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IMK

INVESTIGATIONS INTO THE ICE NUCLEATING ABILITY OF PROPANE FLAME SOOT

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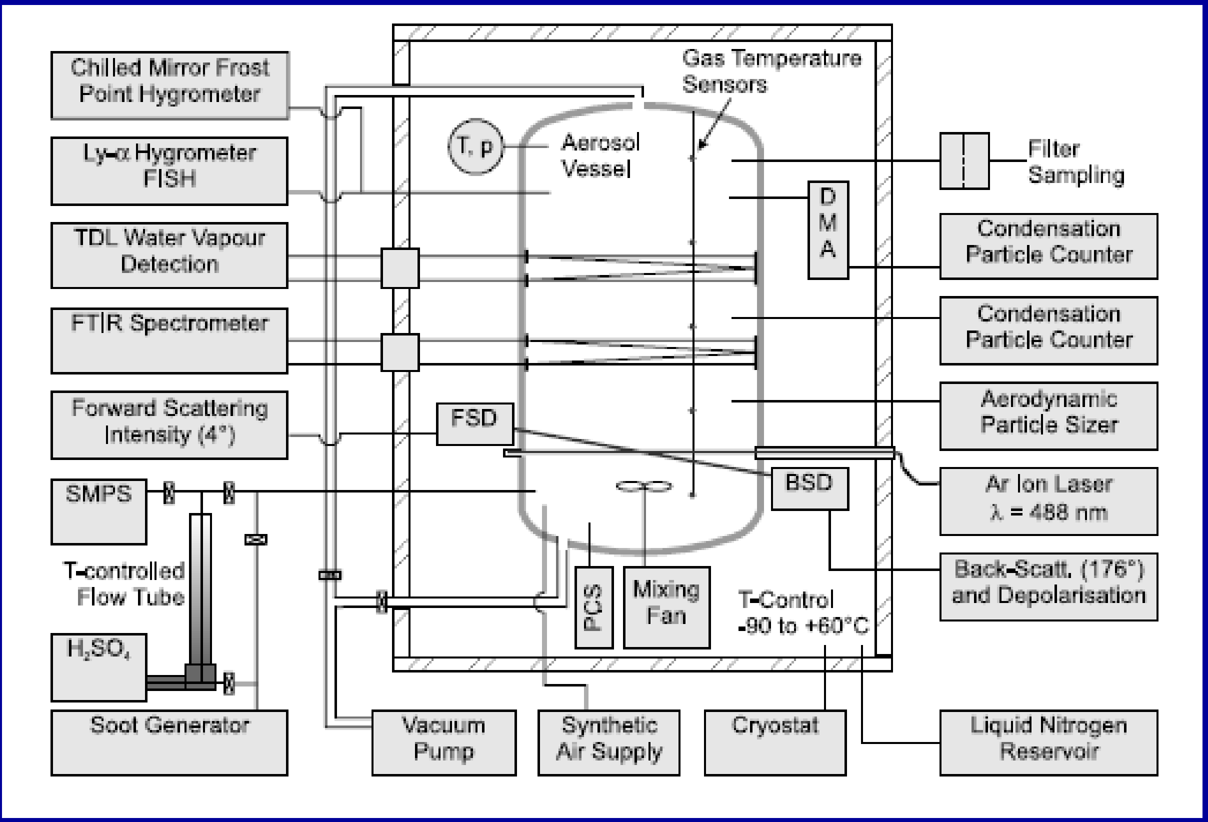
Outline of Talk

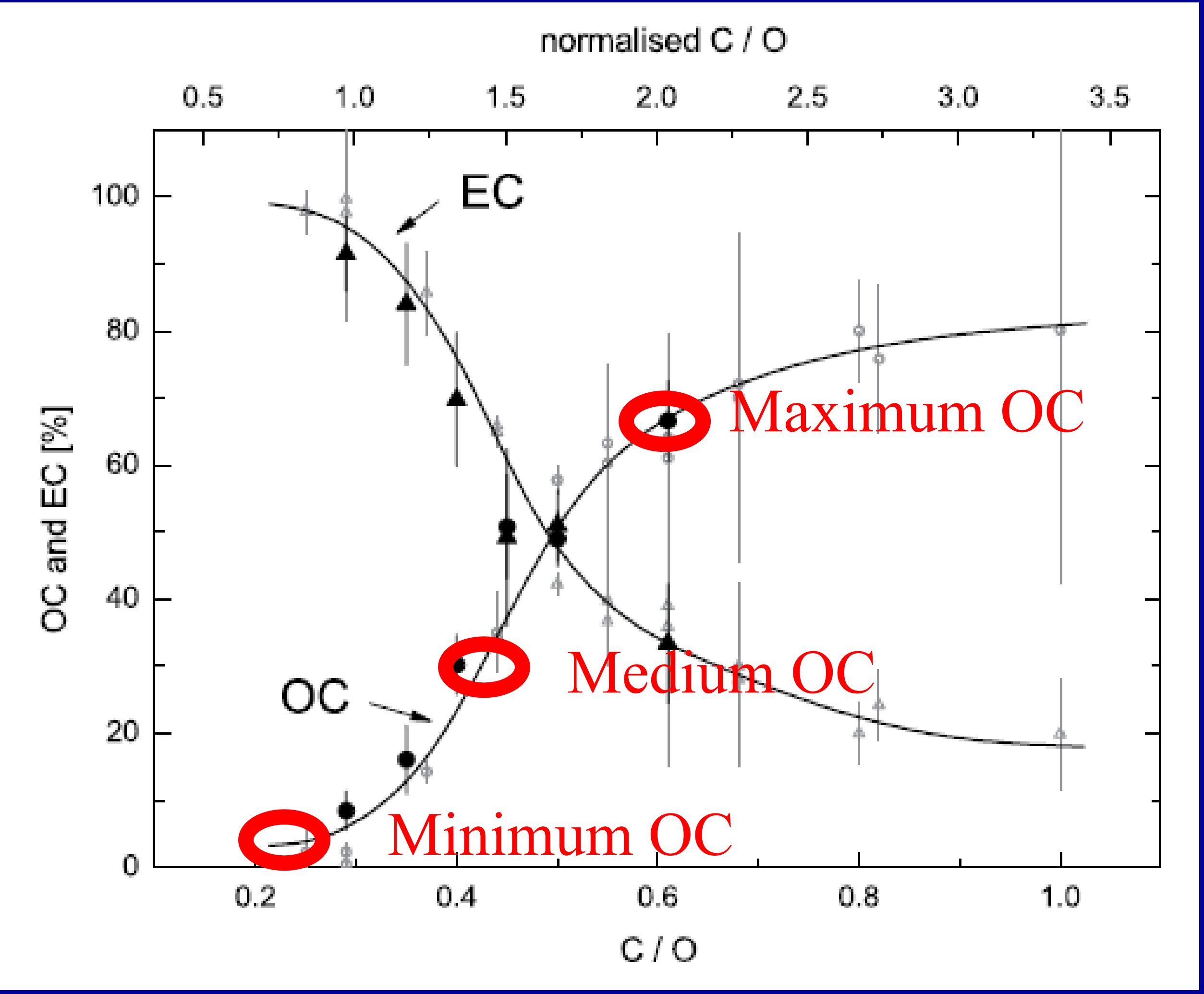
- AIDA Chamber
- Instrumentation
- Experiments
- Results
- Conclusions

AIDA Chamber



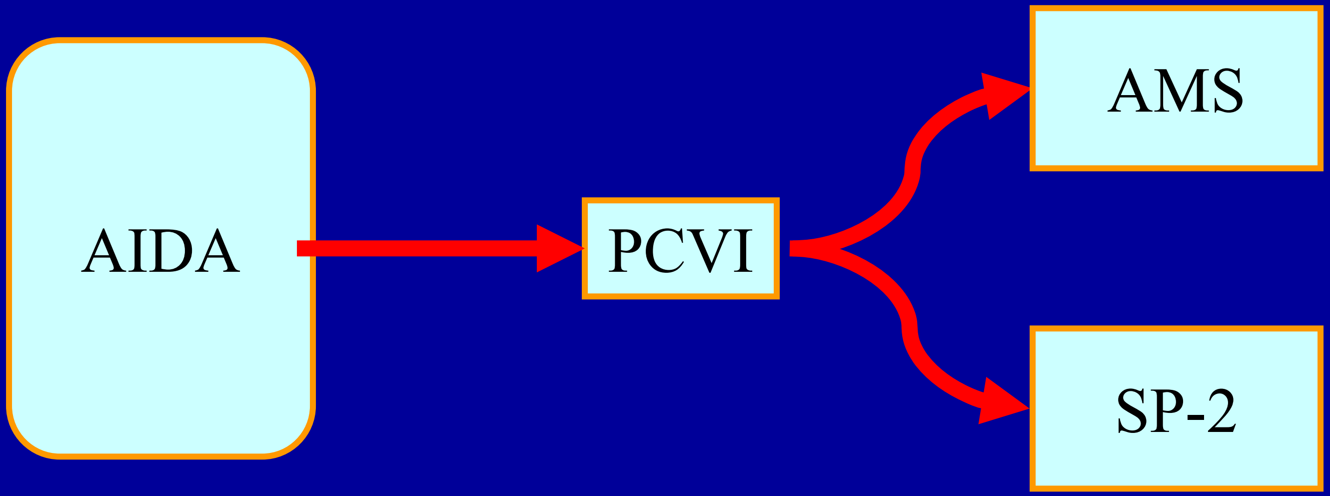
- Volume 84.3m^3
- Operational temperature range $183 \le T \le 333$ K ± 0.5 K
- Walls coated with ice
- Semi-adiabatic expansion reduced chamber temperature → increases relative humidity.

