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Atmospheric Absorption Ratio on Cities of Pernambuco State of Brazil

Nelson Veissid[1], Helmut Muniz da Silva[1] and Manoel Henrique de Oliveira Pedrosa Filho[2]

[1] National Institute for Space Research / INPE, São José dos Campos - SP (Brazil)

[2] Federal Institute of Education, Science and Technology / IFPE, Pesqueira - PE (Brazil)

Abstract

The second satellite of the Brazilian Complete Space Mission (SCD2/MECB) was launched on October 23, 1998 and it hosts on board a solar cell experiment. The experiment permits the simultaneous inference of direct insolation and the insolation that is reflected outside of Earth (planetary albedo). The data of albedo can be grouped into periods of time (annual, seasonal or monthly) or studied for several places (latitude and longitude) during the life of the satellite. In this work, the albedo values is used with the Atmospheric transmission coefficient or clearness index (Kt), measured at four meteorological stations of Pernambuco State of Brazil to calculate the atmospheric absorption coefficient (Ka). The developed method in this work for evaluating the Ka considers that the planetary albedo is composed by two parts: the local and the non local reflectivity. Considering this original concept, a new parameter called atmospheric net ratio (called here Ra) is defined as the quotient between Ka and the net solar irradiance power that is not transmitted through the atmosphere (100%-Kt). The atmospheric net ratio defined by this way is not cloud cover dependent. For example, the values of Ra to Recife are 0.9186±0.0147 and 0.9131±0.0087 to two periods with atmospheric conditions slightly different. The data was taken during the months of January and February of 2013. The values of Ra to the four cities of this work indicate different climate and atmospheric conditions in the cities of Pernambuco State.

Keywords: Atmospheric Absorption, Solar Energy, Satellite, INPE, Pernambuco State of Brazil.

1. Introduction

The SCD2 is a satellite that collects and transmits meteorological data. The data are received from the terrestrial platforms distributed along the Brazilian territory and they work in a remote way. The orbit of SCD2 is 750 km height and inclined around 25° in relation to the plan of the equator. The satellite spin is around 34 rpm. Its spin axis is maintained normal to the plane of the celestial equator. The satellite is illuminated by the Sun during 65 minutes of each 100 minutes long orbit. It is otherwise eclipsed by the shadow of the Earth. Data of SCE are received at real-time only when the satellite is in the ground station field of view located at Cuiabá (16°S, 56°W), MT-Brazil. Unfortunately, this limits the SCE's observation range on the South American continent (i.e., latitude between 10°N and 30°S and longitude between 30°W and 80°W).

Planetary albedo is the Earth Reflectivity measured outside of atmosphere. The Brazilian SCD2 satellite, launched on October 1998, has on board a Solar Cell Experiment and it can calculate the albedo using the telemetered data from experiment (Veissid, 2003 and 2003). To this work, it was choice four cities of Pernambuco state in Brazil located approximately in the same latitude. They are Recife, Afogados, Pesqueira and Araripina with geographical position showed in the figure 1. The areas on Recife, Pesqueira, Afogados

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and Araripina contain 141, 138, 102 and 123 points of data, respectively. These points were taken over a 60-day period in January and February 2016.

The analytical algorithm to calculated Ka is original and it was used by the first time for Veissid et al. (2010) and, after this, several works were presented (Veissid, 2025, 2026 and 2024).

The solar radiation data of these cities, collected to the January and February of 2016, are processed together the values of albedo to obtain the atmospheric absorption coefficient (Ka). The figure 1 shows the data points inside the circles of 5° in diameter of latitude and longitude. Several points are common to more than one circle. The global irradiance and Kt data is obtained at the Pernambuco Solarimetric Network (REDESOLPE in Portuguese), that was a project conceived by FACEPE (Manoel, 2022).

