Usage of the global NM network for assessment of the radiation exposure at flight altitudes

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Outline

1. Introduction
2. Model for exposure to radiation at flight altitudes
3. Spectra of GLEs derived using NM data
4. Examples
5. Summary

Introduction

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

Primary SEP parameters:

energy spectrum

anisotropy

using the information from NMs

Global neutron monitor network

Model for computation of effective dose rate at aviation altitudes (Mishev&Usoskin JSWSC 2015)

New model for effective/ambient dose equivalent estimation based on a full Monte Carlo simulation of CR propagation and interaction with the atmospheric molecules. It is based on yield function formalism.

Extensive GEANT 4 simulation tool PLANETOCOSMICS is used with NRLMSISE 00 atmospheric model.

Exposure of air crew at flight altitudes of 35 & 50 kft

Good agreement with experimental and reference data

Model for computation of effective dose rate at aviation altitudes cont.

Effective dose rate

$$E(h, R_c, \theta, \varphi) = \sum_i \int_{E_{cut,i}(R_c)}^{\infty} \int_{\Omega} J_i(T')Y_i(T', h)d\Omega dT'$$

$$Y_i(T', h) = \sum_j \int_{T^*} F_{i,j}(h, T', T^*, \theta, \varphi)C_j(T^*)dT^*$$

Yield function

$$E = 4\pi^2 \left[\int_{E_{cut}}^{\infty} J_p(T')Y_p(T')dT' + \int_{E_{cut}}^{\infty} J_\alpha(T')Y_\alpha(T')dT' \right]$$

For GCRs

For the GCRs spectrum – force field model

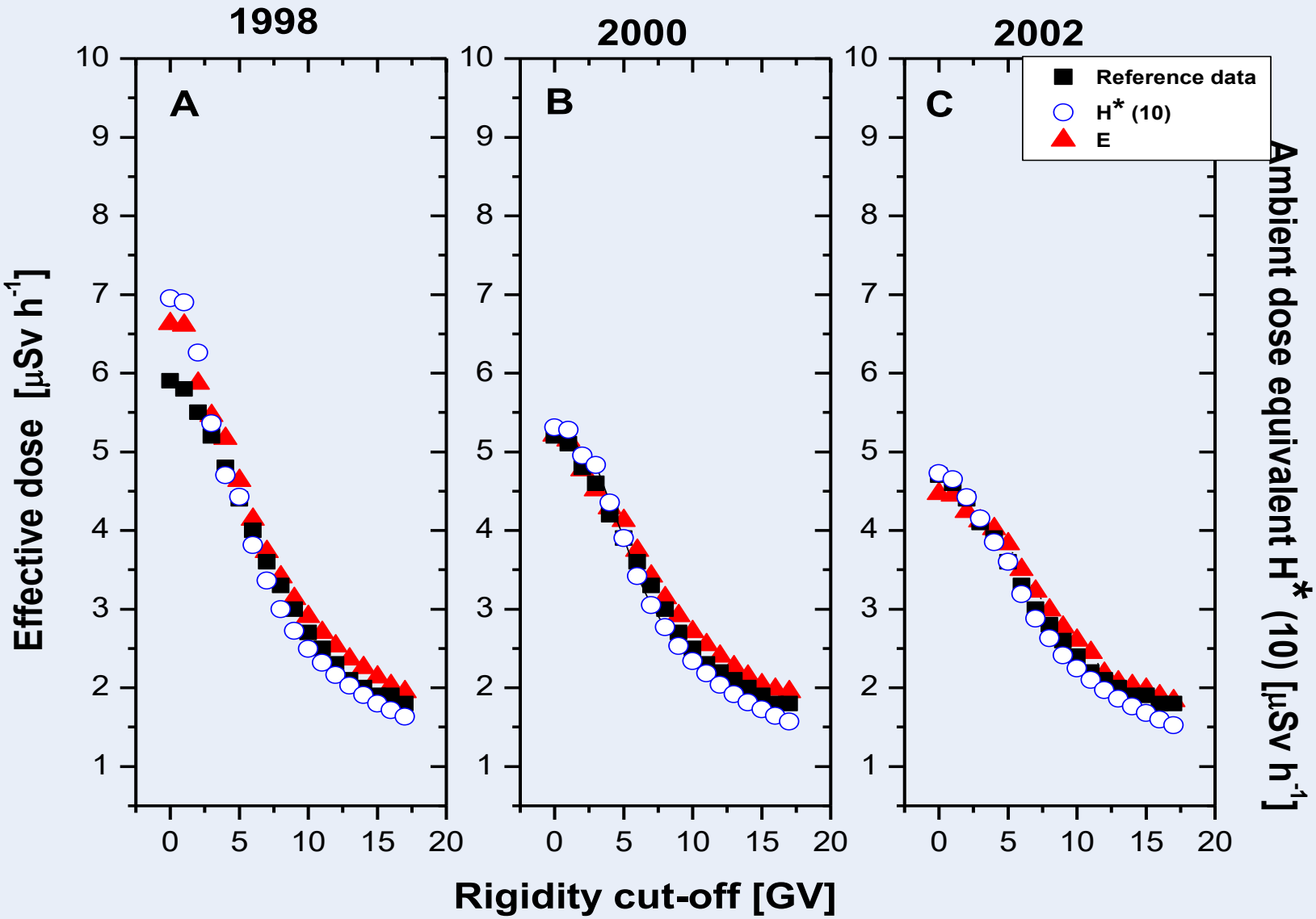
$$J_i(T', \phi) = J_{LIS,j}(T' + \Phi_j)\frac{(T')(T' + 2T_r)}{(T' + \Phi_j)(T' + \Phi_j + 2T_r)}$$

For SEPs

1. Data mostly based on NM data analysis, when available

2. The computations are performed for various reconstructions of SEP spectra, available in literature, thus for some events there are several results

3. An conservative isotropic distribution of SEPs is considered


1998
2000
2002
A
B
C
Reference data
H* (10)
E
Effective dose [μSv h-1]
Ambient dose equivalent H* (10) [μSv h-1]
Rigidity cut-off [GV]
0
5
10
15
20
1
2
3
4
5
6
7
8
9
10

