Aerosol Optical Thickness Measurements on Tsunami Day at a Continental Station, Mysore

K. E. Ganesh[1*], T. K. Umesh[2], B. Narasimhamurthy[2]

[1] *PES Institute of Technology, Department of S&H, Bangalore-85*
[2] *Department of Studies in Physics, University of Mysore, Manasagangotri Mysore-06, INDIA*

Abstract

Daily atmospheric measurements of spectral Aerosol Optical Thickness (AOT), precipitable water vapor (W), and irradiance were being carried out (ISRO-RESPOND Project) at Mysore, India (12.3^{o}N), a continental station, on the day a massive tsunami struck India's coast, December 26, 2004. A comparison was made of that day's data with two other days: December 25, 2004, the day before tsunami and December 27, 2004, the day after. Compared to the values of AOT on December 25, 2004 and December 27, 2004, AOTs on December 26, 2004 were very low throughout the day. Values were almost one-third the magnitude of the other two days. The values measured on December 26, 2004 are unique because no other day in this month showed such low values. Comparison of the results with some other location is not possible at this point, because there appears to be no other study of this kind to support the observed results. Possible conclusions are drawn based on the available information.

Keywords: Atmospheric aerosols; AOT; Tsunami; Asymmetry factor.

INTRODUCTION

Tiny suspended particles in the atmosphere ranging in size from 10^{-3} μm to 10^{2} μm are known as atmospheric aerosols. The Encyclopedia Britannica defines aerosol as "a system of liquid or solid particles uniformly distributed in a finely divided state through a gas, usually air" (2003). The sources and sinks of atmospheric aerosols are so varied and distributed over the globe that their physical and optical effects show distinct variation with geographic locations (Muralikrishnan, 1993). Study of the optical and physical properties of aerosols is important for assessment of their effect on climate. Tropospheric aerosol particles have a short lifetime; as a result their properties vary from one region to another over time. In the presence of any atmospheric perturbations, the variation becomes much

[*] Corresponding author. Tel.: +91(80) 2672 2448 ext. 550; Fax: +91(80)2672 0886
E-mail address: ganeshke@gmail.com

more significant. Because of this kind of variability in aerosol properties, it is difficult to assess aerosol climatology. For a full assessment of aerosol characteristics, such measurements have to be performed frequently in locations with different aerosol types and in varying meteorological conditions (Kaufman *et al*., 1994). In this paper Aerosol Optical Thickness (AOT) characteristics on the tsunami day are discussed**.**

The 2004 Indian Ocean earthquake known by the scientific community as the Sumatra-Andaman earthquake was an undersea earthquake. This occurred on December 26, 2004 at 07:59:48 am IST with a magnitude of more than 9 on the Richter scale. This earthquake triggered a series of lethal tsunamis rising skyscraper high [~35 m]. Under the impact of the giant waves, the eastern coast of India suffered devastating effects. This routine of collecting the data was being conducted at Mysore on December 26, 2004, fortunately it was clear sky day, when remarkable changes in AOT occurred.

INSTRUMENTATION

In order to measure AOT at different wavelengths, a hand-held multi-band sun photometer MICROTOPS II developed by Solar Light Company, USA (2003) is used. The instrument is equipped with five accurately aligned optical collimators, with a full field view of 2.5°. Internal baffles are also integrated into the device to eliminate internal reflections. Each channel is fitted with a narrow-band interference filter and a photodiode suitable for the particular wavelength range. The MICROTOPS II used in the present study has optical filters transmitting the radiation centered at wavelengths of 440, 500, 675, 936 and 1020 nm. The collimators are encapsulated in a cast aluminum optical block for stability. A sun target and a pointing assembly are permanently attached to the optical block and laser-aligned to ensure accurate alignment with the optical channels. When the image of the sun is centered in the bull's-eye of the sun target, all optical channels are oriented directly at the solar disk. Radiation captured by the collimator and band pass filters reaches the photodiodes, producing an electrical current that is proportional to the radiant power intercepted by the photodiodes. The current is first amplified and then converted to a digital signal by a high resolution analog-to-digital converter. The signals from the photodiodes are processed in series. However, with 20 conversions per second, the results can be treated as if the photodiodes were read simultaneously. Optical depth from other processes, such as O_3 and NO_2 absorption, are ignored in MICROTOPS II. The calculation algorithms programmed in the photometer incorporate the predetermined calibration constants one for each wavelength and the contribution due to Rayleigh scattering and molecular absorption has been subtracted from total optical depth. The results of all stored scans can be conveniently viewed on the LCD (Ganesh *et al.,* 2008).

