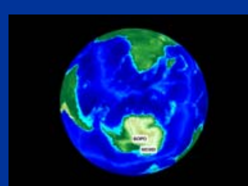
National and Kapodistrian University of Athens, Faculty of Physics
Section of Nuclear and Particle Physics
Athens Neutron Monitor Station

The activities in the Athens Neutron Monitor Station



Helen Mavromichalaki
Athens Cosmic Ray Group

Solar Extreme Events 2007 International Symposium
Workshop on Neutron Monitors
27 September 2007, Athens, Greece

Athens Cosmic Ray Group

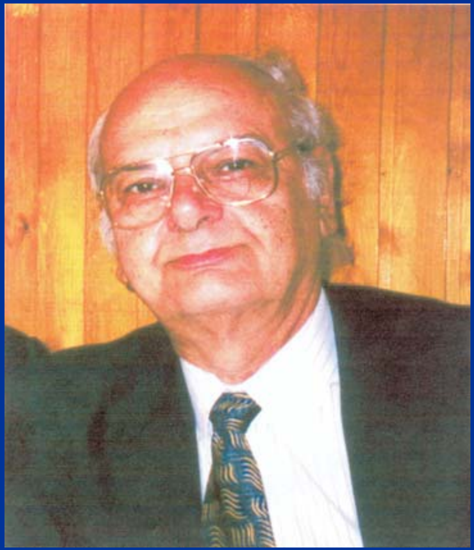
Helen Mavromichalaki	Prof	emavromi@phys.uoa.gr	Head of the Athens Neutron Monitor
Maria Gerontidou	Dr	mgeront@phys.uoa.gr	Solar Cosmic Rays/Proton events
Christina Plainaki	Dr	cplainak@phys.uoa.gr	Galactic/Solar Cosmic Rays/GLEs
Christos Sarlanis	PhD	csarl@isnet.gr	Data acquisition system Local Network Administration
George Souvatzoglou	PhD	gsouv@isnet.gr	Data acquisition system Local Network Administration
Athanasios Papaioannou	Msc	atpapaio@phys.uoa.gr	Galactic Cosmic Rays/Forbush effects
Maria Papailiou	Msc	mpapahl@phys.uoa.gr	Galactic Cosmic Rays/Biological
George Mariatos	Bsc	gmphysics@yahoo.com	Magnetospheric effects / Technical Support

History of the Athens Neutron Monitor Station

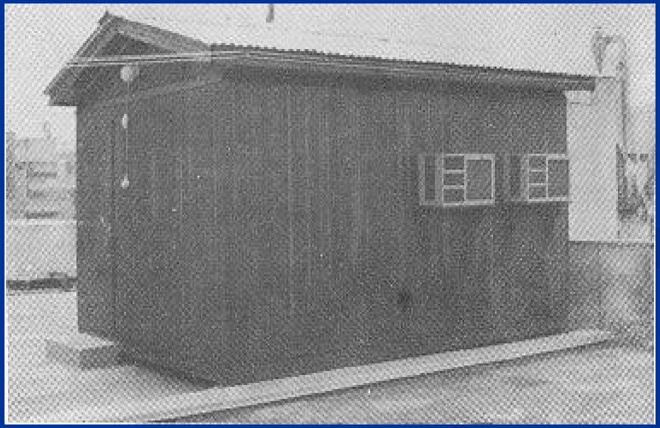
1970 - 1977

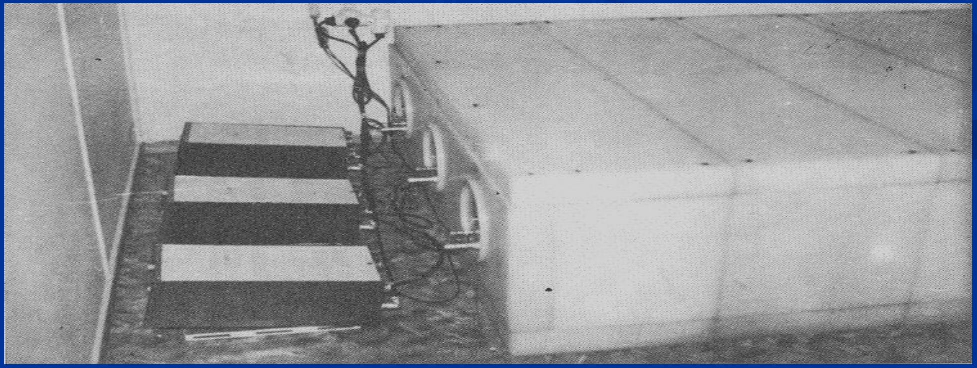
The Old Neutron Monitor of the Athens University

(Super 3NM-64, 40m, 8.72 GV)



Prof. A. Apostolakis



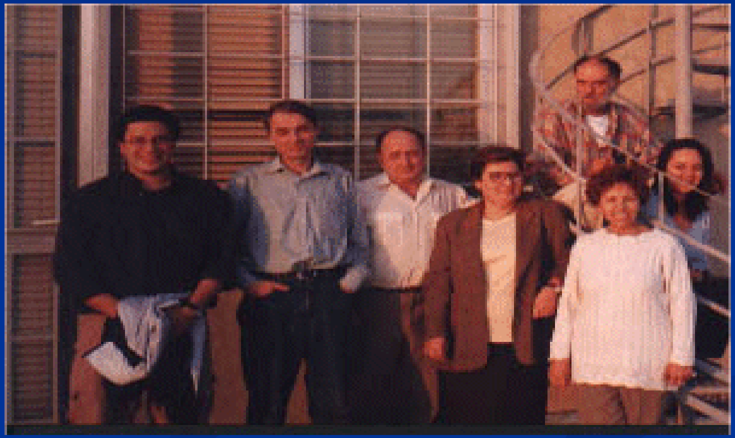


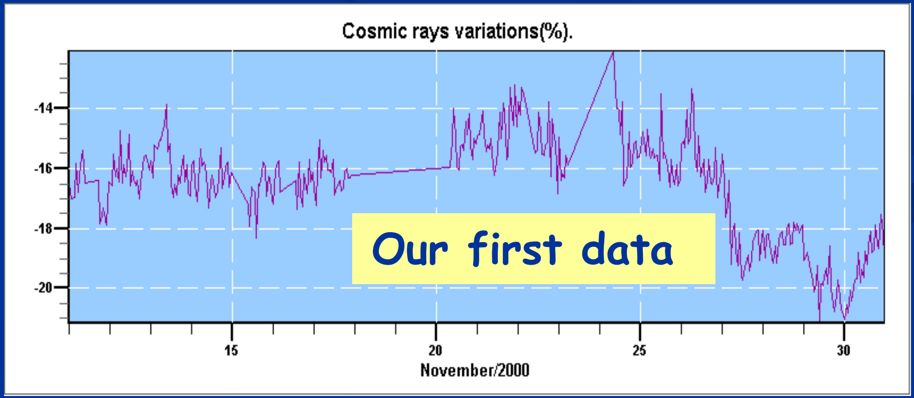
The New Neutron Monitor of the Athens University

University campus (Super 6NM-64, 260m)

November 2000

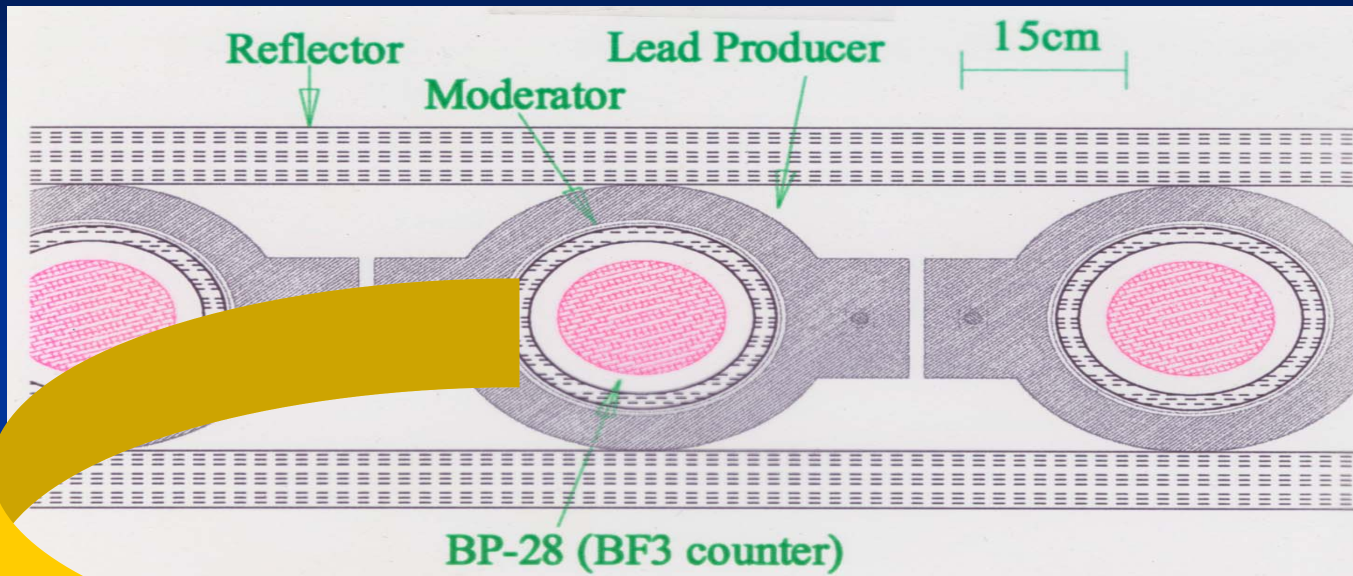
Athens - IZMIRAN groups

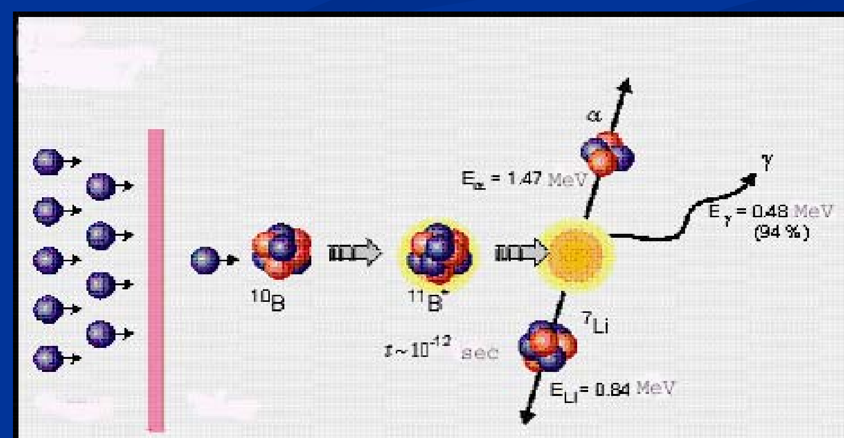




Neutron monitor

records the intensity of the nucleonic component of an atmospheric cascade





$$
{}^{10}_{5}B + {}^{0}_{1}n \rightarrow {}^{11}_{5}B
\begin{array}{l}
\rightarrow {}^{7}_{3}Li^{*} + {}^{4}_{2}a + Q_1 \ (94\%) \\
\rightarrow {}^{7}_{3}Li + {}^{4}_{2}a + Q_2 \ (6\%)
\end{array}
$$

Present status

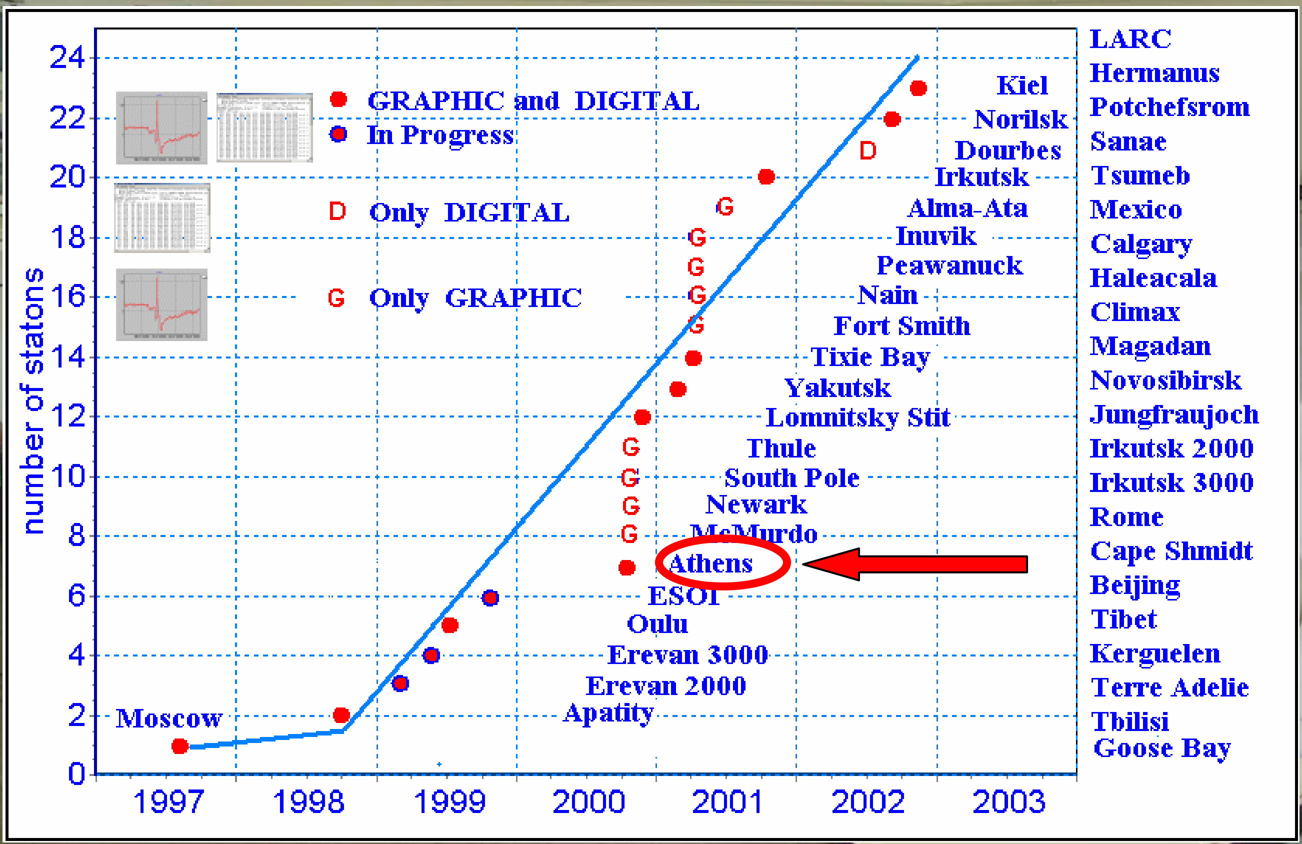
Super 6NM-64

R_c=8.53 GV

Real-time

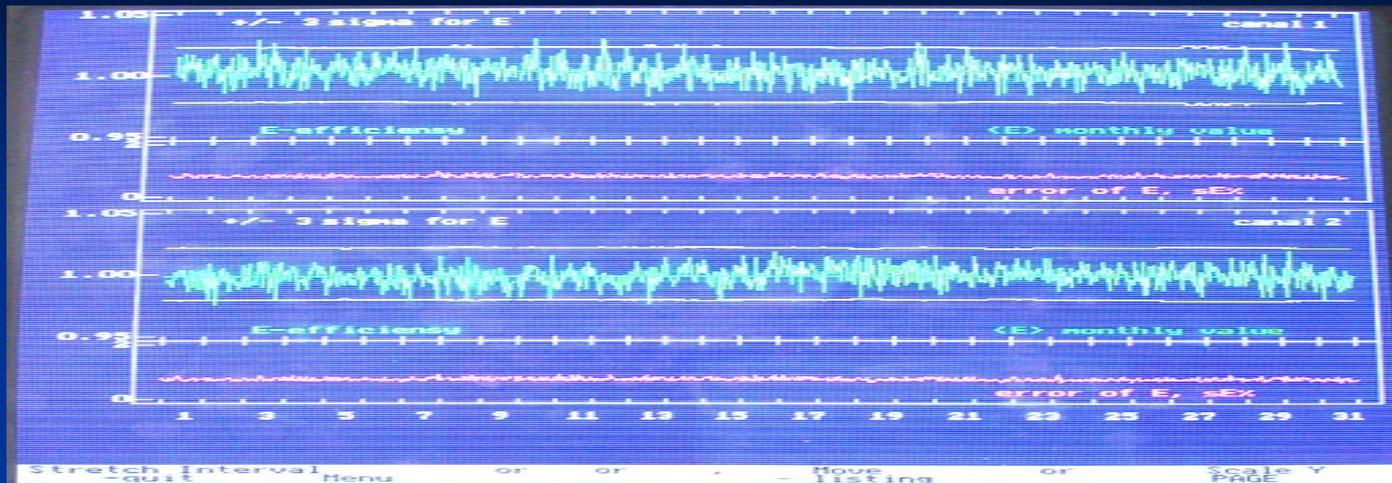
37^0 53´N , 23^0 43´E

H=260m



14 3 2006

Automatic Detector efficiency checks



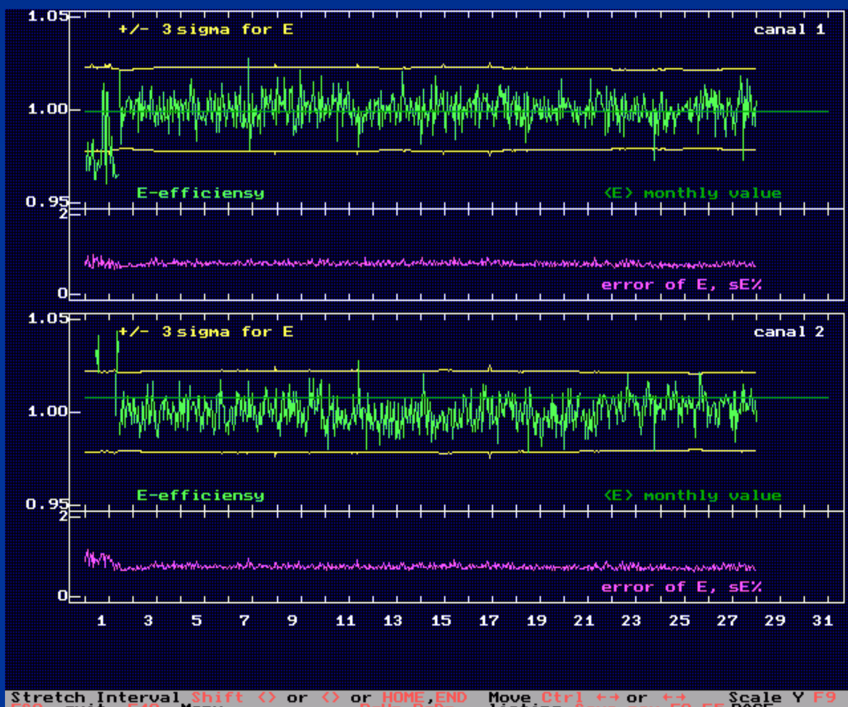
$$\varepsilon_i = \frac{N_i}{N_i^0}\frac{\Sigma N_i^0}{\Sigma N_i} \qquad (j \neq i, j \neq j_m)$$

