



Anthropogenic Aerosols and Radiative Forcing over Bangladesh: Climatic and Socioeconomic Drivers of Atmospheric Change

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**6th Commonwealth
Chemistry Posters
October 1-2, 2025**

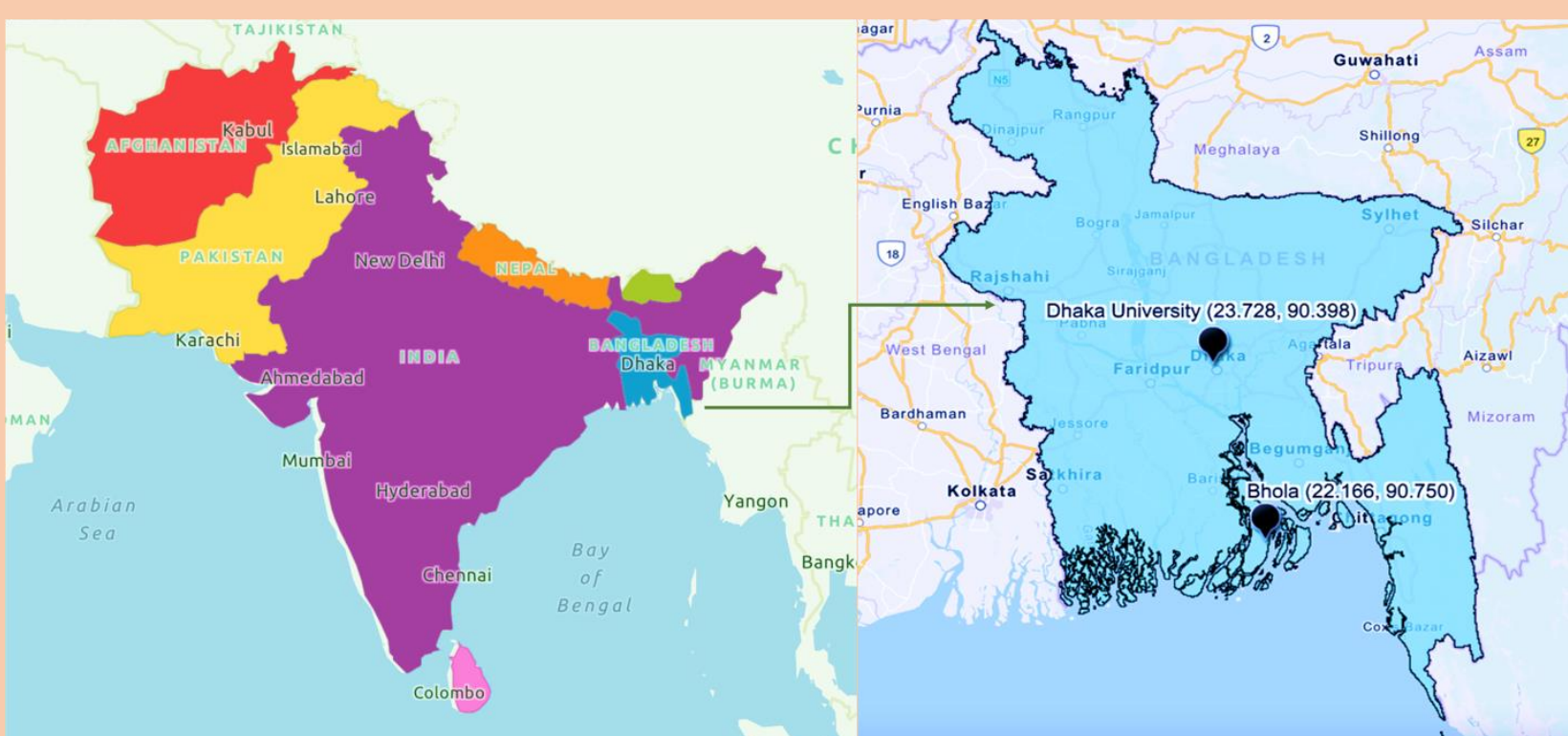


Introduction

Atmospheric aerosols affect human health, alter cloud optical properties, influence the climate and radiative balance, and contribute to the cooling of the atmosphere. Aerosol Optical Depth (AOD) is a crucial parameter for assessing aerosol content and determining the level of air pollution.

