Chapter 5. Seasonal Distribution of Reconstructed Aerosol Light Extinction Coefficients

Regional, monthly, and annual mean ambient speciated b_{ext} for 2016–2019 were calculated for major aerosol species including ammonium sulfate (AS), ammonium nitrate (AN), particulate organic matter (POM), elemental carbon (EC), fine dust (FD), sea salt (SS), and coarse mass (CM). Regional mean b_{ext} values were calculated for the IMPROVE and Chemical Speciation Network (CSN) regions discussed in Chapter 3. CM was not interpolated at CSN sites in Alaska and Hawaii, so b_{ext_CM} is not available in those regions nor are speciated fractional contributions to b_{ext_aer}. Monthly and annual mean b_{ext} values are presented as stacked bar charts, similar to the regional mean mass concentrations presented in the Chapter 3. For nonhygroscopic species, the seasonality of b_{ext} was the same as the seasonality in mass concentrations. Monthly mean b_{ext} values are depicted with the first letter of the month, followed by an “A” for annual mean. The seasonal distributions in fractional contribution of major aerosol species to aerosol b_{ext} (b_{ext_aer}, the sum of speciated b_{ext}) are also presented. Seasonal stacked bar charts for monthly mean b_{ext} are grouped into figures corresponding to three areas of the country: eastern, northwestern, and southwestern United States.

5.1 $PM_{2.5}$ AMMONIUM SULFATE LIGHT EXTINCTION COEFFICIENTS

5.1.1 IMPROVE

Ambient reconstructed extinction coefficients from AS, b_{ext_AS}, were computed using a dry extinction efficiency of 3 $m^2\,g^{-1}$ and a humidification factor (f(RH)) to account for hygroscopic effects (see Chapter 4). The patterns in b_{ext_AS} may closely resemble AS mass concentration patterns, but differences will arise due to hygroscopic effects. The IMPROVE 2016–2019 regional monthly mean rural b_{ext_AS} ranged from 1.08 Mm^{-1} in the Great Basin region in January to 23.41 Mm^{-1} in the Hawaii region in March and 24.51 Mm^{-1} in the Ohio River Valley region in July. Recall that the maximum AS regional monthly mean mass concentration also occurred in the Ohio River Valley region in July (Chapter 3 and Figure 3.1.1). Many of the eastern IMPROVE regions corresponded to high b_{ext_AS} in summer, but values were highest (>18 Mm^{-1}) in the Appalachia, Midsouth, Southeast, and Ohio River Valley regions (Figure 5.1.1). In the Northeast and Southeast regions, b_{ext_AS} values were lower (10–20 Mm^{-1}), as were values toward the central United States, such as the Central Great Plains region. Regardless of the magnitude of b_{ext_AS}, it peaked in the summer in most eastern regions.

In the northwestern United States, the maximum b_{ext_AS} occurred in the Columbia River Gorge region in January (12.70 Mm^{-1}; Figure 5.1.2). With the exception of the winter maximum in the Columbia River Gorge, other regions experienced maximum monthly mean values in spring months (Northern Great Plains, Northern Rockies, and Hells Canyon) or during summer months (Northwest, Oregon/Northern California, Alaska). The lowest maximum monthly mean values occurred in the Hells Canyon, Northern Rockies, and Oregon/Northern California ($\leq$5 Mm^{-1}). The minimum monthly mean b_{ext_AS} occurred in the Northern Rockies region (1.59 Mm^{-1}) and the Oregon/Northern California region (1.54 Mm^{-1}), both in January. The largest minimum monthly mean b_{ext_AS} occurred in the Columbia River Gorge region (4.66 Mm^{-1}) in June.

Most of the regions in the southwestern United States experienced maximum monthly mean b_{ext_AS} in summer or early fall (Figure 5.1.3). The Hawaii region experienced the highest monthly mean maximum b_{ext_AS} (23.41 Mm^{-1}) in March, followed by the West Texas region (11.26 Mm^{-1}) in September, and the California Coast and Southern California regions (~9 Mm^{-1}), both in July. The lowest maximum monthly mean b_{ext_AS} occurred in the Great Basin region (2.66 Mm^{-1}) in May. The minimum monthly mean b_{ext_AS} occurred during winter months for all of the regions in the southwestern United States. The lowest occurred in the Great Basin region in January (1.08 Mm^{-1}), and the largest minimum occurred in the Hawaii region (5.22 Mm^{-1}) in December.

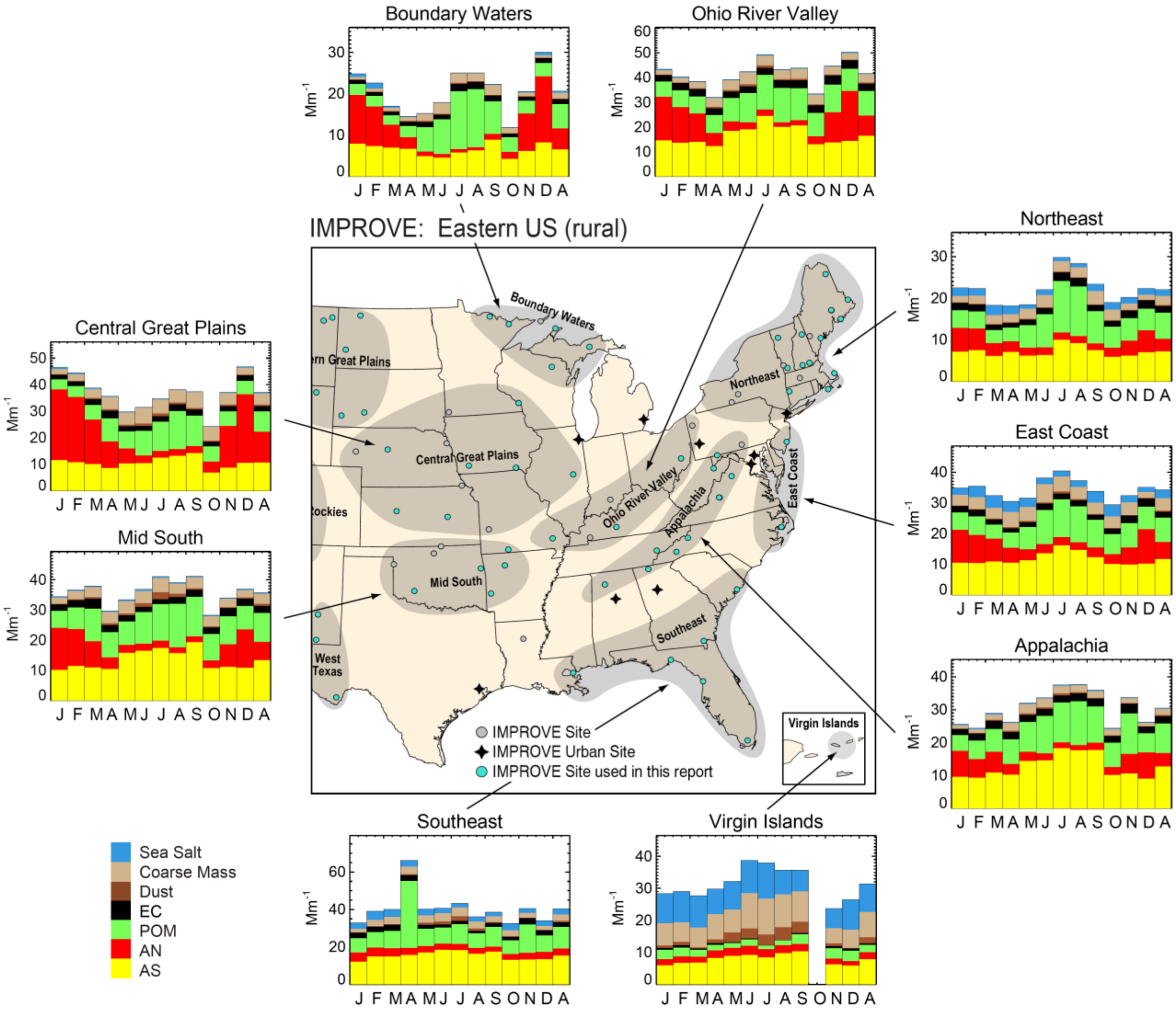

Figure 5.1.1. IMPROVE 2016–2019 regional monthly mean ambient reconstructed speciated aerosol light extinction coefficients (Mm^{-1}) for the eastern United States. Letters on the x-axis correspond to the month and "A" corresponds to annual mean. Shaded areas in the map correspond to regions that include sites used in the analysis, shown as blue dots. Wavelength corresponds to 550 nm.

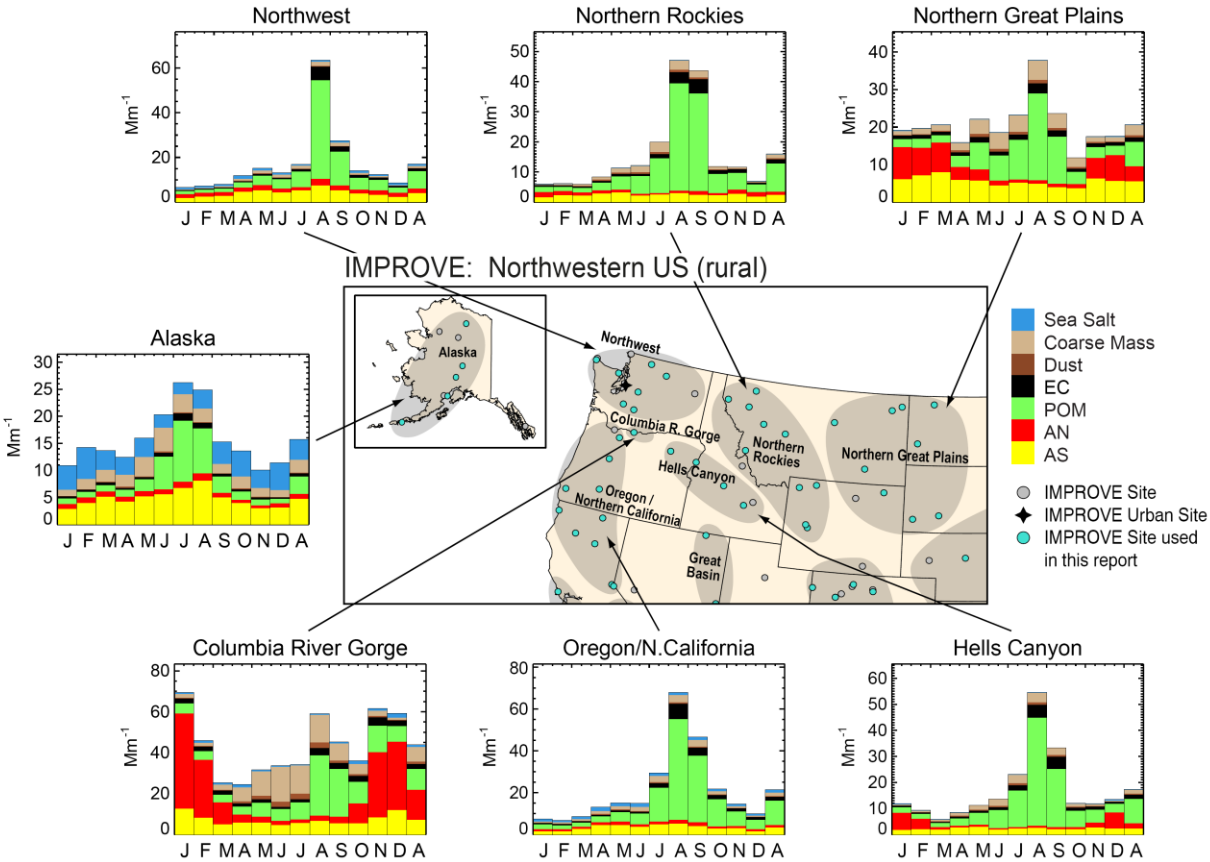

Figure 5.1.2. IMPROVE 2016–2019 regional monthly mean ambient reconstructed speciated aerosol light extinction coefficients (Mm^{-1}) for the northwestern United States. Letters on the x-axis correspond to the month and "A" corresponds to annual mean. Shaded areas in the map correspond to regions that include sites used in the analysis, shown as blue dots. Wavelength corresponds to 550 nm.

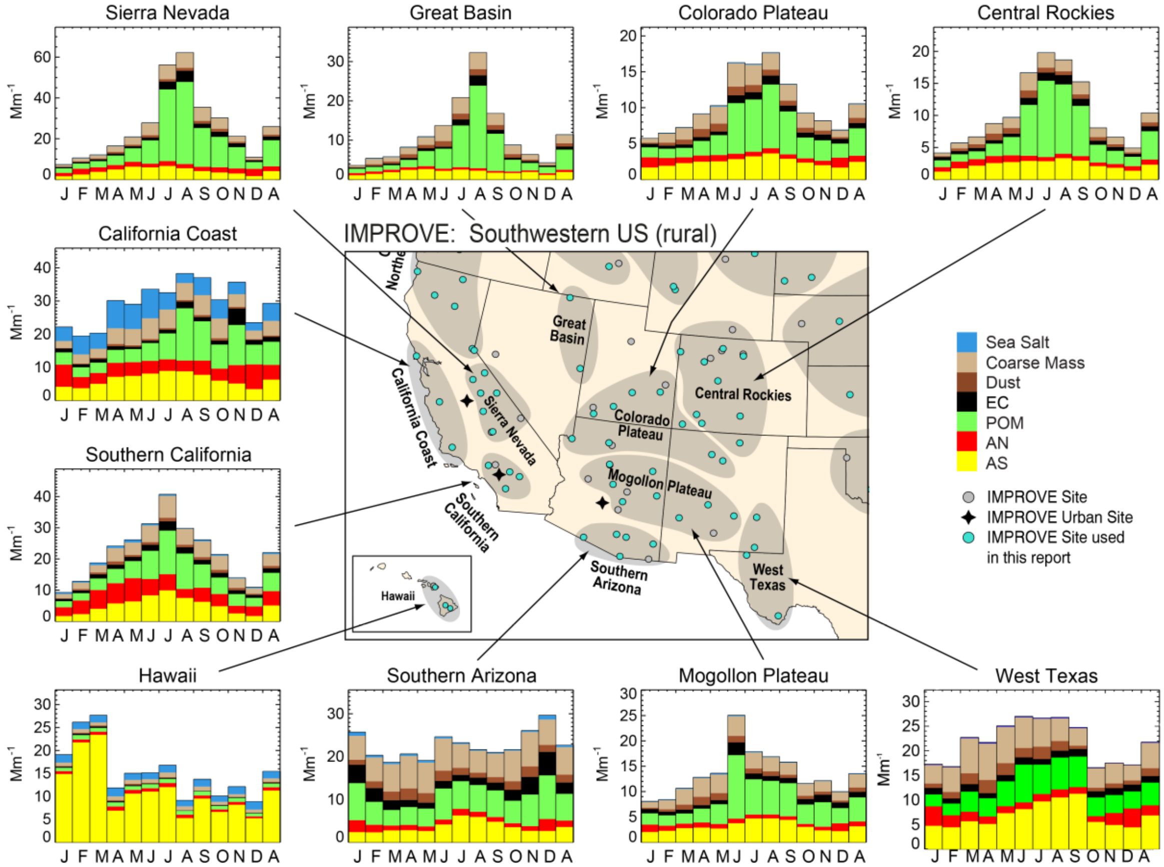

Figure 5.1.3. IMPROVE 2016–2019 regional monthly mean ambient reconstructed speciated aerosol light extinction coefficients (Mm^{-1}) for the southwestern United States. Letters on the x-axis correspond to the month and "A" corresponds to annual mean. Shaded areas in the map correspond to regions that include sites used in the analysis, shown as blue dots. Wavelength corresponds to 550 nm.

