The Aerosol Cloud Radiative forcing studies

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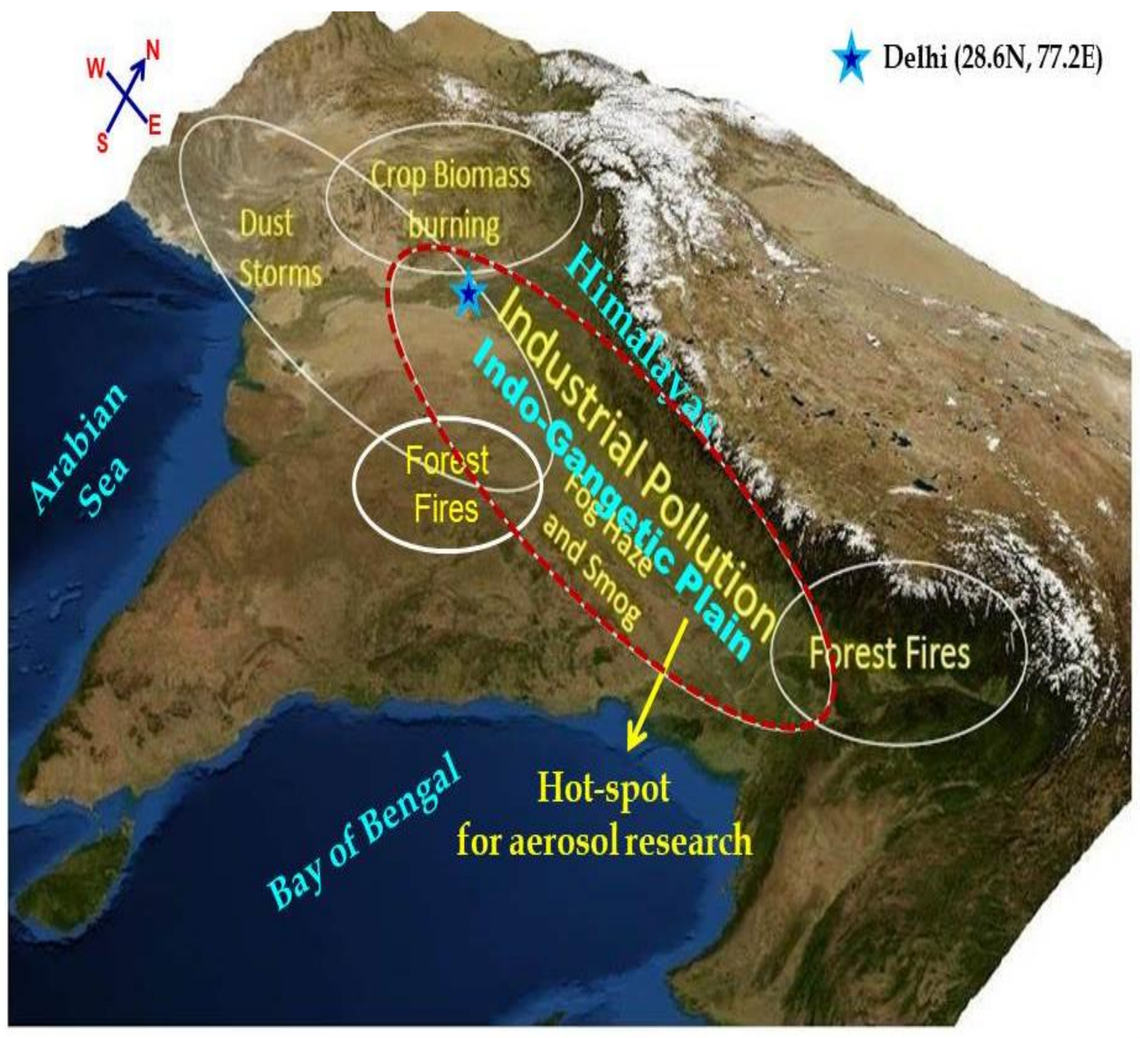
Background

The South Asian region, especially the Indo-Gangetic plain (IGP) in northern India, is a global pollution hotspot due to a variety of natural and anthropogenic emissions of aerosol particles.



