Variability of atmospheric black carbon concentration in two urban valleys of the Central Himalaya

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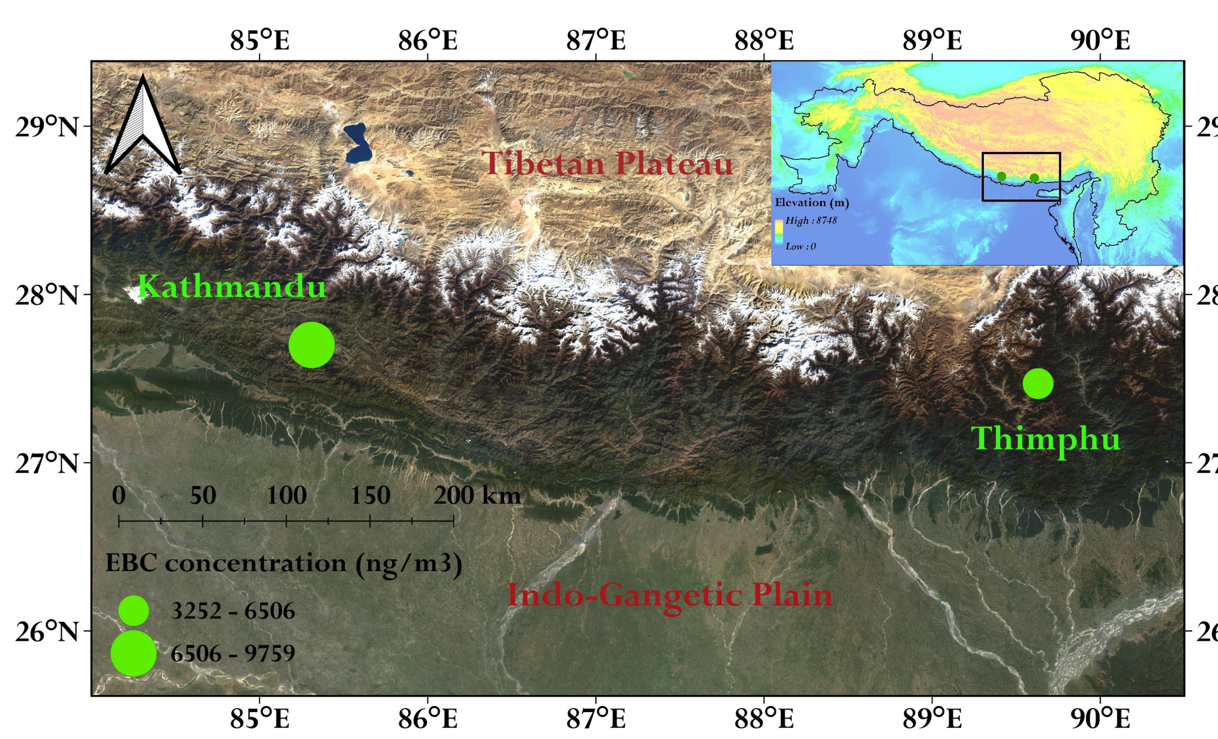
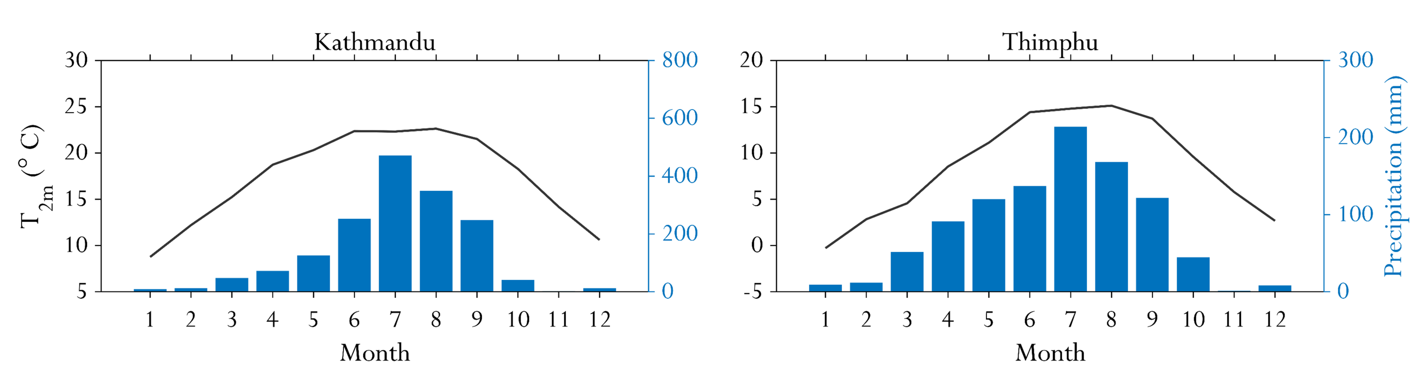
Introduction

