Survey of Neutron Monitor data source discrepancies 1951-2019

Pauli Väisänen, Ilya Usoskin and Kalevi Mursula
Space Climate Research Group, University of Oulu, Finland
email: pauli.vaisanen@oulu.fi

1. Introduction

Table 1. List of recommended data sources for each station. 1=Station homepage, 2=IZMIRAN, 3=WDCCR, 4=NMDB1h, 5=NMDBrevori. Prime stations are in **bold**.

Ahmedabad	4	Herstmonceux	3	**Newark**	4
Albuquerque	3	Hobart	3	**Nobosibirsk**	2
Alert	2	**Huancayo**	4	Nor-Amberd	4
Alma-Ata A	2	**Inuvik**	2	Norilsk	2
Alma-Ata B	4	Invercargill	3	Northfield	3
Alma-Ata C	2	Irkutsk	2	Ottawa	2
Apatity	1	Irkutsk 2	2	**Oulu**	1
Aragats	4	Irkutsk 3	2	Peawanuck	1
Athens	4	Jang Bogo	5	Pic du Midi	2
Bagneres	3	**Jungfraujoch IGY**	4	**Potchefstroom**	1
Baksan	2	Jungfraujoch NM64	4	Prague	3
Barentsburg	2	Kampala	3	Predigtstuhl	3
Beijin	2	**Kerguelen**	4	Resolute Bay	3
Beirut	3	Khabarovsk	3	Rio De Janeiro	3
Berkeley	3	**Kiel**	4	Rome	2
Brisbane	3	Kiel 2	4	**Sanae64**	2
Buenos Aires	3	**Kiev**	3	Sanae80	4
Bure	2	Kingston	2	Santiago	2
Calgary	2	Kiruna	3	Seoul	3
CALM	5	Kodaikanal	3	Simferopol	3
Cape Schmidt	2	Kuhlungsborn	3	South Pole	1
Casey	3	Kula	3	South Pole Bare	4
Chacaltaya	3	Lae	3	Sulfur Mt IGY	3
Chicago	2	Larc	2	Sulfur Mt NM64	2
Churchill	2	**Leeds**	2	Swarthmore	2
Climax	4	Lincoln	3	Sverdlovsk	2
College	3	Lindau_IGY	3	Sydney	3
Cordoba	3	Lindau_NM64	3	Syowa	3
Daejeon	4	**Lomnický Štít**	1	Tashkent	2
Dallas	3	London	3	Tbilisi	2
Darwin	3	Magadan	2	**Terre Adelie**	4
Deep River	2	Makapuu_Pt	3	Thailand	4
Denver	3	Mawson	2	**Thule**	4
Dome B	1	**McMurdo**	1	Tibet	4
Dome C	1	Mexico	3	Tixie Bay	2
Dourbes	4	Mina Aguilar	3	**Tokyo**	2
Durham	2	Mirny	4	**Tsumeb**	4
Ellsworth	3	Mobile CR Laboratory	2	Uppsala	3
ESOISR	2	Morioka	3	Ushuaia	3
Fort Smith	5	**Moscow**	2	Utrecht	3
Freiburg	3	Moscow experimental	2	Weissenau	3
Fukushima	3	**Mt Norikura**	2	Wellington	3
Goettingen	3	**Mt Washington**	2	Victoria	3
Goose Bay	2	**Mt Wellington**	2	Wilkes	3
Hafelekar	2	Munchen	3	Vostok	2
Haleakala_IGY	2	Murchison Bay	3	Yakutsk	2
Haleakala_SM	2	Murmansk	3	Zugspitze	4
Halle	3	Nain	1		
Heiss Is	3	Nederhorst	3		
Hermanus	1	Neumayer 3	4		

Neutron monitor (NM) measurements are used to study the variations of galactic cosmic ray (GCR) fluxes.

