NASA AERONET Field Campaign in Northern India – TIGERZ

Field experiments focused on improving the understanding of atmospheric aerosol columnar optical properties, vertical distributions, and aerosol-cloud interaction, led by NASA's AERONET project and called TIGERZ, will commence in April 2008 and potentially continue through 2011. The field observations will primarily emphasize the pre-monsoon period (April through June); however, a core monitoring capacity will remain in the field to continue data collection through the monsoon months of July through September and into the dry winter season. The TIGERZ campaigns are intended to augment the Continental Tropical Convergence Zone (CTCZ) programme, which is being implemented under the Indian Climate Research Programme (ICRP). Both the CTCZ and STORMS projects are concentrating on furthering the understanding of the Indian monsoon dynamics, mechanisms, and feedbacks through intensive observation efforts primarily during the monsoon months. Feedback mechanisms between aerosol radiative effects and monsoon dynamics have been recently proposed; however, a lack of consensus exists on whether aerosol forcing would be more likely to enhance or reduce the strength of the monsoon circulation. Ramanathan et al. (2005) have suggested that the reduction of solar radiation at the Earth's surface by absorbing aerosols over the Indian subcontinent reduces surface heating, and thereby reduces the temperature contrast between the Indian Ocean and the land mass, the basic impetus of the monsoon circulation. The result is a possible multi-decadal reduction in monsoon strength due to the rapid increase in aerosol loading over India in the previous 30 years. However, the 'Elevated Heat Pump' hypothesis of Lau et al. (2006) suggests that the absorption of solar radiation by dust and black carbon aerosols in pre-monsoon months (April and May) over northern India may result in enhanced convection in that region thereby intensifying the monsoon through a strengthened local Hadley circulation. The spatial distribution and optical properties of aerosols (especially absorption) over India determine the intensity of the forcings that are central to these two aerosol-monsoon interaction hypotheses.

Scientific Focus Areas:

1) *Validation of Aerosol Retrievals from the CALIPSO Satellite*: Figure 1 shows the linear distribution of AERONET sun-sky radiometer sites near to the ground track of the CALIPSO path that is nearest to Kanpur. The set of eight (8) semi-permanent sites will extend from the Ganges river floodplain to the foothills of the Himalayas, a total distance of ~450 km on a south-southeast to north-northwest transect. This set of instruments will provide direct sun inferred aerosol optical depth (AOD) measurements before, during and after satellite overpass to provide validation of the total column integrated AOD estimated from CALIPSO space-borne lidar. Additional Cimel sun-sky radiometers will be used in mobile field campaign mode to make measurements immediately beneath the CALIPSO track and also under tracks on different days (repeat cycle is 16 days) that are offset by ~100 km from the Kanpur track.

2) *Spatial and Temporal Variance of Aerosol Loading and Properties*: The semi-permanent transect of Cimel sun-sky radiometers shown in Figure 1 will also provide

seasonal data on the spatial variance of aerosol loadings and optical properties in a roughly north-south transect in northern India. This transect allows for observation of the transport of aerosol into the foothills of the Himalayas and combined with other AERONET stations in the region, into the mountains and Tibetan plateau (Figure 2). Absorbing aerosols transported into the mountains have important implications for the potential darkening of snow/ice surfaces of glaciers, which may contribute to the rapid melting and retreat of glaciers there. In addition to these measurements an additional five (5)) Cimel instruments will be utilized on selected individual days to characterize the spatial variance of AOD, Angstrom exponent and retrieved properties in and surrounding the city of Kanpur. This instrument deployment will enable the investigation of the interaction in optical properties between coarse mode desert dust particle and the fine mode pollution being emitted continuously from the urban region.

3) *Joint Inversions from Ground Based Sun-Sky Radiometers and CALIPSO data*: Measurements of AOD and sky radiance distributions (in the solar principal plane) simultaneous with CALIPSO satellite overpasses with be utilized to make joint retrievals of aerosol optical properties. Information may be derived about the vertical distribution of total aerosol as well as the vertical variability of particle sizes and possibly absorption. Retrieval of both surface and aerosol properties from joint inversion of AERONET and passive satellite observations (PARASOL and MODIS) by including CALIPSO into a joint retrieval will be investigated. Further, development of enhanced parameterization for aerosol properties (e.g. lidar and depolarization ratios for non-spherical and inhomogeneous aerosol), which can be used to improve the CALIPSO global retrievals, will be carried out.