Data Correction

$$N_i^* = N_i / \varepsilon_i$$

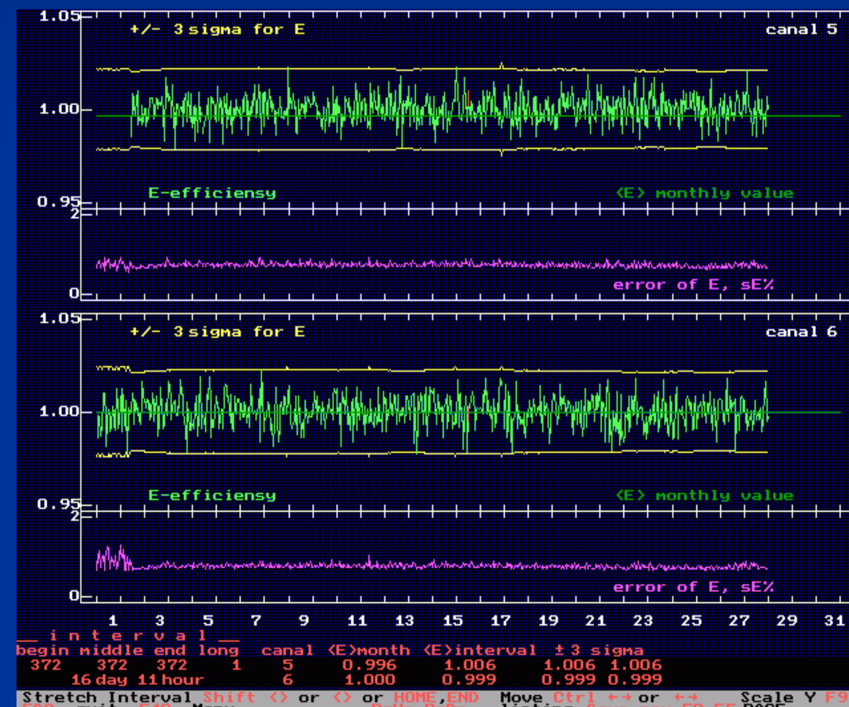
Efficiency of Athens NM 2001-2007

February 2001



Channels 1-2

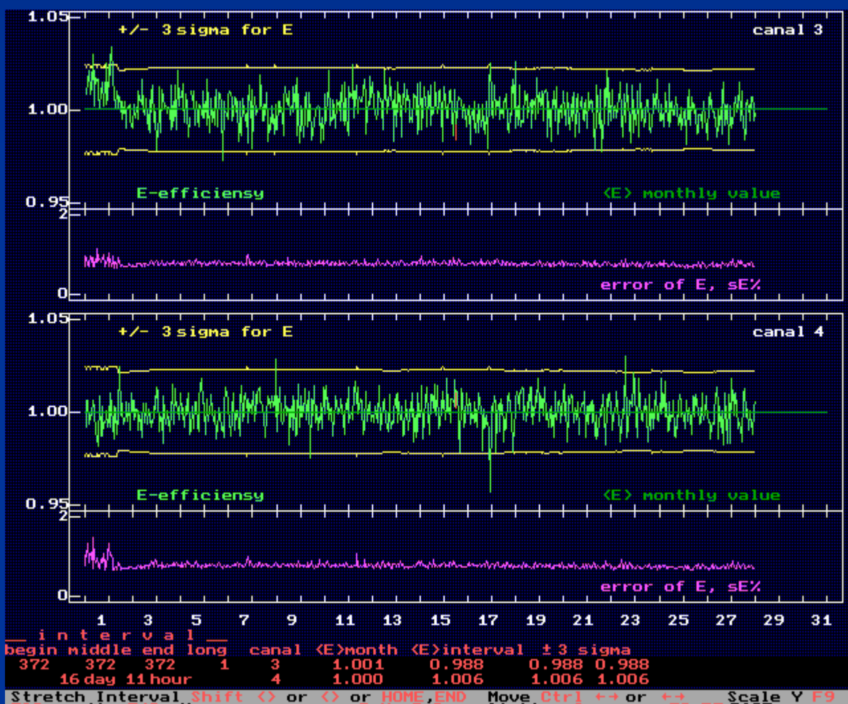
February 2007



Channels 1-2

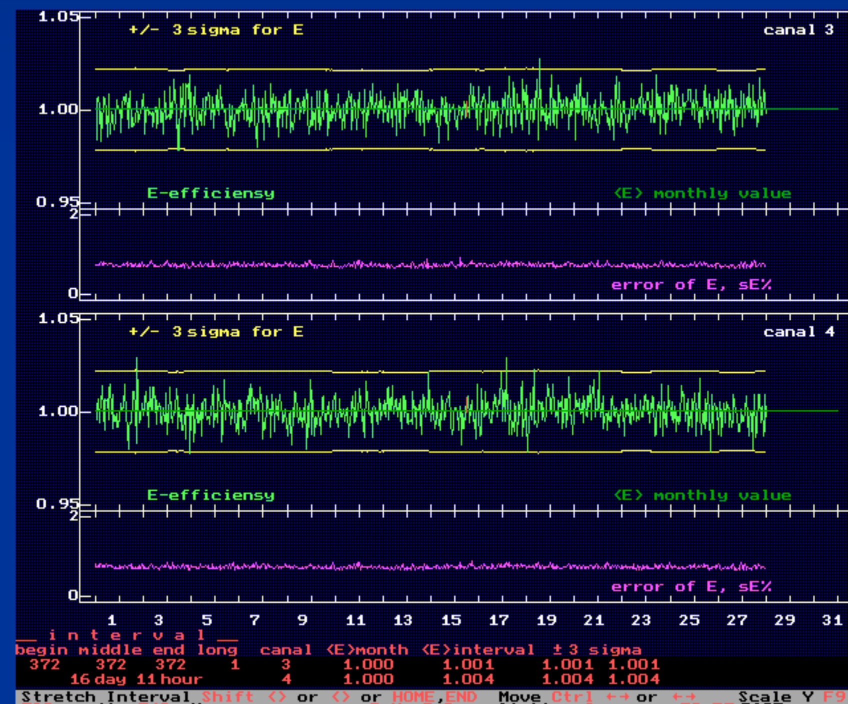
Efficiency of Athens NM 2001-2007

February 2001



Channels 3-4

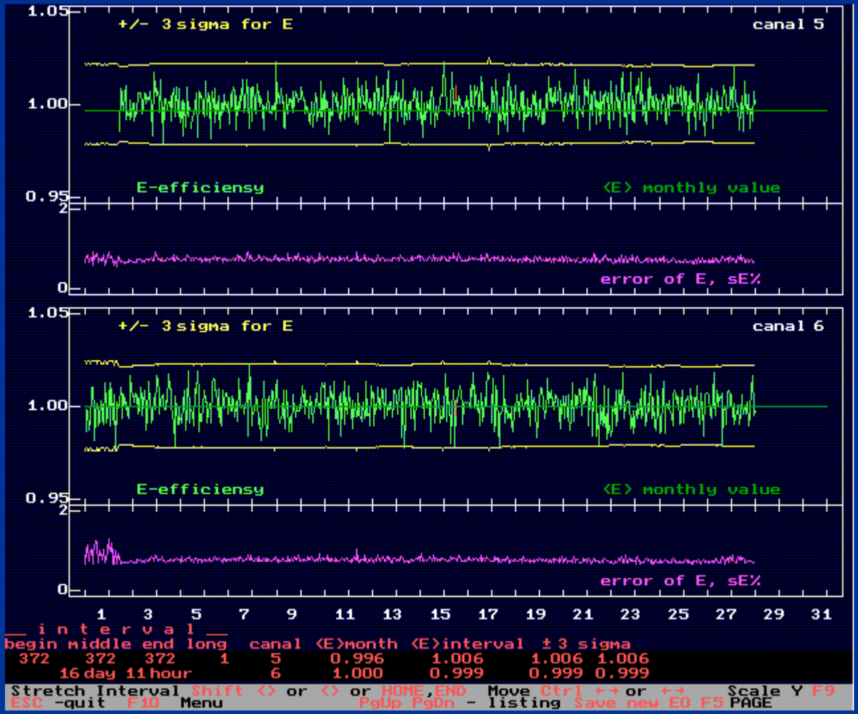
February 2007



Channels 3-4

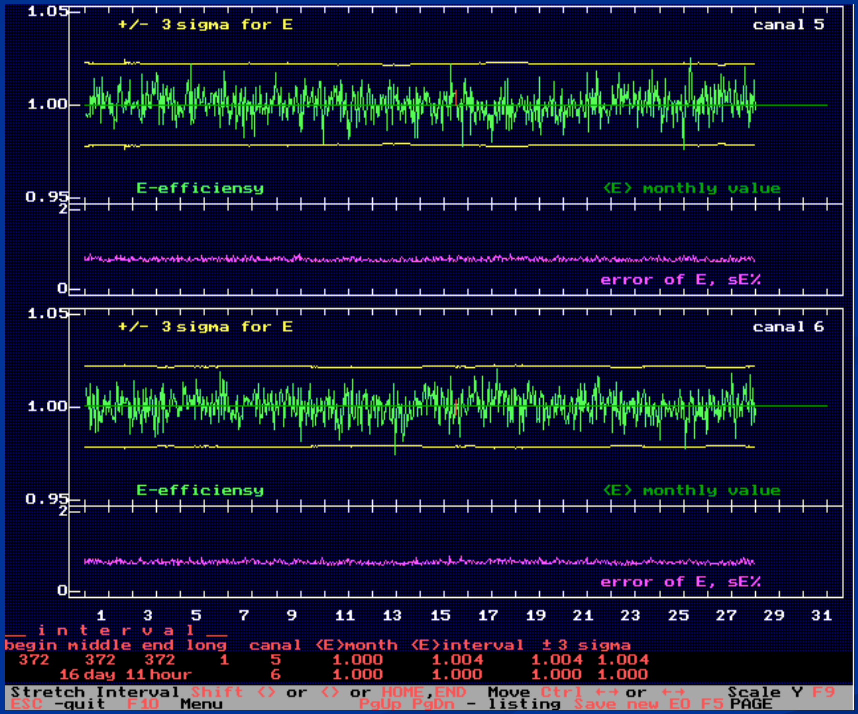
Efficiency of Athens NM 2001-2207

February 2001



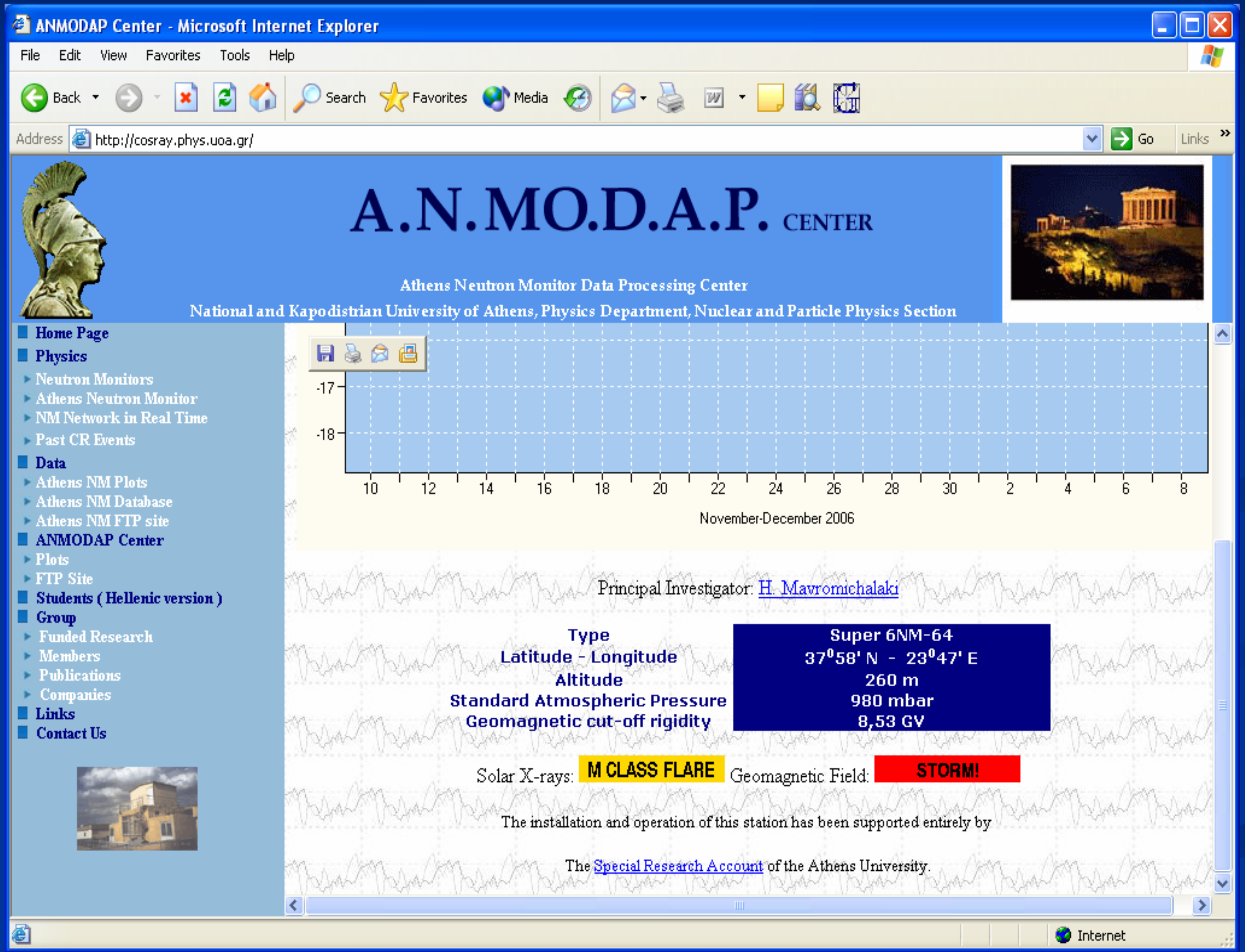
Channels 5-6

February 2007

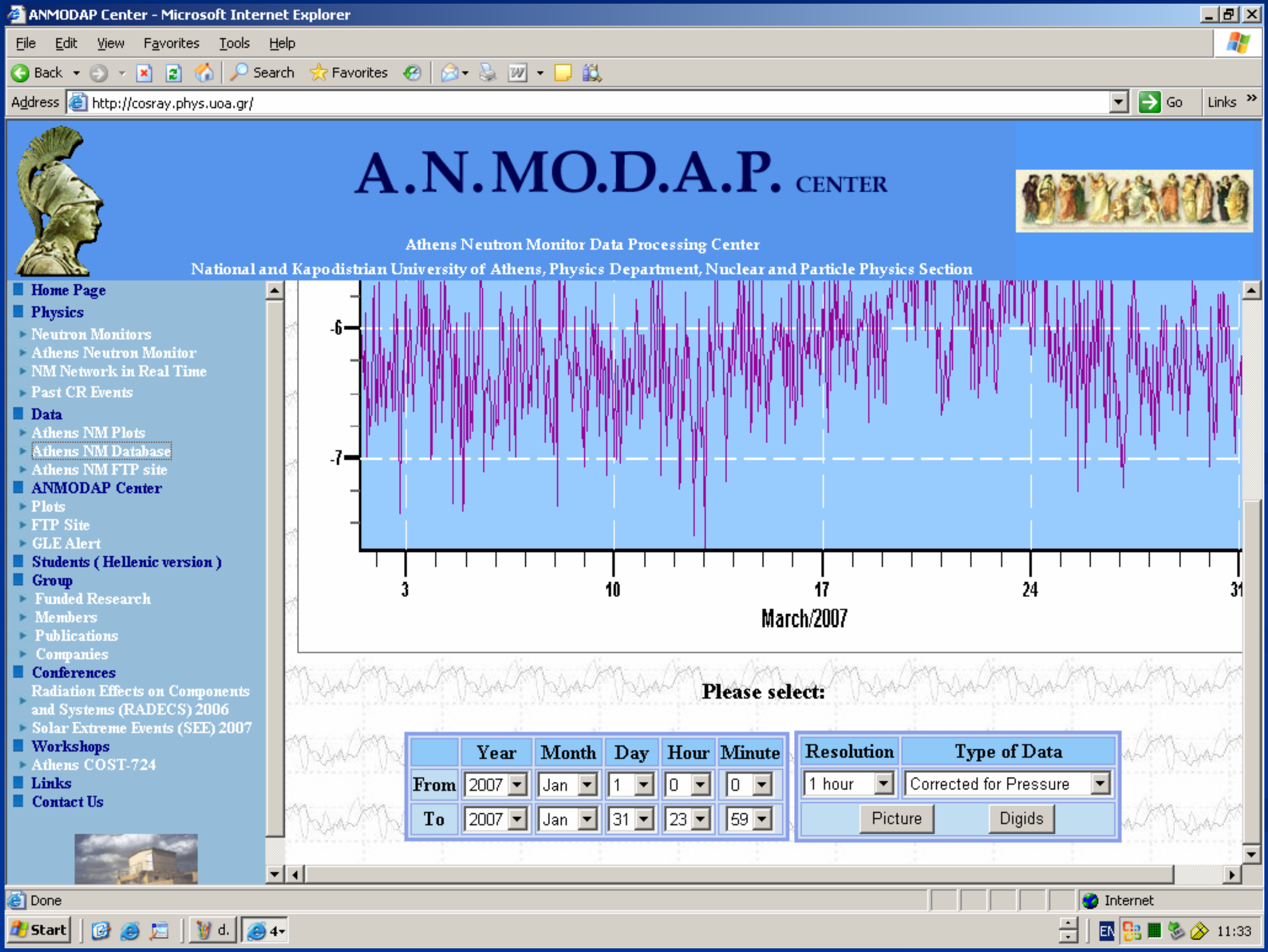


Channels 5-6

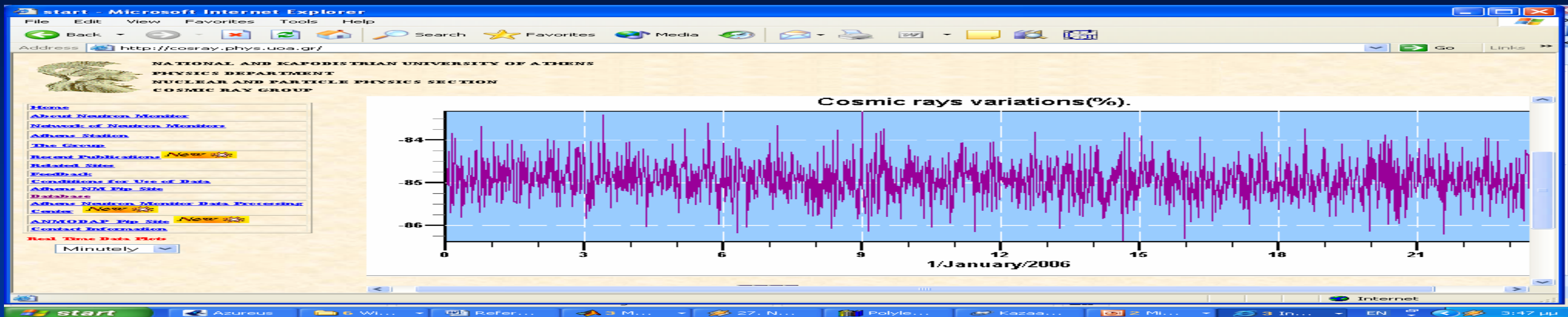
Athens Neutron Monitor Station Web Page
http://cosray.phys.uoa.gr

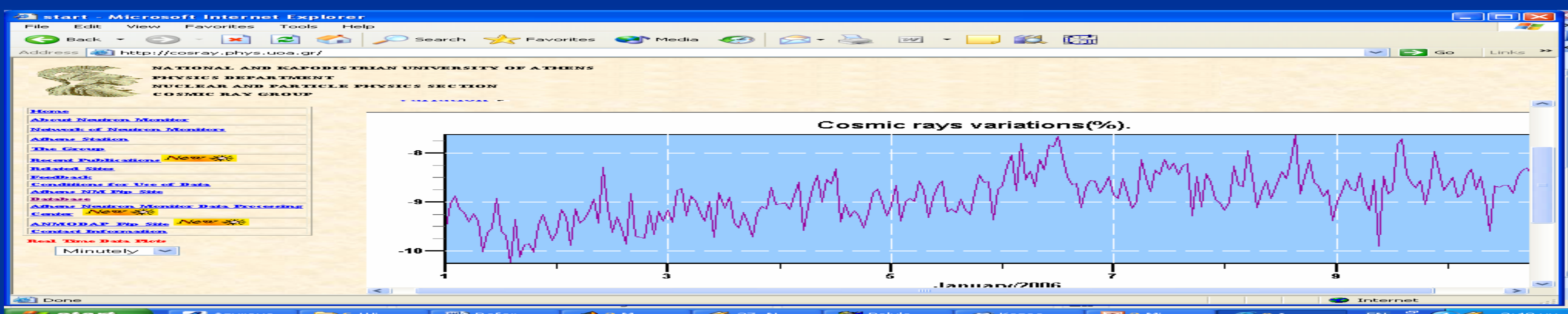


