Supporting Information

Measurement report: Simultaneous measurement on atmospheric gas- and aerosol-phase water-soluble organics in Shanghai: Remarkable increase in light absorbing of Asian dust aerosols during long-range transport

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Text S1 Detailed description of the instruments

The ambient air was sampled and separated by a $PM_{2.5}$ sharp cut cyclone with a flow rate of 16.7 L/min. Then, the air was drawn through the passageway between the inner and outer Pyrex glass tubes in wet annular denuder (WAD) system. In WAD system, gaseous samples were wetted with pure water and collected. Scrub and Impact Aerosol Collector (SCI) was placed downstream of the WAD for collecting aerosol phase samples. The gas and aerosol samples were subsequently injected into the ion chromatography (ICS-5000+, Themo Scientific) for analysis of water-soluble inorganic ions and small molecular organic acids after removing the insoluble species and bubbles.

The gas and particle-phase water-soluble organic carbon and water-soluble organic nitrogen (WSOC/WSON) were simultaneous determined by using a TOC/TN analyzer (TOC-L CPH, Shimadzu, Japan). The concentrations of WSOC were calculated as the difference between water-soluble total carbon (WSTC) and water-soluble inorganic carbon (WSIC). Similar, the concentrations of WSON were calculated as the difference between water-soluble total nitrogen (WSTN) and water-soluble inorganic nitrogen (WSIN).

Organic carbon (OC) and elemental carbon (EC) were determined by DRI Model 2015 Carbon Analyzer (Atmoslytic, Inc., Calabasas, USA) with IMPROVE_A protocol (Chow et al., 2007).

Text S2 Measurement of organic aerosol in filter samples

Organic compounds including nitroaromatic compounds (NACs) were analyzed by using gas chromatography mass spectroscopy (GC/MS, Agilent Co.). One quarter of filter was extracted with the mixture of methanol and dichloromethane (*v*:*v*, 1:2). After ultrasonic extraction, the extracts were concentrated to dryness and reacted with 50 μL

N,O-bis-(trimethylsilyl)trifluoroacetamide (BSTFA) with 1% trimethylsilyl and 10 μL of pyridine at 70 °C for 3 h. Then, the extracts were analyzed by GC/MS. The detected compounds recoveries were better than 85%. In this study, only four NACs were determined, which are 4-nitrophenol (4NP), 2-methoxy-4-nitrophenol (4NGA), 2-methoxy-5-nitrophenol (5NGA), and 5-nitrosalicylicylic acid (5NSA).

One quarter of filter was used to analyze imidazoles (IMs). More information about this analysis method can be found in our previous study (Liu et al., 2023). Herein, total of eight IMs were determined, including 2-mechtlimidazole, 4(5)-methylimidazole, 1-ethylimidazole, 2-ethylimidazole, 1-phenylimidazole, 2-phenylimidazole, 2-imidazolcarboxaldehyde and 4-imidazolcarboxaldehyde. The details of the analytical method can be found in our previous studies (Wang et al., 2006; Liu et al., 2023; Liu et al., 2024).

Text S3 Absorption spectra of water-soluble BrC analysis

The light absorption spectra of the water-soluble BrC was measured by a UV-vis spectrometer (T6 New Century, Persee) over a wavelength range of 200 − 900 nm (Wu et al., 2024). The light absorption coefficients (Abs_λ, M m^{-1}) of the water extracts was calculated by eq (1).

$$Abs_\lambda = (A_\lambda - A_{700}) \frac{V_l}{V_a \times l} \times \ln(10) \quad (1)$$

where A_λ and A_{700} represent the light absorption at the wavelengths of λ and 700 nm measured by the UV-vis spectrometer. V_l refers to the volume of solvent extract. V_a refers to the sampling volume and l corresponds to the path length of the cell (1 cm).

The mass absorption coefficient (MAC_λ, m^2 g^{-1}) of the extracts at the wavelength of λ can be quantified as eq (2)

$$MAC_\lambda = \frac{Abs_\lambda}{M} \quad (2)$$

where M represent the concentration of WSOC.

Text S4 Contribution of organic matter to aerosol liquid water content (ALWC)

Here we used the ALWC calculation method reported by Lv et al (2022b; 2022a). The contribution of organic matter (OM) to ALWC ($ALWC_{org}$) were defined as the following eq (3)

$$ALWC_{org} = \frac{[OM]\rho_W}{\rho_{org}} \frac{\kappa_{org}}{\frac{1}{RH}-1} \quad (3)$$

where OM is the mass concentration of organics, ρ_w is the density of water, ρ_{org} is the density of OM (1.4 g cm^{-3}). κ_{org} is the hygroscopicity parameter of OM (0.06).

