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.

Spectrometry is foiled by instrumental broadening and coincidence.

Broadening is more of a problem for steep spectra.

Coincidence is more of a problem for higher concentrations.

S range 1-0.02% (i.e., 101-100.02% RH) cloud S range.
Higher S_c for smaller (less hygroscopic) particles.

1% S_c -- 25 nm NaCl

0.1% S_c -- 110 nm NaCl

0.02% S_c – 310 nm NaCl

other compositions must have larger sizes for the same S_c.

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. CVI
5. Volatility
6. Size versus S_c

1. Simultaneous high time resolution CCN spectra

2. Differential CCN spectra

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

4. Agreement between instruments

5. Highly variable concentrations

6. Cloud processing.

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:

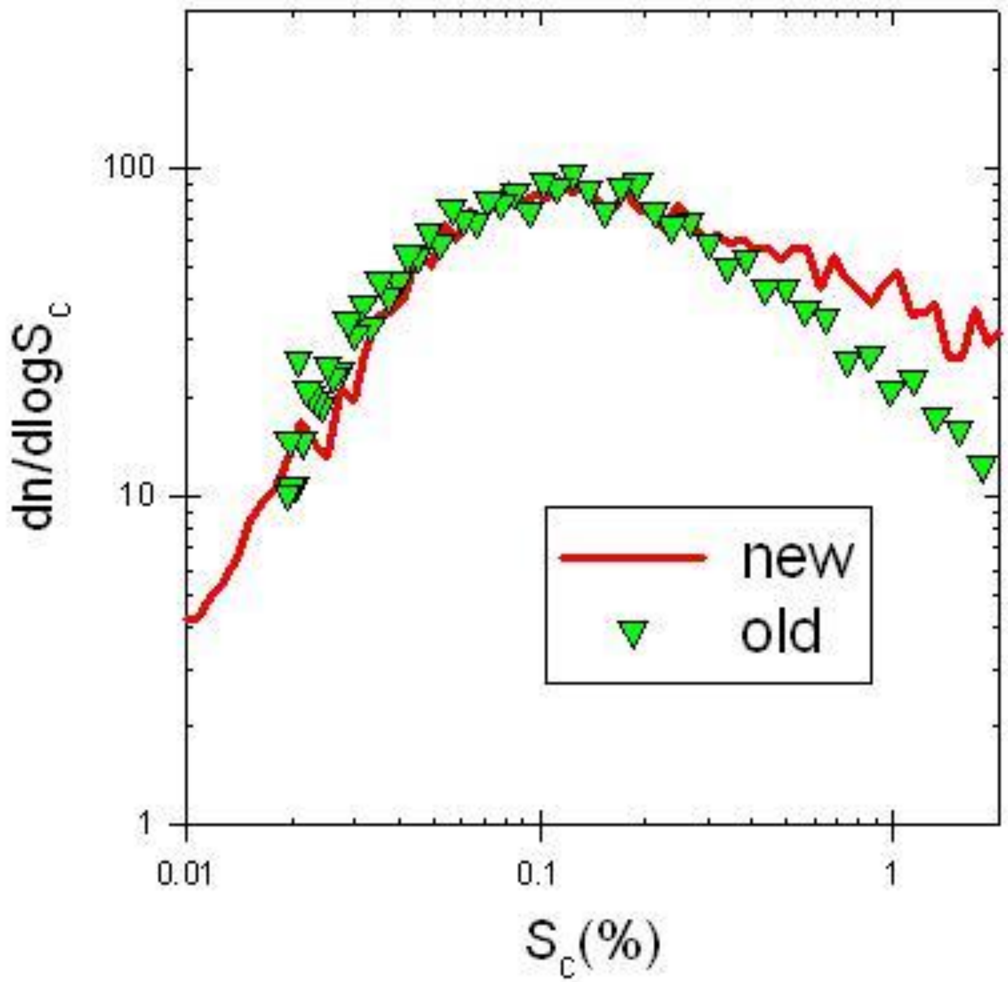
- Many clouds have $S < 0.1\%$
- Static closure—aerosol and CCN
- Dynamic closure—CCN and cloud droplets.
- Large nuclei are embryos for precipitation.
- Droplet spectral width.
- Interface with giant nuclei.
- CCN sizes.

CCN measurements are very challenging. Simultaneous spectra are then even more difficult and thus somewhat controversial.

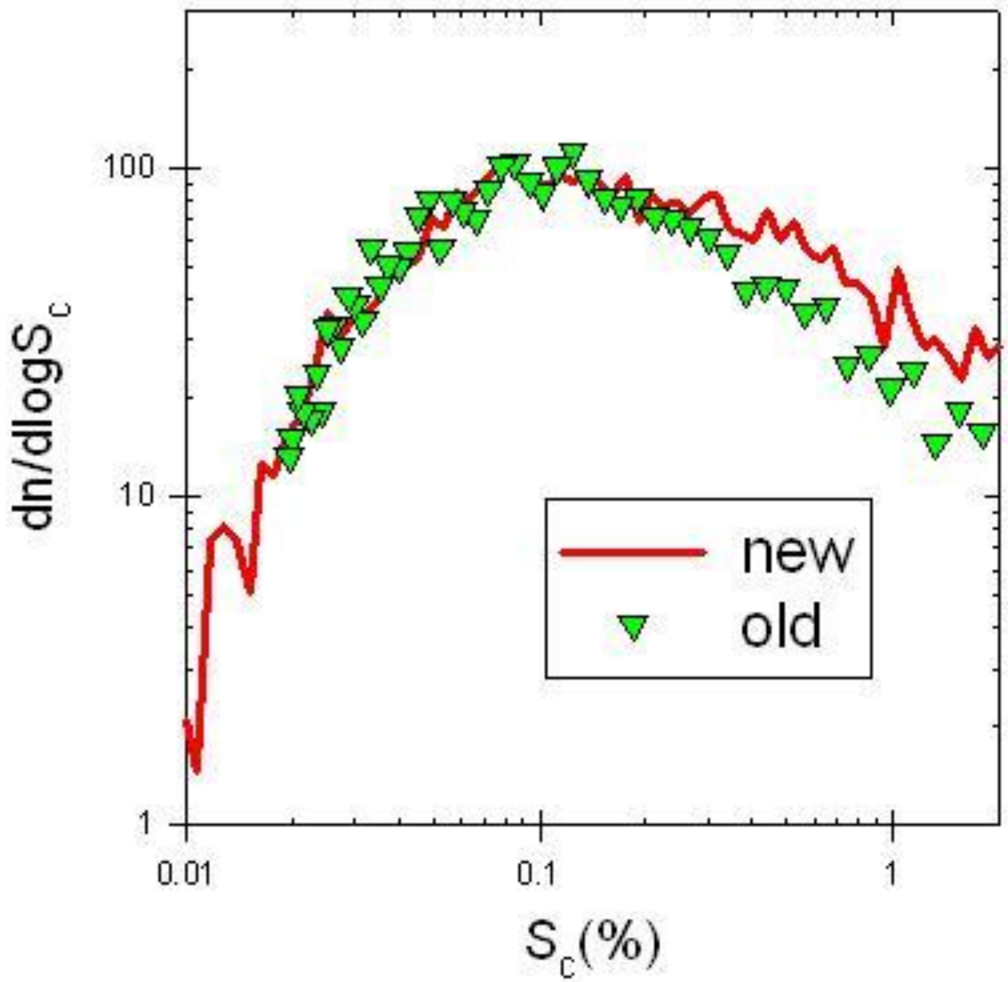
Comparisons of two CCN spectrometers operating at different supersaturation (S) ranges suggest validity over the full extended S range.

RF	date	comparisons	missing	score	
1.00	7.00	30.00	0.00	3.53	
2.00	8.00	13.00	15.00	3.69	
3.00	9.00	39.00	1.00	2.87	
4.00	10.00	29.00	41.00	2.45	
5.00	13.00	--	--	--	new not working
6.00	16.00				
7.00	17.00				
8.00	19.00	27.00	3.00	2.33	
9.00	20.00				
10.00	5.00				
11.00	7.00	31.00		3.39	
12.00	11.00	29.00	3.00	3.55	
13.00	12.00	46.00	0.00	3.63	
14.00	14.00	33.00	16.00	2.52	
15.00	16.00	64.00	0.00	3.36	
16.00	18.00				
17.00	19.00	35.00		2.66	
18.00	23.00	15.00	1.00	2.13	
19.00	24.00	23.00	0.00	1.91	

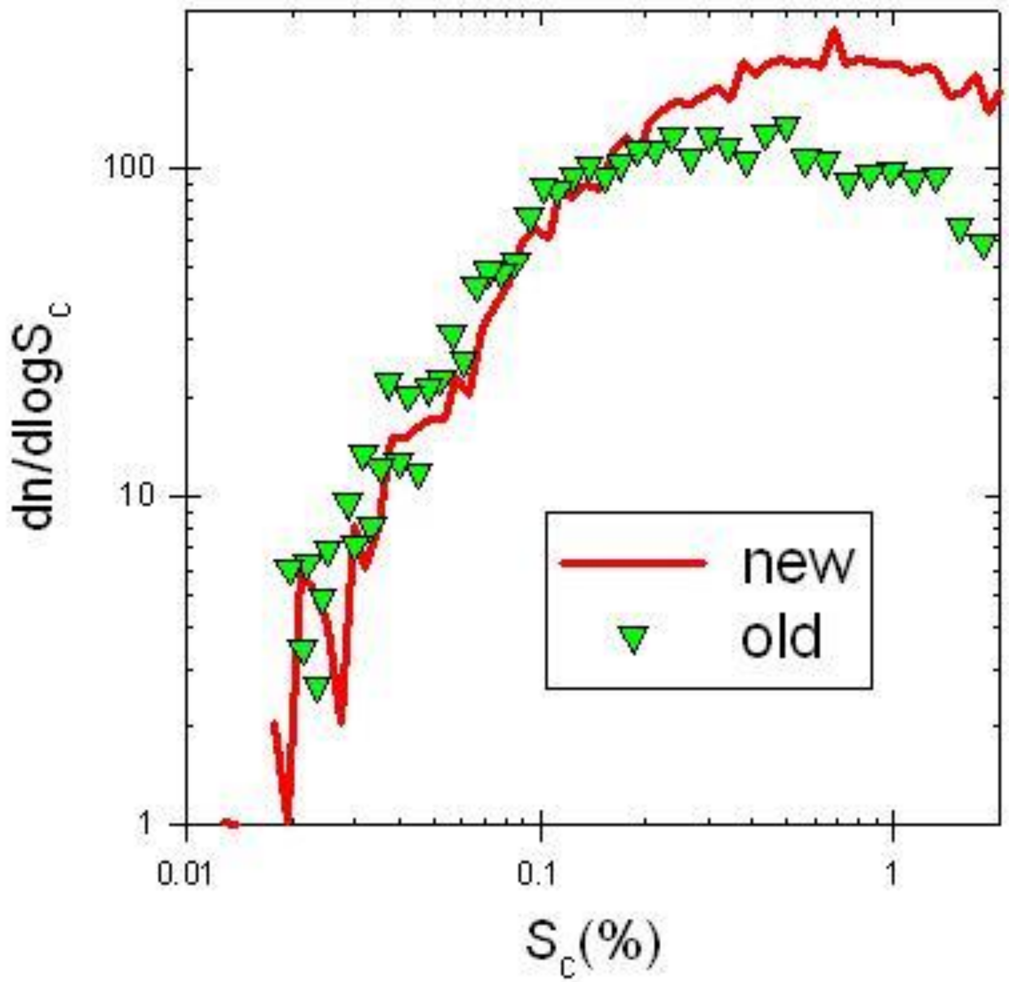
Jan. 12, 2005, 2018:00-2022:00
both spectrometers sampling ambient air
@ 932 mb pressure altitude
CN 171 cm^{-3} CCN @ 1% S 105 cm^{-3}



