TEMPERATURE AND PRESSURE CORRECTIONS IN THE MILAGRO SCALER RATES

EITAN ANZENBERG

ABSTRACT. In this memo, a method for correlating temperature and pressure readings with the scaler rates of Milagro is outlined. Variations of the scalers during the day is suspect to be caused by temperature and pressure fluctuations in correlated and anti-correlated cases. A mathematical approach is taken to minimize the RMS of the scaler rates by varying correction factors and results are shown.

1. Introduction

The scaler analysis method differs from the usual reconstruction method in the way the rates of individual photo-multiplier tubes (PMTs) are collected close to every second (not exactly 1 second due to slight time shift between GPS time and the computer clock where scalers are read out into data files). Next, it's a simple matter of statistically looking for excess signal over noisy background.

Milagro is split into 3 groups: the air-shower layer, the muon layer, and the outriggers. The PMTs are calibrated to sensitivity of ∼1 photo-electron (P.E.) in the low-threshold setting, and ∼5 P.E. in the high-threshold settings. Each group is then split into low and high thresholds, making a total of 6 arrays of PMTs to look at. Each array is furthermore grouped into blocks of 16 PMTS in a square-block configuration. In the air-shower low threshold array the block of 16 is furthermore subdivided into 2 groups of 8 PMTs. Each group is then OR-linked electronically. Within a block of 16 PMTs, a PMT is read out once every 16 seconds. The data is then read out in 16 second cycles and written to a data file.

2. Method

Instruments at Milagro constantly measure the outside temperature and atmospheric pressure, and the counting-house temperatures of the various electronic equipment about every 2 minutes. The scalers have a time resolution of 1 second so the pressure and temperature readings are linearly interpolated to provide a reading for each rate time stamp.

Faulty OR channels within Milagro are excluded in the method outlined in [1]. This is done before the corrections.

There is strong evidence for correlation between the scaler rates and atmospheric pressure, outside and counting-house temperature. This is illustrated in Fig 2.1. Julian dates from here on in are truncated by subtracting 2450000.5 from the Julian day.

To correct for the trends, we devise to add correction terms to the scaler rates. There are 3 factors: outside pressure, outside temperature, and counting house temperature (different for the different arrays, which will be illustrated in §3). Each counting house temperature is corrected individually according to each channel with its temperature reading. Also the low/high threshold arrays are done individually.

$$\text{rate}'_i = \text{rate}_i + C_1(T_{i,1} - T_{0,1}) + C_2(T_{i,2} - T_{0,2}) + C_3(T_{i,3} - T_{0,3}) \tag{1}$$

The constant factors are C_1, C_2, and C_3, while the three T_i correspond to the values of outside pressure and

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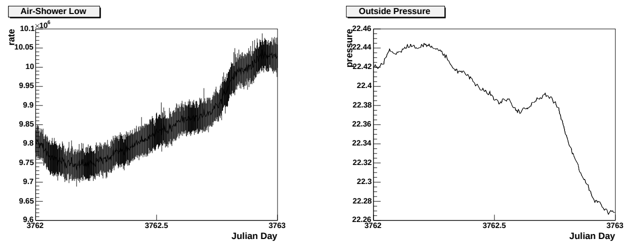

FIGURE 2.1. Rates and outside pressure from the air-shower low array during truncated Julian date 3762

temperature, and counting house temperature. The $rate_i$ are the scaler rates. The three T_0 correspond to constants of the temperatures and pressure, which we will solve for later.

We put the constraint of minimizing the RMS of $rate'_i$, which will minimize the fluctuations of the corrected data. The constants we are allowed to vary are C_1, C_2, and C_3, and we will then solve for the three constants which give us the lowest RMS of $rate'_i$. This is done by taking derivatives with respect to the three factors and equating them to 0.

$$\begin{aligned} \frac{d}{dC_1}\mathrm{RMS}' &= 0 \\ \frac{d}{dC_2}\mathrm{RMS}' &= 0 \\ \frac{d}{dC_3}\mathrm{RMS}' &= 0 \end{aligned} \tag{2}$$

where

$$(\mathrm{RMS}')^2 = \langle \mathrm{rate}'^2 \rangle - \langle \mathrm{rate}' \rangle^2 \tag{3}$$

