



## **ACTRIS 2 (ECAC-ACMCC) Intercomparison of Aerosol Chemical Speciation Monitors, November 2018**

**Project No.:** ACSM-2018-1-9

### **Basic information**

**Location of the quality assurance:** SIRT/ACMCC, LSCE, Lab. 705

**Delivery date:** Before November 13th, 2018

**Setup in the laboratory:** November 14th 2018

**Workshop period:** November 19th to November 23<sup>th</sup>, 2018

Principal investigator	Institute	Participant	Instrument
Minna Aurela	FMI	Minna Aurela	QACSM 140-132 equipped with PM1 lens and standard vaporizer

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## Summary

This report summarizes results obtained for the FMI PM1 Quadrupole Aerosol Chemical Speciation Monitor (QACSM) during the 2018 ACMCC ACTRIS-2 workshop. It is divided into four main sections. The first section describes the instrumental set-up and data treatment methodologies used for the workshop. The second section presents results obtained during the initial intercomparison, where instruments were operated as delivered by participants. The third section describes calibrations and maintenance (if any) performed during the workshop. The last section presents results obtained during a second intercomparison campaign, where instruments were tuned and calibrated at ACMCC.

Performance evaluation includes:

- 1) The instrument performance is within the acceptable limits evaluated using a Z-score analysis, as described by ISO 5725-2.
- 2) The instrument is in overall good agreement - i.e., within  $\pm 30\%$  - with a reference dataset, the latter corresponding to a reference instrument and/or the robust median of intercomparison participants datasets.

The reference dataset is that measured by the SIRTa instrument. This instrument successfully participated in the previous ACSM intercomparisons and didn't travel prior to the workshop (unlike other instruments). It is regularly maintained and calibrated by the ACMCC staff.

Based on these tests, the FMI instrument passed the quality standards required as part of the ACTRIS research infrastructure.

## 1. Overview of the instrumental set-up and data treatment methodologies

Instruments were asked to be delivered at ACMCC no later than the 13<sup>th</sup> of November. They were installed and switched on by ACMCC personnel during the week from the 12<sup>th</sup> to the 16<sup>th</sup> of November. There were four different tables, each containing four instruments. Each table had its own inlet, fitted with a common sampling head. All sampling lines were composed of  $\frac{1}{2}$  inch copper tubes and were the same length for each instrument. Each instrument sampled 3 liters from the main inlet line; this flow was controlled by external sample line flow pumps. Instruments were fitted with or without an individual dryer, as used at their usual sampling site and/or as requested by participants. For the Q-ACSM, data analysis was performed using the Igor Pro (Wavemetrics, v6.3.7) procedure `acsm_local` (v1.5.11.1). A composition dependent collection efficiency was applied to all data sets following the guidelines available in Middlebrook et al., (2012).

Instruments were compared with the SIRTa reference instrument and also with the robust median of all instruments through Z-score analysis. For comparison to both of these reference datasets, it is expected that good instrument performance is met when the participant's results fall within a well characterized uncertainty for aerosol mass spectrometers, taken here as  $\pm 30\%$  (Bahreini et al., 2009, Middlebrook et al., 2012; Crenn et al., 2015).

