

Supplement of Atmos. Meas. Tech., 13, 5407–5422, 2020
<https://doi.org/10.5194/amt-13-5407-2020-supplement>
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Supplement of

Development and application of a mass closure $PM_{2.5}$ composition online monitoring system

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A) Supplementary Text:

Uncertainty analysis on mass concentrations of integrated system

For Xact-625, the combined uncertainty included contribution from flow (1.5%), calibration standard uncertainty (5%), long term stability (calculated from the standard deviation of hourly internal Pd reference, 1.3%), and an element-specific uncertainty associated with the spectral deconvolution calculated by instrument software for each spectrum (US-EPA,1999; Tremper et al.,2018). In our study, each of elements was calibrate individually with a reference sample, the Xact-625 LOD (Limit of detection) was calculated using HEPA field blank measurements during sampling campaign these are shown in Table S1.

The uncertainty of ACSM is similar to AMS, as described previously (Allan et al., 2003; Nga et al., 2011), the overall uncertainty includes uncertainties associated with the Q (flow), IE (Ionization Efficiencies), RIE (Relative Ionization Efficiencies), and CE (Collection Efficiency) (Middlebrook et al., 2012; Freney et al., 2019). In which, IE is the ionization, transmission, and ion detection efficiency of nitrate (typically shortened as “ionization efficiency”), 10% uncertainty. In this study, the capture vaporizer (CV) was equipped, compared with a standard vaporizer (SV), to reduce the particle bouncing effect at vaporizer and the particle bouncing effect at vaporizer and hence improves the quantitative uncertainties caused by CE (Hu et al., 2017b; Zhang et al., 2017), the uncertainty in CE is less than 30%. RIE is the ionization efficiency of species relative to the ionization efficiency of nitrate; for ammonium and sulfate: determined in routine calibrations (10% uncertainty and 30% uncertainty, respectively); for organics: determined for various types of organics in previous laboratory experiments and literature values, an average value is used (20% uncertainty) (Bahreini et al., 2009). Q is the volumetric sample flow rate into the instrument (<0.5% uncertainty). The propagated, overall uncertainty for the total ACSM mass concentration is 20%-30%.

For AE-31 and SHARP-5030i, according to instrument manufacturer's test of instruments, the measurement accuracy is 5%, that is, the measurement error is within 5% of the measured value.

In addition, to guarantee the data quality acquired by the integrated system, relevant quality assurance and quality control (QA/QC) measures are implemented. The calibration of sampling flow rate, blank experiment and instrument calibration were performed periodically to ensure data quality according to relevant national standards. The sampling flow rate was calibrated every month to ensure the sampling flow precision was in the range of $\pm 1.5\%$. The blank experiment and instrument calibration were conducted every two months.

Design of the data analytics platform

The design solution of the data analytics platform was shown in Fig. S2, the data of three online instruments (ACSM, Xact-30
625, AE-31) were processed in same (.csv) format and saved in their respective local computer using data transmission
software, and uploaded data to a same SQL Server remote database for data management. The database was based on the
dedicated server of the integrated system. The data of SHARP-5030i can be directly connected to the server. In addition, an
atmospheric environment data collection and processing system had been established. The data in the SQL Server database
was called to achieve unified processing and display of integrated data.

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B) Supplementary Figure



Figure S1. The picture of the online integrated system.