This study gives a spatial and temporal view regarding inter-annual AOD trend in Bangladesh based on combined ground and satellite-based data. Moreover, Aerosol Radiative Forcing (ARF), aerosol radiative forcing efficiency (ARFE) and heating rate (HR) have been evaluated. Finally, how these types of aerosols and socio-economic factors correlate with AODs are depicted for the first time in this region.

Methodology



➤ Validation of the MODIS and MERRA-2 using AERONET

$$AOD_{550} = AOD_{500} * \left(\frac{550}{500}\right)^{-AE} \quad -AE \quad 440-870$$

MODIS TERRA	MODIS AQUA	MERRA-2
R ² = 0.53	R ² = 0.57	R ² = 0.71

Dataset	Parameters	Spatial Resolution	Temporal Resolution	Temporal Range
MODIS-Terra	Aerosol optical depth (AOD, 550 nm)	1°	Monthly	2002-Present
MODIS-Aqua	Aerosol optical depth (AOD, 550 nm)	1°	Monthly	2002-Present
MERRA-2	Aerosol optical depth (AOD, 550 nm) Anthropogenic aerosol emissions (BCEMAN, OCEMAN, SO ₂ MAN, and SO ₄ MAN)	0.5°× 0.625°	Monthly	1980-Present
	AOD for dust aerosol (DUAOD, 550 nm)			
	AOD for black carbon aerosol (BCAOD, 550 nm)			
	AOD for organic carbon aerosol (OCAOD, 550 nm)			
	AOD for sea salt aerosol (SSAOD, 550 nm)			
	AOD for SO ₄ aerosol (SO ₄ AOD, 550 nm)			

➤ Aerosol speciation over Bangladesh:

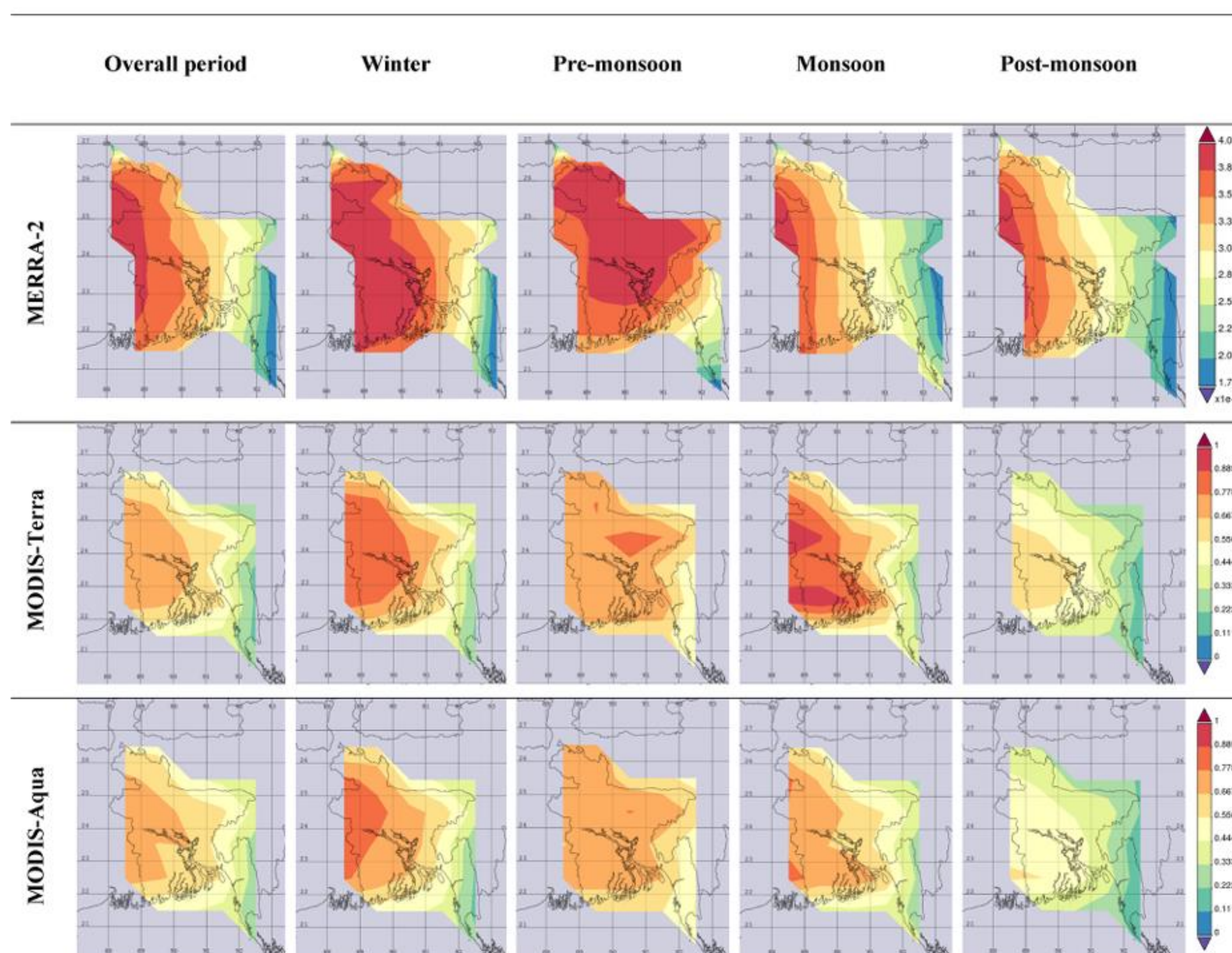
- $AOD_{total} = DUAOD + BCAOD + OCAOD + SSAOD + SO_4AOD + c$
- $AOD_{contribution} = AOD_x / AOD_{total}$

