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Atmospheric Chemistry and Physics Discussions

Interactive comment on "Observations of turbulence-induced new particle formation in the residual layer" *by* B. Wehner et al.

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We really appreciate the helpful comments and suggestions of the reviewers! Thanks!

Specific comments:

Page 338 Line 23 "It should be emphasized that lidar backscatter signals may will not be well correlated with the total particle number concentration because the signal strength is mainly controlled by backscattering of accumulation and coarse mode particles.

"May not" is understating the situation. If there is new particle production, then the premise must be that the number-size distribution shifts as you demonstrate in figure 5. That the magnitude of the lidar backscattering moment of the aerosol distribution

seems to be associated with NPF, at a size range where the backscattering must be orders of magnitude lower, implies that there is layering of the transported aerosol, particulate plus gas phase, yielding gradients amenable to non-linear mixing effects and NPF.

Answer: That's really a good point, thus the sentence has been changed as suggested by the reviewer.

Page 343 Line 7 Even though this increase of turbulence is not very strong, the correlation of increased Eta t and increased N in L1 and L2 is remarkable.

Without some numbers, R-squared for example, its hard to say that the correlation is remarkable. I agree that by ocular analysis there is a correlation and that with a limited data set in a rapidly varying set of mixing layers it is hard to do rigorous, convincing statistics. If the statistics were calculated they should be presented even if the outcome is less than robust. If they were not calculated they should be.

Answer: This is a good point but a quantitative correlation analysis is no possible due to the following reasons: i) the statistics is really poor and ii) N "correlates" sometimes with the peak of energy dissipation but in the next profile the peak of N correlates with the edges of a peak of epsilon – this will give very weak formal correlation. We include the word "qualitative" correlation in the text to soften out statement a little bit. For the future we hope have more similar observations which could allow us to make a formal correlation analysis maybe after conditional sampling or so.

The arguments based on Eta in fig 8 are tenuous. The layer boundaries as defined by [N] generally match the altitude boundaries that would be indicated by Ri and Eta but the altitude values are subjective.

Answer: Yes, there is no formal definition of these layers, there were selected from the profiles of N. To clarify this, we added to the introduction of L1 and L2: '(layers are subjectively indicated as shaded areas L1 and L2 in Fig.3)'

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Line 18 From our observations it is not possible to determine the exact age of the small particles but typically the growth rate can be estimated to a few nm per hour (Kulmala et al., 2004) which results in a particle age of one or two hours or so which is also an indication for our hypothesis that these particles were formed inside these layers.

Doesn't Kulmula's growth rate depend extremely strongly on condensable gas phase concentration such that the age could be as short as minutes up to the "two hours"? Without any particular knowledge of the gas phase concentrations that might have existed in this residual layer, but from the trajectories and your description of "polluted air masses", higher precursor concentrations and shorter times would seem probable. Admittedly the relatively low [N] implies that the air mass was not highly polluted.

Answer: Right, we also think that growth rates vary significantly, in our case we have no idea about any values. The point is only that we cannot conclude automatically that the particles have been formed in the regions where they have been measured and/or nucleation process may be some time ago. Assuming a high concentration of condensable vapors the age may be much shorter. Thus, two hours is an upper estimate but it is likely that the particles are much younger.

We modified the text: From our observations it is not possible to determine the exact age of the small particles but typically the growth rate can be estimated to a few nm per hour (Kulmala et al., 2004) which results in a particle age of one hour or for more polluted conditions as short as a few minutes. This can also be taken as an indication supporting our hypothesis that these particles were formed inside these layers.

Page 344 Line 16 "This short time scale corroborates our hypothesis that the rapid increase of ultrafine particles observed by NAIS is due to vertical mixing of the particles observed earlier by ACTOS in the residual layer, rather than new particle formation at ground level." While I agree with this discussion point, I fail to see mention of the original hypothesis in the introduction that is referred to here.

Answer: In fact, we did not really have this hypothesis before measuring and analyzing

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this case. It came up when we got access to ground data and realized the not-banana-shaped behavior and the similar time scales. We could either include the hypothesis afterwards into our introduction or remove the word hypothesis from the interpretation. We finally decided to do the latter and modified the sentence to: 'Due to this short time scale it is obvious that the rapid increase of ultrafine particles observed by NAIS. . .'

Similarly, the words "remarkable" and "suspect" where they occur should be replaced with more scientific terms.

Answer: Such words are replaced in the revised manuscript.

Table 2 Would it be informative to add Ri and Eta to the table for the level legs or are these parameters not valuable except as profiles?

Answer: The Richardson number describes stratification in terms of developing/suppressing turbulence and is, therefore, a number for profiles only. A mean energy dissipation rate would be possible but I think it is not very informative in this context since nucleation is not supposed to scale with the absolute number of epsilon but the variability.

The values of [N8-20], [S] and [V] are not mentioned quantitatively in the discussion in the context of NPF. Particularly S, and the relatively high values of S, are worth adding.

Answer: Yes that's rights. We focused on the variation, but of course the absolute value could be interesting too. We added to the text: Note that surface area concentration S shows relatively high values within all flight legs and $N_{(6-20nm)}$ varies over three orders of magnitude..

A useful addition to the discussion would be guidance of what observations could be added to better define future experiments of this type or how "re-interpretation" of earlier ground-based observations could be done.

Answer: That's really a good question; other reviewers had similar questions. However, the word re-interpretation might be misleading, we are not planning to investigate all

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ground based measurements again. From our single case study we cannot draw any general conclusion for other measurements especially those without vertical information.

But some speculation is of course possible: If a particle burst occurs (not at smallest detectable sizes, no banana-shaped contour plot) over horizontally homogeneous terrain a vertical transport of newly formed particles is a probable explanation. However, from ground-based measurements alone this is just speculation until it can be validated by some more measurements. Such measurements require beside ground-based aerosol measurements some information about the development of the boundary layer (i.e., lidar or other remote sensing instrumentation) to observe when the nocturnal boundary layer has been removed and a well-mixed boundary layer was built. If this happens shortly before the particle burst appears at the ground a vertical mixing of the newly formed particles is most likely. Since this is just speculation we do not want to add it to the text.

From our observations a few conclusions for upcoming experiments on new-particle formation can be drawn with a particular focus on instrumentation and observation strategy. Many different processes and preconditions for nucleation have been discussed (see introduction for more details and references). This includes different kind of boundary layer processes such as advection due to low-level jets and mixing at its edges or local mixing due to the break-off of the nocturnal inversion or such as in this case local mixing in shallow turbulent layers. All these mentioned phenomena are difficult to predict and their occurrence is limited in space and time which makes it difficult to observe in-situ. However, if such processes are the reason for nucleation only a combination of in-situ, remote sensing and ground-based observations will shed light on the details. Any of these processes can lead to locally increased number concentration of ultrafine particles with subsequent down mixing and with ground-based particle observation only one can only speculate of their origin. The same arguments are valid for nucleation in combination with clouds and subsequent mixing to ground level.

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Modifications in the text: Deleted ‘re’ in âĂŽre-interpretation‘, also âĂŽcomplete‘ in ‘complete misinterpretation’

We added on last sentence: In the future it would be interesting to have simultaneous, vertically resolved aerosol, chemical, and turbulence measurements within the boundary layer.

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