The Neutron Monitor Network's Role in Space Weather Monitoring

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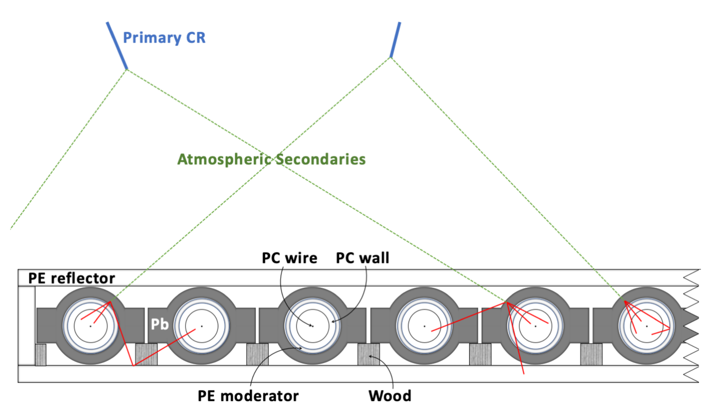
Abstract

The Neutron Monitor Network is integral in monitoring Ground-Level Enhancements (GLEs), sudden increases in cosmic ray intensity typically triggered by solar energetic particle events. These events pose significant challenges to space weather forecasting and infrastructure protection. GLEs can have profound effects on infrastructure, particularly in space-based systems and technologies. High levels of cosmic ray flux during GLEs can disrupt satellite operations, leading to communication glitches, navigation errors, and even hardware damage. Furthermore, increased radiation exposure poses risks to astronauts during spacewalks or long-duration missions, necessitating careful planning and shielding measures. On Earth, GLEs can affect aviation and power grids. Airlines may need to reroute flights to lower altitudes to minimize radiation exposure to passengers and crew. The Neutron Monitor Network's role in detecting GLEs is critical for understanding and mitigating their impacts on infrastructure. By providing early warnings and data on cosmic ray flux enhancements, the network enables stakeholders to take proactive measures to safeguard space-based assets, ensure astronaut safety, and protect terrestrial systems from the disruptive effects of GLE-induced space weather events. In this poster, we give an update on the American operating Simpson Neutron Monitor Network (SNMN). We present the real-time monitoring of the cosmic ray radiation by the SNMN. We present the current GLE alert system based on SNMN data. Finally, we discuss future upgrades to optimize the data products for space weather applications.

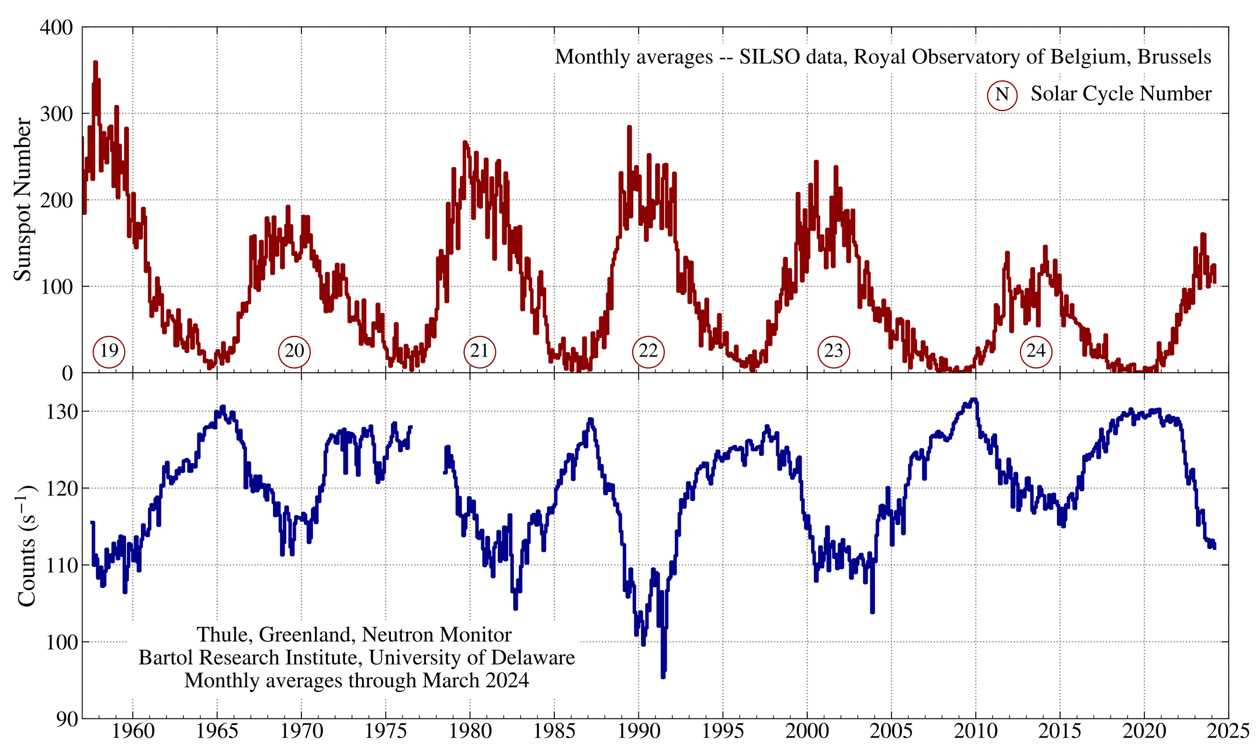
What is a Neutron Monitor?

