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Cosmic ray snow effect in different multiplicities according to Emilio Segre' Observatory NM hourly data

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Abstract. On the basis of cosmic ray hourly data obtained by NM of Emilio Segre' Observatory (height 2025 m above s.l., cut-off rigidity for vertical direction 10.8 GV) we determine the snow effect in CR for total neutron intensity and for multiplicities m≥ 1, m≥ 2, m≥ 3, m≥ 4, m≥ 5, m≥ 6, m≥ 7, and m≥ 8, as well as for m=1, m=2, m=3, m=4, m=5, m=6, and m=7. For comparison and excluding primary CR variations we use also hourly data on neutron multiplicities obtained by NM of University "Roma Tre" (about sea level, cut-off rigidity 6.7 GV) and hourly data of total intensity of NM of the University of Athens (about sea level, cut-off rigidity 8.7 GV). In this paper we will analyze effects of snow in periods from 15 December 1999 to 9 February 2000 (with maximal absorption effect about 16% in the first multiplicity) and from 1 January 2001 up to 5 March 2001 with maximal effect 13% in the total neutron intensity. We use the periods without snow to determine regression coefficients between primary CR variations observed by NM of Emilio Segre' Observatory, and by Rome NM. On the basis of obtained results we suppose in near future to correct data on snow effect by using several NM hourly data. We determine also the correlation of snow effects in total intensity and in different multiplicities. We hope that developed method will be useful for correction of NM data where the snow effect is important.

1 Introduction

Many cosmic ray stations on mountain heights have a problem with NM shielding with variable snow cover on the roof and near walls. With this problem met also some CR stations near sea level but on high latitudes. It is a great pity because modern NM are characterized by very high level of accuracy: the statistical error for one hour of observations is order of 0.1%. Even regular cleaning of Observatory from snow cannot be excluded the disturbance of information in some short periods of time. The "snow' problem became especially sharp in the last years when many mountain Observatories became automatically working, as for example, Emilio Segre' Observatory on Mt. Hermon. A short description of Emilio Segre' Observatory was given in Dorman et al. (1999a). Here we will try to develop a special method to determine snow effect in total NM counting rate as well as in different multiplicities without any measurements of real snow amount on the roof and near walls of Observatory. The developed method can work in near future automatically, to determine snow effect and made corrections on snow effect by using on-line data of two or more NM.

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2 Determining of Regression Relations between ESO NM and Rome NM for Total Neutron Intensity and for Different Multiplicities.

In the first we need to determine regression relations between ESO NM and Rome NM for total neutron intensity and for different multiplicities. We will use one-hour data of Rome NM (what never covered by snow; in near future we suppose to use also Athens NM, Mexico NM, Haleakala NM and some others), corrected on barometric effect. By one-hour data of NM of Emilio Segre' Observatory (also corrected on barometric effect, see in Dorman et al., 1999b, 2001) from 16 June 1998 up to 1 April 2001 in periods when on Mt. Hermon was no snow, we determine regression relations between Rome NM data and ESO NM data:

$$\ln\left(I_{ESO}^{m}\right) = B_m \times \ln\left(I_{Rome}^{tot}\right) + C_m, \qquad (1)$$

where $m = tot.1, 2.3.4, 5, 6, 7, \geq 8$. Results of determining of B_m, C_m and correlation coefficients R_m are shown in Table 1

Table 1. Regression coefficients B_m, C_m and correlation coefficients R_m for total neutron intensity and different multiplicities, according to Eq. (1).

Chan-nel	B_m	C_m	R_m
TOT	0.668±0.001	4.63±0.02	0.966
m=1	0.612±0.002	4.58±0.02	0.956
m=2	0.766±0.001	1.30±0.02	0.977
m=3	0.780±0.002	2.54±0.02	0.973
m=4	0.739±0.002	-3.90±0.02	0.961
m=5	0.660±0.002	-1.81±0.03	0.931
m=6	0.569±0.003	2.79±0.04	0.860
m=7	0.447±0.004	1.22±0.05	0.694
m>=8	0.142±0.007	5.43±0.09	0.169

