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DEPARTMENT OF COMMERCE
UNITED STATES OF AMERICA

THE SOUTH POLE AUTOMATIC CONDENSATION NUCLEI COUNTER: INSTRUMENT DETAILS AND FIVE YEARS OF OBSERVATIONS

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Richard A. Frank, Administrator

Environmental Research
Laboratories
Wilmot N. Hess, Director

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Mark E. Murphy and Barry A. Bodhaine

Abstract. An automatic General Electric (G.E.) condensation nuclei counter has been operating continuously at the Amundson-Scott South Pole station since 1974 as part of the Geophysical Monitoring for Climatic Change (GMCC) program. This instrument (calibrated by a Pollak nuclei counter standard), with its high sensitivity and fast response, can provide continuous aerosol climatology and identify periods of contamination from local sources.

The G.E. counter data were calibrated from the G.E.-Pollak data-pairs generated from the raw one-minute G.E. counter voltages by a linear least squares analysis to determine a best fit regression equation with the Pollak counter data as the independent variable. The annual variation of nuclei concentration is apparent and is repeatably consistent over the five year period. Nuclei concentrations occasionally reach values as low as 7 cm^{-3} during the austral winter (April through September), begin to increase near the time of astronomical sunrise, and reach values as high as about 240 cm^{-3} during summer months. The continuously operating G.E. condensation nuclei counter in conjunction with the Pollak nuclei counter, have produced an excellent data set over the five year period, 1974-1978.

1. INTRODUCTION

This report presents the condensation nuclei data from the Amundson-Scott station at the South Pole, taken by a General Electric condensation nuclei counter from 1974 through 1978. A brief description of the theory and operation of the instrument is included to aid the potential user in data interpretation. A complete set of the hourly means of condensation nuclei data may be obtained from NOAA/ARL/GMCC, Boulder, Colorado 80303.

A modified G.E. condensation nuclei counter is used for continuous recording of data and a Pollak photoelectric nuclei counter for routine on-site calibrations. The Pollak counter was installed in January 1974 and has been operated twice daily by the station observers, providing an excellent time series of data since its installation as described by Hogan (1975, 1978). The G.E. condensation nuclei counter was installed at the South Pole in 1974; however, good continuous data was obtained only after the electronics were modified in January 1975.

Since condensation nuclei concentrations at South Pole range from about 300 cm^{-3} during austral summer to below 10 cm^{-3} in winter, an instrument of high sensitivity is necessary and routine calibration is essential. The Pollak counter used is in close agreement with the standard maintained by Austin Hogan at the State University of New York and the relative calibration has not changed since its installation. Although the G.E. counter is inherently an extremely sensitive instrument, regular maintainence and calibration are necessary for reliable operation over long periods of time.

Liu and Pui (1974) calibrated a G.E. nuclei counter using their differential mobility analyzer technique and found that the instrument showed a linear response over the size range 0.011-0.15 μm and concentrations of up to 6.5 x10^4 cm^{-3}. Although an essentially linear response was found for the G.E. counter, a discrepancy of 40% with a previous calibration was found.

Cooper and Langer (1978) conducted a new study on automatic condensation nuclei counter calibration. In this study, the G.E. counter was tested for calibration and size dependency effects using monodisperse sodium chloride, silver iodide, and wax aerosols generated by the technique of Liu and Pui (1974). They suggest that factory calibration be treated with caution, that particle losses become significant for particles smaller than 0.03 μm in diameter, and that frequent calibration checks be made.

The calibration of a Pollak photoelectric nuclei counter was performed by Liu et al. (1975) using the Liu and Pui (1974) aerosol generator. This was an important experiment because of the fact that the factory calibrations of the G.E. counter were also performed with a Pollak-style counter. In view of the discrepancies in the calibration of these instruments found by Cooper and Langer (1978) and Liu and Pui (1974), the accuracy of the Pollak counter, long used as the Aitken nuclei "standard", was called to question. The Liu et al. (1975) experiments showed agreement between the differential mobility analyzer and the Pollak counter to better than 9% for concentrations less than 10^4 cm^{-3}.

II. INSTRUMENTATION

Pollak nuclei counter SN 15, installed in January 1974 at the South Pole by Austin Hogan, was manufactured by BGI, Inc., as an exact Pollak replica. Operation and calibration of this instrument are conducted as described by Metnieks and Pollak (1959) in an effort to maintain as nearly as possible Pollak's "intrinsic calibration."

The Pollak nuclei counter consists of a fog tube 59 cm long and 2.5 cm in diameter with a convergent-beam light source at the top and a photocell at the bottom. After flushing the instrument with sample air, the fog tube is pressurized with filtered air to an overpressure ratio of 1.21. The subsequent expansion produces a saturation ratio of about 2.81 which activates particles as small as about 10^{-7} cm radius. These particles grow to cloud droplet size and attenuate the light beam to give a deflection on a microammeter which is calibrated in terms of nuclei concentration. There is some controversy over the minimum sized particle which is activated in this instrument (Walter and Jaenicke 1973); however, most investigators give a particle radius of about 1 to 2 x 10^{-7} cm as the minimum sized particle detected.

Calibration for the Pollak nuclei counters used in the GMCC program was provided by Pollak and Metnieks (1960). It should be noted that in the previous calibration provided by Metnieks and Pollak (1959), concentrations less than 626 cm^{-3} were obtained by linear interpolation. However, Pollak and Metnieks (1960) recognized the need for accurate calibration at low nuclei concentrations and established nine fundamental calibration points, the lowest being 23.9 cm^{-3}. Because of the excellent results of Liu et al. (1975), it is reasonable to accept Pollak's calibration for low nuclei concentrations. In any case, this calibration can be verified when a more accurate calibration technique is developed for these extremely low concentrations.

G.E. nuclei counter (catalog no. 112642861), in its modified form, has been in continuous operation at South Pole since January 1975. Modifications to the electronics, suggested by Norman Ahlquist of the University of Washington, have been implemented on the G.E. counter. However, the basic "casting" containing the cloud chamber, optics, humidifier, and rotating valve are used in their original form. This is important because the method of measuring the light scattered by growing droplets at low forward scattering angles and against a dark field is inherently the most sensitive method for making such a measurement.

Briefly, a rotating shutter mounted on the valve shaft provides a bright beam directly through the cloud chamber onto the photomultiplier (PMT) to allow regulation (through the PMT supply) of the effective lamp intensity seen by the PMT. This compensates for any drift in lamp intensity or PMT sensitivity. During the measurement portion of the cycle, the direct beam is blocked and only light scattered in the chamber reaches the PMT. Just before the expansion occurs, a time delay circuit waits 26 ms and then samples the cloud chamber signal to be read out, minus the background level, as nuclei concentration. A logarithmic converter provides instrument output on a logarithmic scale spanning five decades of nuclei concentration, thus eliminating the familiar range change problem under conditions of widely varying nuclei concentration.

Linearity of the instrument over the entire range of nuclei concentrations depends primarily on three factors:

1) the light scattered by the droplets and incident on the PMT must be directly proportional to the nuclei concentration;

2) the anode current of the PMT must be directly proportional to the light falling on its photocathode;

3) the electronics which process the PMT anode current must be linear.

Conditions 2) and 3) are easily achieved with modern electronics and can be checked for the five orders of magnitude of signal over which the instrument operates. Condition 1) has been found to hold true for concentrations less than about 100,000 cm^{-3}. The important point here is that all droplets must grow to the same size in the same time interval, independent of concentration. For low concentrations, the effects of vapor depletion and multiple scattering are eliminated. The electronics of the instrument are adjusted for a logarithmic output of 2 volts per decade according to the relationship $N = 3 \times 10^{v/2}$ where N is nuclei concentration and v is instrument output voltage.

The G.E. counter has been found to agree well with the Pollak counter over the lower three decades (i.e., 1-1000 cm^{-3}) of interest. If a zero filter is placed on the intake of the G.E. counter, the instrument will drift off scale low. Furthermore, at a rate of five samples per second, the instrument has a rapid response time limited only by the intake line length and time of flow through the system.

III. CALIBRATION

The results of Liu and Pui (1974) and Cooper and Langer (1978) concerning calibration discrepancies of automatic nuclei counters are not unexpected. These instruments exhibit long-term electrical and mechanical drift and require a fair amount of maintenance and calibration for continuous operation. It has been found that deterioration of performance in the G.E. counter is usually caused by contamination of the cloud chamber (which increases the background signal) or the valve ports becoming dirty or clogged with grease, possibly causing false expansions or other problems. After any major breakdown the instrument requires a complete recalibration.

The G.E. counter undergoes a daily zero check and a weekly calibration. The daily check involves installing a filter on the instrument intake and adjusting the background compensation circuit. The filter is then removed and the internal voltages are checked. Next the output reading of the G.E. counter is compared to the average of three Pollak observations. The average Pollak observation is converted to an equivalent voltage, and if it differs significantly from the G.E. counter voltage, then the instrument will be readjusted.

The weekly calibration consists of a series of five simultaneous Pollak counter observations and G.E. counter voltage readings performed on ambient aerosol. Then, if necessary, the G.E. counter calibration is adjusted by the proper amount to force it to agree with the average Pollak reading. The G.E. counter voltage is recorded at the end of the purge period of each Pollak observation. It is important to emphasize that the instruments are compared on ambient aerosol at the site during periods of typical and quite constant aerosol concentrations. The instruments are allowed to operate in their regular monitoring configuration, i.e., through the sampling stack (Komhyr, 1979) and intake lines. It is not practical to install an aerosol generator such as the Liu and Pui (1974) instrument at the site for routine calibration purposes, especially for use at low concentrations. The only practical alternative, storing either ambient or nichrome aerosol in a mylar bag and performing repeated dilutions, is not used routinely because of the uncertainties of aerosol diffusion and coagulation losses in the bag which give changing size distributions and make simultaneous sampling difficult.

The signal at the G.E. counter output, spanning five decades, will give an error in aerosol concentration of about 2.5% per 10 mV error in voltage over the entire scale. In practice, the calibration of the G.E. counter is adjusted only if the voltage error exceeds about mV (25% error in concentration).

IV. SCALING OF G.E. COUNTER DATA

Each GMCC Observatory is equipped with a computer data acquisition system which digitizes all station data and stores it on magnetic tape in the form of one-minute voltage means. In addition, hourly means in engineering units are calculated for all instrumentation and written in an additional file on the tape at the end of each hour. Therefore, all data are available in both minute and hourly form at the data reduction facility in Boulder. All routine Pollak counter observations (twice daily at South Pole) are performed manually and recorded by hand on data sheets at the observatory. These data are later punched on computer cards and stored in a disc file in the reduction facility computer.

The first step in scaling the continuous aerosol data is to determine the variability of the data from one minute to the next. This variability is found by producing a histogram of successive one-minute voltage differences calculated from the raw one-minute voltage means for approximately the first two weeks of each month. An example of such a histogram using data from 1978 is shown in Fig. 1. Since, for any one month, the one-minute voltage differences are fairly constant, the maximum (absolute) allowed voltage difference limit is set at two standard deviations away from the mean. The ten percent of the remaining voltage differences above this limit correspond to large concentration changes. These large changes are normally due to the sampling of contaminated air or a change in calibration by the G.E. counter operator. These time periods are not used since the G.E. counter is no longer measuring background aerosol concentrations. The final variability criterion for the year is the maximum of the two-standard deviation values of the individual months. Next, a program is run to select G.E. counter and Pollak counter data pairs to be used as calibration points. The program reads a Pollak counter observation and then tests the one-minute G.E. counter data for five minutes on either side of the Pollak observation to determine if the successive one-minute voltage differences fall within the variability criteria established above. If so, the ten minute mean G.E. counter value and the Pollak observation are accepted as a data-pair calibration point. The process continues until a set of data pairs is generated for a time period during which the calibration of the G.E. counters was not changed or the instrument inoperative. A linear least squares analysis is then run on the data pairs to generate a best-fit regression equation with the Pollak counter observation as the independent variable and G.E. counter data as the dependent variable. By choosing the variability criterion as the maximum two-standard deviation value, some data pairs, from the months with a variability less than this value, may need to be removed. Such points can be removed by checking the standard residuals of the set of data pairs from the regression analysis and eliminating those above the absolute value of two. This

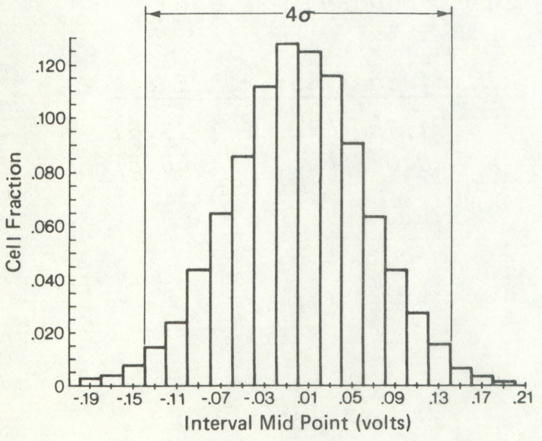

Figure 1. Sample histogram of successive G.E. counter one-minute voltage differences for June 1978.

process is then repeated to make the ratio of the coefficients of the equation and the standard deviation of the coefficients at least two (to insure at least a ninety percent confidence level in the coefficients), minimize the residual standard deviation, and maximize the multiple correlation coefficient squared. Usually a first degree equation is accepted but occasionally a second degree equation gives a slightly better fit. Equations of higher than second degree are never used. Figure 2 shows an example of the linear least squares analysis run on data from 1978. The ratios 11.61 and 59.87 in Figure 2 imply that the confidence level in values for the slope and intercept of the regression equation is complete. Likewise, the value of 0.9570 for the multiple correlation coefficient squared implies that the data set is quite accurately fit by the equation.

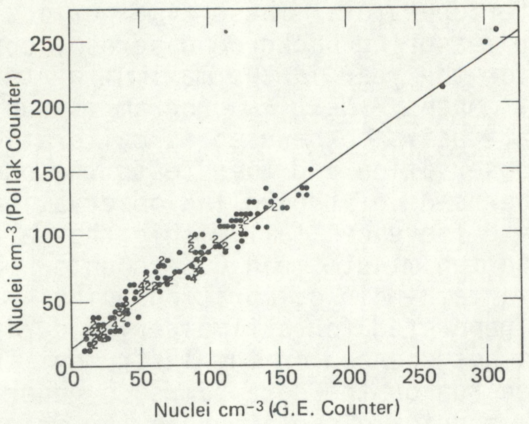

Figure 2. Sample output showing the ratio of the coefficient to the standard deviation of the coefficient for the best-fit regression equation for the time period January 1 to March 6, 1978:
Residual Standard Deviation = 8.426
Multiple Correlation Coefficient Squared = 9.957
Number of points = 163

Indep. Var.	*Coefficient*	*S.D. of Coefficient*	*Ratio*
0	*13.819*	*1.190*	*11.61*
1	*0.7522*	*0.01256*	*59.87*

The final step in the scaling of G.E. counter data is the application of the regression equation to the G.E. counter hourly data so that the results can be presented in the standard hourly form used for archiving all data. Figure 3 shows a graphical display of both G.E. counter and Pollak counter data before and after above procedure was applied to a ten-day interval of data.

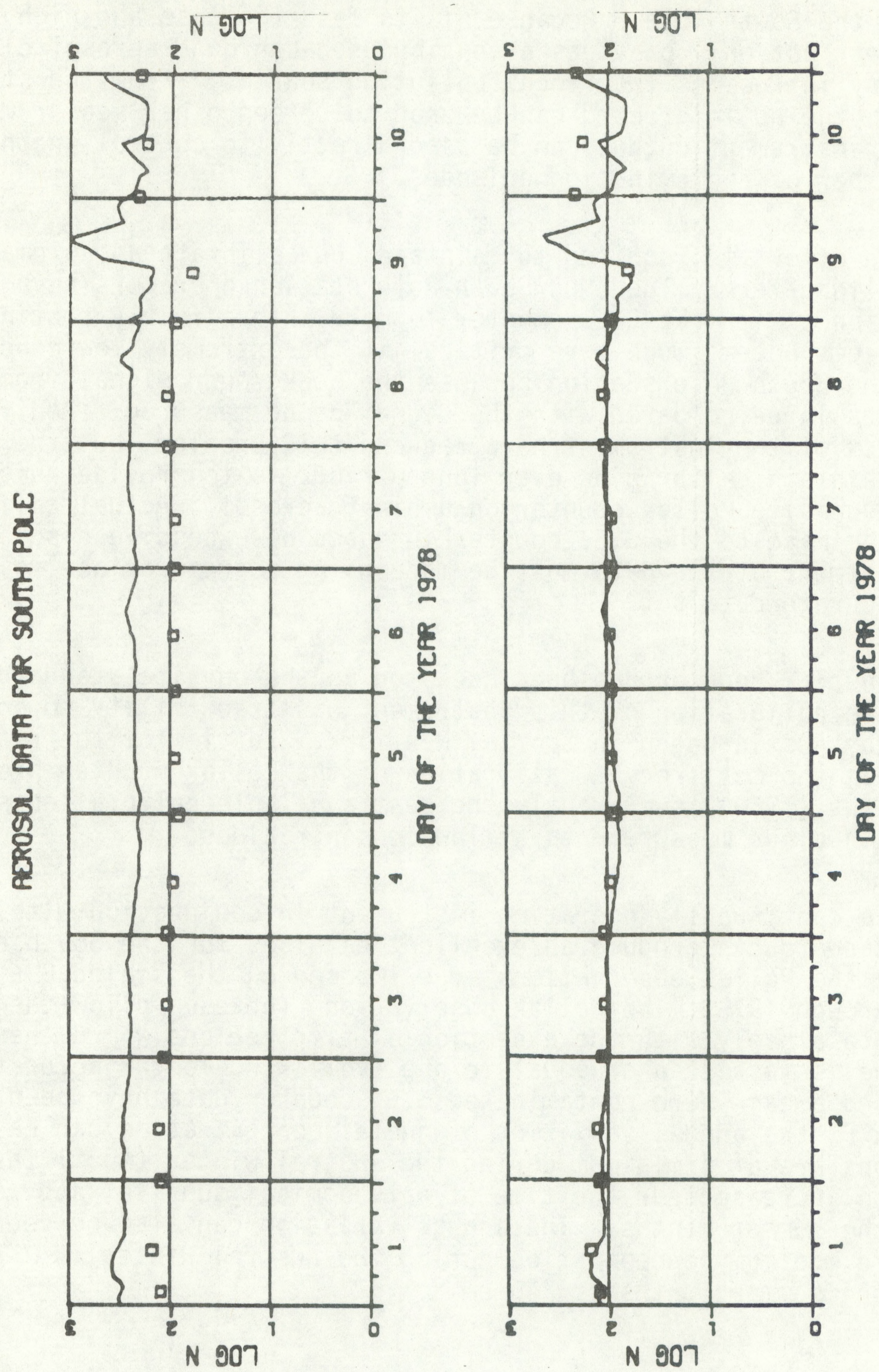

Figure 3. Graphical display of both the G.E. counter (solid line) and Pollak counter (squares) data for the ten day period January 1 to January 10, 1978. The upper graph gives data before the scaling procedure was applied, and the lower graph gives the data after the scaling procedure was applied.

V. DISCUSSION

An automatic condensation nuclei counter has been operating continuously for several years at the South Pole. Because of its fast response and high sensitivity this instrument not only provides a continuous background aerosol climatology, but identifies any intrusions from local pollution sources. From the standpoint of contamination, the nuclei record can be used to screen other measurement program data or the instrument output can be used directly to control another sampler to reduce the number of contamination episodes.

Considerable effort is required to maintain and calibrate an automatic nuclei counter over the long-term. The GMCC South Pole station operators have accumulated enough experience with the G.E. counter to make this a fairly routine task. Calibration problems become much more critical at the extremely low concentrations found at the South Pole station because the background signal from the instrument becomes large compared with the signal being measured. Modifications to the electronics of the instrument have reduced this problem, but the only reasonable way to maintain calibration over long periods is to provide numerous comparisons with an on-site Pollak counter on ambient aerosol. Actual calibration adjustments can be made to the G.E. counter in cases of excessive discrepancies but a final adjustment of the data must be made using regression analysis to produce the most accurate data set.

The Pollak nuclei counter has been accepted as the on-site standard at the Pole station. The calibration of this instrument has traceability to an instrument maintained by Austin Hogan in Scotia, New York. In view of the results of Liu et al. (1975), the most recent calibration of the Pollak counter provided by Pollak and Metnieks (1960) is currently the best available calibration standard for condensation nucleus measurements at low concentrations.

The use of a continuously operating instrument in conjunction with a manually operated standard can produce an excellent data set for the South Pole. Appendix F shows the Pollak observations superimposed on the scaled G.E. counter data for 1974 through 1978. The Pollak observations (boxes) follow the G.E. counter data quite closely with the exception of time periods where the Pollak observation value is less than or equal to one (Pollak no longer accurate and data not used) and areas where contaminated G.E. counter data have been removed. Also in Appendix F, the annual variation of nuclei concentration can be seen. The concentrations are at a minimum during the austral winter (April through September), begin to increase near the time of astronomical sunrise, and reach a maximum during the summer months. The annual variation can also be seen in tables 1 through 4 where minimum concentration during the austral winter is 7 cm^{-3} and the maximum of the summer months is 240 cm^{-3}.

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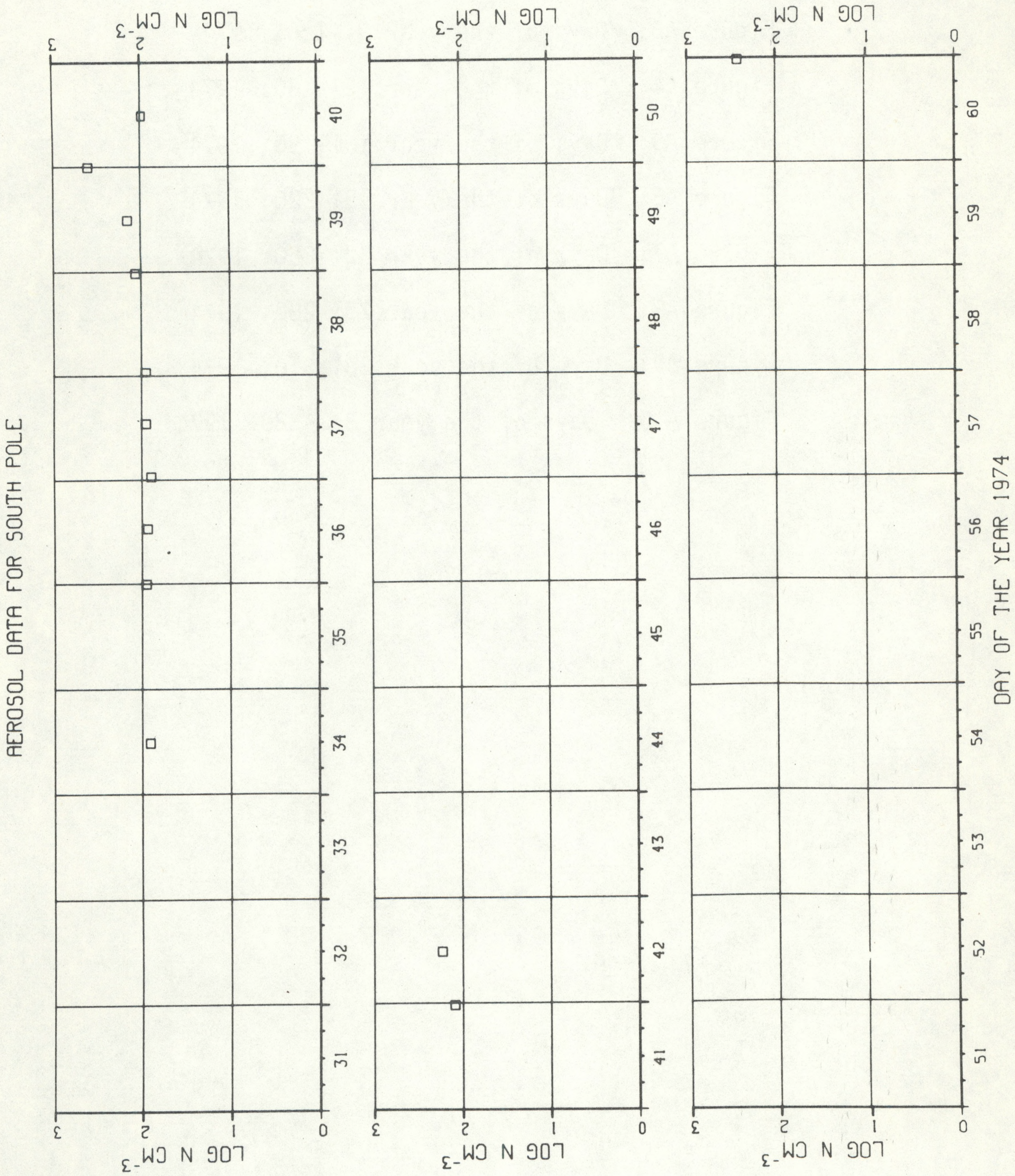
APPENDIX A

Appendix A gives the Pollak counter observations plotted on a logarithmic scale for 1974. The quality of the G.E. counter data was considered marginal and it was impossible to obtain a good fit to the Pollak counter data. Therefore, G.E. counter data are not presented for 1974.

Scaled graphical display of both G.E. counter (solid line) and Pollak counter (squares) data for 1974.


AEROSOL DATA FOR SOUTH POLE
DAY OF THE YEAR 1974
LOG N CM-3
31
32
33
34
35
36
37
38
39
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41
42
43
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60
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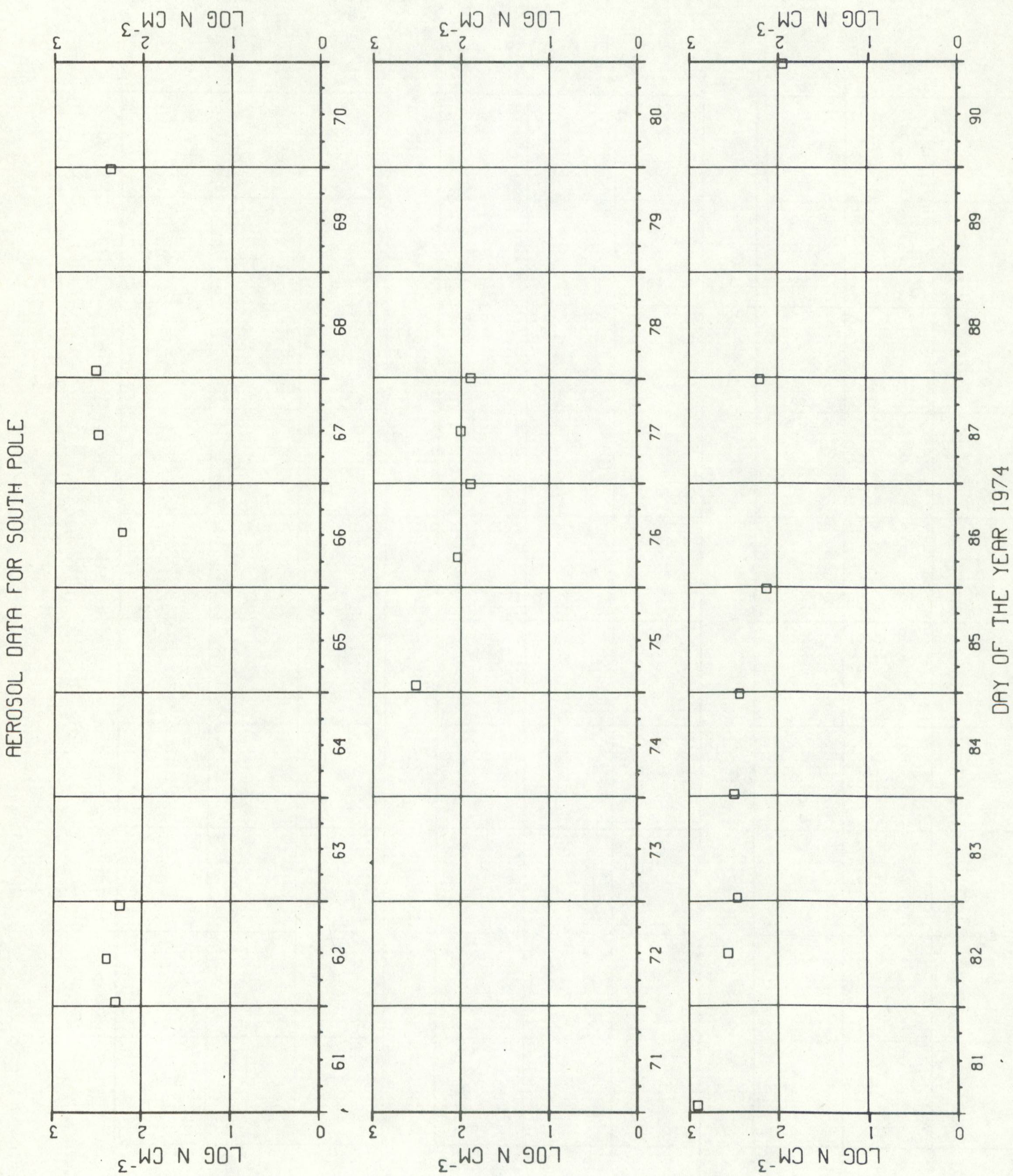
1
2
3


AEROSOL DATA FOR SOUTH POLE
DAY OF THE YEAR 1974
LOG N CM^{-3}
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1
2
3
61
62
63
64
65
66
67
68
69
70
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72
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74
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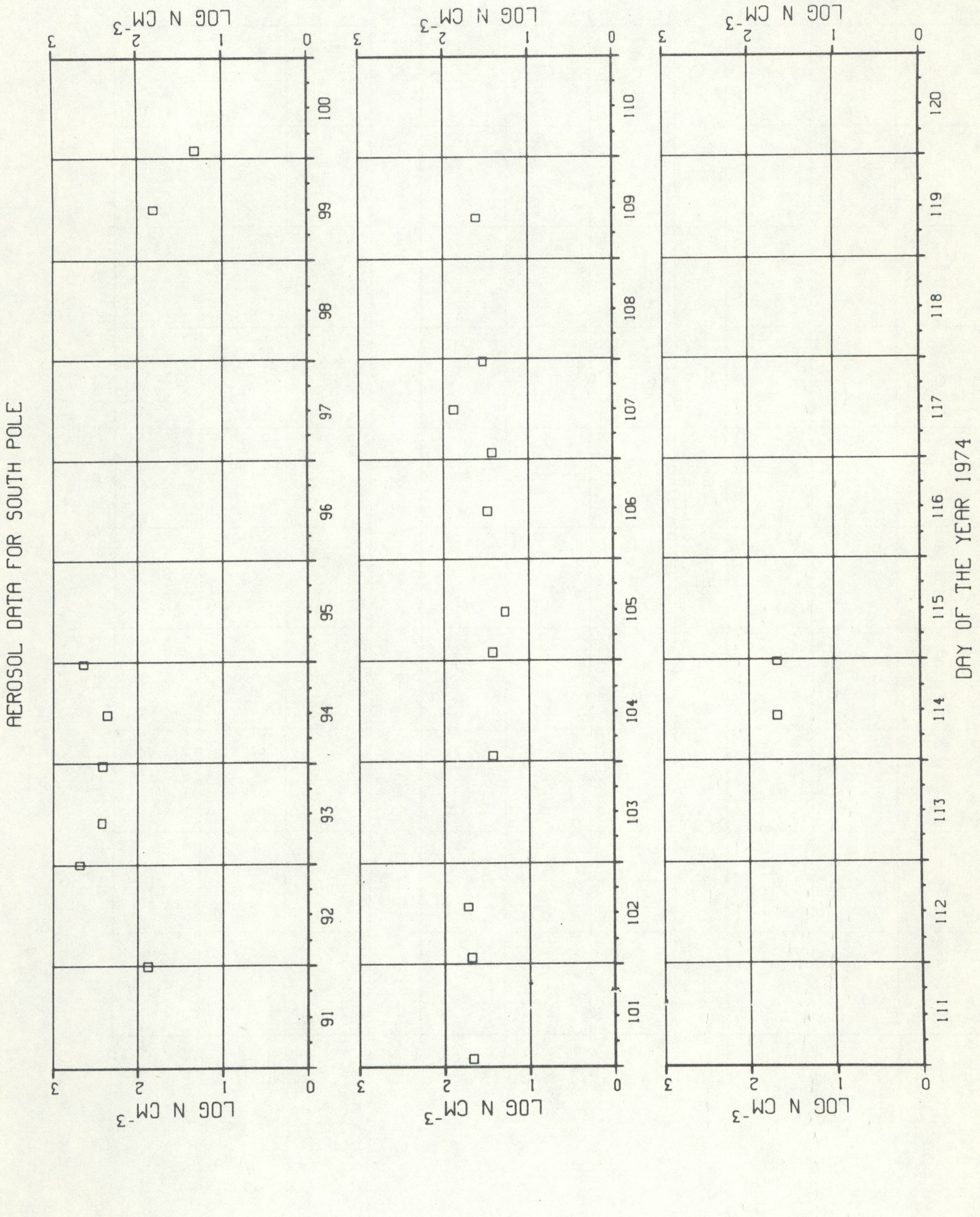
90



