



Cosmogenic ^7Be , ^{10}Be , ^{14}C , ^{22}Na and ^{36}Cl in the atmosphere: Altitudinal profiles of yield functions

S. Poluianov¹, G. Kovaltsov², A. Mishev¹, I. Usoskin^{1,3}

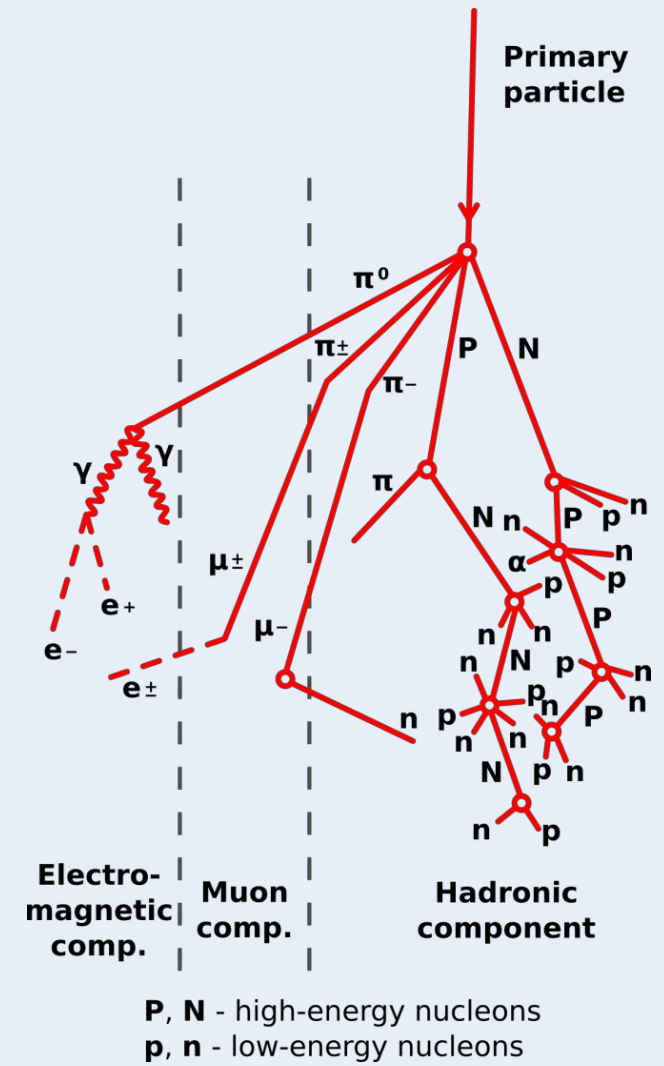
1-Space Climate Res. Unit, University of Oulu, Finland

2-Ioffe Physical-Technical Institute, Russia

3-Sodankylä Geophysical Observatory, University of Oulu, Finland

stepan.poluianov@oulu.fi

- In this work:
- Beryllium-7
 - Beryllium-10
 - Carbon-14
 - Sodium-22
 - Chlorine-36



(after Simpson et al., 1953)

