Comprehensive Assessment of Aerosol Optical Depths Over Bangladesh: Source Characterization, Radiative Properties, and Impact of Socioeconomic Factors

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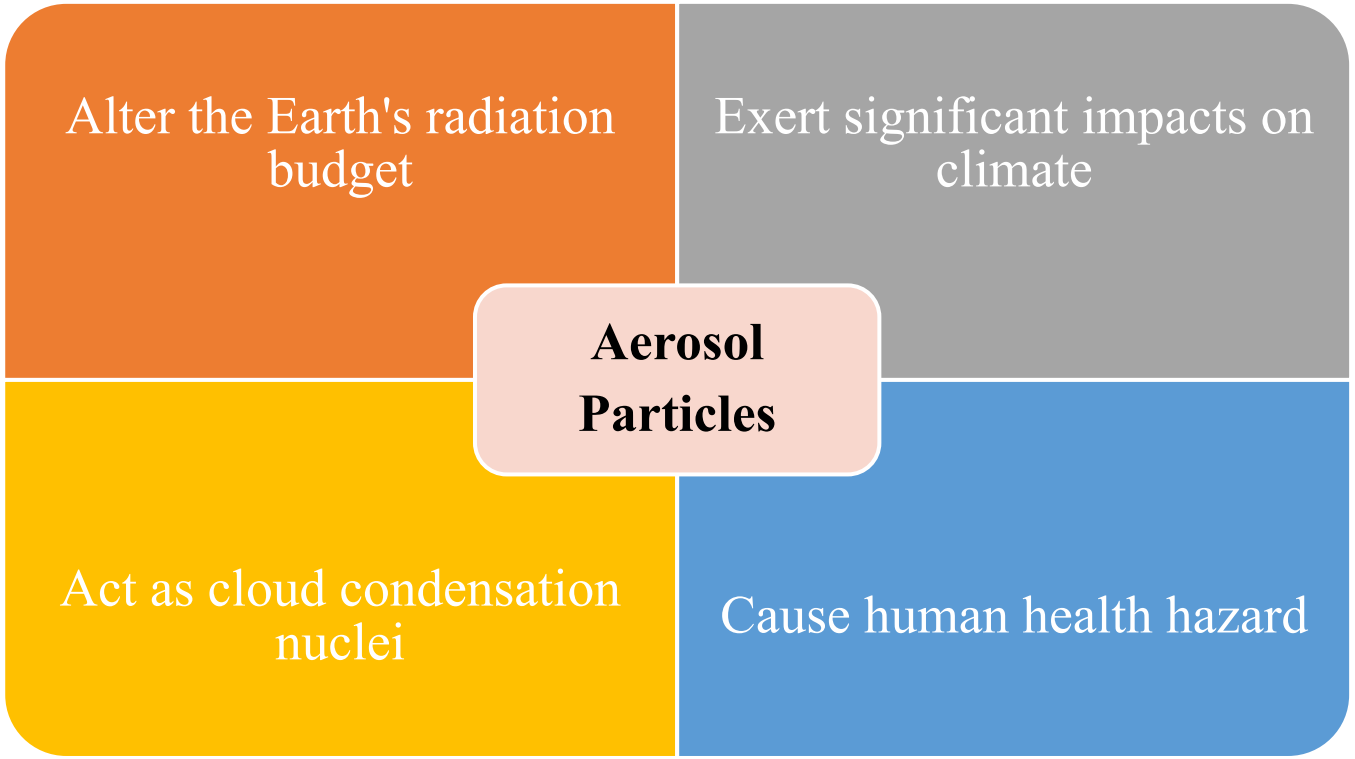
Outlines:

- **Background**
- **Methodology**
- **Results**
- **Summary**

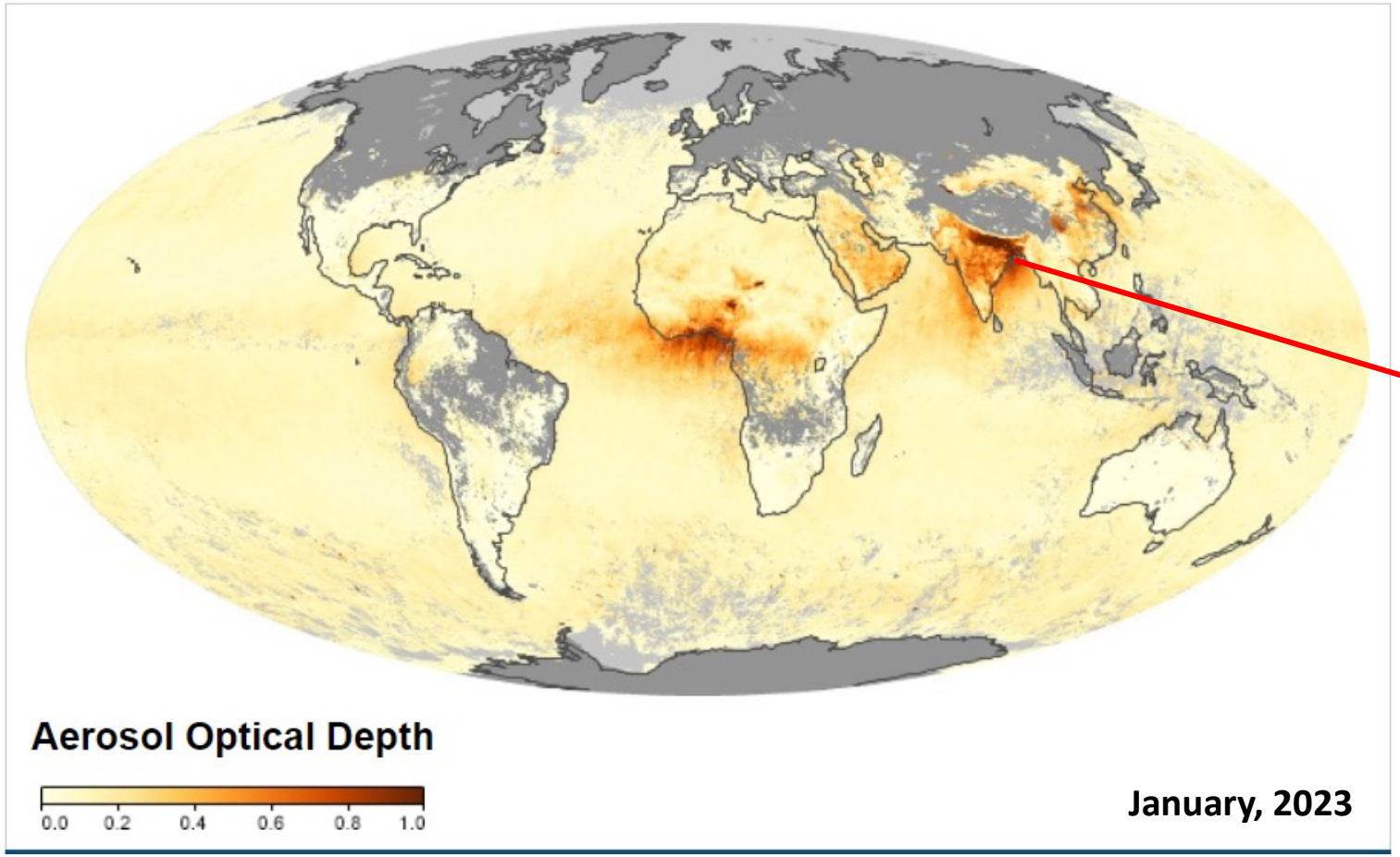
Aerosol optical depth (AOD)

What is AOD?

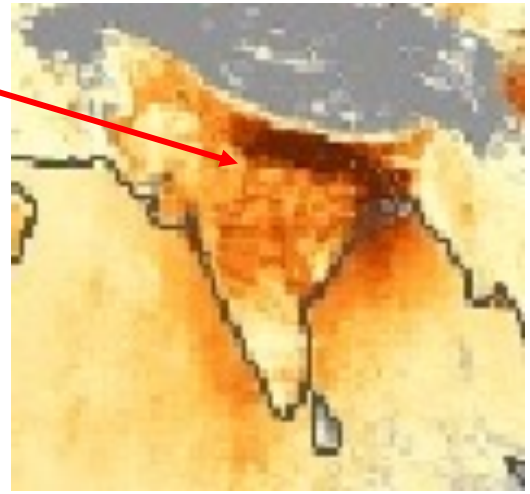
AOD is defined as the sum of aerosol extinction at all atmospheric levels, from the surface up to the top of the atmosphere. It is the main basic parameter for aerosol measurement.



