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Real-time database for high resolution Neutron Monitor measurements

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Abstract: The Kiel Neutron Monitor has been measuring Cosmic Ray intensities for 50 years. Since an upgrade of the counting electronics in the mid 1990's in collaboration with the IZMIRAN group, measurements have been made available with one minute resolution. However, these measurements are available only up to one hour after the measurement. We have now set up a second registration system that is running in parallel to the existing registration system. The new system is registering count rates with 10 second resolution and sends the data to an SQL database immediately after the measurement, from where the measurements are made available via a webpage or by direct access to the database. The real-time availability of cosmic ray intensities significantly improves the capability to predict space weather events that effect humans and infrastructure in space and on ground.

Introduction

The worldwide network of standardized neutron monitors is, after 50 years, still the state-of-the-art instrumentation to measure spectral variations of the primary cosmic ray component in the energy range from 500 MeV to hundreds of GeV. These measurements are an ideal complement to space based cosmic ray measurements. Data from the approximately 50 IGY and NM64 neutron monitor stations is stored locally but also available through data collection sites like the World Data Center (WDC). The data from the WDC is in a standard format, but only hourly values are available. This makes this data suitable for studying long-term trends in cosmic rays. The investigation of short time cosmic ray intensity variations like solar energetic particle events, however, require much better time resolutions of at least 1-minute. Data with this time resolution is available at many stations, but there is no standard data format for this time resolution, and often the data is available only hours or days after the measurement or only on request. Since the analysis of solar cosmic ray events requires high time resolution data, the collection and formatting process for the scientist is very time consuming. The prediction of space weather events, where cosmic ray measurements can play a key role, requires the availability of high-resolution data in near real-time. Real-time data is currently available only from a few stations and only directly from those stations, but not from a central location. A group of European neutron monitor stations is cooperating with the Belgian Institute for Space Aeronomy to solve these problems. We are creating a database for high-resolution neutron monitor measurements to which neutron monitor stations can submit their data in real-time. With this, the data will be easily accessible through various database interfaces, and the reformatting tools for the various stations can be abandoned. Also, since the data is inserted into the database immediately after the measurement, data from all participating stations will be available worldwide through the servers at the European Space Weather Center and database mirrors at several locations.

Current status of the neutron monitor network

The approximately 50 neutron monitor stations that are currently operating are distributed worldwide (Fig. 1). This good global coverage allows to study the spectrum and the source position of solar energetic particle events, but it also provides a

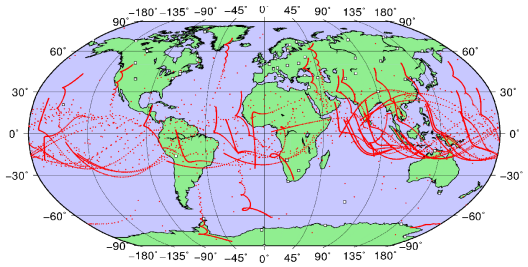

Figure 1: Worldmap indicating the location of the neutron monitor stations and their asymptotic directions.

24h coverage of coronal mass ejections approaching from the sun. To make use of this data for predictions, real-time access is needed. Only a handful of stations can provide that at the moment, and the data is only available from the website of the operator of the neutron monitor. The group at IZMIRAN is collecting all available data on one FTP server, but most data is available only hours or even days after the measurements, which is sufficient for long term storage, but makes the data unsuitable for prediction efforts. In addition, there are still many stations that provide data only with 5-minute resolution, for GLE predictions, however, at least a 1-minute resolution, preferably 10-sec is needed. Also, several stations are not well connected to the Internet, for example the French neutron monitors in the South Atlantic can send their data only once a day via satellite link. But also several high altitude stations are connected by satellite or telephone line, which makes the delivery of high-resolution data in real-time challenging.

The Kiel neutron monitor has been upgraded in the 1990's in collaboration with the IZMIRAN group. Since then measurements are available with one minute resolution and at the full hour the measurements are transfered to a webserver, from where the raw count-rates, as well as atmospheric pressure and pressure corrected count-rates are made available via the Internet.

