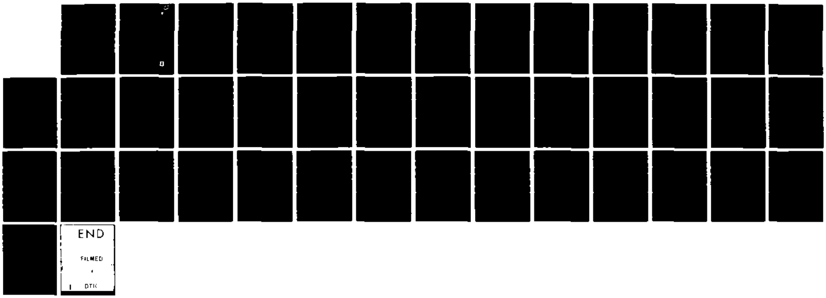
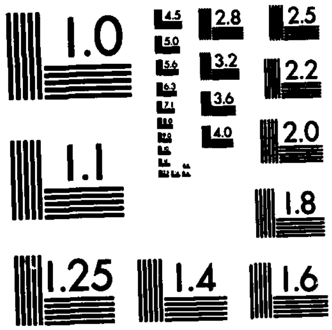
AD-A123 691 AEROSOL MEASUREMENTS WITH A HIGH RESOLUTION SPECTROMETER - A SUMMARY REPORT(U) AIR FORCE GEOPHYSICS LAB HANSCOM AFB MA F K DEARBORN 16 AUG 82 1/1

UNCLASSIFIED AFGL-TR-82-0235 F/G 4/1 NL





MICROCOPY RESOLUTION TEST CHART
NATIONAL BUREAU OF STANDARDS-1963-A

AD A123691

AFGL-TR-82-0235
ENVIRONMENTAL RESEARCH PAPERS, NO. 789

Aerosol Measurements With a High Resolution Spectrometer - A Summary Report

FRANK K. DEARBORN

16 August 1982

Approved for public release; distribution unlimited.

AERONOMY DIVISION PROJECT 6687
AIR FORCE GEOPHYSICS LABORATORY
HANSCOM AFB, MASSACHUSETTS 01731

AIR FORCE SYSTEMS COMMAND, USAF

This report has been reviewed by the ESD Public Affairs Office (PA) and is releasable to the National Technical Information Service (NTIS).

This technical report has been reviewed and is approved for publication.

Alva T. Stair, Jr.

DR. ALVA T. STAIR, Jr
Chief Scientist

Qualified requestors may obtain additional copies from the Defense Technical Information Center. All others should apply to the National Technical Information Service.

Unclassified

SECURITY CLASSIFICATION OF THIS PAGE (When Data Entered)

REPORT DOCUMENTATION PAGE		READ INSTRUCTIONS BEFORE COMPLETING FORM
1. REPORT NUMBER AFGL-TR-82-0235	2. GOVT ACCESSION NO. AD-A123 691	3. RECIPIENT'S CATALOG NUMBER
4. TITLE (and Subtitle) AEROSOL MEASUREMENTS WITH A HIGH RESOLUTION SPECTROMETER—A SUMMARY REPORT		5. TYPE OF REPORT & PERIOD COVERED Scientific. Interim.
		6. PERFORMING ORG. REPORT NUMBER ERP No. 789
7. AUTHOR(s) Frank K. Dearborn		8. CONTRACT OR GRANT NUMBER(s)
9. PERFORMING ORGANIZATION NAME AND ADDRESS Air Force Geophysics Laboratory (LKD) Hanscom AFB Massachusetts 01731		10. PROGRAM ELEMENT, PROJECT, TASK AREA & WORK UNIT NUMBERS 62101F 66870304
11. CONTROLLING OFFICE NAME AND ADDRESS Air Force Geophysics Laboratory (LKD) Hanscom AFB Massachusetts 01731		12. REPORT DATE 16 August 1982
		13. NUMBER OF PAGES 41
14. MONITORING AGENCY NAME & ADDRESS (if different from Controlling Office)		15. SECURITY CLASS. (of this report) Unclassified
		15a. DECLASSIFICATION DOWNGRADING SCHEDULE

16. DISTRIBUTION STATEMENT (of this Report)

Approved for public release; distribution unlimited.

17. DISTRIBUTION STATEMENT (of the abstract entered in Block 20, if different from Report)

18. SUPPLEMENTARY NOTES

19. KEY WORDS (Continue on reverse side if necessary and identify by block number)

Stratosphere
Aerosols
Size distributions
Particulate sizing spectrometer
SAGE solar extinction
Balloonborne instrumentation
Vertical aerosol profiles
Aerosol concentration

20. ABSTRACT (Continue on reverse side if necessary and identify by block number)

A short-history of the development and design of the AFGL/Epsilon Labs balloon-borne aerosol particle spectrometer is presented. Measurement results for a majority of the flights conducted with this instrument are summarized and presented in a compatible graphic form to facilitate intercomparison. An improved method of computing air flow and a means of correcting erroneous air flow data is described which should permit the re-evaluation and correction of early flight data. Application of the foregoing corrective methods to the most recent flight data is detailed. Some peculiarities in this high

DD FORM 1 JAN 73 1473

Unclassified

SECURITY CLASSIFICATION OF THIS PAGE (When Data Entered)

20. (Contd)

resolution data are described and a tentative explanation is proposed.

Preface

The author wishes to express his appreciation for the interest, encouragement and support provided by Drs. R.S. Narcisi and R.E. Good, W.K. Vickery and the AFGL management, without which this work could not have been undertaken. Credit is due to P.E. Meehan and K.E. Hoxie, Bedford Research Associates, for their cooperation and excellence in handling all facets of computer programming and operations. Also, the discussions and assistance contributed by Dr. H.A. Miranda, Epsilon Laboratories, have been enlightening and helpful in conducting this investigation.

Contents

Illustrations

Illustrations

Tables

Aerosol Measurements With a High Resolution Spectrometer — A Summary Report

1. HISTORY

Development of the AFGL/Episilon Aerosol Particle Spectrometer was initiated by Dr. Robert W. Fenn, AFGL-OPA, under a competitive bid contract that was awarded to GCA Corp., Bedford, Massachusetts. Development of this instrument was completed in FY 1968.[1] Principal investigator for the project was Dr. Henry A. Miranda, Jr. Following the formation of Epsilon Laboratories, Inc., Bedford, Massachusetts, by the Principal Investigator and others, follow-on contracts were performed by this organization. Subsequent to a change in direction of research in the Optical Physics Laboratory, the program was transferred to the Aeronomy Laboratory, LKD.

Aerosol spectrometer balloon flights of concern in this report are listed below:

Flight No.	Date	Location	Reference No.
EX-1	28 Oct 1970	Stallion Site, New Mexico	(2)
FR-1	17 May 1973	Holloman, AFB, New Mexico	(3)
FR-2	24 May 1973	Holloman AFB, New Mexico	(3)
BR-2	21 Jan 1975	Holloman AFB, New Mexico	(5)
RV-1	27 May 1980	Holloman AFB, New Mexico	(8)

(Received for publication 12 August 1982)

1. Miranda, H.A., Jr. et al (1970) Aerosol Counters, GCA-TR-70-6-A, Final Report, Contract No. F19628-68-C-0086, GCA Corporation.

2. INSTRUMENTATION

2.1 Optics

The AFGL/Epsilon aerosol spectrometer is a two-channel high resolution forward scattering instrument of advanced design, the optical portion of which is shown schematically in Figure 1.

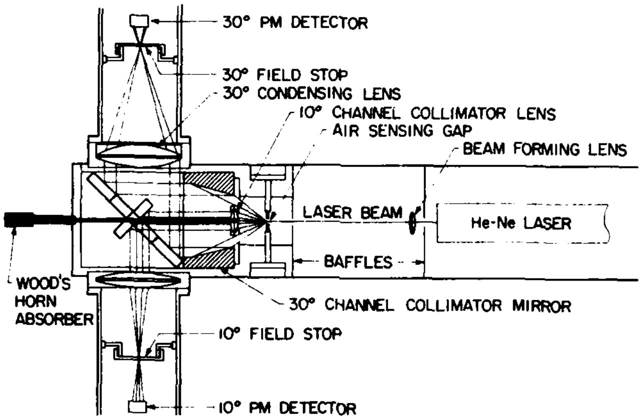


Figure 1. Schematic Drawing of the Aerosol Spectrometer Optical and Air Sampling Design

Ambient air is drawn through a 1-mm I. D. sampling tube under laminar flow conditions. A 3-mm gap in this tube is illuminated in a direction perpendicular to the air flow. The source of illumination is a highly collimated ribbon-shaped beam of 6328 Å HeNe laser light as diagrammed in Figure 2. The collimation feature is most important since it permits a maximum illumination of the 1-mm interaction volume while at the same time maintaining the angle of incidence of the light near zero degrees. The laser is mounted in a pressurized housing to prevent overheating and high voltage arcing at the reduced ambient pressures encountered during balloon flight.

Light scattered by a particle within the interaction volume is collected by two annular systems; a lens for the 10 ± 5 degree light and an off-axis paraboloid-of-revolution mirror for the 30 ± 2.5 degree light. The two collimated beams are directed to individual PM detectors by a pair of 45-degree plane mirrors mounted in the central housing. The detectors, together with associated condensing lenses and image apertures, are housed in two lateral arms. The image apertures are carefully adjusted to allow only the scattered light from the interaction volume to strike the PM detectors. Unused light from the laser beam passes axially through the system and is absorbed, thus reducing the back-scattered laser light to acceptable levels in the vicinity of the interaction volume. The system sensitivity is limited by noise associated with Rayleigh scattered light by ambient air molecules within the small interaction volume, hence all other sources of laser light in the vicinity of this vicinity must be reduced to one part in 10^{11}.

2.2 Flow Control System

A controlled air flow for the sampling system is provided by means of an oil-less carbon vane pump and critical orifice located at the output end of the sampling volume. Sonic flow is maintained at the throat of the orifice by providing a sufficient pressure differential across the device. Flow rate is determined by meas g the pressure drop across the 1-mm inlet tube. A differential pressure transd r, connected as in Figure 3, is used for this measurement. Under static con es, the flow rate at the inlet tube is equal to the flow as determined by the crit orifice. Under dynamic conditions this is not true, however. As the ballo s, the external pressure drops, resulting in a decreased inlet flow rate. This c is sufficiently severe that at times of rapid balloon ascent the inlet flow may even become negative, producing a complete loss of data during portions of the flight upleg. Upon descent, the reverse condition exists, resulting in a flow rate appreciably greater than that determined by the critical orifice rate.

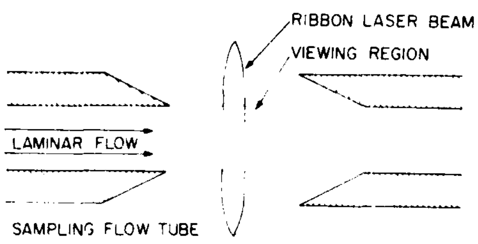


Figure 2. Schematic Drawing of the Sampling Gap Geometry, Airflow, and Laser Illumination

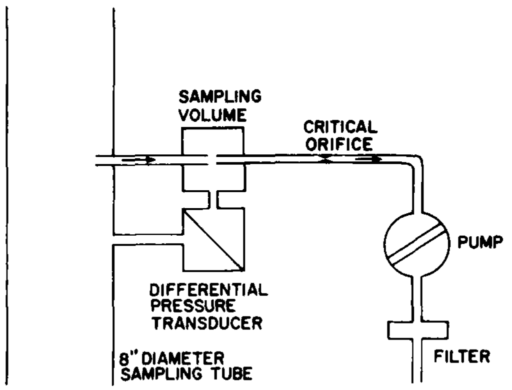


Figure 3. Schematic Drawing of the Air Flow Control System. A nominal flow rate of 200 cm^3 is determined by the critical orifice

2.3 Electronics

As an aerosol particle transits the 0.3-mm width illumination beam, output pulses of a nominal 50-μsec duration are generated by the twin photomultipliers. Special signal processing hardware has been designed to ensure that the peak values of these pulses are accurately measured. This consists of a threshold circuit that tracks the photomultiplier DC background level and a peak detection circuit that is gated whenever the signal exceeds this threshold level. This latter circuit inspects the signals in both channels for a period of 60 μsec following the threshold crossing in either channel and provides an output proportional to the peak value thereof (see Figure 4). Coincident pulses must be present in both channels to qualify as a valid signal, thereby essentially eliminating spurious noise from the data. Particle sizes are derived by summing the signals from both channels. The ratio of the two channels is used for diagnostic purposes such as index of refraction checks.

