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RAINFALL CLIMATOLOGY (1976-2004) AND SEVERE METEOROLOGICAL EVENTS IN NORTHERN MATO GROSSO.

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1. INTRODUCTION

Severe meteorological events usually interfere both with natural and human systems, thus causing the most diverse problems and, even, disasters. Among these events, e.g., the rains above 100 mm/day may cause floods and the collapse of hillsides in urban areas. The sudden and strong decrease of the temperature, besides the well known agricultural and cattle raising effects, may induce the fall of the tree leaves in the non-deciduous “Terra Firme” Amazon forest; also, it may cause acute pulmonary sicknesses in less resistant persons. The cloudiness, which is associated with the temperature and the rainfall (two variables which are essential for the study of climatic changes), may also affect the development of the plants, because it may reduce the daily air temperature from 25 % to 50 %, if compared with the clear sky situation (Dai et al. 1999). Thus, the knowledge of these phenomena, as well as their predictability, is of utmost importance for a region.

So, this work presents the rain climatology for the Fazenda Caiabi (9 deg 58 min S; 56 deg 21 min W), Alta Floresta, Mato Grosso, Brazilian Amazon, and its relationship with El Niño, La Niña and the South American Convergence Zone events for the period 1976 – 2004, that is, since the opening of the Fazenda through the slashing and burning of the forest. The beginning, the end and the duration of the dry season were also obtained. In addition, the severe rain, low temperature and high cloudiness events measured through an automatic weather station (AWS) located at the Fazenda, from June 1999 to September 2005, are presented. Further, after August 2002, CPTECs ETA Regional 40 x 40 km numerical weather prediction model outputs were recorded for the site, and compared with the values actually measured using the AWS.

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2. DATA AND METHODS

For the determination of the rain climatology, daily measurements of rainfall obtained at 8:00 LT with a manual pluviometer at the Fazenda were used. From January 1976 until April 2002 there were no failures, and three months thereafter these measurements were resumed until December 2004. To cover the 2002 failure, data from the micrometeorological tower mentioned below and which was located ca. 4 km away from the manual pluviometer were used. This is acceptable because the annual rainfall differences between the two sites are of the order of 10%, surely caused by the highly convective nature of the rains in the region.

The duration of the dry season for each year of the period 1976 – 2004 was found considering the average daily precipitation for pentadal intervals: the beginning of the season is the initial pentad (i) of the first successive set of three pentads with daily rainfall less than the annual daily average, or (ii) of the set of six successive pentads in which four of them presented a daily rainfall as in (i). The end of the season is the last pentad of sets of the same type as the ones considered for its beginning. This procedure was suggested by Rao and Espírito Santo (2005). No consensus was yet reached on this subject, thus existing other criteria, such as the ones proposed by Kousky (1988) and Gan (2005).

The severe cloudiness was associated with low daily-accumulated solar incident radiation (Akinc - MJ m^{-2} d^{-1}). Thus, for the determination of the severe events of low AKincs (<12 MJ m^{-2} d^{-1}), low temperatures (<12 C) and high rainfall (> 50 mm d^{-1}) for the period 1999 – 2004, the primary data used were the incident solar radiation (Kinc - W m^{-2}), the air temperature (Tair – C) and the rainfall (PPT - mm), which were measured at the micro-meteorological tower installed in a deforested site of the Fazenda. The first ones were measured at the rate of 1 Hz, and recorded on a data-logger as 15´ (900 s) averages, while the rainfall was measured with a tipping pluviograph of 0.25 mm and recorded as 15´ totals. The AKincs were obtained through the integration of the Kincs over the day.

To verify the occurrence of cold fronts in the region, their daily evolution graphs presented monthly by the virtual Climanalise magazine (Seção de Sistemas Frontais e Frontogênese), available at http://cptec.inpe.br.

The El Niño and La Niña statistics were extracted from the site http://cptec.inpe.br/enos#, while the South Atlantic Convergence Zone ones were obtained from Sanches (2001) and Sousa (2005).

For the comparison between the measurements at the Fazenda site and the predictions of the ETA 40 km x 40 km Regional Weather Prediction Model, the predictions after August 13, 2001 for the grid point 56.35° W; 9.96° S were used. For this purpose, they were recorded specially by CPTEC.

The statistical parameters, that is: averages, maxima, minima, standard deviations, root mean squares, correlation coefficients, bias, and the frequency graphs were computed using the QPRO software.

3. RESULTS

Rainfall climatology from 1976 to 2004

The total rainfall and pertinent statistics for each year of the period 1976 – 2004 are shown on Figure 1. The global yearly rainfall average is 2205 ± 253 mm. The frequency diagram (Figure 2) is unimodal and fairly symmetric, with class intervals of 236.88 mm/year.

The average rainfall for each month (Figure 3) shows that January, February, March and December are the most rainy ones; April, May, September, October and November present intermediate values, and the driest months are June, July and August.

The frequency diagrams for each of the months of the period, presented by Sousa and Silva (2005), show the high number of years without rain during months of the dry season (May – 10; June – 20; July - 27; and August – 17); notwithstanding, during the driest months (June, July and August) there are years with rainfall around 70 mm and, even, 112 mm. During the rainiest months (January, February, March and December) the distribution among the rainfall classes is more uniform among the high and the low values.

The average beginning of the dry season for the period is during the pentad 25 (May 1 to 5), its end occurs during pentad 50 (September 3 to 7) and its duration is 25 pentads (Figure 4). These values are compatible with the ones corresponding to the Brazilian Center-Western Region.

The average daily rainfall for each year and the occurrence of El Niño (EN), La Niña (LN) and Southern Atlantic Convergence Zone (SACZ) episodes are shown on Figure 5. So, during strong or moderate El Niño episodes, there is less rainfall than the average for the period; for weak El Niños, the rainfall is slightly higher than its average for the period. For the only one strong La Niña episode, the rainfall was higher than the average, while for the other intensities the response was ambiguous. Concerning the SACZ, the inter-annual tendency of their number (growth or decrease) follows, in general, the inter-annual growth or decrease of the average annual rainfall during the period.

