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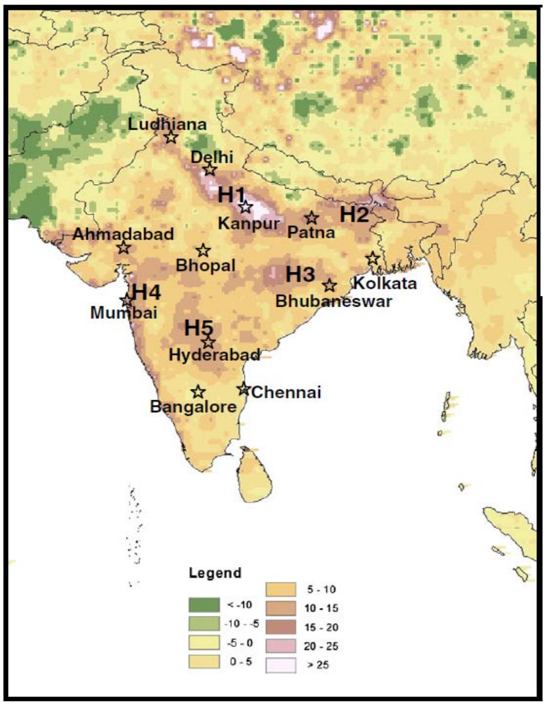

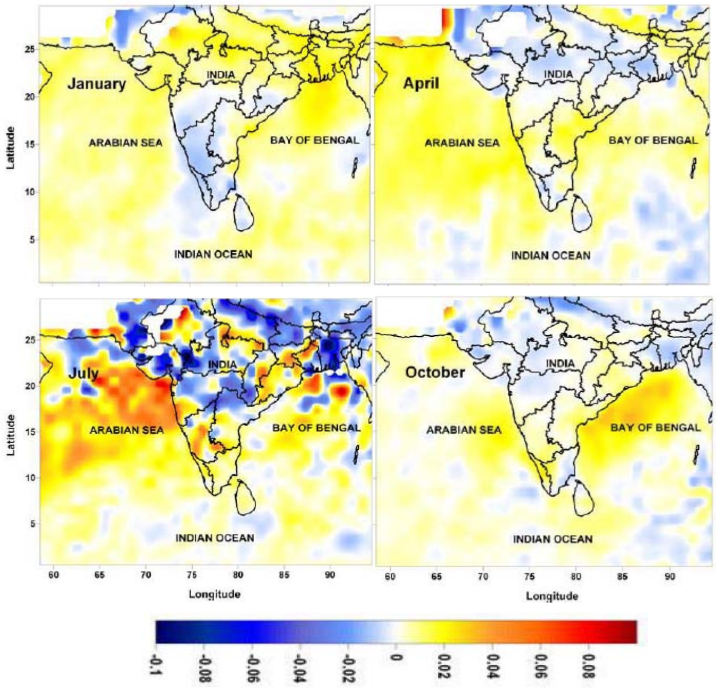

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Cover Photo: (Left) Total changes in surface $PM_{2.5}$ ($\mu g\ m^{-3}$) during 2000-2010 based on MISR data (Courtesy: *Dey et al., 2012, Rem. Sens. Environ. 127, 127-161*) and (Right)

CONTENTS

RESEARCH NEWS

1. Current knowledge in the aerosol trends over northern India

Dr. Dimitris G. Kaskaoutis (Shiv Nadar University, Noida; E-Mail: dimitriskask@hotmail.com)

1.1 Aerosol built-up over India and south Asia

Atmospheric aerosols affect the global climatic system in many ways, by attenuating the solar radiation reaching the ground, modifying the solar spectrum, re-distributing the earth-atmosphere energy budget and influencing cloud microphysics and hydrological cycle. Atmospheric aerosols over south Asia constitute a major environmental and climate issue. Numerous studies dealt with analyzing the aerosol properties, focusing mainly on the spatio-temporal distribution of the Aerosol Optical Depth (AOD) and possible feedbacks of aerosols on climate and monsoon. With the increase in population, urbanization, industrialization and demands for energy, the aerosol load over India is gradually increasing having significant impact on continuation of the solar dimming phenomenon (Badarinath et al., 2010; Kambezidis et al., 2012).

Both ground-based measurements and satellite observations agree to an overall increase in AOD over Indian sub-continent (Ramachandran and Cherian, 2008; Moorthy et al., 2013). These studies limited mainly to yearly variations and trends; the monthly and/or seasonal trends of AOD over different sub-regions had not been analyzed so far. More recently, the aerosol trend analysis over India emphasizes also on seasonality, like the studies by Kharol et al. (2011) using sun photometer and MODIS observations over Hyderabad, Dey and Di Girolamo (2011) using MISR data over Indian subcontinent and adjoining oceanic areas, Kaskaoutis et al. (2011) using MODIS data over south Asia with emphasis over Arabian Sea, Bay of Bengal, Northern Indian Ocean and Indo-Gangetic Plains (IGP), Kaskaoutis et al., (2012a) using AERONET data over Kanpur, Ramachandran et al. (2012) using MODIS data over the capitals of each Indian State, Lodhi et al. (2013) using sun photometer observations over Delhi. Overall, an increasing trend in aerosol loading is highlighted by all these studies

(10.17% during 2000-2009 over whole South Asia, according to Kaskaoutis et al. 2011), which exhibits large spatio-temporal differences being more intense during winter season and, especially over northern India. The AERONET data over Kanpur, available till 2001, gives us the possibility of examining possible trends in the almucantar-derived parameters also, like size distribution, single scattering albedo and refractive index. Such an analysis (Kaskaoutis et al., 2012a) revealed that the statistically significant increasing trend in post-monsoon/winter AOD is reflected in a shift of the columnar size distribution towards relatively larger particles in the accumulation mode, indicating coagulation and condensation of the primarily fine aerosols over a progressively turbid environment. The concurrent increase (7.69%) in AOD_{500} and in Ångström exponent (5.5%) during the period 2001-2010 suggests an increase in anthropogenic aerosols over Kanpur, especially after 2005 (Fig. 1). The increasing aerosol emissions, mainly from anthropogenic activities, are responsible for the presence of the atmospheric brown clouds, which have significant climate implications in view of heating the middle and upper troposphere and influencing the monsoonal circulation (Ramanathan et al., 2007).