Table 1. Comparison of calibration constants.

Wavelength (nm)	Factory calibration constants (F)	Calibration constants obtained at Mysore (M)	[(F-M)/F] x 100
440	6.304	6.300	0.063
500	6.565	6.518	0.716
675	7.183	7.180	0.042
936	7.282	7.200	1.126
1020	7.047	7.040	0.099

CALIBRATION

The instrument was calibrated at regular intervals. Table 1 shows the extent of deviation of calibration constants from the factory set values. The degradation of the filters or the drift in the calibration values was found to be marginal. The calibration was carried out atop Sri Chamundeshwari Hill which is at about 300 m from the ground level using the standard Langley technique (Ganesh *et al*., 2008).

EXPERIMENTAL

Initially, several MICROTOPS II settings are made with the help of a GPS (Global Positioning System) receiver. These include universal date and time, geographic coordinates, altitude and atmospheric pressure of the measurement site. For the observations, the MICROTOPS II is mounted on a tripod in order to minimize the sun targeting error (Fig. 1).

On the days of clear sky, that is when there are no clouds, the measurements are made. The data were collected 04:00-12:00 hrs UT (09:30 – 17:30 hrs, IST) at 15-30 minute intervals. Each set of data contains five values of spectral AOT and one value of water vapor. Experimental observations are carried out on individual days at different sites. Care has been taken during the collection of data so as to avoid strong seasonal effects, such as drizzle and hazy sky.

Fig. 1. Tripod mounted MICROTOPS II under action.

METEOROLOGICAL & PHYSICAL FEATURES OF MYSORE

Mysore is a tropical (12.3°N, 76.65°E) continental station in the Indian subcontinent with a mean height of about 767 m above mean sea level. It is situated on the Deccan Plateau of peninsular India (Fig. 2). The Arabian Sea is 200 km to the west, Bay of Bengal 400 km away on the east, and the Indian Ocean is about 500 km away in the south. Towards the north of Mysore there lies the vast land mass of the Asian continent. Chamundi hills 300 m high stand close to Mysore. K.R. Sagar Dam and Sri Rangapatna where the Cauvery River flows are situated close to Mysore. Around Mysore, there are located mining industries of magnesite ($MgCO_3$) and limestone. Therefore, aerosols arising from several anthropogenic activities like mining, quarrying and farming could be contributing to the observed short- and long-term variations in the aerosol characteristics at Mysore.

The types of forest in Mysore district are semi-evergreen, moist, dry-deciduous, scrub and thorn forests. The dry-deciduous forest is well represented in the wildlife sanctuaries of Nagarahole and Bandipur situated at distances of about 80 km. The main forest areas are located in the southern and southwestern

