Aerosol Radiative Impacts over Indian CTCZ Region: Results from Pilot 2008 Aircraft Experiment

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INTRODUCTION

Monsoonal rainfall over Indian subcontinent is the lifeline for more than hundreds of million people therefore any climatological changes in its characteristics warrant investigation. Recent global modeling studies, albeit few only, that estimated the aerosol effects on monsoon show conflicting results; one group of investigators report enhancement of rainfall in the pre-monsoon season (May-June) and reduction during the main monsoon phase (July-September) (Lau et al., 2003). On the other hand, some studies show an overall reduction in all India rainfall during May-September months (Ramanathan et al., 2005).

The region covered during this experiment spanned from Jaipur in West (dust environment) to Bhubaneswar in East (marine environment) and Nainital in north (pollution) to Nagpur (pollution+dust) in south to understand the spatial and vertical structure of the aerosol layer, which will help verify and constrain the modeled results.

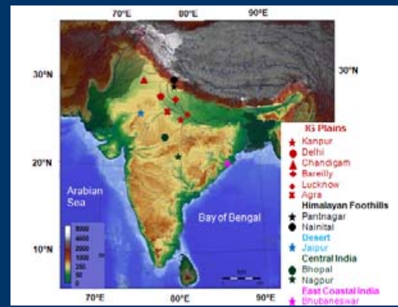

Figure 1: Topographic map of Continental Tropical Convergence Zone (CTCZ) over India.

OBJECTIVES

- To study the variation of optical and microphysical properties over CTCZ region.
- Vertical extent and spatial gradient of absorbing layer, if present
- To find inter-seasonal (pre-monsoon and monsoon) variability of the layer in 2008.
- To estimate the altitude variation of atmospheric heating rates due to aerosols in Kanpur (IG Plains), Pantnagar (Himalayan Foothills), Bhubaneswar (Coastal India) and Indore (Central India).

METHODOLOGY

In-situ measurements of vertical and spatial variation of aerosol optical, microphysical, CCN and BC properties were carried out over the Indian Continental and Tropical Convergence Zone (CTCZ) during pre-monsoon and monsoon seasons of 2008 using King B-200 aircraft. Instruments like Photoacoustic soot spectrometer (DMT, Boulder), Scanning Mobility Particle Sizer (3936, TSI Inc.), Aerodynamic Particle Sizer (3321, TSI Inc.), Aethalometer (AE-21-ER, Magee scientific) Cloud Condensation Nuclei Counter (DMT, Boulder), Optical Particle Counter (1.108, Grim, GmbH), Nephelometer and Spectro-radiometer were mounted onboard for the measurement of above mentioned properties.

Figure 2 (above): Photographs taken during the experiment showing aircraft used in the experiment, sampling inlets and the aircraft cabin.

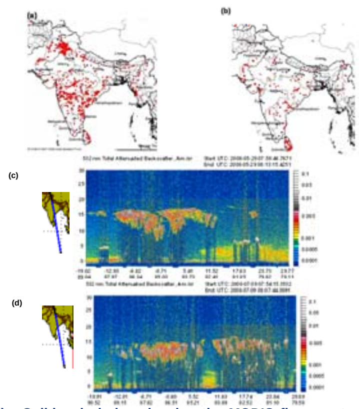

Figure 3(Right): Solid red circles showing the MODIS fire counts for the days of (a) pre-monsoon (May 20-31, 2008) season and (b) monsoon season (Sept. 1-15, 2008). Source: Fire information for Resources Management System, Department of Geography University of Maryland (http://maps.geog.umd.edu/firms/maps.asp). (c) and (d) shows the 532 nm attenuated backscatter on a day of pre-monsoon and monsoon season respectively.

