An Overview of Tropical Aerosol and Cloud Studies in the UTLS over India: Present and Future Perspectives

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WCRP for Invitation and Support

Outline

Talk consists of two parts,

(i) Aerosol and cloud mass exchange processes in the vicinity of tropical tropopause

(ii) Current and future plans for the study of aerosols, gases and clouds in the UTLS region for better understanding of their impacts on weather and climate.

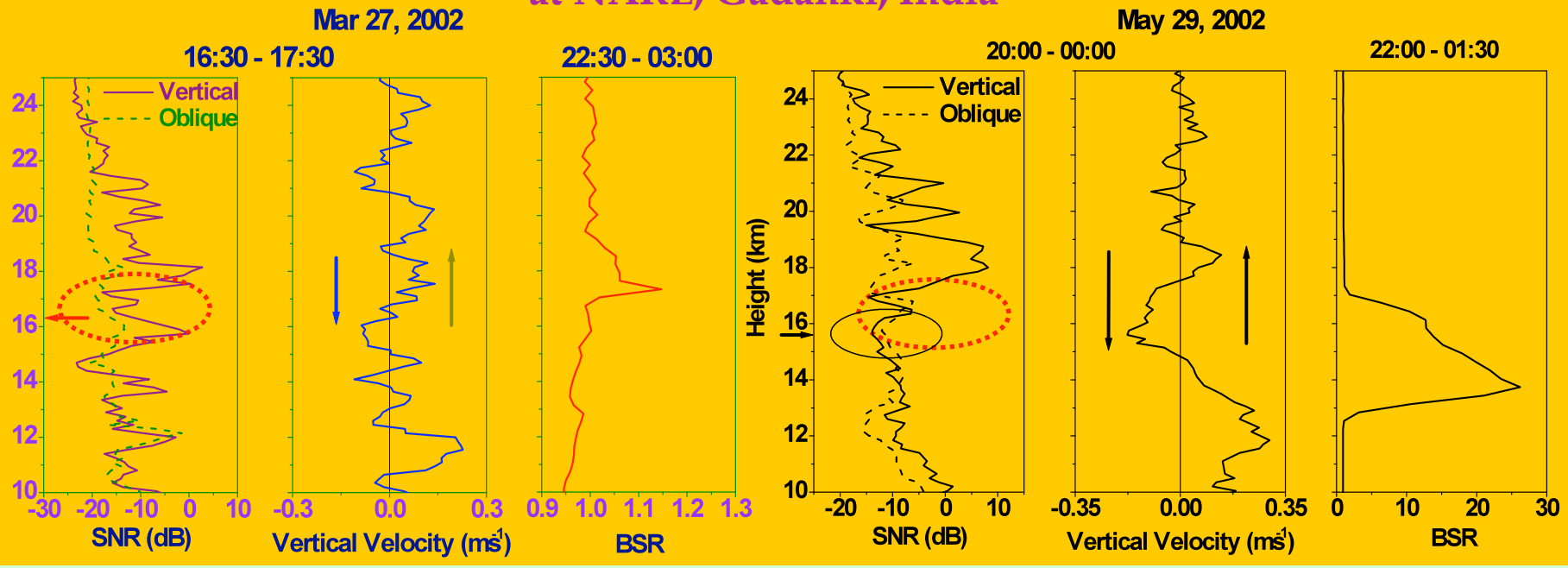
Transport of atmospheric constituents in the vicinity of tropopause takes place mainly through the following three important mechanisms

1. Tropopause folding, frequently leading to the dynamical instability (enhanced turbulence) and mixing of atmospheric constituents between two levels,

2. Atmospheric wave activity, another important mechanism through which the troposphere influences the stratosphere, particularly in the sub-tropical regions, and

