GLE Analysis Based on NM Data

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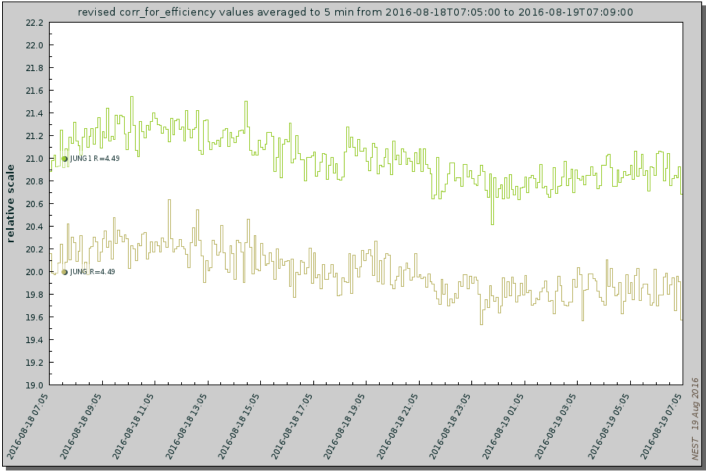
University of Bern, Switzerland and
Foundation High Altitude Research Stations Jungfraujoch and Gornergrat

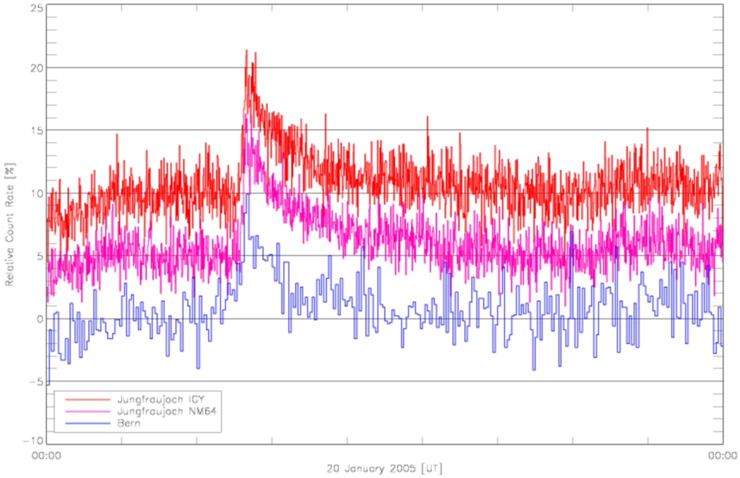
HESPERIA - Summer School
Kiel, 29 August - 2 September 2016

Measurements by Swiss NMs



Plot made by NMDB application NEST

Measurements by Swiss NMs on 20 January 2005



From: "erosh" <erosh@izmiran.ru>
To: "Mavromichalaki Eleni" <emavromi@cc.uoa.gr>
Cc: "Starodubtsev S.A." <starodub@ikfia.ysn.ru>; "Sdobnov V.E." <sdobnov@iszf.irk.ru>; "Roger Pyle" <pyle@bartol.udel.edu>; "Kryakunova Olga" <krolganik@yandex.ru>; "Karel Kudela" <kkudela@upjs.sk>; "Kalevi Mursula" <sclimate@sun3.oulu.fi>; "K. Roehrs" <kroehrs@email.uni-kiel.de>; "Joe H Allen" <Joe.H.Allen@noaa.gov>; "Ilya Usoskin" <ilya.usoskin@oulu.fi>; "Graumann Hugo" <hugo@volt.pjl.ucalgary.ca>; <fskmsp@puknet.puk.ac.za>; "Erwin Flueckiger" <flueckiger@phim.unibe.ch>; "Erwin Flueckiger" <erwin.flueckiger@phim.unibe.ch>; "Erwin Ed" <Edward.H.Erwin@noaa.gov>; "Dorman Lev" <lid@physics.technion.ac.il>; "clifford lopate" <lopate@ulysses.sr.unh.edu>; "Peggy Ann Shea and Don Smart" <sssrc@msn.com>; "Bieber John" <john@bxclu.bartol.udel.edu>
Sent: Thursday, January 20, 2005 08:29
Subject: GLE68!