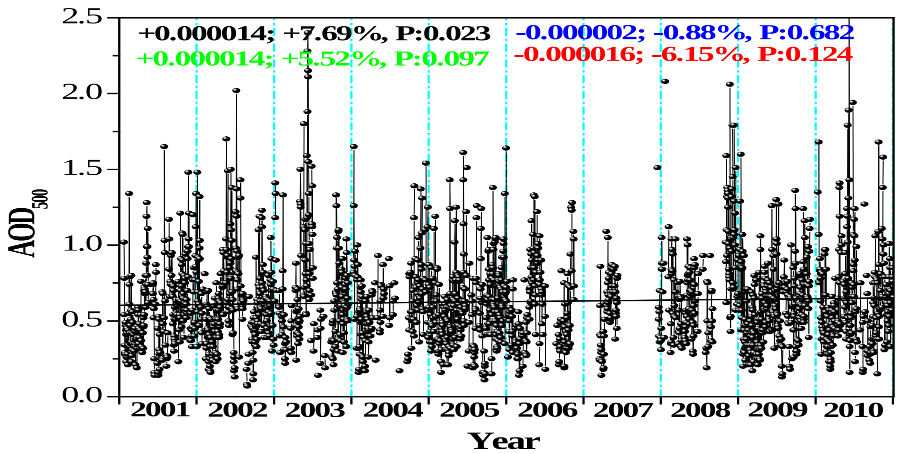

Figure 1. Inter-annual variability and trend of the AOD_{500} daily values over Kanpur for 2001-2010. The slope of the regression analysis along with the % difference and the P value are given. Black for AOD_{500}, green for α(440-870), blue for α(380-500) and red for α(675-870). [Source: Kaskaoutis et al., ERL, 2012]

1.2 Evidence of declining aerosol trend over IGP during pre-monsoon/monsoon seasons

Except the general increasing aerosol trend over India, MODIS (Kaskaoutis et al., 2011) and MISR (Dey and Di Girolamo, 2011) observations firstly revealed a declining AOD trend over IGP during late pre-monsoon and monsoon months (May to September) during the 2000s. However, in the majority of the cases, this declining trend is not statistically significant due to large intra-annual fluctuations in AOD over IGP. However, it's presence attracted the scientific interest to be examined further. Analysis of the AOD trends using Kanpur AERONET data (2001-2010) verified this feature, revealing an AOD decrease of -0.01 per year in June, when the dust activity is at its maximum (Kaskaoutis et al., 2012a). The analysis of the size distribution over Kanpur showed a general decrease in coarse-mode fraction associated with variable dust activity during the 2000s, verified the results of attenuation in dust activity during the second half (2005-2010) of the previous decade. Thus, the AOD decrease seems to be attributed to weakness of dust activity in the northern part of India during the last decade. GOCART model simulations over south Asia revealed a pronounced decreasing trend in dust AOD and in dust contribution to the total AOD over south Asia during 2000-2007, which are in general agreement with the ground-based and satellite observations. However, much more analysis and longer dataset are required for establishing this evidence.

1.3 Reasons for the AOD declining trend

Since the main aerosol type over northern India in late pre-monsoon and monsoon seasons is dust transported mainly from the Thar desert, the fluctuations in dust emission, transport and dust-aerosol lifetime are of considerable importance in order to explain the AOD variability over this region. Kanpur (Fig. 1) as well as Delhi aerosol dataseries revealed considerable high AODs during monsoon of 2002 and late pre-monsoon of 2003, so the interest was focused on examining these periods. A synergy of satellite and ground-based radiometric observations, along with chemical transport modeling and NCEP/NCAR reanalysis data, was used for the assessment of the influence of the weather conditions of summer/monsoon 2002 and 2003 on aerosol properties over northern India (Kaskaoutis et al., 2012b). The meteorology data showed prevalence of westerlies under anti-cyclonic circulation and subsidence favoring the accumulation of aerosols. Subsequently, the anomalous and prolonged dry conditions favored heavy aerosol buildup as indicated by strong positive anomalies (20-80%) of MODIS AOD (Fig. 2). Ground-based sun photometer observations at Delhi and Kanpur also revealed enhanced presence of desert-dust aerosols during July 2002 and May-June 2003, characterized by large AOD and significantly low Angstrom exponent values. The analysis suggested a cause-and-effect association between the deficit of monsoon rainfall, and increased dust activity as well as prolonged aerosol lifetime that influences the dynamics and persistence of the spatio-temporal aerosol loading, and associated optical properties over northern India. The role of rainfall in aerosol properties and variations is very crucial during the monsoon season. On the other hand, the increase in aerosol loading over northern India may also affect precipitation and hydrological cycle (Lau et al., 2006). However, it is difficult to quantify the influence of rainfall in AOD trends over Kanpur, since anthropogenic emissions and dust transport play a significant role in influencing aerosol loading and properties. In synopsis, the deficit of rainfall during monsoon of 2002 and late pre-monsoon of 2003 caused an increase in dust activity and atmospheric aerosol lifetime over northern India strongly influencing the AOD trends over IGP during the last decade.

