MEASUREMENT OF ATMOSPHERIC AEROSOLS CONCENTRATION DURING MONSOON AND WINTER SEASONS

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INTRODUCTION

Atmospheric aerosols are produced by various types of processes such as biomass and fossil fuel burning, agricultural activities, desertification, industrial and vehicular pollution etc. These atmospheric aerosols are very much important to characterize a number of phenomena occurring in the lower troposphere. A study on the variation of atmospheric aerosol concentration in relation to their dependence on some meteorological parameters like as air temperature, relative humidity, wind speed and rain fall etc. helps greatly tounderstand the role of meteorology in the aerosol size distribution and vice versa. The determination of the size distribution of aerosols at any location is very important not only to characterize the aerosol system over the location but also to study the cloud process (**Harrison and Carslaw, 2003; Carslaw et al. 2002**), radiative properties (**Siingh et al., 2007)** and the effect of warming due to green house gases **(Krishnamurthy, 1988)**. Park et al. **(1990)** carried out such studies at high latitudes but the studies at low latitudes are very rare. Sharma et al. **(2003)** measured the aerosol number concentration in summer season (April–July 1999) during morning, noon and evening periods, and the daily variation of aerosol number concentration was related to selected meteorological parameters like relative humidity, temperature, rainfall and wind speed. They found that the aerosol number concentration for upper size ranges (1.0–2.0 and 2.0–5.0 μm) is maximum in June and minimum in July whereas the aerosol number concentration in small size ranges (0.3–0.5 and 0.5–1.0 μm) decreases monotonically till the end of July.

The atmospheric aerosols are generally hygroscopic, and therefore the relative humidity plays an important role to alter the radiative properties of aerosols (**Krishnamurthy, 1988)**. Parameswaran et al. (**1995**) studied the variation of aerosol optical depth for the period from June, 1989 to December, 1990 in relation to various meteorological factors like wind speed, rain fall, relative humidity. Shaw (**1988**) has tried to study the size distribution of atmospheric aerosols in different meteorological conditions. Chakraborty et al. **(2004)** made investigations over the impact of absorbing aerosols on the simulation of climate in the Indian Region using an atmospheric General Circulation Model (GCM). Krishna Moorthy et al. (**2005**) studied on aerosol characteristics and radiative impacts over the Arabian Sea during inter-monsoon season. Bhawa and Devara (**2009**) worked extensively on successive contrasting monsoons (2001–2002) in terms of aerosol variability over a tropical station Pune, India.

In the present paper we have studied the effect of meteorological parameters on aerosol number density of various sizes during disturbed (South-East monsoon, 2006) and fair weather (winter 2006-07) conditions at Roorkee (29º52' N, 77º 53' E, 275 meters above the sea level). Since Roorkee is not an industrial place, therefore the man made particles are produced only by vehicular traffic and house hold activities. The study on distribution of aerosols can be made by employing various available techniques such as Lidar (**Devara and Raj 1998**) and Cascade Impactor (**Pahwa et al., 1994**) For the present study, we measured the aerosol concentration by using a laser scatterometer (**Singh et al., 1999**).

2. METHODOLOGY

The technique for the measurement of suspended particulate matter concentration uses the laser beam scatterometer. This instrument measures the intensity of the scattered laser beam by particles at angles of 45° and 135° (Here the measurements are taken to include the forward as well as backward direction. Therefore, the intensity of the scattered laser beem by the particle was measured at angles of 45^0 and 135^0 by the instrument). By using the intensities of the scattered laser beams, the concentration of particulates were computed.

When the particles are illuminated by a beam of laser light (6328 Å), the intensity of scattered light varies with size, shape, refractive index and concentration of particles. The particulate analyzer consists of a hollow cylinder (length 53 cm and inner diameter 12 cm) which is fitted with an air blower. Two phototransistors are fixed at angles 45^0 and 135^0 from the direction of incident beam. A 5 mW He-Ne laser having wavelength 6328Å is used for incident radiation.The scattered intensity of laser beam is measured at angles 45^0 and 135^0 on a two strip chart recorder. This relative intensity is used to estimate the concentration of pollutants in air. The detail of the experimental set up is available elsewhere (**Singh et al., 1999).** Mikasa **(1992)** suggested that a number of instruments based on Mie scattering of light have been manufactured for particle concentration determination. In the present measurement, only the Mie theory of scattering has been considered. However, Rayleigh scattering by the atmospheric molecules also takes place at the same time. For the present study, the effect of molecular scattering has been neglected and the entire scattered intensity is attributed to the Mie scattering. The resultant scattered light intensity I (θ) in a given direction θ due to the scattering per unit volume is given by

$$I(\theta) = \int_{x_1}^{x_2} I(x, \theta, m)\, n(x)\, dx \qquad ...(1)$$

Where, I(x,θ,m) is the single particle intensity of scattered light at an angle due to particle of size x and refractive index m. The number concentration of particles n(x) dx in the size range x and (x+dx) is given by

$$n(x)dx = N_o C \exp[-(x-M)^2 / 2\sigma^2]\, dx \qquad ...(2)$$

Where N_o = total no. of particles, σ = standard deviation, C = 1 / (σ √2π), λ=wavelength of incident radiation, r = radius of scatterer, and M = modal size parameter (2π r / λ).

The intensity distribution functionhas been computed by other workers for different refractive indices and size parameters (**Parameswarn and Vijaykumar, 1994**). For the present work, we have taken the values of intensity distribution function in the modal size parameter range 0.1-30 for the refractive index 1.33(**Patel, 1986**). Pangonis and Heller **(1960)** has taken the refractive indices in the range 1.33 to 1.5 for the size parameter range of 0.1-30. The same value of 1.33 was also considered by Herman and Goldberg **(1986**). Patel **(1986)** has used normal Gaussian distribution for their measurements on atmospheric particles which may consist of condensed particles and particulates along with the natural aerosols. Therefore, for the present study we have used the normal Gaussian distribution. The ratio of scattered intensities (theoretical values) in the directions θ_1 and θ_2 can be found using Eq. (1). The experimental ratio can be found by the measured scattered intensities at angles 45° and 135°. The experimentally obtained ratio is matched with the theoretical values and the modal size parameter M is selected for which the experimental ratio tallies best with the theoretical one. For the computation of size distribution by Mie theory, a sharp peak distribution of aerosol size with standard deviation ($\sigma = 0.69$) has been selected. Once the modal size parameter is known, the particle size can be known easily using Eq. (2).

