Cosmic Ray Neutron Sensing (CRNS) as a Space Weather Tool?

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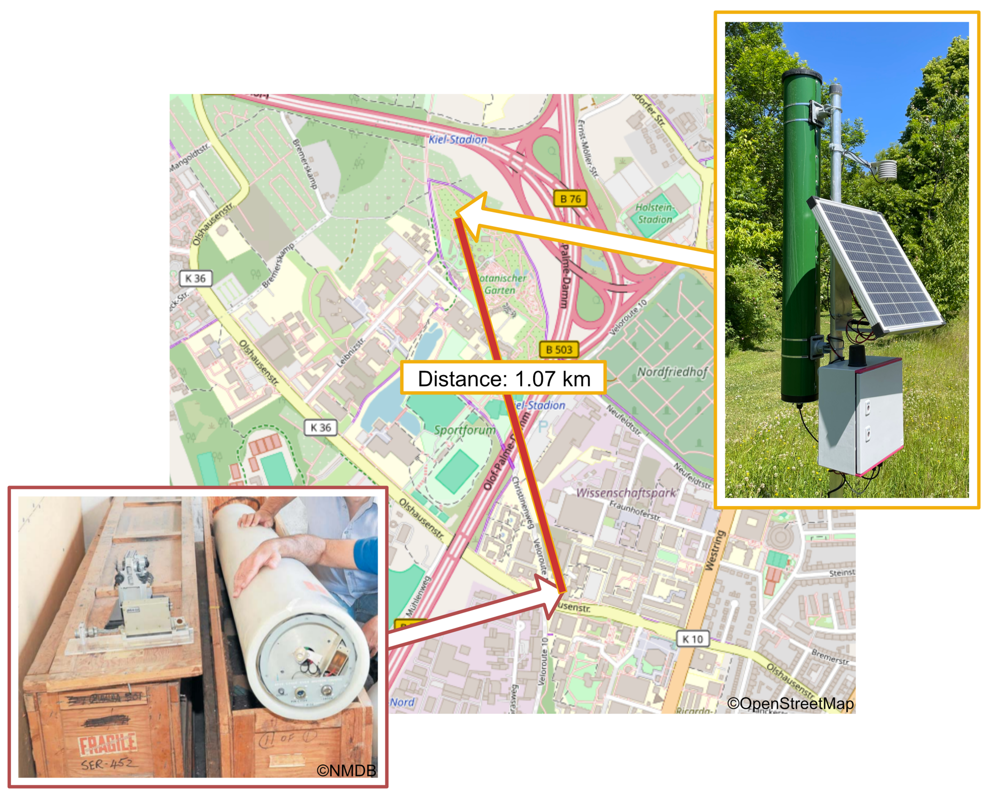
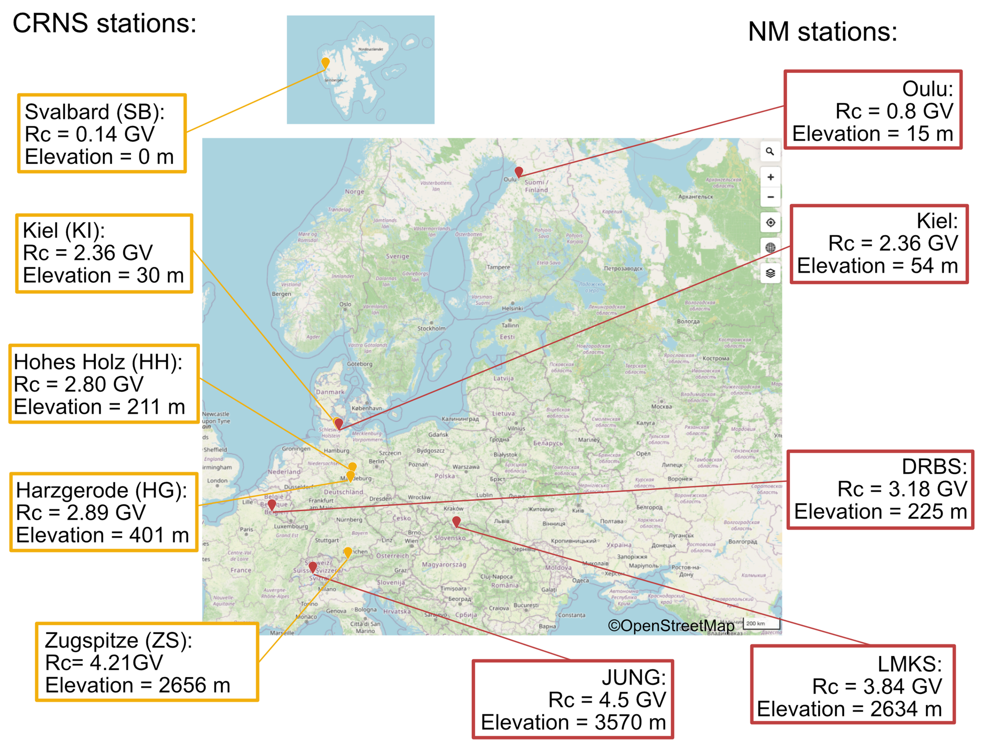
Abstract

