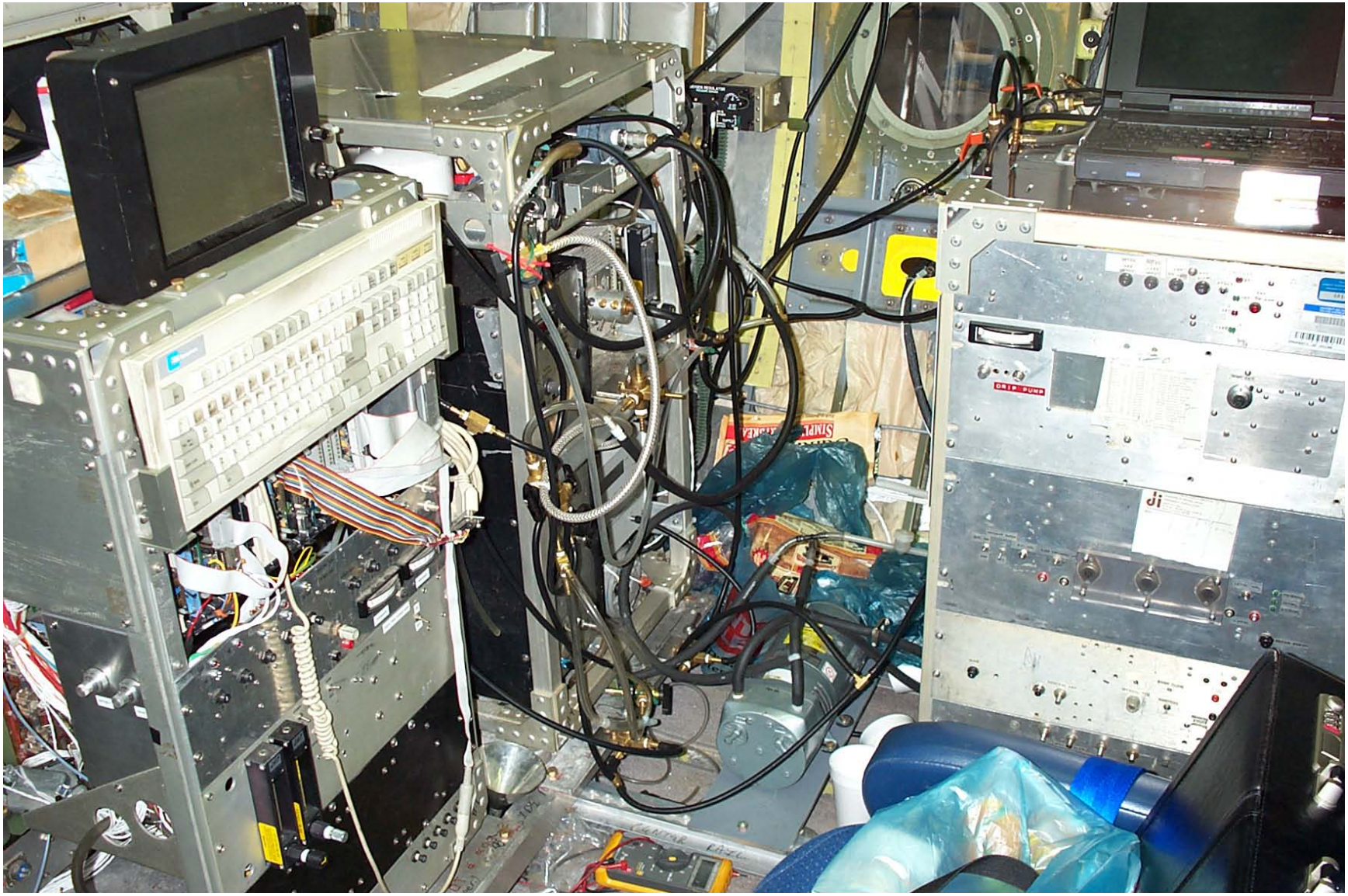


DRI Cloud condensation nuclei (CCN) spectrometers.

Produce a field of supersaturations (S) by thermal diffusion of temperature and water vapor between two parallel plates, where cloud droplets grow on hygroscopic sample particles.
More hygroscopic (e.g., larger) particles produce larger cloud droplets.
Continuous flow through the cloud chamber (~30s) then into an optical particle counter (OPC). CCN spectrum is deduced from the OPC droplet spectrum. A calibration curve relates OPC droplet size to particle hygroscopicity (critical supersaturation—S_c).

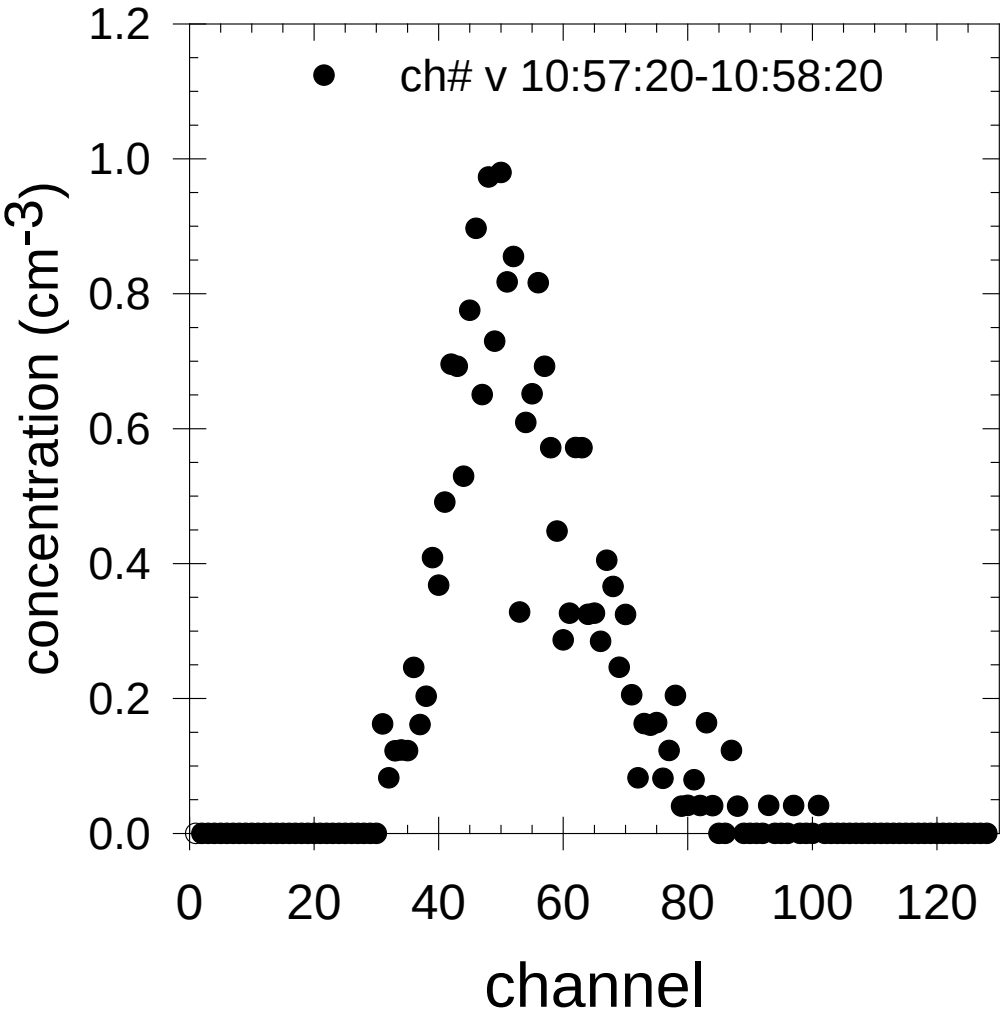
Calibration is done with nuclei of known composition (e.g., NaCl) and size (differential mobility analyzer—DMA—electrostatic classifier--EC).

Assumes that all CCN with the same S_c regardless of composition (or size) produce the same droplet sizes. Calibration holds only if all chamber parameters (i.e., flows and temperatures) remain constant.

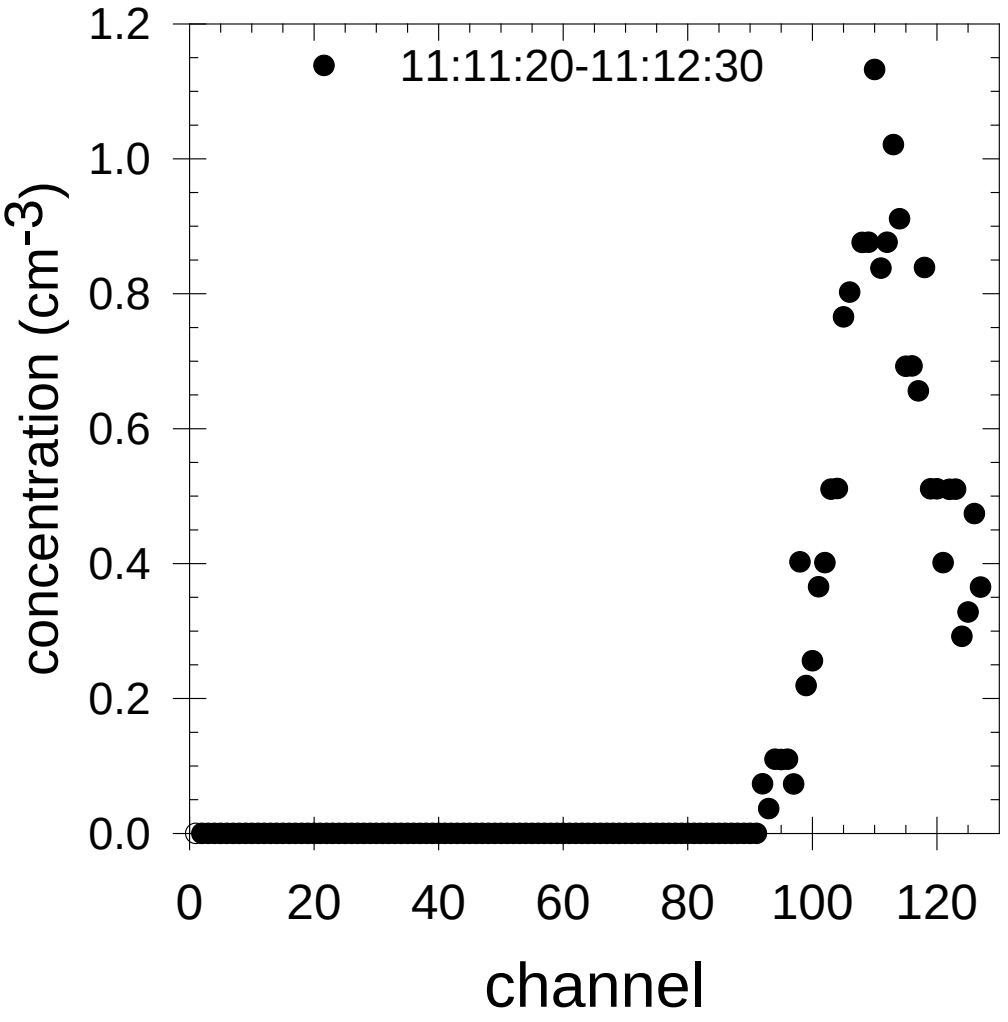
S_c inversely proportional to number of soluble ions.
Traditionally CCN plots are cumulative because clouds act cumulatively on the aerosol— all nuclei with S_c < cloud S produce “activated” cloud droplets.

Also previous CCN instruments had too few data points to produce a differential spectrum.
DRI CCN spectrometers have enough data points to produce differential spectra.

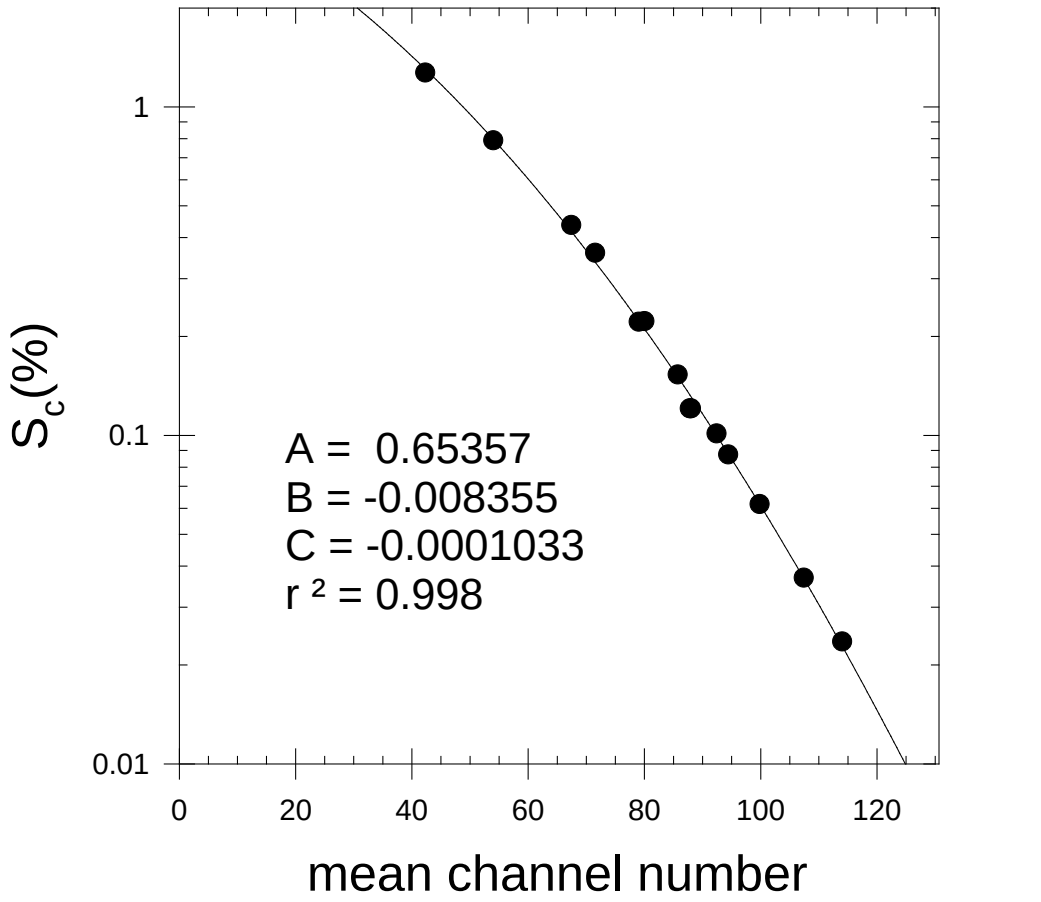
July 25, MASE
NaCl calibration
27 nm ch-53 0.79%



July 25, MASE
NaCl calibration
280 nm ch-114 0.02%



July 25, 2005, 1051-1231
MASE, Sacramento, 6 holes open old sf meter
new spec. OPC 50106
LV = 6.66
HV = 450, gain 8.0, offset 0.2
sf = 1.58-1.59v
DT = 0,1.5,3,5.5,7,8
TM = 25C
EC 10 lpm NaCl calibration curve



Extension the traditional CCN (Aitken) range below 0.1% to Large Nuclei, is necessary because a large proportion of CCN have S < 0.1%. This is needed because:

- Many clouds have S< 0.1%
- Static closure—aerosol and CCN
- Dynamic closure—CCN and cloud droplets.
- Large nuclei are embryos for precipitation.
- Droplet spectral width.
- Interface with giant nuclei.
- CCN sizes.

Why two spectrometers

1. Redundancy

2. different S ranges in each instrument with different optimal S validity; check in overlapping range.

3. In flight calibrations

4. Volatility

5. Size versus S_c

Spectrometry is foiled by instrumental broadening, coincidence and vapor depletion.

Broadening is more of a problem for steep spectra.

Coincidence is more of a problem for higher concentrations.

Vapor depletion—high concentrations.

S range 1-0.02% (i.e., 101-100.02% RH) cloud S range.

Higher S_c for smaller (less hygroscopic) particles.

Fundamental limitations of CCN spectral range.

1. **Instrumental broadening**—same S_c particles not producing identical signals.

   Crossover between channels is more of a problem with steeper spectra.

   Improvements have reduced this problem.

2. **Coincidence**—two droplets simultaneously within detection volume artificially convert two small (high S_c) droplets to one large (low S_c) signal.

   Causes overestimates of low S_c particles.

   Higher concentrations exacerbate coincidence.

   Lower sample flow rates reduce coincidence.

3. Vapor Depletion

high concentrations—competition for water vapor reduces droplet sizes

lower sample flow, but may cause diffusion losses

Not a problem in clean air.

Spectra more challenging for lower part of S range.

Lower S_c (larger particle) concentrations are generally lower.

Thus broadening and coincidence of high concentrations of high S_c particles can obscure measurements of low S_c particle concentrations.

Low S_c measurements by an instrument operating only at low S (not measuring the high S_c particles) should be more accurate; they are not obscured by higher S_c particles.

Therefore, comparisons of low S_c measurements by instruments operating over different S ranges can confirm operation at high S.

Agreement suggests validity of the challenging low S_c measurements by the instrument operating at high S.

If lower S part of range is accurate then higher S part of range is also probably accurate.