[Courtesy: William K. M. Lau]

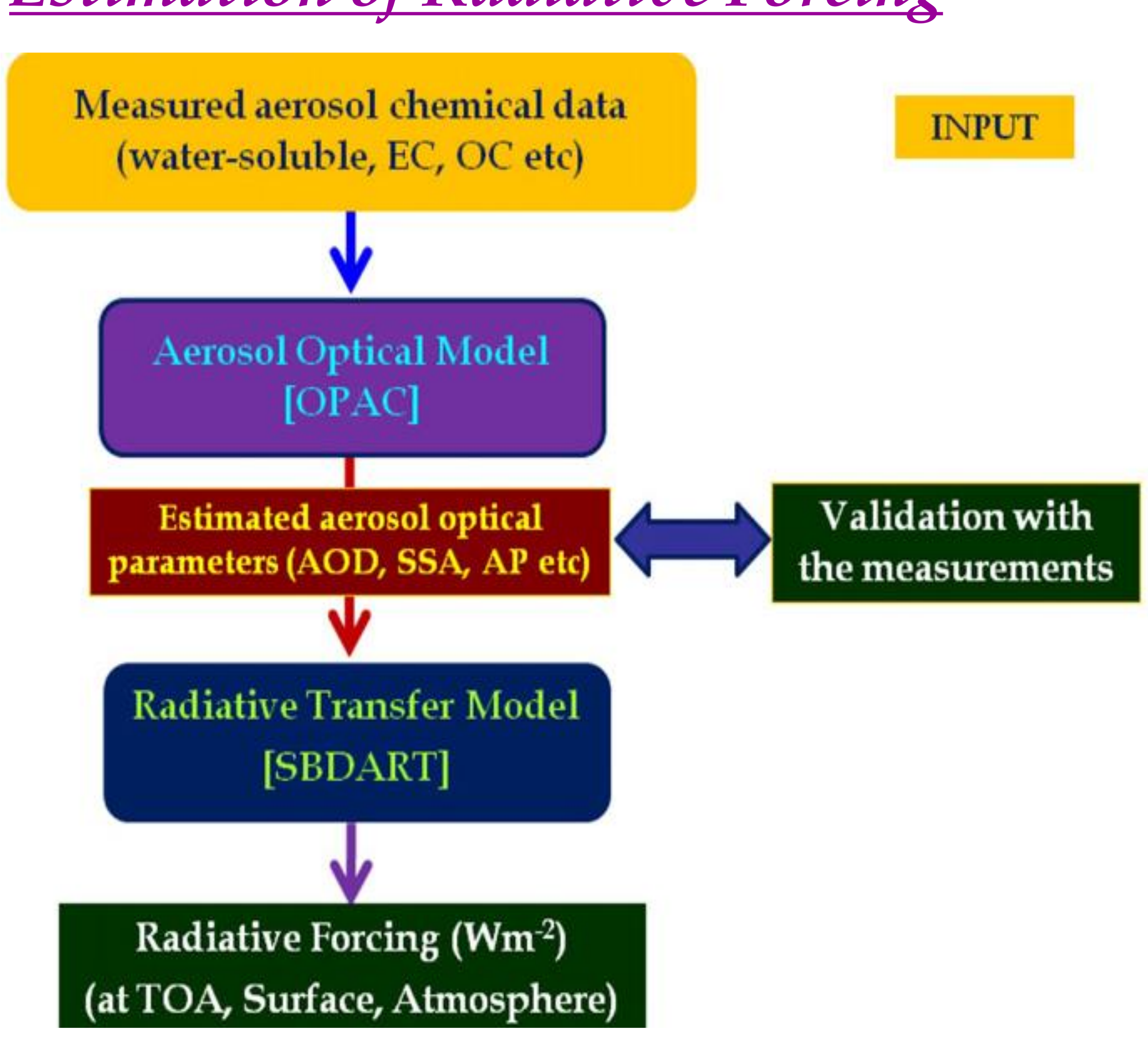
High aerosol loading over the IGP may cause strong radiative forcing over the region. The large aerosol loading over the IGP may also influence the aerosol loading and the associated radiative forcing over the adjoining marine regions due to the pollution outflow from IGP to downwind over the Bay of Bengal (BoB) region.