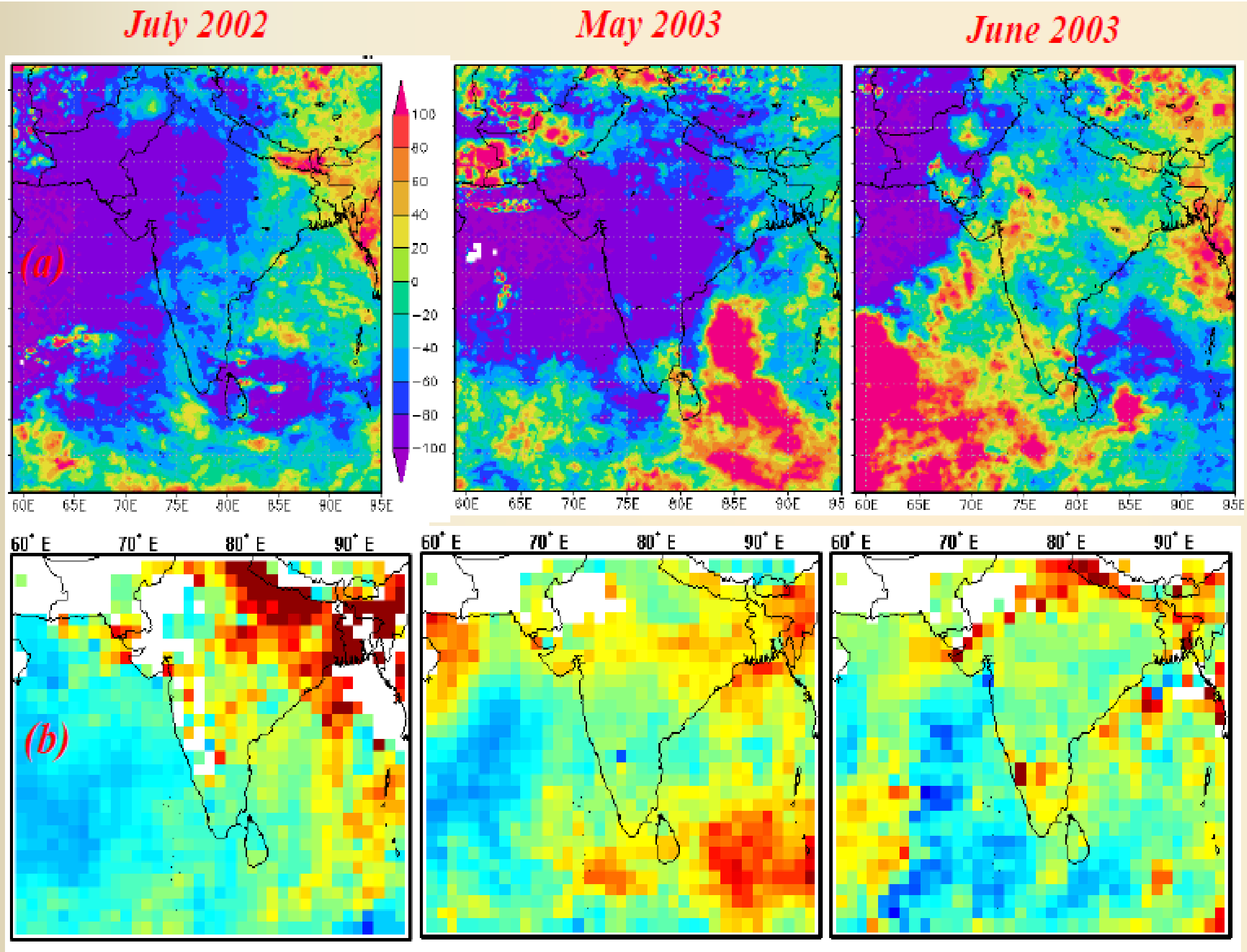

Figure 2: (a) Monthly normalized rainfall anomaly (%) for July 2002 and for May-June 2003 based on the monthly rainfall climatology of TRMM 3B43 V6 during the period 1998-2009, (b) percentage deviation of the Terra-MODIS AOD_{550} for July 2002 and for May-June 2003 from the monthly mean value during the period 2000-2009. [Source: Kaskaoutis et al. JGR, 2012]

1.4 Concluding remarks

It is well known that the two main contrasting seasons over northern India (late post-monsoon/winter and pre-monsoon/monsoon), dictate variations in aerosol type and their spatial, temporal and vertical distribution. Recently, ground-based and satellite observations agree to a significant differentiation in aerosol-loading trends between these two seasons. The trends (increasing for the first and declining for the second season) have been established and consolidated by several recent works and the critical is to examine if they will be in force during the next years also. However, some critical issues have to be better clarified and answered in order the current knowledge about aerosol trends in India to be enhanced further. Some of these issues are summarized in the followings:

Why the neutral-to-declining trend is observed only during the hot and dry period of the year, when the natural aerosols dominate over northern India ? Why this phenomenon is not so obvious over the central Deccan plateau and along the coastal regions ? Does it depend only on the anomalous high aerosol loading during pre-monsoon of 2003 and monsoon of 2002 or do other factors play a role as well? Is this trend a fingerprint of variations in specific aerosol types? Is the change in meteorological conditions, monsoon system and/or El-Nino Southern Oscillation in specific periods and years able to control the aerosol trends and over which regions ? Why the aerosol built-up over whole Indian sub-continent is nearly vanished during late pre-monsoon and monsoon seasons? Is this phenomenon based mostly on the unchanged anthropogenic emissions or on the intra-annual fluctuations of the natural aerosols ? In order to have a clear view of all the above-mentioned queries, systematic monitoring of the aerosol properties from ground and space is needed, along with improvement in the current inventories that the chemical transport models use for the aerosol simulations. Furthermore, the specific role of the synoptic and dynamic meteorology in the aerosol trends over India as well as the changes in the monsoon circulation and annual variations of ENSO have to be better consolidated.

References :

Badarinath, K. V. S., A. R. Sharma, D. G. Kaskaoutis, S. K. Kharol and H. D. Kambezidis (2010), Solar dimming over the tropical urban region of Hyderabad, india: Effect of increased cloudiness and increased anthropogenic aerosols, *J. Geophys. Res., 115*, D21208.

Dey, S. and L. Di Girolamo (2011), A decade of change in aerosol properties over the Indian subcotinent, *Geophys. Res. Lett.*, *38*, L14811.

Kambezidis, H. D, D. G. Kaskaoutis, S. K. Kharol, K. Krishna Moorthy, S. K. Satheesh, M. C. R. Kalapureddy, K. V. S. Badarinath, A. R. Sharma and M. Wild (2012), Multi-decadal variation of the net downward shortwave radiation over south Asia: The solar dimming effect, *Atmos. Environ., 50*, 360-372.

Kaskaoutis, D. G., S. K. Kharol, P. R. Sinha, R. P. Singh, H. D. Kambezidis, A. R. Sharma and K. V. S. Badarinath (2011), Extremely large anthropogenic-aerosol contribution to total aerosol laod over the Bay of Bengal during winter season, *Atmos. CHem. Phys., 11*, 7097-7117.

Kaskaoutis, D.G., Gautam, R., Singh, R.P., Houssos, E.E., Goto, D., Singh, S., Bartzokas, A., Kosmopoulos, P.G., Sharma, M., Hsu, N.C., Holben, B.N. and Takmura, T. (2012a). Influence of Anomalous Dry Conditions on Aerosols over India: Transport, Distribution and Properties, *J. Geophys. Res. 117*, D09106, doi: 10.1029/2011JD017314.

Kaskaoutis, D. G., R. P. Singh, R. Gautam, M. Sharma, P. G. Kosmopoulos and S. N. Tripathi (2012b), Variability and trends of aerosol properties over Kanpur, northern India using AERONET data (2001-10), *Environ. Res. Lett., 7*, doi:10.1088/1748-9326/7/2/024003.