➤ Atmospheric heating rate (HR)

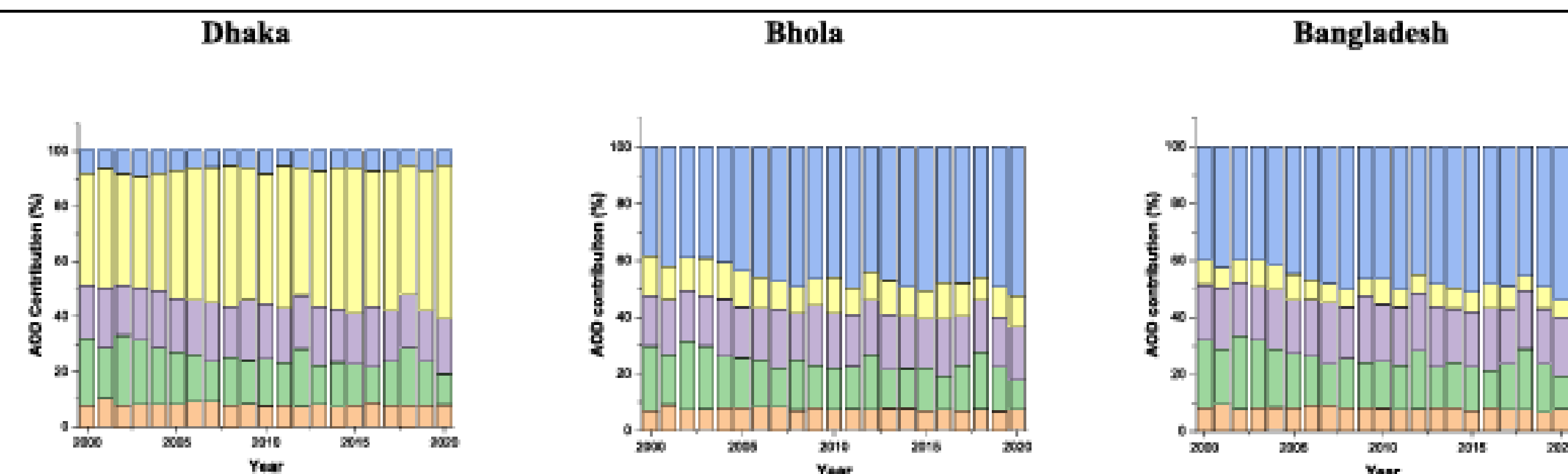
$$\frac{\partial T}{\partial t} = \frac{g}{c_p} \times \frac{\Delta F_{ATM}}{\Delta P} \times 24 \text{ (hr/day)} \times 3600 \text{ (sec/hr)}$$

