

We appreciate the comments from the reviewer and have taken the suggestions into account. In the following we respond to the remarks point by point. Our responses are in italics. Line numbers refer to the revision with changes marked. Changes in the manuscript have been marked in the following way: deleted text in red, new text in blue.

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### **Anonymous Referee #1**

(Received and published: 16 July 2018)

#### GENERAL COMMENTS

The present paper analyses a long-term time series of ground-based lidar data to derive properties of solar and lunar tides in noctilucent clouds. The properties of these weak features are difficult to extract out of all other components of atmospheric variability. Hence, long-term datasets are needed to be able to apply statistical methods. The present paper introduces a new and comparatively long dataset to this kind of research. This ground-based dataset has properties, which are complementary to those of the satellite datasets used before. It provides data for only one location but with a much better temporal resolution, which allows for a direct identification of tides on timescales of hours to one day. Different properties of solar and lunar tides are successfully derived and, when possible, compared to previous results from other measurement techniques, showing agreement in many aspects. There are not many independent derivations of these properties in the literature and the comparison with this complementary dataset is very valuable. The paper is well-written and easy to understand. It fits well to the scope of ACP so that I recommend the publication after addressing some minor points listed below.

#### SPECIFIC COMMENTS

Page 2, line 22: “however, it takes one month to cover all lunar times”: It could be helpful for the reader to explain this by 2 or 3 more sentences.

*We have added text to clarify this relationship: page 2, lines 21-27.*

Page 3, line 2: “the mean probability to observe NLC at this location is 48 %”: Is this information really useful? The reference of 6400 measurement hours appears to be quite arbitrary, as it depends on weather conditions, etc. One could use the total number of possible measurement hours within the 21 seasons, but still I am not sure if this information is needed. Please explain or change accordingly.

*We find it indeed useful to bring up these numbers. First of all they indicate the mean state (here: NLC occurrence frequency) before variability is discussed later in the manuscript. They additionally show that the tracer for our investigation of tides should allow statistically robust conclusions because NLC are no seldom events at this location. Last but not least this large number of measurement hours is quite unique for a ground-based lidar at this geographic location (full sunlight during summer etc.). For these reasons we leave the numbers but adjusted the text for improved readability: page 3, lines 4-5.*

Page 3, lines 5-8: “For details the reader is referred to Fiedler et al. (2009)”: I would find it useful to add some more sentences on the calculation method, although Fiedler

et al. (2009) is referenced. This would make the article more self-contained and help to directly understand it for readers without a strong background in lidar remote sensing.

*We have added text according to the suggestion: page 3, lines 8-17.*

Page 3, line 15: “to the hourly mean values”: It might not directly be clear that the mean values from the epoch averaging are meant in contrast to, e.g., an hourly averaged time series (other approaches fit the sinusoidal functions directly to time series). Using other words like “epoch averages” could make this clearer.

*Done: page 3, line 25.*

Page 3, line 17: “The mean NLC parameters are randomly diversified within their error bars (1000 times for each hour)”: Which distribution function is used for this (e.g., are the random samples normally distributed with the standard deviation set to the error bars or are they uniformly distributed with sharp edges at the error bar range)?

*The random samples are uniformly distributed within the error bar range, which results in a larger error bar compared to the Gaussian weighted random distribution.*

Page 3, line 23 and Figure 1, caption: “The plots contain 6400 hours of lidar measurements”: Is this really the average over all available measurement hours or the average over the 3100 hours, which contain NLC? If 6400 hours is correct: Is it useful to integrate the measurements without NLC in this plot? To my understanding, these measurements are not used in the rest of the analysis and I would have expected to apply the same filters as for the analysis here.

*The phrasing is something inexplicit, the 6400 hours apply for the occurrence frequency, for brightness only times with NLC detections are valid (3100 hours).*

*We corrected the text accordingly: page 3, line 33 – page4, line 1 ; Figure 1 caption.*

Page 4, line 22: “The plots contain 3450 measurement and 2030 NLC hours from 1997 to 2017”: a similar question here: Are the measurement hours without NLC averaged into to mean data? Or what does the differencing between measurement and NLC hours actually mean?

*We think that rephrasing the text (see above) allows the reader to understand the numbers now.*

Page 5, line 1: “most intense for occurrence frequency”: According to the Delta-value in the plots, the total backscatter coefficient varies most. So, to which value is this statement related?

*You are right, we meant the match between measurement and fit. Text is removed: page 5, lines 11-13.*

Page 5, line 19ff: You compare your values of the semidiurnal amplitudes A12 to those of the satellite studies. As you mention also in the introduction, it takes about one month for sun-synchronous satellites to sample all local lunar times. Hence, the satellites strictly observe a superposition of a semidiurnal and a semimonthly lunar tide and it is necessary for the interpretation to assume that the semidiurnal tide dominates over the semimonthly tide. This assumption is commonly made, but is sometimes still under debate. Could you comment on, first, to what extent the good matching of your results with the satellite results support this assumption and, second, if it could be possible in future to also extract the semimonthly tide from your data in order to cleanly separate both?

*From the match of both results one could deduce a dominating semidiurnal component. Basically our data allow such investigations, which will be subject of future work. Nevertheless we added text to make the reader aware of this topic: page 6, lines 4-6.*

Page 6, Line 13: “the observed lunar tidal behavior, different for the NLC parameters”: the phrasing is not very clear to me. Maybe the sentence could be restructured to put emphasis on the “different” and not on “all. . .contribute”.

*Done: page 6, lines 29-30.*

Page 8, Line 33: “The altitude structure of the lunar semidiurnal tide in layered phenomena of the summer mesopause region was never studied so far”: To my understanding, this is not true in this generality. E.g., von Savigny et al., 2017 shows the altitude structure of the semidiurnal lunar tide in MLS temperature up to 90km altitude and also Hoffmann et al., 2018 shows the altitude dependence of the semidiurnal lunar tide in several NLC related parameters. However, I agree that the phase progression has not been quantified and discussed in these studies as the authors do it here.

*We changed the text to be more specific: page 9, lines 13-14; page 10, line 4.*

#### TECHNICAL CORRECTIONS

Page 1, line 25: “even when epoch averaging over many years and where attributed to impacts of atmospheric thermal tides”: A bit hard to understand. First, maybe: “when epoch averaging over many years is applied” and second, “where” has probably to be “were”.

*Done.*

Page 4, line 22: “The plots contain 3450 measurement”, add “s” to measurement

*Both numbers are in units of hours: “3450 measurement and 2030 NLC hours”. We changed the text for a better understanding: page 4, lines 32-33.*