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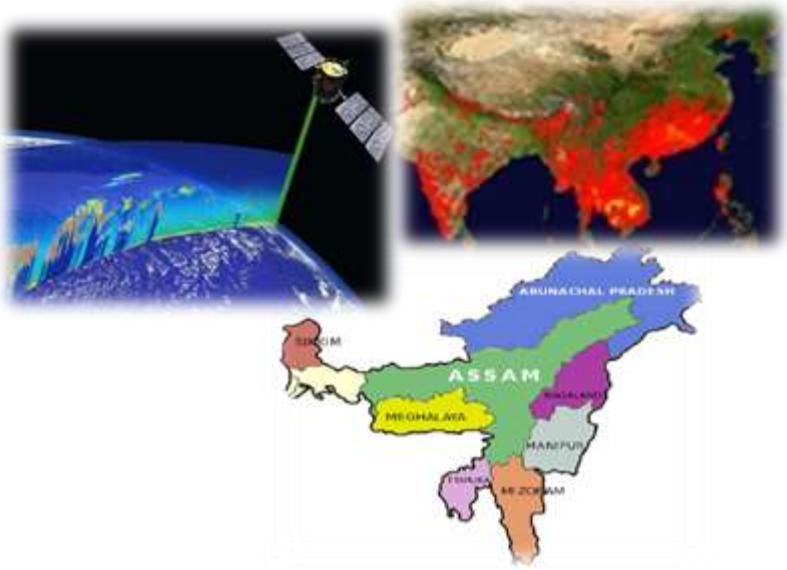

Regional Heterogeneity of Aerosol Characteristics over the North-Eastern Part of India, a region in the Eastern Himalayan Range

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Outline

Outline of my presentation:

1. **Motivation**
2. **Approach**
3. **Results and Discussion**
4. **Summary**

Region of Interest: Why North Eastern part of India (NEI) is Important?

- Unique topography
- Cluster of mountains help orographic lifting of pollutants
- Region is sandwiched between two global biodiversity hotspots Himalaya and Indo-Burma.

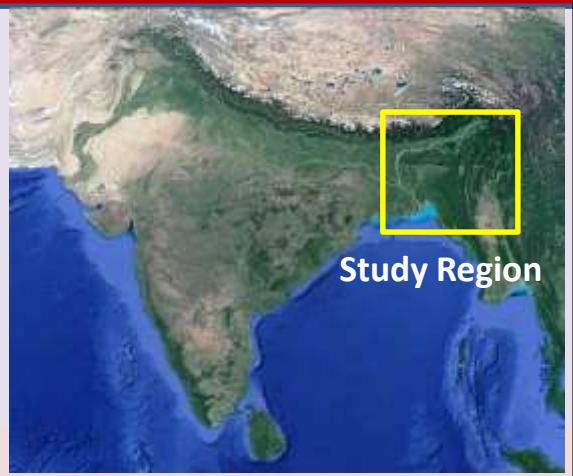


Fig: Regional Topography

Aerosol Sources:

Background/natural sources:

- Forest Cover: VOC generated secondary organic aerosols and biological aerosols (66% area is covered by forests)
- Land : soil organic carbon and mineral dust

Anthropogenic sources:

- Carbonaceous aerosols: biomass burning associated with shifting cultivation (peaks in March-April), open coal mining, brick kilns, oil and gas fields
- Remote aerosols: Mainly from Indo Gangetic Plain, Mainland India, West India and Asia

References: Gogoi et al., 2009 (JGR), 2011 (Atmos.Env.), 2017 (JGR), Pathak et al., 2010 (JGR), 2012 (Atmos.Env.), 2016 (Atmos.Env.) etc.

- Knowledge on the vertical distribution of aerosols throughout the atmosphere is required for assessing both direct and indirect effect and thus the climatic implications at different elevations.
- The information of vertical distribution of aerosols in radiative model is essential to capture the realistic picture of the aerosols on direct and indirect effect.
- Complex region of NEI consequent with ocean, mountains, hills and plains together with strong convective activities can pileup the aerosols to elevated levels.

Objectives:

- To study the vertical distribution of aerosols over the study region.
- To investigate types of aerosols over the study region.

Site description: North-eastern part of India and its adjoining countries locations

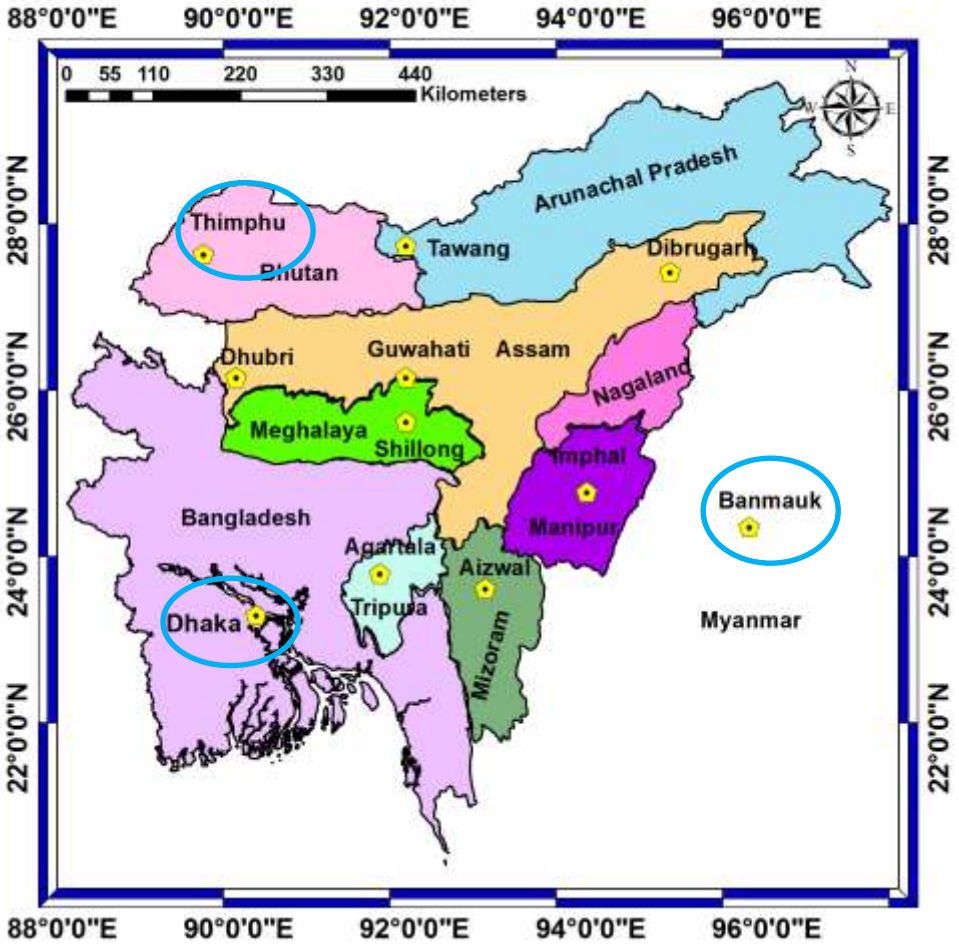


Fig: Study locations over the North-East India and adjoining areas are shown by yellow pentagon.

- Geographical position: surrounded by East-Asia, South-East Asia, China and the mainland India.

