APSS workshop 2014

TSI-APS 3321 intercomparison

Focus of intercomparison:	Flow accuracy and calibration Sizing accuracy Particle number concentration
Number of intercompared devices:	15
Time period:	Sept. 09 to 19, 2014 (run 1) Sept. 29 to Oct 03, 2014 (run 2)
Location:	World Calibration Center for Aerosol Physics at TROPOS, Leipzig, Building 23.2, Lab. 121

During this first voluntary workshop for aerodynamic particle size spectrometer (TSI-type APS), sizing quality and the unit-to-unit variability was analyzed for in total 15 instruments.

This report shows the results of the aerodynamic particle size spectrometer, which were analyzed, suing a laboratory setup, designed for coarse mode particles.

The document is structured as follows:

Chapter 1: Overview and description of the workshop measurement

Chapter 2: Summarized results and conclusion with some remarks

Chapter 3: Detailed results for each specific device

1 General description

Because of the limitations of the laboratory setup, the intercomparison was split into two runs. In the first run all devices (A – F) of TROPOS and two from UBA (Umweltbundesamt) were analyzed. In the second run, seven other devices from ICPF, ISAC, JRC, NEO and UHEL as well as TROPOS F (as reference) were intercompared. All devices were TSI-type APS 3321.

Table 1: Overview of compared devices

ID	**Type**	**Firmware**	**run**
ICPF A	TSI 3321	1.12 13-DEC-2001	2
ICPF B	TSI 3321	1.12 13-DEC-2001	2
ISAC	TSI 3321	4.00 27-DEC-2004	2
JRC A	TSI 3321	1.12 13-DEC-2001	2
JRC B	TSI 3321	4.00 27-DEC-2004	2
NEO	TSI 3321	4.00 27-DEC-2004	2
TROPOS A	TSI 3321	1.12 13-DEC-2001	1
TROPOS B	TSI 3321	1.12 13-DEC-2001	1
TROPOS C	TSI 3321	4.00 27-DEC-2004	1
TROPOS D	TSI 3321	4.00 27-DEC-2004	1
TROPOS E	TSI 3321	4.00 27-DEC-2004	1
TROPOS F	TSI 3321	4.00 27-DEC-2004	1 & 2
UBA A	TSI 3321	4.00 27-DEC-2004	1
UBA B	TSI 3321	4.00 27-DEC-2004	1
UHEL	TSI 3321	1.12 13-DEC-2001	2

The core element in the measurement setup is a mixing chamber (0.75x0.75x0.75m^3). This mixing chamber has eight outlets, which limits the number of devices to be intercompared per run. A fan inside of the mixing chamber ensures a well distributed aerosol, so that all outlets have equal particle number concentrations. All eight devices were mounted under each outlet in two levels with a strict vertical pipe. This arrangement ensures that there are almost no particle losses due to impaction or sedimentation from the mixing chamber to the individual devices. The data acquisition for all devices was done simultaneously and exactly synchronized by an own written program on one PC.

Figure 1: Measurement arrangement with mixing chamber for intercomparison of eight APS

For analyzing the quality of sizing, PSL spheres have been re-suspended, using an nebulizer. To speed up the PSL size calibration, two mixtures of three different PSL particle sizes (0.7, 1.0 and 2.0 µm or 0.9, 1.6 and 3.0 µm) were used.

To analyze the concentration measurement over a wide particle size range of the devices, two procedures were carried out. On one hand, a longer measurement of ambient aerosol overnight, and on the other hand, a prototype of a coarse-mode-nebulizer was applied to produce coarse mode ammonium sulfate particles up to 5 µm in short time.

Table 2: Participants during the workshop (APS intercomparison)

Name	**e-mail**	**Institute/company**
Nadezda Zikova	zikova@icpf.cas.cz	ICPF
Angela Marinoni	a.marinoni@isac.cnr.it	ISAC
Sebastiao Martins dos Santos	sebastiao.santos@jrc.ec.europa.eu	JRC

TROPOS –ACTRIS APSS Workshop Sept 29 – Oct 03, 2014

Kay Weinhold	weinhold@tropos.de	TROPOS
Thomas Müller	muellert@tropos.de	TROPOS
Sascha Pfeifer	pfeifer@tropos.de	TROPOS
Alfred Wiedensohler	ali@tropos.de	TROPOS
Wolgang Völker	wvoelker@tsi.com	TSI®
Carsten Kykal	carsten.kykal@tsi.com	TSI®

2 Summarized results and conclusion

2.1 Flows

The quality of an APSS is in a correct particle sizing and concentration, strongly depends of the aerosol and sheath flow. Therefor both flows for all devices were measured with a bubble-flow-gilibrator. The manufacturer specifies the aerosol flow with 1.0 +/- 0.1 lpm and the sheath flow with 4.0 +/- 0.1 lpm. If the measured flows are outside these ranges one has to recalibrate the flows.

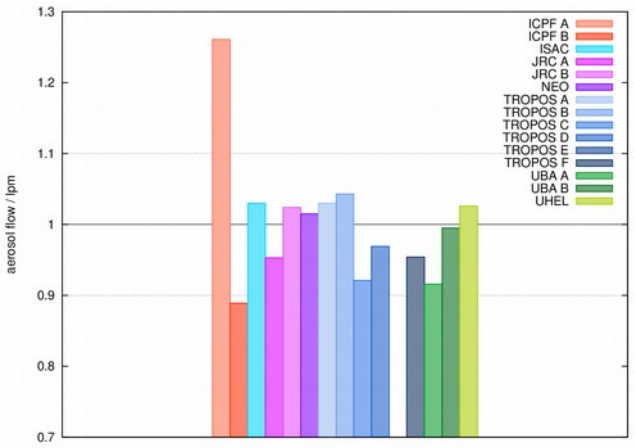


Figure 2: Measured aerosol flow rate before re-calibration and maintenance

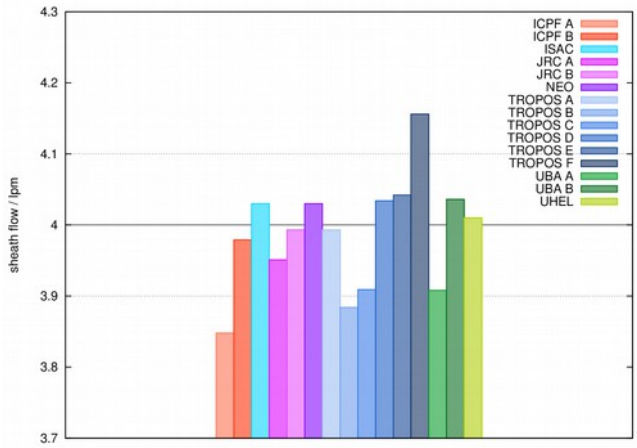


Figure 3: Measured sheath flow rate before re-calibration and maintenance

The measured flow rates for all devices are shown in Figure 1 and 2. The majority of the devices were in the range specified by the manufacturer. Only three devices were outside this range.

At the end of run 1, the pump for the total flow of TROPOS E was broken, which led to a smaller aerosol flow rate. The previous measurements of latex size calibration and particle number size distribution were not influenced by this fact. The aerosol flow rates of the ICPF devices, especially ICPF A, significantly deviated to the default value.

During the workshop, the participants were taught how to re-calibrate the flow rates of an TSI APS 3321. Exemplary, the aerosol and sheath flow rates of ICPF A and B as well as JRC A and B were re-calibrated to 1.015 and 4.030 l/min.

In the following two sub chapters, only the results after the re-calibration are shown. A detailed description how the flow re-calibration influenced the latex size calibration is given in chapter 3.

2.2 Latex Size Calibration

The mean diameters of the PSL particles (mixtures of 3 different PSL sizes) were calculated with a fitting of multimodal logarithmic functions. The relative deviation to the manufacturer's data is shown in Figure 4. The majority of devices show a deviation of less than 10% against the nominal PSL particle size, with a few exceptions.

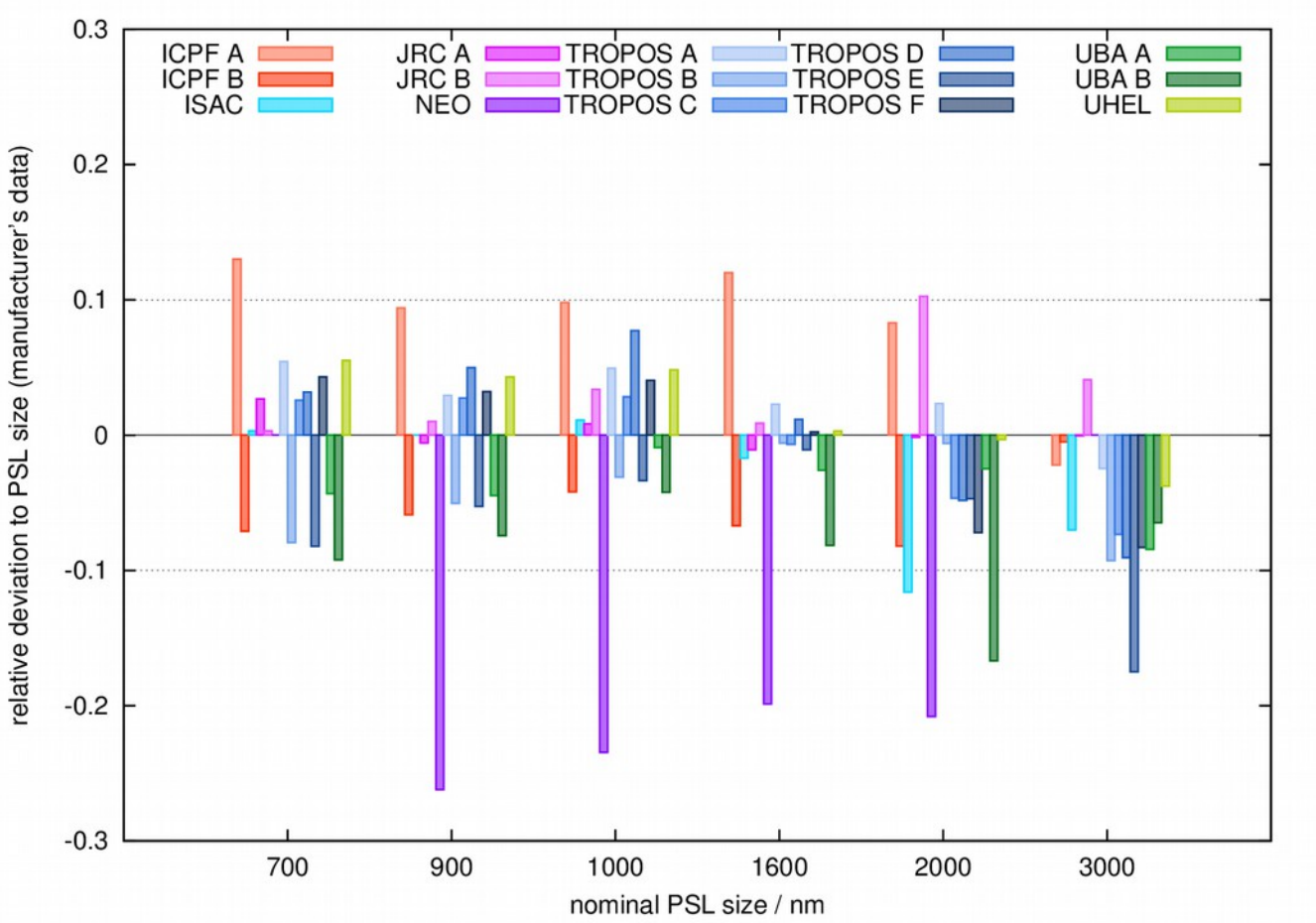


Figure 4: Overview of relative deviation of the measured sizes compared to the nominal PSL particle size

Compared to the results determined before flow re-calibration, ICPF A and B are systematic too high, respectively too low. That means the flow re-calibration led to an overshot in sizing for both devices. In contrast to this, the sizing of JRC A and B has improved, after re-calibration. Furthermore, the results of NEO are noticeable incorrect. The device arrived the workshop with a broken sheath air pump. After re-placing the pump and calibrating the flows, the calibration parameters for sizing still seems to be incorrect. A more detailed description, also for minor deviations of other devices, is given in chapter 3.

2.3 Particle Number Size Distribution (PNSD)

To compare the PNSD of ambient and ammonium sulfate measurements of both runs, using TROPOS F as a reference, one has to correct the incorrect sizing first. Because no adjustment of the time-of-flight calibration table was carried out during the workshop, this was done during post-processing, simple using the average deviation over all PSL sizes. An average particle number size distribution from selective devices with an subjective “good state” (namely ISAC, JRC A, TROPOS F, UHEL) was calculated as a reference curve for comparison. Due to the counting statistics for ammonium sulfate and for the ambient aerosol, ranges up to 5 and up to 3 µm, respectively, were selected.

As shown in Figure 5 and 6, the results of the particle number size distribution for all 15 devices strongly deviate. For some devices, the deviation to the selective average can reach values up to 200% for certain sizes. The results for the first few bins, up to ~0.7 µm, should however not be overvalued. This deviation, the variety for the falling slope towards smaller particle sizes, is well known and is based on differences on the quality of the optics, which leads to differences in the counting events. This counting efficiency, especially the threshold size, varies from device to device (see chapter 3). The majority of devices are in a good agreement for sizes larger 1.0 µm.