- Black carbon (BC), primarily emitted during the incomplete combustion of fossil fuels, biomass, and biofuels, is known to impact the environment and human health significantly.
- BC is one of the most efficient absorbers of solar radiation. BC influences the Earth's radiative balance through a variety of complex direct and indirect processes. One of the direct processes includes deposition and subsequent darkening of the snow surface, which enhances the melting rate of the snow. In another direct process, BC warms up the atmosphere by absorbing solar energy and the radiation reflected by the surface-atmosphere-cloud system. Indirectly, BC affects the optical properties, water content, and life span of the clouds, thus impacting the climate and modulating the precipitation.
- The global trend of BC levels in the atmosphere is highly uncertain due to a lack of observational data. The effective radiative forcing (ERF) of BC during 1850–2014 was recently estimated to be 0.15 ± 0.17 W m^{-2}.
- The eastern and western parts of the Hindu Kush Himalayan (HKH) region have several monitoring stations. There is no ground-based monitoring in Bhutan, and only a few studies have attempted BC monitoring in Nepal. Therefore, BC monitoring is less extensive in the Central Himalayan region.

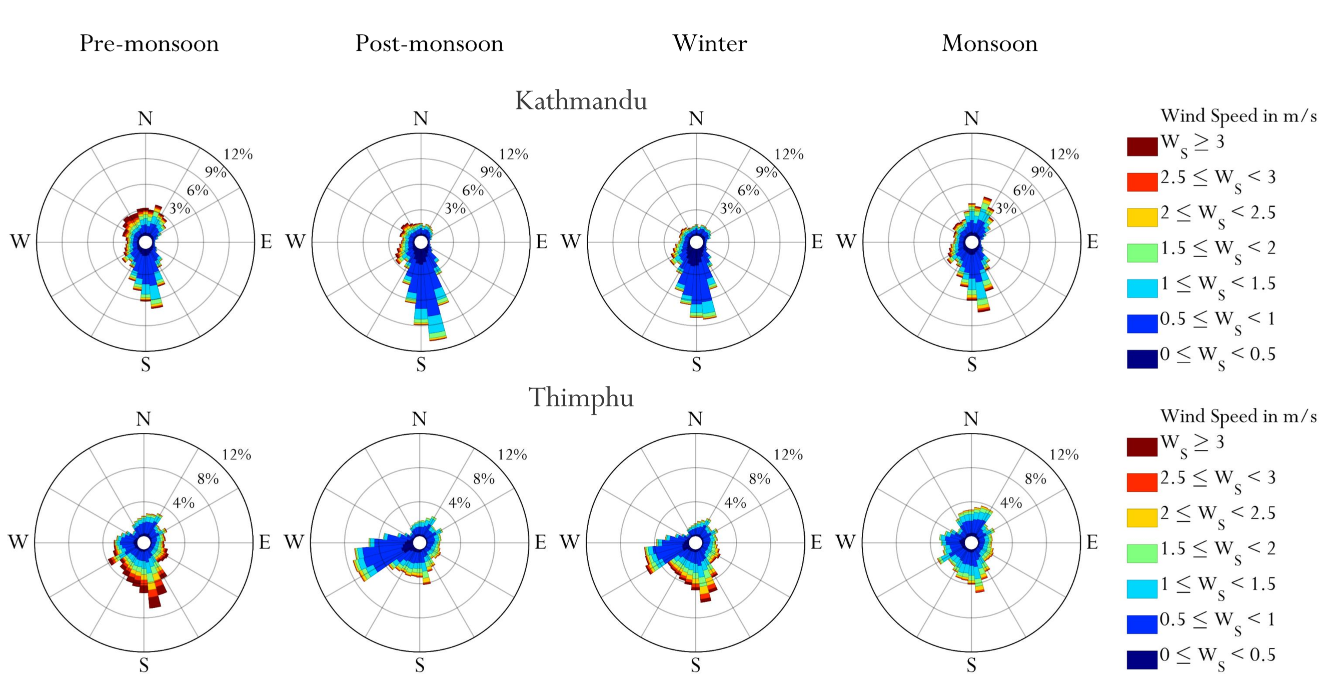
Study area



Map of the study area showing the HKH region in South Asia (inset), location of the EBC monitoring stations, Indo-Gangetic Plain, and Tibetan Plateau.