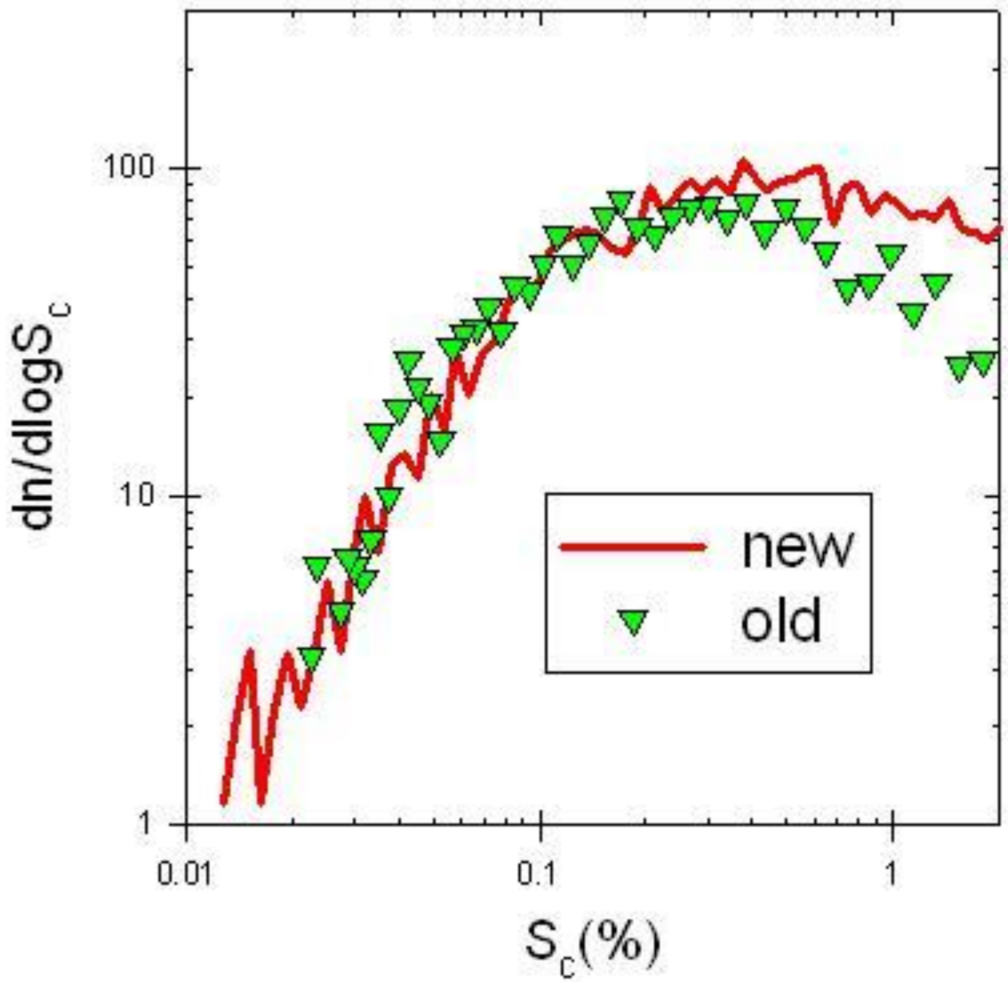
Jan. 12, 2005, 2122:00-2124:00
both spectrometers sampling ambient air
@ 970 mb pressure altitude
CN 198 cm^{-3} CCN @ 1% S   116 cm^{-3}



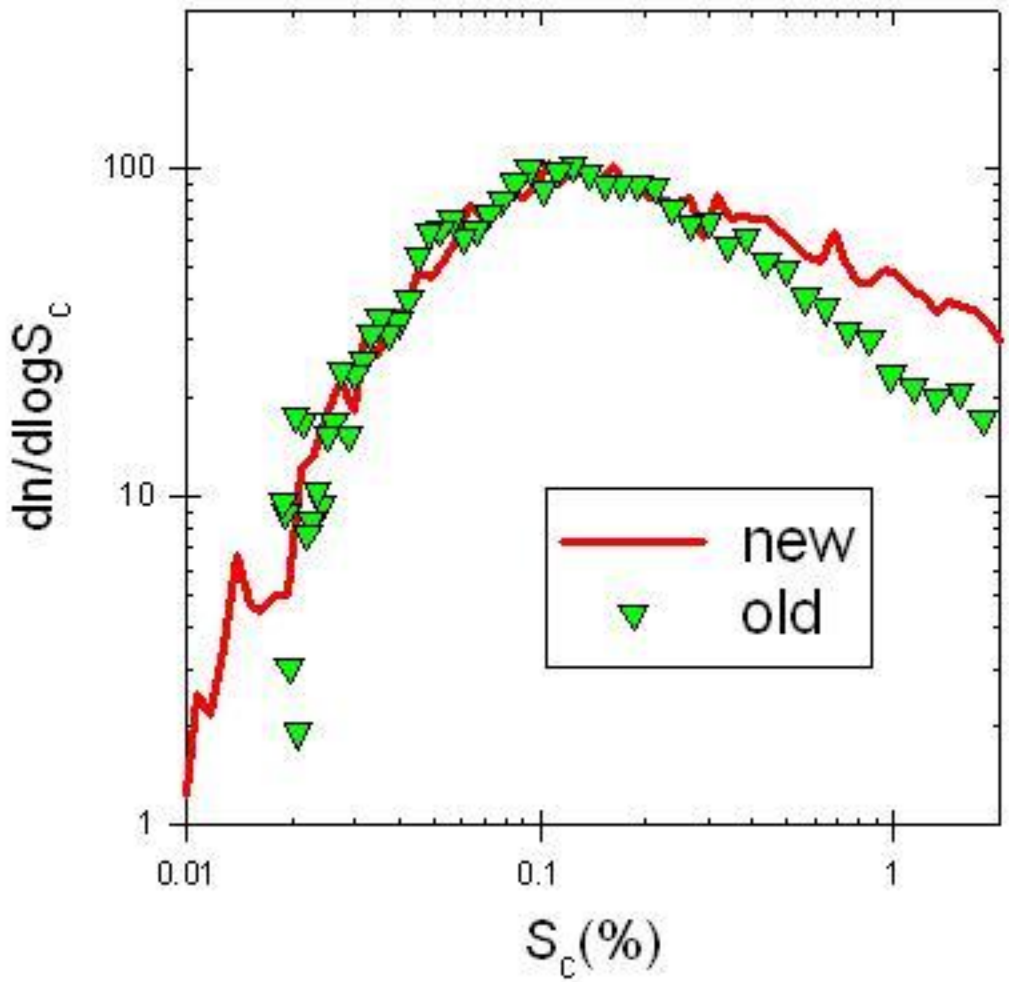
Jan. 12, 2005, 2202:30-2203:50
both spectrometers sampling ambient air
@ 535 mb pressure altitude
CN 610 cm^{-3} CCN @ 1% S 190 cm^{-3}



Jan. 12, 2005, 2231:00-2232:00
both spectrometers sampling ambient air
@ 794 mb pressure altitude
CN 290 cm^{-3} CCN @ 1% S 98 cm^{-3}



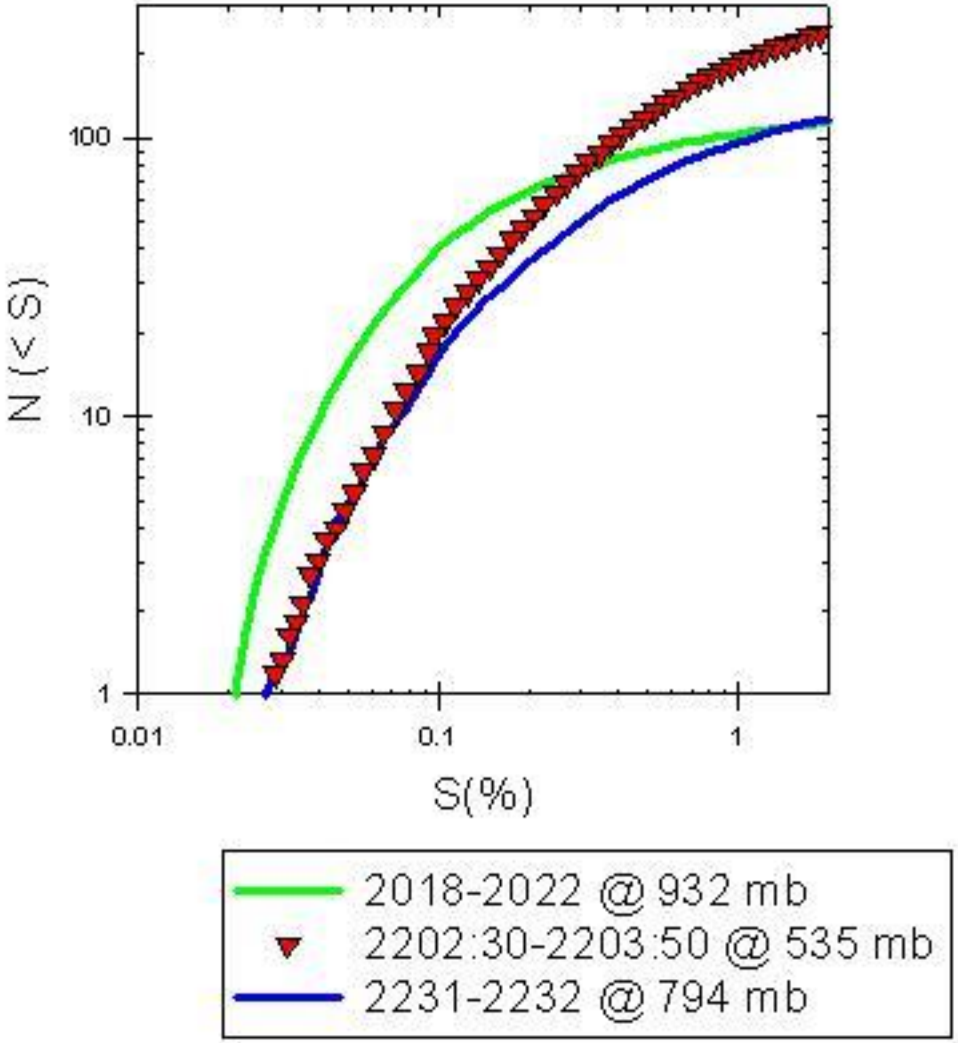
Jan. 12, 2005, 2243:00-2245:30
both spectrometers sampling ambient air
@ 961 mb pressure altitude
CN 287 cm^{-3} CCN @ 1% S   111 cm^{-3}