1. Ambient sampling—1s continuous

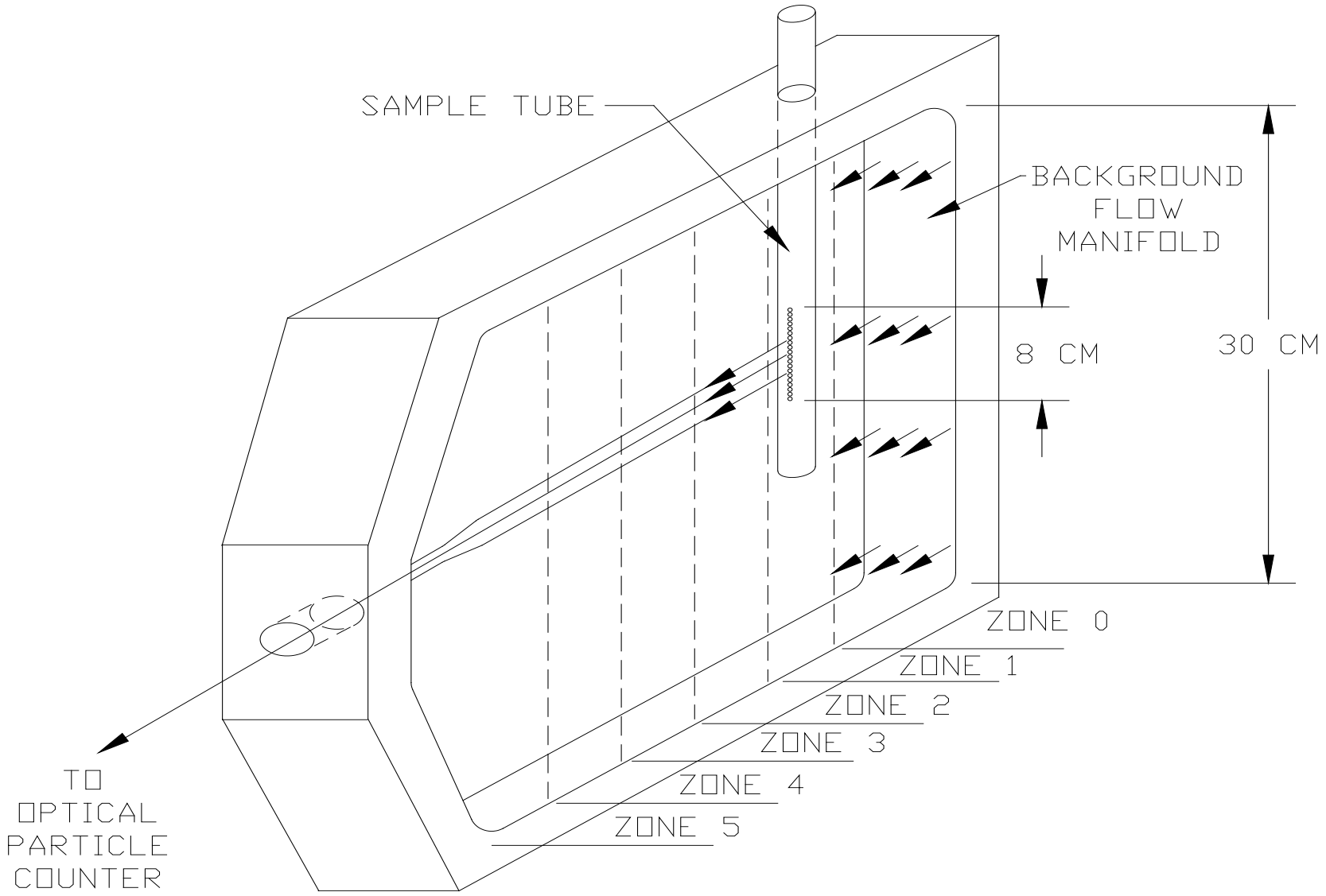
2. Different or similar S ranges?
   Different—better test, greater S range—0.01-2%S
   Similar—redundancy and processing

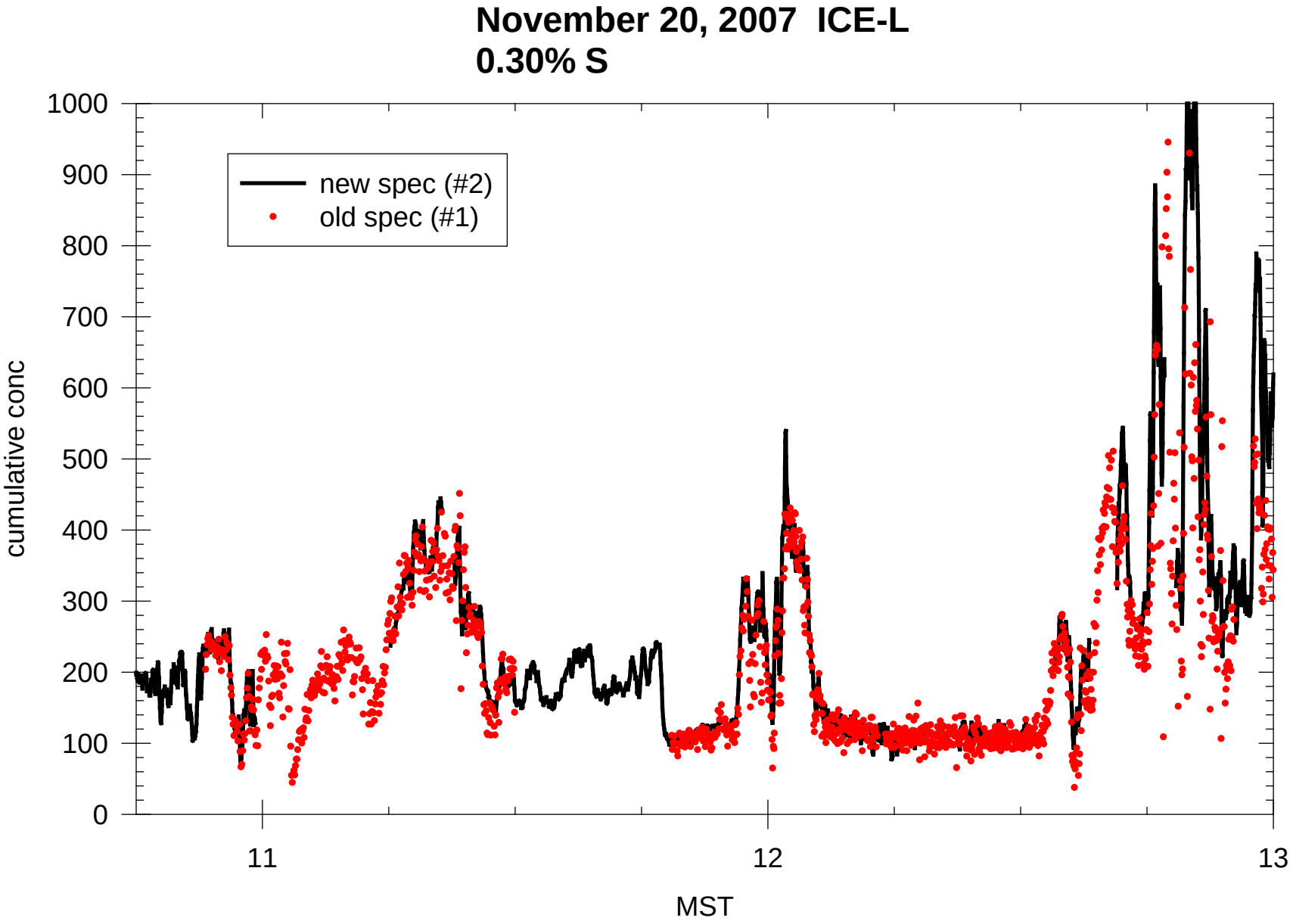
3. Volatility—one remains on ambient other switches back and forth every minute or so to normalize changes. Greater editing job—remove transitions and separate ambient from processed. Change temps from 20C to 1000C takes ~30 min.

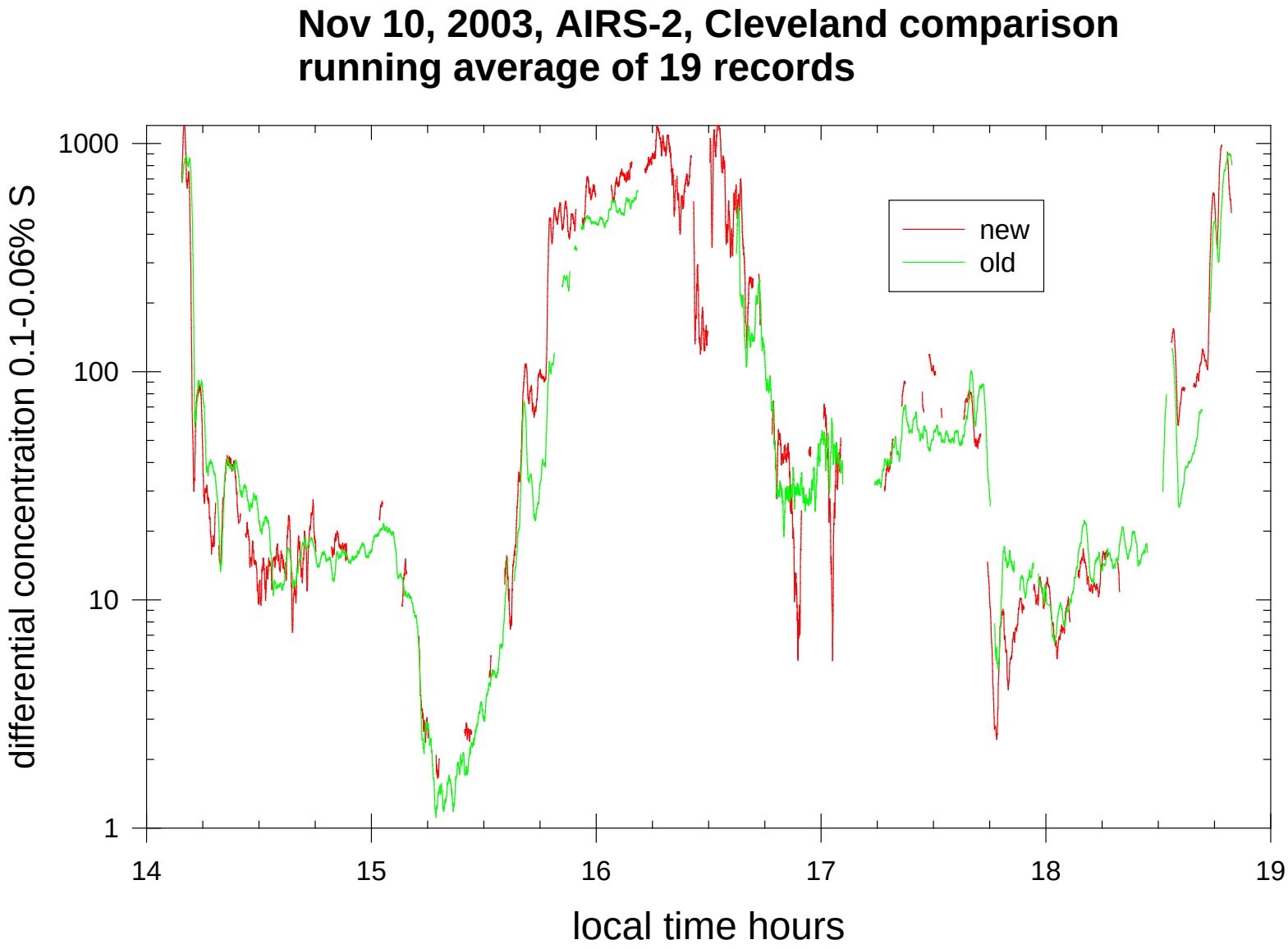
4. Size-S_c –difficult in clean air—constant alt., won't work at high altitude—one continues to monitor ambient, at least one minute per size, one minute transition so at least 10 minutes for 5 sizes. Also calibrations another 10 min.

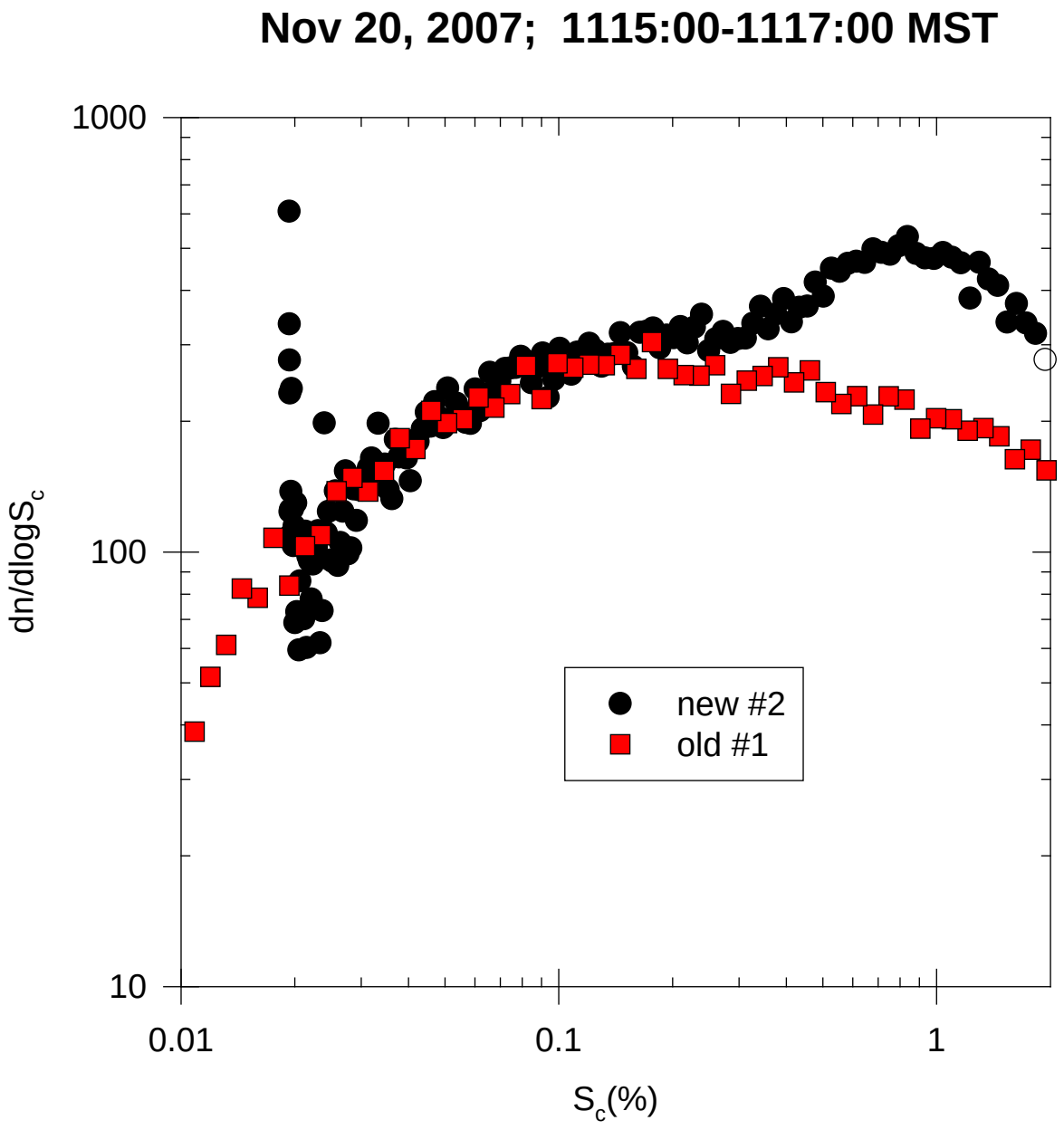
5. Size- S_c squared—test Kohler theory—no ambient

6. Volatility and size-S_c together? Very slow and difficult.

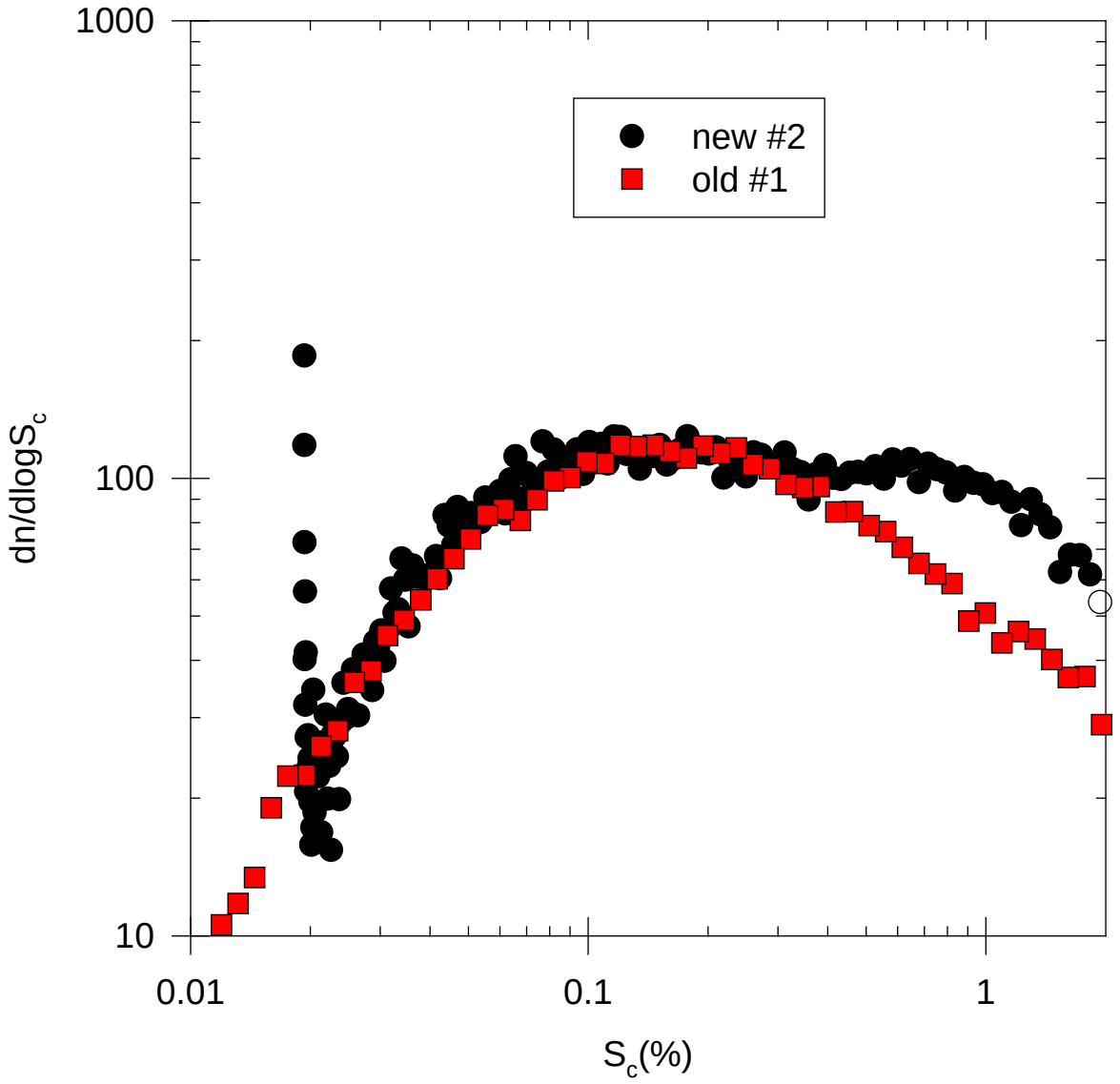

SAMPLE TUBE
BACKGROUND
FLOW
MANIFOLD
8 CM
30 CM
ZONE 0
ZONE 1
ZONE 2
ZONE 3
ZONE 4
ZONE 5
TO
OPTICAL
PARTICLE
COUNTER


November 20, 2007 ICE-L
0.30% S
new spec (#2)
old spec (#1)
cumulative conc
1000
900
800
700
600
500
400
300
200
100
0
11
12
13
MST

