

Role of Black Carbon Aerosols and Atmospheric Transport in Modulating Rainfall Over Western Karnataka, India

-A MERRA-2 and ERA5-Based Analysis (2001–2024)



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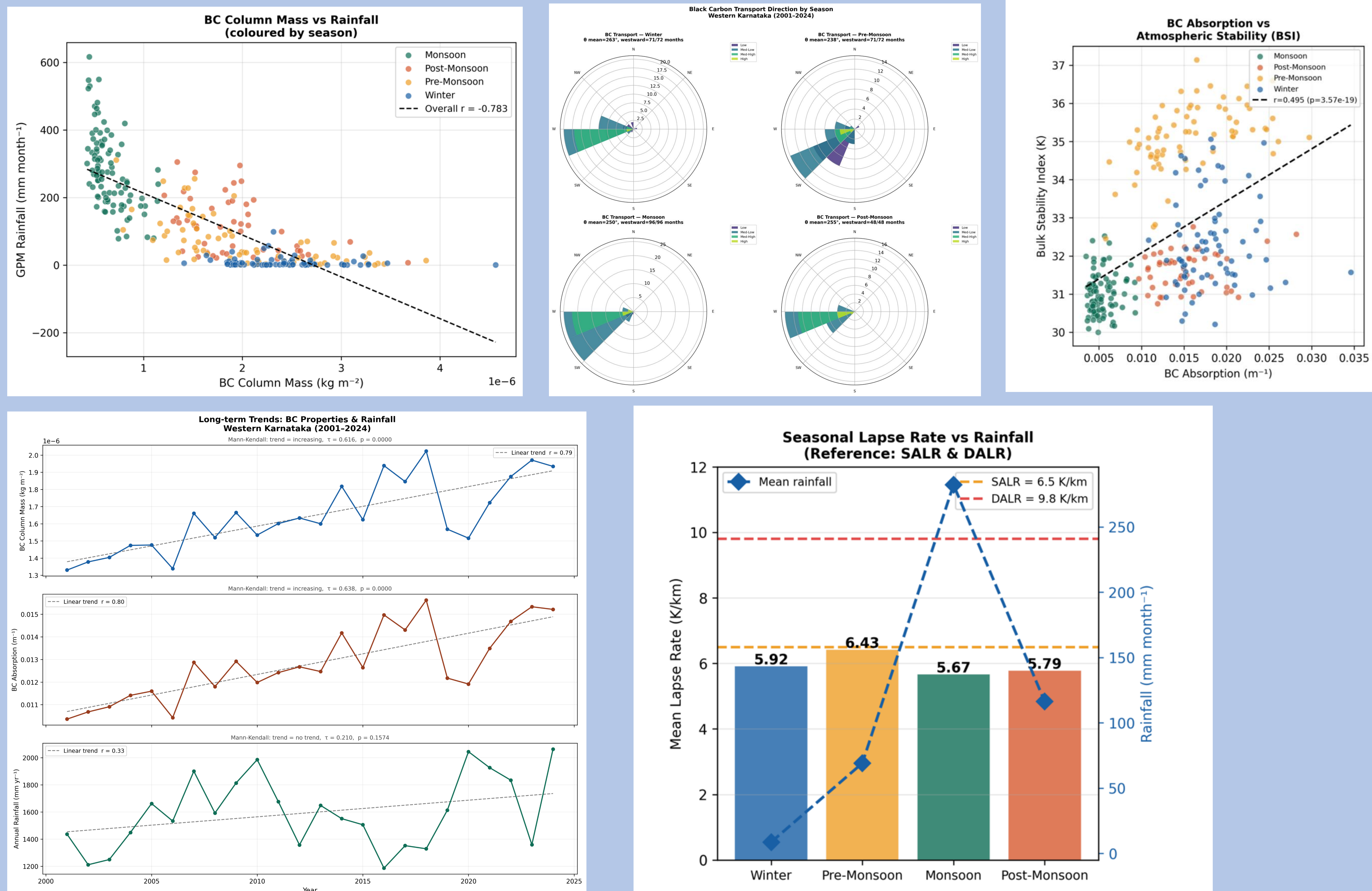
1. Abstract

- Rainfall over the western parts of Karnataka, India, is critically important for water resources, agriculture, and ecology. While aerosol–rainfall interactions have been studied broadly over India, the specific role of black carbon (BC) aerosols and their relationship with atmospheric stability over this topographically complex region remains poorly understood.
- This study examines 24 years (2001–2024) monthly BC aerosol data from MERRA-2 reanalysis, atmospheric temperature profiles from ERA5, and rainfall data from GPM IMERG, over the study region 12°–15°N, 74°–78°E. Also, BC absorption, single scattering albedo (SSA), transport flux magnitude, and transport direction are calculated from MERRA-2 variables, also seasonal climatology is analysed. Environmental lapse rate is calculated from ERA5 temperature profiles.

2. Data and methods

- MERRA-2: BC column mass, extinction, scattering, Ångström exponent and horizontal transport components; MODIS: AOD; ERA5: vertical temperature profiles; rainfall: monthly gridded precipitation data.
- Derived parameters include BC absorption, SSA, transport magnitude/direction and 1000–500 hPa atmospheric lapse rate. Seasonal climatology and anomaly analysis are calculated.
- Pearson/Spearman correlation, partial correlation, regression, lead–lag analysis, PCA and Mann–Kendall trend tests were used to investigate relationships and long-term variability.

3. Results



4. Key findings

- BC loading and rainfall show a strong inverse relationship ($r = -0.783$) with strong seasonal dependence; after removing seasonality, the relationship weakens substantially ($r = -0.150$).
- BC transport is predominantly westward (286/288 months; 99.3%). Transport alignment toward the southwest is associated with substantially lower rainfall, while the 1000–500 hPa lapse rate varies seasonally between 5.67 and 6.43 K km⁻¹.
- BC column mass and absorption show significant increasing trends during 2001–2024, while rainfall shows no significant long-term trend. Seasonal SSA ranges from 0.233–0.301, with the BC Ångström exponent around 1.43–1.50.

4. Summary

- Western Karnataka experiences strong westward BC transport, with strong seasonal variability in BC loading, optical properties and rainfall.
- BC loading, transport characteristics and atmospheric stability are strongly associated with rainfall variability, but the strength of these relationships depends on season and atmospheric state.
- BC loading is significantly increasing since 2001 (Mann-Kendall $\tau = 0.616$, $p < 0.001$), raising serious concern for future monsoon rainfall reliability over the Western Ghats

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