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STUDY OF AEROSOLS AFTER VOLCANIC ERUPTIONS OF 2010.

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ABSTRACT
Earth's atmosphere is a natural colloidal system. Atmospheric aerosols are the suspension of colloidal particles in air. In this type of colloidal system gas is the dispersing medium and fine solid or liquid particles (aerosols) are the dispersed phase. Aerosol measurements have been carried out at Kolhapur (16°42′N, 74°14′E), Maharashtra state, India, by using Semiautomatic Twilight Photometer. The basic principle of this technique is if more number of aerosols exists in the atmosphere then more the scattering takes place. Twilight technique is capable of giving the qualitative picture of aerosol vertical distribution from about 6 km to a maximum of 350 km. the colloidal particles (aerosols) introduced in the Earth's atmosphere during volcanic eruptions of 2010, were slowly spread out following the prevailing wind patterns. These colloidal particles perturb the lower layer of the earth's atmosphere and also contribute to additional scattering in the atmosphere. In the following two years they descended and could be the precursor to the development of clouds.

KEY WORDS: aerosol vertical distribution, Colloidal particle (aerosols), Twilight Photometer, troposphere, volcanic eruption.

INTRODUCTION

Earth's atmosphere is a natural colloidal system. Atmospheric aerosols are the suspension of colloidal particles in air. In this type of colloidal system gas is the dispersing medium and fine solid or liquid particles (aerosols) are the dispersed phase. Depending upon the source size of aerosols varies from 10^{-3} to 10^{2} µm. Particles larger than 100 µm cannot remain suspended in air for long periods. Dust, smoke, mist, fog, haze and smog are various forms of common aerosols. Aerosols affect our environment at the local, regional, and global levels. Aerosols plays very important role in the earth's atmospheric radiation budget, atmospheric chemistry and atmospheric electrical conductivity. All of the properties of aerosol effects and many of the properties are interrelated. The consequences arising from an increased aerosol concentration remain extremely difficult to understand because vertical distribution of aerosols in atmosphere is strong functions of their sources, sinks and their residence times. One of the major natural sources of aerosols is volcanic eruptions. Volcanic eruptions release tons of aerosol particles and gases into the air. The gases contain sulfur dioxide which gets converted to sulfuric acid and then forms into tiny particles. While they remain in the atmosphere, volcanic aerosol particles reflect sunlight and cool the Earth's lower atmosphere and surface. A typical eruption releases a cloud of ash into the lower atmosphere (~14.5 km or lower) and it slowly spreads out following the prevailing wind patterns.

The year 2010 was called as volcanic eruption year. Among them two volcanic eruptions viz. Eyiafiallajokull in Iceland and Mount Merapi in Indonesia were more powerful eruption possible by volcanic standards. The ash plume rose to a height of approximately 9 kilometers due to second phase of Eyiafiallajokull on 14 April 2010. Mount Merapi eruptions of 5 November 2010 plumes of smoke rose up more than 10,000 meters. One attempt is made to study the effect of these volcanic eruptions on the vertical distribution of atmospheric aerosols over Kolhapur (16°42′N, 74°14′E). During the course of the study, the measurement of the atmospheric aerosols carried out by using semiautomatic twilight photometer during the period of 1 January 2009 to 31 December 2011 at location Kolhapur (16°42′N, 74°14′E), Maharashtra state, India. The basic principle of this technique is if more number of aerosols exists in the atmosphere then more the scattering takes place. Twilight technique is capable of giving the qualitative picture of vertical distribution of aerosols suspended in the atmosphere between 6 km to 350 km.

MATERIALS AND METHODS

Instrumental setup

The instrument semiautomatic twilight photometer was designed, developed and tested at IITM, Pune, India. The system is simple and inexpensive, based on passive remote sensing technique and hence can be operated continuously for monitoring very accurately 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 2 cm 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 up to 1V to 10V depending upon the twilight intensity, by using a newly designed fast pre-amplifier. Keeping noise at a minimum level (near about zero) we get the amplified signal. The more details regarding the instrument and Fast pre-amplifier were given elsewhere, (Mane et al., 2012, "a" and "b"). The amplifier output recorded by the digital multimeter, Rishcom-100, having an adapter can store the data automatically for every 10 seconds in the form of date, time and intensity in Volts. 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

The twilight sounding method is analogous to the method of rocket sounding. When the sun is within 0-18º 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. In this method, the solar radiation scans the Earth's atmosphere during the enhancement of the twilight, and the light received from any part of the sky is due primarily to the light scattered by illuminated by molecules and the particles of interest. 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 method for calculating the earth's geometrical shadow height (h) is given by Shah (1970). Thus 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. Therefore,

$$h = R (\sec [\delta] - 1) \quad \text{..... (1)}$$

Where, 'R' is radius of earth and 'δ' is sun's depression.

