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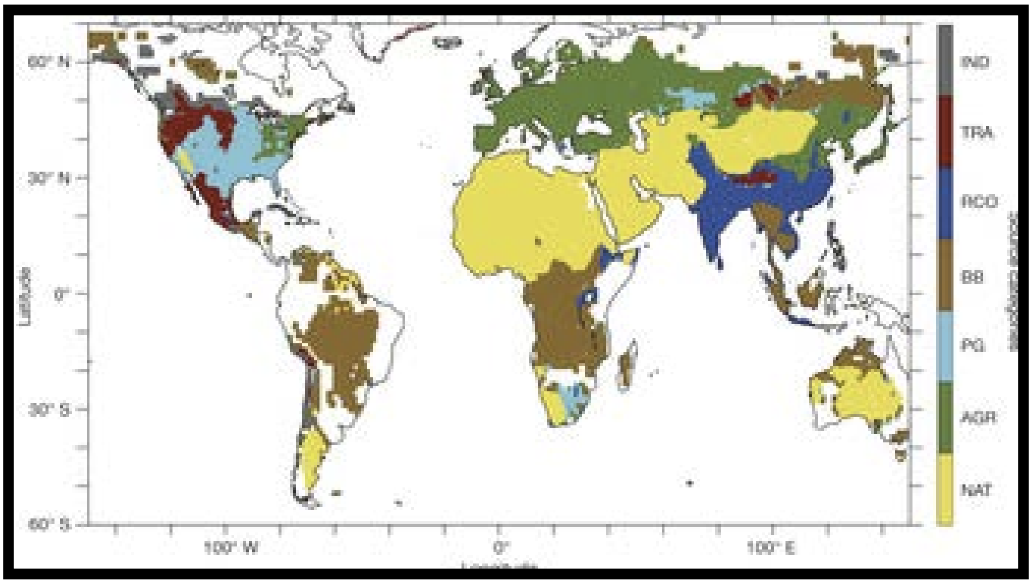

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Cover Photo: Source categories (IND: industry, TRA: traffic, RCO: residential and commercial energy use, BB: biomass burning, PG: power generation, AGR: agriculture, NAT: natural) responsible for the largest contribution to premature mortality attributed to ambient air pollution exposure(Courtesy: Lelieveld et al., Nature, 2015)

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Fractal dimension of natural objects from nano-to macro-scale: an intrinsic property of material

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Summary:

Many natural objects are innately composed of complex geometric figures, termed as fractals, and their mathematics are extremely complicated. The complexity and beauty found in these fractals has inspired several researchers to create them using mathematical formulations and computer aided graphics tools and software. These designs generated in various forms and psychedelic colours have become a digital art medium for design of wall papers, animation movies, fabric printing etc. However, there are simple experiments and simulations to comprehend it. Here, we demonstrate a simple experiment from the literature to estimate the fractal dimension of crumpled paper balls, and also discuss a method for aerosols.

Fractals - an intrinsic property of material

A fractal is an object or a mathematical entity exhibiting self-similarity across different scales, with a seemingly never-ending pattern. Examples of fractals from physical world around us are cauliflower (Fig.1), ferns, trees, rivers, coastlines, mountains, clouds, seashells, hurricanes, etc. The typical well-cited example to understand the concept of a fractal is that of the coastline. The length of the coastline is highly dependent on the length of the measuring scale used. As the length of the measuring scale goes on reducing, the observed length of the coastline will increase. Fractals are different from other regular geometric objects because of the way in which they scale. For example, if we double the radius, then the volume of the sphere increases by a factor of eight (2^3). But if we double the dimensional length of a fractal then the spatial content of the fractal scales by the exponent that is not necessarily an integer. This non-integer exponent is called the fractal dimension of the fractal and is figurative of the huge void spaces which may be present in the fractal objects.

Several works have been carried out to estimate the fractal dimensions of things found in nature. Now a question may arise, why should we study the details of fractal dimension of natural things?. To answer this question, let us discuss the work of Ma *et al.* 2011 [1]. In their study, Graphene Oxide (GO) in aqueous solution was aerosolized and rapidly dried to produce crumpled nano paper like sheet. These crumpled Graphene balls increase the specific capacitance of the material compared to the flat or wrinkled sheets, and hence it is considered to be a promising ultra-capacitor material [2]. The fractal dimension of the dried and crumpled GO sheet is characterized by using a combined mass-mobility diameter measurement. The results show that the fractal dimension of crumpled Graphene Oxide (GO) nano sheet is 2.54±0.02, which is identical to macroscopic crumpled ball of paper or foil indicating self-similarity at both the nano and macro scale.

Fractal dimension of macro-scale objects (crumpled paper balls)

To demonstrate the concept at the macro scale, a simple experiment is carried out, similar to that by Gomes [3] and Amaku *et al.* [4], to find out the fractal dimension of crumpled paper. An A4 size 80 GSM paper is cut into pieces as shown in Fig. 2. The individual paper pieces (see Fig. 2) are crumpled to a spherical shape as shown in Fig. 3. The mass (in g) and diameter (in mm) of these crumpled balls are measured using physical balance and vernier callipers respectively, and tabulated in Table 1. Fitting of the data from the Table 1 (see Fig.4) after taking natural logarithm of both the quantities (i.e., ln$d$ vs. ln$M$) yields the following linear equation:

$$\ln d = 3.09807 + 0.3807 * \ln M \qquad (1)$$

By rearranging Eq.(1), the mass and diameter of these objects are related as,

$$d = kM^{(1/d_f)} \qquad (2)$$

where, k is a constant, and d_f is the fractal dimension of the crumpled paper balls estimated as,

$$d_f = \frac{1}{0.3807} = 2.63 \qquad (3)$$

The fractal dimension obtained from this experiment is very close to the values (similar type of experiments carried out to estimate the fractal dimension of crumpled balls) reported in the literature [3]. This experiment may be repeated by different individuals to obtain statistically significant results. One can carry out this experiment with different kinds of materials such as bread, cheese, etc., as demonstrated by Amaku*et al.*[4] to estimate the fractal dimension.

Fractal dimension of micro- and nano-scale objects (aerosols)

On the other hand, determination of the fractal dimension in the case of micro- and nano-scale objects, such as aerosols, is not as simple. Aerosols are one among the several examples given for fractals. They are solid or liquid particles having sizes ranging from a few nm to several μm suspended in air medium. Coagulation is a phenomenon by which aerosol particles agglomerate and form clusters. Because of incomplete packing of aerosols undergoing several coagulation processes, the actual volume of a cluster is not the same as the sum of the individual solid particles forming the cluster. Practically speaking, aerosol particles may have arbitrarily irregular shape, and their non-sphericity can be described in terms of fractal geometry. For this reason, fractal dimension comes into play which is a characteristic of the type of aerosol.

One method of estimating the fractal dimension for aerosols is to compare their mass- and number-size distributions measured simultaneously.A general theory of this method which allows the particles to be fractal as well is described in the Appendix of Sapra *et al.*[5]. In this study, the fractal dimension is estimated from the exponent values obtained from fitting of the number- and mass- size distribution with respect to actual and aerodynamic diameters[1] respectively. The mass-size distribution with respect to aerodynamic diameter was obtained by using Quartz Crystal Microscope (QCM) while number-size distribution with respect to actual (optical) diameter is obtained using Optical Particle Counter (OPC). The fractal dimensions of incense stick smoke, room, and metallic aerosols were estimated to be 2.6, 2.56, and 1.72 respectively.

