PROCEEDINGS OF SCIENCE

Current Status of WDC for Cosmic Rays (WDCCR)

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The World Data Center (WDC) for Cosmic Rays (WDCCR) was established at the Institute of Physical and Chemical Research (RIKEN) in 1957 as one of the four WDC-D2 centers established in Japan, during the International Geophysical Year (IGY, 1957-1958). The principal task of the WDCCR was to preserve and provide the quality-accessed database of worldwide neutron-monitor (NM) data (pressure-corrected and scale-adjusted 1-hour count rate). The WDCCR was moved to the Solar-Terrestrial Environment Laboratory, Nagoya University (currently, Institute of Space–Earth Environmental Research, Nagoya University), in 1991. Data holdings of WDCCR have been opened in unified formats at https://cidas.isee.nagoya-u.ac.jp/WDCCR/. The total number of available NM stations is 138 as of 2022. Although more than half of these NM stations were closed during the 70-year history of the worldwide NM network, all the data obtained by these stations are preserved and opened by WDCCR. We are keeping also original data sheets submitted by NM stations before the "digital era". Recently, the majority of NM stations and NM data repositories (NMDB, and IZMIRAN) are openng high time-resolutions data, counts/sec or counts/min respectively. Consistency with the long-term one-hour data held by WDCCR with these high time resolution data is preserved by adjusting their time scales.

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1. Introduction

The World Data Center for Cosmic Rays (WDCCR) was cleated in 1957 at the Institute of Physical and Chemical Research (RIKEN), Japan, as one of the initial members of the World Data Center system of ICSU (International Council of Science, currently International Science Council) during the International Geophysical Year (IGY) held in 1957-58 [1]. WDCCR is providing with a database of cosmic-ray neutron-monitor (NM) data (one-hour count rates) in unified formats. Descriptions of the history of NM-related history can be seen in Väisänen et al (2020). The WDCCR was formally moved to the Solar-Terrestrial Environment Laboratory (currently Institute of Space-Environment Research), Nagoya University, in 1991. Data-management works of the WDCCR were temporarily carried out through collaboration with the Department of Environmental Sciences, Ibaraki University in the interval from 1993 to 2006. Upon the creation of the World Data System (WDS) in 2008, the system of WDC was terminated. The WDCCR has continued its activity as the Candidate Member of WDS.

The principal data holdings of WDCCR are Pressure-Corrected and Scale-Adjusted (PCSA) NM count rates per hour obtained by the worldwide NM network since 1953. The time-variation of the number of NM stations (actually the number of NM systems) is shown in Figure 1. The first jump is seen during the International Geophysical Year (IGY) in 1957-1958. The second jump took place in 1964 when a new NM called NM64 or “super-monitor,” was introduced during the International Quiet Sun Year (IQSY, 1964-65). For years after 2015, the number of stations are provisional because works to include more data in the WDCCR database are continued. In some cases, we are waiting to receive the final version of their data.

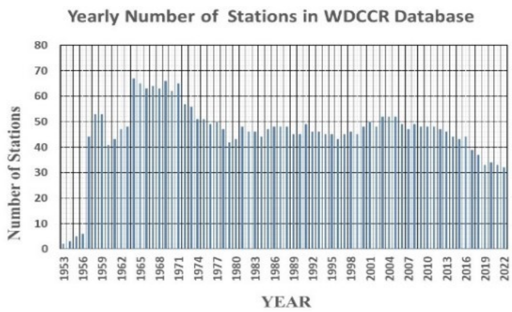


Figure 1. The yearly number of NM stations (or NM systems) in the world from 1953 to 2022. Numbers in rescent years are provisional because works to include more data are in progress.

