



Leibniz Institute for
Tropospheric Research

User manual TROPOS-SMPS

Leibniz Institute for Tropospheric Research

Permoserstr. 15

04318 Leipzig

Germany

Version history

Revision	Hardware modification	Software modification	Description
H1S4.6.8	28.09.12	13.09.12 V 4.6.8	No coincidence correction for external CPC
H1S4.6.7	28.09.12	xx.xx.12 V 4.6.7	Bug removed, when switching between regular measurement and measurement with size standard
H1S4.6.5		xx.xx.12 V 4.6.5	

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1. Product Overview

The TROPOS-SMPS can be used for scientific purpose about the evolution of aerosol particles in time and space as well as for health effect studies in research infrastructure and air quality monitoring networks. The TROPOS-SMPS is designed for long-term measurement of aerosol particles and over there in highly burden regions. The TROPOS-SMPS is a mobility particle size spectrometer, which can measure continuously the particle number size distribution in a size range from 10 to 800 Nanometers. The temporal resolution to measure a complete particle number size distribution is approximately 5 minutes. Measured data are stored on a PC or notebook, which is part of the measuring system. The current particle number size distribution is displayed graphically as part of the data acquisition and control software.

In the standard version (Table 1), the TROPOS-SMPS does not comprise an automated function control unit that is described in a separate publication (Schladitz et al., 2013). However, the TROPOS-SMPS can be extended by an automatic Zero air measurement and an automatic diffusion screen measurement (control unit for the total particle number concentration and a set of diffusion screens for minimize the influence of ultrafine particle on the systems control). An additional condensation particle counter is needed to measure the total particle number concentration.

A radioactive source such as Kr-85, Am-241, or Ni-63 is part of the standard version of the TROPOS-SMPS. Before any operation, it is necessary to obtain a handling permission if the activity of the source exceeds a free limit. Current radioactive sources inside the TROPOS-SMPS named with an activity from 74 to 370 MBq.

Dry compressed air (dew point temperature < -20°C) is necessary to operate the TROPOS-SMPS. The amount of dry compressed air depends on the SMPS version and should be at least 10 Liters/min for the standard version.

Table 1: Equipment of the TROPOS-SMPS in standard version

Description	Quantity	Manufacturer
TROPOS-SMPS	1	(several manufacturer, see Table 4)
- incl. Condensation particle counter		
- incl. Bipolar charger		
- incl. Electronic unit		
- incl. Vacuum pump		
Computer for data acquisition and control	1	
- incl. Windows 7 (installed)		
- incl. LabView 2011 Runtime Engine (installed)		
- incl. SMPS device control software (installed and pre-configured)		
Adapter cable to connect high voltage power supply with the digital-multimeter	1	TROPOS

(digital-multimeter not included in delivery)

Zero-filter (filtration efficiency QA)	1	Balston
User manual in German or English	1	TROPOS
Software CD including	1	TROPOS
- LabView 2011 Runtime Engine executable		
- SMPS data acquisition and control software		
- SMPS data evaluation software		
- Data sheet as a pdf-file for the channel assignment of the LabView hardware		

Table 2: Optional accessories for automatic Zero air and diffusion screen measurement

Description	Quantity	Manufacturer
<i>Zero air</i>		
Ball valves	2	Swagelok, Solon, OH, USA
Filter holder for diffusion lattices	1	TROPOS
Diffusion lattices	40	TROPOS
Tubes, tube fittings und mounting equipment		
<i>Diffusion Screen measurement</i>		
Condensation Particle Counter (3010, 3772)	1	TSI Inc., Shoreview, MN, USA
Perma Pure Nafion [®] sample air dryer (MD-series)	1	Ansyco GmbH, Karlsruhe, Germany
Tubes, tube fittings, shutoff valves and mounting equipment		

Table 3: Accessory kit for maintenance of the TROPOS-SMPS

Description	Quantity	Manufacturer
Gilibrator (volumetric soap bubble flowmeter) with medium and large measuring cell	1	Sensidyne
Digital-multimeter (Voltage range 1000 V, high impedance)	1	PeakTech (e.g. model 3340)
Size standard 200 nm (1% solution polystyrene latex), 15 ml bottle	1	Duke
Ultrasonic nebulizer	1	Pari Boy (e.g. mobile S)

2. Instrument Description

2.1. Methods

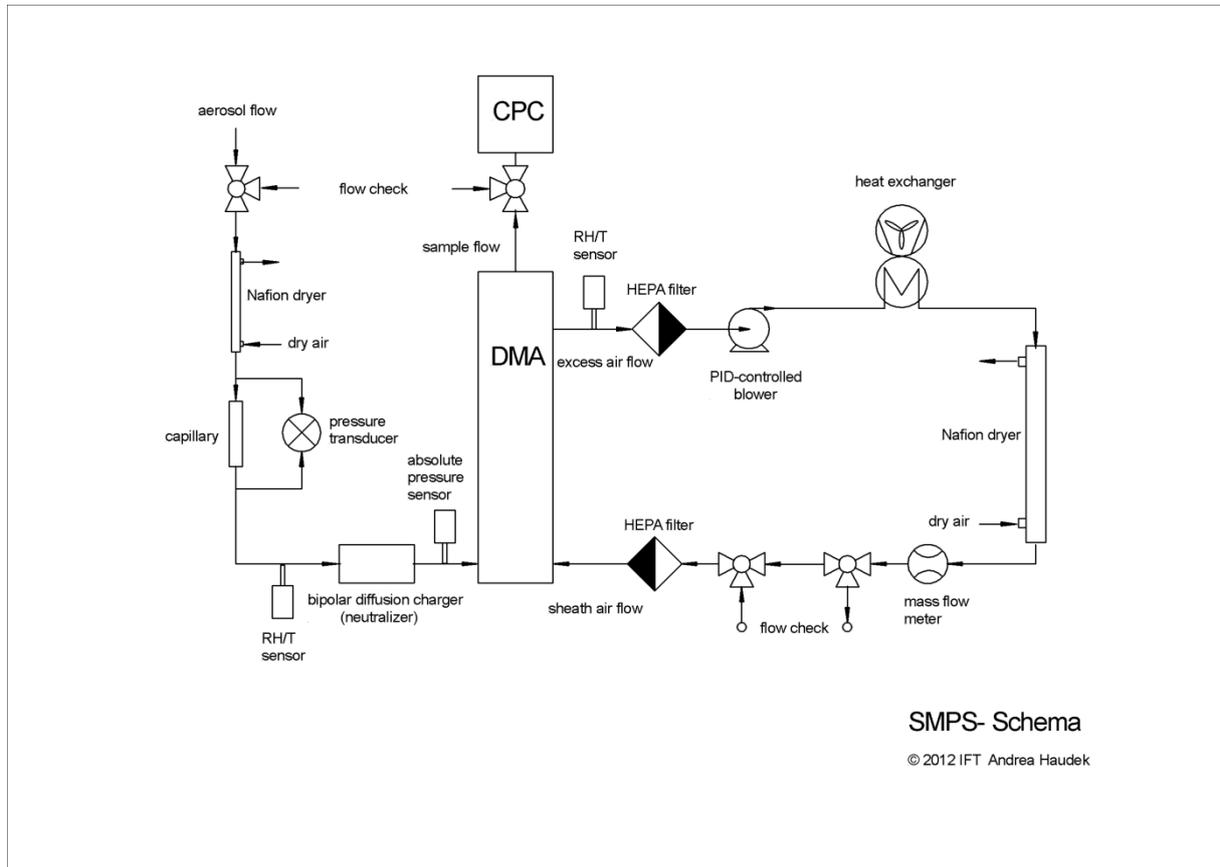


Figure 1: Schematic sketch of the closed-loop TROPOS-SMPS (Wiedensohler et al., 2012)

The principle of a mobility particle size spectrometer is based on the electrical particle mobility. After electrical charging in a bipolar diffusion charger, aerosol particles are classified by their electrical particle mobility in the electric field of a cylindrical capacitor. Afterwards, a particle counter counted the aerosol particles. There is a unique relation between electrical particle mobility of an aerosol particle with an equivalent mobility diameter and the electrical charge. With the knowledge of the bipolar charge equilibrium, the transfer function of the Differential Mobility Analyzer, and the counting efficiency of the Condensation Particle Counter one can calculate the particle number size distribution from measured data.

Figure 1 shows a schematic sketch of a TROPOS-SMPS, which corresponds to the EUSAAR¹ / ACTRIS recommendation for particle number size distribution measurements in the submicrometer size range.

¹ European Supersites for Atmospheric Aerosol Research

Downstream a PM₁ or PM₁₀ inlet, the aerosol flow is dried below 40% relative humidity using a Perma Pure Nafion[®] sample air dryer. The aerosol flow rate is measured with a calibrated pressure transducer (BTEL5000/PTUL5000) via a capillary. The relative humidity and temperature of the aerosol flow is measured with a RH/T sensor. In the TROPOS-SMPS, the aerosol flow passes a bipolar diffusion charger (Kr-85, Am-241, or Ni-63) to bring the aerosol particle population into defined bipolar charge equilibrium. The barometric pressure is measured ahead the inlet of the Differential Mobility Analyzer (DMA). The bipolarly charged particles with the aerosol flow enter the DMA and are there classified according their electrical particle mobility. The sample flow with particle of certain electrical particle mobility is led directly to a Condensation Particle Counter (CPC), which measures the particle number concentration. The critical orifice inside the CPC keeps the sample flow and thus the aerosol flow constant at a rate of 1 l/min. The CPC is connected to a separate vacuum pump or a central vacuum supply. When the TROPOS-SMPS is operating in a container, it is useful to remove the waste air of the vacuum pump outside.

The TROPOS-SMPS uses the “Closed-Loop principle” of the sheath air (Jokinen and Mäkelä, 1997), where the excess air is filtered and then re-used as sheath air. Within the excess/sheath air closed loop, the temperature and relative humidity is measured and then the particles are removed in a filter. A PID - controlled blower guarantees the persistent circulation of the sheath air in this closed loop system. Because the blower warms the sheath air, a heat exchanger with cooling ribs ensures temperature compensation with room air. Downstream the heat exchanger, a Perma Pure Nafion[®] dryer keeps the relative humidity of the sheath air and thus inside the DMA low, although with fluctuating relative humidity of the aerosol flow. Before entering the DMA again, the sheath flow rate (5 l/min) is measured with a calibrated mass flow meter and again filtered.

2.2. DMA

The DMA (TROPOS-modified Hauke-type) is a cylindrical capacitor that can select charged particles according to their electrical mobility Z_p (Knutson and Whitby, 1975):

$$Z_p = \frac{n_e e C_c}{3\pi\eta d_p},$$

where n_e is the number of negative charges, and e the elementary charge ($1.602 \cdot 10^{-19} \text{ C}$). The viscosity of the carrier gas η and the size-dependent Cunningham slip correction factor C_c can be taken from ISO 15900:2009 (Wiedensohler et al., 2012). A schematic sketch of the DMA is shown in Figure 2.

