SCD2 SATELLITE FROM INPE MONITORS THE PLANETARY REFLECTIVITY OVER SOUTH AMERICA

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INTRODUCTION

The solar radiation reflected by the system Earth's surface and atmosphere is known as Albedo. The value of the albedo depends on the nature or quality of the Atmosphere and on the type of surface (Land or Ocean) and cloud cover. Various natural and man-made phenomena (Greenhouse effect, Heat exchange, Aerosols, Deforestation, Volcanic eruption, etc.) change the value of Reflectivity (Veissid, 2003, 2011 and 2012). Therefore the variation of the planetary albedo values can be used to monitor climate change.

The Solar Cell Experiment of the Brazilian Satellite SCD2/MECB acts as an electromagnetic radiation sensor (350-1100 nm) and measures the global albedo over South America. Due to this, the experiment was renamed as "Albedo Experiment". The albedo data corresponds to several daily files stored and processed from the date of launch of the satellite. These data can be grouped into time periods (annual, seasonal or monthly) or being studied by regions in Latitude and Longitude (Veissid & Pereira, 2000).

Albedo Experiment data are transmitted in real time by satellite telemetry and received at the Receiving Station of Cuiabá, Mato Grosso State, Brazil (16° S, 56° W). Figure 1A shows the satellite orbits SCD2 within the sight of this Receiving Station in November 1998.

The temporal statistical distribution of the albedo in a particular region (circle in latitude and longitude with a diameter of 5º) shows a Gaussian behavior for the albedo logarithm. This discovery that the albedo logarithm has a dispersion with Gaussian distribution was first reported by Veissid (2007) and used in several other studies (VEISSID, 2009, 2010 and 2011). Therefore this distribution determines the mean value and its standard deviation or variability as a function over the days of the year (VUOLO, 1996). This behavior allows you to monitor climate variability, for statistical variations of this standard are evidence of climate change (VEISSID, 2002 and 2009). Figure 1B shows the histogram of measurements taken over the city of São Paulo in the last hundred days of the years 1999, 2000 and 2001 (VEISSID 2009 and 2010).

The telemetry points sampled at every half second (see Figure 2A), are submitted to a change of the time variable for the rotation angle. The peak solar radiation or solar amplitude is obtained by the Least Squares method, fitting a parabola around its maximum. Using this algorithm, the ECS telemetric points shown in figure 1 are transformed to the curve of figure 1B. The planetary albedo is the ratio between the height of the two peaks at figure 1B after angular spherical corrections (Veissid, 2000). The reflectivity of the Earth is an important parameter for many areas of study, such as remote sensing and meteorology (VEISSID, 2002 and 2009; VEISSID et al., 2010).

Correia et al. (2002) studied the variation of the global albedo from the Pantanal in southern Mato Grosso State at two distinct seasons: during the dry season, from April to September, when the ground is covered by a typical *Cerrado* vegetation, and during the flood season, when the region is covered by water. The minimum surface albedo, under clear sky condition, is around 20 % in the dry season and 10 % in the wet period.

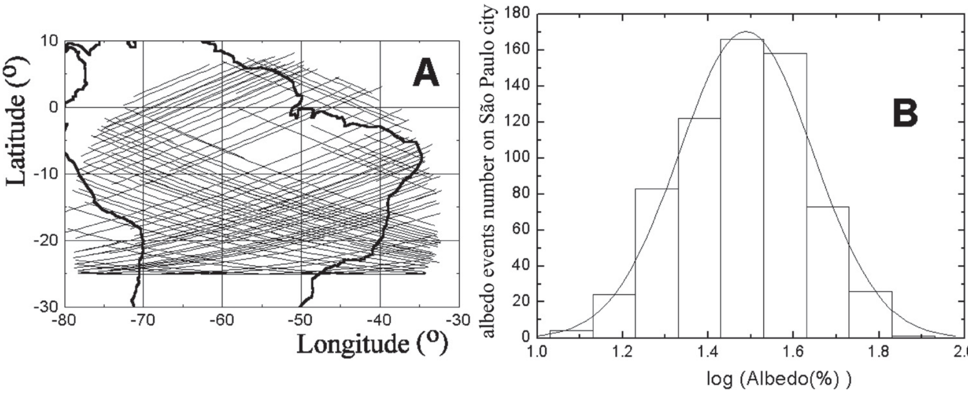

Figure 1 – A) SCD2 satellite orbits in November 1999 inside view of Cuiabá-MT ground station. B) Logarithm histogram of albedo over São Paulo city showing the Gaussian behavior

