WWW.NMDB.EU: The real-time Neutron Monitor database

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***Abstract*. The** *Real time database for high-resolution neutron monitor measurements* **(NMDB) project, supported by the European Commission, is underway to set up a database for European and some non-European neutron monitors. The objective is to ensure an easy use of the data by astrophysicists and a wide user community interested by space-weather applications. The contribution presents the status and future developments of the project, and illustrates some applications.**

***Keywords*: neutron monitor, database, space weather**

I. Introduction

The worldwide network of standardised neutron monitors is, after 50 years, still the state-of-the-art instrumentation to measure primary cosmic rays in the (0.5-20) GeV energy range. These measurements are a uniquely sensitive tool in their energy range, and a necessary complement to space based cosmic ray measurements at lower energies. While hourly data become available after some time in a standard format through the World Data Centers, no unique database existed so far for high-resolution measurements, which are provided by the individual stations, in non-standardised formats, and with varying delays.

The integrated use of data from solar and heliospheric physics, which has become standard in recent years, and the usefulness of neutron monitor measurements for real time applications require a user-friendly access to real-time and historical data and to data products for the non-expert. To this end European and some non-European institutions founded the *Real-time database for high-resolution neutron monitor measurements* (NMDB) project. Its construction is funded for a two-years term (2008-09) by the European Commission as an *e-Infrastructures* project in the *Capacities* section of the *Seventh Framework Programme*. At the end of this period the database will hold real time and historical data from the affiliated neutron monitor stations in a standard format that will be - and is already in part - accessible to outside users. The further operation of the database is to be ensured by the individual national funding agencies.

II. The NMDB project: Consortium, Objectives, and Present Status

The NMDB consortium comprises European public research institutions that operate neutron monitors for astrophysical or space weather applications or plan to do so

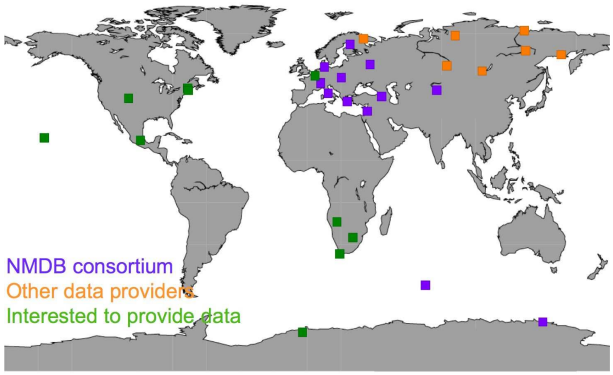

Fig. 1: Neutron monitor stations of or related to the NMDB project.

(Universities of Alcalá, Athens, Bern, Kiel, Oulu, Rome 3, Slovak Academy of Science, IZMIRAN Moscow, Paris Observatory) and some non-European partners (Yerevan Physics Institute, Institute of Ionosphere Almaty, University of Tel Aviv). Figure 1 shows their neutron monitor stations by dark (magenta) squares. Several other Russian stations already provide data (light squares, orange). The present consortium operates 23 neutron monitors. Institutions in Mexico, South-Africa and the United States (green squares) declared their interest to provide data. NMDB attempts to achieve several objectives:

- to upgrade stations and connections to make high-resolution data available in real-time;
- to build a state-of-the-art, centralised database with distributed mirrors;
- to collect high-resolution neutron monitor data in real-time, and make them publicly available in a common format;
- to develop application tools using neutron monitor data, such as solar energetic particle event alert, dosimetry calculations, cosmic ray characteristics outside the geomagnetosphere, at the top and inside the Earth's atmosphere;
- to create a public outreach website about cosmic rays and possible effects on humans, technological systems, and the environment.

By mid-May 2009, about 14 neutron monitor stations already provide data in real time. The web site at http://www.nmdb.eu hosts information on the project and gives access to some data.

A. NMDB setup

NMDB consists of several database servers. Two are set up in Kiel in a master-master configuration. Two more are operated in Kiel as read-only slaves. Data can be written to either master, but need not be written to both, since the data are replicated between them. One of the slaves is used for backup purposes. The other is used as fan out mirror, i.e. it serves as replication master for all other mirrors. Both slaves, as well as all other mirrors outside Kiel, are read-only mirrors. Further read-only mirrors are set up in Athens, Moscow, and Oulu.