Based upon an absolute calibration utilizing Rayleigh scattering from the interaction zone volume (~1 mm^3), it has been ascertained that the minimum detectable pulse height corresponds to about 100 photocathode electrons, hence particle size detection limits are set by noise in background levels and not by counting statistics per se. The on-board processing system accepts signals over a four-decade range extending from 10^{-8} A to 10^{-4} A output from the photomultipliers, the smaller current value corresponding to the 100 photocathode electron value noted above (see Figure 5).

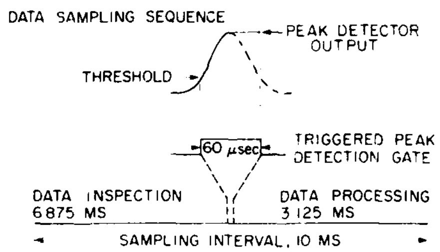


Figure 4. Detailed Drawing of the Signal Peak Detection and Data Sampling Sequence

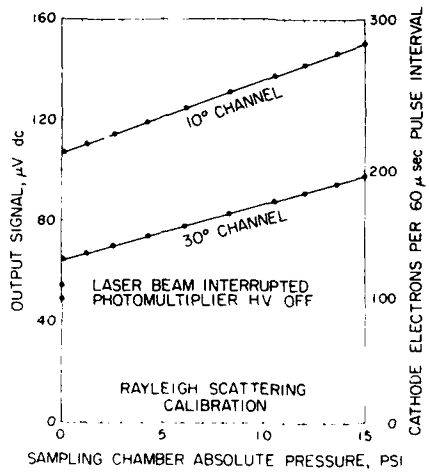


Figure 5. Typical Rayleigh Scattering Run Showing Relative Contributions of Background Signal Components

Prior to the 1975 balloon flight, a method was devised for periodically testing the in-flight performance of the PM tubes, amplifiers and A/D converter, and the required circuitry was added to the instrument. Every fourth minute an exponentially decaying pulsed LED light source illuminates the twin photomultiplier tubes. The LED source generates 256 light pulses of about 50-μsec duration whose amplitudes decay with a time constant of about 0.1 second. Each pulse is synchronized with its associated 10-msec sampling interval and has an amplitude approximately four percent less than the preceding pulse. This confidence check circuit was to prove its worth on the 1975 flight.

The signal processing electronics include pulse peak detection circuitry, crystal controlled clock and timing circuits which provide relative time in hours and minutes and synchronizing pulses necessary for generation of basic timing functions for the entire system, read-in circuits which control the flow of information traffic through the sequence of complex signal processing operations being performed, A/D converter (linear for housekeeping functions, logarithmic for optical data), and magnetic tape recording circuitry which produces a 9-track computer compatible output, including parity, CRC and LRC generation.

2.4 Calibration and Performance

The aerosol spectrometer is calibrated with a multiplicity of polystrene latex spheres whose sizes fall within the measurement range of the instrument, 0.20 - 1.0 μ diameter, approximately. This procedure is used both in the laboratory and prior to each balloon flight. Instrument sensitivity to refractive index has been checked with various other materials. These tests have shown the spectrometer sizing accuracy to be ± 10 percent within a range of 1.33 - 1.60 refractive index. For data reduction purposes, an average refractive index of 1.40 ± 0.0i is assumed and the computer software adjusted accordingly.

2.5 Tape Format

The recordings prepared by the aerosol spectrometer circuitry consist of compatible records of 20-sec duration, adjacent records being separated by 0.6 in. of unrecorded tape, as shown in Figure 6. Eight separate tracks, labelled 0—7, but not in numerical sequence, are used for recording data while the ninth track labelled P, is used for odd bit parity checking. As may be seen from Figure 6, the recording begins with a 16 character unique code followed by 16 characters representing housekeeping functions. At the end of the first 32 characters the recording system automatically switches from a housekeeping mode to a data mode and the remaining 3488 characters are employed for data recordings.

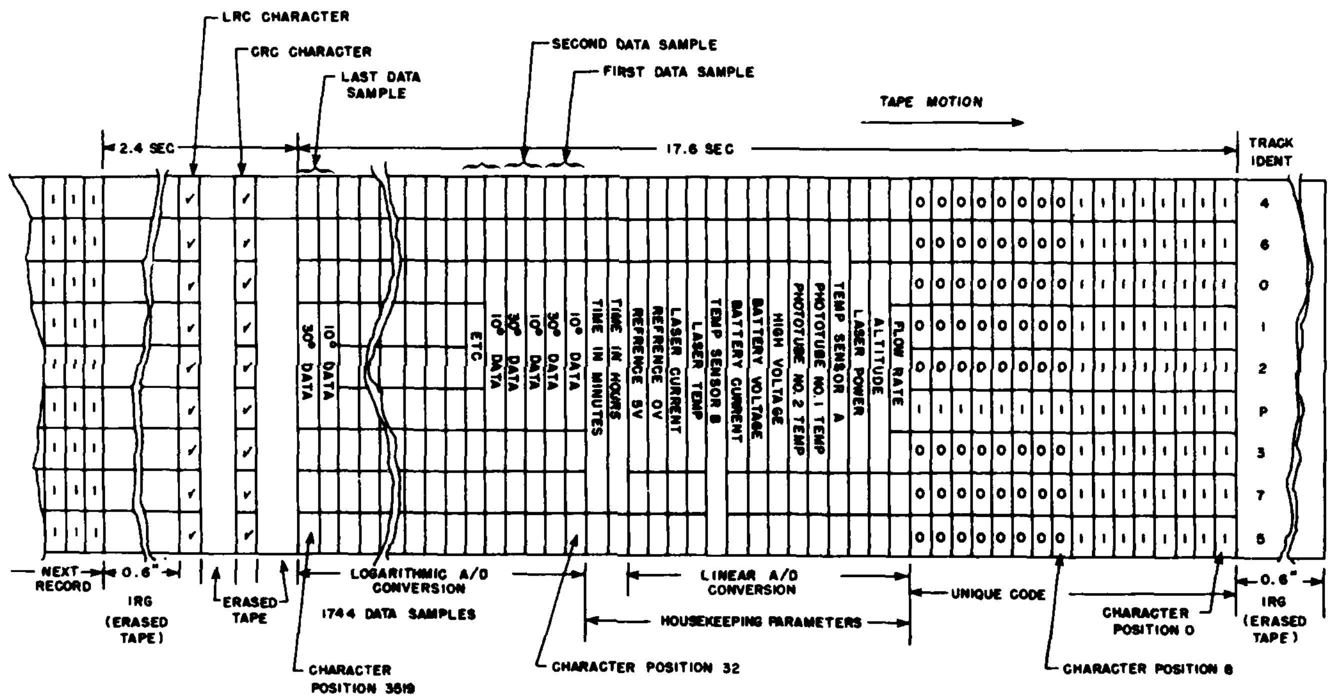


Figure 6. Computer Compatible Magnetic Tape Format Recorded at 800 BPI, NRZ

Since two characters are required for each data sample (10° PM output and 30° PM output), a total of 1744 samples can be stored in each record. Data are tape recorded at a speed of 0.25 in./sec in standard 800 bits per inch, NRZ format. Considering that the recorder is subjected to temperatures well below the manufacturer's rating, the unit performs remarkably well. During the last balloon flight, 1250 records were taped, none of which were lost due to uncorrectable errors. This is an equivalent of zero errors in excess of 2×10^7 bits of recorded information.

The tape format as described was modified slightly in 1974. Each 64th sampling interval is devoted entirely to a measurement of the background level. The background measurement period is of 60-μsec duration and occurs at the initiation of the sampling interval so designated. The remainder of the sampling period normally devoted to accepting input data is blanked out, thereby preempting the detection of optical data signals.

2.6 Telemetry

With the cooperation of the AFGL Balloon Instrumentation Group, LCC, arrangements were made to experimentally pulse-code telemeter the 1980 balloon flight. Although the data rate on the transmission was undesirably high, results were quite encouraging. Data drop-outs existed but not to the extent of seriously degrading the data. The tapes could have been used if the onboard recorder had failed.

3. AEROSOL SPECTROMETER FLIGHTS*

Re-evaluation of data obtained by the Air Force Geophysics Laboratory aerosol spectrometer was initiated in September 1980. The data format shown in Figure 7 was used on all flights prior to 1975. It was felt that while this format was suitable for atmospheric modeling, it did not facilitate the visualization of aerosol concentration versus altitude. As a result, the data were converted to a new format. This was to prove a valuable tool for data and aerosol spectrometer operational analysis.

---

*Poiseuille correction applied to all data in accordance with the 1960 Standard Atmosphere.

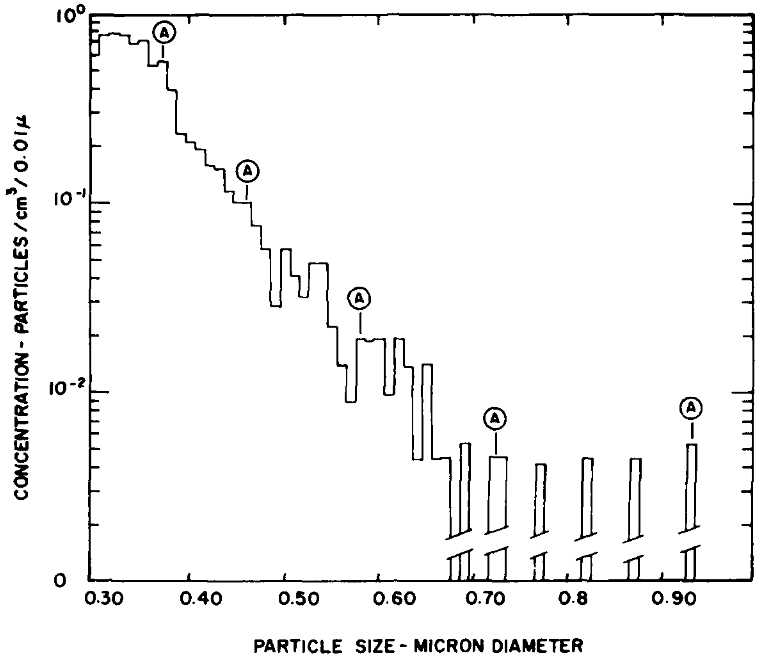


Figure 7. Flight No. RV-1, 27 May 1980. This graph presents particle size vs concentration/cm^3/0.01 μ diameter and is the summation of ten records from 5.90 to 6.23 km altitude

3.1 Flight EX-1, 28 October 1970

The first flight[2] of the aerosol spectrometer occurred under less than ideal conditions. The source of illumination used in the equipment was a Spectra Physics 15-mW laser. Unfortunately, both the output power and the beam position were temperature sensitive. While the drift in power output was corrected in data processing, the beam shift could not be compensated. In addition, the illumination source was circular with a diameter slightly less than that of the sampling tube. This latter condition produced very poor particle sizing resolution due to the extreme non-uniformity of illumination. Although the data obtained from the EX-1 flight were far from perfection, it showed that the instrument was fundamentally sound and could be improved to meet the original design specifications. The ribbon beam source presently employed was installed following the EX-1 balloon

2. Miranda, H.A., Jr., and Dulchinos, J. (1972) A Balloon-borne Aerosol Counter, AFCRL-71-0416, AD737802. Final Report, Contract No. F19628-70-C-0265, GCA Corporation.

flight. Figure 8 depicts the vast improvement in particle sizing resolution after modification of the illumination source.

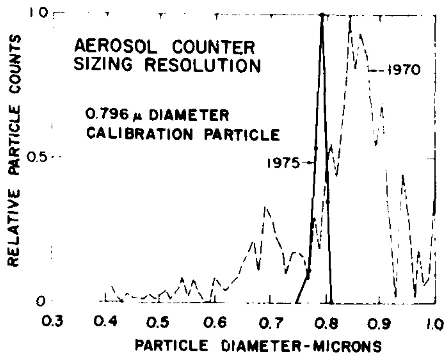


Figure 8. Comparative Size Resolution for the 1970 and 1975 Flights. This major improvement, accomplished prior to the 1973 flight series, resulted from a redesign of the optical system and other modifications

3.2 Flight FR-1, 17 May 1973

This flight[3] was marred by excessive variations in balloon ascent velocity and failure of the air sampling pump at 13.5 km on the flight upleg. The data obtained (Figure 9) show a very strange behavior of the relative concentration of small and large particles, specifically, an increase in small particles was accompanied by a decrease in large particles. The data plot resembles the folds of an accordion, the amplitudes of which decrease with altitude. Although all the reasons for this odd effect are not fully understood, it is believed that the data may be corrected with new computer runs.

