Visibility records and trends since 1956, as a proxy of decadal changes in aerosol loads (SW Greece, Messenia)

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Abstract This study investigates visibility records in Methoni - Peloponnese (SW Greece) during the last 6 decades, based on routine, non-automated observations. The motivation for this study has been to examine how visibility trends and variability can be used as a proxy for changes related to the local/regional climatic parameters or to atmospheric aerosol loadings, the latter due to anthropogenic activities or other natural sources. For this purpose relative humidity and AOD data were considered. The analysis showed high reduction visibility rates from mid 50s to late 70s, followed by a stabilization since around 2000, while an increase in visibility after 2008 could be attributed to the economic crisis and the subsequent reduction in anthropogenic activities/emissions. A trajectory analysis for the whole period allowed the estimation of the relative source contribution, indicating RH as the main controlling factor.

1 Introduction

Visibility in the unpolluted atmosphere is restricted by Rayleigh scattering, the curvature of the earth's surface and natural aerosols (e.g. water drops, dust, forest fires, volcanoes, sea spray, vegetation emissions). These sources cannot be easily amenable to control, however, their impacts must be considered in studies of visibility impairment. In the Mediterranean region, humidity and dust aerosol from arid areas in N. Africa are expected to be the main controlling factors of visibility. Moreover, anthropogenic aerosols during the last decades may also have posed an effect on visibility, taking into account that Eastern Mediterranean has been well identified as a crossroad of air masses carrying numerous and various aerosols types (Lelieveld et al. 2002).

The scope for this study is to examine the trends and the variability of visibility in the Methoni area (Peloponnese, SW Greece) as related to meteorological parameters and aerosol loading information.

2 Data and Methodology

Visibility records in the area of Methoni - Peloponnese (SW Greece) since the mid-50s (1956-2013) are used in this study. The records are based on routine, non-automated observations taking place at the Hellenic National Meteorological Service (HNMS) station. In particular, one observation every three hours was conducted during the whole period (on an annual basis full coverage until 2001, ~70% since then), from which monthly and annual averages were calculated (the records were decoded to provide visibility in km and annual averages were corrected for data gaps). Mean daily values of relative humidity (RH %) were also used from the HNMS station in Methoni (40 m a.s.l.). For a long term time series of AOD we extrapolated the NOAA/AVHRR 4D climatology of AOD for the Mediterranean Sea by Nabat et al. (2013; their figure 13), while since 2000 we deployed MODIS AOD over the area of study.

We also performed an extensive analysis of air-mass origin and meteorological history during transport. For this purpose we calculated 10 day back trajectories at 10, 100, 500 and 1000 m above sea level. A trajectory was calculated every 3 hours through the studied period. The model used was HYSPLIT4 (Draxier and Hess, 1998) applied on NCEP/NCAR reanalysis data archive. The model provides, besides latitude and longitude pairs for all endpoints, meteorological information such as relative humidity and temperature. The trajectories were subsequently used to study the potential contribution from different source regions of air with low visibility (<10km) and air with high visibility (>25km). Also other transport characteristics were investigated in detail.

3 Results and Discussion

3.1 Long term trends in visibility

Visibility on an annual basis (Fig. 1) shows an abrupt reduction from mid 50s to late 70s, from about 26-28 km down to 17-18 km. Since then the reduction rate slowed down considerably and only during the last years (2008-2012) an increasing branch is observed. According to Vrekoussis et al., (2013) this period coincides with a significant acceleration in the reduction of emissions in Greece due to the ongoing economic recession.

