Characterization of aerosol absorption over south Asia based on multi-platform measurements and CAI-2 retrieval of AOD and soot volume fraction

Mukunda M Gogoi, S Suresh Babu

Space Physics Laboratory, Vikram Sarabhai Space Centre, ISRO, India

Ryoichi Imasu

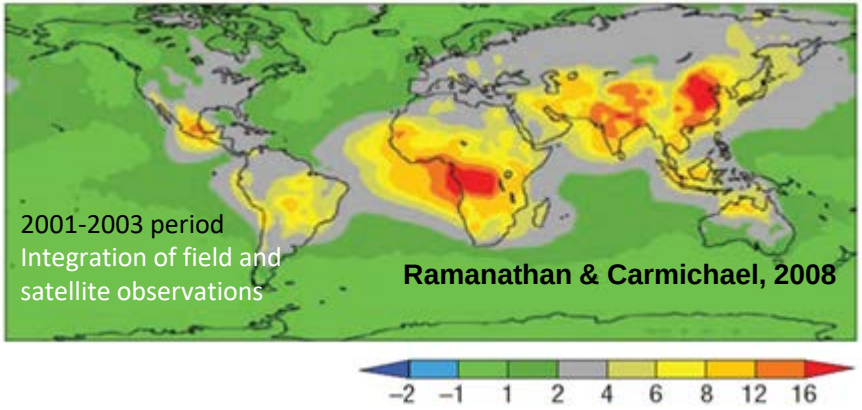
Atmospheric and Ocean Research Institute, University of Tokyo, Japan

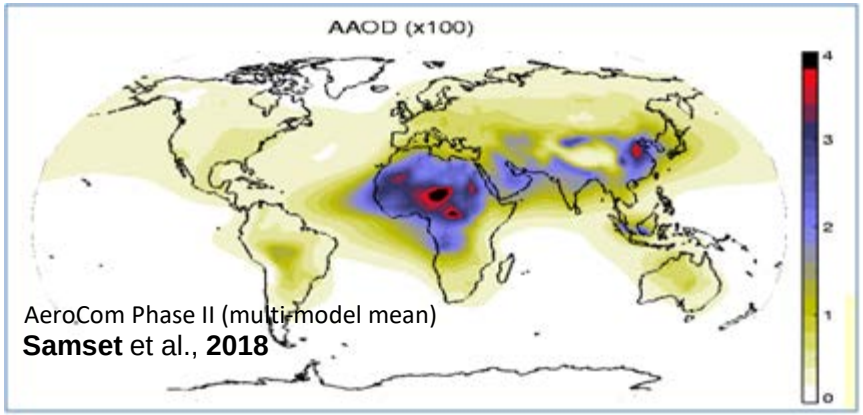
dr_mukunda@vssc.gov.in

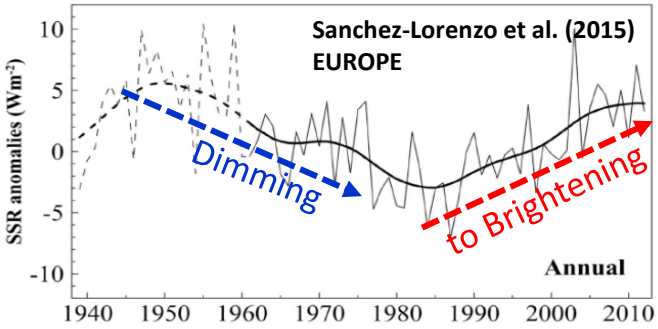
Regional & global impact of **BLACK CARBON,**

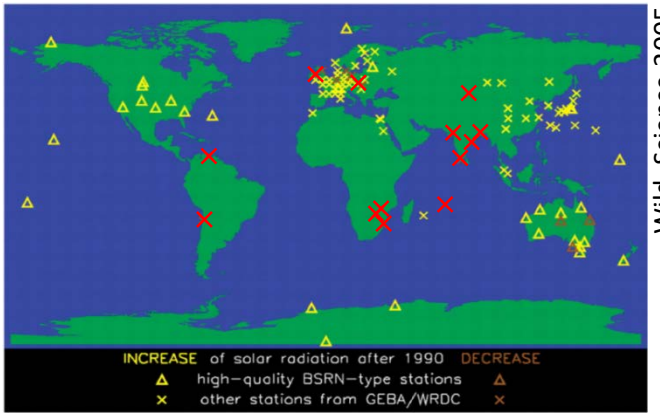
Acts through a complex web of processes

Atmospheric solar heating due to **BC**









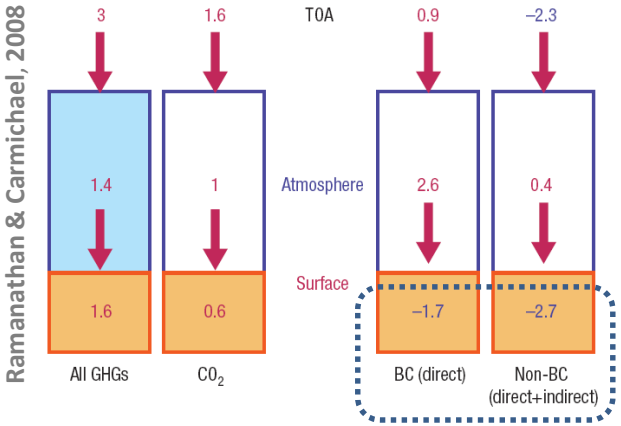
Wild, Science-2005

Observed tendencies in surface solar radiation

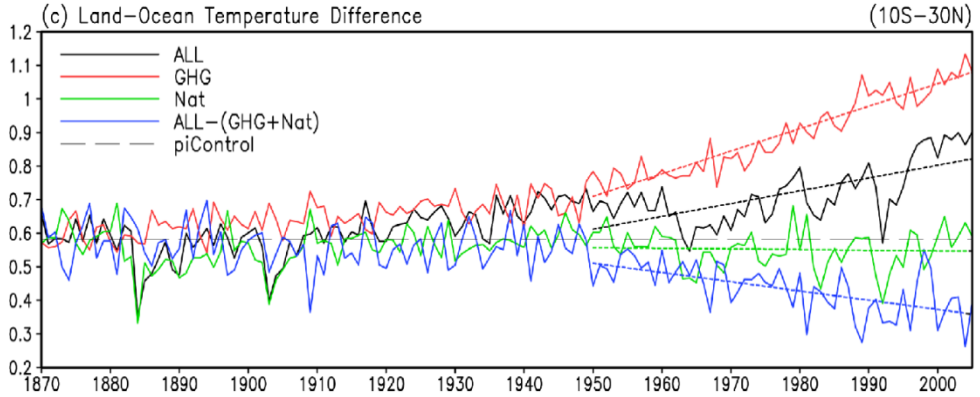
	1950s-1980s	1980s-2000	after 2000
USA	-6	5	8
Europe	-3	2	3
China/Mongolia	-7	3	-4
Japan	-5	8	0
India	-3	-8	-10

