Attribution of Source Specific 370nm UV Light Absorption from Dust, Brown Carbon, and Black Carbon at Two Locations in the San Joaquin Valley.

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Abstract
Yearlong, one-in-three-day, source apportionment results were applied to literature values of source specific BrC, BC, and dust mass absorption cross-sections (MAC) to estimate the source contribution to 370 nm near-UV light absorption at Fresno and Bakersfield, San Joaquin Valley (SJV), California. The reconstructed light absorption agreed well (r² of 0.94 Fresno and 0.90 Bakersfield) with co-located AE33 aethalometer measurements. Near-UV absorption was attributed to total mobile, vegetative detritus, wood combustion, meat cooking, SOA and dust sources. Winter BrC absorption was dominated by wood combustion, accounting for 67% (Fresno) and 53% (Bakersfield) of light absorption at the sites. In summer, wood combustion only accounted for approximately 7% of the near-UV absorption in the SJV. Summer absorption, while significantly lower than winter values, was dominated by SOA and vehicle emissions. In Fresno, summer absorption was comprised of 35% SOA, 39% vehicle BC and 15% vehicle BrC. Bakersfield’s summer absorption was 27% SOA, 44% vehicle BC, and 14% Vehicle BrC. Total BrC absorption correlated well with OC concentrations, when segregated out by season, while the total BrC absorption was highly variable when compared to WSOC concentrations. The results indicate using source specific MAC values is an effective way to model near-UV light absorption associated with BrC sources and mitigation approaches that prioritize wood combustion in winter and vehicle emissions in summer would have the greatest effect in reducing near-UV light absorption in the SJV.

Keywords: Brown Carbon; UV Absorption, Source Apportionment, Vehicle Emissions, Biomass Burning.
1 INTRODUCTION

Fresno and Bakersfield are the two largest population centers in California’s San Joaquin Valley (SJV), with a total population exceeding 4 million people (U.S. Census Bureau, 2015). The region has a long history of air quality concerns, driven by human activity and geographical features that trap pollutants in the valley, characterized by extreme summer heat and relatively stagnant air flow in winter. These conditions lead to particulate matter (PM) concentrations that exceed the USEPA regulatory limits and have resulted in both Bakersfield and Fresno being assigned non-attainment status for fine particulate matter (PM$_{2.5}$) (United States Environmental Protection Agency 2023).

Thus, understanding regional air pollution sources and the associated physical and chemical characteristics is key to quantifying the risks to human health and its impact on climate, while offering policy makers and scientist the tools to develop mitigation strategies. The emissions in these communities are impacted by the major industry sectors that include agriculture and materials transportation, with Bakersfield having a significant petroleum extraction sector and Fresno having an important manufacturing sector (U.S. Bureau of Labor Statistics, 2022). Bakersfield is influenced by inversion conditions, where mountains surrounding the valley trap pollutants, especially during the winter when extensive stagnation periods occur (Whiteaker et al., 2002). For Fresno and other communities in the SJV, a break in California’s coastal range allows air pollution from the San Francisco Bay Area into the valley, air flow tends to travel from the northwest to the southwest while being highly influenced by complex topography and diurnal heating cycles,
leading to inversions and a regional atmospheric eddy that traps pollutants (Lin and Jao, 1995). While PM levels in the SJV are a concern, significant improvements have been observed in the last decade due to aggressive implementation of emission regulations (Henneman et al., 2021). For example, between 2004 to 2018, Southern California Air districts in the region saw PM$_{2.5}$ reduced by 31–51% in urban locations and by 12–35% in rural locations, while elemental carbon (EC) reductions of 28–45% were observed. Organic carbon (OC) reductions were smaller during this period, which resulted in an increase in the average OC/EC ratio from 4.8 in 2004 to 6.9 in 2018. It was speculated this was due to a larger contribution from wildfires and secondary organic carbon (SOC) sources as compared to the contribution changes of fossil fuel emissions (Ahangar et al., 2021). EC and OC aerosol light absorption are important contributors to global climate forcing. These components of PM can effectively absorb visible and near-UV light, altering the radiative balance, and result in significant atmospheric heating (Bond et al., 2013; Ma et al., 2020; Srivastava et al., 2020; Zhang et al., 2020a; Li et al., 2023). Thus, EC and OC concentration trends in the Valley indicate that light absorption characteristics by PM are evolving and the contribution of EC to light absorbing carbonaceous aerosol (LAC) will be reduced, while the relative contribution to absorption by organic species will become more significant. In addition, EC and OC, components of fossil fuel and biomass combustion emissions, have been shown to be linked to negative health outcomes (Alves et al., 2015; Chen et al., 2017; Magalhaes et al., 2018; Song et al., 2022).
In order to understand and mitigate light absorption impacts associated with PM, improved understanding of source-specific light absorption is necessary, resulting in improved modelling and interpretation of observations. Organic carbon components of PM that effectively absorb light in the near-UV visible spectrum are referred to as brown carbon (BrC) (Du et al., 2014; Yan et al., 2014; Zeng et al., 2021; Li et al., 2023). EC and black carbon (BC) are carbonaceous components of PM that are from the incomplete combustion and pyrolysis of fossil and biomass fuels. These species, which strongly absorb light across the entire visible spectrum, are operationally defined by their analytical quantification methods: typically thermal/optically for EC, and light absorption quantification properties (e.g. change in attenuation, photoacoustic effect, incandescence signals) for BC (Bond and Bergstrom, 2006; Olson et al., 2015; Briggs and Long, 2016; Zhao et al., 2021).