- A neutron monitor is a ground-based detector that records the nucleonic component of air showers produced by Cosmic Rays (CR) impinging the Earth's atmosphere.



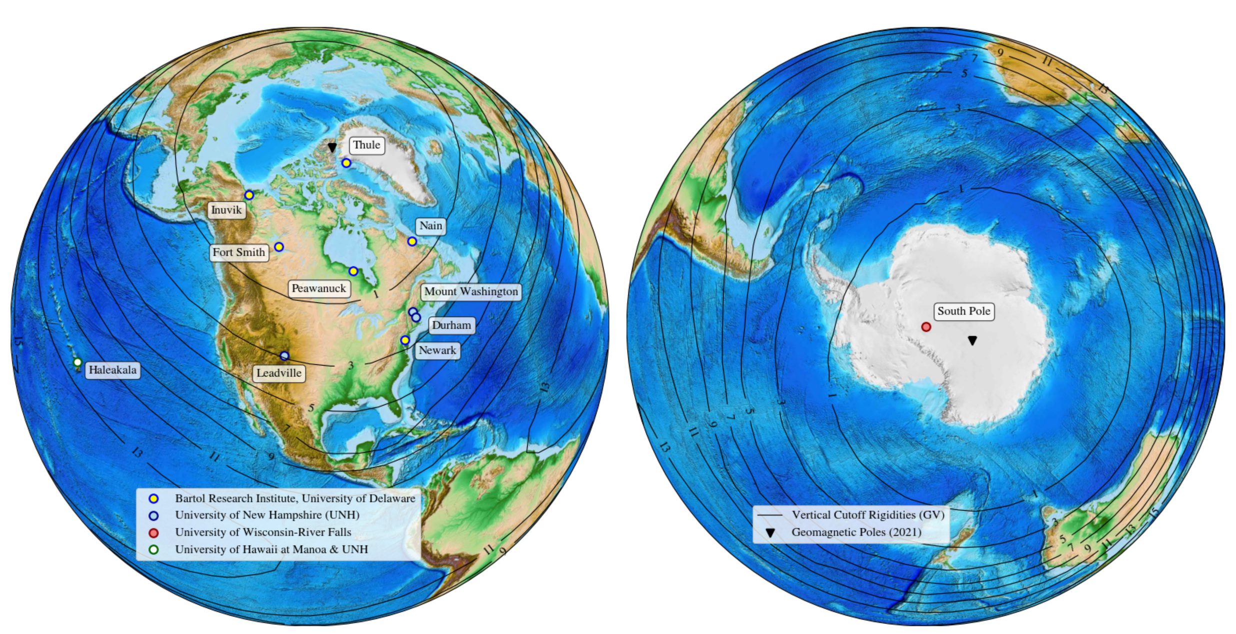
Schematic of neutron detection in a neutron monitor of NM64 design [1]. Secondary particles interact with the lead producer inside the monitor to produce multiple MeV-range tertiary neutrons that can be moderated by polyethylene and detected by one or more of the proportional counters. **Pulses are counted.** NM are sensitive to CR above 1 GV (atmospheric cutoff) and above the local geomagnetic cutoff rigidity (0-18 GV).