Since mid-2024 a cosmic ray neutron sensing detector has been installed in Kiel close to the Kiel neutron monitor. The former is used to measure soil moisture in the surrounding area of the system, the latter is a measure of the incoming cosmic ray-induced neutron environment and is used to correct the CRNS data. The fact that the CRNS detector and the neutron monitor (NM) are at the same location allows a unique insight into the correlation of both measurements. Since both count rates are expected to decrease during Forbush Decreases (FDs), we can investigate their correlation during all FDs observed from mid-2024. In contrast, the correlation is far lower during the occurrence of rain events, which can lead to a similarly shaped decrease in the count rate. The analysis has been repeated utilizing NMs at different locations (e.g., Jungfraujoch) in order to estimate the uncertainties of the above analysis. Furthermore, the count rates of different CRNS detectors have been compared for FDs as well as rain events to see if a distinction between both is possible without the use of a NM.



1 Background

- Neutron monitors (NMs) (Hatton & Carmichael 1964) and cosmic ray neutron sensing (CRNS) detectors (Zreda et al. 2008) both measure secondary neutrons, but in different energy ranges
- For the calculation of soil moisture from CRNS data, NM data is needed as an input, but the correction factor is still a work in progress (Hertle et al. 2025)
- In Kiel: NM64 since 1964 and CRNS detector since mid 2024
- Unique insight into relation between NM and CRNS measurement
- Forbush Decrease (FD) and rain/snow events can look similar in shape, so a method for the separation of both is needed to allow for the use of CRNS stations as a space weather tool
- Method can be tested in Kiel - but would be most useful in regions with large distances to NM



2 Method

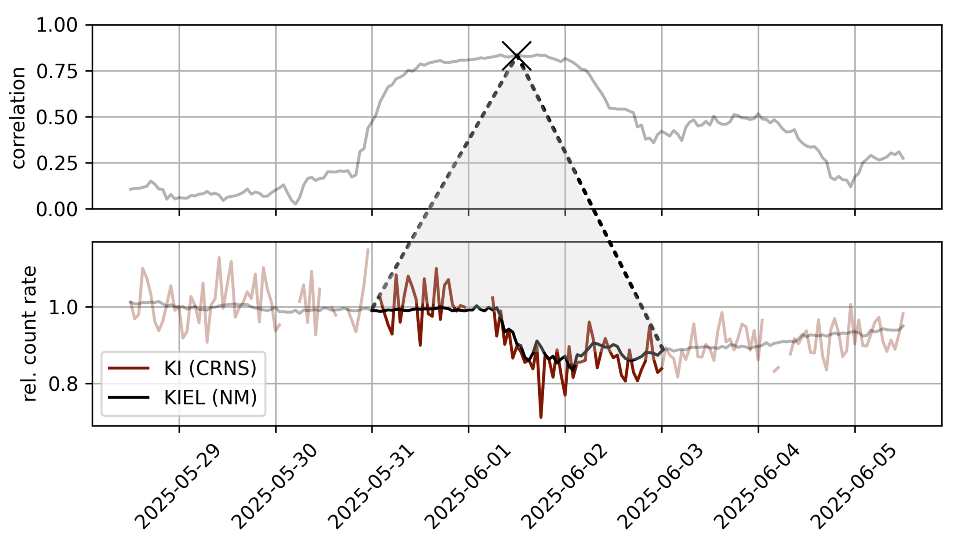


Figure 1: We calculated the correlation between the CRNS detector in Kiel and the Kiel NM for 3 day intervals, using a rolling window to compare the correlation over time.