Global distribution of AOD

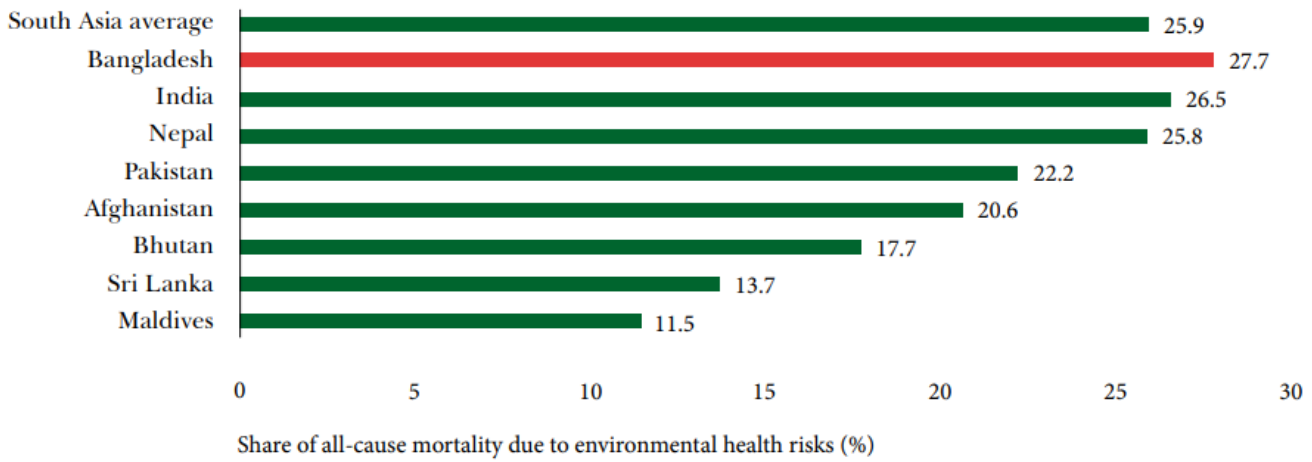


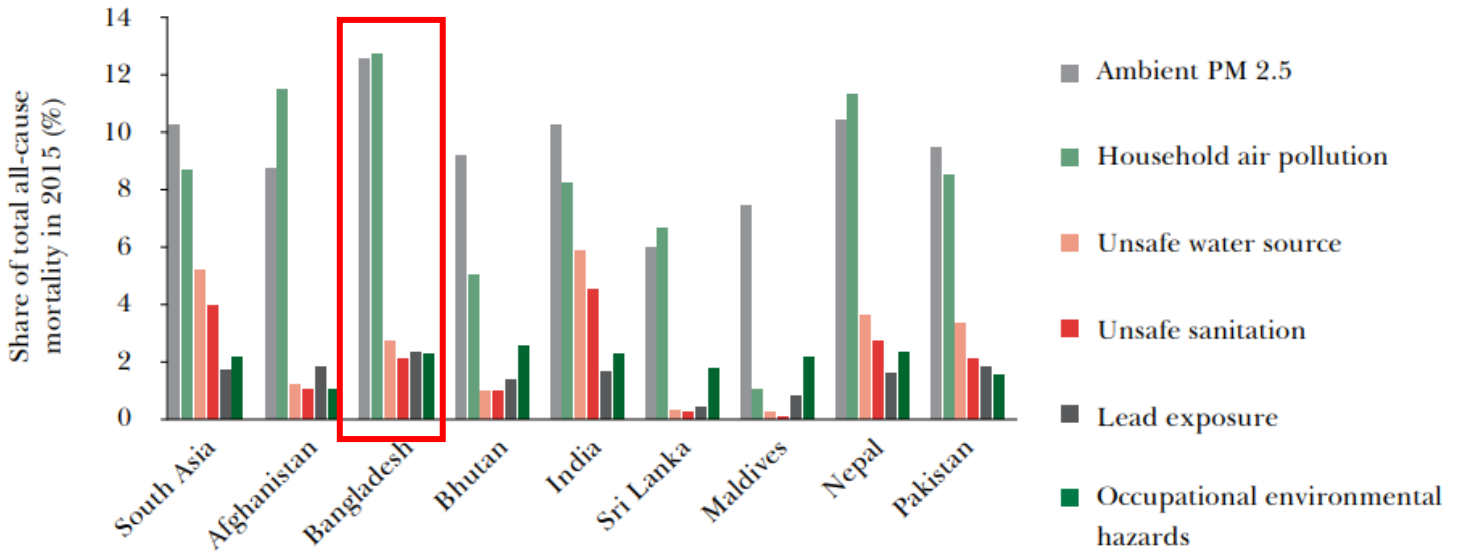
- Dominance of AOD over Africa and Southeast-Asia
- Highest concentration of AOD in December-April



Source: NASA Earth Observations

Air pollution in Bangladesh



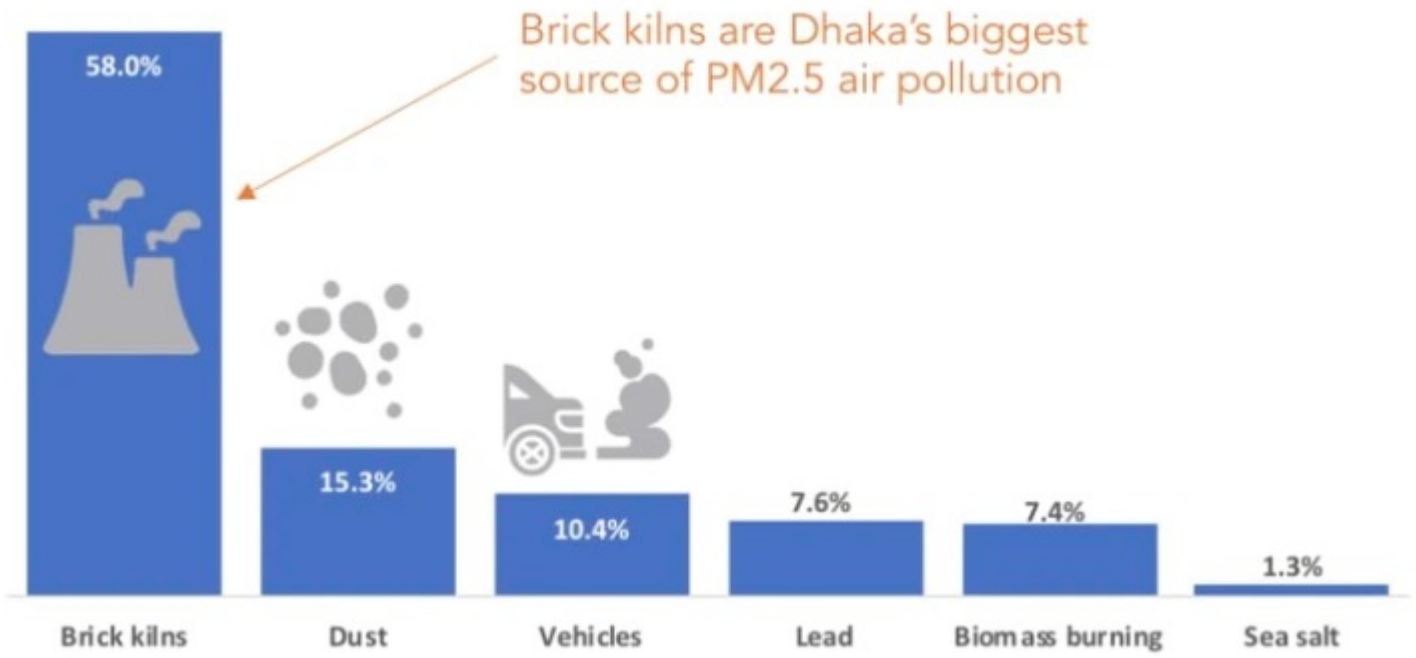


Rank	City, Country	Population-weighted $PM_{2.5}$ ($\mu g/m^3$)
1	Delhi, India	110
2	Kolkata, India	84.0
3	Kano, Nigeria	83.6
4	Lima, Peru	73.2
5	Dhaka, Bangladesh	71.4
6	Jakarta, Indonesia	67.3
7	Lagos, Nigeria	66.9
8	Karachi, Pakistan	63.6
9	Beijing, China	55.0
10	Accra, Ghana	51.9
11	Chengdu, China	49.9
12	Singapore, Singapore	49.4
13	Abidjan, Côte d'Ivoire	47.4
14	Mumbai, India	45.1
15	Bamako, Mali	44.2
16	Shanghai, China	40.1
17	Dushanbe, Tajikistan	39.7
18	Tashkent, Uzbekistan	38.0
19	Kinshasa, Democratic Republic of the Congo	35.8
20	Cairo, Egypt	34.2