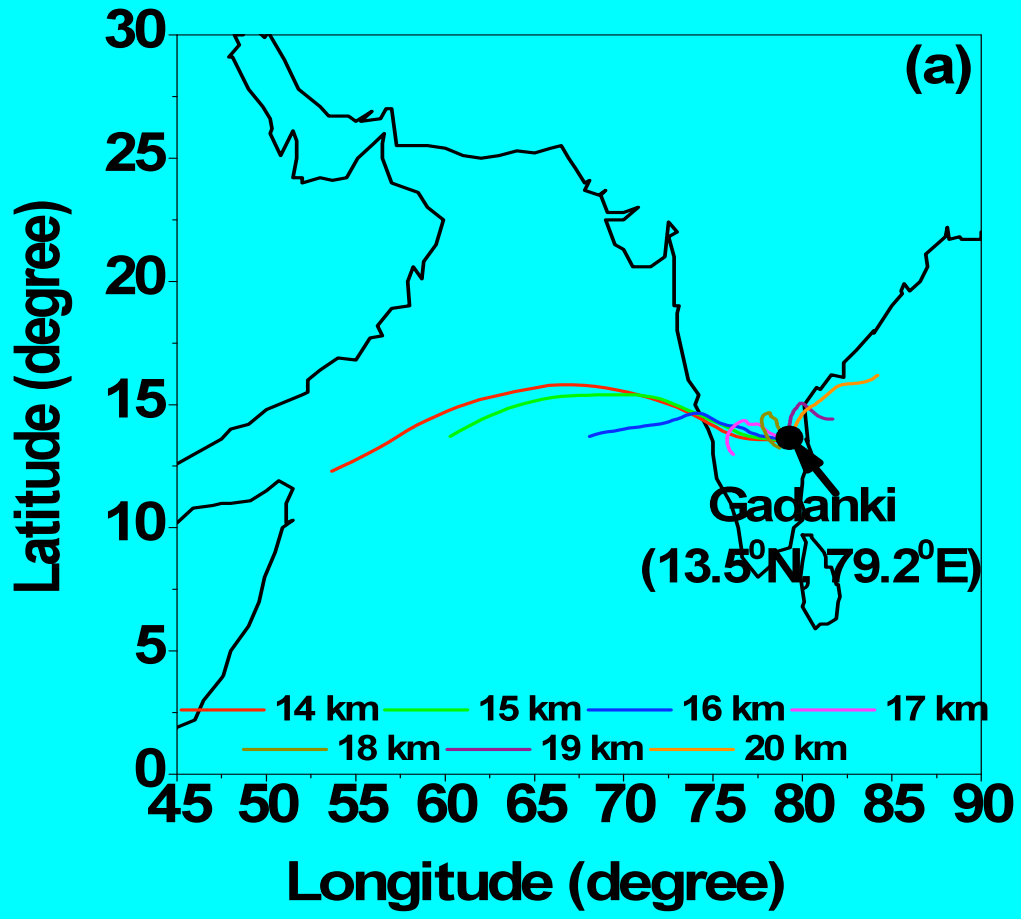
3. Convective activity, which is highly responsible for lifting of material from lower to higher levels in the tropical regions.

Height Profiles of Concurrent MST Radar and Nd:YAG Lidar Observed Parameters on Clear- sky (March 27, 2002) and Cloudy-sky (May 29, 2002) Days at NARL, Gadanki, India



A sharp enhancement in the vertical beam SNR as compared to that in the oblique beam is evident near the altitude of tropopause. This large aspect sensitivity indicates stability of the tropical tropopause. An aerosol layer above the tropopause, as seen from BSR profile of clear-sky day, could be due to (i) the weak inversions that exist around this altitude, and (ii) transport of aerosol from Arabian Sea and their trapping below this inversion layer.

Smaller mass transport across the tropopause, ranging from ~0.01 to 0.13 kg m^{-2} sec^{-1} on clear-sky days while it varies from ~0.1 to 0.7 kg m^{-2} sec^{-1} in the presence of cirrus in the vicinity of tropopause.

