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Informal Report

REPORT ON INTERCOMPARISONS OF CONDENSATION NUCLEUS COUNTER MEASUREMENTS DURING THE ACE-1 INTENSIVE STUDY

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ABSTRACT

This report summarizes findings from intercomparisons of aerosol particle concentrations measured by condensation nucleus counters (CNC's) on various platforms and ground-based stations during the Southern Hemisphere Marine Aerosol Characterization Experiment (ACE-1). Five CNC's on the NCAR C-130 are intercompared. The C-130 CNC's are then intercompared to ship and ground-based measurements during periods of C-130 overflights.

1. Intercomparison of C-130 CNC's

Five flights where aerosol particle concentrations spanned the range of conditions encountered during ACE-1 were used for the C-130 CNC intercomparison. The flights considered for this study were, 16, 17, 21, 22 and 27. All were part of the ACE-1 intensive based at Hobart, Tasmania. The data were carefully screened in an attempt to remove all anomalous particle concentrations from shatter of water droplets at sampling inlets. The five CNC's included in the C-130 intercomparison include two UCNC's, a TSI 3025 and the prototype of this instrument, the PHA UCNC, two TSI model 3010 CNC's, and a TSI 3760 CNC. All concentrations reported here are at the altitude of the measurement. The particle size-dependent counting efficiencies of the various CNC's were measured prior to the ACE-1 study and the results reported by Wiedensohler et al. [1977]. The various CNC's, acronyms and counting efficiencies are given in Appendix A. All C-130 CNC's, except the RAF 3076, sampled from the community aerosol inlet.

Time Series Plots. Figure 1 shows the time series plot for a period of "clean" conditions during Flight 22. Figure 1a compares the PHA UCNC and the UH 3025 UCNC. Figure 1b compares the other three CNC's; UH 3010, RAF 3760, and DRI 3010. The UCNC's are in good agreement. The other three CNC's track well but the concentrations are offset. Figure 2a and 2b show the same comparisons but for a period of high particle concentrations. These measurements were made in a region of cloud venting where concentrations of nanoparticles (3 to 10 nm diameter) were also high. In this case, during periods of high concentrations, the PHA UCNC tended to be higher than the UH 3025 UCNC. Figure 2b again shows some evidence of an offset between the other three CNC's.

Correlation Coefficients: Tables 1 and 2 give the correlation coefficients (Pearson Product Moment Coefficient of Correlation) for the five CNC's on the C-130 for flights 16, 17, 21, 22, and 27. Table 1 is for all data and Table 2 for a period when practically no nanoparticles were present. Periods of zero or low nanoparticle concentrations were determined from the PHA UCNC measurements of nominally 3 to 4 nm diameter particle concentrations, referred to here as $\tilde{N}$(3-4nm). This measurement was used due to it's high sensitivity for measuring nanoparticles. Table 2 includes only periods when $\tilde{N}$(3-4nm) was less than 0.1 cm^{-3}. Generally, the CNC's were better correlated when few nanoparticles were present. At these times, differences in CNC lower detection limits would not influence the measurements. Note that in both tables the best correlation was between the two University of Hawaii (UH) instruments. These CNC's sampled from the same line suggesting that much of the scatter in the measurements was due to sampling differences.

