

Multi-intercomparison of ACSM, MULTI-ACSM

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Introduction and motivation

The Aerosol Chemical Speciation Monitor (ACSM) is an instrument that allows the determination of the chemical composition of submicron particles in real time (Ng et al., 2011), which is a very useful information to assess the air quality and to find and quantify the main sources of submicron particulate matter. The instrument was developed with the final goal to be used in air quality networks around the world. Given its relatively recent development, it is currently being used by research teams so that its performance is being tested and improved.

Within ACTRIS, in the frame of the WP21 (JRA2), there is a European network of ACSMs. All these instruments have been running for almost a year at different European sites. IDAEA-CSIC, although not officially participating in JRA2, also participates in the activities of this JRA2, given our willing to use this technology in Spain, being the first research group who is using it. Thus, we also carried out the sampling campaign of one year with our ACSM. As a continuation of this activity, an inter-comparison exercise including several ACSM instruments was proposed within ACTRIS. This is the first time that such an inter-comparison is carried out. IDAEA-CSIC, in line with our high motivation to use this instrument, also participated in this inter-comparison.

Scientific objectives

The objective of this project is to perform a multi-intercomparison of different ACSMs belonging to the aforementioned European network. The final goal is to assess the performance and comparability of ambient results from these ACSMs, so that the comparability of previous and future results obtained with different instruments can be assured. Hence a quality-controlled ACSM European dataset can be warranted.

Reason for choosing station

The selection of the Site Instrumental de Recherche par Télédétection Atmosphérique (SIRTA site) was done within the ACTRIS ACSM community (JRA2). The main reasons to choose this station are listed below:

- a) its space availability to host more than 10 of these instruments;
- b) the very different atmospheric conditions during the selected period at this location, so that the instruments performance will be tested under different types of pollution;
- c) the possibility of using additional instrumentation deployed at SIRTA to complement and validate the measurements with the ACSM.

Method and experimental set-up

Experimental set-up

A total of 14 ACSM instruments (including 1 e-ToF-ACSM) and 1 HR-ToF-AMS instrument were installed at SIRTA side by side (Figure 1). The instruments were installed in three groups of four and a group of two. Each group shared a single PM_{2.5} inlet.



Figure 1. Picture of the SIRTA laboratory with the ACSM instruments installed.

Time schedule and activities

The whole multi-intercomparison exercise started on the 12th November 2013 and will last until 1st December 2013.

The instruments were shipped prior to the start of the experiment. All the instruments were unpacked and set in the laboratory by SIRTA researchers. Two people from Aerodyne Research (which is the developer and manufacturer of the ACSM instrument) also participated in the exercise. The instruments were started on the 11th November 2013. Lens alignment (necessary to make sure that the instrument is well set after shipping) was performed on the 11th November 2013 on all the instruments.

During the first week of the whole exercise, which coincides with this TNA, several activities were carried out. They are detailed below:

- A general tuning to the instrument was carried out, adjusting the different parameters to reach the optimum signal.
- An ammonium nitrate and an ammonium sulfate calibrations were performed using the same calibration system for all the instruments, assuring comparability in the results.
- A qualitative organic calibration was carried out. To this end, a mixture of known organic compounds was atomized using a spray drier and fed into the different inlets on the roof (this was done for each of the inlets feeding the groups of 4 ACSM instruments).
- Tests for possible leaks in the sampling system inlet were performed.
- A test with a HEPA filter in the inlet was performed to determine the detection limit for different species.
- A test with ammonium nitrate fed through the inlet connected to a group of 4 ACSM instruments was performed (this was carried out for all the inlets).
- The sampling settings were discussed and set equally for all the instruments. They were set to scan 28 sets of 1 open and 1 filter scans, which results in a time resolution of approximately 30 minutes.
- A first assessment of the performance of the data measured during one of the nights was carried out by the Aerodyne personnel.

During the second and third weeks, all the instruments are operating at stable conditions side by side. The instruments are controlled by SIRTA researchers. The instruments can also be accessed remotely so that each participant can keep track of the performance of the instrument.

The instruments will be packed by the SIRTA personnel at the end of the exercise.

Complementary instrumentation

Additional collocated instruments deployed were: a TEOM-FDMS (measuring PM mass), an SMPS (number size distribution), a nephelometer (light scattering), an aethalometer (black carbon), a PILS-IC (ions), an OCEC Sunset field analyzer (organic carbon and elemental carbon concentrations), and samplers using filters (PM mass and chemical composition offline).