Wild, 2012

Competing influences of Greenhouse Warming and Aerosols

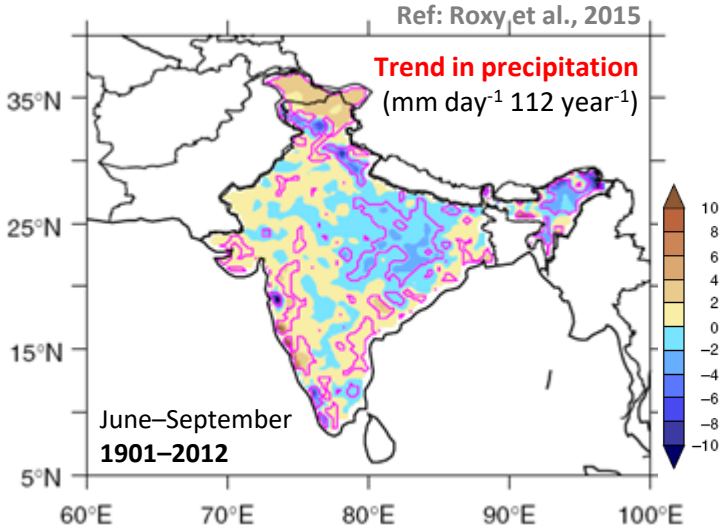


Aerosol induced local stability via solar dimming and semi-direct effects, strongly weakens the monsoon large-scale circulation, negating to a large extent the tendency to increase rainfall from GHG warming.



Ref: Lau et al., 2017

Ref: Roxy et al., 2015

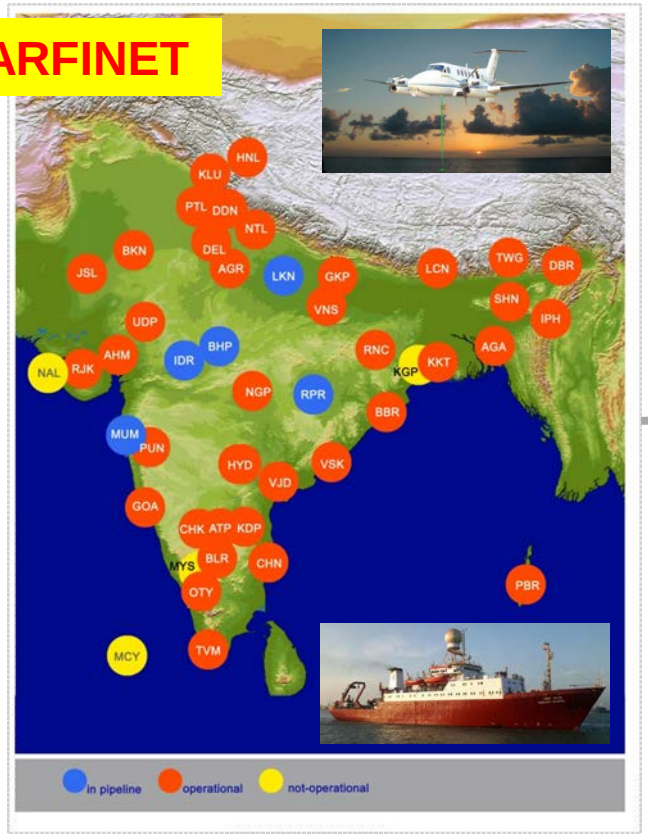


Improved understanding of the large heterogeneity in the nature and sources of absorbing aerosols and their climate impact is of paramount importance over the south Asian region

Key questions???

- **How do absorbing aerosols lead to climate warming?**
- **What is the net effect of atmospheric absorption on global and regional temperature change in terms of both magnitude and time scale?**
- **What kind of real-world data exists from monitoring networks and other observational research?**

ARFINET



Aerosol Optical Depth (since 1985)
BC mass concentrations (since 2000)
PM10 and PM2.5

AOD (MWR)
380, 400, 450, 500, 600, 650, 750, 850, 935, 1025 nm.

CAI-2: Centre wavelengths (μm)
0.34, 0.435, 0.87, 1.6 (+20°)
0.38, 0.55, 0.87, 1.6 (-20°)
Resolution (km): 0.5, 1
Swath (km): 1000, 500

ASSIMILATION

RT computation

Regional
RADIATIVE FORCING

Impact on
SOLAR ENERGY

Climate Models

Regional Climate
IMPACT ASSESSMENT

Impact on
MONSOON

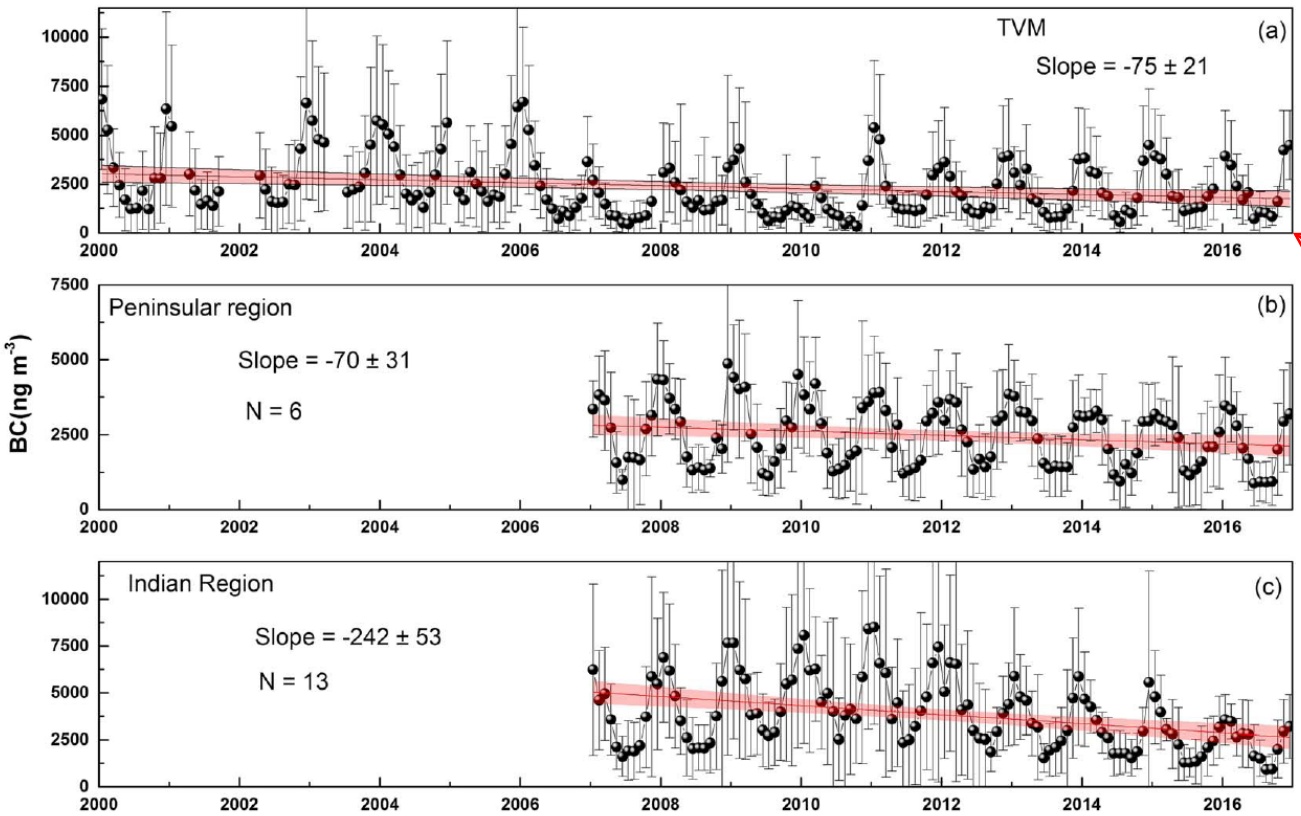
MODIS | **MISR** | **OMI** | **CALIPSO**

