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Temperature Effects on Cosmic Ray Muons Recorded by Multi-Wire Detector at central Saudi Arabia

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In this study, cosmic ray (CR) data and radiosonde measurements from Riyadh, Saudi Arabia (Rc= 14.4 GV) for the period of one year, were used to study the effect of ground temperature, level of muon production, and temperature at that level, on CR muons observed by newly installed multi wire (MW) detector. The regression analyses between the recorded CR muons and these variables were carried out and the required coefficients were determined. It has been found that the level of muon production and ground temperature are inversely correlated with the CR muons. On the other hand, the temperature at the pion production level is positively correlated with CR muons.

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1. Introduction

Atmospheric temperature is one of the most important atmospheric variables that affect the secondary CRs. It is important to determine and remove its effect to, properly, study the variations of the primary CRs intensity [e.g., 1]. Different parameters representing this variable have been used to study its effect on the secondary CR intensity [1, 2]. Some researchers have used the temperature at ground levels [3-4], others used the weighted temperature, [1, 5], while others used the temperature at the pion production level and the height of that level [1, 6-7]. In correcting CR muons from the temperature effect, researchers have used these variables interchangeably [3].

In the present work, CR measurements collected by the KACST multi wire (MW) detector, for the period from November 2017 to December 2018, are utilized to study the influence of ground temperature, level of pion production, and the temperature at that level, on the detected CR muons, and determine the appropriate correction coefficients.

2. Expremental Datta and Methedology

The construction, calibration procedures, and all technical issues for the MW detector have been described in [8-9].The detector, basically, consists of three layers of 40 × 40 MW champers stacked together and powered by a high-voltage supplier. Each layer consists of an array of 16 anodes and 16 field wires. The signals from the detector were selected from the background noise using a discriminator, which are then amplified using a commercial amplifier circuits. A data acquisition card (MtRD Board) receives signals from the amplifier and send them to a Raspberry Pi computer card [10]. The data were acquired every 1 second. The detector was installed at King Abdulaziz City for Science and Technology (KACST), Riyadh (Rc = 14.4 GV), Saudi Arabia and has been in operation since November 2017. Twice daily radiosonde data were obtained from Riyadh airport for the study period.

The temperature effect on the observed CR intensity (I) may be expressed by one or more variables in the following equation:

$$\frac{I-I_0}{I_0} = \alpha\left(T_g - T_{g0}\right) + \beta(T - T_0) + \gamma(H - H_0) \quad (1)$$

where I_0 ,T_{g0}, T_0 and H_0 are, in respective, the mean values of intensity, ground temperature, temperature at the production layer, and the height of that layer for the considered period. α, β, and γ, are the ground temperature, temperature at the production layer, and height coefficients respectively.

The first term of this equation represents the effect of the temperature at the ground level [3,11], while the second and third terms represent the effect of the height and the temperature of an atmospheric layer where muons and are produced, respectively. These variables have been either considered individually or in combination with two or more variables by several researchers [4,7, 6, 11]. In the present work, the influence of these three variables on the CR muons were investigated and established.

3. Results and Discussion

3.1 Ground Temperature Effect

Fig. 1 is an example indicates the daily variations of the CR muons with ground temperature for a time of around three months. The relationship between the two variables, during the whole study period, is illustrated in Fig. 2

It is obvious from both figures that the CR muons decrease as the ground temperature increases. This implies that, during winter times, muons will be more observed compared with warm times. This relationship is consistent with previously established experimental results [1,3,7]. The temperature coefficient obtained from the regression analysis between the two variables was -0.16 ± 0.0027 % / C, with a correlation coefficient of 0.74.