Method for GLE analysis
Mishev et al., JGR 2014

The GLE analysis procedure

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

2. Making an initial guess of the inverse problem

3. 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

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

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

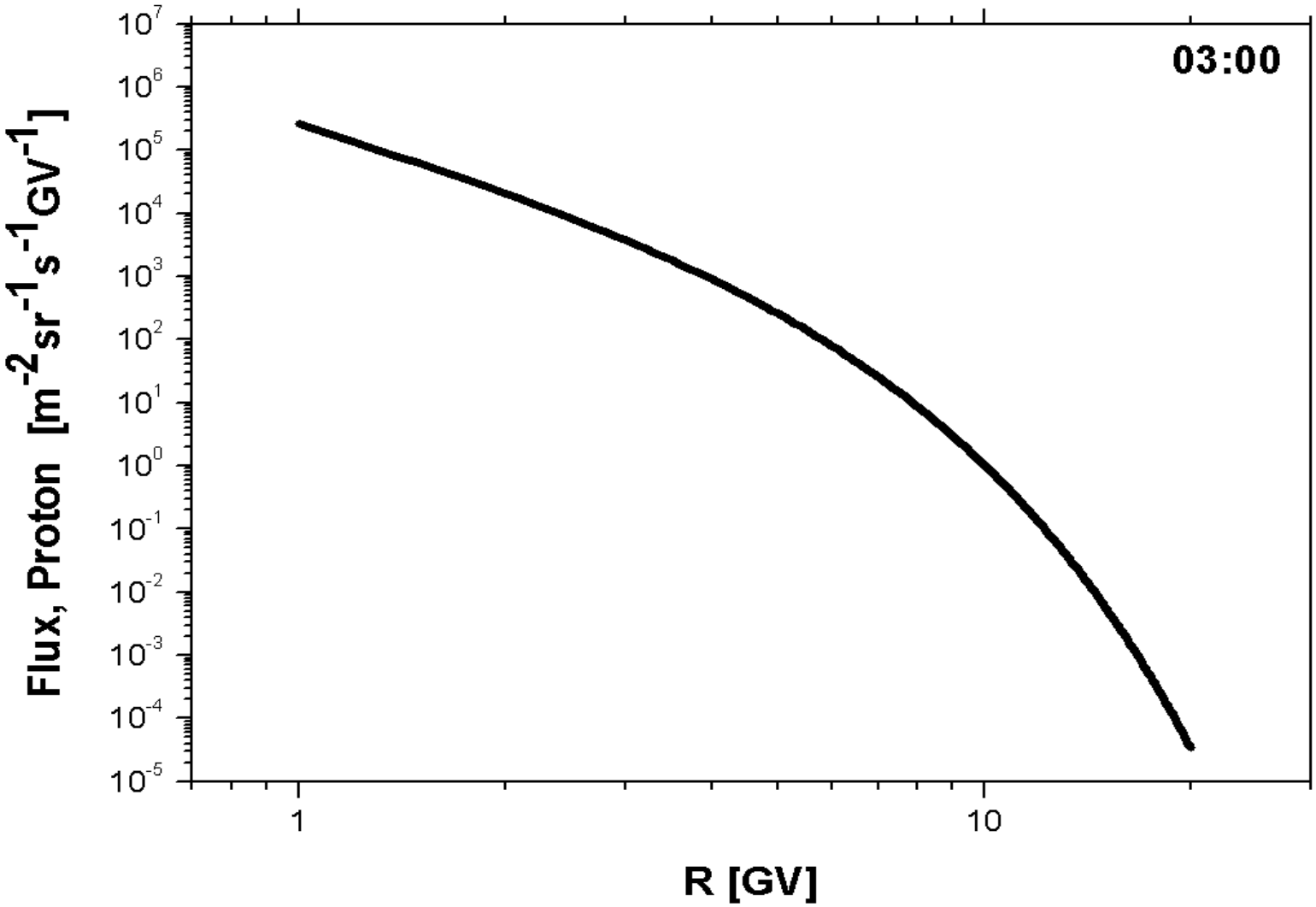
PAD – Gaussian like

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