CAST Soot Generator

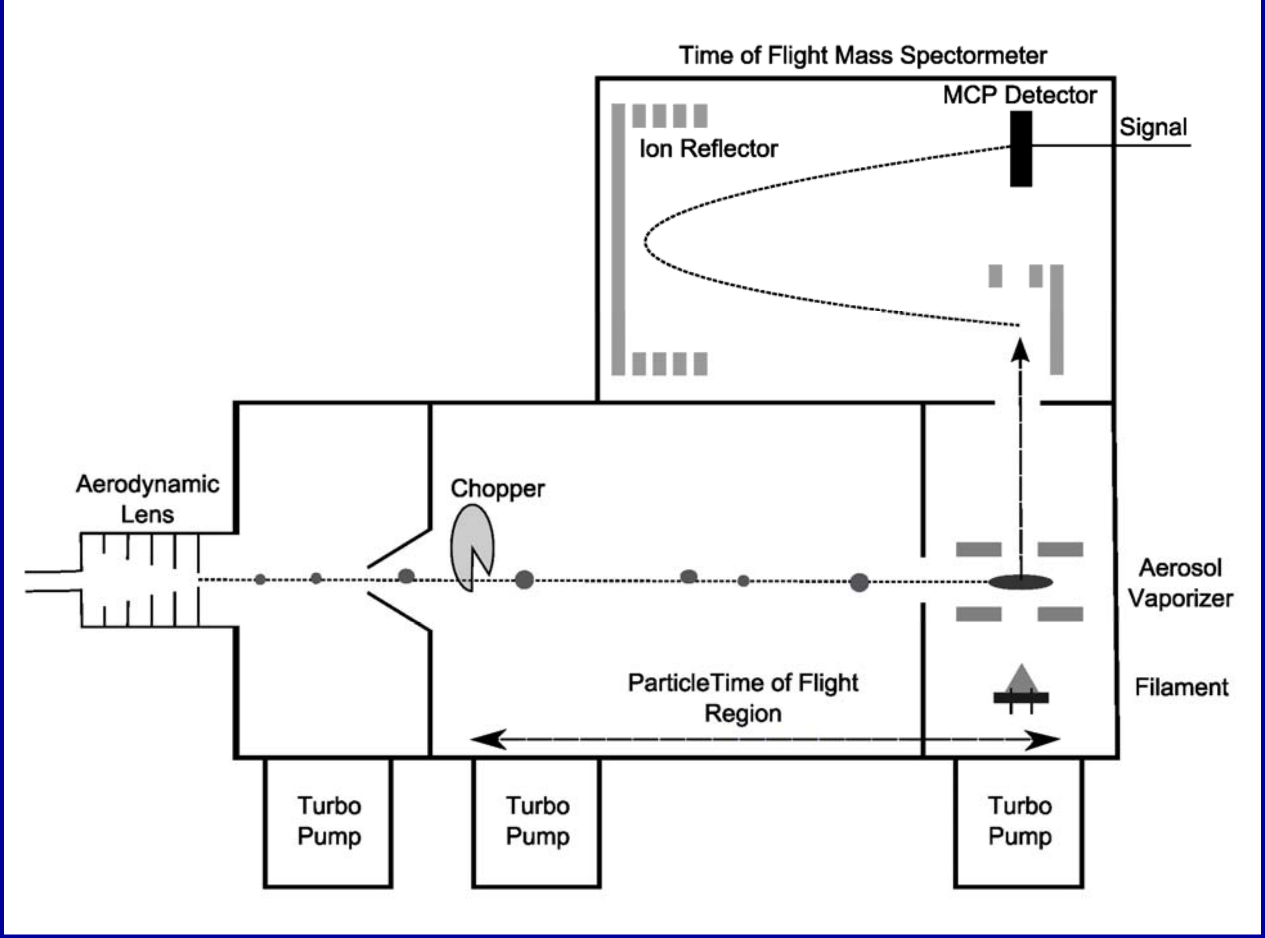


- Propane Flame soot generator. Different OC achieved by altering fuel:air mixture
- Minimum ~ 5% OC
- Medium ~ 30% OC
- Maximum ~ 60-70% OC