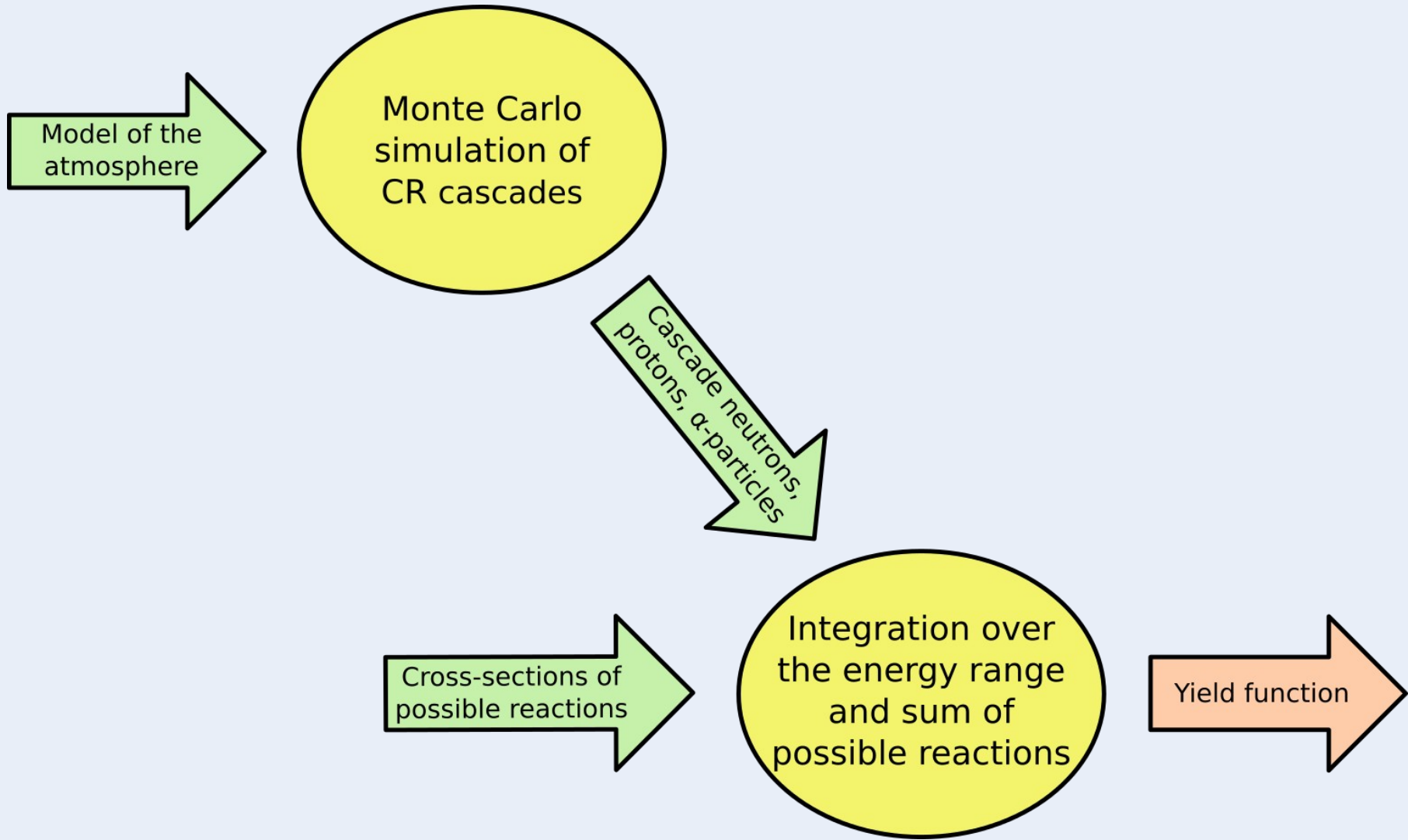
- The approach simplifies computation of the nuclide production rate.
- The yield function $Y(E,h)$ is the production of the nuclide by primary particles of a given type with the unit differential intensity.
- The so-called “production function” $S(E,h)$ and yield function $Y(E,h)$ are directly related one to another.
- The nuclide production rate:

$$Q(h, P_{cutoff}) = \sum_i \int_{E(P_{cutoff})}^{\infty} Y_i(E, h) J(E) dE$$

This allows us to separate the production process (in $Y(E,h)$) of the nuclide by an energetic particle and the spectrum of cosmic rays ($J(E)$).