The fractal dimension of incense stick smoke and room aerosol show that their structures are close to spherical particles. The value for metallic aerosols is quite close to the known d_f of about 1.8 for Cluster-Cluster Aggregates (CCAs), which are known to be highly porous. The metal aerosols were produced by evaporation of metal powder in plasma torch followed by natural cooling of the vapour in the experimental chamber/vessel. The vapour nucleates to form particles that grow in the vessel due to coagulation. It follows from diffusion theory that the probability of sticking is highest at the end points of the aggregates. As a result, sharper tips continue to grow during coagulation giving rise to highly ramified branched structures, known as Diffusion Limited Aggregates (DLA). They have considerable void inside and hence a low density. DLAs, in turn, agglomerate with each other giving rise to even more branched fractal structures having lower densities. These are called Cluster-Cluster Aggregates (CCAs). The present estimate of $d_f$for metallic aerosols show that they form CCAs in dry experiments as expected, however, one needs to verify the fractal structure by direct microscopic observations.

To summarize, this article provides a brief introduction to the concept of fractals, and simple techniques to estimate the fractal dimension of crumpled paper balls and aerosols.

Suggested readings:

[1] X Ma, M R Zachariah, and C D Zangmeister, Crumpled nanopaper from graphene oxide, *Nano Lett.*, 12, pp.486−489, 2012.

[2] J Luo, H D Jang, and J Huang, Effect of sheet morphology on the scalability of graphenebased ultra-capacitors, *ACS Nano*, 7(2), pp.1464–1471, 2013.

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[5] B K Sapra, Y S Mayya, Arshad Khan, Faby Sunny, Sunil Ganju, and H S Kushwaha, Aerosol studies in a nuclear aerosol test facility under different turbulence conditions, *Nuclear Technology*, 163, pp.228-244, 2008.

Further readings:

[1] http://classes.yale.edu/fractals/

[2] http://math.rice.edu/~lanius/frac/

S.	Diameter (d), mm				Mass
No.	Orientation 1	Orientation 2	Orientation 3	Average	(M), g
1	28.75	28.40	32.02	29.72	2.5999
2	23.71	24.68	26.95	25.11	1.3028
3	19.71	18.18	21.50	19.80	0.6401
4	13.14	15.12	14.84	14.37	0.3204
5	11.78	11.38	12.34	11.83	0.1651
6	7.87	7.91	8.14	7.97	0.0783
7	5.75	6.81	6.78	6.45	0.0410

Table 1: Experimental values of physical diameter and mass of crumpled paper balls shown in Fig. 3

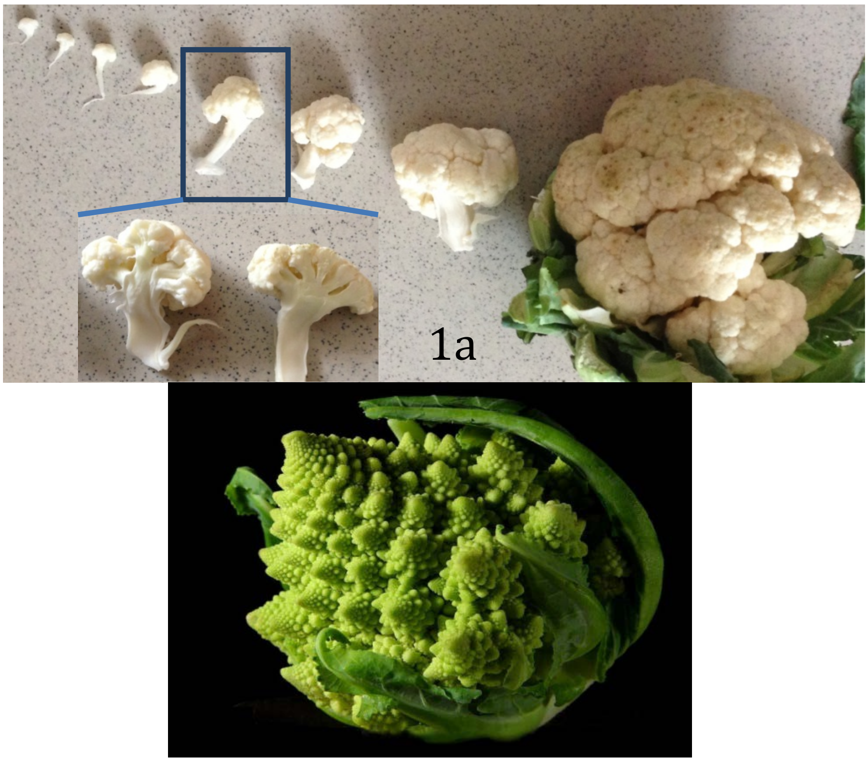

Fig. 1a: Cauliflower, a commonly available vegetable at home, **1b:** Romanesco broccoli - a natural macro-size fractal (https://en.wikipedia.org/wiki/Romanesco_broccoli).

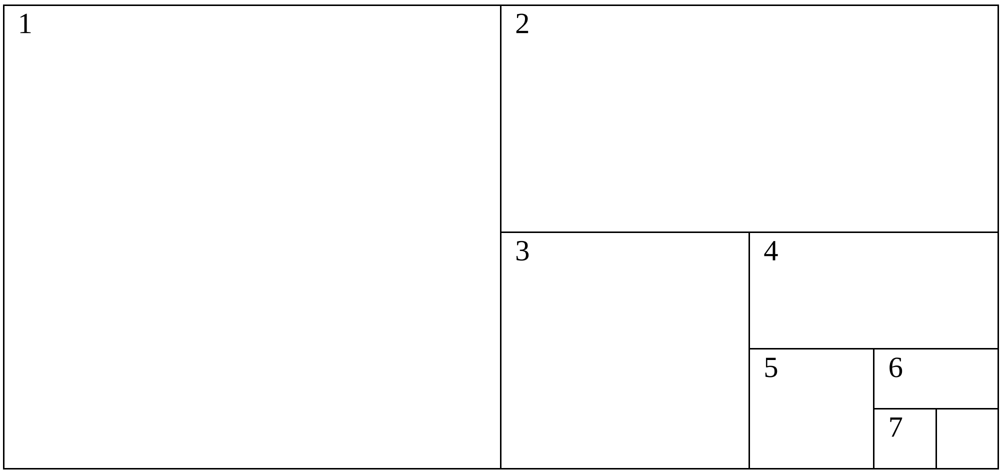

Fig. 2: Pieces of paper used in the experiment (7 nos.)