Sources for NM datasets include the Neutron Monitor Database (NMDB), World Data Center for Cosmic Rays (WDCCR), The Pushkov Institute of Terrestrial Magnetism, Ionosphere and Radiowave Propagation (IZMIRAN) repositories and individual homepages of stations/teams.

In a recent survey (Vaisanen et al. 2021), it was noted that the datasets from different sources are not identical. We analysed the data coverages and quality by comparing to 29 "prime" stations with long, stable data. We compiled a list of recommended NM data sources. This list is available in Table 1. An overview of each source is shown in Table 2.

Here we will present an overview and visualisation of the recommended dataset from 147 stations.

Table 2. Overview of data source recommendations.

Data repository (click for hyperlink)	Available stations	Recommended sources	Secondary sources
NMDB (1h)	53	29	10
NMDB (revori)	51	3	2
WDCCR	138	59	24
IZMIRAN	81	50	18
Polar Geophys. Inst.	1	1	
Bartol Inst.	8	5	3
Jungfraujoch NM	2	0	2
Lomnický Štít NM	1	1	
Mexico NM	1	0	1
Oulu NM	3	3	
South African stations	5	2	2
Yakutsk + Tixie Bay	2	0	0

2. Data and corrections

A simple visualisation of the raw data is shown in the top panel of Figure 1. We can see that station count rates are at different levels, but the curve shapes follow each other. There is still a lot of outliers and errors though.

In order to better visualise and analyse the data, we remove outliers with a hampel filter and scale all datasets so that the median for years 1975-1976 (or 1995-1996, if not available) is unity. For stations with no coverage during those years, we scale them to the median of stations within the same rigidity bin that have coverage during 1975-76 or 1995-96. After scaling, we removed all datapoints ±30 % off from the overall average or ±10 % off from the local median.

The result of this process is shown in the bottom panel of Figure 1, where we see that the curves overlap and can be more easily be analysed. Some problems are still visible, which we try to fix by using median statistics in the analysis. Better results would require a more thorough, station-specific corrections.

Figure 1. Top: Raw hourly count rates from all stations (147). Bottom: Corrected and scaled data of all stations

Since the count-rate variability is affected by the stations' rigidity cut-off R, we group the stations into rigidity bins:

Low rigidity stations:
R<1.75 GV
Medium rigidity stations:
1.75 GV<R<2.75 GV
High rigidity stations:
R>2.75 GV

For each rigidity bin, we compute 27-day moving averages of the hourly median of all of the bin's stations, the median absolute deviations (MAD) and the maximum number of available stations.

3. Results

Figure 2 shows the result for the different rigidity bins. Although the overall level is roughly the same, we can see that higher rigidity cutoffs means relatively less variability during solar maximum times. The MAD curves show that low and medium rigidity stations vary only very slightly during 1965-2000, after which the deviations seems to increase. This could be due to changes in stations, temporal distance from the scaling years (1975-76 or 1995-96), or a change in the global modulation of GCR. The deviations for high rigidity stations has a clear solar cycle trend, which is probably due to the fact the the high rigidity bin is too wide. The deviations in the high rigidity bin seem to behave different in the most recent cycles, with deviations being lower than before.

In the bottom panel, we show the coverage of the different bins and the total coverage (both raw and corrected+scaled data). We can see that the was about 30 stations before 1965, followed by about 50 stations until 1975. Until 2017, there were about 40-45 active stations, but the number has been dropping in recent years. This recent development is alarming, since the utility of the global NM network comes especially from the high coverage of long-term measurements.