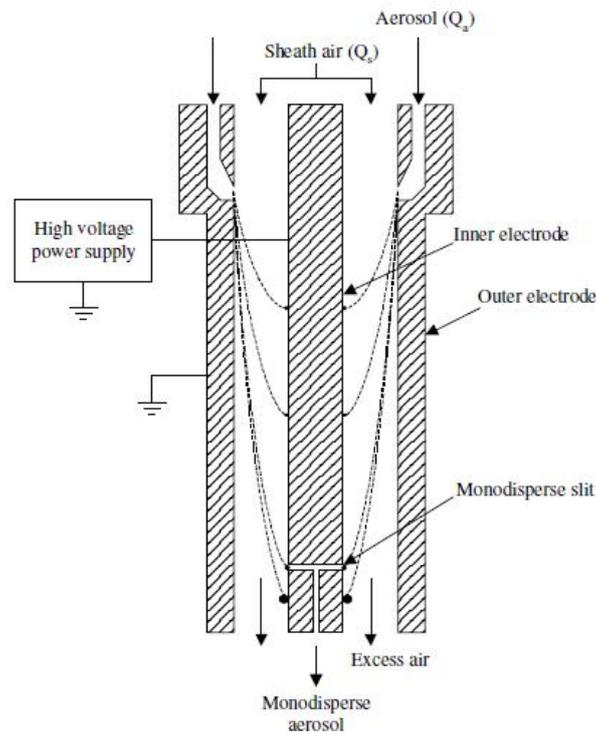


Figure 2: Schematic sketch of a DMA showing trajectories of particles with different electrical mobility.

A high voltage (here negative) is employed between the inner center electrode (positive potential) and the outer-grounded electrode. A particle free sheath air flow rate Q_{Sh} and an aerosol flow rate Q_A are injected into the DMA. Due to the electric field, positively charged particles precipitate onto the outer electrode, while neutral particles are not attracted by the electric field and leave the DMA as excess air Q_{Ex} . If there are no leaks, $Q_{Sh}=Q_{Ex}$ and

$Q_A=Q_S$. A DMA-independent ideal transfer function describes the probability that particles with negative charges with certain mobility Z_p enter the sampling slit of the DMA.

2.3. Condensation Particle Counter

The Condensation Particle Counter (CPC) is based on the physical property of condensation of butanol vapor on particles, which grow to several micrometers to be optically detectable. The sample flow is sucked through the CPC with a constant flow. First, the aerosol flow is saturated with butanol vapor in a slightly heated saturator. Afterwards, the aerosol is led through a condenser to reduce the temperature by approximately 17K. The butanol vapor becomes supersaturated, condenses onto the particles, and the aerosol particles grow to micrometer sized droplets. After focusing the droplets into the optical detection unit, the droplets pass a laser beam, where they are individually counted. Since the equilibrium saturation ratio of a droplet is a function of droplet size, particles smaller than a certain size are not activated to a droplet. This CPC specific counting efficiency is specific for different kinds of CPCs. The CPC TSI model 3010 and 3772 are able to detect 50 % of particles at a size of 10 or 8.5 nm, respectively. The specific detection efficiency curve is taken into account in the data handling / inversion software (cf. Chapter 4.2).

2.4. Bipolar Diffusion Charger (Neutralizer)

A typical bipolar diffusion charger comprises a radioactive source such ^{85}Kr , ^{210}Po , ^{241}Am , ^{63}Ni or ^{14}C . In the charger, the radioactive alpha or beta particles, the gamma radiation or the bremsstrahlung ionize the aerosol carrier gas. The positive and negative ions are transported to the particles by diffusion and electrostatic forces. The larger the particle is, the more positively and negatively charged ions can be captured on them. The bipolar charge equilibrium can be analytically calculated for a particle size between 1 and 100 nm (Wiedensohler, 1988; Wiedensohler et al., 2012).

2.5. TROPOS-SMPS

Table 4 lists the components, typically used in a TROPOS-SMPS excluding the CPC and bipolar diffusion charger.

Table 4: Constituents of the TROPOS-SMPS. Data sheets can be found in the appendix expect for self-made products from TROPOS.

Constituents	Manufacturer
Rack	Knürr GmbH, Arnsdorf, Germany
Perma Pure Nafion [®] sample air dryer (MD-series)	Ansyco GmbH, Karlsruhe, Germany
Large sample air dryer in sheath air closed loop	Perma Pure LLC, Toms River, NJ, USA (Nafion [®] - tubes) Self-made by TROPOS (Casing for sample air dryer)
Pressure transducer (BTEL5000/PTUL5000 series)	Sensortechncs GmbH, Purchheim, Germany
Humidity and Temperature sensor (HIH-4602-A/C series)	Honeywell, Minneapolis, MN, USA
Absolute pressure sensor (HDIB002...U...series)	Sensortechncs GmbH, Purchheim, Germany
Differential Mobility Analyzer	TROPOS-modified Hauke medium-type
High voltage power supply (Model HCE 7 – 12500)	FuG Elektronik GmbH, Rosenheim, Germany
Total particle filter (HEPA), 2 Pieces	Self-made by TROPOS
PID - controlled blower (Model Minispiral 12/24V HDC)	AMETEK, Saugerties, NY, USA
Heat Exchanger (Model 4105G1SB)	LYTRON, Woburn, MA, USA
Mass flow meter (4000/4100 series)	TSI Inc., Shoreview, MN, USA

3. System-Setup

On delivery, the TROPOS-SMPS is pre-configured to the on-site operational conditions. The pre-configuration incorporates the settings for the mean barometric pressure of the station and temperature (i.e. the air-conditioned container) as well as the storage path and a unique filename (e.g. "SMPS_abbrev. of the site_") of the measured data. After built-up, the compressed air and vacuum supply should be connected to the TROPOS-SMPS by use of quick-release fastener on the backside of the instrument. The hardware configuration depends on the SMPS version. Doing so by double-click on the shortcut *Hardware.exe*, which is situated on the desktop of the computer for data acquisition and control. The following window appears (cf. Figure 3). For the standard version of the TROPOS-SMPS, all LEDs on the left hand side should be deactivated (dark green). To set them in active or inactive state, push the button next to the LED. The standard temporal resolution of a complete number size distribution measurement is 5 minutes. In certain cases, this value can be modified in the box next to "Start scan every full ... minute(s)" (cf. Figure 3). Changed settings should be confirmed by pushing the "Save" button on the lower right corner. After pushing the "Save" button a user prompt with a question appears to avoid changes by unauthorized persons. The security code is always the number "42".

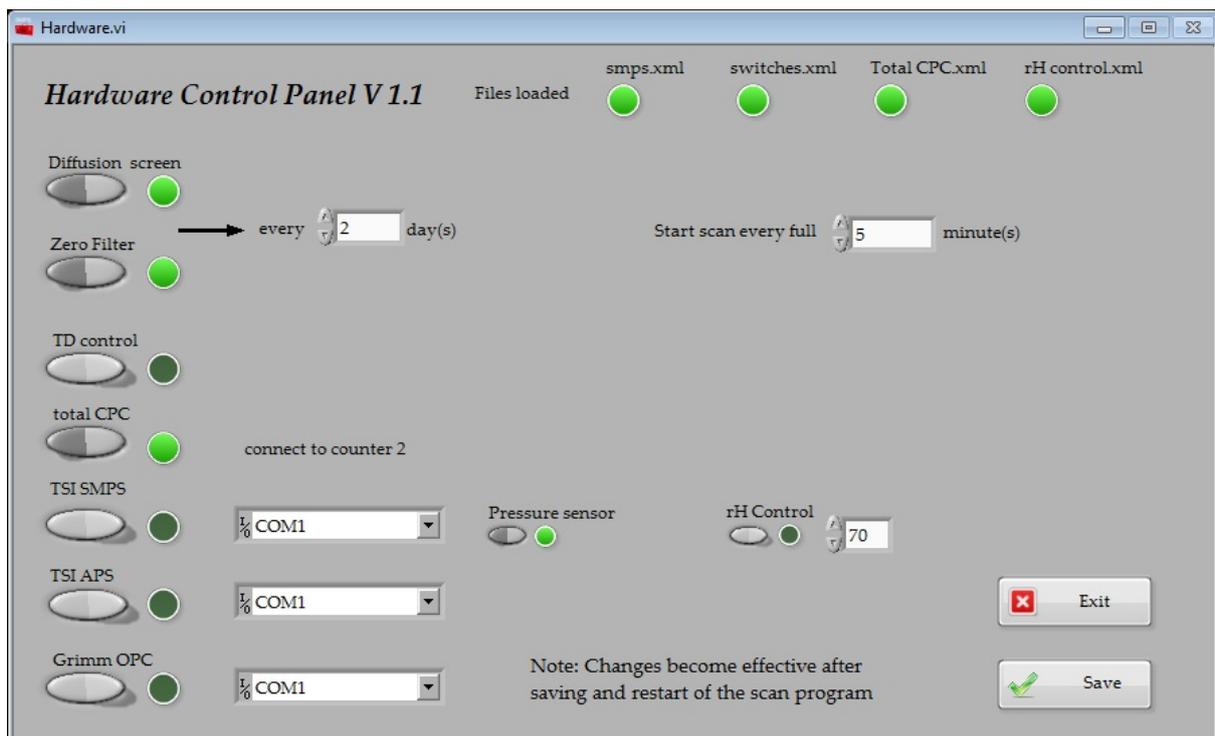


Figure 3: Program window for hardware configuration

If the TROPOS-SMPS is equipped with the automated Zero air measurement, the LED “Zero Filter“ should be activated (LED lime green). In this case, the approximate repetition time as a multiple of 24 hours must be entered in the numeric field „every ... day(s)“ (cf. Figure 3). For Zero air measurement, the exact repetition time is $x \cdot 24 - 1$ hours, where x is the integer value from the numeric field “every...day(s)”. The complete Zero air test takes 1 hour including blanking times (usually 5 minutes) at the beginning and at the end of the test. If the TROPOS-SMPS is equipped with the diffusion screen measurement, the LEDs “Diffusion Screen“ and “total CPC“ should additionally be in active state by pushing the adjacent button. The diffusion screen measurement takes additionally 1 hour including blanking times at the beginning and at the end of the test. Beyond that, it is not possible to enter different repetition times for both, the Zero air and diffusion screen measurement. First, the diffusion screen measurement and afterwards the Zero air measurement are carried out. The exact repetition time is $x \cdot 24 - 2$ hours, where x is the integer value from the numeric field “every...day(s)”.

4. TROPOS-SMPS Operation

After setting-up, the TROPOS-SMPS is switched-on pushing the master switch, which is positioned on the front panel of the electronic unit. Beyond that, the high voltage power supply and the CPC should be switched-on. A warm-up time of at least 2 hours for the high voltage power supply and 10 minutes for the CPC should be considered. On a next step, the correct sizing is done by calibrating the sheath air flow rate using a certified size standard of 200 nm (e.g. NIST² certified polystyrene size standard). Attention should be paid to the real size of the particles, which is displayed on the bottle. At last step, the offset of the high voltage power supply at low voltages is checked and calibrated using a digital-multimeter (For the operation steps see chapter 5.1). Afterwards, start running the data acquisition and control software by double-click on the shortcut *Scan.exe* that can be found on the desktop of the computer. Other mentioned programs in this manual do have a shortcut on the desktop.