- In CTCZ, during the pre-monsoon, desert aerosols from West mix with the anthropogenic aerosols (Industrial, crop burning etc.) from Indo-Gangetic (IG) plains and stack up against the high rise mountain ranges in the North. These aerosols get washed out with the monsoon rainfall. CALIPSO backscatter images on the left shows the aerosol loading during the two seasons.
- Multilevel/Spiraling sorties were carried out over Kanpur, Delhi, Bareilly, Bhubaneswar, Chandigarh, Indore, Jaipur and Pantnagar for which heating rates were computed.
- OPAC Model was used in the calculation of optical properties. It was constrained by observed profiles of scattering and absorption Coefficients, total particle concentration at different levels by fine tuning the number concentrations of constituents in the model.
- SBDART code was used to find the net radiative flux from top and bottom of each atmospheric layer and finally heating rate was calculated using the following expression

$$\frac{\partial T}{\partial t} = \frac{g}{C_p}\frac{\Delta F}{\Delta P}$$

RESULTS

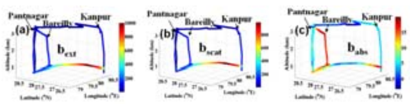

Figure 4: Extinction, scattering and absorption coefficient profiles from Kanpur towards Himalayan Foothills in the pre-monsoon season (May 30, 2008)

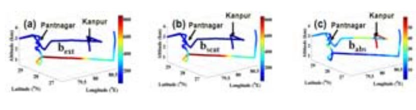

Figure 5: Extinction, scattering and absorption coefficient profiles from Kanpur towards Himalayan foothills in the monsoon season (Sept. 9, 2008)

Pre-monsoon Season:

- Extinction coefficient is higher within the boundary layer over IG Basin (Kanpur to Bareilly).
- Highly absorbing aerosols near Himalayan foothills

Monsoon Season:

- Washout of aerosols over Kanpur after rain can be seen from extinction and scattering coefficients within the boundary layer but absorption coefficient resembles the pre-monsoon values.
- Higher extinction and scattering coefficients are due to high RH (>70%) in the aerosol.

Aerosol properties over CTCZ

- IG plains showed highest loading during both seasons as compared to other parts of CTCZ.
- Central and Coastal India are relatively cleaner in terms of aerosol loading.
- Variation in extinction coefficient was highest over Himalayan foothills during pre-monsoon season.
- A layer with higher absorption coefficients in the range of 30 Mm^{-1} was observed between 1.5 to 2.5 km altitude over IG plains during monsoon seasons. This layer was observed within 3 hrs after rains indicating quick build up of absorption aerosols.

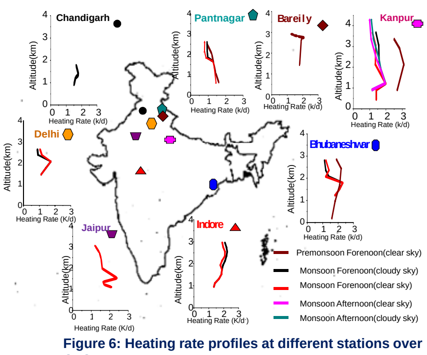

Figure 6: Heating rate profiles at different stations over CTCZ.

- Kanpur (IG plains) show higher heating rates at different levels compared to other locations for both pre-monsoon and monsoon season.
- Heating rates (HR) in pre-monsoon were relatively higher than that during monsoon for corresponding locations.
- HR increases by more than 10% in the presence of clouds. Non-precipitating clouds, by impeding the solar radiation, cool surfaces and reinforce the stability of the atmosphere.

SUMMARY

- First attempt to get spatial and Vertical profiles of optical, microphysical, CCN and BC properties over CTCZ during both pre-monsoon and monsoon seasons
- First hand estimate of Heating Rates (HR) over entire CTCZ region.
- Calculations were constrained from real time absorption, scattering and total mass concentration data at different levels which helps to constrain the OPAC model better than previous studies.
- Results from CTCZ 2008 experiment showed that heating rates over Kanpur were twice that of Tripathi et al., 2007 (Constraints for OPAC model were BC mass concentration and total particle mass concentration) when compared at similar altitudes (1 to 1.5 km)
- Cloud increase the heating rate at that level as compared to no-cloud condition.

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