SI 1. EESI sources comparison to external sources

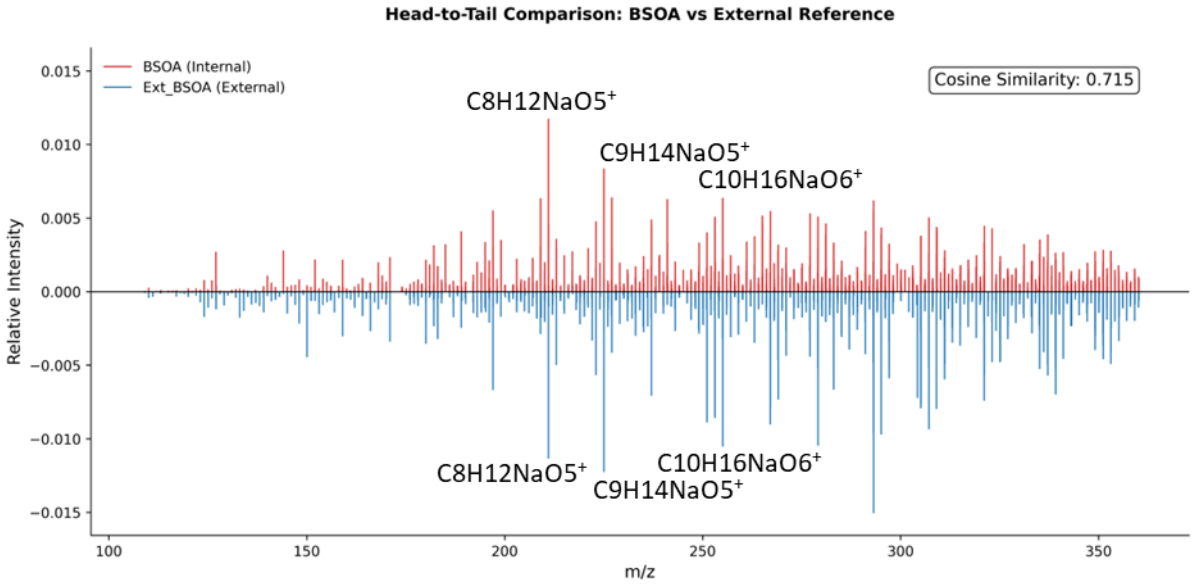


Figure S1. BSOA mass spectrum from the present study in comparison to a BSOA mass spectrum found for North India by (Hao et al., 2025)

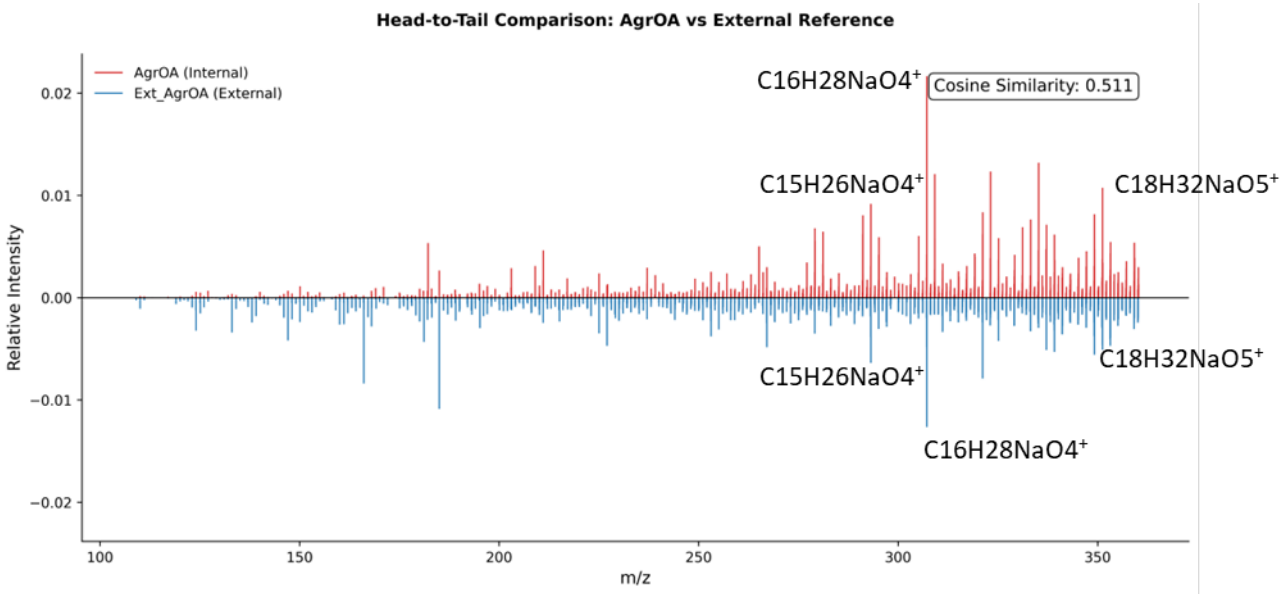


Figure S2. FireOA mass spectrum from the present study in comparison to a mass spectrum related to aged OA from agricultural fires found for North India by (Hao et al., 2025)