Visibility until the mid 70s seems to be driven by changes in RH. In particular, despite the overall trend, two characteristic peaks in RH in 1962-1963 and 1967-1970 are well reflected on visibility that shows considerable drop. After the mid-70s the RH appears stable and so does the visibility, while a new hump during 1997-2002 in the RH is again reproduced by visibility before the gap in the series. For the main period of available AOD data, no signal of aerosol impacts on visibility is easily recognizable. However, it should be noted that in Nabat et al., (2013), different datasets (satellite and models) show great variability both in terms of absolute values and long term trends, thus making safe conclusions difficult to be drawn. The spatial representativity of these data compared to the point observation and specific direction recording at Methoni, should also be taken into account. AOD as revealed from the MODIS data for a grid including the Methoni station, decreases since late 90s, while its last period decrease (since 2008) coincides with a significant increase in visibility despite the concurrent spike in RH too.

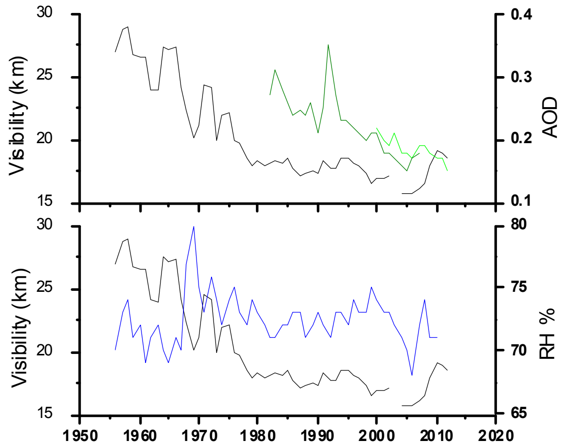

Fig. 1. Inter-annual variability of visibility (black), RH (blue) and AOD (MODIS: light green, NOAA/AVHRR-Nabat et al. 2013: dark green).

To follow the long term visibility changes on a seasonal basis, we produced the monthly cycles of visibility per decade (Fig. 2). In the first two decades clearer conditions are found during summer and fall. The biggest change is observed during the 70s when visibility in spring and summer showed a rapid decrease, probably following the industrialization in the extended area (the nearby Megalopoli lignite power plant began its production in 1971) and the appearance of photochemical smog, especially in nearby urban centers (e.g. Athens) and during summer time. Thence visibility further deteriorated and showed up no distinct seasonality.

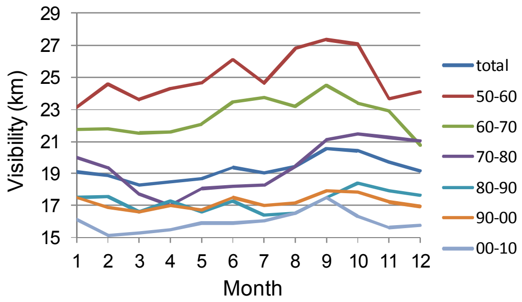

Fig. 2. Seasonal cycle of visibility (at 9:00 UTC) per decade.

3.2 Role of source area and transport characteristics

The visibility observations used in this study are not automated and are quantified based on known distance to reference points. This means that the visibility observations typically are discrete and unevenly spaced. The current dataset thus includes 16 “type” values between 0.8 and 30km. In order to make the data more accessible it was arranged into five visibility bins (0.8-8km, 10km, 15km, 20km and 25-30km). In this section we study the transport characteristics associated with observations that sorts under the highest and lowest visibility bin, respectively.

Figure 3a shows the likelihood that air originating from any grid is associated with observations of visibility that is less than 10km (i.e. visibility bin 0.8-8km). Figure 3b in turn shows the average transport height over the different grids at which an air parcel associated with the lowest visibility bin resides.

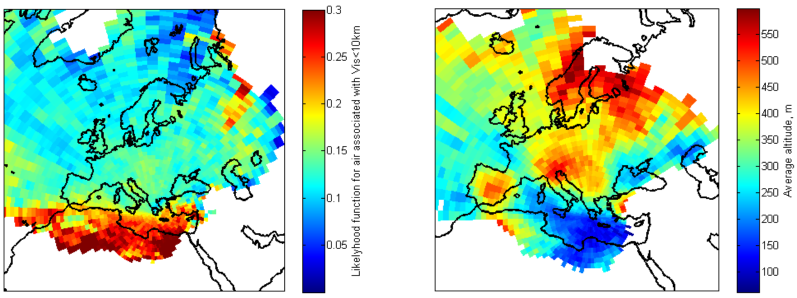

Fig 3 a) Likelihood function for different source regions to contribute with visibility <10km. The figure shows the number of times a grid has been associated with the criteria of visibility <10km normalized by the total amount of times air has resided over the grid. b) Average altitude over the grid cell during transport of air associated with visibility <10km.