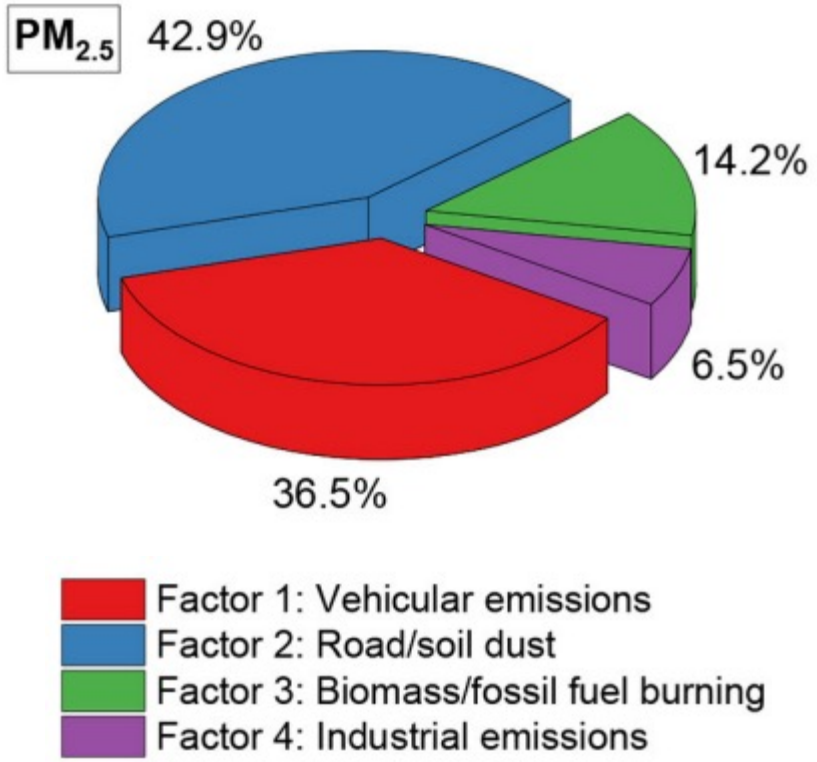
Source: Country environmental analysis 2018, World Bank

Source: State of Global Air, 2022

Air pollution in Bangladesh



Source: Begum et al. 2014



Source: Pavel et al. 2021.

Research Methodology

Satellite products (MODIS)		Reanalysis Product (MERRA-2)	Ground-based products (AERONET)	
TERRA	AQUA		Direct products	Inversion products
AOD_{550}	AOD_{550}	AOD_{550} BCAOD OCAOD SSAOD SO4AOD DUAOD	AOD_{500} AOD_{870} AOD_{340} FMF_{500} $AE_{440-870}$	$AAE_{440-870}$ $EAE_{440-870}$ RRI_{440} SSA_{440}

- **Validation of the satellites (MODIS) and MERRA-2 using AERONET**

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

MODIS TERRA	MODIS AQUA	MERRA-2
$R^2 = 0.53$	$R^2 = 0.58$	$R^2 = 0.72$

Research Methodology

Aerosol speciation over Bangladesh

- $AOD_{total} = DUAOD + BCAOD + OCAOD + SSAOD + SO_4AOD + C$
- $AOD_{contribution} = AODx / AOD_{total}$

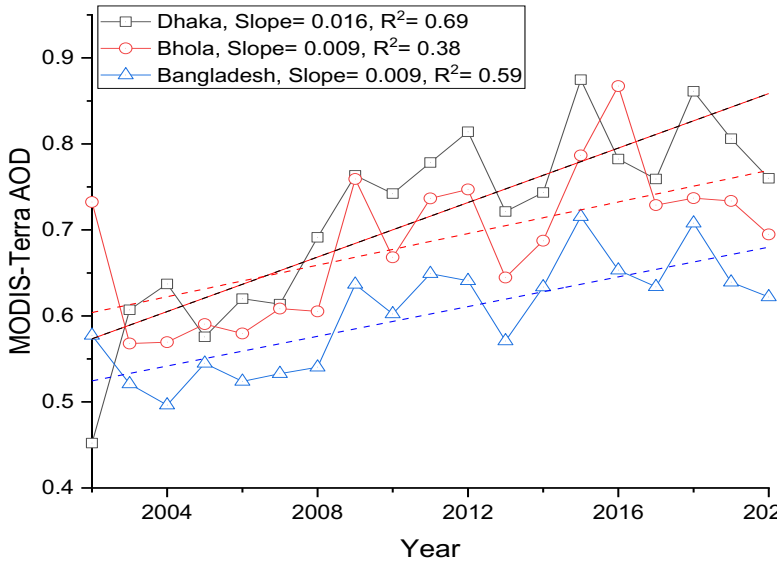
[Qin et al. 2018. Remote Sensing.]

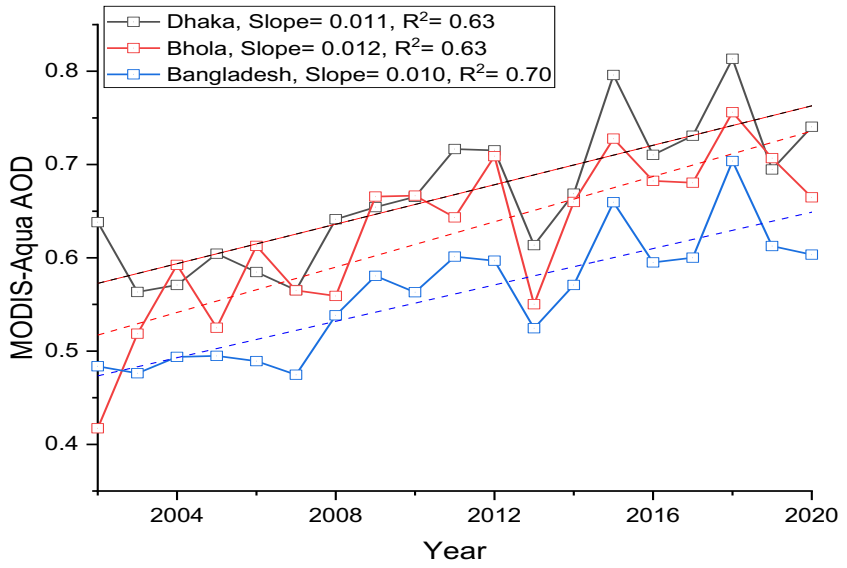
Atmospheric heating rate (HR)

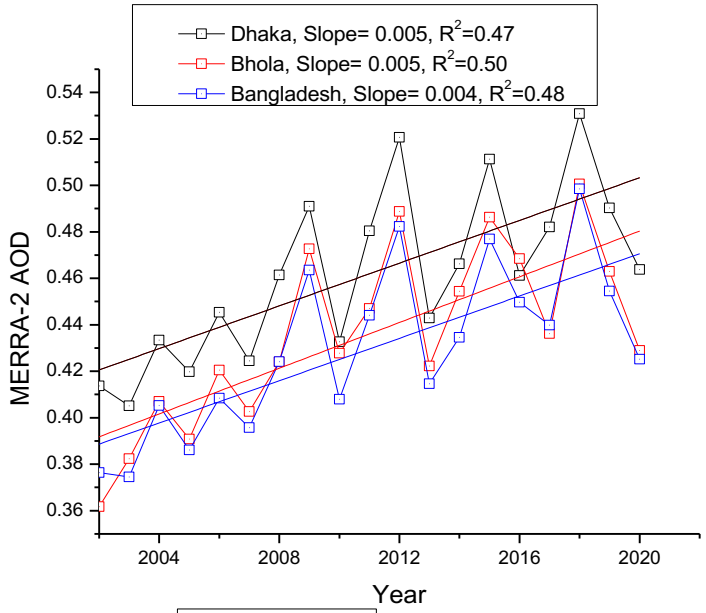
- $\frac{\partial T}{\partial t} = \frac{g}{C_p} \times \frac{\Delta F_{ATM}}{\Delta P} \times 24\ (hr/day) \times 3600\ (sec/hr)$

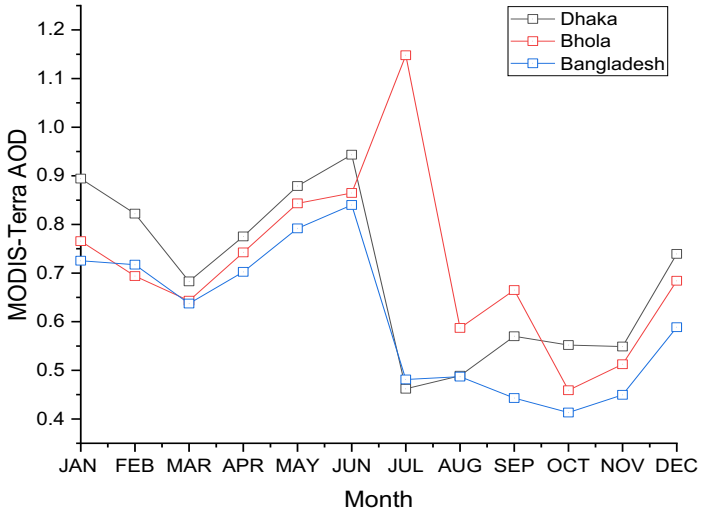
[Filonchyk et al. 2021. Atmospheric Environment.]

