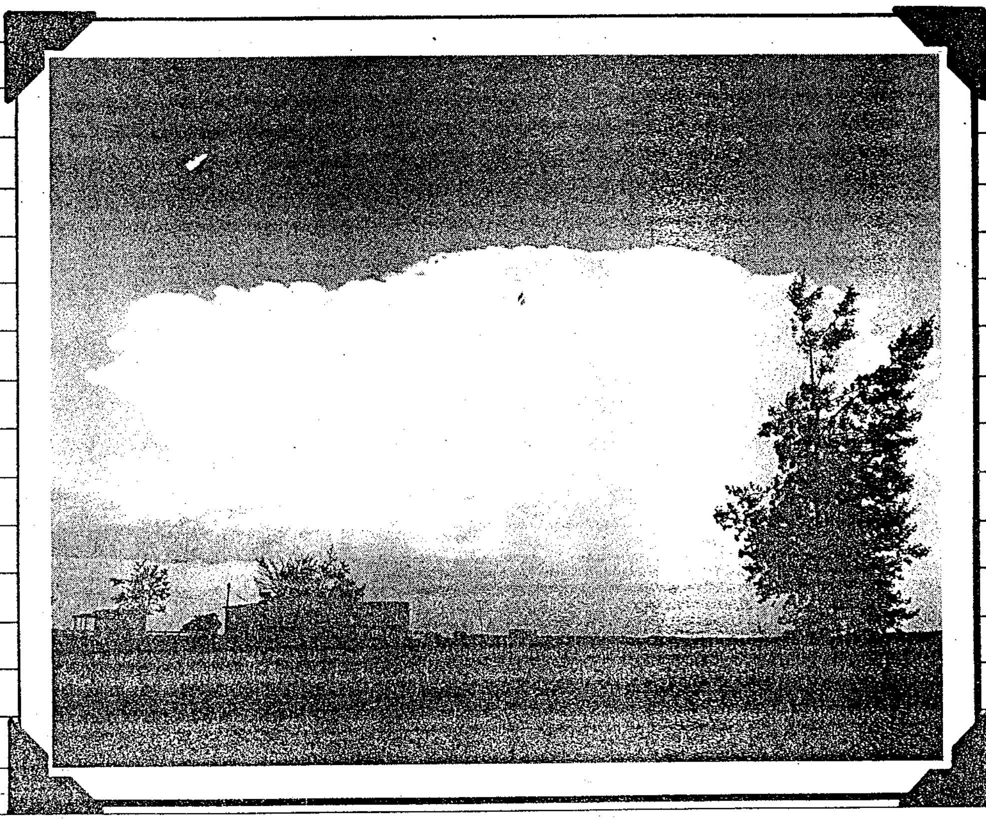
The National Hail Research Experiment summer 1976 summary report



National Center for Atmospheric Research

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THE NATIONAL HAIL RESEARCH EXPERIMENT

SUMMER 1976 SUMMARY REPORT

December 1977

National Center for Atmospheric Research
Boulder, Colorado

This research was performed as part of the National Hail Research Experiment, managed by the National Center for Atmospheric Research and sponsored by the Weather Modification Program, Research Applications Directorate, National Science Foundation.

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I. INTRODUCTION

The 1976 National Hail Research Experiment (NHRE) summer field program was conducted from 18 May 1976 through 31 July 1976. The period 18 May 1976 to 1 June 1976 was used to establish the field test sites, calibrate all measuring systems, perform aircraft tower flybys and intercomparisons, and to conduct a series of trial research missions as a final check on data quality and the data reduction procedures. Field research missions were carried out during the period 1 June 1976 through 31 July 1976 on a larger and more comprehensive scale than during previous seasons. No seeding was conducted. The scope and quality of the data set collected appear to be unprecedented. Approximately 130 persons representing the National Center for Atmospheric Research (NCAR), the Desert Research Institute (DRI) of the University of Nevada, the National Oceanic and Atmospheric Administration (NOAA), Oregon State University, the South Dakota School of Mines and Technology (SDSM&T), the University of Wisconsin, the University of Wyoming, and the Federal Aviation Administration (FAA), participated in the summer operation.

The purpose of this document is to present the research objectives and plans for the 1976 field season, describe the observational systems and networks, summarize the daily research activities, discuss the quality and availability of the observed data, and in summary present highlights and conclusions.

II. THE 1976 FIELD PROGRAM

The approach used during the 1976 field program was coordinated, multiple aircraft storm penetrations and cloud base measurements in conjunction with conventional and Doppler radar observations. The objectives included:

- identifying the location and microphysical structure of embryo growth regions (particularly "first radar echo" regions);
- determining the trajectories of hailstones and their growth environment; and
- determining the dynamical structure and evolution of the storm.

Two additional objectives, not directly related to the above, were also planned. The first was designed to assess the feasibility of ontop seeding and the second continued the observation of hailfall parameters and their relation to crop damage.

The summer field program was conducted in the tri-state area of Colorado, Nebraska, and Wyoming, shown in Figure 1. The solid line encompasses the special use airspace assigned to NHRE by the FAA. The NHRE flight operations were, in most cases, conducted within this airspace. However, in order to utilize the major ground-based systems, an attempt was made to take the majority of observations in the area east of the Grover site.

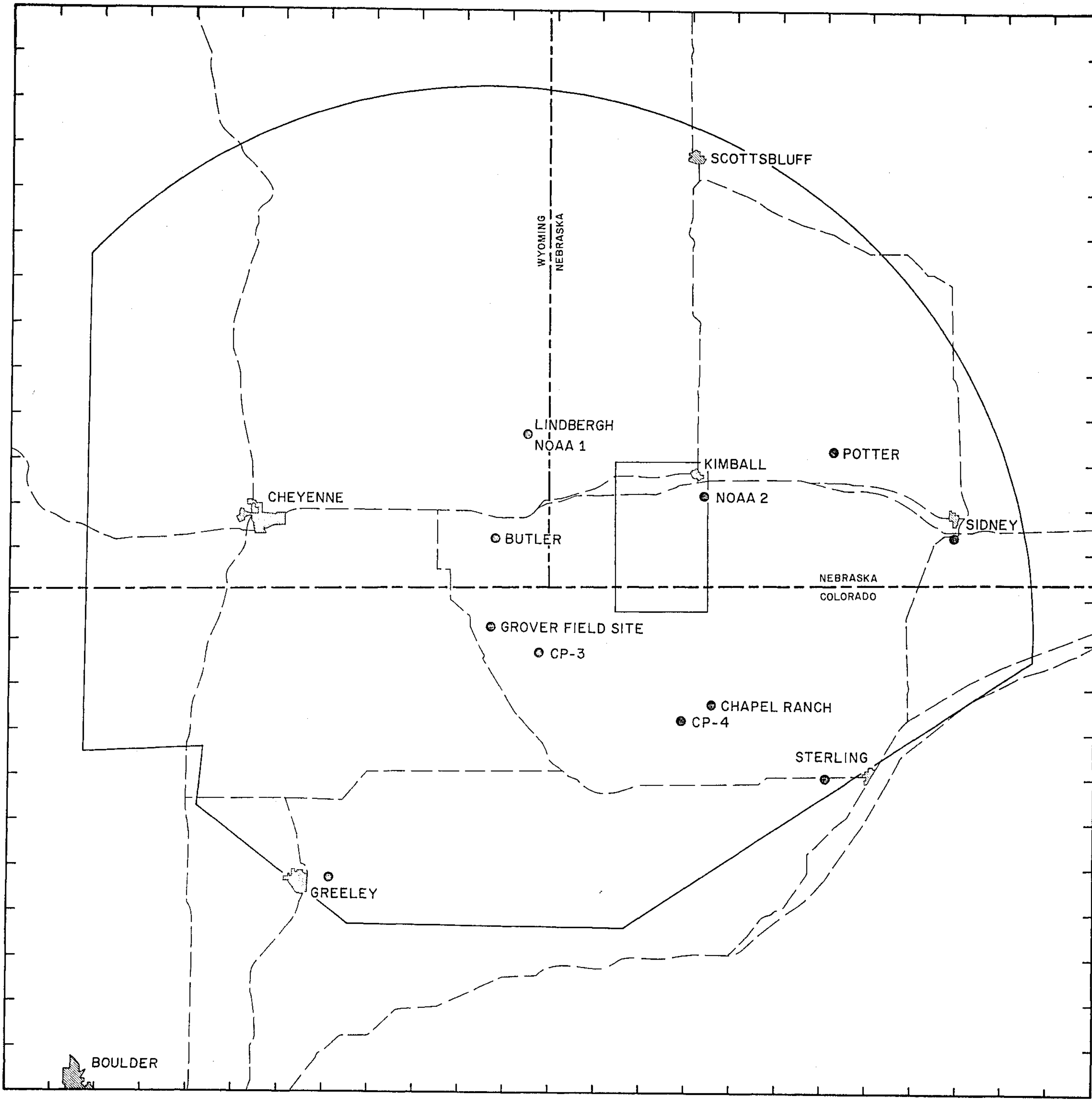


Figure 1. The 1976 NHRE experimental area located in the tri-state area of Colorado, Wyoming, and Nebraska. The solid line delineates the Special Use Airspace assigned by the FAA within which the majority of the research flight missions were flown. The dots identify NHRE observing sites. These are discussed in detail later in this document.

The major components of the summer 1976 program were:

Aircraft:	Two NCAR Queen Airs One NCAR Sabreliner A University of Wyoming Queen Air An armored South Dakota School of Mines & Technology T-28 An NCAR/NOAA sailplane (with towplane)
Radar:	An NCAR CP-2 dual-wavelength radar at Grover Two NCAR C-band Dopplers Two NOAA X-band Dopplers
Aircraft Tracking:	Two DRI (University of Nevada) M33 systems
Rawinsondes:	Three sites located at Grover and Sterling, Colorado, and Potter, Nebraska
Mesonet:	31 conventional, 15 Portable Automated Mesonet (PAM) stations over an area of about 6,400 km^2
Cloud Photography:	Four routine sites; located at Lindbergh, Nebraska, and Grover, Sterling, and Greeley, Colorado
Precipitation Network:	727 total sites, with a dense network of 660 km^2
Mobile Precipitation Sampling Teams:	Four vehicles (two NCAR; two University of Wyoming)
Aerosol Sampling Teams:	Two ground sites (Chapel Ranch, near Grover, operated by NCAR; Sidney, Nebraska, operated by the University of Wyoming). Data also from the three Queen Airs and the two University of Wyoming mobile sampling teams.
Hail Crop Damage Network:	400 hail cubes
Cooperative Mesoscale Studies:	NOAA microbarograph array, FM-CW Doppler, IR Doppler, scintillation triangles, acoustic sounder, X-band Doppler
Tethered Balloon Studies:	Oregon State University

In response to the 1976 objectives, field observational missions were grouped into the following two types of studies:

A. Initiation of Precipitation Formation Study

The objective of these experiments was to develop an understanding of the initiation of precipitation formation in northeast Colorado cumulus, sufficient to develop confidence in a technique of seeding similar clouds to increase the concentration of potential hail embryos. Progress toward accomplishing this objective was made by defining the microphysical processes involved and the flow fields in which the processes occur in order to understand the embryo growth trajectories. Attempts were made to answer the above questions in only natural clouds.

Aircraft involved in the initiation of precipitation formation experiments included the University of Wyoming Queen Air and the NOAA/NCAR sailplane for in-cloud microphysical measurements; the towplane, to deploy the sailplane; and the NCAR Queen Air N304D to measure updraft strength, state parameters, and natural populations of nuclei below cloud base. In these experiments, scientific personnel aboard the Wyoming Queen Air were responsible for selecting the cloud for coordinated research. The pilot of the Wyoming Queen Air acted as the mission coordinator during the experiment. Regardless of the exact experiment to be performed the Wyoming Queen Air (N10UW) usually began penetrations through the cloud at the $-5^{o}C$ level (aaproximately 15,000 to 16,000 ft. MSL) as the cloud top passed through this level. During this period the sailplane continued on tow at about 20,000 ft. As the top of the cloud approached this altitude the

the sailplane would release and penetrate the turret spiraling upward in the updraft (see Figure 2).

B. Mature Storm Study

The second major coordinated flight experiment was the mature storm study. The purpose of this study was to locate and characterize the hail growth region in different types of storms and to estimate the trajectories of the hail and thereby deduce the regions of embryo formation. The aircraft involved were the South Dakota School of Mines and Technology (SDSM&T) T-28, the Wyoming Queen Air, and the two NCAR Queen Airs. The T-28, the primary research aircraft in the mature storm studies, made repeated penetrations at one level in the vicinity of -10 to -15°C, in such a manner that the flight path would transect the high reflectivity portion of the storm and the developing inflow areas. Since the T-28 had only about 1 hour research time on station, it was not deployed until the storm had reached the mature stage.

During the penetrations the three Queen Air aircraft operated in the vicinity of cloud base (see Figure 3). The mission coordinator for these aircraft was the scientist aboard the NCAR Queen Air N304D. The three Queen Airs flew near cloud base measuring three-dimensional air velocities to delineate the horizontal extent and structure of the updraft and also measuring aerosol properties and the standard thermodynamic parameters. The actual flight patterns depended on actual storm conditions. Generally, in addition to cloud base measurements, one of the Queen Airs would make vertical soundings in front of the storm after flying a level semicircular

NHRE 1976 INITIATION OF PRECIPITATION FORMATION STUDY

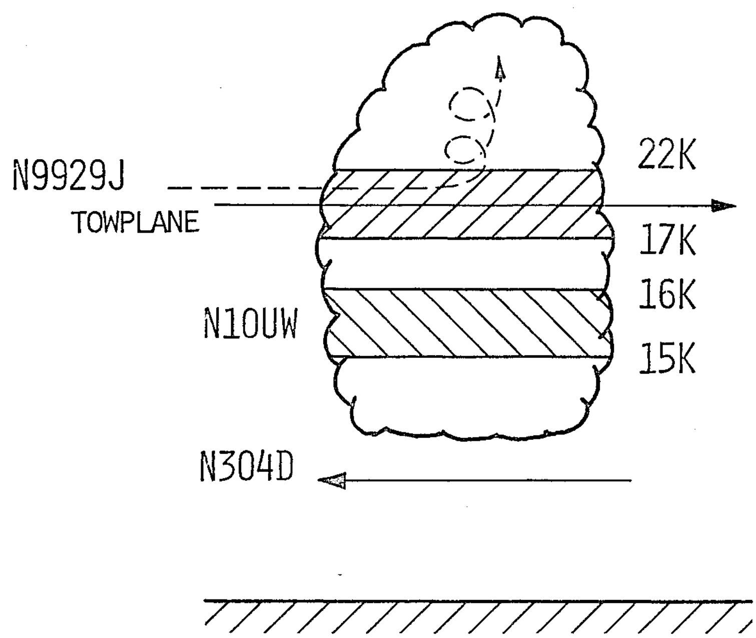


Figure 2. Illustration of the coordinated flight profiles employed in the Initiation of Precipitation Formation Studies. The penetrations of the clouds and the traverse through the updrafts just below cloud base continued until the cloud dissipated or the storm became too severe for continued penetration by the sailplane and the Wyoming Queen Air.

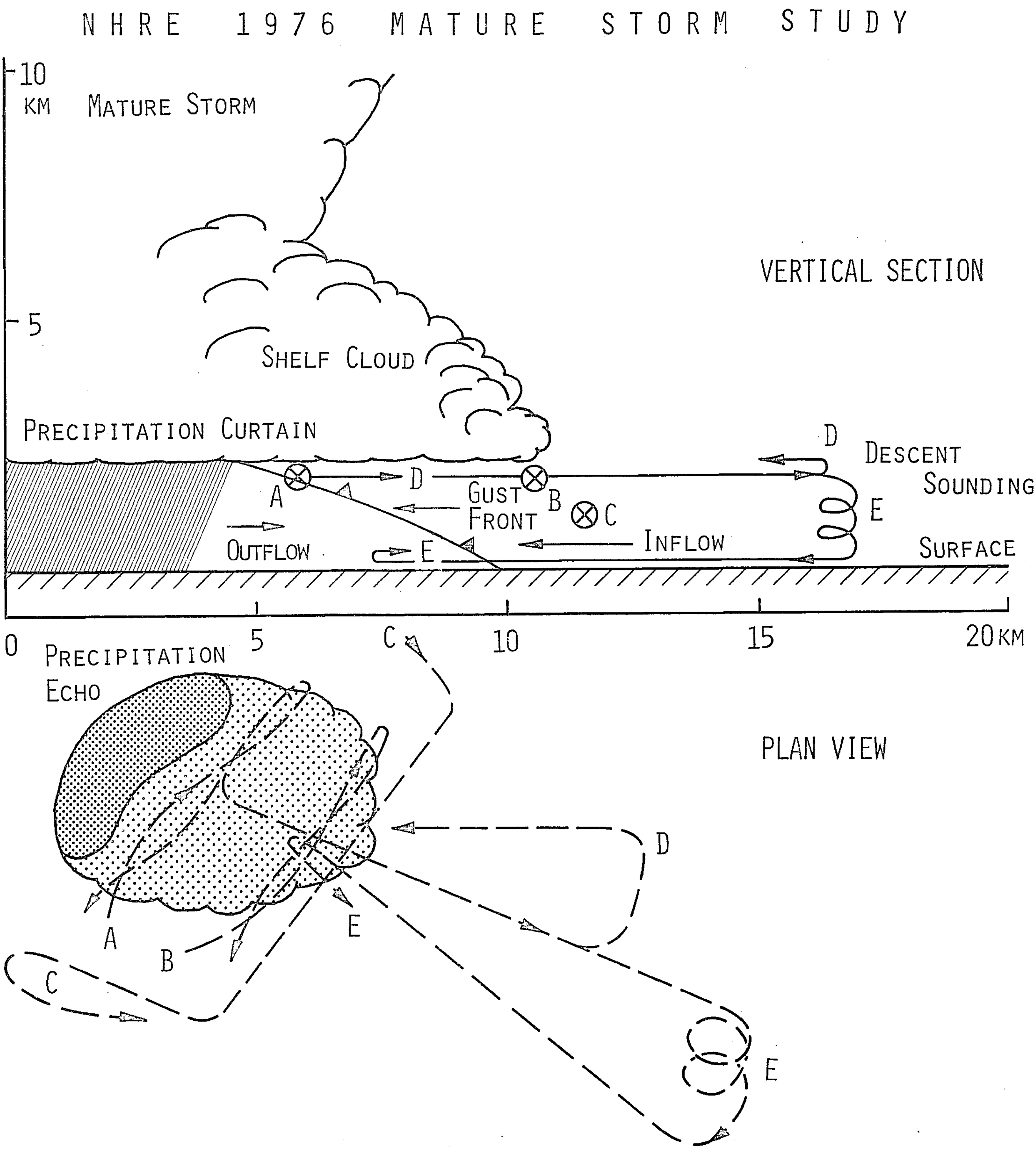


Figure 3. The flight procedures associated with the Mature Storm Studies are shown in the above illustration.

pattern in advance of the storm to help define the boundary of the moist air. Under favorable conditions, the Wyoming Queen Air penetrated through cloud base into the weak echo region to measure microphysical parameters and airflow structures of the updraft.

During 1976 a preliminary study of the ontop seeding technique was carried out with the NCAR Sabreliner. The objective was to determine the feasibility of seeding from above and to evaluate required aircraft response, performance, and onstation time necessary to perform this type of seeding operation.

On a typical day the Sabreliner was fueled, preflighted, and on stand-by while radar developments were observed and a knowledge of storm radar history was developed. At an appropriate time, the Sabreliner took off climbing towards the area selected. Throughout climb-out and the remainder of the flight, radar information was relayed to the Sabreliner crew who in turn provided visual observations to the coordinator in the Grover Operations Center. Observations of interest included visual cloud descriptions and their relationship to radar displays, the location of growth zones and a description of the zone in terms of whether it was composed of individual turrets versus a general area of growth, an estimate of rate of growth of turrets, the visibility or restrictions to visibility in the prospective seeding area and its effects on aircraft maneuverability. Additional requirements were designed to assess the aircraft crew's ability to observe all storms and associated growth regions, the ability to manuever the aircraft into position for seeding, and the requirement and opportunity for second seeding passes including the response time required to perform such maneuvers.

The second ancillary program continued the study designed to relate measured hailfall parameters and crop damage. A hail cube network, whose sites were located adjacent to crops, was operated during the 1976 hail season. After each hailfall the hail cubes were changed and an assessment of crop damage was made.

III. SUPPORT FACILITIES AND OBSERVATIONAL SYSTEMS

This section describes the operational and measurement facilities deployed during the 1976 summer field observation program. A description of the Grover complex along with operational details for each system are presented as well as those people responsible for each system.

A. Support Facilities

Figure 4 lists the NHRE facilities and personnel that were responsible for each major observing system and for other functions essential to meet the field research objectives. Figure 1, presented earlier on page 3, shows the Special Use Airspace assigned to NHRE by the FAA, the location of the Grover site, the Doppler radars, the dense precipitation network, and the rawinsonde sites. The location of the mesometeorological network and the crop damage network are presented later in this section (Figures 21 and 31, respectively).

The Grover Field Site is located about three miles north of the Town of Grover, Colorado. An aerial photograph is presented in Figure 5. Located at the site are communications, logistics, observing and coordinating components essential for coordination of the complex observational program described in section IIIB.-Observational Systems. In addition to selected observational capabilities, the site is equipped so that information essential for operational control can be processed and displayed in the Operations Center. Also included are radio and longline communications, teletype and facsimile circuits, a radar surveillance capability, aircraft tracking and essential administrative and logistical services. These activities are pictorially presented in Figures 6 through 10 that follow.

A list of visitors to the Grover field site during the summer of 1976 is presented in Table 1.

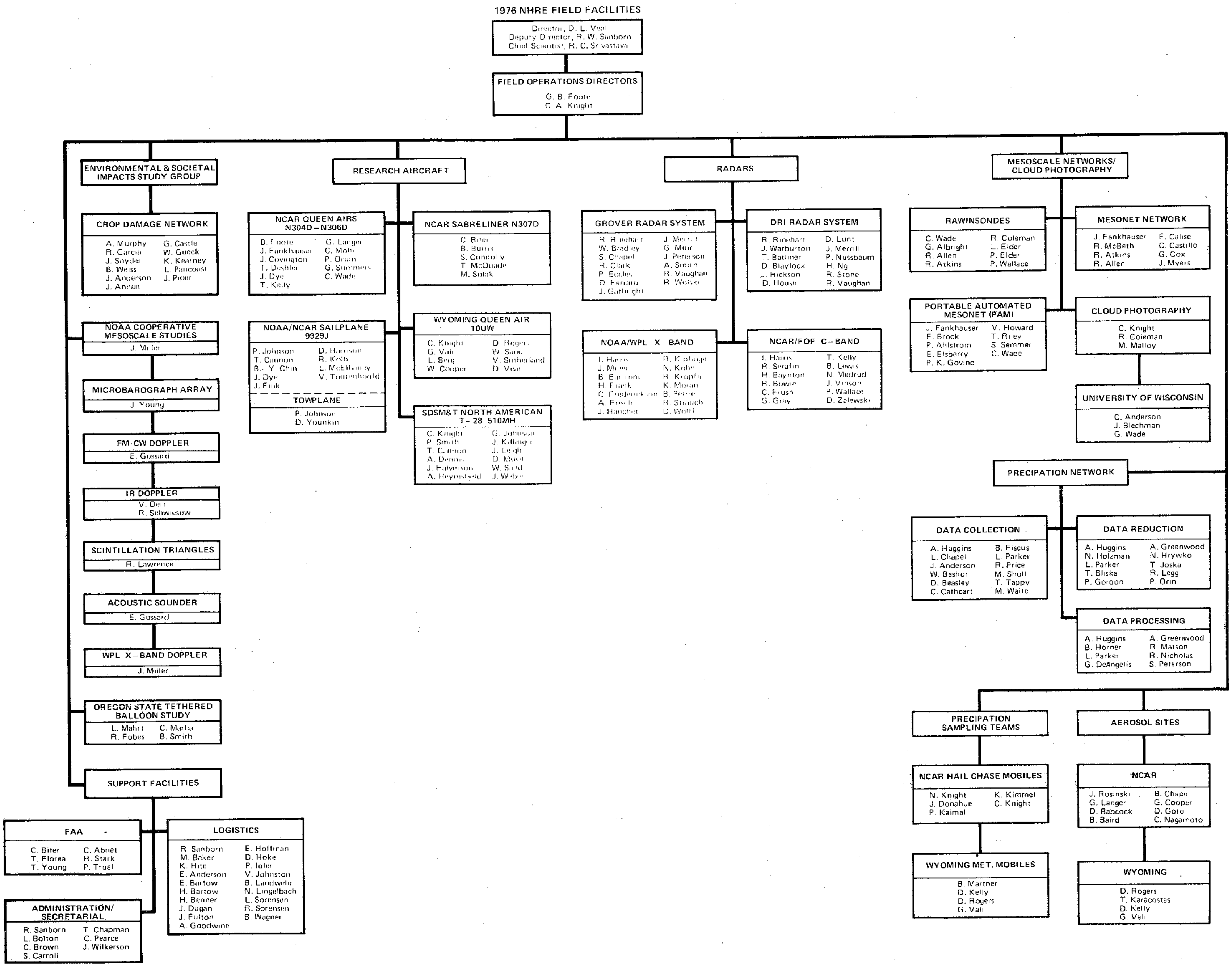


Figure 4. NHRE field facilities and personnel.

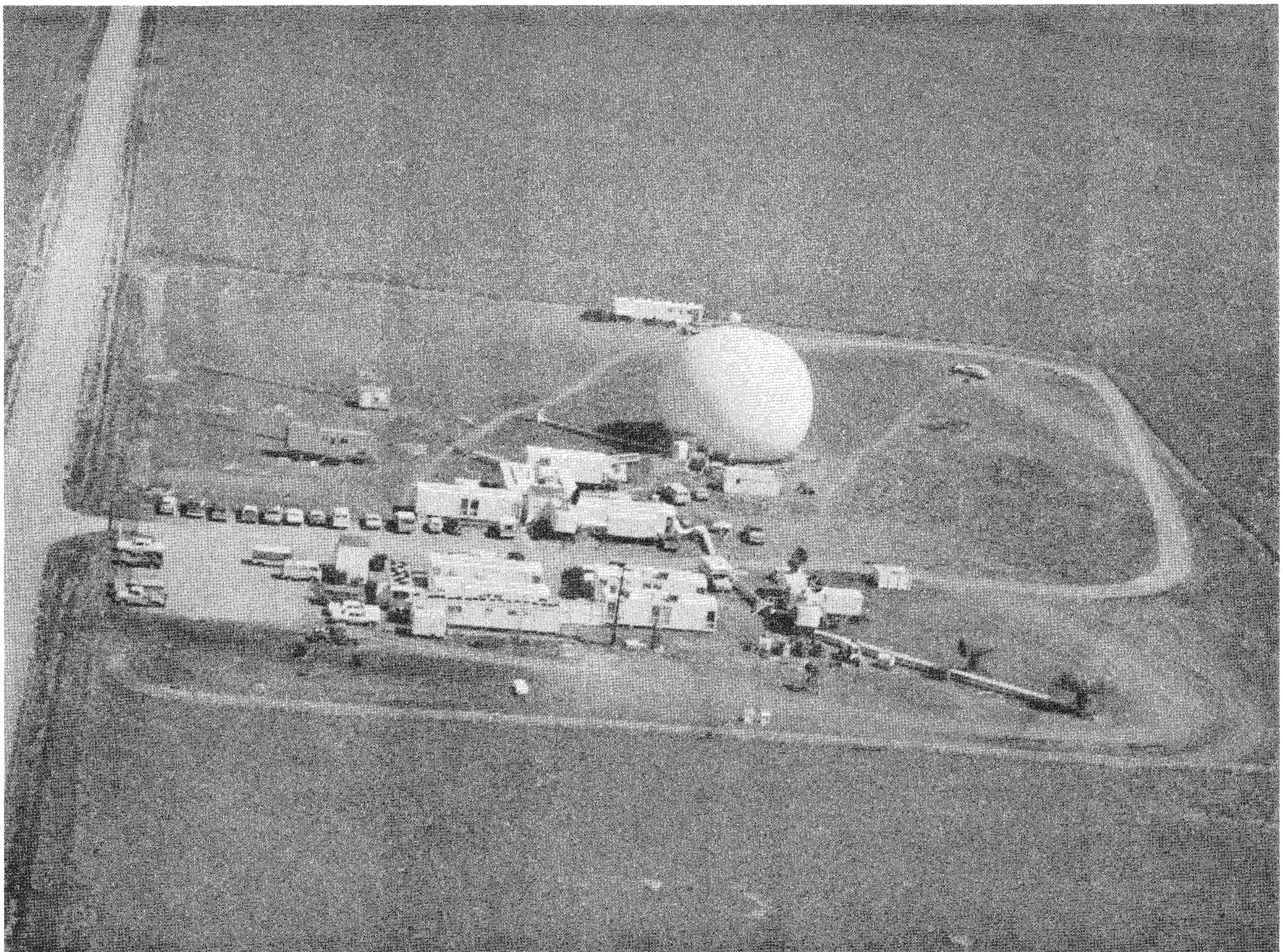


Figure 5. Aerial photograph of NHRE field headquarters located 3 miles north of Grover, Colorado.

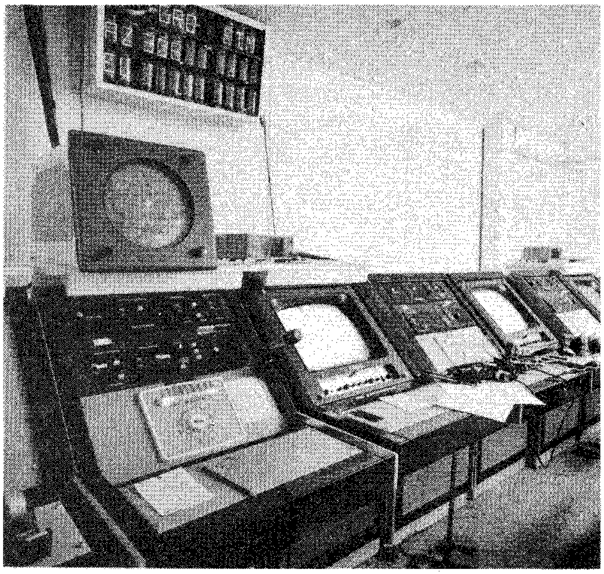


Figure 6a. The center of activity at the Grover field headquarters is the Operations Room. TV monitors with headsets are available for monitoring and controlling research activities such as the multiple aircraft operations, ground-based mobiles, and radar observations.