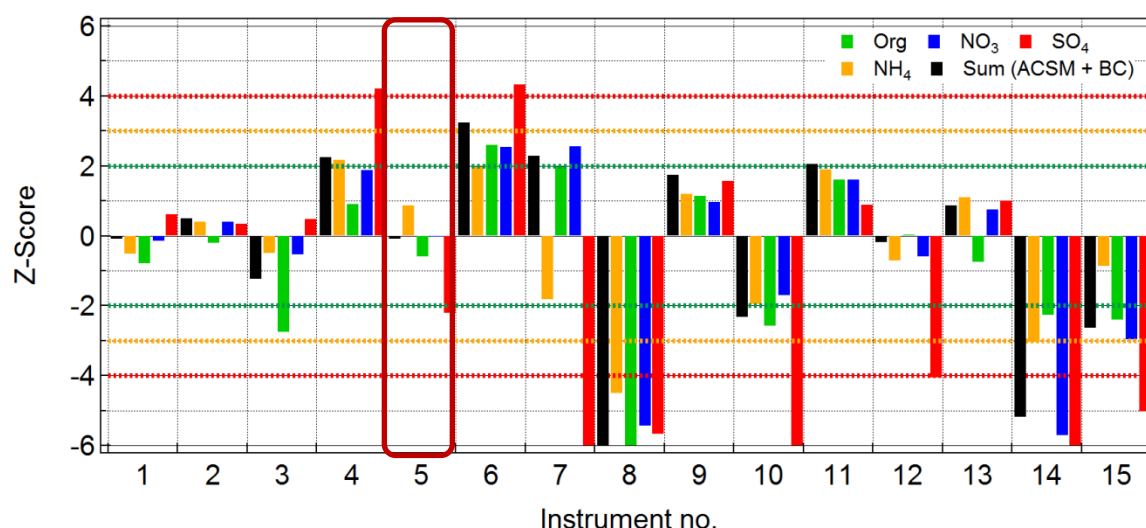
The Z-score analysis was applied following the standards defined by the international standard organization (ISO). This method has been evaluated according to ISO 5725-2 and provides a means to evaluate instrument performance relative to other instruments participating in the intercomparison. Such a method has been applied within other European intercomparison exercises (JRC technical intercomparison reports), and was validated during the first ACTRIS1 ACSM intercomparison (Crenn et al., 2015). The Z-score tests evaluates if the variations in the different instruments from the reference value fall within a defined criterion, following Eq.1:

$$Z_i = \frac{X_I - X^*}{\sigma_*} \quad (\text{Eq. 1})$$

Where  $X_I$  is the median of all instruments,  $X^*$  is the robust median of selected instruments and  $\sigma^*$  is the standard deviation of these latter instruments. The robust median target values were determined based on datasets obtained by PM<sub>1</sub> ACSM only (i.e., for consistency, the few PM<sub>2.5</sub> ACSMs were not considered for this target value calculation). According to this test, instrument performance is considered acceptable when values fall between 2 and -2 (indicated by the green lines in Figures 2.1 and 4.4).

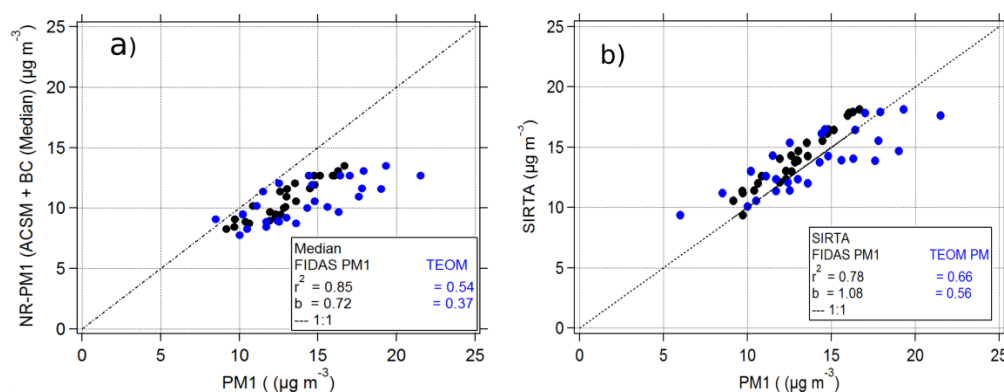
## 2. Results from initial intercomparison campaign

Once installed by ACMCC personnel, instruments were turned on with tunings indicated by participants, and sampled ambient air at the station from the 16<sup>th</sup> to the 19<sup>th</sup> of November 2018 for the initial intercomparison. Fifteen instruments were compared all together during a limited period of 18<sup>th</sup> Nov 18hrs to 19<sup>th</sup> Nov 08 hrs. The Z-score test illustrates the instrument performances during this period, (Figure 2.1) where each instrument was compared to the robust median of the participating instruments. The robust median was calculated here as the median of all instruments excluding outliers and PM<sub>2.5</sub>-inlet ACSMs (i.e., instruments # 8, 14, and 15).