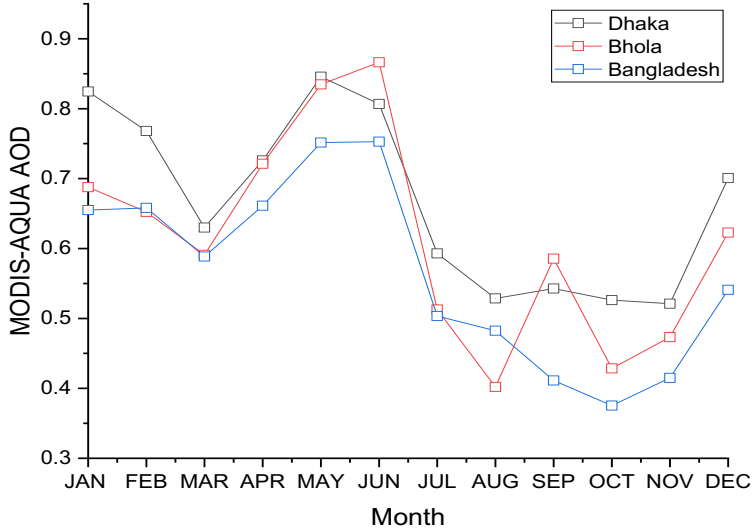
Temporal variations of MODIS and MERRA-2 AODs