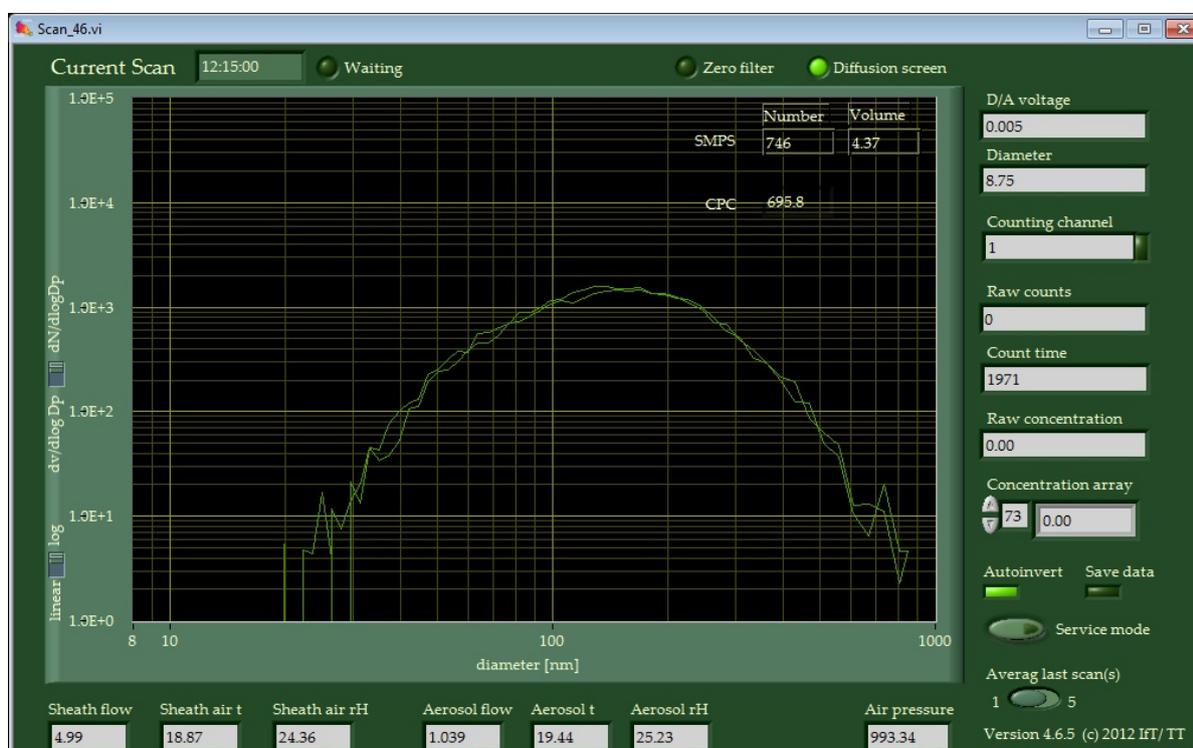


Figure 4: Permanently opened window for data acquisition and control (during a measurement with diffusion screens and external CPC).

Usually, the data acquisition and control software is set to start with a measurement to the next full 5 minutes. The program starts drawing yellow hollow circles on the front panel. A complete measurement comprises an up- and downscan, whereas the voltage rises from 0 V to 10 V during up scanning and vice versa during down scanning. The subsequent measurement is displayed by a solid green line to visualize the temporal variability of the particle number size distribution. The up- and downscan can be traced by the numerical displays “D/A voltage” and “Diameter” on the right hand side of the front panel of the data

² National Institute of Standards and Technology, Gaithersburg, MD, USA

acquisition and control software. Further status values, i.e. sheath air and aerosol flow rates as well as temperature and relative humidity are displayed on the bottom of the front panel. If the automated function control is activated in the hardware control panel (Figure 3), a LED announcement appears on the top of the front panel. During regular measurement operation, the LED is inactive (LED dark green), while during Zero air or diffusion screen measurement the LED becomes active (LED lime green).

It is useful to perform a manual Zero air test of the TROPOS-SMPS with a total particle filter after initial installation or after returning from intercomparison workshops. A manual Zero air test is done as follows: The delivered Zero filter is mounted on the open end of the 3-way valve nearby the aerosol inlet. Wait at least three measurements (approximately 15 minutes). On the front panel of the data acquisition and control software read the total particle number concentration value from row "SMPS" and column "Number". The total particle number concentration should be not more than 10 particles/cm³, otherwise the TROPOS-SMPS has a leak or the CPC produces false counts. To stop the measurement and thereupon the data acquisition, shut down the program *Scan.exe* by double-click on the red cross on the right upper corner.

4.1. Data format

The measurement data are stored in a file path according to the pre-configuration of the TROPOS-SMPS. They were saved as daily files in the following subfolders:

APS	data of an externally connected aerodynamic particle size spectrometer
Average	average values of the last 1 or 5 raw-files (Adjustable via a scroll bar at „Average last scan(s)“ in <i>Scan.exe</i> program)
config	empty folder
diagnostics	contains sensor parameters of temperature, relative humidity, atmospheric pressure, sheath air and aerosol flow rates, and status parameter (0/1) of the current measurement
integral	contains total values, e.g. particle number concentration, particle surface area concentration, and particle volume concentration – for this, pre-inverted data from the subfolder "inverted" ³ were used without correction for diffusional losses
inverted	pre-inverted data, no quality assurance , no correction for diffusional losses ³
OPC	data of an externally connected optical particle size spectrometer
raw	contains raw data of electrical mobility distribution (average of up- and downscan)
raw long	contains raw data of electrical mobility distribution (separate up- and downscan)

³ preliminary data, which should only be used for a quick view

Daily files in the subfolders raw and dia are needed for the final data evaluation procedure. The data format of a random *.raw and *.dia-file is shown in Figure 5 and Figure 6.

The screenshot shows a Notepad window titled 'SMPS_ust1_20130101.raw - Notepad'. The window contains a large table of data with 17 columns. The first column contains a unique file identifier (e.g., 0.000000, 0.083333, 0.166667, etc.). The next three columns contain time and location information (e.g., 293.15, 1000.00, 71). The remaining 13 columns contain numerical values representing various atmospheric parameters, such as temperature, pressure, and particle concentration. The data is organized into pairs of rows, with the first row of each pair representing 'Odd rows' and the second row representing 'Even rows'.

Figure 5: Data format of a certain raw-file

The data format of a tab-separated raw-file is exemplified in the following:

Odd rows:

Starting time (Hour.Proportion of hour); mean on-site temperature (room temperature in Kelvin, e.g. in the container); mean on-site atmospheric pressure (in hPa or mBar); number of the subsequent columns; empty column; particle diameter (1st to nth number of the subsequent columns)

Even rows:

Starting time (Hour.Proportion of hour); mean on-site temperature (room temperature in Kelvin, e.g. in the container); mean on-site atmospheric pressure (in hPa or mBar); number of the subsequent columns; empty column; raw concentration in particles/ cm³ (1st to nth number of the subsequent columns)

The screenshot shows a Notepad window titled "SMPS_usti_20130101.dia - Notepad". The text content is a list of comma-separated data points. Each line represents a data record with fields for Sheathair, Aerosol, Pressure, MAAP, Sensor4, and various status parameters (CPC, TD, Zero). The data is organized into groups, with some lines starting with a number (e.g., 0.000000, 1.000000, 2.000000) indicating different stages or sensors. The values are numerical, representing flow rates, temperatures, pressures, and humidities.

Figure 6: Data format of a certain dia-file

The data format of a comma-separated dia-file is exemplified in the following:

Starting time (Hour.Proportion of hour), "Sheathair":, "flow", sheath air flow rate (in liters per minute), „t", temperature of the sheath-air (in °C), "rH", relative humidity of the sheath-air (in %), "Aerosol", "flow", aerosol flow rate (in liters per minute), "t", temperature of the aerosol (in °C), "rH", relative humidity of the aerosol (in %), "Pressure", measured atmospheric pressure of the absolute pressure sensor (in hPa), "MAAP", "t", temperature of a 3rd. T/RH sensor (e.g. MAAP), "rH", relative humidity of a 3rd MAAP, "Sensor4", "t", temperature of a 4th T/RH sensor, "rH", relative humidity of a 4th T/RH sensor, "total CPC", Particle number concentration of an external CPC (optional), "TD", status parameter for an external thermodenuder (0=OFF, 1=ON); (optional), "Zero", status parameter of Zero air measurement (0=OFF/inactive, 1=ON/active); (optional), "Screen", status parameter of diffusion screen measurement (0=OFF/inactive, 1=ON/active); (optional), "Service", status parameter for pushed service button (0=OFF, 1=ON)

4.2. Data handling und Inversion

4.2.1. Evaluation procedure for particle number concentration in “Bavaria-Hesse format”

Particle number concentrations stored in the data format “Bavaria-Hesse format” are calculated by two evaluation procedures called „SMPS-BY_HESS“ and „SMPS-BY_HESS_2“. The user manuals are attached electronically to the programs.

4.2.2. Evaluation procedure for particle number size distribution in “TROPOS-format”

An evaluation procedure called *DMPS-Inversion-2.13.exe* converts raw data (*.dia and *.raw) into real particle number size distributions. *DMPS-Inversion-2.13.exe* was written and compiled with LabView, version 8.5.1 and runs with LabView’s Runtime Engine version 8.5.1 or higher. Actually, *DMPS-Inversion-2.13.exe* is compatible with *.dia and *.raw-files generated by the data acquisition and control software (*Scan.exe*) up to version 4.5.x. Raw data generated by a *Scan.exe* version 4.6.x or higher are not compatible to *DMPS-Inversion-2.13.exe*.

Initially, the following subfolder structure (cf. Figure 7) should be created in a folder above called, e.g. DATA.

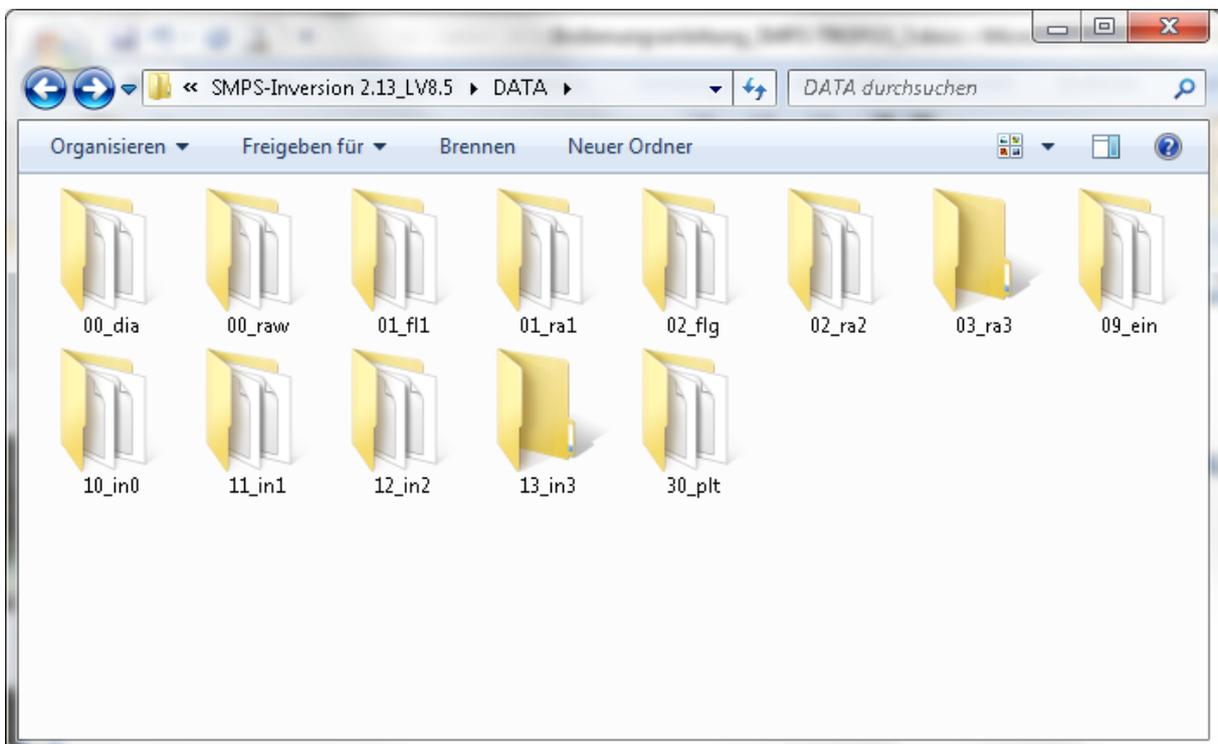


Figure 7: Pattern for the folder DATA for *DMPS-Inversion-2.13.exe*.