3. OBSERVATIONS

As the site of observation at Roorkee is not an industrial one, therefore the man made particles are produced only by vehicular traffic and house hold activities. Therefore, the observations have been taken from 10 am-5 pm in order to measure the aerosol concentration due to domestic human activities and vehicular traffic. The observations have been taken daily between 10 a.m. to 5 p.m. for whole monsoon and winter season at a height of 12 meters from ground surface at Physics department, Indian Institute of Technology, Roorkee India. Aerosol concentration is measured by exposing the particles to laser light and measuring the scattering intensities at forward (45º) and backward (135º) positions with the help of phototransistors. The scattered intensity of light varies with the particle size and their concentration. The size parameter of particles can be determined by comparing the ratio of scattered intensities with the theoretical values of scattered intensities of visible light (**Singh et al., 1999**). Knowing the size parameter, the size and concentration of aerosol particles for the size range 0.05-3.0 μm can be obtained easily. The meteorological parameters such as air temperature, wind speed, relative humidity and rain fall have been measured by well-known usual meteorological instruments. Further, the daily mean value has been considered for presenting the results.

4. RESULTS AND DISCUSSION

The observations on meteorological parameters like temperature, wind speed, relative humidity and rain fall along with aerosol concentration have been shown in Figures 1 and 4 for the monsoon and winter season respectively. The variation of aerosol concentration with wind speed (WS), average temperature (AT), relative humidity (RH) and rain fall (RF) are shown in Figures 2 and 5. The nature of mode radius with these meteorological parameters has been shown in Figures 3 and 6 respectively for both seasons. Observation of these data shows that the aerosol concentration decreases during monsoon season while RH was minimum in June and was almost constant during July to September, 2006 but having highest values.

In the month of June and July, the average aerosol concentration was maximum while RH was minimum in these months (Fig 1). Also, aerosol concentration varies in phase with temperature and wind speed (Fig 2). Sharma et al. (**2003**) and Pahwa et al. (**1994**) suggest that the size distribution of atmospheric aerosols varies significantly with change in temperature and RH. Parameswaran et al. (**1995**) Found that the RH does not affect significantly the aerosol concentration and size distribution up to a limit of 95 %. Here at Roorkee in the month of August and September, 2006 average RH was almost close to this limit. Devara and Raj (**1998**) have observed that the higher relative humidity and lower temperature during monsoon period at Pune (India) caused the growth of cloud droplets which results higher rainfall. The same physical process appears to be happened in 2006 during the SE monsoon at Roorkee. The decrease in aerosol concentration varies in phase with the increasing activity of monsoon. This is attributed to the RH, which was the powerful factor to lower the aerosol concentration involving rain out process.

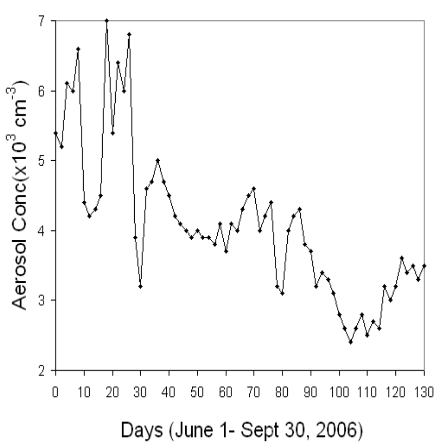
The mode radius of aerosols decreases continuously during monsoon season Wind does not play significant role in governing the mode radius while it varies in phase with average temperature and out of phase with RH. Parameswaran et al. **(1995**) have found that that the aerosol size distribution remains unaffected by relative humidity up to a limit of 95%. After this value, the mode radius increases with RH. However, the finding of this chapter is contrary to the work of Parameswaran et al. **(1995**). During monsoon period, the aerosols are removed from the atmosphere by scavenging which explains our observations that the mode radius is inversely correlated with relative humidity. For other seasons, it is not true condition.

The winter season (November, 2006 – February, 2007) at Roorkee was quit different from SE monsoon. The rain did not occur significantly during this period. Wind also did not play any effective role during first half (November – December, 2006) but varied in phase with the concentration during second half (January – February, 2007, Figs. 4 and 5). The high humidity and low temperature was observed during this season (Fig4). The aerosol concentration increases with increased in RH and decreased in temperature. The same is true for mode radius also.

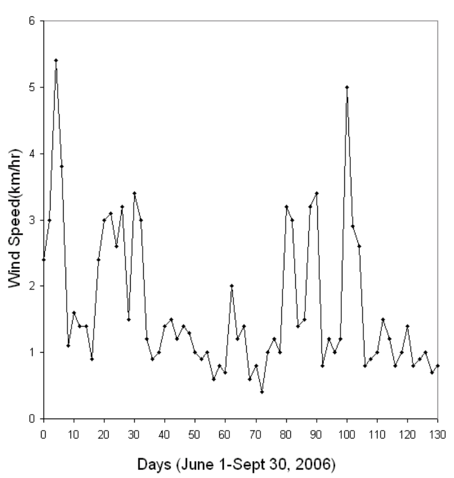
The wind speed plays an important role to govern the mode radius as larger number of particles become air-borne and hence take part in condensation due to low temperature and high RH. The average value of RH was found to be above 90 % during the second half of winter and about 80 % during first half. The average temperature touches a minimum of 10º C during January, 2007. The increased mode radius and aerosol concentration is attributed to the growth of particles due to high RH and low temperature for the whole season.

5. CONCLUSIONS

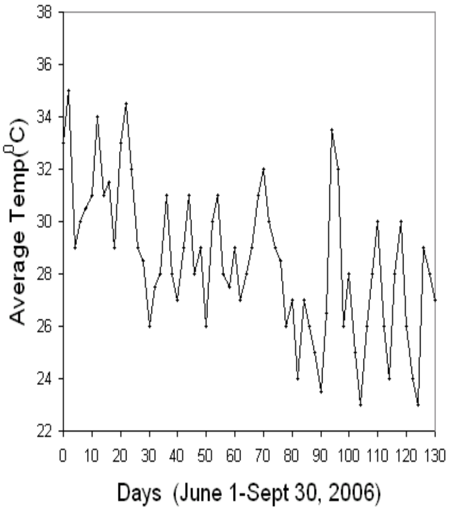
The results indicate a strong correlation between the aerosol number density, their size distribution and meteorological parameters in different weather conditions. The meteorological parameters like as wind speed, relative humidity and temperature play an important role to determine the aerosol behavior at any location, but heavy rain can alter the number density and size distribution of atmospheric aerosols more effectively than RH and WS. The present study shows that the aerosol number concentration and their size distribution is highly affected by the meteorological conditions. Although, the observations were taken at Roorkee only, however, the findings are expected to be valid for all subtropical regions.