Study Location Table

- Thimphu (THM) (27.5° N, 89.6°E, 2737 m AMSL)
- Tawang (TWN) (27.6° N, 91.9°E, 2668 m AMSL)
- Shillong (SHN) (25.6° N, 91.9°E, 1496 m AMSL)
- Aizwal (AZL) (23.7° N, 92.8°E, 1001 m AMSL)
- Imphal (IPH) (24.82° N, 93.95°E, 790 m AMSL)
- Banmauk (BNK) (24.4° N, 95.8°E, 279 m AMSL)
- Dibrugarh (DBR) (27.4° N, 94.9°E, 111 m AMSL)
- Guwahati (GHY) (26.1° N, 91.6°E, 55 m AMSL)
- Dhubri (DHB) (26.02° N, 90.0°E, 28 m AMSL)
- Agartala (AGA) (23.9° N, 91.2°E, 14.9 m AMSL)
- Dhaka (DAC) (23.4° N, 90.2°E, 4 m AMSL)

Columnar aerosol loading scenario over the study region

Ground based observation

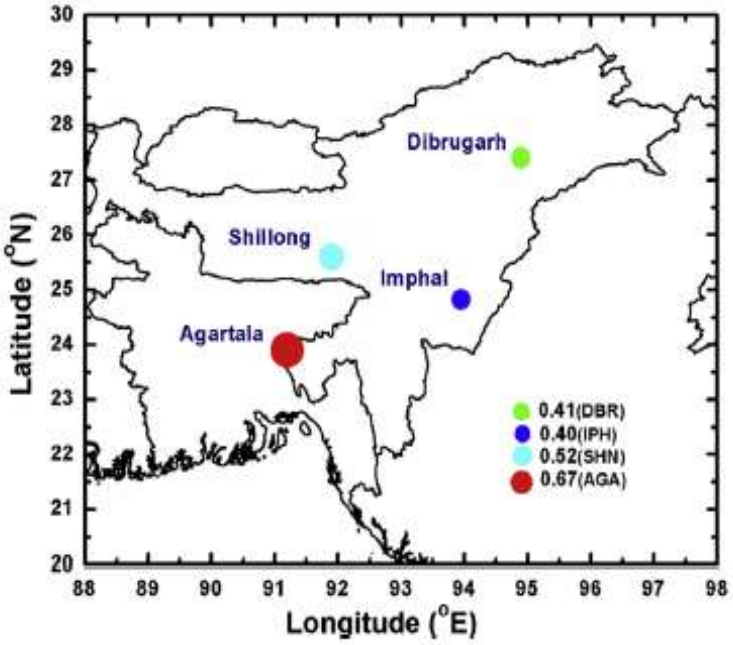


Fig: Spatial variability of climatological average AODs over NEI from ground based ARFINET observation.

Pathak et al., 2016 (Atmos. Envs.)

Satellite based observation

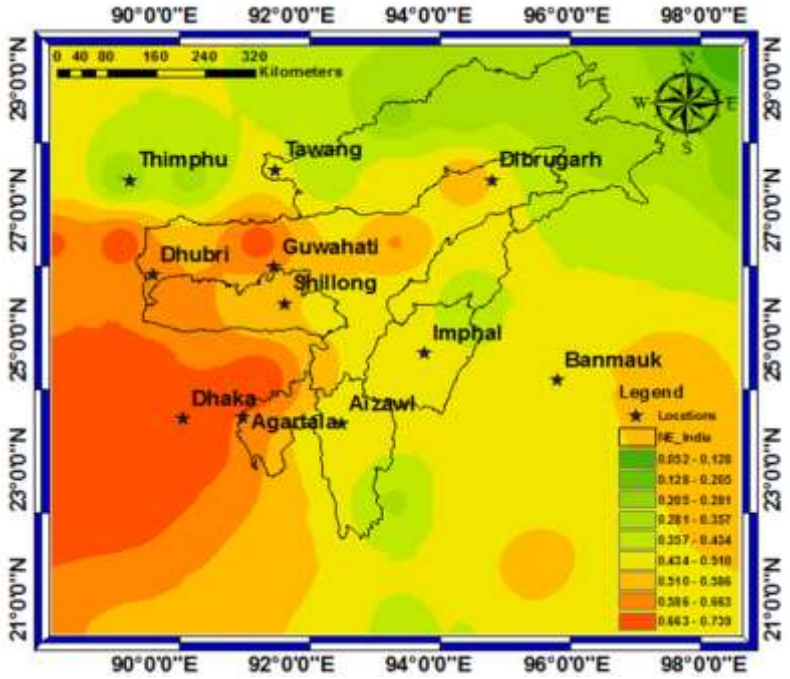


Fig: Spatial variability of climatological average AODs from MODIS satellite over NEI and its adjoining areas.

Dahutia et al., (IJOC, Under Revision.)

Meteorology: Regional meteorology

The region experiences tropical monsoon climate:

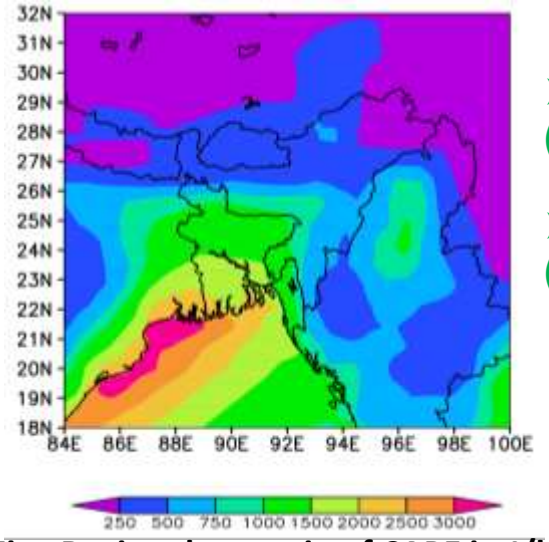
a) Westerly wind

b) Mild temperature

c) Hot and humid weather

d) Comparatively more rainfall than other parts of India during the pre-monsoon (March, April and May months) season.

Instability: The Convective Available Potential Energy (CAPE) in J/kg in a parameter to measure the degree of instability

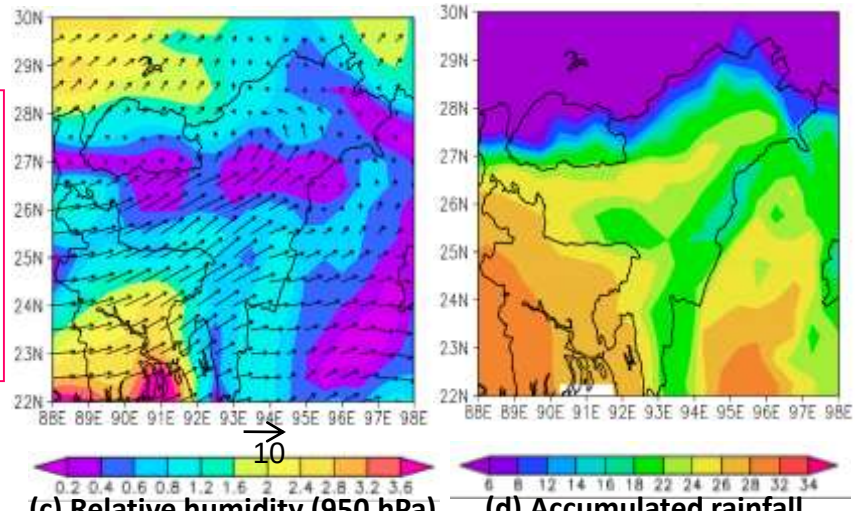


➢Less unstable (CAPE<1400J/kg)

➢More unstable (CAPE>2600J/kg)

Fig: Regional scenario of CAPE in J/kg

(a) Wind speed & direction (850 hPa) (b) Temperature



(c) Relative humidity (950 hPa) (d) Accumulated rainfall

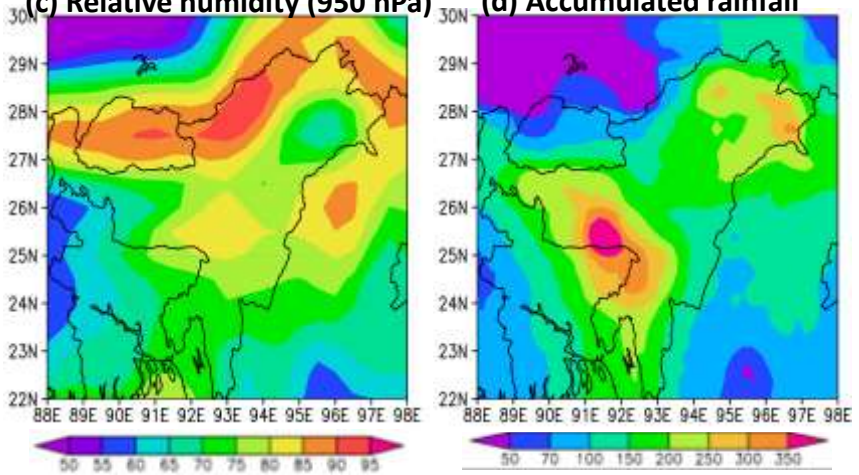


Fig: Regional meteorology during March-April-May months

Data and Quality Control

Satellite:
CALIPSO: Cloud-Aerosol Lidar and Infrared Pathfinder Satellite Observations
Instrument:
CALIOP: Cloud-Aerosol Lidar Orthogonal Polarization
Data product:
Aerosol Level 2 5km Profile data (V4.10) (CAL_LID_L2_05kmAPro-Standard-V4-10)
Data Period:
March-April-May (2012-2016)

Parameters used:
a) Extinction_Coefficient_532
Quality Control:
1. CAD_Score (-20 to -100)
2. Extinction_QC_Flag_532 (0 &1)
3. Fill values are ignored
4. COD>4 are ignored

b) Total_Backscatter_Coefficient_532

Approach

Aerosol Subtype :

❑ Lidar ratio (ratio of extinction to backscatter coefficient)

Lidar ratio at 532 nm

Marine (20±6 sr)
Desert Dust (DD) (40±20 sr)
Polluted Continental (PC) (70±25 sr)
Clean Continental (CC) (35±16 sr)
Polluted Dust (PD) (55±22sr)
Biomass Burning (BB) (70±28 sr)

If the elevated layers are present then it will be biomass burning otherwise polluted continental though the lidar ratio is same. (Following the algorithm Omar et al.,2009, Journal of Atmospheric and Oceanic Technology).

