

## ***Interactive comment on “Ionization effect of solar particle GLE events in low and middle atmosphere” by I. G. Usoskin et al.***

**I. G. Usoskin et al.**

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We thank Reviewer 1 for his/her useful comments. We have revised the manuscript with all the changes being highlighted by bold face. Our answers are given below.

*1. I suggest adding some notes about the applicability of the obtained results to the introduction. It would be helpful also to clarify which community will be the most interested in the provided ionization rates. I think that the results can be applied for the calculation of the middle atmosphere response to strong solar proton events.*

**Reply:** We have modified the Introduction respectively.

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2. *It would be interesting to compare the calculated ionization rates with the results of other models. I recall that similar calculations for several events have been made by several groups (e.g., Ch. Jackman et al. and Wissing and Kallenrode, 2009). In particular Wissing and Kallenrode (2009) emphasized that the electrons can substantially contribute to the total ionization rate in the mesosphere. As far as I understood the ionization by electrons was not taken into account by the authors, so this comparison will help to understand the uncertainties of the applied approach.*

**Reply:** The Reviewer is correct, electrons are not considered here since we are focused on the lower and middle atmosphere, while electrons are important in the upper atmosphere ( $< 1$  hPa) – see, for instance, Wissing and Kallenrode (2009). A direct comparison between the models is of little value because of their quite different tuning. While AIMOS and Jackman's model are developed to work with the upper atmosphere (and hence they neglect higher energy SEP and GCR), our model is better suited for lower and middle atmosphere (but it neglects other ionization sources – electrons, EPP, UVI). We have performed a full comparison of our model with the one by Jackman (2005) in the range where they overlap (SEP in the middle-upper atmosphere): our group and Jackman have independently computed the ionization rate for the event of 20.01.2005 using the same prescribed shape for SEP and obtained similar results for the upper layer above 10 hPa (Jackman, personal communication 2010), but Jackman's model tends to underestimate the ionization in the lower layers because of neglecting nuclear interactions (see discussion in Usoskin et al., 2010). We didn't make such a detailed comparison with AIMOS model as it is known to agree in general with that by Jackman (Wissing Kallenrode, 2009). We have updated the text in this respect.

3. *It also of interest to discuss the possibility of the extension of the provided tables to the past. Would be possible to apply some proxies and reconstruct ionization rates back to the beginning of 20th century and even further back?*

**Reply:** It is potentially doable but the main obstacle is that spectra of SEP are not

known in the past. For example, there are some large fluence SEP events reconstructed in the past centuries using the record of nitrates in polar ice (McCracken, 2001), but the energy spectrum remains unknown that may lead to order of magnitude uncertainties (cf., Usoskin et al., GRL, 2006). In this paper we prefer to limit ourselves to more or less robust data.

#### *Minor comments and technical corrections*

1. *Page 30382, Line 15:* " . . . the main source . . . ". I would add "of ionization"
2. *Page 30383, Line 3:* " . . . changes little . . . ". I would use " . . . is rather stable. . . "
3. *Page 30384, Line 12:* " . . . can be significant . . . ". If it is convincingly shown by Mironova et al., 2008, then it is better to formulate it more definitely. Otherwise, this statement is vague.
4. *Page 30384, line 23:* Frobush is a typo.
5. *Page 30384, line 26:* "..summary. . ." is not good, consider "total" or "combined"
6. *Page 30385, line 19:* better to say "given by Usoskin and Kovaltsov (2006) and Usoskin et al., (2010).
7. *Page 30386, second paragraph:* I suggest adding a little bit more information about satellite data. In particular, what time periods are covered by different satellite and how homogeneous the time series are.
8. *Page 30387, equations:* I could not find what stands for  $\gamma_1$ ,  $\gamma_2$ ,  $R_0$  and  $J_0$ .

**Reply:** All these minor comments were explicitly considered.

9. *Page 30389, lines 18-19:* It would be interesting to compare with the results of

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*AIMOS model, which shows some ionization rates even in the low latitude area.*

**Reply:** We have briefly discussed this in the revised text – see also our reply to point 2 above.

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Interactive comment on Atmos. Chem. Phys. Discuss., 10, 30381, 2010.

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