Analysis of Aerosol Vertical Extinction Profiles Using Satellite Data–A Case Study over Dehradun

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Abstract—*Atmospheric aerosols affect the earth's climate system both directly and indirectly. Once aerosols are produced, they can get transported from areas of high emissions to clean remote and marine environments under favourable meteorological conditions. The study of vertical distribution of aerosols in the troposphere is important for determining their effects on the earth system and associated climatic conditions. The study presents analysis of vertical distribution of aerosols obtained from CALIPSO (Cloud-Aerosol and Infrared Pathfinder Satellite Observation) LIDAR level-2 data. The study area chosen is Dehradun, capital of Uttarakhand, a city having small scale industries and located in a valley surrounded by hills. The seasonal variation of aerosol extinction coefficient (the fraction of light lost to scattering and absorption by aerosol particles as a function of altitude), along with backscatter coefficients; for summer (March-April-May-June) and winter (December-January-February) periods have been considered. Such findings are crucial to establish the regional climatology of aerosol vertical profile sand could serve as much needed inputs to radiative transfer studies.*

Keywords: *Aerosol, Calipso, Vertical profile, Extinction coefficient*

1. INTRODUCTION

Aerosols affect the earth's climate system both directly and indirectly [1]. Aerosols are considered one of the largest uncertainties in climate modelling [2]. Owing to the variable lifetimes of aerosols in the troposphere (hours to days) occurring due to many different sources with different spatial extents and emissions, they are highly variable in both space and time [3]. Aerosol have both cooling and heating effects on climate system by scattering the solar radiations back to space and also absorbing them on the other hand, respectively. The study of vertical distribution of aerosols in the troposphere is important for determining their effects on the earth's climatic system. Aerosol vertical profiles enable the determination of their long-range transport, required characterizations of aerosol vertical distributions along with their mixing processes [4]. Vertical distribution patterns can be used to parameterize climate and aerosol models. The Cloud-Aerosol Lidar and Infrared Pathfinder

Satellite Observation (CALIPSO) is a satellite developed by NASA-CNES for monitoring of cloud and aerosol properties in vertical distribution **[**5**,** 6]**.** It carries a lidar (CALIOP) and gives aerosol vertical profiles compared to most of other satellites providing columnar aerosol properties. The objective of CALIPSO is to provide vertically resolved information on aerosol size and distribution, extinction coefficient, hydration state and cloud properties [7]. The atmospheric aerosol extinction coefficient determines the extinction characteristics of aerosols: a large AEC indicates strong absorption and scattering or high aerosol content **[**7]**.** In this paper, we analysed the vertical profile distribution of aerosol extinction coefficients and aerosol backscatter coefficients extracted from CALIPSO level 2 data. The results of this study could be useful for parameterization of aerosol vertical distribution over the study area. The atmosphere aerosol data is collected for the two seasons i.e. summer (March-April-May-June) and winter (December- January- February) for the year 2014.

2. STUDY AREA AND DATA USED

2.1. Study area

The study area is Dehradun city, capital of Uttarakhand situated in Doon valley on the foothills of the Himalayas. The geographical location of the study area is located between 30° 15' 58" N to 30° 24' 16" N latitude and 77° 58' 56" E to 78° 06' 05" E longitude [**Fig.1**]. It is located at altitude of approx. 700 m above mean sea level extending over 350 sq. km and is separated by two (Rispana and Bindal) rivers. It is a gateway to many beautiful hill stations like Mussorie – Queen of Mountains and Garwal Himalayas of Uttarakhand state. Climate varies from tropical to temperate with maximum temperature in summer 40°C (average temperature is around 27°C) whereas in winter, minimum temperature around 2°C (average temperature of 13°C). About 87 percent of the rainfall is through monsoons and is received through the month of June to September, July and August being the heaviest.