Table S1. Relative abundances (%) of ammonium, nitrate, and sulfate in $PM_{2.5}$ or PM_{10} during dust storm periods in different regions of China.

Sampling site		Sampling time	NH_4^+	NO_3^-	SO_4^{2-}	Type	Reference
Desert region	Tengger	03, 2023	0.03	0.5	4.1	PM_{10}	This study
	Taklimakan	04, 2008	-	0.3	4.2	$PM_{2.5}$	(Wu et al., 2012)
Upwind region	Tongyu	04-06, 2006	0.18	1.26	2.43	$PM_{2.5}$	(Shen et al., 2011)
	Yulin	2006-2008	0.45	0.81	3.53	$PM_{2.5}$	(Wang et al., 2011)
Downwind region	Shanghai	10, 2019	3.8	10.1	6.4	$PM_{2.5}$	(Wu et al., 2020)
	Shanghai	03-04, 2023	3.3	8.1	5.3	$PM_{2.5}$	This study

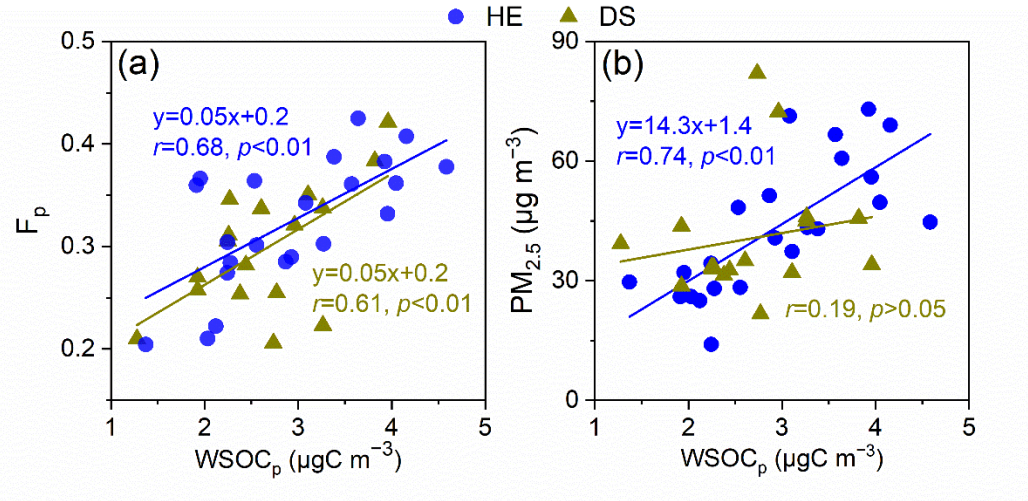

Figure S1. Linear regression analysis for $WSOC_p$ with (a) partitioning coefficient of WSOCs (F_p) and (b) $PM_{2.5}$ during the haze event (HE) and dust storm (DS) event, respectively

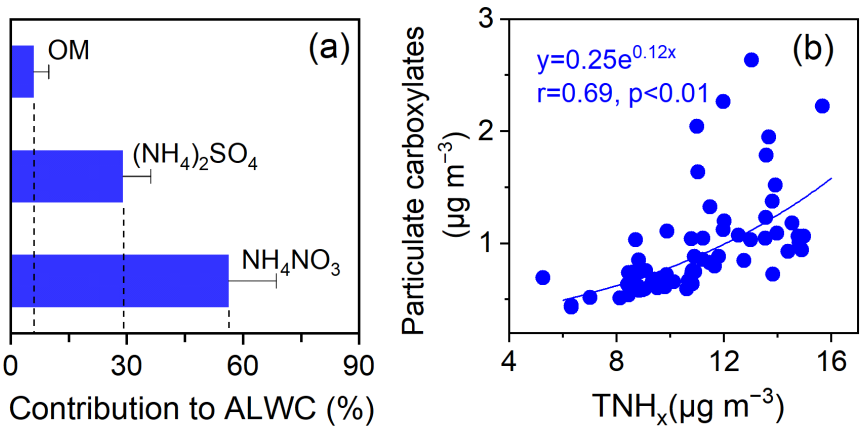

Figure S2. (a) Contributions of NH_4NO_3, $(NH_4)_2SO_4$ and OM to ALWC in the haze event (HE); (b) Particulate carboxylates as a function of TNH_x in the haze event (HE).