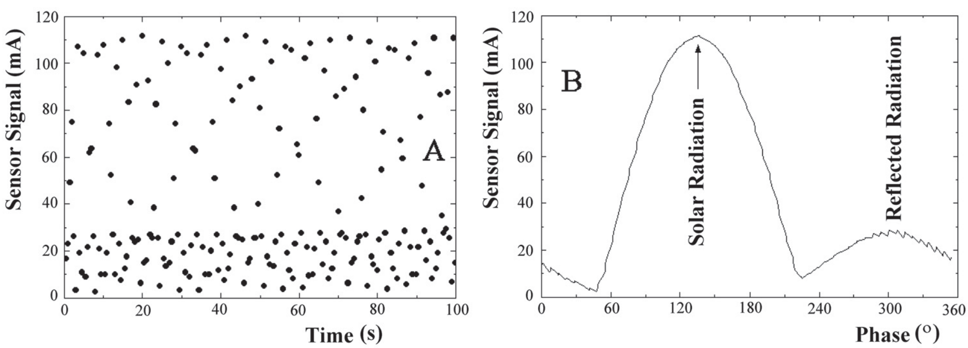

Figure 2 – Example of experiment telemetry signal as a function of time (A) and the curve of these data as a function of the satellite angle of rotation (B)

The curve of figure 2B shows that the EA realizes the solar radiation and the radiation reflected by the Earth simultaneously. The intrinsic speed of the satellite by spin is 35 rpm and the rotation axis perpendicular to the ecliptic plane of the Earth. The difference of 180° between the two peaks in this figure shows that the satellite is geometrically aligned between the Earth and the Sun.

EXPERIMENTAL MEASUREMENTS

The SCD2 satellite covers the sight shown in figure 1. The Pantanal, which is the region chosen for this work, constitutes a rectangle in Latitude and Longitude with a side of 3° centered at 18.5° South latitude and 56.5° West longitude. From this point on, in this study the region is mentioned several times as "Pantanal rectangle". All data measured during the Albedo Experiment in this region are shown in figure 3 for the 11-year period (1999-2009).

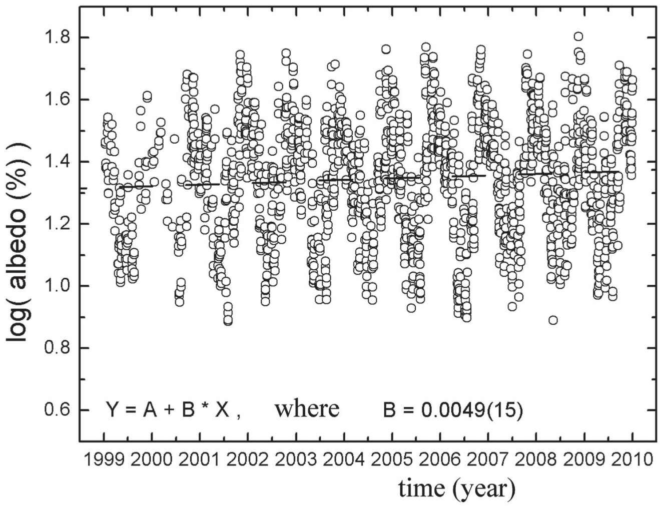

Figure 3 – Measurements of the planetary albedo on the Pantanal region

Figure 3 shows seasonal variation and also the average of the experimental points. The straight line obtained from the linear fit has a positive slope of 0.0049 log (%) per year. This positive slope is due to the fact that in 1999 the reflectivity had an average of 20.9 % and in 2009 it was 24.0 %. The intermediate years had an increase in value of almost the linear average albedo.

Each point of figure 3 corresponds to an albedo measurement made when the satellite SCD2 orbited on the Pantanal rectangle. The dispersion of these points is significant and represents the activity of the surface-atmosphere system. Cloud cover and reflectivity of the flooded areas make the albedo to oscillate between a maximum and a minimum value, respectively. In this basis, the analysis of these values as a function of time allows to monitor climate change in the Pantanal region, when a period of at least ten years is considered.

RESULTS

Figure 3 show that the albedo data from the Pantanal region has a seasonal variation. Therefore this study was done with values from yearly quarters. The values were separated into quarters December 1998 until November 2009 and correspond to the quarterly periods DJF (December, January and February), MAM (March, April and May), JJA (June, July and August) and SON (September, October and November). The results are shown separately for each quarter in figure 4. It also shows the values of the adjusted straight lines.

The study of trends from all quarters shows an increase in the value of the planetary albedo over the years 1999 to 2009. The quarter with the most pronounced increase was the JJA with a 0.0055 log rate (%)/year. Considering a regular variation, this means that in JJA (1999) the mean albedo value was 14.1 % and that at JJA (2009) was 16.0 %.