While BC light absorption properties are generally better understood and constrained by the findings of extensive research, BrC’s impact is much more complex (Bond et al., 2013). BrC optical properties are variable across source and chemical composition, making it difficult to quantify the impact to atmospheric light absorption and identify the major sources driving these impacts. Recent studies have assigned BrC absorption to source emissions; however, these studies often are limited by the number of sources, the observational time periods, and the difficulty of segregating the impact of BC relative to BrC. (Chen et al., 2020; Zhang et al., 2020b; Zhang et al., 2021; Yuan et al., 2022). There is a long history of studies that have shown the relationship between BrC and biomass burning (Chen and Bond, 2010; Gadhavi and Jayaraman, 2010; Lack et al., 2012; Lack et
al., 2013; Srinivas and Sarin, 2013; Cai et al., 2014; Saleh et al., 2014; Alves et al., 2015; Forrister et al., 2015; Hettiyadura et al., 2021), However, recent studies have shown other sources, such as vehicle traffic, coal combustion, and secondary organic aerosol (SOA) can be important BrC contributors, especially when biomass burning emissions are not a significant source in the airshed (Yan et al., 2017; Kasthuriarachchi et al., 2020b; Olson et al., 2021; Liu et al., 2022).

BC and aerosol impacts are key components to climate models. However, BrC has been problematic to accurately incorporate into these models, which has led to a range of estimates of BrC radiative forcing of 0.03–0.57 W m\(^{-2}\) (Saleh, 2020; Li et al., 2023). Including BrC in climate models has been shown to have significant impacts on cloud fraction, liquid water path, precipitation, and surface flux (Li et al., 2023). Thus, improving methods to better estimate source-specific contribution of BrC to light absorption can help improve the model results. In recent years, as source-specific BrC mass absorption cross-sections (MAC) have been reported in the literature, the ability to reconstruct light absorption by BrC in the near-UV has become an effective approach to estimate the complex and variable nature of BrC absorption (Olson et al., 2021; Liu et al., 2022; Dey et al., 2023).

In this study we apply literature values of BrC MACs to yearlong source apportionment results in the SJV. The reconstructed absorption, which includes BrC, BC, and dust contributions at 370nm wavelength agree well with values measured independently using an aethalometer. The results allow estimation of light absorption when biomass burning emissions were not the dominant
contribution to OC mass, allowing improved estimates of near-UV absorption from sources such as vehicle emissions, SOA, and dust.

2 METHODS

2.1 Sample Collection:

Sample collection and site description are detailed in previous publications (Skiles et al., 2018; Bae et al., 2019). Two hundred sixty-three PM$_{2.5}$ 24-hour integrated samples were collected on the US EPA’s national sampling 1-in-3 day schedule posted on the EPA’s AMTIC website. The Fresno, California (36.78538° N, -119.77321° W) site is located in a mixed commercial residential neighborhood, approximately 1 kilometer away from the nearest freeway. The Bakersfield, California (35.35662° N, -119.06261° W) site is located in a commercial district that includes a number of nearby restaurants, a major freeway and petroleum storage/processing facility are located approximately 1.75 km away from the sample site. Sample collection occurred from January 2015 through February 2016. PM$_{2.5}$ samples were collected on pre-baked 90-mm quartz-fiber filters (Pall Gellman, Ann Arbor, MI) using medium volume filter samplers (URG-3000B URG, Chapel Hill, NC) from midnight-to-midnight local Pacific Time. Sample flows were checked before and after the sample collection period, and flow meters were calibrated quarterly on site using a dry-gas flow meter.