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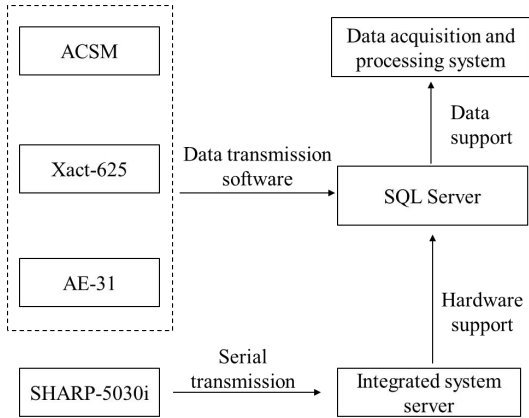
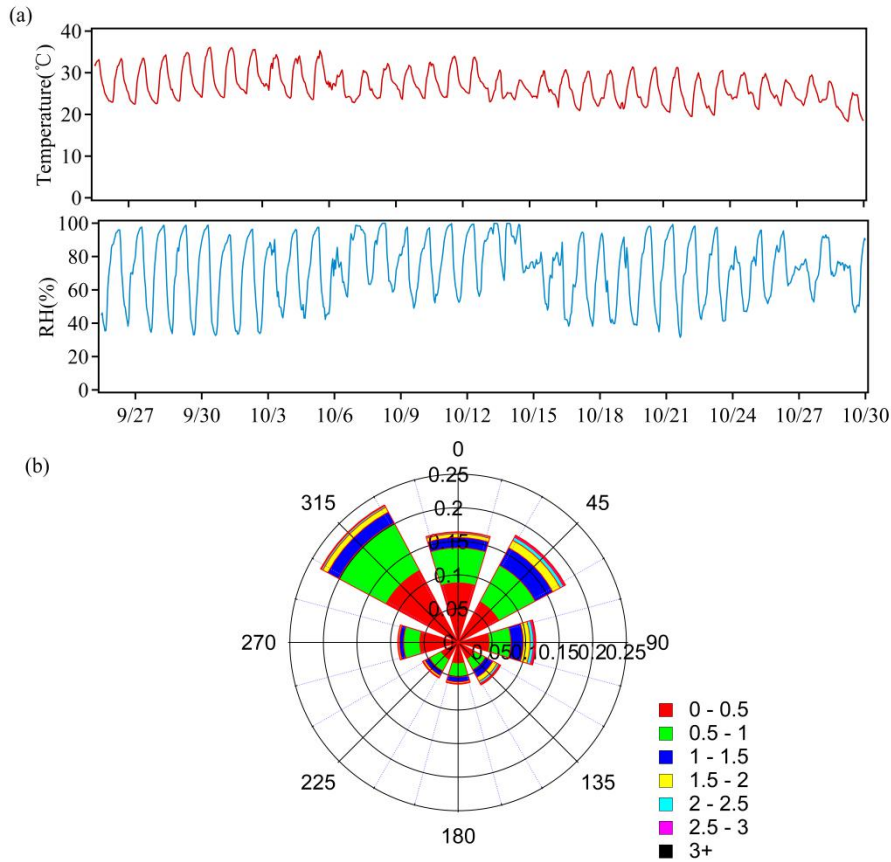


Figure S2. Design solution of data analytics platform.



45 Figure S3. Meteorological conditions during sampling campaign: temperature and relative humidity (a), and wind roses (b).