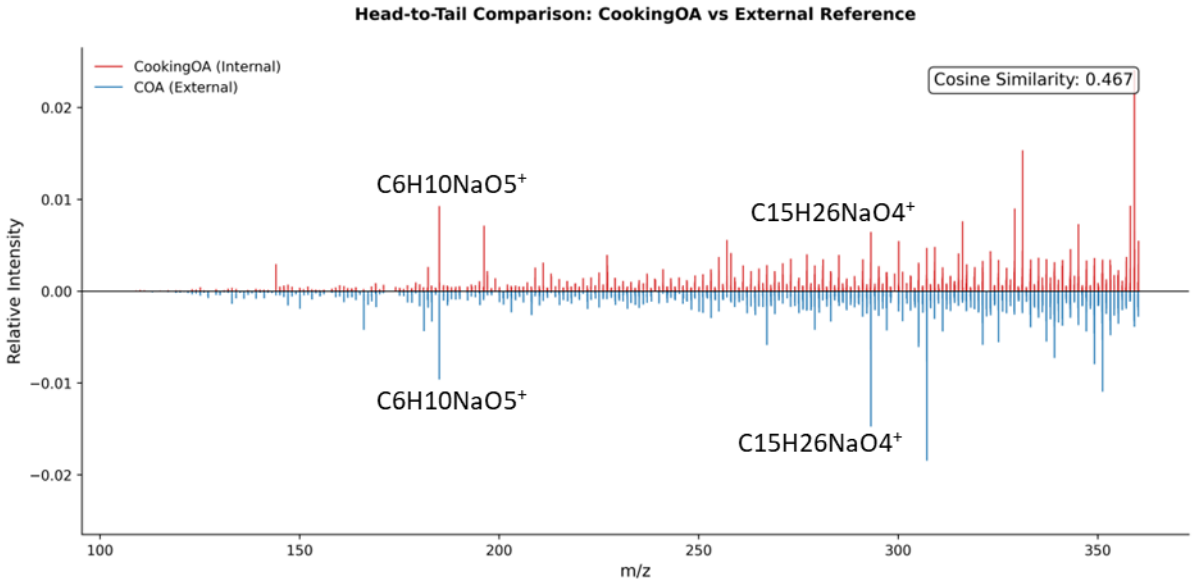


Figure S3. Background OA mass spectrum from the present study in comparison to the mass spectrum of laboratory generated cooking emissions (BBQ cooking)

Table S1. Data validation and Factor timeseries correlation matrix (R Pearson) vs externally measured data.

Correlation matrix		External Measurement										
		Nitrate	Sulfate	Levoglucosan	Phthalic acid	Pinic acid	Hydroxyglutaric acid	Glucose	Mannitol	Hydroxybenzoic acid	MBTCA	PM2.5 fires
EESI Measurement	Nitrate	0.82	-	-	-	-	-	-	-	-	-	-
	Sulfate	-	0.93	-	-	-	-	-	-	-	-	-
	Levoglucosan	-	-	0.73	-	-	-	-	-	-	-	-
Factors	PBOA	-0.21	-0.17	0.02	0.03	-0.25	-0.08	0.63	0.55	0.00	-0.05	0.01
	BSOA	0.55	0.40	0.31	0.74	0.63	0.72	0.00	-0.15	0.37	0.59	0.59
	FireOA	0.73	0.37	0.43	0.66	0.48	0.45	-0.13	-0.23	0.64	0.38	0.73
	dSFOA	0.80	0.40	0.58	0.68	0.52	0.49	-0.07	-0.17	0.79	0.43	0.63
	wSFOA	0.11	-0.12	0.43	0.45	0.16	0.03	0.59	0.53	0.35	0.19	-0.54
	BackgroundOA	-0.14	0.02	0.04	-0.40	-0.31	-0.18	-0.46	-0.29	-0.33	-0.40	-0.04
	HOA	0.66	0.44	0.31	0.69	0.41	0.44	0.20	0.06	0.55	0.40	0.37

Table S2. Sources timeseries (R Pearson) correlation matrix

Correlation matrix		Factors						
		PBOA	BSOA	FireOA	dSFOA	wSFOA	BackgroundOA	HOA
Factors	PBOA	1	-0.12	-0.19	-0.16	0.38	-0.39	0.04
	BSOA	-0.12	1	0.54	0.58	-0.02	-0.14	0.48
	FireOA	-0.19	0.54	1	0.57	-0.1	-0.01	0.54
	dSFOA	-0.16	0.58	0.57	1	0.2	-0.17	0.6
	wSFOA	0.38	-0.02	-0.1	0.2	1	-0.28	0.4
	BackgroundOA	-0.39	-0.14	-0.01	-0.17	-0.28	1	-0.19
	HOA	0.04	0.48	0.54	0.6	0.4	-0.19	1

