Author's response to referee#1

The authors are grateful to the anonymous referee # 1 for his/her time devoted to this paper and the useful comments and suggestions, aiming at the improvement of the manuscript.

All comments and recommendations of referee#1 were taken very seriously into consideration for the preparation of a revised version of the manuscript. Additional effort has been put to implement and incorporate suggestions in the manuscript to the best possible degree and prepare a revised version accounting for all comments of referee #1.

In the following, we present our answers to the referee's comments as well as the changes performed in the manuscript in the following order:

A. Comments of referee #1

B. Authors' answers to each comment of referee #1

C. Changes in the manuscript to account for comments of referee #1

A. Comments of referee #1

In this article, Founda and coauthors describe the long term trend in visibility in Athens, Greece and compare this trend to meteorological variables, visibility changes at a nonurban site in the area, and satellite-derived aerosol optical depth values. The rapid degradation of visibility after 1950 and slight recovery since 2005 are correlated with meteorological conditions associated with air mass origin, PM10 surface measurements, and aerosol optical depth; these relationships suggest that visibility is a proxy for local and regional atmospheric aerosol levels. This trend and associated analyses provide a novel dataset for understanding long term changes in aerosol concentration near Athens. I'd suggest publication after the following comments have been addressed.

Major comments:

1) While the grouping of 3 periods of visibility trends are appropriate when discussing changes over time, the middle period (1949-2003) is not appropriate when discussing frequencies (Figure 5) and seasonality (Figure 6) because the early part of the period has substantially different visibility conditions from the later period. When not showing a time series, the 1949-2003 period needs to be separated into several periods of more similar visibility conditions.

2) I think that a more comprehensive comparison between emissions changes and visibility trends would help improve the article. Figure 11 needs to have emissions on the y-axis as a magnitude rather than a rate of change, and plotting other types

of emissions (NOx, EC, OC, etc) would be interesting to see if available. If the emission data could be segregated by air mass origin, it would be interesting to see if increases/decreases of emissions in certain parts of Europe have affected the visibility in Athens.

3) To add value in the visibility-satellite AOD comparison, I'd suggest examining the much longer-term dataset of AOD values from the Advanced Very High Resolution Radiometer (AVHRR) satellite. Although AVHRR retrieves AOD only over ocean grid cells, selecting the nearest ocean cell to Athens would enable an visibility-AOD comparison since 1981 when visibility values were still degrading.

Minor comment:

1) Many typos and text spacing problems persist in the document and have to be corrected. The first of many are listed by page number; line number (suggested correction): Page 1; Line 18 ("34%"), Page 1; Line 22 ("the 1950s"), Page 2; Line 46 ("containing"), Page 3; Line 82 ("oldest time"), Page 4; Line 90 ("construction"), Page 5; Line 118 ("...the year. The periods..."), Page 5; Line 129 ("Mediterranean"), Page 5; Line 136 ("60%"), Page 6; Line 173 ("Po Valley"), Page 7; Line 180 ("...subsequent reduction in vehicle use..."), Page 7; Line 201 ("with the naked eye."), Page 8; Line 208 ("Davis (1991)."), Page 10; Line 272 ("Overall, visibility did not exceed..."), Page 11; Line 312 ("different approaches, as for instance..."), Page 12; Line 343 ("...resulting in the reduction of visibility."), Page 13; Line 364 ("In other cases..."), Page 14; Line 491 ("increase of construction in the city."). I'd recommend an grammatical editor to correct these and other errors prior to publication in final form.

2) Figure 2a should be referenced in the text before Figure 2b.