2 Determining of Snow Effect on Mt. Hermon in Total Neutron Intensity and in Different Multiplicities.

By Eq. (1) and regression coefficients B_m, C_m listed in Table 1, we determine the expected on Mt. Hermon total neutron intensity and expected counting rates for different multiplicities on the basis of Rome NM hourly data for neutron intensity and expected counting rates for different multiplicities on the basis of Rome NM hourly data for periods when Emilio Segre' Observatory was covered by snow. To determine the snow effect we need to extract these expected intensities from really observed. Results are shown in Fig. 1 and 2 for winter 1999/2000 for total intensity and different multiplicities. From Fig.1 and 2 can be seen that the biggest snow effect was observed on Mt. Hermon for the multiplicity m=1; snow .effect decreases with increasing of neutron multiplicity m .

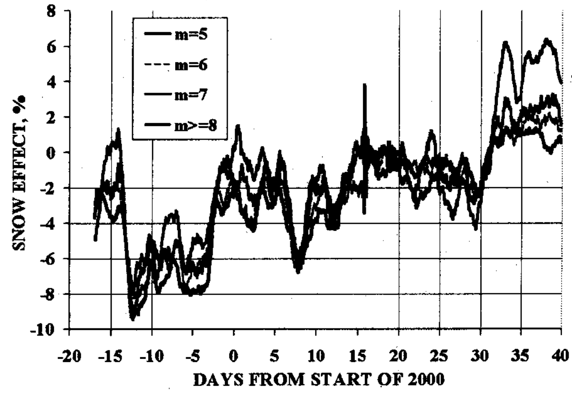

Figure 2. The same as in Fig. 1, but for multiplicities m=5, 6, 7 and >=8.