AEROSOL DATA FOR SOUTH POLE
LOG N CM-3
DAY OF THE YEAR 1974
91
92
93
94
95
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102
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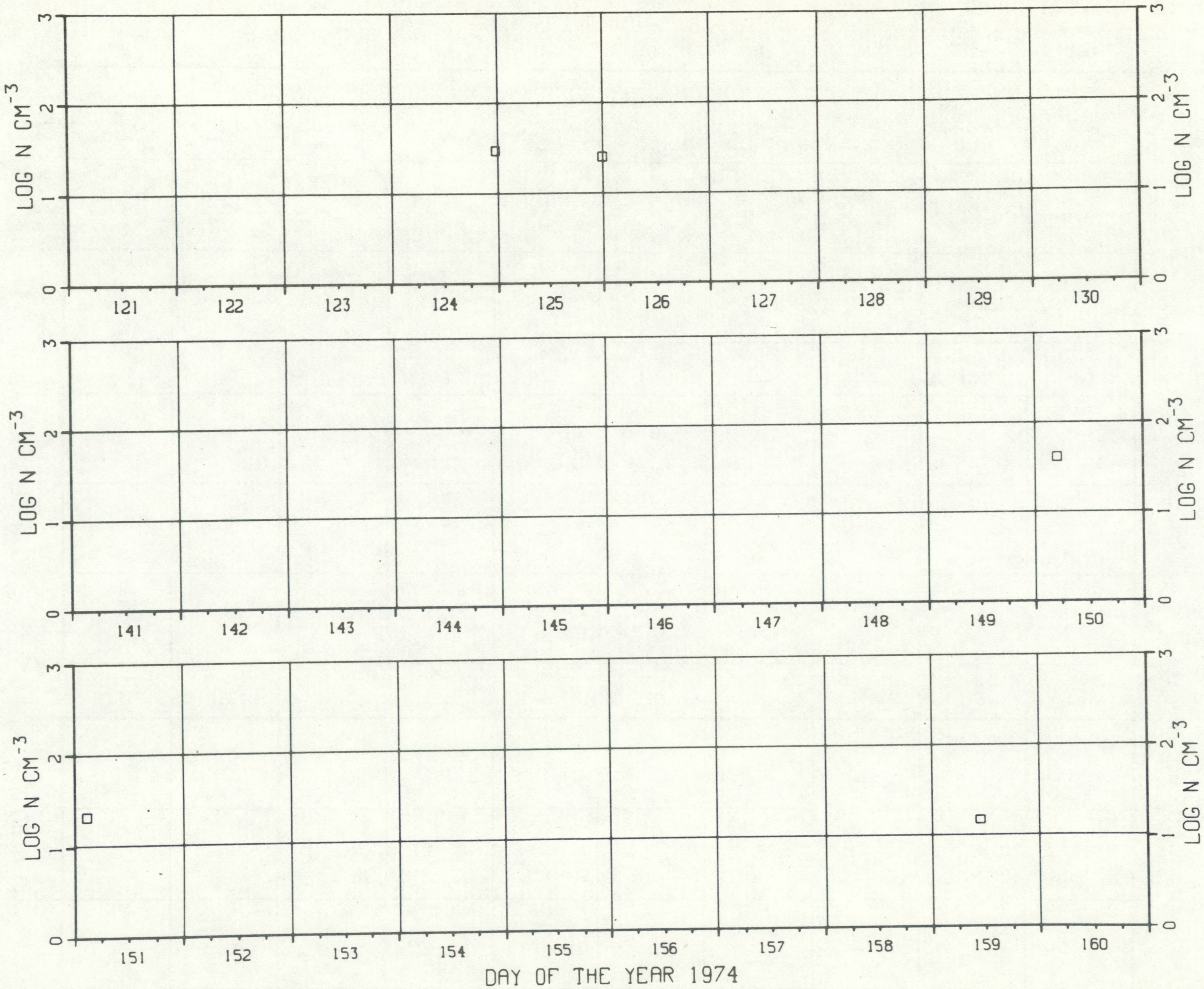
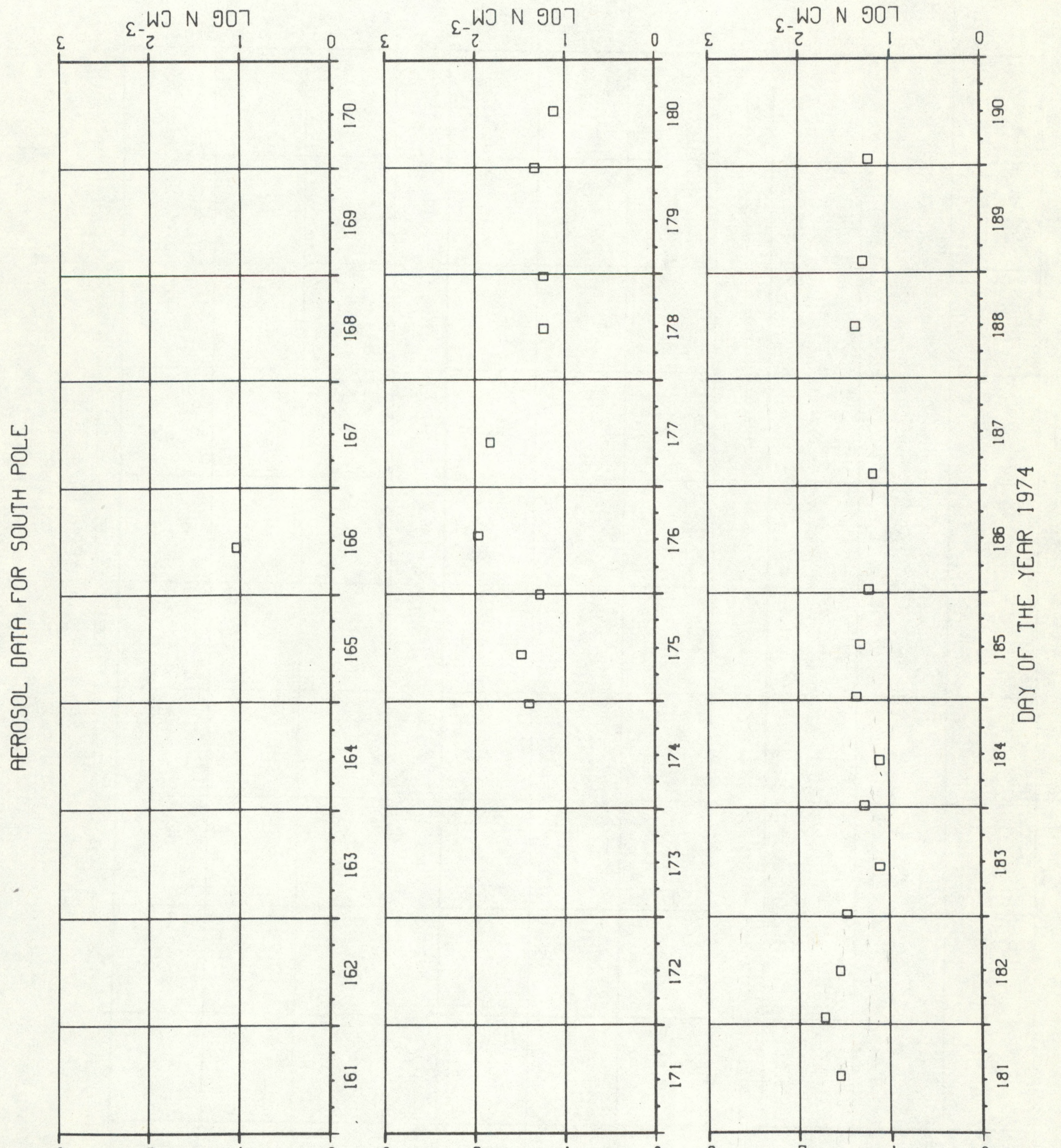
AEROSOL DATA FOR SOUTH POLE

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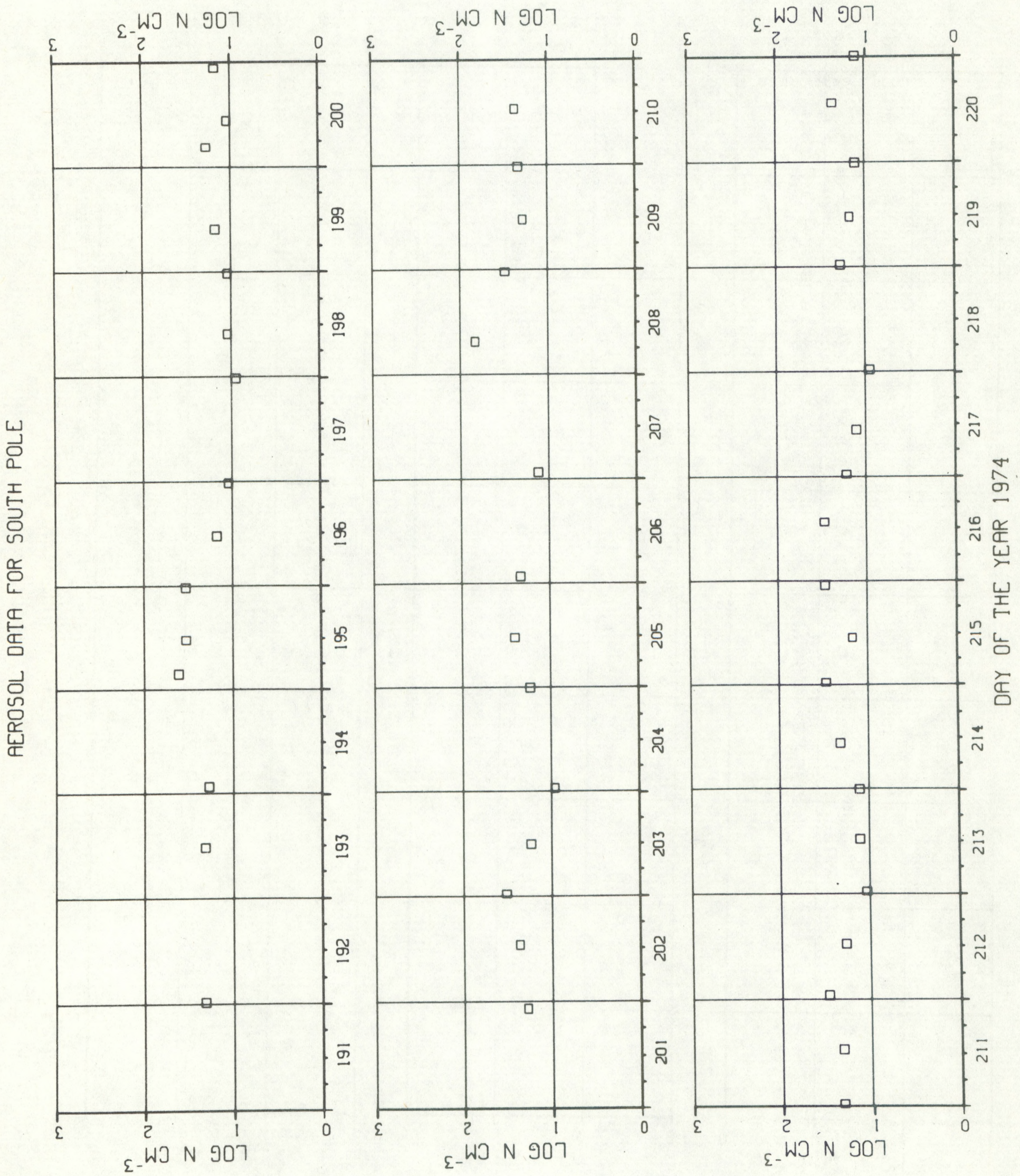
LOG N CM-3
DAY OF THE YEAR 1974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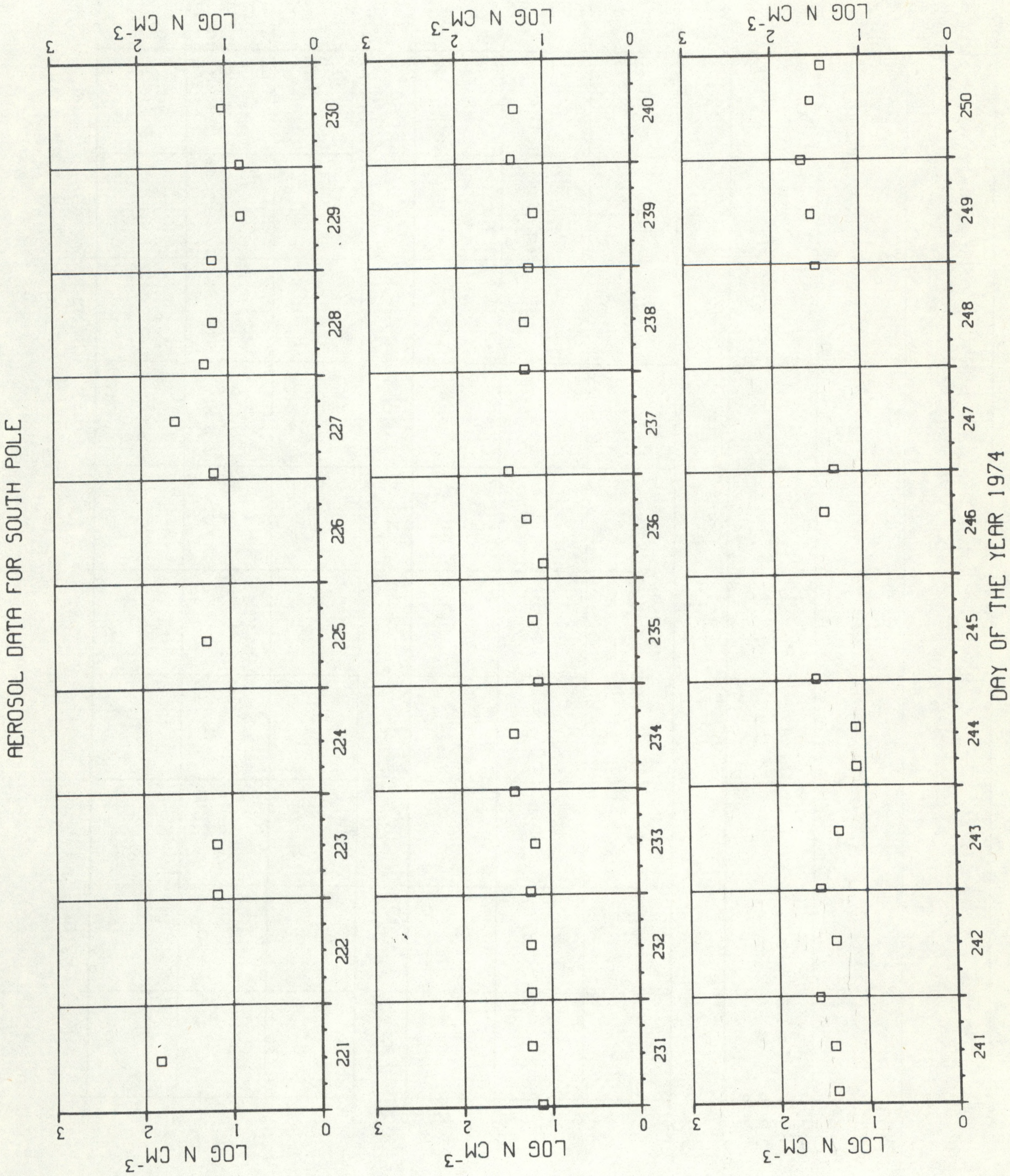
DAY OF THE YEAR 1974
LOG N CM-3



AEROSOL DATA FOR SOUTH POLE
LOG N CM-3
221
222
223
224
225
226
227
228
229
230
231
232
233
234
235
236
237
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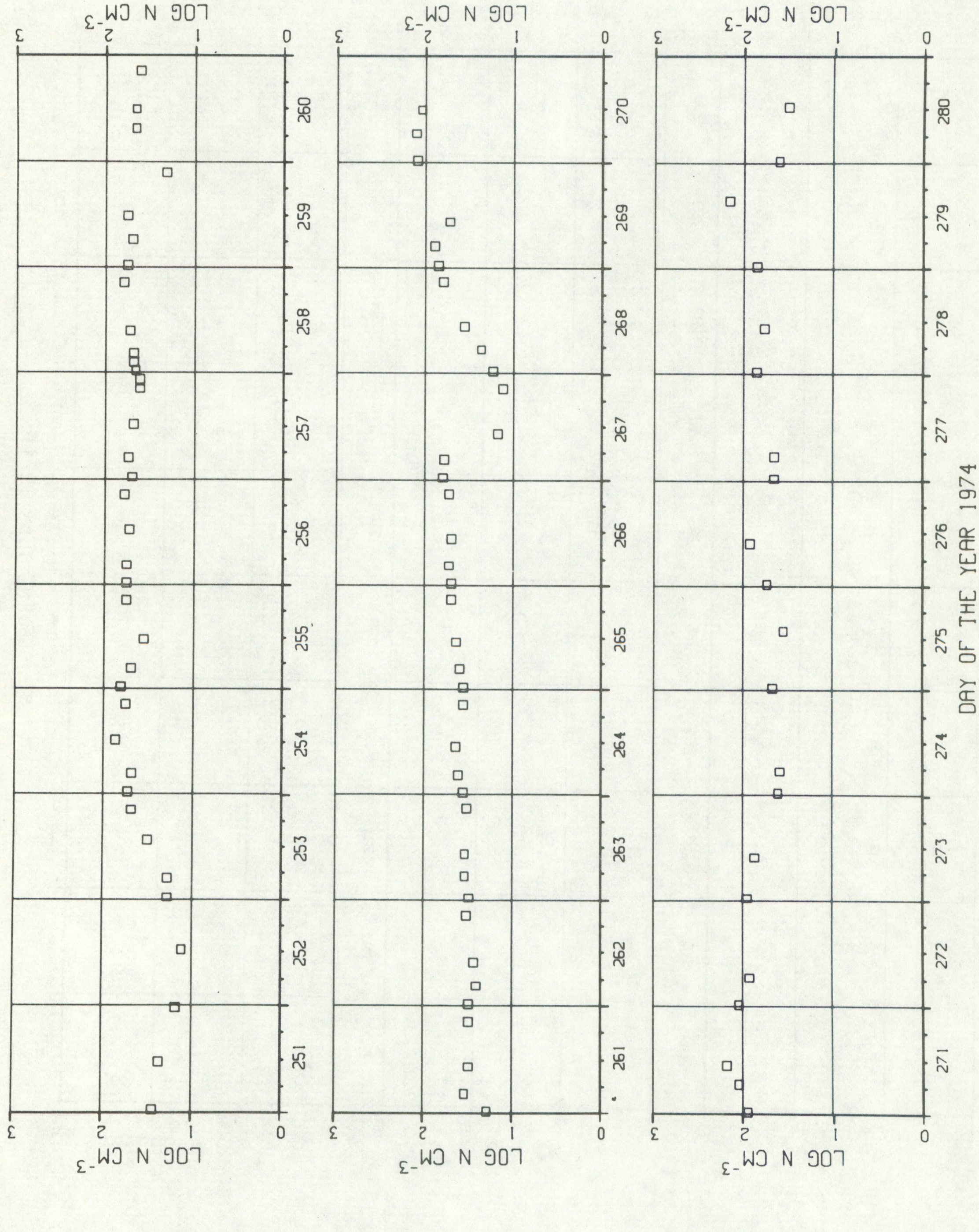
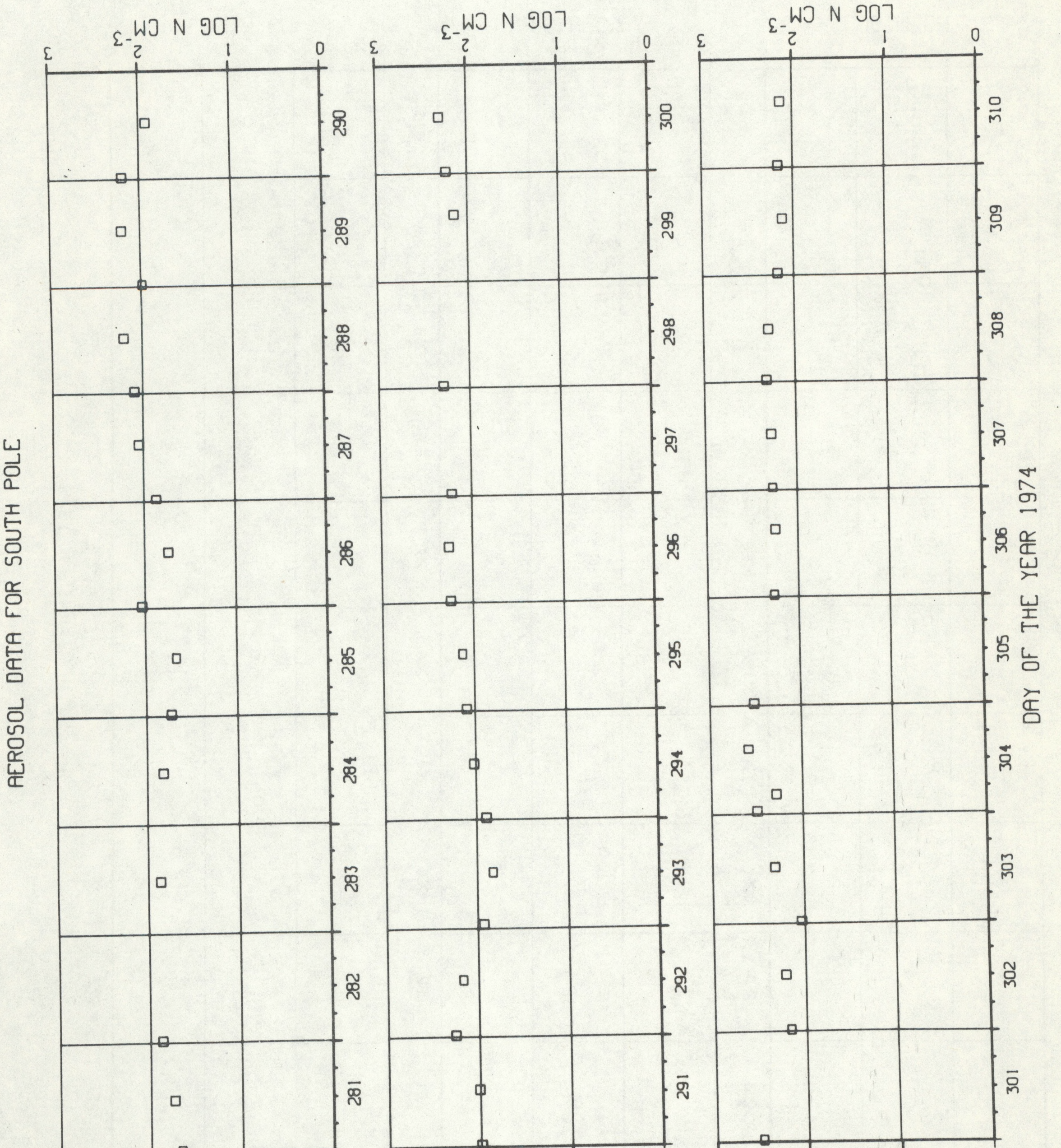
241
242
243
244
245
246
247
248
249
250
DAY OF THE YEAR 1974

AEROSOL DATA FOR SOUTH POLE





AEROSOL DATA FOR SOUTH POLE
DAY OF THE YEAR 1974
LOG N CM-3
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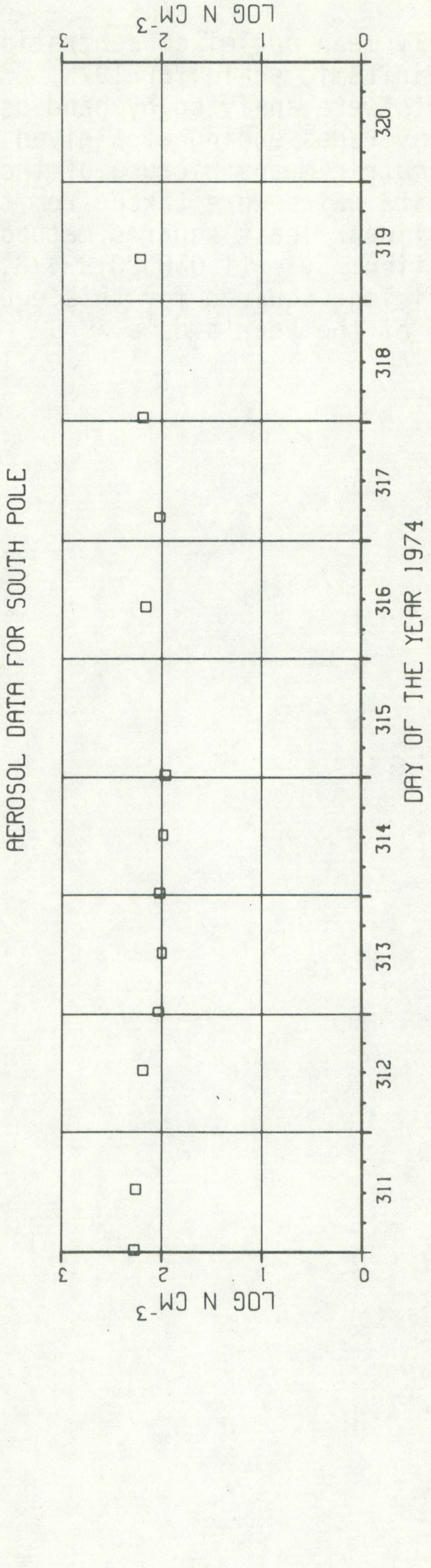
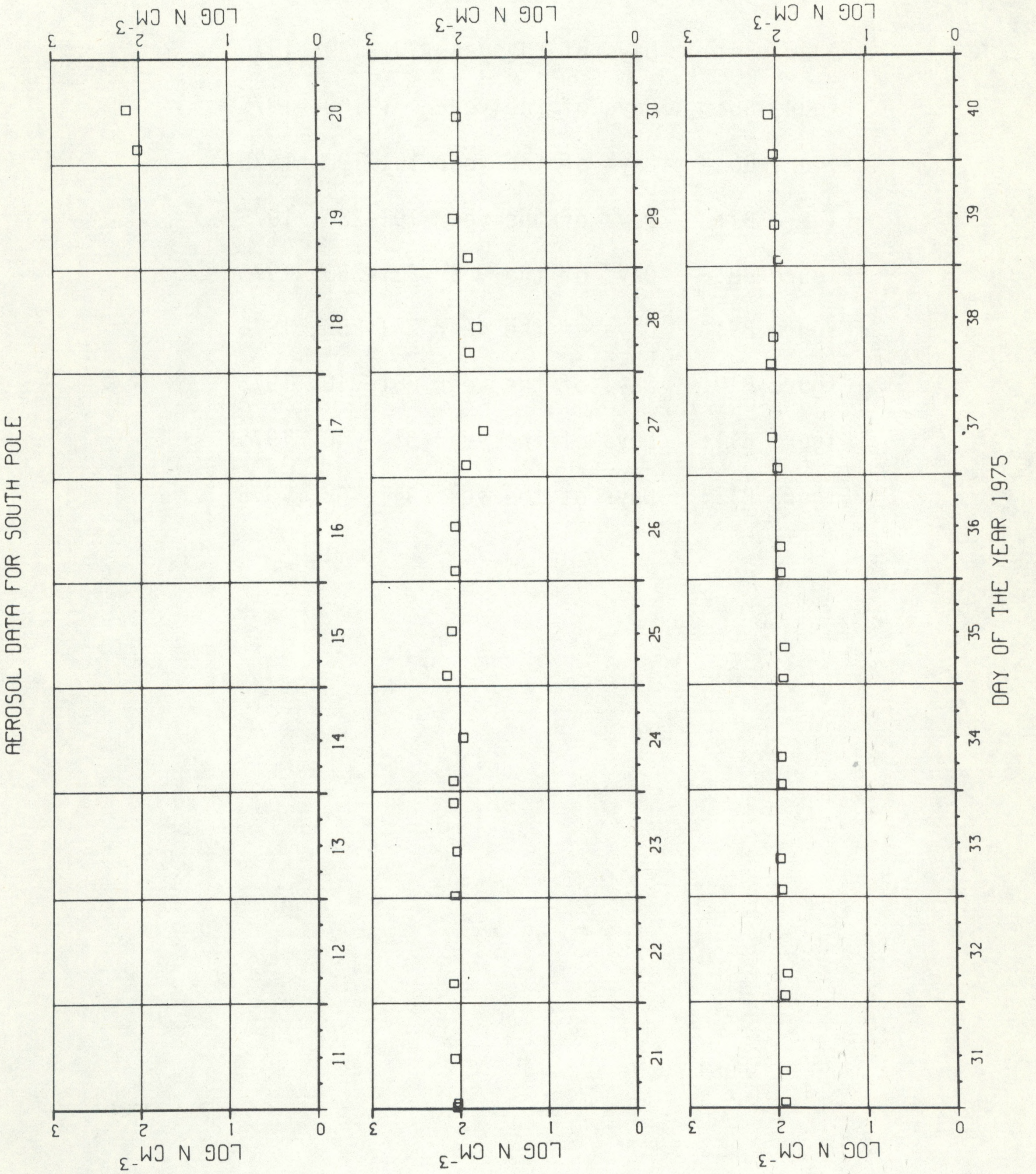
291 292 293 294 295 296 297 298 299 300
301 302 303 304 305 306 307 308 309 310

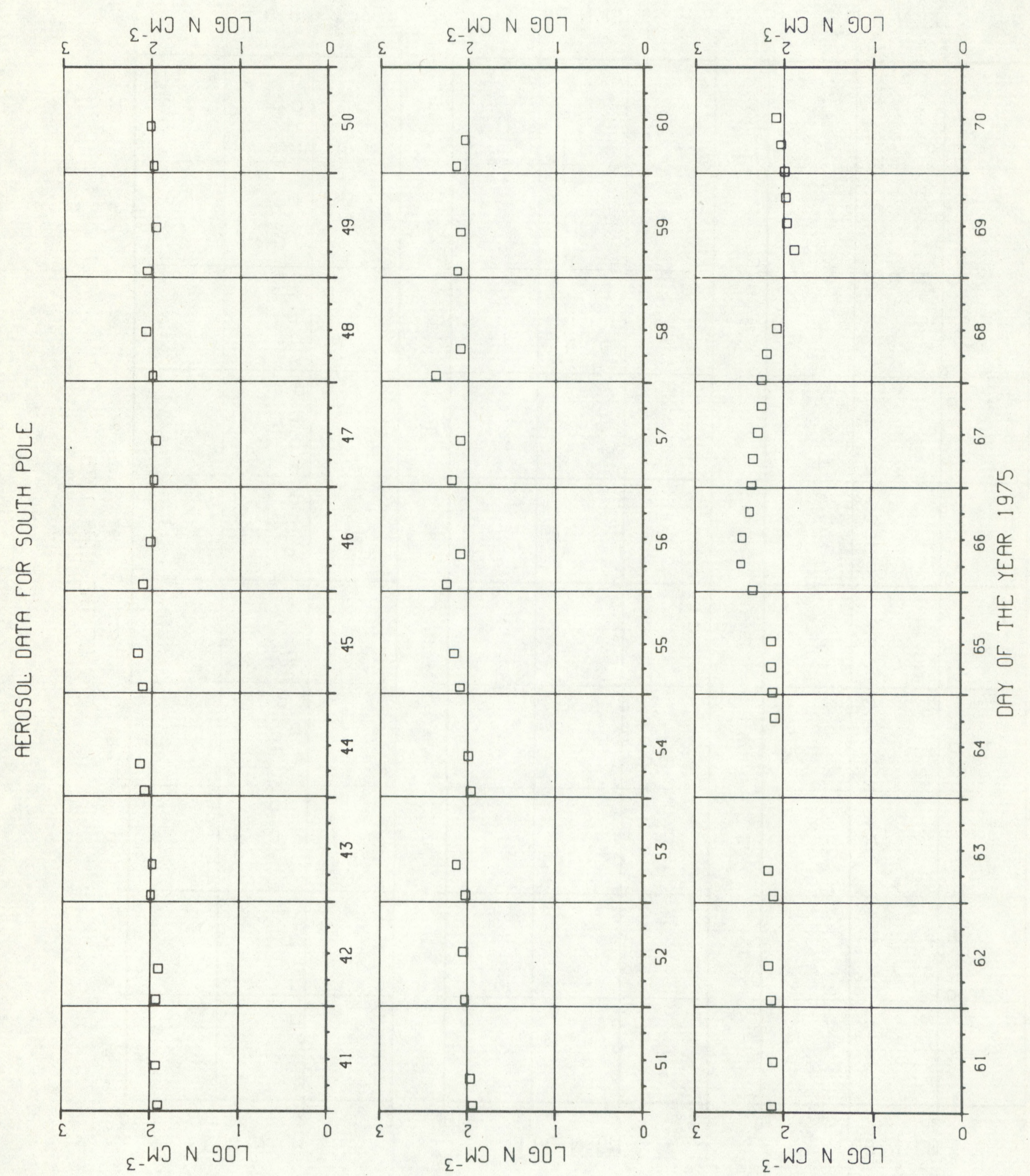

AEROSOL DATA FOR SOUTH POLE
DAY OF THE YEAR 1974
LOG N CM-3
LOG N CM-3
0
1
2
3
311
312
313
314
315
316
317
318
319
320

APPENDIX B

Appendix B gives the hourly mean nuclei concentrations and Pollak counter observations, plotted on a logarithmic scale for 1975. Since no data tapes exist for the year, strip charts were analyzed by hand using the usual equal area method to produce hourly averages ending at a given hour. These hourly means are also essentailly geometric means because of the logarithmic form of the output. The G.E.-Pollak data pairs were taken from the hourly mean nuclei concentrations. Applying the linear least squares method to the data pairs resulted in the following equation: $y = (1.01052019 * G.E.) - 0.346687234$. The multiple correlation coefficient squared for this equation is 0.9931. The equation was used to scale all of the year's data.

Scaled graphical display of both G.E. counter (solid line) and Pollak counter (squares) data for 1975.


