Which rainfall dataset can be used to study African monsoon at intra-seasonal timescale?

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Abstract :

The main goal of this paper is to provide consistent informations on the use of large scale rainfall datasets to study the West African monsoon at intra-seasonal time-scale. The 5-day versions of the GPCP and CMAP datasets are compared on the 1979-2004 period with respect to *in situ* precipitations over the West African region. It is shown that (i) CMAP underestimates (overestimates) precipitations compared to GPCP on the continent (ocean); (ii), important errors are located on the southern and northern margins of the ITCZ and on heavy rainfall regions. Large differences exist between CMAP and the other sources (CILSS and GPCP); (iii) overall GPCP is closer to observations than CMAP in terms of correlation whereas CMAP is better in terms of bias; (iv) a multi-year downward tendency in the annual CMAP minus GPCP differences is observed. So, an improved dataset available for download on the web and based on the GPCP variability and the CMAP distribution is proposed.

Introduction:

This article aims at comparing different precipitation datasets frequently used for climatology purposes on the West African Monsoon (hereafter named WAM) region. As well known, WAM has been marked by a severe drought during last decades and exhibit important inter-annual variability. This situation had disastrous human and economic consequences (Folland et al 1986, Fontaine and Janicot 1993), in particular over the Sahel area one of the poorest regions in the world and thus very dependent on its agriculture. The deterioration of the network of ground measurements during last decades is another cause for interest in this type of research since climatologists have to use reliable data on relatively long period (in general higher than 30 years).

The goal of this article is thus to provide to the users comparison between two global rainfall products (gauge and satellites' estimation) at short temporal time scales (lower than one month, i.e. pentade to decade) for allowing better intra-seasonal diagnostics such as rainfall vagaries during the rainy season. In this context climatologists need data on intra-seasonal temporal scales (average of a few daily precipitations on a given space) and use in particular the 5-day version of the CMAP (Climate Prediction Center Merged Analysis of Precipitation*,* Xie and Arkin, 1997) and GPCP (Global Precipitation Climatology Project, Huffman et al., 1997, Xie et al. 2003) datasets. The comparison of these data was already carried out at monthly time scale by *Gruber et al., 2000* and Yin et al; (2003) for the quasi-global time/space scale (between 60°N and 60°S), and confronted to *in situ* observations on the Sahel region (Ali et al., 2004 and 2005*)* in terms of statistical distribution, skew and error. GPCP and CMAP are here selected because these authors conclude that at a monthly time scale and among several other estimates, CMAP is the best product overall followed by GPCP and GPCC.

GPCP and CMAP have the advantage to be available over a long period (1979-present) and to provide values over ocean: this is fundamental for studying the monsoon system and namely intra-seasonal variability time-scale, since the Sahelian rainy season and its onset are partially controlled by early spring precipitations, i.e when the Inter-Tropical Convergence Zone (ITCZ) is located over both the Guinean coast and the Gulf of Guinea (Louvet et al. 2003).

The aim of this study is twofold: comparing these datasets at a five and ten days temporal scale versus *in situ* observations over the sub-Saharian West Africa for providing a more accurate product (i.e, closer to reality) over the WAM domain.

1/ Data sources:

GPCP and CMAP datasets are provided on a 2°5 longitude x 2°5 latitude space resolution and provide average values of 5-day precipitations (expressed in mm/day). The sources used for the constitution of these satellite estimates are not rigorously the same ones and concatenation's algorithms are also different, as detailed in Gruber et al. (2000). The pentad CMAP is defined by combining satellite estimates from IR, OLR, SSMI and MSU over ocean and by combining IR, OLR and SSM/I satellite estimates and the GTS gauge data over land; the GPCP pentad analysis is defined by adjusting the pentad CMAP against the monthly GPCP so that the overall magnitude of the pentad GPCP agrees with that of the monthly GPCP. Over land areas, the gauge data dominates the final analysis while uncertainties exist in the magnitude of precipitation over ocean (Dr. Xie's personal communication).

These rainfall estimates are compared with *in situ* observations at different timescale (5-day to 10-day). We selected the decadal rainfall amounts of the CILSS (Centre Inter-étatique de Lutte contre la Sécheresse au Sahel) provided by the Centre Régional Agrométéorologie–Hydrologie–Météorologie (CRA) on the period 1979-2000, each year being documented from early May to mid-September. These *in situ* data resulting from an operational network represent the best observational product existing currently over the Sudano-Sahelian latitudes and have been transformed on a 0°5x0°5 grid (thanks to a krieging method (Ali et al. 2004). A second *in situ* data source comes from daily rainfall amounts compiled by 3 institutes: IRD (Institut de Recherche pour le Développement), ASECNA (Agence pour la Sécurité de la Navigation Aérienne en Afrique et à Madagascar) and CIEH (Comité Inter-africain d'Etudes Hydrauliques). Here daily values were interpolated on the 2.5°x2.5° grid of NCEP/NCAR reanalysis (National Center for Environnemental Prediction and National Center for Atmospheric Research, Kalnay et al., 1996), by assigning each station value to the nearest grid point and averaging all the related values. These data are available over the 1979-1992 period between 1st March and 30th November. Additionally, we used NOAA's OLR (Outgoing Longwave Radiation, Liebmann and Smith 1996) for comparison with GPCP and CMAP. This dataset does not really contain precipitation values but is frequently used in tropical climatology because OLR provides a very good estimate of convective precipitations.

2/ Comparison of the GPCP and CMAP datasets:

This comparison is made by computing the relative error (noted RE) between the two datasets. This is defined by calculating the relative CMAP minus GPCP differences over the period 1979-2004 in mm/day :

$$RE = \left[(CMAP-GPCP) / (CMAP+GPCP)/2 \right] *100$$

Thus, any positive (negative) RE expresses an overestimation of CMAP (GPCP) taking into account the mean seasonal variations of the estimated rainfall amounts. This quantity is obviously sensitive to the denominator number and hence cannot be correctly used when this value is lower than ~1 mm/day: analysing relative errors on negligible quantities of rains has no sense.

Mean seasonal maps.

Fig. 1 shows mean relative errors by season (JFM, AMJ, JAS and OND) over areas where mean seasonal rainfall exceeds 1mm/day. We first observe that continent and ocean have different behaviours as showed first by Gruber et al. (2000) and Yin et al. (2003): negative (positive) REs are mainly encountered over the continent (ocean) meaning that CMAP underestimates (overestimates) precipitations compared to GPCP on the continent (ocean), whatever the season is. Moreover, uncertainties remain regarding the satellites' estimation of precipitations. Despite distinct differences amongst the dataset over both ocean and continent, other discrepancies are to be noticed. For example, this bias affects directly the position of the rainbelt within the ITCZ (Inter-Tropical Convergence Zone) since the strongest REs are located on the southern and northern margins of the rain band. Over ocean high REs stand in coastal regions with weak precipitations, i.e mainly close to Congo's coast during the JFM, AMJ and OND seasons. In JAS, lowest REs are located between 10°W and 10°E southward to the coastal area. Thus, the greatest REs in absolute values are positioned on areas where "cold" Sea Surface Temperatures (SST) prevail, i.e > 25°C in seasonal average (not shown here). Over land, the largest errors are encountered primarily on regions with heavy rainfall (more than 10 mm/day). Thus over the Fouta Djalon region (Guinea Conakry, Sierra Leone) large differences are observed (-20%, GPCP overestimates CMAP data) certainly because it is a mountainous area close to the ocean: it is difficult to estimate precipitations in mountainous regions at a 5-day time scale due to both the scarcity of available *in situ* data and more generally because the low spatial density of raingauges limiting the local reality of GPCC algorithms (Rudolph et al. 1996). However, the Adamaoua mountains (Cameroon) with more or less the same geographical characteristics, display clearly lower REs. Gruber et al. (2000) have shown that at global scale great differences will tend to appear near the coastal regions (land/water boundaries) according to the different estimation methods over land and sea. In West Africa they mainly concern continental areas: for example Guinea Conakry, Sierra Leone and not Liberia. Indeed, the fewer the pluviometric stations per grid point, the greater the incertitude relative to the estimation: the Adamaoua mountains have a better raingauge network (in terms of number of gauges and their repartition) than the Fouta Djalon area.