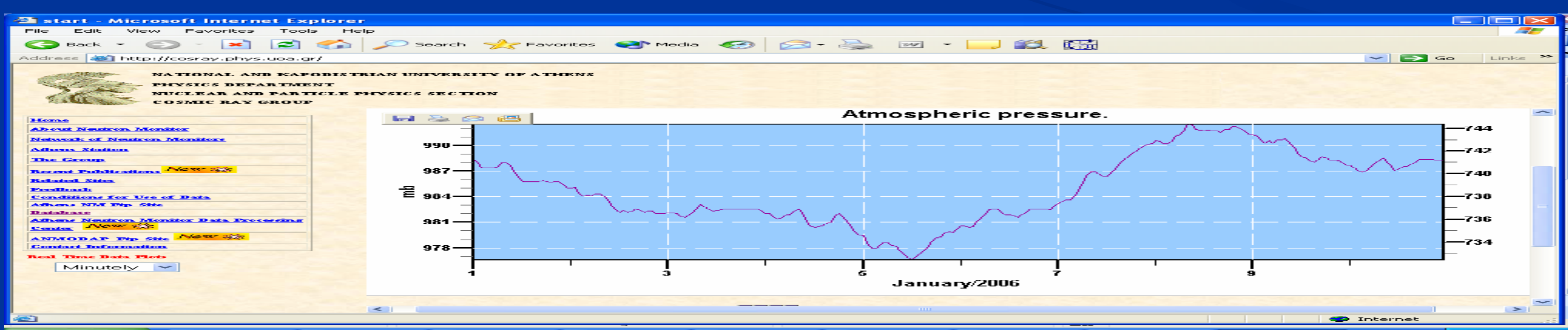
Athens Neutron Monitor Station Data and Graphs
http://cosray.phys.uoa.gr



Athens Neutron Monitor Cosmic Ray Data

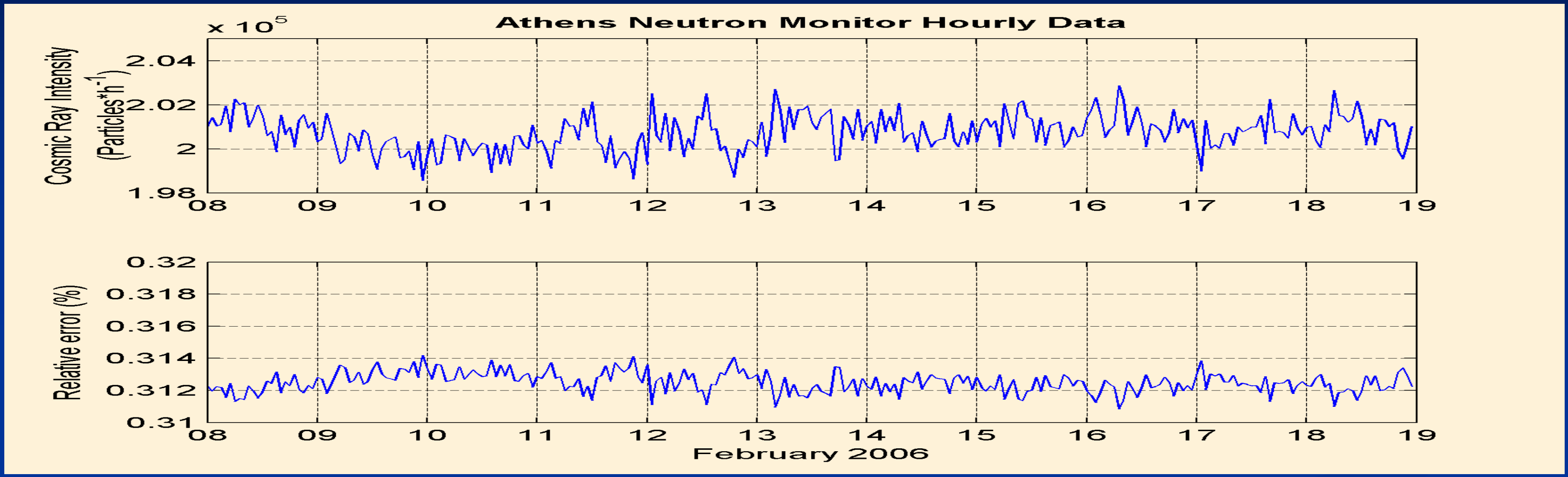






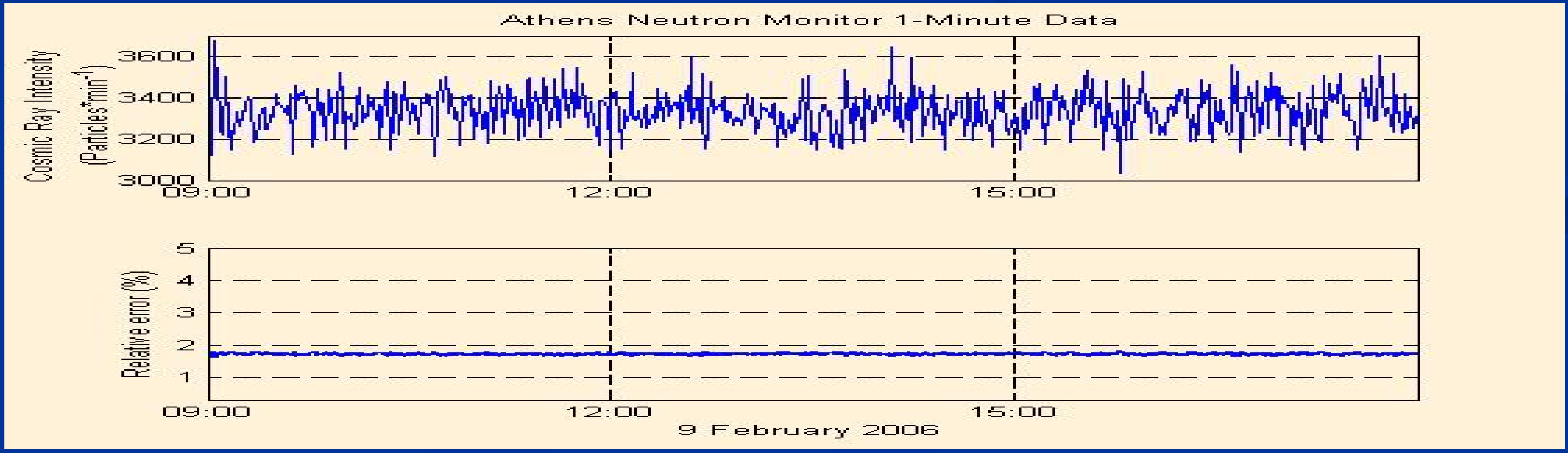
Statistical error for hourly Neutron Monitor data

< 0.31 %

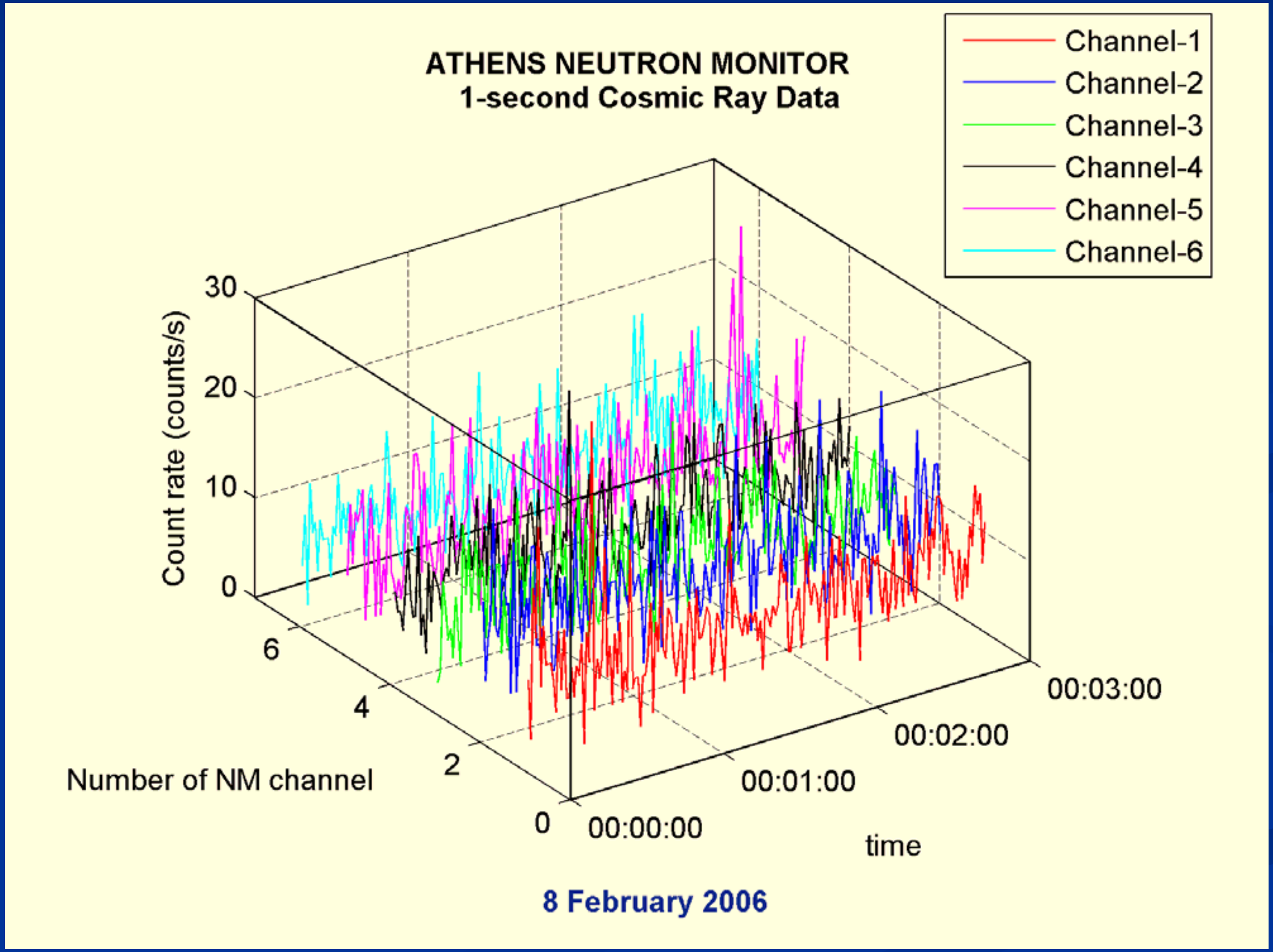


Statistical error for 1-min Neutron Monitor data

< 1.70 %



1-sec Neutron Monitor Data recorded by Athens Neutron Monitor



The Athens NM station provides data with resolution of

- 1-hour
- 1-min
- 1-sec

The advantages of the Athens NM station

- Estimates solar cosmic ray spectra, due to its cut-off rigidity (8.53 GV), which is close to the upper energy of the particles originating from the Sun