AEROSOL DATA FOR SOUTH POLE
LOG N CM^{-3}
DAY OF THE YEAR 1975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DAY OF THE YEAR 1975
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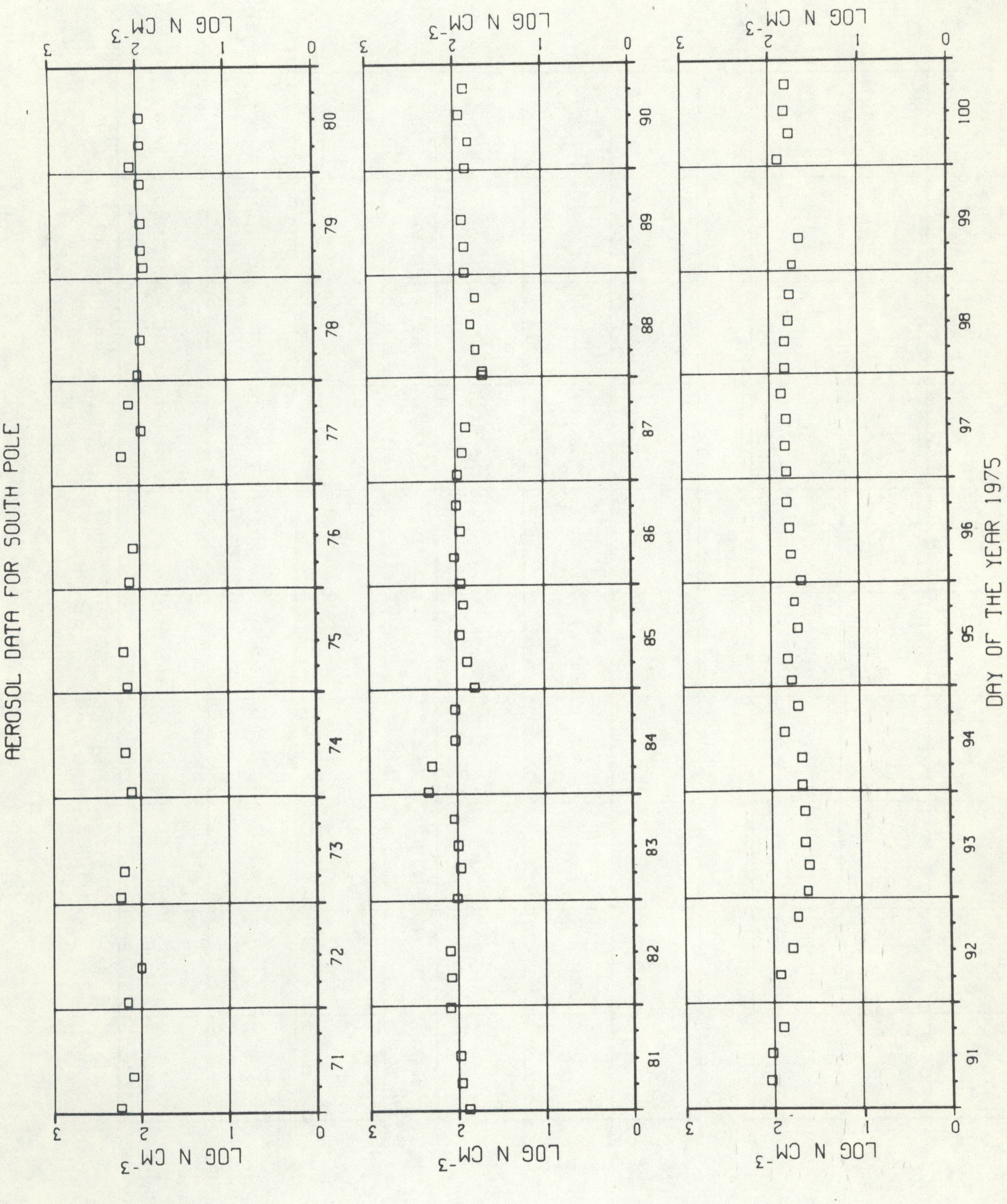
0 1 2 3


AEROSOL DATA FOR SOUTH POLE
LOG N CM-3
DAY OF THE YEAR 1975
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72
73
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75
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77
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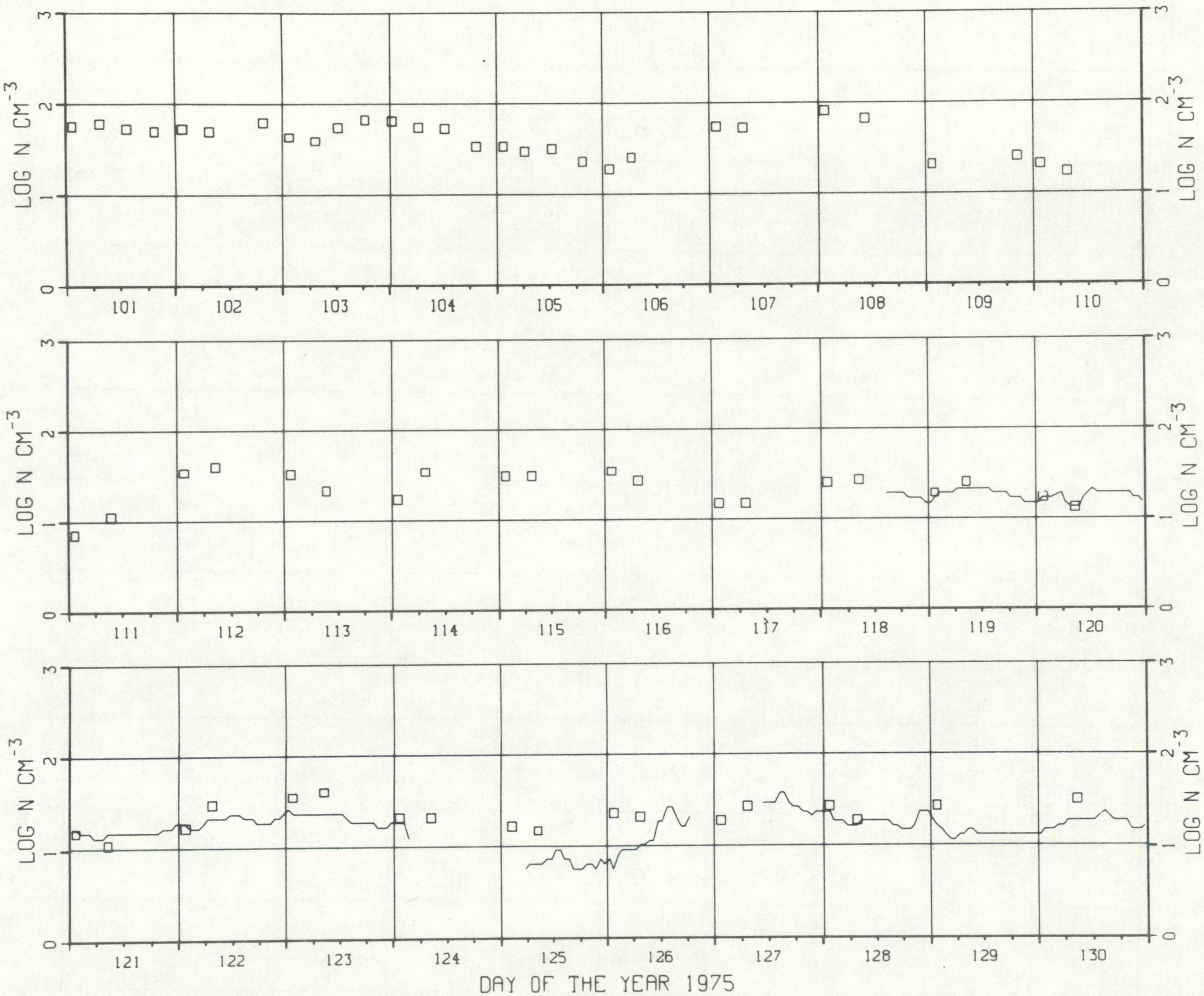
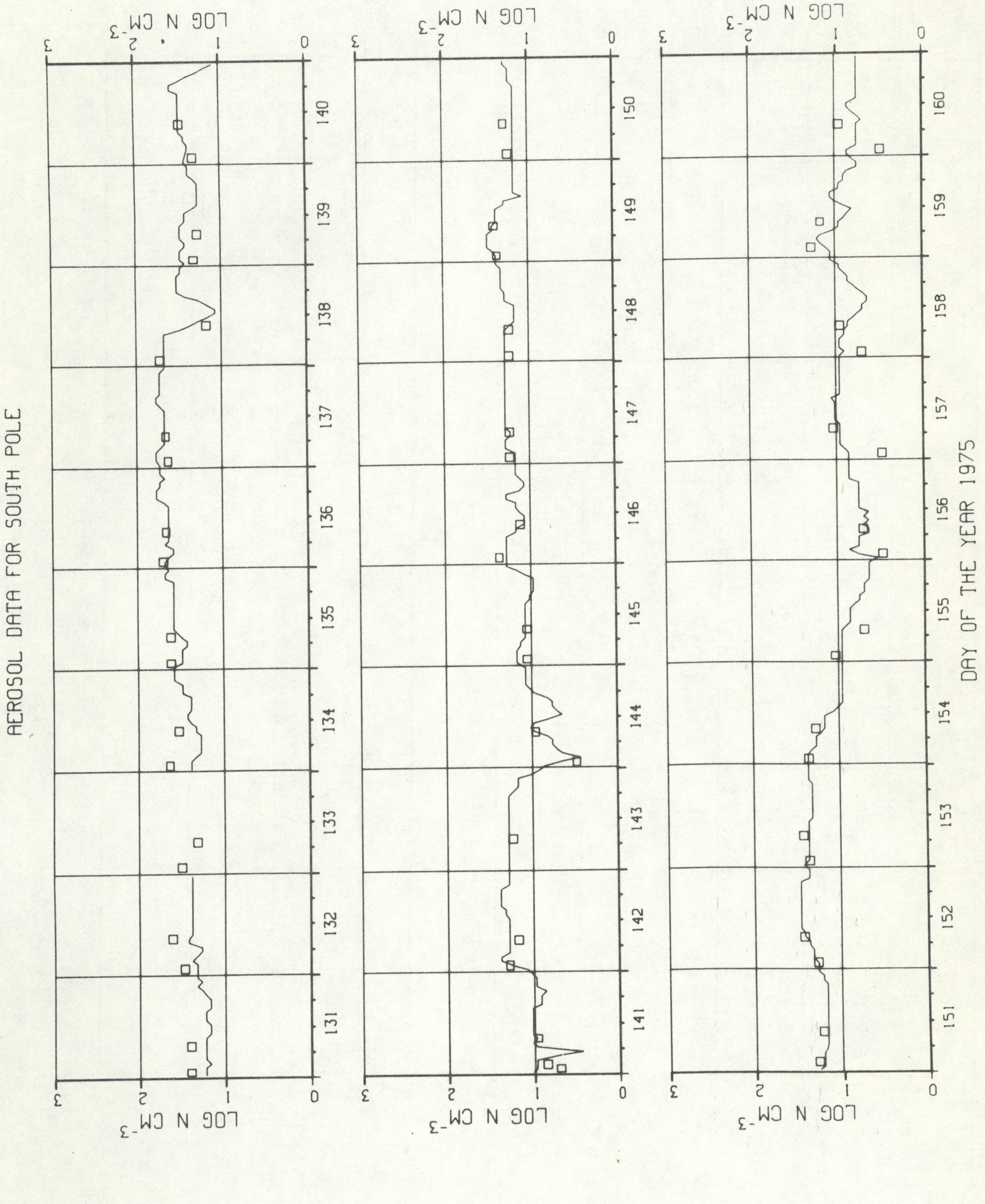
AEROSOL DATA FOR SOUTH POLE




AEROSOL DATA FOR SOUTH POLE
LOG N CM-3
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142
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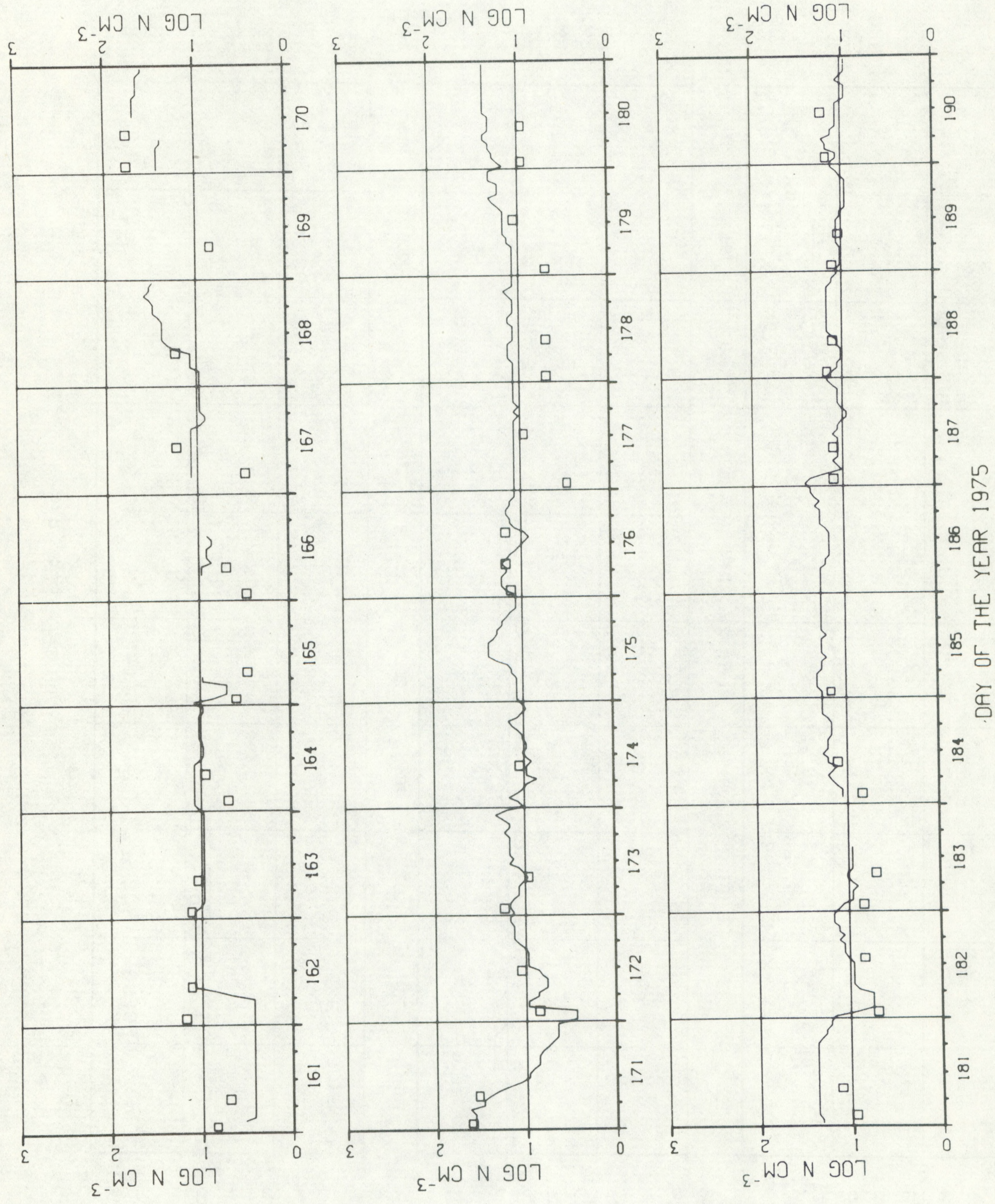
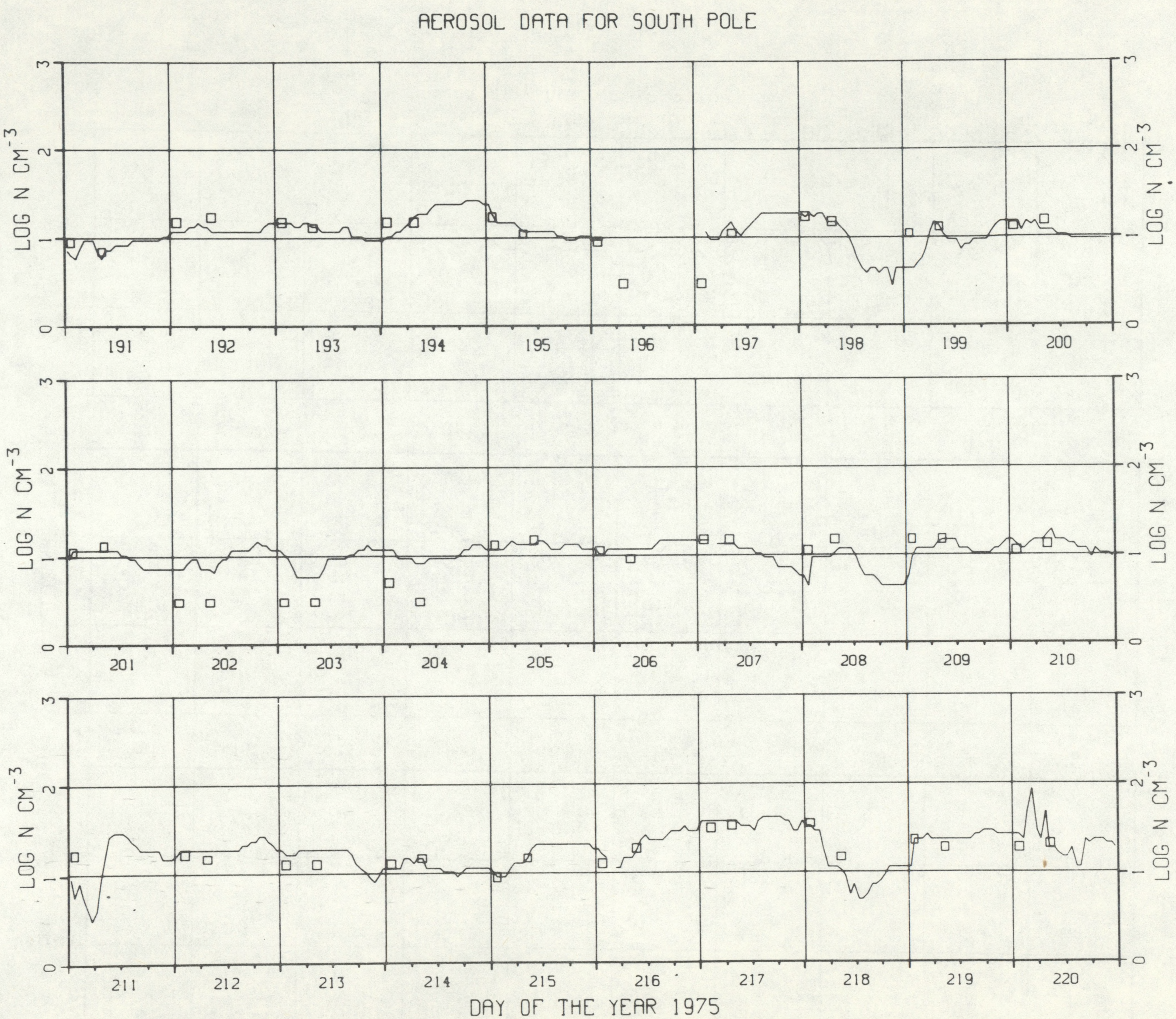
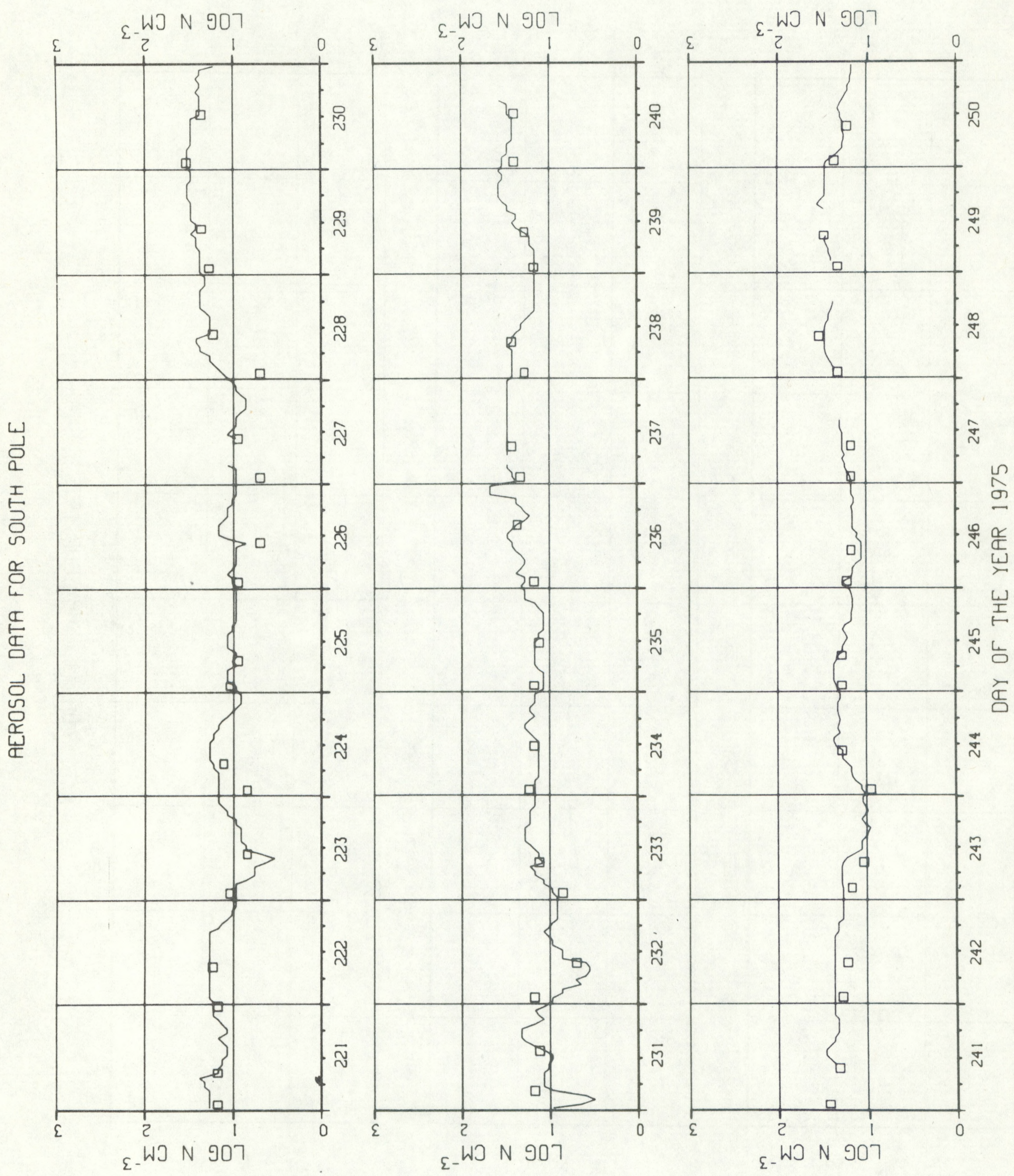
151
152
153
154
155
156
157
158
159
160
DAY OF THE YEAR 1975

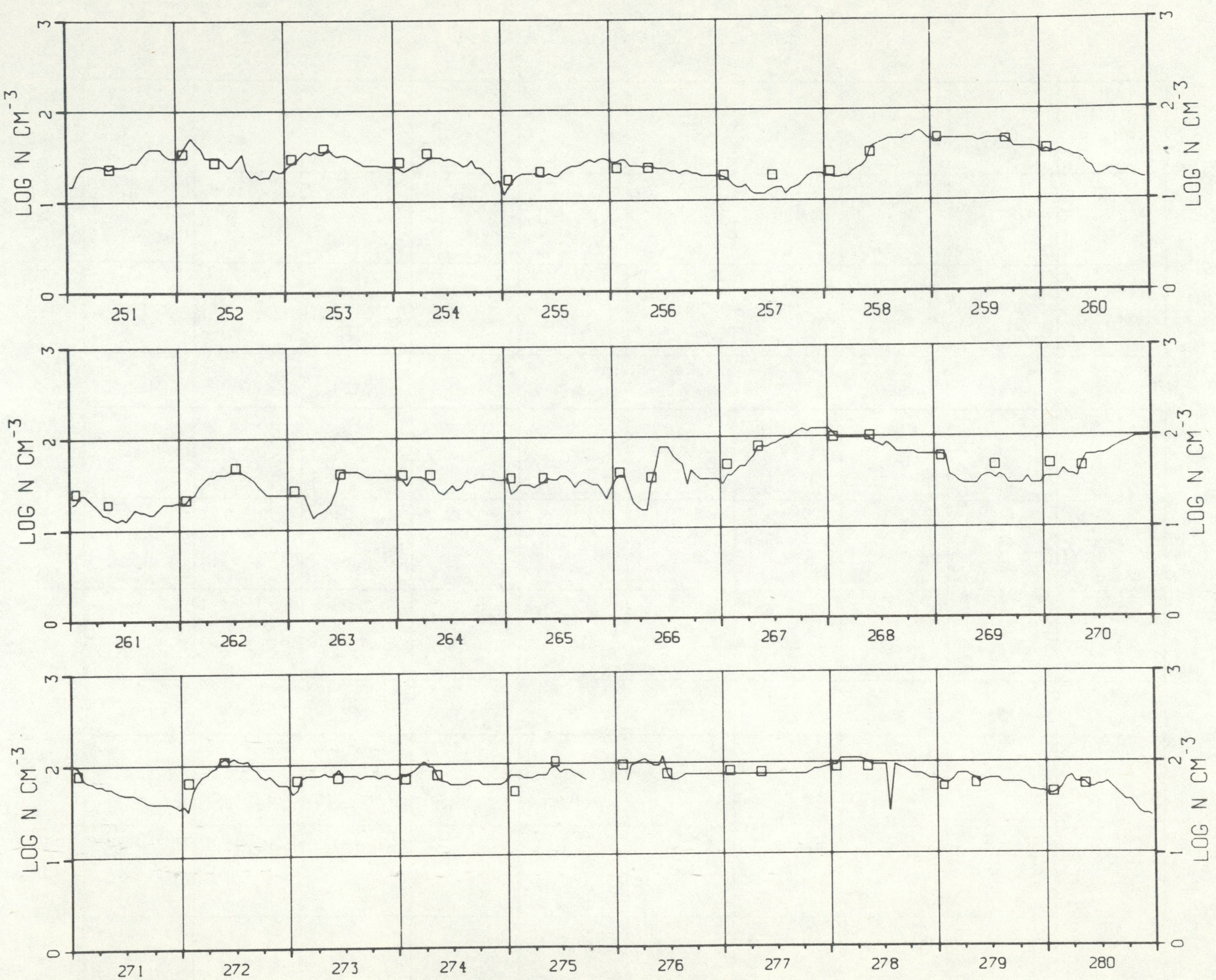
AEROSOL DATA FOR SOUTH POLE




AEROSOL DATA FOR SOUTH POLE
LOG N CM^{-3}
191 192 193 194 195 196 197 198 199 200
201 202 203 204 205 206 207 208 209 210
211 212 213 214 215 216 217 218 219 220
DAY OF THE YEAR 1975

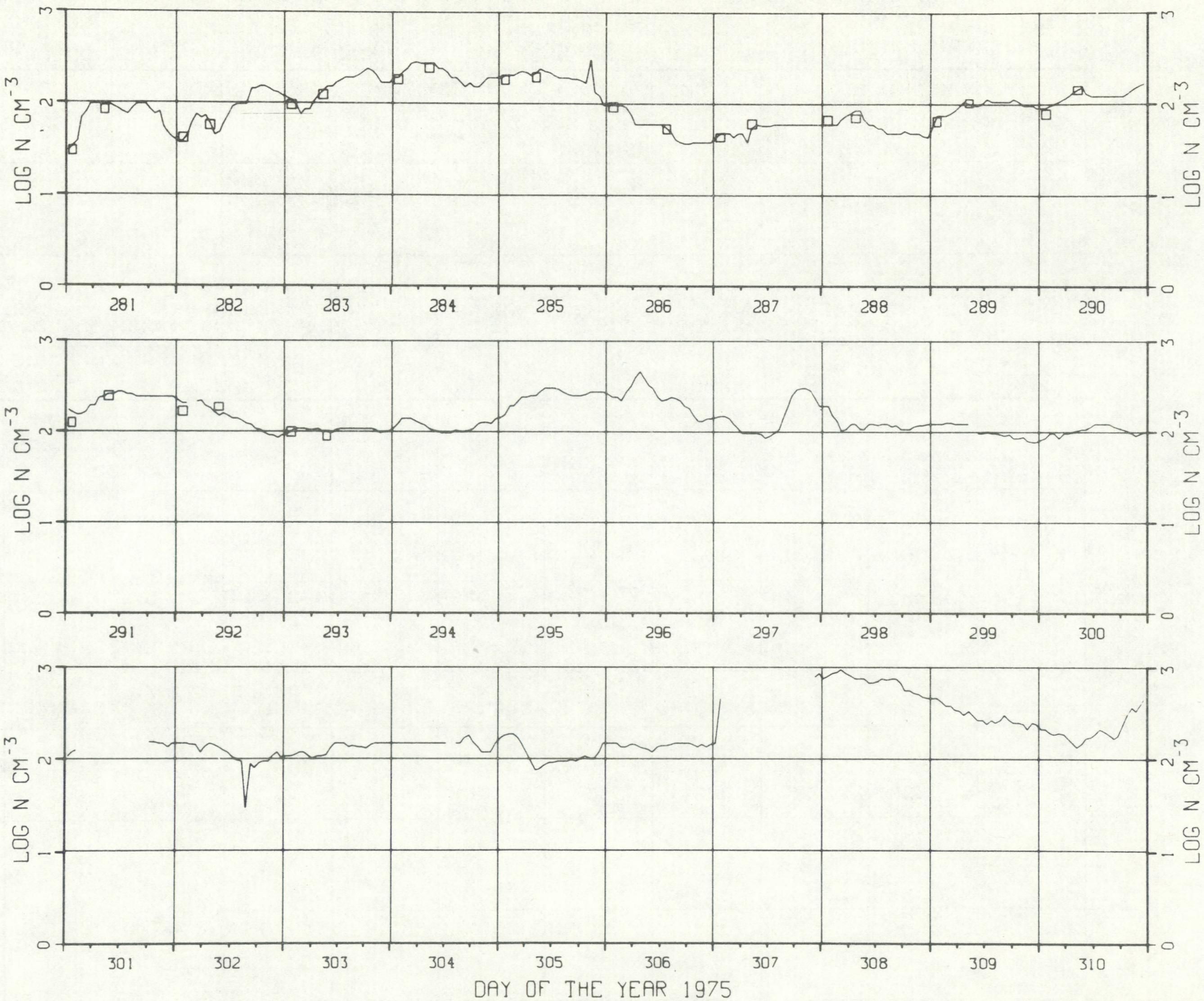

AEROSOL DATA FOR SOUTH POLE
LOG N CM^{-3}
DAY OF THE YEAR 1975
221
222
223
224
225
226
227
228
229
230
231
232
233
234
235
236
237
238
239
240
241
242
243
244
245
246
247
248
249
250

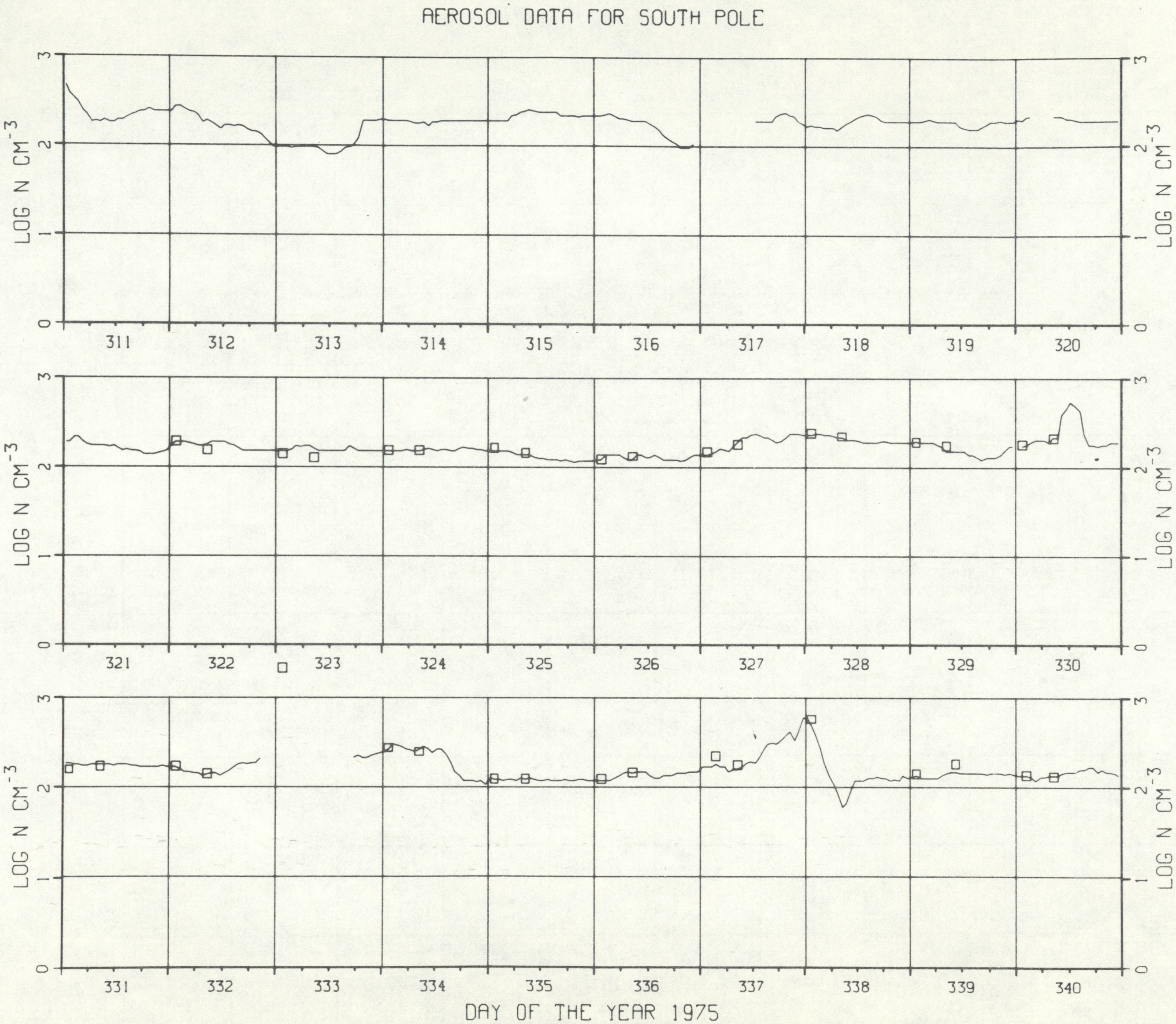
AEROSOL DATA FOR SOUTH POLE



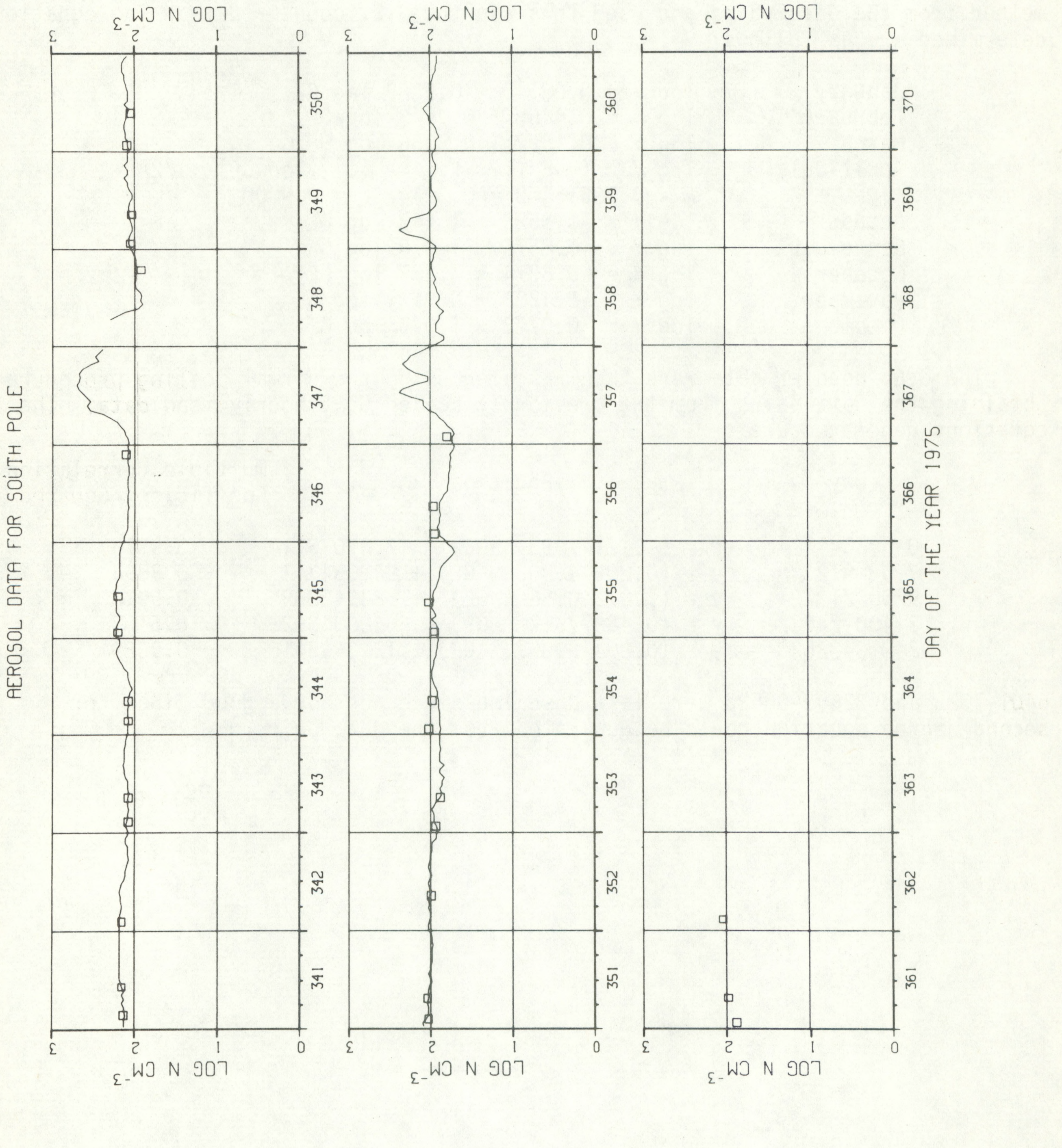
DAY OF THE YEAR 1975

AEROSOL DATA FOR SOUTH POLE





AEROSOL DATA FOR SOUTH POLE
LOG N CM^{-3}
DAY OF THE YEAR 1975


AEROSOL DATA FOR SOUTH POLE
LOG N CM-3
DAY OF THE YEAR 1975
341
342
343
344
345
346
347
348
349
350
351
352
353
354
355
356
357
358
359
360
361
362
363
364
365
366
367
368
369
370
0
1
2
3

