Performance of the current and extended global NM network for solar particle registration and analysis

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Outline

1. **Introduction**
2. **Current status of the global NM network**
3. **Registration, alerts and analysis of GLEs using the NM network**
4. **Performance of extended, actual and reduced global NM network**

Introduction

An important topic of solar physics, space weather, atmospheric physics is

Assessment

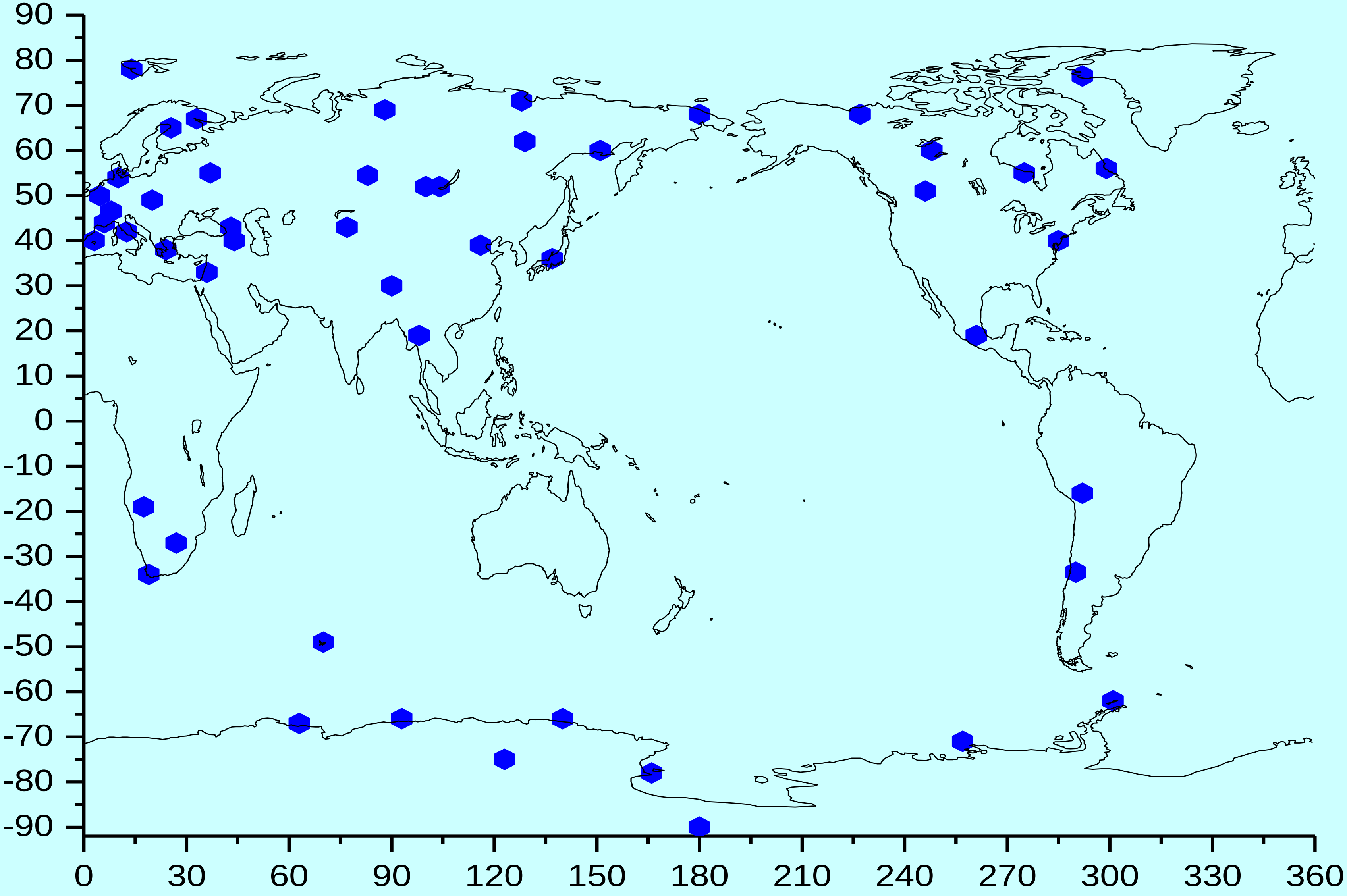
Primary SEP parameters:

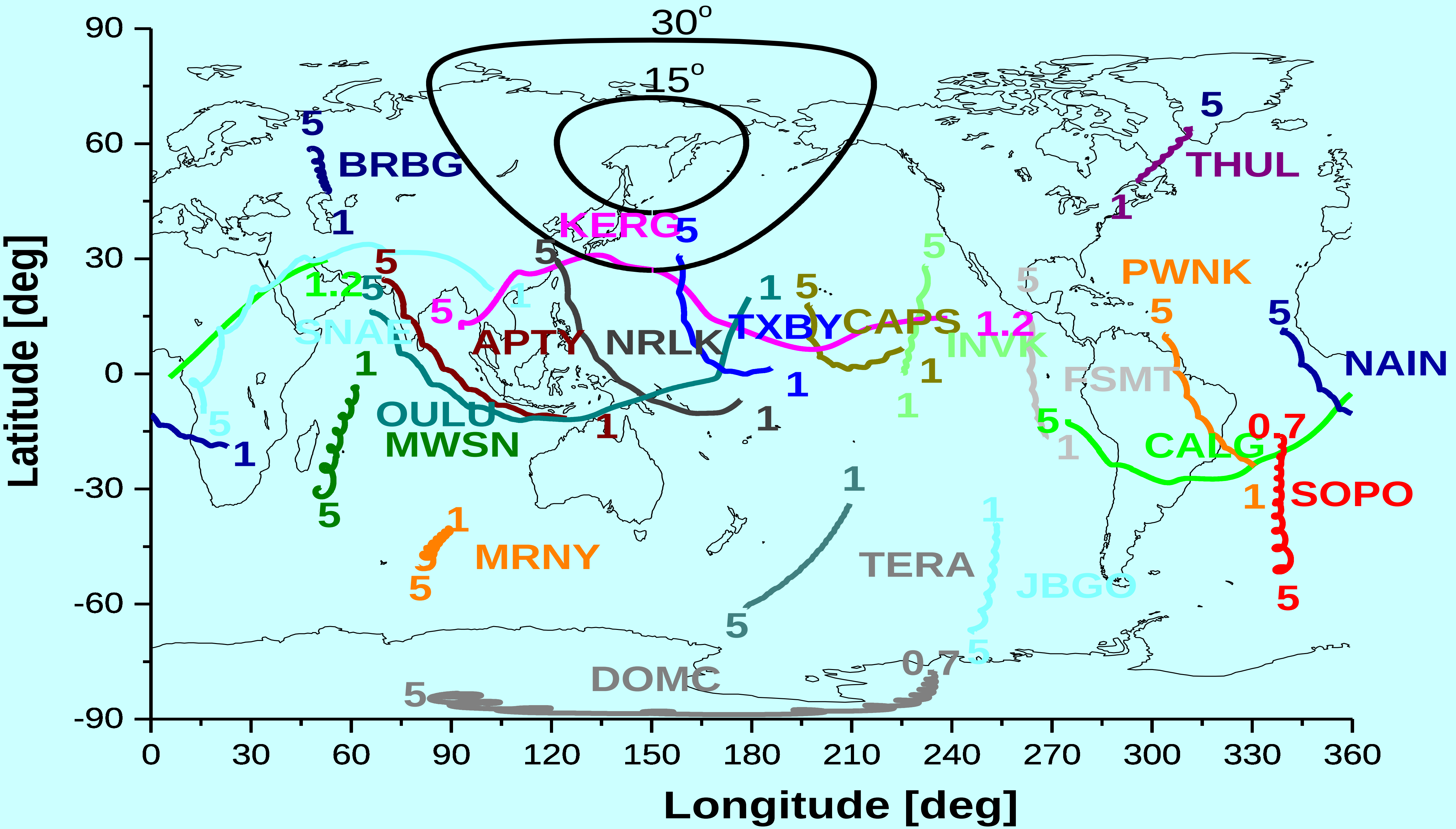
energy spectrum

anisotropy

using the information from NMs

Global neutron monitor network





30°
15°
BRBG
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KERG
PWNK
TXBY
CAPS
SNAE