Copy the relevant raw data from the TROPOS-SMPS (*.dia, *.raw) in the respective subfolders called 00_dia and 00_raw. All evaluation parameters were adjusted in the device-specific Excel® ini-file. To evaluate data stems from a TROPOS-SMPS, use the parameters that are shown Figure 8. Depending on the specific design of the TROPOS-SMPS only a small number of parameters have to be adjusted:

- Adjust the data path of the folder DATA in the field „Root directory“
- Adjust the column *prefix* for all rows below „DIRECTORY INFO“
- Adjust the column *length of pipe [m]* for “Particle losses segment 1, 2, 3...”
- Adjust the column *flow [l/min]* for “Particle losses segment 1, 2, 3...”.

INITIALISIERUNGSDATEI FÜR TDMP5-SMPS-AUSWERTUNG		DATENTYPEN	
%		Binär	ON/OFF
%		Zeichenkette	00_raw\
%	SMPS Annaberg-Buchholz (40 Bins)	Gleitkommazahl	0.8
%		Wid	6\DATEN
DIRECTORY INFO			
Root Directory	E:\Projekte\ULTRASCHWARZ\Auswerttools\SMPS-Inversion 2.13_LV8.5\DATA		
%	save output?	subfolder	prefix
[Raw mobility distributions]	OFF	00_raw\	SMPS Anna_20
[Raw diagnostics parameter]	OFF	00_dia\	SMPS Anna_20
[Mobility distributions LEVEL 0]	ON	01_ra1\	SMPS Anna_20
[Diagnostics parameter LEVEL 0]	ON	01_fi1\	SMPS Anna_20
[MD with flow correction]	ON	02_ra2\	SMPS Anna_20
[Flagging]	ON	02_fi2\	SMPS Anna_20
[MD after overlap adjustment]	ON	03_ra3\	SMPS Anna_20
[Last MD before inversion]	ON	09_ein\	SMPS Anna_20
[First size distribution after inversion]	ON	10_in0\	SMPS Anna_20
[SD LEVEL 1]	ON	11_in1\	SMPS Anna_20
[SD LEVEL 2]	ON	12_in2\	SMPS Anna_20
[PLT for contour plot]	ON	30_plt\	SMPS Anna_20
BASIC EVALUATION SETTINGS			
TDMP5 (ON), DMPS/SMPS (OFF)?	OFF		
Write new overlap file?	OFF		
Directory of overlap file	MD path		
Type of overlap correction	0 = "Quotient from daily average (Auto)"	1 = "Quotient from file (own analysis)"	
Time format raw MD	0 = "Julian Day (JD)"	1 = "hours (hh.xx)"	2 = "hours (hh:mm)"
Remove redundant TAB?	0 = OFF	1 = Remove redundant TAB	2 = Add column for pressure
Time increment (days) raw SD	0	% in Tagen	
Temp increment (K) raw SD	0	% in K	
Time increment (days) raw DP	0	% in Tagen	
File format raw DP	0 = "SMPS (*.dia)"	1 = "SMPS (*.dia) from TSI"	2 = "TDMP5 (*.flw)"
Type of conc. adjustment	0 = no correction	1 = linear correction with flow	2 = squared correction with flow
Eliminate bad data immediately?	OFF		
Settings DMA transfer fct. (only TDMP5)			
Apply DMA factor in TDMP5?	OFF		
DMA factor	1		
DMA factor range	0 = UDMA	1 = DMA	2 = full size range
Reduce number of bins before inversion			
Merge to the half number of bins?	OFF		
Settings Extrapolation			
Activate mobility distribution extrapolation?	OFF		
Moving average window width	0		
Number of bins in extrapolation	5		
New maximum diameter in nm	1000		
READING DIAGNOSTIC PARAMETERS			
Number of diagnostic parameters			
%	column	Minimum	Optimum
[Aerosol inlet flow]	1	0.9	1
[DMA sheath flow]	1	4.9	5
[Temp aerosol inlet flow]	5	10	20
[Temp DMA sheath flow]	2	10	20
[RH aerosol inlet flow]	5	0	25
[RH DMA sheath flow]	5	-10	25
DATA EVALUATION PARAMETERS			
Multiple charge inversion			
Activate multiple charge correction?	ON		
Type of charge	0 = negative charge (STANDARD)	1 = positive charge (e.g. TSI)	
DMA transfer function parameter A0	0.20	% Vienna medium (28 cm) 5:1	DMA parameters flow ratio A0
DMA transfer function parameter D0		% Hier nur noch null eintragen!	Vienna short (11 cm) (TDMP5; 20:2) 0.1
CPC-efficiency (scalar)			Vienna medium (28 cm) (SMPS; 5:1) 0.2
Activate scalar CPC efficiency correction?	OFF		TSI Long (SMPS; 5:0.5) 0.1
Scalar CPC efficiency	1	% Dies ist ein Wirkungsgrad und sollte in der Regel <= 1 sein.	TSI Long (SMPS; 5:1) 0.2
Directories for correcting functions			
Activate correction function 1?	OFF		
File path correction function 1	\\pc-weinhold\g\PROGRAMME\Effizienzkurven TD DMA etc\thermodenuder43.txt		
Activate correction function 2?	OFF		
File path correction function 2	\\pc-weinhold\g\PROGRAMME\Effizienzkurven TD DMA etc\thermodenuder43.txt		
Activate correction function 3?	OFF		Effektive Längen
File path correction function 3	\\pc-weinhold\g\PROGRAMME\Effizienzkurven TD DMA etc\thermodenuder43.txt		
Activate correction function 4?	OFF		Vienna short (11 cm) 4.6 m
File path correction function 4	\\pc-weinhold\g\PROGRAMME\Effizienzkurven TD DMA etc\thermodenuder43.txt		
COMMENT	length of pipe (m)	flow (l/min)	Name of element
Particle losses segment 1	ON	1.5	16 667
Particle losses segment 2	ON	1	1
Particle losses segment 3	ON	3.85	1
Particle losses segment 4	ON	4.6	1
Particle losses segment 5	OFF	0	0
Standardised CPC efficiency correction	ON	3772	Verfügbar: 3010, 3025, 3772
Standardise T & p			
Activate T & p standardisation?	OFF		
Mean ambient pressure at the station (hPa)	1010	% Hier bitte immer Werte eintragen	
Altitude of the Station (m)	545	% Hier bitte immer Werte eintragen	
Mode of pressure correction	1	0 = Stationsdruck (konstant)	1 = Höhe der Station (konstant)
Mean temperature in the station (K)	293.15	% Hier bitte immer Werte eintragen	2 = Luftdruck aus *.raw-Datei
Mode of temperature correction	0	0 = Temperatur (konstant)	1 = Temperatur aus *.raw-Datei
Convert size distributions to new grid			
Activate new grid binning?	ON		
New grid Dp start (nm)	10		
New grid Dp end (nm)	800		
New grid number of bins	40		
New grid interpolation type	0 = nearest neighbour	1 = linear	2 = spline
Output 2D matrix for graphical display			3 = cubic Hermii 4 = Lagrange
Activate matrix output?	ON		
Matrix output lower margin	0		
Matrix output upper margin	1.00E+09		
Matrix replace missing values	-9999		
Matrix minimum quota	1		
Matrix number of daily points	72		
END ANALYSIS ADJUSTMENTS			
END INITIALIZATION			

Figure 8: Example of an Excel ini-file to initialize the *DMPS-Inversion-2.13.exe*.

Store the Excel ini-file as a tab-separated txt ini-file by preserving the file name.

The user interface of the program appears after double-click on *DMPS-Inversion-2.13.exe*. Insert the path of the txt ini-file in the field "Read INI file" (cf. Figure 9) and insert the acronym of the operator or the operator name in the field „User name“. Start the program by click on the grey arrow (showing to the right direction) in the menu bar.

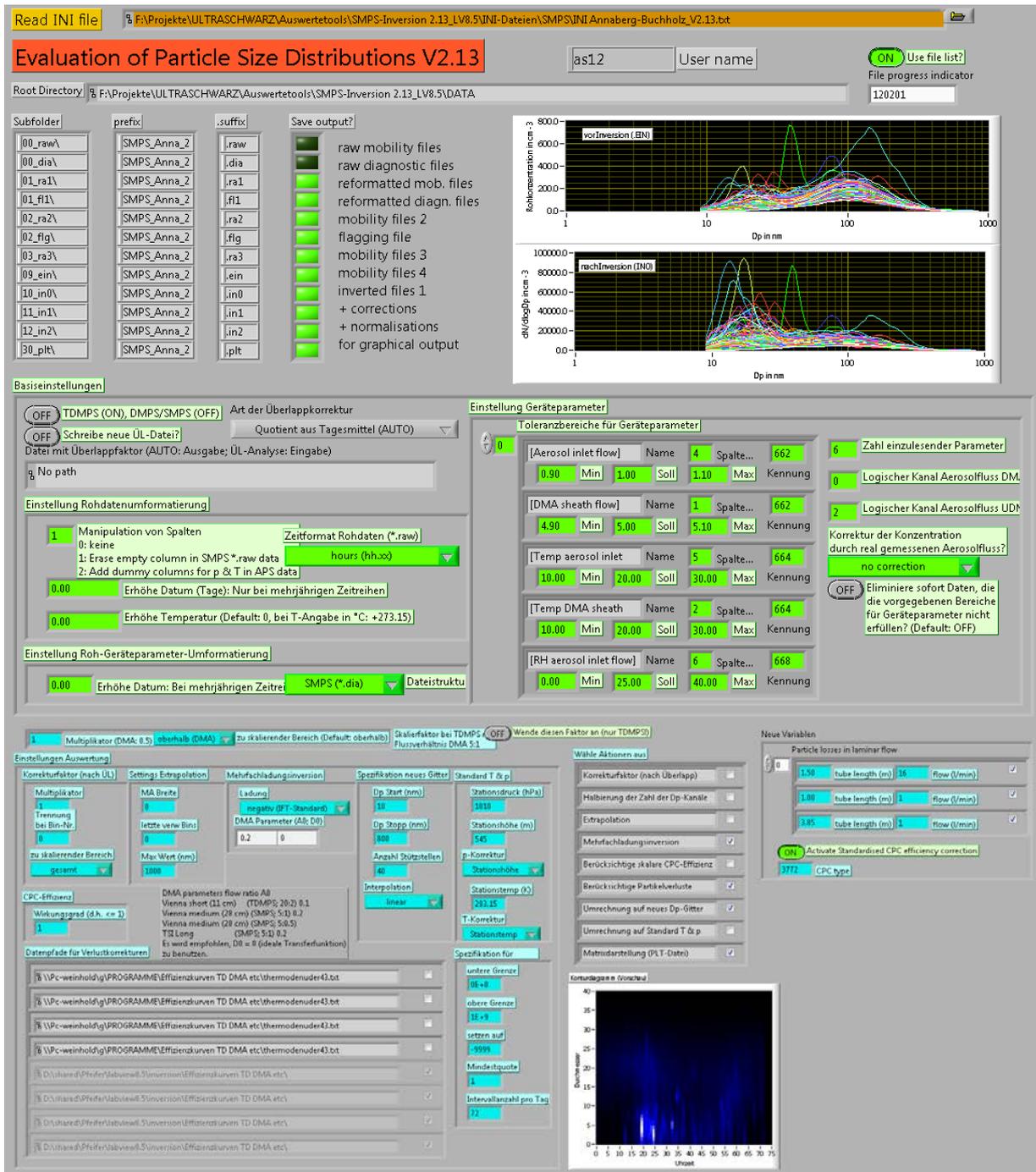


Figure 9: Program window of *DMPS-Inversion-2.13.exe*

The program generates data of the particle number size distribution without technical and final end validation. The unchecked data are stored on a daily basis in the folder 12_in2. During the execution process, a log-file named Log_DD-MM-YYYY_HH-MM.log is being saved in the folder DATA that bears information about the evaluation parameters.