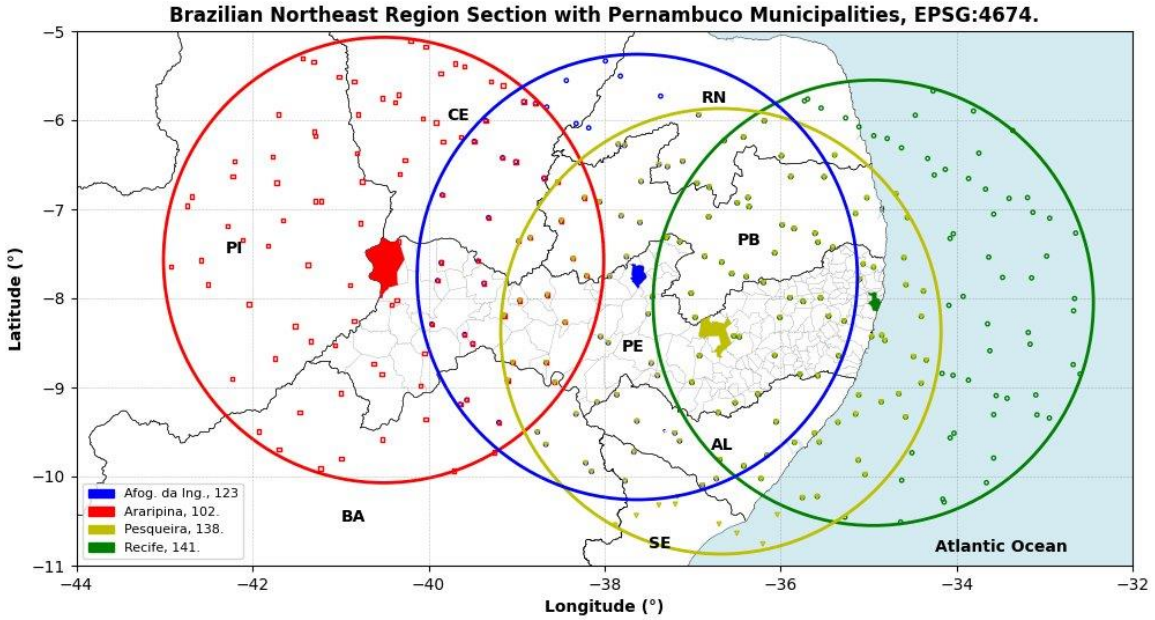

Figure 1: The cities of Pernambuco state in Brazil with solar radiation data used in this work.

The work of Formagini et al. (2024) emphasizes the importance of albedo studying in the area of Photovoltaic, mainly to bifacial modules.

2. Numerical Method to Obtain Ka

An elementary treatment of atmosphere can stablish that the transmission plus absorption and plus reflection is 100% (Kt+Ka+Kr=100%), where Albedo is the sum of local reflection (direct sun rays reflected) plus non local reflection (diffused sun rays reflected) or Albedo is Kr+Krnl (Veissid et al.,2010). So after an algebraic work, we can obtain the equation 1.

$$Albedo = (1 - \mathrm{Ra}).(100\% - \mathrm{Kt}) + Krnl \qquad \text{(eq. 1)}$$

Where Ra=Ka/(100%-Kt) is the atmospheric net ratio (Veissid et al., 2010). So, the atmospheric absorption coefficient (Ka) is given by equation 2.

$$Ka = \mathrm{Ra}.(100\% - \mathrm{Kt}) \qquad \text{(eq. 2)}$$

Where the parameter Kt is the Atmospheric transmission coefficient or clearness index (Veissid et al., 2010). The parameter Krnl is obtained experimental by data and corresponds to Atmospheric reflection coefficient of diffused radiation. We are supposing that Kr is Atmospheric reflection coefficient of direct radiation. In this way, the albedo measured by the experiment is sum of Kr and Krnl (local plus non local). The data of

Recife city was divided in two periods, because the atmospheric conditions are slightly different. The figure 2 shows the values of Kt and albedo on Recife city obtained simultaneously to the first period. The figure 3 shows the values of Kt and albedo on Recife city to the second period.

