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Cosmic ray radiation effects on space environment associated to intense solar and geomagnetic activity

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ABSTRACT

Intense cosmic ray fluxes recorded by the Neutron Monitor Network - during Forbush decreases - can be responsible for a number of radiation effects in electronics and sensor systems of spacecrafts and aircrafts. Monitoring, modeling and prediction of them from the real-time Data basis of ANMODAP Center is considered.

COSMIC RAY EFFECTS ON SPACECRAFT & AIRCRAFTS

▪ Space systems most dangerous effects due to cosmic ray particles include (Dyer & Rodgers, 1998; Daly, 2004):

a) radiation damage to spacecraft electronics, solar cells and materials from Earth's radiation belt particles and solar energetic particles,

b) single event effects (SEE) in spacecraft electronics due to ionisation tracks from galactic cosmic ray or solar energetic particle ions or due to ionisation products of nuclear interactions between radiation belts or solar protons and component materials,

c) interference to spacecraft imaging and sensing systems,

d) electrostatic charging from 'hot' (~keV electron temperatures) plasmas and energetic (~MeV) electrons.

▪ The International Commission on Radiological Protection (ICRP), in 1990, recommended that the radiation exposure due to cosmic rays at high altitudes must be taken into account as part of occupational exposure to radiation. Recently, a comprehensive database using aircraft measurements made by a low-Let-Radiation Spectrometer to enable a mapping of doses and Linear-Energy Transfer spectra at aviation latitudes is used to generate a detailed description of the cosmic ray induced particle environment and determine the effects from long and short term variations (Stassinopoulos et al, 2003). Spurny et al.(2004) with a similar equipment on board of Czech Airlines during the year 2001 were able to register the solar cosmic ray event GLE60 on April 15, as well as the Forbush Decreases on April 12 and November 06, 2001.

▪ The estimation of probability rate regarding satellite and aviation anomalies needs to follow a specific path:

➢ First of all a global monitoring of all parameters referring to Space and Earth Weather must be established.

➢ A search for specific criteria between anomalies and universal characteristics of Space and Earth Weather is crucial in order to construct models suitable for prediction.

THE ANMODAP CENTER OF ATHENS

▪ Taking into account the above suggestions a data processing centre has been established in Athens neutron monitor station since 2004 (ANMODAP Center).

▪ The idea is that early detection of an Earth-directed proton event by NMs offer the opportunity of preventive prognosis of dangerous particle fluxes and can provide an alert with low probability of false alarm (Belov et al., 2001; 2005).

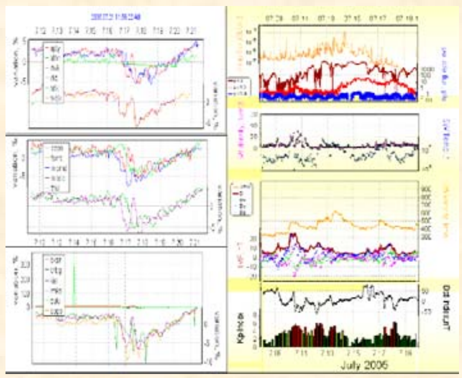

Figure 1:Neutron monitors data from ANMODAP center (left panel) & satellite data from GOES and ACE (right panel) in July 2005– [http://cosray.phys.uoa.gr]

▪ The Athens centre provides reliable data using independent programs for simultaneous data collection from twenty-three different stations in a periodic scheme with a specific time period determined automatically or even manually. A feasible and statistically proven method using total counts from several stations in real time together with satellite data from ACE and GOES are being used (Mavromichalaki et al., 2005a; 2005b).

THE JULY 2005 EFFECT

▪ Galactic CR density started to fail from 10th of July and by the 16th of July had a decrease ~2%, after a series of relatively weak Forbush effects. Most dramatic events occurred on 16th of the month, when FD reached 8% in several stations, only in a few hours. The CR intensity recovered rapidly up to the starting level, but in the mid of the next day a sharp decrease started again and reached the same 8% at many stations, followed by the classical FE profile.

▪ The decrease was the result of the solar and geomagnetic activity and had a significant signature to almost all NM stations despite their geographical position.

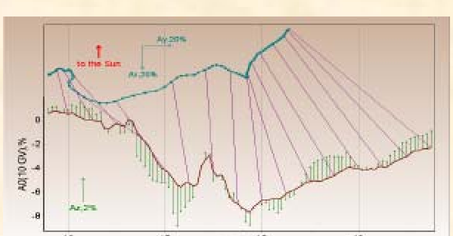

Figure 2:Variation of 10GV cosmic ray density and the equatorial first order anisotropy during the unique events of July 2005. The north-south anisotropy is presented by vertical arrows along density curve.

▪ The anisotropy vector Az increases significantly within the declining phase of the FD on the 16th to 17th of July and changes its direction in the mid of 17th of July. This increase of the amplitude and the direction change are typical responses of the first order anisotropy to a shock. AE is constantly changing its direction and increases, especially during the second FD which followed the sharp enhancement of the mid 17th of the month. Az changes sign from positive to negative throughout this disturbed period. The big equatorial component of CR anisotropy at this time is evidence of an intensive inflow of particle flux from the eastern direction that provided a fast recovery of the FD.

Figure 3: The remarkable series of Forbush effects recorded in July 1959

▪ A similar event to the July 2005 one, recorded in July 1959.The July 1959 period is truly one of the most remarkable seasons in the history of cosmic rays, as a lot of strong solar events took place, modulating interplanetary space and resulting notable variations to the intensity of CR. Both cases, presented the same features although evolved at different background situations

CONCLUSIONS

▪ Cosmic rays are responsible for single event effects in electronics and background noise in sensor systems. It is one of the reasons why cosmic rays and especially extreme events are a unique mean to the quest of space weather prediction.

▪ Intense and short duration events in CR intensity as those of July 2005 and July 1959 resulted by special interplanetary conditions, consist a new kind of events important for space weather forecasting and possible radiation effects. A real time prediction of all dangerous space weather phenomena will minimize the reliability and the timely forecasting of the arrival of dangerous fluxes from space.

Acknowledgements

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