Dear all,

there is a new GLE68 ! from the western flare started at 6:36UT with the max at 7:01.
It seems to be the greatest in the current cycle.
At some stations it is already ~100%!

Successes!

IZMIRAN CR Department

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Fw: Huge GLE in progress - KMail

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----- Original Message -----

From: Marc Duldig

To: Peggy Ann Shea and Don Smart ; Erwin FlÃ¼ckiger ; Roger Pyle ; Harm Moraal

Cc: Ken McCracken

Sent: Thursday, January 20, 2005 5:09 AM

Subject: Huge GLE in progress

Dear Friends

You may already know that there is a huge GLE in progress. Raw eyeball estimate of Mawson data indicates 200% in 1 min data, onset around 6.50 UT.

Oulu shows 225% peak just after 7 UT with smooth decay. Mawson seems to see a second structured peak around 7.20 UT but the pressure correction on the real time quick look data could be suspect.

It is clear in the Jungfrau data.

What a declining phase we are in this time around!

Regards

Marc

*Book1.gnumeric - Gnumeric | gle69 - Dolphin | Fw: Huge GLE in progress - KM | C069 : mc - Konsole <2> | Kwrite | infos.dvi - Okular

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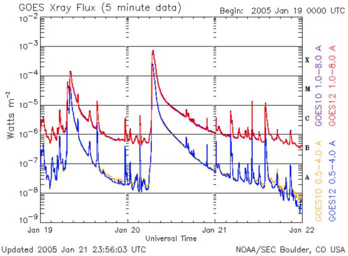
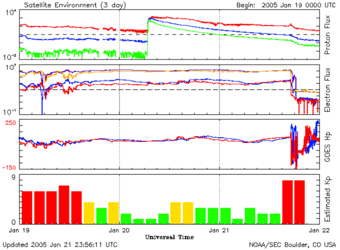
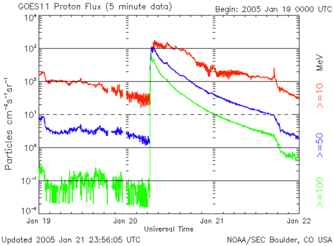
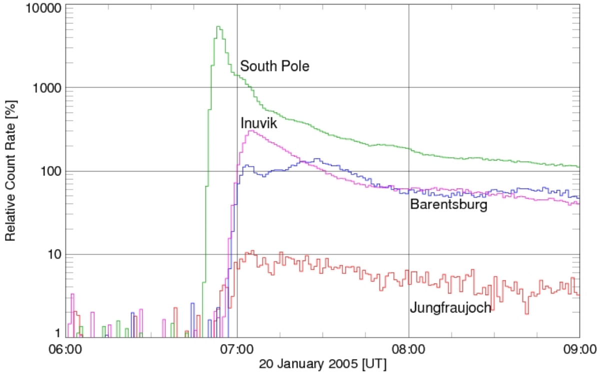
Measurements in space around 20 January 2005



