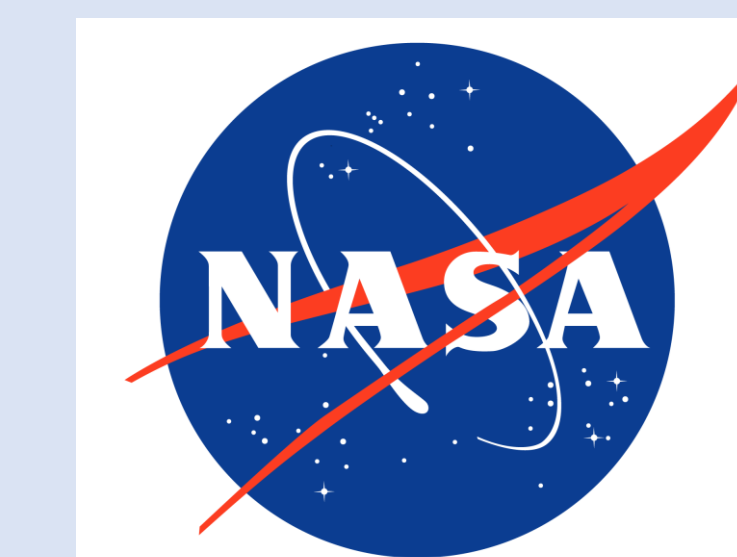


# First Detection of gamma-ray enhancement during the 2025 November 11 GLE by Detectors located at Antarctic and Arctic Stations