Instrumentation

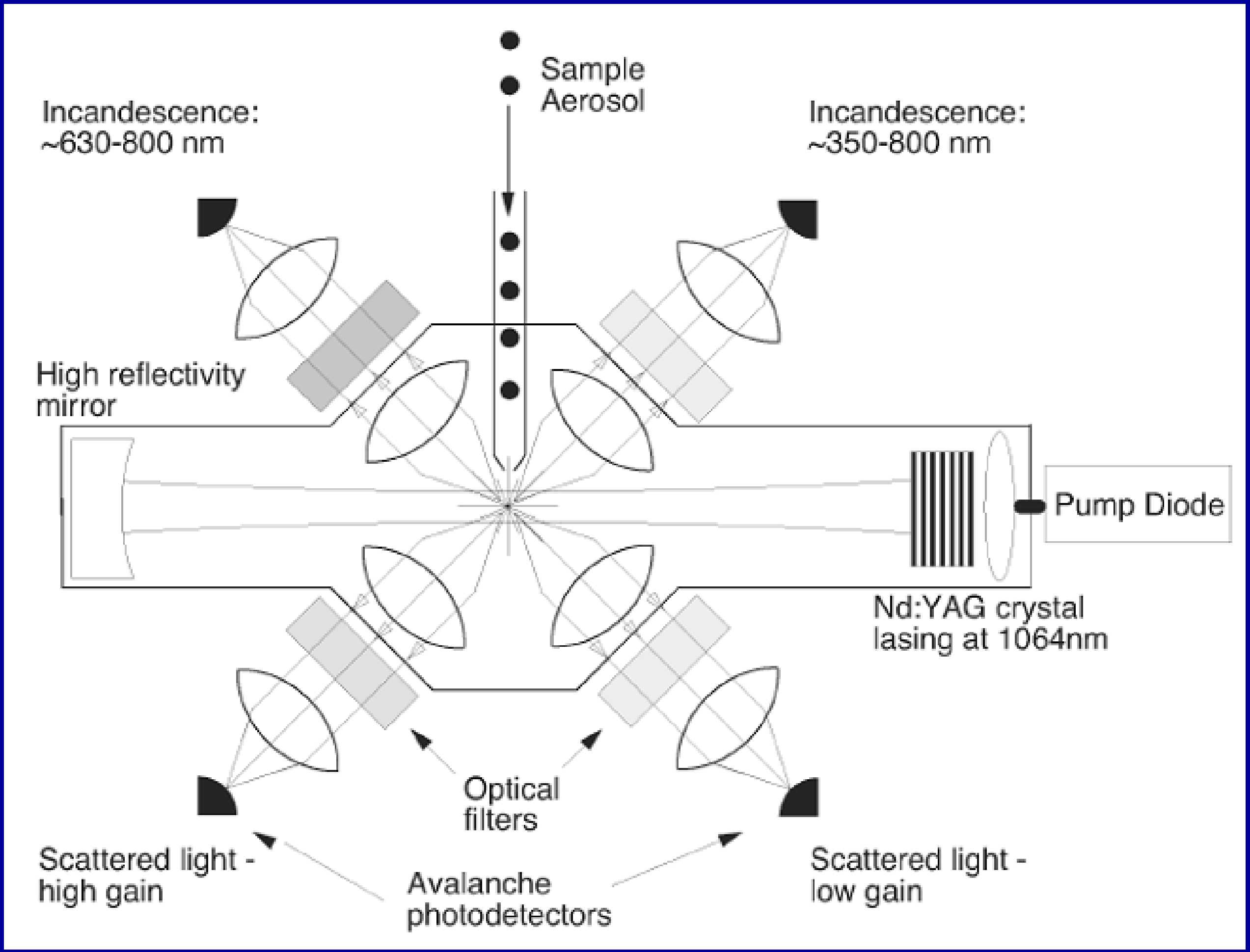


Time of Flight AMS

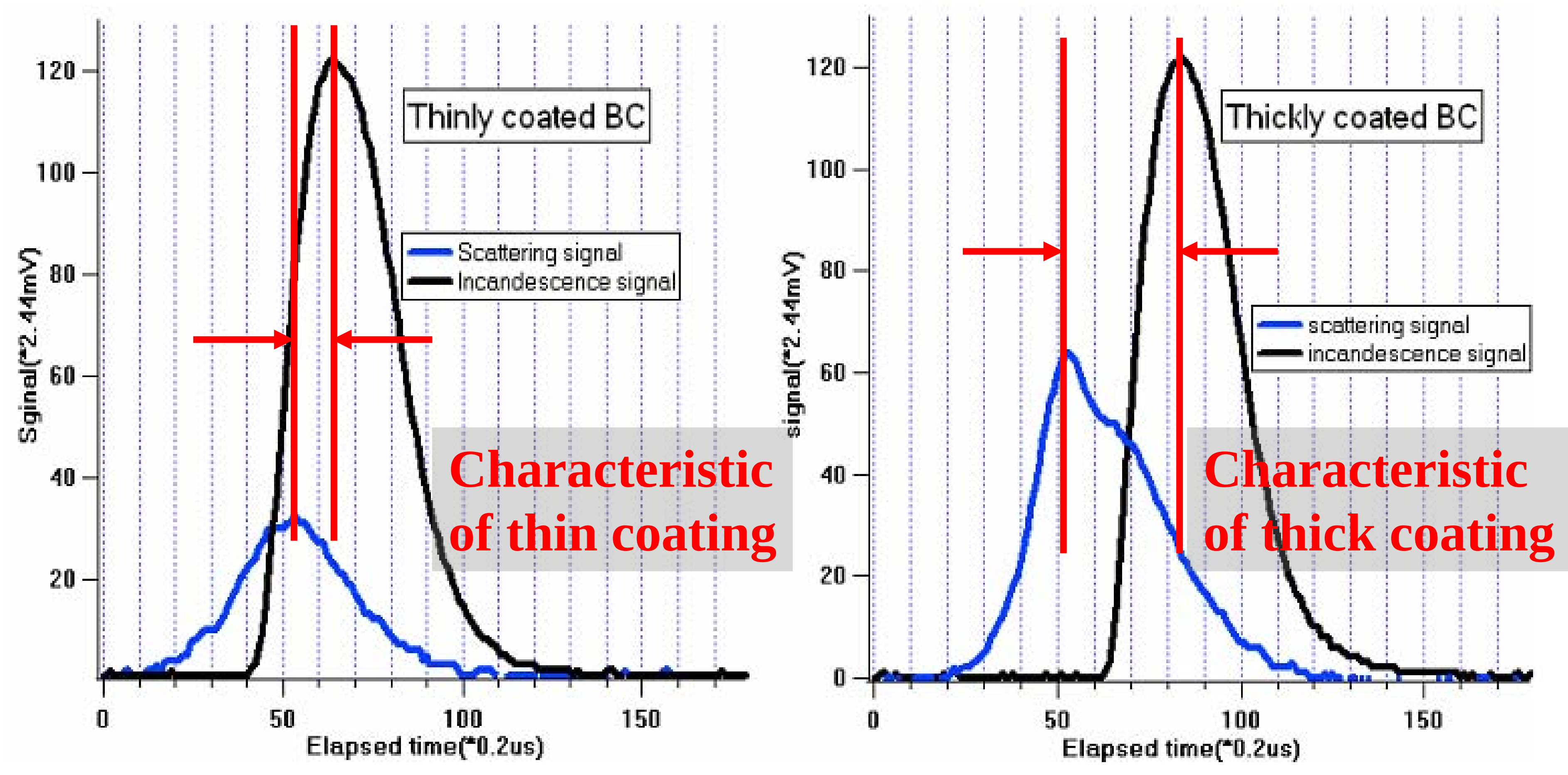


determines the size and composition of aerosol

Single Particle Soot Photometer

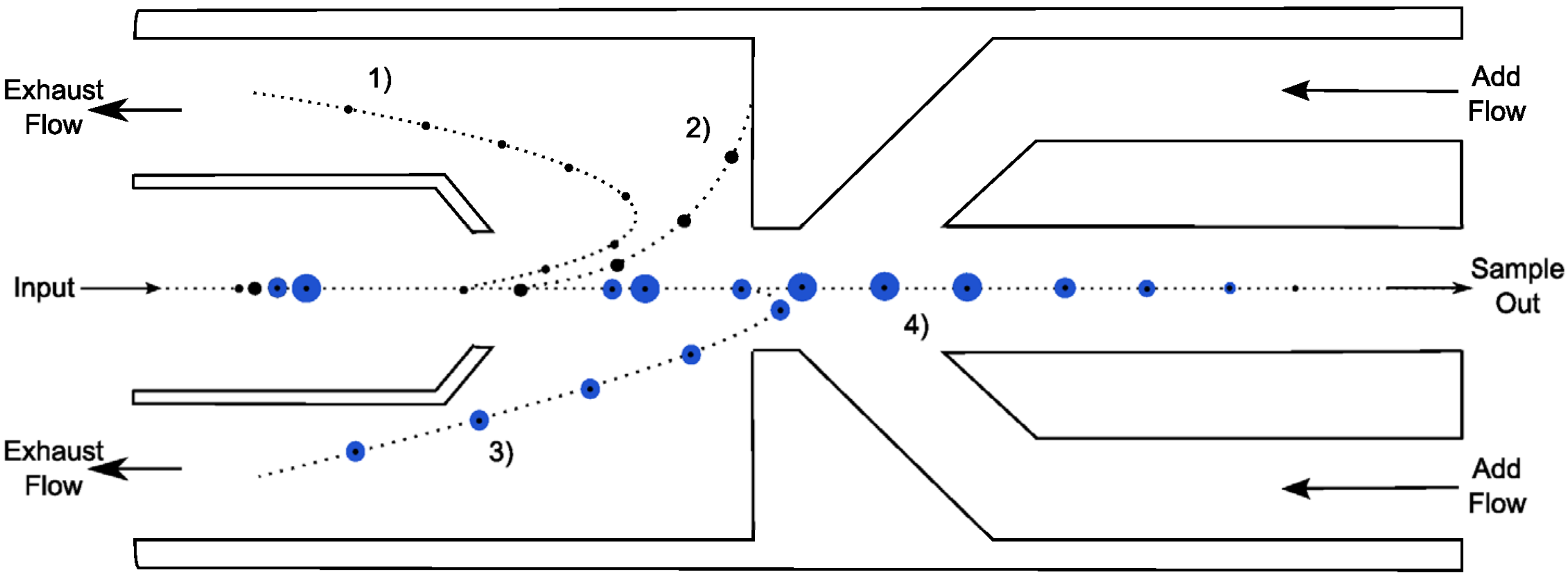


determines the size, mass and incandescing temperature of aerosol particles 0.15-1μm in diameter on a single particle basis



Thinly coated BC
Scattering signal
Incandescence signal
Sginal(*2.44mV)
Elapsed time(*0.2us)
Characteristic of thin coating
Thickly coated BC
scattering signal
incandescence signal
signal(*2.44mV)
Elapsed time(*0.2us)
Characteristic of thick coating

Pumped Counterflow Virtual Impactor



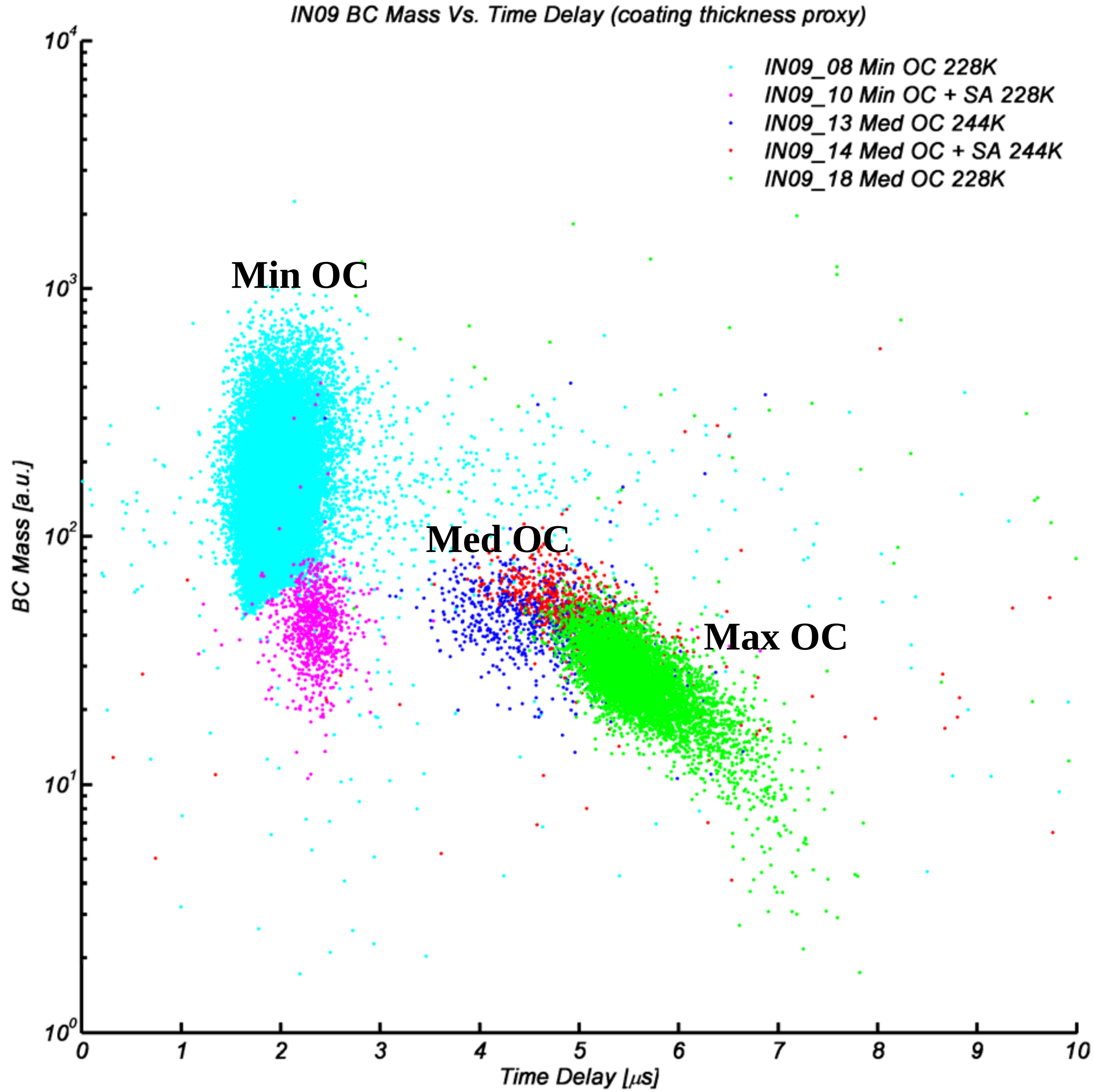
1) Small aerosol follows the exhaust flow stream lines - Not Sampled
2) Larger aerosol are knocked off a sampling trajectory by the counterflow and are impacted - Not Sampled
3) Small hydrometeors and large aerosol do not have sufficient inertia to pass stagnation region - Not Sampled
4) Sufficently large hydrometeors pass stagnation region and evaporate - Sampled

Experiments

1. Influence of Soot Organic Carbon Content on Ice Nucleation Efficiency
   228K, Pumping Speed Varied

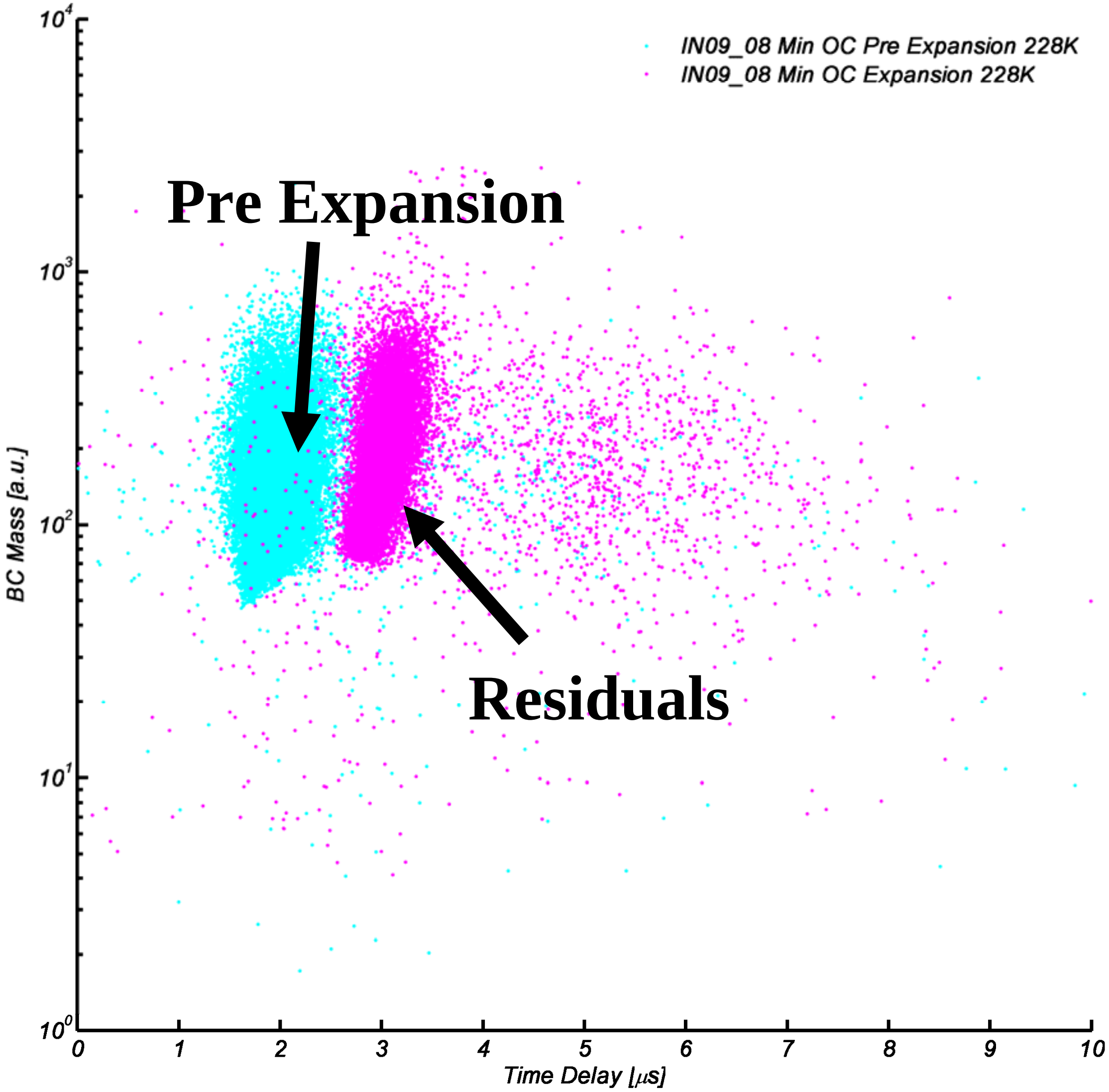
2. Influence of Externally Mixing Sulphuric Acid with Soot on Ice Nucleation Efficiency
   228K & 244K

Pre expansion Coating thickness and OC



- Delay between scattering and incandescing signals gives a proxy for the coating thickness of the soot.
- Minimum OC soot has thinnest coating.
- Coating thickness increases with OC.