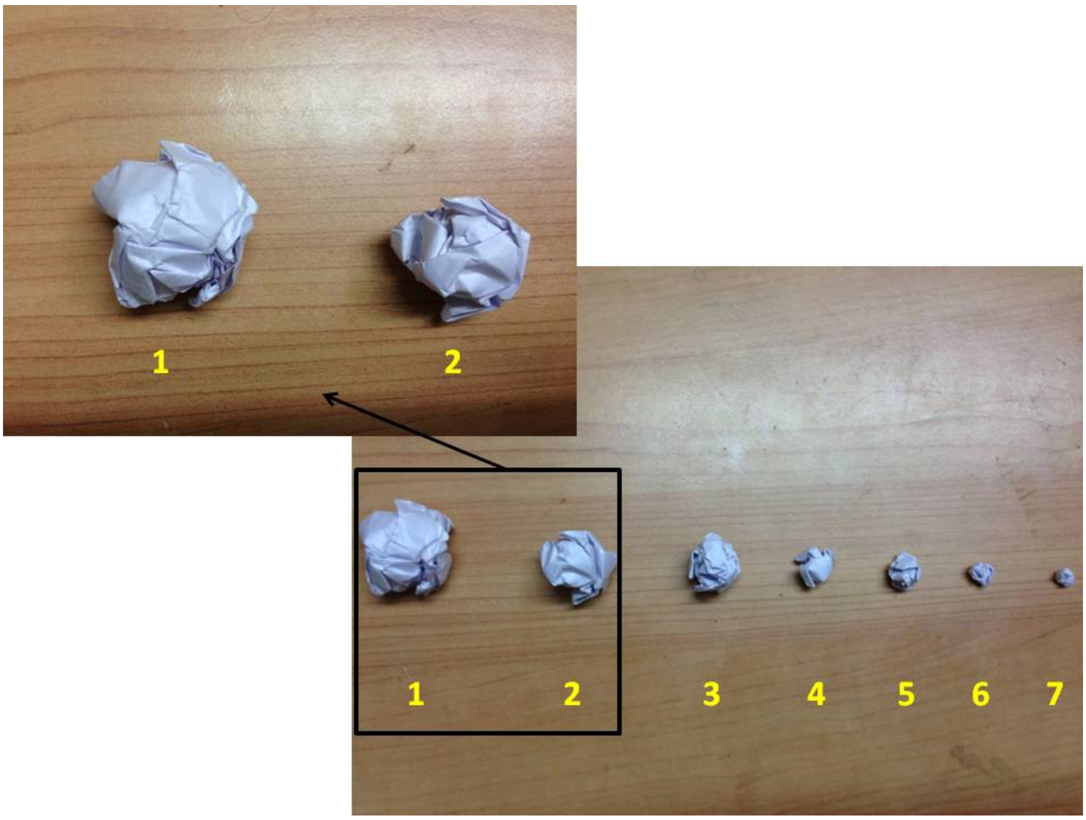

Fig. 3: The crumpled pieces of paper depicted in Fig. 2

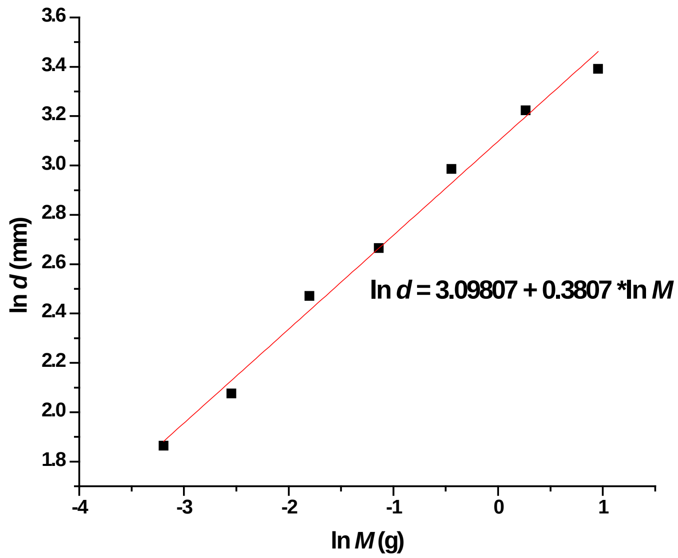

Fig. 4: Plot of ln (*M*) vs. ln (*d*) for the crumpled balls

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Impact of Road-Space-Rationing Method on Regional Air Quality

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Summary

Following the implementation of the Delhi Government's policy of Road-Space-Rationing (Odd-Even) method, the Amity University Haryana (AUH), Panchgaon-Manesar-Gurgaon monitored, from the day one, its efficacy by making systematic high resolution particulate matter (PM_1, $PM_{2.5}$ and PM_{10}) and spectral variation of black carbon (BC) aerosol mass concentration measurements in conjunction with concurrent solar and local meteorological measurements in its campus. These measurements revealed a significant reduction in the pollution levels on implementation of the odd-even scheme. It was found that due to overlapping of some prominent meteorological phenomena like western disturbances (WDs); fogs etc., inherent to the tropical winters, the results were found to be unclear on the days when the sky was not clear. However, the trends were found to be promising and encouraging. The Government has decided to repeat the policy, in a phased manner, during the forthcoming summer and post-monsoon seasons with more advance preparedness. Thus, the policy shows promising results and it is hoped that this useful exercise would bring down the vehicular pollution and associated health hazards to a considerable extent. Added, considering this experiment conducted in the Delhi region as a model, many other States in the Nation are planning to implement similar policy in their regions.

Introduction

Pollution in many Indian cities, Delhi in particular, is rapidly increasing and significantly hazarding the economy and health of population (Ex. Dockery et al., 2005; Balakrishnan et al., 2012). It is known that pollution is highly dynamic and exhibits tremendous space-time variations; and pollution levels over urban areas can be estimated only when the relative levels over any background area (high-altitude or rural) are known (Devara, 1998). Studies have indicated excess mortality (and morbidity) in Delhi due to cardiovascular/cardiopulmonary and respiratory causes, based upon occupational related acute exposures of pathogens (microorganisms) alone (Goodel and Rando, 2015). Furthermore, additional factors such as variance in solar radiation, toxicity of atmospheric and biogenic emissions, and wind-blown dust and soil, all result in exacerbation of the issue (CPCB, 2011). In order to curb these anthropogenic emissions, and to develop cost-effective methods for health improvements (especially pre-mature deaths), Government of Delhi had recently implemented an odd-even formula (Road Space Rationing). While the debate on the success of this initiative may continue, what cannot be denied is the fact that with the reduction of vehicles on road, the total pollution load during the stretch of twelve hours (08:00am to 08:00pm) has come down by at least a factor of two. This is primarily because of subsequent reduction in traffic congestion resulting in considerable reduction in commuting time. This directly relates to about 50% reduction in the fuel consumption for the same distance traveled on odd-even days. This is by no means an improvement both from the point of view of commuters and human health, and also from the point view of air quality and fuel economy.

Experimentation, Results and Discussion

The experimental station, Panchgaon (28.31^{o}N, 76.90^{o}E, 285 m above mean sea level), Haryana State, is a rural location, situated around 50 km from Delhi. This site is surrounded, in the north-east direction, by two cities, namely, Gurgaon (~ 24 km) and Manesar (~9.5 km) which possess several small- and large-scale industries, the study site receives pollution whenever the wind blows in the north-east sector. It is about 5 km away from the Delhi-Jaipur National Highway (NH8) in the north-east (NE) direction, and is surrounded by vegetation and enveloped by vegetation Aravalli hillocks of average elevation of about 200 m (Devara et al., 2014).