Differences between CMAP and GPCP are also due to the differences in rain gauge sources: CMAP data uses an uncorrected version of the Global Precipitation Climatology Center whereas GPCP has been built with a corrected version, as shown by Gruber et al. (2000) for the period after 1986. Note that REs during the two rainy seasons occurring in AMJ and OND along the Guinean coast are rather similar for the Sierra Leone surroundings, but they are not for central Guinea where errors in OND exceed those in AMJ. Overall the African coastal regions do not concentrate the largest CMAP-GPCP differences (see also Gruber et al 2000).

The CMAP and GPCP data are compared in terms of inter annual variability using seasonal maps of correlation coefficients (calculated with 5-day anomalies) between each grid point at a 5-day time scale (Fig. 2). Notice that values are globally high over ocean except south of the Nigeria and Ivory Coast and that the correlation and REs patterns are statistically linked: the highest REs and the lowest correlation coefficients are encountered in same areas. However, other regions of dissension can be pointed out, for example, central Nigeria (low correlations from April to December). As in Fig. 1, there is no clear homogeneous adequacy between these two datasets. These concerns remain true when calculations are made on a monthly time step (not shown here) albeit correlations decrease. This arises the question of systematic biases. Inter annual evolution of the CMAP minus GPCP rough differences in mm/year have hence to be analysed for selected regional indexes.

Mean regional indexes.

In order to verify CMAP / GPCP internal coherency on regional scale this section presents some annual rainfall amounts averaged over key-regions. These indexes have been defined within the framework of AMMA program research (African Monsoon Multidisciplinary Analysis) and with regards to homogeneous precipitation characteristics as displayed in Table 1: globally, the negative differences dominate indicating that GPCP estimates are higher than CMAP values except over Ocean (here the Guinea Gulf region).

Bars in Fig. 3 represent annual relative errors between annual rainfall amounts of CMAP minus annual rainfall amounts of GPCP over selected regions (in percentage). This figure shows that differences are not constant all along the period. Arkin and Xie, (http://www.cgd.ucar.edu/cas/guide/Data/xiearkin.html), Arkin (personal communication) and Yin et al. (2003) talk about an artificial downward trend which concerns only the Ocean domain of CMAP after 1996. The diagrams display also clear inter-annual variability and positive correlations ranging from +0.33 to +0.81 (i.e., 10% to 65% of common variance) for Central Sudan and Central Sahel respectively, these values being significant at the 95% level except over Central Sudan. The relative differences between the 2 datasets increase during the 1979-2004 period and can exceed 15%. The lowest correlations must be associated with certain sign reversings in some years or periods (e.g., 1980-1983 over central Sudan and Guinea). Thus, any statistical analysis based on annual rainfall CMAP or GPCP estimates will be sensitive to the chosen period or to the years selected. However, these inadequacies can be reduced because it exists a small number of large CMAP-GPCP differences which are, fortunately, isolated in time and space. So, for each pentad and grid point concerned, we calculate the relative differences and re-adjust all pentad values with differences greater than 50% during the rainy season over the CILSS region, following the equation:

$$newCMAP(t)=((oldCMAP(t-1)+GPCP(t)+oldCMAP(t+1))/3$$

The new version of CMAP increases correlations (bars and line in Figs. 3) and reduces biases as in 1987 (Fig. 3c). This corrected version will be used hereafter.

As said above, GPCP and CMAP pentad precipitation analyses are defined by merging several kinds of observation-based individual data sets (i.e., GTS gauge observations and Satellite measurements). One of the common source of CMAP and GPCP data is the Outgoing Longwave Radiation (OLR) since low OLR values are used to locate the organized convective systems in the Tropics due to the relationship between low OLR, high cloud-tops and convective precipitation. However it exists non-precipitating high clouds; the links change also with latitude and are sensitive to spatial variations of surface parameters. In fact the correlations between the 5-day regional series of OLR, CMAP and GPCP (Table 2) over the 1979-2004 period indicate that GPCP is generally closer to OLR than CMAP, except over the Guinean Gulf during the OND period. It is noteworthy that GPCP data register higher correlations with OLR than CMAP although the differences are small. Over land dry areas show logically low correlations, but the main discrepancies are located over Central Sudan and the smallest over Central Sahel.

From a zonal point of view:

To study the onset of rainy seasons, it is important to count on realist pluviometric meridional gradient. Indeed, Sultan and Janicot *(*2000), Louvet et al. (2003), Fontaine and Louvet (2006) for example, have shown that the onset phenomena can be diagnosed by the near concomitant decrease/increase at the Guinean/Sahelian latitudes associated to the abrupt northward shift of the rainbelt within ITCZ. Thus we have to estimate the relative reality of satellite datasets in terms of meridional rainfall gradients at the time of the onset by comparing with in situ observations. In this context we will focus on the IRD data over the available period 1979-1991, since the CILSS data document only the Sahelian belt.

Two rainfall indexes are first defined using the 5-day IRD, CMAP and GPCP data over the 7.5°W - 7.5°E window, due to some lacks in IRD data outside: a Southern index (SI) averaging precipitation over land between 5°N and 7.5°N and a Northern Index (NI) averaging between 12.5°N ad 17.5°N. Then as proposed by Fontaine and Louvet (2006), an onset index is defined as the difference between the NI and SI standardized indexes, after elimination of time variability < 15 days by a butterworth time filter (Murakami, 1979): when the rainbelt migrates northward (southward), the values increase (decrease). So, the onset date is defined as the first pentad of a 20-day (or longer) period registering positive values.

The date of monsoon onset is a very sensitive parameter because it well depicts both the position and timing of the rainbelt within the ITCZ. The subsequent dates are displayed in Fig. 4 by data set and year. Notice that if the mean date is similar in all data sources: the 37th pentad, (i.e. end of June), the yearly differences can be strong: 25 days, between CMAP and IRD, or between CMAP and GPCP. Overall the dates defined through GPCP seem to be closer to observation (IRD) than those from CMAP due to the highest correlation between GPCP and IRD over land.