(a)



(b)



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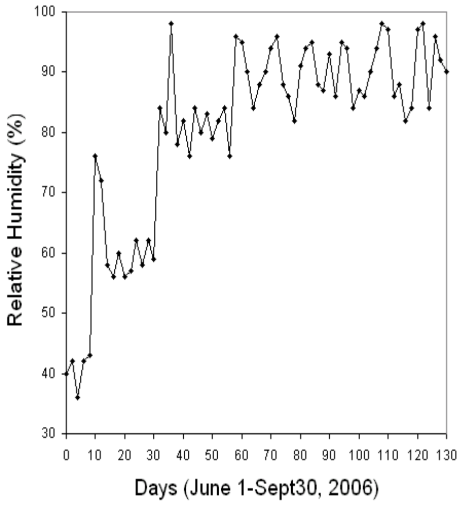

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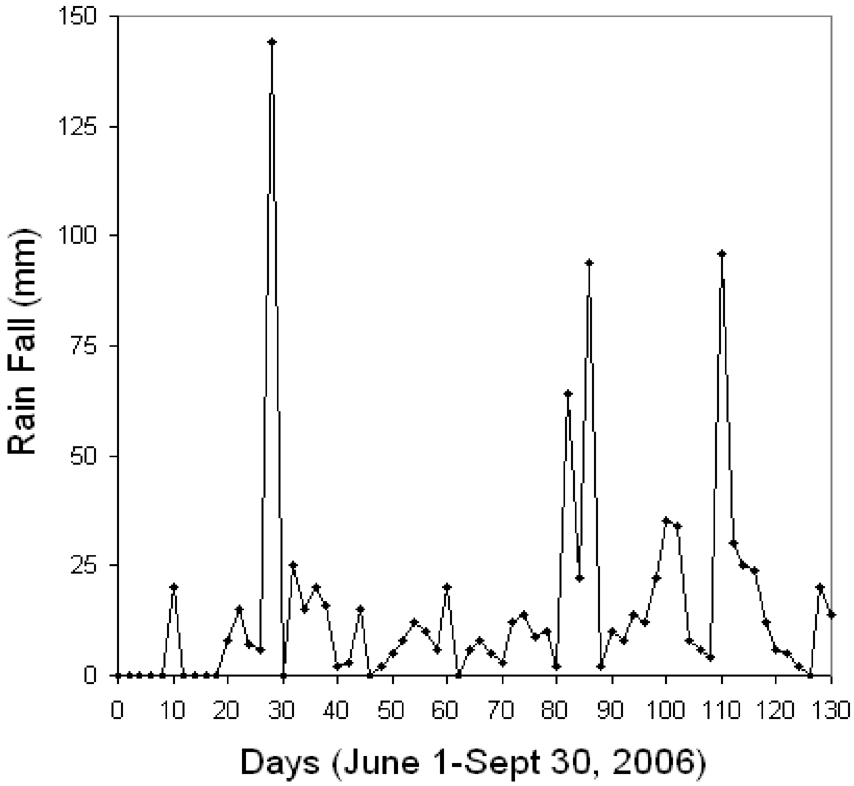
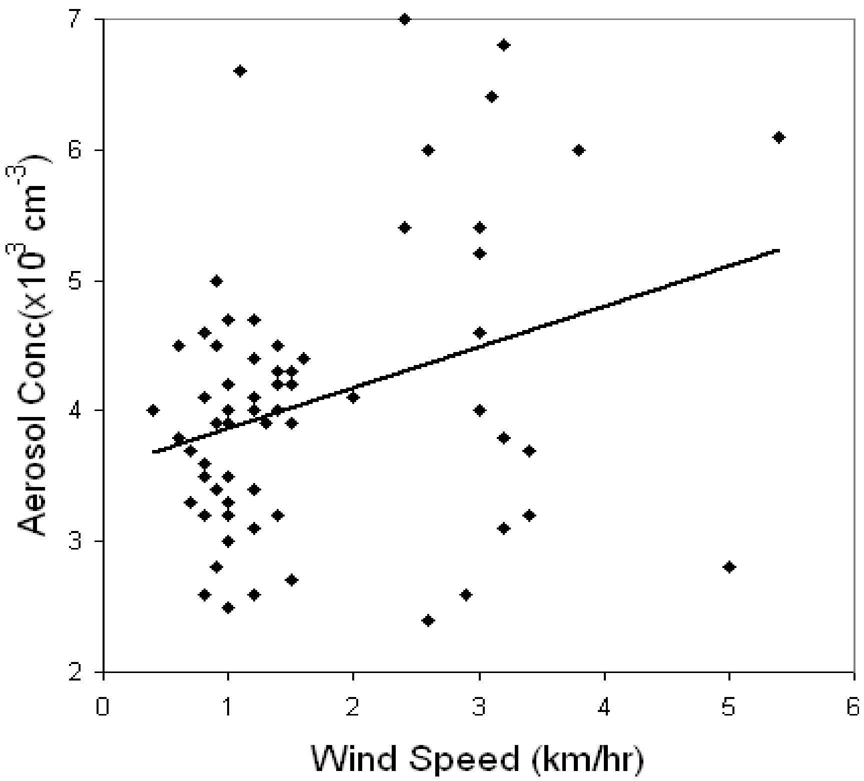
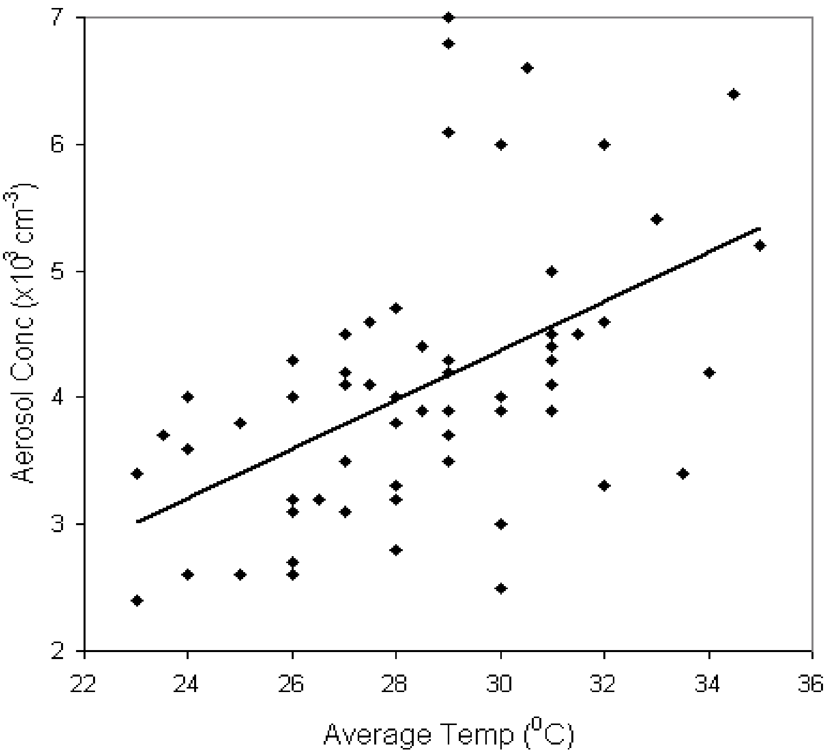