Current data sources of the NM database of WDCCR are individual NM stations, NMDB (the Neutron Monitor Database, https://www.nmdb.eu/) and the data portal of IZMIRAN (Pushkov Institute of Terrestrial Magnetism, Ionosphere and Radio Wave Propagation, Russian Academy of Sciences, http://cosrays.izmiran.ru/). Current NM data taken by former USSR stations are opened from IZMIRAN via individual data portals of these NM stations. Recently, a number of NM stations in active are opening their data from NMDB instead to open at their own site. A fractional diagram showing the current situation of NM data sources in 2021 is given in Figure 2.

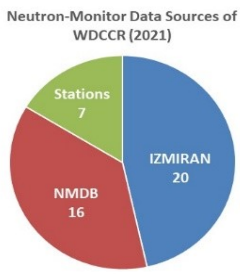


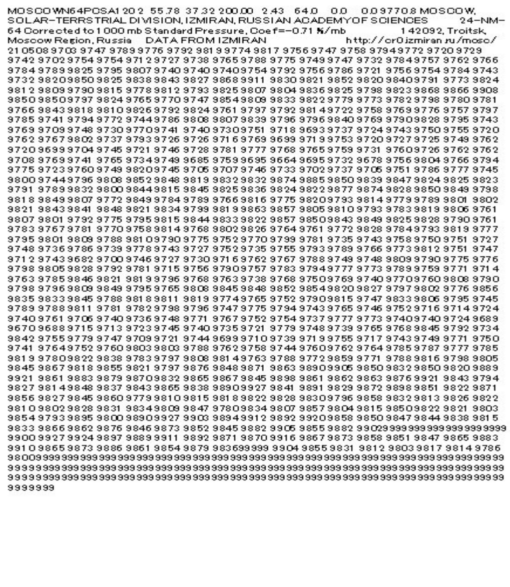
Figure 2. A fractional diagram of the current numbers of NM data sources with respect to NM stations, NMDB and IZMIRAN, as of 2021. These numbers are provisional because works to include more data are in progress.

2. WDCCR Database

Detailed information on the WDCCR Database is given in the READ_ME page of the WDCCR Web site (https://cidas.isee.nagoya-u.ac.jp/WDCCR/index.html). Data (numerical data and plots) can be sorted visually with respect to YEAR or STATION. It should be stressed that the WDCCR database is a “fixed-length” one. The number of days in one month is fixed to be 31 days. So, every year has 12 x 31 = 372 days in the WDCCR database. Hourly counts in days that do not exist in the normal calendar (e.g. "31 April") are filed by 99999, which means "no data". All tabulated data are “scaled counts” per hour. The Real Count is (Scaled Count + Constant)*SF, where SF is the scaling factor. The SF and the Constant are selected to limit the number of digits do not exced five. In many stations, the Constant is zero. The WDCCR is opening three kinds of formatted data, LONGFORMAT, SHORTFORMAT, and CARDFORMAT, although these three kinds of data formats include the same data. Among them, the CARDFORMAT data consists of 80-byte lines covering the time interval of 12 hours. Data in this format are only used in our data-management works because no important information on data, e.g. SF, is included.

2.1 LONGFORMAT

The basic data format of WDCCR database is the monthly LONGFORMAT data consists of 4096 characters. As shown in Figure 2 (folded representation of one-line data), the first 376 characters are allocated to basic information of the data (name of station, geographical coordinates, elevation, scaling factor, cut-off rigidity, coefficient of atmospheric correction, contact point, etc). This format was created by RIKEN people in 1960s, in the era of digital magnetic tape (MT), attempting to minimize the size of the data files. Although such long-line data are not convenient to manage in the PC era, we are keeping data in this format as the basic dataset of WDCCR. The data of this format is useful to perform long-term data analysis.