3.3 Flight FR-2, 24 May 1973

Flight FR-2[3] was very successful; balloon ascent velocity was well controlled and the instrument functioned throughout the entire flight which was conducted during a period when atmospheric aerosol levels were relatively low as measured by James M. Rosen and associates at the University of Wyoming.[4]

---

3. Miranda, H.A., Jr., Dulchinos, J., and Miranda, H.P. (1973) Stratospheric Balloon Aerosol Particle Counter Measurements, AFCRL-TR-73-0700, AD777135, Final Report, Contract No. F19628-73-C-0138, Epsilon Laboratories.

4. Hoffman, D.J., and Rosen, J.M. (1981) On the background stratospheric aerosol layer, J. Atmos. Sci. 38:1.

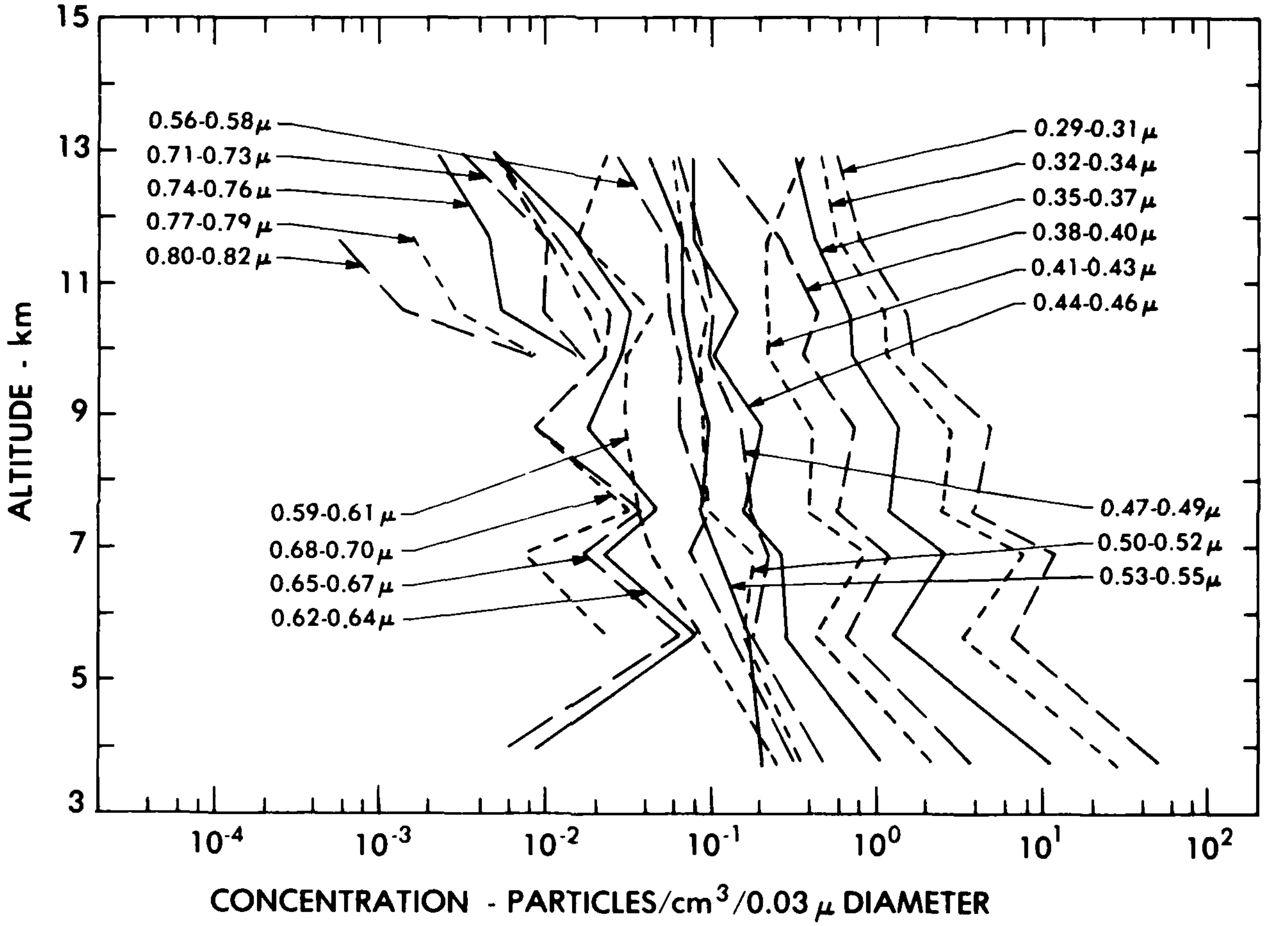


Figure 9. Flight No. FR-1, 17 May 1973. Particle concentration vs altitude

An examination of the high resolution data of Figures 10 and 11 reveals some rather interesting features. Between 12 and 26 km altitudes, particles of 0.23 to 0.28 μ diameter exhibit a relatively constant concentration. This is not true of the larger particles, however. For example, note the pronounced fluctuations in concentration for 0.41 to 0.67 μ diameters. An extreme example of this unexpected behavior appears in the 0.50 to 0.52 μ data which shows an order of magnitude drop in concentration at 16.5 km. Had the data been plotted on a smaller differential altitude scale, the variation in concentration would have been even more pronounced. A final point of interest is the transition from more or less constant concentrations with increasing altitude to a condition of sharply decreasing concentration. How abrupt this transition region may be is unknown due to the rather large integrated altitude interval.

Particle concentration behavior on the high altitude upleg, float, and downleg portions of the FR-2 flight, Figure 12, indicates that the "accordion effect" observed on the FR-1 flight is still in evidence, although in a different form. The original plots were derived from data taken under more or less constant balloon velocity conditions, hence the "accordion effect" was not easily discernable under these circumstances. The FR-2 data has been empirically adjusted to compensate for the "accordion effect." This correction factor, although not rigorously proven, is believed to be reasonably accurate.

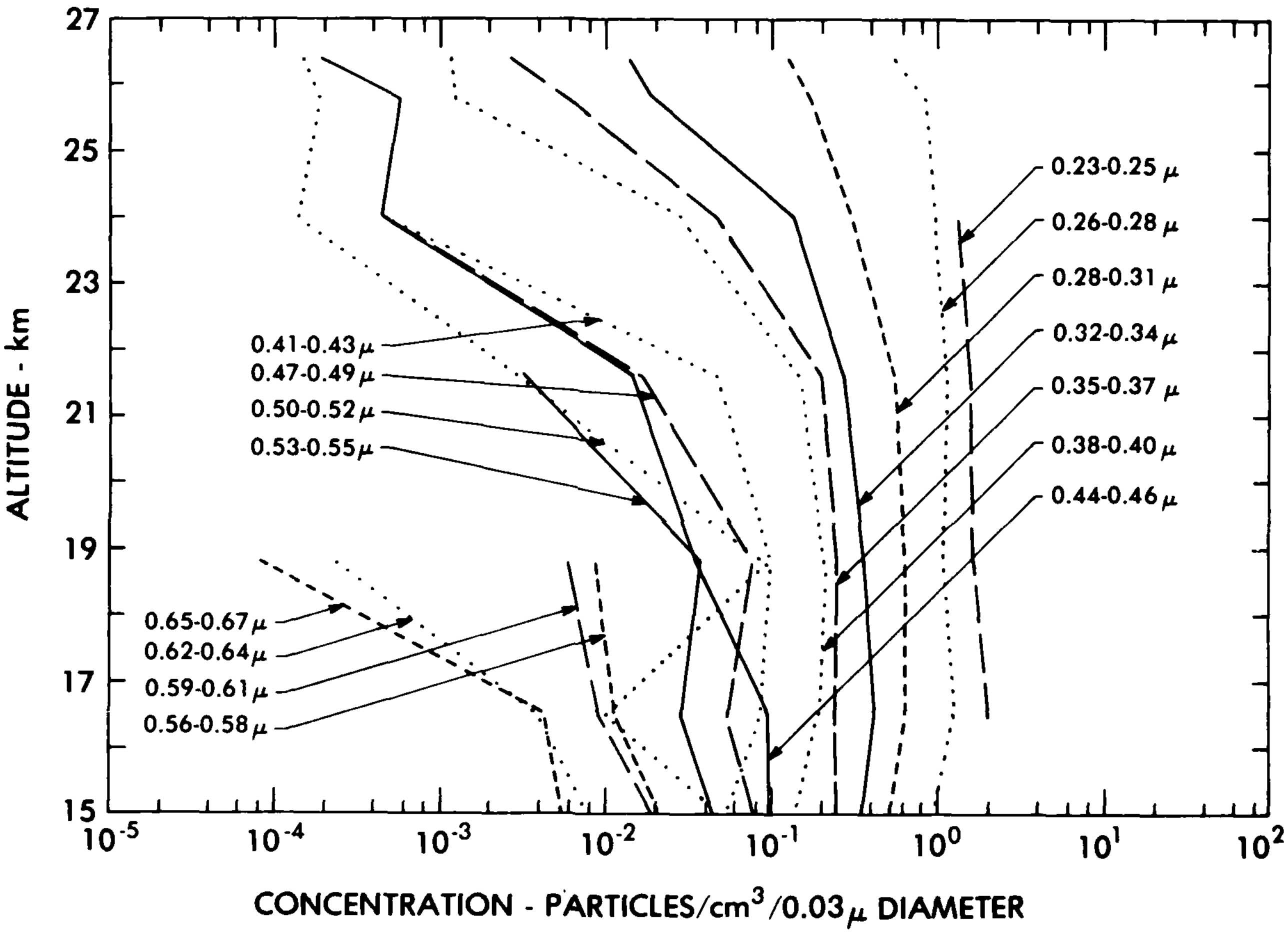


Figure 10. Flight No. FR-2, 24 May 1973. Particle concentration vs altitude

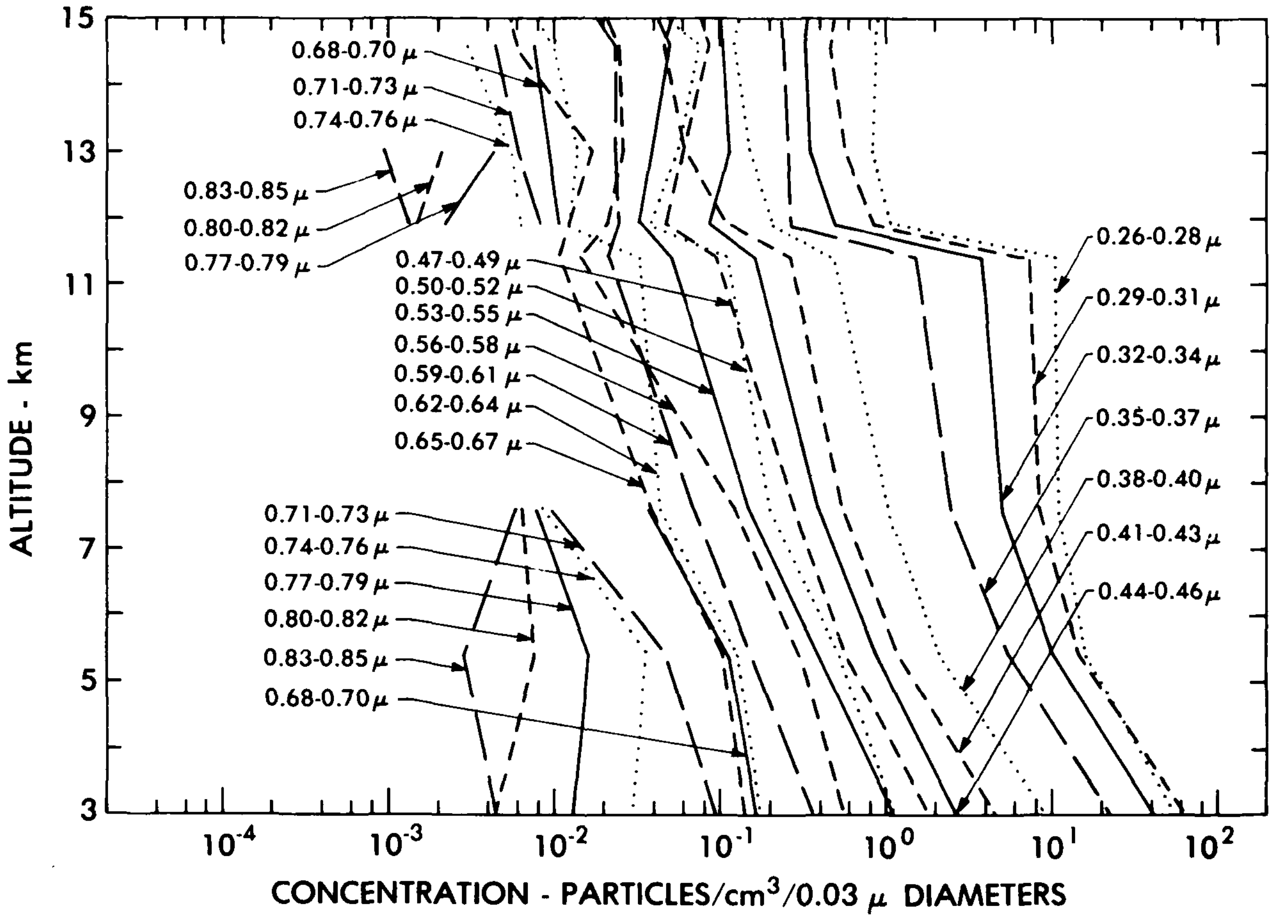


Figure 11. Flight No. FR-2, 24 May 1973. Particle concentration vs altitude

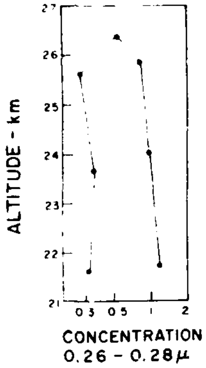


Figure 12. Flight No. FR-2, 24 May 1973. Modified "accordian effects"

3.4 Flight BR-2, 21 January 1975

The choice of this flight[5] date was indeed fortuitous in that an eruption of the Fuego volcano in Guatamala had occurred in mid-October 1974 which resulted in the deposition of an intense stratospheric dust layer over a very wide geographical area as discussed by Volz.[6] McCormick and Fuller[7] report results of lidar measurements conducted on 26 November 1974 at Hampton, Virginia in which a double dust layer was observed, specifically, a broad peak at approximately 16 km and a second peak at 20 km about 1-km in thickness. The aerosol enhancement was clearly observable to the naked eye over a broad geographical area by virtue of the characteristically long and colorful sunsets and sunrises.