Kharol, S. K., K. V. S. Badarinath, A. R. Sharma, D. G. Kaskaoutis and H. D. Kambezidis (2011), Multiyear analysis of Terra/Aqua MODIS aerosol optical depth and ground observations over tropical urban region of Hyderabad, India, *Atmos. Environ., 45*, 1532-1542.

Lau, K. M., M. K. Kim and K. M. Kim (2006), Asian summer monsoon anomalies induced by aerosol direct forcing: the role of Tibetan Plateau, *Clim. Dyn., 26*, 855-864.

Lodhi, N. K., S. N. Beegum, S. Singh and K. Kumar (2013), Aerosol climatology at Delhi in the western Indo-Gangetic Plain: Microphysics, long-term trends and source strengths, *J. Geophys. Res., 118*, 1361-1375.

Moorthy, K. K. et al. (2013). Buildup of aerosols over the Indian region, *Geophys. Res. Lett., 40*, 1011-1014.

Ramachandran, S., and R. Cherian (2008), Regional and seasonal variations in aerosol optical characteristics and their frequency distributions over India during 2001-2005, *J. Geophys. Res., 113,* D08207.

Ramanathan, V. et al. (2007), Atmospheric brown clouds: Hemispherical and regional variations in long-range transport, absorption, and radiative forcing, *J. Geophys. Res., 112*, doi:10.1029/2006JD008124.

2. Heterogeneity in aerosol characteristics over the Indo-Gangetic Basin: Types and implications to radiative forcing

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Though the level of scientific understanding of aerosols has been increased by incorporating different *in-situ* measurements along with various satellite measurements, still it is far less than that of greenhouse gases (IPCC, 2007). Heterogeneity in various aerosol characteristics over a wide range of spatial and temporal scales could be one of the major causes of difficulties in reducing the level of scientific understanding due to aerosols. Also, this is ~~also~~ one of the causes of enhanced uncertainty in estimation of radiative forcing. Thus, it is important to improve aerosol characterization on regional basis with high spatial and temporal resolutions; particularly over the region, where large heterogeneity may take place.

The Indo-Gangetic Basin (IGB) is one such region situated in northern part of India where aerosols from different sources exhibit large spatial and temporal variability in their loading and their various characteristics such as chemical, optical, microphysical and radiative. The region is one of the densely populated and heavily polluted regions of Indian subcontinent, surrounded by the variety of natural and man-made emission sources. It is of great research interest due to its unique topography surrounded by the Himalayas to the north, moderate hills to the south, Thar Desert and Arabian Sea in the west, and Bay of Bengal in the east. The mean aerosol optical depth (AOD) over the region was observed to be ~50% higher than any other regions in India, with relative abundance of fine-mode aerosol loading at the eastern part compared to the other parts of the IGB.

Although, satellites are proved to be the good tool to understand the broad spatio-temporal characteristics of aerosols and associated effects over a wider region (Di Girolamo et al., 2004; Jethva et al., 2005; Prasad and Singh, 2007; Dey and Di Girolamo, 2010); they are unable to provide an in-depth view of aerosol characterizations on local scale and pose higher uncertainties as compared to the ground-based instruments (Tripathi et al., 2005). As a result, aerosol properties change may lead to even larger uncertainty in satellite retrievals, as this is not considered in the aerosol retrieval algorithm (Kahn et al., 2009).

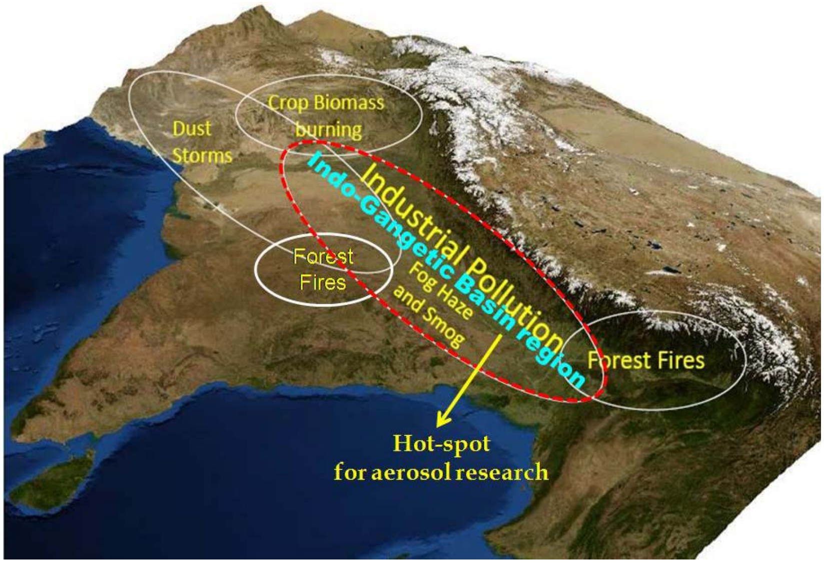

Fig. 1 The IGB region, illustrating unique topography surrounded by the variety of emission sources. (*Adopted after modification from personal presentation of William K. M. Lau*)

Significant heterogeneity optical and microphysical properties of aerosols and associated radiative impacts have been studied for the first time using ground-based automatic sun/sky radiometer measurements at different locations over IGB during the pre-monsoon period (April-June) (Srivastava et al., 2011; Tiwari et al., 2013), which is hypothesized to affect the Indian summer monsoon circulation and also the global climate system. The sun/sky radiometers were deployed world-wide (including few stations in India, particularly in north India) under the Aerosol Robotic Network (AERONET) program of NASA, USA (Holben et al., 1998). The pre-monsoon period is of particular interest because this is the key period when locally generated and regionally transported aerosol loading peaks over the IGB region and spread up to climatically sensitive regions of Himalayan foothills (Devi et al., 2011; Gautam et al., 2011; Srivastava et al., 2012a), which has been linked to influence the monsoon circulation activities and rainfall distributions, particularly in India (Lau et al., 2006, 2010). Further, due to high level of anthropogenic emissions over the IGB, aerosol distribution in terms of types and loading undergo strong variability associated with the episodic yet strong influence of dust transport and biomass burning aerosols, particularly during the pre-monsoon period (Gautam et al., 2011; Srivastava et al., 2012b).

