BSMA2

&

some examples of nucleation in urban air

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Advantages of BSMA

- Absolute calibration according to measurements of air flow, electric current and voltage.

Clusters and smallest nanoparticles are subjects of rapid transformations. The size distribution can be rapidly changed when the air is heated during the passage through the inlet tubing and the mobility analyzer.

- Passage time of the air from inlet to collector less than 0.1 s.
- Heating of the air during passage less than 0.3 K.

The multichannel method offers the best size and time resolution in the case of the very low concentration of particles. A specific disadvantage of the multichannel method is that the measurement errors are specific for channels, and it is not easy to prove that a peculiarity in the measured mobility distribution was not caused by a technical trouble in some individual mobility channel.

- Ions of all mobilities are measured from the same collector with the same electrometer.

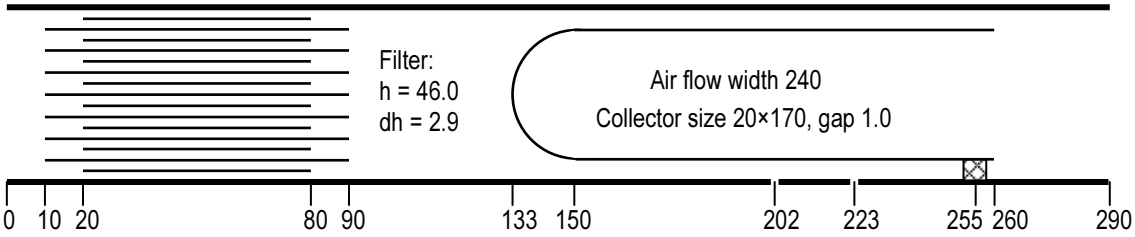
Disadvantages of BSMA

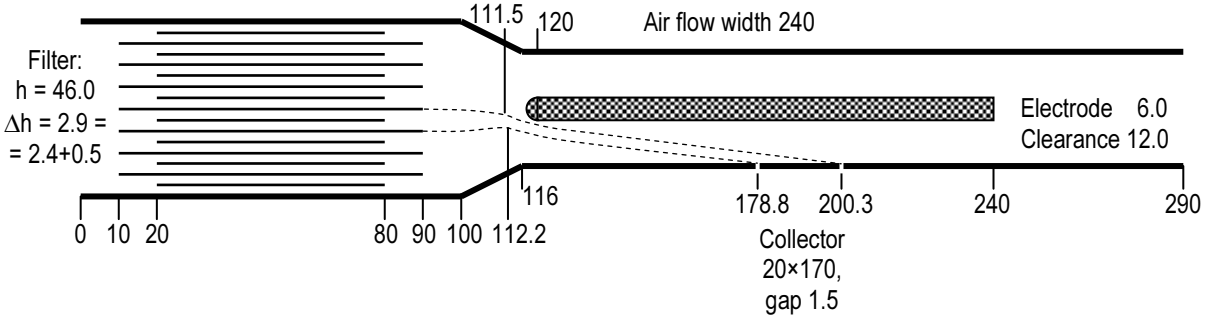
- Relatively high noise level.
- Failure of measurements during snowfall, drizzling rain and fog.
- Problems in case of high relative humidity.
- Pollution of inlet mesh and filter with small insects during summer measurements.
- Inconvenient procedure of cleaning of insulators.

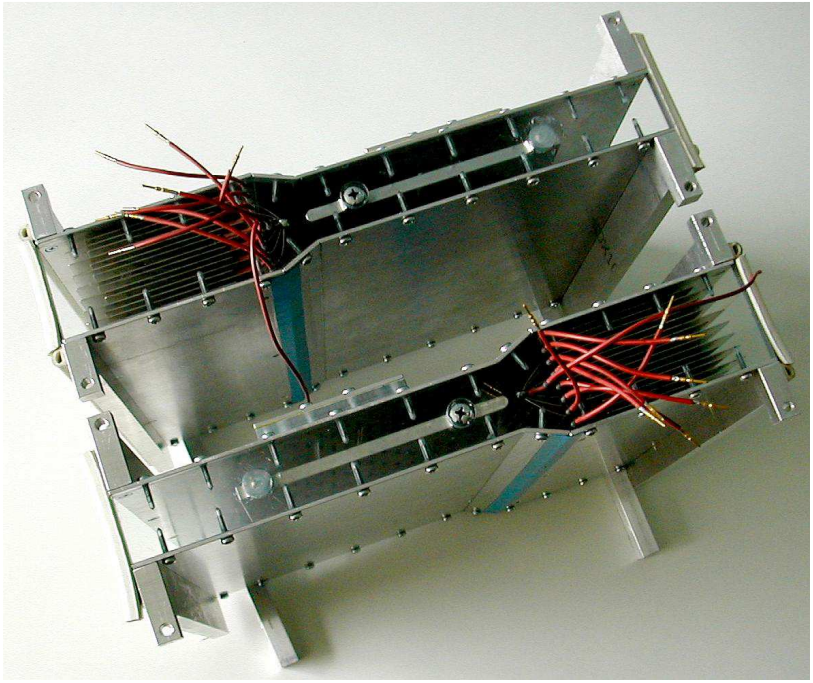
Objectives for design and manufacturing of BSMA2

- Improvement and test of aspiration condenser.
- Improvement and test of the measurement software.
- Careful calibration of the instrument.
- Nucleation measurements in Tartu.

Aspiration condenser







Two oppositely directed aspiration condensers

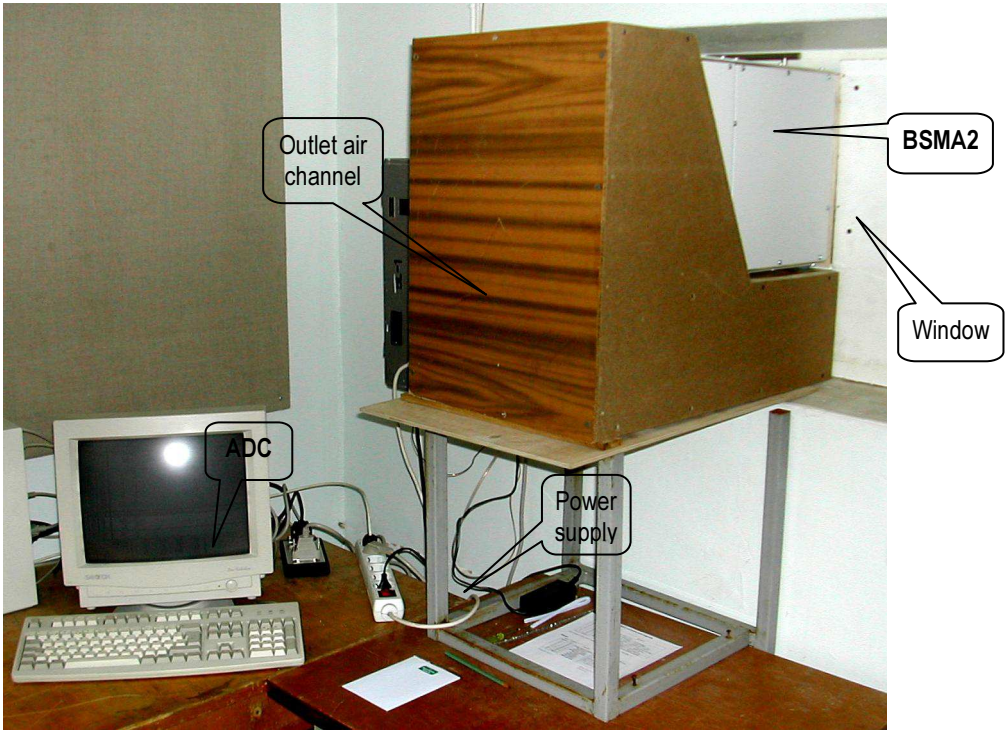
Standard air flow in one condenser 26 l/s.