The IMPROVE fractional contribution of b_{ext_AS} to b_{ext_aer} ranged from 0.047 in the Hells Canyon region in August to 0.846 in Hawaii in March. The maximum fractions in continental U.S. (CONUS) regions were 0.498 in the Ohio River Valley region in July and 0.496 in the Appalachia region in September. Other regions in the eastern United States corresponded to maximum monthly mean fractions around 0.4–0.45 that occurred mostly during summer and early fall months (Figure 5.1.4). Fractions in the Midsouth, Northeast, and Boundary Waters regions peaked during spring months. The seasonal pattern in the Boundary Waters region differed from other regions with lower fractions in summer months, likely due to the contributions from b_{ext_POM}. The lowest monthly mean maximum contribution in the eastern United States occurred in the Virgin Islands region in September (0.292). The lowest minimum monthly mean mass fraction also occurred in the Virgin Islands region in January (0.212). The minimum fractional contribution of b_{ext_AS} in other regions was round 0.3 and typically occurred in winter months, except in the Northeast region in June, the Boundary Waters region in July, and the Midsouth and Southeast regions in spring months.

The seasonality of the fractional contribution of b_{ext_AS} to b_{ext_aer} in regions in the northwestern United States differed from that observed for eastern regions, with minima in b_{ext_AS} contributions in summer months, largely due to the strong contributions from b_{ext_POM} during summer (Figure 5.1.5). The fractional contribution ranged from 0.056 (Northern Rockies region in September) and 0.076 (Oregon/Northern California in August) to 0.392 in the Northwest (April) and 0.389 in the Northern Great Plains in March. The lowest maximum monthly mean contribution occurred in the Hells Canyon region (0.329) in March.

The seasonality of the fractional contribution of b_{ext_AS} to b_{ext_aer} in regions farther north in the southwestern United States followed those of the northwestern region, with lower contributions that occurred in the summer months due to the role of b_{ext_POM} contributions (Figure 5.1.6). Contributions of b_{ext_AS} in regions farther south tended to have flat seasonality, or summer/early fall maxima. The minimum monthly mean fractional contributions were 0.070 in the Great Basin region (August) and 0.089 in both the Sierra Nevada region (August) and the Southern Arizona region (December). The maximum contribution occurred in the Hawaii region in March (0.846) and in the West Texas region in September (0.455). Maximum contributions in other regions were around 0.3 and occurred either during spring months or late summer/early fall months.

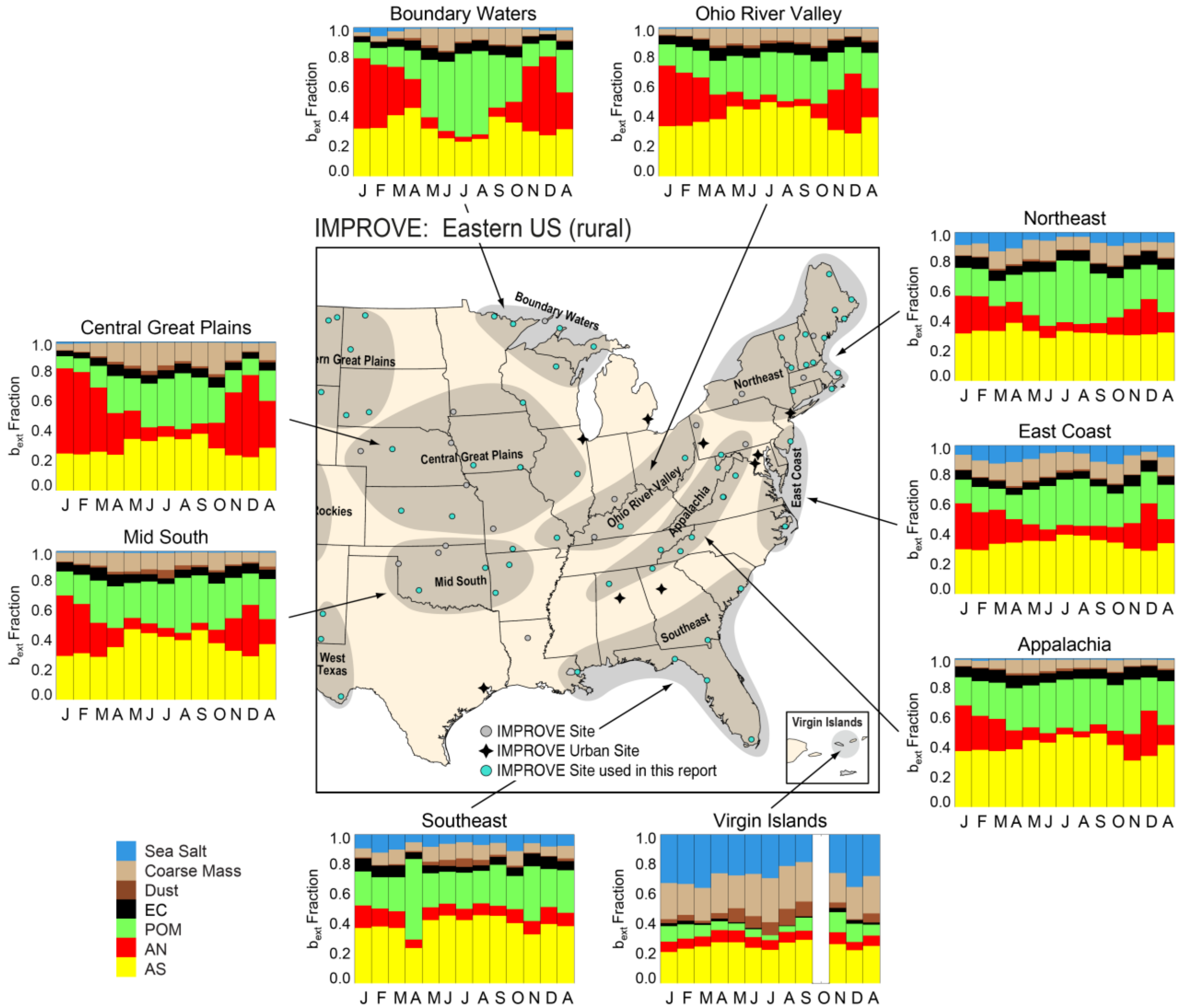

Figure 5.1.4. IMPROVE 2016–2019 regional monthly mean speciated fractional contributions to ambient aerosol light extinction coefficients for the eastern United States. Letters on the x-axis correspond to the month and "A" corresponds to annual mean. Shaded areas in the map correspond to regions that include sites used in the analysis, shown as blue dots. Wavelength corresponds to 550 nm.

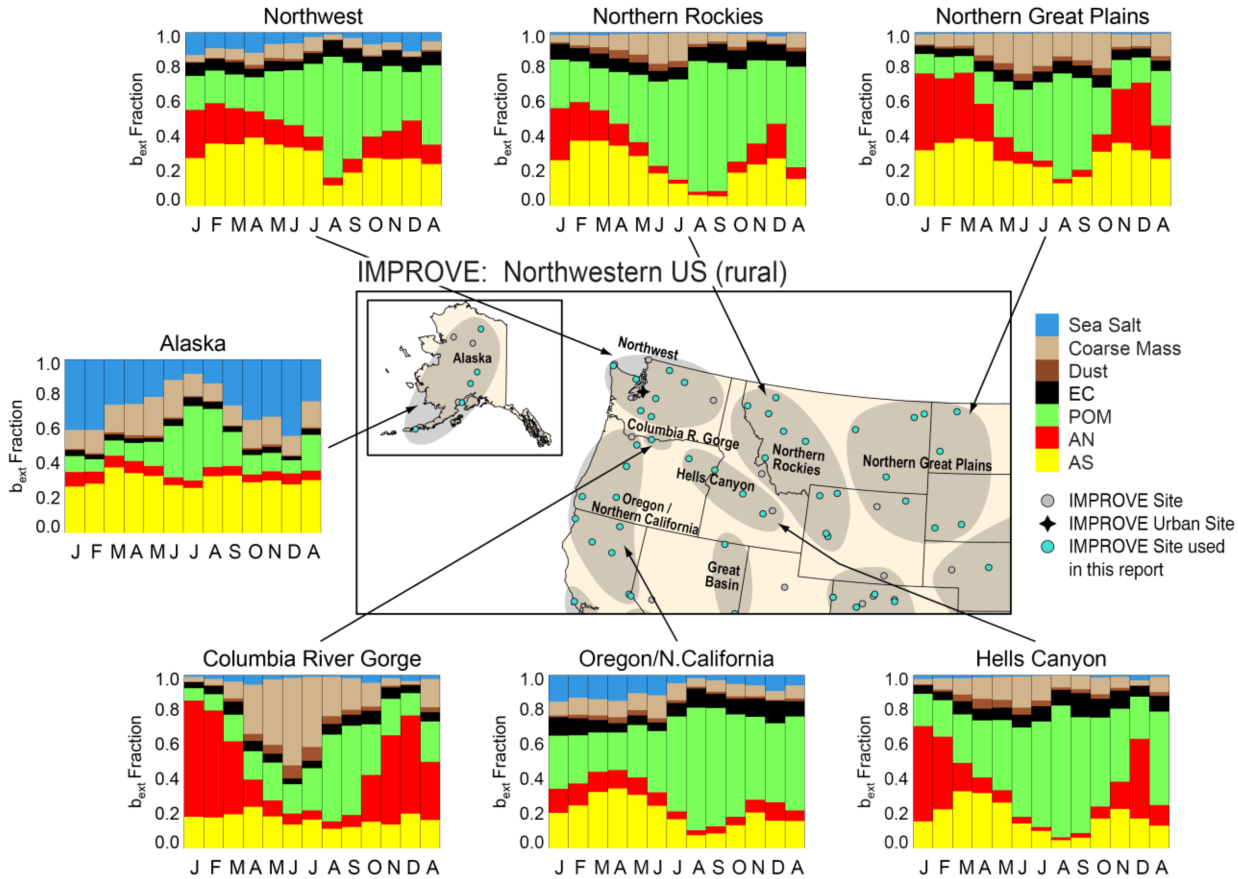

Figure 5.1.5. IMPROVE 2016–2019 regional monthly mean speciated fractional contributions to ambient aerosol light extinction coefficients for the northwestern United States. Letters on the x-axis correspond to the month and “A” corresponds to annual mean. Shaded areas in the map correspond to regions that include sites used in the analysis, shown as blue dots. Wavelength corresponds to 550 nm.

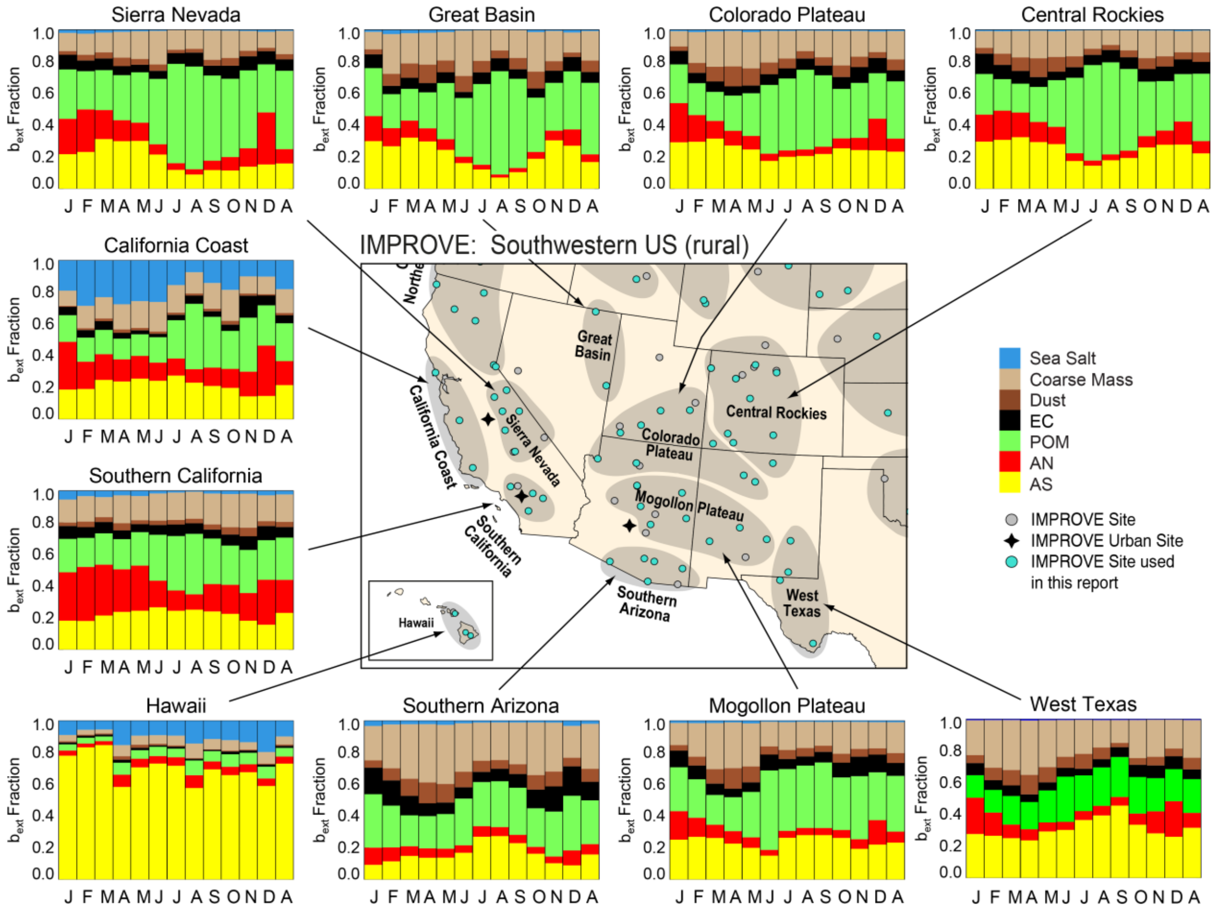

Figure 5.1.6. IMPROVE 2016–2019 regional monthly mean speciated fractional contributions to ambient aerosol light extinction coefficients for the southwestern United States. Letters on the x-axis correspond to the month and "A" corresponds to annual mean. Shaded areas in the map correspond to regions that include sites used in the analysis, shown as blue dots. Wavelength corresponds to 550 nm.

5.1.2 CSN

The lowest urban b_{ext_AS} occurred in the Northwest Nevada region in February (1.61 Mm^{-1}). The highest CSN b_{ext_AS} occurred in the Alaska region in January (42.0 Mm^{-1}) and the East Texas/Gulf region in March (29.33 Mm^{-1}). Most of the monthly mean maxima in other regions in the eastern United States were much lower, around 15–18 Mm^{-1}, although the maximum value in the Ohio River Valley region was 23.28 Mm^{-1} in July. Other maxima occurred in summer or early fall for eastern regions. Although maxima occurred mostly in summer, the seasonal variability was low, as can be seen in Figure 5.1.7. The minimum monthly mean b_{ext_AS} for eastern regions occurred mostly in fall or spring months, with the lowest in the Central US region (7.15 Mm^{-1}) in October. Other minima were around 8–10 Mm^{-1}, except in the East Texas/Gulf region, where the minimum b_{ext_AS} of 18.62 Mm^{-1} occurred in October.