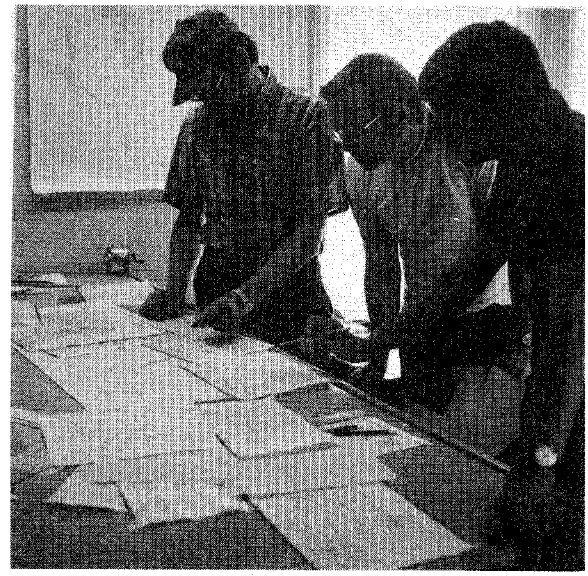


Figure 6b. Daily weather forecasts were prepared to include the most favorable area for storm formation, cloud bases and tops, significant temperature levels, storm movements and intensity, time of first 10 cm radar echoes, and time of mature storm development. From left to right: Dennis Musil of the SDSM&T, Charles Wade of NCAR, and Jean-Pierre Chalon, a scientific visitor to NCAR from Meteorologie Nationale, France, assess the weather conditions prior to the daily briefing.

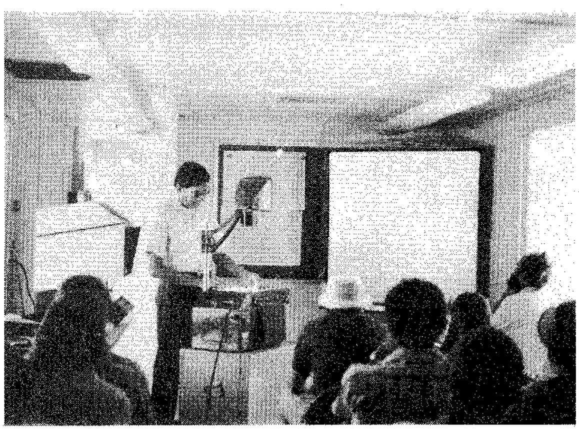


Figure 6c. At 1115 MDT staff briefings were held daily to discuss the weather outlook, equipment status and tentative schedules and plans for the day. This daily weather briefing is being presented by Dennis Musil.

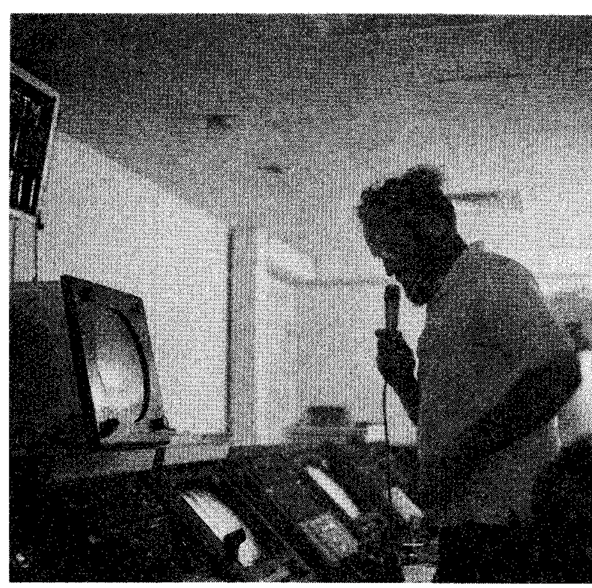


Figure 6d. Another view of the Operations Room showing Charles Knight, one of two Operations Directors, presenting the daily radio briefing and discussing the planned operations with those activities not located at Grover.

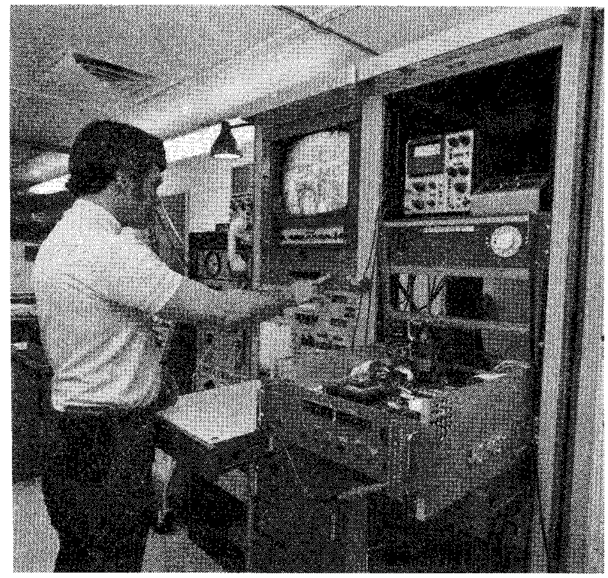


Figure 7a. Ronald Rinehart is shown adjusting the controls for the 10 cm Grover radar antenna shown in Fig. 7b.

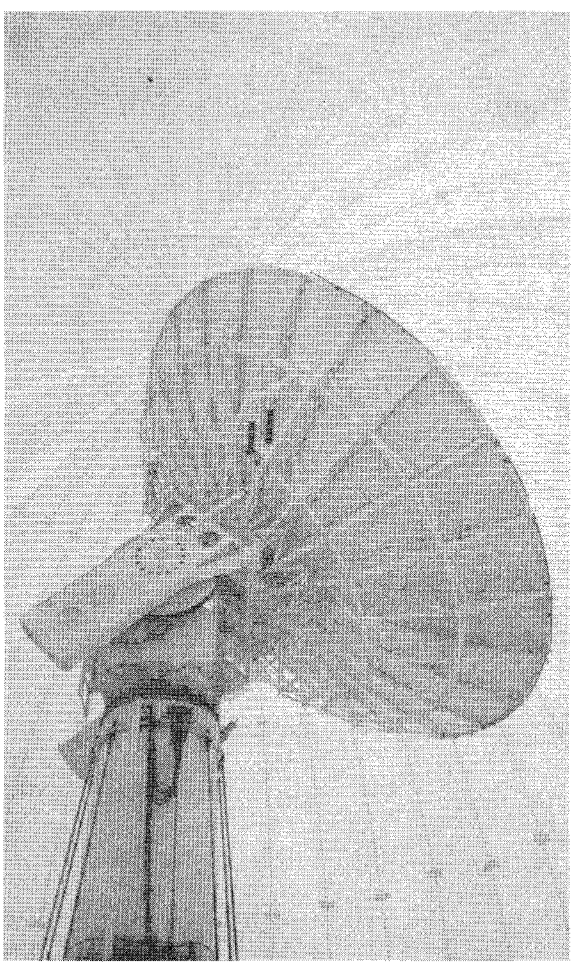


Figure 7b. Pictured is the CP-2 S-band radar antenna which provides prime radar support. It is slaved with an M33 X-band radar, and the simultaneously collected S- and X-band reflectivity data are used in hailstorm studies. The reflectivity Z from the CP-2 is the primary measurement used in developing the real-time operational radar displays.

Figure 7c. Ackley Smith (with headset) and John Merrill check out the Data Acquisition and Display System (DADS). DADS is the primary operational data recording and display unit capable of displaying S-band reflectivities in various selectable formats on the TV monitors in the Operations Room. MINA II is a second independent processing and recording system which records reflectivities at both wavelengths but displays only S-band reflectivity.

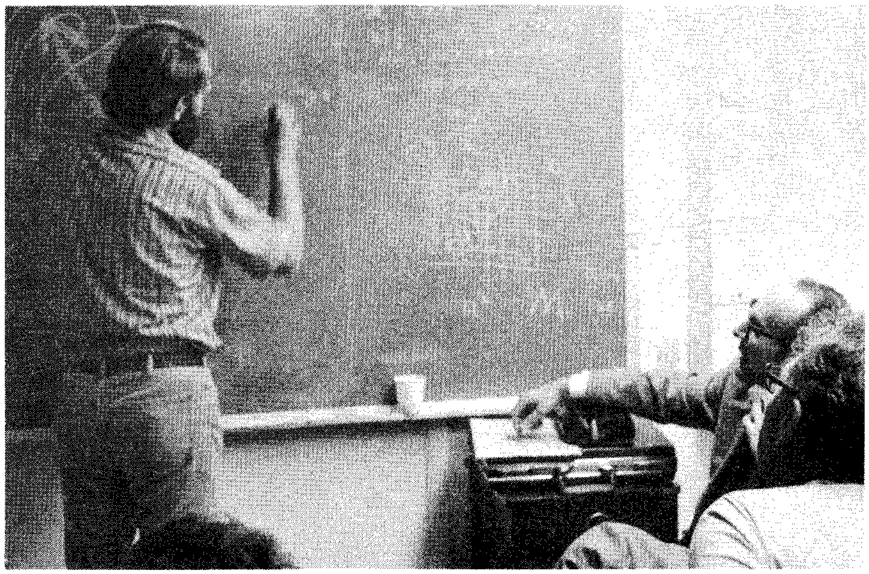


Figure 8a. Because of the diverse research equipment and facilities, many foreign visitors were attracted to the NHRE field site. Discussing hail suppression in NHRE are Brant Foote (standing), an Operations Director, and I. T. Bartishvili (translator) and A. I. Kartsivadze (foreground) visiting scientists from the Soviet Union. Sitting out of range of the camera were I. I. Burtsev, also part of the Russian delegation attending the WMO Weather Modification Conference held in Boulder, August 2-6, 1976, and J. M. Nunez from the Argentina hail program. The Russina scientists were accompanied on their trip to Colorado by Thomas Henderson of Atmospherics, Inc., Fresno, CA.

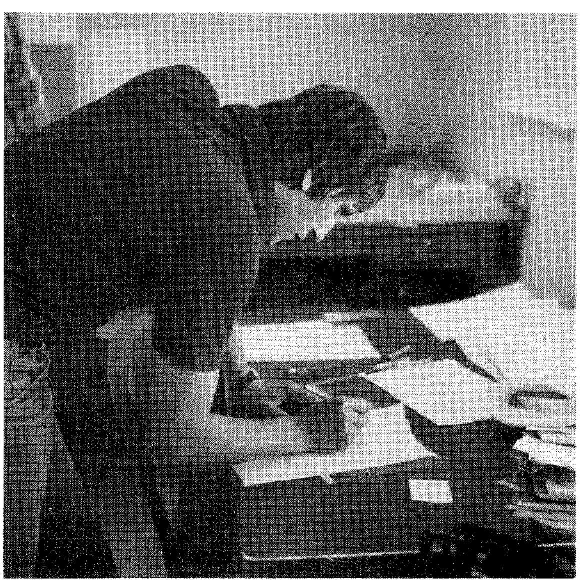


Figure 8b. Jean-Pierre Chalon of Meteorologie Nationale, France, is shown here analyzing weather data received over the National Facsimile Network.

Figure 8c. Another foreign visitor was Professor Krzysztof Haman (right) from the University of Warsaw, Poland. Here he discusses his prototype automatic hail camera with Alex Long, an NHRE scientist.

Figure 9a. Keeping an open channel for the dissemination of factual information and value perspectives to the residents of the area is one of the main functions of the Citizens' Council of the NHRE. Here members and their families are guided by Ackley Smith through the DADS trailer at the field site. The Council serves as a "listening mechanism" for NHRE and a point of personal contact with NHRE to the area residents.

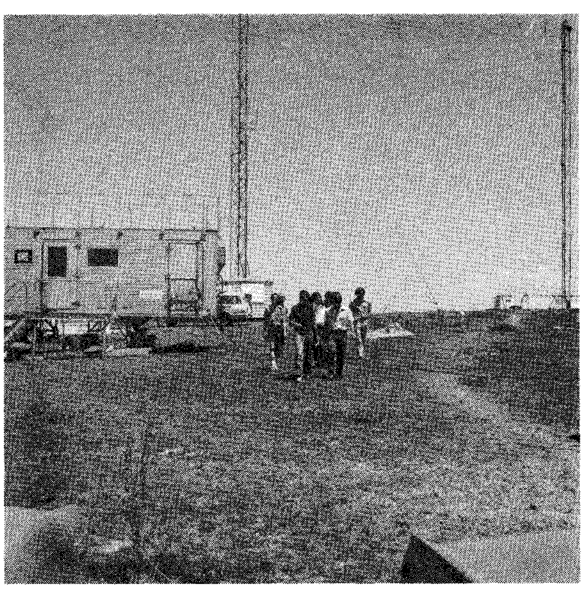


Figure 9b. Several tours were conducted during the summer which included visits to the various radar sites as well as the Butler airstrip. A small group of visitors is being shown around the Grover site by Jean-Pierre Chalon.

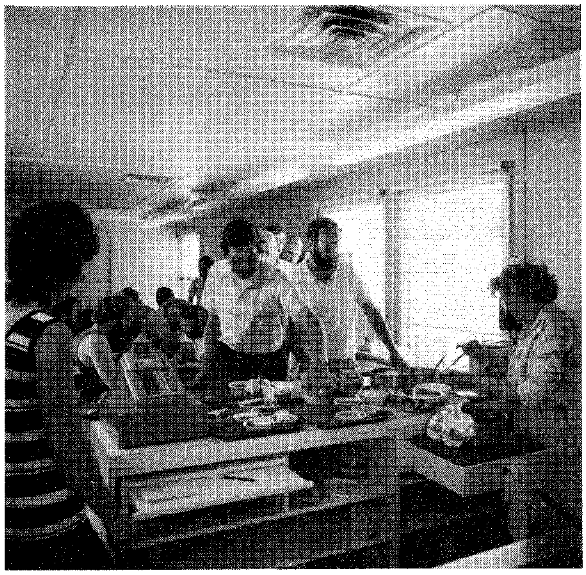


Figure 10a. An important aspect of any field experiment is adequate logistical support. Meals were served three times daily throughout the operational season at the Grover site cafeteria. Jo Duggan (left) and Helen Benner (right) serve lunch to staff and visitors.

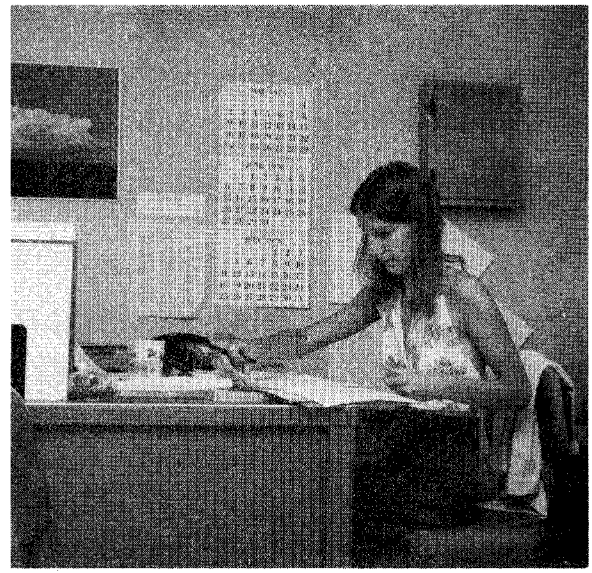


Figure 10b. Laura Lee Bolton served as the field headquarters secretary. Typing, taking telephone messages, greeting visitors, and dispatching vehicles were among her daily duties.

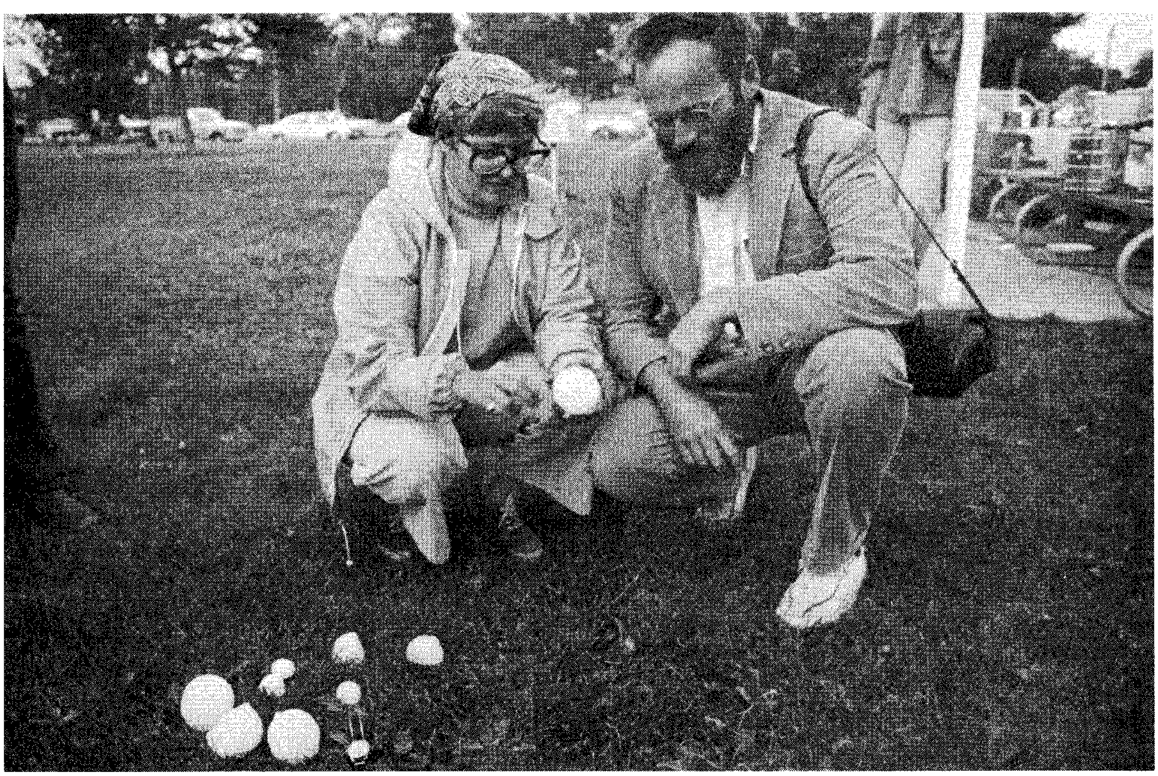


Figure 10c. Research often spilled over into less structured activities such as the evening picnics planned for the staff, families and visitors. Charles and Nancy Knight inspect hailstones gathered from a recent storm.

Table 1.

Visitors to NHRE Field Site

COUNTRY	AFFILIATION	VISITOR
Argentina	Comision Nacional Energia Atomica Division Cristalogrofia, Buenos Aries	Lora Levi
	Comision Nacional de Investigaciones Espaciales, Buenos Aires	Maria Elena Saluzzi DeTorres Martin Iturrioz Jose Miguel Nunez
	Servicio Meteorologico Nacional Buenos Aires	Louisa Lubart
Canada	Atmospheric Environment Service Downsview, Ontario	Peter W. Summers
	Research Council of Alberta Alberta	Jim Renick L. Wojtiw
	University of Toronto, Toronto	Paul I. Joe Glen Lesins Peter W. Stagg
France	Meteorologie Nationale Trappes	Jean-Pierre Chalon
Italy	Istituto di Fisica Dell'Atmosfera Bologna	Franco Prodi
Japan	Meteorology Research Institute	N. Kodaira
Poland	University of Warsaw, Warsaw	Richard Balcer Krzysztof Haman
South Africa	National Physical Research Laboratory CSIR, Pretoria	Ernest Carte Gerhard Held Jack Warner
	South Africa Weather Bureau, Pretoria	Piet S. duToit
Soviet Union		I. T. Bartishvili I. I. Burtsev A. I. Kartsivadze
United States California	Meteorology Research, Inc., Altadena	Elena S. Lobl

Table 1. continued

	Atmospherics, Inc., Fresno	Thomas Henderson
	University of California, Los Angeles	Sol N. Grover
Colorado	National Center for Atmospheric Research, Boulder	Francis Bretherton John Firor Henry Lansford Clifford Murino Robert Serafin Computing Facility (8 visitors)
	National Oceanic and Atmospheric Administration, Boulder	Stan Barnes Joe Golden Douglas Lilly
	RDD Research, Boulder	Randi Londer
	Bureau of Reclamation, Denver	Archie Kahan Bernard Silverman
	National Hail Research Experiment area, Grover	Citizens' Council Members
Illinois	Illinois Institute of Technology	Richard Fetter
Nevada	Desert Research Institute, Reno	George Linkletter Joseph Warburton
New York	Museum of Natural History, New York, N.Y. (Editor, Natural History Magazine)	Sally Lindsay
Oklahoma	National Severe Storms Laboratory, Norman	Ron Alberty Don Burgess Craig Goff Jesse Jennings Ed Kessler Stephen Nelson Dale Sirmans Ken Wilk
	University of Oklahoma	John McCarthy Pamela Stephens, UCAR Fellow
Oregon	Oregon State University	Larry Mahrt Bart Smith

Table 1. continued

South Carolina	Clemson University	Richard Taylor Carlton Ulbrich
South Dakota	South Dakota School of Mines & Technology	Phillip Chen Arnett Dennis Dennis Farley Harold Orville R. L. Schwaller Paul Smith J. F. Spahn S. F. Weber
Washington, D.C.	National Science Foundation	Currie Downie R. Marcus Price Edward Todd

B. Observational Systems

In the remainder of this section the observational facilities displayed during the 1976 field season will be described.

1. Research aircraft. Aircraft used during the 1976 operations period were:

NCAR Queen Air N304D
NCAR Queen Air N306D
NCAR Sabreliner N307D
NOAA/NCAR Sailplane N9929J (and towplane)
University of Wyoming Queen Air N10UW
South Dakota School of Mines & Technoloyg T-28 N510MN

With the exception of the Sabreliner, the aircraft listed above were used for coordinated research missions investigating isolated cumulus congestus or so-called "feeder clouds" associated with hailstorms as well as mature storms. The Sabreliner was flown on separate missions to assess the feasibility of seeding new cumulus towers from above. The research missions are discussed in more detail in section II.-The 1976 Field Program.

The NCAR aircraft operated out of the Research Aviation Facility located at the Jefferson County Airport near Broomfield, Colorado. The SDSM&T T-28 and the University of Wyoming Queen Air were based at the University of Wyoming, Department of Atmospheric Sciences hangar located at Brees Field, Laramie, Wyoming. The NOAA/NCAR Sailplane and towplane were based at the Butler, Wyoming, airstrip which is located about 12 miles north of the Grover field site. A description of each aircraft and the instrumentation carried by that aircraft are included in Figures 11 through 17 that follow.

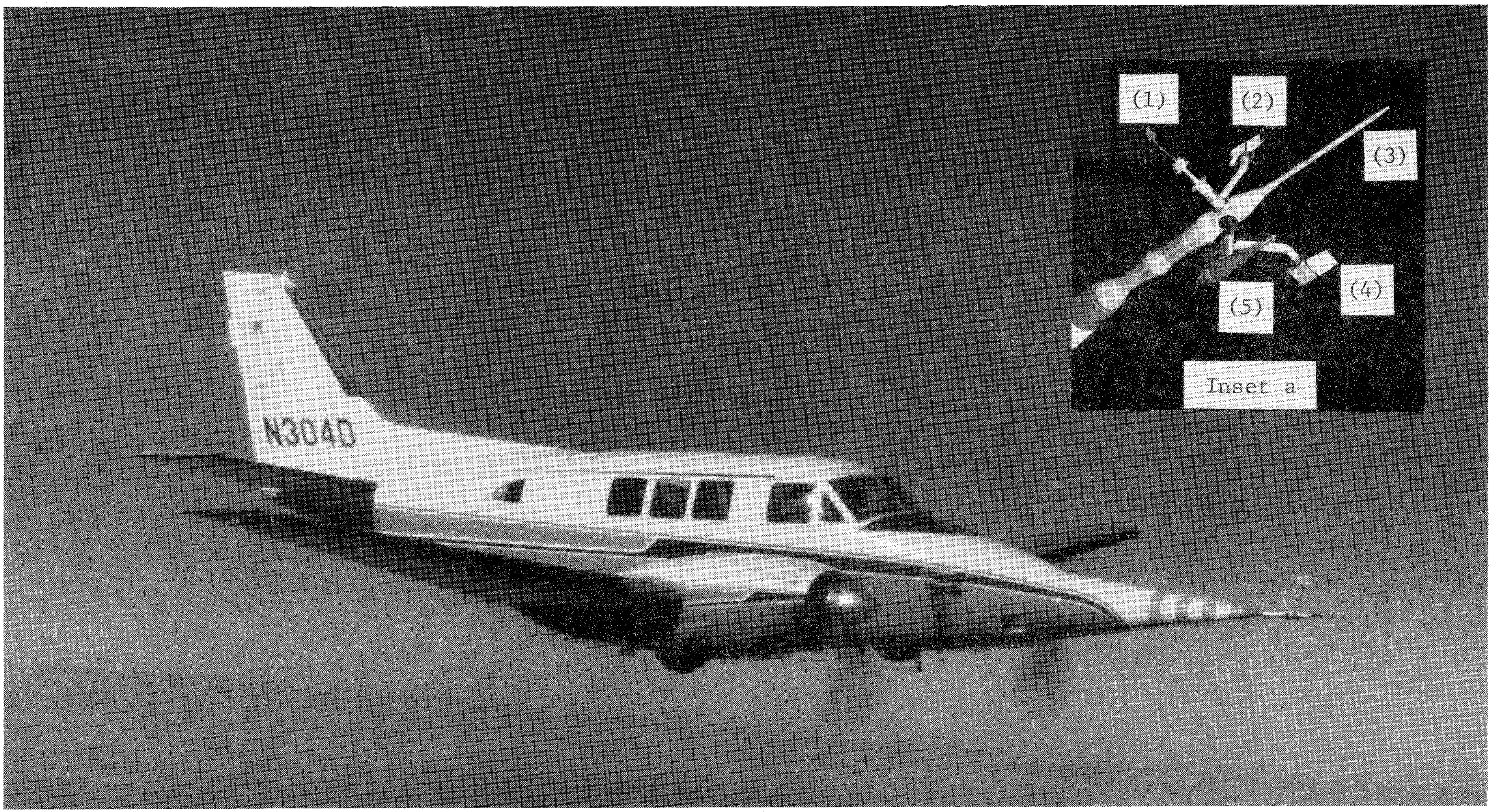


Figure 11. Queen Air N304D, operated by the NCAR Research Aviation Facility, Jefferson County Airport, Broomfield, Colorado, was instrumented similarly to Queen Air N306D. The nose boom carried sensors for determining turbulence and gust parameters. Inset a: (1) rotating angle of attack vane; (2) fixed side-slip vane; (3) probe tip containing sampling ports for dynamic and static pressure; (4) fixed angle-of-attack vane; and (5) fast response temperature sensor.

Figure 12. The meteorologically instrumented Beechcraft Queen Air N306D, also operated by the Research Aviation Facility, was used to obtain air motion and precipitation physics data in updraft and inflow regions of hailstorms. Sampling intakes for cloud physics measurements are located on the top of the fuselage. Inset a: Instrumentation mounted beneath the wing included: (1) wing-mounted pitot tube for sensing dynamic pressure; (2) Rosemount total temperature sensor; (3) reverse flow temperature sensor.

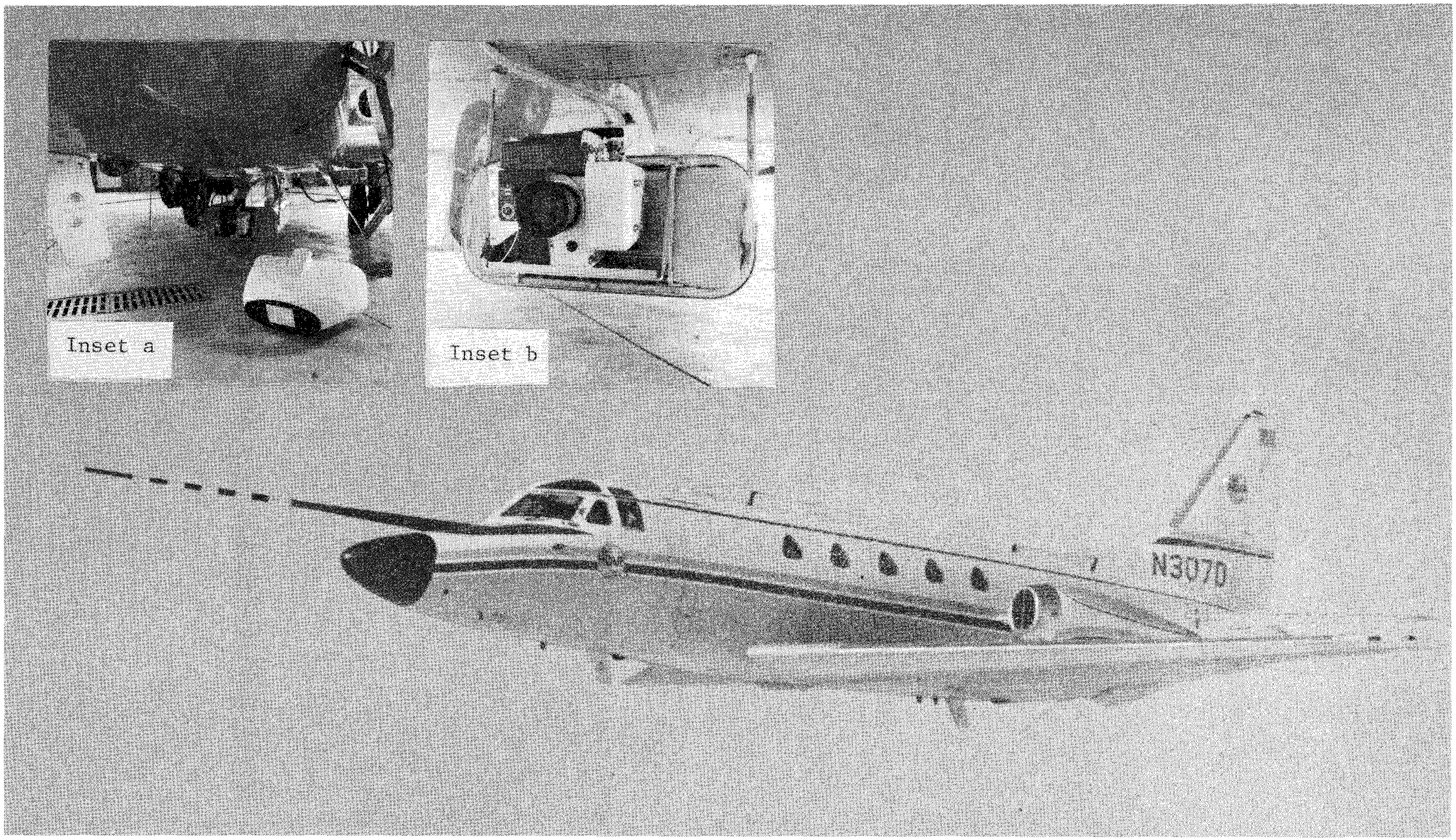


Figure 13. A third aircraft operated by the Research Aviation Facility was the North American Sabreliner N307D. Its primary mission was to assess the feasibility of ontop cloud seeding. Insets a-b show a close up of a pod (mounted beneath the Sabreliner) containing a 35 mm time-lapse camera used for documenting the cloud conditions during seeding trials.

