Proceedings of ICRC 2001: 3541 © Copernicus Gesellschaft 2001

ICRC 2001

# Alert service for extreme radiation storms

**V. Babayan, N. Bostanjyan, A. Chilingarian, N. Gevorgyan, A. Hovanissyan, G. Hovsepyan, G. Gharagyozyan, S. Kazaryan, L. Melkumyan, S. Sokhoyan, and S. Zarunyan**

Cosmic Ray Division of Yerevan Physics Institute, Yerevan 375036, Armenia

**Abstract.** The Aragats Solar Environment Center (ASEC) located on Mt. Aragats are providing real time monitoring of the extreme Radiation Storms. Two neutron monitors (NM) and a Solar Neutron Telescope operating on Aragats research stations are continuously measuring fluxes of Solar and Galactic Cosmic Rays.

Currently, detectors are monitoring for possible abrupt variations of count rate. *Strong Radiation Hazard Alert* is issued if all 3 out of 3 monitoring detectors demonstrate more than $3 \cdot \sigma$ excess compared to predetermined variation coefficient ($\sigma$ - mean square deviation) of each detector.

## 1 Introduction

Violent explosions on the Sun, so called Sun Energetic Phenomena (SEP), including Flares (SF) and Coronal Mass Ejections (CME) dominate the space weather conditions and happen frequently during the years of maximum of solar activity. Some of them can be powerful enough to disrupt space-borne electronics and harm space station crews. Meanwhile, currently available services cannot effectively warn against these dangerous disturbances in advance, nor can they predict the severity of the impact.

Nowadays satellites are becoming increasingly important in communication, navigation, exploration and research. Geosynchronous, long duration commercial and military missions incur environmental damage from high intensity fluxes of solar particles.

There are a number of experiments observing the Sun. These experiments continuously measure radio, optical, $X-$ and $\gamma - ray$ fluxes[1], solar wind velocity, temperature and density[2], as well as properties of the solar magnetic field[1]. Along with information available from the space-borne sensors on the position and properties of SEP, on-line data taken in one-minute intervals on high energy particle intensities could be used to determine the model and, consequently, the expected hazard of a SEP event. In spite of large numbers of photons arriving from The Sun at the speed of light, they are less reliable indicators of the severity of approaching storms, compared to high-energy particles.

The relativistic particles arrive much earlier than the medium energy particles, which are most dangerous for spacecraft electronics and astronauts because of their huge intensities. Therefore, the expected extreme radiation storm can be predicted with high accuracy before the most dangerous fluxes of lower energy particles arrive, and there is enough time to estimate the peak intensity and profile of the event, and to switch off satellite electronics if the hazard is serious. Dorman (1999) demonstrated the ability of ground based detectors to predict severe radiation hazards 30 minute before a main phase by analyzing time-intensity profiles of radiation storms accompanying most violent SF.

## 2 Historical events

In Figure 1 we display the most powerful radiation storm of the 22nd cycle from September 29, 1989. It is seen from the picture that high energy particles arriving at same time as X-rays (11:46 GMT) are triggering a very fast and very significant increase in neutron monitor count rate both at Aragats and in Apatity[3] Neutron Monitors. The high intensity flux of "killer" electrons and protons arrives half a hour later (12:15 GMT), allowing time for alerts and subsequent preventive measures for satellite operators. Here is worth to note the difference in the spectra of Aragats and Apatity monitors that is due to large difference in rigidity. Differences of the spectra, indicate that low energy particles arriving 1-2 hours later than high-energy particles are continuously registered by the Apatity monitor, but not by the Aragats monitor.

