Establishing and Using the real-time Neutron Monitor Database (NMDB)

H. Mavromichalaki, M. Gerontidou, G. Mariatos, M. Papailiou, A. Papaioannou, C. Plainaki, C. Sarlanis, G. Souvatzoglou for the NMDB team

Nuclear and Particle Physics Section, Physics Department, Athens University
Pan/polis15771 Athens, GR (emavromi@phys.uoa.gr)

Outline

- Introduction

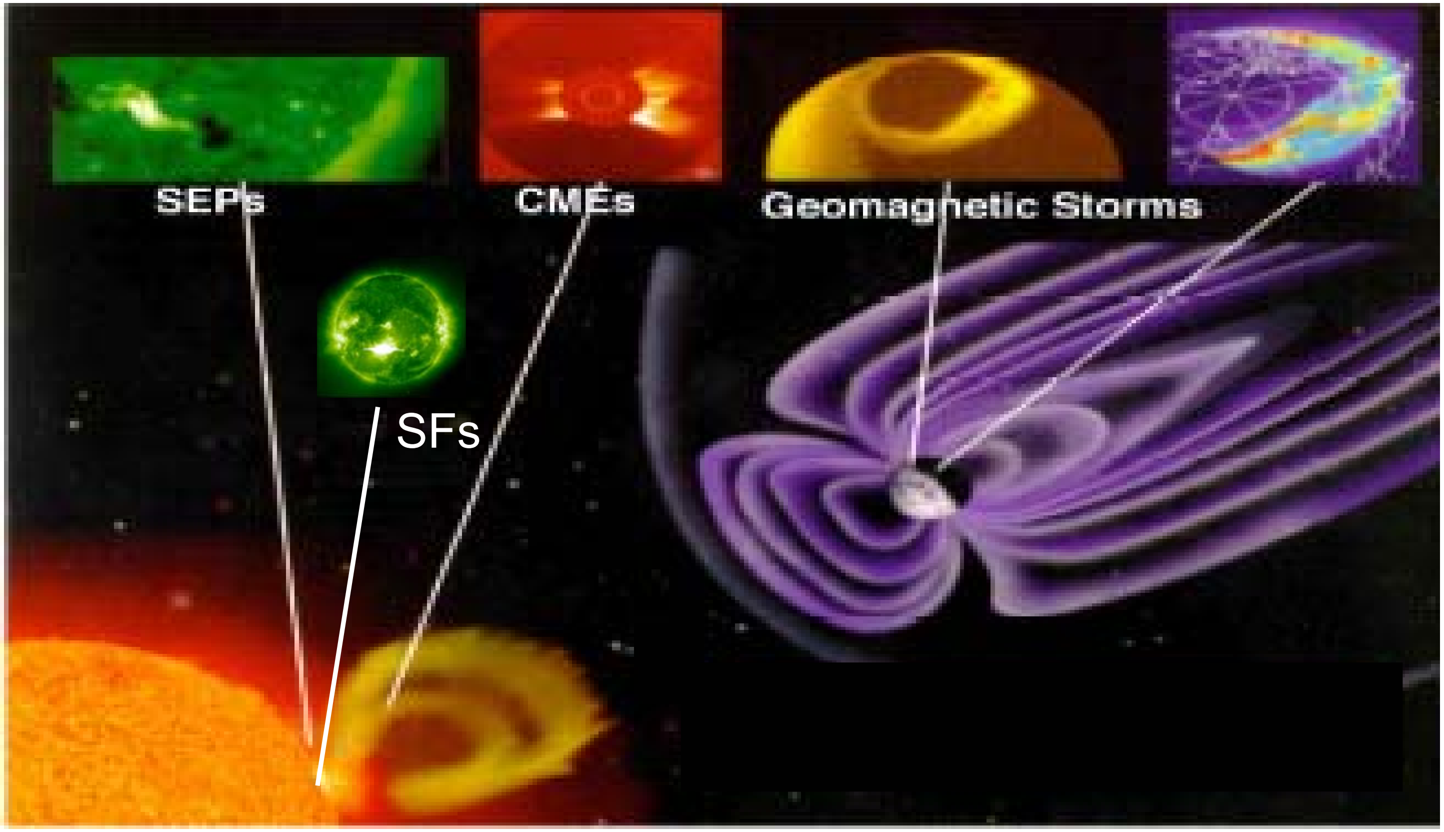
  - ✓Sun, Earth & Cosmic Ray Connection
  - ✓Cosmic Ray Travel
  - ✓Cosmic Ray Spectrum
  - ✓Cosmic Ray Shower
  - ✓Neutron Monitor
  - ✓Cosmic Ray Modulation
  - ✓Neutron Monitors Distribution

- NMDB

  - ✓Background of the project
  - ✓Structure of NMDB
  - ✓Goals of the project
  - ✓Creating the database
  - ✓Using NMDB / User tools
  - ✓Applications with 1-min real-time data

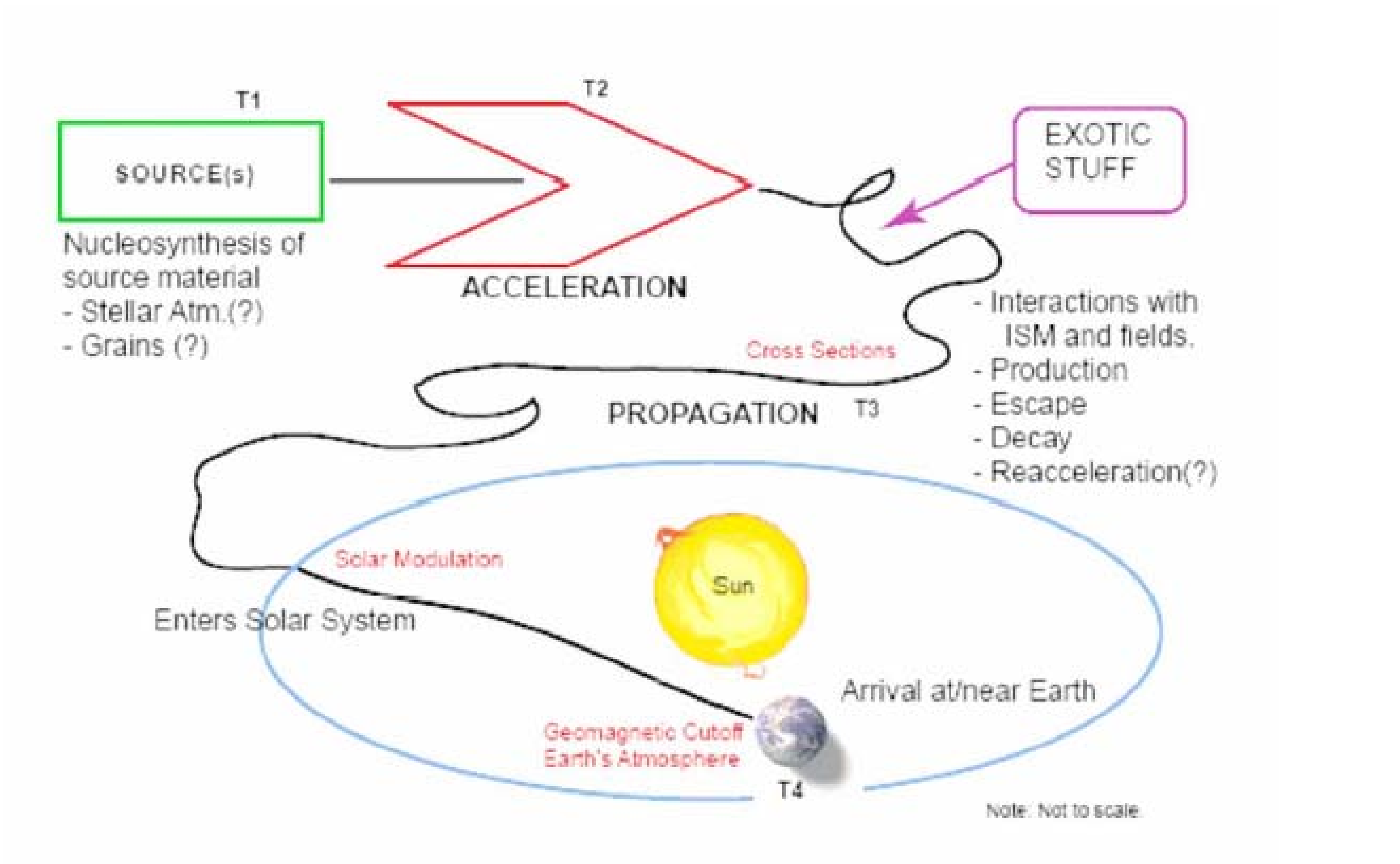
- Conclusions

Sun-Earth & Cosmic Ray Connection



The Sun produces energetic particles and cosmic rays and modulates the galactic cosmic ray flux