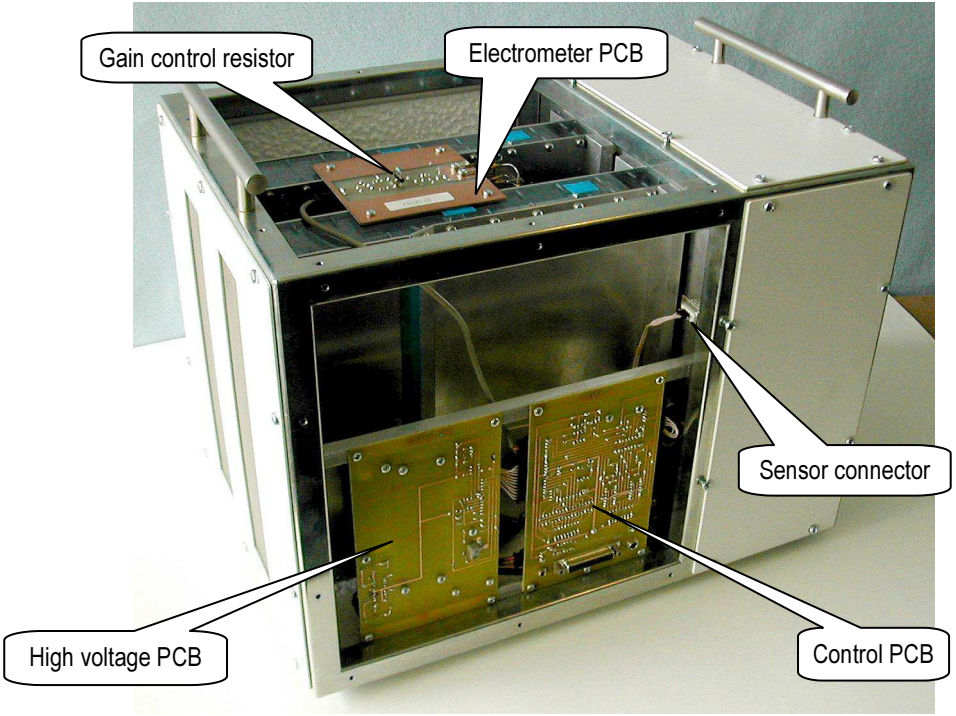
Velocity in the filter 2.8 m/s and between electrodes 4.5 m/s.

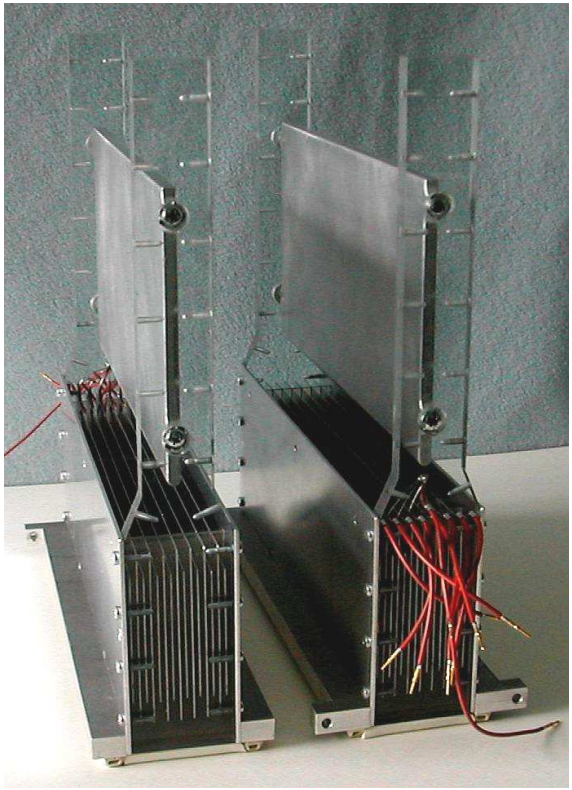
Reynolds number in the filter about 450 and between the electrodes 3600.

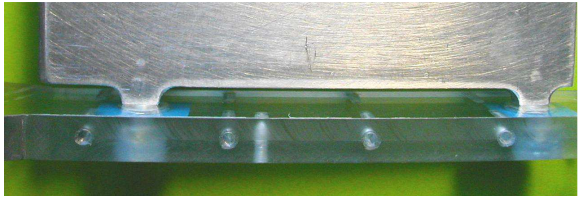
Filter voltage 510 V,
$Z = 0.005\ cm^2V^{-1}s^{-1}$.

Analyzer voltage
up to 3000 V,
$Z \approx 0.03\ cm^2V^{-1}s^{-1}$.


Outlet air channel
BSMA2
Window
ADC
Power supply


Gain control resistor
Electrometer PCB
Sensor connector
High voltage PCB
Control PCB

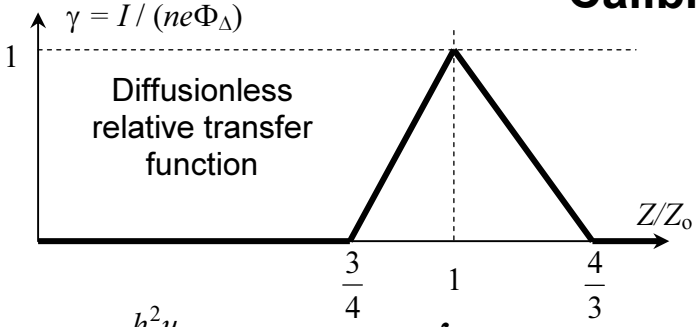




Specifications

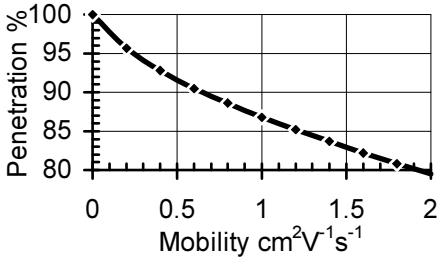
- *Length* **44 cm**, *width* **32 cm**, *height* **36 cm**, *mass* **16.0 kg**.
- *Power* DC **23-24 V**, **60 W** or AC 47–63 Hz, **90–260 V**, **70 W**.
- *Suitable power units* ZVC65SG24 or Mascot 2020.
- *Air flow rate* **52 l s^{-1}**.
- *Passage time* of air from the inlet grid to the ion collector **0.06 s**.
- *Heat emission* of the electronics inside of the analyzer section **20 W**.
- *Increase of air temperature* during measurement due to the heat emission **0.2 K**.
- *Thermal insulation* inside of the cover panels: foam polystyrene **10 mm**.
- *Mobility* range **0.032–3.2 cm^2 V^{-1} s^{-1}**.
- *Fraction concentration* standard range **0–40000 cm^{-3}**.
- The range can be increased changing the electrometer gain control resistor.
- *Mobility resolution* **16** mobility **fractions**.
- Electrometric amplifier: INA116.
- *Humidity* of analyzed air in case of unpolluted insulators: up to **99%.**
- *Standard deviation* of a fraction concentration in the conditions of simultaneous measurement of two polarities, 10-minute averaging, clean insulators,
  moderate radon concentration, moderate humidity, and low wind: about **5 cm^{-3}**.

Calibration



$$Z_\circ = \frac{h^2 u}{Vl} \qquad I(Z_\circ) = e\Phi_\Delta \int \gamma(Z_\circ, Z) f(Z) dZ$$

$$f(Z_\circ) \approx \frac{24}{7} \frac{I(Z_\circ)}{e\Phi_\Delta Z_\circ} \qquad n_{(a,b)} \approx 0.99 \frac{I(Z_\circ)}{e\Phi_\Delta}$$



Measurement program

Mobility scanning scheme: decade to eight fractions.

Span: two decades of mobility.

16 mobility fractions ($cm^2V^{-1}s^{-1}$): **0.032–0.042** **0.042–0.056** **0.056–0.075**
0.075–0.100 **0.100–0.133** **0.133–0.178** **0.178–0.237** **0.237–0.316**
0.316–0.422 **0.422–0.562** **0.562–0.750** **0.750–1.00** **1.00–1.33**
1.33–1.78 **1.78–2.37** **2.37–3.16**

Voltage decreases during a 19 second scan exponentially from 3000 V to 25 V.

A 10-minute cycle includes:

- calibration of voltage decay,
- balancing of the bridge circuit,
- about 29 scans of mobility distribution,
- calculation of the size distribution
  using measurements of air temperature and pressure,
- saving of the results.

d : nm border	center	Z : $cm^2V^{-1}s^{-1}$ –20 C & 1050 mb	Z : $cm^2V^{-1}s^{-1}$ 10 C & 1000 mb	Z : $cm^2V^{-1}s^{-1}$ 40 C & 950 mb
0.422		2.3646	2.7158	3.0916
	0.487	2.0676	2.3590	2.6706
0.562		1.8005	2.0429	2.3022
	0.649	1.5573	1.7593	1.9756
0.750		1.3356	1.5038	1.6840
	0.866	1.1347	1.2743	1.4239
1.000		0.9545	1.0697	1.1932
	1.155	0.7937	0.8865	0.9847
1.334		0.6432	0.7110	0.7814
	1.540	0.4960	0.5426	0.5920
1.778		0.3717	0.4071	0.4456
	2.054	0.2816	0.3104	0.3418
2.371		0.2175	0.2409	0.2662
	2.738	0.1698	0.1885	0.2087
3.162		0.1330	0.1477	0.1636
	3.652	0.1040	0.1155	0.1279
4.217		0.0811	0.0900	0.0997
	4.870	0.0630	0.0699	0.0773
5.623		0.0488	0.0541	0.0598
	6.494	0.0376	0.0417	0.0461
7.499		0.0290	0.0321	0.0354

Mobility distribution is measured alternately in three regimes marked

+ − 0

+) gate of positive ions opened, gate of negative ions closed,
−) gate of negative ions opened, gate of positive ions closed,
0) both gates closed.