*Correspondence to:* N. Gevorgyan
(nerses@crdlx5.yerphi.am)

[1] GOES satellites – http://spidr.ngdc.noaa.gov/

[2] ACE satellite – http://www.srl.caltech.edu/ACE/ASC/

[3] http://pgi.kolasc.net.ru/CosmicRay/

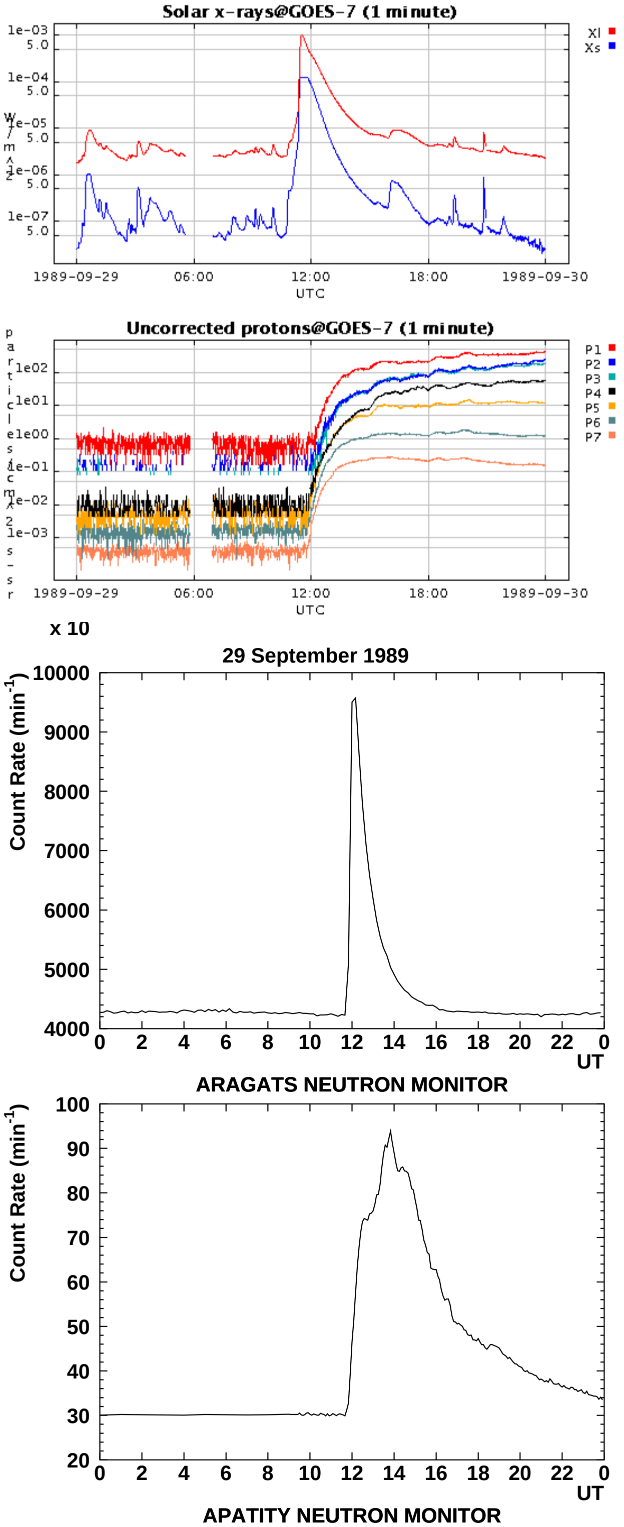


**Fig. 1.** September 29, 1989

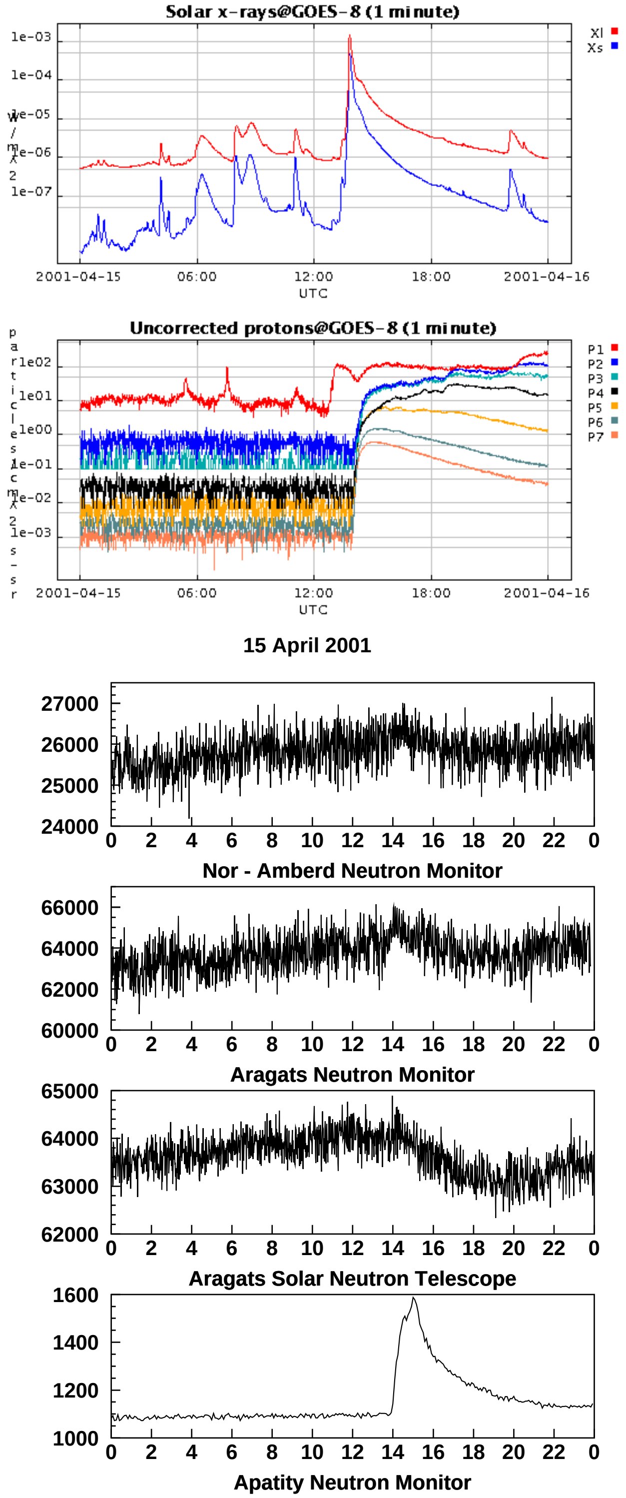


**Fig. 2.** April 15, 2001

Another interesting issue is evident from Figure 2, where the most intensive radiation storm of 23rd cycle is shown. The source of the explosion was near the Sun's western limb, so the blast was directed mostly away from Earth. This flare, nearly as powerful as one in March 1989 that triggered the collapse of a power grid in Canada, caused – no such calamities. The $X - ray$ signal was registered at 13:35 GMT. Both the Apatity monitor and GOES-8 registered an abrupt enhancement at 14:00 GMT. ASEC monitors registered only a few percent of enhancement, proving that maximum energy of the protons in the flux was approximately $7.6GeV$ (rigidity cutoff for ASEC monitors). It demonstrates that alerts for extreme radiation storms have to be made using monitors located at low latitudes to avoid false alarms from considerably weak storms, that triggering peaks in GCR intensities only at high latitudes and at satellite sensors.

## 3 Structure of Aragats Solar Environment Center

CRD runs two high altitude stations (see Fig. 3) on the slope of mount Aragats in Armenia (cutoff rigidity $\sim 7.6GV$); Nor-Amberd station (2000m a.s.l.) and Aragats station (3200 m a.s.l.). Two 18NM-64 neutron monitors are in operation, one at Nor-Amberd, and another at Aragats research station (Chilingarian et al., 1999). Data from these neutron monitors is available online at http://crdlx5.yerphi.am/neutron/. Solar neutron telescope (SNT) at Aragats station consists of $4m^2 \times 60cm$ thick scintillation detectors with anti-coincidence shielding, vetoing near vertical charged flux (Matsubara et al., 1999). Data from solar monitor is available online at http://crdlx5.yerphi.am/solar.html.