- Before reaching Earth, CR have traveled through the interplanetary medium. They carry unique information about interplanetary magnetic fields, large-scale heliospheric structures, local space environment, and solar activity.For the last six decades, NMs have been the premier instruments to study the CR variations:



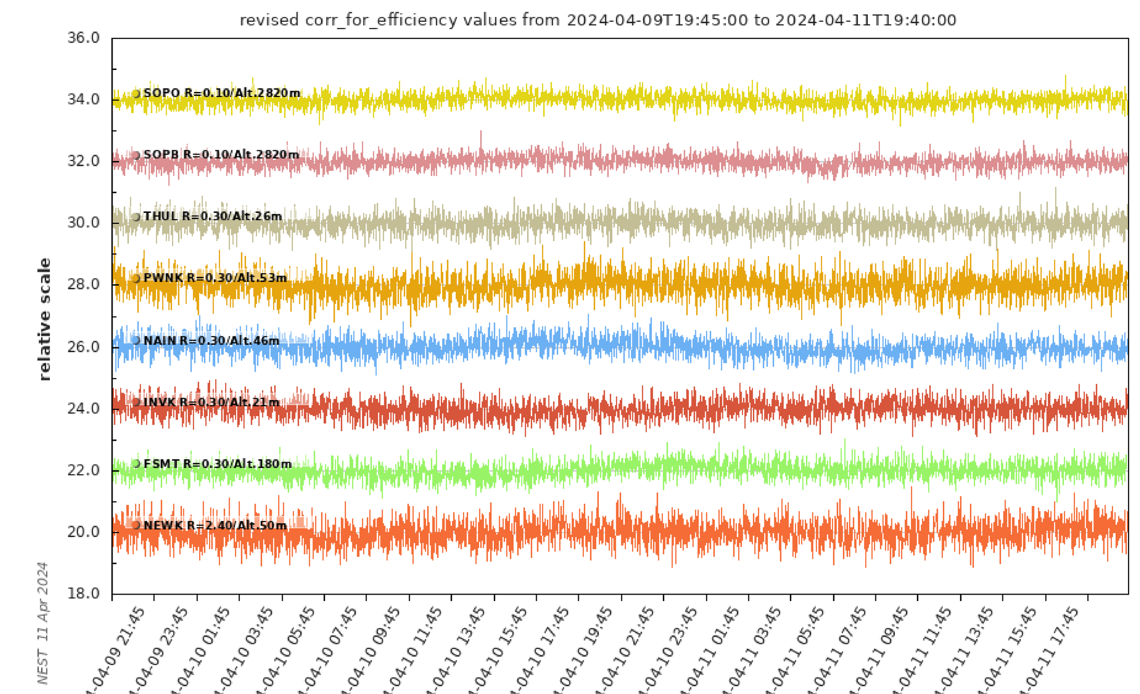
The Simpson Neutron Monitor Network

- Since 2021, the US owned and operated neutron monitors constitute the now called Simpson Neutron Monitor Network in honor of its inventor John Simpson.
- Current 2024, the neutron monitor located at Haleakala (Maui, Hawaii) is expected to be redeployed after being decommissioned for many years.



