amt-2016-182
Title : Radiation fog formation alerts using attenuated backscatter power from automatic Lidars and ceilometers

Response to Reviewer 3.

The authors would like to thank the Anonymous reviewer #3 for helpful comments and suggestions. A response is provided for each comment, shown in blue color.

Reviewer 3 introductory comment:

Anonymous Referee #3

GENERAL COMMENTS

This paper describes a new algorithm for now-casting of fog formation. Fog now- casting can be very valuable, especially for airports where low visibility can cause major disturbances. This algorithm uses the hygroscopic growth of the attenuated backscatter to provide alerts prior the formation of radiation fog. The algorithm was tested on 45 fog cases from 2011 to 2015 at two sites (SIRTA and Uccle).
This manuscript presents a new and valuable technique that can be applied on a large number of existing stations. The manuscript is clearly written and the algorithm is well described. The analysis of the alert occurrence also provides interesting results concerning the altitude where the cooling process lead to aerosol activation.
However, the possibility of false-alarms was not evaluated. A discussion about the algorithm limitations is missing to fully appreciate the usefulness of these observations to complement the Numerical Weather Predictions (NWP).
Therefore I recommend the publication of this manuscript but only after the correction of the following major comment.

MAJOR COMMENT

As the author mentioned in the introduction, air traffic at busy airports can be significantly disrupted in case of low visibility. New observations and warnings can be very valuable for airport forecasters but only if their forecasting skills are higher than NWP's.
This study shows an evaluation of PARAFOG performance between 2011 and 2015. If no false alarm occurred during this period, the authors should mentioned it. If it is not the case, the authors should present a case study and statistics about the hit-rate and false-alarm occurrences. For the same SIRTA site, Menut et al. (2013) described a method to forecast fog from ground based measurements with an hit-rate of 87%. They also mentioned a false-alarm rate of 39%. Similar statistics are required to evaluate the performances of the PARAFOG algorithm.
Further discussions about algorithm limitations and possible improvements of the algorithm would also be valuable.

Response to Major Comment:

This is a very important issue, as in the end, one wants to know how often a fog prediction method provides "hits" and "false alarms" as this is a common metrics. In our paper, we present the basis for the study of fog formation by means of the light scattering measured by ALCs and we present PARAFOG to derive pre-fog formation alerts in order to highlight the potential of this methodology. Therefore, we discuss the occurrences and characteristics of these alerts based on 45 fog case studies (fog occurs in each case). We also demonstrate that the PARAFOG algorithm can be used on two different ALC datasets measured at two different sites. These results should be considered as the basis for the development of an algorithm for nowcasting fog formation.

Our work should be evaluated according to i) the set of observations in near real-time that could be useful to track the evolution of key processes and key parameters that drive fog formation and ii) the experimental observations that could complement the information predicted by NWP models that is made available to airport forecasters in support of their fog forecast.

From our recent experience participating in a field campaign at Charles-de-Gaulle airport, it is our understanding that airport forecasters use an ensemble of information (several NWP forecasts, satellite measurements, surface measurements, knowledge of local climatology) to derive their own "subjective" fog forecast. In our paper, we suggest that there is useful information in the ALC attenuated backscatter time series.

To address the question of "hit rates" and "false alarm rates", we must develop a method to define what constitutes a "hit" and a "false alarm" based on PARAFOG alert levels. We must study how alerts should be interpreted to make an alarm in an objective way, which will allow us to derive hit rates and false alarms rates based on the occurrence of low visibility. This requires an in-depth study, preferably at multiple sites to provide a robust evaluation. We are currently preparing a follow-on study based on ALC measurements at several locations in Europe.

To reflect this discussion, the following changes have been made in the manuscript:

Last paragraph of Section 4 (page 18), the following sentence has been added: "The behavior of the PARAFOG algorithm prior to quasi-fog situations should be tested further to estimate the potential for minor, moderate and severe alerts to occur in such conditions."

First paragraph of Section 5 (page 18), the text within parenthesis has been added: "…based on about 45 fog cases (fog occurs in each case) observed near Paris and Brussels…"

Last paragraph of the conclusion (page 23) has been rewritten: "To further evaluate the performance of PARAFOG, several developments are suggested: (1) a method for objective interpretation of alert levels should be developed to derive hit rates and false alarm rates; (2) performance tests should be carried out at other locations using datasets that include both pre-fog events and non-fog events; (3) alert threshold values should be adapted to reference relative humidity, and possibly to aerosol types using for example PM2.5 measurements."