❑Particulate_Depolarization_Ratio_Profile_532 (PDR)

Meteorological Parameters :

Surface Wind (m/sec)
Pressure (hPa)
Temperature (°C)
Relative Humidity (%)

Selected Location: Thimphu (THM) (27.5˚ N, 89.6˚E, 2737 m AMSL)

THM	Aerosol Profile
Total overpass	58
Vertical profile	38
Tropopause height	15.85
Tropopause temp	-70.06

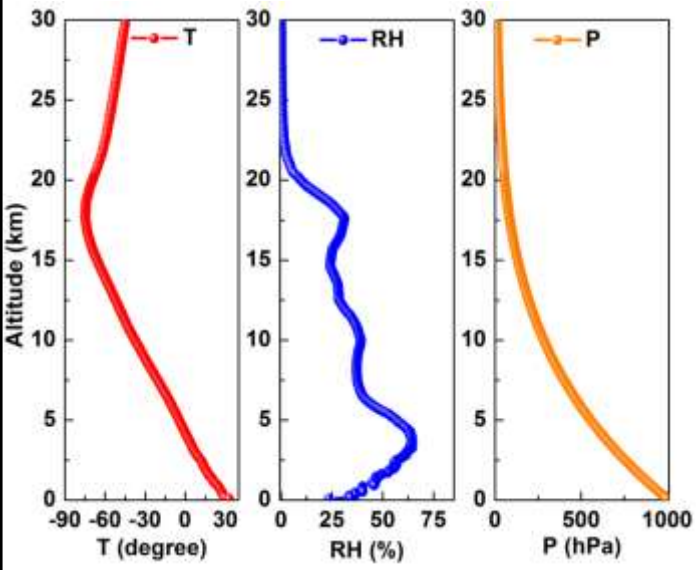
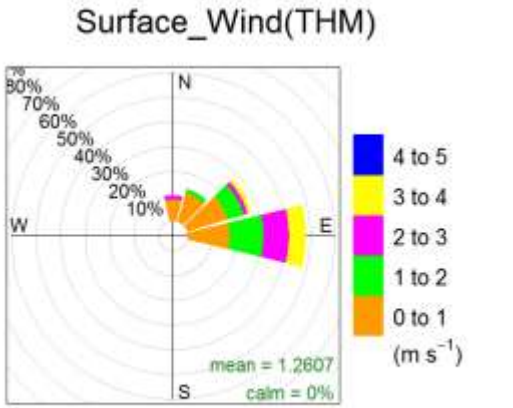


Fig: Average Temperature (degree), Relative humidity (%) and Pressure (hPa) vertical profile over THM



Frequency of counts by wind direction (%)

Fig. Surface wind frequency counts

- Frequency of surface wind is maximum in NE direction.
- Aerosols of THM is mainly contributed by biomass burning (BB), Polluted dust (PD) and Desert dust (DD) where PD is dominating.
- PDR ranges from ~0.001-0.5

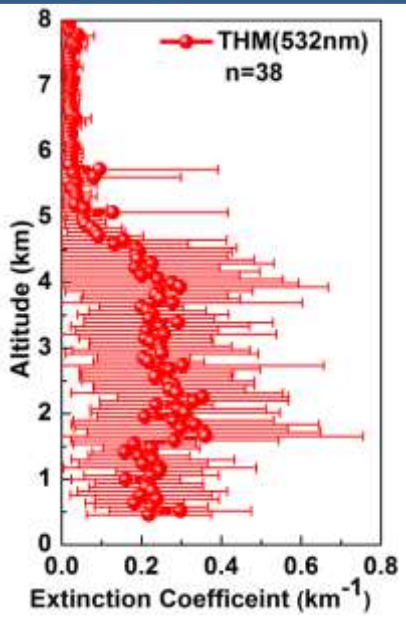


Fig: Average vertical profile of extinction coefficient (km^{-1}) at 532 nm

Fig: Percentage occurrence of aerosol types

Selected Location: Tawang (TWN) (27.6° N, 91.9°E, 2668 m AMSL)

TWN	Aerosol Profile
Total overpass	70
Vertical profile	48
Tropopause height	16.49
Tropopause temp	-73.42

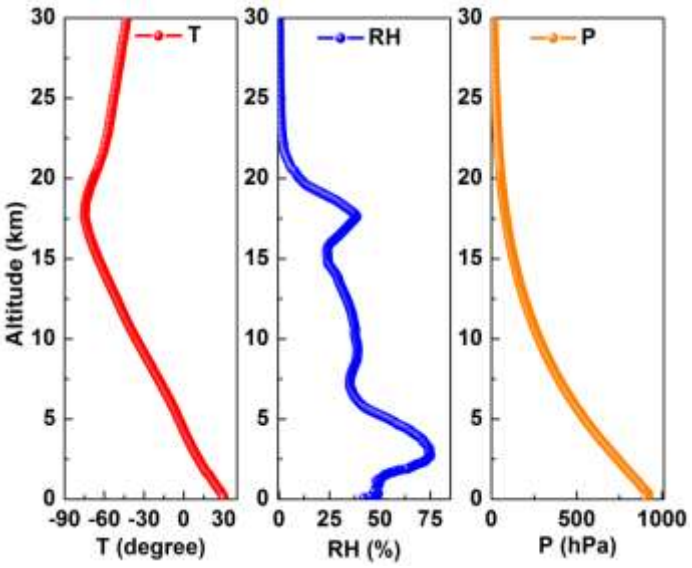


Fig : Average Temperature (degree), Relative humidity (%) and Pressure (hPa) vertical profile over TWN

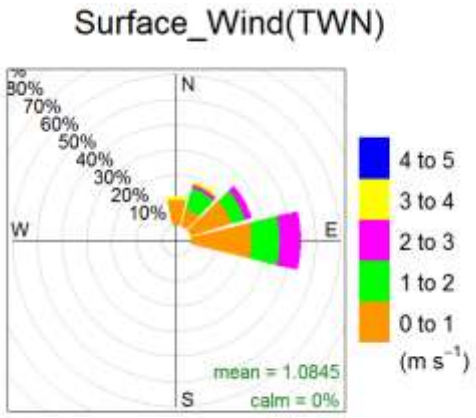


Fig. Surface wind frequency counts

- Surface wind is in NE direction.
- TWN is mainly dominated by PD.
- PDR ranges from ~0.001-0.6

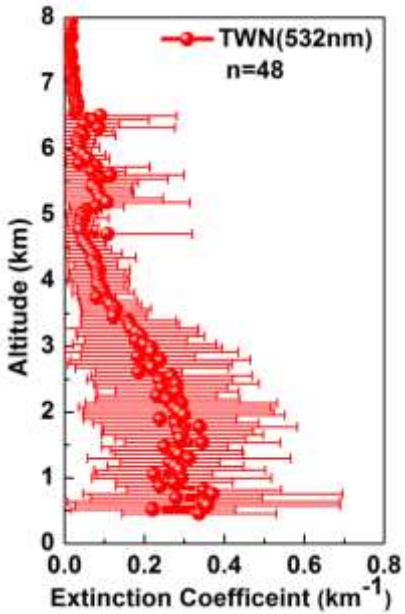


Fig : Average vertical profile of extinction coefficient (km^{-1}) at 532 nm

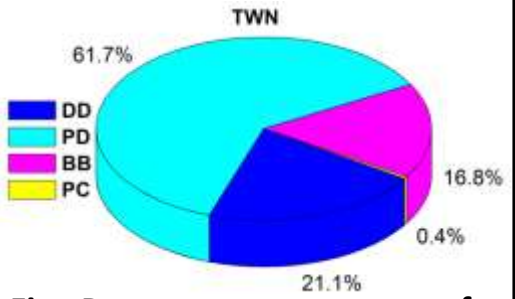


Fig: Percentage occurrence of aerosol types

Selected Location: Shillong (SHN) (25.6˚ N, 91.9˚E, 1496 m AMSL)