After that, the data is subject to a technical and final end validation by using the program called *Apply flagging (FLG) to SMPS data.exe*. It converts unchecked *.in2-data into technical and final end validated *.in3-data with the aid of *.flg-data reside in the folder

02_flg. A pre-technical validation occurs during the first evaluation step applying the *DMPS-Inversion-2.13.exe*. Numerical flag codes (cf. Figure 9) were set to the respective timestamp in the *.flg-file when a measured parameter was outside a given tolerance range. The numerical flag codes are described elsewhere (Wiedensohler et al., 2012). To end validate the data, an arbitrary global flag code (> 0) should be added on the right next to the last column in the respective row of the *.flg-file. One reason to add a global flag code is the technical maintenance of the SMPS-TROPOS along with an influence of the measurements by the technician.

Datei	Bearbeiten	Format	Ansicht	?						
25.652	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	24.000
25.679	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	24.000
25.682	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	
25.688	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	
25.691	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	
25.694	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	
25.698	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	
25.701	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	
25.704	662.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	
25.708	662.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	
25.711	662.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	
25.714	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	
25.718	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	
25.721	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	
25.724	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	
25.728	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	
25.731	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	
25.734	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	

Figure 10: Data format of a certain flg-file with an added flagging code (e.g. 24.000)

Datei	Bearbeiten	Format	Ansicht	?										
25.6825	293.1	945.0	40	10.000	11.189	12.520	14.008	15.674	17.538	19.624	21.957	24.568	27.490	30.000
25.6825	293.1	945.0	40	3.32E+3	3.85E+3	4.54E+3	5.29E+3	5.65E+3	5.53E+3	5.74E+3	5.45E+3	5.05E+3	3.85E+3	9.6E+3
25.6876	293.1	945.0	40	10.000	11.189	12.520	14.008	15.674	17.538	19.624	21.957	24.568	27.490	30.000
25.6876	293.1	945.0	40	2.94E+4	3.11E+4	3.74E+4	3.63E+4	3.54E+4	3.86E+4	4.67E+4	5.53E+4	5.61E+4	5.34E+4	4.9E+4
25.6910	293.1	945.0	40	10.000	11.189	12.520	14.008	15.674	17.538	19.624	21.957	24.568	27.490	30.000
25.6910	293.1	945.0	40	9.54E+3	1.06E+4	1.18E+4	1.33E+4	1.29E+4	1.34E+4	1.42E+4	1.54E+4	1.56E+4	1.45E+4	1.3E+4
25.6943	293.1	945.0	40	10.000	11.189	12.520	14.008	15.674	17.538	19.624	21.957	24.568	27.490	30.000
25.6943	293.1	945.0	40	8.65E+3	1.10E+4	1.28E+4	1.41E+4	1.76E+4	2.11E+4	2.10E+4	1.87E+4	1.66E+4	1.50E+4	1.3E+4
25.6976	293.1	945.0	40	10.000	11.189	12.520	14.008	15.674	17.538	19.624	21.957	24.568	27.490	30.000
25.6976	293.1	945.0	40	1.25E+4	1.60E+4	2.03E+4	2.77E+4	3.35E+4	2.79E+4	1.64E+4	1.30E+4	1.21E+4	1.19E+4	1.1E+4
25.7009	293.1	945.0	40	10.000	11.189	12.520	14.008	15.674	17.538	19.624	21.957	24.568	27.490	30.000
25.7009	293.1	945.0	40	1.11E+4	1.38E+4	1.73E+4	2.67E+4	3.17E+4	2.84E+4	2.43E+4	2.01E+4	1.66E+4	1.37E+4	1.2E+4
25.7143	293.1	945.0	40	10.000	11.189	12.520	14.008	15.674	17.538	19.624	21.957	24.568	27.490	30.000
25.7143	293.1	945.0	40	1.84E+4	2.39E+4	3.01E+4	3.56E+4	4.19E+4	4.64E+4	4.85E+4	4.60E+4	3.77E+4	2.64E+4	2.0E+4
25.7176	293.1	945.0	40	10.000	11.189	12.520	14.008	15.674	17.538	19.624	21.957	24.568	27.490	30.000
25.7176	293.1	945.0	40	1.73E+4	1.82E+4	1.98E+4	1.91E+4	1.82E+4	1.83E+4	1.73E+4	1.55E+4	1.40E+4	1.28E+4	1.2E+4
25.7209	293.1	945.0	40	10.000	11.189	12.520	14.008	15.674	17.538	19.624	21.957	24.568	27.490	30.000
25.7209	293.1	945.0	40	1.97E+4	2.84E+4	3.75E+4	3.91E+4	3.40E+4	2.80E+4	2.26E+4	1.89E+4	1.71E+4	1.51E+4	1.3E+4

Figure 11: Data format of a certain in3-file

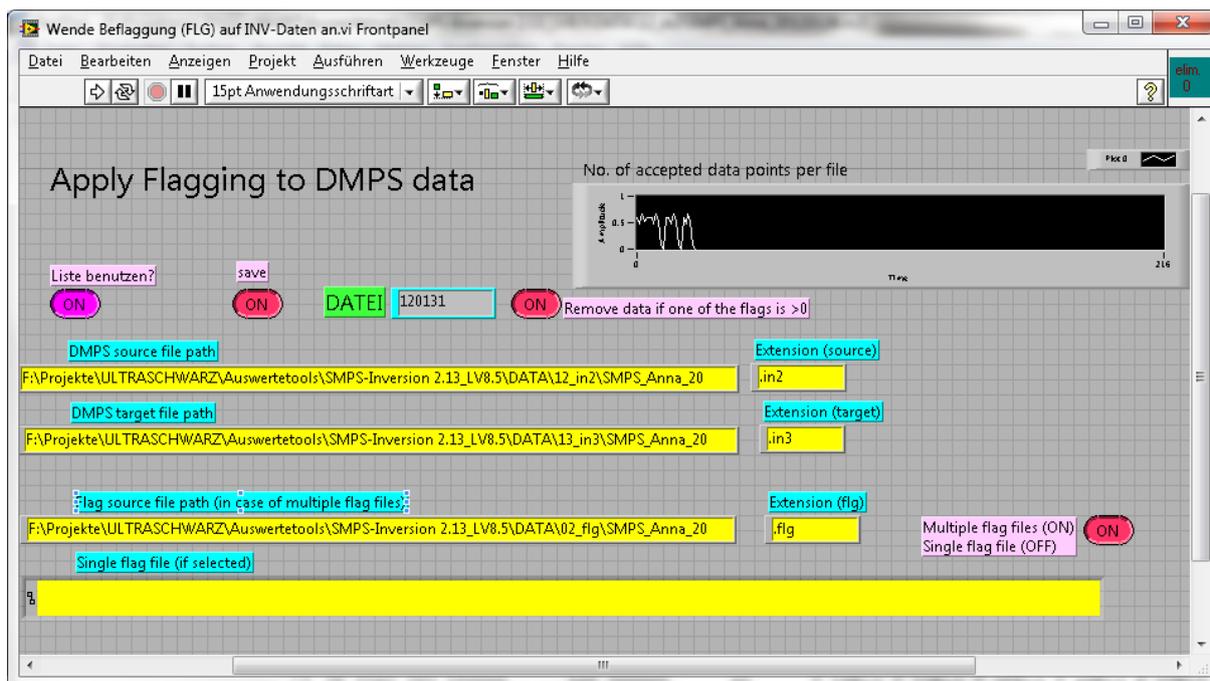


Figure 12: Program window of *Apply flagging (FLG) to SMPS data.exe*

Start the program *Apply flagging (FLG) to SMPS data.exe* with double-click. Adjust the parameters by pressing the buttons as shown in Figure 12. Insert the path name of the folder 12_in2 in the field „DMPS source file path“, insert the folder 13_in3 in the field „DMPS target file path“, and insert the folder 02_flg in the field „Flag source file path (in case of multiple flag files)“, respectively. Don't forget to put the specific prefix (cf. Figure 8) at the end of the path string. Start the program by clicking on the grey arrow (showing to the right direction) in the menu bar.

Technical and end validated data of the particle number size distribution were generated by the program and were stored in the folder 13_in3. An example of a *.in3-file is illustrated in Figure 11. A *.in3-file has a double-spaced structure, where the particle diameter in nanometers is given in odd rows and the normalized particle number concentration $dN/d\log D_p$ is given in even rows. The first column indicates the proportion of the Julian day of the year and the second and third column indicate the mean temperature and mean barometric pressure for the on-site operational conditions. The fourth column indicates the number of the following columns (particle diameter / number concentration).

4.2.3. Evaluation steps for particle number size distribution in “NASA Ames-format”

Parameters of particle number size distributions were permanently stored in data centers such as EBAS or WMO GAW-WDCA in a format called NASA Ames 1001. Beyond that, the parameters of particle number size distributions were stored in different evaluation steps (Level 0, Level 1, and Level 2). Level 0, Level 1, and Level 2 are documented in a separate publication (Wiedensohler et al., 2012). Templates of Level 0 to Level 2 for particle number size distributions can be found under URL www.gaw-wdca.org under Tab „Submit Data“.

Level 0 to Level 2 files can be generated from the processed data by using supplementary programs (not included in the delivery of the TROPOS-SMPS).

To generate Level 0 files, *.ra1, *.fl1 and *.flg-files from the folders 01_ra1, 01_fl1, and 02_flg are mandatory.

To generate Level 1 files, *.in2 and *.flg-files from the folders 12_in2 and 02_flg are mandatory.

To generate Level 2 files, *.in3 and *.fl1-files from the folders 13_in3 and 01_fl1 are mandatory.

Special attention should be paid, to transform measured data into Coordinated Universal Time (UTC).

5. Maintenance

During maintenance of the TROPOS-SMPS or of the inlet system, press the service button on the front panel of the data acquisition and control software (*Scan.exe*). The service button is marked in Figure 13 with a red arrow. After a while (when the next measurement started) a red bar with a label “Service Mode” appears on the front panel. During activated „Service Mode“, the status parameter for pushed service button in the “.dia–file is „1“ (cf. Chapter 4.1). After the maintenance activities have been completed, the service button should be pressed again. The red bar “Service Mode“ disappears.



