

## ***Interactive comment on “Impact of geomagnetic events on atmospheric chemistry and dynamics” by I. Suter et al.***

**I. Suter et al.**

suter.ivo@bluewin.ch

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We greatly appreciate the constructive comments and suggestions of I. Usoskin, which help to clarify some unclear points in our manuscript. Specific issues are addressed as follows:

Comment 1: The authors needs to clarify the terminology about the Laschamp event. It is usually not called a reversal, but rather an excursion. Although some data suggest that the z-component of the dipole might had become slightly negative for a short while, it returned back very soon without the reversal. The smallest dipole moment was about 1/8 of the present day value. The authors are requested to clarify the text accordingly.

Authors reply: We changed the text in the intro accordingly and consistently use the

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term 'excursion' in the revised version of the manuscript (note also the change in our title "Impact of geomagnetic excursions on atmospheric chemistry and dynamics").

Comment 2: When simulating the cosmic ray variability, the authors consider two cases:  $\phi=400$  and 0 MV. This choice does not look obvious, as 400 MV corresponds to the solar cycle minimum periods of the modern epoch (see cited Usoskin et al., 2005), though the recent cycle minimum ca. 2009 had lower values of the modulation parameter. Zero-modulation is never reached in practice (even during the Muander minimum there was a weak residual modulation of  $\phi$  about 100 MV). This is fine as an extreme case but the authors should describe what conditions are represented by these  $\phi$  values.

Authors reply: We have added this information in the chapter "model setup"

Comment 3: It is surprising that the authors do not apply an 11-yr cycle to the simulated cosmic ray modulation, considering instead a steady state case. Including the 11-yr cycle would be natural, as this reviewer believes.

Authors reply: We thank I. Usoskin for this idea, and will include the 11-yr cycle in our future studies. We will mention this shortcoming in the conclusions.

Comment 4: The authors simulate cases with the greatly inclined dipole (45 and even 90 deg inclination). That's fine, but the longitude of the geomagnetic pole must be also shown and discussed. I guess, it would be quite a difference for the results, if the pole was located, e.g., over central Pacific and mid-Africa. Anyway, this should be specified. In addition, this reviewer assumes that the centered geomagnetic dipole model was applied, not an eccentric one. This also should be stated clearly.

Authors reply: The geomagnetic dipole was assumed as centered and its longitude set to 291.5°E in all the simulations. The necessary information is added to the manuscript.

Comment 5: page 6606, line 1: "events" -> "excursions"

Authors reply: "events" -> "excursions"

Comment 6: p.6606, line 10: after "due to enhanced ionization" add "by galactic cosmic rays"

Authors reply: "by galactic cosmic rays" added

Comment 7: p. 6607, l. 1: write "up to up to  $10^{20} eV$ "

Authors reply: " $1 \text{ MeV} - 5 \times 10^{13} \text{ MeV}$ " changed to "up to  $10^{20} \text{ eV}$ "

Comment 8: p.6607, l. 7-8, replace Potgieter, 1998 with a more recent review (Potgieter, Liv. Rev. Solar Phys., 2013).

Authors reply: updated to "Solar Modulation of Cosmic Rays , Potgieter, Living Rev. Solar Phys., 2013"

Comment 9: p. 6607, l.8: "only a few" -> "several" (geomagnetic influence in fact may start already at 20 radii).

Authors reply: "only a few" -> "several"

Comment 10: next line: remove "at least at lower latitudes".

Authors reply: removed

Comment 11: p. 6607, l. 11 - see general comment above, about reversal.

Authors reply: While the cited paper suggests the possibility of a short term full reversal other sources indeed only find lower inclination or a partial reversal. The text in the paper has been updated accordingly.

Comment 12: p.6609, l.20: replace "ionization cascade" with "nucleonic-muon-electromagnetic cascade"

Authors reply: "ionization" replaced by "nucleonic-muon-electromagnetic"

Comment 13: p.6610, l.4. what is the "hybrid sigma-p levels"? This sounds as a very particular jargon which needs to be explained.

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Authors reply: "Hybrid sigma-p levels" describes the vertical coordinate system with terrain following coordinates at the bottom (sigma levels) and pressure coordinates (isobaric) aloft. Explanation added.

Comment 14: p. 6610, l.8: "primitive" -> "basic"?

Authors reply: "primitive equations" is a commonly used expression to describe the basic set of equations in most atmospheric models. I.e. Conservation of momentum, energy and mass.

Comment 15: last paragraph of Sect. 3 - see general comments above.

Authors reply: The longitude of the geomagnetic dipole was  $291.5^{\circ}\text{E}$  in all the simulations, i.e. over east Canada or the west Atlantic. A geomagnetic dipole was assumed to be centered. Updated paragraph accordingly. "The geomagnetic dipole was assumed as centered and its longitude set to  $291.5^{\circ}\text{E}$  in all the simulations."  $\phi=400\text{MV}$  is indeed at the lower end of natural variability, since the authors do not know the exact value of  $\phi$  during the Laschamp event the choice was arbitrary. "The reference  $\phi$  value was arbitrarily chosen and lies at the lower end of natural variability, while a zero  $\phi$  is very unlikely and should be considered as a sensitivity test only"

Comment 16: p. 6618, l.25: "We find" -> "our simulation suggests"

Authors reply: "We find" -> "Our simulation suggests"

Comment 17: p. 6619, l.23-25. This sentence is confusing and needs revision. First, the ion induced/mediated nucleation is not in its infancy. Both in-situ (e.g., Mironova et al., ACP, 2012) and in-vitro (Kirkby et al., Nature, 2011; Enghoff et al., GRL, 2011) studies suggest that the effect does exist but is very weak, observable only in extreme conditions. Another potential mechanism related to the global current circuit (ref. To works by Tinsley, Harrison, Yu) is not mentioned.

Authors reply: Modified accordingly

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Comment 18: The last sentence needs to be removed. Promises are good but better just do the work.

Authors reply: removed

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Interactive comment on Clim. Past Discuss., 9, 6605, 2013.

**CPD**

9, C3635–C3639, 2014

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