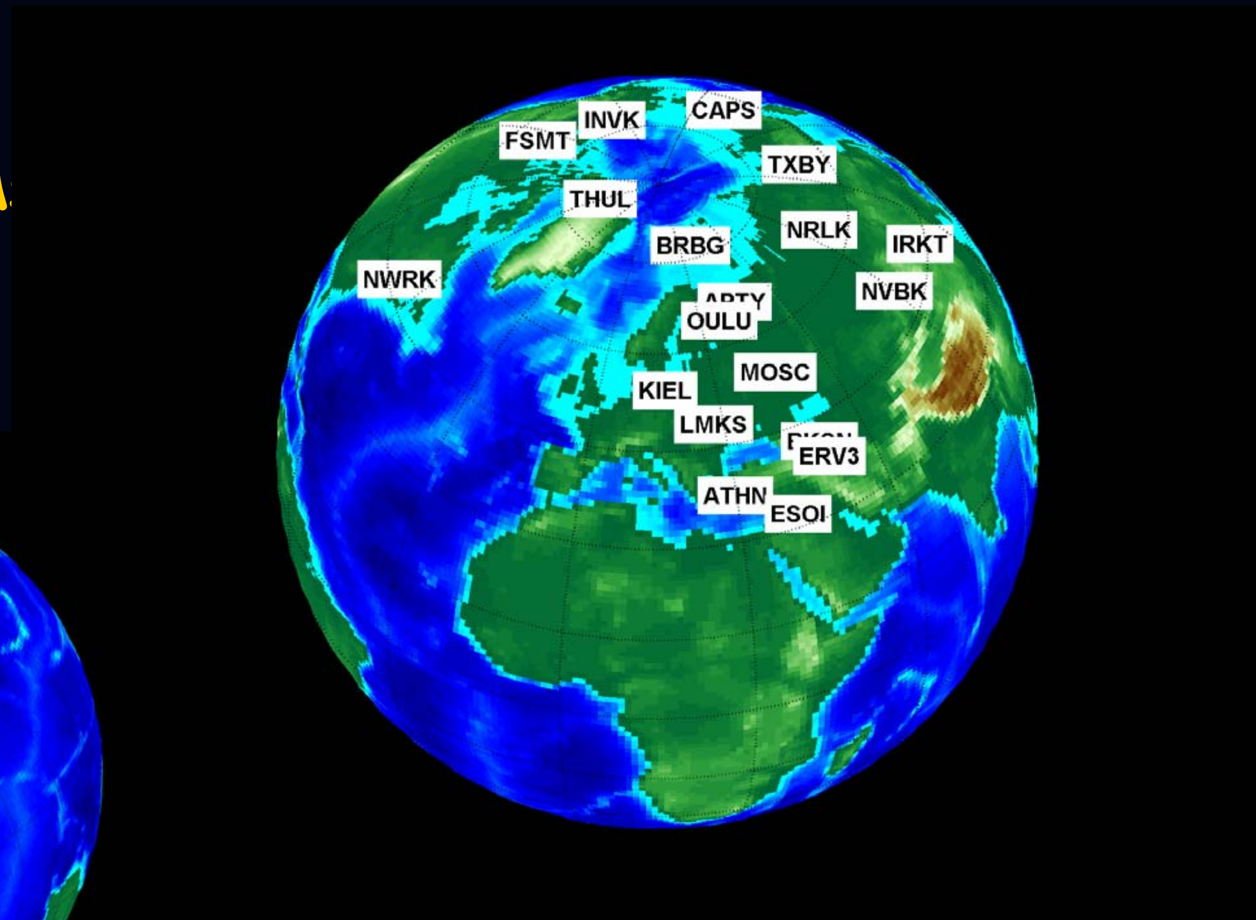
- As a low latitude station, Athens is important for the study of geomagnetic effects in CR during geomagnetic storms

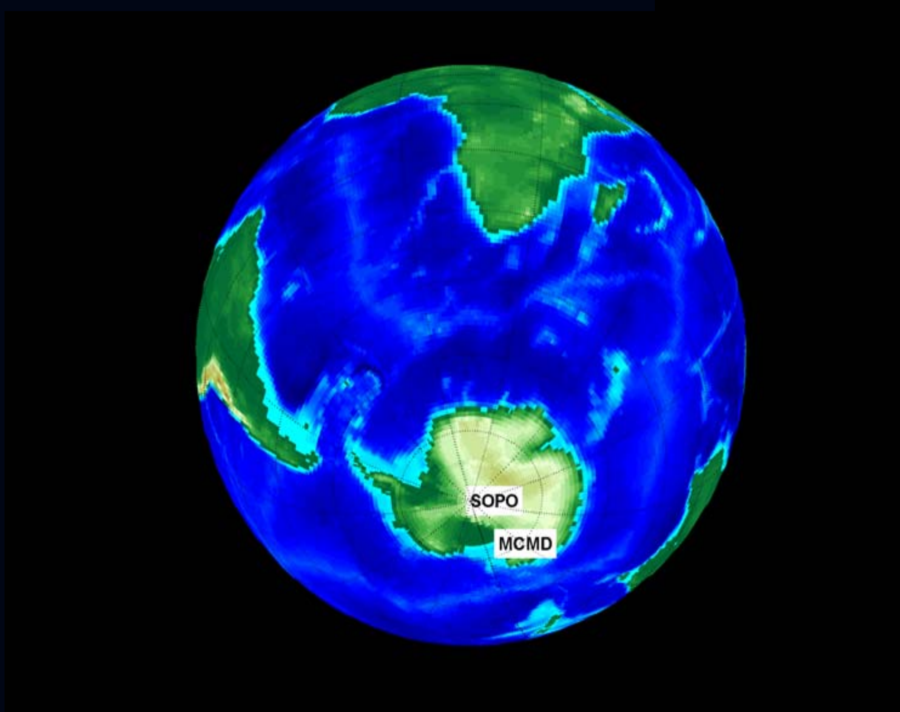
- Athens data can be used for the correction of snow effect at stations of close cut-off rigidities

- Apart from all, the new electronics systems and real time technology, makes Athens data accurate and the station useful for the Space Weather studies

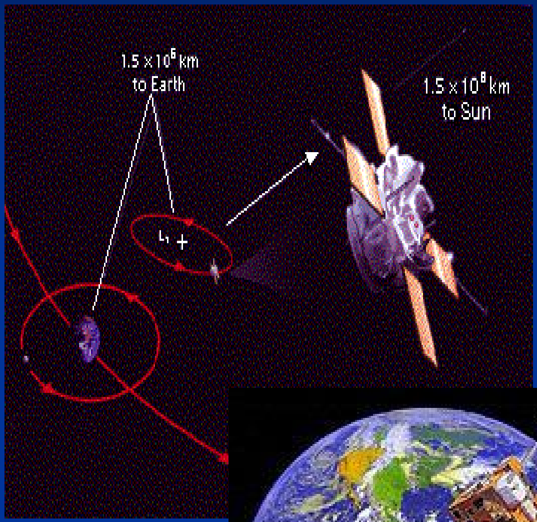
Athens Neutron Monitor Data Processing Center
ANMODAP Center

21 real time NM





GOES and ACE Satellite Data



ACE

Solar wind temperature (K)
Solar wind density (cm^{-1})
Solar wind velocity (km/s)
Interplanetary Magnetic Field B (nT)
IMF Bx component (nT)
IMF By component (nT)
IMF Bz component (nT)
Dst (nT)

GOES

Particle Flux (pfu)
Particle Flux (pfu)
Particle Flux (pfu)
X-ray flux ($\mu W/ m^2$)

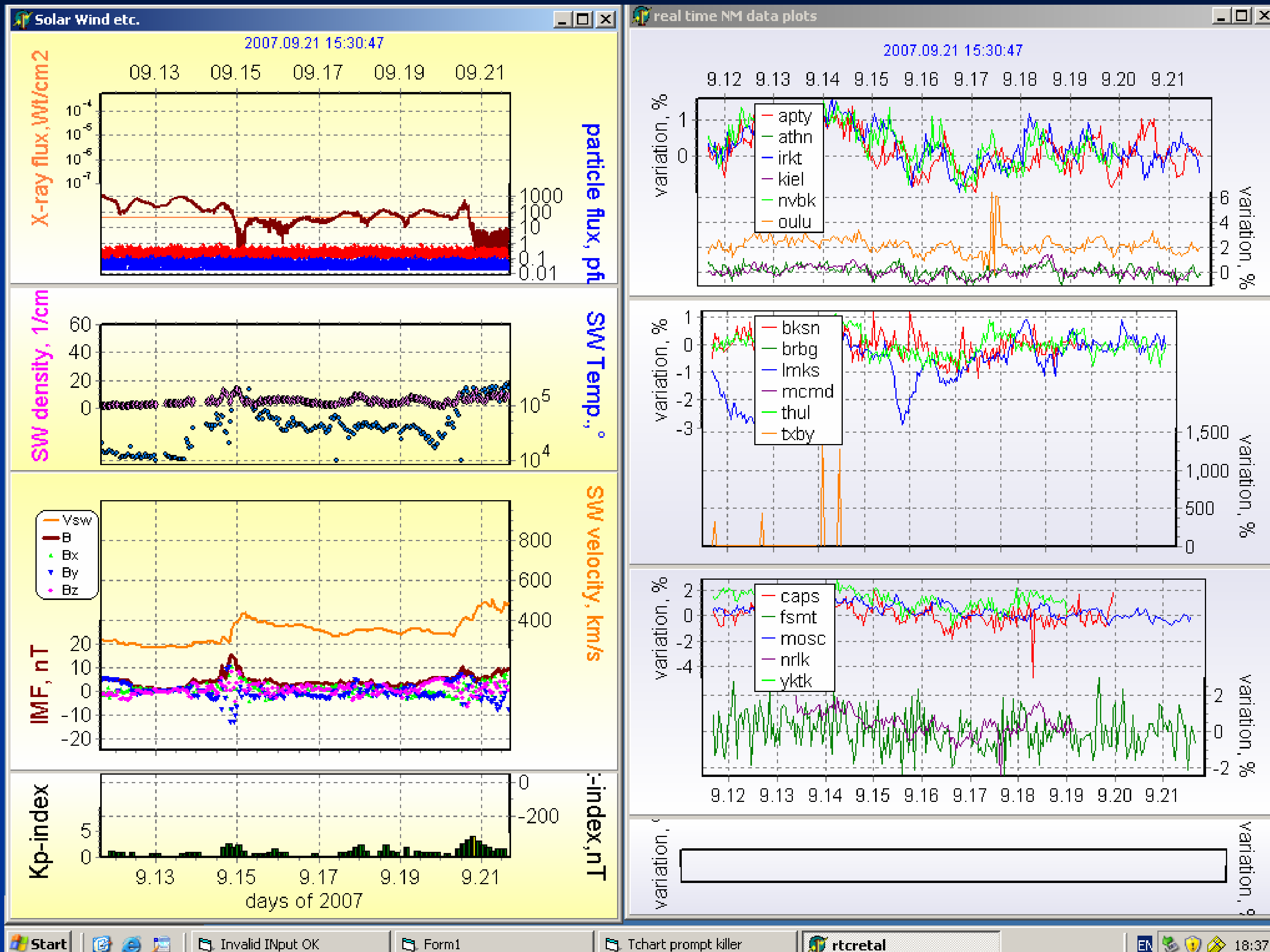
Athens Neutron Monitor Data Processing Center

provides real time monitoring of cosmic ray variations

Data from 21 real-time NM stations as well as satellites are collected and presented in ANMODAP Center

Stations	Abbrev.	Lat (^{0})	Long(^{0})	Alt (m)	H_0 (mb)	R_c (GV)
APATITY	APTY	67.55	33.33	177	977.80	0.55
ATHENS	ATHN	37.97	23.72	260	974.70	8.53
BAKSAN	BKSN	43.28	42.69	0	818.50	6.91
BARENTSBURG	BRBG	78.12	14.42	0	964.70	0.20
CAPESCHMIDT	CAPS	68.92	180.53	0	1021.30	0.52
EREVAN	ERVN	40.17	44.25	2000	798.30	7.36
EREVAN-3	ERV3	40.17	44.25	3200	683.90	7.36
ISRAEL	ESOI	33.30	35.79	2025	800.00	10.41
FORTSMITH	FSMT	60.00	-112.00	0	996.10	0.30
INUVIK	INVK	68.35	-133.72	21	1019.10	0.14
IRKUTSK	IRKT	52.47	104.03	433	965.00	3.49
KIEL	KIEL	54.34	10.13	54	981.40	2.36
LOMNICKY STIT	LMKS	49.20	20.22	2634	733.00	3.88
McMURDO	MCMD	-77.85	166.72	48	985.10	0.00
MOSCOW	MOSC	55.47	37.32	200	991.90	2.30
NORILSK	NRLK	69.26	88.05	0	1015.30	0.53
NOVOSIBIRSK	NVBK	54.80	83.00	163	999.20	2.69
NEWARK	NWRK	39.68	-75.75	50	1008.60	2.21
OULU	OULU	65.05	25.47	0	990.00	0.77
SOUTH POLE	SOPO	-88.00	210.00	2820	687.70	0.05
THULE	THUL	76.50	-68.70	260	1011.50	0.00
TIXIE BAY	TXBY	71.60	128.90	15	1019.90	0.43
YAKUTSK	YKTK	62.02	129.73	105	1020.70	1.55

Data Presentation in A.N.MO.DA.P Center



Scientific Studies at the Athens NM

- **Study of Forbush Decreases (FDs)**

(Mavromichalaki et al, IJMPA 2005; Papaioannou et al, Proc. SESWW 2005)

- **Study of Ground Level Enhancements (GLEs)**

(Plainaki et al., AGU 2004)

- **Study of Geomagnetic Events**

(Mariatos et al, IJMPA 2005)

- **Study of Biological effects of Cosmic Rays**

(Petropoulos et al., Proc. Acad. of Athens 2006, Papailiou et al., Proc EEF 2007)