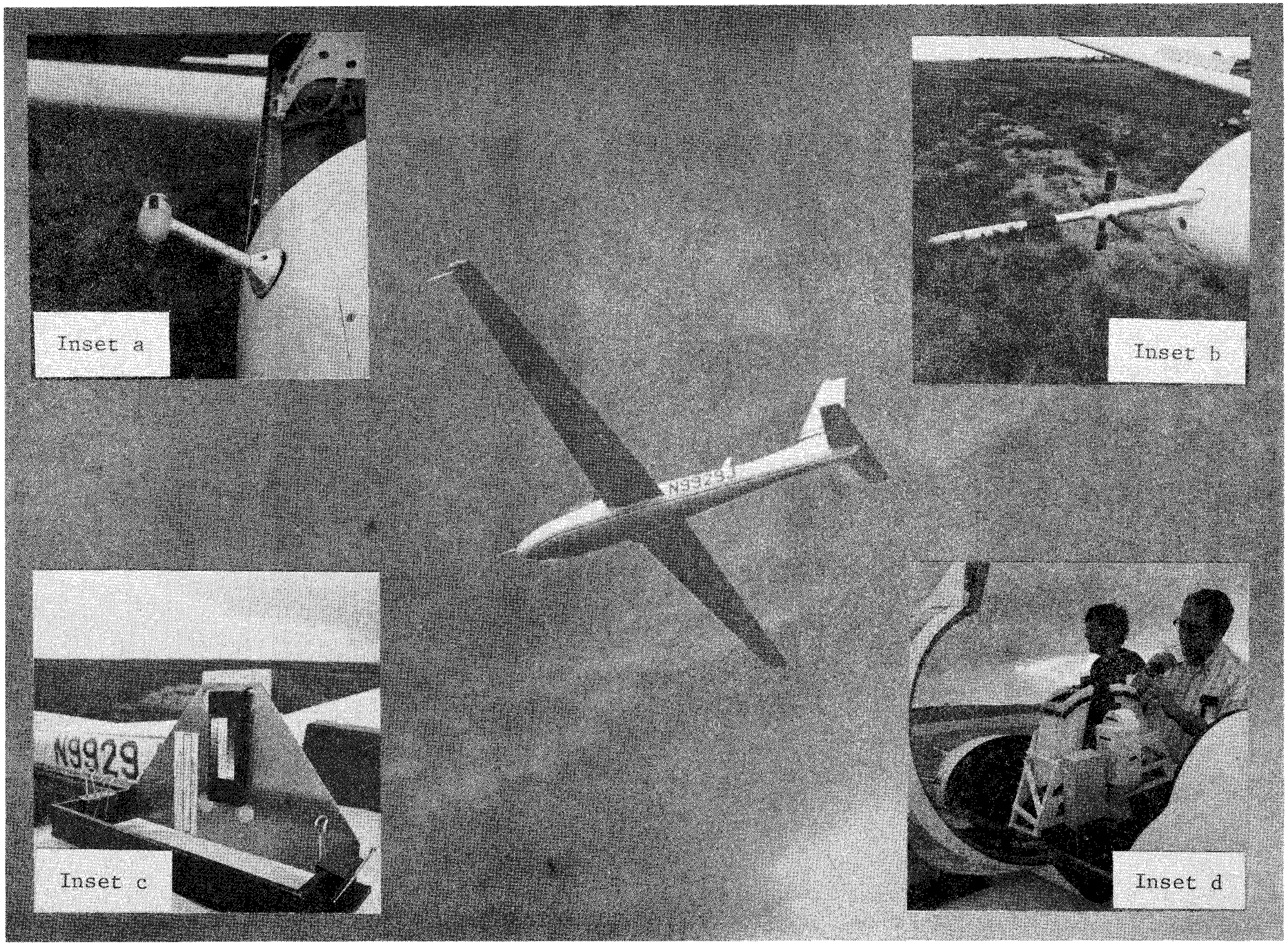


Figure 14. The NOAA/NCAR Sailplane N9929J is operated by NCAR. The meteorologically-instrumented sailplane was used extensively in summer 1976 during the initiation of precipitation studies to obtain precipitation physics data. Inset a: Reverse flow temperature probe for measuring temperatures in cloud. Inset b: Nose boom with electric field measuring probes. Inset c: Bracket with grey scale target used for processing control of the Cloud Particle Camera (CPC) film. Inset d: CPC being serviced by Reece Kolb (left) and Lawrence McElhaney (right), both of NCAR.

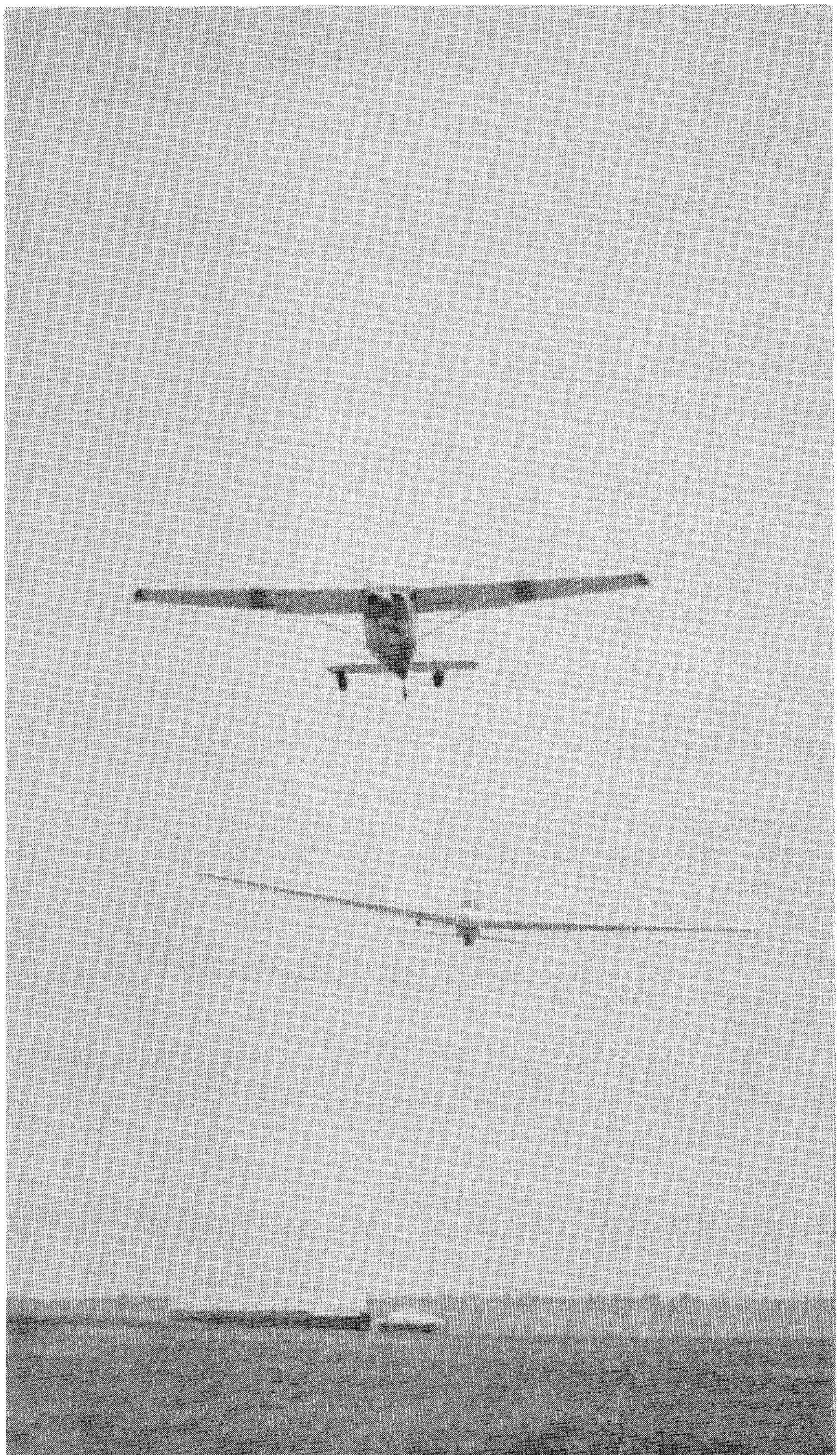


Figure 15a. The NOAA/NCAR sailplane piloted by Vim Toutenhoofd of NCAR, on tow behind a Cessna 180 towplane piloted by Dave Younkin.

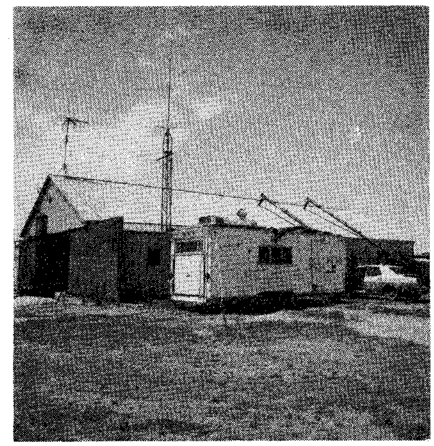


Figure 15b. Sailplane ground station located next to hangar at Butler airstrip. Note communications and telemetry antennas.

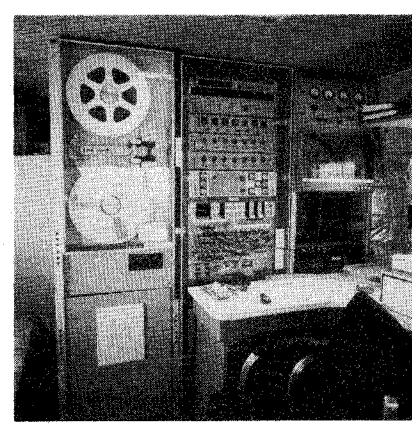
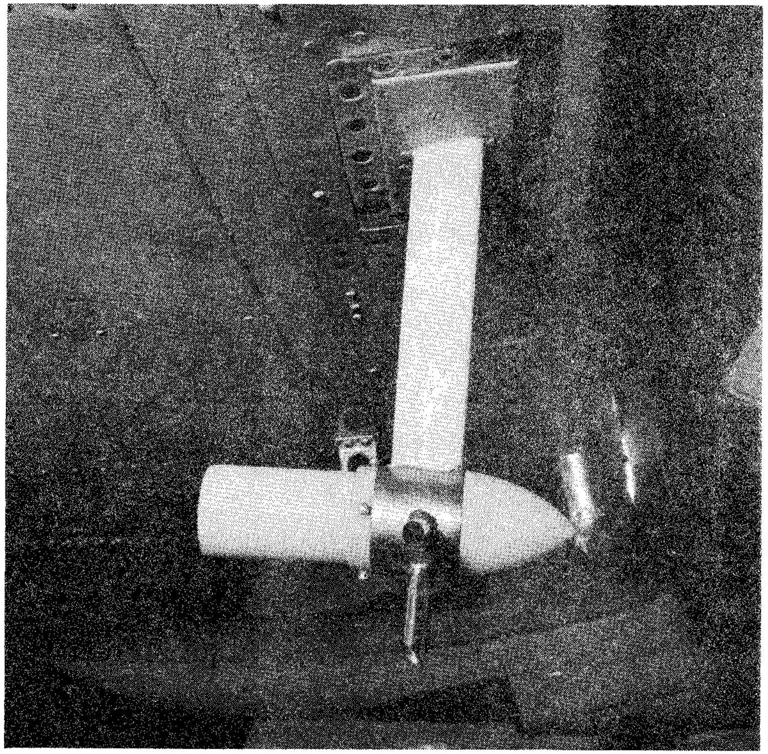
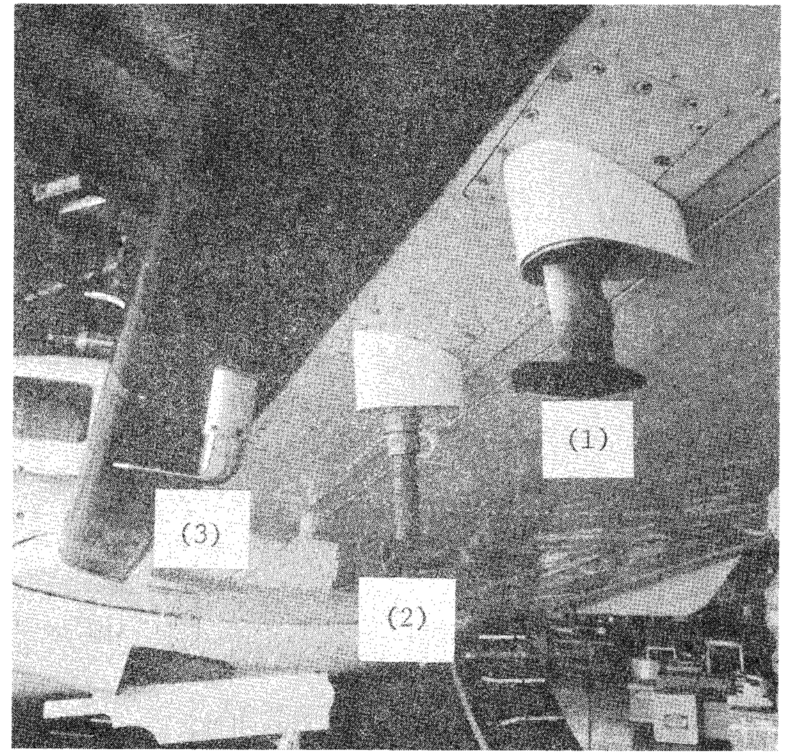


Figure 15c. Interior of the ground station showing telemetry receiver and data recording equipment.

Figure 16. The Beechcraft Queen Air N10UW, operated by the Department of Atmospheric Science, University of Wyoming, Laramie, Wyoming. See the following page for the description of instrumentation.





Queen Air N10UW was used to obtain precipitation physics and air motion data in and around thunderstorms. It participated in the initiation of precipitation formation and mature storm studies. A computer-directed data system for real-time decision-making is located onboard the aircraft. Instrumentation featured in Figure 16 (preceding page) include: (1) decelerator for sampling cloud particles; (2) 2-D particle spectrometer probe (Knollenberg); (3) rotating vane for side-slip measurements; and (4) forward-scattering spectrometer probe (Knollenberg).

Other basic instrumentation mounted beneath the wings are shown in Figure 16a: reverse flow temperature sensor, and Figure 16b: (1) Rosemount total temperature sensor, (2) sensing head of a Johnson-Williams liquid water content sensor, and (3) pitot tube for sensing observed airspeed.

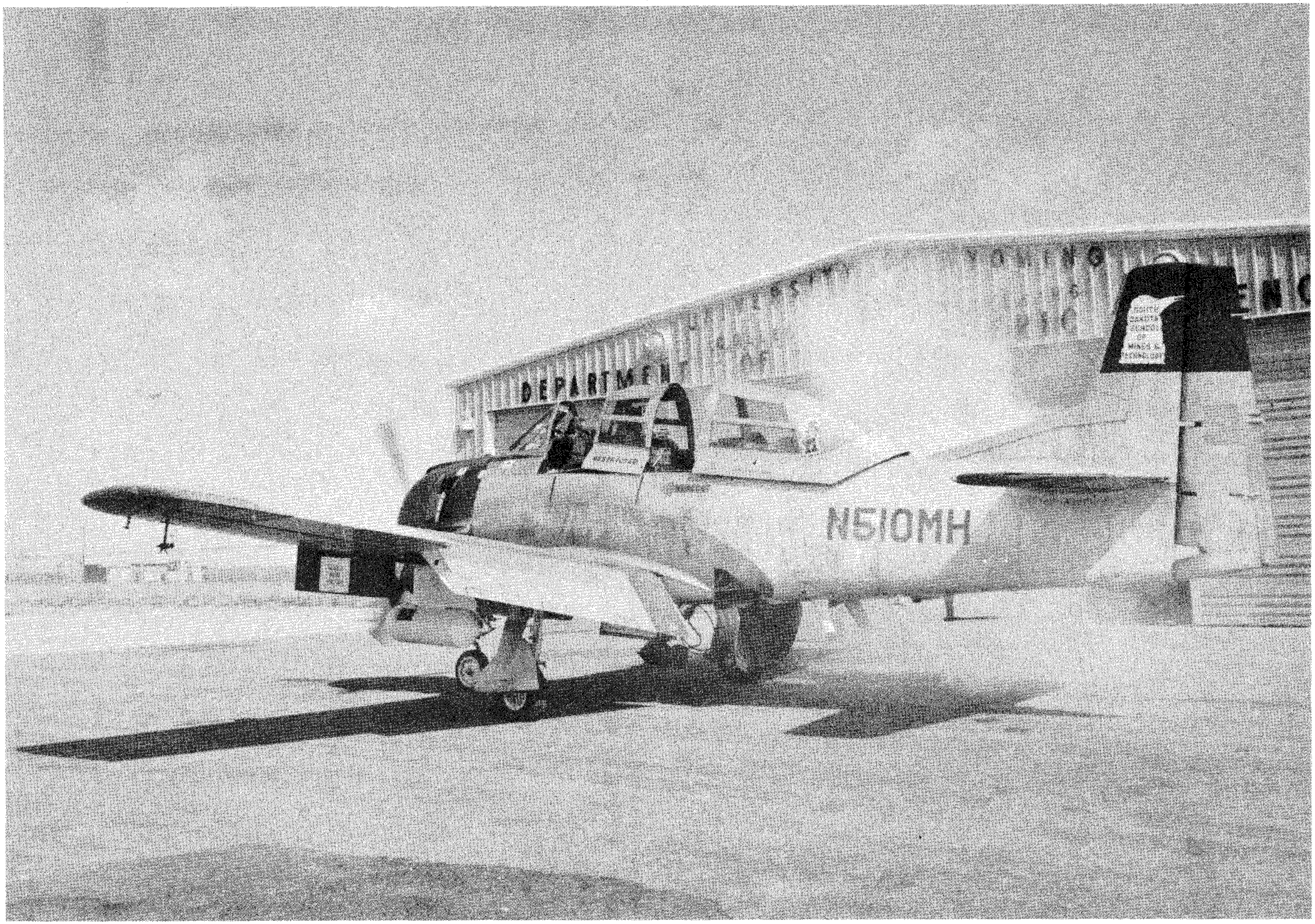
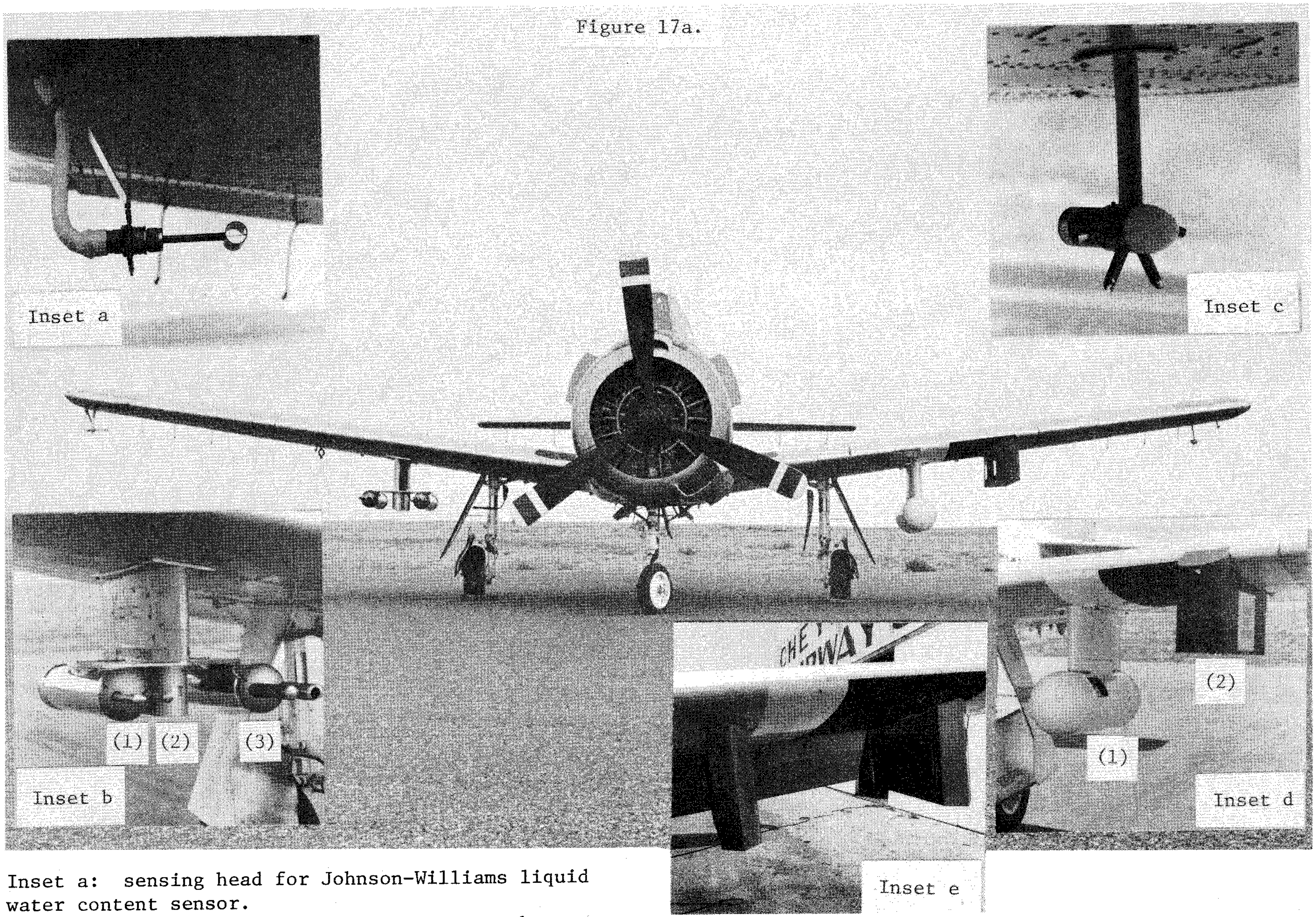


Figure 17. The armored North American T-28 N510MH, operated by the Institute of Atmospheric Science, South Dakota School of Mines & Technology, Rapid City, South Dakota, was used for penetrating the more severe portions of hailstorms. Typical flight altitudes were in the 5-7 km range in or near the weak echo region of hailstorms. The T-28 served as the central measurement platform for the mature storm studies.

The National Hail Research Experiment Summer 1976 Summary Report - Link Page

Next PART0002

Figure 17a.



Inset a: sensing head for Johnson-Williams liquid water content sensor.
Inset b: (1) 2-D particle spectrometer probe
(2) foil sampler
(3) axially-scattering spectrometer probe.
Inset c: reverse flow temperature probe

Inset d: (1) cloud particle camera housing
(2) housing for flash lamps.
Inset e: hail sensor (interchanged with the NCAR cloud particle camera).

2. Radar Systems

a. Grover Radar System

The radar system consists of a 10-cm radar, a slaved M33, 3-cm radar, and two independent processing and recording systems. Radar reflectivity, at the two wavelengths, is the primary measurement made by the Grover radar system. These reflectivity measurements comprise the two signals of the dual-wavelength radar which are processed only after the fact.

Operationally, the reflectivity Z from the S-band CP-2 is the primary measurement used by the Operations Director and other personnel in the Operations Room. The data are displayed by two separate processing systems -- DADS (Data Acquisition and Display System) and MINA II (Multiplexed Input NHRE Averager II). Each system provides quantitative information in the form of PPIs for use in the direction of field operations.

The Data Acquisition and Display System (DADS) is the primary operational data recording and display unit and is capable of displaying S-band reflectivities in various selectable formats on TV monitors in the operations room. Operators may request different formats such as larger or smaller scale PPIs with varying coordinate systems, such as polar coordinate systems with the origins at the Grover headquarters or either the Cheyenne or the Sidney VORTACs. Additionally, the storm PPIs may be represented by as many as three different contour levels where the magnitude of each level is selectable as well as the angular elevation of the requested PPI. The MINA II system recorded reflectivities at both wavelengths but displayed only the S-band reflectivity.

b. DRI Radar System

The Desert Research Institute (DRI), University of Nevada, radar system consists of two M33 radars. Each radar contains an S-band surveillance radar and an X-band tracking radar. The surveillance radar presents a PPI for 90 km radius from Grover. The X-band radar was used to track targets (aircraft, chaff, or cloud tops) within 120 km of Grover. The tracking coordinates are recorded by DADS.

Figure 18 shows the overall Grover and DRI Radar Systems.

c. Doppler Radars

A network comprised of four Doppler radars, two from NOAA and two from NCAR, were deployed during the summer field experiment. The location of the Doppler radars are shown in Figure 1, page 3.

The Operations Director selected the storm to be observed while the Radar Director provided guidance to the radars as to the location of the activity, the depth to be scanned, the time for commencement of scans and the mode of operation for each radar. The basic mode of operation was for at least three of the radars to sector scan, covering an entire storm in 2-3 minutes. The fourth radar usually scanned the same sector, but at times it was directed to scan in elevation or to point vertically. Each radar operator determined the azimuth, elevation and range limits for scans to be used, updating these limits as new information was received from the Radar Director.

Two C-band Doppler radars were operated by the NCAR Field Observing Facility (FOF). The CP-3 radar as shown in Figure 19 was located 11 km SE of Grover, while the second, CP-4, was located approximately 46 km ESE of Grover.

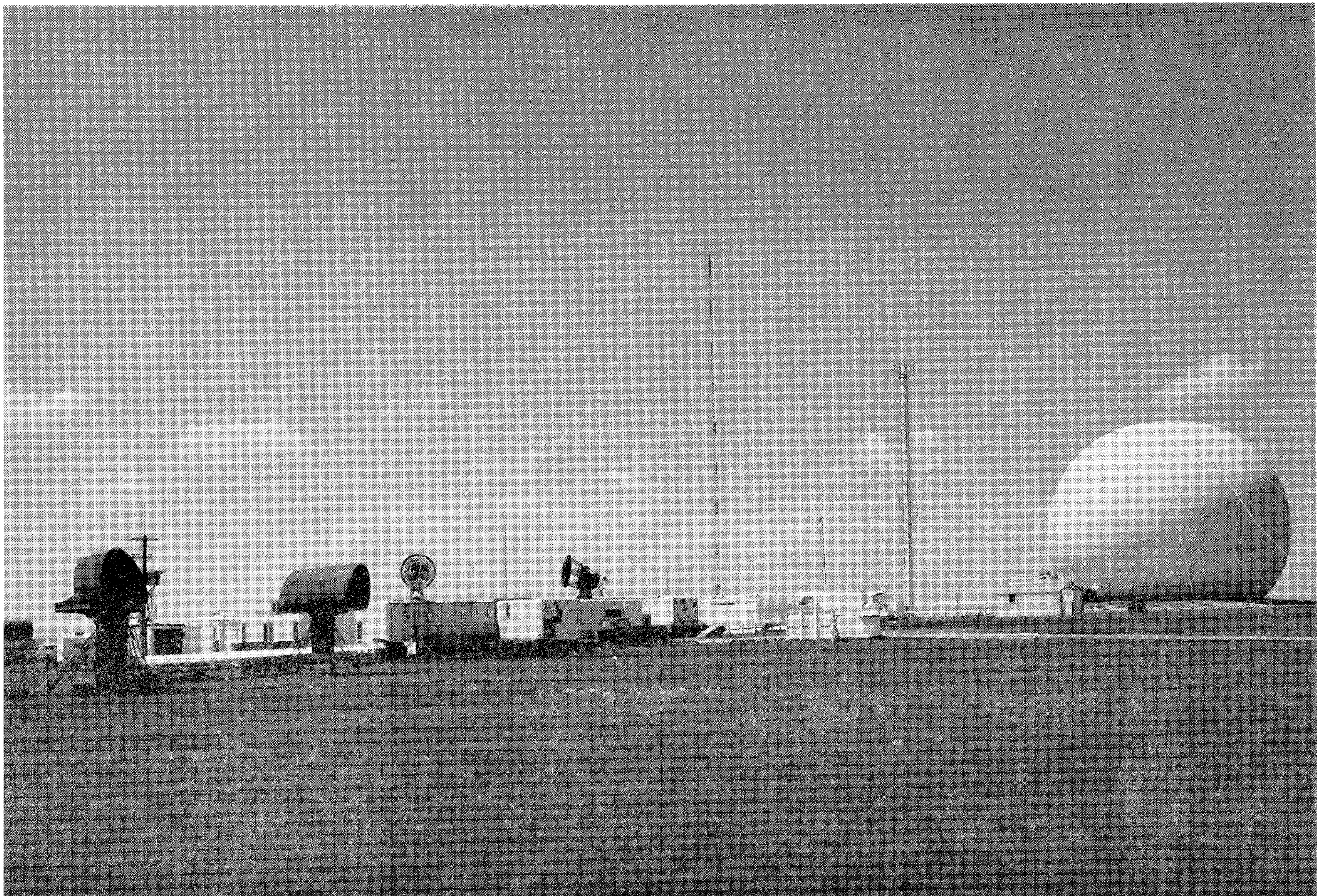


Figure 18. NCAR and DRI radar systems located at the Grover field site. The DRI radars are those located to the left while the NCAR S-band radar antenna is situated in the radome to the right.

