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Atmospheric Chemistry and Physics Discussions

Interactive comment on "NLC and the background atmosphere above ALOMAR" *by* J. Fiedler et al.

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Responses to referee comments on the manuscript ACPD-2011-29.

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1) Responses to comments by referee #1.

We thank M. DeLand for his review.

1.A) Specific Comments

1.A.1) P. 5649, lines 10-11: figure 2 content.

We agree about the difficulty in understanding the local time variations from this relatively busy figure. However we prefer to stay with this figure as it gives a good impression about the importance of local time relative to seasonal variability at a glance. In the revised manuscript we will extend the figure caption with a hint to Fig. 4 which shows more details.

1.A.2) P. 5651, lines 13-16: periods of harmonic fits.

We will rephrase the sentence to point out that 8-hour and 6-hour periods are presumably more dependend on sampling issues than longer periods.

1.A.3) P. 5659, lines 18-21: tidal NLC parameters and SBUV time series.

Several specific questions have been raised by the other reviewer. We suppose that the discussion covers the subject touched here and refer to 2.A.3.

It needs much more detailed investigations of the model data to decide if LIMA can help understanding the sources of the observed tidal parameter changes, which is worthwhile beyond doubt. In case of success the next step could be an extention into years prior to RMR-lidar data.

1.A.4) P. 5659, lines 16-20: solar influence on ECMWF data.

The same point was made by the other reviewer and we refer to 2.A.4.

1.A.5) P. 5660, lines 3-6: 27-day signal in NLC.

We mean here the year-to-year variations and will change the text accordingly.

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2) Responses to comments by referee #2.

We thank the anonymous referee for his comprehensive review.

2.A) Specific Comments.

2.A.1) Figure 6.

We agree that color gradings are sometimes hard to distinguish and had therefore

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already included the numbers for temperature and wind variations at 83 km over the 3 days in the text (p. 5653, lines 3-5). The ranges are dT: 8 K, du: 35 m/s, dv: 25 m/s, which is representative for the daily variability during the NLC season as calculated by LIMA. In the revised manuscript we prefer to include these numbers additionally in the figure caption instead of drawing contours which would compete with the NLC countours.

2.A.2) Figure 8.

The temperature variability over local time is 3.4 K, cf. p. 5656, line 2. This smaller value in comparison to Fig. 6 is mainly caused by averaging over 14 NLC seasons, thus suppressing all patterns which are not stable in phase, like gravity waves and certain tidal components. The hourly mean temperatures are based on many single hourly temperatures (between 150 and 250 values per hour during 14 years) and the error bars are the errors of the means. We will rephrase the text in the revised version.

To address the diurnal variation of water/ice mass we have chosen the method used earlier in Baumgarten et al. (2008) and Fiedler et al. (2009). It is based on the mean cloud water content (CWC) for faint, weak, medium and strong clouds and fits better than the method suggested by the reviewer. The CWC is calculated from the water content carried in the different cloud classes and the occurrence frequencies. The amount of water is described by the ice volume density obtained from our 3-color NLC observations. As a result, for BETAmax>1 the CWC varies by a factor of 2.8 over the diurnal cycle, compared to a factor of 2.0 occurrence frequency (OF) variation. Note that the OF variation over the diurnal cycle increases with brightness limit: factor 2.0 for BETAmax>1, factor 3.1 for BETAmax>4 (shown in Fig. 8) and factor 8.8 for BETAmax>13.

In the revised version we will adress this topic with text as well as figure changes. Fig. 8 will additionally show the zonal wind variation (both from LIMA model and MF radar), which is helpful for the discussion of reviewer comment #40. An addional figure (two panels) will show the diurnal OF variation for faint, weak, medium and strong clouds as well as the corresponding CWC variations.

We will not show results from AIM experiments here for comparison as this would be outside the scope of the manuscript. However, there is a manuscript in preparation concerning the relationship of cloud observations by AIM and ALOMAR RMR-lidar.

2.A.3) Time series at single local times, Fig. 10.