The equipment experienced abnormally low temperatures on this particular flight which resulted in a low level oscillation in the PMT preamplifier circuits. This oscillation produced disturbances in the data between 0.43 and 0.54 μ. This condition was detected by the confidence check system previously described. Data for this flight have been smoothed in this particle regime.

Results from this flight are shown in Figure 13 and are in sharp contrast to the FR-2 data obtained in 1973. To facilitate a comparison of these flights, three selected size intervals from each flight are shown in Figure 14. Below the Junge layer no great differences in concentration are observable, with the possible exception of 0.5 μ diameter or larger. The Junge layer, centered at 19 km, shows a major increase in concentration for all particle sizes after the Fuego eruption. Above the Junge layer the larger particles exhibited an increase in concentration and were present at appreciably higher altitudes.

---

5. Miranda, H.A., Jr., and Dulchinos, J. (1975) Balloon Measurements of Stratospheric Aerosol Size Distribution Following a Volcanic Dust Incursion, AFCRL-TR-75-0518, ADA018372. Final Report, Contract No. F19628-75-C-0004, Epsilon Laboratories.

6. Volz, F.E. (1975) Volcanic twilight from the Fuego Eruption, Science 189:48.

7. McCormick, M.P., and Fuller, W.H., Jr. (1975) Lidar measurements of two intense stratospheric dust layers, Appl. Opt. 14:4.

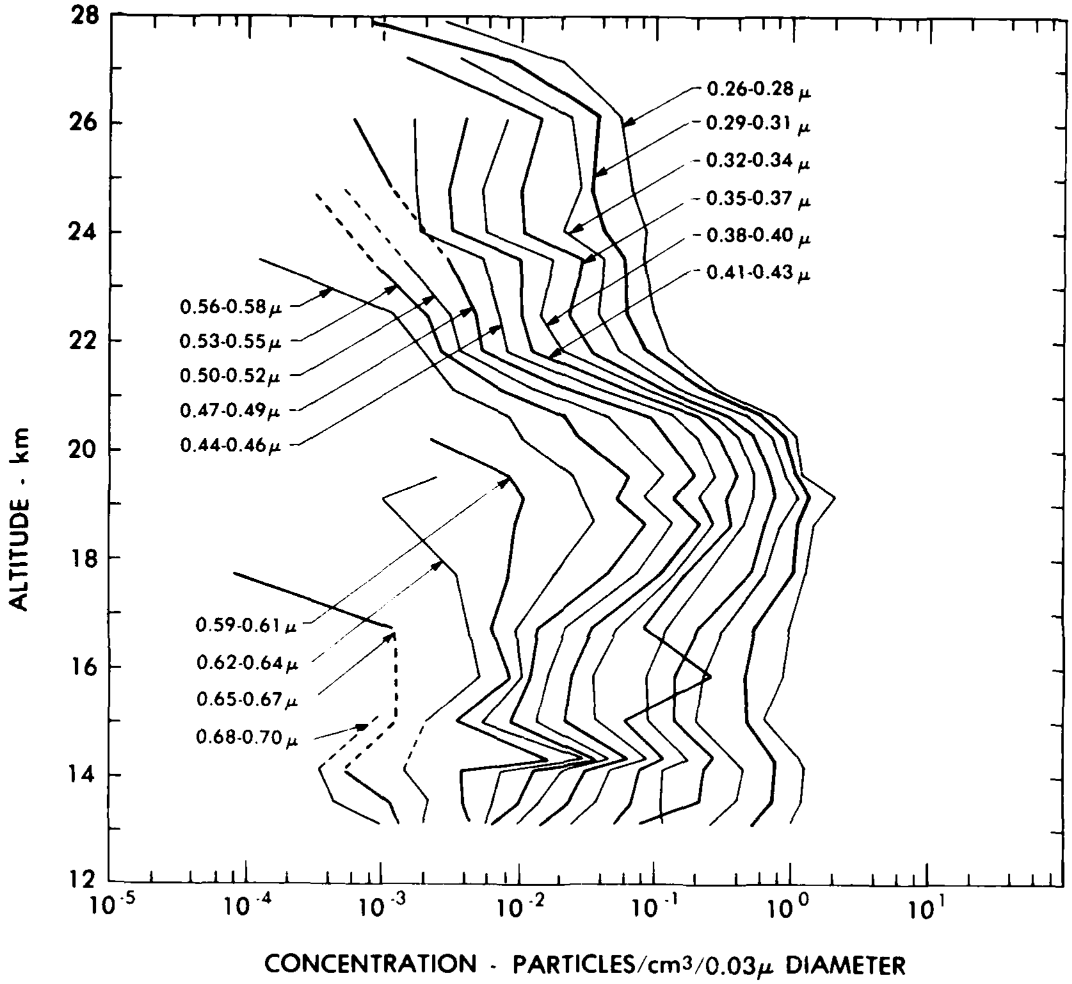


Figure 13. Flight No. BR-2, 21 January 1975. Particle concentration vs altitude three months after the Fuego volcanic eruption

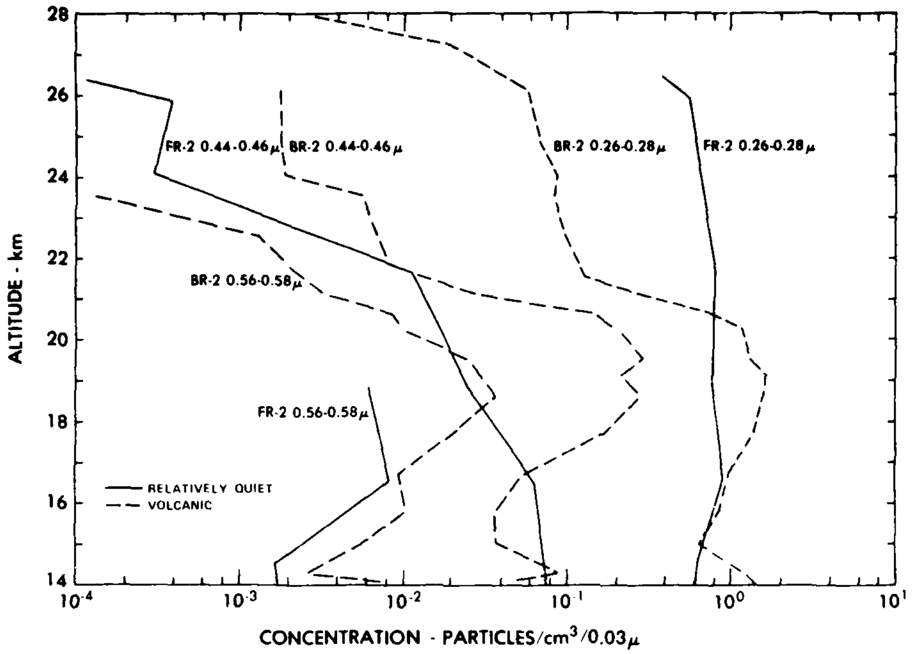


Figure 14. Comparative Particle Concentrations vs Altitudes for the FR-2 and BR-2 Flights for Three Selected Size Intervals

3.5 Flight RV-1, 27 May 1980

On the date chosen for this flight[8] the NASA SAGE Spacecraft would be viewing within a few hundred km of our projected sampling region at local sunset, thereby providing an opportunity of correlating our results with the solar tangential extinction data collected by the spacecraft instruments.[9] At the same time, the Ames instrumented aircraft, whose mix of instruments included a wire impactor, was to have established rendevous with our balloon and continue on to Wyoming for simultaneous measurements with James Rosen's dustsonde balloon flight, data from which was to be used as a "Ground Truth" measurement for the SAGE satellite program. Unfortunately, the Mt. St. Helens volcanic eruption interposed and the Ames aircraft was diverted to measure that event.

---

8. Miranda, H. A., Jr. (1980) Stratospheric Aerosol Measurements, AFGL-TR-80-0366, ADA097716. *Final Report, Contract No. F19628-79-C-0130*, Epsilon Laboratories.

9. McCormick, M. P., Hamill, P., Pepin, T. J., Chu, W. P., Swissler, T. J., and McMaster, L. R. (1979) Satellite studies of the stratospheric aerosol, Bull. Am. Met. Soc. 60:1038.

At the time of the eruption of Mt. St. Helens, the aerosol level had approached a stable background level.[4] Fortunately, the resultant debris from the eruption had not reached the Holloman AFB region at the time of the RV-1 flight. An opportunity to obtain an aerosol background measurement of this nature may not occur in one or more decades, therefore, the information obtained from this flight is of considerable importance.

The RV-1 balloon flight was launched at 07:00 MST. The rise rate was well controlled and within acceptable limits during the entire upleg portion of the flight. Upon reaching an altitude of approximately 28 km, however, it was discovered that the helium release valve would not respond to ground control signals. The maximum altitude reached was about 28.7 km, and the flight was terminated as the equipment temperature was becoming excessive.

The Aerosol spectrometer functioned over the entire flight although, for reasons still unknown, the air flow was abnormally low above the 15-km region. Because of the unexpected flow behavior, it was decided to apply to the RV-1 data a modified processing procedure as described below.

4. IN-HOUSE STUDIES

An important preliminary step in the re-analysis of existing data was to copy all available flight tapes as a safety measure. It was then necessary to modify all computer programs originally written for the Mitre IBM-360 for use on the AFGL CDC-6600 computer system. This work, performed ably by Bedford Research Associates, required a considerable amount of time and effort as the two computer systems, while speaking a common language, have distinctly different dialects. Additional programs were written to assist in this data study.

An examination of the "accordian effect" depicted in Figures 9 and 12 shows clearly that it is related to balloon velocity. This, in turn, points to possible errors in air flow measurements, although the exact relationship could not be established in 1973 because of the lack of additional data runs. In any event, this could only partially explain the observed facts.

A careful consideration of the possible sources of error in the aerosol measurements performed with this instrument may ascribe them to four categories:

(a) Flow meter error—this may arise from initial calibration errors, hysteresis effects and changes in calibration during flight.

(b) Flow calculation error—affects all particle concentration calculations proportionally.

(c) Pulse height measurement error—this may occur under reduced flow conditions as the pulse length is inversely proportional to flow rate. If the peak amplitude of a pulse occurs after the sampling gate is closed, the measured pulse and corresponding particle size is less than its true value and results in a redistribution of particle sizes. During the downleg portion of a balloon flight the flow rate may be appreciably greater than the norm and the photomultiplier pulses are shortened accordingly. If the PMT amplifiers be of insufficient bandwidth, the pulses will not reach full amplitude which also results in the undersizing of particles.

(d) Altitude calculation error—the usage of the arithmetic mean altitude, can under some circumstances, lead to disturbances in the plotted data and is a function of the concentration slope.

The foregoing error sources may be present singly or in any combination thereof. This presents a rather complex analytical problem.

Determination of the particulate concentration is critically dependent upon an accurate measurement and calculation of the total volume of air sampled per record. Measurement of this parameter has proven less than satisfactory due to unreliability of the flowmeter units employed. Balloon flights through 1973 used a potentiometric transducer which was subject to hysteresis effects as well as possible offset and nonlinearity if the unit was subjected to accidental overpressure. The transducer used on the 1973 flight series had sustained damage, either by overpressure or a hard landing. When this damage occurred is not known. For the 1975 and 1980 flights, the original flowmeter was replaced with a variable reluctance type transducer. The performance of this device has been more satisfactory, although replacement of this unit with a more rugged version is desirable.