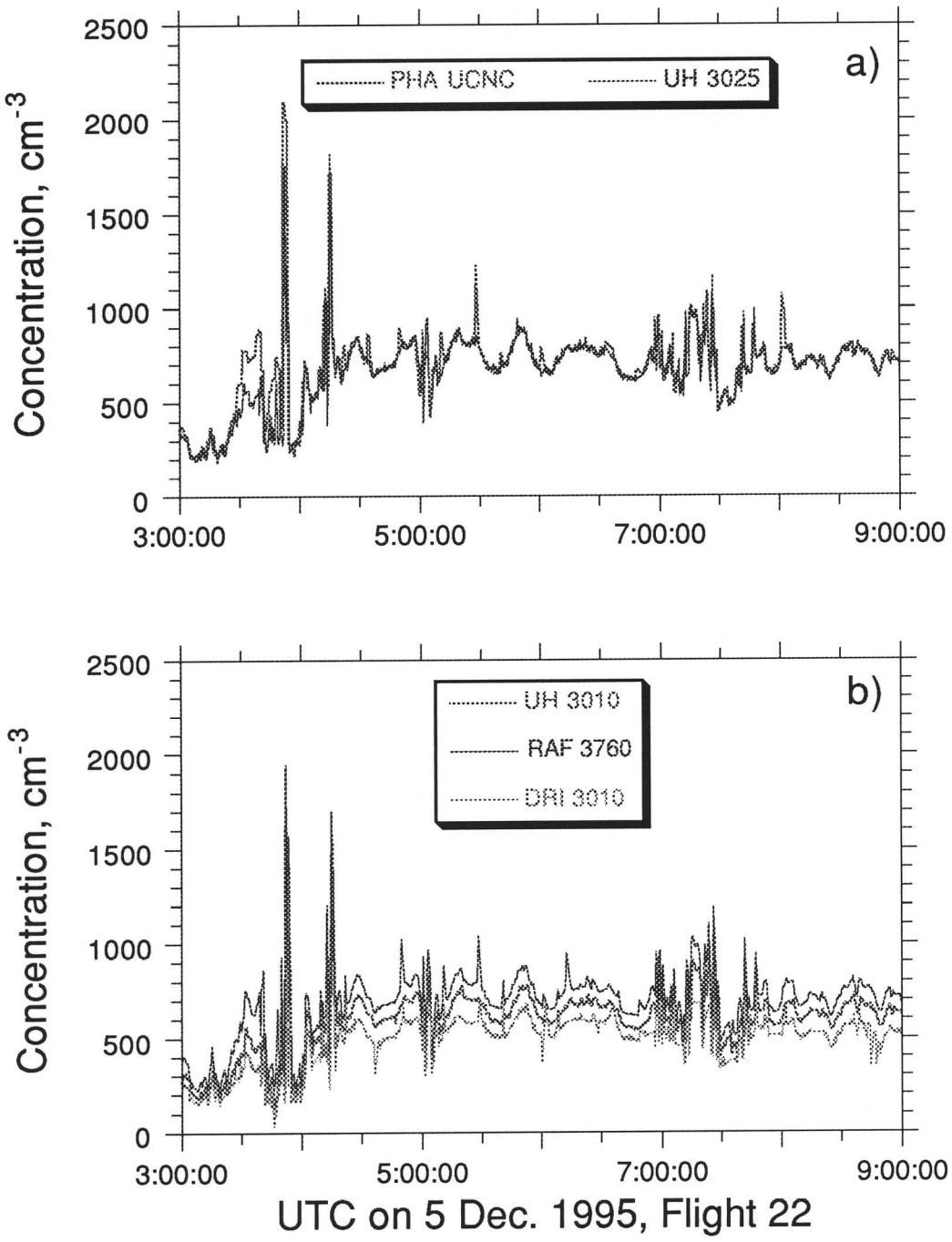

Figure 1: Comparison of C-130 CNC measurements during a period of relatively low particle conditions.

