Chapter 5

Correction of Historical Data

In this chapter, the 18-month ARM data set is used to validate the relationships developed in Chapter 4. The offset estimated from net IR data is compared to that estimated from the PSP-B&W difference. The technique using cloud cover fraction is also validated.

5.1 Analysis of the Offset

Diffuse solar irradiances are measured with standard shaded PSP's at the ARM SGP site. Shaded B&W pyranometers have also been in use since mid-1999. Net IR data are available from collocated PIR's. Modified PSP's have been used for specific field campaigns but not operationally. In the ARM data set, the daytime PSP offset can be estimated by three different techniques:

- nighttime regression between PSP offset and net IR,
- difference between PSP and B&W output, assuming the B&W has zero offset,
- daytime regression between PSP offset and cloud cover fraction

Figure 5.1 shows a time series of monthly mean PSP offset from July 1999 to January 2001. The nighttime offset is shown in black, the daytime offset estimated from net IR data is shown in green, and the daytime offset estimated from PSP-B&W is shown in blue. The lines are polynomial fits of data. The offsets show an annual cycle with a

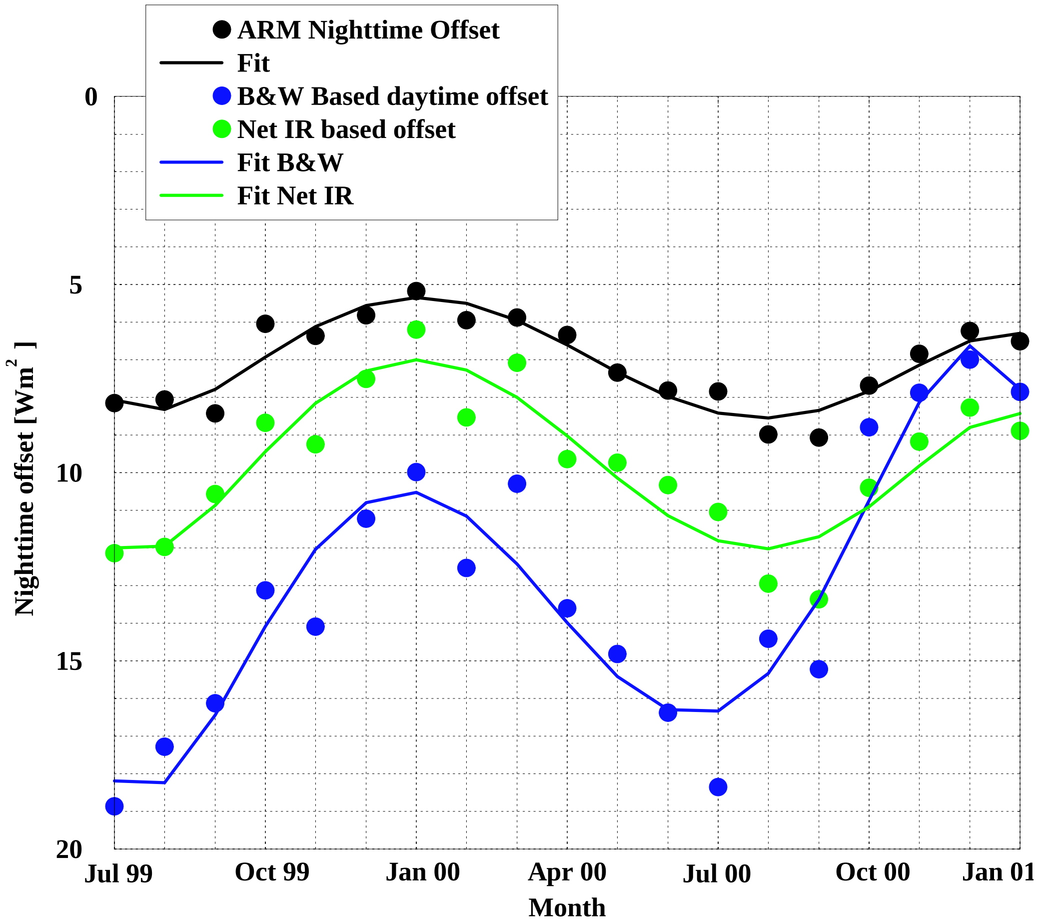

Figure 5.1: Evolution of the nighttime and daytime offset estimate from July 1999 to January 2001

maximum during wintertime and a minimum during summertime. The month-to-month variability of the nighttime and net IR-based daytime offsets are well correlated. Note that the day/night difference is twice as large in summertime than it is in wintertime. This is due to larger diurnal cycles of surface temperature in summertime. The standard PSP was replaced in August 2000 for its annual calibration but the PIR and the ventilation systems remained identical. The nighttime and daytime offset based on net IR deviate slightly from the general trend in August and September 2000. The nighttime offset and the daytime offset estimated using the net IR show a coherent and logical result: a yearly variation depending on the local atmospheric conditions (such as humidity, precipitation, number of clear sky days) and a small instrument dependence as long as the ventilation system is not changed. The annual cycle of the daytime offset based on PSP-B&W is also correlated to the nighttime offset from July 1999 to July 2000. After the PSP change, the difference between the PSP and the B&W output are not consistent with the other curves, which reveals the weakness of this technique. The use of the PSP-B&W difference to estimate the PSP offset is based on two assumptions: (1) the B&W has no offset, (2) the calibration of the two instruments are consistent and does not introduce a bias. The PSP-B&W intercalibration issue can be observed in this example, hence the use of B&W to determine the offset can only be done with very well calibrated data.