Results

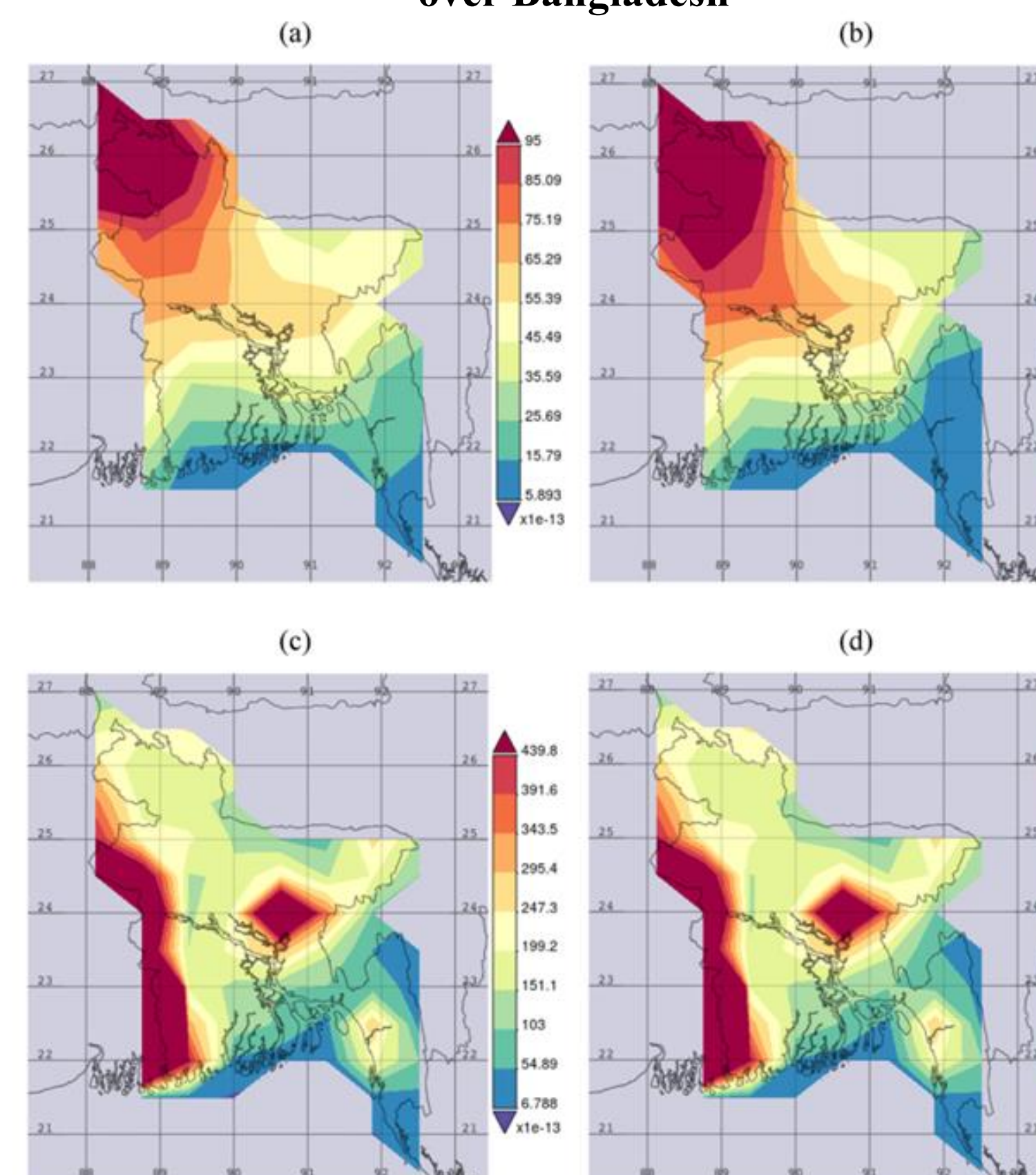
❑ Spatial distributions of annual and seasonal mean AODs over Bangladesh from MODIS-Aqua, MODIS-Terra, and MERRA-2 (2002-2020)