To make the results more readable and applicable, we calculated the total particle number, surface area, and volume concentration relative to the results of the “selective average” for the range of 0.7 – 5.0 µm for ammonium sulfate (see Figure 7) and 0.7 – 3 µm for the ambient aerosol (see Figure 8).

Increasing the lower integration diameter would improve the results for some devices. On the other hand, one would lose a better insight of the quality and performance in the lower detection range of the devices. A question, which is not answered in this framework, would be, whether one could correct the size-depended counting efficiency in a post-processing.

The results are disenchanting. While for ammonium sulfate measurements half of the devices are in a range of +/-10% relative to the “selective average”. The quality for the ambient aerosol measurements is worse than for ammonium sulfate. Just TROPOS F is in this specified for both cases. While the other three devices of the “selective average” ISAC, JRC A and UHEL show at least stable results inside or close of this range for all calculated parameters and measurements.

The results depend on the selected size range as well as on the “selected average” devices. Furthermore, a correction for the aerosol flow rate would also influence the result. Independently of this, the overall deviation can be given to 10% for ammonium sulfate and 20% for the ambient aerosol. A more detailed description for each device is given in chapter 3.

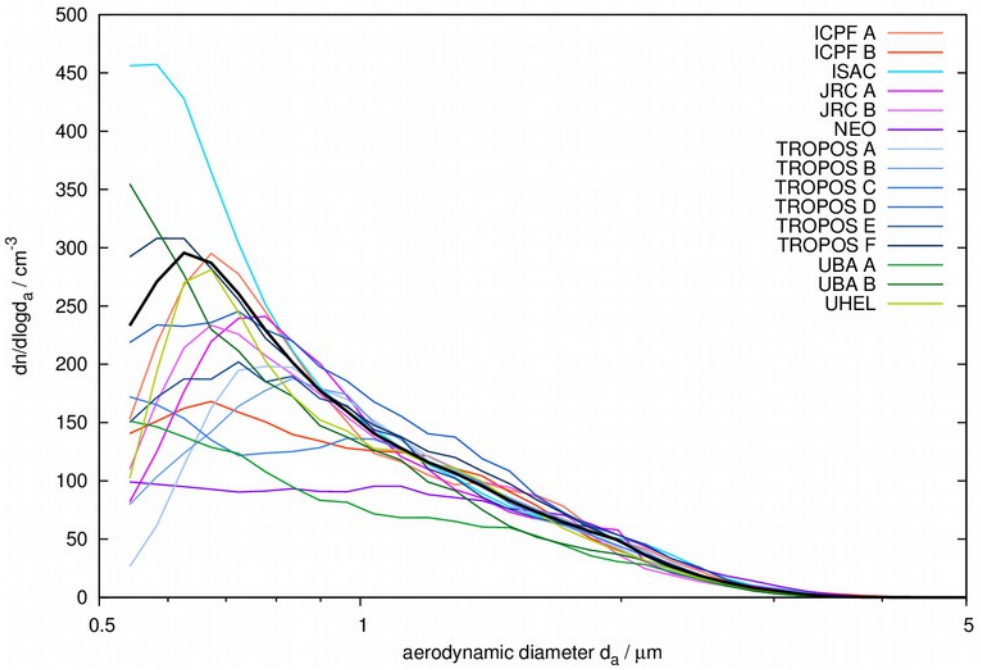


Figure 5: Overview of the measured size distributions for ammonium sulfate

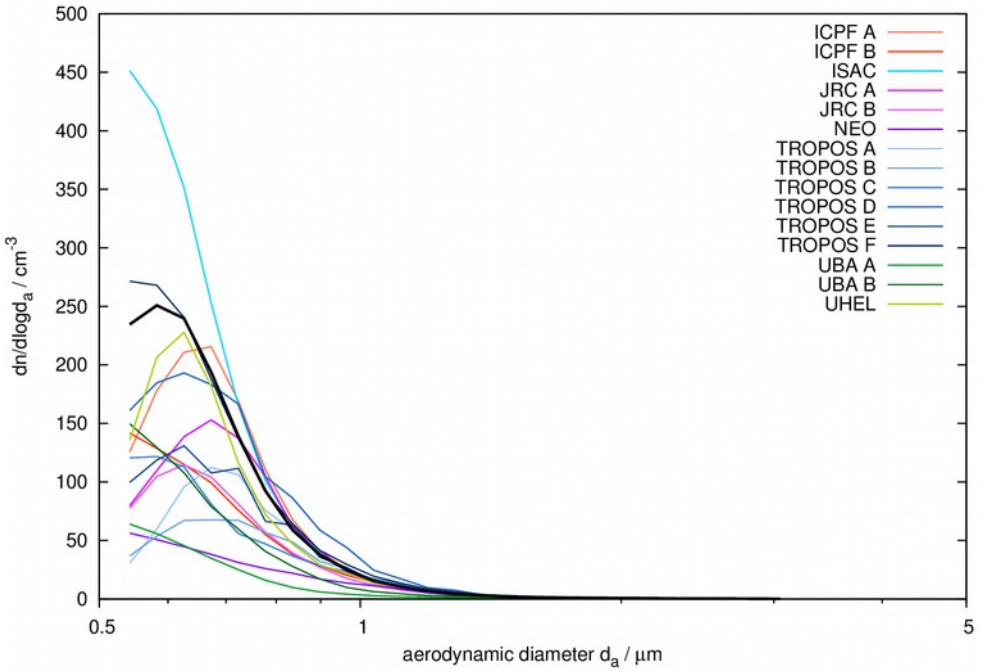


Figure 6: Overview of the measured size distributions for ambient aerosol

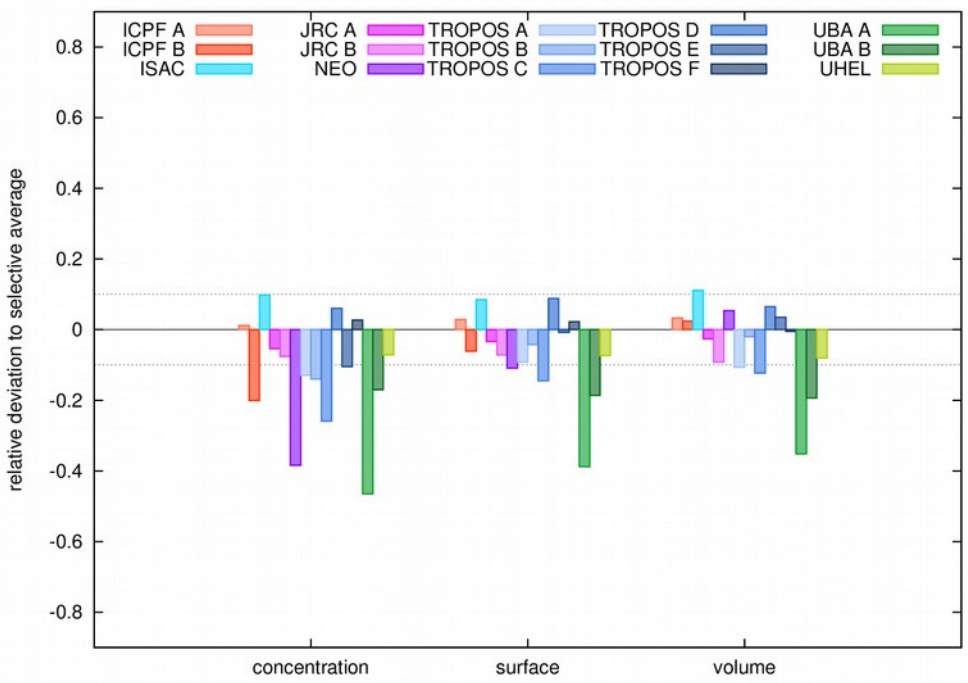


Figure 7: Overview of the relative deviation of the total number, surface area, and volume concentration relative to the results of the "selective average" for ammonium sulfate

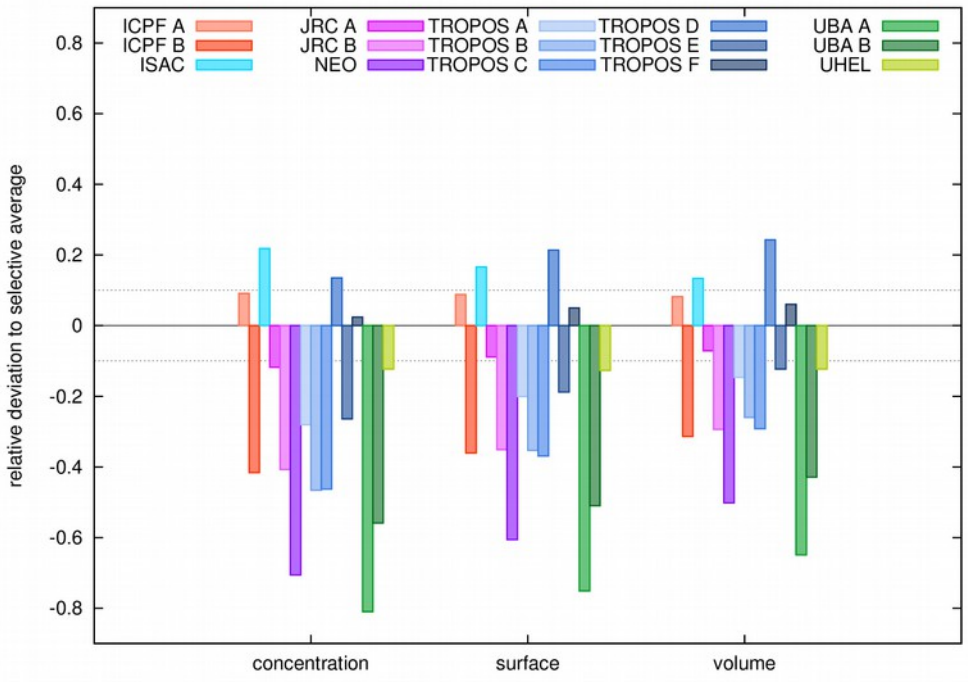


Figure 8: Overview of the relative deviation of the total number, surface area, and volume concentration relative to the results of the "selective average" for ambient aerosol

2.4 Final remarks

The overall quality for the 15 APSS should be assessed as “moderately up to poor”. The quality of three devices (UBA A, UBA B and NEO) should be classified as very poor. Four devices (ISAC, JRC A, TROPOS F, UHEL) have a more a relative good quality. The majority of devices suffers under poor counting efficiency for particles smaller than 1.0 µm, which makes it difficult to give a general threshold value for all devices. A question is, whether this can be corrected in a post-processing. Independently of minor maintenance (replacing filters, cleaning nozzles), the user should check the flow rates as recommended in the manual, and re-calibrate these, if necessary. The quality of sizing should be checked with PSL over a wider size range, not only on diameter. It would be more complicated, however useful, if the user would be able to re-adjust the sizing with the TOF measurements by himself.

3 Detailed results

3.1 ICPF A

Auxiliary information:

- flow re-calibration was performed
- minimum trustworthy size: ~0.7 µm

Flows:

Aerosol flow (before)	**1.261**
Sheath flow (before)	**3.848**
Aerosol flow (after)	**1.015**
Sheath flow (after)	**4.030**

PSL Sizing:

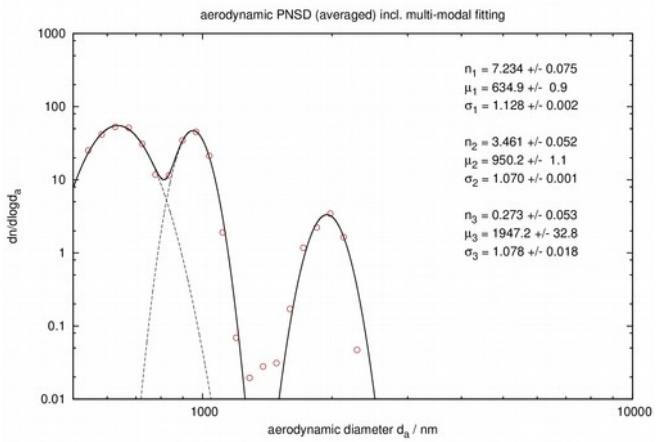
Nominal size	700	900	1000	1600	2000	3000
Measured deviation in % (before)	**-12.6**	**-10.9**	**-9.2**	**-4.8**	**-5.0**	**-13.3**
Measured deviation in % (after)	**13.0**	**9.4**	**9.8**	**12.0**	**8.3**	**-2.2**

PNSD (ammonium sulfate):