SHN	Aerosol Profile
Total overpass	87
Vertical profile	68
Tropopause height	16.85
Tropopause temp	-74.91

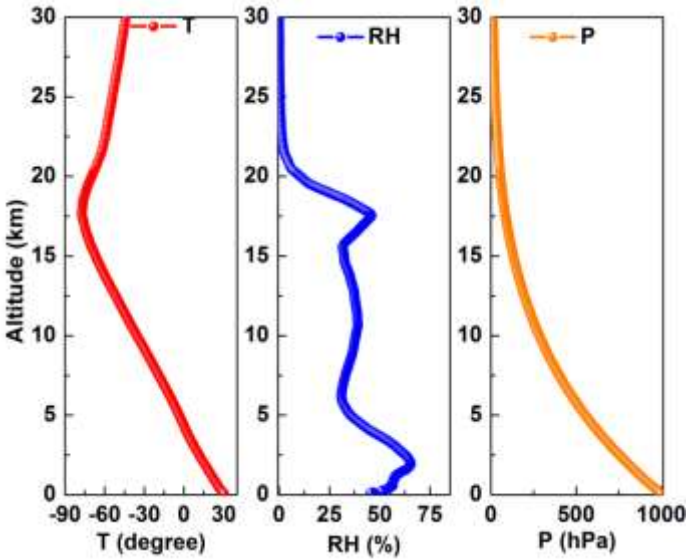
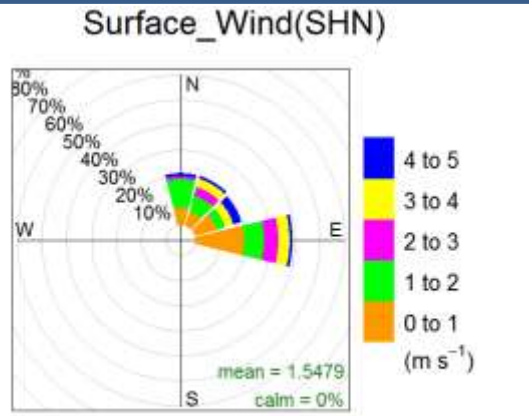


Fig: Average Temperature (degree), Relative humidity (%) and Pressure (hPa) vertical profile over SHN



Frequency of counts by wind direction (%)

Fig. Surface wind frequency counts

- Surface wind is in NE direction.
- SHN is mainly dominated by PD.
- PDR ranges from ~0.003-0.59

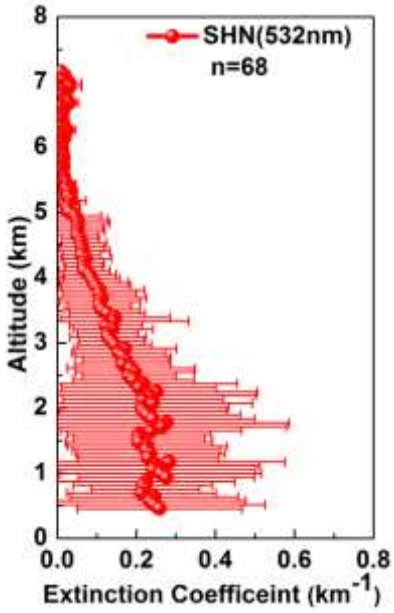


Fig: Average vertical profile of extinction coefficient (km^{-1}) at 532 nm

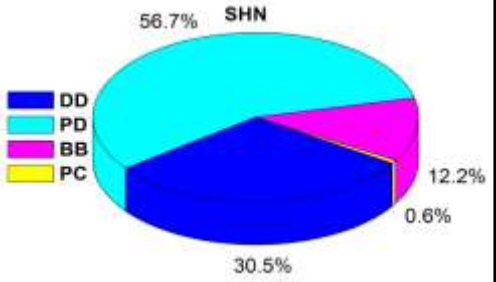


Fig: Percentage occurrence of aerosol types

Selected Location: Aizwal (AZL) (23.7˚ N, 92.8˚E, 1001 m AMSL)

AZL	Aerosol Profile
Total overpass	70
Vertical profile	59
Tropopause height	16.88
Tropopause temp	-77.14

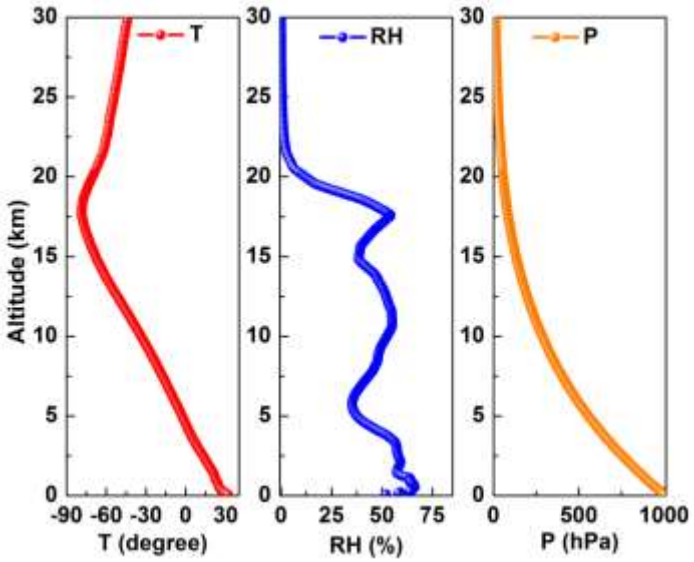
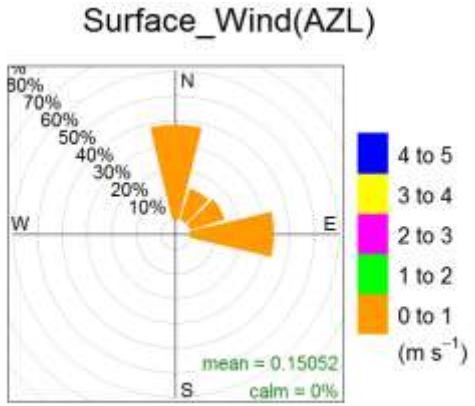


Fig: Average Temperature (degree), Relative humidity (%) and Pressure (hPa) vertical profile over AZL



Frequency of counts by wind direction (%)

Fig. Surface wind frequency counts

- Surface wind is in NE direction.
- AZL is mainly dominated by PD.
- PDR ranges from ~0.006-0.56

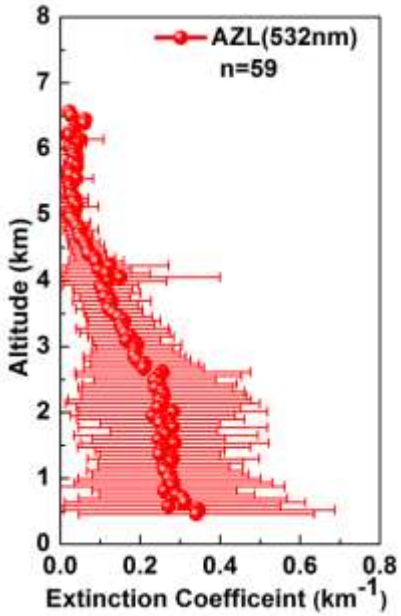


Fig: Average vertical profile of extinction coefficient (km^{-1}) at 532 nm

Fig: Percentage occurrence of aerosol types

Selected Location: Imphal (IPH) (24.82˚ N, 93.95˚E, 790 m AMSL)

IPH	Aerosol Profile
Total overpass	65
Vertical profile	46
Tropopause height	16.66
Tropopause temp	-75.78

