

## ***Interactive comment on “Nitrification of the lowermost stratosphere during the exceptionally cold Arctic winter 2015/16” by Marleen Braun et al.***

### **Anonymous Referee #1**

Received and published: 31 March 2019

General Comments: The authors have reported the observed HNO<sub>3</sub> (and O<sub>3</sub>) from ~8 km up to 14 km from GLORIA during the PGS aircraft campaign took place from December 2015 to March 2016. The unique aircraft data will be useful for the atmospheric chemistry community. They have mainly focused on four flights data and also used a chemical transport model CLaMS to investigate the nitrification of the lowermost stratosphere for Arctic winter 2015/16. It is clearly shown that there are still large variabilities of measured HNO<sub>3</sub> (and O<sub>3</sub>) in the LMS along the flight track and CLaMS seems to simulate HNO<sub>3</sub> quite well though the model is not perfect to capture some fine structures and also underestimates the observed HNO<sub>3</sub>. Therefore, the authors have also done four sensitivity experiments to try to understand the discrepancies. Overall, the manuscript is well structured. The data analysis and model results are reasonable.

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However, there are some important messages still missing or misleading in the current version. These need to be clarified.

Specific Comments:

1) Selection of aircraft data. It has been mentioned that 18 research flights were carried out between December 2015 and March 2016, but only five flights data are used. Some of other aircraft data may be not suitable for this work, but the authors have not mentioned why they chose these specific 4-5 flights data?

2) CIONO2. I think the comparison of CIONO2 between GLORIA and CLaMS would help since GLORIA has also measured CIONO2 (Johansson et al., 2018) and CLaMS simulates CIONO2.

3) Abstract is not well written and some key points are not supported anywhere (for example the sentence in Lines 10-11, I am also not sure if the conclusion in the Lines 11-12 is a fair statement because other satellite has measured HNO3 in this region). What are missing in CLaMS when the authors conclude the model underestimates ....(Lines 15-16). What is the implication for this work to improve HNO3 simulation in the lowermost stratosphere though some has mentioned in the Introduction?

4) Section 3.2 (Page 5). I am confused with the description. If CLaMS can save daily output at 12:00 UTC, why it can not save the model output along flight track (time, locations etc)? I am not sure why CLaMS needs to re-run forward/backward trajectory for the flight track though I understand CLaMS is based on trajectory calculations..

5) Results explanation. Sometimes it is very hard to follow. For example, Page 7 Lines 9-10. Maybe the coarse vertical resolution is one factor. That will be easier to confirm by increasing the model vertical resolution in the LMS. Pages 9 and 10: What are the key points here? Sorry it is hard to understand the Lines 1-2 in Page 10. Lines 15-18 in Page 12. Not so sure the points of the estimation of lower limit nitrification (though there is an almost linear relationship from the reference in Figure 5).

6) Sensitivity experiments in the Page 13. The descriptions of the model sensitivity experiments are too general. Some of these can only be understandable by the people who are familiar with CLaMS. For example, 'ice settling' simulation, the authors just have one extra criteria to consider in the model (Line 17-18), but we don't know how settling velocity is calculated in the standard CLaMS model . 1.5 times settling velocity for the whole altitude range or something like that needs to add. For the temperature offset, why decrease global temperature by 1K rather than 1.5 or 2 K? Just simple say "NAT formation is T dependent" seems not enough.

7) Discussion and Conclusion. Can you add more why the nitrification for Arctic winter 2015/16 has much more than previous work as you mentioned in the Lines 20-26 in the Page 17?

Technical corrections: 1) Abstract, Page 1 Line 1, change "cold" to "low". 2) Page 1 Line 5, why it is only spatial resolution? Does high temporal resolution matter for this case? 3) Page 1 Line 9. Are you sure about 11 ppbv of HNO<sub>3</sub> is observed at 11 km from GLORIA? The only one I can see from Figures 4 and 5 but it occurs above 12 or 13 km (?)

4) Page 3 Line 7-8. What do you mean "mesoscale temperature is not well known"? 5) Page 3 Lines 18-20. This is too general. 6) Page 4 Line 2. "spectra and spectra"? 7) Page 4 Line 25-26. A reference is needed. Is the same reference as Tritscher et al. (2018)? 8) Page 5 Line 20. Add a reference for MERRA2. Why not to use ECMWF ERA interim because you have also done the model simulations based on the meteorological conditions. 9) Page 5 Line 22. Better to use "x" rather than . after "1.2" 10) Page 6 Line 3. Better to add an altitude range after 1.2 ppmv. 11) Page 7 Lines 8-9. Can you make "the enhancement at low altitude" clear? Is it enhancement of HNO<sub>3</sub> inside the vortex region compared with outside vortex. Or you mean 2-3 ppbv HNO<sub>3</sub> inside the vortex. 12) Page 12. The unit in the text should be consistent with the figure.

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Interactive comment on Atmos. Chem. Phys. Discuss., <https://doi.org/10.5194/acp-2019-108>, 2019.

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