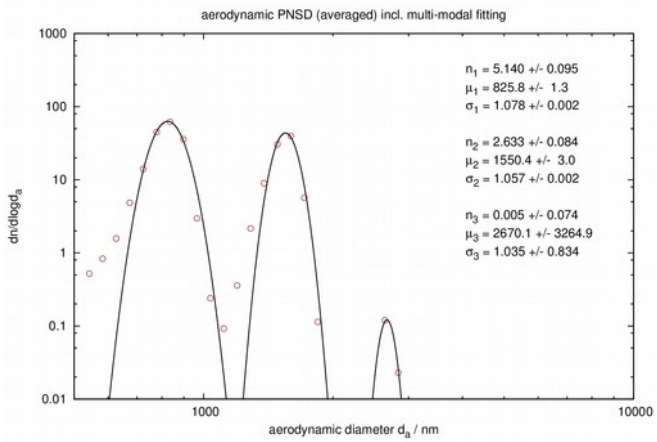
	Concentration	Surface	Volume
Deviation relative to selective average in %	**1.2**	**2.9**	**3.3**

PNSD (ambient):

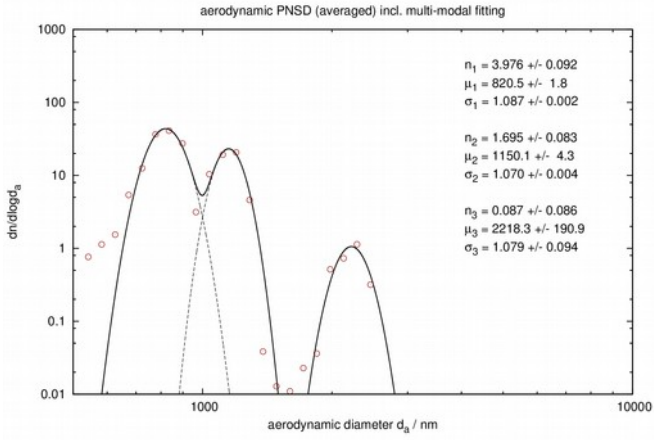
	Concentration	Surface	Volume
Deviation relative to selective average in %	**9.1**	**8.8**	**8.2**



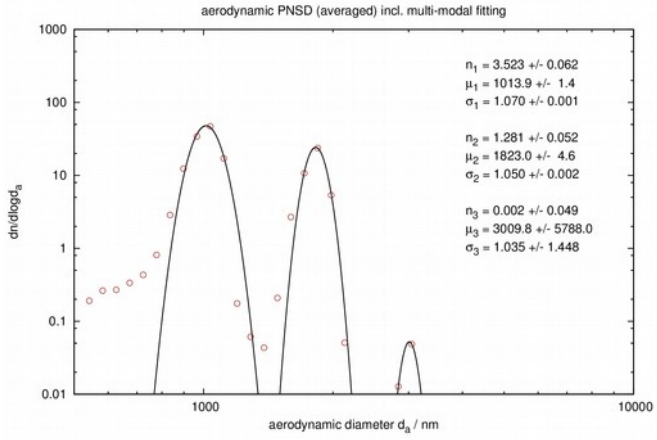
Mode fitting results of PSL mixture (0.7,1.0,2.0) before flow re-calibration



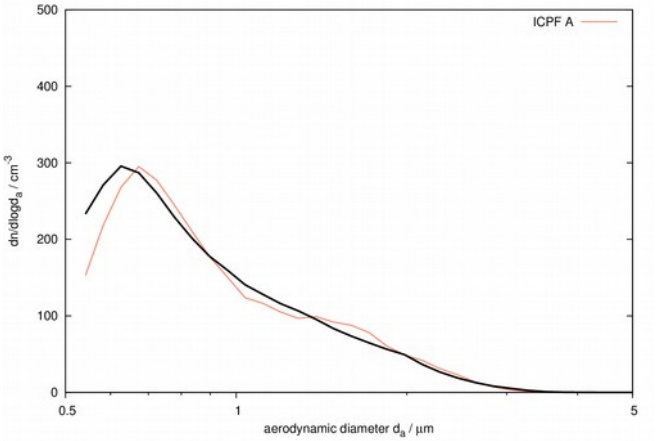
Mode fitting results of PSL mixture (0.9,1.6,3.0) before flow re-calibration



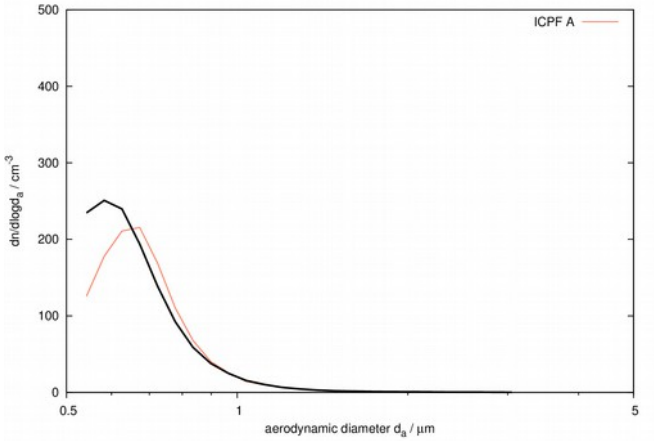
Mode fitting results of PSL mixture (0.7,1.0,2.0) after flow re-calibration



Mode fitting results of PSL mixture (0.9,1.6,3.0) after flow re-calibration



Measured PNSD of ammonium sulfate compared to selective average after flow re-calibration



Measured PNSD of ambient aerosol compared to selective average after flow re-calibration

3.2 ICPF B

Auxiliary information:

- flow re-calibration was performed
- optics/nozzle should to be checked (cleaning, calibration/alignment)
- minimum trustworthy size: ~1.0 µm

Flows:

Aerosol flow (before)	**0.889**
Sheath flow (before)	**3.979**
Aerosol flow (after)	**1.015**
Sheath flow (after)	**4.030**

PSL Sizing:

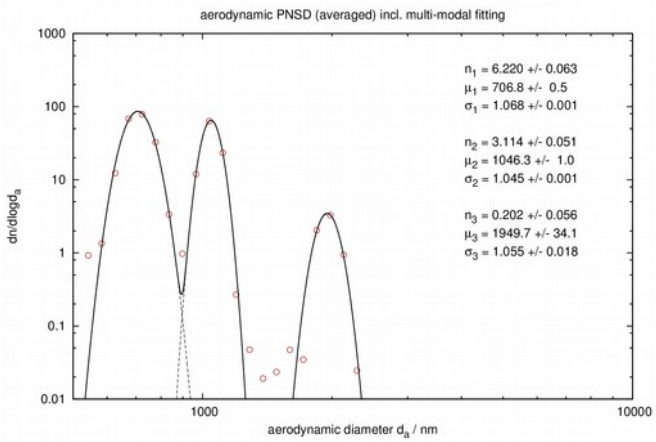
Nominal size	700	900	1000	1600	2000	3000
Measured deviation in % (before)	**-2.7**	**-1.5**	**-0.1**	**-2.4**	**-4.9**	**2.4**
Measured deviation in % (after)	**-7.1**	**-5.9**	**-4.2**	**-6.7**	**-8.2**	**-0.5**

PNSD (ammonium sulfate):

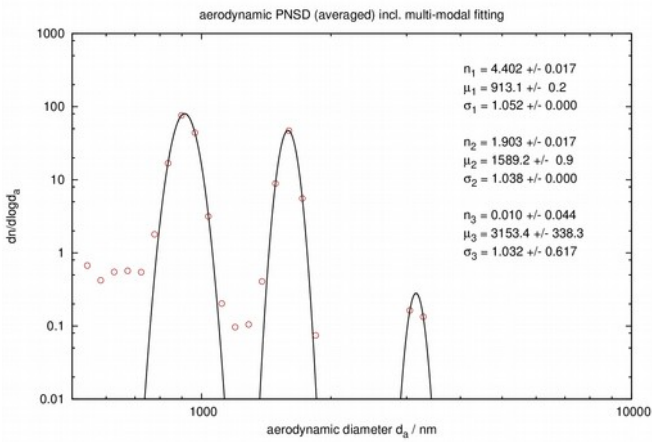
	Concentration	Surface	Volume
Deviation relative to selective average in %	**-20.1**	**-6.1**	**2.4**

PNSD (ambient):

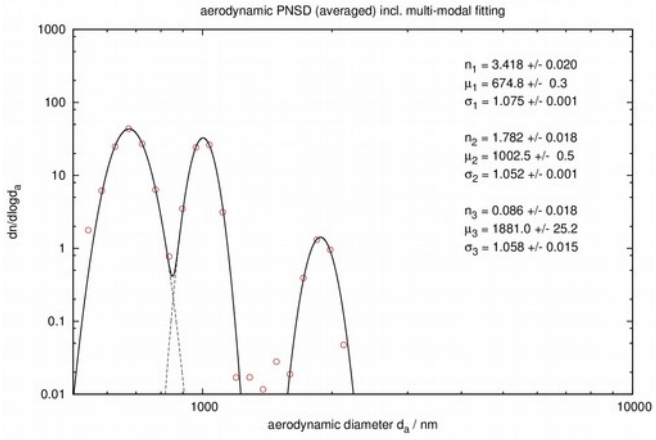
	Concentration	Surface	Volume
Deviation relative to selective average in %	**-41.6**	**-36.1**	**-31.4**



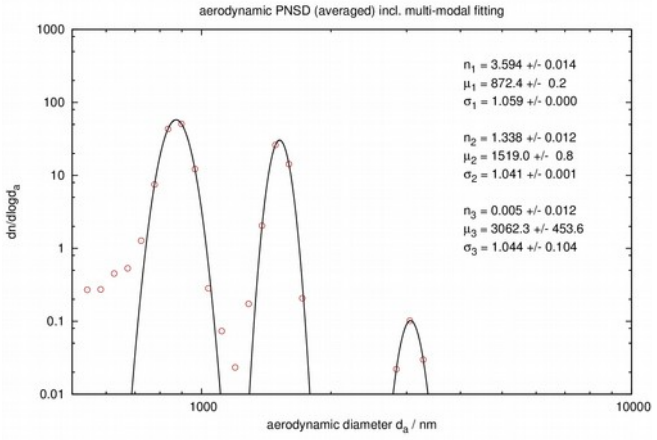
Mode fitting results of PSL mixture (0.7,1.0,2.0) before flow re-calibration



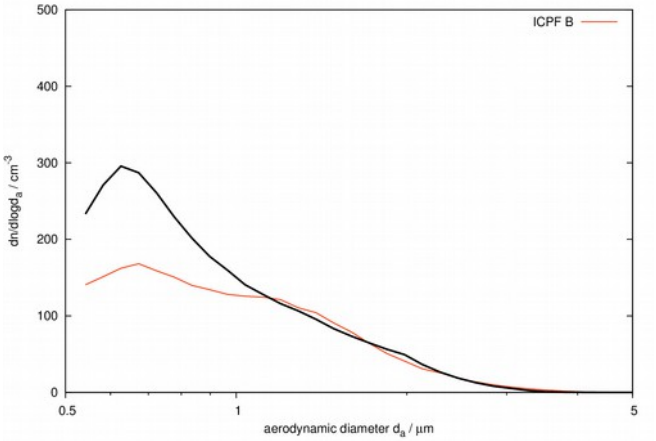
Mode fitting results of PSL mixture (0.9,1.6,3.0) before flow re-calibration



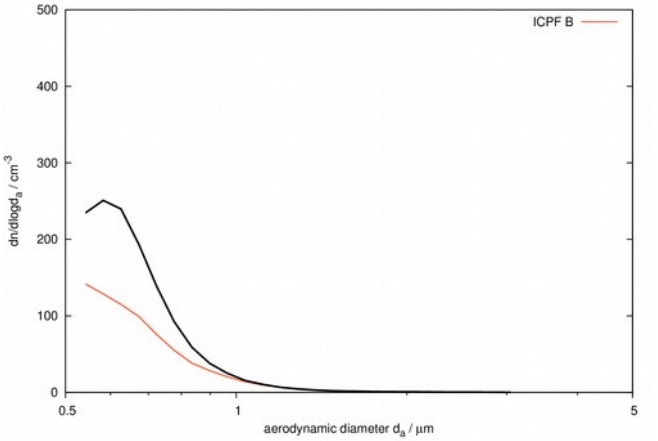
Mode fitting results of PSL mixture (0.7,1.0,2.0) after flow re-calibration



Mode fitting results of PSL mixture (0.9,1.6,3.0) after flow re-calibration



Measured PNSD of ammonium sulfate compared to selective average after flow re-calibration



Measured PNSD of ambient aerosol compared to selective average after flow re-calibration

3.3 ISAC

Auxiliary information:

- arrived later
- flow re-calibration was performed, but no measurements before
- minimum trustworthy size: ~0.8 µm

Flows:

Aerosol flow:	**1.030**
Sheath flow:	**4.030**

PSL Sizing:

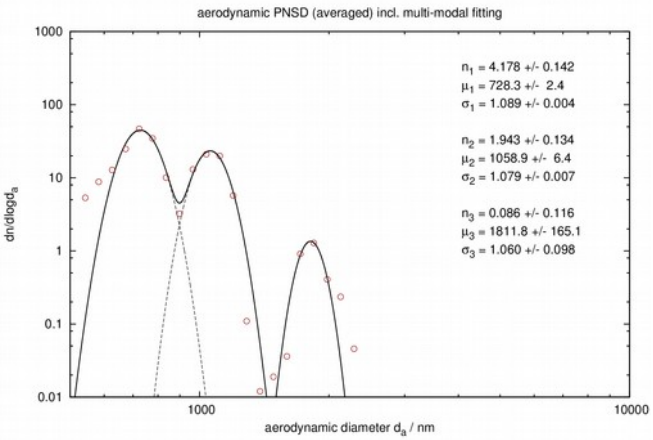
Nominal size	700	900	1000	1600	2000	3000
Measured deviation in %	**0.3**	**0.0**	**1.1**	**-1.7**	**-11.6**	**-7.0**