(e)

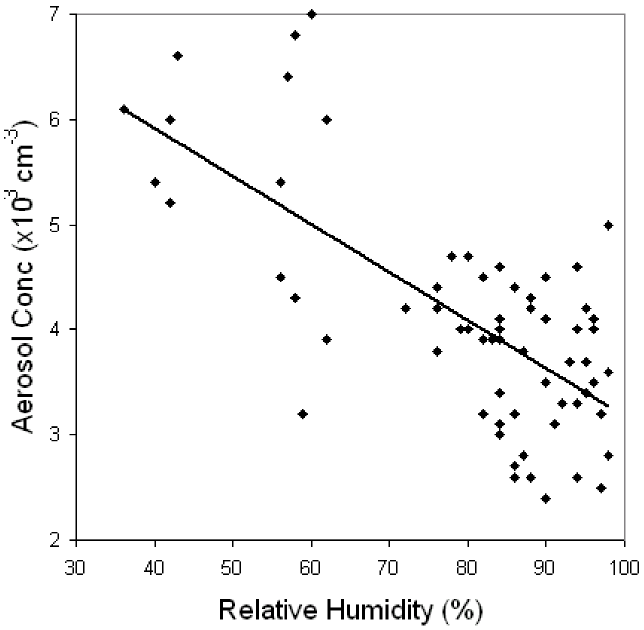
Fig 1 (a,b,c,d,e): Variation of Aerosols, wind speed, Average temp, Relative humidity and Rain fall with days for monsoon season (June 1-Sept30, 2006).


Aerosol Conc(x10^3 cm^-3)
Wind Speed (km/hr)
7
6
5
4
3
2
0
1
2
3
4
5
6

(a)


Aerosol Conc (x10^3 cm^-3)
Average Temp (^0C)
7
6
5
4
3
2
22
24
26
28
30
32
34
36

(b)



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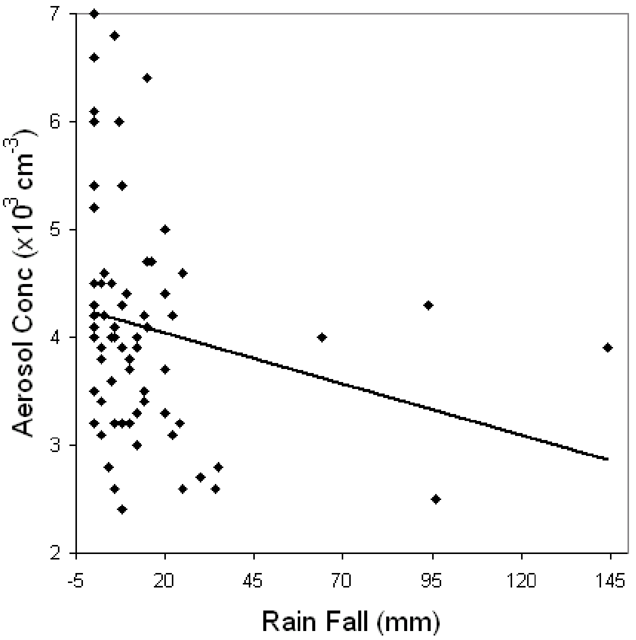
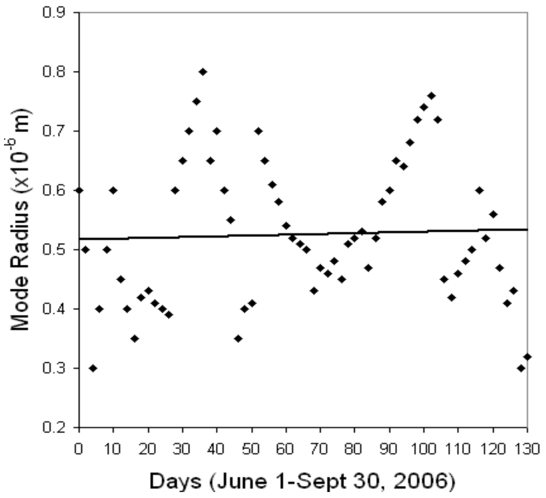
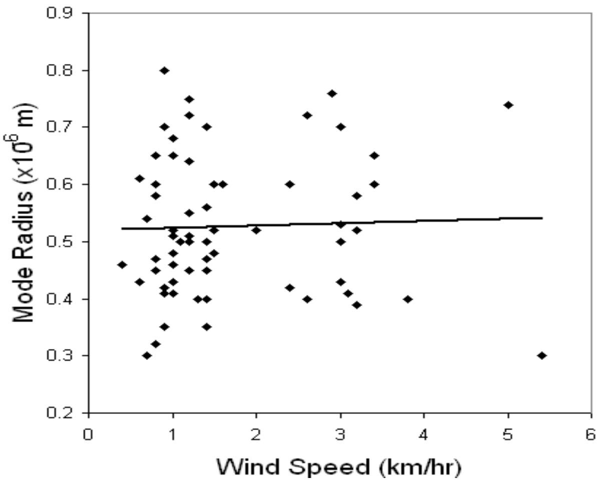


(d)

