NMDB@Athens

Hybrid symposium on cosmic ray studies with neutron detectors

Rolf Bütikofer [1], Agnieszka Gil-Świderska [2], Karl-Ludwig Klein [3], Olga Kryakunova [4], Monica Laurenza [5], Helen Mavromichalaki [6], David Ruffolo [7], Danislav Sapundjiev [8], Christian T. Steigies [9], Du Toit Strauss [10]

Correspondence

1　International Foundation ›High Altitude Research Stations Jungfraujoch and Gornergrat‹ and Physics Institute, University of Bern, Switzerland, rolf.buetikofer@unibe.ch

2　Institute of Mathematics, Siedlce University, Poland, agil@cbk.waw.pl

3　Observatoire de Paris, LESIA, Université PSL, CNRS, Sorbonne Université, Université Paris Cité, France, ludwig.klein@obspm.fr

4　Institute of Ionosphere, Almaty, Kazakhstan, krolganik@yandex.kz

5　INAF - National Institute for Astrophysics, Rome, Italy, monica.laurenza@inaf.it

6　Athens Cosmic Ray Group, Faculty of Physics, National and Kapodistrian University of Athens, Greece, emavromi@phys.uoa.gr

7　Department of Physics, Faculty of Science, Mahidol University, Bangkok, Thailand, ruffolo.physics@gmail.com

8　Royal Meteorological Institute of Belgium, KMI-IRM, Brussels, Belgium, dasapund@meteo.be

9　Extraterrestrial Physics, Institute of Experimental and Applied Physics, Kiel University, Germany, steigies@physik.uni-kiel.de

10　Center for Space Research, North-West University, Potchefstroom, South Africa, dutoit.strauss@nwu.ac.za

Abstract

A brief overview is given regarding the presentations delivered at the NMDB@Athens meeting which was held, in a hybrid fashion, in September 2022. Participants joined both remotely but also physically at the National and Kapodistrian University of Athens, Greece. Unlike traditional cosmic ray meetings and conferences where the focus is mainly on the science related to neutron monitor measurements, the ›NMDB@Athens‹ meeting uniquely also addresses hardware issues related to these instruments and, importantly, also databases where different data products can be accessed by a growing and increasingly diverse user base. The present overview outlines and introduces the more detailed articles contained in the proceedings.

1. Introduction

Neutron monitors (NMs) have been used for more than 70 years to monitor the flux of cosmic rays (CRs) in the near-Earth environment. In addition to the continuously present galactic cosmic ray (GCR) flux, occasionally solar energetic particle events with sufficient energy can trigger a so-called ground level enhancement (GLE) event. The unique long-term and highly accurate NM data record spans seven solar cycles and includes 73 GLEs until 2022. This data record is invaluable to CR and heliospheric research, but is increasingly also used in various new research areas, including Space Weather, hydrology research and many more. A major aim of the Neutron Monitor Database (NMDB) is to provide a central repository of corrected data to make NM data accessible to a wider scientific community.

Following the very successful NMDB@Home2020 virtual meeting in 2020, it was decided to continue with this meeting series, but to move to a hybrid setting, given the lingering COVID-19 uncertainties. The present paper intends to give an overview regarding the presentations and discussions during the meeting and to set the stage for the authors' contributions that follow.

2. Cosmic rays in the heliosphere: spatial and time variability

The session started with a tutorial by M. Laurenza on CRs in the heliosphere. V. Yanke presented a paper on the residual modulation of GCRs in the heliosphere. P.Yu. Gololobov studied the CR angular distribution dynamics during the Forbush decrease in November 2021. E. Ntina analysed magnetospheric effects on CRs during the magnetic storm of March 2015. Further presentations were given by K. Munakata on the bi-directional anisotropy of CR intensities, by K. Poopakun on the solar magnetic polarity effect on NM count rates, by P. Väisänen on revised NM scaling factors, by P. Muangha on CR intensity and spectral changes, and, lastly, by S. Belov on real-time monitoring the angular distribution of CRs with the Ring of Stations method.

3. Ground level enhancement analysis and space weather research and services

Space weather is a branch of space physics and heliophysics, concerned with the time varying conditions within the Solar System. The global NM network has been used successfully for space weather tasks, specifically for investigation of GLEs, as one of the most dangerous space weather phenomena. The introductory lecture (tutorial) was presented by A. Papaioannou. It was devoted to GLE events that are critical for the establishment of Space Weather services and the determination of their corresponding radiation risk. The presentation included a hands-on tutorial that demonstrated how the NMDB can be utilised for GLE analysis.

A. Papaioannou and co-workers presented an overview of the first GLE event of solar cycle 25, recorded on 28 October 2021 (GLE73). A. Mishev and co-workers also reported on GLE73. This event was detected on 28 October 2021 by several NMs, specifically those in the polar region as well as by space-borne instruments. The strongest signal at the ground was registered by the DOMC/DOMB NMs located at

the Antarctic plateau at the Concordia French-Italian research station. R. Bütikofer and Ch. Steigies also discussed the GLE event on 28 October 2021 as observed by the NM network. H. Mavromichalaki and co-workers presented the updated GLE Alert++ System of the Athens Neutron Monitor Station (A.Ne.Mo.S.). An accurate alert was issued successfully by the ESA R-ESC federated product GLE Alert Plus, as well as by the updated GLE Alert++ System. It should be emphasised that the GLE Alert++ signal was issued 45 minutes earlier than the one issued by the GOES satellites. J. Rodriguez and B. Kress presented the results of GOES observations of solar protons during GLEs. The connection between CRs and space weather was also discussed during M. Abunina's tutorial lecture.