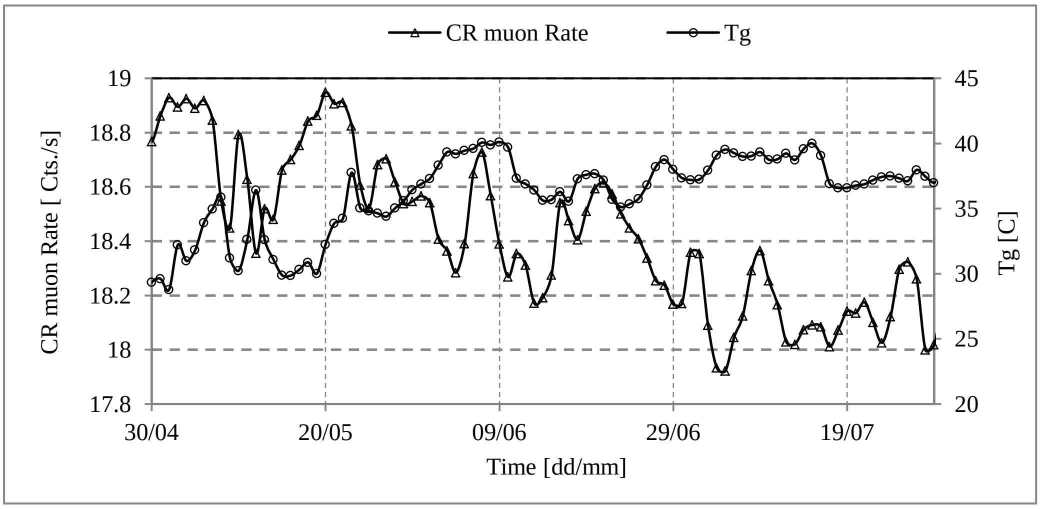


Fig. 1: *Daily variations of the ground temperature and CR muons recorded by the MW detector for the period between 30 April – 30 July 2018.*

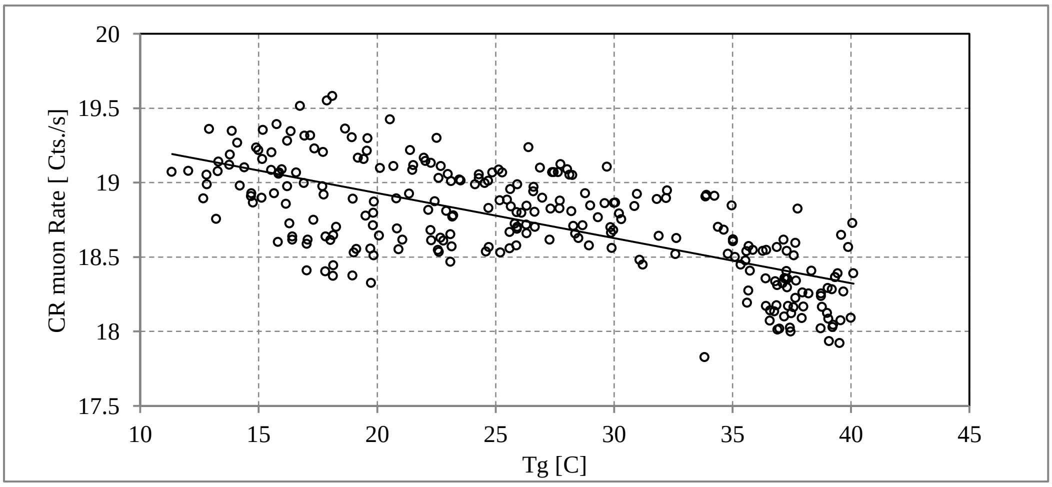


Fig. 2: *Scatterplot between the daily averages of the CR muons observed by the MW detector and the ground temperature (T_g) during the study period. The solid line is the regression line.*

Fig. 3 is an example compares the daily time series of the uncorrected and corrected further for the effect of the ground temperature for a time of around three months. While a maximum difference of about 10 % was observed between the two variables in rare occasions, the CR intensities did not differ much from each other in most of the times with a mean difference of 3.3×10^{-2} %.

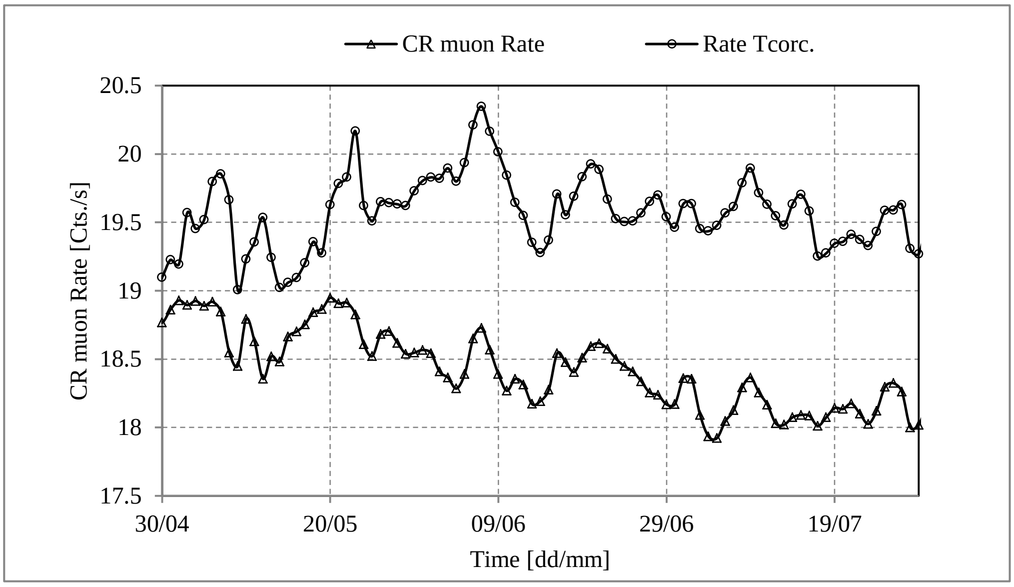


Fig.3: *Shows the daily values of the uncorrected and corrected muons for the effect of the ground temperature for the period between 30 April – 30 July 2018.*