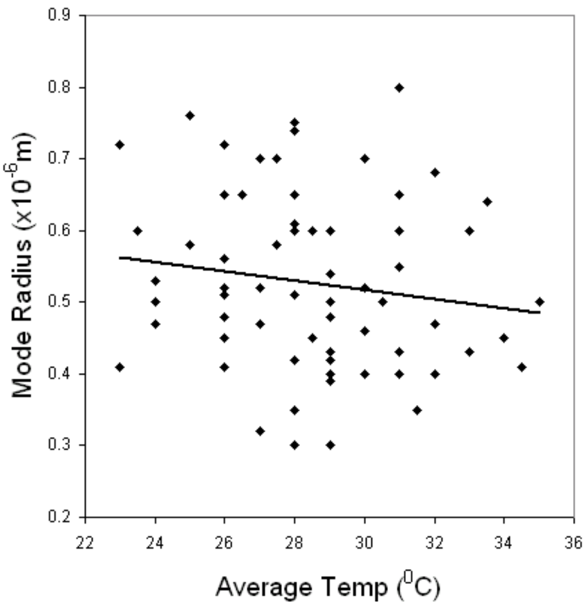
Fig 2 (a,b,c,d): Variation of Aerosol concentration with Wind speed, Average temperature, Relative humidity and Rain fall for monsoon season (June 1-Sept 30, 2006).


Mode Radius (x10^{-6} m)
Days (June 1-Sept 30, 2006)

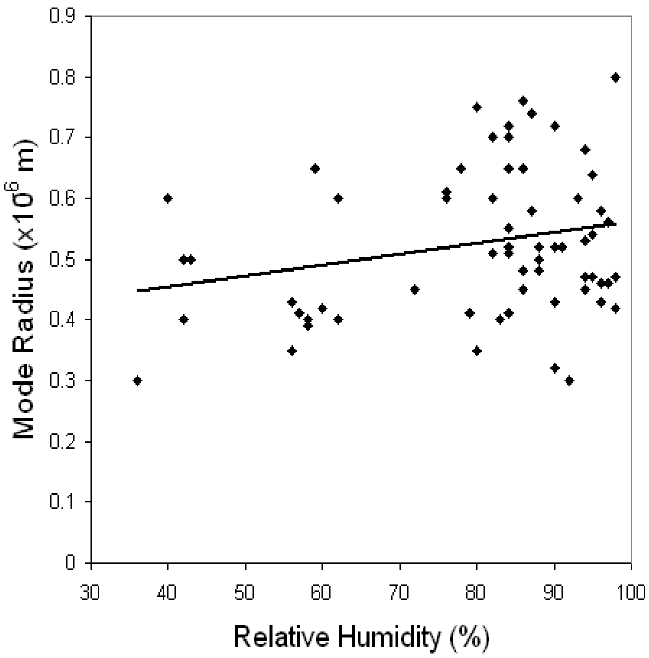
(a)


Mode Radius (x10^{6} m)
Wind Speed (km/hr)

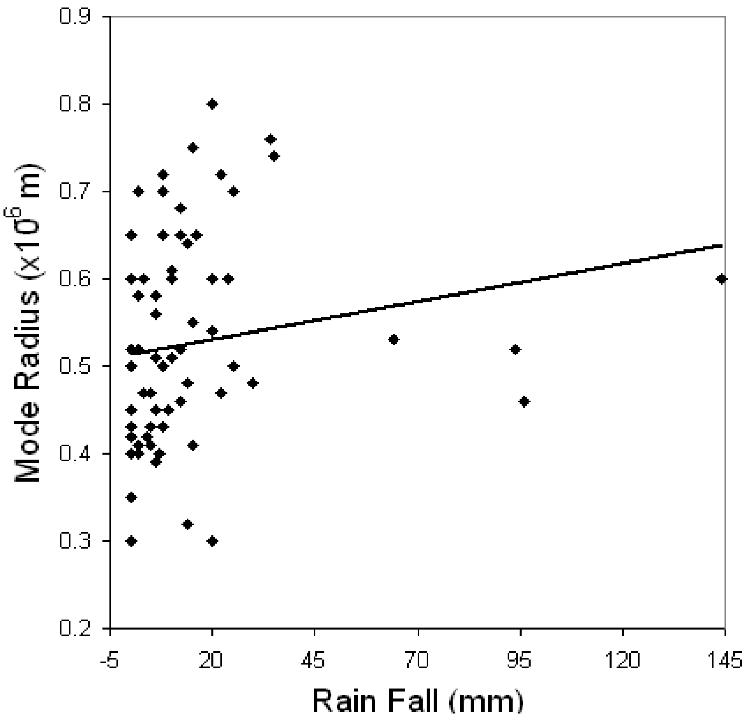
(b)


Mode Radius (x10^{-6}m)
Average Temp (^{0}C)

(c)

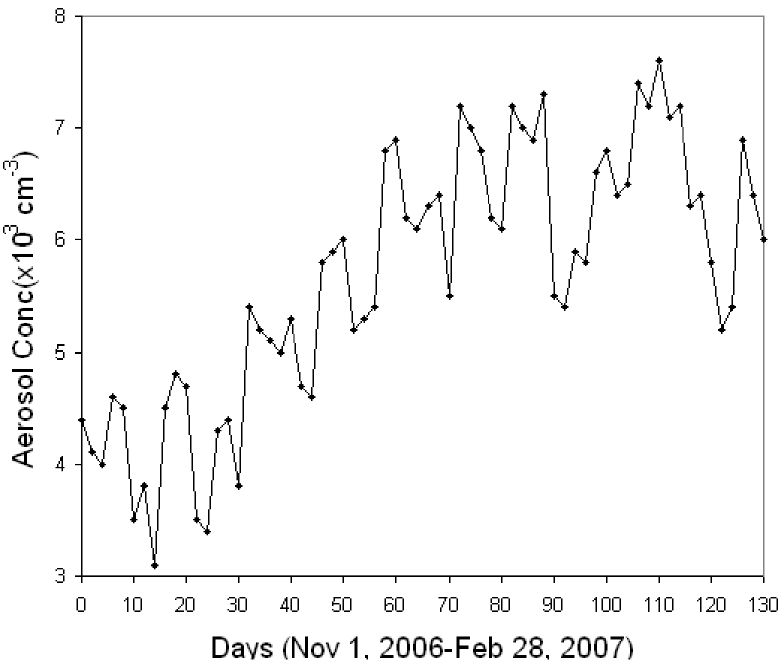


(d)

