ISSN: 2277-5536 (Print); 2277-5641 (Online)

STUDY OF AEROSOL VERTICAL PROFILES DURING CLOUDY DAYS

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ABSTRACT
Aerosol measurements have been carried out at Kolhapur (16°42′N, 74°14′E) by using Twilight Photometer, which is indigenously designed and developed at the Indian Institute of Tropical Meteorology, a tropical station, Pune. The basic principle of this technique is if more number of aerosols exists in the atmosphere then more scattering takes place. Twilight observations have been carried out manually during the period 1 January 2009 to 30 December 2011 to study the vertical distribution of aerosols. The twilight scattering method yields the reasonable, qualitative picture of the vertical distribution of aerosols from about 6km to a maximum of 350km. This being a passive technique, clear sky conditions are preferable for obtaining the vertical profiles of aerosols. But in this study an attempt has also been made to conduct experiment during cloudy sky conditions.

KEY WORDS: Aerosol, semiautomatic twilight photometer, Twilight scattering method

INTRODUCTION

Twilight scattering method (TSM) is extensively used by varies workers in all over the world to study the vertical distribution of aerosol particles which is a strong function of their sources, sinks and their residence times. All this study is reviewed by Jadhav *et al.* (2000). In the present work aerosol measurements have been carried out at Kolhapur (16°42′N, 74°14′E) by using newly designed Semiautomatic Twilight Photometer during the period 1 January 2009 to 30 December 2011 to study the vertical distribution of the tropospheric aerosols.

In the resent years most of the twilight observations were carried out by Padma Kumari *et. al*. (2002, 2008) at Pune, which is highly industrialized and polluted city. Kolhapur city, a location in the south-waste Maharashtra is selected for this study because this station is free from any large scale industrial and urban activities or biomass burning and also surrounded by agricultural land mainly. It has an elevation of 569 meters which is higher than that of Pune. Kolhapur's climate is a blend of coastal and inland climate of Maharashtra. The TSM yields a reasonable qualitative picture of the vertical distribution of aerosols from about 6 km to a maximum of 350 km. This being a passive technique, clear sky conditions are preferable for obtaining the vertical profile of aerosols. But in this study an attempt has also been made to conduct experiment during cloudy sky conditions.

MATERIALS AND METHODS

Instrumental setup

The instrument semiautomatic twilight photometer was designed, developed and tested at IITM, Pune, India. The vertical distribution of atmospheric aerosols will be monitored during this study. The system is simple and inexpensive based on passive remote sensing technique and hence can be operated continuously for monitoring the day-to-day variability of the aerosols. The semiautomatic twilight photometer consists of a simple experimental set up. It comprises of a telescopic lens of diameter 15 cm having a focal length of 35 cm. A red glass filter peaking at 670 nm with a half band width of about 50 nm is used. The red filter of 2cm diameter and an aperture of 0.6 cm diameter are placed at the focal length of convex lens, provides approximately 1^0 field of view [(Aperture diameter/Focal length of lens) X57= (0.6cm/35cm) X 7=0.9771 degree].A photomultiplier tube (PMT-9658B) is used as a detector. The PMT requires high voltage supply and hence a DC-DC converted with high output voltage (700V) is used as a power supply. The output signal (current) of the PMT, used for detecting the light intensity during the twilight period, is very low. It is of the order of nano to microamperes. The amplitude or strength of this low signal is amplified by using a newly designed fast pre-amplifier. For the measurement of twilight zenith sky intensity, a disk with various apertures is mounted over the telescopic lens. One aperture at a time is used for the measurement. In this configuration the solid angle of photometer remains the same but light gathering power of the system is controlled. The PMT supply voltage (700 Volts) is kept constant throughout the observation period. During evening, the twilight photometer is operated for a time spell of ~90 minutes after the local sunset and during morning it is operated ~90 minutes before the sunrise.