Methodology

Measurements and Analysis

- Aerosol sampling was carried out using a single stage APM-550 medium volume air sampler (off-line; Envirotech Pvt. Ltd., India) for $PM_{2.5}$ mass recordings based on impactor designs standardized by USEPA (United States Environmental Protection Agency).
- Analysis of inorganic ions (NO_3^- and SO_4^{2-}) was performed via the Reagent Free Ion Chromatograph (IC: DIONEX-2000, RFIC, make; USA).
- However, some part of filter is used for the analysis of OC and EC concentrations by semi-continuous thermal/optical carbon analyzer (Sunset Laboratory).
- Daytime samples of $PM_{2.5}$ have usually been utilized for the estimations of aerosol optical properties and radiative forcing.

Estimation of Radiative Forcing



Flow diagram of the methodology adopted for the estimation of aerosol radiative forcing using SBDART model, in conjunction with the crucial aerosol optical parameters estimated from OPAC model.

- Optical Properties of Aerosols and Clouds (OPAC) model used to get the crucial aerosol optical properties that are required for radiative forcing estimation.
- The OPAC derived aerosol optical parameters were used to estimate the shortwave (0.3–3.0 µm) aerosol direct radiative forcing (ADRF) using the Santa Barbara DISORT Atmospheric Radiative Transfer (SBDART).

Results & Discussion

Aerosol Characteristics

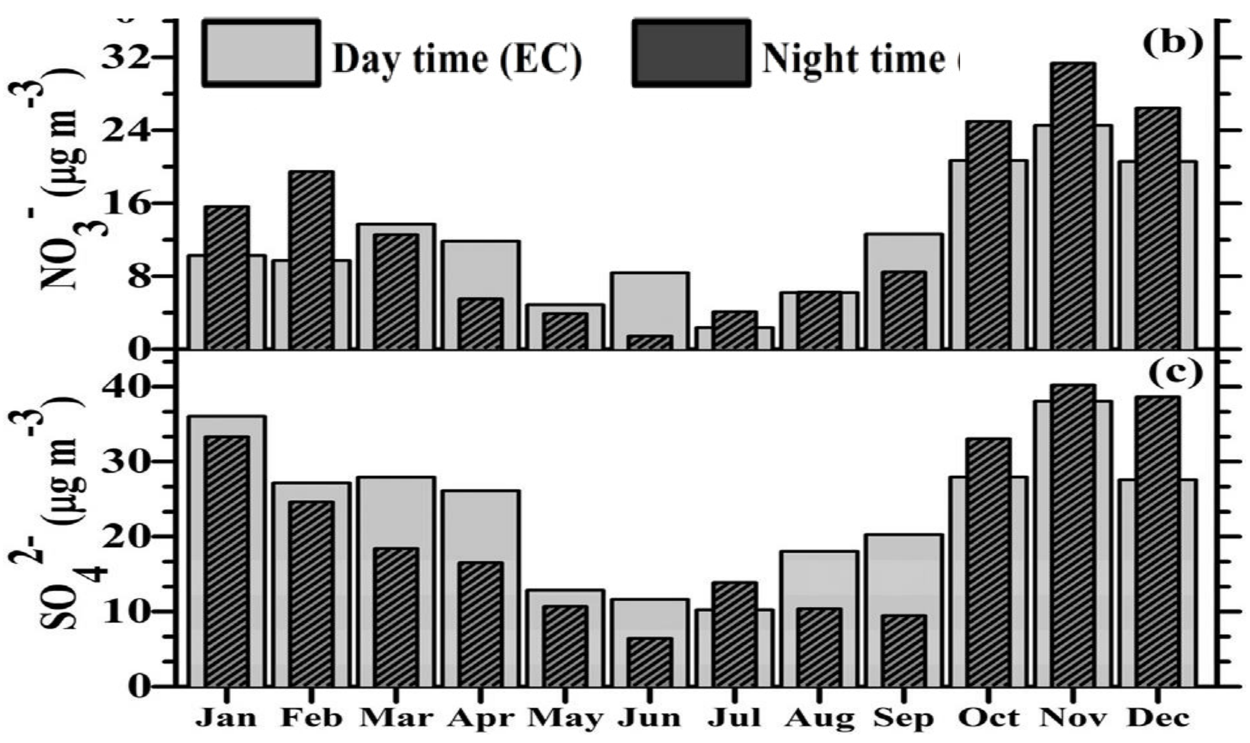


Fig. 1. Monthly-mean concentrations of ionic species (NO_3^- and SO_4^{2-}) during day and night.

