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Comment on acp-2020-1228

Anonymous Referee #1

Referee comment on "Model simulations of chemical effects of sprites in relation with observed HO_2 enhancements over sprite-producing thunderstorms" by Holger Winkler et al., Atmos. Chem. Phys. Discuss., https://doi.org/10.5194/acp-2020-1228-RC1, 2021

Comments to the Authors:

Review of MS with titled "*Model simulations of chemical effects of sprites in relation with satellite observations***"** by H. Winkler *et al.*, submitted for publication in Atmospheric Chemistry and Physics.

This is an interesting paper showing the efforts made by the authors to model the SMILES measured HO_2 chemical signature associated to sprite streamer chemical activity in the mesosphere (70 - 80 km). **What is the final cause of the measured HO_2 increase?.** There are no clear conclusions in the paper since available measurements and model results do not completely match. There is not a clear causal link between the enhanced HO_2 observations and the sprite streamer + transport modeling described in this paper. The paper is mostly clear and well written. There are, however, some comments I would like to make.

Satellite observations

This section is devoted to briefly explain SMILES measurements from the ISS of enhanced mesospheric HO_2 over sprite-producing thunderstorms.

Already here the authors indicate that ISUAL detected three thunderstorm systems producing sprites prior to SMILES observations. Authors also highlight that WWLLN indicated strong lightning activity in these 3 thunderstorms systems and that more sprites than those detected by ISUAL could have been occurred.

I miss here a thorough discussion about the 3 thunderstorms systems producing the sprites that seem to have triggered HO_2 detections by SMILES. In particular, how many positive and negative lightning occurred?. What were their corresponding charge moment change (CMC)?. Where (and when) did they occur?. It is known (see *Qin et al. GRL 2013*) that lightning CMC values can largely determine the type/morphology of sprite (columnar or carrot-like). In particular, CMCs > 500 C km favor carrot sprites, while column sprites (with less streamers) are usually associated to lightning with CMCs lower than ~ 500 C km. I think that an exhaustive analysis of those 3 thunderstorm systems is crucial here because they critically condition the frequency and type of sprites produced.

At least one carrot sprite (associated to event A) was reported in *Yamada et al. GRL 2020* (see Figure 1d). A sprite halo with downward many propagating streamers looking like the onset of a carrot sprite (event B, see Figure 1e in *Yamada et al. GRL 2020*) was also detected by ISUAL prior to measurements by SMILES. The image shown in figure 1f of *Yamada et al. GRL 2020* also seems to be a carrot-like sprite.

Sprite chemistry and vertical transport simulations

Line 147: I would replace "*afterglow region*" by streamer glow or streamer trailing glow region. The word "*afterglow*" somehow indicates chemical delayed reactions, but the chemistry in sprite glows are driven by an active electric field (~Ek).

In a time-integrated image of a sprite, the image is mostly dominated by the sprite glows (see *Stenbaek-Nielsen and McHarg*, *JPD-AP 2008*). Streamers only leave relatively faint traces in long exposure images. Thus, if we consider optical emissions as a driver for energy input into the mesosphere, this implies that the main local energy dissipation is in the sprite streamer trailing glows and beads, as studied by *Parra-Rojas et al. JGR-Space Physics* (2015).

Line 160-161: The duration of the glow luminosity (field) can be up to 100 ms (see

Stenbaek-Nielsen and McHarg JPD-AP, 2008). At 80 km, *Gordillo-Vázquez and Luque GRL 2010* used 8 ms long sprite trailing glows at 80 km. However, the authors use only 1.3 ms, which is a bit too short. *Parra-Rojas et al. JGR-Space Physics (2015)* implemented long (5 ms - 100 ms) sprite trailing glows in a 1D sprite kinetic model. Unfortunately, they did not study the evolution of HO_2 species.

What is the impact in the predicted HO_2 concentration (number of molecules) of not considering the streamer glow field (roughly Ek)?.

When discussing large proton hydrates kinetics (page 7) in the D-region, the authors explicitly indicate the key recombination of $H^+(H_2O)$n with electrons taking place in the mesosphere but seem to not consider (though mentioned in line 201) proton hydrates recombinations with negative ions. In this regard, the Mitra-Rowe (M-R) scheme consider the kinetics of positive hydrated ions like $H^+(H_2O)_n$ (see Gordillo-Vázquez et al JGR-Space Physics 2016) applicable to the 70-85 km region. The authors do not seem to consider recombination of $H^+(H_2O)_n$ with negative ions such as CO_3^- and O_2^-. Were these reactions considered?.

Line 232: Suggest to replace: "*... the concentration of HO_2 increases.*" by "*... the concentration of HO_2 slightly increases above ambient values.*"

Line 235-236: The red dashed line is missing in Fig. 10.

Line 255-260: What types of sprites are reported by *Heavner et al. (2000)*, *Kuo et al. 2008* and *Takahashi et al. 2010*?. The ~10e22 photons per sprite streamer is a reasonble number that agrees with available detailed simulations. The 10e24 photons per sprite could be typical of column-like sprites (with some tens to a few hundreds of streamers).

I agree in that it is unlikely that the measured HO_2 enhancenment is only due to 3 sprites.

Line 284: 38000 (7600) sprite events is completely unrealistic.

As said above, a careful analysis of the the 3 thunderstorms and the produced types (lightning polarities, CMCs, ...) of sprites (column/carrot, producing infrasound?, ...) would be important to advance in the understanding of the underlying reasons leading to HO_2 enhancements in the mesosphere.

Finally, it would also be interesting if the authors could show a plot of the model predicted ozone (O_3) density, whether it is predicted to stay the same, increase or decrease at 75 km, 77 km and 80 km. SMILES did not measure a clear change of O_3 due to sprite chemical activity.

Some details:

What are the branching rations of each channel in: a) H2O + e --> OH- + H / OH + H- and b) H2 + e --> H + H + e / H- + H / H+ + H + 2e.

Figure 10: No dashed red line.

Figure 12: Caption: I think the authors mean "black line" instead of "black areas"?.

Reaction 12 should be: H + O2 + M --> HO2 + M instead of "H + O2 + M --> OH + O2 + M" that would not be well balanced.

Recommendation:

I think this paper could be published in ACP. However, before final acceptance, the authors should try to appropiately address the comments / questions stated above.