The variable air flow experienced during the balloon flights as detailed in Section 2.2, while fundamentally undesirable, provides a means of checking the calibration and performance of the flowmeter under flight conditions. This may be accomplished under the following assumptions:

(a) The number of particles detected is proportional to the volume of air sampled per record.

(b) The number of particles per record or multiple records at a given flow rate is sufficiently large statistically.

(c) Over limited differential altitudes, the particle concentration is relatively constant. As an example, note the constancy of the 0.23 to 0.28 particle concentration between 12 and 26 km for the FR-2 flight (see Figure 10).

The air flow varies over a rather wide range during most of a ballon flight. This should provide adequate data for analysis of the flowmeter operation. This corrective procedure should be applicable even under disturbed conditions such as those following the Fuego eruption.

To test the foregoing theory, new computer programs were devised to obtain the necessary information in concise form. The method of flow calculation previously used assumed the flow rate to be constant for a period greater than

17 seconds. For individual records, this does not permit calculation of the flow rate with sufficient accuracy, and the program was modified to calculate the mean flow at the midpoint of the data measurement period. This has proven quite satisfactory and has been incorporated in the main data reduction program.

5. RV-1 DATA ANALYSIS

A complete reduction and plotting of the available data in a standard format was undertaken as an in-house project as the contractor's Final Report on the RV-1 flight included information between 0.30 and 0.36 μ only. The initial task was an evaluation of any possible effects on the data due to an abnormally low air flow experienced on this flight. Of particular interest was the region near zero or reverse flow. An example of this investigation is shown in Figure 15. The leading and lagging phase shift of the flow curve is the result of modification in the flow calculation procedure. The tracking phase between the flow and number of particles counted per record is rather good as may be observed in Figure 16.

A computer printout was obtained tabulating the total number of particles and the calculated flow rate per record for the entire flight. Referring again to Figure 15, it will be seen that no particles were detected between Records No. 518 through No. 524 although the original flow calculations indicated a continuous flow. The same condition was noted over various portions of the flight and it was concluded that the formula used to compute the flow rate was in error. A review of the pre-flight flowmeter calibration proved this assumption true and the formula was modified accordingly. The flight tape was completely reprocessed using essentially the same data blocks originally employed by Epsilon Laboratories, with the exception of small portions of the tape involving inadequate or zero air flow. Figures 17 through 23 present corrected data between 0.30 and 0.36 μ in 0.01-μ intervals in the same format used in the Epsilon Laboratories Final Report.

As previously noted, the stratospheric aerosol burden was at an unusually low level and had reached, or closely approached, a stable background condition and was, in fact, considerably lower than during the FR-2 flight in 1973. While undoubtedly many volcanic events had occurred between 1975 and the RF-1 flight in 1980, apparently these eruptions were of insufficient strength to inject an appreciable amount of material into the stratosphere.[4]

The RF-1 flight data, Figures 24 and 25, show that essentially no particles of 0.38-μ diameter or greater were present above the troposphere. This differs markedly from the FR-2 measurement, Figures 10 and 11, which show the presence of much larger particles within and well above the Junge layer. The concentration of the smaller particles measured, however, is essentially the same for both flights. Figure 26 illustrates the remarkably close agreement in concentration versus altitude above 15 km for particles of 0.32 to 0.34 μ diameter. This agreement adds confidence as to the validity of the RV-1 data.

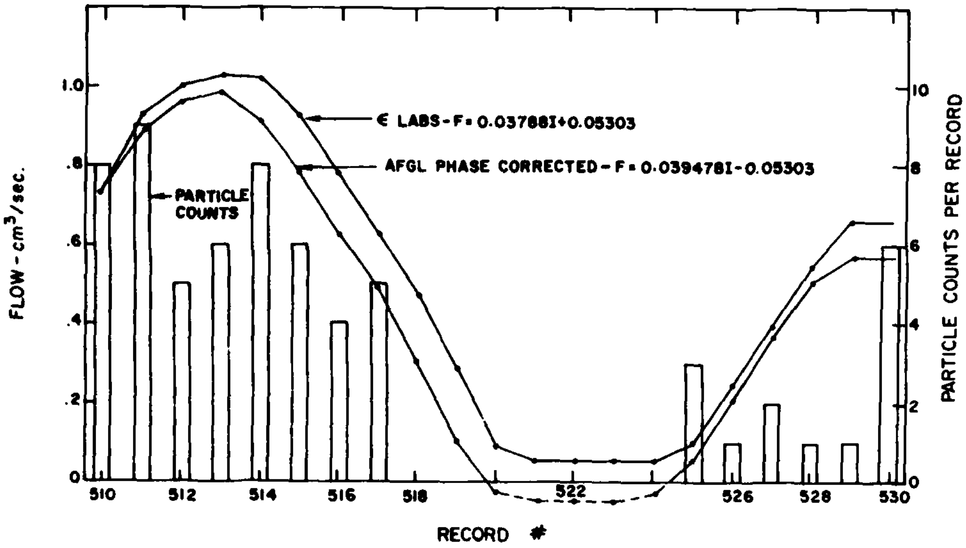


Figure 15. An Example of the Method Employed to Detect and Correct an Error in the RV-1 Data Formula. Also included is an improved means of flow calculation for individual records

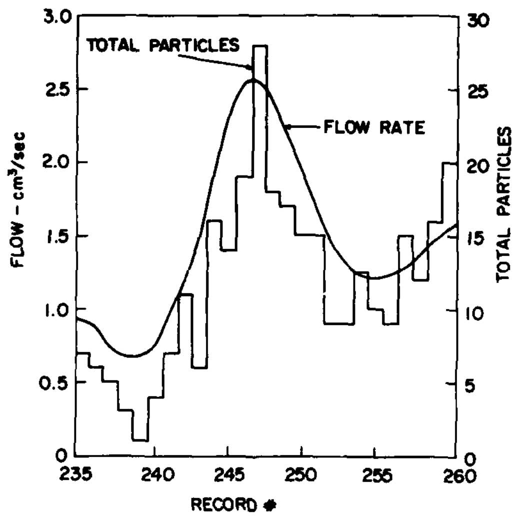


Figure 16. Improvement in Tracking of the Flow vs Particle Count Resulting From Modification of the Flow Calculational Method

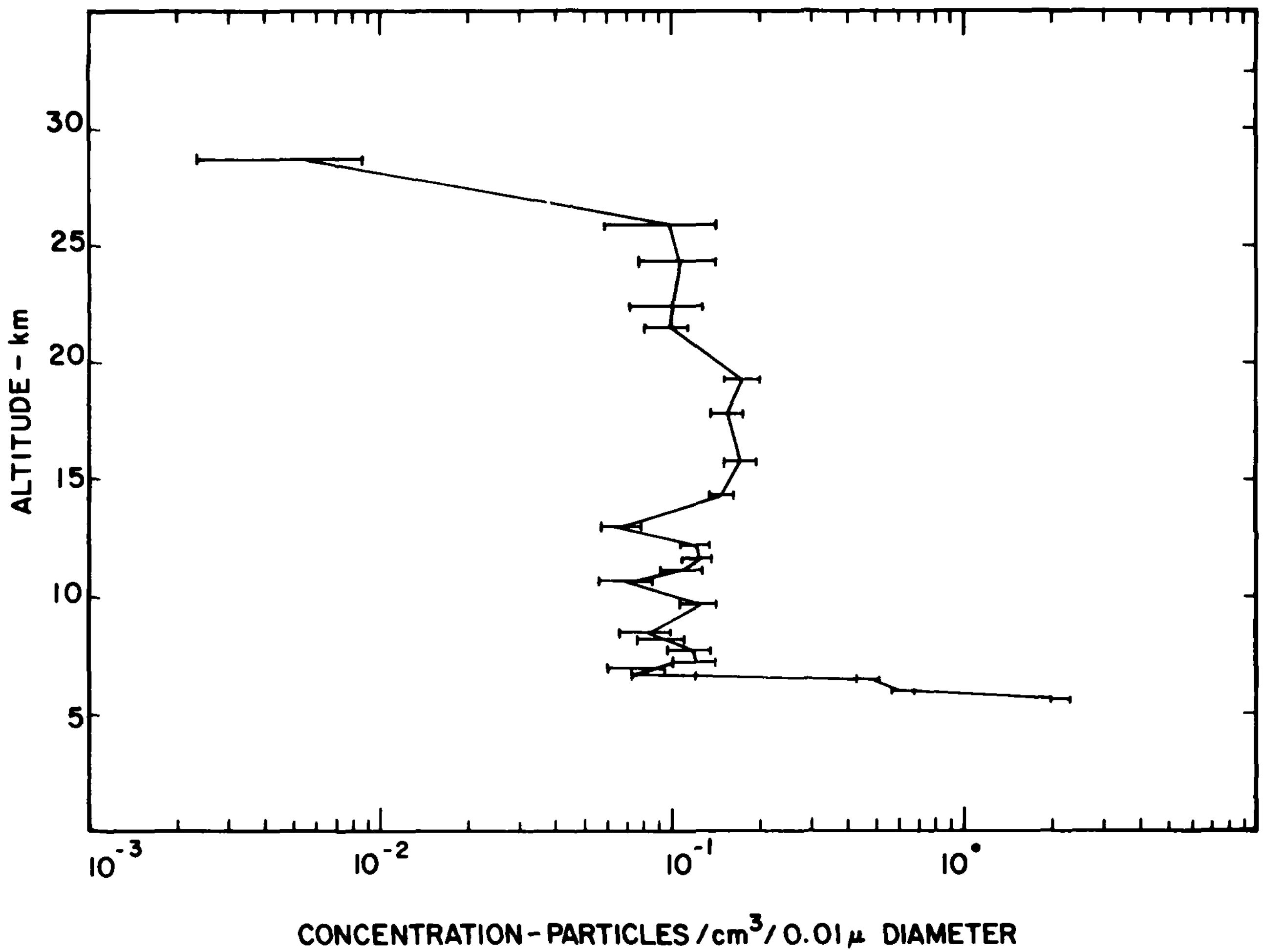


Figure 17. Flight No. RV-1, 27 May 1980. Altitude profile of 0.30 μ diameter particle concentration

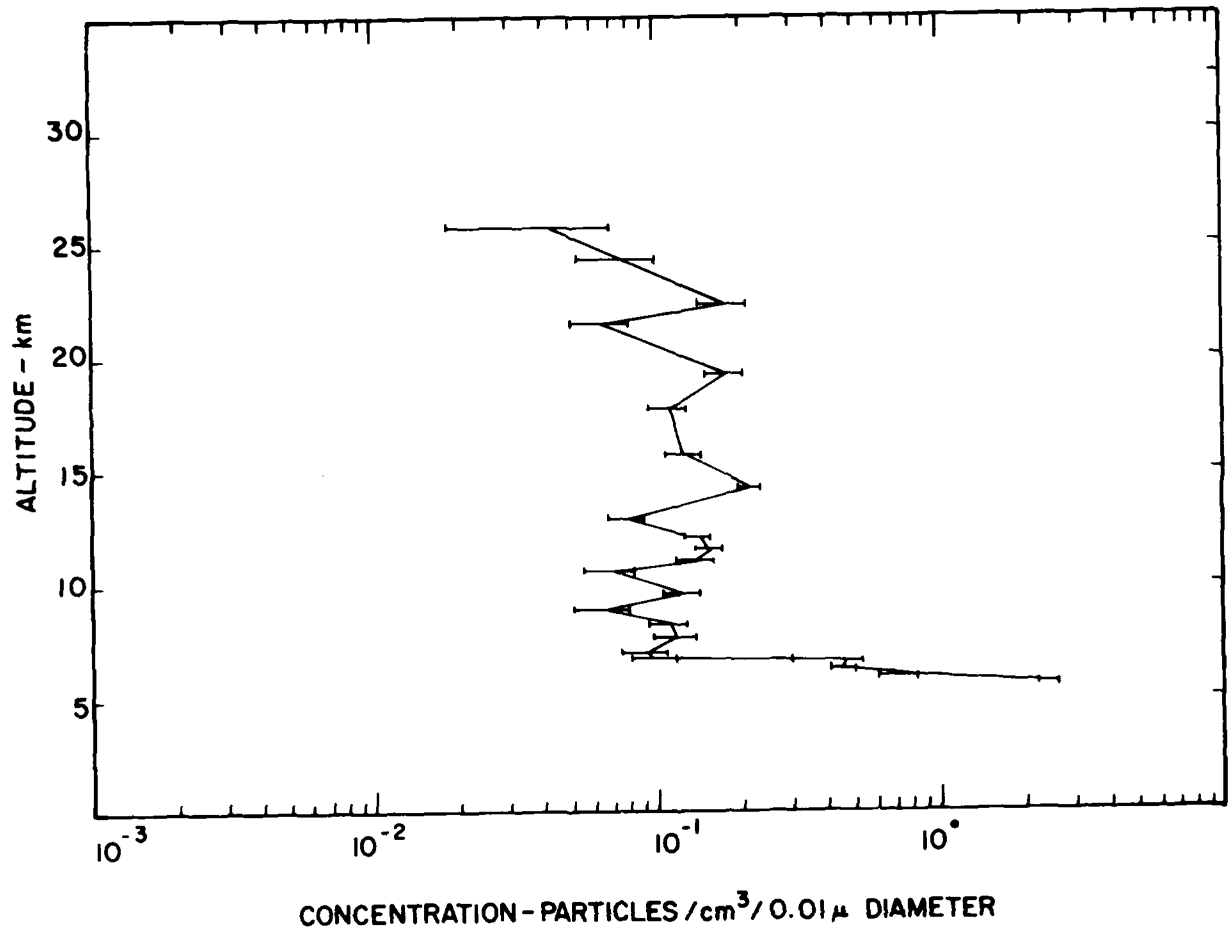


Figure 18. Flight No. RV-1, 27 May 1980. Altitude profile of 0.31 μ diameter particle concentration