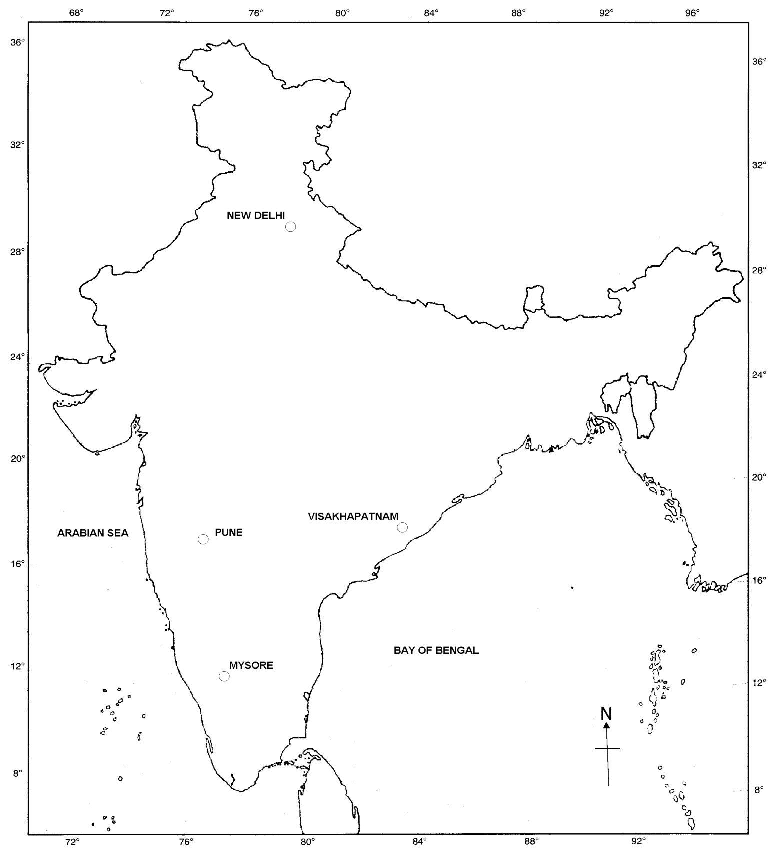

Fig. 2. Geographic identity of Mysore.

parts of the district. A moderate climate prevails throughout the year. Monsoon, winter and summer are the seasons. The annual mean daily temperatures are 30^0C maximum and 19^0C minimum. Mysore records about 760 mm rain a year, a major portion of which is received during monsoon. Winter gets either little rain or no rain. The summer rains are limited to a few days. Around Mysore, there are lakes and water reservoirs built across the rivers. The city of Mysore has a population of about one million (according to a recent census). The number of petrol- and diesel-powered vehicles are about 2 lakh. About 50 small-scale factories, mostly chemical and engineering, make the industrial picture of Mysore. Slash burning is practiced by farmers. An irrigation facility has resulted in year-round farming activities within a radius of 50 km from Mysore.

RESULTS

Observations of AOT on Tsunami Day

In Mysore, about 500 km away from the east coast, routine AOT measurements were being recorded with a MICROTOPS II Sun Photometer throughout December 2004. The measurements showed rather interesting results on December 26, 2004, the day that tsunami struck India's coast. A comparison of values of AOT with the days before and after (December 25 and December 27, 2004) shows that AOTs on December 26, 2004 were very low throughout the day; almost one-third the magnitude of the other two days. In fact the December 26, 2004 is unique in that no other day in December 2004 showed such low values (Figs. 3 and 4).

The photometer also recorded very low precipitable water vapor (W). Fig. 5 depicts the observations of AOT and W on the three days 25, 26 & 27 of December 2004.

The spectral AOTs of the three days (December 25-27, 2004) were also fitted to Angstrom turbidity equation to obtain the sets of α and. B. Plots of α versus β are shown in Figs. 6-8. It may be seen that the slope is very large on tsunami day. This indicates the presence of finer aerosols in very large number compared to coarse ones. The value of intercept ~ 3.9 is an indication of the dominance of the Rayleigh scattering (Iqbal, 1983). This was also evident from the "very blue" appearance of the sky on that day. The studies made by Kim *et al.* (2005), Glantz *et al.* (2006), Ritweej *et al.* (2007) supports the fact that aerosol properties change with respect to changes in wind speed and direction.

Asymmetry in AOT Values on Tsunami Day

Large difference between the AOT values of forenoon (τ_{FN}) and afternoon (τ_{AN}) is said to be the asymmetry of AOT (Ganesh *et al.*, 2008). The extent of asymmetry varies with the site, as well as with the wavelength. For a quantitative study, asymmetry factor $\eta\lambda$ is defined through the expression:

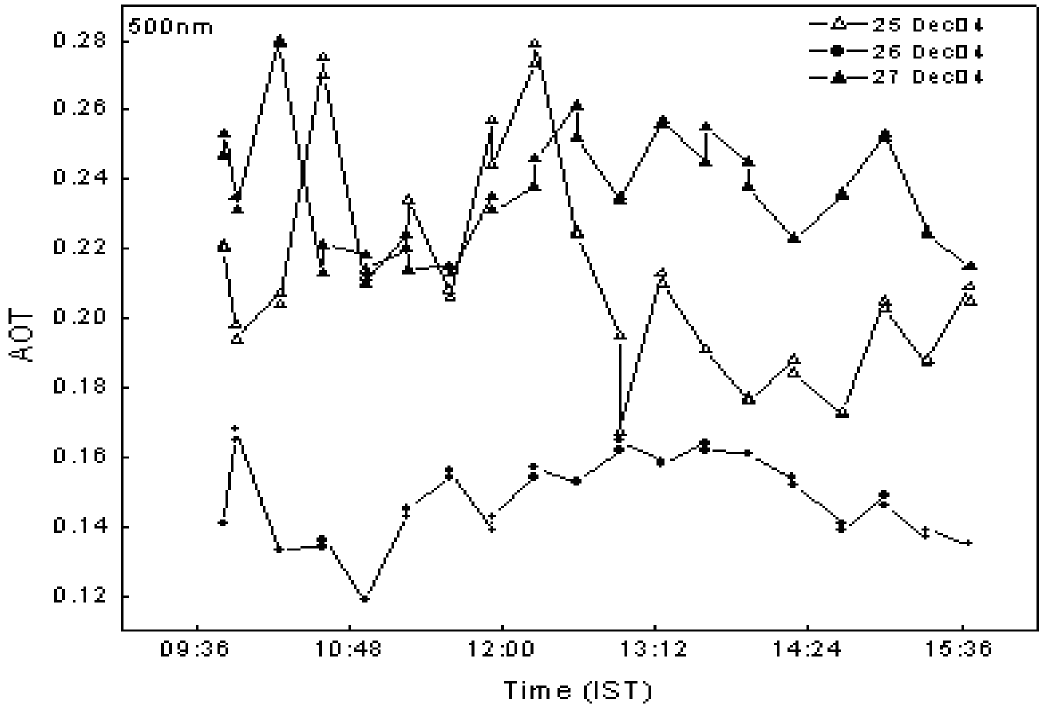

Fig. 3. Spectral variation of AOT with time.

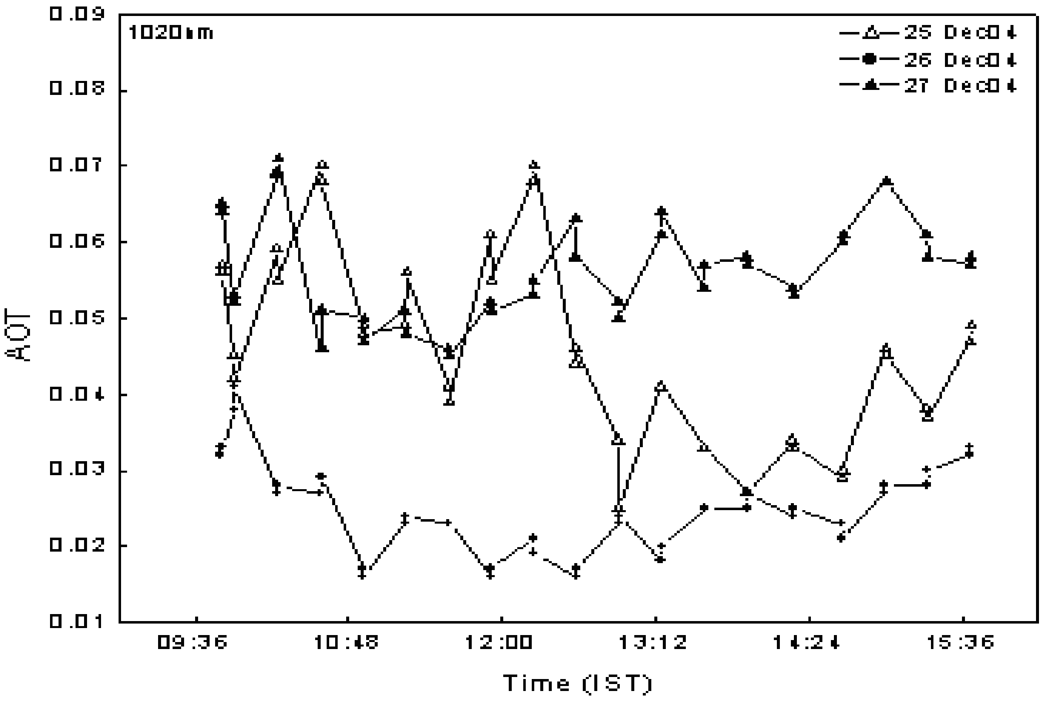

Fig. 4. Spectral variation of AOT with time.