Comparison to *in situ* observations and data merging:

Simple statistics (means, standard deviations, first and fourth quintiles and correlations) are efficient to point out the main discrepancies between Satellite estimates and *in situ* measurements (CILSS and IRD). Fig. 5 displays the results for the selected regions. GPCP is closer to observations than CMAP in terms of correlation (intra-seasonal rhythms) whereas CMAP is better in terms of bias (pentad anomalies) except over the Ocean (region#5). Correlations are sensitive to the spatial scale. For example, the GPCP indexes show greater correlations when they are defined over larger regions (whole CILSS or WAM-Central for example). This is attested also with IRD data over the Central Guinea region. The CMAP data are generally closer to *in situ* observations in terms of statistical distribution (area averages, first and fourth quintiles) but standard deviations are lower for the whole CILSS region, central WAM and central Sudan (Fig. 5). The Western Sudan, documented by a small number of rainfall stations (Ali et al. 2004 and 2005), is very specific. Satellite estimates comprise unquestionable uncertainties, but the above results show that compared to the IRD and CILSS datasets, GPCP shows higher correlations and lower standard deviations, whereas CMAP has closer means and percentiles. Thus, it is possible to define an improved dataset (called MERGE hereafter) based on GPCP variability and CMAP distribution. This is easily achieved by subtracting GPCP mean values and adding up CMAP mean values to the GPCP data at each grid point and pentad.

Fig. 6 displays the respective CMAP, GPCP and MERGE statistics versus *in situ* CILSS and IRD observations per index. Correlations are not displayed because MERGE has by construction the same variability than GPCP. The relationship between CILSS and Satellite estimates (CMAP, GPCP and MERGE) is illustrated in Fig. 7. For the whole CILSS and WAM continental regions, MERGE is clearly more confident, i.e., the closest to the bisecting line: the GPCP tends to overestimate whereas the CMAP data overestimate low values but underestimate high values. Over the other selected regions MERGE improves GPCP for low values but underestimates heavy rainfall. The Hovmoeller diagram (time/latitude) in fig. 8 attests also that that the annual movement of the rain band is well depicted both over ocean and continent.

Interannual comparison and examples of MERGE results

Figs. 9 detail correlations and inconsistencies versus *in situ* precipitation for the whole CILSS region and over the common period 1979-2000. The first panel focuses on the inter-annual evolutions of correlation coefficients computed between the successive nine 10-day anomalies in JAS versus the mean significant level at p=0.1 taking into account autocorrelations in the series (line). Notice the good global accordance, except in years 1982 and 1987, and the high correlations encountered with GPCP and MERGE. Due to the small length of time series (only 9 decades per year are considered) the inter-annual variations in the relationships cannot be detailed more.

Figs. 9 b,c present the root mean square error (RMSE) and the mean bias. RMSE is the mean square root of the sum of the variance and is hence always positive whereas the BIAS indicates the mean of differences between the series and gives access to the sign of these differences: RMSE= mean (satellite-CILSS) ^{2} and BIAS= mean (satellite-CILSS).

The strongest errors come across CMAP data especially in 1986, 1994 and 1999 but are not systematic: CMAP biases are negative in years 1980-1987 but positive after with larger differences in 1999. Both figs. attest decreasing discrepancies between *in situ* values and Satellite estimates when MERGE is considered. This arises for a small part because RMSE takes into consideration the variance: MERGE is a multivariate estimate and deflates therefore the variance versus CMAP and GPCP. However, as shown by the negative grey bars in Figs. 9 c, the main reason is that hybrid data reduce errors all over the period although they under evaluate precipitation versus *in situ* measurements.

Previous sections have proved that the CMAP and GPCP biases were more important in specific years and regions (Fig. 6 for example). They showed also the difficulty of Satellite estimates to correctly capture the annual meridional migration of the rainbelt. Fig. 10 illustrates simply the improvements obtained with MERGE in this framework. The scatter plot in fig. 10 is relative to western WAM in 1998, a year. Note the good adequacy between MERGE (in green) and CILSS whereas both GPCP and CMAP data (red and blue respectively) are far from observations.

Discussion and conclusion

The aim of this study was to compare different precipitation datasets frequently used for climatology purposes or climate impacts on the West African Monsoon at short temporal scales (less or equal than 10-day) as the 5-day versions of the GPCP and CMAP data. The final objective was to provide a diagnostic on the bias of large scale rainfall dataset over West Africa where the number of meteorological stations has decreased since some decades. This study was also developed to help future users to choose the adequate dataset over the region for impact studies for example. Globally, the results show that in all seasons CMAP underestimates (overestimates) precipitations compared to GPCP on the continent (ocean). The strongest relative errors are located on the southern and northern margins of the ITCZ and over land; they are primarily encountered on heavy rainfall regions, as over Fouta Djalon and Nigeria. Other investigations showed that specific but large differences exist between CMAP and the other sources (CILSS and GPCP): so, a correction has been applied on the CMAP data. Additionally, if spatial distribution and time variations of the 5-day CMAP and GPCP are quite similar, a multi-year downward tendency in the annual CMAP minus GPCP differences is observed on the 1979-2004 period. The timing of the meridional displacement of the rainbelt is also somewhat different, sometimes far from *in situ* observations. Overall GPCP is closer to observations than CMAP in terms of correlation (intra-seasonal evolution) whereas CMAP is better in terms of bias. Thus, an improved dataset set called "MERGE" based on the GPCP variability and the CMAP distribution has been proposed for the West Africa region. This new product is available for download on the Climatology Research Center of University of Burgundy Website:

http://www.u-bourgogne.fr/climatologie/AMMA_D1.1.3/other_rainfall_product.html

MERGE is a more confident product at a fine temporal resolution (5-day) for West African studies over the recent period.