PNSD (ammonium sulfate):

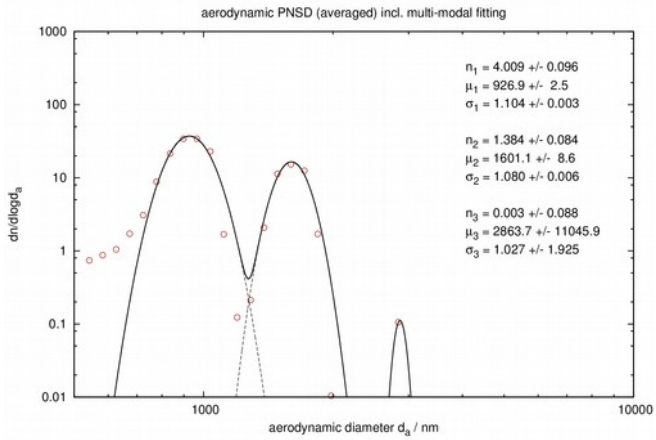
	Concentration	Surface	Volume
Deviation relative to selective average in %	**9.8**	**8.5**	**11.1**

PNSD (ambient):

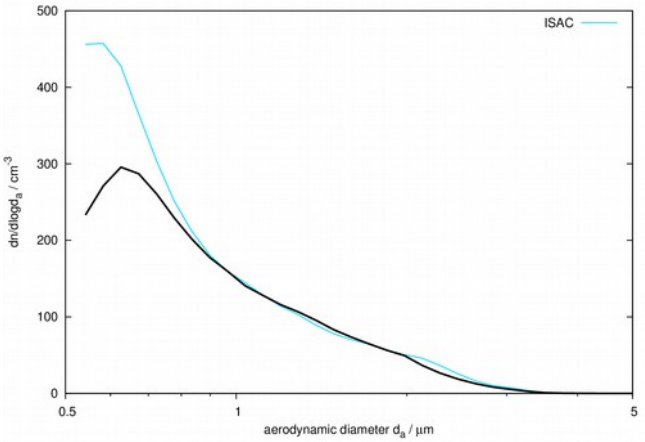
	Concentration	Surface	Volume
Deviation relative to selective average in %	**21.8**	**-16.6**	**-13.4**



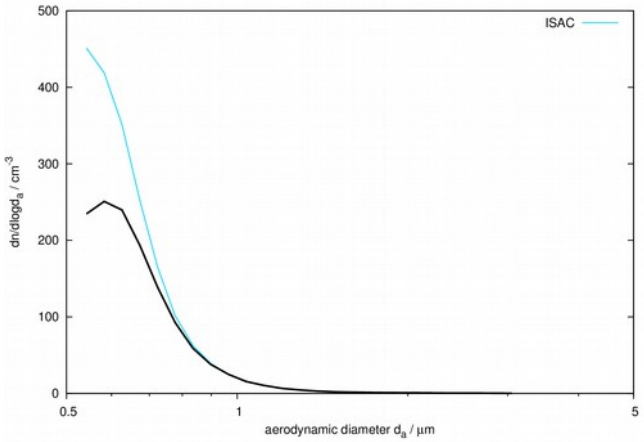
Mode fitting results of PSL mixture (0.7,1.0,2.0)



Mode fitting results of PSL mixture (0.9,1.6,3.0)



Measured PNSD of ammonium sulfate compared to selective average



Measured PNSD of ambient aerosol compared to selective average

3.4 JRC A

Auxiliary information:

- flow re-calibration was performed, although the flows were acceptable
- minimum trustworthy size: ~0.75 µm

Flows:

Aerosol flow (before)	**0.953**
Sheath flow (before)	**3.951**
Aerosol flow (after)	**1.015**
Sheath flow (after)	**4.030**

PSL Sizing:

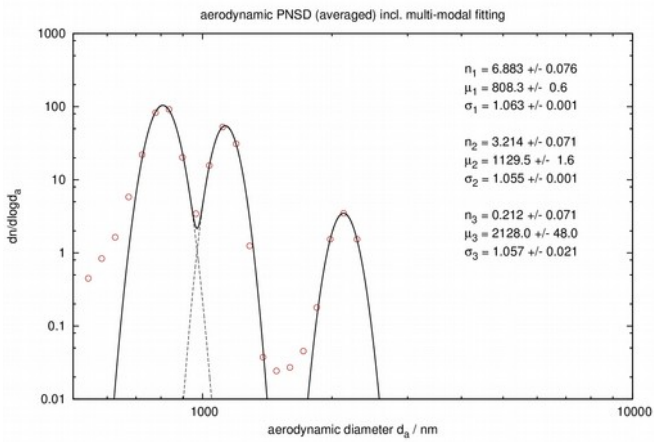
Nominal size	700	900	1000	1600	2000	3000
Measured deviation in % (before)	**11.3**	**6.6**	**7.9**	**5.2**	**3.8**	**3.7**
Measured deviation in % (after)	**2.7**	**-0.6**	**0.8**	**-1.1**	**-0.2**	**0.0**

PNSD (ammonium sulfate):

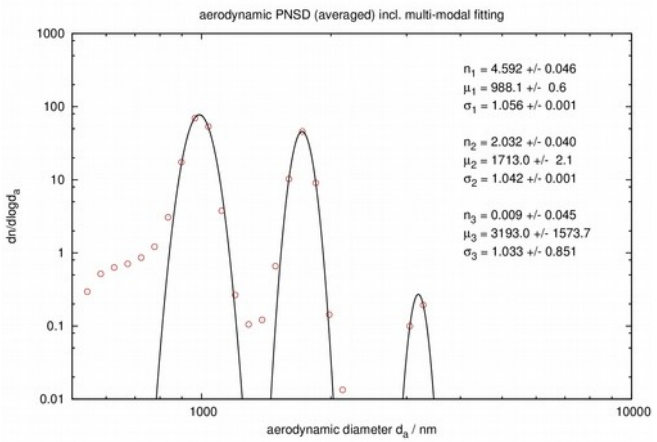
	Concentration	Surface	Volume
Deviation relative to selective average in %	**-5.4**	**-3.4**	**-2.6**

PNSD (ambient):

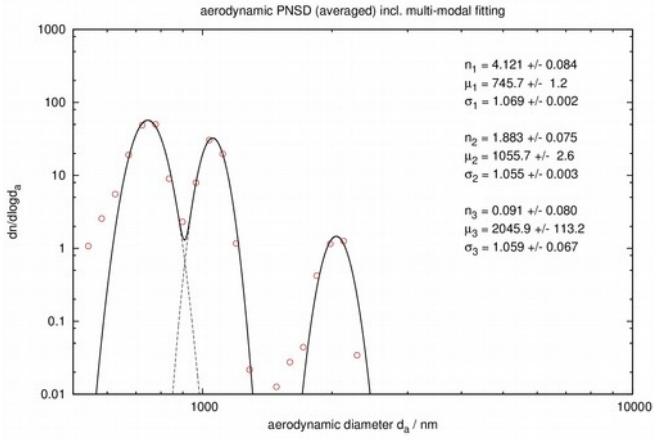
	Concentration	Surface	Volume
Deviation relative to selective average in %	**-11.8**	**-8.9**	**-7.2**



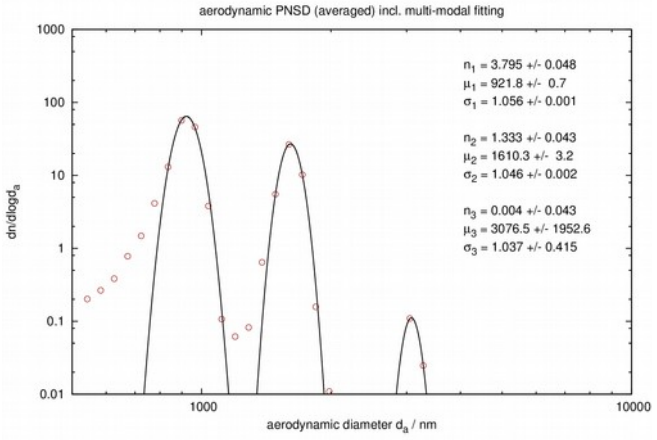
Mode fitting results of PSL mixture (0.7,1.0,2.0) before flow re-calibration



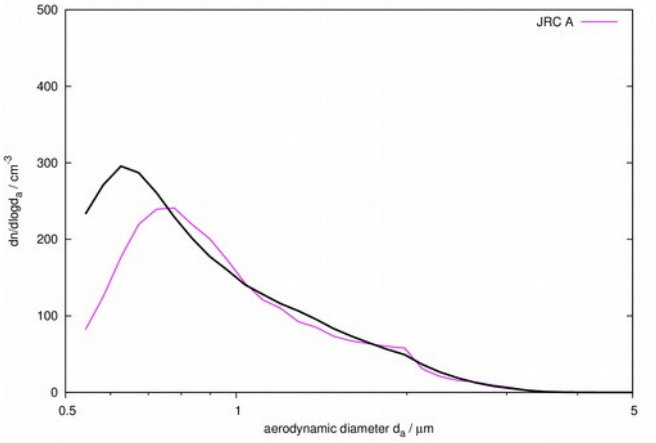
Mode fitting results of PSL mixture (0.9,1.6,3.0) before flow re-calibration



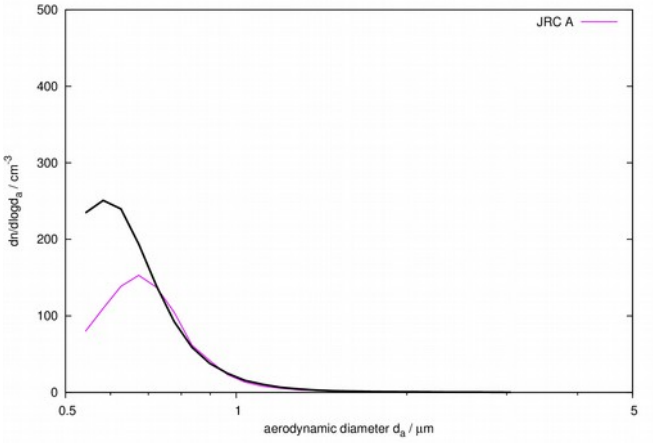
Mode fitting results of PSL mixture (0.7,1.0,2.0) after flow re-calibration



Mode fitting results of PSL mixture (0.9,1.6,3.0) after flow re-calibration



Measured PNSD of ammonium sulfate compared to selective average after flow re-calibration



Measured PNSD of ambient aerosol compared to selective average after flow re-calibration

3.5 JRC B

Auxiliary information:

- flow re-calibration was performed, although the flows were acceptable
- inexplicable deviation between ammonium sulfate and ambient
- minimum trustworthy size: ~0.8 µm (ammonium sulfate), ~1.0 µm (ambient)

Flows:

Aerosol flow (before)	**1.024**
Sheath flow (before)	**3.993**
Aerosol flow (after)	**1.015**
Sheath flow (after)	**4.030**

PSL Sizing:

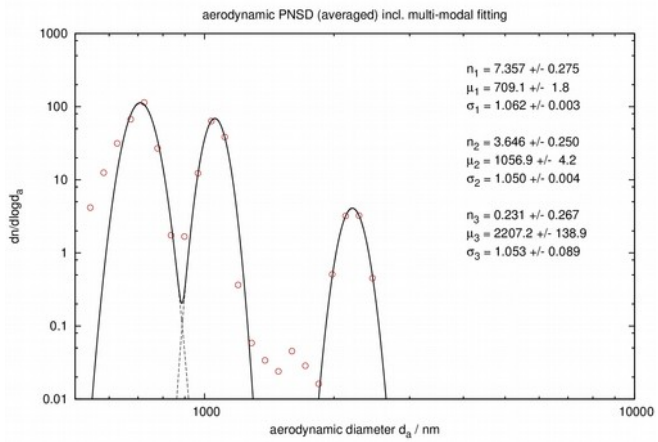
Nominal size	700	900	1000	1600	2000	3000
Measured deviation in % (before)	**-2.4**	**-1.3**	**0.9**	**-0.6**	**7.7**	**2.8**
Measured deviation in % (after)	**0.3**	**1.0**	**3.4**	**0.9**	**10.3**	**4.1**

PNSD (ammonium sulfate):

