The present study has been carried out to characterize the physical and optical properties of aerosols that are mainly present over urban regions. Major part of this research work is devoted to understand the seasonal and inter-annual variabilities in various aerosol parameters measured over Ahmedabad, an industrialized urban location in western India. Two cases of long range transport of aerosols have been studied. First one refers to transport of naturally produced dust aerosols from various arid and semi arid regions of west Asia, Northern Africa and North West India to our study location which is an urban site in western India. This provided us an unique opportunity to study the behavior of urban aerosols, mainly characterized by presence of anthropogenic aerosols such as soot, sulfates etc., which gets influenced by the transported dust particles from western arid regions. Other transport pathway which has been studied during the present work involves transport of anthropogenic aerosols from highly populated urban and industrialized areas of Indo-Gangetic plain to the otherwise clean oceanic region of Bay of Bengal as well as transport of aerosols from North Indian regions to central India during the Dry winter season. Finally implications of variabilities in aerosol parameters in terms of their potential capability to perturb the radiation budget of the Earth-Atmosphere system are quantified in terms of model estimates of aerosol radiative forcing at all the study locations. We have carried out further model estimates to know the sensitivity of aerosol radiative forcing to various parameters required as input for the radiative transfer calculations. Important results obtained from the present study are summarized as below.

- Major aerosol parameters studied include: column AOD spectra, aerosol mass concentration, their number size distribution, BC mass concentration, wavelength de-
pendency in absorption by aerosols, scattering coefficient, single scattering albedo and vertical distribution of aerosols in the atmosphere.

- The four years data obtained over Ahmedabad are classified into four major seasons viz. Dry (December to March), Pre-Monsoon (April-May), Monsoon (June-September) and Post-Monsoon (October-November).

- Results from size distribution measurements show the dominance of smaller size particles during Dry and Post-Monsoon seasons while increase in coarser particles during Pre-Monsoon and Monsoon seasons, a signature of the long range transport of dust particles from the west.

- Average clear sky AOD at 0.5 \( \mu m \) is found to be 0.31 ± 0.07, 0.41 ± 0.09, 0.43 ± 0.12 and 0.42 ± 0.07 during Dry, Pre-Monsoon, Monsoon and Post-Monsoon seasons respectively. Higher AODs during Monsoon is a combined effect of increased dust transported from the west as well as increased boundary layer height which could accommodate more aerosols.

- Vertical distribution of aerosol for Dry and Post-Monsoon seasons are characterized by high values of extinction coefficients within first few hundred meters from the surface while Monsoon season profiles show presence of a thick and stable aerosol layer between 0.5 and 2.0 km, contributing significantly to the columnar AODs.

- Seasonal variation in near surface aerosol number concentration is found to be maximum for nucleation mode aerosols (60% spread about the mean), followed by in the case of accumulation (26%) and coarse (17%) mode aerosols. Higher nucleation mode particles shows the influence of anthropogenically produced particles.

- Highest value of surface level BC mass concentration is obtained during Post-Monsoon (7.3 ± 3.7 \( \mu g/m^3 \)) while lowest value is measured during Monsoon season (1.5 ± 0.8 \( \mu g/m^3 \)). Large production of soot particles from waste burning activities, having increased absorption efficiency, in addition to the fossil fuel and industrial emissions brings down the single scattering albedo to 0.73 during Post-Monsoon and Dry season compared to relatively higher values around 0.85 during Pre-Monsoon season.

- Bay of Bengal cruise study shows higher aerosol number concentrations as well as
higher extinction values over northern and coastal areas of Bay of Bengal, indicating transport of anthropogenic aerosols from the Indo-Gangetic plain during winter season.

- Estimated value of aerosol scale height is found to be low over northern Bay of Bengal due to relatively larger contribution of boundary layer aerosols to the total columnar AOD values, showing that majority of transport takes place within the planetary boundary layer over BoB in contrast to the western region where free tropospheric transport is found to be important.

- We find an excess absorption of about 30% compared to what is expected from equivalent mass of BC from fossil fuel burning over the central Indian region, indicating presence of significant quantities of other absorbing aerosols from biofuel/biomass burning. During winter the central and peninsular India is influenced by the fine soot particles of fossil fuel origin from the north which gets mixed with the locally produced soot particles mainly produced from biofuel/biomass burning.

- An overall increasing trend in single scattering albedo is observed towards the end of dry winter season, indicating unequal changes in source strength or removal processes of absorbing and scattering type aerosols.