In a recent study, Srivastava et al. (2012b) have inferred different aerosol types over the central and eastern parts of IGB using multi-year ground-based sun/sky radiometer measured aerosol products associated with the size and radiation absorptivity of aerosols during pre-monsoon period. High dust enriched aerosols (i.e. polluted dust, PD) were found to contribute more over the central IGB region at Kanpur (~62%) as compared to the eastern IGB region at Gandhi College (~31%) whereas vice-versa was observed for polluted continental (PC) aerosols, which contain high anthropogenic and less dust particles. Contributions of carbonaceous particles having high absorbing (mostly black carbon, MBC) and low absorbing (mostly organic carbon, MOC) aerosols were found to be ~11% and 10%, respectively at Gandhi College, which was ~ 46% and 62% higher than the observed contributions at Kanpur; however, very less contribution of non-absorbing (NA) aerosols was observed only at Gandhi College (~2%). Further, Srivastava et al. (2013) in another study have also inferred similar aerosol types over the western IGB region at Delhi. The inferred aerosol types, e.g. PD, PC, MBC and MOC over Delhi were identified to be contributed ~48%, 32%, 11% and 9%, respectively to the total aerosols. The measured optical properties for the above inferred aerosol types differed considerably, which may influence the overall radiation budget and thereby climate change over the wide region.

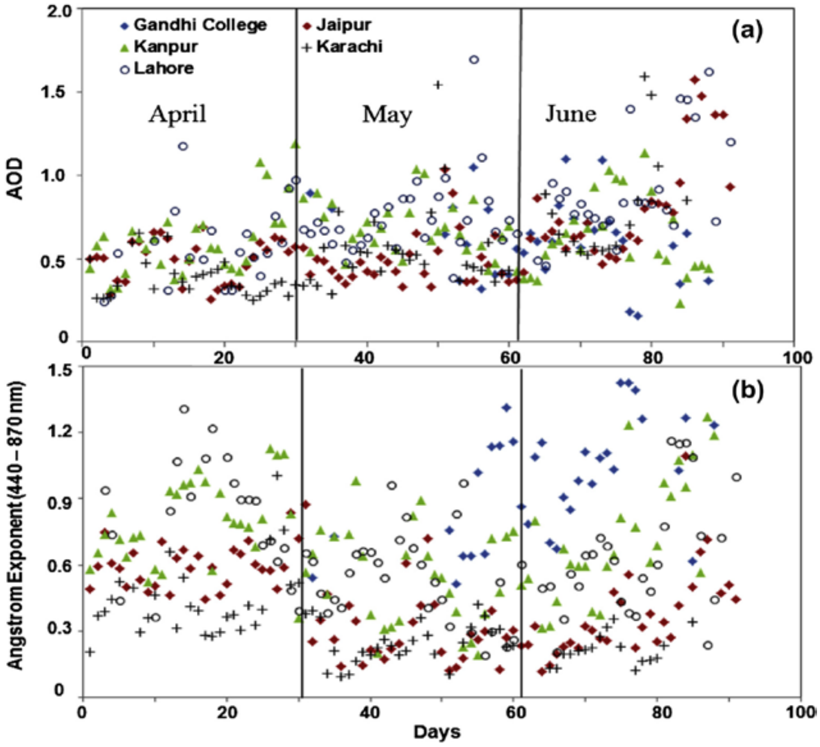

Fig. 2 Spatio-temporal variability in AOD and angstrom exponent (AE) during pre-monsoon (2011) over IGB. (*Adopted from Tiwari et al., 2013*).

References

Devi JJ, Tripathi SN, Gupta T, Singh BN, Gopalakrishnan V, Dey S (2011) Observation-based 3-D view of aerosol radiative properties over Indian Continental Tropical Convergence Zone: implications to regional climate. Tellus 63B: 971-989.

Dey S and Di Girolamo L (2010) A climatology of aerosol optical and microphysical properties over the Indian subcontinent from 9 years (2000–2008) of Multiangle Imaging Spectroradiometer (MISR) data. J. Geophys. Res. 115: D15204, doi:10.1029/2009JD013395.

Di Girolamo L, et al. (2004) Analysis of Multi-angle Imaging Spectro-Radiometer (MISR) aerosol optical depths over greater India during winter 2001-2004. Geophys. Res. Lett. 31: L23115, doi:10.1029/2004GL021273.

Gautam R, Hsu NC, Tsay SC, Lau KM, Holben B, Bell S, Smirnov A, Li C, Hansell R, Ji Q, Payra S, Aryal D, Kayastha R, Kim KM (2011) Accumulation of aerosols over the Indo-Gangetic plains and southern slopes of the Himalayas: distribution, properties and radiative effects during the 2009 pre-monsoon season. Atmos. Chem. Phys. 11: 12841–12863.

Holben BN, et al. (1998) AERONET–A federated instrument network and data archive for aerosol characterization. Remote Sens. Environ. 66: 1–16, doi:10.1016/S0034-4257(98)00031-5.

Intergovernmental Panel on Climate Change (IPCC) (2001) Climate Change 2001: The Scientific Basis, edited by J. T. Houghton et al., Cambridge Univ. Press, New York, 881 p.

Jethva H, Satheesh SK, Srinivasan J (2005) Seasonal variability of aerosols over the Indo-Gangetic basin. J. Geophys. Res. 110: D21204, doi:10.1029/2005JD005938.

Kahn RA, et al. (2009) MISR aerosol product attributes and statistical comparisons with MODIS. IEEE Transactions on Geoscience and Remote Sensing 47(12): 4095-4114.

Lau KM, Kim MK, Kim KM (2006) Asian summer monsoon anomalies induced by aerosol direct forcing: The role of the Tibetan Plateau. Clim. Dyn. 26(7-8): 855-864, doi:10.1007/s00382-006-0114-z.

Lau KM, Kim MK, Kim KM, Lee WS (2010) Enhanced surface warming and accelerated snow melt in the Himalayas and Tibetan Plateau induced by absorbing aerosols. Environ. Res. Lett. 5: 1-10.

Prasad AK and Singh RP (2007) Changes in aerosol parameters during major dust storm events (2001–2005) over the Indo-Gangetic Plains using AERONET and MODIS data. J. Geophys. Res. 112: D09208, doi:10.1029/2006JD007778.

Srivastava AK, Tiwari S, Devara PCS, Bisht DS, Srivastava MK, Tripathi SN, Goloub P, Holben BN (2011) Pre-monsoon aerosol characteristics over the Indo-Gangetic Basin: Implications to climatic impact. Ann. Geophys. 29: 789–804.

Srivastava AK, Singh S, Pant P, Dumka UC (2012a) Characteristics of black carbon over Delhi and Manora Peak-a comparative study. Atmos. Sci. Let., 13: 223–230.

Srivastava AK, Tripathi SN, Dey S, Kanawade VP, Tiwari S (2012b) Inferring aerosol types over the Indo-Gangetic Basin from ground based sunphotometer measurements. Atmos. Res. 109-110: 64-75.