With the exception of the Alaska region, maximum b_{ext_AS} for regions in the northwestern United States (Figure 5.1.8) ranged from ~5 to 12 Mm^{-1} and peaked in summer and winter months. The highest b_{ext_AS} occurred in the North Dakota region (12.56 Mm^{-1}) in March, and the lowest maximum occurred in the Northwest region in January (5.34 Mm^{-1}). The minimum monthly mean b_{ext_AS} ranged from 2 to 5 Mm^{-1}, with the lowest in the Northwest region (2.07 Mm^{-1}) and the Alaska region (2.18 Mm^{-1}), both in June. With the exception of the Alaska region, the seasonality in b_{ext_AS} was relatively flat.

The range in the b_{ext_AS} in regions in the southwestern United States was 1.61 Mm^{-1} in the Northwest Nevada region in February to 23.74 Mm^{-1} in the Los Angeles region in July, followed by the San Diego region (21.28 Mm^{-1}), also in July (Figure 5.1.9). Both regions had a strong seasonal pattern. Most other regions experienced monthly mean maximum b_{ext_AS} from ~3 to 10 Mm^{-1}, mostly during summer or early fall months. The exceptions were the Sacramento/Central Valley, Utah, Front Range CO, and Hawaii regions, which experienced maxima in January or February. Minimum monthly mean b_{ext_AS} ranged from ~2 to 6 Mm^{-1}, with the minima occurring during a variety of months depending on region, but none during summer months.

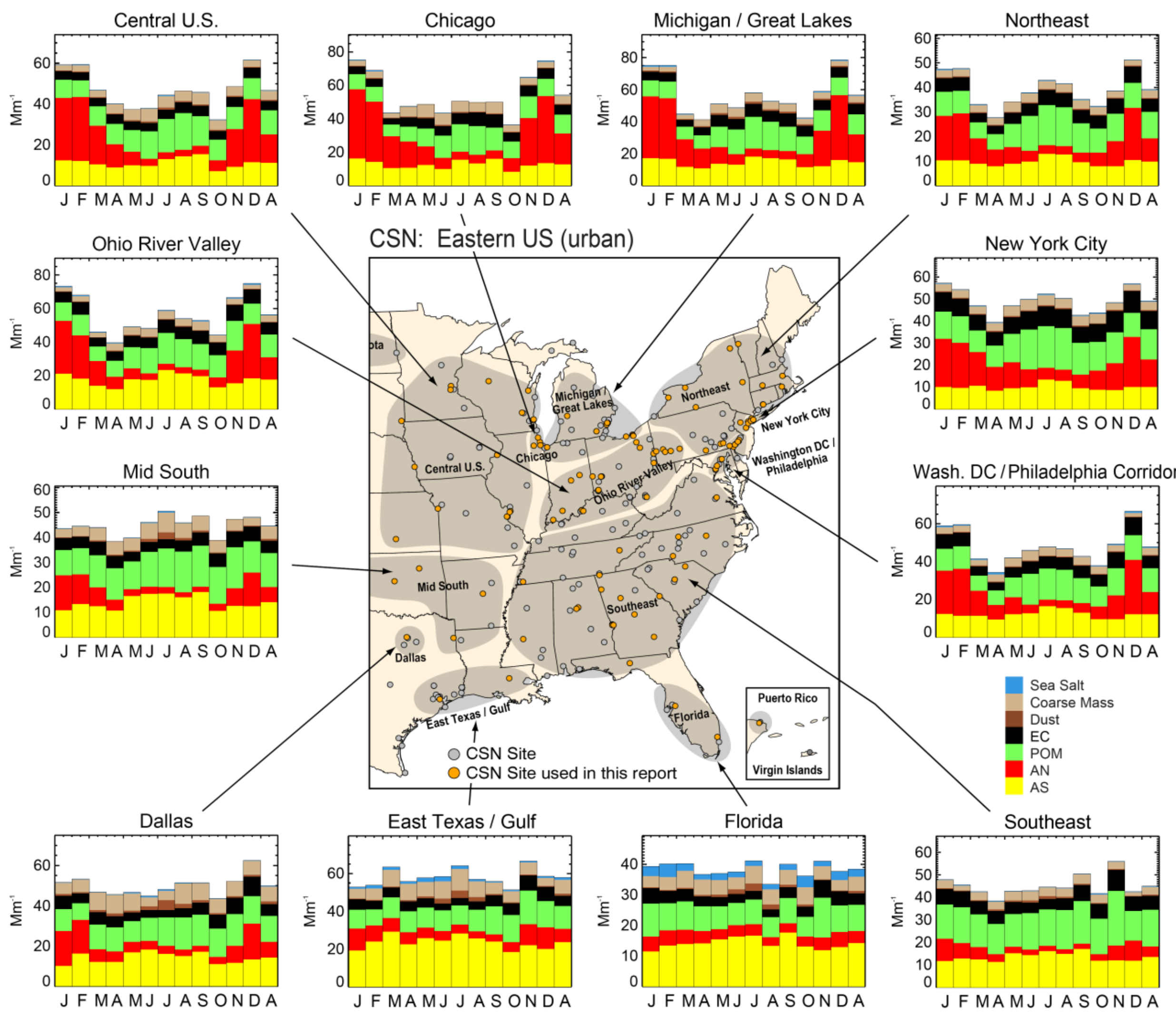

Figure 5.1.7. CSN 2016–2019 regional monthly mean ambient reconstructed speciated aerosol light extinction coefficients (Mm^{-1}) for the eastern United States. Letters on the x-axis correspond to the month and "A" corresponds to annual mean. Shaded areas in the map correspond to regions that include sites used in the analysis, shown as orange dots. Wavelength corresponds to 550 nm.

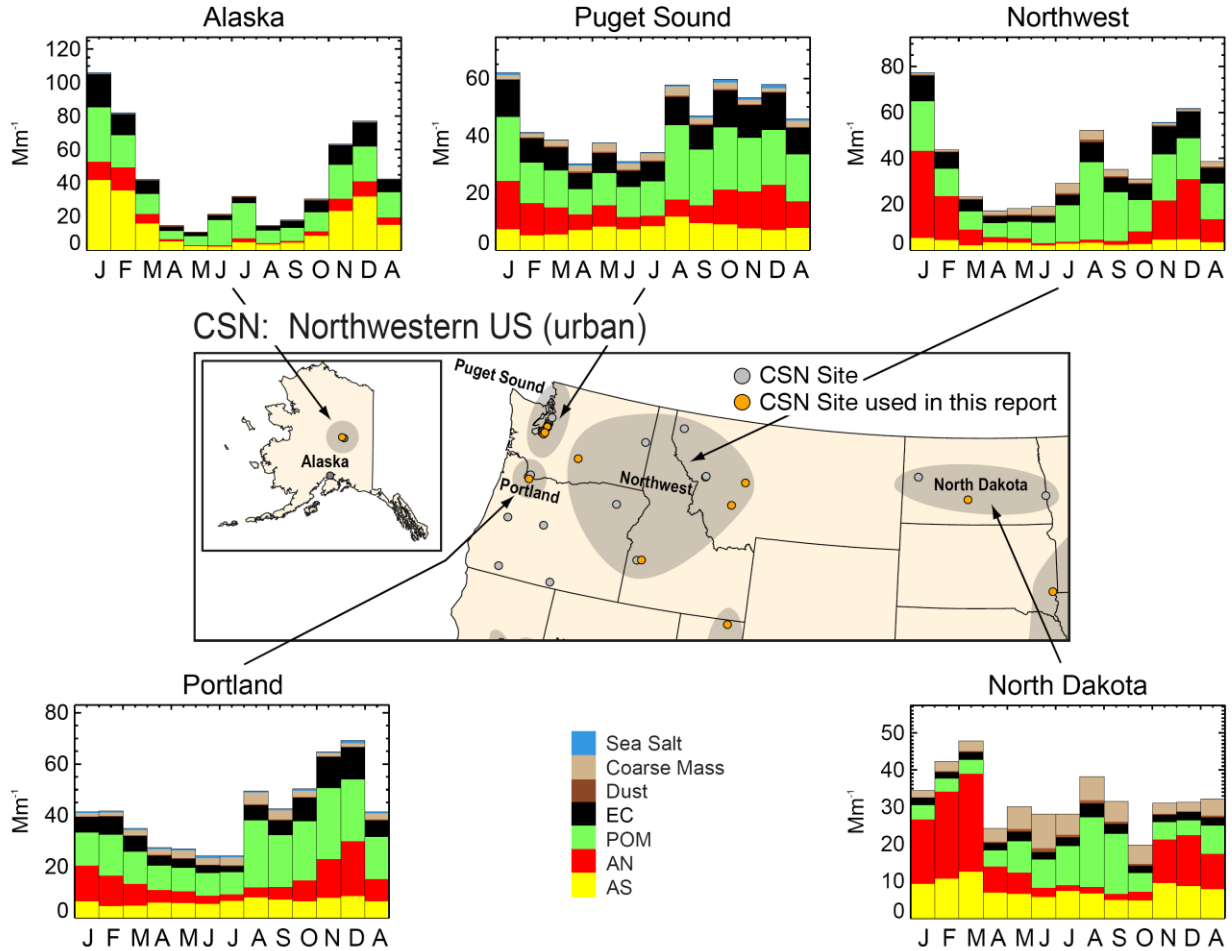

Figure 5.1.8. CSN 2016–2019 regional monthly mean ambient reconstructed speciated aerosol light extinction coefficients (Mm^{-1}) for the northwestern United States. Letters on the x-axis correspond to the month and "A" corresponds to annual mean. Shaded areas in the map correspond to regions that include sites used in the analysis, shown as orange dots. Wavelength corresponds to 550 nm.

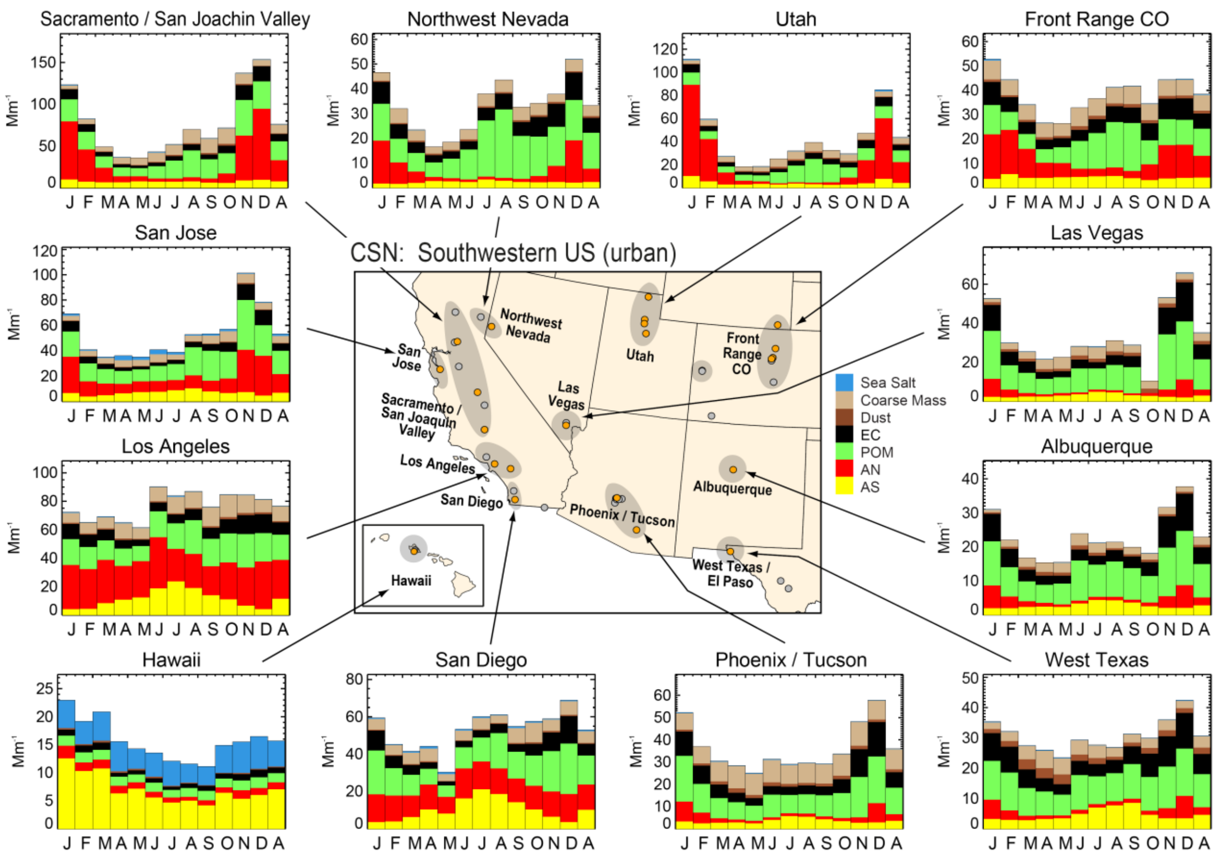

Figure 5.1.9. CSN 2016–2019 regional monthly mean ambient reconstructed speciated aerosol light extinction coefficients (Mm^{-1}) for the southwestern United States. Letters on the x-axis correspond to the month and "A" corresponds to annual mean. Shaded areas in the map correspond to regions that include sites used in the analysis, shown as orange dots. Wavelength corresponds to 550 nm.

CSN regional mean b_{ext_AS} fraction ranged from 0.032 in the Las Vegas region in December and 0.038 in the Northwest Nevada region in January to 0.464 in the East Texas/Gulf region in March. The maximum contributions of b_{ext_AS} to b_{ext_aer} in the eastern United States were typically around 0.3-0.4 (Figure 5.1.10) in summer and early fall months. The lowest contributions were around 0.2-0.3 in winter months, lending to low seasonal variability in b_{ext_AS} contributions in regions in the eastern United States. While the seasonal patterns were quite similar across regions, the maximum contributions occurred in regions farther south.

The relative contribution of b_{ext_AS} to b_{ext_aer} decreased considerably in regions in the western United States. Minimum b_{ext_AS} contributions in regions in the northwestern United States were around 0.1, with the highest minimum in the North Dakota region (0.158 in September; Figure 5.1.11). The maximum contributions for these regions reached 0.2–0.3, with the highest contribution (0.306) in the North Dakota region in November. Contributions were also relatively flat. The Alaska region was not included because CM estimates were not available there.

Monthly mean contributions of b_{ext_AS} to b_{ext_aer} were lowest in regions in the southwestern United States relative to other areas of the country (Figure 5.1.12). Minimum contributions were below 0.1, and maximum contributions were around 0.2–0.3, with the highest contribution of 0.354 in the San Diego region in July. A stronger seasonal variability occurred at regions in the southwestern United States relative to other regions, with summer maximum contributions common, especially in regions farther south, like the West Texas, Phoenix/Tucson, San Diego, and Los Angeles regions. However, the Sacramento/Central Valley, Northwest Nevada, and Utah regions had maximum contributions in spring months.