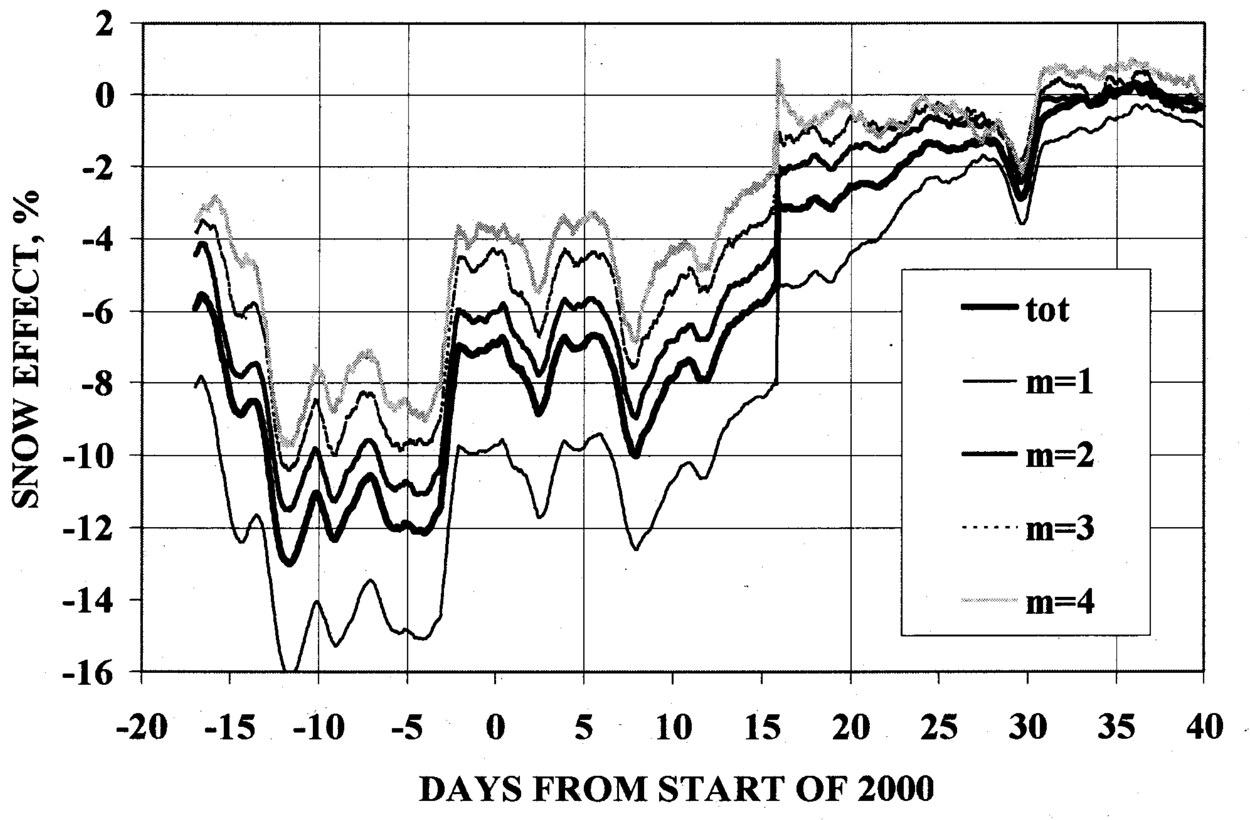

Figure 1. Cosmic ray snow effect on Mt. Hermon in period of winter 1999/2000 in the total neutron intensity and in the neutron multiplicities m=1, 2, 3 and 4

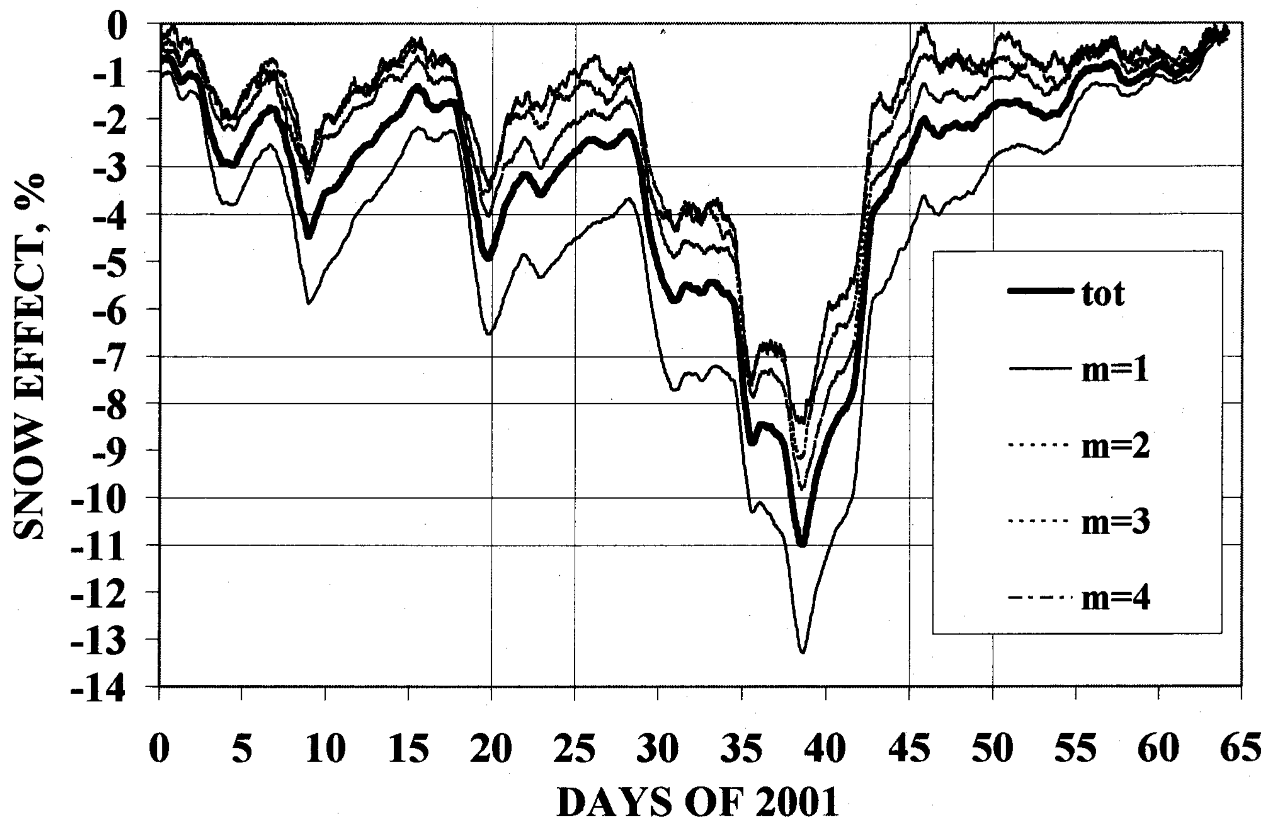

Figure 3. Cosmic ray snow effects on Mt. Hermon in period of winter 2000/2001 in total neutron intensity and in neutron multiplicities m=1, 2, 3 and 4

The snow effects observed on Mt. Hermon in winter 2000/2001 in total intensity and in different neutron multiplicities are shown in Fig. 3 and 4..