SI 2. Carbon number distribution plot

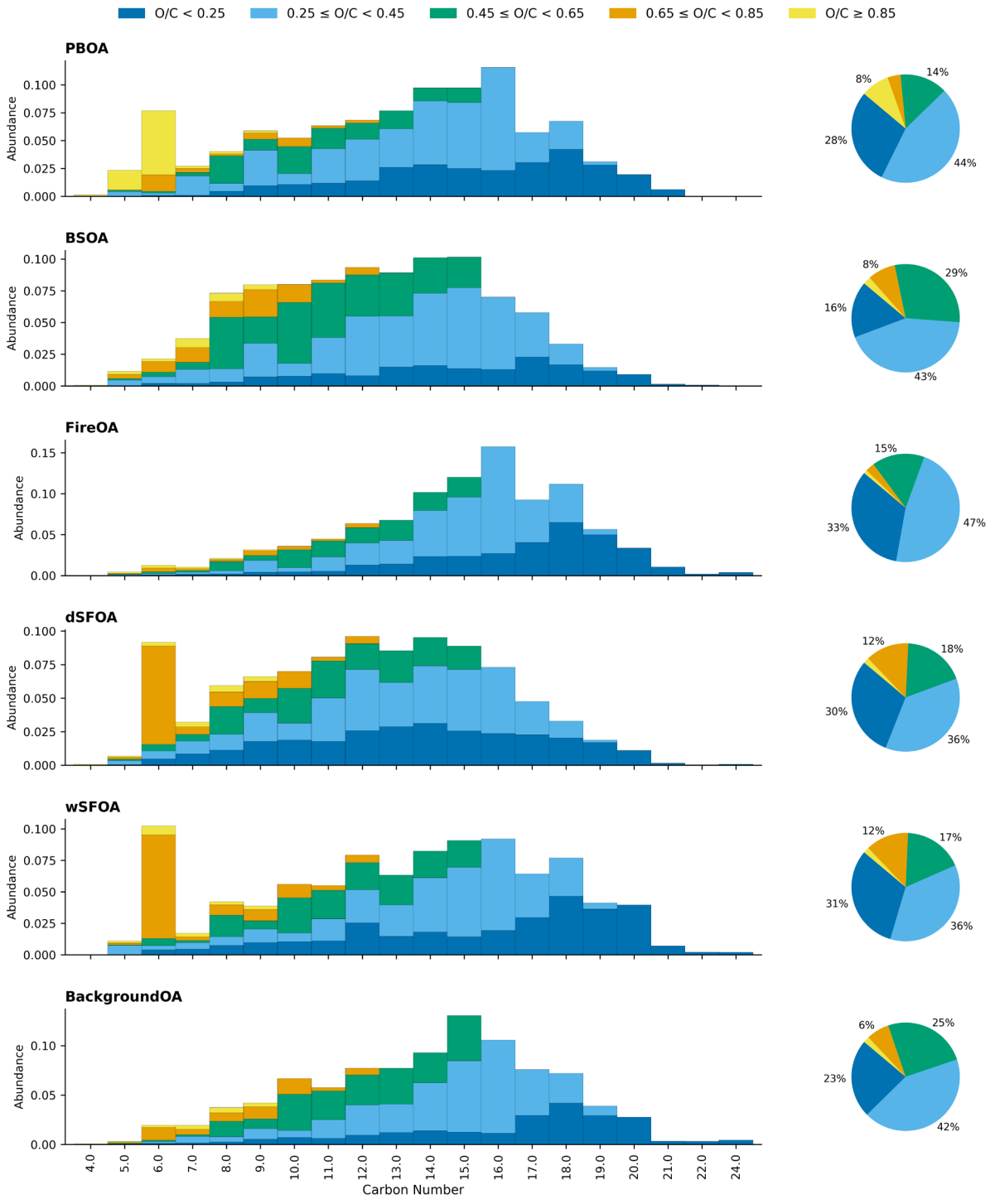


Figure S4. Carbon number distribution plot with O:C ratios for all CHO compounds of the PMF-derived OA types based on EESI-ToF data.