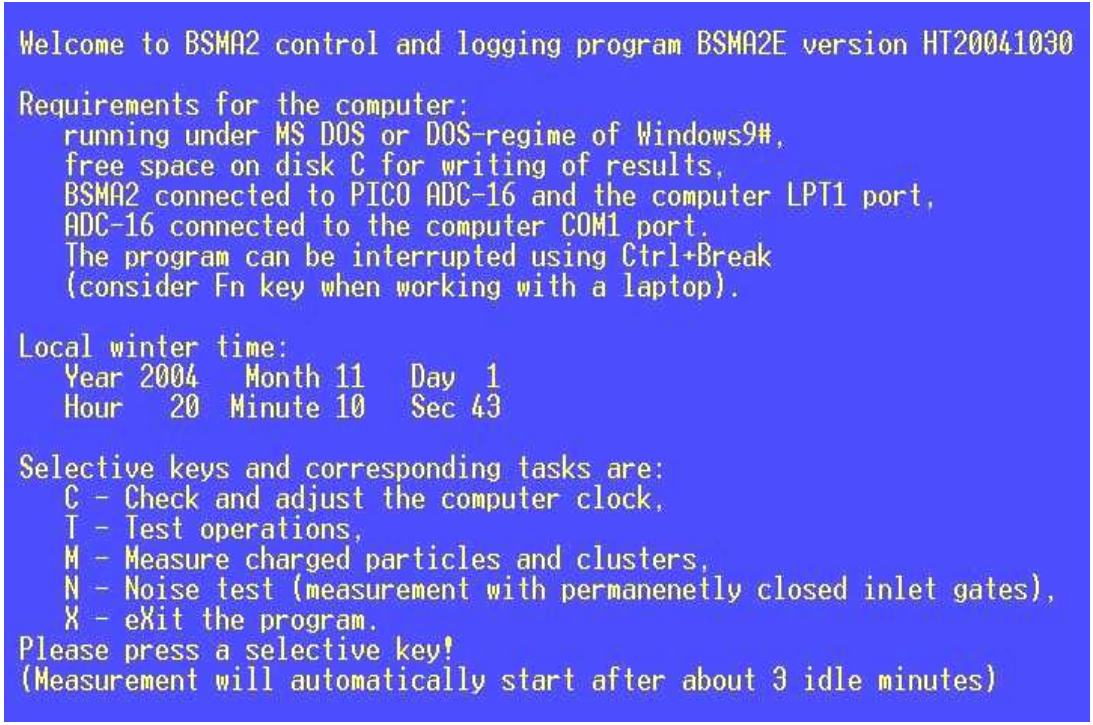
Regimes are alternated as **0 − 0 + 0 − 0 + 0 − 0 + 0 − 0...**

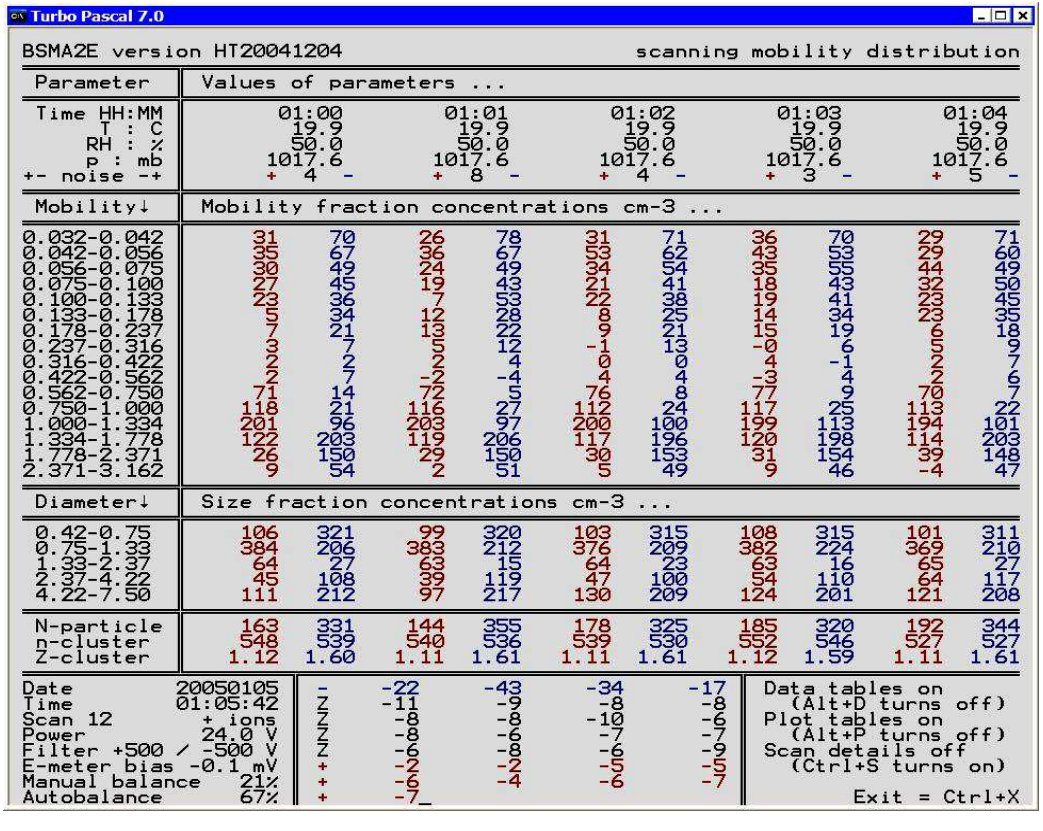
Scan results are calculated for **+** and **−** regimes as $y_i = x_i - (x_{i-1} + x_{i+1}) / 2$.

Measurement errors are estimated for **0** regime as $z_i = x_i - (x_{i-2} + x_{i+2}) / 2$.

Cycle results are calculated as classified averages of y_i where minimum and maximum element in a cycle are excluded.

Saved results include for every cycle mobility and size distributions for both polarities, estimate of noise, temperature, pressure, humidity, and some technical control values.


Welcome to BSMA2 control and logging program BSMA2E version HT20041030
Requirements for the computer:
running under MS DOS or DOS-regime of Windows9#,
free space on disk C for writing of results,
BSMA2 connected to PICO ADC-16 and the computer LPT1 port,
ADC-16 connected to the computer COM1 port.
The program can be interrupted using Ctrl+Break
(consider Fn key when working with a laptop).
Local winter time:
Year 2004 Month 11 Day 1
Hour 20 Minute 10 Sec 43
Selective keys and corresponding tasks are:
C - Check and adjust the computer clock,
T - Test operations,
M - Measure charged particles and clusters,
N - Noise test (measurement with permanenetly closed inlet gates),
X - eXit the program.
Please press a selective key!
(Measurement will automatically start after about 3 idle minutes)