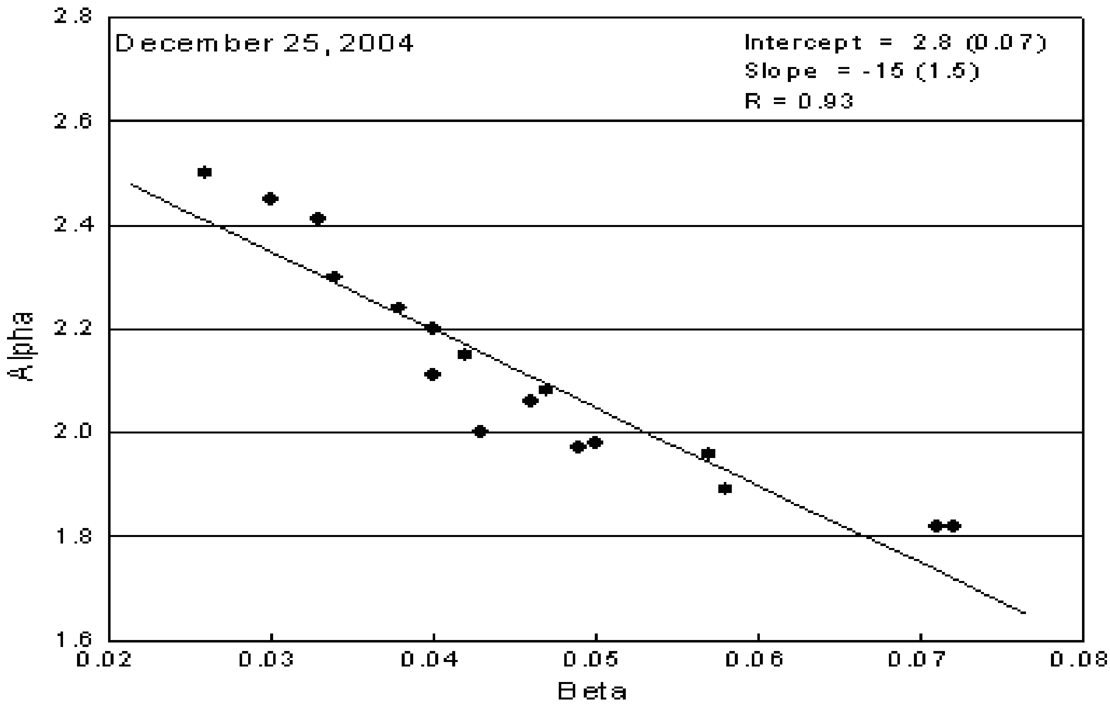

Fig. 5. Variation of precipitable water vapor with time.