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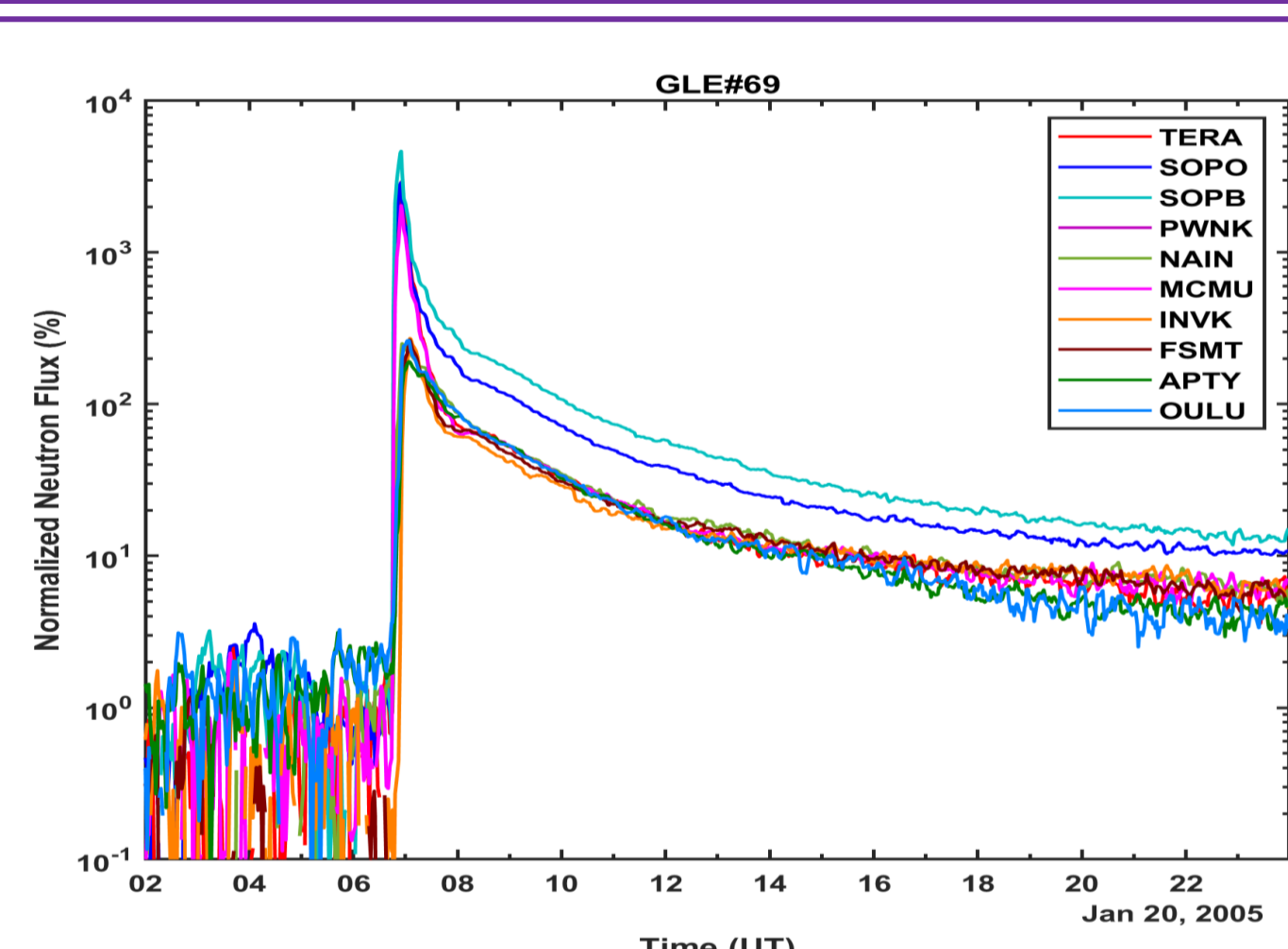
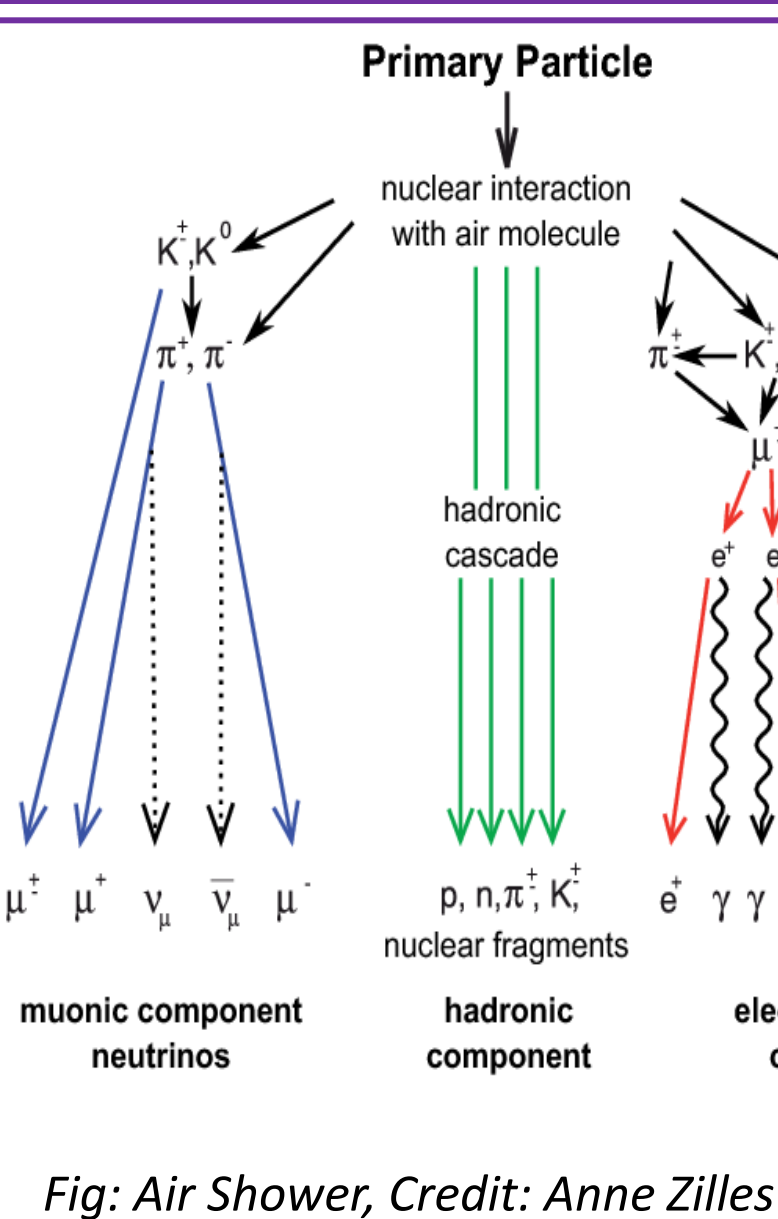


## ABSTRACT

The ground-level enhancement (GLE) on 11 November 2025, designated as GLE#77 (OULU GLE database), was associated with an intense X-class solar flare, a fast halo coronal mass ejection (CME) and a strong solar energetic proton (SEP) event. This GLE is studied using ground-based NaI(Tl) gamma-ray detectors at Arctic and Antarctic stations, together with neutron monitor data and proton measurements from the GOES-18 satellite. The event was detected simultaneously by gamma-ray detectors near the poles in both the Northern and Southern Hemispheres, and the observed enhancements are consistent with the increases recorded by neutron monitors. The analysis reveals two distinct peaks in gamma-ray and neutron monitor data: a prompt peak at 10:38 UT and a delayed peak at 13:08 UT. The prompt peak was observed even at high-rigidity neutron monitor stations (low latitudes), whereas the delayed peak was not detected at stations with geomagnetic cutoff rigidity greater than 6 GV. The timing of these peaks corresponds well with proton flux enhancements measured by GOES-18 at energies >150 MeV for the prompt peak and 12-99 MeV for the delayed peak. These results indicate that the GLE amplitude strongly depends on geomagnetic cutoff rigidity, while showing a weak dependence on the solar zenith angle.