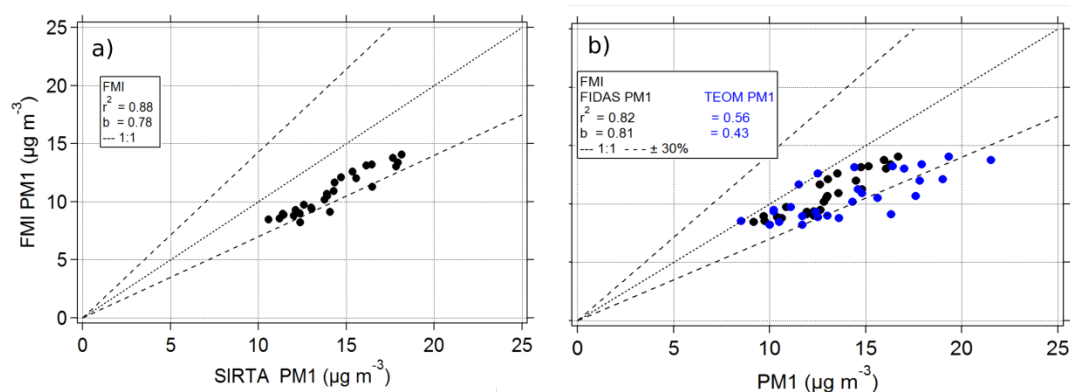
**Figure 2.1. Z-score calculation for each species measured by the ACSM for each instrument that participated in the initial intercomparison campaign (18<sup>th</sup> Nov 18hrs to 19<sup>th</sup> Nov 08 hrs). The red rectangle highlights the FMI instrument.**

The FMI instrument showed good agreement with the robust median values for NH<sub>4</sub>, NO<sub>3</sub>, and Org species. The SO<sub>4</sub> species were lower than the median of all instruments with a z-score of -2 (extending past the acceptable performance). However, given the large variability in instrument performance prior to calibration, the median value can be considered as a weak reference for comparison. This is illustrated in Figure 2.2 below where the median NR-PM1 + BC mass concentration is compared with the NR-PM1 mass concentration measured from the FIDAS and the TEOM-FDMS instruments, giving a slope of 0.72 and 0.37 respectively. In comparison the NR-PM1 + BC mass concentration measured from the SIRTA instrument compares better with slope values of 1.08 and 0.56 respectively for the FIDAS and TEOM-FDMS instruments (Figure 2.2b).



**Figure 2.2. Comparison of a) Robust Median NR-PM1 and b) SIRTAs NR-PM1 + BC mass concentrations with those of the FIDAS and TEOM PM1 mass concentration.**

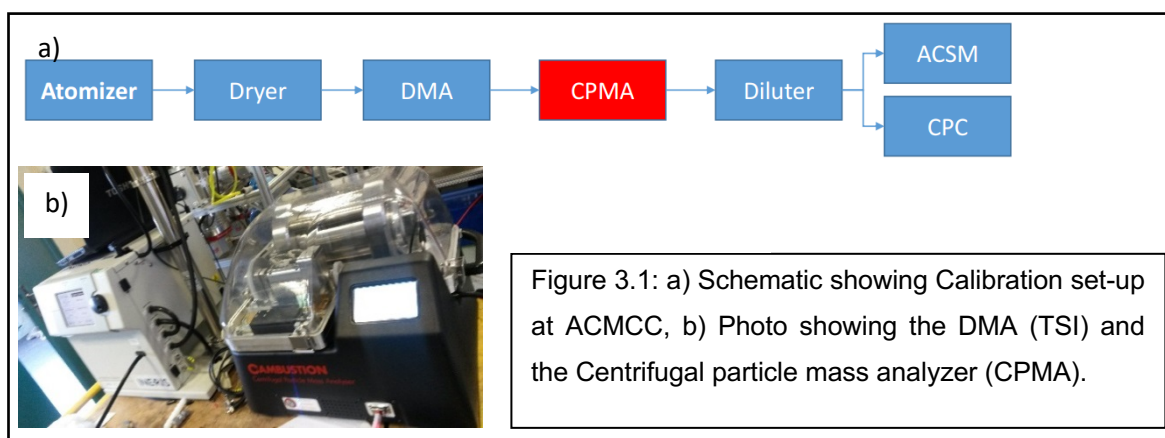
For this reason, comparison with the SIRTAs instrument seems to be more representative of the NR-PM1 than the robust median of ACSM instruments. The FMI measured mass concentrations underestimated those from both SIRTAs and the FIDAS instrument but were within  $\pm 30\%$  of the reference values.



