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Measurements of Mass Absorption Cross-Section of Flare-Generated Black Carbon and Climatic Implications

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Black carbon (BC) has long-been implicated as potentially the second-most important direct radiative forcer after carbon dioxide (e.g. Jacobson 2001). This notion is a consequence of BC's strong absorption over the visible spectrum in addition to the forward-scattering nature of combustion-generated BC (soot) aerosols. In climate science, a critical optical metric of BC aerosols is the mass-absorption cross-section (MAC), a spectral quantity that denotes an aerosol's propensity to absorb light per unit mass. Bond and Bergstrom (2006) showed that the simple forcing efficiency of an aerosol (a mass-based radiative forcing metric based on Chylek and Wong's (1995) forcing equation) is linearly related to its MAC. Many have performed measurements of MAC from atmospheric BC aerosols, with the literature including experimental and field measurements of fresh and aged BC aerosols from myriad sources. In their well-cited review, Bond and Bergstrom (2006) highlight the breadth of existing literature data, but suggest that a consistent value of BC MAC exists. Importantly however, the authors also suggest that BC MAC could vary for different combustion sources, and that investigations of BC optical properties from many combustion sources do not exist.

One important source of atmospheric BC is gas flaring, a ubiquitous practice in the oil and gas industry, where gases associated with production are deemed uneconomic to preserve for downstream processing and are disposed of in an open-atmosphere flame. With approximately 140 billion cubic metres flared annually (Elvidge et al. 2016), gas flaring admits an abundance of BC into earth's atmosphere. North of the Arctic circle, BC emissions from gas flaring dominate (Stohl et al. 2013) and, during winter months, BC from flaring-heavy regions in Russia is transported poleward, contributing to arctic haze and presumably reducing surface albedo through airborne and deposition effects. Flares, which are almost exclusively buoyancy-driven, turbulent, diffusion flames (BTDFs), are difficult to simulate in the laboratory, since gas compositions can be complex and relatively large burner diameters and flow rates are necessary to match combustion regimes. Consequently, measurements of BC MAC from flares or realistic flare surrogates are notably lacking, despite the critical above-noted climatic impacts of flare BC.

This work presents measurements of BC MAC from flares at Carleton University's Flare Facility (CUFF). Experiments of large BTDFs burning gas compositions representative of Alberta, Canada's upstream oil and gas industry are performed at CUFF. Simultaneous photoacoustic and thermal/optical analyses of diluted combustion products enable the direct computation of MAC at three wavelengths spanning the visible spectrum. Results are compared to the review of Bond and Bergstrom (2006) and climatic implications are discussed.