3.2 Effects of the height and temperature at the muon production layer

Following the procedure adapted by several researchers [e.g., 3,6] the altitude of the 100 hPa was selected as the height of muon production layer. From available data, atmospheric temperatures and the heights at 100 hPa were extracted from each radiosonde profile.

Fig. 4.a is an example presents the daily variations of the CR muons and the atmospheric temperature at the production layer for a time of around five months. Fig. 4.b indicates the relationship between the two variables during the study period.

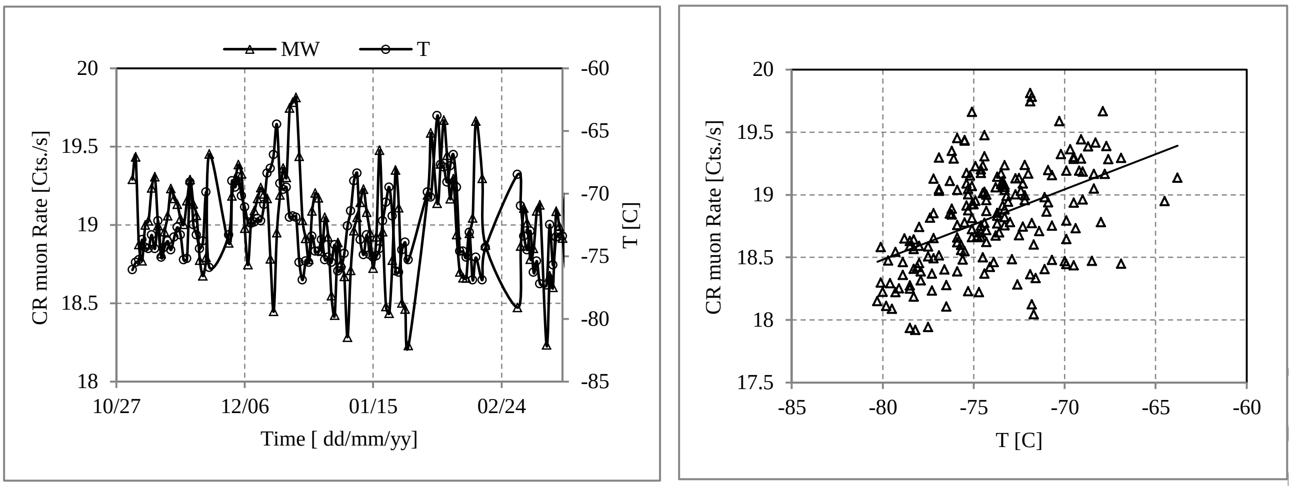


Fig4: *(a) Variations of thed aily values of the temperature at the muon production layer and the CR muons for the period between 1 November 2017 – 15 March 2018. (b)Scatter plots between the daily values of the CR muon rate and the temperature at the muon production layer for the whole study period.*

The positive relationship between the muon rate and the temperature at the muon production layer indicates that the number of the detected muons will increase as the temperature increases, and the opposite occurs as the temperature decreases.

Fig. 5 is scatter plot indicates the relationship between the muon rate and the height of muon production layer. It is evident that the height of muon production layer is inversely correlated with the muon rates. This negative correlation suggests that more muons decay as they travel longer distances before reaching the detection level according to the increase of the height of the production layer. These relationships are in agreement with those previously established by several researchers [3-4, 6].

