2.5°). The Climate Prediction Center of the National Oceanic and Atmospheric Administration (NOAA; available online at http://www.cpc.noaa.gov/) reported a La Niña event from 1998 to 2001, a moderate El Niño in 2002/03, and a weak El Niño in 2004/05. Different studies have shown that during El Niño events, negative anomalies of precipitation during the wet season are observed in eastern Amazonia and Northeast Brazil and an opposite pattern is observed during La Niña events (Ropelewski and Halpert 1987). Over Africa the early (late) phase of El Niño is often related to cold (warm) SSTs in the tropical Atlantic and Indian Oceans, resulting in wetter (drier) rainfall patterns over most of eastern and southern Africa. However, a direct effect of ENSO over the Congo basin was not found (Nicholson and Kim 1997; Nicholson 1997; Nicholson and Selato 2000).

Figure 7 shows the annual anomalies for different datasets. Over the Amazon basin, the year 2000 showed wetter than normal rainfall in the Amazon, which was consistent with a La Niña episode. A transition to drier conditions was apparent in all the datasets in 2001, especially CPC and CLMNLS showing negative anomalies over most of the region. The negative anomalies expected during 2002/03 were observed in all the datasets, especially in the southwest Amazon. In 2004 and 2005, the gauge-only datasets showed most of the Amazon undergoing dry conditions, whereas satellite-based or satellite–rain gauge–merged datasets showed much weaker or spatially limited dry anomalies as observed in TRMM and CMAP. However, in 2005 all
Fig. 7. Precipitation anomaly for the period 2000–05 for (a) CLMNLS, (b) CPC, (c) GPCC, (d) TRMM, (e) GPCP, and (f) CMAP. The spatial resolution is 1° × 1° except for GPCC and CMAP, which have 2.5° × 2.5° spatial resolution. GPCC climatological precipitation for the period 1961–90 was used for the anomaly.
datasets showed below-normal precipitation over the south-west area of the Amazon basin.

In Northeast Brazil the year 2000 was wetter than normal, which was consistent with a La Niña episode. Except for TRMM, drier conditions were observed over this region, which was consistent with a warm phase of the Atlantic SST dipole (Nobre and Shukla 1996; Hastenrath 2000) in 2001 as reported by Fundação Cearense de Meteorologia e Recursos Hídricos (FUNCEME; available online at www.funceme.br). The warm phase is defined by positive SST anomalies in the northern tropical Atlantic and negative anomalies in the southern tropical Atlantic. The opposite condition, or cold phase, often causes floods in Northeast Brazil as observed in 2002 (except CPC). The 2002/03 El Niño coincided with near-neutral conditions in the Atlantic, producing a drier than normal rainy season in inland areas during 2003, shown in all datasets except TRMM. The overall agreement among all the datasets showing positive rainfall anomalies in 2004 could be a consequence of the Southern Atlantic convergence zone (SACZ) event, formed over most of Northeast Brazil and causing as much as 3 times the normal monthly rainfall during the wet season (see the January 2004 issue of Climanalise, available online at http://www.cptec.inpe.br/products/climanalise/0104/index.html).

Over the Congo basin, the datasets showed a similar rainfall pattern during the year 2000, with positive anomalies in the west of the basin and in the central part of the Democratic Republic of Congo. Positive anomalies were observed during all years in CMAP, suggesting bias in this dataset. The early phase of ENSO produces reduced rainfall in the Congo River basin, especially near its delta (Nicholson and Kim 1997). Therefore, the below-normal precipitation in the western Democratic Republic of Congo and northern Angola observed in TRMM, GPCP, GPCP, and CMAP in 2001 and 2003 were consistent with that pattern. The reverse pattern during the mature phase of 2002 El Niño was observed in all datasets except GPCP. However, 2004 did not show a typical mature El Niño– precipitation pattern, probably due to a weak response in the Atlantic and Indian SSTs to this event.

7. Conclusions

In this work we compared three gauge-only (CLMNLS, CPC, and GPCP) and three satellite and rain gauge combined (TRMM, GPCP, and GPCC) precipitation datasets for periods in which these datasets overlap. The comparison of gauge-only datasets showed that GPCC and CPC have lower discrepancies over South America (highest $r^2$ and lowest RMSD). Over the Congo basin, GPCP and GPCC appear to be similar, although differences among datasets were larger than those in South America. The long-term domain average showed 5% differences among the datasets over the Amazon region, 22% over the Congo area, and 11% over Northeast Brazil. Although the overall seasonal precipitation pattern was similar for all the datasets, large uncertainties were observed in the spatial and temporal patterns of the interannual to decadal variations, including disagreement in sign of the interannual anomalies for the period after 1998 over South America and for the entire analysis period (1986–2004) over the Congo area. In general, CMAP and CLMNLS were different from all the other datasets. GPCC, TRMM, and GPCP significantly agree over the tropical areas in South America.

Acknowledgments. This work is supported by NASA Grant NNG04GK90G and by NOAA and CPPA projects (Grant 00048977). Thanks to the Weather Forecast and Climate Studies Center (CPTEC) of the National Institute for Space Research (INPE) for providing its data used in this study. Thanks to Dr. Hui Wang for his insightful suggestions and to Ms. Susan Ryan for her editorial assistance. The authors are thankful to the three anonymous reviewers for their important suggestions, which led to significant clarification of the discussion in this work.

REFERENCES