- Expect Min OC to be of a *fractal* morphology.
- Med and Max OC are likely to be non-fractal *blobs*.



- Significant difference in coating thickness proxy between pre expansion and residual soot.

- Either the soot is gaining coating during nucleation – unlikely

OR

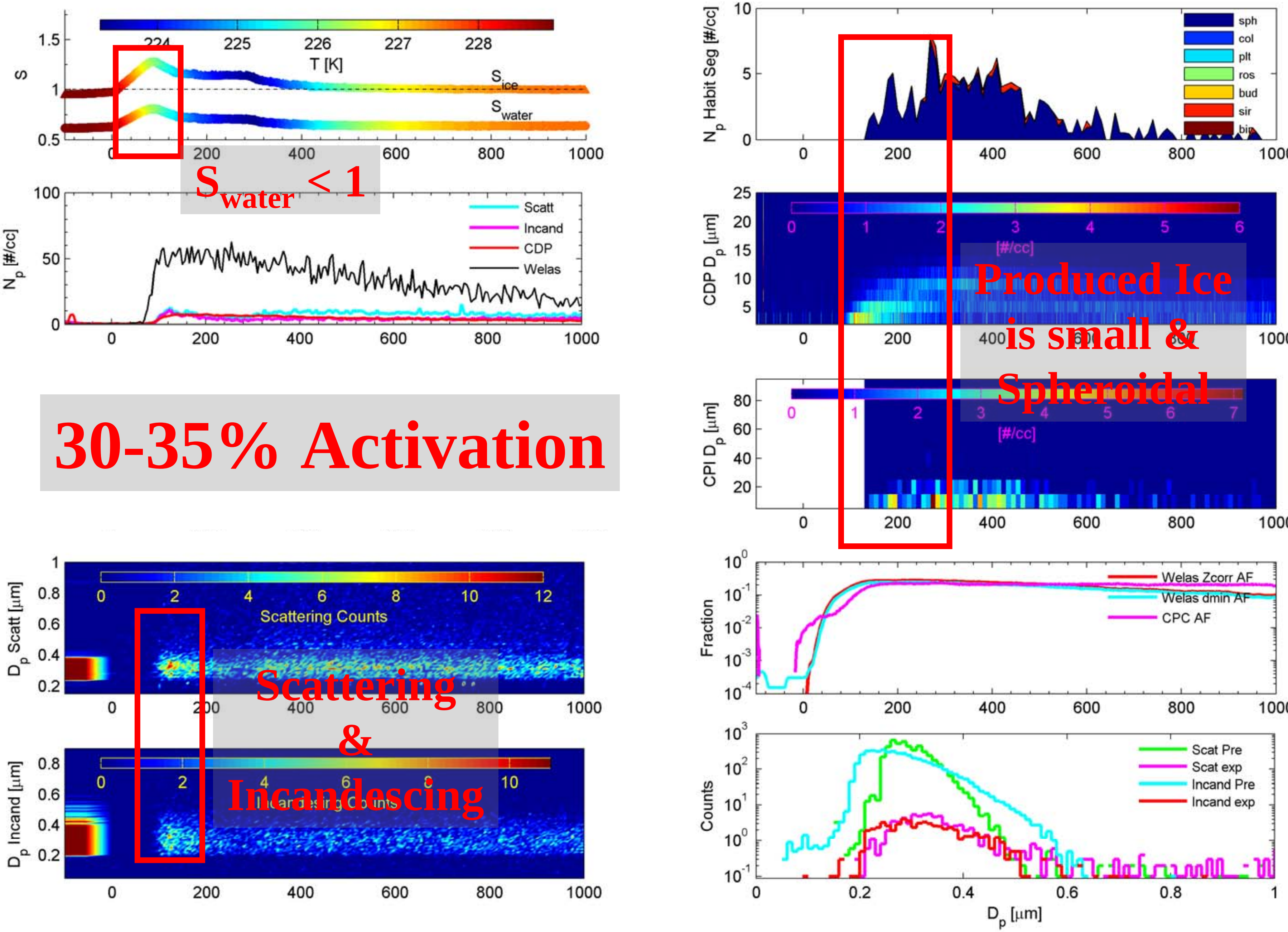
Volatiles are condensing on the soot - possible

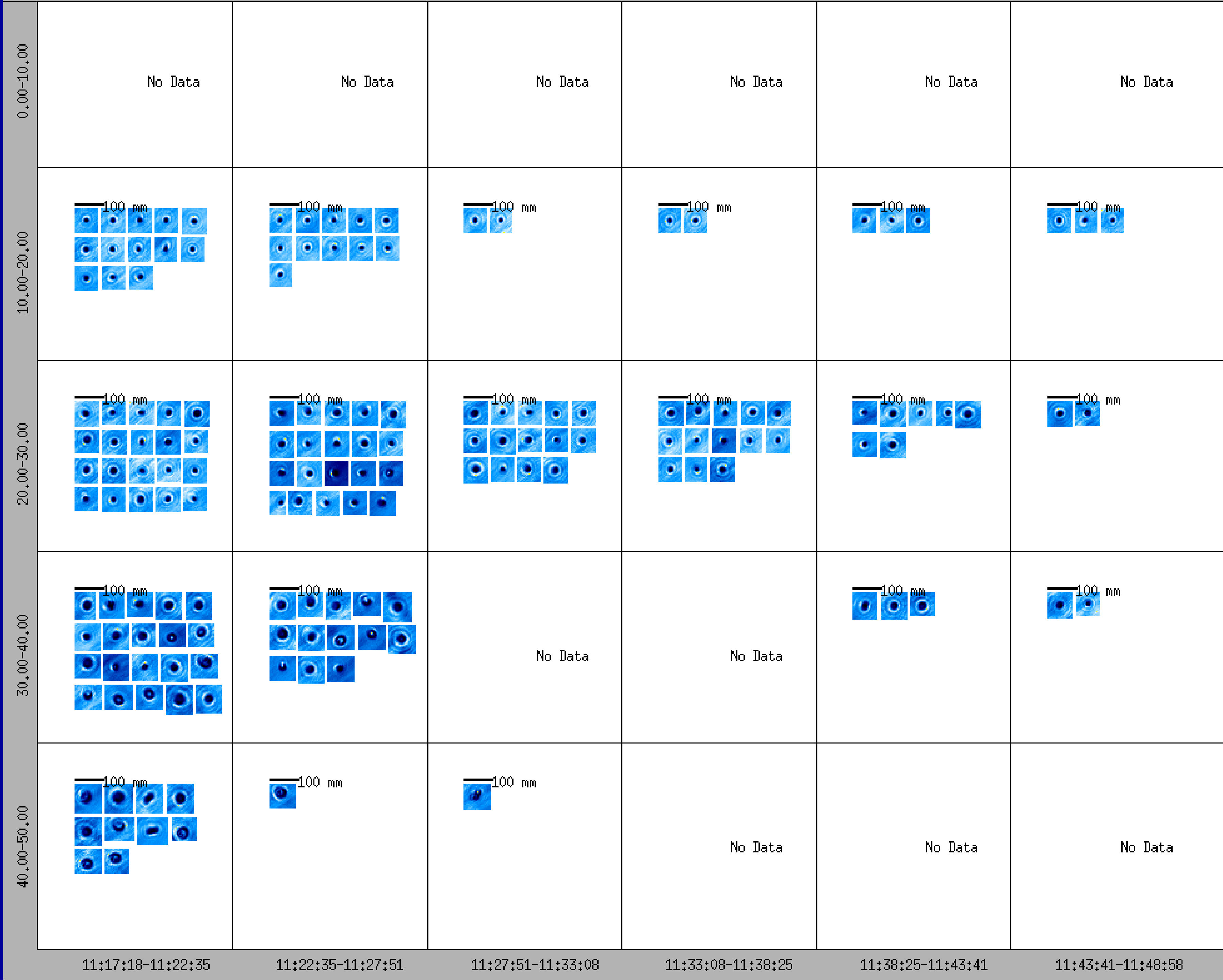
OR

Change in morphology is occurring (fractal to blob) which is changing the incandescing time - probable