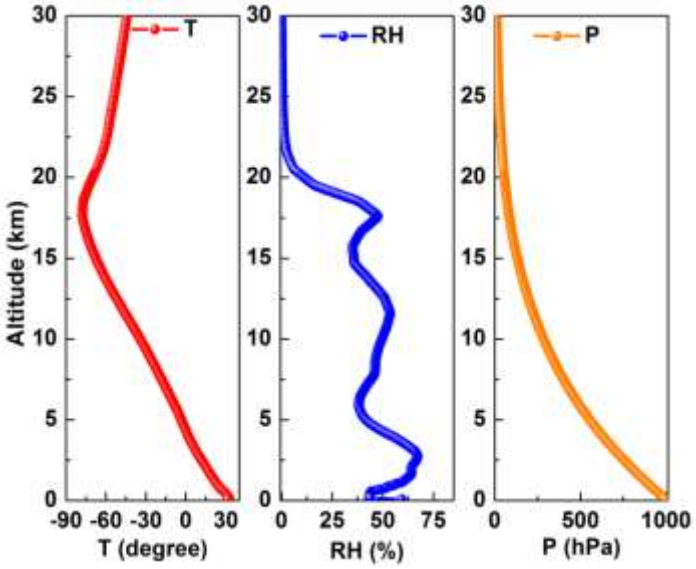


Fig: Average Temperature (degree), Relative humidity (%) and Pressure (hPa) vertical profile over IPH

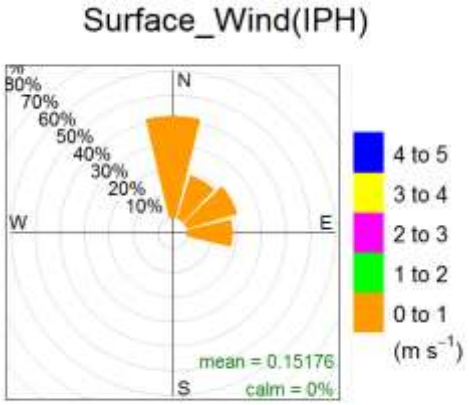


Fig. Surface wind frequency counts

- Surface wind is in NE direction.
- IPH is mainly dominated by PD.
- PDR ranges from ~0.008-0.65

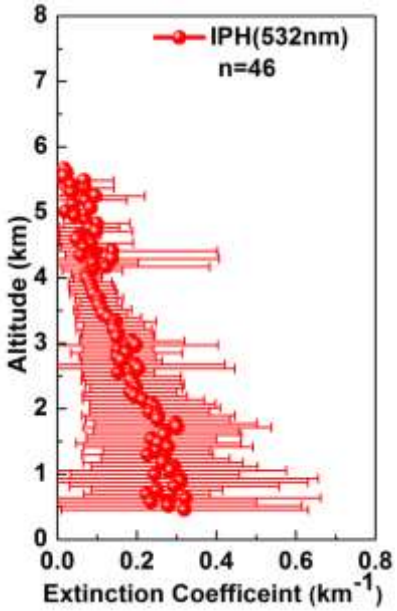


Fig: Average vertical profile of extinction coefficient (km^{-1}) at 532 nm

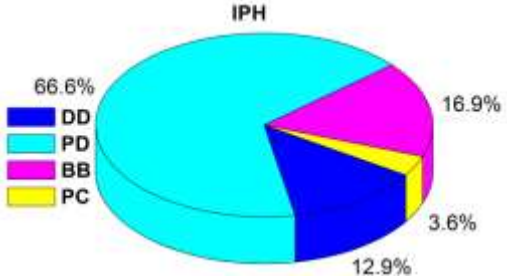


Fig: Percentage occurrence of aerosol types

Selected Location: Banmauk (BNK) (24.4˚ N, 95.8˚E, 279 m AMSL)

BNK	Aerosol Profile
Total overpass	71
Vertical profile	55
Tropopause height	16.49
Tropopause temp	-75.79

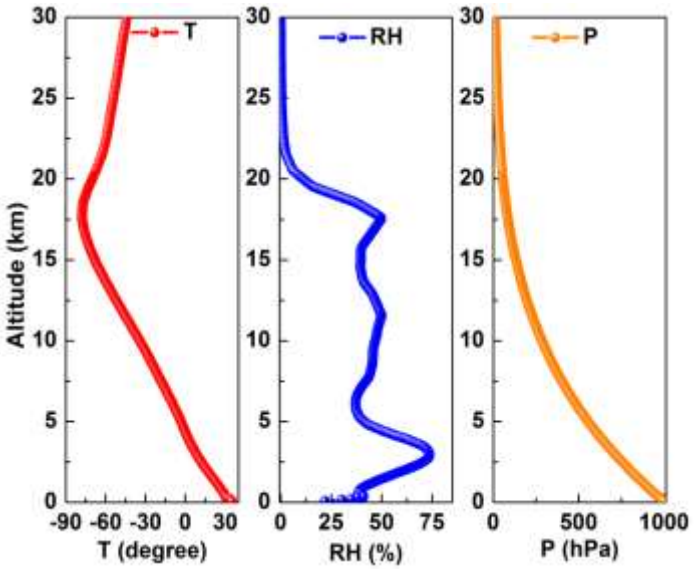
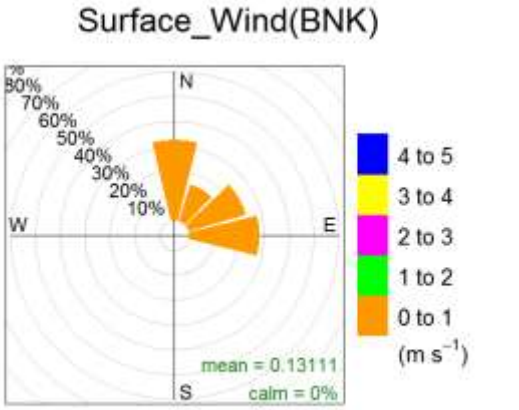


Fig: Average Temperature (degree), Relative humidity (%) and Pressure (hPa) vertical profile over BNK



Frequency of counts by wind direction (%)

Fig. Surface wind frequency counts

- Surface wind is in NE direction.
- BNK is mainly dominated by PD.
- PDR ranges ~0.004-0.99

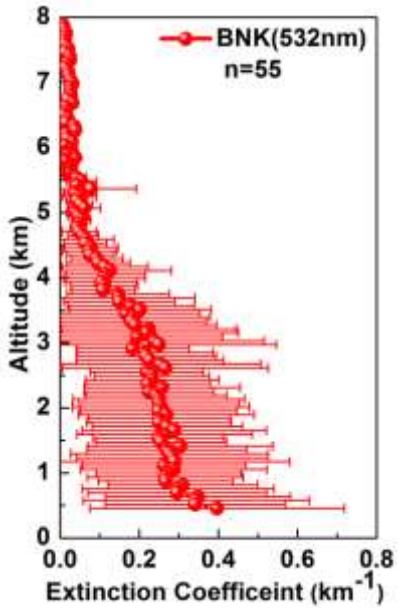


Fig: Average vertical profile of extinction coefficient (km^{-1}) at 532 nm

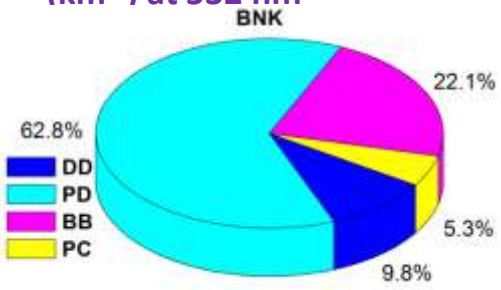


Fig: Percentage occurrence of aerosol types

Selected Location: Dibrugarh (DBR) (27.4˚ N, 94.9˚E, 111 m AMSL)

DBR	Aerosol Profile
Total overpass	69
Vertical profile	44
Tropopause height	15.79
Tropopause temp	-70.86

