Enriched Brown Carbon and Rapid Aging in Wildfire Smoke Revealed by a Carbonaceous Aerosol Speciation Sampler (CASS)

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Black carbon (BC) and brown carbon (BrC) are primary short-lived climate forcers from wildland fires, yet their dynamic optical properties in urban air remain poorly constrained at high time resolution. A Carbonaceous Aerosol Speciation Sampler (CASS) was deployed at the UNLV air quality monitoring station to continuously quantify aerosol light absorption at seven wavelengths (370–950 nm) and total carbon (TC), enabling hourly resolution of BC, BrC, and non-absorbing white carbon (WtC). Hourly data from July 2025 through January 2026 are presented, with focus on the Gifford Fire smoke intrusion of August 3–16, 2025, which produced hazardous air quality conditions in Las Vegas.

Carbon mass apportionment used a spectral mass balance approach within the Hybrid Environmental Receptor Model (HERM), applying predefined BC and WtC profiles alongside unconstrained BrC profiles and a sensitivity-optimized WtC minimization constraint. Cluster analysis identified three regimes: summer wildfire smoke and aging, summer background, and winter episodes. During the wildfire period, aerosol transitioned from WtC- to BrC-dominated composition with absorption Ångström exponent (AAE) elevated well above unity. The BC fraction remained stable while BrC/BC ratios fluctuated on hourly timescales, consistent with intermittent smoke impact and rapid photobleaching, suggesting BrC-to-WtC conversion occurring within hours under summer photochemical conditions. Approximately 70% of hourly AAE_{BrC} values fell between 3 and 4, with mass absorption efficiency at 520 nm predominantly between 1 and 2 $m^2\ g^{-1}$.

This work represents the first application of the carbon apportionment model to hourly CASS data, resolving variable BrC content and optical properties across seasons and source regimes. Findings highlight the transient nature of wildfire BrC enrichment under high-insolation conditions, with implications for real-time aerosol radiative forcing estimates during wildfire events.