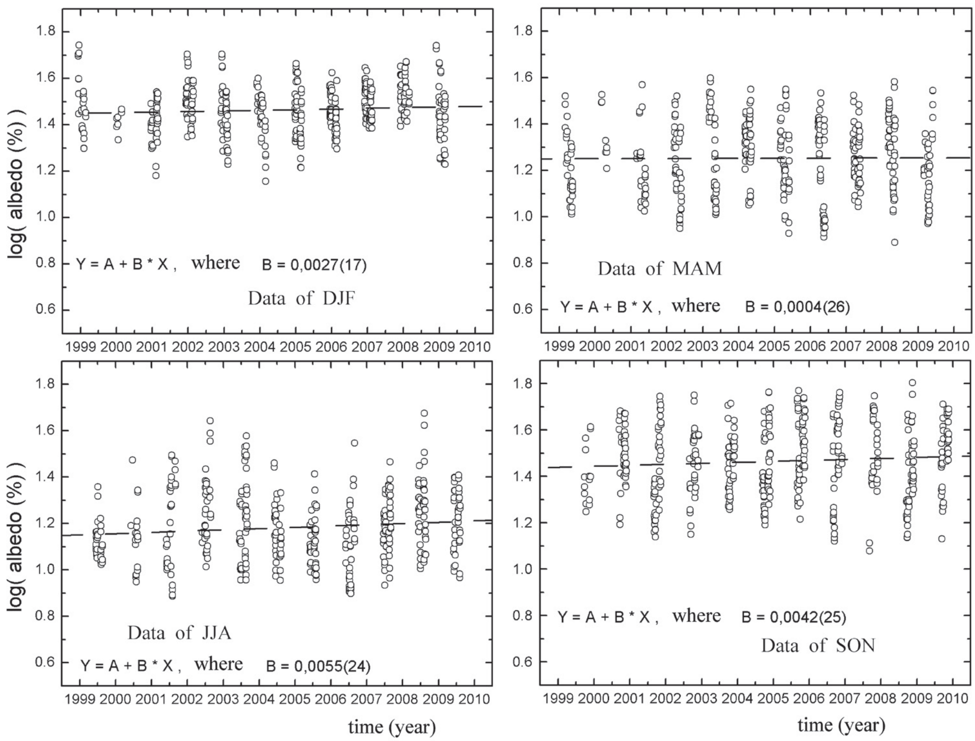

Figure 4 – Values of the planetary albedo of Figure 3 separated by quarterly periods

FIVE YEARS STANDARD

The dispersion values can be analyzed by comparing with some standard to study and understand the variations. The standard chosen in this work was a five-year period (1999 to 2003). The dispersion of the planetary albedo logarithm has a Gaussian distribution, and this fact allows determine the average value and the standard deviation of variability, as reported in the introductory part of this work. In this context, there is a frequency of events repetition, within a range of plus/minus standard deviation of variability around the average of 68 %. Figure 5A shows the calculated curves of the monthly average and the range limited by envelopment of one standard deviation above the average and another one below. In the graph of figure 5A the albedo values within this envelopment corresponds to 68 % of the points and, logically, out of the envelopment are the other 32 % of the points distributed symmetrically with 16 % above and 16 % below the envelopment limits. The years beyond this period of five years will repeat the 68 % frequency rates.

In case that this count frequency of albedo values is far away from 68 % value, this means that a change in climate is taking place. For example, if the albedo values occur with a higher incidence than that expected on the upper part of the above threshold from the envelopment, this indicates an increase in cloud cover. Otherwise, a decrease in frequency values below the bottom of the envelopment, indicates a decrease in the area of flooded Pantanal wetlands. Table 1 shows this study of frequency made at points of figures 5B and 5C.

Expected values in this table are 16 % for the second and third column and 68 % for the fourth column. The year 2008 had greatest frequency value for the portion above the envelopment (26.5 %). All the values were above 16 % and this shows a cloud cover increasing trend when compared to the 1999-2003 period.

The year 2007 was that had lowest frequency value for part below the envelopment (8.9 %). The years 2004, 2006 and 2009 were symmetrical in the distributions around the average value, despite the expected frequency was lower than 68 %.

