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Meteorological and Tracer Data - July/August 1982 Field Study in Brush Valley, Colorado

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June 1984

Prepared for
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Pacific Northwest Laboratory
Operated for the U.S. Department of Energy
by Battelle Memorial Institute

Battelle

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PACIFIC NORTHWEST LABORATORY
operated by
BATTELLE
for the
UNITED STATES DEPARTMENT OF ENERGY
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GREEN RIVER AIR QUALITY MODEL DEVELOPMENT
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Interagency Agreement DW89930094-01-1

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Richland, Washington 99352

(a) Sandia National Laboratory, Albuquerque, New Mexico.

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PREFACE

The U.S. Environmental Protection Agency is sponsoring the Green River Ambient Model Assessment (GRAMA) program. The objective of the GRAMA program is to develop improved, site-specific air quality models that can be applied to the complex terrain of the Green River Formation of western Colorado, eastern Utah and southern Wyoming. The Green River Formation is a geologic formation containing large reserves of oil shale, coal and other natural resources. Development of these resources may lead to a degradation of the air quality of the region. Air quality models are needed for planning and regulatory purposes to assess the magnitude of these regional impacts. This report documents an atmospheric tracer experiment conducted in one of the valleys of the Green River Formation to collect data to evaluate a new air quality model. This model was developed as part of the GRAMA program, and is especially designed to predict air pollutant concentrations during the period of morning inversion break up due to elevated point sources of pollution located in deep valley terrain.

ABSTRACT

Special meteorological and atmospheric tracer studies were conducted during a 3-week period in July and August of 1982 in the Brush Creek Valley of northwestern Colorado. The experiments were conducted by the U.S. Department of Energy's Pacific Northwest Laboratory (PNL) as part of the U.S. Environmental Protection Agency's Green River Ambient Model Assessment (GRAMA) program. The objective of the field experiments was to obtain data to evaluate a model, called VALMET, developed at PNL to predict dispersion of air pollutants released from an elevated stack located within a deep mountain valley in the post-sunrise temperature inversion breakup period. Three tracer experiments were conducted in the valley during the 2-week period. In these experiments, sulfur hexafluoride (SF_6) was released from a height of approximately 100 m, beginning before sunrise and continuing until the nocturnal down-valley winds reversed several hours after sunrise. Dispersion of the sulfur hexafluoride after release was evaluated by measuring SF_6 concentrations in ambient air samples taken from sampling devices operated within the valley up to about 8 km down valley from the source. An instrumented research aircraft was also used to measure concentrations in and above the valley. Tracer samples were collected using a network of radio-controlled bag sampling stations, two manually operated gas chromatographs, a continuous SF_6 monitor, and a vertical SF_6 profiler. In addition, basic meteorological data were collected during the tracer experiments. Frequent profiles of vertical wind and temperature structure were obtained with tethered balloons operated at the release site and at a site 7.7 km down the valley from the release site. Experiments were conducted in cooperation with the U.S. Department of Energy's ASCOT (Atmospheric Studies in Complex Terrain) program. A great deal of supplementary meteorological data is available from the ASCOT program, including additional tethered balloon data, data from a network of meteorological towers, acoustic sounder data, and data from laser anemometers.

Analysis of the tracer data is proceeding as this data volume is being written. Further evaluation and revision of the VALMET model are tasks that may be carried out as the tracer data are analyzed, if future funding is provided.

This report, which presents the data collected for the U.S. Environmental Protection Agency in the meteorological and tracer experiments, is being submitted in partial fulfillment of the U.S. Environmental Protection Agency Interagency Agreement DW89930094-01-1 with the U.S. Department of Energy.

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ACKNOWLEDGMENTS

The work presented in this report includes contributions from many individuals. Contributions to the field portion of the experiment include:

Participants	Contribution
Pacific Northwest Laboratory	
C. David Whiteman	Field Program Manager
Richard N. Lee	SF_6 Analyst
Roger I. Schreck	Tethered Balloon Operator, Field Crew Manager
Donald W. Glover	Technician-in-Charge, SF_6 Release Technician
Montie M. Orgill	Flight Meteorologist
Tom R. Heimbigner	Pilot
Environmental Protection Agency, Environmental Sciences Research Laboratory	
Alan H. Huber	Project Officer/Gas Chromatographer (GC2)
Environmental Protection Agency, Region VIII	
Richard W. Fisher	Manager, EPA Operations/ Gas Chromatographer (GC2)
Bill Bernardo	Gas Chromatographer (GC1)
John Notar	Gas Chromatographer (GC1)
Sandia National Laboratory	
Bernard D. Zak	Manager, Sandia Operations
Hugh Church	SF_6 Profiler/Tethered Balloon Operator
Lee Jensen	SF_6 Profiler/Tethered Balloon Operator
Gerry Gay	SF_6 Profiler Designer and Builder
Temporaries, Inc.	
8 Field Laborers	Laborers, SF_6 Bag Sampling Grid

Mr. Fred Lloyd of Pacific Northwest Laboratory provided valuable field assistance necessary to operate the PNL SF_6 bag sampling system.

Dr. Paul Gudiksen of DOE's Lawrence Livermore National Laboratory provided essential assistance in planning and coordinating the DOE and EPA experiments and the subsequent processing and analysis of data. Various necessary field arrangements for equipment storage locations, expendable supplies, telephone communications, operating locations, FAA clearances, access to field sites, etc. were capably handled by DOE field technicians Pat Ellis and Ken Lamson of Lawrence Livermore National Laboratory. The assistance thus provided by DOE was essential to the success of the EPA experiments.

Dr. Russ Dietz of DOE's Brookhaven National Laboratory provided the continuous SF_6 monitor that was flown on the Cessna 411 research aircraft.

Dr. Sumner Barr of DOE's Los Alamos National Laboratory kindly allowed us to reproduce his written description of the synoptic weather conditions which occurred during the field experiments.

Mr. John Archuleta of DOE's Los Alamos National Laboratory provided a partial listing of Grand Junction, Colorado rawinsonde data that has been included in Appendix C.

Mr. Roger I. Schreck and Mr. K. Jerry Allwine of PNL assisted in analysis of tracer experiment data after the field experiments were concluded. Dr. Harlan P. Foote of PNL digitized Brush Valley topographic data to produce Figure 5.

The tracer experiments were supported by the U.S. Environmental Protection Agency through a related services contract (DE-AC06-76RLO 1830) with the U.S. Department of Energy. Funding came from EPA Headquarters, Washington and from the Region VIII office in Denver. Dr. Al Galli, Mr. Bill Keith and Mr. Rich Fisher are thanked for their assistance in arranging the necessary funding.

SECTION 1

INTRODUCTION

In the summer of 1982, atmospheric tracer experiments were conducted for the U.S. Environmental Protection Agency (EPA) in the Brush Creek Valley in the oil shale region of northwestern Colorado. This report presents the resulting data, which were collected to evaluate the initial version of an atmospheric transport and diffusion model called VALMET [1], developed for individual valleys. The VALMET model was developed for the EPA at the U.S. Department of Energy's (DOE's) Pacific Northwest Laboratory.

The EPA tracer experiments were conducted as a supplement to a large meteorological field program that was designed by the U.S. DOE's Atmospheric Studies in Complex Terrain (ASCOT) program. Organizations participating in the ASCOT field program are listed in Table 1. The goal of the ASCOT field program was to have an initial look at the meteorology of valleys in the oil shale region of Colorado in preparation for the planning of a major multi-year complex terrain meteorological research program that would begin in FY 1984 in this region.

The 1982 DOE ASCOT field program included four 24-hour experiments conducted from July 26 to August 8. Brush Creek Valley was chosen by the ASCOT investigators for the first two experiments (July 29-30, 1982, and July 30-31, 1982), in which diurnal changes in valley wind and temperature structure were studied. These experiments relied primarily on multiple tethered balloon sounding systems. Brush Creek Valley is deep, narrow, and near-linear. Brush Creek is a tributary to Roan Creek, which drains the south side of Roan Plateau on the southern edge of the Piceance Basin. The third ASCOT experiment (August 3-4) investigated the meteorology of multiple valleys in the Roan Creek region during a 24-hour period. For this experiment, the tethered balloon atmospheric sounding systems were dispersed from Brush Creek to surrounding valleys. Finally, the last experiment (August 5-6) was designed to have a first look at the regional meteorology of the entire Colorado oil shale area by dispersing tethered balloon and upper air sounding devices over the Piceance Basin region.

The EPA field program conducted three tracer experiments in the Brush Creek Valley on the same nights as the last three ASCOT experiments (July 30-31, August 3-4, and August 5-6, 1982). While the EPA experiments were conducted within the 24-hour periods that defined the ASCOT experiments, they were of shorter duration, focusing on the inversion breakup period. Sufficient supplementary funding was available to EPA in 1982 to plan and execute this limited atmospheric tracer program, which was run in

TABLE 1. PARTICIPANTS IN THE DOE ASCOT EXPERIMENTS

Group	Instrument systems	Contact
Los Alamos National Laboratory (LANL)	Tethersonde Pibals Airsondes Minisonde Electronic weather station	Dr. Sumner Barr Dr. Bill Clements
Lawrence Livermore National Laboratory (LLNL)	Tethersonde Laser anemometers Remote weather stations	Dr. Paul Gudiksen Dr. Bill Porch
NOAA Wave Propagation Laboratory (WPL)	Tethersonde Acoustic sounders Laser anemometers	Dr. Bill Neff Dr. R.B. Fritz
NOAA Atmospheric Turbulence and Diffusion Laboratory (ATDL)	Tethersonde (2) Airsondes (2) Acoustic sounder	Dr. Ray Hosker
Colorado State University (CSU)	Tethersonde Airsonde Aircraft smoke release and meteor. data	Dr. Tom McKee Dr. Pete Sinclair
U.S. Forest Service, Rocky Mountain Forest and Range Exp. Station (USFS)	Upper air soundings	Dr. Doug Fox

conjunction with ASCOT's meteorological investigations. ASCOT's fixed instruments in Brush Creek Valley provided basic meteorological support to the EPA program, thereby decreasing experiment costs. In addition, the EPA program benefitted from tethered balloon data collected in Brush Creek Valley during ASCOT's first two experiments. Conversely, the EPA program added information to the ASCOT program that, due to DOE budget limitations, would not otherwise have been obtained.

EPA's Brush Creek tracer experiments were designed to provide the initial data required to evaluate VALMET. The collection of tracer concentration data on a cross-valley arc and comparison of this with model calculations was not considered a sufficient test of the model. Rather, the approach taken was to collect meteorological and tracer data to test the full range of meteorological assumptions and parameterizations used in modules within the model. For example, the model predicts that convective boundary layers will grow over heated surfaces after sunrise, that upslope flows will develop within these boundary layers, that pollutants from the elevated nocturnal plume will fumigate into the convective boundary layers, and that they will be transported out of the valley by the upslope flows. Thus, within the restraints of the resources available, it was necessary to observe the development of convective boundary layers over the slopes, the upslope wind systems, fumigation of pollutants, and transport of pollutants up the slope. This required a continued, elevated tracer release within the valley during periods when a strong nocturnal temperature inversion had formed, and observation of the subsequent transport and diffusion of the tracer plume as the valley temperature inversion broke up following sunrise. Multiple experiments were run during clear weather periods using a variety of measurement systems to record the changing meteorological and tracer plume structure in the valley. The experiments focused on the plume breakup during the short post-sunrise inversion breakup period. Good spatial time resolution of the observations was necessary to record features of the inversion breakup adequately. Manually-operated portable gas chromatographs and a continuous tracer gas analyzer were used to provide this time resolution. Good spatial resolution of the measurements was necessary on a valley cross section to view the expected convective boundary layer and tracer plume structure. To meet this need, a network of surface-based bag samplers was located throughout the valley, including the valley sidewalls. Vertical profiles were made through the elevated plume using a vertical SF_6 profiler, a balloon-borne sampling device. A continuous tracer gas monitor was operated from an aircraft to monitor tracer gas concentrations in the upper valley atmosphere. Finally, tethered balloon systems were used to make observations of the changing atmospheric structure within the valley.

This report describes the experimental design and presents the meteorological and tracer data collected in the EPA tracer experiments conducted in the Brush Creek Valley of Colorado during July and August, 1982. First, recommendations for future work are presented. Next is an initial evaluation of the VALMET model. Then the experimental design is discussed, including information on the topography of Brush Creek Valley, the types and locations of instrument systems used, and the weather conditions encountered during the field experiments. A chapter is provided on each of the data collection and analysis systems, including the tracer release system, the mobile analysis laboratory, the bag sampling system, the vertical SF_6 sampling system, the tethered balloon data collection system, the portable gas chromatograph system, the continuous tracer gas analysis system, and the aircraft data collection system. Data collected with each of these systems is presented in this report in the form of data tables. In addition, the tracer and meteorological data listed in Appendix A will be provided to EPA on a magnetic tape which will accompany this report.

Information on the quality of the sulfur hexafluoride data is presented in the sections of this report dealing with the mobile analysis laboratory and the portable gas chromatographs. Complete information on the Quality Assurance program used in collecting the experimental data was provided to EPA in July of 1982 [2].

SECTION 2

RECOMMENDATIONS

The Brush Creek tracer experiments conducted in July and August 1982 were designed to provide the initial data necessary to evaluate the VALMET air pollution model developed for the EPA at PNL. The data sets are uniquely qualified for this purpose. They include meteorological data collected by EPA and DOE participants to evaluate model assumptions regarding nocturnal and post-sunrise wind field and temperature structure evolution in the valley. They also include tracer concentration data collected from networks of surface and airborne sampling and analysis equipment. Special features of the sulfur hexafluoride tracer data set include:

- use of a vertical SF_6 profiling system to determine how the vertical structure of the SF_6 plume varied with time
- extension of the bag-sampling network to include tracer observations high (150 m) on the valley sidewalls
- use of portable gas chromatographs and SF_6 monitors to observe rapid variations in tracer concentrations which occur during the post-sunrise period when fumigations of the elevated nocturnal plume occur on the valley sidewalls
- use of a research aircraft to determine how pollutants are dispersed into the upper reaches of the valley following sunrise.

The experiments described in this report should be considered as initial experiments designed to provide a better understanding of the basic physics of valley meteorology. The experiments were designed with the aid of a numerical model of air pollution dispersion that appears to have promise in predicting air pollution concentrations in deep valleys. Further work is recommended to complete a full analysis of the EPA and DOE tracer and meteorological data from the 1982 experiment, to evaluate and improve the VALMET model using this data, and to report the results in the scientific literature.

Based on the preliminary results of the 1982 experiment, a second cooperative tracer experiment will be conducted with the DOE ASCOT program in the Brush Creek Valley in the fall of 1984. This experiment has been designed by GRAMA investigators to collect data to further evaluate the VALMET model and, for the first time, to evaluate portions of a regional scale model [3], called MELSAR, developed at PNL for the EPA. A key module of MELSAR predicts the timing and amount of pollutants released from a valley when valley circulations become coupled with the regional scale flows above the valley after sunrise. We recommend that the 1984 data be processed and analyzed so that the VALMET and MELSAR models can be evaluated further and, if necessary, modified to provide better simulations of air pollution dispersion in the complex terrain of EPA's Region VIII.

SECTION 3

EVALUATION OF THE VALMET MODEL

The VALMET model [2,4] was developed to predict valley air pollution concentrations arising from an elevated continuous source located within a valley during the post-sunrise temperature inversion breakup period. The model predicts air pollution concentrations on the valley floor and sidewalls of the valley on a cross section an arbitrary distance down-valley from the elevated source. VALMET has two parts, a nighttime part to predict concentrations on the valley cross section at sunrise, and a daytime part to predict concentrations at the same locations after sunrise. The post-sunrise simulation uses numerical techniques that simulate the fumigation of the nocturnal plume onto the valley floor and sidewalls as a convective boundary layer grows upward from the heated valley surfaces, as upslope flows develop in the convective boundary layers over the slope, and as compensating subsiding motions occur over the valley center.

The tracer experiments described in this report were designed to provide the data required to evaluate an initial version of VALMET. We did not consider it sufficient to simply collect tracer concentration data on a cross-valley arc and compare this with model calculations. Rather, the approach taken was to collect meteorological and tracer data to test the full range of meteorological assumptions and parameterizations used in modules within the model. For example, the model predicts that convective boundary layers will grow over heated surfaces after sunrise, that upslope flows will develop within these boundary layers, that pollutants from the elevated nocturnal plume will fumigate into the convective boundary layers, and that they will be transported out of the valley by the upslope flows. Thus, within the restraints of the resources available, it was necessary to observe the development of convective boundary layers over the slopes, the upslope wind systems, fumigation of pollutants, and transport of pollutants up the slope. In addition, it was necessary to simulate an elevated release of pollutants and to observe the characteristics of the nocturnal plume.

The EPA tracer experiments were conducted in a valley chosen by DOE using criteria unrelated to the testing of the VALMET model. The Brush Creek Valley was a useful "target of opportunity" for the initial evaluation of VALMET, but, as is usual with such opportunities, there were advantages and disadvantages to the choice of this particular valley.

There were several advantages to choosing the Brush Creek Valley for the initial evaluation of VALMET. First, the valley has a rather simple topography. The narrow, 25-km-long valley has no major changes in valley orientation along its length. It has nearly equal sidewall inclinations. The valley drains a plateau, so that the ridges are at a constant altitude regardless of location along the valley axis. The valley has no major tributaries. Second, the valley axis is oriented from NW to SE so that the sidewalls would be exposed to quite different insolation during the post-sunrise temperature inversion breakup period. The effect of this unequal heating was a major uncertainty in the model formulation. On the basis of meteorological data collected in wider Colorado valleys, and numerical model results, the VALMET model was developed under an assumption of horizontal homogeneity of atmospheric structure on a valley cross section. This assumption could be readily tested in the Brush Creek Valley, where the narrowness of the valley and the NW-SE orientation of the valley would clearly maximize any horizontal gradients in atmospheric structure between the sidewalls. Third, the Brush Creek Valley would be heavily instrumented with meteorological sensors by the ASCOT program. Access to their meteorological data would be a great benefit to the model evaluation effort.

Along with the above advantages, there was a major disadvantage to conducting an initial evaluation of VALMET using data from the Brush Creek Valley. This disadvantage was related to the short segment of the valley that was accessible for tracer instrumentation. VALMET is a two-dimensional model, predicting concentrations on a cross section oriented perpendicular to the valley axis some distance down-valley from a source. Restrictive assumptions are present in VALMET regarding a required homogeneity of the temperature and wind structure in the along-valley direction. The Brush Creek Valley, however, is a short tributary valley that flows into the Roan Valley a few kilometers below the valley cross section where most measurements were made. Consequently, tracer plume carried down the Brush Creek Valley during the night would be carried into Roan Creek. Reversal of the down-valley winds (to up-valley) after sunrise would result in a large part of the tracer plume being carried up the Roan Creek Valley, rather than being carried back up the Brush Creek Valley as assumed in the model. Evaluation of VALMET would be complicated by this violation of a major assumption in the model, which had been designed for longer valleys.

The evaluation of the VALMET model will be the subject of future work. A short summary in now being written for the proceedings of the American Meteorological Society's Third Conference on Mountain Meteorology, to be held in Portland, Oregon in October 1984. It is appropriate here, however, to make some initial qualitative statements concerning the evaluation of the model. First, with respect to the nocturnal portion of the model, the nocturnal plume was carried down the valley, as expected. The nocturnal plume, although released above the valley center, was found to be displaced towards one sidewall as it was transported down the valley. The valley is not strictly linear, but turns slightly with down-valley distance. Because the plume was displaced towards the "outside" of the turn, it is conceivable that inertial effects are responsible for the displacement of the plume from the valley centerline. Future field experiments, such as the one planned by EPA and DOE in the same valley in the fall of 1984, will focus more research attention on this feature. The nocturnal plume was carried down the valley in a rather strong "jet" of down-valley winds, with the level of maximum winds at about release height. The nocturnal model, based on the Gaussian formulation, is incapable of treating vertical shears in transport winds but, when winds at release height are used for transport, approximates transport and diffusion along the valley direction fairly well.

Assumptions in the daytime portion of the model were verified with actual meteorological and tracer data. The post-sunrise period was characterized by the growth of convective boundary layers over the sunlit valley surfaces. The tracer plume fumigated the valley sidewalls as convective boundary layers grew upwards into the remnants of the nocturnal temperature inversion containing the elevated tracer plume. Tracer was carried from the valley by upslope flows, which developed within the growing convective boundary layers. Corresponding subsiding motions over the valley center were noted in the temperature profiles at several of the tethered balloon sites, but the limited vertical resolution of the tracer plume did not allow this feature to be seen in the tracer concentration analyses.

Due to the northwest-southeast orientation of the deep, steep-walled valley, very significant differences occurred in the timing and rates of convective boundary layer growth on the opposing sidewalls following sunrise. As a result of the unequal heating of the different sidewalls, a cross valley flow developed, carrying the elevated plume towards the warmer sidewall. Due to the cross valley advection, tracer concentrations were higher on this sidewall than predicted by the model. A future modification of the VALMET model will be required to handle this situation properly in narrow valleys where post-sunrise insolation on the opposing sidewalls is quite different. The Brush Creek tracer experiments were the first direct experimental confirmation of the importance of this physical effect on tracer plume dispersion.

The short length of the Brush Creek Valley, as expected, affected the results of the tracer experiments. The primary effect, from initial analyses, seems to be that the tracer concentrations in the valley fell more rapidly than expected after the post-sunrise wind reversal. This is thought to be due to the nocturnal plume being carried largely up Roan Creek after the wind reversal rather than reversing direction to come back up Brush Creek.

SECTION 4

BACKGROUND INFORMATION

TOPOGRAPHY

The Brush Creek Valley is a 25-km long valley located about 50-70 km NNE of Grand Junction in northwestern Colorado. Brush Creek is a tributary to Roan Creek, a major valley draining the south side of Colorado's Roan Plateau, located at the southern edge of the Piceance Basin (Figure 1). The Brush Creek Valley is a near-linear, unobstructed valley draining from NW to SE (Figure 2). The valley is deep (~ 650 m), narrow (3 km or less between the upper sidewalls) and, other than short box canyons on the east side, has no major tributaries. Topographic cross sections through the valley at various distances above the valley mouth are shown in Figure 3. From these cross sections, average sidewall slopes are 30-40 degrees. The topography of Brush Creek is unusual in that the valley floor has a rather steep slope while the altitude of the ridgetops changes little with up-valley distance. A topographic cross section along the streambed of Brush Creek is shown in Figure 4. The lowest 10 km of Brush Creek has a slope of about 14 m/km. Up-valley from the release site the valley floor rises more steeply, sidewalls become steeper, and the valley attains a "v-shaped" cross section. Figure 5 gives a pictorial representation of the lowest 10-15 km of the Brush Creek Valley viewed from the southwest, as obtained from a computer-generated, digital topographic model. The topographic model includes the effects of solar shading to emphasize the valley relief and utilizes a topographic grid interval of 100 ft (31 m). This figure shows clearly the characteristics of the short box canyons on the east side of the valley. The west sidewall is more homogeneous with fewer and shallower canyons. The drainage area of the entire canyon is approximately 106 km^2.

EQUIPMENT SITES

Several figures are presented here showing the location of data collection equipment within Brush Creek Valley. Figure 6 shows the location of EPA and ASCOT tethered balloon sounding sites as well as the laser anemometer paths operated by ASCOT participants. The SNL and PNL sites were operated as part of the EPA experiments. Further information on the topographic characteristics of individual tethered balloon sites is given in Table 2. Sulfur hexafluoride tracer was released from the PNL site. Figure 7 shows the operating locations of the two manually operated gas chromatographs on the west sidewall of Brush Creek as well as the location of the continuous SF_6 monitor on the valley floor near the SNL site. The PNL sulfur hexafluoride release site is also indicated on the figure.

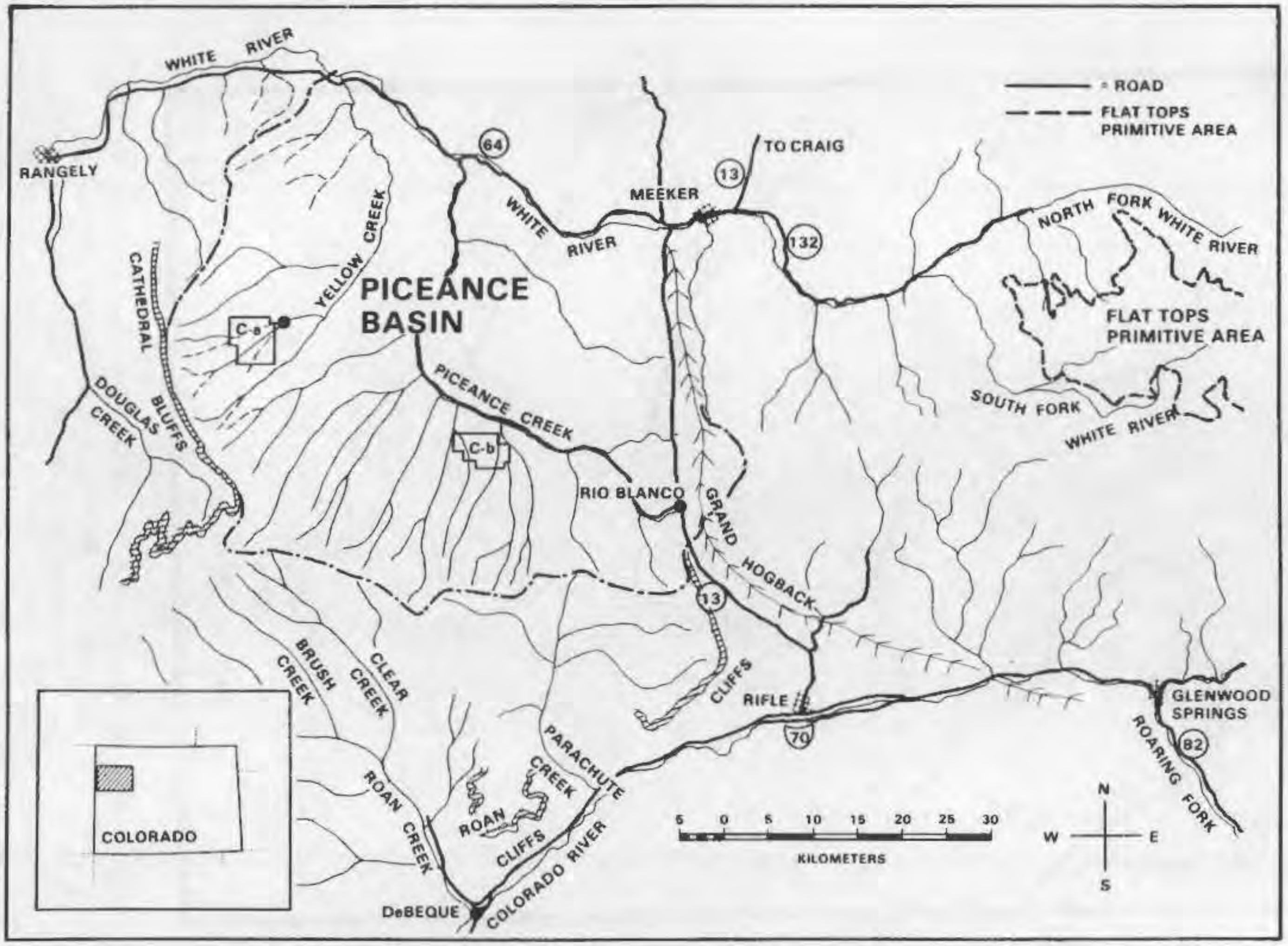

Figure 1. Piceance Basin region of Western Colorado. The Brush Creek-Roan Creek region where the tracer experiments were conducted is shown in the lower left portion of the figure.

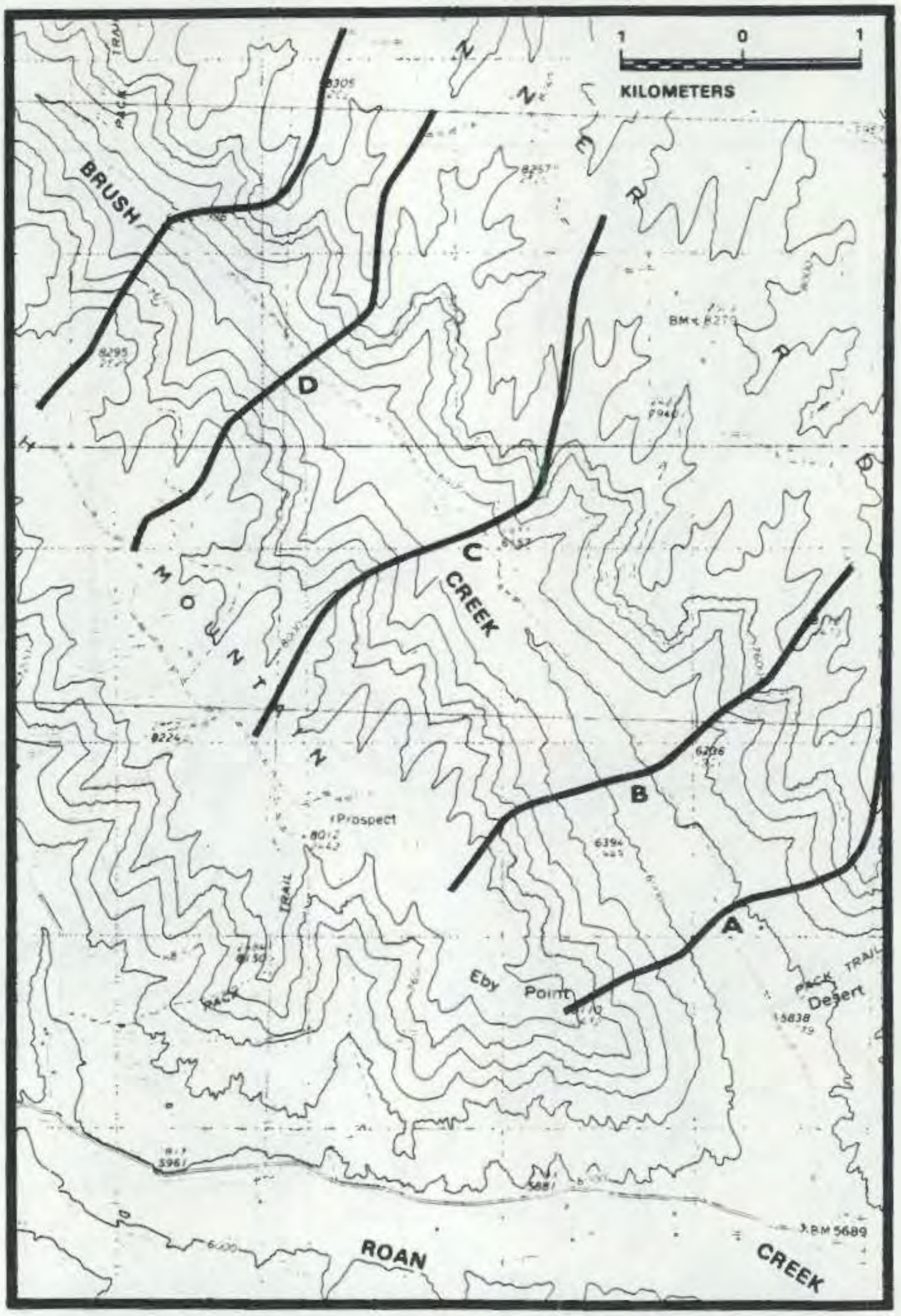

Figure 2. Topography of the lowest 12 km of the Brush Creek Valley. North is at the top of the map. Contour interval is 40 ft (12 m). The cross valley arcs used in determining profiles of valley topographic cross sections are also shown. The upper arc passes through the tracer release site.

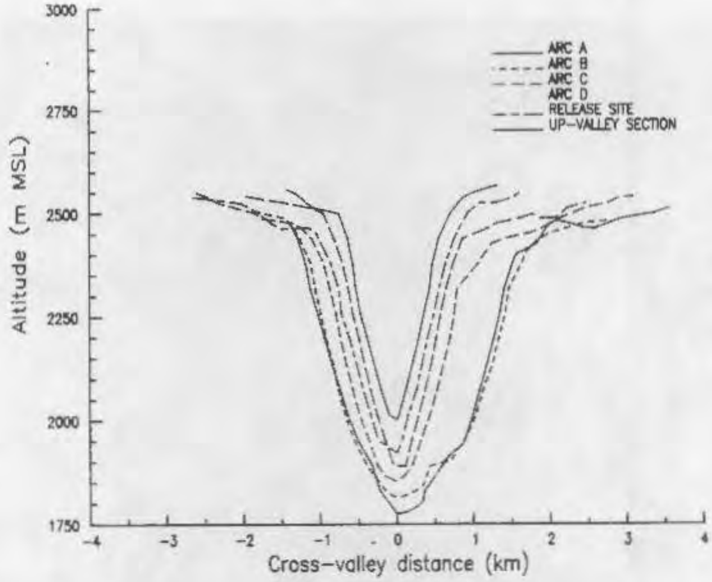

Figure 3. Cross sections through the Brush Creek Valley at locations corresponding to those shown in the previous figure. The cross section labeled "Up-Valley Section" is 4 km up-valley from the tracer release site.

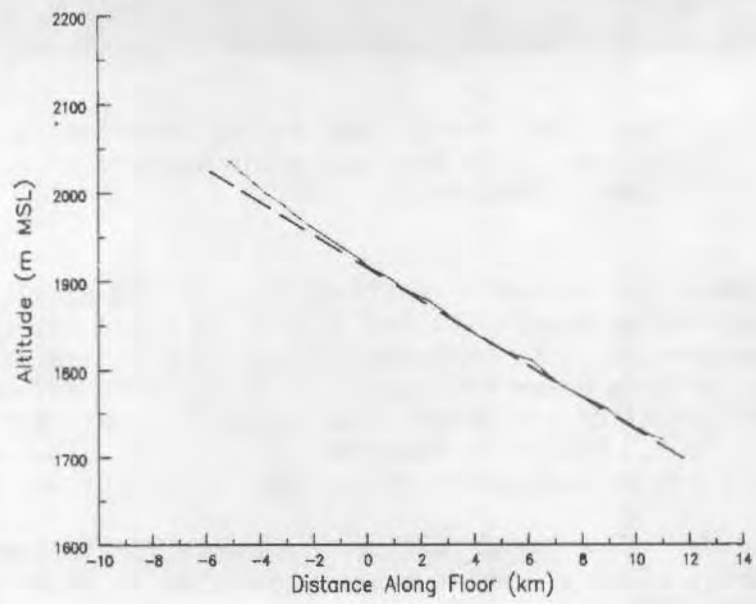

Figure 4. Along-valley topographic section of the Brush Creek Valley. Down-valley distances are measured from the tracer release site. The valley floor, uniform in steepness below the release site, becomes steeper above the release site. The mean slope of the valley floor (14 m/km) is indicated with the dashed line. The confluence of Brush and Roan Creeks is 10.4 km from the tracer release site.

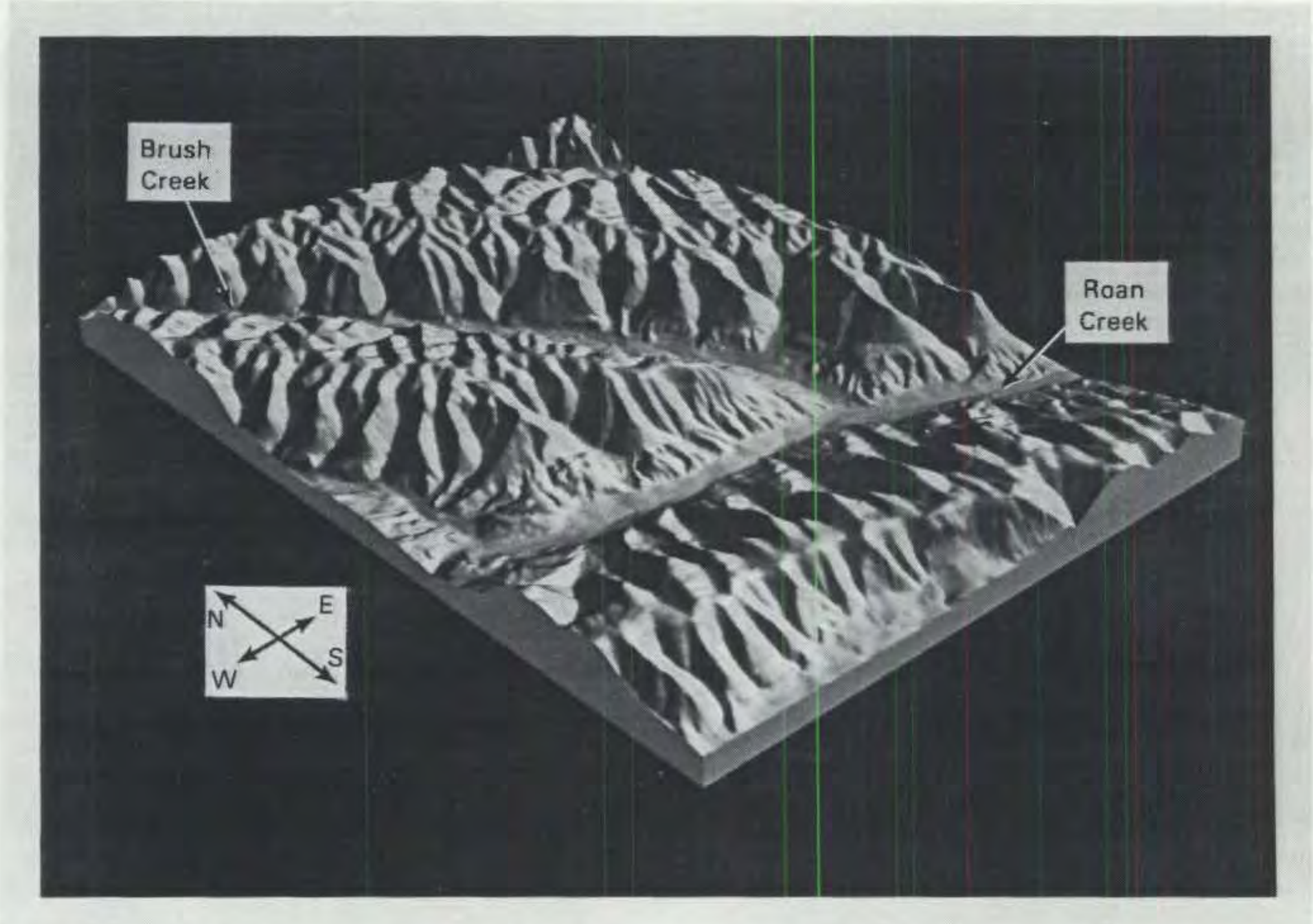

Figure 5. View of the Brush Creek Valley experimental area from the southwest. No vertical scale exaggeration is used in the figure. Scale 1:1.

Figure 8 shows the network of radio-controlled bag sampling stations. Five consecutive samples were collected at each of these sites during each of the tracer experiments. Note that the letters in the site designations correspond to the arcs drawn in Figure 2. Topographic information on the SF_6 data collection sites and other sites of special interest in the valley is given in Table 3. Figure 9 shows the relative locations of all the data collection sites on the topographic cross section at Arc A.

The reader is referred to other documents for information on the full range of meteorological research equipment used in Brush Creek Valley by DOE investigators [5].

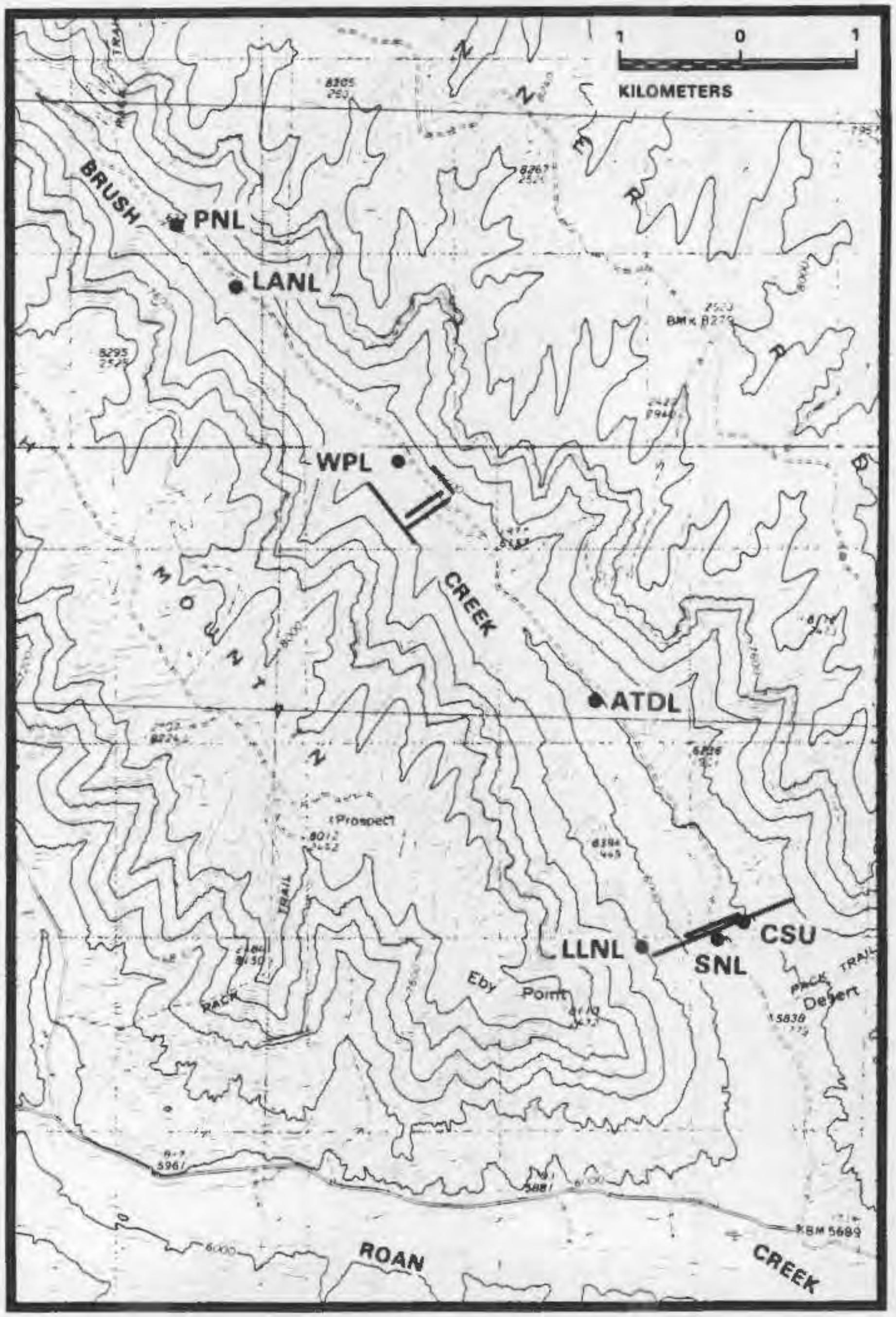

Figure 6. Topographic map of the lower portion of the Brush Creek valley showing the location of the seven tethered balloon sounding systems and six laser anemometer paths used in the 1982 experiments.