SI 3. Data Validation

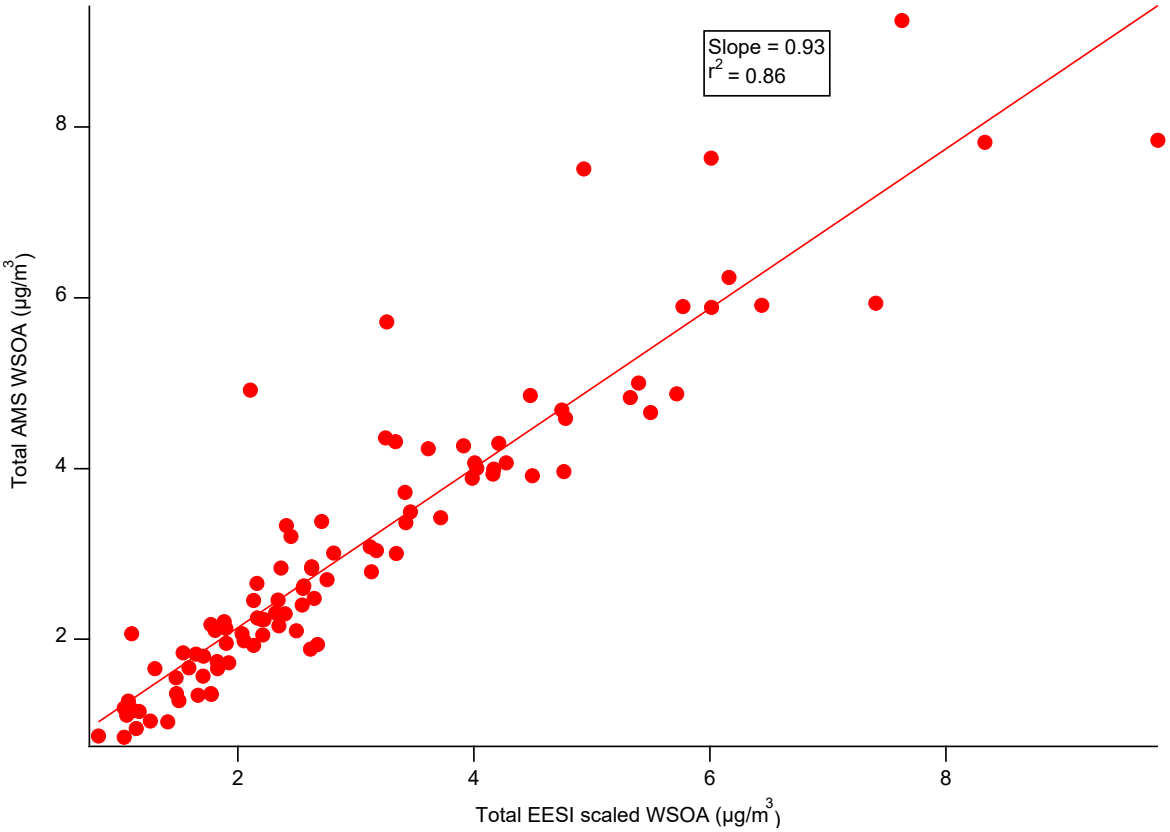


Figure S5: Total water-soluble organic aerosol (WSOA) from the AMS vs total EESI scaled WSOA correlation plot