Minimizing RMS' also minimizes $(\mathrm{RMS}')^2$, therefore we don't have to square root Eq (3) in the next step. This method allows us to minimize the 3 factors simultaneously. We get 3 equations from the 3 derivatives, and 3 unknowns (C_1, C_2, and C_3). Here they are in matrix form:

$$\begin{bmatrix} \sum_i^n (T_{i,1})^2 - \frac{1}{n}(\sum_i^n T_{i,1})^2 & \sum_i^n T_{i,1}T_{i,2} - \frac{1}{n}\sum_i^n T_{i,1}\sum_i^n T_{i,2} & \sum_i^n T_{i,1}T_{i,3} - \frac{1}{n}\sum_i^n T_{i,1}\sum_i^n T_{i,3} \\ \sum_i^n T_{i,1}T_{i,2} - \frac{1}{n}\sum_i^n T_{i,1}\sum_i^n T_{i,2} & \sum_i^n (T_{i,2})^2 - \frac{1}{n}(\sum_i^n T_{i,2})^2 & \sum_i^n T_{i,2}T_{i,3} - \frac{1}{n}\sum_i^n T_{i,2}\sum_i^n T_{i,3} \\ \sum_i^n T_{i,1}T_{i,3} - \frac{1}{n}\sum_i^n T_{i,1}\sum_i^n T_{i,3} & \sum_i^n T_{i,2}T_{i,3} - \frac{1}{n}\sum_i^n T_{i,2}\sum_i^n T_{i,3} & \sum_i^n (T_{i,3})^2 - \frac{1}{n}(\sum_i^n T_{i,3})^2 \end{bmatrix} \begin{bmatrix} \mathbf{C_1} \\ \mathbf{C_2} \\ \mathbf{C_3} \end{bmatrix} = \begin{bmatrix} \frac{1}{n}\sum_i \mathrm{rate}_i \sum_i T_{i,1} - \sum_i \mathrm{rate}_i T_{i,1} \\ \frac{1}{n}\sum_i \mathrm{rate}_i \sum_i T_{i,2} - \sum_i \mathrm{rate}_i T_{i,2} \\ \frac{1}{n}\sum_i \mathrm{rate}_i \sum_i T_{i,3} - \sum_i \mathrm{rate}_i T_{i,3} \end{bmatrix} \tag{4}$$

The matrix equation is easily solved using Kramer's rule.

Now, we'd like the corrected rates to not change in average rate; in other words, we want the corrected average rates to equal the untouched corrected rates, Eq (5).

$$\langle \mathrm{rate}' \rangle = \langle \mathrm{rate} \rangle \tag{5}$$

This gives us equations for the constants T_0 in Eq (1), shown in Eq (6). Now, although solving for the factors, C_1, C_2, and C_3, does not require solving for T_0 (as seen in their absence from Eq (4)), it is good to keep the average rate unchanged.

$$T_{0,1} = \frac{1}{n}\sum_{i}^{n}(T_{i,1})$$
$$T_{0,2} = \frac{1}{n}\sum_{i}^{n}(T_{i,2}) \quad (6)$$
$$T_{0,3} = \frac{1}{n}\sum_{i}^{n}(T_{i,3})$$

Now we have solved for all the constants in Eq (1). The next section has plots of the corrected rates.

3. Results

Truncated Julian day 3762 was chosen (at random) for its recentness.

Along with the outside temperature and pressure readings, there are 4 different counting-house temperatures. Three (air-shower 1 and 2, and muon layers) are read from thermocouples, while the last (outrigger) is read from a thermister. The air-shower (AS) electronics are too big to be housed together, so they are split in half and two thermocouples read temperatures from above them (the fan blows from the floor to the ceiling). The AS1 readings correspond to electronics used for the first 28 low threshold OR-channels (first 14 of the high threshold), and AS2 correspond to the next 26 low threshold OR-channels (next 13 high). The muon and outrigger readings cover their respective OR channel range. The AS1 readings are almost identical to the AS2, and because this is an illustrative memo, only the AS1 will be shown from here-on-in. For the analysis, both AS1 and AS2 readings were used for their respective OR channels, and the corrected rates are combined in the last step.

Table 1 show the values of C_1, C_2, and C_3, calculated using the method in §2 for the different arrays.

Group	C_1	C_2	C_3
Air-shower low 1	-1993	753717	3095
Air-shower low 2	-1572	628384	1531
Air-shower high 1	-206	91797	249
Air-shower high 2	-251	95262	294
Muon low	-2217	955826	3975
Muon high	-333	128892	301
Outrigger low	-460	80791	500
Outrigger high	-197	67063	-411

Table 1. Table of values for the constants C_1 (outside temperature), C_2 (outside pressure), and C_3 (counting-house temperature).

We defined C_3 as the counting house temperature for the different Milagro groups. For example, for the muon layer, it corresponds to the muon counting-house temperatures. The same goes for the constants, $T_{0,1}$, $T_{0,2}$, and $T_{0,3}$. These were just averages as shown in Eq (6). The averages for the readings are shown:

$$\langle\text{Outside temperature}\rangle = 29.81$$
$$\langle\text{Outside pressure}\rangle = 22.39$$
$$\langle\text{Air-shower 1 temperature}\rangle = 17.93$$
$$\langle\text{Air-shower 2 temperature}\rangle = 17.78$$
$$\langle\text{Muon temperature}\rangle = 23.22$$
$$\langle\text{Outrigger temperature}\rangle = 69.65$$

Temperatures are read as degrees celsius except for outrigger, which is in farenheit. Pressure is read in mm Hg. Fig 3.1 show the readings from the various instruments in Milagro during day 3762.