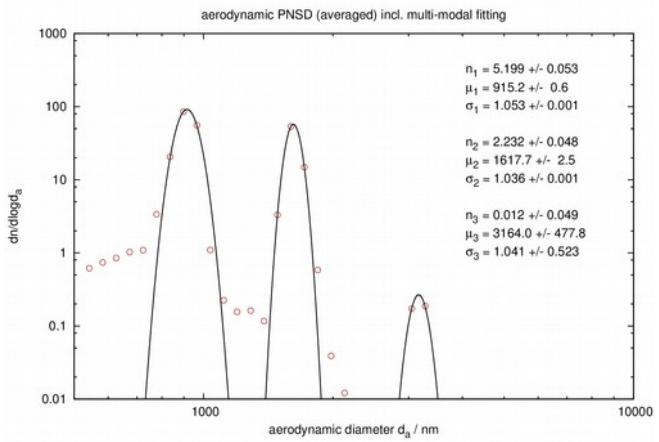
	Concentration	Surface	Volume
Deviation relative to selective average in %	**-7.6**	**-7.2**	**-9.2**

PNSD (ambient):

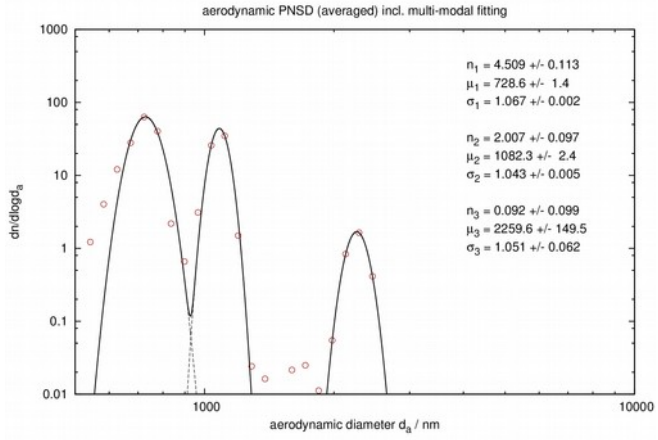
	Concentration	Surface	Volume
Deviation relative to selective average in %	**-40.7**	**-35.1**	**-29.4**



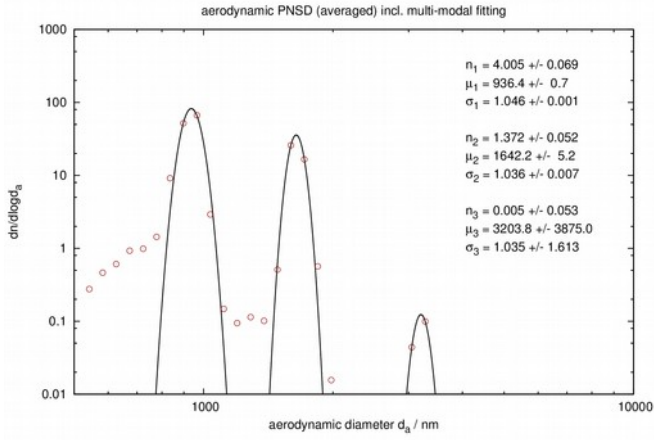
Mode fitting results of PSL mixture (0.7,1.0,2.0) before flow re-calibration



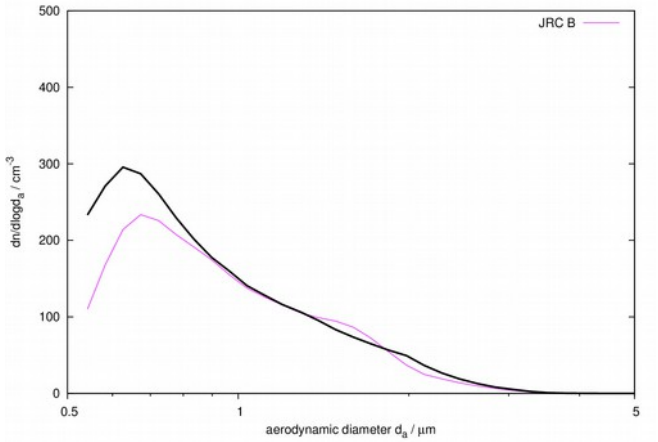
Mode fitting results of PSL mixture (0.9,1.6,3.0) before flow re-calibration



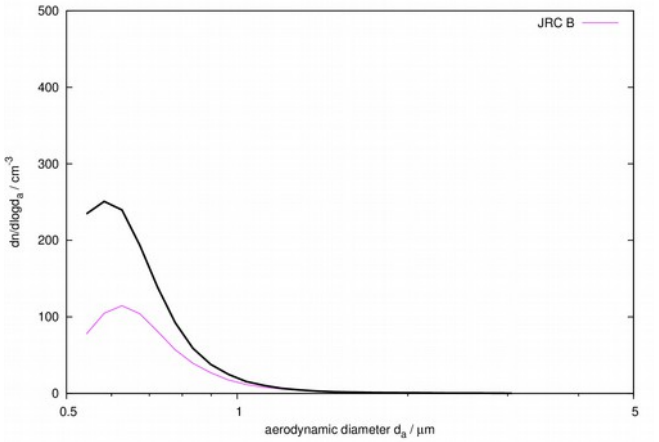
Mode fitting results of PSL mixture (0.7,1.0,2.0) after flow re-calibration



Mode fitting results of PSL mixture (0.9,1.6,3.0) after flow re-calibration



Measured PNSD of ammonium sulfate compared to selective average after flow re-calibration



Measured PNSD of ambient aerosol compared to selective average after flow re-calibration

3.6 NEO

Auxiliary information:

- device arrived with a broken total pump, which was replaced
- flow re-calibration was performed
- optics/nozzle should to be checked (cleaning, calibration/alignment), needs TOF re-calibration
- minimum trustworthy size range: ~1.6 µm

Flows:

Aerosol flow:	**1.015**
Sheath flow:	**4.030**

PSL Sizing:

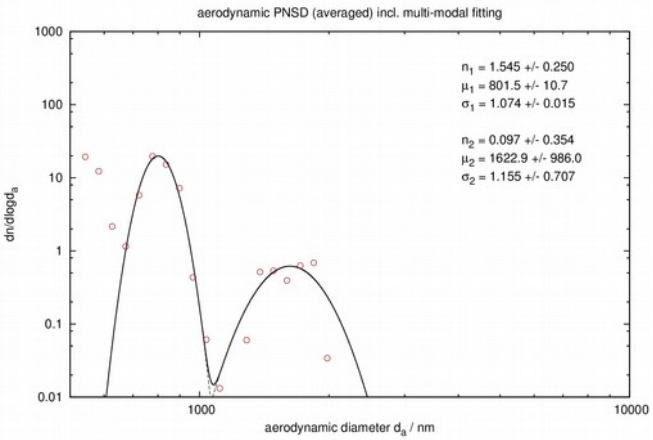
Nominal size	700	900	1000	1600	2000	3000
Measured deviation in %	**na**	**-26.2**	**-23.4**	**-19.9**	**-20.8**	**na**

PNSD (ammonium sulfate):

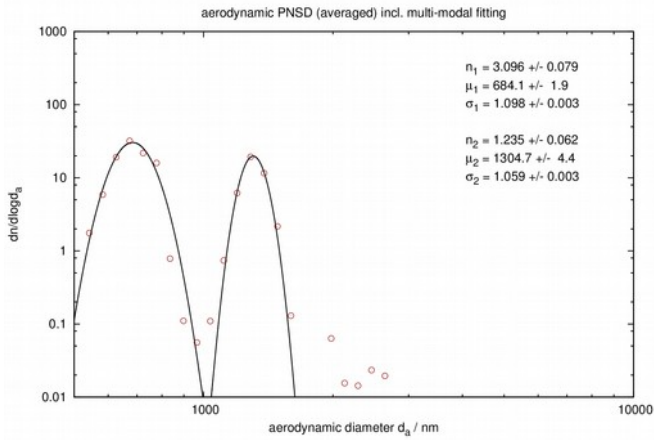
	Concentration	Surface	Volume
Deviation relative to selective average in %	**-38.4**	**-10.9**	**5.4**

PNSD (ambient):

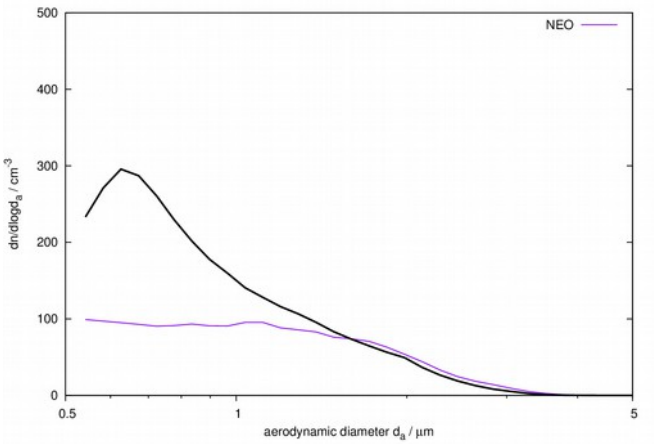
	Concentration	Surface	Volume
Deviation relative to selective average in %	**-70.6**	**-60.6**	**-50.2**



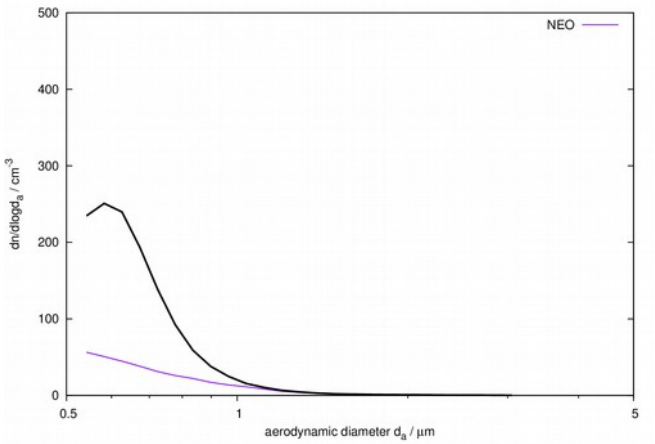
Mode fitting results of PSL mixture (0.7,1.0,2.0)



Mode fitting results of PSL mixture (0.9,1.6,3.0)



Measured PNSD of ammonium sulfate compared to selective average



Measured PNSD of ambient aerosol compared to selective average

3.7 TROPOS A

Auxiliary information:

- minimum trustworthy size: ~0.8 µm

Flows:

Aerosol flow:	**1.030**
Sheath flow:	**3.993**

PSL Sizing:

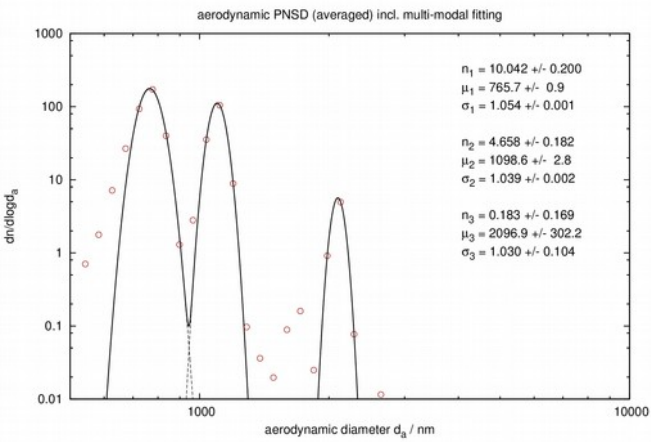
Nominal size	700	900	1000	1600	2000	3000
Measured deviation in %	**5.4**	**2.9**	**4.9**	**2.3**	**2.3**	**-2.5**

PNSD (ammonium sulfate):

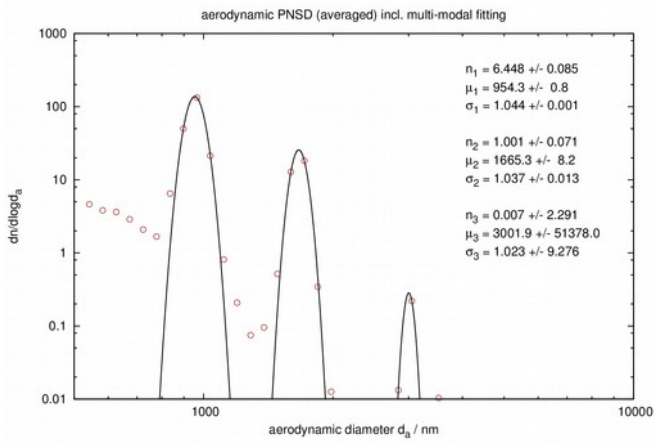
	Concentration	Surface	Volume
Deviation relative to selective average in %	**-12.9**	**-9.2**	**-10.7**

PNSD (ambient):

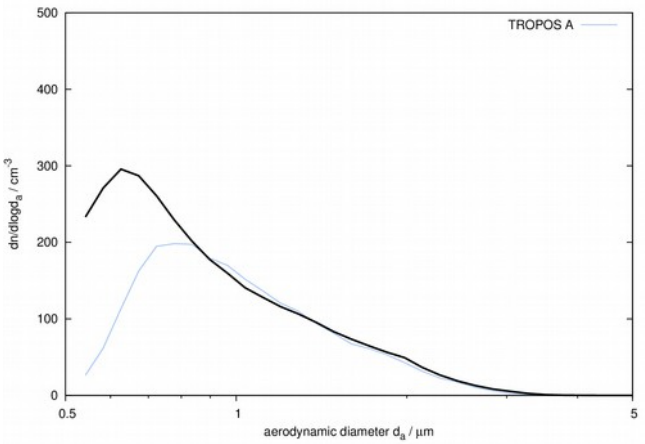
	Concentration	Surface	Volume
Deviation relative to selective average in %	**-28.1**	**-20.1**	**-14.7**