Basic principle of twilight technique

When the sun is within 0-18° below the horizon, the lower part of the atmosphere comes under the Earth's shadow while the upper part is sunlit. The boundary between the illuminated and shadowed parts is monotonously shifting up during the evening twilight and down during the morning twilight. The twilight technique is based on the fact that the luminosity of the twilight sky at a given moment depends on the momentary height of earth's shadow. The twilight sky brightness at any given moment is caused by the sum of all light that is scattered towards an observer from all air molecules and aerosol particles above this boundary. It is assumed that bulk of the scattered light comes to an observer from the lowest, and therefore densest, layer in the sunlit atmosphere at the time of measurement. The contribution of the rest of the atmosphere above this layer can be neglected due to an exponential decrease of air density with increasing altitude. The height of this lowest layer (twilight layer) increases with increasing earth's shadow height. The lower atmospheric layers now submerged in shadow, no longer contribute to the sky brightness, and the scattered light comes more and more from the higher altitudes, which are still illuminated by direct sunlight.

The earth's geometrical shadow height (h) is defined as the vertical height from the surface of the earth, of a point where the solar ray grazing the surface of the earth meets the line of slight. Using a simple geometry we can write the relation as:

$$h = R (\sec [\delta] - 1) \qquad ..... (1)$$

Where, 'R' is radius of earth and 'δ' is sun's depression.
As the sun sinks below the horizon, the effective height of the Earth's shadow rises and scattering takes place to higher levels. Most of the light received at the ground will be the primary scattered light by the particles for the solar depressions less than 6-7 deg (Shah 1970). Therefore,

$$- (1/I) (dI/dh) = -d\log I/dh \qquad ….. (2)$$

Here, 'I' is the mean zenith sky intensity. Variations in the vertical profile of the molecular density were very small and their effect on the observed intensity was nearly constant, hence the variations in the value of – (1/I) (dI/dh) can be assumed to be mainly due to changes in aerosols density. Thus,

$$- (1/I) (dI/dh) \sim -d\log \text{(aerosol number density)}/dh$$

RESULTS AND DISCUSSION

The TSM being a passive technique, clear sky conditions are preferable for obtaining the vertical profile of aerosols. But in this study an attempt has also been made to conduct an experiment during cloudy sky conditions. Suppose if there exist an isolated cloud in the field of view of the twilight photometer, the color of the cloud changes from yellow to orange (or deep red in humid or polluted atmosphere) as the sun sinks. It then fades to gray as the earth's shadow falls on it. The rate of change of red light due to cloud would show a large maximum at this time. The same consideration is applied to a dust layer on which the sun sets, but the maximum in the rate of change of intensity is not usually as intense as that observed due to cloud.

4.1. <u>Relation between vertical profiles obtained during very clear sky days and cloudy days</u>

Figure 1. Shows few typical profiles of (1/I) (dI/dh) against shadow heights (h) obtained during very clear sky days and cloudy days also. From this figure it was observed that there exist some considerable peaks for the graphs obtained during cloudy days. The peaks observed at clear days were less intense. The solar ray grazing the surface of earth traverses through the long air path. Therefore the incident light will suffer attenuation in passing through the atmosphere owing to molecular scattering. The attenuation will depend on the wavelength. Moreover, the particles of dust and of condensed water, which exist in varying quantities in the troposphere, will add to further attenuation. So, some portion of the earth's atmosphere will be almost opaque to the grazing rays. This is known as screening height. It is wavelength dependent, decreasing with increasing wavelength (Volz and Goody, 1962). The calculations made by Shah (1970), shows that the maximum scattered light for red color, come from a height of about 6 Km above the surface of the earth. He assumed the screening height for red light has to be 6 Km. Thus considering this fact we can study only high level clouds, using twilight photometer.

4.2. <u>Measurement of the thickness of the cloud</u>

Considering the above fact the height and the thickness of the cloud can be measured. Figute-2 shows the typical profile of (1/I) (dI/dh) against shadow heights (h) obtained at cloudy day. This figure shows two layers of cirrus clouds. First layer of cirrus clouds is from 10.9Km to 11.6 Km, peaking at 11.26Km. Second layer of cirrus clouds is from 12.69Km to 14.07Km, peaking at 13.26Km. Thus thickness of first layer is about 0.7Kms and that of second layer is about 1.38Kms.

