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Real-Time Cosmic Ray Distributed (RECORD) database: A status report

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In this paper we report on more than a year of operation of the Real-Time Cosmic Ray Distributed (RECORD) database. This collaborative international program was first announced at the 28th ICRC in 2003. Since that time, the database was launched and tested for more than a year. At present, the RECORD database contains 1-min data of cosmic ray intensity collected at five stations Lomnicky Štit, Moscow, Oulu, Tixie Bay and Yakutsk. Within the framework of the database, three data servers are arranged, in Moscow, Oulu and Yakutsk, which are continuously replicated. The attendant software allows user to retrieve and analyze data from any server using high-level programming languages. The database also allows an effective tool for inter-calibration of different instruments. Possibilities of the RECORD database for the use in space weather diagnostics and forecast are illustrated on an example of the event in January 2005.

1. Introduction

There are many similar ground-based cosmic ray stations (called neutron monitors, NMs) around the Globe. Using simultaneous data from several stations is equivalent to a unique multidirectional cosmic ray detector. Generally, this can be performed via a standard ftp-based world data center (e.g., WDC-C2 in Japan). However, data in such centers are updated once a year allow only for a retrospective study. On the other hand, modern technological developments allow for real time use of data from remote sources. In order to combine these two approaches, a launch of the first real time cosmic ray database under the acronym RECORD was recently announced [1], which provides standardized cosmic ray data from several NMs in real time. Here we present the status report of the RECORD database and discuss new opportunities of space weather forecast made possible due to this database.

2. RECORD database

The Real-Time Cosmic Ray Distributed (RECORD) database, which is the unique distributed cosmic ray database operating in real time, was announced in 2003 by an international consortium (Finland, Russia and Slovakia). The aim of the project was to develop a modern tool for a combined real-time analysis of data from different far spaced NMs. Since the first launch of a pilot database in 2003, it was tested during about 2 years. At present the RECORD database contains 1-min, 5-min and 1-hour data of cosmic ray intensities from five NMs: Lomnicky Štit, Moscow, Oulu, Tixie Bay and Yakutsk. More European stations are to join the consortium. RECORD database runs on the PostgreSQL server on three Linux boxes located in Moscow (central server), Yakutsk and Oulu. Each server manages the original data set (cosmic ray intensities and atmospheric pressure) of the corresponding home station(s) updated in real-time. This original dataset is continuously repli-

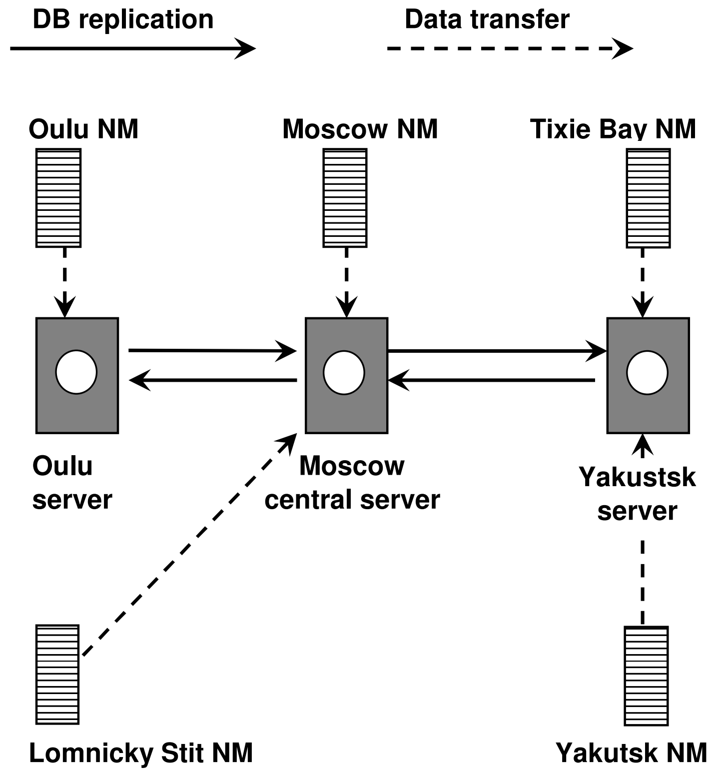

Figure 1. Schematic representation of data transfer (dashed arrows) and database replication (solid arrows) between the cosmic ray stations within the RECORD database.

cated first to the central server (IZMIRAN, Moscow) and then, from this central server, to other foreign servers. The replication is performed automatically in real-time, thus all three databases keep identical real-time data allowing potential user to use either of them. In a case of one servers failure, data are automatically available from the others (see Figure 1). An interactive web- interface allows browsing and downloading of the data. The interface allows different time sampling of data, from 1 minute to 1 year. An access to data is available also from remote user programs written in programming languages like C, Fortran, Perl. A specially developed Fortran-77 library allows user to avoid explicit usage of SQL language when addressing the database directly from his program. The RECORD database can be accessed through either of three mirror servers, in Yakustsk (http://record.ysn.ru), Moscow (http://cosmos.izmiran.rssi.ru) and Oulu (http://cosmicrays.oulu.fi). A detailed description of the database and access methods is available at either of them. Such an approach to the data recording, archiving and access makes it possible, in addition to keeping a customary cosmic ray archive database (e.g., WDC-C2), to solve in real-time a number of applied problems, such as continuous inter-calibration of data obtained from different NMs and recognition of apparent errors, monitoring of the current cosmic radiation environment, and other problems related to space weather, as illustrated in the following Section.