2.2 Chemical Analysis
Chemical analysis and quality assurance discussions are detailed in previous publications (Skiles et al., 2018; Bae et al., 2019). EC, OC, water soluble OC (WSOC), and organic molecular markers were analyzed at the UW-Madison Water Science Engineering Laboratory and the Wisconsin State Laboratory of Hygiene in Madison, Wisconsin. Crustal elements (by energy dispersive X-ray fluorescence) and water soluble ions (by ion chromatography) results were obtained from co-located US EPA Chemical Speciation Network (CSN) data, obtained from the California Air Resources Board (Solomon et al., 2014). Dust mass was calculated as the sum of major crustal elemental oxides, including metal oxides of Si, Al, Fe, Mg, Ti, Ca, and water-insoluble K (Stone et al., 2009; Cheung et al., 2012).

A 1.0 cm\(^2\) punch was analyzed for EC/OC using the modified NIOSH 5040 protocol with a thermal-optical EC/OC analyzer (UW-TOT, Sunset Labs, Tigard, OR) (Schauer et al., 2003). Half-sections of the quartz filters were analyzed by gas chromatography mass spectrometry (GCMS) for organic molecular markers (Sheesley et al., 2007; Heo et al., 2013). Samples were extracted by Soxhlet in a 50:50 methylene chloride (DCM)/acetone mixture, recoveries were evaluated with isotopically labeled standards, and results were blank subtracted for use in the source apportionment model. The GCMS spike recoveries and detection limits for individual organic tracers are listed in the Supplemental Materials of Skiles et al., 2018.

### 2.3 Absorption Measurements
During the sampling campaign co-located aethalometers (AE33, Aerosol Magee Scientific Berkeley, CA) were operated at both Fresno and Bakersfield from November 2015 through February 2016 and from February 2015 through December 2015, respectively. The AE33 were operated in dual-spot mode which allows linear correction for filter tape loading (Drinovec et al., 2014). The AE33 performs real-time scattering and loading correction, with scattering correction based on the manufacturer’s suggested scattering correction value identified as Cref. Filter based Cref values have ranged from 2.8–4.1 in the literature (Kim et al., 2019; Yus-Diez et al., 2021). Olson et al. (2021) used a Cref equivalent to 3.85 for Magee Scientific AE31 results, while recently a Cref = 2.57 was recommended for AE33 results from the derivation of PM10 dust results (Drinovec et al., 2020). In this research we applied a Cref of 3.0, as a reasonable compromise of AE33 scattering correction and MAC values previously reported based on AE31 scattering correction assumptions. Scattering correction was not the focus of this study, but it should be noted the applied Cref has a linear impact to the quantified light absorption by the AE33, as applied in this research, when comparing reconstructed absorption to measured results (Supplemental Materials – Fig. S1). The value of 3.0 was deemed reasonable, as we would expect PM2.5 scattering correction to be slightly larger than that of PM10 and less than values reported for the AE31 filter tape scattering corrections. In parallel with the scattering correction, the wavelength-specific BC concentrations (BC_\lambda, ng m^{-3}, \lambda = AE33 channel wavelength in nm), as reported by the AE33, were converted to absorption coefficients (\sigma_\lambda, Mm^{-1}) by multiplying the
BC$_{\lambda}$ by the AE33 specific attenuation ($\alpha_{\lambda}$, values of $\alpha_{370} = 18.47$ m$^2$ g$^{-1}$ and $\alpha_{880} = 7.77$ m$^2$ g$^{-1}$)

and dividing by 1000.

### 2.4 Source apportionment:

Chemical Mass Balance (CMB, EPA-CMB8.2) model source apportionment results, including intercomparison with an independently run Positive Matrix Factorization (PMF, EPA-PMF5.0) source apportionment, are detailed in previous publications (Skiles et al., 2018; Bae et al., 2019).

