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Establishing and Using the real-time Neutron Monitor Database (NMDB)

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Abstract. The European Commission is supporting the Neutron Monitor database as an e-Infrastructures project in the Seventh Framework Programme in the Capacities section. The prospective goal of the network is to make the receiving of all data (either with 1 min resolution or with 1 hour resolution) in real time from all servers around Europe possible. This system has been designed with the capability to support a large number of stations and therefore the upgrade of the system is rather flexible. It is important to outline that the designed collection system has the ability to provide reliable data, based on the issue that all participating stations have been standardized at a common recording format. At this point, the database has been fulfilled together with user tools and applications. The most important application was the establishment of an Alert signal when dangerous solar particle events are heading to the Earth, resulting into a Ground Level Enhancement (GLE) registered by neutron monitors. As a sequence, the mapping of all GLE features in near real-time mode which provides an over all picture of this phenomenon and is being used as an input for the calculation of the ionization of the atmosphere, was made possible. The latter calculations are useful for radiation dose calculations within the atmosphere at several altitudes and will reveal the absorbed doses during flights. Athens Cosmic Ray Group was responsible for the upgrade and standardization of all participating stations as well as, for the design and implementation of a novel affordable registration system. Moreover, the software of GLE Alert and the Neutron Monitor Basic Anisotropic Ground Level Enhancement (NM-BANGLE) one, originating from the Athens Group, was customized into NMDB necessities. In this work, a description of the project, its goals and achievements together with its usefulness for potential users, studying the Sun and Interplanetary Medium is presented.

1. Introduction

The worldwide network of standardized neutron monitors is, after 50 years, still the state-of-the-art instrumentation to measure variations of the primary cosmic rays. These measurements are an ideal complement to space based cosmic ray measurements. Unlike data from satellite experiments neutron monitor data has never been available in high resolution from many stations in real-time. The data is often only available from the individual stations website, in varying formats, and not in real-time. The Neutron Monitor Database (NMDB) project involves twelve different countries which cooperate within the Seventh

Framework Programme of the European Commission, aiming at the creation of a real-time database with high resolution cosmic ray data (Steigies et al., 2008a,b). A European digital repository for cosmic ray data has been set up, with the central database containing all neutron monitor data acquired in the last 50 years together with new continuously updated observations from 17 NMs with 1-min and 1-hour resolution, operated by the institutes that constitute the NMDB consortium. Within this project a number of real-time applications have also been developed.

1.1. Aims and Scopes of NMDB

The key point of the project was to develop a flexible database with important easy to use applications. NMDB had to overcome four significant challenges:

(a) To design a database capable of hosting data of 1-min and 1-hour resolution, in real-time, together with historical ones and meta-data, making it a very useful tool characterized by completeness.

(b) To provide fine tuning among all data providers, as most NMs were not synchronized, in the sense that not all had the same resolution or a common time stamp, through the definition of a common format for all neutron monitors.

(c) To develop user tools with which neutron monitor data will be uploaded to the database and by which users will get access to NMDB for downloading data.

(d) To compute comprehensive parameters from the neutron monitor data in near real-time (cosmic ray characteristics in near-Earth space, ionization rate of the atmosphere, radioactive dose rates) for a broad field of applications.

Nevertheless, NMDB also aimed at communicating the work done with everyone interested. Therefore, a web-based system of training courses for students at University level, researchers and engineers from outside CR community, together with public outreach activities have been developed.

2. Using NMDB

While facing the aforementioned challenges and keeping the usable part of the project in mind, an easy-to-use direct access tool for NMDB has been created by the Observatory of Paris group, named: Neutron Monitor Data Base Event Search Tool (NEST). Through NEST it is possible to perform a variety of data retrieving and checking. In specific, one can take quick plots of particular events (GLEs, FDs) or even check the latest data that were submitted to the database and thus see if everything is operating smoothly. On top of which, it is envisaged that a user can choose as many NM stations as preferable to his/her work, for any time scale (hours, days, months, years) and either take data in a simple ASCII file or actually plot the results. Furthermore, one can choose several data types as: corrected with pressure, corrected with efficiency, uncorrected and single pressure data (Fig. 1). Moreover, other user tools as: CR fluctuations, which refer to the analysis of CR diurnal variation - a rather stable and dominant part of the power spectra constructed by long term series, a Checker tool for the NMDB tables (both made available by the Kosice group) and a meta data table editor (a joined effort of the Oulu and Kosice groups) have been created and set in operation via the website: www.nmdb.eu.