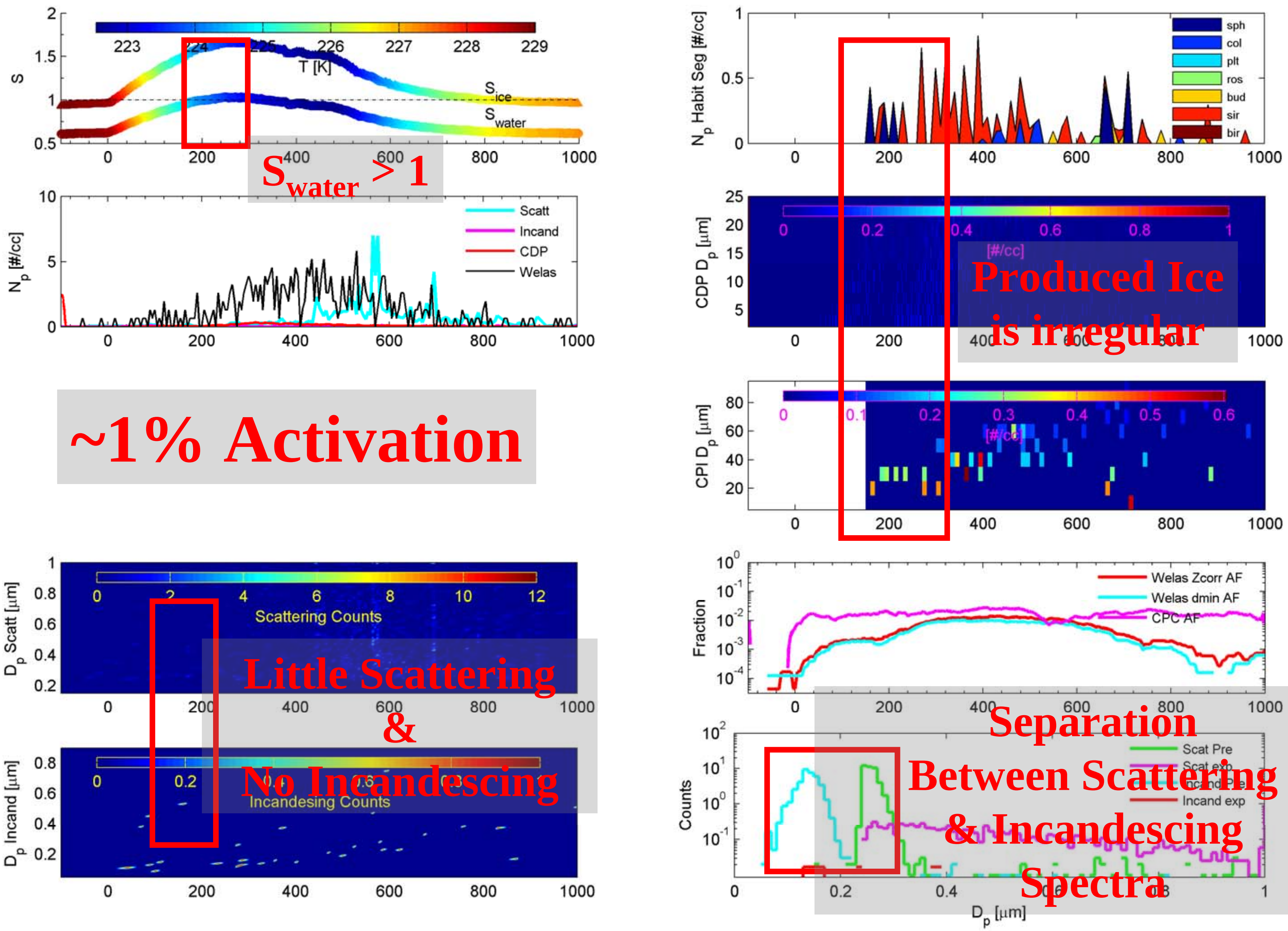
Influence of coating thickness 228K

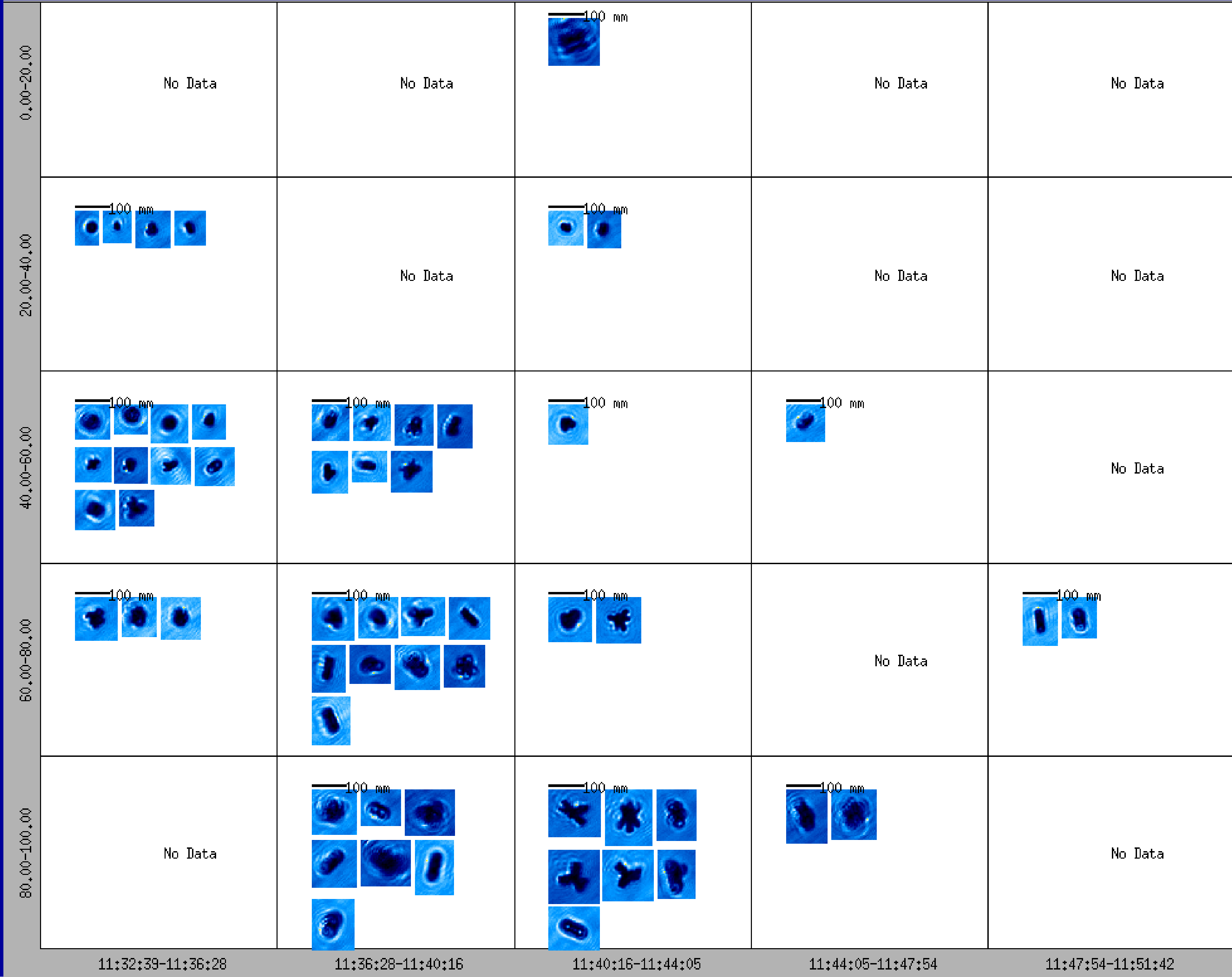
IN09 08 Min OC T~228K

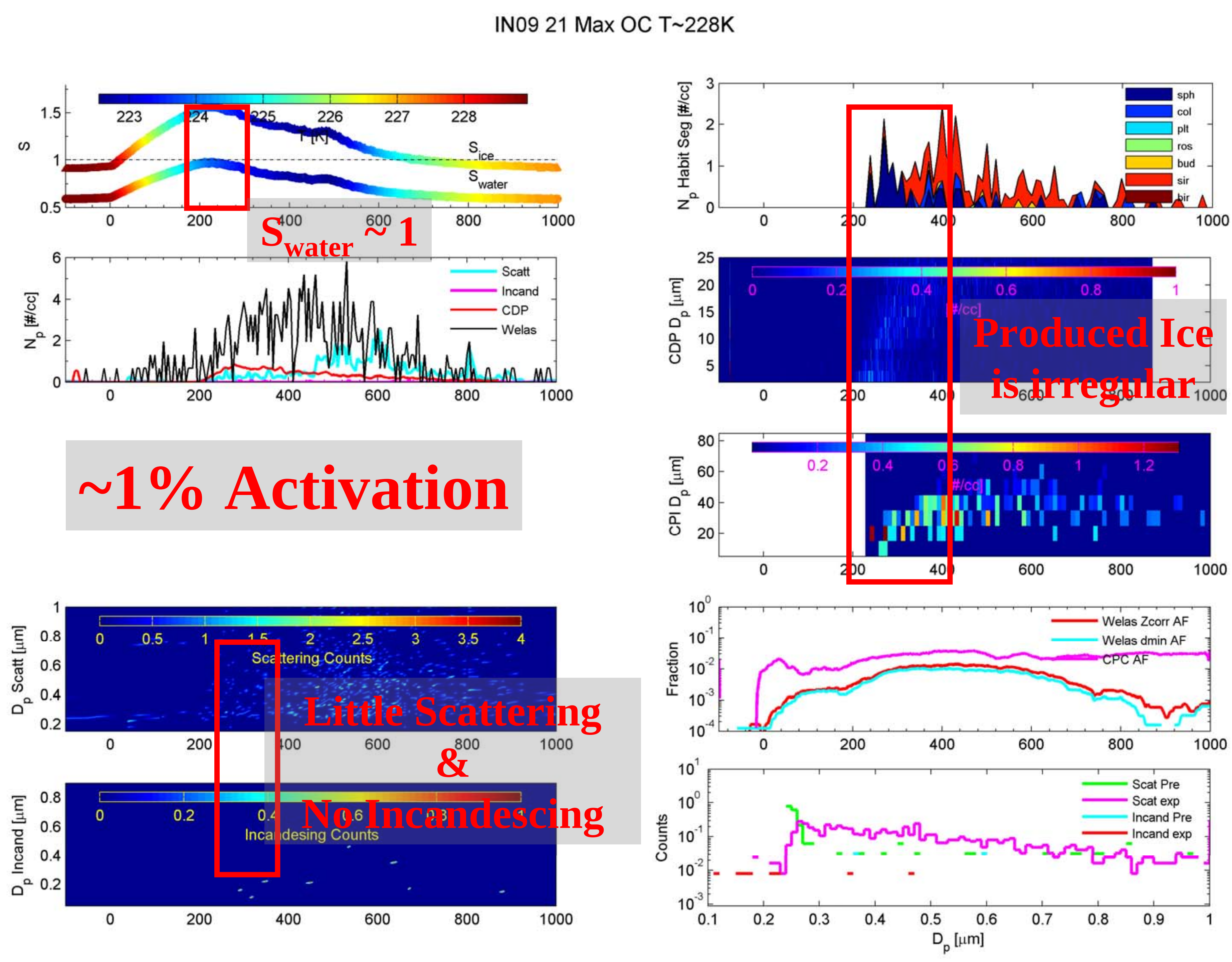


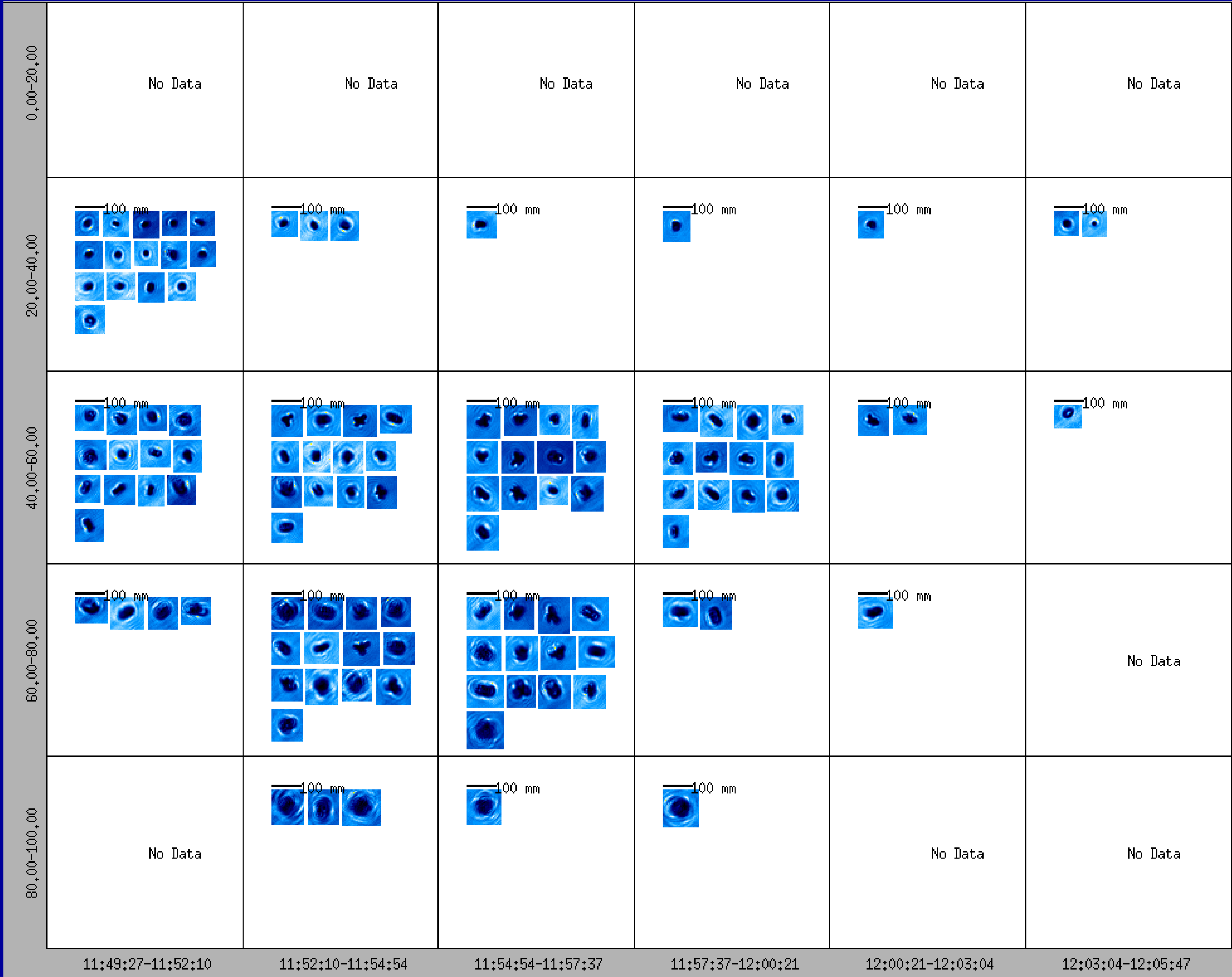

0.00-10.00
No Data
No Data
No Data
No Data
No Data
No Data
10.00-20.00
100 mm
100 mm
100 mm
100 mm
100 mm
100 mm
20.00-30.00
100 mm
100 mm
100 mm
100 mm
100 mm
100 mm
30.00-40.00
100 mm
100 mm
No Data
No Data
100 mm
100 mm
40.00-50.00
100 mm
100 mm
100 mm
No Data
No Data
No Data
11:17:18-11:22:35
11:22:35-11:27:51
11:27:51-11:33:08
11:33:08-11:38:25
11:38:25-11:43:41
11:43:41-11:48:58

IN09 18 Med OC T~228K

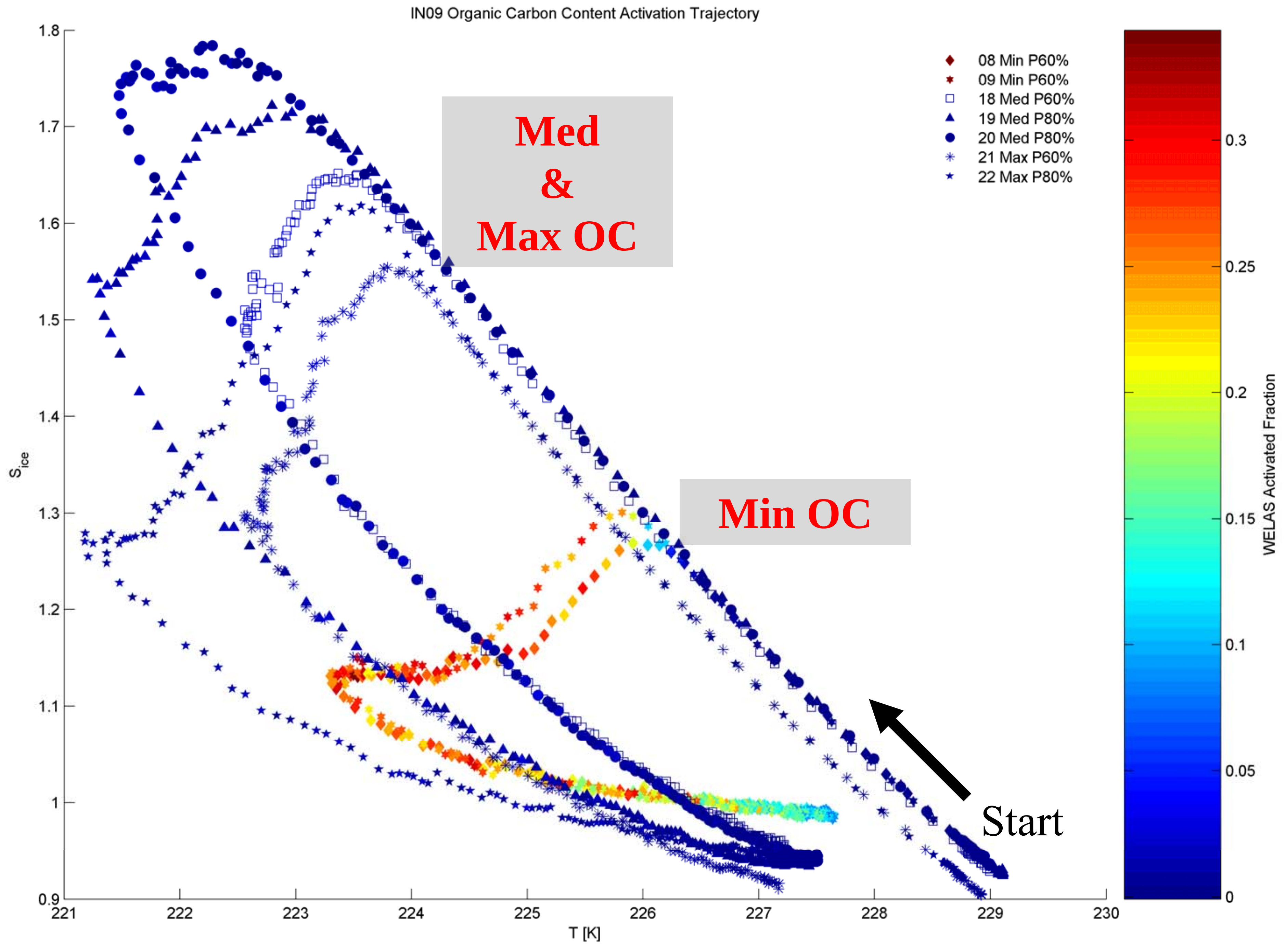



0.00-20.00
20.00-40.00
40.00-60.00
60.00-80.00
80.00-100.00
100 mm
No Data
11:32:39-11:36:28
11:36:28-11:40:16
11:40:16-11:44:05
11:44:05-11:47:54
11:47:54-11:51:42


IN09 21 Max OC T~228K
S
T [K]
223
224
225
226
227
