AGU PUBLICATIONS

Journal of Geophysical Research: Atmosphere

Supporting Information for

The impacts of dust storms with different transport pathways on aerosol chemical compositions and optical hygroscopicity of fine particles in the Yangtze River Delta

Xiaorui Song[1], Yuying Wang[1], Xin Huang[1], Yuxiang Wang[1], Zhanqing Li[2], Bin Zhu[1], Rongmin Ren[3], Junlin An[1], Jiade Yan[1], Rui Zhang[1], Yi Shang[1], Puning Zhan[1]

[1]Key Laboratory for Aerosol–Cloud Precipitation of China Meteorological Administration, Nanjing University of Information Science & Technology/Special Test Field of National Integrated Meteorological Observation, Nanjing 210044, China.
[2]Department of Atmospheric and Oceanic Science, University of Maryland, College Park, Maryland 20740, USA.
[3]State Key Laboratory of Remote Sensing Science, College of Global Change and Earth System Science, Beijing Normal University, Beijing 100875, China.

Contents of this file

Figures S1

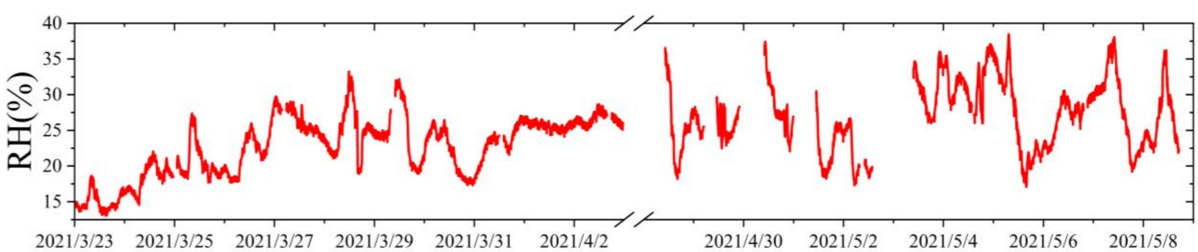

Figure S1. The time series of RH in the dry nephelometer.

Figures S2

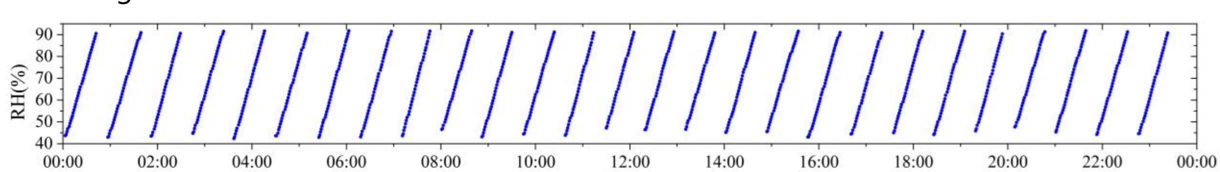

Figure S2. An example of a whole day RH cycle on 24 March 2021 in the dual-nephelometer system.

Figures S3

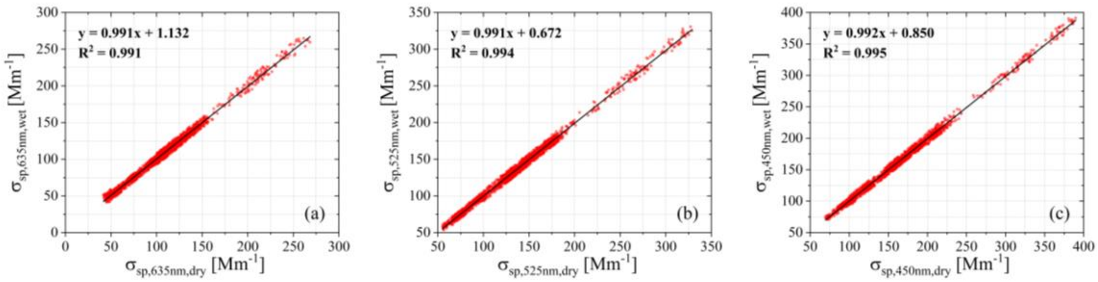

Figure S3. Results of parallel experiments of two nephelometers at dry condition in two and a half days.

