

# ***Interactive comment on “Statistical response of middle atmosphere composition to solar proton events in WACCM-D simulations: importance of lower ionospheric chemistry” by Niilo Kalakoski et al.***

## **Anonymous Referee #3**

Received and published: 30 January 2020

General Comments: The authors use the WACCM-D model, a variant of the Whole Atmosphere Community Climate Model (WACCM), to study the statistical response of the atmosphere to the 66 largest solar proton events (SPEs) that occurred in years 1989–2012. WACCM-D, unlike the standard WACCM, includes a comprehensive ion chemistry set for the lower ionosphere with 307 reactions of 20 positive ions and 21 negative ions. Compared to the standard WACCM, WACCM-D produces a larger response in O<sub>3</sub> and NO<sub>x</sub>, a weaker response in HO<sub>x</sub> and simulates changes in HNO<sub>3</sub> and Cl<sub>x</sub>, which are in better agreement with observations. It is recommended that ion

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chemistry reactions (similar to those in WACCM-D) be included in future models to study the impact of energetic particle precipitation (EPP) on the middle atmosphere. The article presents a good comparison of the WACCM-D versus standard WACCM results for the SPEs. The paper provides interesting results for the 66 largest SPEs in years 1989-2012. I do think that the paper should be published. The paper is generally well-written, but I have five specific comments and some suggested technical corrections/suggestions.

#### Specific Comments:

1) p. 5, line 23; p. 6, lines 6-10, mention of figures: Figure 3 is mentioned on p. 5 in line 23. The next four figures mentioned are Figures 6 and 7 in line 6 and Figures 8 and 9 in line 7. It is curious that Figures 4 and 5 are not mentioned until line 10 on p. 6 of the text. I assume that the two figures (4 & 5) will be positioned in the manuscript right after Figure 3. It is certainly reasonable that Figures 4 & 5 be positioned before Figures 6, 7, 8, and 9. Therefore, it is suggested that Figures 4 & 5 be mentioned in the text between line 23 on p. 5 and line 6 on p. 6.

2) p. 16, Figure 3: Unless the two plots are repositioned, currently “(top)” should be changed to “(left)” and “(bottom)” should be changed to “(right)” in the figure caption.

3) pp. 17-20, Figures 4-7: It is unclear what intervals and mixing ratio values the contour lines illustrate. There are no numbers associated with the contour levels. Possibly remove the contour lines as their significance is vague. The colors in the figures are fairly clear.

4) p. 23, Figure 10: It might be helpful to label the 100 and 1000 pfu dashed lines on the three far left y-axes as “1000 pfu” and “100 pfu.”

5) p. 24, Table A1: The date with the largest Proton Flux (pfu) of 43000 has a Start date “23-Mar-1991” and a Maximum date “24-Mar-1991.” I was surprised to see that this solar proton event (SPE) had the largest Proton Flux, as I have not read or heard

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much about this particular SPE. Perhaps some research of the measured atmospheric impact of this very large SPE is needed in a future study.

#### Technical Corrections/Suggestions:

1) p. 1, line 13: Change “weaker response” to “a weaker response”

2) p. 2, line 17: Change “chemistry which connects SPE ionization to changes in neutral species” to “chemistry, which connects SPE ionization to changes in neutral species;”

3) p. 2, line 28: Change “Difference” to “The difference”

4) p. 3, line 11: Change “of number” to “of a number”

5) p. 3, line 21: Change “in long-term” to “in a long-term”

6) p. 4, line 30: Change “underpresented” to “underrepresented”

7) p. 5, line 6: Change “been seen” to “be seen”

8) p. 5, line 21: Change “have also” to “also have”

9) p. 7, line 4: Change “is a reduced” to “is reduced”

10) p. 7, line 7: Change “with short-lived” to “with a short-lived”

11) p. 7, line 11: Change “in mesosphere” to “in the mesosphere”

12) p. 7, line 13: Change “Large increase” to “A large increase”

13) p. 7, line 15: Change “Longer-term” to “A longer-term”

14) p. 7, line 20: Change “Response” to “The response”

15) p. 8, line 8: Change “clear no connection” to “no clear connection”

16) p. 8, line 13: Change “reason” to “reasons”

- 17) p. 9, line 9: Change “astronger” to “a stronger”
- 18) p. 9, line 12: Change “for weakest” to “for the weakest”
- 19) p. 9, line 19: Change “from detailed” to “from a detailed”
- 20) p. 10, line 1: Change “due the less” to “due to less”

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