

## ***Interactive comment on “Mesospheric Anomalous Diffusion During Noctilucent Clouds” by Fazlul I. Laskar et al.***

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We thank the reviewer for the thoughtful comments and suggestions. Below we answer them individually. The authors' response start with "Response".

The manuscript is dedicated to study of the relation between NLC events and ambipolar diffusion behavior at heights of mesopause. The subject is quite interesting as well as results, but there are some questions before publication.

1. The authors report the difference between mean  $\log_{10}(\text{Da})$  profiles for yNLC and nNLC. They used three stations (two in region of NLC - Andenes (69N,16E), Juliusruh (55N,13E)) and one is out of that region - (1S,136E)). So one can expect significant difference between profiles for yNLC and nNLC for midlatitude stations and no difference

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for equatorial. Accords to fig. 3 we can see differences for all three stations.

Response: Yes, from a separation based on yNLC and nNLC that is what expected. Before answering this we would like to excuse that during data analysis of the previous manuscript we made a mistake. The mistake was that, in the previous analysis we had removed some meteors having extreme diffusion values using a 3 sigma filtering. This however was done only for the nNLC case and by mistake was not performed for the yNLC case. This has led to such systematic shift between yNLC and nNLC profiles at all the latitudes.

After correction of the above mistake/bug, we see that the yNLC and nNLC based separation exist only at high-latitudes and not at mid- and low-latitudes (please see revised Fig. 3). At mid-latitudes (Juliusruh), the NLC occurs on rare occasions (Nielsen et al., 2011). A quantitative estimation by Hervig et al., (2016) showed that the NLC at mid-latitude are at least 5-times weaker than those at high-latitudes. So, from the NLC based separation point of view, the mid-latitude is roughly similar to low-latitudes. Thus, as per expectation such separation is observed only at high-latitude, which can be seen in Figure 3.

References: Nielsen, K., G. E. Nedoluha, A. Chandran, L. C. Chang, J. Barker-Tvedtnes, M. J. Taylor, N. J. Mitchell, A. Lambert, M. J. Schwartz, and J. M. Russell (2011), On the origin of mid-latitude mesospheric clouds: The July 2009 cloud outbreak, *J. Atmos. Sol. Terr. Phys.*, 73(14-15), 2118–2124.

Hervig, M. E., Gerding, M., Stevens, M. H., Stockwell, R., Bailey, S. M., Russell III, J. M., and Stober, G.: Mid-latitude mesospheric clouds and their environment from SOFIE, *J. Atmos. Sol.-Terr. Phy.*, 149, 1–14, <https://doi.org/10.1016/j.jastp.2016.09.004>, 2016.

2. NLC maximum is at height near 83km (fig.3). But significant distinction in  $D_a$  for NLC and non-NLC time can be seen at lower heights. Why? Juliusruh  $D_a$  profiles show less affection of NLC effect than Andenes. Why? Juliusruh is situated in middle of band of

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NLC occurrence so we have to expect major effect?

Response: In the revised manuscript (Figure 3) such differences are seen predominantly at NLC maximum altitudes. Some significant differences are also seen over the NLC peak, which may have some contributions from thermal tides. As NLC occurs very rarely over Juliusruh, such differences are below 95% significance level as can be seen in the revised Figure 3.

3. The manuscript is dedicated to revealing the connection between NLC and Da. However, the major affection (as authors admitted) to Da for proposed segregation is due to temperature oscillations. It's good idea to exclude diurnal and semidiurnal oscillation (for ex. with help of harmonic fitting) from produced times series of  $\log_{10}(\text{Da})$ . After that one can expect removing the affection of "temperature" and we will see pure results.

Response: As we mentioned above, in the revised analysis, after correcting the bug in the analysis program, we see that the tidal effects are very weak. Moreover, during a colder phase of thermal tide diffusion is expected to be lower, however, what we observe is the reverse, in other words, cold phase is expected to increase NLC production, which should lead to enhanced diffusion. So, we conclude that the effect that we observe during NLC is not from thermal effects but from electrodynamic interactions between trail and background electrons.

Also, the tidal affects are taken into account as we compare the occurrence rates of NLC times and the observations without NLC. There is a weak daily pattern visible in Figure 5 that could be removed using the suggested harmonic fit. Further, we inspected individual days and due to the day-to-day tidal variability a harmonic fit is not going to lead to a much better removal of tidal effects. However, the reviewer is right that a potential tidal effect could reduce or even increase the reported effect. Looking at a model (LIMA, NAVGEM-HA) results of tidal amplitudes typically 1-3 K are expected for the semi-diurnal tide and up to 5 K at 90 km altitude for the diurnal tide. However, as

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mentioned before, there is a huge local time variability of the tides and tidal amplitudes that are difficult to be removed.