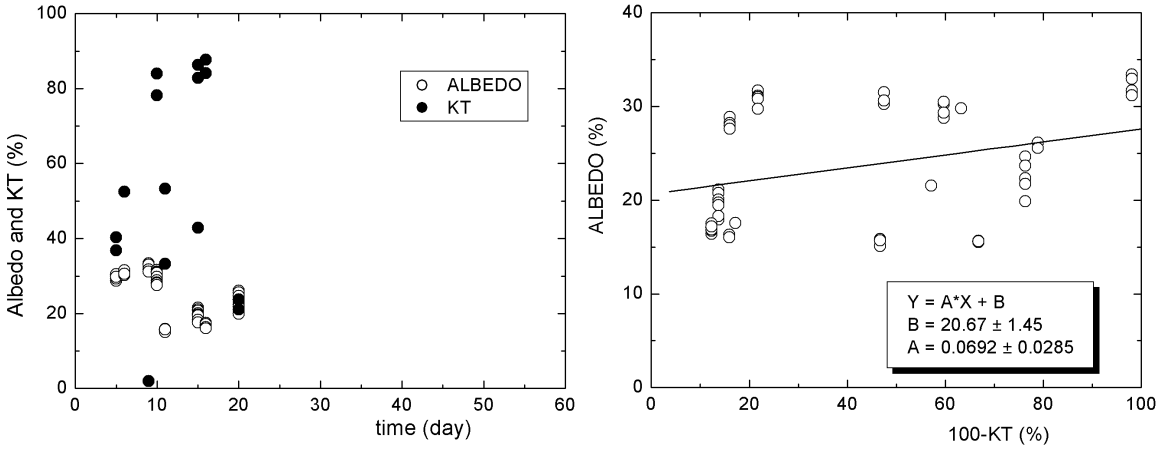

Fig. 2: Data of albedo from SCD2 and atmospheric transmission obtained simultaneous taking in Recife city for the first period.

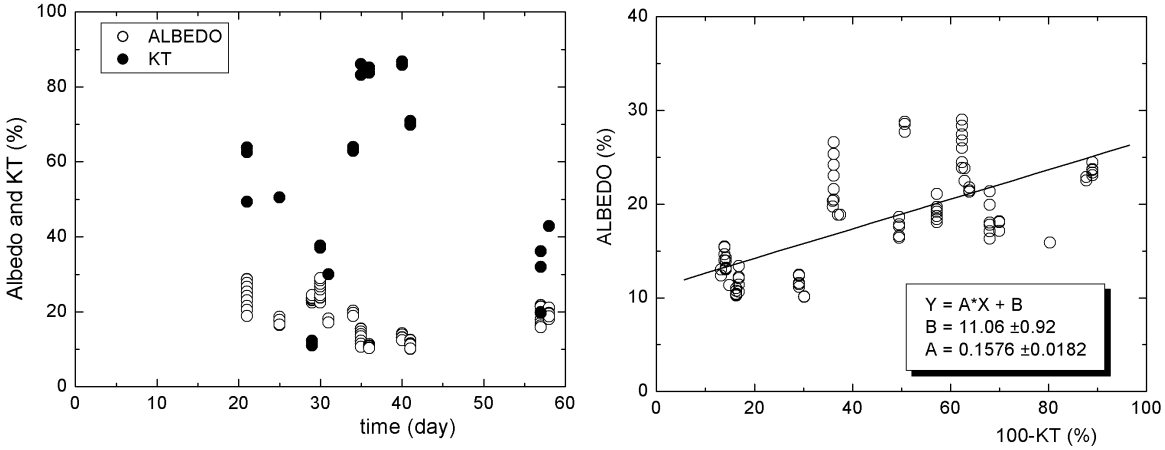

Fig. 3: Data of albedo from SCD2 and atmospheric transmission obtained simultaneous taking in Recife city for the second period.

Graphic at right side of figure 2 shows clearly the equation 1. The parameter A is the value of 1-Ra and the parameter B is the value of Krnl. In this case A=1-Ra=0.0692 and Ra==0.9308 and this mean that 93.08% of net radiation (100%-Kt) was assimilated by the atmosphere. In other words, 93,08% of irradiation that not cross the atmosphere was absorbed by then. Now is possible to understand the mean of Ra like atmospheric net ratio and this atmospheric net ratio is not a function of cloud coverage. This affirmation can be view at figure 2 right side, where the inclination of adjusted straight line is equal to 20% and to 80% at the value of Kt, that represents cloud coverage different. This fact is an original contribution of the work at the meteorological and climate areas.