From 5 Up to 14 parameters

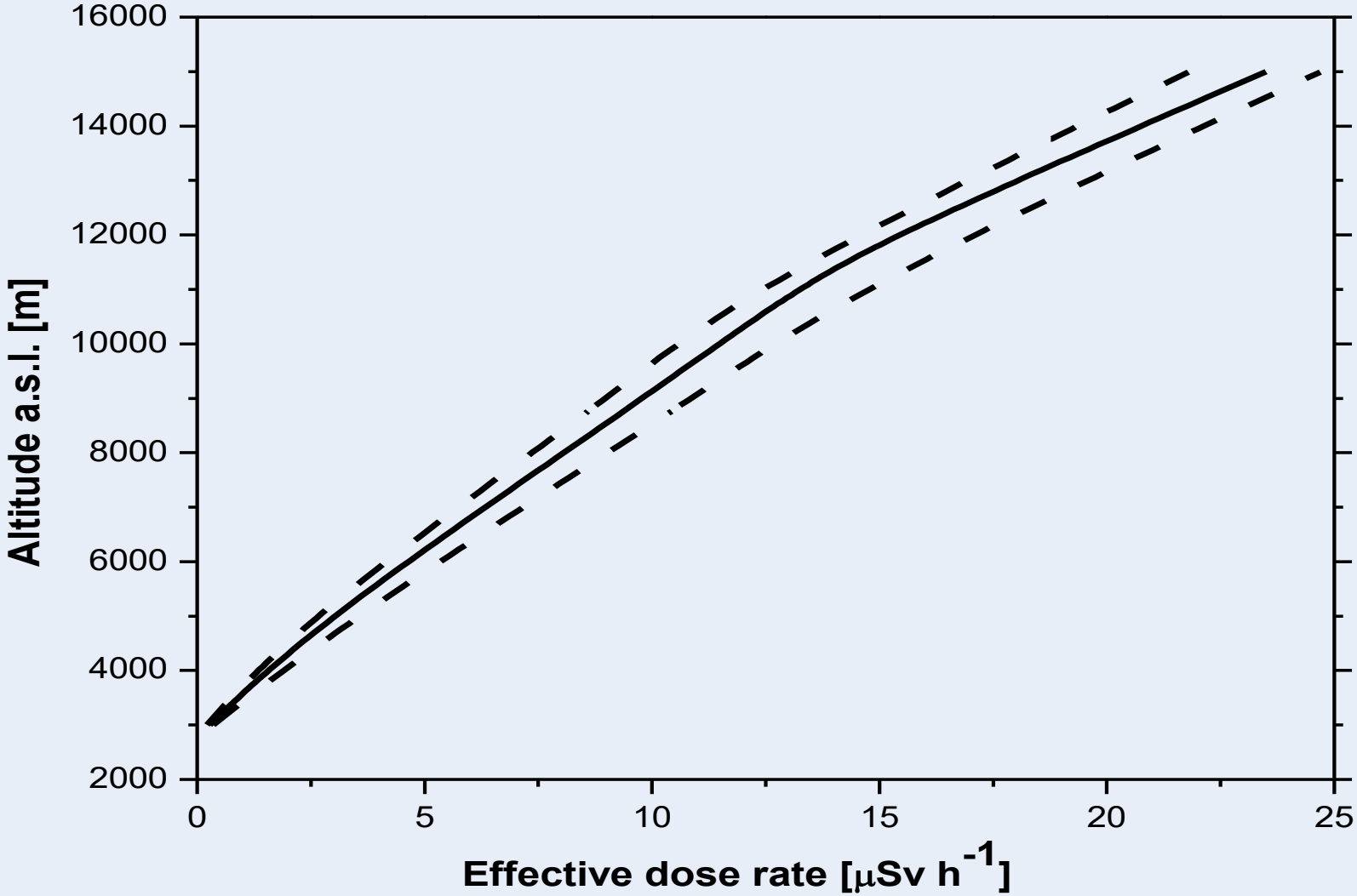
EXAMPLES

GLE 70 – 13.12. 2006



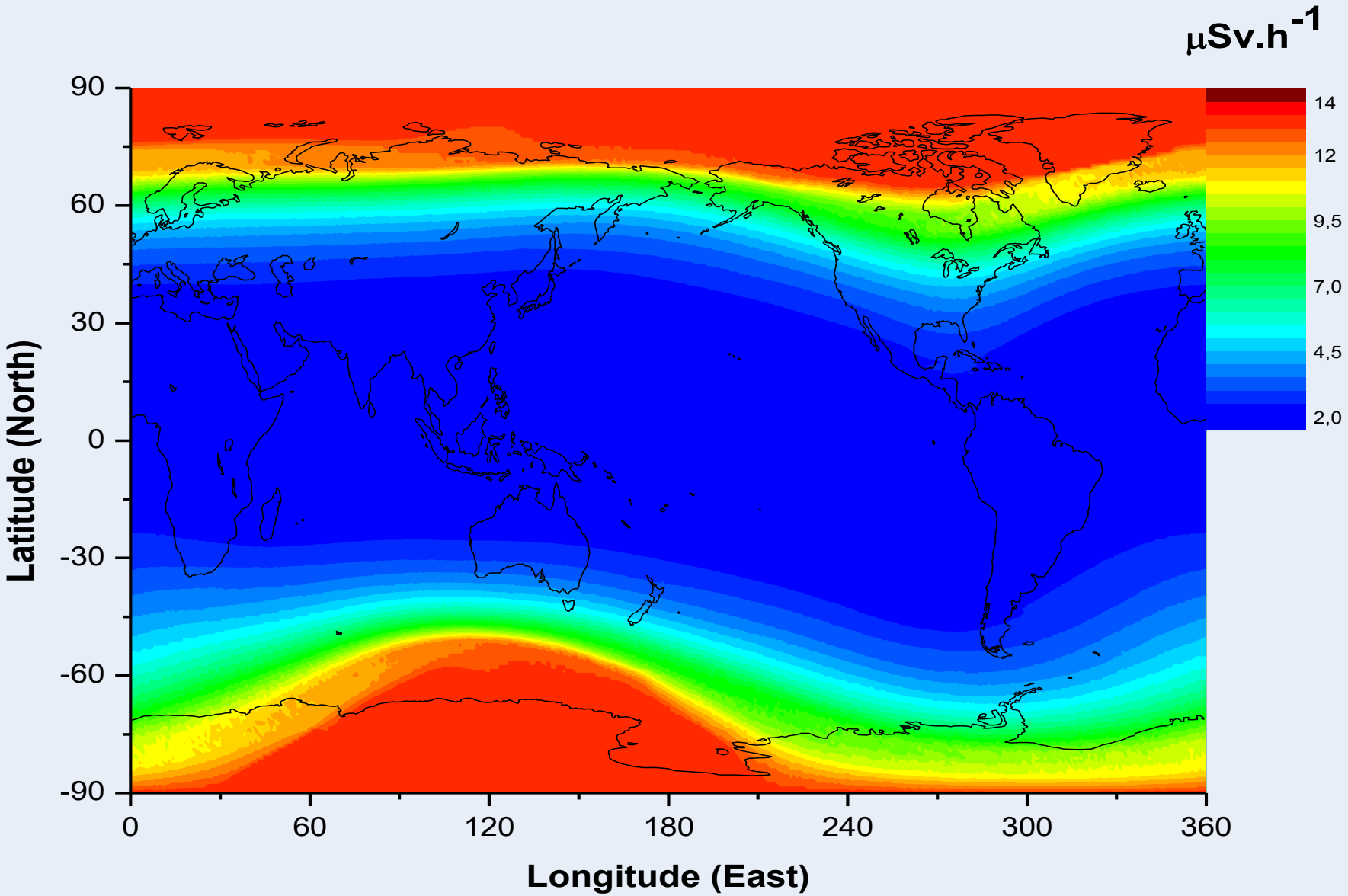
Mishev & Usoskin Sol. Phys. 2015

Effective dose rate as function of altitude during main phase of GLE 72

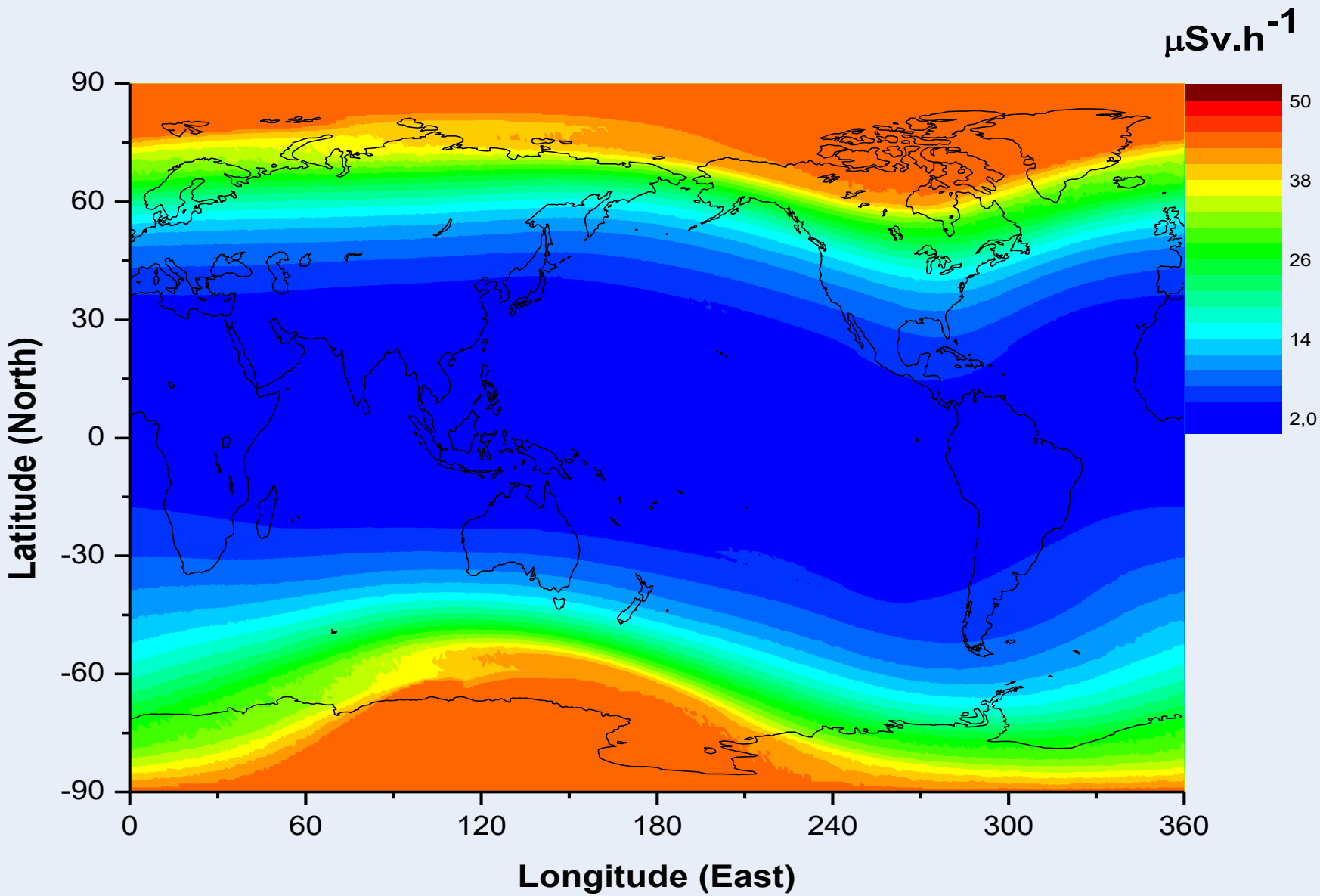


Mishev & Usoskin Space Weather 2018

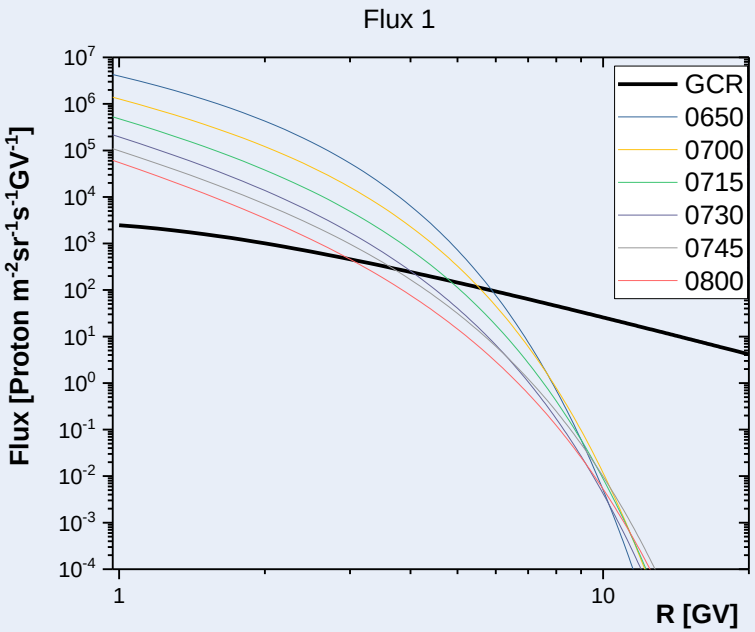
Distribution of effective dose rate at 35 kft altitude during GLE #72