Sample concentrations and source profiles of select organic tracers, EC, and OC, with associated uncertainty values, were input in the CMB model. Through a series of sensitivity analyses, five major source categories were determined to best represent the carbonaceous source contribution at the two locations:

- **Total Mobile Sources** – Characterized by heavy poly-aromatic hydrocarbons (PAH) for gasoline vehicle emissions, hopanes for smoking vehicle emissions, and EC for diesel emissions. Due to observed co-linearity for diesel, gasoline, and smoking vehicles, a single mobile source was identified that combined each of these emission contributors.

- **Vegetative Detritus** – A very minor source characterized by odd-alkanes; monthly average source contributions did not exceed 0.2 $\mu$g m$^{-3}$. 
• Wood Combustion – Characterized by levoglucosan, a product of cellulose pyrolysis; observations were associated with extreme wintertime pollution events and were generally more prevalent at the Fresno location than at the Bakersfield site.

• Meat Cooking – Characterized by cholesterol as a molecular marker; its contribution was seasonal, with the highest apportioned OC mass occurring between October and February. In summer it is likely that portions of meat cooking emissions at the two sites were oxidized and categorized as unapportioned mass by the CMB model.

• CMB Other – Characterized residual OC mass not apportioned to the previous source categories and represents SOA. This was corroborated through a strong correlation between SOA identified by PMF and non-biomass WSOC results (Bae et al., 2019).

2.5 Absorption Attribution:

For aethalometer data, the BrC contribution to near UV-light absorption was determined by calculating the difference between total light absorption and the light absorption associated with BC at 370 nm wavelength (Kirchstetter et al., 2004; Lack and Langridge, 2013; Olson et al., 2015; Martinsson et al., 2017; Olson et al., 2021). Applying the difference method, non-BC absorption is determined by projecting the corrected AE33 $\sigma_{880}$ to 370 nm wavelength using an aerosol Angstrom exponent (AAE) of 1 and subtracting the projected BC absorption contribution value from the corrected total AE33 $\sigma_{370}$ value. A range of AAE values (0.7 to 1.4 or higher) have been reported
for BC estimation across the visible spectrum, due to particle morphology and mixing state; however, an AAE of 1 is the generally accepted value for pure BC aerosols, and was therefore applied to the AE33 data to segregate the BC absorption from total bulk absorption at 370 nm (Moosmueller et al., 2011; Zhang et al., 2020c). (Olson et al., 2021) discusses the sensitivity of the AAE = 1 assumption when applying this method to BrC attribution; see supplemental materials for a brief summary of the calculation with the associated equations. A number of studies have assumed a BC AAE = 1 and biomass burning AAE = 2 (or near 2) and used these projections to estimate the difference between fossil fuel BC and SOA absorption contribution relative to biomass burning BrC absorption (Martinsson et al., 2017; Kaskaoutis et al., 2021). In this study we apply an AAE of 1 to measured BC specifically, segregate this projected component from the total corrected 370 nm absorption, and compare these segregated components to the sum of all the CMB sources near-UV light absorption. Additionally, by subtracting the dust absorption, the BrC only contribution to near-UV absorption can be compared to OC source apportioned concentrations.

The reconstructed light absorption was calculated by multiplying source apportioned OC, total EC, and dust by the literature values of MAC$_{\text{370}}$ for these sources. The following MACs were used to estimate each sources light absorption at 370 nm wavelength.

A single BC MAC value was applied to the total EC measured; detailed discussion of the EC apportionment is described in (Skiles et al., 2018; Bae et al., 2019). Apportioned EC was mostly associated with total mobile sources, with a small fraction associated with wood combustion and
the vegetative detritus source. A MAC$_{EC, 370} = 10.5$ m$^2$ g$^{-1}$ was used to estimate the BC contribution to near-UV absorption. The MAC$_{EC, 370}$ was calculated using an AAE = 1 in the power law equation where the reference absorption at 520nm wavelength was MAC$_{EC, 520} = 7.5$ m$^2$ g$^{-1}$ (Bond and Bergstrom, 2006; Olson et al., 2015).