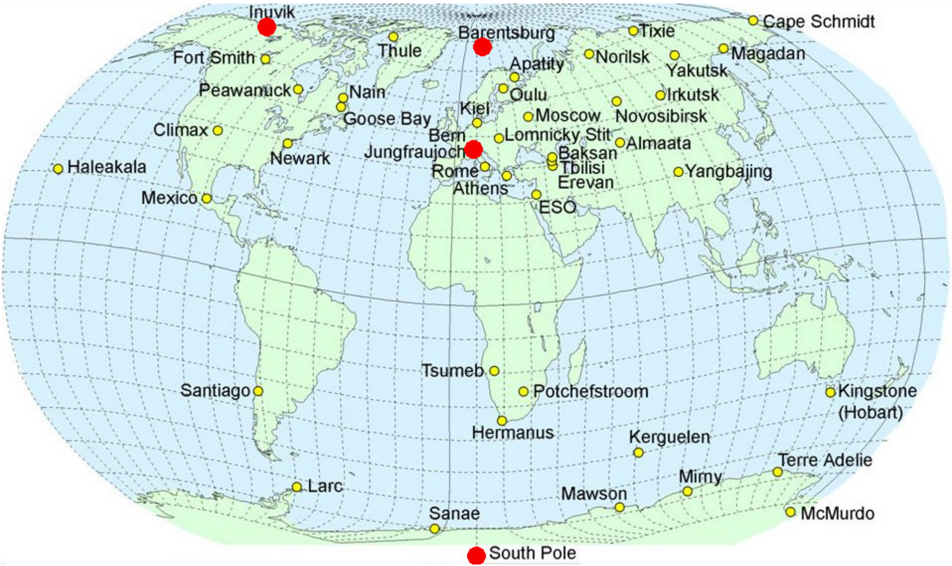




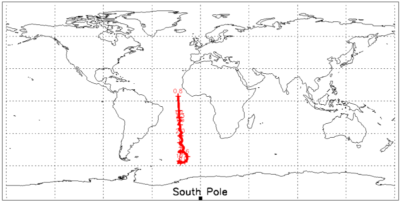
NM data of worldwide network on 20 January 2005



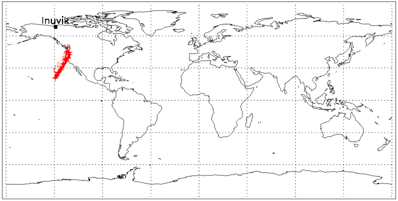
NM stations: Barentsburg, Inuvik, Jungfraujoch, South Pole


Inuvik
Barentsburg
Cape Schmidt
Tixie
Thule
Fort Smith
Norilsk
Magadan
Apatity
Yakutsk
Peawanuck
Nain
Oulu
Irkutsk
Goose Bay
Kiel
Moscow
Novosibirsk
Climax
Bern
Lomnicky Stit
Almaata
Newark
Jungfraujoch
Baksan
Haleakala
Tbilisi
Rome
Yangbajing
Erevan
Athens
Mexico
ESO
Tsumeb
Santiago
Potchefstroom
Kingstone
(Hobart)
Hermanus
Kerguelen
Terre Adelie
Mirny
Larc
Mawson
Sanae
McMurdo
South Pole