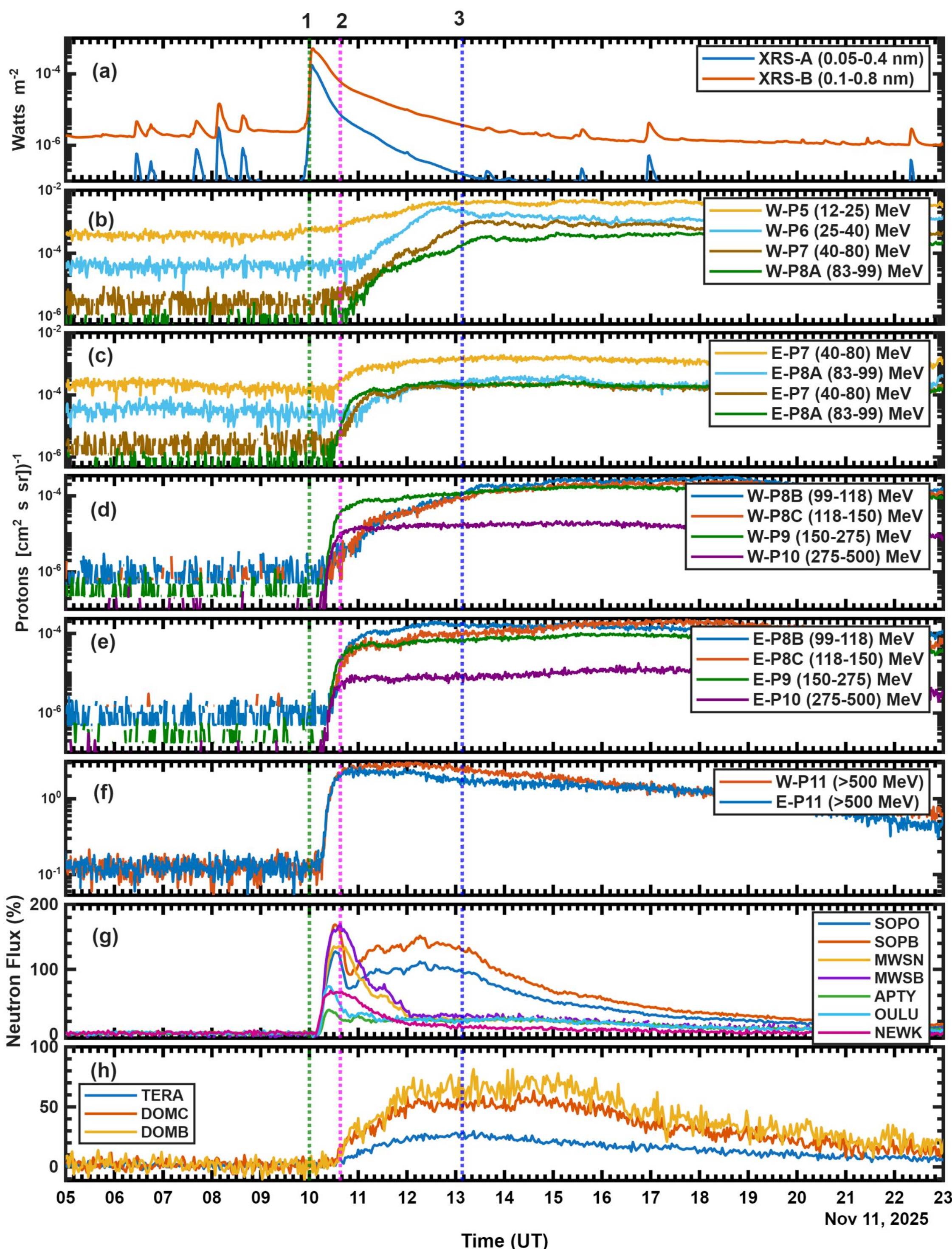
## INTRODUCTION

- **Ground Level Enhancement (GLE)** is the sudden, short-lived enhancements at multiple neutron monitor stations, including at least one near sea level, together with a corresponding increase in space-borne proton flux measurement (Forbush 1946; Poluianov et al 2017).
- Rare and extreme manifestations of solar energetic particle (SEP) events.
- To date, 77 GLEs have been documented (NMDB & OULU database)