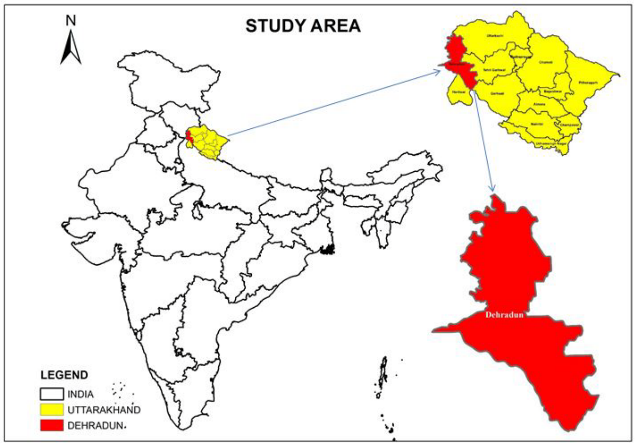

Fig. 1: Location map of study area

2.2 CALIPSO

The Cloud-Aerosol Lidar and Infrared Pathfinder Satellite Observations (CALIPSO) mission launched by NASA Langley Research Centre in collaboration with the French Space Agency CNES in 2005. The altitude of satellite is 705 km and it is inclined at 98^0 [8-9]. It carries lidar, CALIOP (Cloud-Aerosol Lidar with Orthogonal Polarization) to provide vertical profiles of aerosol and cloud properties. The data used for study freely downloaded from the website http://www-calipso.larc.nasa.gov.in. The present study deals with the aerosol extinction and backscatter coefficients for summer (March-April-May-June) and winter (December-January-February) seasons in 2014. The satellite viewing zenith angle has been considered to be within one degree overpass over the study area. **Fig.2** illustrates calipso overpass over the study area for each date of summer (27/3/2014) and winter (5/12/2013) seasons respectively.

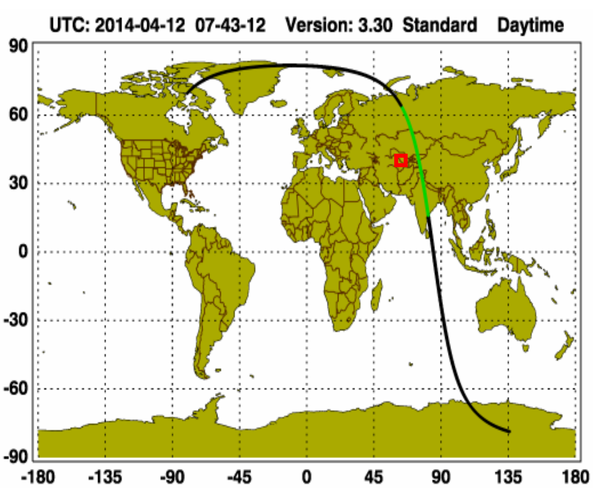

Fig. 2(a): Calipso overpass for 27-03-2014 (red box indicating study area)

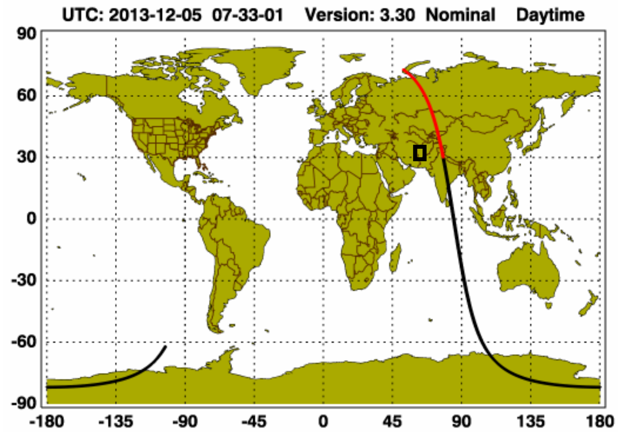

Fig. 2(b): Calipso overpass for 05-12-2013 (black box indicating study area)

2.3. HYSPLIT Model

Hybrid Single Particle Lagrangian Integrated Trajectory (HYSPLIT) Model developed by NOAA and Australia Bureau of metrology is used for trajectory calculation in the study. The model used Global Data Assimilation System, GDAS (recomputed at 0.5^0 grid) files. The model was run online, available at www.arl.noaa.gov/HYSPLIT.php. One day back trajectories have been computed for the study area for all dates.