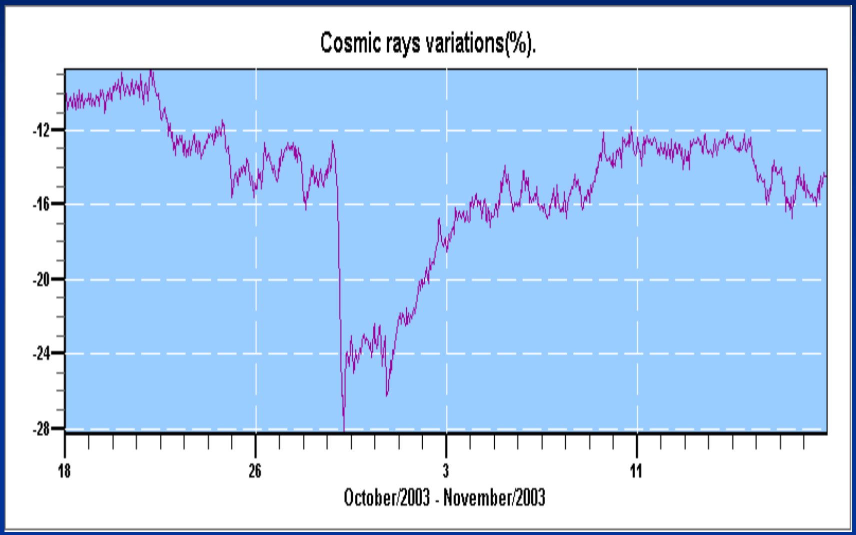
- **Study of Great Proton Events**

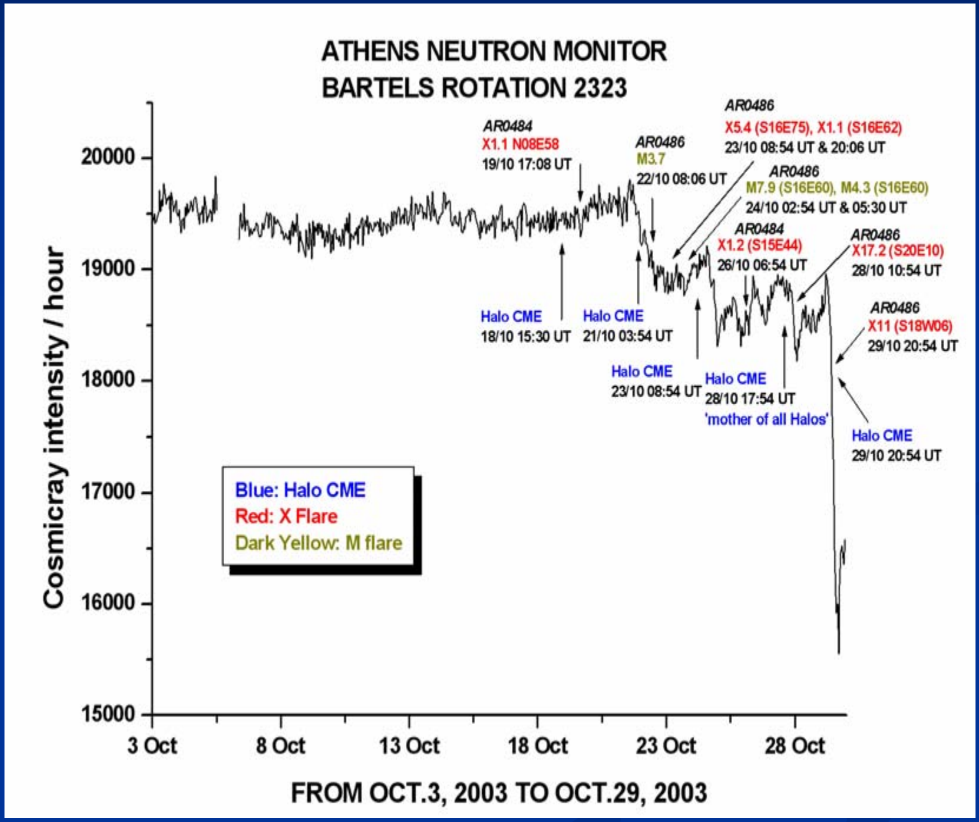
(Gerontidou et al., Solar Phys., 2004)

- **Study of electronics upgrade for NMs**

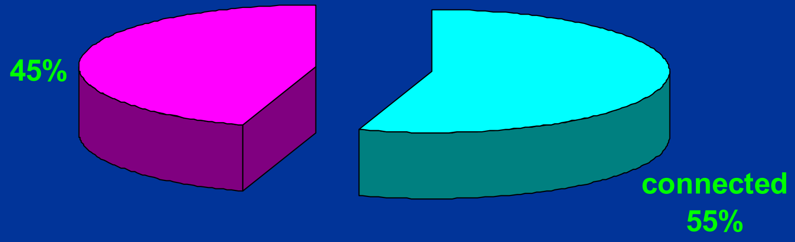
(Mavromichalaki et al, IEEE 2005)

Forbush decrease Oct - Nov 2003



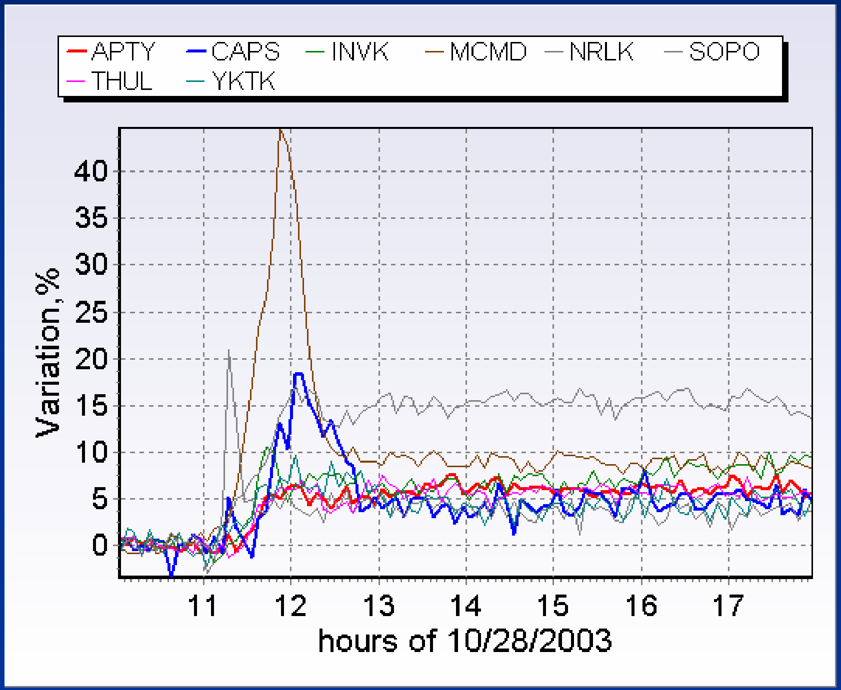


Forbush decreases to Halo CMEs



GLE65: 28 October 2003

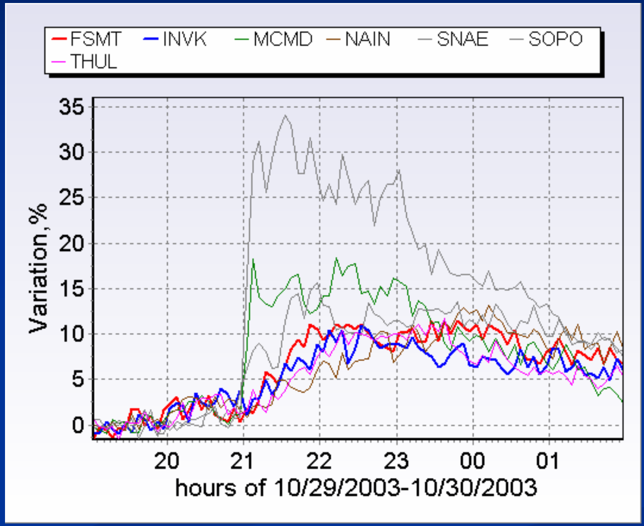
GLE 65 : Greek effect



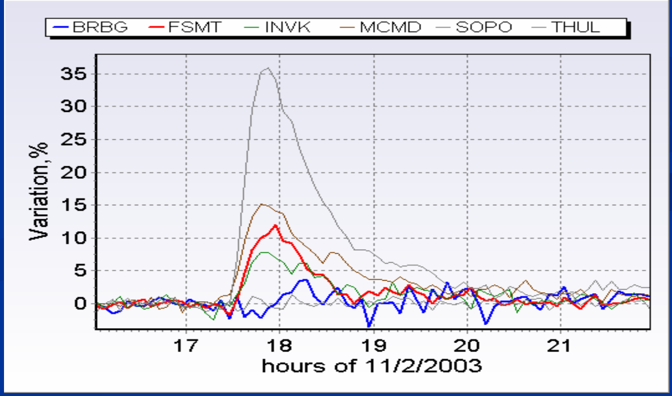
X17.2 Flare from AR 486

CME u~2459km/s

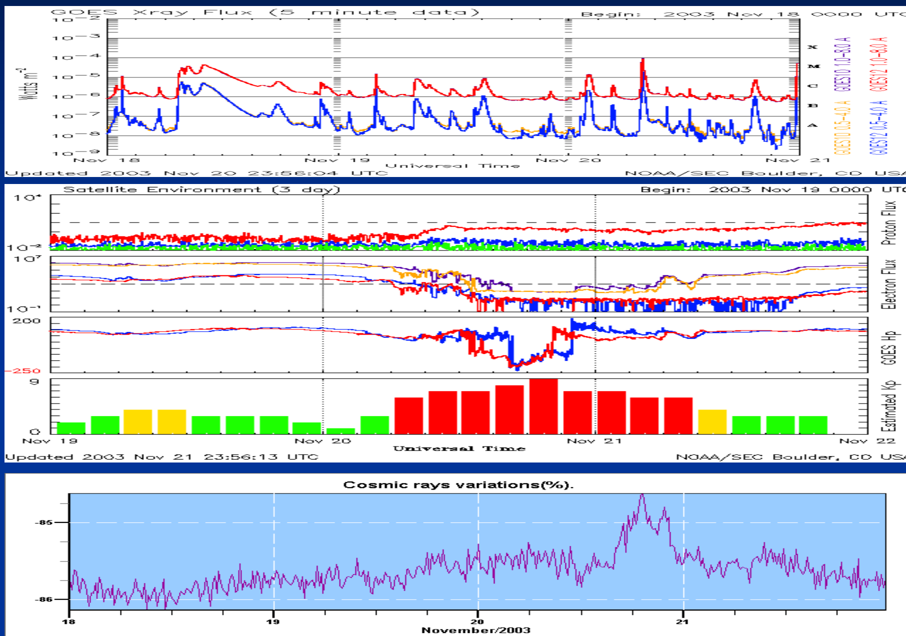
GLE66: 29 October 2003

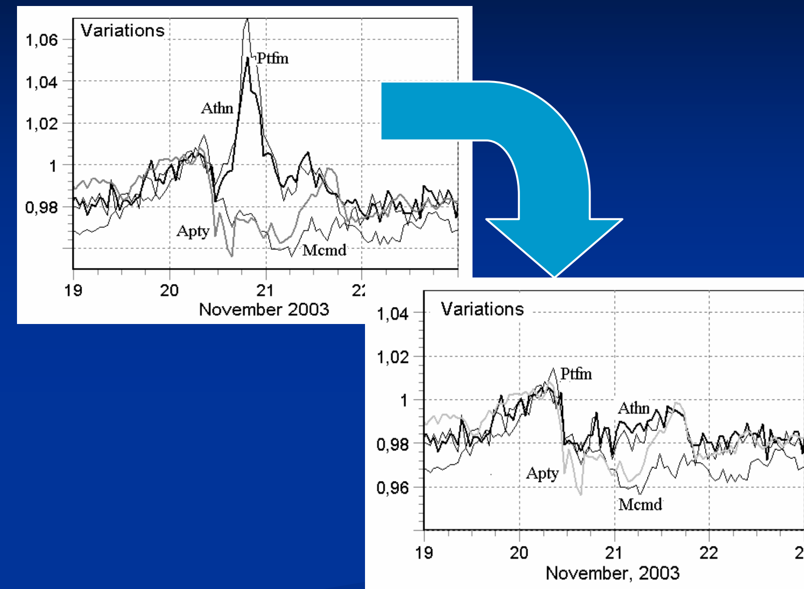


GLE67: 2 November 2003

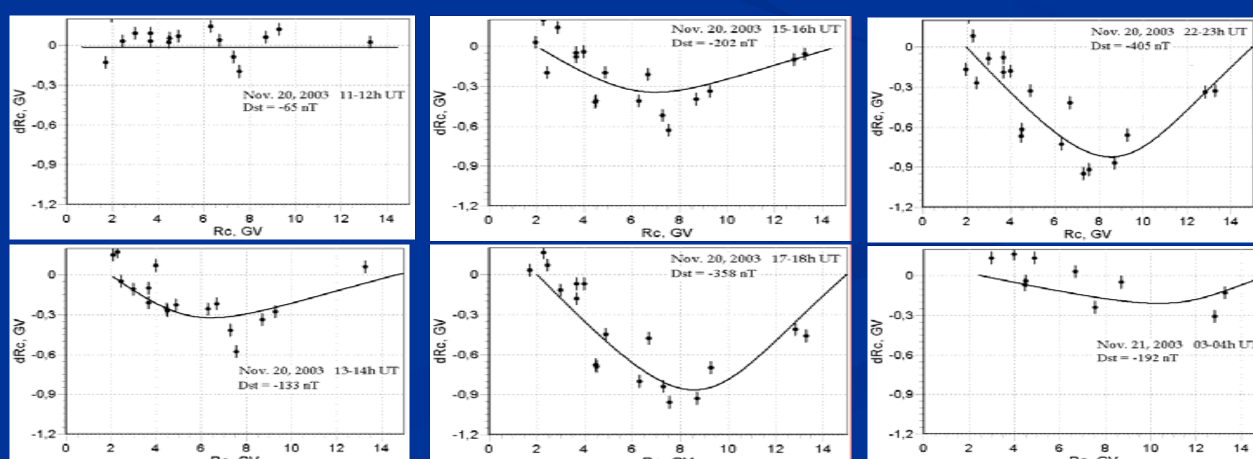


Geomagnetic effect on 20 November 2003



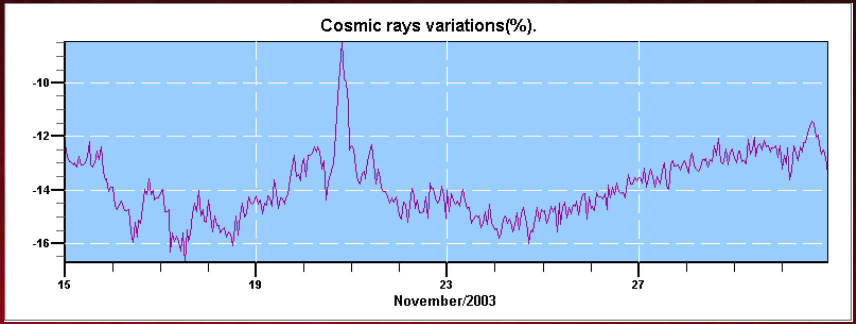


Variation of cutoff rigidity

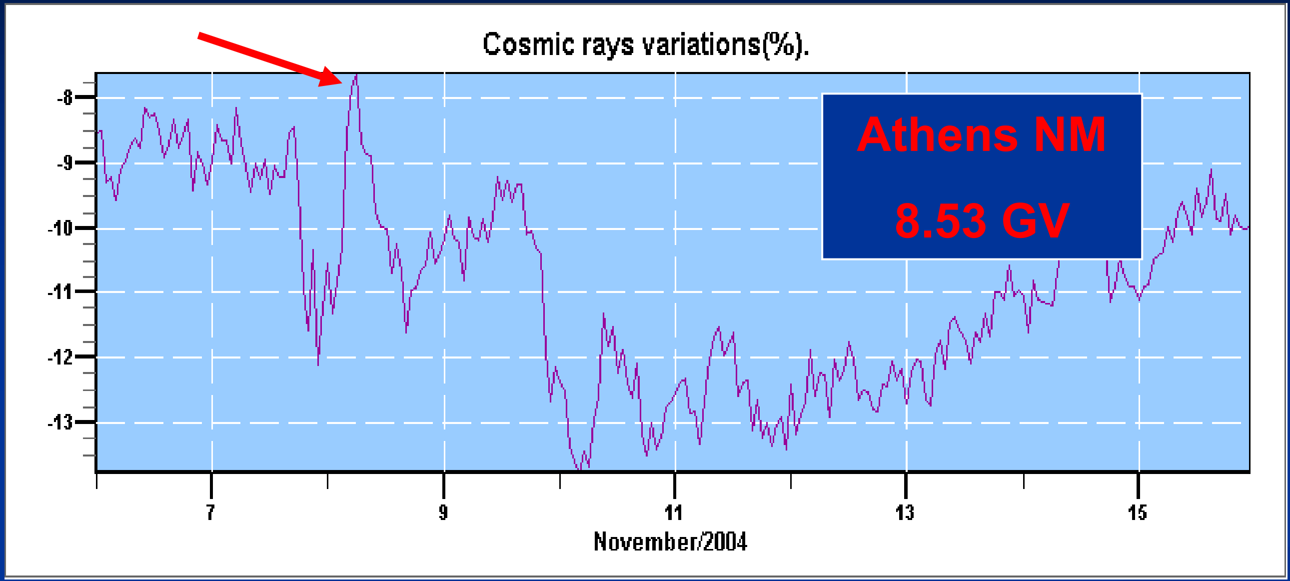


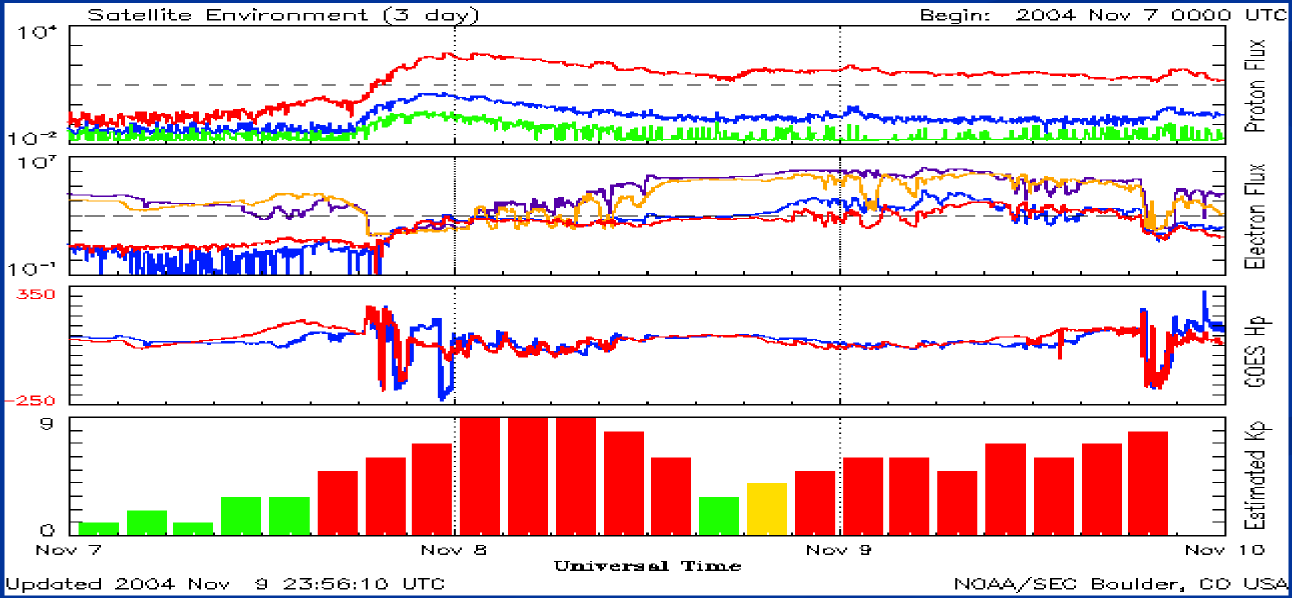
Aurora in Athens : 20 November 2003 !