Turbo Pascal 7.0

BSMA2E version HT20041204 scanning mobility distribution

Parameter	Values of parameters ...									
Time HH:MM	01:00		01:01		01:02		01:03		01:04	
T : C	19.9		19.9		19.9		19.9		19.9	
RH : %	50.0		50.0		50.0		50.0		50.0	
p : mb	1017.6		1017.6		1017.6		1017.6		1017.6	
+- noise -+	+ 4	-	+ 8	-	+ 4	-	+ 3	-	+ 5	-
Mobility↓	Mobility fraction concentrations cm-3 ...									
0.032-0.042	31	70	26	78	31	71	36	70	29	71
0.042-0.056	35	67	36	67	53	62	43	53	29	60
0.056-0.075	30	49	24	49	34	54	35	55	44	49
0.075-0.100	27	45	19	43	21	41	18	43	32	50
0.100-0.133	23	36	7	53	22	38	19	41	23	45
0.133-0.178	5	34	12	28	8	25	14	34	23	35
0.178-0.237	7	21	13	22	9	21	15	19	6	18
0.237-0.316	3	7	5	12	-1	13	-0	6	5	9
0.316-0.422	2	2	2	4	0	0	4	-1	2	7
0.422-0.562	2	7	-2	-4	4	4	-3	4	2	6
0.562-0.750	71	14	72	5	76	8	77	9	70	7
0.750-1.000	118	21	116	27	112	24	117	25	113	22
1.000-1.334	201	96	203	97	200	100	199	113	194	101
1.334-1.778	122	203	119	206	117	196	120	198	114	203
1.778-2.371	26	150	29	150	30	153	31	154	39	148
2.371-3.162	9	54	2	51	5	49	9	46	-4	47
Diameter↓	Size fraction concentrations cm-3 ...									
0.42-0.75	106	321	99	320	103	315	108	315	101	311
0.75-1.33	384	206	383	212	376	209	382	224	369	210
1.33-2.37	64	27	63	15	64	23	63	16	65	27
2.37-4.22	45	108	39	119	47	100	54	110	64	117
4.22-7.50	111	212	97	217	130	209	124	201	121	208
N-particle	163	331	144	355	178	325	185	320	192	344
n-cluster	548	539	540	536	539	530	552	546	527	527
Z-cluster	1.12	1.60	1.11	1.61	1.11	1.61	1.12	1.59	1.11	1.61

Date	20050105	-	-22	-43	-34	-17
Time	01:05:42	Z	-11	-9	-8	-8
Scan 12	+ ions	Z	-8	-8	-10	-6
Power	24.0 V	Z	-8	-6	-7	-7
Filter +500 / -500 V		Z	-6	-8	-6	-9
E-meter bias -0.1 mV		+	-2	-2	-5	-5
Manual balance	21%	+	-6	-4	-6	-7
Autobalance	67%	+	-7_			

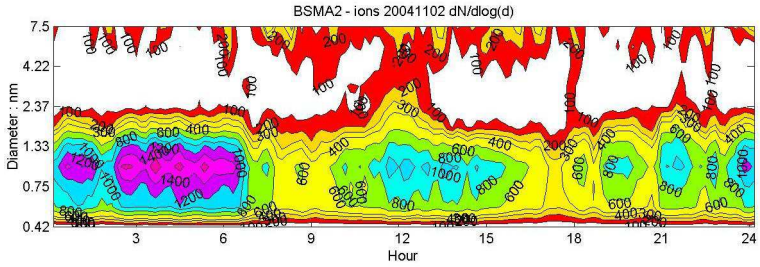
Data tables on
(Alt+D turns off)
Plot tables on
(Alt+P turns off)
Scan details off
(Ctrl+S turns on)

Exit = Ctrl+X

```
program PLOTTAB;
.......
   writeln ('Data can be smoothed repeating N times',
           ' averaging over the triads of neighbors.');
   writeln ('Recommended standard smoothing grade N = 1.');
   write ('Please tell your choice of the smoothing grade N (0...5) : ');
   readln (grade);
.......
```

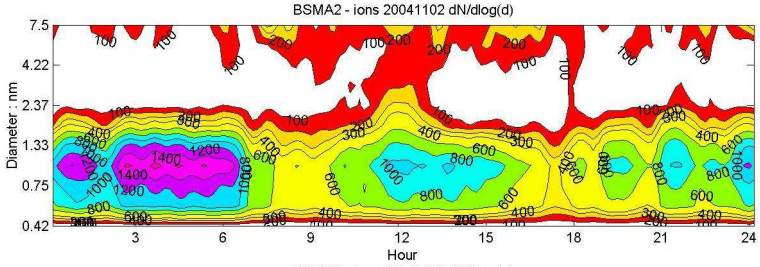
```
function BSMA2PLT; %HT20041106
% Diurnal contour plots from BSMA2E plot tables
% All days of one month in one folder are processed in one session
% Input filenames must be pYYMMDD.xl and nYYMMDD.xl
% Output filenames are [prefix YYMMDD.jpg]

% Please modify the input data in following 3 lines:
  prefix = 'BSMA'; % for output file name, could be modified
filepath = 'C:\PLOT\'; % where the files are located, could be modified
    yymm = '0411'; % year and month, could be modified
.......
```

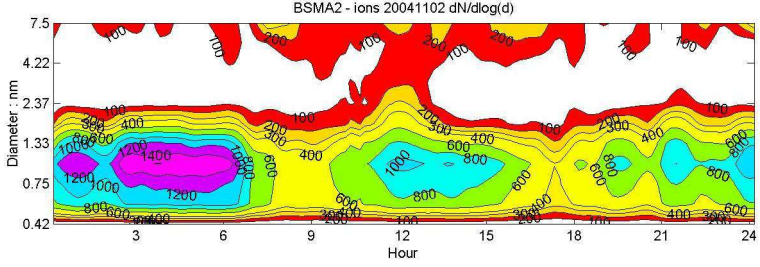


Smoothing grade:

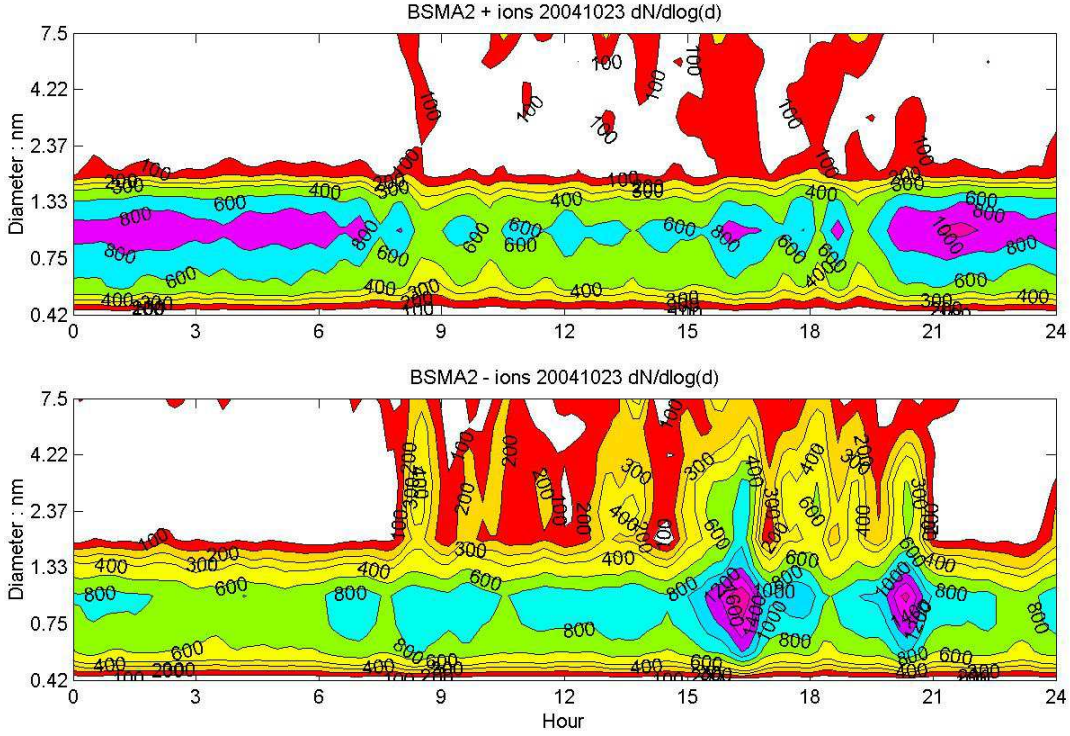
0

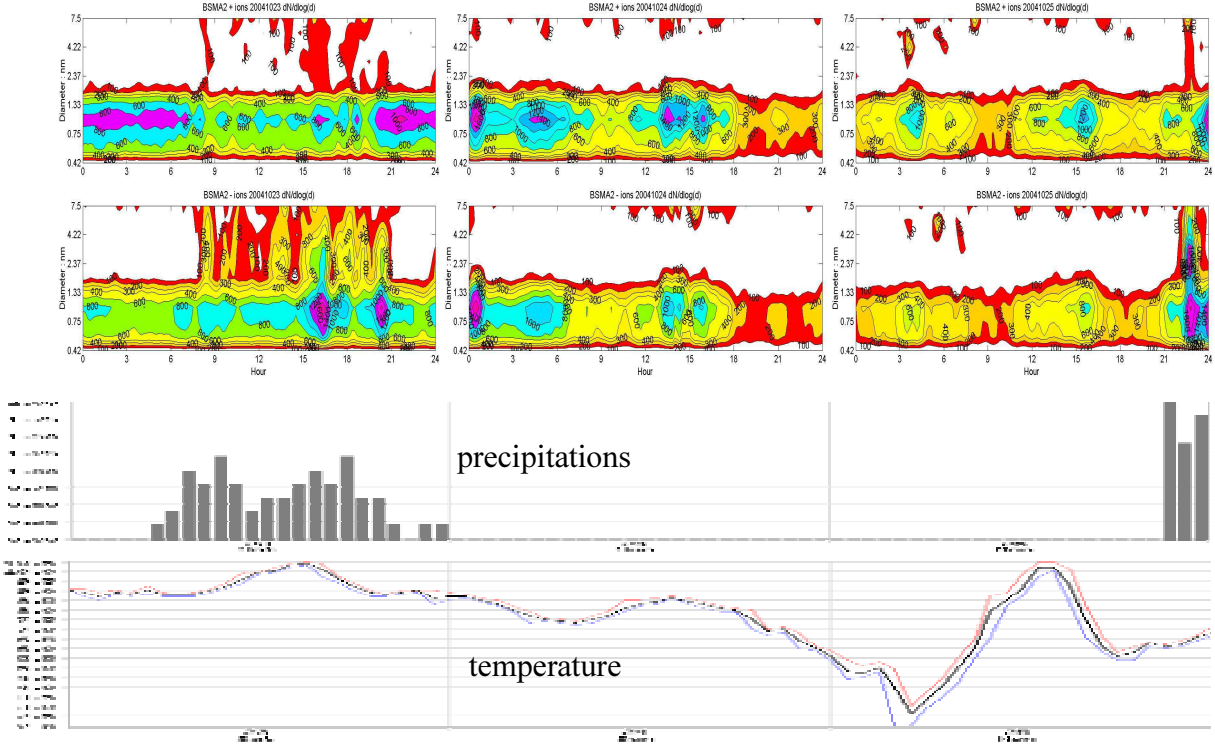


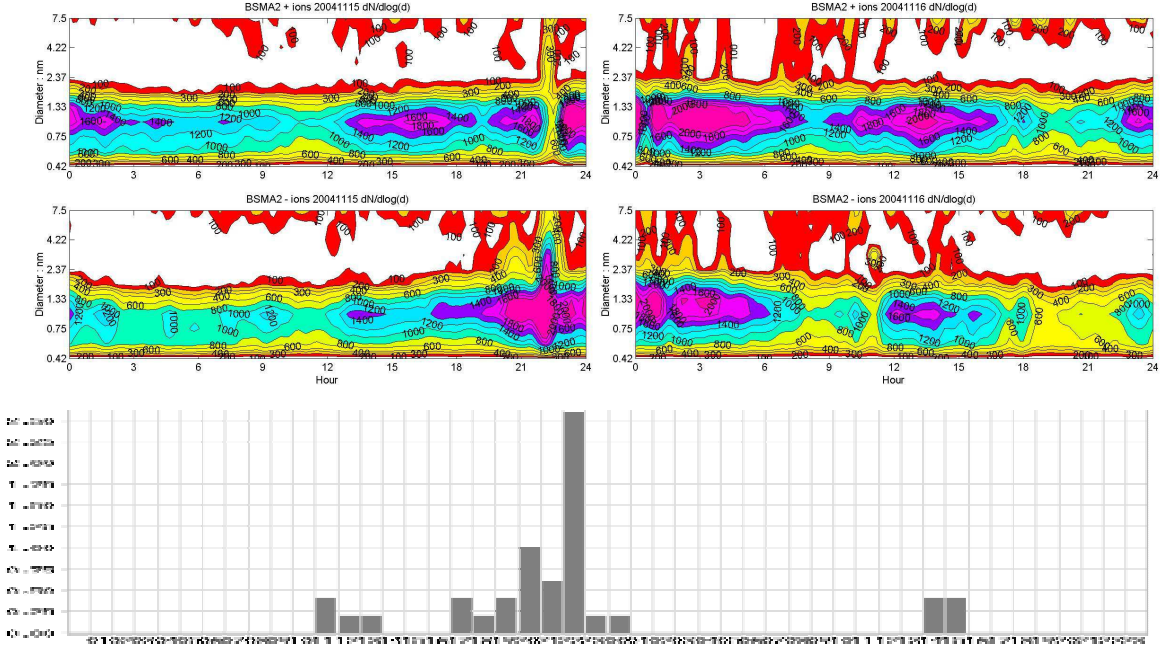
1

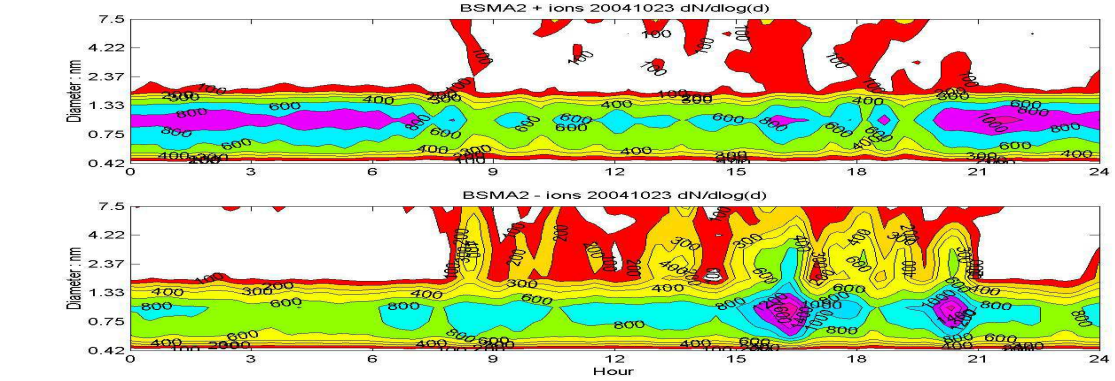


3

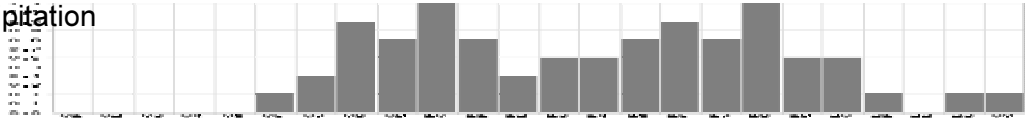

BSMA2 + ions 20041023 dN/dlog(d)
BSMA2 - ions 20041023 dN/dlog(d)
Diameter : nm
7.5
4.22
2.37
1.33
0.75
0.42
0
3
6
9
12
15
18
21
24
Hour

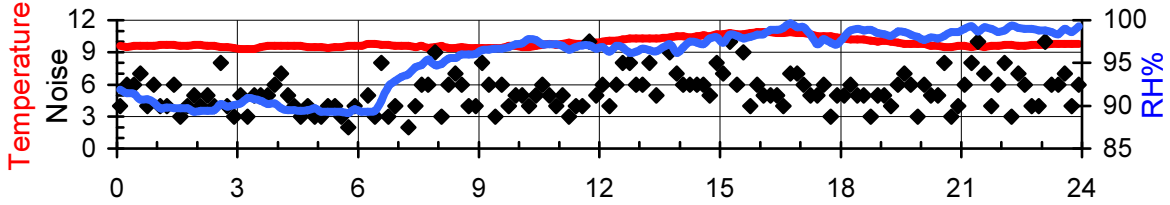

BSMA2 + ions 20041023 dN/dlog(d)
BSMA2 + ions 20041024 dN/dlog(d)
BSMA2 + ions 20041025 dN/dlog(d)
BSMA2 - ions 20041023 dN/dlog(d)
BSMA2 - ions 20041024 dN/dlog(d)
BSMA2 - ions 20041025 dN/dlog(d)
Diameter - nm
Hour
precipitations
temperature

