

## Digitizations of Historical Solar Cosmic-Ray Measurements for the GLE 1 – 4

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Sporadic intense solar eruptions accelerate high-energy particles, called solar energetic particles (SEPs), which can reach Earth, depending on the relative Sun-Earth geometry. SEP events with hard energy spectra can be detected by ground-based detectors making the so-called ground level enhancements (GLEs). So far, 73 such GLEs have been registered by the network of ground-based detectors from 1942 onward. However, little is known about the first four GLEs, as they took place before the regular measurements by the nowadays standard neutron monitors (NMs) and only through bihourly data from the Carnegie Institute (i.e., ionization chambers at Cheltenham, Huancayo, Godhavn, Christchurch, and Climax). In this study, we investigate historical measurements of these early GLEs by available ground-based detectors and digitize their measurements in analog diagrams of early scientific publications. Our results significantly improve the time resolution (mainly hourly and occasionally down to 15 minutes) and extend the geographical coverage of the historical GLE measurements to Europe, East Asia, and Russia as well. Our results provide the necessary basis to study GLEs 1-4, that is to derive their spectral and angular characteristics.

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## References

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