4) Cloud-Aerosol Interactions: A special zenith sky radiance measurement mode will be activated in most Cimel sun-sky radiometers during the TIGERZ field campaigns. These spectral measurements of clouds have been shown to be effective in the remote sensing retrieval of cloud optical depth (Barker and Marshak, 2001; Marshak et al., 2004; Chiu et al., 2006). Additionally, a possibility exists for the retrieval of cloud effective droplet radius with this set of observations when the 1.6 μm channel is available. A combination of the retrieved cloud properties with the aerosol optical properties measured before and/or after the cloud observations allows for potential investigation of indirect aerosol effects on both pre-monsoon and monsoon clouds (non-precipitating clouds only).

5) *Improved Characterization of Aerosol properties*: The multi-year climatology of aerosol optical depth, Angstrom exponent, and precipitable water from AERONET data at Kanpur for 2001 through 2006 is shown in Figure 3. The monthly average AOD reaches its annual peak in the pre-monsoon months of May and June, ~0.80 at 500 nm. The Angstrom exponent during these months is very low, averaging ~0.4, thus indicating the dominance of coarse mode desert dust aerosol in this season. During the peak monsoon months of July and August the AOD decreases but still remains high at >0.5 at 500 nm, while the Angstrom steadily increases as desert dust events become less frequent. The multi-year climatology of retrieved single scattering albedo and volume size distributions are shown in Figures 4 and 5, as a function of

the fine mode fraction (FMF) of the optical depth at 675 nm. It is noted that the absorption is strong even for the dust dominated FMF of 0.4. Further understanding of the optical properties of dust/pollution mixtures is a goal of the combined CTCZ and TIGERZ campaigns. Combined observations of in situ aerosol properties taken in profiles above the Cimel sun-sky radiometer locations especially in combination with ground-based, airborne, and space-borne lidar will provide new insights into these mixtures of aerosol types. Potential differences in aerosol mixtures between observations made in the foothills of the Himalayas versus in the Ganges floodplain will be examined (Figure 2). Additional analyses will focus on the possible enhanced absorption in the ultraviolet wavelengths resulting from organic aerosols, which will be most strongly evident in the winter months when fine mode pollution aerosols dominate.

6) CTCZ/TIGERZ collaboration will provide an opportunity to test in detail satellite retrievals of fine, coarse and mixed aerosol properties. In particular this collaboration will allow assessment of MISR AOD and especially particle property retrieval sensitivity using the Research aerosol algorithm, as well as assessment of the current version of the Standard algorithm. TIGERZ will provide information on aerosol and surface characteristics to improve the MODIS aerosol retrieval in this very important region. Following the pilot study year of 2008, the measurement of UV absorption properties may lead to identification of absorbing organics from incomplete combustion. We also expect to test new remote sensing inversion of cloud microphysical properties.

7) International collaboration also provides opportunities for synergism with network measurement programs including MWR, AERONET and Marine Aerosol Network (MAN). MWR has a twenty-year record of observations in India while AERONET has a global distribution of measurements. TIGERZ will provide the impetus for multiple comparisons of the two networks that will spatially and temporally broaden the results coming from the two networks and thus provide an improved database for testing the competing hypothesis of Aerosol impacts on the monsoon. Additionally the MAN of handheld sun photometers will be compared to the handheld sun photometers used during the ICAR observations in the Bay of Bengal and Arabian Sea. These data will be related to the AERONET standard reference measurements and likely incorporated into the MAN database for comparison to satellite retrievals over those water bodies.

8) Lastly, CTCZ/TIGERZ long-term collaboration will provide an opportunity to attract other resources to the aerosol-monsoon research activities. We anticipate collaborations to develop with groups that will allow assessment of the indirect radiative forcing efforts. In particular TRMM/CLOUDSAT may augment precipitation monitoring in the I-G. Clearly, airborne cloud microphysical measurements, airborne AOD measurements and aerosol modeling will be areas to exploit foreign and domestic expertise and resources in subsequent years.