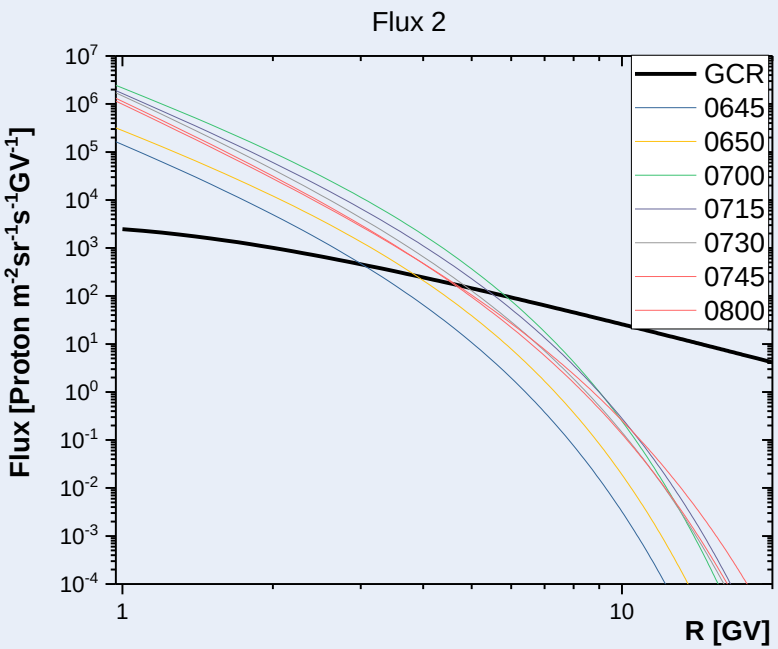


Distribution of effective dose rate at 35 kft altitude during GLE #70



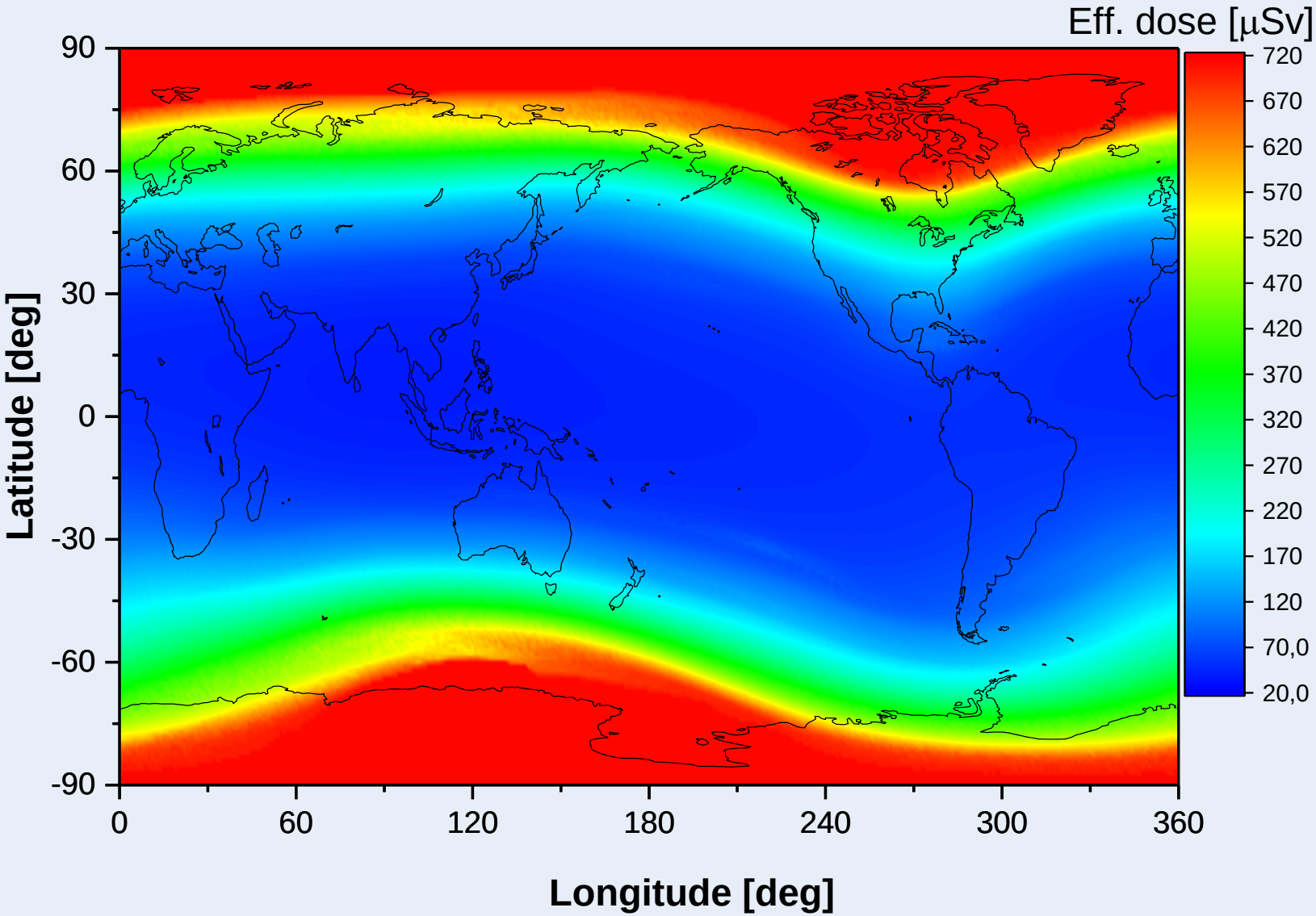
Major GLE 69 on 20 January 2005



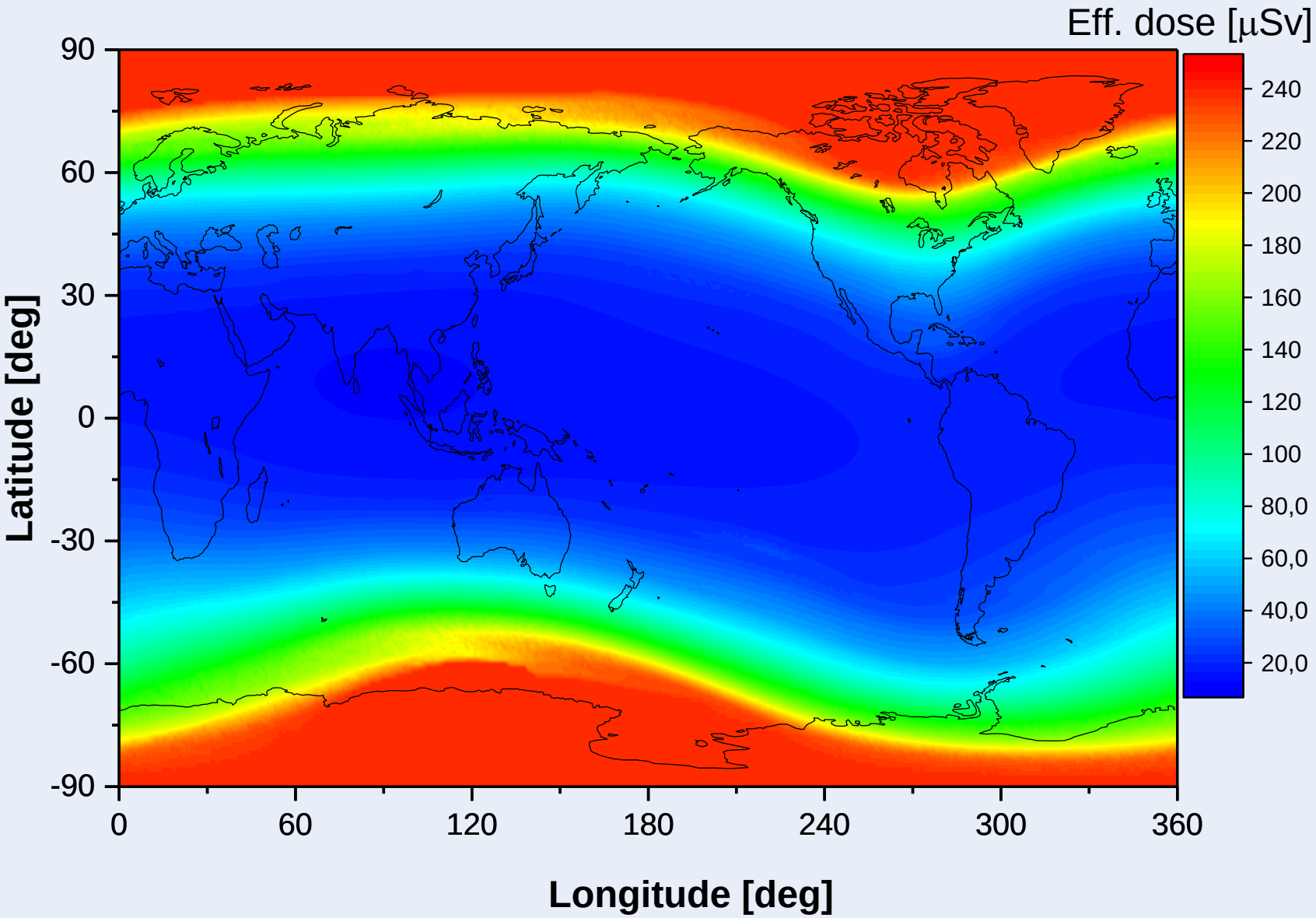


Effective dose rate ≈ 0.54 mSv h^{-1} and 0.13 mSv h^{-1}

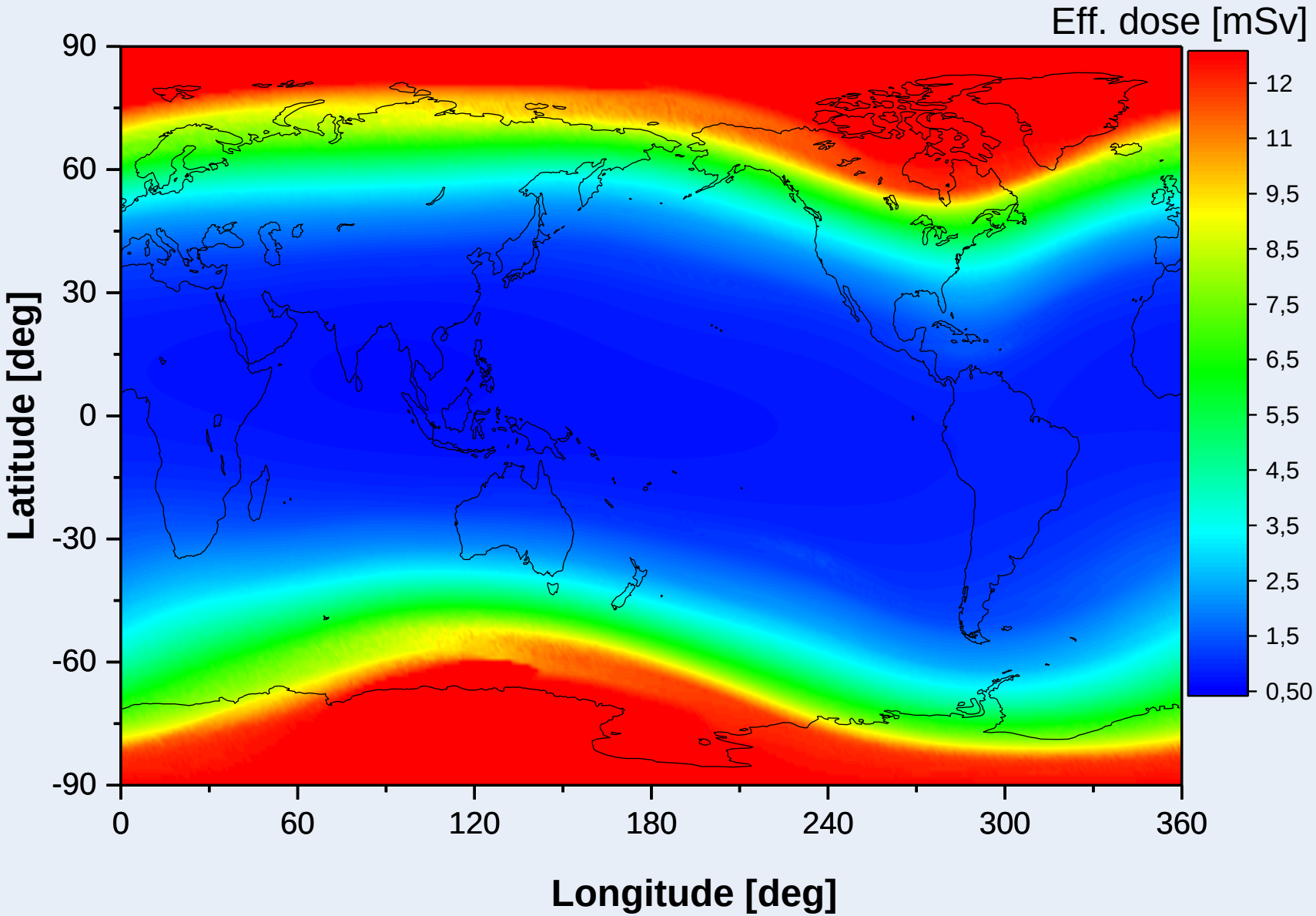