Figures S4

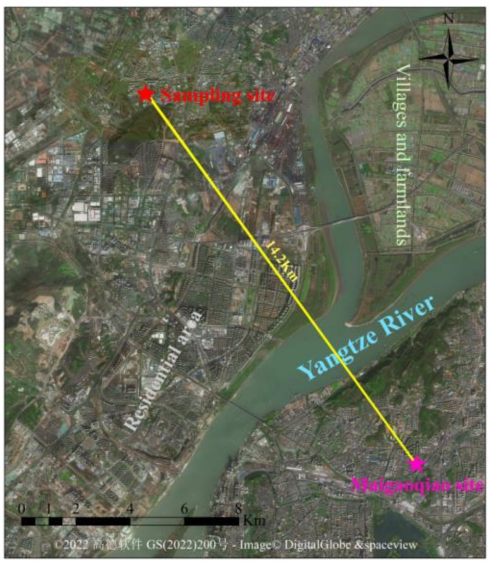

Figure S4. Geographical location of sampling site and Maigaoqiao site and the surrounding areas

Figures S5

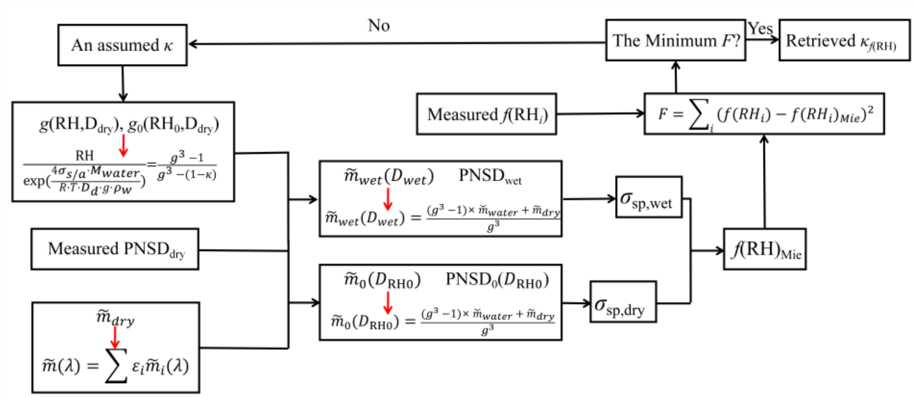

Figure S5. The flow chart of the retrieval algorithm for aerosol hygroscopicity parameter by Mie model, $\kappa_{f(\mathrm{RH})}$.

Text S1.

According to the calculation of aerosol scattering coefficient at a fixed wavelength with the Mie model (Bohren and Huffman 1983), and the assumption of a spherical and uniform internal mixing of particles, the input parameters mainly include particle size, refractive index, and particle number size distribution (Fig. S5).

By using an assumed κ, the diameter growth factor, g, is obtained with a modified version of Köhler theory which is proposed by Petters and Kreidenweis (2007),

$$\mathrm{RH} = \frac{g^3-1}{g^3-(1-\kappa)} \cdot \exp\left(\frac{4\sigma_{\mathrm{s/a}} \cdot M_{\mathrm{water}}}{\mathrm{R} \cdot \mathrm{T} \cdot D_{\mathrm{d}} \cdot g \cdot \rho_{\mathrm{w}}}\right), \quad \text{(S1)}$$

where g is the diameter growth factor, g(RH), κ is the hygroscopicity parameter, R is the universal gas constant, T is the temperature, D_d is the diameter, ρ_w is the density of water, $\sigma_{s/a}$ is the surface tension of the solution/air interface, and M_{water} is the molecular weight of water.