APPENDIX C

Appendix C gives the hourly mean nuclei concentration and Pollak counter observations plotted on a logarithmic scale for 1976. The 1976 data were originally scaled by Barry Bodhaine (see "GMCC #5 Summary Report for 1976" for details) to compensate for bad Pollak data taken between April and July. Briefly, data pairs were taken for January through March and August through December and a calibration equation was determined to scale the G.E. counter data from April to July. For each of the other months, an equation was determined by a linear least squares method from the data pairs and used to scale the G.E. counter data. The equations determined are as follows:

January	$\log Y = 0.03140 + 0.9289 \log GE$
February	$\log Y = 0.4468 + 0.7448 \log GE$
March	$\log Y = 0.1592 + 0.8956 \log GE$
April-July	$\log Y = (-B + \sqrt{B^2 - 4A (C - \log GE)})/2A$
	$A = 0.08515,\ B = 0.3914,\ C = 0.9000$
August	$\log Y = -0.9523 + 1.443 \log GE$
September	$\log Y = -0.8375 + 1.378 \log GE$
October	$\log Y = -0.5274 + 1.287 \log GE$
November	$\log Y = -0.4203 + 0.8931 \log GE$
December	$\log Y = -0.0772 + 1.070 \log GE$

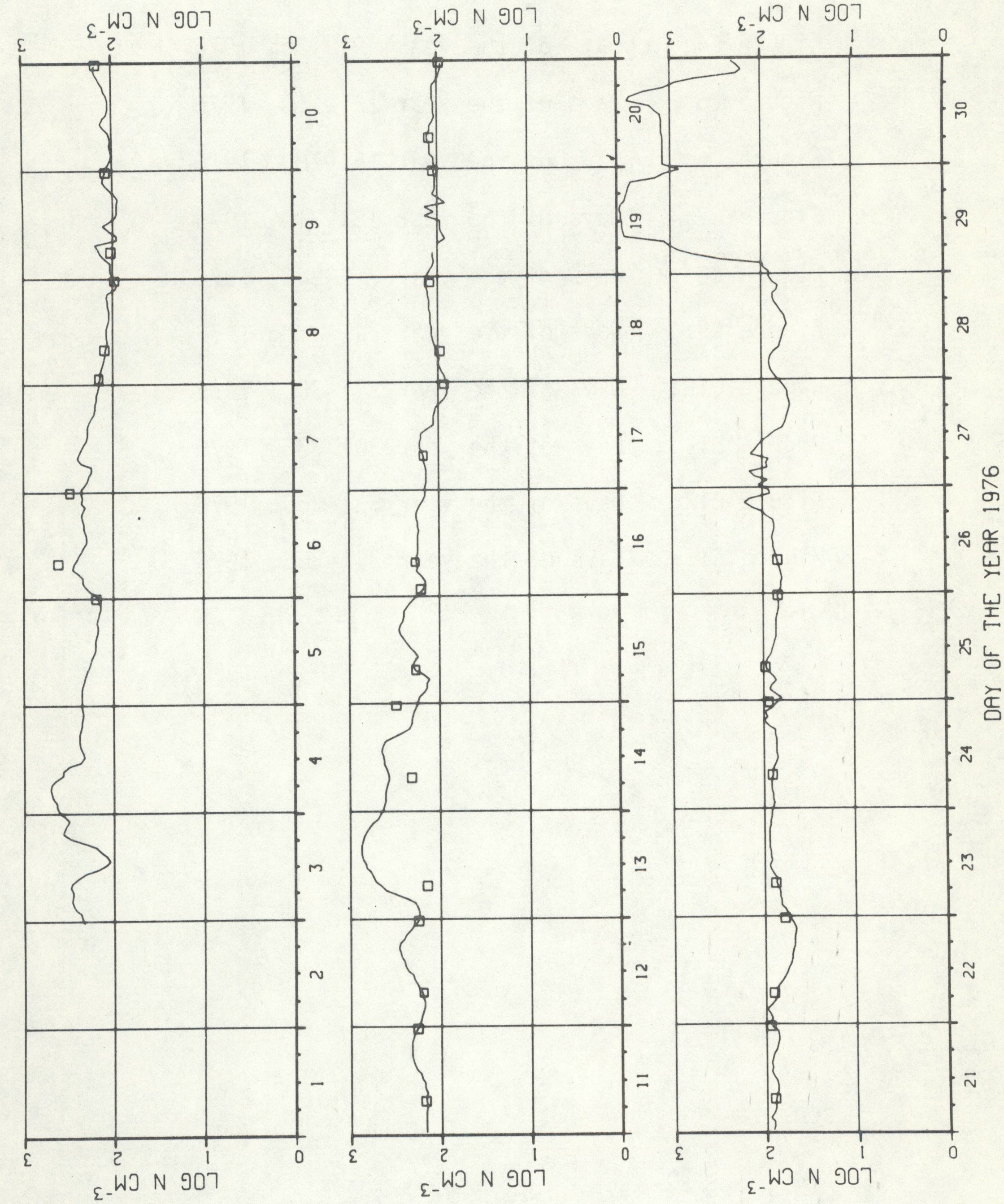
The G.E. counter data were then rescaled using the normal scaling procedure obtaining the data pairs from the previously scaled G.E. hourly mean data. The equations generated are:

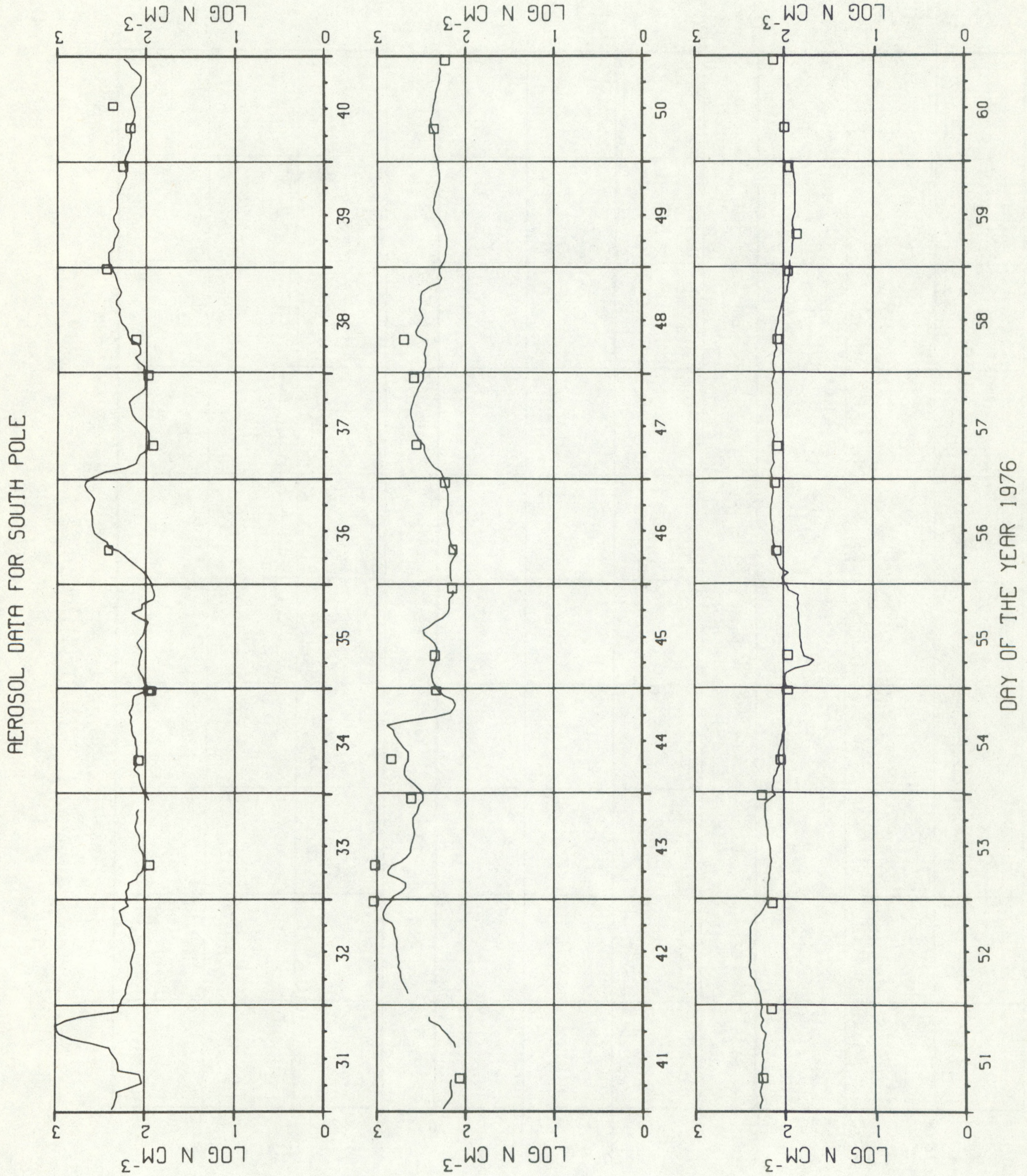
Day	Equation	Multiple Correlation Coefficient Squared
0-5923	y = (1.17147235 * GE) - 12.4767671	0.9775
7703-9123	y = (0.803445803 * GE) + 24.354741	0.5894
9200-21323	y = (1.07240556 * GE) - 1.82948339	0.9929
21400-24722	y = (0.48877817 * GE) + 6.48835382	0.5191
24813-32523	y = (0.804159857 * GE) + 12.3435016	0.9089

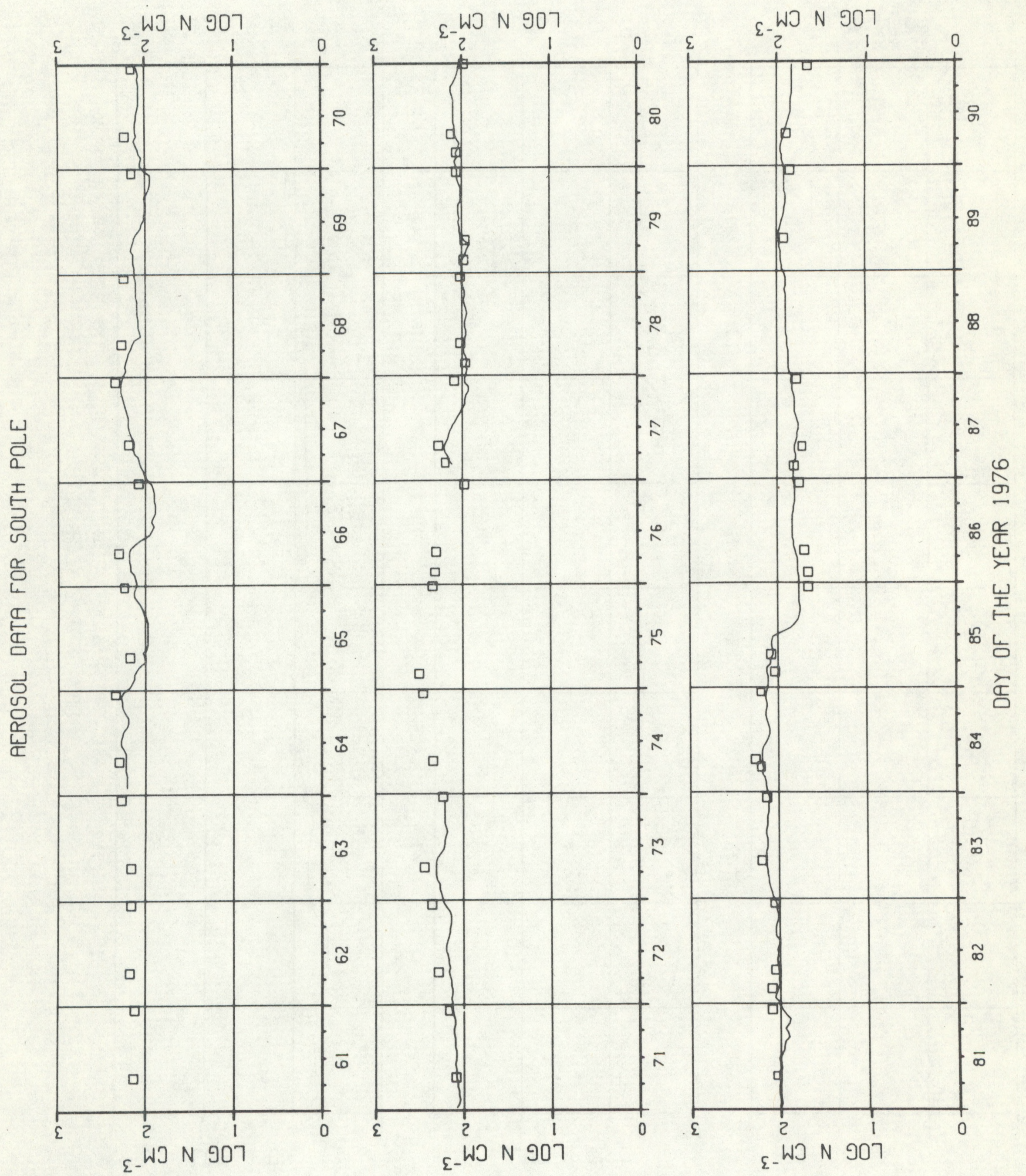
6401-7322 and 32603-36523 were left unscaled since neither a good linear or second degree equation could be generated from the data pairs.

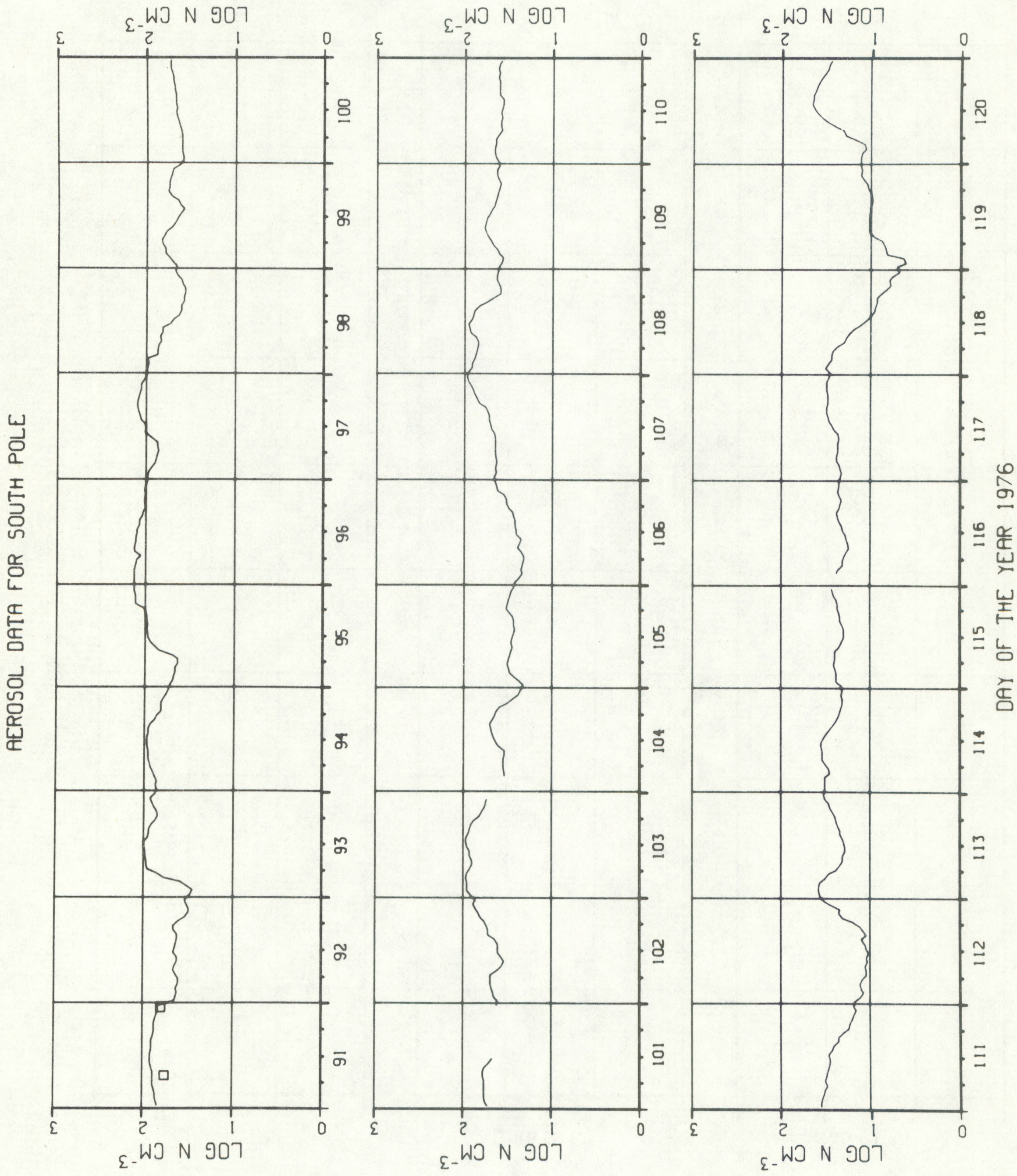
Scaled graphical display of both G.E. counter (solid line) and Pollak counter (squares) data for 1976.

AEROSOL DATA FOR SOUTH POLE

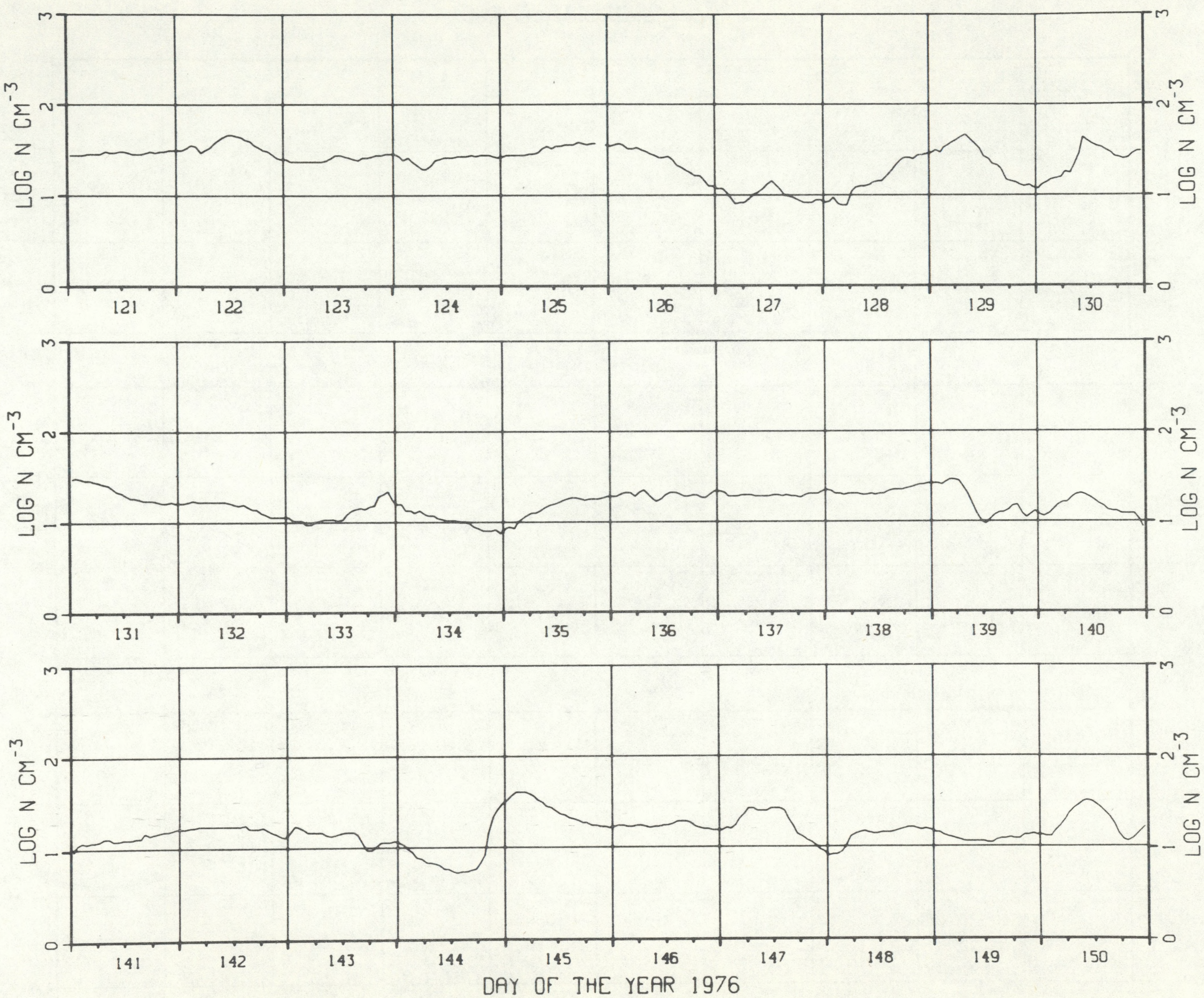


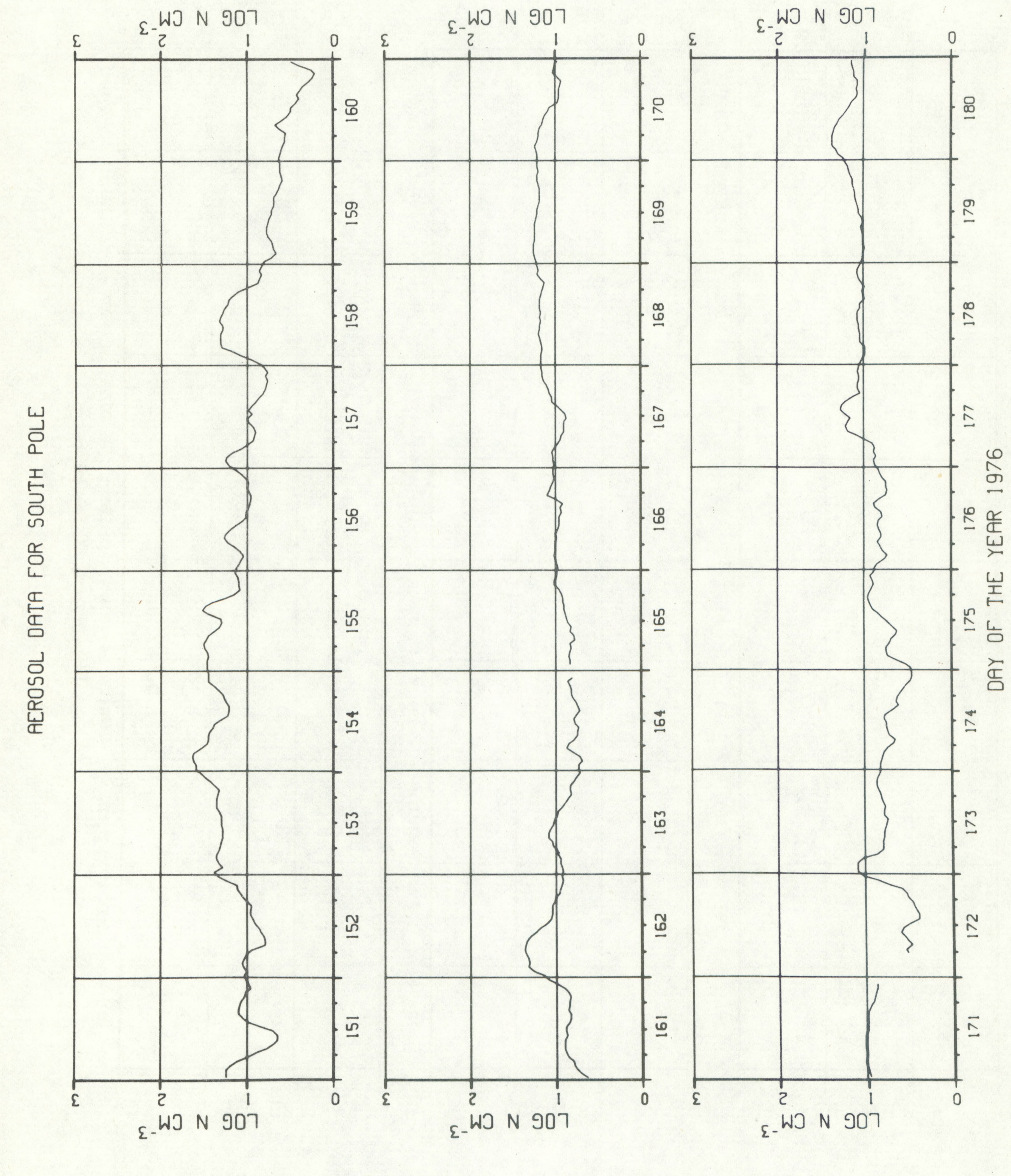

AEROSOL DATA FOR SOUTH POLE
LOG N CM-3
DAY OF THE YEAR 1976
31
32
33
34
35
36
37
38
39
40
41
42
43
44
45
46
47
48
49
50
51
52
53
54
55
56
57
58
59
60
0
1
2
3

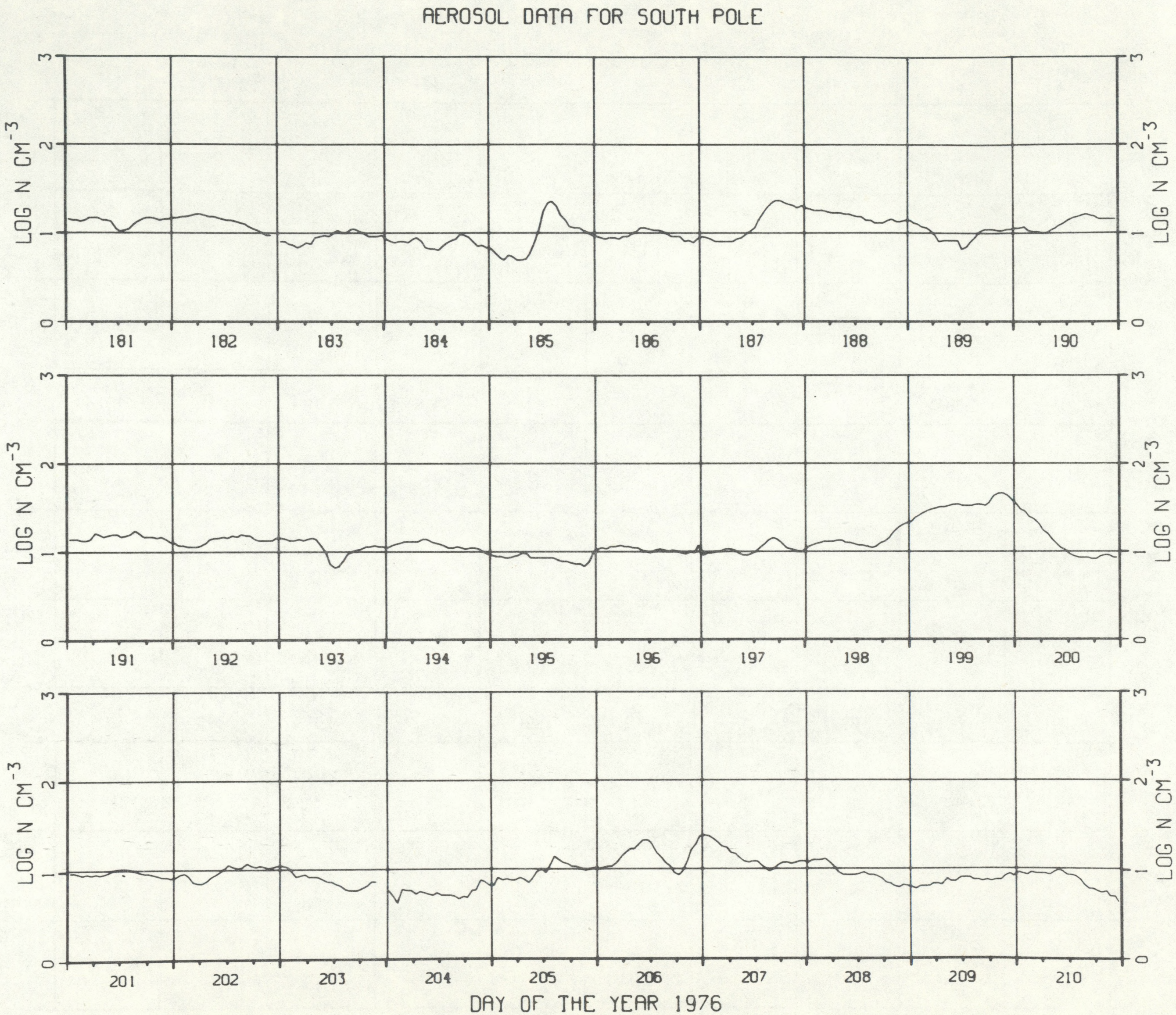

AEROSOL DATA FOR SOUTH POLE
LOG N CM-3
DAY OF THE YEAR 1976
61 62 63 64 65 66 67 68 69 70
71 72 73 74 75 76 77 78 79 80
81 82 83 84 85 86 87 88 89 90
0 1 2 3

