

Ann. Geophys. Discuss., referee comment RC1
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Comment on [angeo-2021-28](#)

Anonymous Referee #1

Referee comment on "What caused the frequent and widespread occurrences of noctilucent clouds at middle latitudes in 2020?" by Peter Dalin et al., Ann. Geophys. Discuss., <https://doi.org/10.5194/angeo-2021-28-RC1>, 2021

Review of "What caused the frequent and widespread occurrences of noctilucent clouds at middle latitudes in 2020 " by Dalin et al.

General Comments

This paper describes mid-latitude NLCs, with an emphasis on the enhanced number of NLCs seen during the Northern summer of 2020. The Authors attribute the active 2020 season to volcanic enhancement of water vapor in 2015, with a time lag of 5 years for the water vapor to be transported from the lower stratosphere to the mesopause.

I recently reviewed this paper when it was submitted to JASTP, and note that the paper was rejected at that time (March 2021). In reading the paper now, I see that the Authors have done very little to improve the manuscript, and in particular, they have ignored most of the comments I made in my review for JASTP. As such, my review below is largely a restatement of concerns from the JASTP submission. It is my opinion that Authors approach here was inconsiderate of other peoples time.

- 1) The Authors argue that transport from the lower stratosphere to the polar mesopause requires roughly 5 years, an assertion that is not supported by the paper. There is an attempt to quote some previous studies that addressed transport from the troposphere to the stratosphere, and within the stratosphere and mesosphere, but the Authors did not derive a convincing story from these previous works. They alternately quote stratosphere - mesopause transport times as 2 years and 5 years. As this is the key aspect of their argument, it is mandatory that they get this part of the story correct, and support it clearly with recent references. If the Authors can make clear and convincing arguments regarding H₂O transport and lifetime, then I believe this study will constitute a significant new result. In comparing the JASTP submission and the present paper, I see that they completely ignored my comments in this regard.
- 2) The study is based on a correlation analysis, where the visual NLC record is compared to time series of temperature, water vapor, solar Lyman-alpha, and volcanic emissions. As such, it would be very useful to have a figure where the NLCs are plotted along with T and H₂O, and another figure where NLCs are shown along with Lyman-alpha and volcanic emissions. Currently, all of these time series are in different figures and it is difficult to see if there are correlations or not.

Specific Comments

- Line 54: The statement "meaning that the summer mesopause at middle latitudes has become more wet" is redundant.
- Line 150: This definition is unnecessary, given the audience.
- Line 163: Please state the time frame for the MLS results, i.e., are they 1 or 2 day means?
- Page 5; Fig 1: It looks like the Gaussian fit ignores features like the cold periods around day 170 & 195. Do cold times like these correlate to more NLC sightings? It would be interesting to add a plot of the NLC sightings underneath the T time series.
- Line 187: This statement makes no sense: "...with 42 NLC cases in 2020 in the past 30 years...", please clarify.
- Line 296: There are other relevant references that you should mention here like Hartogh et al. (2010); Hervig and Siskind (2006), and Lübken et al. (2018). In looking at these papers you will see that there is some disagreement on what the H₂O - solar response actually might be.
- Figure 8: it would be appropriate to only show results from 2004 - present, as this is the time period you analyze for NLCs, T, and H₂O.
- Line 349: The link goes to a missing page.
- Figure 9: I think the curve in Fig 9c is supposed to be from subtracting the red and black curves in Fig 9b. It appears, however, that there is still a strong linear component in Fig 9c, that seems like it should be absent since the black curve is basically a straight line. Please comment and/or check the results.
- Line 322: Please state here the pressure and latitude for the H₂O used in the analysis.
- Line 337: This statement gets to the heart of your work, and needs a reference to support it. In fact, the amount of water injected into the stratosphere by volcanoes seems to be highly variable, and is still debated in the literature. Since you ignored this comment last time, I list below some relevant references. You need to look at these and other papers, and summarize them in your article. LeGrande, A., Tsigaridis, K. & Bauer, S. Role of atmospheric chemistry in the climate impacts of stratospheric volcanic injections. *Nature Geosci* 9, 652–655 (2016).
<https://doi.org/10.1038/ngeo2771>. Joshi, M. M. & Jones, G. S. The climatic effects of the direct injection of water vapour into the stratosphere by large volcanic eruptions. *Atmos. Chem. Phys.* 9, 6109–6118 (2009).
Glaze, L. S., Baloga, S. M. & Wilson, L. Transport of atmospheric water vapor by volcanic eruption columns. *J. Geophys. Res.* 102, 6099 (1997).
- Line 357: It seems like the SO₂ plume mass would be relevant to consider as well as the altitude. These data are in the data base that you used, and it would be useful to plot the plume mass results in addition to altitudes (perhaps as an addition to Fig 10), as this would help the reader interpret the volcanic impact. For example, is it possible that there were massive injections that did not get very high, or vice versa?
- Figures 10 & 11: You need to plot the volcanic height / emission time series along with the time series of water vapor and NLCs. This will allow the reader to visually assess the correlations, or lack thereof.
- Line 420: This is a rather long sentence.
- Line 464: Temperatures of 175K are above the frost point, and this discussion is therefore confusing. It would be more relevant to analyze the 0.0046 hPa results, which is closer to where NLCs form. Please comment on this.
- Line 467: Here you state that both temperature and water contributed to the increased NLC activity in 2020. Yet in the abstract and conclusions, you state that the 2020 NLCs were due mostly to increased H₂O. Please check these statements and be sure they are consistent.
- Line 482: You cannot state that plume height had a positive impact on H₂O. Your