Graphic at right of figure 3 is to same city of figure 2 (Recife), but is to another period from day 21 until the last day of 60. The graph of second period on Recife city shows values of A and B parameters very different of values of first period. This implies that the atmosphere has undergone a change in its characteristics.

Also, the data of Pesqueira city was divided in two periods, because the atmospheric conditions are slightly different. The figure 4 shows the values of Kt and albedo on Pesqueira city obtained simultaneously to the first period of 25 days. The figure 5 shows the values of Kt and albedo on Pesqueira city to the second period.

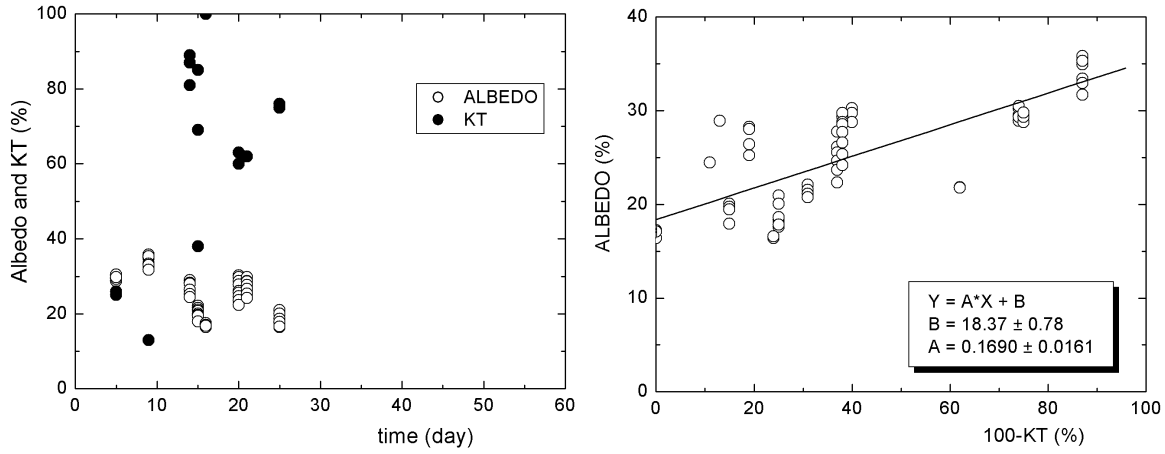

Fig. 4: Data of albedo from SCD2 and atmospheric transmission obtained simultaneous taking in Pesqueira city for the first period.

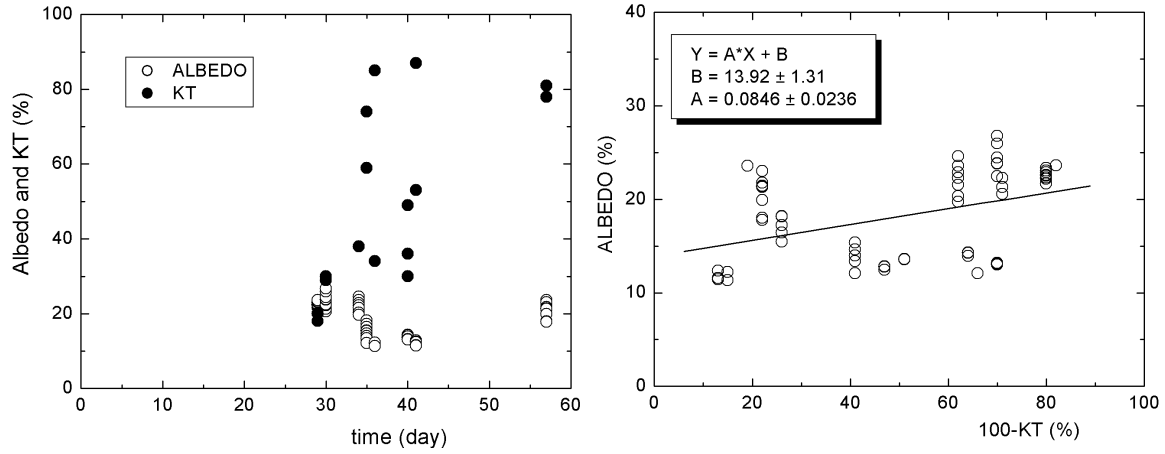

Fig. 5: Data of albedo from SCD2 and atmospheric transmission obtained simultaneous taking in Pesqueira city for the second period.

