Relationship between black/brown carbons and airborn particulate matter's chemical composition during smoke haze and non-smoke haze period in Northern Thailand

Chanawan Sonthey[1] , Supattarachai Saksakulkra[2]
[1]Environmental Science program, Facalty of Science, Chiang Mai University, Chiang Mai 50200, Thailand
[2]Environmental Science Research Center, Facalty of Science, Chiang Mai University, Chiang Mai 50200, Thailand

Introduction

Fine particulate matter (PM2.5) represents a global environmental challenge. In Northern Thailand, extensive dry season biomass burning drives smoke haze, emitting massive quantities of carbonaceous aerosols. Specifically, black carbon and brown carbon within these emissions profoundly impact human health and regional climate forcing. Characterizing their distinct optical properties, chemical compositions, and emission sources across both smoke haze and non-smoke haze periods is essential for evaluating regional atmospheric dynamics.

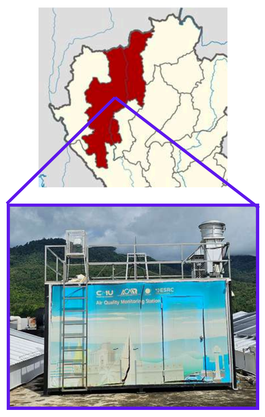
Objective

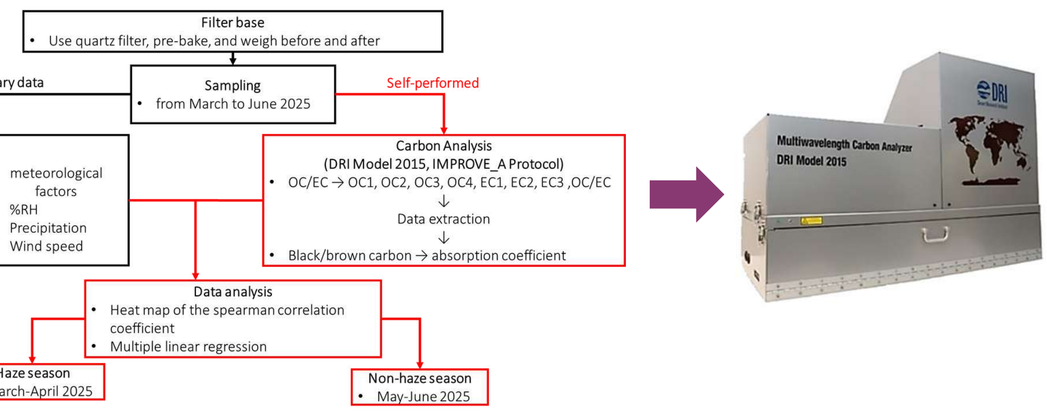
1. To investigate BrC and BC contributions using thermal-optical method with muti wavelength lasers .
2. To evaluate the relationship between BC and BrC with $PM_{2.5}$ chemical composition in Chiang Mai

Methodology

- Collected $PM_{2.5}$ on quartz fiber filter by High Volume sampler, categorized into smoke haze (Mar and April) and non smoke haze (May and June) periods in 2025.
- Study site locate at ambient air monitoring station on the rooftop of SCB1 Building, Chiang Mai university
- Utilized the DRI Model 2015 applying the Thermal Optical Transmittance (TOT) method across 7 wavelengths to differentiate carbon fractions and Black/Brown carbons contributions.