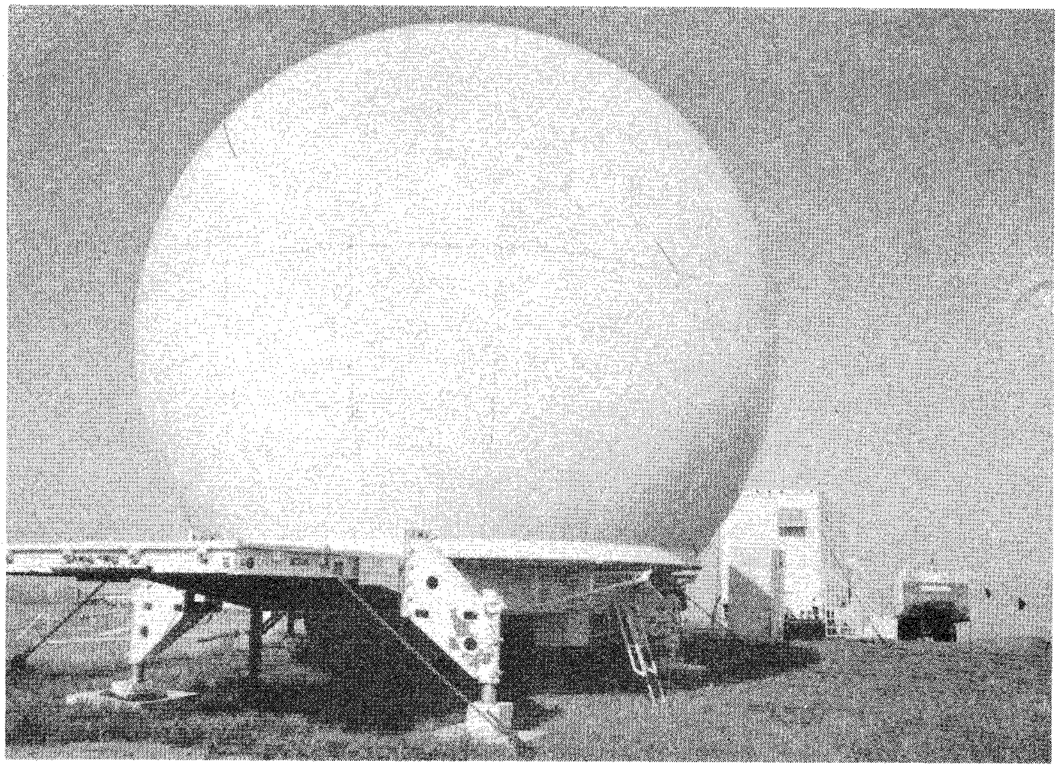


Figure 19. CP-3 C-band Doppler radar operated by the Field Observing Facility of NCAR.

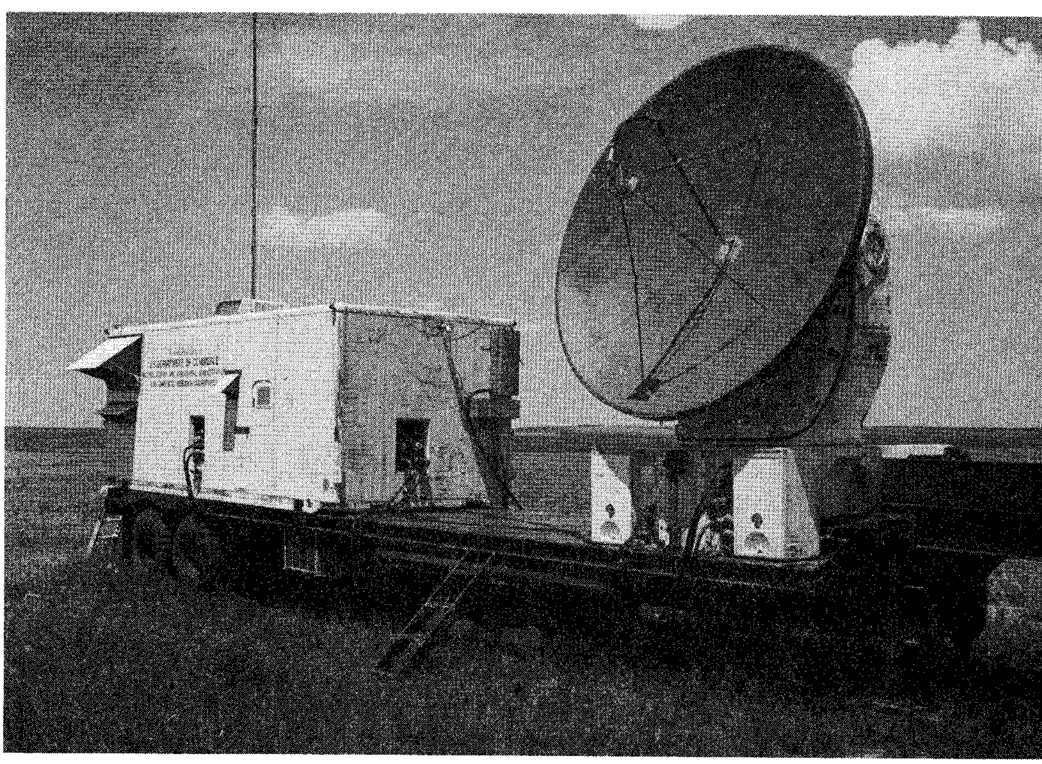


Figure 20. NOAA 1 X-band Doppler radar operated by the Wave Propagation Laboratory of NOAA.

The NOAA/Wave Propagation Laboratory (WPL) X-band Doppler radars were located near Lindbergh, Wyoming (NOAA1) and Kimball, Nebraska (NOAA2). The Lindbergh radar is shown in Figure 20.

3. Upper Air and Surface Mesoscale Networks and Cloud Photography

a. Rawinsondes

Three rawinsonde sites were maintained during summer 1976. The equipment used consisted of one GMD-1 (located north of Potter, Nebraska) and two RD-65A (Sterling and Grover) rawinsonde ground stations The locations are shown in Figure 21. Side-by-side comparisons of the three systems were conducted prior to and after the summer experiment. All rawinsondes were baselined by FOF prior to the summer operations and each was checked prior to release to help assure proper operation and that no drift in the base line had occurred. Figures 22 and 23 depict typical launching activities at the Grover site.

b. The Mesometeorological Network

Figure 21 also shows the location of the surface mesoscale stations and of the network with respect to Grover and the rawinsonde sites. The network was comprised of 45 stations, 31 of which were conventional-type stations, and 14 were PAM (Portable Automated Mesonet) stations. One PAM station was located at the Grover headquarters (Figure 24a-d). All stations had the capability to measure wind velocity, temperature, humidity, and precipitation. A hailcube was also located at each site.

Mesonet operations and servicing were conducted seven days a week throughout the entire operational period. Typically, each site was serviced in the morning and if a storm occurred that day the hailcubes were changed immediately after storm passage to prevent the possibility of contamination from a later storm.

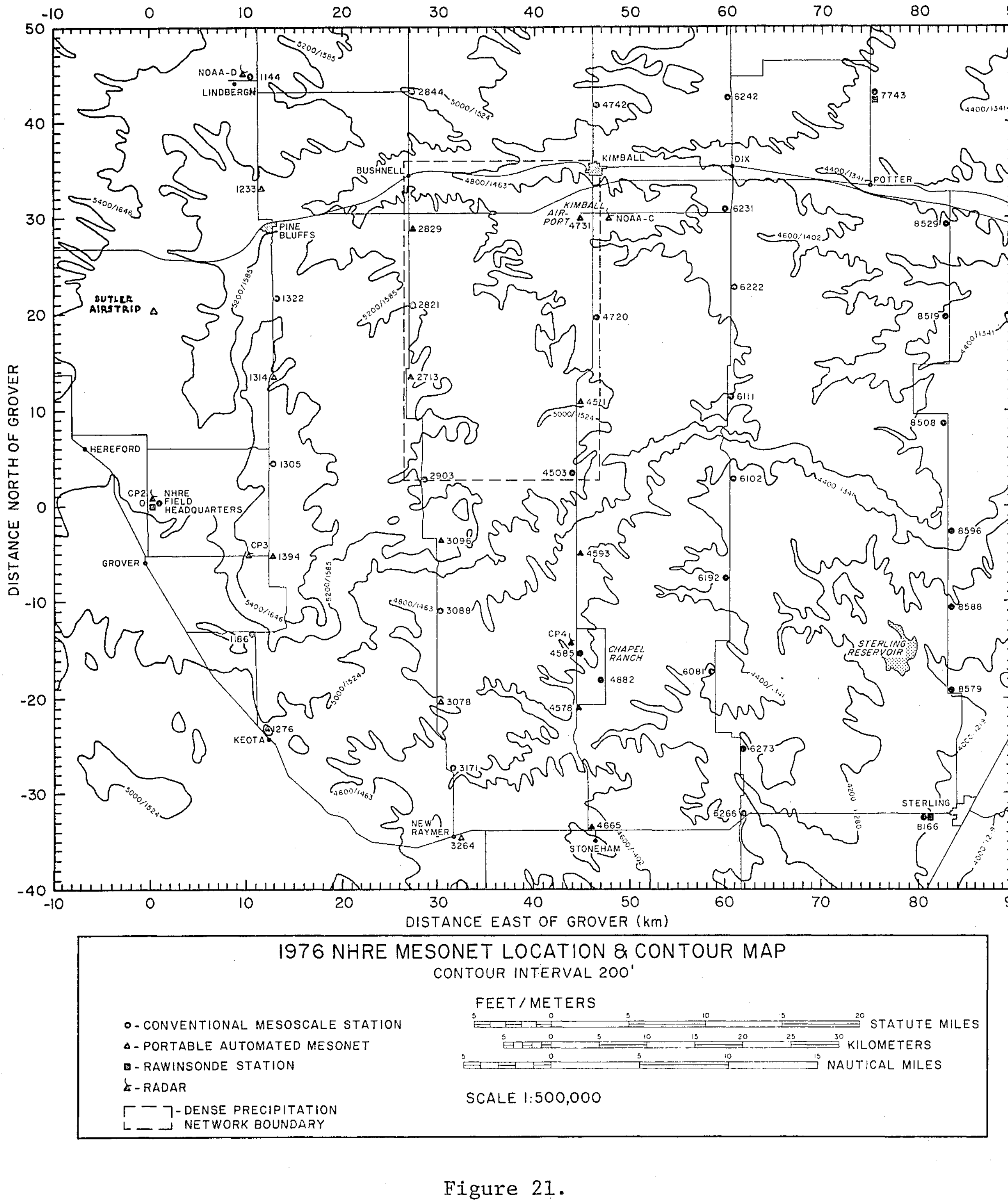

1976 NHRE MESONET LOCATION & CONTOUR MAP
CONTOUR INTERVAL 200'
FEET/METERS
DISTANCE EAST OF GROVER (km)
DISTANCE NORTH OF GROVER
o - CONVENTIONAL MESOSCALE STATION
Δ - PORTABLE AUTOMATED MESONET
▣ - RAWINSONDE STATION
RADAR
DENSE PRECIPITATION NETWORK BOUNDARY
STATUTE MILES
KILOMETERS
NAUTICAL MILES
SCALE 1:500,000
NOAA-D
LINDBERGH
BUSHNELL
KIMBALL
DIX
POTTER
PINE BLUFFS
KIMBALL AIR-PORT
NOAA-C
BUTLER AIRSTRIP
HEREFORD
NHRE FIELD HEADQUARTERS
GROVER
KEOTA
NEW RAYMER
STONEHAM
CHAPEL RANCH
STERLING RESERVOIR
STERLING

Figure 21.

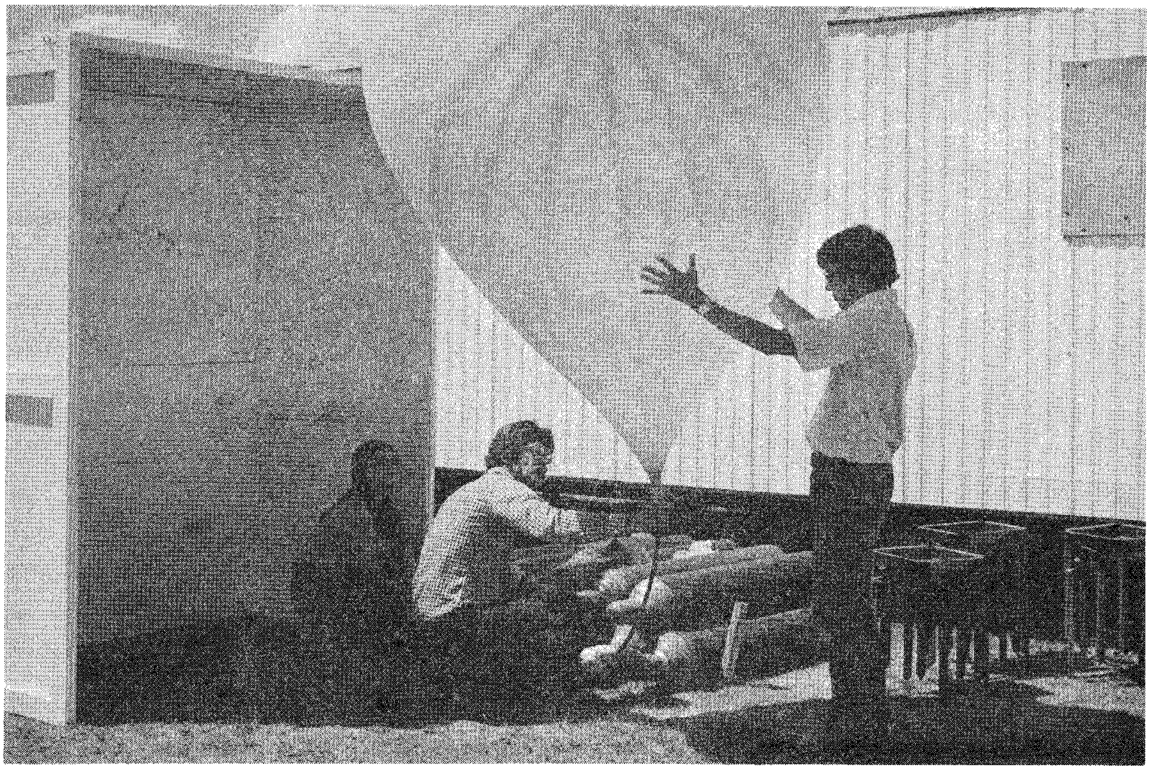


Figure 22. From left to right, Patricia Wallace, Gerald Albright and Neil Holzman fill a rawinsonde balloon with helium in preparation for a launch.

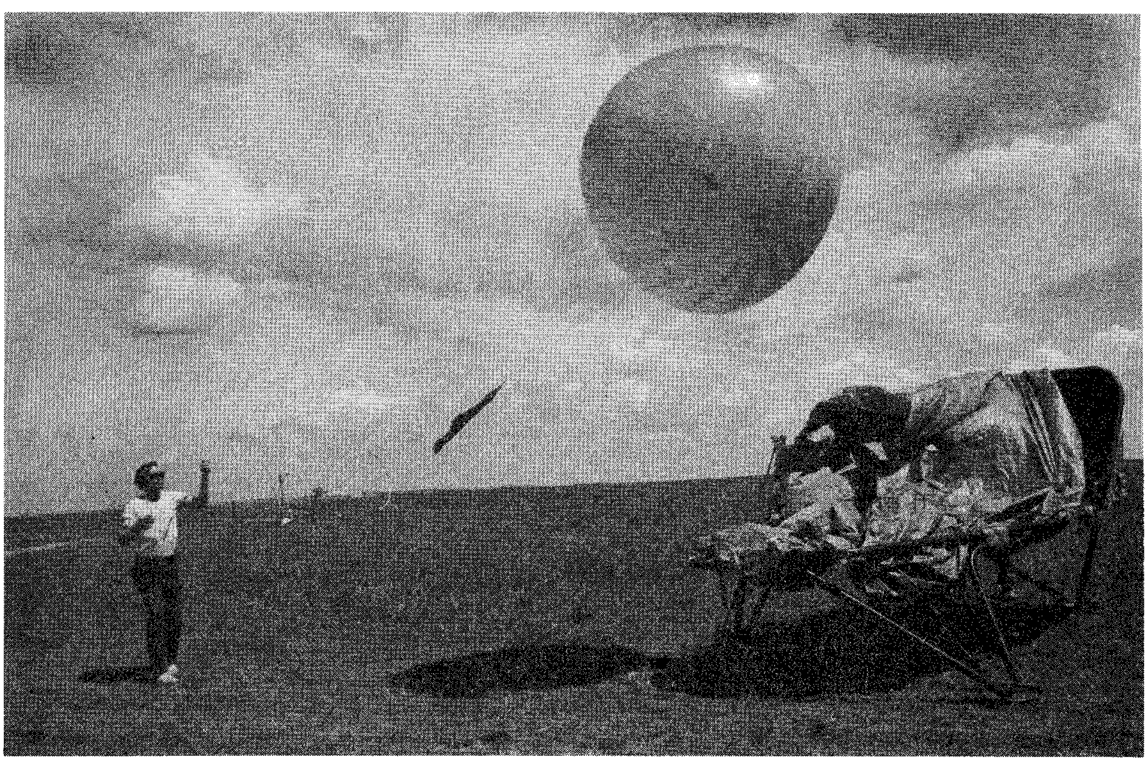


Figure 23. Charles Wade launches a rawinsonde from the Grover RD-65A ground station.

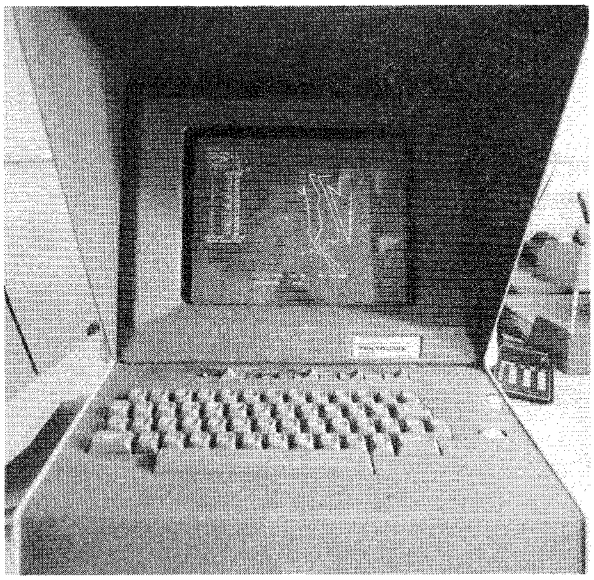


Figure 24a. Control panel for the PAM operations.

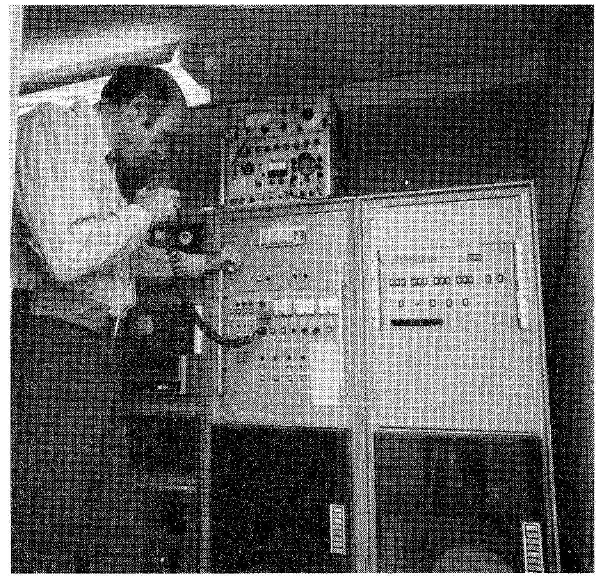


Figure 24b. Fred Brock of the Field Observing Facility maintaining radio communications with the PAM field sites.

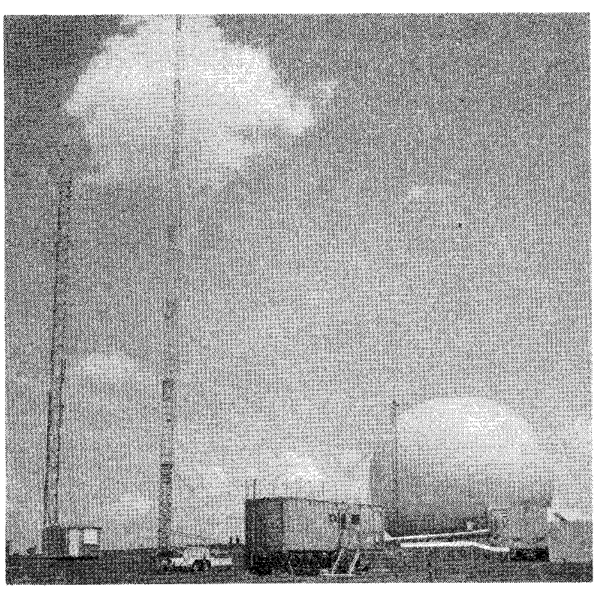


Figure 24c. (foreground) Transmitter tower and PAM trailer at the Grover field site.

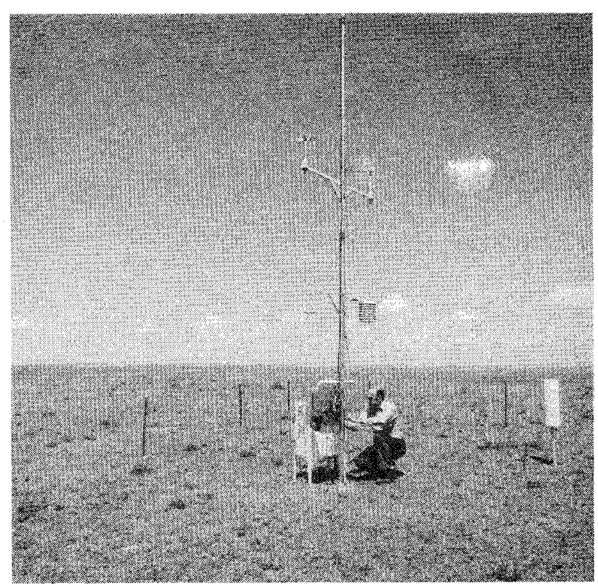


Figure 24d. A typical remote field installation being serviced by Fred Brock.

c. Cloud Photography

Daily time-lapse cloud photographs were taken from three sites: Grover, Sterling and the Weld County Airport, Greeley, Colorado. Additional cameras were operated only on storm days. These were located at the Lindbergh and Potter, Nebraska, the Butler, Wyoming airstrip, and the Chapel Ranch located about 8 miles north of Stoneham, Colorado. The University of Wisconsin maintained time-lapse cloud photography equipment at the Grover and Butler airstrip sites. These locations are shown in Figure 21. A typical time-lapse site is shown in Figure 25.

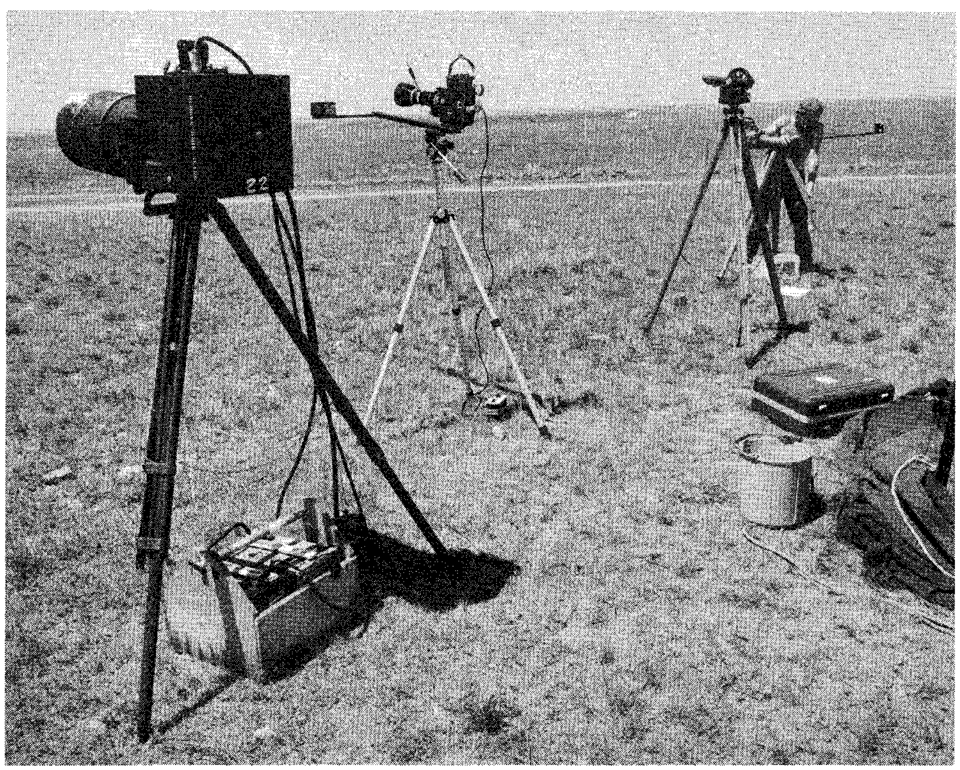


Figure 25. Jerry Blechman of the University of Wisconsin makes adjustments on a Bolex time-lapse camera at the Grover field site. Time-lapse cloud photography was used for documenting storm development and visual features which help identify storm types.

Additional photographs were obtained by hand-held and time-lapse cameras available to crews operating the mobile precipitation sampling vehicles. Several aircraft were also equipped with time-lapse cameras, either in the forward-viewing or side-viewing mode. The scientific observer onboard each aircraft also had a hand-held camera available.

4. Precipitation Network

The precipitation network was located southwest of Kimball, Nebraska. Its location is also shown in Figure 21. The network consisted of 727 sites within an area of approximately 660 km^2. Instruments within the network included hailpads and wedge rain gages with a density approximately one per km^2 and hailcubes and Belfort rain gages at a density of approximately one per 10 km^2. In addition, ten modified separators were collocated with Belforts and hailcubes in the dense network. Twenty-five additional separators were positioned along two of the north-south lines of the mesonet stations. Examples of the precipitation measuring instruments are shown in Figures 26a-c. Examples of recording and reduction activities are featured in Figures 27a-b.

5. Precipitation Sampling Teams

Both the University of Wyoming and NCAR operated two precipitation sampling vehicles (see Figures 28a-b and 29a-b, respectfully). The primary mission was to collect sequential precipitation samples (primarily hail). NCAR personnel also took time 35 mm photographs of the storms and measured surface winds. The Wyoming vehicles routinely recorded meteorological parameters (temperature, dew point pressure and wind). Pilot balloon observations were also made by the Wyoming crews immediately ahead of the storm and time-lapse photographs were also taken.

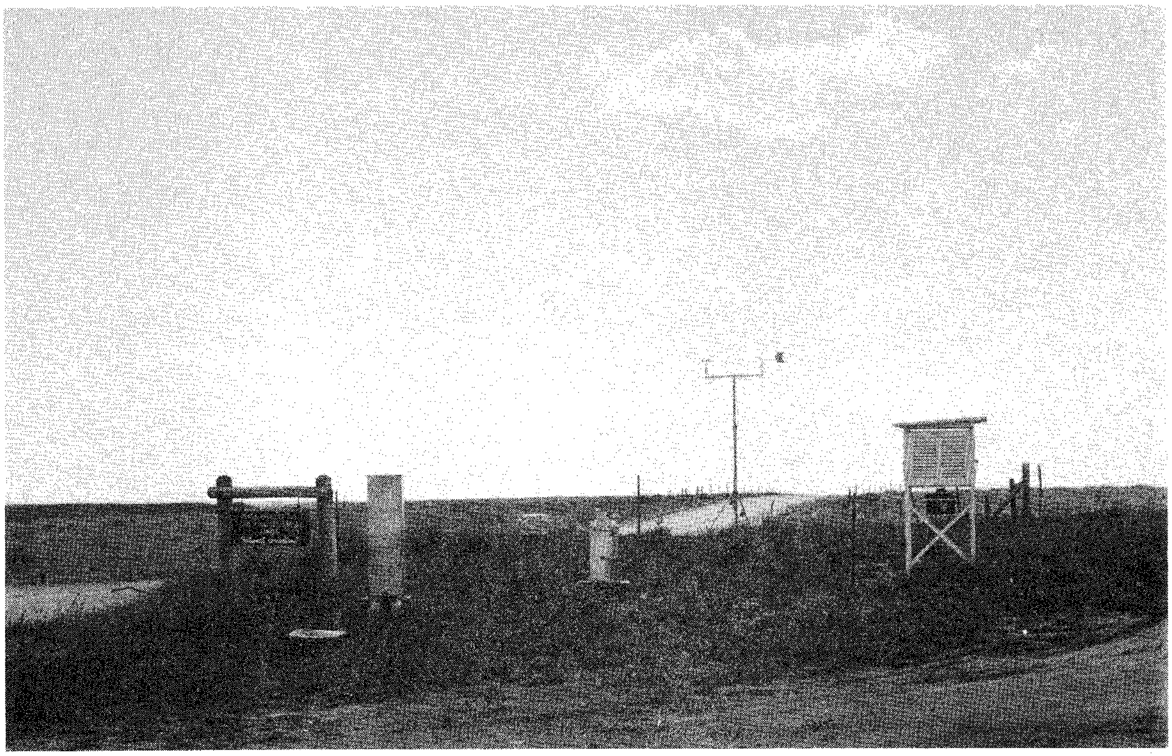


Figure 26a. Precipitation and mesometeorological instrument site. The instruments from left to right are the rain/hail separator, a weighing rain gage, an anemometer, and an instrument shelter.