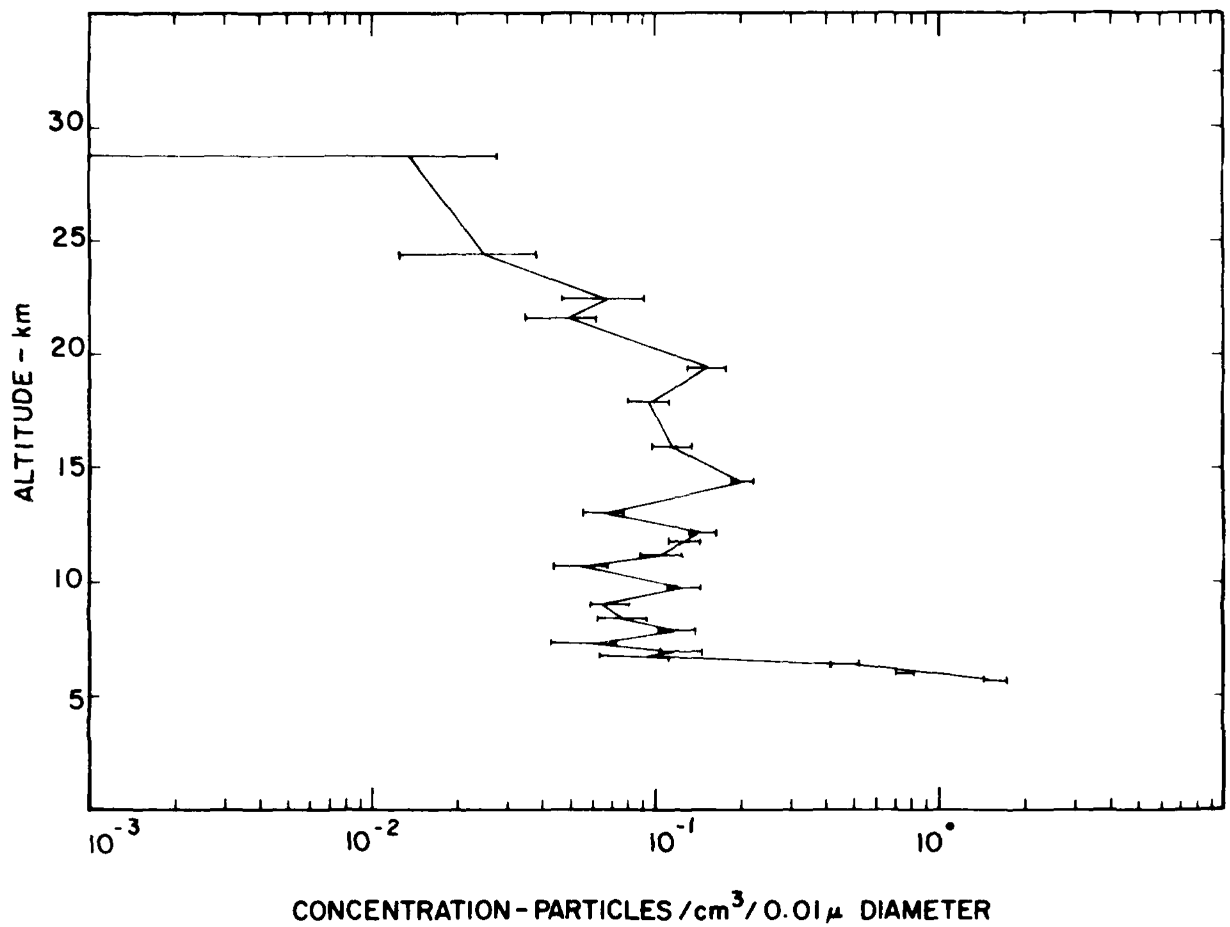


Figure 19. Flight No. RV-1, 27 May 1980. Altitude profile of 0.32 μ diameter particle concentration

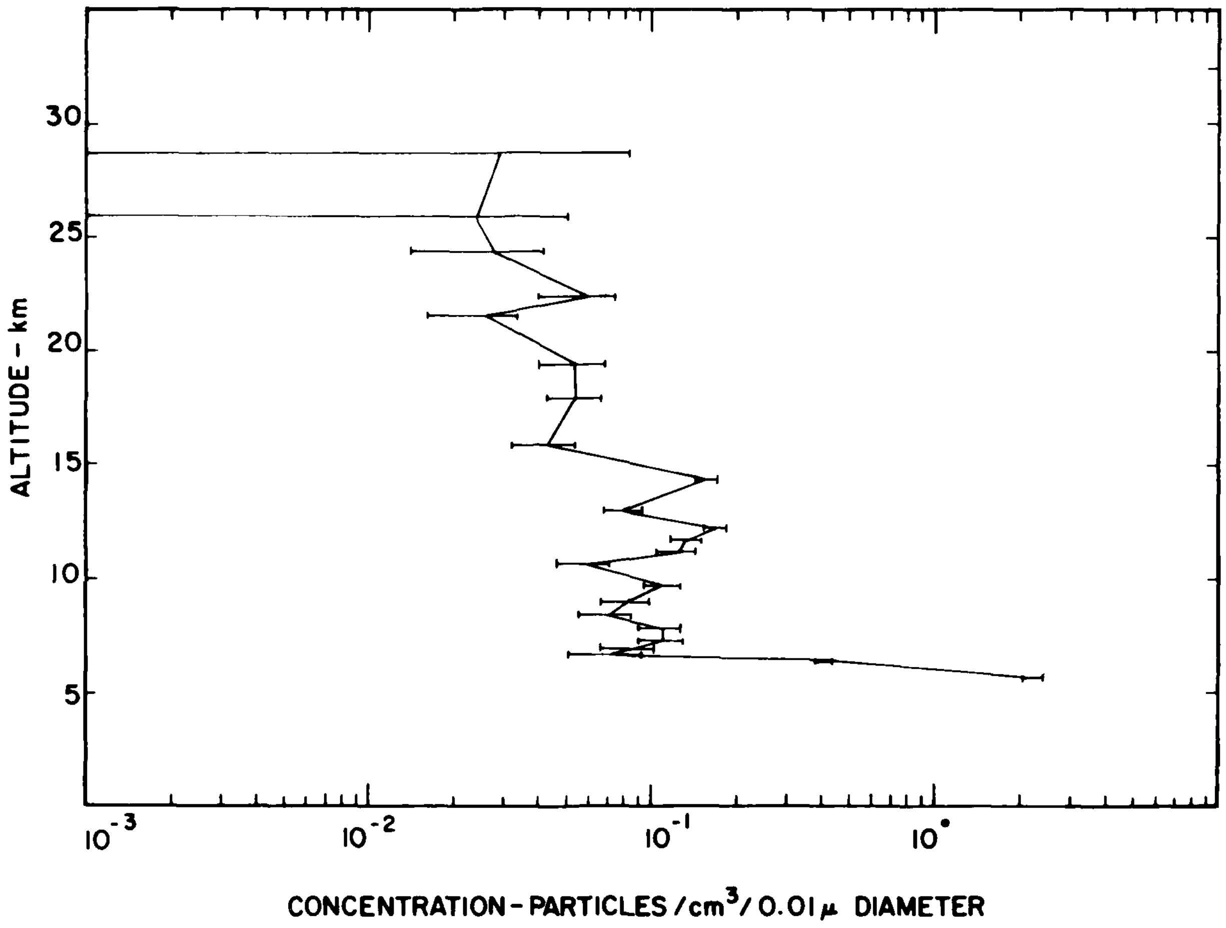


Figure 20. Flight No. RV-1, 27 May 1980. Altitude profile of 0.33 μ diameter particle concentration

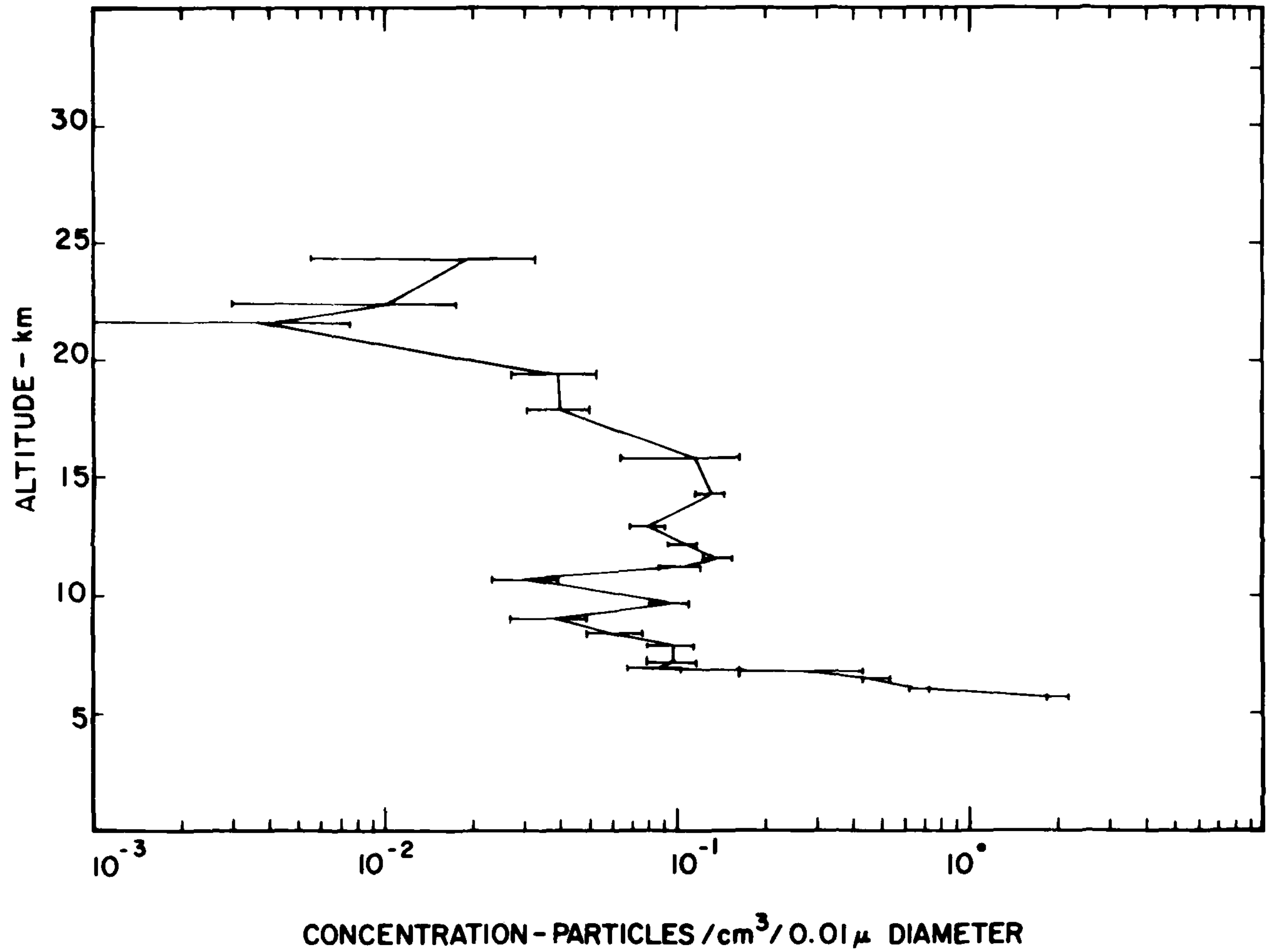


Figure 21. Flight No. RV-1, 27 May 1980. Altitude profile of 0.34 μ diameter particle concentration