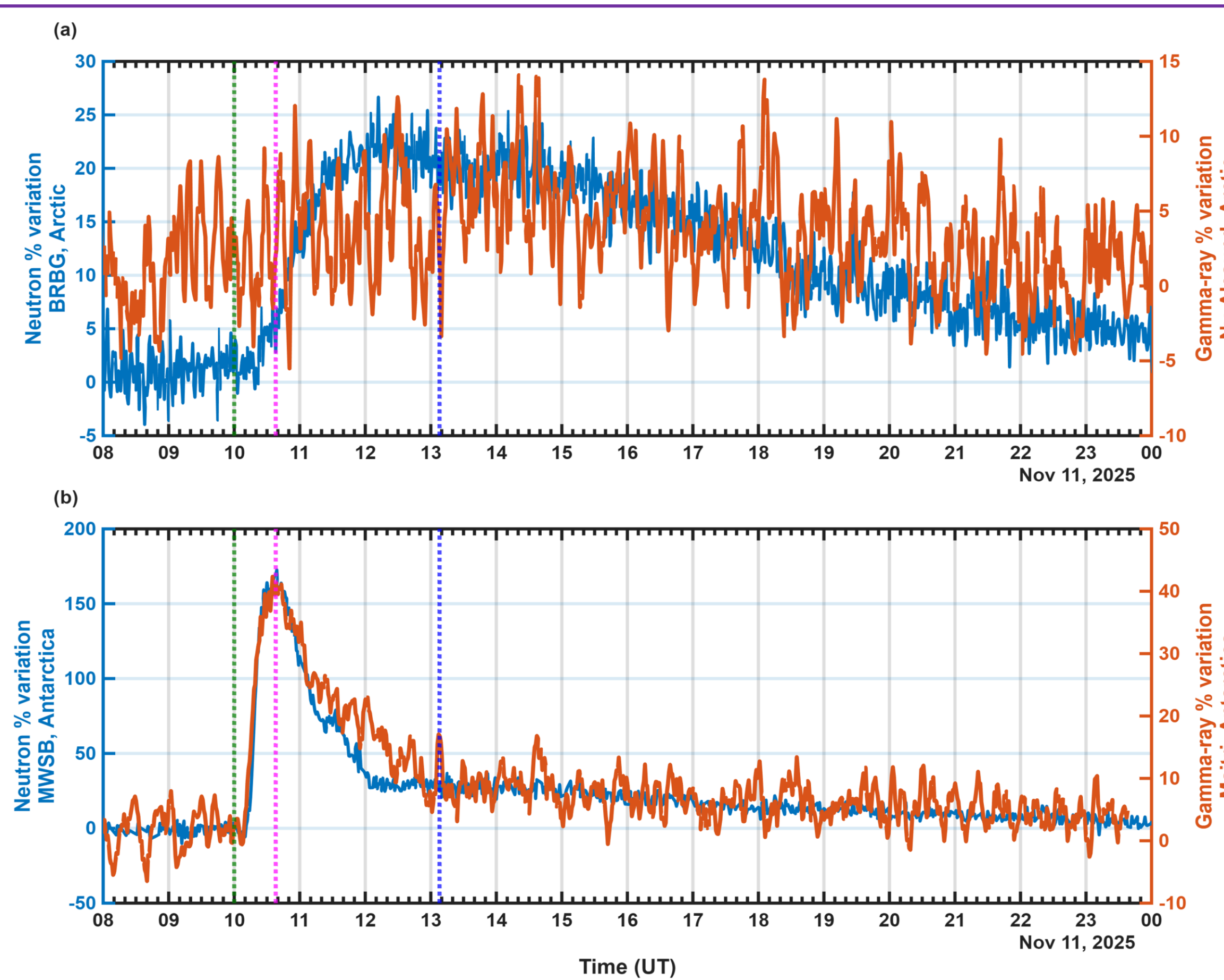
## Ground Level Enhancement on 2025 November 11 (GLE#77)

- GLE#77 originated from active region AR 4274 during an X5.1 solar flare on 11 November 2025, with a start time at 09:49 UT, a peak at 10:04 UT, and an end time at 10:17 UT, as measured by the GOES-18 satellite.
- A pronounced enhancement in proton flux above 12 MeV commencing at ~10:10 UT is observed across multiple proton flux channels,
- The Global Neutron Monitors (NM) Network recorded noticeable increases in neutron flux with the onset between 10:10 and 10:20 UT.
- Based on the neutron and proton fluxes, we have identified a prompt peak at 10:38 UT and a delayed peak at 13:08 UT.