**Figure 2.3. Comparison of FMI NR-PM1 with the a) SIRTAs NR-PM1 + BC mass concentrations and b) with PM1 mass concentration from FIDAS and TEOM PM1 mass concentration.**

### 3. Optimization of (relative) ionization efficiency values

Following initial intercomparison, instruments were checked, maintained and/or tuned (when needed) during the following week (19<sup>th</sup> to 23<sup>rd</sup> Nov). A series of calibrations were performed on each individual instrument at ACMCC during and after the workshop, using monodisperse (300 nm) ammonium nitrate and ammonium sulfate nebulized particles. The calibration set up is illustrated in Fig. 3.1.



**Figure 3.1: a) Schematic showing Calibration set-up at ACMCC, b) Photo showing the DMA (TSI) and the Centrifugal particle mass analyzer (CPMA).**

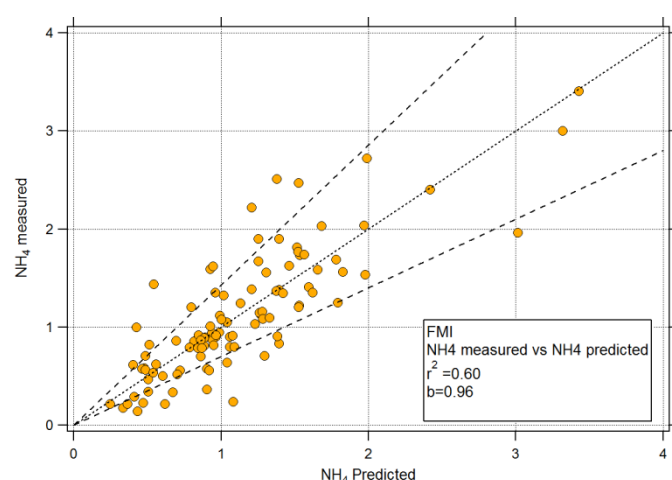
The calibration set up included a differential mobility analyzer (DMA, TSI®) to select particles of diameter 300 nm. This DMA was calibrated prior to use, using 300 nm polystyrene latex spheres. The aerosol particles were then passed into a Centrifugal Particle Mass Analyser (CPMA) that separates particles by their actual mass and removes doubly charged aerosol particles. These particles are then passed simultaneously into the ACSM and into a condensation particle counter (CPC). This CPC was calibrated prior to the workshop, based on comparison with an electrometer.

The nitrate response factor (RF) was calculated for each instrument and applied to the raw ACSM signal to obtain quantitative information. This value is determined from a known quantity of a known chemical species that enters into the instrument. The relative ionization efficiency (RIE) is a chemical dependent value that is commonly determined experimentally for the ammonium and sulfate species.

Calibration values provided by FMI for initial intercomparison as well as the ones recommended by the ACMCC for the workshop period (based on results from the full scan calibration mode) are listed in Table 3.1. The  $\text{NH}_4$  measured vs  $\text{NH}_4$  predicted values are illustrated in Figure 3.2, showing good agreement between the two values with a slope of 0.96 with the new RIE  $\text{NH}_4$  value.

FMI 140-132	RF $\text{NO}_3$	RIE $\text{NH}_4$	RIE $\text{SO}_4$	Ref Airbeam	Vap.Temp (°C)
<b>Initial</b>	6.51 e-11	3.74	0.58	9.56e-08	552
<b>Calibrated</b>	4.27 e-11	3.93	0.44	9.78e-08	526