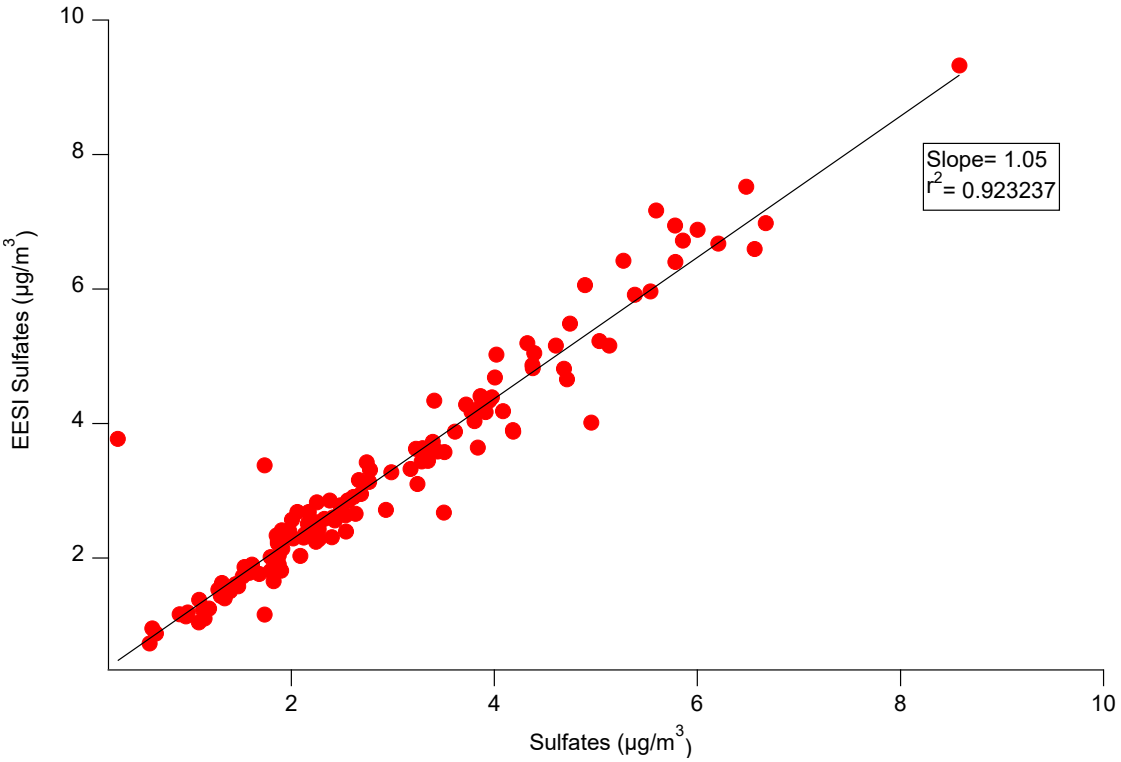


Figure S6: Total Sulfates measure by the EESI-ToF vs external sulfates correlation plot (Nguyen et al., Chemical Characterization of PM_{10} in aTropical Megacity: Seasonal Variations and Organic Matter Contributions in Ho Chi Minh City, Vietnam. Under review in Atmospheric Environment, 2026)

SI 4. Details on EESI-ToF ion filtering:

- Stage 1: Deleting empty columns

After field blank subtraction, ions with positive concentration in 50% fraction of the samples or more were retained and other ions removed.

- Stage 2: Deleting ions by sample to water blank ratio

Ions were retained if their concentrations exceeded water blank levels by at least a factor of 1.5 in more than 60% of samples, this ensures significantly higher concentrations of the ions above background water contamination.

- stage 3: Deleting ions by sample to field blank ratio

Sample to field blank ratio was calculated, then ions with ratio > 2 in more than 40% of the samples were retained. This stage ensures all background noisy ions related to field conditions are excluded.

- stage 4: signal to noise ratio limit (S/N)

After field blank subtraction and related uncertainty propagation, ions were subjected to signal to noise ratio filtration. S/N ratio was calculated by dividing signal to its error. Ions are kept if their 95th percentile is above the S/N ratio limit of 8.5.

- stage 5: filtering inorganic ions

Inorganic measured ions are removed as they can interfere and affect directly the PMF output results with their high intensity.

SI 5. PMF bootstrap runs filtration

The figure shows the Pearson correlation coefficients between the time series of each PMF bootstrap run and the corresponding base run source. For sources where all bootstrap runs yielded an R>0.8, the full set of runs was retained due to their high similarity. For sources with a broader range of correlation values, we selected bootstrap runs starting from the approximate inflection point of the similarity curve, which is in our case approximated around R=0.7, thereby excluding runs with substantially lower similarity to the base solution.

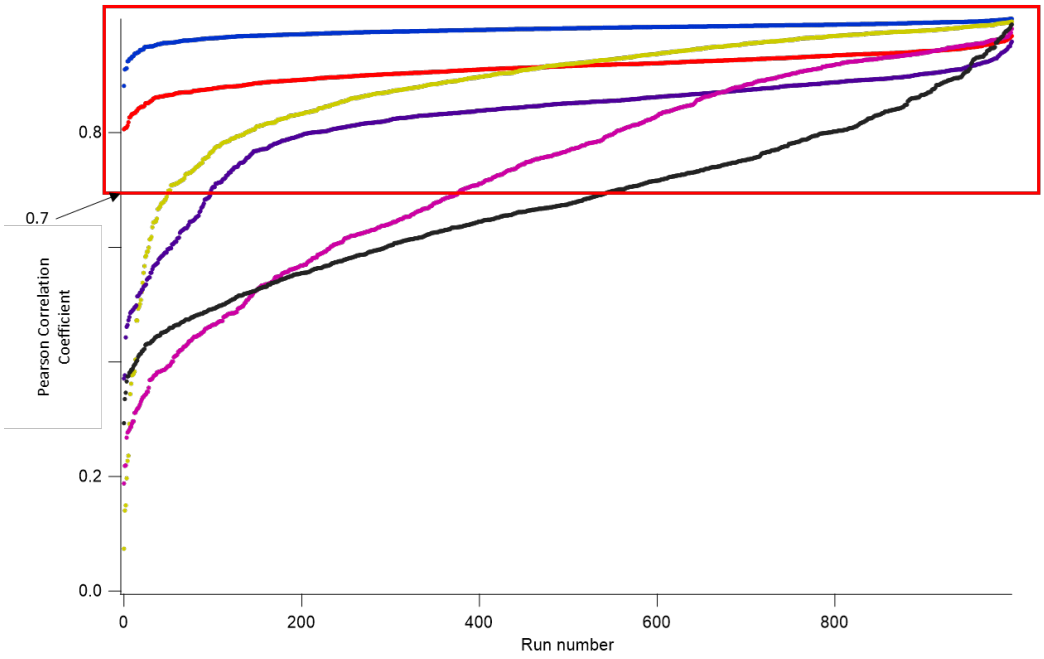


Figure S7: Variation of R Pearson correlation between base case sources and bootstrapped sources in each PMF run with the run number, with the acceptance limit highlighted with the red box

SI 6. HOA Estimation:

Since near-molecular characterizations were performed based on the water-soluble OA, water-insoluble Hydrocarbon-like Organic Aerosol (HOA) related to liquid fossil fuel combustion from traffic could not be quantified directly. For this reason, HOA had to be estimated from a combination of our EESI-ToF data combined with some external measurements data.