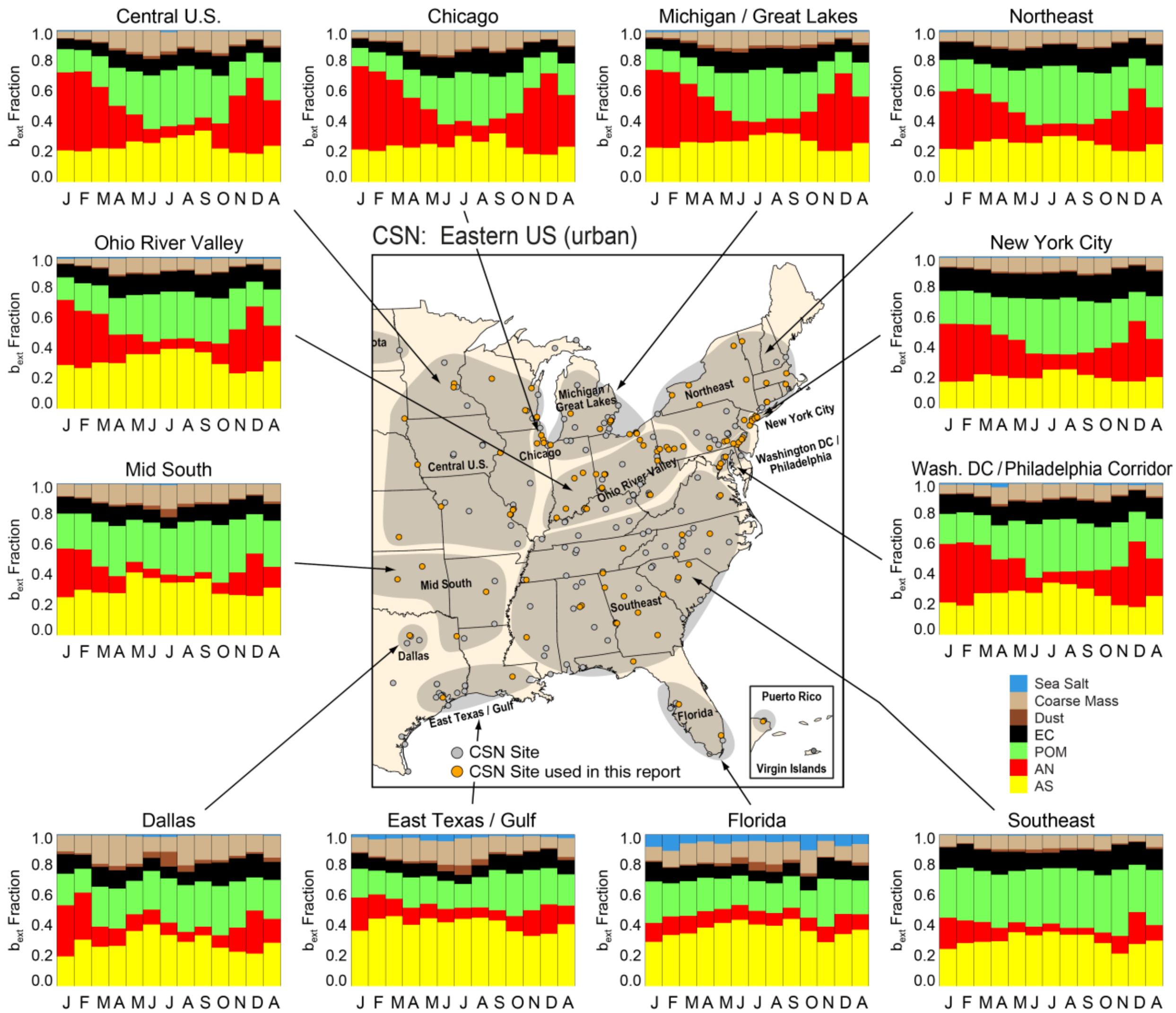

Figure 5.1.10. CSN 2016–2019 regional monthly mean speciated fractional contributions to ambient aerosol light extinction coefficients for the eastern United States. Letters on the x-axis correspond to the month and "A" corresponds to annual mean. Shaded areas in the map correspond to regions that include sites used in the analysis, shown as orange dots. Wavelength corresponds to 550 nm.

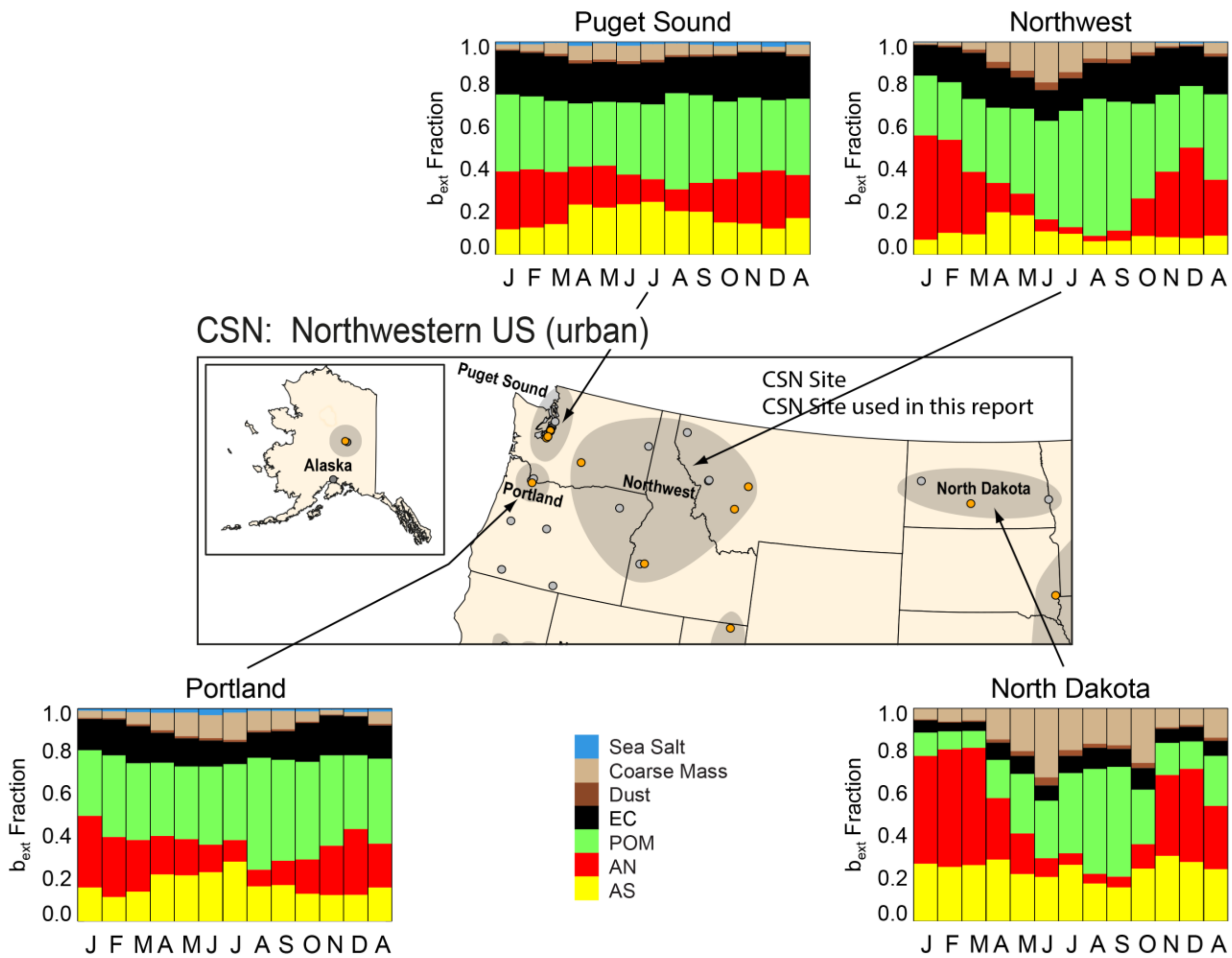

Figure 5.1.11. 2016–2019 regional monthly mean speciated fractional contributions to ambient aerosol light extinction coefficients for the northwestern United States. Letters on the x-axis correspond to the month and "A" corresponds to annual mean. Shaded areas in the map correspond to regions that include sites used in the analysis, shown as orange dots. Wavelength corresponds to 550 nm.

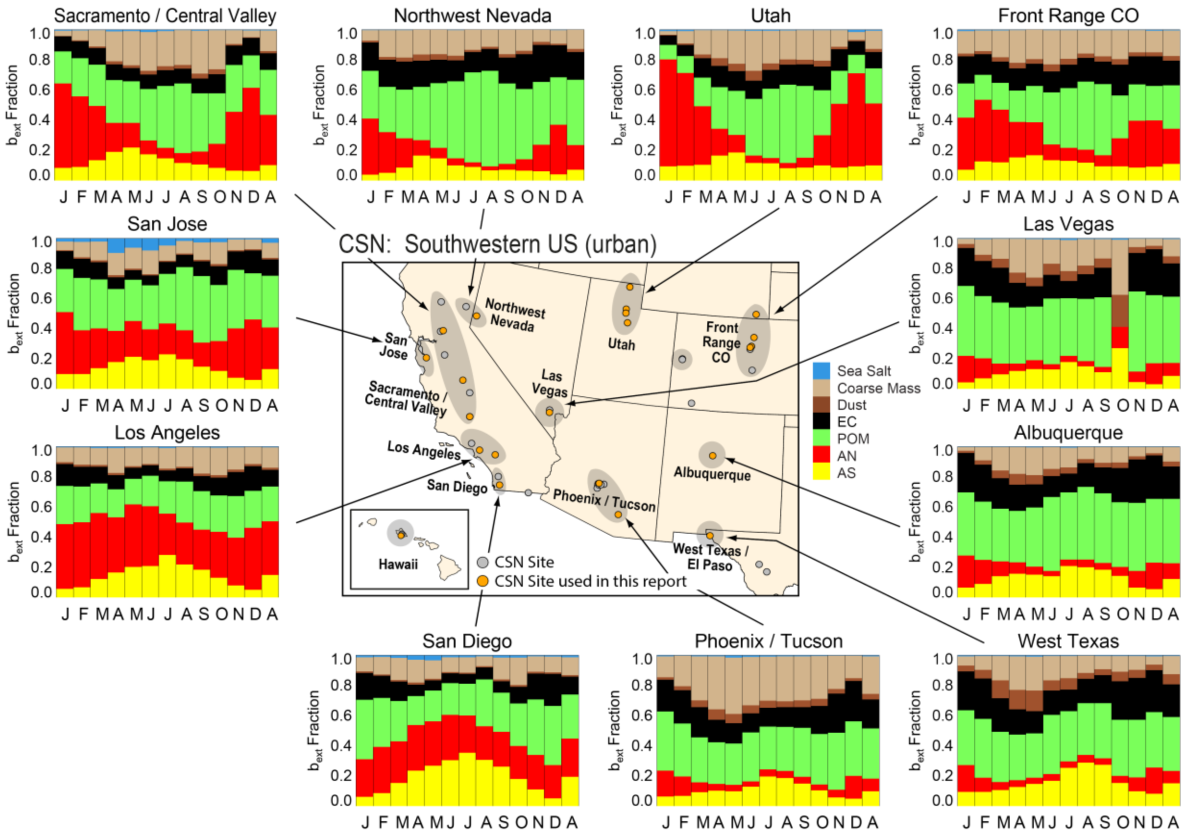

Figure 5.1.12. CSN 2016–2019 regional monthly mean speciated fractional contributions to ambient aerosol light extinction coefficients for the southwestern United States. Letters on the x-axis correspond to the month and "A" corresponds to annual mean. Shaded areas in the map correspond to regions that include sites used in the analysis, shown as orange dots. Wavelength corresponds to 550 nm.

5.2 $PM_{2.5}$ AMMONIUM NITRATE LIGHT EXTINCTION COEFFICIENTS

The extinction efficiency and f(RH) values used to compute reconstructed light extinction coefficients from AN, b_{ext_AN}, were the same as those used to compute b_{ext_AS}. In a similar manner, while general patterns of b_{ext_AN} mostly follow AN mass concentrations, differences may occur due to hygroscopic effects.

5.2.1 IMPROVE

Winter maxima in 2016–2019 regional monthly mean b_{ext_AN} were common in many IMPROVE regions, consistent with favorable AN formation in winter conditions. In fact, the maximum b_{ext_AN} in rural IMPROVE regions occurred in winter (46.59 Mm^{-1}) in the Columbia River Gorge region in January. The minimum IMPROVE regional, monthly mean b_{ext_AN} (0.378 Mm^{-1}) occurred in the Great Basin region in October.

Similar to AN mass concentrations, b_{ext_AN} was highest in regions farther north in the eastern United States and those closer in proximity to agricultural activities (Figure 5.1.1). The highest monthly mean b_{ext_AN} in the eastern United States occurred in the Central Great Plains region (26.66 Mm^{-1}) in January and in the Ohio River Valley region (20.25 Mm^{-1}) in December. These regions also experienced relatively high seasonal variability, with low b_{ext_AN} during summer months. The minimum b_{ext_AN} for eastern regions was around 1–2 Mm^{-1}, with the lowest (0.755 Mm^{-1}) in the Boundary Waters region in August. In regions farther south, the seasonal variability was quite low; in the Southeast region, monthly mean maximum b_{ext_AN} was less than 5 Mm^{-1} year round. In the Northeast region monthly mean maximum b_{ext_AN} was around 5 Mm^{-1}, and the region experienced a larger seasonal variability.

Regional monthly mean b_{ext_AN} varied considerably between regions in the northwestern United States (Figure 5.1.2). The Northern Great Plains, Hells Canyon, and Columbia River Gorge regions experienced higher b_{ext_AN}` relative to other regions, especially during winter months. The maximum monthly mean b_{ext_AN} in the Northern Great Plains and Hells Canyon regions was 8.51 Mm^{-1} and 6.49 Mm^{-1}, respectively, both in January. In contrast, values in the Oregon/Northern California, Northwest, Alaska, and Northern Rockies regions were low, with maximum monthly mean b_{ext_AN} below 3 Mm^{-1} and low seasonal variability. Maximum monthly mean b_{ext_AN} occurred in August for the Northwest, Alaska, and Oregon/Northern California regions, coincident with peaks in b_{ext_POM}.

With the exception of the California Coast (7.45 Mm^{-1} in December) and Southern California (7.43 Mm^{-1} in May) regions, maximum monthly mean b_{ext_AN} was <4 Mm^{-1} in regions in the southwestern United States (Figure 5.1.3). Most other regions had low seasonal variability, except the West Texas region where monthly mean b_{ext_AN} ranged from a minimum of 1.17 Mm^{-1} in October to 3.94 Mm^{-1} in January. Monthly mean b_{ext_AN} in the Hawaii region was <1 Mm^{-1} year round.

The contribution of b_{ext_AN} to b_{ext_aer} ranged from 0.0169 in the Hells Canyon region in August to 0.671 in the Columbia River Gorge region in January. Regions farther north in the eastern United States experienced a high degree of seasonality in the fractional contribution of b_{ext_AN} (Figure 5.1.4). Monthly mean contributions during summer months in the Boundary Waters, Central Great Plains, and Ohio River Valley regions were around 0.03–0.06, compared to over 0.5 during winter months. Regions farther from agricultural sources, such as the East Coast, Northeast, and Appalachia regions, had lower maximum monthly mean contributions (~0.3 or less) in winter months. The Southeast region had the lowest year-round monthly mean contributions, ranging from 0.06 to 0.15.