Again, the data of Afogados city was divided in two periods, because the atmospheric conditions are slightly different. The figure 6 shows the values of Kt and albedo on Afogados city obtained simultaneously to the first period. The figure 7 shows the values of Kt and albedo on Afogados city to the second period. The first period covers the first 17 days, and the second period covers the remaining days.

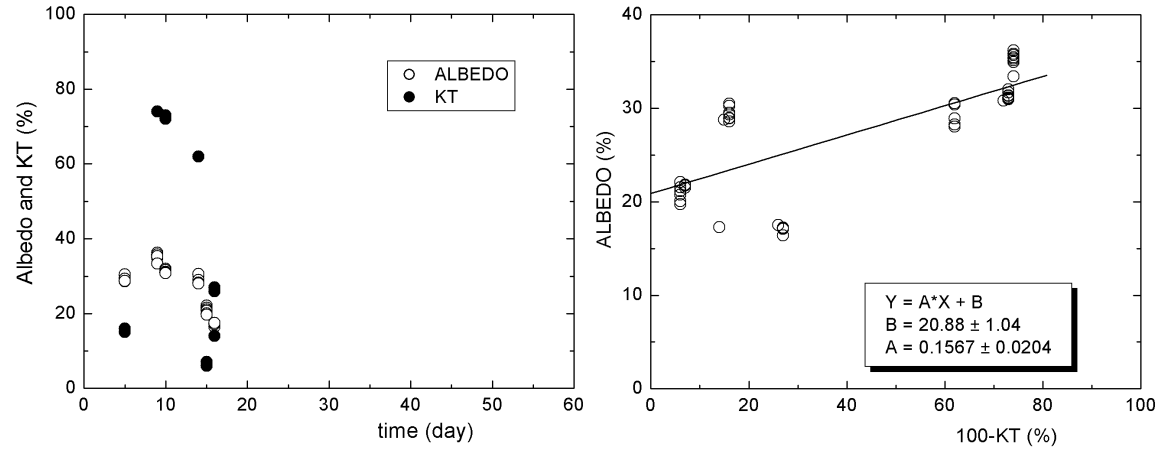

Fig. 6: Data of albedo from SCD2 and atmospheric transmission obtained simultaneous taking on Afogados city for the first period.

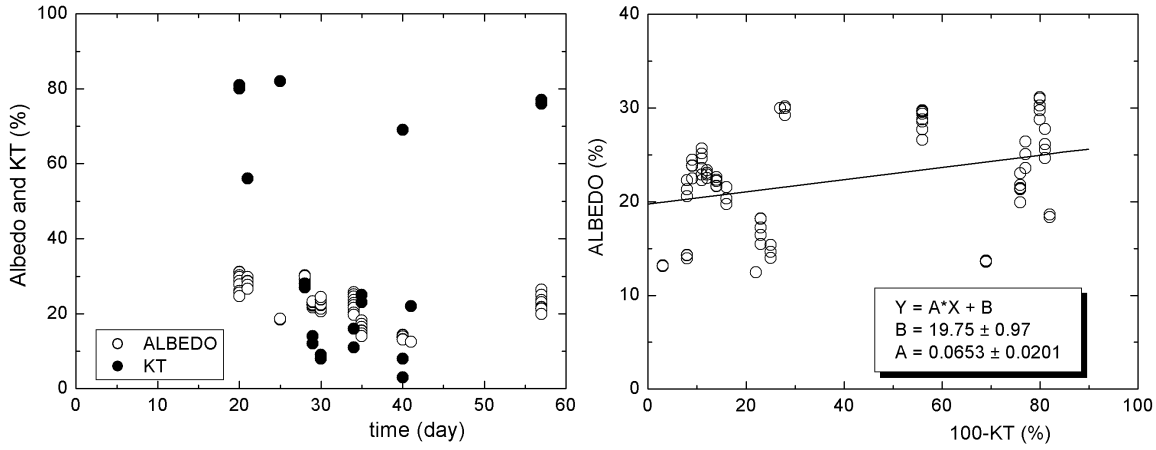

Fig. 7: Data of albedo from SCD2 and atmospheric transmission obtained simultaneous taking on Afogados city for the second period.