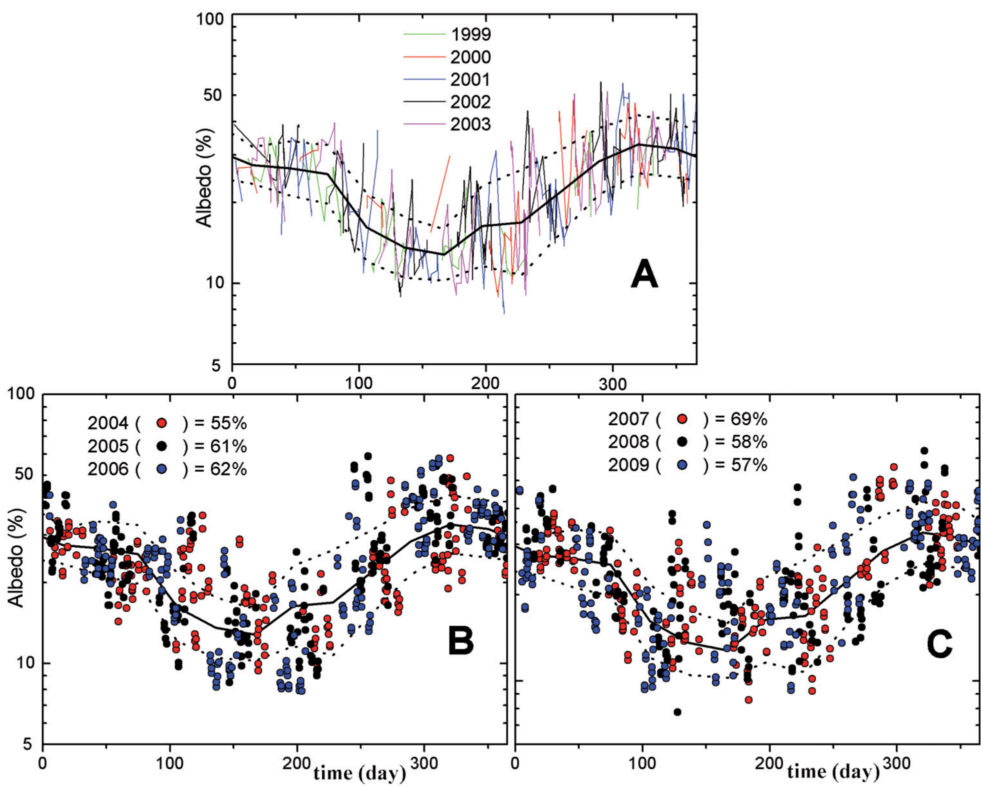

Figure 5 – A) Pattern of five years, B) Values of the planetary albedo of 2004, 2005 and 2006 years and C) Values of the planetary albedo of 2007, 2008 and 2009 years on the pattern curves of five years

Table 1 – Frequency of events for data showed at the Figure 5

YEAR	Above (%)	Below (%)	Inside (%)
2004	23.6	21.3	55.1
2005	23.5	15.5	61.0
2006	19.1	19.0	61.9
2007	22.2	8.9	68.9
2008	26.5	15.5	58.0
2009	20.8	21.8	57.4

CONCLUSIONS

A simple experiment placed aboard a Brazilian satellite allows the estimation of the planetary albedo in real time. Data processed with a suitable algorithm allows monitoring the climate variability because the albedo corresponds to the reflectivity of solar energy by the Atmosphere-Surface system. For example, the clouds produce reflectivity between 60 % and 80 %, and in the ocean it is less than 5 %. The continents reflect between 10 % and 30 %, depending on soil cover. The methodology used is free from the effects of sensor degradation (solar cells) from the Experiment because the two signals suffer a proportional reduction which is compensated by the ratio in the calculation of the albedo. A similar fact happens also with the effect of the temperature.

The region chosen for this work corresponds to a rectangle with a side of 3° centered 18.5° southern Latitude and 56.5° western Longitude. The planetary albedo data from this region are shown in figure 3, and these data were analyzed in two distinct ways. At the first one, they were separated by quarters and also analyzed by comparison with the pattern generated in the first five years. These two types of studies have shown that the reflectivity has a tendency to increase and that it has different magnitudes in the different quarters analyzed. The quarters June, July and August were the ones who showed greater increase. This increase is probably explained by a greater intensity of cloud cover.

The study of incidence frequencies of events on the standard envelopment produced in the five years period 1999-2003 showed significant results. Every year, with the exception of 2007, there was a significant increase in the dispersion of the albedo values relative to the average value. The years 2005 and 2006 had an increased incidence of albedo values below the lower limit of the envelopment during the dry season of the wetland area. In the years 2004, 2008 and 2009 this increase was during the rainy season.

Data analysis in later years will allow establish safely if climate change is occurring in the Pantanal region. The Albedo Experiment of satellite SCD2 continues to operate and probably will be operational for over ten years or more, because orbit control and SCD2 satellite conditions are encouraging.

Data and partial conclusions of this work were presented in 2014 at the 5th Pantanal Geo-Symposium in Campo Grande - MS (VEISSID, 2014) .

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