Rainfall, AKinc and Temperatures – April 2000 to September 2003

The monthly averages of the daily rainfalls for the period between April 2000 and September 2003 (mm/day), presented on Figure 6, show a regular periodicity, which is also the case for the daily maxima for each month; the year 2002 presents a well defined maximum during the rainy season, while for 2001 and 2003 slight bimodalities do occur.

The monthly averages of the accumulated incident solar radiation AKinc (MJ m^{-2} d^{-1} – Figure 7) are relatively regular until November 2002; thereafter, until September 2003, this regularity occurs with lower values. The maxima for each month concentrate around 22 MJ m^{-2} d^{-1}, and with the minima this occurs around 8 MJ m^{-2} d^{-1}. During the 21 months of this period, there are 6 months with minima below 5 MJ m^{-2} d^{-1}, which correspond to very heavy cloudiness.

The monthly averages of the air temperatures (Figure 8) are stable around 24 C, and their maxima oscillate little around 35 C; their minima, however, range from 12 C to 20 C.

Severe meteorological events between April 1999 and September 2005

Severe rainfall events during the period: 35; for 3 of them it rained more than 100 mm d^{-1} (192.5, 122.2 and 103.6); for 14 the rainfall was around 78.5 mm d^{-1} and for 18 it was around 50 mm d^{-1} (Figures 9 and 10). None of them was related to cold fronts.

High cloudiness events: 163; among them, 6 presented AKinc below 3 MJ m^{-2} d^{-1}, and 26 presented it between 3 MJ m^{-2} d^{-1} and 6 MJ m^{-2} d^{-1} (Figures 11 and 12). Only 7 of these events were associated with cold fronts.

Very low air temperature (strong “friagens”): only 2 events (7.9 C and 11.2 C), both associated with cold fronts.

Sousa and Silva (2005) present a table with the whole set of these events, which completes the initial one presented by Gielow et al, (2004).

Comparison between the measurements and the ETA model predictions – two cases

For the extreme rainfall event of January 8, 2002 (192.5 mm d^{-1}), the Figure 13 presents the hourly measurements at the Fazenda and the corresponding predictions obtained with the ETA 40 km x 40 km Model for the air temperature and relative humidity, and the rainfall. The absolute value of the correlation coefficient is 0.55 for the two last variables, while for the air temperature it is 0.19, with a bias of 2 C, thus showing a over-estimation of the prediction. Despite the strong discrepancies for the rainfall during the three hours with the strongest precipitation, the relatively acceptable correlation coefficient for the day is possibly due to the smaller discrepancies after 15:00 LT.

Finally, Figure 14 shows the measured and the predicted hourly time series (i) for a typical non-rainy week during the dry season, and (ii) for the week with the extreme rainfall.

The predictions are good for the evolution of the air temperature and relative humidity series (i) and for the times of their maxima and minima. However, for the air temperature these maxima are under-estimated, and the minima are over-estimated; for the relative humidity the maxima are under-estimated, while for the minima there is a good agreement.

The predictions for the extreme rainfall during the week (ii) distribute it continuous and homogeneously along this week, while the corresponding air temperature and relative humidity are also poorly predicted.

4.CONCLUSIONS

The rainfall climatology for the Fazenda Caiabi between 1976 and 2004 shows an annual mean average of 2205 ± 253 mm mm. The months of January, February, March and December are the most rainy; April. May, September, October and November present intermediate rainfall, while June, July and August are the driest months. The dry season starts at Pentad 25 (May 1 to 5) and ends at Pentad 50 (September 3 to 7). El Niño affects the rainfall, decreasing it during strong and moderate events, and increasing it slightly during weak events. For La Niña events, the response is ambiguous. The inter-annual trend of the annual number of Southern Atlantic Convergence Zones (increase or decrease) follows, in general, the inter-annual increase or decrease of the average annual rainfall.

There was no association with cold fronts for the 35 severe rainfall events between April 1999 and September 2005, and only three of them were above 100 mm d^{-1}, with a maximum of 192.5 mm d^{-1}. There were 163 severe cloudiness events, with six of them presenting an accumulated incident solar radiation bellow 3 MJ m^{-2} d^{-1} (minimum: 1.92 MJ m^{-2} d^{-1}); only seven events were associated with cold fronts. Both of the very low temperature episodes (7.9 C and 11.2 C) were associated with cold fronts.

Concerning the ETA 40 km x 40 km Regional Numerical Weather Prediction Model run by CPTEC, it is shown preliminarily that this model (i) does not predict extreme rainfall episodes and (ii) for non-rainy weeks, it predicts well the trends of the air temperature and relative humidity, but over or under-estimates their maxima and minima.