High-resolution Black Carbon (BC) and Particulate Matter (PM_1, $PM_{2.5}$ and PM_{10}) mass concentration have been carried out employing the Air Quality Monitoring Facility established at Amity University Haryana (AUH), Panchgaon-Manesar-Gurgaon from 29 December 2015 to 20 January 2016, encompassing the Road-Space-Rationing (Odd-Even) method implemented by the Delhi Government for reducing air pollution in the Delhi region. The daily marching of these air quality drivers is portrayed in figures from 1 through 5 below. The time-concentration cross-sections of BC mass variation, observed with Magee Scientific-make 7-wavelength Aethalo-

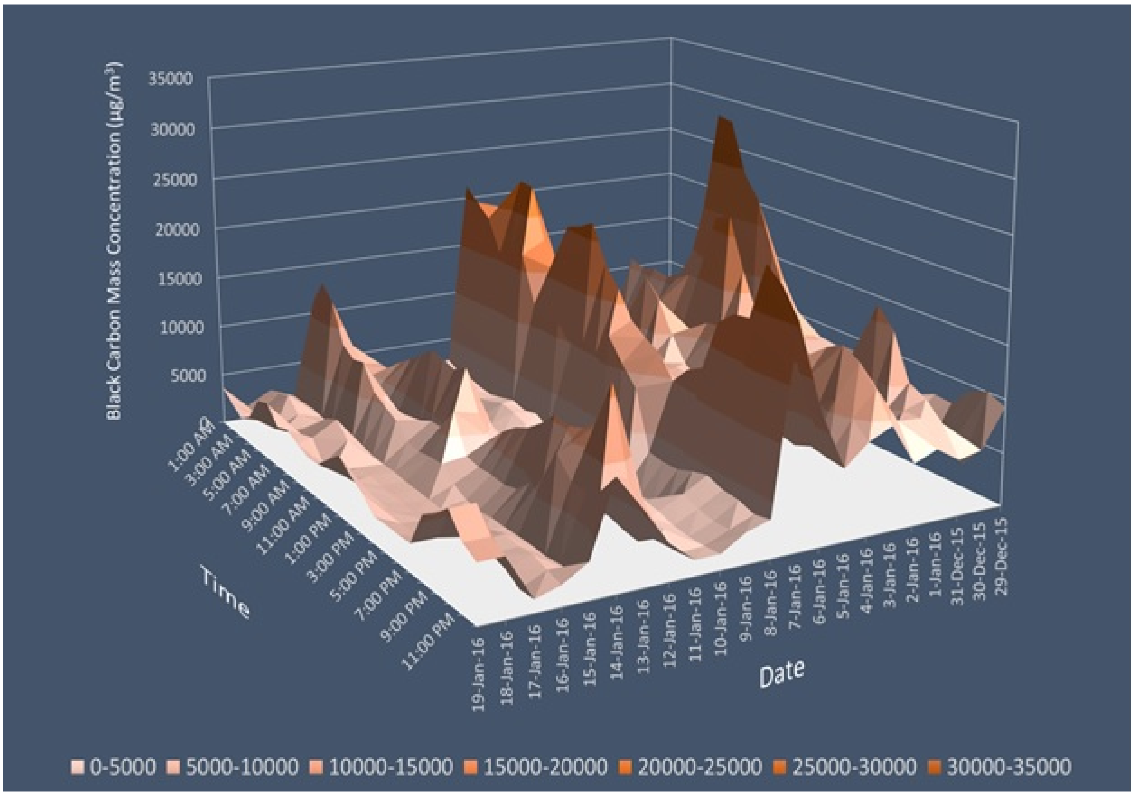


Figure 1: 3-dimensional view of date-wise diurnal variation of BC mass concentration observed over AUH during the study period. Bi-modal distribution with significant enhancement in BC concentration during 6th-8th January 2016, peaking on 7th, due to FOG may be noted.

meter during the study period, are shown plotted in Figure 1. One can clearly visualize the hour-by-hour variation of BC mass and its association with local meteorology, from commencement of the

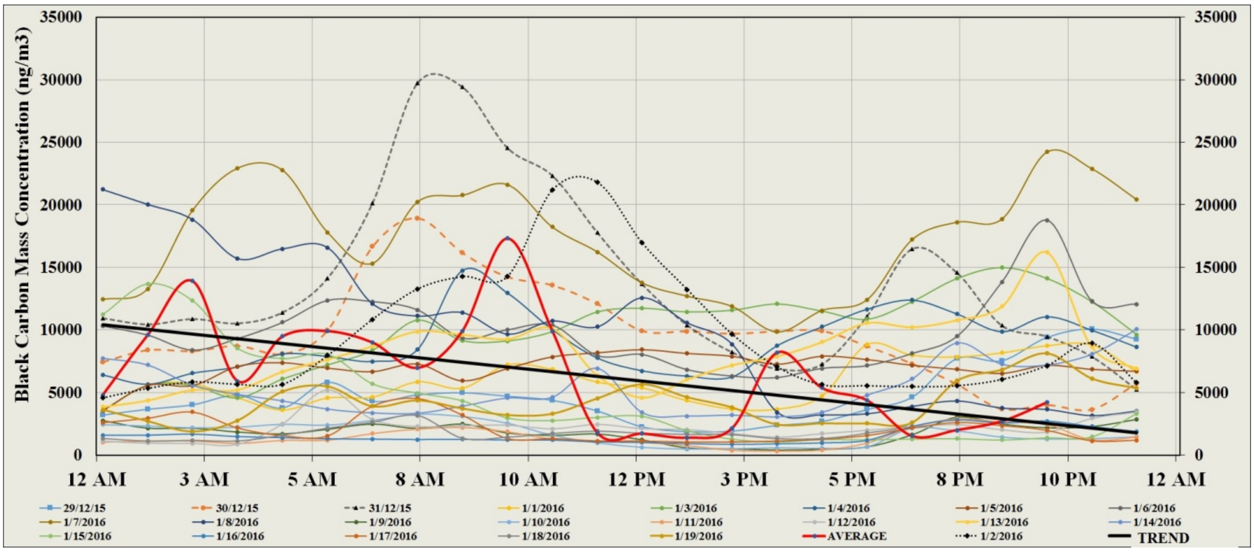


Figure 2: Diurnal variation of BC mass concentration on different observation days over AUH, Panchgaon-Manesar-Gurgaon. The thick curve in red color indicates mean diurnal variation of BC

mass concentration for the entire study period, and the solid line in black color passing through it denotes best fit line, depicting the decreasing trend.

program i.e. 29 December 2015 through 20 January 2016 over AUH, Panchgaon. It may also be interesting to see here that the BC values are lower under clear-sky and higher under foggy conditions due to the reasons explained in the paragraphs to follow. Further, it may be noted that the daily mean mass concentration of the black carbon also shows drastic reduction at AUH monitoring station from 15 micrograms per cubic meter on 31 January 2015 (before commencement of the initiative) to approximately 1.4 micrograms per cubic meter on 11th January 2016. Figure 2 displays the daily diurnal variation in BC mass concentration during the study period. The common feature that is observed on all the days that BC mass concentration depicts bi-modal distribution with primary peak around 0800 h and secondary peak around 2000 h, both may primarily be due to the transport activities in and around the study region. The black carbon mass concentration was higher on 31 December 2015, and thereafter, it showed