4. The authors consider the total relation between ambipolar diffusion coefficient and half decay time of meteors by skymet radar (eq. 2). But it maybe not totally correct. Some effects may bias estimates of  $\log_{10}(\text{Da})$  to greater values. Besides, height determination at edge of meteor band near 80km and 100km is quite unreliable due to possible jumps from middle of meteor band (90km) due to ambiguity of phase measurements. Thus significant increase of  $\log_{10}(\text{Da})$  at lower heights seems to unreliable.

Response: The reviewer brings up two questions about the analysis procedure. The half decay time from the meteor radar is obtained according to Hocking et al., [2001]. Without going into the details of signal processing the reviewer is right that the absolute value might not be true. However, the applied method is consistently used in all the analysis and whatever offset exists in the absolute value does not map through to the relative comparison presented herein. The authors do not claim to infer absolute values of ambipolar diffusion coefficients based on the half decay time. Recent solutions, invoking a full wave scattering model of an ambipolar diffusing plasma, indicate that the derivation of absolute diffusion coefficients may remain illusive and is not solved by signal processing alone for most of the present systems.

The range estimation mentioned by the reviewer is no longer of relevance herein. The Andenes and Juliusruh meteor radar are operated at a pulse repetition frequency of 625 Hz leading to an unambiguous range determination of 220 km (two way monostatic backscatter case) or in other words only low elevation meteors might fold into the meteor layer as referred to by the reviewer. We did not include meteors below  $65^\circ$  off zenith angle in our analysis to avoid this type of contamination. Further, we conduct a cleaning of folded meteor echoes due to interferometric issues at low elevation angles. These meteors are usually folded to near zenith angles and have large phase errors. These meteors are removed as well. Some discussion on these lines are added in P2 L 25-30.

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Only in the year 2012 and 2013 the radars used a higher pulse repetition frequency. However, as the profiles shown in Figure 3 indicate, there is no jump between the mean profiles. Similar features are also reported in Younger et al., 2015 (GRL) with an ATRAD type meteor radar, which are usually operated at even lower pulse repetition frequencies.

Reference: Younger, J. P., I. M. Reid, R. A. Vincent, and D. J. Murphy (2015), A method for estimating the height of a mesospheric density level using meteor radar, *Geophys. Res. Lett.*, 42, 6106–6111, doi:10.1002/2015GL065066.

Besides, the RMS error is increasing here. Why? Looks like distribution of  $\log_{10}(\text{Da})$  at these heights is quite wide and not Gaussian. What's the result of simple averaging of  $\log_{10}(\text{Da})$  in this case?

Response: The error at the edges (below 80 km or above 95 km) are increasing due to the lesser number of meteors. A version of the Figure 3 with simple averaging of  $\log_{10}(\text{Da})$  is shown below (Illustration 1). As the behavior of the plots and differences are similar to that in Figure 3, we keep the Da plots in Figure 3 in the manuscript.

5. Experimental Data. No references to descriptions, no explanation. Just “data”. Why should one know what those data are? How did they get them? How processed? Ok, Andenes and Juliusruh MR are quite familiar and results are already published before. As for Biak, results are quite rare as well as data maybe quite unreliable. I have downloaded MPD data from [http://database.rish.kyoto-u.ac.jp/arch/iugonet/mwr\\_bik/index\\_mwr\\_bik.html](http://database.rish.kyoto-u.ac.jp/arch/iugonet/mwr_bik/index_mwr_bik.html) and found a great percentage of ambiguous meteors. It says about illness of system. Such data should be used carefully.

Response: The reviewer made a good suggestion. We added a few lines on how the radars are operated and referring to the analysis presented in Hocking et al., 2001. However, a detailed description of the data signal processing might not be helpful and does not provide a significant improvement to the results. The Andenes and Juliusruh MR well documented radars. However, as suggested by the reviewer, we add a few

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lines pointing out why Biak is more complicated and the data has to be used with more care. A reference (Batubara et al., 2018) containing technical and other details of the Biak system is also added in the revised manuscript. Possible range aliasing issue in Biak system are added in P2 L 29-32.