Cosmic Ray Travel



Integral Spectrum of Cosmic Rays

Primary Cosmic Rays

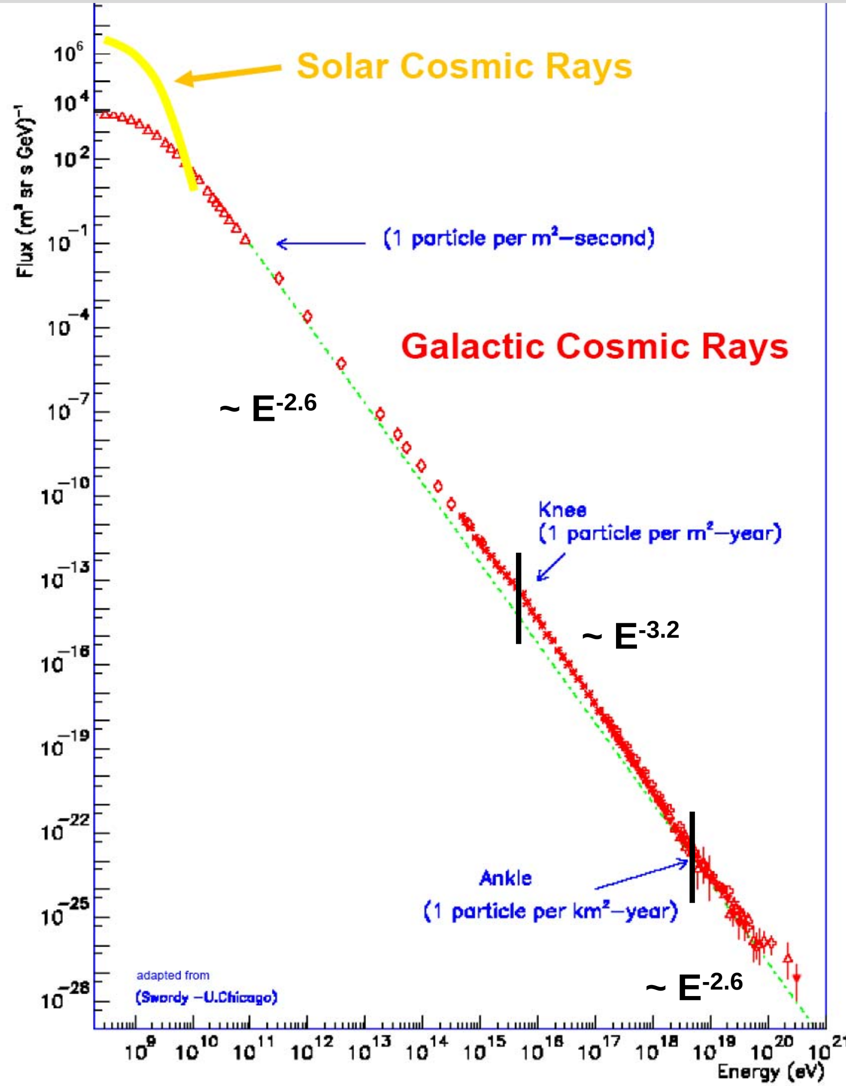
90 % protons
9 % a particles
1 % heavier nuclei

Energies: 10^6 – 10^{21} eV

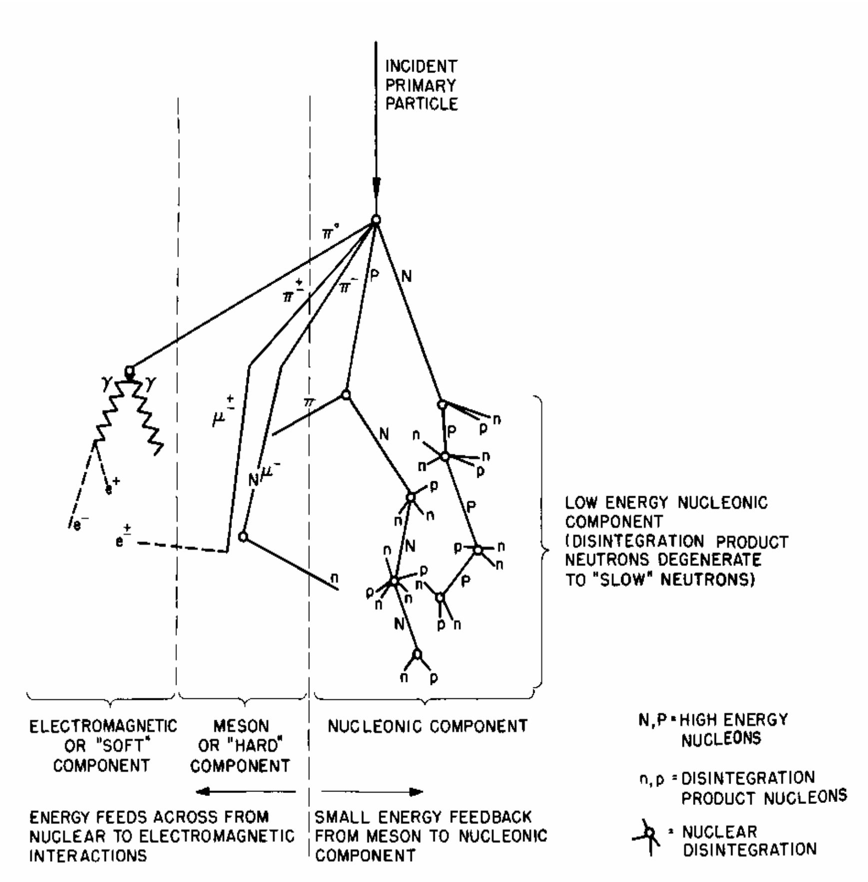
10^9 -10^{15} eV: γ ~ 2,6

10^{15} – 10^{18} eV: γ ~ 3,2

> 10^{18} eV: γ ~ 2,6

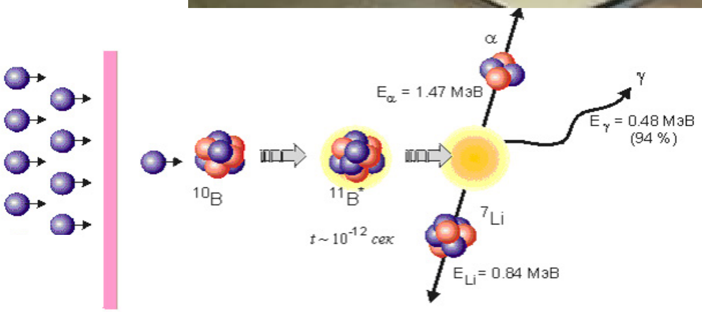


Cosmic Ray Cascade /Neutron Monitors



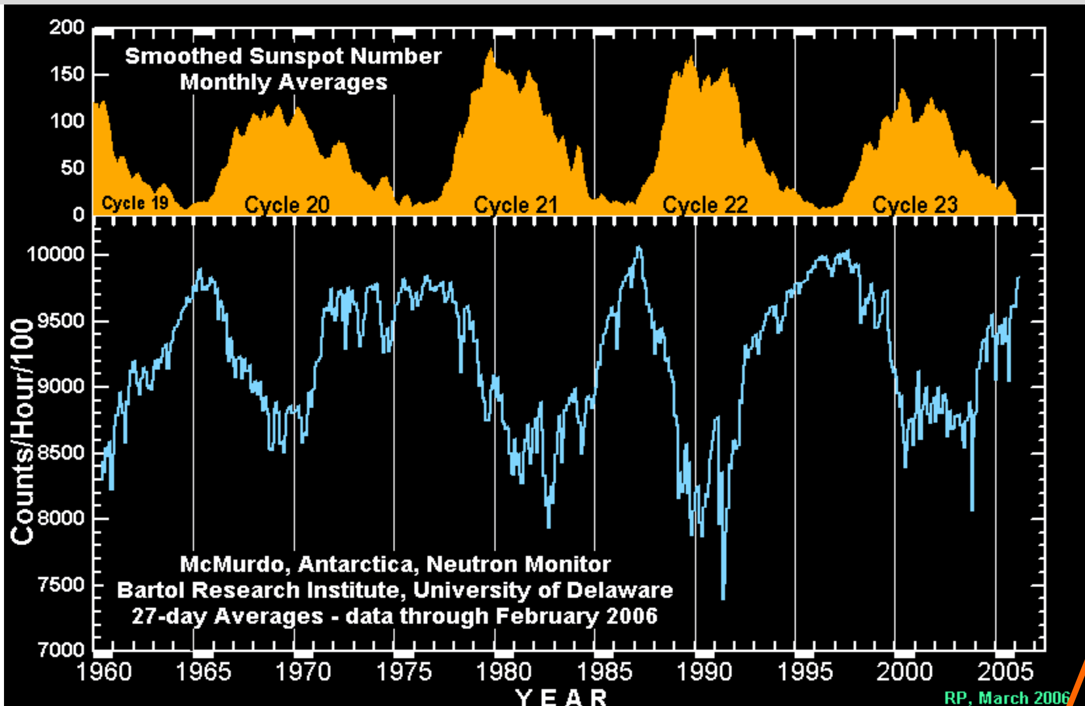
Schematic Diagram of Cosmic Ray Shower

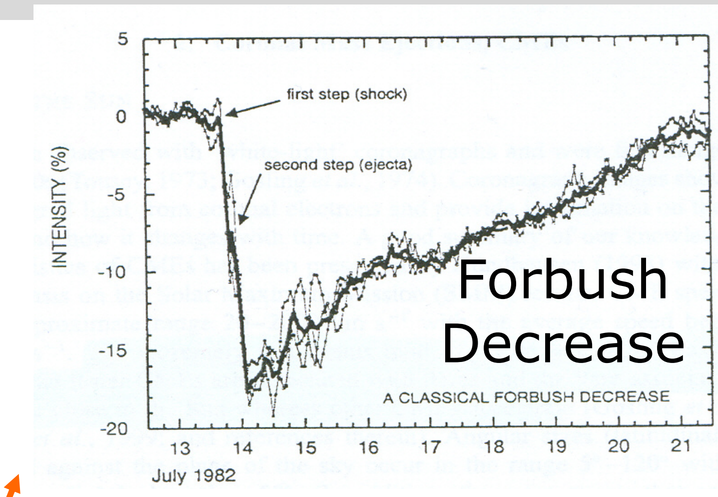
✓ Neutron monitors are standard devices located at different points on the globe.