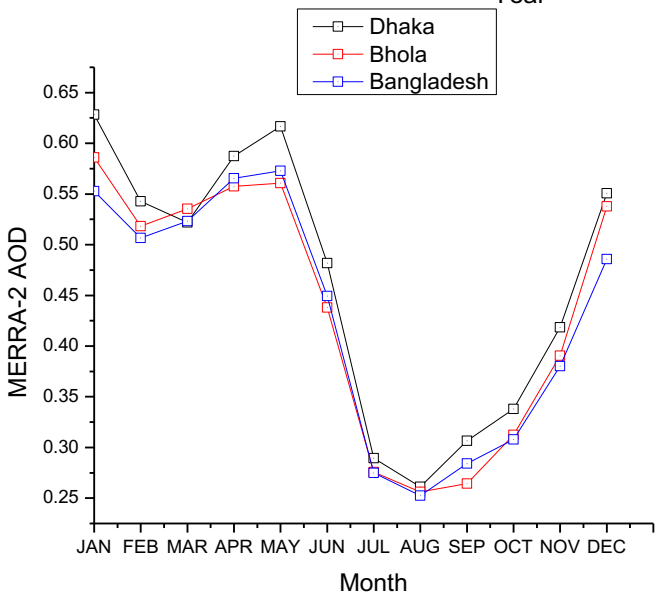




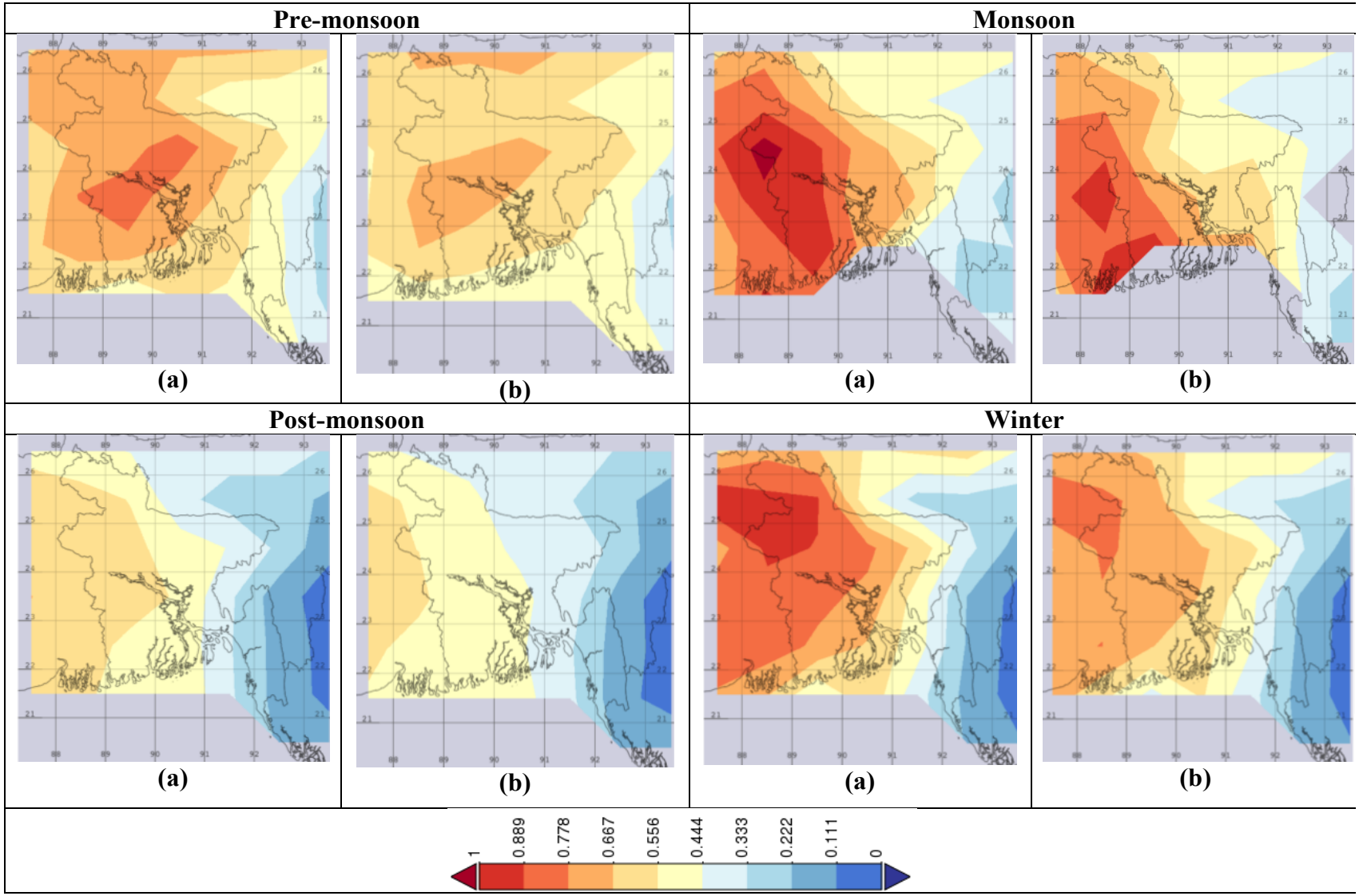






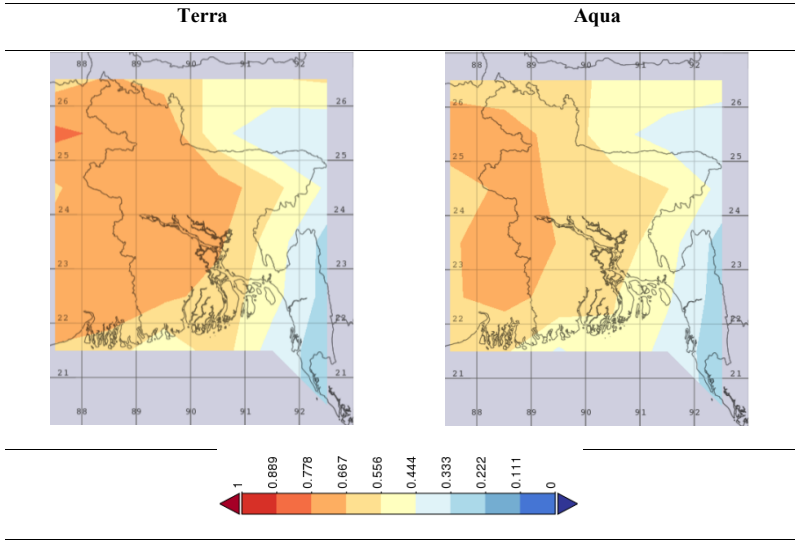


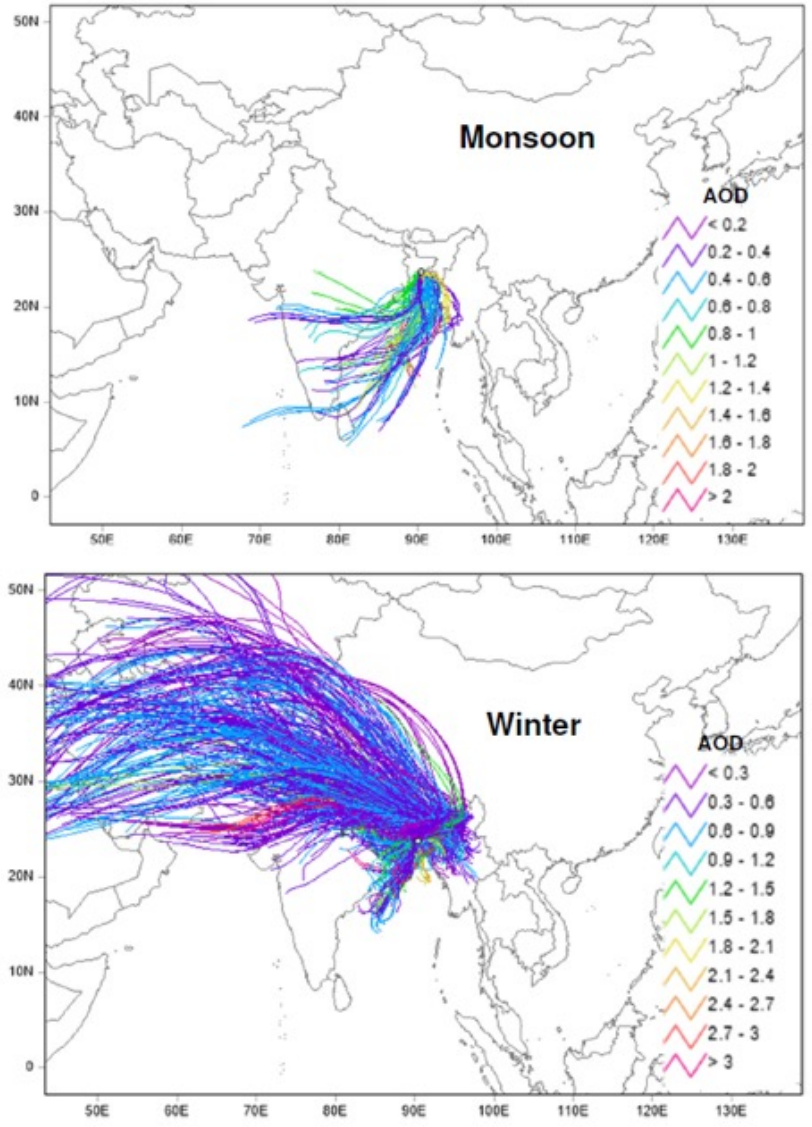
Spatial distribution of MODIS AODs over Bangladesh



Zaman et al. 2021. Atmospheric Research.

NOAA HYSPLIT backward air-mass trajectories





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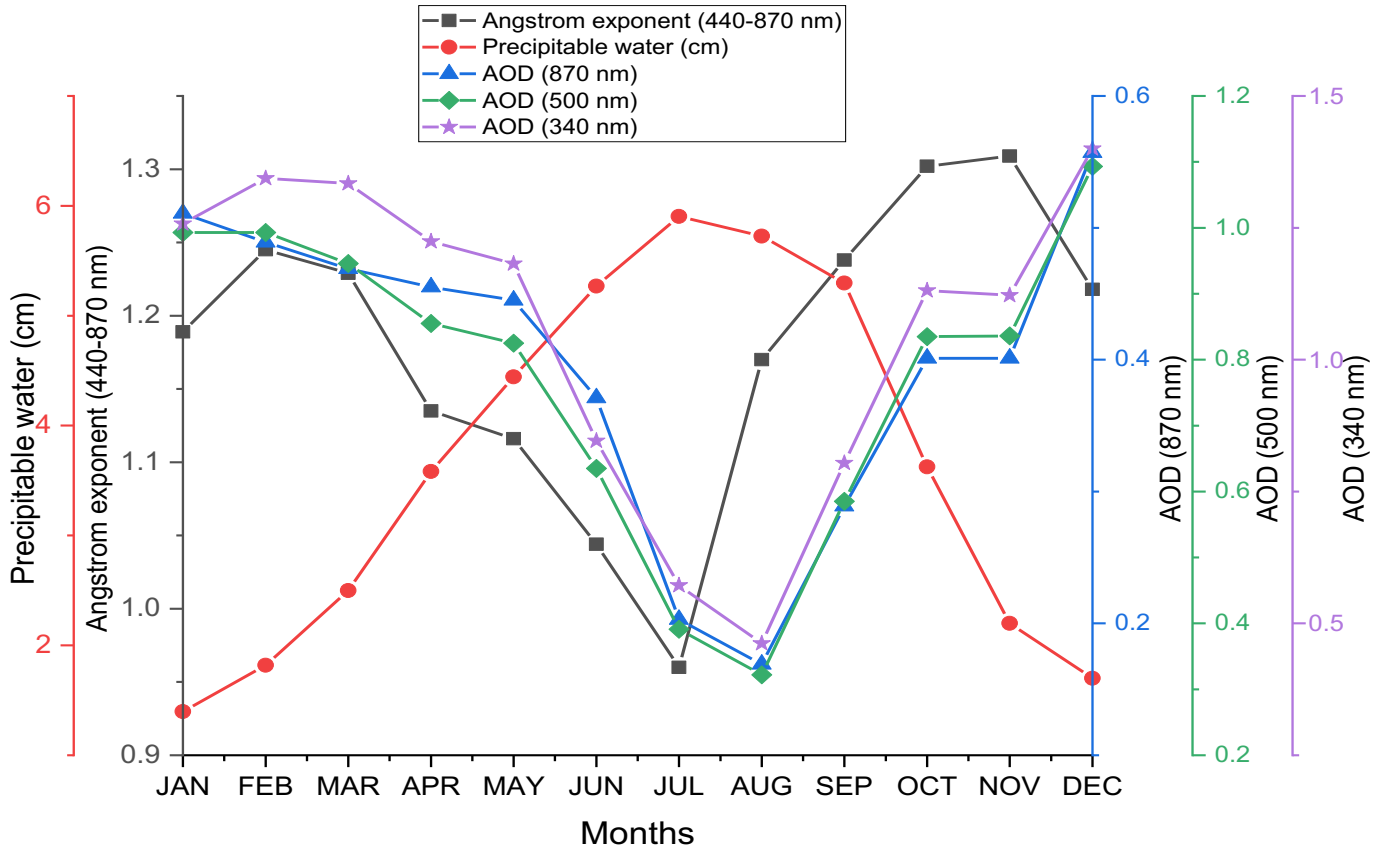
Annual cycles of aerosol optical parameters (AERONET)



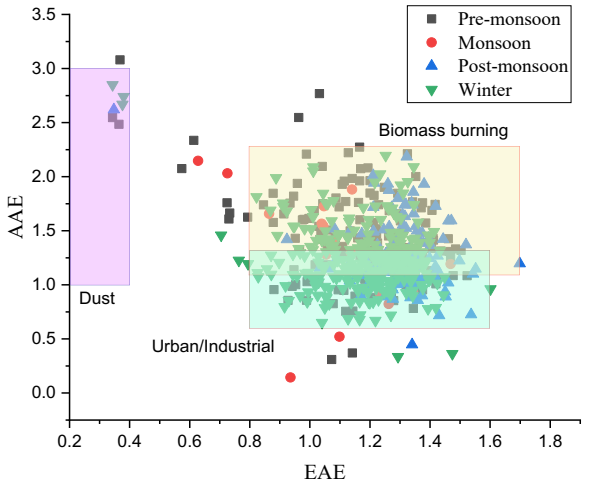
- Similar seasonal variation patterns were found for all AODs
- The values of AE were >1 in all four seasons, indicating that fine-mode particles dominate the aerosol types in Bangladesh
- Both AOD and AE decreased as the amount of precipitable water increased

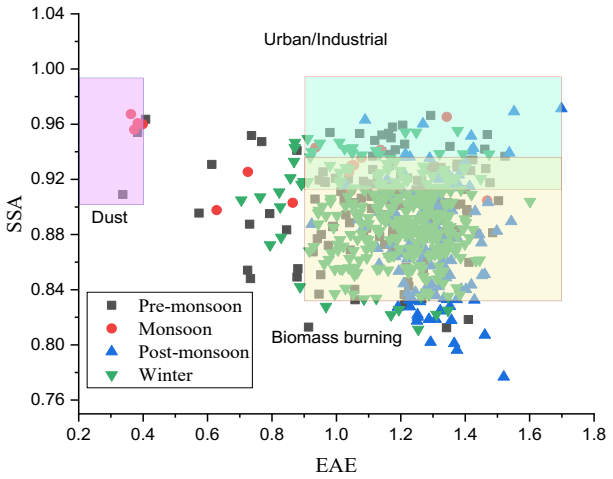
Zaman et al. 2021. Atmospheric Research.