- The highest concentrations of NO_3^- and SO_4^{2-} were found during the Oct–Nov months due to agricultural biomass-burning.
- Annually, the mass concentration of NO_3^- and SO_4^{2-} were found to be 12.3 (13.8) µgm^{-3} and 25.0 (22.4) µgm^{-3} during daytime (night time).
- The daytime concentrations dominate from March to September, while during the rest of the months, NO_3^- and SO_4^{2-} are more abundant during night-time (except of SO_4^{2-} during Jan–Feb).
- Larger concentrations of NO_3^- and SO_4^{2-} during daytime may be due to excess of photochemical formation in addition to local emissions during the rush hours, while the low-mixing layer during night-time seems to be the most responsible factor for the higher concentrations along with additional emissions from biofuel and waste-material burning for heating purposes in winter.

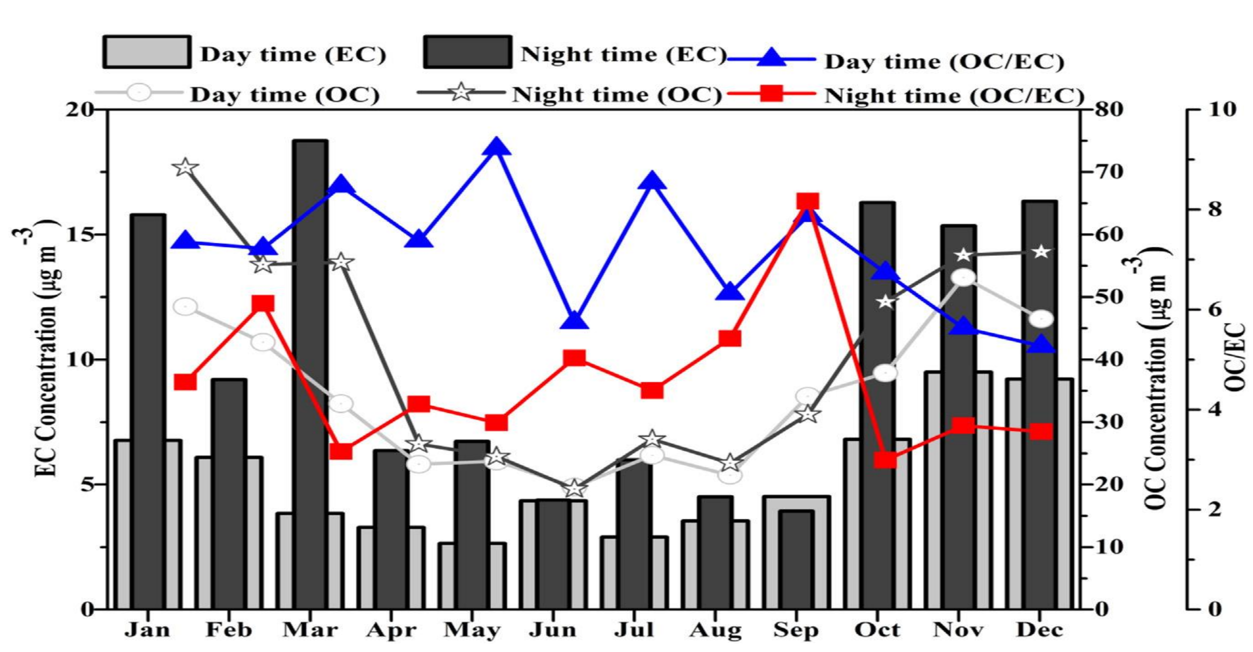


Fig. 2. Monthly-mean variation of EC, OC and OC/EC during day and night-time.

- Annually, night-time OC is ~23% higher than the daytime whereas the night-time EC is double than that in daytime.
- The abundance of EC during night-time is much more favoured by the primary emissions from bio-fuel combustion in Delhi, while the similarity in OC concentrations between day and night during the hot period (April–September) is attributed to the increased SOC formation during daytime as a result of high insulation within a humid polluted environment.