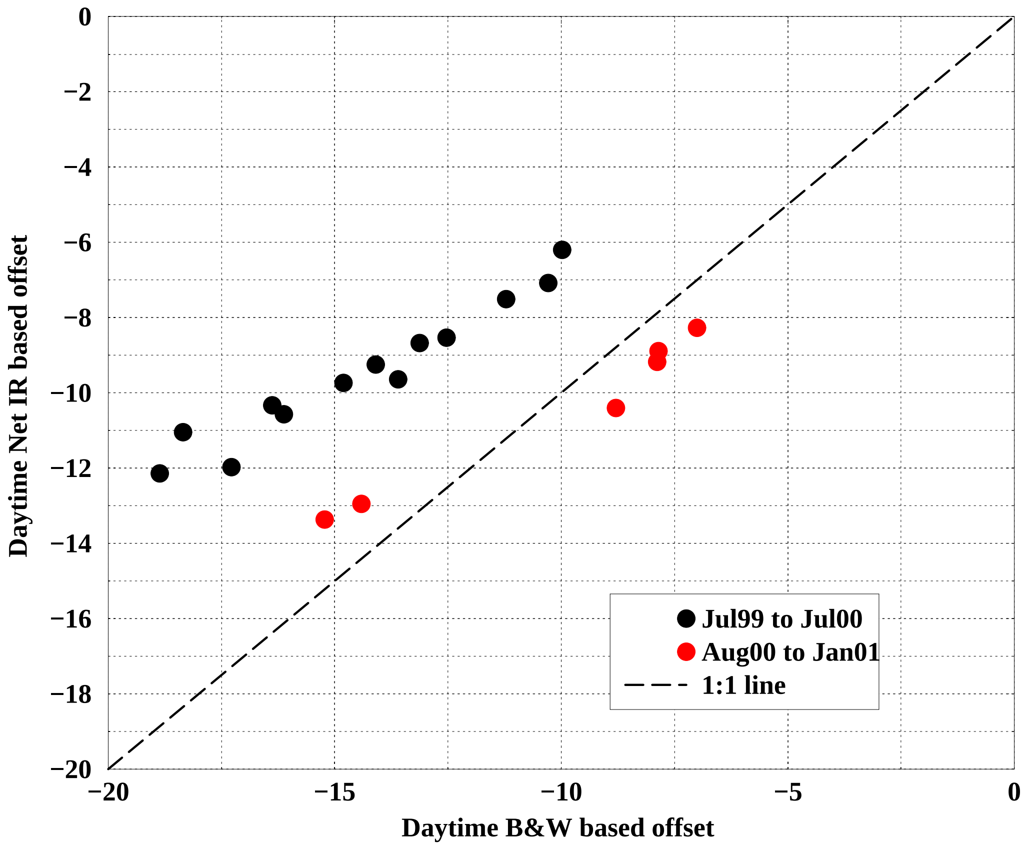

Figure 5.2: Monthly mean daytime net IR-based offset versus monthly mean daytime B&W-based offset.

Figure 5.2 shows the monthly mean daytime net IR-based offset versus monthly mean daytime B&W-based offset. Data from July 1999 to July 2000 are plotted in black and from August 2000 to January 2001 in red. The calibration consistency between the B&W and PSP before and after August 2000 is different and hence the offset estimate will also be different.