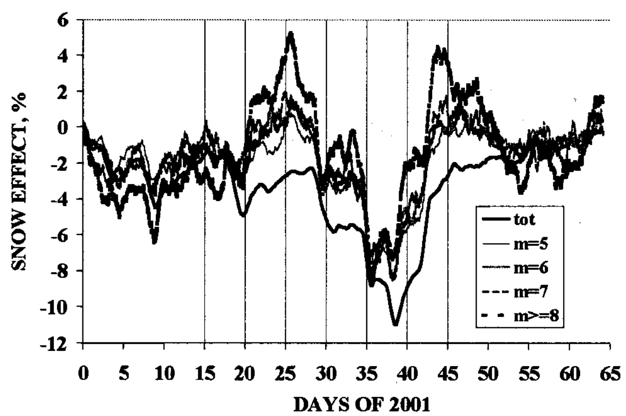

Figure 4. The same as in Fig. 3 but for multiplicities m=5, 6, 7 and >=8. For comparison is shown also the snow effect in total intensity.

3 Regression Relations between Snow Effects in Total Intensity and in Different Neutron Multiplicities

It can be seen from Fig. 1-4 that there are correlation of snow effects in total intensity and in different multiplicities .In Fig. 5 and 6 are shown different comparisons of snow effects observed in winter 1999/2000.

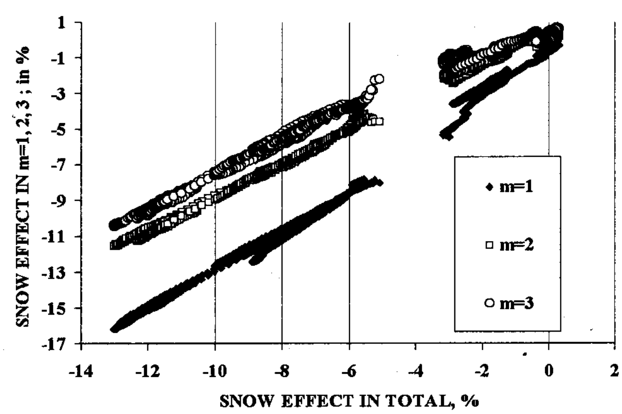

Figure 5. Comparison of snow effects in neutron multiplicities m=1, 2 and 3 with snow effect in total neutron intensity. Observations in winter 1999/2000.