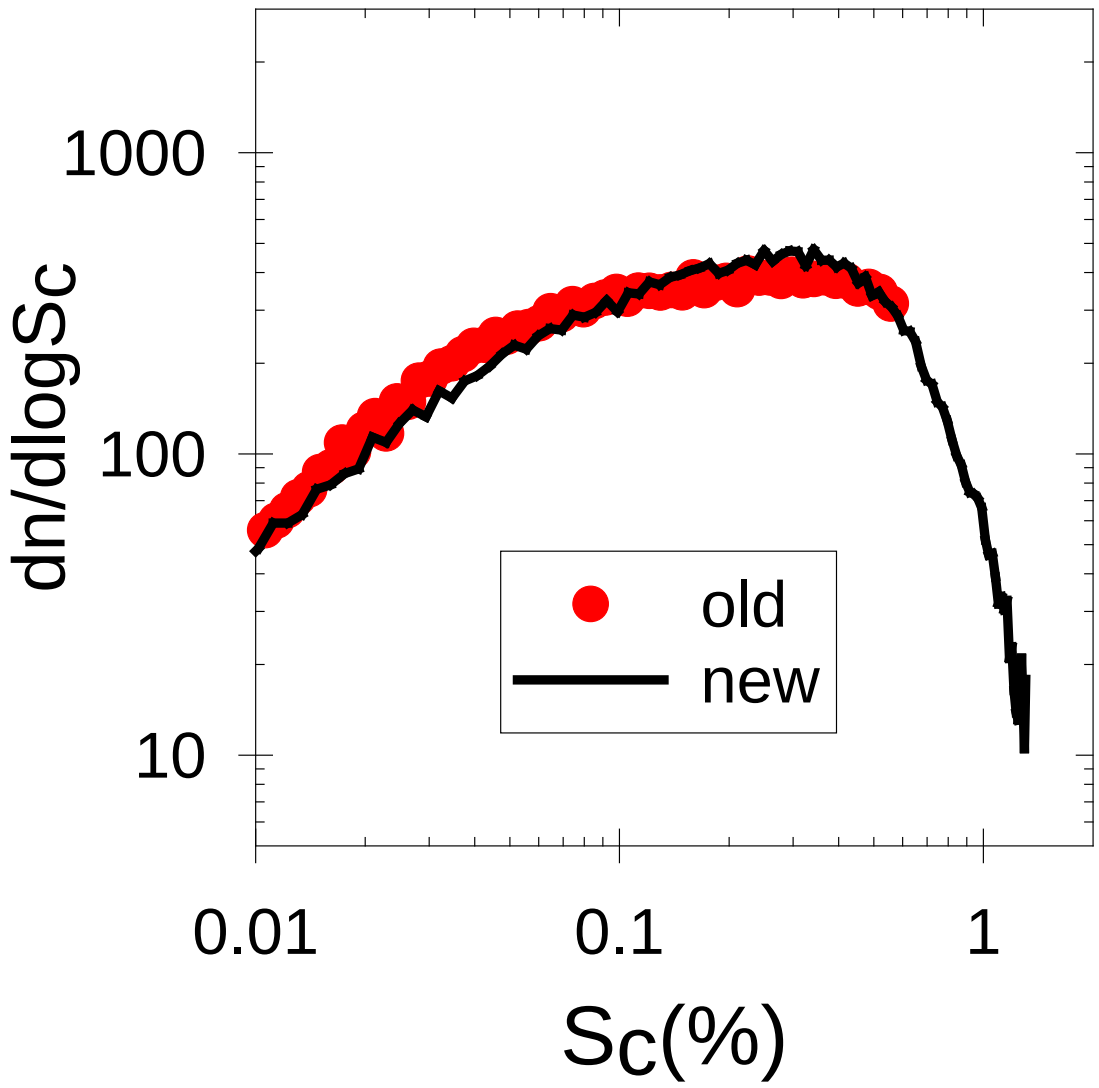

Nov 10, 2003, AIRS-2, Cleveland comparison
running average of 19 records
differential concentraiton 0.1-0.06% S
1000
100
10
1
14
15
16
17
18
19
local time hours
new
old


Nov 20, 2007; 1115:00-1117:00 MST
1000
100
10
dn/dlogS$_c$
0.01
0.1
1
S$_c$(%)
new #2
old #1

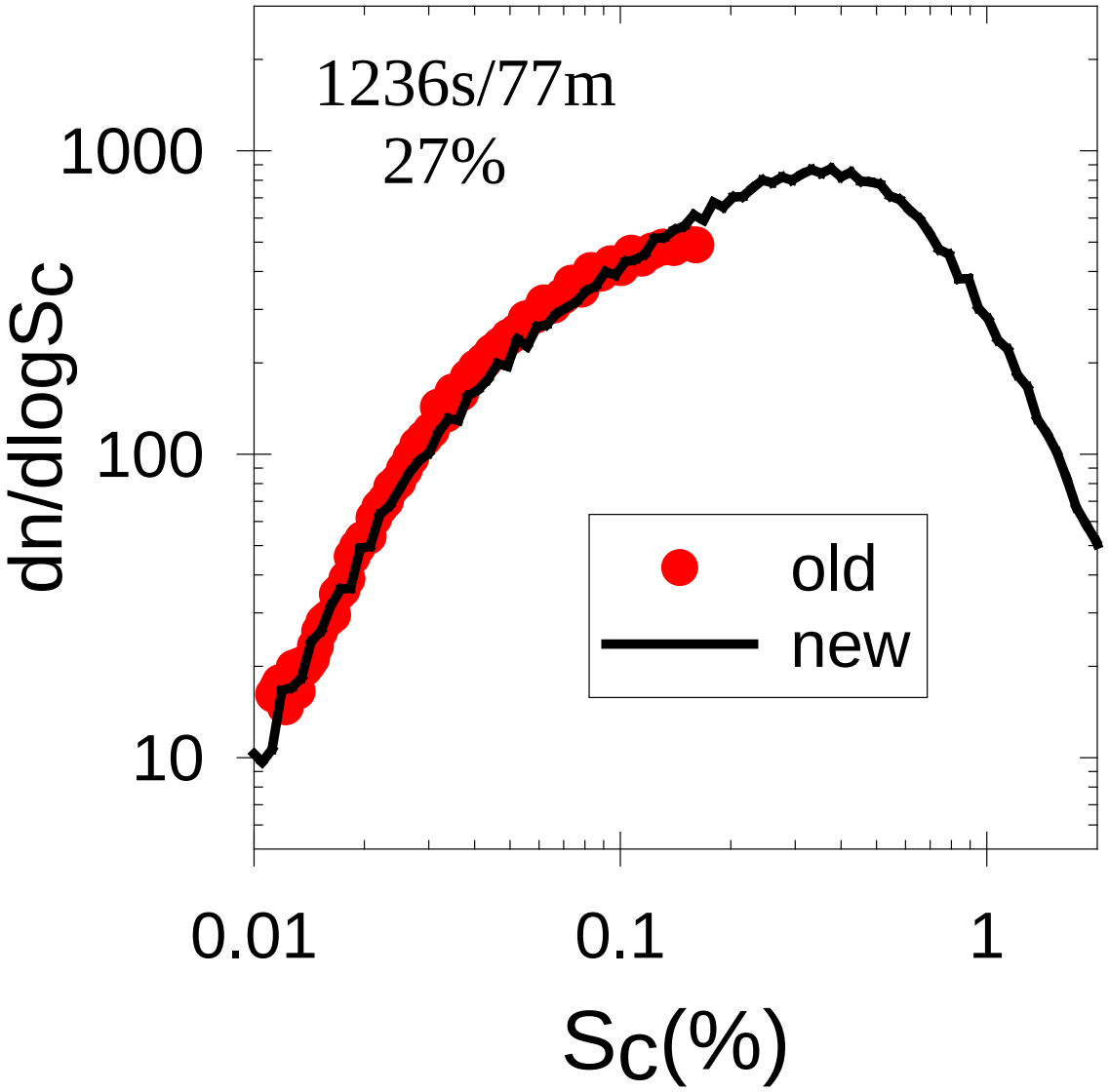
Nov 20, 2007; 1215:00-1230:00 MST



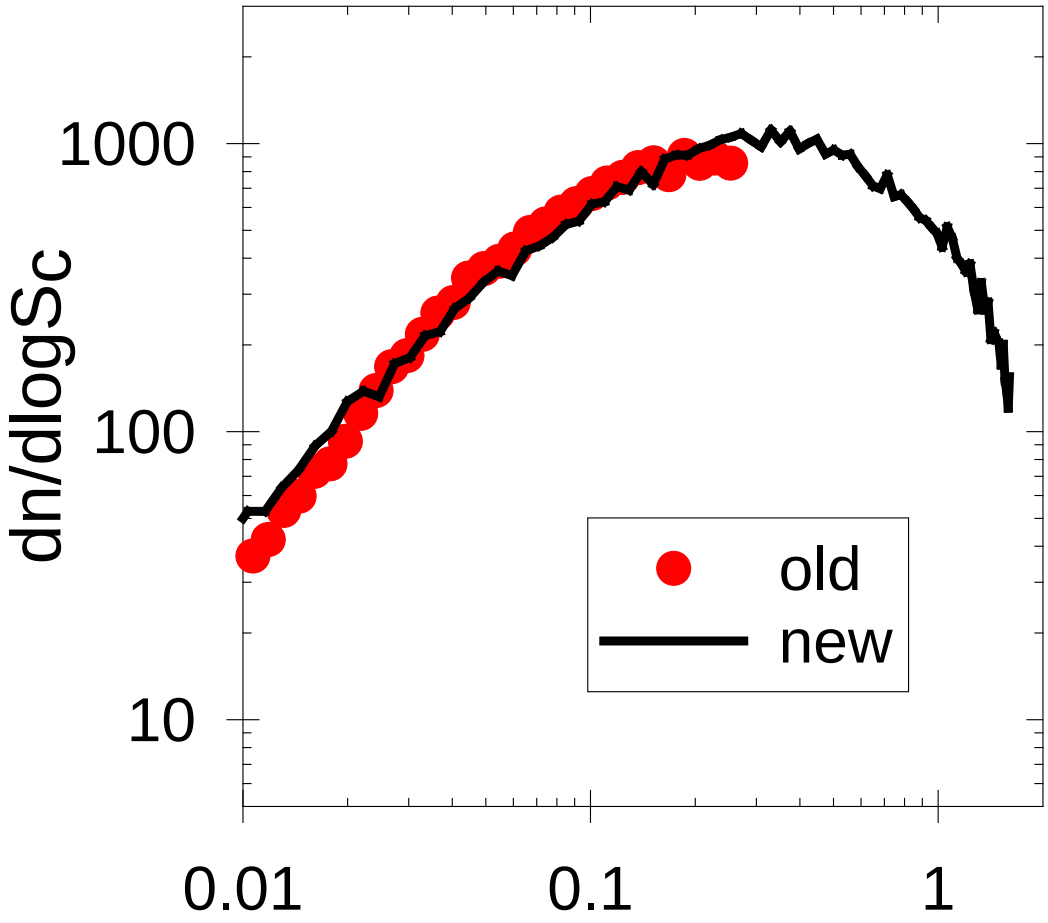
July 22 below

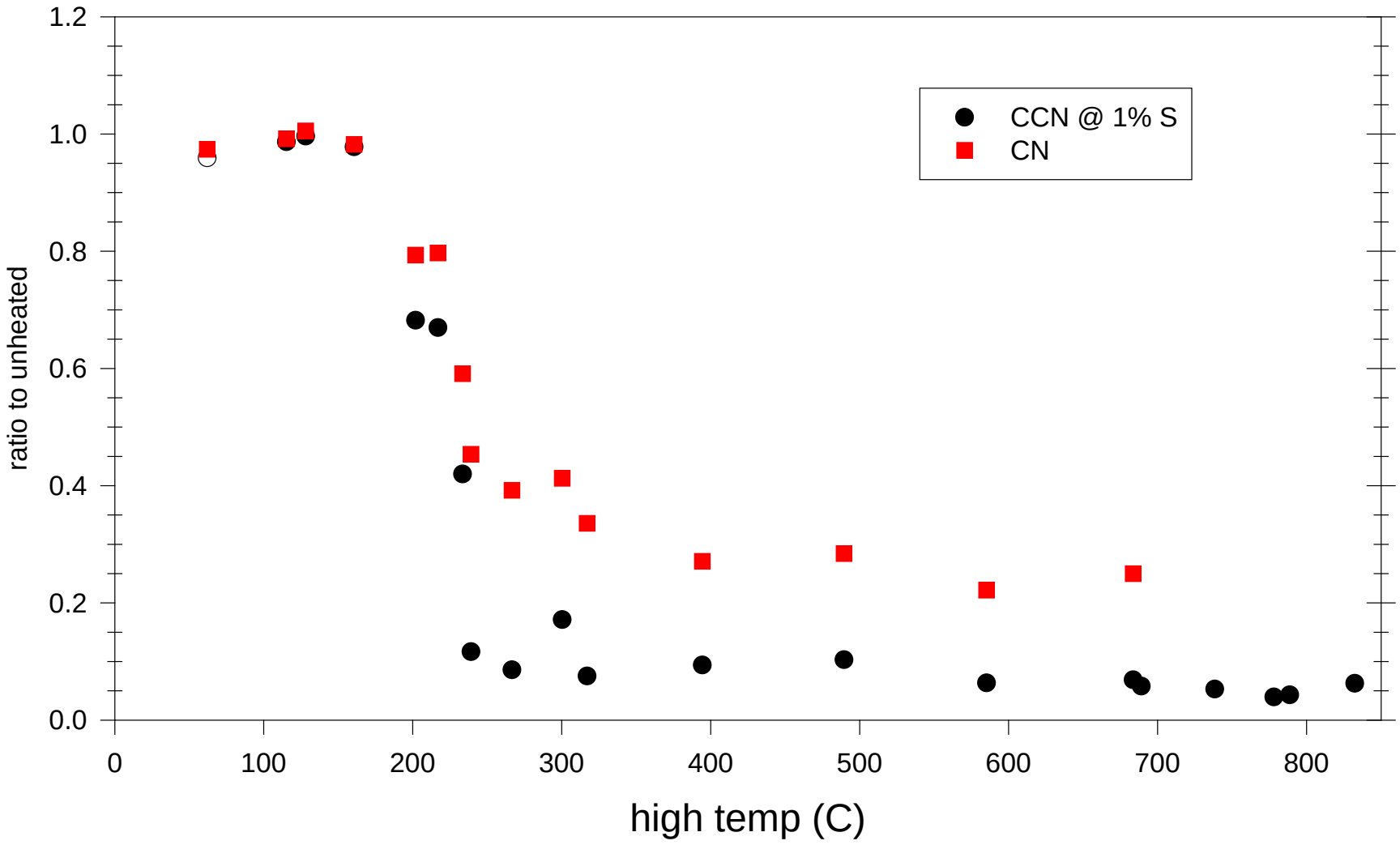


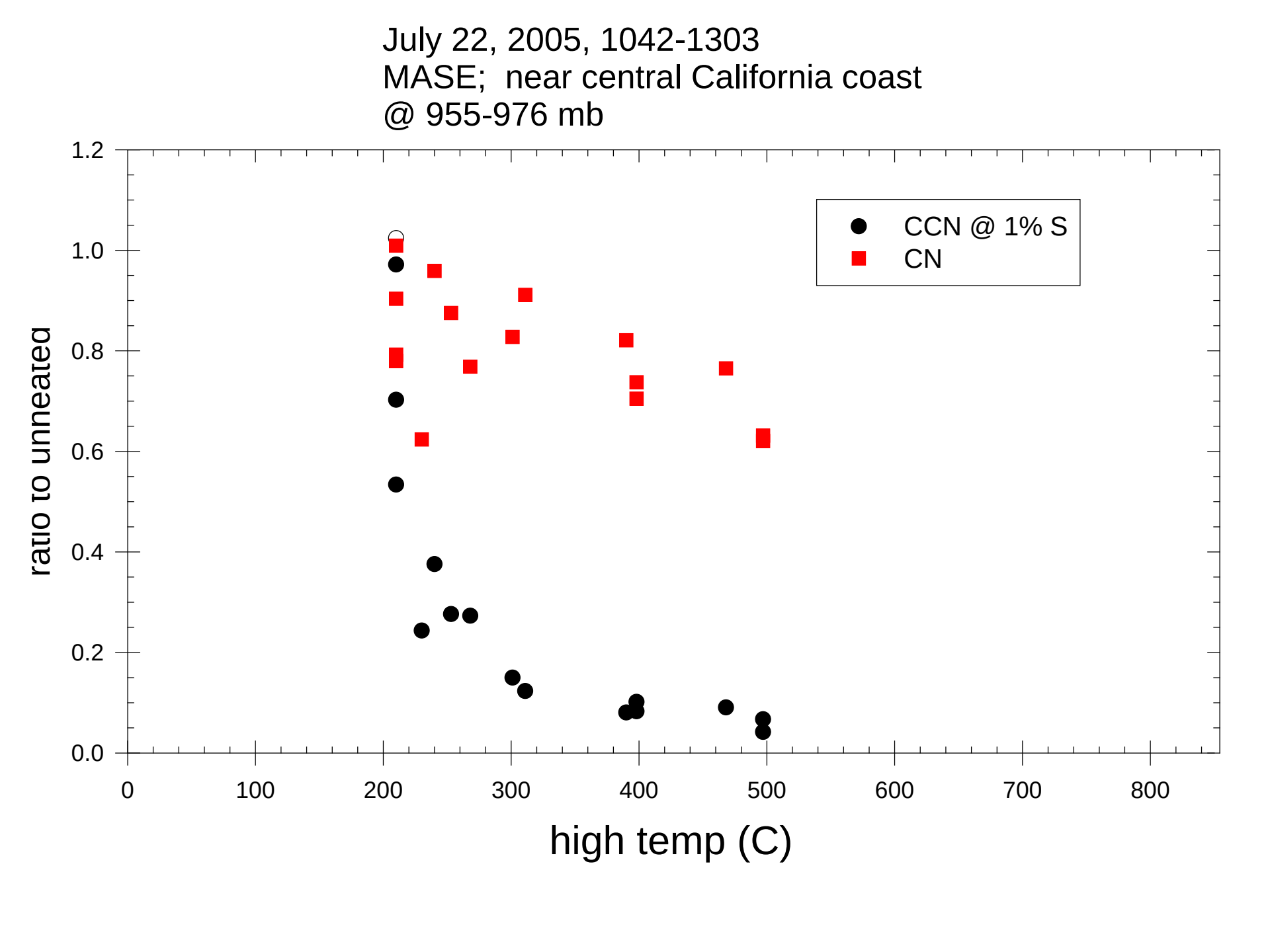
July 18 below



July 17 above




Sept 2 2007 PASE RF11
1231-1553 XST
CCN @ 1% S
CN
ratio to unheated
high temp (C)
0.0
0.2
0.4
0.6
0.8
1.0
1.2
0
100
200
300
400
500
600
700
800


July 22, 2005, 1042-1303
MASE; near central California coast
@ 955-976 mb
CCN @ 1% S
CN
ratio to unheated
high temp (C)
0.0
0.2
0.4
0.6
0.8
1.0
1.2
0
100
200
300
400
500
600
700
800

To compare different sizes or critical supersaturations (S_c) Fitzgerald et al. (JAS 1982) introduced the hygroscopicity or solubility parameter, B, (non-dimensional).