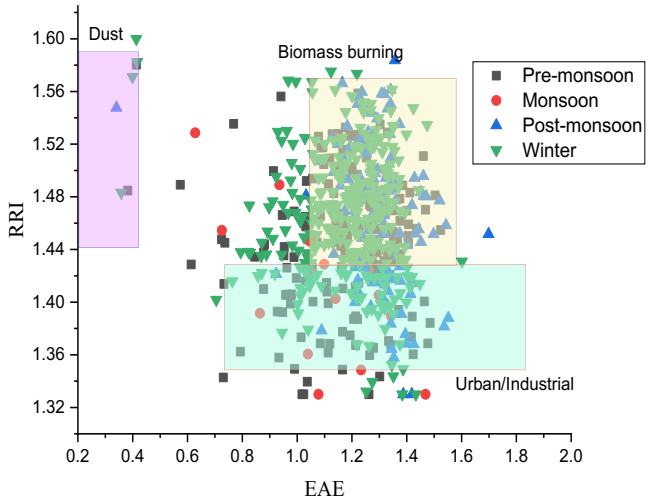
Aerosol types characterization

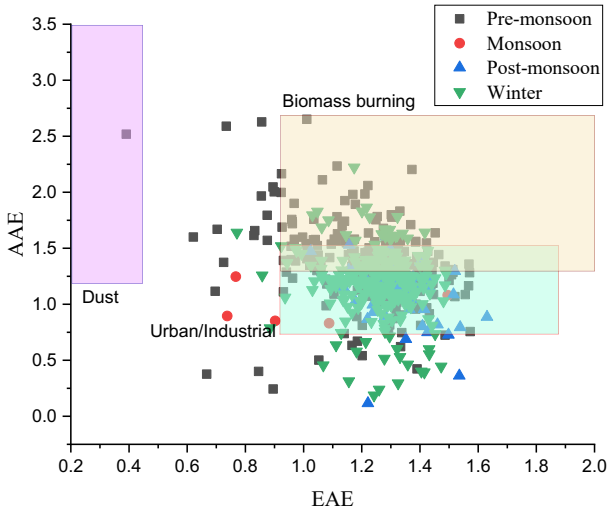
- Biomass burning
- Urban/Industrial
- Dust

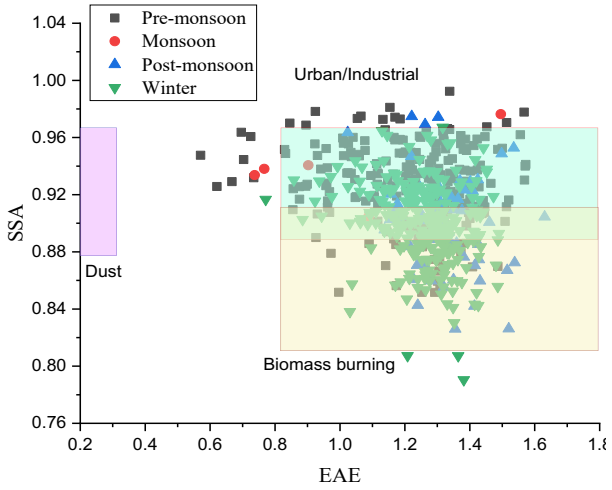
Aerosol Types	EAE vs AAE		EAE vs SSA		EAE vs RRI	
	EAE	AAE	EAE	SSA	EAE	RRI
Biomass-burning	0.80–1.70	1.10–2.30	0.90–1.70	0.82–0.91	1.00–1.50	1.43–1.57
Urban/Industrial	0.80–1.60	0.60–1.30	0.90–1.70	0.89–0.96	0.70–1.74	1.35–1.43
Dust	0.01–0.40	1.00–3.00	0.10–0.40	0.88–0.96	0.01–0.41	1.44–1.59

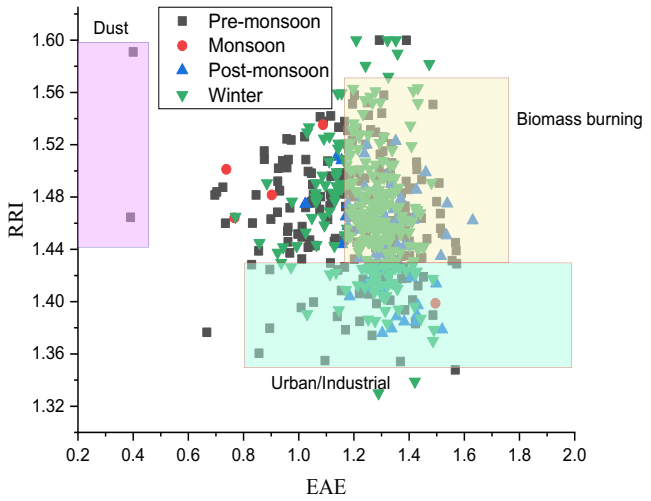








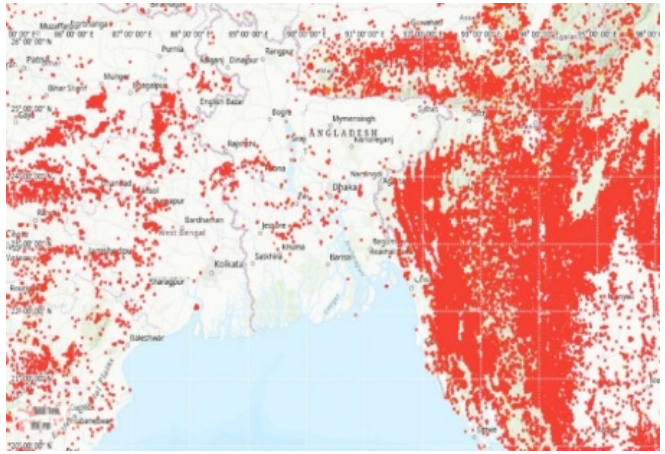




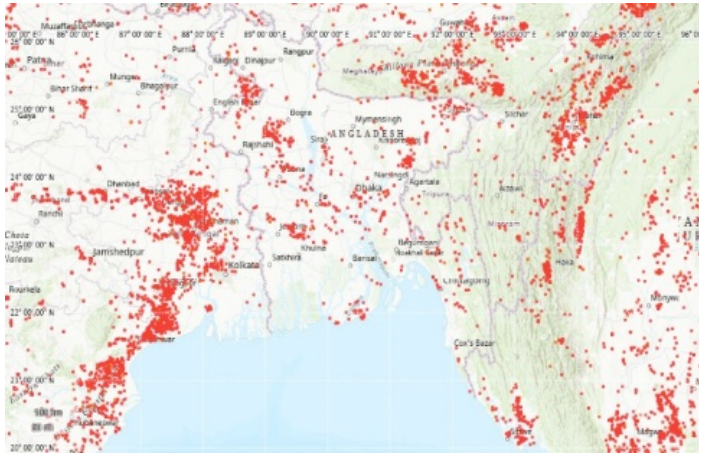
Zaman et al. 2022. Elementa, UC Press.

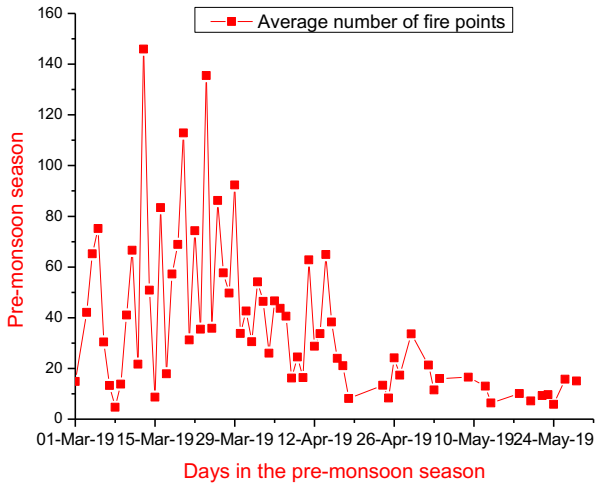
MODIS onboard Terra and Aqua detected fire counts