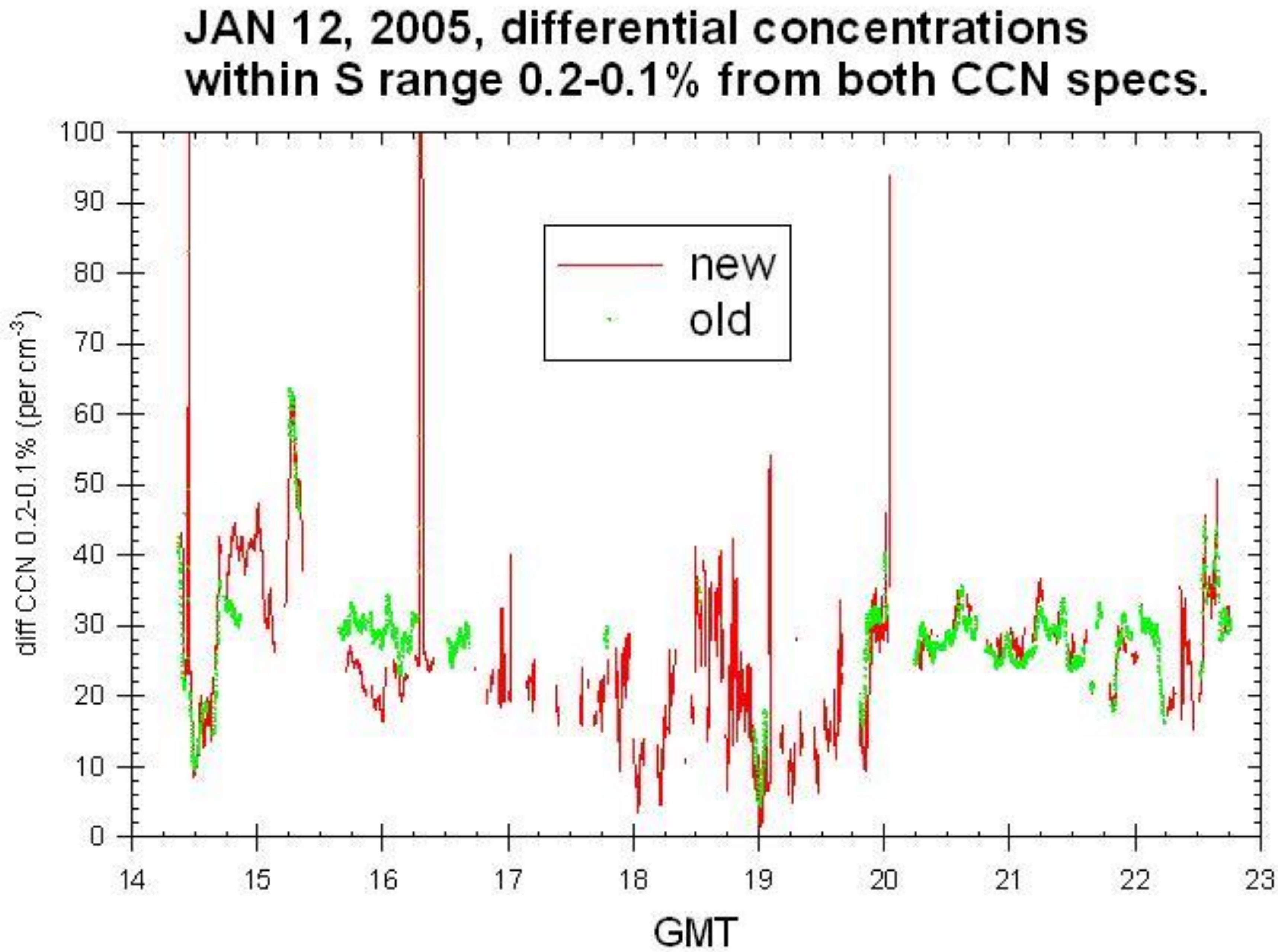


Jan. 12, 2005,
cumulative composite

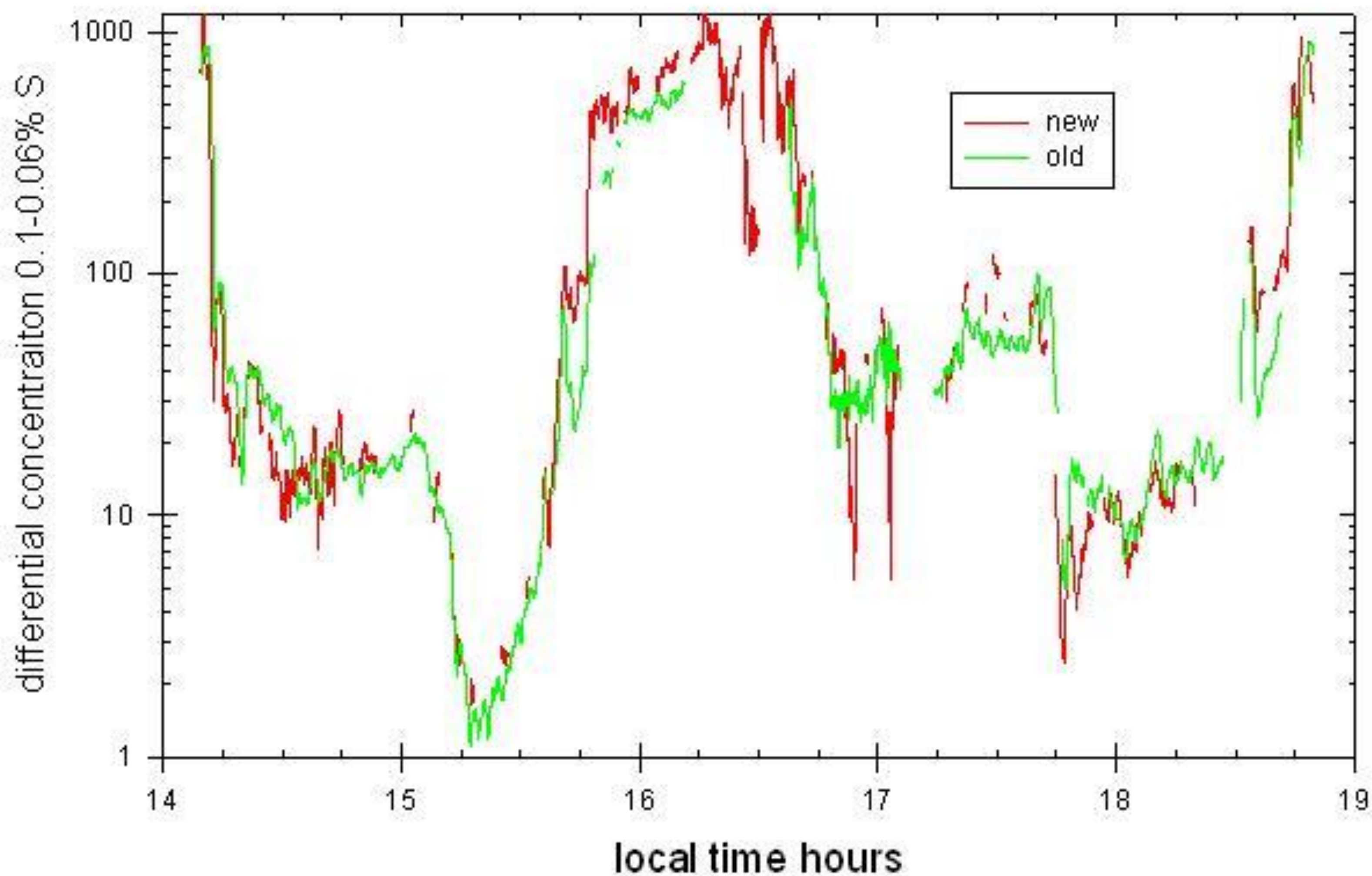
CN 171, 610, 290 cm^{-3}

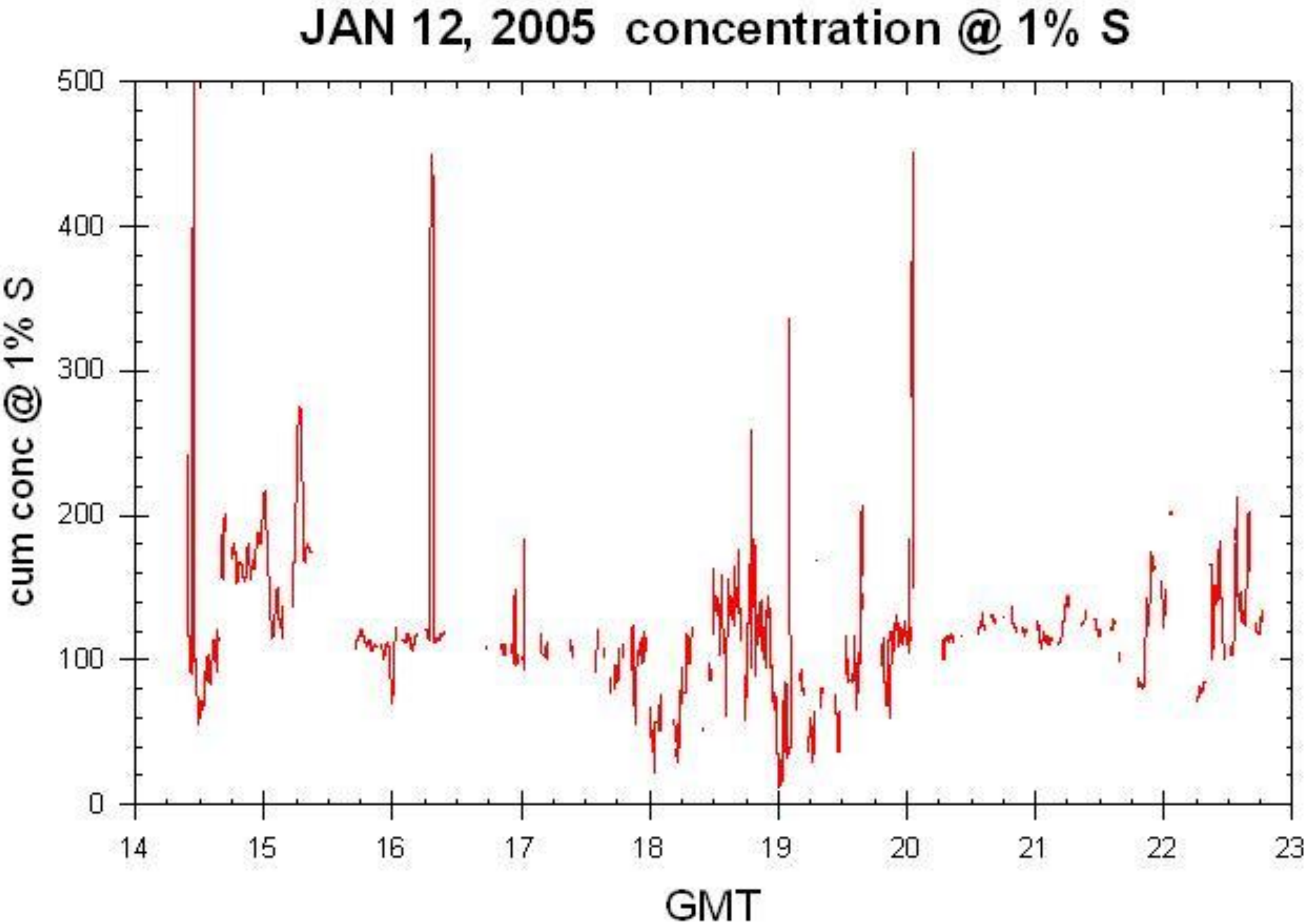
CCN @ 1% S 105, 190, 98 cm^{-3}

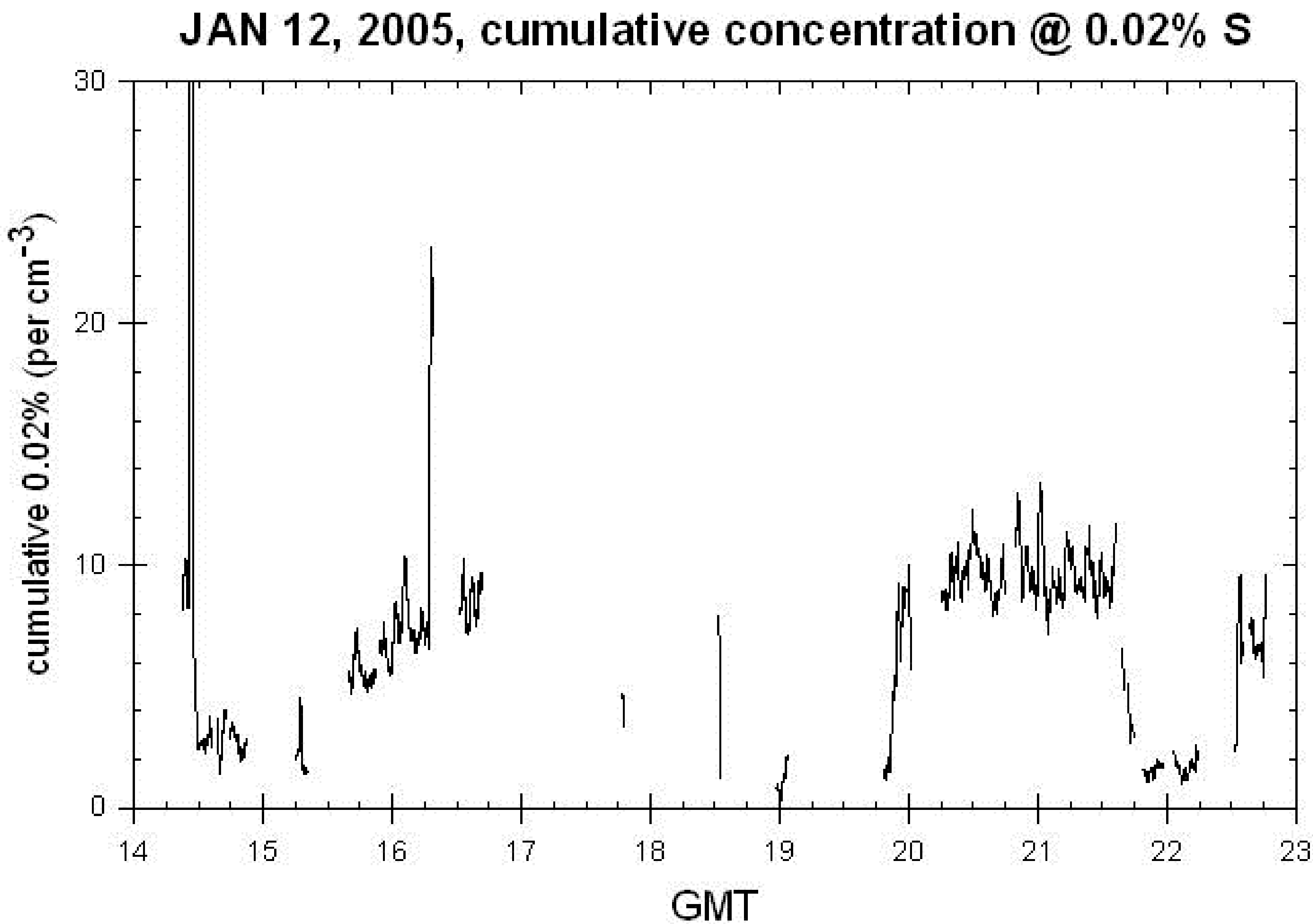


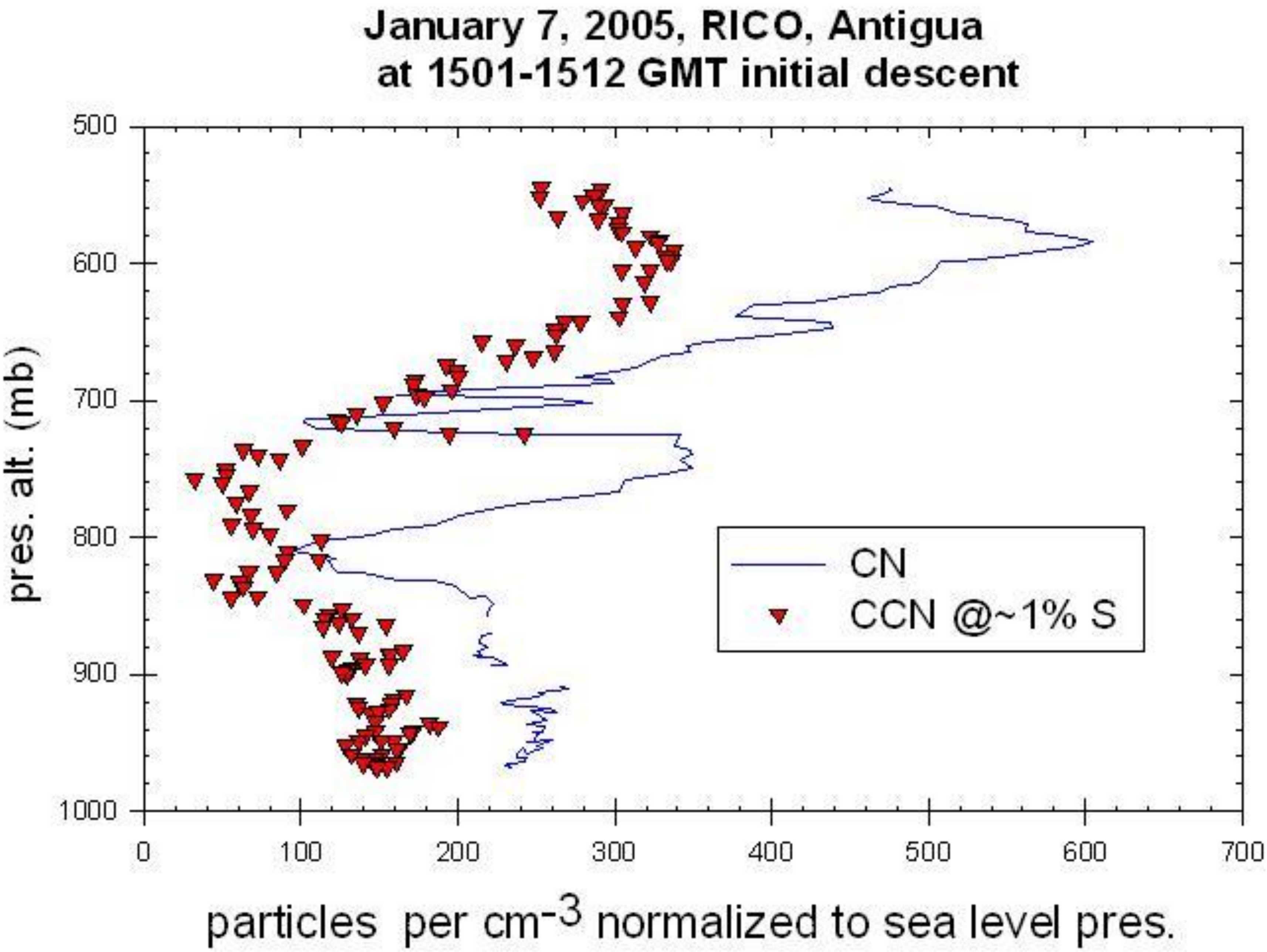

JAN 12, 2005, differential concentrations
within S range 0.2-0.1% from both CCN specs.
