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Molecular composition, optical properties, and radiative forcing of water-soluble brown carbon in seasonal snow samples from northern Xinjiang, China

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Water-soluble organic carbon (WSOC) and its brown carbon (BrC) components in the cryosphere have significant impact on the biogeochemistry cycling and snow/ice surface energy balance. In this study, snow samples were collected across regional area of northern Xinjiang, China to investigate the chemical composition, optical properties, and radiative forcing (*RF*) of WSOC. Based on the geographic differences and proximity of emission sources, the sampling sites were grouped as urban (U), remote (R), and soil-influenced (S) sites, for which WSOC concentrations were measured as 1968±953 ng g^{-1} (U), 885±328 ng g^{-1} (R), and 2082±1438 ng g^{-1} (S), respectively. The S sites showed the higher mass absorption coefficients at 365 nm (MAC_{365}) of 0.94±0.31 m^2 g^{-1} compared to those of U and R sites (0.39±0.11 m^2 g^{-1} and 0.38±0.12 m^2 g^{-1}, respectively). Molecular-level characterization of WSOC using high-resolution mass spectrometry (HRMS) provided further insights into chemical differences among samples. Specifically, much more reduced S-containing species with high degree of unsaturation and aromaticity were identified in U samples, suggesting an anthropogenic source. Aliphatic/proteins-like species showed highest contribution in R samples, indicating their biogenic origin. The WSOC components from S samples showed high oxygenation and saturation levels. The WSOC-induced *RF* were estimated as 0.04 to 0.59 W m^{-2}, which contribute up to 16% of that caused by BC, demonstrating the important influences of WSOC on the snow energy budget. Furthermore, the molecular composition and light-absorbing properties of BrC chromophores were unraveled by application of a high-performance liquid chromatography (HPLC) coupled to photodiode array (PDA) detector and HRMS. The chromophores were classified into five major types, i.e., (1) phenolic/lignin-derived compounds, (2) flavonoids, (3) nitroaromatics, (4) oxygenated aromatics, and (5) other chromophores. Identified chromophores account for ~23% – 64% of the total light absorption measured by the PDA detector in the wavelengths of 300 – 370 nm. In the representative U and R samples, oxygenated aromatics and nitroaromatics dominate the total absorbance. Phenolic/lignin-derived compounds are the most light-absorbing species in the S sample. Chromophores in two remote samples exhibit ultraviolet-visible features distinct from other samples, which are attributed to flavonoids. Identification of individual chromophores and quantitative analysis of their optical properties are helpful for elucidating the roles of BrC in snow radiative balance and photochemistry.