- In order to study the wintertime haze and fog over Indo-Gangetic belt, complementary measurements of various physical and optical parameters of aerosols were made from New Delhi in December 2004. Average clear sky AOD at 0.5 $\mu m$ is $0.91 \pm 0.48$, which is higher than AOD values reported for most other cities in India during the same season. Single scattering albedo at 0.525 $\mu m$ varied between 0.6 and 0.8 with an average value of 0.68 for the period of our study in New Delhi.

- Lidar observations during a Fog event reveal a collapse of the vertical distribution of aerosols to an extremely dense and shallow atmospheric layer of merely 200 m height from the surface, while scattering and absorption characteristics remain almost same prior to the formation of fog, slightly higher Relative humidity resulted in fog formation on 18 December while 19 remained hazy.

- Two different approaches are followed to generate spectral values of various aerosol
parameters required as input for the radiative transfer calculations, and the computed aerosol radiative forcing values are found comparable for both methods.

- Magnitude of surface forcing are found to be highest during Post-Monsoon ($-63 \pm 10 \text{ W/m}^2$), which is followed by Dry season ($-54 \pm 6$) and lower values during Pre-Monsoon ($-41.4 \pm 5$) and Monsoon ($-41 \pm 11$) seasons, over Ahmedabad.

- In the case of TOA, aerosol forcing is found to be negative during Dry ($-26 \pm 3 \text{ W/m}^2$) and Post-Monsoon ($-22 \pm 3 \text{ W/m}^2$), while positive values are obtained during Monsoon ($14 \pm 4 \text{ W/m}^2$) and Pre-Monsoon ($8 \pm 2 \text{ W/m}^2$) seasons.

- Different properties of aerosols and differences in their vertical distribution give rise to different heating rates within the atmosphere for different seasons. Surface level heating rates are found to be highest during Post-Monsoon ($5.6^0 \text{ K/day}$) while higher atmospheric heating is observed between $1-2$ km altitudes during Monsoon season.

- Results from several sensitivity studies have emphasized the importance of diurnal variations in the amount of insolation, solar zenith angle and other related factors in modulating the values of aerosol radiative forcing over our location.

- Result from a sensitivity study showed LW aerosol forcing to decrease with increase in water vapor column content in the atmosphere.

- In the study over central India, a large negative forcing at the surface in the range of $-15$ to $-40$ $\text{W/m}^2$ is found, while forcing at the TOA varied between $+0.7$ to $-11$ $\text{W/m}^2$. Negative ARF at the TOA over central India and its increasing trend towards the end of Dry winter season indicates the presence of significant amount of scattering type aerosols and their increasing relative dominance over the period of our study.

- Our results indicate towards a possible gradient that exists in the atmospheric forcing due to aerosols from the Arabian Sea in the west ($7.8 \text{ W/m}^2$), peninsular India in the middle ($22 \pm 4 \text{ W/m}^2$) and the BoB in the east ($25 - 31 \text{ W/m}^2$), during the winter season.

For semi-arid region like Ahmedabad, rainfall and aerosol loading in the atmosphere are intricately related to each other. This is because on the one hand amount and type
aerosols which act as cloud condensation nuclei (CCN) together with the available moisture in the atmosphere decides the amount of rainfall that occurs over the region, while on the other hand, more frequent rainfall leads to moist soil and helps vegetation to grow, which in turn curtails the amount of soil derived dust aerosol loading in the atmosphere and can have possible impacts on subsequent weather patterns. Besides this, we observe in our study that, due to large difference between TOA and surface forcing values, larger amount of heat is trapped by aerosols within the atmosphere during Monsoon and Pre-Monsoon seasons. This can have much larger implications for the regional scale dynamical process such as wind flow, convection scheme and even precipitation patterns [Ramanathan et al., 2005]. It is very much essential to understand how the Earth-Atmosphere system responds to such large scale perturbations with cooling at the surface and warming in the lower troposphere. Since aerosols are key to the formation of CCN required for rainfall, seasonal and inter-annual variabilities of major aerosol parameters measured over this site will be very useful for the future studies related to the role of aerosols on monsoon rainfall over the region. The monsoon rain serves as a source of fresh water and helps millions of farmers across the country whose livelihood depends on agriculture. So, it is of great interest to study, using regional scale climate model (RegCM), how the seasonal and inter annual variabilities in aerosol parameters measured over different regions are correlated with the spatial distribution of the monsoon rainfall and affecting other climate parameters in general. Finally, it is necessary that observations and modelling studies should complement each other for further improvement in our understanding of climate change occurring in recent times (post-industrial period) as this will help reducing uncertainties in the future projections of how aerosols influence climate.
Summary and Scope for Future Work