Preliminary results and conclusions

The results from the calibration of the IDAEA-CSIC instrument were successful. The nitrate response factor (also called ionization efficiency) was $5.38\text{e-}11$ and the relative ionization efficiencies for ammonium and sulfate were 4.73 and 0.82, respectively. These values are within the usual ranges obtained in these instruments. The results from these calibrations for the IDAEA-CSIC instrument are shown in Figure 2.

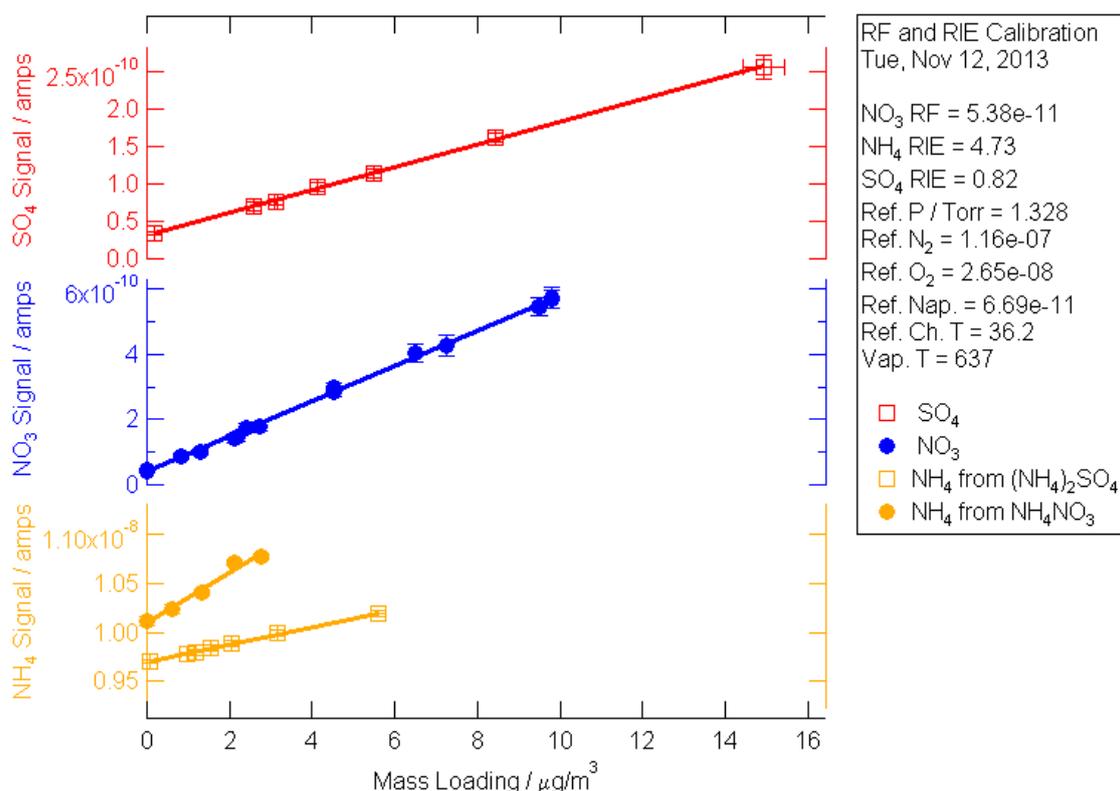


Figure 2. Ammonium nitrate and ammonium sulphate calibration of the ACSM belonging to IDAEA-CSIC.

The instruments started to run in a stable manner from the 15th November on, after all the tests performed during the first week. As a first comparison, the measurements taken from each of the ACSM instruments from the 15th to the 18th November are shown in Figure 3; for the sake of brevity only organics, sulfate and nitrate concentrations are shown.

For all the species, the relative time variation is similar for all the instruments. Hence, all the instruments were able to detect high concentration episodes, such as that in the night from 17th to 18th November for organics, and they were able to detect low concentration episodes or periods. Nevertheless, the concentrations may be as different as a factor of 2 for organics, a factor of 1.8 for nitrate and a factor of 2.6 for sulfate between the minimum and the maximum concentrations for the same sampling period. It should be pointed that these are raw data after applying minimum corrections and it is very likely that further corrections should be applied, hence leading to much better agreement among instruments.

The higher deviations in the sulfate concentrations may be linked to the difficulty in determining the relative ionization efficiency for sulfate, and the relatively high variability of this parameter between instruments. Further and deeper analysis of the data will reveal the reasons for the discrepancies among instruments.