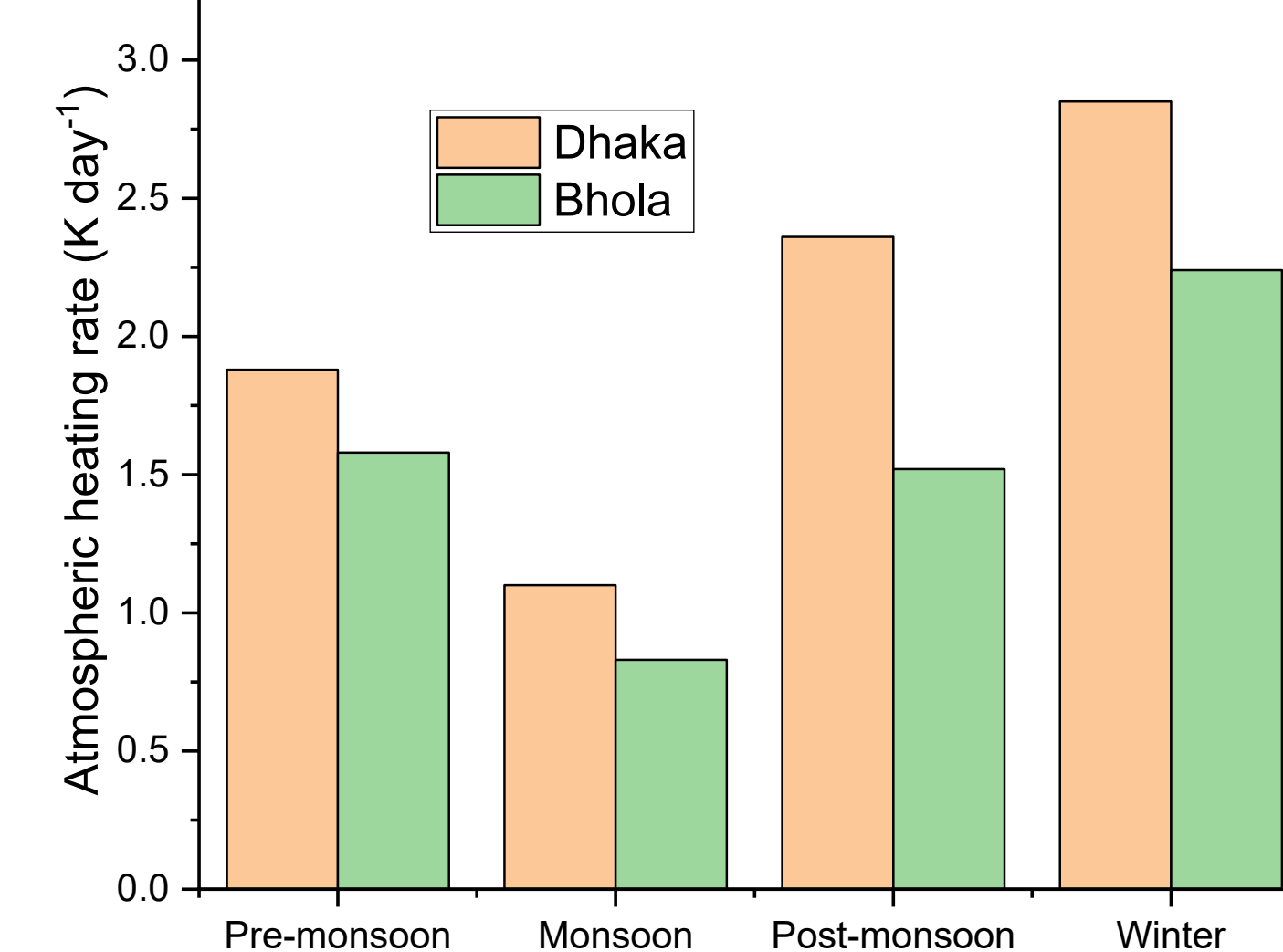
❑ Yearly percentage contribution of each aerosol type (sea salt, sulfate, organic carbon, dust, and black carbon)