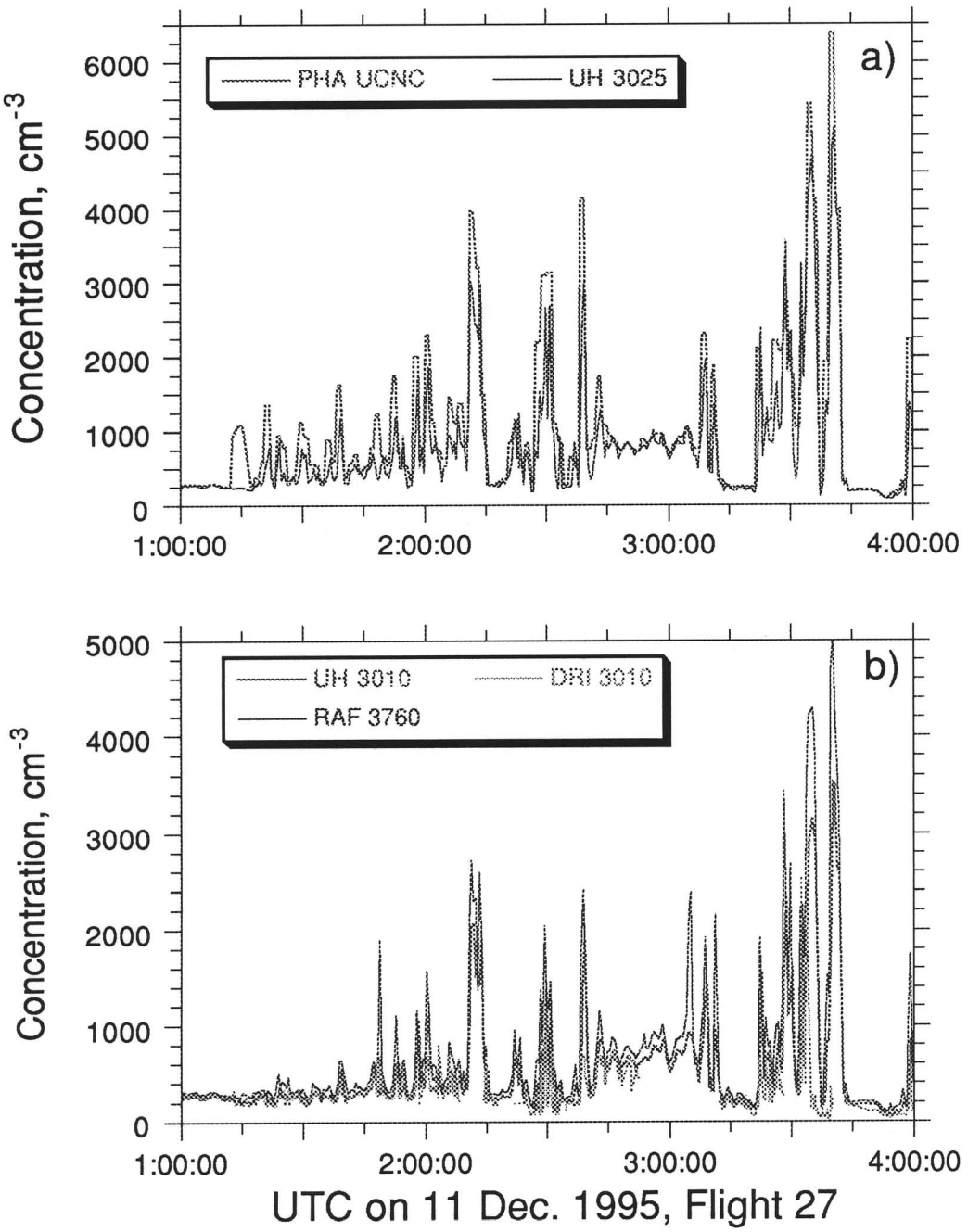

Figure 2: Comparison of C-130 CNC measurements made in regions of cloud venting. These were regions of high total particle and nanoparticle (3-10 nm) concentrations.

Table 1: Correlation Coefficients For All Data for Flights 16, 17, 21, 22, 27

	PHA UCNC	UH 3025	RAF 3760	UH 3010	DRI 3010
PHA UCNC	1				
UH 3025	0.873	1			
RAF 3760	0.854	0.893	1		
UH 3010	0.807	0.927	0.894	1	
DRI 3010	0.285	0.372	0.369	0.482	1

Table 2: Correlation Coefficients For $\tilde{N}(3\text{-}4nm) < 0.1\ cm^{-3}$ for Flights 16, 17, 21, 22, 27

	PHA UCNC	UH 3025	RAF 3076	UH 3010	DRI 3010
PHA UCNC	1				
UH 3025	0.911	1			
RAF 3760	0.928	0.935	1		
UH 3010	0.903	0.995	0.931	1	
DRI 3010	0.874	0.899	0.887	0.897	1