- High altitude resolution is highly demanded

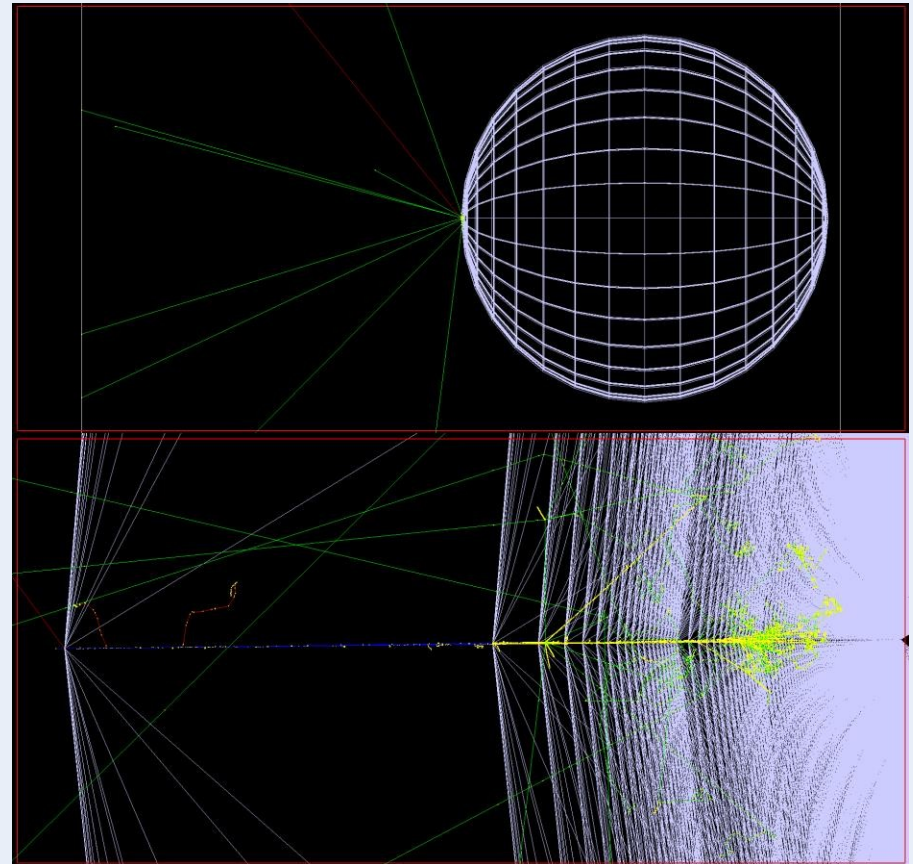
Yield function computation



- Monte Carlo simulation with Geant4
- Model of the atmosphere NRLMSISE-2000
- Depth resolution 1–10 g/cm²
- $E_{\text{prim}} = 20 \text{ MeV/nuc} - 100 \text{ GeV/nuc}$