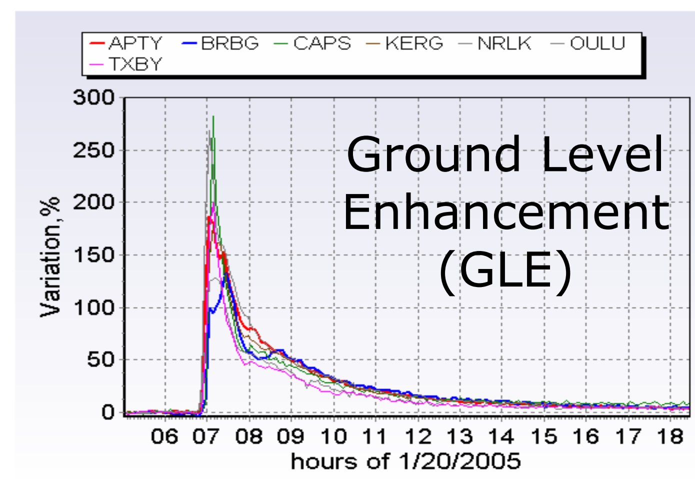
$$ {}^{10}_{5}B + {}^{1}_{0}n \rightarrow {}^{11}_{5}B \begin{cases} \rightarrow {}^{7}_{3}Li^{*} + {}^{4}_{2}a + Q_1 \ (94\%) \\ \rightarrow {}^{7}_{3}Li + {}^{4}_{2}a + Q_2 \ (6\%) \end{cases} $$

Cosmic Ray Modulation





Forbush 1957; Belov 2001

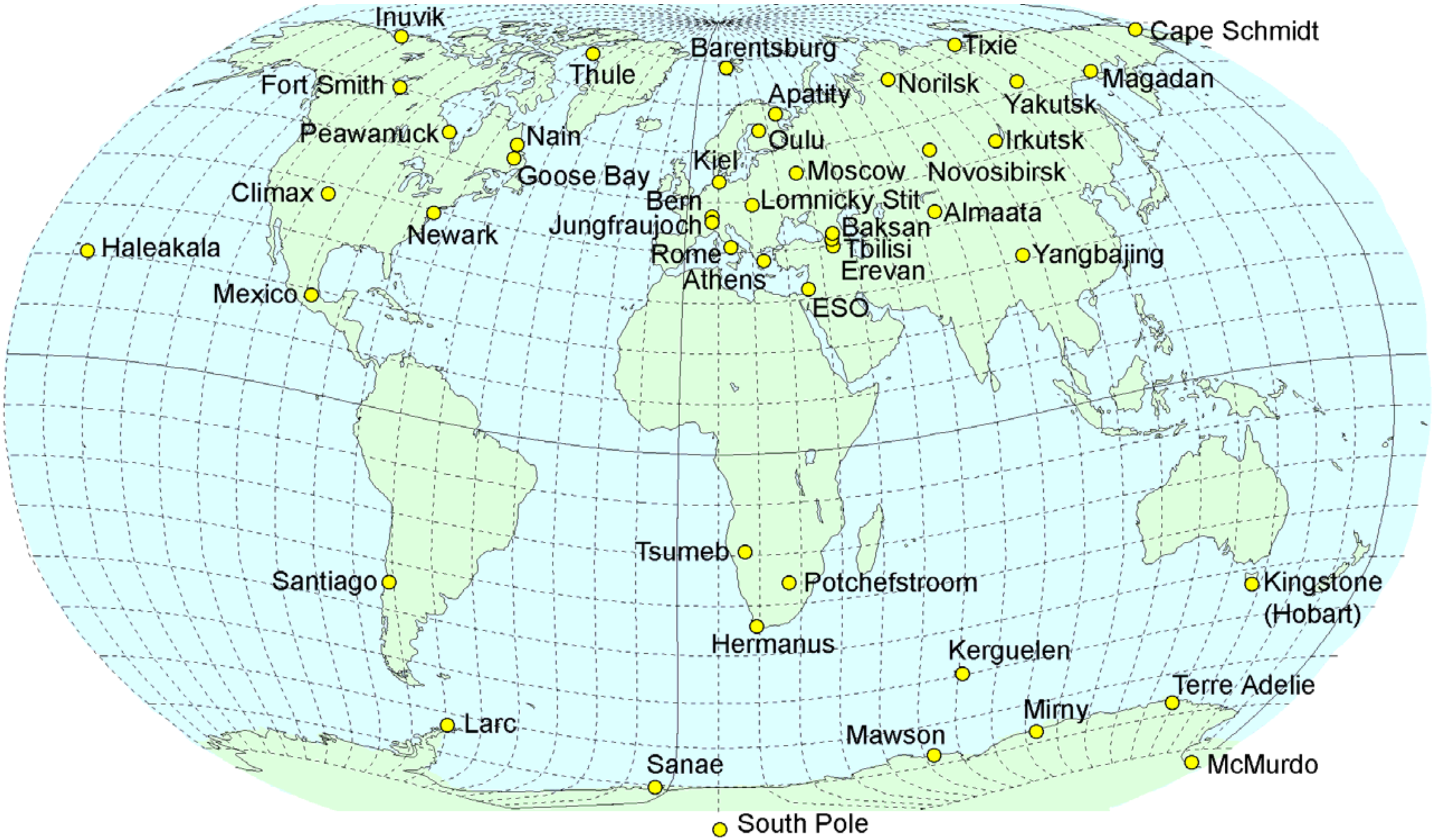


Bonrie et al. 2001

Modulation of Cosmic Rays

Heliospheric phenomena
registered at Earth

Neutron Monitor Distribution



Real-time Neutron Monitor Database (NMDB)

http://www.nmdb.eu

- 12 partners
- 28 NM stations in real-time

Background of the project

NM Advantages

- Cosmic ray intensity has been continuously measured with Neutron monitors since the International Geophysical Year 1957/58
- Approximately 50 Neutron monitors are operating worldwide
- Neutron monitors measurements can not be scrambled by any intense event
- Cost-effective reliable detectors
- Wide detection range
- Ready to use

What did we need to take care of

- High resolution data (1-min or better) are needed to study solar cosmic ray events
- Only few NM stations could provide data in real-time
- No common data format, no data center for high resolution data in real time
- No common real-time applications

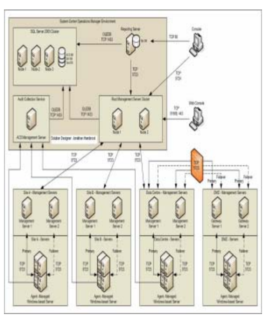
NMDB structure

NMDB

WP1 | **WP2** | **WP3** | **WP4** | **WP5** | **WP6**

WP1 leader **CAU**

Management

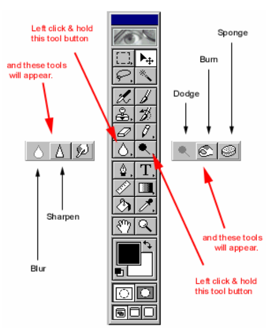


WP2 leader **CAU / ALCALA**

Architectural Design

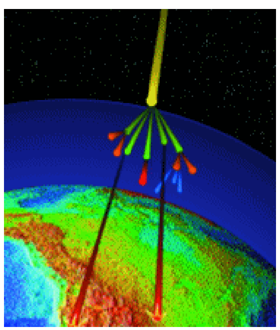
WP3 leader **NKUA**

Data Acquisition



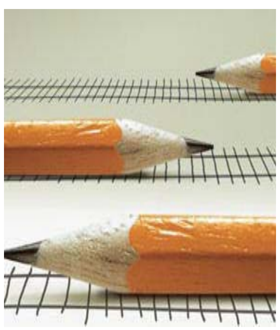
WP4 leader **OULU**

User Tools



WP5 leader **IZMIRAN**

Applications



WP6 leader **OBSPARIS**

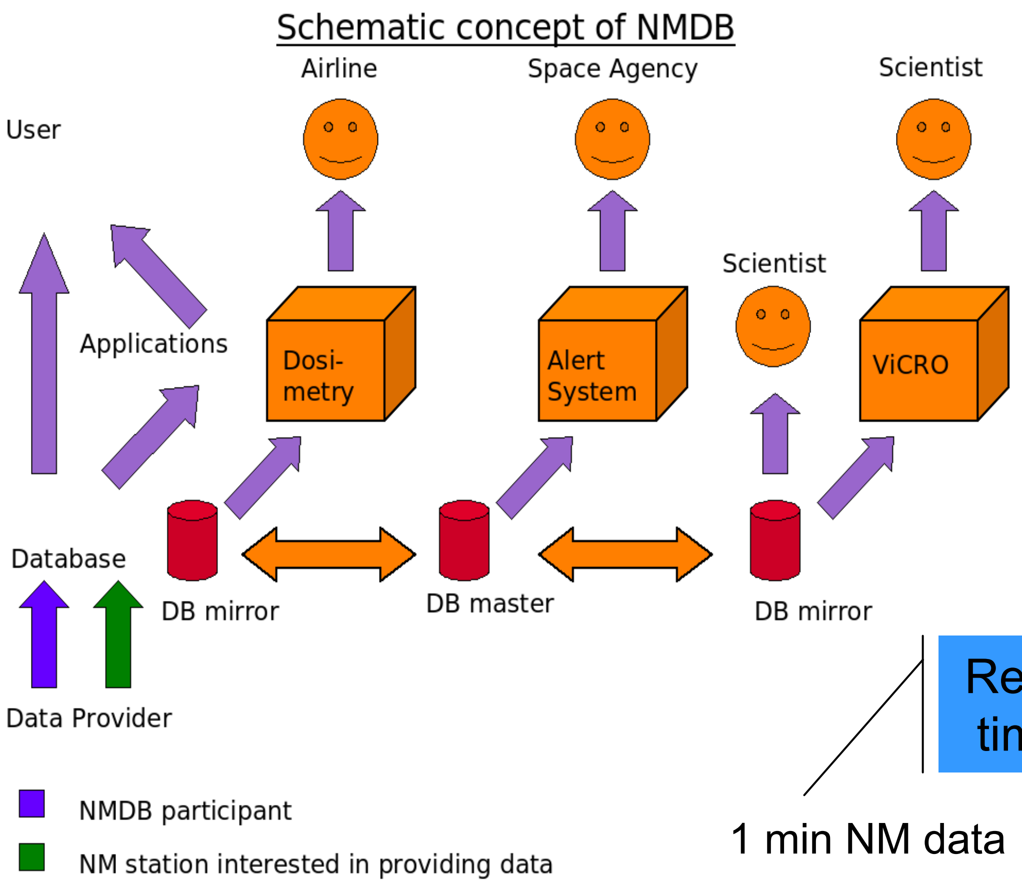
Education/ Outreach

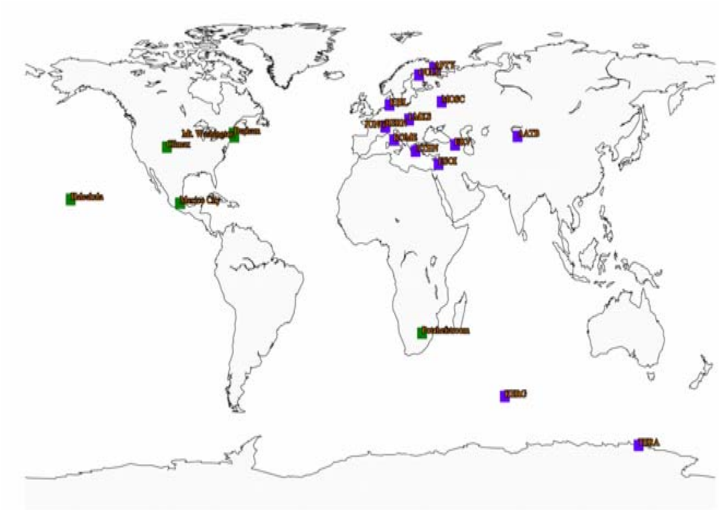
Goals of the project

- Upgrades stations and connections to make high-resolution NM data available in real-time
- Collect high resolution NM data in real-time, make it public available in common format
- Build a state of the art, centralized database with distributed mirrors
- Create an innovate registration system for cosmic rays
- Develop application tools using NM data
- Create a public outreach website to inform about cosmic rays and possible effects on humans, technological systems and environment
- Realize the first ever Training Course on Cosmic Ray Physics and Applications