TABLE 2. TOPOGRAPHIC CHARACTERISTICS OF THE 1982 TETHERED BALLOON SITES

Site	Elev. (m MSL)	N Latitude (dd	mm	ss)	W Longitude (dd	mm	ss)	UTM E* (m)	UTM N (m)	Dist.† (km)	Drainage Area (km^2)	Up-Valley Direction (°true)	Valley Floor Width (m)	Elevation Angles W Sidewall (deg)	E Sidewall (deg)	Topo Low Point‡ (m MSL)
PNL	1922	39	34	46.6	108	27	00.2	719011	4383997	0.0	61.9	318	267	35.0	36.5	1920
LANL	1908	39	34	32.4	108	26	40.6	719491	4383572	0.7	62.8	320	187	37.7	34.6	1907
WPL	1871	39	33	43.8	108	25	38.4	721018	4382116	2.8	75.0	321	307	30.0	37.8	1864
ATDL	1820	39	32	35.4	108	24	31.0	722687	4380053	5.4	84.9	323	434	33.6	32.1	1817
LLNL	1922	39	31	23.1	108	24	05.0	723373	4377842	7.7	95.3	331	744	37.3	36.4	1777
SNL	1780	39	31	34.8	108	23	48.9	723747	4378214	7.7	95.3	327	744	37.3	36.4	1777
CSU	1798	39	31	37.5	108	23	40.3	723950	4378303	7.7	95.3	324	744	37.3	36.4	1777

* Universal Transverse Mercator coordinates, Zone 12.

† Down-valley distance from release site.

‡ Low point of topographic cross section through the site indicated.

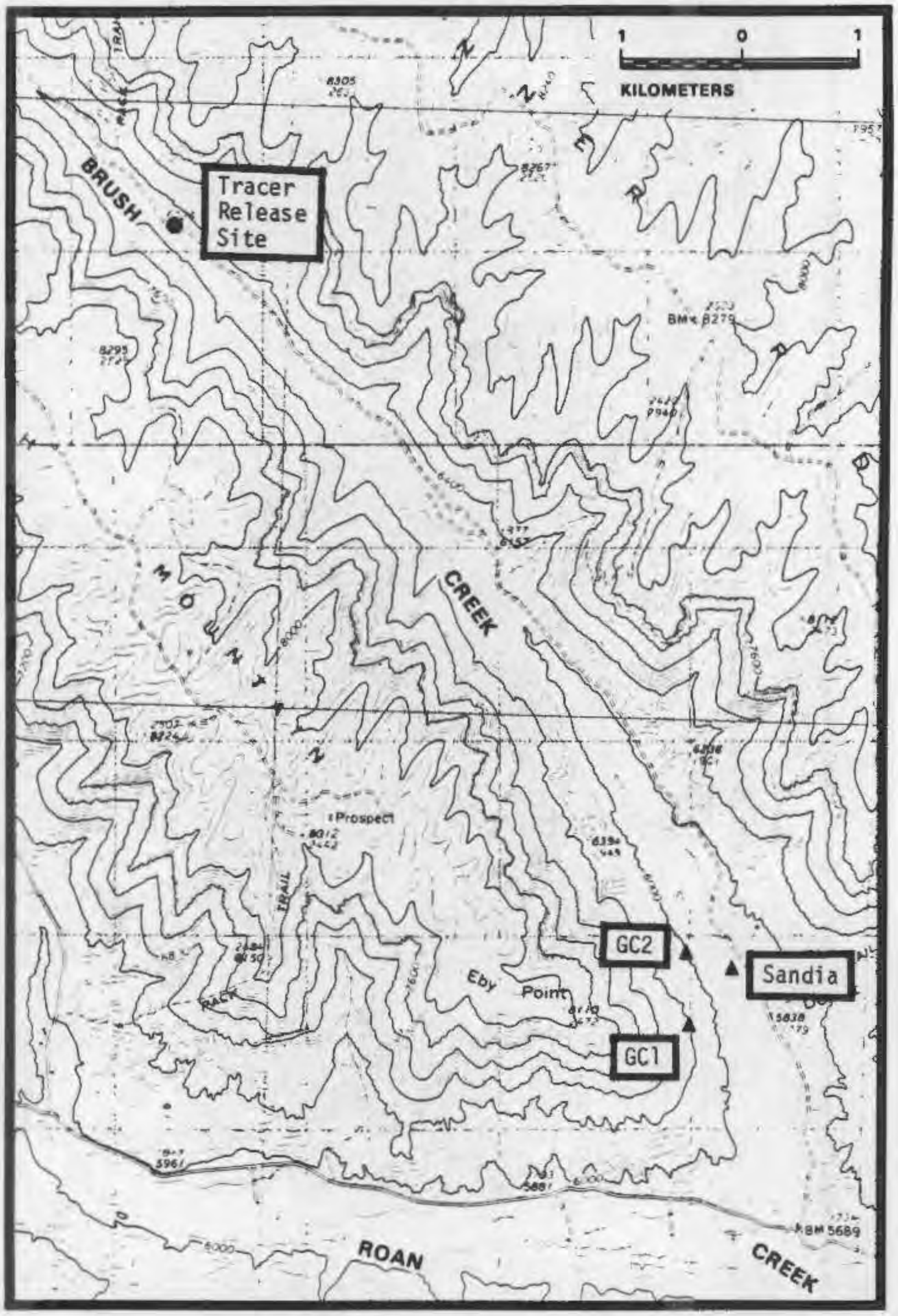

Figure 7. Location of the gas chromatograph sites (GC1 and GC2), the continuous SF_6 monitoring site (Sandia or SNL), and the tracer release site.

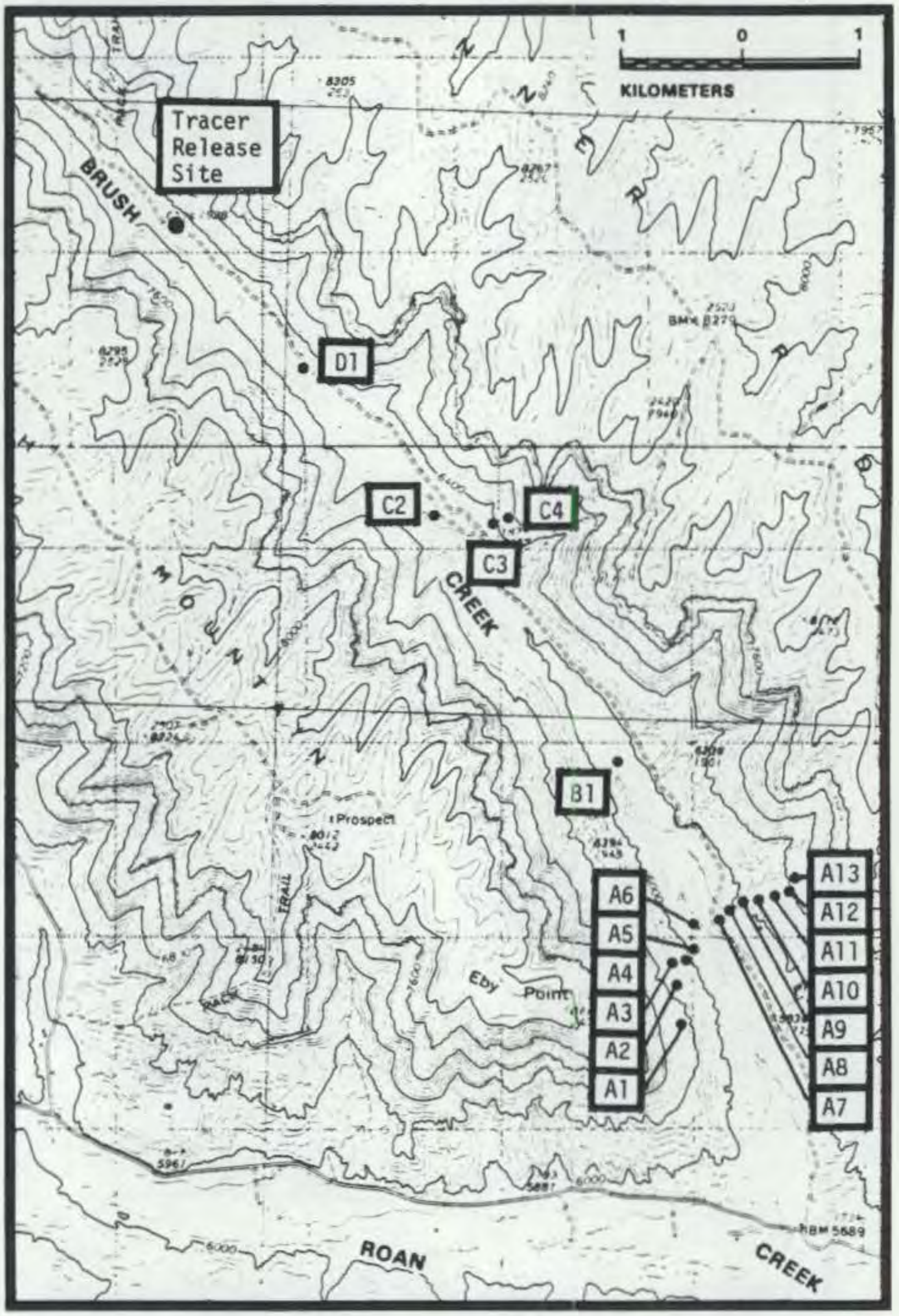

Figure 8. Locations of the radio-controlled bag sampling stations. The tracer release site is also shown.

TABLE 3. TOPOGRAPHIC AND LOCATION INFORMATION FOR BRUSH CREEK SITES

Site	Distance* (km)	Drainage Area (km^2)	Elevation (m MSL)	N Latitude (dd mm ss)	W Longitude (dd mm ss)	UTM†E (m)	UTM†N (m)
Roan-Brush Crk	10.4	106	1725	39 30 14.0	108 23 27.3	724335	4375738
Brush Crk Gate	10.3	106	1734	39 30 14.4	108 23 19.7	724516	4375755
Arc A	7.7	95.3	--	--	--		
A1			1983	39 31 13.3	108 24 03.4	723420	4377541
GC1			1952	39 31 12.5	108 24 00.4	723492	4377518
A2			1922	39 31 23.1	108 24 04.4	723387	4377842
A3			1873	39 31 28.9	108 24 03.4	723406	4378022
A4			1847	39 31 29.7	108 24 00.4	723477	4378049
CG2			1829	39 31 31.6	108 24 01.4	723451	4378107
A5			1810	39 31 32.0	108 23 58.4	723522	4378121
A6			1790	39 31 37.5	108 23 58.9	723505	4378290
Stream			1777	39 31 34.4	108 23 51.4	723687	4378200
Sandia			1780	39 31 34.8	108 23 48.9	723747	4378214
A7			1792	39 31 39.8	108 23 48.3	723757	4378369
A8			1807	39 31 43.7	108 23 46.3	723801	4378490
A9			1829	39 31 44.5	108 23 40.3	723943	4378519
A10			1864	39 31 45.3	108 23 35.3	724062	4378547
A11			1893	39 31 47.2	108 23 30.3	724180	4378609
A12			1924	39 31 50.0	108 23 24.7	724311	4378699
A13			1941	39 31 50.7	108 23 23.7	724334	4378722
Arc B	6.1	89.0	--	--	--		
B1			1811	39 32 21.9	108 24 24.5	722855	4379642
Arc C	3.3	76.7	--	--	--		
C1			1996	39 33 19.7	108 25 37.8	721054	4381374
C2			1853	39 33 29.0	108 25 27.8	721284	4381667
C3			1946	39 33 28.6	108 25 08.7	721740	4381668
C4			1996	39 33 29.8	108 25 04.7	721835	4381708
Arc D	1.7	67.5	--	--	--		
D1			1884	39 34 08.0	108 26 13.0	720171	4382839
Release Arc	0.0	61.9	--	--	--		
Release Site			1920	39 34 46.6	108 27 00.2	719011	4383997
Up-Valley Arc‡	-4.0	47.7	1999	39 35 55.6	108 29 38.9	715165	4386018

* Distance down-valley from tracer release site along valley floor.

† Universal Transverse Mercator coordinates, zone 12.

‡ Coordinates given for intersection of this arc with Brush Creek.

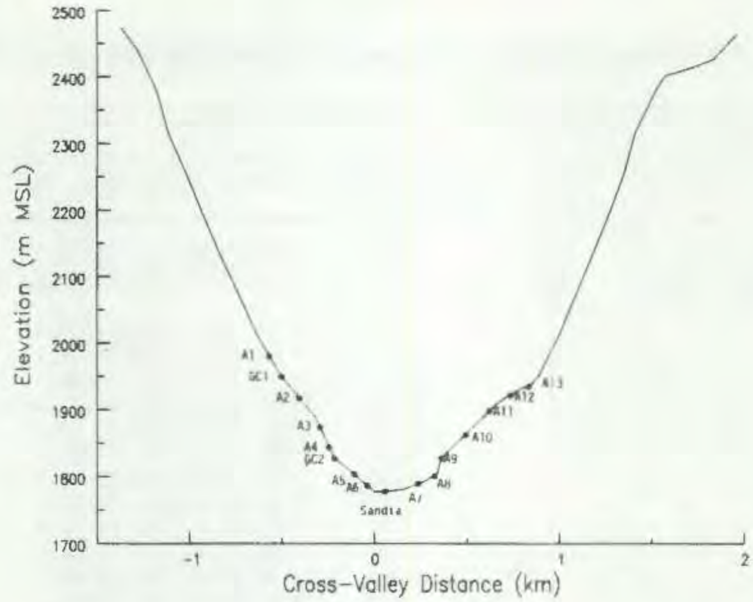

Figure 9. Valley cross section at Arc A, showing the locations of the measurement sites.

SYNOPTIC WEATHER CONDITIONS DURING THE EXPERIMENTAL PERIOD
Contributed by Sumner Barr, LANL

The experimental period extended from July 26 until August 6, 1982, with experiments conducted on the nights of July 28-29, July 30-31, August 3-4, and August 5-6. Synoptic weather charts (surface, 700 m and 500 mb) for the 4 experimental nights are presented in Appendix B. Appendix C lists the Grand Junction, Colorado rawinsonde data for the July 26 to August 6 period. When referring to these synoptic data, the reader should remember that 7 hours must be subtracted from Greenwich Mean Time (GMT) to determine Mountain Standard Time (MST).

The large-scale weather patterns and circulations during the period of the 1982 experiments in the Brush Creek, Colorado, area were quite typical for summertime. The general situation during the experimental period was characterized by weak westerly winds above ridge top with day-to-day directional variations between southwesterly and northwesterly. The most important weather features were air mass thunderstorms that depended critically on the humidity of air in western Colorado. Because a major region of moist air was never far from the experiment site, thunderstorms and nocturnal cloudiness were continual factors in the planning and execution of experiments.

During the setup phase before the first ASCOT experiment southwesterly winds had provided a supply of moist air throughout the area. The moisture and the thermal instability that is characteristic of the area in the summertime produced afternoon and evening thunderstorms in the mountains. By Wednesday, July 28, the ridge in west Texas and eastern New Mexico that had been driving the southerly wind weakened considerably, leaving a light westerly wind above the ridge tops. The moisture that had been advected into the area earlier remained because the winds weren't strong enough to disperse it, but the source of new moist air was removed. In the afternoon prior to the first Brush Creek experiment there was a heavy thunderstrom, but during the experimental period only scattered to broken cloudiness was present. The surface synoptic chart shows a shallow, cool high pressure cell north of the site, centered in eastern Montana. Regional surface winds were northeasterly and winds veered with altitude to westerly at 500 mb. Synoptic weather charts for the first experimental night are available in Appendix B as Figures B-1 through B-7.

By the second ASCOT experiment on July 30-31 a high pressure ridge aloft had re-established in western Utah and Idaho producing northwesterly flow over the experimental region. At the surface a large but weak high pressure cell covered the intermountain area. A small low pressure center, probably of thermal origin, sat over the Utah-Colorado border in the afternoon of July 30 and dissipated through the night. It did not appear to affect winds or weather. The northerly flow moved the moist air into New Mexico. Dew points in the lowest 2 km over Grand Junction were 7°C lower than the first experiment, and above that the air was much drier than the first case. This was reflected in fewer clouds and a much larger diurnal temperature variation at a site in Brush Creek Valley (20°C vs 12°C). Synoptic weather charts for the second experimental night are available in Appendix B as Figure B-8 through B-16.

By the afternoon of August 3, a ridge at 500 mb had moved eastward to the Great Lakes, a trough in the intermountain area had weakened, and the winds aloft had veered to west-southwest. The third ASCOT experiment was conducted in a relatively stationary southwesterly wind regime in the altitude range above the ridge tops. The major features in the surface chart were a small high pressure cell centered at the Four Corners Area and a weak cold front that moved southward from Wyoming into the northeast corner of the experimental area for the end of the observation period. The Grand Junction soundings showed evidence of moist layers at about 6 km MSL, but otherwise the atmosphere was dry. The potential for some shallow convection due to daytime heating was indicated by the soundings but the weather was fair throughout the 24 hour experimental period. Synoptic weather charts for the third experimental night are available in Appendix B as Figures B-17 through B-24.

The final series of measurements took place during the night of August 5-6 under the influence of high pressure at both the surface and aloft. The southwesterly upper winds were light, giving a good opportunity for development of local circulations without much adverse interference from large scale, synoptic features. Synoptic weather charts for the fourth, and final, experimental night are available in Appendix B as Figures B-25 through B-33.

SECTION 5

TRACER RELEASE SYSTEM

A description of the sulfur hexafluoride tracer release system and the procedures used to conduct the release are given in an article by Whiteman and Glover [6]. Therefore, only a short summary is given here.

Sulfur hexafluoride was released from three "K"-size high pressure SF_6 gas cylinders using a pressure-regulated, temperature-controlled manifold system (Figure 10). Release of SF_6 from this system was controlled by a full time operator who monitored and, when necessary, adjusted the flow rate from the manifold using an accurate flow meter to maintain a uniform flow rate. The SF_6 was released from the manifold into a hose carried aloft by a tandem tethered balloon system (Figure 11). This resulted in a controlled elevated release of SF_6 gas above the valley floor at the release site. At the conclusion of the release and before the balloons were retrieved, the SF_6 was purged from the manifold and hose system using high pressure helium gas. This ensured that no SF_6 gas was released at ground level at the conclusion of each experiment. The total mass of SF_6 released during an experiment was obtained by measuring the difference in cylinder weights before and after each release. The weights were determined using a calibrated scale (Accu-Weight 301, TADA53, Accuracy 0i1, lb.; Acme Scale Co., San Leandro, California).

A tethered balloon system varies its position relative to its tether point, depending on the ambient wind conditions to which the tethered balloon is exposed. It is therefore of interest in characterizing the SF_6 release, to determine how the balloon's position varies in time. Due to the predominance of strong along-valley winds at the release site, the balloon's position was generally along the valley axis, as drawn through the release site. In other words, the balloon was located either down-valley or up-valley from the tether point, with no appreciable drift off the valley centerline toward either sidewall. Because the release was made primarily during the morning down-valley flow period, the balloon was typically in a position down the valley from the tether point, at an elevation angle near 30-40 degrees. The release height was measured occasionally during the SF_6 releases by means of elevation angle sitings of the balloon with a theodolite, and corresponding distance measurements from the theodolite to the balloon subpoint. In order to obtain information on the shorter period

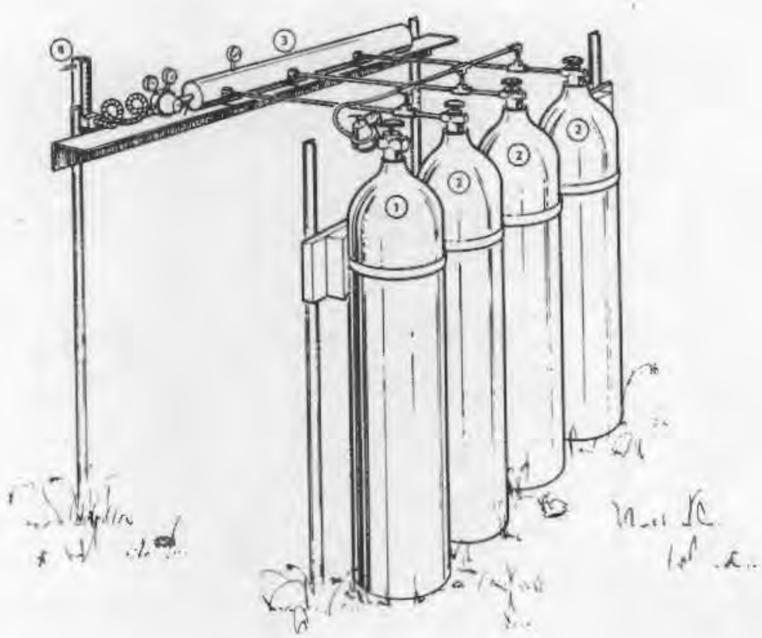

Figure 10. Diagram of the ground-based portion of the SF_6 release system. SF_6 is dispensed from 3 "K" size cylinders (2) into a heated, insulated manifold (3). A temperature gage on the manifold monitors the manifold temperature. Tracer is released from the manifold through a two-stage pressure regulator and a heated, insulated coil. The flow rate is adjusted to maintain a constant setting on an accurate flowmeter (4). After release, the SF_6 cylinder valves are closed and the release system is purged by opening the pressure regulator on a high pressure helium cylinder (1).

fluctuations of the balloon's height, an Airsonde® was attached to the balloon so that changes in the balloon's pressure or altitude could be recorded. This was done for a short period during the August 4, 1982, experiment. The data are presented in Figure 12. During the period from 0354 to 0506 MST the balloon maintained an average altitude of 104.7 m with a standard deviation of 4.2 m. These measurements were taken during a period when the down-valley winds, although constant in direction, were decreasing in speed from 7.4 to 6.4 m/s. The balloon seemed to be sinking slightly during the latter part of the period, as the ambient winds decreased.

A Tethersonde® data collection system [7] was operated at the release site to provide frequent atmospheric profiles through the valley depth to monitor changes in valley vertical wind and temperature profiles. These data were necessary to document changes in temperature inversion structure

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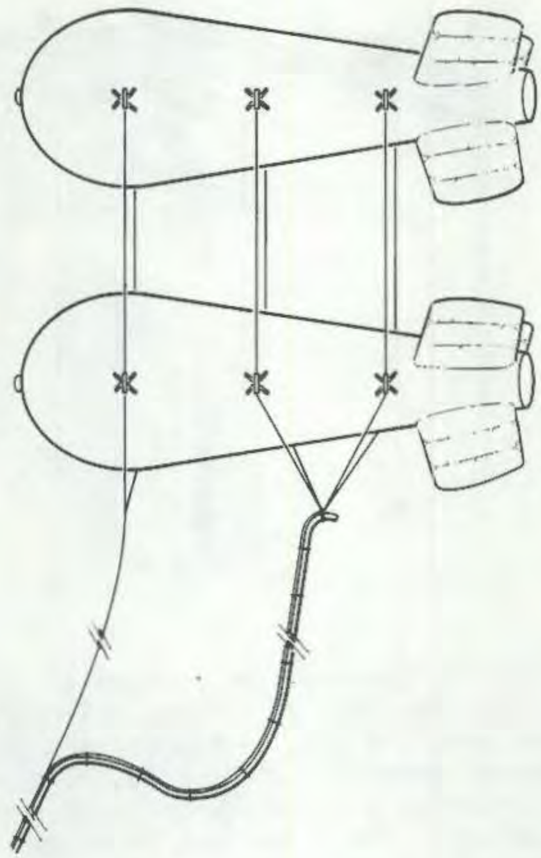

Figure 11. Diagram of the airborne portion of the SF_6 release system. The balloons are approximately 7 m long and 2 m in diameter. The SF_6 hose falls about 60 m before being attached to the tetherline by plastic wire ties.

and local wind systems near the release site. Results from these measurements are presented in a later section.

During the 2-week experimental period, three elevated SF_6 releases were made. The release information is summarized below in Table 4. All the releases were conducted during the 24-hr DOE experimental periods.

It is worth mentioning that the first SF_6 release planned in the experimental period, on the morning of July 29, was aborted due to an SF_6 leak detected at the manifold. Weather conditions on this morning were marginal for the planned experiments so that the entire SF_6 experiment was cancelled. Following the detection of this leak, the release system was repaired and carefully checked, using the high manifold pressures that would be encountered under normal use. No further leaks were detected in later experiments. A log of release site events for the three SF_6 experiments is given as Tables 5-7, below.

TABLE 4. SF_6 RELEASE DATA

Date	Release Pd (MST)	SF_6 used (kg)	Duration (h)	Release rate (kg/h)	Release rate (g/s)	Release height (m)
7-29-82	NONE					
7-31-82	0458-0757	8.77	2.98	2.94	0.82	102
8-04-82	0428-0806	32.77	3.63	9.03	2.51	105
8-06-82	0410-0946	42.59	5.60	7.61	2.11	112

TABLE 5. RELEASE SITE EVENTS, JULY 31, 1982

Event	Time (MST)	Description and comments of release technician
1	0448	Begin elevated SF_6 release Manifold temperature 40°C, steady Winds seem very turbulent at lower balloon Tetherline 158 m, poly tubing 177 m *106 m agl release height, 28°C elevation angle
2	0600	Release continuing All systems still very stable
3	0700	All systems still OK Manifold temperature still 40°C Lower balloon flying with nose up Winds dying down and we may lose some lift soon
4	0715	Winds very slight at the surface
5	0725	88 m, 30°C elevation angle
6	0730	Winds reverse to up-valley at generator site
7	0757	SF_6 release terminated Helium flush started
8	0810	Helium flush terminated

*Release heights based on theodolite sightings and measured baselines.

Summary:
SF_6 released 19 lb 5 oz = 8.77 kg
Release duration 2.98 hours
Average release rate 0.82 g/s

TABLE 6. RELEASE SITE EVENTS, AUGUST 4, 1982

Event	Time (MST)	Description and comments of release technician
1	0428	Begin elevated SF_6 release Slightly higher release rate than on previous experiment Manifold temperature 25°C Airsonde® attached to release balloon to measure height Release rate steady
2	0457	*105 m agl release height, 35°C elevation angle
3	0541	96 m, 30°C elevation angle Have doubts about Airsonde® performance
4	0550	Airsonde® dead
5	0603	108 m, 33°C elevation angle
6	0645	108 m, 33°C elevation angle
7	0700	119 m, 37°C elevation angle
8	0720	Winds at generator level change to up-valley
9	0806	Release terminated Flush started
10	0815	Flush terminated

*Release heights based on theodolite sightings and measured baselines.

Summary:

SF_6 released	72 lb 3 oz = 32.77 kg	
Release duration		3.63 hours
Average release rate		2.51 g/s

TABLE 7. RELEASE SITE EVENTS, AUGUST 6, 1982

Event	Time (MST)	Description and comments of release technician
1	0410	Begin elevated SF_6 release Approximately the same release rate as in previous experiment Manifold temperature 25°C
2	0428	All systems OK Slightly higher release elevation than other experiments
3	0507	*115 m agl, 37°C elevation angle
4	0546	103 m, 34°C elevation angle
5	0705	109 m, 35°C elevation angle
6	0728	Winds at release height suddenly turned to up-valley
7	0735	Winds very odd at release site Winds at release height are blowing up-valley, stable Ascending Tethersonde® shows winds switching from up-valley to cross-valley to down-valley
8	0742	Surface winds now almost calm Wind wisps now and then seem to be going down-valley
9	0744	Sunlight now on valley floor
10	0946	SF_6 release terminated Flush started
11	0955	Flush terminated

*Release heights based on theodolite sightings and measured baselines.

Summary:

SF_6 released	93 lb 13 oz =	42.59 kg
Release duration		5.60 hours
Average release rate		2.11 g/s

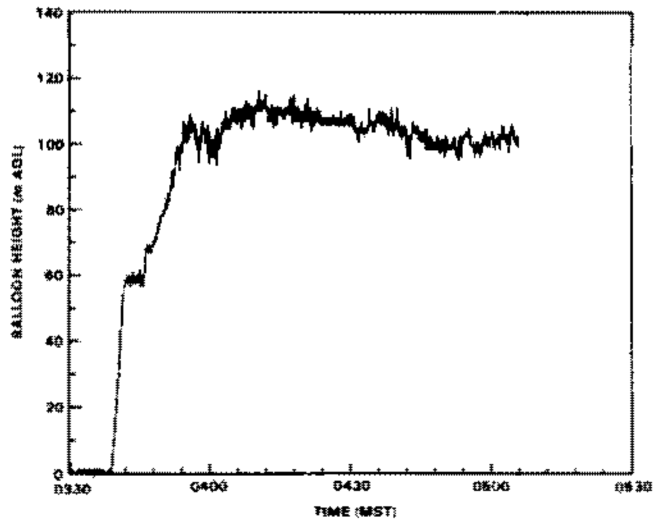

Figure 12. Balloon height versus time for August 4, 1982.

SECTION 6

MOBILE ANALYSIS LABORATORY

The Battelle-Northwest mobile analysis laboratory was used to measure SF_6 tracer gas in ambient air samples collected during tracer releases in Brush Creek. The primary source of ambient air samples was the network of bag samplers. In addition, samples collected in syringes carried by the vertical SF_6 profiler, manually collected syringe samples obtained at the launch site, and syringes and bags used for sample collection on the Cessna 411 research aircraft were processed at the mobile laboratory. This facility offered a fully equipped gas chromatograph (GC) laboratory with 110 VAC power, sample storage space, and GC column reconditioning equipment. The tracer analysis system was operated from the mobile laboratory, which housed a full complement of support gases, including both zero air and SF_6-in-air calibration gas mixtures.

The mobile laboratory was set up 65 km south of the release point on the Grand Mesa. At this location, no contamination of the analysis equipment would be expected because it was isolated from both the release site and the tracer storage facility. All samples were processed within 45 hours of their collection and most samples were analyzed within 3 to 36 hours.

Sulfur hexafluoride was measured using a Hewlett-Packard Model 5736A gas chromatograph equipped with an electron capture detector (Valco Model 140B). For bag samples, a 1/8-in.-OD Teflon® tube and Metal Bellows* pump were used to transfer samples from the bags to a Carle†, 8-port, two-loop gas sampling valve (GSV). Syringe samples were transferred to the sample loop through a septum sealed port of the GSV. Sample injection into the nitrogen carrier stream was accomplished by rotation of the GSV, and a Hewlett-Packard Model 3380A recording-integrator was simultaneously started to record the sample chromatogram. The SF_6 tracer gas was separated from oxygen and other potentially interfering atmospheric components using a 6 foot x 1/4 in. stainless steel column packed with 60/80, NO-treated, 5A Molecular Sieve. The column was operated at ambient temperature (~20°C) and the detector at 300°C. The concentration of tracer gas was determined by peak area using the external standard calibration method. Gas standards consisting of NBS traceable SF_6 in ultra-pure-air mixtures (50.0 and 420 ppt) stored in aluminum cylinders were introduced at approximately one-

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* Metal Bellows Corp., Sharon, Massachusetts.

† Hach Company, Carle GC Systems, Loveland, Colorado.

hour intervals to quantify detector response. Analytical precision was determined by replicate analysis of randomly selected field samples.

The result of replicate analyses at the mobile laboratory are summarized in Table 8. Included in this listing are syringe and bag samples collected at the ground, from the vertical SF_6 profiler, and from the aircraft. While the objective of subjecting 10% of the total number of samples to replicate analysis was not met, the results listed in Table 8 provide an indication that data quality objectives were realized. A precision of >95% is indicated for samples in which the SF_6 concentration was greater than 100 ppt and a precision of >90% is indicated for samples in the 10-100 ppt concentration range.

TABLE 8. REPLICATE SAMPLE ANALYSIS, MOBILE LABORATORY

SF_6 concentration < 100 ppt		SF_6 concentration > 100 ppt	
Sample	SF_6 concentration (ppt)	Sample	SF_6 concentration (ppt)
1	62.9, 57.7	1	266, 278
2	87.8, 95.8	2	368, 351
3	28.2, 23.4	3	123, 128
4	90.1, 83.8	4	316, 297
5	13.4, 12.3	5	239, 229
6	9.3, 9.0	6	872, 862
7	50.2, 48.2	7	106, 113
8	68.8, 69.8	8	532, 533
		9	646, 673
		10	389, 417
		11	758, 767
		12	1950, 1903
		13	338, 345
		14	734, 772
		15	819, 814
		16	542, 542, 545
		17	716, 719
		18	630, 626
		19	440, 442
		20	360, 345

Previous experience with SF_6 sample collection and storage in the containers utilized in these experiments has demonstrated that sample integrity is maintained for storage periods of up to 3 days. This was confirmed for a limited number of field samples and standards during the Brush Creek experimental series as indicated by the data in Table 9. As indicated above, samples from this experimental series were analyzed within 45 hours of collection.

TABLE 9. REPLICATE ANALYSES TO EVALUATE SAMPLE INTEGRITY

Sample	Container	Time of analysis	SF_6 concen-tration (ppt)	Time of analysis	SF_6 concen-tration (ppt)
Field	Bag	8/1/82, 0857	351	8/2/82, 1644	368
Field	Bag	8/6/82, 2214	646	8/7/82, 0916	673
Field	Syringe	8/6/82, 2145	758	8/7/82, 1415	767
Std.	Bag	8/1/82	105	8/7/82	106
Std.	Bag	8/1/82	317	8/7/82	292

Finally, approximately one in every six samples was a SF_6 standard (SF_6 in ultra-pure-air, 50.5 or 420 ppt) used to quantify detector sensitivity. Throughout any given analysis period, the standard deviation of the calculated sensitivity varied from 0.6 to 5.9%.

SECTION 7

RADIO-CONTROLLED BAG SAMPLING SYSTEM

Radio-controlled bag sampling stations were installed at 19 sites to collect ambient air samples within the Brush Creek Valley (Figure 8). Sampling stations were arranged in a line down the valley axis from the release site. Two cross-valley arcs were oriented perpendicular to this line at 3.3 and 7.7 km from the release point, thereby providing good definition of SF_6 concentrations high on the valley sidewalls--an important feature of the experimental design.

Sites were numbered as shown in Figure 8. On the cross-valley arcs, Arcs A and C, the individual sites are numbered from west to east. The first station on Arc C, station C1, is not identified on the map, since radio communication problems were encountered at this site, and no usable data were collected there.

The sampling stations (Figure 13) consisted of an antenna mounted on a 5 m cane pole, a receiver, a radio signal decoder, and the battery power and switching circuitry necessary to sequentially activate five air sampling pumps, each connected to a separate double-walled polyethylene sampling bag (Industrial Bag, 10 x 15 in., 0.0025 in. thickness with meter flow adapter fully inserted; B Bar B, New Albany, Indiana). The sampling pumps, operated in a pulsed mode, had been adjusted before the experiments so that they would deliver approximately 50 cc/min to the 4-liter sampling bags. The separate polyethylene inlets of all five pumps were colocated at a height of approximately 1.5 m above ground level. A visit to the sampling sites was necessary before each experiment to prepare the site for sampling. Since another SF_6 experiment was being conducted in the valley on alternate nights from the one described here, new sampling bags were installed and receivers were activated the afternoon before our morning release. At this time, sampling bags were installed and labeled with the site number, experiment number, and bag sequence number (1,2,3,4, or 5). Also, the electronics were cycled so that sampling would begin with the first bag, and the radio receiver was activated.

During an experiment, bag sampling stations were activated remotely from a transmitting station at the base of Sampling Arc A at the SNL site. The five sampling pumps at each sampling station were activated in sequence. The transmitting site consisted of a signal encoder, transmitter and antenna. The transmitter was operated so that, for example, the number 1 sampling pumps were activated simultaneously at all sites. At the end of

Figure 13. Sampling station of the type used in the 1982 Brush Creek experiments. The Brush Creek stations differed slightly from the one pictured here by having five, instead of three, sampling pumps. The signal encoder, receiver, and sampling pump controller are sitting on a concrete block in front of the cane pole which supports the vertical receiving antenna. The sampling pumps are attached to the cane pole, with inlets at the 1-1/2-m level. The outlet tubes from the pumps go to the cardboard box which contains the individual sampling bags.

the sampling period for the number 1 sampling pumps, the number 2 pumps were all activated, etc. At the completion of the fifth sample the receivers were automatically deactivated. The sampling periods could be chosen by the operator of the radio control system. In the Brush Creek tracer experiments, the sampling periods varied from 30 minutes to 1 hour, depending on the developing meteorological conditions. After each experiment the sampling bags were collected, inserted and sealed into protective plastic bags, and transported to the mobile analysis laboratory where analyses were immediately begun. The facilities and procedures at the mobile laboratory are described in the next section.

The performance of the bag sampling system was good during the August 4 and August 6 experiments, but the system failed to work during the July 31 experiment due to a failure of the signal encoder at the transmitter site. As a result of the encoder failure, no bag sampler data are available for the July 31 experiment.

Tables 10 and 11 present the bag sampler data for the August 4 and August 6 experiments. Annotations to Tables 10 and 11 list any missing or low volume samples. Low volume samples are less reliable than a normal volume sample, and should be used with caution. The low volume samples in most cases were due to sampling pumps that were pumping at a lower rate than expected. Despite the pre-experiment adjustment of the pumps to a pumping rate of 50 cc/min, the pumping rates of some of the pumps changed when installed in the field. The effect of the low volume sample is expected to be an underestimation of the sulfur hexafluoride concentration at a site because of the relatively large volume fraction of the sample that is composed of clean (non-SF_6) air that is initially present in the inlet tubing which leads to the sampling bags. Low volume "samples," in some cases, may be caused by complete or intermittent failures of the pumps.

TABLE 10. SF_6 CONCENTRATIONS (PPT) IN BAG SAMPLES, AUGUST 4, 1982

Bag 1	0532-0602 MST
Bag 2	0602-0652 MST
Bag 3	0652-0742 MST
Bag 4	0742-0832 MST
Bag 5	0832-0917 MST

Site	Bag 1	Bag 2	Bag 3	Bag 4	Bag 5
A1	10*	328	651	238	40
A2	61	591	935	87	48
A3	91	641	872	368	18*
A4	239*	>63	845*	375	-
A5	413*	642*	835	379	76
A6	293*	453	775	435	<10
A7	492*	16*	781	368	72
A8	13*	84*	338*	27	58*
A9	590	237*	718	301	63
A10	14	582	585	277	71
A11	424	394	371	264	69
A12	317	207	188	232	61
A13	79	44	59	38*	53
B1	662*	924	835	316	78
C2	25*	32*	18*	30*	15*
C3	52*	84	52	91	46
C4	0	0	0	32	24
D1	1500	1720*	1640	-	113*

*Low volume sample, quality unsure.
-Missing sample.

TABLE 11. SF_6 CONCENTRATIONS (PPT) IN BAG SAMPLES, AUGUST 6, 1982

Bag 1	0458-0528 MST
Bag 2	0528-0558 MST
Bag 3	0558-0658 MST
Bag 4	0658-0758 MST
Bag 5	0758-0858 MST

Site	Bag 1	Bag 2	Bag 3	Bag 4	Bag 5
A1	174	90	39*	32*	105
A2	214	166	779	904	341
A3	327	387*	709	785	61*
A4	375	603	777	819	49*
A5	418	37*	817	805	325
A6	160	316	669	762	332
A7	223	542	692	716	355
A8	360	699	461*	665	270
A9	289*	368*	825	650	307
A10	666	556	814	630	391
A11	645	709	591	561	380
A12	430	442	440	360	413
A13	101	215	143	38*	276
B1	406	944	863	673	342
C2	48*	1164	423*	45*	1278
C3	247	117	103	51	58
C4	146	48	18	18	49
D1	1720*	1110	1730	1950	187*

*Low volume sample, quality unsure.

SECTION 8

VERTICAL SF_6 PROFILER

A vertical SF_6 profiling system, designed and operated by SNL [8] was used in the tracer experiments to determine time average SF_6 concentrations over different height intervals above the Sandia National Laboratory site at the base of the major arc, Arc A. The vertical profiling system accomplishes this by means of an airborne sampling system which collects sequential samples of ambient air as it is carried aloft by a tethered, helium-filled balloon.

The 2.3 kg, automated, sequential sampler (Figures 14 and 15) consists of a rack of six 50-cc syringes, electrically operated valves, sections of capillary tubing, a timing circuit and a battery. The sampling train on each syringe consists of an electrically operated solenoid valve and a capillary tube. The valves are controlled by an on-board solid-state time/sequencer so that the syringes are sequentially filled through the individual sections of capillary tubing as the balloon ascends.

Before each ascent, new 50-cc syringes (Plastipak® syringe, Becton-Dickinson, Rutherford, New Jersey) are installed on the sampling package, the solenoid valves are closed, and the plungers of the six syringes are pulled back and fixed in place in a syringe rack, providing a vacuum in each of the syringes. The timer and strobe circuits are then switched on and the balloon ascent is begun. During the ascent, air samples are obtained sequentially through the automatic timing/sequencer circuitry as the valves are opened and closed sequentially and samples are drawn through individual sections of capillary tubing. Once the balloon attains its highest trajectory and the six samples have been collected, the balloon is brought quickly to the ground, the syringes are removed from the sampling rack, and new syringes are installed for the next profile. Each of the syringes is labeled with the experiment number, profile number, and sequence number (1,2,3,4,5, or 6).

The vertical SF_6 profiler is carried by a tethered balloon, which also carries a separate atmospheric sounding payload (TS-2A Tethersonde®, AIR, Inc., Boulder, Colorado). The balloon (TS1-BR-4 Balloon) used for the vertical sampling system is a 7.5-m^3 helium-filled, blimp-shaped balloon supplied by AIR, Inc. The balloon is fabricated from 1.5-mil urethane plastic and is constructed with an internal stretch cord and an expansion stinger to allow the balloon to maintain its aerodynamic shape and to present a low drag coefficient at any rated altitude and wind load.