## 4 Details on the alert service

Alert service is comprised of distributed network of detectors, readout computers and server issuing alert via e-mails. To fit the requirements of alert service, it should eliminate the network bottlenecks associated with failures in connections from data acquisition through alert delivery to end users. This process is passing through 4 phases:

– Data readout from the detector;

– Transfer of the latest data to the server;

– Data analysis and alert triggering;

– Alert delivery.

### 4.1 Data readout

Collected data are stored on the hard disk of on-line computer each minute. After being stored data is available for transfer. Use of multitasking operating system is mandatory in such schemes for simultaneous access to the same data file. (We use Linux[4] OS.) At this stage we have a few seconds of delay ($< 3s$).

### 4.2 Transfer

To make the data available to the server, readout computer should support data exchange services, such as NFS, File Sharing (Windows), FTP and HTTP services. FTP is the best choice as secure and robust against connection failures and the most efficient (in terms of computer resource usage). Each minute server initiates parallel downloading programs for each of 3 detectors. These programs performs routine treatment of the data as well. This stage takes less than $25$ seconds.

[4] http://www.kernel.org/

### 4.3 Analysis and alert triggering

Each minute server initiates program that performs checks on latest available data from all 3 detectors. 3 independent data channels ensure robust operation against possible outliers (false signals due to technical or human errors). If all 3 detectors demonstrate more than $3 \cdot \sigma$ increase in count rate alert is issued by sending e-mail to the mailing list running on the same server. This operations requires less than $3$ seconds.

### 4.4 Alert delivery

Alert delivery timeliness in reaching the end user is the main priority. To ensure timely delivery of alert the best solution is to keep messages short and fit them to one TCP/IP packet (maximum size is 1500 bytes).

$$1500\, byte - TCP\ header - mail\ headers \approx 1000\, byte$$

Therefore, the message body should contain around 1000 characters. In such situation we expect that $1 - 3$ minutes will be spend on e-mail delivery. For reliable operation we plan to establish a reserve Internet link.

### 4.5 Synchronization

The key factor of smooth operation of the alert service is the synchronization of server and readout computers at scales less than 1 second. Synchronization achieved by using GPS as reference clock and Network Time Protocol (NTP) service. This will keep time spent on data readout — mail generation cycle within 1 minute limit. Therefore, tt will be possible to keep overall time delay in range of $2 - 4$ minutes.

## 5 Mailing list

Mailing list server is Majordomo with address for administrative messages at majordomo@crdlx5.yerphi.am . *Strong Radiation Hazard* mailing list address is alert-hazard@crdlx5.yerphi.am .

## 6 Conclusion

To make our alert service efficient, we continuously check for possible failures of detectors, on-line computers, LAN's and satellite antennas. The three fold coincidence of our alert service will make it robust against false alarms. Testing performed in the beginning of 2001 proved reability and robustness of our alert service. In future we plan to use additional data from the multi-directional muon telescope now under construction. Our flexible scheme of data integration makes possible to use data from other detectors worldwide.