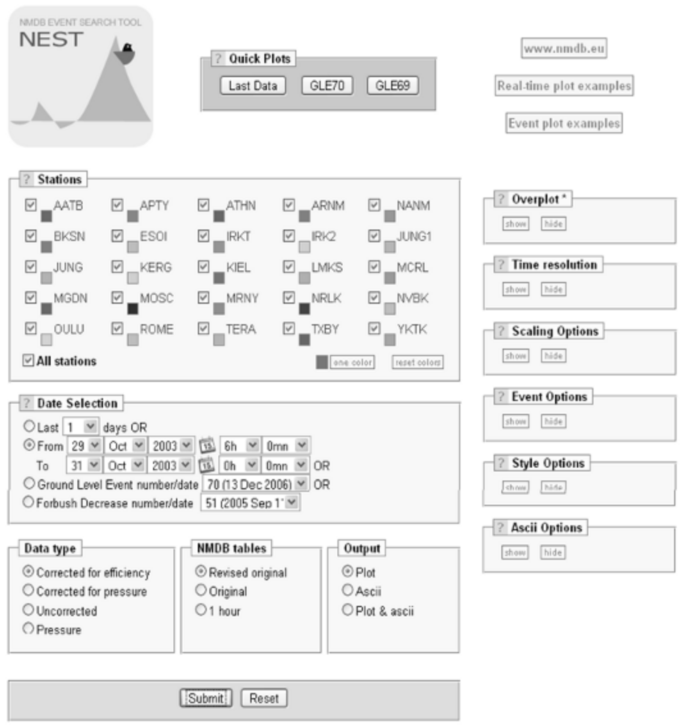

Figure 1. Interface of the NEST Tool

3. Applications with 1-min NM data

Minutely data are being used for the determination of ground level enhancements (GLEs) characteristics and their impact within the atmosphere. The sequence of applications provide a warning signal (Alert), mapping of the events with reliable output on spectrum derivation, anisotropy and particle's arrival directions and calculation of effective radiation dose for several atmospheric depths.

3.1. GLE Alert system

One of the most important goals of the NMDB project was the creation of a system for high-resolution registration and evaluation of this type of event in real time. Several groups (Athens group, IZMIRAN group, Aragats group, Tel-Aviv group) participating in the NMDB project run various GLE Alert functions - some of which are of use for real-time applications. The physical concept of the Alert software is based on the idea that the early detection of an Earth-directed cosmic ray event by NMs gives a good chance of preventive monitoring SEP-flux rise, providing an alert with a very low probability of false alarm (Souvatzoglou et al., 2009; Dorman, 2004). The cosmic ray-flux in the energy range above 500 MeV/nucleon cannot be recorded by satellites with enough accuracy because of their small detecting area. However, it can be measured by ground-based NMs with high statistical accuracy (on average, 0.5% for 5 min). The proposed GLE Alert approach, adapted by NMDB has been validated by a statistical analysis of the last ten successfully recorded GLEs by NMs, from 2001 until 2006 using 1-minute data, which was performed by the Athens NM group (Souvatzoglou et al., 2009). Through this analysis, GLE alarms were produced automatically in the Athens Neutron Monitor Data Processing (ANMODAP) (Mavromichalaki et al., 2009) system for nine out of ten events, while the remaining one was characterised as a non-GLE one. The alarm times compared to satellite data can distinguish them into GLEs or magnetospheric events. The GLE alert from the Athens system precedes the GOES alert (>100 MeV or >10 MeV protons) by 4 to 33 min. More detailed information can be found in Mavromichalaki et al. (2007). At this point it is worth noting that from mid 2006 the GLE Alert system operates in real-time at the Athens NM station, using as input data from the ANMODAP Center. As a result the solar cosmic ray event on December 13, 2006 (GLE70) was the first GLE that was successfully detected in real-time by the Alert system of ANMODAP Center. The actual online display of the GLE70 Alert at the Athens NM webpage can be seen at the right panel of Fig. 2. It is noticable that three stations, such as Fort Smith, Moscow and Norilsk, provided the General Alert stage.