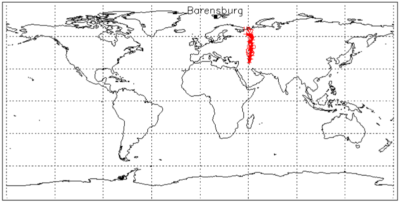
Asymptotic directions



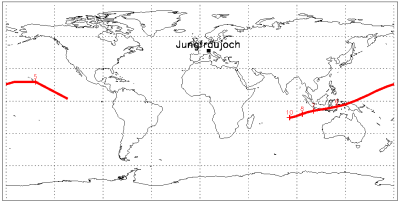
$R_c = 0.0\,\text{GV}$



$R_c \approx 0.3\,\text{GV}$

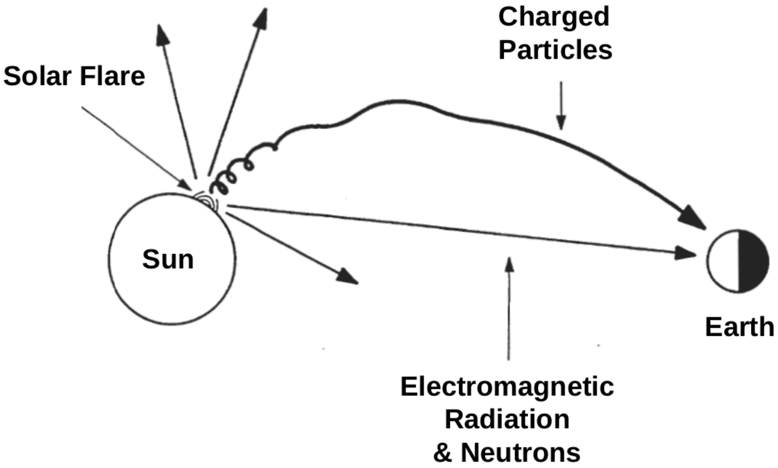


$R_c = 0.0\,\text{GV}$



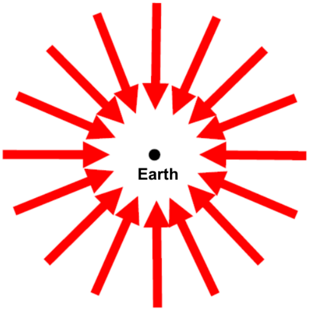
$R_c \approx 4.5\,\text{GV}$

Transport from the Sun to the Earth

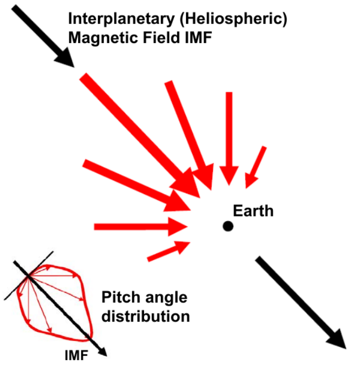


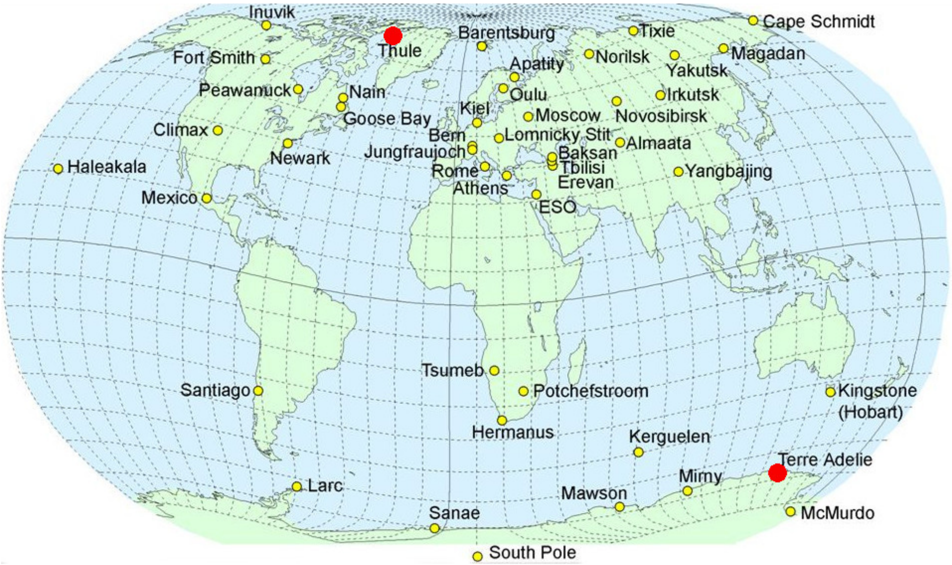
SCR Anisotropy I

GCR



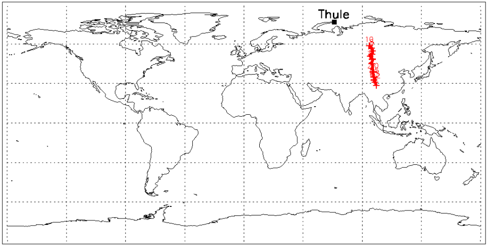
SCR

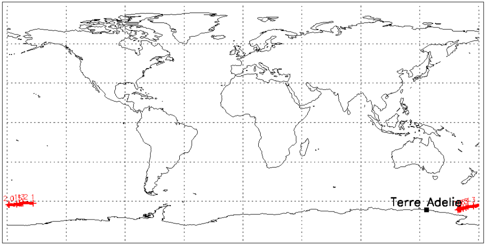




Inuvik
Thule
Barentsburg
Tixie
Cape Schmidt
Fort Smith
Norilsk
Magadan
Yakutsk
Apatity
Peawanuck