Easiest Access to NM data

Creating the database





Real-time

- 1 min NM data
- 1 hour NM data
- environmental data

Historical

- 1 min NM data
- 1 hour NM data
- environmental data

Meta-data

- Application's meta-data

C. Steigies; O. Rother; C. Sarlanis; A. Ibragimov

Using NMDB

Station: All
Table: All

	Station	Table	Original data (1min)	1 hour data	Enviromental data
1.	Almaaty	AATB	Online	Online	Offline
2.	Apatity	APTY	Online	Online	Offline
3.	Aragats	ARNM	Online	Offline	Offline
4.	Athens	ATHN	Online	Online	Offline
5.	BKSN	BKSN	Online	Online	Offline
6.	ERV3	ERV3	Offline	Offline	Offline
7.	ERV	ERV	Offline	Offline	Offline
8.	Mt Hermon	ESOI	Offline	Offline	Offline
9.	IRK2	IRK2	Offline	Offline	Offline
10.	IRKT	IRKT	Offline	Offline	Offline
11.	Jungfraujoch, IGY	JUNG1	Online	Online	Online
12.	Jungfraujoch, NM64	JUNG	Online	Online	Online
13.	Kerguelen	KERG	Offline	Offline	Offline
14.	Kiel	KIEL	Offline	Offline	Offline
15.	LEIK	LEIK	Offline	Offline	Offline
16.	Lomnicky stit	LMKS	Online	Online	Online
17.	Mobile Cr lab.	MCRL	Online	Online	Offline
18.	Magadan	MGDN	Offline	Online	Offline
19.	Moscow	MOSC	Offline	Offline	Offline
20.	MRNY	MRNY	Online	Offline	Offline
21.	Nor-Amberd	NANM	Online	Offline	Offline
22.	Norilsk	NRLK	Offline	Offline	Offline
23.	Novosibirsk	NVBK	Offline	Offline	Offline
24.	Oulu	OULU	Online	Online	Offline
25.	Rome	ROME	Online	Online	Offline
26.	Terre Adelie	TERA	Offline	Offline	Offline
27.	TXBY	TXBY	Offline	Offline	Offline
28.	Yakutsk	YKTK	Offline	Offline	Offline
			Online: 13 Offline: 15	Online: 11 Offline: 17	Online: 3 Offline: 25

Checking NMDB Stations at a Glance

1 – min data

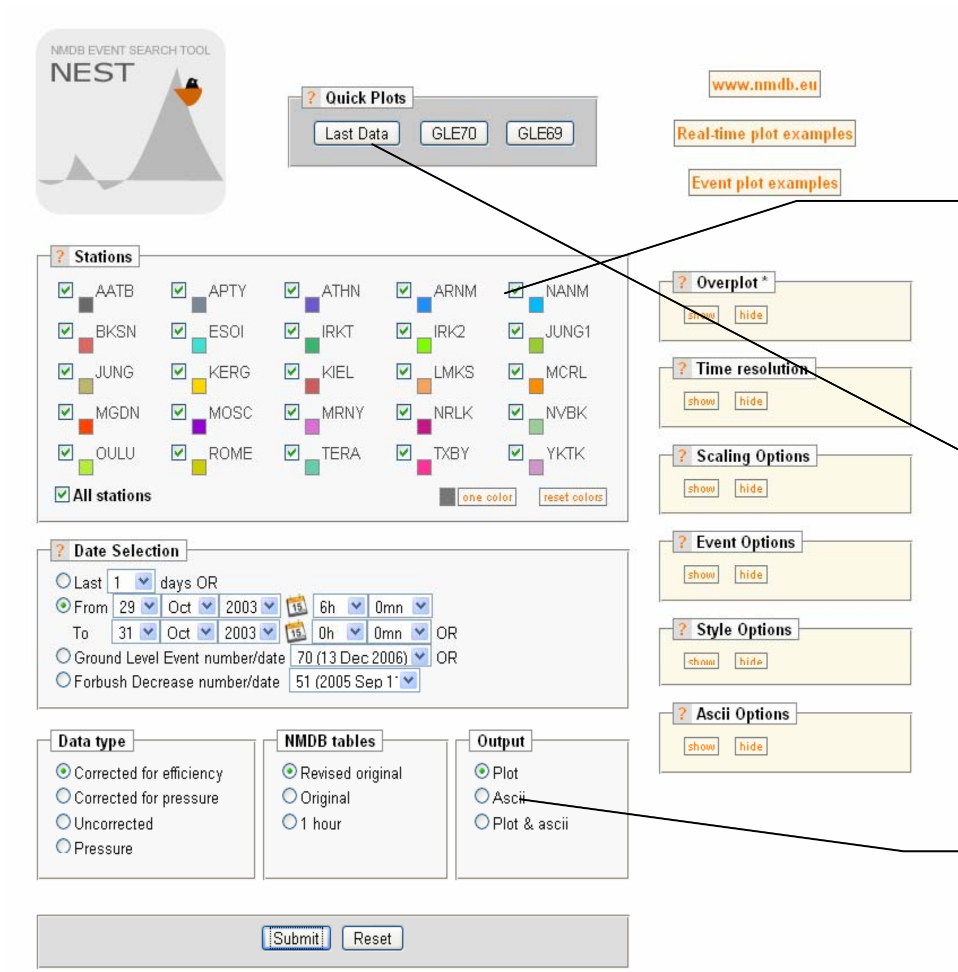
1 – hour data

environmental data

IEP SAS , I. Strharsky

Using NMDB

NMDB Event Search Tool - NEST



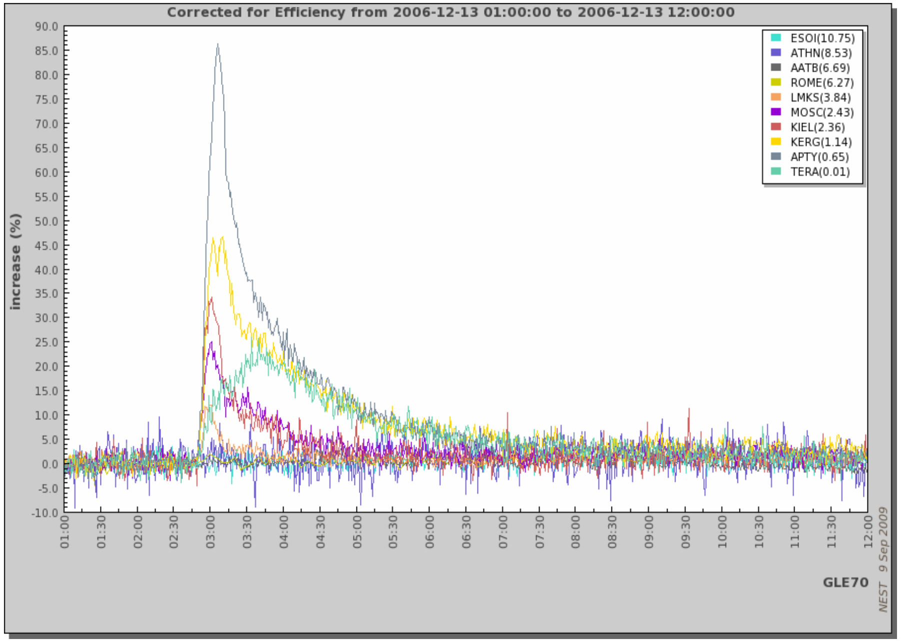
Choose the stations you want

Check the latest submitted data to NMDB – See if everything works !