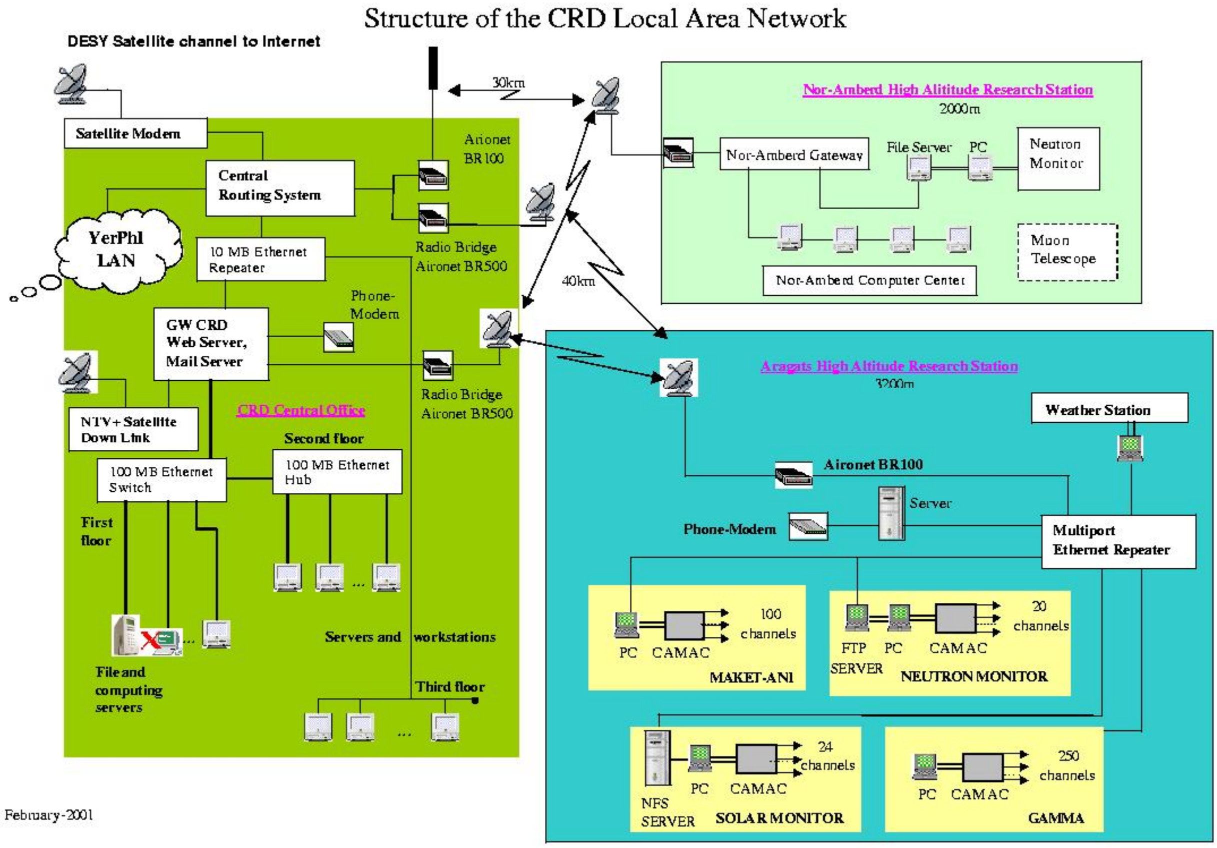


**Fig. 3.** Local Area Network and monitoring facilities of ASEC

At the beginning strong radiation storms are very anisotropic, and only after a few dozens of minutes become quasi isotropic. Thus, to improve our alert service it is necessary to analyze on-line data of the worldwide network of cosmic ray stations [Dorman et al., (1993)] as well.

*Acknowledgements.* We kindly acknowledge Y. Muraki for collaboration in running Solar Scintillation Telescope, L.I. Dorman for fruitful discussions on creating the worldwide alert service, H. Soghoyan and A. Daryan for discussions on time synchronization and H. Vardanyan for attentive reading of this paper. The work has been partly supported by the research grant N 00-784 of the Armenian government, NATO NIG-975436 and CLG-975959 grants and ISTC A216 grant.

## References

Dorman, L. I., On the prediction of great energetic events to save electronics of spacecraft, Proc. 26th ICRC, 6, 382, Salt-Lake-City, 1999.

Chilingarian, A. A., et al., Registration of the Solar Activity during Cycle 23 with the ANI Cosmic Ray Observatory facilities, Proc. $26^{th}$ ICRC, 6, 460, Salt-Lake-City, 1999.

Matsubara, Y., and Muraki, Y., et al., Observation of Solar Neutrons by the World-Wide Network of Solar Neutron Detectors, Proc. of $26^{th}$ ICRC, 6, 42, Salt-Lake-City, 1999.

Dorman, L.I., Venkatesan D. 1993, Space Sci. Rev., 64, 183