Aerosol Radiative Forcing

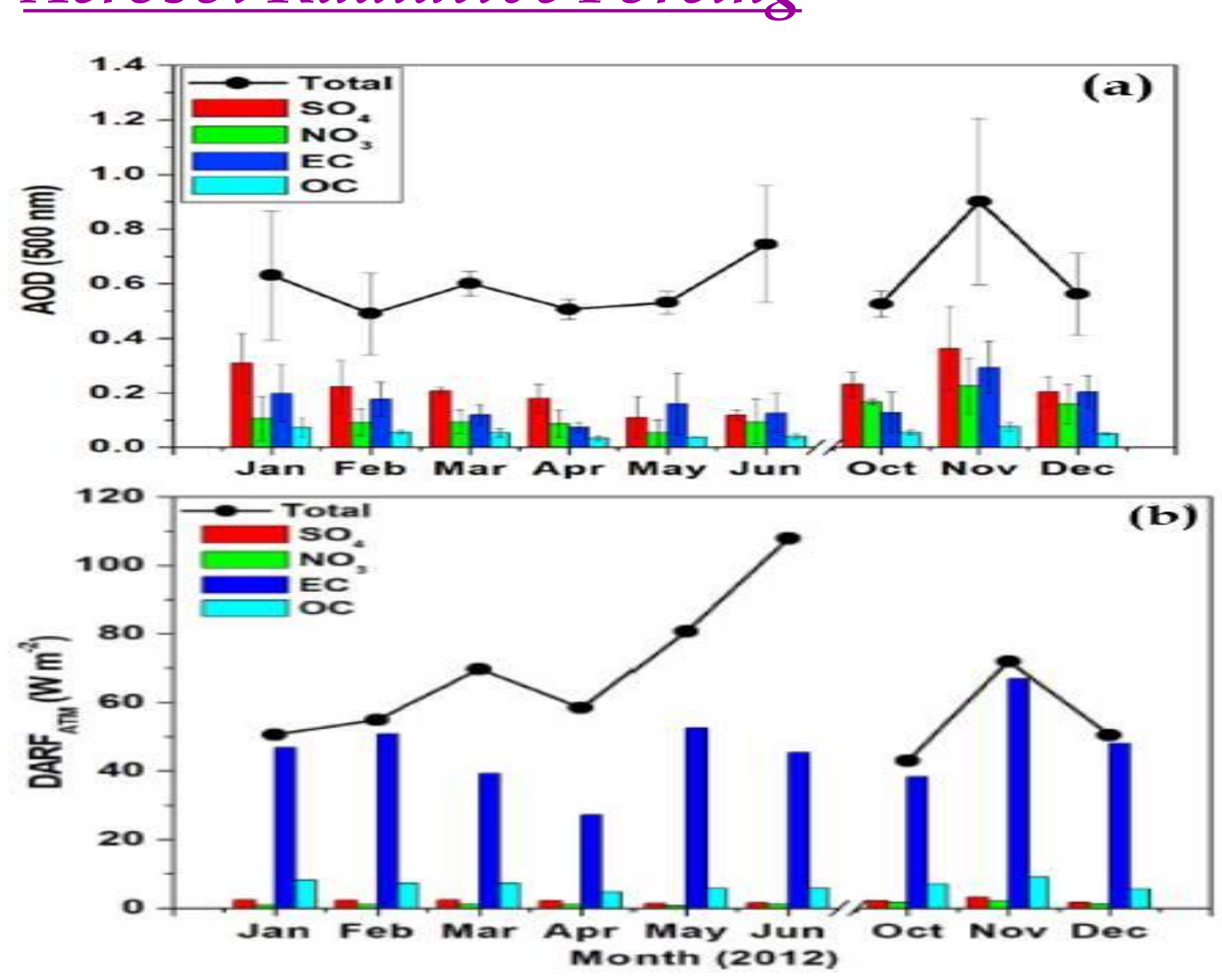


Fig. 3. Monthly variability of AOD_{500} and the associated atmospheric radiative forcing for the total aerosols along with different aerosol species (SO_4, NO_3, OC and EC).