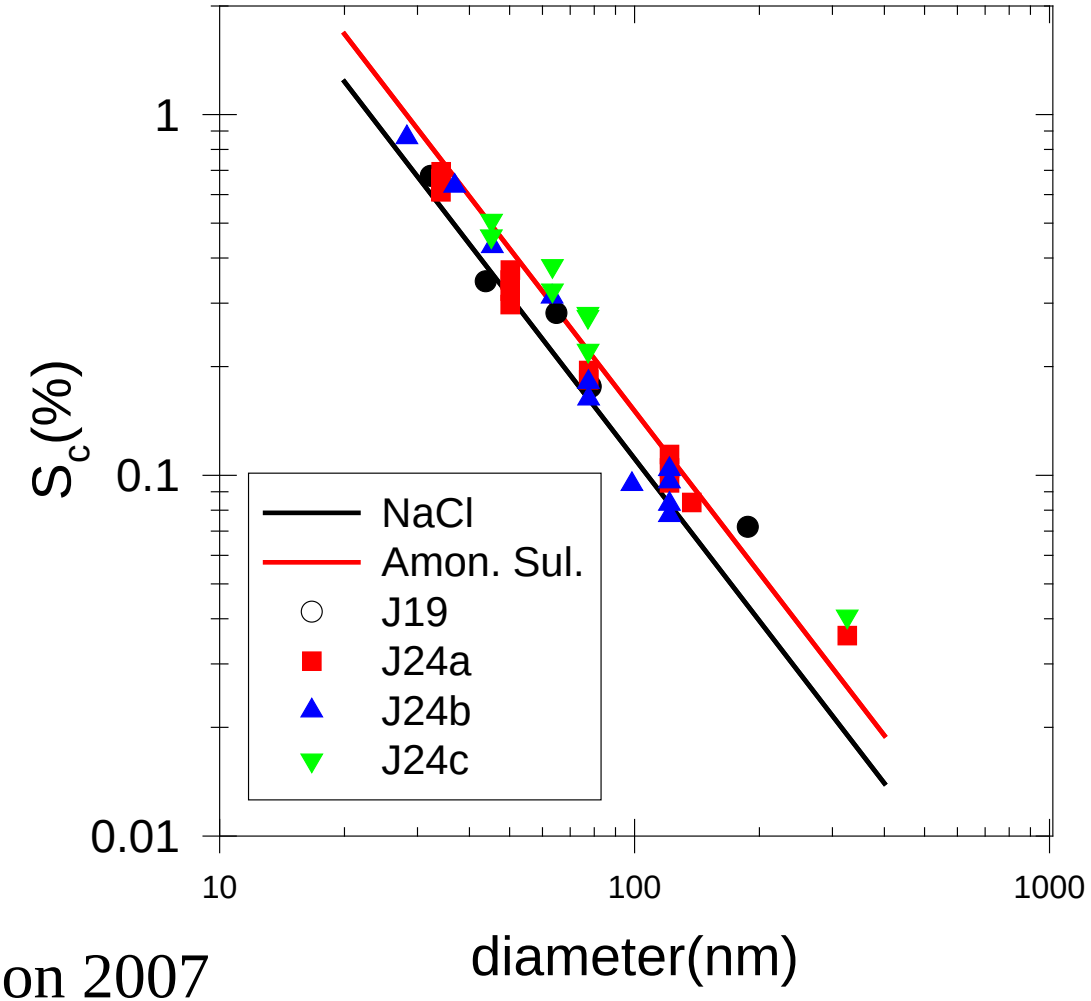
B = 1.23 for NaCl

B = 0.70 for ammonium sulfate

lower for less hygroscopic substances.

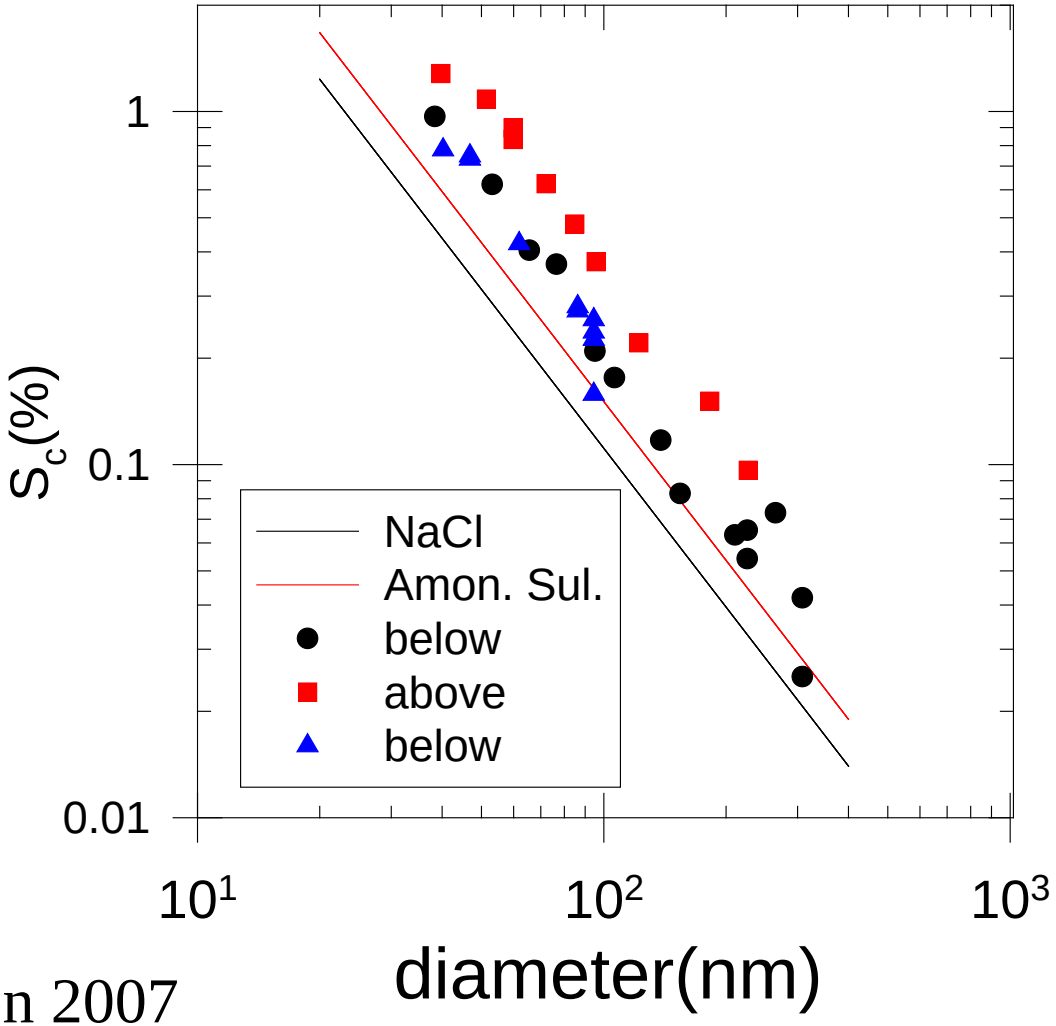
Particle critical Supersaturation (S_c)

versus dry particle diameter
January 19 and 24, 2005
RICO Eastern Caribbean near Antigua
low altitude



From Hudson 2007

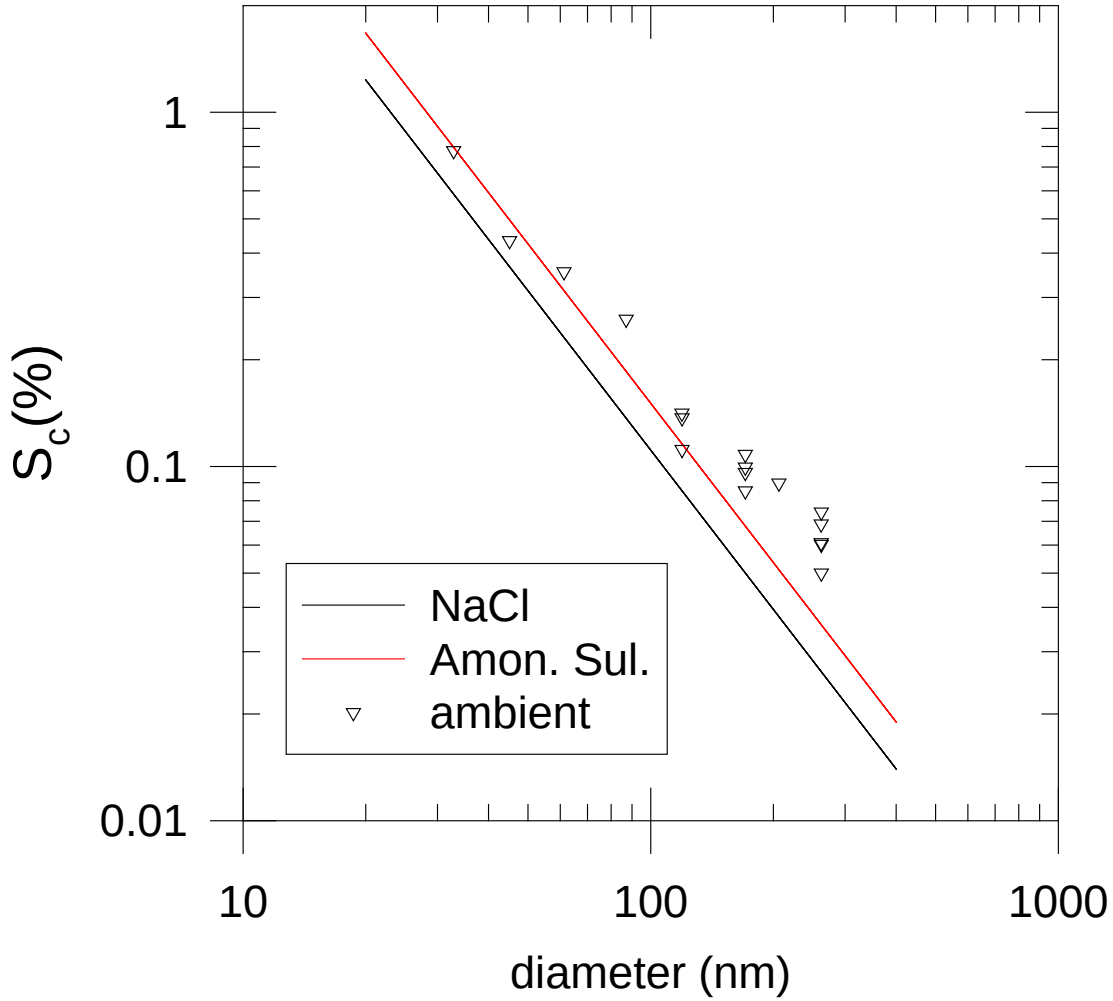
Particle critical supersaturation (Sc) versus dry diameter
July 25, 2005
MASE off the Central California Coast
below and above stratus cloud layer



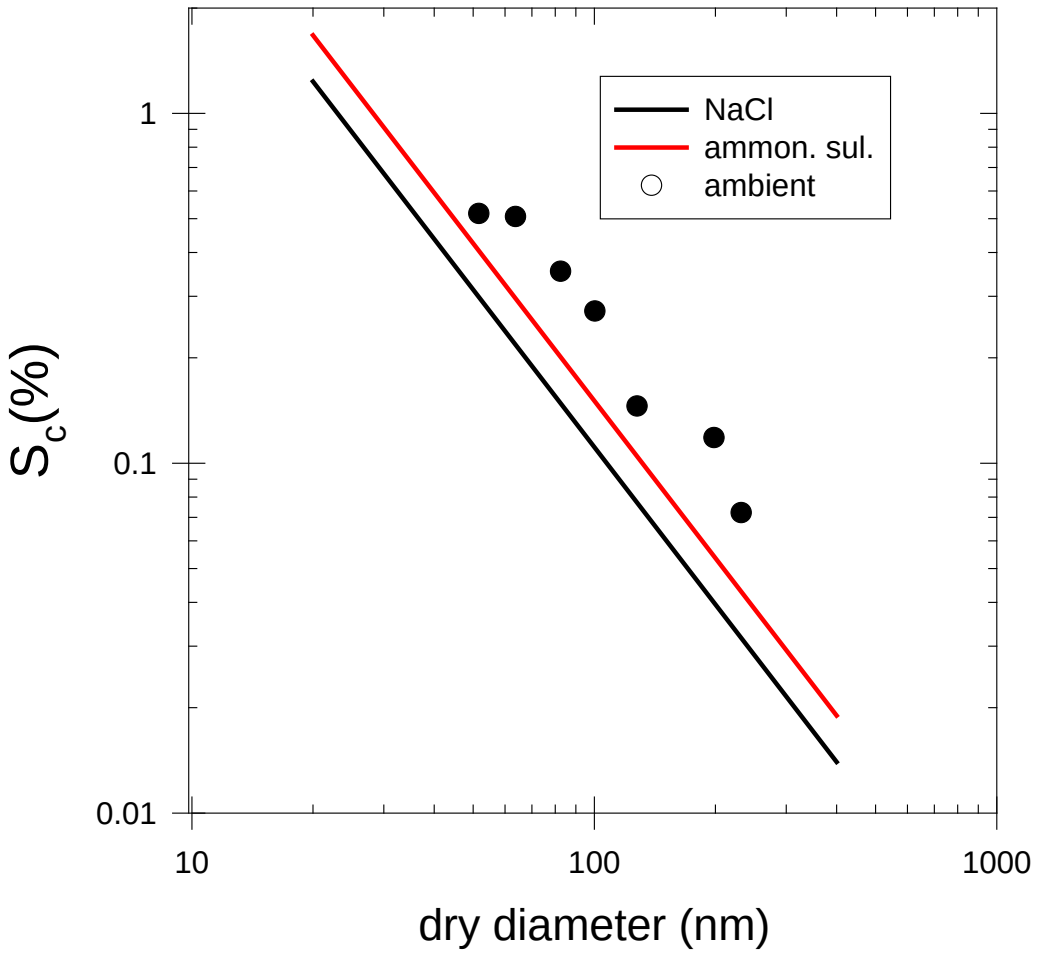
From Hudson 2007

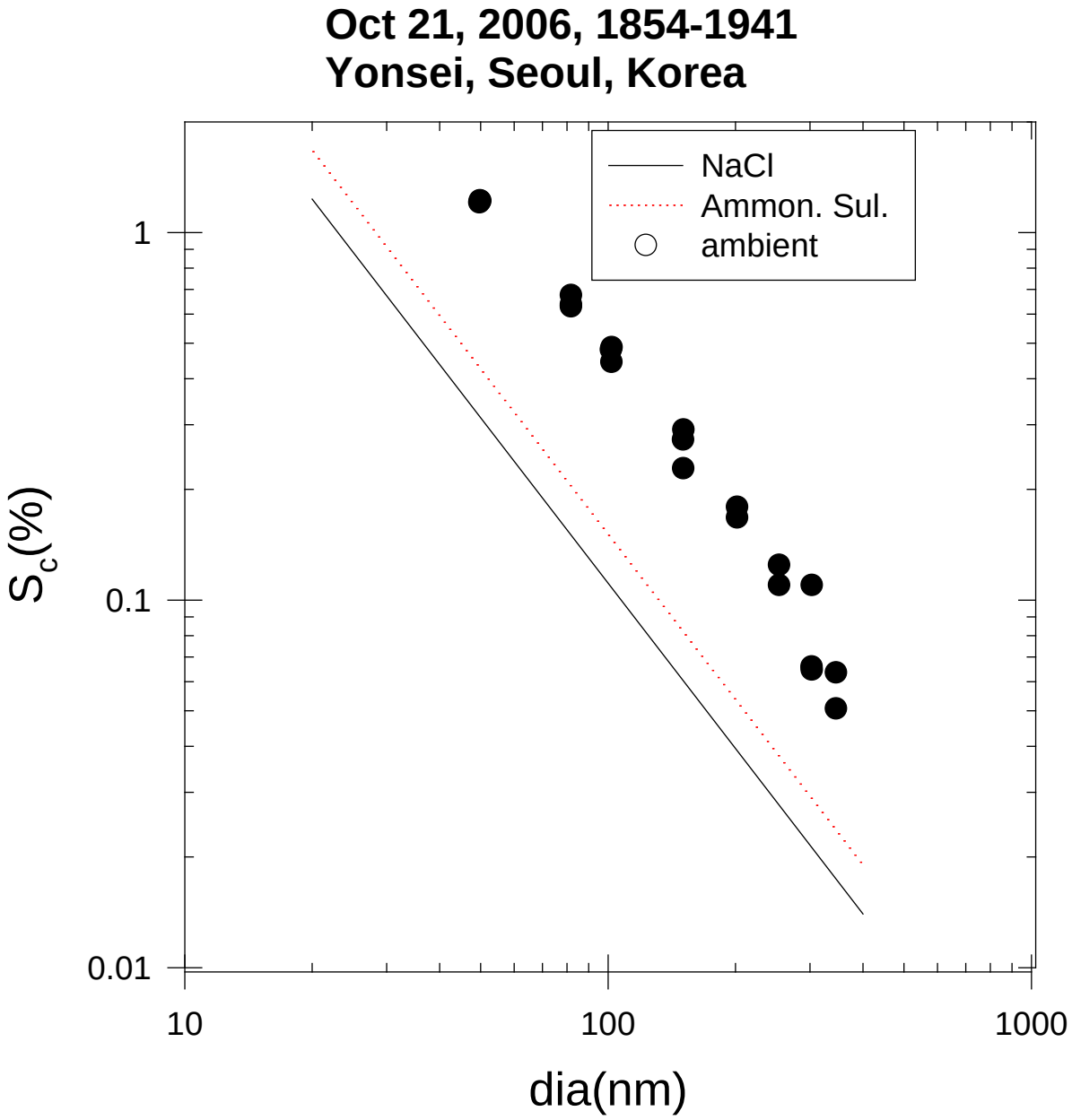
Particle critical Supersaturation (S_c)