Nitrate and sulfate concentrations measured by the IDAEA-CSIC ACSM instrument (140-110) from 15th to 18th November 2013 were compared to the levels of nitrate and sulfate measured by the collocated PILS instrument (Figure 4). Note that the PILS data are raw data and the units are not comparable. The time series depicted for both techniques for nitrate concentrations track each other, which indicates that the relative time variation measured by the two different techniques is similar. The same is observed for the sulfate concentrations. Nevertheless, a deeper and further analysis should be carried out when the PILS data are processed.

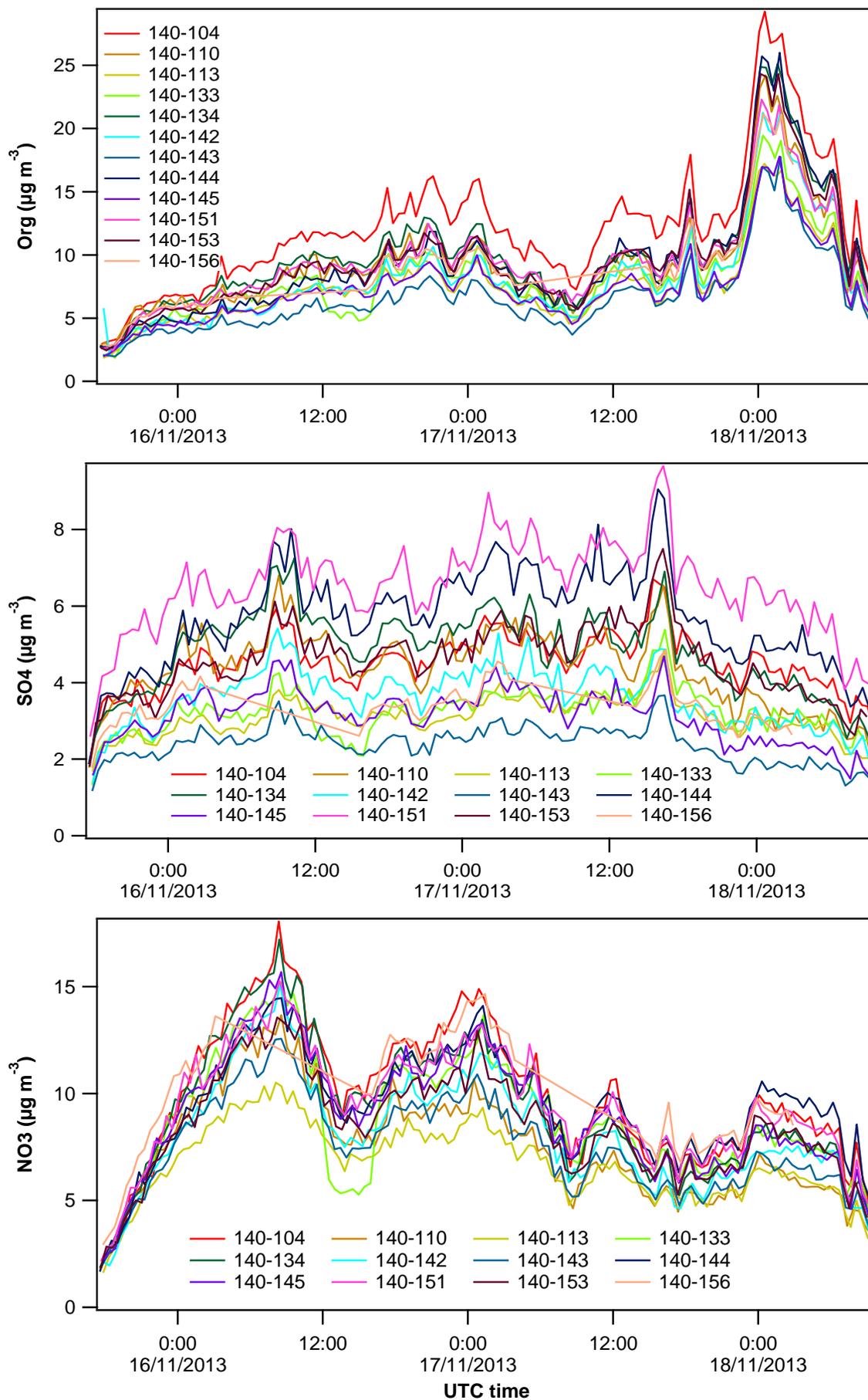


Figure 3. Organic, sulfate and nitrate concentrations measured by the different ACSM instruments from 15th to 18th November 2013.