Kiel Neutron Monitor

While the Kiel Neutron Monitor measures count-rates with 1 minute resolution, the current setup

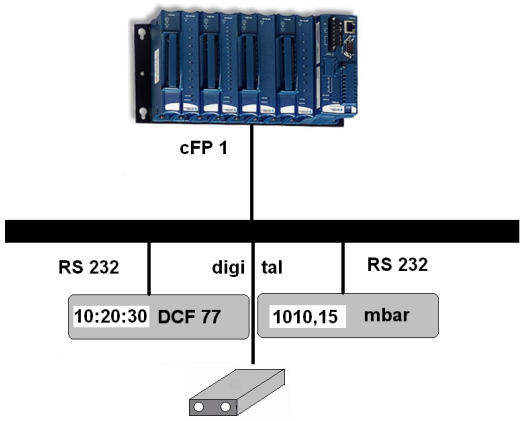

Figure 2: The new registration system of the Kiel Neutron Monitor.

lacks the ability to deliver this data in real-time. Thus a new registration system based on a compact FieldPoint (Fig. 2) programmed in real-time LabView has been set up. This new registration system is connected to a barometer with 0.01 mbar resolution, which is a 10-fold improvement in resolution over the current pressure measurement, and to a DCF77 radio clock, that improves the timing accuracy of the measurements to better than 1 ms. The FieldPoint records count-rates, atmospheric pressure and housekeeping values of the high voltage power supply and stores it with 1 minute resolution in the same format as the current BIN files, as well as in 10 second resolution, that makes use of the higher resolution of the pressure measurement, on flash media. The FieldPoint checks the data for consistency and performs the correction of the count-rates for atmospheric pressure. An Ethernet connection allows these measurements to be transferred up to several times per minute to a Linux server which then inserts the measurements into a local SQL database. This setup with the FieldPoint registering the counts of two counter tubes is in operation since February 2007 and the SQL database can be accessed via a webpage.

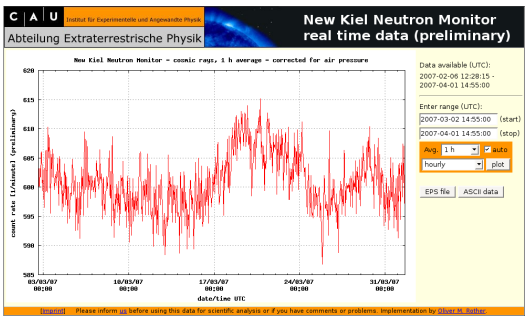

Figure 3: Webinterface to database of the new registration system of the Kiel Neutron Monitor.

Standardized registration system

While the ruggedized compact FieldPoint has been running stable for several months, we will develop a registration system using standard PC hardware that will be programmed with free and open source software. This affordable system will offer more flexibility in running a local database on the registration system and synchronizing the database with a central server. The standardized registration system can be deployed to those stations, that are not recording 1-minute data yet. This registration system will provide all data ready to be inserted into the centralized server of the real-time database at minimum cost for the stations.

Real-time database

To overcome the problems of different data formats and data availability, a centralized database will be set up at the European Space Weather Center. This database will store time and date of the measurements, the atmospheric pressure, corrected and uncorrected count-rates, as well as special remarks for the measurements, like snow covering the detector or high winds which influence the measurements of atmospheric pressure. The SQL database can be accessed via a webportal, where plots of cosmic ray data can be generated, just as many stations are providing already today. This webportal, however, will make data from all participating stations available, and it will include all data immediately after the measurement. The database will also be accessible from commonly used software packages like Octave, IDL, Excel, and others. Examples for various languages will be provided on the database server. This will eliminate the need for every scientist to write his own conversion tools for the individual stations, the dataformat is decided by the queries sent to the database, and the end user can start working with the data immediately. With the availability of this data in real-time space weather predictions using cosmic ray data become possible for the first time. The user can specify the timeframes for the data he is interested in and also request averaged data. Since the averaging is performed by the database and only the averaged data needs to be transfered to the user, the delivery of the data is much faster than with the current FTP based data collections. We are planning to run several mirrors that replicate the whole database in several countries, for example in Moscow and Athens, where prediction efforts are underway, so that frequent users of the data can have an even faster response time. But we are also interested in operating mirrors outside of Europe to speed up access for international users and to minimize the amount of data that needs to be transferred across continents.

Access to the real-time database

As a demonstration of the real-time database, the measurements of the new Kiel registration system are stored in an SQL database and are made available via a webpage (Fig. 3). The user can select to plot the timeframe of the data he is interested in, as well as several averaging periods. With the centralized database it will be possible to display and download data for all neutron monitor stations that submit their data to the database. Besides the access to the database from a webpage, which is performed by PHP scripts running on the webserver, it will be possible to access the database directly from languages like perl, python, octave, IDL but also from spreadsheet programs like Open-Office Calc and Excel. This allows the user to use the software of his choice for importing the data and solely concentrate on analyzing the data.

Conclusions

The real-time database is a much needed tool to enable easy access to 50 years of neutron monitor data. All data will be available in an easy-to-use fashion. By making current measurements also accessible in real-time, new applications can be developed to predict space weather effects by using the network of neutron monitors.

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