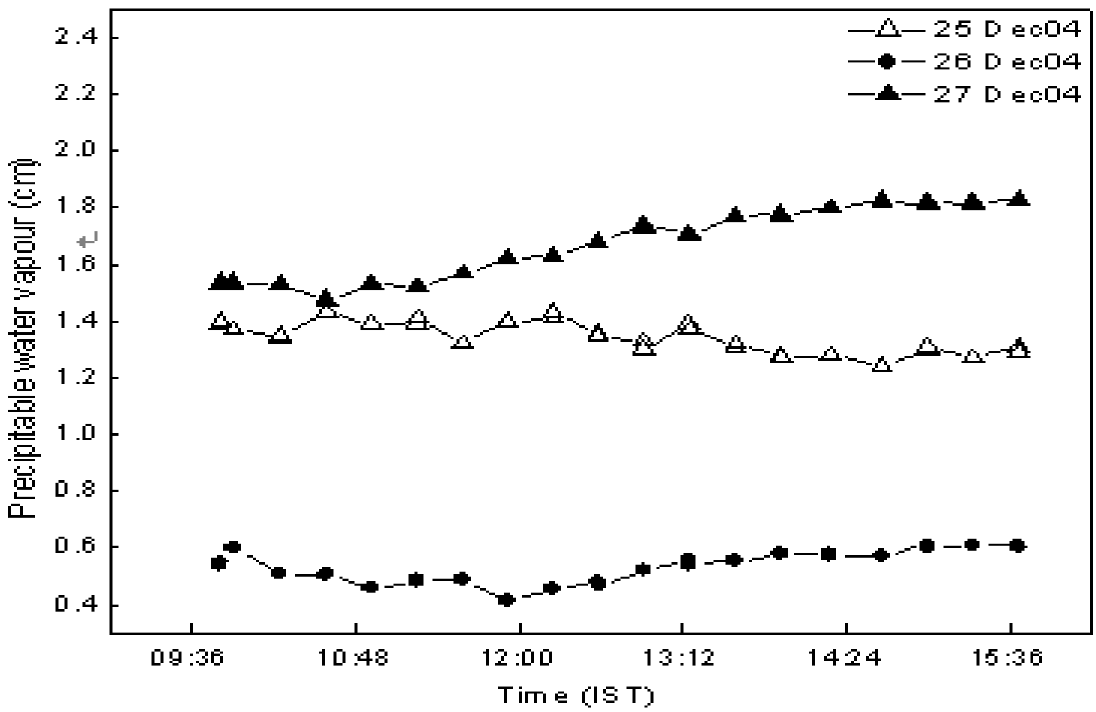

Fig. 6. Plots of Alpha versus Beta.

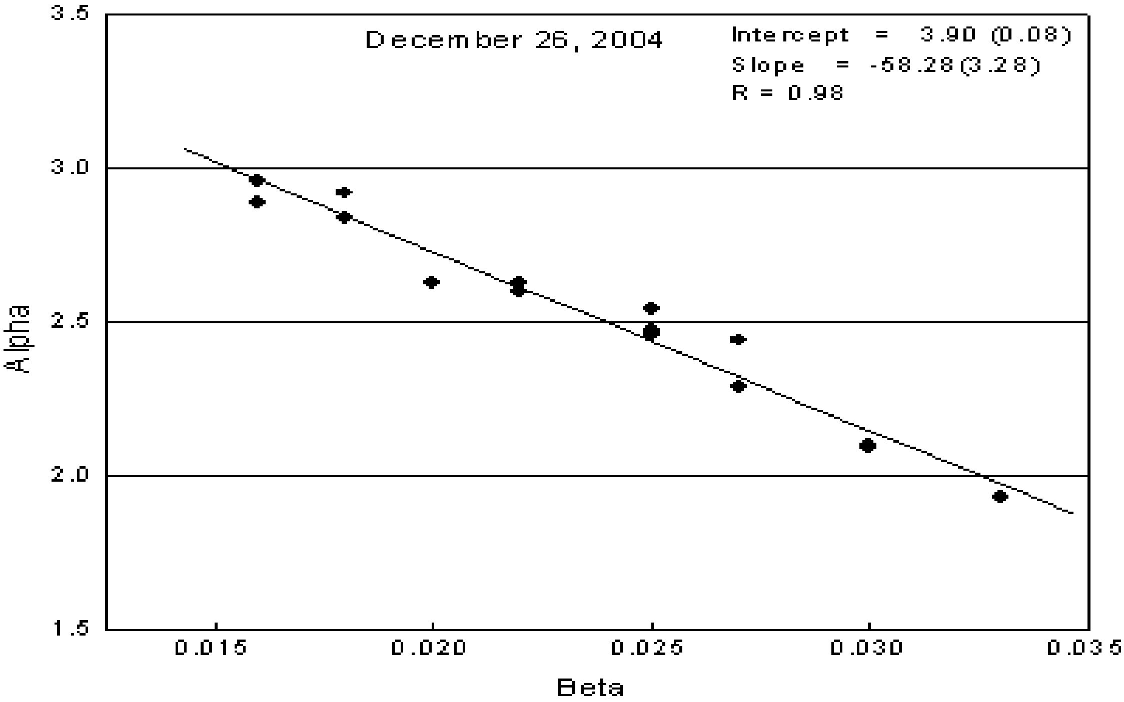

Fig. 7. Plots of Alpha versus Beta.