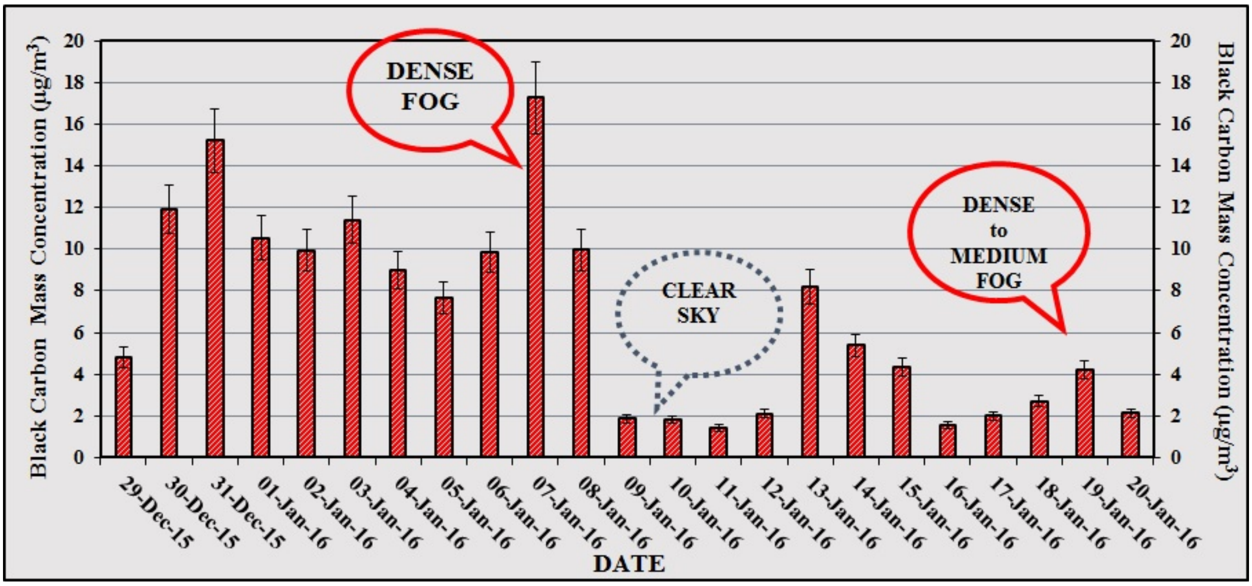


Figure 3: Day-to-day variation in BC mass concentration during 29 December 2015 – 20 January 2016.

gradual decrease during fair weather conditions on remaining days. The minimum blackcarbon concentration observed on each day around noon hours is ascribed to the local

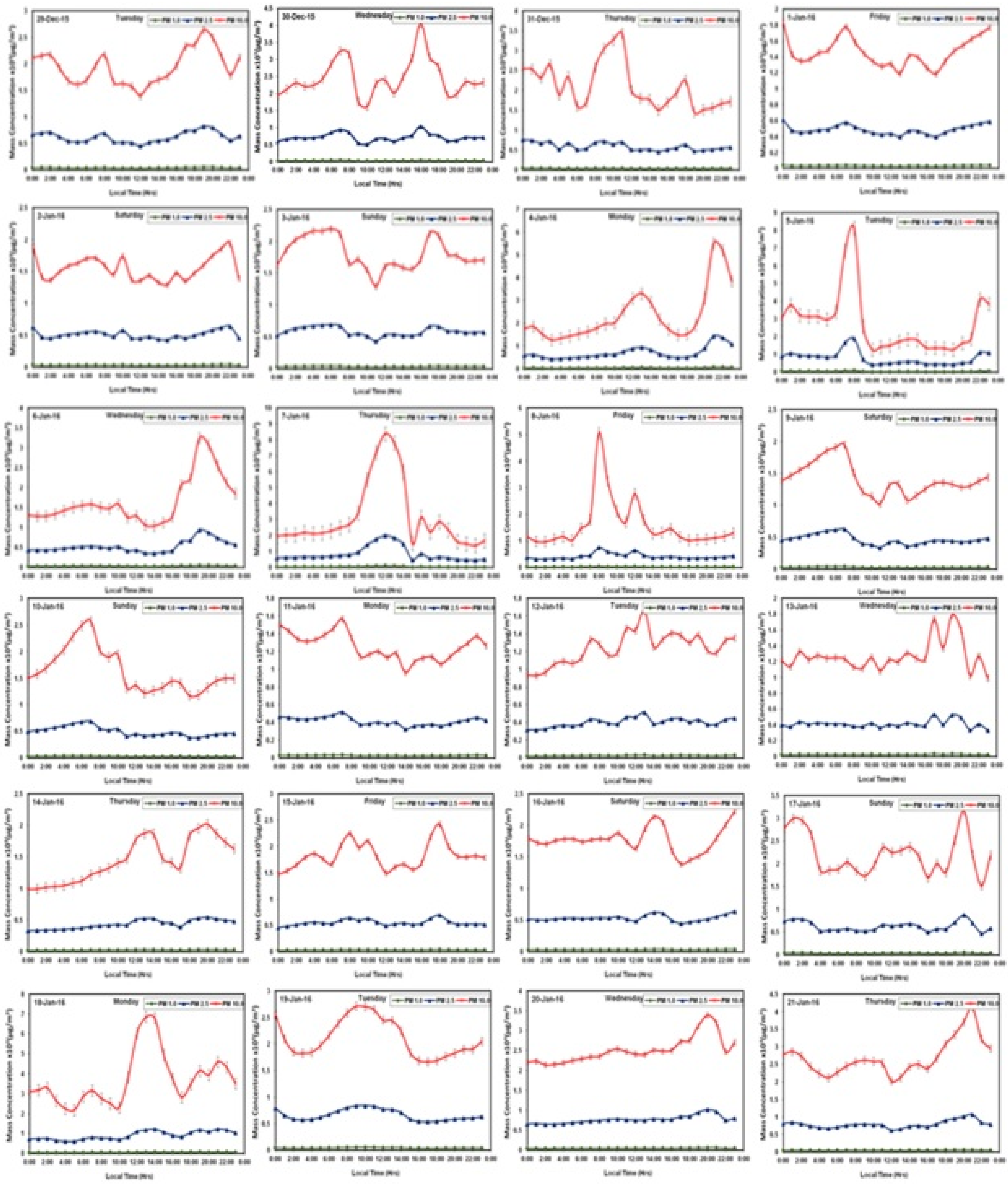


Figure 4: Diurnal variation of Particulate Matter (PM_1, $PM_{2.5}$ and PM_{10}) on different observation days over AUH, Panchgaon-Manesar-Gurgaon.

planetary boundary layer (PBL) height variations. The day-to-day variation in BC mass concentration during the study period is shown plotted in Figure 3. Higher concentration during the turbid-sky conditions and less concentration during the clear-sky conditions may be noted. Figure 4 portrays the diurnal variation of PM_1, $PM_{2.5}$, PM_{10} and Figure 5 displays the daily mean mass concentrations of $PM_{2.5}$ and PM_{10} recorded with TSI-make Aerodynamic Particle Sizer (APS) over AUH, Panchgaon. It is glaringly seen that PM_{10} concentrations dominate as compared to $PM_{1.0}$ and $PM_{2.5}$ concentrations. The higher PM_{10} concentrations are attributed to dust outbreak in and around the experimental site, whenever wind speeds are strong. It may be noted that the observed $PM_{2.5}$concentrations over Panchgaon are over four times lower than that of concentrations over urban Delhi. $PM_{2.5}$, being particulate matter which adversely affects the health and PM_{10} concentrations influences the earth-atmosphere radiation balance vis-à-vis local short-term climate changes.