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MOSCOWN64PCSA1202  55.78  37.32 200.00  2.43  64.0  0.0  0.09770.8 MOSCOW,
SOLAR-TERRSTRIAL DIVISION, IZMIRAN, RUSSIAN ACADEMYOF SCIENCES        24-NM-
64 Corrected to 1000 mb Standard Pressure, Coef=-0.71 %/mb       142092, Troitsk,
Moscow Region, Russia    DATA FROM IZMIRAN                    http://cr0.izmiran.ru/mosc/
2105089703 9747 9789 9776 9792 9819 9774 9817 9756 9747 9758 9794 9772 9720 9729
9742 9702 9754 9754 9712 9727 9738 9765 9788 9775 9749 9747 9732 9784 9757 9762 9766
9784 9789 9825 9795 9807 9740 9740 9740 9754 9792 9756 9786 9721 9756 9754 9784 9743
9732 9820 9850 9825 9838 9843 9827 9868 9911 9830 9821 9852 9820 9840 9791 9773 9824
9812 9809 9790 9815 9778 9812 9793 9825 9807 9804 9836 9825 9798 9823 9868 9866 9908
9850 9850 9797 9824 9765 9770 9747 9854 9809 9833 9822 9779 9773 9782 9798 9780 9781
9766 9843 9818 9810 9826 9792 9824 9761 9797 9792 9814 9722 9758 9769 9776 9757 9797
9785 9741 9794 9772 9744 9786 9808 9807 9839 9796 9796 9840 9769 9790 9828 9795 9743
9769 9709 9748 9730 9770 9741 9740 9730 9751 9718 9693 9737 9724 9743 9750 9755 9720
9762 9767 9802 9737 9793 9726 9726 9716 9769 9699 9719 9753 9720 9727 9725 9749 9762
9720 9699 9704 9745 9721 9746 9728 9781 9777 9768 9765 9759 9731 9760 9726 9762 9762
9708 9769 9741 9765 9734 9749 9685 9759 9695 9664 9695 9732 9678 9756 9804 9766 9794
9775 9723 9760 9749 9820 9745 9705 9707 9746 9733 9702 9737 9705 9751 9786 9777 9745
9800 9744 9796 9808 9852 9848 9819 9832 9832 9874 9885 9850 9839 9847 9824 9825 9823
9791 9789 9832 9800 9844 9815 9845 9825 9836 9824 9822 9877 9874 9828 9850 9849 9798
9818 9849 9807 9772 9849 9784 9789 9766 9816 9775 9820 9793 9814 9779 9789 9801 9802
9821 9843 9841 9848 9821 9834 9799 9819 9863 9857 9805 9810 9793 9783 9819 9806 9761
9807 9801 9792 9775 9795 9815 9844 9833 9822 9857 9850 9843 9849 9825 9828 9790 9761
9783 9767 9781 9770 9758 9814 9768 9802 9826 9764 9761 9772 9828 9784 9793 9819 9777
9795 9801 9809 9788 9810 9790 9775 9752 9770 9799 9781 9735 9743 9758 9750 9751 9727
9748 9736 9786 9739 9778 9743 9727 9752 9735 9755 9793 9789 9766 9773 9812 9751 9747
9712 9743 9682 9700 9746 9727 9730 9716 9762 9767 9788 9749 9748 9809 9790 9775 9776
9798 9805 9828 9792 9781 9715 9756 9790 9757 9783 9794 9777 9773 9789 9759 9771 9714
9763 9785 9846 9821 9819 9796 9768 9763 9738 9768 9750 9769 9740 9770 9760 9808 9790
9798 9796 9809 9849 9795 9765 9808 9845 9848 9852 9854 9820 9827 9797 9802 9776 9856
9835 9833 9845 9788 9818 9811 9819 9774 9765 9752 9790 9815 9747 9833 9806 9795 9745
9789 9788 9811 9781 9782 9798 9796 9747 9775 9794 9743 9765 9746 9752 9716 9714 9724
9740 9761 9706 9740 9736 9748 9771 9767 9752 9754 9737 9777 9773 9740 9740 9724 9689
9670 9688 9715 9713 9723 9745 9740 9735 9721 9779 9748 9739 9765 9768 9845 9792 9734
9842 9755 9779 9747 9709 9721 9744 9699 9710 9739 9719 9755 9717 9743 9749 9771 9750
9741 9764 9752 9760 9803 9803 9788 9762 9758 9744 9760 9762 9764 9785 9787 9777 9785
9819 9780 9822 9838 9783 9797 9808 9814 9763 9788 9772 9859 9771 9788 9816 9798 9805
9845 9867 9818 9855 9821 9797 9876 9848 9871 9863 9890 9905 9850 9832 9850 9820 9889
9921 9861 9883 9879 9870 9832 9865 9867 9845 9898 9861 9862 9863 9876 9921 9843 9794
9827 9814 9848 9837 9843 9865 9838 9890 9927 9841 9891 9829 9872 9898 9851 9822 9871
9856 9827 9845 9860 9779 9810 9815 9818 9822 9828 9830 9796 9858 9832 9813 9826 9822
9810 9802 9828 9831 9834 9809 9847 9780 9834 9807 9857 9804 9815 9850 9822 9821 9803
9854 9793 9895 9800 9890 9927 9903 9894 9912 9892 9920 9858 9850 9847 9844 9838 9815
9833 9866 9862 9876 9846 9873 9852 9845 9882 9905 9855 9882 99029999999999999999999
9900 9927 9924 9897 9889 9911 9892 9871 9870 9916 9867 9873 9858 9851 9847 9865 9883
9910 9865 9873 9886 9861 9854 9879 983699999 9904 9855 9831 9812 9803 9817 9814 9786
98009999999999999999999999999999999999999999999999999999999999999999999999999999999999
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9999999
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Figure 3. One-month LONGFORMAT 4096-byte one-line data of Moscow NM in February 2022 (folded). “No data” is indicated by 99999.