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NRLK
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NAIN
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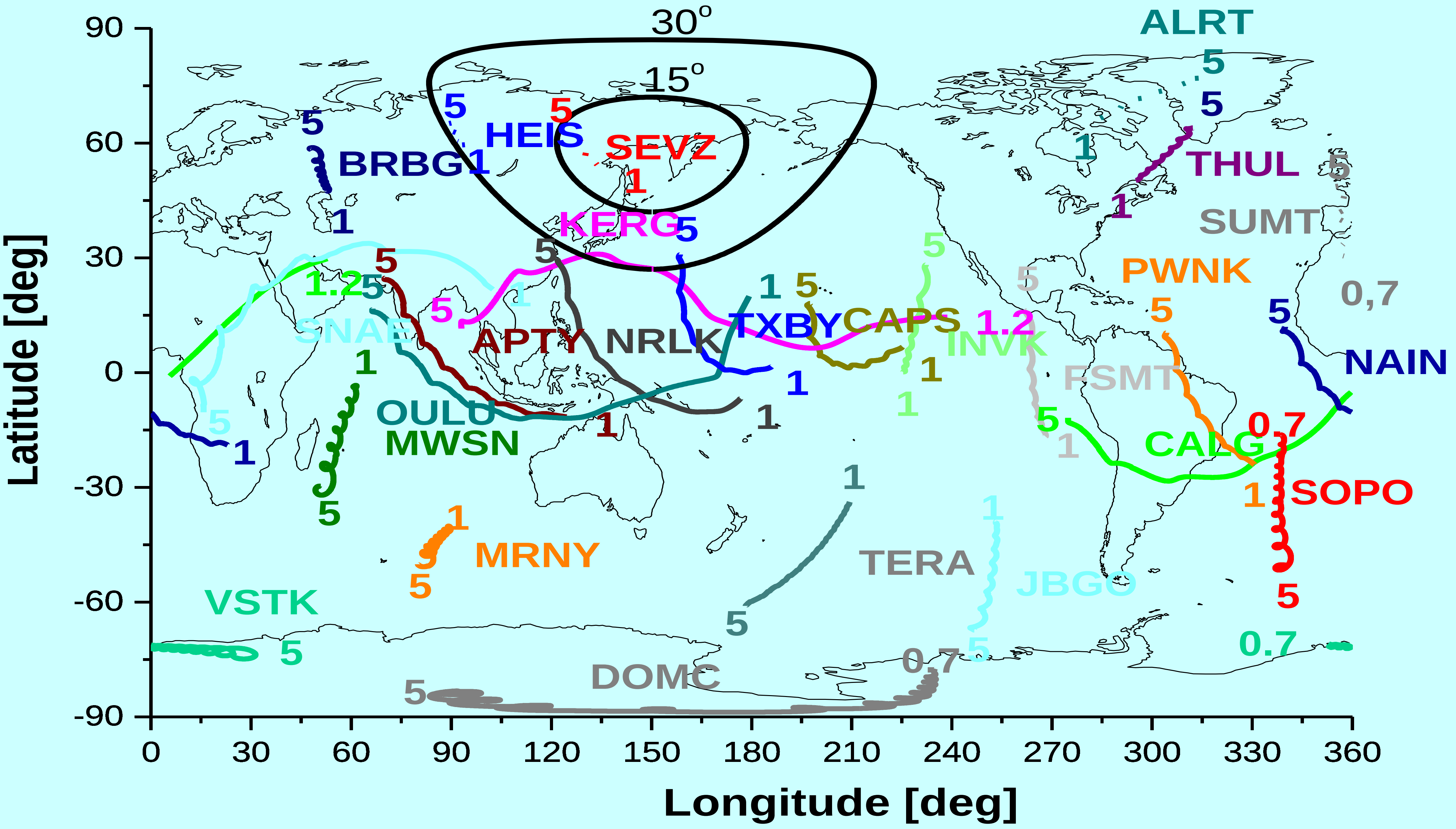
OULU
MWSN
CALG
SOPO
MRNY
TERA
JBGO
DOMC
Latitude [deg]
Longitude [deg]