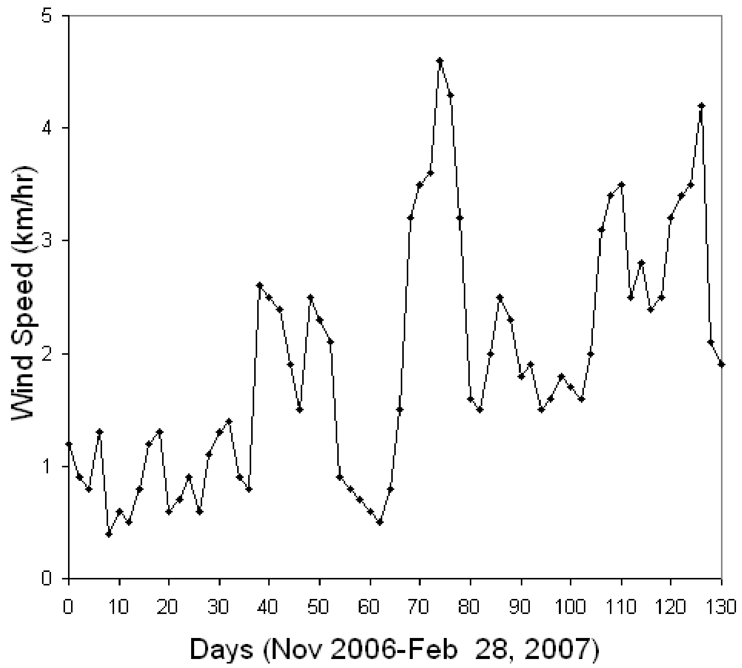


(e)

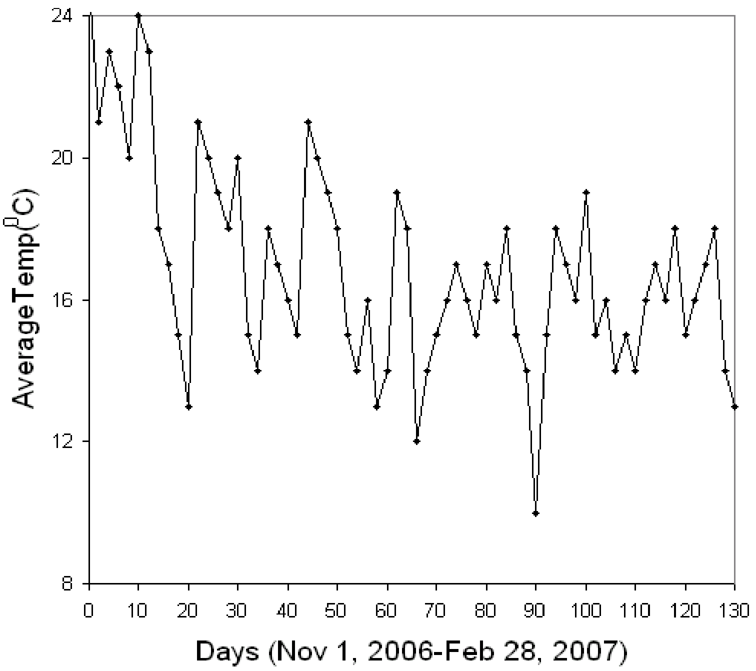
Fig 3 (a,b,c,d,e): Variation of mode radius with days, Wind speed, Average temp and Relative humidity for monsoon season (June 1-Sept 30, 2006).


Aerosol Conc($\times 10^3$ cm^{-3})
Days (Nov 1, 2006-Feb 28, 2007)

(a)


Wind Speed (km/hr)
Days (Nov 2006-Feb 28, 2007)

(b)



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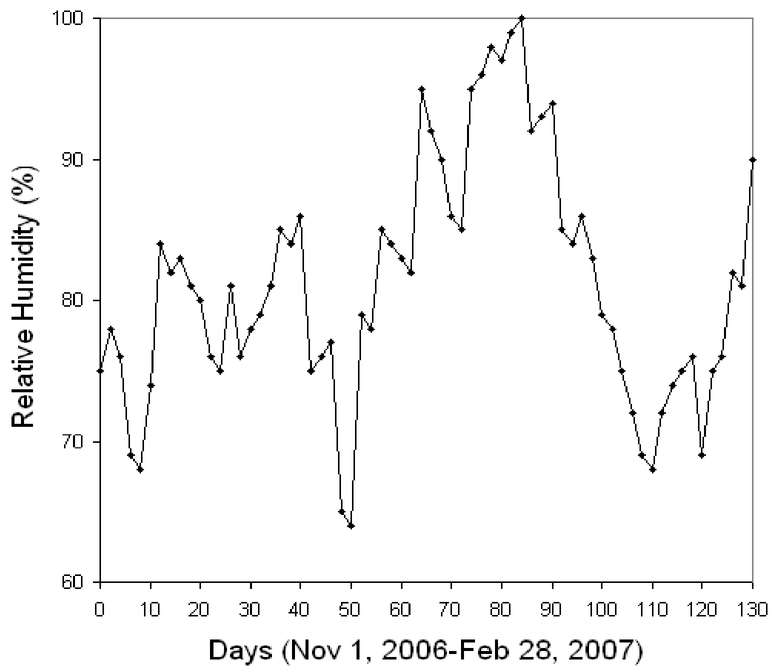
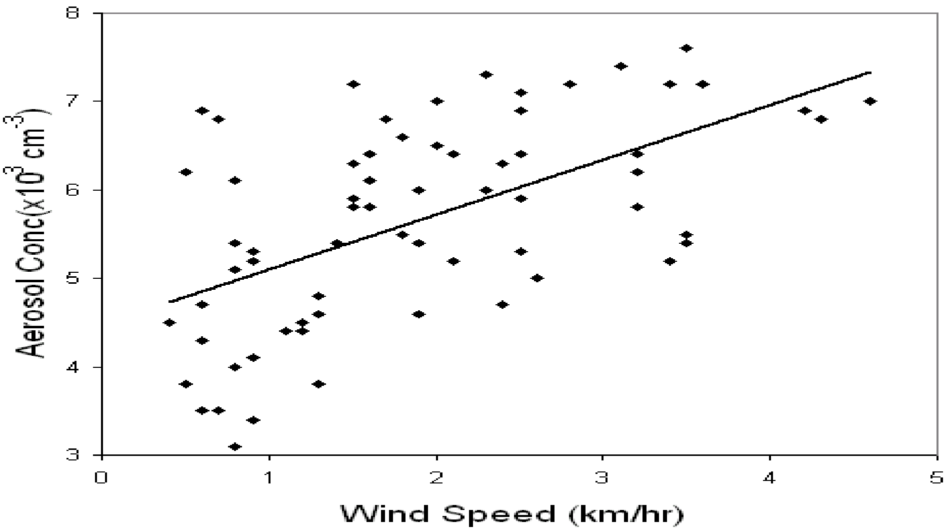
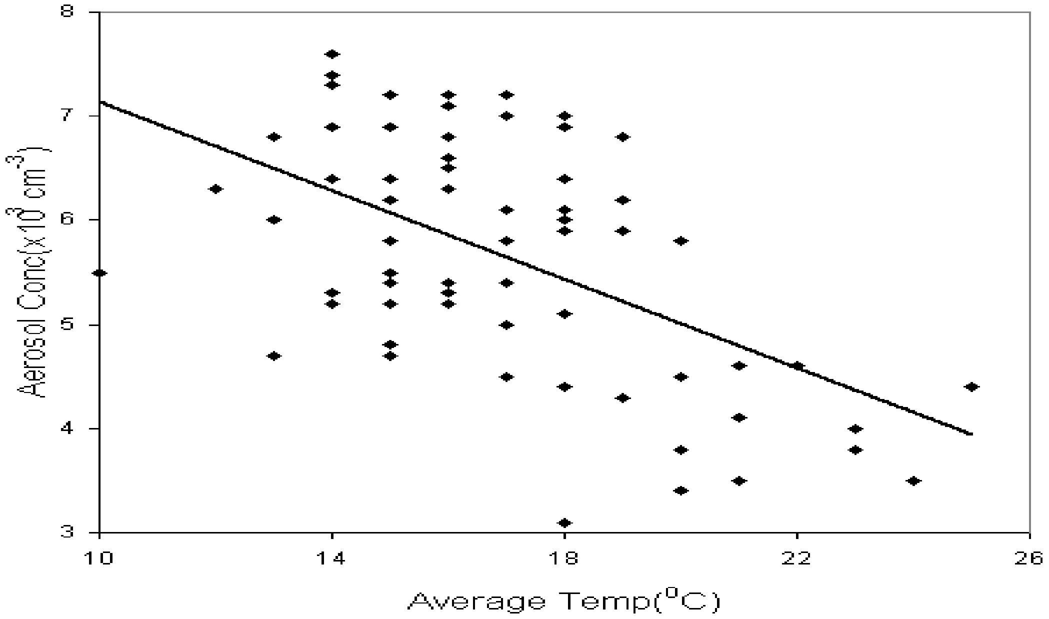