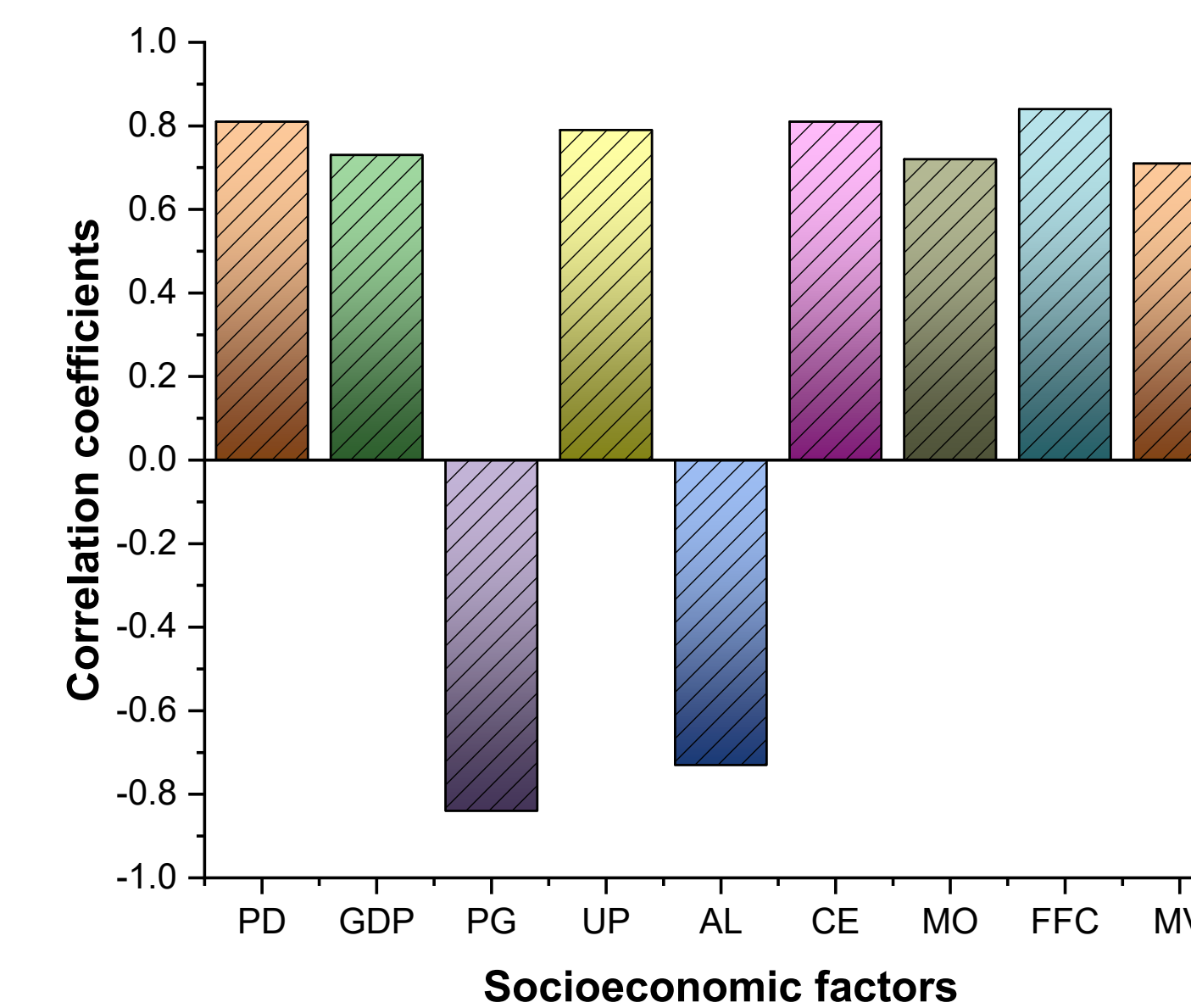
❑ Spatial variations of the anthropogenic aerosol emissions (a) black carbon, (b) organic carbon, (c) SO₂, and (d) SO₄ over Bangladesh