A. Sáiz and co-workers reported about modelling the time profiles of solar energetic particle observations, while J.J. Blanco and co-authors also reported on solar activity as observed by NMs. The Oulu group (S. Koldobskiy et al.) conducted a new reconstruction of solar energetic particle fluence for GLE events. K.-L. Klein reported about the relationship between rise times and decay times of relativistic solar particle events observed by NMs. N. Shlyk and co-workers reported about solar energetic particle events and Forbush decreases driven by the same solar sources.

A new approach to study high-energy magnetospheric electron enhancements in geostationary orbit was proposed by O. Kryakunova and co-workers. Measurements of galactic CRs on the Earth's surface by the worldwide network of NMs are accurate and allow one to calculate the behaviour of their density and anisotropy beyond the magnetosphere boundary using the Global Survey Method. CRs carry important information about the state of the interplanetary medium and the near-Earth space. The behaviour of the density and anisotropy of galactic CRs before and during electron flux enhancements in events connected with the arrival at Earth of high-speed streams from coronal holes, coronal mass ejections associated with solar flares or disappearing solar filaments is revealed.

Using NMDB data, P. Gololobov and co-workers presented results from a new method for short-term forecasting of intense geomagnetic storms with an advance of 1-2 days. The success rate of this forecasting is about 80%. It is important that only with the creation of NMDB it became possible to implement it in real time mode.

E.O. Flückiger and R. Bütikofer reported on the results of solar neutron observations from ground-based detectors. The report gave a historical overview of the 3 June 1982 event and summarises its main scientific impact over the last 40 years.

4. Cosmic rays in the atmosphere

The session started with a tutorial, presented by S. Poluianov, regarding the formation of secondary particle cascades in the atmosphere. It was followed by a presentation by A. Chilingarian and co-workers regarding the observations of extensive air showers by the Aragats NM. The same group, presented by H. Martoyan and co-workers, discussed results of the SEVAN East-European particle detector network regarding the November 2021 Forbush decrease. In other talks, R. Kataoka and co-workers presented results of a machine learning method to account for local environmental effects in the NM count rate as measured at the Syowa Station in Antarctica. Lastly, P. Makrantoni and co-workers, discussed the levels of CR induced radiation at aviation altitudes.

5. Neutron detectors: instrumentation, stability, and response functions

Major renovations have been performed at the Calgary NM from 2009 until 2017. C. Bland and A. Kouznetsov presented a multiple regression method to estimate the efficiency factor which is used to scale the data to provide a continuous time series with the previous instrument, which has been in operation since the 1960s. The method takes solar modulation as well as changes in NM sensitivity into account.

J. Ryan and co-workers reported on the status of US-based NMs and the NSF funded Simpson NM network. This network will secure the operation, repair, and upgrades of the existing US stations and even plans to (again) set-up a station on the summit of Haleakala on Maui to take the network to a new operational and scientific level.

The detailed plan for the "Haleakala Neutron Monitor Redeployment and Calibration with AMS data" is given in the paper by C. Consolandi and co-workers. Not only will the Haleakala NM be redeployed near the initial station, but it will also be calibrated with AMS data and modelled by simulating the detector response. Thereby the station will be well suited to fill the large gap in the NM network in the Pacific Ocean, but also will be able to measure solar neutrons due to its high altitude and low latitude location.

A redesigned mini-NM has been installed on a South African Research vessel and performed several latitude scans from South Africa to Antarctica. R.D. Strauss and co-workers analysed effects of temperature variation and high-frequency interference on the measurements. To avoid the negative impact of these effects, the instrument will be moved to a more suitable location on the vessel where it can be operated continuously for several years.

Further presentations were given by A. Lukovnikova about new registration systems, by D. Ruffolo on electronics for deriving spectral information from a single NM, by D. Sapundjiev about neural networks to identify faulty tubes, by P. Väisänen on correcting snow effects, and by V. Yakum on latitude surveys with a "semi-leaded" NM.

6. Neutron detector response functions

A. Mishev presented different methods of determining NM response functions in a tutorial. M. Livada and co-workers calculated the GCR spectral index of the Forbush decrease in June 2015.

7. Databases and catalogues

C. Steigies gave a report on the status of NMDB and an interactive tutorial on accessing real-time data from NMDB using the programming language Python. With the scripts provided, everybody can quickly read data from the NMDB real-time file and make data analysis or generate plots. In a further presentation a small Python library was presented that allows retrieving data that is made available via NEST into Python and generates a pandas data frame. A final contribution by D. Aslanyan presented the catalogue of thunderstorm ground enhancement events registered on Mt. Aragats.

8. Conclusion

The NMDB@Athens meeting, building on the success of the NMDB@Home2020 virtual meeting, brought together NM scientists from around the world; participants attended from Africa, the Americas, Asia, Australia, and Europe, representing almost all time zones. A variety of topics were discussed, ranging from instrumental topics to space weather applications using NM measurements. Especially encouraging were discussions surrounding the opening of new stations and the refurbishing of older stations. This, along with other recent advances, will allow the NMDB to provide historical and real-time data to an ever growing and more diverse community of users.

Acknowledgements

In Memoriam

The participants of the symposium took note of the recent passing away of eminent members of the community, including Dr. Evgenia Alexandrovna Eroshenko (1940–2021), Dr. Lev Isaacovich Dorman (1929–2022), and Prof. Pieter Stoker (1927–2022). We are privileged to have known these colleagues who pioneered the field of cosmic ray research.

Peer-review statement

Each full-length conference proceeding included in this volume has been peer-reviewed by two independent reviewers.