The data of Araripina city was taken in one period only, because the atmospheric conditions was the same during full period. The figure 8 shows the values of Kt and albedo on Araripina city obtained to the full period.

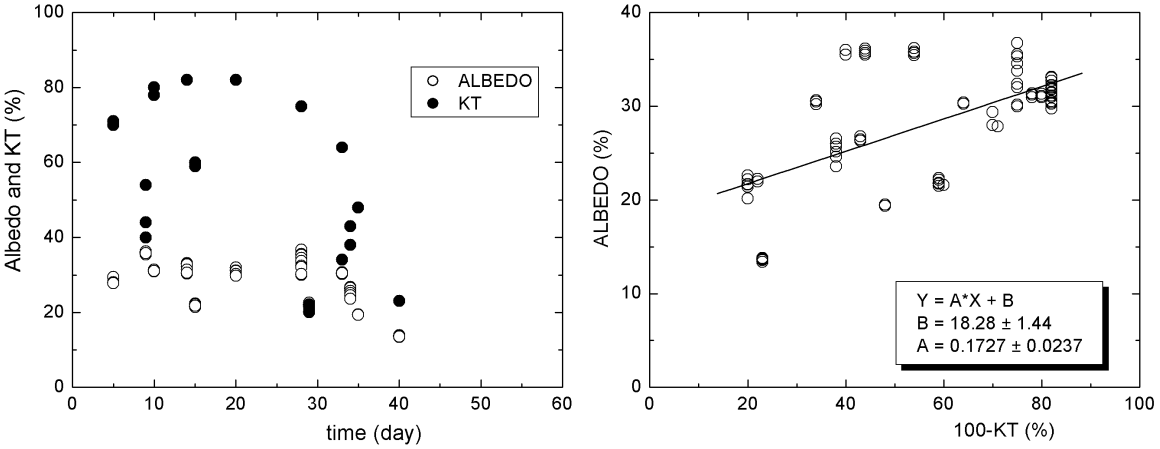

Fig. 8: Data of albedo from SCD2 and atmospheric transmission obtained simultaneous taking on Araripina.

3. Results and Conclusion

The figure 9 shows a high dispersion due to the long time (60 days) for only one value of Krnl. The graphic shows where the values are calculated (figures 2 to 8). As demonstrated by Veissid et al. (2010) the behavior of Krnl during the year has a senoidal behavior, but in this work the period of the study is less than one year (only 60 days). As a function of this short period, the equation to Krnl(%)=22.15(89)-0.186(31)X, where X is the day of the year, was obtained on analyze of all the cities and all periods. The figure 9 shows the points used to obtain this Krnl equation. So, this equation (22.15-0.186*X) was used to obtain the graphics of figures 10 to 13.