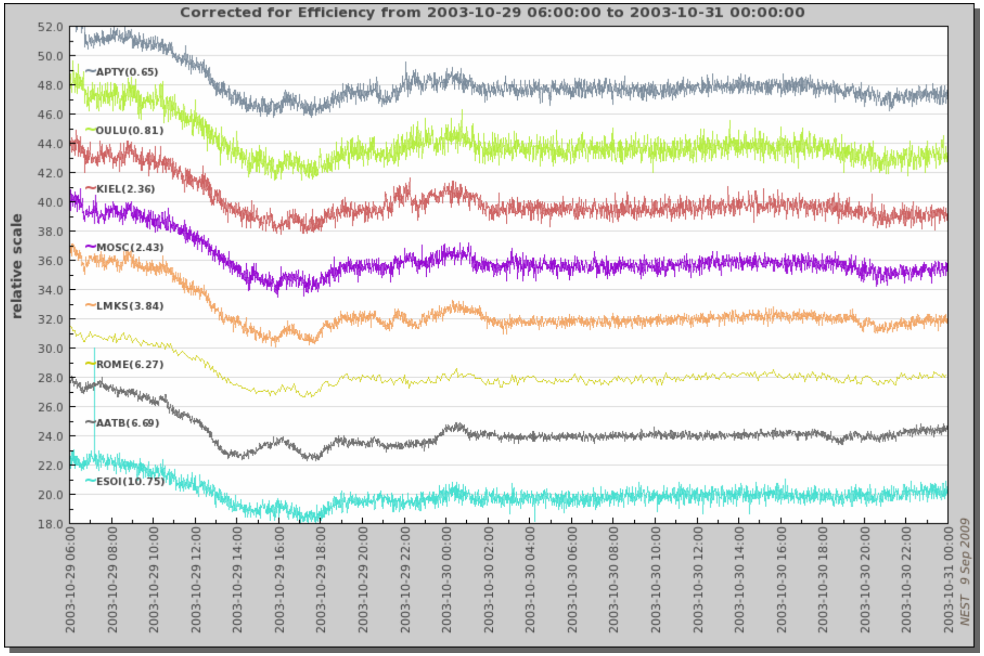
Take data & plots

NEST tool, OBSPARIS, N. Fuller

Using NMDB



✓ GLE illustrated by NEST

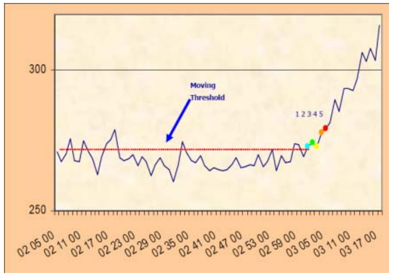


✓ Forbush decrease illustrated by NEST

Applications with 1-min real-time data

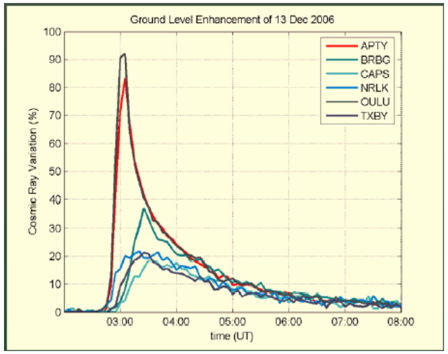
neutron monitor database

Alert function

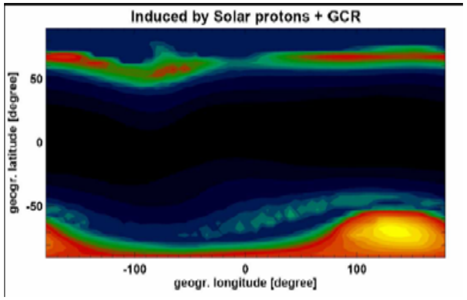


In real or quasi-real time

GLE Model approach



Atmosphere's ionization



Mavromichalaki et al., 2009

Applications with 1-min real-time data

GLE Alert Algorithm

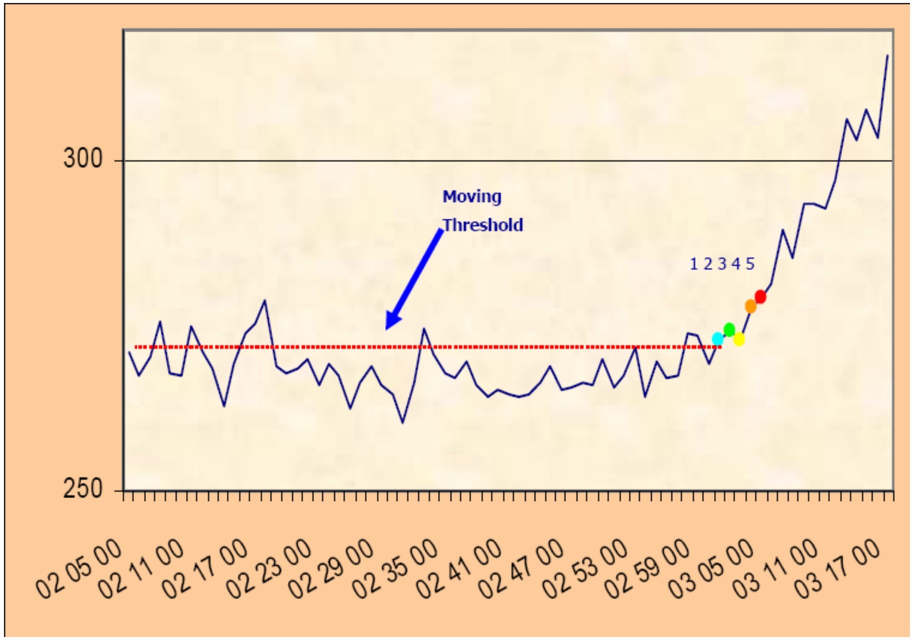
Several groups (NKUA, IZMIRAN, TAU, ALMATY), participating at NMDB project, hold various GLE Alert functions – some of which operate in real-time. Under the cooperation of NMDB, these groups will work together and will provide the best possible Alert

➢ Steps of the Station Alert

1. We define a moving threshold

2. When the last measurement exceeds this threshold, the algorithm marks a pre-alert point

3. If we get 5 pre-alert points in succession we define a Station Alert

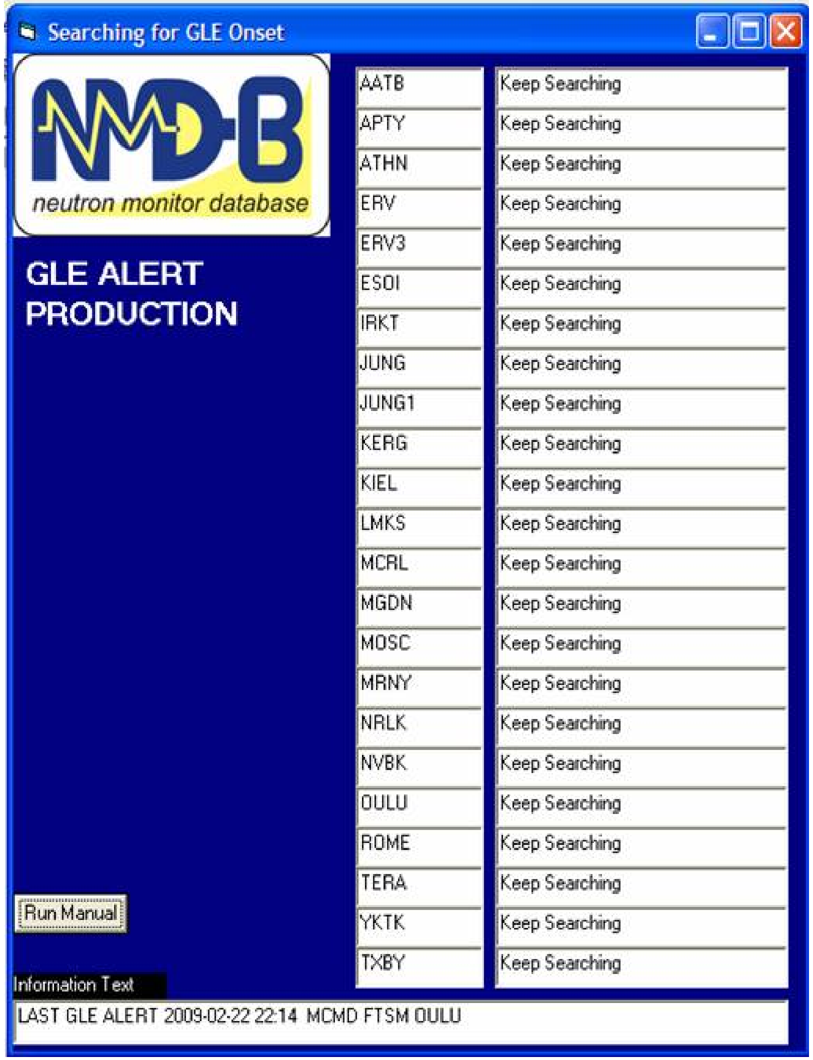


GLE Alert Algorithm

➢ <u>Steps of the General Alert</u>

1. A Supervision program named program named <u>Check_For_alert</u> checks every minute the status of every station.

2. If this program detects at least three stations in "station alert mode" then produces a Generall GLE Alert Signal



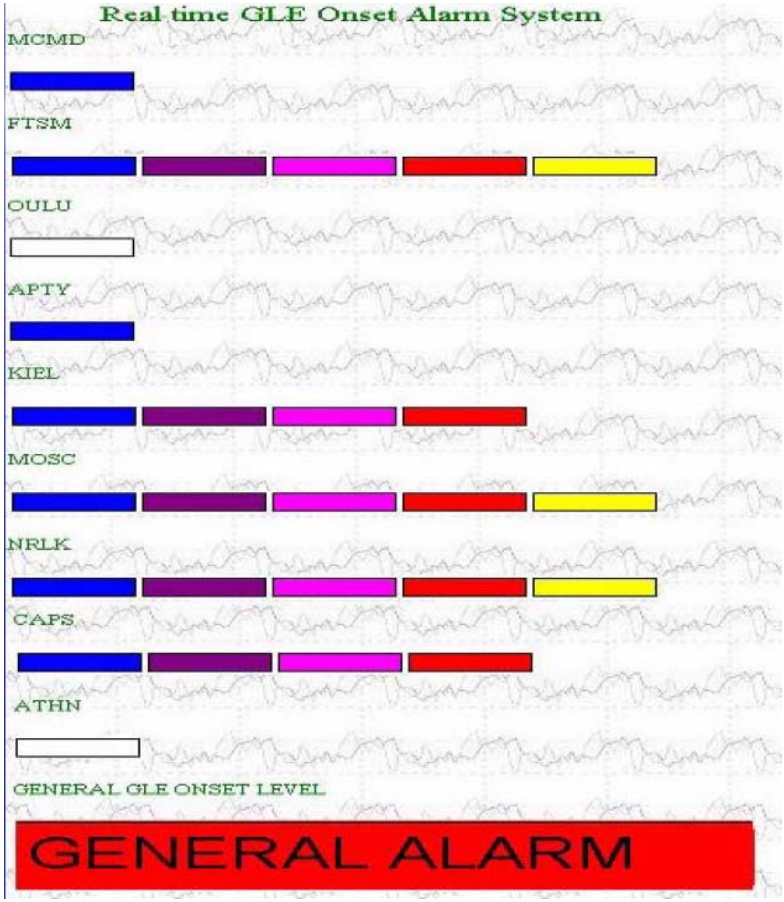
GLE Alert Algorithm

The first real-time GLE Alert signal (NKUA, 2009)