new
old
diff CCN 0.2-0.1% (per cm-3)
GMT
0
10
20
30
40
50
60
70
80
90
100
14
15
16
17
18
19
20
21
22
23

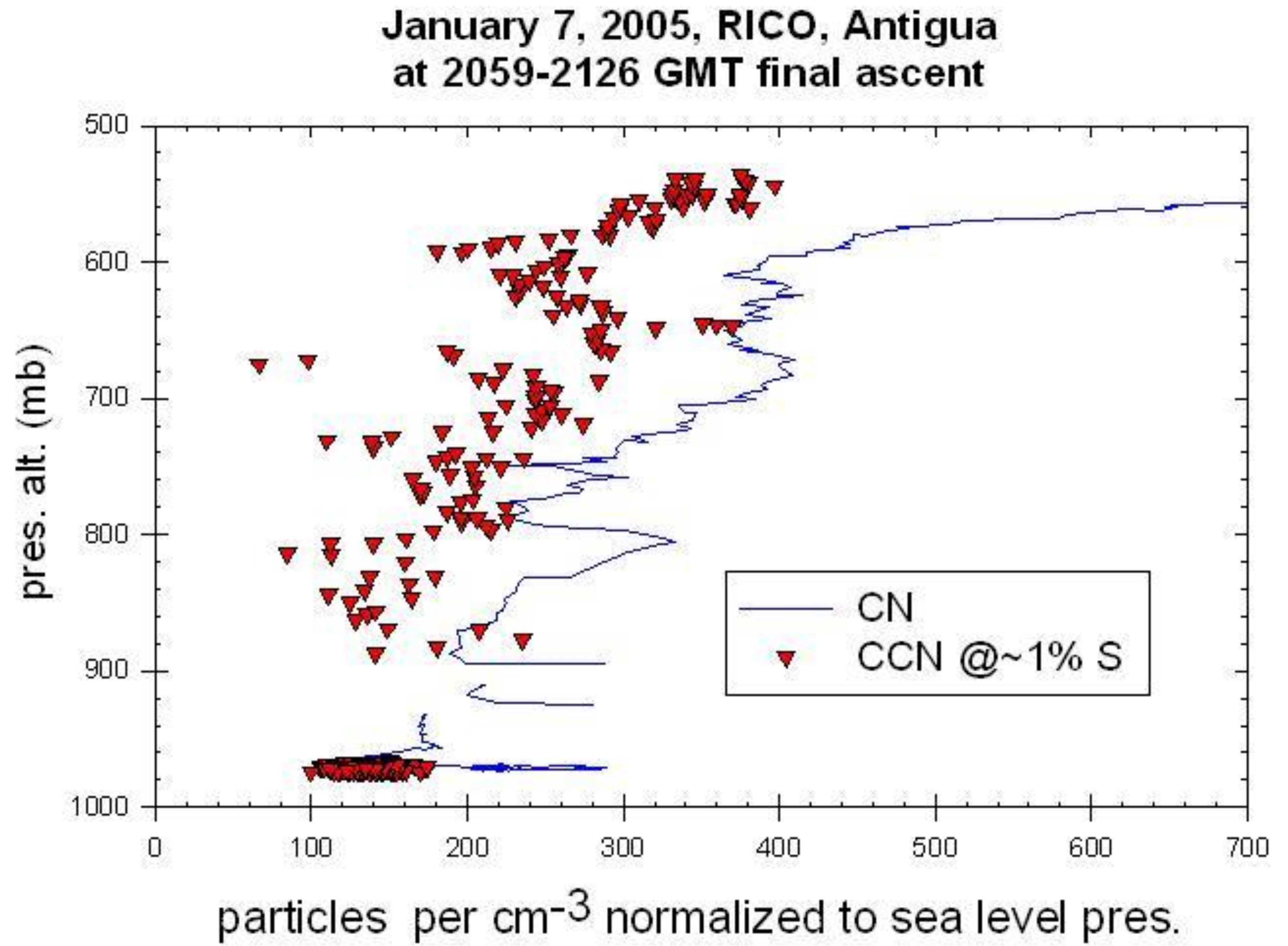
Nov 10, 2003, AIRS-2, Cleveland comparison
running average of 19 records



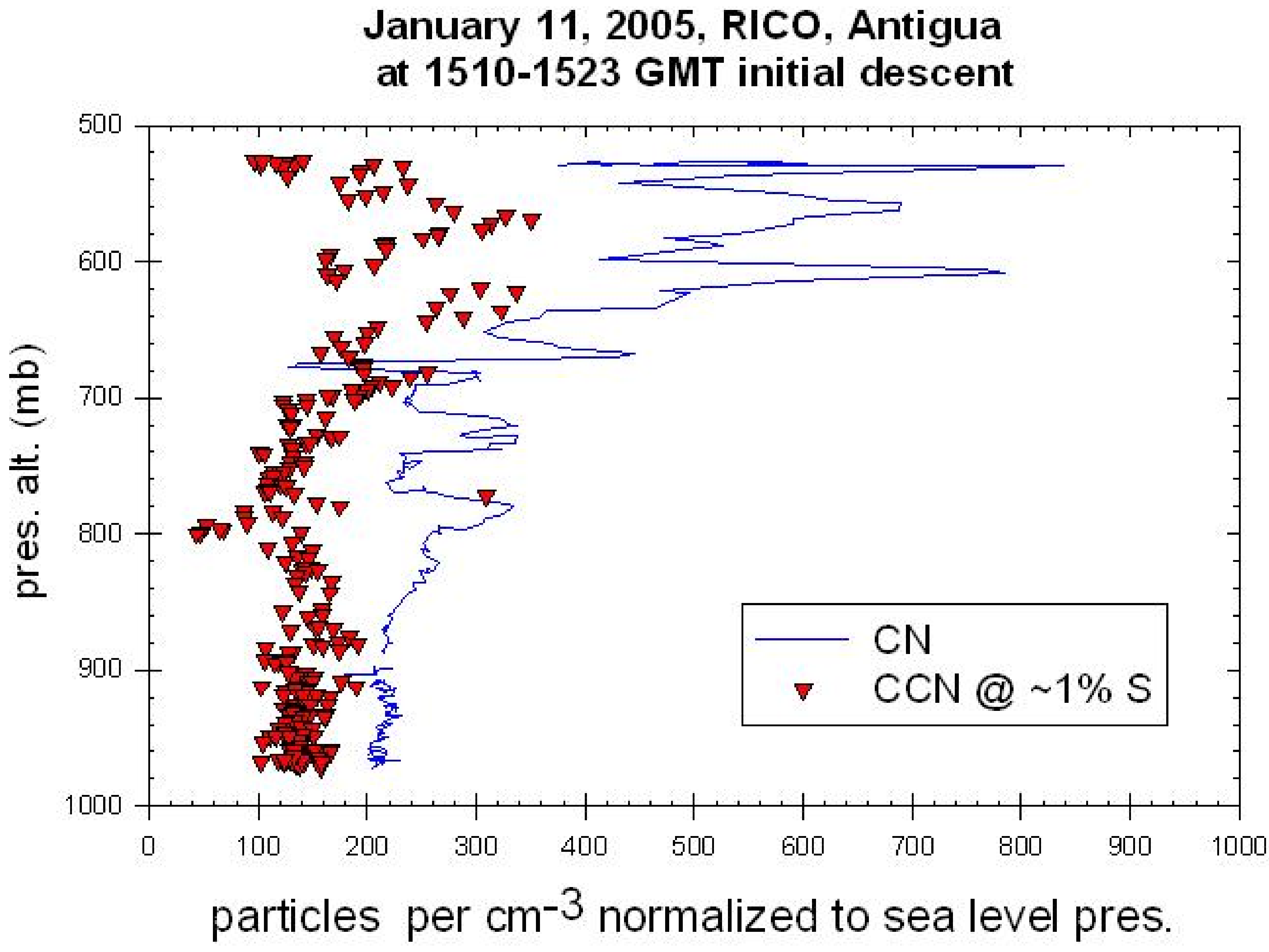

JAN 12, 2005 concentration @ 1% S
cum conc @ 1% S
500
400
300
200
100
0
14
15
16
17
18
19
20
21
22
23
GMT