Nain
Oulu
Irkutsk
Goose Bay
Kiel
Moscow
Novosibirsk
Climax
Bern
Lomnicky Stit
Almaata
Newark
Jungfraujoch
Baksan
Haleakala
Tbilisi
Rome
Yangbajing
Erevan
Athens
Mexico
ESO
Tsumeb
Santiago
Potchefstroom
Kingstone
(Hobart)
Hermanus
Kerguelen
Terre Adelie
Mirny
Larc
Mawson
McMurdo
Sanae
South Pole

Anisotropy of SCR flux III





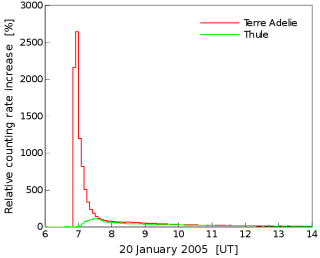
Anisotropy of SCR flux IV

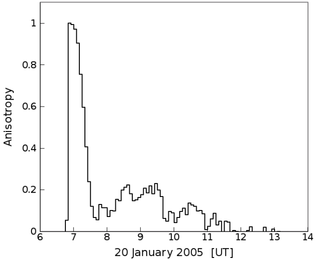
$$A(t) = \frac{\Delta N_1(t) - \Delta N_2(t)}{\Delta N_1(t) + \Delta N_2(t)}$$

where

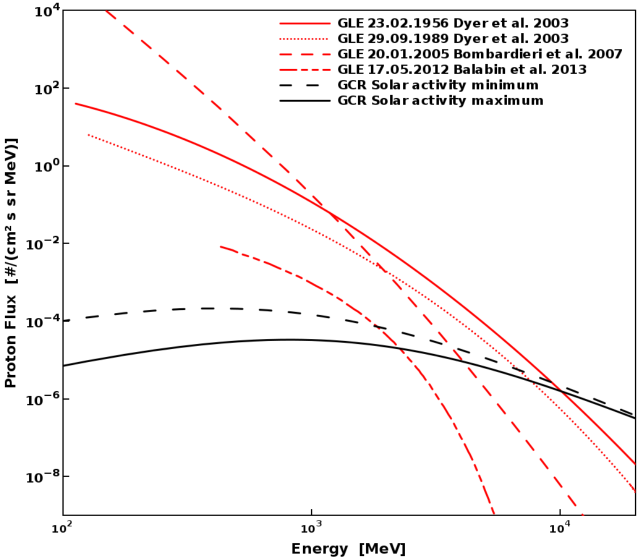
$\Delta N_1(t)$ Relative count rate increase of NM station 1 at time t