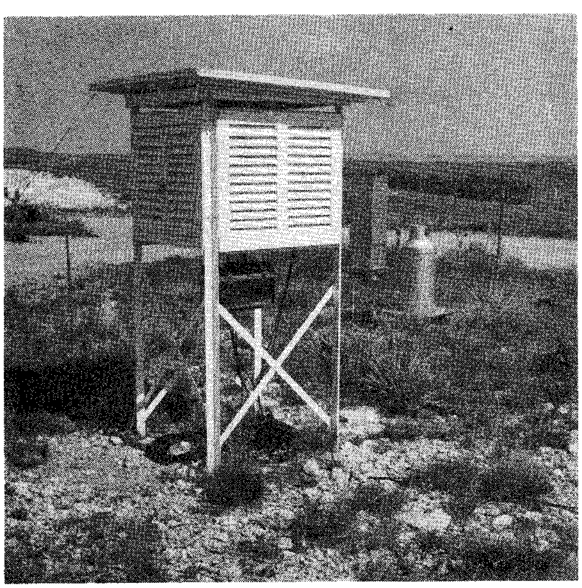


Figure 26b. An instrument shelter which contains temperature, RH and wind recorders. The rain/hail separator and Belfort weighing precipitation gage are to the right.

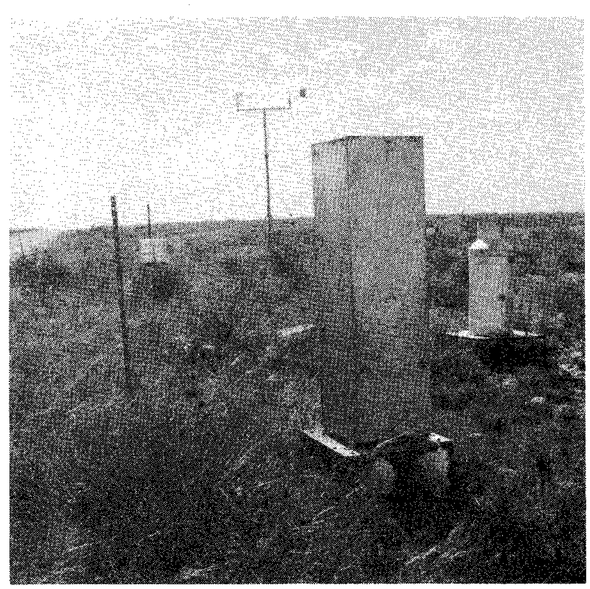


Figure 26c. From left to right, hailcube, anemometer, rain/hail separator, and Belfort weighing precipitation gage.

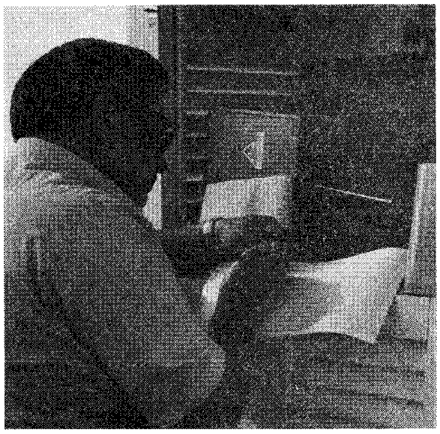


Figure 27a. Ralph Coleman is shown on the left recording mesometeorological data gathered from weather devices within an instrument shelter.

Figure 27b. Thomas Bliska, below, is sizing hailpad dents with a self-measuring divider. The hailpads are gathered from the hailcubes as shown in Figure 26c.

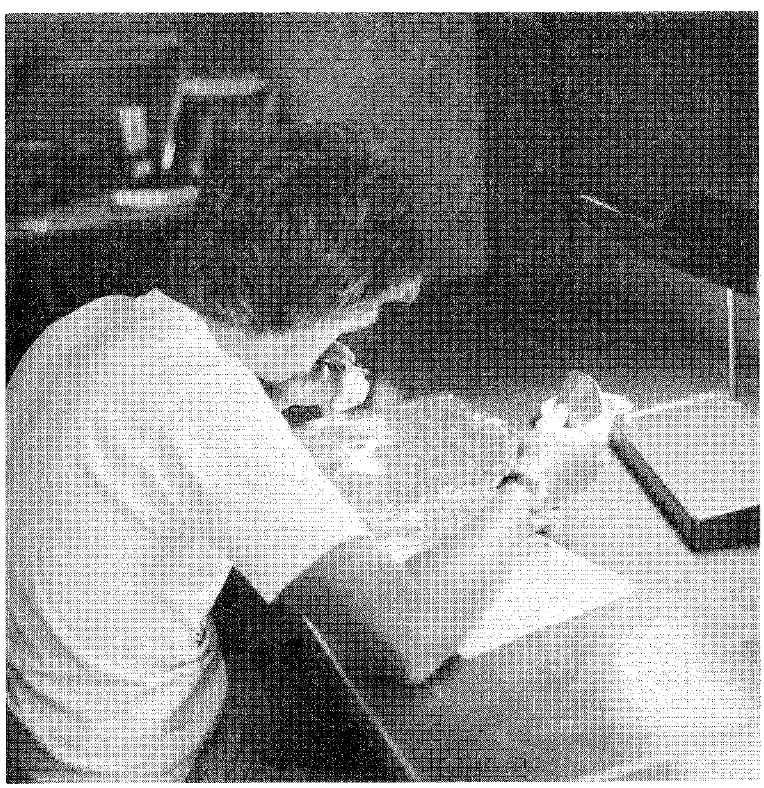


Figure 28a. Brooks Martner of the University of Wyoming monitoring the recording of data during an aerosol sampling mission.

Figure 28b. The University of Wyoming sampling vehicle (below) is equipped with (from left to right) an anemometer, aerosol sampling intake, the hail collector and catchers for precipitation sampling.

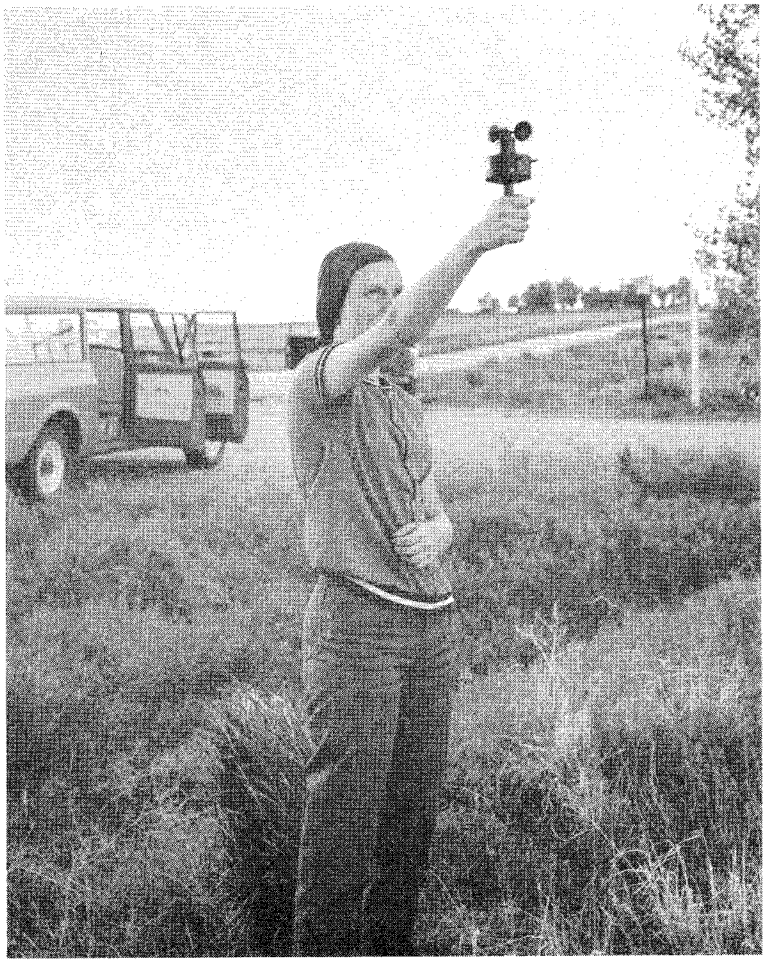


Figure 29a. Kathy Kimmel takes a wind reading using a hand-held anemometer.

Figure 29b. Nancy Knight (left) and Kathy Kimmel (behind door) await a storm. The NCAR sampling vehicle is equipped with a hail catcher that is used for collecting time-resolved hail samples.

6. Aerosol Sampling

Nuclei measurements were obtained from two ground stations and three aircraft. One ground station was located at the Chapel Ranch (see Figure 30a-b). This station had the following instruments: (1) two NCAR ice nuclei counters to obtain measurements of ice nuclei at different temperatures; (2) a sequential membrane filter sampler; (3) an Allee-type cloud condensation nucleus counter and an NCAR counter for continuous CCN counts; (4) a GEE nucleus counter and (5) an optical counter.

The University of Wyoming site at the Sidney, Nebraska Airport (see Figure 30c-d) included the following: (1) Deposition Freezing Contact ice nucleus counter (DFC); (2) condensation/freezing ice nucleus counter (CFC); (3) a sequential membrane filter sampler; (4) a nucleus spectrometer; (5) a NCAR ice nucleus counter; (6) a CCN counter, (7) Environment One condensation counter; and (8) aerosol-sizing instruments.

Nuclei measurements were also made on the two NCAR Queen Airs, and the Wyoming Queen Air. Queen Air 304D was instrumented with a sequential membrane filter sampler, an NCAR ice nucleus counter, a thermal diffusion Cloud Condensation Nucleus counter, a soot-coated slide impactor, an acoustical counter, and an Aitken particle counter. In addition, bag samples were obtained and these samples were delivered to the Wyoming Sampling Station at the Sidney, Nebraska Airport. Queen Air N306D was instrumented with sequential membrane filter samplers, soot-coated impaction slides, and an Aitken particle counter together with the bag samples. The Wyoming Queen Air carried a sequential membrane filter sampler, precipitation samplers, impactors, and it also had the capability to collect bag samples.

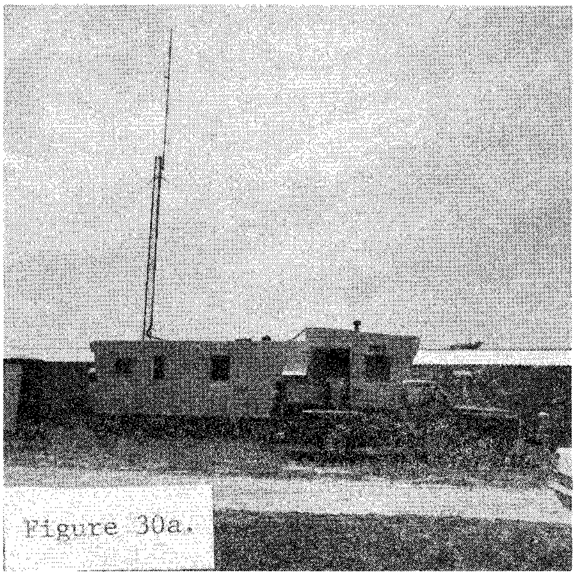


Figure 30a.

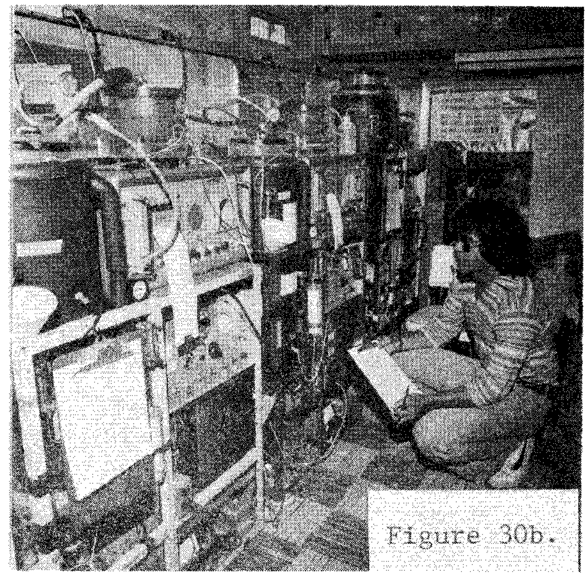


Figure 30b.

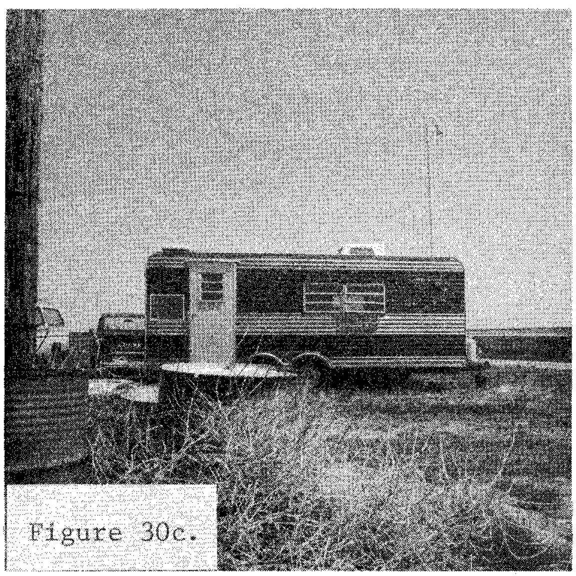


Figure 30c.

Figure 30a. Chapel Ranch aerosol station, operated by NCAR.

Figure 30b. David Goto of NCAR checking out ice nucleus counters inside Chapel Ranch aerosol station.

Figure 30c. Sidney aerosol station, operated by the University of Wyoming.

Figure 30d. Gerhard Langer of NCAR coordinating intercomparison of ice nucleus counters at Sidney aerosol station, located at the Sidney, Nebraska airport.

Figure 30e. Dave Rogers and Ted Karacostas of the University of Wyoming inside the Sidney aerosol station.

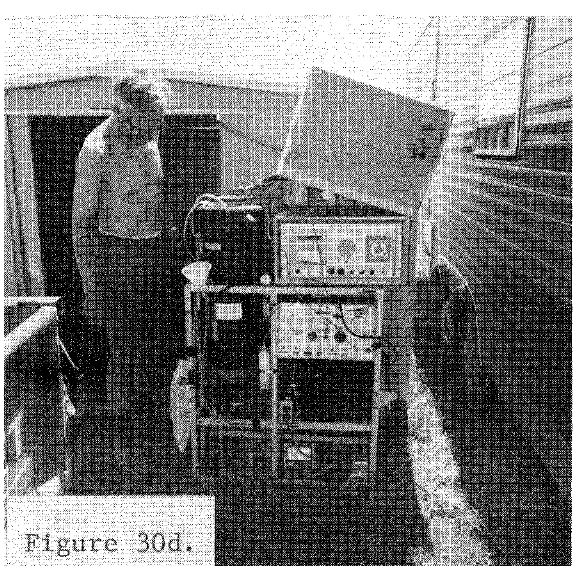


Figure 30d.

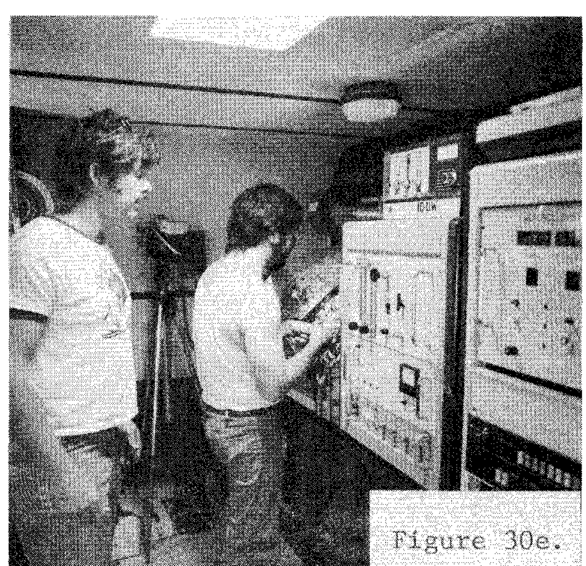


Figure 30e.

7. Hail Crop Damage Network

The network (see Figure 31) consisted of approximately 400 hailcube sites, located next to growing crops. Installation of the network was completed during the first week of May, 1976 and its operation continued through the first week of September. The hailcube sites were checked continuously during the season, and in the event of hailfall all struck hailpads were removed.

The farmers on whose land the hailcubes were located completed damaged report forms whenever a hailstorm struck their fields. These damage estimates were checked by trained crop damage appraisers based in Sterling and Kimball.

8. Cooperative Mesoscale Study by NOAA

The NOAA Wave Propagation Laboratory conducted a series of mesoscale field studies. The instrumentation involved is listed in the Field Facilities chart, Fig. 4. The X-band dual-Doppler radar system was discussed under section 2.c-Radar systems. The additional instruments were located within two optical beam triangles shown in Figure 32. The instrumentation (in addition to the optical beam array) included a microbarograph array of four instruments located at the outside points of the optical triangle network, plus a monostatic accoustic echo sounder, an FM-CW Doppler and an infrared Doppler located at the center of the optical array. Another set of instrumentation within this network included five chaff cutters with microbarograph triggers. The three most northern instruments were located at the north point of the optical triangle, the center and the southern points, with two additional

1976 ESIG CROP DAMAGE NETWORK

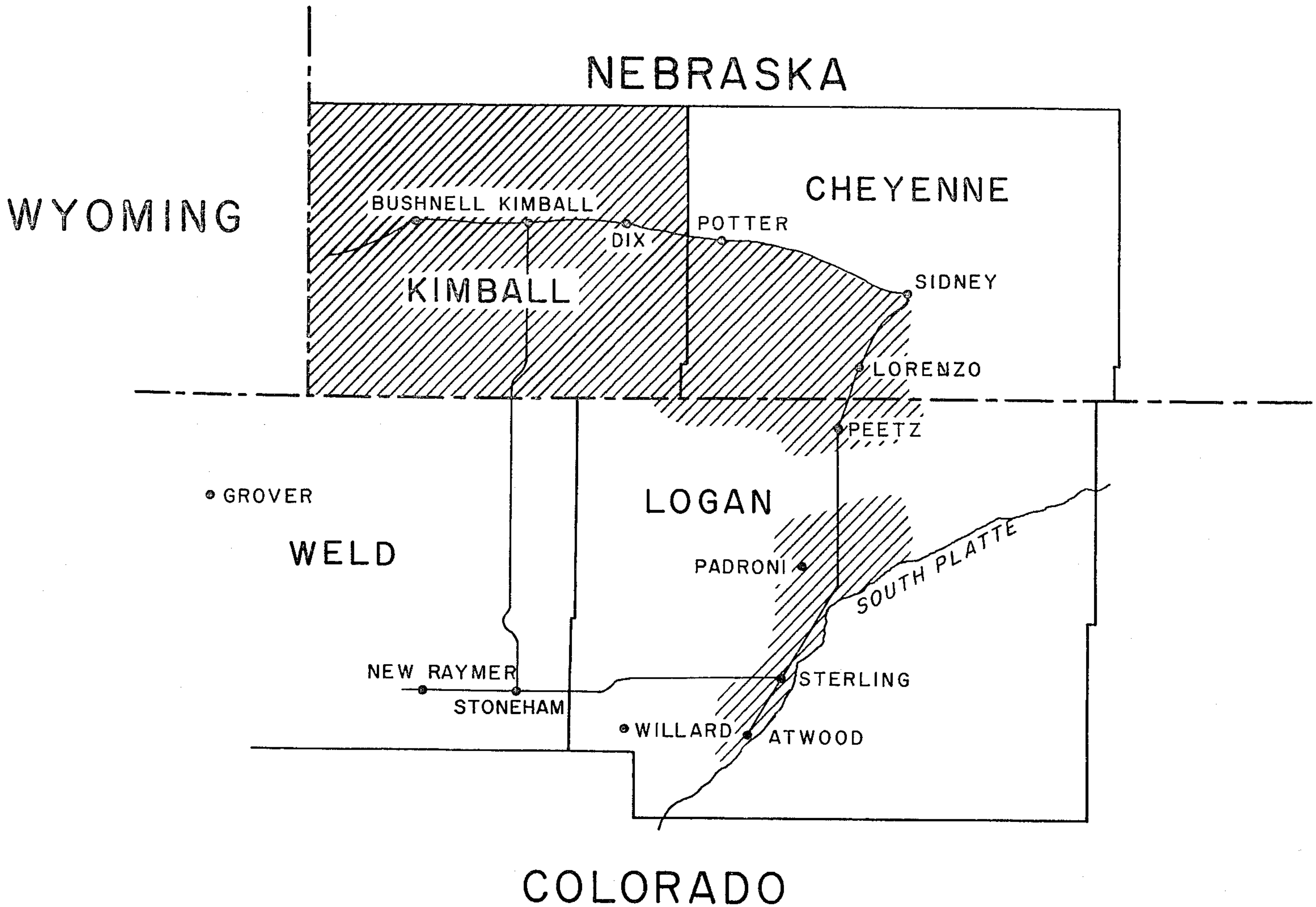


Figure 31.

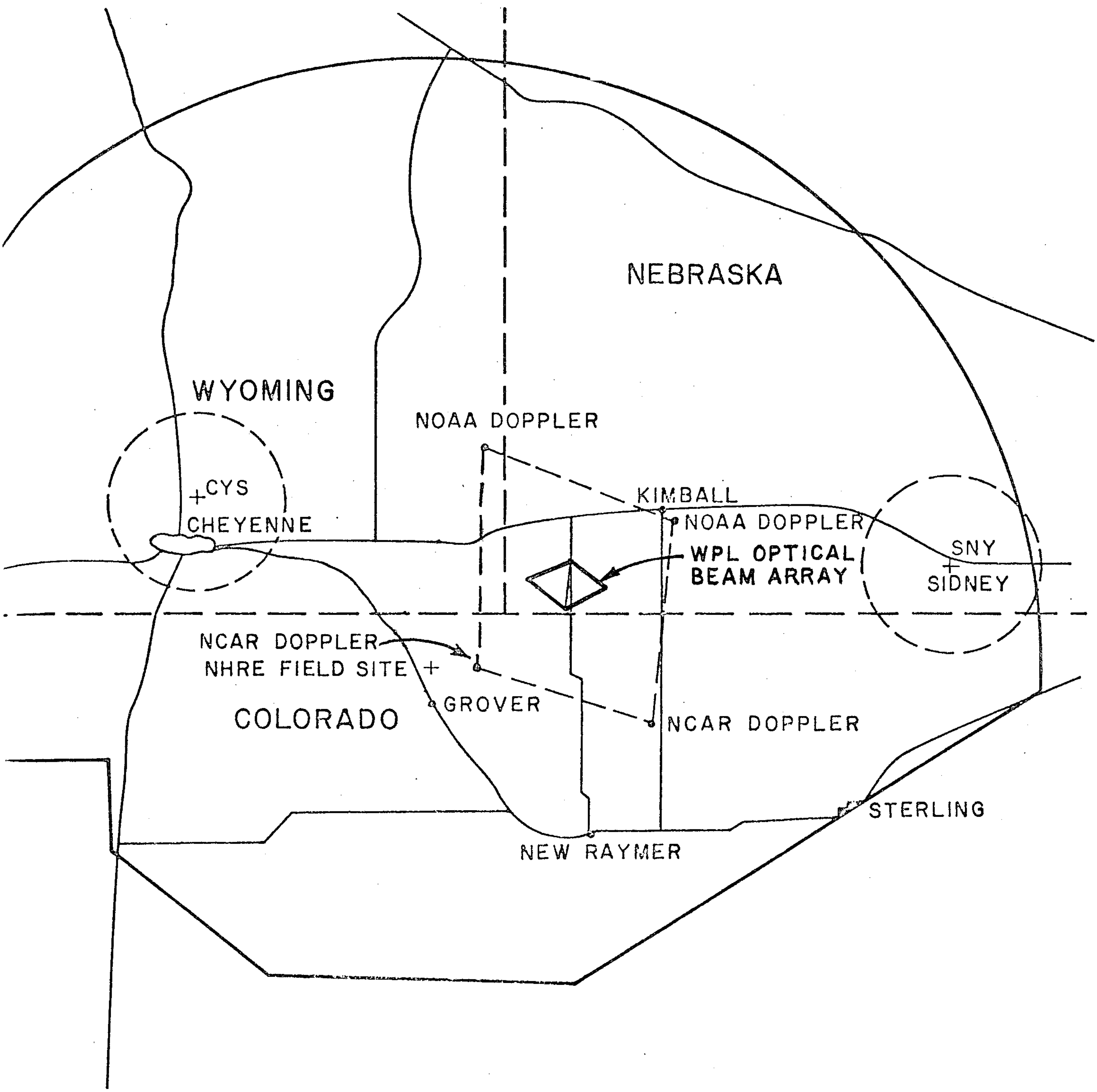

NEBRASKA
WYOMING
NOAA DOPPLER
CYS
CHEYENNE
KIMBALL
NOAA DOPPLER
WPL OPTICAL
BEAM ARRAY
SNY
SIDNEY
NCAR DOPPLER
NHRE FIELD SITE
GROVER
COLORADO
NCAR DOPPLER
STERLING
NEW RAYMER

Figure 32.

instruments located south of the triangle with a spacing of approximately 10 kilometers. This mesoscale network, together with the X-band dual-Doppler radar, was used to obtain data on atmospheric convergence, atmospheric gravity waves, and boundary layer profiles and processes.

9. Tethered Balloon Study

A tethered balloon system, under the direction of Dr. Larry Mahrt of Oregon State University, was used to obtain measurements in the atmospheric boundary layer. The system, supplied by the Field Observing Facility of NCAR, was located at the Chapel Ranch (see Figure 1). Measurements obtained by the system included temperature, dew point, pressure, wind speed and wind direction. The operation was hampered by gusty wind conditions and one system was lost. Some data was obtained, but the scheduled 4-week operation was curtailed after 2 weeks.

References

The National Hail Research Experiment Operations Plan, 1976. National Center for Atmospheric Research, Boulder, Colorado, April 1976, 74 pp.

IV. DAILY SUMMARIES

This section presents a summary of each day's operations carried out during the field observation program conducted June 1 through July 31, 1976. From the daily summaries that follow, interested personnel will be able to determine the type of study or studies pursued each day, the period or time that selected observations were made, and the systems involved in the day's investigations. An assessment can also be made of how the observations mesh in both time and space.

The data presented for each day includes a brief description of the day's activity, selected radar data that is representative of the period during which aircraft observations were made, and a summary showing the systems and the time or period of observations. Highlighted are the type of study or studies, the aircraft involved, whether rain or hail were observed and comments concerning radar coverage. The radar contours have been superimposed on a map that shows selected geographical locations, fixed observing sites, areas within which the precipitation network was located, and the Cheyenne coordinate system. The radar contours are in 10 dBZ steps with a minimum contour of 15 dBZ. On those days when more than one investigation was carried out radar data representing each study has been included. The operational systems along with the period or time of observation is presented in tabular form. A summary table is included for each day on which CP-2 radar data is available and aircraft missions flown. These summaries are generally self-explanatory. The figures in parentheses in the remarks section concerning the precipitation network are the total point observations of rain and hail observed in the network on that particular day.

It should be noted that some of the facilities operated continuously or for extended periods during the summer. These were the DRI M33 radar equipped with time-lapse photography, the mesometeorological network, the precipitation network and the Sterling rawinsonde.

The daily summaries are presented in chronological order on the remaining pages of this section.

June 1, 1976: An Initiation of Precipitation Formation Study was attempted with Queen Airs 10UW and 304D, but a suitable opportunity was not located. The storms grew vigorously reaching moderate intensities, but were of short duration--30 minutes to one hour. Representative radar data are shown in Figure 33. Several 3 cm chaff drops were made using both a chaff cutter and chaff gun. All radars, C-, S-, and X-band observed the chaff. This severely curtailed the planned use of chaff in the Initiation of Precipitation Formation Studies. The SDSM&T T-28 did not fly because of dynamic pressure system problems.

June 2, 1976: A Mature Storm Study was planned using the T-28 and the three Queen Airs. After the Queen Airs were airborne it was reported that the T-28 was grounded because of a broken fuel pump. At this time the mission was changed to an Initiation of Precipitation Formation Study and the echo identified in Figure 34 was observed. Some Doppler data were collected, but the storm was not well-organized and was too far east for good resolution. Some rain and hail was observed in the dense network. The mobile sampling teams collected time-resolved hail and precipitation samples.

June 3, 1976: No significant activity occurred within the operating area. An isolated storm was observed to the south, but it was outside the range of the Grover radar. No radar data were collected and no aircraft missions were flown.