We adopted an approach to estimate HOA detailed previously in (Hao et al., 2025). Briefly, measured elemental carbon (EC) can be described as the sum of fossil-fuel EC (EC_{ff}) and non-fossil EC (EC_{nf}). EC_{nf} is primarily emitted from biomass burning, thus Levoglucosan measured externally can be helpful for such estimation. We assumed EC to be the sum of fossil fuel component (EC_{ff}) and a non-fossil component (EC_{nf}) ($EC = EC_{ff} + EC_{nf}$) and used levoglucosan to separate the two depending on their time series. This requires two assumptions about levoglucosan: that it is emitted only by non-fossil combustion, we assume that ($\frac{Levoglucosan}{EC_{ff}} = 0$). EC_{nf} was estimated using a fixed ($\frac{levoglucosan}{EC_{nf}}$) ratio of 0.54, taken from (Hao et al., 2025) for India, since no equivalent ratio has been established for Vietnam. We note that using levoglucosan as an EC_{nf} marker involves uncertainties, given levoglucosan's chemical depletion in the atmosphere.

Second, following (Crippa et al., 2013), $\left(\frac{OC}{EC}\right)_{HOA}$ was fitted as part of the MLR. We find an $\left(\frac{OC}{EC}\right)_{HOA}$ value of 0.93 ± 0.13 similar to India (0.6) (Bhattu et al., 2024), accounting for HOA's RIE being different from other OA types, following RIE correction factor (0.4) from (Daellenbach et al., 2024). Finally, HOA was then calculated as HOC* $\left(\frac{OA}{OC}\right)_{HOA}$ where $\left(\frac{OA}{OC}\right)_{HOA} = 1.21$ derived from (Mohr et al., 2012).

Table 3: Comparison of Solubilities and $\frac{HOC}{EC_{ff}}$ values from different MLR runs, including the fitted approach used for $\left(\frac{OC}{EC}\right)_{HOA}$ to the usage of the standard value of 0.6 from India (Bhattu et al., 2024), followed by OM:OC ratios for each of the sources identified.

	PBOA	BioSOA	FireOA	dSFOA	wSFOA	BackgroundOA	hoc/Ecf
	Solubilities						
ratio fitted	0.2 ± 0.02	0.876 ± 0.08	0.72 ± 0.3	0.25 ± 0.03	0.17 ± 0.01	0.35 ± 0.03	0.93 ± 0.13
India standard value	0.239	0.9	0.67	0.3	0.17	0.4	0.6
OM:OC ratio	2.832	2.179	2.948	2.306	1.238	2.408	-

