Satellite and LIDAR observations of long-range transport of aerosols from biomass burning – A study over Indian Region

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INTRODUCTION

- Urban areas have always been known to be a major source of particulate pollution, which is expected to continue to increase due to world population growth and increasing industrialization especially in developing countries.
- Further, biomass burning episodes such as agriculture residue burning, controlled burning as well as forest fires occurring near the cities carry particulate matter over to the cities and contribute to added aerosol loading in the urban environments.
- Agriculture crop residue burning in tropics is an important source of atmospheric aerosols and monitoring their long range transport is an important element in climate change studies.

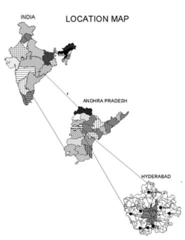
OBJECTIVES

- To analyze seasonal, weekly and diurnal variations of aerosol properties over urban environment of Hyderabad.
- To study the effect of aerosols on the incoming solar radiation in different spectral bands using synchronous measurements.
- To study spatial variation of aerosols using satellite measurements and analyze the effect of anthropogenic activities on aerosol size distribution in urban environment.

DATASETS AND METHODOLOGY

- MICROTOPS-II sun photometer was used to measure aerosol optical depth (AOD) at different wavelengths viz., 380, 440, 500, 675, 870 and 1020nm.
- Multi-Filter Rotating Shadow band Radiometer (MFRSR) having bands at 415.9, 496.6, 622.4, 670.2, 686.3 and 938.5 nm and broad band at 400 – 1100nm, was used for measurements of diffuse, total global and direct-beam irradiance at visible and NIR regions.
- Micro pulse Lidar system operating at 532 nm was used to measure the variations in vertical profile of aerosols.
- Terra/Aqua MODIS data sets were analysed for occurrence of active fire locations over the Indian region.
- MODIS AOD_{550} and OMI-AI datasets were analysed to understand the spatial distribution of aerosols over the region.
- Radiative forcing efficiency of urban aerosols was determined using simultaneous measurements of aerosol optical depth and ground reaching solar irradiance. The measured radiative forcing estimates were compared with SBDART model simulations.

STUDY AREA



Geographic Location

Latitude - 17° 10' and 17° 50' N

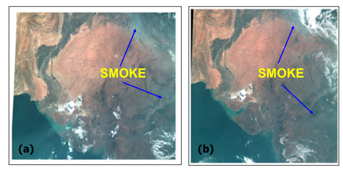
Longitude - 78° 10' and 78° 50' E

IRS-P6 LISS-IV False Color Composite (FCC) of 22nd February, 2007

Hyderabad is the fifth largest city in India; its population is 5,751,780 inhabitants according to the census of 2001, a purely urbanized area. Climate of the region is semi-arid with a total rainfall amount of ~700mm occurring mostly during the monsoon season (June-September). Measurements on Aerosol properties and solar radiations for the present study were carried out in the premises of the National Remote Sensing Centre (NRSC) campus at Balanagar located within the Hyderabad urban center.

RESULTS & DISCUSSION

Figure – 1 (a & b)



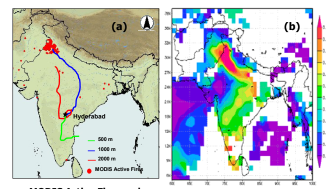
IRS-P4 OCM FCC on 14th October 2007 | **IRS-P4 OCM FCC on 16th October 2007**

Figure – 1 (a & b) shows the IRS-P4 False Color Composite (FCC) on 14th and 16th October, 2007. Smoke plume due to agriculture crop residue burning is clearly visible over northern Indian region in figure – 1 (a & b).

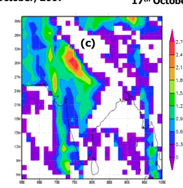
OCM Spectral Bands	
Spectral Band	Wavelength (nm)
C1	402-422
C2	433-453
C3	480-500
C4	500-520
C5	545-565
C6	660-680
C7	745-785
C8	845-880

MODIS fires data indicated intense biomass burning activities over Indo-Gangetic Plain (IGP) particularly in Punjab State due to paddy crop residue burning (figure – 2a). Such fire events are common in the Indo-Gangetic Plains and some parts of central Indian region due to the prevailing farming practices during October / November each year. The winds over the study area above the boundary layer height (~1.5 km) are originating from the biomass burning regions. Spatial distribution of Terra-MODIS derived AOD_{550} (figure-2b) and Aura OMI derived Aerosol Index (AI) (figure – 2c) also showed high aerosol loading over the region corresponding to MODIS fire data shown in figure – 2a.