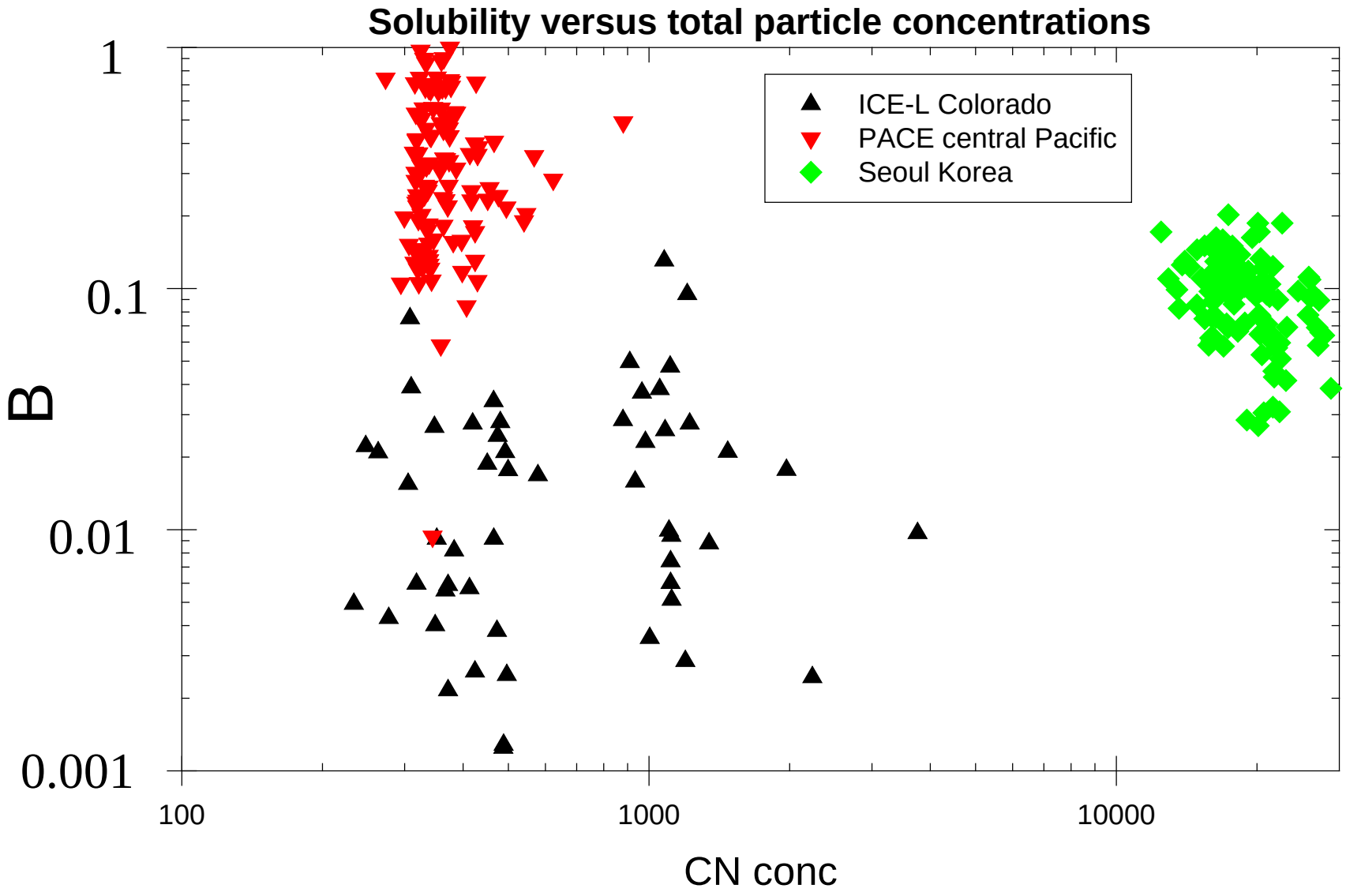
versus dry diameter
September 2, 2007 1417-1637 local time
PASE near Christmas Island
low altitude

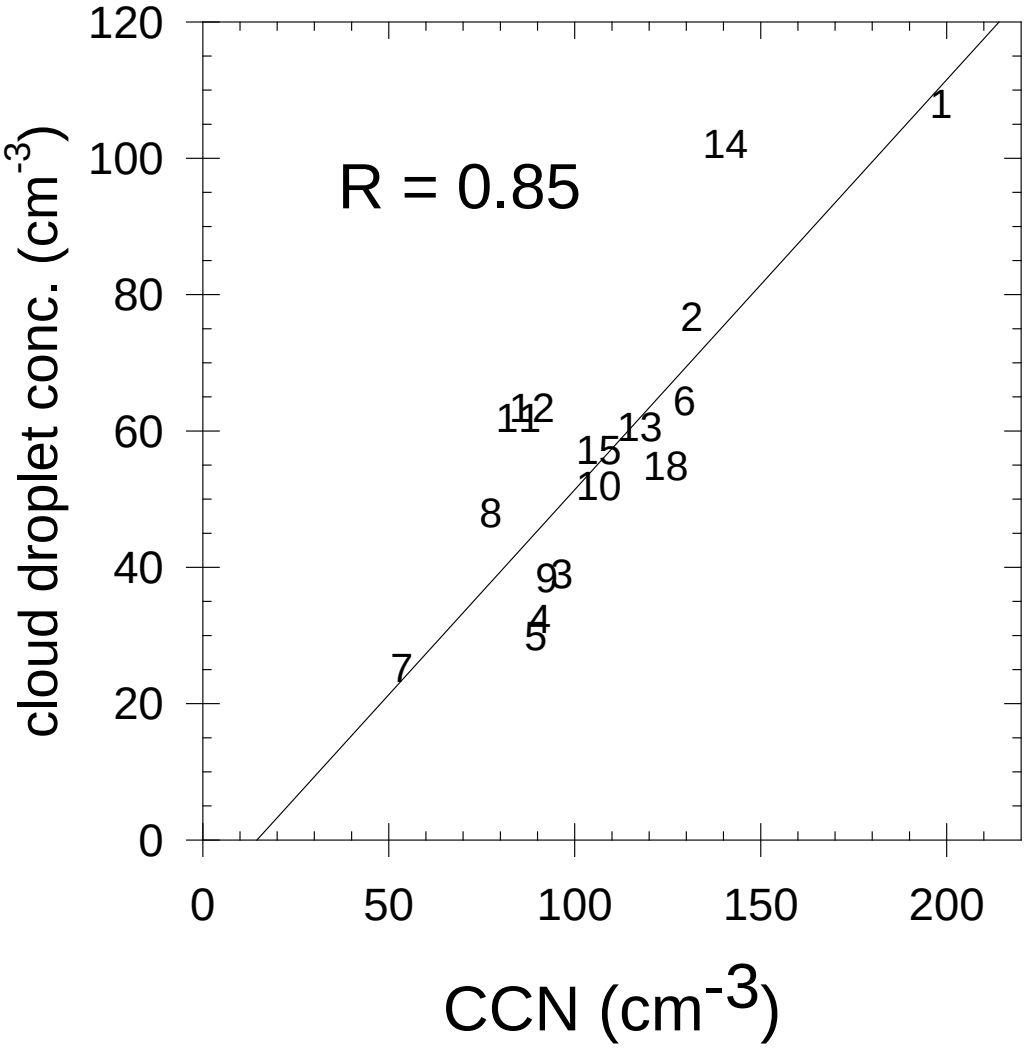


Aug 15, 2008 1121-1136
Twin Otter, POST
off central California coast
size-Sc ambient



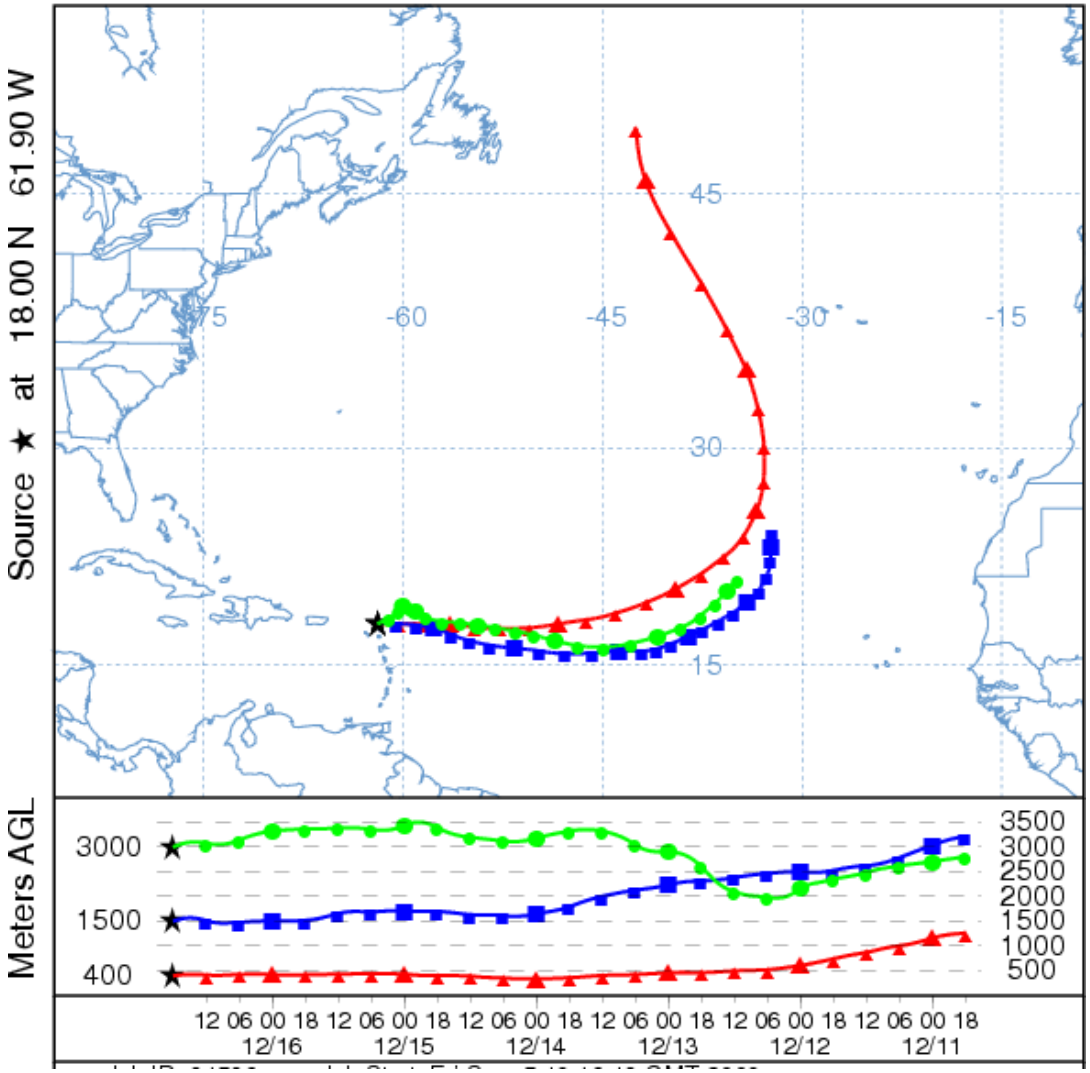

Oct 21, 2006, 1854-1941
Yonsei, Seoul, Korea
NaCl
Ammon. Sul.
ambient
1
0.1
0.01
S_c(%)
10
100
1000
dia(nm)


Solubility versus total particle concentrations
ICE-L Colorado
PACE central Pacific
Seoul Korea
B
1
0.1
0.01
0.001
100
1000
10000
CN conc



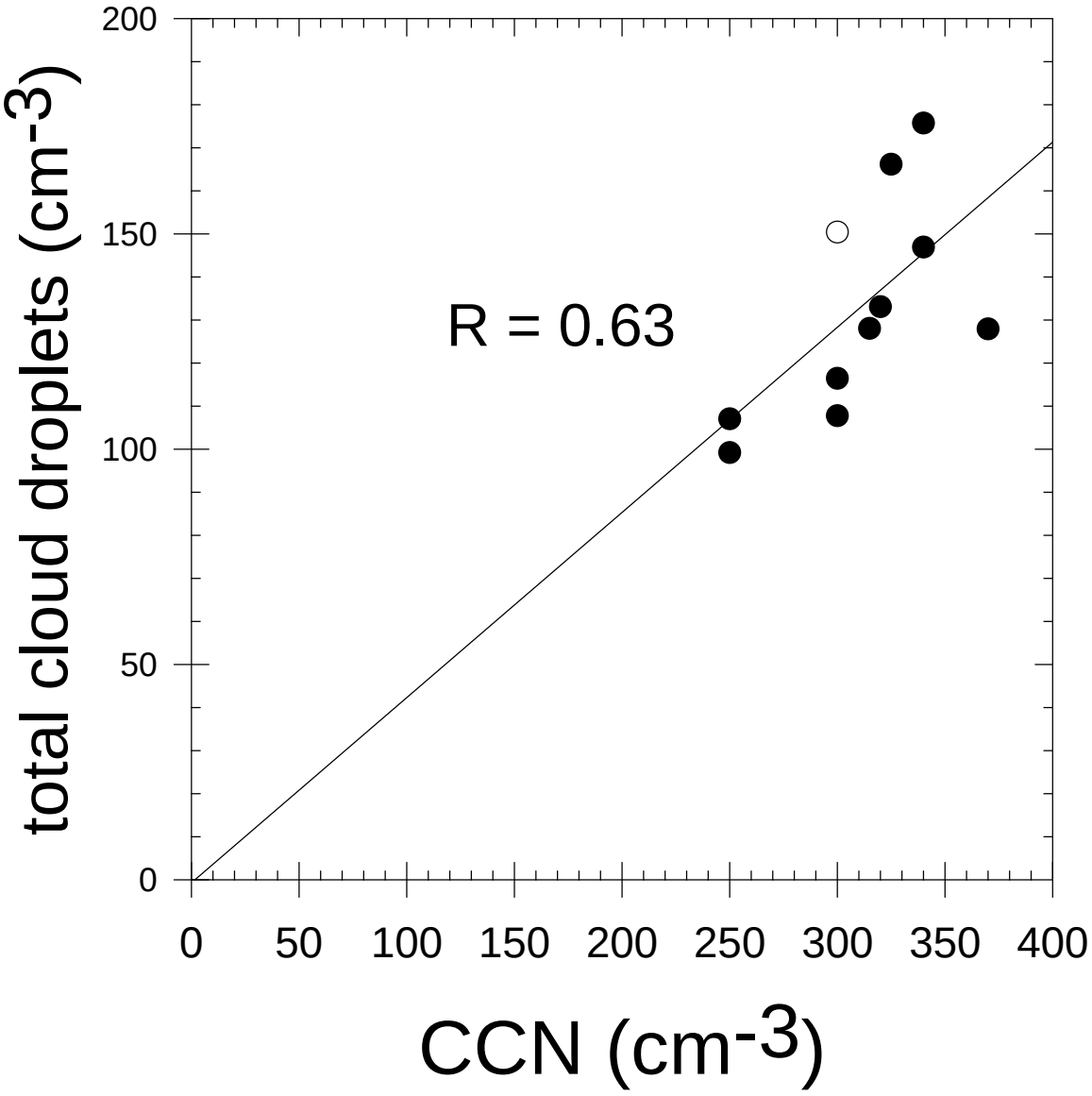
RICO flight ave
Cloud droplet conc
For LWC > 0.1gm^{-3}
Versus CCN conc

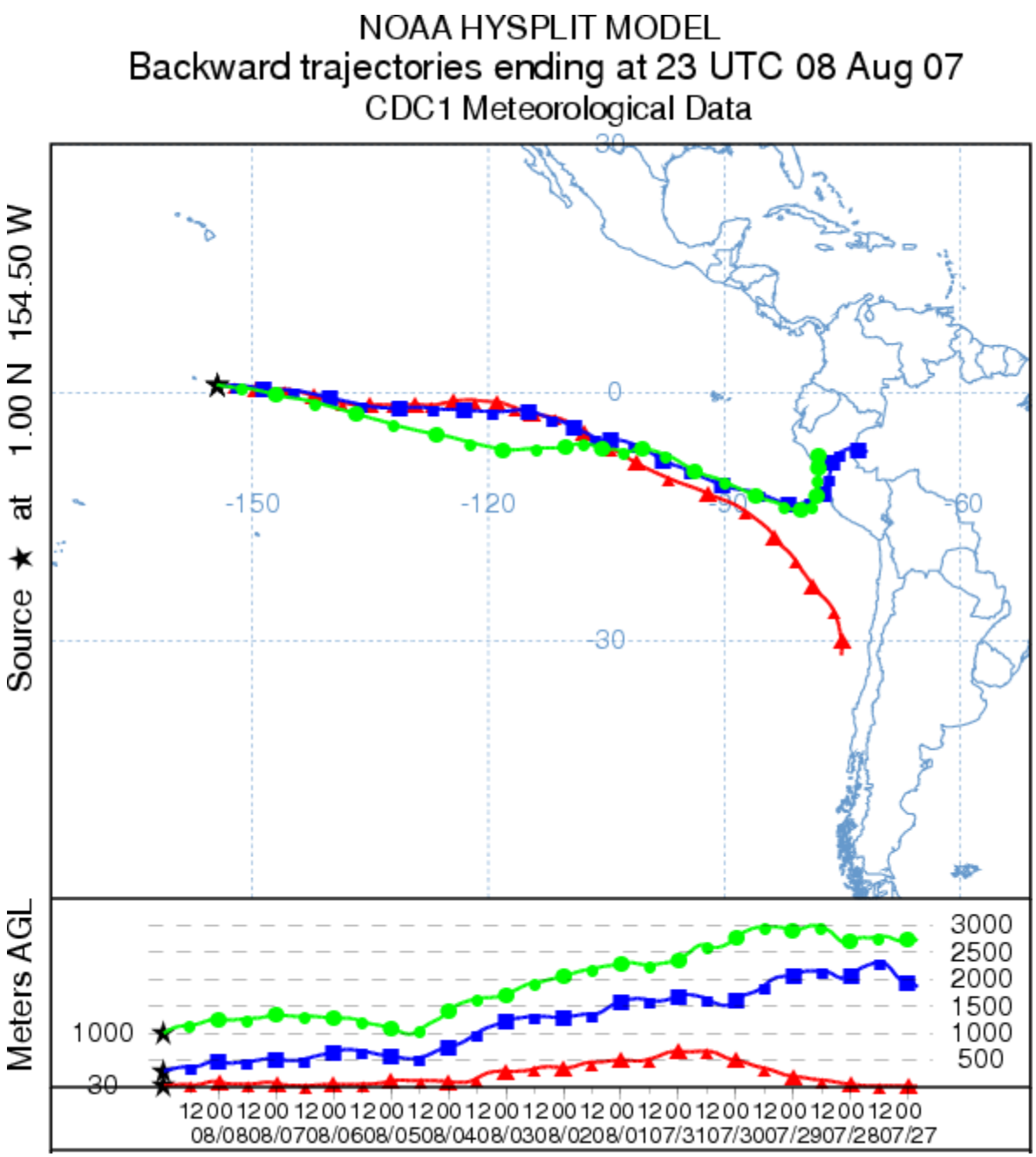
NOAA HYSPLIT MODEL
Backward trajectories ending at 18 UTC 16 Dec 04
FNL Meteorological Data