In the northwestern United States, the monthly mean contributions of b_{ext_AN} to b_{ext_aer} ranged from a minimum of 0.030 in the Oregon/Northern California region in August to 0.549 in the Hells Canyon region and 0.671 in the Columbia River Gorge region, both in January (Figure 5.1.5). Monthly mean contributions in the Northern Great Plains reached 0.443 in January. The regions with higher contributions were closer to agricultural activity and oil and gas development. Contributions in other regions, such as the Northern Rockies and Northwest regions, reached nearly 0.3 in winter. Contributions in the Alaska region were also low year round (0.042 in July to 0.084 in January).

The relative contribution of b_{ext_AN} to b_{ext_aer} was lower in the southwestern United States relative to other areas (Figure 5.1.6). Monthly mean contributions ranged from 0.019 in the Great

Basin region in August to 0.328 in the Sierra Nevada region in December and 0.338 in the Southern California region in February. Other regions experienced elevated monthly mean contributions during winter months, but values only reached 0.15–0.3. The Hawaii region experienced a maximum monthly mean contribution of 0.081 in August and low contributions the rest of the year.

5.2.2 CSN

The CSN regional monthly mean b_{ext_AN} ranged from 0.53 Mm^{-1} in the Alaska region in May, 0.64 Mm^{-1} in the Hawaii region in August, and 0.82 Mm^{-1} in the Albuquerque region in May to 84.82 Mm^{-1} in the Sacramento/Central Valley region in December. Similar to the seasonal patterns observed in IMPROVE regions in the eastern United States, b_{ext_AN} was highest (30–40 Mm^{-1}) during winter months in regions farther north, such as the Central U.S., Michigan/Great Lakes, and Chicago regions (Figure 5.1.7). The range in seasonality decreased in regions farther south, such as the East Texas/Gulf, Florida, and Southeast regions, where values were near 10 Mm^{-1} or less during winter months. These values were double what was observed in southern IMPROVE regions in the eastern United States.

In the northwestern United States, regional, monthly mean CONUS b_{ext_AN} ranged from 0.91 Mm^{-1} in the Northwest region in July to 37.97 Mm^{-1} in the Northwest region in January, roughly four times higher than the IMPROVE maximum monthly mean value (Figure 5.1.8). The maximum b_{ext_AN} occurred during winter months in all regions in the northwestern United States except in the North Dakota region, where the monthly mean maximum value of 26.40 Mm^{-1} occurred in March. This is a region near oil and gas development activity. The maximum monthly mean values in the northwestern United States were lower than those observed in eastern CSN regions.

Maximum values of regional monthly mean b_{ext_AN} in urban regions were considerably higher in the southwestern United States (5.1.9) compared to the northwestern United States. The Sacramento/Central Valley and Utah regions experienced high monthly mean b_{ext_AN} (~80 Mm^{-1} and higher) during winter months. These areas are subject to inversions and increased particulate matter concentrations during winter. Winter monthly mean maxima and strong seasonal variability in b_{ext_AN} were also observed in regions farther south, such as the Phoenix/Tucson, Albuquerque, and West Texas regions, but monthly mean maxima b_{ext_AN} were much lower (<10 Mm^{-1}). In contrast, monthly mean b_{ext_AN} values in regions in southern California, such as the Los Angeles, and San Diego regions, were elevated year round. In the Los Angeles region, monthly mean values ranged from 20.36 Mm^{-1} in September to 35.84 Mm^{-1} in June, also a different seasonal pattern from what was observed in most other regions in the southwestern United States.

CSN regional monthly mean b_{ext_AN} fractional contributions ranged from 0.026 and 0.027 in August in the Northwest and Northwest Nevada regions, respectively, to 0.71 in the Utah region in January. Contributions of b_{ext_AN} to b_{ext_aer} in the eastern United States were highest in regions farther north (Figure 5.1.10). During winter months in the Central U.S., Chicago, and Michigan Great Lakes regions, b_{ext_AN} contributed over half of b_{ext_aer} and decreased to less than 0.1 during summer months. The range in seasonal contributions was much lower in regions farther south, such as the East Texas/Gulf and Florida regions, where monthly mean contributions ranged from ~0.05 in summer months to ~0.2 or less during winter months.

The highest monthly mean contributions of b_{ext_AN} to b_{ext_aer} (0.55) in the northwestern United States occurred in the North Dakota region in February (Figure 5.1.11). Contributions in this region dropped by a factor of ten (0.05) during summer months. The Northwest region experienced a higher range in contributions from summer to winter months compared to the Puget Sound and Portland regions, where contributions during winter months were lower (~0.3) and summer contributions were higher (~0.10).

While the Utah region corresponded to the highest monthly mean contributions in winter months (0.71), other regions in the southwestern United States also experienced high contributions during winter months, such as the Sacramento/Central Valley region (0.56 in January), the Northwest Nevada region (0.49 in January), and the Front Range CO region (0.41 in February). These regions also experienced much lower contributions (~0.05) during summer months (Figure 5.1.12). Regions in California experienced less seasonality in b_{ext_AN} contributions, such as the San Jose, Los Angeles, and San Diego regions, suggesting additional urban sources during summer months. The lowest contributions occurred in regions in the southwest areas, such as the Phoenix/Tucson, West Texas, and Albuquerque regions. These regions experienced higher monthly mean contributions in winter relative to summer but ranged from ~0.03 to ~0.2 or less.

5.3 $PM_{2.5}$ PARTICULATE ORGANIC MATTER LIGHT EXTINCTION COEFFICIENTS

5.3.1 IMPROVE

POM was considered to be nonhygroscopic in reconstructed b_{ext} calculations. On a similar dry mass basis, b_{ext_POM} would be higher than b_{ext_AS} or b_{ext_AN} because its extinction efficiency is higher (4 $m^2\ g^{-1}$ compared to 3 $m^2\ g^{-1}$; see section 4.1).

The minimum IMPROVE 2016–2019 regional monthly mean b_{ext_POM} occurred in the Hawaii region in December (0.66 Mm^{-1}) and the Central Rockies region in January (1.06 Mm^{-1}). The maximum regional monthly mean b_{ext_POM} occurred in the Oregon/Northern California region in August (47.99 Mm^{-1}). Monthly mean b_{ext_POM} in the eastern United States ranged from ~3 to 7 Mm^{-1} to 35 Mm^{-1} (Figure 5.1.1), which occurred in April in the Southeast region due to the impacts of biomass smoke (see Chapter 2). Most regions in the eastern United States experienced monthly mean maxima during July and August, and values were consistently near 14 Mm^{-1}. The Virgin Islands region experienced a maximum monthly mean b_{ext_POM} (3.25 Mm^{-1}) during December. Most of the regional minima monthly mean b_{ext_POM} occurred during January or March, with the exception of the Southeast region, which occurred in October, and the Virgin Islands region in July.

Biomass smoke influence on b_{ext_POM} was obvious in many northwestern United States regions, with strong impacts during summer months (Figure 5.1.2). All of the regions experienced maximum monthly mean values during August, with the exception of Alaska (July).

The highest monthly mean b_{ext_POM} occurred in the Oregon/Northern California, Northwest, and Hells Canyon regions (>40 Mm^{-1}). Maximum monthly mean values were lower in the Columbia River Gorge region (29.50 Mm^{-1}) and the Northern Rockies region (35.11 Mm^{-1}). Minimum monthly mean values occurred from January through March for most regions and were less than 4 Mm^{-1}, with the exception of the Alaska region, which corresponded to a minimum in December.

The northerly regions in the southwestern United States were also influenced by biomass smoke with higher b_{ext_POM} during summer months (July and August), such as the Sierra Nevada, Great Basin, and Central Rockies regions (Figure 5.1.3). The highest monthly mean b_{ext_POM} occurred in the Sierra Nevada region (40.24 Mm^{-1}) in August. These regions also had their lowest (<2 Mm^{-1}) monthly mean b_{ext_POM} during January. Less seasonality was observed in regions farther south. The Southern Arizona, Mogollon Plateau, and West Texas regions had b_{ext_POM} that ranged from 2 to 3 Mm^{-1} in February and March to around 10 Mm^{-1} during summer months, except for the Southern Arizona region, which had a maximum in December.

The contributions of b_{ext_POM} to b_{ext_aer} ranged from 0.029 in the Hawaii region in March, 0.030 in the Virgin Islands region in July, and 0.071 in the Columbia River Gorge region in January to 0.76 in the Hells Canyon region in August. In the eastern United States, the regional maximum monthly mean b_{ext_POM} contribution was ~0.3–0.5, with the highest contribution in the Boundary Waters region (0.56) in August (Figure 5.1.4). The April maximum in the Southeast region corresponded to biomass smoke influence. Other monthly mean maxima generally occurred in August, except the Appalachia region (November). Minimum contributions of b_{ext_POM} to b_{ext_aer} occurred mostly during winter months or early spring (e.g., the Northeast and East Coast regions). Minimum monthly mean contributions were around 0.1–0.2. The lowest occurred in the Virgin Islands region in July (0.03) and the Central Great Plains region in January (0.08).

Contributions of b_{ext_POM} to b_{ext_aer} were much higher for many northwestern U.S. regions relative to the eastern United States, and the maximum monthly mean contributions occurred in August for nearly all regions (Figure 5.1.5). The b_{ext_POM} contributions ranged from 0.071 in the Columbia River Gorge (January) and Alaska (February) regions to 0.76 in the Hells Canyon region (August). With the exception of the Alaska region (0.43 in July) and the Columbia River Gorge (0.52 in September), the maximum monthly mean contributions were over 0.7, highlighting the importance of biomass burning influence on b_{ext_aer} in these regions.

In the southwestern United States, contributions of b_{ext_POM} ranged from 0.142 in the West Texas region (January) to 0.65 in the Great Basin and Sierra Nevada regions, both in August (Figure 5.1.6). Regions farther north were likely influenced by biomass smoke, similar to regions in the northwestern United States area. Minimum monthly mean contributions were typically around 0.15–0.2 for other regions and occurred in early spring or late winter months. Maximum monthly mean contributions were lower farther south and ranged from 0.3 to 0.4, such as in the Southern Arizona, Mogollon Plateau, and West Texas regions. The maximum contribution in the Southern Arizona region occurred in December; other regions experienced maxima during summer months.

5.3.2 CSN

The regional, monthly mean b_{ext_POM} in CSN regions ranged from 1.33 Mm^{-1} in the Hawaii region (July) and 3.58 Mm^{-1} in the North Dakota region in February to 42.69 Mm^{-1} in the Sacramento/Central Valley region in November. In the eastern United States the monthly mean b_{ext_POM} values were highest during July and August in most regions (~15–20 Mm^{-1}) and reached 24 Mm^{-1} in the Southeast region in November (Figure 5.1.7). Minimum values in regions across the eastern United States (~8–10 Mm^{-1}) were roughly half the maximum monthly mean values (~15–18 Mm^{-1}).

The seasonal variability in b_{ext_POM} in CSN regions in the northwestern United States was much lower than for IMPROVE regions (Figure 5.1.8). The strong influence of biomass smoke was not as evident. Monthly mean maximum b_{ext_POM} occurred during August in the Puget Sound (26.11 Mm^{-1}), Northwest (33.72 Mm^{-1}), and North Dakota regions (18.84 Mm^{-1}). However, in the Portland region, the maximum monthly mean b_{ext_POM} occurred in November (27.59 Mm^{-1}). Most regions experienced minimum monthly mean b_{ext_POM} during spring or winter months (~4–9 Mm^{-1}), except the Portland region with a minimum monthly mean b_{ext_POM} in July (8.83 Mm^{-1}).

The maximum regional monthly mean b_{ext_POM} in the southwestern United States occurred in the Sacramento/Central Valley region (42.69 Mm^{-1}), followed by the San Jose region (39.45 Mm^{-1}), both in November (Figure 5.1.9). Other regions had maximum monthly mean b_{ext_POM} in December, such as the San Diego region and others in the southwest part of the country (e.g., Phoenix/Tucson, West Texas). However, in the Northwest Nevada, Los Angeles, Front Range CO, and Utah regions, monthly mean b_{ext_POM} was highest in August or September, perhaps due to biomass smoke influence that affected some regions in the northwestern United States.

Monthly mean contributions of b_{ext_POM} to b_{ext_aer} ranged from 0.079 in the North Dakota region in March to 0.645 in the Northwest region in August (Figure 5.1.10). In the eastern United States, contributions ranged from 0.121 in January in the Chicago region to 0.437 in the Southeast region in November. Monthly mean contributions in the Southeast region were greater than 0.3 during all months. In regions farther north, contributions were greater in the summer months, in part due to contributions of b_{ext_AN} to b_{ext_aer} during winter months. All regions experienced their lowest monthly mean b_{ext_POM} contributions (~0.12–0.3) during winter months, with the exception of Florida (October). Months corresponding to maximum contributions varied depending on region but mostly occurred during summer months, except for the Southeast and Florida regions in November and in October for the Dallas, East Texas/Gulf, and Midsouth regions.

In the northwestern United States regional monthly mean b_{ext_POM} contributions to b_{ext_aer} ranged from 0.079 in March in the North Dakota region to 0.645 in the Northwest region in August (Figure 5.1.11). Most of the maximum contributions occurred during summer months (~0.45–65), and with the exception of the North Dakota region, minimum contributions in other regions were around 0.3. Both the Puget Sound and Portland regions experienced relatively flat contributions of b_{ext_POM} to b_{ext_aer} compared to the Northwest and North Dakota regions, highlighting the importance of b_{ext_POM} contributions during winter farther west.

Contributions of b_{ext_POM} were significant in many southwestern urban regions (Figure 5.1.12), ranging from 0.278 in Los Angeles (November) to 0.635 in the Northwest Nevada region in August. Regions farther north experienced maximum contributions during summer, in part due to the contributions of b_{ext_AN} during winter months, when b_{ext_POM} contributions were lowest. Farther south, maximum contributions around 0.4–0.5 occurred during summer months (Albuquerque and West Texas) and in January in the Phoenix/Tucson region.

5.4 $PM_{2.5}$ ELEMENTAL CARBON LIGHT EXTINCTION COEFFICIENT

Monthly mean EC mass concentrations were low compared to other species, and urban concentrations were higher than rural concentrations. Recall that EC light extinction coefficients (b_{ext_EC}) were computed by scaling the EC mass by its extinction efficiency (10 m^2 g^{-1}), which is higher than the other species, due to its ability to both scatter and absorb visible light. This higher extinction efficiency increased EC's relative contribution to b_{ext} compared to reconstructed fine mass (RCFM).

5.4.1 IMPROVE

The rural IMPROVE 2016–2019 regional monthly mean b_{ext_EC} ranged from 0.09 Mm^{-1} in the Hawaii region in August and 0.28 Mm^{-1} in the Great Basin region in February to 7.44 Mm^{-1} in the Oregon/Northern California region in August. The lowest monthly mean b_{ext_EC} in the eastern United States occurred in the Boundary Waters region in March; other eastern regions had minimum b_{ext_EC} around 1–2 Mm^{-1} (Figure 5.1.1). Minimum values occurred during January for the Appalachia, Ohio River Valley, and Central Great Plains regions, while other regions had minimum values during spring and summer months. The highest monthly mean b_{ext_EC} (3.69 Mm^{-1}) occurred in the Ohio River Valley region in November, similar to the Appalachia region (2.94 Mm^{-1}). The Midsouth and Southeast regions also had higher monthly mean maximum values (~3 Mm^{-1}).