In following the method of Shah (1970), it is assumed that the red twilight comes from a distance of 6 Km. The shadow heights were computed for zenith sky observations, and the raw data were utilized for the analysis of '1/I (dI/dh)' curve, where 'I' is the observed intensity, 'dI' and 'dh' are the differences in intensities and shadow heights respectively observed at time't' and't+dt'.

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 of interest (Shah, 1970). Therefore,

$$\frac{1}{I}\frac{dI}{dh} = \frac{d\log I}{dh} \quad \text{.....(2)}$$

The effect of the Rayleigh scattering component on the value of '1/I (dI/dh)' has been studied by Bigg (1956). Variations in the vertical profiles 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,

$$\frac{1}{I}\frac{dI}{dh} = \frac{d\log(\text{aerosol number density})}{dh} \quad \text{.....(3)}$$

Logarithmic gradient of the intensity cannot give the information about the aerosol number density. Therefore an empirical formula stated in equ.-4 is derived by the actual Lidar observation and the Photometric observations (Padma Kumari et al., 2004). Thus,

Aerosol number density per cm^3 = $Antilog_{10}$ {10['1/I (dI/dh)']-1} ….. (4)

The aerosol-loading factor (Q) is defined as (Jadhav and Londhe, 1992),

$$Q = \sum_{h_1}^{h_2} - (1/I)\,(dI/dh) \quad \text{….. (5)}$$

In this equation h_1 and h_2 represents the lower and upper limits of the shadow heights respectively.

From equations 4 and 5 we can write,

$$Q = \sum_{h_1}^{h_2} \text{Aerosol number density per } cm^3 \quad \text{….. (6)}$$

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RESULTS AND DISCUSSION

Figure-1 and 2 shows graphs of 'Q_1' and 'Q_2' plotted against day numbers respectively for all of the three years. In these figures Y-axis represents aerosol loading and X-axis represents day numbers. The numbers from 1 to 365 corresponds to dates from 1 January 2009 to 31 December 2009. Similarly the numbers from 366 to 730 represents dates from 1 January 2010 to 31 December 2010. Also the numbers from 731to 1095 stands for dates from 1 January 2011 to 31 December 2011. The red and blue arrows signify the dates of volcanic eruptions Eyiafiallajokull in Iceland and Mount Merapi in Indonesia respectively. In the twilight sound method (TSM), data collection at Kolhapur is generally possible for the period ~mid-October of any year to ~mid-May of the succeeding year. Data was not collected during ~mid-May to ~mid-October in any year because of the existing monsoon conditions (rains and widespread cloud cover). This is being a passive technique, clear sky conditions are essential for obtaining the vertical profiles of aerosols.

In the month of October 'Q_2' showed higher values (~85% increase) for 2010 than 2009 and 2011. In both the months, November and December no change in 'Q_2' for years 2009 and 2011, whereas for the year 2010 aerosol loading is nearly double than rest of the two years. The values of 'Q_2' in the month of January and February, 2011 were nearly two times than the values of 'Q_2' for year 2010 in the same months. In the months of March and April the values of 'Q_2' were ~50% higher for 2011 than 2010. The values of aerosol loading showed many fluctuations in the months of October and May for all of the three years.