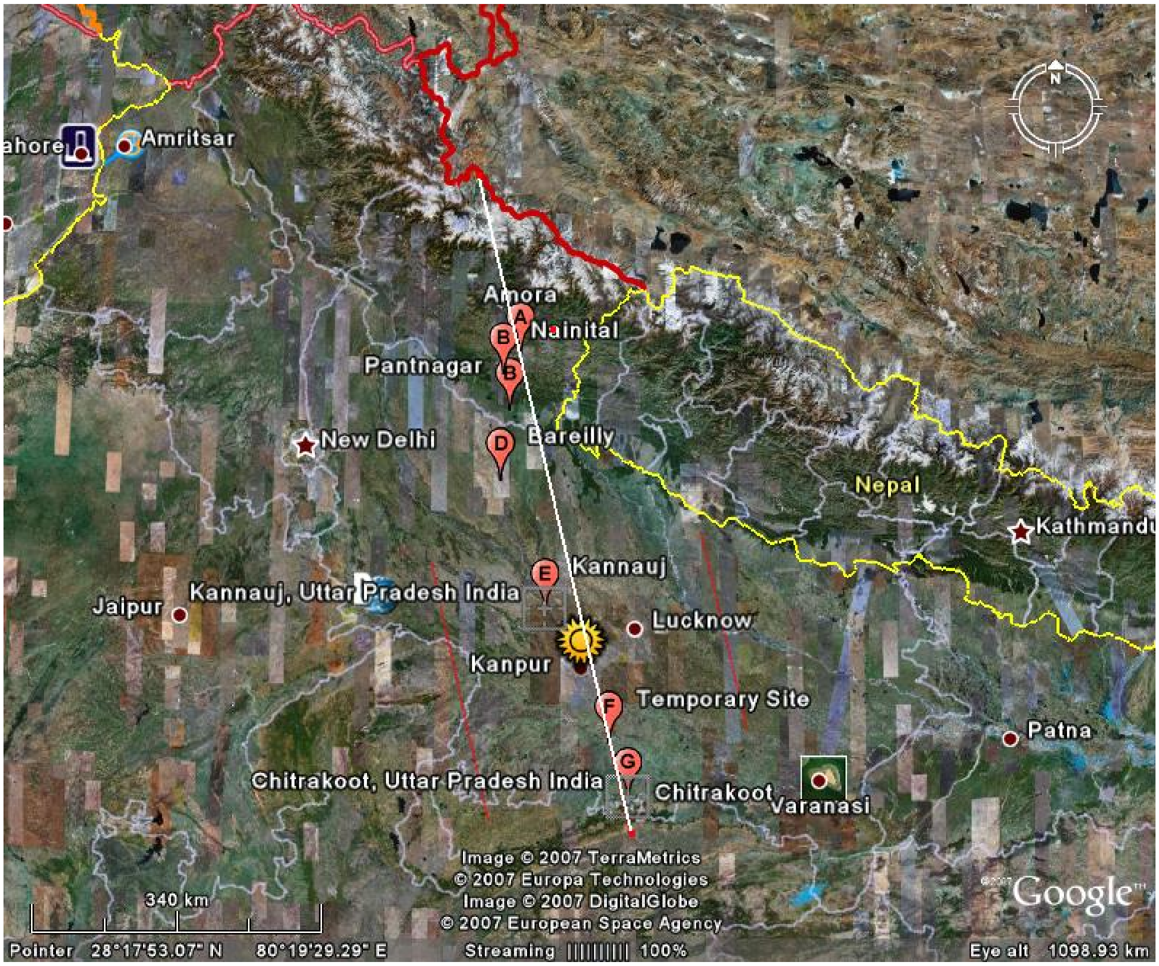

Figure 1 A map showing the clostest daytime CALIPSO track to Kanpur and the eight proposed AERONET sites. A to G is approximately 450km.