4.3. <u>Existence of invisible cirrus clouds</u>

Tropical cirrus clouds play an important role in the radiation budget of the tropics. Despite their impact on the climate of the earth, relatively little is known about their processes. Tropical cirrus appears in a variety of forms, ranging from optically thick anvil cirrus closely associated with deep convection to optically thin cirrus layers frequently observed just below the tropopause. The thin cirrus layers extend several hundred to more than a thousand kilometers horizontally (Winker and Trepte, 1998) and persist for time periods of several hours to several days before dissipating. Though they play a less significant role in the earth's radiation budget than thick cirrus, their impact on the upper tropospheric thermal structure and vertical velocity, on the lower stratospheric water vapor mixing ratio, and on remote sensing applications are not negligible (Mc Farquhar *et al.,* 2000). These clouds are invisible for normal eyes; but one can observe a typical peak at the height of their existence. Figure-3 shows the typical profiles of (1/I) (dI/dh) against shadow heights (h) obtained at invisible cloudy days. This figure shows one layer of cirrus clouds, from 8.51Km to 8.76 Km, having thickness of about 0.25Kms.

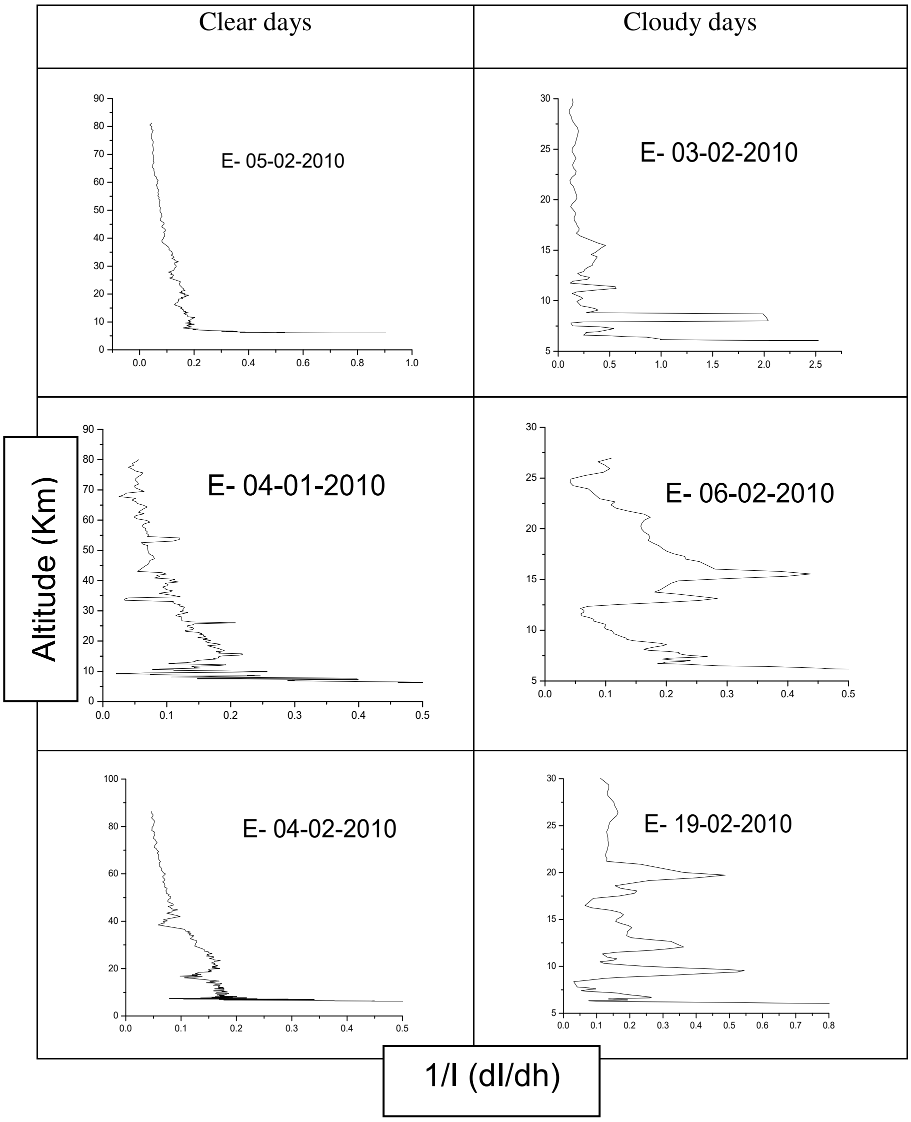

Figure-1: Shows few typical profiles of (1/I) (dI/dh) against shadow heights (h) obtained during very clear sky days and cloudy days also.