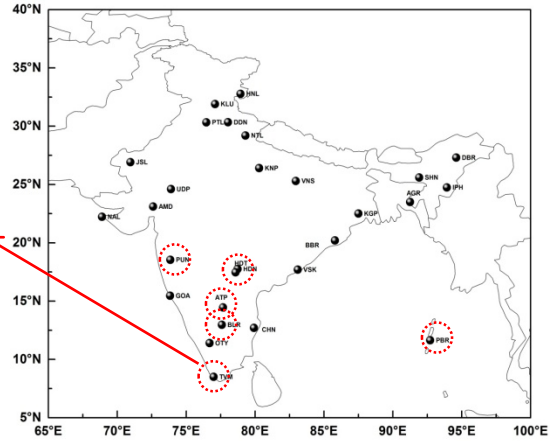
CAI-2

Aerosol optical Depth
Angstrom exponent
Soot volume fraction
PM2.5

Long-term scenario of BC over India

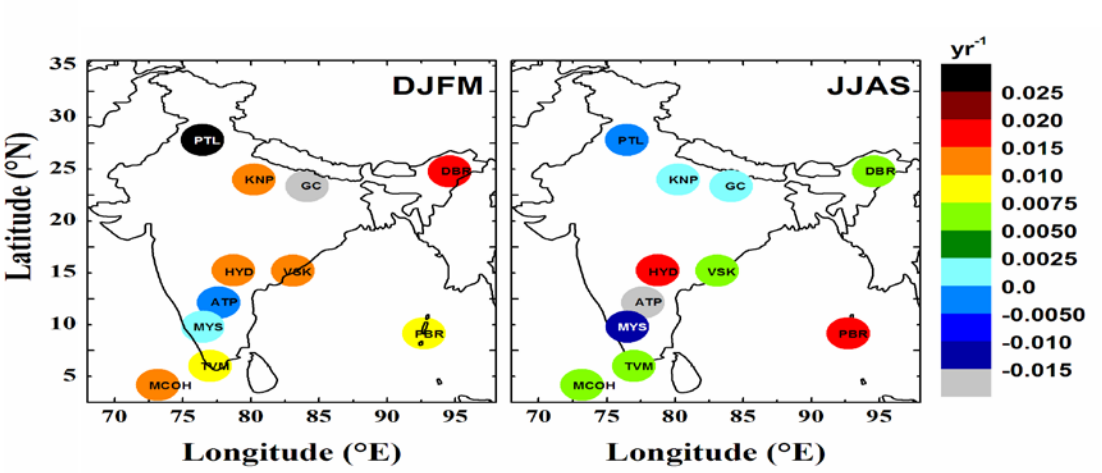
Decreasing trend (- 242 ng m^{-3} yr^{-1})

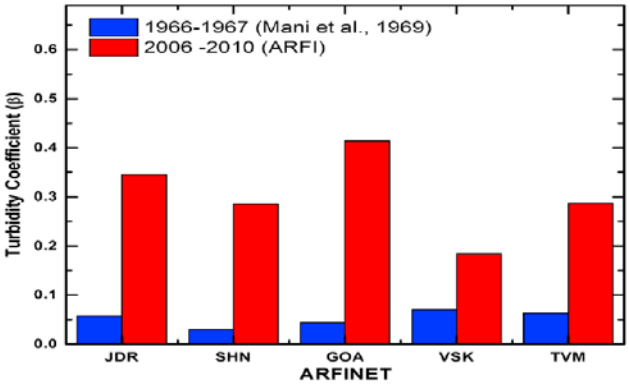


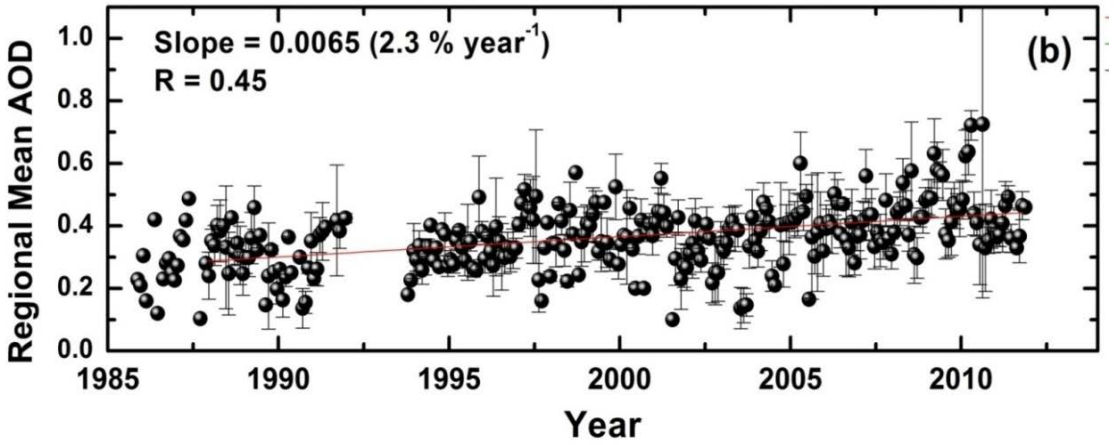


Manoj et al., GRL - 2019

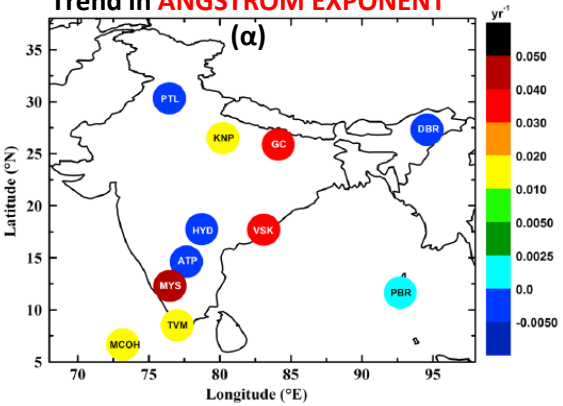
Build up of *columnar aerosols* over the Indian region