228
S_{ice}
S_{water}
S_{water} ~ 1
N_p [#/cc]
Scatt
Incand
CDP
Welas
~1% Activation
D_p Scatt [µm]
Scattering Counts
Little Scattering
&
No Incandescing
D_p Incand [µm]
Incandesing Counts
N_p Habit Seg [#/cc]
sph
col
plt
ros
bud
sir
bir
CDP D_p [µm]
[#/cc]
Produced Ice
is irregular
CPI D_p [µm]
#/cc]
Fraction
Welas Zcorr AF
Welas dmin AF
CPC AF
Counts
Scat Pre
Scat exp
Incand Pre
Incand exp
D_p [µm]



0.00-20.00
20.00-40.00
40.00-60.00
60.00-80.00
80.00-100.00
No Data
100 mm
11:49:27-11:52:10
11:52:10-11:54:54
11:54:54-11:57:37
11:57:37-12:00:21
12:00:21-12:03:04
12:03:04-12:05:47


IN09 Organic Carbon Content Activation Trajectory
Med
&
Max OC
Min OC
Start
08 Min P60%
09 Min P60%
18 Med P60%
19 Med P80%
20 Med P80%
21 Max P60%
22 Max P80%
S_ice
T [K]
WELAS Activated Fraction
1.8
1.7
1.6
1.5
1.4
1.3
1.2
1.1
1
0.9
221
222
223
224
225
226
227
228
229
230
0.3
0.25
0.2
0.15
0.1
0.05
0