2.2 SHORTFORMAT

Owing to the extremely long lines of the 4096-byte LONGFORMAT data, it is difficult to check the data of this format on the display of a PC. It is also difficult to add information on data in its headder section because the structure of this format is very tight and complicated. After the traditional format employed by NM stations and IZMIRAN, we created the SHORTFORMAT consisting of 22-line header section (information on data) and 62-line one-month (31 days) data, namely hourly counts for one-day (24 hours) are tabulated in two lines. An example is shown in Figure 4.

Fugure 4. SHORTFORMAT data of Moscow NM in January 2022 (shows only data for initial two days of the month).

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Cosmic-Ray Neutron Monitor Data (Hourly, Pressure-Corrected and Scale-Adjusted Counts)
Collections: WDC for Cosmic Rays,Inst.for Space-Earth Environmental Reserach,Nagoya Univ
Data Access: http://cidas.isee.nagoya-u.ac.jp/WDCCR/index.html
Project: ICSU WDC
Citation: WDC for Cosmic Rays, Ins. for Space-Earth Environmental Res., Nagoya Univ.
Station ID  MOSCOW
Station:  MOSCOW, SOLAR-TERRSTRIAL DIVISION, IZMIRAN, RUSSIAN ACADEMY OF SCIENCES
Instrument: 24-NM-64 Corrected to 1000 mb Standard Pressure, Coef=-0.71 %/mb
Latitude(deg.):  55.78  Longitude(deg.):  37.32  Altitude(m):  200.00
Cut-Off Rigidity(GV):   2.43
Year: 2022  Month:  1
Scaling Factor(SF):   64.0   Constant(CONST):    0.0  Real Counts=(DATA+CONST)*SF
Temporal Resolution: 1 hour
UTC Start Hour:    0.0
142092, Troitsk, Moscow Region, Russia    DATA FROM IZMIRAN
http://cr0.izmiran.ru/mosc/
Monthly Average:  9495.5
Updated(YYYY MM DD): 2023 05 06
********************************************************************************
ID    YYYY MM DD 1    0    1    2    3    4    5    6    7    8    9   10   11
ID    YYYY MM DD 2   12   13   14   15   16   17   18   19   20   21   22   23
********************************************************************************
MOSCOW 2022 01 01 1  9550 9549 9579 9598 9637 9592 9586 9612 9667 9619 9571 9593
MOSCOW 2022 01 01 2  9600 9585 9560 9521 9554 9542 9596 9530 9559 9447 9485 9495
MOSCOW 2022 01 02 1  9496 9480 9502 9520 9534 9525 9537 9522 9528 9583 9583 9497
MOSCOW 2022 01 02 2  9515 9528 9523 9487 9494 9517 9504 9517 9571 9533 9529 9464
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3. Data-Quality Assessment