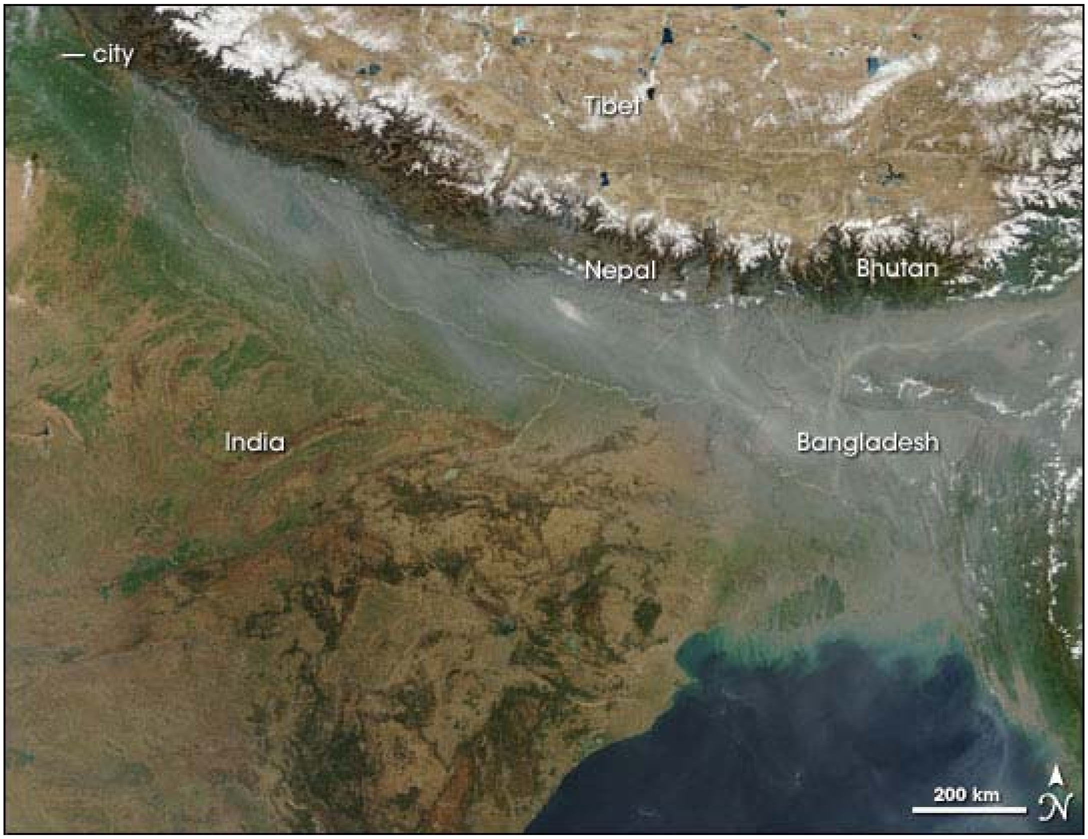

Figure 2 Spatial distribution of aerosols over the I-G Plain and along the Himalayan mountains on February 5, 2006

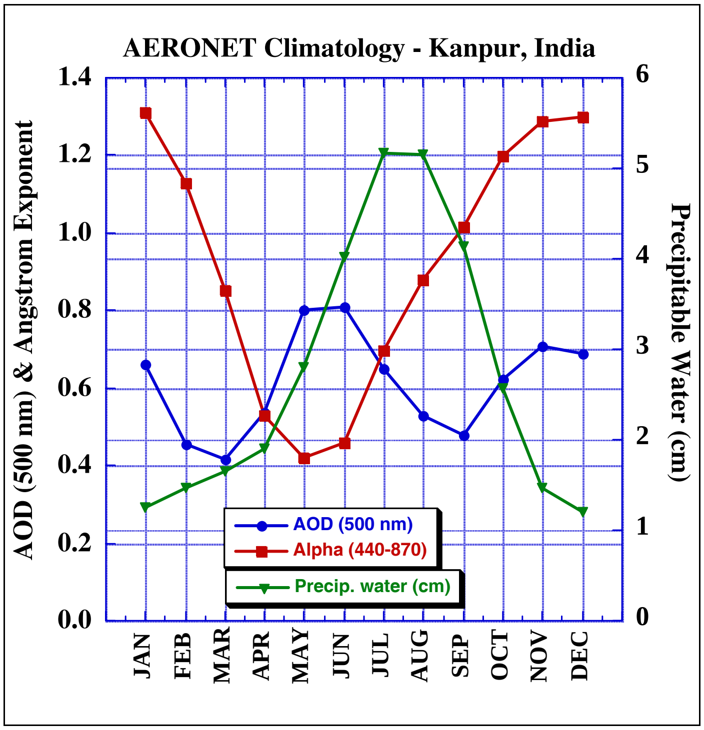

Figure 3 Multi-year climatology of aerosol optical depth, Angstrom exponent and precipitable water from AERONET data at Kanpur for 2001 through 2006