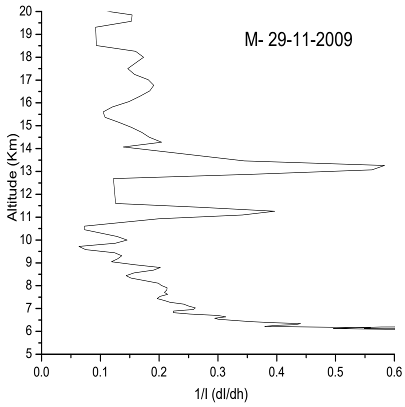

Figure-2: Shows the typical profile of (1/I) (dI/dh) against shadow, heights (h) obtained at cloudy day.

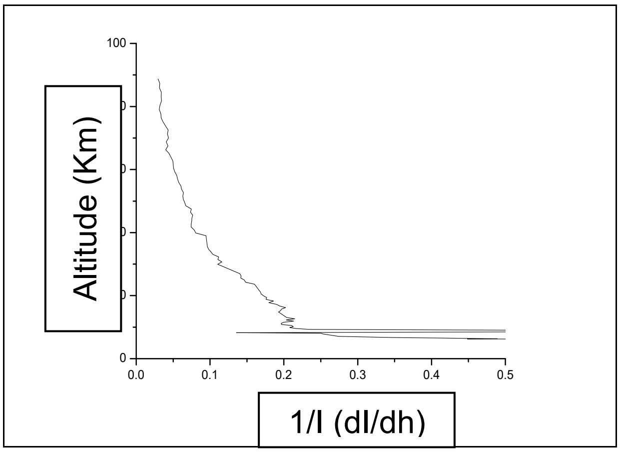

Figure-3: Shows the typical profiles of (1/I) (dI/dh) against shadow heights (h) obtained at invisible cloudy days.

SUMMARY AND CONCLUSIONS

- The aerosol vertical profiles during clear sky days show that the value of (1/I) (dI/dh) decreases in the beginning which implies the concentration of particles decreases with height and increases slightly at stratospheric altitudes and then decreases as altitude increases.
- Using twilight technique the height and thickness of an isolated cloud exist in the field of view of the twilight photometer can be calculated.
- Using twilight technique existence of thin invisible cirrus cloud in the field of view of the twilight photometer can be discovered.

ACKNOWLEDGEMENTS

One of the authors (Sou. Pratibha B. Mane) is grateful to the Shivaji University authorities, Kolhapur, for the encouragement during the course of this work.

REFERENCES

B. Padma Kumari, Londhe A. L., Trimbake H. K. and Jadhav D. B. (2004). Comparison of aerosol vertical profiles derived by passive and active remote sensing techniques-a case study. *Atmospheric Environ.* **38**(39): 6679-6685.

B. Padma Kumari., Kulkarni S. H., Jadhav D. B. Londhe A. L and Trimbake H. K. (2008). Exploring Atmospheric Aerosols by Twilight Photometry. *J. Atmospheric Oceanic Tech*. **25**(9): 1600-1607.

URL: http://en.wikipedia.org/wiki/Kolhapur.

Jadhav D. B., B. Padma Kumari and Londhe A. L. (2000). A review on twilight photometric studies for stratospheric aerosols, *Bull. Ind. Aerosol Sci. Tech. Asso.* **13**: 1 – 17.

Jadhav D. B. and Londhe A. L. (1992). Study of atmospheric aerosol loading using the twilight method, *J. Aerosol Sic*. **23:** 623-630.

Junge C. E. and Manson J. E. (1961). Stratospheric aerosol studies. *J. Geophys. Res*. **66:** 2163-2182.

Mc Farquhar G. M., Heymsfield A. J., Spinhire J. and Hart B. (2000). Thin and sub visual tropopause tropical cirrus: Observations and radiative impacts. *J. Atmos. Sci.* **57**: 1841 - 1853.

Shah G. M. (1970). Study of aerosol in the atmosphere by twilight scattering. *Tellus.* **22:** 82-93.

Volz F. E. and Goody R. M. (1962). The Intensity of the Twilight and Upper Atmospheric Dust. *J. Atmos. Sci.* **19**: 385-406.

Winker D. M. and Trepte C. R. (1998). Laminar cirrus observed near the tropical tropopause by LITE. *Geophys. Res. Lett.* **25:** 3351 - 3354.