30°
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Latitude [deg]
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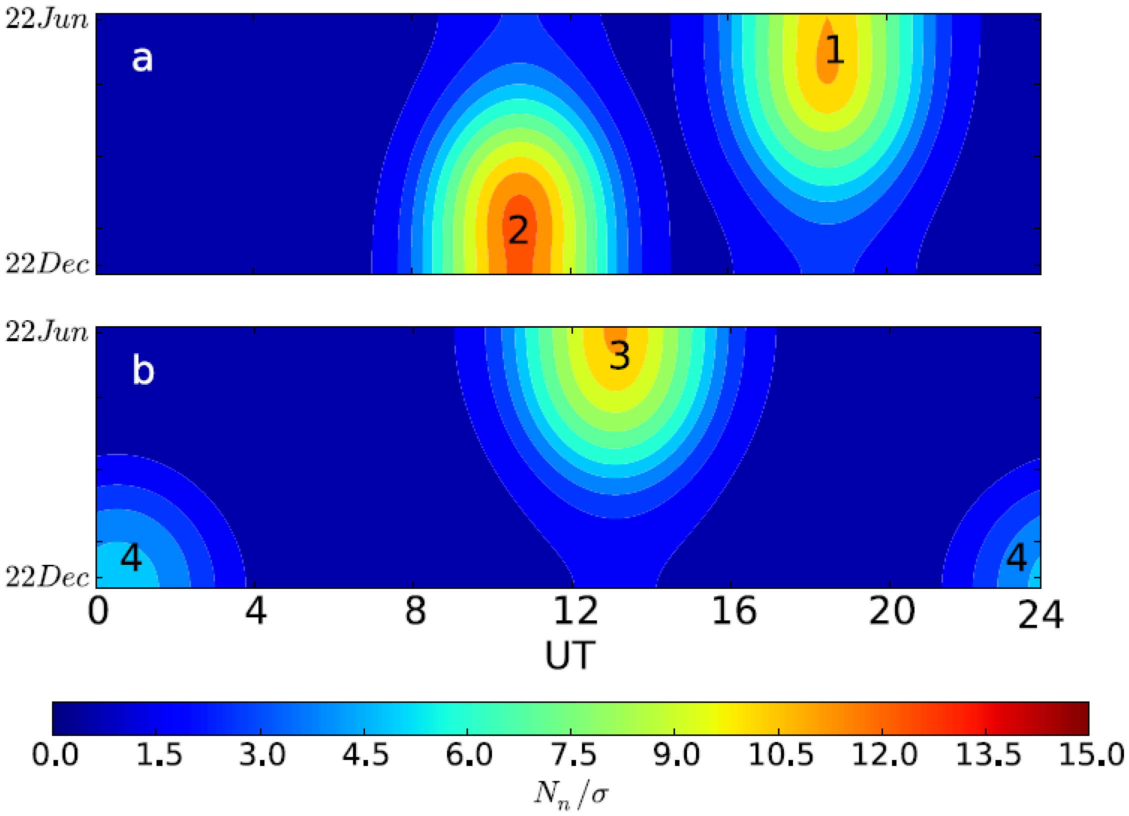
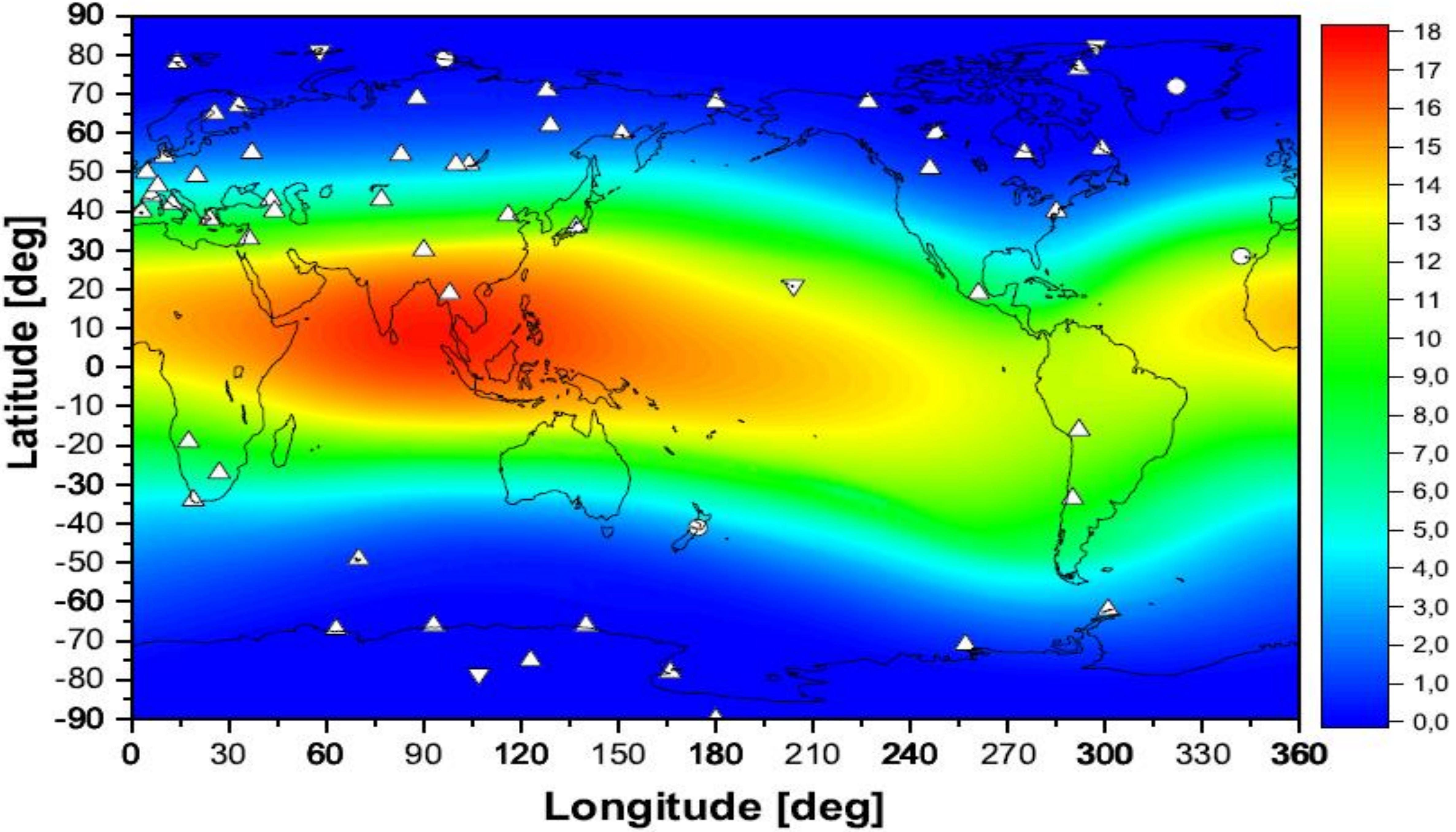
90
120
150
180
210
240
270
300
330
360