Figure – 2 (a - c)

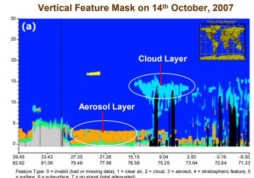


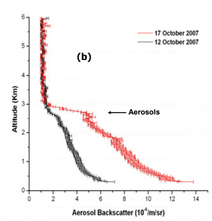
MODIS Active Fires and Wind Back-trajectories on 17th October, 2007 | **TERRA MODIS Aerosol Optical Depth at 550 nm (AOD_{550}) on 17th October, 2007**



AURA OMI Aerosol Index (AI) on 17th October, 2007

Figure – 3 (a & b)



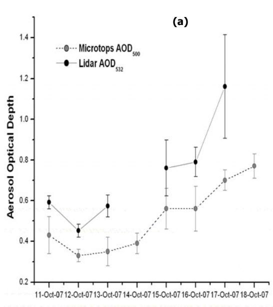


Aerosol backscatter profiles

Figure – 3 (a) shows the nearest CALIPSO pass available on 14th October 2007, covering central part of the Indian region. The CALIPSO derived vertical feature mask image suggested vertically extended aerosol layer (**~5km height**) over central Indian region on 14th October 2007, associated with agricultural crop residue burning practices over the region. The enhanced aerosol loading seen in CALIPSO data over central Indian region between (15.15° – 27.35° N, 76.59° – 79.46° E) suggests long-range transport of aerosols from agriculture crop residue burning in the down wind direction. Figure – 3 (b) shows the lidar aerosols backscatter profile on 12th & 17th October, 2007 at 1930hrs. The **elevated aerosol layers at ~2.5 km** over the study area are mainly due to transportation of aerosols from biomass burning regions on 17th October, 2007.

Figure – 4 (a & b)

Daily mean variations in daytime/nighttime Aerosol Optical Depth (AOD)



Diurnal variations of Angstrom exponent (α) & AOD_{500} on 12th & 17th October, 2007

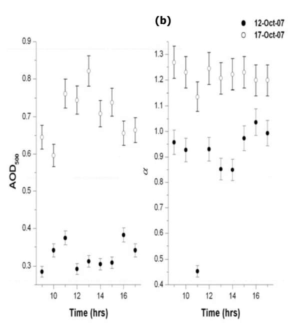


Figure – 4 (a) shows the daily average variations of AOD_{500} measured using MICROTOPS – II sun photometer and nighttime AOD_{532} estimated from lidar data on during 11th – 18th October, 2007, together with their standard deviations. It can be clearly seen from Figure – 4(a) that AOD values showed increasing trend during 12th – 18th October, 2007suggesting additional aerosol loading over the region. The relative variations in MICROTOPS – II AOD_{500} and Angstrom exponent (α) on 12th & 17th October, 2007 corresponding to normal and high aerosol conditions shown in figure – 4 (b) respectively. The AOD and 'α' values observed to be **~ 53%** and **~ 44% high** on 17th October 2007 (high aerosol loading day) compared to 12th October, 2007 (normal day) suggesting abundance of fine mode particles in the atmosphere.

Figure – 5

Aerosol Radiative Forcing

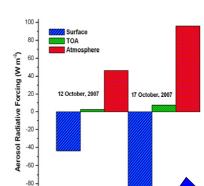


Figure – 5 shows the spatial distribution of daytime mean shortwave (0.25 - 4.0 µm) direct radiative forcing at the surface (SRF), TOA and atmosphere on 12th October, 2007 (normal day) and 17th October, 2007 (high aerosol loading day). Enhanced loading of aerosols from crop residue burning (shown in figure-2a) have high impact with considerable reduction in ground reaching solar radiation over the region. Shortwave radiative forcing of aerosols at surface, TOA and in atmosphere was found to be **~50% higher** on 17th October, 2007 compared to 12th October, 2007. Such high forcing by aerosols transported from crop residue burning has implications for climate change studies.

CONCLUSIONS

- The transport of aerosols in the downwind direction as reflected in MODIS aerosol optical depth, Aerosol Index (AI) and CALIPSO LIDAR observations causes considerable increase in aerosol optical depth (**~53%**) and corresponding decrease in ground reaching solar irradiance (**~12%**) at the measurement site located ~2000km in the downwind direction. Such a large transport of aerosols is possible in favorable wind conditions.
- Nighttime micro pulsed lidar observations showed elevated plumes at a height of ~2.5 Km with higher values of aerosol optical depth in the range 1.0 - 1.5 on 17th October 2007, compared to 12th October 2007, (normal day) values of 0.39-0.51.
- Radiative forcing due to enhanced loading of aerosols associated with crop residue burning observed to be in the range of **-107.81 W m^{-2}** compared to **–53 W m^{-2}** under normal conditions in the month. Model and measured estimates on radiative forcing showed good correlation (R = 0.98).

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