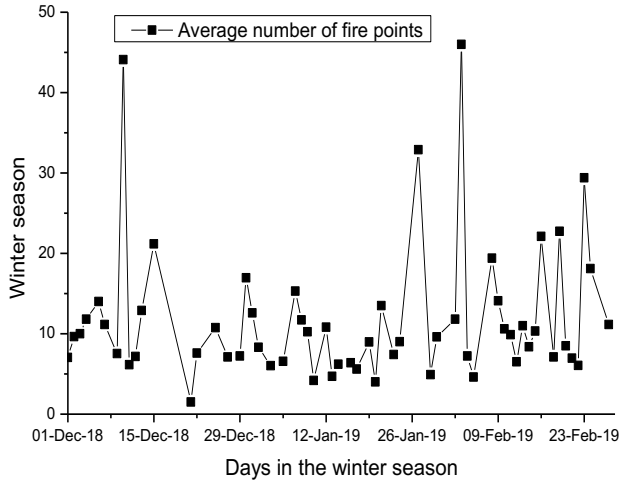
Pre-monsoon



Winter





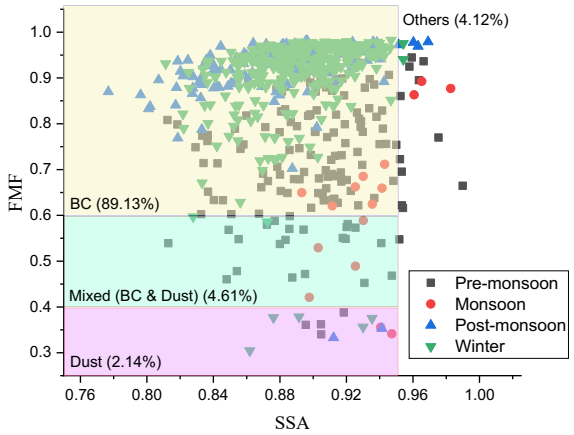


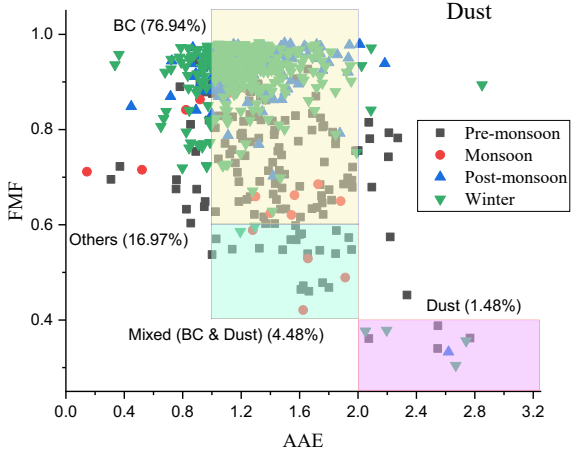
Zaman et al. 2022. Elementa, UC Press.

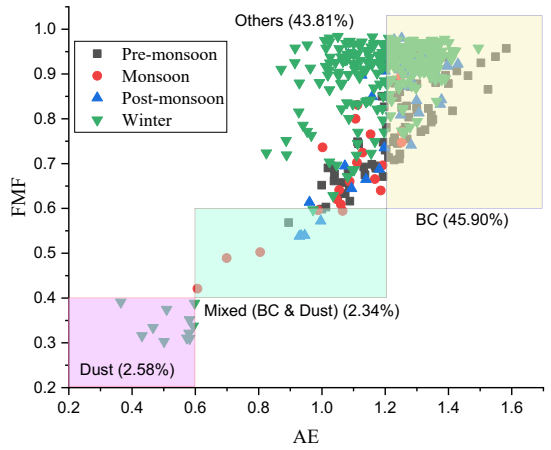
Aerosol types characterization

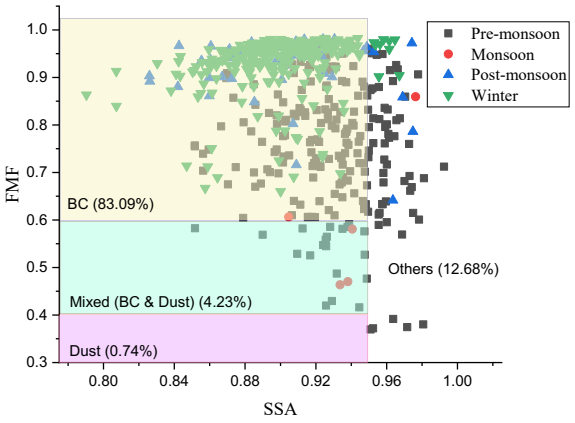
- Black carbon (BC)
- Mixed (BC and Dust)
- Dust

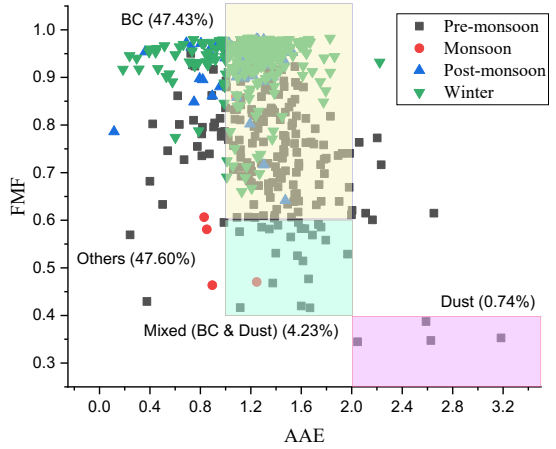
Aerosol Types	FMF vs. AE		FMF vs. AAE		FMF vs. SSA	
	FMF	AE	FMF	AAE	FMF	SSA
BC	FMF > 0.6	AE > 1.2	FMF > 0.6	1.0<AAE <2.0	FMF > 0.6	SSA ≤ 0.95
Mixed (BC and Dust)	0.4 ≤ FMF ≤ 0.6	0.6 ≤ AE ≤ 1.2	0.4 ≤ FMF ≤ 0.6	1.0 < AAE < 2.0	0.4 ≤ FMF ≤ 0.6	SSA ≤ 0.95
Dust	FMF < 0.4	AE < 0.6	FMF < 0.4	AAE > 2.0	FMF < 0.4	SSA ≤ 0.95