SI 7. A-value selection

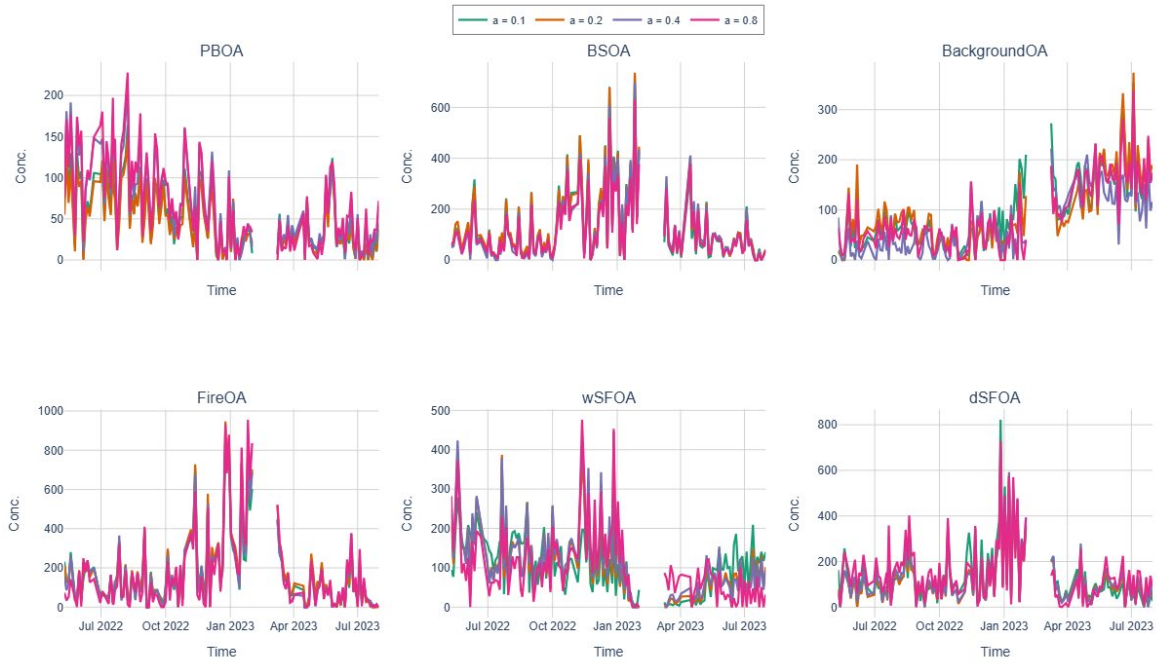


Figure S8: Sources timeseries change with a-value variability

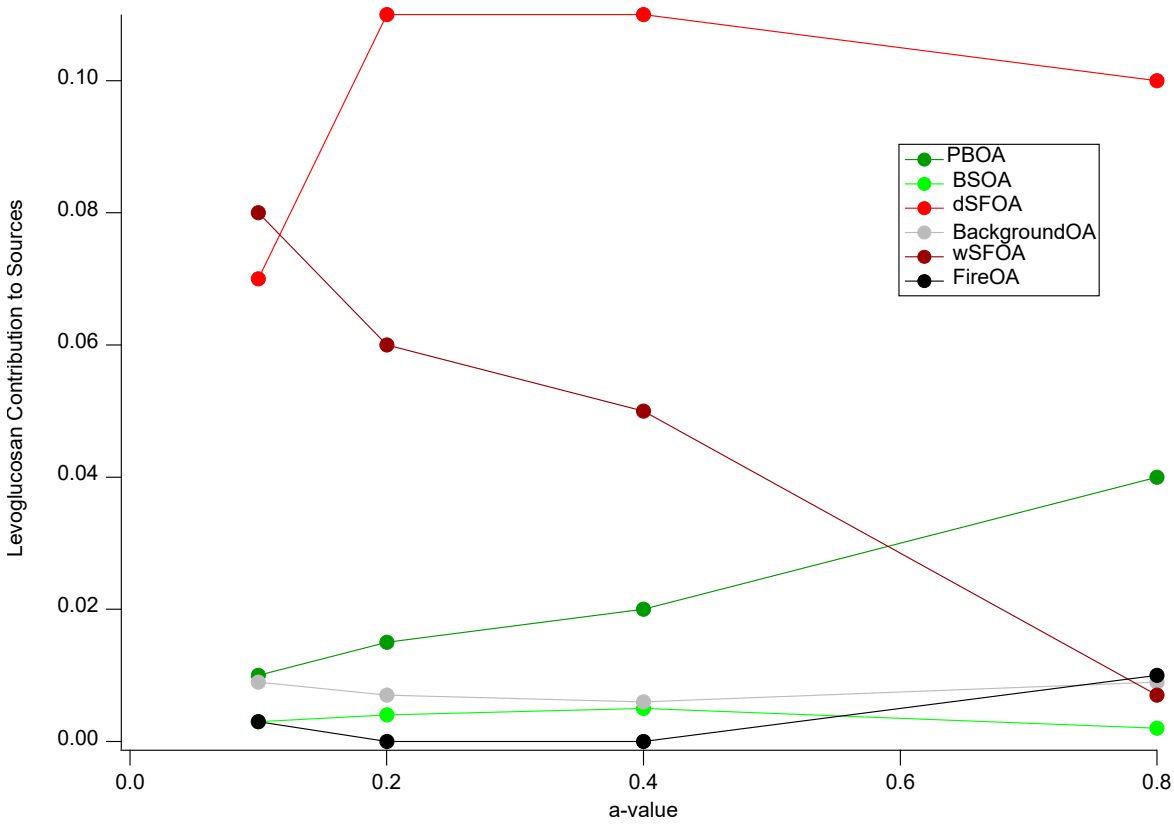


Figure S9: Variation of $C_6H_{10}O_4$ contribution to sources with distinct a-values

SI 8. Measurement techniques

Instrument used	Analyzed tracers
Shimadzu Total Organic Carbon (TOC) Analyzer	Water soluble organic carbon (WSOC)
Sunset Laboratory analyser	OC, EC
ThermoFisher INTEGRION + ISQ EC MS	Inorganic ions and cations
ThermoFisher ICS 5000+ High-Performance Liquid Chromatography followed by pulsed amperometric detection (HPLC-PAD)	Anhydro-sugars (including levoglucosan, mannosan, and galactosan), sugar alcohols (arabitol and mannitol), and saccharides (glucose and trehalose)

SI 9. Description of analytical methods

This is referenced from Nguyen et al., 2026 (submitted) from IGE, France

All the following analyses were carried out at IGE at the Air-o-Sol analytical platform. The field blanks were subjected to the same preparation and analytical procedures as the collected samples. The average concentrations from these field blanks were subtracted from the analytical results of each chemical species to obtain atmospheric concentration levels.