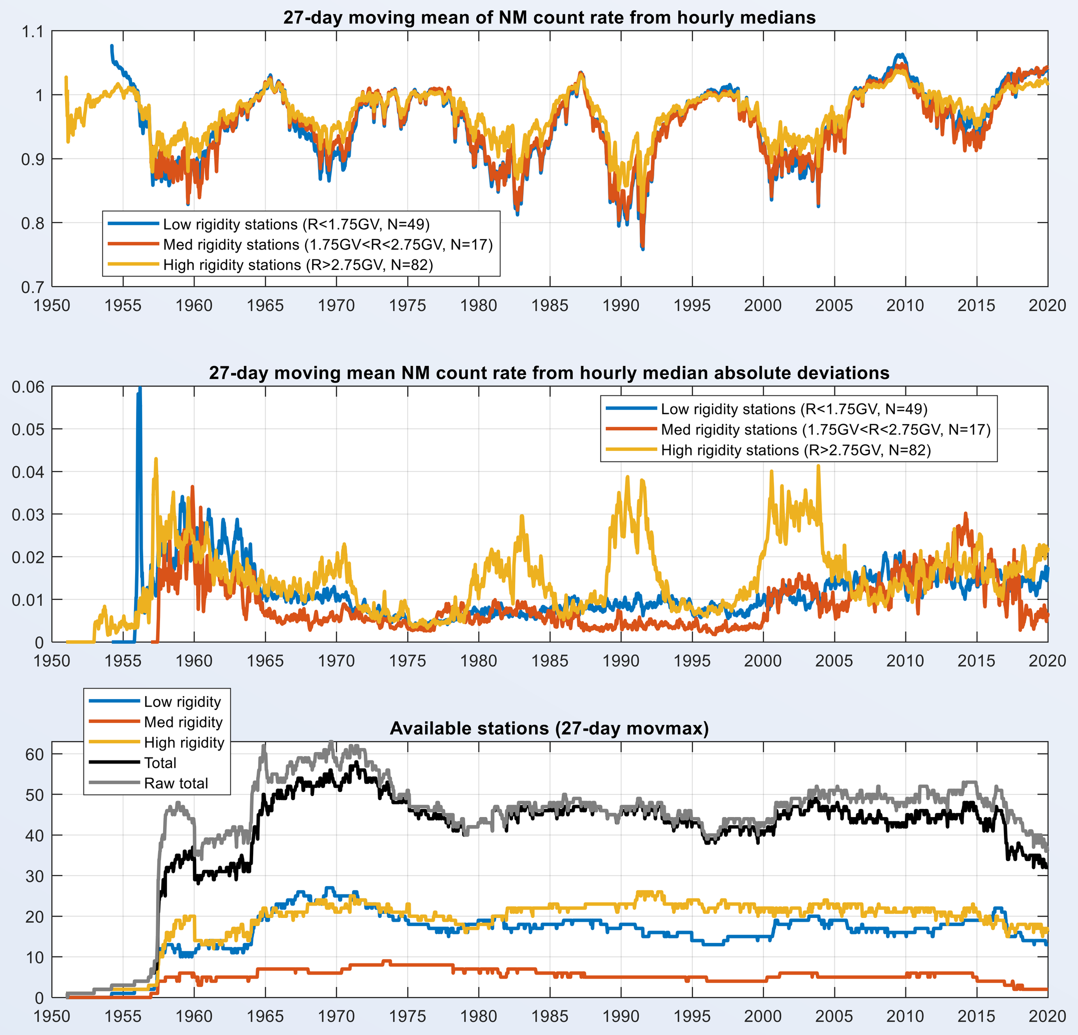

Figure 2. Moving averages (top), deviations (middle) and coverages (bottom) of NM stations of the different rigidity bins.

Reference:

Väisänen, P., Usoskin, I., & Mursula, K. (2021). Seven decades of neutron monitors (1951–2019): Overview and evaluation of data sources. Journal of Geophysical Research: Space Physics, 126, e2020JA028941. https://doi.org/10.1029/2020JA028941

4. Summary

- We collected the recommended data sets using the table from Vaisanen et al. 2021.
- After corrections, the data quality is good and usable for analysis.
- Deviations between different stations in the same rigidity bin are different before and after 2005.
- The recommended dataset offers good quality measurements from the global NM network.
- Further corrections and improvements to the datasets would be useful, preferrably at the source.