June 1, 1976 16-34-28 MDT Max. dBZ 60.1

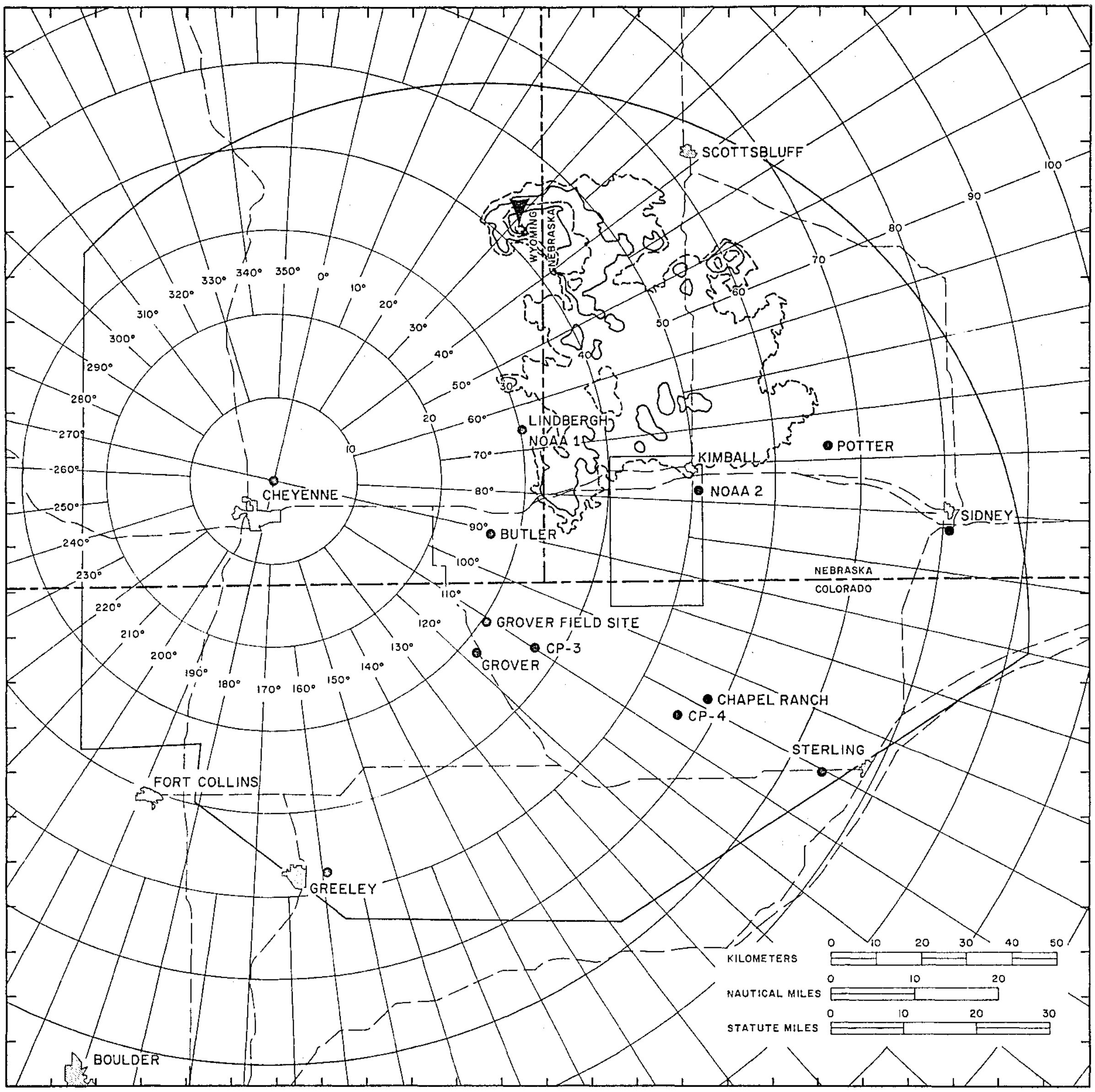


Figure 33.

Table 2.

OPERATIONS SUMMARY

June 1, 1976

OBSERVATIONAL SYSTEMS	0700	0800	0900	1000	1100	1200	1300	1400	1500	1600	1700	1800	1900	2000	2100	REMARKS
RADAR																
CP-2 DWL								▬	▬	▬	▬					
CP-3 C-Band										▬						
CP-4 C-Band																
NOAA-1 X-Band										▬						
NOAA-2 X-Band										▬						
AIRCRAFT																
Wyoming 10UW										▚▚▚	▚▚					
SDSM&T 10MH																
NCAR 29J																
NCAR 304D																
NCAR 306D											////	////				
NCAR 307D																
METEOROLOGICAL																
Rawinsondes																
Grover																
Potter																
Sterling	▲						▲			▲						
Conventional	▬	▬	▬	▬	▬	▬	▬	▬	▬	▬	▬	▬	▬	▬	▬	
PAM				▬	▬	▬	▬	▬	▬	▬	▬	▬	▬			
PRECIPITATION																
Mobiles																
Wyoming																
Precipitation										▬						
NCAR																
Precip Net	▬	▬	▬	▬	▬	▬	▬	▬	▬	▬	▬	▬	▬	▬	▬	Rain (38) in dense network
AEROSOL, CCN, IN																
Chapel Ranch	▬	▬	▬	▬	▬	▬	▬	▬	▬	▬	▬	▬	▬	▬	▬	
Sidney										▬						
CLOUD PHOTOGRAPHY																
Butler																
Chapel Ranch																
Greeley																
Grover								▬	▬	▬	▬					
Lindbergh																
Potter																
Sterling																
NCAR Mobiles																
Wyoming Mobiles																

Initiation of Precipitation Formation ▚▚▚

Mature Storm Study ////.

June 2, 1976 19-31-12 MDT Max. dBZ 44.2

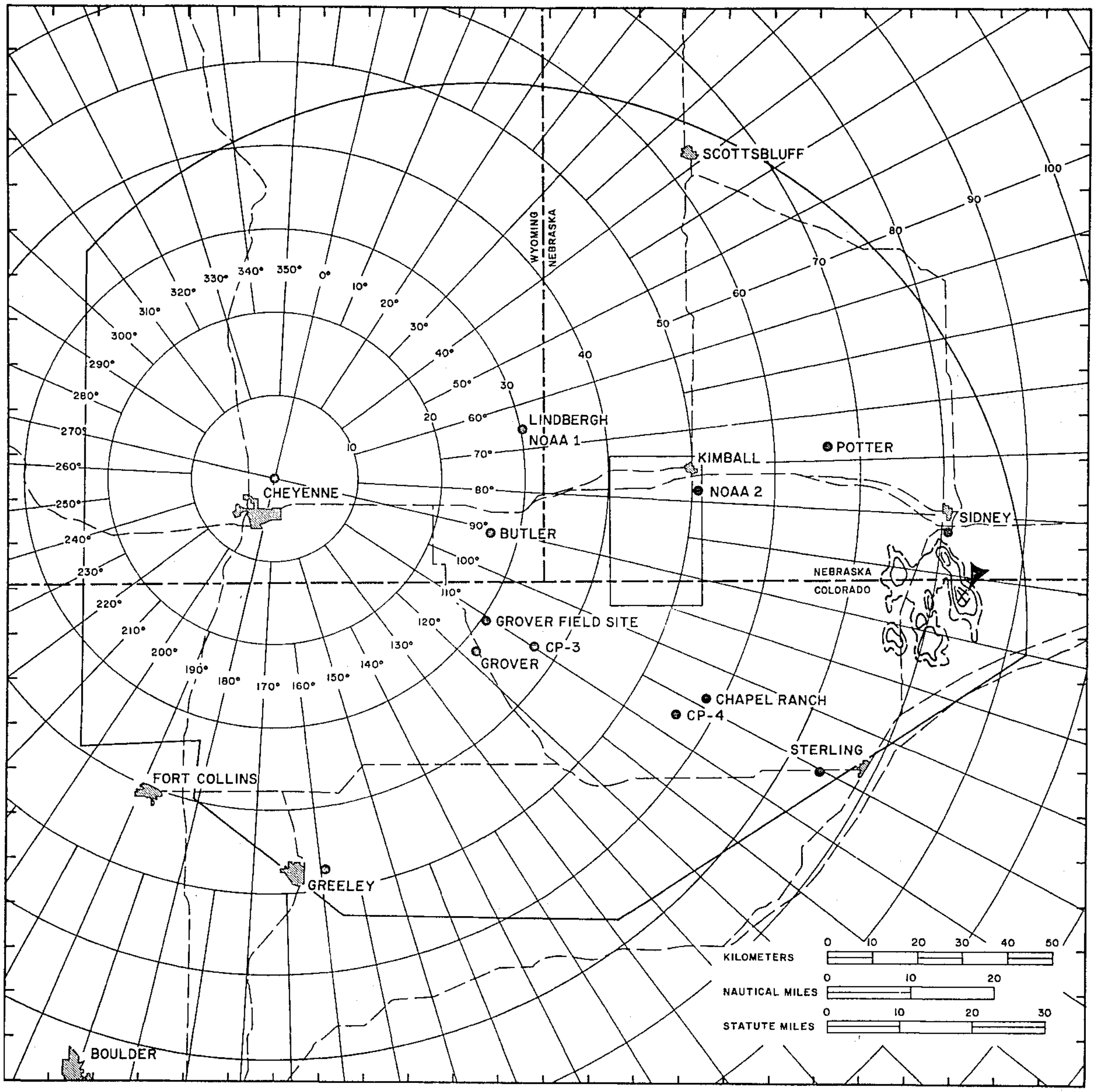
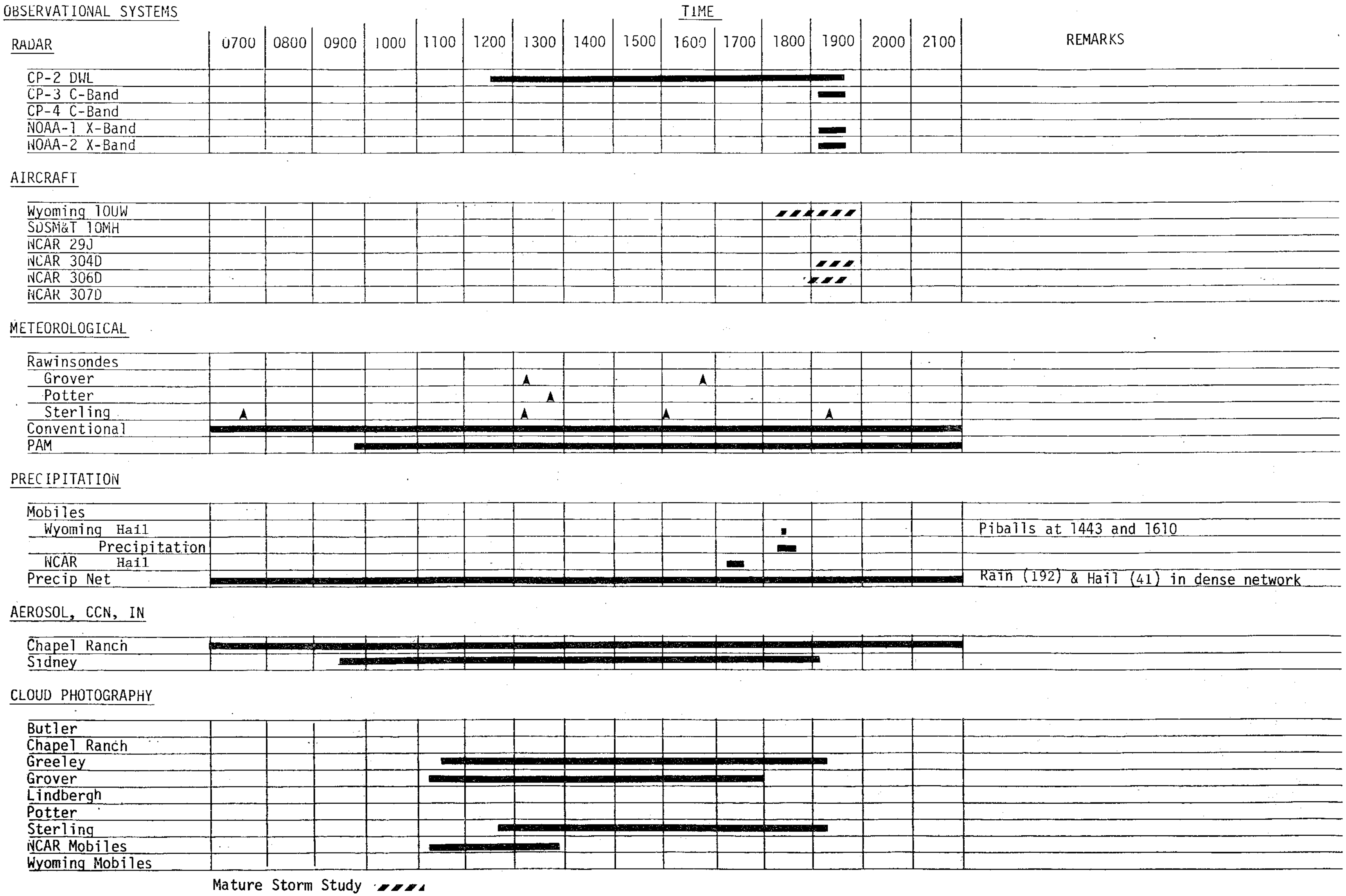


Figure 34.

Table 3.

OPERATIONS SUMMARY

June 2, 1976



June 4, 1976: A Mature Storm Study was conducted by the T-28 and the three Queen Airs on the storm shown in Figure 35. The T-28 made five penetrations. Queen Air 10UW also made several penetrations of the updraft above cloud base while Queen Air 304D sampled the updraft core at cloud base and Queen Air 306D made observations in the inflow in advance of the storm. Some Doppler data were collected. Hail and rain were observed in the dense network and the mobile sampling teams collected time-resolved samples of hail and precipitation, but these collections were from a later storm.

June 5, 1976: No significant activity occurred. General overcast conditions prevailed during the afternoon. All systems stood by until late in the day. No research missions were flown.

June 6, 1976: The most significant development occurred in the Greeley area as indicated by the radar data presented in Figure 36. These storms propagated to the north, but dissipated just as they entered the airspace. The mobile sampling teams were deployed to the western side of the operating area, but no samples were collected. No Doppler data were collected and no aircraft missions were flown.

June 7, 1976: Queen Airs 10UW and 304D flew an Initiation of Precipitation Formation mission on the storm shown in Figure 37. Some Doppler data were collected. No precipitation samples were taken. The storm shown is the only one that developed in the area and is of only marginal interest.

June 4, 1976 17-38-02 MDT Max. dBZ 58.7

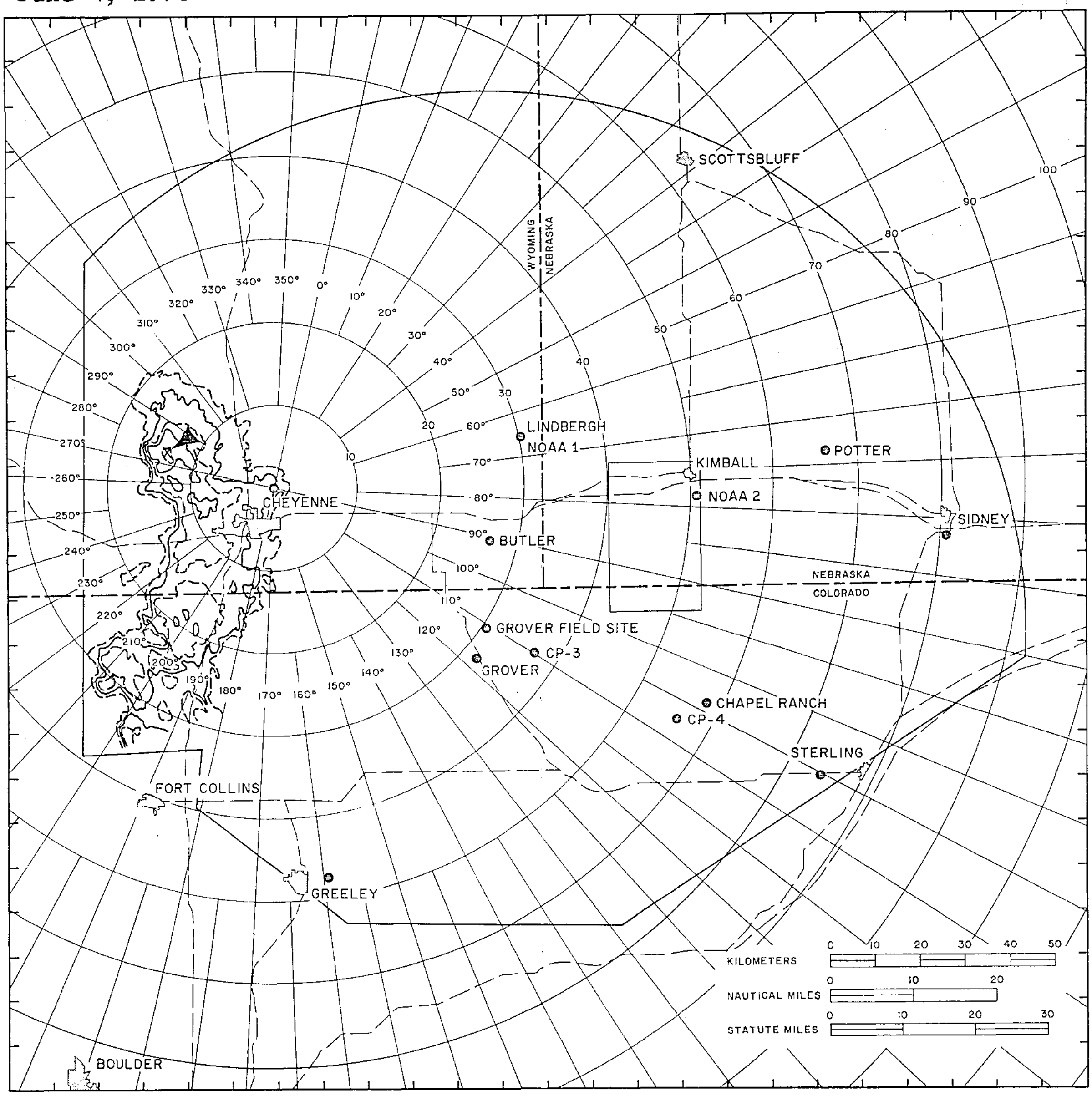
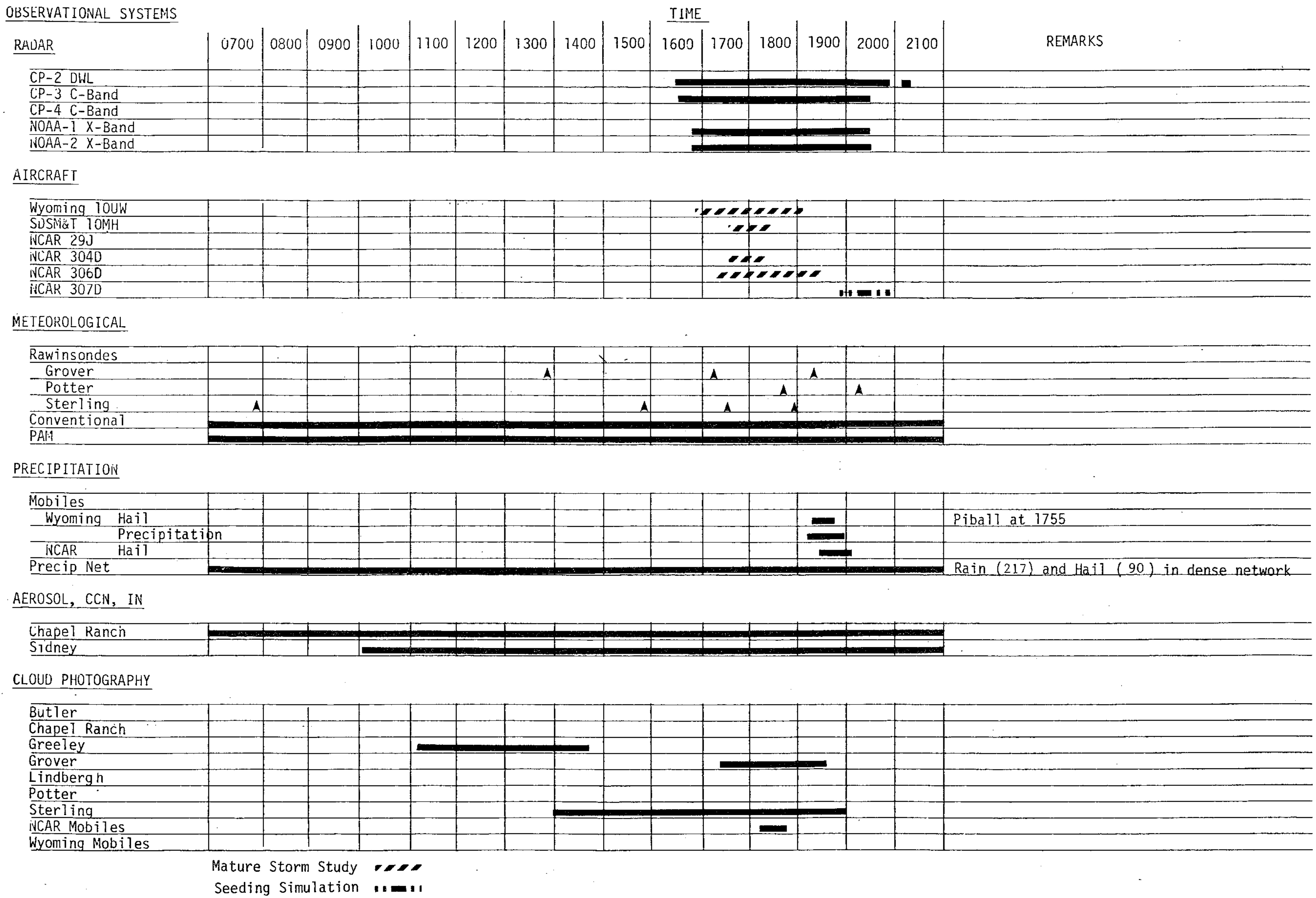


Figure 35.

Table 4.

OPERATIONS SUMMARY

June 4, 1976



June 6, 1976 16-04-18 MDT Max. dBZ 55.8

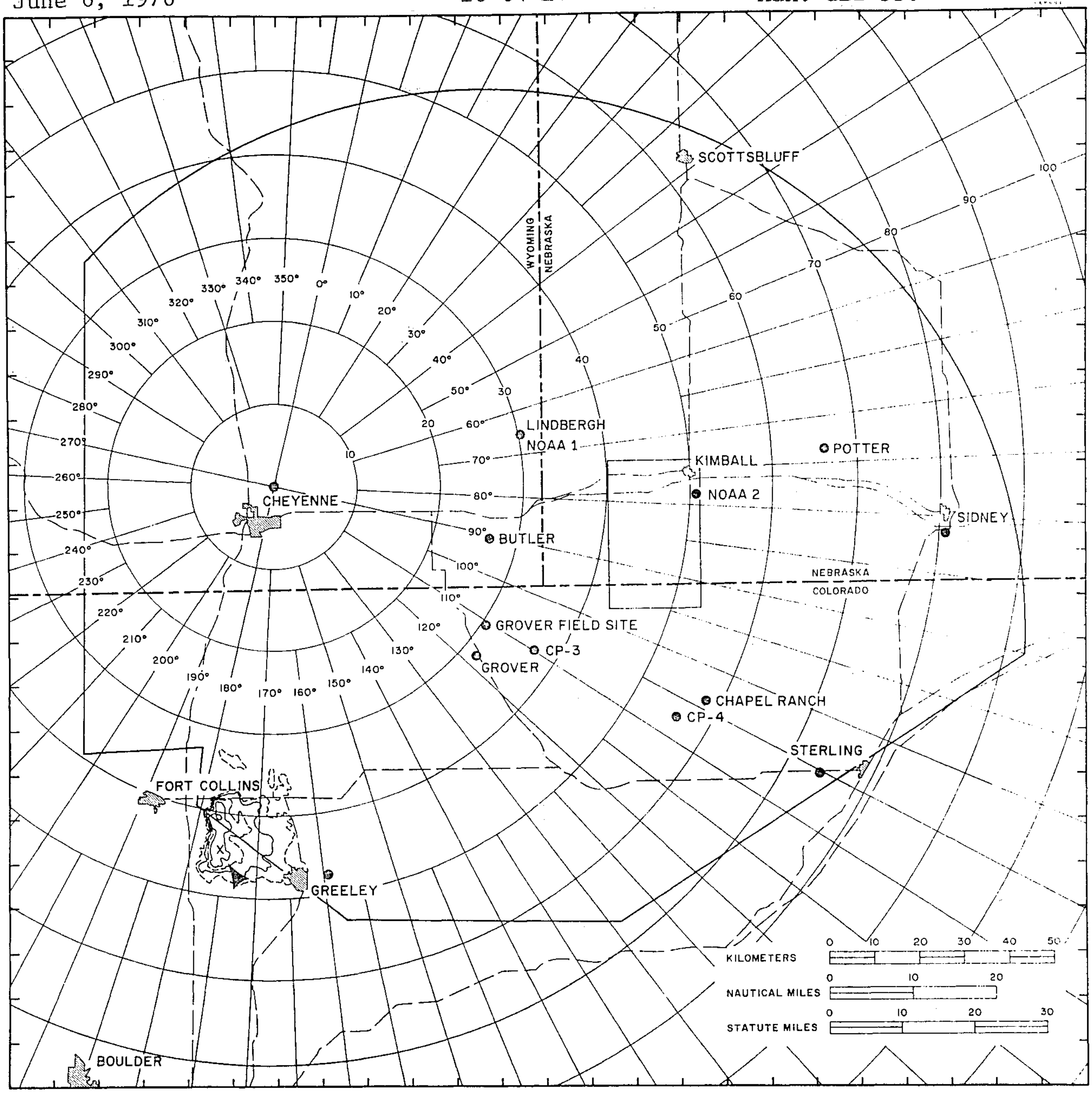


Figure 36.

Table 5.

OPERATIONS SUMMARY

June 6, 1976

OBSERVATIONAL SYSTEMS	0700	0800	0900	1000	1100	1200	1300	1400	1500	1600	1700	1800	1900	2000	2100	REMARKS
RADAR																
CP-2 DWL																
CP-3 C-Band																
CP-4 C-Band																
NOAA-1 X-Band																
NOAA-2 X-Band																
AIRCRAFT																
Wyoming 10UW																
SDSM&T 10MH																
NCAR 29J																
NCAR 304D																
NCAR 306D																
NCAR 307D																
METEOROLOGICAL																
Rawinsondes																
Grover																
Potter										▲						
Sterling	▲						▲			▲	▲					
Conventional																
PAM																
PRECIPITATION																
Mobiles																
Wyoming																
NCAR																
Precip Net																
AEROSOL, CCN, IN																
Chapel Ranch																
Sidney																
CLOUD PHOTOGRAPHY																
Butler																
Chapel Ranch																
Greeley																
Grover																
Lindbergh																
Potter																
Sterling																
NCAR Mobiles																
Wyoming Mobiles																

June 7, 1976 17-00-49 MDT Max. dBZ 42.7

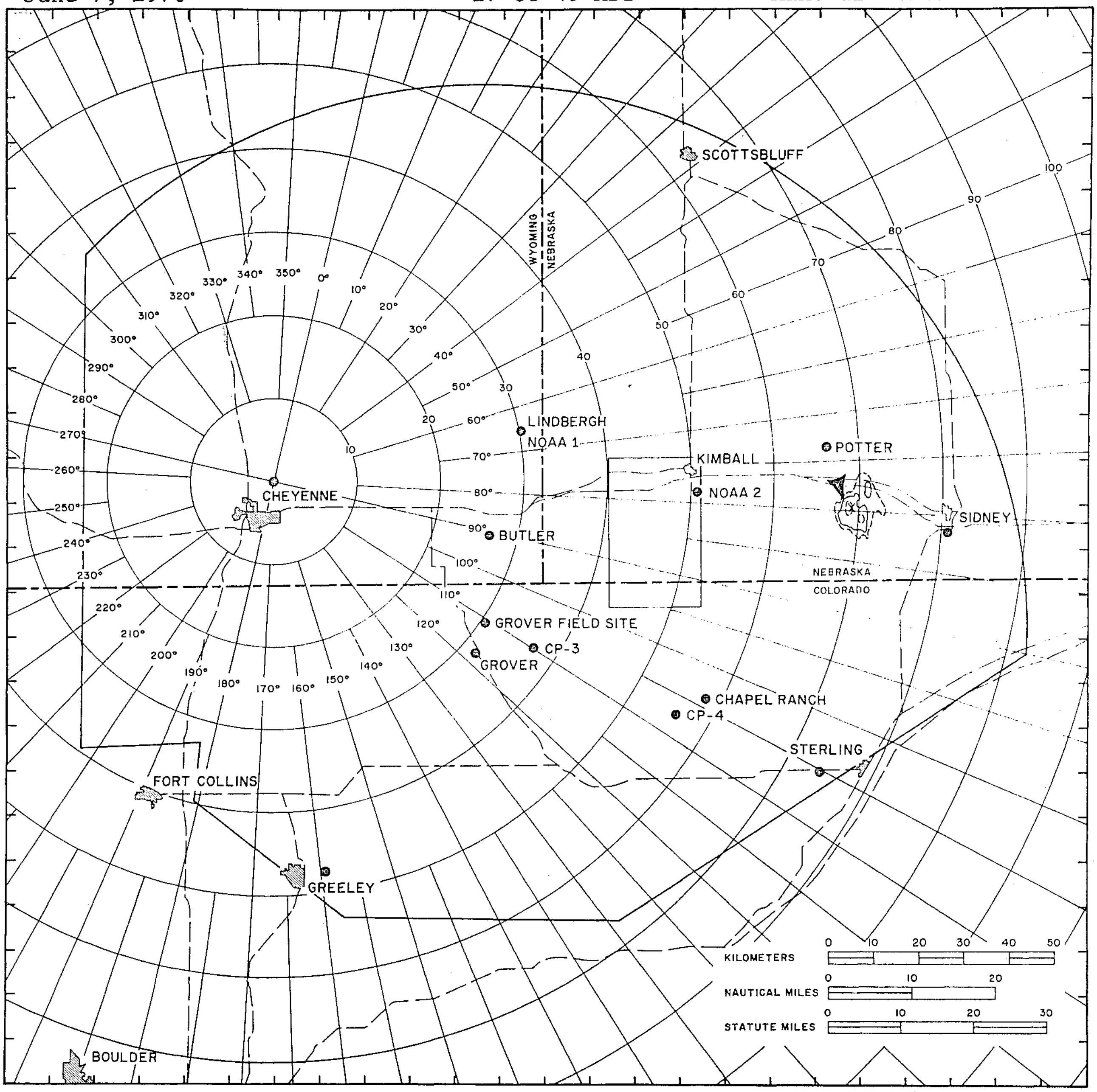
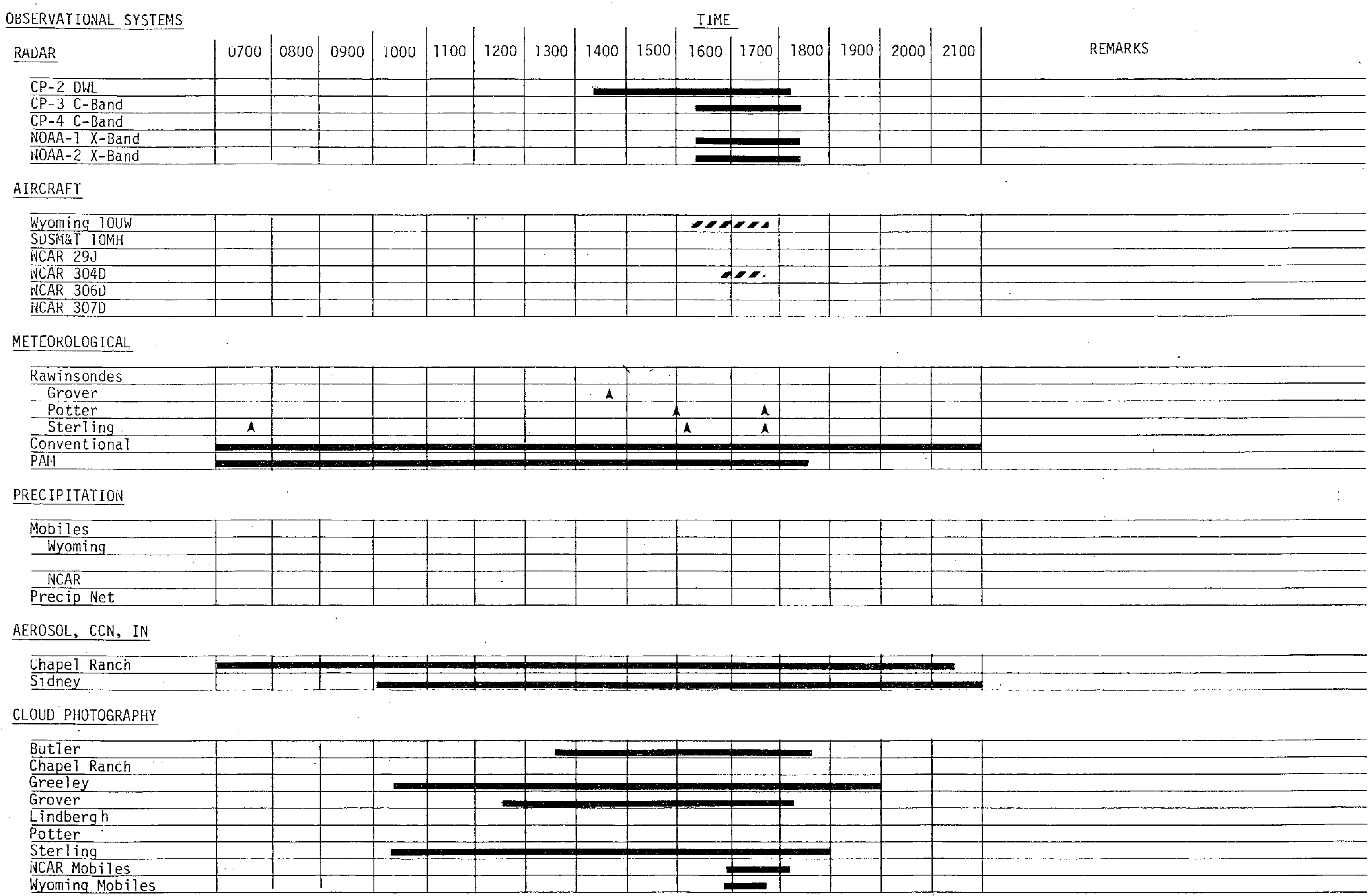


Figure 37.