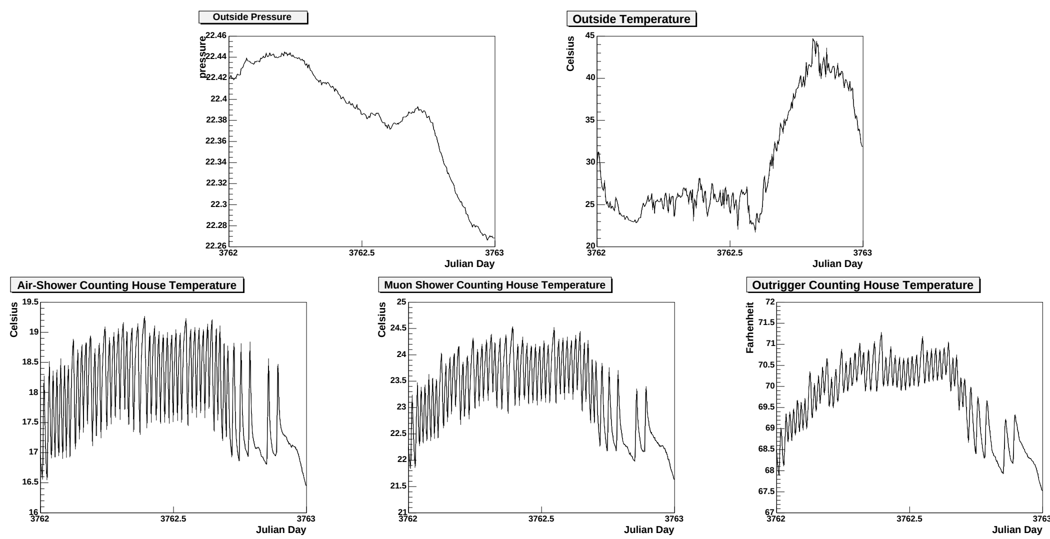

FIGURE 3.1. Readings from various instruments at Milagro. Note: The air-shower temperature reading is from the 1st thermocouple.

Figure 3.2 shows the results of correcting the rates. The left side is the original rates, the right is the corrected rates. The RMS of each array, from data corresponding to the plots in Fig 3.2 are shown in Table 2. The middle coloumn is the uncorrected RMS, and the right is the corrected.

Group	Original RMS	Corrected RMS
Air-shower low	9.413×10^4	1.751×10^4
Air-shower high	1.259×10^4	2.57×10^3
Muon low	6.427×10^4	1.138×10^4
Muon high	8.988×10^3	2.522×10^3
Outrigger low	7.519×10^3	2.362×10^3
Outrigger high	4.451×10^3	1.020×10^3

TABLE 2. Table of RMS of graphs in Figure 3.2.