Effective dose at altitude of 50 kft during GLE #69 integrated over the first 3h of the event



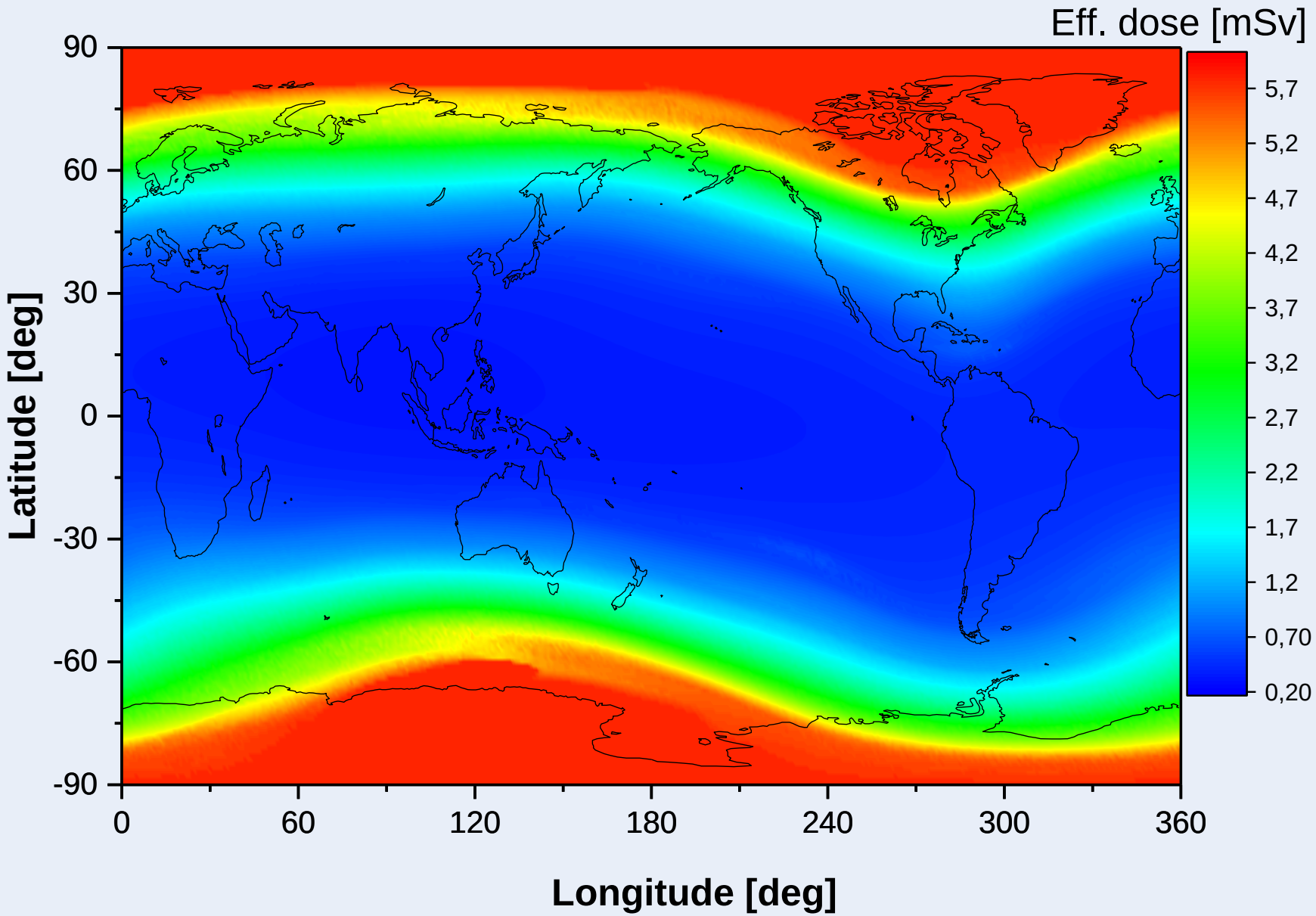
Effective dose at altitude of 35 kft during GLE 69 integrated over the first 3h of the event



Effective dose at altitude of 50 kft during GLE #5 integrated over the first 3h of the event



Effective dose at altitude of 35 kft during GLE #5 integrated over the first 3h of the event