5.2 Net IR vs PSP offset Relationship

5.2.1 Coefficients of the Regression

The first technique proposed to correct the offset is based on the net IR

$$Offset = A(netIR). \tag{5.1}$$

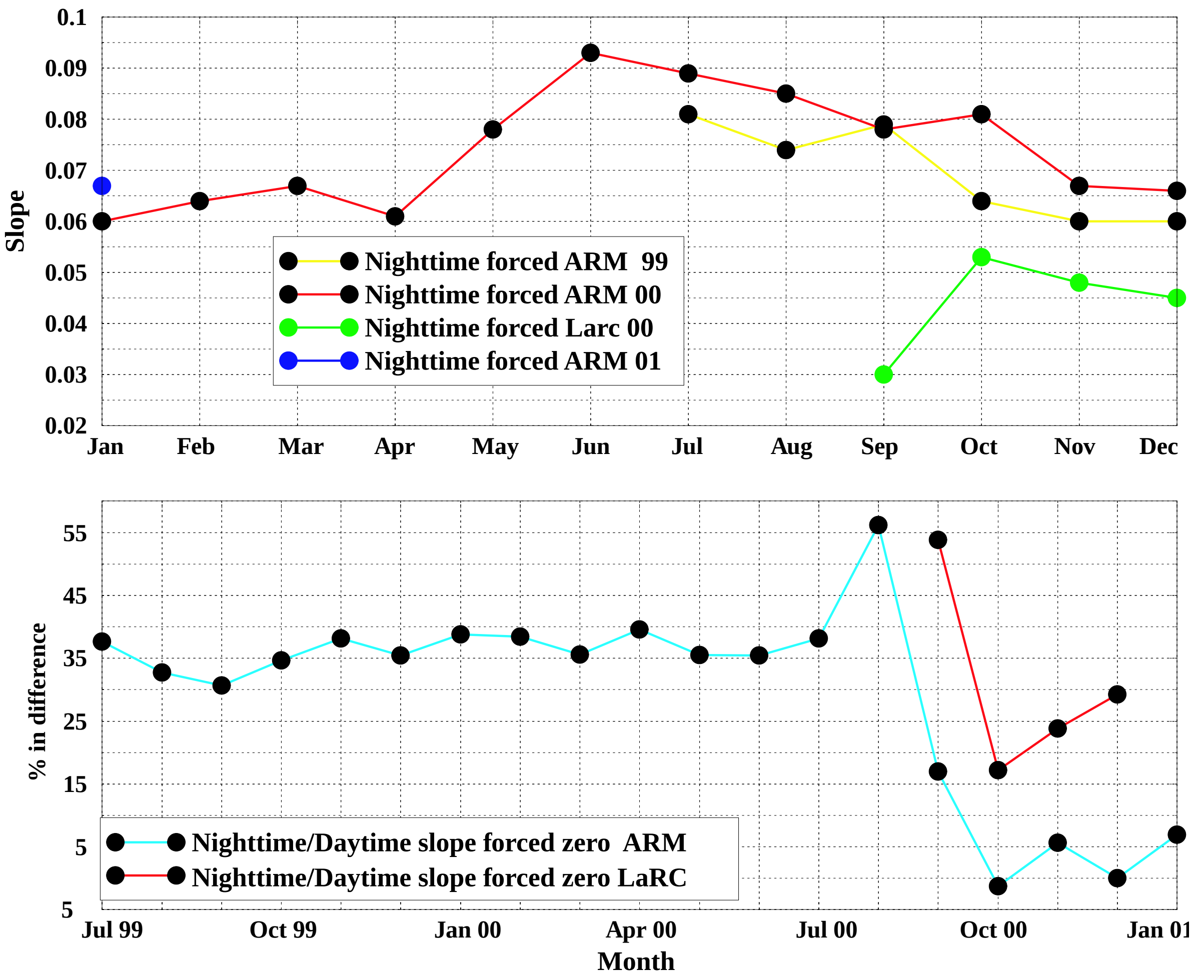

Figure 5.3: (a) Evolution of the slopes of equation 5.1 in the ARM data set and the LaRC data set and (b) Ratio between the nighttime slope forced through zero and the daytime slope forced through zero.

Figure 5.3 (a) shows the variation of the nighttime slope A in 1999, 2000 and 2001, in yellow, red and blue, respectively, for the ARM data set. The LaRC data set is shown in green. The month-to-month variation is significant. It is strongly recommended to calculate and apply the coefficients of Equation 5.1 on a monthly basis to obtain the maximum accuracy in the correction.

Figure 5.3 (b) shows the ratio between the nighttime slope of the Equation 5.1 and the daytime slope of Equation 5.1. The PSP offset in the daytime slope is an estimate based on PSP-B&W. This ratio remains constant from July 1999 to July 2000 but when the PSP is replaced the ratio changes quite significantly and stabilizes at another value. This result reveals that there is a stable ratio between daytime and nighttime slope for each particular instrument. However due to the uncertainty of the estimation of the daytime offset because of the PSP-B&W intercalibration issue no solid conclusions can be drawn about the value of the day-night slope ratio.

5.2.2 Accuracy of the correction

The only way to validate the net IR technique using the ARM data set is to use the daytime B&W-based offset estimate as a reference. However it has been proven in the previous section that the data from this offset estimate contains an uncertainty related to the instrument calibration.

Figure 5.4 shows the monthly variation of the B&W-based daytime offset estimate plotted in black. The corrected irradiance is defined as

$$TrueE = PSPoutput - A(netIR), \tag{5.2}$$

where A is the slope of Equation 5.1 determined month by month. The difference between the corrected irradiance and the B&W irradiance is an estimate of the offset not accounted for by the net IR technique. This remaining error is plotted in red. Before August 2000 the PSP-B&W difference is larger (in absolute value) than the net IR-based offset. After the PSP is replaced by a recently calibated PSP, the PSP-B&W difference and net IR-based offset agree within 1 Wm^{-2}. However in Chapter 4 we concluded that the net IR-based offset underestimates the offset based on PSP temperature measurements. Collocated PIR, B&W and modified PSP measurements are required to conclude on this discrepancy.

Figure 5.5 shows a histogram of the daytime offset estimate in black and the offset after correction using the net IR relationship for the months of January 2000 and July 2000. The offset presents a typical binomial distribution due to clear and overcast days.