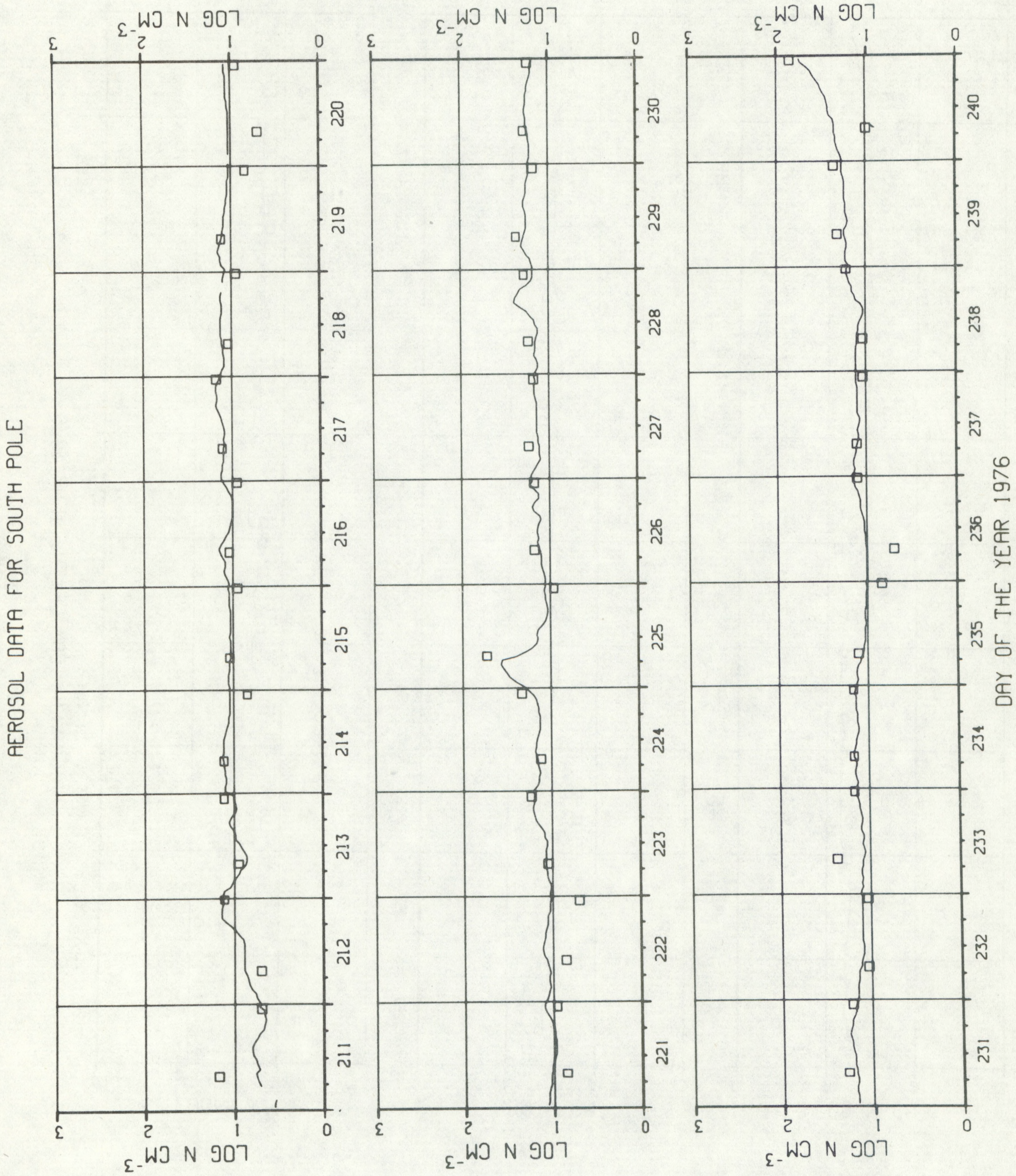

AEROSOL DATA FOR SOUTH POLE
DAY OF THE YEAR 1976
LOG N CM-3
0
1
2
3
91
92
93
94
95
96
97
98
99
100
101
102
103
104
105
106
107
108
109
110
111
112
113
114
115
116
117
118
119
120

AEROSOL DATA FOR SOUTH POLE




AEROSOL DATA FOR SOUTH POLE
LOG N CM-3
0
1
2
3
151
152
153
154
155
156
157
158
159
160
161
162
163
164
165
166
167
168
169
170
171
172
173
174
175
176
177
178
179
180
DAY OF THE YEAR 1976


AEROSOL DATA FOR SOUTH POLE
LOG N CM-3
181
182
183
184
185
186
187
188
189
190
191
192
193
194
195
196
197
198
199
200
201
202
203
204
205
206
207
208
209
210
DAY OF THE YEAR 1976


AEROSOL DATA FOR SOUTH POLE
DAY OF THE YEAR 1976
LOG N CM^{-3}
0
1
2
3
211
212
213
214
215
216
217
218
219
220
221
222
223
224
225
226
227
228
229
230
231
232
233
234
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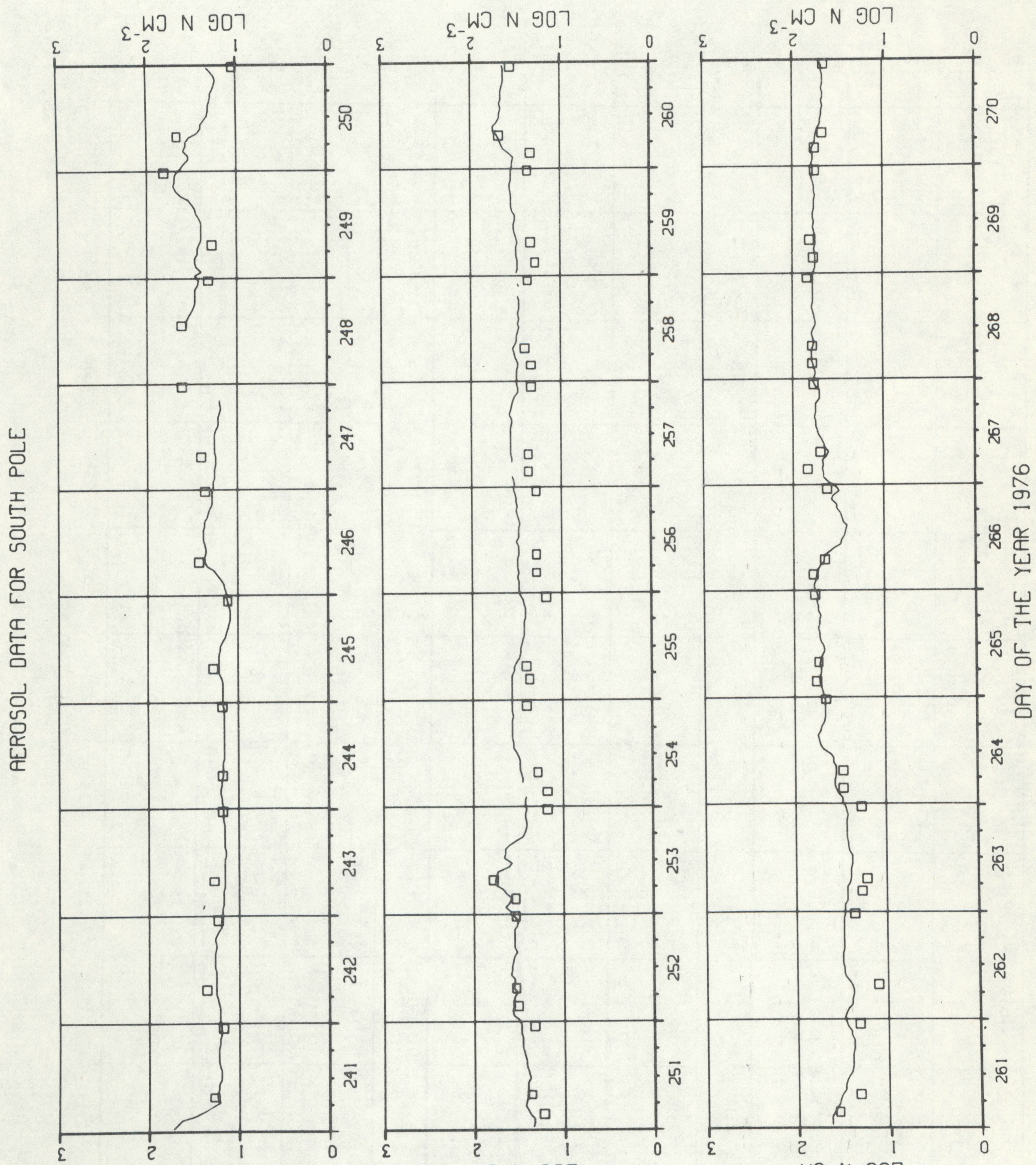
236
237
238
239
240


AEROSOL DATA FOR SOUTH POLE
LOG N CM^{-3}
DAY OF THE YEAR 1976
241
242
243
244
245
246
247
248
249
250
251
252
253
254
255
256
257
258
259
260
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263
264
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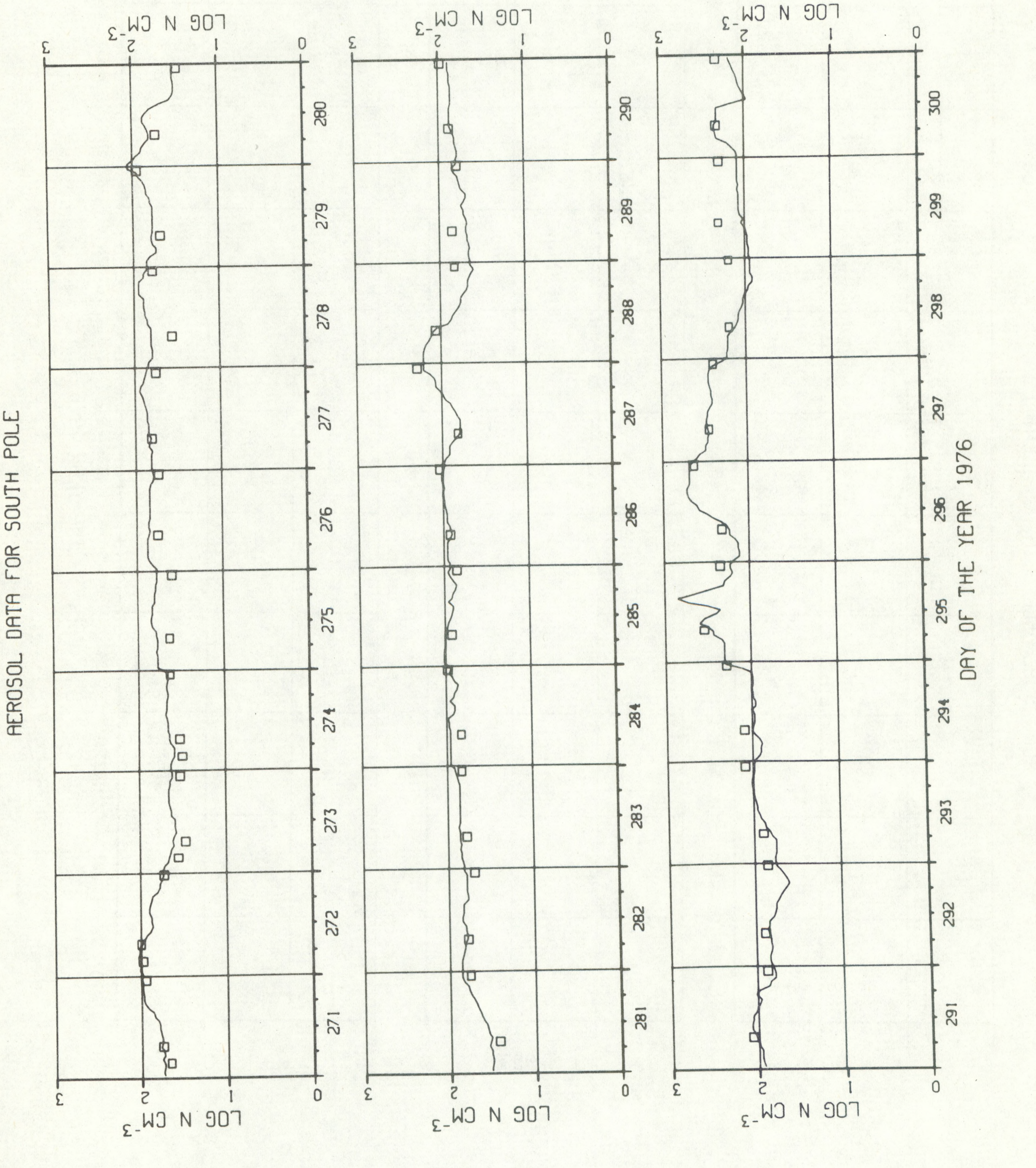
266
267
268
269
270


AEROSOL DATA FOR SOUTH POLE
DAY OF THE YEAR 1976
LOG N CM-3
271
272
273
274
275
276
277
278
279
280
281
282
283
284
285
286
287
288
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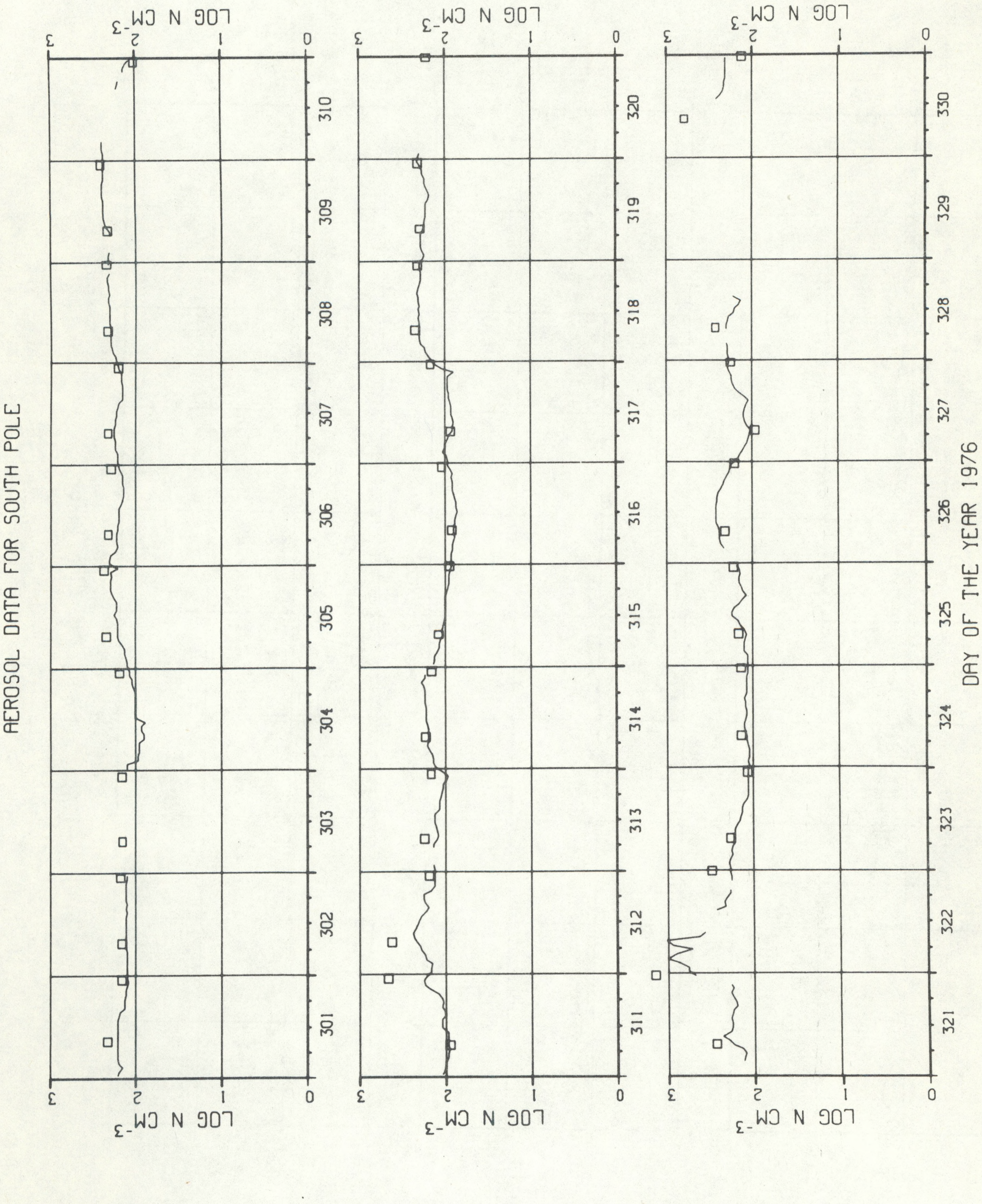
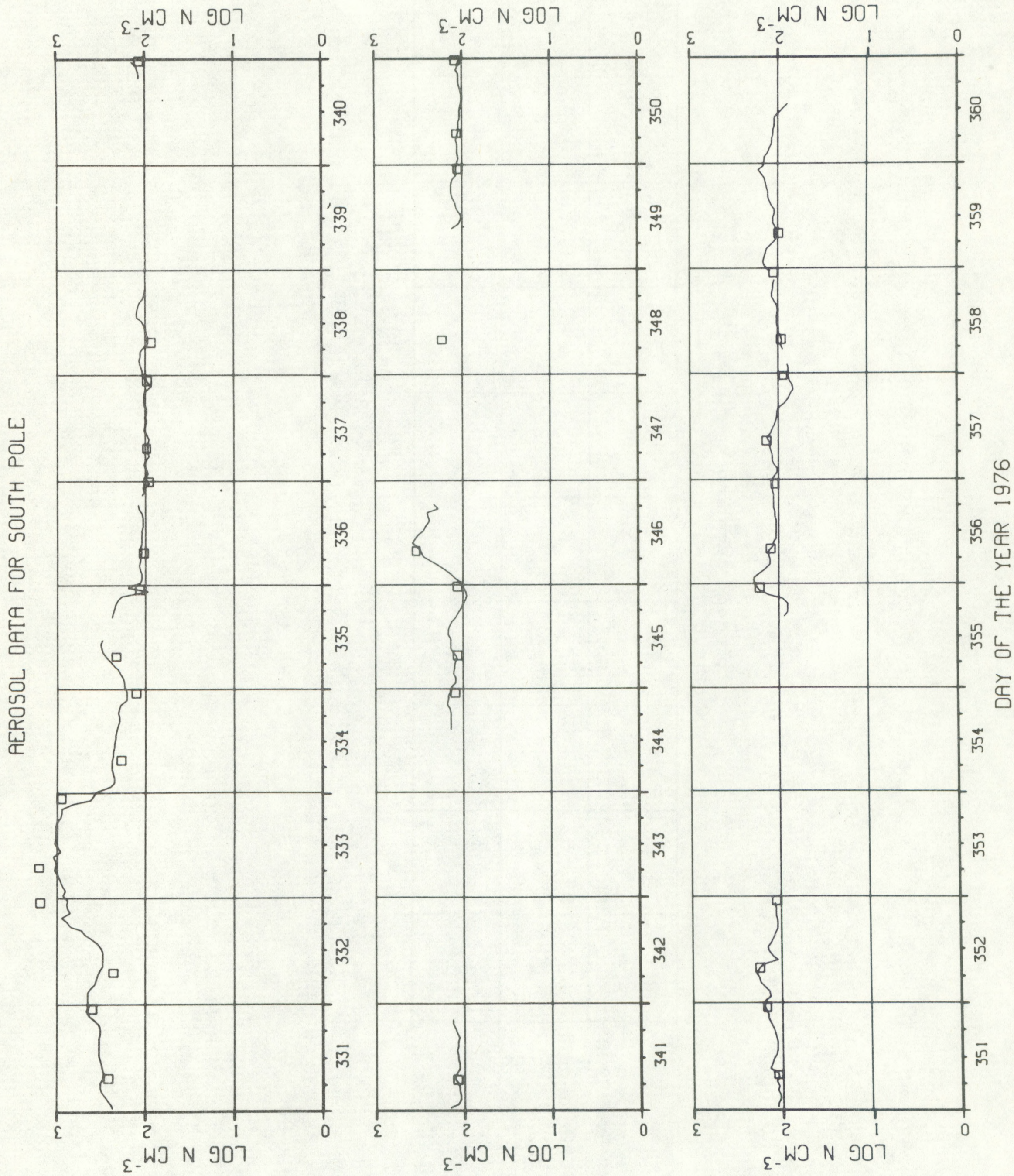
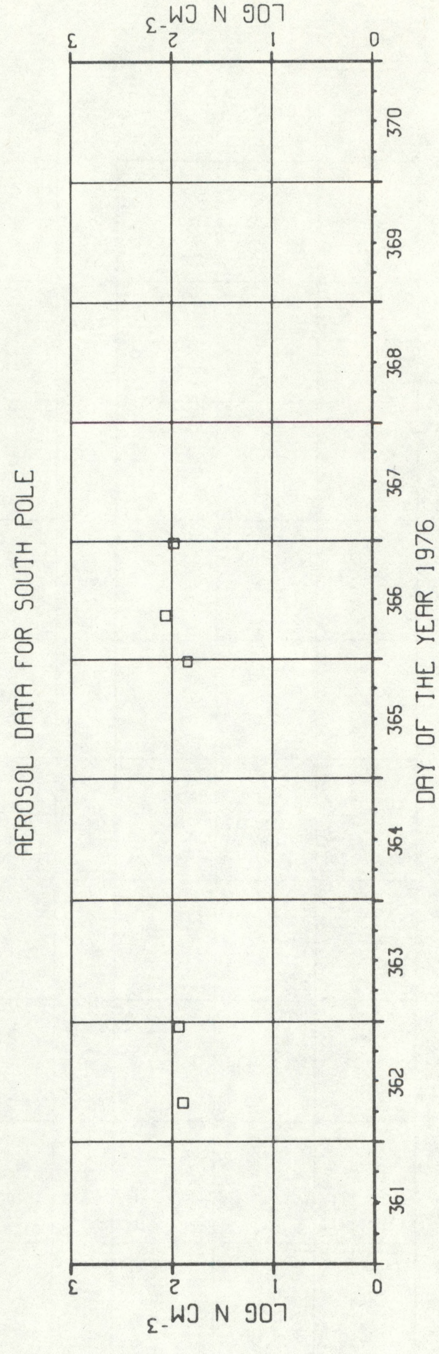
296
297
298
299
300


AEROSOL DATA FOR SOUTH POLE
LOG N CM-3
0
1
2
3
301
302
303
304
305
306
307
308
309
310
311
312
313
314
315
316
317
318
319
320
321
322
323
324
325
326
327
328
329
330
DAY OF THE YEAR 1976


AEROSOL DATA FOR SOUTH POLE
LOG N CM^{-3}
3
2
1
0
331
332
333
334
335
336
337
338
339
340
341
342
343
344
345
346
347
348
349
350
351
352
353
354
355
356
357
358
359
360
DAY OF THE YEAR 1976


AEROSOL DATA FOR SOUTH POLE
DAY OF THE YEAR 1976
LOG N CM-3
361
362
363
364
365
366
367
368
369
370
0
1
2
3

APPENDIX D

Appendix D contains the hourly mean nuclei concentrations and Pollak counter observations plotted on a logarithmic scale for 1977. A histogram of successive minute voltage difference for each month was generated and the variability criterion was determined to be ±0.04665 volts.

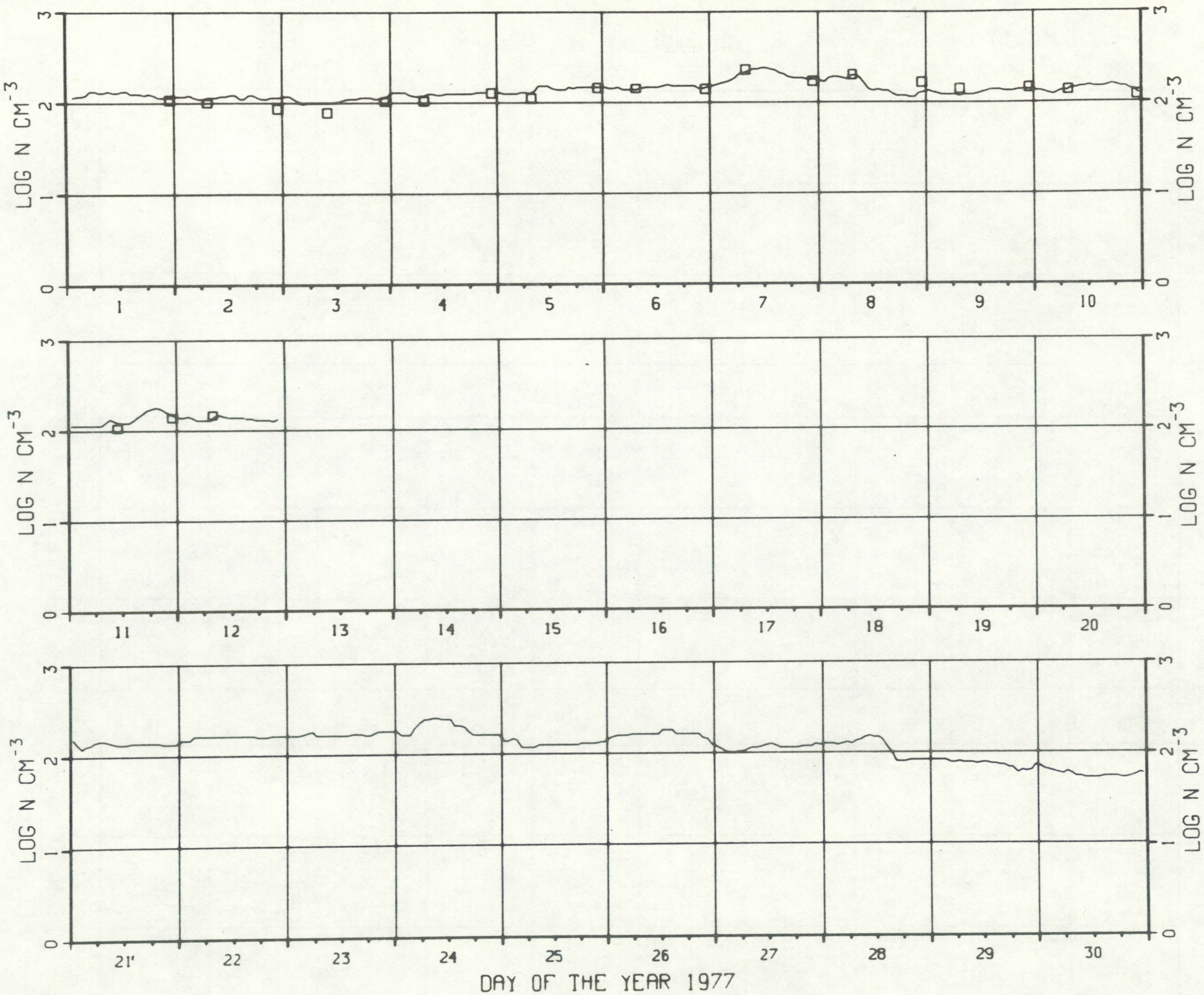
The data pairs were obtained from the minute data and grouped into periods where the G.E. counter was operating. The equations generated are:

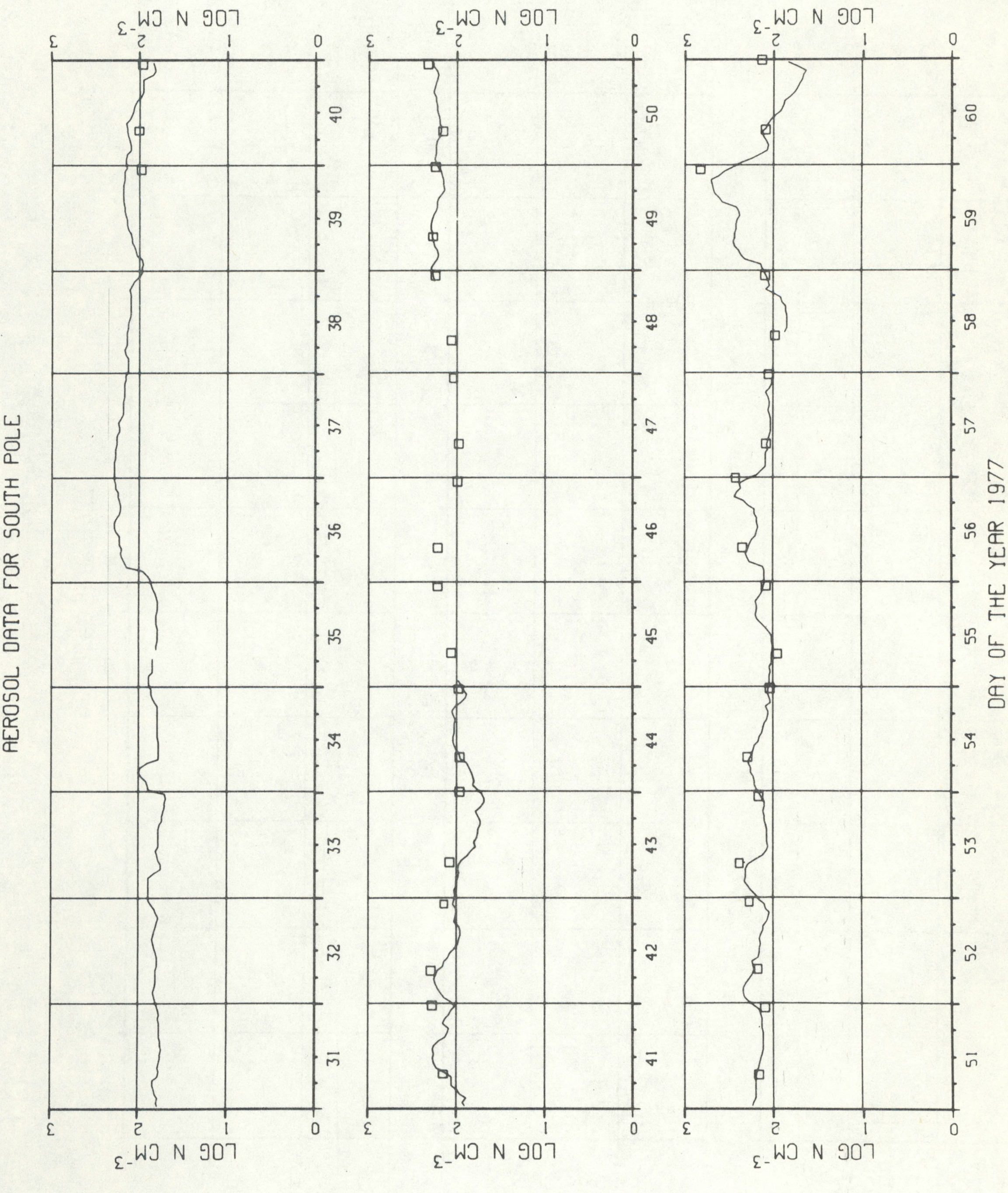
Day	Equation	Multiple Correlation Coefficient Squared
0-4502	y = (0.823139951 * GE) + 38.3010709	0.8755
4821-7806	y = (1.37940695 * GE) - 12.9866026	0.8752
8509-21301	y = (1.08488203 * GE) + 2.94789511	0.9562
21308-22003	y = (1.35120205 * GE) - 1.83283432	0.8436
22020-28710	y = (1.19633482 * GE) - 2.77289020	0.9712
28801-29422	y = (1.21895399 * GE) - 18.088862	0.9245
29510-31021	y = (1.03946233 * GE) + 20.97070371	0.8887
34903-36522	y = (0.57400184 * GE) - 23.5263183	0.8729

Days 34422-34523 were scaled using linear regression with the scale factors of 0.765337613 and 0.808528478.

Scaled graphical display of both G.E. counter (solid line) and Pollak counter (squares) data for 1977.