Monthly average Temperature and accumulated Precipitation at both sites



Wind rose of seasonal wind speed and wind direction observed at both sites

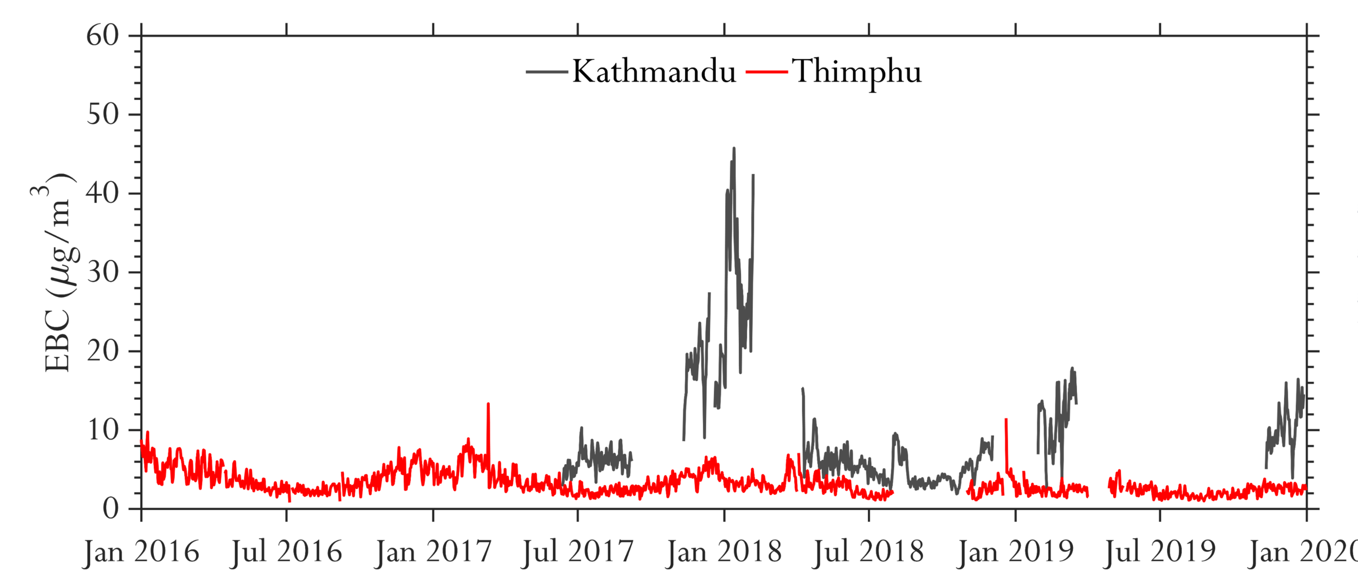
Methodology

- **EBC measurement**: All the black carbon concentration measurements were carried out using a multi-wavelength aethalometer (AE33, Magee Scientific, USA) and denoted as Equivalent black carbon (EBC). The equipment was operated at a constant flow rate of 2 L min^{-1} with a time resolution of 1 min at each site.
- **Source apportionment using AAE**: The aerosol absorption coefficient (b_{abs}) and wavelength (λ) follow the relationship $b_{abs} = \lambda^{-\alpha}$, where α is AAE. In the case of fresh ambient aerosols, we used the AAE values of 0.9 and 1.68 for fossil fuel (FF) and biomass sources (BB), respectively.
- **CWT analysis**: CWT analysis for any individual grid cell (i, j) yields a weighted concentration for this cell based upon the sample concentrations associated with the trajectories overflying across it. CWT helps reveal the source strength of a particular cell with respect to the receptor site under analysis. The CWT equation is given as follows:

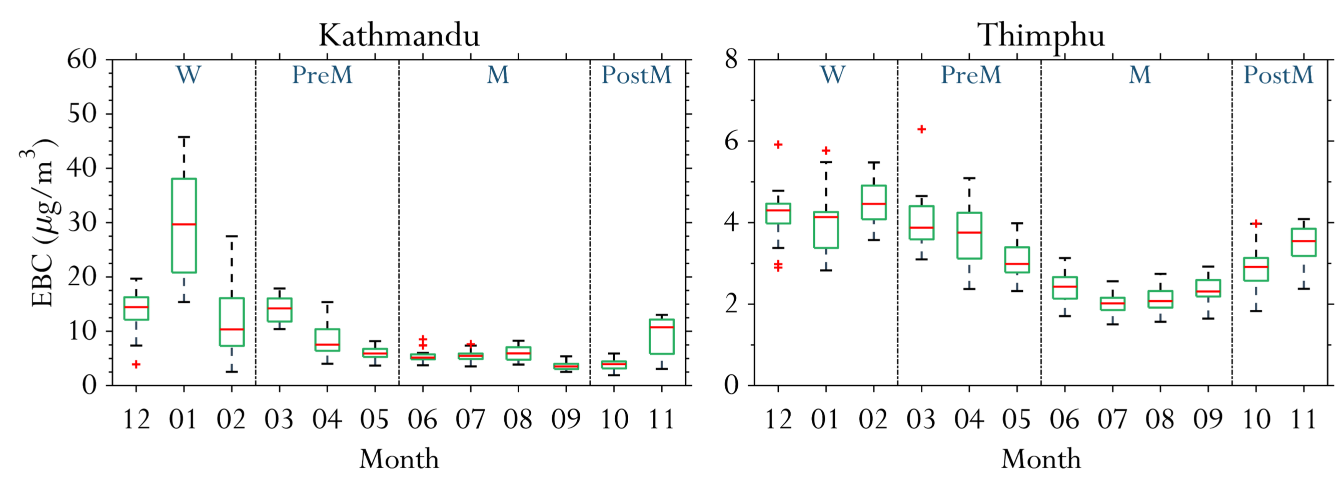
$$CWT_{ij} = \frac{\sum_{l=1}^{L} C_l \tau_{ijl}}{\sum_{l=1}^{L} \tau_{ijl}}$$

where CWT_{ij} is the average weighted concentration of the ij^{th} cell, C_l is the concentration of the grid cell with back trajectory index l, L is the total number of trajectories, and τ_{ijl} is the time spent by trajectory l in the ij^{th} cell. A higher value of C_l indicates that the air mass traveling over the ij^{th} cell would be associated with a higher pollutant concentration at the receptor site.