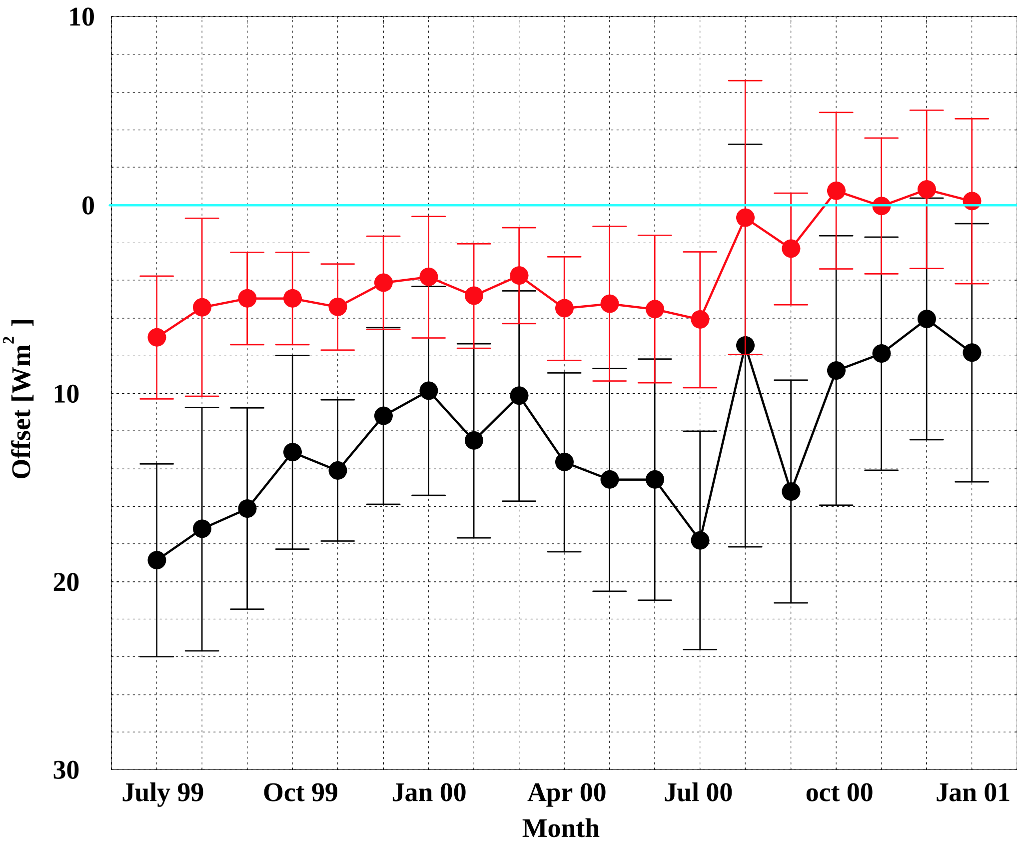

Figure 5.4: Monthly variation of the B&W based daytime offset estimate (black) and the remaining error after correction using the net IR relationship (red). The error bars represent the standard deviation around the monthly mean.

5.3 Cloud Cover vs PSP Offset Relationship

The second technique proposed to correct the PSP offset is based on the cloud cover fraction

$$\mathit{Offset} = A(CF) + B. \tag{5.3}$$

The cloud fraction has been retrieved month by month from July 1999 to January 2001 for the ARM data set. The Long/Ackerman algorithm was used for this task.

5.3.1 Coefficients of the Regression

Figure 5.6 shows the B&W-based offset estimate versus the cloud cover fraction and the net IR-based offset estimate versus the cloud cover fraction in black and red respectively. The data are binned in 5% cloud cover intervals plotted in green for the

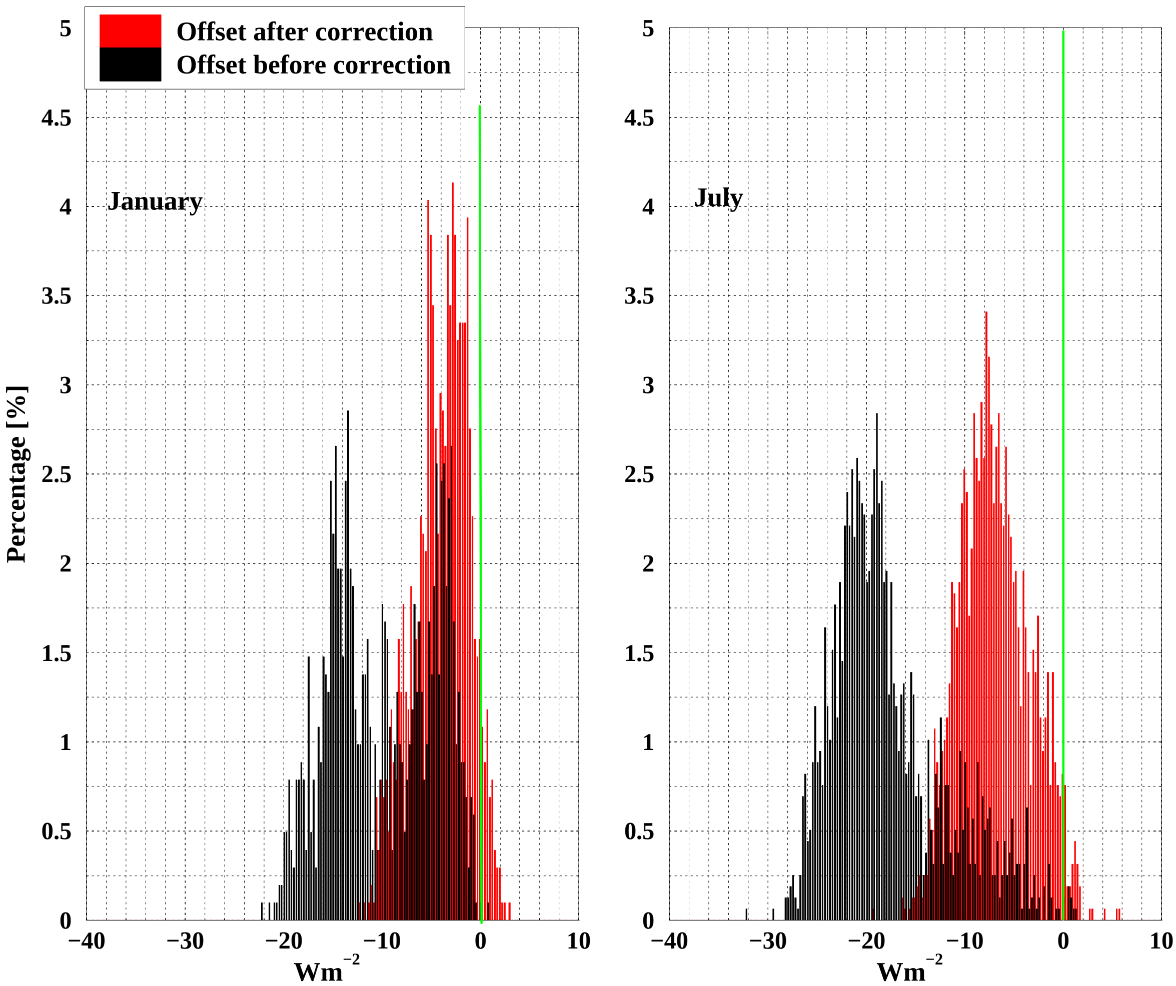

Figure 5.5: Histrogram of the PSP offset estimated from the B&W during daytime (black) and the error after correction using the net IR relationship (red), in January and July 2000.