AEROSOL DATA FOR SOUTH POLE





AEROSOL DATA FOR SOUTH POLE
DAY OF THE YEAR 1977
LOG N CM-3
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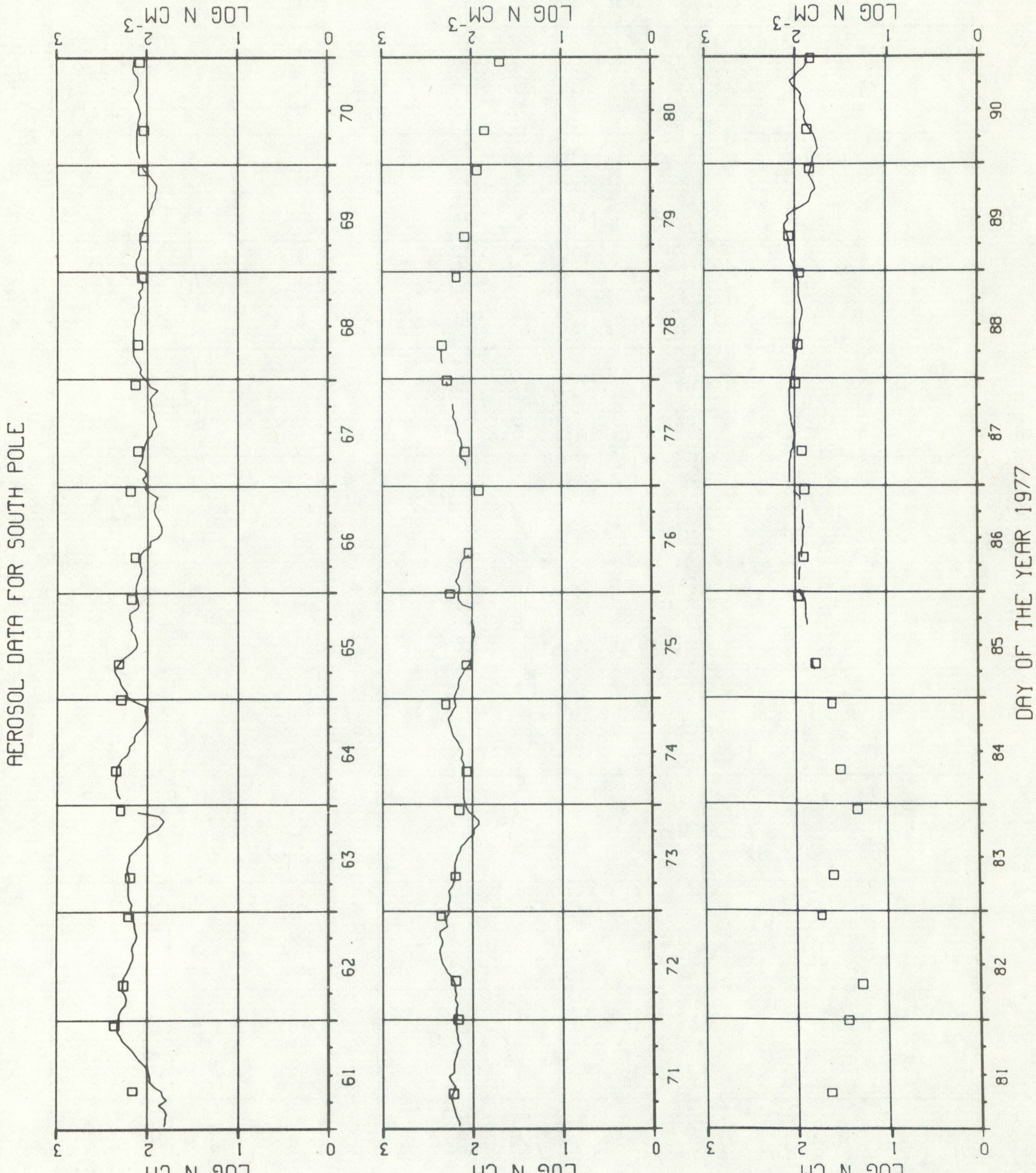
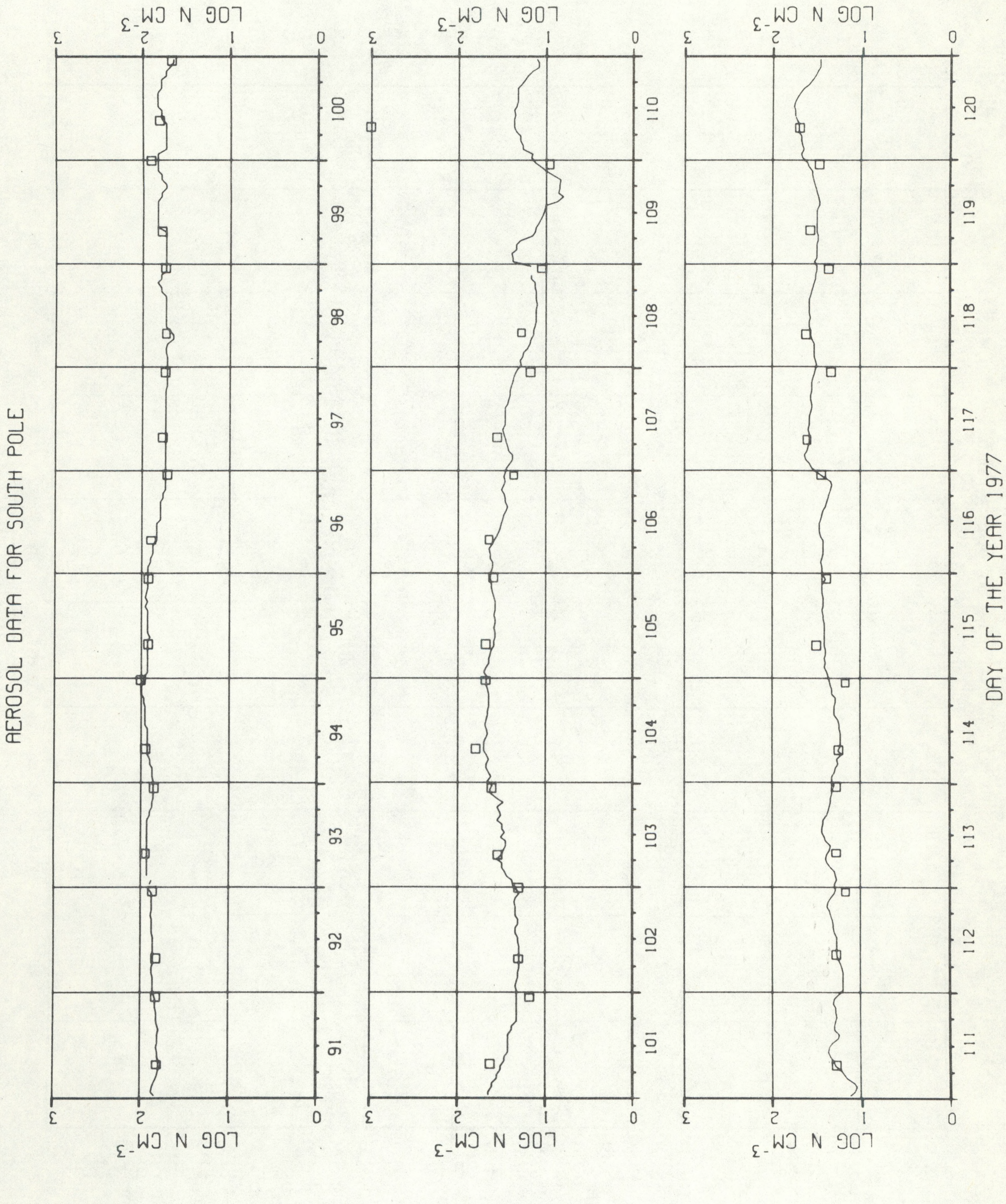
41 42 43 44 45 46 47 48 49 50
51 52 53 54 55 56 57 58 59 60
3 2 1 0


AEROSOL DATA FOR SOUTH POLE
LOG N CM-3
0
1
2
3
61
62
63
64
65
66
67
68
69
70
71
72
73
74
75
76
77
78
79
80
81
82
83
84
85
86
87
88
89
90
DAY OF THE YEAR 1977



AEROSOL DATA FOR SOUTH POLE
DAY OF THE YEAR 1977
LOG N CM^{-3}
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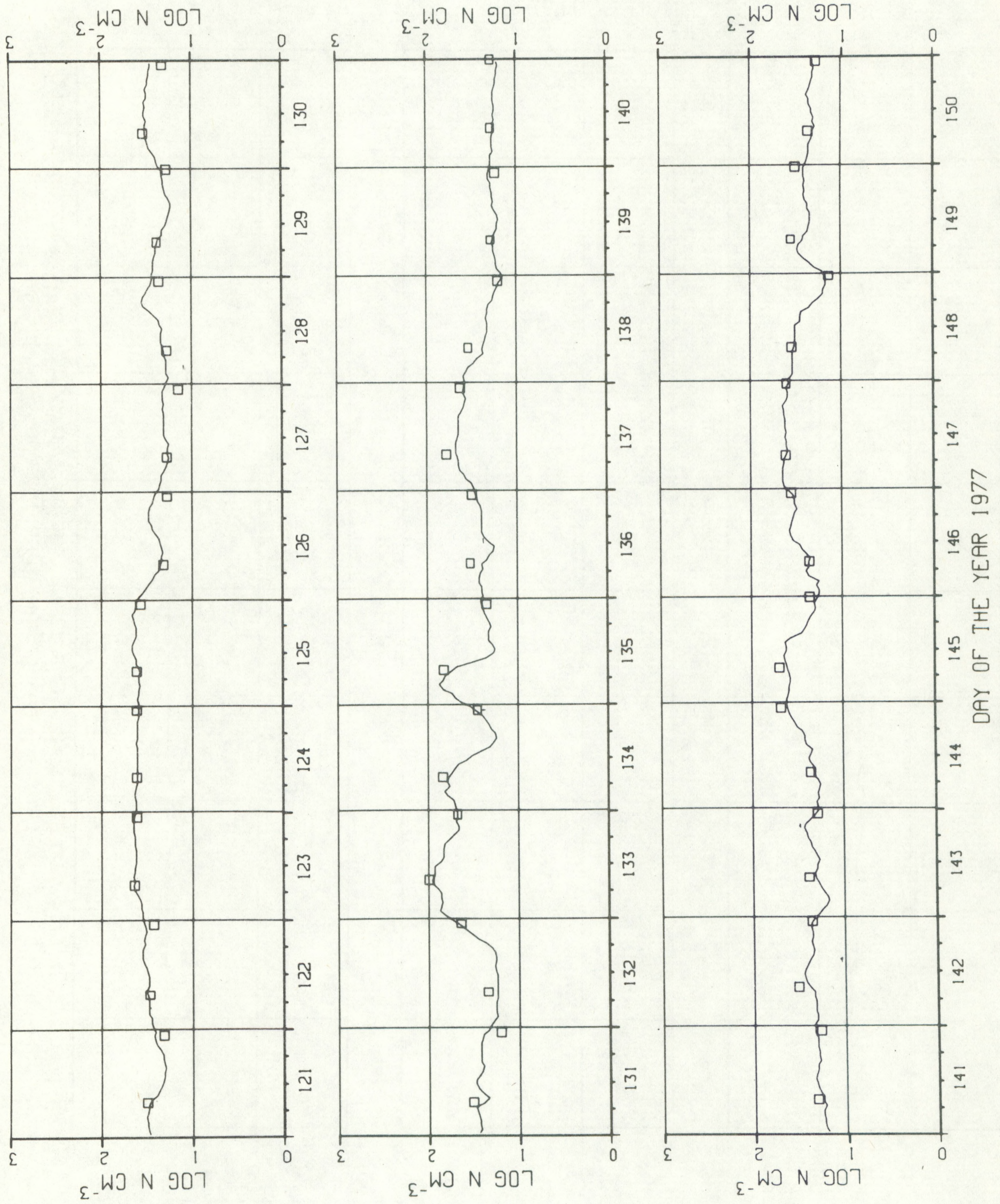
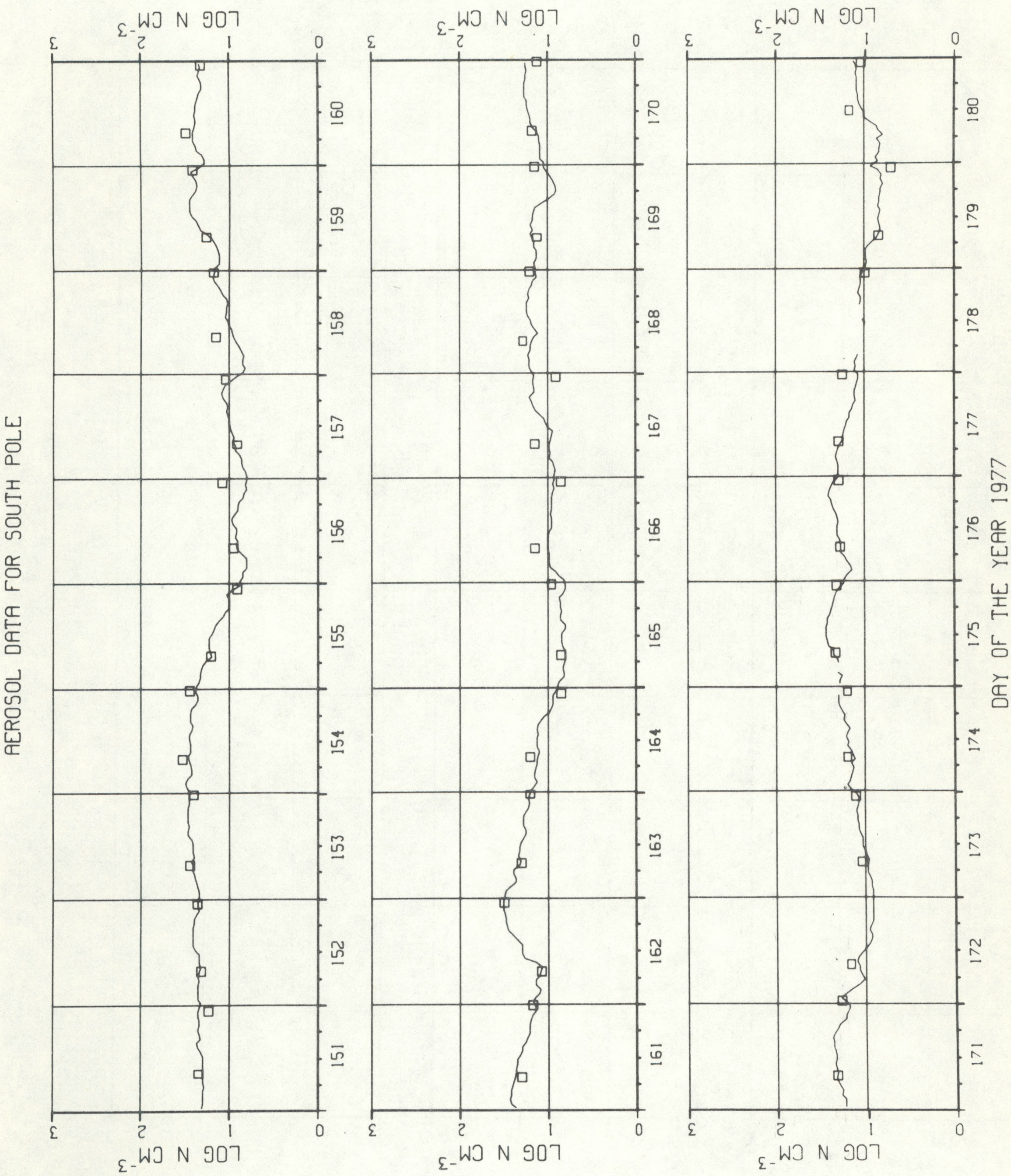
101 102 103 104 105 106 107 108 109 110
111 112 113 114 115 116 117 118 119 120
0 1 2 3

AEROSOL DATA FOR SOUTH POLE




AEROSOL DATA FOR SOUTH POLE
LOG N CM-3
0
1
2
3
151
152
153
154
155
156
157
158
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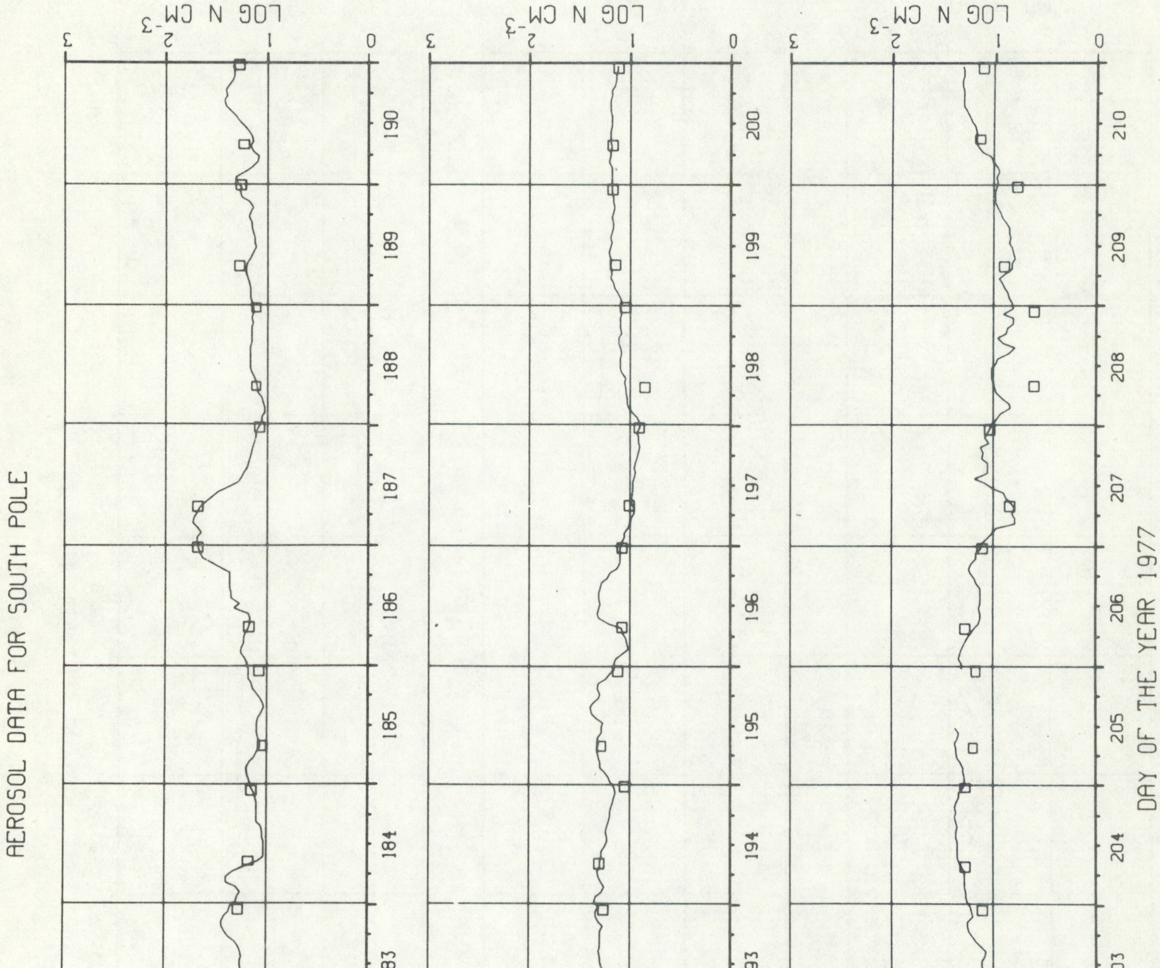
160
161
162
163
164
165
166
167
168
169
170
171
172
173
174
175
176
177
178
179
180
DAY OF THE YEAR 1977


AEROSOL DATA FOR SOUTH POLE
DAY OF THE YEAR 1977
LOG N CM^{-3}
0
1
2
3
181
182
183
184
185
186
187
188
189
190
191
192
193
194
195
196
197
198
199
200
201
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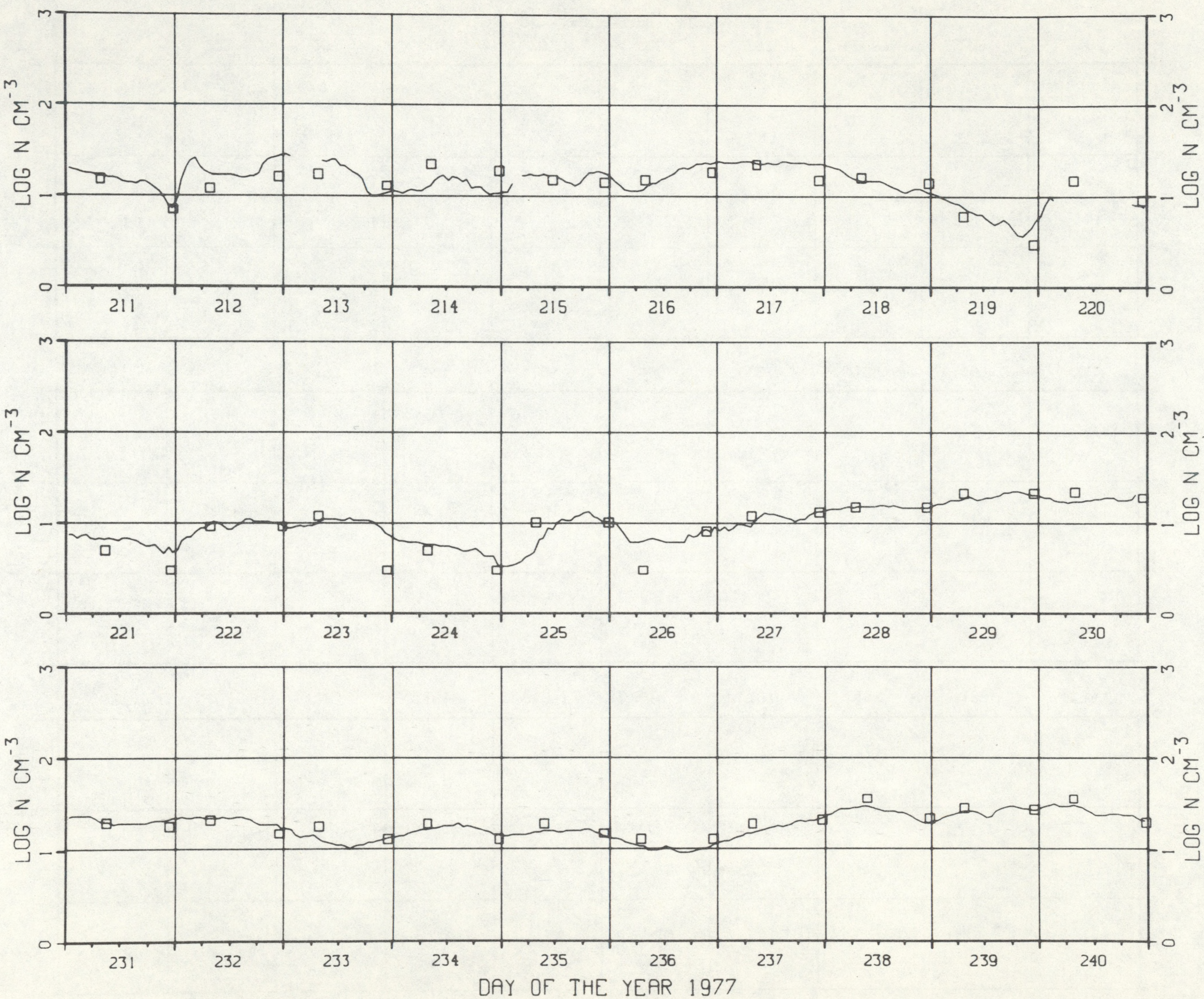
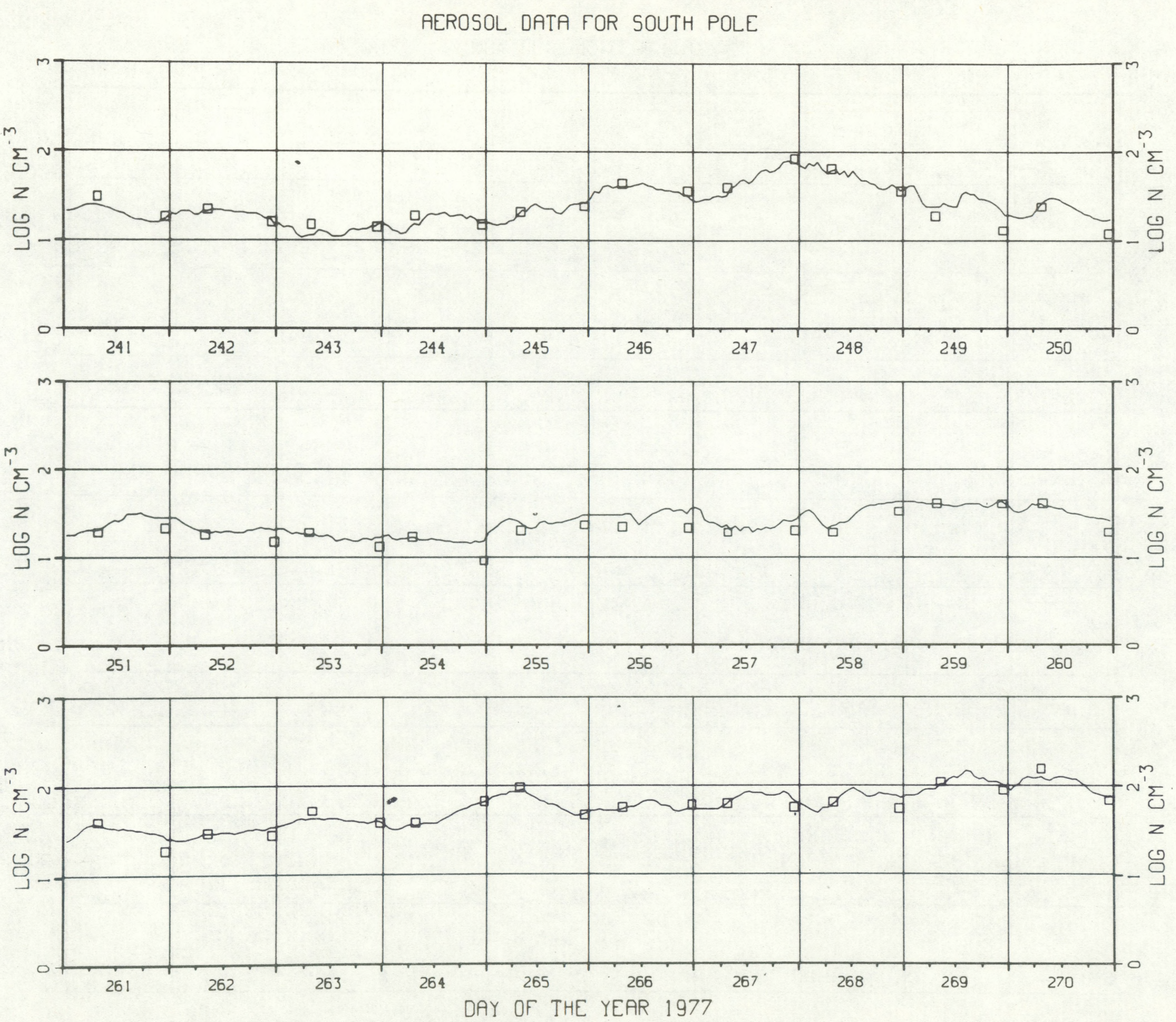
208
209
210

AEROSOL DATA FOR SOUTH POLE




AEROSOL DATA FOR SOUTH POLE
LOG N CM^-3
0
1
2
3
241
242
243
244
245
246
247
248
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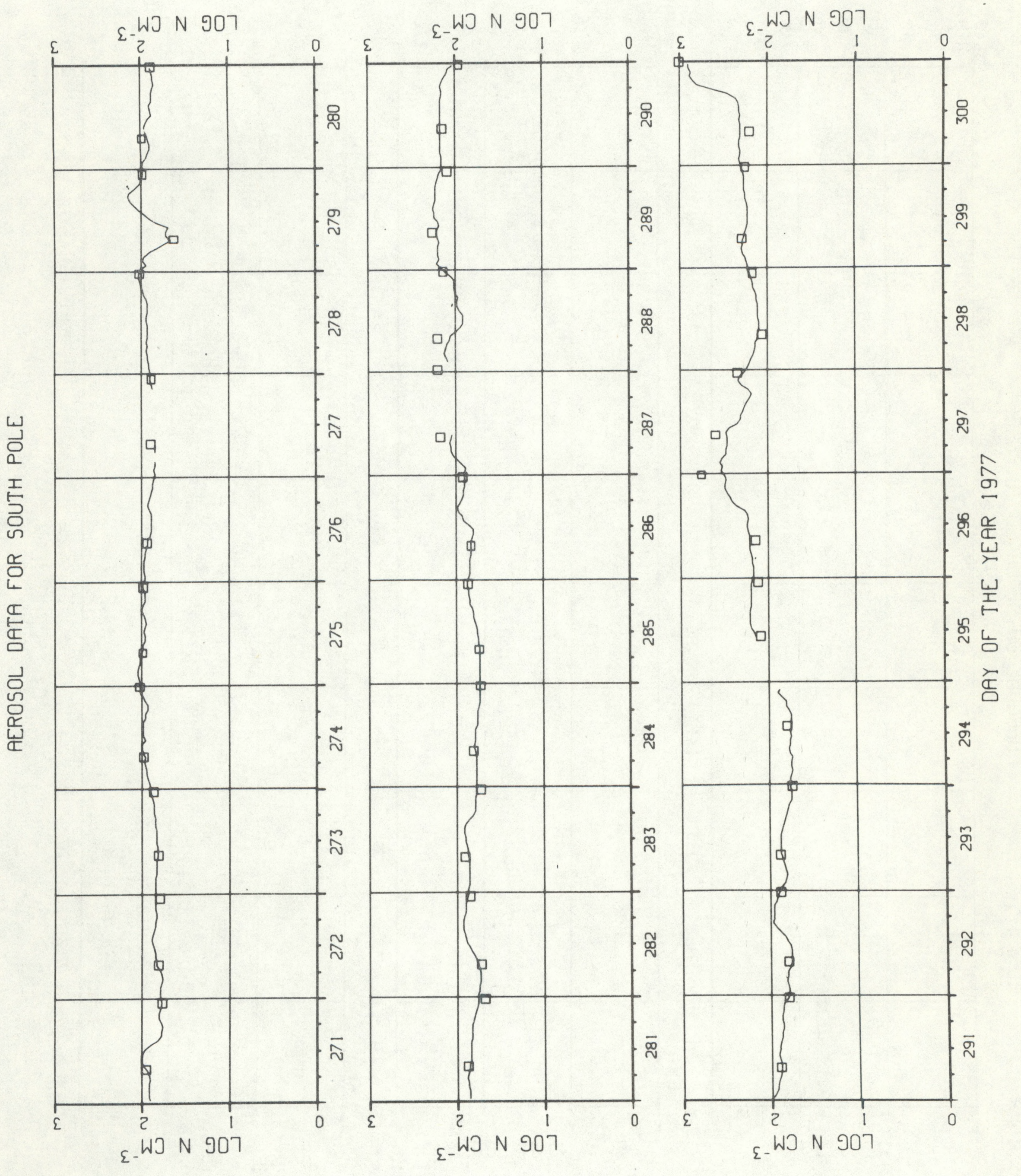
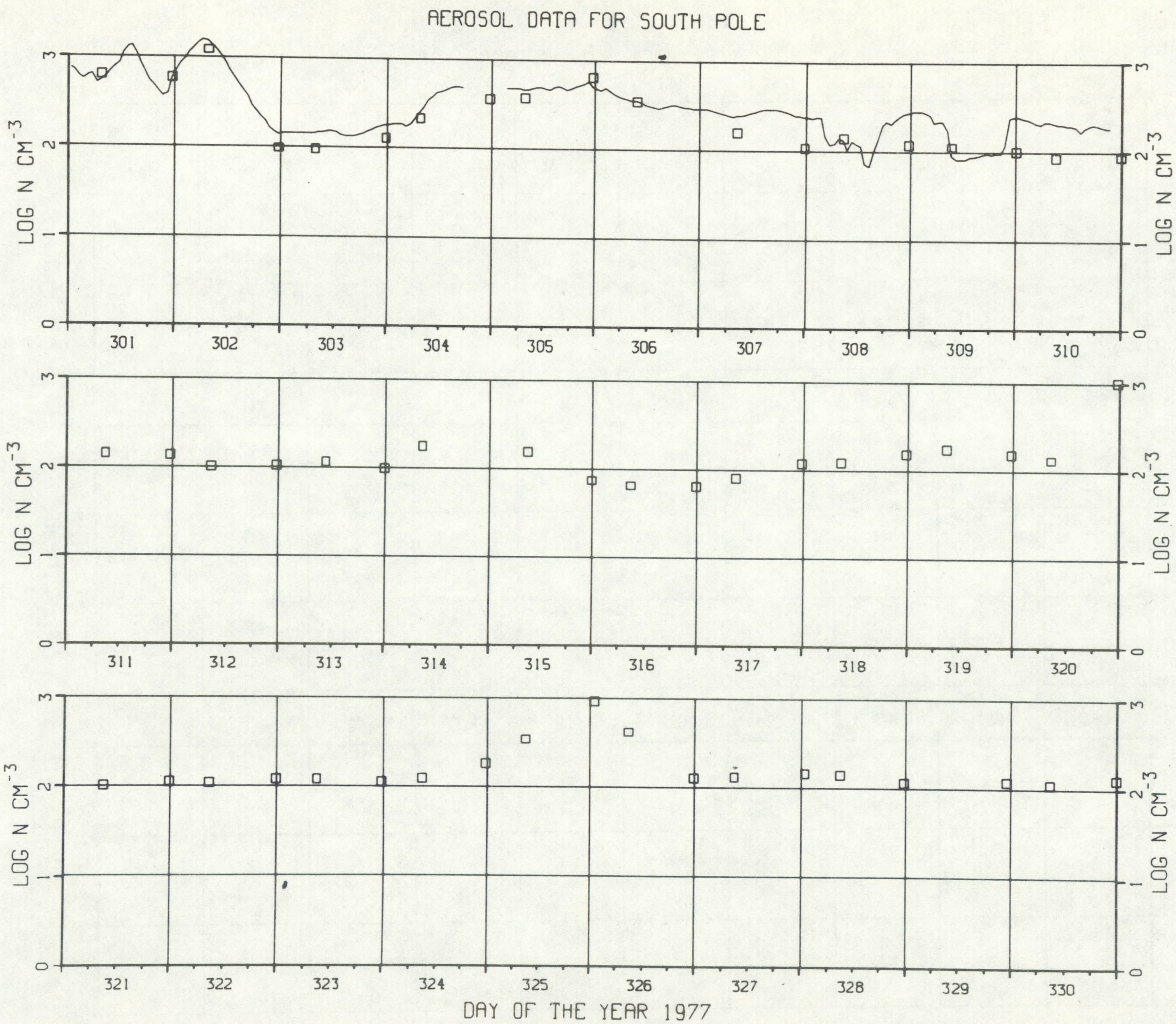
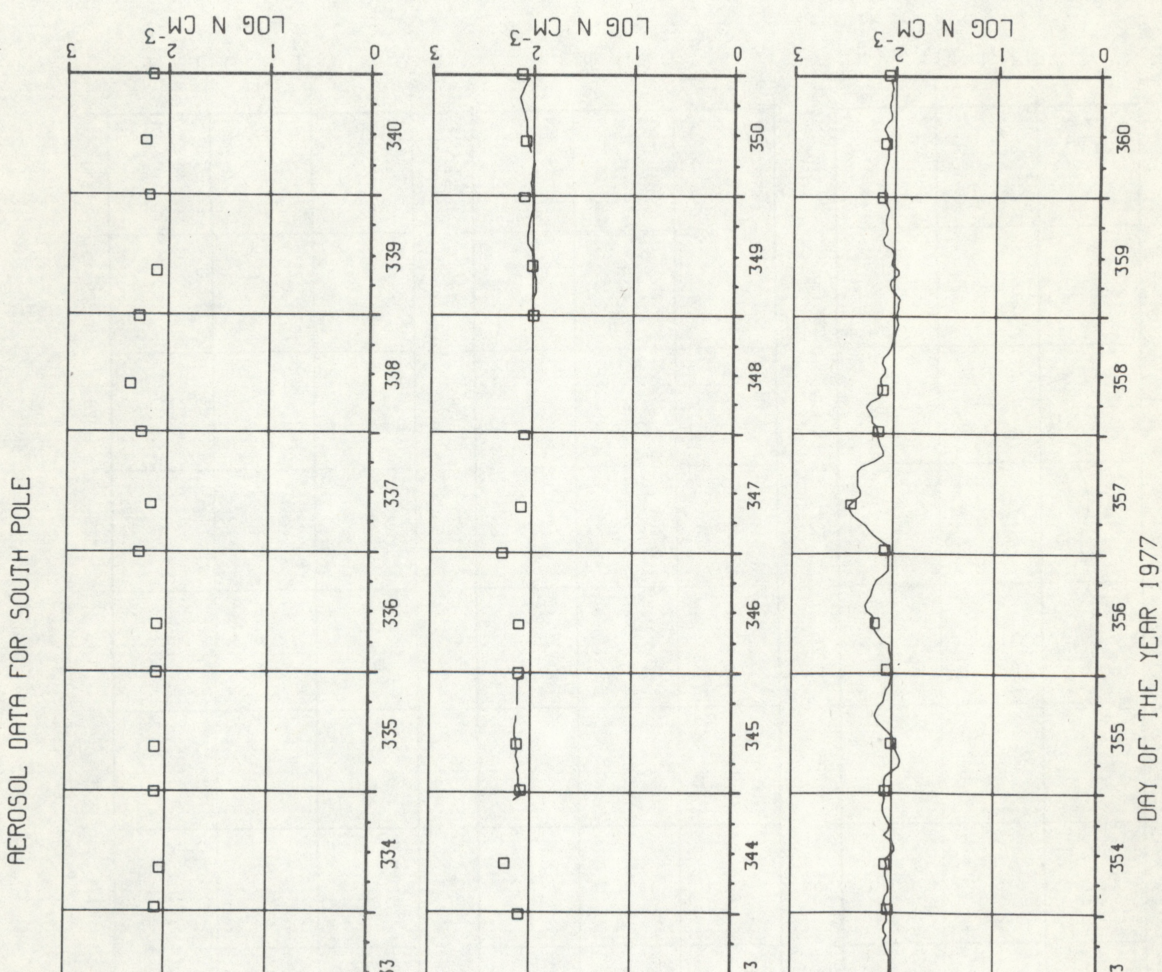
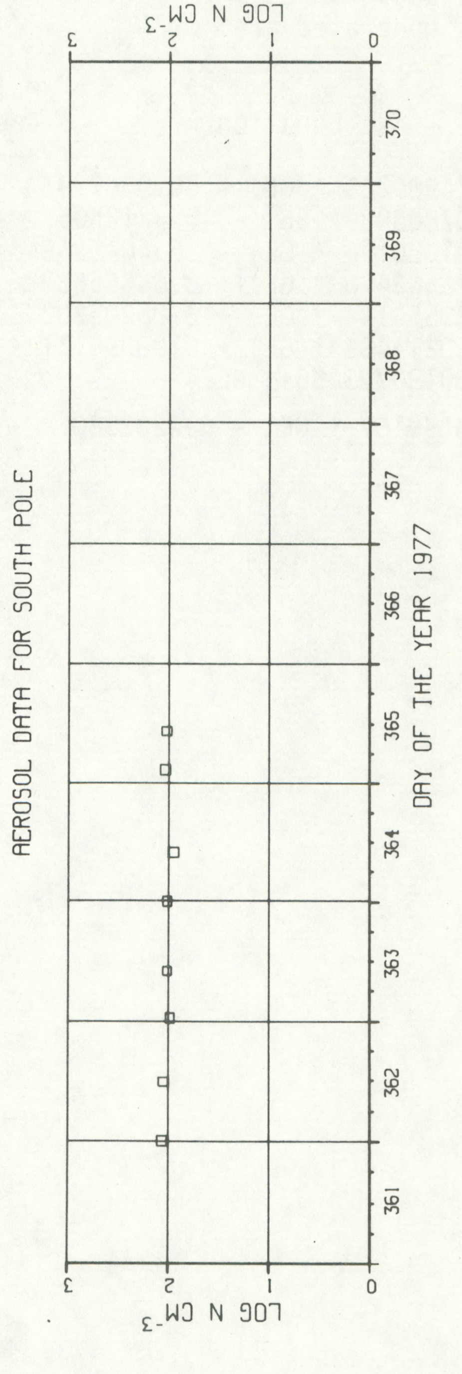
250
251
252
253
254
255
256
257
258
259
260
261
262
263
264
265
266
267
268
269
270
DAY OF THE YEAR 1977