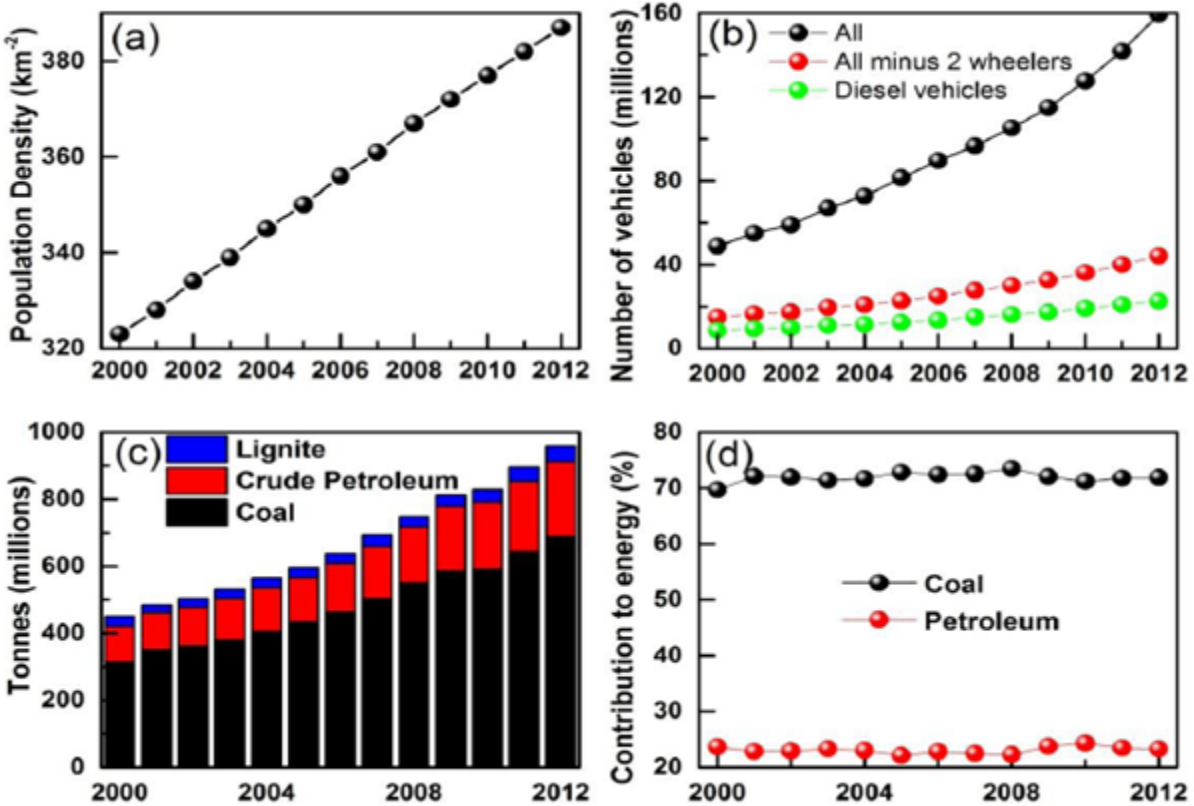


Trend in ANGSTROM EXPONENT



Babu et al., JGR- 2013

India *during the period 2000-2012*



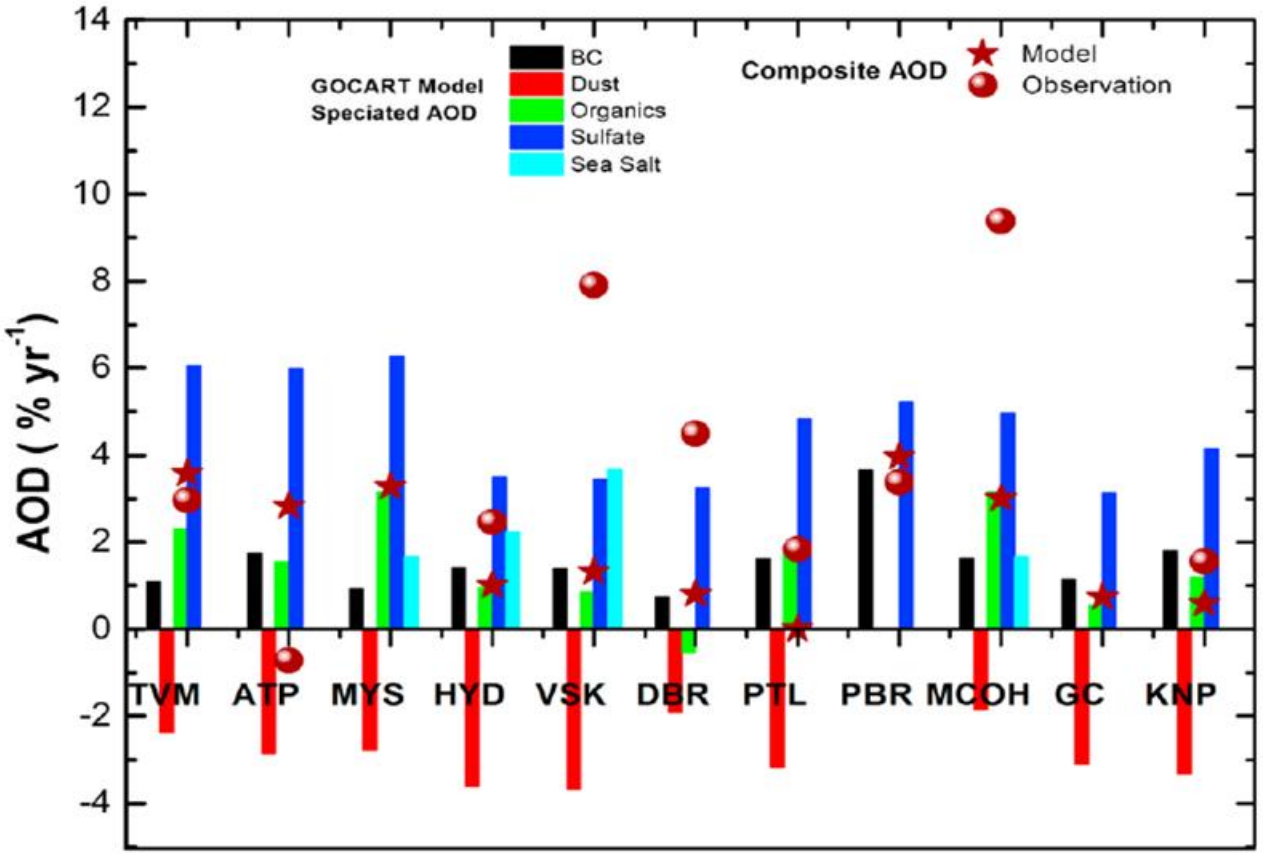
(a) The population density (b) The number of registered vehicles (c) The total energy production from conventional sources and (d) The contribution of coal and petroleum to the total energy (in %)

Manoj et al., GRL - 2019

Trends in AOD of different aerosol species

Increasing trend of BC AOD

AOD trends are generally dominated by changing anthropogenic SO2 emissions



Babu et al., JGR- 2013

In concert with the overall increase in the anthropogenic activities, an increasing trend of ~ 4% is observed in the regional AOD over the last decade.