Athens Neutron Monitor

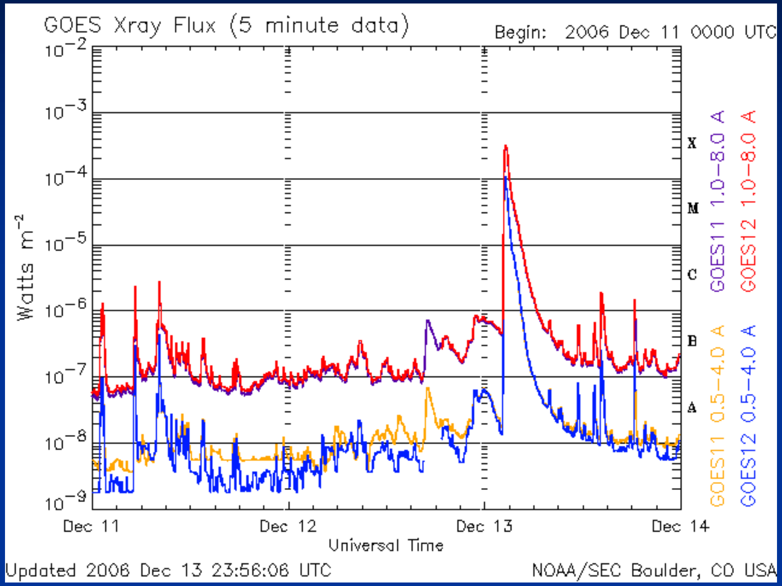


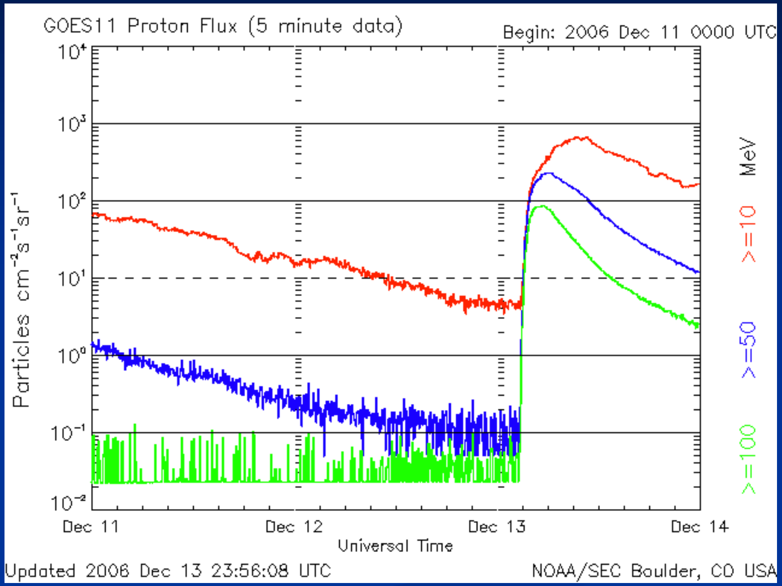
Geomagnetic effect : 9 November 2004

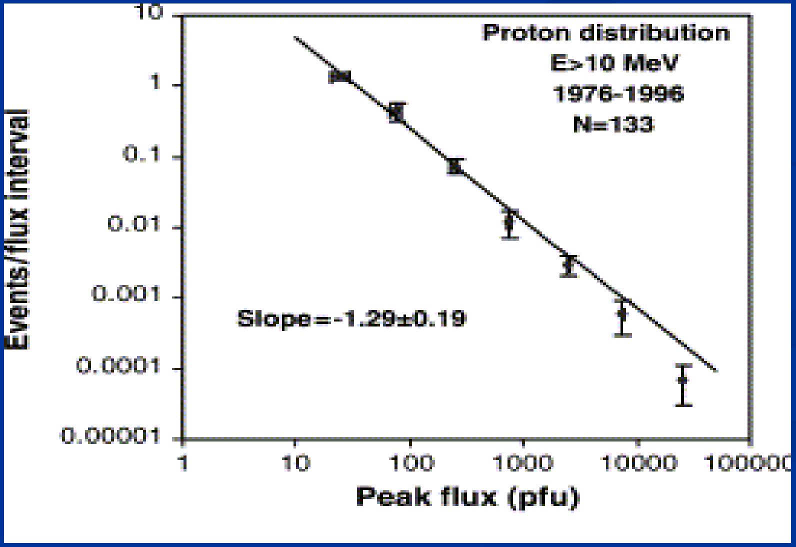




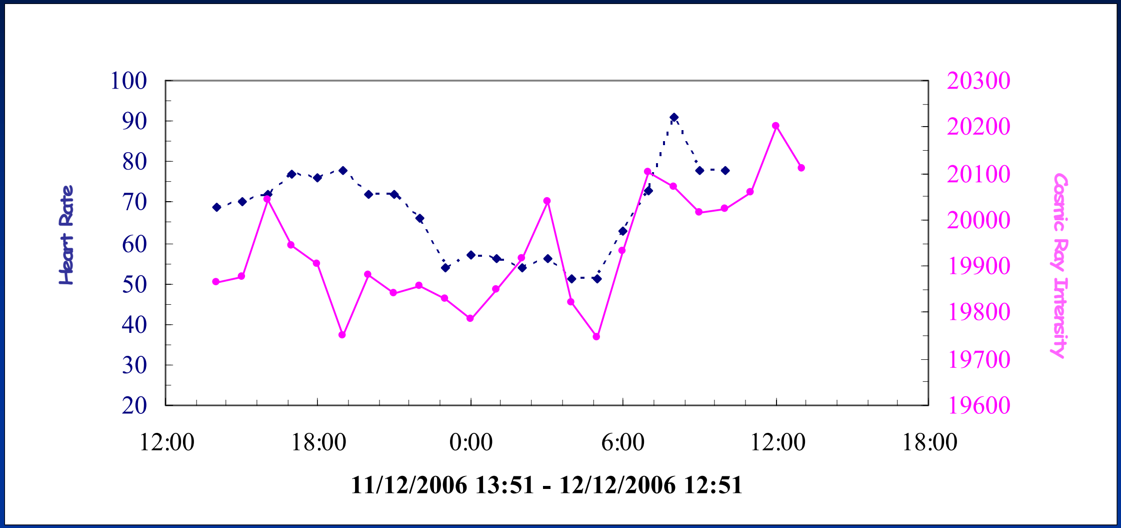
Database of Solar Proton Events

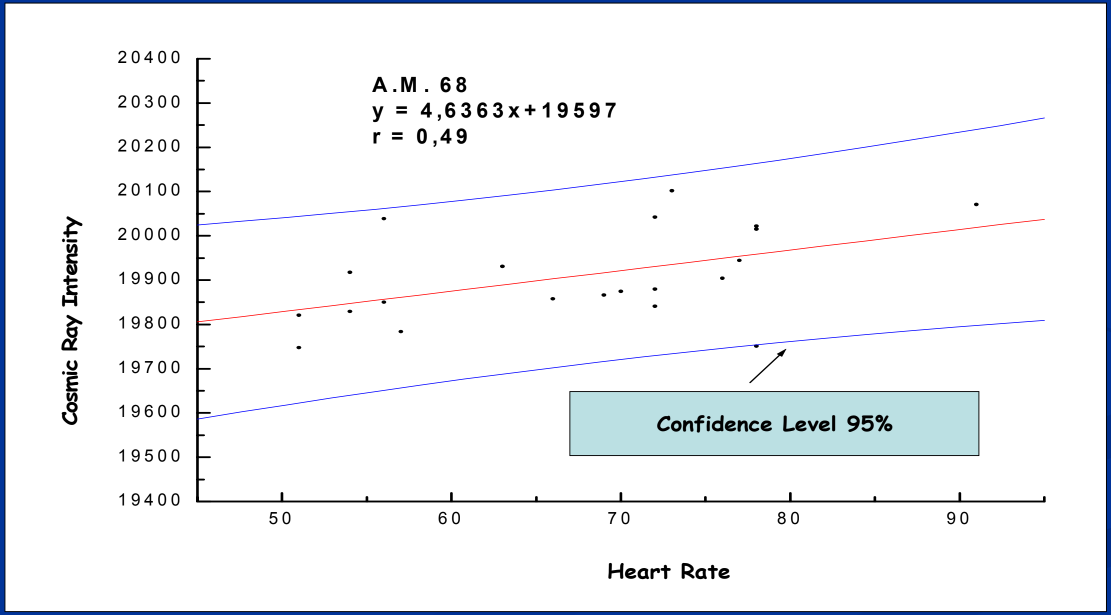






Biological Effects, December 2006





GLE Modeling NM-BANGLE Model

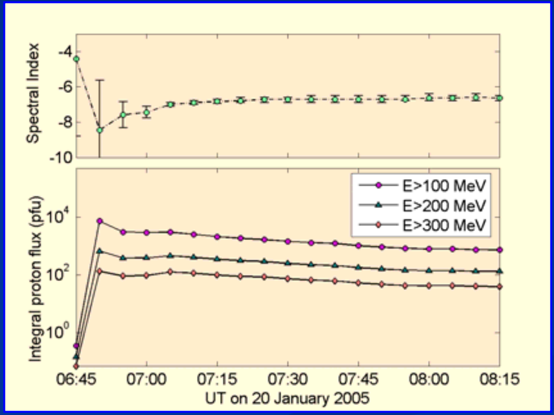
Results displayed for energies greater than 100 MeV, 200 MeV and 300 MeV are obtained by extrapolation

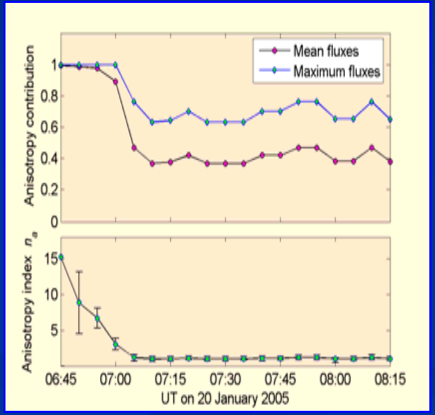
Integral proton fluxes

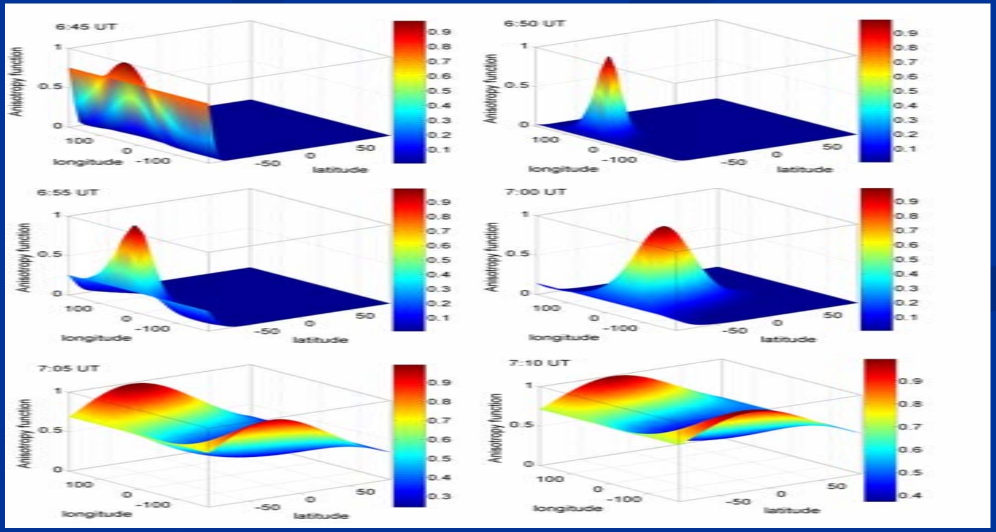
Spectral Index

CR Anisotropy

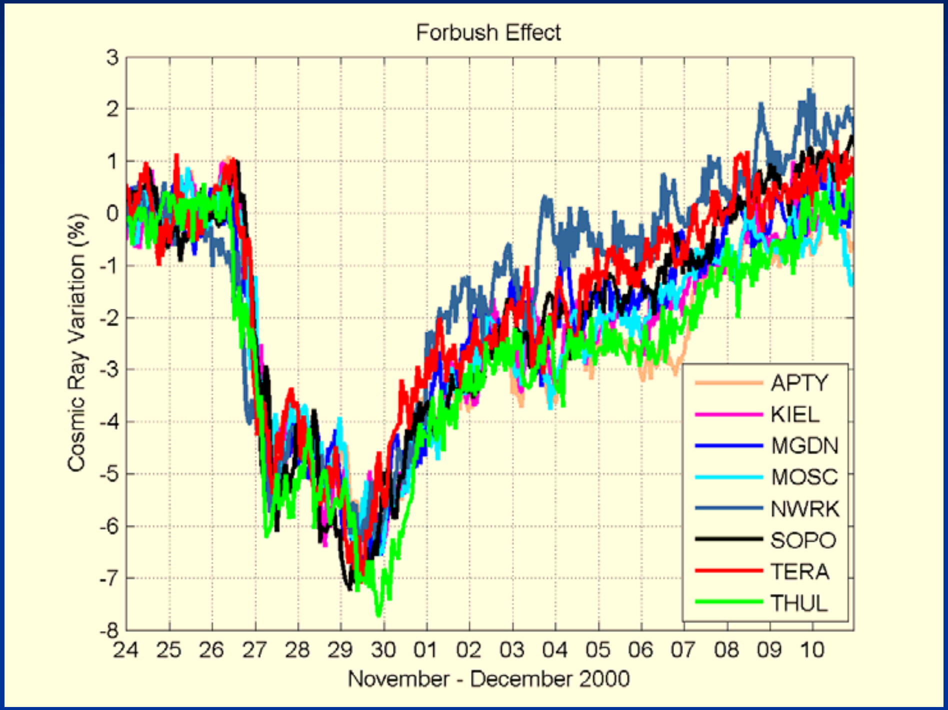
Position of the anisotropy

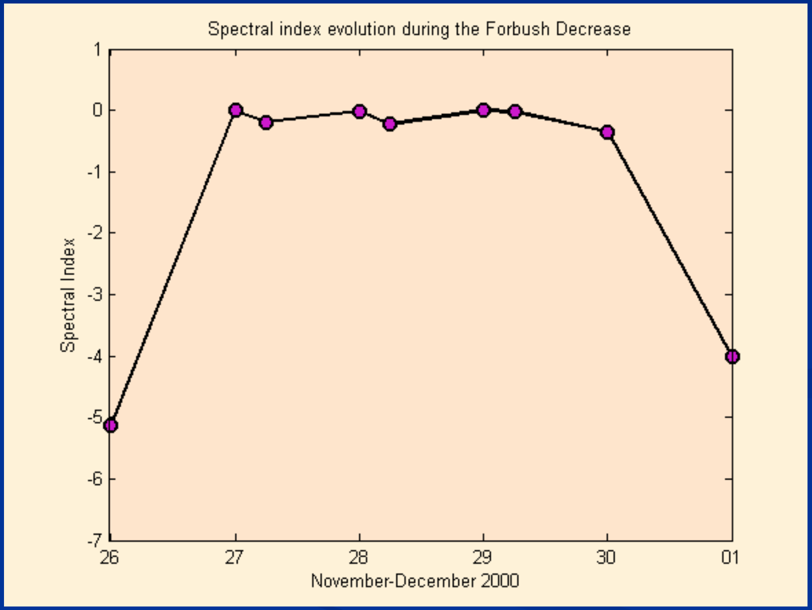






Cosmic Ray Variation Model - Preliminary





Onset time of the variation
(e.g. decrease)