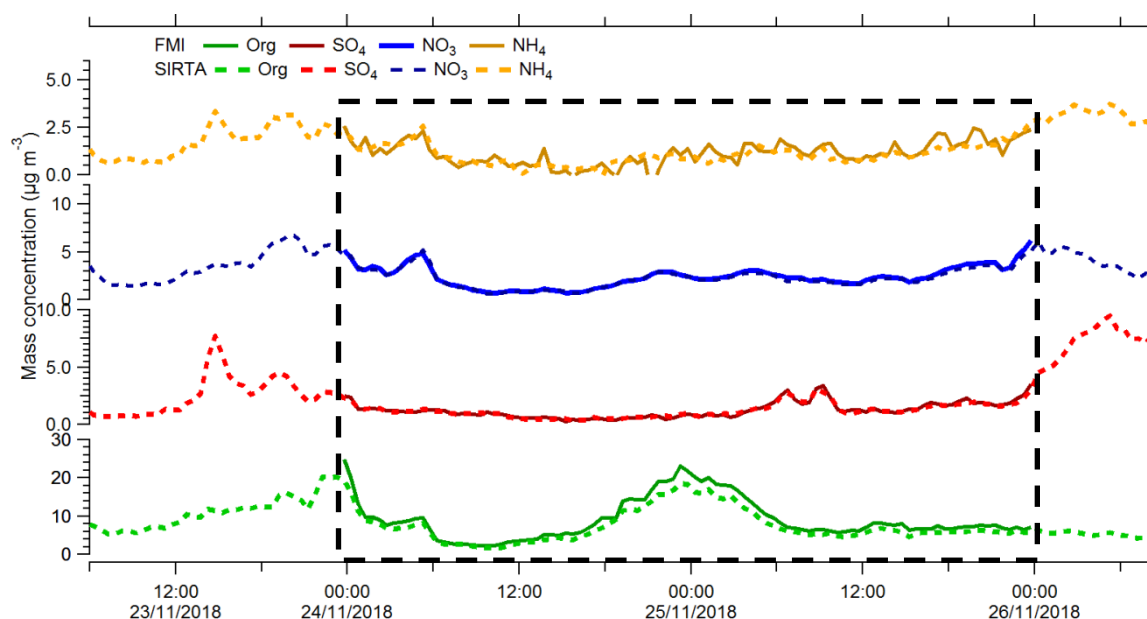
**Table 3.1: Calibration values for the FMI instrument for each calibration method.**



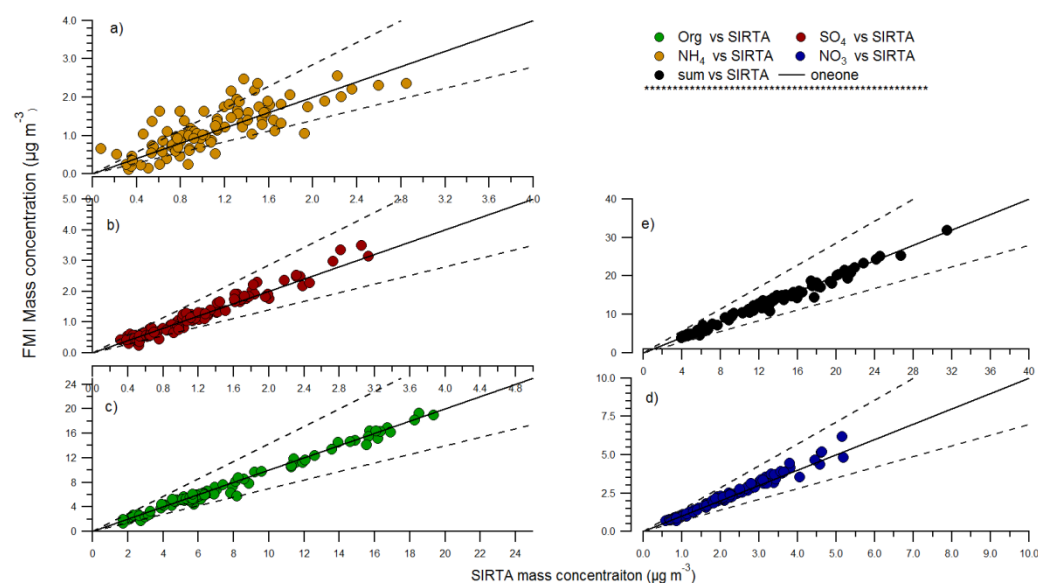
**Figure 3.2  $\text{NH}_4$  measured vs  $\text{NH}_4$  predicted for the FMI instrument using the calibrated RIE  $\text{NH}_4$  values listed in Table 3.2.**

#### 4. Results from the second intercomparison campaign

A second intercomparison campaign took place from the 23<sup>th</sup> to the 26<sup>th</sup> of November, considering calibration results and tuning performed at the ACMCC. The performance of the FMI instrument was again evaluated through comparison with the SIRTa instrument, and later with the robust median of the participating PM1 QACSM instruments. As mentioned earlier, the instrument performance can be considered as acceptable if data points were within  $\pm 30\%$  of these reference values. The FMI instrument shows good temporal agreement with both the median and that of the SIRTa instrument (Fig 4.1), and falls well within  $\pm 30\%$  (Fig 4.2).