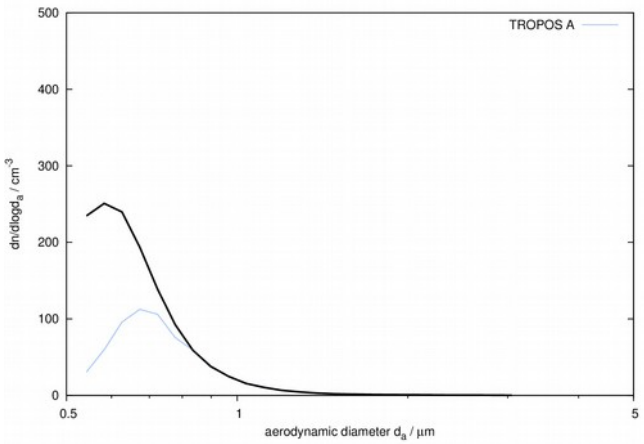
Mode fitting results of PSL mixture (0.7,1.0,2.0)



Mode fitting results of PSL mixture (0.9,1.6,3.0)



Measured PNSD of ammonium sulfate compared to selective average



Measured PNSD of ambient aerosol compared to selective average

3.8 TROPOS B

Auxiliary information:

- minimum trustworthy size: ~0.9 µm

Flows:

Aerosol flow:	**1.043**
Sheath flow:	**3.884**

PSL Sizing:

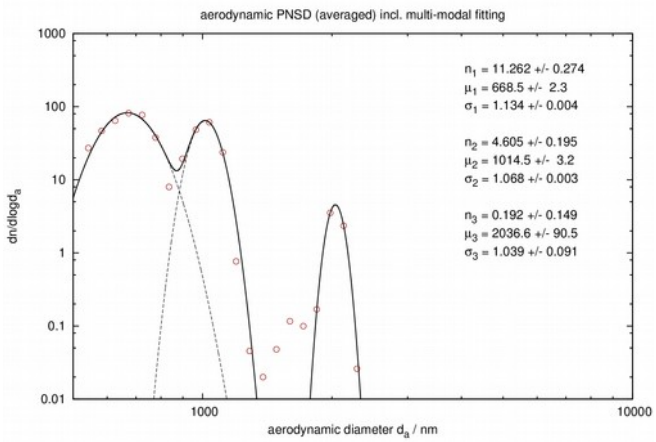
Nominal size	700	900	1000	1600	2000	3000
Measured deviation in %	**-7.9**	**-5.0**	**-3.1**	**-0.6**	**-0.6**	**-9.3**

PNSD (ammonium sulfate):

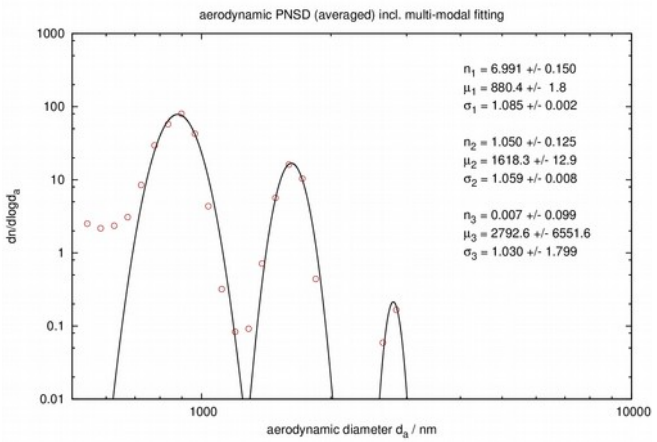
	Concentration	Surface	Volume
Deviation relative to selective average in %	**-14.0**	**-4.2**	**-2.0**

PNSD (ambient):

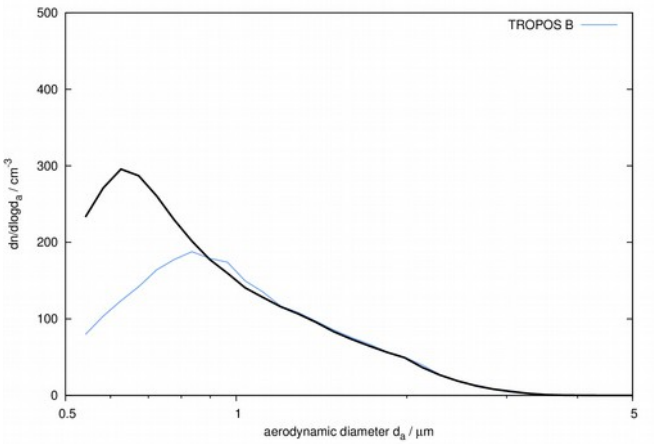
	Concentration	Surface	Volume
Deviation relative to selective average in %	**-46.6**	**-35.3**	**-26.0**



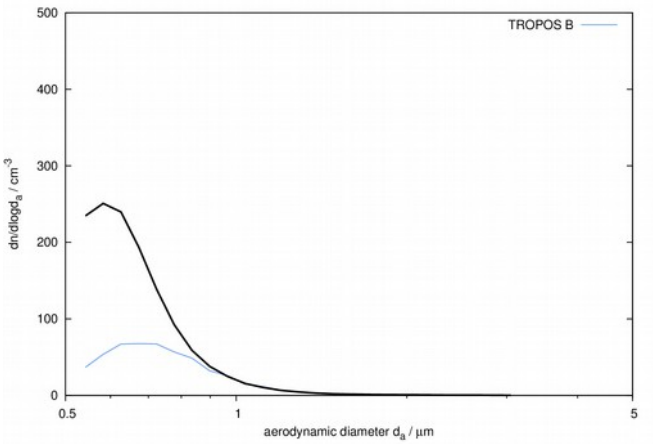
Mode fitting results of PSL mixture (0.7,1.0,2.0)



Mode fitting results of PSL mixture (0.9,1.6,3.0)



Measured PNSD of ammonium sulfate compared to selective average



Measured PNSD of ambient aerosol compared to selective average

3.9 TROPOS C

Auxiliary information:

- minimum trustworthy size: ~1.0 µm

Flows:

Aerosol flow:	**0.921**
Sheath flow:	**3.909**

PSL Sizing:

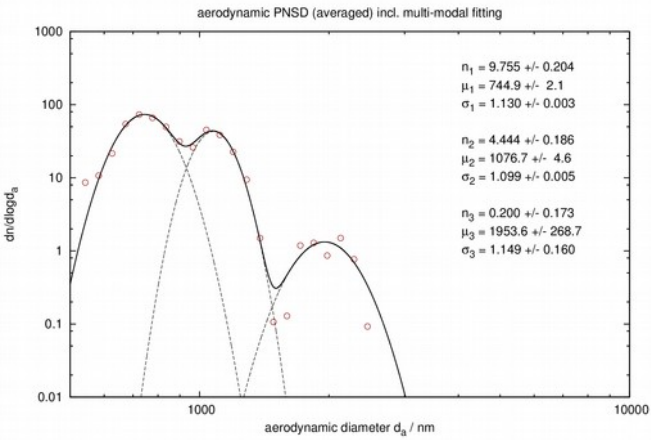
Nominal size	700	900	1000	1600	2000	3000
Measured deviation in %	**2.6**	**2.7**	**2.8**	**-0.7**	**-4.7**	**-7.3**

PNSD (ammonium sulfate):

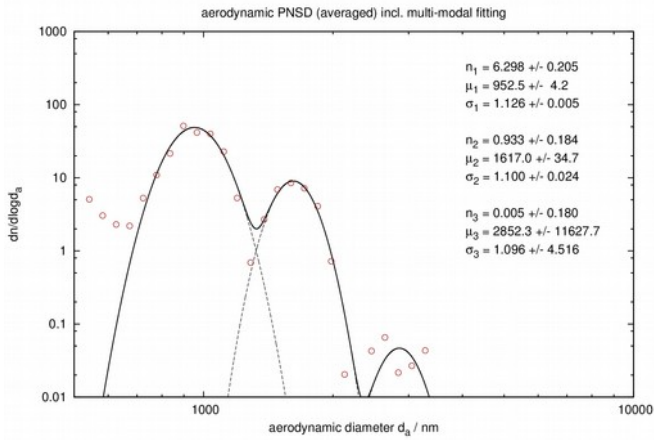
	Concentration	Surface	Volume
Deviation relative to selective average in %	**-25.9**	**-14.5**	**-12.3**

PNSD (ambient):

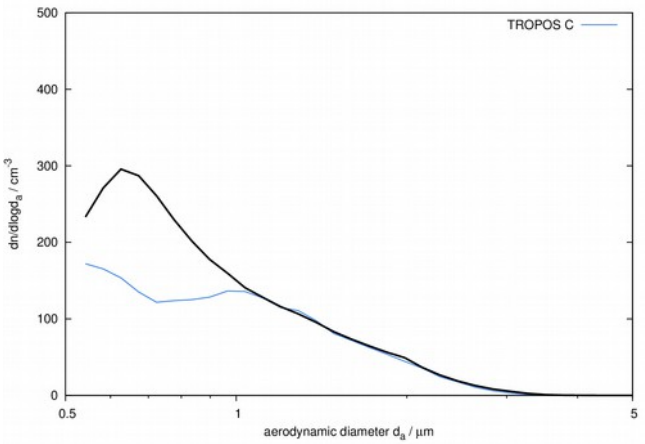
	Concentration	Surface	Volume
Deviation relative to selective average in %	**-46.3**	**-36.9**	**-29.2**



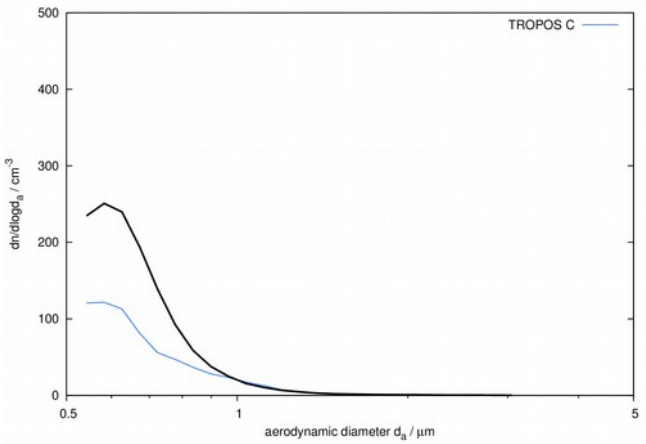
Mode fitting results of PSL mixture (0.7,1.0,2.0)



Mode fitting results of PSL mixture (0.9,1.6,3.0)



Measured PNSD of ammonium sulfate compared to selective average



Measured PNSD of ambient aerosol compared to selective average

3.10 TROPOS D

Auxiliary information:

- minimum trustworthy size: ~0.7 µm

Flows:

Aerosol flow:	**0.969**
Sheath flow:	**4.034**

PSL Sizing:

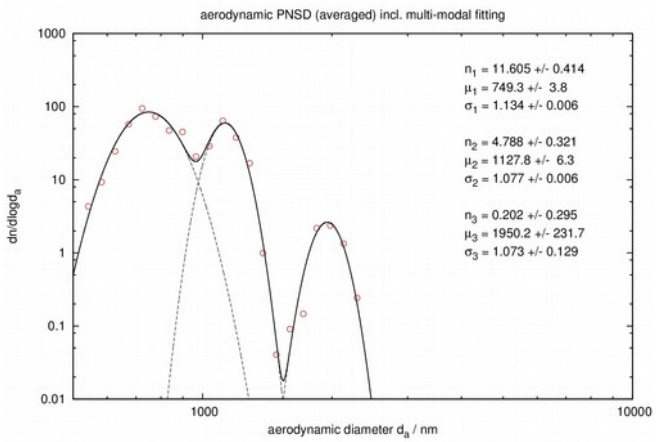
Nominal size	700	900	1000	1600	2000	3000
Measured deviation in %	**3.2**	**5.0**	**7.7**	**1.2**	**-4.8**	**-9.1**

PNSD (ammonium sulfate):

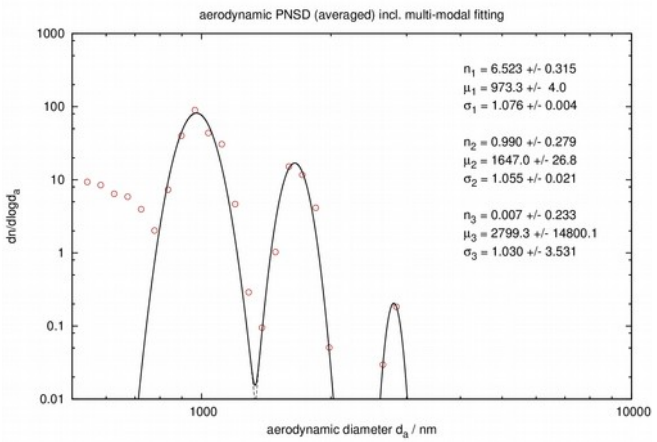
	Concentration	Surface	Volume
Deviation relative to selective average in %	**6.0**	**8.8**	**6.5**