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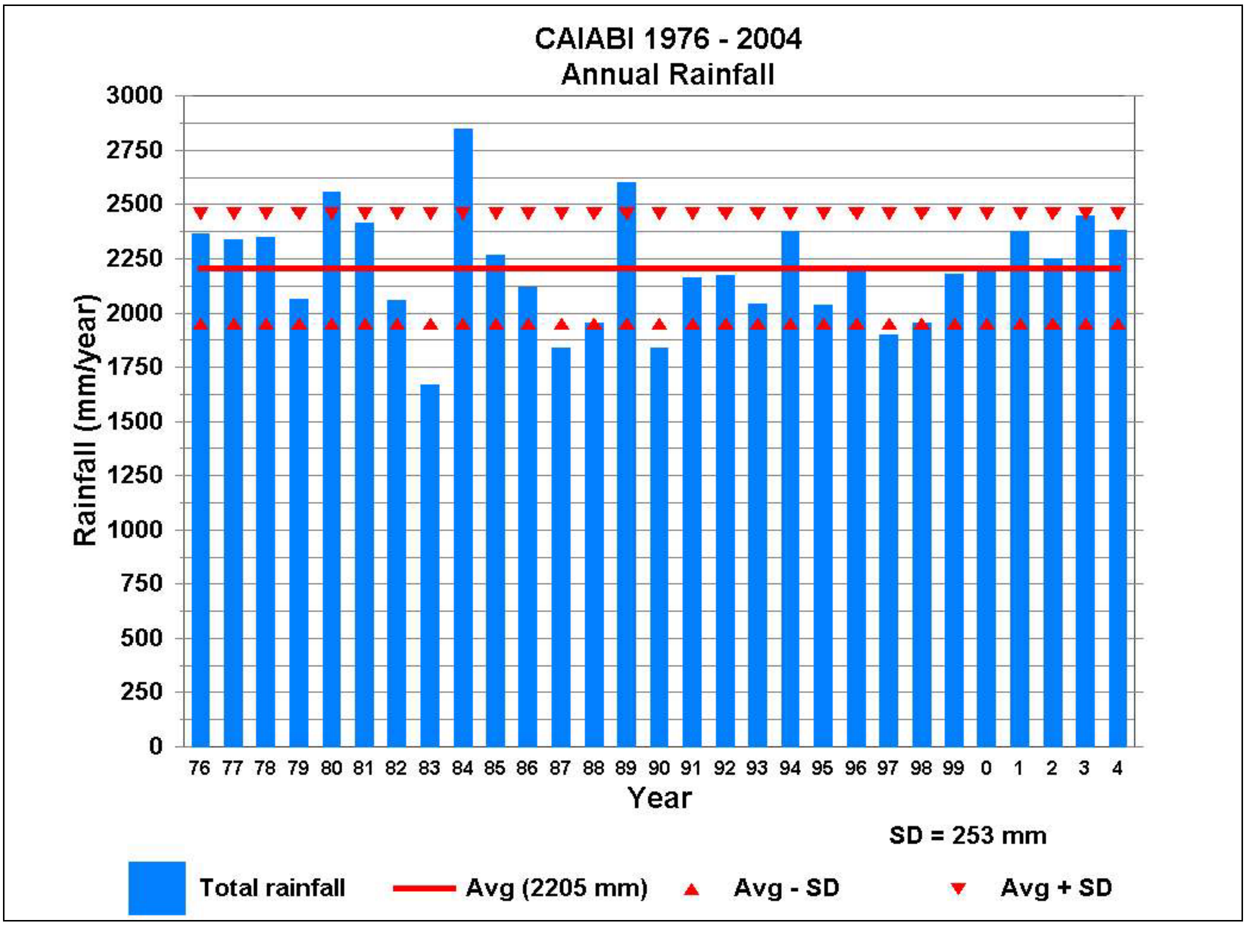
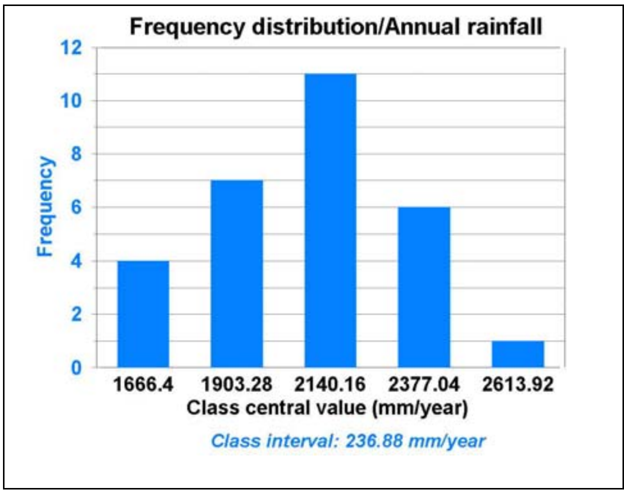


Fig. 1 Annual rainfall at Fazenda Caiabi from 1976 to 2004.



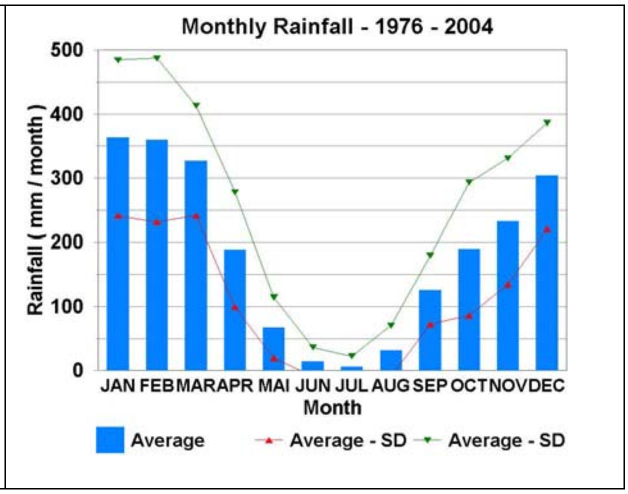


Fig. 2 Frequency distribution of the rainfall at Caiabi – 1976 – 2004.

Fig. 3 Monthly average rainfall at Caiabi from 1976 to 2004.