- SO_4 contributed highest (~36%) to the total AOD; however, lowest contribution (~9%) was for OC.
- Though, EC contributed only ~3% to $PM_{2.5}$, it contributes highest (~70%) to the total atmospheric forcing ($DARF_{ATM}$) and associated heating rate. Interestingly, OC was observed the second highest contributor (~10%) as warming species among the anthropogenic species.

Impact of pollution outflow from IGP over the BoB

During the pre-monsoon season (March–May), the strong westerlies carry transported dust aerosols along with anthropogenic aerosols onto the Bay of Bengal (BoB).

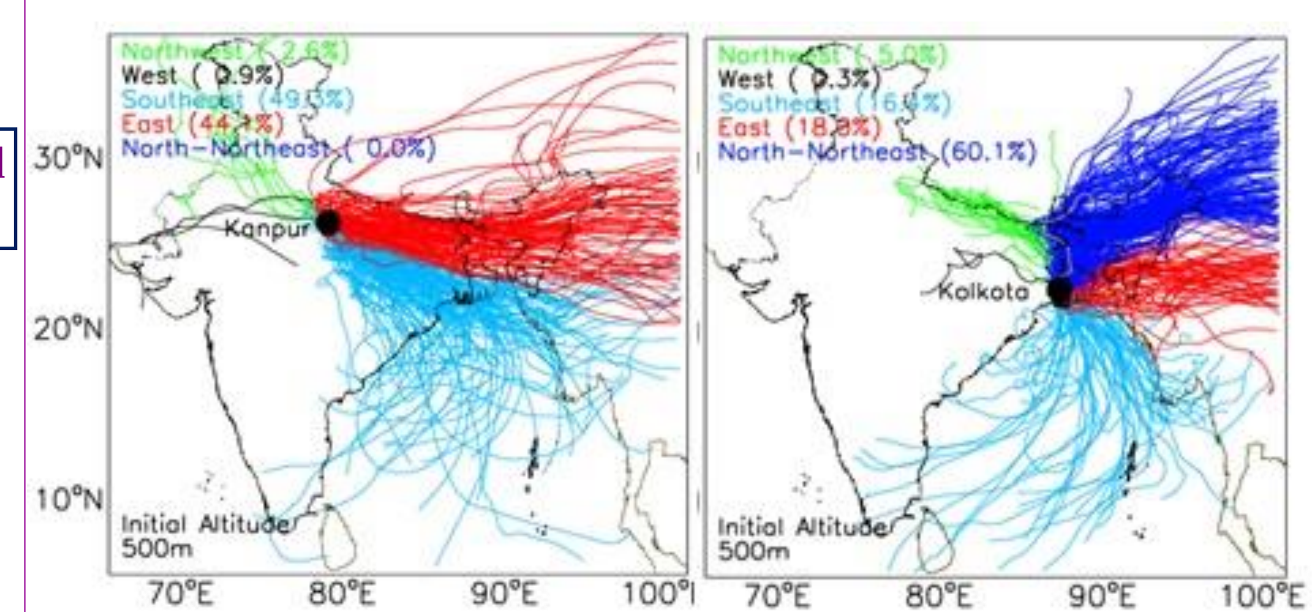


Fig. 4. 5-days forward trajectory clusters from (a) Kanpur at the central IGP and Kolkata at the eastern IGP during pre-monsoon of 2015-19.

- The majority of the south-east ward trajectories (~90%) from both the locations flow over the eastern parts of the BoB, influencing the aerosol loading over the region.
- The outflow from IGP modulates the aerosol loading and the aerosol direct radiative forcing (ADRF) over the BoB.