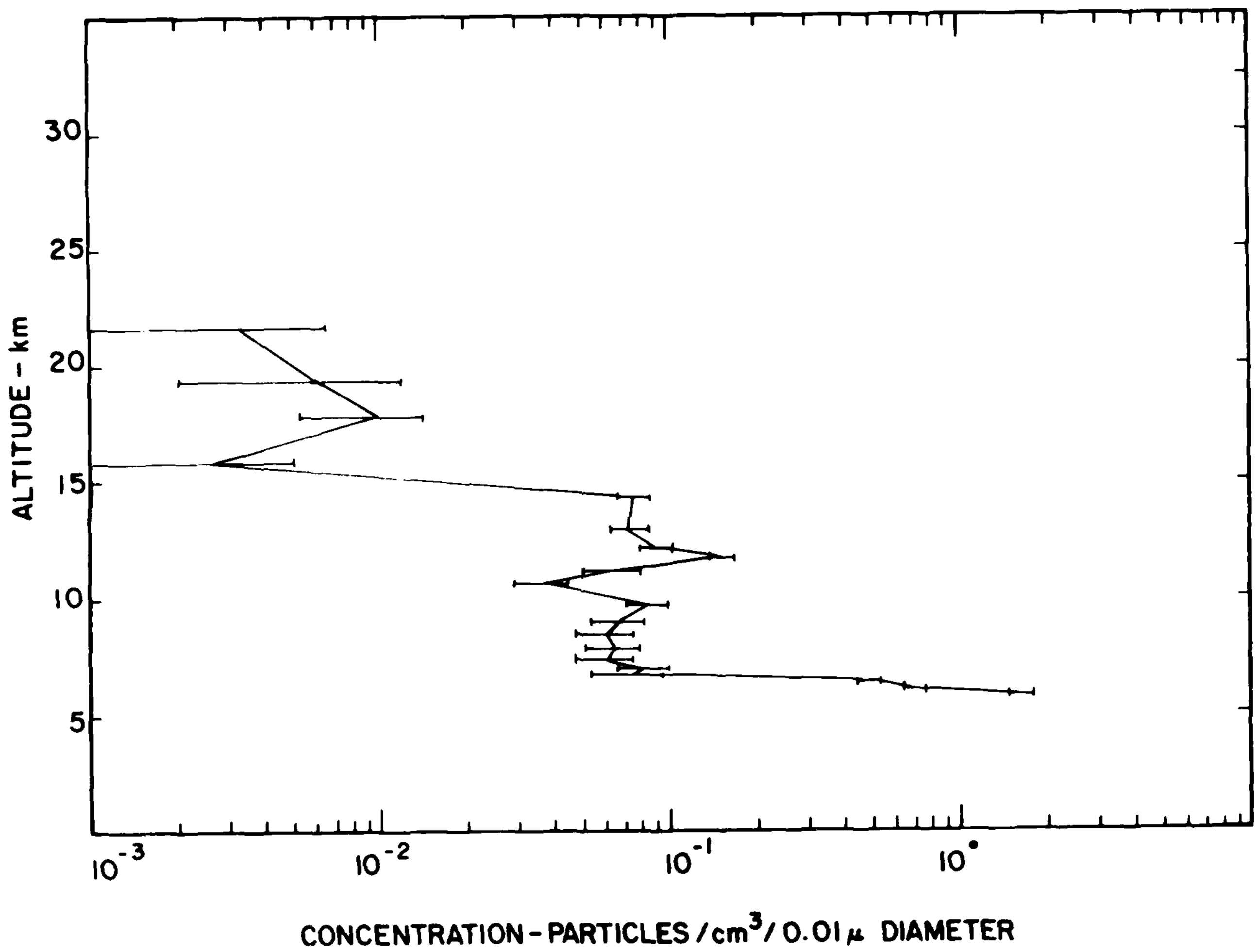


Figure 22. Flight No. RV-1, 27 May 1980. Altitude profile of 0.35 μ diameter particle concentration

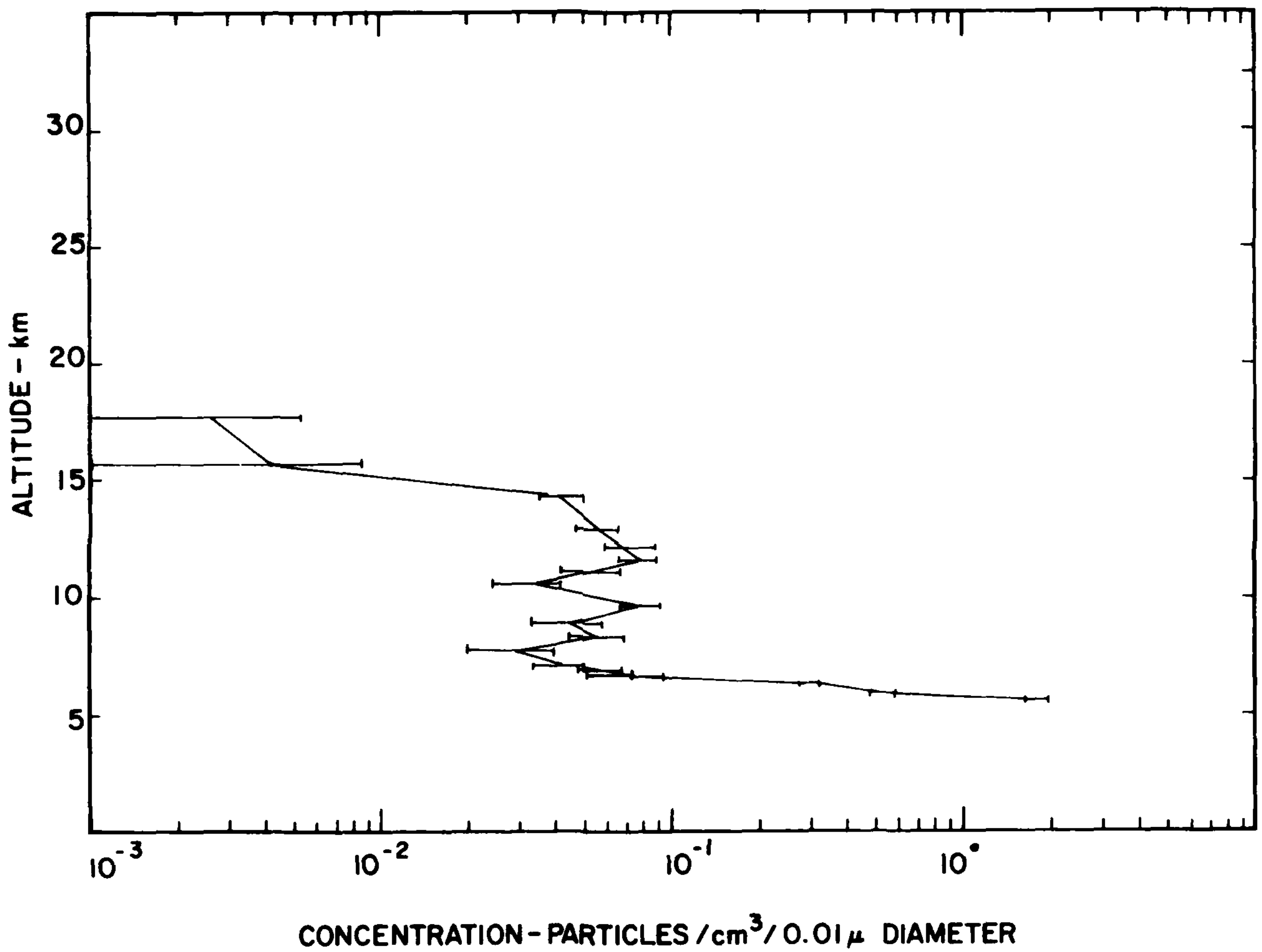


Figure 23. Flight No. RV-1, 27 May 1980. Altitude profile of 0.36 μ diameter particle concentration

