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Monitoring rain rate with proximal gamma-ray spectroscopy

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We present an exhaustive study of the gamma activity increase measured at ground level for the atmospheric radon daughter ^{214}Pb. We demonstrate the effectiveness of proximal gamma-ray spectroscopy in continuously gathering reliable measurements of rain-induced ^{214}Pb gamma signal related to the rain intensity and amount. Since every impulse of rain produces a sudden increase of gamma signal, we study such transient activity to obtain information on precipitations and rain formation.

A novel spectroscopic instrument specifically tailored for gathering reliable and unbiased estimates of atmospheric and terrestrial gamma emitters has been developed. After seven months of continuous acquisition, we analyze the temporal evolution of the ^{214}Pb net count rate with an innovative and reproducible mathematical model for extracting information on this radon daughter's content in the rain water. The effectiveness of the model is proved by an excellent coefficient of determination (r^2 = 0.91) between measured and reconstructed ^{214}Pb count rates. We observe that the impulsive increase of ^{214}Pb count rates ΔC is clearly related to the rain rate R by the power law dependence $\Delta C = A \cdot R^{0.50 \pm 0.03}$, where the parameter A is equipment dependent. This means that the expected increase of atmospheric ^{214}Pb activity measured at ground level during a rain event is proportional to the square root of the rain rate $\sqrt{R}$.

We observe that the ^{214}Pb abundance (G) of the rain water is inversely related to the rain rate $G \propto 1/R^{0.48 \pm 0.03}$ and to the rain median volume diameter λ_m with $G \propto 1/ \lambda_m^{2.2}$. We proved that, for a fixed rainfall amount, the longer is the rain duration (i.e. the lower is the rainfall intensity and the smaller is the mean raindrop volume), the higher is the ^{214}Pb content of the rain water.

Since the developed algorithm is detector independent, it can be used for analysing the data collected by the networks of thousands of gamma sensors distributed around the Earth, typically utilised for monitoring the air radioactivity in case of a nuclear fallout. From this spectroscopic technique we shall learn a lot more about the rain formation and scavenging mechanisms which are responsible for the attachment of ^{214}Pb to rain droplets in-cloud. Finally, our research provides a comprehensive characterization of the background radiation assessments relevant for radioprotection, earthquake predictions, cosmic rays research and anthropic radiation monitoring.