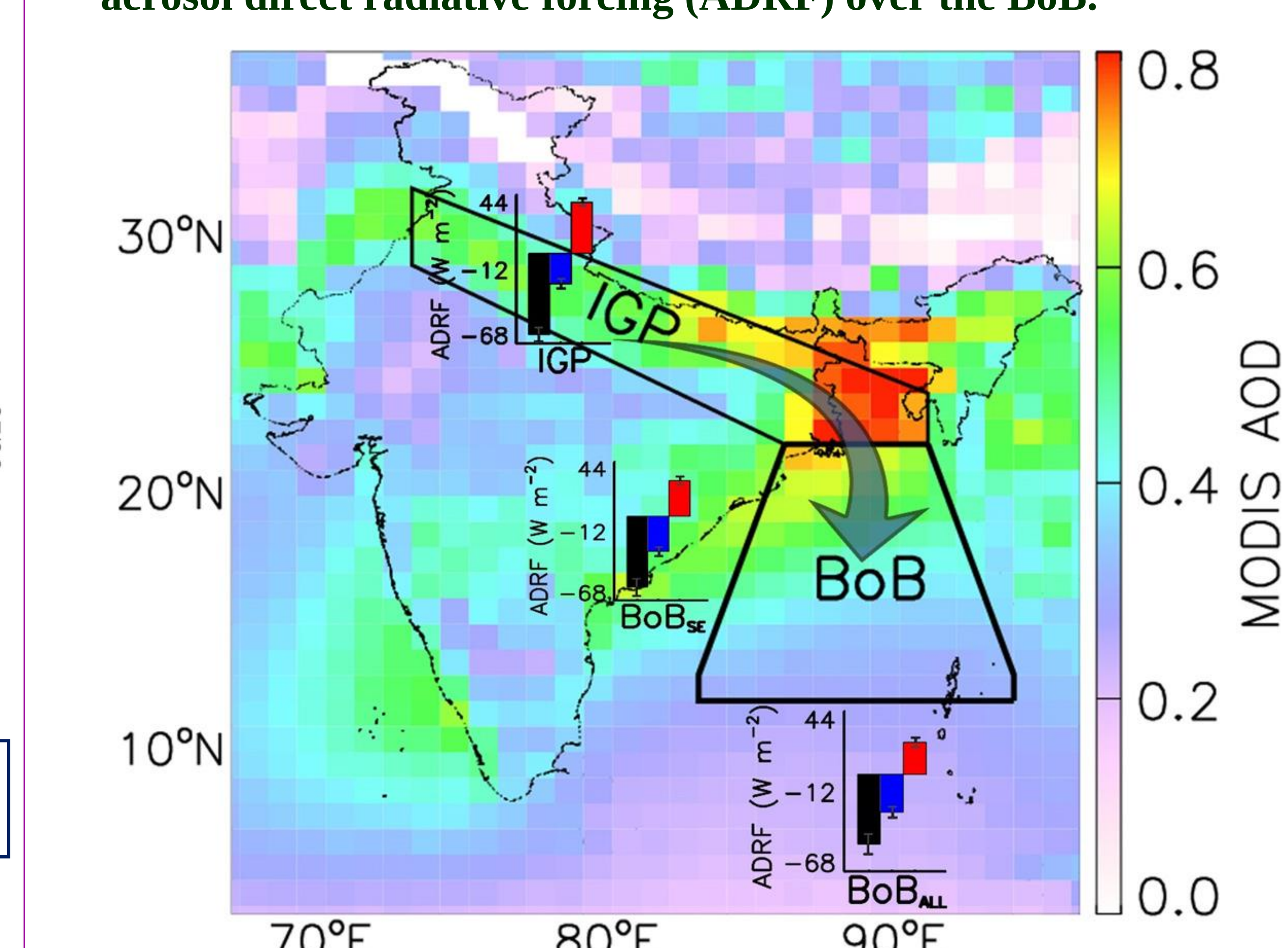


Fig. 4. Average MODIS derived AOD along with the associated mean aerosol direct radiative forcing over the IGP and the BoB during the pre-monsoon season (Mar-May) of 2015-2019.

- The aerosol direct radiative forcing (ADRF) over the BoB is estimated to be much higher in magnitude when the winds originate from the IGP, mostly during the pre-monsoon season (March–May) compared to the seasonal average.
- The difference in the ADRF between BoB_{ALL} and BoB_{SE} is more prominent in atmospheric forcing (-27.6±6.8%) than the surface (-14.8±5.2%) or at the top of the atmosphere (5.7±4.6%) forcing.
- The presence of absorbing aerosols in the lower level transport from IGP is evident from the difference in the atmospheric forcing.

Conclusions

The IGP region has been the focus of the current research work due to high aerosol loading (because of variety of emission sources), strong seasonal variability of aerosol composition, and complex mixing processes. The results underline the importance of IGP pollution outflow towards the downwind continental and the marine regions, especially over the BoB, which can have significant climatic implications.

Acknowledgement

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