Spectral Index

Applications

- **Derivation of the asymptotic directions of viewing**

(Plainaki et al., JGR, 2006)

- **Space Weather Monitoring – GLE-Alert**

(Mavromichalaki et al., Adv. Space Res., 2005; IEEE, 2006)

- **Cosmic Ray Variation Analysis**

(Papaioannou et al, SESWW 2005, Belov et al, ECRS 2006)

- **Geomagnetic effect analysis**

(Belov et al., Annales Geophys., 2005; JGR, 2005)

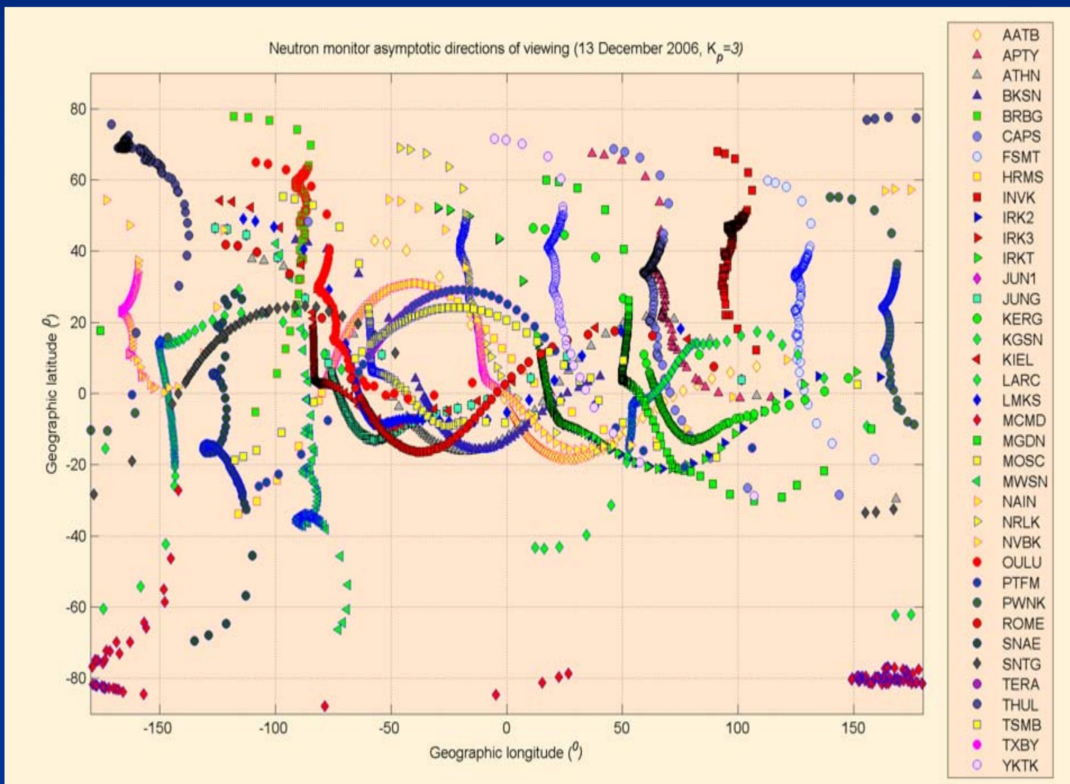
- **GLE-Study / NM-BANGLE Model**

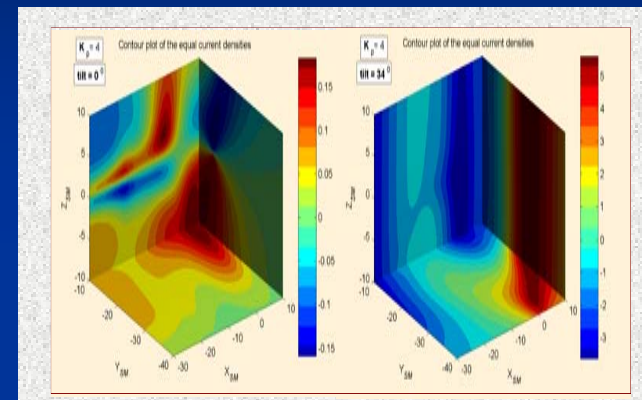
(Eroshenko et al., Solar Phys., 2004, Plainaki et al., JGR, 2006)

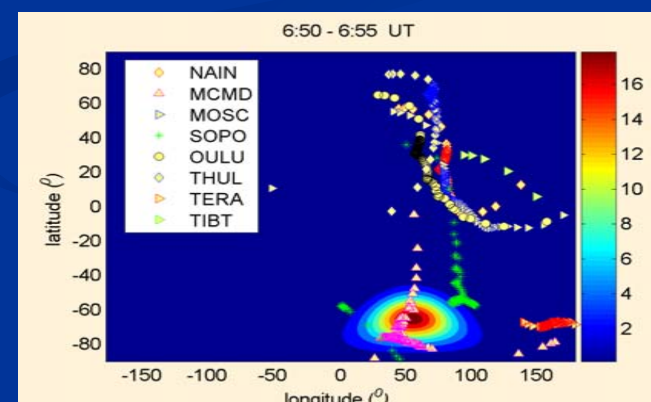
- **Radiation Dose Calculation**

(Mavromichalaki et al., IEEE, 2006)

Derivation of the asymptotic directions of viewing

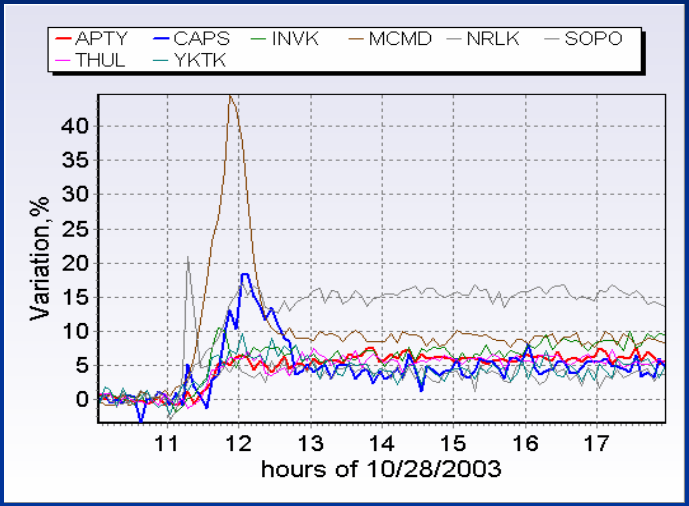


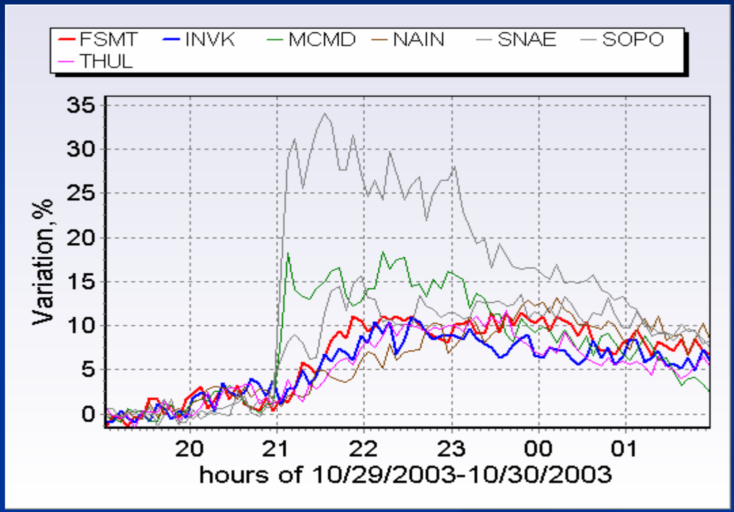




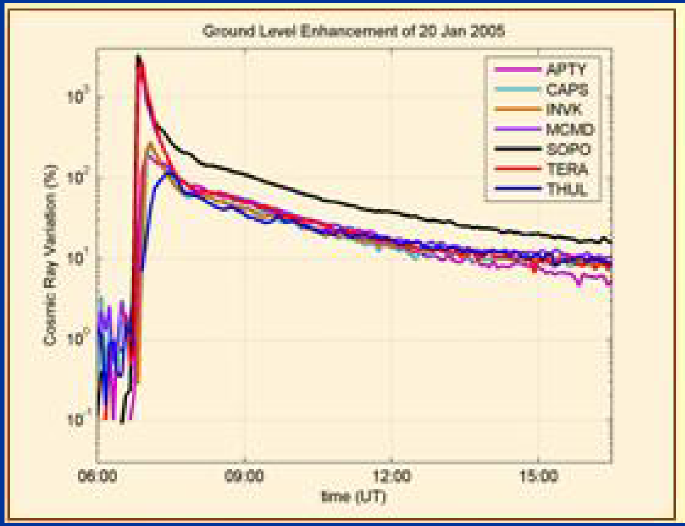
Solar Orbiter Workshop, 2006

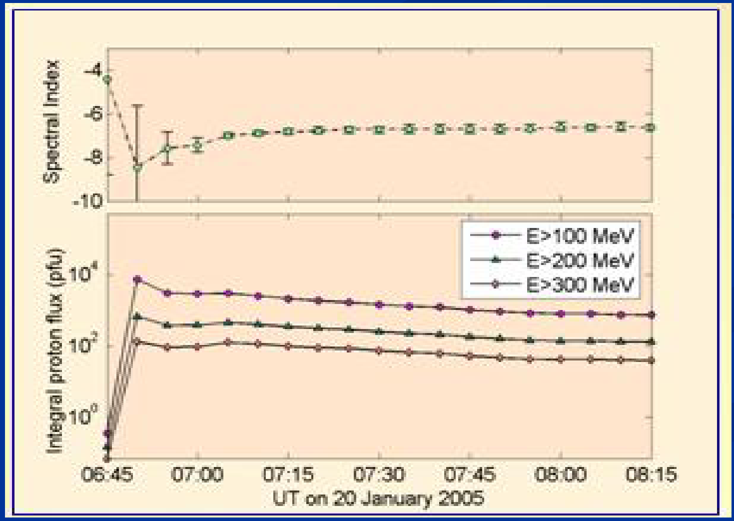
GLE Study – NM BANGLE





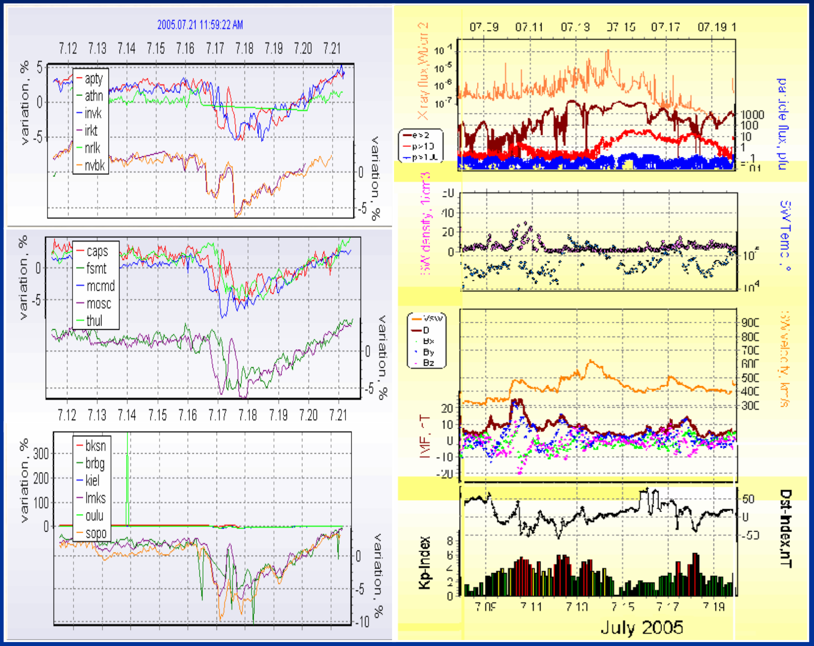
COSPAR 2004

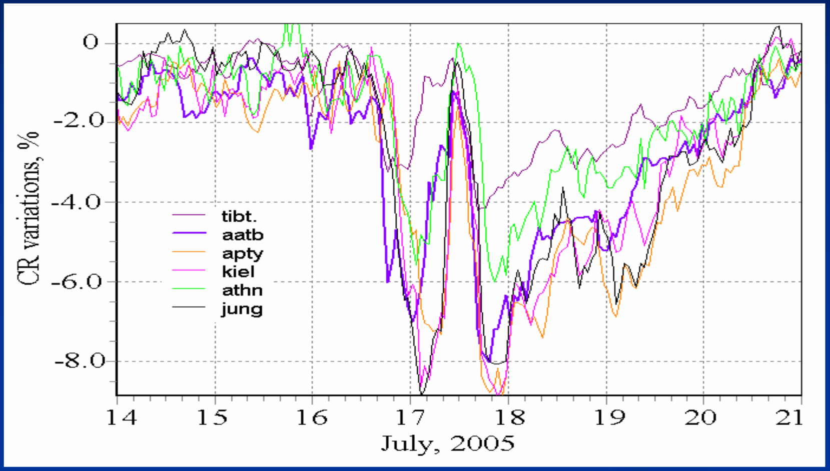




ECRS 2006

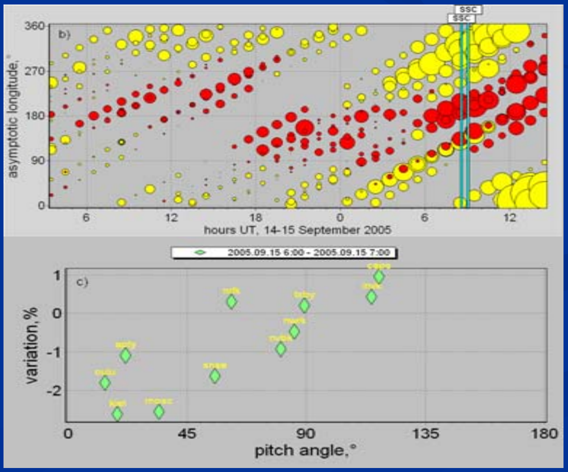
Cosmic Ray Variation Analysis

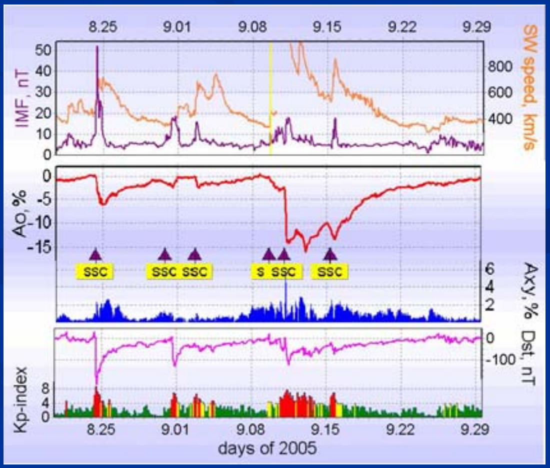




Second ESWW ,2005

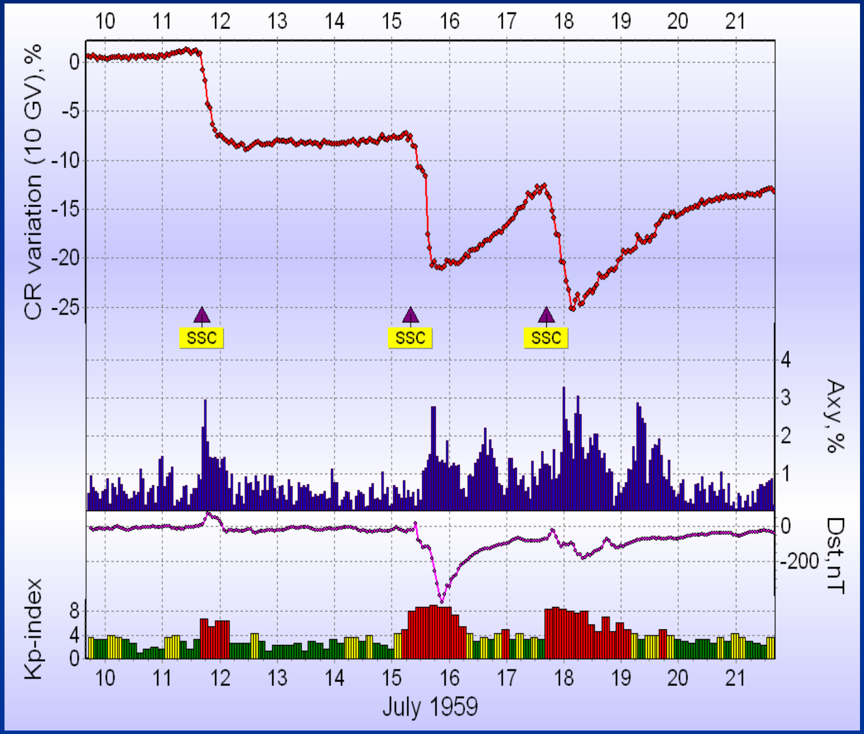
Interplanetary disturbances				Associated flares					FE		Kp	Dst
Date	Time (UT)	Vm (km/s)	VH	Date	Time (UT)	Lat. (°)	Long. (°)	Import	A0 (%)	Axy (%)		(nT)
24.08	4:43	1113	18.7	22.08	16:46	13°S	65°W	M5.6	6.4	2.61	8.67	-216
09.09	14:01	931	3.21	07.09	17:17	11°S	77°E	X17.0	3.2	2.37	5.67	-60
11.09	01:14	1328	8.89	09.09	19:13	12°S	67°E	X6.2	12.1	5.84	7.67	-123
12.09	06:00	1282	4.77	10.09	21:30	13°S	47°E	X2.1	5.1	2.87	7	-84
15.09	09:04	1118	1.53	13.09	19:19	10°S	09°W	X1.5	4.2	1.52	3.33	-38