B&W-based offsets and in light blue for the net IR-based offsets. A linear regression, shown in yellow and dark blue, is fitted through both binned data. Figure 5.8 and 5.7 are the same scatterplots as 5.6 but for July 2000 and January to December 2000, respectively. The linear relationship between daytime offset estimate and cloud cover observed during the LaRC experiment can also be observed in Figures 5.6, 5.7 and 5.8. However when the offset is estimated using B&W data the relationship is not as linear as when the offset is based on the temperature gradient between dome and body or when the offset is estimated using the net IR output. Figure 5.9 shows the variations of the slope of Equation 5.3 when the daytime offset is estimated using B&W data and net IR data plotted in black and red, respectively. The slopes derived from B&W data present a huge variation when the PSP is replaced in August 2000, therefore it seems more reasonable to estimate the offset using net IR data. However we know from Chapter 4 that the net IR technique underestimates

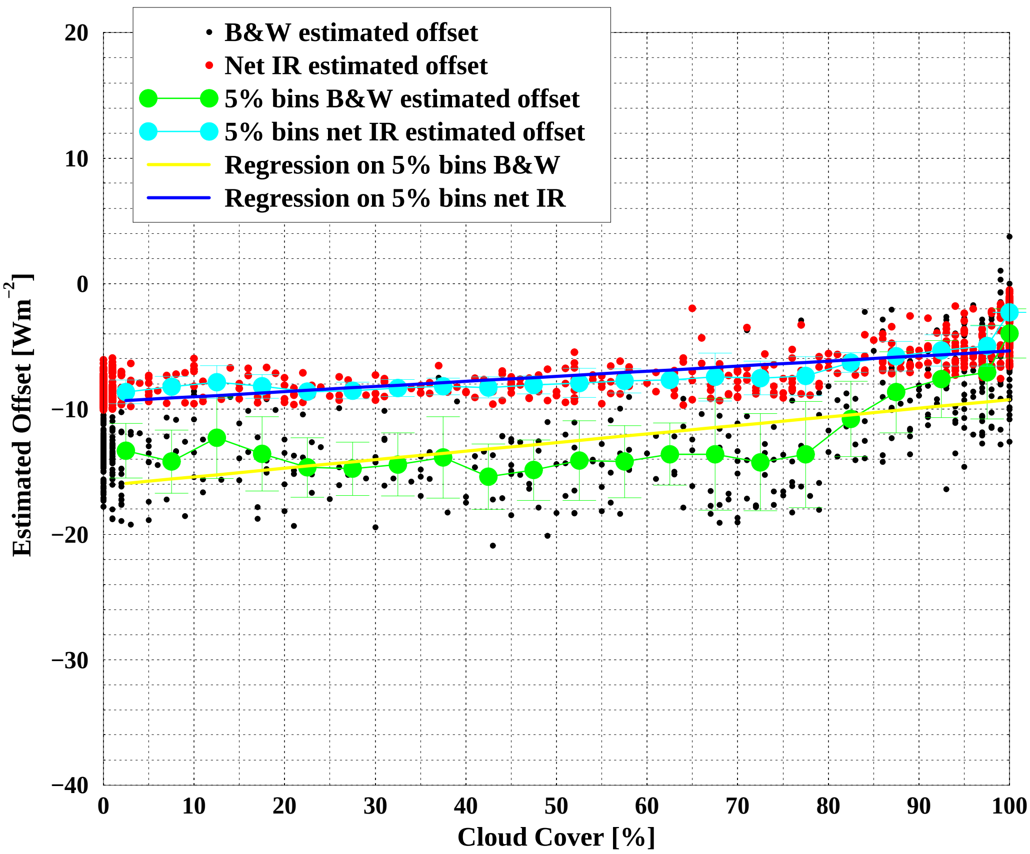

Figure 5.6: Scatterplot B&W estimated offset and net IR estimated offset versus cloud fraction in January 2000