Distributions of Measurements for C-130 CNC's: In this analysis the distributions of CNC measurements for Flights 16, 17, 21, 22, and 27 were analyzed for three different conditions: all data, periods of low nanoparticle concentrations and periods of high nanoparticle concentrations. Figure 3 shows the percentile plots for the various CNC's for all data. For each CNC, the bottom and top of the box represent 5% and 95% of the measured concentrations. The middle dotted line is the median particle concentration (the value is also given) and the lower and upper dotted lines show the range from 25% to 75% of the data. Figure 4 is a percentile plot for low nanoparticle concentrations ($\tilde{N}(3\text{-}4nm) < 0.1\ cm^{-3}$) and Figure 5 are periods when the University of Hawaii CNC's indicated that the number of particles between 3 and 10 nm were larger than the total CN (Dp>10 nm) concentration, (i.e., UH: $\{N_{3025}\text{-}N_{3010}\}/N_{3010} > 1$).

Figures 3 and 4 show that the PHA UCNC, the UH 3025 UCNC, and the RAF 3760 CNC were in good agreement, particularly when few nanoparticles were present. During periods when nanoparticle concentrations were higher than those of particles larger than 10 nm, due to higher nanoparticle counting efficiencies, Figure 5 shows that both the PHA UCNC and the UH 3025 UCNC recorded higher concentrations than the other three. Also during these periods of high nanoparticle concentrations, the PHA UCNC recorded the highest concentrations. This was also observed in Figure 2a. Since Wiedensohler et al. [1997] found that the size-dependent counting efficiencies of these two instruments were similar the cause for this difference may be due to higher sampling and transport losses of nanoparticles for the UH 3025 UCNC. Differences in nanoparticle losses could include differences in where the two instruments extracted sample air from the community aerosol inlet and differences in losses within individual sampling lines from the community aerosol inlet to the CNC's.

As observed in the time series plots, Figures 3, 4 and 5 show that the UH 3010 and the DRI 3010 both tended to have a systematic offset relative to the other three CNC's. This was observed for all the ranges of concentrations studied, suggesting that the differences may be from uncertainty associated with the sample flow rate.

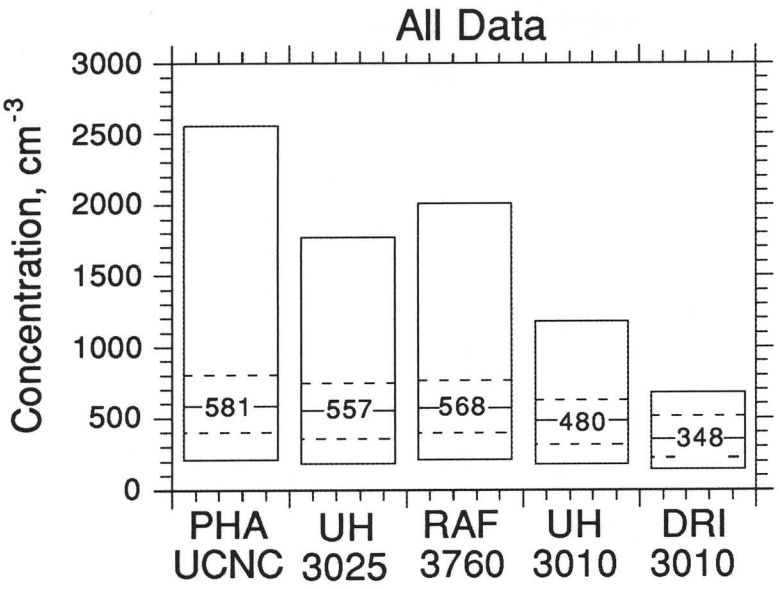

Figure 3: Percentile plots for C-130 CNC's based on measurements for flights 16, 17, 21, 22, and 27. For each CNC, the bottom and top of the box represents 5% and 95% of the data, respectively. The dotted lines represent 25% and 75% of the data and the center line the median particle concentration.