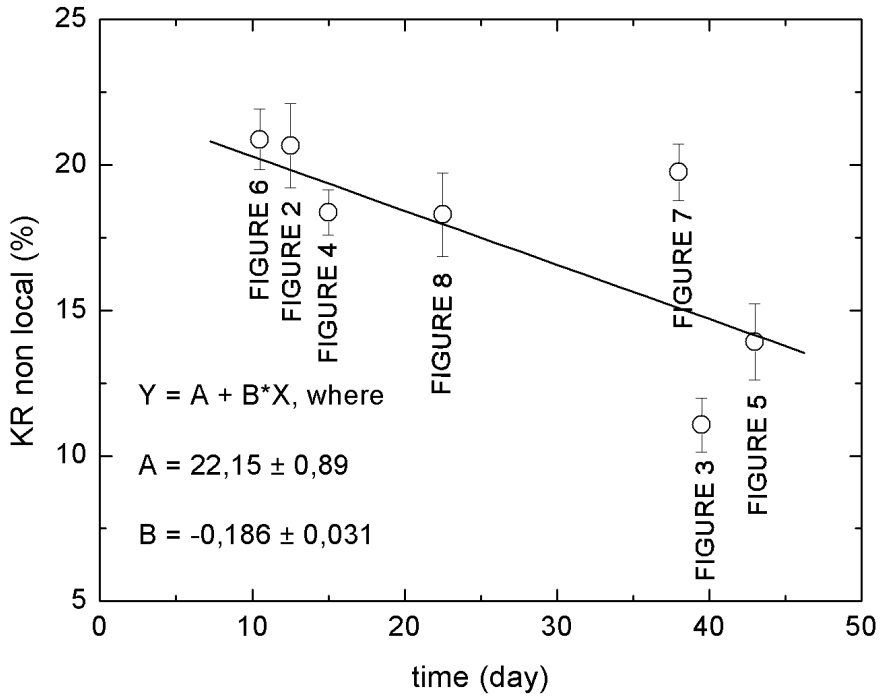

Fig. 9: Curve of Krnl to the cities of Pernambuco state. The figure shows where the values of the points are calculated.

The figures 10, 11, 12, 13 and 14 are graphic representative of equation 2 to Recife, Pesqueira, Afogados and Araripina cities, respectively.

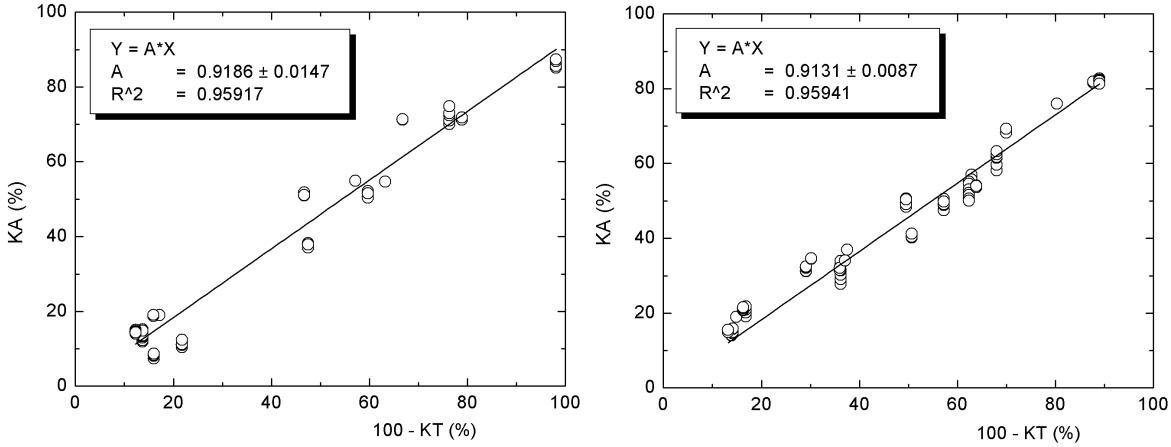

Fig. 10: Curve of Ka X (100%-Kt) to the Recife city, where left side is to the first period and another is to the second period.

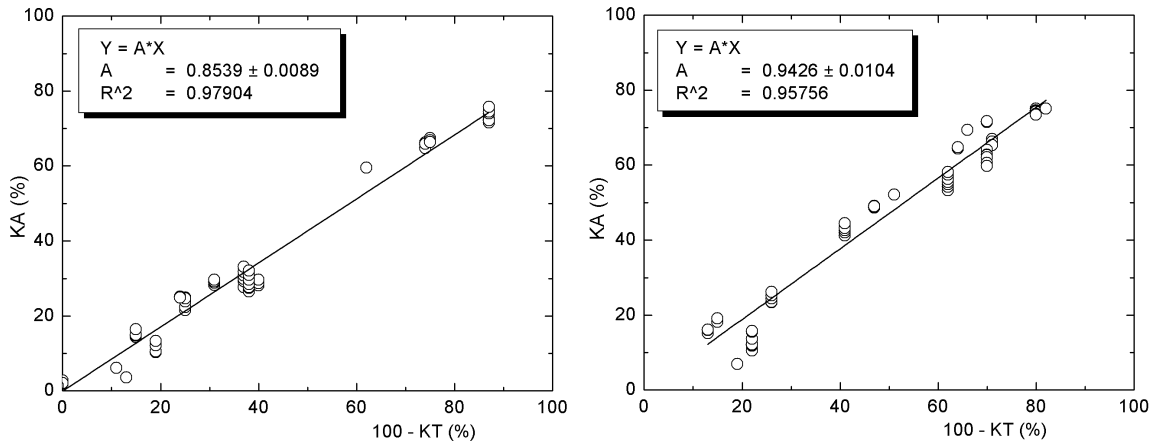

Fig. 11: Curve of Ka X (100%-Kt) to the Pesqueira city, where left side is to the first period and another is to the second period.