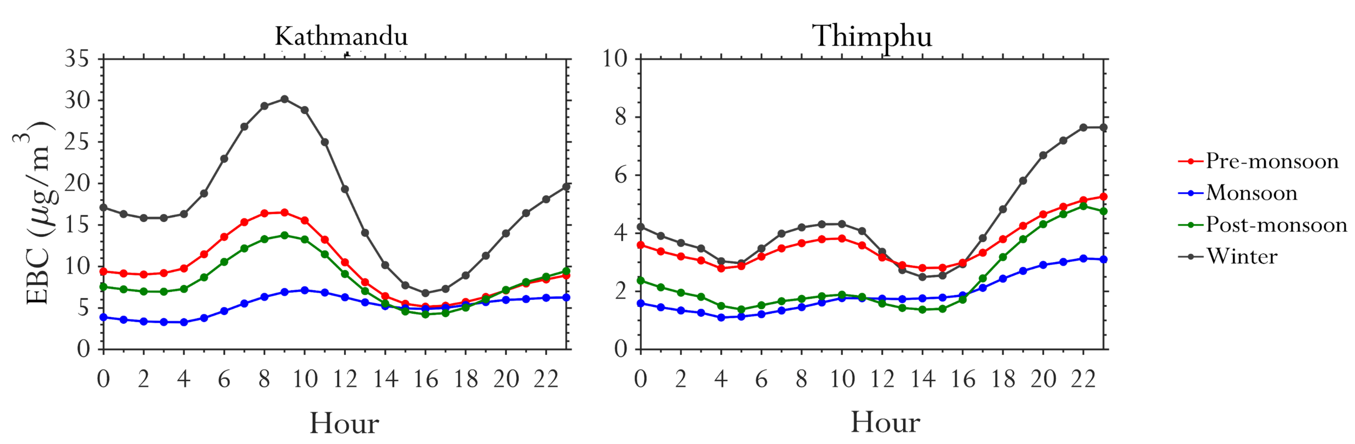
Results



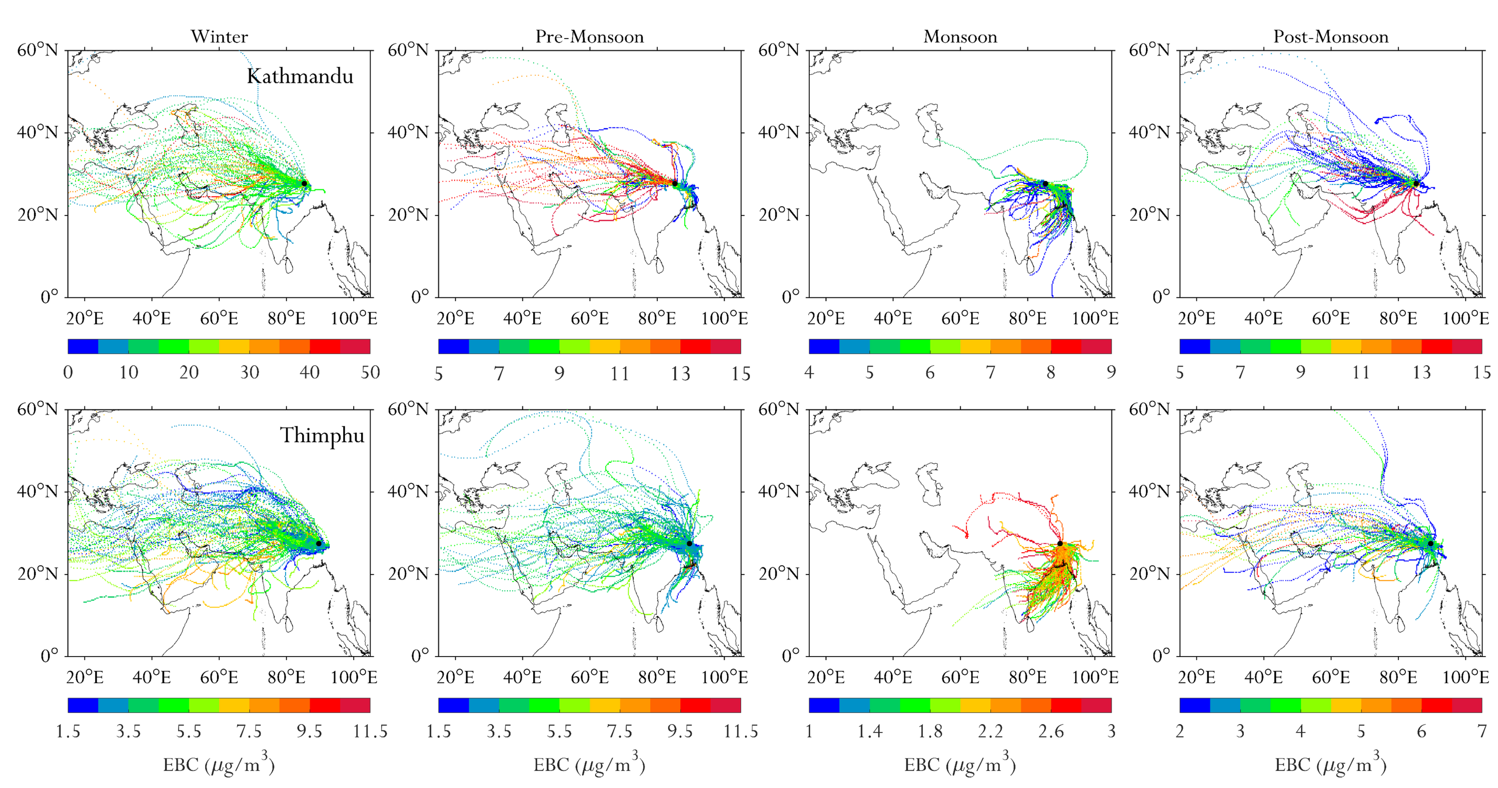
Daily variations in EBC values at Kathmandu and Thimphu



Monthly and seasonal variations in EBC values at both sites



Diurnal variations in EBC values at both sites



CWT analysis at both sites

Conclusions

- The mean daily EBC concentrations at Kathmandu and Thimphu were 9.8 ± 7.4 μg m^{-3}, and 3.3 ± 1.5 μg m^{-3}, respectively.
- Despite their location in the Himalaya, these two sites showed significant EBC concentrations.
- The high concentration of EBC in Kathmandu compared to Thimphu is mainly attributed to rapid and unplanned urbanization due to population growth, land-use changes, and socioeconomic transformation.
- The source apportionment analysis revealed 33.8% and 53.9% contribution of BB at Kathmandu and Thimphu, respectively.
- The CWT analyses showed that long-range transport dominated during winter at both sites, while transport from South Asia, along with local and regional pollutants, dominated during monsoon. In other seasons, local and regional emissions dominated along with long-range transported pollution.

References

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