A single dust MAC value was applied to the total dust concentration calculated based on the major crustal element oxides. A MAC$_{Dust, 370} = 0.24 \pm 0.01$ m$^2$ g$^{-1}$ at 370 nm was used to estimate the dust’s contribution to near-UV absorption (Drinovec et al., 2020).

The selection of source-specific MAC values applied to estimate BrC absorption at 370 nm wavelength are detailed in (Olson et al., 2021). The following source BrC MACs were used in this study; values not previously described by Olson are briefly expanded upon. These literature MAC values were primarily quantified via bulk OC quantification methods, such as the Aethalometer, however, vegetative detritus and mobile source MACs were determined by UV-Vis absorption measurements of water soluble and methanol extracted OC fractions, respectively. Total mobile source MAC$_{Mobile, BrC} = 1.1 \pm 0.67$ m$^2$ g$^{-1}$, which was a higher winter value reported by (Xie et al., 2017). The vegetative detritus source MAC$_{Veg, BrC} = 0.33 \pm 0.17$ m$^2$ g$^{-1}$ reported by (Hassouna et al., 2012), was based on extractable organics dominated by plant materials in soil. Wood Combustion source MAC$_{Wood, BrC} = 5.5 \pm 1.21$ m$^2$ g$^{-1}$ reported by (Kumar et al., 2018), a value that is higher than the MAC previously used by Olson et al. for wood smoke absorption (MAC$_{Biomass, BrC} = 1.16 \pm 0.10$ m$^2$ g$^{-1}$). The meat cooking source MAC$_{Meat, BrC} = 0.03$ m$^2$ g$^{-1}$ was derived from
(Cheng et al., 2022), where 29% of absorption from meat cooking at 370 nm was from BrC. Based on this observation we estimated the MAC$_{\text{Meat, BrC}}$ using unpublished meat cooking OC/EC ratio of 143:1. This estimate is speculative, however, due to the low OC mass apportioned to meat and the low absorption associated with meat cooking emissions, the uncertainty does not impact the study results. The CMB other (SOA) source MAC$_{\text{SOA, BrC}} = 0.67 \pm 0.23 \text{ m}^2 \text{ g}^{-1}$ was reported by (Kasthuriarachchi et al., 2020a) based on SOA associated with Less Oxidized – Oxidized Organic Aerosols (LO-OOA) measured with an Aerodyne Research SP-AMS. A discussion on sensitivities to MAC value uncertainties is available in (Olson et al., 2021).

3 RESULTS AND DISCUSSION

A yearlong CMB source apportionment study using organic molecular markers showed the strong seasonality of OC mass apportionment. In both Bakersfield and Fresno wintertime OC was dominated by biomass burning and meat cooking, while summer OC was dominated by a source identified as CMB-Other which was interpreted to be SOA. The contribution of carbonaceous aerosols by total vehicle sources was generally constant throughout the year at both locations. Given these results, it is possible to estimate the BrC light absorption contribution, including at times when biomass burning is not a significant source of carbonaceous aerosols. Using literature MAC values for sources and the apportioned OC, EC and dust, we can quantify the light absorption in the near-UV for individual days. Figure 1 shows a comparison of the daily average corrected
AE33 near-UV absorption to reconstructed light absorption using MAC values applied to daily CMB results for dust and the 5 sources that contributed to BrC and BC absorption. Both locations show strong agreement between reconstructed and measured absorption, with slopes of 0.97 and 0.81 and $r^2$ of 0.94 and 0.90, for Fresno and Bakersfield respectively. A number of factors could account for differences between measurements, including the uncertainty of MACs applied to the apportioned mass and scattering correction ($C_{ref}$) used by the AE33 and literature-based values we applied to apportioned mass. Even so, the agreement shows that reconstructed absorption predicts measured absorption well, even over significant seasonal changes in source contribution.