## Gamma-ray observations at Arctic and Antarctic

- The clear increase associated with the GLE is seen in the gamma-ray data recorded at Ny-Alesund station in arctic and Maitri station in Antarctica in the 3-8.5 MeV energy range.
- The gamma-ray intensity increased by approximately 14% at 14 UT in Ny-Alesund, Arctic and 42% at 10:38 UT in Maitri, Antarctic.
- This signature matches well with the neutron flux variations at BRBG NM from Arctic and MWSB NM from Antarctic.

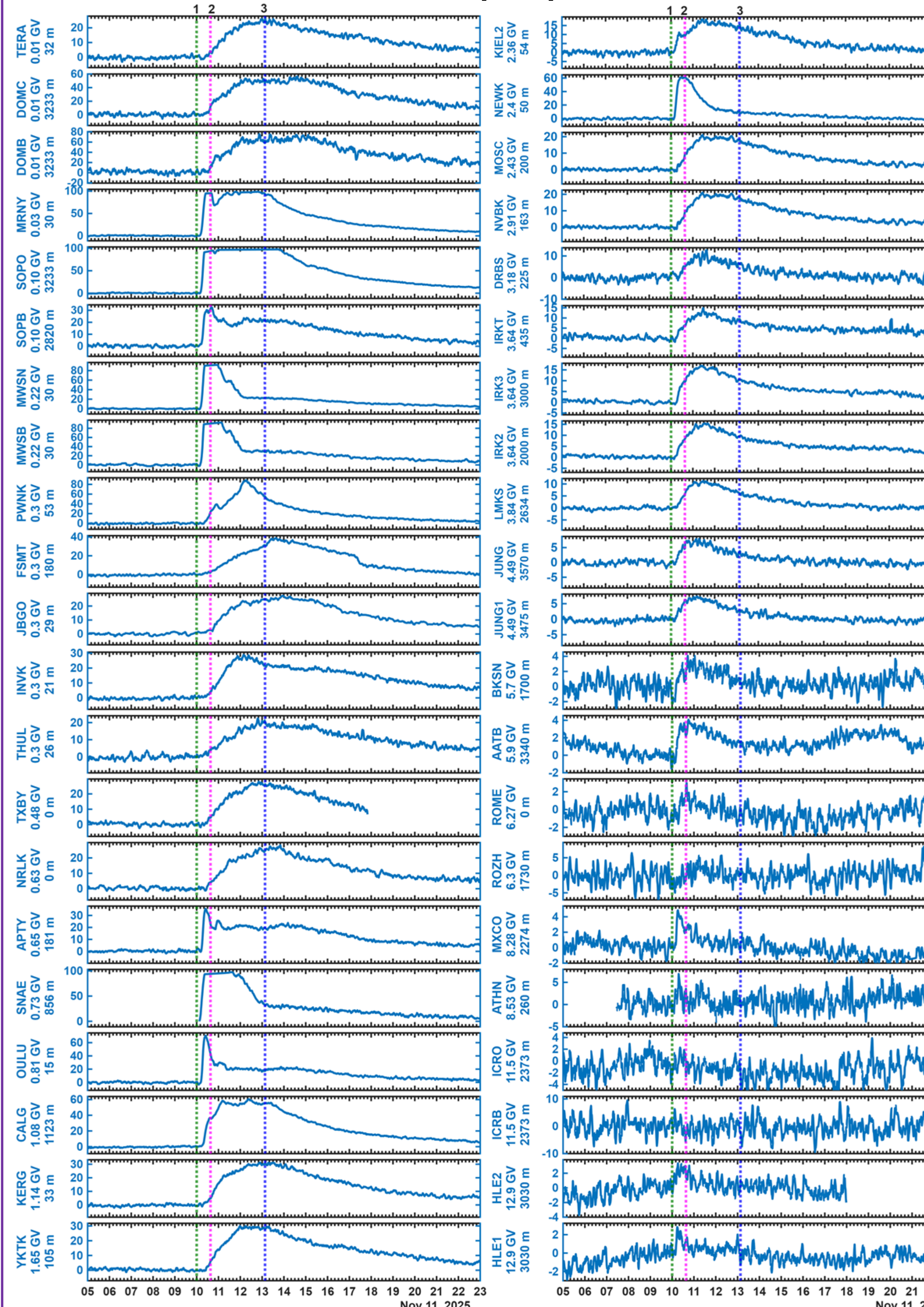


## DATA USED

- NM data taken from the NMDB, OULU database, and Polar Geophysical Research Institute with 1-minute resolution, the Solar flare X-ray and solar proton fluxes from GOES-18.
- The NaI (TI) detector data from Indian Arctic Station at Ny-Alesund and Antarctic Station Maitri, with a time resolution of one minute, gamma-ray flux in the 3 MeV – 8.5 MeV, a rectangular cuboid detector (10.16 cm X 10.16 cm X 40.64 cm) in size.