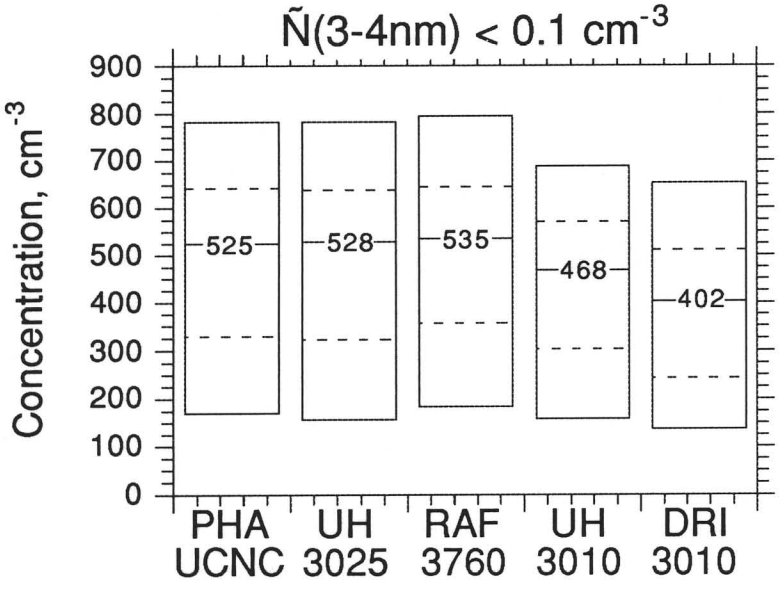

Figure 4: Same as Figure 3 except only data during conditions of practically zero nanoparticle concentrations is considered. At these times, differences in CNC nanoparticle detection efficiencies will not influence the comparison.

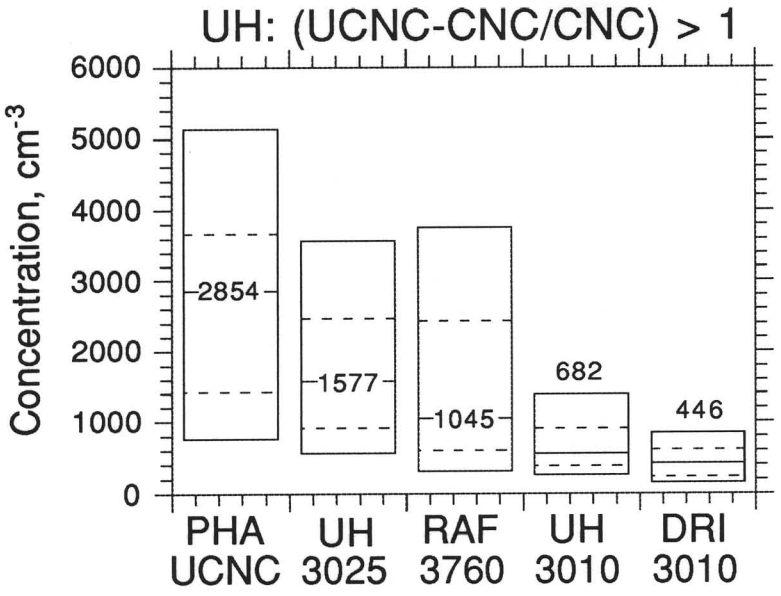

Figure 5: Same as Figure 3 except only periods of high nanoparticle (3-10 nm) concentrations are considered. These are periods when nanoparticle concentrations were higher than the concentration of particles larger than ~10 nm diameter.

2. Intercomparison of C-130 with Macquarie Island, Cape Grim and R/V Discoverer

Tables B1 through B5, in Appendix B, summarize the CNC measurements, sample locations, temperatures and relative humidities recorded during the various platform intercomparisons. The Discoverer and C-130 were intercomparied during three separate flights. For the second Disco./C-130 intercomparison flight, two passes were made at different altitudes. These data were analyzed separately. The third Disco./C-130 intercomparison flight was not analyzed due to rain at the time of the measurements. The Macquarie Island intercomparison consisted of only a brief flyby of the ground-based station whereas more extensive flybys of Cape Grim were made during two separate flights.