It is clear, from Figure 3a, that the regions that most likely are associated with observations of poor visibility generally is located south of Methoni, and notably southern Mediterranean region as well as north Africa. Surprisingly, neither Western nor Eastern Europe seem to be associated with a high likelihood of bringing air that is associated with low visibility to Methoni, suggesting other sources and/or mechanisms than anthropogenic emissions alone are needed to result in poor visibility. A low visibility source sector seen in NE Europe could probably be related to long range transport of industrial pollutants. As can be seen in figure 3b, the observations of low visibility is further more associated with low level transport over the Mediterranean ocean. This suggests either that strong sources of particles do exist in either the Mediterranean itself or northern Africa in the form of e.g. desert dust. Although this at least partly could explain the observed features, the role of relative humidity is likely of bigger importance. High relative humidity significantly causes soluble particles to grow, thereby enhancing their light scattering ability. The fact that the air is transported from hotter regions to (relatively) cooler regions during low level transport over open water strengthen the hypothesis that RH, in fact, is the most dominating controlling factor for poor visibility. Another contributing factor is also the fact that sea salt is highly hygroscopic which further enhances the attenuation of light.

The opposite relation is true for the largest visibility bin (25-30km). Observations in this visibility range are typically associated with a northerly, subsiding airflow, bringing drier air to the receptor. This again highlights the strong control RH excerpts on the visibility in the Mediterranean region.

A first attempt to investigate the separate effects of RH and AOD on visibility is shown in Fig. 4. Humidity and AOD during the common period 2000-2013 were averaged for different visibility bins. In both cases, the decrease in visibility is due to the combined increase in both RH (in the range from 55% to almost 80%) and AOD (in the range from 0.05 to over 0.3).

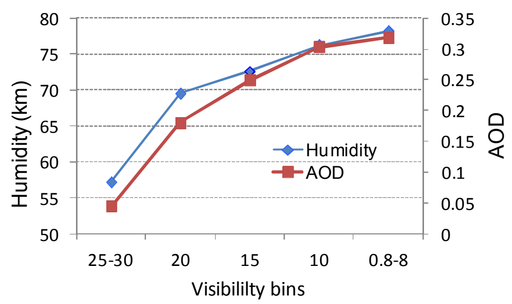

Fig. 4. Relation between humidity and visibility after binning the data.

4 Conclusions

The current study revealed high reduction visibility rates at Methoni station (SW Peloponnese), from the mid 50s to late 70s. Until the mid 70s, visibility seems to be driven by changes in RH reproducing characteristic peaks during specific periods. After the mid-70s, both time series showed some trend of stabilization. On a seasonal basis, the biggest change was observed during spring and summer in the 70s, probably following the industrialization in the extended area. The specific impact of AOD on visibility at this coastal site was proven a challenging task, however, binning of data revealed important relations. Moreover, an increase in visibility after 2008 could probably be attributed to the economic crisis and the subsequent reduction in anthropogenic activities/emissions. Finally, the trajectory analysis showed that the source regions of air masses associated with poor visibility are generally located south of Methoni and at low altitudes demonstrating the direct effects of dust from N. Africa, water vapor from the Mediterranean and/or combination of both (including hygroscopic particle growing processes).

Overall, further analysis is required, in conjunction with observations from more sites so that the conclusions draw are safer, more representative for the whole area and the decomposition of RH-AOD becomes feasible.

Acknowledgements

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