3. Space weather applications

The possibility of using the RECORD database for space weather forecast is illustrated on an example of the strong space weather events in January 2005. We note that all processes of data access, computations of different parameters of the cosmic ray intensities as well as plotting and forecasting were done in real-time by means of a direct access to the RECORD database from external (user) program. Figure 2 shows an example of the real-time cosmic ray data analysis. Upper panel depicts the recorded cosmic ray (normalized) intensities from three NMs, Moscow, Oulu and Tixie Bay during the period of 15-24 January 2005. All the three stations were operating in the normal mode, no systematic trends or apparent errors are known for this period. During these days, two strong ($> 10\%$) Forbush decreases were observed on 17 and 21 January by all stations as well as a very strong ground level enhancement (GLE No. 68) whose amplitude exceeded 100% (strongest for the last decades). Lower panel of Figure 2 shows the results of short-term forecasting of large-scale disturbances on the basis of an analysis of the dynamical variations of cosmic ray fluctuation spectrum [2]. Power spectrum of cosmic ray fluctuations (quasi-stationary short-term variations with the period from minutes to several hours) is known to suffer substantial dynamical changes related to strong disturbances of the solar wind / interplanetary magnetic field. It is important that such changes become notable in cosmic ray fluctuations hours before the arrival of the disturbances to the Earth (due to their high velocity and sensitivity to interplanetary turbulence cosmic rays serve as a probe for approaching disturbances), and therefore an on-line analysis of the power spectrum of cosmic ray fluctuations provides a tool for short-term space weather forecasting. Here we present a qualitative index/predictor of space weather disturbances which is shown lower panel of Figure 2. Briefly, the index takes the value of 1 if there is a significant (systematically exceeding the 95% confidence level) signal in the given frequency range of the fluctuation spectrum, and 0 otherwise. If the predictor takes systematically the value of 1, a space weather event alarm is produced. This index/predictor, which is based on the amplitude dynamics of the fluctuation spectrum, is somewhat different from the index used by [3] which is based on the high frequency dynamics of the spectrum. One can see from Figure 2 that the alarm flag is raised nearly one day before the start of a Forbush decrease and hours before the GLE event, forecasting thus major space weather disturbances. The work on the space weather forecast is developed in Yakutsk since 1999 [3]. The use of data from far spaced NMs via the RECORD database allows improving the quality of forecasting reducing the false alarm probability.

4. Conclusions

Here we present the first real-time distributed database of cosmic ray intensities which combines the features of a customary searchable archive of past cosmic ray data and off-line analysis and of a dynamic on-line database with the real-time access to data from user client program. Currently the database, which is running on three mirror servers in Russia and Finland, contains data from five cosmic ray stations, Lomnicky Štit, Moscow, Oulu, Tixie Bay and Yakutsk. The RECORD provides a powerful tool for real-time space weather forecasts as illustrated on an example of events in January 2005.

5. Acknowledgements

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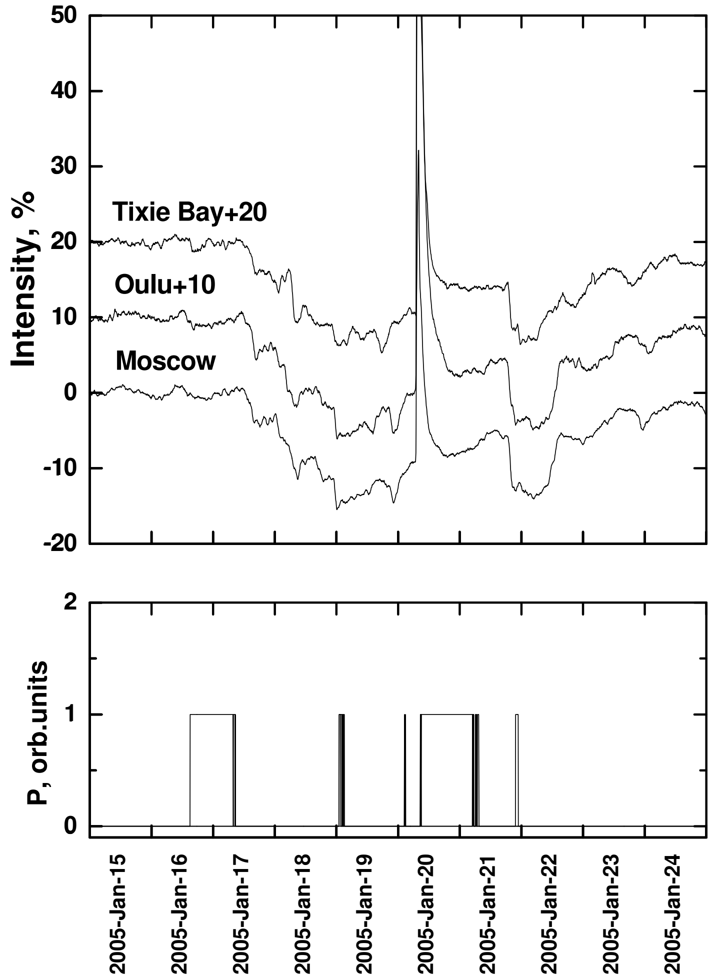

Figure 2. Example of the space weather forecasting for January 2005 events. Upper panel shows the normalized count rate of three NM (10% and 20% offset is added to Oulu and Tixie Bay data). Lower panel shows the space weather predictor index (see text).

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