The daily diurnal mean mass concentration values of PM_1, $PM_{2.5}$, PM_{10} and BC are presented in Table 1. It is interesting to note that $PM_{2.5}$ mass concentration is four times lower than that of urban Delhi. Likewise, the major PM_{10} concentration at Amity University Haryana is also less than half of what is reported from urban Delhi. It may be noted here that both PM and BC variations are highly influenced by the meteorological phenomena (associated bidirectional

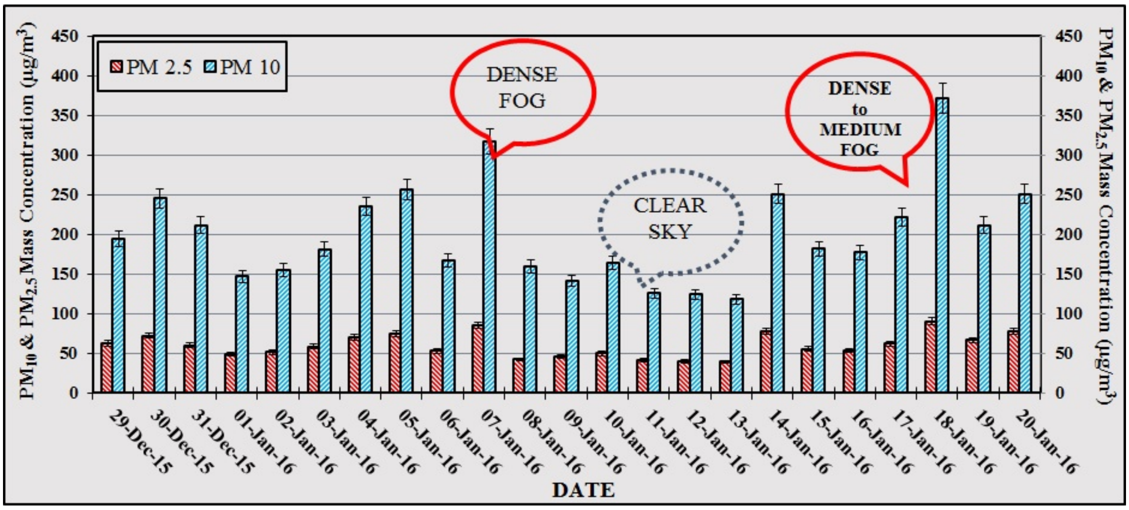


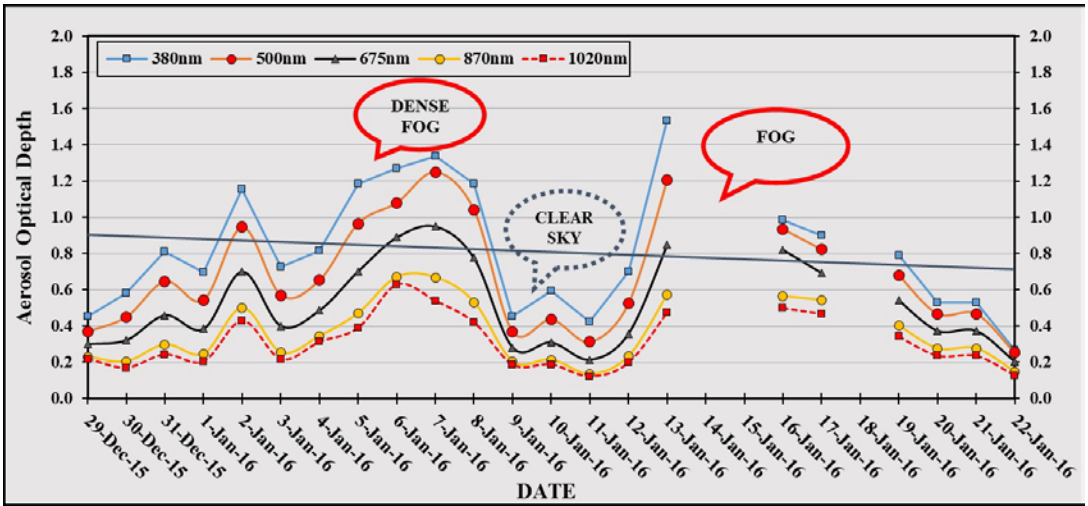
Figure 5: Day-to-day variation in PM mass concentration during 29 December 2015-20 January 2016

feedbacks on air pollutants) such as Western Disturbances (WDs) and Fog. The high wind speeds associated with WD (and long-range transport) remove pollutants, resulting in low concentrations in the study region. At the same time, these winds also may bring fresh particles from the surrounding regions and make the study region rich in concentration. On the other hand, fog (associated with low temperature) situations generally enhance the pollution levels due to secondary aerosol (new particle) formations, growth of exist-sting particles (depending on composition) and local boundary-layer dynamics. Therefore, the fluctuations in mass concentration during such complex meteorological situations should be treated with caution.

Table 1: Daily diurnal mean PM and BC mass concentrations from 29 December 2015 to 20 January 2016.

Date	PM1	PM2.5	PM10	BC
	Mass Concentration (μg/m^3)			
29/12/2015	4.14	62.51	194.10	4.81
30/12/2015	4.53	72.30	245.44	11.91
31/12/2015	3.81	59.65	211.72	15.22
01/01/2016	3.31	48.90	146.70	10.55
02/01/2016	3.46	51.25	155.10	9.95
03/01/2016	3.86	58.42	181.14	11.40
04/01/2016	4.39	70.30	234.97	9.00
05/01/2016	4.52	74.05	256.85	7.63
06/01/2016	3.45	52.97	166.51	9.85
07/01/2016	4.94	85.29	317.83	17.27
08/01/2016	2.71	42.28	159.23	9.98
09/01/2016	3.10	46.29	141.56	1.86
10/01/2016	3.25	49.74	164.10	1.80
11/01/2016	2.82	41.57	125.82	1.42
12/01/2016	2.69	40.03	124.34	2.10
13/01/2016	2.67	39.24	118.06	8.19
14/01/2016	4.96	77.44	251.19	5.38
15/01/2016	3.60	55.31	182.15	4.34
16/01/2016	3.45	53.31	177.40	1.53
17/01/2016	3.93	62.42	221.53	2.01
18/01/2016	5.31	90.49	371.75	2.71
19/01/2016	4.32	66.80	211.50	4.21
20/01/2016	4.96	77.44	251.19	2.13

Figure 6 displays day-to-day spectral variations in column-integrated aerosol optical depth (AOD), Ozone (TCO) and Precipitable Water Content (PWC). These observations are representative of atmospheric extinction (attenuation) up to stratospheric altitudes (~50 km).