With regard to a multicomponent aerosol particle, the Zdanovskii–Stokes–Robinson assumption can be applied to calculate the particle refractive index: $\widetilde{m}_{\mathrm{dry}}(\lambda) = \sum \varepsilon_{\mathrm{i}} \widetilde{m}_{\mathrm{i}}(\lambda)$. Due to the effect of water uptake on the particle refractive index, the size-resolved refractive index $\widetilde{m}_{\mathrm{wet}}(D_{\mathrm{wet}})$ after aerosol hygroscopic growth can be calculated.

$$\widetilde{m}_{wet}(D_{wet}) = \frac{(g^3-1)\times\widetilde{m}_{water}+\widetilde{m}_{dry}}{g^3}, \quad \text{(S2)}$$

$\widetilde{m}_{\mathrm{water}}$ is the refractive index for pure water. The refractive index statistics of each component are shown in Table S1.

Table S1. The refractive index ($\widetilde{m}$) and density (ρ) of aerosol chemical compounds used for the Mie model.

	λ	Organics	NH_4NO_3	$(NH_4)_2SO_4$	NH_4HSO_4	H_2SO_4	BC	pure water
	450nm		1.559[b]	1.536[b]		1.438[d]	1.75+0.46i[e]	
$\widetilde{m}$	550nm	1.48[a]	1.556[b]	1.530[b]	1.473[c]	1.434[d]	1.75+0.44i[e]	1.33[f]
	700nm		1.553[b]	1.524[b]		1.432[d]	1.75+0.43i[e]	
ρ	(µg/m^3)	1.4[g]	1.72[h]	1.77[h]	1.78[h]	1.83[h]	1.7[a]	

[a] Nessler et al., (2005); [b] Gosse et al., (1997); [c] Li et al., (2001); [d] Palmer and Williams, (1975); [e] Hess et al., (1998); [f] Seinfeld and Pandis, (2006); [g] Alfarra et al., (2006); [h] Lide (2008).

The $f(\mathrm{RH})_{\mathrm{Mie}}$ corresponding to each given RH can be obtained by using the mean PNSD, the size-resolved refractive index, and g calculated with the assumed κ. By comparing the estimated f(RH) results to the field measurements, the least summation of the deviation between measured f(RH) and $f(\mathrm{RH})_{\mathrm{Mie}}$ should be achieved at a particular κ. Thus, the assumed κ is regarded as the average equivalent $\kappa_{f(\mathrm{RH})}$.

Figures S6

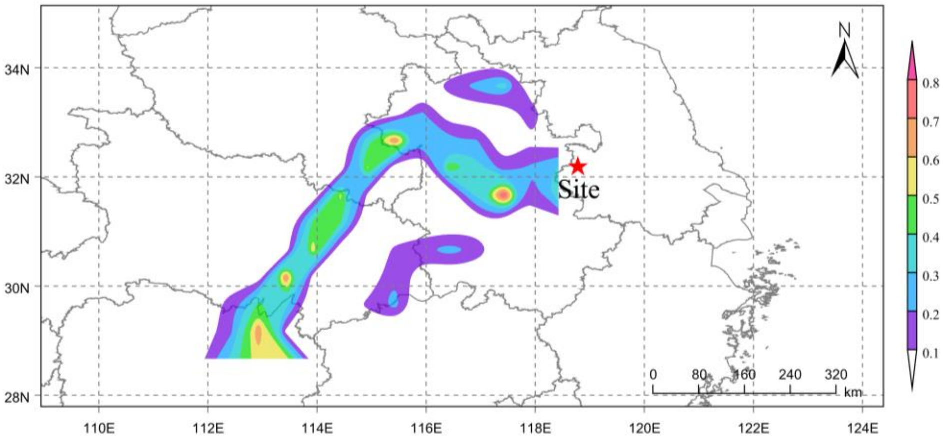

Figure S6. Potential source contribution function plot for organics in $PM_{2.5}$ during Dust2.