B. Author's answers to the comments of referee #1

<u>Major Comments</u>

1. Indeed, the grouping of the historical time series was mainly indicated by the different slopes of trends observed in the three sub-periods 1931-1948, 1949-2003 and 2004-2013. It is true that the early part of the much longer sub-period (1949-2003) is characterized by different visibility conditions compared to the latter part. For this reason, the initial grouping was maintained only in trend analysis. In all other cases, namely when studying frequency distribution (Fig. 5), seasonality (Fig.6) but also variation of visibility with wind direction (Fig. 10), the long period 1949-2003, was further divided into two parts, 1949-1975 and 1976-

2003. Figures 5, 6 and 10 were reproduced, where the plots concerning the 1949-2003 sub-period, were replaced by plots for the periods 1949-1975 and 1976-2003 (see section C below). The text in the manuscript in sections 3.2, 3.3 and 4.4.2 was revised accordingly, accounting for the new information derived from this additional grouping.

2. Historical data of other types of emissions for Europe such as NOx and OC were also considered and discussed in the manuscript. Plot of rates of changes of SO_2 emissions in Fig. 11 of the manuscript was now replaced with the plot of SO_2 emissions as a magnitude for a more direct comparison with visibility variations. Moreover, a plot of historical NOx emissions for Europe was added in Fig. 11. Details are provided in section C below.

3. We have followed the reviewer's recommendation and used the AVHRR satellite data (available since 1981) in addition to support the current MODIS related analysis concerning AOD and visibility. The additional analysis was incorporated in the manuscript accordingly as described below (see section C).

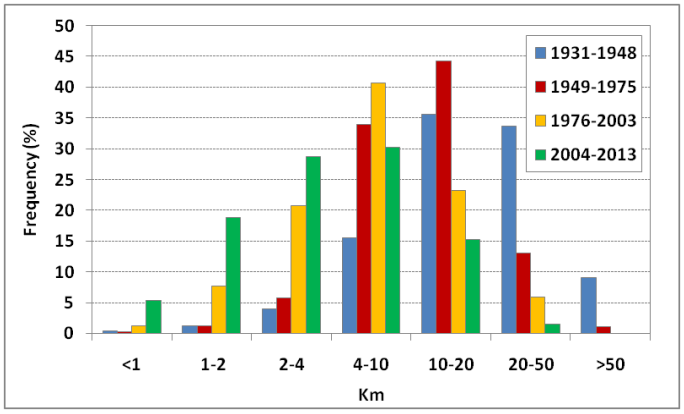
Minor comments of referee #1

1. Although a grammatical editor had been already used, for some reason it didn't work properly and a number of grammatical and syntax errors remained in the text. Additional effort and a new editor have been used now to cope with this problem. All suggested first corrections by the referee were applied in the text. Additional syntax errors were also found and corrected.

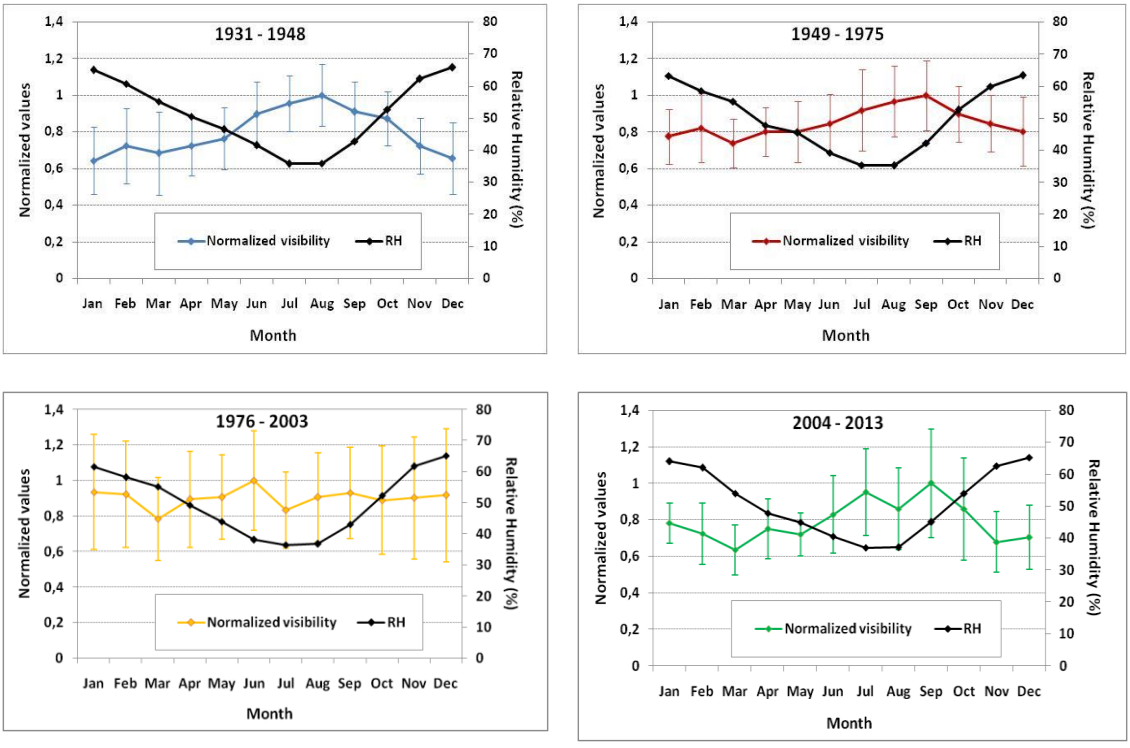
2. This was corrected.