Since the periods for these intercomparisons were relatively brief, statistical analysis was limited and the findings should be viewed with some degree of skepticism. Table 3 summarizes the findings. For each comparison, the average percent difference of the ship or ground based measurement to the RAF 3760 CNC is calculated. The RAF 3760 CNC was chosen since it was fairly representative of the aircraft CNC measurements. Table 3 shows that the R/V Discoverer UCNC recorded generally lower particle concentrations than the C-130. Cape Grim and C-130 CNC measurements were fairly close and Macquarie Island measurements were slightly lower than the aircraft measurements.

Table 3: Average percent difference of ship and ground-based UCNC's and CNC's with the C-130-based RAF 3760 CNC, (e.g., $\{N_{UCNC}/N_{RAF\ 3760}-1\}*100$)

Station	Station UCNC % Difference $(N_{UCNC}/N_{RAF\ 3760}-1)*100$	Station CNC % Difference $(N_{CNC}/N_{RAF\ 3760}-1)*100$
R/V Disco. #1	-20	-
R/V Disco. #2a	-13	-
R/V Disco. #2b	-22	-
Cape Grim #1	+2.5	+1.5
Cape Grim #2	+3.1	+5.2
Macquarie Is.	-10	-7

3. References

Wiedensohler, A., D. Orsini, D. S. Covert, D. Coffmann, W. Cantrell, H. Halvlicek, F. J. Brechtel, L. M. Russell, R. J. Weber, J. Gras, J. G. Hudson, M. Litchy, Intercomparison study of the size-dependent counting efficiency of 26 condensation particle counters, *Aerosol Sci. Tech.*, in press, 1997.

Appendix A: Acronyms and Descriptions of CNC's

D_p:	Particle Diameter
CN:	Condensation Nucleus
CNC:	Condensation Nucleus Counter
UCNC:	Ultrafine Condensation Nucleus Counter
TSI:	Thermo-Systems Inc., St. Paul MN.
3025, 3760, and 3010:	TSI designations for their various CNC's.
Cape Grim UCNC:	University of Washington TSI 3025 UCNC, D_{p50}=2.3 nm
Cape Grim CNC:	University of Washington TSI 3010 CNC, D_{p50}=12 nm
DRI 3010:	Desert Research Institute (DRI), TSI 3010 CNC, D_{p50}=15 nm.
Macquarie Is. UCNC:	Colorado State University TSI 3025 UCNC, D_{p50}=2.5 nm
Macquarie Is. CNC:	Colorado State University TSI 3010 CNC, D_{p50}=12 nm
RAF 3760:	Research Aviation Facility (RAF) National Center for Atmospheric Research (NCAR), TSI 3760 CNC, D_{p50}=15 nm nominally (D_{p50} was not measured during comparison prior to ACE-1).
R/V Discoverer UCNC:	Pacific Marine Environmental Laboratory Research Vessel Discoverer, TSI 3025 UCNC, D_{p50}=2.5 nm
UM PHA UCNC:	University of Minnesota (UM), UCNC with Pulse Height Analysis (PHA), D_{p50}=2.5 nm.
UH 3025:	University of Hawaii (UH), TSI 3025 UCNC, D_{p50}=2.4 nm.
UH 3010:	University of Hawaii (UH), TSI 3010 CNC, D_{p50}=15 nm.

Appendix B: Comparisons of Ship and Ground-Based CN Measurements with the C-130 Aircraft Measurements

Table B1: Discoverer/ C-130 Comparison #1
Flight 15, 25 Nov. 1995 (Julian day 329)
Time period (UTC): ~ 1:00:00 - 1:30:00 Disco; 1:10:00 - 1:14:00 C-130

	DISCO.		C-130	
Measurement	Mean	Range	Mean	Range
UCNC, cm^{-3}	349	332-368	444 UM 434 UH	423-504 UM 411-467 UH
CNC, cm^{-3}	-	-	327 DRI 393 UH 434 RAF	317-341 DRI 375-413 UH 418-495 RAF
Altitude, m	-	-	48	31-114
Latitude, deg. S	-	47.30-47.385	-	47.488-47.646
Longitude, deg. E	-	144.79-144.87	-	145.07-145.20
T, °C	8.7	-	8.4	7.8-8.6
RH, %	81	-	74	71-76