3. RESULTS

CALIPSO Lidar _L2 data was processed to analyse the atmospheric aerosol vertical profile data. The vertical aerosol extinction coefficients were extracted for the specified latitude/ longitude of the study area. This processing is done for all the datasets mentioned in **Table 1**. It is to be noted that here that the repeat period of CALIOP is 16 days.

Table 1: Satellite overpass over the study area

S. No	Date of pass	Satellite viewing zenith angle (degrees)
	Winter	
1	05-12-2013	0.48
2	21-12-2013	0.50
3	07-02-2014	0.82
Summer		
1	12-4-2014	0.39
2	28-4-2014	0.48
3	14-5-2014	1.09
4	30-5-2014	0.76

The Hysplit trajectories for the corresponding dates of overpass of satellites have also been computed at three altitudes (a) 700m (the average altitude of the study area) (b) 1.5km (c) 2.5 km and are shown in **fig. 3.**

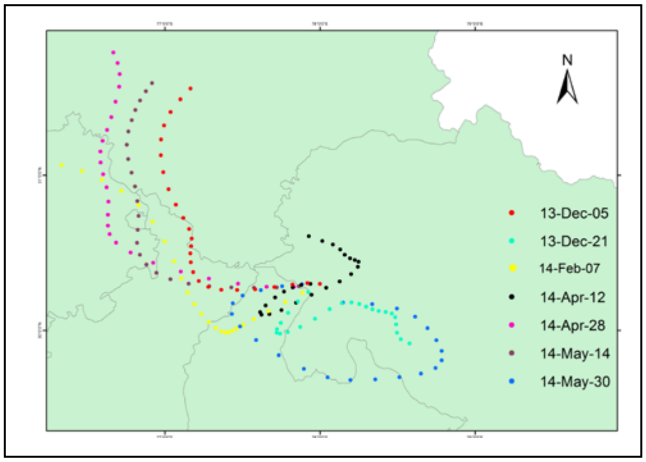

Fig. 3(a): Hysplit Trajectories for the dates of overpass of satellite at an altitude of 700m

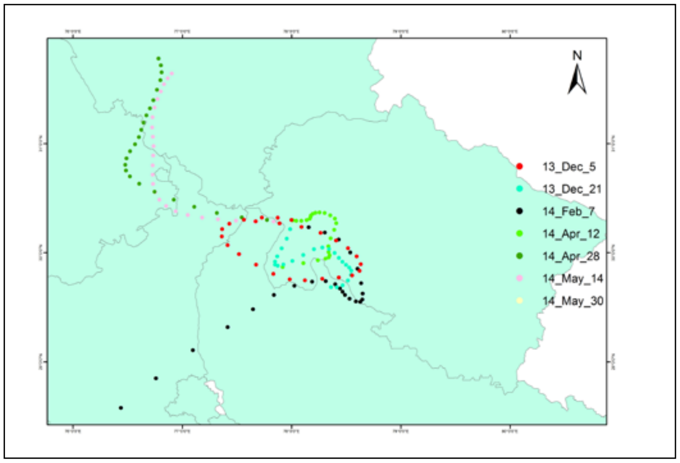

Fig. 3(b): Hysplit Trajectories for the dates of overpass of satellite at an altitude of 1.5 km

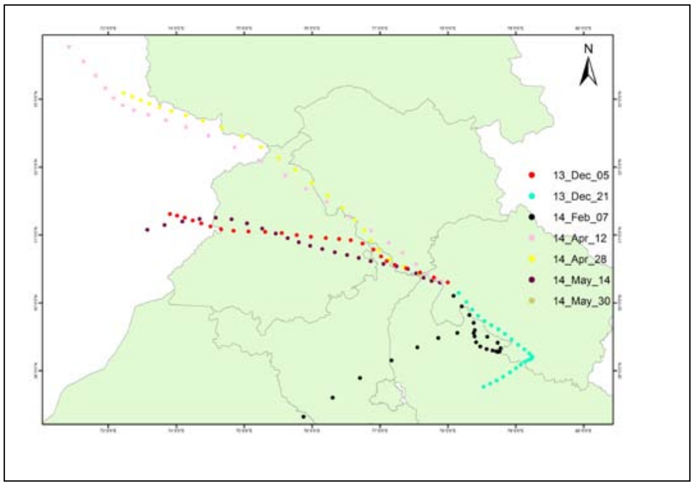

Fig. 3(c): Hysplit Trajectories for the dates of overpass of satellite at an altitude of 2.5 km