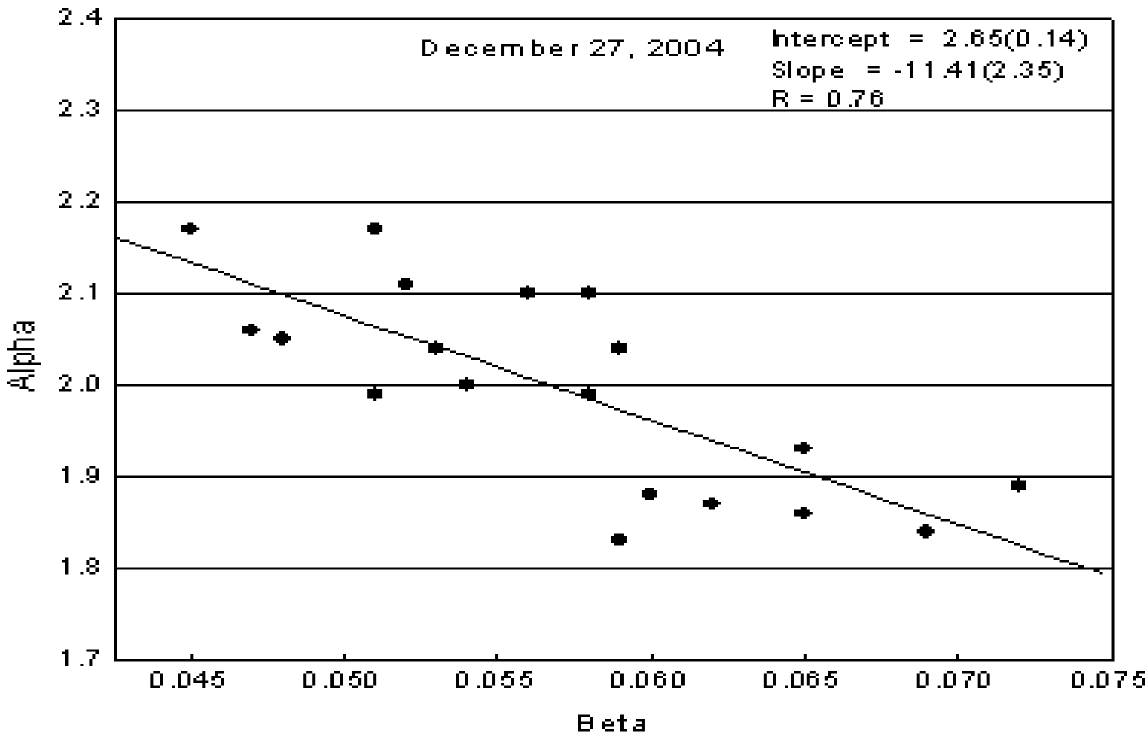

Fig. 8. Plots of Alpha versus Beta.

$$\eta_\lambda = \left[\frac{\tau_{FN} - \tau_{AN}}{\tau_{FN}} \right] x\,100 \qquad (1)$$

Table 2 summarizes the asymmetry factor values for three days December 25-27, 2004. Not much change in asymmetry-factor values is observed on tsunami day. Low values of AOT is the consequence of change in wind direction from northeasterly to easterly.

DISCUSSION

It may be observed from the Fig. 8 that the values of water vapor are the lowest on tsunami day. Particle growth cannot take place in the absence of water vapor. Because of this effect, AOT values are reduced automatically. A plot of α versus β indicated linearity between the two parameters. This indicates the dominance of finer aerosols compared to coarse ones (Cachorro *et al.*, 1987). These results may be attributed to drift in air mass caused by the change in wind direction on the tsunami day from northeasterly to easterly. Change in wind direction did not add any extra particulate load into the experimental site as evidenced by the AOT values on tsunami day. This may be due to the occurrence of the tsunami during early morning hours in which anthropogenic activities were about to start. This work demonstrates the importance of aerosol observation on days, such as the one on which the tsunami occurred, that involve atmospheric perturbations due to natural events.