❑ Aerosol heating rate over Bangladesh in four seasons

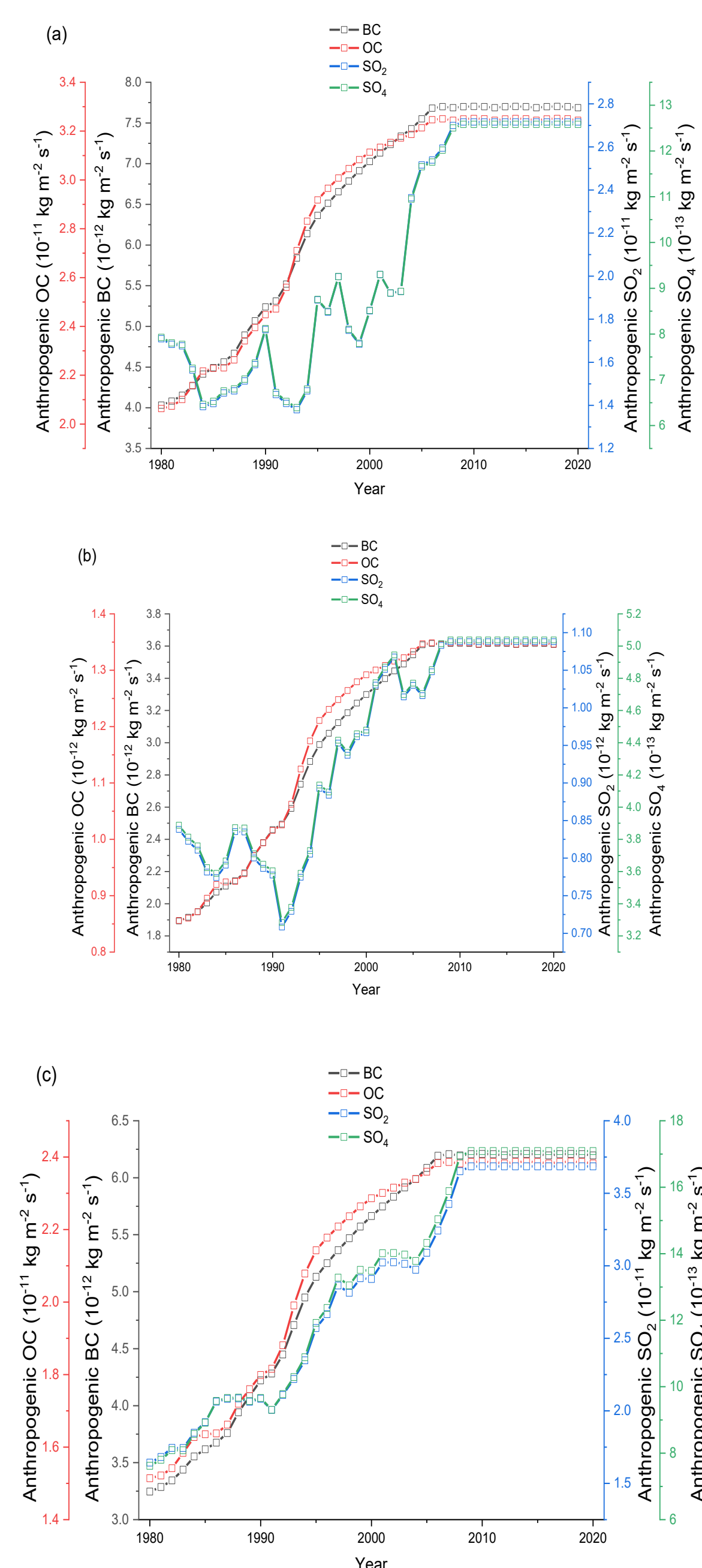


❑ Pearson correlation coefficients (R) of MERRA-2 AOD and socioeconomic factors.



PD= population density, GDP= gross domestic product per capita, PG= population growth (% annual), UP= urban population (%), AL= agriculture land (%), CE= carbon emissions (kilo tons of CO₂), MO= manufacturing output (BS), FFC= fossil fuel consumption, MV= number of registered motor vehicles

❑ Evolution of the yearly anthropogenic aerosol emissions (black carbon, organic carbon, SO₂, and SO₄) over Bangladesh (a) Dhaka, (b) Bhola, (c) Bangladesh



Conclusions

- Spatio-temporal variations of AOD over the country's capital (Dhaka) and most southern island (Bhola) were analyzed for the last two decades (2000-2020) using MERRA-2 and MODIS
- AOD over Bangladesh showed strong seasonal patterns and were found in increasing trends
- Higher concentrations of BC and OC were observed in the northwestern (Rajshahi) part of the country, while SO₂ and SO₄ levels were found to be extremely high in the country's center (Dhaka) and northwestern regions
- Anthropogenic aerosols (~75%) are more dominant in Dhaka while in Bhola, natural aerosols (~63 percent) outnumbered anthropogenic aerosols
- HR values of >1.5 K day⁻¹ indicated the ascendancy of light absorbing aerosols in this region
- All the socioeconomic factors were positively correlated with AOD except population growth and agriculture land

References

Zaman, S.U., Pavel, M.R.S. and Salam, A., 2025. Quantification of anthropogenic aerosol and radiative properties over Bangladesh. *Remote Sensing Applications: Society and Environment*, 37, p.101511. <https://doi.org/10.1016/j.rsase.2025.101511>

Acknowledgment

The authors acknowledge the NASA GSE-DISK for providing the satellite (MODIS), reanalysis (MERRA-2) data and for providing two Cimel sunphotometers to operate in Bangladesh. The authors also acknowledge Dr. James H. Crawford from NASA, USA for his valuable comments regarding the manuscript.