$\Delta N_2(t)$ Relative count rate increase of NM station 2 at time t

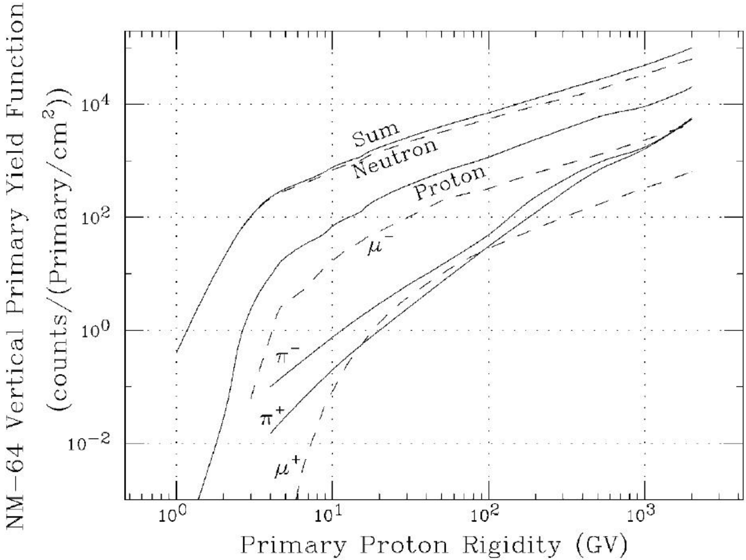




SCR spectrum



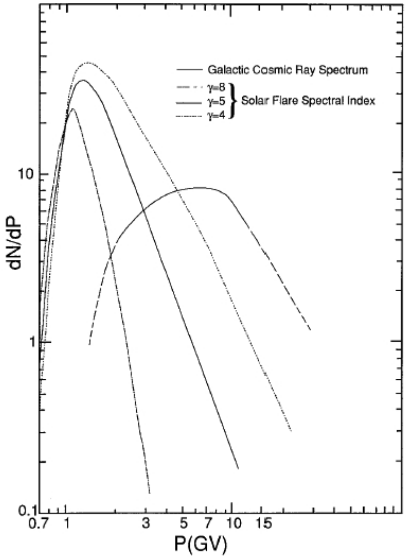
NM yield function



Count rate of a NM station

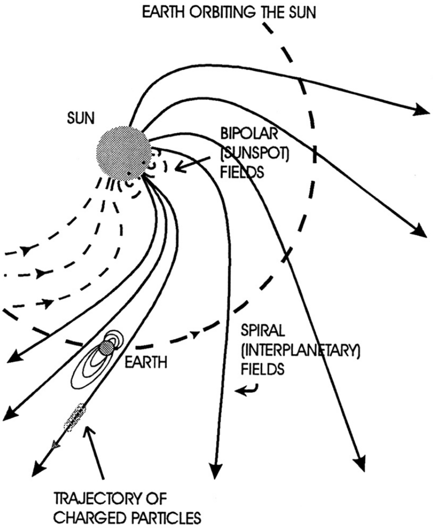
$$N(t) = A \cdot \int_{P_c}^{\infty} S(P, z) \cdot J(P, t) \, \mathrm{d}P$$

NM response



$$I(R) = A \cdot R^{-\gamma}$$

Incident direction of SCR particles into geomagnetosphere



Differential rigidity spectrum

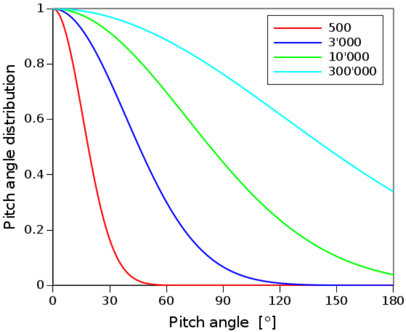
$$I(R,t) = A(t) \cdot R[\mathrm{GV}]^{-(\gamma(t)+\Delta\gamma(t)\cdot(R-1.0))}$$

where

$A(t)$ is given in [m^{-2} s^{-1} sr^{-1} GV^{-1}] and

R in [GV]

Pitch angle distribution



$$F(\vartheta) = e^{-\frac{\vartheta^2}{Fpar}}$$

where

ϑ	pitch angle in [°]
$Fpar$	parameter describing the pitch angle distribution

NM count rate change during GLE

$$\Delta N(t) = \sum_{R_c}^{\infty} S(R) \cdot I(R,t) \cdot F(\delta(R),t) \cdot \Delta R$$

where

R_c	effective vertical cutoff rigidity
$S(R)$	yield function
$I(R,t)$	solar particle intensity
$F(\delta(R),t)$	pitch angle distribution of solar particles
$\delta(R)$	angular distance between direction of vertically incident particles at the NM and direction of IMF near Earth

Determination of SCR characteristics based on NM data

By comapring the calculated, ΔN^{mod}, and the measured, ΔN^{meas}, of selected NM stations the solar cosmic ray characteristics (spectrum, direction of anisotropy, and pitch angle distribution) can be determined by a trial and error procedure:

$$\sum_i \left(\Delta N_i^{mod} - \Delta N_i^{meas} \right)^2 = minimal$$