(d)

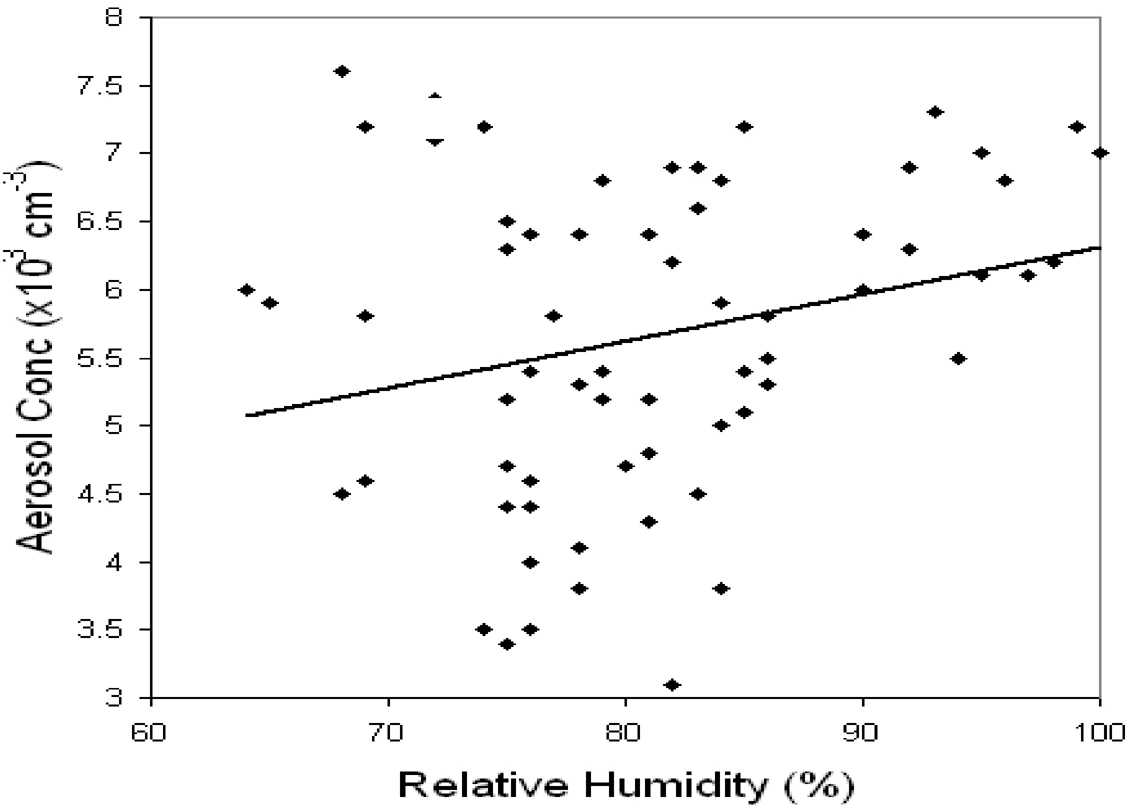
Fig4 (a,b,c,d): Variation of Aerosols, wind speed, Average temp, Relative humidity and Rain fall with days for winter season (Nov 1, 2006-Feb 28, 2007).