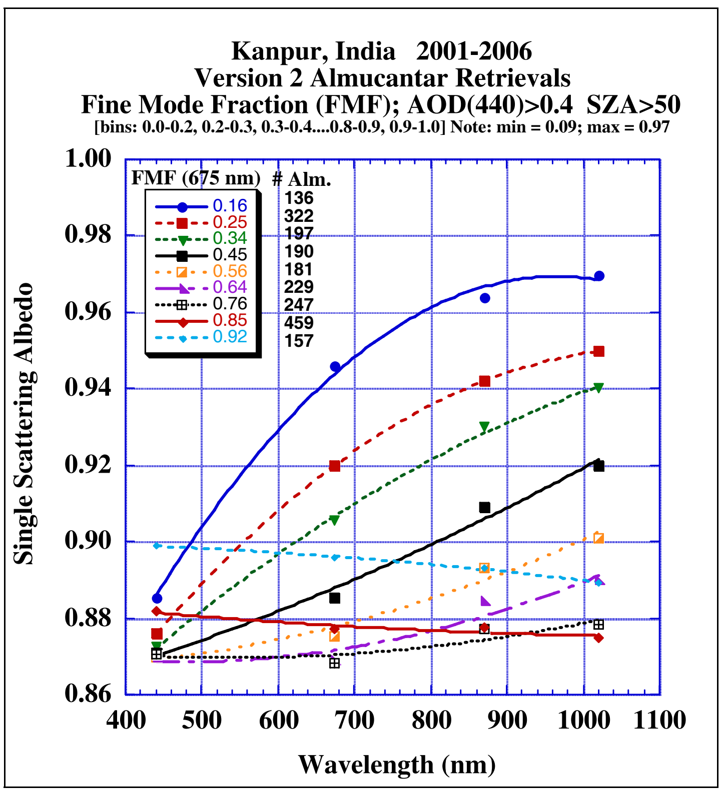

Figure 4 Multi-year climatology of retrieved single scattering albedo as a function of the FMF of the optical depth at 675 nm

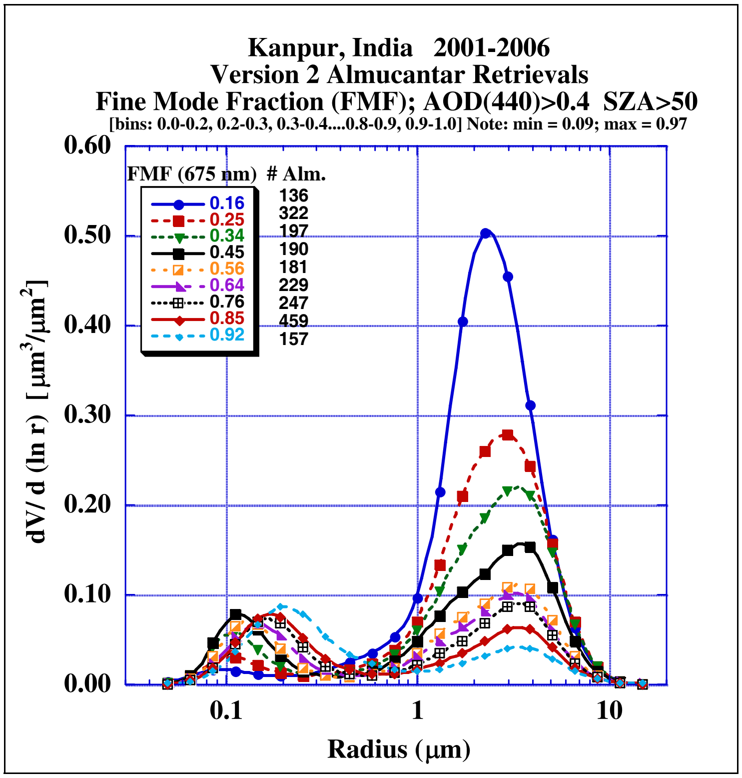

Figure 5 Multi-year climatology of retrieved volume size distributions as a function of the FMF of the optical depth at 675 nm