Registration of solar neutrons



Examples of sensitivity of the individual neutron monitors to the reference SNE as a function of time of occurrence of the event. Panel a: Mexico NM (1) and Tsumeb NM (2). Panel b: Possible improvement in world NM network sensitivity with a hypothetical 12NM64 at Canary islands (3) and New Zealand (4).

Station	latitude [deg]	Longitude [deg]	P_c [GV]	Altitude [m]
Apatity (APTY)	67.55	33.33	0.57	177
Barenstburg (BRBG)	78.03	14.13	0.01	51
Calgary (CALG)	51.08	245.87	1.08	1128
Cape Schmidt (CAPS)	68.92	180.53	0.45	0
Dome C (DOMC)	-75.06	123.20	0.01	3233
Forth Smith (FSMT)	60.02	248.07	0.381	0
Inuvik (INVK)	68.35	226.28	0.16	21
Jang Bogo(JNBG)	-74.37	164.13	0.1	29
Kerguelen (KERG)	-49.35	70.25	1.01	33
Mawson (MWSN)	-67.6	62.88	0.22	0
Mirny (MRNY)	-66.55	93.02	0.03	30
Nain (NAIN)	56.55	298.32	0.28	0
Neumayer (NEUM)	-70.40	351.04	0.85	0
Norilsk (NRLK)	69.26	88.05	0.52	0
Oulu (OULU)	65.05	25.47	0.69	15
Peawanuck (PWNK)	54.98	274.56	0.16	52
Sanae (SNAE)	-71.67	357.15	0.56	52
South Pole (SOPO)	-90.00	0.0	0.09	2820
Terre Adelie (TERA)	-66.67	140.02	0.02	45
Thule (THUL)	76.60	291.2	0.1	260
Tixie (TXBY)	71.60	128.90	0.53	0
Alert (ALRT)	82.5	297.67	0.0	57
Heiss island (HEIS)	80.62	58.05	0.1	20
Haleakala (HLEA)	20.71	203.74	12.91	3052
Vostok (VSTK)	-78.47	106.87	0.0	3488
Canary Islands (CANI)	28.45	342.47	11.76	2376
New Zealand (NZLD)	-43.59	170.27	3.28	1029
Severnaya Zemlya (SEVZ)	79.29	96.5	0.11	10
Summit (SUMT)	72.34	321.73	0.01	3126



Latitude [deg]
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Longitude [deg]
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6,0
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4,0
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2,0
1,0
0,0

Method for GLE analysis

Modelling the global NM network response

$$\frac{\Delta N(P_{cut})}{N(t)} = \frac{\sum_i \frac{1}{13} \sum_k \int_{P_{cut}}^{P_{max}} J_{sep_i}(P,t) S_{i,k}(P) G_i(\alpha(P,t)) A_i(P) dP}{\sum_i \int_{P_{cut}}^{\infty} J_{GCR_i}(P,t) S_i(P) dP}$$

Computation of asymptotic viewing cones and Pc of the NM stations:
Computation of particle trajectory in a model magnetosphere.