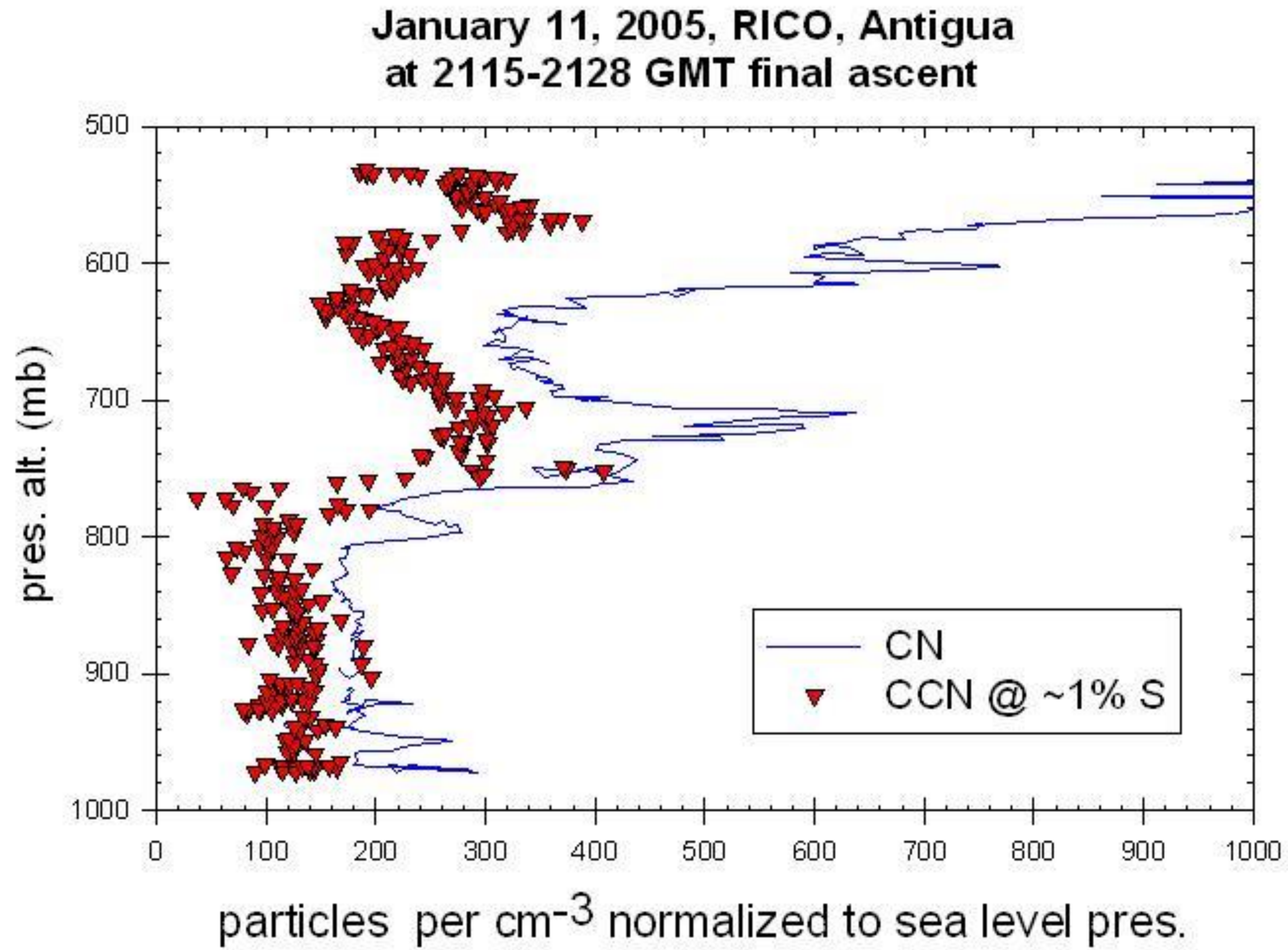

JAN 12, 2005, cumulative concentration @ 0.02% S
cumulative 0.02% (per cm-3)
0
10
20
30
14
15
16
17
18
19
20
21
22
23
GMT


January 7, 2005, RICO, Antigua
at 1501-1512 GMT initial descent
pres. alt. (mb)
500
600
700
800
900
1000
0
100
200
300
400
500
600
700
particles per cm-3 normalized to sea level pres.
CN
CCN @~1% S

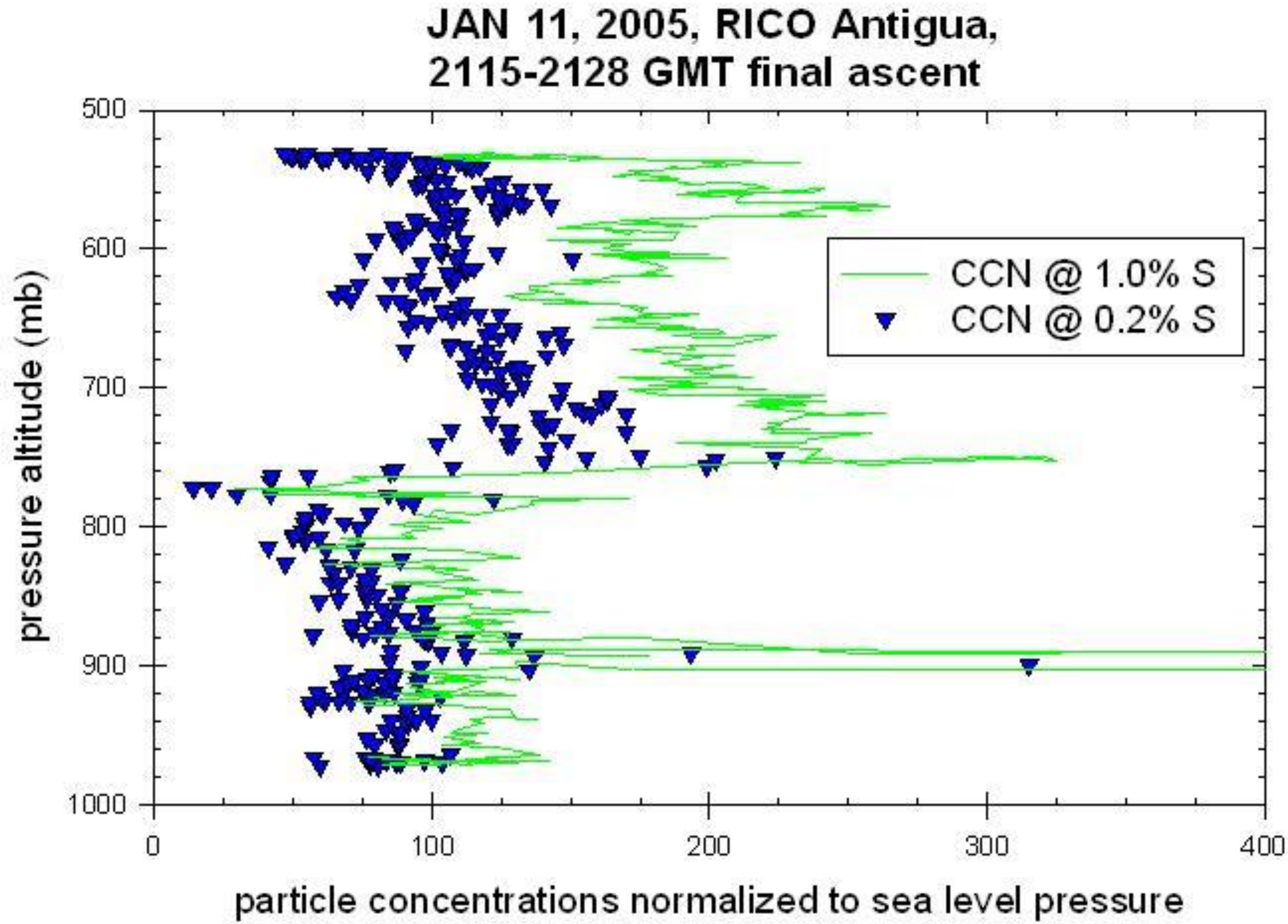


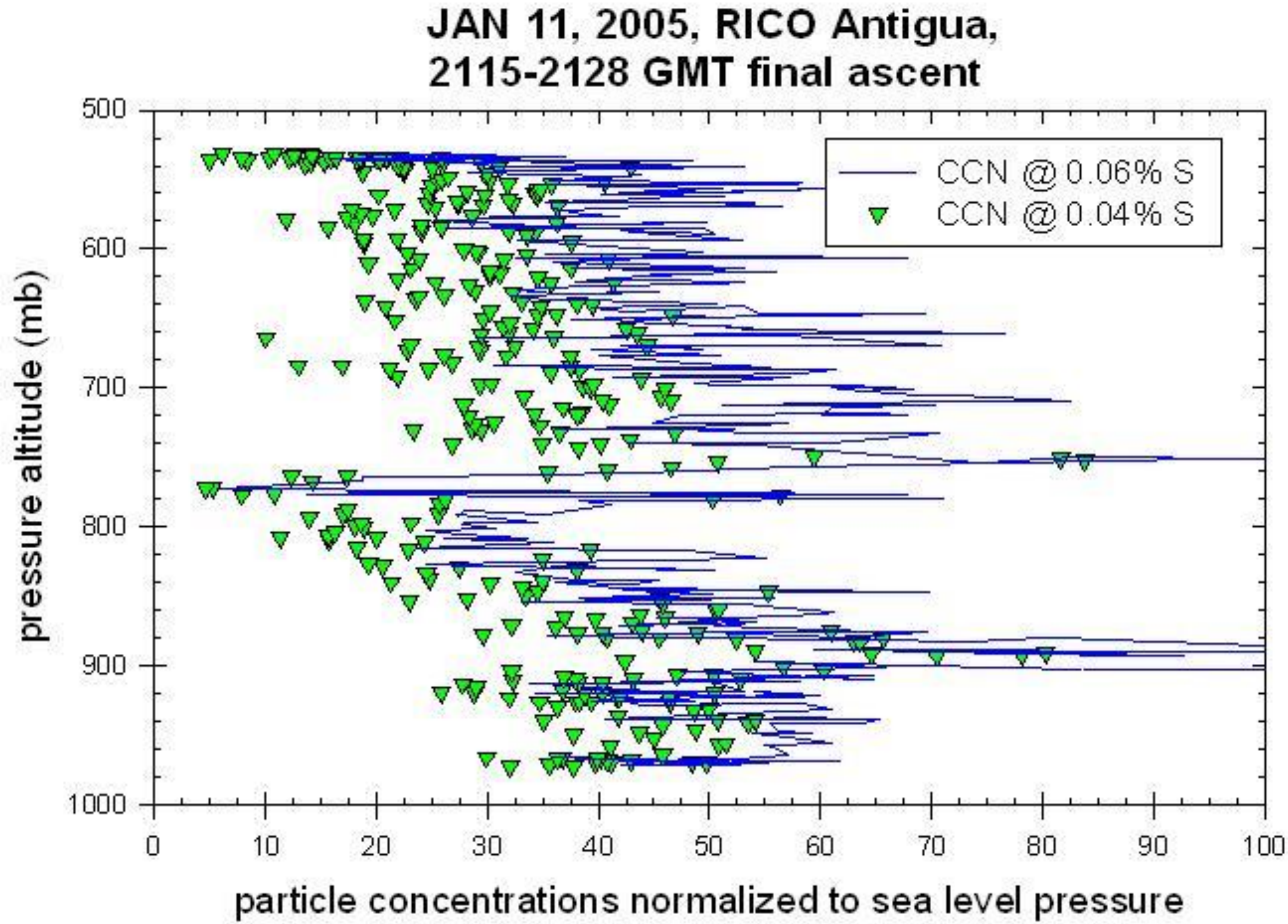
January 7, 2005, RICO, Antigua
at 2059-2126 GMT final ascent
pres. alt. (mb)
500
600
700
800
900
1000
0
100
200
300
400
500
600
700
particles per cm-3 normalized to sea level pres.
CN
CCN @~1% S