The database will hold the original measurements and possibly successive corrected versions, as they will be provided by the stations. Every station prepares its original and revised data sets, for example as comma-separated values. Then automated procedures (real-time for most of them) send the data to a master MySQL server. Since many stations have developed their own scripts, the NMDB consortium offers solutions in several programming languages to new data providers.

B. Real-time applications of NMDB data

NMDB responds to two types of needs: those of researchers in astrophysics of high-energy particles, and those of a wide community interested in space weather applications. The former aspect is illustrated by Kudela et al.'s contribution to this conference on cosmic ray fluctuations. The real-time aspect of NMDB addresses a community whose needs cannot be satisfied by neutron monitor count rates, but require more evolved data products. One is the near- real time determination of ionisation and radiation dose rates induced by cosmic rays in the Earth's atmosphere. The results are fundamental for monitoring aircrew and address a possible connection of space weather with terrestrial climate (R. Bütikofer et al., this conference). Another application is a solar energetic particle (SEP) alert, based on early warning from neutron monitors, which, since they observe the fastest solar nucleons, can give an early warning of the imminence of a large SEP event (E. Mavromichalaki et al.).

C. Data visualisation tools in NMDB

The NMDB Front End (NMDBFE) will be the entry point for data visualisation. It is being developed to give rapid access to queries for long time ranges, and will be useful to study long-term trends in cosmic ray modulation.

The *NMDB EVENT SEARCH TOOL* (NEST) is developed for event-based queries. The user either chooses a time interval or an event. The event list gives access to GLEs or Forbush decreases (Fig. 2). This tool presently allows one to visualise corrected and uncorreceted data and atmospheric pressure. It is planned to also display other environmental parameters including wind speed, humidity, and temperature, providing extensive possibilities to evaluate the data quality.

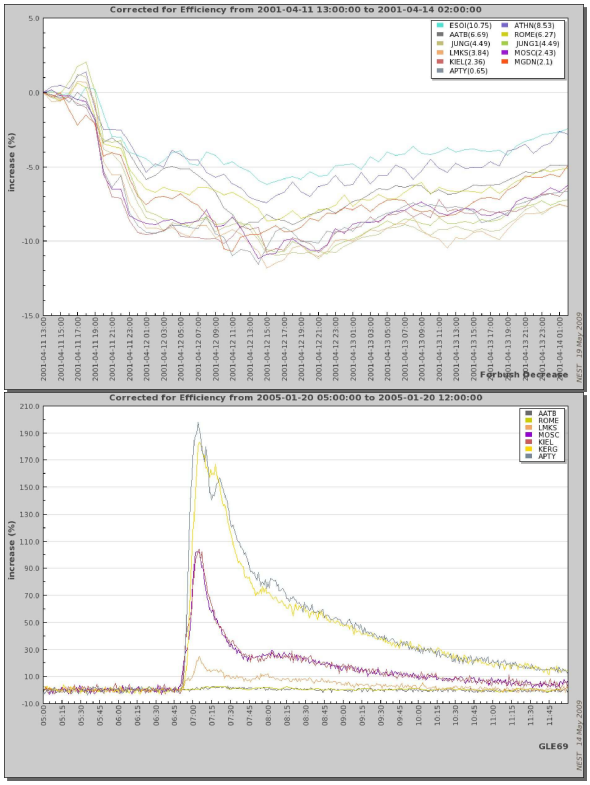

Fig. 2: Time profiles of individual events from NEST. *Top*: Forbush decrease 2001 April 11 (1 hr integration). *Bottom*: GLE 2005 January 20 (1 min integration).

D. Training and public outreach activities

A series of four brochures for the general public will be published. Two are presently available, describing (1) elements of cosmic ray physics and applications, (2) the NMDB work programme. PDF files can be downloaded from www.nmdb.eu.

A public outreach web site on cosmic rays, their origin, measurement, and impact on the Earth is under construction. Training material for students (University level), engineers and researchers who want to become familiar with the field will also be provided on line.

A training course at the University of Athens (2009 September 14–19) will address students, post docs, researchers and engineers interested by a broad range of applications of cosmic rays, from astrophysics of energetic particles to their impact on the Earth.

III. Conclusion and Perspectives

NMDB has started to host data, real-time and historical, from European and some non-European neutron monitors. It is a step towards an easier use of a unique multi-instrument facility for cosmic ray physics and space weather applications. A logical next step will be to open the database to other non-European stations.

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