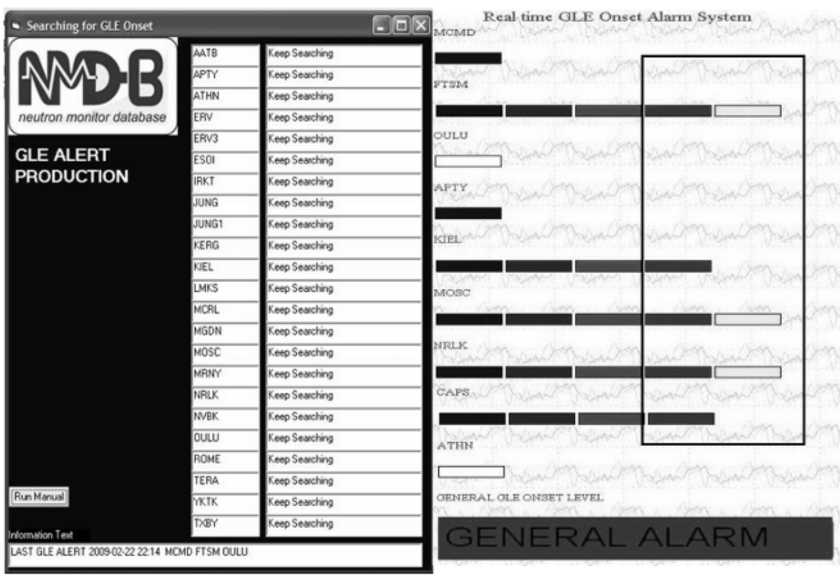

Figure 2. GLE Alert executable (left panel) and the Online Alert display (right panel), the black line at the right panel indicates the establishment of the GLE Alert

3.2. Ground Level Enhancement modeling

In order to understand the physics of the processes that take place under extreme solar conditions such as those producing relativistic solar cosmic rays (GLEs), accurate and reliable models should be used. The NM-BANGLE model calculates the evolution of several GLE parameters such as the solar cosmic ray spectrum derivation and anisotropy, revealing crucial information on the energetic particle propagation and distribution in the region at the top of the Earth's atmosphere, including the arrival direction of solar cosmic rays with respect to Earth's magnetic field. The total output of the NM-BANGLE model is a multi-dimensional GLE picture consisting of the following outputs: a) spectral index of the solar CR rigidity spectrum, assumed to be a power-law in its current version, b) position of the CR anisotropy direction (latitude and longitude), c) a parameter characterizing the form of the anisotropic CR flux and d) the amplitude of the solar cosmic ray intensity (Plainaki et al., 2007).

3.3. CR particle trajectories

Transportation through geomagnetosphere CR trajectories through geomagnetosphere have been calculated with the Geant4 software MAGNETOCOSMICS (http://cosray.unibe.ch/ laurent/magnetocosmics/) which has been developed by the University of Bern (Desorgher 2004).

Transportation through Earth's atmosphere The interactions of the GCR and the SCR with the Earth's atmosphere have been calculated by using yield functions that were computed with the Geant4 PLANETOCOSMICS (Desorgher 2005) code.

Computation of the effective radiation dose rate The effective dose rates caused by CRs are calculated for selected atmospheric depths at the specified grid points from the secondary particle flux in the atmosphere by using the flux to dose conversion factors based on FLUKA calculations by Pelliccioni (2000). More details on the computations regarding the ionization within the atmosphere can be found at Buetikofer et al. (2009). Contour plots of computed effective dose rates at several atmospheric depths have been produced (Fig. 3).

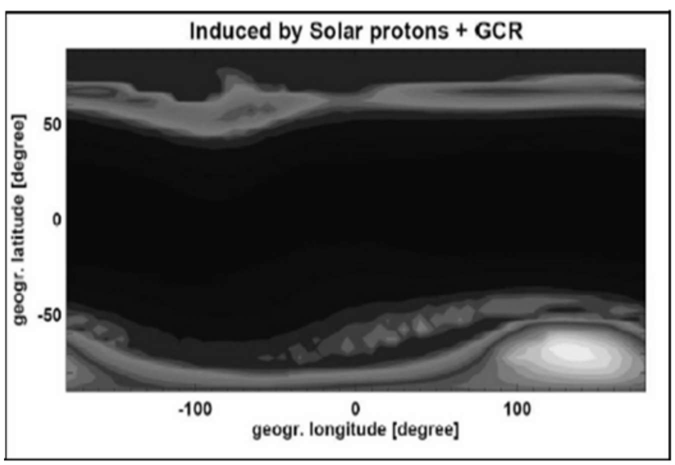

Figure 3. Contour plot of the effective dose for the case of GLE69

All of the forth mentioned steps (3.1. 3.2 & 3.3) have been interconnected and implemented in real or quasi real time mode resulting into a solid structured application which triggers all calculations with the initiation of the GLE Alert.

4. Conclusions

Today the impact of space science on every day life is well perceivable. Communication, space satellites, air travels at high altitudes, power supply factories and many other daily activities depend on space conditions. This is a major motivation for NMDB: combine current knowledge and sufficiently explore space environment. Neutron monitors are the only registration equipments that detect every significant event and can not be scrambled, in any case. NMDB's prime aim was the construction of one easy to use database. In order to do so, all neutron monitors that took part in this effort were updated with the technological advantages of nowadays. Furthermore, from the scientific viewpoint, NMDB is the connector of many stand alone applications that several participating groups owned but never before had used as one. Thus NMDB is a newly constracted asset for the future studies of the Sun, Interplanetary Medium and Sun-Earth connection, resulting into an operative space weather tool.

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