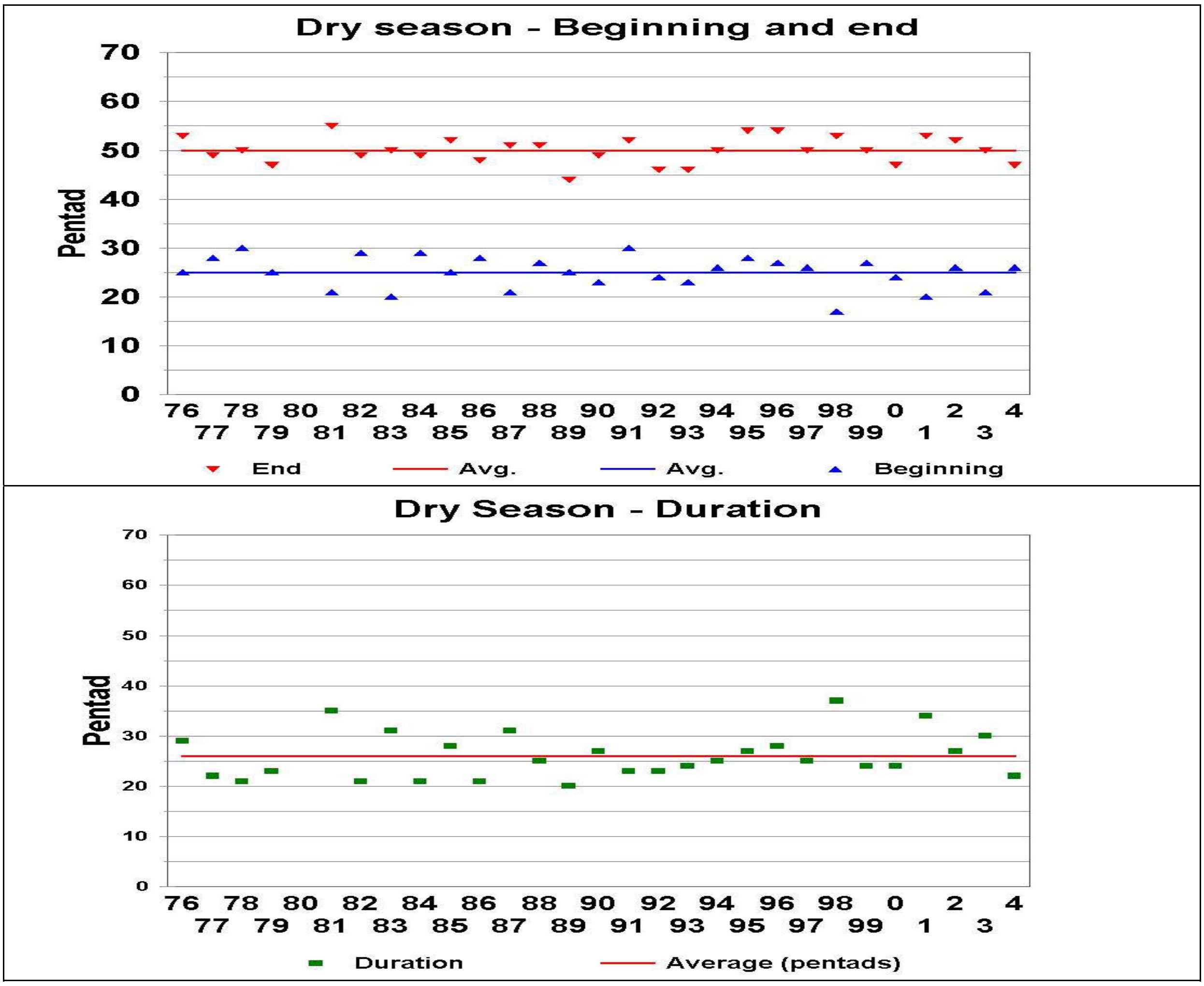


Fig. 4 Beginning, end and duration of the dry season at Caiabi – 1976 – 2004

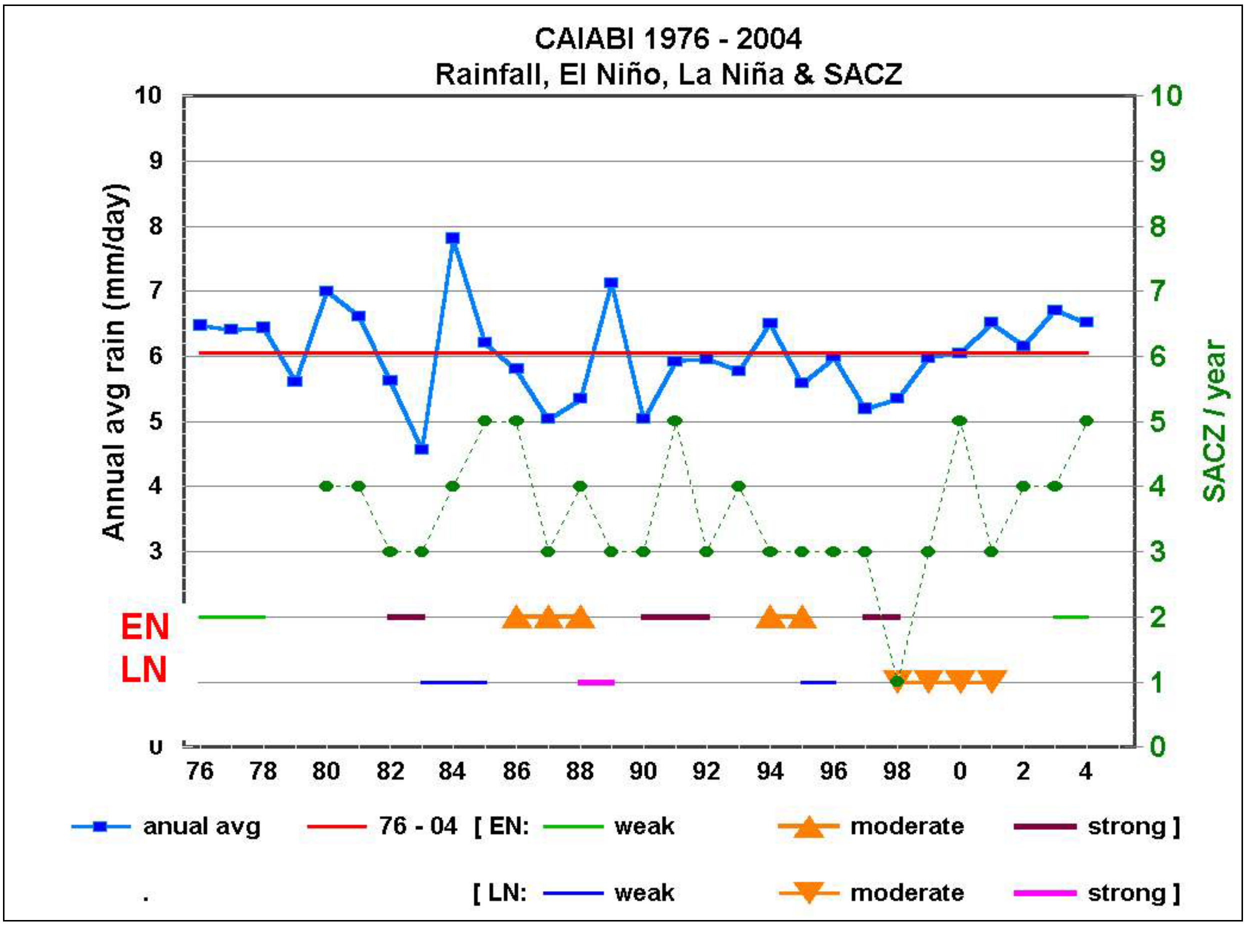


Fig. 5 The occurrence of El Niño, La Niña and South Atlantic Convergence Zone episodes and the average annual daily rainfall at Caiabi from 1976 to 2004.