✓ The Ground Level Enhancement (GLE) event of the December 13, 2006 – GLE70

✓ Using the steps and the algorithms described at the previous slides, a real-time Alert signal was registered

✓ This is the reconstructed display of the Alert at the webpage. You can notice that three stations (FTSM, MOSC, NRLK) provide the General Alert stage



Souvatzoglou et al., 2009

Validation of GLE Algorithm

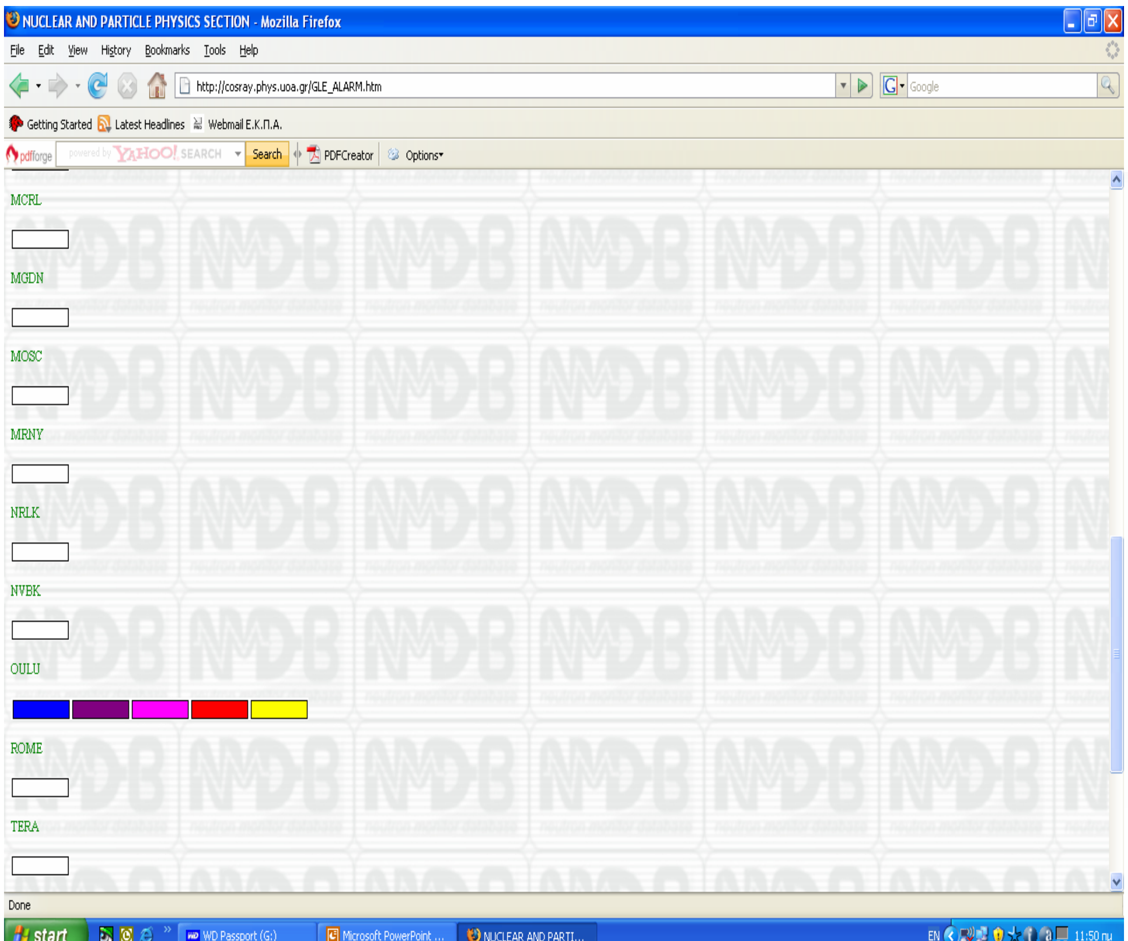
GLE No	Event date	Flare time (UT)	Flare	GOES Alert(100 MeV, >1 pfu)	NM Stations Alert
60	15 April 2001	13:19	X14.4	14:21	13:59
61	18 April 2001	02:11	C2	03:11	02:43
62	04 Novemeber 2001	16:03	C2	17:07	16:50
63	26 December 2001	04:32	C2	06:14	06:07
64	24 August 2002	00:49	X3.1	01:48	01:35
65	28 October 2003	09:51	X17.2	11:51	11:17
66	29 October 2003	20:37	X10.0	———	21:08
67	2 November 2003	17:03	X8.3	17:56	17:39
68	17 January 2005	——-	——-	———	NO GLE
69	20 January 2005	06:36	X7.1	07:04	06:52
70	13 December 2006	02:48	X3.4	03:12	02:53

✓ The above table shows that GLE Alert which depends solely on ground based observations precedes the one triggered by GOES at a time window of 7 - 34 minutes. There is also a single case (GLE66) where the NM GLE algorithm issues an Alert while satellite data did not.

Souvatzoglou et al., 2009

GLE Alert Algorithm

Real-time Illustration of GLE Alert



Online real-time GLE Alert

RESULT of the GLE Alert for the last 12 minutes

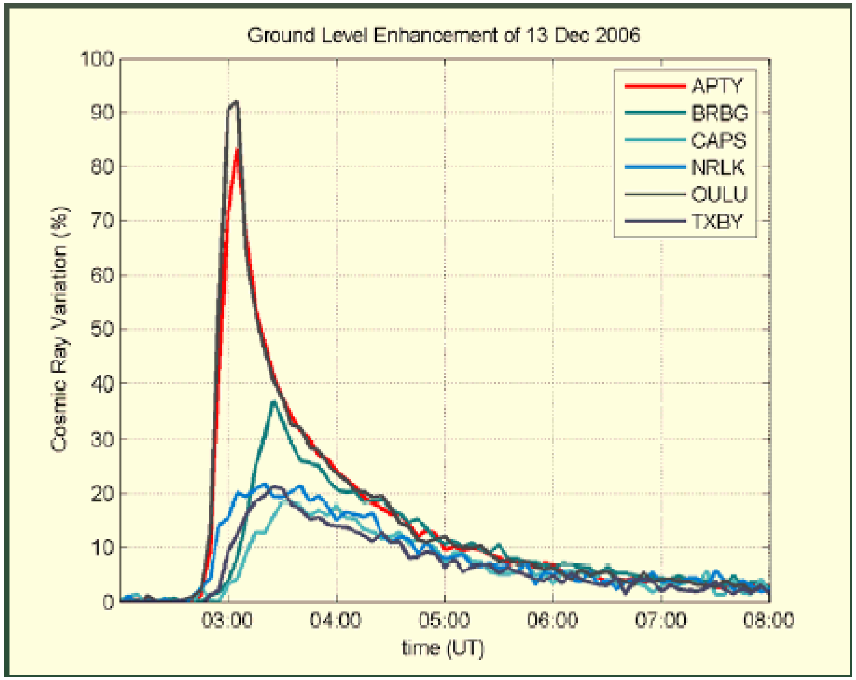
DateTime	Total Stations	Used Stations	Stations with increase >2 sigma	Watch	Warning!	Alert !
2009-09-16 08:33:00+00	15	8	1			
2009-09-16 08:34:00+00	15	8	1			
2009-09-16 08:35:00+00	15	7	0			
2009-09-16 08:36:00+00	15	7	1			
2009-09-16 08:37:00+00	15	7	2			
2009-09-16 08:38:00+00	15	7	3	✓	✓	
2009-09-16 08:39:00+00	15	7	1			
2009-09-16 08:40:00+00	15	5	1			
2009-09-16 08:41:00+00	15	5	3	✓	✓	
2009-09-16 08:42:00+00	15	5	1			
2009-09-16 08:43:00+00	15	3	0			
2009-09-16 08:44:00+00	15	0	0			

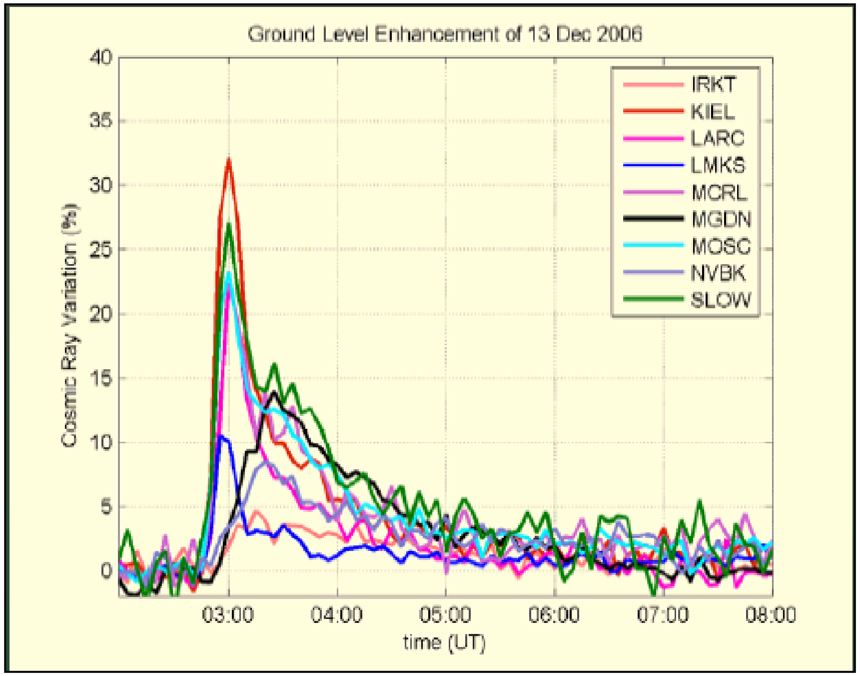
National & Kapodistrian University of Athens