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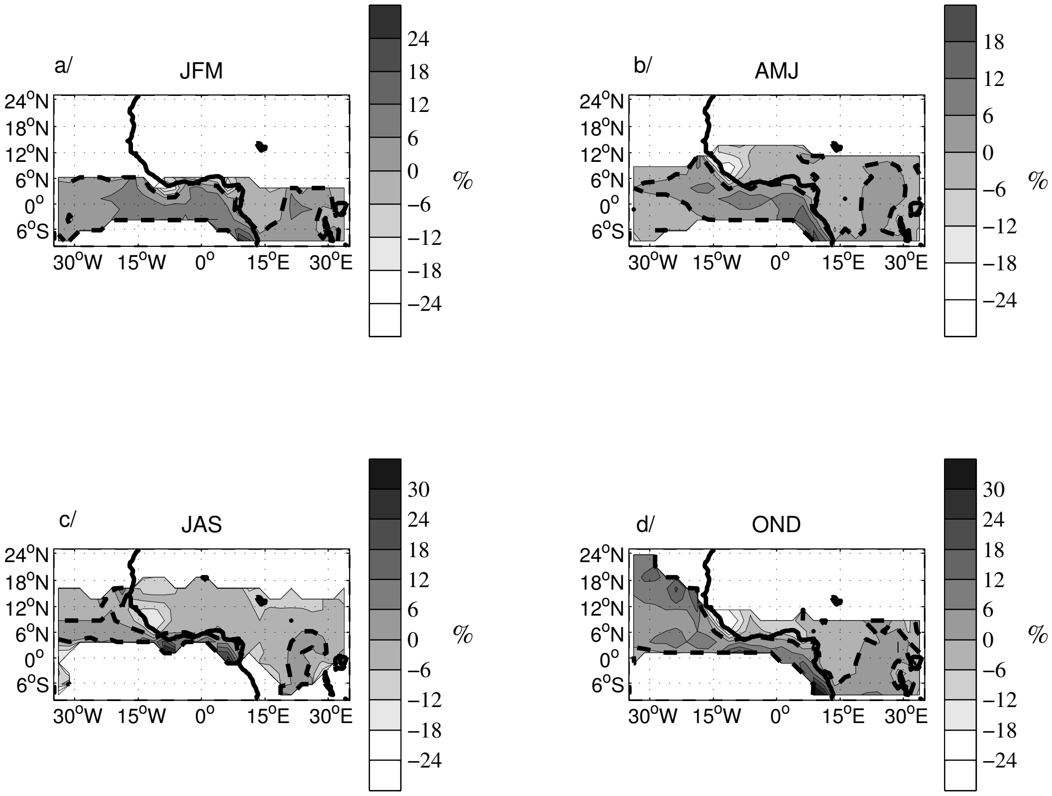
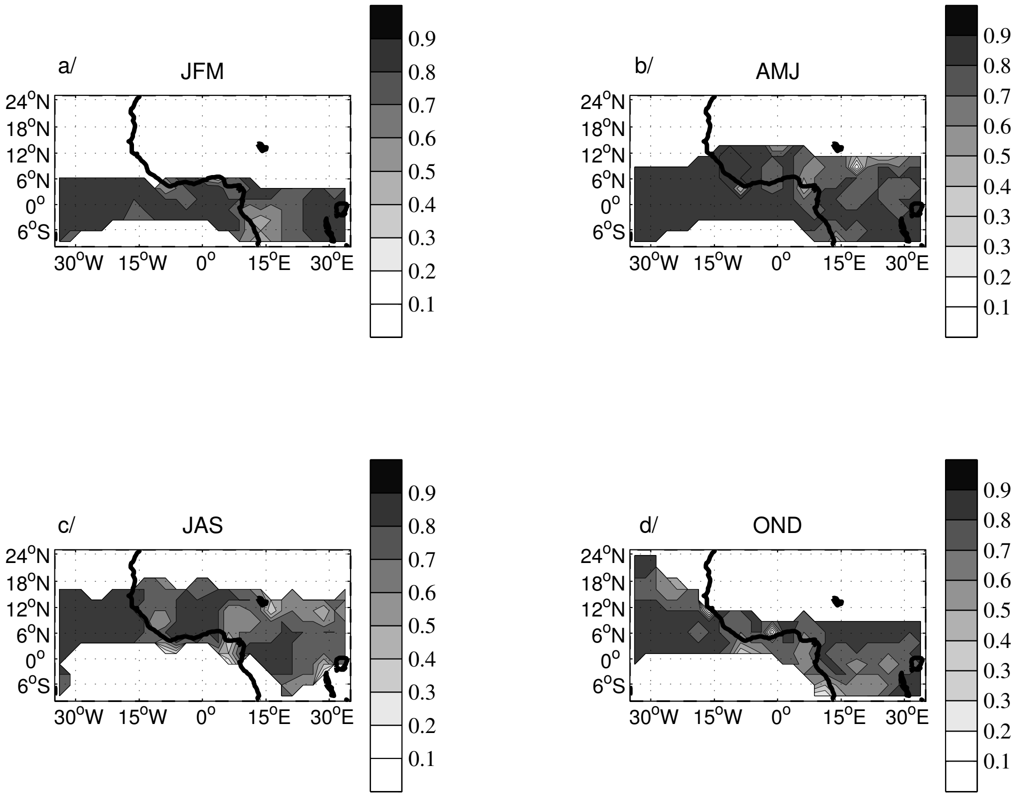
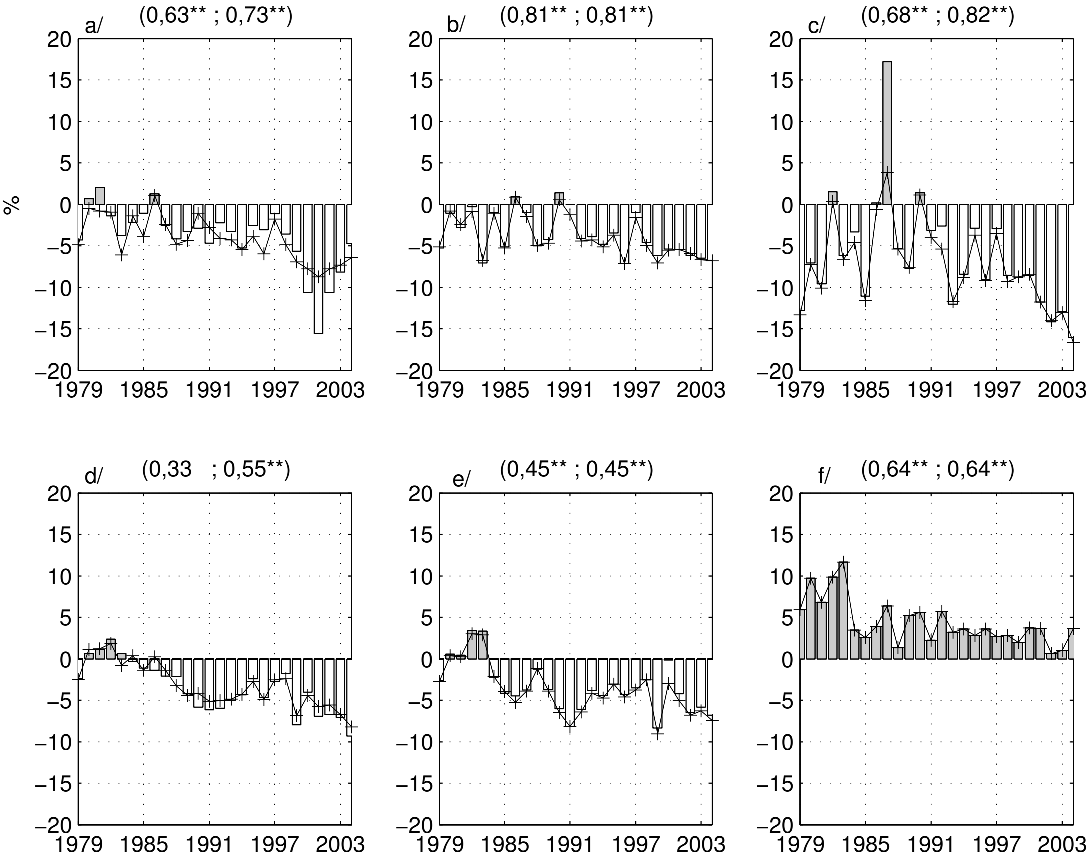
Figures:



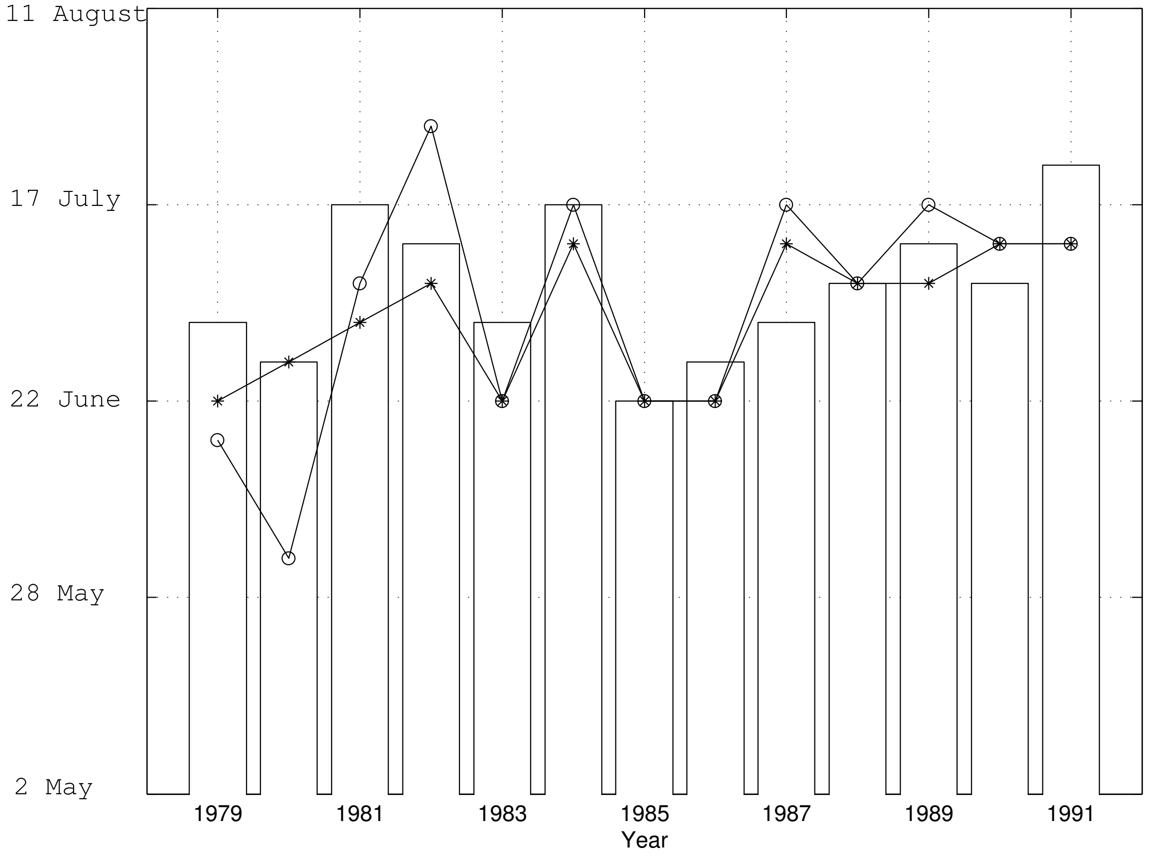
1/ Mean seasonal evolution of relative errors in percentages between CMAP and GPCP over the period 1979-2004 at a 5-day time scale: January to March (JFM), April to June (AMJ), July to September (JAS), and October to December (OND). Differences < 1mm/day are not displayed. The zero line is the thick dashed line.



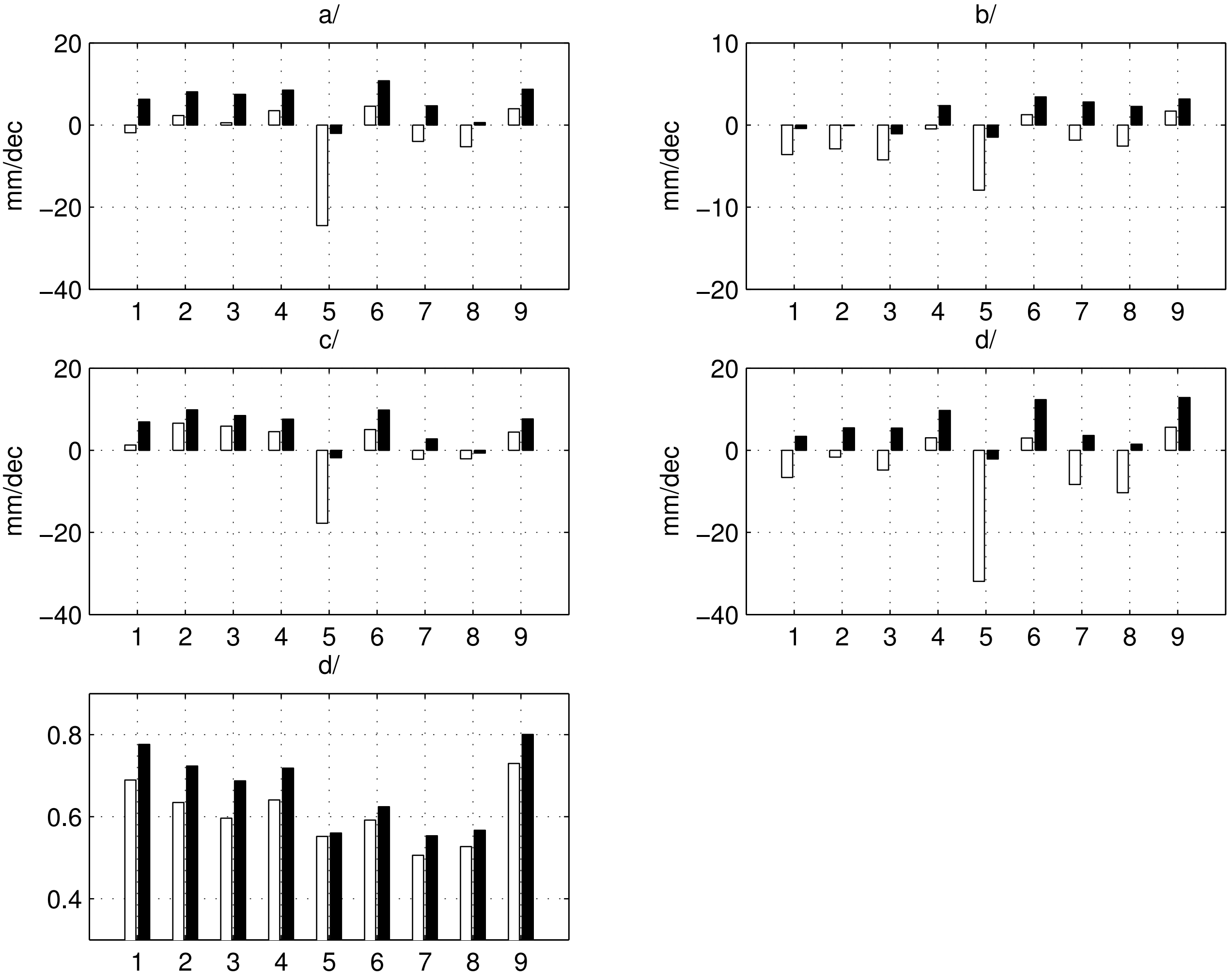
2/ As in figure 1 but in terms of correlation coefficients (calculated with 5-day anomalies).