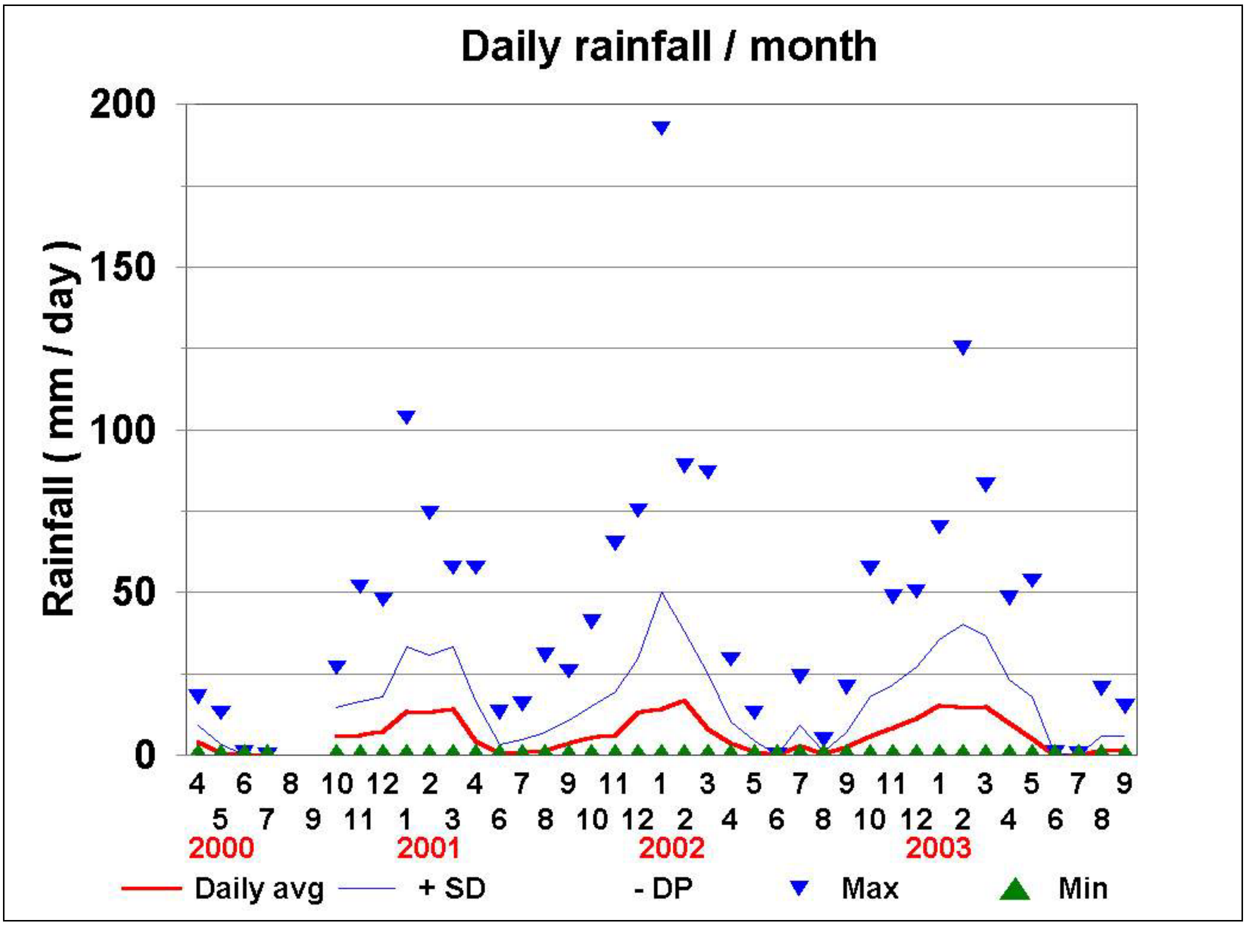


Fig. 6 Monthly daily rainfall at Caiabi from April 2000 to September 2003.