The black line with the symbols at the right panel is the reconstructed behavior taking into account all local times: The left panel shows one thin black curve per year. Each curve describes the diurnal behavior using 24 data points (one per hour). The mean value of them is the data point for the corresponding year at the right panel (= RMR curve). The colored curves at the right panel are generated from the color coded single local times at the left panel and illustrate the importance of local time coverage for multi-year time series. As the reviewer assumes this is not directly comparable with the SBUV time series. For that the values for the specific local times of all contributing satellites for each year should be averaged. Note that the procedure for obtaining multi-year time series from several satellites as applied by Shettle et al. (2009) is more complex.

For better comparison with SBUV local times we extended our analysis as follows: We took the local times for ALOMAR overpasses of all satellites operated between 1998 and 2009 (DeLand et al. 2007, figure 2; DeLand, private communication 2009). Then the OF/brightness values at the corresponding local times are averaged for each year. The result are time series based on RMR-lidar data but filterd by SBUV local times. These 'SBUV' curves are compared to the RMR curves. The differences between both time series (RMR and 'SBUV') are up to 50% (OF) and 12% (brightness) for single years. The slopes, resulting from linear regressions, of the 'SBUV' curves are larger by a factor of 3.0 (OF) and 1.4 (brightness) compared to RMR. In general, due to the combination of several local times per year, the 'SBUV' curves follow much closer the

RMR curves than the colored curves for single local times. We will extent the discussion of this topic in the revised manuscript. The 'SBUV' curves will be added.

Like the reviewer we assume that during the first years the SBUV dataset is biased due to missing afternoon data. However, this should have been corrected in the most recent published time series due to the local time adjustments by Shettle et al. (2009). The slope differences between fixed and variable phases for our 'SBUV' curves are +14% (OF) and -26% (brightness). Note that this is the slope of the linear regression regarding 12 years, including solar cycle variations, and thus not comparable to the trend of the SBUV series starting 1979. Obviously variable phases can impact long-term observations but to which extent remains speculation as long as the actual phases (in the past) are unknown. We will add this topic in the revised manuscript.

For our analysis we used NLC above the long-term limit. Limitation to solely strong clouds would considerably reduce the data amount as well as the significance of tidal parameters. Note that even our strong NLC (BETAmax>13) occur twice as frequent compared to cloud detections by SBUV instruments (cf. Fig. 7 in Fiedler et al. 2009), which suggests that SBUV detects only the strongest part of our strong clouds class definition. This might weaken the relevance of variable phases and amplitudes determined from our lidar dataset for SBUV timeseries. Additionally the variability of tidal parameters could change with longitude which in turn would result into a different zonal mean behavior as seen by SBUV.

2.A.4) Lyman-alpha and temperature.

Solar activity variation is expected to impact NLC formation primarily due to Lyman-alpha induced photolysis of water vapor and temperature variation in the mesopause region. Seasonal mean temperature variations at NLC altitudes over the solar cycle are calculated to be up to 3 K, cf. p. 5653, line 19, which is primarily caused by solar heating in the ultraviolet. The LIMA version used for our work includes such heating processes, cf. p. 5647, lines 21-23. The model version used in Luebken et al. (2009)

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did not, but their ice module contained Lyman-alpha induced photolyses of water vapor.

On the other hand solar cycle induced radiation variablity impacts the whole atmosphere, decreasing with altitude, and the effects are included in the assimilated tropospheric/stratospheric ECMWF data. This solar cycle information will impact mesospheric altitudes through vertical coupling, but certainly to a much lesser degree than solar heating processes at these altitudes.

We will rephrase this passage in the revised version.

2.B) Technical Comments.

We will consider the helpful detailed comments in the revised manuscript. Topics not discussed below will be changed as suggested by the reviewer.

2.B.40) Relation between NLC occurrence and zonal wind.

We have investigated in more detail the diurnal behavior of the zonal wind. It turns out that on multi-year average the strongest westward winds occur in the early morning around 4 local time, like the temperature minimum. Thus the tidal behavior appears responsible to a large extent for the coincidence. We will change the discussion in the revised manuscript and add the zonal winds both from LIMA model and MF radar in Fig. 8, see 2.A.2.

2.B.42) Yes, we mean Lyman-alpha radiation.

2.B.46) Yes, we mean Lyman-alpha radiation.

2.B.43) We mean from ... to ..., will be changed.

2.B.45) We mean from ... to ..., will be changed.

2.B.48) Will be modified according to 2.A.3.

Interactive comment on Atmos. Chem. Phys. Discuss., 11, 5641, 2011.

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