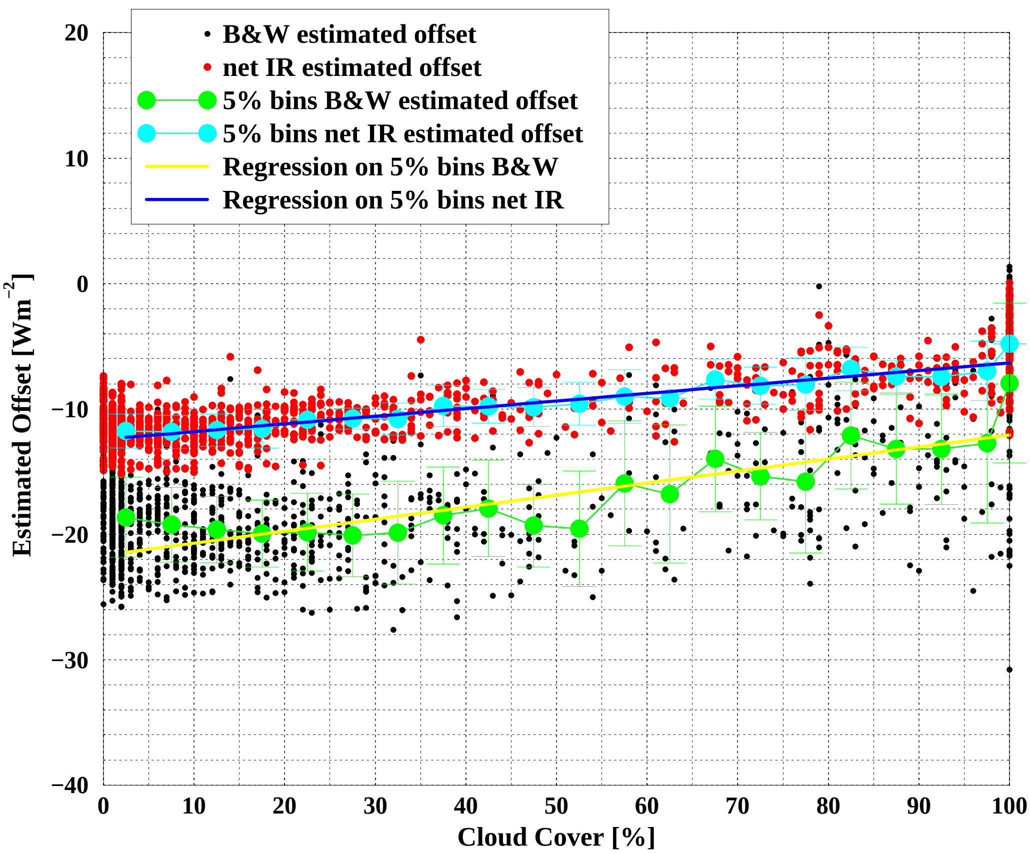

Figure 5.7: Scatterplot B&W estimated offset and net IR estimated offset versus cloud fraction in July 2000

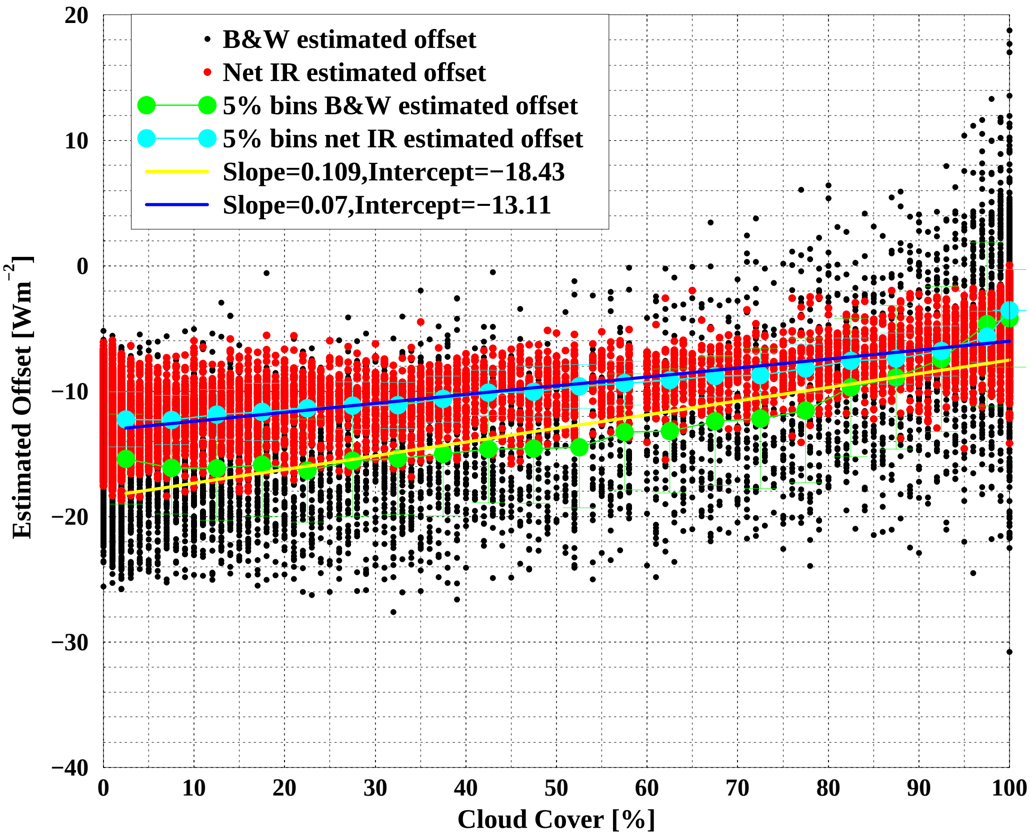

Figure 5.8: Scatterplot B&W estimated offset and net IR estimated offset versus cloud cover fraction for the entire year 2000

the offset somewhat.