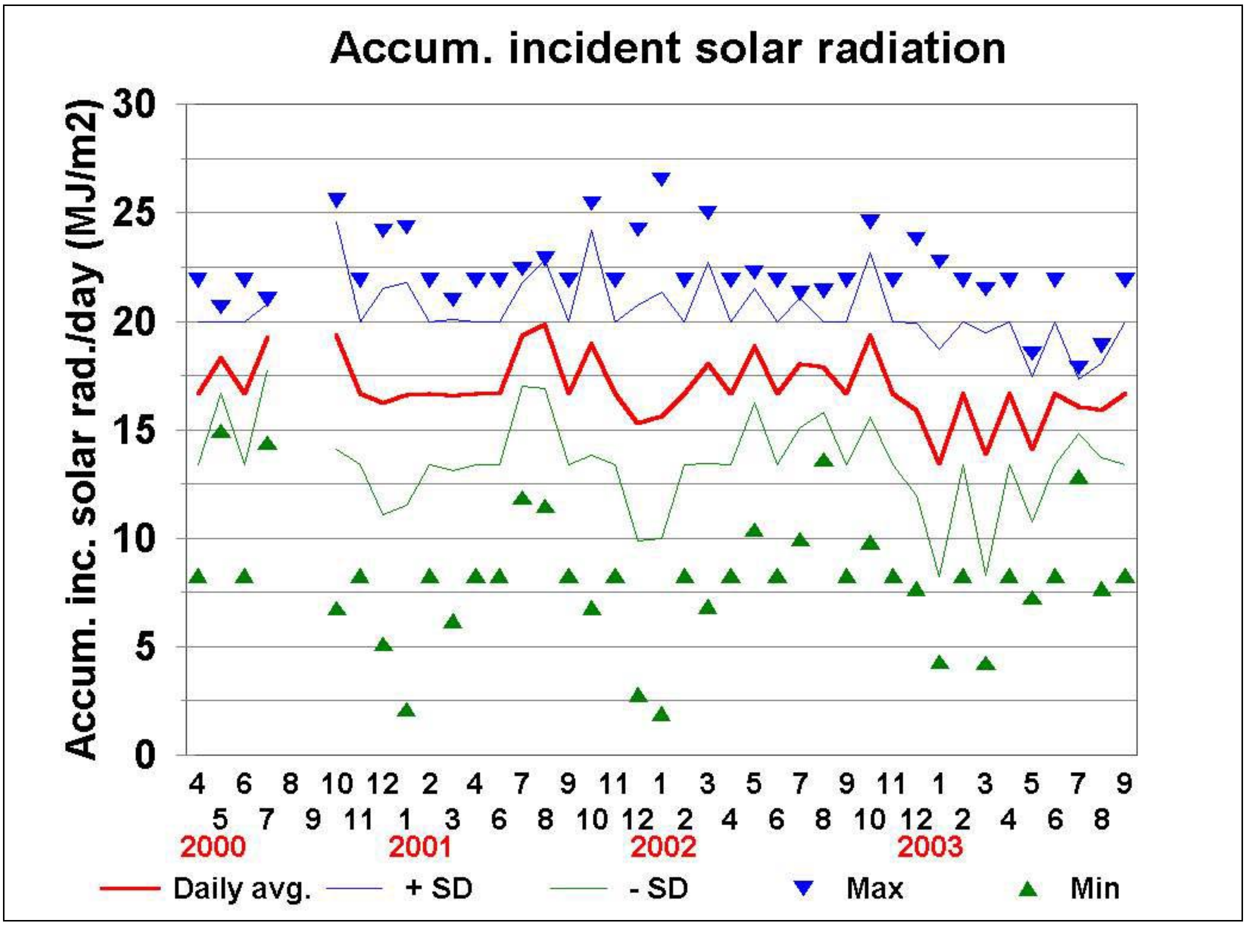


Fig. 7 Monthly daily accumulated solar incident radiation (Akinc) at Caiabi from April 2000 to September 2003.

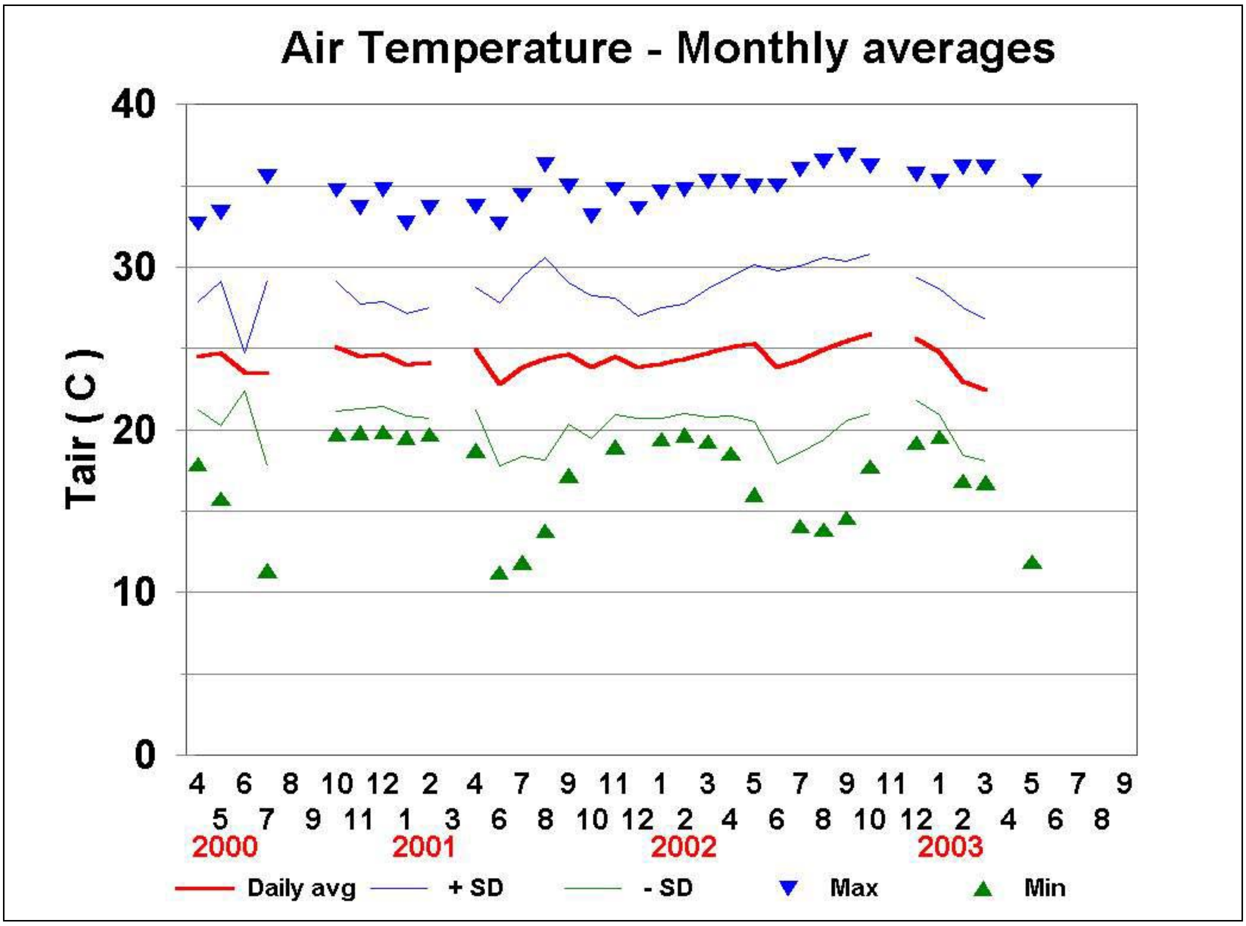


Fig. 8 Monthly daily air temperature at Caiabi from April 2000 to September 2003.