C. Changes in the manuscript to account for the comments of referee#1

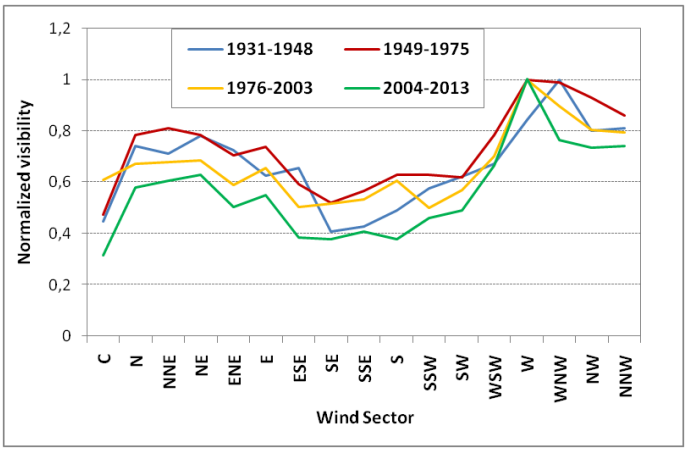
1. In order to comply with major comment 1, Figs 5, 6 and 10 concerning the frequency distribution, seasonality and variation of visibility with wind direction were reproduced. In the new figures, the sub period 1949-2003 was replaced by two additional sub-periods, namely 1949-1975 and 1976-2003. The new Figures 5, 6 and 10 are displayed below



New Fig. 5. Frequency distribution of different visibility ranges (Table 2) in Athens for the sub-periods, 1931-1948, 1949-1975, 1976-2003 and 2004-2013.



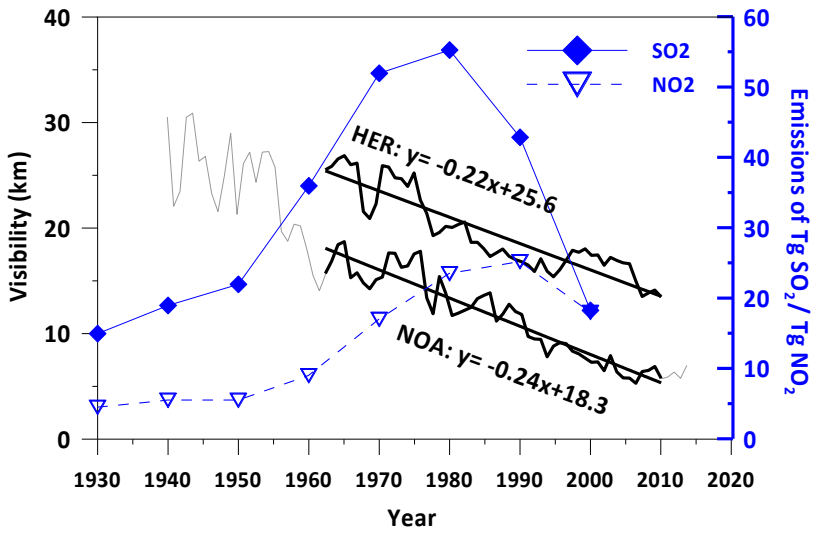
New Fig. 6. Normalized mean monthly values of visibility in Athens for the sub-periods 1931-1948, 1949-1975, 1976-2003 and 2004-2013, along with mean monthly values of relative humidity (RH) for each sub-period. Vertical lines represent standard deviations of monthly visibility means.