Using the MACs described previously, one-in-three day near-UV light absorption can be determined for each of the CMB sources identified. Figure 2 shows the near-UV light absorption for Fresno and Bakersfield in 2015. On a daily basis BC is a consistent contributor to light absorption, which in the SJV is almost exclusively from vehicle emissions throughout the year, with biomass burning contributing to BC in winter months. Additionally, vehicle BrC absorption remains consistent throughout the year. Thus, the near-UV absorption from vehicles is generally the major LAC source throughout the year. However, in winter, wood combustion leads to extreme light absorption events. This is due to both the high concentration of wood combustion emissions and the strong light absorption characteristics of wood smoke PM. Finally, in summer SOA is often the largest contributor to BrC light absorption, especially in the late summer months. Light absorption due to vehicles, SOA, and dust ranged from 5 to 15 Mm$^{-1}$ in both Fresno and Bakersfield.
in summer. Wood combustion BrC was greater in Fresno in winter compared to Bakersfield: while Fresno often had wood combustion BrC absorption exceeding 30 Mm$^{-1}$, in Bakersfield, wood combustion BrC absorption rarely exceeded 20 Mm$^{-1}$. This difference is likely due to greater wood burning in Fresno, which saw slightly lower average wintertime temperatures, and wintertime inversions trapping both local and regionally transported emissions (Skiles et al., 2018). BC absorption at both locations weakly correlated ($r^2 = 0.58$), where Bakersfield had approximately 20% higher average BC compared to Fresno. This indicates that BC is influenced by local sources (i.e., not regionally uniform), and Bakersfield is more influenced by vehicle emissions than Fresno, which corresponds to the observation that Bakersfield had greater BC absorption compared to Fresno (Supplemental Materials – Fig. S3).

Fresno had greater overall BrC absorption than Bakersfield. The two locations correlated more strongly than observed with BC, supports the assumption that BrC is more impacted by regional sources, SOA and wood combustion. The overall absorption was approximately 30% greater in Fresno than Bakersfield (Supplemental Materials – Fig. S2). The ratio of WSOC to OC remained relatively consistent across the year, the WSOC tended to be higher when the SOA source was the largest contributor to OC mass (Supplemental Materials - Fig. S4). However, when the wood combustion source was a dominant contributor to OC mass, the 370 nm absorption was the highest, though that did not always relate to a corresponding increase in WSOC concentration (Supplemental materials – Fig. S5). This can be observed in the higher influence of WSOC on BrC
light absorption at Fresno compared to Bakersfield, in which Fresno had greater BrC absorption from wood combustion of the two locations (Figure 3). While there is a strong trend between WSOC and BrC absorption, the results show a high degree of variability, indicating that the BrC absorption can be highly variable compared to WSOC levels, especially for wood combustion.

Applying source specific MACs to source apportionment results enables prediction of near-UV absorption – and the results show a strong seasonal impact on near-UV light absorption. Figure 4 shows BrC absorption versus the measured OC for both sites, segregated by season (Spring ⇒ Mar, Apr, May; Summer ⇒ Jun, Jul, Aug; Fall ⇒ Sep, Oct, Nov; Winter ⇒ Dec, Jan Feb). Thus, the slope of the line represents the bulk seasonal 370 nm BrC MACs in the SJV. The slopes indicate the MAC_{BrC,bulk, season} are variable, but are similar at each location when considering outliers. In Spring, the slope for Fresno is influenced by two outliers, otherwise the BrC absorption agrees well with that in Bakersfield, which has a MAC_{BrC,bulk, Spring} slope of 1.3 m^2 g^{-1} with an r^2 = 0.75. In summer, Bakersfield data has a single outlier, but otherwise shows good agreement with the Fresno MAC_{BrC,bulk, Summer} slope of 0.83 m^2 g^{-1} (r^2 = 0.97). The relationship in the fall is similar at both locations, with an average slope MAC_{BrC,bulk, fall} of 2.79 m^2 g^{-1} (r^2 = 0.66 and 0.72). Fall BrC in SJV is influenced by both elevated SOA and woodsmoke. Finally, both locations showed the strongest winter BrC absorption, with similar magnitude. A reasonable estimate of MAC_{BrC,bulk, winter} of 2.85 m^2 g^{-1} (r2 = 0.59 and 0.78) could be applied to quantify the SJV BrC 370 nm light absorption. In
addition, these seasonal bulk MACs could be applied to corrected AE33 absorption measurements to estimate seasonal OC contribution to PM mass.