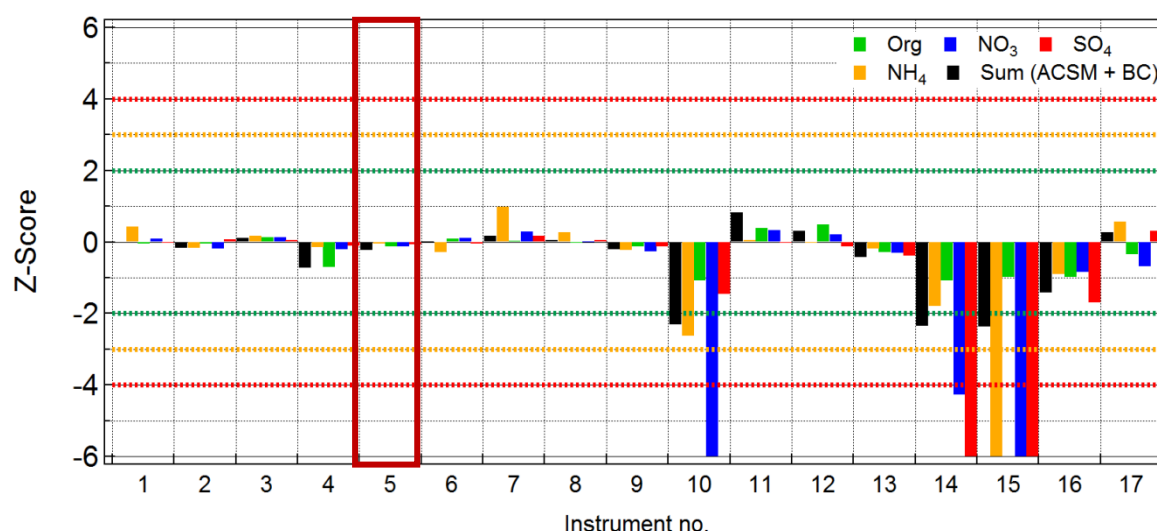


**Figure 4.1.** Comparison of FMI with SIRTa instrument and robust median data for Ammonia, Nitrate, sulphate, and organic, during the second intercomparison campaign. The highlighted box indicates the intercomparison period (24/11 00hrs to 26/11 00hrs).



**Figure 4.2.** Correlations between different chemical species measured by the FMI and the SIRTa instrument during the second intercomparison campaign (24<sup>th</sup> Nov 00hrs to 26<sup>th</sup> Nov 00hrs).

The second method of evaluation was made using the Z-score comparison. As described in section 1, instrument performance is considered acceptable when Z-score values fall between 2 and -2 (indicated by the green lines in Figures 4.4). Figure 4.4 shows the Z-score calculated for each instrument using the robust median as a reference. The robust median was calculated as the median of all instruments but outliers and PM<sub>2.5</sub>-inlet ACSMs (i.e., instruments # 10, 14, 15, and 16). The FMI instrument is no. 5 (red rectangle), showing that this instrument is well within acceptable limits of this statistical test.



**Figure 4.4. Z-score calculation for each species measured by the ACSM for each instrument that participated in the second intercomparison campaign (period 24<sup>th</sup> Nov 00hrs to 26<sup>th</sup> Nov 00hrs). The red rectangle highlights the FMI (no.5) instrument.**

## 5. Conclusion

The FMI arrived at the ACMCC in good operational order. With the exception of SO<sub>4</sub> mass concentrations, which were lower than the median, all other species compared well with reference instrument and median values. After calibration and tuning the instrument performance was improved and was well within the acceptable limits of the Z-score test.

## 6. References

- Bahreini, R., Ervens, B., Middlebrook, A. M., Warneke, C., de Gouw, J. A., DeCarlo, P. F., et al. (2009). *J. Geophys. Res.* 114:D00F16, doi:10.1029/2008JD011493.
- Crenn, V., Sciare, J., Croteau, P. L., et al., (2015), *Atmos. Meas. Tech.*, 8, 7239-7302, doi:10.5194/amtd-8-7239-2015.
- ISO, 5725-5, 1998. Accuracy (trueness and precision) of measurement methods and results-Part 5: Alternative Methods for the Determination of the Precision of a standard measurement method. International Organization for Standardization.
- Middlebrook, A. N. R., Bahreini, J. L., Jimenez, and M. R. Canagaratna (2012) *Aerosol Sci. Tech.*, 46:258–271.