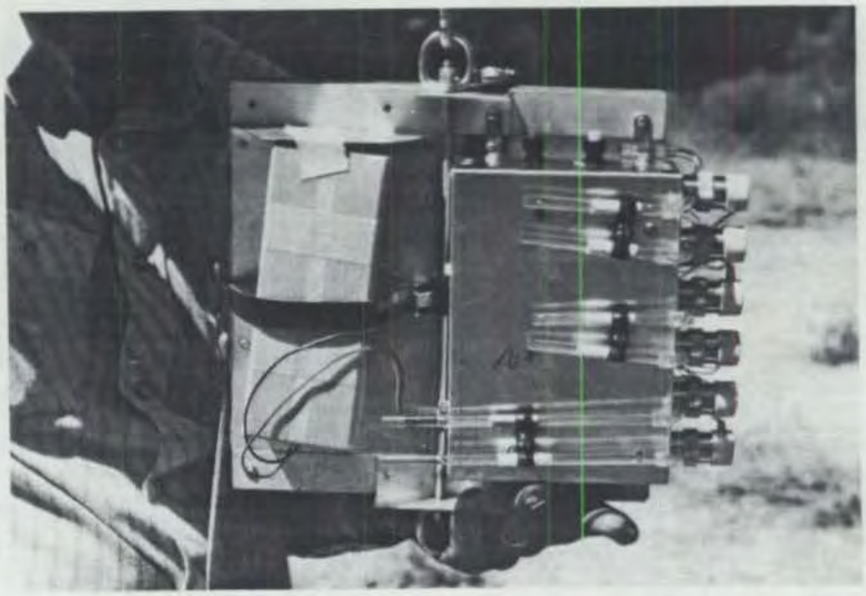

Figure 14. View of the front side of the Sandia National Laboratory vertical SF_6 profiling package.

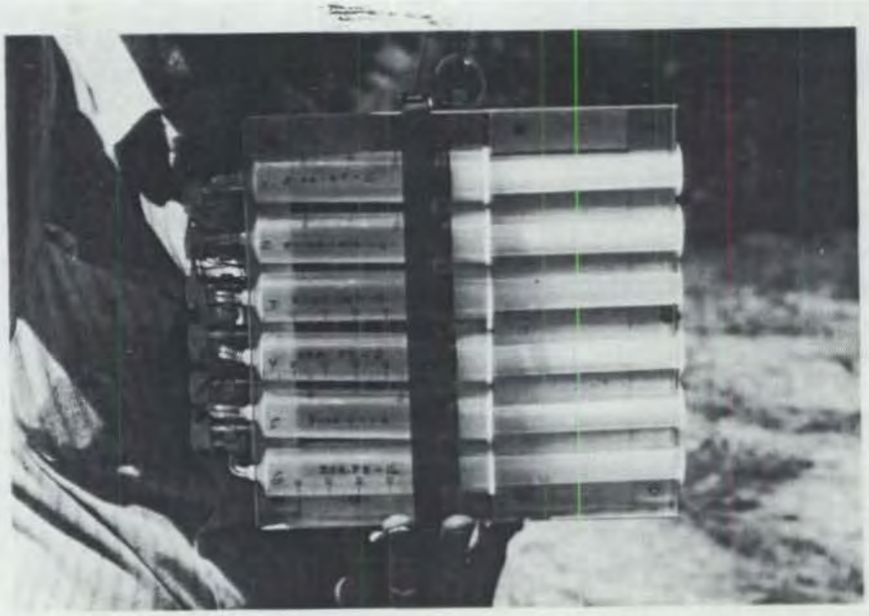

Figure 15. View of the opposite side of the Sandia National Laboratory SF_6 profiling package.

The winch (TS-2AW) used to control the ascent and descent of the balloon is also supplied by AIR Inc., as part of their tethered balloon data collection system. The winch is loaded with 1 km of 360 pound test tetherline. The winch was modified to increase its power. This was necessary to handle the 7.5-m^3 balloon.

The tethered balloon data, when processed, includes height as a function of time for each ascent. By comparing the times at which the syringe samples were sequenced, the height range for the integrated samples in each of the syringes can be determined. The SF_6 concentration in each of the syringes is obtained using the laboratory gas chromatograph described in an earlier section of this report. The syringe samples were usually the first samples analyzed following each experiment.

Before the experiment, the length of capillary tubing on each syringe was adjusted, and the timing circuitry was set so that the six syringes were sequenced to obtain better vertical resolution near the ground than at higher levels of the valley atmosphere. In particular, the first four syringes were each set to take 3-minute samples. The final two syringes took 6-minute samples. The sampling times were chosen so that the complete balloon ascent would take 24 minutes. This is a normal ascent time for a tethered balloon profile to a height of about 600 m, the altitude desired in these experiments. In the field, we discovered that the timing circuitry on board the sampling package was sensitive to ambient temperatures. The sampling intervals thus varied from their preset values. Field calibrations of the timing circuitry over a range of ambient temperatures allowed us to compute the actual sampling times for each syringe sample. The data presented in this report have been corrected for these ambient temperature effects. The SF_6 profiler data from the SNL site are listed below in Table 12. Occasional grab samples of air were also collected at the SNL site at a height of about 1 m above ground. These data are listed below in Table 13.

TABLE 12. SANDIA NATIONAL LABORATORY SULFUR HEXAFLUORIDE PROFILER SOUNDINGS

July 31, 1982

Sounding 1 0503-0529MST		Sounding 2 0613-0637MST		Sounding 3 0709-0733MST		Sounding 4 0812-0836MST		Sounding 5 0917-0941MST	
Z(m)	C(ppt)	Z(m)	C(ppt)	Z(m)	C(ppt)	Z(m)	C(ppt)	Z(m)	C(ppt)
0-63	84	0-71	171	0-87	454	0-95	173	0-98	30
63-132	30	71-147	563	87-172	543	95-185	128	98-192	27
132-209	55	147-210	493	172-258	495	185-275	90	192-283	6
209-285	86	210-284	247	258-342	63	275-363	5	283-365	18
285-438	11	284-439	11	342-506	17	363-533	-	365-529	5
438-590	47	439-575	<10	506-597	-	533-594	-	529-597	-

August 4, 1982

Sounding 1 0333-0353MST		Sounding 2 0448-0515MST		Sounding 3 0620-0643MST		Sounding 4 0731-0755MST		Sounding 5 0841-0907MST	
Z(m)	C(ppt)	Z(m)	C(ppt)	Z(m)	C(ppt)	Z(m)	C(ppt)	Z(m)	C(ppt)
0-77	0	0-76	210	0-75	702	0-83	748	0-85	90
77-148	-	76-155	604	75-151	-	83-168	539	85-168	90
148-219	0	155-225	-	151-231	962	168-251	233	168-250	81
219-278	0	225-299	-	231-306	141	251-334	16	250-328	70
278-443	-	299-460	16	306-464	Trace	334-498	17	328-462	47
443-599	9	460-597	-	464-596	11	498-599	25	462-596	13

August 6, 1982

Sounding 1 0318-0342MST		Sounding 2 0450-0516MST		Sounding 3 0605-0630MST		Sounding 4 0715-0739MST		Sounding 5 0826-0850MST	
Z(m)	C(ppt)	Z(m)	C(ppt)	Z(m)	C(ppt)	Z(m)	C(ppt)	Z(m)	C(ppt)
0-71	0	0-85	58	0-84	664	0-86	671	0-96	282
71-150	0	85-171	299	84-164	1080	86-175	542	96-190	242
150-228	0	171-254	389	164-243	734	175-265	758	190-277	110
228-285	0	254-329	426	243-336	69	265-353	200	277-366	122
285-431	0	329-493	53	336-496	8	353-529	21	366-538	24
431-521	0	493-599	0	496-600	50	529-595	22	538-567	20

TABLE 13. SANDIA NATIONAL LABORATORY GROUND-LEVEL SYRINGE SAMPLES

July 31		August 4		August 6	
Time (MST)	Conc (ppt)	Time (MST)	Conc (ppt)	Time (MST)	Conc (ppt)
0336	12	0324	0	0312	0
0618	27	0453	0	0452	Trace
0717	531	0621	441	0619	532
0815	266	0738	792	0803	646
0920	61	0854	99	0859	110
1000	7	1055	13	0939	32

SECTION 9

TETHERED BALLOON DATA COLLECTION SYSTEMS

INTRODUCTION

Tethered balloon data collection systems were used to obtain atmospheric profiles of wind, temperature, and humidity within the valley to elevations of approximately 650 m above ground level (agl). Using these systems, meteorological sensors are carried aloft by a helium filled, blimp shaped balloon. Data collected by the system are time multiplexed and are radioed to a ground receiver station where the data are received, processed, displayed and stored digitally for later analysis. Ground receiver station personnel control the altitude of the tethered balloon by means of a small winch.

SYSTEM COMPONENTS AND OPERATING PRINCIPLES

The tethered balloon data collection system used in the Brush Creek experiments was originally developed at the National Center for Atmospheric Research (NCAR). The system components, operating principles and system operating characteristics have been described by Morris et al. [9]. The commercial version of this system (Tethersonde®, Model TS-2A, Atmospheric Instrument Research, Inc., Boulder, Colorado) differs little from the initial version, except for the provision for digital data acquisition at the ground station. A complete and useful Operation Manual for this commercial system is available from the Tethersonde® manufacturer. Whiteman [7] has tested the operating characteristics of the commercial system using the NCAR Environmental Chamber and Wind Tunnel facilities.

The components of the system include 1) the airborne package (Figure 16), 2) the plastic, helium filled balloon (Figure 17), 3) the electric winch used to control the altitude of the balloon and airborne package (Figure 18) and 4) the ground receiving station and associated equipment (also shown in Figure 18). These components will be discussed, in turn, in the following section following a similar discussion by Whiteman [7].

The battery powered airborne sensor and telemetry package weighs about 1 kg and is shown in Figure 16. The wind speed sensor, a three-cup anemometer, and a fan aspirated tubular radiation shield are located on the top of the package. The radiation shield consists of two concentric tubes. A bead thermistor is exposed in the middle of the airstream in the central cylinder and is followed by an identical bead thermistor covered by a wick. A distilled water reservoir on the top of the package feeds water to the

Figure 16. Tethersonde® battery-powered airborne sensor and telemetry package.

wick of the wet bulb thermistor. Two sensors are located inside the package. A pressure transducer senses pressure changes as the package changes elevation or as local changes in pressure occur. A potentiometric compass, fixed to the base of the package, enables the package to sense wind direction. The package, in its normal operating position (Figure 17) hangs from the balloon on a rope ladder that resists tortional movements away from the orientation of the balloon. When wind direction is to be sensed by the multiplexing circuitry, an electromagnetic field locks the compass needle, which is pointing north, to a potentiometer winding, which is fixed to the base of the compass and turns with the balloon. The resistance of the potentiometer winding is then an indicator of wind direction. The basic data transmitted by the airborne package includes dry bulb temperature, wet bulb temperature, pressure, airborne battery voltage, wind direction and wind speed. The data are transmitted by the airborne package at 403 MHz in a time-multiplexed format such that a complete frame of basic data takes approximately 20 to 30 seconds.

The balloon used with the data collection system (Figure 17) is made of a light plastic material and can be obtained in various sizes. The balloons used in the Brush Creek experiments were of 4.25 and 7.5 cubic meters

Figure 17. Normal operating configuration of Tethersonde® balloon and airborne package at the Sandia site.

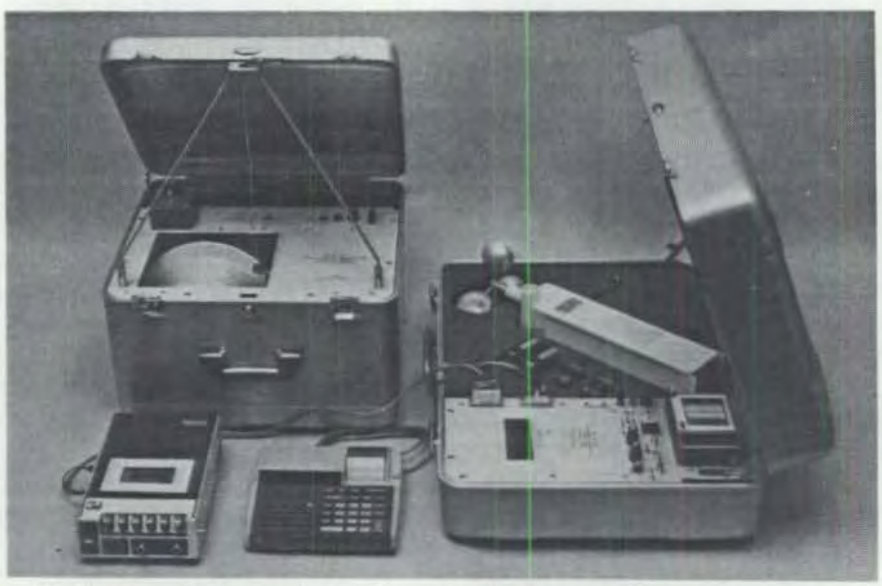

Figure 18. Tethersonde® equipment. Left, rear-electric winch. Left to right, foreground-Hewlett Packard HP-97 Programmable Printer/Calculator, ground station with airborne package.

volume. A "stinger" at the rear of the balloon allows the volume of the helium in the balloon to expand slightly as the balloon ascends, thereby protecting the seams of the balloon from ripping under the strain of differential pressure.

An elecric winch (Figure 18) is used to control the ascent and descent rate of the balloon. The level-wind winch can be operated on 110 VAC or 12 VDC power and is controlled by a small switchbox attached to the winch by 10 m of electric cable. The operator can control the speed of ascent/descent by varying the setting of a potentiometer. The winch is reversed by a toggle switch on the switch box. An emergency electronics override switch is available on the winch to apply full power to bring the balloon in at a rapid rate.

The ground station/carrying case portion of the data collection system contains a receiver/discriminator that receives the time-multiplexed signals from the airborne package and converts them to meteorological units. Signal conditioning and further digital processing occur within the microprocessor-controlled ground station. A digital display flashes meteorological values as they are processed. Digital ports allow data to be sent to a Hewlett-Packard Programmable Printer/Calculator where the data may be processed further and/or printed as they are collected. The data may also be recoded on a standard audio cassette recorder and played back at a later time into the ground station at a speeded up rate to be reconverted to a digital format for transmission to a computer in a standard computer compatible form. The ground station, powered by 110 VAC or 12 VDC, has the capability of recharging the nickel-cadmium batteries used to power the airborne package.

DATA COLLECTION PROCEDURES

Procedures for initiating an atmospheric sounding at the ground receiving station have been thoroughly described in the operation manual by the manufacturer. In the following paragraphs we will discuss other sounding procedures that are not directly related to the operation of the ground receiving equipment. Immediately before each sounding the sonde is attached to the balloon and tethered approximately 1 m above the ground. The instrument package is carefully allowed to come to an equilibrium with the ambient conditions. The distilled water supply and airborne battery are checked every few flights and replenished or replaced when necessary. Special forms are used by the operator to record information on system operation, weather conditions, etc., as the balloon sounding progresses. Complete (up and down) profiles of the valley atmosphere in the Brush Creek experiment usually took from 20-75 minutes, depending on the sounding altitude desired and the rate of ascent and descent.

Tethersondes® were used extensively in the Brush Creek experiments by both DOE and EPA investigators. The DOE experiments used up to 5 Tethersondes®, taking hourly soundings from late afternoon to late morning on July 28/29 and on July 30/31. In these soundings, attempts were made to obtain profiles through the entire valley depth of 650 m. The EPA experiments utilized two Tethersonde® data collection systems. One, operated from the tracer release site from a 4.25 m^3 balloon, was used primarily to make frequent up and down profiles through the SF_6 release height in order to measure the winds. These short profiles, up to approximately 150 m, allowed us to determine how the wind and temperature structure was evolving in the lower part of the valley atmosphere during the time of tracer release, from before sunrise to late morning. Interspersed with the short profiles was an occasional deep sounding, made to observe changes in wind and temperature profile evolution in the upper part of the valley atmosphere. A second Tethersonde® was operated for EPA by SNL at the SNL site. This Tethersonde® was attached to a 7.5 m^3 balloon, which also carried the SNL vertical SF_6 profiler (Section 8). The mode of operation of this Tethersonde® was dictated by the SF_6 profiler operation. Deep up-soundings were made as frequently as possible during the tracer release period. The SF_6 profiler required the up-sounding to be completed in approximately 24 minutes. The balloon was then retrieved quickly to reload the SF_6 syringes. Due to the quick retrieval, only the up-sounding could be used for data analysis purposes. A complete sounding cycle took from 40 minutes to an hour and 15 minutes. Soundings were generally made through the entire valley depth of 650 m.

CALIBRATION

The Tethersonde® data collection systems were originally calibrated by the manufacturer, with calibrations traceable to the National Bureau of Standards. However, most of the Tethersondes® used in the DOE and EPA experiments had not been recently calibrated, so that a special calibration procedure was established by DOE investigators. Following this procedure, all Tethersondes® were intercompared using secondary calibration standards. An Assmann psychrometer was used to check Tethersonde® dry bulb and wet bulb temperatures, a calibrated compass was used to check wind direction indications, and a set of motors was used to turn the Tethersonde® anemometer shafts at known rates to check wind speed indications. The calibration information was recorded, and all the Tethersonde® temperature (dry and wet bulb) data have been corrected using the minor corrections determined from the field calibrations.

DATA PROCESSING

Scans of Tethersonde® data are printed out on an HP-97 printer/calculator as the sounding is conducted. At the same time that the data are being displayed in real time on the HP-97, all data are recorded in a digital form on a small magnetic tape by means of a standard audio cassette recorder. The Tethersonde® data are therefore available in two redundant forms at the end of each experiment. It should be mentioned that due to the rather slow speed of the HP-97 printer, the printer record contains only every second, third or fourth frame of actual data. The preferred data set is therefore the digitally recorded one since it is a full data set and its digitally recorded format makes it most convenient for further processing in a digital computer.

Following the field experiment, the cassette tape data are played back to the Tethersonde® ground station and a digital port transfers data to a Silent 700 data terminal (Texas Instruments, Inc., Houston, Texas) where it is recorded on digital magnetic tape. This tape is played into a VAX 11/780 computer (Digital Equipment Corp., Maynard, Massachusetts) to create permanent files of data accessible by the computer. For ease in editing, the data are coded in a standard format.

Various quality control steps are incorporated in the processing of the basic data. Tethersonde® data, as processed from cassette tapes, is spot-checked against redundant HP-97 printer output.

The basic digital data are processed further on a computer. Wind directions are corrected to true north using the magnetic declination of the site. Using the hydrostatic equation, heights are calculated from Tethersonde® pressure and temperature values. Other secondary meteorological parameters such as potential temperature, mixing ratio, relative humidity, along- and cross-valley wind components, etc. are calculated using standard formulas. Since no freezing temperatures were encountered in the summer field experiments no special corrections were required due to frozen wet bulb wicks. Computer plots of the Tethersonde® data were checked to locate and correct any bad data points included in the data files. The final data set is too extensive for inclusion in this report, but it will be submitted to EPA on a digital magnetic tape which will accompany this report.

SPECIAL PRE-EXPERIMENT TETHERSONDE® DATA

It was necessary to visit the Brush Creek valley experimental area in advance of the summer field experiment in order to obtain basic meteorological data that would help in planning the summer tracer experiment. Thus, in June a field technician traveled to the valley and collected Tethersonde® data at the SNL site. Data were collected during the morning and evening transition periods of June 11, 1982. The morning was clear and undisturbed; the evening sky was clear to the north, but with scattered cumulus to the south of the valley. The data for this special pre-experiment are being submitted to EPA with this report.

SUMMER EXPERIMENT TETHERSONDE® DATA

The EPA summer experiment Tethersonde® data from the PNL and SNL sites are too voluminous to be reproduced here. They will be submitted to EPA in a digital form along with this report. They are also available from the ASCOT data archive at Lawrence Livermore National Laboratory, along with the ASCOT tethered ballon data. Table 14 presents wind speed data at the SF_6 release height at the PNL site, as extracted from individual Tethersonde® soundings.

Four examples of plotted tethered balloon data are presented as Figures 19 through 22. Figure 19 presents a typical pre-sunrise tethered balloon sounding at the PNL sulfur hexafluoride release site. Potential temperatures, along-valley wind component (u'), cross-valley wind component (v'), and total wind speed (ws) are plotted as a function of height, as obtained from a tethered balloon up-sounding. Also included in the figure are vector winds as a function of height. The length of the vector

TABLE 14. WIND SPEED AT RELEASE HEIGHT, RELEASE SITE - BRUSH CREEK, COLORADO

July 31, 1982 102 m Height		August 4, 1982 108 m Height		August 6, 1982 112 m Height	
Time* (MST)	Speed (m/s)	Time (MST)	Speed (m/s)	Time (MST)	Speed (m/s)
6.12	5.87	3.98	7.44	3.99	5.15
6.54	6.20	4.40	6.81	4.20	6.26
6.70	4.73	5.37	6.27	4.55	5.82
7.10	3.00	5.51	6.88	4.67	7.20
7.23	1.78	6.10	6.61	5.03	5.57
7.53	3.06	6.24	7.53	5.12	5.37
7.66	2.53	6.57	6.03	5.37	6.00
8.04	2.35	6.67	6.30	6.22	6.30
8.53	1.80	6.95	3.13	6.52	6.43
		7.09	2.92	6.74	5.00
		7.52	0.88	7.02	4.75
		7.94	3.20	7.11	5.33
				7.41	1.76
				7.92	2.32
				8.24	1.43
				8.74	1.87
				9.10	3.17
				9.54	3.60

*Times are given in decimal hours, MST.

corresponds to wind speed (see legend for proper scale) and the orientation of the vector represents the wind direction. A vector pointing straight down in the figure would represent a wind blowing toward the south. An alternative plotting format for the wind sounding is given in Figure 20. Figures 21 and 22 show typical tethered balloon soundings for the SNL site.

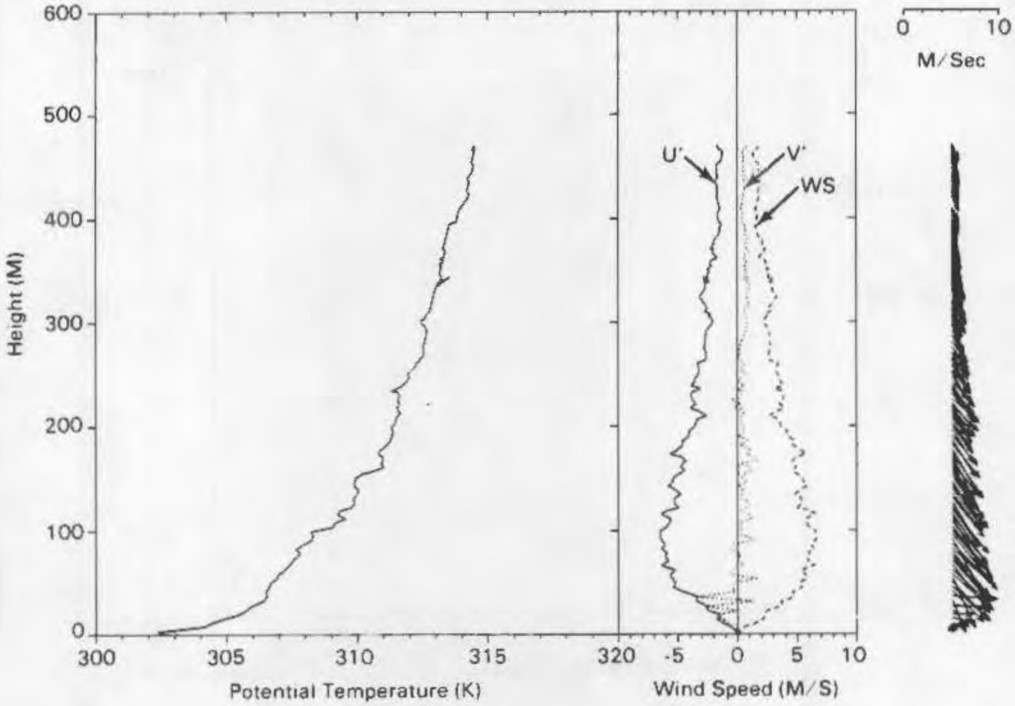

Figure 19. Tethered balloon sounding from the PNL site, August 6, 1982, 0518-0540 MST.

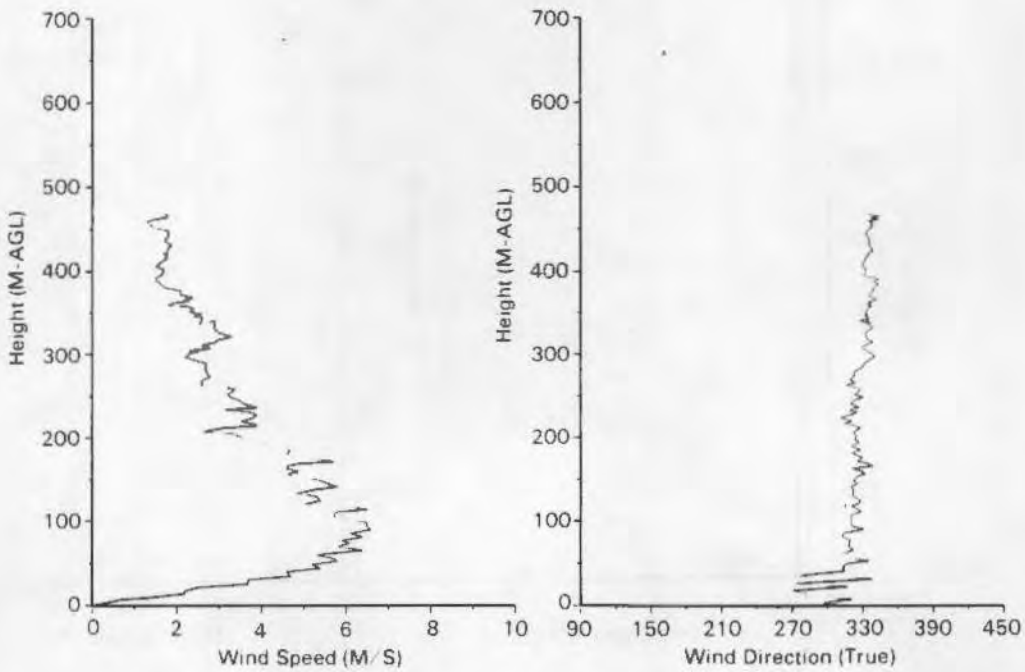

Figure 20. Wind sounding from the PNL site, August 6, 1982, 0518-0540 MST.

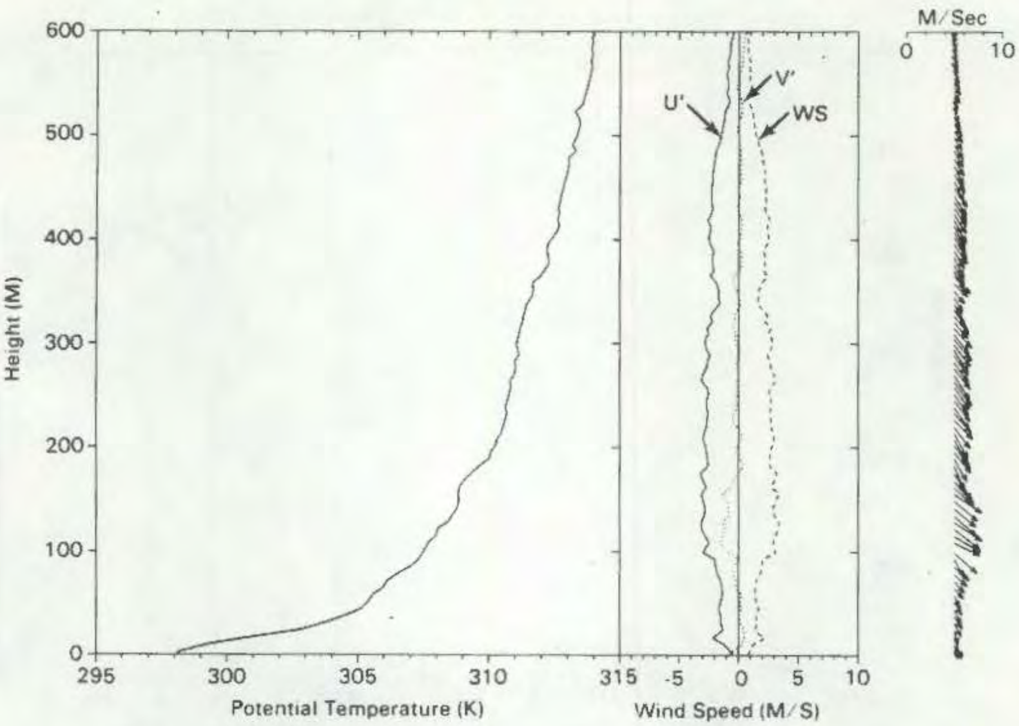

Figure 21. Tethered balloon sounding from the SNL site, August 6, 1982, 0441-0515 MST.

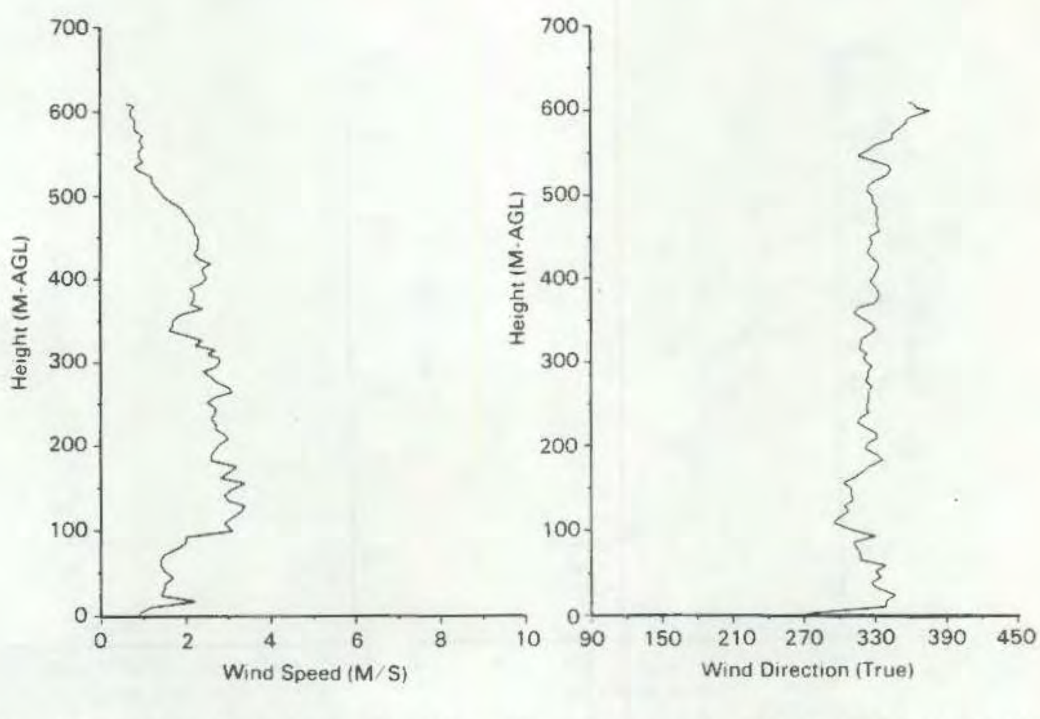

Figure 22. Wind sounding from the SNL site, August 6, 1982, 0441-0515 MST.

SECTION 10

FIELD PORTABLE GAS CHROMATOGRAPHS

Field portable SF_6 monitors were used in the tracer experiments to obtain near-real-time SF_6 concentration data. The near-real-time availability of these data was useful in operational decision making during the tracer experiment and provided data on the temporal resolution of the SF_6 plume that could not be obtained with the bag sampling system.

The experiments used Systems, Science and Software (La Jolla, California) Model 215 AUP Field Portable Tracer Gas Monitors. These devices are special purpose gas chromatographs designed for monitoring SF_6. During operation a grab sample is injected into the ultra pure nitrogen carrier stream using a gas sampling valve with a 2-cc sample loop. Use of an Alumina column results in the elution of SF_6 ahead of the oxygen peak. Both the column and the electron capture detector are designed to operate at ambient temperature, which results in an analysis time of 3-4 minutes. The detector signal was recorded on a strip chart recorder, and SF_6 concentration was determined from peak height.

The SF_6 monitors were operated at two locations on the west sidewall of Brush Creek (sites GC1 and GC2 in Figure 7). At the upper site, GC1, a single SF_6 monitor was used to measure SF_6. At the lower site, GC2, SF_6 concentration was measured with greater time resolution by the alternate use of two of these units. The field chromatographs and strip chart recorders were powered by gasoline (GC2) or propane-fueled 110 VAC generators. They were operated in the open using tables constructed on site (Figure 23).

Chromatographers were trained in chromatograph and recorder operation prior to the beginning of the experiments. Reconditioned chromatograph columns were installed in the field chromatographs at the beginning of each experimental period. Column reconditioning, consisting of passing ultra pure nitrogen through the column at approximately 100°C, was accomplished at the mobile laboratory. In-field calibrations were performed by the operators before, during and after the operational period using NBS traceable SF_6 in ultra-pure-air gas mixtures.

Careful records of operating parameters and equipment performance were maintained by the chromatograph operators, and sets of annotated chromatograms were the result of the measurement program. Chromatograph data, after modification by calibration corrections, are listed below in Tables 15-18.

Figure 23. Site GC1 on the west sidewall of Brush Creek. The field portable gas chromatograph and strip chart recorder were operated in the open from wooden table tops by EPA chromatographers.

Table 15 presents SF_6 data collected at the GC1 site on July 31, August 4, and August 6. Tables 16, 17, and 18 display SF_6 concentrations for samples analyzed with the two field chromatographs operated at site GC2. In general, samples were collected sequentially so that the data reported for chromatograph 12 is for a distinctly different sample than that reported for chromatograph 14. In some instances, however, the same sample was analyzed using both chromatographs and this data may be used to evaluate data comparability. This information, displayed in Table 19, indicates agreement to be within 10%. Unfortunately, the concentration range covered by these samples did not extend below 350 ppt.

It must be emphasized that the field chromatographs were operated at ambient conditions and were therefore subject to a wide temperature variation during the early morning to mid-morning experimental period. In response to the change in chromatograph performance which accompanied a change in ambient temperature, calibration standards were examined throughout the analysis period to provide updated sensitivity data for the calculation of SF_6 concentration. The magnitude of the observed sensitivity change is illustrated in Table 20. Detector sensitivity expressed as the ppt

TABLE 15. GAS CHROMATOGRAPH DATA, SITE GC1

July 31 Time (MST)	July 31 Conc (ppt)	August 4 Time (MST)	August 4 Conc (ppt)	August 6 Time (MST)	August 6 Conc (ppt)
0530	<10	0617	242	0507	137
0537	<10	0620	178	0510	>406
0543	<10	0625	458	0512	289
0548	152	0627	526	0514	228
0555	45	0629	437	0517	314
0601	259	0631	246	0519	304
0606	262	0633	>546	0521	243
0630	>419	0636	427	0526	223
0644	303	0638	553	0528	319
0648	517	0640	>635	0530	254
0651	566	0645	538	0532	188
0654	508	0647	639	0534	177
0658	781	0649	404	0537	124
0708	757	0651	715	0539	165
0713	464	0653	648	0542	167
0716	561	0657	891	0544	84
0720	561	0700	875	0547	66
0725	476	0702	976	0549	56
0730	464	0705	1051	0552	35
0733	403	0707	1043	0557	198
0738	415	0715	740	0600	68
0742	366	0717	891	0609	360
0747	293	0720	723	0620	>418
0750	391	0723	521	0622	>436
0754	317	0725	908	0626	519
0759	378	0727	942	0628	790
0803	439	0730	925	0630	548
0807	415	0732	706	0632	>850
0813	403	0734	690	0637	853
0818	415	0736	538	0639	1196
0823	415	0738	723	0641	1705
0828	293	0740	563	0643	1578
0832	232	0742	606	0645	1743
0856	96	0747	410	0647	1909
0859	87	0751	403	0650	1769
0903	72	0753	544	0652	1754
0907	67	0755	339	0654	1552
0914	87	0757	346	0659	1349
0929	37	0800	262	0701	1349

(continued)

TABLE 15. (continued)

August 31 Time (MST)	Conc (ppt)	August 4 Time (MST)	Conc (ppt)	August 6 Time (MST)	Conc (ppt)
0934	21	0803	233	0706	1183
0939	21	0807	304	0708	1234
0943	13	0809	255*	0710	1247
0948	11	0812	233	0712	1311
		0819	120	0714	1273
		0821	74	0716	1196
		0824	64*	0718	1069
		0826	71	0720	1018
		0828	64	0722	942
		0830	78	0724	802
		0833	71	0726	789
		0837	28	0728	585
		0839	53	0730	674
		0841	67	0732	662
		0843	57	0734	764
		0845	78	0736	713
		0847	39	0738	789
		0850	89	0740	764
		0852	97	0742	738
		0854	96	0744	776
		0857	64	0746	725
		0859	32	0748	674
		0901	27	0753	683*
		0907	18	0756	613
		0910	14	0758	642
		0913	<10	0801	608
		0915	<10	0803	573*
		0917	<10	0805	613
		0919	0	0808	637
		0921	<10	0810	682
		0923	<10	0812	613
		0925	<10	0815	558
		0928	<10	0818	543*
				0821	499
				0824	375
				0827	237
				0829	207
				0831	207
				0833	158*
				0840	193

(continued)

TABLE 15. (continued)

August 31 Time (MST)	Conc (ppt)	August 4 Time (MST)	Conc (ppt)	August 6 Time (MST)	Conc (ppt)
				0842	238
				0844	205
				0847	109*
				0850	99
				0854	79
				0857	101
				0900	104
				0902	94*
				0905	76
				0908	61
				0911	30
				0915	28
				0918	51
				0922	68
				0927	74
				0930	33
				0933	46*
				0937	30
				0940	25
				0943	10
				0946	23
				0958	<10
				1005	<10
				1010	10

*Sample taken with aircraft directly overhead.

TABLE 16. GAS CHROMATOGRAPH DATA, SITE GC2, JULY 31, 1982

Instrument Ser. No. 12		Instrument Ser. No. 14		Instrument Ser. No. 12		Instrument Ser. No. 14	
Time (MST)	Conc (ppt)	Time (MST)	Conc (ppt)	Time (MST)	Conc (ppt)	Time (MST)	Conc (ppt)
0500	-	0500	0	0732	599	0732	>597
0530	13	0530	89	0736	557	0736	>508
0535	61	0535	63	0741	508	0741	>538
0538	44	0538	42	0745	465	0746	500
0541	70	0531	92	0751	501	0751	545
0546	53	0546	57	0756	441	0756	418
0549	106	0549	131	0802	338	0802	392
0552	150	0552	197	0807	233	0807	202
0556	255	0556	280	0815	324	0815	-
0600	370	0600	>375	0820	275	0820	-
0604	511	0604	>471	0826	254	0826	-
0607	572	0607	>548	0836	177	0836	-
0611	475	0611	455	0841	504	0841	-
0615	607	0615	569	0847	177	0847	-
0623	687	0623	641	0853	194	0853	152
0641	-	0641	507	0900	177	0900	>67
0645	-	0645	486	0905	186	0905	>57
0650	-	0650	610	0912	141	0912	95
0655	-	0655	667	0918	124	0918	86
0700	-	0700	548	0922	88	0922	86
0706	-	0706	507	0929	71	0929	-
0710	-	0710	496	0935	53	0935	19
0713	>571	0713	455	0939	18	0939	<10
0718	571	0718	445	0944	<18	0944	<10
0722	578	0722	440	0949	<18	0949	<10

tracer concentration/1% full scale peak height is recorded for the analyzer ranges employed for ambient sample analysis.

Special visual observations of slope and valley wind systems were made on August 4 and August 6 at chromatograph site GC2 to assist in the interpretation of tracer data. These observations taken at the ground at the sidewall site are listed in Tables 21 and 22.