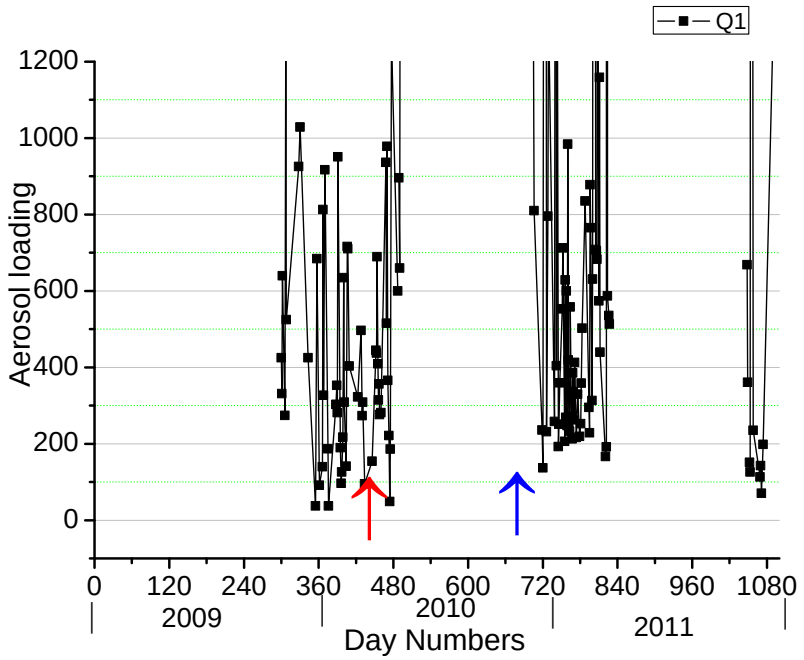

Figure-1: Graphs of 'Q_1' (The aerosol-loading for the heights between 6 to7 Km) plotted against day numbers

No data coverage was possible from 7 April 2010 due to privilege cloud cover. The reason behind the higher aerosol loading in the period October 2010 to April 2011 could be as follows. The ash plume rose in the atmosphere due to Eyiafiallajokull and Mount Merapi eruptions started slowly sliding. Some aerosols remain behind causing additional aerosol loading in middle troposphere (Earth's atmosphere is divided into five main layers. The troposphere is the lowest layer of Earth's atmosphere. The troposphere is located between about 0km and 17 km altitude above the Earth's surface.)

In both the months, November and December no change in 'Q_1' for years 2009 and 2011, whereas for the year 2010 aerosol loading is nearly double than rest of the two years. The values of 'Q_1' in the month of January and February, 2011 were nearly two times than the values of 'Q_1' for year 2010 in the same months. In the months of March and April the values of 'Q_1' were ~50% higher for 2011 than 2010. The values of aerosol loading showed many fluctuations in the months of October and May for all of the three years.

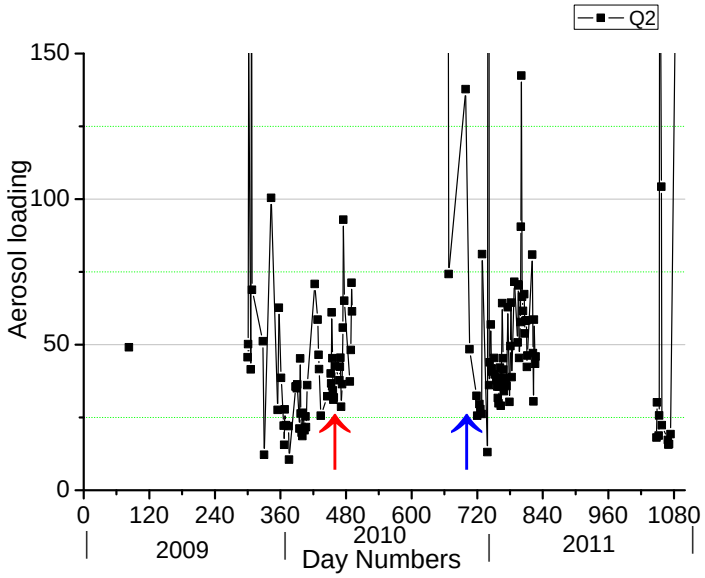

Figure 2. Graphs of 'Q_2' (The aerosol-loading for the heights between 8 to11 Km) plotted against day numbers

Very few data events were collected in October, November and December 2011 due to frequently observed high level cirrus clouds and invisible clouds. No data coverage was possible from January to May 2012. The explanation for this is as follows. The aerosols introduced in the atmosphere due to volcanic eruptions, were slowly spread out following the prevailing wind patterns. In the following year 2011, these aerosols descended showing additional aerosol loading at 6-7 km level. In the next year 2012, further sliding down of these aerosols could be the precursor to the development of high level cirrus cloud cover for long period of time.

SUMMARY AND CONCLUSIONS

The results acquired reveal that the colloidal particles (aerosols) introduced in the Earth's atmosphere during volcanic eruptions of 2010, were slowly spread out following the prevailing wind patterns. These colloidal particles perturb the lower layer of the earth's atmosphere and also contribute to additional scattering in the atmosphere. In the following year 2011, these aerosols descended showing additional aerosol loading at 6-7 km level. In the next year 2012, further sliding down of these aerosols could be the precursor to the development of high level cirrus cloud cover for long period of time.

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