Aerosol Conc(x10^3 cm^{-3})
Wind Speed (km/hr)
8
7
6
5
4
3
0
1
2
3
4
5

(a)

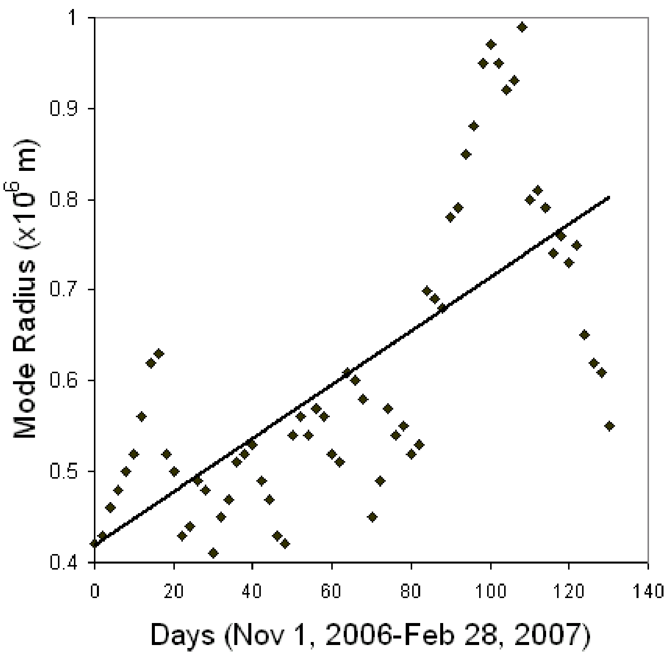

Aerosol Conc(x10^3 cm^{-3})
Average Temp(^{o}C)
8
7
6
5
4
3
10
14
18
22
26

(b)

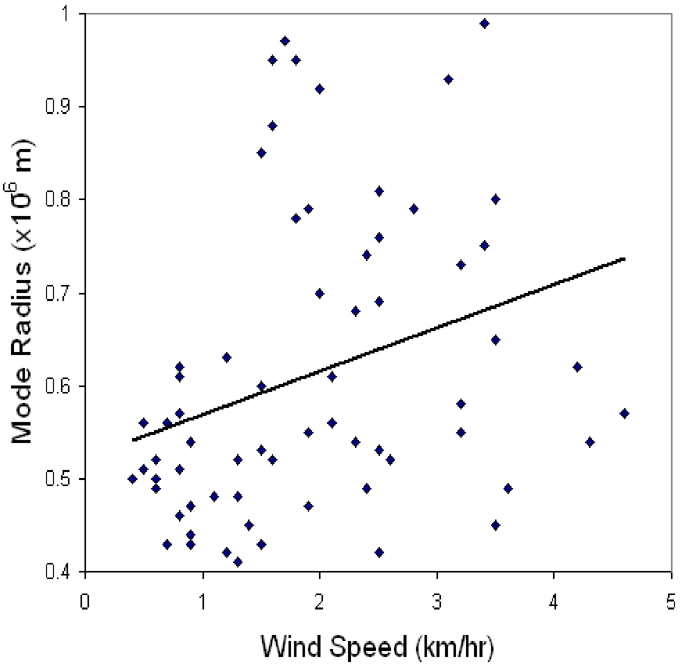


(c)

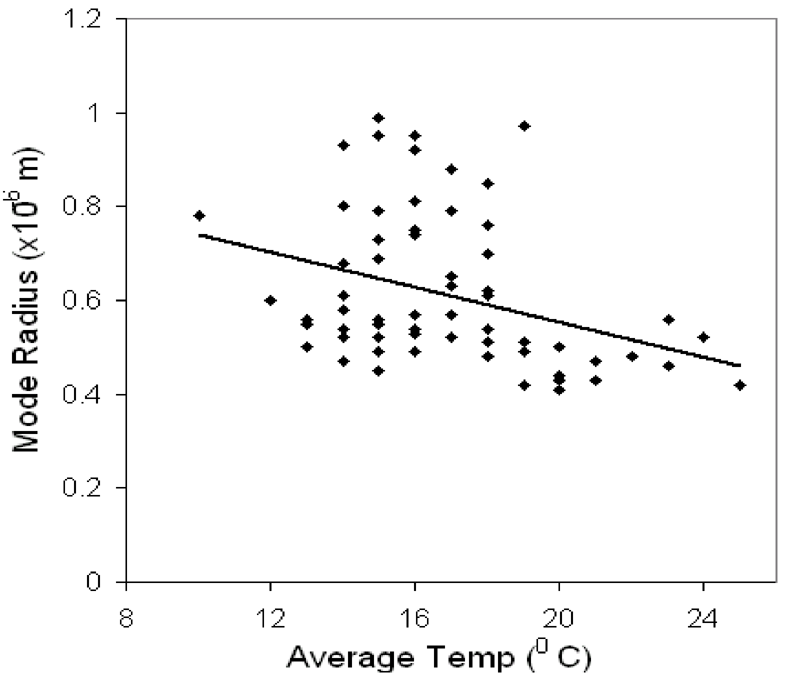
Fig 5 (a,b,c): Variation of Aerosol concentration with Wind speed, Average temperature, Relative humidity for winter season (Nov 1, 2006-Feb 28, 2007).



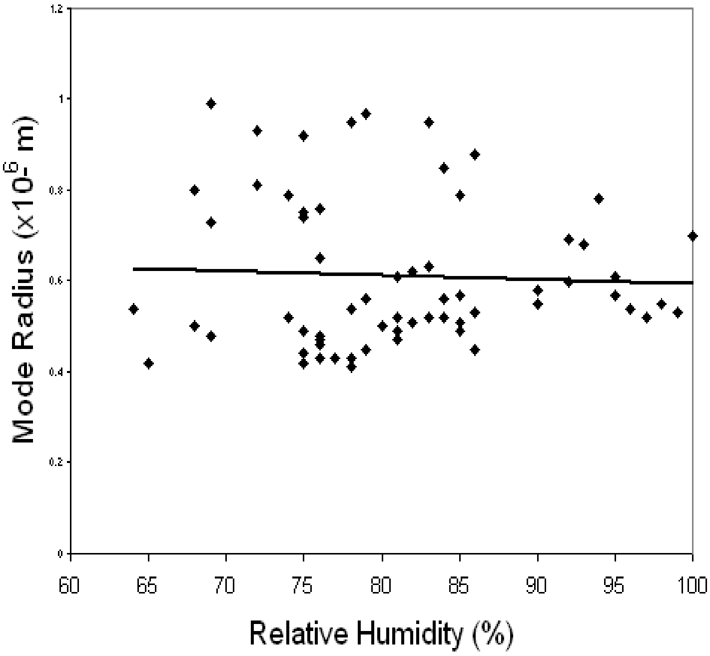
(a)


Mode Radius (x10^6 m)
Wind Speed (km/hr)
1
0.9
0.8
0.7
0.6
0.5
0.4
0
1
2
3
4
5

(b)


Mode Radius (x10^6 m)
Average Temp (^{0} C)
1.2
1
0.8
0.6
0.4
0.2
0
8
12
16
20
24

(c)



(d)

Fig 6 (a,b.c,d): Variation of mode radius with days, Wind speed, Average temp and Relative humidity for winter season (Nov 1, 2006-Feb 28, 2007)