Application of a optimization procedure (inverse method)
primary solar proton parameters:
(energy spectrum, anisotropy axis direction, pitch-angle distribution)

Modeling of spectra and PAD of SEPs

Modified power law or exponent

$$J_{||}(P) = J_0 P^{-(\gamma + \delta\gamma(P-1))}$$

$$J_{||}(P) = J_0 \exp(-P/P_0)$$

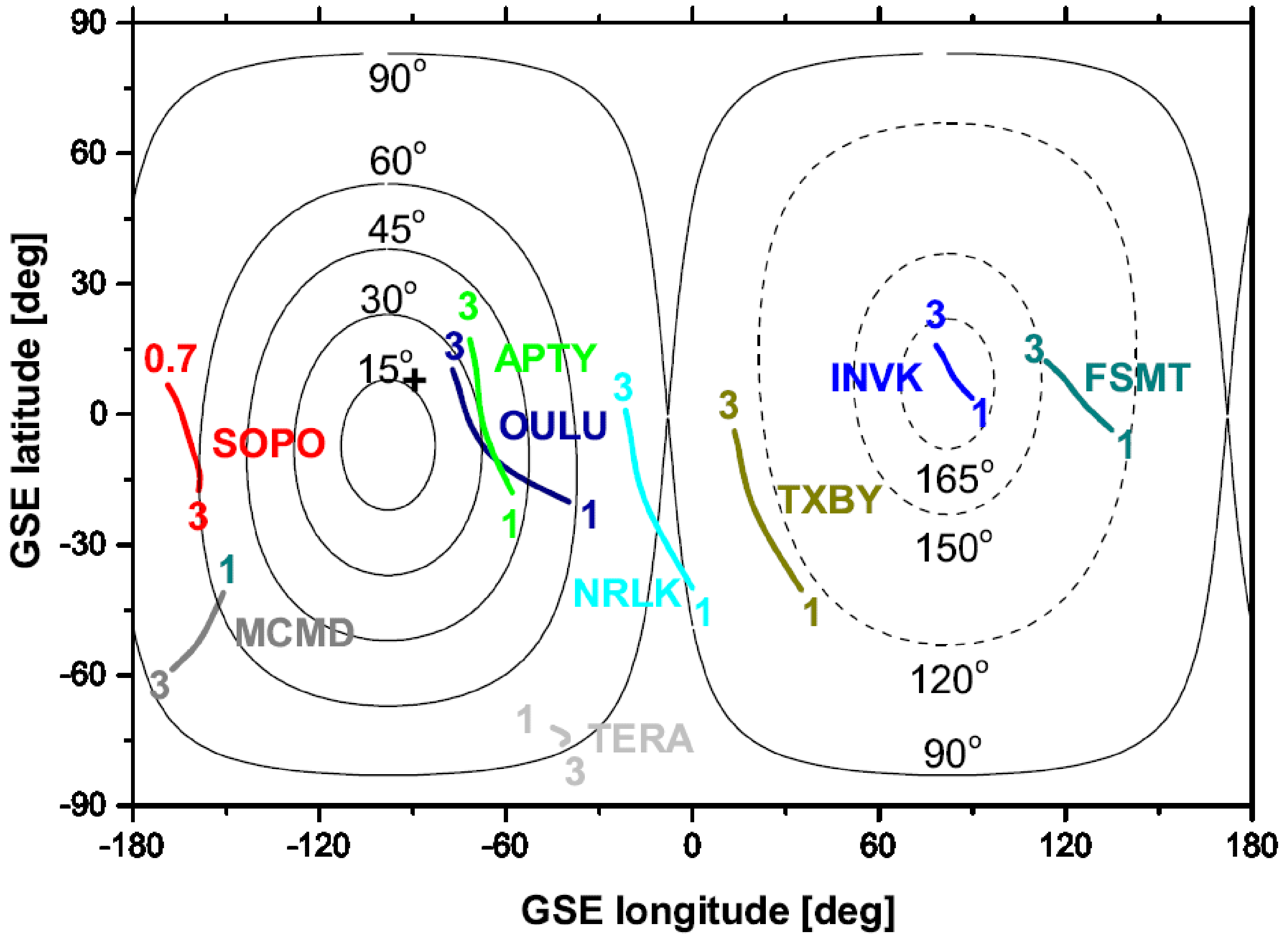
PAD – Gaussian like