The WDCCR is applying quality control procedures at a minimum level. Validity of the dating of reported data can be checked in the majority of cases by checking occurrence timings of several outstanding cosmic-ray phenomena, such as Forbush decreases, GLEs, and solar-rotation-depended variations of the neutron flux. Apparently wrong data (e.g. unnaturally huge counts without any events like GLEs) are removed when the monthly average of neutron flux shows a significant shift by the presence of these erroneous data points. Elimination of such data points is mentioned in the information part of the database.

4. Adujstment of Units of NM Data

The WDCCR is traditionaly managing NM data of one-hour time resolution since its establishment in 1957. The database will be useful to study long-term phenomena, like solar-cycle variations of the cosmic-ray flux and relatively slow transient phenomena like Forbush decreases. However, the demand to use more high time-resolution data has been increased to study transient phenomena like GLEs (Glound-Level Enhancements). In 2008, the Neutron Monitor Database (NMDB) project started under the EU FP7 program, providing an accessible database of archival and real-time verified data with the time-resolution of counts/sec [2]. In parallel, IZMIRAN is opening their database mainly in the unit of inpulses per min (ipm), which is eqivalent to counts/min. These NM data portals are providing with one-hour averages of counts/sec or counts/min, respectively. The one-hour real counts can be calculated symply by multiplying the hourly averages of counts/sec by 3600 sec, or multiplying hourly averages of counts/min by 60 sec. The listed counts in WDCCR database is the hourly number scaled by the Scaling Factor (SF) and the Constants in such a way that Scaled Count = Real Counts/SF – Constant. We confirmed continuations with previously preserved one-hour data for each station. Information of data conversion for stations included in the current database for 2021 (not completed in this stage) is shown Table 1. A part of stations are providing with traditional scaled one-hour counts as indicated in the table. It should be noted that the conversion procedures will be revised after changes given by data probiders.

Table 1. Conversion from original one-hour averages of high-time reolution data (Counts/min or Counts/sec) to Counts/hour data of WDCCR database (provisional listing as of 2021). Colum 1: Station code, Colum 2: Scaling Factor (SF), Colum 3: Constant (Const), Colum 4: Typical scaled value of counts/hour in the WDCCR database, Colum 5: Data Source, and Colum 6: Argorizm of conversion from original data to WDCR one-hour scaled counts.

