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
Regional & global impact of BLACK CARBON,
Acts through a complex web of processes

Atmospheric solar heating due to BC

2001-2003 period integration of field and satellite observations

Ramanathan & Carmichael, 2008

AeroCom Phase II (multi-model mean)
Samset et al., 2018
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.
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?
ASSIMILATION

GOSAT-2

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

RT computation
Regional RADIATIVE FORCING
Impact on SOLAR ENERGY
Climate Models
Regional Climate IMPACT ASSESSMENT
Impact on MONSOON

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

GOSAT-2

MODIS MISR OMI CALIPSO

Aerosol optical Depth
Angstrom exponent
Soot volume fraction
PM2.5
Long-term scenario of BC over India
Decreasing trend (-242 ng m\(^{-3}\) yr\(^{-1}\))
Build up of *columnar aerosols* over the Indian region

Trend in ANGSTROM EXPONENT ($\alpha$)
India during the period 2000-2012

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

Manoj et al., GRL - 2019
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 automobiles are being promoted

Variation in the vertical distribution of aerosols
Decreasing trend of CO ($6.15 \times 10^{15}$ molecules cm$^{-2}$yr$^{-1}$)
Increasing trend of Absorption AOD ($1.8 \times 10^{-4}$ 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.

Daily mean absorption AOD at 500nm

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

Absorption coefficient at 781 nm (Mm⁻¹)

Nair et al., GRL 2016
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]
SHIP – borne measurements

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