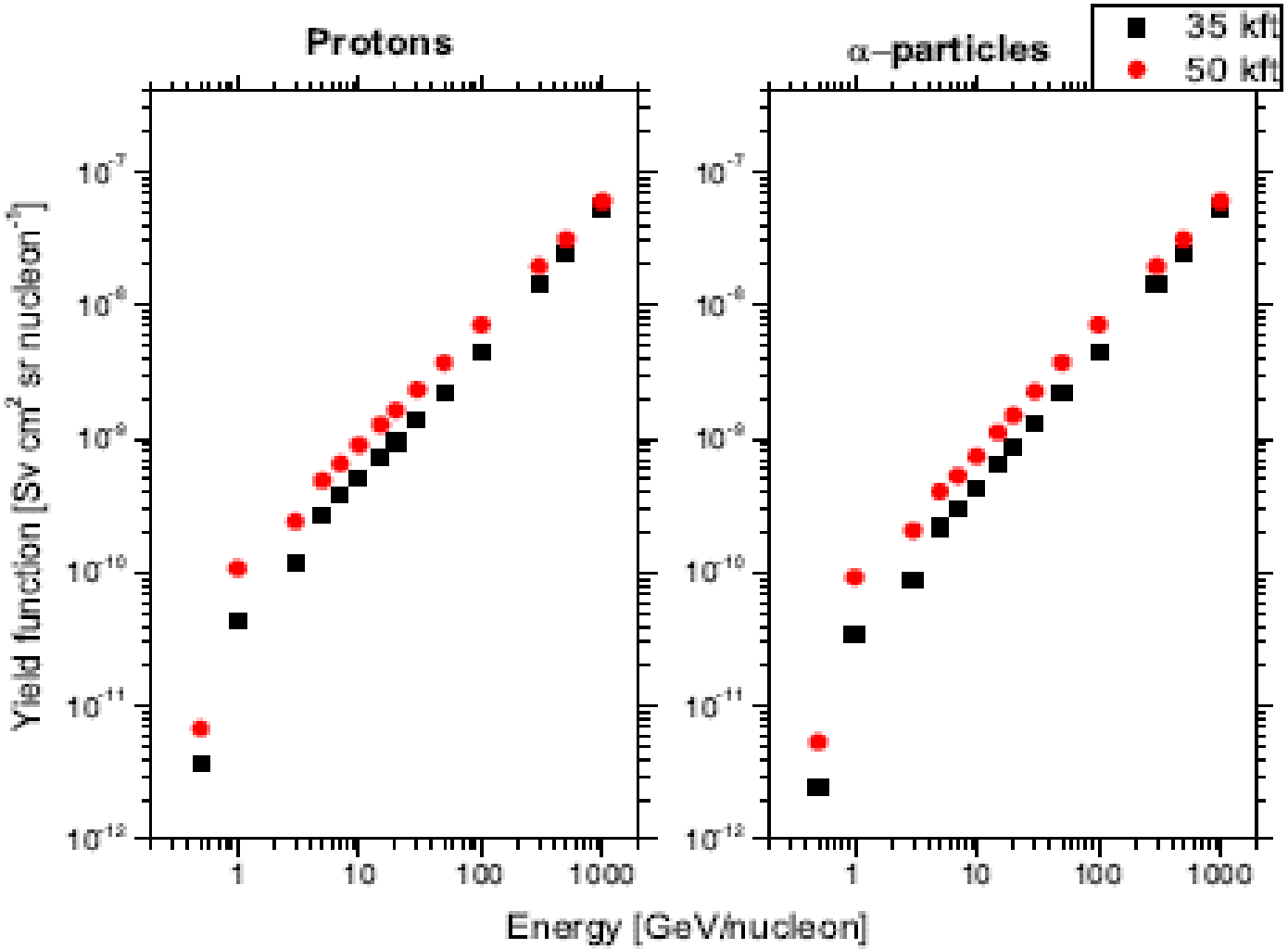


Conclusion

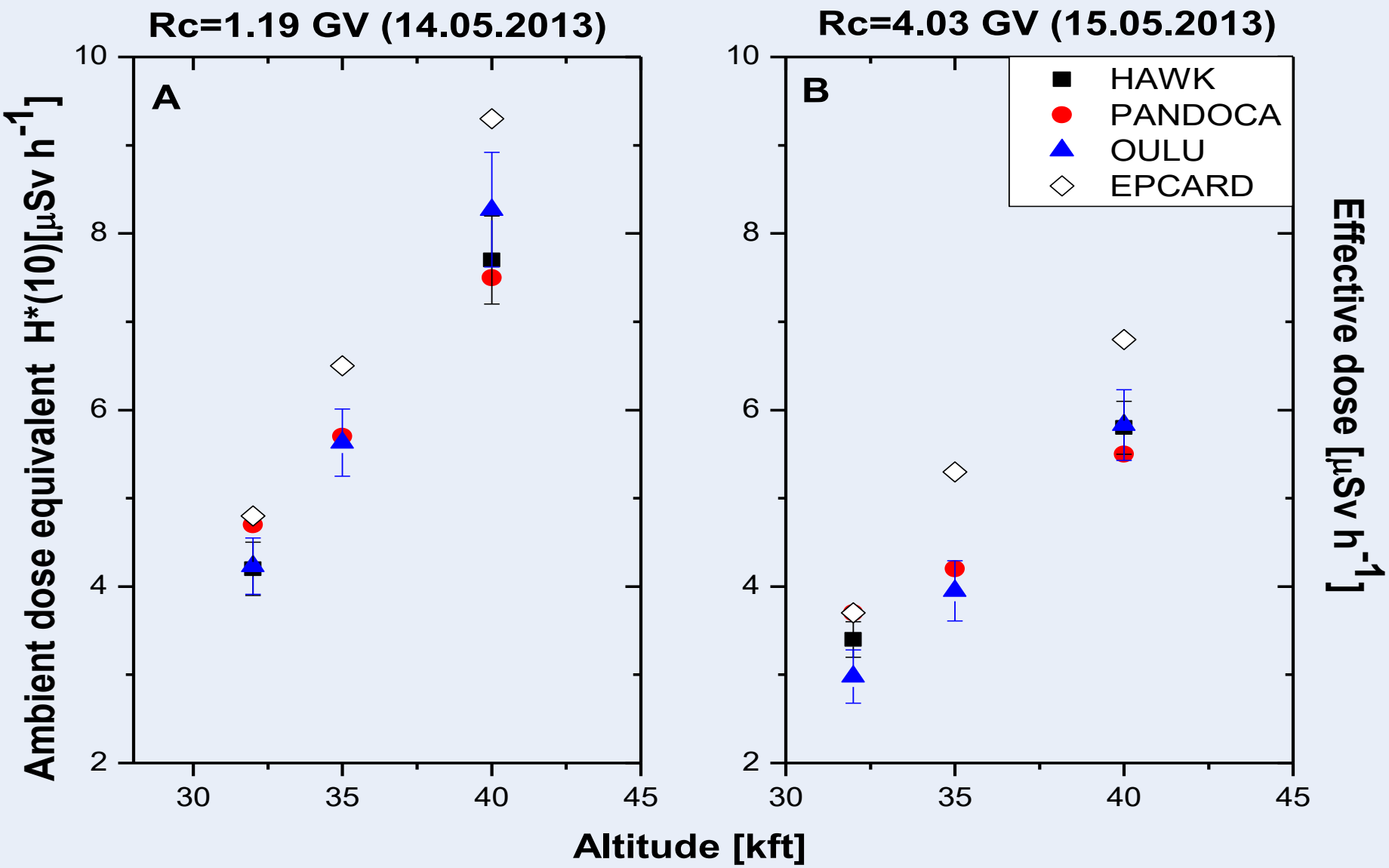
1. New NM yield function
2. Method for GLE and sub-GLE analysis based on NM data
3. Computation of effective dose rate at several altitudes
4. Upgrade of GLE database