An increase in the anthropogenic activities and the increase in total column aerosol, the decreasing trend in the BC concentration is baffling.

Several possibilities that might explain the general decreasing trend of BC

Control measures by statutory agencies

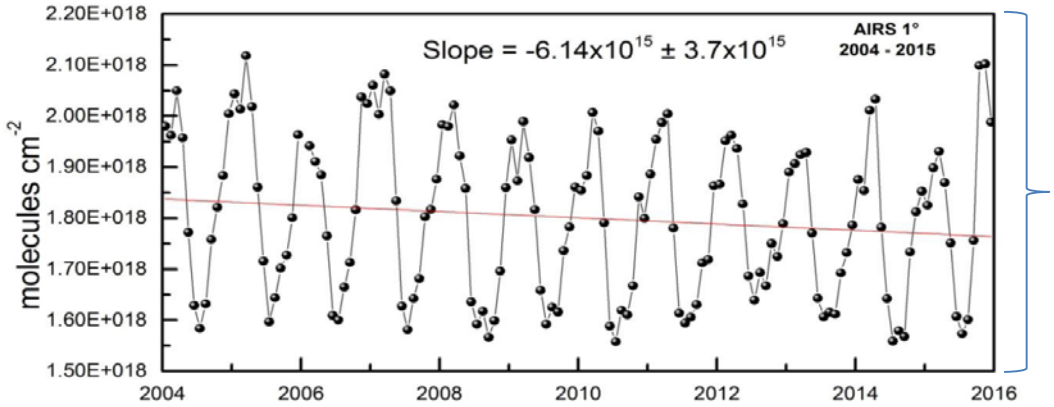
- **Mass Emission Regulation** (1991): Regulation/ Monitoring of industrial and vehicular pollution
- **India 2000 emission standard**: Bharat Stage II (BS II), BS III and BS IV
- **Improvement of the fuel quality**

Infrastructure development

- Electrification in inhabited villages (98.1% have **access to electricity as on Mar-2016)**
- **Electrification** of the **railway network** (45% as on Apr-2017).
- Use of **electric vehicles** and **CNG** to run automomobiles are being promoted

Variation in the vertical distribution of aerosols

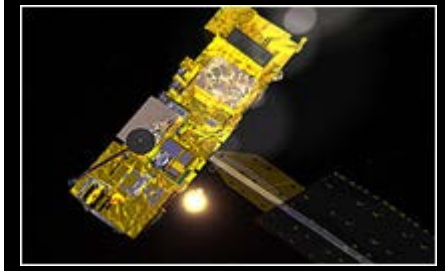
Decreasing trend of CO (6.15 x 10^{15} molecules $cm^{-2}yr^{-1}$)
Increasing trend of Absorption AOD (1.8 x 10^{-4} yr^{-1})

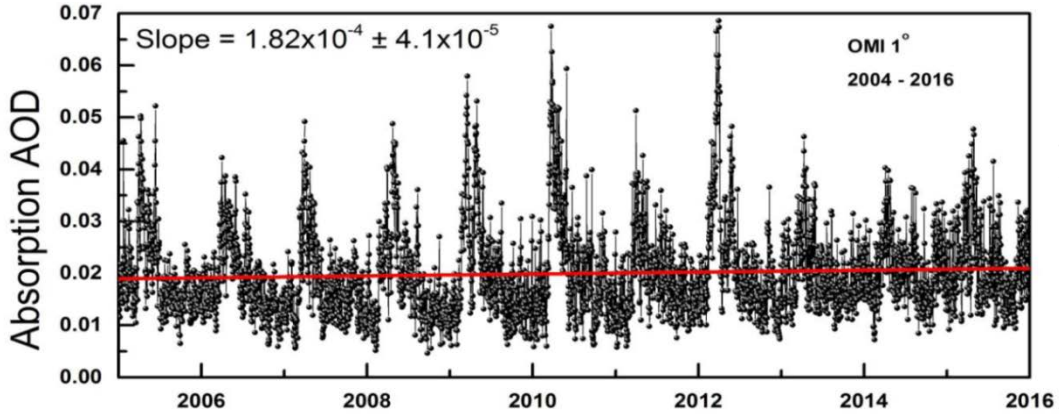


Monthly mean CO,

each point represents the average value for the spatial region 65°E to 100°E and 5°N to 40°N.

Atmospheric IR sounder





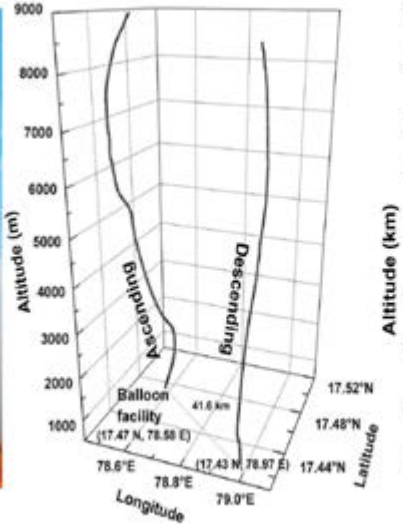
Daily mean absorption AOD at 500nm

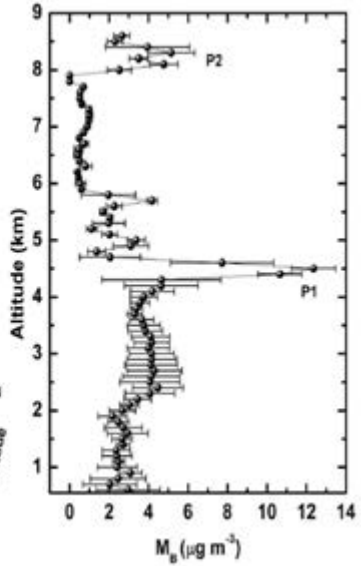
OMI

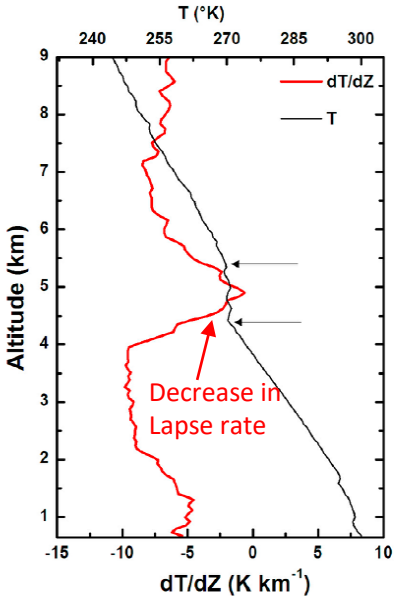
Uplifting of pollutants to higher altitudes

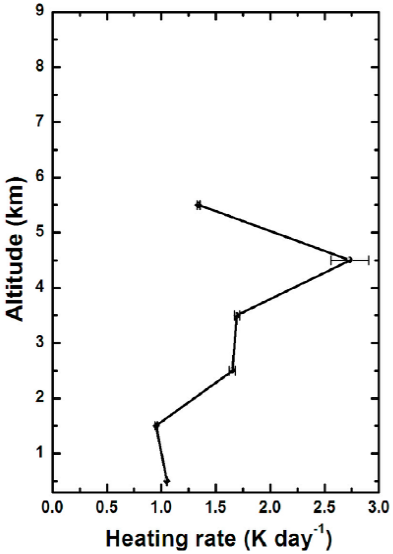
High altitude BALLOON-BORNE measurement

Do BC make their own home up in the atmosphere ?