6. NLC mainly observed in mid-latitudes (43-65 latitude's degree, or 50-70 latitude's degree by other sources). Why to use lidar for detection of NLC located in high-latitude (69N)? How it affects on detection of NLC? How it affects on segregation for other stations (Juliusruh and Biak)? In other words, if we see NLC event at current time at certain station should we expect it at other stations in same hours?

Response: In the past there were some comparison of NLC occurrence rates with local measurements at mid-latitudes and satellites (SOFIE, Hervig et al., 2016). The NLC occurrence rate drops off by a factor of 5 between the polar latitudes around Andenes and the mid-latitudes at Juliusruh. Hence, the effect should be most pronounced at high-latitudes. Advection of NLC over large horizontal distances can indeed link higher latitudes with the mid-latitudes (Kaifler et al., 2018). However, the main reason to compare Juliusruh and Andenes are to delineate potential tidal affects. Climatologies of tides indicate (at least for the wind) that tidal pattern is rather similar between Andenes and Juliusruh (Pokhotelov et al., 2018). This is also the reason why the Biak station was included. However, there is no physical reason why an NLC should be seen at all three stations at the same time.

References: Pokhotelov, D., Becker, E., Stober, G., and Chau, J. L.: Seasonal variability of atmospheric tides in the mesosphere and lower thermosphere: meteor radar data and simulations, *Ann. Geophys.*, 36, 825-830, <https://doi.org/10.5194/angeo-36-825-2018>, 2018.

Kaifler, N., Kaifler, B., Wilms, H., Rapp, M., Stober, G., & Jacobi, C. (2018). Mesospheric temperature during the extreme midlatitude noctilucent cloud event on 18/19 July 2016. *Journal of Geophysical Research: Atmospheres*, 123, 13,775–13,789.

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<https://doi.org/10.1029/2018JD029717>

Please also note the supplement to this comment:

<https://www.atmos-chem-phys-discuss.net/acp-2018-1028/acp-2018-1028-AC2-supplement.pdf>

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Interactive comment on Atmos. Chem. Phys. Discuss., <https://doi.org/10.5194/acp-2018-1028>, 2018.

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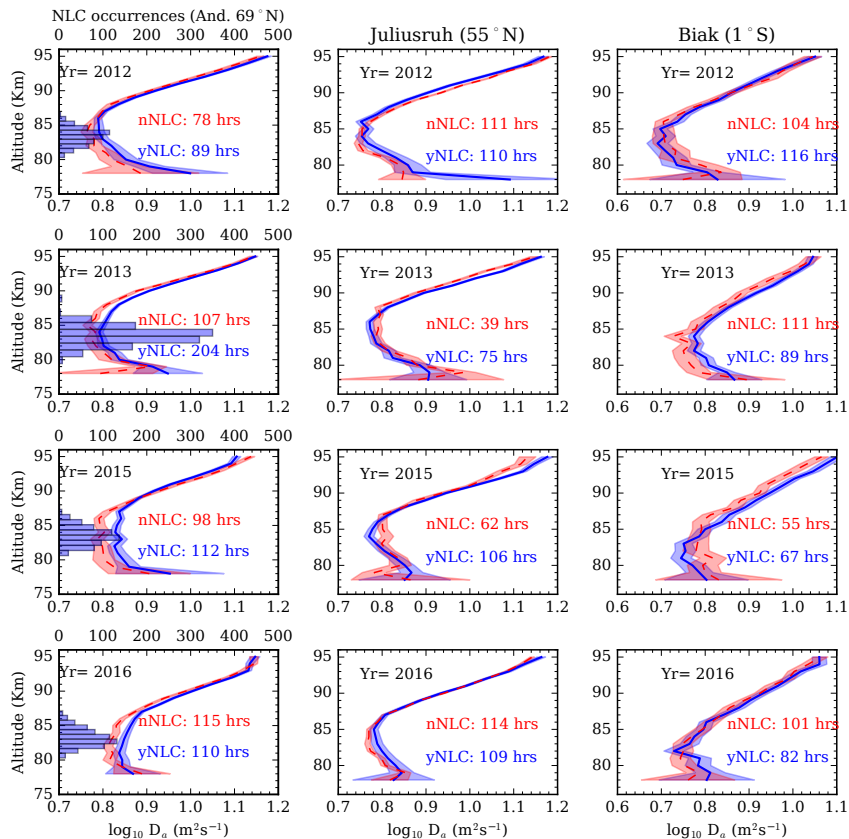
Illustration 1: A version of Figure 3 with simple averaging of the  $\log_{10}(D_a)$ .

Fig. 1.

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