The seasonal relative contribution to near-UV light absorption is highlighted in Figure 5 (the average absorption coefficients and standard error is reported in Supplemental Materials - Table S1). In winter near-UV absorption was dominated by wood combustion, accounting for 67% and 52% in Fresno and Bakersfield respectively; however, in summer only 7% of the absorption was attributed to wood combustion. Summer absorption was dominated by SOA BrC and BC primarily associated with vehicle emissions (combined 74% in Fresno and 72% in Bakersfield). Additionally, total vehicle BrC was an important summertime light absorption source, with 15% and 14% in Fresno and Bakersfield respectively. This leads to vehicle BrC and BC combined contributing to more than ~50% of the summer near-UV absorption in the SJV. Springtime distribution of light absorption was similar for both locations, with Fresno having higher wood combustion BrC absorption (34%) compared to Bakersfield (19%). Fall contributions again were very similar between the locations, with Bakersfield being more influenced by BC absorption. Dust was a small but quantifiable source of near-UV light absorption at both locations ranging from 2 to 7% at the sites in spring, summer, and fall, while in winter there was no quantifiable dust absorption. These results indicate the importance of light absorption from vehicles and SOA in summer in the SJV, while winter absorption is dominated by wood combustion sources.
4 CONCLUSIONS

Source-specific MACs for BrC, BC and dust can be applied to traditional source apportionment results to accurately predict near-UV light absorption in the SJV. This indicates that these MAC values could be implemented in climate models that utilize emission inventories in order to reduce the uncertainty of near-UV light absorption estimated from PM emissions. The results of this study showed near-UV absorption is highly seasonal, with wood combustion emissions being the major source of BrC absorption in winter, but vehicle emissions and SOA are the most important source of absorption in summer. This seasonality shows that different mitigation approaches would need to be implemented to reduce near-UV absorption throughout the year. While reduction of BrC from wood combustion would have the greatest winter seasonal reduction, the underlying vehicle BrC and BC components would still be an important contributor, especially because these vehicle emissions in have a larger impact in summer. Thus, there is value in implementing policies that reduce PM emissions from vehicles as a method to reduce climate forcing associated with near-UV light absorption. The following key findings of source specific near-UV absorption in the SJV were identified:

- Wood combustion sources dominated in winter months, with absorption coefficients in Fresno often exceeding 30 Mm⁻¹, while Bakersfield showed absorption values generally lower, near 20 Mm⁻¹.
Summer near-UV absorption due to vehicles, SOA, and dust ranged from 5 to 15 Mm\(^{-1}\) in both Fresno and Bakersfield, with little contribution from wood combustion BrC.

Winter BrC absorption was dominated by wood combustion, accounting for 67% (Fresno) and 53% (Bakersfield), while in summer, wood combustion only accounted for approximately 7% of the near-UV absorption.

Summer absorption was dominated by SOA and vehicle emissions. In Fresno it was comprised of SOA (35%), vehicle BC (39%), and vehicle BrC (15%); in Bakersfield absorption was due to SOA (27%), vehicle BC (44%), and vehicle BrC (14%).

Additionally, the relationship between OC and BrC absorption is related to source contribution and seasonality, while WSOC absorption relationships show more variability, making it difficult to predict absorption outcome based solely on WSOC. The findings show that source apportionment results are an important tool for understanding PM light absorption and there is significant value to having improved multiwavelength MACs from a diverse and representative set of emissions sources.

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**DISCLAIMER**

The views, opinions, and findings contained in this report are those of the author(s) and do not represent a position of policy of the California Air Resources Board.
Figure 1 Reconstructed 370 nm light absorption using carbonaceous aerosol source apportionment results and with source specific MACs compared to co-located aethalometer derived light absorption.
Figure 2 Near UV light absorption apportioned to sources in Fresno (top) and Bakersfield (bottom). Wood combustion is the dominant source of BrC absorption in winter months, while in summer, CMB other (SOA) and mobile sources are the primary contributor of BrC light absorption. Blank spaces indicate filter-based appointment result were not available due to missed sample day or QA/QC criteria.
Figure 3 (Top) Trend in BC and BrC absorption between the two SJV locations, Bakersfield is more influenced by BC while Fresno had higher BrC contributions to absorption. (Bottom) Both locations show similar increases in BrC with WSOC concentrations, however Fresno was more influenced by wood combustion than Bakersfield. The amount of light absorption was highly variable with increases in WSOC.
Figure 4 Seasonal BrC absorption vs OC concentration at Fresno and Bakersfield. The slope represents the bulk BrC MAC for each season.
Figure 5 The seasonal source contribution to near-UV light absorption in Fresno (Top) and Bakersfield (Bottom).
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