Chiang Mai, Thailand





Result & Discussion

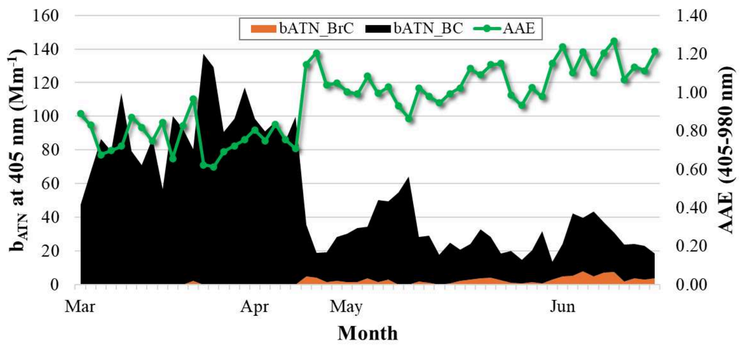


Figure 1. Time series of b_{ATN} at 405 nm by BC and BrC along with AAEs

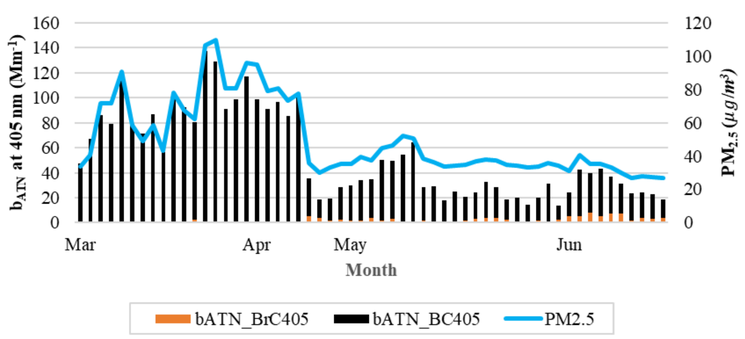


Figure 2. Time series of BC and BrC b_{ATN} at 405 nm with daily $PM_{2.5}$ concentrations.

- **Optical properties and the filter shadowing effect**

Optically, brown carbon (BrC) is distinguished by strong light absorption that significantly increases toward short wavelengths, establishing 405 nm as the standard for its detection (Laskin et al., 2015). As illustrated in Figures 1 and 2, during the smoke haze period (March-April), $PM_{2.5}$ concentrations exceeding 40-50 μg/m³ overloaded the filters, causing an optical saturation that made BrC completely undetectable. As concentrations dropped in the non smoke haze period (May-June), this artifact disappeared, allowing BrC measurement.

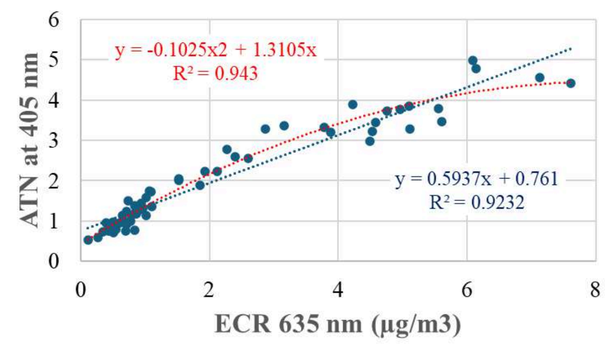


Figure 3. Attenuation at 405 nm (ATN405) versus elemental carbon by reflectance (ECR) at 635 nm

Figure 3 demonstrates the optical shadowing effect. At high elemental carbon loadings, the relationship with attenuation (ATN 405 nm) deviates from linearity. In the superior polynomial fit (R^2 = 0.943), the negative quadratic coefficient (-0.1025) mathematically represents the downward curvature of the response. This flattening confirms that excessive soot accumulation causes optical sensor saturation, completely masking true BrC absorption.