AEROSOL DATA FOR SOUTH POLE
LOG N CM-3
DAY OF THE YEAR 1977
271 272 273 274 275 276 277 278 279 280
281 282 283 284 285 286 287 288 289 290
291 292 293 294 295 296 297 298 299 300
0 1 2 3


AEROSOL DATA FOR SOUTH POLE
LOG N CM^-3
301
302
303
304
305
306
307
308
309
310
311
312
313
314
315
316
317
318
319
320
321
322
323
324
325
326
327
328
329
330
DAY OF THE YEAR 1977


AEROSOL DATA FOR SOUTH POLE
LOG N CM-3
0 1 2 3
331 332 333 334 335 336 337 338 339 340
341 342 343 344 345 346 347 348 349 350
351 352 353 354 355 356 357 358 359 360
DAY OF THE YEAR 1977


AEROSOL DATA FOR SOUTH POLE
DAY OF THE YEAR 1977
LOG N CM-3
0
1
2
3
361
362
363
364
365
366
367
368
369
370

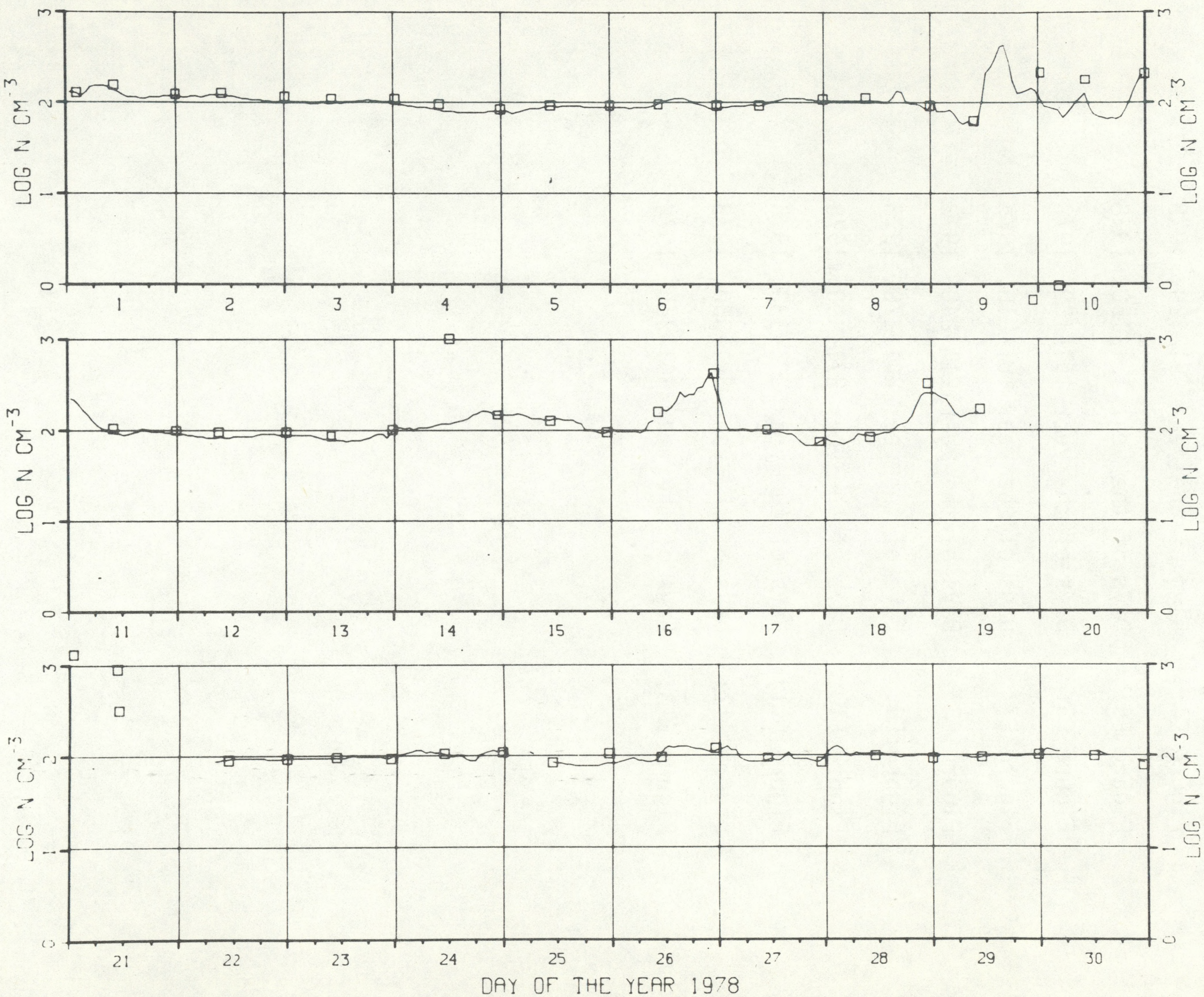
APPENDIX E

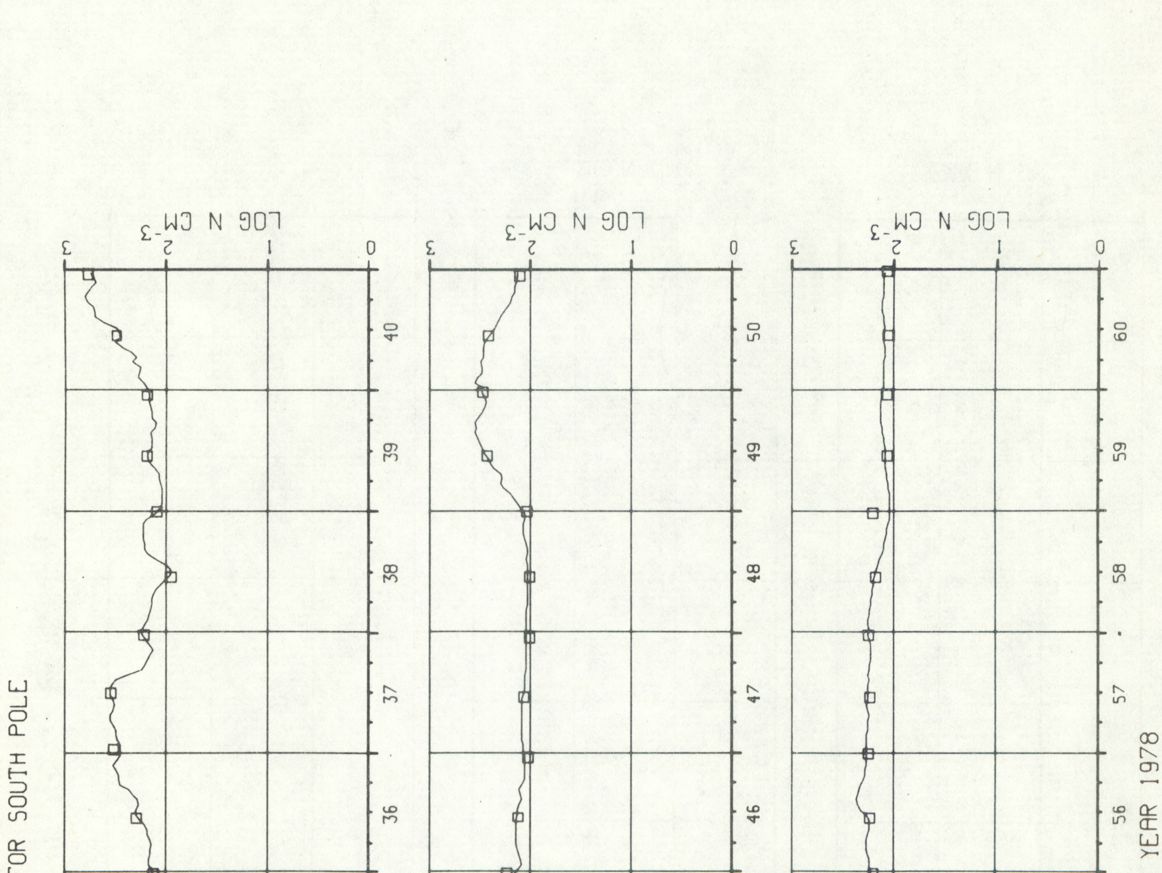
Appendix E gives the hourly mean nuclei concentrations and Pollak counter observations plotted on a logarithmic scale for 1978. A histogram was run for each month and the variability criterion was determined to be ±0.05 volts from the successive one minute voltage difference. The data pairs were likewise obtained from the minute data and grouped into periods where the G.E. counter was operating. The equations generated are:

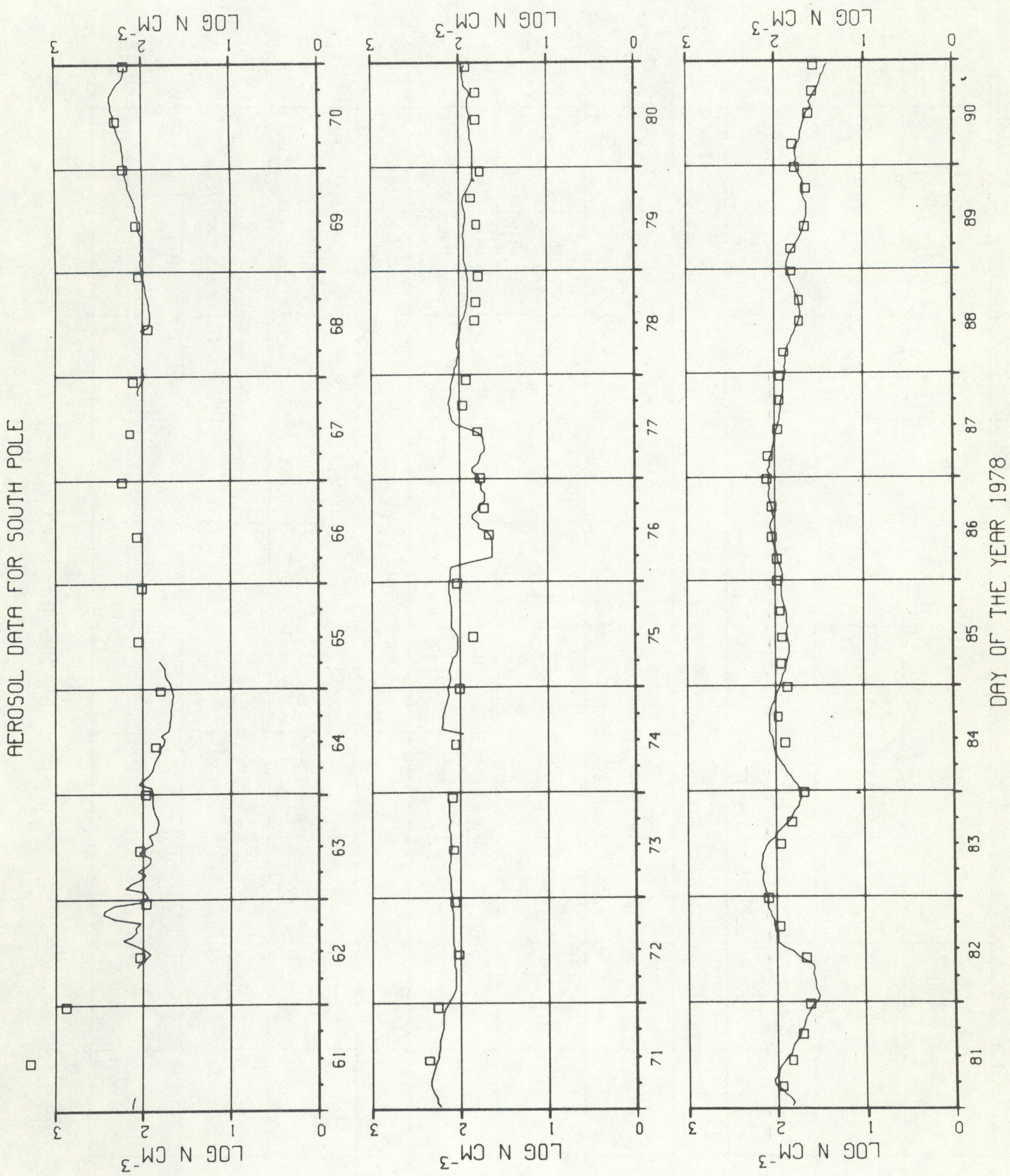
Day	Equation	Multiple Correlation Coefficient Squared
0-6507	y = (0.574989281 * GE) - 50.9867993	0.9929
6811-7322	y = (1.30780883 * GE) - 45.4212506	0.8544
7414-11306	y = (1.191320156 * GE) - 56.4019368	0.9512
11307-16005	y = (0.772563470 * GE) + 3.66565630	0.8997
16007-18803	y = (0.172554144 * GE) + 3.06205332	0.8272
18804-24810	y = (0.353211403 * GE) + 6.98995121	0.9769
24811-36523	y = (-0.00120733256 * GE^2)	
	+ (1.16859157 * GE) - 6.4232580	0.9570

Scaled graphical display of both G.E. counter (solid line) and Pollak counter (squares) data for 1978.

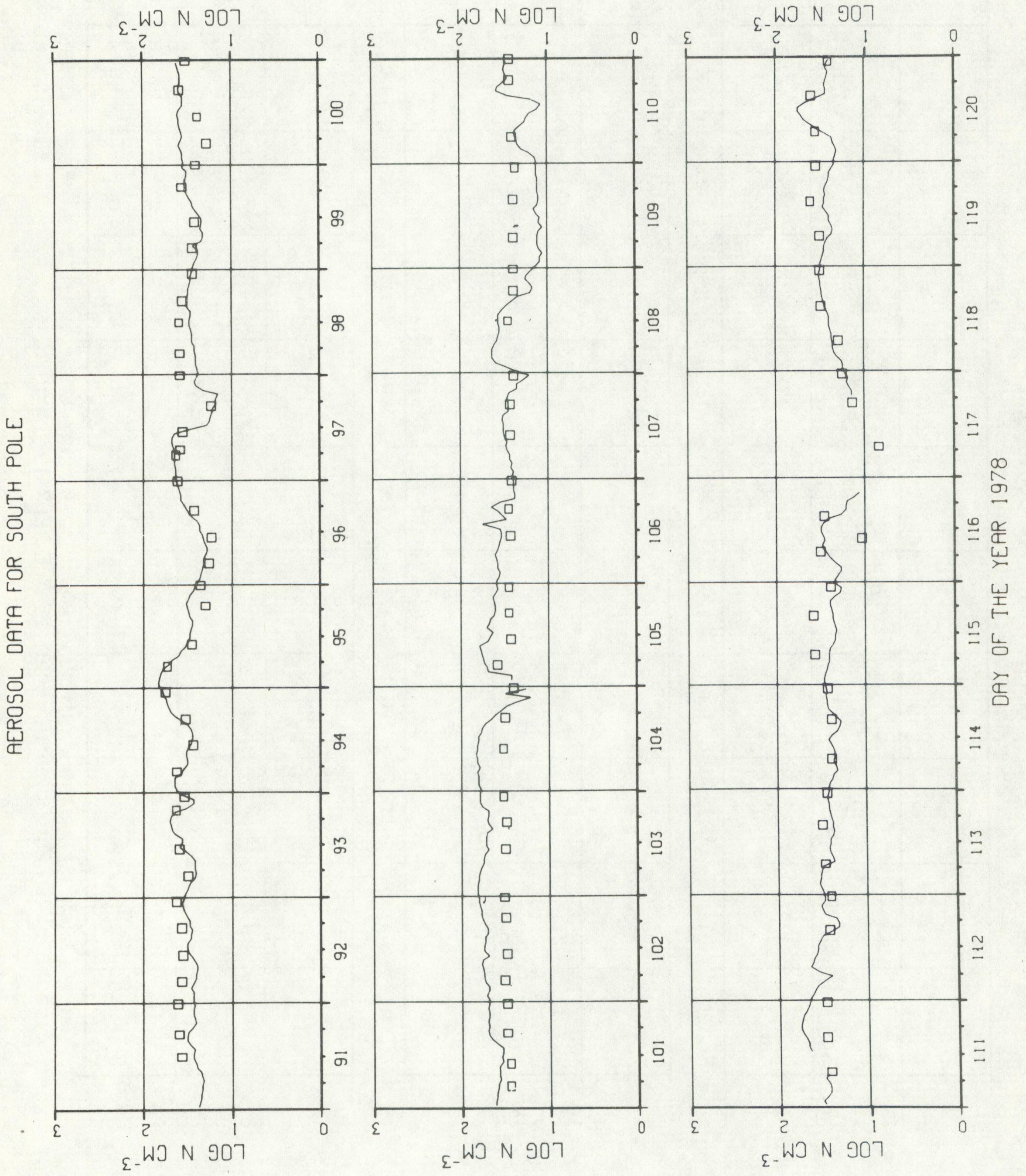
AEROSOL DATA FOR SOUTH POLE




AEROSOL DATA FOR SOUTH POLE
LOG N CM⁻³
DAY OF THE YEAR 1978



AEROSOL DATA FOR SOUTH POLE
LOG N CM^-3
0
1
2
3
61
62
63
64
65
66
67
68
69
70
71
72
73
74
75
76
77
78
79
80
81
82
83
84
85
86
87
88
89
90
DAY OF THE YEAR 1978


AEROSOL DATA FOR SOUTH POLE
LOG N CM^{-3}
0
1
2
3
91
92
93
94
95
96
97
98
99
100
101
102
103
104
105
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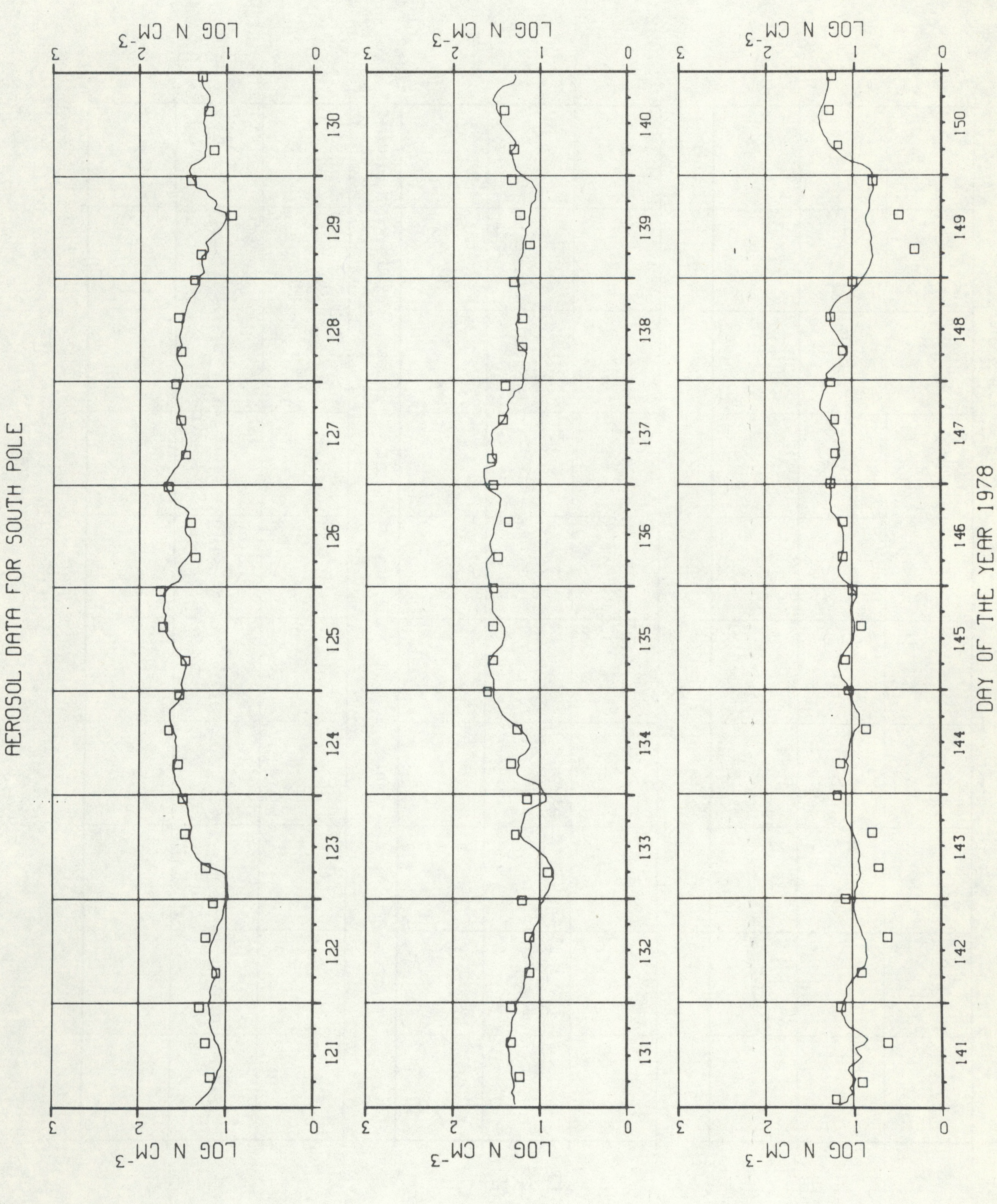
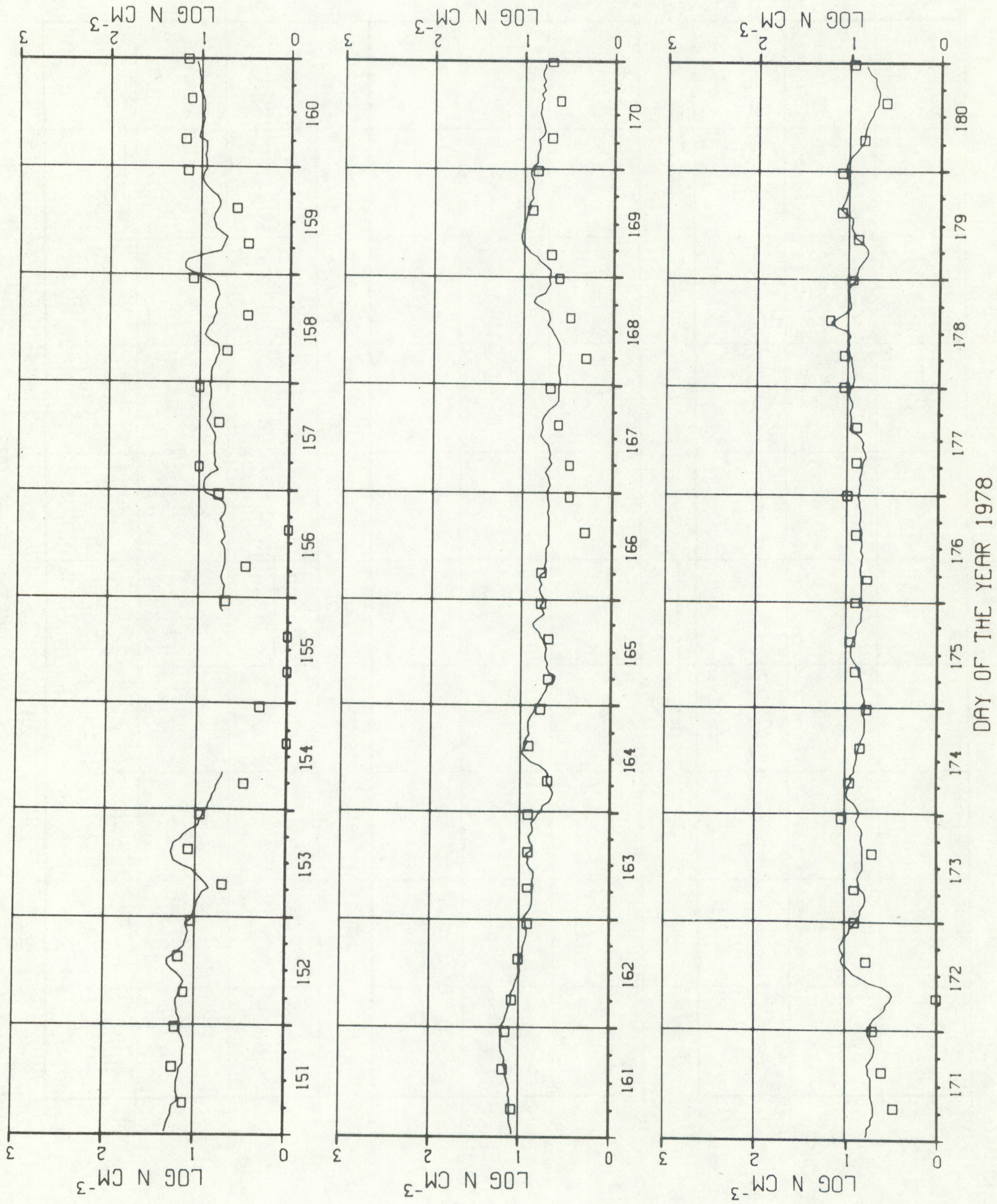
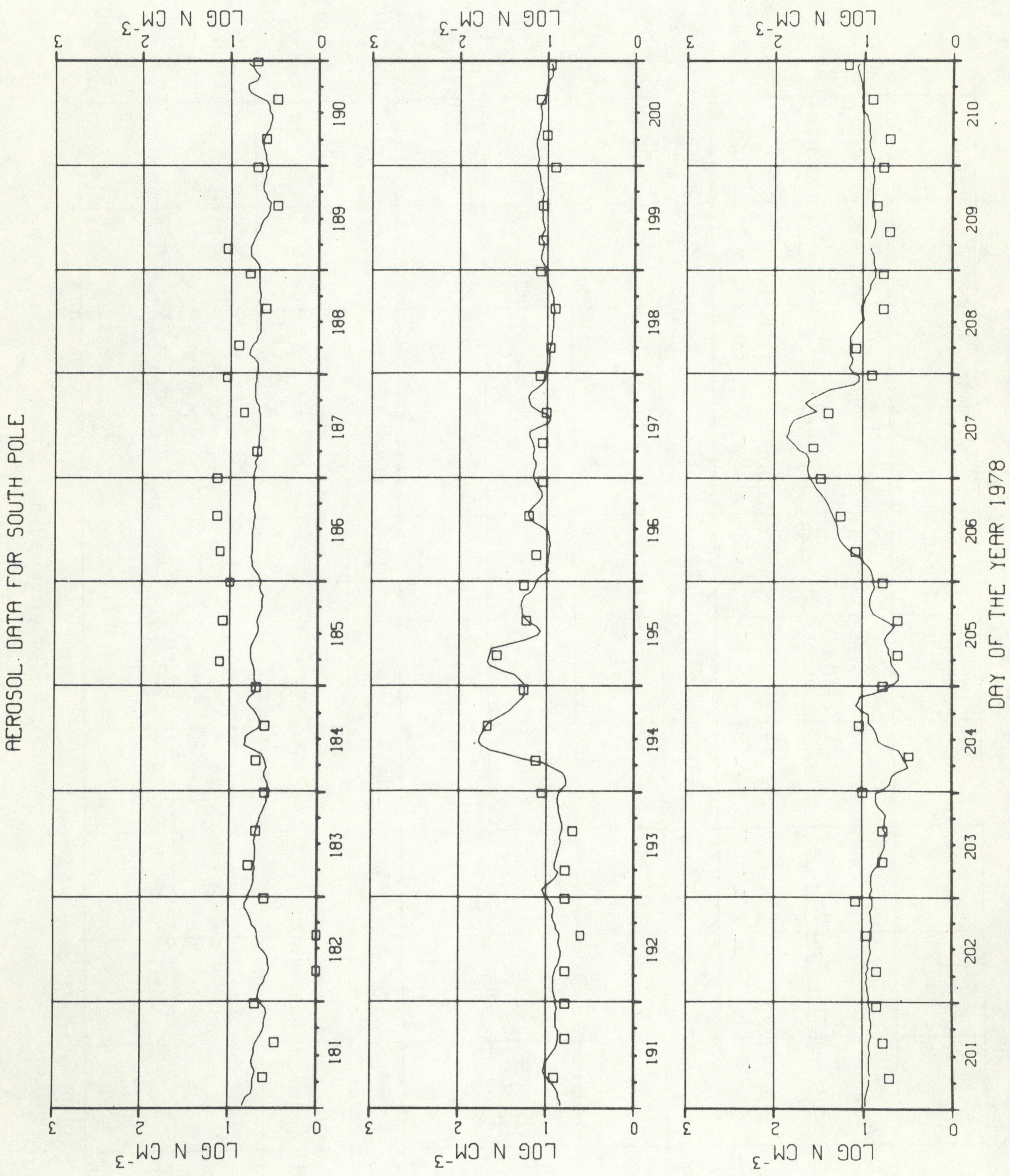
107
108
109
110
111
112
113
114
115
116
117
118
119
120
DAY OF THE YEAR 1978


AEROSOL DATA FOR SOUTH POLE
LOG N CM-3
0
1
2
3
121
122
123
124
125
126
127
128
129
130
131
132
133
134
135
136
137
138
139
140
141
142
143
144
145
146
147
148
149
150
DAY OF THE YEAR 1978