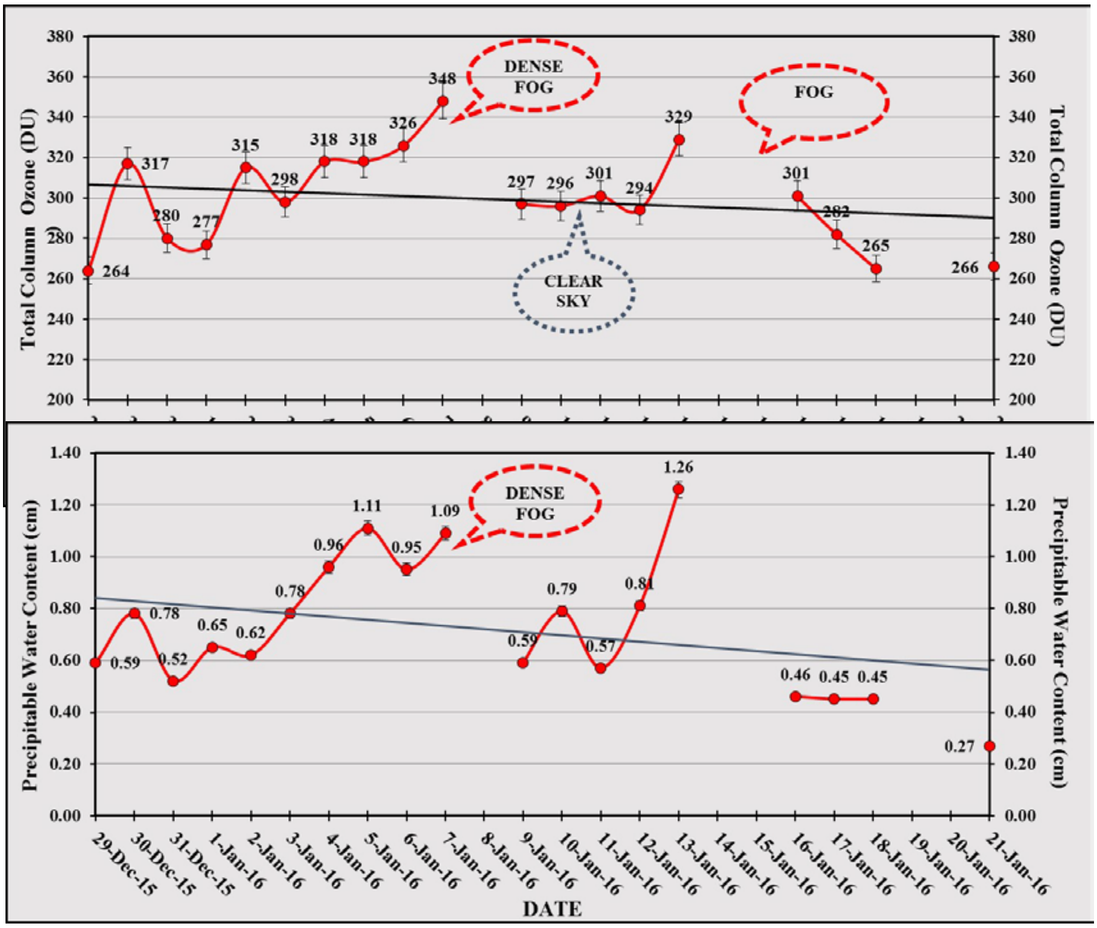


Figure 6: Solar radiometric observations for AOD, TCO and PWC during 29 December 2015 – 20 January 2016. The data gaps in the plot are due to obscuration of Sun either due to clouds and/or fog. The dashed lines in the TCO and PWC frames indicate linear trend in the variations.

The plot clearly shows the wavelength dependence (more extinction at shorter wavelengths). It is evident from the figure that higher AODs observed on 02 & 04January, 2016, which may be due to combined effect of Western Disturbances-induced Air Mass trajectories (Figure 4).However, because winds can advect foreign particles from upwind regions, and also scavenge existing particles over the study region, the influence of winds on air quality is complex.

The air-mass back-trajectories of 5-day (120 hours) have been obtained using the NOAA-ARL HYSPLIT (Hybrid Particle Lagrangian Integrated Trajectory) model for all theobservation

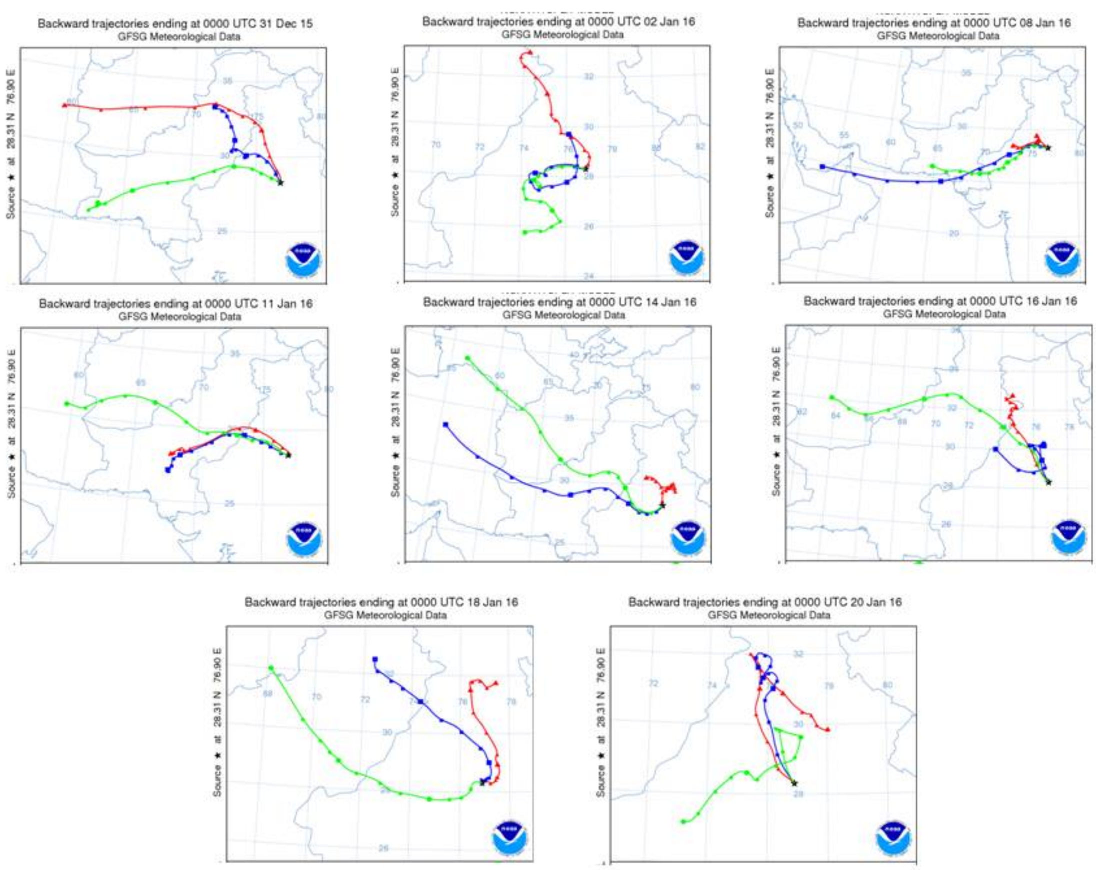


Figure 7: 5-Day Back Trajectories using NOAA HYSPLIT Model from 29-Dec-2015 to 20-Jan-2016. The asterik in each frame indicates location of the observation site (AUH, Panchgaon). The red, green and blue colored trajectories refer to 500, 1000 and 1500 m above ground level.

days and shown plotted in Figure 7. Evidently, on 02, 06, 07, 12, 19 and 20 January 2016, particulate fraction is relatively dominant from the land-origin. On the remaining days, the contribution to the pollution at the observing site comes from both land and marine sources.