EC-OC

Organic carbon (OC) and elemental carbon (EC) were analysed with a Sunset Laboratory analyser following the EUSAAR2 (European Supersites for Atmospheric Aerosol Research) thermo-optical protocol (Cavalli et al., 2010) and according to the recommendations of the EN 16909 European standard. To adapt to these highly loaded filters, the EUSAAR2 method was slightly adapted, with OC4 temperature plateau extended by 120 s and EC4 extended by 40 s. A punch of 1 cm^2 was used, and automatic split time was generally selected in order to differentiate between EC and OC. In case of negative pyrolytic fraction (often occurring for high dust content – 60 samples affected out of 133), split time was defined as the O_2 introduction time, to get a null value for pyrolytic fraction. Quality control was verified periodically: sucrose calibration (5 points) and accuracy verification with reference

material filter from Sunset Laboratory every 3 months (OC and EC certified), homemade QC rooftop filter and blank filter every week, and daily sucrose filter for OC quantification correction.

Ions, Sugars & Organic acids

A solid/liquid extraction was performed on 3 punches of 18 mm diameter of quartz filter soaked in a 10 mL of ultra-pure water under vortex agitation for 20 min at 1000 rpm. The extract was then filtered with a pre-rinsed 0.2 µm sterile filter (15 mm, Rotilabo, Roth).

The aqueous extract was analyzed at IGE to determine the concentration of approximately 11 soluble inorganic anions and cations, including nitrate, chloride, phosphate, sulfate, sodium, ammonium, potassium, magnesium and calcium, as well as about thirty light organic acids (C1 - C7). This analysis was carried out using dual ion chromatography coupled to mass spectrometer (IC-MS) device ThermoFisher INTEGRION + ISQ EC MS detection on the anion line connected to the AS/AP autosampler for sequential 100 µL injection, with separation on an AG11HC-4 µm column and AS11HC-4 µm 2 mm pre-column for the anions and CG16-4 µm and CS16-4 µm 2 mm for the cations. The eluants are KOH produced from integrated cartridge for the anions and isocratic manually mixed MSA for the cations. The anions run includes a 1 – 48 mM gradient of KOH and lasts 37 minutes, at a flow rate of 0.38 ml/min. The cations run is isocratic and lasts 35 min, at a flow rate of 0.16 ml/min. Both lines include classical eluant auto regenerated suppressors from the IC ThermoFisher instruments. The detection is performed with conductivity for the inorganic anions and cations, and with the MS for the organic acids, in the negative ion polarity mode (-2700V) in SIM mode tuned for each species. External calibration is performed with authentic standard solutions prepared weekly and analyzed every 40 samples, with 6 points with species concentrations adapted to the common concentrations encountered in atmospheric PM samples. Limit of detection is lower than 3 ng m^{-3} for major ions and lower than 0.1 ng m^{-3} for organic acids. Procedural and analytical error is lower than 10% for major ions and 15% for organic acids.

Anhydro-sugars (including levoglucosan, mannosan, and galactosan), sugar alcohols (arabitol and mannitol), and saccharides (glucose and trehalose) were detected and quantified in the aqueous extract at IGE using a ThermoFisher ICS 5000+ High-Performance Liquid Chromatography followed by pulsed amperometric detection (HPLC-PAD) equipped with a 4 mm diameter Metrosep Carb 2 column (150 mm, Metrohm) and 50 mm pre-column in isocratic mode with 15% of an eluant of sodium hydroxide (200 mM) and sodium acetate (4 mM) and 85% water, at 1 mL min^{-1} (Samaké et al., 2019; Waked et al., 2014). Quantification was based on 6 points external calibration performed with authentic standard solutions prepared freshly before analysis, with species concentrations adapted to the common concentrations encountered in atmospheric PM samples. Quality control was checked using homemade standard mix for reproducibility and with SRM2786 extracts for accuracy. Procedural and analytical errors are lower than 10%. This method is described in details in Annex A.2 of the CEN/TC 264 (2024) standard.

SI. 10 Laboratory-generated Cooking OA

POA from cooking was generated by barbecuing sausages (purchased locally in Switzerland) over hot charcoal coals. During the initial phase the organic aerosol mass was ~50 µg m^{-3} coming from the coals, and sampling via 2 injection diluters (Dekati) providing a dilution of 100x. When the meat began to

drip into the hot coals the organic aerosol mass increased to 1,000 – 2,000 µg m^{-3}, which is when the filters were collected after a single injection diluter. Samples also included field blanks. EESI analysis was performed following the same steps as the ambient samples, as explained above. The filters were treated and analyzed in the same way as the real samples.

References:

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Nguyen et al., Chemical Characterization of PM10 in a Tropical Megacity: Seasonal Variations and Organic Matter Contributions in Ho Chi Minh City, Vietnam. Under review in Atmospheric Environment, 2026