Atmospheric Electric Field Effects on Cosmic Rays detected at Sierra Negra, Mexico

Newton Bosch B. J.[1], González L. X.[1,2], Valdés Galicia J. F.[1], Muraki Y.[3], Matsubara Y.[3], Sako T.[4], Watanabe K.[5], Morales Olivares O. G.[6], Monterde-Andrade F.[1]

[1]*Instituto de Geofísica, Universidad Nacional Autónoma de México. Ciudad de México, 04510, México.*

[2]*LANCE/SCiESMEX. Instituto de Geofísica, Unidad Michoacán, Universidad Nacional Autónoma de México. Morelia, Michoacán, 58190, México.*

[3]*Institute for Space-Earth Environmental Research, Nagoya University. Furo-cho, Chikusa-ku, Nagoya 464-8601, Japan.*

[4]*Institute for Cosmic Ray Research, University of Tokyo. Kashiwanoha, Kashiwa, Chiba, 277-8582, Japan.*

[5]*National Defense Academy of Japan, 1-10-20 Hashirimizu, Yokosuka, Kanagawa 239-8686, Japan.*

[6]*Escuela Nacional de Ciencias de la Tierra, Universidad Nacional Autónoma de México. Ciudad de México, 04510, México.*

The atmospheric electric field (AEF) effects on secondary cosmic rays (CR) were formally studied after the publication of the acceleration of β-particles hypothesis in 1925. The AEF effect on the intensity of the soft component is an increase in which the linear term dominates. For the hard component, a decrease in the intensity with a dominant quadratic term is expected. The hadronic component occasionally presents small increments during thunderstorms.

In the case of high altitude detectors, there have been several experiments in the last decades. One of the most relevant is the Mount Norikura Cosmic Ray Observatory (2770 m a.s.l.) in Japan. Fluctuations of around 1% in the counting rate of the detectors of the Mount Norikura Observatory were found when thunderstorms occurred during 2002. These detectors were: a 12-tube neutron monitor, the Nagoya meson monitor, the Nagoya Solar Neutron Telescope and a muon telescope. Based on these results, we studied the possible effects of thunderstorms' AEF on the CR detected at Sierra Negra, an inactive volcano that stands at 4580 m a.s.l. located in Puebla, Mexico.

The Sierra Negra Cosmic Ray Observatory comprises the Solar Neutron Telescope (SNT) and the Boltek EFM-100 AEF monitor, among others. The EFM-100 was installed in October 2019 and has been in continuous operation since then, the SNT has been in operation since 2004.

The SNT has four energy deposition thresholds that correspond to E ≥ 30 MeV, 60 MeV, 90 MeV and 120 MeV. For each energy deposition threshold there are charged particle channels (S1, S2, S3 and S4) and neutron channels ($S1_{Anti}$, $S2_{Anti}$, $S3_{Anti}$ and $S4_{Anti}$). Observing the measurements of the EFM-100, 15 thunderstorms were identified from October 2019 to March 2020. We analyzed the pressure corrected data registered by the SNT's S1 and $S2_{Anti}$ channels, the most stable channels, during these thunderstorms. The data was also normalized to the mean during fair weather conditions.

On the basis of the general theory of AEF effects in the secondary CR components proposed by Dorman, we calculated as a first approximation the effects on the total charged component (0.81-2.44%) and the neutron component (1.5-4.53%) at the observation level of Sierra Negra's summit. Simulations of air showers in the presence of a simplified electric field were performed with the CORSIKA code to complete these calculations.

We identified significant fluctuations coinciding with the occurrence of 10 thunderstorms. Finally, the maximum percentage variation of the counting rate of both channels, for each thunderstorm, was calculated relative to the polynomial fit. The results range from -1.64% to +1.27% variations for the S1 channel and -2.98% to +4.9% for the $S2_{Anti}$ channel, which fall around the values of the calculated AEF effects.

We conclude that the effects of the AEF on the secondary CR intensity are probably significant at the summit of Sierra Negra. The observed variations could generally be explained by the effects of AEFs associated with muon and electron mechanisms. The counting rate variations in the $S2_{Anti}$ channel are significant and coincide with the storm's occurrence, however, the physical cause is not yet completely determined. Although some processes have been established for the indirect influence of AEFs on neutrons, these processes affect lower-energy neutrons. As future research, a higher number of thunderstorms will be analyzed to validate the results quantitatively and increase their statistical power.