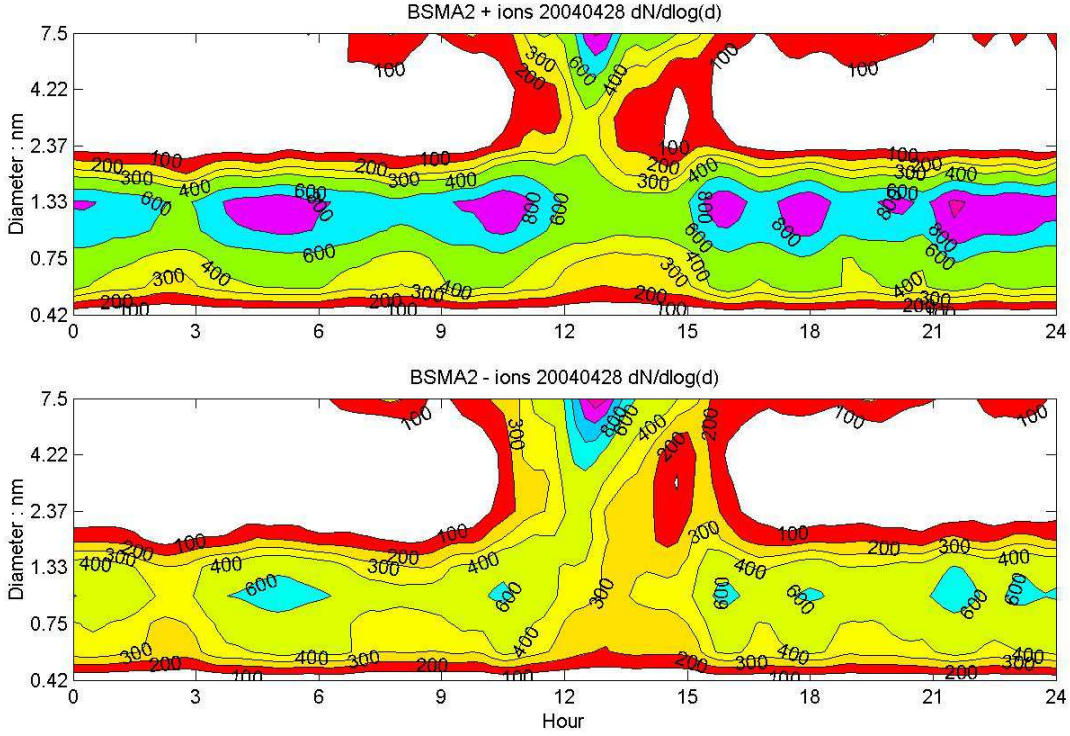

BSMA2 + ions 20041115 dN/dlog(d)
BSMA2 + ions 20041116 dN/dlog(d)
BSMA2 - ions 20041115 dN/dlog(d)
BSMA2 - ions 20041116 dN/dlog(d)
Diameter , nm
Hour