PASE

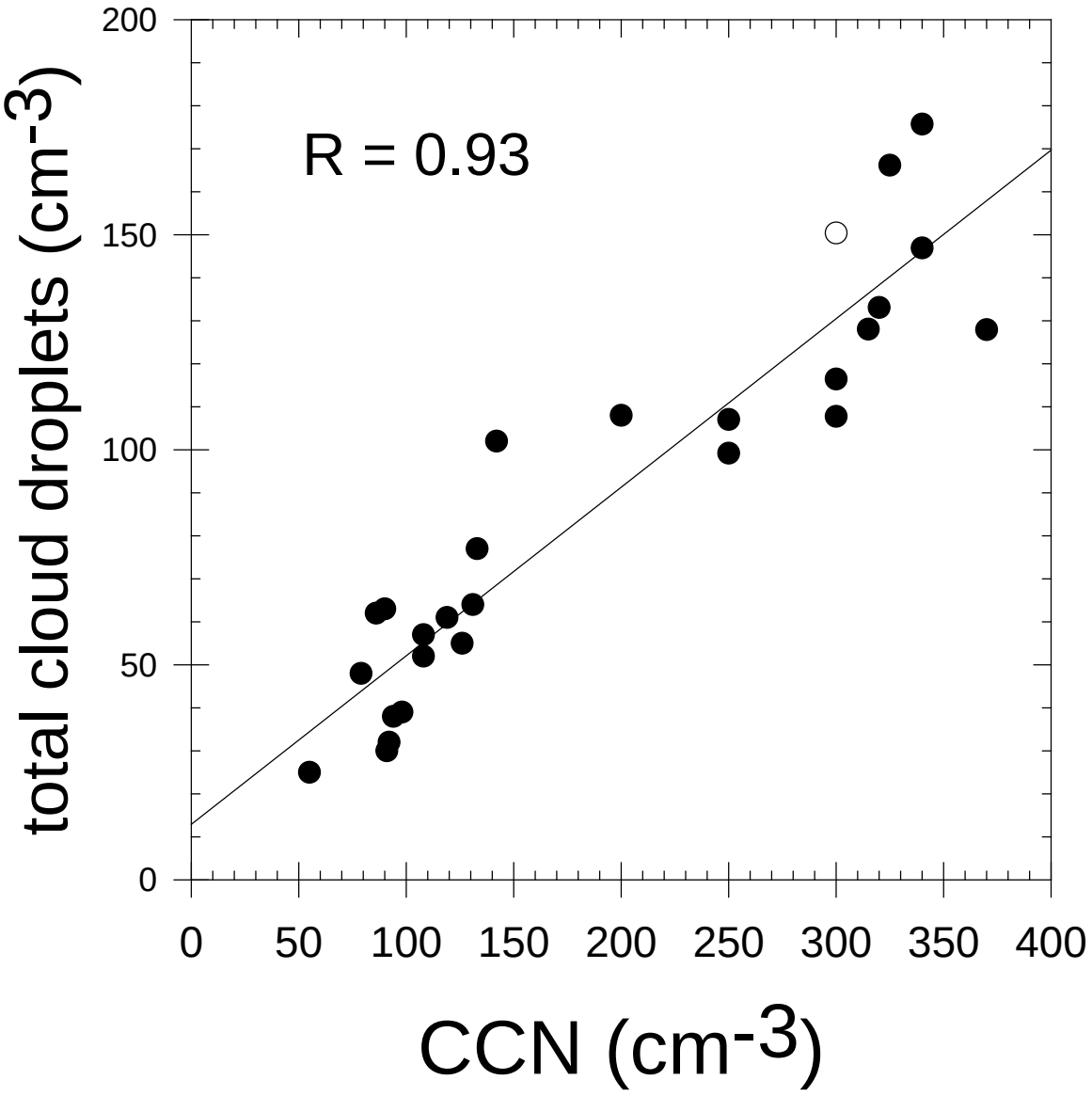
for LWC > 0.1 g m^{-3}

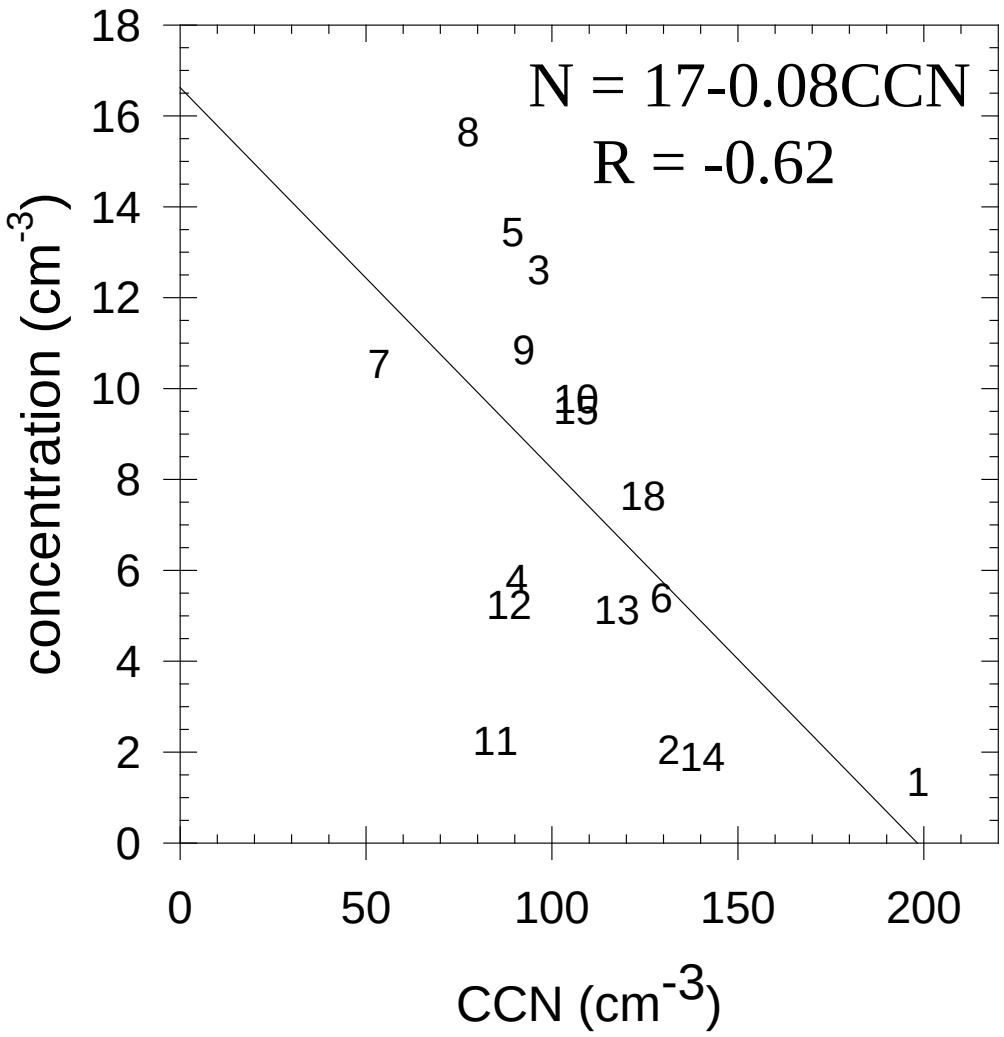



NOAA HYSPLIT MODEL
Backward trajectories ending at 23 UTC 08 Aug 07
CDC1 Meteorological Data
Source ★ at 1.00 N 154.50 W
30
0
-30
-150
-120
-90
-60
Meters AGL
3000
2500
2000
1500
1000
500
1000
30
12 00 12 00 12 00 12 00 12 00 12 00 12 00 12 00 12 00 12 00 12 00 12 00 12 00
08/0808/0708/0608/0508/0408/0308/0208/0107/3107/3007/2907/2807/27

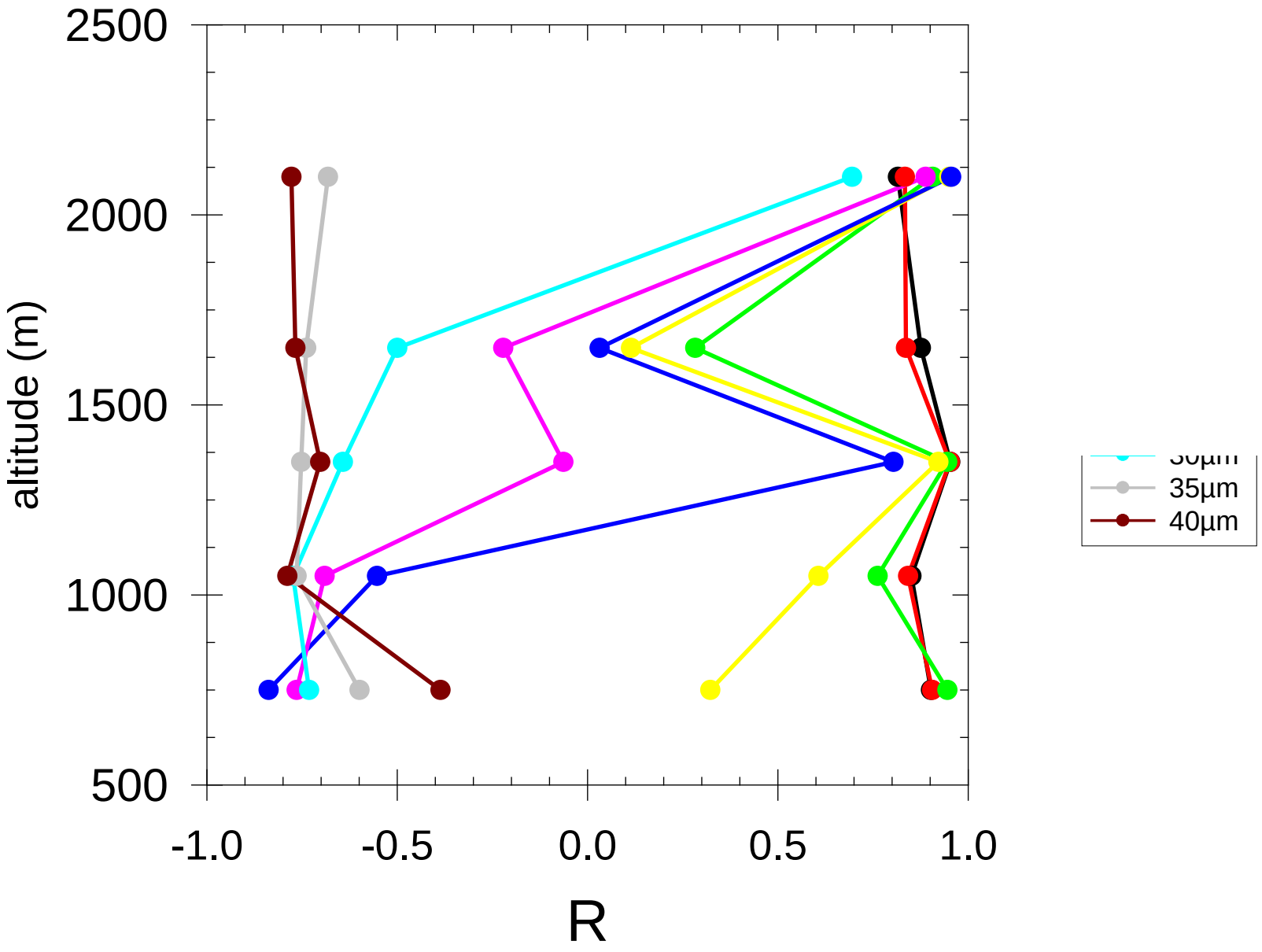
RICO and PASE

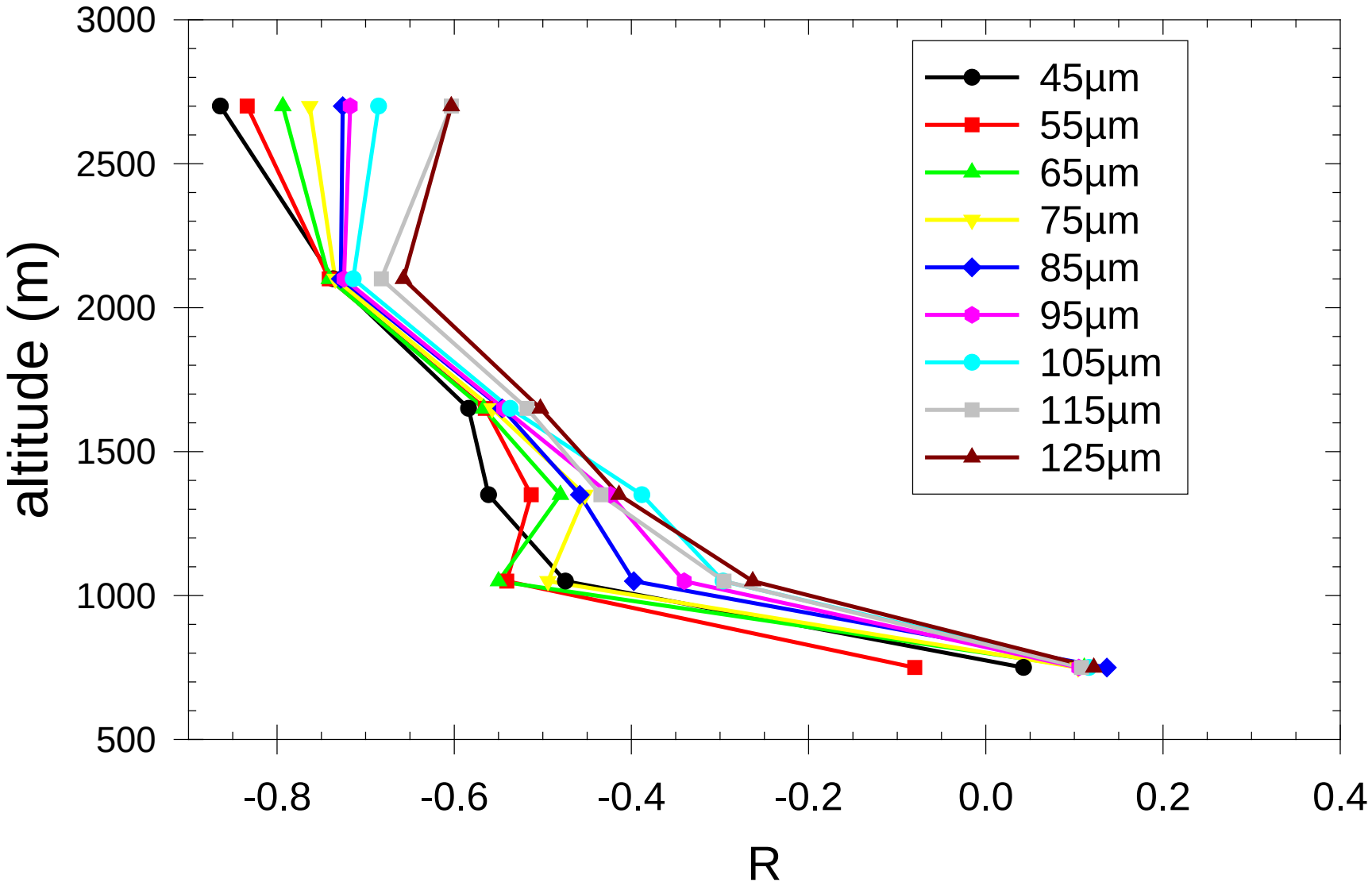
for LWC > 0.1 g m^{-3}

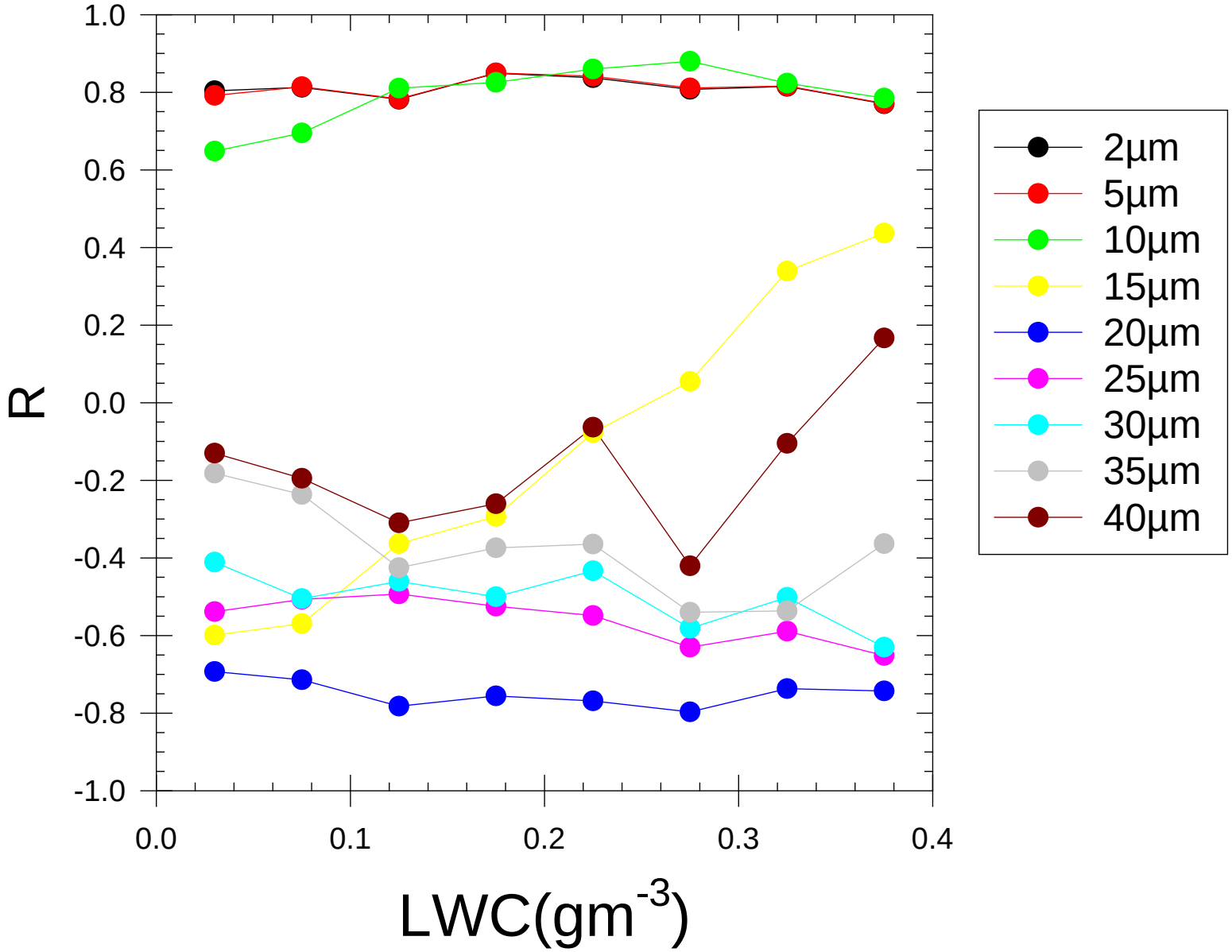




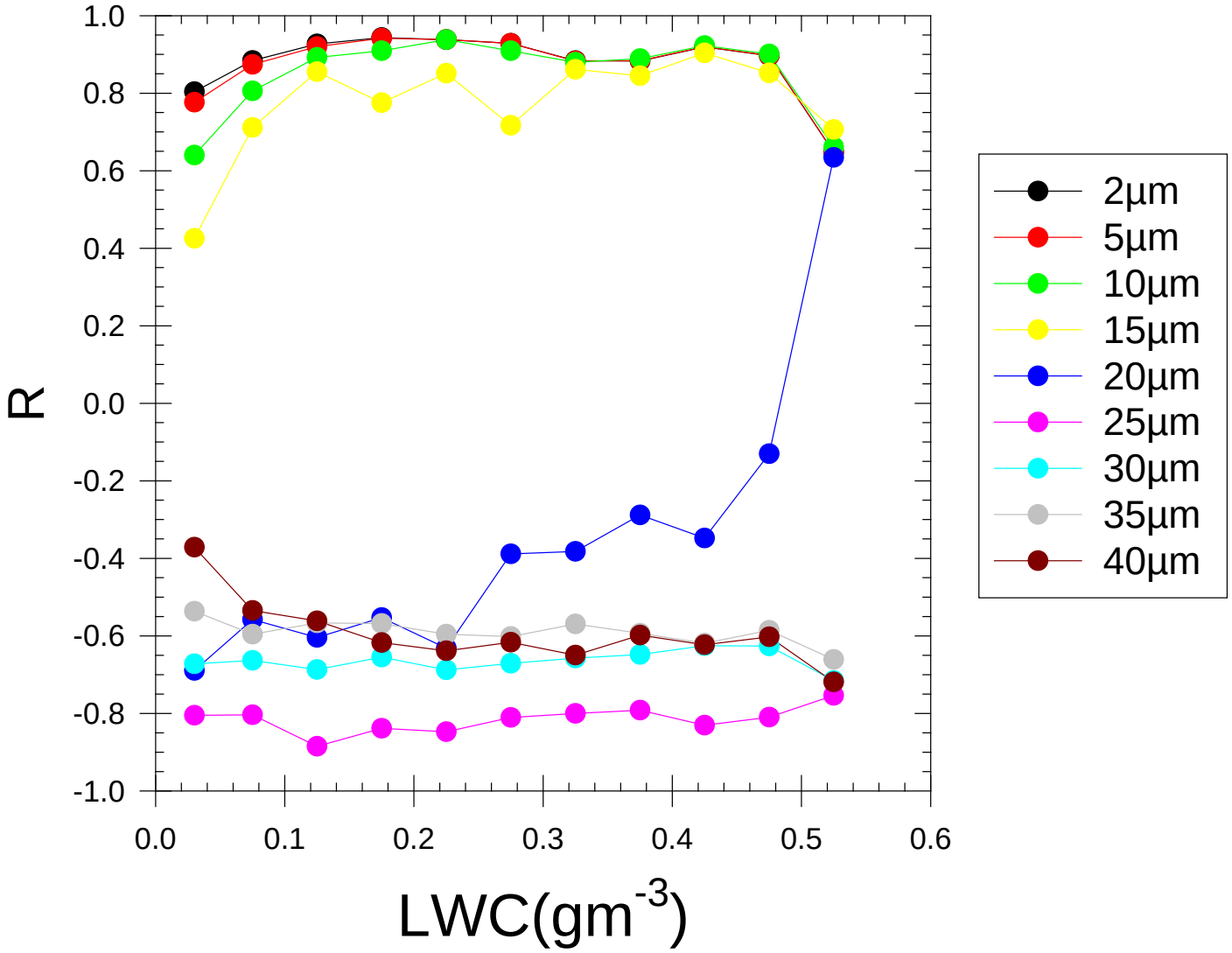
600-900m altitude and 16 flights with FSSP LWC > 0.1 gm^{-3} droplets larger than 20 µm diameter. Note smaller droplet concentration range.