TABLE 17. GAS CHROMATOGRAPH DATA, SITE GC2, AUGUST 4, 1982

Instrument Ser. No. 12		Instrument Ser. No. 14	
Time (MST)	Conc (ppt)	Time (MST)	Conc (ppt)
0425	0	0425	0
0447	0	0447	0
0451	0	0451	0
0455	0	0455	0
0458	0	0458	<10
0501	26	0501	12
0505	99	0505	96
0509	321	0509	359
0512	44	0512	24
0516	18	0516	24
0520	73	0520	64
0523	18	0523	72
0526	73	0526	80
0529	>511	0529	387
0532	668	0532	693
0535	>686	0535	>725
0543	64	0543	69
0546	161	0546	151
0549	193	0549	212
0552	553	0552	459
0555	476	0555	452
0557	367	0557	356
0600	206	0600	206
0603	438	0603	411
0606	373	0606	390
0609	354	0609	356
0611	270	0611	247
0614	309	0614	288
0618	315	0618	336
0621	412	0621	425
0625	637	0625	1055
0627	959	0627	1041
0631	946	0631	1069
0635	985	0635	1082
0640	1017	0640	1123
0644	1094	0644	1069
0652	766	0652	836
0656	772	0656	849
0659	759	0659	836
0702	766	0702	849
0705	901	0705	1007
0708	894	0708	986
0711	927	0711	1028
0714	940	0714	1041
0718	946	0718	1041
0720	946	0720	1028
0723	972	0723	1055
0729	991	0729	1096
0732	1030	0732	1144
0736	927	0736	993
0742	714	0742	760
0745	695	0745	767
0749	335	0749	829
0753	759	0753	849
0755	746	0755	801
0758	727	0758	767
0801	425	0801	425
0806	315	0806	322
0808	412	0808	418
0812	399	0812	418
0815	290	0815	315
0819	245	0819	185
0822	257	0822	274
0826	-	0826	96
0829	84	0829	75
0834	84	0834	96
0837	77	0837	75
0840	77	0840	89
0844	84	0844	89
0847	84	0847	96
0852	103	0852	116
0856	129	0856	137
0906	59	0906	62
0912	24	0912	28
0919	<10	0919	14
0922	12	0922	11
0925	<10	0925	11
0942	0	0942	<10
0950	<10	0950	11

\- No chromatogram

TABLE 18. GAS CHROMATOGRAPH DATA, SITE GC2, AUGUST 6, 1982

Instrument Ser. No. 12		Instrument Ser. No. 14		Instrument Ser. No. 12		Instrument Ser. No. 14	
Time (MST)	Conc (ppt)	Time (MST)	Conc (ppt)	Time (MST)	Conc (ppt)	Time (MST)	Conc (ppt)
0358	0	0358	0	0629	878	0629	994
0402	0	0402	0	0631	878	0631	994
0425	0	0425	0	0635	878	0635	962
0427	0	0427	0	0638	855	0638	982
0430	0	0430	0	0640	855	0640	962
0432	0	0432	0	0642	833	0642	898
0436	10	0436	0	0645	911	0645	975
0439	<10	0439	0	0648	>933	0648	>1084
0443	34	0443	27	0651	1033	0651	>1270
0445	38	0445	36	0653	989	0653	1142
0448	44	0448	62	0657	>1078	0657	1219
0450	133	0450	129	0701	>1111	0701	1270
0454	212	0454	182	0703	>1089	0703	1270
0457	167	0457	169	0706	>1122	0706	1283
0500	147	0500	156	0709	>1089	0709	1225
0502	382	0502	236	0711	1089	0711	1200
0505	546	0505	494	0715	977	0715	1142
0506	652	0506	752	0719	989	0719	1103
0515	461	0515	462	0722	922	0722	1039
0518	561	0518	565	0725	911	0725	1026
0523	694	0523	757	0728	833	0728	937
0525	611	0525	609	0731	800	0731	898
0528	700	0528	417	0735	739	0735	808
0531	600	0531	539	0742	722	0742	795
0534	494	0534	539	0745	744	0745	821
0537	700	0537	744	0747	744	0747	834
0540	539	0540	577	0750	750	0750	821
0543	911	0543	>1091	0755	717	0755	776
0546	978	0546	1052	0757	678	0757	738
0551	744	0551	821	0802	644	0802	731
0555	389	0555	404	0804	694	0804	738
0558	533	0558	590	0807	722	0807	770
0601	456	0601	500	0811	444	0811	526
0607	594	0607	667	0814	289	0814	308
0610	811	0610	872	0817	367	0817	430
0614	556	0614	616	0820	511	0820	558
0617	917	0617	1046	0823	400	0823	430
0619	905	0619	988	0826	156	0826	128
0622	900	0622	1014	0829	211	0829	263
0627	878	0627	1001	0831	250	0831	257

(continued)

TABLE 18. (continued)

Instrument Ser. No. 12		Instrument Ser. No. 14		Instrument Ser. No. 12		Instrument Ser. No. 14	
Time (MST)	Conc (ppt)	Time (MST)	Conc (ppt)	Time (MST)	Conc (ppt)	Time (MST)	Conc (ppt)
0834	111	0834	154				
0844	20	0844	23				
0847	41	0847	54				
0857	110	0857	140				
0901	72	0901	85				
0904	81	0904	93				
0908	52	0908	70				
0911	49	0911	62				
0915	17	0915	31				
0918	49	0918	62				
0922	64	0922	74				
0925	32	0925	47				
0929	58	0929	58				
0935	35	0935	39				
0941	29	0941	31				
0944	-	0944	27				
0950	14	0950	16				
0958	<10	0958	12				
1002	<10	1002	16				
1007	17	1007	12				

TABLE 19. AMBIENT SAMPLES ANALYZED ON FIELD CHROMATOGRAPHS 12 AND 14 AT SITE GC2

Time (MST)	SF_6 Concentration (ppt) S/N 12	S/N 14	$[SF_6]12/[SF_6]14$
July 31, 1982			
0607	572	>548	<1.04
0611	475	455	1.04
0732	599	>597	<1.00
0736	557	>508	<1.10
August 4, 1982			
0532	668	693	0.96
0557	367	356	1.03
0627	959	1041	0.92
0714	940	1041	0.90
0755	746	801	0.93
August 6, 1982			
0534	494	539	0.92
0701	>1111	1270	>0.87

TABLE 20. VARIATION IN FIELD CHROMATOGRAPH SENSITIVITY DURING AUGUST 4, 1982 EXPERIMENT, S/N 14 AT GC2 SITE.

Time (MST)	Analysis Range	Sensitivity (ppt/%f.s.)
0435	E	7.97
0439	E	7.97
0444	E	7.97
0538	D	15.13
0540	D	14.75
0650	D	13.11
0900	D	11.80
0903	E	5.67
0909	E	5.79
0933	E	5.62
0936	E	5.57

TABLE 21. VISUAL OBSERVATIONS AT GC2 SITE, AUGUST 4, 1982

Time (MST)	Comments
0755	Winds remain upslope with down-valley component
0808	Upslope winds are beginning to shift toward the up-valley direction
0823	Light, gusty winds
0834	Definite up-valley component to upslope winds
0847	Moderate to gusty upslope winds with up-valley component
0933	Increased gustiness in upslope winds

TABLE 22. VISUAL OBSERVATIONS AT GC2 SITE, AUGUST 6, 1982

Time (MST)	Comments
0430	1/10 to 2/10 scattered cumulus clouds
0505	Cool breeze
0635	Sun at site
0640	Strong down-valley flow remains
0657	Light, gusty upslope with 45° down-valley component
0722	Upslope flow with 45° down-valley component
0728	Upslope only
0731	Upslope with 45° down-valley component
0755	Upslope with 15° down-valley component
0811	Upslope and turbulent flow
0820	Strong upslope only
0826	Upslope with 30° up-valley component
0851	Upslope with >45° up-valley component
0929	Moderate gustiness in upslope flow (and in genera).

SECTION 11

CONTINUOUS SF_6 TRACER DATA AT THE SANDIA NATIONAL LABORATORY SITE

A continuous tracer analyzer was operated at the SNL surface site on Arc A to obtain real-time SF_6 data. Although operational problems during the experimental program reduced analyzer sensitivity and limited data collection to a fraction of the total release period, the concentration data that was collected supports the results of grab samples taken by SNL personnel and analyzed several hours later at the field laboratory. It also provided information on the arrival of the plume front at this surface site.

The basic features of the continuous tracer analyzer are illustrated in Figure 24. Analyzer operation is based on the sensitivity of the electron capture detector (ECD) to perfluoro compounds and the greater stability of atmospheric tracer gases, such as SF_6, compared to potential interfering compounds (e.g., freons). The incoming sample is mixed with a slight excess of hydrogen upstream of a catalytic reactor in which atmospheric oxygen is converted to water and low molecular weight halocarbons undergo thermal degradation. The product gas stream is then directed to an efficient drier where water and halocarbon decomposition products are selectively removed. The perfluoro tracer is thus transported in the atmospheric nitrogen-excess hydrogen carrier stream to a pulsed constant frequency ECD for measurement.

During the Brush Creek experimental series, the continuous tracer analyzer was calibrated by periodic exposure to a NBS traceable SF_6 in ultrapure air mixture contained in a polyethylene sampling bag of the type utilized for sample collection. The standard gas samples employed were also used to calibrate the field chromatographs described in Section 10 and the laboratory gas chromatograph operated at the mobile analysis laboratory.

During the field experiment, operational problems were encountered with the continuous SF_6 tracer gas analyzer due to a malfunction of the drier. SF_6 data were obtained from the continuous analyzer on August 6, 1982, and are presented in Table 23.

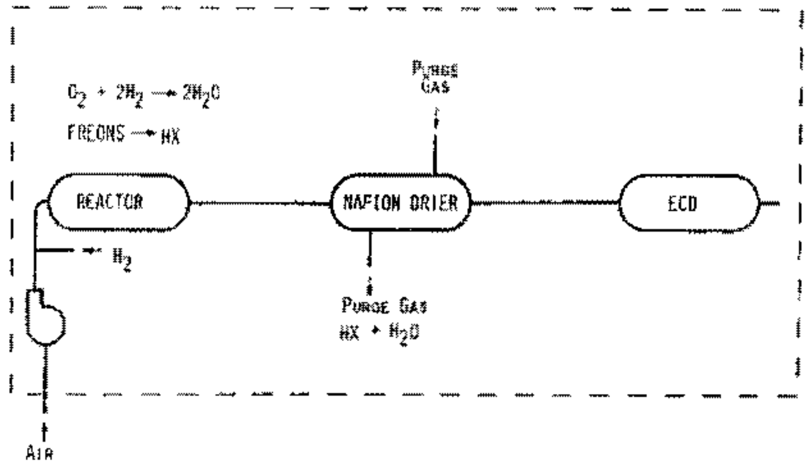

Figure 24. Simplified schematic of continuous tracer analyzer.

TABLE 23. CONTINUOUS TRACER DATA, SANDIA SITE, AUGUST 6, 1982

Time (MST)	SF_6 Concentration (ppt)
0500	0
0547	225
0550	250
0552	270
0555	360
0557	380
0559	405
0602	450
0606	430
0609	495
0611	520
0614	540
0800	600
0802	840
0806	720
0808	720
0813	780
0823	480
0826	420
0830	300
0835	240
0840	240

SECTION 12

AIRCRAFT DATA

INTRODUCTION

The purpose of the aircraft sampling was to provide data on the location, altitude, and concentration of SF_6 within the Brush and Roan Creek drainages. The experiments were designed to determine how SF_6 in the local flows within Brush Creek would be released from the valley into the upper prevailing flows after sunrise.

INSTRUMENTATION

The airborne sampling was conducted with a PNL twin-engine Cessna 411 (Figure 25), which carried a Brookhaven National Laboratory (BNL) continuous operating perfluorocarbon sniffer (COPS) designed to continuously monitor ambient air for the detection of perfluorinated compounds, namely, perfluorocarbons (PFC) and SF_6. The COPS operates by drawing in air continuously with a pump, combusting the oxygen with hydrogen over a catalyst, drying the gas, passing it through an electron capture detector, and monitoring the output signal. Only SF_6 and PFCs survive the combustion process. The output signal was collected on a DAS-32 data acquisition system and monitored with a strip chart recorder. The continuous SF_6 sampling was supplemented with periodic grab samples taken in 10-liter double-walled polyethylene bags or in 50-cc syringes.

Geographic coordinates (latitude, longitude) were obtained from a VLF-Omega® (GNS-500A) navigation system. These data and air temperature, dew point, turbulence parameters, altitude, wind direction and speed were monitored and recorded on magnetic tape by the data acquisition system.

CALIBRATION AND TESTING PROCEDURES

The COPS was bench- and flight-tested on July 26, 1982, prior to departure for Colorado. The instrument appeared to operate satisfactorily during flight testing although no SF_6 was released. The response of the COPS was observed to be very sensitive to altitude changes - a feature that required some redesign of proposed flight sampling patterns.

® Global Systems, Irvine California.

Figure 25. Battelle Pacific Northwest Laboratories' Cessna 411 research aircraft.

On the first sampling flight on July 29, the COPS malfunctioned. Extensive bench-testing of the instrument eventually restored the COPS to its proper operating mode.

On the second sampling flight on July 31, the COPS responded improperly to altitude and air speed changes during descents into Brush Creek. After further testing of flow rates and instrument response, on August 2 a filter was placed in the COPS sampling line and modifications were made to the grab bag sampling inlet line. Additional flight testing of the COPS and monitoring of flow rates were accomplished the same day. These modifications restored the COPS to a fully responsive and operational mode for the remaining sampling flights.

Calibration of the COPS was performed once or twice during a flight operational day. These calibrations were performed before or after research flights. Known SF_6 calibration gases in concentrations from 420 to 1050 ppt were used to calibrate the response of the instrument.

AIRCRAFT EXPERIMENTAL DESIGN AND SAMPLING OPERATIONS

Figure 26 shows the aircraft flight paths in relation to the topography and surface sampling sites in Brush Creek. Sampling flight paths covered the valley axis, valley sidewalls and valley entrance. Sampling was also conducted in Roan Creek, primarily down valley from the Brush Creek-Roan Creek confluence.

A typical flight sampling sequence proceeded as follows: A sampling altitude was attained in Roan Creek near the town of DeBeque. The path then

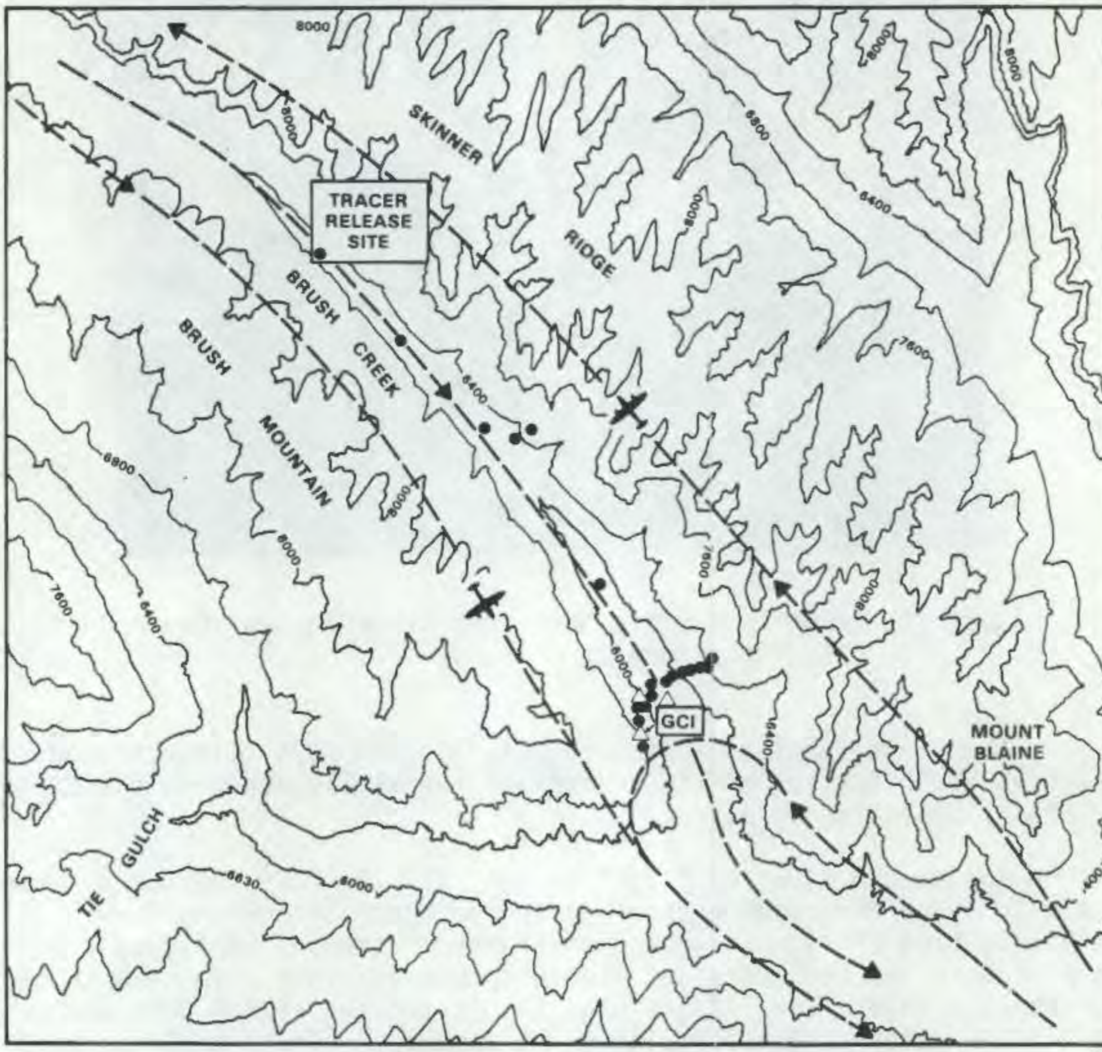

Figure 26. Illustration of typical flight paths in the Brush Creek-Roan Creek region. Surface sampling sites are indicated with dots. The locations of the gas chromatographs and the continuous SF_6 monitor are indicated with triangles.

proceeded to the entrance of Brush Creek and then turned to proceed back to Roan Creek. A different altitude was selected and the pattern repeated. Three altitudes, 1980 m MSL, 2134 m and 2286 m were flown once to start the sampling and then periodically during the remainder of the sampling period. After these initial sampling paths, a series of sampling passes was made along the side of Brush Mountain and down through the valley into Roan Creek where the aircraft would change altitude for the next sampling pass. After sunrise, sampling passes were generally confined to valley upper-sidewalls (Brush Mountain and Skinner Ridge) with an occasional pass through the valley. On one day some sampling flights were made going up-valley but these were discontinued in favor of the safer down-valley path. In general, all sampling paths were accomplished at an approximately constant altitude except when it was necessary to descend into Brush Creek from its head. Occasional variations from this sampling procedure took place when it was necessary to check sampling equipment.

The airborne sampling was conducted during the period 0530 to 0930 MST for the four experimental periods of July 29, July 31, August 4, and August 6, 1982. A brief discussion of each experimental sampling flight follows, with reference to bag sample data collected from the aircraft (Tables 24 through 27), syringle sample data (Table 28), and continuous SF_6 concentration data (Figures 27 through 29).

TABLE 24. CESSNA 411 AIRCRAFT BAG SAMPLES

Sample No.	Concentrations (ppt)		
	July 31	August 4	August 6
1	0	135	219
2	0	117	184
3	0	0	5
4	0	0	0
5	0	0	0
6	0	0	12
7	0	0	Trace
8	0	11	10
9	0	0	Trace
10	144	0	116
11	-	Trace	213
12	-	Trace	106
13	-	-	222
14	-	-	0
15	-	-	Trace
16	-	-	38

July 29, 1982

July 29 was cloudy, with cloud bases essentially obscuring the Roan plateau area. The aircraft could not safely sample in Brush Creek due to the cloud cover. Thus all sampling that did take place occurred near the entrance to Brush Creek and within the Roan Creek Valley. Radio communication was poor so that the cancellation of the SF_6 release was not known to the aircraft crew until later in the day. The COPS instrument did not operate properly on this day, but occasional syringe samples were collected over a period of 1 hour and 40 minutes. Nine syringe samples were obtained with the majority taken at the entrance of Brush Creek. Five of the samples

TABLE 25. SF_6 CONCENTRATIONS (PPT) IN AIRCRAFT BAG SAMPLES
JULY 31, 1982

Location/Time(MST)	2286 (7500)	2317 (7600)	2377 (7800)	2408 (7900)	2438 (8000)	2515 (8250)
	Altitude (m and ft MSL)					
Brush Crk Valley						
1) 0537			0.0			
2) 0600				0.0		
3) 0621 West Sidewall				0.0		
5) 0636					0.0	
6) 0641 West Sidewall				0.0		
9) 0720-0721	0.0					
Roan Crk West Sidewall						
4) 0623				0.0		
Entrance to Brush Crk						
7) 0643:30				0.0		
8) 0702 Down Roan Crk Valley-East Side		0.0				
West Ridge Brush Crk						
10) 0806:11						144

showed concentrations between a trace and 7.1 ppt (Table 28). These concentrations probably arose from the leak in the SF_6 release system that occurred on this day. The release was aborted after the leak was detected.

July 31, 1982

The weather on this experimental day was clear and aircraft sampling proceeded as scheduled. The airborne sampling lasted 3 hours and 35 minutes. Grab bag sampling replaced the syringe sampling and 10 grab samples were taken during the sampling period. Later analysis showed that most of the samples did not contain measurable amounts of SF_6 except sample no. 10 taken along the upper sidewall of Brush Mountain around 0806 MST (Tables 24 and 25). The COPS instrument showed evidence of SF_6 along Brush Mountain between 0800 and 0845 MST (Figure 27).

TABLE 26. SF_6 CONCENTRATIONS (PPT) IN AIRCRAFT BAG SAMPLES
AUGUST 4, 1982

	Altitude (m and ft MSL)					
Location/Time(MST)	1981 (6500)	2134 (7000)	2286 (7500)	2408 (7900)	2530 (8300)	2545-2560 (8350-8400)
Entrance to Brush Crk						
1) 0538:50-0540	135					
2) 0545 -0548:54	117					
3) 0557:11-0559:42		0.0				
4) 0607:10-0610:20			0.0			
West Ridge Brush Crk						
5) 0619:05-0621:42					0.0	
7) 0645 -0649:48						0.0
10) 0711 -0716					0.0	
12) 0731:06-0734:22						<5.0
Brush Crk Valley						
6) 0626 -0628			0.0			
8) 0653 -0657				11.4		
East Ridge Brush Crk						
9) 0704 -0708					0.0	
11) 0722 -0724						<5.0

August 4, 1982

The weather for this experimental day was also clear, and aircraft sampling proceeded as scheduled. Twelve grab bag samples were taken at various locations within the Brush Creek area. Five of the samples showed concentrations between a trace and 135 ppt (Tables 24 and 26). The highest concentrations were detected at the entrance to Brush Creek and in the valley (Figure 28). The sampling of SF_6 was terminated early in the morning due to commitments to the regional scale measurement task of the ASCOT program.

August 6, 1982

In terms of weather and complete aircraft sampling operations this morning was the best of the four mornings. Sixteen grab bag samples were taken at different locations and altitudes. Thirteen of the samples had SF_6 concentrations from a trace to 222 ppt. The higher concentrations

TABLE 27. SF_6 CONCENTRATIONS (PPT) IN AIRCRAFT BAG SAMPLES
AUGUST 6, 1982

Location/Time(MST)	Altitude (m and ft MSL) 1981 (6500)	2134 (7000)	2286 (7500)	2408 (7900)	2530 (8300)
Entrance to Brush Crk					
1) 0556-0600	219				
2) 0608-0611	184				
3) 0623-0626		4.6			
4) 0634-0637			0.0		
6) 0701-0704		12.2			
9) 0725-0729			Trace		
Brush Crk Valley					
5) 0652-0656			0.0		
8) 0718-0721			10.1		
11) 0758-0801			213		
13) 0813-0816			222		
16) 0857-0901				37.5	
West Sidewall Brush Crk					
7) 0712-0714					Trace
10) 0751-0754					116
12) 0806-0809					113
East Sidewall Brush Crk					
14) 0820-0825					0.0
15) 0836-0840					Trace

(>100 ppt) were found at the entrance to Brush Creek, within the valley and along Brush Mountain (Tables 24 and 27 and Figure 29). The COPS instrument performance was essentially trouble free throughout the aircraft sampling period. Problems with the data acquisition system after 0745 MST affected some of the data output signal of the SF_6. Thus, in the data processing it was necessary to use part of the strip chart data for assessing concentrations of SF_6 (next section).

DATA PROCESSING

The magnetic tapes from the DAS 32 data acquisition system were transferred to a disk file on a UNIVAC 1110 computer. A VAX 11/780 computer was used to list the complete data set in engineering units. A time series plot

TABLE 28. SF_6 CONCENTRATIONS (PPT) IN AIRCRAFT SYRINGE SAMPLES, JULY 29, 1982

Location/Time(MST)	Altitude (m and ft MSL) 1981 (6500)	2134 (7000)	2286 (7500)	2347 (7700)
Brush Crk Entrance				
1) 0636			Trace	
2) 0646		7.1		
3) 0656	2.3			
4) 0703		2.5		
5) 0712			0.0	
6) 0720				3.8
7) 0728		0.0		
8) 0740	0.0			
West Sidewall Roan Crk				
9) 0747-0752	0.0			

of the uncorrected SF_6 output signal for the four experimental periods was made for the purpose of examining the data . As a result of the COPS sensitivity to altitude and the drift of the output signal it was necessary to determine baseline values (zero offset) and the baseline drift for each sampling pattern. A sampling pattern consisted of a flight path from the southern- (northern-) most position to the northern- (southern-) most position of the Brush Creek-Roan Creek area. These baseline values and baseline drifts were then applied to the uncorrected SF_6 output signal and another disk file was generated having the corrected SF_6 data in ppt. These data were then replotted in time series for examination and correlation with the geographical coordinates and grab bag samples. The corrected SF_6 data and approximate geographical locations for the experimental periods are shown in Figures 27 through 29.

During the August 6 airborne sampling period, a problem with the data acquisition system after 0745 MST resulted in the loss of the SF_6 output signal to the magnetic tape. However, the output signal to the strip chart was not affected. Thus, for the time period after 0745 MST strip chart SF_6 data were digitized manually and placed on the SF_6 concentration disk file after correction for baseline drifts, etc. These digitized data were merged with the earlier data available from magnetic tape.

The 1-second data tabulations from the airborne sampling are too voluminous to be included in this report but will be submitted to EPA on a magnetic tape that will accompany this report. Some experimental plotting of the data using 5-sec averages has been accomplished using various

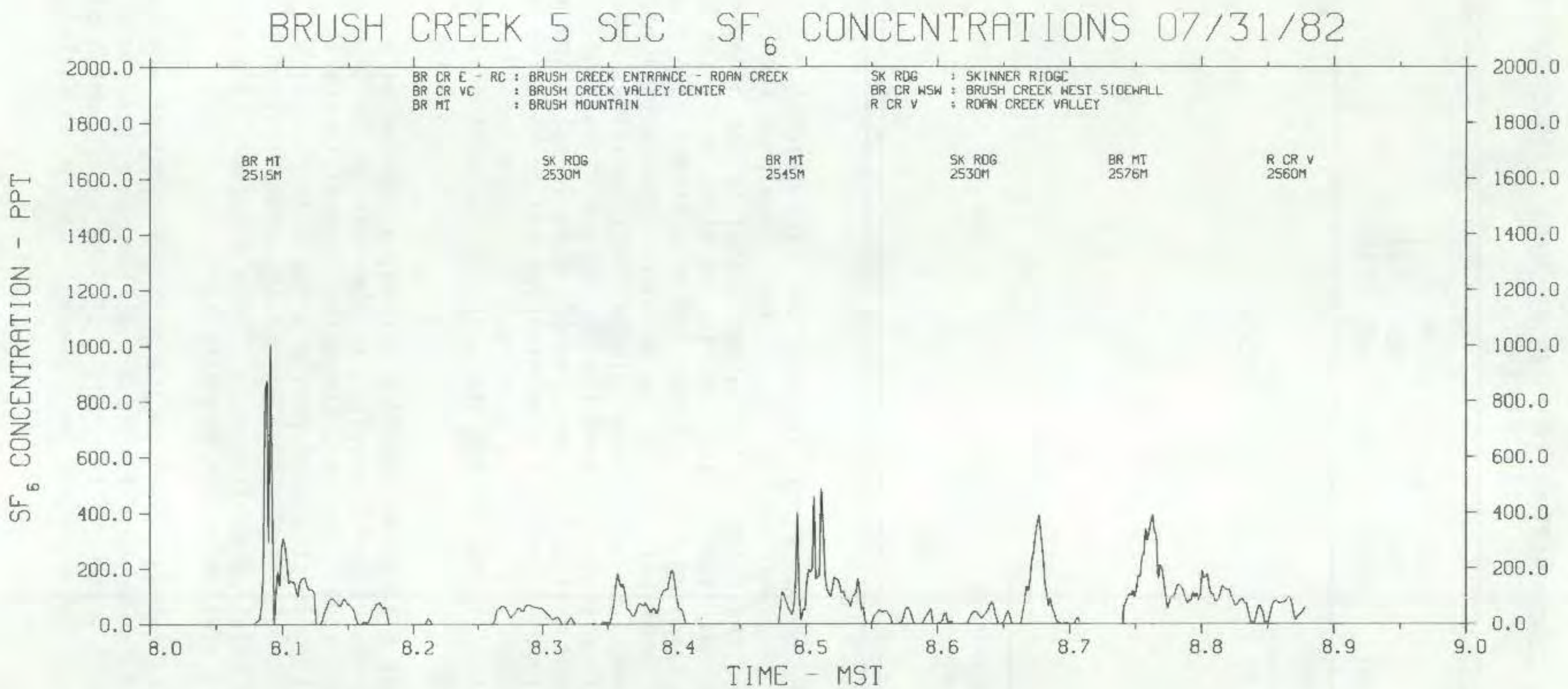

Figure 27. Time series of 5-sec averaged SF_6 concentration data collected from the Cessna 411 research aircraft on July 31, 1982.

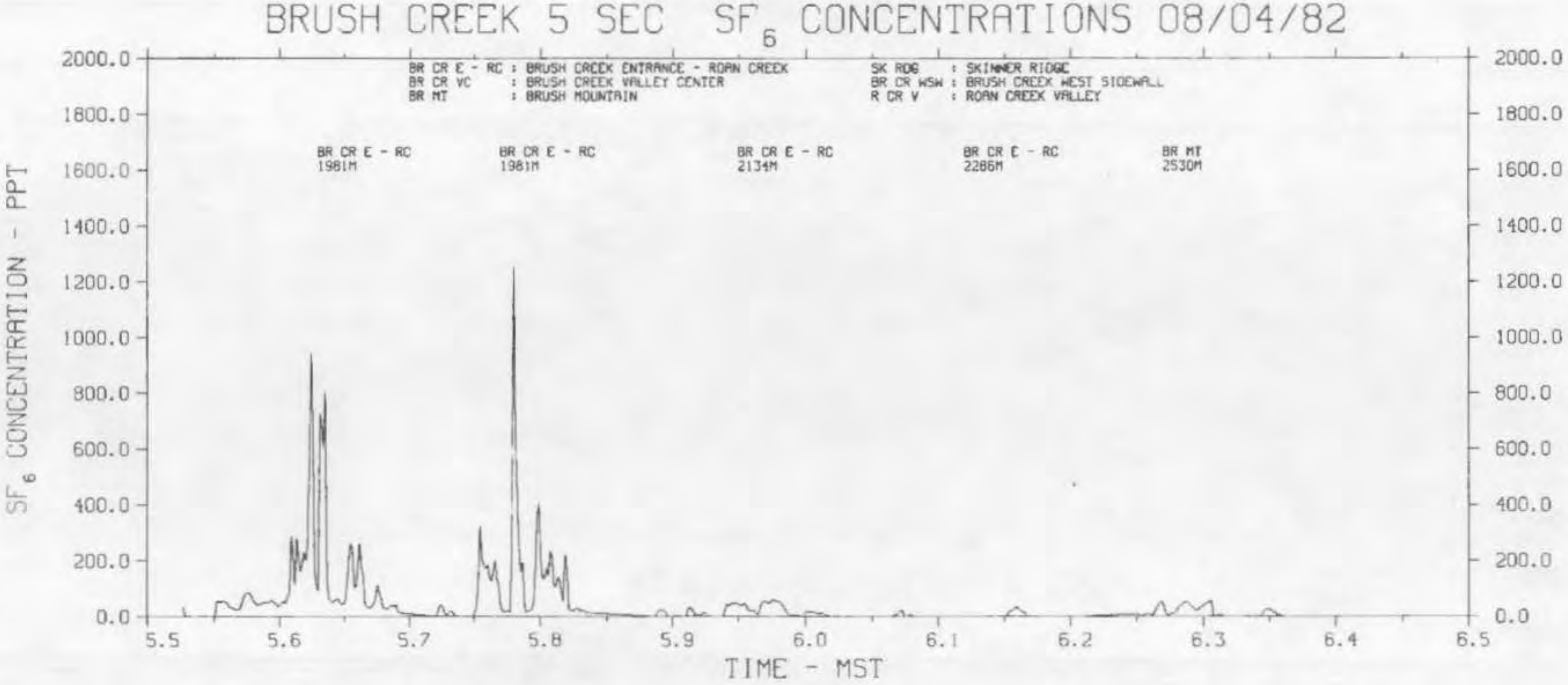

Figure 28. Time series of 5-sec averaged SF_6 concentration data collected from the Cessna 411 research aircraft on August 4, 1982

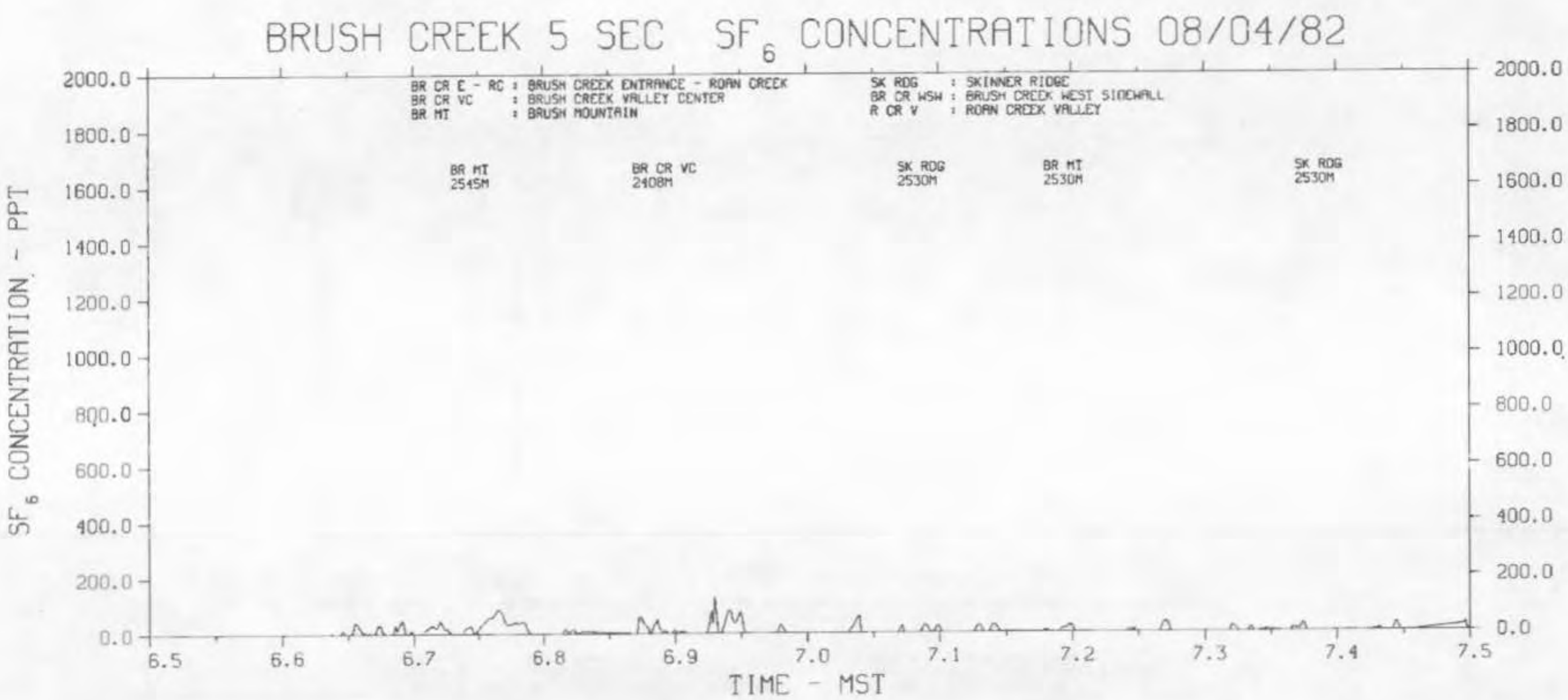

Figure 28. (continued)

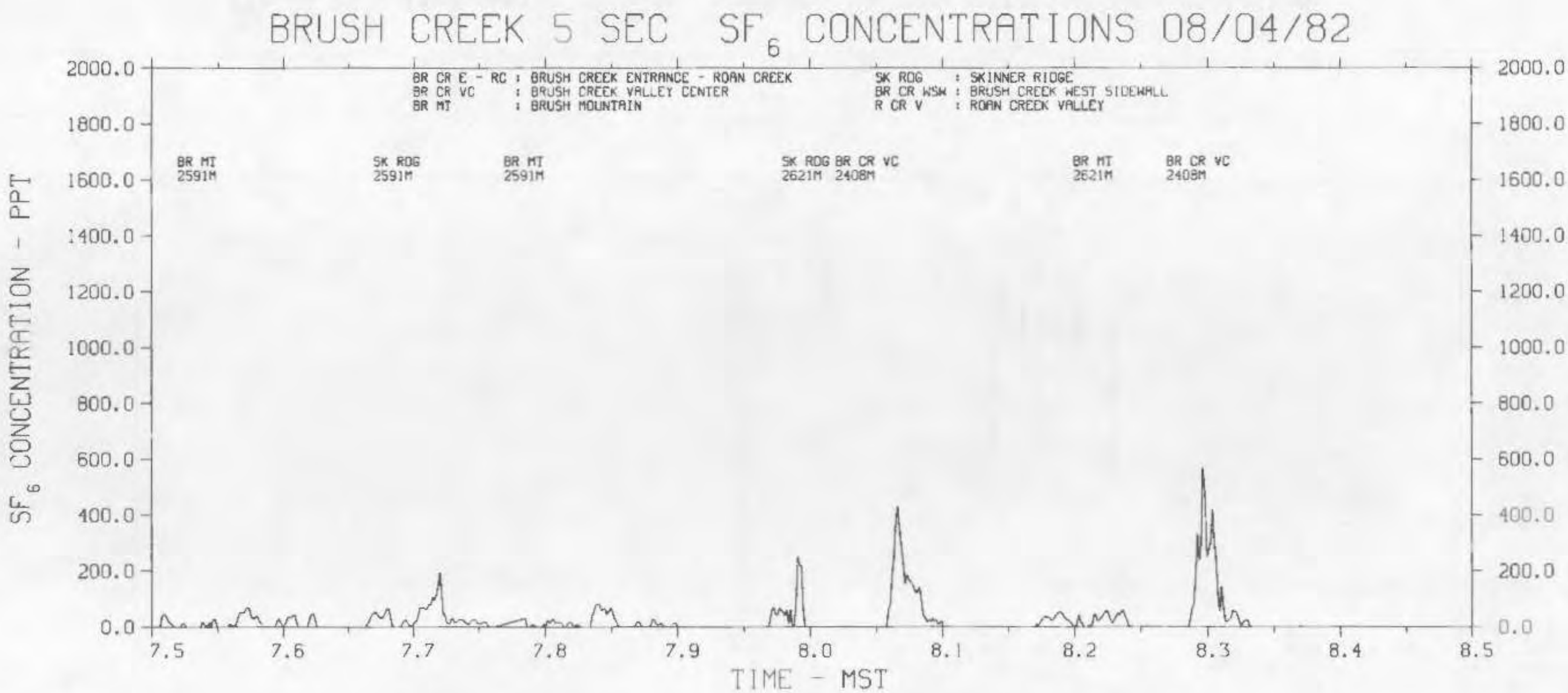

Figure 28. (continued)

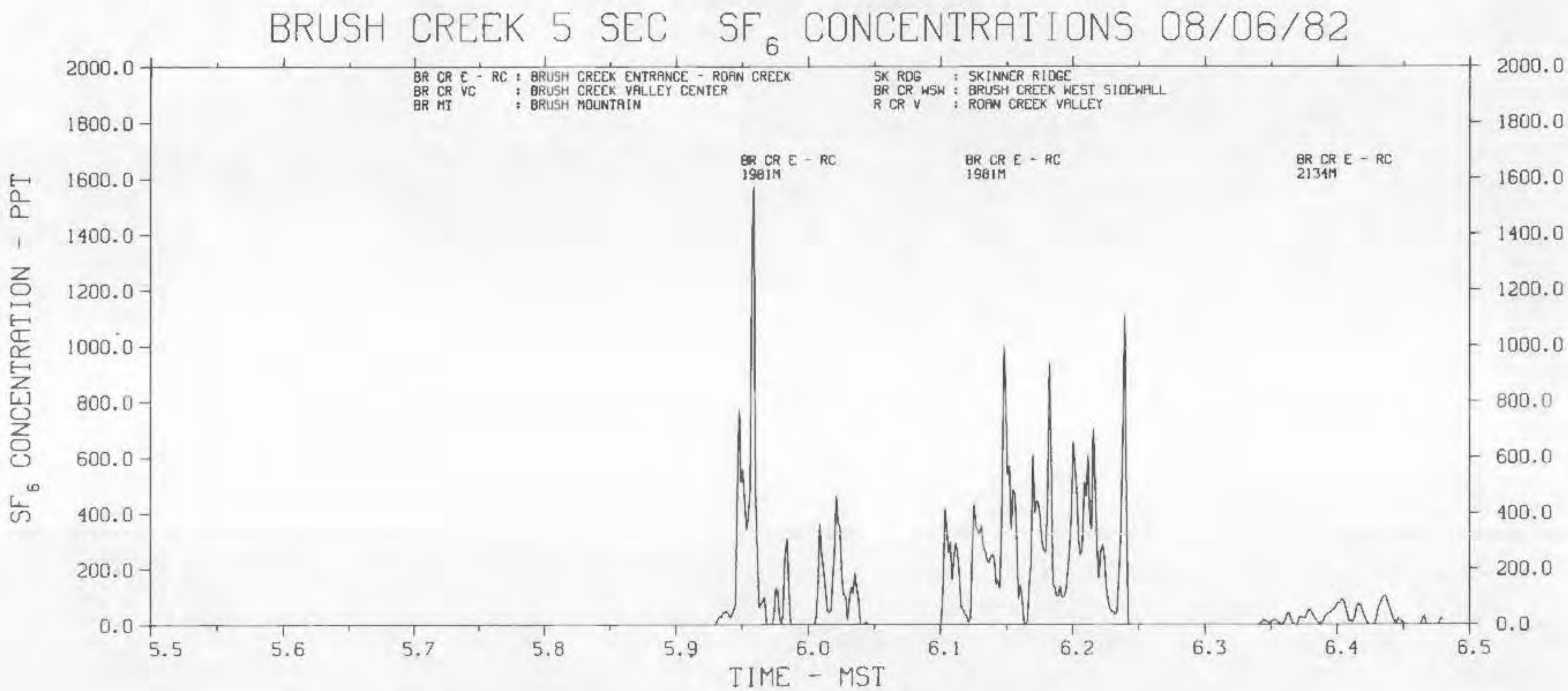

Figure 29. Time series of 5-sec averaged SF_6 concentration data collected from the Cessna 411 research aircraft on August 6, 1982.