PNSD (ambient):

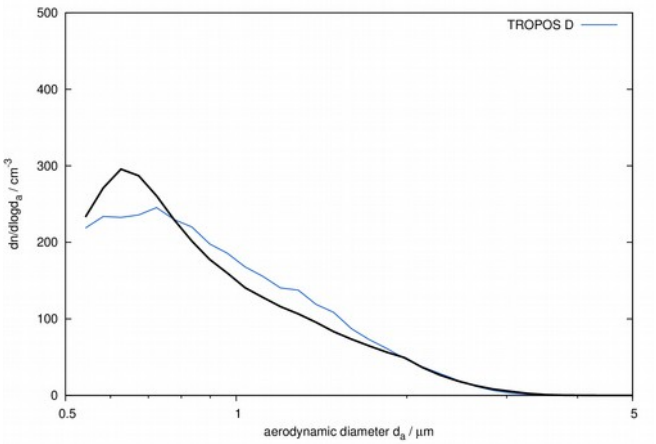
	Concentration	Surface	Volume
Deviation relative to selective average in %	**13.5**	**21.4**	**24.3**



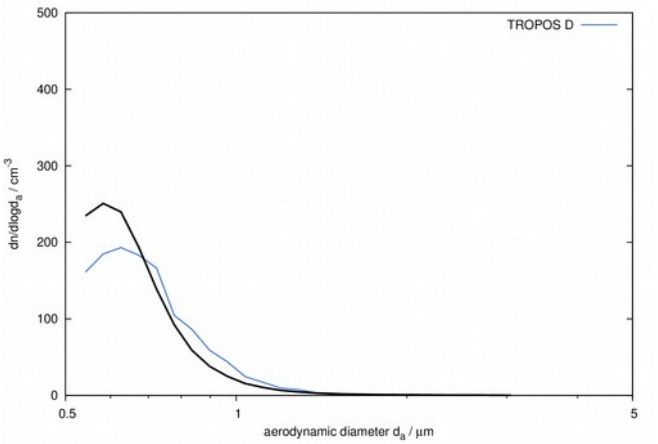
Mode fitting results of PSL mixture (0.7,1.0,2.0)



Mode fitting results of PSL mixture (0.9,1.6,3.0)



Measured PNSD of ammonium sulfate compared to selective average



Measured PNSD of ambient aerosol compared to selective average

3.11 TROPOS E

Auxiliary information:

- total pump was broken after the measurements (other data is not influenced by this defect)
- minimum trustworthy size: ~0.8 µm

Flows:

Aerosol flow:	**na**
Sheath flow:	**4.042**

PSL Sizing:

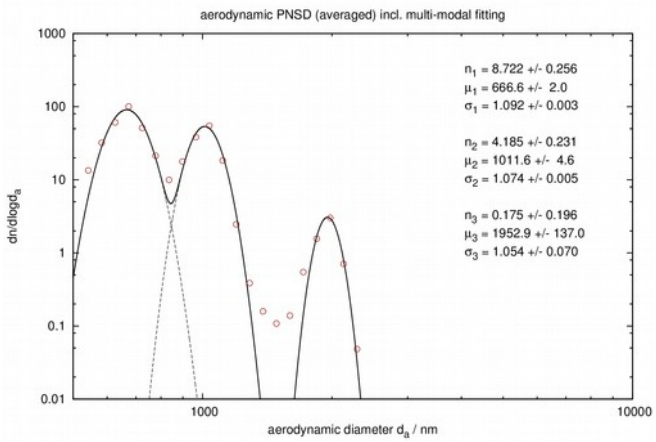
Nominal size	700	900	1000	1600	2000	3000
Measured deviation in %	**-8.2**	**-5.3**	**-3.4**	**-1.1**	**-4.7**	**-17.5**

PNSD (ammonium sulfate):

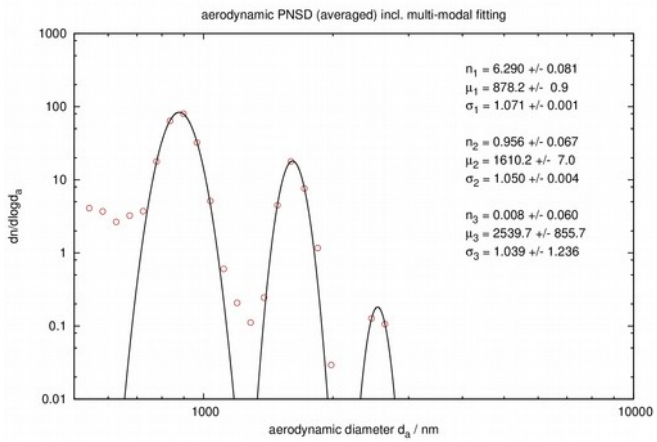
	Concentration	Surface	Volume
Deviation relative to selective average in %	**-10.5**	**-0.8**	**3.5**

PNSD (ambient):

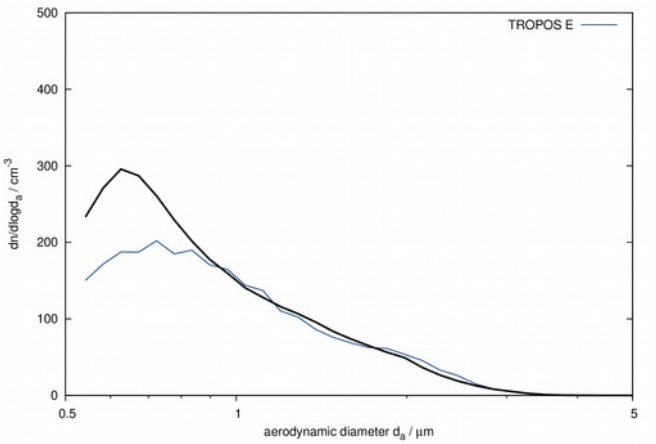
	Concentration	Surface	Volume
Deviation relative to selective average in %	**-26.4**	**-18.8**	**-12.3**



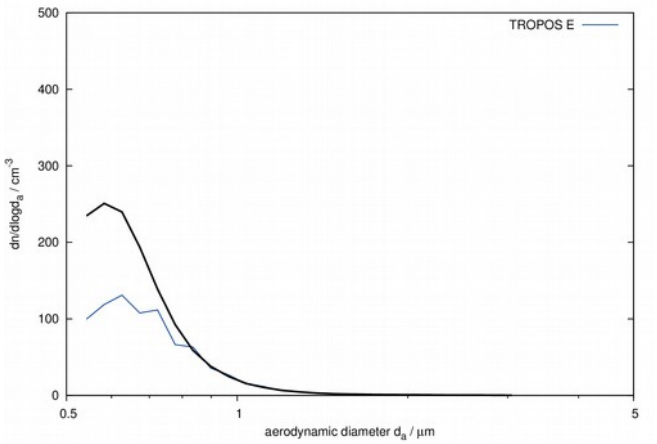
Mode fitting results of PSL mixture (0.7,1.0,2.0)



Mode fitting results of PSL mixture (0.9,1.6,3.0)



Measured PNSD of ammonium sulfate compared to selective average



Measured PNSD of ambient aerosol compared to selective average

3.12 TROPOS F

Auxiliary information:

- newest device in this intercomparission
- sheath flow outside the specified range, but manufacturer's nominal setting
- minimum trustworthy size: ~0.7 µm

Flows:

Aerosol flow:	**0.954**
Sheath flow:	**4.156**

PSL Sizing:

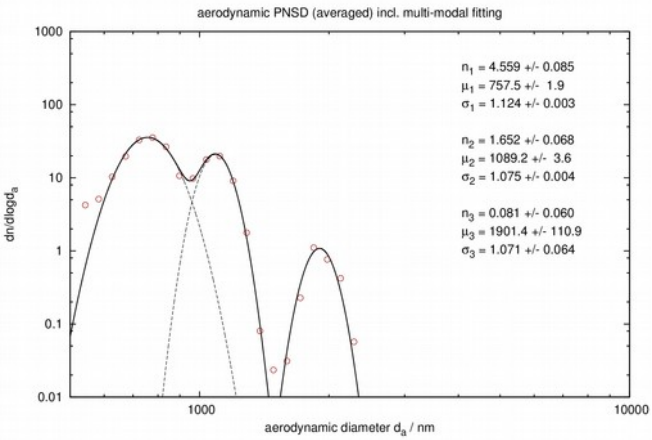
Nominal size	700	900	1000	1600	2000	3000
Measured deviation in %	**4.3**	**3.2**	**4.0**	**0.2**	**-7.2**	**-8.3**

PNSD (ammonium sulfate):

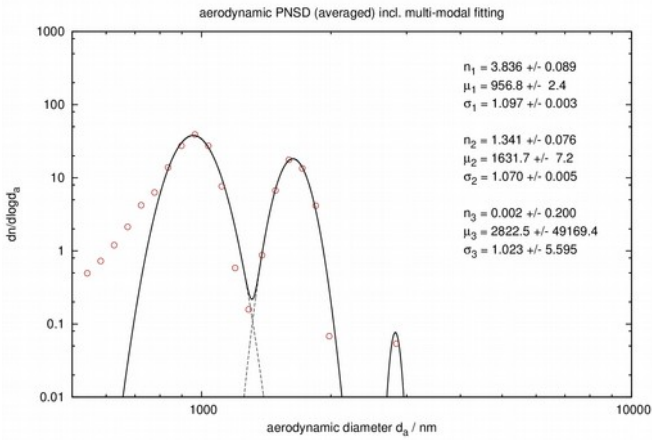
	Concentration	Surface	Volume
Deviation relative to selective average in %	**2.7**	**2.2**	**-0.5**

PNSD (ambient):

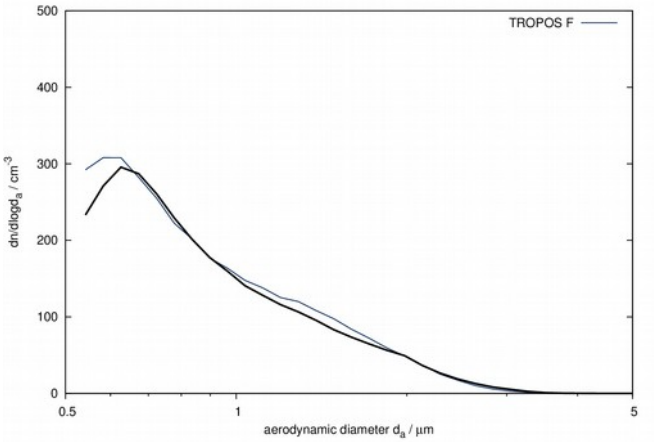
	Concentration	Surface	Volume
Deviation relative to selective average in %	**2.4**	**5.0**	**6.0**



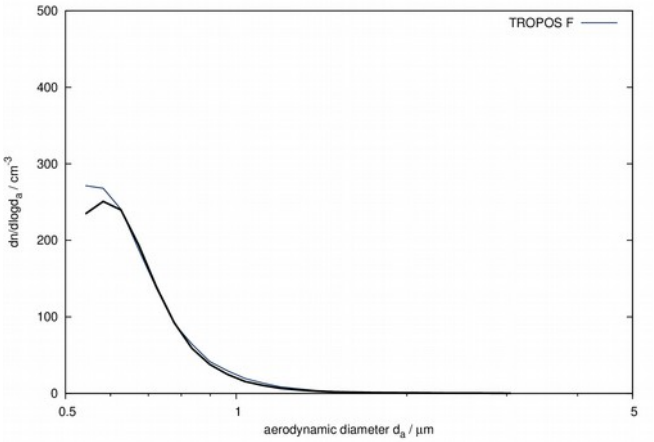
Mode fitting results of PSL mixture (0.7,1.0,2.0)



Mode fitting results of PSL mixture (0.9,1.6,3.0)



Measured PNSD of ammonium sulfate compared to selective average



Measured PNSD of ambient aerosol compared to selective average

3.13 UBA A

Auxiliary information:

- optics/nozzle should to be checked (cleaning, calibration/alignment)
- minimum trustworthy size: na

Flows:

Aerosol flow:	**0.916**
Sheath flow:	**3.908**

PSL Sizing:

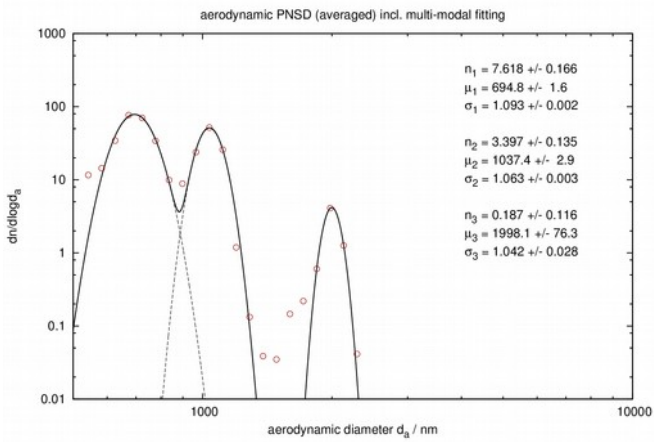
Nominal size	700	900	1000	1600	2000	3000
Measured deviation in %	**-4.3**	**-4.5**	**-0.9**	**-2.6**	**-2.5**	**-8.4**