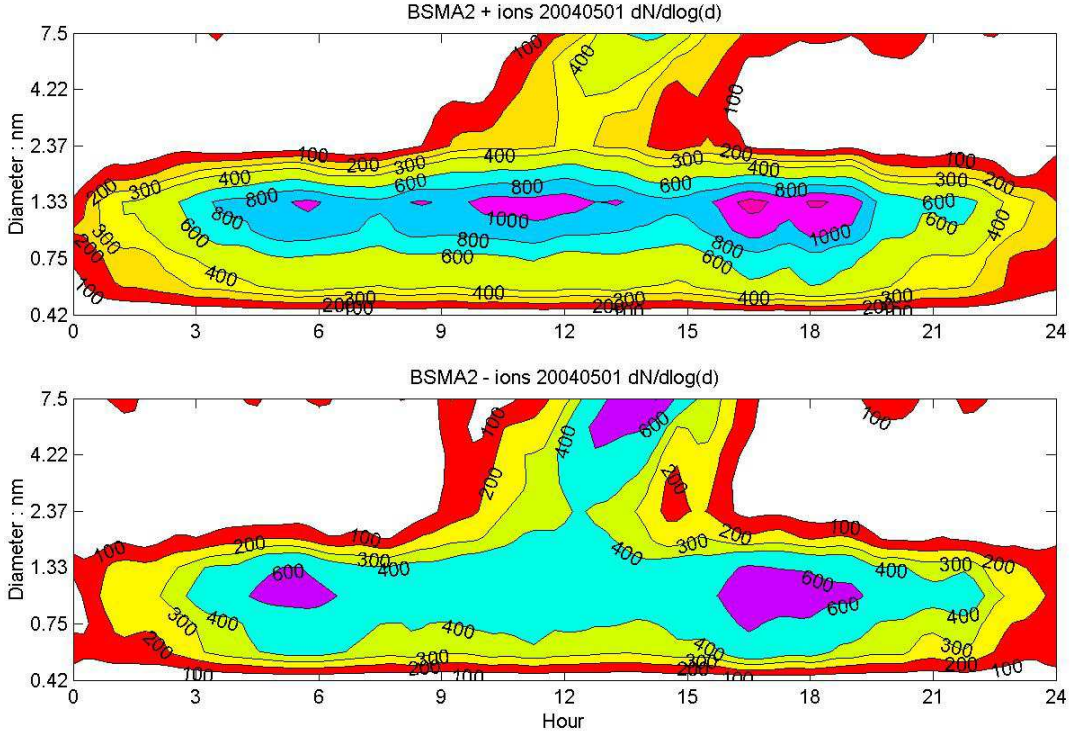


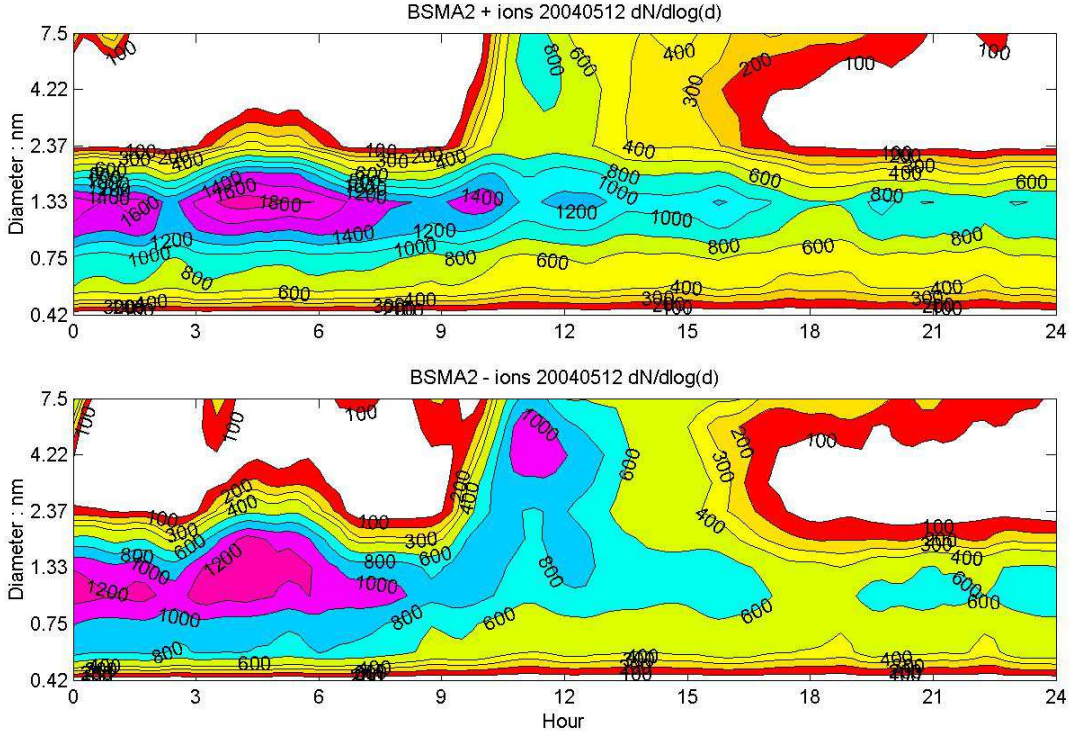
Precipitation

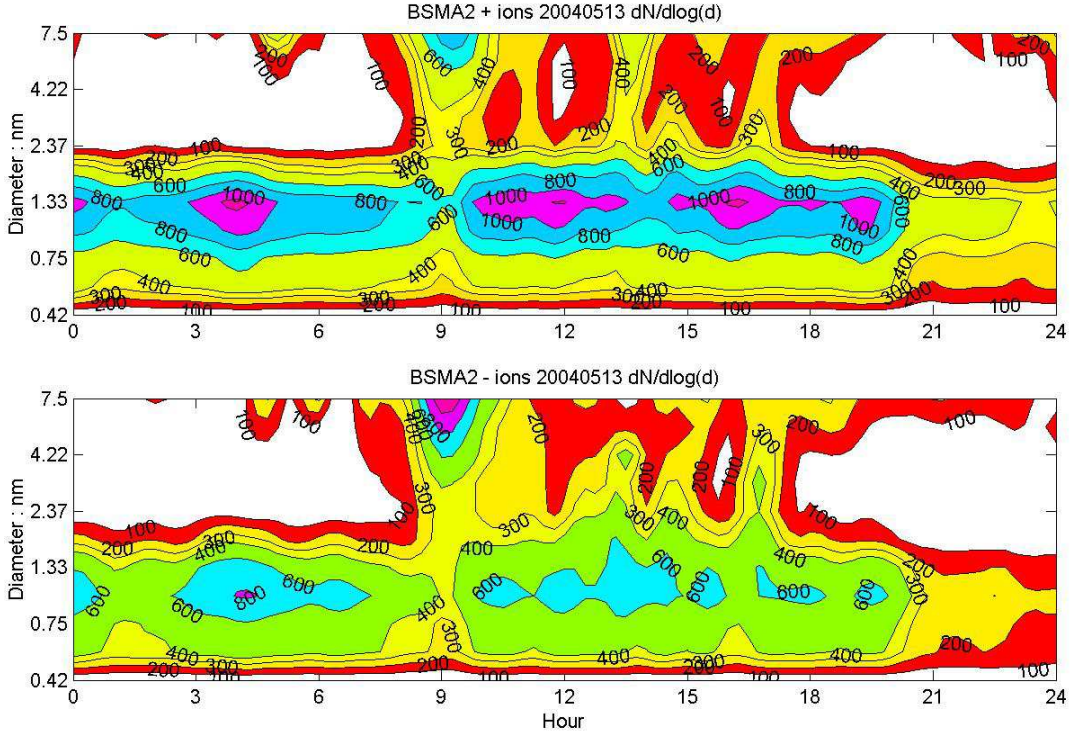


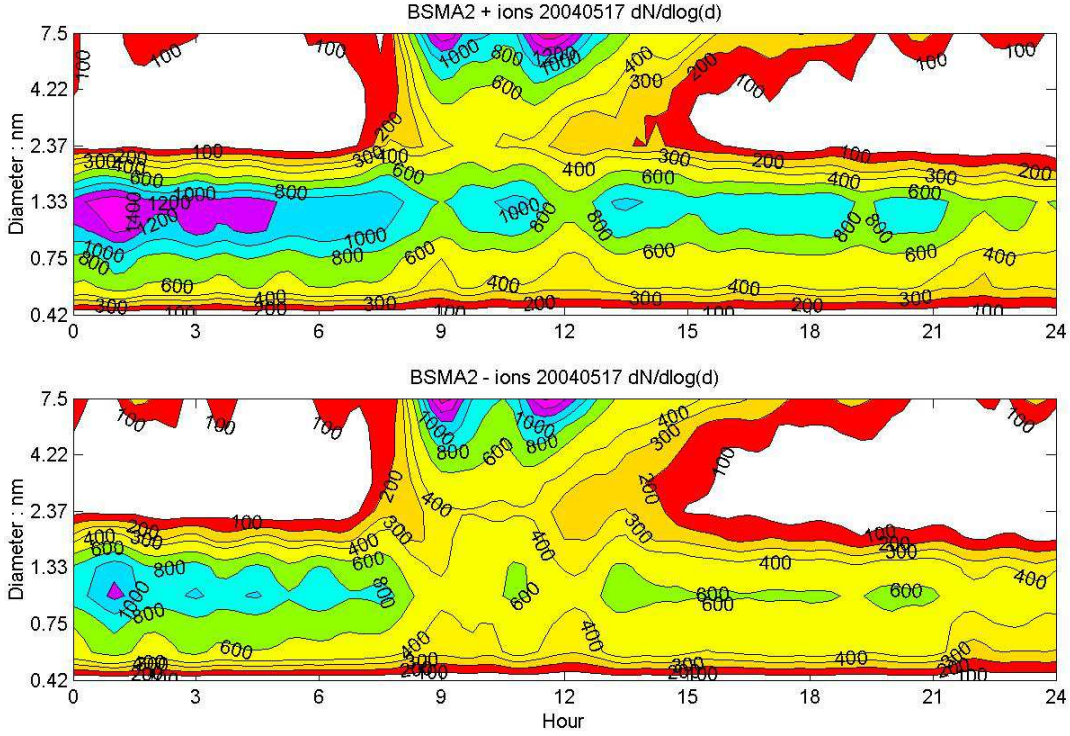


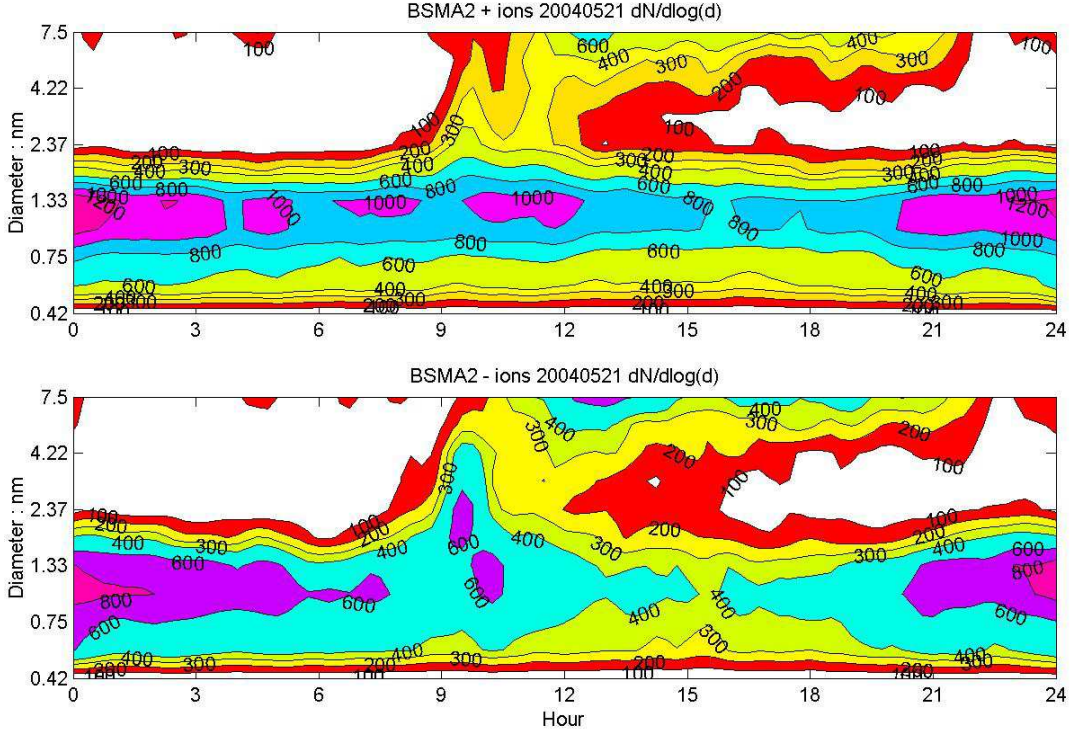

BSMA2 + ions 20040428 dN/dlog(d)
BSMA2 - ions 20040428 dN/dlog(d)
Diameter : nm
7.5
4.22
2.37
1.33
0.75
0.42
0
3
6
9
12
15
18
21
24
Hour