## RESULTS

### Neutron Monitor (NM) Observations



### Variation of amplitudes of prompt and delayed peaks with geomagnetic rigidity and solar zenith angle

- The neutron monitor data show a complex responses during this GLE event with either distinct prompt or delayed peak or both.
- GLEs are limited to the higher latitude stations and not observed at lower latitudes (higher rigidity stations).
- Due to strong intensity of GLE#77, it is observed even at lower latitudes with rigidity beyond 6GV. This is something unique about this GLE!

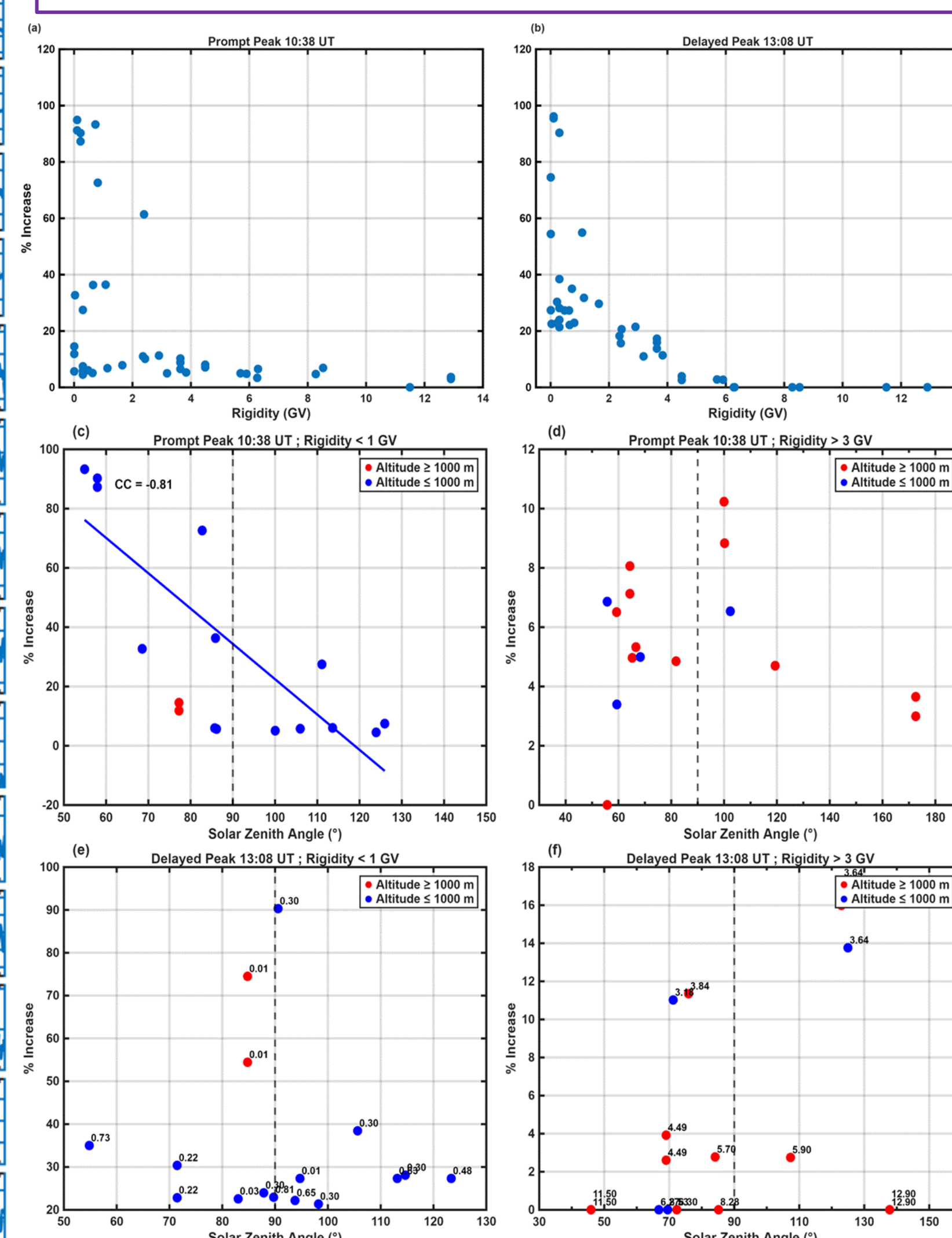
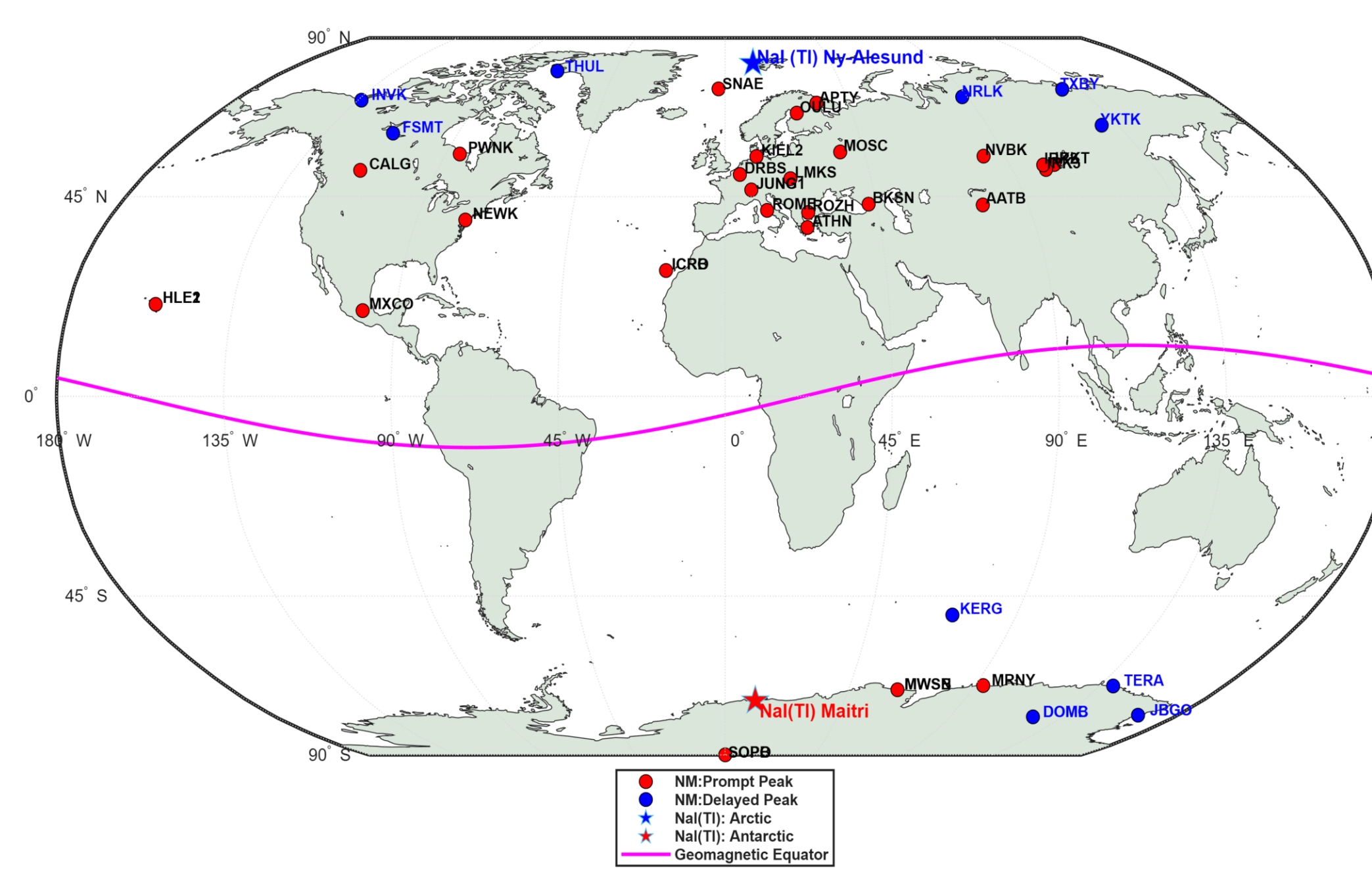
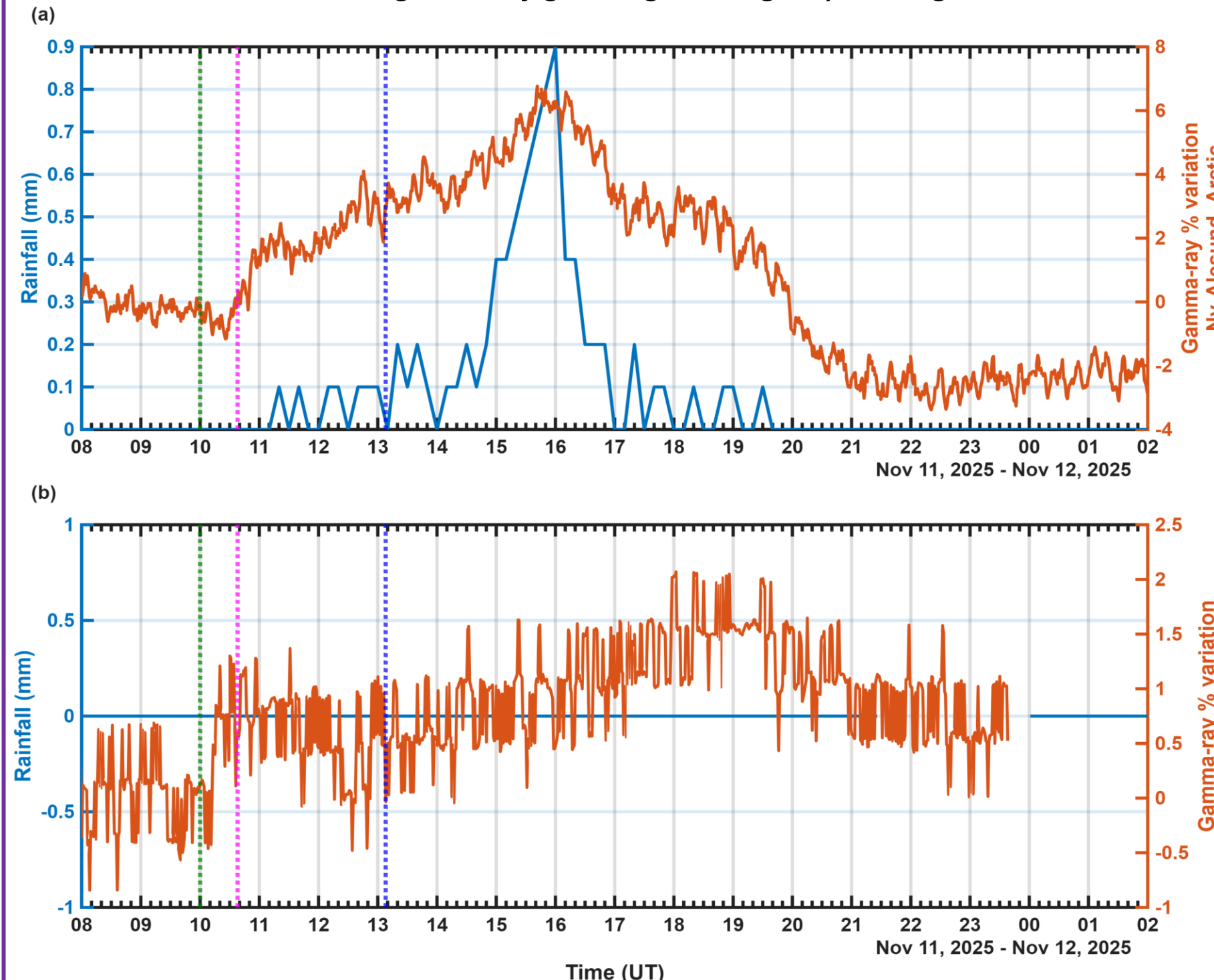