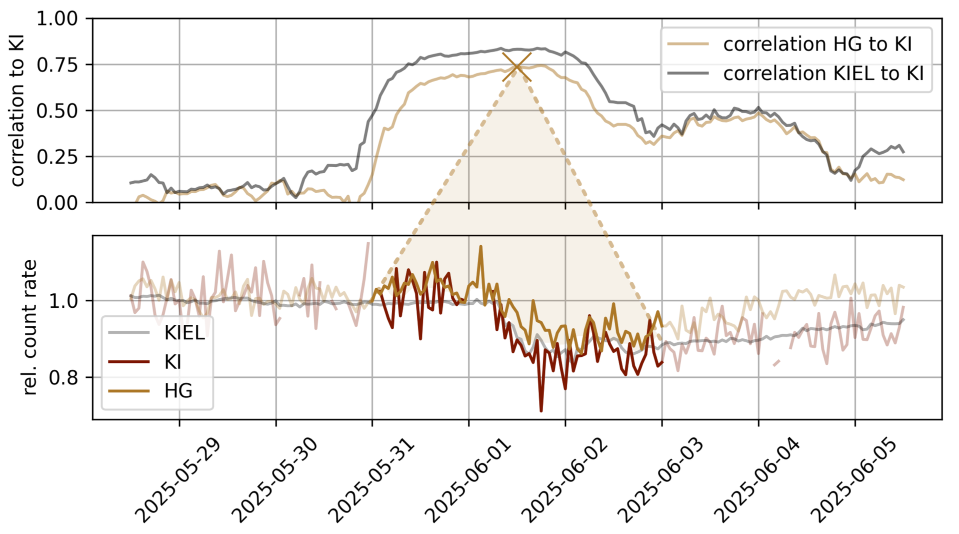


Figure 2: The same method was repeated with other detectors, always using the same reference detector (here KI), to find out about similarities and differences in the correlation.

Figure 3: *Below:* The whole measuring period. The time resolution is always kept at 1 hour to preserve the fast changes during FDs, so the different statistics in NM and CRNS lead to large differences in noise.

3 Results

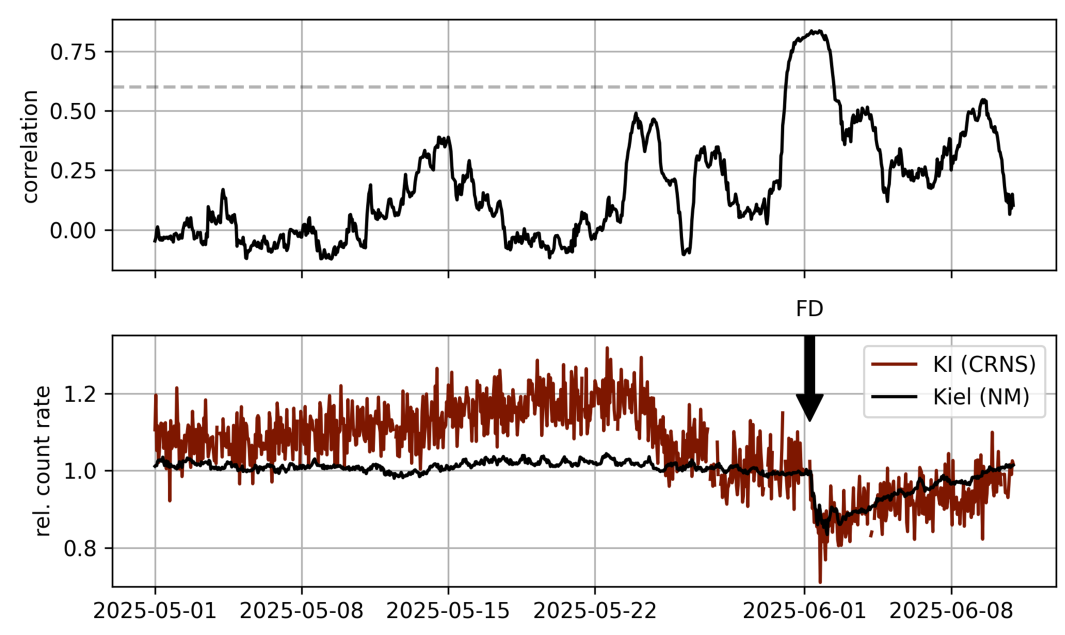


Figure 4: Comparison between Kiel CRNS and NM shows a high correlation only during events like FDs.