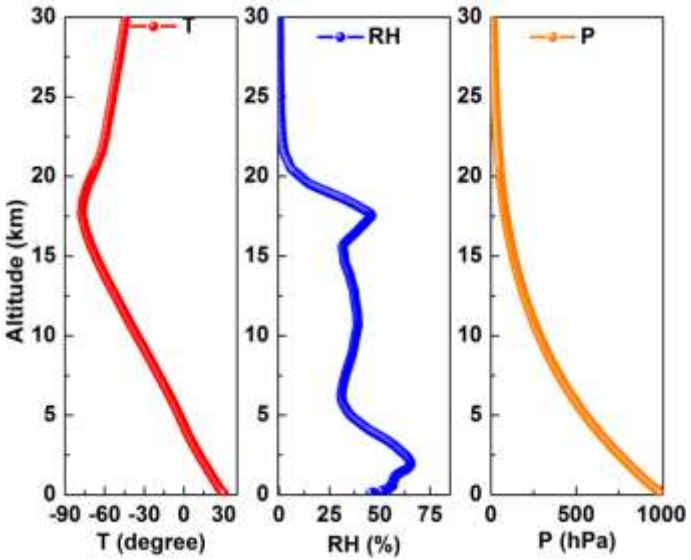
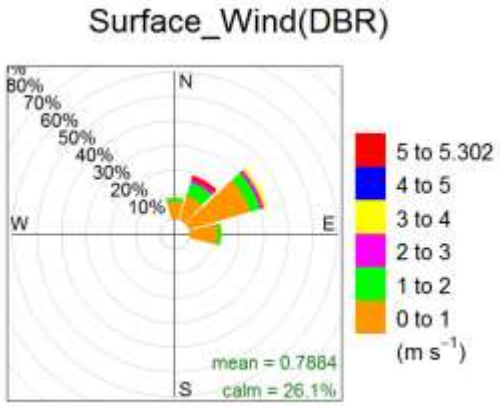


Fig: Average Temperature (degree), Relative humidity (%) and Pressure (hPa) vertical profile over DBR



Frequency of counts by wind direction (%)

Fig. Surface wind frequency counts

- Surface wind is in NE direction.
- Dominated by PD.
- PDR ranges from ~0.004-0.96

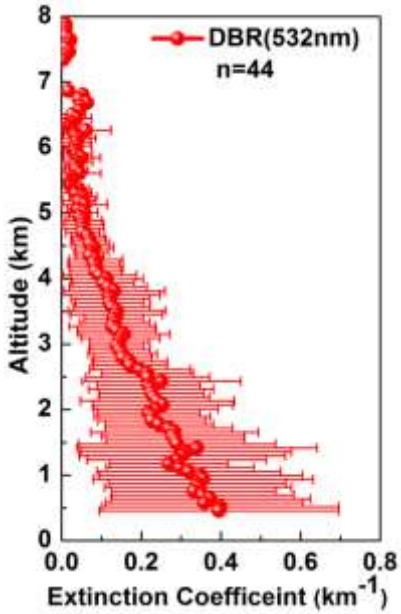


Fig: Average vertical profile of extinction coefficient (km^{-1}) at 532 nm

Fig: Percentage occurrence of aerosol types

Selected Location: Guwahati (GHY) (26.1˚ N, 91.6˚E, 55 m AMSL)

GHY	Aerosol Profile
Total overpass	53
Vertical profile	43
Tropopause height	16.85
Tropopause temp	-75.53

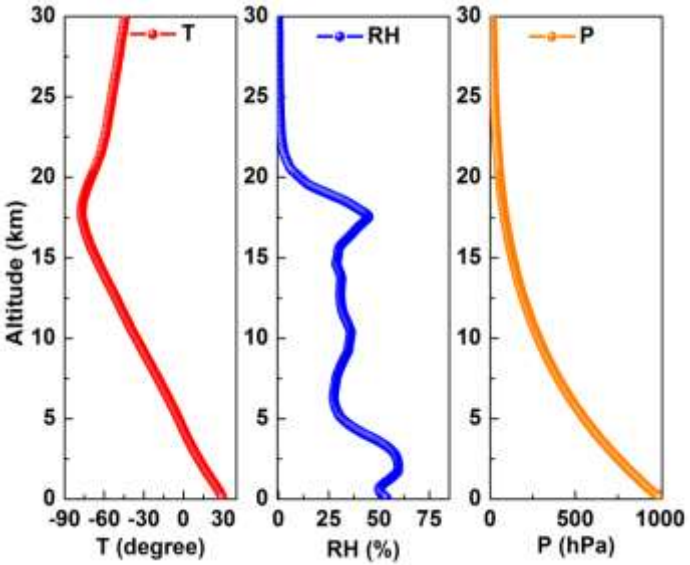


Fig: Average Temperature (degree), Relative humidity (%) and Pressure (hPa) vertical profile over GHY

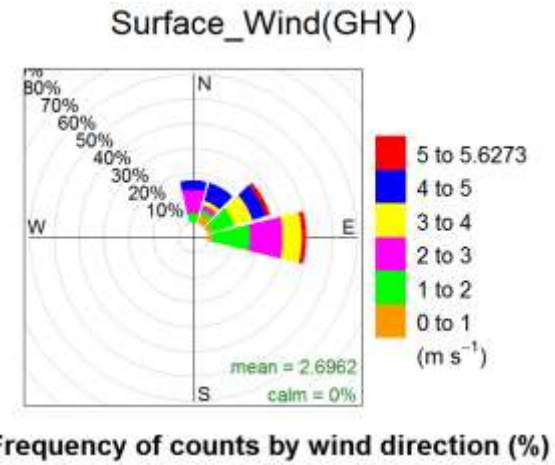


Fig. Surface wind frequency counts

- Surface wind is in NE direction.
- GHY is mainly dominated by PD.
- PDR ranges from ~0.004-0.99

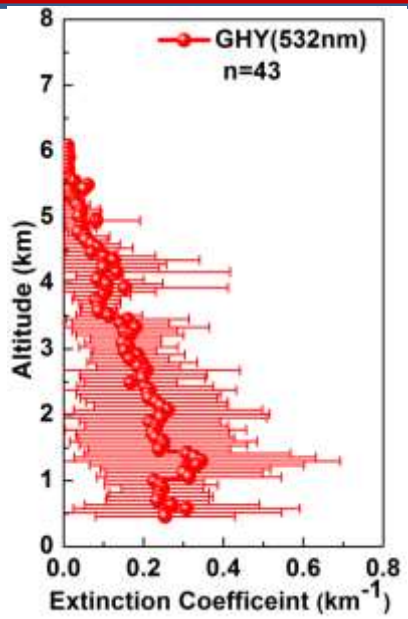


Fig: Average vertical profile of extinction coefficient (km^{-1}) at 532 nm

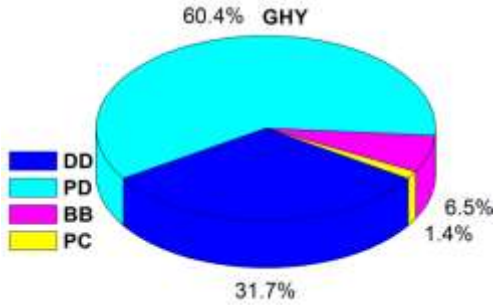


Fig: Percentage occurrence of aerosol types

Selected Location: Dhubri (DHB) (26.02˚ N, 90.0˚E, 28 m AMSL)

DHB	Aerosol Profile
Total overpass	47
Vertical profile	37
Tropopause height	16.10
Tropopause temp	-72.50

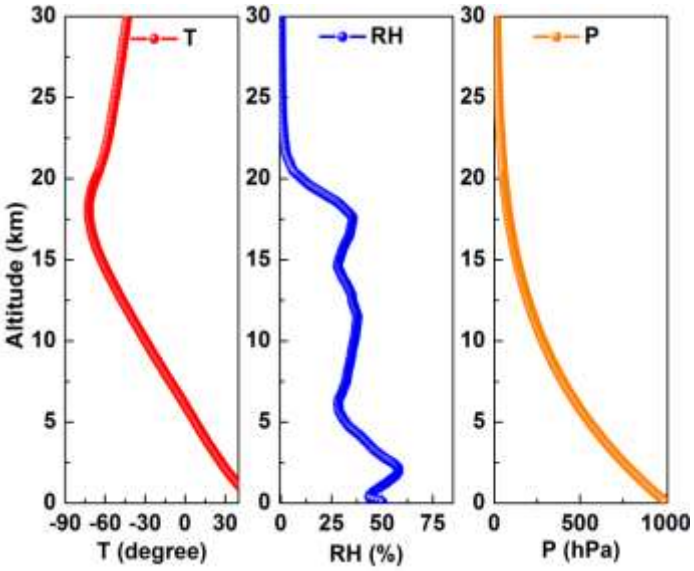


Fig: Average Temperature (degree), Relative humidity (%) and Pressure (hPa) vertical profile over DHB