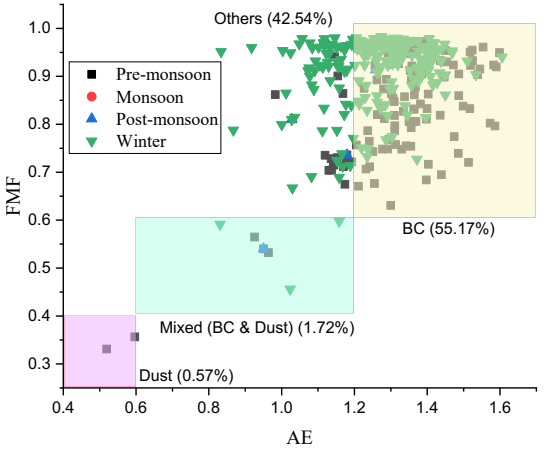






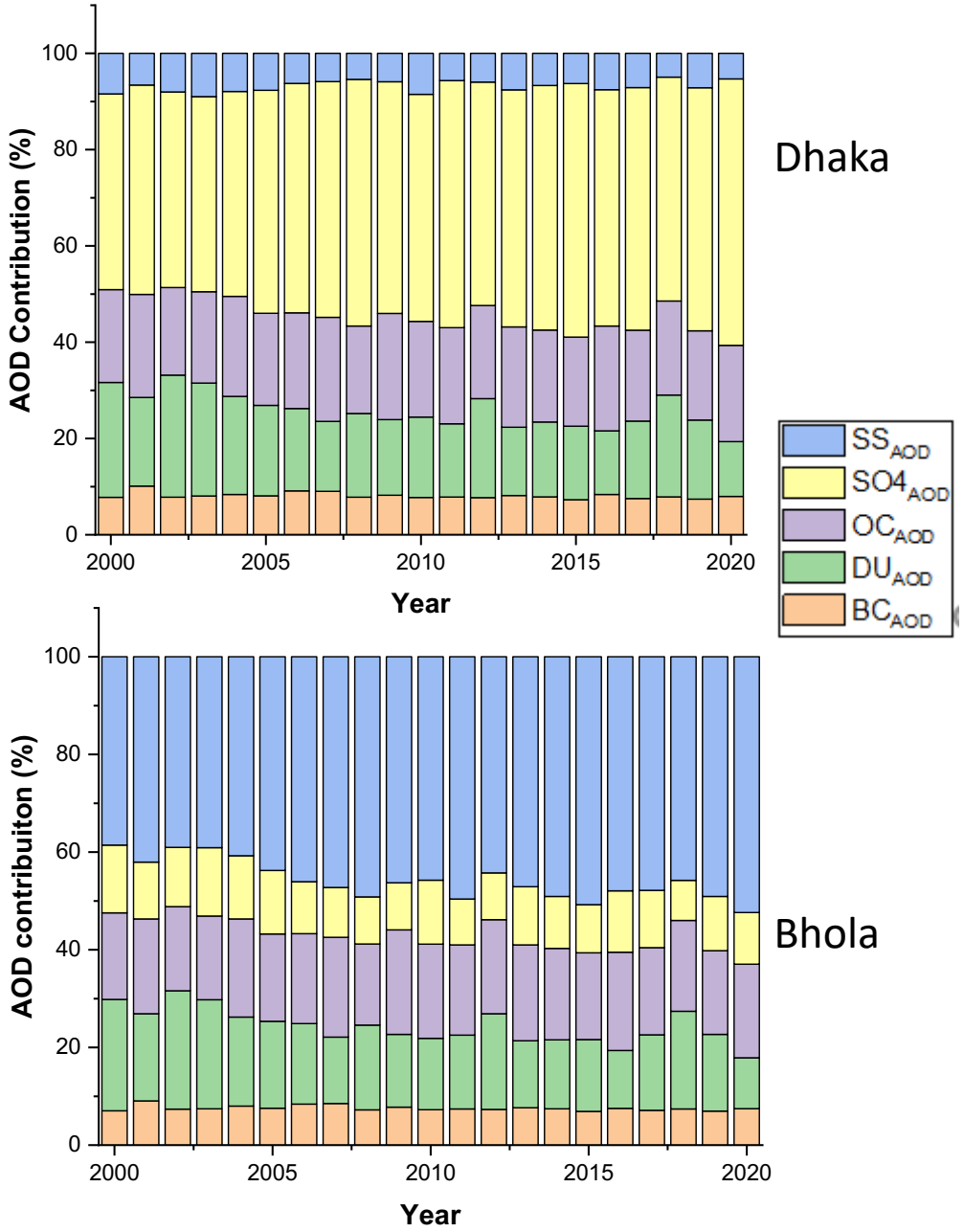






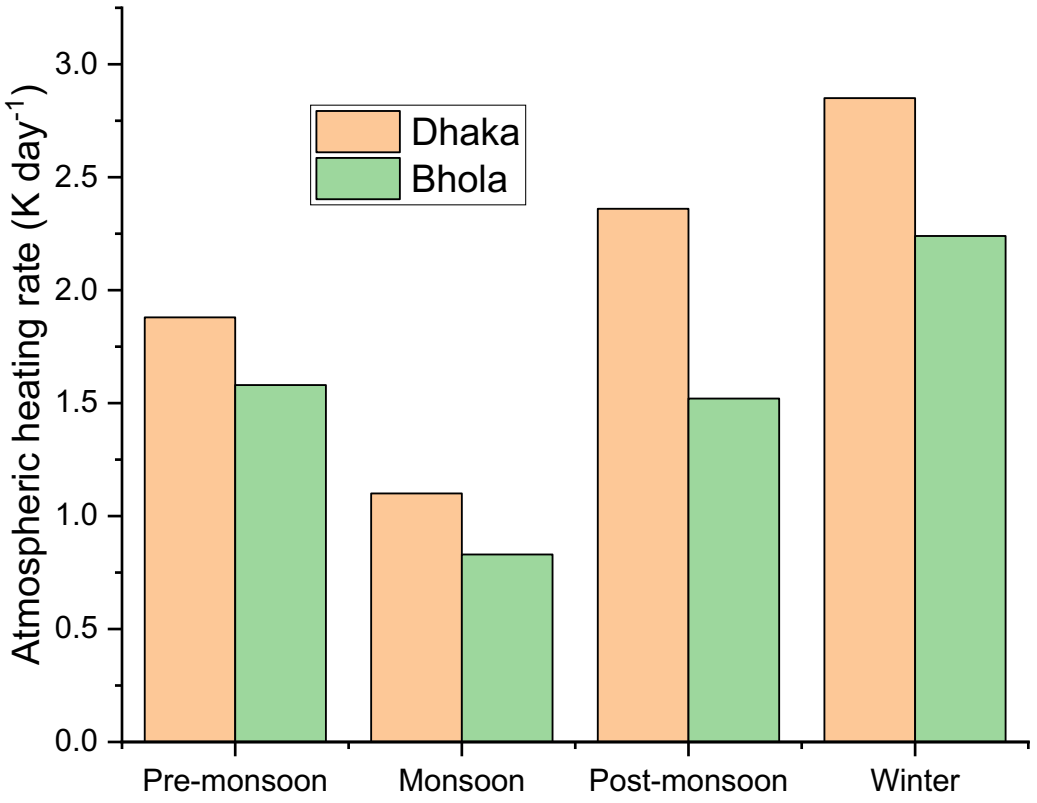
Zaman et al. 2022. Elementa, UC Press.

Aerosol speciation over Bangladesh



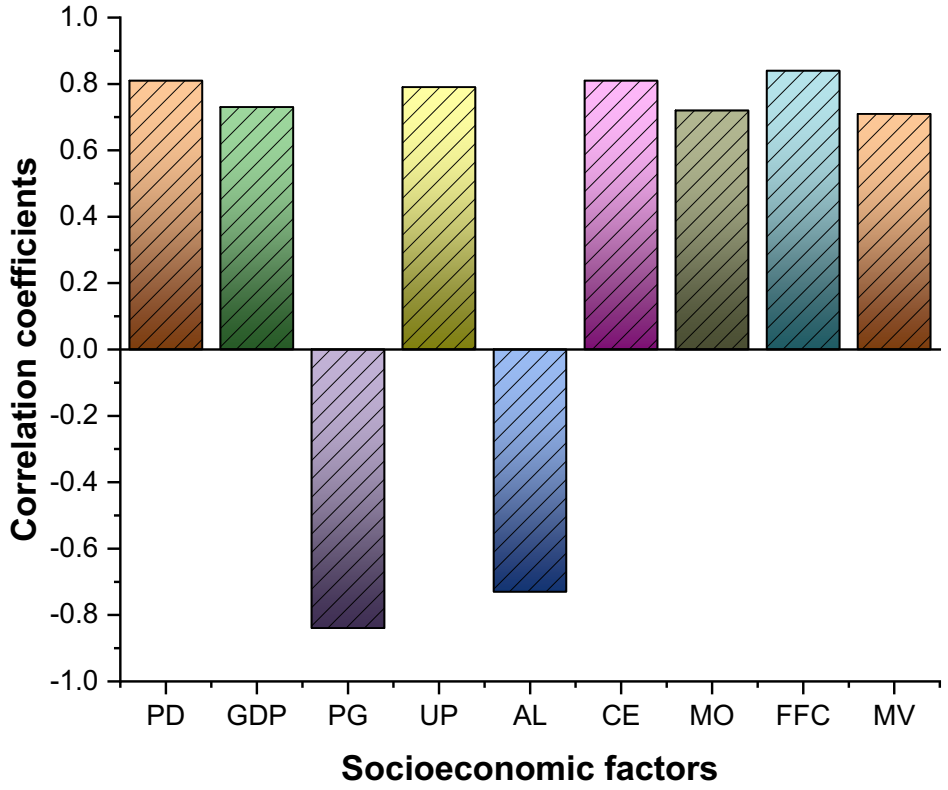
- Dhaka suffers more from anthropogenic aerosols (BC, OC, SO_4) (~75%) than natural aerosols (Sea salt, Dust) (~25%)
- Dominance of natural aerosols (~63%) over anthropogenic (~37%) prevails in Bhola

Atmospheric Heating Rate



- The greater HR in winter suggests the existence of absorbing aerosols, which are plainly BC from burning of fossil-fuel, transportation, and increasing emissions from domestic heating
- HR of over 1.5 K day^{-1} over Bangladesh indicate the existence of considerable amounts of light-absorbing aerosols (BC, BrC, and mineral dust)
- These aerosols are essentially responsible for the global warming in this region

Correlation between AOD and socioeconomic factors



- Spatial and temporal variations of aerosols in Bangladesh are **substantially influenced** by the socioeconomic factors

- Population growth and agricultural land have been decreasing in Bangladesh, while AOD has been increasing,
- Therefore the **negative** relationships between them are anticipated.

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 CO_2)

MO= manufacturing output (B$), FFC= fossil fuel consumption, MV= number of registered motor vehicle.

Summary

- High AOD values (>0.70) were obtained in most of the western parts of the country
- Decreasing patterns of AOD were observed from northwest to southeast
- Biomass-burning and Urban/Industrial types were identified as the main **aerosol types** in Bangladesh
- Black carbon (BC) was the prominent absorbing aerosol (45.9%–89.1%) in all seasons
- Dhaka suffers more from anthropogenic aerosols (75%) while natural aerosols dominate (63%) in Bhola
- Higher heating rate indicate the dominance of absorbing aerosols
- Socioeconomic factors have a significant impact on aerosol loadings in Bangladesh