Maximum monthly mean b_{ext_EC} values were highest in regions in the northwestern United States. Values ranged from 0.47 Mm^{-1} in February in the Northern Rockies region to 7.44 Mm^{-1} in the Oregon/Northern California region in August (Figure 5.1.2). Maximum monthly mean b_{ext_EC} occurred during summer months for all of the regions with the exception of the Columbia River Gorge region (November). Summer maxima were likely associated with biomass burning influence.

In the southwestern United States, regional monthly mean b_{ext_EC} ranged from 0.28 Mm^{-1} in February in the Great Basin region to 5.47 Mm^{-1} in the Sierra Nevada region in August and 5.49 Mm^{-1} in December in the Southern Arizona region. Regions farther north experienced maximum b_{ext_EC} in summer months (usually August), such as the Sierra Nevada, Great Basin, Colorado Plateau, and Central Rockies regions, likely due to biomass smoke influence (Figure 5.1.3). Higher monthly mean b_{ext_EC} in the Southern Arizona region during winter months suggests additional sources; this region corresponded to the largest minimum monthly mean b_{ext_EC} in the southwestern United States (1.39 Mm^{-1} in May).

Monthly mean b_{ext_EC} contributions to b_{ext_aer} ranged from 0.003 in the Virgin Islands region in July and 0.021 in the California Coast region in June to 0.185 in the Southern Arizona region in December. Contributions were less than 0.1 in all eastern IMPROVE regions (Figure 5.1.4) and generally higher during fall and winter months. The lowest monthly mean minimum contribution in eastern regions was 0.036 in the Central Great Plains region in January. Most of the minimum monthly contributions ranged between 0.03 and 0.06, while the maximum contributions were 0.090 in the Ohio River Valley in October and 0.092 in the Northeast region in November.

Contributions of b_{ext_EC} to b_{ext_aer} were higher in regions in the northwestern United States (Figure 5.1.5). In the Oregon/Northern California and Hells Canyon region, monthly mean maximum contributions were ~0.13 in December and September, respectively. The Northern Rockies and Northwest regions had maximum contributions around 0.1 in September and August, respectively. Minimum monthly mean contributions were around 0.05, meaning that contributions year round were greater than 0.05 in most regions. The lowest contributions occurred in the Alaska region (0.022) in May and the Columbia River Gorge region (0.033) in June.

In the southwestern United States, the maximum monthly contribution occurred in the Southern Arizona region (0.185) in December. Other regions had contributions higher than 0.1, such as the California Coast (0.139, November), Central Rockies (0.127, January), and the Mogollon Plateau (0.123, November). Maximum contributions in remaining regions were around 0.1, mostly during winter months (Figure 5.1.6). Minimum contributions were around 0.05, with the lowest in the California Coast region in June (0.021).

5.4.2 CSN

CSN regional monthly mean b_{ext_EC} values ranged from 0.58 Mm^{-1} in the Hawaii region in July and 1.77 Mm^{-1} in the North Dakota region in February to 20.10 Mm^{-1} in the Las Vegas region in December. In the eastern United States, the minimum monthly mean b_{ext_EC} was 2.60 Mm^{-1} in the Florida region in August (Figure 5.1.7). The largest minimum b_{ext_EC} occurred in the New York City region (6.21 Mm^{-1} in April). The New York City region also had the largest maximum b_{ext_EC} of 9.88 Mm^{-1} in December. Several other regions had the maximum monthly mean b_{ext_EC} around 9 Mm^{-1} (the Dallas, Ohio River Valley, Washington D.C./Philadelphia Corridor, and Southeast regions). Maximum b_{ext_EC} occurred during November and December for most regions, except the Central U.S. and Chicago regions (both August) and the Michigan Great Lakes region (September). The lowest maximum b_{ext_EC} occurred in the Central U.S. region (5.32 Mm^{-1}).

The North Dakota region of the northwestern United States had the lowest maximum monthly mean b_{ext_EC} of the region (3.79 Mm^{-1} in August). Other regions had maximum b_{ext_EC} in winter months, with the highest in the Alaska region (19.59 Mm^{-1}) in January. This seasonal pattern is different from what was observed in rural regions, where b_{ext_EC} peaked in summer months, suggesting additional urban sources. Minimum monthly mean b_{ext_EC} was around 1–2 Mm^{-1}, except in the Puget Sound region (5.62 Mm^{-1}) in June (Figure 5.1.8).

Monthly mean values of b_{ext_EC} in the southwestern United States were comparable to other regions and ranged from 0.58 Mm^{-1} in Hawaii in July and 2.08 Mm^{-1} in the San Diego region in May to 20.10 Mm^{-1} in the Las Vegas region in December (Figure 5.1.9). All of the regions in the southwestern United States had maximum monthly mean b_{ext_EC} during winter months, nearly all in December. Minimum monthly mean b_{ext_EC} values were around 2–5 Mm^{-1} and nearly all occurred in May.

Monthly mean contributions of b_{ext_EC} to b_{ext_aer} were higher in CSN regions compared to IMPROVE regions. The contributions ranged from 0.042 in the North Dakota region in February to 0.305 in the Las Vegas region in December. In the eastern United States, maximum contributions were around 0.13 and higher, with a maximum contribution of 0.200 in the New York City region in November (Figure 5.1.10). Maximum contributions occurred mostly in fall months (November). Minimum monthly mean contributions were greater than 0.06 for all regions, and the largest minimum contribution occurred in the New York City region (0.147) in February; the seasonal range in b_{ext_EC} contribution in the New York City region was low.

In the northwestern United States, b_{ext_EC} contributions ranged from 0.042 in the North Dakota region in February to nearly 0.23 in the Puget Sound and Northwest regions in January and October, respectively (Figure 5.1.11). The North Dakota region was an outlier in the northwestern United States, where contributions were generally greater than 0.1.

Maximum monthly mean b_{ext_EC} contributions in the southwestern United States were less than 0.3, with the maximum in Las Vegas. Regions in California (e.g., Sacramento/Central Valley, San Jose, and Los Angeles) had lower maximum contributions compared to those regions farther east, such as the Northwest Nevada, Front Range CO, Albuquerque, Las Vegas, West Texas, and Phoenix/Tucson regions. The minimum contribution of 0.143 occurred in July in the West Texas region (Figure 5.1.12).

5.5 $PM_{2.5}$ FINE DUST LIGHT EXTINCTION COEFFICIENTS

The FD extinction efficiency used to compute b_{ext_FD} in the IMPROVE algorithm is 1 m^2 g^{-1}. The dust extinction efficiency is lower than for most other species, and dust is nonhygroscopic; therefore the seasonal and spatial patterns in b_{ext_FD} were similar to FD mass concentrations. However, the magnitude of b_{ext_FD} may change relative to other species, as well as its relative contribution to b_{ext_aer}.

5.5.1 IMPROVE

The IMPROVE 2016–2019 regional monthly mean b_{ext_FD} ranged from 0.034 Mm^{-1} in the Northwest region in December to 4.01 Mm^{-1} in the Virgin Islands region in August and 2.70 Mm^{-1} in the Southern Arizona region in April and 2.72 Mm^{-1} in the Columbia River Gorge region in July. In the eastern United States, long-distance transport of dust from North Africa in summer is well documented and is the likely reason for high dust concentrations and consequent light extinction in summer in the Virgin Islands region (Figure 5.1.1). Monthly mean b_{ext_FD} in the eastern United States ranged from 0.087 Mm^{-1} in the Boundary Waters region in January to 2.38 Mm^{-1} and 2.46 Mm^{-1} in the CONUS regions of the Midsouth and Southeast, respectively, both in July. Nearly all eastern regions had maximum monthly mean b_{ext_FD} during July, with the exception of the Boundary Waters and Northeast regions (May).

Monthly mean values of b_{ext_FD} in northwestern U.S. regions were low; with the exception of the high value in the Columbia River Gorge region, maximum monthly b_{ext_FD} was less than 1–2 Mm^{-1} in all other regions (Figure 5.1.2). The Northwest and Alaska regions had the lowest values year round (<0.3 Mm^{-1}). Maximum monthly mean values occurred in July and August, except for the Alaska region (April). Minimum values occurred in January and December, except for Alaska (September).

The highest maximum monthly mean b_{ext_FD} in the southwestern United States occurred in regions farther south that are known to be influenced by dust, such as the Southern Arizona region (2.70 Mm^{-1}) and the West Texas region (2.66 Mm^{-1}), both in April. Other regions had maximum b_{ext_FD} ranging from 1 to 2 Mm^{-1}, although during different months. The Central Rockies and Colorado Plateau regions experienced their highest monthly mean b_{ext_FD} during June, while the maximum in the California Coast and Sierra Nevada regions occurred in October. The maximum b_{ext_FD} in the Southern California region occurred in July (Figure 5.1.3).

Contributions of b_{ext_FD} to b_{ext_aer} ranged from 0.003 in the Hawaii region in September and the Columbia River Gorge region in January to 0.131 in the Southern Arizona region in April. Maximum monthly mean contributions b_{ext_FD} to b_{ext_aer} in the eastern United States were negligible, less than 0.03 in most regions, except the Midsouth (0.060) and the Southeast (0.060) regions, both in July (Figure 5.1.4), likely due to long-range transport of North African dust.

In the northwestern United States, contributions of monthly mean b_{ext_FD} to b_{ext_aer} ranged from a minimum of 0.003 (January) to 0.080 (July), both in the Columbia River Gorge region (Figure 5.1.5). The lowest maximum contribution occurred in the Alaska region (0.019) in April. Maxima in other regions in the northwestern United States were around 0.02–0.05, nearly all in April.

Monthly mean contributions of b_{ext_FD} to b_{ext_aer} in the southwestern United States ranged from 0.003 in the Hawaii region in September and 0.006 in the California Coast region in January to 0.130 in the Southern Arizona and West Texas regions in April (Figure 5.1.6). Other regions had maximum contributions in April of ~0.1. Southern California and the California Coast regions both experienced maximum contributions during fall months (0.02–0.05).

5.5.2 CSN

The CSN maximum monthly mean b_{ext_FD} value of 4.75 Mm^{-1} occurred in the Dallas region in July, compared to the lowest value of 0.09 Mm^{-1} in the Hawaii region in September and 0.15 Mm^{-1} in the North Dakota region in January. In regions in the eastern United States, b_{ext_FD} was negligible (Figure 5.1.7), except in regions farther south that have influence from transport of North African dust. For example, in addition to the Dallas region, the East Texas/Gulf (4.04 Mm^{-1}), Florida (2.39 Mm^{-1}), Midsouth (2.83 Mm^{-1}), and Southeast (1.23 Mm^{-1}) regions all had maximum b_{ext_FD} during July. The Michigan/Great Lakes and Central U.S. regions also had maximum b_{ext_FD} of ~1 Mm^{-1} in summer months.

Regions in the northwestern United States experienced very low monthly mean b_{ext_FD}, and the highest maximum occurred in the North Dakota region (1.06 Mm^{-1}) in June and 1.01 Mm^{-1} in the Northwest region in August. In other regions, the maximum monthly mean b_{ext_FD} was less than 1 Mm^{-1} and not visible on the bar charts in Figure 5.1.8. Minimum monthly mean b_{ext_FD} was ~0.1–0.3 Mm^{-1} for all regions in the northwestern United States.

The relative values of b_{ext} for all species in the southwestern United States demonstrated that while a species may contribute significantly to RCFM, it may not contribute as significantly to b_{ext} because it is not as efficient at scattering light as other species. The effects of the larger extinction efficiency for EC compared to that for FD were obvious in magnitudes of speciated b_{ext} in Figure 5.1.9. For most regions, the b_{ext_FD} values were much lower than b_{ext_EC}. The range in monthly mean b_{ext_FD} in the southwestern United States was 0.09 Mm^{-1} in Hawaii in September and 0.31 Mm^{-1} in the San Jose region in May to 3.34 Mm^{-1} in the West Texas region in April. The Sacramento/Central Valley and Las Vegas regions also had higher b_{ext_FD} (2.23 Mm^{-1}) in October. Over half of the southwestern regions experienced their maximum b_{ext_FD} during October and November, while the Front Range CO (1.51 Mm^{-1}), Albuquerque (1.13 Mm^{-1}), and Utah (1.62 Mm^{-1}) regions had maximums in June.

The highest CSN monthly mean contribution of b_{ext_FD} to b_{ext_aer} occurred in the Las Vegas region (0.213) in October. Several CONUS regions had minimum contributions of ~0.003 (Portland, Northwest, and Sacramento/Central Valley). In the eastern United States, the maximum b_{ext_FD} contribution occurred in the Dallas region (0.100) in July. Similar to b_{ext_FD}, regions with the highest maximum b_{ext_FD} contributions (~0.05) occurred in regions influenced by North African dust transport (e.g., East Texas/Gulf, Midsouth, and Florida regions) in July (Figure 5.1.10).

Contributions of b_{ext_FD} to b_{ext_aer} were insignificant in regions in the northwestern United States (Figure 5.1.11). Monthly mean maximum contributions were less than 0.04 in all regions. These occurred in April in the Puget Sound and Portland regions and in June in the Northwest and North Dakota regions.

The lowest minimum monthly mean b_{ext_FD} contribution in the southwestern United States occurred in the Sacramento/Central Valley region (0.003) in January, compared to the maximum of 0.213 in the Las Vegas region in October and the West Texas (0.137) region in May. Other regions in California had low maximum contributions (<0.03), while regions farther south were closer to 0.05–0.07 (e.g., Albuquerque and Phoenix/Tucson) during spring months (Figure 5.12). Of all the urban regions, those in the southwestern United States corresponded to the highest contributions of b_{ext_FD} to b_{ext_aer}.

5.6 $PM_{2.5}$ SEA SALT LIGHT EXTINCTION COEFFICIENTS

SS was treated as a hygroscopic species in the algorithm for computing the reconstructed light extinction coefficient for sea salt (b_{ext_SS}). While SS mass concentrations were relatively low, except in coastal regions, values of b_{ext_SS} were significant in some regions due to hygroscopic effects.

5.6.1 IMPROVE

IMPROVE 2016–2019 regional monthly mean b_{ext_SS} ranged from 0.032 Mm^{-1} in the Central Rockies region in November to 8.81 Mm^{-1} in the California Coast region in June and 11.09 Mm^{-1} in July in the Virgin Islands region. Monthly mean b_{ext_SS} was significant year round in the Virgin Islands region, with estimates over 6 Mm^{-1} (Figure 5.1.1), and the maximum monthly mean b_{ext_SS} was higher than b_{ext_FD} by nearly a factor of 3 due to hygroscopic effects of SS, as well as a higher SS dry extinction efficiency. In the eastern United States, b_{ext_SS} was significantly lower than b_{ext} from other species in most regions (<5 Mm^{-1}) and was barely visible on the bar charts associated with the East Coast, Southeast, and Northeast regions. Maximum monthly mean b_{ext_SS} values in these regions were 3.93 Mm^{-1} (March), 4.67 Mm^{-1} (February), and 2.35 Mm^{-1} (March), respectively.