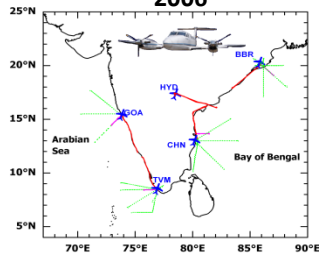
rapid decrease in the environmental lapse rate and a sharp increase in the atmosphere stability, probably caused by the atmospheric warming by the BC layers

Babu et al., GRL-2011

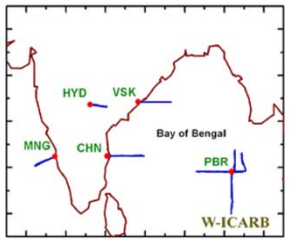
AIRCRAFT Experiments

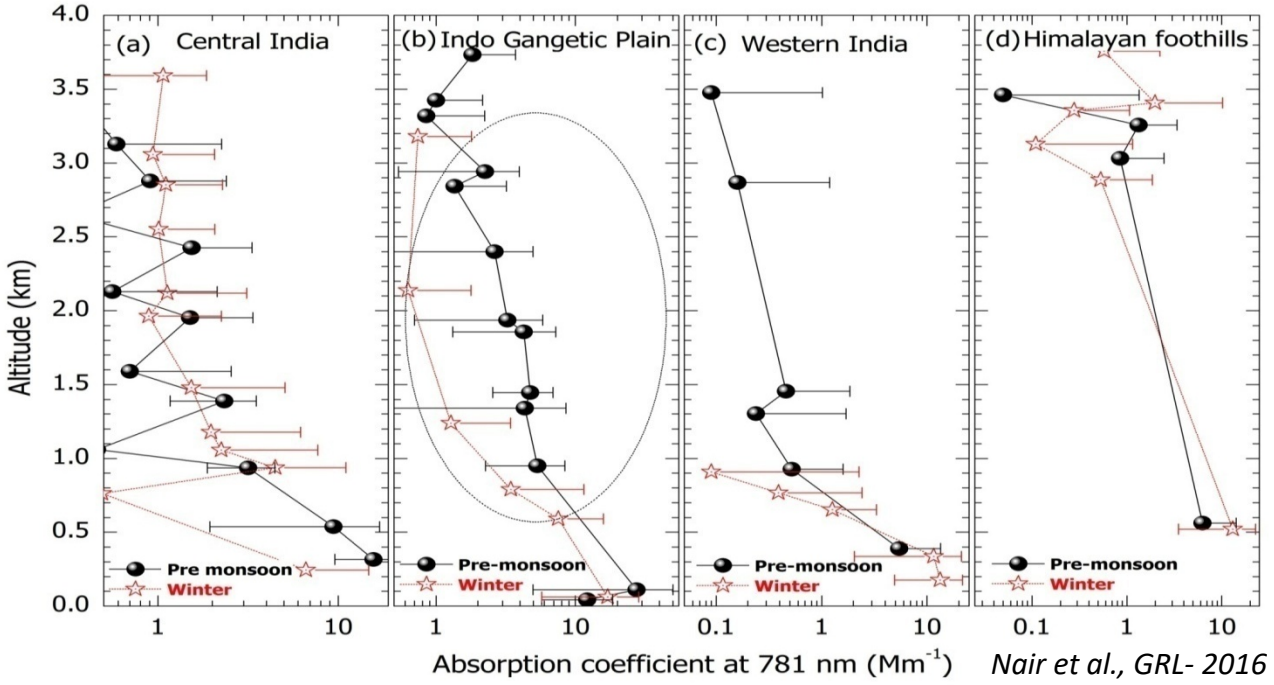
2012-
2013-
2016

2006



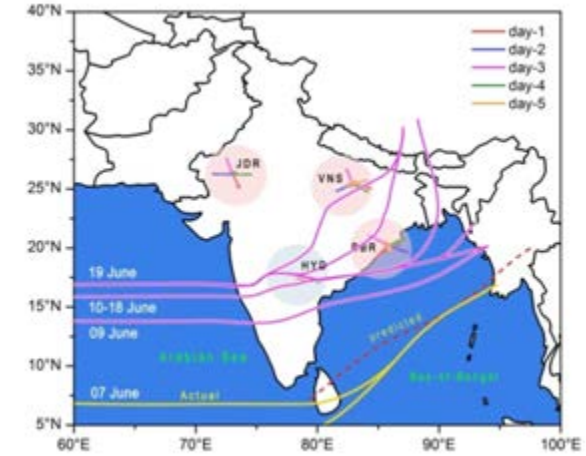
2008-2009

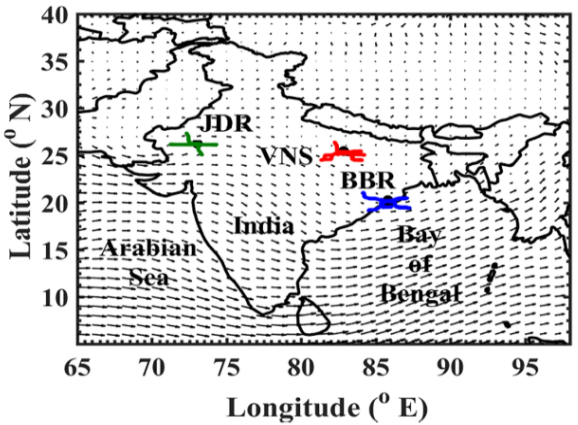


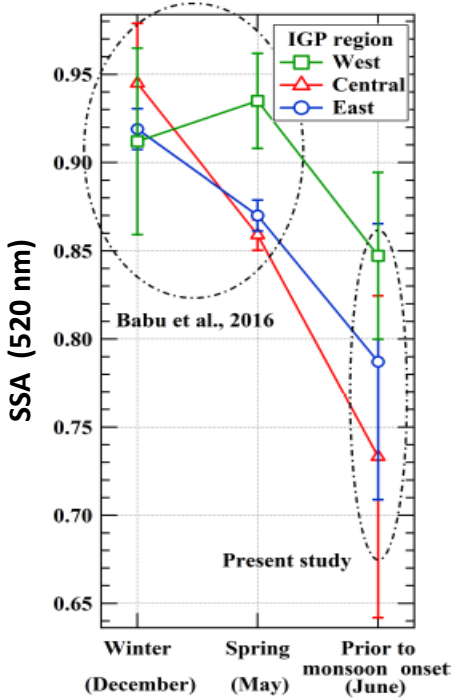


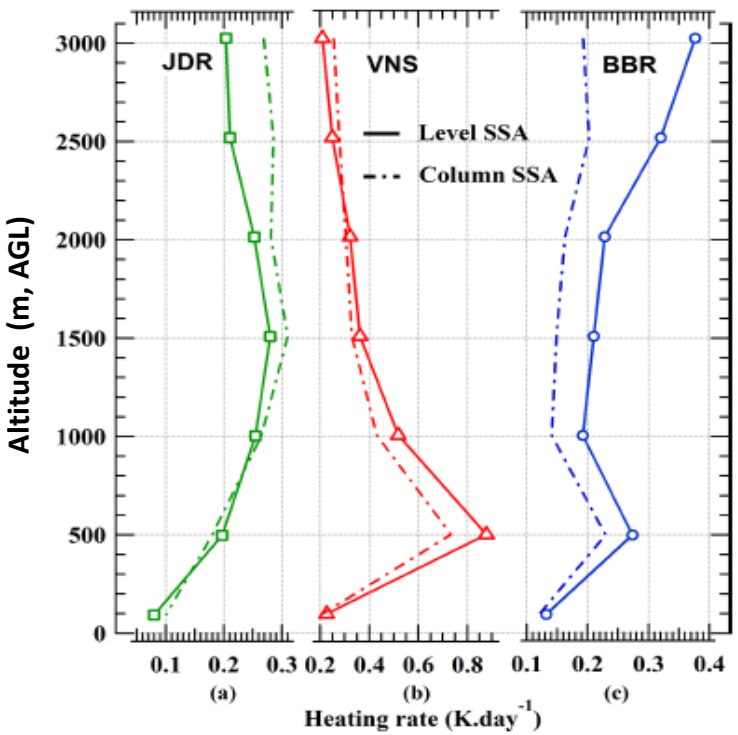
Nair et al., GRL- 2016