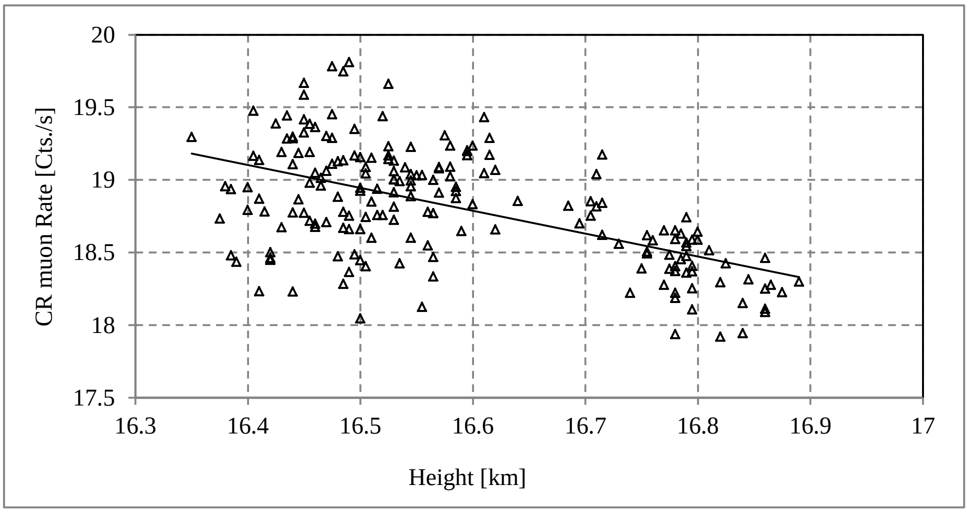
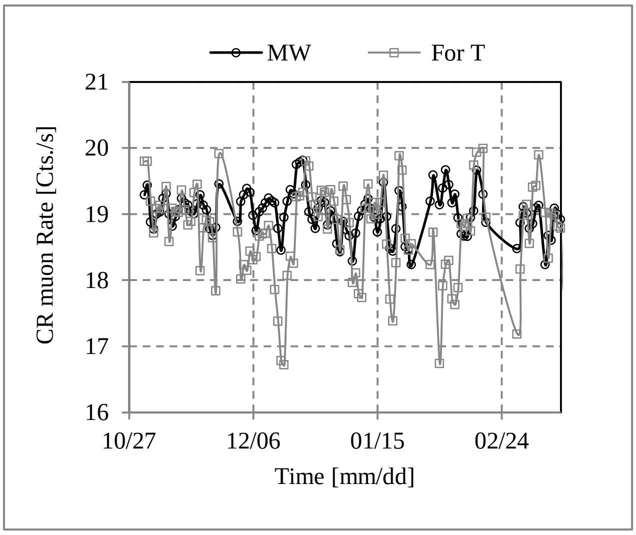


Fig. 5: *Scatter plots between the daily values of the CR muon rate and the height of the muon production layer for the whole study period. The solid line is the regression line.*

Regression analyses between the CR muons and the two variables (T and H) gave a temperature coefficient of +0.298 %/ K (correlation coefficient 0.53) and height coefficient of -8.37% /km (correlation coefficient = 0.56).
Fig. 6 shows daily averages of muon measurements corrected for (a) temperature at the muon production layer and(b) height of that layer. The uncorrected muon rates for these two variables were plotted for comparison purposes.
While, the corrections have been made made to the muon rate using these variables, there are still some occasions when the temperatures at the muon production layer and the height of that layer have minor effects. By considering the entire period of measurements, mean differences between corrected and uncorrected CR muon intensities for the height and for the temperature at the muon production layer were 0.22% and 0.16 %, respectively.



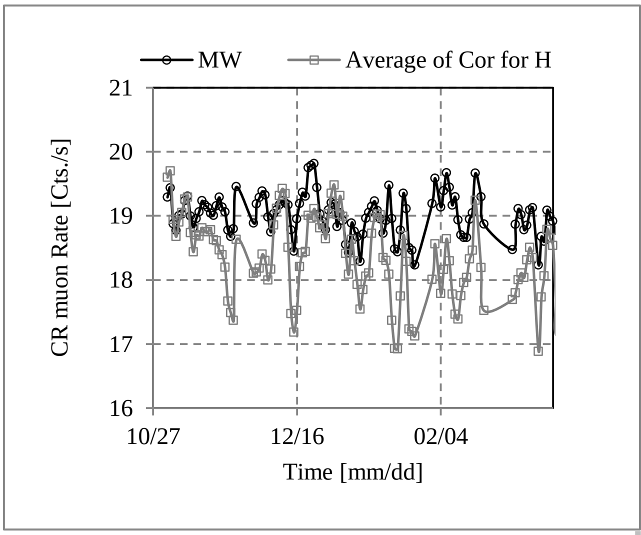


***Fig. 6:** The daily variations of the uncorrected muon rate against those corrected for (a) temperature at the production layer and (b) height of that layer, for the period between 1 November 2017 – 15 March 2018.*

Conclusions

In this study, CR muon count rate observed with a multi-layer multi-wire (MW) detector were used to study the temperature effects on the detected muon intensity.
Regression analyses between the CR data and air temperature, level of muon production, and temperature at that level, were carried out and the required coefficients were obtained.
The results show that while CR muons positively correlated with the temperature at the muon production level, they are inversely correlated with the othet two variables.

Acknowledgments

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