Fig. 4 shows the vertical extinction coefficient profiles of aerosols for the dates considered (a) summer (b) winter season. Also, aerosol backscatter coefficients for 532 nm have also been extracted for the above dates. **Fig. 5** shows the backscatter coefficient (532nm) profiles of aerosols. The average summer and average winter season profiles are also calculated are depicted in **fig. 6** and **7** respectively. The average extinction and backscatter profiles of the two seasons show the presence of aerosol layers at different altitudes. The presence and association of these layers to other meteorological factors is the further topic of research in this area. The results could be integrated to find the columnar values of aerosol parameters and can be compared to other satellite and /or ground based measurements which would further enhance the understanding in the field.

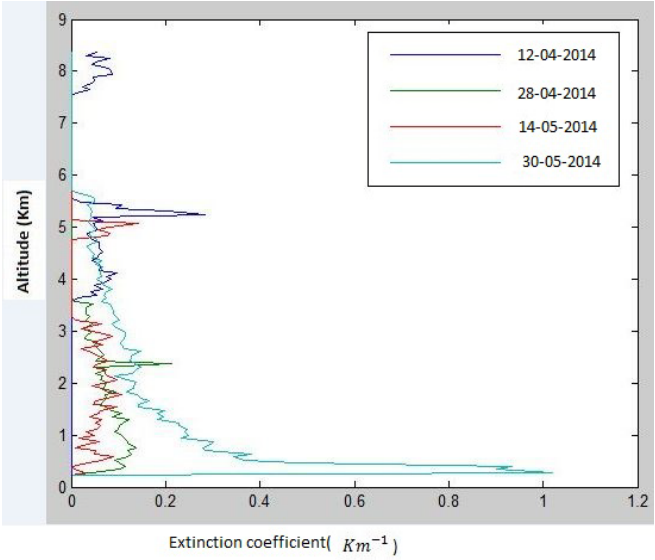

Fig. 4(a) Extinction coefficient profiles for summer season

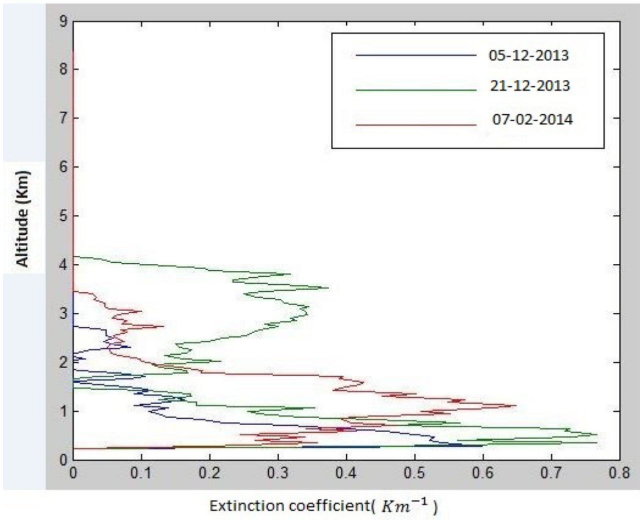

Fig. 4(b) Extinction coefficient profiles for winter season

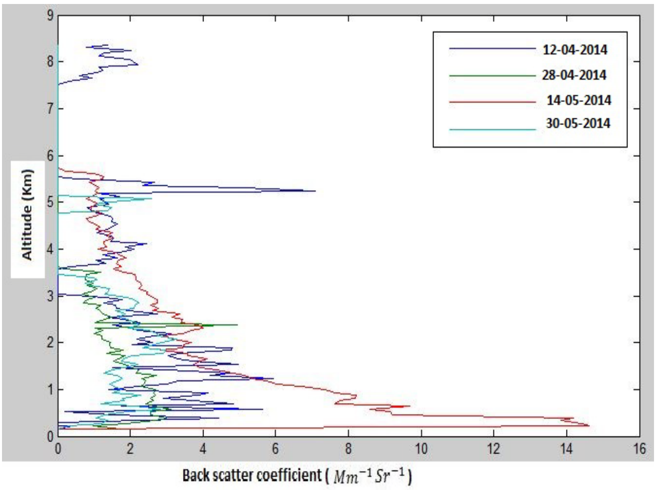

Fig. 5(a): Backscatter coefficient profiles for summer season

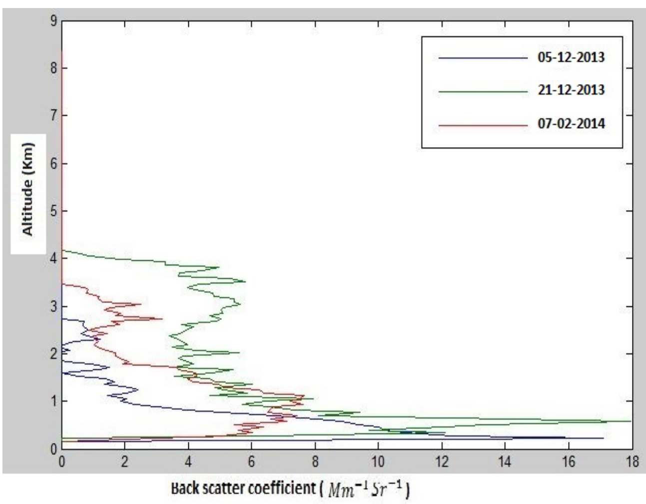

Fig. 5(b) : Backscatter coefficient profiles for winter season

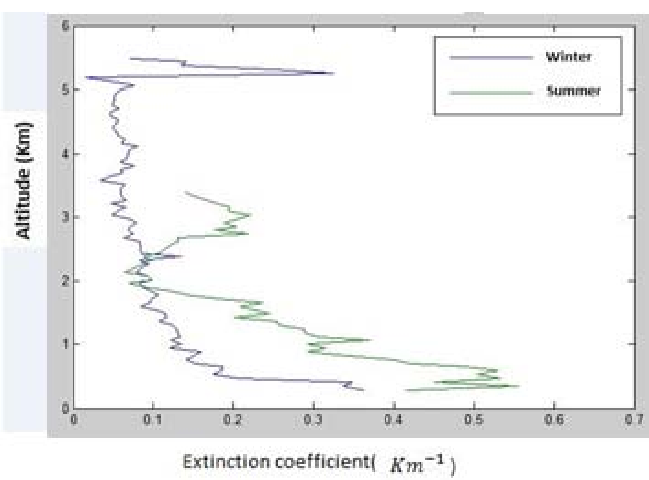

Fig. 6: Average extinction profiles for summer and winter seasons respectively

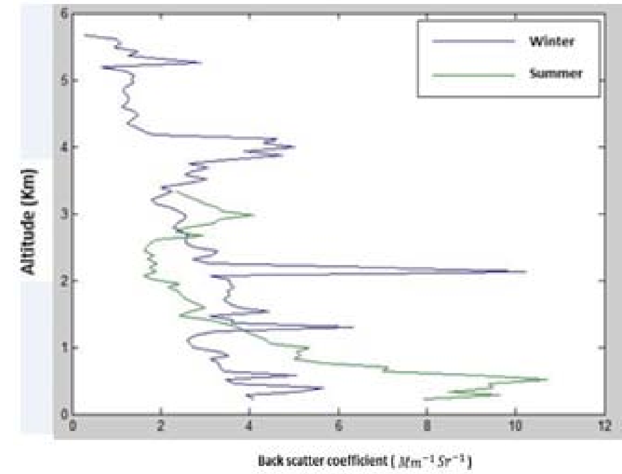

Fig. 7: Average backscatter profiles for summer and winter seasons respectively

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