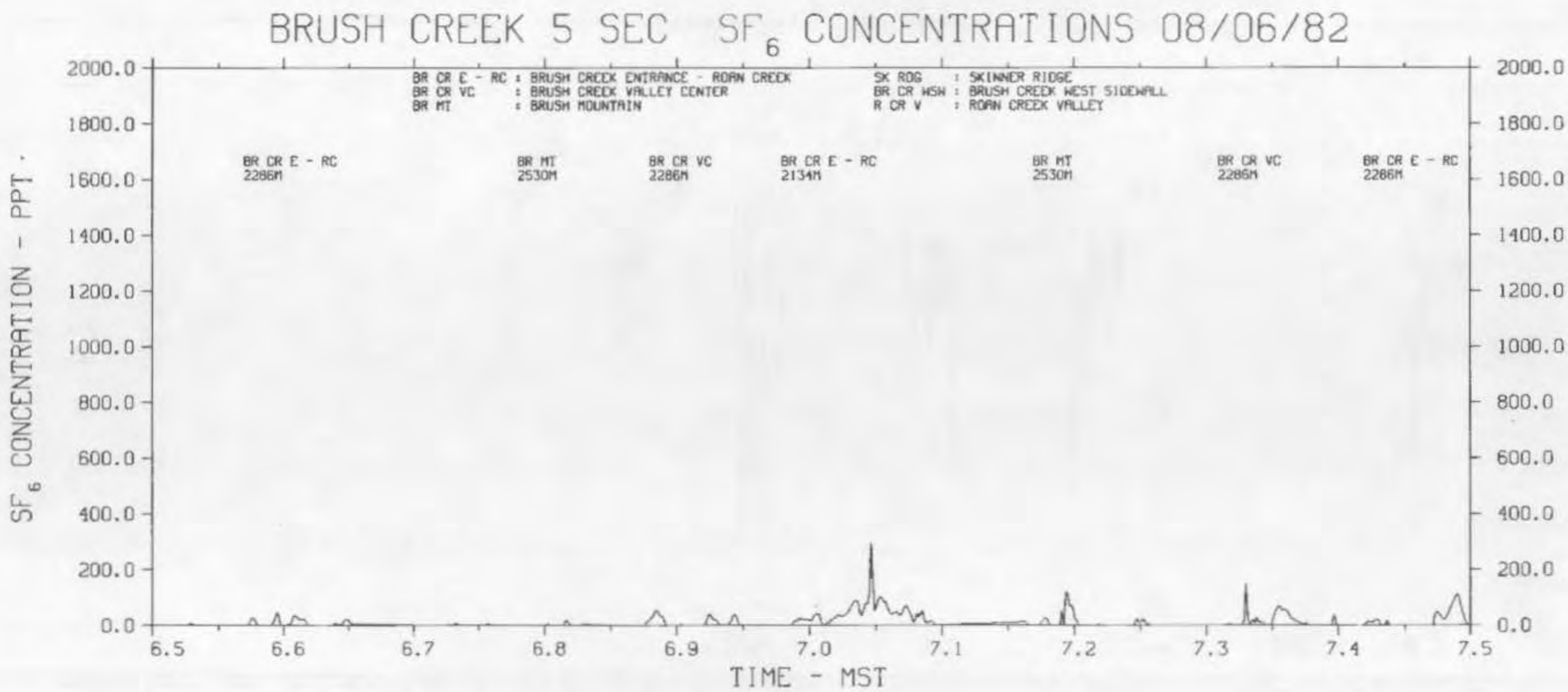

Figure 29. (continued)

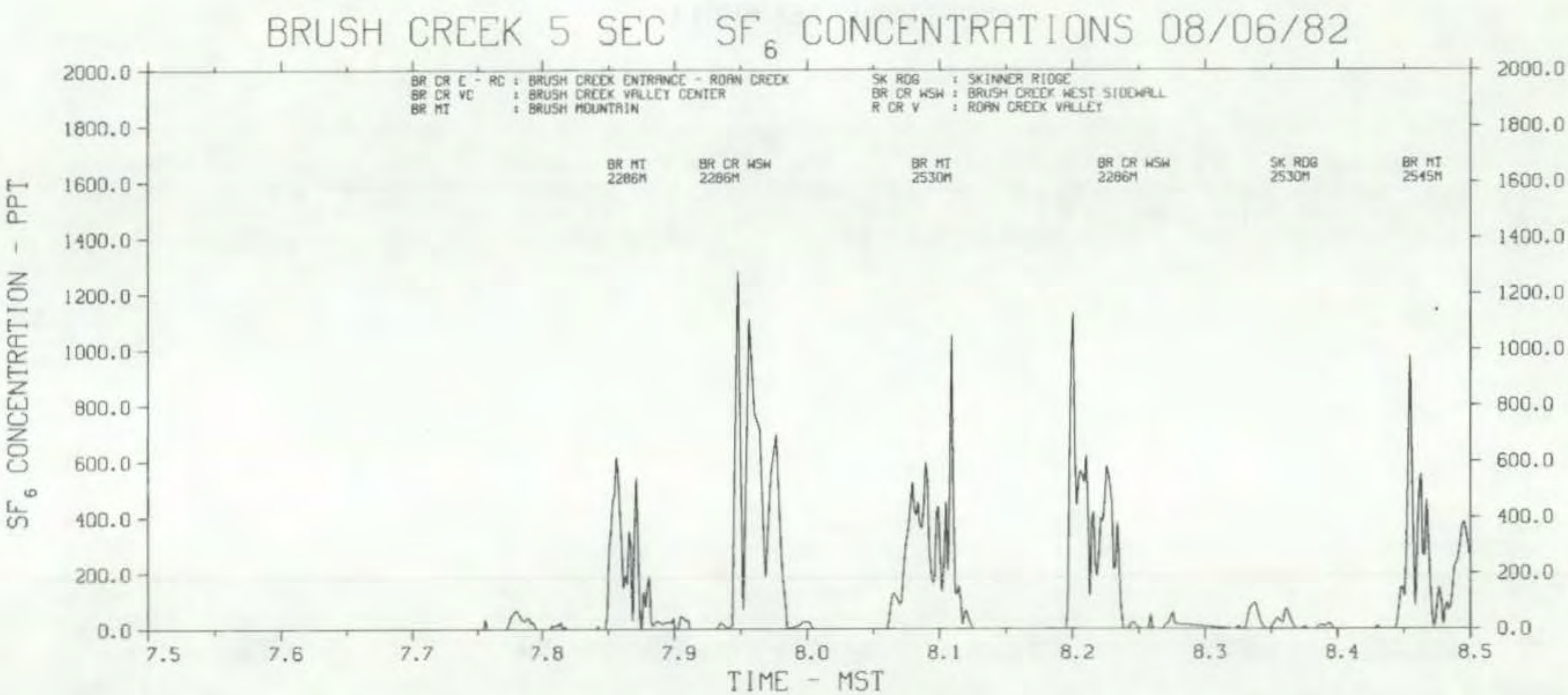

Figure 29. (continued)

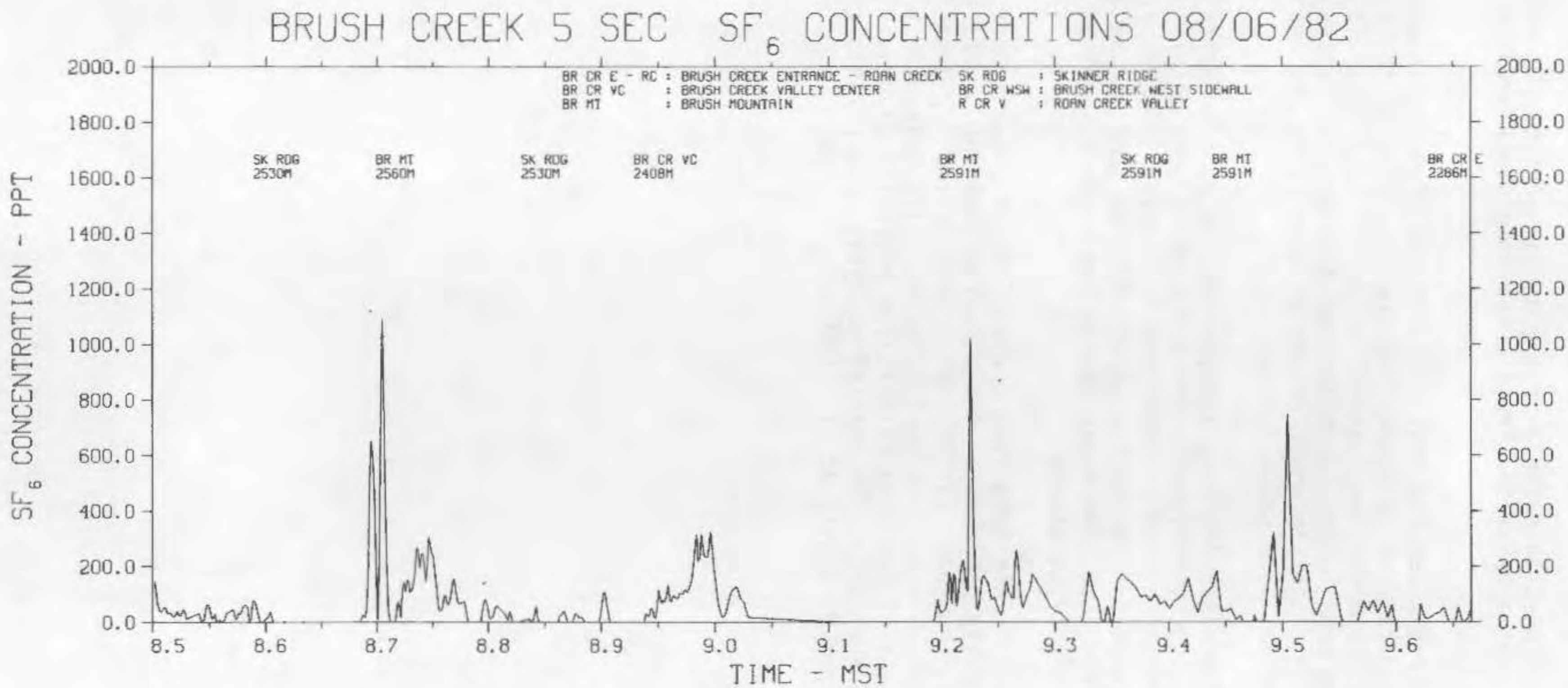

Figure 29. (continued)

computer plotting routines. An example of a computer plot of SF_6 concentration data over the topography of the Brush Creek-Roan Creek area is shown in Figure 30.

An examination of the experimental plots of the SF_6 data showed that some of the position data were in error. Apparently, some of the position errors occurred when the Global navigation system in the aircraft slipped into a dead reckoning mode before the pilot could update the system. Landmark and other written flight information can be used in future analyses to adjust this erroneous position data.

The syringe and bag samples were analyzed at the mobile laboratory on the Grand Mesa. SF_6 concentrations in the air samples were determined using the laboratory gas chromatograph as described in Section 5. The syringe and bag samples were transported to the laboratory site as soon as the sampling flight had terminated. Each sample was tested two or more times to assure the accuracy of the SF_6 calculations.

At present, the aircraft data from the 1982 Brush Creek tracer experiments have not been fully processed. Additional processing of the position and altitude data is required. Further processing of the SF_6 data is also required in order to remove any residual baseline drift caused by altitude changes. Full analysis of the data will follow after the processing is complete, if funding is available. An initial analysis of a portion of the data has been performed by Orgill et al. [10].

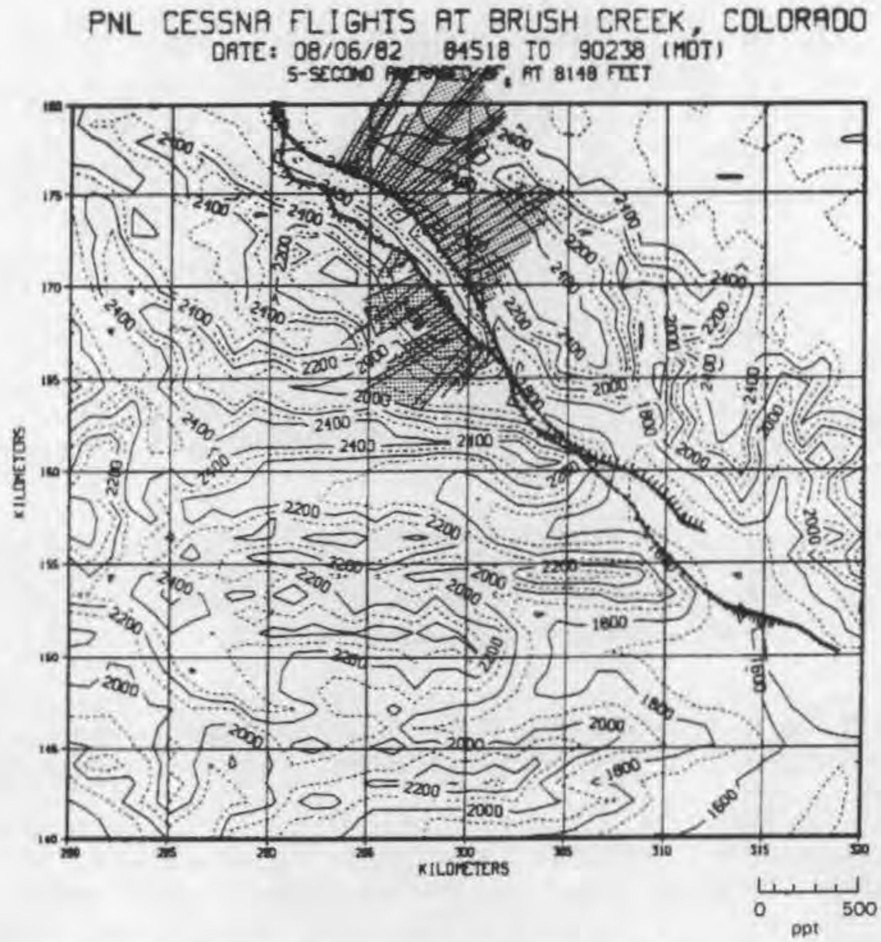

Figure 30. Example of 5-sec averaged SF_6 data plotted on a topographic map showing the aircraft flight path. SF_6 concentrations are indicated by the length of line segments plotted to the left of the aircraft flight path. The example is for August 6, 1982 at an altitude of 8148 ft (2483 m) MSL.

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APPENDIX A

DATA TAPE CONTENTS

In this appendix, the contents of a data tape are described. The tape will be submitted to EPA as a part of the report of the Brush Valley experiments of 1982.

The 1600 bpi data tape was created in a FILES11 format on a VAX 11/780 computer under the VAX/VMS Version 3.6 operating system. The tape contains 8 files with the names and contents of the files listed below in Table A-1.

TABLE A-1. CONTENTS OF DATA TAPE

File Name	Contents
RAWIN. DAT; 1	Grand Junction, Colorado, rawinsonde data, July 28-August 7, 1982.
TABLE. DAT; 1	Tracer data, topographic data, and miscellaneous data • Topographic and location information for Brush Creek sites. • August 4, 1982 SF_6 concentration data, bag sampling sites. • August 6, 1982 SF_6 concentration data, bag sampling sites. • Gas chromatograph data, Site GC2, July 31, 1982. • Gas chromatograph data, Site GC2, August 4, 1982. • Gas chromatograph data, Site GC2, August 4, 1982. • Gas chromatograph data, Site GC1, July 31, August 4, and August 6, 1982.

TABLE A-1. (continued)

File Name	Contents
	• Cessna 411 Aircraft bag sample data, July 31, August 4 and August 6, 1982.
	• SNL ground-level syringe samples, July 31, August 4, and August 6, 1982.
	• SNL SF_6 profiler soundings, July 31, August 4, and August 6, 1982.
	• Continuous tracer data, SNL site, August 6, 1982.
	• SF_6 concentrations in aircraft syringe samples, July 29, 1982.
	• SF_6 concentrations in aircraft syringe samples, July 31, 1982.
	• SF_6 concentrations in aircraft syringe samples, August 4, 1982.
	• SF_6 concentrations in aircraft syringe samples, August 6, 1982.
	• Wind speed at release height, PNL site, July 31, August 4, and August 6, 1982.
TETHER. NNL; 1	Tethered balloon profiles, SNL site, June 11, 1982.

No.	Date	Starting Time (decimal hrs, MST)
1	6-11-82	4.0564
2		4.9997
3		5.9669
4		7.0017
5		7.9975
6		9.0244
7		17.9075
8		18.9942
9		20.0019
10		21.0042
11		22.0019

TABLE A-1. (continued)

File Name	Contents
TETHER. PNL; 1	Tethered balloon profiles, PNL site, July/August Experiment, 1982.

No.	Date	Starting Time (decimal hrs, MST)
1	7-31-82	6.0217
2		6.4336
3		6.9942
4		7.4219
5		7.9703
6	8-04-82	3.8494
7		4.2761
8		4.7406
9		5.2636
10		5.9319
11		6.4553
12		6.8453
13		7.4311
14	8-06-82	3.8786
15		4.4544
16		4.9114
17		5.2919
18		6.3922
19		6.9008
20		7.2803
21		8.1319
22		9.0294

TABLE A-1. (continued)

File Name	Contents
TETHER. SNL; 1	Tethered balloon profiles, SNL site, July/August Experiment, 1982.

No.	Date	Starting Time (decimal hrs, MST)
1	7-31-82	3.7853
2		5.0722
3		6.2122
4		7.1544
5		8.2025
6		9.1919
7	8-04-82	3.5097
8		4.7597
9		6.1897
10		7.4025
11		8.6750
12	8-06-82	3.2953
13		4.8519
14		6.0769
15		7.2631
16		8.4447
17		9.4436

File Name	Contents
JULY31.CMB;1	One-second time series of aircraft data, including date, time, SF_6 concentration, altitude, latitude, longitude, air speed, ground speed, wind direction and wind speed data for July 31, 1982.
AUG4.CMB;1	One-second time series of aircraft data, including date, time, SF_6 concentration, altitude, latitude, longitude, air speed, ground speed, wind direction and wind speed data for August 4, 1982.
AUG6.CMB;1	One-second time series of aircraft data, including date, time, SF_6 concentration, altitude, latitude, longitude, air speed, ground speed, wind direction and wind speed data for August 6, 1982.

APPENDIX B

WEATHER CHARTS

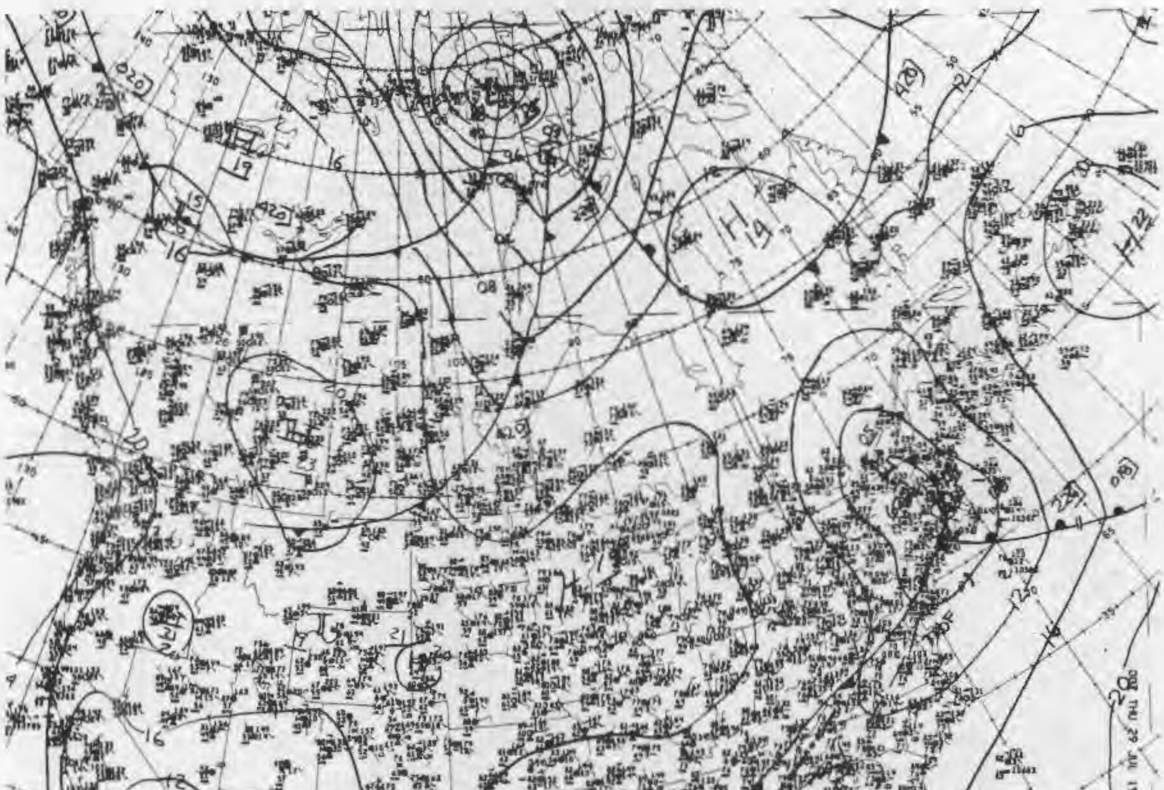

Figure B-1. Surface weather chart, July 29, 1982, 0000 GMT.

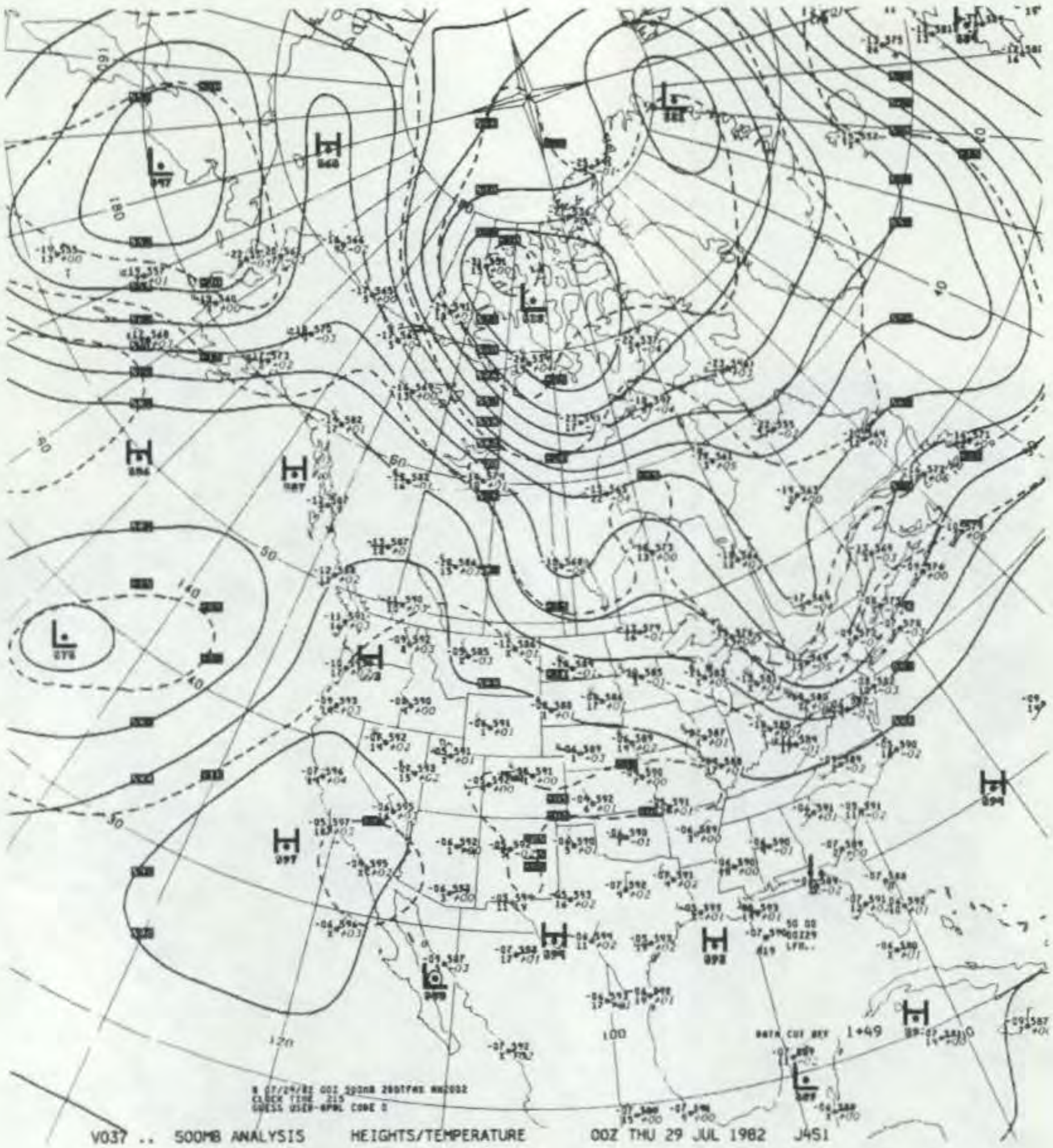

Figure B-2. 500 mb chart, July 29, 1982, 0000 GMT.

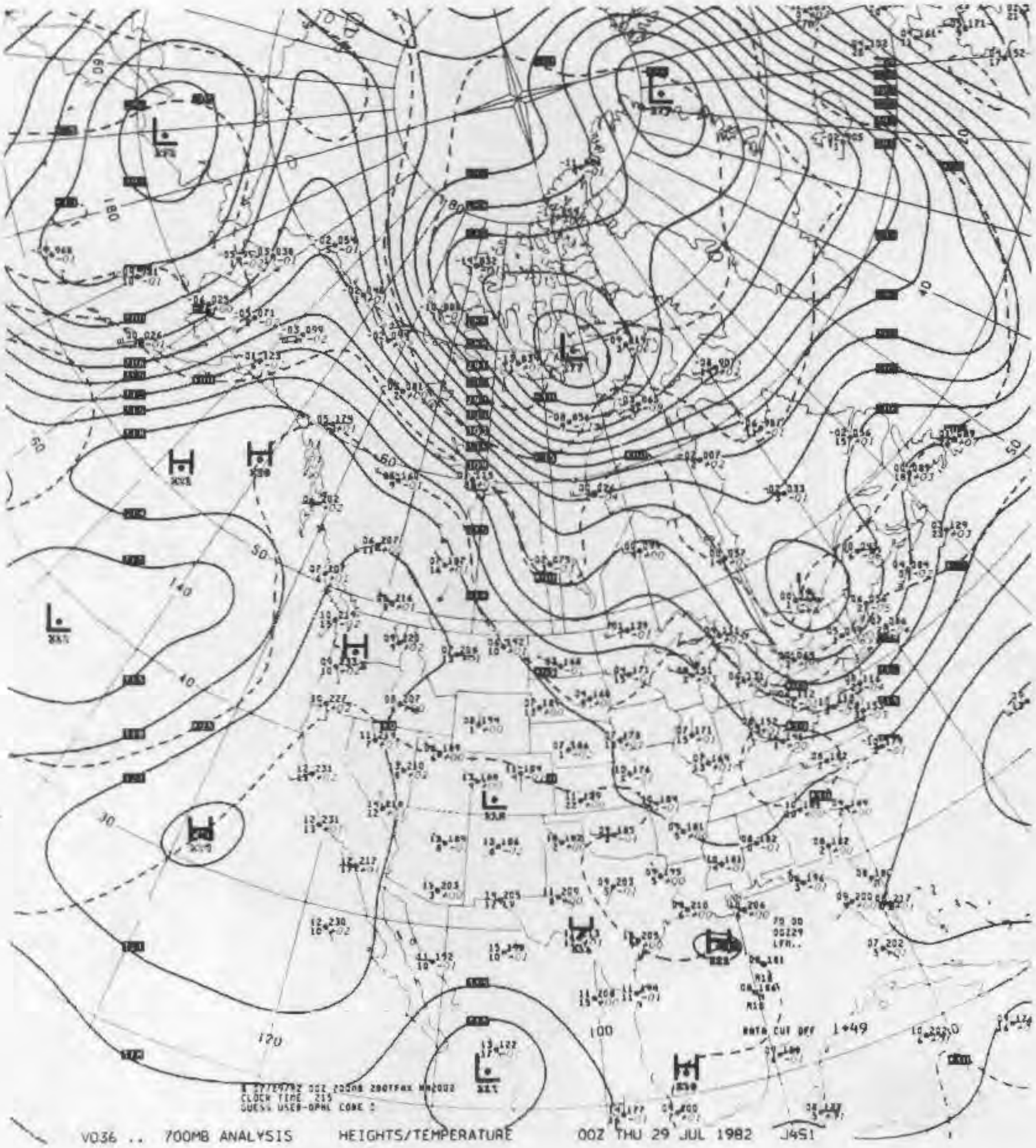

Figure B-3. 700 mb chart, July 29, 1982, 0000 GMT.

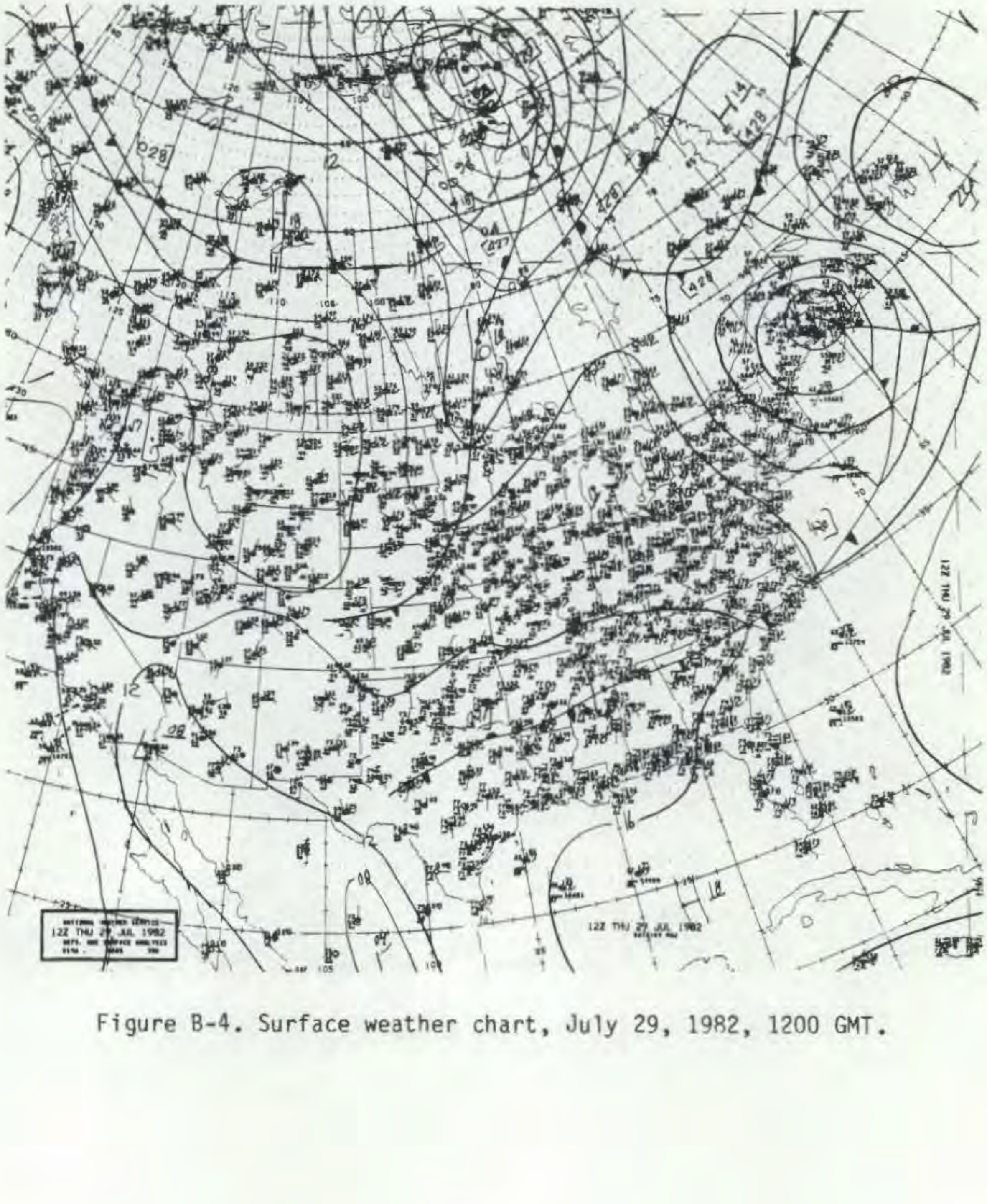

Figure B-4. Surface weather chart, July 29, 1982, 1200 GMT.

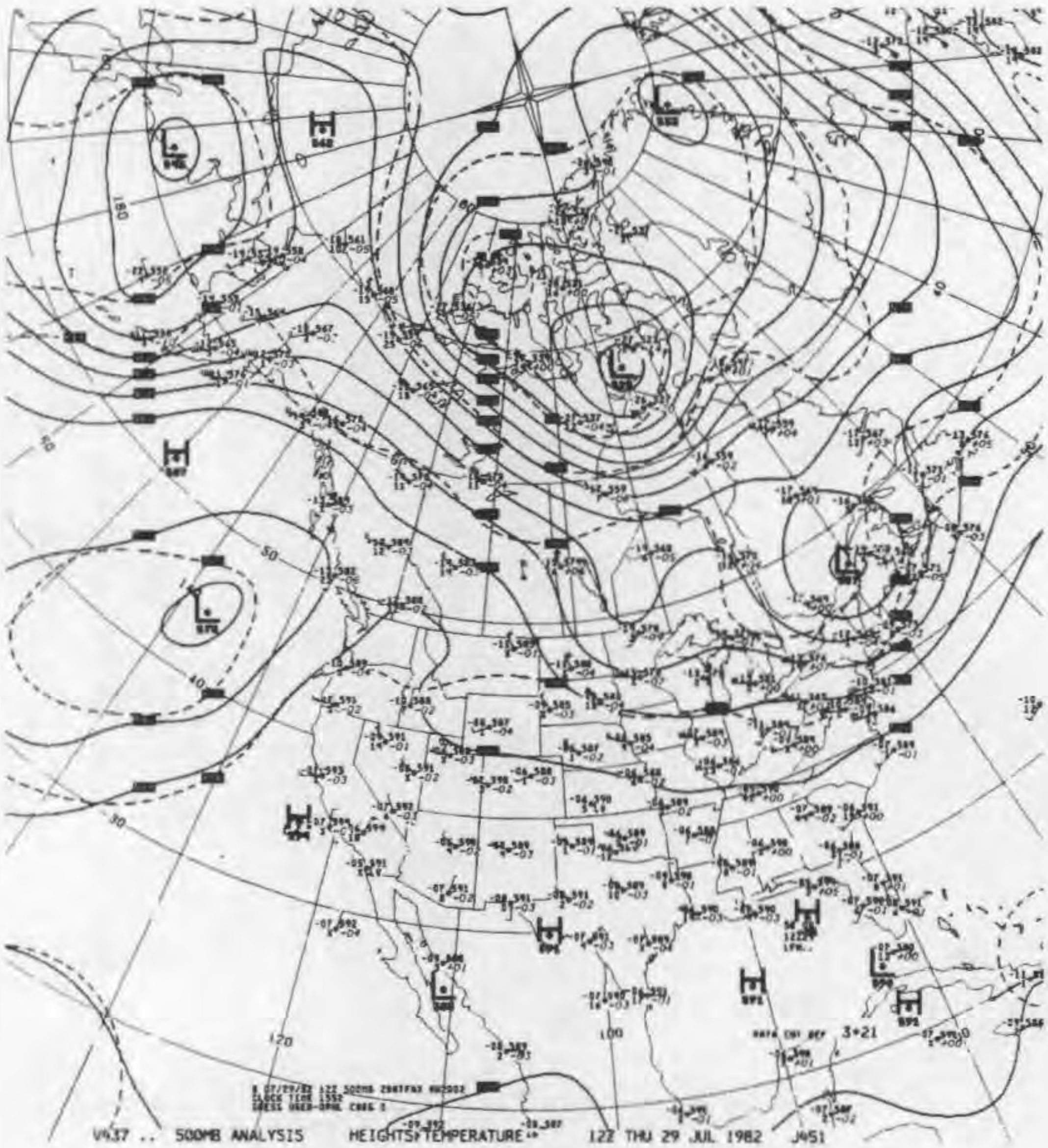

Figure B-5. 500 mb chart, July 29, 1982, 1200 GMT.

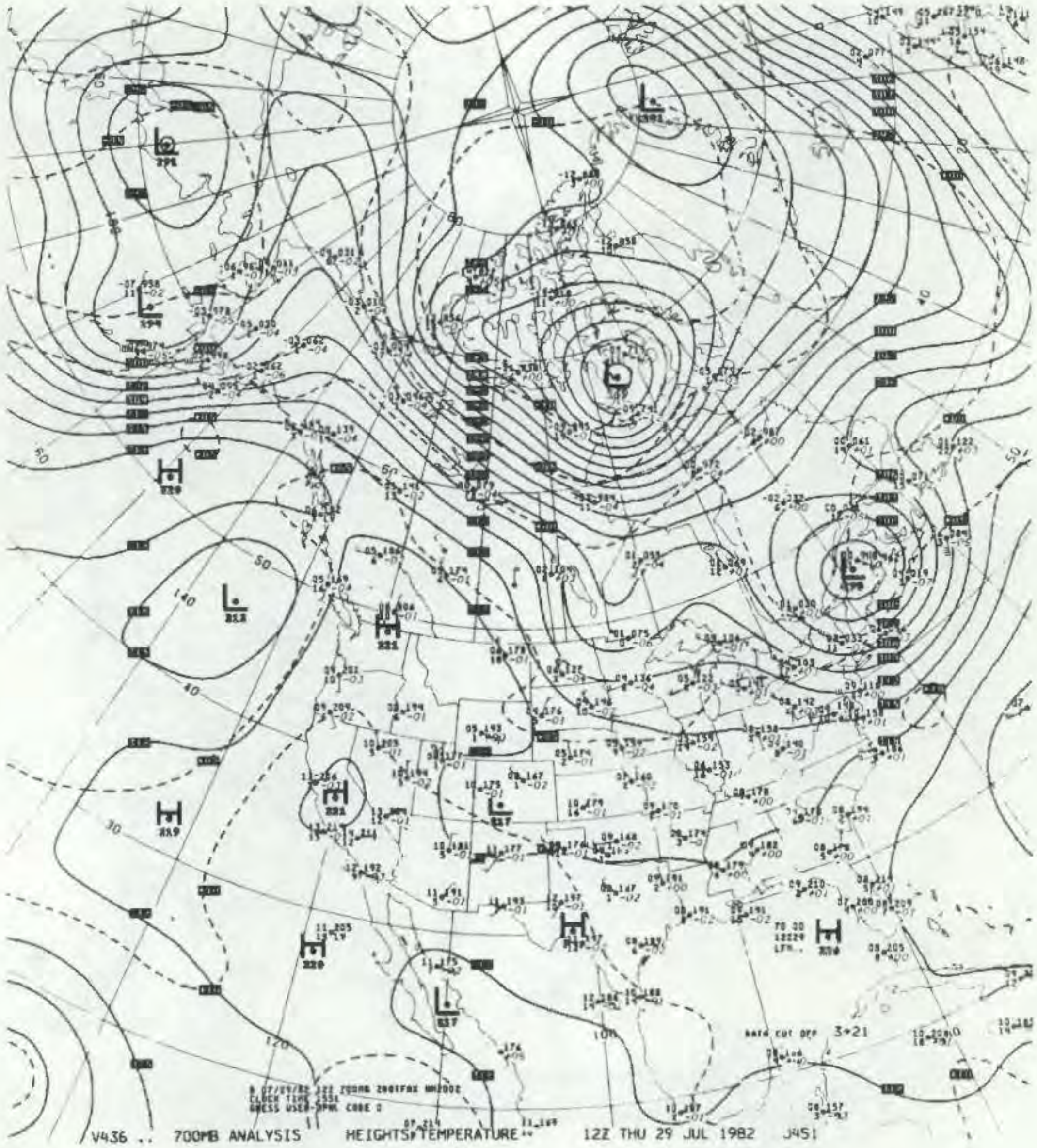

Figure B-6. 700 mb chart, July 29, 1982, 1200 GMT.

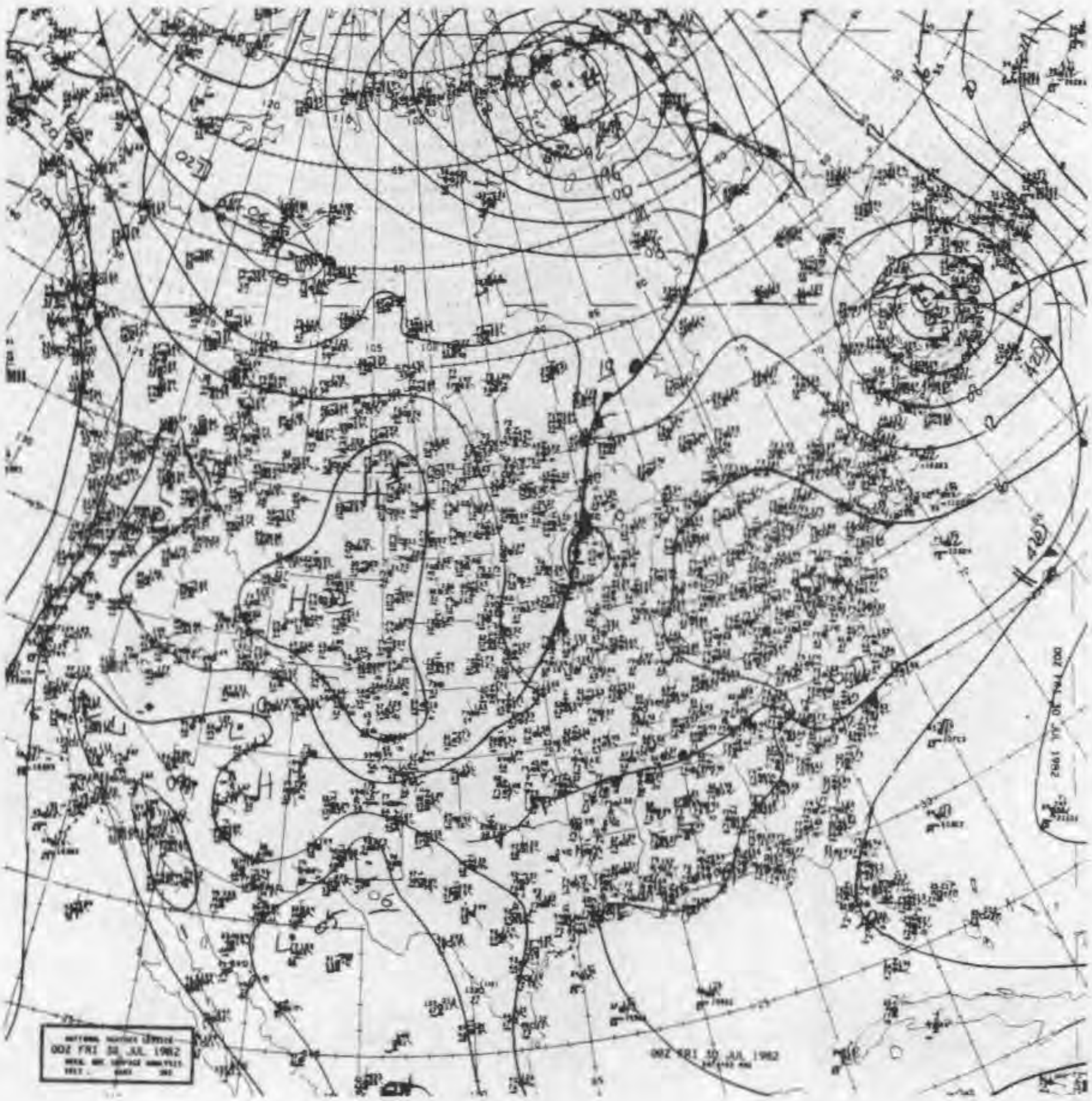

Figure B-7. Surface weather chart, July 30, 1982, 0000 GMT.