Section of Nuclear & Particle Physics
Athens Cosmic Ray Group

Applications with 1-min real-time data

GLE Modelling – NM BANGLE



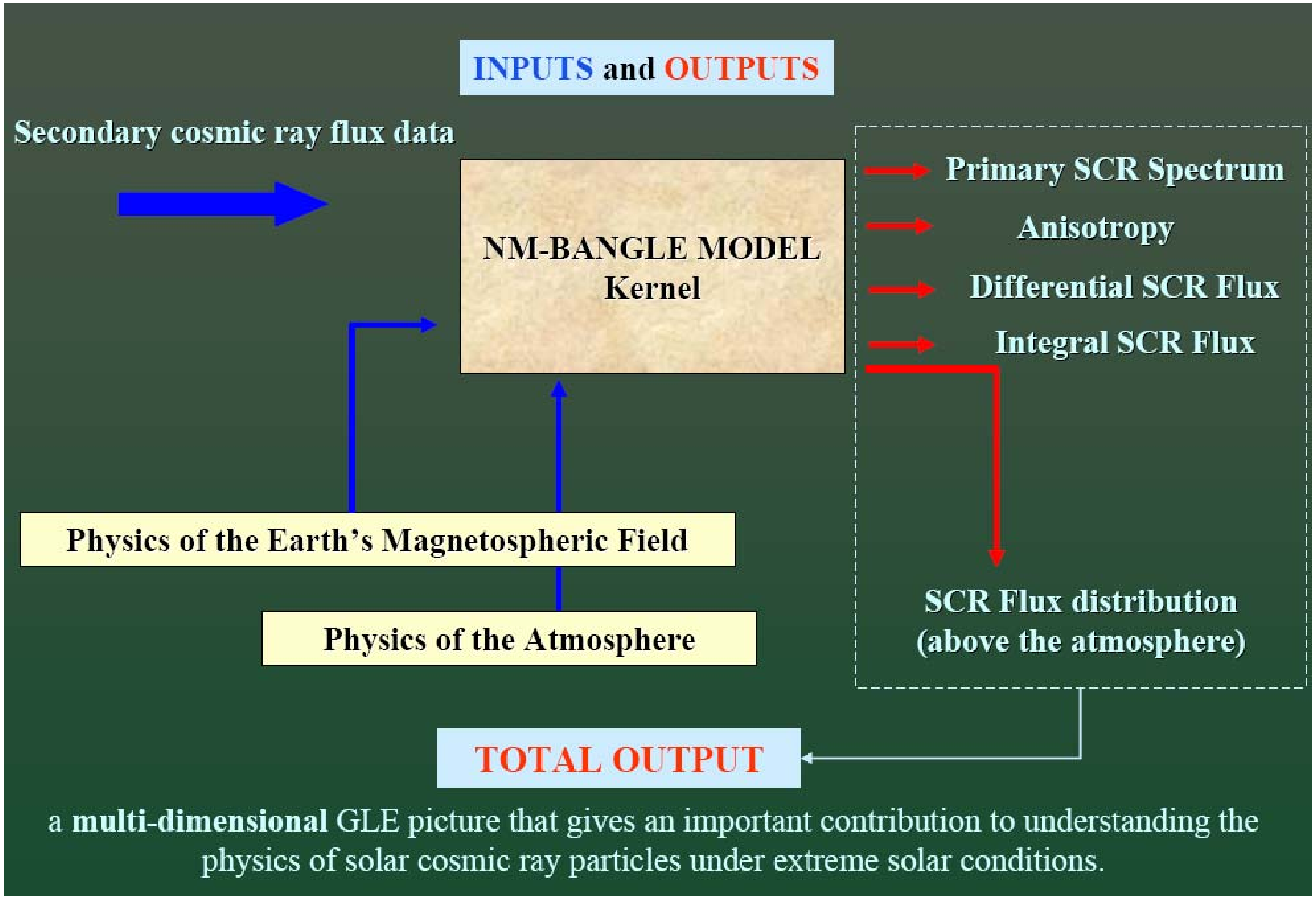


- Several groups participating at NMDB project, created GLE models. One of the most sophisticated ones is the NM-BANGLE