Srivastava AK, Yadav V, Pathak V, Singh S, Tiwari S, Bisht DS, Goloub P (2013) Variability in aerosol characteristics over Delhi in the western Indo-Gangetic Basin: Identification of aerosol types and implications to radiative forcing. Science of the Total Environment (*under review*).

Tiwari S, Srivastava AK, Singh AK (2013) Heterogeneity in pre-monsoon aerosol characteristics over the Indo-Gangetic Basin. Atmos. Environ. 77: 738-747.

Tripathi SN, Dey S, Chandel A, Srivastva S, Singh RP, Holben B (2005) Comparison of MODIS and AERONET derived aerosol optical depth over the Ganga basin, India. Ann. Geophys. 23: 1093-1101.

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3. Satellite-based estimation of $PM_{2.5}$ distribution over India

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3.1 Satellite-based $PM_{2.5}$ measurement

Recent global burden of disease study (e.g.) pointed out ambient air pollution is one of the leading causes of mortality in the Indian subcontinent. In this region, particulate matter is one of the major criteria pollutants. Particles smaller than 2.5 µm ($PM_{2.5}$) can reach our alveoli; hence they are considered as very good indicator for health impact assessments (WHO, 2006). Epidemiological studies examining the impacts of $PM_{2.5}$ on human health depends on robust statistics of $PM_{2.5}$ concentration at various spatial and temporal scales (e.g. Anenberg et al., 2010). Unfortunately, such long-term measurements are not available in India under the ground-based network maintained by Central Pollution Control Board. Moreover, mostly these in-situ measurements are confined to urban regions, thereby overlooking large semi-urban and rural population.

To address this critical issue, satellite data were analyzed to estimate surface $PM_{2.5}$ concentration over India for the period 2000-2010. Multiangle Imaging Spectro Radiometer (MISR), onboard NASA EOS-Terra satellite retrieves columnar aerosol optical depth (AOD) routinely since Mar 2000 at 17.6 km resolution. The quality of MISR-AOD retrieval has been discussed in the literature (Kahn et al., 2010; Dey and Di Girolamo, 2010). The method used a conversion factor (η) to convert the columnar AOD to surface $PM_{2.5}$. η has been derived from a chemical transport model (van Donkelaar et al., 2010). The model utilized the emission inventory to estimate 3-D aerosol distribution based on the synoptic meteorology, where the vertical distribution is constrained by CALIPSO-derived aerosol profiles and columnar AOD by satellite-retrieved AOD. Thus η is a function of emission and meteorology (the two factors that influence the aerosol distribution) and not just the regression coefficient between AOD and $PM_{2.5}$. Furthermore, the utility of this η lies in the fact that the chemical transport model does not need to be operated every time; rather it can be simply used to convert satellite-retrieved AOD to surface $PM_{2.5}$ at any site.

The $PM_{2.5}$ concentration derived by the above method was validated against the coincident in-situ observations. The under-estimation in the satellite-based estimates of $PM_{2.5}$ with respect to in-situ observations is mostly attributed to two factors – (i) under-estimation in MISR-retrieved AOD relative to ground-based measurements in India (Dey and Di Girolamo, 2010) and (ii) model uncertainty. Further detailed analysis (as documented in Dey et al., 2012) revealed that the error in this new method is linear and a bias correction was applied to the entire dataset. Bias-corrected satellite-based $PM_{2.5}$ showed much improved correlation with in-situ data. Space-time distribution of $PM_{2.5}$ over the Indian subcontinent was examined using the bias-corrected dataset.

3.2 $PM_{2.5}$ Distributions and Health Implications

Decadal statistics of satellite-based $PM_{2.5}$ revealed that the mean annual concentration exceeds World Health Organization standard of 10 μg m^{-3} over 70% (49% of the inhabited area) of the region, where 83% of the total 1.4 billion population lives (Fig. 1a). This enormous pollution is not only observed in the urban areas, but also observed in the semi-urban and rural areas. Further analysis focusing on 46 major urban areas (where population exceeds 1 million) revealed that the $PM_{2.5}$ concentration is higher than the Indian standard (60 μg m^{-3}) in 18 urban areas. These cities are (in decreasing order of mean annual concentration) Delhi, Meerut, Ludhiana, Agra, Kolkata, Patna, Lucknow, Kanpur, Mumbai, Asansol, Allahabad, Amritsar, Varanasi, Dhandbad, Jaipur, Jamshedpur, Surat and Bhbaneswar. It may be noted that annual $PM_{2.5}$ concentration in many big urban areas (e.g. Bangalore, Chennai) is lower than that in rural areas in the Indo-Gangetic Basin. The episodic nature of such high particulate pollution has also been examined. Daily $PM_{2.5}$ exceeding the World Health Organization interim target of 75 μg m^{-3} (which has potentially 5% higher short-term mortality risk relative to exposure to clean air with annual $PM_{2.5}$ less than 25 μg m^{-3}) in 40-50% of the clear days in the Indo-Gangetic Basin and Mumbai metropolitan area. If the lower interim target (37.5 μg m^{-3}, Fig. 1b) is considered, frequency occurrence of daily

$PM_{2.5}$ exceeding the level is observed to be >75% of the time in a year. This suggests that the enormous pollution in these areas is rather persistent and thus bears more critical health implications. Five major hotspots (where $PM_{2.5}$ has increased by >15 μg m^{-3} in the last decade) were identified in the analysis (left cover photo). These are western Indo-Gangetic Basin (H1), parts of rural areas of Bihar and West Bengal (H2), parts of Orissa and Chhattisgarh (H3), industrial belt in Gujarat and Maharashtra (H4) and industrial belt surrounding Hyderabad (H5).

