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Comment on angeo-2021-28

Anonymous Referee #2

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-RC2, 2021

The paper "What caused the frequent and widespread occurrences of the noctilucent clouds at middle latitude in 2020?" by Dalin et al., examined ground-based NLC network data from Canada, western Europe and Russia for the unusual 2020 summer NLC season. Utilizing the zonal mean MLS temperature and water vapor measurements between 2005 and 2020, they found moderate temperature decrease in the mesopause region and significant increase of water vapor during summer of 2020. The correlation between solar activities and water vapor is not clear and the variability in solar activities can't count for the increase of water vapor during the past few years. The satellite SO2 data were used as a proxy to water vapor changes induced by strong volcanic eruptions during 2013-2015. A strong correlation of ~0.5 was found with a 5-year lag for the aerosols to propagate into mid-to-high latitude mesopause region through meridional circulation. The authors conclude that the increase of the water vapor during 2017-2020 were caused mainly by the volcanic eruptions. This paper is well written and very easy to read. There are some concerns that should be addressed before publication.

In general, the authors focused on the year to year variability of NLC occurrence, mesospheric temperature and water vapor. Not much detail on their behaviors was given or discussed during this special 2020 NLC season.

- It is nice that long-term data from 3 ground-based NLC observation networks are analyzed. The year-to-year variability is good for establishing the fact that 2020 summer NLC sighting reached maximum since 2005. However, it is not very clear what had happened during the 2020 summer NLC season other than that total number of NLC occurrence increased dramatically. It will be very helpful to get a better global picture if the authors can add a figure contains DOY and longitude of each events (total of 61) that occurred below 50N during the 2020 summer NLC season.
- Consider adding the 2020 summer temperature and H2O time series to figure 1 to compare with 2009, the other active NLC season. Along with the above added figure, it will help relate the temperature/water vapor to NLC occurrences during the 2020

summer.

- The ground-based NLC observations below 50N showed increased NLC activity during summer 2020 (Figure 3), it would be more logical/consistent to show the temperature and water vapor results in figure 9 and 11 using the 45-50 N latitude bin.
- A moderate temperature decrease and significant increase of water vapor in the mesopause region are part of the main results. Thus, the authors focused on understanding the cause of the water vapor increase in this paper. However, as discussed in section 5 (page 20 and 21), though smaller, the observed temperature change has much larger impacts on the saturation ratio S than the observed water vapor increase. Discussions on why the temperature was colder for 2020 were missing. Can the authors justify this, please? In the meantime, please use the temperature from Figure 5a to calculate their impact on the saturation ratio S. At 74 km, it is way too low in altitude (temperature too high) for the atmosphere to reach saturation for the NLCs to form.
- The authors discussed at length the dynamic factors that can affect the occurrence of NLC in the introduction and discussion by citing other people's previous published works when low latitude sightings of NLC occurred. The increases of planetary wave, tides and gravity wave activities played important roles for the enhanced NLC, especially for the lower latitude events. However, annual (summer), zonal mean MLS temperature and water vapor were used to examine their year to year variability. This approach won't be able to detect any planetary waves and tides. No further analysis was done to pursue this possible cause of the enhanced NLC activities. Is there colder region that corresponding to increase NLC sighting during the summer of 2020? Is it possible that planetary waves, tides and gravity waves played a role in the increased NLC sighting during summer 2020?
- The trends/changes in the mean temperature and H2O are discussed with different starting year, with temperature starting from 2016 and H2O from 2017 where there is a maximum or minimum. Please use the same starting year for both temperature and H2O when changes are discussed.

Some minor points:

- Please provide longitude ranges for the 3 NLC database.
- Line 178-184: is the Japanese data used in this paper for NLC occurrence other than here and in Figure 2? Is an example of NLC from one of the 3 datasets available?
- Line 186-190: Please rephrase this sentence. It is hard to get to the point the first sentence of this paragraph trying to establish. Also, add country to Moscow in the bracket to be consistent with Edmonton and Hokkaido.
- Line 338 and 492: in the mesopause region not "at"
- Line 525: I am not sure how can the authors "emphasize that volcanic eruptions warm up the cold tropopause region that in turn facilitate a transfer of H2O…". There is no evidence provided by this paper associated with "warmed up tropopause region" during the past 5 years. Please consider remove this sentence or rephrase.
- Line 536: remove one "also"