$$G(\alpha) = \propto \sum_i \exp - (\alpha_i - \alpha_i')^2 / \sigma_i^2$$

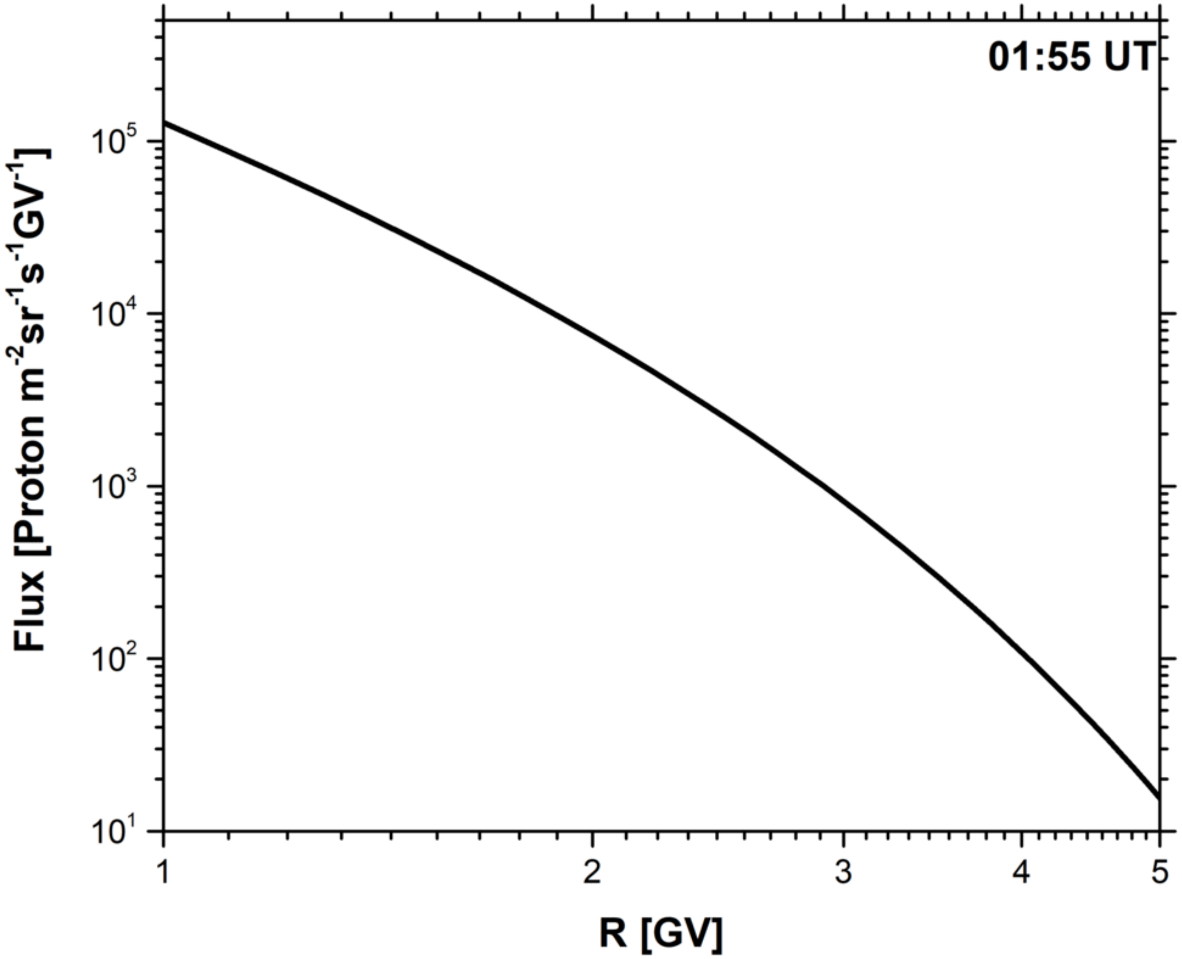
From 5 Up to 14 parameters

$$\mathcal{D} = \frac{\sqrt{\sum_{i=1}^{m} \left[\left(\frac{\Delta N_i}{N_i} \right)_{mod.} - \left(\frac{\Delta N_i}{N_i} \right)_{meas.} \right]^2}}{\sum_{i=1}^{m} \left(\frac{\Delta N_i}{N_i} \right)_{meas.}}$$