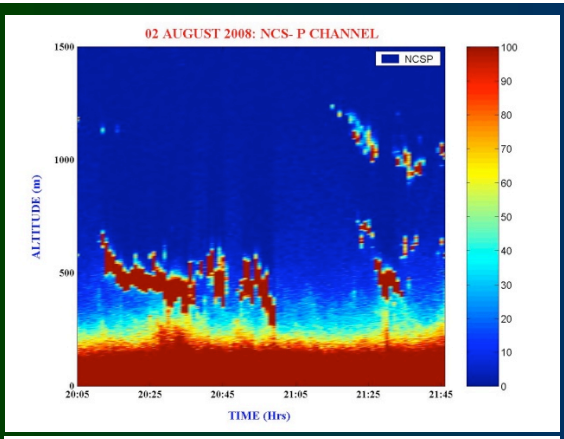


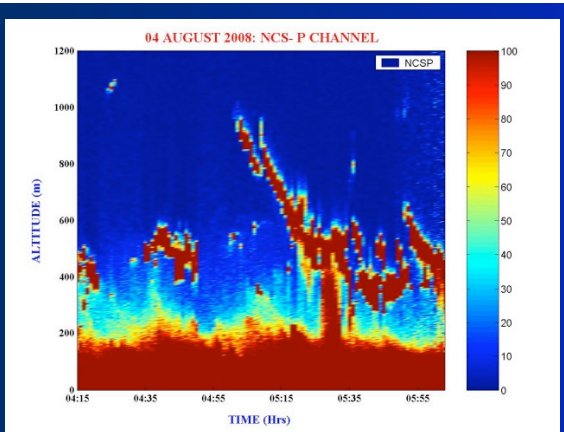
48 hours back-trajectories at different altitude levels from 14 to 20 km on March 27, 2002

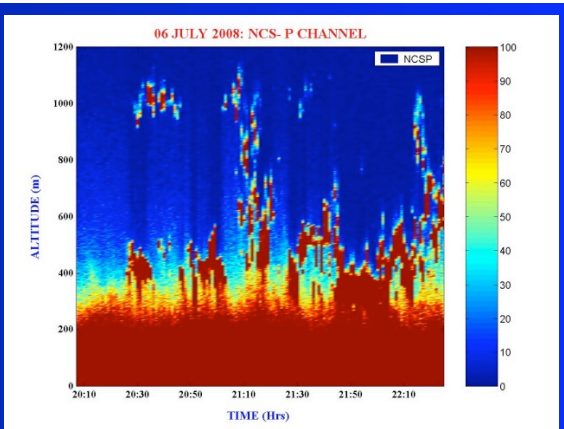
Dual Polarization Micro Pulse Lidar (DPMPL) Operating at IITM, Pune, India

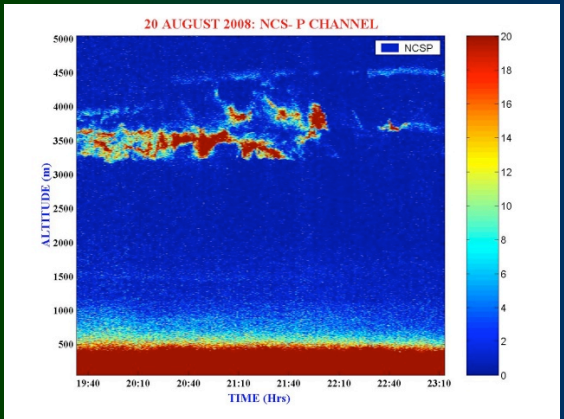
- Autonomous MPL with polarization change facility at transmitter
- Spatial resolution up to 30 cm
- Temporal resolution less than a minute
- Altitude coverage beyond stratospheric altitudes