PNSD (ammonium sulfate):

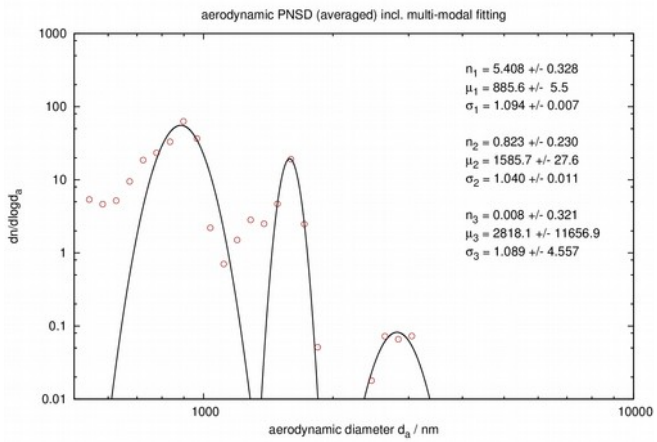
	Concentration	Surface	Volume
Deviation relative to selective average in %	**-46.5**	**-38.8**	**-35.2**

PNSD (ambient):

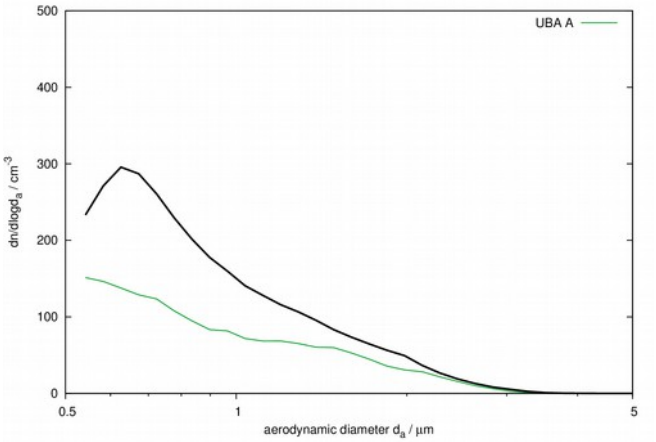
	Concentration	Surface	Volume
Deviation relative to selective average in %	**-81.0**	**-75.1**	**-64.9**



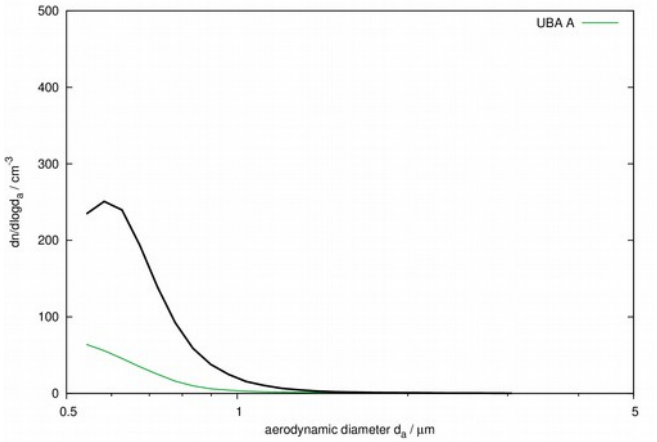
Mode fitting results of PSL mixture (0.7,1.0,2.0)



Mode fitting results of PSL mixture (0.9,1.6,3.0)



Measured PNSD of ammonium sulfate compared to selective average



Measured PNSD of ambient aerosol compared to selective average

3.14 UBA B

Auxiliary information:

- arrived with damaged and corrode inner nozzle, fixed provisionally
- optics/nozzle should to be checked (cleaning, calibration/alignment), needs TOF calibration
- minimum trustworthy size: na

Flows:

Aerosol flow:	**0.995**
Sheath flow:	**4.036**

PSL Sizing:

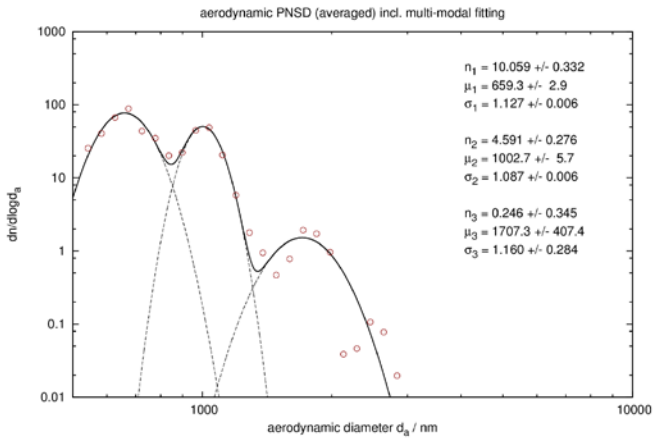
Nominal size	700	900	1000	1600	2000	3000
Measured deviation in %	**-9.2**	**-7.4**	**-4.2**	**-8.2**	**-16.7**	**-6.5**

PNSD (ammonium sulfate):

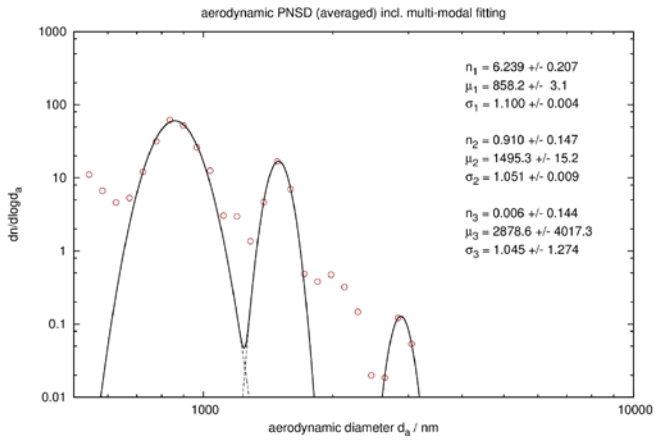
	Concentration	Surface	Volume
Deviation relative to selective average in %	**-17.0**	**-18.6**	**-19.4**

PNSD (ambient):

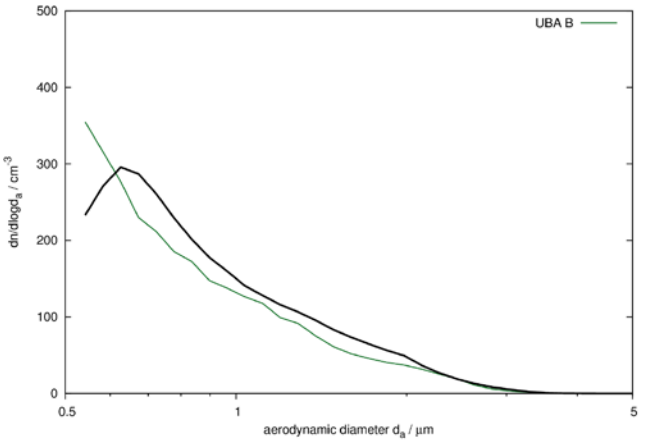
	Concentration	Surface	Volume
Deviation relative to selective average in %	**-55.9**	**-51.0**	**-42.9**



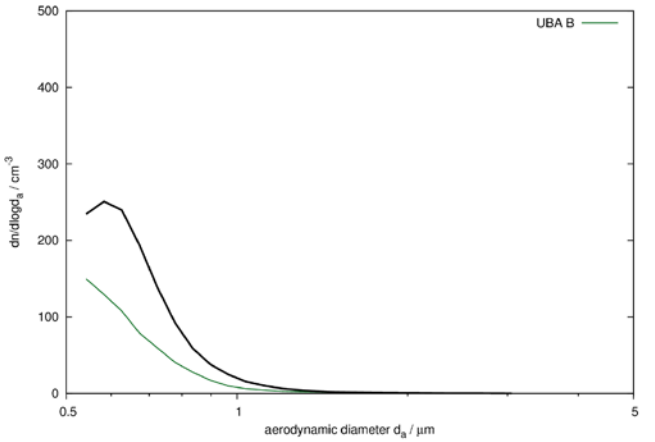
Mode fitting results of PSL mixture (0.7,1.0,2.0)



Mode fitting results of PSL mixture (0.9,1.6,3.0)



Measured PNSD of ammonium sulfate compared to selective average



Measured PNSD of ambient aerosol compared to selective average

3.15 UHEL

Auxiliary information:

- minimum trustworthy size: ~0.7 µm

Flows:

Aerosol flow:	**1.026**
Sheath flow:	**4.010**

PSL Sizing:

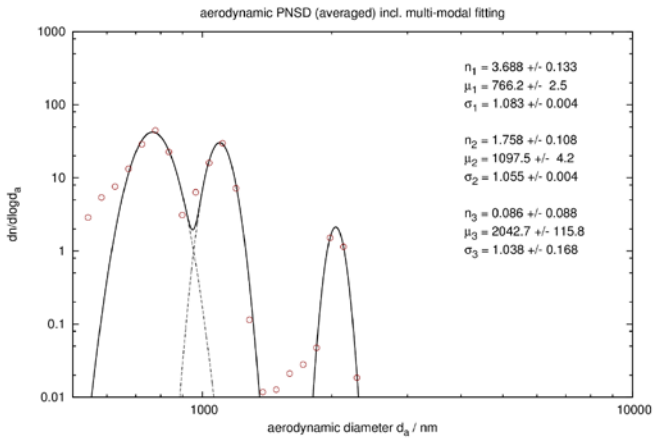
Nominal size	700	900	1000	1600	2000	3000
Measured deviation in %	**5.5**	**4.3**	**4.8**	**0.3**	**-0.3**	**-3.8**

PNSD (ammonium sulfate):

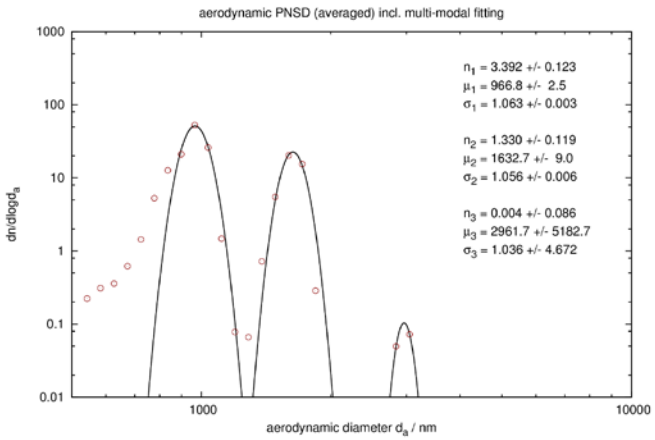
	Concentration	Surface	Volume
Deviation relative to selective average in %	**-7.1**	**-7.3**	**-8.0**

PNSD (ambient):

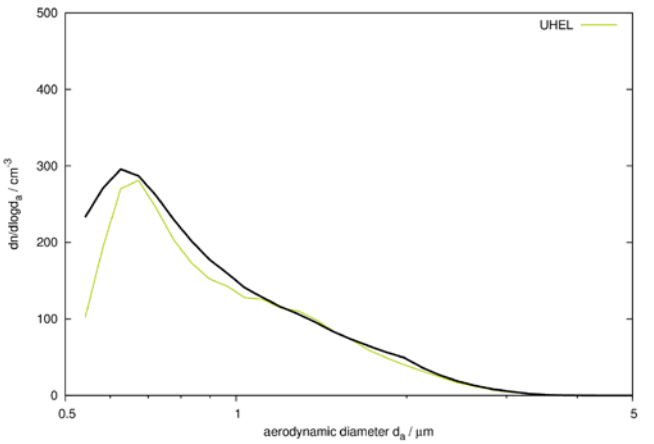
	Concentration	Surface	Volume
Deviation relative to selective average in %	**-12.3**	**-12.7**	**-12.3**



Mode fitting results of PSL mixture (0.7,1.0,2.0)



Mode fitting results of PSL mixture (0.9,1.6,3.0)



Measured PNSD of ammonium sulfate compared to selective average

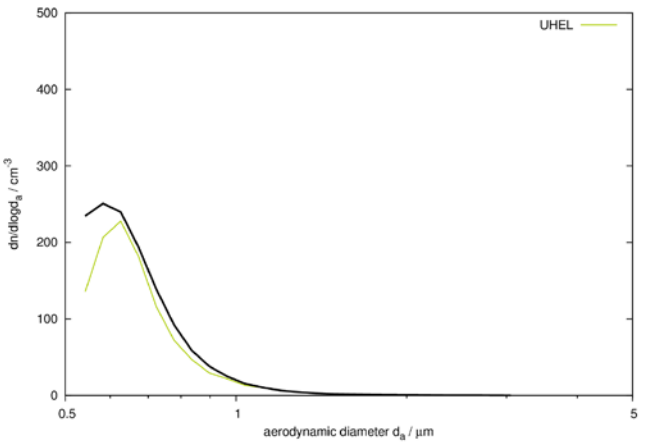


Illustration 1: Measured PNSD of ambient aerosol compared to selective average