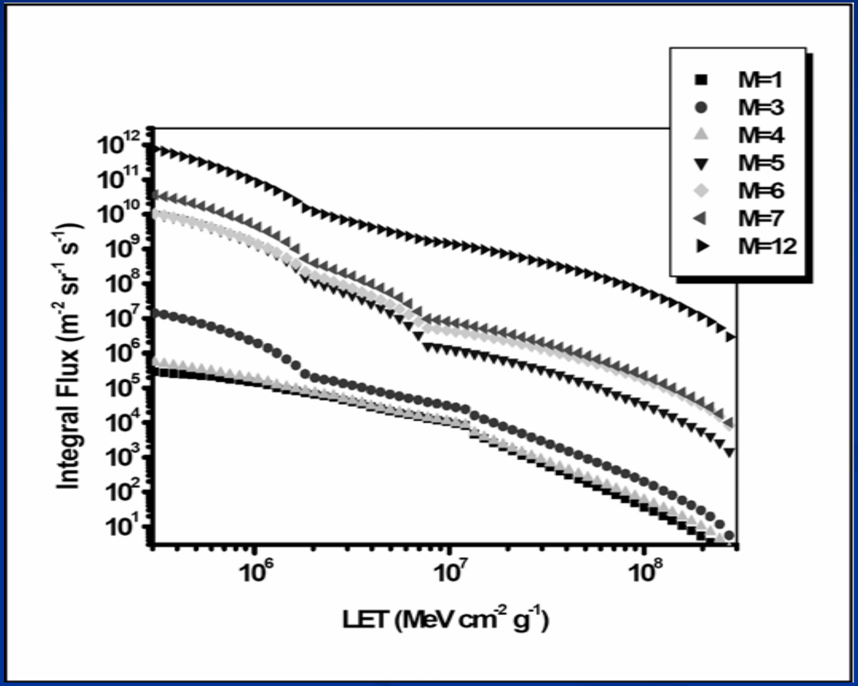




ECRS,2006

Radiation Dose Simulations

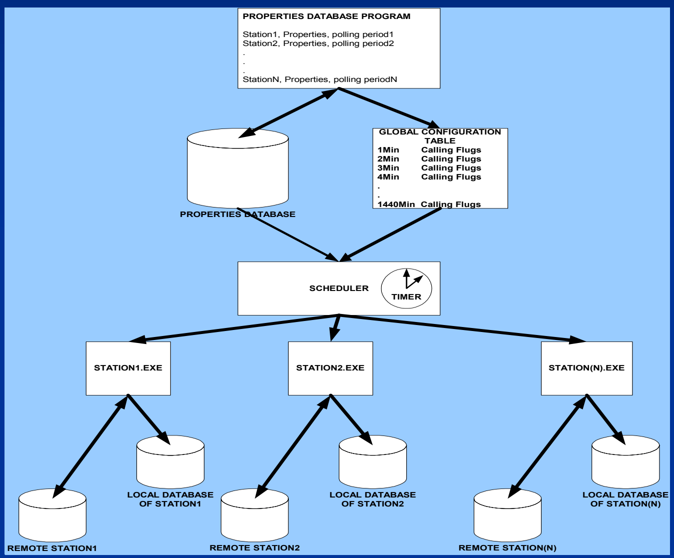


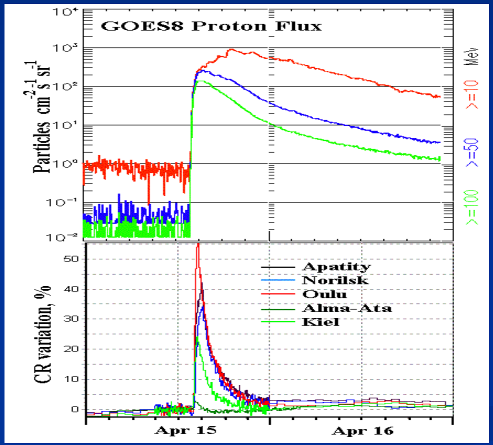


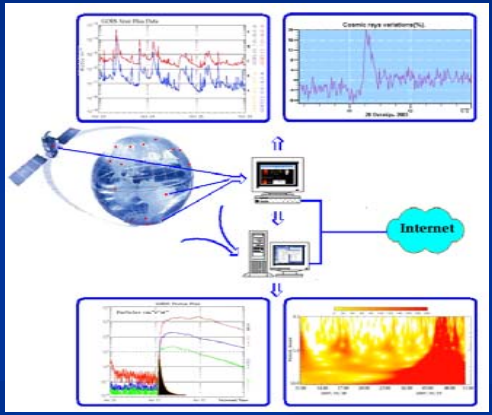
RADECS, 2006

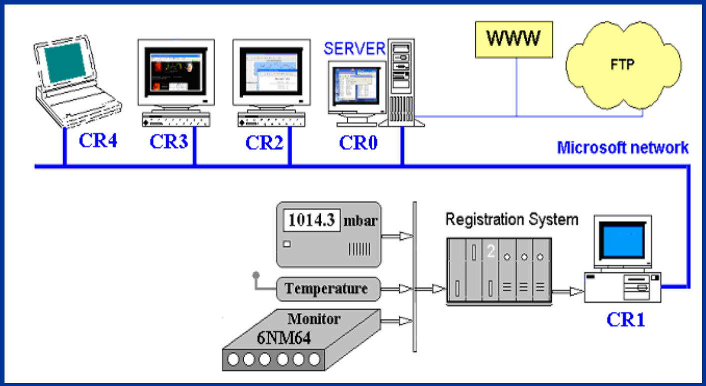
Space Weather Monitoring

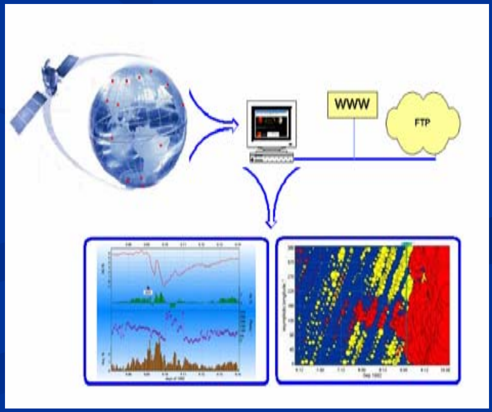
COSPAR, 2004, ESWW 2004







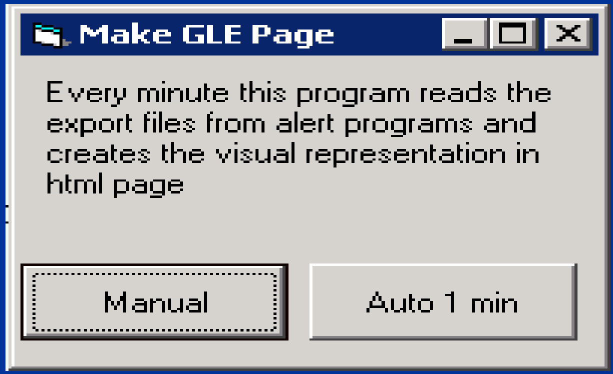


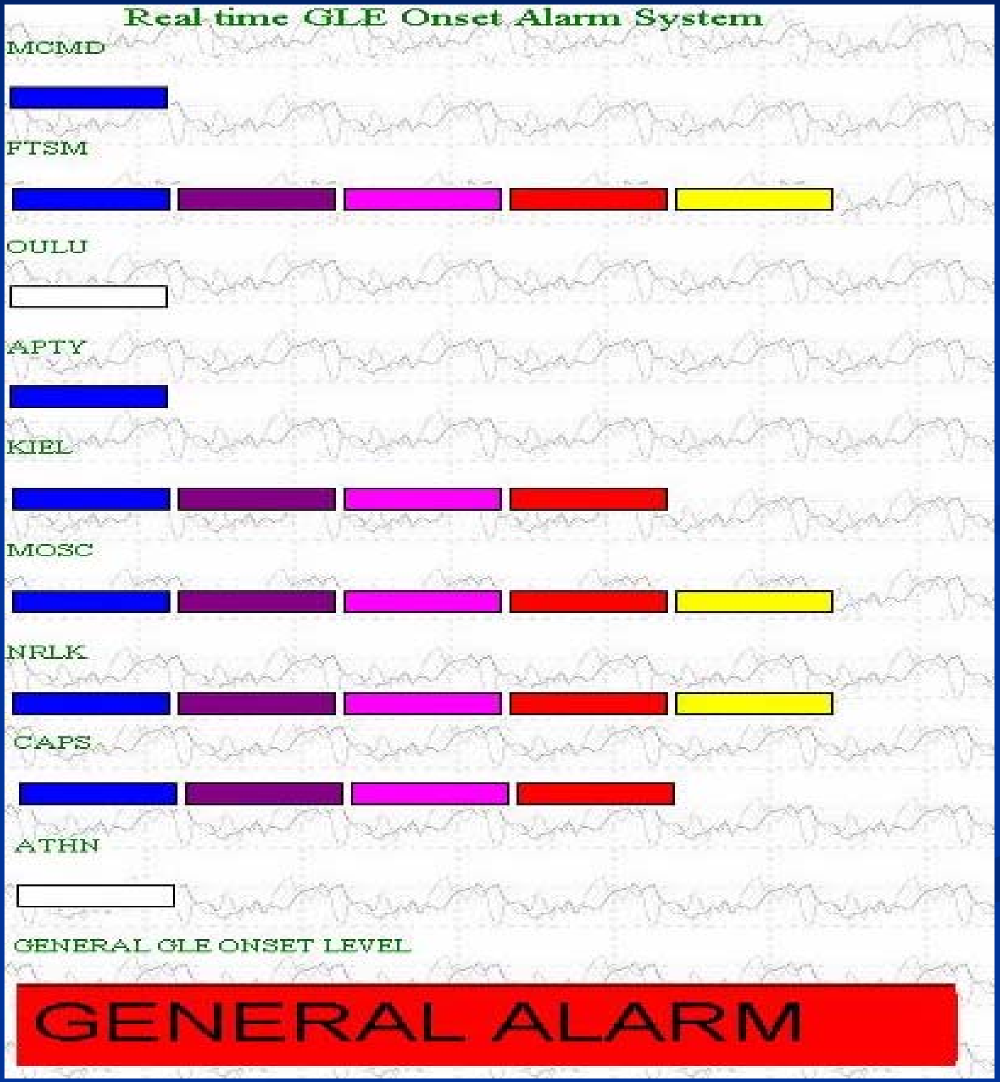


Network Presentation of Alert evolution

The network presentation of the GLE alert created with a program named **Make_Page** this program every minute creates a web page that describes the status of every station that participates the GLE alert network

Every bar presents a pre-alert point





Summarizing

- The Athens NM station, provides the scientific community with analytical studies on **Cosmic ray variations** (Forbush decreases; GLEs), **Geomagnetic Effects**, **Great Solar Proton Events**, **Biological impact** of CRs & **Radiation dose** estimations of GCR.

- Modeling of significant CR events as Ground Level Enhancement (**NM-BANGLE**), and Cosmic Ray Variations (**FORD**) has been realized.

- Moreover, an **Alert algorithm** has been developed and tested, providing the Onset of either a geomagnetic storm or GLE

- The Athens Neutron Monitor Data Processing Centre (**ANMODAP**) based on the activity of the cosmic ray group in Athens University, provides real time monitoring of cosmic ray variations.

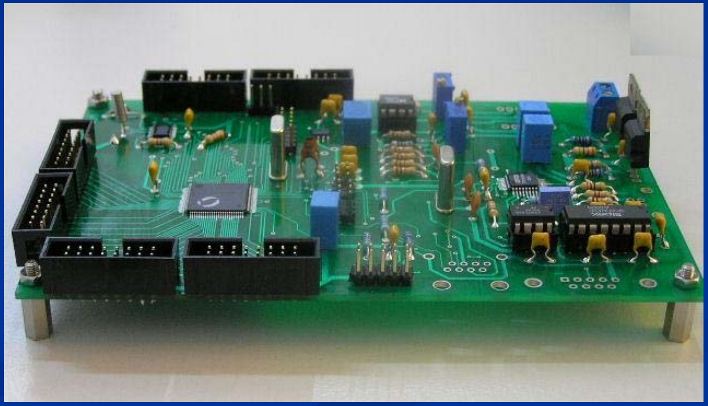
- Data from 21 real-time NM stations as well as satellites are used in ANMODAP in order to forecast: a) GLE onset b) Geomagnetic storm onset.

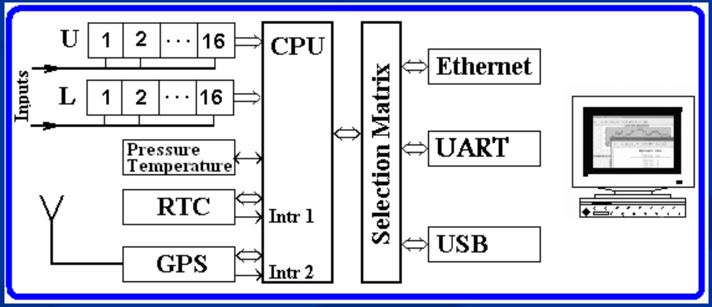
What Next?

System of data accumulation for multidirectional muon telescopes and neutron monitor stations

Properties

- ❑ Hard real time implementation
- ❑ GPS synchronization and time stamping
- ❑ Ethernet connectivity – Internetwork ready
- ❑ µsec accuracy event recording
- ❑ Analog parameters measurement and recording
- ❑ Very low power consumption
- ❑ Portability - mobility





In co-operation with IZMIRAN

What Next?

A Study for an Unmanned Aerial Vehicle carrying radiation spectrometer networked to the new Athens Center applied to Space Weather events forecasting

- ❑ The LET radiation spectrometer advantages are:

- o The very small dimensions, weight and power consumption.
- o The UAV, powered from photovoltaic generators, flying on high altitudes with propellers on small electrical motors
- o carrying simple networking equipment
- o will be achieve long range telecommunication links with terrestrial footprint larger than Greece .

In co-operation with TEI of Pireus & NASA Radiation Office

What Next?

A combination of the GLE-Alert system with the NM-BANGLE model, in real-time, has been planned. This will provide Solar and Atmospheric parameters and will give the possibility for a reliable space weather prognosis of the arrival of dangerous energetic particles for human health and electronic components and systems.

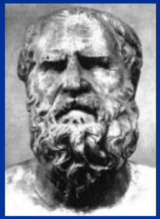
A collaboration of several countries regarding the Biological effects of Cosmic rays, has been planned for the near future

Funded Research

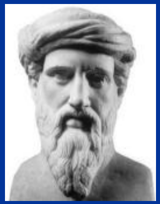
Recent projects

PENED, 2003-2006

Heraclites 2003-2006



Pythagoras, 2005-2007



FP7 - NMDB, 2008-2010

Collaboration

COST Action

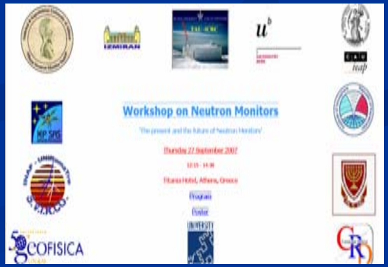
Organized Workshops & Conferences

RADECS, 2006

Real Time NM database, 2007

SEE, 2007

NMDB, 2007



NM workshop, 2007

Athens Neutron Monitor Station (2006)

RADECS 2006

Athens Neutron Monitor Station (2007)

COST-724
Workshop

Thank you

For your attention & your participation to this workshop