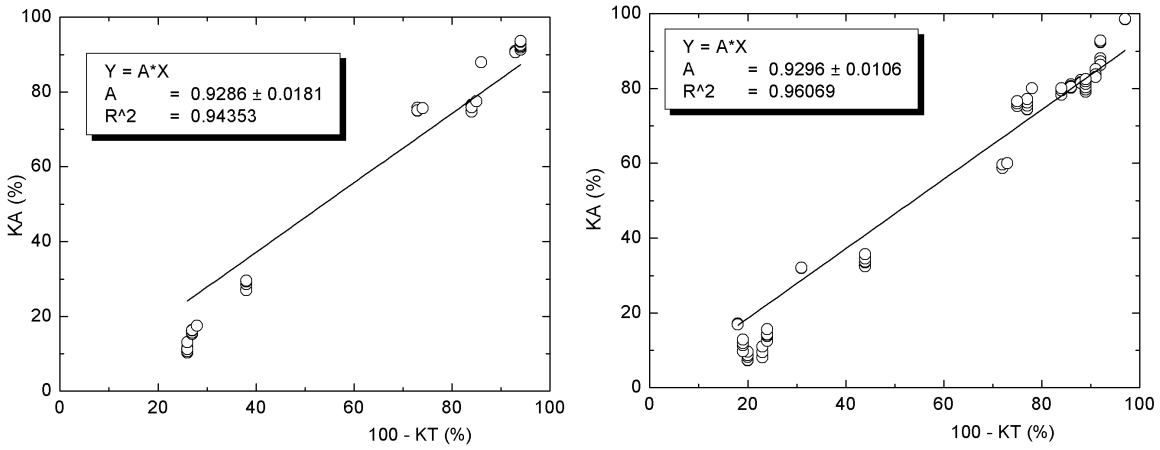

Fig. 12: Curve of Ka X (100%-Kt) to the Afogados city, where left side is to the first period and another is to the second period.

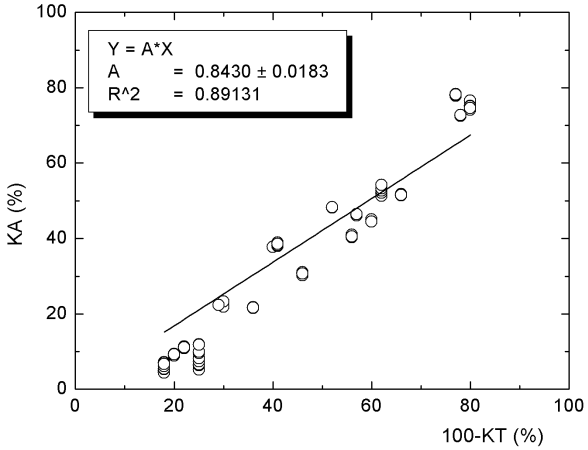

Fig. 13: Curve of Ka X (100%-Kt) to the Araripina city to the full period.

The figure 4 shows that linear fitting is taking with straight line passing to the origin, see equation (2). The correlation factor R^2 indicates a good result to Recife, Pesqueira and Afogados cities, but the curve of Araripina city shows a not so good result. To Araripina, we found that is necessary another equation to Krnl to calculate Ka. The curves of figures 10 to 13 shows a very interesting phenomenon, which is: The atmospheric net ratio (Ra) is not function of cloud coverage. The same value of Ra shows different values of Kt, where Kt is high means clear sky and Kt is lower than 0.2 means sky totally covered, but the value of Ra

is the same.

4. Acknowledgments

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5. References

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