CONCLUSIONS

The results presented in this paper are the fruit of routine work on atmospheric measurements for the month of December 2004. By making use of the available information the following conclusions are drawn to the best of our knowledge. The AOTs recorded on the tsunami day December

Table 2. Spectral asymmetry values.

Wavelength	AOT & η	25-Dec-04	26-Dec-04	27-Dec-04
	τ_{FN}	0.228	0.142	0.234
500	τ_{AN}	0.210	0.147	0.236
	$\boldsymbol{\eta_{500}}$	**7.890**	**-3.520**	**-0.978**
	τ_{FN}	0.053	0.026	0.054
1020	τ_{AN}	0.045	0.025	0.056
	$\boldsymbol{\eta_{1020}}$	**15.090**	**3.846**	**-4.222**
	τ_{FN}	1.380	0.501	1.549
W (cm)	τ_{AN}	1.338	0.531	1.665
	$\boldsymbol{\eta_{w}}$	**3.043**	**-5.988**	**-7.495**

26, 2004 were very low compared to all other days in the month of December 2004.

A plot of Angstrom's, parameters α versus β showed a linear behavior. The slope of this graph which is a measure of the ratio of change in small to large particle concentration, is large on December 26, 2004. This indicates the dominance of finer aerosols compared to the coarse ones. The value of intercept greater than three is an indication of Rayleigh scattering to a larger extent.

These results may be attributed to drift in air mass caused by the change in wind direction on tsunami day from northeasterly to easterly.

This study emphasizes the importance of aerosol observation during the days involving atmospheric perturbations due to natural events.

ACKNOWLEDGEMENTS

Heartfelt thanks to the Indian Space Research Organization for funding the project. Special thanks to the University of Mysore for the facilities and to my colleagues in the Department for their help and inspiration. Finally, immense gratitude to Prof. B Narasimhamurthy, as this paper is the result of his final guidance; may God rest his soul in peace.

REFERENCES

Cachorro, V.E. de Frutos, A.M. and Casanova, J.L. (1987). Determination of the Angstrom Turbidity Parameters. *Appl. Opt.* 26: 3069.

Ganesh, K.E. Umesh, T.K. and Narasimhamurthy, B. (2008). Site Specific Aerosol Optical Thickness Characteristics over Mysore. *Aerosol Air Qual. Res.* 8: 295.

Glantz P, D.E. Nilsson, and W. von Hoyningen-Huene. (2006). Estimating a Relationship Between Aerosol Optical Thickness and Surface Wind Speed over the Ocean. *Atmos. Chem. Phys. Discuss.* 61: 1621.

Iqbal, M. (1983). *An Introduction to Solar Radiation*, Academic Press. Ontario, Canada.

Kaufman, Y.J., Gitelson, A., Karnieli, A., Ganor, E., Fraser, R.S., Nakajima, T., Mattoo, S. and Holben, B.N. (1994). Size Distribution and Scattering Phase Function of Aerosol Particles Retrieved from Sky Brightness Measurements. *J. Geophys. Res.* 99: 10341.

Kim, Ki-Hyun., Kim, Min-Young., Hong, S.M., Youn, Y.H. and Hwang, S.J. (2005). The Effects of Wind Speed on the Relative Relationships between Different Size Fractions of Airborne Particles *Chemosphere*. 59: 929-937.

Muralikrishnan (1993). Ph.D Thesis, University of Mysore, Mysore.

Ritweej Rajeev Ranjan, Joshi, H.P. and Iyer, K.N. (2007). Spectral Variation of Total Column Aerosol Optical Depth over Rajkot: A Tropical Semi-arid Indian Station. *Aerosol Air Qual. Res.* 7: 33-45.

Solar Light Company, (2003). Philadelphia 19126, USA, MICROTOPS user manual.

Received for review, August 11, 2008
Accepted, November 19, 2008