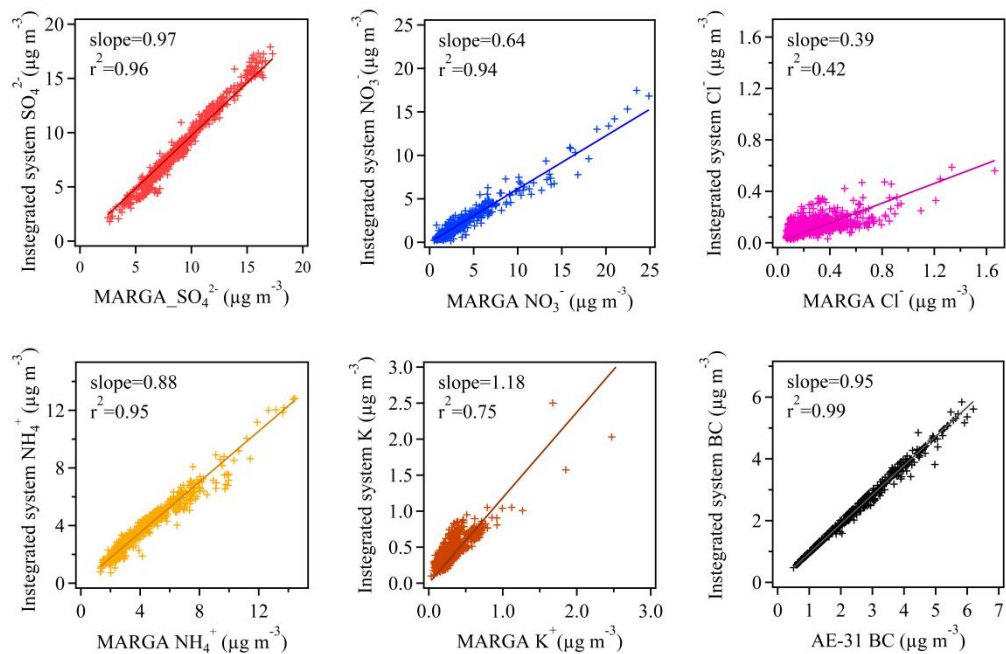
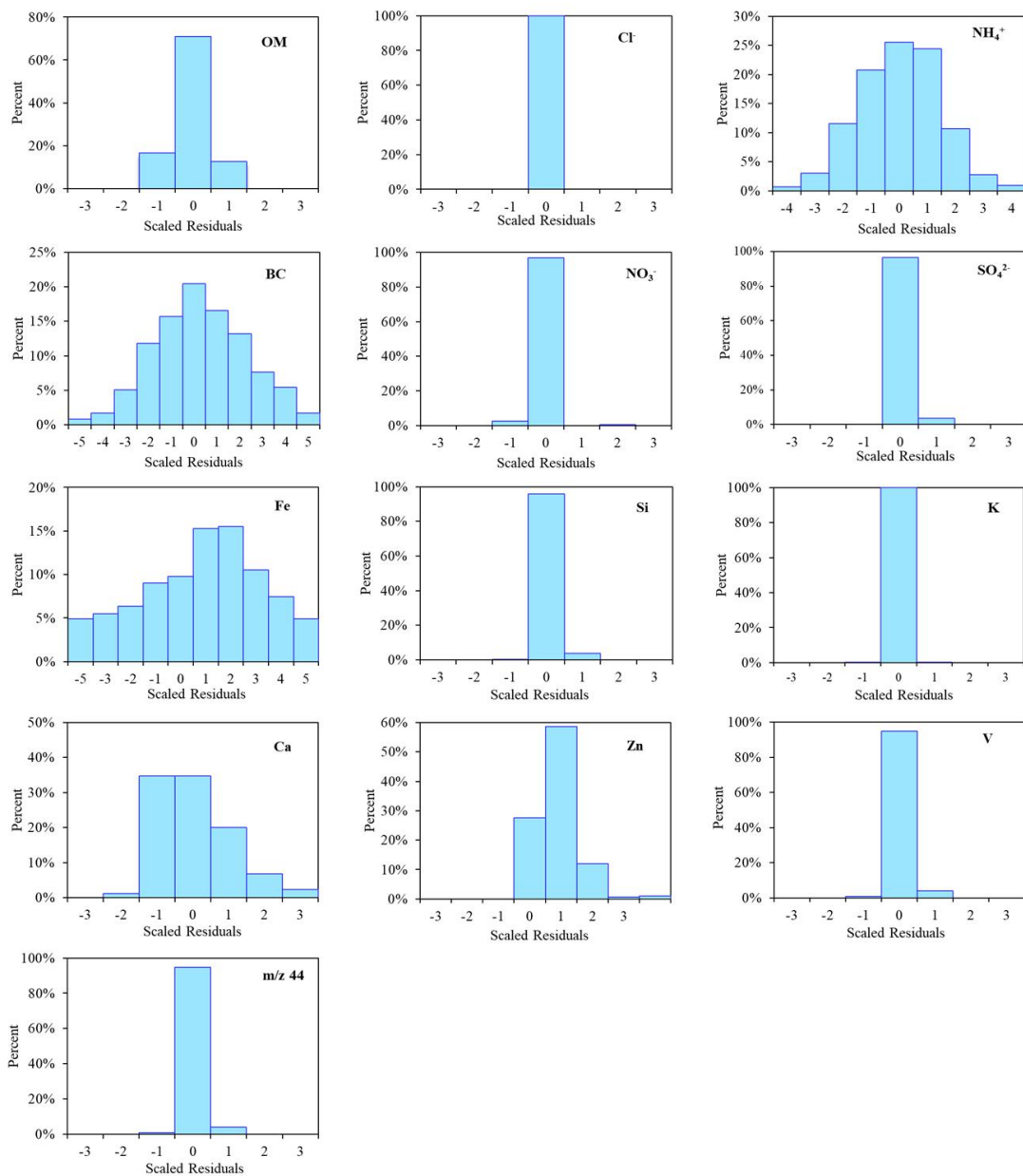
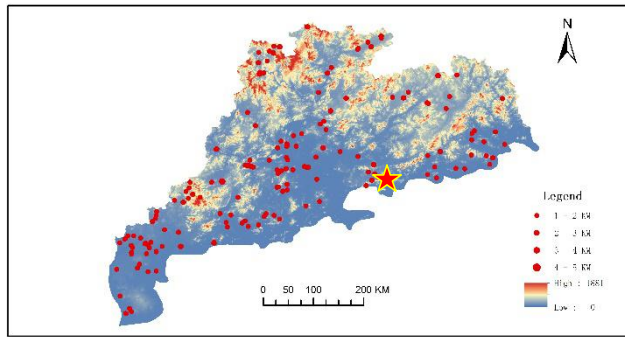