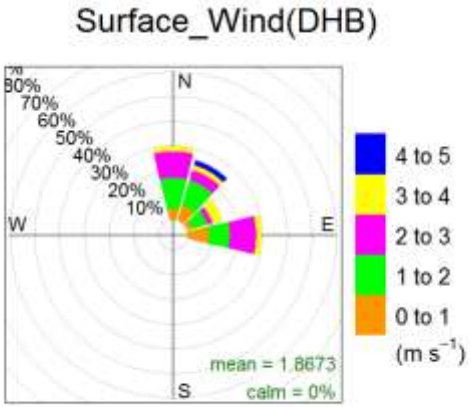


Fig. Surface wind frequency counts

- Surface wind is in NE direction.
- DHB is mainly dominated by PD.
- PDR ranges from ~0.004-0.99

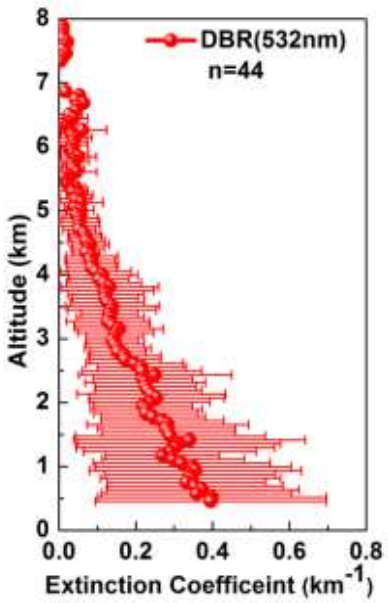


Fig: Average vertical profile of extinction coefficient (km^{-1}) at 532 nm

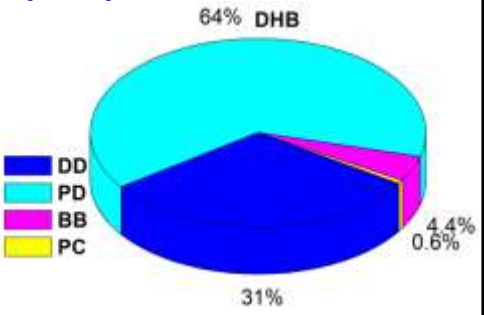


Fig: Percentage occurrence of aerosol types

Selected Location: Agartala (AGA) (23.9˚ N, 91.2˚E, 14.9 m AMSL)

AGA	Aerosol Profile
Total overpass	71
Vertical profile	66
Tropopause height	16.90
Tropopause temp	-77.07

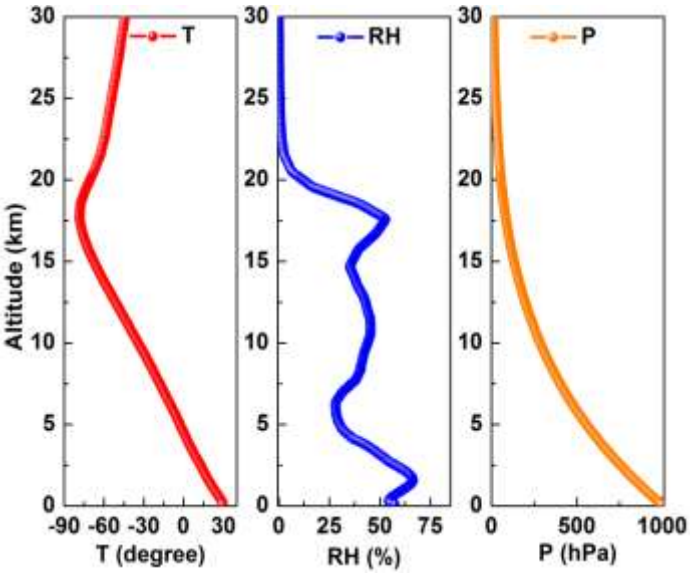
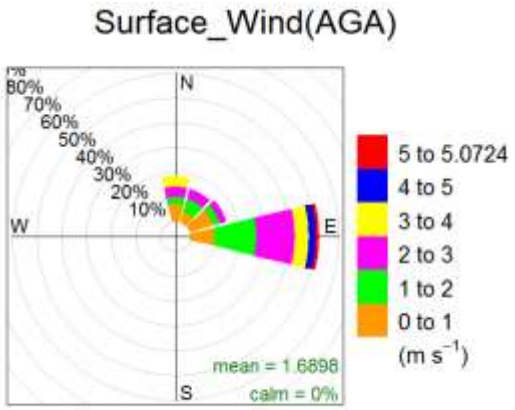


Fig: Average Temperature (degree), Relative humidity (%) and Pressure (hPa) vertical profile over AGA



Frequency of counts by wind direction (%)

Fig. Surface wind frequency counts

- Surface wind is in E direction.
- AGA is mainly dominated by PD.
- PDR ranges from ~0.001-0.9

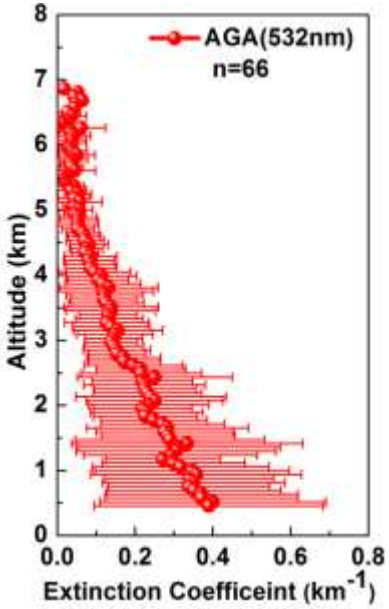


Fig: Average vertical profile of extinction coefficient (km^{-1}) at 532 nm

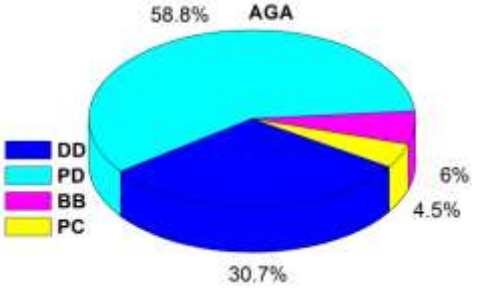


Fig: Percentage occurrence of aerosol types

Selected Location: Dhaka (DAC) (23.4˚ N, 90.2˚E, 4 m AMSL)

DAC	Aerosol Profile
Total overpass	71
Vertical profile	57
Tropopause height	16.71
Tropopause temp	-76.84

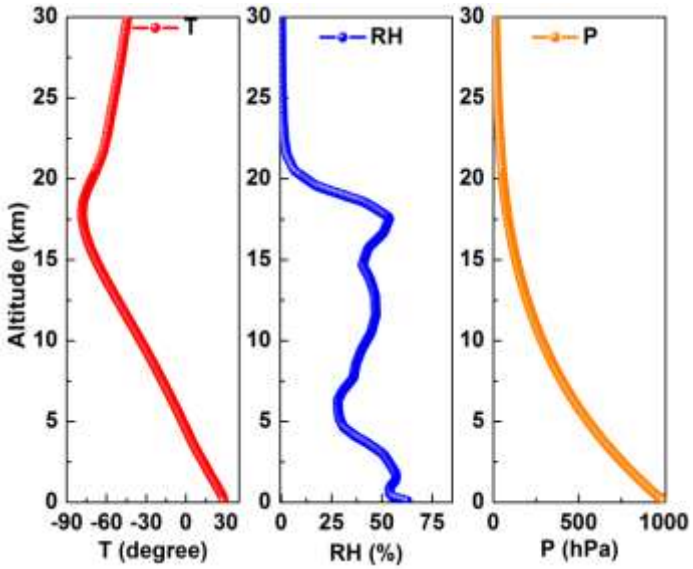


Fig: Average Temperature (degree), Relative humidity (%) and Pressure (hPa) vertical profile over DAC

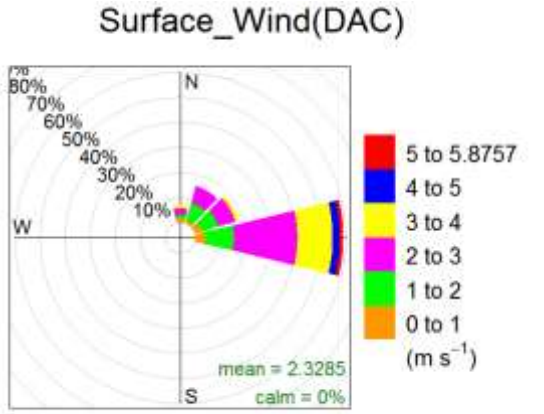


Fig. Surface wind frequency counts

- Surface wind is in NE direction.
- Dominated by PD.
- PDR ranges from ~0.003-0.97