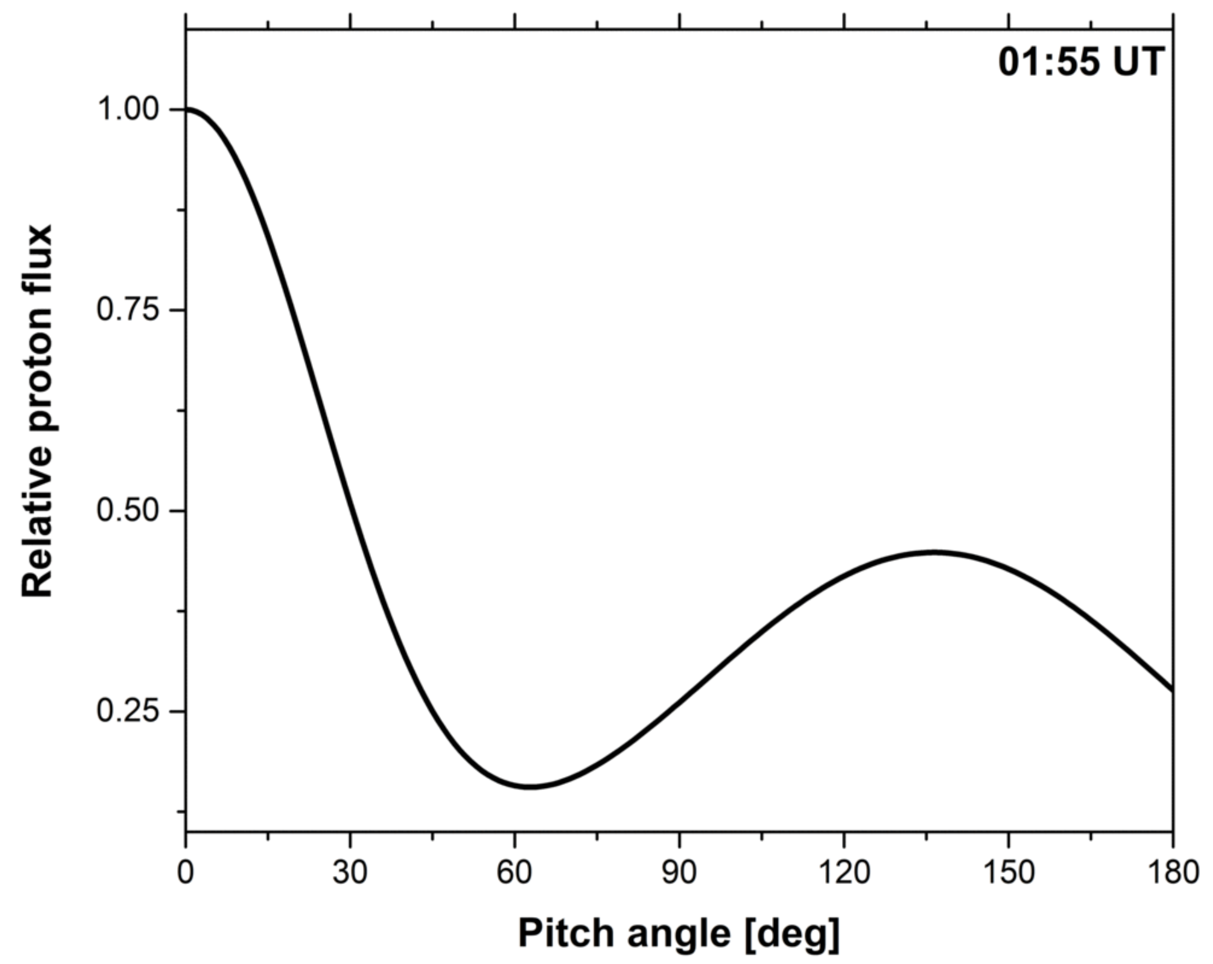
Asymptotic directions during GLE # 71 on 17 May 2012



Rigidity spectra during GLE 71, 17 May 2012



Angular distribution during GLE 71, 17 May 2012



Performance of extended, actual and reduced global NM network

Quality of the fit $\mathcal{D}$ during the analysis of several GLEs (main phase of the event) as a function of the number of the used NM stations. Columns 1–2 correspond to the GLE, while columns 3–5 to correspond to $\mathcal{D}$ and number of the used stations (in the brackets), column 3 corresponds to extended NM network, column 4 to the actual network used for the analysis; column 5 to reduced number of stations, respectively. N.A. depicts the case when it is not possible to unfold the SEP spectra. The details for the analysis of the presented GLEs are given in (Mishev et al., 2014; Mishev and Usoskin, 2016a; Kocharov et al., 2017; Mishev et al., 2018b) and this work.

GLE #	Date	Extended NM network	Actual NM network	Reduced nNM etwork
GLE # 5	23.02.1956	1.6(37)	2.5(15)	N.A.(10)
GLE # 59	14.07.2000	4.1(39)	4.8(30)	19(20)
GLE # 67	02.11.2003	4.5(39)	7.1(34)	38(21)
GLE # 69	20.01.2005	3.0(38)	3.5(33)	35(25)
GLE # 70	13.12.2006	3.2(38)	4.2(32)	43(22)
GLE # 71	17.05.2012	5.0(34)	7.1(24)	N.A.(19)
GLE # 72	10.09.2017	5.2(31)	6.1(23)	33(18)

Conclusion

1. **Current status of the global NM network**
2. **Performance of**

   extended

   actual

   reduced global NM network

THANK YOU