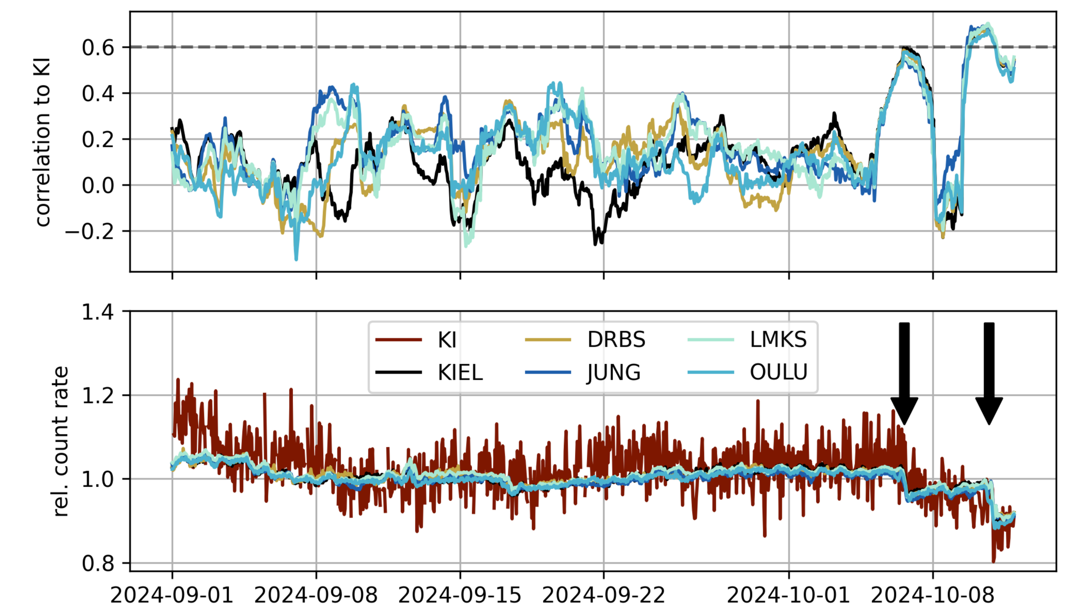


Figure 5: Comparison to other NMs shows significant differences during quiet times but very similar correlation during events.

4 Comparison with other CRNS stations

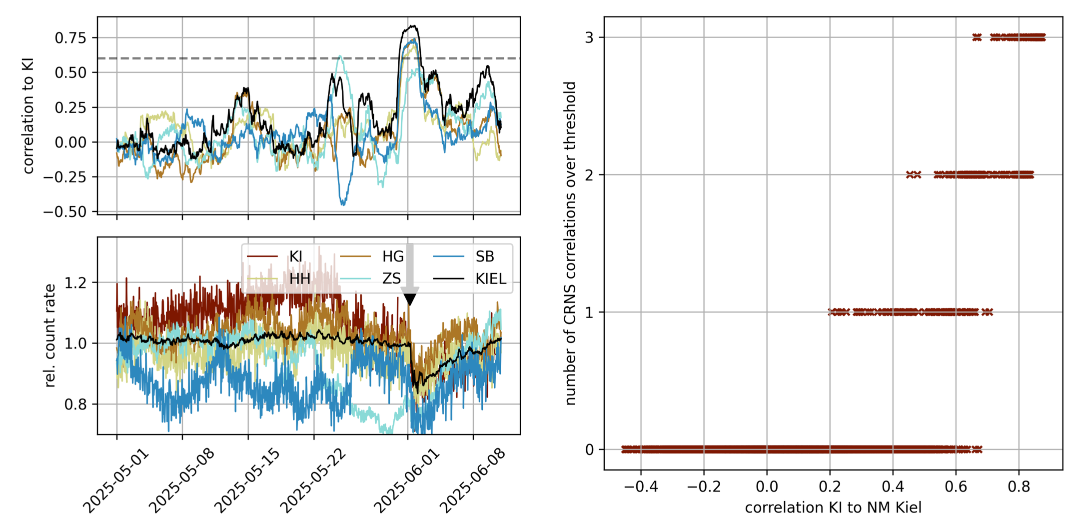


Figure 6: Comparison to other CRNS stations shows a high correlation of at least some stations during events. This allows replacing the comparison with the Kiel NM with other CRNS stations, as all times with high correlation to Kiel NM also show correlation above R=0.5 with at least 2 other CRNS detectors.