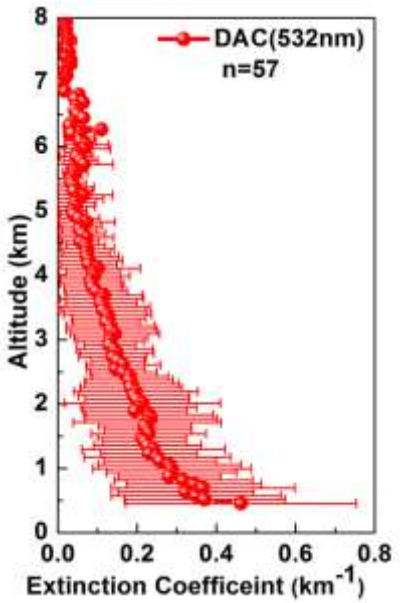


Fig: Average vertical profile of extinction coefficient (km^{-1}) at 532 nm

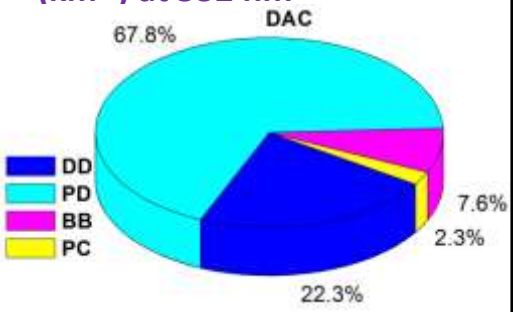


Fig: Percentage occurrence of aerosol types

Regional Scenario: North-Eastern part of India and adjoining areas (22-30°N,88-98°E)

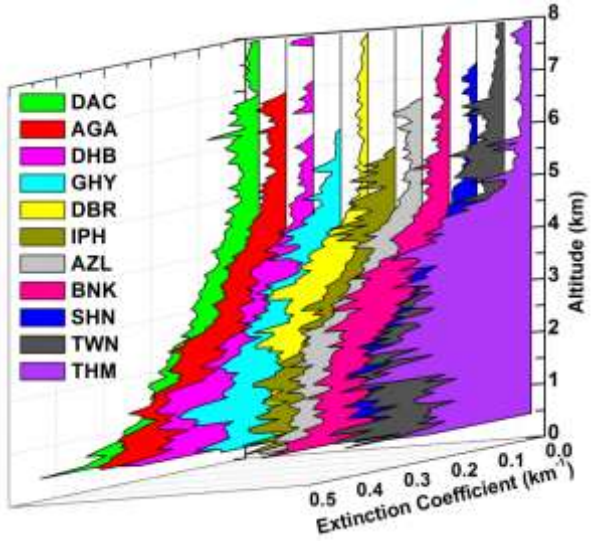


Fig: Vertical profile of extinction coefficient over all locations.

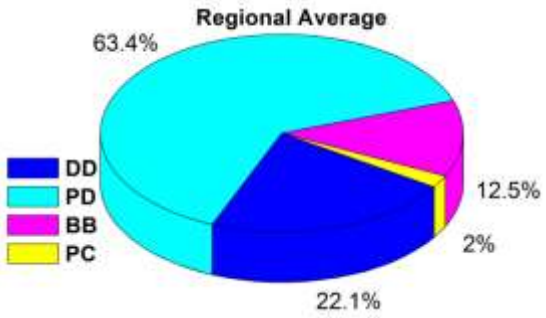


Fig: Regional occurrence of aerosol types

- Study locations show a heterogeneity of aerosol vertical distribution and aerosols types.
- All locations are mainly dominated by polluted dust (dust mixed with smoke) (PD) followed by desert dust (DD).
- Strong convective activities contributed to the occasional presence of elevated aerosol layers (EAL).
- PDR the range ~0.001-0.99, also indicates the presence of the PD, DD, BB and PC over this region.

Acknowledgement and References:

Acknowledgement:

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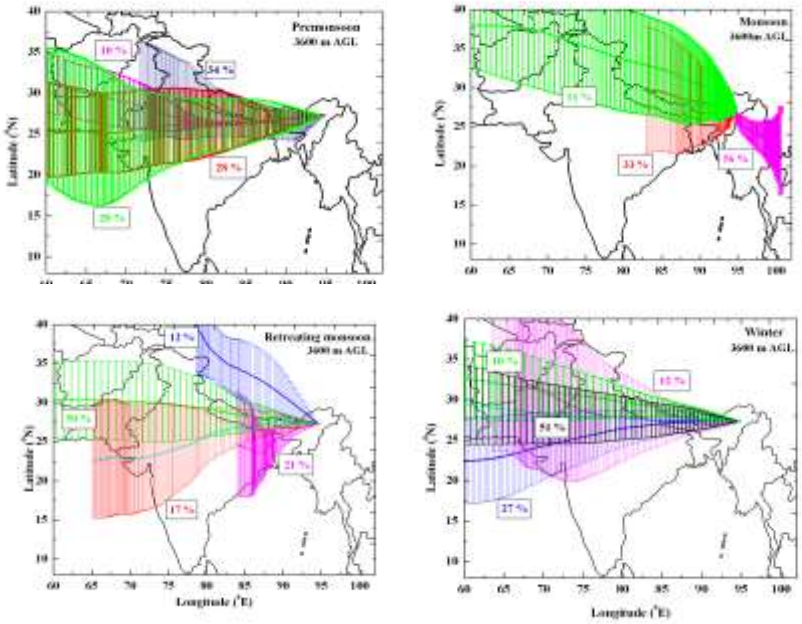
Thank you…

Identification of probable remote source regions of aerosols

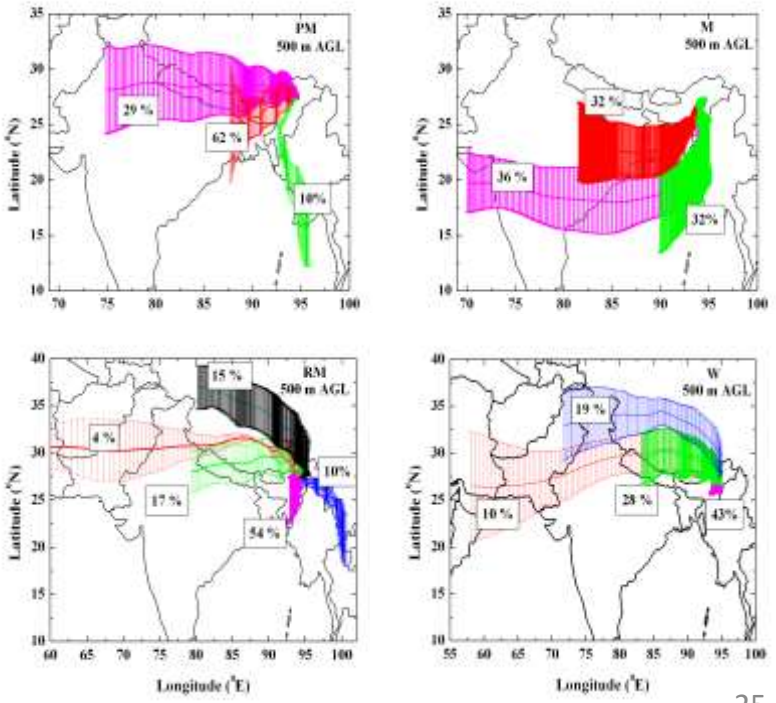
3.6 Km AGL



➢Upper and lower level winds contribute differently to column and surface aerosol loading.

➢Upper layer (3.6 km AGL) wind trajectories carries aerosols from distant locations in Pre-monsoon (west) and monsoon (south-east Asia).

O.5 Km AGL



➢Near the surface (0.5 km AGL) the local confinement of wind trajectories is prominent in winter and retreating monsoon.

➢ CWT analysis indicates same sources contributing to the aerosol loading over Dibrugarh.

Pathak et al., Atmospheric Environment, 2012