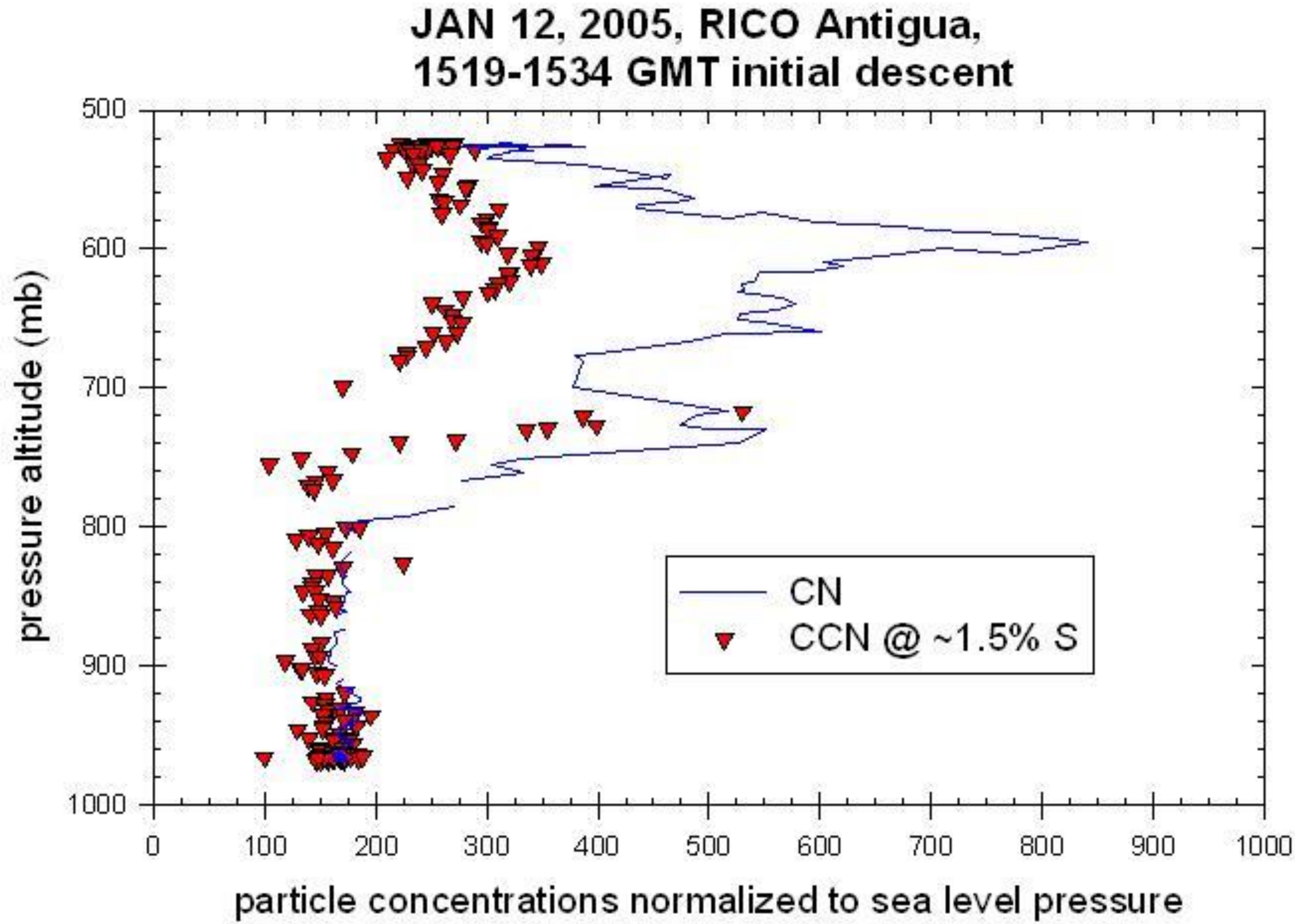

January 11, 2005, RICO, Antigua
at 1510-1523 GMT initial descent
pres. alt. (mb)
500
600
700
800
900
1000
0
100
200
300
400
500
600
700
800
900
1000
particles per cm-3 normalized to sea level pres.
CN
CCN @ ~1% S

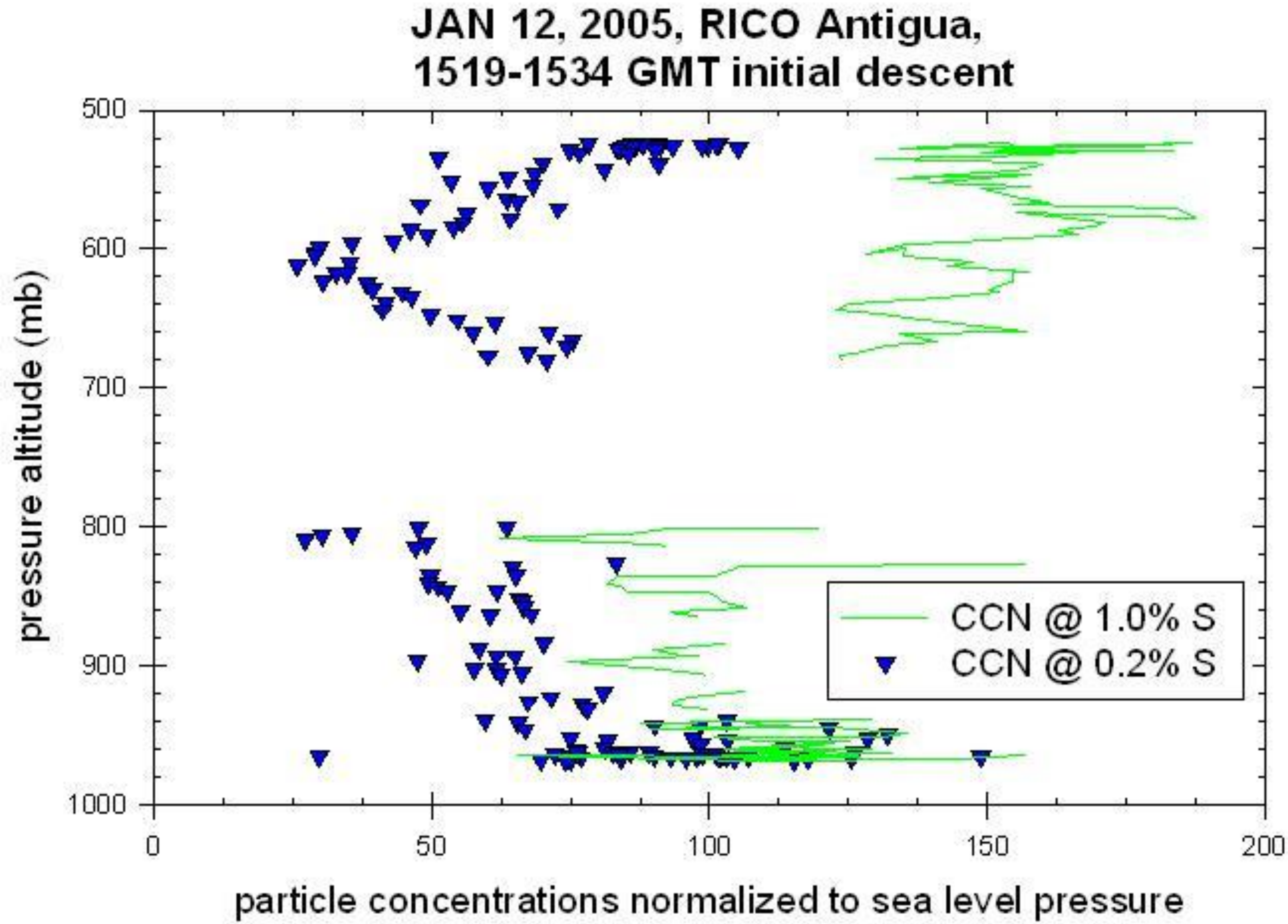


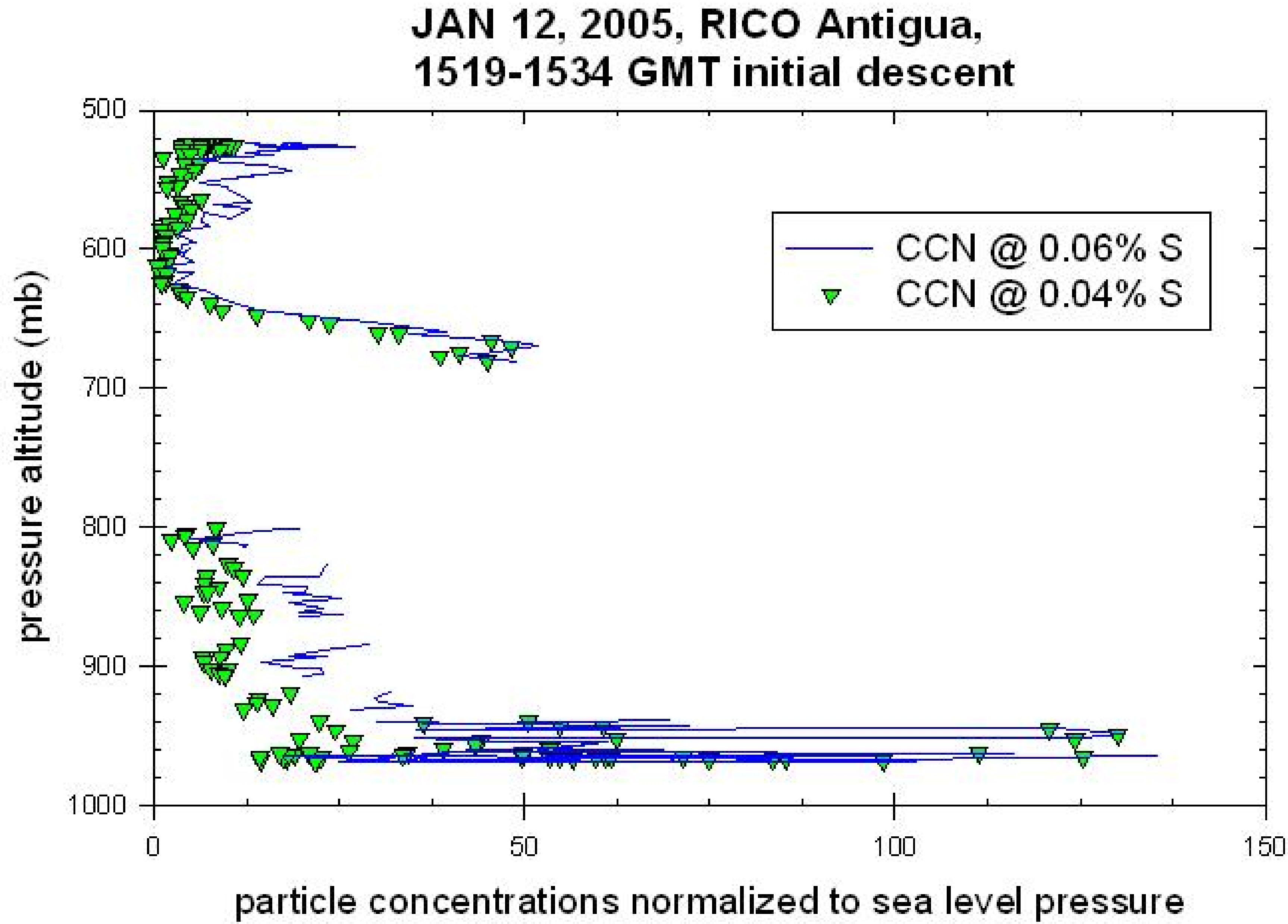
January 11, 2005, RICO, Antigua
at 2115-2128 GMT final ascent
pres. alt. (mb)
500
600
700
800
900
1000
0
100
200
300
400
500
600
700
800
900
1000
particles per cm-3 normalized to sea level pres.
CN
CCN @ ~1% S