The first regional scale analysis of $PM_{2.5}$ over India has revealed many interesting facts and further emphasized on the following key issues that remain to be resolved:

(i) generation of a health database and cohort studies at the five hotspots shown above to establish exposure-response function for India

(ii) examination of composition of $PM_{2.5}$ at these hotspots, because health impacts of particles strongly depends on the composition

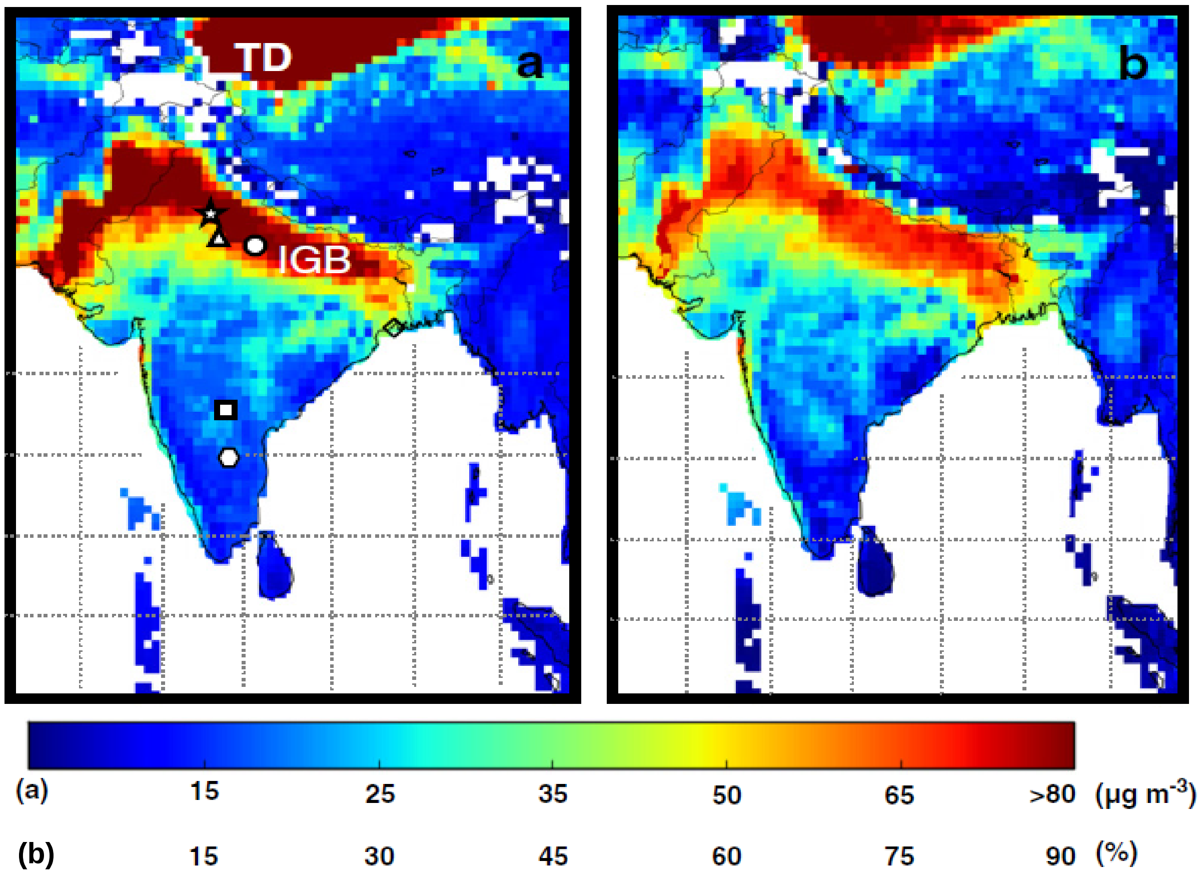

Fig. 1 Spatial distribution of (a) mean annual $PM_{2.5}$ as estimated from satellite-based bias-corrected datasets and (b) frequency occurrences of daily $PM_{2.5}$ exceeding WHO Interim target 3 (37.5 μg m^{-3}) in a year. The figure is adopted from Dey et al. (2012).

References:

Dey, S., L. Di Girolamo, A. Van Donkelaar, S. N. Tripathi, T. Gupta and M. Mohan (2012), Variability of outdoor fine particulate ($PM_{2.5}$) concentration in the Indian Subcontinent: A remote sensing approach, Rem. Sens. Environ., 127, 153-161.

Dey, S. and L. Di Girolamo (2010), A climatology of aerosol optical and microphysical properties over the Indian Subcontinent from 9 years (2000-2009) of MISR data, J. Geophys. Res., 115, D15204.

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4. Absorption enhancement by black carbon (BC) cored polydisperse aerosols under hygroscopic conditions

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Of the different aerosol species present in atmosphere, Black Carbon (BC) has great importance due to its highly absorbing nature. The estimation of radiative impact of BC strongly depends on the accurate measurement of its absorption coefficient, mass concentration and its mixing state. Mixing of BC with other inorganic species induces change in optical properties. Internal mixing of BC (homogeneous or a core-shell structure) shows more realistic absorption estimates as compared to external mixing models in which BC particles co-exist with other particles in a physically separated manner (Bondet al., 2006). Absorption by BC increases when BC particles are mixed and/or coated with other less absorbing materials, which are hygroscopic in nature. This enhanced absorption in a core-shell structure is because of the focusing effect of coated materials (shell) which act as a lens (Fuller 1995; Fuller et al., 1999).

In a recent study, the hygroscopic growth of aerosols during winter season over an urban site (Kanpur) in the Indo-Gangetic Plane (IGP) was estimated and the enhancement in BC absorption coefficient observed for the same period was explained based on this. From the calculated hygroscopic growth factor (g_{exp}) , a model has been derived to predict the chemical composition of particles. Absorption and scattering coefficients are derived using a core-shell assumption based on Mie theory. These derived optical parameters are compared with experimental values and the closure is found to be very close. The estimated optical properties agree within 5% for absorption coefficient and 30% for scattering coefficient with that of measured values. The enhancement of absorption is found to vary according to the thickness of the shell and BC mass, with a maximum of 2.3 for a shell thickness of 18 nm for the particles (Shamjad et al., 2012).

To quantify the hygroscopic growth of particles, a laboratory experiments were setup using two Scanning Mobility Particle Sizers (SMPSs) operating in parallel for 5 days in winter season of February 2011. One SMPS (TSI-model 3696) measures the ambient size distribution while other SMPS (Grimm-model no: 5.403) has a dryer attached to its inlet to remove the water content from the atmospheric aerosols thereby, measuring dry size distribution. The ratio of mode diameters of the ambient distribution to that of dry distribution is reported as g_{exp}. Using this hygroscopic growth factor (i.e. Zdanovskii-Stokes-Robinson (ZSR) approach), a model has been developed to predict the chemical composition of particles. An internal mixing of BC with a core-shell structure is assumed to be present during the winter season over Kanpur and the refractive index of core and shell is calculated using volume mixing rule. The core is assumed as a mixture of all species (BC, WISOC, WSOC, $(NH_4)_2SO_4$ and NH_4NO_3) in dry state and shell as a mixture of soluble species (WSOC, $(NH_4)_2SO_4$ and NH_4NO_3) with water content. Observed parameters such as size distribution, radii of core and shell, and their refractive indices are used to calculate the optical parameters of aerosol using Mie theory. These optical parameters showed good agreement with measured values. Enhancement in absorption (γ) due to hygroscopic growth is also calculated from Mie Theory. Figure 1 shows the variation in γ as a function of BC mass fraction and shell thickness. This figure shows a clear trend of increase in γ values as shell thickness increases for a constant BC mass fraction. While a maximum γ of 2.3 is observed for the shell thickness of 18 nm, the lowest γ of 1.035 corresponds to very thin coating (2 nm) (Shamjad et al., 2012).