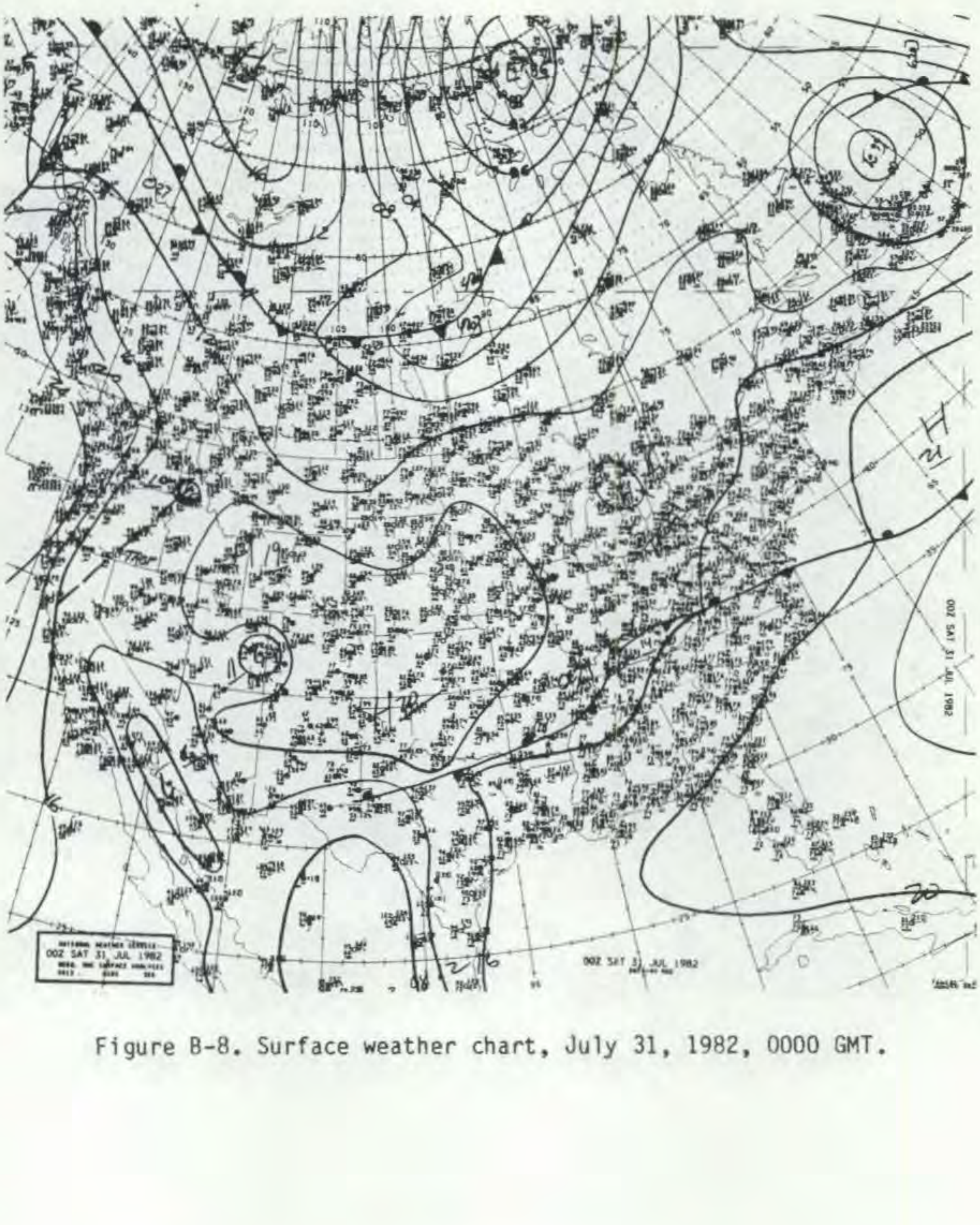

Figure B-8. Surface weather chart, July 31, 1982, 0000 GMT.

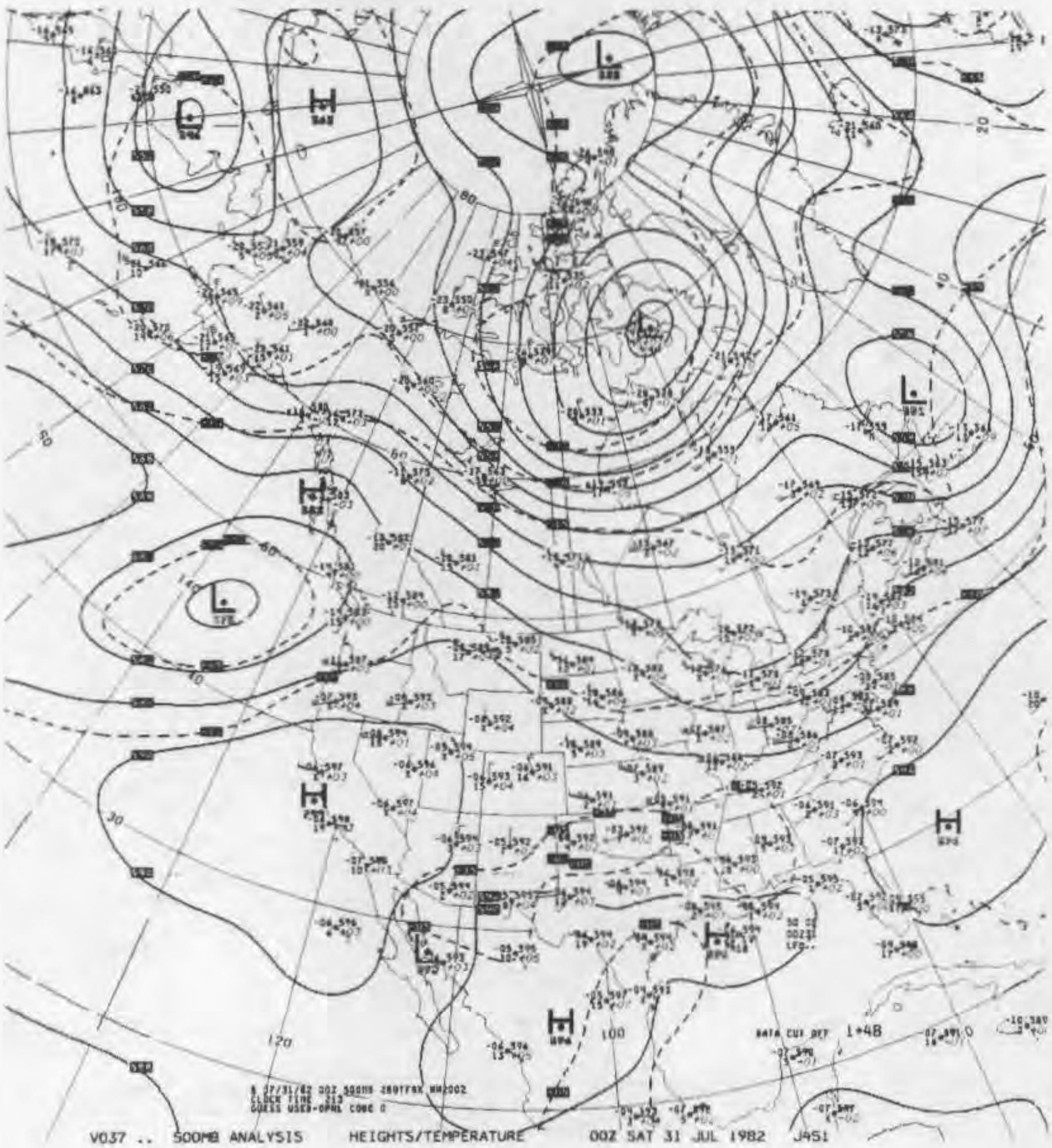

Figure B-9. 500 mb chart, July 31, 1982, 0000 GMT.

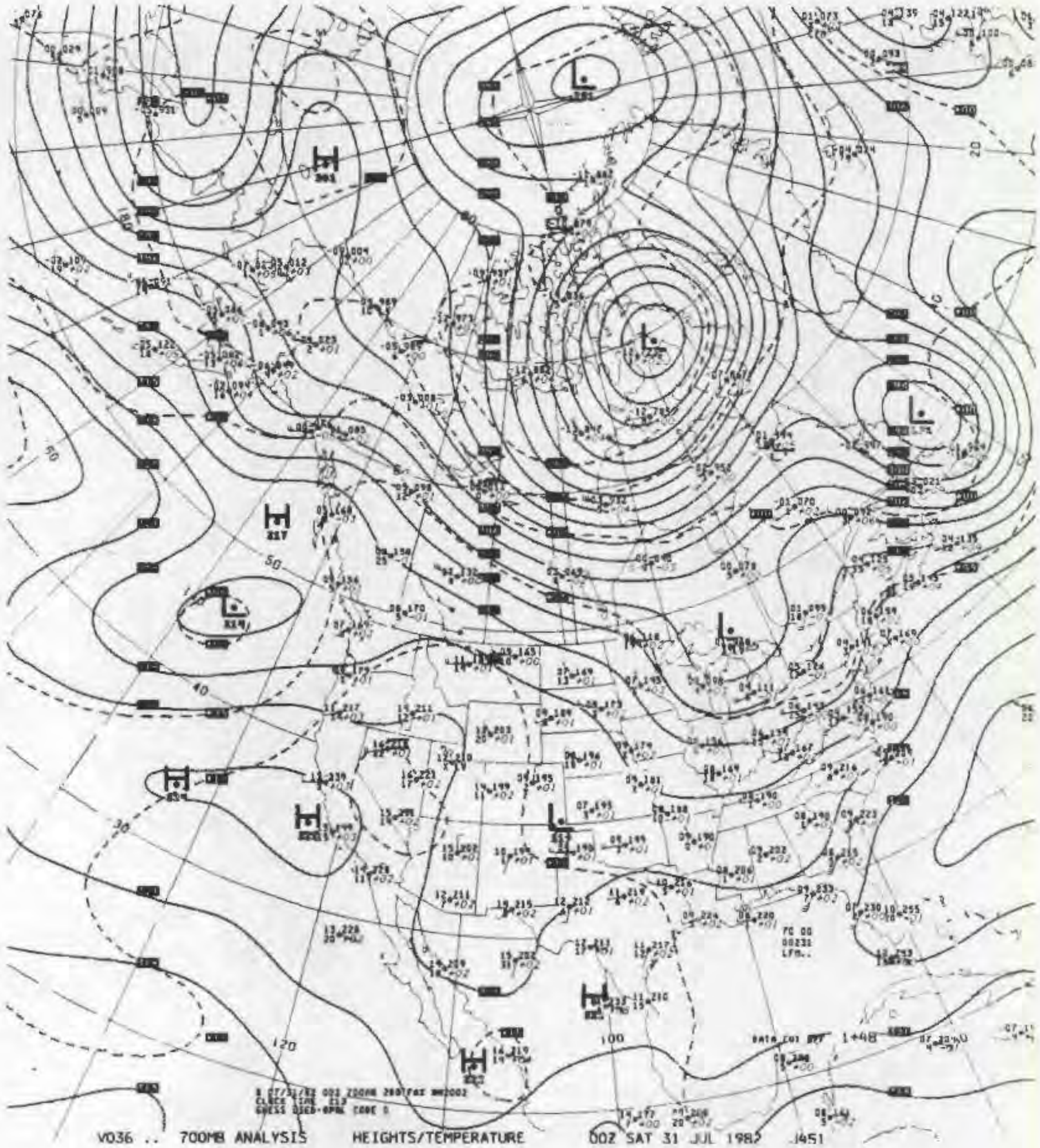

Figure B-10. 700 mb chart, July 31, 1982, 0000 GMT.

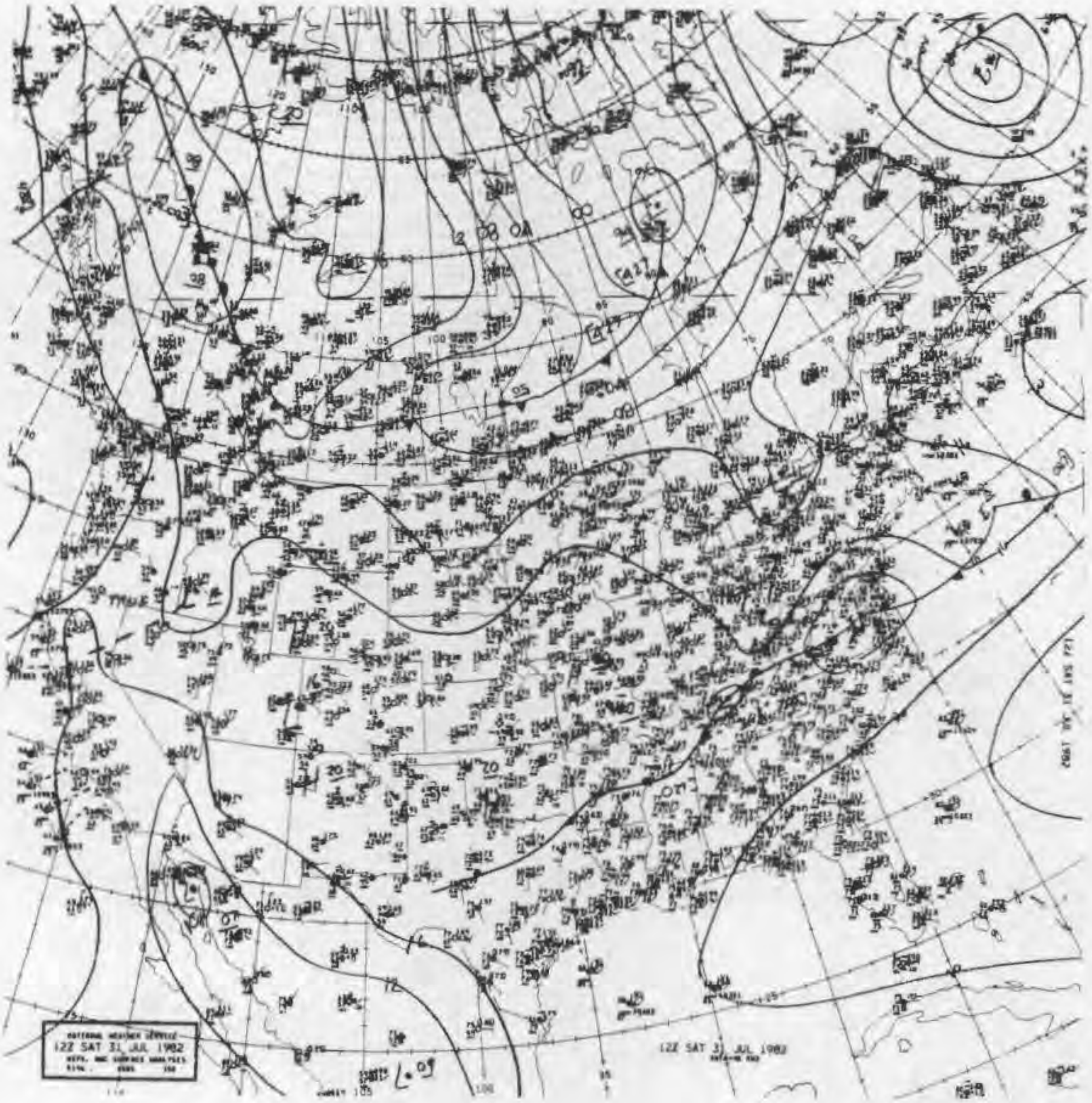

Figure B-11. Surface weather chart, July 31, 1982, 1200 GMT.

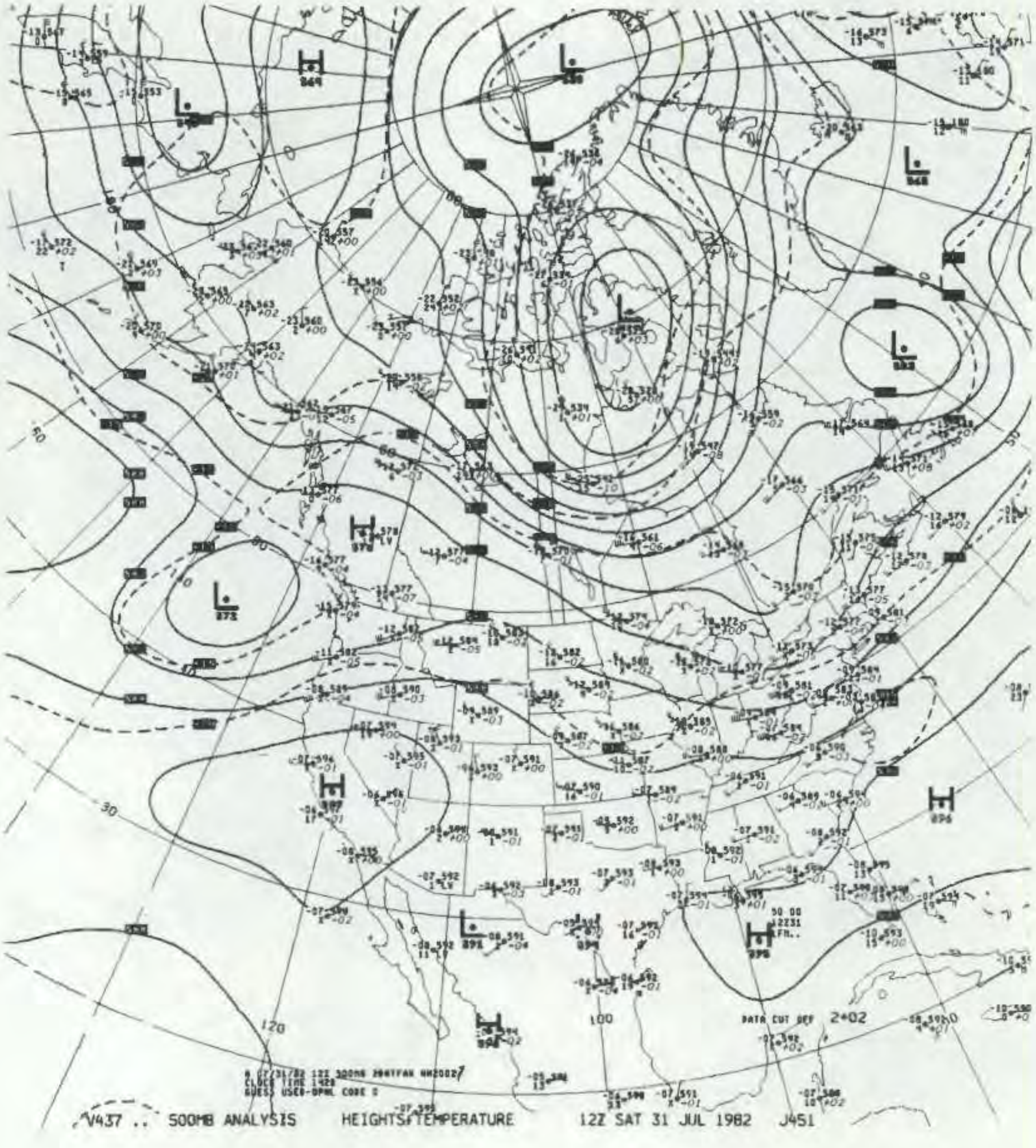

Figure B-12. 500 mb chart, July 31, 1982, 1200 GMT.

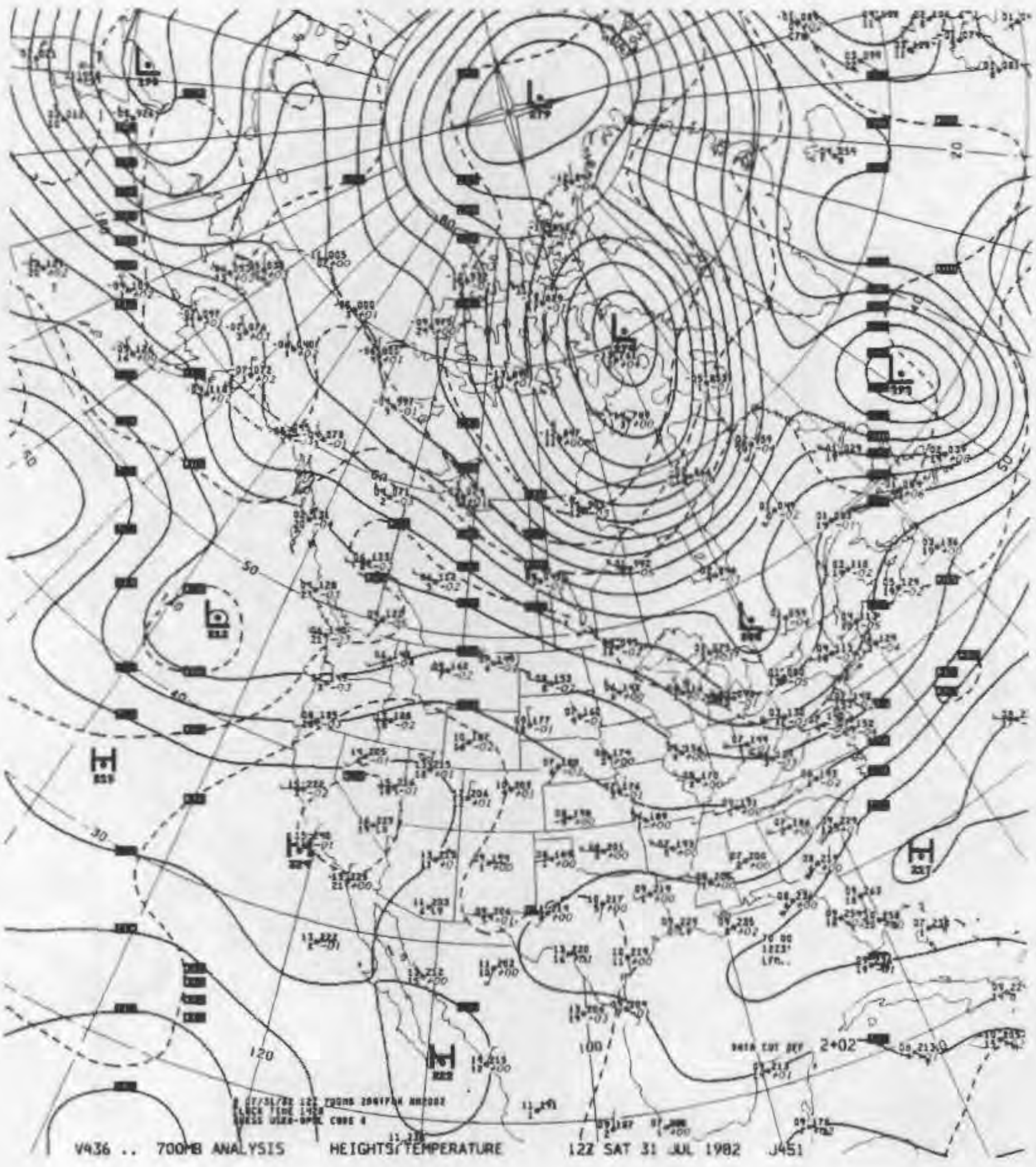

Figure B-13. 700 mb chart, July 31, 1982, 1200 GMT.

Figure B-14. Surface weather chart, August 1, 1982, 0000 GMT.

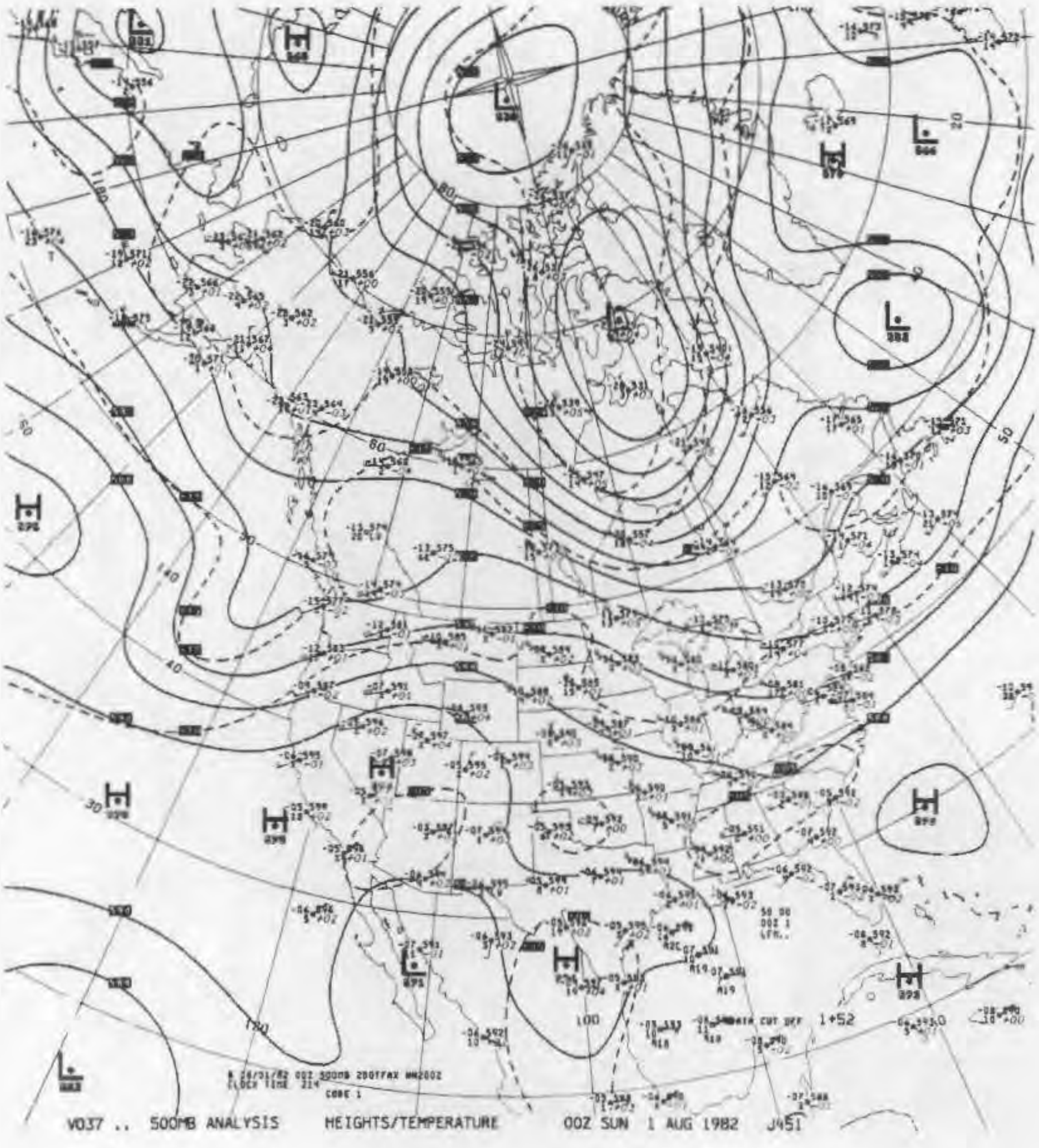

Figure B-15. 500 mb chart, August 1, 1982, 0000 GMT.

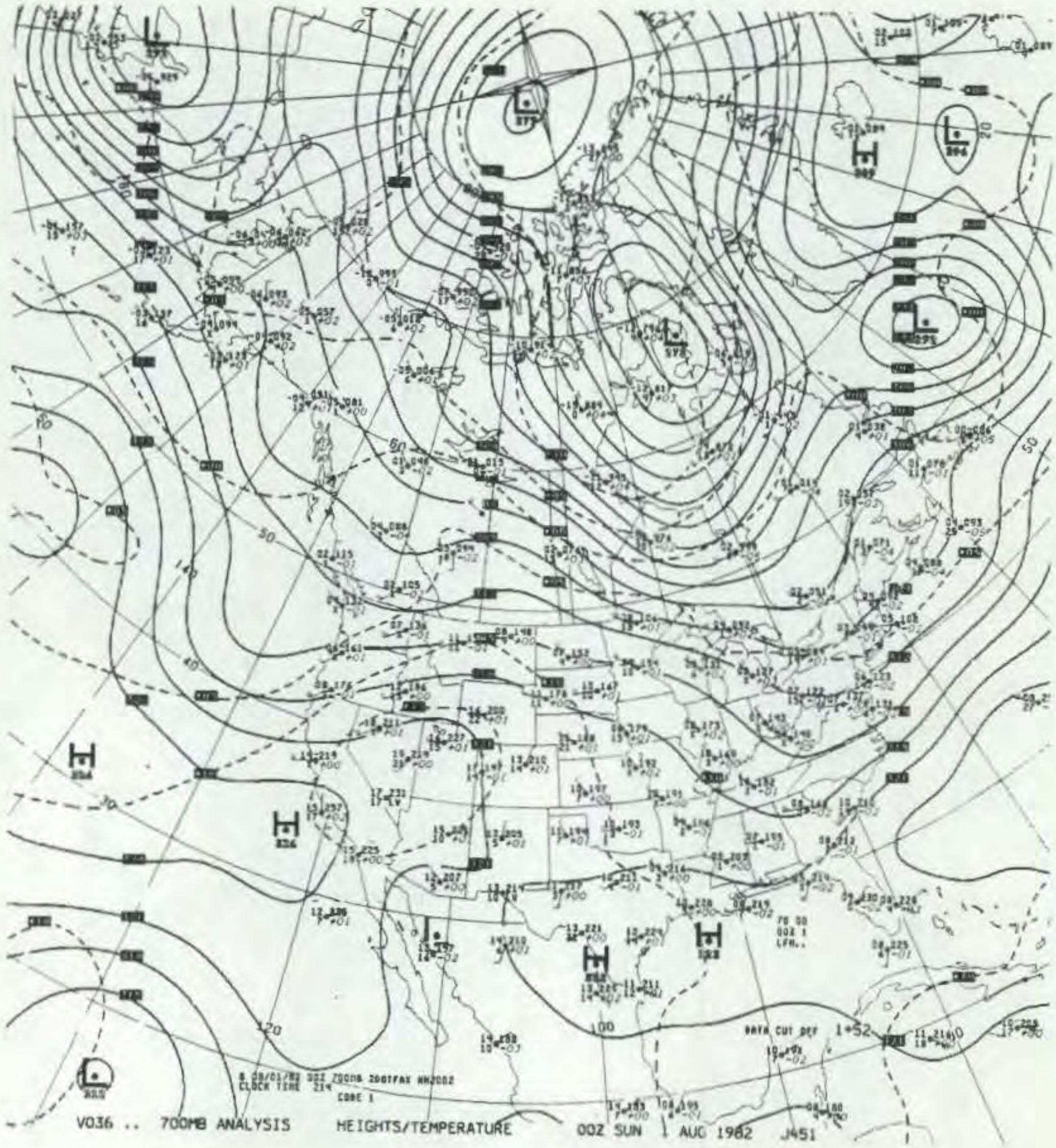

Figure B-16. 700 mb chart, August 1, 1982, 0000 GMT.

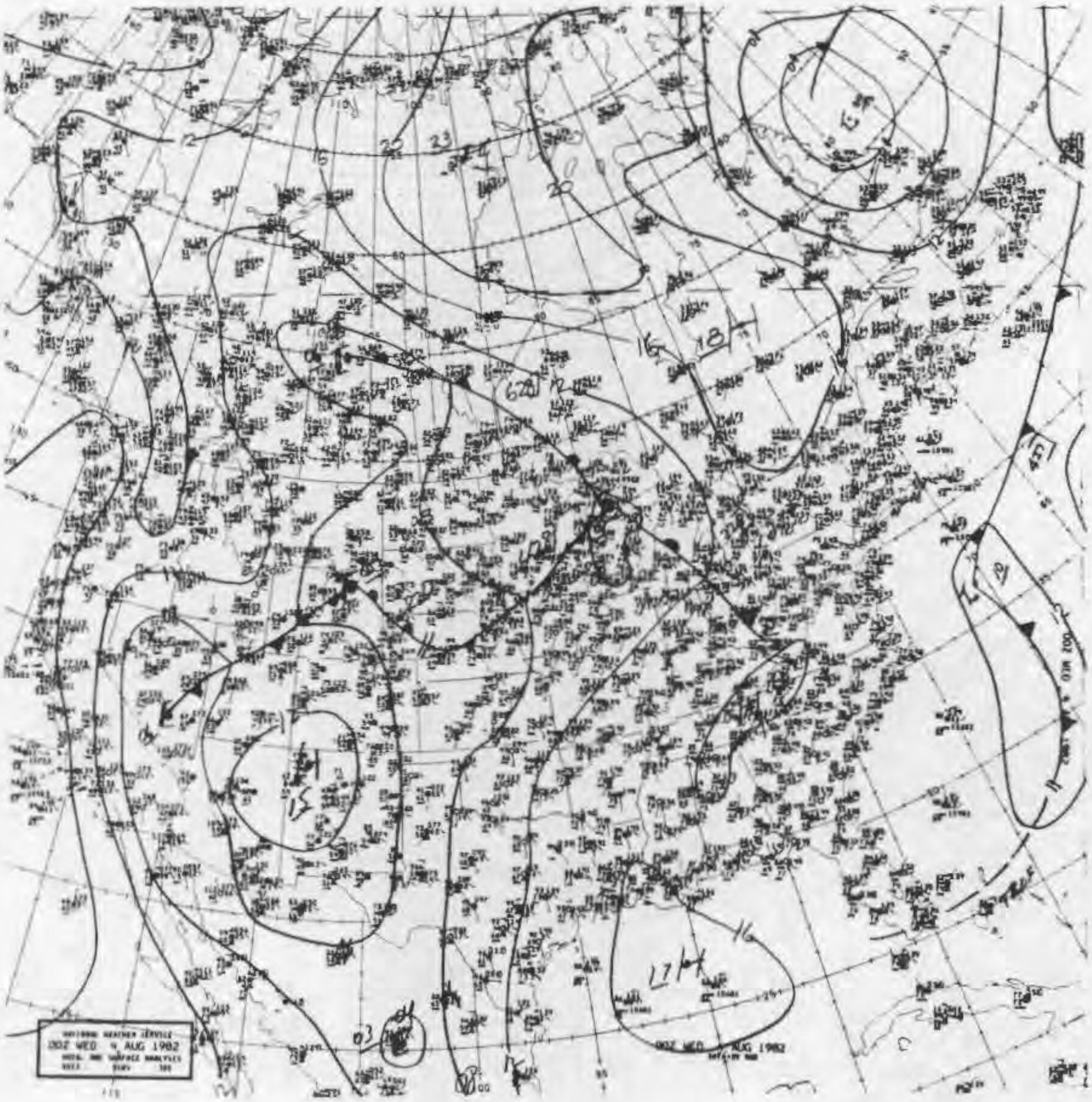

Figure B-17. Surface weather chart, August 4, 1982, 0000 GMT.

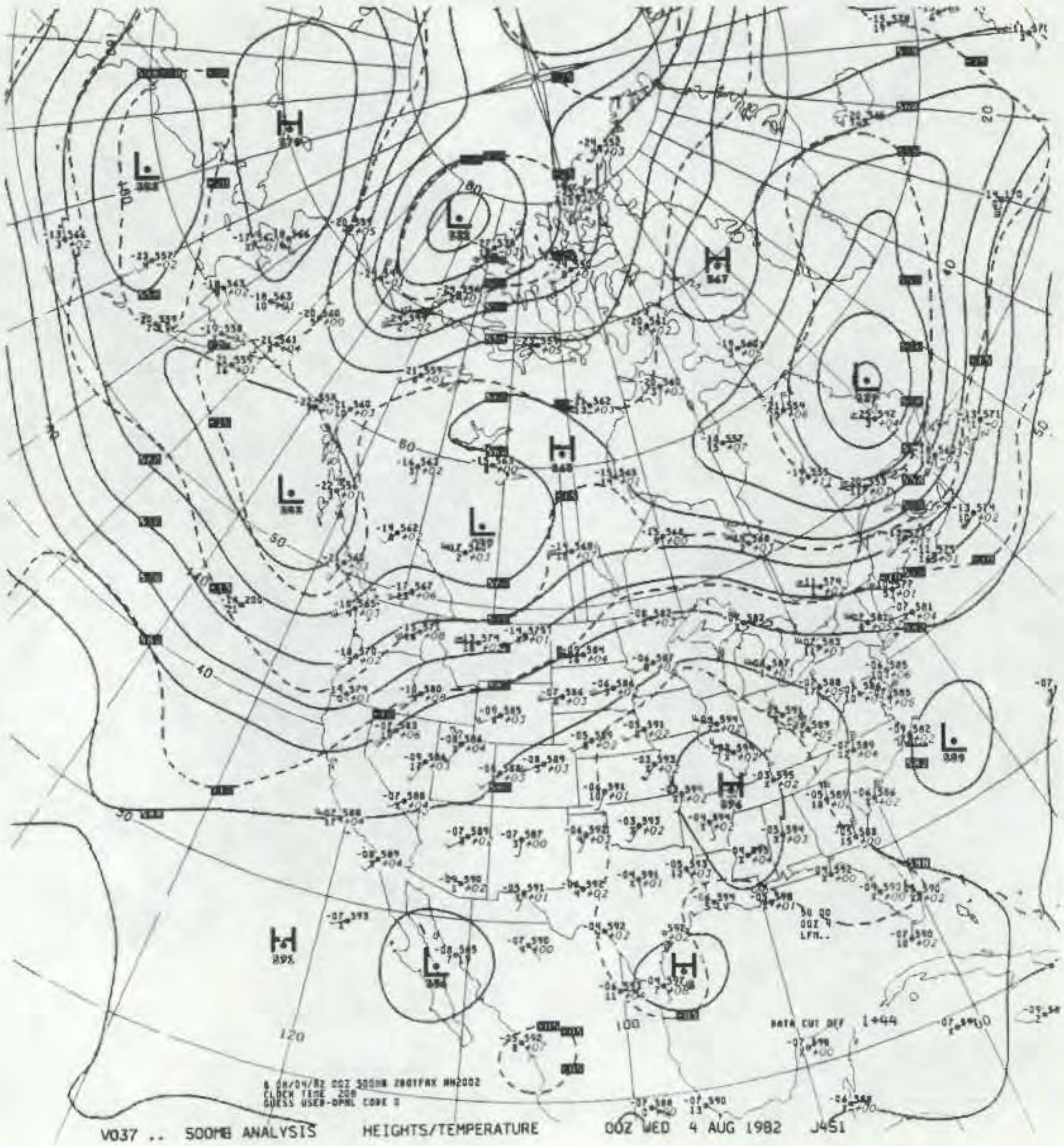

Figure B-18. 500 mb chart, August 4, 1982, 0000 GMT.

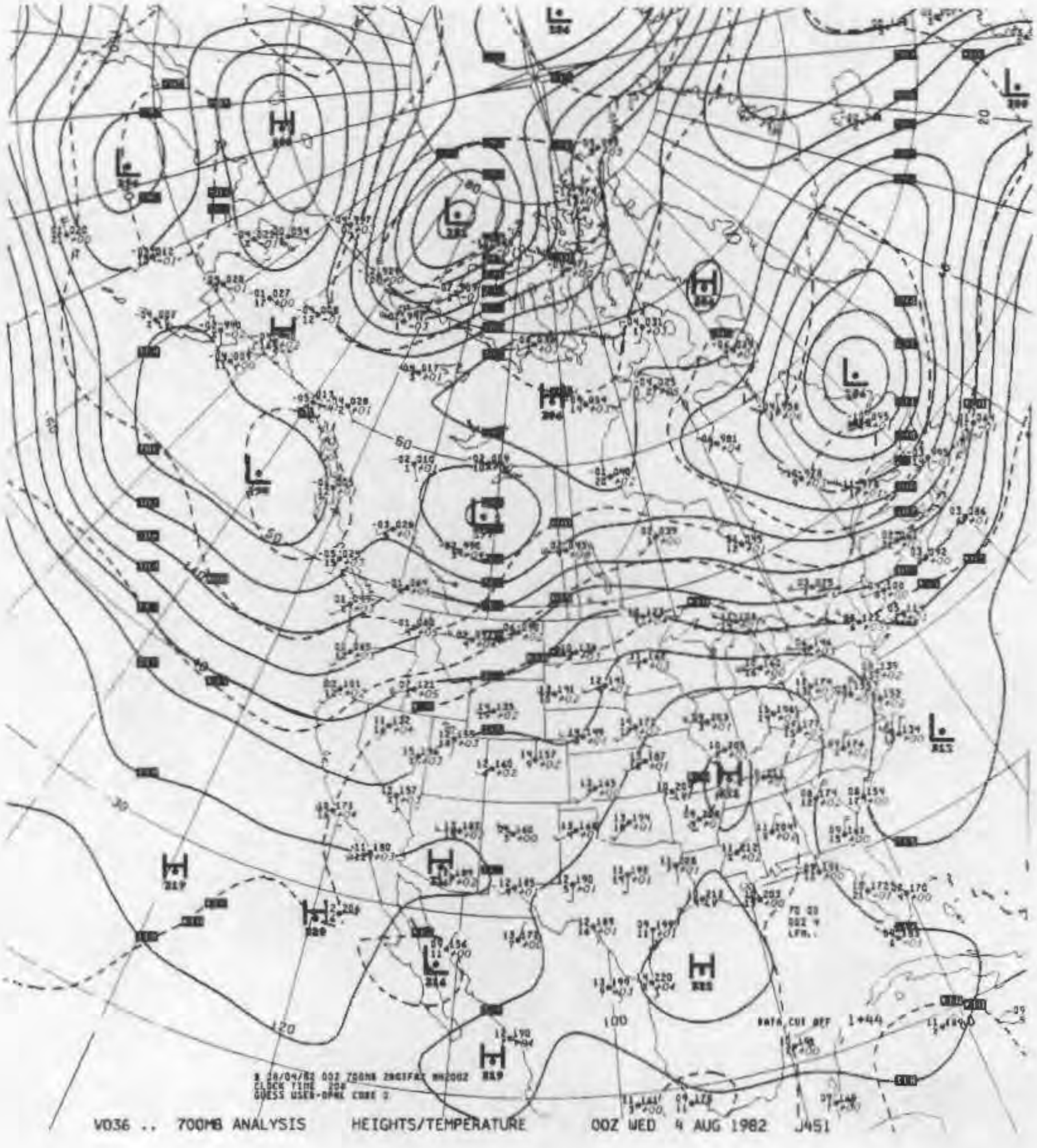

Figure B-19. 700 mb chart, August 4, 1982, 0000 GMT.