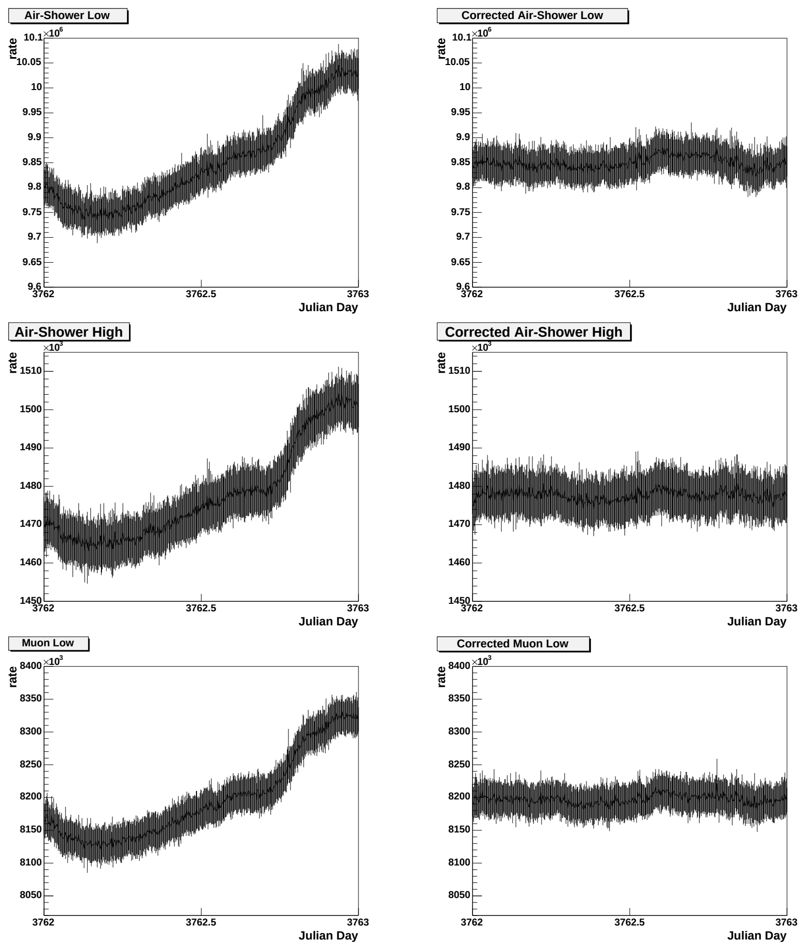

FIGURE 3.2. Plots of scaler rates from day 3762. Corrected rates are on the right.

4. DISCUSSION

The method outlined in this memo works better in some cases than others. For example, the outrigger low rates are affected by a sharp peak towards the end of the Julian date, and this peak is not found in any of the plots of Fig 3.1. For the air-shower low, the corrected rates introduce a spiky nature that is attributed to the spiky temperature readings of the air-shower thermocouple. Please remember, the method outlined in §2 only finds the correction terms that minimize the overall RMS, not the correction terms which smooth the rates out during smaller time scales (to inhibit the spiky nature).

For the air-shower, muon, and outrigger high thresholds, the corrected rate looks better. The long time-scale trends are corrected rather accurately, but short term spiky nature is still present.

How our method affects the scaler data analysis as outlined in [1] is worth mentioning, although on first inspection, it doesn't seem to affect it by much. For bursts on short time scales, long term corrections won't affect the background RMS calculation by much. For longer duration bursts, though, it is a good idea to check out the change in decector sensitivity. For short duration bursts, it might be best served to not use the outside pressure and temperature correction and only look to minimize the rates by using counting-house readings (to effectively set C_1 and C_2 to zero). This is the only short term rapid change reading on time

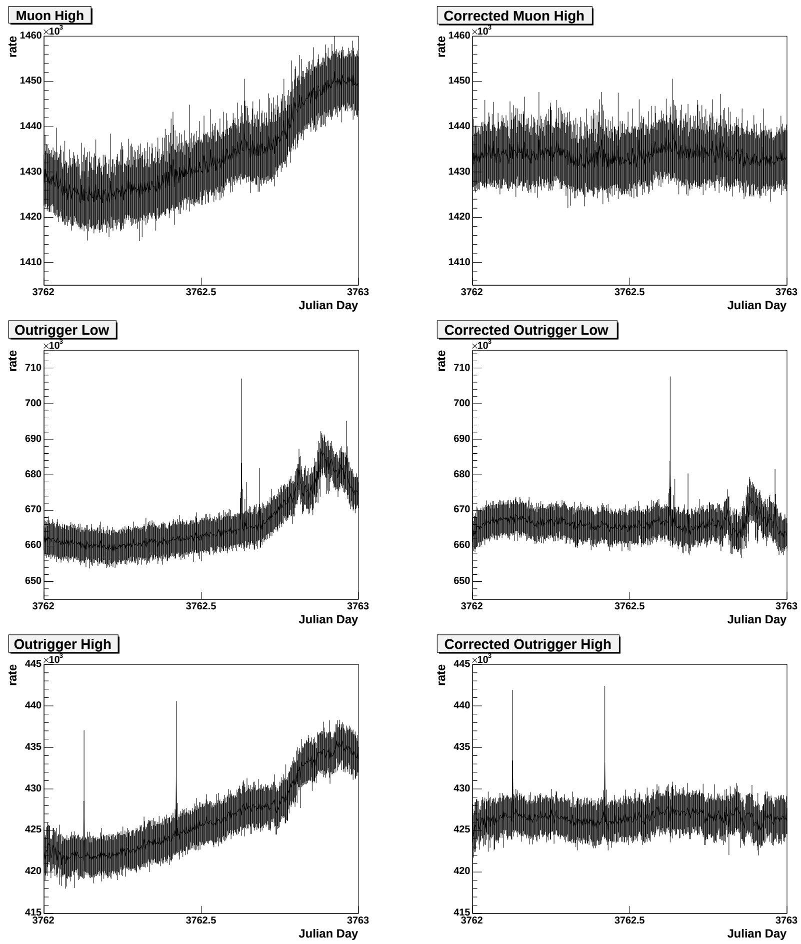

Figure 3.2. Plots of scaler rates from day 3762. Corrected rates are on the right.

scales relevant to short duration bursts, and these corrections are the ones that affect the scaler analysis for these bursts the most.

References

[1] Anzenberg, Eitan, *GRB Scaler Data Analysis using the Milagro Detector,* Undergraduate Senior Thesis, UCSC, Santa Cruz, CA, June 2006.