Table 6.

OPERATIONS SUMMARY

June 7, 1976



Mature Storm Study

June 8, 1976: This storm developed in the Cheyenne, Wyoming, area and moved southeastward toward Briggsdale, Colorado. It was north of Briggsdale that the storm developed a large persistent vault. During the early stage shown in Figure 38 both the T-28 and Queen Air 10UW penetrated the storm while Queen Air 304D sampled the updraft core just below cloud base, and the T-28 made eight penetrations during this stage of development. These observations continued during the early stages as the storm matured. The Doppler radar collected data, but the location of the storm is not ideal for multiple-Doppler analysis. During the mature stage shown in Figure 39, the storm produced a hailswath approximately 10 miles long, 1½ miles wide and as much as 6 inches deep. The maximum storm diameter observed was approximately 1 inch. NCAR Queen Air 306D was the only aircraft that observed the storm during this mature stage.

June 9, 1976: An Initiation of Precipitation Formation Study was conducted with Queen Airs 10UW and 304D. This storm is shown in Figure 40. Subsequently, these aircraft worked a second storm southeast of Sidney, Nebraska. Multiple Doppler radar data were collected on the first storm. Radar data for the second is questionable since it was partially out of range of the Grover radar. Some rain was observed in the dense network. The Wyoming mobile teams sampled precipitation but no hail was observed.

June 10-20, 1976: No significant weather occurred during this period. No radar data were collected and no aircraft missions were flown. The weather on June 17 was dominated by cool moist air which resulted in widespread rain throughout the area. Some CP-2 radar data were collected on June 17 but none has been processed since no aircraft missions were flown. On June 18 overcast skies and intermittent light rain continued throughout the area. No radar data were collected. A CCN counter flight was flown with Queen Air 304D. During June 19-20 the weather conditions continued unfavorable. No radar data were collected and no aircraft missions were flown.

June 8, 1976 14-46-31 MDT Max. dBZ 62.0

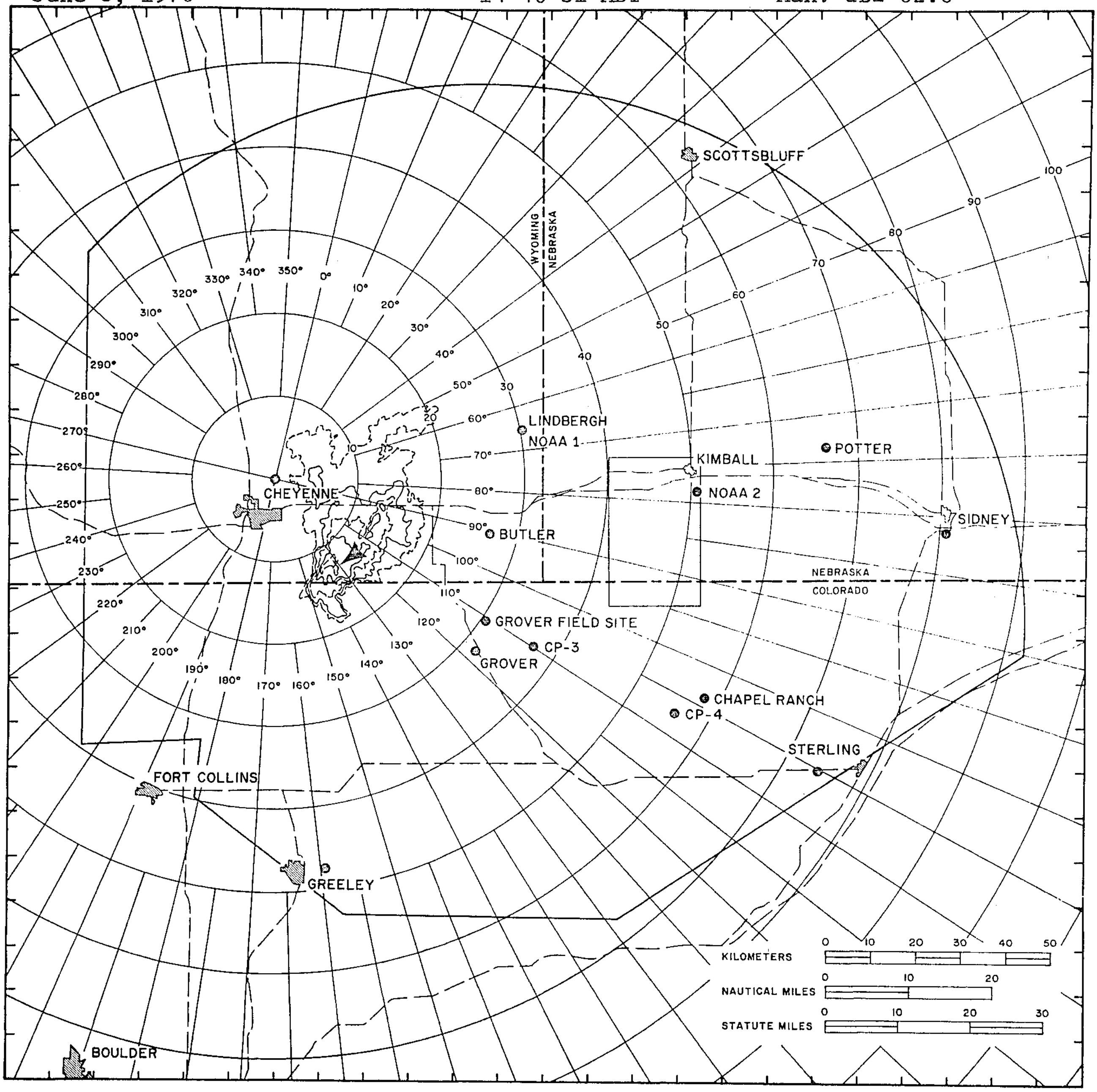


Figure 38.

June 8, 1976 16-49-08 MDT Max. dBZ 72.2

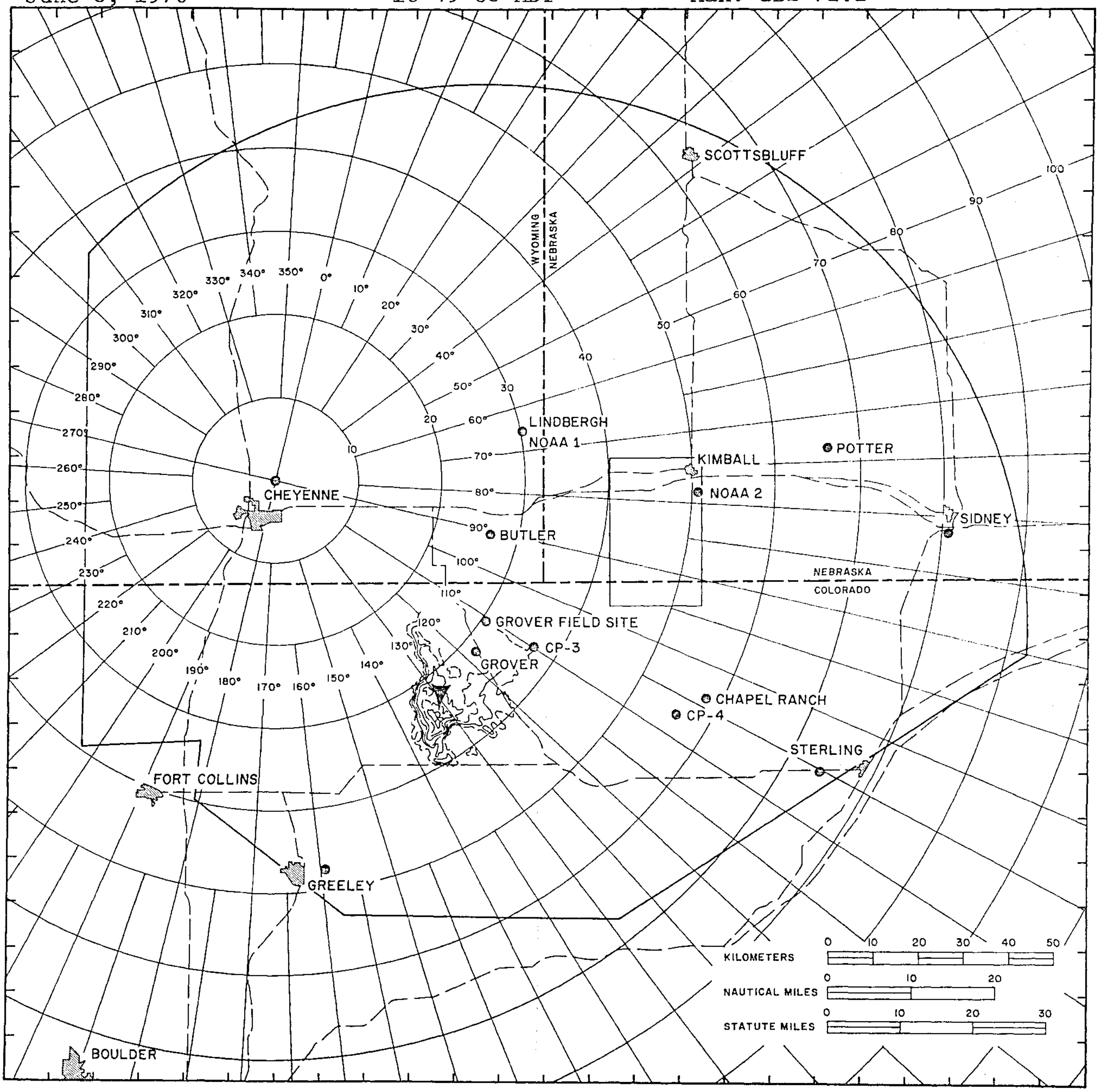


Figure 39.

Table 7.

OPERATIONS SUMMARY

June 8, 1976

OBSERVATIONAL SYSTEMS	TIME															
RADAR	0700	0800	0900	1000	1100	1200	1300	1400	1500	1600	1700	1800	1900	2000	2100	REMARKS
CP-2 DWL																
CP-3 C-Band																
CP-4 C-Band																
NOAA-1 X-Band																
NOAA-2 X-Band																
AIRCRAFT																
Wyoming 10UW																
SDSM&T 10MH																
NCAR 29J																
NCAR 304D																
NCAR 306D																
NCAR 307D																
METEOROLOGICAL																
Rawinsondes																
Grover																
Potter																
Sterling																
Conventional																
PAM																
PRECIPITATION																
Mobiles																
Wyoming Hail																
Precipitation																
NCAR Hail																
Precip Net																Rain (2) in dense network
AEROSOL, CCN, IN																
Chapel Ranch																
Sidney																
CLOUD PHOTOGRAPHY																
Butler																
Chapel Ranch																
Greeley																
Grover																
Lindbergh																
Potter																
Sterling																
NCAR Mobiles																
Wyoming Mobiles																

Initiation of Precipitation Formation

Mature Storm Study

June 9, 1976 16-12-42 MDT Max. dBZ 52.0

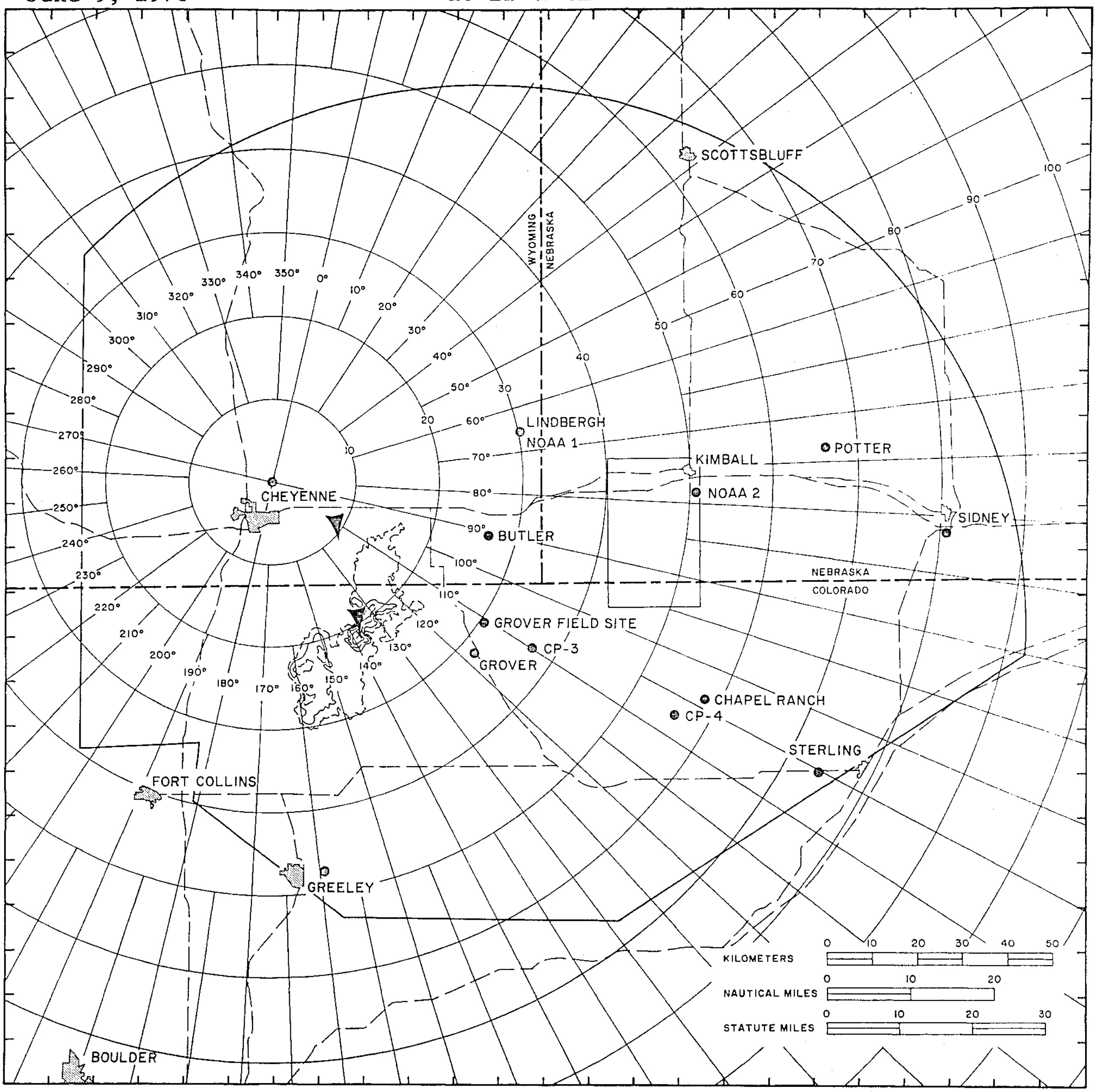


Figure 40.

Table 8.

OPERATIONS SUMMARY

June 9, 1976

OBSERVATIONAL SYSTEMS	0700	0800	0900	1000	1100	1200	1300	1400	1500	1600	1700	1800	1900	2000	2100	REMARKS
RADAR																
CP-2 DWL																
CP-3 C-Band																
CP-4 C-Band																
NOAA-1 X-Band																
NOAA-2 X-Band																
AIRCRAFT																
Wyoming 10UW																
SDSM&T 10MH																
NCAR 29J																
NCAR 304D																
NCAR 306D																
NCAR 307D																
METEOROLOGICAL																
Rawinsondes																
Grover																
Potter																
Sterling																
Conventional																
PAM																
PRECIPITATION																
Mobiles																
Wyoming																
Precipitation																
NCAR																
Precip Net																Rain (47) in dense network
AEROSOL, CCN, IN																
Chapel Ranch																
Sidney																
CLOUD PHOTOGRAPHY																
Butler																
Chapel Ranch																
Greeley																
Grover																
Lindbergh																
Potter																
Sterling																
NCAR Mobiles																
Wyoming Mobiles																

Initiation of Precipitation Formation

June 21, 1976: This storm developed northwest of Grover and moved southwestward over the dense precipitation network. This is an excellent case since the observations by the NOAA/NCAR Sailplane 9929J and Queen Airs 10UW and 304D commenced well before the formation of first radar echo. During the formative stage the sailplane and Queen Air 10UW penetrated the storm while Queen Air 304D flew in the updraft region just below cloud base. Radar data for the storms are presented in Figure 41. Later, in the more mature stage, the storm was worked by the SDSM&T T-28 (five penetrations) and Queen Air 306D. They were joined later in the investigation by 10UW and 304D. The mature stage is illustrated in Figure 42. Some rain and 13 hail observations were observed by the dense network. The mobile sampling teams collected a small number of time-resolved precipitation samples and a single hail collection.

June 22, 1976: This day is also of interest since both Queen Air 10UW and the sailplane investigated the storm, illustrated in Figure 43, early in its life-cycle as it developed into a mature storm. Later the T-28 made three penetrations supported by the three Queen Airs. The radar return showing the storm during this portion of the investigation is shown in Figure 44. This storm was also ideally located with respect to the Doppler array and the surface networks. Queen Air 304D was not available during part of the investigation due to failure of the inertial navigation system. Time-resolved precipitation and hail samples were collected by the mobile sampling teams.

June 23-25, 1976: Strong surface winds dominated the weather on June 23. No significant weather occurred. No radar data were collected and no aircraft missions were flown. June 24th and 25th were taken off.

June 21, 1976 17-02-44 MDT Max. dBZ 49.7

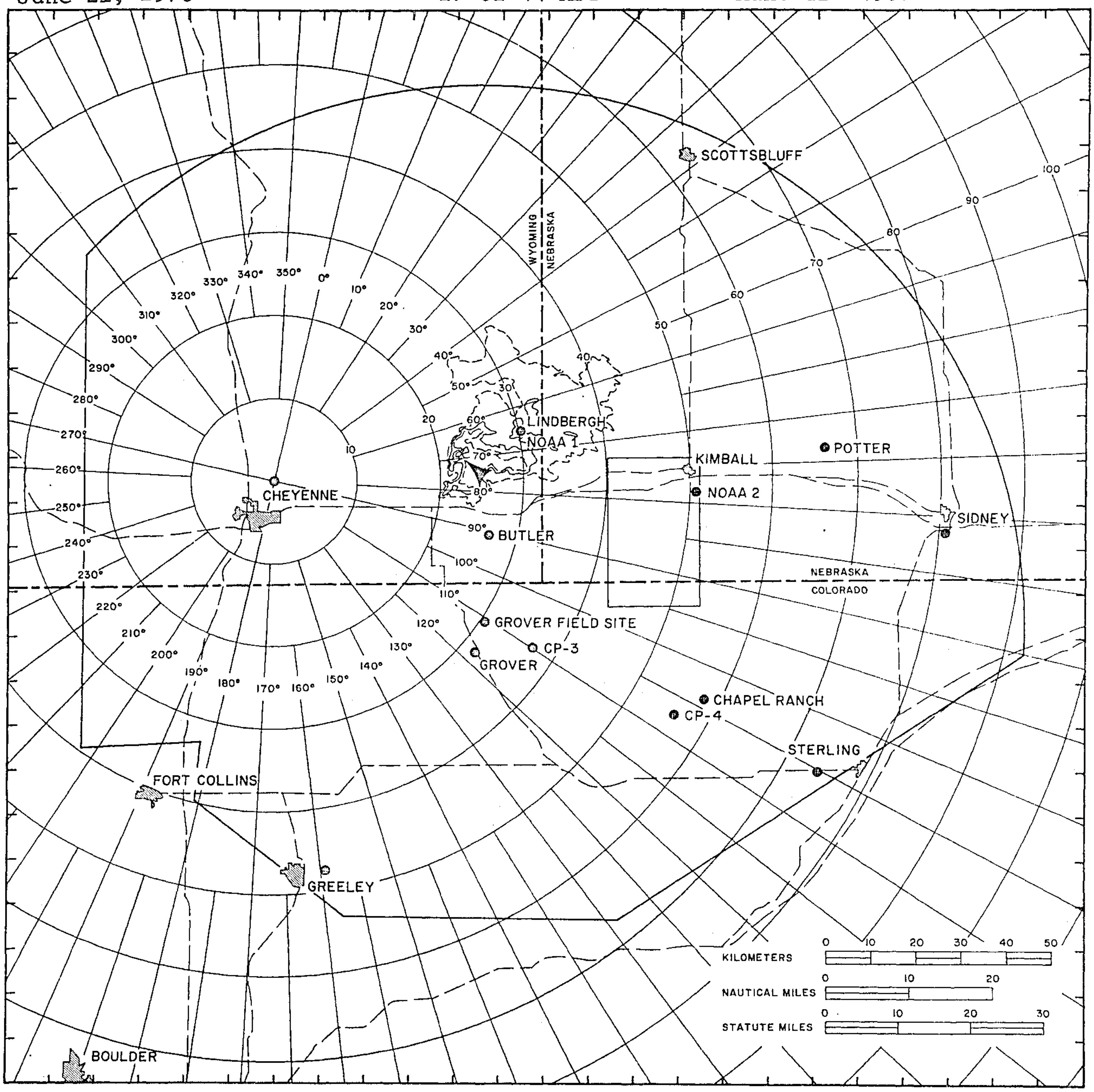


Figure 41.

June 21, 1976 18-46-15 MDT Max. dBZ 51.2

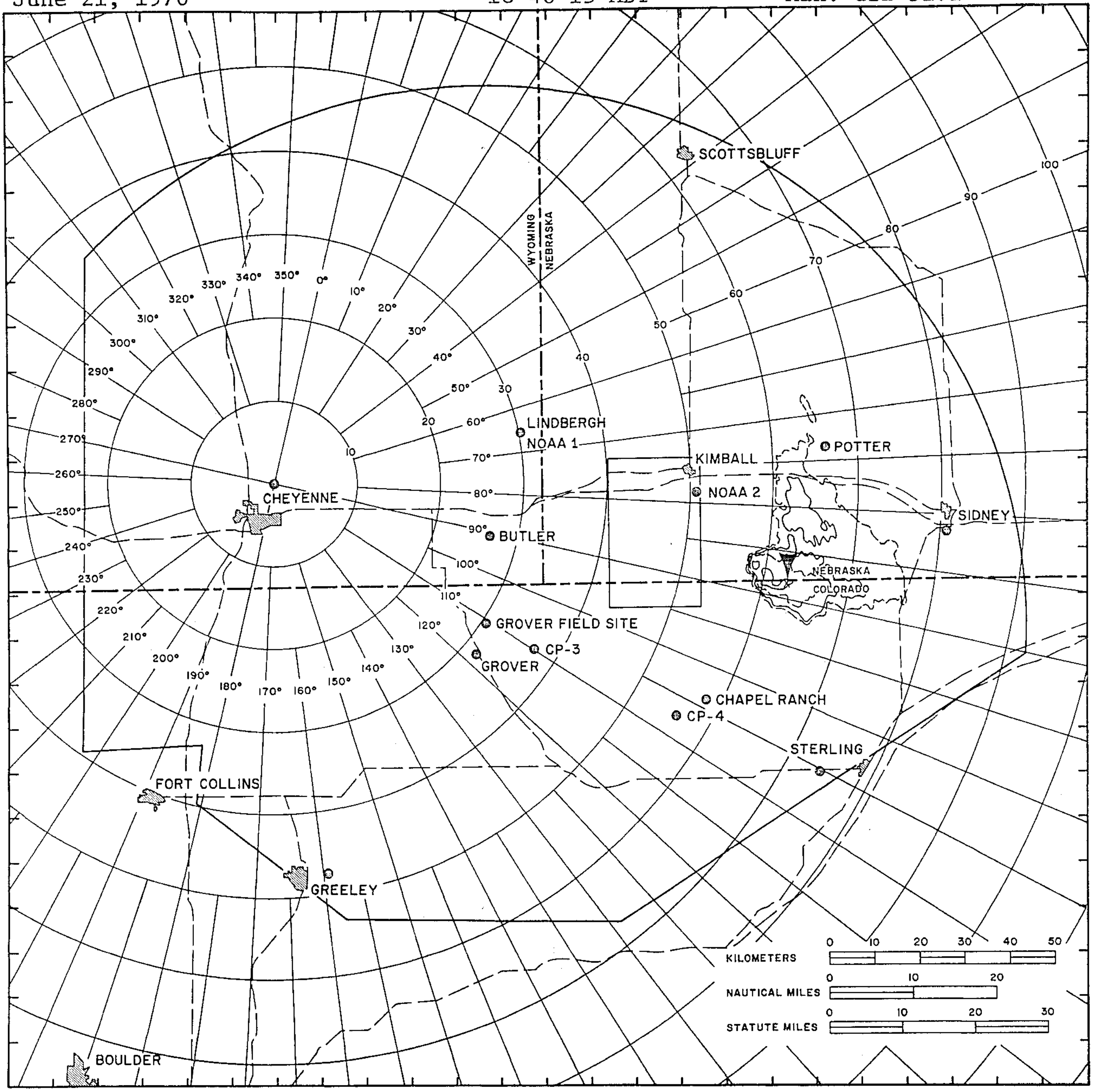


Figure 42.

Table 9.

