

**Final author comments on the manuscript “Invariants of the Spatial-Energy Structure and Modeling of the Earth’s Ion Radiation Belts” by Alexander S. Kovtyukh for Anonymous Referee #1**

I am very grateful to Referee #1 for very helpful comments: they help clarify the essence of my work. All of them are taken into account in the revised manuscript.

General comments

(1) This paper presents a parametric model for the density of various ion species in the Earth radiation belts. This model describes the global structure of the radiation belts for protons, helium, and for ions of the CNO group. Based on extensive satellite data, the parameters of the models have been fitted, independently for the proton populations and for the other ions. The validity of the model is discussed, species by species, by comparison with in-flight data. The solar cycle dependency is presented. Finally, a physical interpretation of the model is detailed.

(2) In many places of this manuscript, starting with the title, the word “model” is found and in almost all cases this word has the most general meaning; no empirical or mathematical models are used in this manuscript and in Fig. 1-9 are presented experimental data. Associations with models also invoke the word “parameters”. But the invariant parameters of ERB (presented in Section 2 and in Figs. 1-6) are not the parameters of mathematical or empirical models. These parameters obtained directly from the results of various experiments. Model (theoretical) calculations were made only to the maximum energy of ions, which can be trapped in the ERB (green line in Figs. 1-6).

(3) More detailed definitions of all quantities considered here are given (lines 97-102, 138-147, 159-160, 201-218, 363-367, 471-477). The words “model” and “parameter” conserved only where it comes to specific ERB models.

(1) Overall, the paper is difficult to understand. Firstly, the English is very poor (see technical corrections hereafter), and difficult to grasp.

(2) I agree that I don't speak English well enough and I corrected the text of the manuscript.

(3) I edited the manuscript. Many words and sentences are clarified. New paragraphs added and some paragraphs moved.

(1) Secondly, the model is not appropriately explained, as the author refers to previously published literature, which could not be accessed by this reviewer.

(2) Empirical or mathematical models of the ERB are not used in this manuscript. There made only a systematization of the experimental data and is considered how to use the results obtained in this paper for modeling of ion fluxes in the ERB.

(3) All necessary explanations are given in the manuscript (lines 97-102, 138-147, 159-160, 201-218). The words “model” and “parameter” conserved only where are mentioned a specific ERB models.

(1) Thirdly, as described in the specific comments, the figures are not very clear and

supportive of the arguments developed in this paper.

(2) The descriptions of the figures are supplemented with the necessary explanations (in the text and in the captions of the figures).

(3) I added the necessary explanations to the figures (lines 191-192, 199-202, 205-214).

### Specific comments

(1) Section 2 of this paper presents the model parameters and their measured values, but not the model itself, which is only suggested by the description of the parameters. A detailed and self-sufficient description of the model should be given in this section.

(2) The invariants presented in Section 2 are not connected to any particular model, but they can be used in works on the creation of both empirical and mathematical models of spatial-energy distributions of the ERB ions.

(3) Detailed definitions of all quantities considered here are given (lines 97-102, 138-147, 159-160, 201-218). The words “model” and “parameter” conserved only where it comes to specific ERB models.

(1) On section 3, numerous similar figures are presented. It is not clear how these figures were obtained from the data. In particular, these figures present iso-lines on power of tens, with most satellite data points placed on the iso-lines, which suggest some interpolation was done on the satellite data. Section 3 should detail how this figures were made.

(2) Points on Figs. 1-9 were obtained from the experimental radial profiles of differential ion fluxes. Iso-lines in Figs. 1-9 are envelopes of the experimental points. Figs. 1-6 were constructed without using the interpolations and extrapolations of the experimental data. Figs. 7-9 were constructed with using the interpolation and extrapolation of the data.

(3) The choice of representations of the experimental data and methods of constructing of Figs. 1-9 are explained in details (lines 172-181, 191-192, 205-218, 363-367).

(1) The conclusions of the comparison of figures 1 to 4 proposed at line 269 are not clearly apparent in the figures.

(2) For comparison Figs. 1-2 with Figs. 3-4 and with Figs. 5-6 are given concrete values of the fluxes of protons and helium ions (lines 306-309) and fluxes of protons and CNO group ions (lines 347-352).

(3) A more accurate formulation of the conclusions about stronger solar-cyclic variations of heavy ion fluxes compared to proton fluxes is given (lines 306-309, 353-354, 499-500).

(1) Similarly, the low-altitude effects described at line 352 cannot be clearly seen on the figures, because the transformation  $B/B_{eq}$  to altitude is not straightforward (for instance, the 1000 km altitude line could be drawn on figure 7-9 to support the arguments of this paragraph).

- (2) For Figs. 7-9 my interpretation were simplified, and after that it is not necessary to put on these figures the dependences  $B/B_0(L)$  for fixed heights.
- (3) A simpler interpretation of Figs. 7-9 is given (lines 396-398).

A reference should be provided at line 347 for the dependency of the radial diffusion rate on  $B/B_{eq}$ .

- (2) For the dependency of the radial diffusion rate on  $B/B_0$  a reference are added (at line 395).
- (3) I made it (line 395).

A figure supporting the information at line 362-364 about the CNO group data could be provided.

- (2) There are not enough data for CNO group ions and they are very fragmentary. Constructing for them figures like to Fig. 7-9 while is impossible. But one can made assumptions on the basis of available data and general considerations.
- (3) I clarified the relevant conclusion (lines 400-407).

#### Technical corrections

(1) Numerous English errors have been found, for instance on lines 21, 24, 34, 48, 63, 67, 69, 79, 118, 132, 134, 137, 161, 163, 166, 173, 185, 193, 201, 215, 220, 226, 239, 271, 290, 314, 338, 379, 387, 389, 398, 403, 469.

- (2) I gratefully accept these corrections to the text of the manuscript.
- (3) I corrected all these errors.

(1) In the figure legends, the MeV unit is displayed in Cyrillic.

- (2-3) I corrected all these errors.

(1) Moreover, the model lines on the figures are not described in the legends.

- (2) I describe all lines which are shown in Fig. 1-6.
- (3) I made these additions (lines 719-721, 725-727, 731-733, 737-739, 743-745, 749-751).

I am very grateful to Referee #1 for very helpful comments.

With grand regard,  
Alexander S. Kovtyukh