2500
2000
1500
1000
500
altitude (m)
-1.0
-0.5
0.0
0.5
1.0
R
35μm
40μm

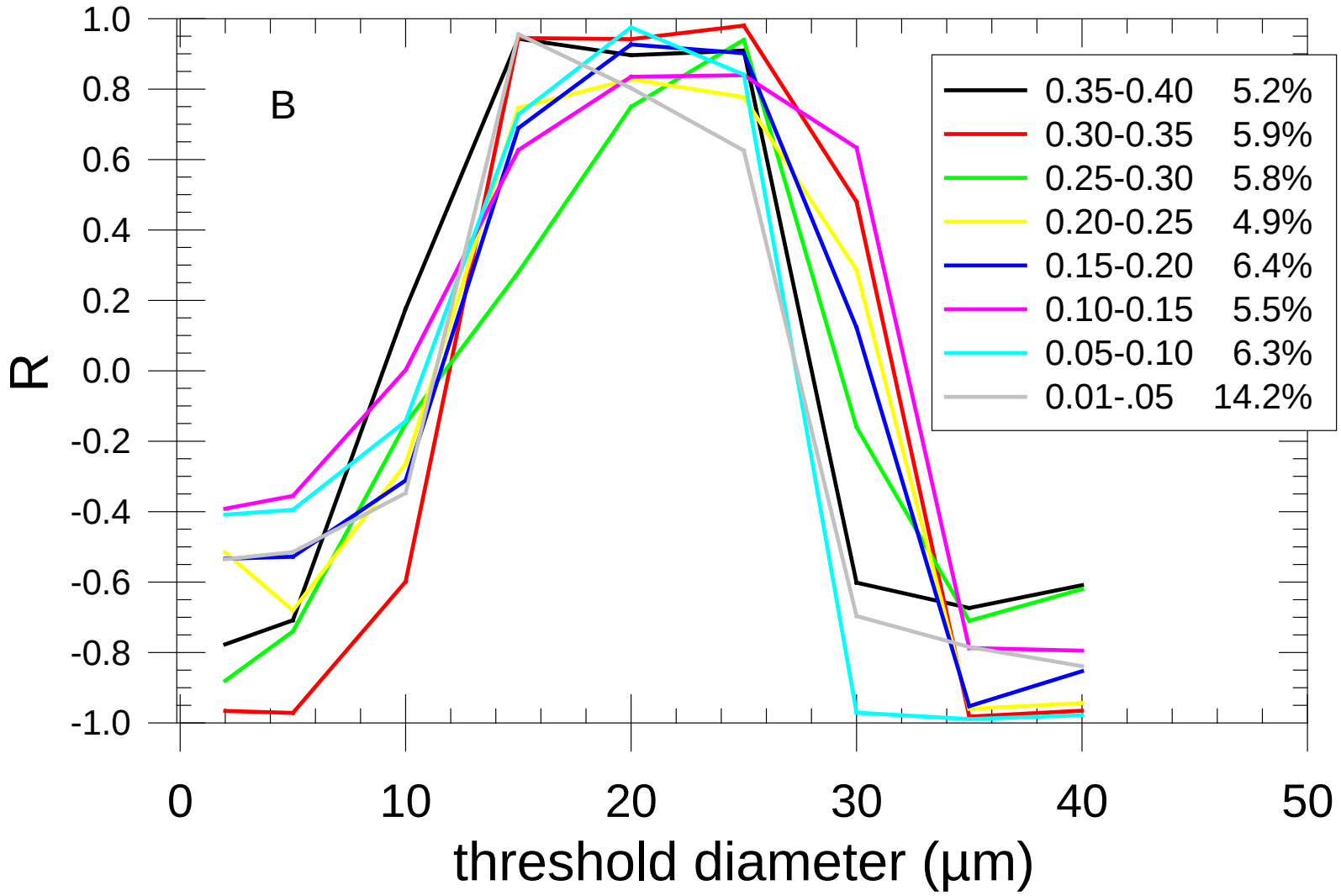

3000
2500
2000
1500
1000
500
altitude (m)
-0.8
-0.6
-0.4
-0.2
0.0
0.2
0.4
R
45µm
55µm
65µm
75µm
85µm
95µm
105µm
115µm
125µm



600-900 m altitude

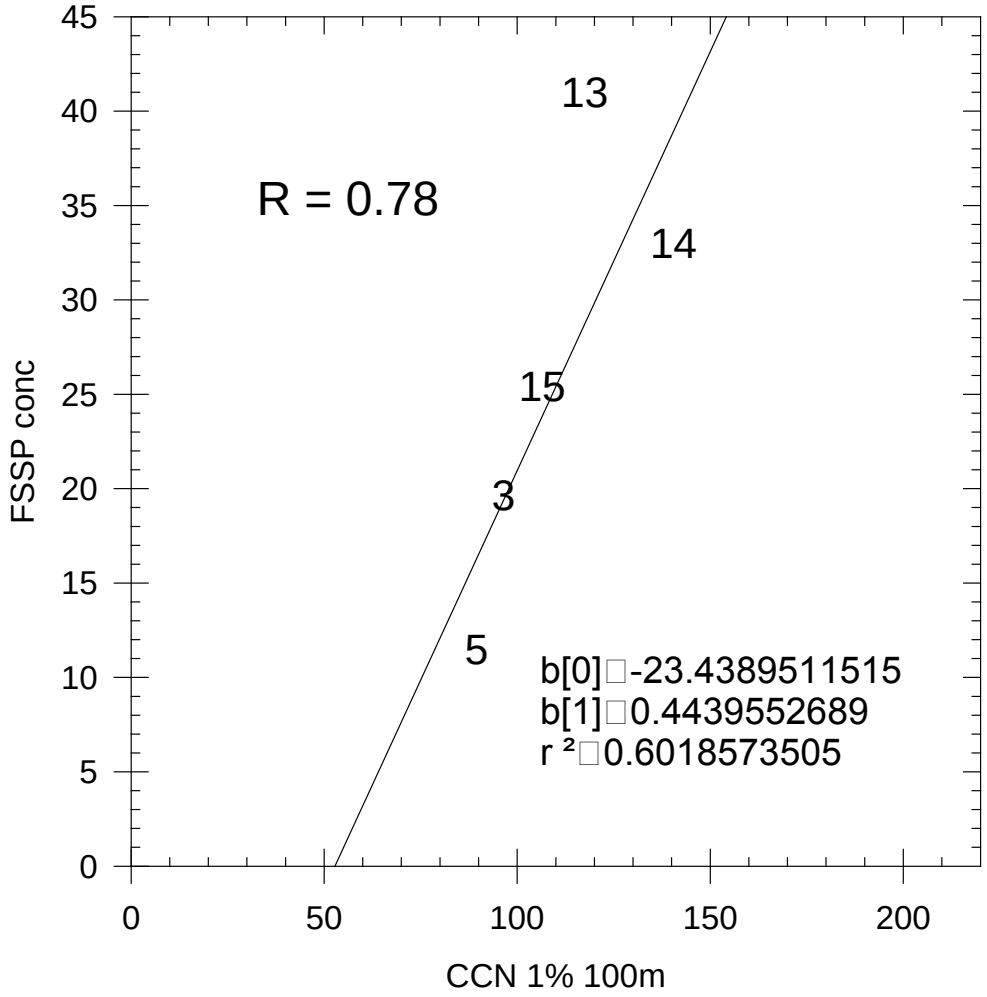


900-1200m altitude range.

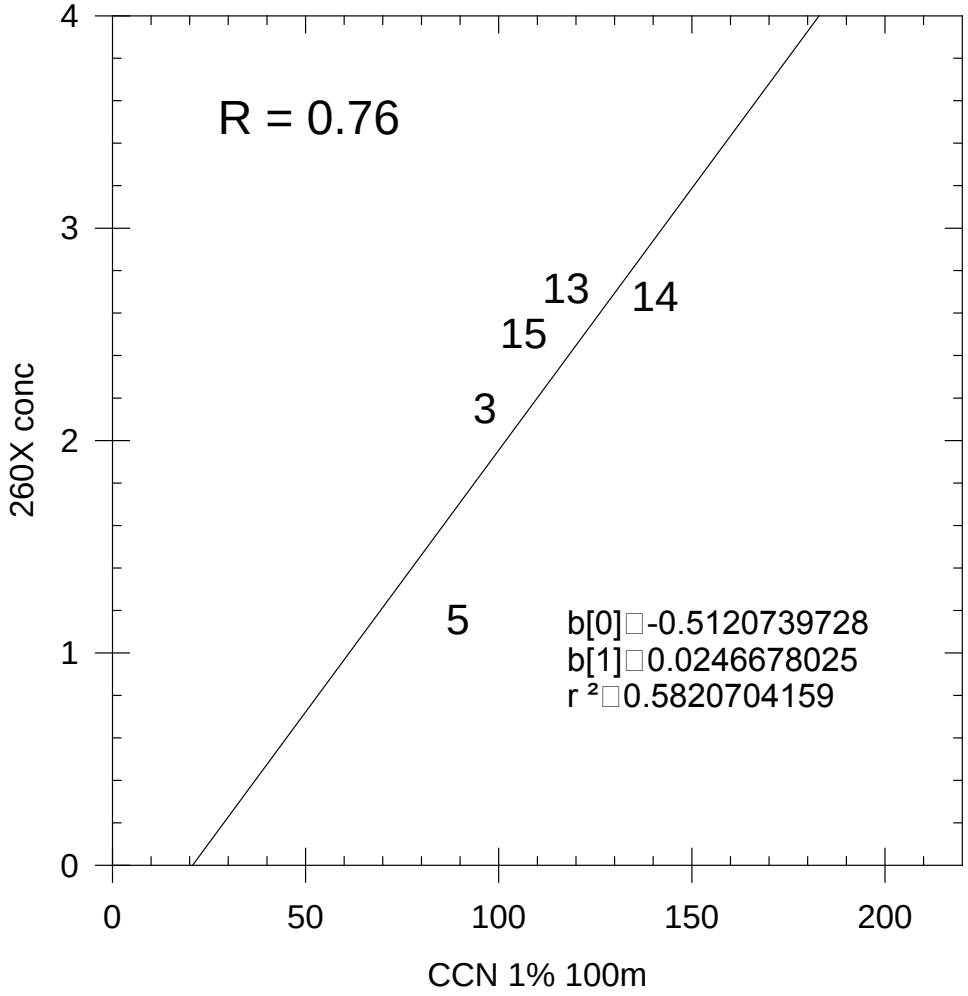

B
R
1.0
0.8
0.6
0.4
0.2
0.0
-0.2
-0.4
-0.6
-0.8
-1.0
0
10
20
30
40
50
threshold diameter (µm)
0.35-0.40 5.2%
0.30-0.35 5.9%
0.25-0.30 5.8%
0.20-0.25 4.9%
0.15-0.20 6.4%
0.10-0.15 5.5%
0.05-0.10 6.3%
0.01-.05 14.2%

2400-3000m

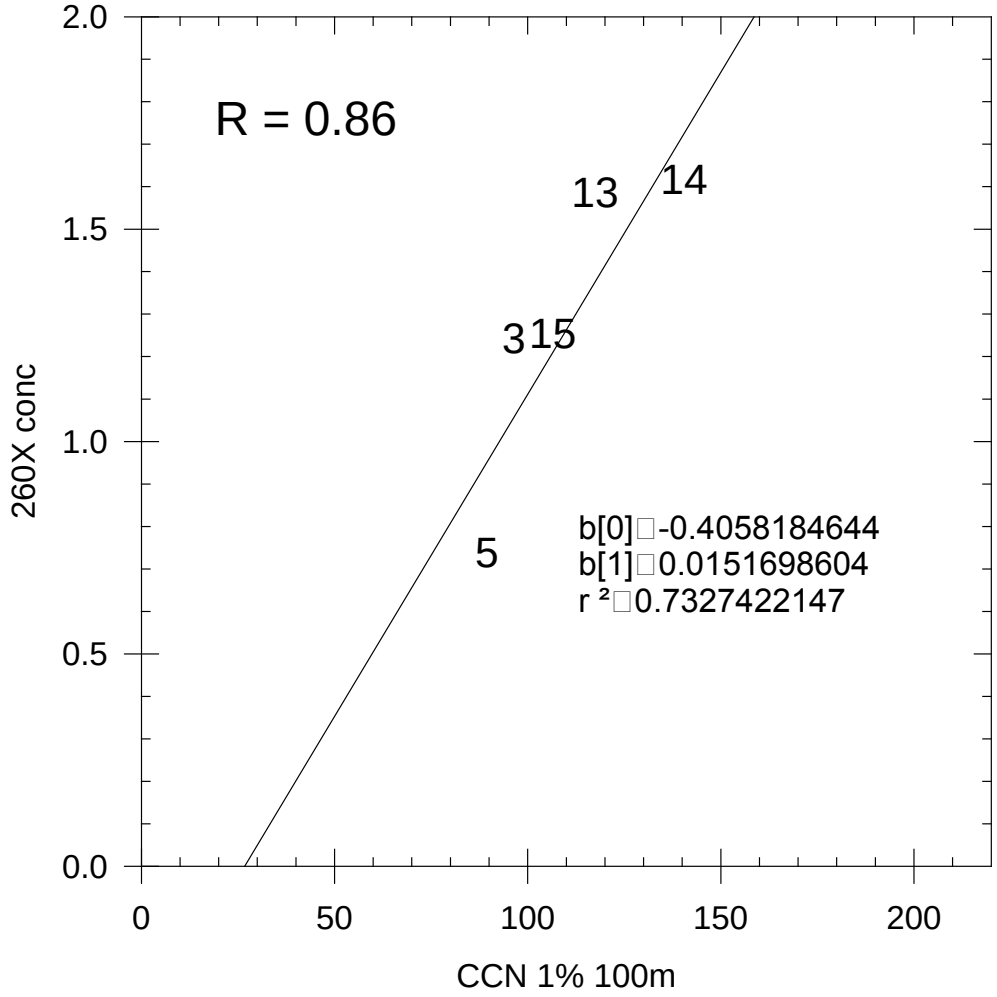
RICO 2004-05, Antigua
droplet concentration for all parcels with
FSSP conc > 1, 3000m and up altitude
FSSP conc all
for 5 flights



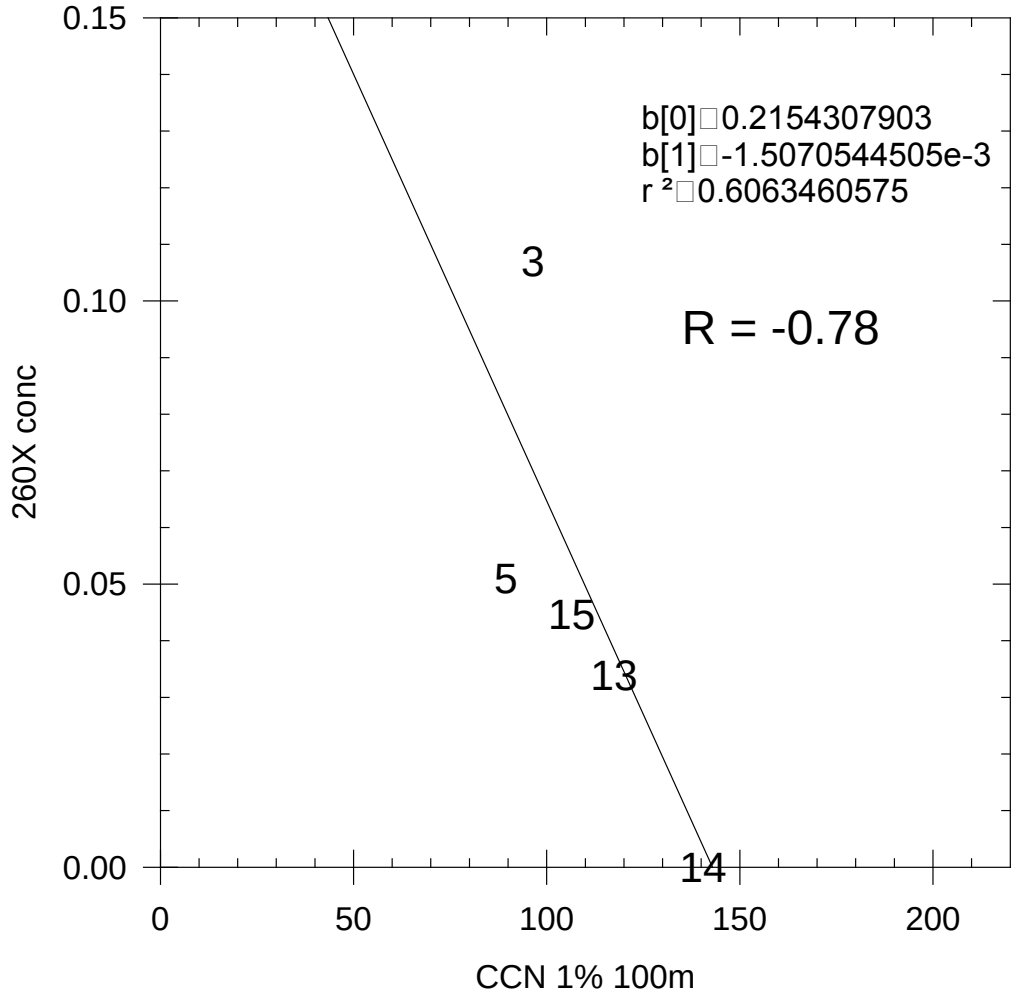
RICO 2004-05, Antigua
droplet concentration for all parcels with
FSSP conc > 1, 3000m and up altitude
260X conc > 295 µm
for 5 flights