THANK YOU

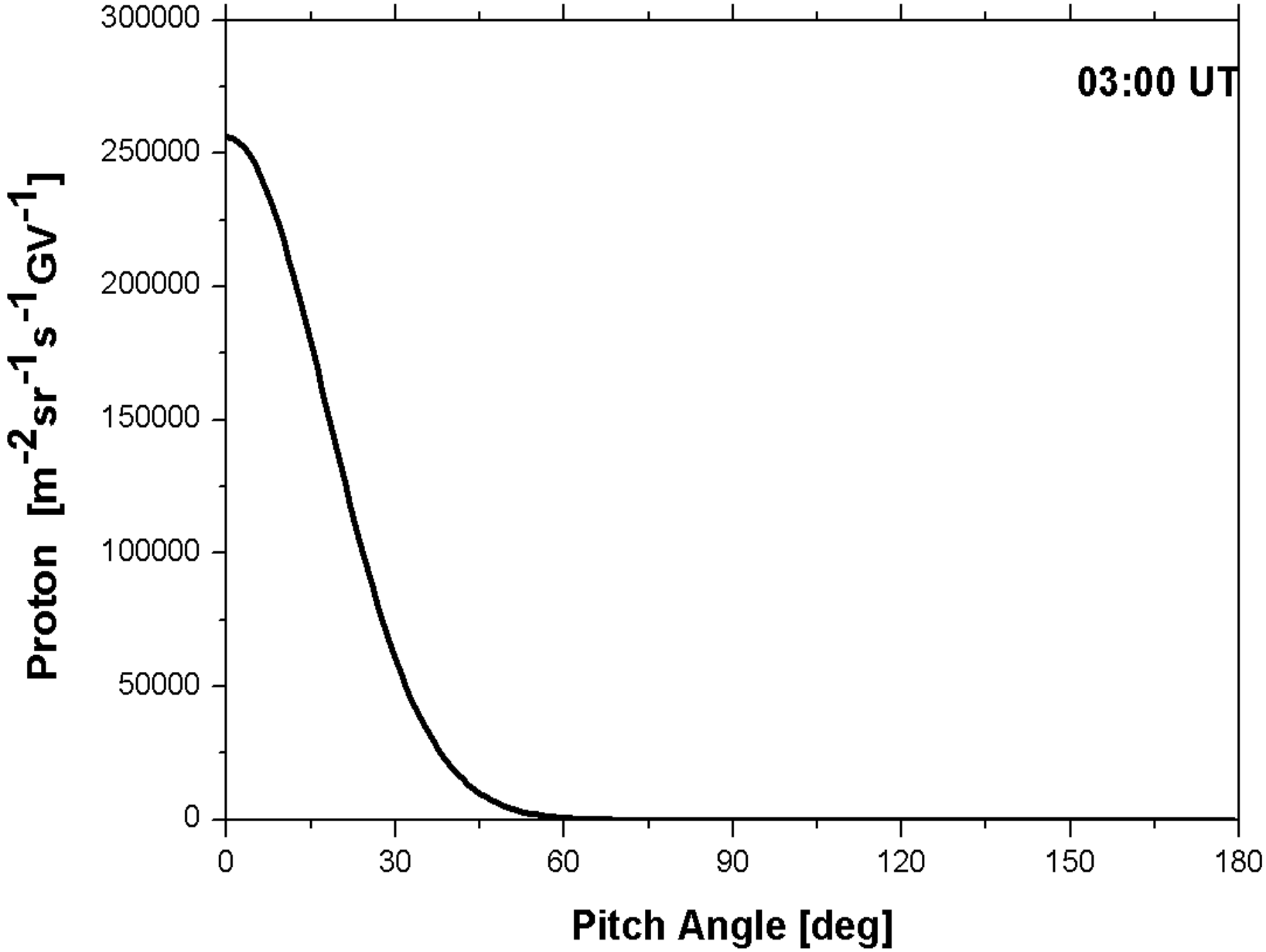
Effective dose yield function at 35 kft



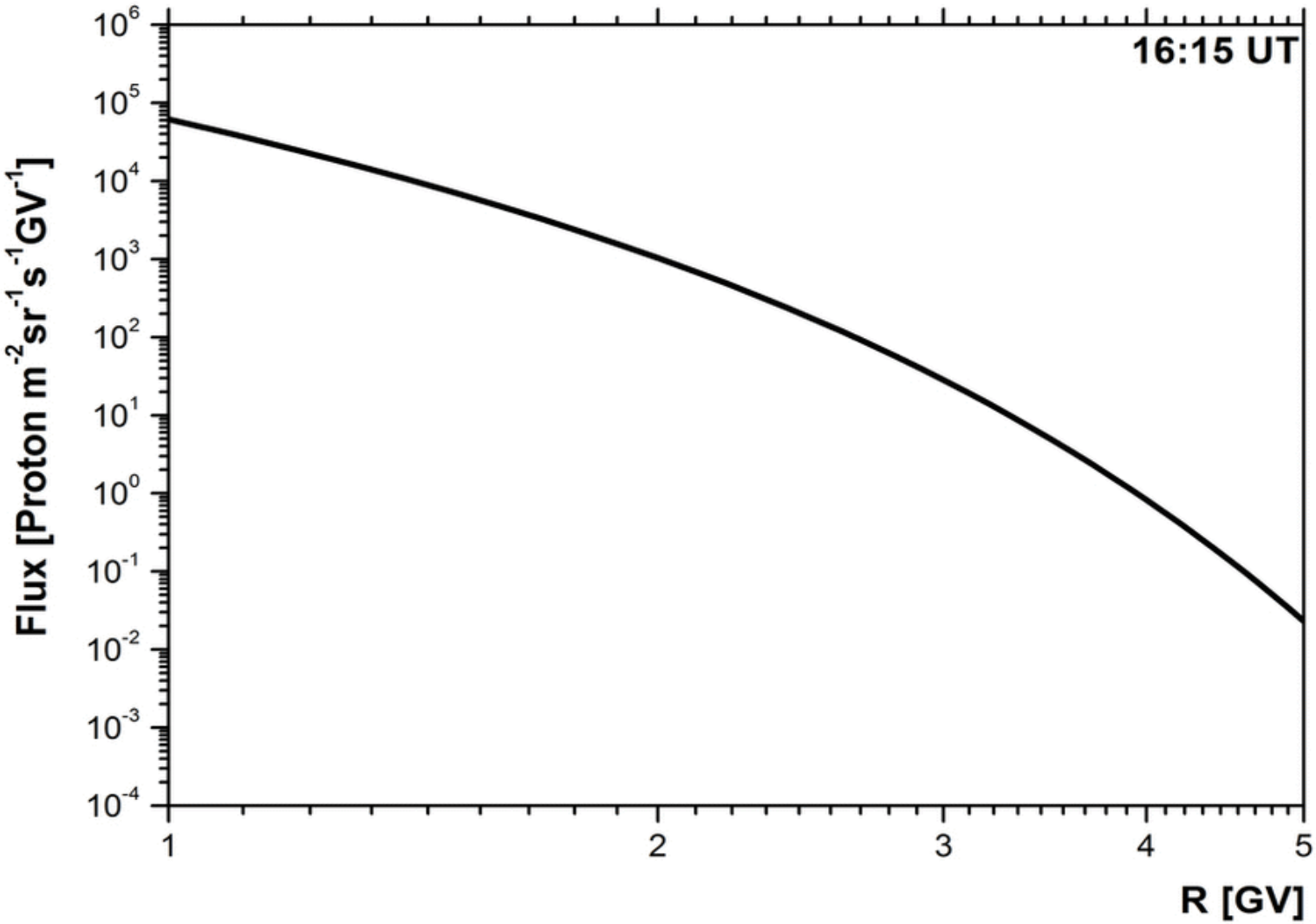
Comparison with measurements and models



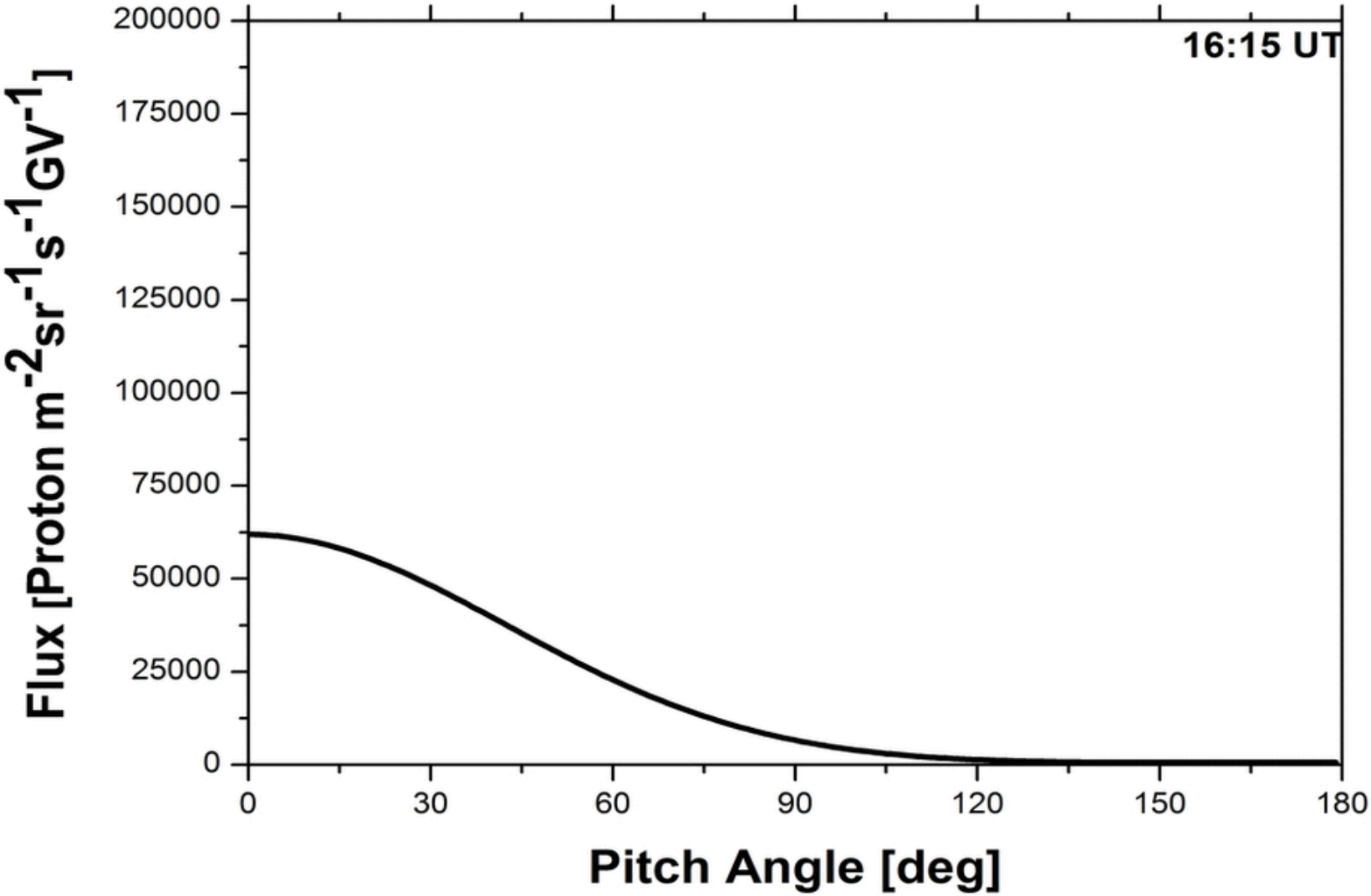
GLE 70 – 13.12. 2006



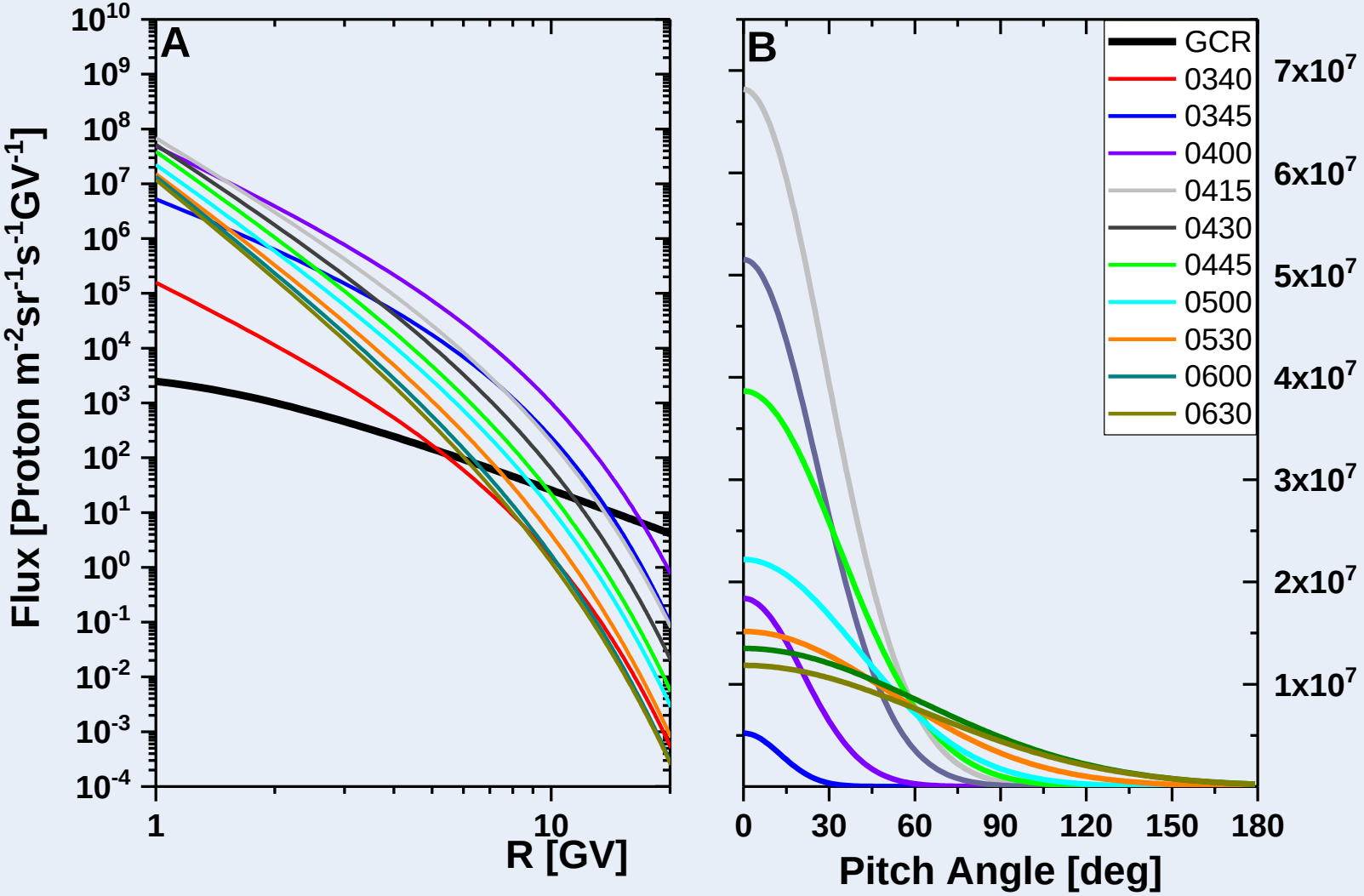