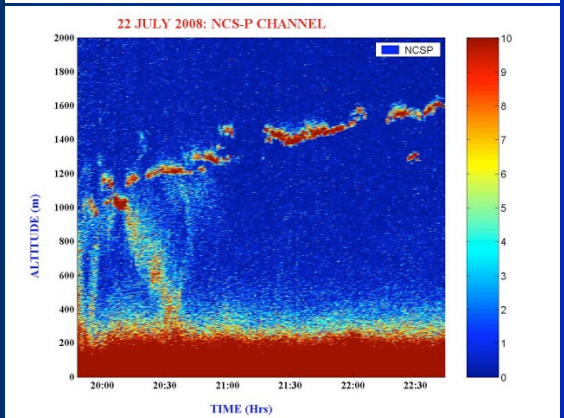
Devara et al., Mobile lidar profiling of tropical aerosols and clouds. *J. Atmos. Ocean. Tech.*, **25**, 2008, 1288-1295.

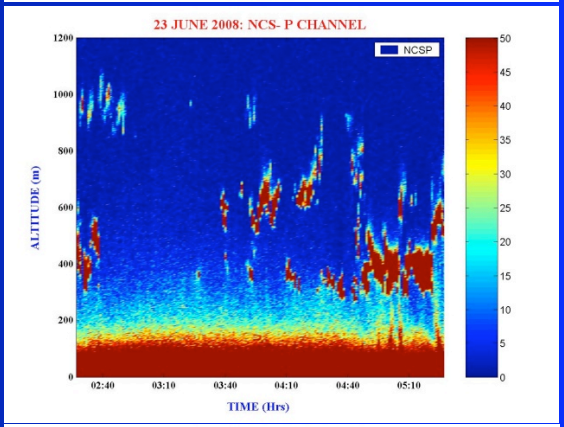


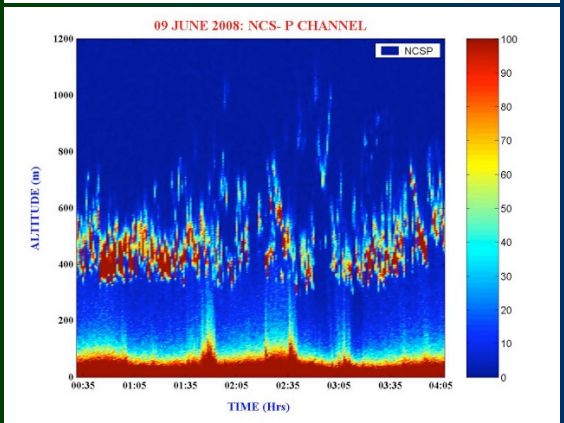


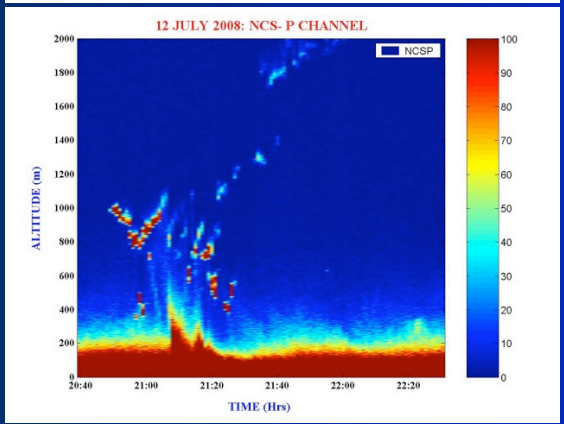


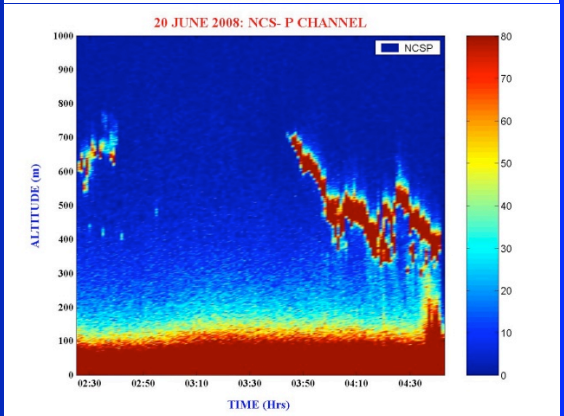












Typical boundary layer and stratiform cloud evolution profiles observed with DPMPL during south-west monsoon 2008