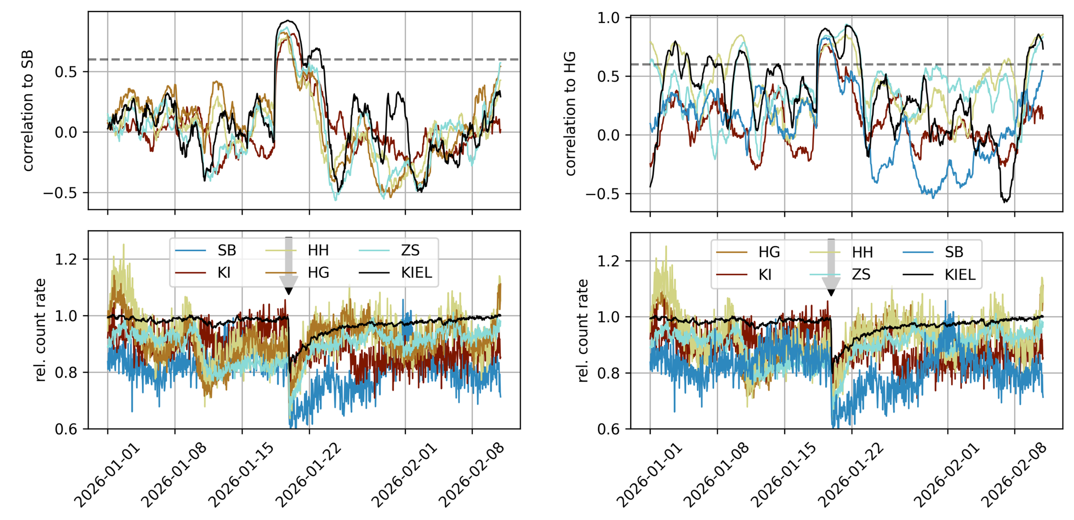
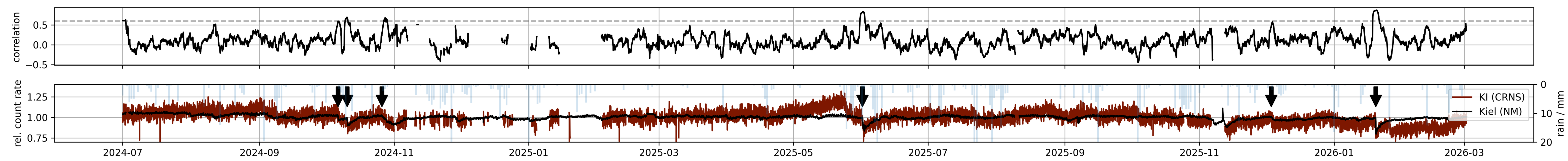


Figure 7: However, the usefulness of the method depends a lot on the specific CRNS station used as reference detector: Svalbard (left) shows similar results to Kiel, while Harzgerode (right) shows high correlation even during times without space weather events.



5 Discussion

- Correlation between the CRNS detector and the NM in Kiel is high only during space weather events; this allows for a separation between rain events and cosmic ray events leading to a drop in count rate
- The choice of NM does not lead to a significant difference in correlation during space weather events, only during quiet times
- In Kiel and Svalbard, similar results can be reached using the correlation to other CRNS detectors, replacing a single NM above a threshold with multiple CRNS detectors above a lower threshold
- In Harzgerode this method does not work, as the correlation to NM as well as CRNS detectors (especially Hohes Holz and Zugspitze) is far higher in quiet times. Reasons for this behavior are yet unknown.

6 Outlook

- Further investigation into thresholds and more CRNS stations
- Especially relevant in locations without NM coverage, such as Australia
- Correlation between calculated soil moisture and NM on different time scales could also help to improve the correction of incoming radiation

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