Rigidity spectra during GLE 72, 10 September 2017

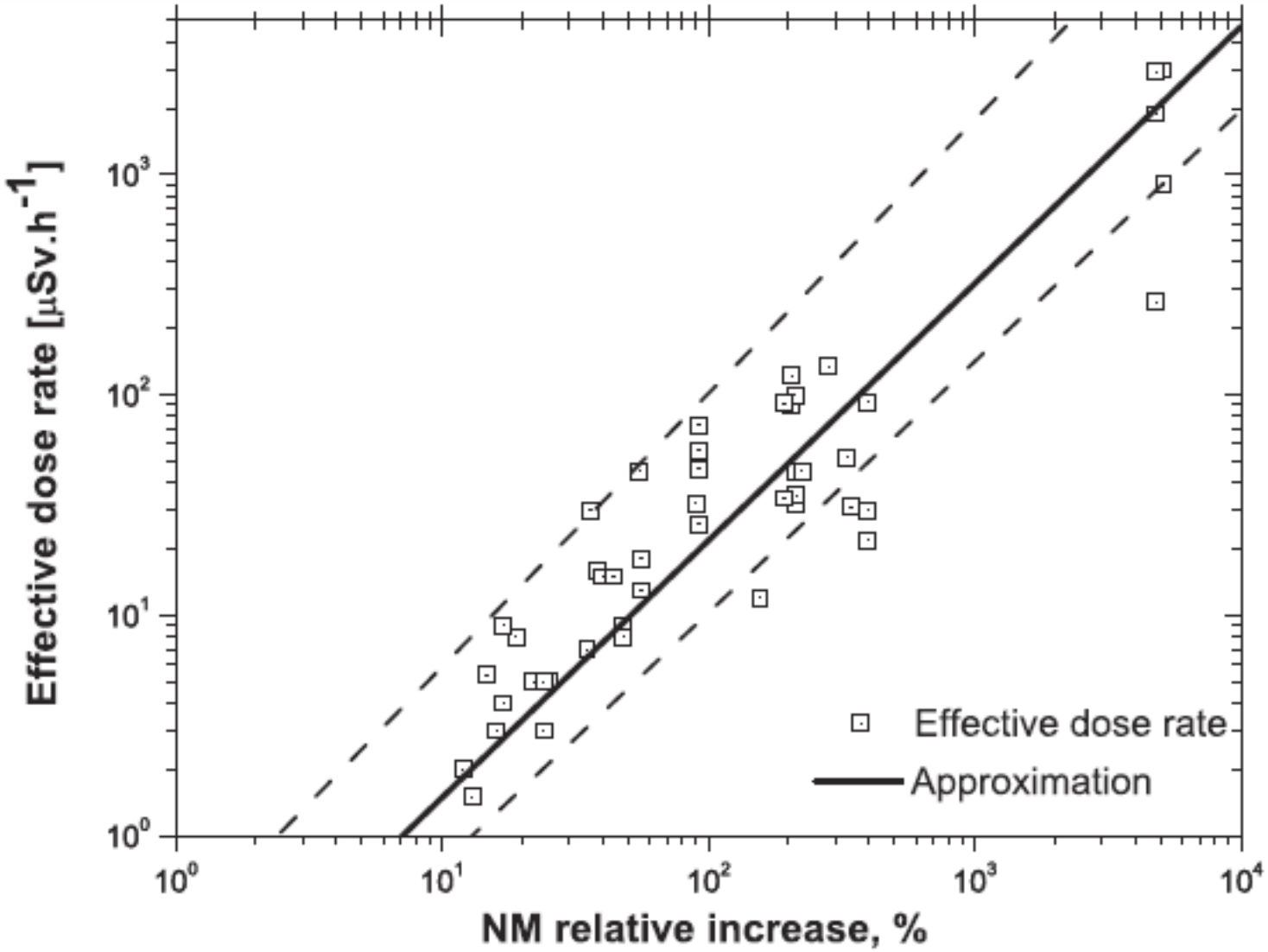


PAD distribution during GLE 72, 10 September 2017



GLE # 5 spectra and PAD




Effective dose rate [μSv.h-1]
10^3
10^2
10^1
10^0
10^0
10^1
10^2
10^3
10^4
NM relative increase, %
Effective dose rate
Approximation