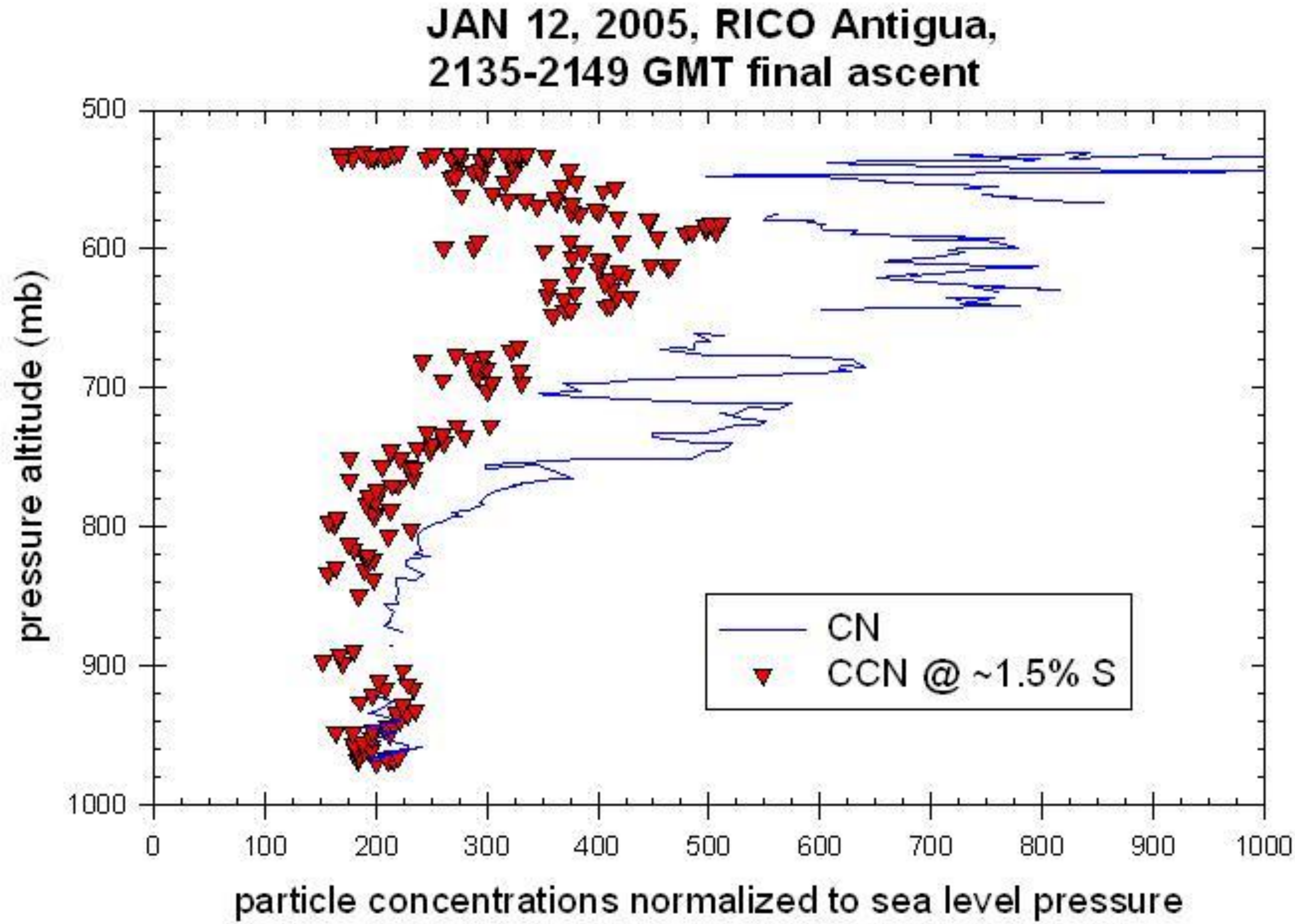

JAN 11, 2005, RICO Antigua,
2115-2128 GMT final ascent
pressure altitude (mb)
500
600
700
800
900
1000
0
100
200
300
400
particle concentrations normalized to sea level pressure
CCN @ 1.0% S
CCN @ 0.2% S

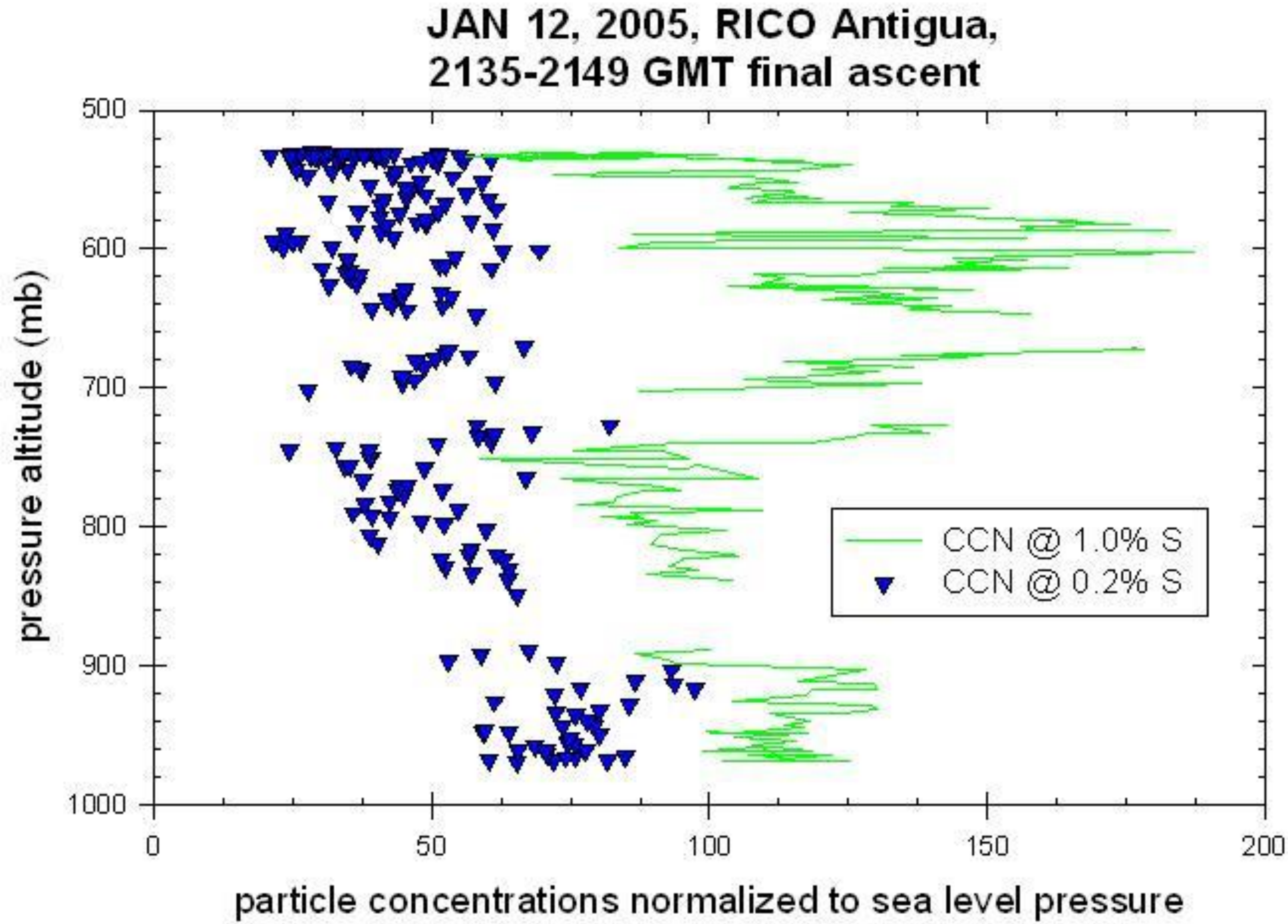

JAN 11, 2005, RICO Antigua,
2115-2128 GMT final ascent
CCN @ 0.06% S
CCN @ 0.04% S
pressure altitude (mb)
500
600
700
800
900
1000
0
10
20
30
40
50
60
70
80
90
100
particle concentrations normalized to sea level pressure

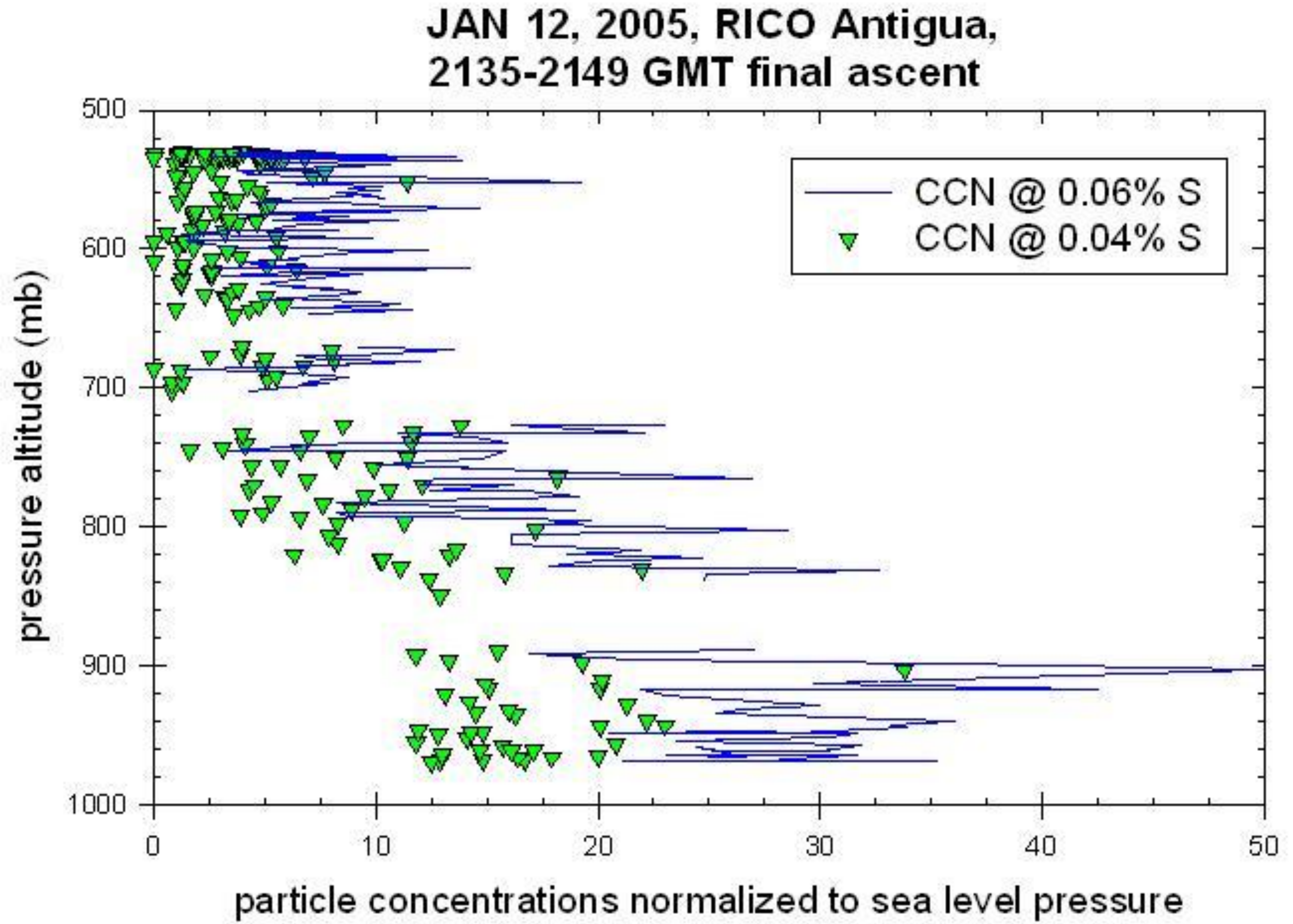

JAN 12, 2005, RICO Antigua,
1519-1534 GMT initial descent
pressure altitude (mb)
500
600
700
800
900
1000
0
100
200
300
400
500
600
700
800
900
1000
particle concentrations normalized to sea level pressure
CN
CCN @ ~1.5% S


JAN 12, 2005, RICO Antigua,
1519-1534 GMT initial descent
pressure altitude (mb)
500
600
700
800
900
1000
0
50
100
150
200
particle concentrations normalized to sea level pressure
CCN @ 1.0% S
CCN @ 0.2% S