We agree with the referee that the limitations of the methodology should be discussed. The following paragraph has been added after the fourth paragraph of the conclusions (page 23):

"Known limitations in our ability to track hygroscopic growth of aerosols using PARAFOG are (1) the minimum height at which ALC measurements can be reliably used due to ALC optical overlap; (2) water vapor absorption at 905-910 nm that affects attenuated backscatter values as specific humidity changes; (3) change in aerosol type (e.g., form marine salt to anthropogenic aerosols) within a few hours prior to fog formation."

SPECIFIC COMMENTS

Page 3 line 14 and l 20: Please replace "Roman-Cascon et al. 2015" by "Roman- Cascon et al. 2016"
Response: changed.

Page 5 lines 19-21: What is the impact over the oversampling on the PARAFOG algorithm ?

The major impact of the oversampling on PARAFOG is to delay up to 10 minutes (maximum) the determination when conditions are favorable and not favorable for pre-fog alerts based on the relative humidity (oversampled). In the worst cases, it may reduce the alert duration up to 10 minutes.

Page 11 line 8 eq. 12: Please define the greek letter xi

Response: We have changed the letter by 'z'. A sentence has been included in the text with the meaning:

"…where z is the variable representing altitude."

Page 15 line 10 eq. 18: What does the acronym RG stands for ?

Response: RG stands for Ration Gradient (or attenuated backscatter ration gradient). The definition of RG has been added to the text.

Page 16 line 7: could you discuss the impact of these thresholds ?

Response: these thresholds define the alerts (minor, moderate, and severe). Lower threshold values would alert about hygroscopic growths without leading to a real fog formation (false alarms). Conversely, larger threshold values would alert once the fog formation is almost finished reducing the prediction time.

Page 19 line 4: How the mean extinction was calculated ? What was the Lidar Ratio assumption?

Response: We make a rough estimate of the extinction, based on the two-way attenuation T^2 between the surface and 250-350 m above surface, assuming that both backscatter and

extinction coefficients are invariant with altitude in that range. A T^2 value of 0.95 in 250 m yields an extinction of ~0.85 x 10^{-04} m^{-1} (Figure 10b), while a T^2 value of 0.40 in 350 m yields an extinction of ~1 x 10^{-03} m^{-1} (Figure 10a). We do not make any Lidar ratio assumptions here. To reflect that this is a simple calculation, we change the extinction values reported in the text to "approximately 10^{-04} m^{-1}" and "approximately 10^{-03} m^{-1}"

Page 27 line 19 : Please replace " Román-Cascón, C., Steeneveld, G. J., Yagüe, C., Sastre, M., Arrillaga, J. A., & Maqueda, G., Forecasting radiation fog at climatologically contrasting sites: evaluation of statistical methods and WRF. Quarterly Journal of the Royal Meteorological Society, 2015" by "Román-Cascón, C., Steeneveld, G. J., Yagüe, C., Sastre, M., Arrillaga, J. A., & Maqueda, G., Forecasting radiation fog at climatologically contrasting sites: evaluation of statistical methods and WRF. Quarterly Journal of the Royal Meteorological Society, 2016"

Response: replaced.

Page 33 figure 1: Please add units for the relative difference.

Response: done, figure updated.

Page 33 figure 1: Please check the caption. "(bottom)" and "(top)" are inverted

Response: caption has been corrected.

Page 37 figure 5: Please check the caption. Could you replace "time series" by "scatter plot".

Response: figure caption changed.

Page 38 figure 6: Please check the caption. Units is missing for the altitude of aerosol activation ("100m agl" instead of "100 agl"). (a) and (b) labels are missing, could you replace it by (top) and (bottom)?

Response: caption corrected. (a) and (b) labels have been added.

Page 39 figure 7: Please check the caption. Units is missing for the altitude of aerosol activation ("100m agl" instead of "100 agl"). (a) and (b) labels are missing, could you replace it by (top) and (bottom)?

Response: caption corrected. (a) and (b) labels have been added.

Page 39 figure 7: Where is the horizontal visibility line?

Response: visibility measurements not available at UCCLE (caption updated accordingly).

Page 40 figure 8: (a) and (b) labels are missing, could you replace it by (top) and (bottom)?

Response: (a) and (b) labels have been added.

Page 41 figure 9: (a) and (b) labels are missing, could you replace it by (top) and (bottom)?

Response: (a) and (b) labels have been added.