Plainaki et al., 2007

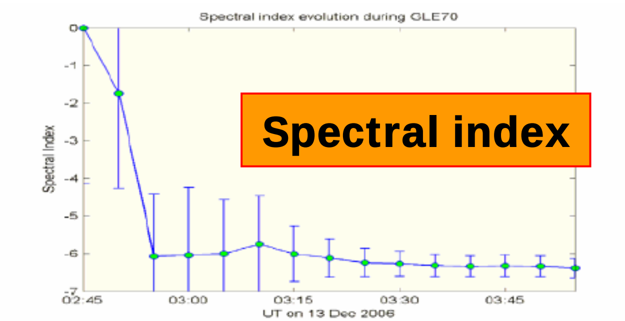
GLE Modelling – NM BANGLE

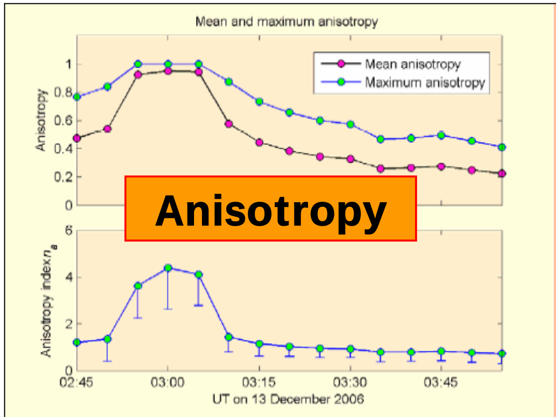
Kernel of NM BANGLE

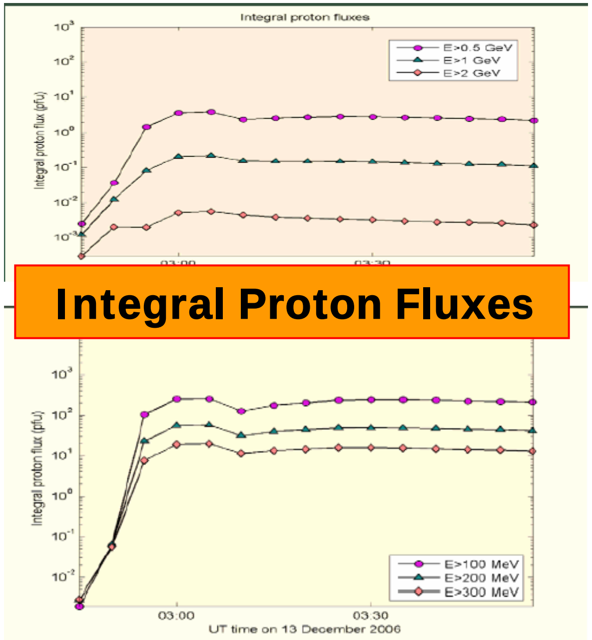


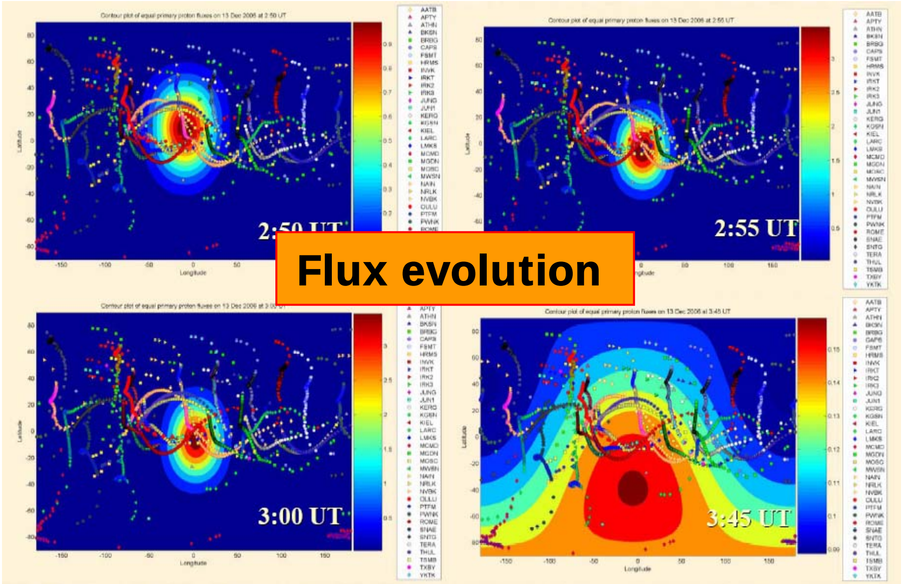
GLE Modelling – NM BANGLE

NM BANGLE - Results





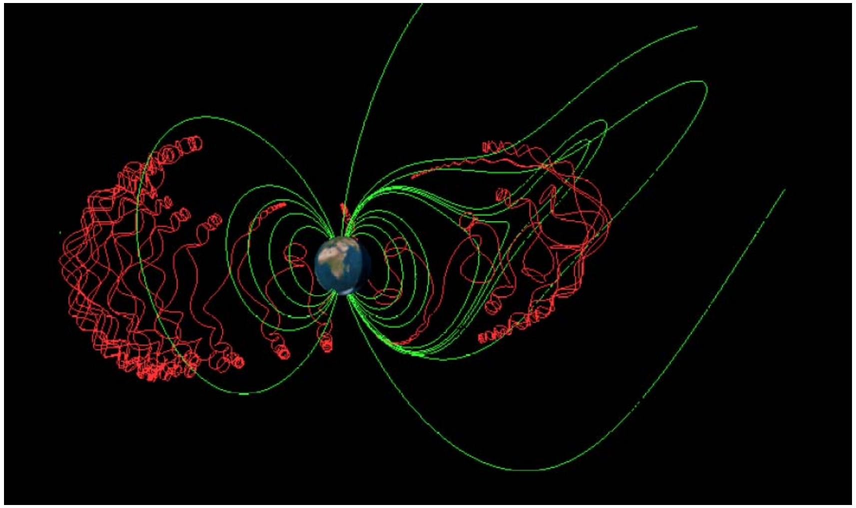


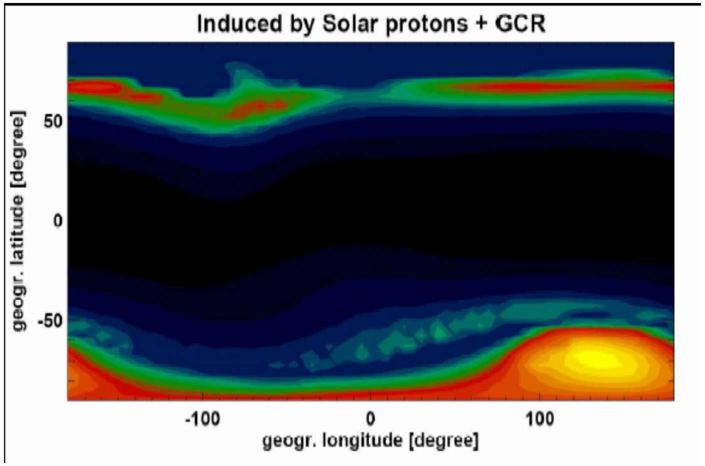


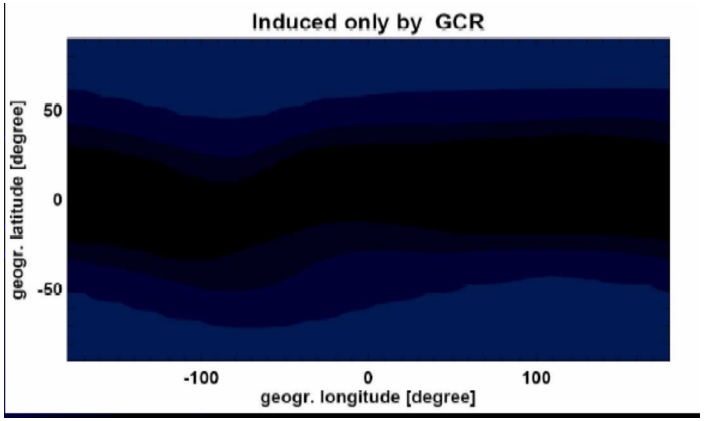
Applications with 1-min real-time data

Atmospheric Ionization – Planetocosmics code (UBERN)

The Planetocosmics code can illustrate particle trajectories affected by a magnetic field and calculate the ionization of the atmosphere during solar energetic particles

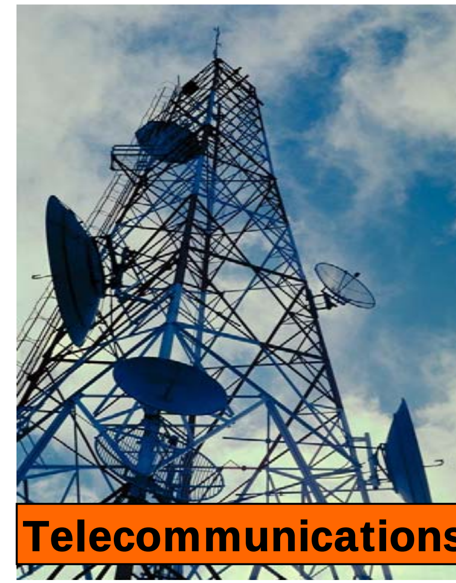




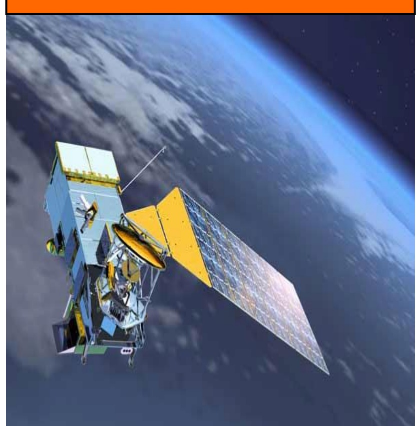


Desogher et al., 2005

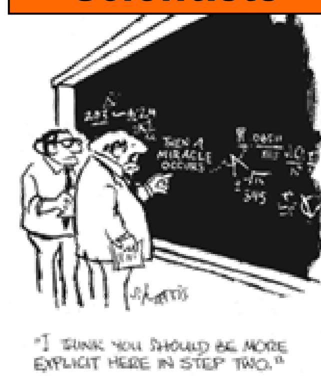
Possible users of NMDB



Satellite Operation Centers



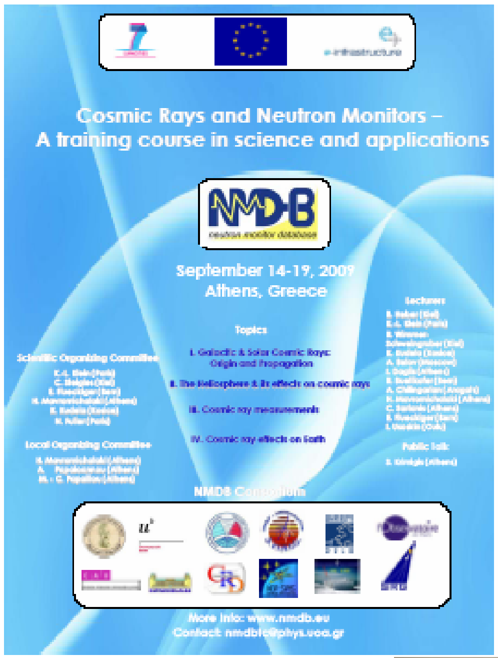
Scientists

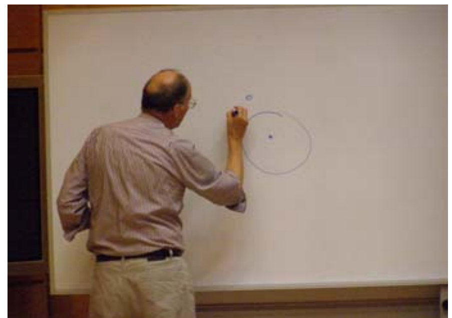


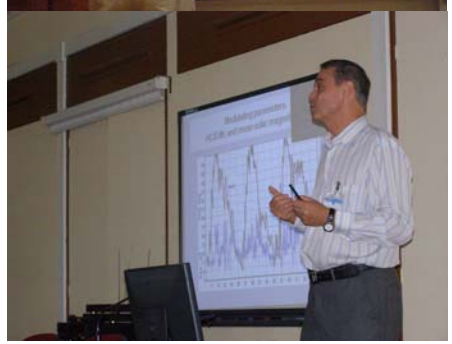
National & Kapodistrian
University of Athens

Section of Nuclear & Particle Physics
Athens Cosmic Ray Group

NMDB Training Course, September 14-19, 2009, Athens, Greece







Training course
Facts & figures

✓55 students (PhD, Post-doc) from 16 countries

✓14 lectures & 4 lab courses

✓16 student presentations

✓1 Public talk

✓Visit at the Athens NM

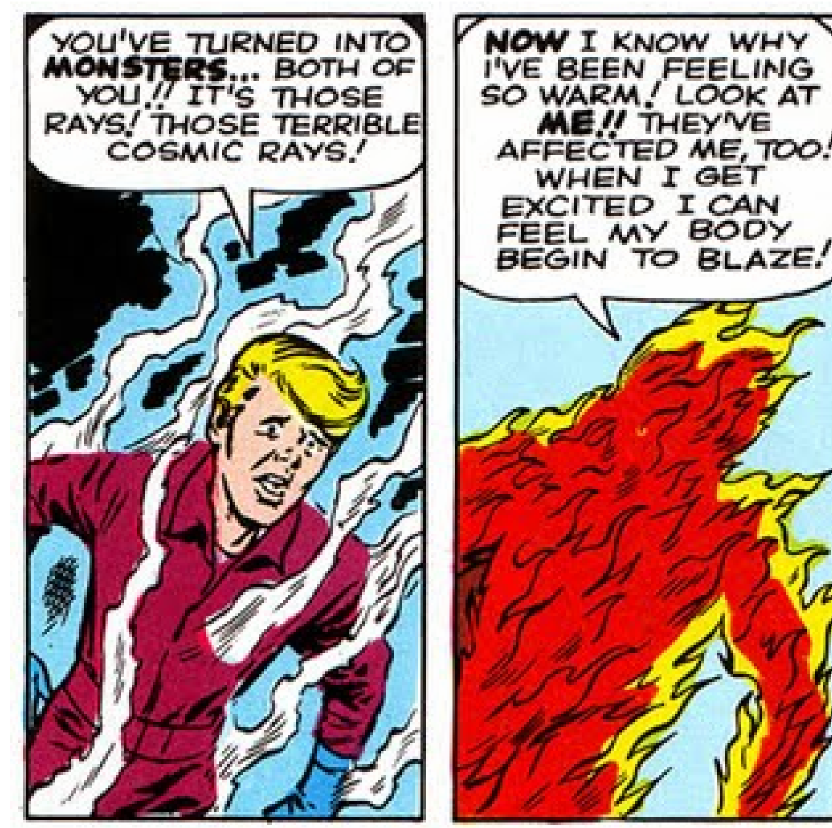
Conclusions

- All NM stations have been upgraded providing high-resolution NM data in real-time
- High resolution NM data in real-time,are being collected and made public in common format
- A state of the art, centralized database with distributed mirrors, have been build
- An innovate registration system for cosmic rays have been implement
- Application tools using NM data have been developed
- A public outreach website with the scope to inform about cosmic rays and possible effects on humans, technological systems and environment have been created.
- The first ever Training Course on Cosmic Ray Physics and Applications have been realized

NMDB database is an open tool
All applications can be used as a service for scientists and for all

Fantastic 4 Effect !

FROM FANTASTIC FOUR #1



Thank you for your attention ☺

neutron monitor database

Project's website:

http://www.nmdb.eu

e-infrastructure

CAPACITIES