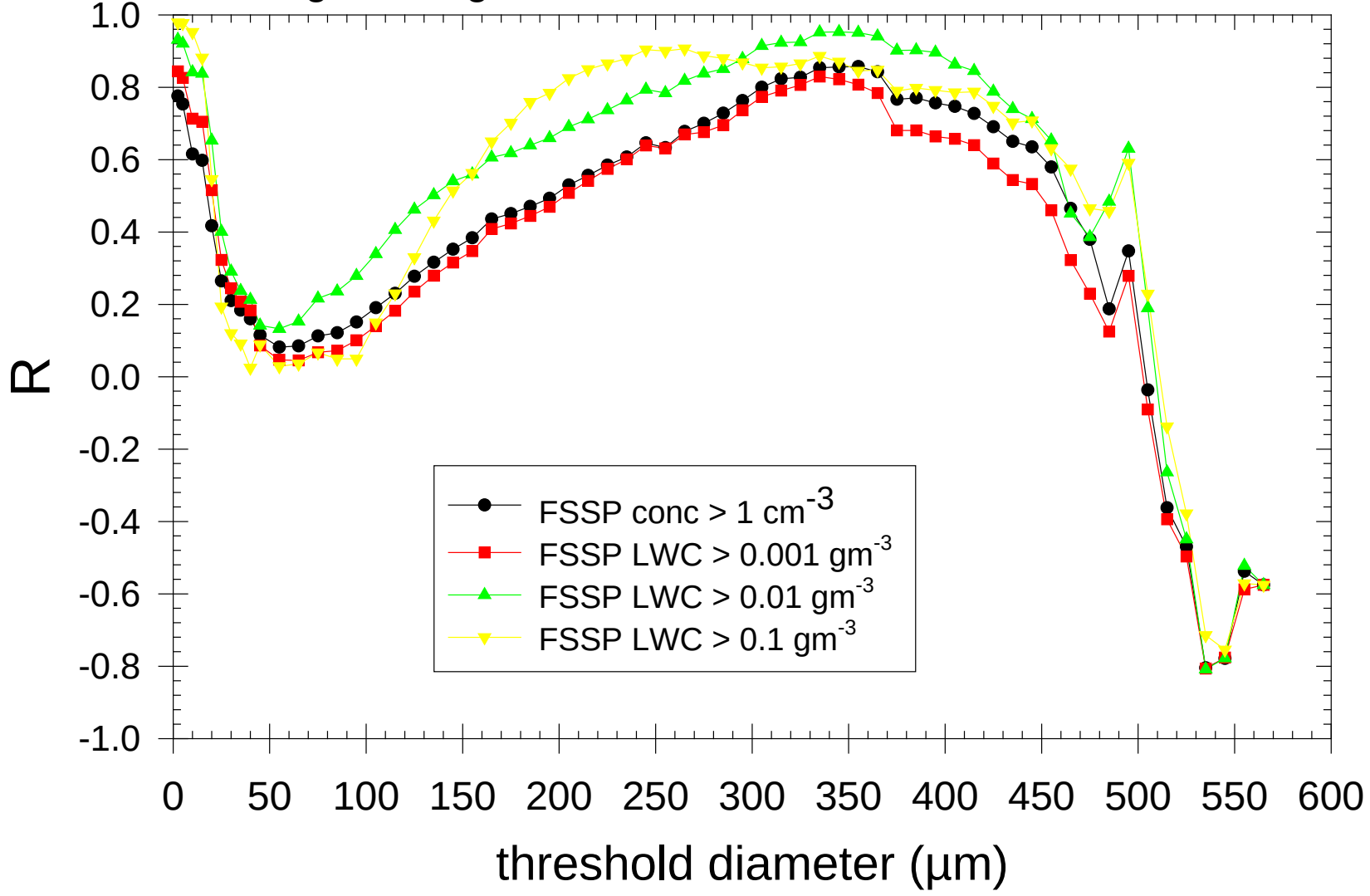
RICO 2004-05, Antigua
droplet concentration for all parcels with
FSSP conc > 1, 3000m and up altitude
260X conc > 245 μm
for 5 flights



RICO 2004-05, Antigua
droplet concentration for all parcels with
FSSP conc > 1, 3000m and up altitude
260X conc > 545 μm
for 5 flights



Correlation coefficients (R) between CCN @ 1% concentrations at 100m altitude versus cumulative cloud droplet and drizzle drop concentrations within 3000+m altitude during the same five flights using various criteria



3 CCN spectrometers

#1 (old) rectangular

S range 0.02-0.4%

#2 (new) rectangular

S range 0.1-1.5%

#3 double cylinder

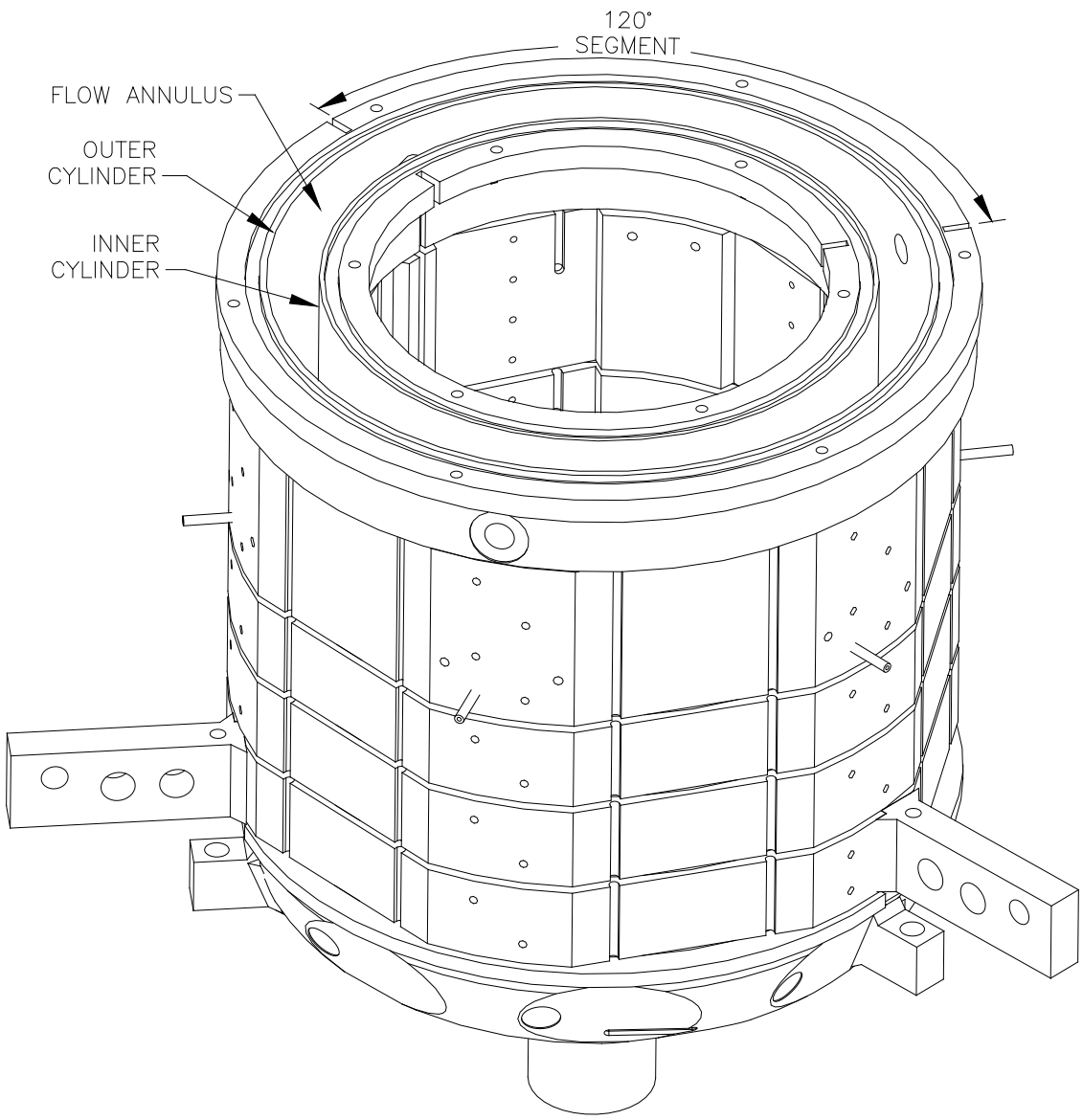
first aircraft deployment—ICE-L Dec 07

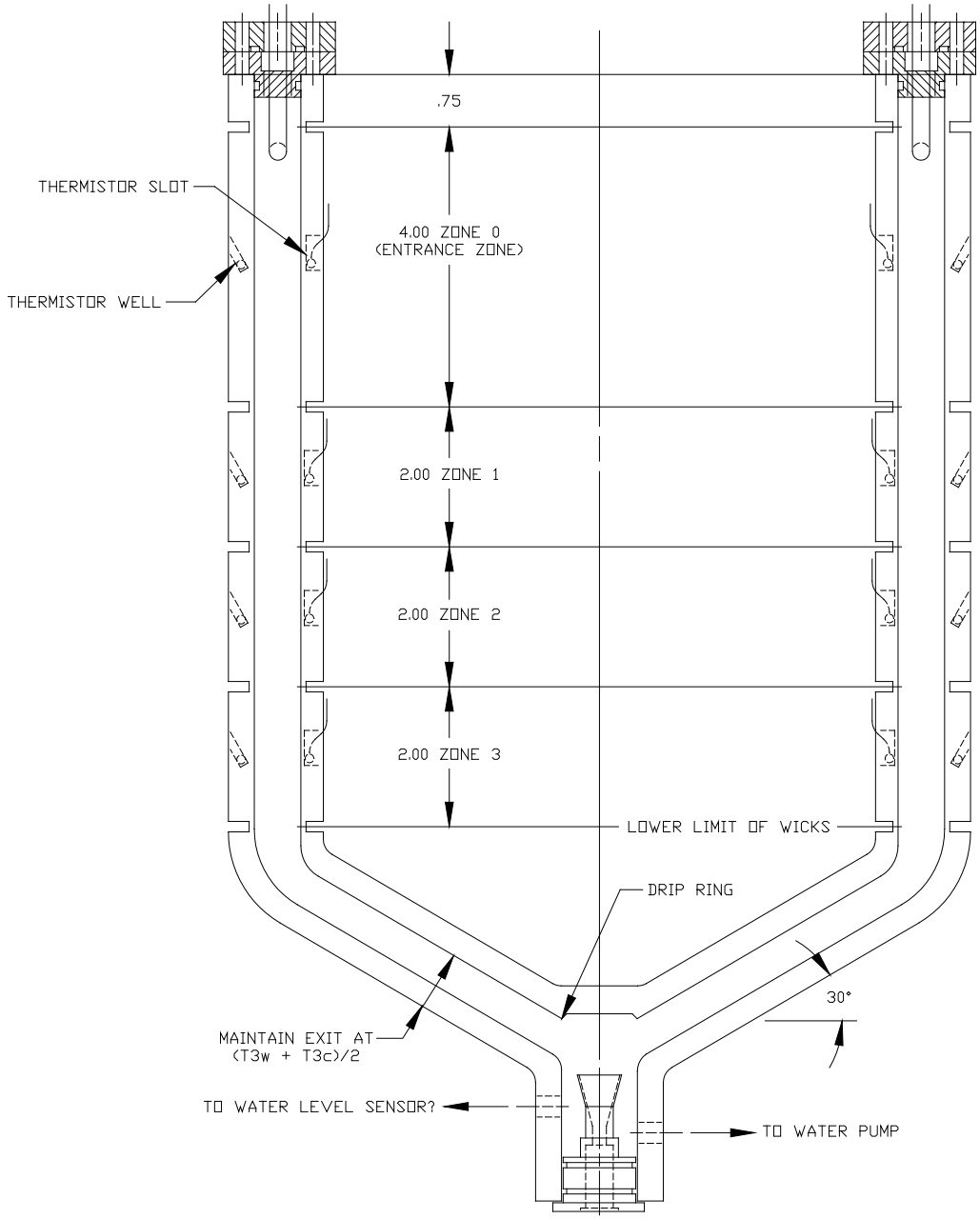
1. Simultaneous high time resolution CCN spectra

2. Differential CCN spectra

3. Supersaturation (S) range extended below 0.1%.

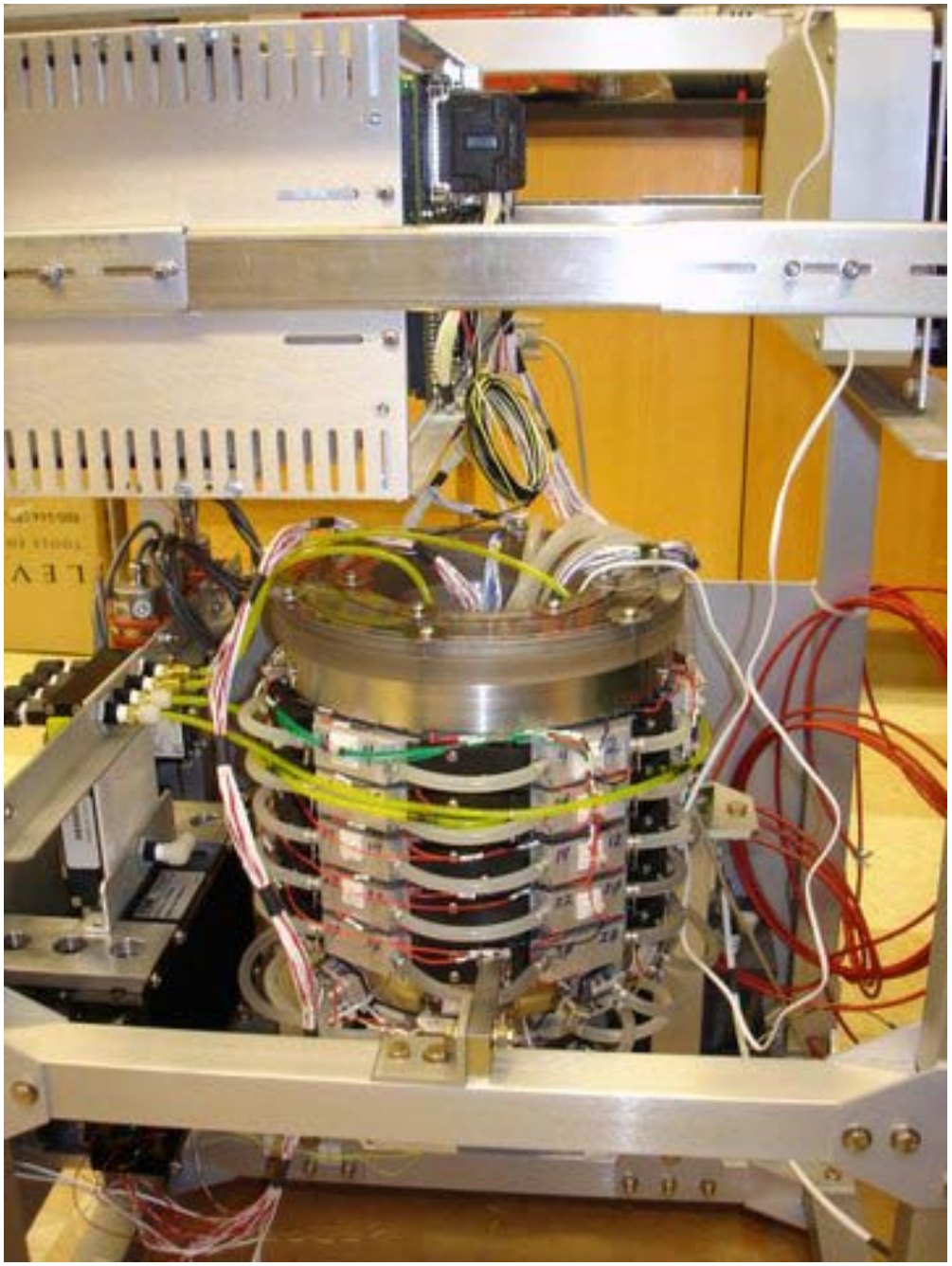
4. Agreement between instruments


120°
SEGMENT
FLOW ANNULUS
OUTER
CYLINDER
INNER
CYLINDER


.75
THERMISTOR SLOT
4.00 ZONE 0
(ENTRANCE ZONE)
THERMISTOR WELL
2.00 ZONE 1
2.00 ZONE 2
2.00 ZONE 3
LOWER LIMIT OF WICKS
DRIP RING
30°
MAINTAIN EXIT AT
(T3w + T3c)/2
TO WATER LEVEL SENSOR?
TO WATER PUMP

DRI CCN Spectrometer #3

- Cylindrical rather than rectangular
  - All sample has same path to OPC
    - —should have less instrument broadening.
  - No edge/wall effects so sample can fill entire area between plates instead of confined to central area to avoid wall effects
    - —allows higher sample flow for the same chamber width/circumference.
  - Split azimuthally—provides two parallel chambers with separate sample flows with different S ranges—two chambers in one.
  - Has been aircraft tested on 5 C-130 flights in ICE-L in Dec. 07. Operated successfully.



But

Does not produce a narrower spectrum of calibration aerosol.
Although convection is not a problem up to at least 12C delT
in rectangular chamber it becomes a problem in cylindrical at 5C.
Works at low S and does provide higher sample flow
—better stats for low conc large particles.
Try to stabilize and enhance S by decreasing the mean T
downward (along the flow).
But this decreases S.
So try increasing T downward like DMT.
Works but going against convection
So should try inverting chamber (flow upward)
Stable against convection
Are streamwise and transverse
(between plates) S additive?
To produce higher S with
limited del T.
Is streamwise S enough? Will spectrum
really be narrower?

Cylindrical or rectangular?