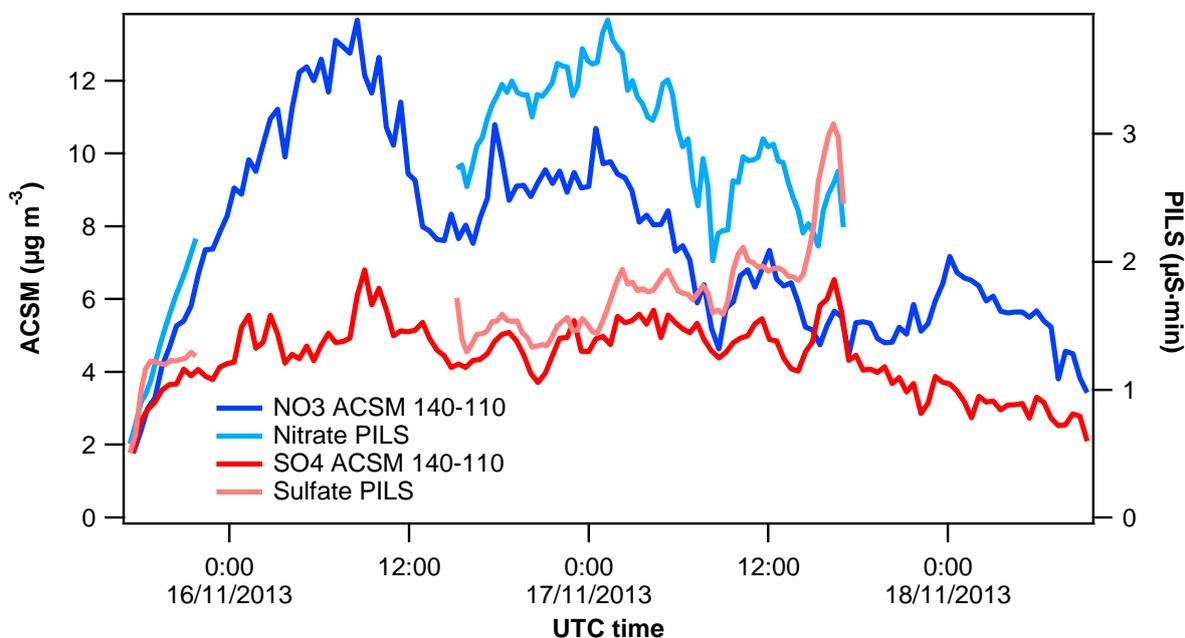


Figure 4. Nitrate and sulfate concentrations measured by the IDAEA-CSIC ACSM instrument (140-110) from 15th to 18th November 2013 compared to the levels of nitrate and sulfate measured by the collocated PILS instrument (note that units are not comparable).

Outcome and future studies

For the first time, a multi-intercomparison including such a big number of ACSM instruments sampling real ambient air has been performed. Given the relatively recent development of this type of instrument, the results of this experience will be extremely useful for the current and potential ACSM-users and for the scientific community. Hence, the comparability of previous and future results obtained with different instruments can be assured.

A first assessment of the performance and comparability of these ACSM instruments has been carried out. Only simple corrections were applied to the raw data, so the results should be interpreted with caution. The outcome is positive in the sense that the relative time variation of a given species concentration was similar for all the instruments. This was observed for organics, nitrate and sulfate, which are the species registered in higher concentrations by the ACSM. Nevertheless, the concentrations may be as different as a factor of 2 for organics, 1.8 for nitrate and 2.6 for sulfate between the minimum and the maximum concentrations. The time series of nitrate and sulfate concentrations measured by the IDAEA-CSIC ACSM instrument track the time series of nitrate and sulfate signal measured by collocated PILS instrumentation. This outcome again shows the good performance of the ACSM instruments.

The activities in the immediate future will consist on the deeper evaluation of the results of this inter-comparison. This will imply a careful assessment of the results from each of the instruments and the application of the proper corrections, followed by the statistical analysis of the comparison among instruments. A special attention should be paid to the sulfate signals and relative ionization efficiencies for the different instruments, which can be responsible for the relatively poorer agreement among instruments for this species. The results from the collocated instruments will be also a key point to choose the correct collection efficiency for the ACSM instruments and to assess whether there are any shifts and changes in the performance of the ACSM instruments. After these further corrections a much better agreement among instruments than the one shown in this report is expected.

References

Ng, N.L., Herndon, S.C., Trimborn, A., Canagaratna, M.R., Croteau, P.L., Onasch, T.B., Sueper, D., Worsnop, D.R., Zhang, Q., Sun, Y.L., Jayne, J.T., 2011. An Aerosol Chemical Speciation Monitor (ACSM) for routine monitoring of the composition and mass concentrations of ambient aerosol. *Aerosol Sci. Technol.* 45, 770-784.