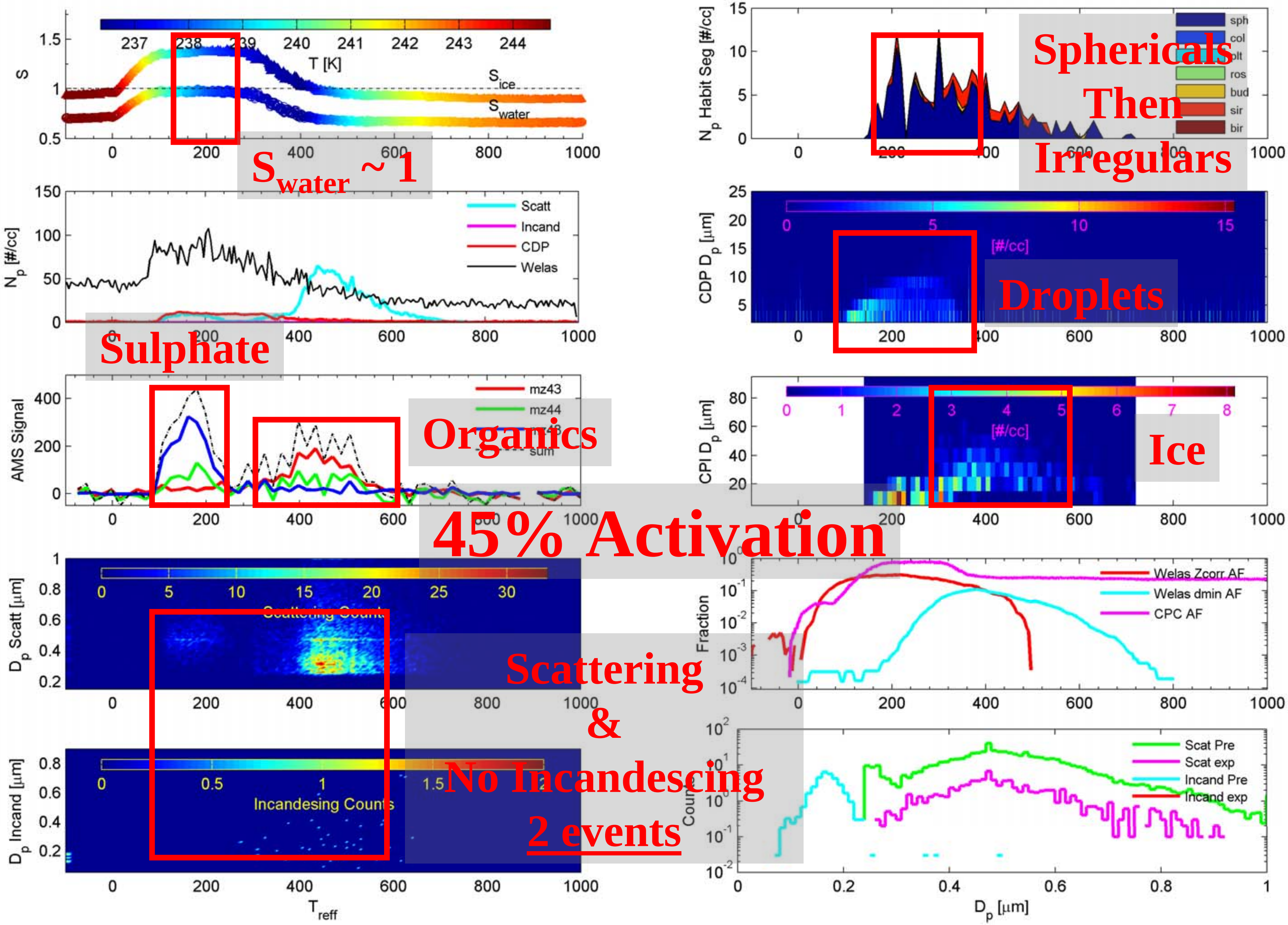
Expansion	Type	Pumping	Temperature	S_{ice} Peak	Temperature Peak	Activated Fraction
IN09_08	Min OC	60%	228K	1.30	226K	0.30-0.35
IN09_09	Min OC	60%	228K	1.30	226K	0.30-0.36
IN09_18	Med OC	60%	228K	1.60	223.5K	0.02-0.03
IN09_19	Med OC	80%	228K	1.80	222.5K	0.02-0.03
IN09_20	Med OC	80%	228K	1.80	222.5K	0.02-0.03
IN09_21	Max OC	60%	228K	1.55	224K	0.01
IN09_22	Max OC	80%	228K	1.62	223.5K	0.02-0.03

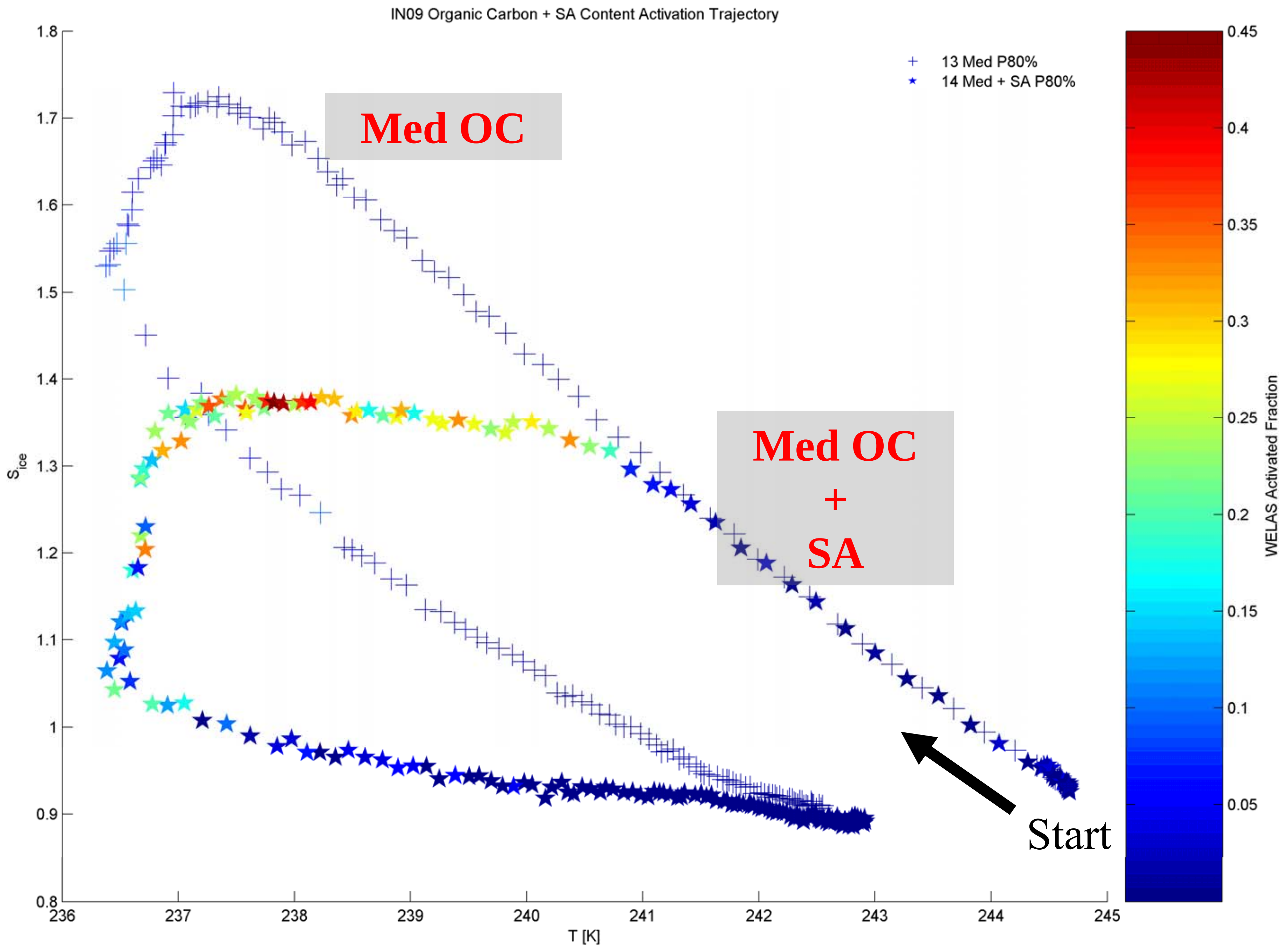
Min OC IN active – 30/35% AF, S_{ice} 1.30, 226K

Med & Min OC NOT IN active – few% AF, S_{ice} 1.80, 224K

Influence of mixing with Sulphuric Acid

IN09 14 Med OC+SA P80%





IN09 Organic Carbon + SA Content Activation Trajectory
13 Med P80%
14 Med + SA P80%
Med OC
Med OC
+
SA
Start
S_ice
T [K]
WELAS Activated Fraction
1.8
1.7
1.6
1.5
1.4
1.3
1.2
1.1
1
0.9
0.8
236
237
238
239
240
241
242
243
244
245
0.45
0.4
0.35
0.3
0.25
0.2
0.15
0.1
0.05

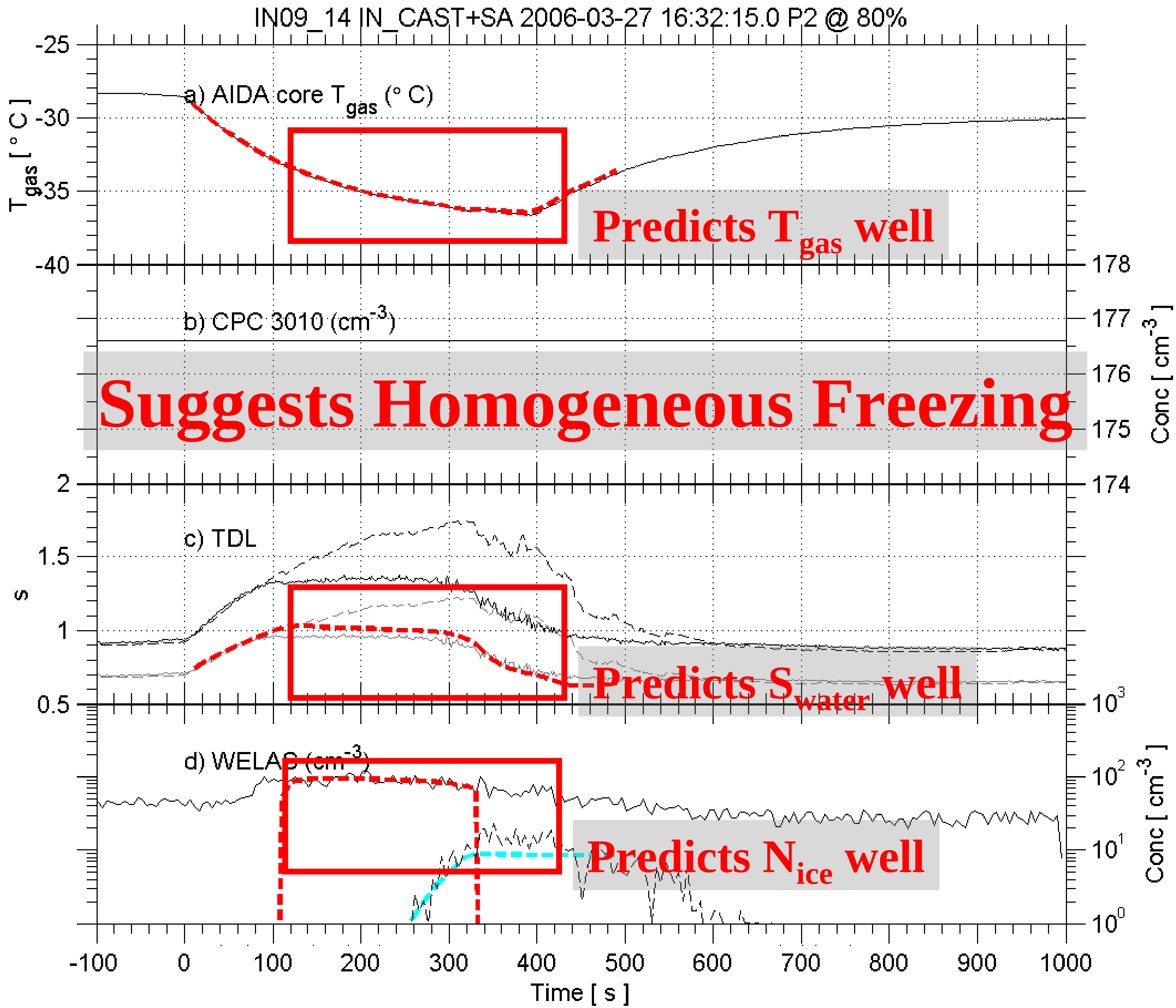
This ice could have come about by two obvious mechanisms:

1. *The supercooled sulphuric acid droplets have homogeneously frozen. Soot had no part to play in the onset of freezing.*

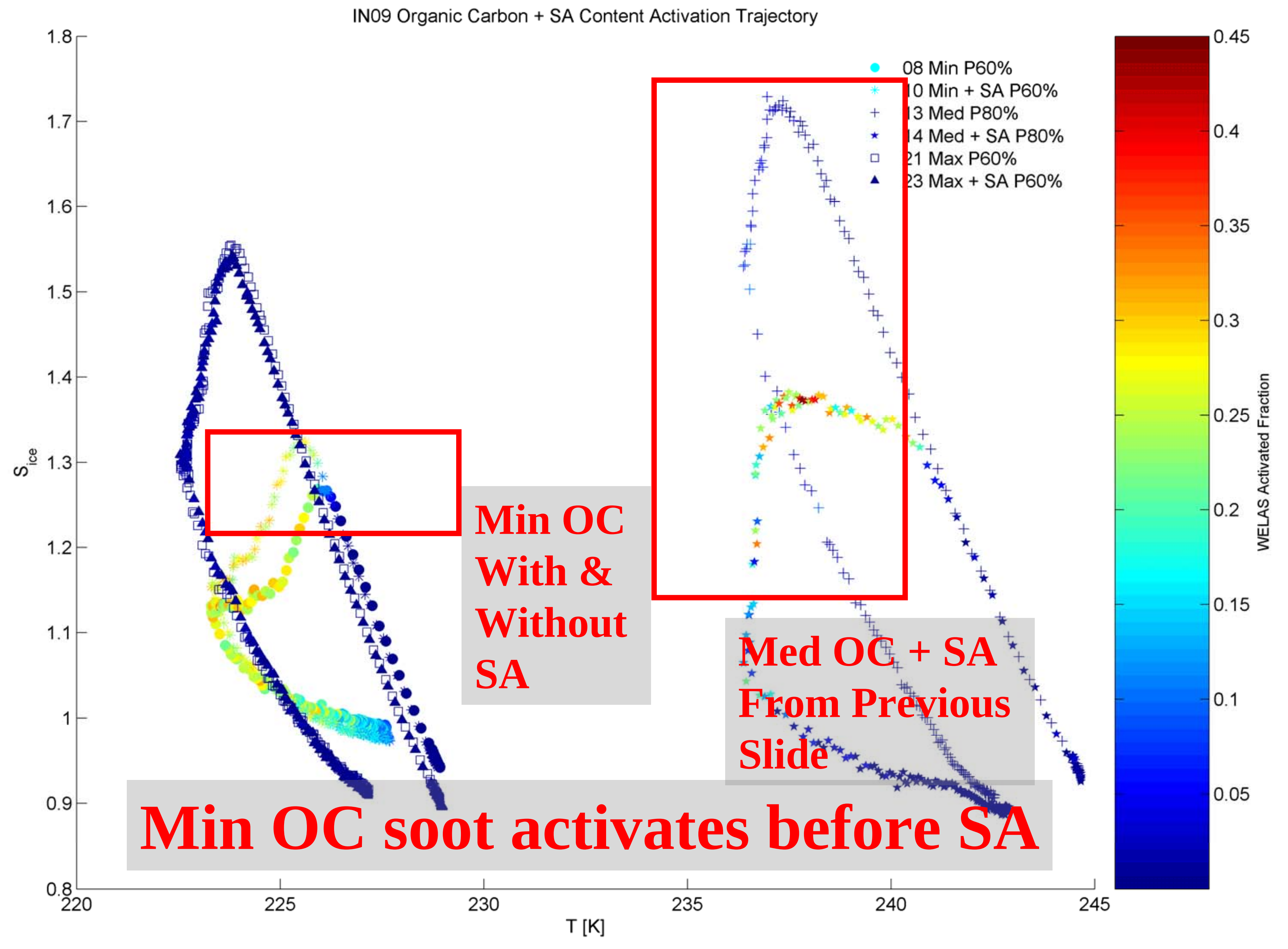
If this is true then it should be possible to model the observed freezing using the Koop parameterisation [*Koop, et al.*, 2000].

2. *Immersion and/or contact freezing mechanisms can occur under these conditions. Both soot and sulphuric acid are necessary.*

DeMott has shown the flame soot from an acetylene burner to be an efficient immersion freezing nuclei once water had condensed upon it and that soot may catalyse heterogeneous freezing



IN09_14 IN_CAST+SA 2006-03-27 16:32:15.0 P2 @ 80%
a) AIDA core T gas (° C)
T gas [° C]
Predicts T gas well
b) CPC 3010 (cm-3)
Conc [cm-3]
Suggests Homogeneous Freezing
c) TDL
s
Predicts S water well
d) WELAS (cm-3)
Predicts N ice well
Conc [cm-3]
Time [s]



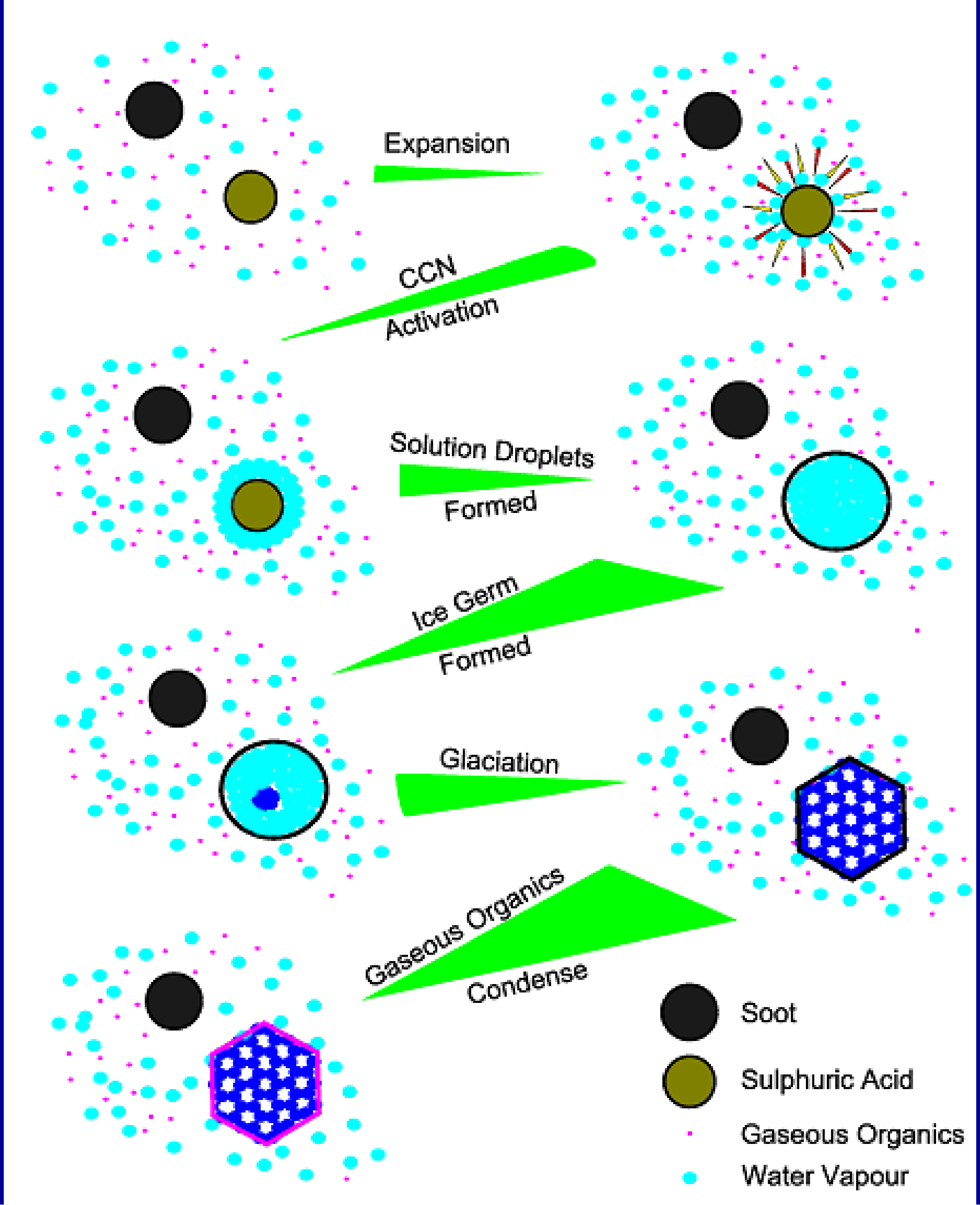
IN09 Organic Carbon + SA Content Activation Trajectory
08 Min P60%
0 Min + SA P60%
3 Med P80%
4 Med + SA P80%
21 Max P60%
23 Max + SA P60%
WELAS Activated Fraction
S ice
T [K]
1.8
1.7
1.6
1.5
1.4
1.3
1.2
1.1
1
0.9
0.8
220
225
230
235
240
245
0.45
0.4
0.35
0.3
0.25
0.2
0.15
0.1
0.05
Min OC With & Without SA
Med OC + SA From Previous Slide
Min OC soot activates before SA

Conclusions

Only the minimum organic carbon content soot is significantly active as ice nuclei under untreated conditions and may be a significant source of IN.

Both the medium and maximum organic carbon content flame soot did not activate notably and can be considered to be poor ice nuclei.

Upon being externally mixed with sulphuric acid the minimum organic carbon content soot exhibited no change in activation properties, indicating that heterogeneous ice formation on soot of this type is preferable to the homogeneous freezing pathway.


Expansion
CCN Activation
Solution Droplets Formed
Ice Germ Formed
Glaciation
Gaseous Organics Condense
Soot
Sulphuric Acid
Gaseous Organics
Water Vapour