From the above, it can be said that the study of air quality monitoring clearly reveals the benefit of odd-even campaign. The study, however, continues to bring out a clearer picture in respect of the correlation between weather condition and air quality.

Suggestions for Future Work

- We need to march beyond odd-even initiative as major gains shall be obtained by initiatives like re-routing the traffic in mega and metro cities like Delhi and Gurgaon. Further, it will be important for the Government of Delhi to consider segregating the mixed traffic as at present. Initiatives like battery operated rickshaws in certain areas of Delhi and CNG in the others, bringing back electric trams to Delhi and motivating the automobile industry to produce cost-effective battery operated automobiles and hybrid vehicles which will go a long way to solve further the problem of air pollution.

- The Government of Delhi may offer free charging of batteries from solar-powered charging stations to the battery-vehicle owners and even reduce the road tax by 50% for such vehicles. The Government of Delhi may also be well advised to offer say approximately 20% fuel subsidies to whoever opts for car-pooling. It may also be pertinent to note that while on one hand the odd-even initiative has created a hope for improving air quality, the regulators must come down heavily on Delhi metro and other major construction agencies who are contributing heavily to ever rising dust.
- In-ordinate delay in completion of projects like construction of fly-overs, re-construction of East Kidwai Nagar etc. is also a matter of grave concern.
- As the sample size is small and perturbed by varied meteorological conditions, we need to collect more data, covering from the surface through to earth observation, during fair weather conditions, to make more useful conclusion. We also need to understand the toxicity of pollutants and develop biomarkers that help setting-up of permissible respiratory levels for human health.

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RESEARCH NEWS

1. Source attributed premature mortality from ambient $PM_{2.5}$ exposure

Lelieveld, J., J. S. Evans, M. Fnais, D. Glannadaki and A. Pozzer (2015): *The contribution of outdoor air pollution sources to premature mortality on a global scale*,Nature, 525: 367-371.

Estimate of premature mortality burden due to ambient air pollution continues to be a hot topic among researchers across the world. Such estimates have large uncertainty because of the lack of adequate in-situ measurements of $PM_{2.5}$ and region-specific concentration risk function across large range of ambient air pollution exposure. More importantly, lack information about source-attributed exposure hinders in formulating appropriate policy to curb pollution. Using a global chemistry model, the authors concluded that emissions from household energy use for cooking and heating, primarily in China and India, have the largest contribution to global premature mortality. In large part of USA, traffic and power generations are dominant contributors, while agricultural emissions are largest contributor in eastern USA, Europe, Russia and East Asia.

2. Aerosol acidity remains high despite declining sulfate concentration

Weber, R. J., H. Guo, A. G. Russell and A. Nenes (2016):*High aerosol acidity despite declining atmospheric sulfate concentrations over the past 15 years,* Nature Geoscience, doi:10.1038/ngeo2665.

Atmospheric sulfate aerosol concentration has decreased over the last 15 years, while ammonium nitrate concentration remains almost constant. pH buffering by partitioning of NH_3 between particle and gaseous phases led to a relatively constant particle pH of 0-2. Particle acidity is important to understand the health impacts of aerosols, especially for fine particulate matter ($PM_{2.5}$). Until atmospheric sulfate concentration reduces to near pre-industrial level, aerosol acidity is unlikely to reduce.

3. Aerosol burden expected to increase in a warmer world

Allen, R. J., W. Landuyt and S. T. Rumbold (2016): *An increase in aerosol burden and radiative effects in a warmer world,* Nature Climate Change, 6: 269-274.

Analysis of state-of-the-art climate models revealed that climate change is associated with a negative aerosol-climate feedback of -0.02 to -0.09 $W\ m^{-2}\ K^{-1}$ for direct effect with indirect effect to be likely larger. This is due to an increase in aerosol burden in tropics and northern hemispheric midlatitudes, because of a decrease in wet deposition due to less large scale precipitation over land.

4. Challenges in quantifying aerosol-induced changes in cloud properties

Ghan, S., M. Wang, S. Zhang, S. Ferrachat, A. Gettelman, J. Griesfeller, Z. Kipling, U. Lohmann, H. Morrison, D. Neubauer, D. G. Patridge, P. Stier, T. Takemura, H. Wang and K. Zhang (2016): *Challenges in constraining anthropogenic aerosol effects on cloud radiative forcing using present-day spatiotemporal variability,* Proceedings of the National Academy of Sciences of the United States of America, doi:10.1073/pnas.1514036113.

Aerosol-cloud interaction depends on numerous confounding factors, many of which are difficult to measure or model. Uncertainty at every step, starting from emission inventory to relationships between aerosol and cloud parameters, and cloud parameters and precipitation, results in a large uncertainty to isolate aerosol impact on cloud and precipitation.

5. Recent Indo-Pacific SST trends suppress rainfall in mid-latitude East Asia

Ueda, H., Y. Kamae, M. Hayasaki, A. Kitoh, S. Watanabe, Y. Miki and A. Kumai (2015): *Combined effects of recent Pacific cooling and Indian Ocean warming on Asian monsoon,* Nature Communications, 6, doi:10.1038/ncomms9854.

While SST shows a cooling trend in the tropical Pacific Ocean in the last 15 years, it continues to increase in the Indian Ocean. Indo-Pacific SST anomalies cause intensification of convection over the tropical western Pacific basin, resulting in suppression of rainfall in East Asia through tele-connection. Though the Indian Ocean SST effect opposes the tropical Pacific SST effect, it is not strong enough to compensate it completely.

FORTHCOMING EVENTS

1. IASTA Conference 2016 -

The IASTA biennial conference will be held from 14 to 16 Dec, 2016 at Physical Research Laboratory (PRL), Ahmedabad. More information will be announced in the IASTA webpage soon.

2. AAAR 35th Annual Conference-

35th annual conference of American Association for Aerosol Research will be held from 17 to 21 Oct, 2016 at Oregon Convention Center, Portland, Oregon, USA. Detailed information can be found in: **http://www.aaar.org/index2.cfm?section=meetings_and_events**.

3. 22nd European Aerosol Annual Conference -

22nd European aerosol annual conference will be held from 4 to 9 Sep, 2016 in Yours, France. Detailed information can be found in: **http://wwweac2016.fr**.

4. FEA International Aerosol Congress -

The 29th FEA International Aerosol Congress and 18th Exhibition will be held from 4 to 6 Oct in Istanbul, Turkey. Detailed information can be found in: **https://www.aerosol2016istanbul.com/aerosol-2016**.