Real Time Monitoring of the Cosmic Ray Radiation

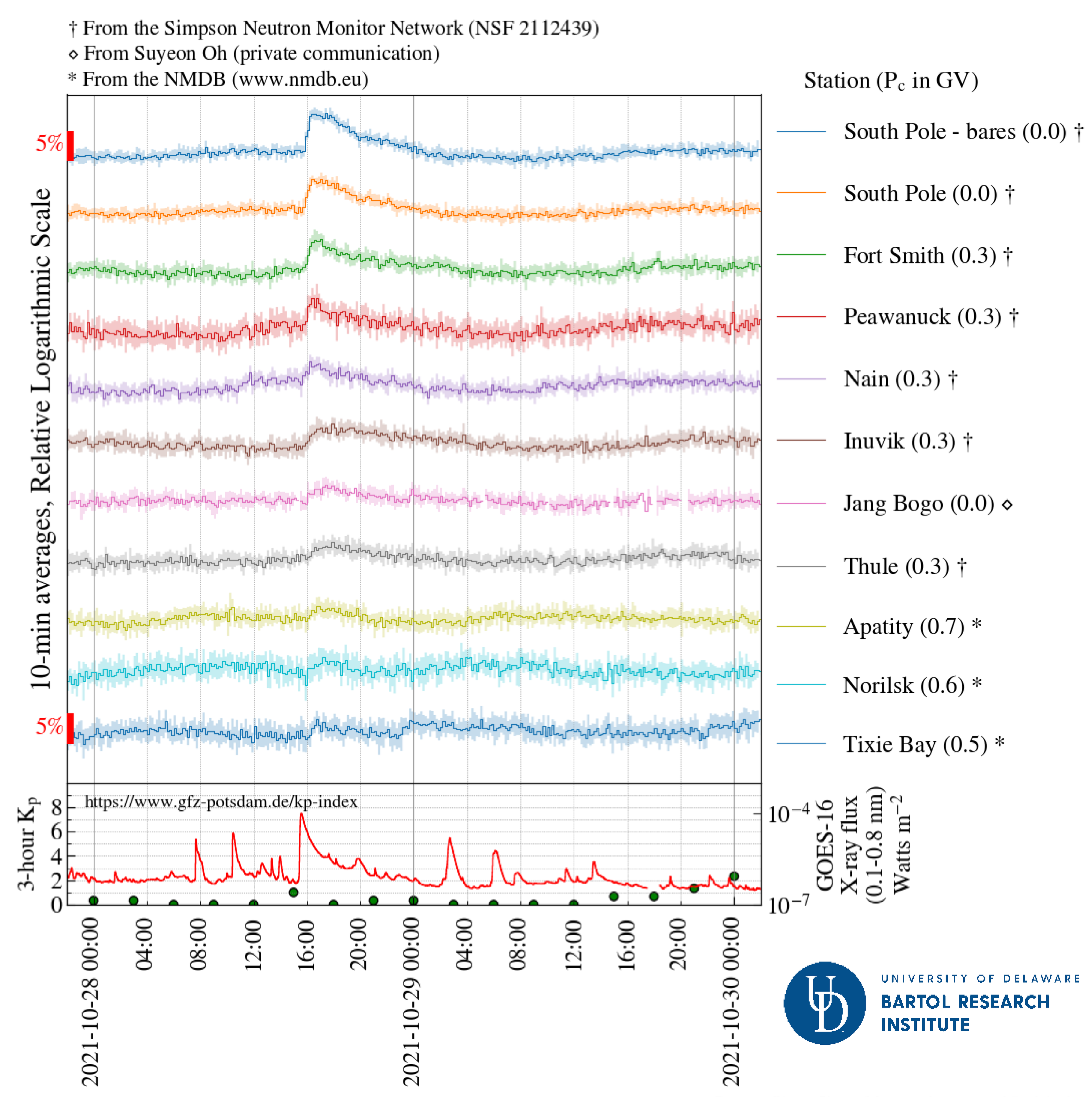
- Eight detectors of the SNMN send their data in real-time to the Neutron Monitor DataBase (NMDB, `www.nmdb.eu`)