Figures S7

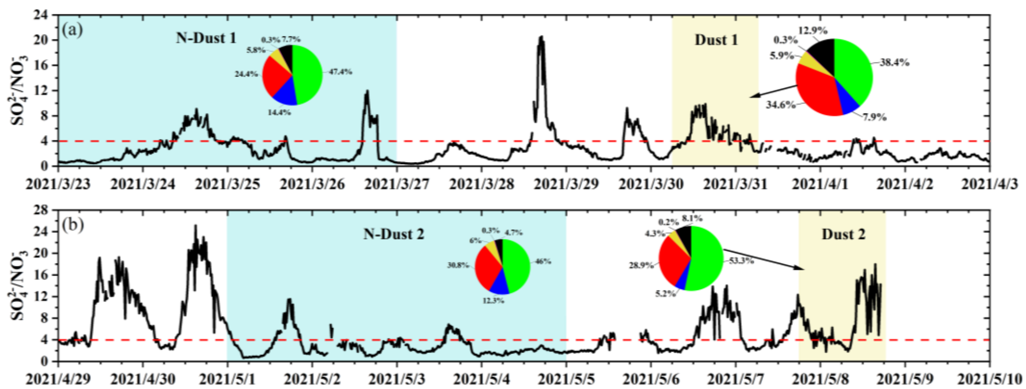

Figure S7. The time series of mass ratio of sulfate to nitrate during (a) from March 23 to April 3, and (b) from April 29 to May 10, 2021.

Table S2. Detailed measurement information, including sites, time periods, the fitted parameter equations, wavelengths (WL), and references.

Sites	Time periods/aerosol type	Parameter equations	WL (nm)	References
Xintai, Shanxi	August 2014	$f(\mathrm{RH}) = (\frac{1-\mathrm{RH}}{1-\mathrm{RH}_0})^{-0.24}$	532	Lv et al., (2017)
	September 2014	$f(\mathrm{RH}) = (\frac{1-\mathrm{RH}}{1-\mathrm{RH}_0})^{-1.09}$		
Beijing	Polluted Urban Aerosol	$f(\mathrm{RH}) = 0.85 + 0.1(1-\mathrm{RH})^{-1} + 0.001(1-\mathrm{RH})^{-2}$	525	Yan et al., (2009)
	Clean Urban Aerosol	$f(\mathrm{RH}) = 0.98 + 0.02(1-\mathrm{RH})^{-1} + 0.004(1-\mathrm{RH})^{-2}$		
	October to November, 2007	$f(\mathrm{RH}) = 1 + 8.8\mathrm{RH}^{9.7}$	550	Liu et al., (2013)
Raoyang, Hebei	2014	$f(\mathrm{RH}) = 1 + 0.9\mathrm{RH} + -0.02(\mathrm{RH})^2 + 0.06(\mathrm{RH})^3$	520	Wu et al., (2017)
Guangzhou, Guangdong	September 2014	$f(\mathrm{RH}) = 0.66(1-\mathrm{RH})^{-0.63}$	525	Liu et al., (2018)

Figures S8

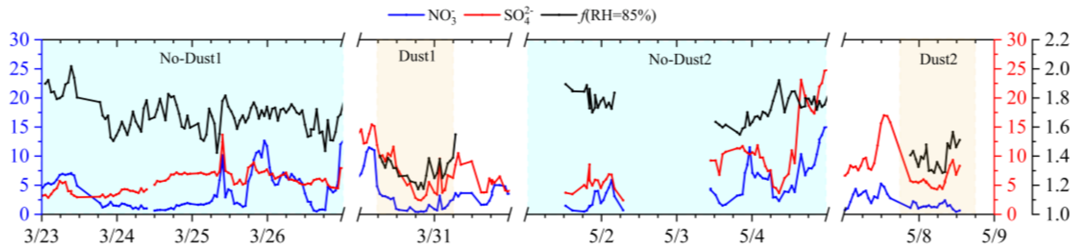

Figure S8. The time series of *f*(RH=85%), the mass concentrations of sulfate and nitrate (units: μg/m^3) during the observation period.

Reference:

Alfarra, M. R., Paulsen, D., Gysel, M., Garforth, A. A., Dommen, J., & Prévôt, A. S. H., et al. (2006). A mass spectrometric study of secondary organic aerosols formed from the photooxidation of anthropogenic and biogenic precursors in a reaction chamber. *Atmospheric Chemistry and Physics, 6*(12), 5279-5293. https://doi.org/10.5194/acp-6-5279-2006.