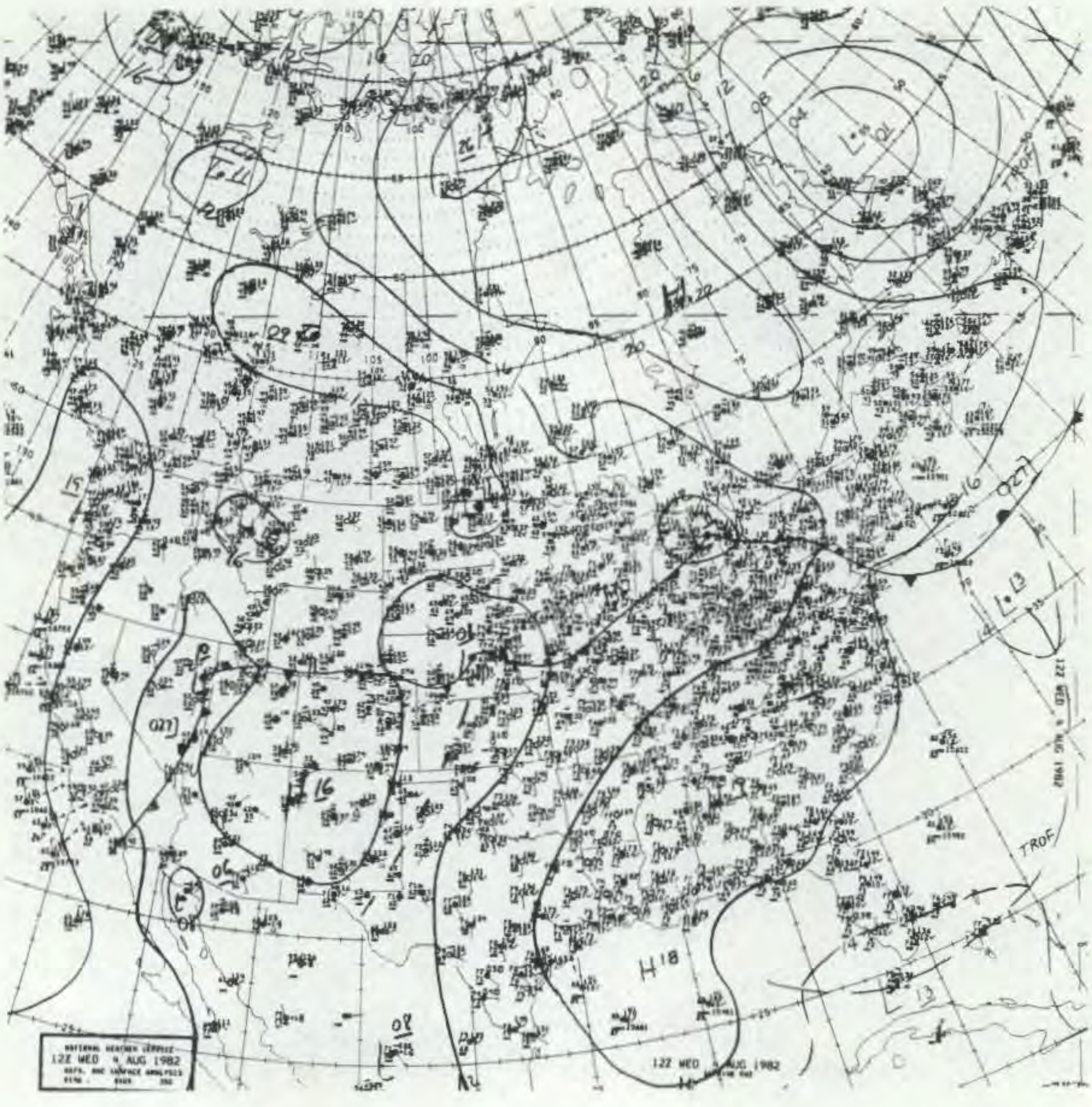

Figure B-20. Surface weather chart, August 4, 1982, 1200 GMT.

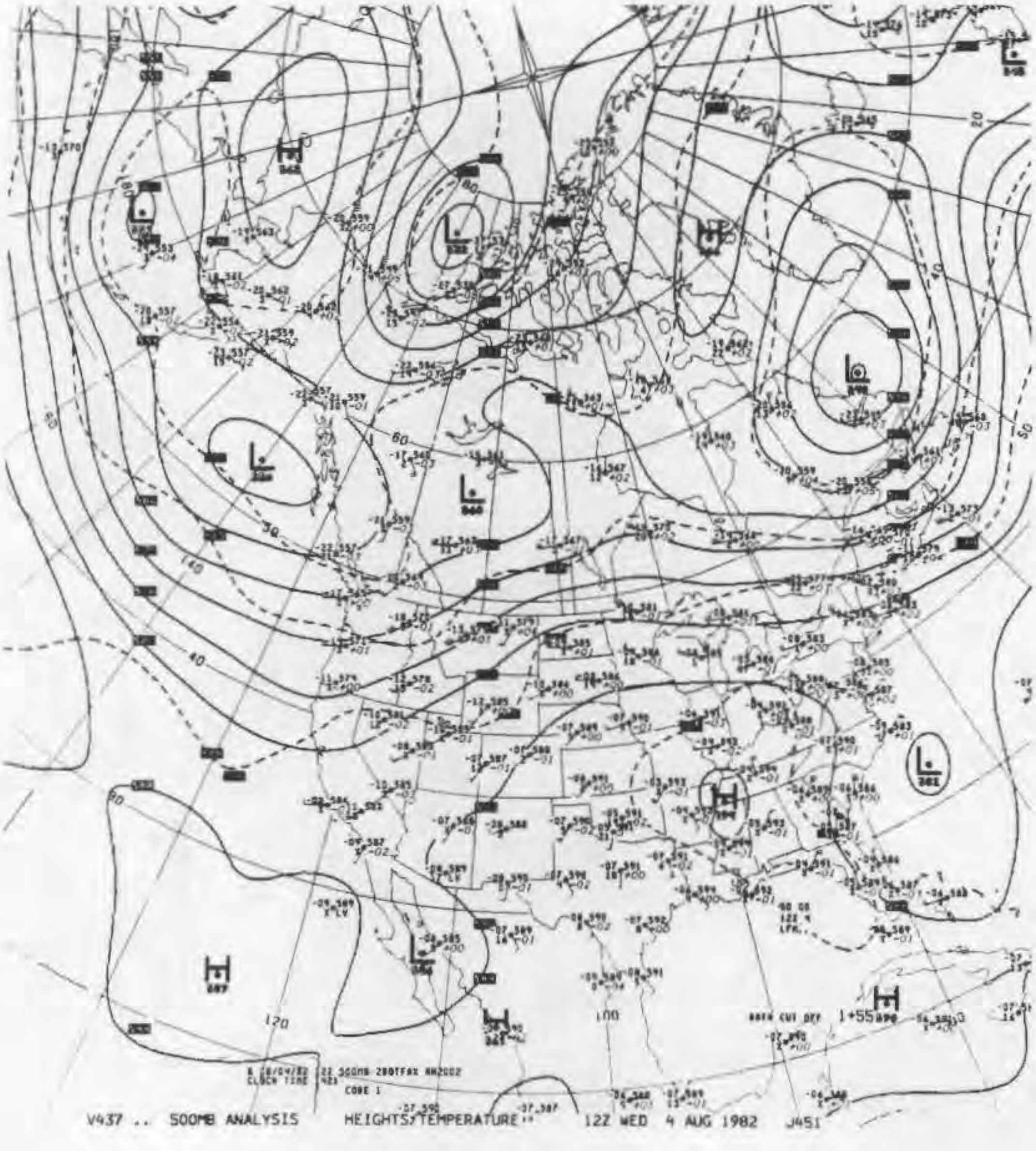

Figure B-21. 500 mb chart, August 4, 1982, 1200 GMT.

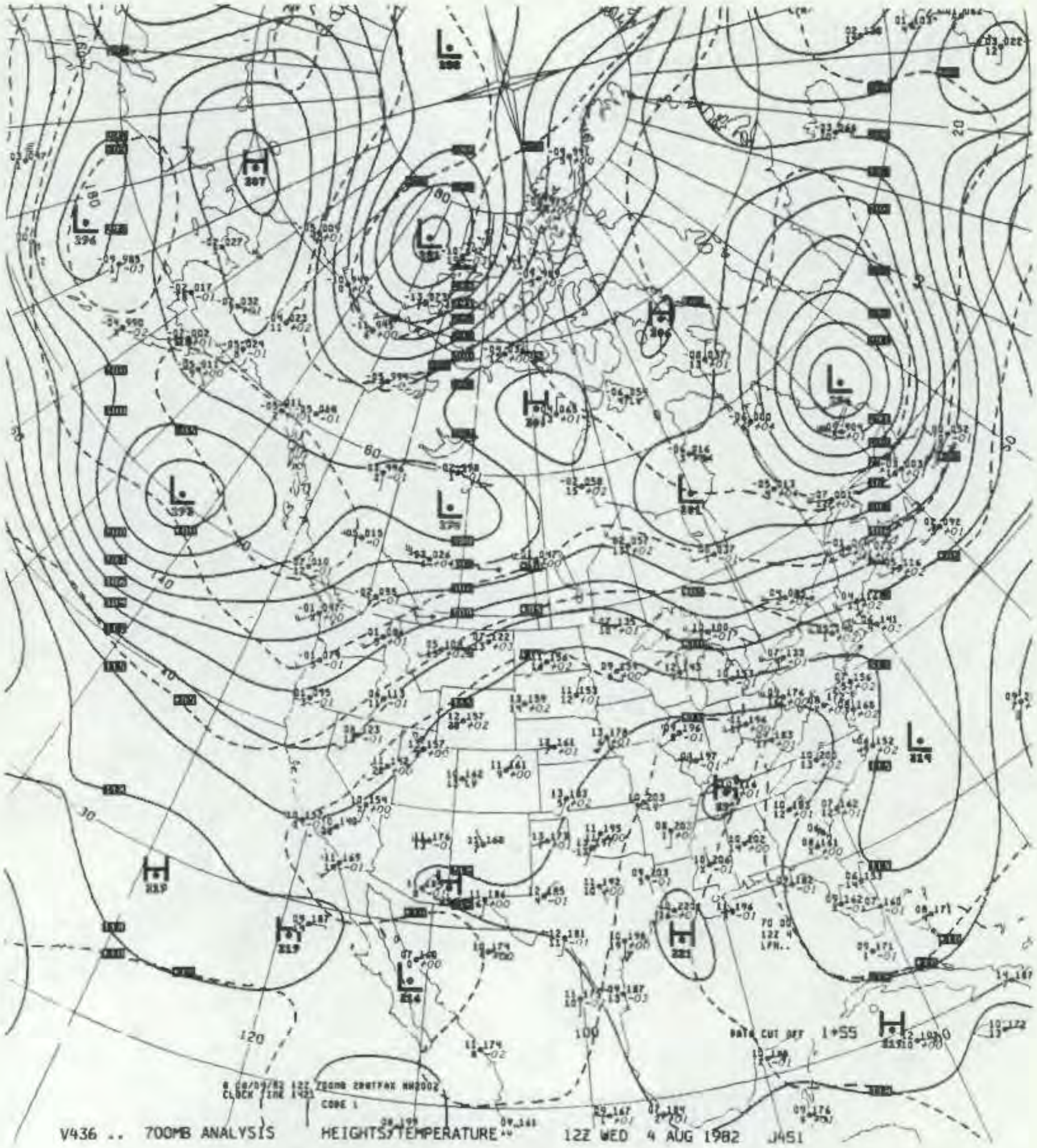

Figure B-22. 700 mb chart, August 4, 1982, 1200 GMT.

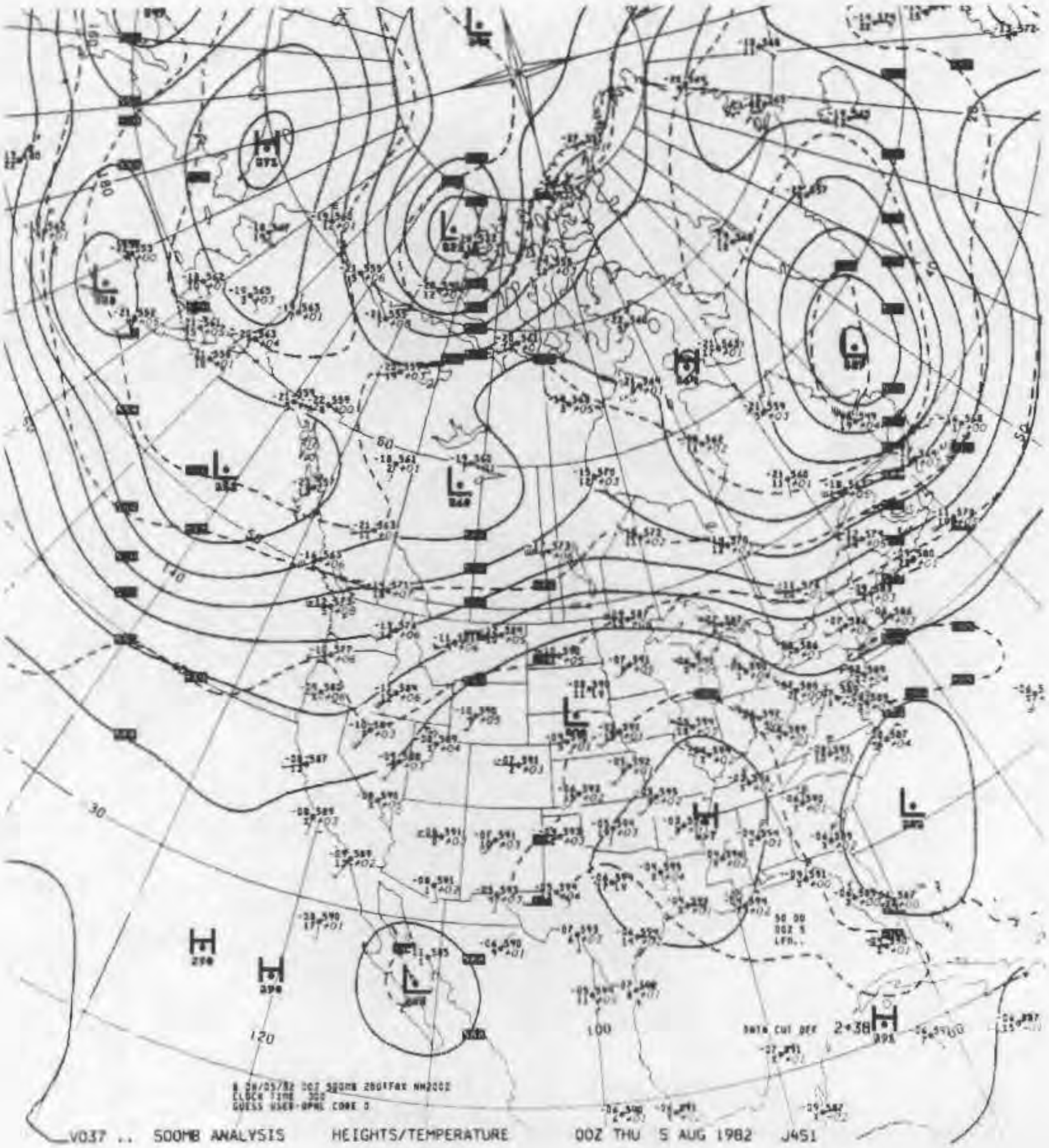

Figure B-23. 500 mb chart, August 5, 1982, 0000 GMT.

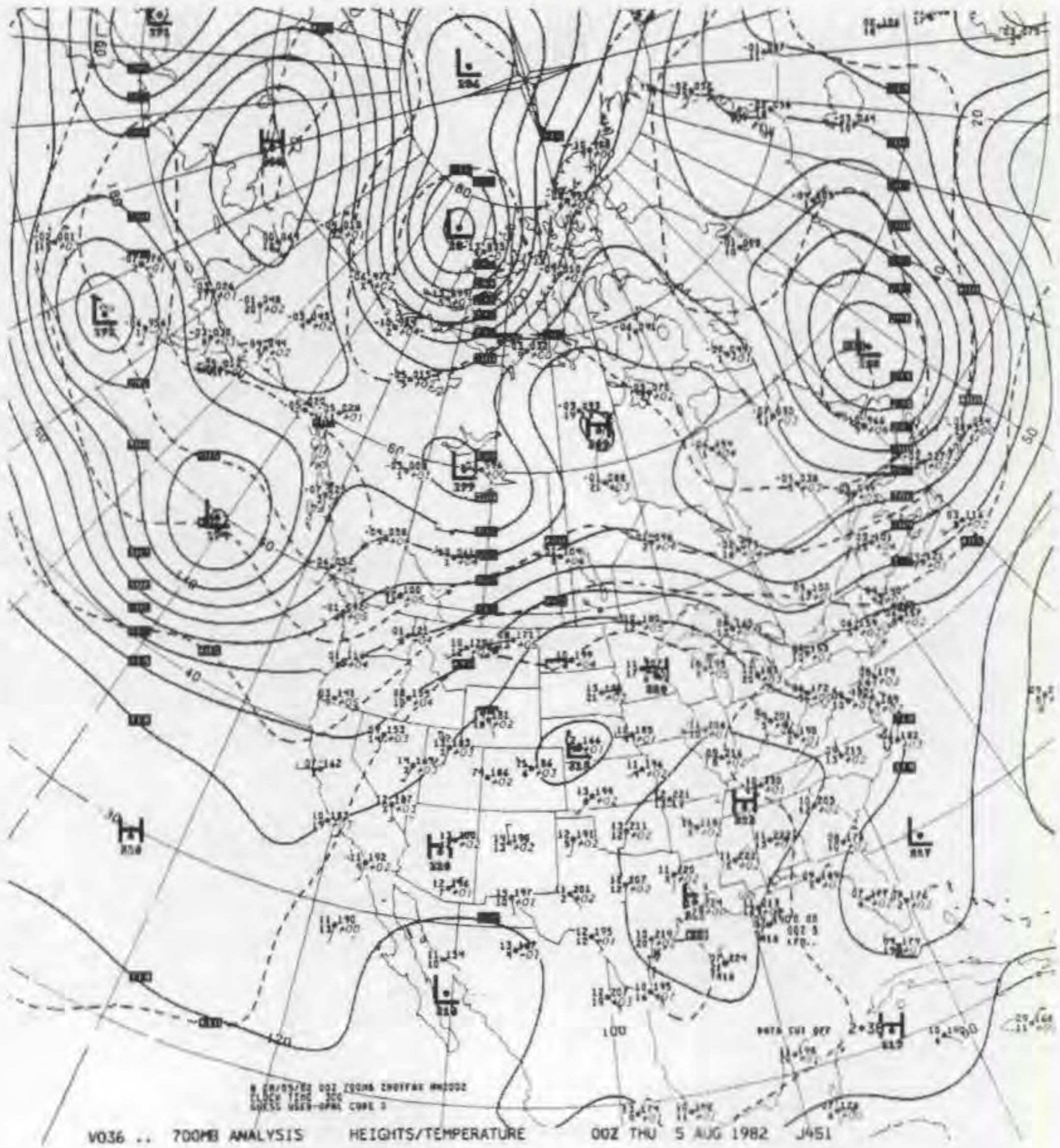

Figure B-24. 700 mb chart, August 5, 1982, 0000 GMT.

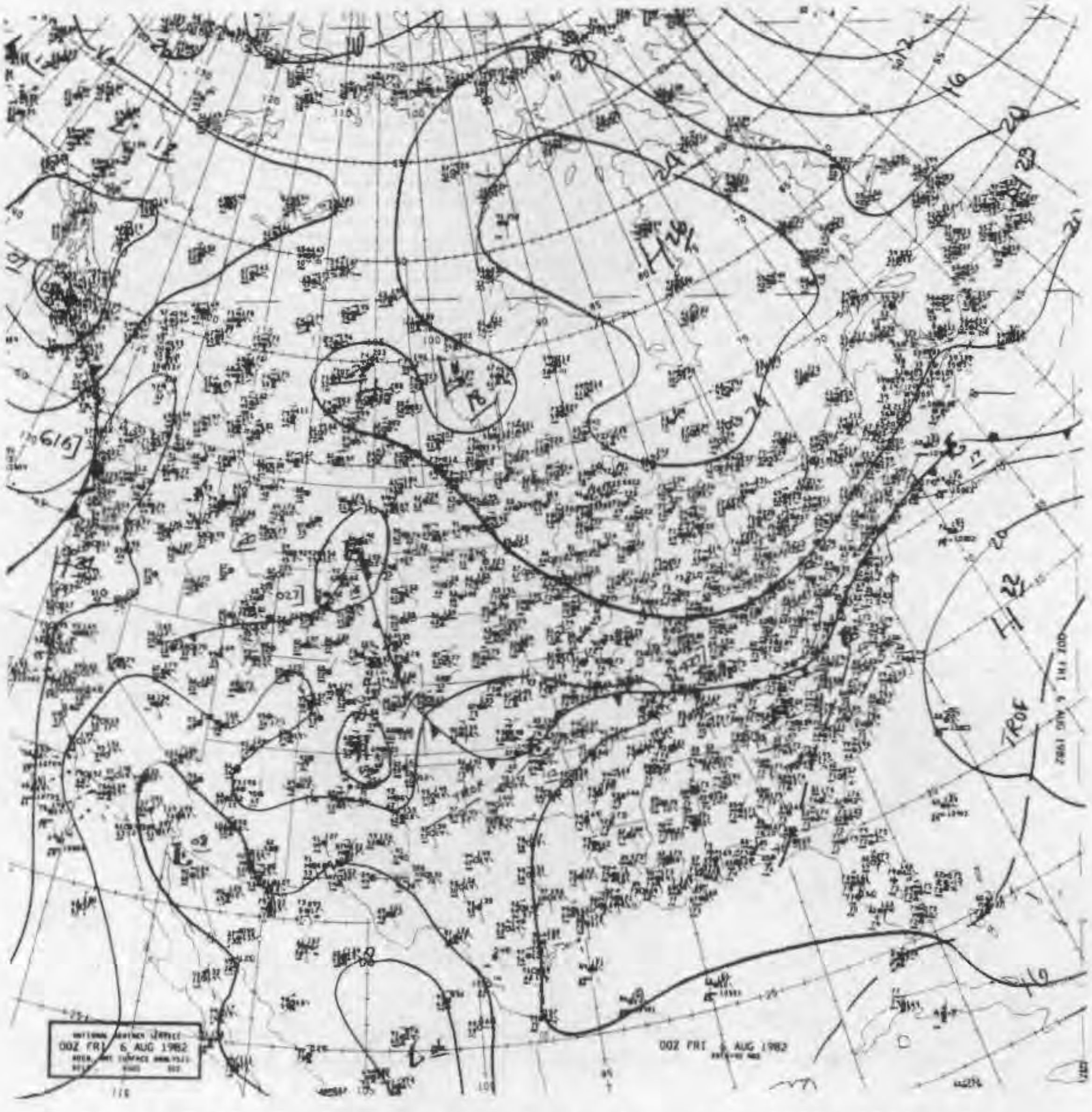

Figure B-25. Surface weather chart, August 6, 1982, 0000 GMT.

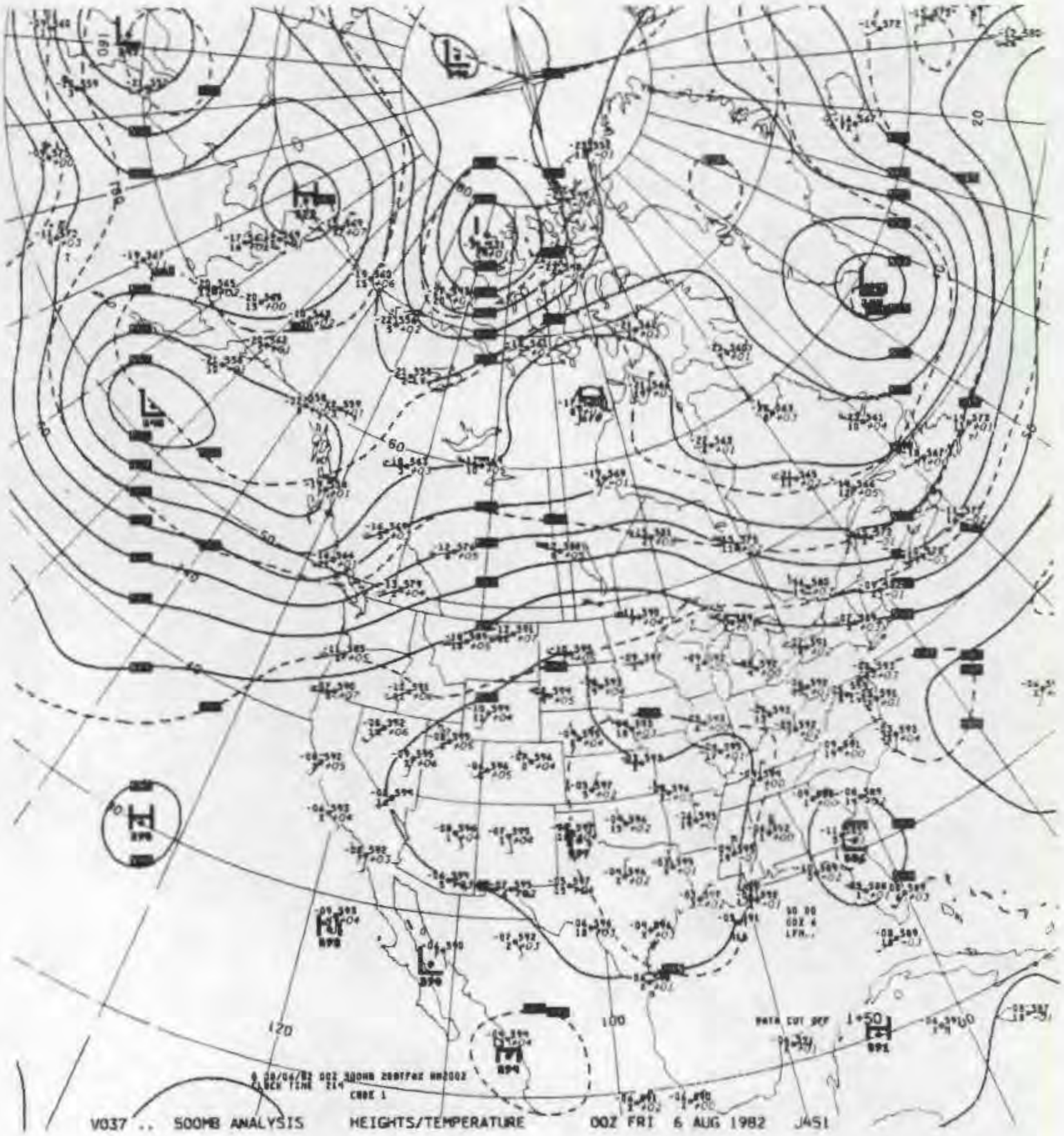

Figure B-26. 500 mb chart, August 6, 1982, 0000 GMT.

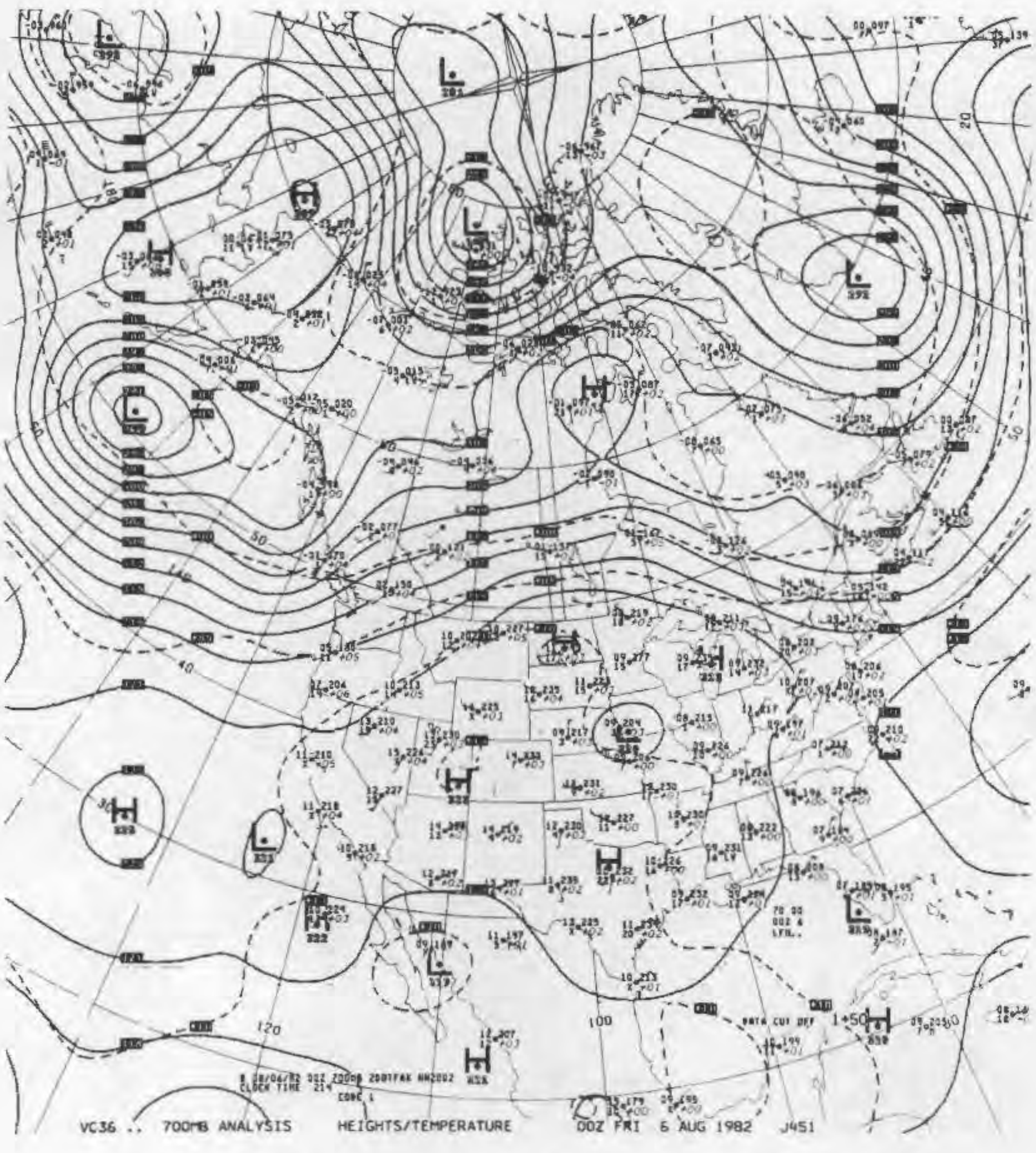

Figure B-27. 700 mb chart, August 6, 1982, 0000 GMT.

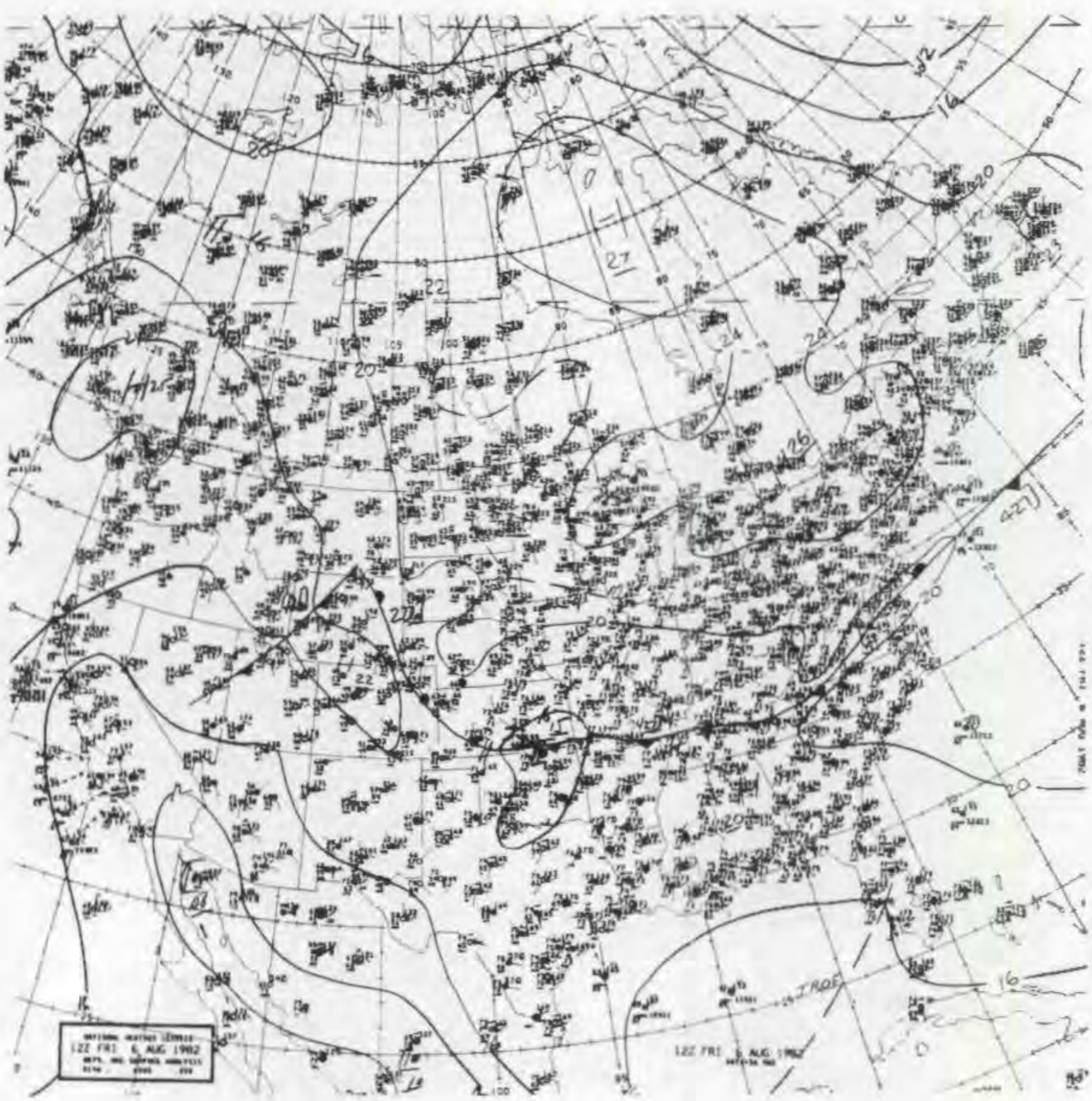

Figure B-28. Surface weather chart, August 6, 1982, 1200 GMT.

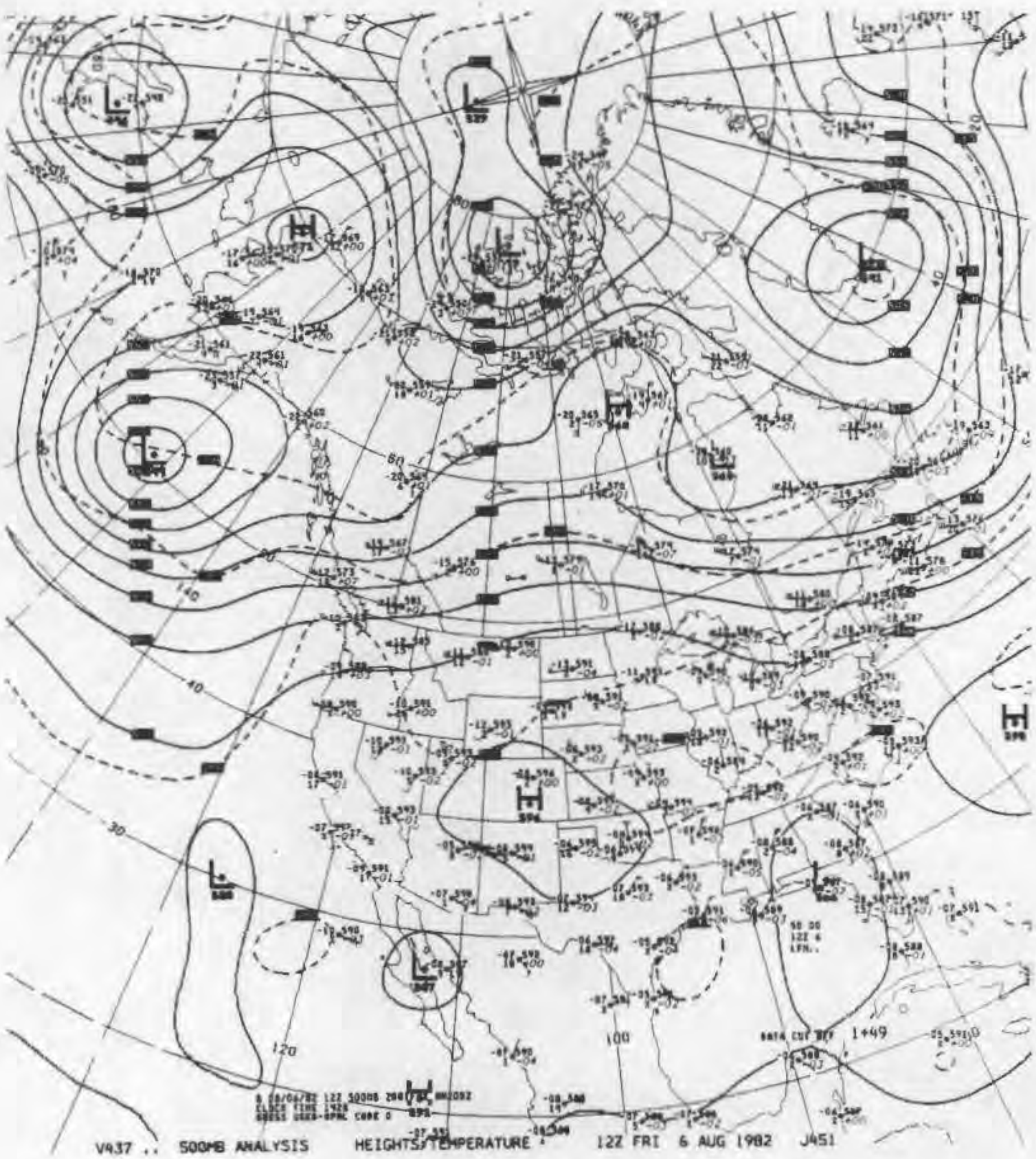

Figure B-29. 500 mb chart, August 6, 1982, 1200 GMT.

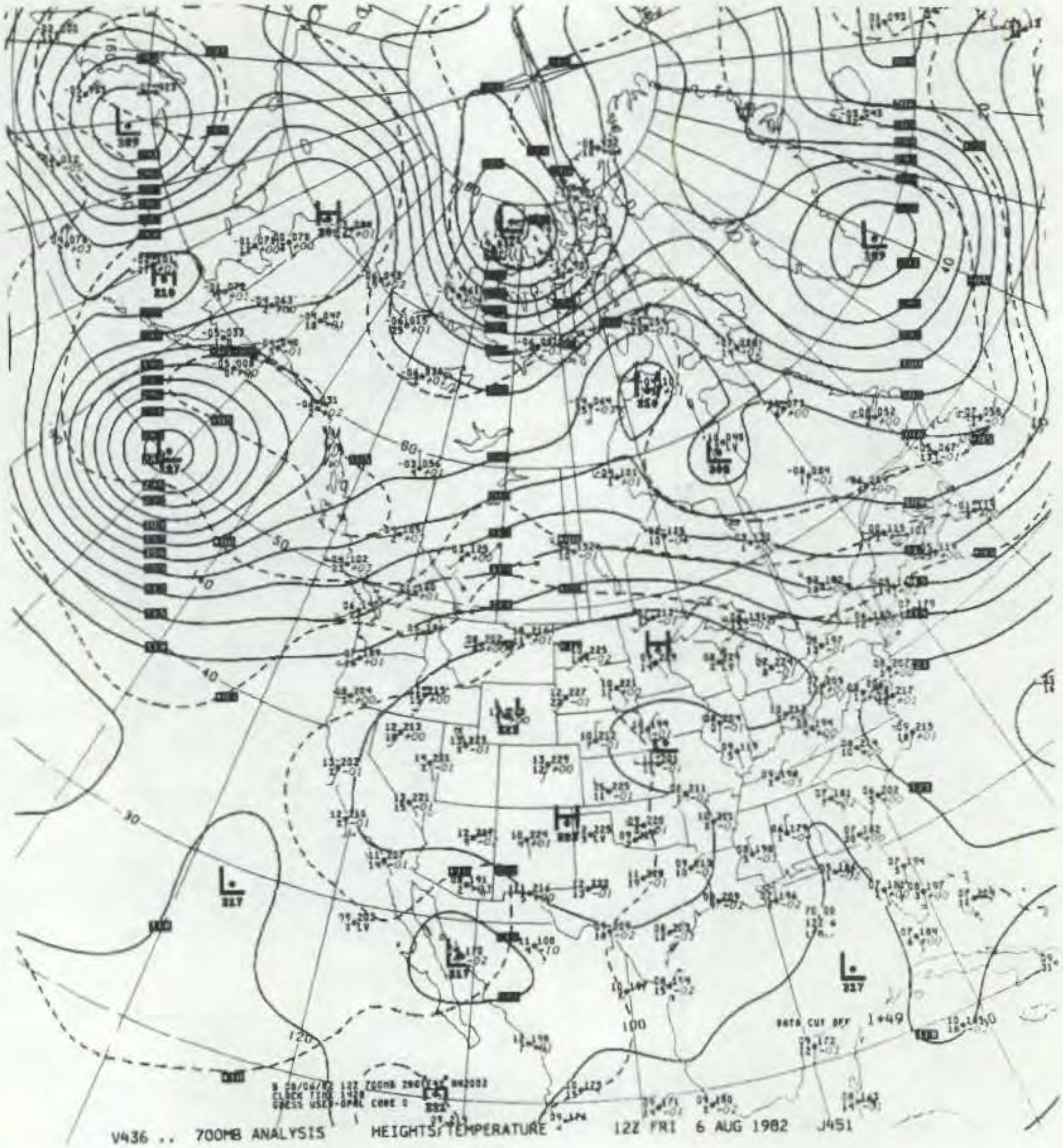

Figure B-30. 700 mb chart, August 6, 1982, 1200 GMT.