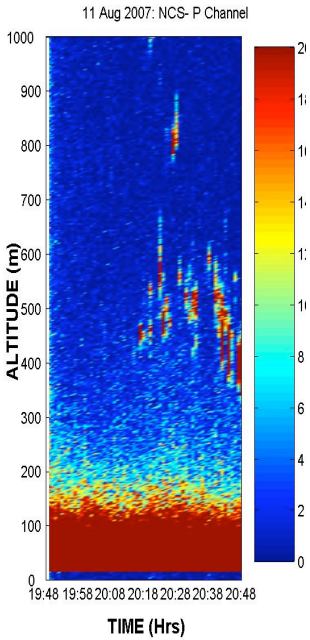
Facilities being augmented to the existing ones for enlarging the scope of observations in the UTLS region for aerosol-cloud-climate interaction studies

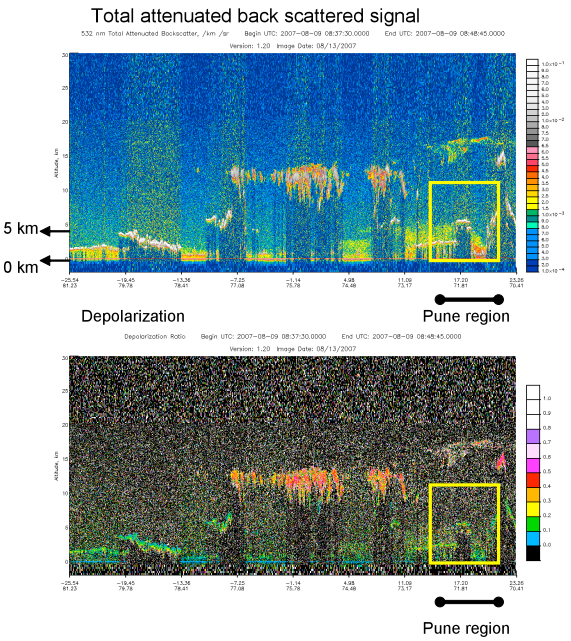
- **Compact Doppler 3-D Wind Lidar**
- **Portable Doppler Polarimetric Ka-band (35GHz) and X-band (9 GHz) Radars**
- **Multi-parameter Raman lidar**
- **Dual-wavelength** (20-22 GHz and 51-59 GHz) **Microwave Radiometer**
- **GP sonde Upper Atmospheric Sounding System**