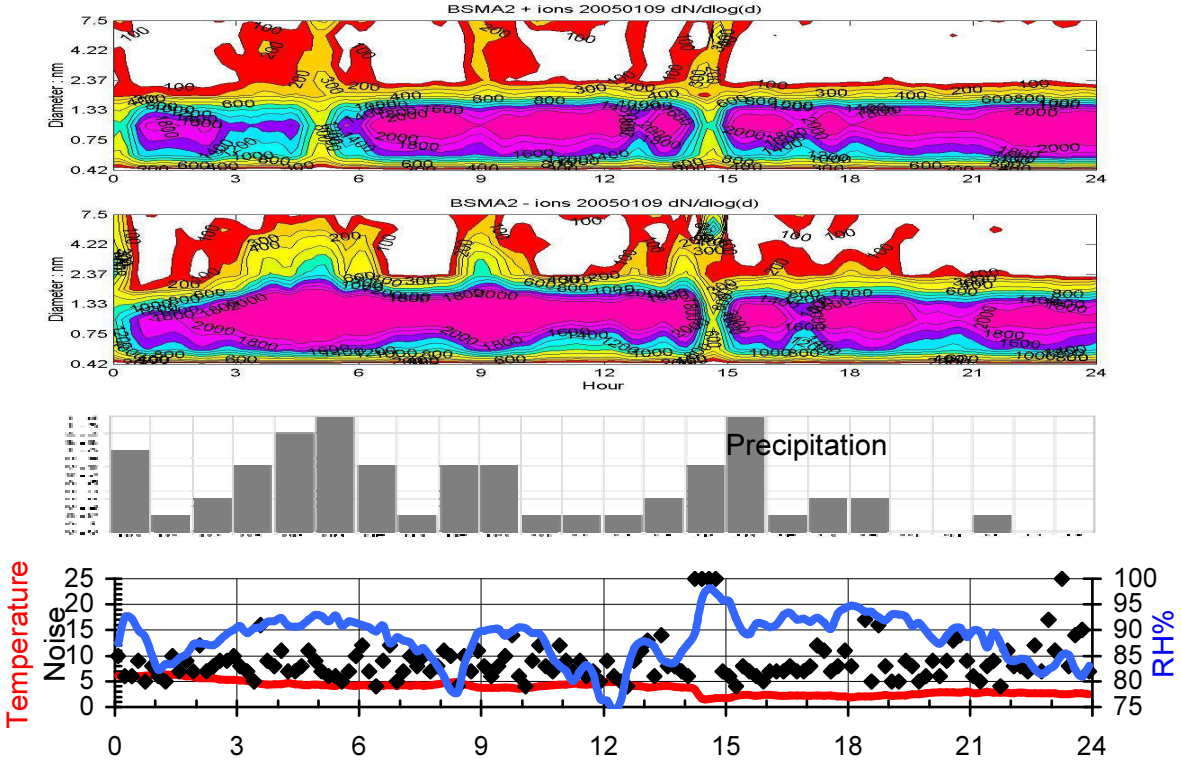

BSMA2 + ions 20040501 dN/dlog(d)
BSMA2 - ions 20040501 dN/dlog(d)
Diameter : nm
7.5
4.22
2.37
1.33
0.75
0.42
0
3
6
9
12
15
18
21
24
Hour

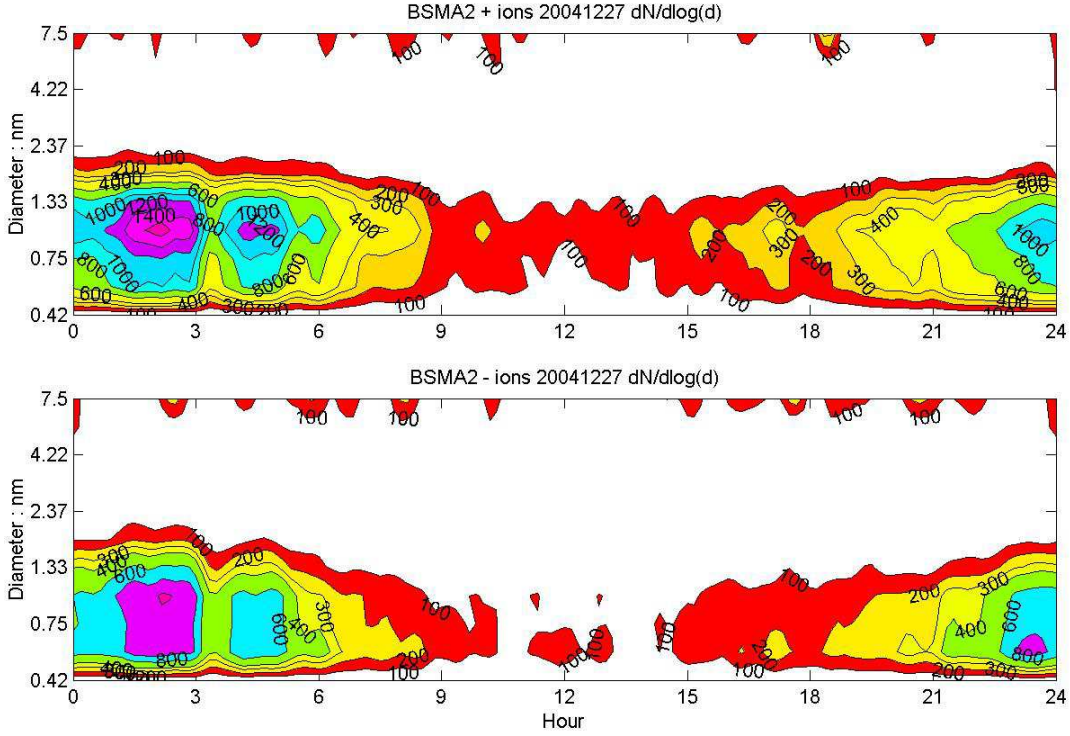

BSMA2 + ions 20040512 dN/dlog(d)
BSMA2 - ions 20040512 dN/dlog(d)
Diameter : nm
7.5
4.22
2.37
1.33
0.75
0.42
0
3
6
9
12
15
18
21
24
Hour

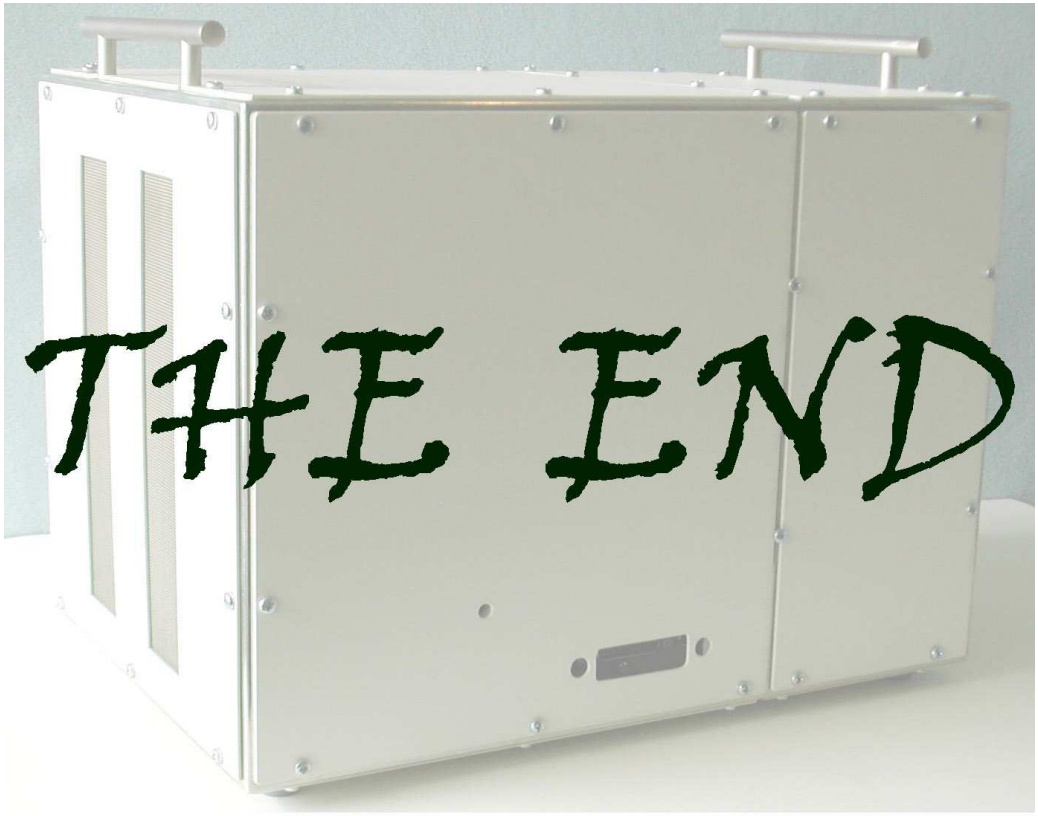

BSMA2 + ions 20040513 dN/dlog(d)
BSMA2 - ions 20040513 dN/dlog(d)
Diameter : nm
7.5
4.22
2.37
1.33
0.75
0.42
0
3
6
9
12
15
18
21
24
Hour


BSMA2 + ions 20040517 dN/dlog(d)
BSMA2 - ions 20040517 dN/dlog(d)
Diameter : nm
7.5
4.22
2.37
1.33
0.75
0.42
0
3
6
9
12
15
18
21
24
Hour


BSMA2 + ions 20040521 dN/dlog(d)
Diameter : nm
7.5
4.22
2.37
1.33
0.75
0.42
0
3
6
9
12
15
18
21
24
BSMA2 - ions 20040521 dN/dlog(d)
Diameter : nm
Hour


BSMA2 + ions 20050109 dN/dlog(d)
BSMA2 - ions 20050109 dN/dlog(d)
Diameter, nm
7.5
4.22
2.37
1.33
0.75
0.42
0
3
6
9
12
15
18
21
24
Hour
Precipitation
Temperature
Noise
RH%
25
20
15
10
5
0
100
95
90
85
80
75


BSMA2 + ions 20041227 dN/dlog(d)
Diameter : nm
7.5
4.22
2.37
1.33
0.75
0.42
0
3
6
9
12
15
18
21
24
BSMA2 - ions 20041227 dN/dlog(d)
Diameter : nm
Hour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