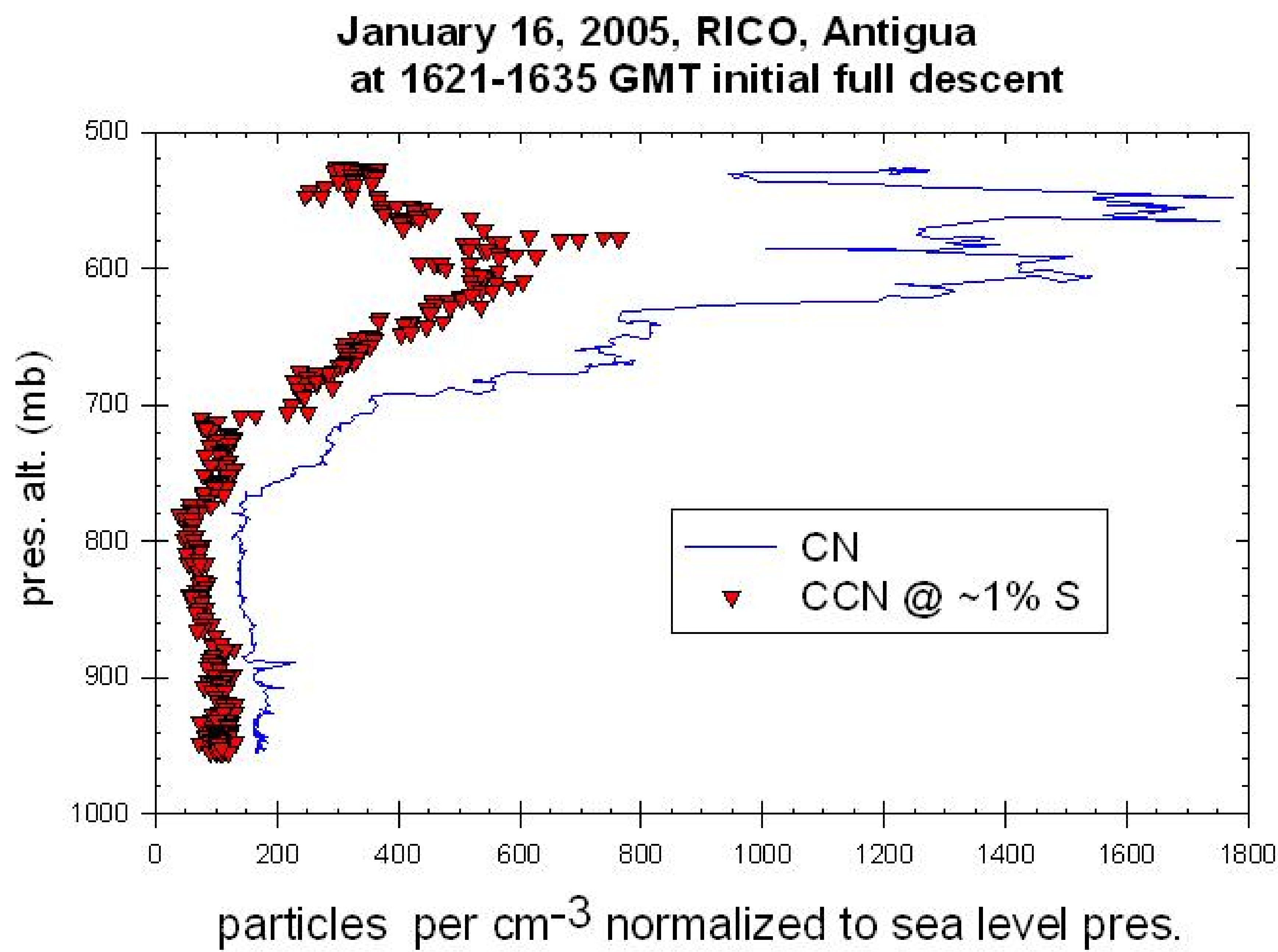

JAN 12, 2005, RICO Antigua,
1519-1534 GMT initial descent
pressure altitude (mb)
500
600
700
800
900
1000
0
50
100
150
particle concentrations normalized to sea level pressure
CCN @ 0.06% S
CCN @ 0.04% S

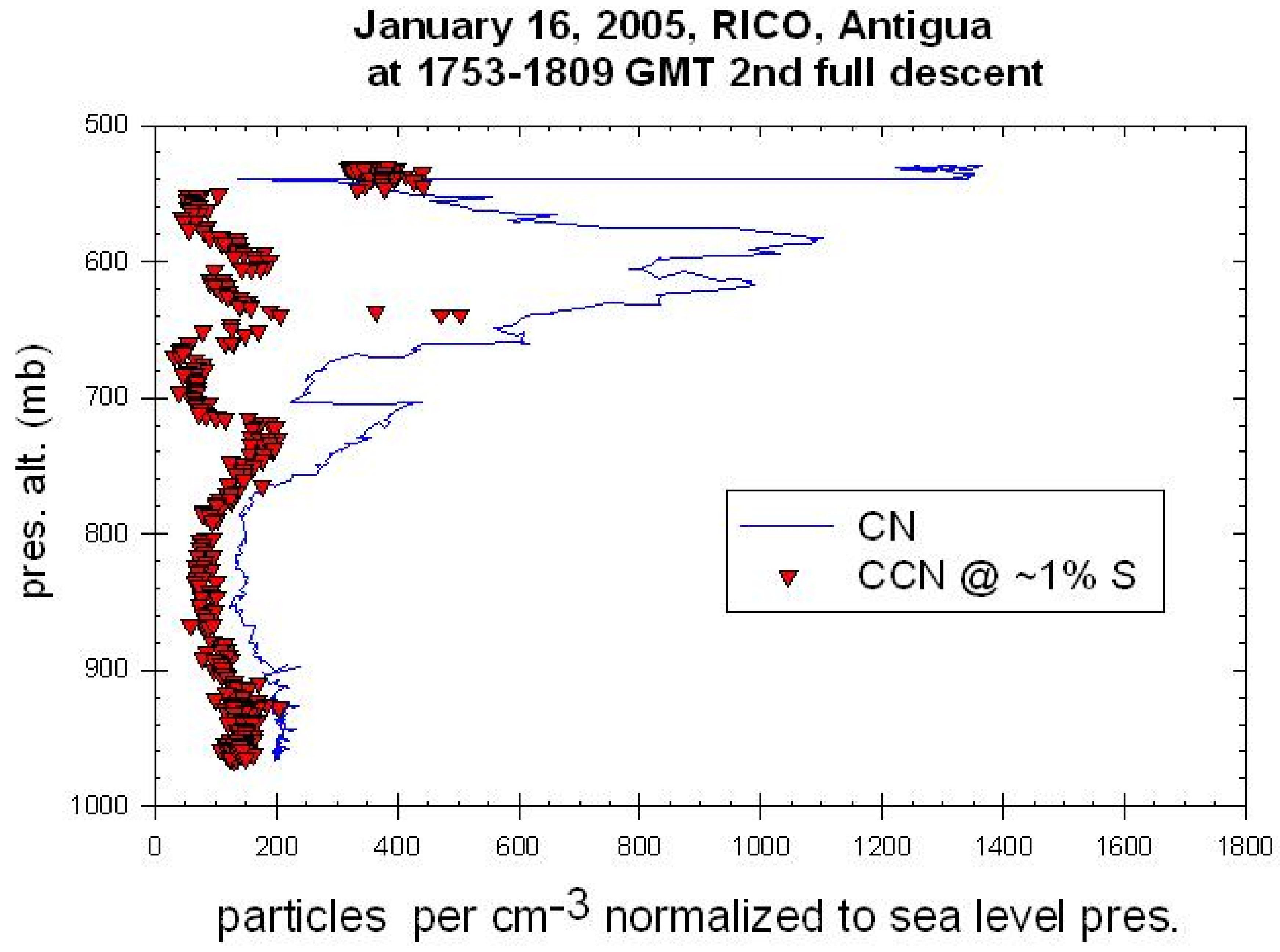

JAN 12, 2005, RICO Antigua,
2135-2149 GMT final ascent
pressure altitude (mb)
500
600
700
800
900
1000
0
100
200
300
400
500
600
700
800
900
1000
particle concentrations normalized to sea level pressure
CN
CCN @ ~1.5% S

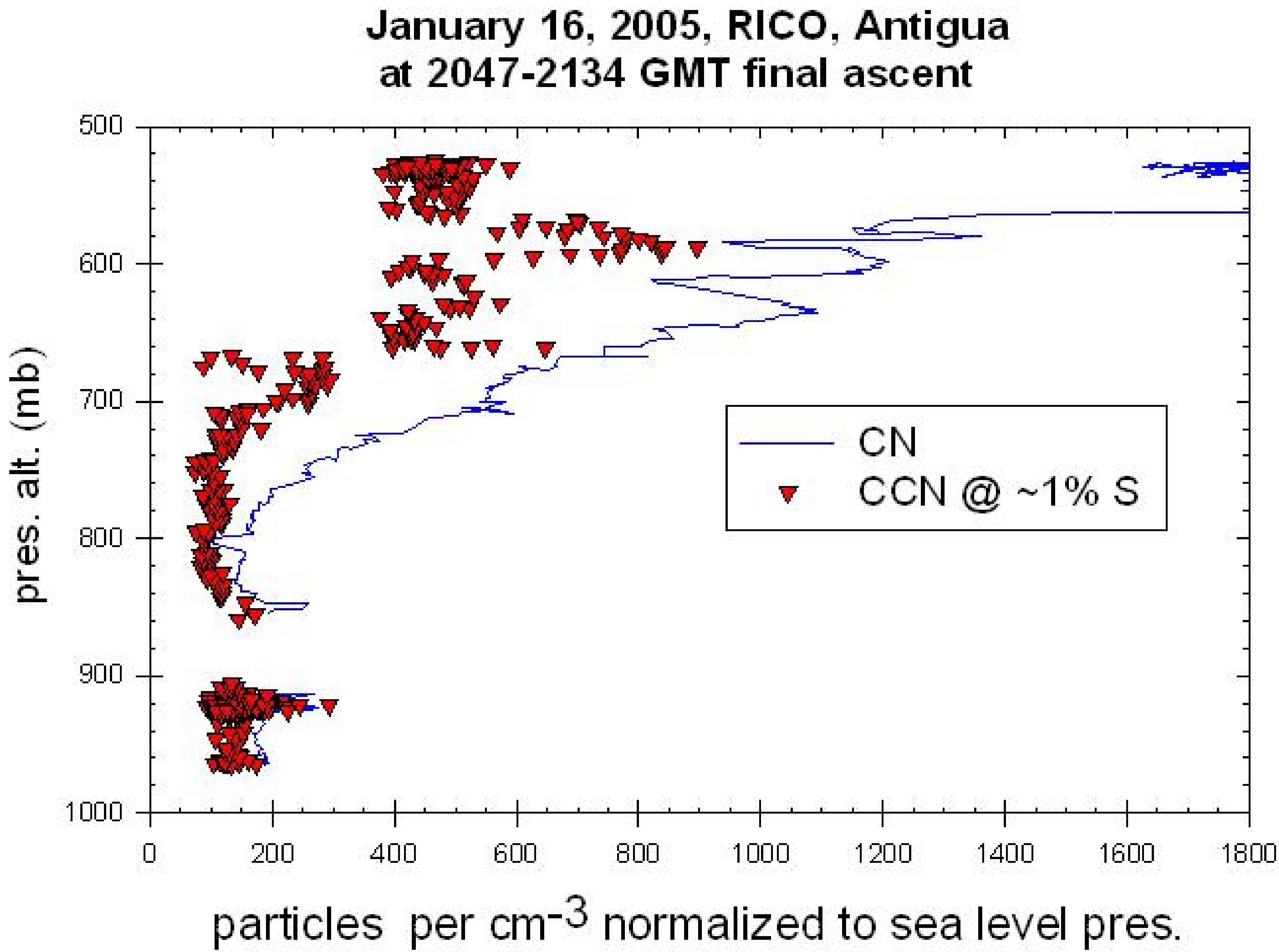

JAN 12, 2005, RICO Antigua,
2135-2149 GMT final ascent
pressure altitude (mb)
500
600
700
800
900
1000
0
50
100
150
200
particle concentrations normalized to sea level pressure
CCN @ 1.0% S
CCN @ 0.2% S



JAN 12, 2005, RICO Antigua,
2135-2149 GMT final ascent
CCN @ 0.06% S
CCN @ 0.04% S
pressure altitude (mb)
500
600
700
800
900
1000
0
10
20
30
40
50
particle concentrations normalized to sea level pressure


January 16, 2005, RICO, Antigua
at 1621-1635 GMT initial full descent
pres. alt. (mb)
500
600
700
800
900
1000
0
200
400
600
800
1000
1200
1400
1600
1800
particles per cm-3 normalized to sea level pres.
CN
CCN @ ~1% S


January 16, 2005, RICO, Antigua
at 1753-1809 GMT 2nd full descent
pres. alt. (mb)
500
600
700
800
900
1000
0
200
400
600
800
1000
1200
1400
1600
1800
particles per cm-3 normalized to sea level pres.
CN
CCN @ ~1% S


January 16, 2005, RICO, Antigua
at 2047-2134 GMT final ascent
pres. alt. (mb)
500
600
700
800
900
1000
0
200
400
600
800
1000
1200
1400
1600
1800
particles per cm-3 normalized to sea level pres.
CN
CCN @ ~1% S