Figure 13: Program window for data acquisition and control with activated service button „Service mode“.

5.1. Monthly maintenance plan

To fulfill the monthly maintenance plan use the testing equipment from Table 3.

5.1.1. Function control of the SMPS

The function control of the SMPS starts with a visual inspection as follows:

- High voltage power supply (green LED is on)

- CPC-status LED display (green LED is on)
- Liquid level of Butanol storage bottle sufficient
- Program window for data acquisition and control opened / data are recorded immediately

An overview of mandatory flow rates checks gives Table 5.

Table 5: Flow rate check of the TROPOS-SMPS

	Set-point value	Remark
Aerosol flow rate	1 Liter/min ($\pm 5\%$)	Check flow on open end of 3-way valve nearby aerosol inlet; any adjustment of the flow is not possible
Sheath air flow rate	Set-point value in Liter/min ($\pm 2\%$) (Set-point value is setting-up using a 200 nm size PSL standard)	Integrate bubble flow meter in sheath air closed loop as shown on the photo below →  Wait a while until the downscan is nearing completion → Rotate both 3-way valves simultaneously about 180 degree → Wait until the sheath air flow rate has been stabilized → Measure the sheath air flow rate with the bubble flow meter

Flow rate of the counter flow of the aerosol Nafion dryer (Pressurized air or vacuum)	1.5-2 Liter/min	If necessary check and adjust on needle valve
Flow rate of the counter flow of the sheath air dryer (Pressurized air)	Depends on the dew point temperature; at least 5-10 Liter/min	If necessary check and adjust on needle valve or pressure regulator

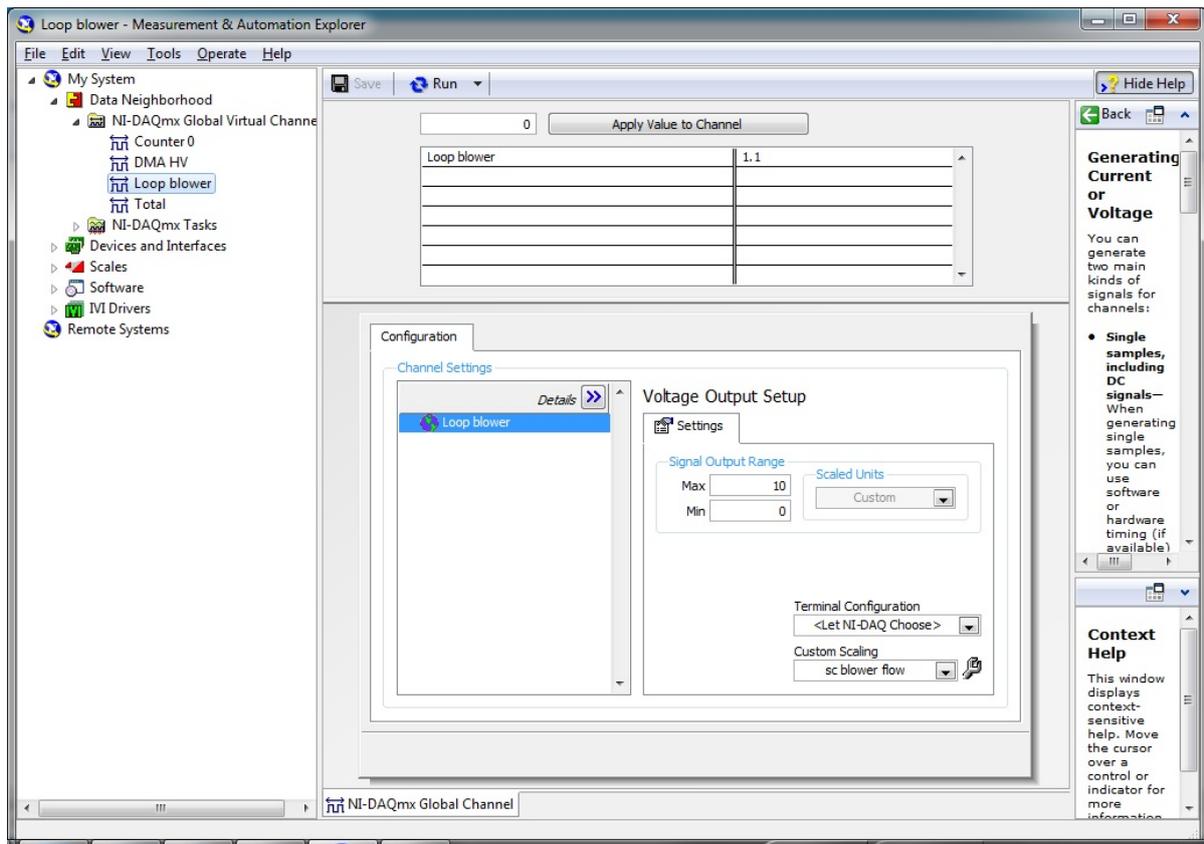


Figure 14: Measurement & Automation.exe–Program window to adjust and calibrate the blower voltage

A procedure is described below how to detect an error, when the aerosol flow rate deviates more than 5% from the set-point value (1 Liter/min):

- Check the aerosol flow rate on the CPC inlet using a bubble flow meter
- Set-point value reached?
 - o If not: CPC problem → CPC for technical maintenance
 - o If so: Go one step further (possible leak upstream the CPC) ↓
- Switch blower off
 - o Start *Measurement&Automation.exe*
 - Goto *My System\Data Neighborhood\NI-DAQmx Global Virtual Channels\Loop Blower* (cf. Figure 14)
 - Set 0 Volt (Click on button “Apply Value to Channel”)
 - Press “Run” and afterwards press “Stop”
 - o The sheath air closed loop is stopped
- Set-point value reached on aerosol inlet?
 - o If so: Problem within sheath air closed loop →(possible leak)
 - o If not: Go one step further (possible leak upstream of the closed loop) ↓
- Bypass the DMA
 - o Connect the CPC directly behind the bipolar charger
- Set-point value reached on aerosol inlet?
 - o If so: Problem is within the DMA →(leaky, replace the O-rings)
 - o If not: Go one step further (possible leak upstream of the DMA) ↓
- Bypass the aerosol dryer
 - o Connect the CPC directly behind the Nafion[®] sample air dryer
- Set-point value reached on aerosol inlet?
 - o If so: Problem located between Nafion[®] sample air dryer and DMA inlet →(tighten the tube fittings, be careful not to over-tighten the fittings)
 - o If not: Go one step further (problem with Nafion[®] sample air dryer) ↓
 - Disconnect vacuum supply of Nafion[®] sample air dryer
 - Plug lateral inlet and outlet of Nafion[®] sample air dryer
- Set-point value reached on aerosol inlet?
 - o If so: Nafion[®] sample air dryer has a leak → Nafion[®] sample air dryer for technical maintenance
 - o If not: Contact TROPOS

A systematic procedure is described for error detection below, if the sheath air flow rate deviates more than 2% from the set-point value:

- Start *Measurement&Automation.exe*
 - Goto *My System\Scales\NI-DAQmxScales\sc dma loop flow* (cf. Figure 15)

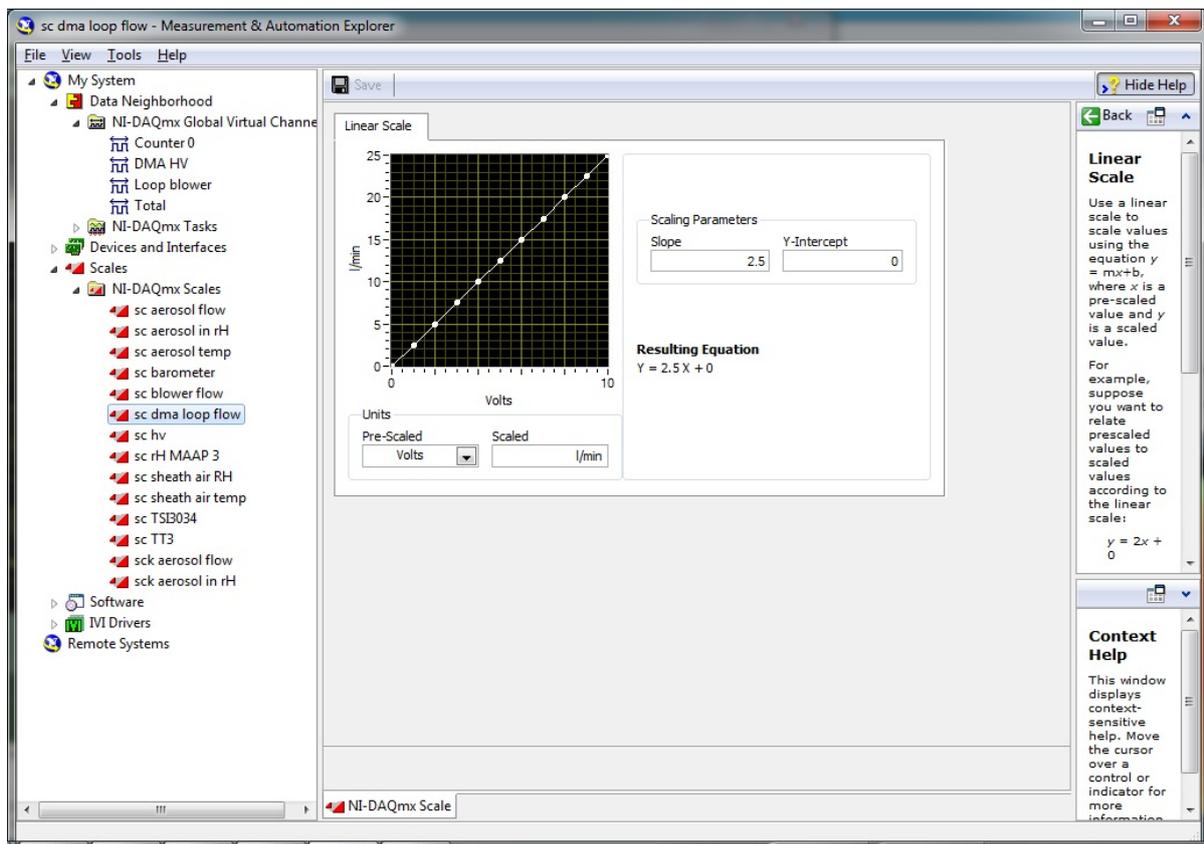


Figure 15: *Measurement & Automation.exe*—Program window to adjust and calibrate the sheath air flow rate (only slope of the calibration curve)

- Adjust slope value **slightly**
- Click on “Save” button
- Check the sheath air flow rate as shown in Table 5 (**Be careful:** The data acquisition and control software (*Scan.exe*) considers any changes in *Measurement&Automation.exe* before a new measurement begins)
 - o If sheath air flow rate is too low → reduce slope value
 - o If sheath air flow rate is too high → enhance slope value
- Shutdown the *Measurement&Automation.exe*

5.1.2. Leak test of the TROPOS-SMPS

To check the TROPOS-SMPS for leaks, the delivered zero filter (filtration efficiency QA) is plugged on the open end of the 3-way valve nearby the aerosol inlet. Wait at least three measurements (approximately 15 minutes). Read the total particle number concentration value from row „SMPS“ and column „Number“ from the front panel of the data acquisition and control software. The total particle number concentration should not exceed 10 particles/cm³, otherwise the TROPOS-SMPS has a leak, or the CPC produces false counts.