New Fig. 10. Variation of visibility with wind direction (sectors) over the sub-periods 1931-1948, 1949-1975, 1976-2003 and 2004-2013. Visibility is normalized by its maximum value at a certain sector for each sub-period. Sector 'C' corresponds to calms (wind speed < 0.3 m s-1). Frequency of each sector approximates closely its climatic value (Fig. 3) in all sub-periods.

The text in the manuscript (sections 3.2, 3.3, 4.4.2 and Conclusions) was revised accordingly, to account for the new information derived from this additional grouping.

2. Historical data of other types of emissions in Europe such as NOx and OC were also considered and discussed in the analysis. Fig. 11 of the manuscript was reproduced. In the new figure, graph of the rates of changes of SO_2 emissions was replaced with graph of historical emissions as a magnitude, for a more direct comparison with visibility variations. Moreover, a plot of historical NOx emissions for Europe was added in Fig. 11. Historical emissions of SO_2 and NOx for Europe were now derived from the studies of Vestreng et al. (2007, Fig. 1) and Vestreng et al. (2008, Fig. 4) respectively since they provide updated emissions data.

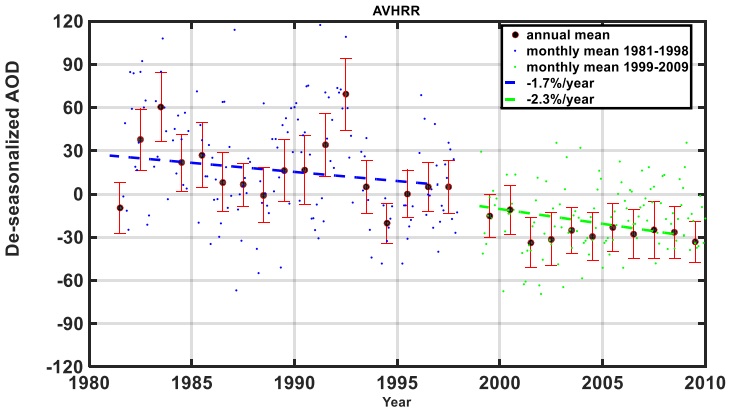


New Fig. 11. Inter-decadal variability of the annual visibility at NOA (urban) and HER (background) stations. Bold black lines represent the common period of observations (1956-2009) at the two stations along with linear trends and slopes. Solid blue line illustrates historical European emissions of SO_2 as included in Vestreng et al., 2007 and blue dashed line illustrates historical European emissions of NO_2 as included in Vestreng et al., 2008.

Historical emissions and trends of Organic Carbon as included in the study of Bond et al., (2007, Fig. 6) were also discussed. The segregation of emissions according to air mass origin was also now discussed in the text. Information for segregation was based on the same studies but also the study of Mylona (1996) and van Aardenne et al., 2001. Emphasis is given on air masses from N, NE directions (North, Eastern Europe), since on an annual basis, air masses from the N and NE sectors dominate in the area of interest (Figs 2, 3 of the manuscript).

3. Section 2.5 has been changed including the reviewer's suggestion to include the AVHRR analysis in addition to the one of MODIS. In this section, we describe the data set used with the respective references and the specific analysis and data set details for the Athens case.