Fig: Normalized neutron flux (% variations) recorded at 42 neutron monitor stations, arranged from top to bottom in increasing order of geomagnetic rigidity, during 11 November 2025 (GLE #77)



## CONCLUSIONS

- This is the first GLE event recorded by a Gamma-ray detector simultaneously in the Arctic and Antarctic.
- A clear prompt peak at 10:38 UT and a delayed peak at 13:08 UT were observed in the worldwide network of NM stations and also in the gamma-ray detectors located at Northern and Southern polar latitudes. Signatures of the prompt peak of the GLE was clearly observed in low latitude (high rigidity) neutron monitors.
- The delayed peak was not seen at the stations with rigidity > 6 GV. Prompt and delayed peak timings coincided with the peaks in the proton flux with energies > 150 MeV and 12-99 MeV, respectively, observed by GOES-18 satellite.
- It is found that the GLE amplitude has a strong dependence on the geomagnetic cutoff rigidity and a weak dependence on the solar zenith angle.

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**ACKNOWLEDGEMENTS:** The NaI (TI) experimental set-up at Maitri, Antarctica, is operated by the Indian Institute of Geomagnetism (IIG). This work is supported by the Department of Science and Technology (DST), Government of India. We acknowledge NASA, The Catholic University of America, and SCOSTEP SVS program for providing support. We acknowledge the NMDB, OULU database, Polar Geophysics Institute Russian Academy of Sciences, and GOES-R Program.

Scan for more details