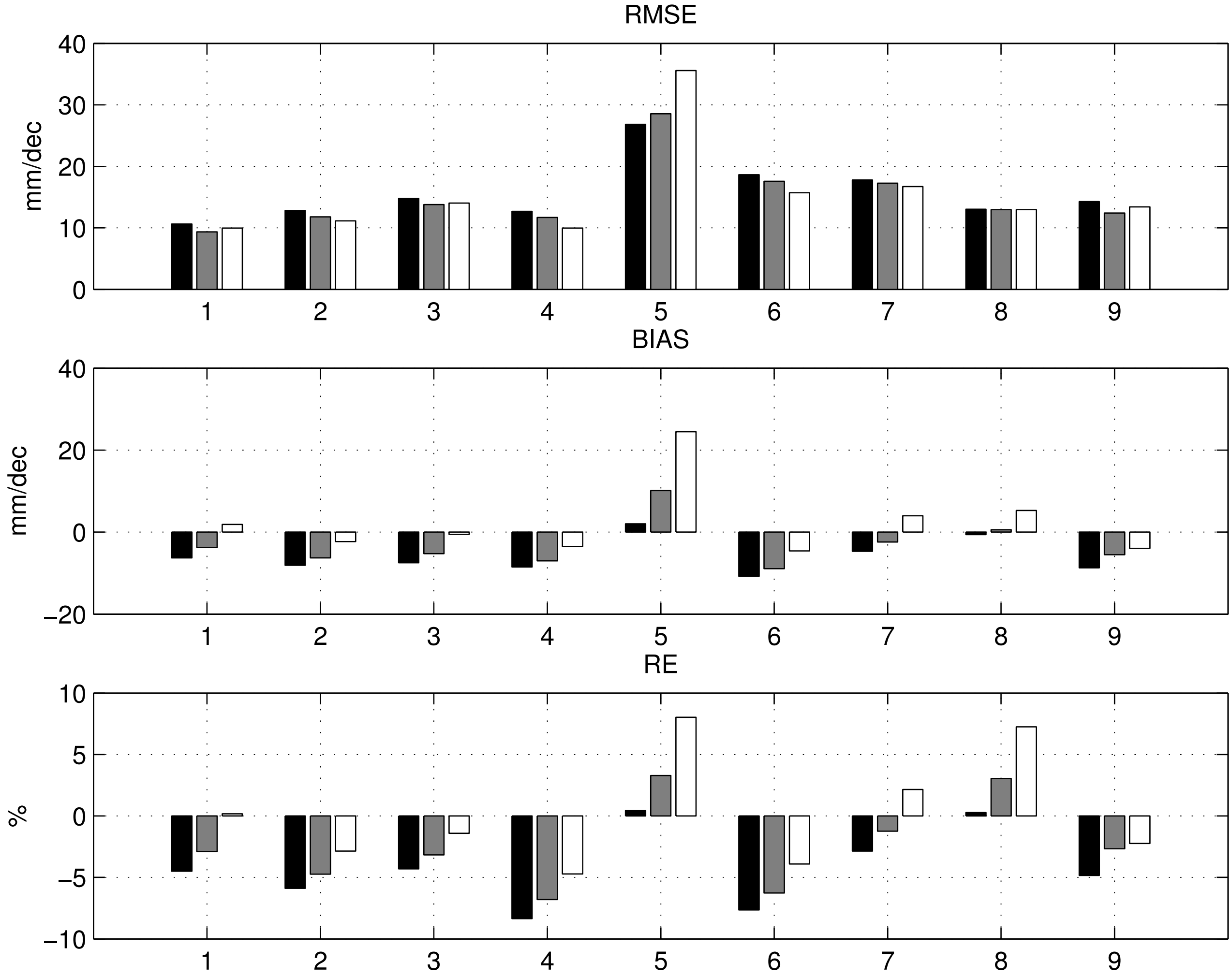
3/ Annual relative errors between annual rainfall amounts of CMAP minus annual rainfall amounts of GPCP over selected regions (bars in percentage): a) Western Sahel, b) Central Sahel, c) Eastern Sahel, d) Central Sudan, e) Central Guinea and f) Guinea Gulf. Correlation coefficients in brackets (first number calculated with the uncorrected version, second with the corrected one). Two asters indicate significant correlations at the 95% level of significance, taking into account autocorrelations in the series. The curves show the results obtained with the corrected version of CMAP.



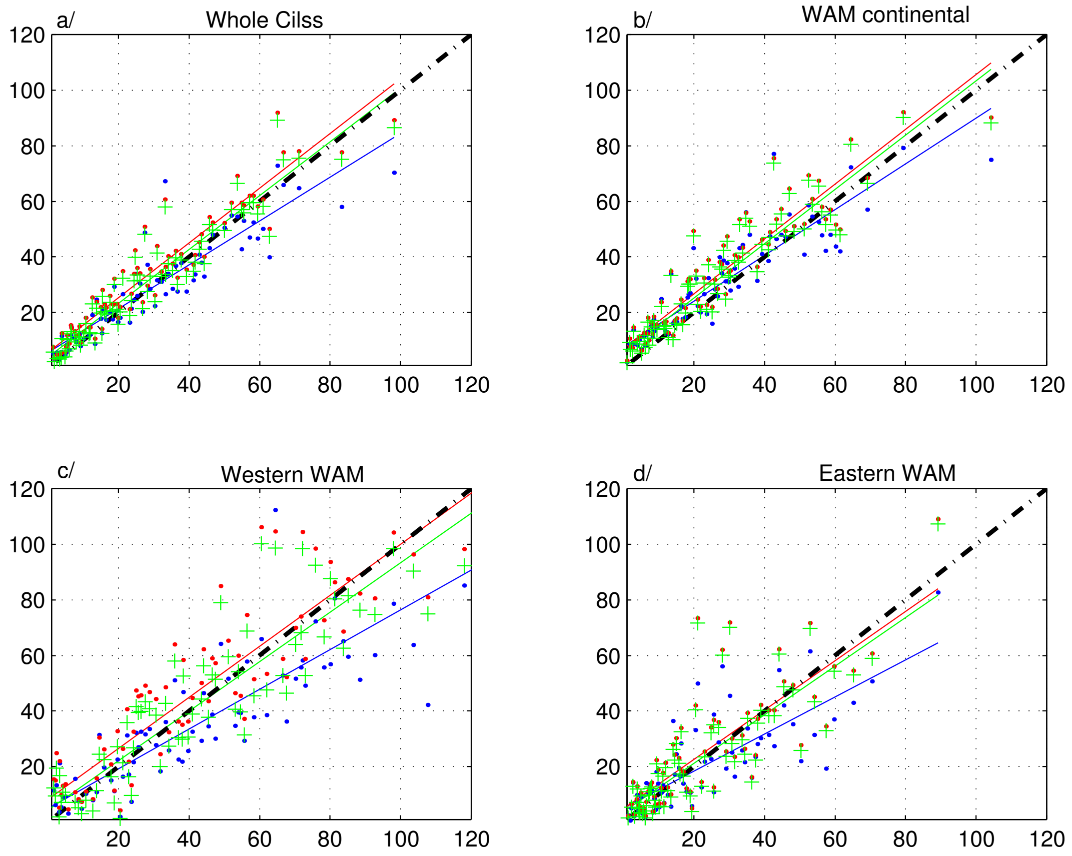
4/ Dates of the Sahelian rainy season onset over the period 1979-1991 (see text for the method): IRD data (white bars), CMAP data (curve with circles) and GPCP data (curve with asters).