Then section 3.6 has been changed accordingly including the results of the analysis of AVHRR data. In addition, we have included a new figure (Fig. 12a) showing the AOD changes in Athens area from 1981 to 2009 based on AVHRR and we have superimposed the AVHRR related results to Figure 13, describing now the AOD - visibility index relationship from two different data sets.



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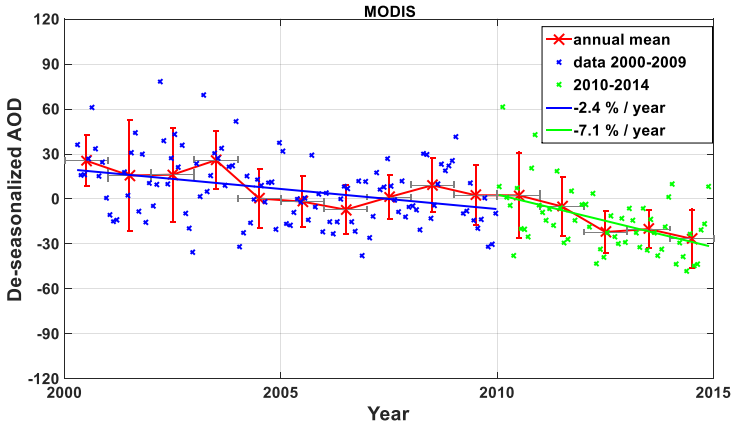

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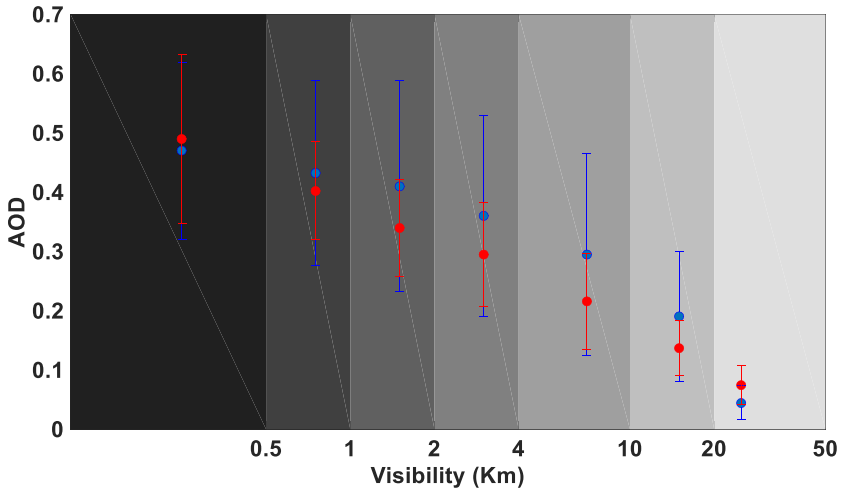
199 **New Fig. 12**. a) Variability of deseasonalized monthly AVHRR-based AOD_{630nm} from 1981 to 2009
200 (black), along with linear trends for the periods 1981-1997 (blue), 1998-2009 (green). Vertical bars
201 describe the standard deviation of the annual value based on the monthly ones .b) Variability of
202 MODIS-based deseasonalized monthly AOD_{550nm} from 2000 to 2014 (red), along with linear trends for
203 the periods 2000-2009 (blue), 2010-2014 (green). Vertical bars describe the standard deviation of the
204 annual value based on the monthly ones and grey horizontal bars the respective year.



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206 **New Fig. 13**. MODIS at 550nm (blue) (2000-2014) and AVHRR at 630nm (red) (1991-2009), AOD June-
207 August mean values and standard deviations for each visibility index. Shaded areas represent visibility
208 ranges (km) for each visibility class (Table 2). AOD averages have been represented here in the
209 average distance from each class

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213 **Minor comments of referee #1**

214 **1.** All suggested first corrections by the referee were applied in the text. Additional syntax
215 errors were also found and corrected.

216 **2.** Figure 2a is now referenced in the text before Fig. 2b.

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