Aerosol Single Scattering Albedo: inter-seasonal variability









Emphasizing the importance and necessity of having altitude resolved SSA information as against a single value for the entire column.

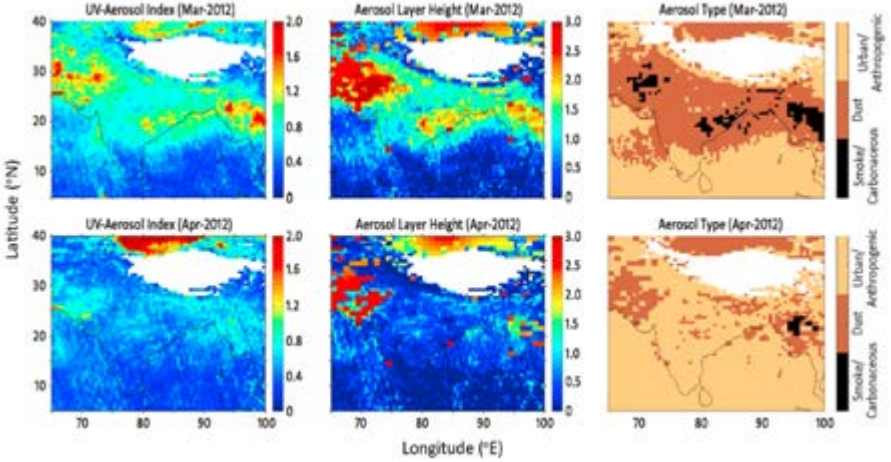
Vaishya et al., ACP- 2018

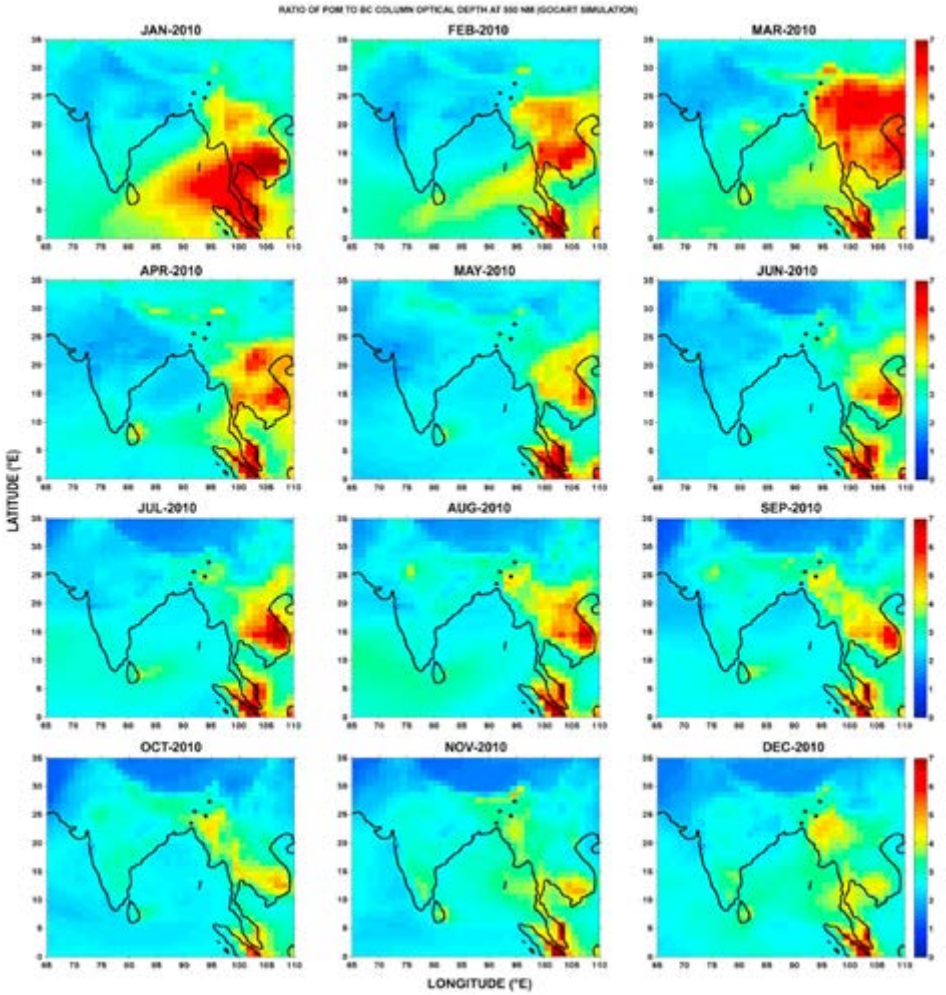
Ratio of column integrated optical depth due to POM and BC

- **GOCART model simulation**

  indicative of the **presence of more absorbing aerosols at higher altitude**, associated with the stronger convection of the intense biomass burning aerosols.