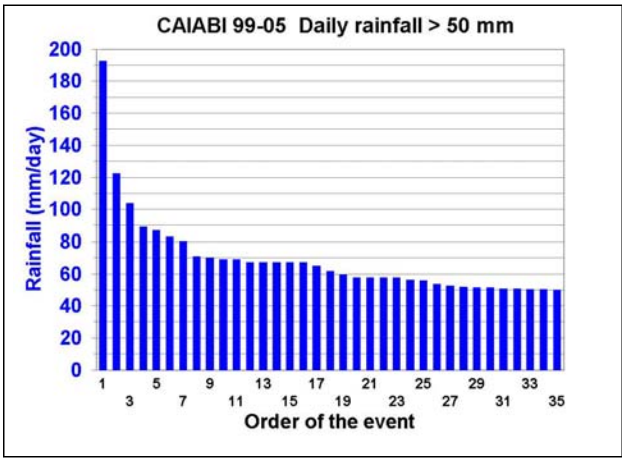


Fig. 9 Ordenation of the severe rainfall events at Caiabi from June 1999 to September 2005.

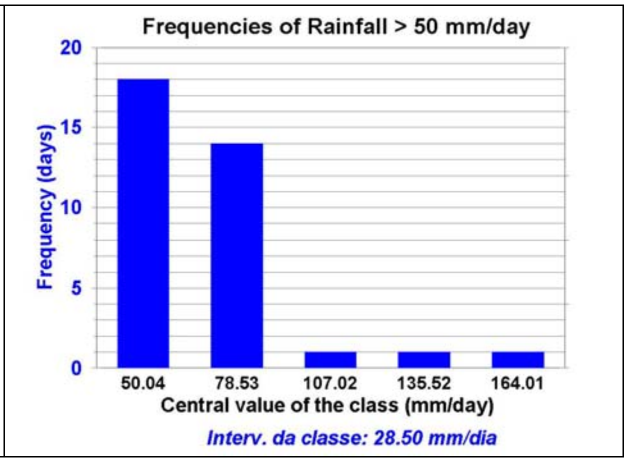


Fig. 10 Distribution of the severe rainfall events presented on Fig. 9.

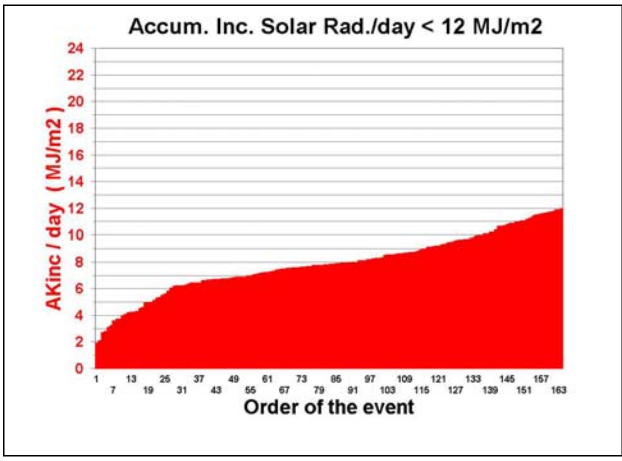


Fig. 11 Ordenation of the low accumulated incident solar radiation per day events at Caiabi from June 1999 to September 2005.