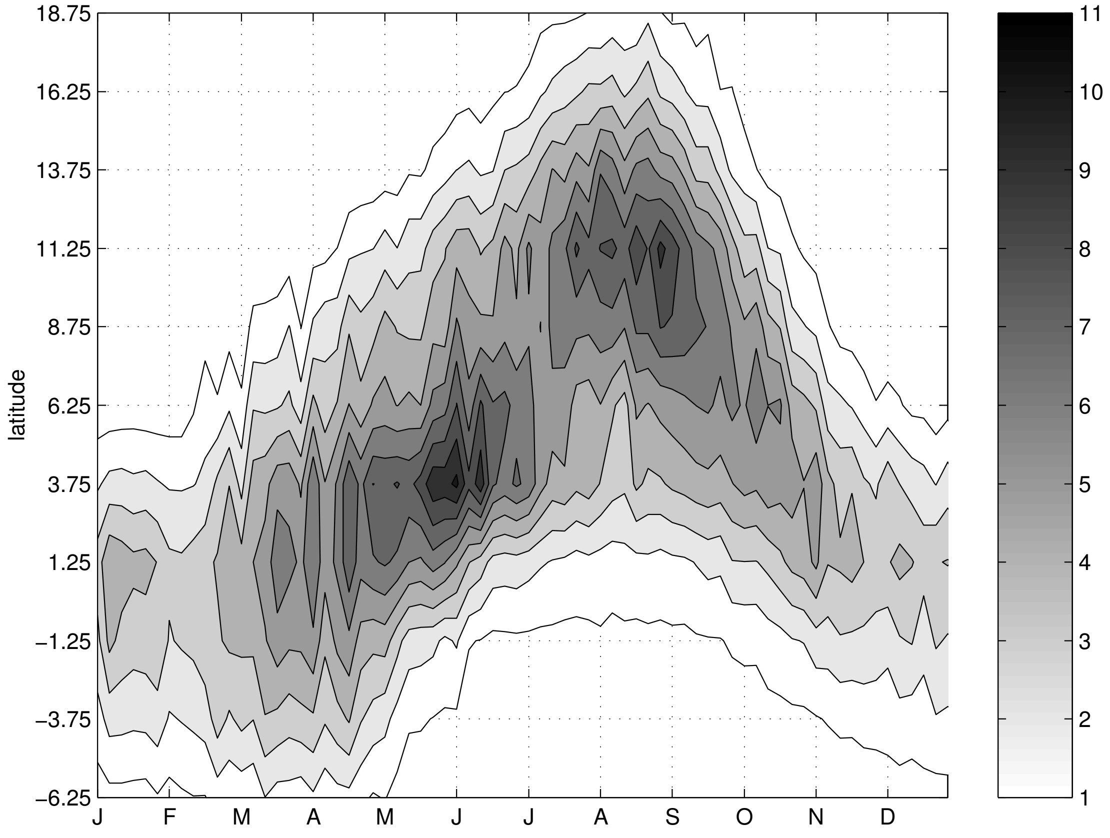
5/ Basic statistics regarding the CMAP (GPCP) minus CILSS (minus IRD for the 9th index) differences at a 10-day time scale over selected regions during the JAS season except for the 9th index which is at 5-day time scale (see numbers on X-axis): 1 Whole CILSS, 2: WAM Central, 3: Central Sudan, 4: Central Sahel, 5: Western Sudan, 6: Western Sahel, 7: Eastern Sudan, 8: Eastern Sahel and 9: Central Guinea. White bars (black) illustrate results for CMAP (GPCP). (x-axis): a) average, b) standard deviation, c) first quintile, d) fourth quintile, e) correlation coefficients. Period 1979-2000.



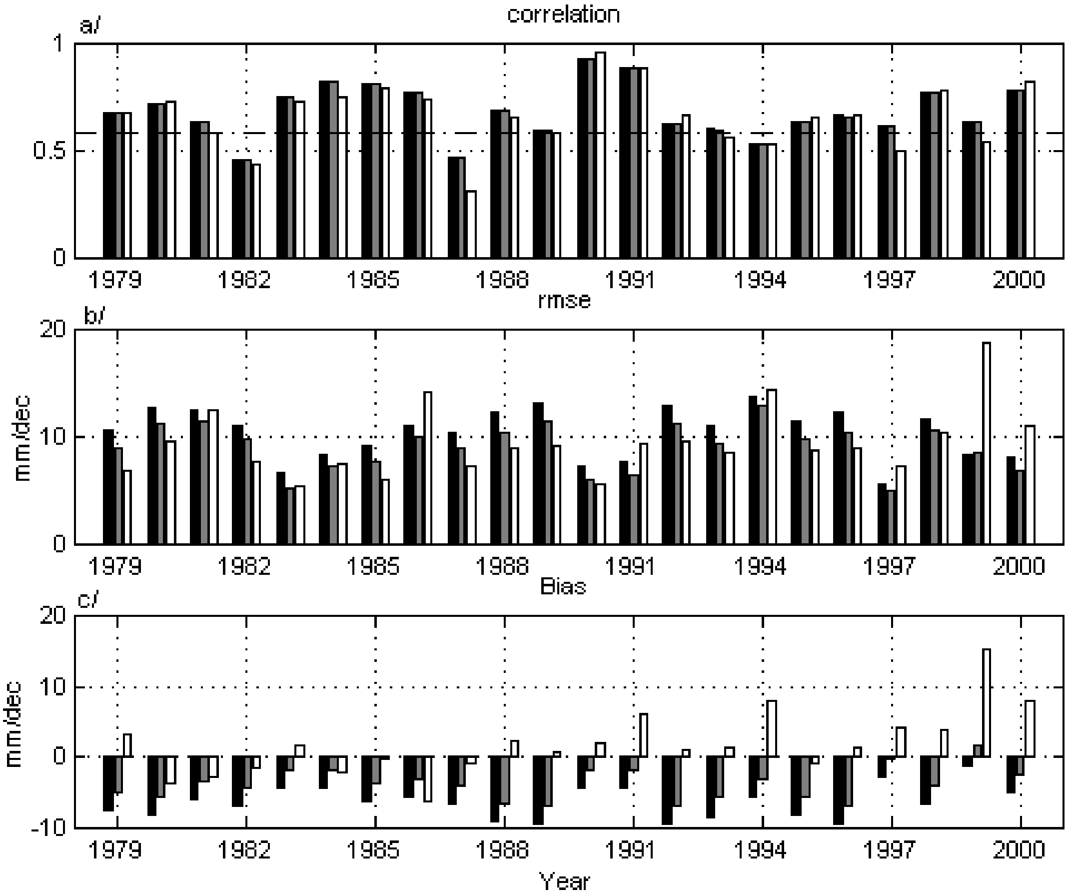
6/ Basic statistics CMAP (white bar), GPCP (black bar) and MERGE (grey bar and the a/ ABSE, b/RMSE, c/ Bias, and d/ relative error with respect to CILSS/IRD indexes. On the x-axis, 1: Whole CILSS, 2: WAM Central, 3: Central Sudan, 4: Central Sahel, 5: Western Sudan, 6: Western Sahel, 7: Eastern Sudan, 8: Eastern Sahel and 9: Central Guinea.