Bohren, C. F., & Nevitt, T. J. (1983). Absorption by a sphere: A simple approximation [Software]. *Applied Optics, 22*(6), 774-775. https://doi.org/10.1364/AO.22.000774.

Gosse, S. F., Wang, M., Labrie, D., & Chylek, P. (1997). Imaginary part of the refractive index of sulfates and nitrates in the 0.7–2.6-μm spectral region. *Applied Optics, 36*(16), 3622-3634. https://doi.org/10.1364/AO.36.003622.

Hess, M., Koepke, P., & Schult, I. (1998). Optical properties of aerosols and clouds: The software package OPAC. *Bulletin of the American Meteorological Society, 79*(5), 831-844. https://doi.org/10.1175/1520-0477(1998)079<0831:OPOAAC>2.0.CO;2.

Li, J., Wong, J. G. D., Dobbie, J. S., & Chýlek, P. (2001). Parameterization of the optical properties of sulfate aerosols. *Journal of the Atmospheric Sciences, 58*(2), 193-209. https://doi.org/10.1175/1520-0469(2001)058<0193:POTOPO>2.0.CO;2.

Lide, D. R.: Handbook of Chemistry and Physics, 89th (InternetVersion 2009), *CRC Press/Taylor and Francis,* Boca Raon, Fl, 2008.

Liu, L., Tan, H., Fan, S., Cai, M., Xu, H., & Li, F., et al. (2018). Influence of aerosol hygroscopicity and mixing state on aerosol optical properties in the Pearl River Delta region, China. *Science of The Total Environment, 627*, 1560-1571. https://doi.org/10.1016/j.scitotenv.2018.01.199.

Liu, X., Gu, J., Li, Y., Cheng, Y., Qu, Y., & Han, T., et al. (2013). Increase of aerosol scattering by hygroscopic growth: Observation, modeling, and implications on visibility. *Atmospheric Research, 132-133*, 91-101. https://doi.org/10.1016/j.atmosres.2013.04.007.

Lv, M., Liu, D., Li, Z., Mao, J., Sun, Y., & Wang, Z., et al. (2017). Hygroscopic growth of atmospheric aerosol particles based on lidar, radiosonde, and in situ measurements: Case studies from the Xinzhou field campaign. *Journal of Quantitative Spectroscopy and Radiative Transfer, 188*, 60-70. https://doi.org/10.1016/j.jqsrt.2015.12.029.

Nessler, R., Weingartner, E., & Baltensperger, U. (2005). Adaptation of dry nephelometer measurements to ambient conditions at the jungfraujoch. *Environmental Science & Technology, 39*(7), 2219-2228. https://doi.org/10.1021/es035450g.

Palmer, K. F., & Williams, D. (1975). Optical constants of sulfuric acid; Application to the clouds of venus? *Applied Optics, 14*(1), 208-219. https://doi.org/10.1364/AO.14.000208.

Petters, M. D., & Kreidenweis, S. M. (2007). A single parameter representation of hygroscopic growth and cloud condensation nucleus activity. *Atmospheric Chemistry and Physics, 7*(8), 1961-1971. https://doi.org/10.5194/acp-7-1961-2007.

Seinfeld, J. H. and Pandis, S. N.: Atmospheric chemistry and physics: from air pollution to climate change, *John Wiley & Sons,* 2006.

Wu, Y., Wang, X., Yan, P., Zhang, L., Tao, J., & Liu, X., et al. (2017). Investigation of hygroscopic growth effect on aerosol scattering coefficient at a rural site in the southern North China Plain. Science of The Total Environment, 599-600, 76-84. https://doi.org/10.1016/j.scitotenv.2017.04.194.

Yan, P., Pan, X., Tang, J., Zhou, X., Zhang, R., & Zeng, L. (2009). Hygroscopic growth of aerosol scattering coefficient: A comparative analysis between urban and suburban sites at winter in Beijing. Particuology, 7(1), 52-60. https://doi.org/10.1016/j.partic.2008.11.009.