If the value of 10 particles/cm³ is exceeded find out the size range where false counts were registered. This can be easily done by looking on the front panel of the data acquisition and control software. Tighten all tube fittings using a suitable open-end or adjustable spanner.

Table 6: Leak check of the TROPOS-SMPS

	Set-point value	Remark
Zero-point behavior	Total particle number concentration <10 particles/cm ³	If the allowed concentration is exceeded, check the size range of the false counts

5.1.3. High voltage check up to 1000 Volts

The delivered adapter cable to connect high voltage power supply with the digital-multimeter is needed to check the high voltage power supply of the TROPOS-SMPS. Pay special attention during the high voltage check. Be sure that the power switch of the high voltage power supply is switched-off when the adapter cable is plugged in and out. The high voltage check is described below:

- Start *Measurement&Automation.exe*
 - o Go to *My System\Data Neighborhood\NI-DAQmx Global Virtual Channels\DMA HV* (cf. Figure 16)
 - o Set “Max“ *Signal Output Range* to 800m (800m means 800 mV)
 - o Click on „Save“ button
 - o Set 0 Volt (Click on button “Apply Value to Channel”)
 - o Press “Run” and afterwards press “Stop”
 - o The DMA is now in a dead-voltage state
- Switch-off high voltage power supply on the front panel of the electronic unit
- Unplug the HV cable to the DMA on the rear of the high voltage power supply
- Connect the digital-multimeter (blue cable in black socket, red cable in red socket) with connector on the rear of the high voltage power supply using the adapter cable
- Switch the digital-multimeter to direct current
- Switch-on high voltage power supply on the front panel of the electronic unit
 - o Insert step-by-step the voltages from Table 7 in the field next to “Apply Value to Channel”
 - o Click on button “Apply Value to Channel”
 - o Press “Run” and afterwards press “Stop”

- Take a note of the values screened by the digital-multimeter
- Calibrate if necessary (see instructions below)
- Switch-off high voltage power supply on the front panel of the electronic unit, Unplug the digital-multimeter and reconnect the DMA with the electronic unit
- Reset „Max“ *Signal Output Range* to 10 (10 means 10 V)
- Click on “Save” button
- Shutdown the *Measurement&Automation.exe*

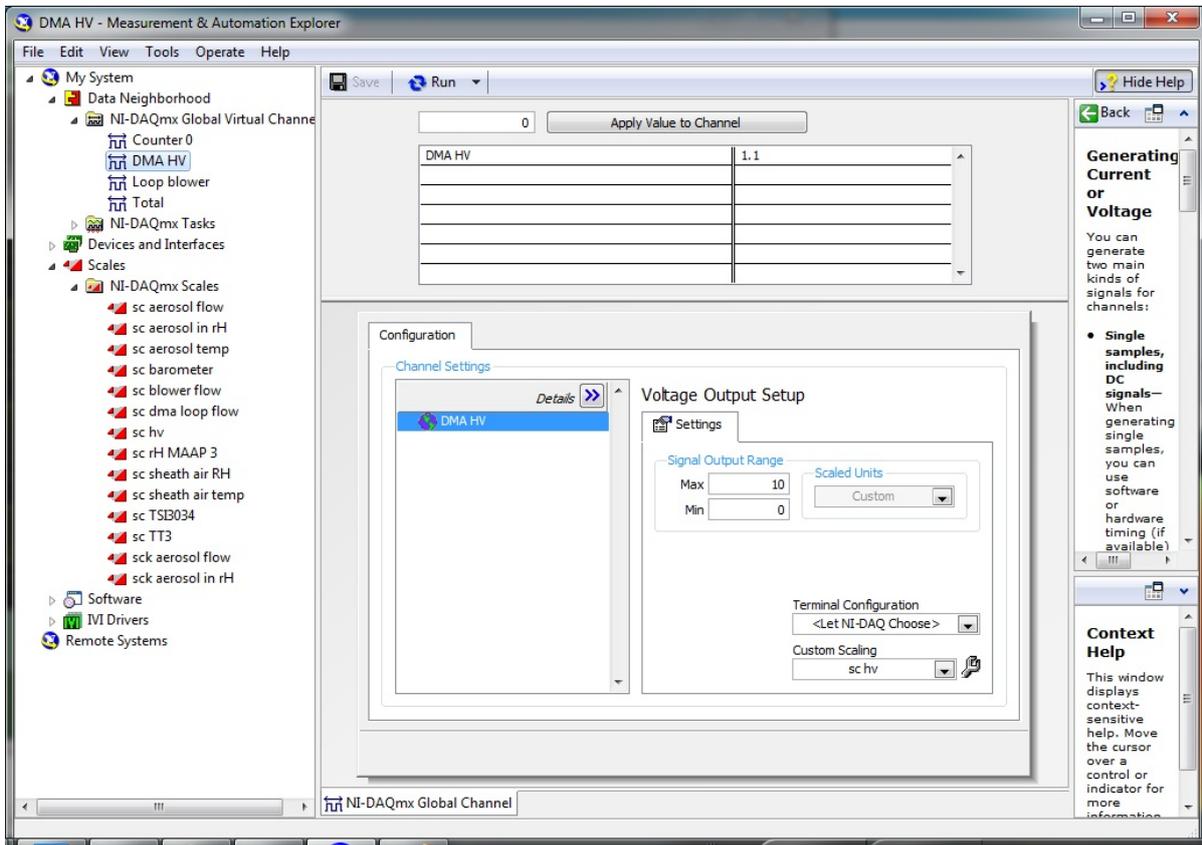


Figure 16: *Measurement & Automation.exe* to check the high voltage of the DMA

Table 7: Voltages mandatory for HV check

	Set-point value	Set-point value (multiplied by factor 1250)
Voltage	0 V	0 V ± 3 V
	0.004 V	5 V ± 25%
	0.008 V	10 V ± 25%
	0.08 V	100 V ± 10%
	0.8 V	1000 V ± 1%

A re-calibration of the HV is needed, if the measured voltages exceed the intervention criterion defined as the set-point value \pm uncertainty. In the following, a calibration procedure of the high voltage is described:

- Start *Measurement&Automation.exe*
 - o Go to *My System\Scales\NI-DAQmxScales\sc hv* or *My System\Scales\NI-DAQmxScales\sc DMA hv* (cf. Figure 17)
 - o Click on “Edit...” button
 - o Adjust values in column “Pre-Scaled Values”
 - o Confirm with “OK” and return to main menu
 - o Click on “Save” button and repeat high voltage check procedure
 - o If necessary repeat all steps again until measured fits set-point voltage

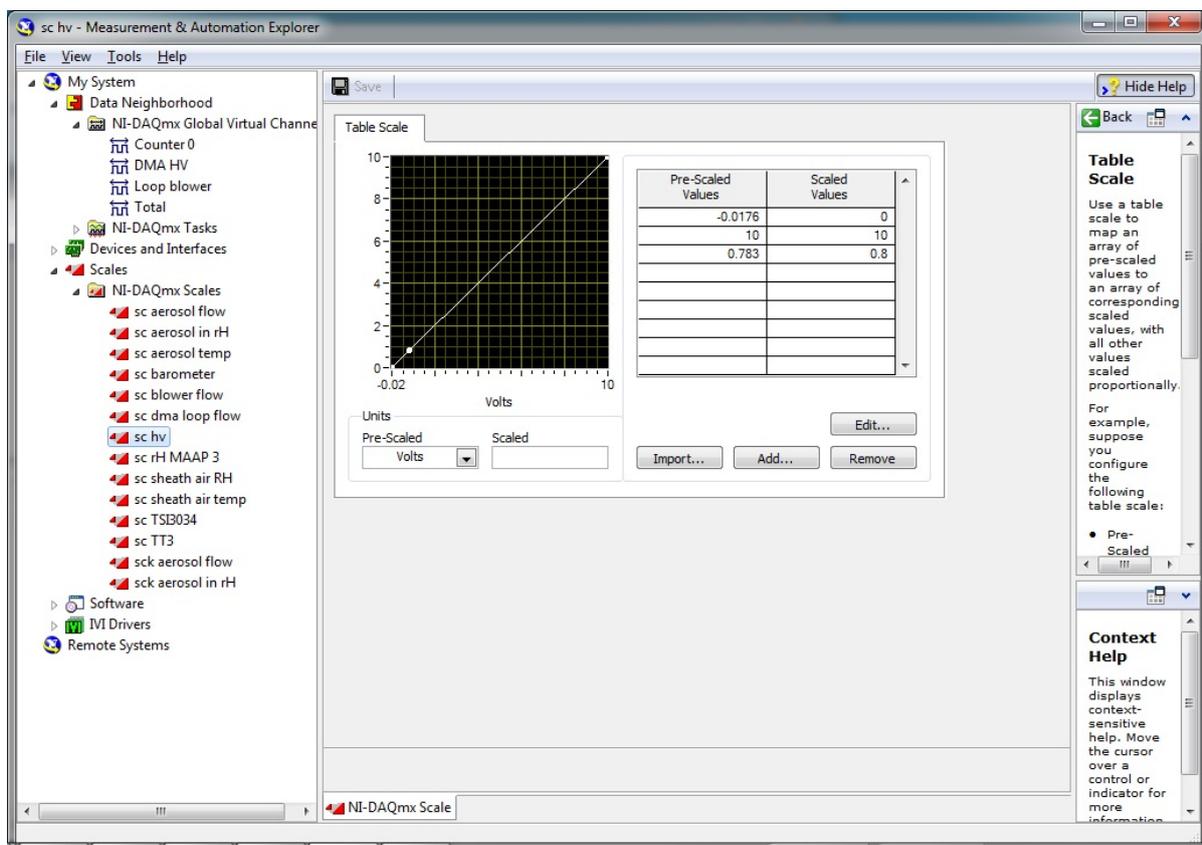


Figure 17: *Measurement & Automation.exe* to calibrate the high voltage of the DMA

5.1.4. Calibration of sizing accuracy with size standard and calibration of the sheath air flow rate

The sheath air flow rate has a big influence on the sizing accuracy of the TROPOS-SMPS. A size standard is used to determine the exact sizing of the instrument and therefore to calibrate the sheath air flow rate. This procedure is performed using an ultrasonic nebulizer (e.g.: PariBoy mobile S), pure water, and a 200 nm size standard. Build-up the ultrasonic nebulizer according to the instructions and fill pure water in the water reservoir! Mix one droplet of the size standard (1% solution polystyrene latex) with the pure water.

Caution: If the TROPOS-SMPS is equipped with an optional diffusion screen measurement, the valve in front of the inlet of the external CPC should be open to ambient, otherwise the CPC will be clogged due to high particle concentrations.

The calibration of the sheath air flow rate is described in the following:

- Shutdown the *Scan.exe*-program
- Start *Change Measurement Mode.exe* or *SizeRange.exe*
- On a next step a window with the text “SMPS is set for LATEX scans.” and a user prompt appears. After confirmation with “OK” a second input window appears. Set the pressure and the temperature of the actual on-site operational conditions (cf. Figure 18) in the appropriate fields.