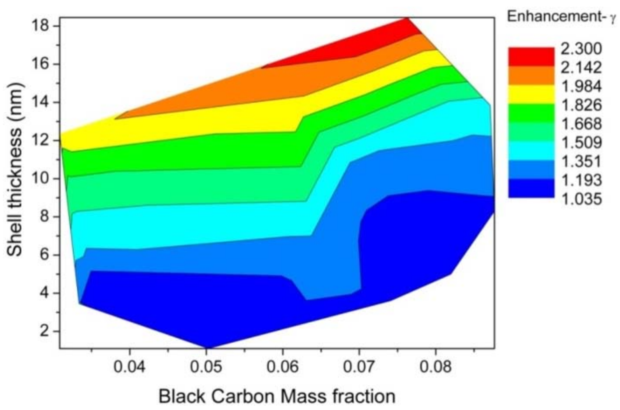

Figure 1: Absorption enhancement as a function of BC mass fraction and shell thickness. Each color shows range of absorption enhancement(Figure 4, Shamjad et al., 2012).

The study showed that a coating of soluble material over black carbon can significantly increase the absorption depending upon the thickness of the coating and type of coating material. High RH conditions and the presence of hygroscopic materials are very much favorable for forming such coatings. Knowledge of easily measurable hygroscopic growth factors can be effectively used to identify the volume fractions of different species present in the ambient aerosol. Using this information in conjunction with the size distribution data, an effective optical closure can be performed to match the experimental optical parameters.

REFERENCES

1. Bond, T. C.; Habib, G.; Bergstrom, R. W., Limitations in the enhancement of visible light absorption due to mixing state. *J. Geophys. Res.,* **2006,** *111*, (D20).

2. Fuller, K. A., Scattering and absorption cross sections of compounded spheres. III. Spheres containing arbitrarily located spherical inhomogeneities. , *J. Opt. Soc. Am. A 12, 893-904 (1995)* **1995**.

3. Fuller, K. A.; Malm, W. C.; Kreidenweis, S. M., Effects of mixing on extinction by carbonaceous particles. *Journal of Geophysical Research-Atmospheres* **1999,***104*, (D13), 15941-15954.
4. P. M, Shamjad.; Tripathi, S. N.; Aggarwal, S. K.; Mishra, S. K.; Joshi, M.; Khan, A.; Sapra, B. K.; Ram, K., Comparison of experimental and modeled absorption enhancement by Black Carbon (BC) cored polydisperse aerosols under hygroscopic conditions. *Environmental Science & Technology* **2012**.

INTERNATIONAL RESEARCH NEWS

1. Aerosols considered as a dominant factor in influencing the tropical storm variability

A new study (*Dunstone et al.,* 2013) has revealed aerosols as a driving factor in influencing the variability of tropical Atlantic storms. Simulations by CMIP models for the period 1860-2050 have shown that the anthropogenic aerosols lowered the frequency of the North Atlantic tropical storms during the 20^{th} century. Rapid decline in anthropogenic aerosol loading over the North Atlantic at the end of the 20^{th} century has resulted in an increase in the frequency of tropical storms. The decadal variability in the North Atlantic tropical storms has been strongly linked to aerosol-induced north-south shifts of the Hadley circulation. These results indicate the importance of the dynamic impact of anthropogenic aerosols on the atmospheric circulation. This study raises an important issue, which is even more critical in the Indian context because of large anthropogenic aerosol loading in India as documented by numerous studies in the recent past based on in-situ, ship-borne and satellite based observations.

Reference: Dunstone, N. J., D. M. Smith, B. B. B. Booth, L. Hermanson and R. Eade (2013), Anthropogenic aerosol forcing of Atlantic tropical storms, *Nat. Geosci., 6*, 534-539.

2. Aerosol cooling effect strengthened by biogenic emission in response to warming

A recent study (*Paasonen et al.*, 2013) has confirmed a negative feedback mechanism between the climate, aerosols and biosphere. Measurements at eleven continental stations across the world have revealed an increase in biogenic emission in response to rising air temperature. Enhanced formation of secondary organic aerosols under the warming climate leads to a cooling at the top-of-atmosphere through direct (scattering solar radiation) and indirect (by enhancing cloud albedo) effects, thereby establishing a negative climate feedback. The study has also concluded that the cloud albedo effect dominates over the direct effect in this negative feedback mechanism. Estimated magnitude of this feedback on a global scale is -0.01 $W\ m^{-2}\ K^{-1}$. In more polluted regions, the biogenic feedback is partly suppressed by anthropogenic aerosol induced radiative forcing.

Reference: Paasonen, P. et al. (2013), Warming-induced in aerosol number concentration likely to moderate climate change, *Nat. Geosci.*, *6*, 438-442.

FORTHCOMING EVENTS

1. 8th International Symposium on Modern Principles for Air Monitoring and Biomonitoring (AIRMON 2014)

The 8th international symposium on modern principles of air monitoring and bio-monitoring will be held at Marseille, France from June 15-19, 2014. The symposium has few sessions dedicated to air pollution (e.g. nano-aerosol sampling and measurements, cumulative exposure and epidemiology, bio-aerosols). The deadline for "Abstract Submissions" is 15th December, 2013. More detailed information about this symposium can be found out in the conference website: *http://www.atoutcom.com/airmon2014/*.

2. International Conference on Aerosol Technology

The international conference on aerosol technology will be held at Karlsruhe, Germany from June 16-18, 2014. The conference focuses on various technological aspects of aerosols. More detailed information about this symposium can be found out in the conference website: *http://www.gaef.de/AT2014/*.

3. Asian Aerosol Conference (AAC-2013)

The 8th Asian Aerosol Conference (AAC-2013) will be held at Australian Technology Park, Sydney, Australia during 2-5 December 2013. For more details, please visit the website *http://www.aac2013.com/index.html*