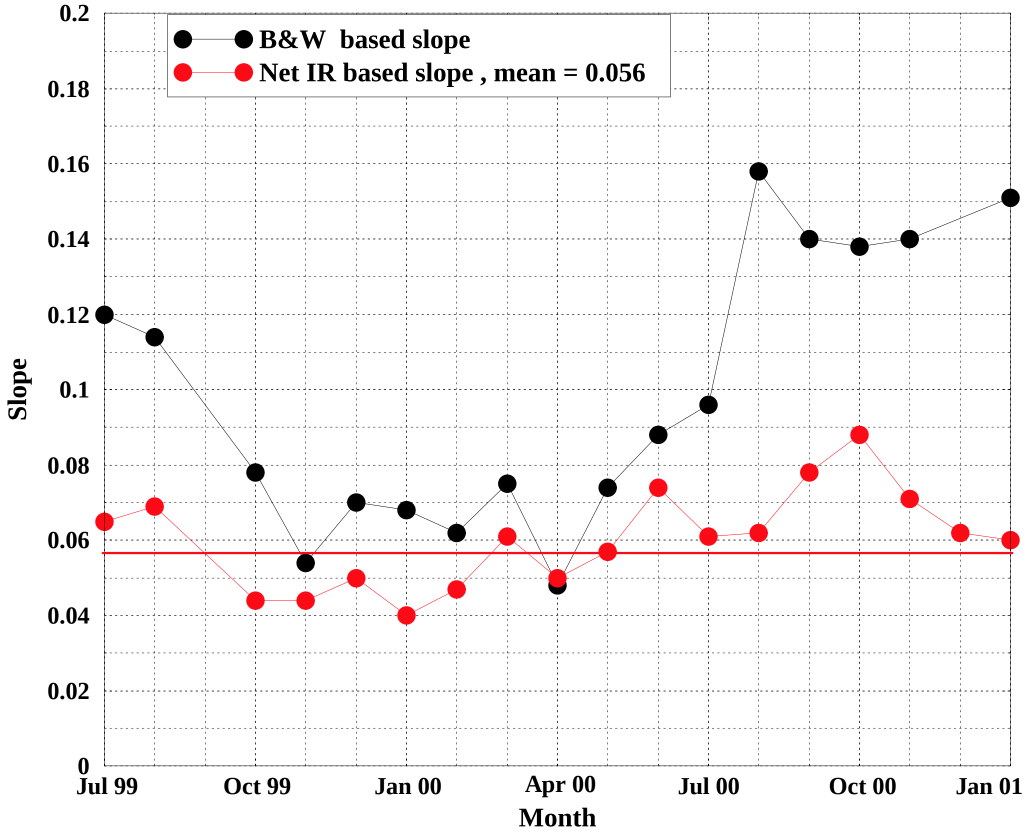

Figure 5.9: Monthly variation of the slope of Equation 5.3 when the daytime offset is estimated using B&W data (black) and net IR data (red)

5.3.2 Accuracy of the correction

How can the coefficients of Equation 5.3 be estimated in a historical data set? To determine both coefficients it is necessary to know the slope and one intercept point (clear sky or overcast conditions) or two points (clear sky and overcast). The slope is not constant during the year, therefore the second option seems to be the most reasonable. The hypothesis used to retrieve these points is that it exists a relationship between the daytime and nighttime offset when the sky is clear and overcast. To find the clear-sky points at night a mean of the 10% most negative values has been calculated for each month. To find the overcast conditions a mean of the 10% least negative values has been calculated for each month. Figure 5.10 shows

$$\lambda = \frac{Offset_{Day} - Offset_{Night}}{Offset_{Night}} 100, \tag{5.4}$$

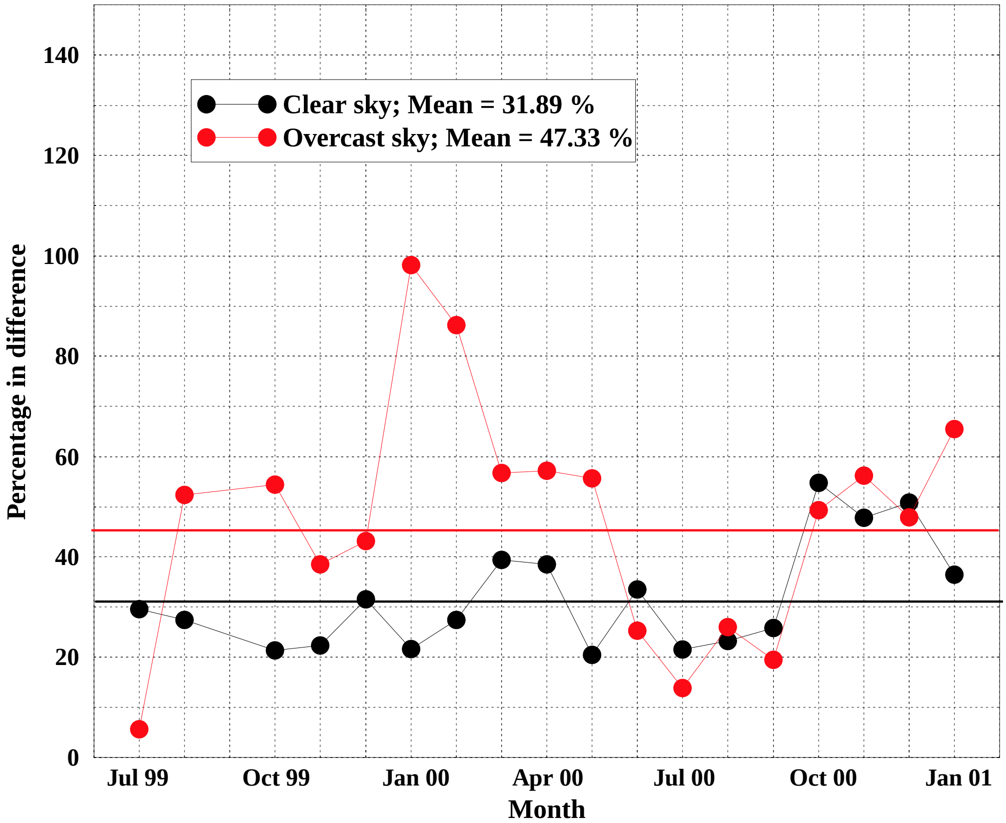

Figure 5.10: Monthly ratio λ during clear sky and overcast conditions

for clear sky conditions and overcast conditions in black and red, respectively. Note that here the negative daytime offset estimate is based on net IR data. Figure 5.10 reveals that on average under clear-sky conditions the daytime offset is 32% larger than the nighttime offset. Under overcast conditions the daytime offset is 47% larger than the nighttime offset. Based on this information, we can use the nighttime offset data and the daytime cloud cover fraction data to estimate the daytime offset.