- By the end of 2024, the monitors at Leadville, Mount Washington and Duhram will provide real-time data to NMDB.
- Additional monitoring can be found at `https://neutronm.bartol.udel.edu/`

Ground Level Enhancement

- *A GLE event is registered when there are near-time coincident and statistically significant enhancements of the count rates of at least two differently located neutron monitors including at least one neutron monitor near sea level and a corresponding enhancement in the proton flux measured by a space-borne instrument(s)* [3].
- The official database of neutron monitor count rates during GLE reports the data from 1956 at `https://gle.oulu.fi/`.
- Last GLE as recorded by high latitude NM:



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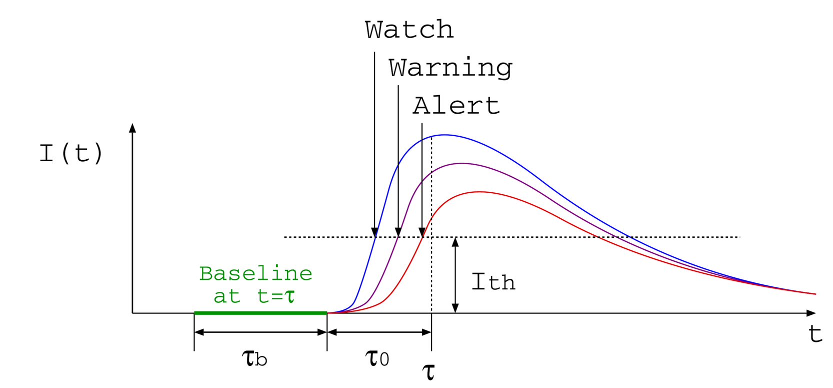
GLE Alert System

- To help mitigate the hazardous effects from such events, the data from the neutron monitor network serves as a real-time (within several minutes) alert system for GLE.
- **You can subscribe to the real-time GLE alert system** based on the signal of the neutron monitors operated by the Bartol Research Institute at `http://www.bartol.udel.edu/~mangeard/glealarm/subscribe.html` [2]:

$$I(\tau) = \left\{ \frac{1}{\tau_c} \sum_{t=\tau-\tau_c}^{\tau} N(t) \right\} / \left\{ \frac{1}{\tau_b} \sum_{t=\tau-\tau_0-\tau_b}^{\tau-\tau_0} N(t) \right\} \quad (1)$$



Condition for issuing three levels of alarm. Intensity increases recorded at three stations during a typical (notional) GLE are illustrated [2]. I(t) is a trailing moving average value for the current count rates. It is calculated every minute from the observed count rate averaged over the preceding τ_c minutes, and expressed as a percentage of the baseline.

- **For the eight studied GLEs, the GLE alert precedes the earliest alert from GOES (100 MeV or 10 MeV protons) by ∼10 – 30 min [2].**
- Example of a recent Warning message sent during the fast recovery of a large Forbush decrease:

> 2024-03-25 01:54:00 (UT): Warning alarm
> Rate increase(s):
> Newark (NEWK): 2024-03-25 01:54:00 (UT), 4.56%
> South Pole (SOPO): 2024-03-25 01:54:00 (UT), 11.13%
> https://neutronm.bartol.udel.edu/~mangeard/glealarm/GLE_Alarm.png

Optimizing the data products for SW Applications

- **Improve visibility** with a new dedicated website:
  - General information related to the network
  - Archival data and Real-time data monitoring
  - Data products for Space weather applications
- **Upgrade the GLE alert system**
  - Extension to the full Simpson Neutron Monitor Network, with the flexibility to include data from non US neutron monitor
  - Improved operational reliability
  - Post-detection notifications containing relevant information to the user
- **Improve the characterization of the Solar Energetic Protons (SEP) spectrum above 1 GV.** This is crucial to reduce the uncertainties in the calculation of the SEP-induced effective dose rates encountered by crews in the aviation during GLE. Ideally in real-time.
- **Develop a real-time anisotropy analysis of the Cosmic Rays intensity** as a possible forecast system to Coronal Mass Ejection impact on Earth.

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