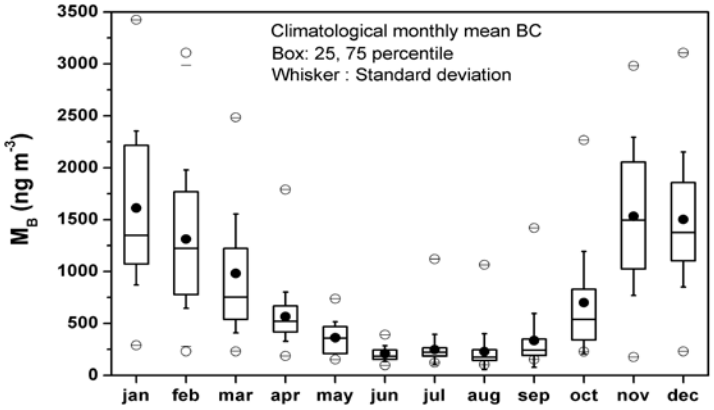
UVAI, Aerosol Layer Height & Aerosol Type

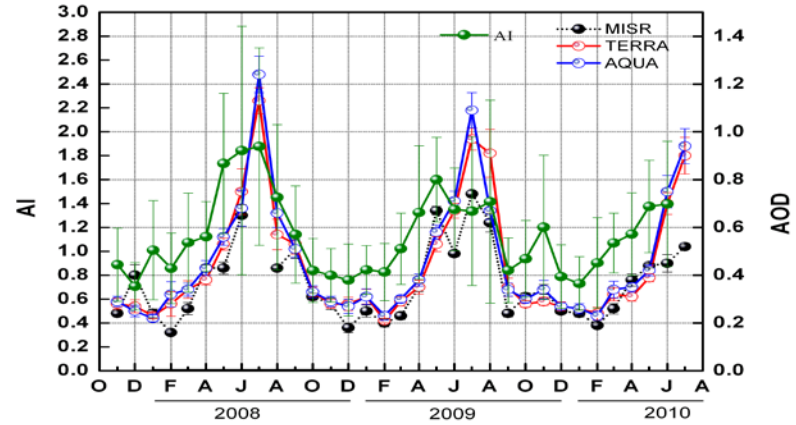


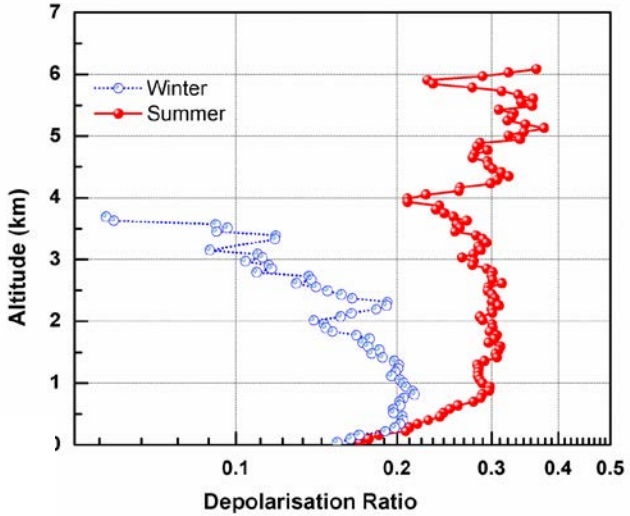


Gogoi et al., JGR- 2017

Elevated dust *North-western India (**CALIPSO**)*

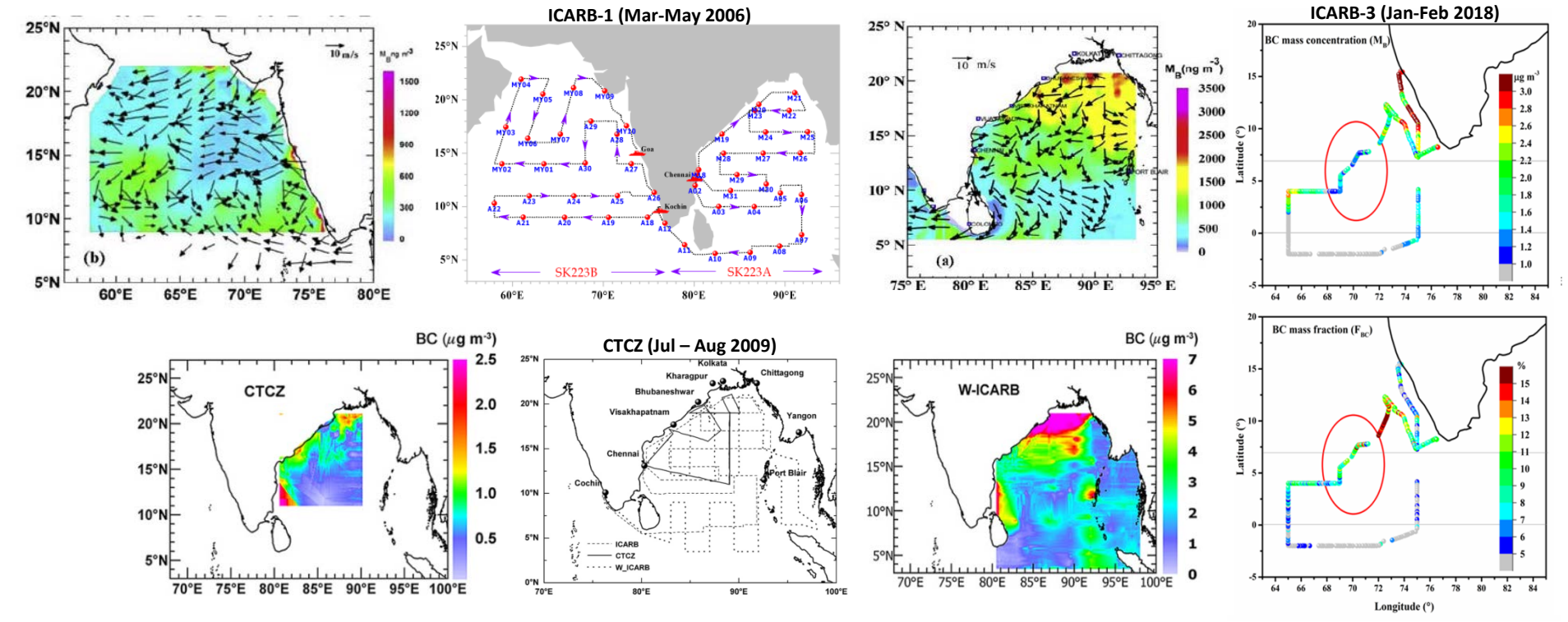






The higher **depolarization ratios** (>0.3), indicates the presence of non-spherical particles (e.g., dust), which contribute to the large aerosol extinction at higher levels, without affecting the near-surface observations.

[Gogoi et al., **AE**-2013]



[Nair et al., JGR-2018, Kompalli et al., AE-2013; Babu et al., JGR-2012; Gogoi et al., **AE**-2019]

SHIP – borne measurements

Summary

A synergistic approach of combining both ground based and space borne observations is necessary for the accurate characterizations of aerosols over south Asia.

It is proposed to combine the CAI-2 retrievals of AOD and soot volume fraction with the ground based ARFINET data to retrieve a more accurate regional picture of aerosol absorption over the south Asian region.

Thank you

Acknowledgement:

Japan Aerospace Exploration Agency; National Institute for Environmental Studies
Ministry of Environment, Japan; GOSAT RA Secretariat
Director-Space Physics Laboratory, ARFI project of ISRO-GBP