UM University of Minnesota; UH University of Hawaii; DRI Desert Research Institute; RAF NCAR Research Aviation Facility

Table B2: Discoverer/ C-130 Comparison #2
Flight 22, 5 Dec. 1995 (Julian day 339)
Pass a) Time period (UTC): 4:34:00 - 4:37:00

	DISCO.		C-130	
Measurement	Mean	Range	Mean	Range
UCNC, cm^{-3}	578	546-640	739 UM 670 UH	639-865 UM 631-728 UH
CNC, cm^{-3}	-	-	450 DRI 587 UH 662 RAF	304-483 DRI 552-627 UH 636-708 RAF
Altitude, m	-	-	39	28-50
Latitude, deg. S	41.343	-	-	41.339-41.466
Longitude, deg. E	139.06	-	-	138.95-139.06
T, °C	11.2	-	11.4	11.3-11.5
RH, %	54	-	56	54-57

Pass b) Time period (UTC): 5:39:00 - 5:41:00

	DISCO.		C-130	
Measurement	Mean	Range	Mean	Range
UCNC, cm^{-3}	518	513-521	704 UM 670 UH	667-760 UM 645-734 UH
CNC, cm^{-3}	-	-	540 DRI 593 UH 667 RAF	501-681 DRI 570-630 UH 654-739 RAF
Altitude, m	-	-	158	155-160
Latitude, deg. S	41.382	-	-	41.260-41.359
Longitude, deg. E	138.992	-	-	139.11-139.15
T, °C	11.1	-	10.4	10.3-10.4
RH, %	58	-	56	56-57

Table B3: Cape Grim/ C-130 CN Comparison #1
Flight 14, 24 Nov. 1995 (Julian day 328)
Time period (UTC): ~ 1:55:00 - 1:58:00

	Cape Grim		C-130	
Measurement	Mean	Range	Mean	Range
UCNC, cm^{-3}	491	467-515	501 UM 471 UH	454-533 UM 407-556 UH
CNC, cm^{-3}	486	464-508	373 DRI 427 UH 479 RAF	355-400 DRI 392-469 UH 431-721 RAF
Altitude, m	94+mast	-	46	37-62
Latitude, deg. S	40.6822	-	-	40.621-40.673
Longitude, deg. E	144.688	-	-	144.48-144.67
T, °C	10.2	-	10.9	10.4-11.2
RH, %	68	67-70	58	53-67

Table B4: Cape Grim/ C-130 CN Comparison #2
Flight 27, 10 Dec. 1995 (Julian day 344)
Time period (UTC): ~ 23:33:00 - 23:36:00

	Cape Grim		C-130	
Measurement	Mean	Range	Mean	Range
UCNC, cm^{-3}	1047	-	1160 UM 1019 UH	1087-1232 UM 933-1135 UH
CNC, cm^{-3}	1069	-	768 DRI 898 UH 1016 RAF	673-843 DRI 823-986 UH 941-1102 RAF
Altitude, m	94+mast	-	102	90-116
Latitude, deg. S	40.6822	-	-	40.647-40.653
Longitude, deg. E	144.688	-	-	144.56-144.76
T, °C	9.4	-	9.6	9.4-9.8
RH, %	65	63-66	54	52-56

Table B5: Macquarie Island/ C-130 CN Comparison
Flight 16, 27 Nov. 1995 (Julian day 331)
Time period (UTC): ~ 3:05:00 - 3:15:00 Macquarie Island; 3:11:00 - 3:12:00 C-130.

	Macquarie Is.		C-130	
Measurement	Mean	Range	Mean	Range
UCNC, cm^{-3}	501	498-504	558 UM 570 UH	- UM 540-585 UH
CNC, cm^{-3}	519	515-524	- DRI 521 UH 558 RAF	- DRI 517-524 UH 547-568 RAF
Altitude, m	5	-	67	41-90
Latitude, deg. S	54.50	-	-	54.43-54.47
Longitude, deg. E	158.95	-	-	158.97-159.03
T, °C	6.3	-	3.8	3.5-4.2
RH, %	47	-	59	56-67