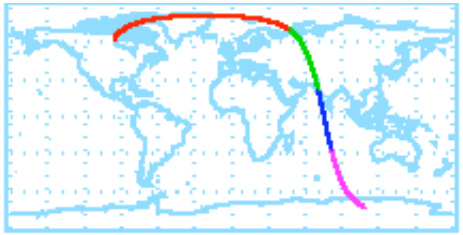
CALIPSO

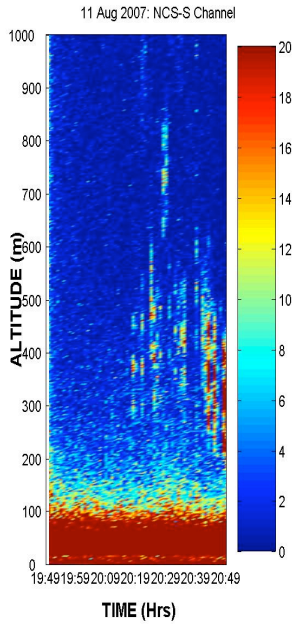
Date: August 9, 2007

Validation

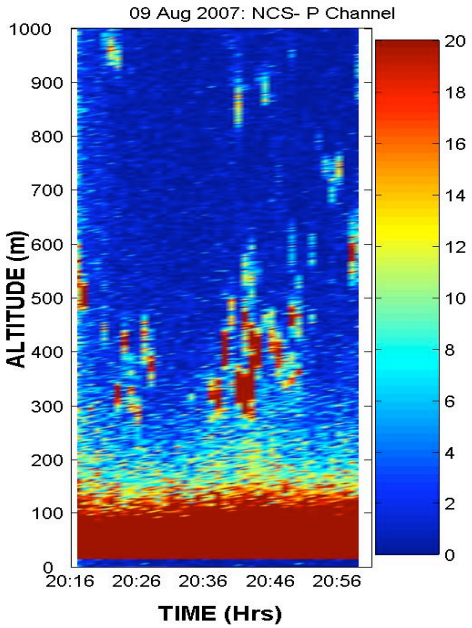


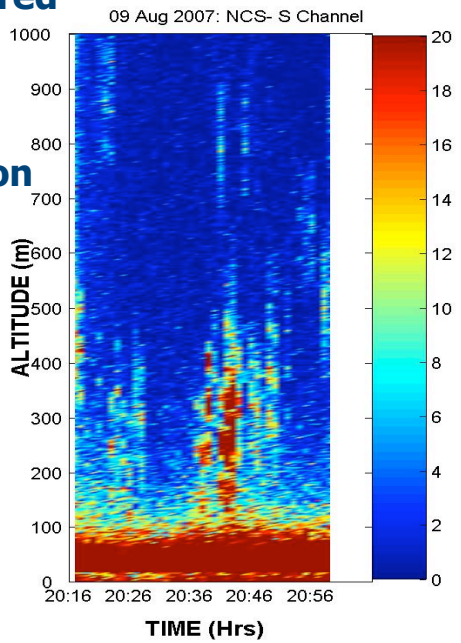




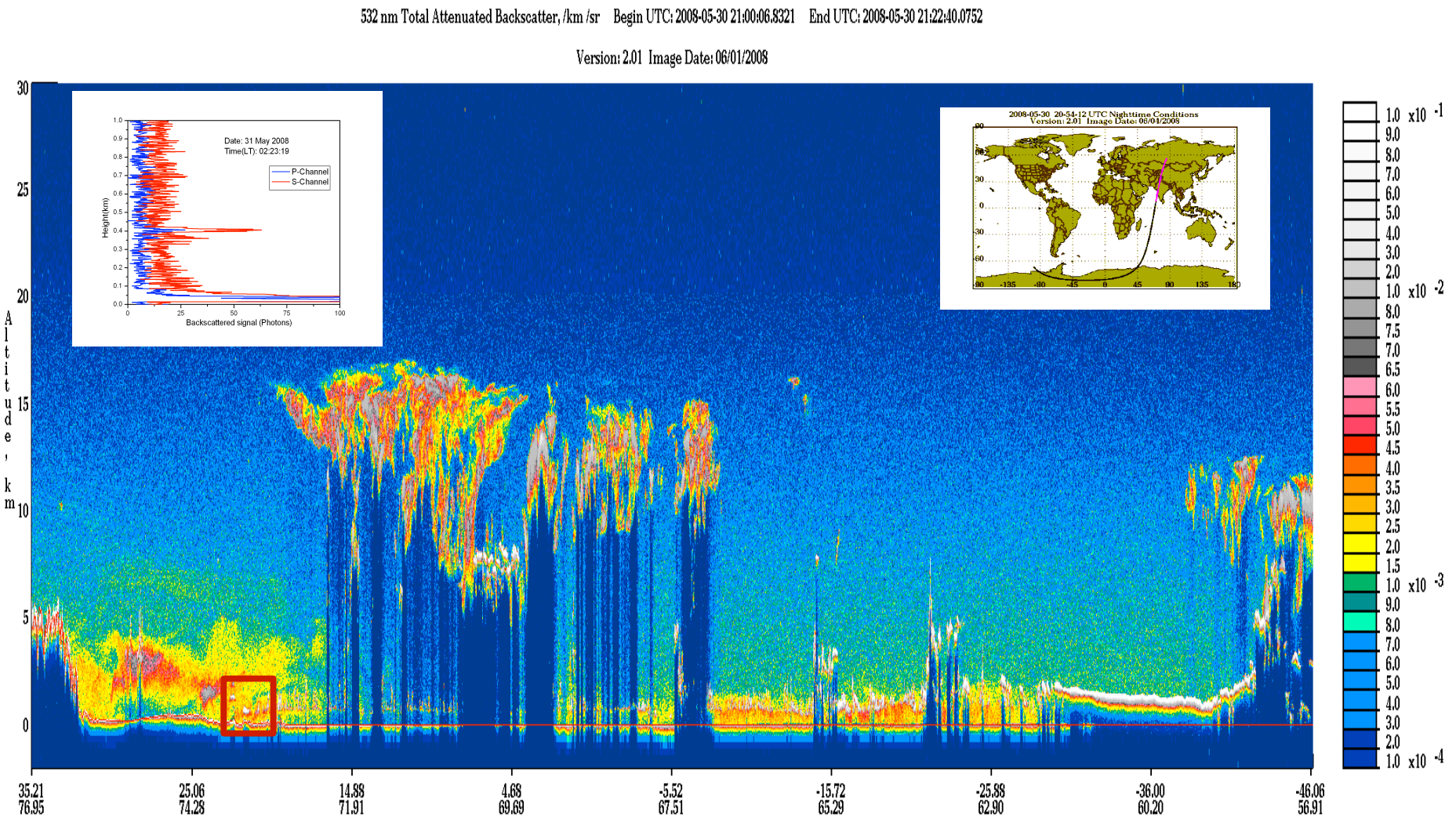


Cloud-Aerosol Lidar and Infrared Pathfinder Spaceborne Observations (CALIPSO) Validation Experiments on 9 and 11 August 2007 at IITM, Pune, India using DPMPL





The low-level clouds observed with DPMPL and CALIPSO at 02:30 hrs on 31 May 2008



The current National programs in India that have relevance to SPARC are

1. Continental Tropical Convergence Zone (CTCZ) Experiment

To undertake detailed land and marine observations and modeling studies of the processes specific to the CTCZ such as atmosphere-hydrosphere-biosphere feedbacks (with more emphasis on land-surface processes and physico-chemical, optical and radiative characteristics of aerosols etc.) in addition to observations aimed at elucidation of the nature of cloud systems in the CTCZ.

2. Cloud Aerosol Interactions and Precipitation Enhancement Experiment (CAIPEEX)

CAIPEEX has two components viz. (1) cloud – aerosol interaction and (2) precipitation enhancement experiment.

