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Visibility trends in Tehran during 1958–2008

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HIGHLIGHTS

► Historical visibility database are explored to investigate visibility trend.
► We examined correlation of visibility trend with precipitation, fog and humidity.
► More decrease for Tehran metropolitan area than sparsely populated parts.
► The most decreasing trend of visibility is observed during winter time.

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ABSTRACT

Visibility, in the absence of certain weather conditions (e.g., fog and rain), is an excellent indicator of air quality because its impairment results from light scattering and absorption by atmospheric particles and gases. In this study, the historical airport visibility database is explored during the last five decades for the city of Tehran, Iran. Seasonal and long-term variations of the visibility are investigated using cumulative percentiles. The correlation of the long-term visibility trend with precipitation, fog and high relative humidity are also examined.

The trends of visual range of the best, median, and worst visibilities at 10th, 50th and 90th percentiles of daily visibility data indicate an overall downward trend for all the percentiles. Results show a larger decrease in visibility for the Tehran metropolitan area than the sparsely populated and less polluted parts of the city. The largest trend in decreasing visibility is observed during winter time followed by spring, fall and summer. Decreasing trends in visibility occur for all stations and do not significantly depend on the special weather events.

1. Introduction

Atmospheric visibility is defined as ‘the greatest distance at which an observer can just see a black object viewed against the horizon sky’, which in quantitative terminology is known as the visual range (Malm, 1999). Visibility degradation may result from light scattering and absorption by atmospheric particles and gases that can originate from natural or anthropogenic sources. It is an important factor in everyday life, especially in aviation industry and surface traffic. It has also significance for aesthetic/psychological costs, tourism, and landscape vista preservation. Visibility is regularly measured at synoptic meteorological stations all over the world as a standard meteorological parameter. In the absence of certain weather conditions (e.g., fog and rain), visibility is a qualitative indicator of air quality as its impairment can be recognized easily even with the naked eye (Baumer et al., 2008).

The treatment of visibility requires a mathematical description of the interaction of light with the atmosphere. This description is based on a simple energy balance, known as the radiative transfer equation. The following description provides a qualitative understanding of this process. The intensity of the light beam in the direction of an observer, $I(x)$, decreases with distance from the source as light is absorbed or scattered. Lambert’s law of extinction states that the change in the intensity of radiation emerging from the end of a path of length dx is proportional to the incoming intensity of the beam at that point:

$$-dI = b_{\text{ext}} I dx \tag{1}$$

The proportionality coefficient, called the extinction coefficient (b_{ext}), is in general a function of location, time, and wavelength (Chandrasekhar, 1950; Latimer et al., 1978). The extinction coefficient is determined by scattering and absorption of particles and gases and varies with pollutant concentration and wavelength of light.

When an observer looks at a distant target, image-forming information from the target is reduced through the scattering

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and absorption processes as it passes through the atmosphere to the human observer. Sunlight, light from clouds, and ground-reflected light are also added to the sight path by scattering from particulates located in the sight path. It is this air light that forms the diaphanous, visible screen recognized as haze. The intensity of the air light scattered into the sight path of the observer depends on the distribution of intensities in all directions, including direct sunlight, diffuse sky light or surface reflection, and light scattering characteristics of air molecules and aerosols. The total intensity in x-direction added by air light over a short interval (dI), is obtained by spherical integration overall directions:

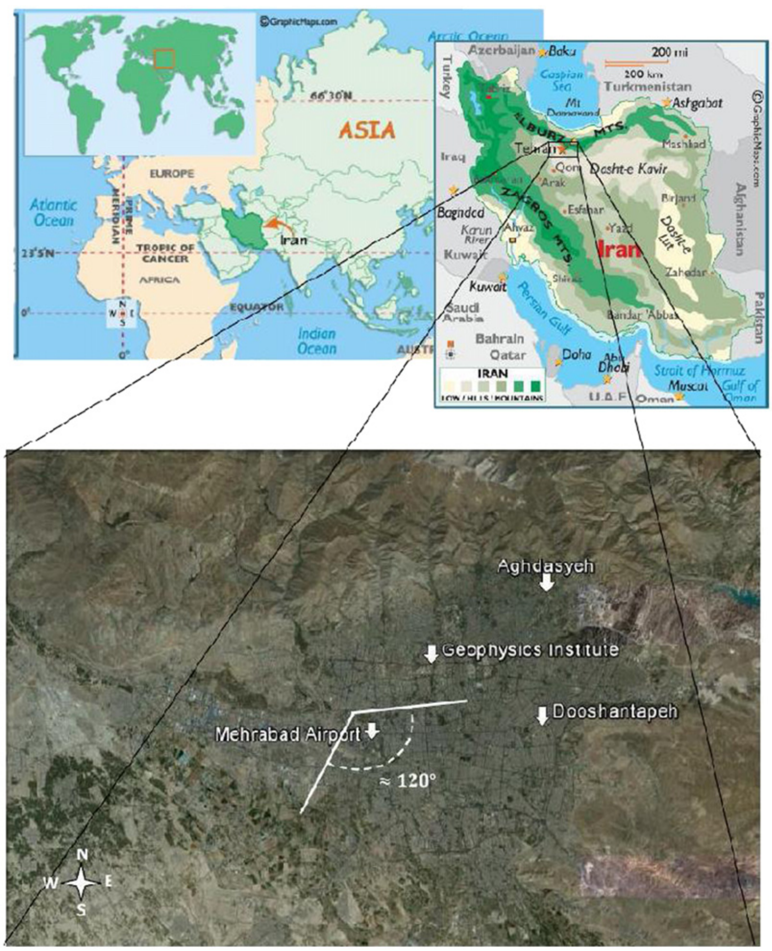
$$dI = b_{\text{ext}}\left[w\int Q_{\nu}(\theta_{\nu})I_{\nu}d\Omega\right]dx \quad (2)$$

where the parameters in the bracket are the sum of light intensity from all directions scattered into the line of sight. The total intensity depends on aerosol and air scattering parameters ($w\sum Q_{\nu}$), illumination intensity (I_{ν}) and angle (θ_{ν}) summed overall directions (Ω) (Husar, 1976).

Since the extinction coefficient and other scattering parameters vary with wavelengths, the added light can cause a color change. The overall changes in light intensity from an object to the observer are resulted by the extinction of transmitted light and the addition of air light. The change in intensity for a short interval (dI) is thus:

$$\begin{aligned} dI &= -dI_{(\text{extinction})} + dI_{(\text{air light})} \\ &= -b_{\text{ext}}Idx + b_{\text{ext}}w\int Q_{\nu}(\theta_{\nu})I_{\nu}d\Omega dx \end{aligned} \quad (3)$$

This equation known as the radiative transfer equation forms the basis of atmospheric visibility (Husar, 1976). Determining the visibility impairment requires an understanding of the physical and technical factors that affect atmospheric extinction. Light scattering and absorption by particles are the most important effects in



Station Name	Length of Dataset	Latitude	Longitude	Elevation	Description
Mehrabad	1951-2008 (57 years)	35 41 N	51 19 E	1190.8 M	Urban(Airport)
Dooshantapeh	1971-2008 (37 years)	35 42 N	51 30 E	1209.2 M	Urban
Aghdasyeh	1987-2008 (21 years)	35 47 N	51 37 E	1548.2 M	Urban (sparsely populated)
Geophysics	1991-2008 (17 years)	35 44 N	51 23 E	1418.6 M	Urban

Fig. 1. The locations of synoptic stations used in this study along with some information for each station. The observations were made facing dominantly south-eastward with a sector of 120°.