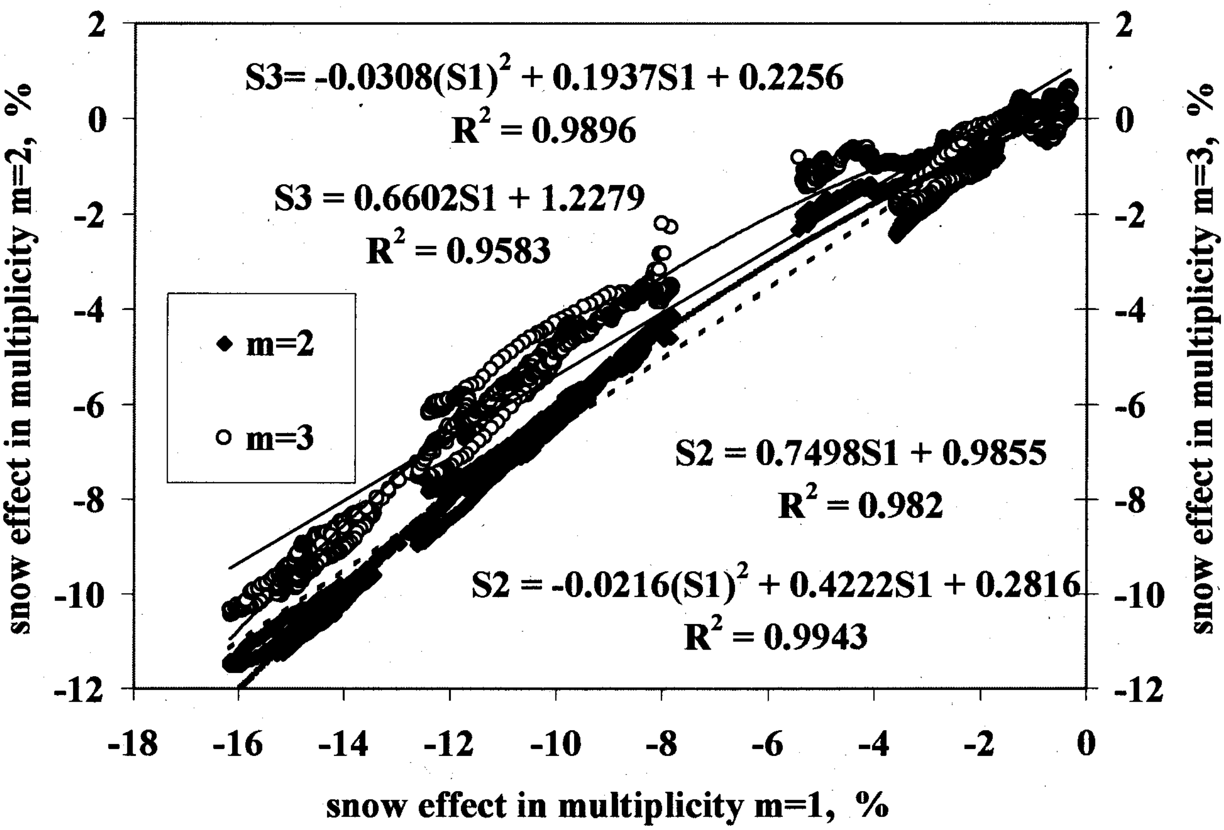

Figure 6. Comparison of snow effects in m=2 and m=3 with snow effect in m=1. Linear and parabolic regression relations with correlation coefficients are also shown. Observations in winter 1999/2000.

The connection of snow effects in different channels shown in Fig. 5 and 6 in the first approximation can be described by linear regression relations

$$S_m = D_{mt}S_t + E_{mt}\ ;\ S_m = D_{m1}S_1 + E_{m1} \qquad (2)$$

between snow effects in different multiplicities S_m and in total neutron intensity S_t (see Table 2) or in the first multiplicity S_1 (see Fig. 6).

Table 2 Regression coefficients D_{mt}, E_{mt} and correlation coefficients R_{mt} for winters 1999/2000 and 2000/2001.

m	Winter 1999/2000			Winter 2000/2001		
	D_{mt}	E_{mt}	R_{mt}	D_{mt}	E_{mt}	R_{mt}
1	1.218	-0.008	0.996	1.201	-0.006	0.991
2	0.922	0.004	0.997	0.913	0.004	0.996
3	0.817	0.007	0.992	0.849	0.006	0.990
4	0.741	0.010	0.981	0.816	0.006	0.980
5	0.671	0.010	0.965	0.747	0.006	0.932
6	0.600	0.011	0.928	0.694	0.005	0.843
7	0.603	0.015	0.937	0.657	0.005	0.766
>=8	0.580	0.019	0.719	0.423	-0.001	0.370

4. Discussion and Conclusions

Obtained results show that snow effects in total neutron intensity and in different multiplicities on Mt. Hermon are comparable with great Forbush-decreases and with long-term cosmic ray variations connected with solar activity cycles. Developed method give a possibility to determine snow effects with a good accuracy and then eliminate them from observation data. The found regression relations in snow effects for total neutron intensity and for different multiplicities (see Table 2 and Fig. 6) can be explained by competition of two processes: absorption by snow and by generation in snow additional multiple neutrons. This problem will be considered in details in other paper. We suppose to extend this research in near future by using data of several Observatories without snow effects for more exact determining of cosmic ray primary variations. Applying of developed method will be important for many mountain cosmic ray Observatories and for some Observatories near sea level with great snow effects.

References

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