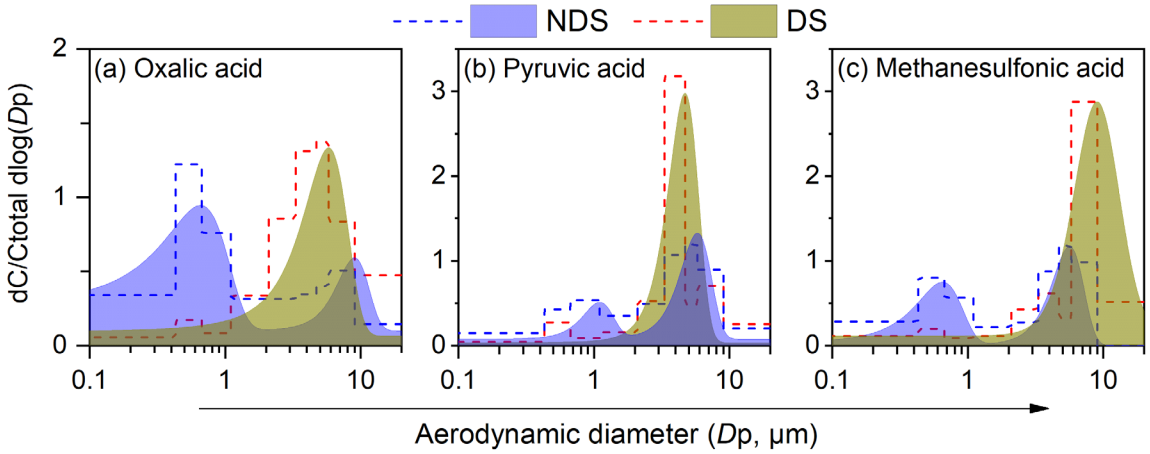

Figure S3. Size distribution of (a) oxalic acid, (b) pyruvic acid and (c) methanesulfonic acid during the non-dust storm (NDS) and dust storm (DS) events in Shanghai.

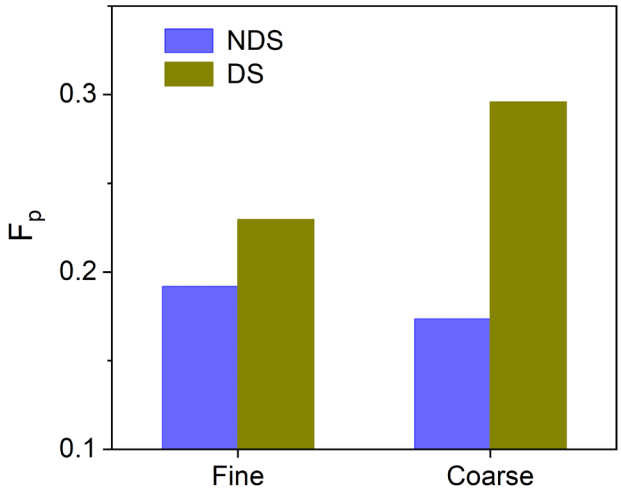

Figure S4. The partitioning coefficients (F_p) of WSOCs in the fine (<2.1μm) and coarse (>2.1μm) in the non-dust storm (NDS) and dust storm (DS) periods in Shanghai during spring of 2023.

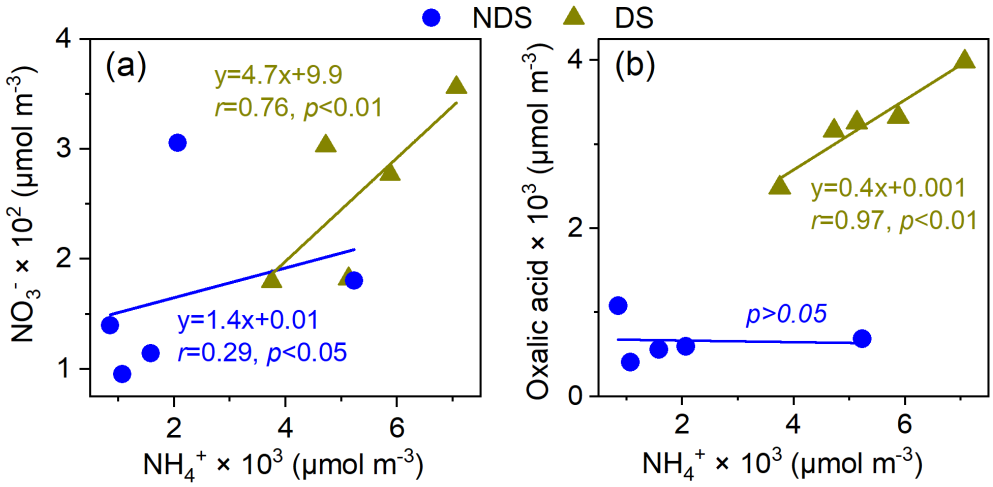

Figure S5. Liner fit regression for the NH_4^+ with (a) NO_3^- and (b) oxalic acid in coarse mode (>2.1 μm) of particles in the non-dust storm (NDS) and dust storm (DS) periods in Shanghai during spring of 2023.

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