The Alaska region in the northwestern United States had the highest maximum monthly mean b_{ext_SS} in that area (5.76 Mm^{-1}) in February and had monthly mean b_{ext_SS} over 2 Mm^{-1} year round. The Northwest, Oregon/Northern California, and Columbia River Gorge regions had maximum monthly mean b_{ext_SS} around 2 Mm^{-1} or less (Figure 5.1.2). The maximum b_{ext_SS} occurred in December for the Northern Rockies, Hells Canyon, and Columbia River Gorge regions.

In the southwestern United States, the California Coast region had the highest maximum monthly mean b_{ext_SS} (8.81 Mm^{-1}) that peaked in June, and monthly mean b_{ext_SS} was higher than 2 Mm^{-1} year round (Figure 5.1.3). The Hawaii region also had non-negligible b_{ext_SS}, with monthly mean values that ranged from 1.23 Mm^{-1} (October) to 1.83 Mm^{-1} (April), with low seasonal variability. Other regions in the southwestern United States had maximum monthly mean b_{ext_SS} less than 1 Mm^{-1}.

The fractional contribution of b_{ext_SS} to b_{ext_aer} ranged from 0.0013 in the Hells Canyon region in August to 0.440 in the Alaska region in December. The highest monthly mean contributions occurred outside of CONUS regions: Virgin Islands (0.358, March) and Hawaii (0.197, December). Coastal regions in the eastern United States also corresponded to higher maximum monthly mean contributions, such as the East Coast (0.126) in October, Northeast (0.129) in March, and the Southeast (0.119) in February. Contributions in noncoastal regions in the eastern United States were less than 0.05 (Figure 5.1.4).

Contributions of b_{ext_SS} to b_{ext_aer} in the northwestern United States were also highest at coastal regions, such as the Northwest (0.129) in January, Oregon/Northern California (0.153) in January, and Columbia River Gorge (0.054) in April. In the other regions, the contributions were 0.03 or less year round (Figure 5.1.5).

Similar to other areas, the southwestern United States had the only significant contributions of b_{ext_SS} in coastal regions, such as the California Coast and Hawaii regions. The maximum monthly mean b_{ext_SS} at other regions occurred in the Southern California region (0.055) in January; other regions had contributions of 0.03 or less (Figure 5.1.6).

5.6.2 CSN

The range in b_{ext_SS} in CSN regions was similar to the range for IMPROVE regions, with the lowest in Albuquerque in September (0.012 Mm^{-1}) and the highest regional mean in the Florida region (4.30 Mm^{-1}) in February. In the eastern United States, maximum monthly mean b_{ext_SS} was less than 1 Mm^{-1} in all regions except the Florida region (4.30 Mm^{-1}, February) and the East Texas/Gulf region (2.50 Mm^{-1}) in June (Figure 5.1.7).

Only two regions in the northwestern United States had maximum monthly mean b_{ext_SS} over 1 Mm^{-1}. The Puget Sound (1.32 Mm^{-1}) and Portland (1.08 Mm^{-1}) regions had the highest b_{ext_SS} during December. The monthly mean b_{ext_SS} values are not visible in the bar charts for the other regions (Figure 5.1.8).

Similar magnitudes of b_{ext_SS} occurred in the southwestern United States (Figure 5.1.9), with maximum monthly mean values less than 1 Mm^{-1}, except in the San Jose (3.50 Mm^{-1}) and San Diego regions (1.24 Mm^{-1}), both in April, and the Utah region in December (1.29 Mm^{-1}).

Monthly mean contributions of b_{ext_SS} to b_{ext_aer} ranged from zero in the North Dakota region in April to 0.086 in the San Jose region in April. In the eastern United States the only regions with non-negligible contributions were the Florida region in February (0.104) and the East Texas/Gulf region in June (0.04). All other regions had maximum contributions of 0.01 or less (Figure 5.1.10).

The maximum b_{ext_SS} contribution in the northwestern United States was around 0.02 in the Puget Sound region in December and the Portland region in June. The North Dakota and Northwest regions had maximum mean contributions of 0.002 and 0.005, respectively (Figure 5.1.11).

In the southwestern United States, maximum monthly mean b_{ext_SS} values were ~0.1 or less. The highest occurred in the San Jose region in April (0.086). Other regions had maxima of 0.01 or less (Figure 5.1.12) and were not visible on the regional bar charts.

5.7 COARSE MASS LIGHT EXTINCTION COEFFICIENTS

CM concentrations are estimated routinely by the IMPROVE network and were interpolated to CSN sites from EPA FRM data in order to calculate b_{ext_CM}, b_{ext_aer}, b_{ext_tot}, and dv at CSN sites (see Chapter 2). Therefore, estimates of light extinction coefficients from CM (b_{ext_CM}) for the CSN have additional uncertainty. The extinction efficiency for CM is 0.6 $m^2\ g^{-1}$, and since CM is considered to be nonhygroscopic, b_{ext_CM} is scaled to CM concentrations (see section 4.1). The seasonality of b_{ext_CM} often follows b_{ext_FD}, especially if they have similar sources; differences in seasonality may indicate different sources or perhaps a non-mineral-dust–related composition of CM.

5.7.1 IMPROVE

Values of regional monthly mean b_{ext_CM} ranged from 0.28 Mm^{-1} in the Northwest and Northern Rockies regions in December and January, respectively, to 17.03 Mm^{-1} in the Columbia

River Gorge in June. In the eastern United States, the regional monthly mean b_{ext_CM} ranged from 0.61 Mm^{-1} in the Boundary Waters region in January to 11.25 Mm^{-1} in the Virgin Islands region in July and 5.94 Mm^{-1} and 6.00 Mm^{-1} in the Central Great Plains and East Coast regions, respectively, in June (Figure 5.1.1). The high b_{ext_CM} in the Virgin Islands region was similar in magnitude to b_{ext_SS} during that same month, suggesting that the b_{ext_CM} was most likely related to SS and perhaps dust, as it increased during similar months. Maximum monthly mean values around 4–5 Mm^{-1} occurred during July in regions farther south that were influenced by North African dust transport in summer (Midsouth and Southeast regions). The lowest maximum monthly mean b_{ext_CM} of ~3 Mm^{-1} occurred in the Boundary Waters (June), Appalachia (May), and Northeast (September) regions. Minimum monthly mean b_{ext_CM} values were around 1–2 Mm^{-1} in most regions, with the highest minimum b_{ext_CM} in the Virgin Islands region (4.72 Mm^{-1}) in November. Only the Midsouth and Southeast regions had similar months with monthly mean maximum b_{ext_CM} and b_{ext_FD} (July).

Minimum monthly mean b_{ext_CM} values in the northwestern United States were lower than minimum values in the eastern United States, with several regions having minimum monthly mean values around 0.2–0.5 Mm^{-1}, all in winter months (Figure 5.1.2). In addition to the high value in the Columbia River Gorge region, other maximum values were around 4–5 Mm^{-1} during summer months, roughly a third of that of the Columbia River Gorge region. About half of the regions had b_{ext_CM} maxima during the same months as b_{ext_FD} maxima, except for Alaska (April maximum for b_{ext_FD}, June maximum for b_{ext_CM}) and Columbia River Gorge (July for b_{ext_FD}, June for b_{ext_CM}) and Northern Rockies (August for b_{ext_FD}, July for b_{ext_CM}). Other regions had maxima b_{ext_CM} during August.

Minimum monthly mean b_{ext_CM} occurred during winter months for all regions in the southwestern United States, except the Southern Arizona region (5.13 Mm^{-1} in August; Figure 5.1.3). Other minimum monthly mean values ranged from 0.5 to 3.0 Mm^{-1}. Maximum monthly mean b_{ext_CM} values ranged from 7 to 8 Mm^{-1} in the Sierra Nevada (August), Southern Arizona (November), Southern California (July), and West Texas (April) regions. Maxima in other regions were around 2–4 Mm^{-1} and occurred during summer months. Half of the regions had similar months for maximum b_{ext_CM} and b_{ext_FD} (Central Rockies, Colorado Plateau, Great Basin, Southern California, and West Texas).

Both the minimum (0.018) and maximum (0.506) monthly mean contributions of b_{ext_CM} to b_{ext_aer} occurred in the Columbia River Gorge region in December and June, respectively. In the eastern United States, minimum mean contributions of b_{ext_CM} were around 0.02–0.05, with the highest minimum of 0.20 in the Virgin Islands region (Figure 5.1.4). Contributions were lowest during winter months for all regions, except the Southeast region (April) and the Virgin Islands region (November). The largest maximum monthly mean b_{ext_CM} contribution also occurred in the Virgin Islands region (0.30), but in other regions contributions were around 0.1–0.2, with the Central Great Plains region having contributions of 0.212 in October, perhaps associated with agricultural harvesting. Other contributions were highest during spring and fall months.

In the northwestern United States, contributions from b_{ext_CM} were the highest in the Columbia River Gorge region (0.506 in June), the Northern Great Plains (0.233 also in June), and the Alaska region (0.225) in May (Figure 5.1.5). Other regions had maximum contributions around 0.13–0.18, all in June. Minimum monthly mean contributions ranged from 0.029 (Northwest region in August) to 0.101 (Alaska region in August). Minimum contributions occurred during summer months in the Northwest, Oregon/Northern California, and Alaska regions, perhaps due to the strong contributions from b_{ext_POM} during summer months. Other regions experienced minimum contributions from b_{ext_CM} during winter months.

The lowest monthly mean b_{ext_CM} contributions in the southwestern United States were around 0.09 in the California Coast (January), Central Rockies (August), and Colorado Plateau (January) regions. The lowest contribution in the Hawaii region occurred in March (0.026). Maximum monthly mean contributions ranged from 0.175 in the Central Rockies region in October to 0.372 in the Southern Arizona region in May. Most of the regions had contributions around 0.2 or higher, such as the West Texas region (0.342 in April). For many regions in the southwestern United States, b_{ext_CM} was one of the top third contributors, along with b_{ext_AS} and b_{ext_POM} (Figure 5.1.6).

5.7.2 CSN

The monthly mean b_{ext_CM} interpolated to CSN sites ranged from 0.46 Mm^{-1} in the Northwest region in December to 18.70 Mm^{-1} in the Sacramento/Central Valley region in October. In the eastern United States, minimum monthly mean b_{ext_CM} values were around 2–3 Mm^{-1}, with the highest minimums in the Dallas (4.33 Mm^{-1} in June) and East Texas/Gulf (4.31 Mm^{-1} in December) regions (Figure 5.1.7). Most of the eastern regions had minimum monthly mean b_{ext_CM} during December or January. The maximum monthly mean b_{ext_CM} occurred in the East Texas/Gulf (11.45 Mm^{-1}, July) and Dallas regions (10.11 Mm^{-1} in August), suggesting a large seasonality in those regions. Other maxima ranged from 4 to 5 Mm^{-1}. Values from 6 to 7 Mm^{-1} occurred in the Midsouth (July), Central United States (June), and Chicago (May) regions. Only the Midsouth, East Texas/Gulf, and Florida regions experienced maxima for both in b_{ext_FD} and b_{ext_CM} in July, as well as the Washington D.C./Philadelphia Corridor region in June.

In the northwestern United States, monthly mean b_{ext_CM} minima were around 1–2 Mm^{-1}, with the lowest in the Northwest region and the highest minimum in the North Dakota region (1.78 Mm^{-1}, January, Figure 5.1.8). Monthly mean maximum b_{ext_CM} were around 3–4 Mm^{-1} in most regions, except in the North Dakota region (9.09 Mm^{-1}) in June, perhaps related to agricultural activity. Other regions had maximum b_{ext_CM} during August. This is the same month that b_{ext_FD} was highest in those regions.

The Sacramento/Central Valley region in the southwestern United States had the highest maximum monthly mean b_{ext_CM} in that region (18.70 Mm^{-1}) in October (Figure 5.1.9), also likely related to agricultural activity. Most of the regions in California had maxima in October, and maximum values ranged from 8 to 15 Mm^{-1}. The Phoenix/Tucson region had a maximum monthly mean b_{ext_CM} (10.62 Mm^{-1}) in November, while the maximum monthly mean b_{ext_CM} in Albuquerque region was only 3.47 Mm^{-1}. The Sacramento/Central Valley, Los Angeles, Albuquerque, and West Texas regions all had similar months with monthly mean maximum b_{ext_FD} and b_{ext_CM}.

In CSN regions, the monthly mean b_{ext_CM} contributions to b_{ext_aer} ranged between 0.007 (Northwest region, December) to 0.376 (Phoenix/Tucson region, May). In regions in the eastern United States, b_{ext_CM} contributed from 0.029 (Washington D.C./Philadelphia Corridor region in December) to 0.203 (Dallas region) in April (Figure 5.1.10). Most of the monthly mean maxima were around 0.1–0.2 across eastern regions, and most occurred in late spring to summer months.

The maximum monthly mean b_{ext_CM} contributions in the northwestern United States were similar in magnitude (0.1–0.2), with the largest in the North Dakota region. Other maxima also occurred in June and July (Figure 5.1.11). Lower contributions occurred during winter months, around 0.01–0.05. With the exception of the North Dakota region, contributions of b_{ext_CM} were generally similar to or less than contributions from b_{ext_EC}.

Higher contributions of b_{ext_CM} to b_{ext_aer} were observed in the southwestern United States (Figure 5.1.12). Maximum contributions ranged from 0.158 in the San Jose region in June to 0.376 in the Phoenix/Tucson region in May and 0.356 in the Las Vegas in October. Otherwise, contributions were 0.2–0.3 in most regions. The lowest contributions (~0.02) occurred in the Albuquerque and Utah regions in January, with larger contributions from other species such as b_{ext_AN} and b_{ext_POM}.

5.8 RECONSTRUCTED AEROSOL LIGHT EXTINCTION COEFFICIENTS

The reconstructed aerosol light extinction coefficient (b_{ext_aer}), as defined earlier, is the sum of light extinction coefficients from the previous components discussed above, namely, AS, AN, POM, EC, FD, SS, and CM. Rayleigh scattering is not included but would add roughly 10–12 Mm^{-1} to b_{ext_aer}, depending on the site.

5.8.1 IMPROVE

The 2016–2019 regional monthly mean IMPROVE b_{ext_aer} ranged from 3.61 Mm^{-1} in the Great Basin region in January to 69.48 Mm^{-1} in Columbia River Gorge region in January, where b_{ext_AN} was the major contributor (0.671).

Maximum b_{ext_aer} occurred in both summer and winter months, depending on region (Figure 5.1.1). In the Boundary Waters, Central Great Plains, and Ohio River Valley regions, the maximum monthly mean b_{ext_aer} occurred in December (30–50 Mm^{-1}) and was associated mainly with the contributions from b_{ext_AN}, followed by b_{ext_AS}. These regions also had a peak in b_{ext_aer} in summer months, due to b_{ext_POM} and b_{ext_AS}. In other eastern regions, such as the East Coast, Northeast, and Appalachia regions, the maximum b_{ext_aer} occurred during summer months (~30–40 Mm^{-1}) and was associated with b_{ext_AS} and b_{ext_POM}. The maximum b_{ext_aer} in the Southeast region (66.21 Mm^{-1}) occurred in April and was associated with elevated b_{ext_POM} due to biomass smoke. The maximum b_{ext_aer} in the Virgin Islands region (38.71 Mm^{-1}) occurred in June, with b_{ext_AS}, b_{ext_CM}, and b_{ext_SS} as the major contributors. The lowest minimum monthly mean b_{ext_aer} in the eastern United States occurred in the Boundary Waters region in October (11.88 Mm^{-1}). Many regions experienced the lowest b_{ext_aer} in October (~20–30 Mm^{-1}).