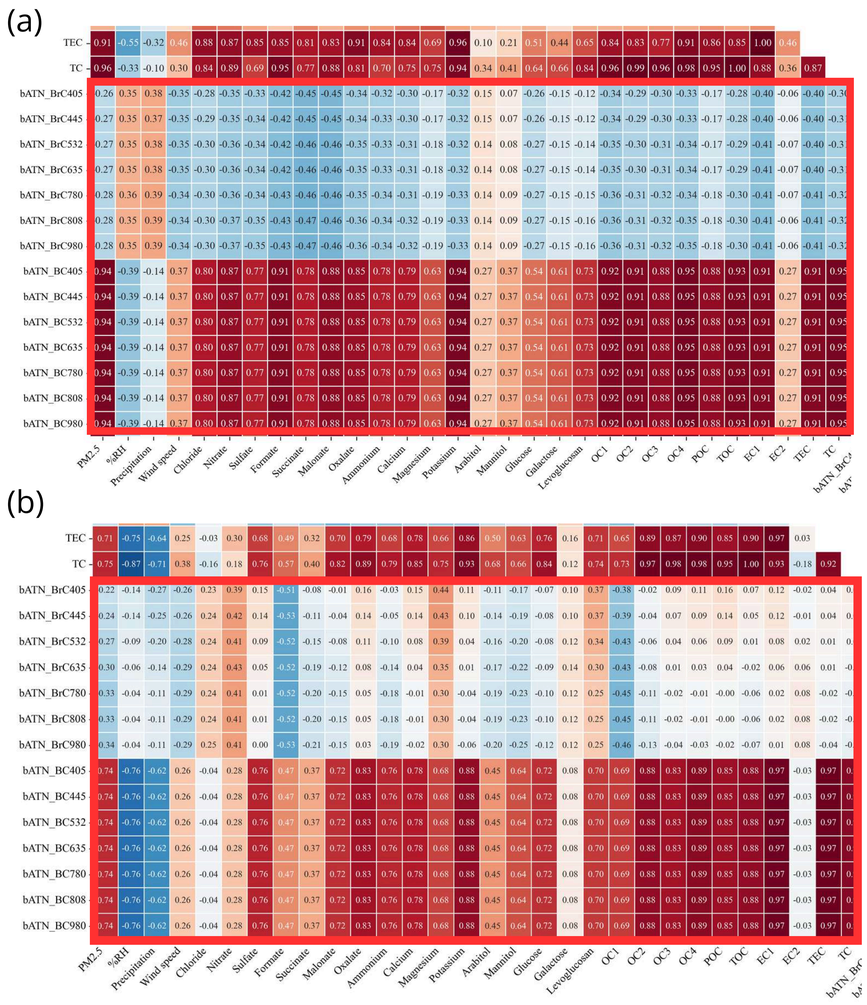


Figure 4. (a) Correlation matrix heat map during the smoke haze period (b) Non-smoke haze period

- **Chemical Associations and Meteorological Influences**

Figure 4. (a) reveals that during the smoke haze period, BC strongly correlated with burning tracers like chloride (r = 0.80) and nitrate (r = 0.87), indicating extensive emissions and rapid aging (Andreae & Gelencsér, 2006). Conversely, BrC displayed negative correlations with particulate mass (r = -0.26), confirming the optical shadowing artifact. Figure 4. (b) shows the non smoke haze period, where precipitation caused a strong wet scavenging effect, negatively correlating with BC (r = -0.62) and BrC (r = -0.27). Without shadowing, accurate detection is restored, linking BrC to levoglucosan (Lack et al., 2013).

Conclusion

- Heat map analysis confirms that during the smoke haze period, BC showed strong positive correlations with water-soluble ions and sugars, while the "Shadowing Effect" caused BrC false negatives. In non smoke periods, accurate detection reveals that BrC correlations shift to positive values with levoglucosan, alongside weak links to secondary inorganic ions. This confirms that while biomass burning remains a source, the BrC signal is easily masked by extreme BC loading.
- Extreme BC loading masked BrC signals, it is hypothesized that standard 24-hour sampling causes filter saturation when $PM_{2.5}$ exceeds 40–50 μg/m³.
- During peak haze episodes, reduce sampling duration to 12 hours or less and lower the flow rate of the high-volume sampler to avoid filter saturation and ensure more accurate optical transmission.

Acknowledgment

This project was support by Environmental Science Research Center, Chiang Mai University

References:

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