The method is as follows and it is summarized in Figure 5.12: (1) determine the monthly ratio (Equation 5.4) for all data for clear sky and overcast conditions for each month (2) calculate the mean ratio for clear sky and overcast conditions, (3) compute the mean of 10% lowest values (clear sky) and the 10% largest values (overcast) of the nighttime offset and multiply them by the ratio calculated in (2) month by month to find the daytime offset estimate for clear sky and overcast sky, (4) knowing the daytime offset estimate for clear sky and overcast conditions determine the slope and intercept of Equation 5.3, (5) correct the offset. Figure 5.11 shows the monthly variation of the net IR-based daytime offset estimate in black. The thermal offset is corrected using Equation 5.3 with coefficients A and B determined month by month

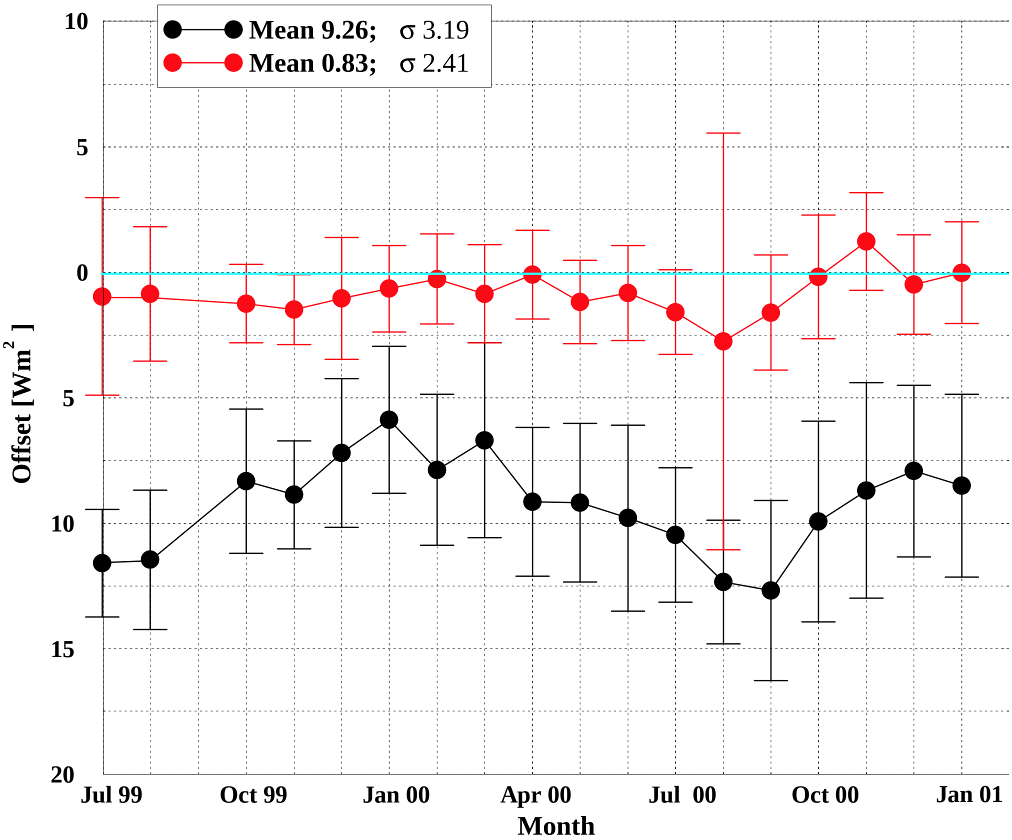

Figure 5.11: Monthly variation of the net IR based daytime offset estimate (Black) and the remaining error after correction using the cloud cover relationship (red).

$$TrueE = PSPoutput - (A(CF) + B), \tag{5.5}$$

the remaining error, therefore, will be:

$$Error = ((A(CF) + B) - offset_{netIR}, \tag{5.6}$$

where offset is an estimate of the offset based on net IR data. This remaining error is plotted in red. The offset is almost completely removed (bias=-1Wm^{-2}) (without taking into account the error estimating the daytime offset using the net IR relationship) in the mean with a standard deviation of 2.4 Wm^{-2}.

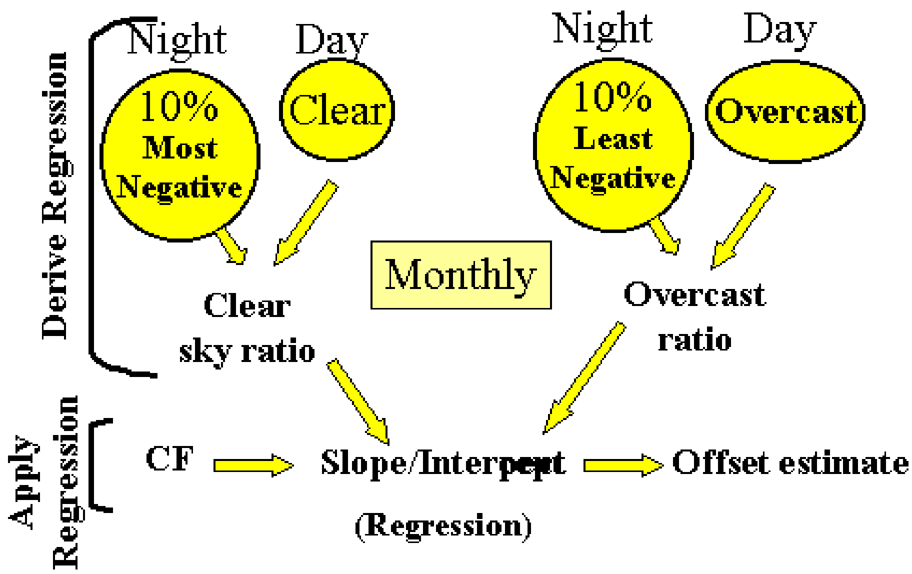

Figure 5.12: Flow chart of the procedure to estimate the offset using the cloud cover relationship