AEROSOL DATA FOR SOUTH POLE




AEROSOL DATA FOR SOUTH POLE
DAY OF THE YEAR 1978
LOG N CM-3
0
1
2
3
181
182
183
184
185
186
187
188
189
190
191
192
193
194
195
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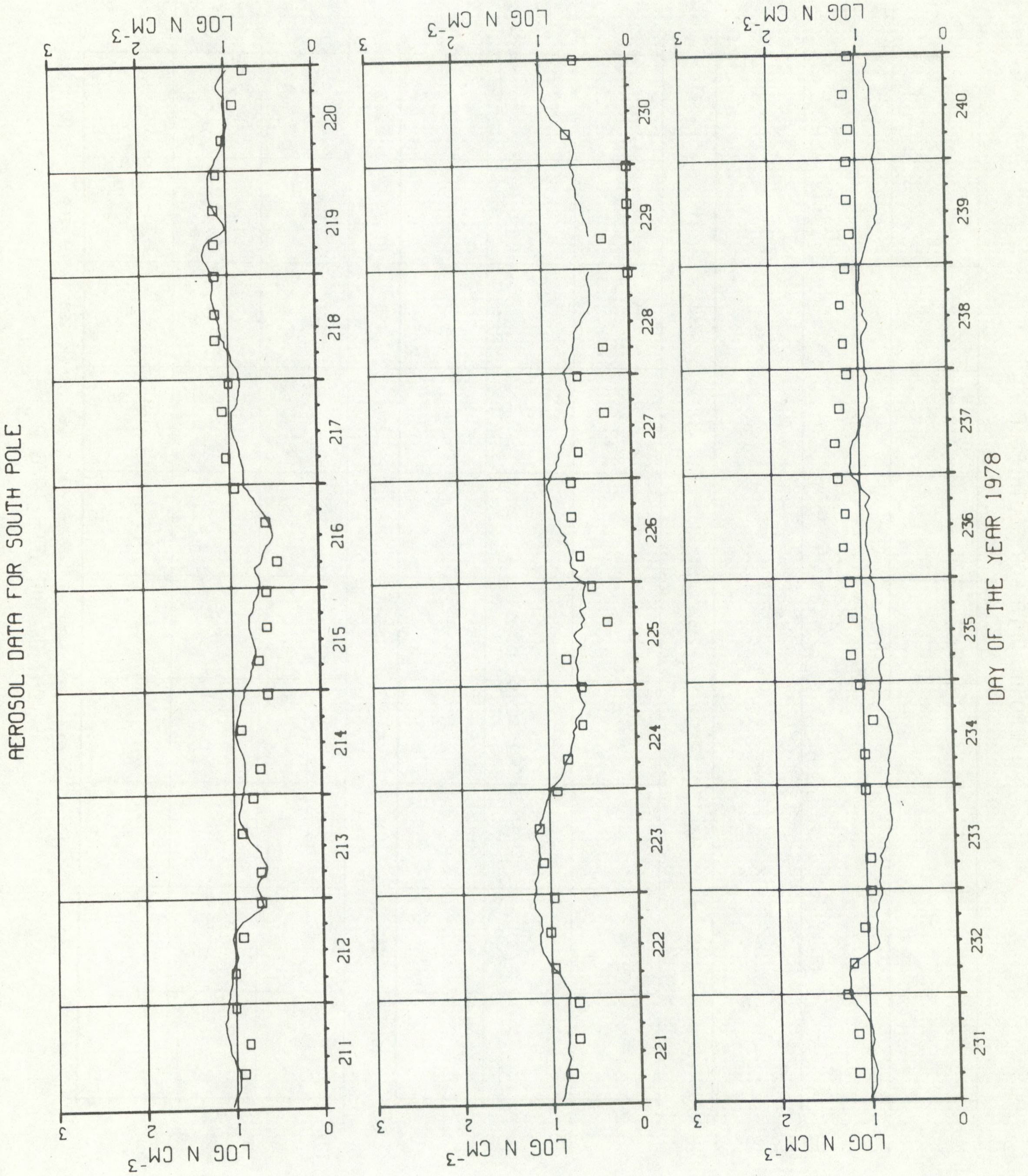
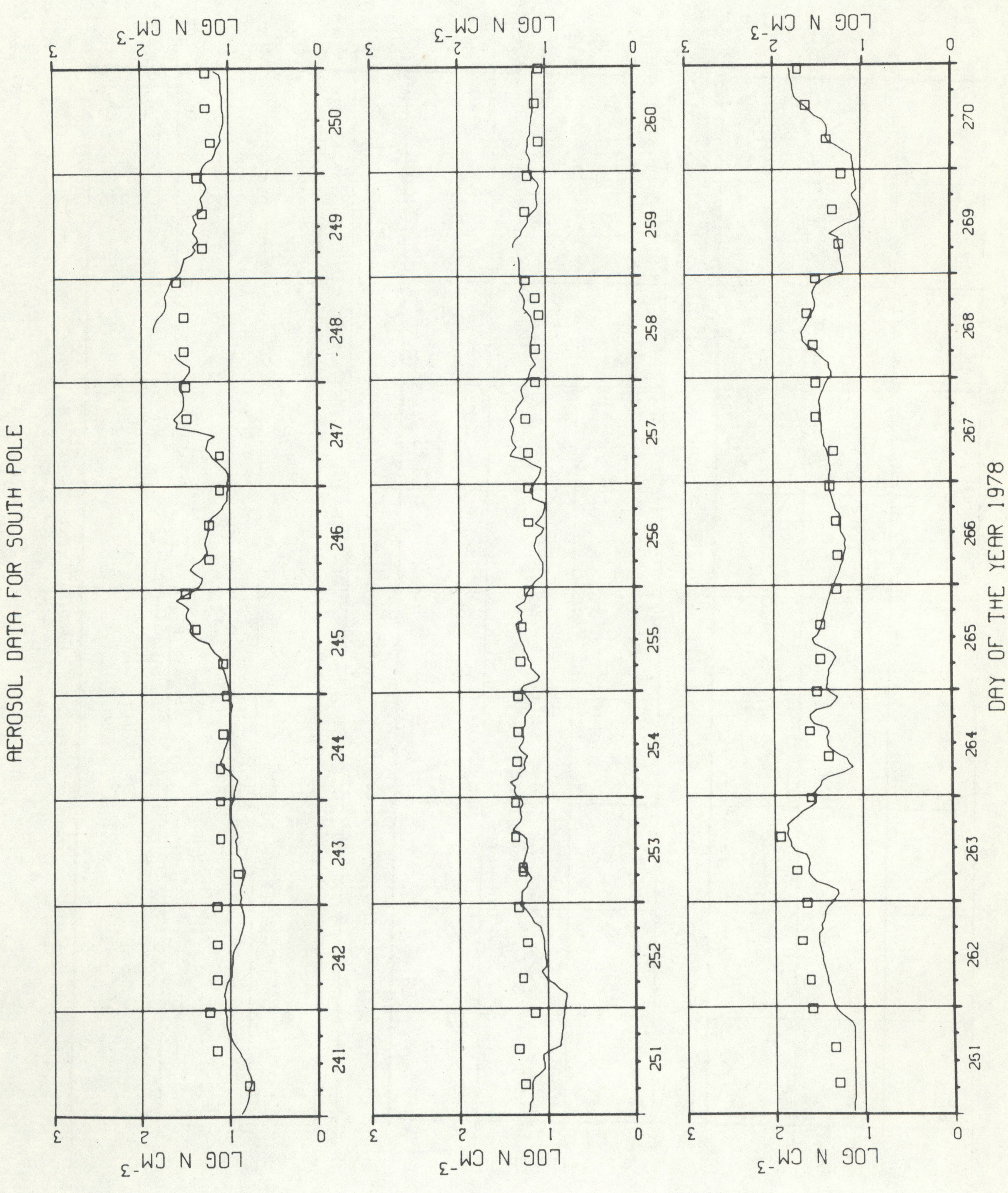

AEROSOL DATA FOR SOUTH POLE
LOG N CM-3
0
1
2
3
211
212
213
214
215
216
217
218
219
220
221
222
223
224
225
226
227
228
229
230
231
232
233
234
235
236
237
238
239
240
DAY OF THE YEAR 1978


AEROSOL DATA FOR SOUTH POLE
DAY OF THE YEAR 1978
LOG N CM-3
241
242
243
244
245
246
247
248
249
250
251
252
253
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255
256
257
258
259
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261
262
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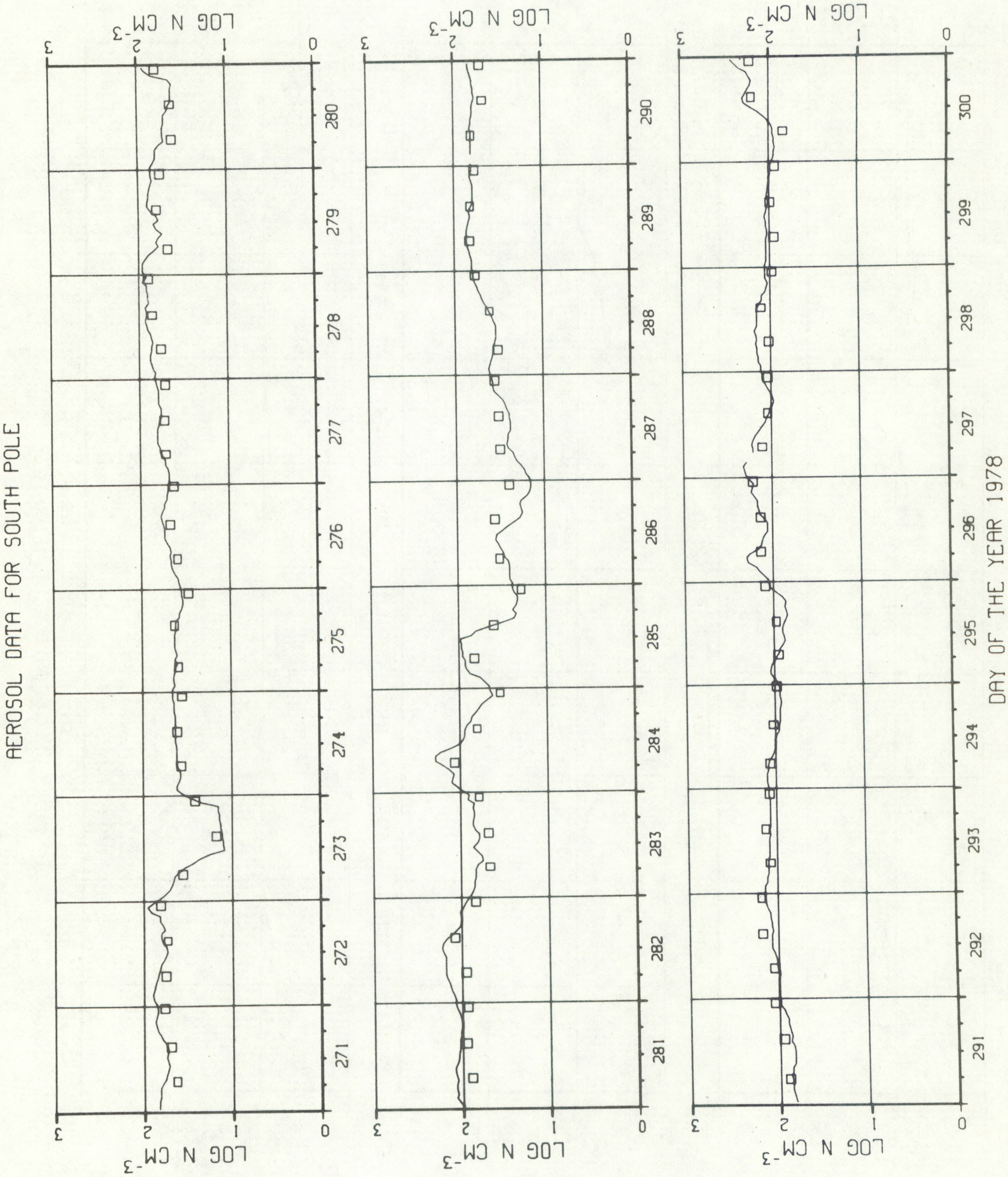
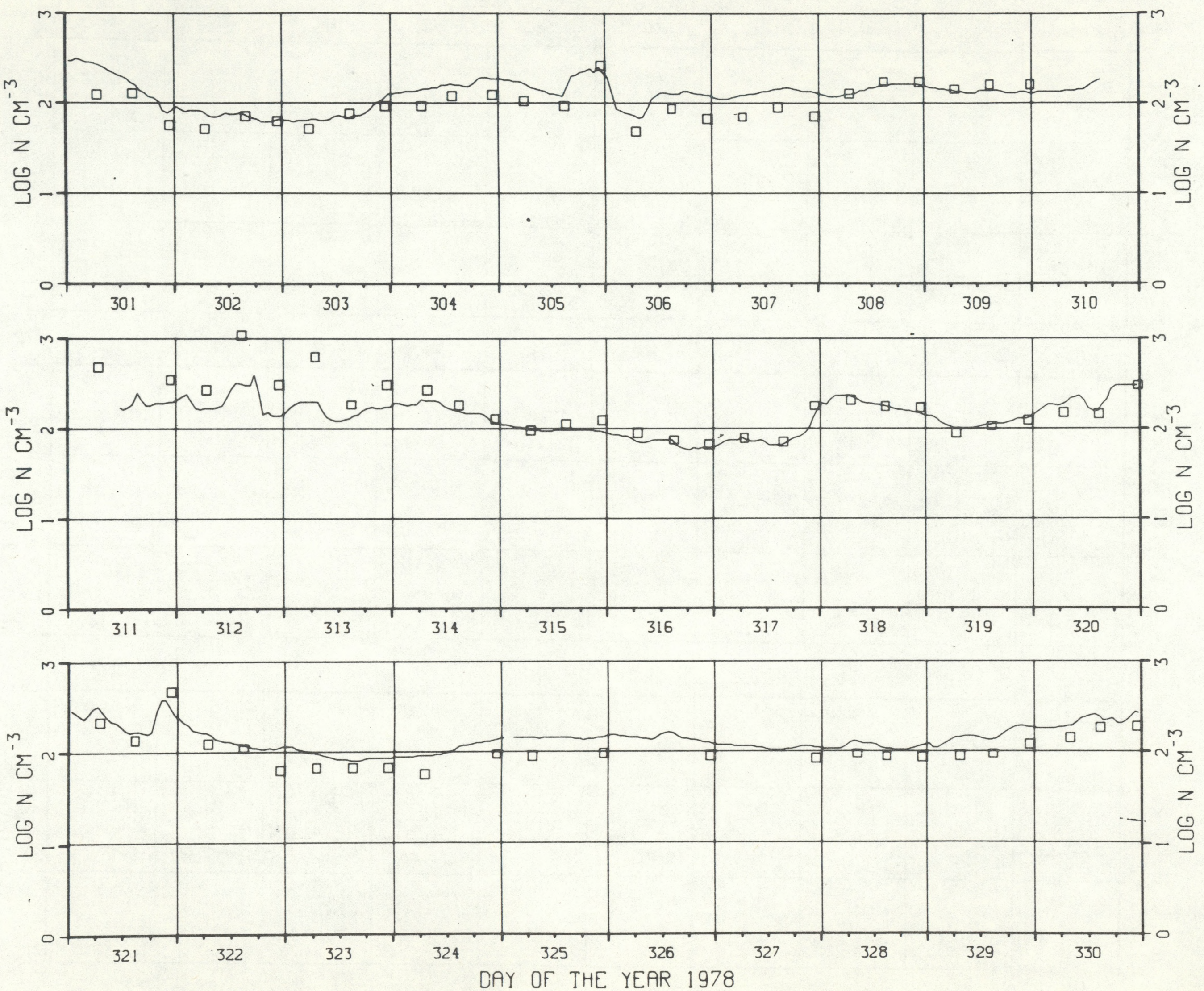
267
268
269
270



AEROSOL DATA FOR SOUTH POLE
LOG N CM^{-3}
DAY OF THE YEAR 1978
271 272 273 274 275 276 277 278 279 280
281 282 283 284 285 286 287 288 289 290
291 292 293 294 295 296 297 298 299 300

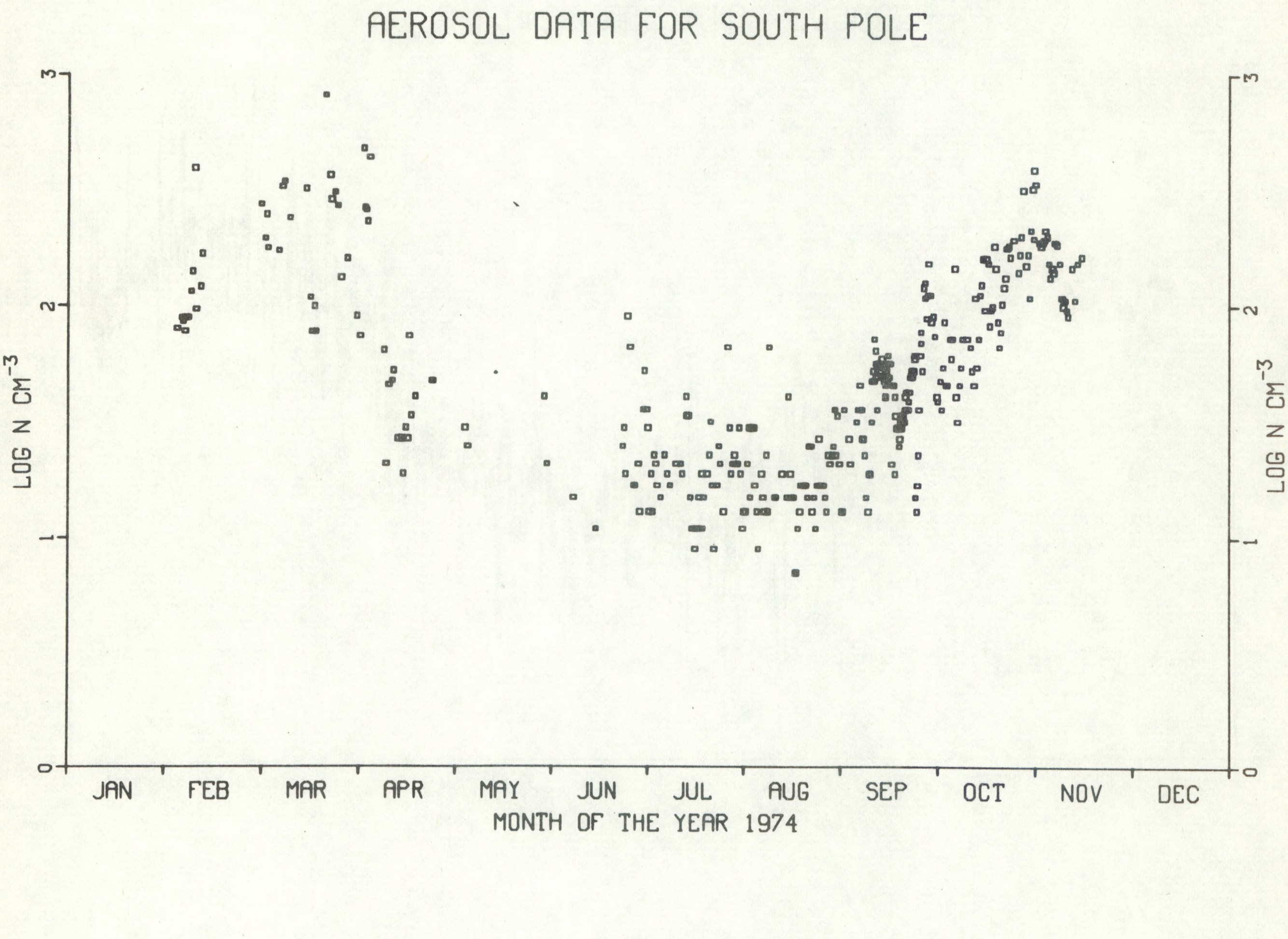
AEROSOL DATA FOR SOUTH POLE

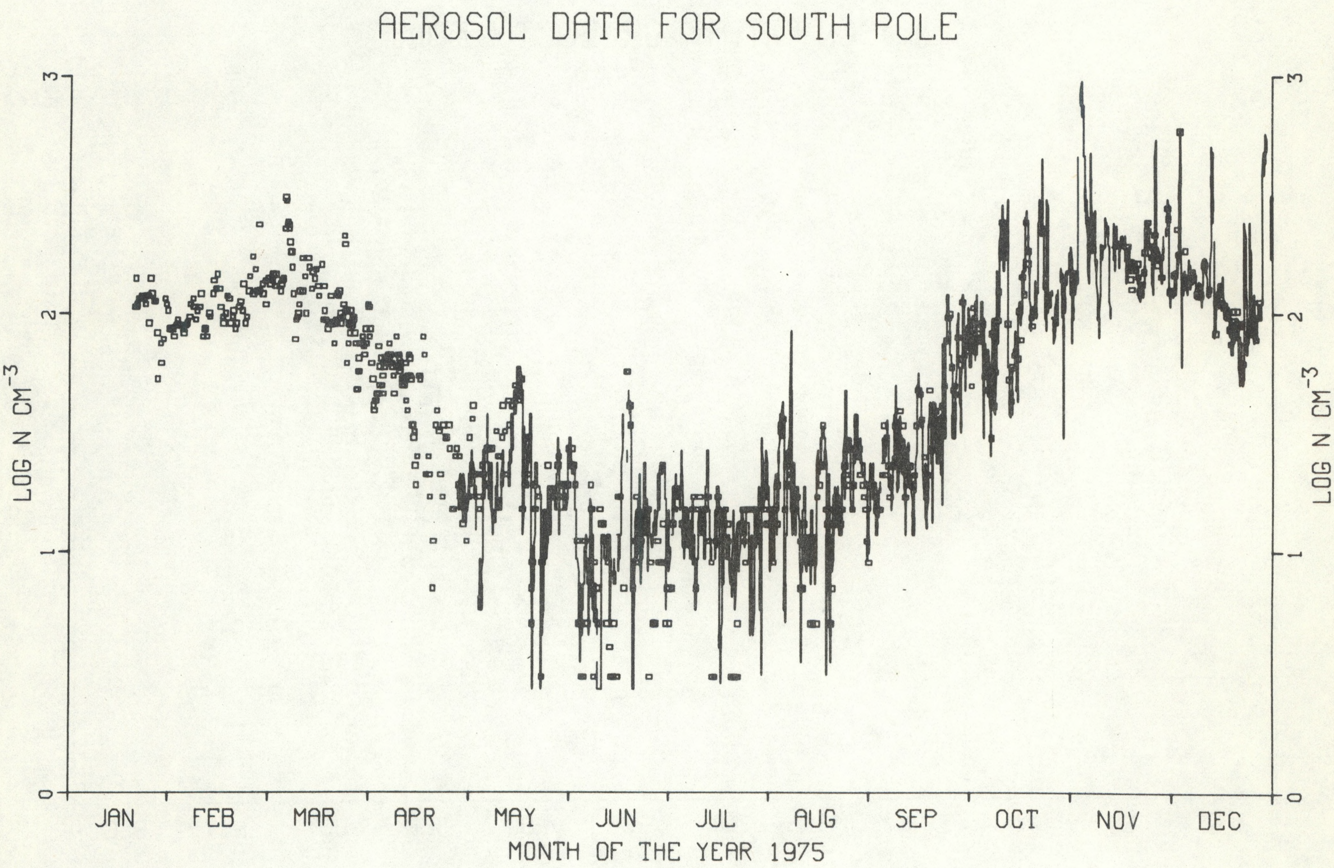


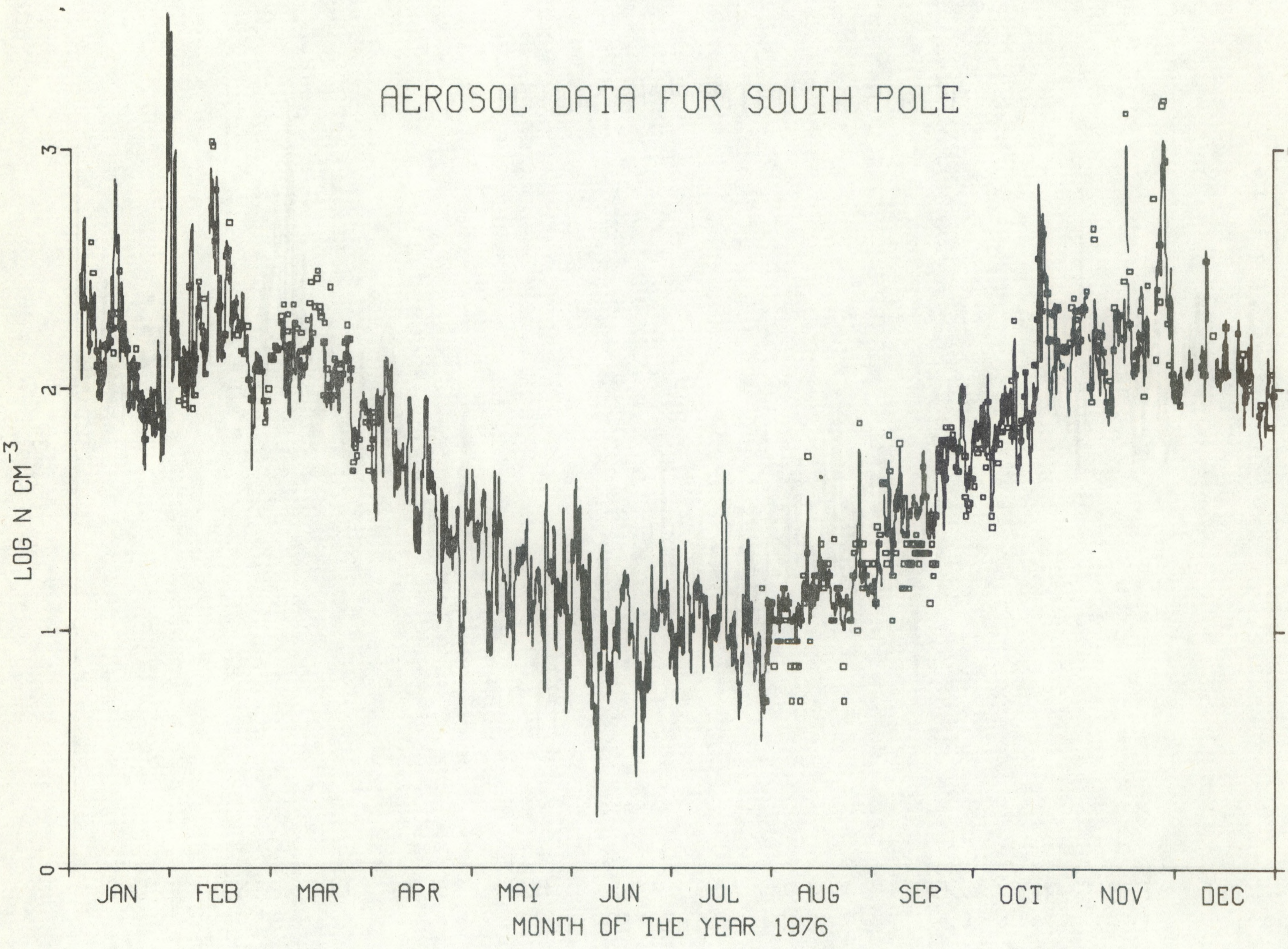
APPENDIX F

Appendix F contains the plots of each complete year on a single graph plotted on a logarithmic scale for 1974 through 1978.

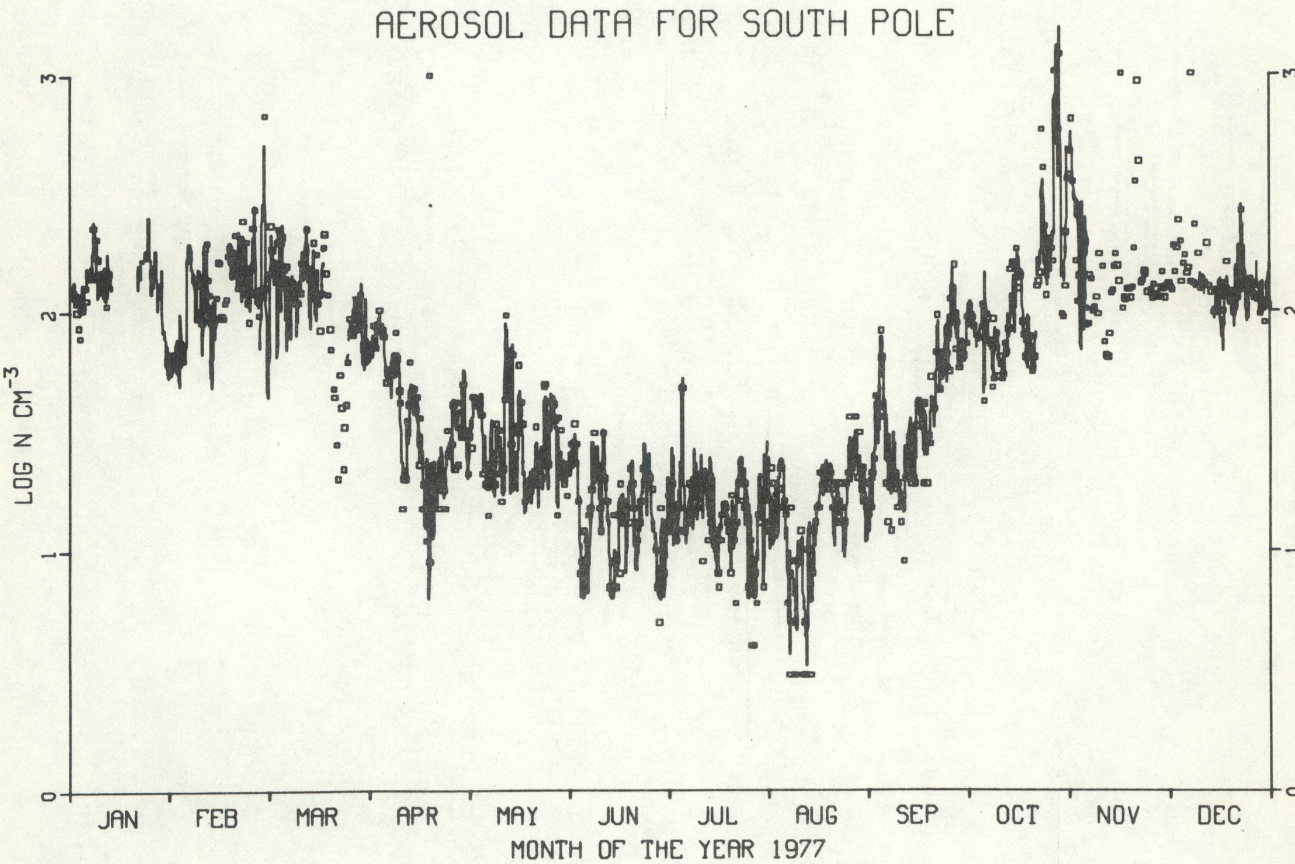
Scaled graphical display of each complete year on a single graph of both G.E. counter(solid line) and Pollak counter (squares) data for 1974 through 1978.

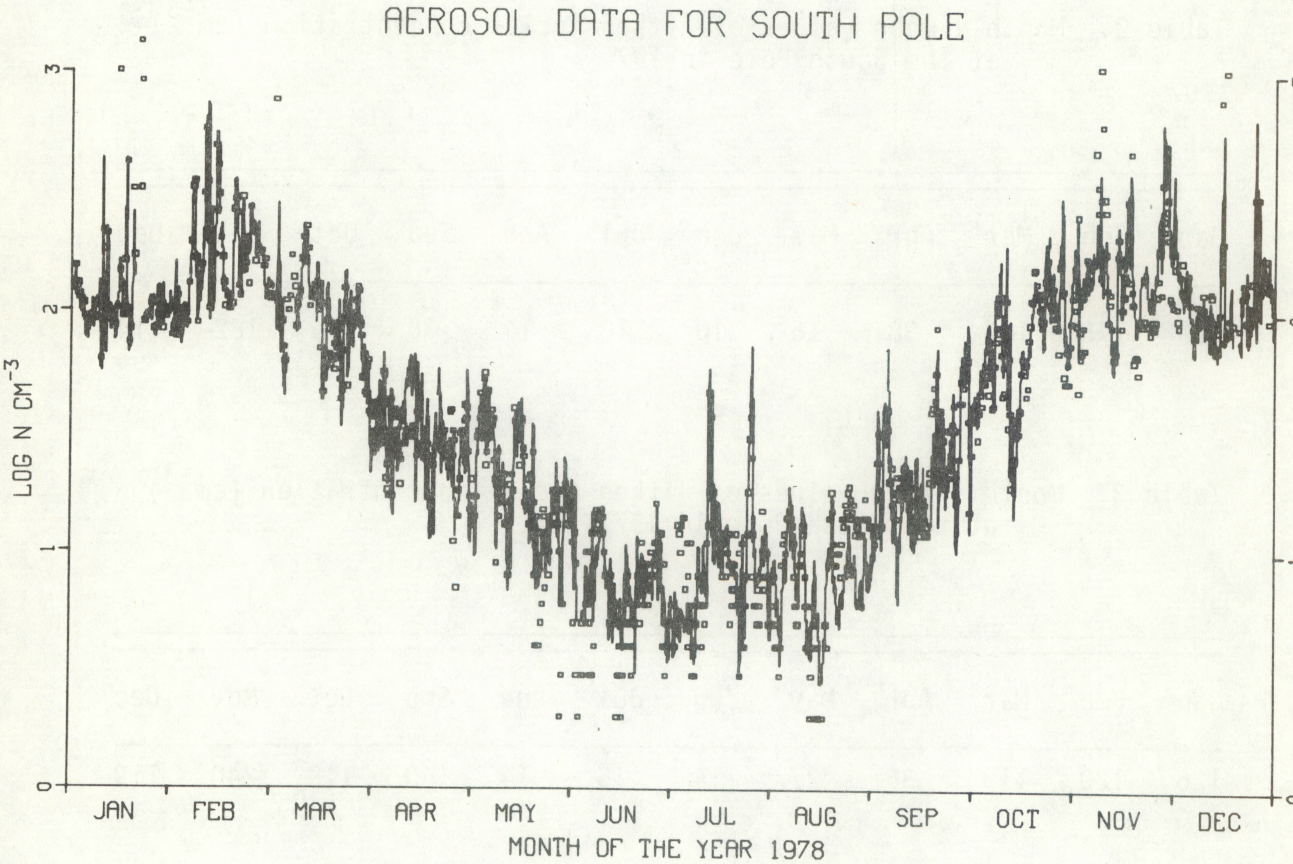

AEROSOL DATA FOR SOUTH POLE
LOG N CM^{-3}
0
1
2
3
JAN
FEB
MAR
APR
MAY
JUN
JUL
AUG
SEP
OCT
NOV
DEC
MONTH OF THE YEAR 1974


AEROSOL DATA FOR SOUTH POLE
LOG N CM^{-3}
0
1
2
3
JAN
FEB
MAR
APR
MAY
JUN
JUL
AUG
SEP
OCT
NOV
DEC
MONTH OF THE YEAR 1975



AEROSOL DATA FOR SOUTH POLE
LOG N CM^{-3}
0
1
2
3
JAN
FEB
MAR
APR
MAY
JUN
JUL
AUG
SEP
OCT
NOV
DEC
MONTH OF THE YEAR 1976


AEROSOL DATA FOR SOUTH POLE
LOG N CM^-3
0
1
2
3
JAN
FEB
MAR
APR
MAY
JUN
JUL
AUG
SEP
OCT
NOV
DEC
MONTH OF THE YEAR 1977



AEROSOL DATA FOR SOUTH POLE
LOG N CM^-3
0
1
2
3
JAN
FEB
MAR
APR
MAY
JUN
JUL
AUG
SEP
OCT
NOV
DEC
MONTH OF THE YEAR 1978

Table 1. Monthly mean values of Aitken nuclei concentration (cm^{-3}) at the South Pole in 1975

Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
			18	19	11	12	17	31	106	185	127

Table 2. Monthly mean values of Aitken nuclei concentration (cm^{-3}) at the South Pole in 1976

Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
159	173	107	38	16	10	10	14	36	94	182	114

Table 3. Monthly mean values of Aitken nuclei concentration (cm^{-3}) at the South Pole in 1977

Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
126	120	119	36	27	14	15	14	40	118	240	119

Table 4. Monthly mean values of Aitken nuclei concentration (cm^{-3}) at the South Pole in 1978

Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
103	168	92	31	18	7	8	7	21	77	151	113