correlation analysis does allow you to state that plume heights are positively correlated with enhanced H₂O, with a time lag. Please re-word this statement.

- Paragraph starting on Line 494: Here you discuss transport times for gases emitted in the troposphere to reach the stratosphere (~5 years). However, your hypothesis is to only consider volcanos that injected material directly into the stratosphere. Below you state that the transport time from the stratosphere to the upper mesosphere is ~2 years. If this is true then your entire study has a major problem. This is because your analysis considered only volcanic plumes that penetrated into the stratosphere, and that the time lag to reach the NLC region is therefore 2 years and not 5 years.
- Line 497: It is irrelevant here to consider the transport times of long lived tracers (e.g., HF). This is because tropospheric water vapor is very short lived, with lifetimes of less than 10 days (please read van der Ent and Tuinenburg, 2017; Hodnebrog et al., 2019). As a result, a water vapor plume in the troposphere will never impact the stratosphere, as it will enter the hydrologic cycle and be dispersed long before it can travel to the middle atmosphere. Furthermore, the bulk of tropospheric H₂O that enters the stratosphere does so via the tropical tropopause, where the entry value is limited by cloud formation.
- Line 507: The relationship between Krakatoa and the first reported NLCs is NOT a well-known fact, but rather a common speculation. Please revise this statement accordingly.
- Line 509: This discussion is confusing. You state that the Krakatoa plume reached 40-50 km altitude, which is near the stratopause. The next statement is that the troposphere - mesopause transport times should therefore be 6-8 years, but these ideas do not seem to be connected as you imply. Please clarify. You also seem to be mixing up transport from the troposphere to the mesopause (~5 years?) and from the stratosphere to the mesopause (~2 years?). The stratosphere - mesopause times were stated above as ~2 years (line 494), but now you say 6-8 or 5 years? Please review this discussion and make sure you have it correct.
- Line 538: Looking at Figure 5a - 5b there are 3-4 K decreases in T during 2016-2020. This seems significant, and in fact you state above that this cooling had a large impact on S. Please revise this statement.
- Line 541: the phrase "meaning that the summer mesopause at middle latitudes has become more wet" is redundant and can be deleted.
- Line 548: You can fairly state that the increase in volcanic activity is correlated with (or consistent with) the high H₂O, but you cannot prove that it explains it.
- Line 557: This is generally acknowledged as being due to rising CH₄.