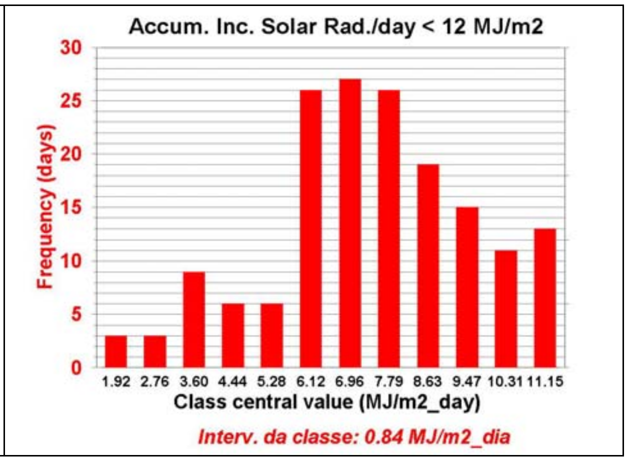


Fig. 10 Distribution of the events of high cloudiness presented on Fig. 11

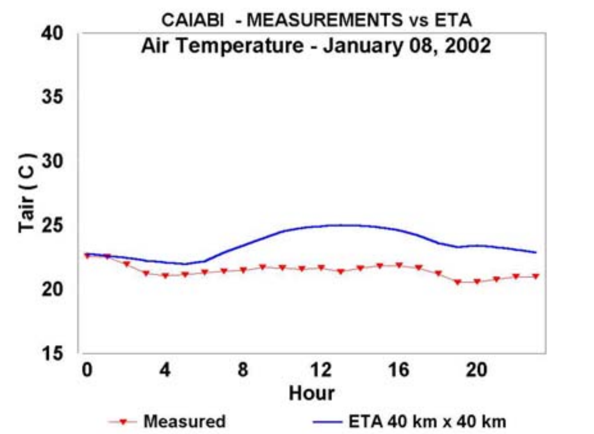
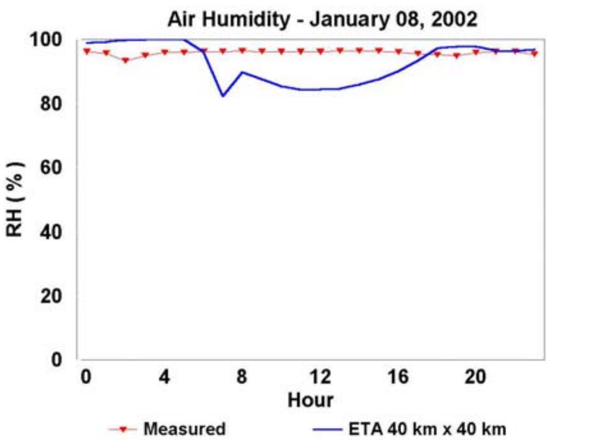
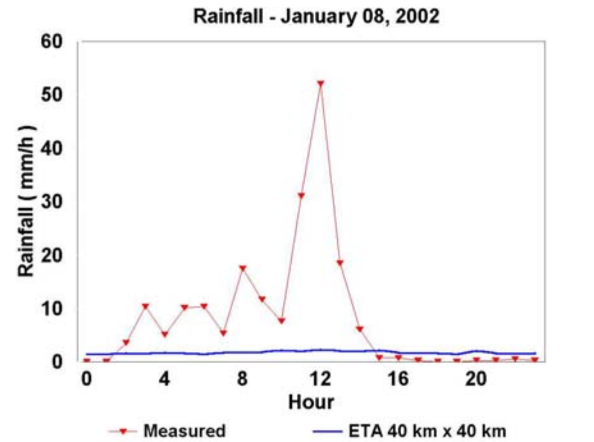
	**CAIABI – January 8, 2002** **Measurements vs ETA Predictions** **9° 58' S; 56° 21' W** **Tair** **C.C. = 0.19** **Bias = 2.07 C** **RMS = 2.31 C**
	**RH** **C.C. = - 0.54** **Bias = - 2.82 %** **RMS = 7.11 %**
	**Rainfall** ***Measured :192.50 mm/day*** ***ETA prediction : 42.33 mm/day*** **C.C. = 0.54** **Bias = - 6.26 mm** **RMS = 13.32 mm**

Fig. 13 Micrometeorological measurements and the ETA model predictions for Caiabi on January 08, 2002, the day with the maximum rainfall of 192.5 mm.

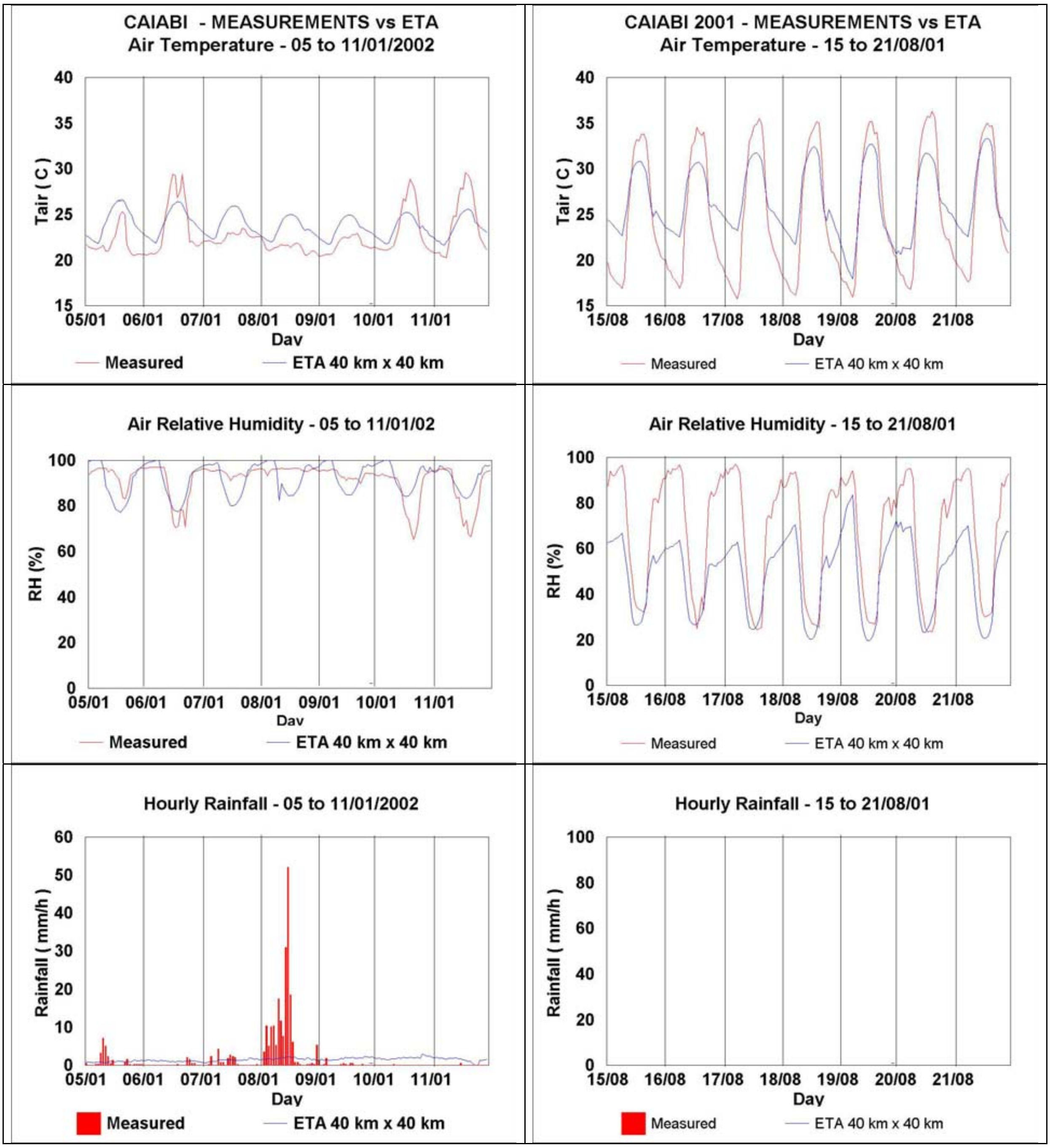


Fig. 14 Micrometeorological measurements and the ETA model predictions for two weeks: (i) with the maximum rainfall and (ii) without rainfall.