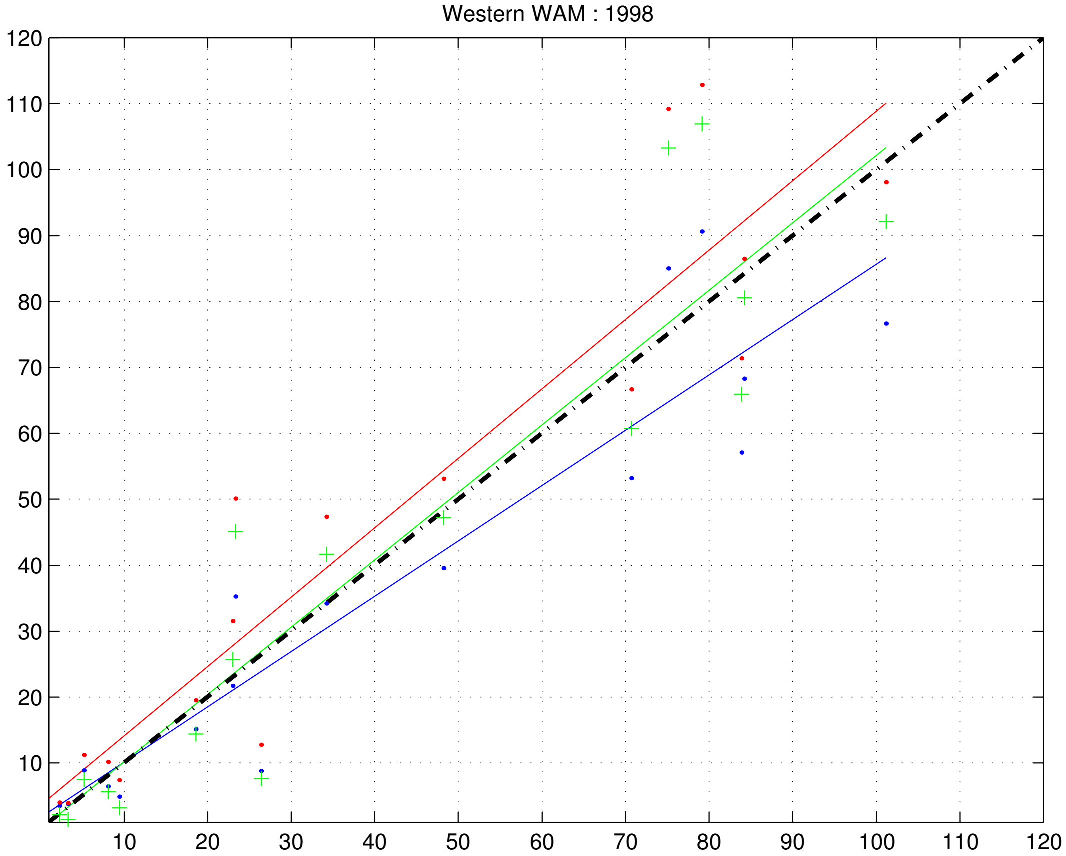
7/ Scatter plots of the CMAP (blue), GPCP (red) and MERGE (green) indexes with respect to CILSS indexes with superimposition of linear regression lines for : a) Whole CILSS, b) WAM continental, c) Western WAM and d) Eastern WAM.



8/ Mean annual cycle of MERGE precipitation averaged between 10°W and 10°E over the 1979-2004 period. Only values > 1mm/day are displayed



9/ Inter-annual statistics for the whole CILSS region in JAS using CMAP (white bar), GPCP (black bar) and MERGE (gray bar): a/ correlation, b/RMSE and c/ Bias.



10/ as in Figure 7 but only for the year 1998 on Western WAM region.

Tables

Table 1: Listed below is a consensual list of basic useful spatial rainfall indexes for West Africa defined by the AMMA program.

Spatial indexes	Boundaries
WAM continental domain	05N-20N ; 10W-10E
WAM oceanic domain	05S-05N ; 15W-10E
Western WAM	10N-18N ; 17W-10W
Eastern WAM	10N-18N ; 10E-20E
Western Sahel	13N-18N ; 18W-10W
Central Sahel	13N-18N ; 10W-10E
Eastern Sahel	13N-18N ; 10E-20E
Central Sudan	09N-13N ; 10W-10E
Central Guinea	05N-09N ; 10W-10E
Gulf of Guinea	Eqt.-05N ; 10W-10E
Western Sudan	09N-13N ; 18W-10W
Eastern Sudan	09N-13N ; 10E-20^{E}
Central Guinea	05N-09N ; 10W-10E

Table 2 : Linear coefficient correlations calculated on pentad anomalies between OLR and GPCP and CMAP over selected indexes. All of the correlations are significant at the 95% level of significance, taking into account autocorrelations in the series. These values have been calculated for each index during the rainy season, for example from July to September (JAS) over the Central Sudan region.

	GPCP/OLR	**CMAP/OLR**
Guinea Gulf (JFM/OND)	-0.79/-0.69	-0.81/-0.61
Central Guinea (AMJ)	-0.60	-0.51
Central Sudan (JAS)	-0.59	-0.49
Central Sahel (JAS)	-0.66	-0.61
WAM continental (AMJAS)	-0.60	-0.55
WAM oceanic (JFM/OND)	-0.83/-0.75	-0.81/-0.71

Table 3: List of cited acronyms

AMMA	African Monsoon Multidisciplinary Analysis
AMJ	April May June
ASECNA	Agence pour la Sécurité de la Navigation Aérienne en Afrique et à Madagascar
CIEH	Comité Inter-africain d'Etudes Hydrauliques
CILSS	Centre Inter-étatique de Lutte contre la Sécheresse au Sahel
CMAP	Climate Prediction Center Merged Analysis of Precipitation
CRA	Centre Régional Agrométéorologie–Hydrologie–Météorologie
GPCC	The Global Precipitation Climatology Centre
GPCP	Global Precipitation Climatology Project
GTS	Global Telecommunications System
IR	Infrared Red
IRD	Institut de Recherche pour le Développement
ITCZ	Inter-Tropical Convergence Zone
JAS	July August September
JFM	January February March
MSU	Microwave Sounding Unit
NCAR	National Center for Atmospheric Research
NCEP	National Center for Environmental Prediction
NI	Northern Index
NOAA	National Oceanic and Atmospheric Administration's
OLR	Outgoing Longwave Radiations
OND	October November December
RE	relative error
RMSE	root mean square error
SI	Southern Index
SSMI	Special Sensor Microwave/Imager
SST	Sea Surface Temperatures
WAM	West African Monsoon