- Primary protons and α -particles with the isotropic distribution

Output:

altitudinal and energetic distribution of fluences of neutrons, protons and α -particles



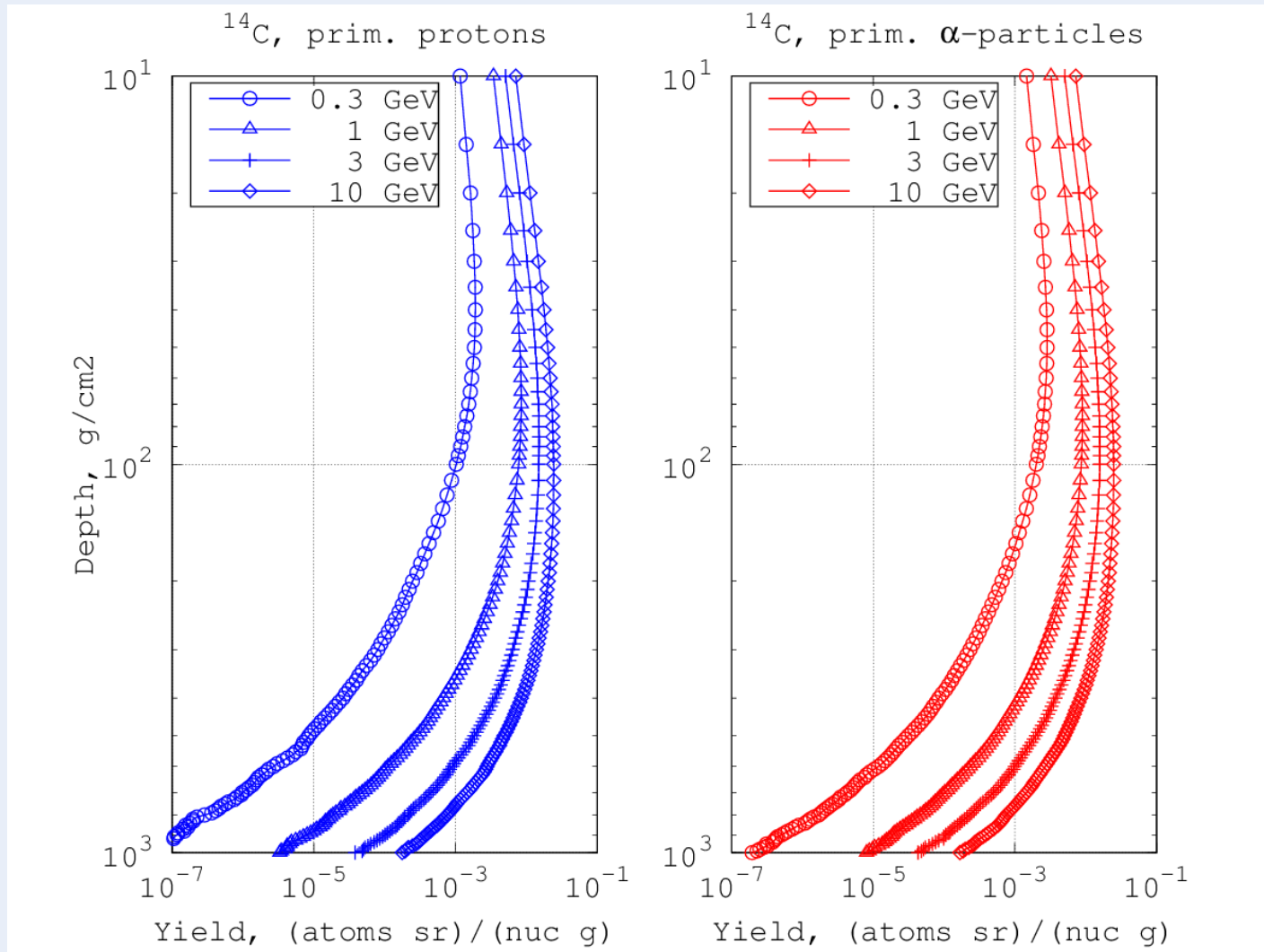
Yield function:

$$Y(E_0, h) = \pi \sum_j k_j \int_{E'_{min}}^{\infty} I(E_0, E', h) \sigma_j(E') dE'$$

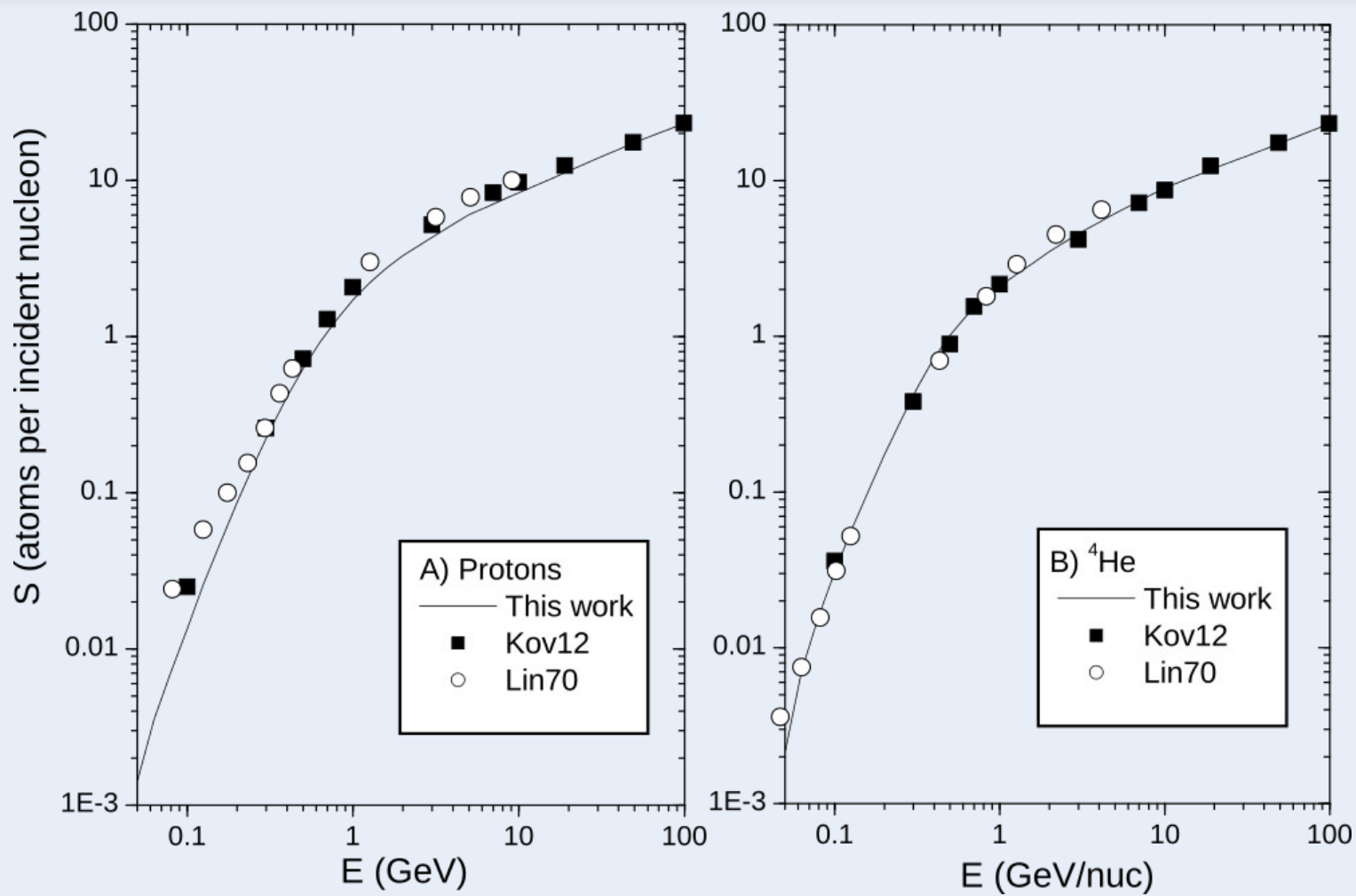
where:

- E_0 - the primary particle's kinetic energy
- h - the atmospheric depth
- k_j - the number of target atoms in 1 gram of air
- j - the index of the target atom
- I - the cascade particle's fluence
- σ - the cross-section of a nuclear reaction
- E' - the cascade particle's energy

Example: the yield function of ^{14}C



Verification. Columnar production func. of ^{14}C .



- Kov12 – Kovaltsov et al., *Earth Planet. Sci. Lett.*, 2012
- Lin70 – Lingenfelter and Ramaty, *Proc. 12th Nobel symp.*, 1970

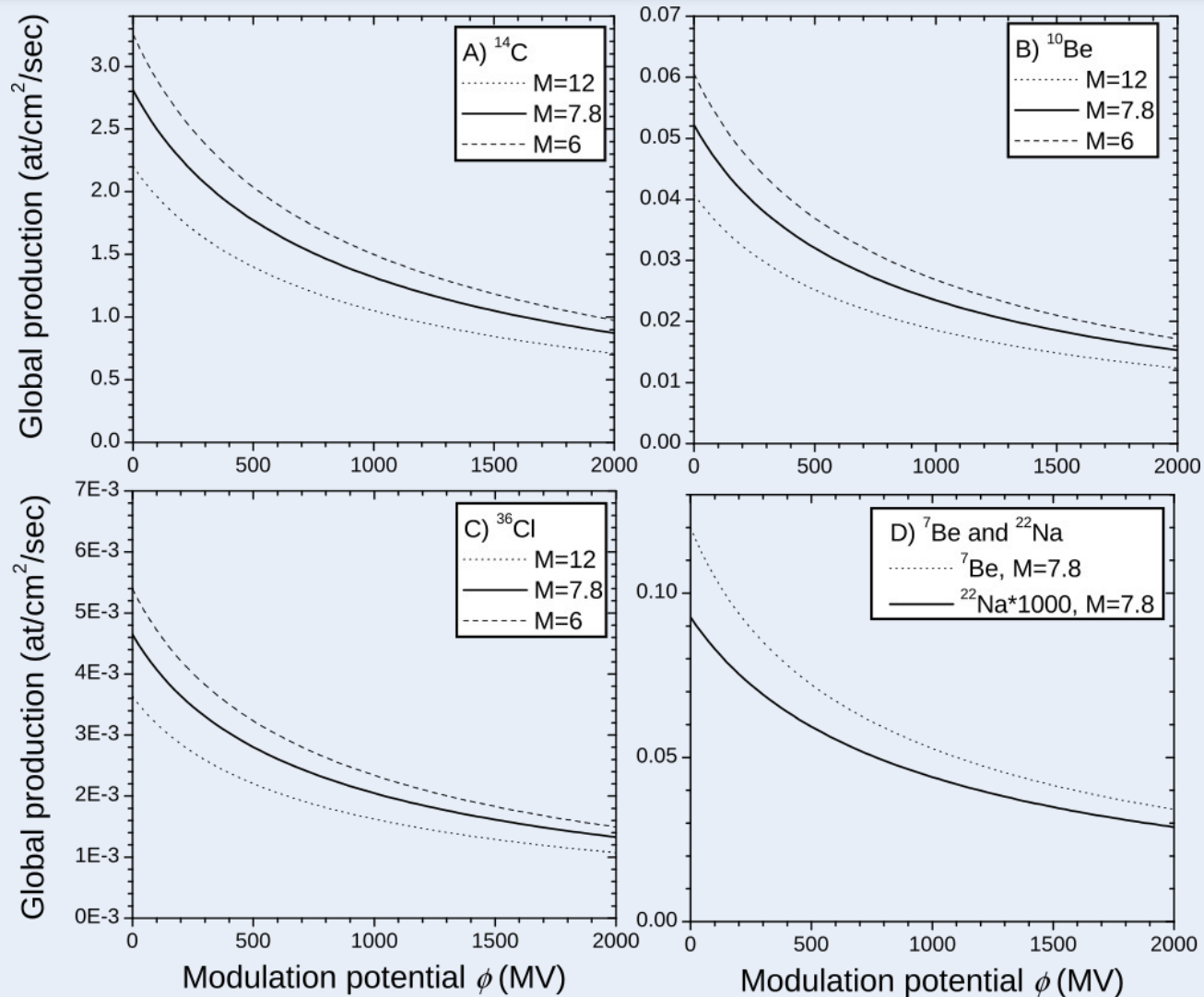
Verification.