Understanding of cloud-aerosol interaction is necessary for the second component. Aircraft observational program has been proposed for this. The program intends to address following key uncertainties in respect of cloud-aerosol-climate interactions:

Cloud/Precipitation microphysics issues; Cloud dynamics issues; Cloud modeling issues; Climate variability in monsoon environment ; Seeding-related issues; Aerosol distribution issues and so on.

3. Aerosol Radiative Forcing over India (ARFI)

The main emphasis of this program is to map elemental and organic carbon aerosol measurements and estimate aerosol radiative forcing over different stations in India. It is envisaged to understand better the aerosol-chemistry-climate interactions.

4.Integrated Campaign of Aerosols, gases and Radiative Budget (ICARB-II)

This program undertakes studies with a special reference to Elevated Heat Pump (EHP) Mechanism to understand the impact of aerosols (both scattering and absorbing type) on weather and climate through their impact on heating profile induced large-scale circulation.

5. MEGHA-TROPIQUES

- **Unique ISRO-CNES satellite mission that allows study of the water cycle and energy exchanges besides many other applications in tropics.**

•Has four sensors (ScaRAB, SAPHIR, MADRAS and GPS-RO), operating in optical, thermal and electromagnetic wave regions for characterizing land-atmosphere-ocean parameters and Earth's radiation budget.