The maximum monthly mean b_{ext_aer} occurred during summer months for all regions in the northwestern United States except the Columbia River Gorge region (January), where the highest monthly mean b_{ext_aer} in the region occurred due to the contributions of b_{ext_AN}. The Oregon/Northern California and Northwest regions also had elevated b_{ext_aer} (67.85 Mm^{-1} and 63.55 Mm^{-1}, respectively) in August due to b_{ext_POM} from biomass smoke (Figure 5.1.2). The lowest monthly mean maximum b_{ext_aer} occurred in the Alaska (26.24 Mm^{-1}) and Northern Great Plains regions (37.83 Mm^{-1}). Minimum monthly mean b_{ext_aer} ranged from ~6 Mm^{-1} (Northern Rockies and Hells Canyon regions in March) to 24.49 Mm^{-1} (Columbia River Gorge region in April).

In the southwestern United States, monthly mean b_{ext_aer} ranged from 3.62 Mm^{-1} in the Great Basin region in January to 62.23 Mm^{-1} in the Sierra Nevada region in August. Maximum b_{ext_aer} occurred in summer months for most of the regions, except for the Southern Arizona region (29.65 Mm^{-1}) in December, due to b_{ext_POM}, b_{ext_EC} and b_{ext_CM} (Figure 5.1.3). For regions farther north, the role of b_{ext_POM} in the summer maxima, along with elevated b_{ext_POM}, indicated the impacts of biomass smoke on b_{ext_aer} in these regions. Farther south, such as in the West Texas region, additional contributions from b_{ext_AS} and b_{ext_CM} led to higher summer maxima (26.97 Mm^{-1}). Regions in California, such as the California Coast (38.30 Mm^{-1}) and Southern California (40.71 Mm^{-1}) regions also had significant contributions of b_{ext_AS}.

5.8.2 CSN

The urban CSN regional monthly mean b_{ext_aer} ranged from 15.40 Mm^{-1} in the Albuquerque region in April to 153.69 Mm^{-1} in the Sacramento/Central Valley region in December, when b_{ext_AN} was the highest contributor. Most urban regional maxima occurred in winter months, along with peaks in b_{ext_AN} and b_{ext_POM}. In the eastern United States, maximum monthly mean b_{ext_aer} occurred during winter months, and most of that was dominated by b_{ext_AN} (Figure 5.1.7). Maxima occurred during summer monthly only in the Midsouth and Florida regions (July). In most eastern regions, smaller peaks in b_{ext_aer} also occurred during summer months, such as in the Northeast region. The highest monthly mean maximum b_{ext_aer} occurred in the Michigan/Great Lakes region in December (78.57 Mm^{-1}), but values greater than 70 Mm^{-1} also occurred in the Chicago and Ohio River Valley regions. Maxima in other regions were around 50–65 Mm^{-1}, with the lowest maximum in the Florida region (41.10 Mm^{-1}).

Regional monthly mean b_{ext_aer} in the northwestern United States ranged from to 17.02 Mm^{-1} to 77.30 Mm^{-1} in the Northwest region in April and January, respectively (Figure 5.1.8). Other minima were around 20–30 Mm^{-1}. Maximum monthly mean b_{ext_aer} occurred during winter months in all regions except for the North Dakota region in March. Contributions from b_{ext_AN} and b_{ext_POM} led to high b_{ext_aer} during winter.

For nearly all regions in the southwestern United States, monthly mean b_{ext_aer} was highest during winter months, with the highest value in the Sacramento/Central Valley region (Figure 5.1.9). Other regions with maxima over 100 Mm^{-1} included the San Jose region (101.43 Mm^{-1}) and the Utah region (111.29 Mm^{-1}). For most winter maxima in b_{ext_aer}, b_{ext_AN} was the major contributor, followed by b_{ext_POM} in most regions. Farther south, contributions from b_{ext_POM} were higher than b_{ext_AN}. The only exception to winter maxima occurred in the Los

Angeles region in June (90.27 Mm^{-1}), where b_{ext_AN}, b_{ext_POM}, and b_{ext_AS} were all major contributors. The lowest maximum (37.77 Mm^{-1}) occurred in the Albuquerque region. Regional monthly mean maximum b_{ext_aer} was higher in the southwestern United States area relative to the eastern and northwestern United States, largely due to the role of b_{ext_AN} and b_{ext_POM} during winter.

5.9 DECIVIEW

Estimates of deciview (dv) include the site-specific Rayleigh scattering coefficient, and therefore the regions corresponding to maximum and minimum dv may differ from b_{ext_aer} described in the previous section.

5.9.1 IMPROVE

Regional monthly mean dv across the network ranged from 2.39 dv in the Central Rockies to 20.98 dv in the Columbia River Gorge region, both in January. In the eastern United States, the monthly mean dv ranged from 8.51 dv in the Boundary Waters region in October to 18.31 dv in the Southeast region in April and 18.16 dv in the Ohio River Valley in December. The high value in the Southeast was likely due to biomass smoke influence. Maxima in summer months occurred in the East Coast (16.55 dv), Appalachia (15.75 dv), and Northeast (14.14 dv) regions.

In the northwestern United States, monthly mean dv ranged from 3.94 dv in the Northern Rockies in January to 20.98 in the Columbia River Gorge, also in January. All other regions in the area had summer maxima in dv, with values ranging from 15 dv to 20 dv. Recall from the previous section that b_{ext_AN} was the major contributor to b_{ext_aer} during winter in the Columbia River Gorge region.

The highest maximum regional monthly mean dv in the southwestern United States occurred in the Sierra Nevada region (19.18 dv) and the lowest maximum in the Colorado Plateau region (9.71 dv), both in August. The minimum monthly mean dv ranged between 2.39 dv in the Central Rockies region in January to 10.76 dv in the California Coast region in February.

5.9.2 CSN

CSN regional monthly mean dv ranged from 9.32 dv in the Albuquerque region in April to 27.80 dv in the Sacramento/Central Valley region in December. The highest maximum monthly mean dv in the eastern United States occurred in the Michigan/Great Lakes region in December. Most of the maxima in the eastern United States occurred during winter months, around 18–20 dv. Summer maxima occurred in the Midsouth and Florida regions (16–18 dv). The lowest maxima occurred in the Florida region (16.50 dv). The lowest minimum monthly mean dv occurred in the Northeast region in April (13.51 dv).

Maximum regional monthly mean dv occurred during winter months in the northwestern United States, with values around 20 (20.92 dv in the Portland region in December and 20.75 dv in the Northwest region in January), except in the North Dakota region (17.73 dv) in March.

Minimum values in the northwestern United States were near 10–14 dv, with the lowest minimum monthly mean dv in the Northwest region (10.04 dv) compared to the highest minimum in the Puget Sound region (14.27 dv), both in April.

In the southwestern United States, monthly mean dv ranged from 9.79 dv (Northwest Nevada in April) to the highest in the Sacramento/Central Valley region. Most of the maximum monthly mean dv occurred during December and January (~15–30 dv) except in the Los Angeles region (23.15 dv, June). The lowest monthly mean maximum values occurred in farther south, such as the Albuquerque (15.64 dv) and West Texas (16.57 dv) regions.

5.10 SUMMARY

The seasonal patterns in b_{ext} corresponding to major aerosol species were similar to the seasonal distributions in mass concentrations presented in the Chapter 3. This similarity was expected for most species because mass concentrations were converted to b_{ext}, with mass extinction efficiencies that essentially just scaled the values to b_{ext}. However, for AS, AN, and SS, the conversion to b_{ext} accounted for relative humidity effects and hygroscopic growth that can be considerable in environments with high relative humidity. No significant differences were observed between the seasonal distributions in mass compared to b_{ext}. Occasionally, the season that corresponded to the majority of the maximum and minimum regional absolute b_{ext} or relative b_{ext} changed for many of the species examined here. In addition, some species that were important for their contributions to RCFM were less important in reconstructed b_{ext_aer} (e.g., FD), while others became more important (e.g., EC, POM, and hygroscopic species). Differences in urban and rural b_{ext_aer} were evident, especially in seasonal patterns. Many of the urban regions had maximum b_{ext_aer} during winter, due to the role of b_{ext_AN} and b_{ext_POM}, whereas many rural areas across the United States experienced maximum b_{ext_aer} during summer months, due to the role of b_{ext_POM} and b_{ext_AS}. The contributions of b_{ext_CM} were important in both urban and rural regions in the southwestern United States.

In both urban and rural regions, monthly mean b_{ext_AS} was higher in the eastern United States, with average maximum values that ranged from 16 to 18 Mm^{-1}. The seasonal range was mostly flat, although with a small increase during summer months for both networks. The similarity in magnitude of b_{ext_AS} suggested regional impacts of b_{ext_AS} on visibility in both urban and rural regions. Average maximum monthly mean values of b_{ext_AS} were similar for both the northwestern and southwestern United States regions, with somewhat higher values for CSN regions (9 Mm^{-1} compared to 6 Mm^{-1}). Maximum values occurred mostly during summer months except in the CSN Alaska region, where maximum b_{ext_AS} occurred during winter months. Contributions of b_{ext_AS} to b_{ext_aer} were higher in rural regions across the United States. In the eastern United States, contributions reached an average maximum of 0.45 for IMPROVE regions and 0.37 for CSN regions, compared to the northwestern United States (0.35 and 0.26 for IMPROVE and CSN, respectively), and the southwestern United States (0.31 and 0.23 for IMPROVE and CSN, respectively).

Regional average monthly mean maximum b_{ext_AN} was higher in urban regions. For all CSN regions, average maximum b_{ext_AN} ranged from 23 to 29 Mm^{-1}, with the highest values in regions in the southwestern United States. Rural estimates varied considerably depending on region, with average maximum values around 13 Mm^{-1} in the eastern United States, compared to 11 Mm^{-1} and 3 Mm^{-1} in the northwestern and southwestern United States, respectively. For nearly all regions, monthly mean maximum b_{ext_AN} was highest during winter months, reflecting favorable formation conditions. Maximum contributions of b_{ext_AN} were similar for urban and rural regions in the eastern and northwestern Untied States (~0.4), but in the southwestern regions, higher contributions occurred in urban (0.36) relative to rural regions (0.23). These contributions were usually higher during winter months, except in some urban and rural regions in the southern part of California that had higher contributions year round.

Discrepancies between urban and rural average monthly mean maximum b_{ext_POM} suggested the importance of different sources in urban and rural areas. The influence of biomass smoke led to high average monthly mean maximum b_{ext_POM} in the rural northwestern United States, with values near 37 Mm^{-1} (IMPROVE) and 27 Mm^{-1} (CSN) and differences in seasonality. Rural areas experienced strong summer peaks in b_{ext_POM} while urban regions often had higher b_{ext_POM} year round and during winter months, suggesting additional urban sources and lower impacts from biomass smoke. The opposite was true for the southwestern United States, where CSN regional mean b_{ext_POM} was higher than in IMPROVE regions (26 Mm^{-1} versus <16 Mm^{-1}). Regional mean b_{ext_POM} was very similar for urban and rural regions in the eastern United States (~16–17 Mm^{-1}), with summer peaks suggesting more regional sources, perhaps related to biogenic emissions. Maximum contributions of b_{ext_POM} to b_{ext_aer} were around 0.35–0.4 in both urban and rural regions in the East. Average maximum contributions were higher in the northwestern United States and higher in IMPROVE regions (0.7 versus 0.5 in CSN regions). Although b_{ext_POM} contributions in urban and rural regions in the southwestern United States were higher than in the East, like in eastern regions they were similar in magnitude (~0.46–0.48).

The largest urban and rural discrepancies were observed for monthly mean maximum b_{ext_EC}. Urban b_{ext_EC} was higher, with values four times higher in the eastern and southwestern United States and over two times higher in the northwestern United States. In most urban regions, b_{ext_EC} was higher during winter months, suggesting urban sources that led to higher b_{ext_EC} relative to summer biomass smoke influence. Contributions from b_{ext_EC} to b_{ext_aer} were also higher in urban regions for all areas. In the eastern United States, regional average urban maximum contributions of b_{ext_EC} were 0.16, compared to 0.09 in rural regions. This range was also observed in the northwestern United States (0.19 versus 0.10) and the southwestern United States (0.22 versus 0.11).

Even with the bias in FD between CSN and IMPROVE networks, the average maximum b_{ext_FD} was similar (~1–2 Mm^{-1}) at urban and rural regions across the United States. The highest monthly mean urban b_{ext_FD} occurred in regions in the eastern and southwestern United States (1.6–1.7 Mm^{-1}), while rural regions experienced maximum b_{ext_FD} in the southwestern United States, a region known to experience frequent dust impacts. The role of FD in visibility is reduced relative to its contributions to RCFM because FD is less efficient at scattering light due to its larger size. Visibility impacts of b_{ext_CM} were higher than b_{ext_FD} due to its greater mass, even though it has an even lower mass scattering efficiency (0.6 m^2g^{-1} versus 1 m^2g^{-1}). Average monthly mean maximum b_{ext_CM} values were similar for urban and rural regions and were around 5–6 Mm^{-1}, except in the southwestern U.S. urban regions where the average maximum urban

b_{ext_CM} was 9 Mm^{-1}, due to higher values near the Central Valley. Contributions from b_{ext_CM} were similar in urban and rural regions (0.15–0.25) and were higher for both in regions in the southwestern United States.

Visibility impacts of b_{ext_SS} were low, except in coastal regions. For both urban and rural regions, the average monthly mean maximum b_{ext_SS} was 1–2 Mm^{-1}, even with the large bias between the CSN and IMPROVE. Average contributions of b_{ext_SS} to b_{ext_aer} in CSN regions were 0.01–0.02 and were somewhat higher in rural regions (0.05–0.07).

Finally, reconstructed b_{ext_aer} estimates suggested higher visibility impacts in urban regions. In the eastern United States, average maximum b_{ext_aer} was ~62 Mm^{-1}, around 20 Mm^{-1} greater than in IMPROVE regions, and dv values ranged from 16 (IMPROVE) to 20 (CSN). For rural regions, average maximum monthly mean b_{ext_aer} was highest for regions in the northwestern United States (~57 Mm^{-1}) but somewhat lower than in urban regions (64 Mm^{-1}) in the same area (dv values were 19 and 20 for IMPROVE and CSN, respectively). While average maximum b_{ext_aer} was highest for urban regions in the southwestern United States (76 Mm^{-1}, 21 dv), it was lowest in rural regions in the same area (33 Mm^{-1}, 14 dv).

In both urban and rural regions, the role of b_{ext_AN} and b_{ext_POM} were very important, often driving the seasonality of the maximum b_{ext_aer} due to the seasonality of specific sources (e.g., biomass smoke) or during periods with favorable formation conditions (e.g., b_{ext_AN}). However, b_{ext_AS} was within the top third contributing species in most regions, in part due to its hygroscopic nature, and was still an important contributor to b_{ext_aer}.

Appendices associated with this chapter include tables of regional monthly mean b_{ext} for IMPROVE and the CSN (5.1) and tables of b_{ext} fraction for IMPROVE and the CSN (5.2).