Global production of ^{14}C .

By GCRs, integrated over the globe
with the present geomagnetic field, moderate solar activity

This work	
1.60 at/(s cm ²)	
Earlier similar works	
2.02 at/(s cm ²)	Masarik and Beer, JGR 1999
1.64 at/(s cm ²)	Kovalstov et al., EPSL 2012
From the carbon cycle inventory	
1.6–1.8 at/(s cm ²)	e.g., Goslar, R 2001

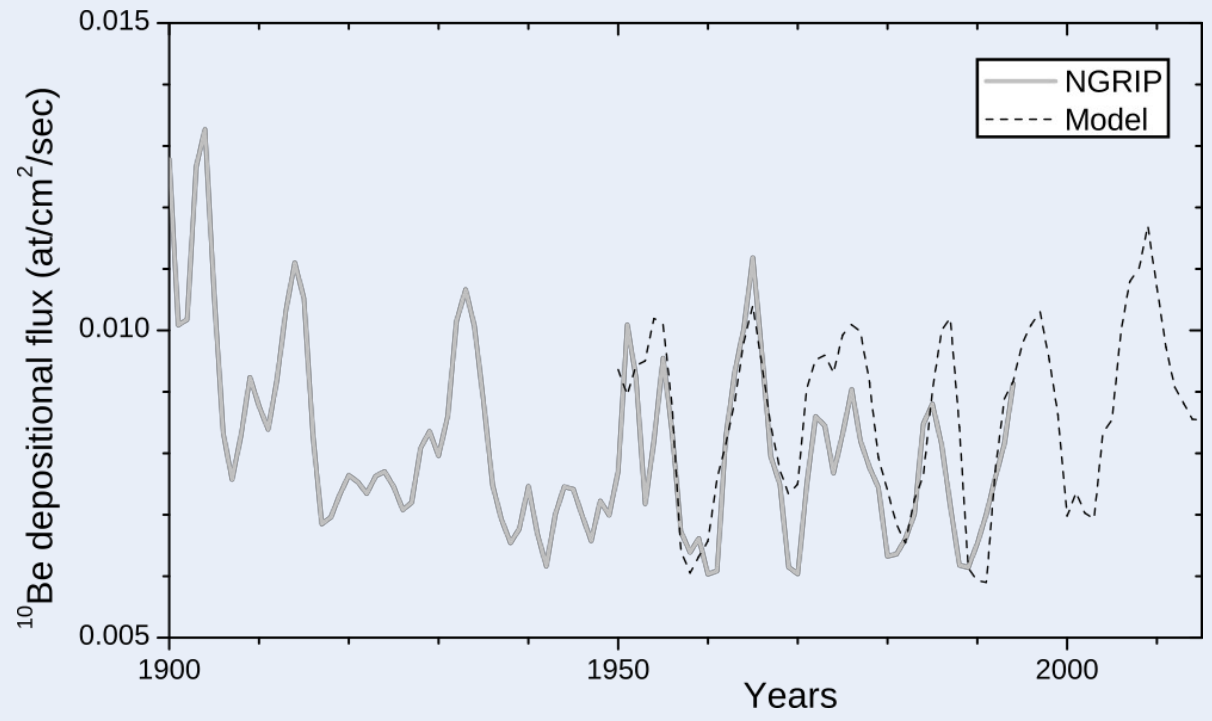
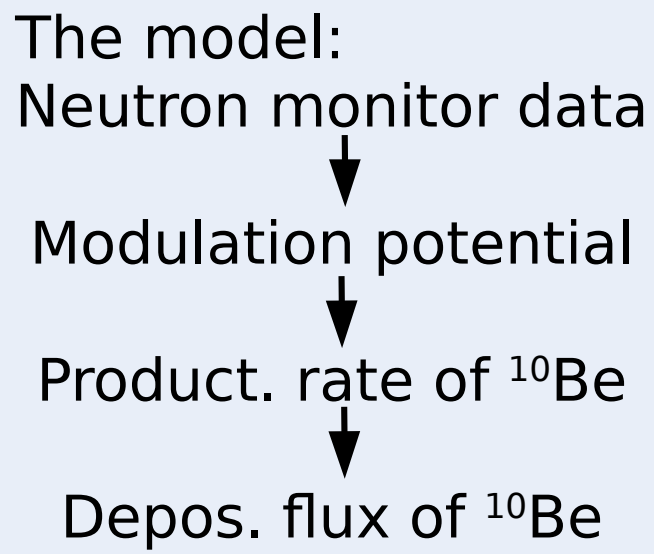
Global nuclide production vs. solar activity.



Here M is the geomagnetic dipole intensity in 10^{22} Am²

The depositional flux:

- NGRIP line - measured (in Greenland)
- Model line - computed



The results are published as



The screenshot shows the top portion of a research article page. On the left, the journal title "JOURNAL OF GEOPHYSICAL RESEARCH Atmospheres" is displayed, with "AN AGU JOURNAL" below it. To the right is the JGR logo. The article type "Research Article" is indicated. The title "Production of cosmogenic isotopes ^7Be , ^{10}Be , ^{14}C , ^{22}Na , and ^{36}Cl in the atmosphere: Altitudinal profiles of yield functions" is prominently featured. Below the title, the authors "S. V. Poluianov, G. A. Kovaltsov, A. L. Mishev, I. G. Usoskin" are listed with an email icon. The publication date "First published: 12 July 2016" and the DOI "10.1002/2016JD025034" are also visible. On the right side of the page, there is a thumbnail of the journal's table of contents for Volume 121, Issue 13, dated 16 July 2016, with pages 8125–8136. A "View issue TOC" link is provided below the thumbnail.

JOURNAL OF GEOPHYSICAL RESEARCH
Atmospheres
AN AGU JOURNAL

JGR

Research Article

Production of cosmogenic isotopes ^7Be , ^{10}Be , ^{14}C , ^{22}Na , and ^{36}Cl in the atmosphere: Altitudinal profiles of yield functions

S. V. Poluianov, G. A. Kovaltsov, A. L. Mishev, I. G. Usoskin ✉

First published: 12 July 2016

DOI: 10.1002/2016JD025034

View issue TOC
Volume 121, Issue 13
16 July 2016
Pages 8125–8136

...including detailed description, tabulated values and several examples of application

- Cosmogenic production of nuclides
 ^7Be , ^{10}Be , ^{14}C , ^{22}Na and ^{36}Cl in the Earth's atmosphere
- New detailed altitudinal profiles of their yield functions
- Good agreement with previous works

Thank you!