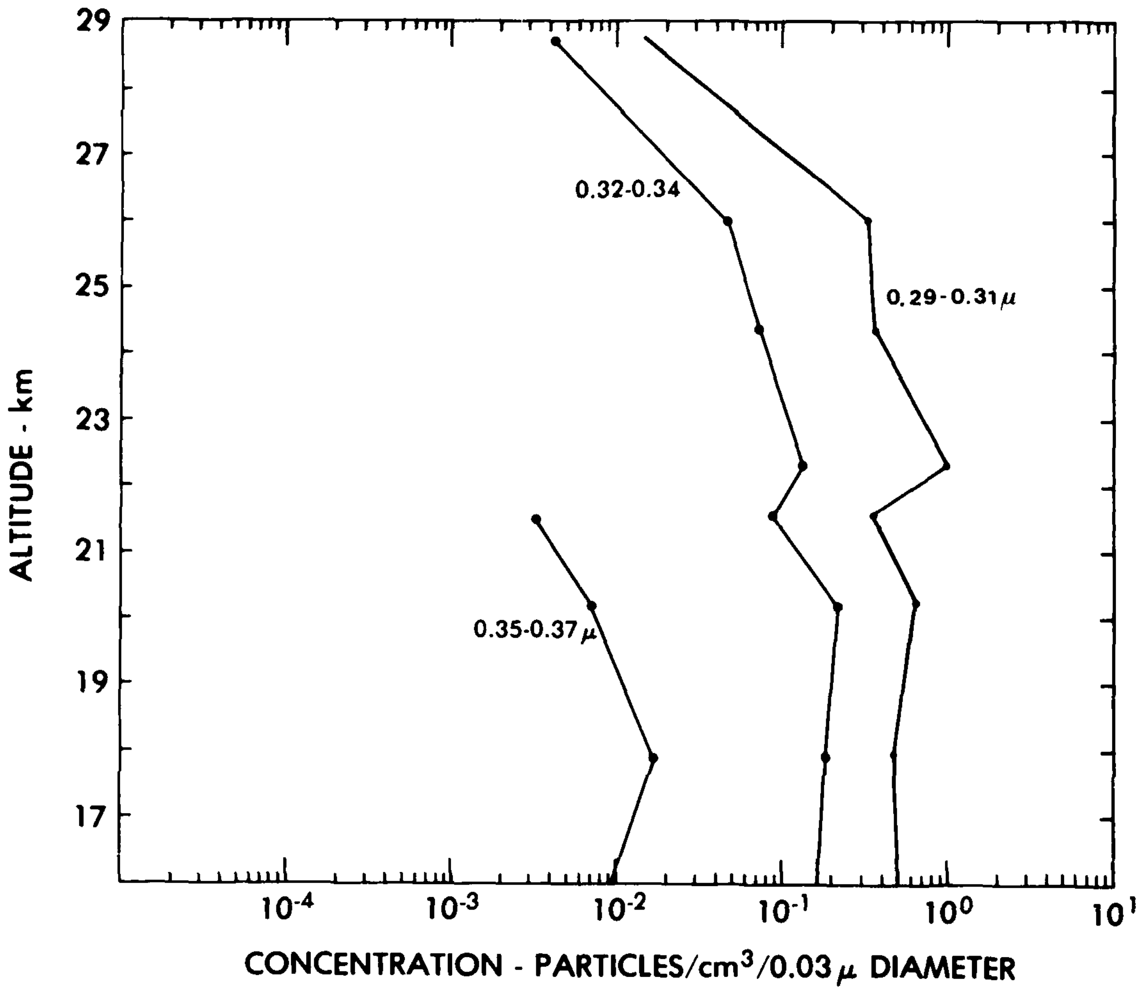


Figure 24. Flight No. RV-1, 27 May 1980. Particle concentration vs altitude

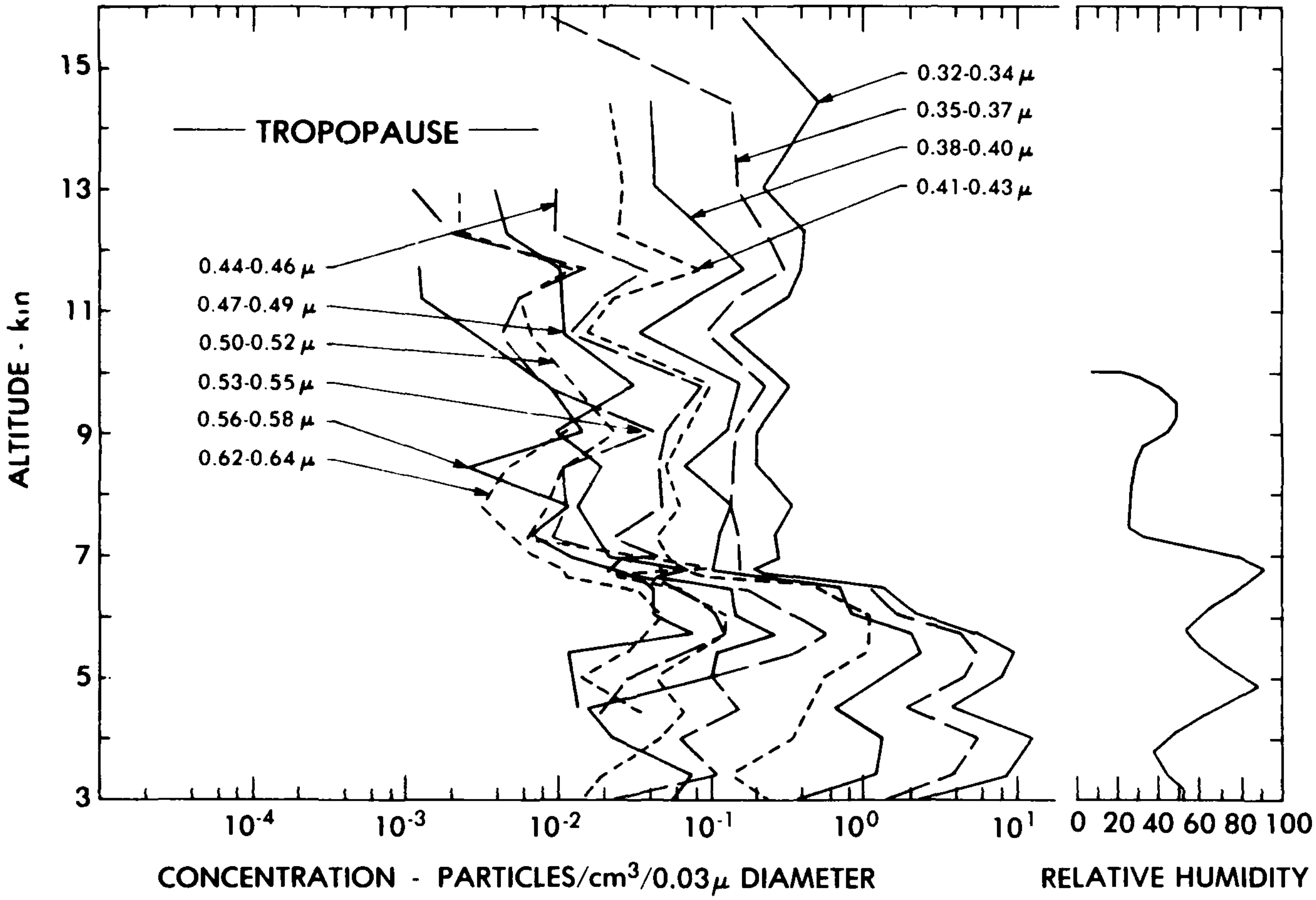


Figure 25. Flight No. RV-1, 27 May 1980. Particle concentration vs altitude

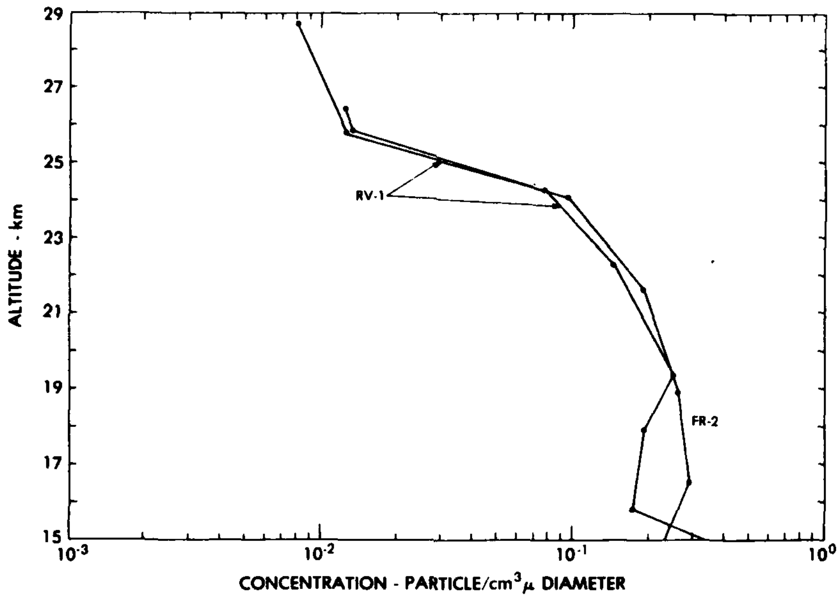


Figure 26. Flight Nos. FR-2 and RV-1. Comparative particle concentration vs altitude for 0.32 to 0.34 μ diameter

The 13 to 15 km region of the RV-1 flight is quite interesting. Very thin cirrus clouds were present at the 9 km level during the flight. An examination of Figure 25 data shows a strong enhancement in the concentration of larger particles at several altitudes, although no clouds were observed visually. One region of particular interest (6.064 to 7.268 km) is detailed in Figure 27 and Table 1. The change in concentration with altitude, when examined on a record-by-record basis, is much more abrupt than shown graphically, the maximum rate being a factor of two at 6.553 km over a vertical distance of 20 meters.

Figure 7, a summation of 10 records over a differential altitude of 0.3 km, reveals some rather unexpected information. It may be seen that there is a tendency for discrete particle sizes to exist, surrounded by regions of smaller or zero particle concentration. The points labelled A on the graph are inter-related by a common diameter ratio of 1.26, corresponding to a volume ratio of two, which indicates coagulation between particles of like diameter, under the assumption that the particles are in the liquid state. In like manner, the origin of the 0.77, 0.82 and 0.87 μ particles may be traced back one or more steps. Volumetric combination ratios of 2:1, 3:2 and so on, have also been found. Figure 28, a short portion of computer printout from the RV-1 flight shows three cases of the coagulation of equal diameter particles. Additionally, the growth and shrinkage of particles in response to variable ambient conditions may readily be observed.

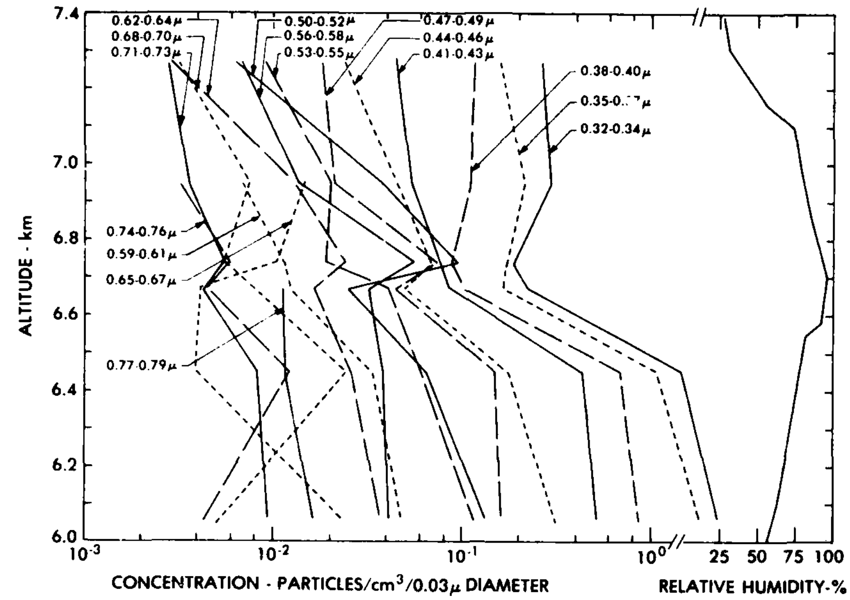


Figure 27. Flight No. RV-1, 27 May 1980. Particle concentration vs altitude, 6.064 to 7.268 km

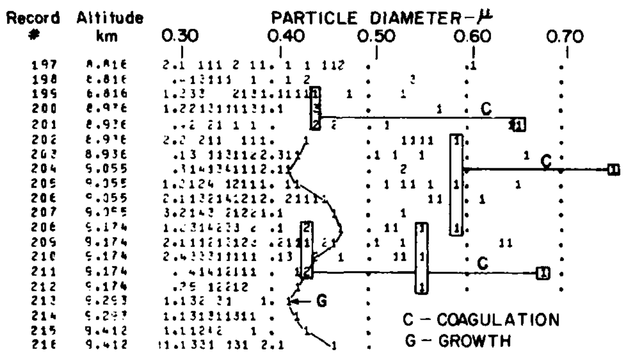


Figure 28. Flight No. RV-1, 27 May 1980. Computer printout of ir. dual records illustrating particulate g. h and coagulation

A close examination of many such records indicates this phenomenon to be quite prevalent in the data. Such a high degree of internal correlation cannot be accounted for on a statistical basis alone. It has been determined that the phenomenon observed may exist to at least 28 km.

Table 1. RA-1, 27 May 1960

Concentration - Particles cm^{-3}/0.01 μ						
Size	Altitude - km					
μ	6.064	6.446	6.672	6.745	6.946	7.268
0.80	0	0	0	0	0	2.81E^{-3}
0.81	0	0	0	5.76E^{-3}	0	0
0.82	4.46E^{-2}	0	3.98E^{-3}	0	0	0
0.83	0	0	0	0	0	0
0.84	0	0	0	5.76E^{-3}	0	0
0.85	0	4.15E^{-3}	4.13E^{-3}	0	0	0
0.86	0	0	0	0	[illegible]	0
0.87	4.46E^{-3}	3.92E^{-3}	0	1.14E^{-2}	0	0
0.88	0	0	0	5.51E^{-3}	0	0
0.89	0	0	0	0	0	0
0.90	0	0	0	0	0	0
0.91	0	0	0	0	3.56E^{-3}	0
0.92	0	0	0	0	[illegible]	0
0.93	5.29E^{-3}	0	0	0	0	0
0.94	0	0	0	0	0	0
0.95	0	0	0	0	0	0
0.96	0	0	0	0	0	0
0.97	0	0	4.36E^{-3}	0	0	0
0.98	0	0	0	0	0	0
0.99	0	0	4.07E^{-3}	0	0	0
1.00	0	0	0	0	0	0
>1.0	0	3.92E^{-3}	8.28E^{-3}	0	0	0

The information presented in this report is obviously [illegible] data obtained by the high resolution aerosol spectrometer [illegible] highly complex. It should be noted that only the RA-1 flight has been [illegible] a critical review. Those interested in the data plotted in more [illegible] of concentration versus size at various altitudes should consult [illegible] Epsilon Laboratories Final Reports. Regardless of the format employed, [illegible] presentation of such complex data is necessarily incomplete. It is hoped, therefore, that computer tapes of corrected and reduced data, along with other pertinent information, may be made available to the scientific community.

References

1. Miranda, H.A. Jr. et al (1970) Aerosol Counters, GCA-TR-70-6-A, Final Report, Contract No. F19628-68-C-0086, GCA Corporation.

2. Miranda, H.A., Jr., and Dulchinos, J. (1972) A Balloon-borne Aerosol Counter, AFCRL-71-0416, AD737802. Final Report, Contract No. F19628-70-C-0265, GCA Corporation.

3. Miranda, H.A., Jr., Dulchinos, J., and Miranda, H.P. (1973) Stratospheric Balloon Aerosol Particle Counter Measurements, AFCRL-TR-73-0700, AD777135. Final Report, Contract No. F19628-73-C-0138, Epsilon Laboratories.

4. Hoffman, D.J., and Rosen, J.M., (1981) On the background stratospheric aerosol layer, J. Atmos. Sci. 38:1.

5. Miranda, H.A., Jr., and Dulchinos, J. (1975) Balloon Measurements of Stratospheric Aerosol Size Distribution Following a Volcanic Dust Incursion, AFCRL-TR-75-0518, ADA018372. Final Report, Contract No. F19628-75-C-0004, Epsilon Laboratories.

6. Volz, F.E. (1975) Volcanic twilight from the Fuego Eruption, Science 189:48.

7. McCormick, M.P., and Fuller, W.J., Jr. (1975) Lidar measurements of two intense stratospheric dust layers, Appl. Opt. 14:4.

8. Miranda, H.A., Jr. (1980) Stratospheric Aerosol Measurements, AFGL-TR-80-0366, ADA097716. Final Report, Contract No. F19628-79-C-0130, Epsilon Laboratories.

9. McCormick, M.P., Hamill, P., Pepin, T.J., Chu, W.P., Swissler, T.J., and McMaster, L.R. (1979) Satellite studies of the stratospheric aerosol, Bull. Am. Met. Soc. 60:1038.

FILM

2-83