•MADRAS (Microwave Analysis and Detection of Rain & Atmospheric Structures): Consisting of multi-frequency imaging radiometer that provides rainfall, integrated water vapor, liquid water, ice, cloud type (stratiform or convective) and sea surface wind speed.

•SAPHIR (Sounder for Atmospheric Profiling of Humidity in the Inter-tropics by Radiometry): Consisting of a millimeter wave profiler that measures vertical distribution of humidity from surface up to upper tropospheric altitudes in six atmospheric layers.

•ScaRAB (Scanner for Radiation Budget): Includes an optical IR radiometer that yields short-wave and long-wave radiative fluxes from the top-of-atmosphere, albedo and large-scale cloud properties.

6. Indian Satellite for Aerosols and Gases (I-STAG)

Objectives:

(i) Retrieval of atmospheric aerosol extinction, ozone and water vapor density profiles over the tropics with a vertical resolution of about 0.5 km

(ii) Investigation of the spatial and temporal variability of these species and determine their cross-boundary transport.

Payloads:

(i) Multi-Angle Polarization Imager **(MAPI)**
Multi-spectral (0.4 to 1.2 μm; 2.0 to 4.0 μm and 10.5 to 12.5 μm)

(ii) Measurement of Aerosols by Viewing Earth's Limb **(MAVELI)**

(iii) Measurement of Atmospheric Gases by Infrared Spectrometer **(MAGIS)**
[Fourier Transform Infrared (FTIR) Spectrometry]

Orbit altitude: 600 km; Inclination: 30 degrees, Speed: 7.56 km/sec;
No. of orbits per day: 14.89

7. Indian Lidar Network (I-Link)

Right now, a few Research organizations and a very few Universities have stationary/ mobile lidar systems for monitoring aerosols, gases and temperature in the boundary layer, free-troposphere and stratosphere. In addition, a well-planned program to establish country-wide network of micro pulse lidars for regular monitoring of aerosols, pre-cursor gases and clouds up to the UTLS region has been drawn. Some of these lidars are also being planned to be operated in conjunction with ST Radars/Doppler Sodars for better characterization of aerosols and clouds in terms of their radiative forcing in regional climate diagnosis and prediction programs.

8. Space Borne Lidar (SBL)

An ISRO project, as a National Program, called "Aerosol Cloud Climatology Laser Radar in Mission to Space (ACCLAIMS)" has been undertaken to study the role of aerosols, gases and clouds in the atmosphere-land-ocean interactions. The pilot experiment is planned to test performance of the payload "Backscatter Lidar" with a National Balloon Facility in Hyderabad.

Altitude: 600 km; No. of orbits per day: 15; Wavelengths: 532 and 1064 nm
Height resolution: ~ 30 m

Summary and Conclusions

- Clear-sky conditions associate with large aspect sensitivity, larger values of SNR and larger stability of the troposphere as compared to cloudy-sky conditions.
- In the presence of cirrus clouds, reversal in vertical velocity was observed. This implies large mixing, low aspect sensitivity and disturbed tropopause conducive for transport / exchange of atmospheric constituents in the UTLS region.
- Larger values of mass flux (0.1 to 0.7 kg $m^{-2}sec^{-1}$) were found in the presence of clouds as compared to clear-sky values.
- The mean transport was found to be upward in the case of clear-sky conditions and downward in the case of cloudy-sky conditions, leading to both TSE and STE processes.
- Studies are also in progress to examine in detail the STE/TSE processes in the tropical region using the Dual Polarization Micro Pulse Lidar (DPMPL) and Ka- (35 GHz) / X-band (9 GHz) Doppler Radars, Microwave Radiometer, Doppler Wind and Raman Lidars and GP sondes at IITM, Pune, India.
- Several Nation-wide ground-based, aircraft, ship observational campaigns and Satellite mission programs have been underway to understand the role of aerosol, pre-cursor gases and clouds in climate change.


Thank you