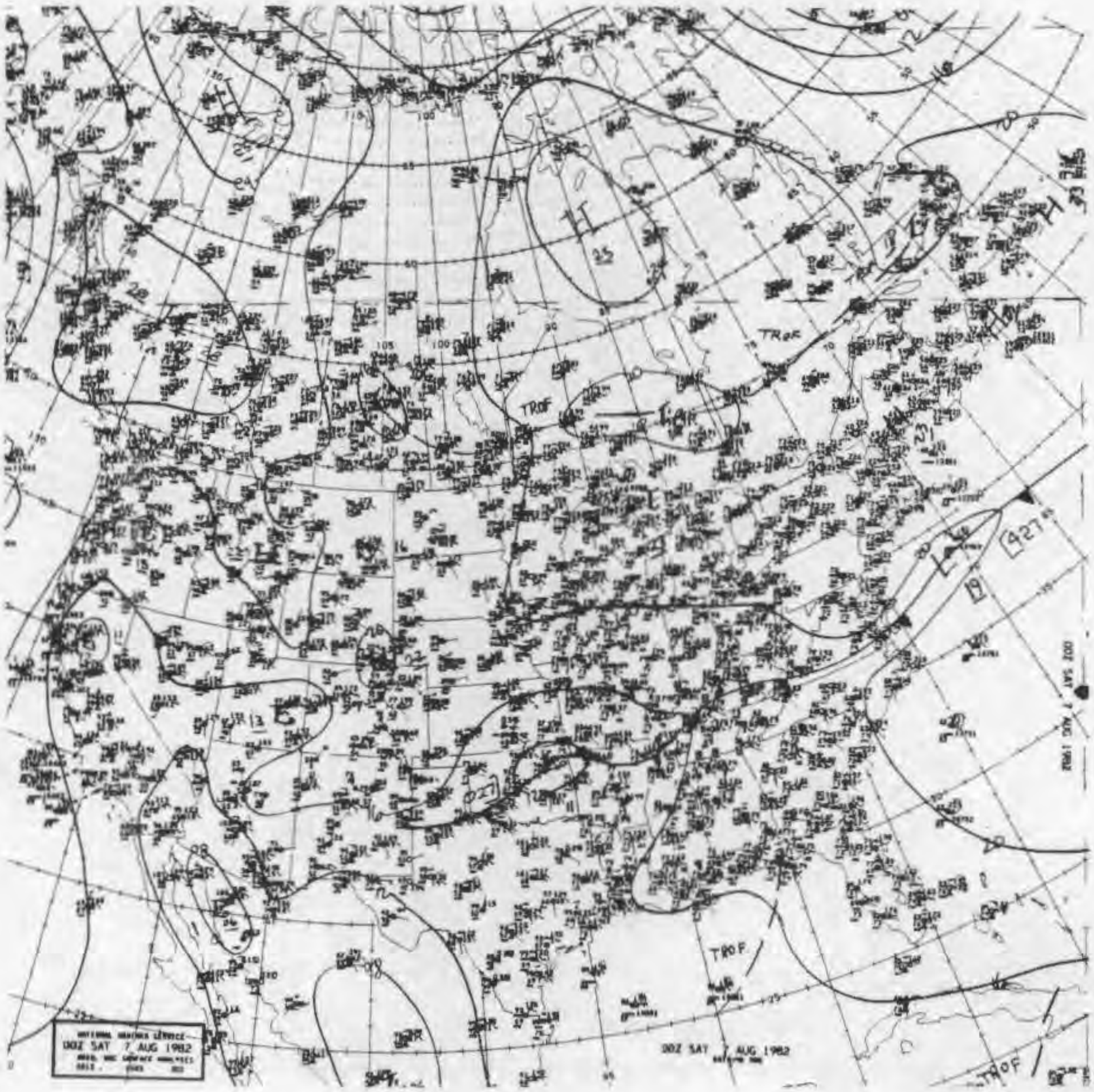

Figure B-31. Surface weather chart, August 7, 1982, 0000 GMT.

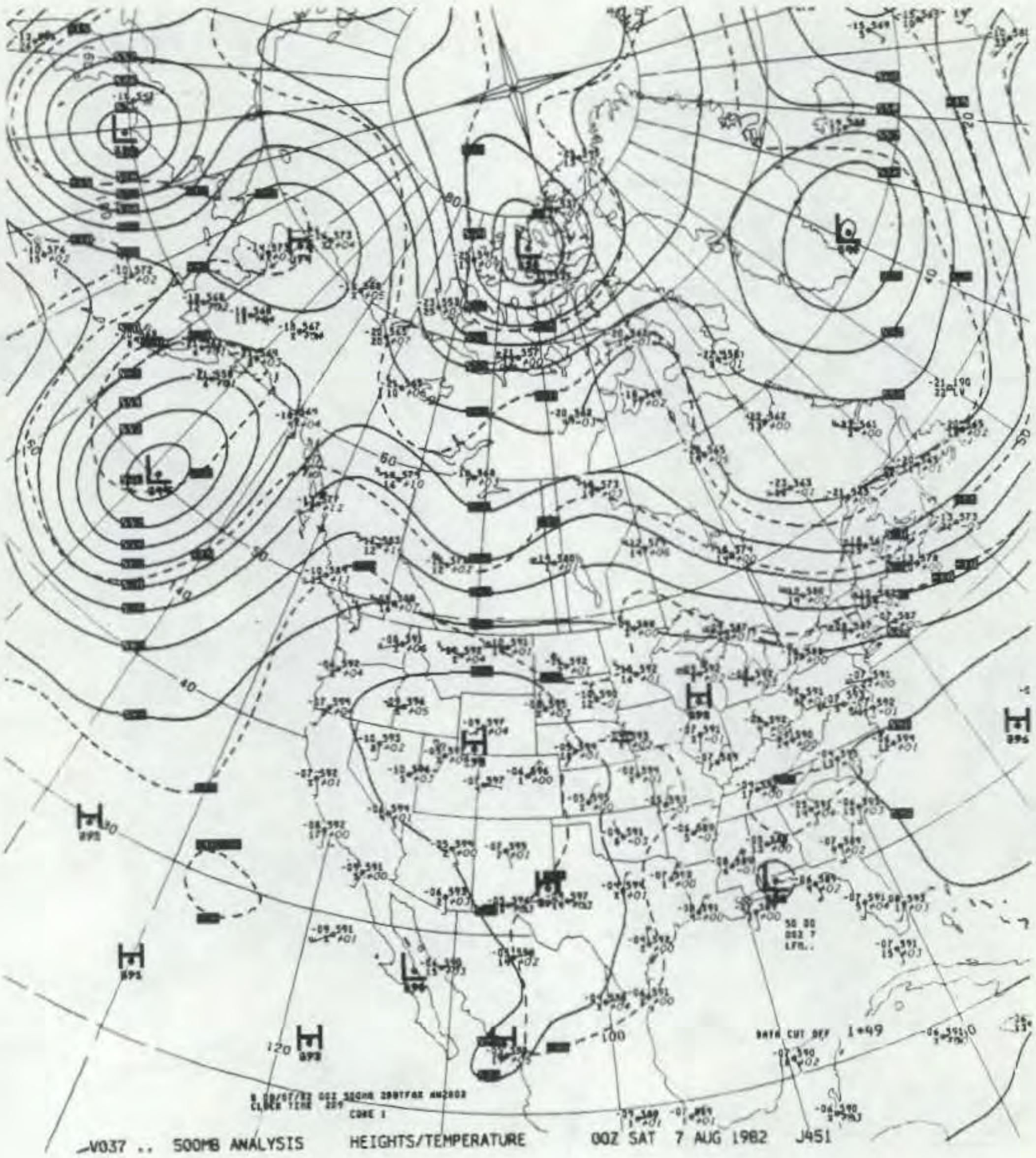

Figure B-32. 500 mb chart, August 7, 1982, 0000 GMT.

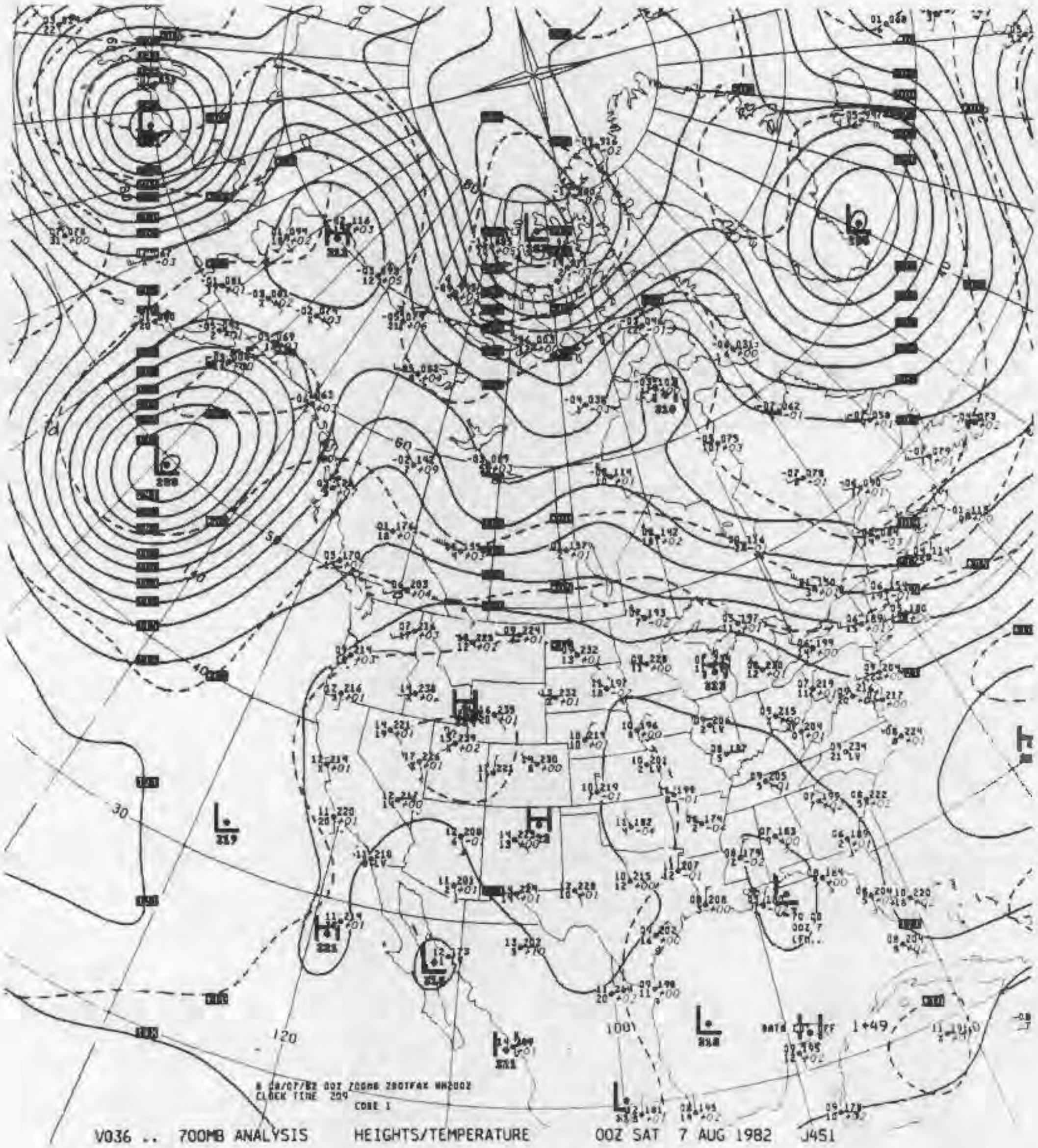

Figure B-33. 700 mb chart, August 7, 1982, 0000 GMT.

APPENDIX C

UPPER AIR SOUNDINGS, GRAND JUNCTION, COLORADO

The following tables give the Grand Junction, Colorado (GJT) rawinsonde data for the experimental period. Data were collected by National Weather Service personnel and were obtained from the National Climatic Center.

Abbreviations used in the table are as follows:

PRES	Barometric pressure in millibars
HGT	Height of reading in meters above sea level
T	Temperature in °C
TD	Dewpoint temperature in °C
DIR	True wind direction in degrees
SPD	Wind speed in meters per second

TABLE C-1. GRAND JUNCTION RAWINSONDE DATA, JULY 28, 1982, 0000 GMT
GJT 82072800

	MANDATORY AND SIGNIFICANT LEVELS						WINDS				
	PRES (mb)	HGT (m)	T (°C)	TD (°C)	DIR	SPD (m/s)	HEIGHT (m)	HEIGHT (ft)	DIR	SPEED (m/s)	SPEED (kt)
1	854	1474	28.8	10.8			1474	4836	270	3	6
2	700	3195	13.0	4.0			1829	6000	300	3	5
3	573	4844	0.8	-2.0			2134	7000	310	4	7
4	527	5514	-2.1	-10.1			2438	8000	310	5	9
5	500	5931	-4.3	-7.0			2743	9000	315	4	8
6	448	6790	-9.5	-10.8			3658	12000	280	3	6
7	421	7269	-11.5	-15.6			4267	14000	240	4	7
8	417	7342	-11.5	-18.5			4877	16000	230	5	9
9	356	8536	-19.7	-31.7			6096	20000	220	6	12
10	317	9387	-26.3	-35.3			7620	25000	235	6	12
11	300	9782	-29.9	-41.9			8839	29000	255	6	12
12							9144	30000	250	7	13

TABLE C-2. GRAND JUNCTION RAWINSONDE DATA, JULY 28, 1982, 1200 GMT
GJT 82072812

	MANDATORY AND SIGNIFICANT LEVELS						WINDS				
	PRES (mb)	HGT (m)	T (°C)	TD (°C)	DIR	SPD (m/s)	HEIGHT (m)	HEIGHT (ft)	DIR	SPEED (m/s)	SPEED (kt)
1	856	1474	20.4	14.4	130	5	1474	4836	130	5	10
2	850	1528	20.6	14.6	135	5	1829	6000	155	7	13
3	836	1672	20.8	14.8			2134	7000	170	7	13
4	737	2754	15.0	9.0			2438	8000	160	12	24
5	700	3187	11.2	8.8	195	5	2743	9000	155	12	24
6	690	3307	10.2	8.6			3658	12000	225	6	11
7	521	5590	-4.3	-5.0			4267	14000	250	5	10
8	500	5920	-5.9	-9.1	290	6	4877	16000	240	6	12
9	428	7127	-11.5	-17.5			5182	17000	250	6	11
10	422	7235	-12.5	-24.5			5791	19000	295	6	11
11	400	7640	-15.1	-27.1	250	7	6096	20000	285	6	12
12	371	8205	-18.7	-24.7			7620	25000	250	7	14
13	347	8700	-22.5	-34.5			8839	29000	250	8	15
14	330	9067	-25.5	-30.0			9144	30000	240	8	16
15	323	9222	-26.5	-37.5							
16	311	9495	-28.7	-43.7							
17	300	9750	-30.5	-39.5	235	9					

TABLE C-3. GRAND JUNCTION RAWINSONDE DATA, JULY 29, 1982, 0000 GMT
GJT 82072900

	MANDATORY AND SIGNIFICANT LEVELS						WINDS				
	PRES (mb)	HGT (m)	T (°C)	TD (°C)	DIR	SPD (m/s)	HEIGHT (m)	HEIGHT (ft)	DIR	SPEED (m/s)	SPEED (kt)
1	854	1474	27.2	13.2	280	5	1474	4836	280	5	9
2	850	1514	26.8	12.8	280	5	1829	6000	295	9	17
3	700	3188	12.6	8.5	310	5	2134	7000	305	8	15
4	688	3333	11.0	7.9			2438	8000	320	6	12
5	570	4877	0.0	-0.4			2743	9000	315	5	10
6	500	5920	-4.9	-9.2	260	7	3658	12000	300	6	11
7	450	6744	-8.5	-13.5			4257	14000	310	7	13
8	443	6866	-9.3	-14.0			4877	16000	305	6	11
9	437	6971	-9.9	-20.9			5486	18000	270	7	13
10	415	7368	-12.7	-19.7			6096	20000	260	7	13
11	408	7497	-13.5	-25.5			6706	22000	240	7	14
12	400	7650	-14.9	-26.9	230	9	7620	25000	230	9	17
13	360	8439	-20.1	-28.1			8534	28000	225	9	18
14	329	9102	-23.9	-32.9			9144	30000	245	8	15
15	304	9674	-28.7	-58.7							
16	300	9770	-28.9	-39.9	255	8					

TABLE C-4. GRAND JUNCTION RAWINSONDE DATA, JULY 29, 1982, 1200 GMT
GJT 82072912

	MANDATORY AND SIGNIFICANT LEVELS						WINDS				
	PRES (mb)	HGT (m)	T (°C)	TD (°C)	DIR	SPD (m/s)	HEIGHT (m)	HEIGHT (ft)	DIR	SPEED (m/s)	SPEED (kt)
1	855	1474	19.4	14.4	140	2	1474	4836	140	2	3
2	850	1527	19.2	14.3			3658	12000	5	3	5
3	802	2026	17.0	12.0			4267	14000	325	4	7
4	773	2340	14.2	13.6			4877	16000	320	3	6
5	700	3175	10.0	9.4			6096	20000	250	2	4
6	556	5057	-0.9	-4.5			7620	25000	295	6	12
7	525	5514	-3.9	-6.1			8839	29000	255	12	23
8	518	5620	-4.9	-9.3			9144	30000	255	14	28
9	500	5900	-6.7	-9.9	285	3					
10	468	6413	-10.7	-11.3							
11	461	6530	-9.1	-14.1							
12	434	6995	-11.7	-16.7							
13	400	7610	-15.5	-32.5	295	6					
14	342	8773	-24.1	-31.1							
15	300	9720	-30.5	-44.5	255	16					

TABLE C-5. GRAND JUNCTION RAWINSONDE DATA, JULY 30, 1982, 0000 GMT
GJT 82073000

	MANDATORY AND SIGNIFICANT LEVELS						WINDS				
	PRES (mb)	HGT (m)	T (°C)	TD (°C)	DIR	SPD (m/s)	HEIGHT (m)	HEIGHT (ft)	DIR	SPEED (m/s)	SPEED (kt)
1	853	1474	31.0	12.0	300	7	1472	4829	300	7	13
2	850	1500	28.8	14.8	300	7	1732	5846	295	7	14
3	700	3183	13.2	7.2	5	3	2095	6873	311	6	12
4	500	5920	-5.3	-16.3	325	4	2408	7900	314	5	9
5	400	7640	-15.5	-29.5	255	7	2702	8866	329	3	6
6	300	9750	-29.5	-59.5	250	18	2969	9742	358	3	6
7							3239	10628	5	3	6
8							3522	11555	344	3	6
9							3839	12593	317	4	8
10							4159	13644	301	5	10
11							4466	14653	303	6	11
12							4755	15601	305	6	12
13							5039	16532	309	6	12
14							5278	17317	321	6	11
15							5541	18180	324	6	11
16							5846	19181	324	4	8
17							6143	20155	324	4	8
18							6438	21121	308	5	10
19							6732	22087	287	6	11
20							7028	23059	278	6	11
21							7348	24108	265	5	10
22							7669	25161	251	7	13
23							7997	26236	245	9	18
24							8324	27309	238	11	22
25							8651	28382	243	13	25
26							8961	29400	248	15	30
27							9294	30491	247	17	33

TABLE C-6. GRAND JUNCTION RAWINSONDE DATA, JULY 30, 1982, 1200 GMT
GJT 82073012

	MANDATORY AND SIGNIFICANT LEVELS						WINDS				
	PRES (mb)	HGT (m)	T (°C)	TD (°C)	DIR	SPD (m/s)	HEIGHT (m)	HEIGHT (ft)	DIR	SPEED (m/s)	SPEED (kt)
1	855	1472	20.0	12.8			1472	4829	140	3	6
2	850	1525	20.0	12.7			1754	5755	129	3	5
3	806	1983	19.1	11.1			2029	6658	129	3	5
4	791	2145	17.7	10.0			2278	7474	112	2	4
5	750	2598	14.8	8.3			2545	8350	72	2	3
6	736	2758	13.6	9.3			2839	9313	30	2	3
7	729	2839	13.2	9.0			3116	10224	345	2	3
8	708	3085	11.9	6.2			3382	11095	325	3	5
9	700	3180	11.3	5.2			3641	11944	326	2	4
10	675	3483	8.4	4.4			3919	12858	316	2	4
11	658	3693	6.4	4.0			4188	13741	308	3	6
12	627	4088	3.8	0.7			4441	14570	308	5	9
13	608	4338	2.5	-1.5			4705	15438	314	6	11
14	589	4595	0.4	-2.5			4975	16322	314	6	12
15	565	4927	-2.0	-1.7			5213	17103	299	7	14
16	545	5213	-4.5	-8.0			5487	18000	276	8	15
17	536	5344	-5.6	-7.8			5775	18946	258	6	12
18	520	5582	-7.1	-7.8			6040	19817	267	5	9
19	511	5718	-6.3	-15.9			6340	20799	294	5	10
20	500	5888	-7.4	-16.9			6593	21631	287	7	14
21	495	5966	-8.2	-17.1			6863	22516	281	9	18
22	481	6189	-9.3	-23.5			7132	23400	284	10	20
23	458	6566	-11.0	-27.8			7402	24284	282	10	19
24	400	7591	-19.0	-34.8			7670	25164	277	12	23
25	367	8227	-22.9	-35.1			7935	26034	269	15	30
26	360	8368	-23.7	-30.9			8200	26903	263	17	32
27	349	8594	-24.4	-39.1			8481	27824	260	17	33
28	323	9155	-27.6	-42.6			8762	28748	259	19	36
29	300	9681	-32.0	-45.0			9043	29667	257	20	38
							9313	30554	256	21	40

TABLE C-7. GRAND JUNCTION RAWINSONDE DATA, JULY 31, 1982, 0000 GMT
GJT 82073100

	MANDATORY AND SIGNIFICANT LEVELS						WINDS				
	PRES (mb)	HGT (m)	T (°C)	TD (°C)	DIR	SPD (m/s)	HEIGHT (m)	(ft)	DIR	SPEED (m/s)	(kt)
1	854	1472	29.5	7.9			1472	4829	270	4	8
2	850	1513	29.4	8.1			1699	5574	281	2	4
3	828	1746	27.4	7.4			1918	6294	281	2	4
4	750	2610	19.8	5.8			2134	7002	286	3	6
5	700	3199	14.2	3.3			2350	7711	281	4	7
6	657	3730	9.8	3.1			2566	8420	280	4	8
7	608	4369	4.2	1.9			2824	9264	295	5	9
8	580	4752	1.5	-0.8			3091	10142	306	6	11
9	563	4992	0.7	-4.5			3411	11192	316	7	13
10	554	5121	-0.4	-10.7			3766	12355	323	7	14
11	545	5252	-1.4	-9.6			4121	13519	331	7	13
12	519	5640	-4.0	-18.9			4451	14603	351	6	11
13	500	5933	-5.9	-20.8			4725	15500	354	6	11
14	462	6549	-9.0	-39.0			4968	16298	354	5	10
15	400	7646	-17.7	-47.7			5226	17144	2	4	8
16	300	9741	-31.5	-61.5			5484	17993	9	4	8
17							5757	18887	10	5	9
18							6040	19816	353	6	12
19							6308	20694	347	8	15
20							6580	21587	347	9	17
21							6893	22616	349	9	17
22							7207	23644	348	9	17
23							7520	24672	339	8	16
24							7820	25657	328	7	14
25							8111	26611	306	7	14
26							8402	27566	297	9	17
27							8693	28520	300	8	16
28							8984	29475	293	7	14
29							9275	30429	281	8	16

TABLE C-8. GRAND JUNCTION RAWINSONDE DATA, JULY 31, 1982, 1200 GMT
GJT 82073112

	MANDATORY AND SIGNIFICANT LEVELS						WINDS				
	PRES (mb)	HGT (m)	T (°C)	TD (°C)	DIR	SPD (m/s)	HEIGHT (m)	(ft)	DIR	SPEED (m/s)	(kt)
1	857	1472	22.2	7.1			1472	4829	70	4	8
2	850	1544	23.1	7.9			1835	6021	76	5	10
3	765	2453	17.0	3.6			2199	7214	91	6	11
4	755	2566	17.2	3.5			2566	8417	74	6	11
5	750	2622	16.8	3.0			2817	9241	50	5	10
6	700	3206	12.1	0.5			3095	10153	20	5	10
7	680	3448	9.8	0.1			3351	10994	354	6	12
8	660	3696	9.3	-6.9			3613	11854	332	8	15
9	546	5234	-2.5	-32.5			3907	12817	321	8	15
10	540	5321	-2.2	-32.2			4208	13807	326	6	12
11	500	5928	-6.0	-36.0			4510	14796	326	6	11
12	456	6642	-11.7	-41.7			4812	15786	323	7	13
13	447	6794	-12.4	-42.4			5113	16775	330	6	12
14	400	7631	-19.7	-49.7			5408	17743	358	5	9
15	392	7781	-19.6	-49.6			5697	18691	10	5	9
16	375	8110	-20.9	-50.9			5985	19637	346	5	10
17	335	8932	-27.7	-57.7			6271	20573	332	6	11
18	318	9305	-29.3	-59.3			6556	21510	334	6	12
19	300	9719	-32.7	-62.7			6850	22474	331	6	12
20							7129	23389	326	7	14
21							7408	24304	325	8	16
22							7691	25233	331	9	18
23							8011	26283	335	10	19
24							8308	27258	333	9	18
25							8592	28188	331	11	22
26							8875	29118	334	12	24
27							9131	29957	334	11	22
28							9388	30800	330	11	21

TABLE C-9. GRAND JUNCTION RAWINSONDE DATA, AUGUST 1, 1982, 0000 GMT
GJT 82080100

	MANDATORY AND SIGNIFICANT LEVELS						WINDS				
	PRES (mb)	HGT (M)	T (°C)	TD (°C)	DIR	SPD (m/s)	HEIGHT (m)	HEIGHT (ft)	DIR	SPEED (m/s)	SPEED (kt)
1	852	1427	31.5	6.5	270	4					
2	850	1493	31.5	6.4	269	4					
3	835	1652	31.0	6.8	267	4					
4	800	2034	27.4	5.0	254	3					
5	750	2598	21.8	2.1	301	2					
6	700	3191	16.6	2.3	354	1					
7	650	3817	11.4	-0.3	350	3					
8	604	4425	6.1	-2.9	2	8					
9	600	4479	5.7	-2.8	3	8					
10	585	4686	3.8	-2.2	10	8					
11	558	5068	0.7	-4.9	16	5					
12	550	5184	-0.3	-8.5	357	5					
13	541	5316	-1.6	-12.7	356	5					
14	523	5585	-2.5	-32.5	32	8					
15	500	5940	-5.0	-35.0	23	6					
16	450	6761	-9.6	-39.6	332	4					
17	400	7661	-14.9	-44.9	338	8					
18	350	8658	-23.1	-53.1	337	9					
19	300	9762	-32.7	-62.7	313	9					

TABLE C-10. GRAND JUNCTION RAWINSONDE DATA, AUGUST 1, 1982, 1200 GMT
GJT 82080112

	MANDATORY AND SIGNIFICANT LEVELS						WINDS				
	PRES (mb)	HGT (m)	T (°C)	TD (°C)	DIR	SPD (m/s)	HEIGHT (m)	(ft)	DIR	SPEED (m/s)	(kt)
1	854	1474	21.0	3.0	120	5	1474	4836	120	5	9
2	850	1513	22.8	3.8	120	5	1829	6000	120	6	11
3	840	1616	23.6	3.6			2134	7000	120	6	11
4	770	2373	21.8	-1.2			2438	8000	170	5	9
5	700	3188	14.8	-1.2	205	4	2743	9000	195	4	8
6	563	4976	-2.1	-6.8			3658	12000	245	3	6
7	546	5219	-3.9	-12.9			4267	14000	315	2	4
8	531	5439	-3.3	-33.3			4877	16000	335	3	6
9	500	5910	-5.7	-35.7	250	3	6096	20000	215	3	5
10	489	6084	-5.9	-35.9			7620	25000	205	2	3
11	400	7630	-17.1	-47.1	205	2	9144	30000	250	3	6
12	300	9710	-35.1	-65.1	295	3					

TABLE C-11. GRAND JUNCTION RAWINSONDE DATA, AUGUST 2, 1982, 0000 GMT
GJT 82080200

	MANDATORY AND SIGNIFICANT LEVELS						WINDS				
	PRES (mb)	HGT (m)	T (°C)	TD (°C)	DIR	SPD (m/s)	HEIGHT (m)	(ft)	DIR	SPEED (m/s)	(kt)
1	848	1474	33.4	8.4			1474	4836	140	4	8
2	842	1538	33.0	8.0			1828	6000	115	2	4
3	623	4142	8.6	-2.4			2134	7000	80	2	3
4	517	5649	-4.7	-8.8			2438	8000	30	1	2
5	500	5912	-6.7	-7.7			2743	9000	30	1	2
6	468	6426	-10.3	-11.6			3658	12000	70	1	1
7	437	6952	-12.5	-27.5			4267	14000	190	3	5
8	264	10615	-37.7	-46.7			4877	16000	205	7	13
9							5486	18000	210	10	20
10							6096	20000	190	15	29
11							7010	23000	180	16	31
12							7620	25000	190	14	27
13							8230	27000	195	14	28
14							9144	30000	230	16	31

TABLE C-12. GRAND JUNCTION RAWINSONDE DATA, AUGUST 2, 1982, 1200 GMT
GJT 82080212

	MANDATORY AND SIGNIFICANT LEVELS						WINDS				
	PRES (mb)	HGT (m)	T (°C)	TD (°C)	DIR	SPD (m/s)	HEIGHT (m)	HEIGHT (ft)	DIR	SPEED (m/s)	SPEED (kt)
1	851	1474	20.0	14.0	120	4	1474	4836	120	4	8
2	850	1482	20.4	13.4	120	4	1829	6000	125	5	10
3	700	3134	9.6	4.7	195	10	2134	7000	145	6	11
4	500	5850	-5.9	-6.5	235	13	2438	8000	160	6	11
5	400	7570	-17.1	-20.8	240	13	2743	9000	190	7	14
6	300	9660	-32.9	-42.9	215	15	3658	12000	190	15	30
7							4267	14000	205	15	30
8							4877	16000	220	16	31
9							6096	20000	240	13	26
10							7620	25000	240	14	27
11							8534	28000	215	15	30
12							9144	30000	220	15	29

TABLE C-13. GRAND JUNCTION RAWINSONDE DATA, AUGUST 3, 1982, 0000 GMT
GJT 82080300

	MANDATORY AND SIGNIFICANT LEVELS						WINDS				
	PRES (mb)	HGT (m)	T (°C)	TD (°C)	DIR	SPD (m/s)	HEIGHT (m)	HEIGHT (ft)	DIR	SPEED (m/s)	SPEED (kt)
1	852	1474	20.6	16.5	320	4	1474	4836	320	4	7
2	850	1488	20.6	14.6	320	4	1829	6000	300	3	5
3	837	1622	21.4	13.4			2134	7000	305	4	7
4	727	2825	11.6	8.7			2438	8000	315	4	8
5	700	3141	10.4	6.3	320	5	2743	9000	335	5	9
6	687	3297	9.0	4.7			3048	10000	330	6	11
7	650	3754	5.8	4.4			3658	12000	265	3	5
8	500	5860	-6.1	-7.6	225	9	3962	13000	235	5	10
9	400	7580	-15.9	-18.7	225	9	4267	14000	230	7	14
10	300	9690	-30.3	-36.3	225	22	4877	16000	210	8	15
11							5182	17000	210	9	17
12							5486	18000	225	9	18
13							6096	20000	230	8	16
14							7010	23000	215	10	19
15							7620	25000	225	9	18
16							8534	28000	235	10	20
17							9144	30000	225	20	38

TABLE C-14. GRAND JUNCTION RAWINSONDE DATA, AUGUST 3, 1982, 1200 GMT
GJT 82D80312

	MANDATORY AND SIGNIFICANT LEVELS						WINDS				
	PRES (mb)	HGT (m)	T (°C)	TD (°C)	DIR	SPD (m/s)	HEIGHT (m)	HEIGHT (ft)	DIR	SPEED (m/s)	SPEED (kt)
1	852	1474	18.2	14.2	120	5	1474	4836	12D	5	9
2	850	1494	18.2	14.0	120	5	1829	6000	150	11	21
3	811	1898	18.2	12.2			2134	7000	175	7	14
4	735	2735	13.2	7.2			2438	8000	210	4	8
5	700	3144	9.2	5.7	250	7	2743	9000	240	5	9
6	653	3718	6.0	1.0			3048	10000	245	6	11
7	584	4624	-.5	-1.8			3658	12000	255	9	17
8	566	4874	-2.1	-6.9			4267	14000	235	7	14
9	543	5202	-4.9	-5.4			4877	16000	260	6	11
10	513	5649	-6.7	-8.2			5182	17000	260	6	11
11	500	5850	-7.7	-12.7	235	11	6096	20000	225	12	24
12	481	6151	-8.3	-38.3			7620	25000	225	22	43
13	444	6769	-11.5	-26.5			9144	30000	220	26	50
14	405	7465	-17.9	-26.9							
15	400	7560	-18.1	-22.7	225	22					
16	391	7730	-18.3	-19.8							
17	356	8424	-23.3	-29.3							
18	300	9650	-32.5	-40.5	215	29					

TABLE C-15. GRAND JUNCTION RAWINSONDE DATA, AUGUST 4, 1982, 0000 GMT
GJT 82080400

	MANDATORY AND SIGNIFICANT LEVELS						WINDS				
	PRES (mb)	HGT (m)	T (°C)	TD (°C)	DIR	SPD (m/s)	HEIGHT (m)	(ft)	DIR	SPEED (m/s)	(kt)
1	852	1472	25.6	10.2	160	5					
2	850	1488	25.7	10.9	159	5					
3	808	1932	23.4	10.1	112	1					
4	800	2019	22.7	9.8	87	1					
5	750	2576	17.5	7.6	219	2					
6	718	2947	13.7	6.1	232	3					
7	700	3161	11.9	5.7	240	4					
8	678	3428	9.9	3.2	248	5					
9	650	3778	7.0	2.1	237	5					
10	647	3815	6.6	1.9	236	5					
11	628	4059	4.4	2.3	233	6					
12	602	4403	1.7	0.9	230	7					
13	600	4430	1.5	0.7	230	7					
14	574	4786	-1.3	-2.9	229	7					
15	556	5040	-2.0	-2.5	233	8					
16	550	5126	-2.5	-3.0	233	8					
17	500	5877	-7.4	-8.0	229	8					
18	495	5955	-8.2	-8.9	228	8					
19	478	6224	-12.5	-20.2	230	9					
20	472	6321	-12.6	-42.6	230	10					
21	450	6684	-14.4	-26.3	229	11					
22	448	6718	-14.6	-24.7	229	11					
23	433	6976	-15.3	-45.3	229	11					
24	400	7572	-18.0	-48.0	228	13					
25	376	8032	-20.4	-35.8	228	17					
26	355	8455	-23.1	-29.7	220	22					
27	350	8562	-23.6	-30.0	218	22					
28	340	8770	-24.7	-30.8	215	23					
29	329	9008	-26.6	-33.3	211	24					
30	309	9458	-30.0	-35.9	203	23					
31	300	9668	-31.7	-38.8	202	23					

TABLE C-16. GRAND JUNCTION RAWINSONDE DATA, AUGUST 4, 1982, 1200 GMT
GJT 82080412

	MANDATORY AND SIGNIFICANT LEVELS						WINDS				
	PRES (mb)	HGT (m)	T (°C)	TD (°C)	DIR	SPD (m/s)	HEIGHT (m)	(ft)	DIR	SPEED (m/s)	(kt)
1	854	1474	18.4	10.4	140	2	1474	4836	140	2	4
2	850	1508	18.6	8.6	140	3	1829	6000	125	5	9
3	831	1703	20.8	9.8			2134	7000	150	4	8
4	700	3162	10.4	-2.6	350	1	2438	8000	195	3	5
5	672	3500	7.8	-5.2			2743	9000	275	2	3
6	624	4107	4.2	-25.8			3658	12000	145	2	4
7	500	5870	-6.7	-18.7	220	8	4276	14000	215	5	9
8	400	7570	-20.7	-21.2	210	15	4572	15000	210	6	11
9	300	9650	-33.7	-43.7			4877	16000	220	8	15
10							5182	17000	230	8	15
11							6096	20000	220	8	16
12							7620	25000	210	15	30
13							8230	27000	205	17	33
14							9144	30000	210	20	38

TABLE C-17. GRAND JUNCTION RAWINSONDE DATA, AUGUST 5, 1982, 0000 GMT
GJT 82080500

	MANDATORY AND SIGNIFICANT LEVELS						WINDS				
	PRES (mb)	HGT (m)	T (°C)	TD (°C)	DIR	SPD (m/s)	HEIGHT (m)	(ft)	DIR	SPEED (m/s)	(kt)
1	853	1474	29.4	5.4	280	4	1474	4836	280	4	8
2	850	1503	29.4	4.4	285	4	1829	6000	315	1	2
3	605	4397	3.4	-2.6			2134	7000	335	1	2
4	544	5250	-2.7	-12.7			2438	8000	310	1	2
5	500	5914	-6.7	-24.7			2743	9000	280	2	4
6	422	7219	-14.7	-44.7			3658	12000	255	5	10
7	400	7620	-17.3	-47.3	215	13	4267	14000	250	8	15
8	300	9700	-32.9	-62.9	220	25	4877	16000	250	5	10
9							6096	20000	220	3	6
10							6401	21000	235	6	11
11							7620	25000	215	13	26
12							8839	29000	210	16	31
13							9144	30000	215	18	35

TABLE C-18. GRAND JUNCTION RAWINSONDE DATA, AUGUST 5, 1982, 1200 GMT
GJT 82080512

	MANDATORY AND SIGNIFICANT LEVELS						WINDS			
	PRES (mb)	HGT (m)	T (°C)	TD (°C)	DIR	SPD (m/s)	HEIGHT (m)	HEIGHT (ft)	DIR	SPEED (m/s) (kt)
1	856	1472	20.7	3.7	120	4				
2	850	1535	22.4	5.5	121	4				
3	800	2060	20.1	0.7	117	2				
4	750	2613	17.5	-4.5	274	2				
5	700	3198	13.3	-1.0	338	1				
6	650	3816	7.6	-1.1	126	2				
7	630	4072	5.1	-1.2	147	2				
8	600	4468	1.6	-3.0	188	4				
9	566	4935	-2.7	-5.2	203	5				
10	555	5091	-3.2	-15.2	207	4				
11	550	5163	-3.6	-16.0	210	4				
12	510	5755	-7.3	-23.1	201	6				
13	500	5910	-6.7	-23.4	201	7				
14	450	6724	-12.2	-29.0	204	7				
15	400	7614	-18.4	-35.4	220	12				
16	372	8154	-20.3	-50.3	220	15				
17	350	8605	-24.1	-47.7	221	15				
18	300	9705	-33.7	-41.1	224	17				

TABLE C-19. GRAND JUNCTION RAWINSONDE DATA, AUGUST 6, 1982, 0000 GMT
GJT 82080600

	MANDATORY AND SIGNIFICANT LEVELS						WINDS				
	PRES (mb)	HGT (m)	T (°C)	TD (°C)	DIR	SPD (m/s)	HEIGHT (m)	(ft)	DIR	SPEED (m/s)	(kt)
1	856	1472	31.7	2.8	300	3					
2	850	1530	31.5	1.5	300	3					
3	800	2069	26.9	-3.1	304	4					
4	750	2633	21.8	-8.2	276	6					
5	700	3224	15.8	-5.0	267	2					
6	650	3847	10.4	-8.3	193	1					
7	633	4066	8.4	-9.5	193	1					
8	608	4398	6.1	-7.6	194	1					
9	600	4506	5.2	-8.6	194	1					
10	550	5209	-1.1	-15.2	51	2					
11	543	5311	-2.1	-16.2	54	2					
12	500	5962	-6.1	-36.1	238	3					
13	469	6461	-8.7	-38.7	212	5					
14	463	6561	-9.3	-21.4	209	6					
15	450	6781	-11.2	-23.6	201	7					
16	446	6849	-11.8	-24.3	200	7					
17	430	7128	-13.9	-19.1	201	9					
18	409	7507	-15.3	-45.3	212	11					
19	400	7675	-16.1	-27.7	216	11					
20	387	7923	-17.7	-27.8	216	11					
21	374	8178	-19.5	-31.5	214	12					
22	367	8318	-20.6	-29.2	212	12					
23	362	8419	-21.0	-31.3	210	13					
24	350	8670	-22.9	-33.2	208	14					
25	310	9544	-29.9	-40.0	221	13					
26	300	9777	-31.6	-38.0	224	14					

TABLE C-20. GRAND JUNCTION RAWINSONDE DATA, AUGUST 6, 1982, 1200 GMT
GJT 82080612

	MANDATORY AND SIGNIFICANT LEVELS						WINDS				
	PRES (mb)	HGT (m)	T (°C)	TD (°C)	DIR	SPD (m/s)	HEIGHT (m)	(ft)	DIR	SPEED (m/s)	(kt)
1	857	1472	24.0	5.7	120	4					
2	850	1544	24.0	3.5	125	5					
3	800	2071	21.4	1.5	139	6					
4	779	2301	20.2	0.5	143	5					
5	769	2412	20.7	-0.1	145	4					
6	750	2627	19.4	-3.4	153	2					
7	700	3215	15.0	-15.0	37	1					
8	655	3772	9.9	-6.6	75	1					
9	650	3836	9.4	-6.4	75	1					
10	608	4385	4.4	-4.2	244	1					
11	600	4493	3.3	-4.4	244	1					
12	589	4642	1.7	-4.7	244	1					
13	554	5133	-2.9	-4.2	000	0					
14	550	5190	-3.4	-5.3	207	1					
15	543	5292	-4.4	-7.4	207	1					
16	528	5513	-4.9	-14.3	213	2					
17	500	5939	-7.6	-23.4	239	3					
18	487	6143	-9.2	-20.2	250	3					
19	471	6401	-9.6	-27.1	266	3					
20	450	6752	-11.6	-27.4	262	2					
21	400	7645	-17.1	-28.4	239	3					
22	355	8529	-23.9	-31.7	235	6					
23	350	8635	-24.8	-33.1	234	6					
24	336	8928	-27.4	-37.1	236	6					
25	300	9735	-32.6	-42.4	233	7					

TABLE C-21. GRAND JUNCTION RAWINSONDE DATA, AUGUST 7, 1982, 0000 GMT
GJT 82080700

	MANDATORY AND SIGNIFICANT LEVELS						WINDS				
	PRES (mb)	HGT (m)	T (°C)	TD (°C)	DIR	SPD (m/s)	HEIGHT (m)	(ft)	DIR	SPEED (m/s)	(kt)
1	855	1472	34.4	4.0	280	4					
2	850	1523	32.3	2.3	273	4					
3	800	2064	27.4	1.6	254	3					
4	750	2628	22.0	0.7	306	2					
5	700	3221	16.7	-0.6	10	3					
6	650	3847	11.5	-3.4	44	5					
7	607	4413	6.6	-6.0	82	4					
8	600	4500	5.8	-6.5	93	3					
9	550	5213	-0.3	-10.5	95	3					
10	521	5643	-4.1	-13.1	95	2					
11	500	5966	-7.0	-11.4	93	2					
12	478	6316	-9.8	-15.4	113	2					
13	465	6529	-9.8	-26.0	136	2					
14	450	6781	-11.3	-28.6	155	2					
15	439	6971	-12.5	-30.7	161	2					
16	400	7675	-17.5	-28.2	181	5					
17	365	8356	-20.8	-35.6	192	7					
18	350	8668	-23.2	-41.3	195	7					
19	300	9774	-32.0	-62.0	210	8					

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