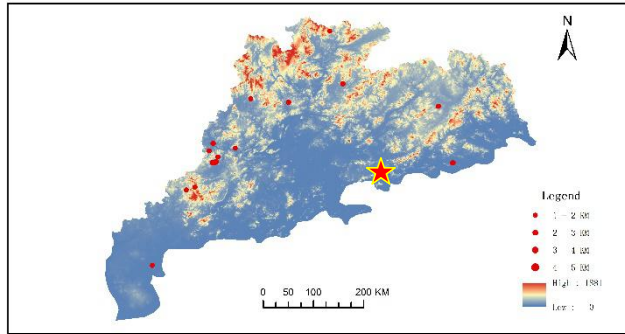
Figure S4. Scatter plots with the linear regression parameters among online integrated system and other instruments.



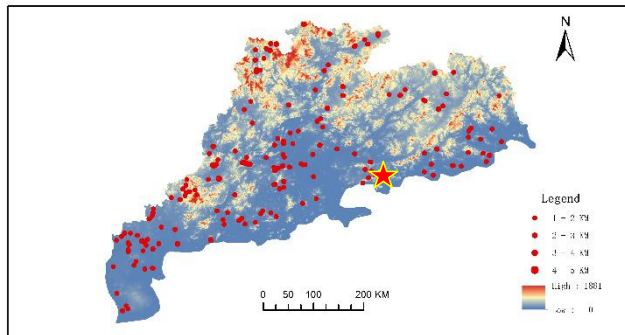
50 Figure S5. The scaled residuals of species output by ME-2.



DAY

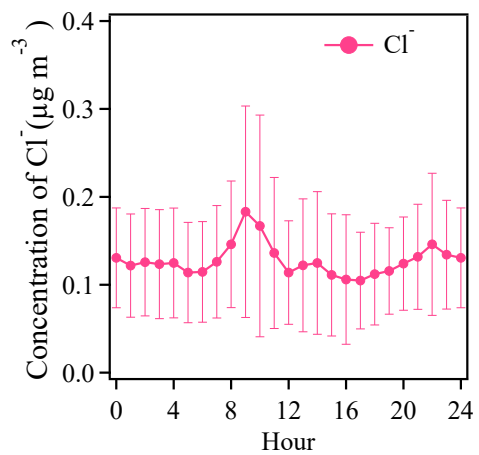


NIGHT



ALL

Figure S6. Spatial distribution of fire points in Guangdong (divided into day and night) during observation (the five-pointed star was used to represent sampling site).



55 **Figure S7. Diurnal variation of the Cl⁻ during the observation.**

C) Supplementary Table:

Table S1. The concentrations and detection limit of PM2.5 and chemical species during the sampling campaign.

	Species	Average concentration	Standard deviation	Detection Limit
Organic ($\mu\text{g m}^{-3}$)	OM	14.1	7.4	0.3
Inorganic ions ($\mu\text{g m}^{-3}$)	SO ₄ ²⁻	8.6	3.3	0.4
	NO ₃ ⁻	1.8	1.9	0.2
	NH ₄ ⁺	3.8	1.7	0.5
	Cl ⁻	0.1	0.07	0.2
	BC	2.1	1.0	0.1
Trace elements (ng m^{-3})	Si	380.6	185.0	17.8
	K	443.9	269.1	1.17
	Ca	103.0	53.8	0.3
	Ti	14.4	8.2	0.16
	V	3.2	2.3	0.12
	Cr	2.9	2.0	0.12
	Mn	24.3	13.0	0.14
	Fe	288.7	132.2	0.17
	Co	0.03	0.1	0.14
	Ni	2.9	1.3	0.1
	Cu	11.3	7.7	0.079
	Zn	102.2	60.9	0.067
	As	5.8	4.7	0.063
	Se	2.2	1.2	0.081
	Mo	0.5	0.5	0.1
	Cd	7.3	3.2	2.5
	Sn	19.8	8.3	4.1
	Sb	28.0	10.2	5.2
	Ba	3.9	7.4	0.39
Hg	1.9	0.7	0.12	
Pb	18.6	9.5	0.13	

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