Station	SF	Const	Typical Counts/h	Source	Conversion from Original Data to WDCCR One-Hour Counts Data
ALMA-B	512	0	8500	IZMIRAN	Counts/hour(scaled)
APATIT	64	0	8000	IZMIRAN	Counts/hour(scaled)
ATHENS	100	0	2000	Athens Uni	Counts/sec*3600/SF
BAKSAN	100	0	7500	IZMIRAN	Counts/hour(scaled)
BARENTS	60	0	10400	IZMIRAN	Counts/hour(scaled)
DOMB	60	0	340	Oulu Univ	Counts/min
DOMC	60	0	1240	Oulu Univ	Counts/min
EREVAN	100	0	17300	IZMIRAN	Counts/hour(scaled)
ESOISR	10	0	61000	IZMIRAN	lpm*60/SF
FORT S	100	0	8000	NMDB	Counts/sec*3600/SF
HERMAN	100	0	4500	NMDB	Counts/sec*3600/SF
INTHAN	100	0	22000	NMDB	lpm*60/SF
INUVIC	100	0	7300	NMDB	Counts/sec*3600/SF
IRKUT2	256	0	5900	IZMIRAN	lpm*60/SF or NMDB (cps*3600/SF)
IRKUT3	512	0	3200	IZMIRAN	lpm*60/SF or NMDB (cps*3600/SF)
IRKUTS	100	0	7900	IZMIRAN	lpm*60/SF or NMDB (cps*3600/SF)
JUNG64	200	0	6900	Bern Univ	Counts/hour(scaled)
JUNGFUR	100	0	5900	Bern Univ	Counts/hour(scaled)
KERGUE	400	0	2100	NMDB	Counts/sec*3600/SF
KIEL	100	0	6300	NMDB	Counts/sec*3600/SF
KIEL2	100	0	6800	NMDB	Counts/sec*3600/SF
LOMNIC	1000	0	17000	NMDB	Counts/sec*3600/SF
MAGADA	64	0	11100	IZMIRAN	Counts/hour(scaled)
MAWSON	60	0	15500	IZMIRAN	Counts/hour(scaled)
MCMURD	100	0	10030	IZMIRAN	lpm*60/SF
MEXICO	10	0	82500	Mexico Univ	Counts/hour(scaled)
MIRNY	60	0	7600	IZMIRAN	lpm*60/SF
MOSCOW	64	0	9800	IZMIRAN	Counts/hour(scaled)
NAIN	100	0	8100	NMDB	Counts/sec*3600/SF
NEWARK	100	0	3600	NMDB	Counts/sec*3600/SF
NORILS	64	0	7400	IZMIRAN	Counts/hour(scaled)
NOVOCI	128	0	5500	IZMIRAN	lpm*60/SF
OULU	60	0	6800	Oulu Univ	Counts/min
PEAWAN	100	0	8100	NMDB	Counts/sec*3600/SF
POTCHE	100	0	2150	NMDB	Counts/sec*3600/SF
ROME	100	0	4600	NMDB	Counts/sec*3600/SF
SANAE6	100	0	6200	IZMIRAN	Counts/hour(scaled)
SOUTH	100	0	11700	NMDB	Counts/sec*3600/SF
TBILIS	64	0	9800	IZMIRAN	Counts/hour(scaled)
TERRE	200	0	2200	NMDB	Counts/sec*3600/SF
TIXIE	100	0	6400	IZMIRAN	Counts/hour(scaled)
TSUMEB	100	0	20020	NMDB	Counts/sec*3600/SF
YAKUTS	128	0	6500	IZMIRAN	Counts/hour(scaled)

5. Cocluding Remarks

Although current NM databases tend to be shifted to manage high time-resolution data (counts/sec or counts/min), preservation of long-term one-hour data in a unified formats will be useful to study phenomena with the time scale of longer than several hours, like Forbush Decreases and solar-cycle variations of cosmic-ray neutron flux. Preservation of NM data of closed stations will be important also to follow the global changes of cosmic-ray environment and to keep evidences in the history of international NM network. In this stage, conversion procedures to adjust time resolutions for many stations have been established but further works are needed to include more stations. In some cases, inconsistencies were found between nominal units and actually opened count numbers. Details of the conversion procedures of the conversion procedure will be needed to follow further revisions of data.

Acknowledgement

We would express our thank to former stuff of RIKEN for their dedicated works to establish the fundermental base of WDCCR during the initial half interval of its 75-year history. It should be acknowledged that the activity of WDCCR fully depends on collaborations with NM stations in various countries in the world and two conprehensive NM data repositories: NMDB, founded under the European Union's FP7 programme, and IZMIRAN of Russian Academy of Sciences. We would thank Drs. C. Steigies of Univeristyof Keil and I. Usoskin of Oulu University for their valuable advices on management of NM data.

References

[1] T. Watanabe, *Data Science Journal,* **8**, S102-S107, 2009.

[2] P. Väisänen, I. Usoskin, and K. Mursul, *Journal of Geophysical Research: Space Physics*, 126(5), 2021