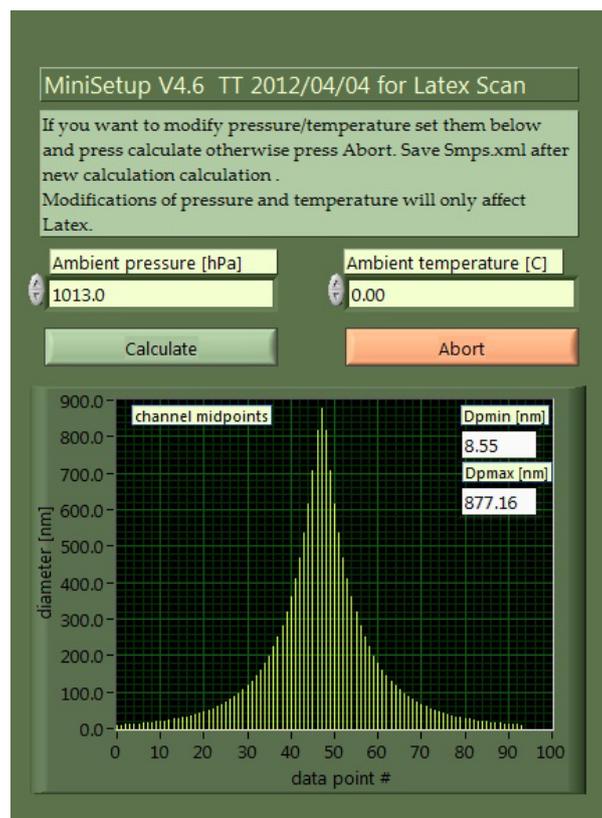
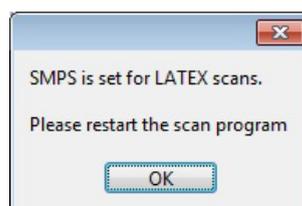


Figure 18: *MiniSetup*–Program window to insert pressure and temperature for the size standard measurement

- Go on by pressing the “Calculate” button, while another user prompt appears:



- Confirm the window by pressing “OK“ and the TROPOS-SMPS is now ready for the size standard measurement
- Start the *Scan.exe*-program
- Turn-over the 3-way valve nearby the aerosol inlet
- Switch-on the ultrasonic nebulizer and keep the fog of the nebulizer near the open end of the 3-way valve
- Wait at least one measurement
- Read the diameter from the x-axis, on which the particle size distribution has a local peak value (see red arrow in Figure 19). The peak value should be nearby the exact particle size of the size standard (cf. Table 8).



Figure 19: Program window for data acquisition and control during the measurement with the size standard.

Table 8: Calibration of sizing accuracy with 200 nm size standard

	Set-point value	Remark
Size standard	Particle size of the size standard (about 200 nm)	Attention should be paid to the real size of the particles that is displayed on the bottle.

- Adjust the slope value of „sc dma loop flow“ (cf. Figure 15) as long as the peak value of the particle size distribution fits the particle size of the size standard

- **Caution:** Changes in „sc dma loop flow“ and thus in *Measurement&Automation.exe* were overtaken only once before a new measurement begins
- Measure the new sheath air flow rate and take a note of the new set-point value in the logbook
- Switch over back to the standard measurement mode
- Start again *Change Measurement Mode.exe* or *SizeRange.exe*
- The following window appears:



- Confirm and close the window by pushing the “OK“ button and restart *Scan.exe*

5.2. Annual maintenance

5.2.1. Check and calibration of the humidity sensors

- No specified procedure

5.2.2. Calibration of the sheath air flow rate (only Offset)

- Shutdown the *Scan.exe*-program
- Start *Measurement&Automation.exe*
 - o Go to *My System\Data Neighborhood\NI-DAQmx Global Virtual Channels\Loop Blower* (cf. Figure 14)
 - o Set 0 Volt (Click on button “Apply Value to Channel“)
 - o Click on “Save” button
 - o The sheath air closed loop is stopped
- Remove the black tube from the DMA
 - o The aerosol flow is stopped
- Start *Measurement&Automation.exe*
 - o Go to *My System\Data Neighborhood\NI-DAQmx Tasks\tsk dma loop flow* (cf. Figure 20)
 - o Select “none” for *Custom Scaling*
 - o Press “Run”
 - o Read from the Table below the value in the column “Number“ and row “SMPS”
 - o Repeat pressing the “Run”-button at least 4 times and read the values from the Table
 - o Calculate a mean value
 - o Go to *My System\Scales\NI-DAQmxScales\sc dma loop flow* (cf. Figure 15)

- Insert the mean value in “Y-Intercept“
- Click on the “Save“ button
- Go again to *My System\Data Neighborhood\NI-DAQmx Tasks\tsk dma loop flow* (cf. Figure 20)
- Select „sc dma loop flow“ for *Custom Scaling*
- Click on the “Save“ button
- Shutdown the *Measurement&Automation.exe*

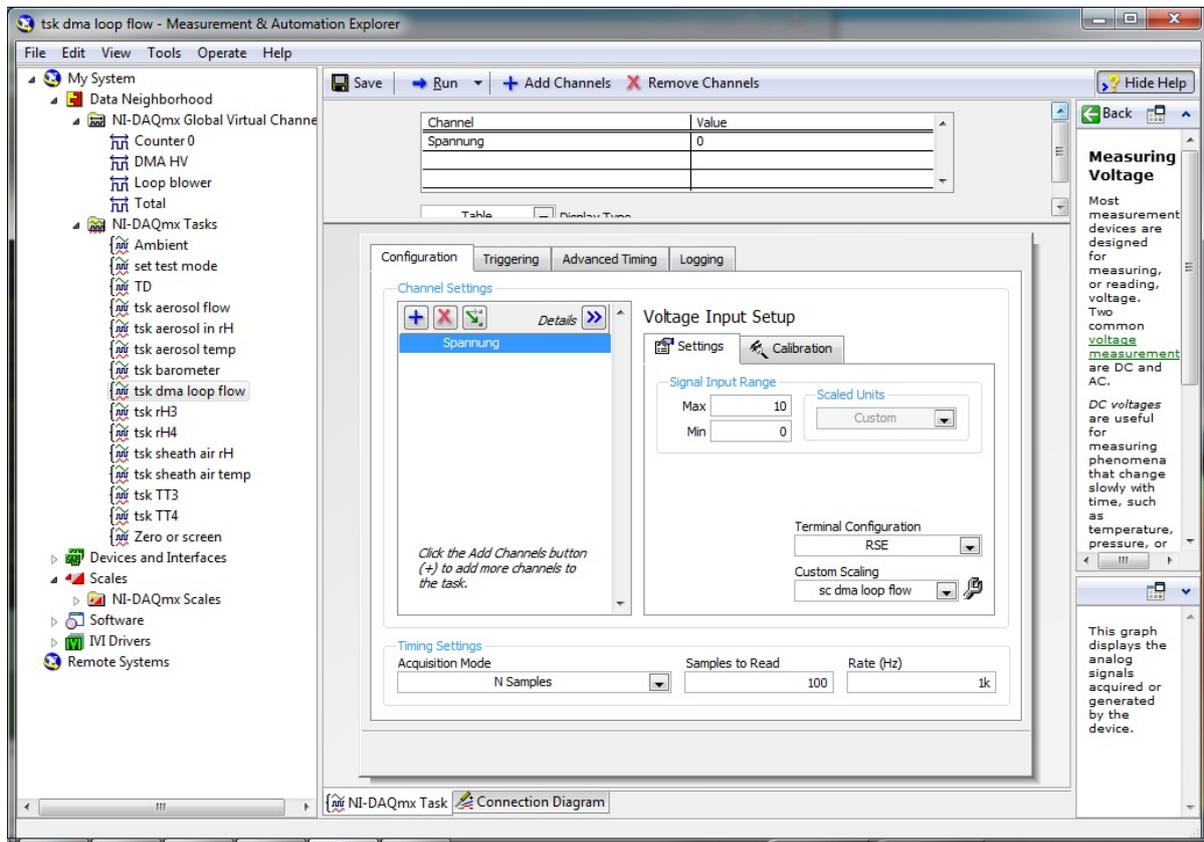


Figure 20: *Measurement & Automation.exe*–Program window to adjust and calibrate the sheath air flow rate (only intercept of the calibration curve).

5.2.3. Calibration of the pressure transducer

- Check the aerosol flow rate on the aerosol inlet during a regular measurement (should be 1 Liter/min)
- At the same time take a note of the aerosol flow rate visualized in the *Scan.exe*-program
- Start *Measurement&Automation.exe*
 - Go to *My System\Scales\NI-DAQmx Scales\sc aerosol flow*
 - Adjust „sc aerosol flow“ as long the measured value fits the visualized value in the *Scan.exe*-program and press the “Save“ button in the meantime
- Shutdown the *Measurement&Automation.exe*

5.2.4. Cleaning the DMA

Equipment required: Propanol for cleaning

Hand towels

Cotton buds, (better: Cotton spiral)

Lint-free clothes

Particle-free pressurized air

Filter cartridges

- Removing and cleaning of the DMAs according to instruction⁴
- Exchange of the total particle filter (HEPA) in the sheath air closed loop

5.2.5. Calibration of the CPC and check of the saturator sponge inside the CPC

- The calibration of Condensation Particle Counter means the record of the detection efficiency for particles < 40 nm by using an electrometer
- This can be done by the manufacturer TSI or TROPOS (fee)
- If the saturator sponge of the CPC has a yellowish/brown color it should be replaced by a new one (new saturator sponges can be found in the spare part cases)
- An instruction of replacement of the saturator sponge can be found in the manual of the CPC

⁴ A manual for cleaning the DMA is attached in the appendix.

References

Jokinen, V., and Mäkelä, J. M.: Closed-loop arrangement with critical orifice for DMA sheath/excess flow system, *J. Aerosol Sci.*, 28, 643-648, 1997.

Knutson, E. O., and Whitby, K. T.: Aerosol Classification by Electric Mobility: Apparatus, Theory, and Applications, *J. Aerosol Sci.*, 6, 443-451, 1975.

Schladitz, A., Merkel, M., Bastian, S., Birmili, W., Weinhold, K., Löschau, G., and Wiedensohler, A.: A concept of an automated function control for ambient aerosol measurements using mobility particle size spectrometers, submitted to *Atmos. Meas. Tech. Discuss.*, 2013.

Wiedensohler, A.: An approximation of the bipolar charge distribution for particles in the submicron size range, *J. Aerosol Sci.*, 19, 387-389, 1988.

Wiedensohler, A., Birmili, W., Nowak, A., Sonntag, A., Weinhold, K., Merkel, M., Wehner, B., Tuch, T., Pfeifer, S., Fiebig, M., Fjåraa, A. M., Asmi, E., Sellegri, K., Depuy, R., Venzac, H., Villani, P., Laj, P., Aalto, P., Ogren, J. A., Swietlicki, E., Roldin, P., Williams, P., Quincey, P., Hüglin, C., Fierz-Schmidhauser, R., Gysel, M., Weingartner, E., Riccobono, F., Santos, S., Grüning, C., Faloon, K., Beddows, D., Harrison, R. M., Monahan, C., Jennings, S. G., O'Dowd, C. D., Marinoni, A., Horn, H. G., Keck, L., Jiang, J., Scheckman, J., McMurry, P. H., Deng, Z., Zhao, C. S., Moerman, M., Henzing, B., de Leeuw, G., Löschau, G., and Bastian, S.: Particle mobility size spectrometers: harmonization of technical standards and data structure to facilitate high quality long-term observations of atmospheric particle number size distributions, *Atmos. Meas. Tech.*, 5, 657-685, doi:10.5194/amt-5-657-2012, 2012.