OPERATIONS SUMMARY

June 21, 1976

OBSERVATIONAL SYSTEMS	0700	0800	0900	1000	1100	1200	1300	1400	1500	1600	1700	1800	1900	2000	2100	REMARKS
RADAR																
CP-2 DWL									■	■	■	■	■	■		
CP-3 C-Band																
CP-4 C-Band										■	■	■	■			
NOAA-1 X-Band										■	■	■	■			
NOAA-2 X-Band										■	■	■	■			
AIRCRAFT																
Wyoming 10UW										\\\\	\\\\		////			
SDSM&T 10MH												////				
NCAR 29J										\\\\	\\\\					
NCAR 304D										\\\\	\\\\		////			
NCAR 306D												////	////			
NCAR 307D													▬▮▬	▬▮▬		
METEOROLOGICAL																
Rawinsondes																
Grover								▲		▲	▲		▲			
Potter																
Sterling	▲						▲			▲	▲		▲			
Conventional	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	
PAM	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	
PRECIPITATION																
Mobiles																
Wyoming																
Precipitation										■						
NCAR Hail											■					
Precip Net	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	Rain (333) and Hail (10) in dense network
AEROSOL, CCN, IN																
Chapel Ranch	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	
Sidney	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	
CLOUD PHOTOGRAPHY																
Butler							■	■	■	■	■	■	■			
Chapel Ranch								■	■	■	■					
Greeley					■	■	■	■	■	■	■	■	■			
Grover							■	■	■	■	■	■	■	■		
Lindbergh						■	■	■	■	■	■	■	■			
Potter																
Sterling																
NCAR Mobiles																
Wyoming Mobiles																

Initiation of Precipitation Formation \\\\
Mature Storm Study ////
Seeding Simulation ▬▮▬

June 22, 1976 15-15-27 MDT Max. dBZ 60.3

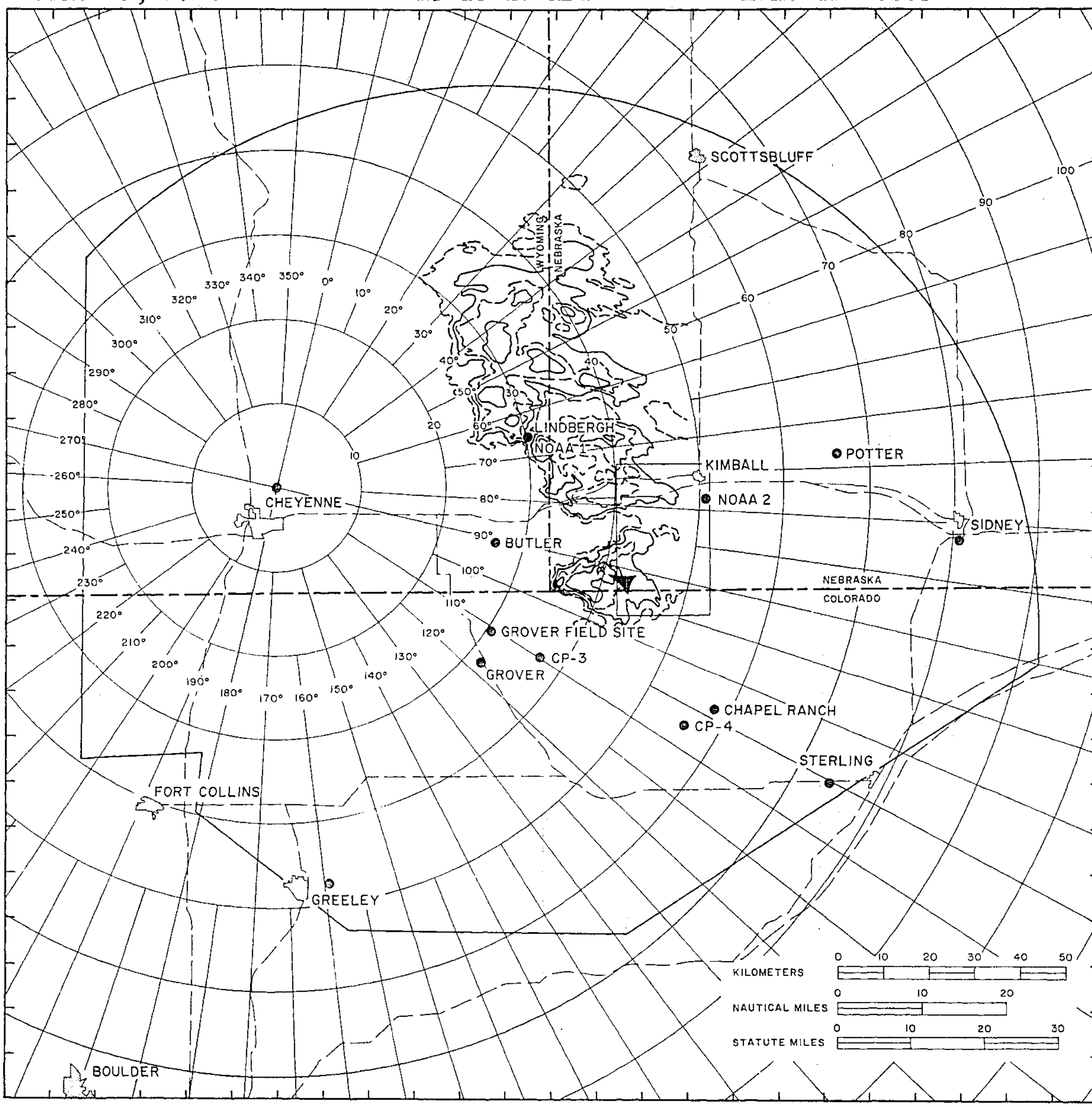


Figure 43.

June 22, 1976 16-31-27 MDT Max. dBZ 62.0

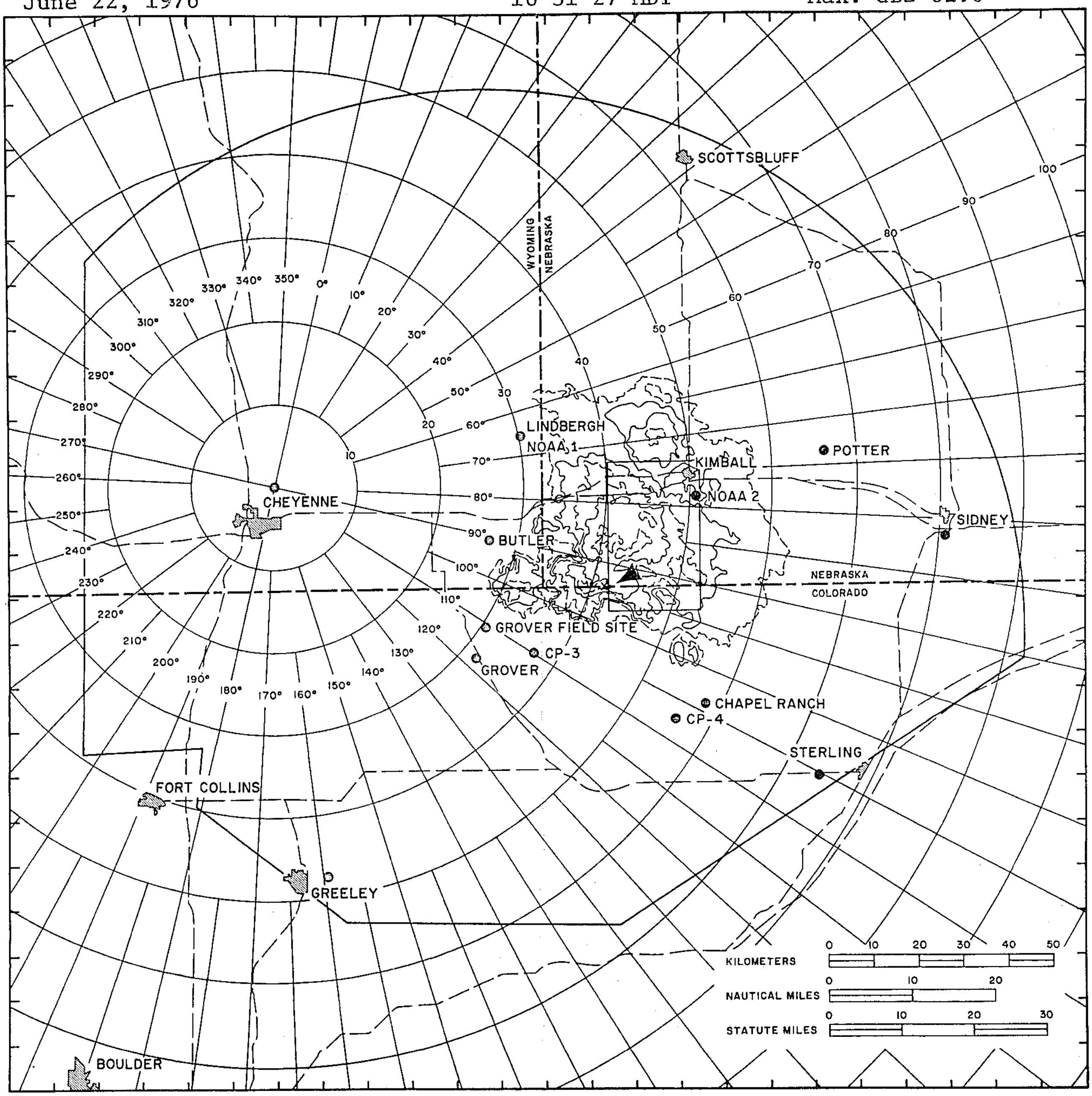
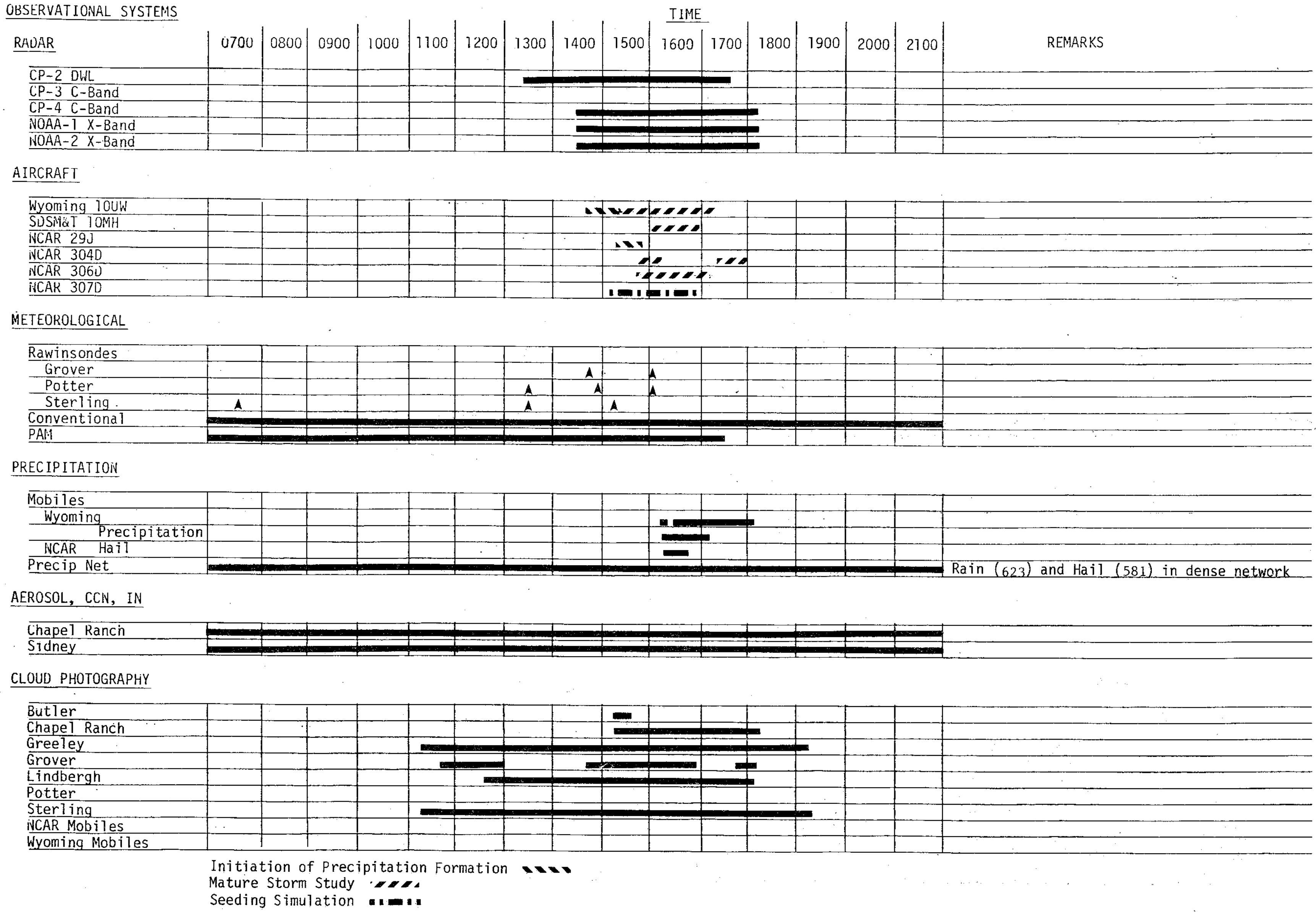


Figure 44.

Table 10.

OPERATIONS SUMMARY

June 22, 1976



June 26, 1976: An Initiation of Precipitation Formation Study was attempted with the sailplane and Queen Airs 10UW and 304D on a weak cumulus congestus that developed over the western part of the area. The investigation was delayed because strong winds prevented the sailplane from taking off. The study was attempted later, but by this time, the intensity of the updrafts had diminished. No radar is presented for this day.

June 27-29, 1976: All systems stood by during this period. However, no significant weather occurred and, consequently, no radar were collected and no aircraft missions were flown.

June 30, 1976: The sailplane and Queen Airs 10UW and 304D investigated a growing cumulus congestus northwest of Cheyenne, Wyoming (see Figure 45). The sailplane encountered updrafts of 10 to 15 m/sec. Grover radar data is available, but multiple Doppler radar data were not available during this stage of the investigation. A second investigation was conducted on the storm shown in Figure 46. The T-28 and the three Queen Airs participated in this study. The T-28 made five penetrations and the storm was observed by the Doppler radars. Time-resolved collections of hail and precipitation were made by the mobile sampling teams, but these collections were made prior to the start of the aircraft investigations.

June 30, 1976 14-43-37 MDT Max. dBZ 46.0

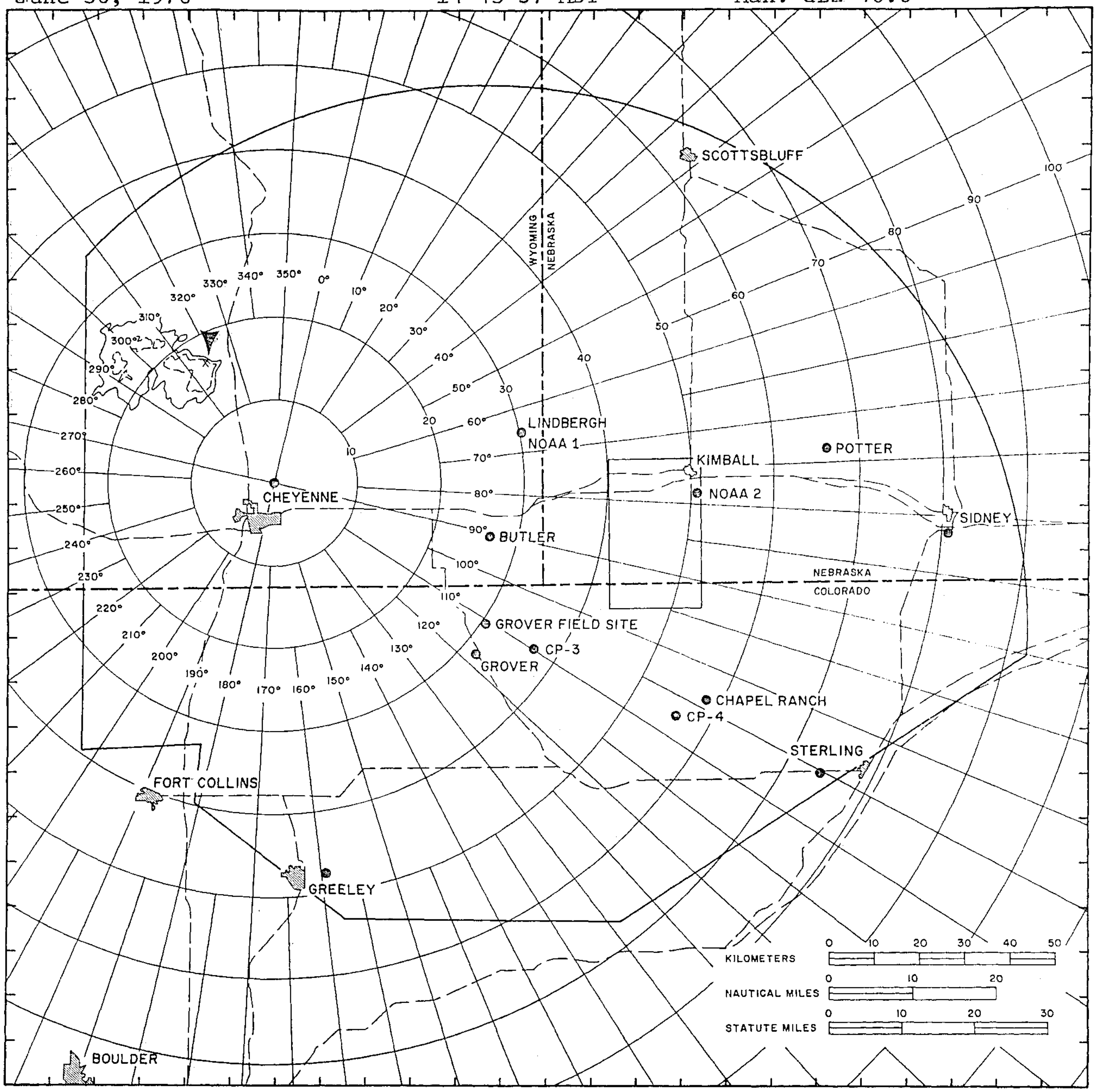


Figure 45.

June 30, 1976 18-38-03 MDT Max. dBZ 53.5

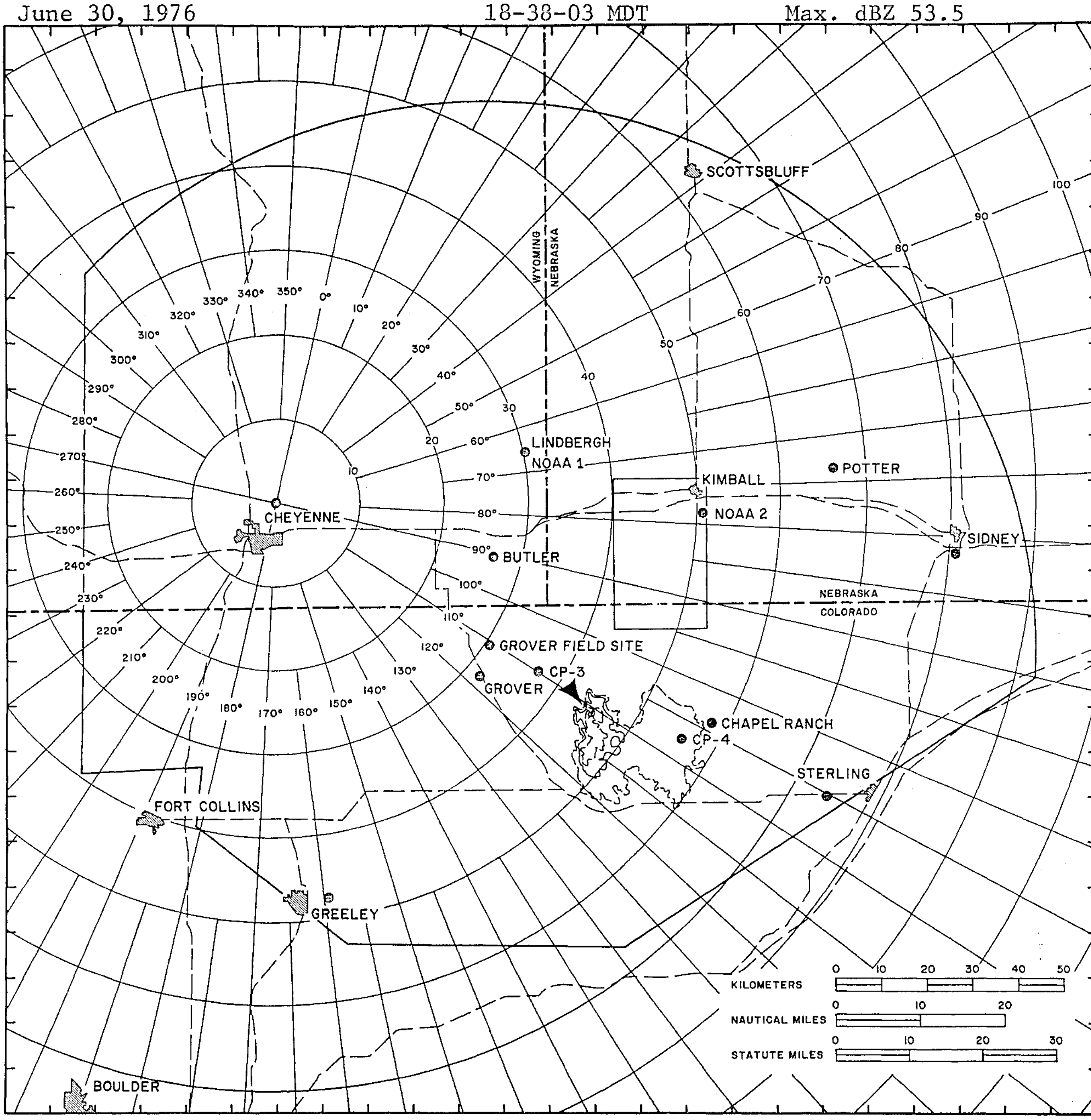


Figure 46.

Table 11.

OPERATIONS SUMMARY

June 30, 1976

OBSERVATIONAL SYSTEMS	0700	0800	0900	1000	1100	1200	1300	1400	1500	1600	1700	1800	1900	2000	2100	REMARKS
RADAR																
CP-2 DWL																
CP-3 C-Band																
CP-4 C-Band																
NOAA-1 X-Band																
NOAA-2 X-Band																
AIRCRAFT																
Wyoming 10UW																
SDSM&T 10MH																
NCAR 29J																
NCAR 304D																
NCAR 306D																
NCAR 307D																
METEOROLOGICAL																
Rawinsondes																
Grover																
Potter																
Sterling																
Conventional																
PAM																
PRECIPITATION																
Mobiles																
Wyoming Hail																
Precipitation																
NCAR Hail																
Precip Net																Rain (44) and Hail (11) in dense network
AEROSOL, CCN, IN																
Chapel Ranch																
Sidney																
CLOUD PHOTOGRAPHY																
Butler																
Chapel Ranch																
Greeley																
Grover																
Lindbergh																
Potter																
Sterling																
NCAR Mobiles																
Wyoming Mobiles																

Initiation of Precipitation Formation

Mature Storm Study

Seeding Simulation

July 1, 1976: Queen Air 10UW and the sailplane collaborated on an Initiation of Precipitation Formation Study on the storm illustrated in Figure 47. Later in the day, the three Queen Airs collaborated on a Mature Storm Study involving the storm shown in Figure 48. Doppler radar data were collected. Several time-resolved precipitation collections were made including a single hail sample.

July 2, 1976: An Initiation of Precipitation Formation Study was conducted using the sailplane and Queen Airs 10UW and 304D on the storm shown in Figure 49. Several coordinated penetrations were made by the sailplane and 10UW while 304D flew in the updraft region at cloud base. This storm was also in a good location with respect to the Doppler radar network. No time-resolved precipitation samples were collected. Later the T-28 and the three Queen Airs investigated the storm shown in Figure 50. The T-28 made a single penetration without tracking support from Grover. This storm was not ideally located with respect to the Doppler radars. Rain and hail were observed by the dense network and good time-resolved collections of precipitation and hail were made by the mobile sampling teams.

This day can be characterized by high reflectivities and heavy severe hailfall. Hailstones 5-6 cm in diameter were collected near Raymer, Colorado.

July 3, 1976: Convective activity was limited to the extreme eastern portion of the area in the vicinity of Sidney, Nebraska. An Initiation of Precipitation Formation Study was conducted by Queen Airs 10UW and 304D since support was tenuous at that range for all radars. No radar data is presented as radar data for this date has not been processed.

July 1, 1976 13-30-32 MDT Max. dBZ 47.0

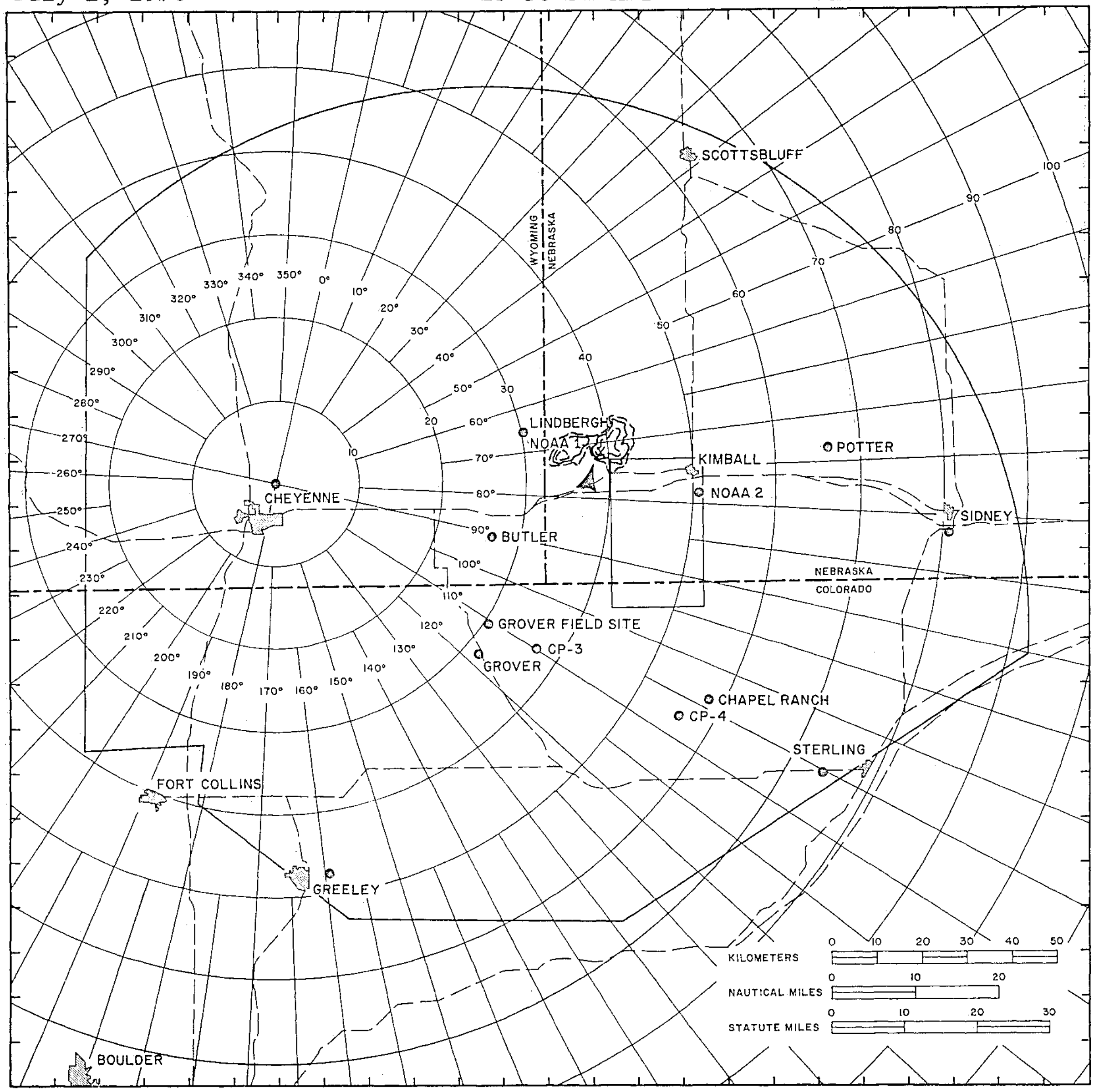


Figure 47.

July 1, 1976 15-16-55 MDT Max. dBZ 53.6

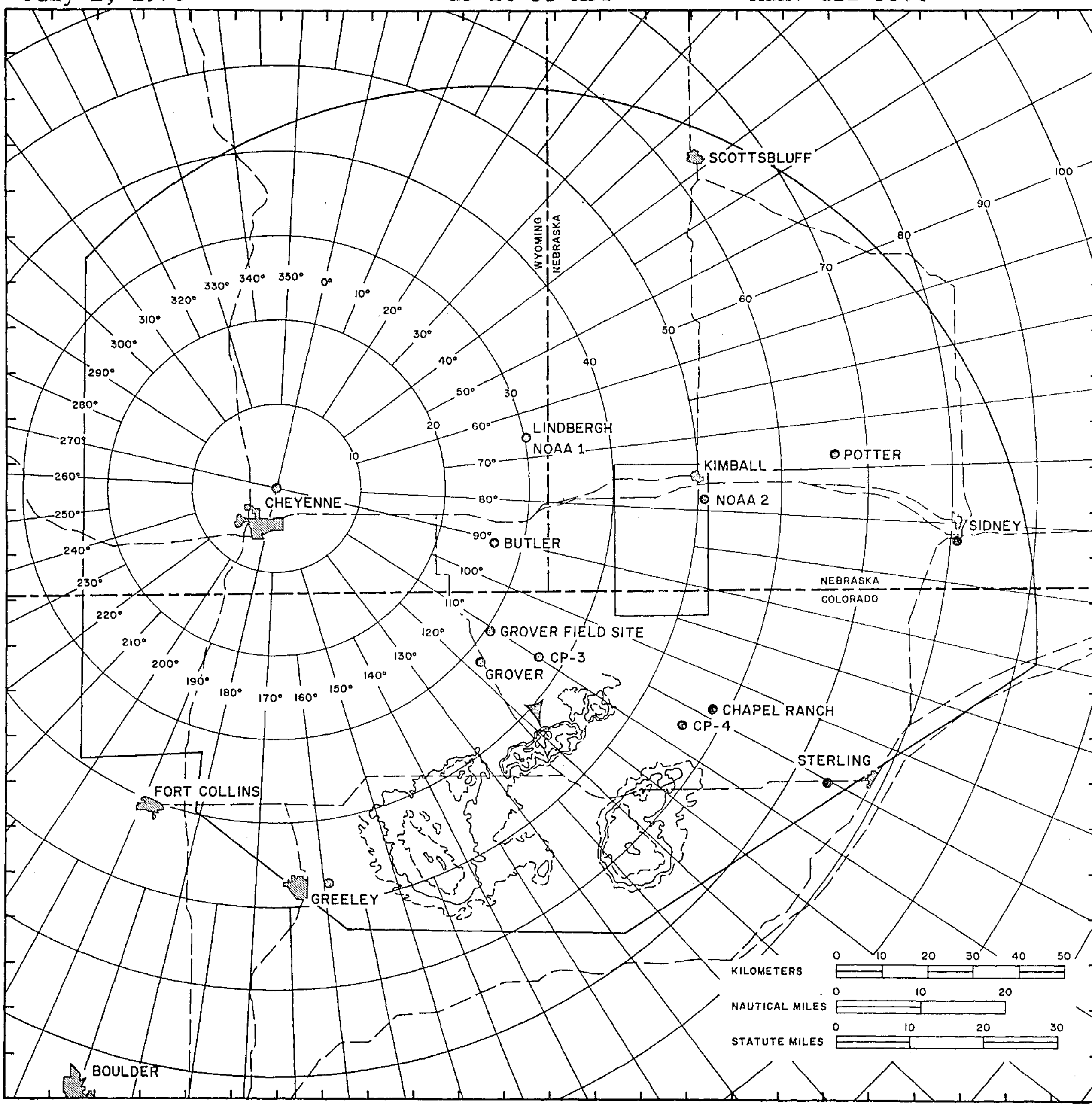
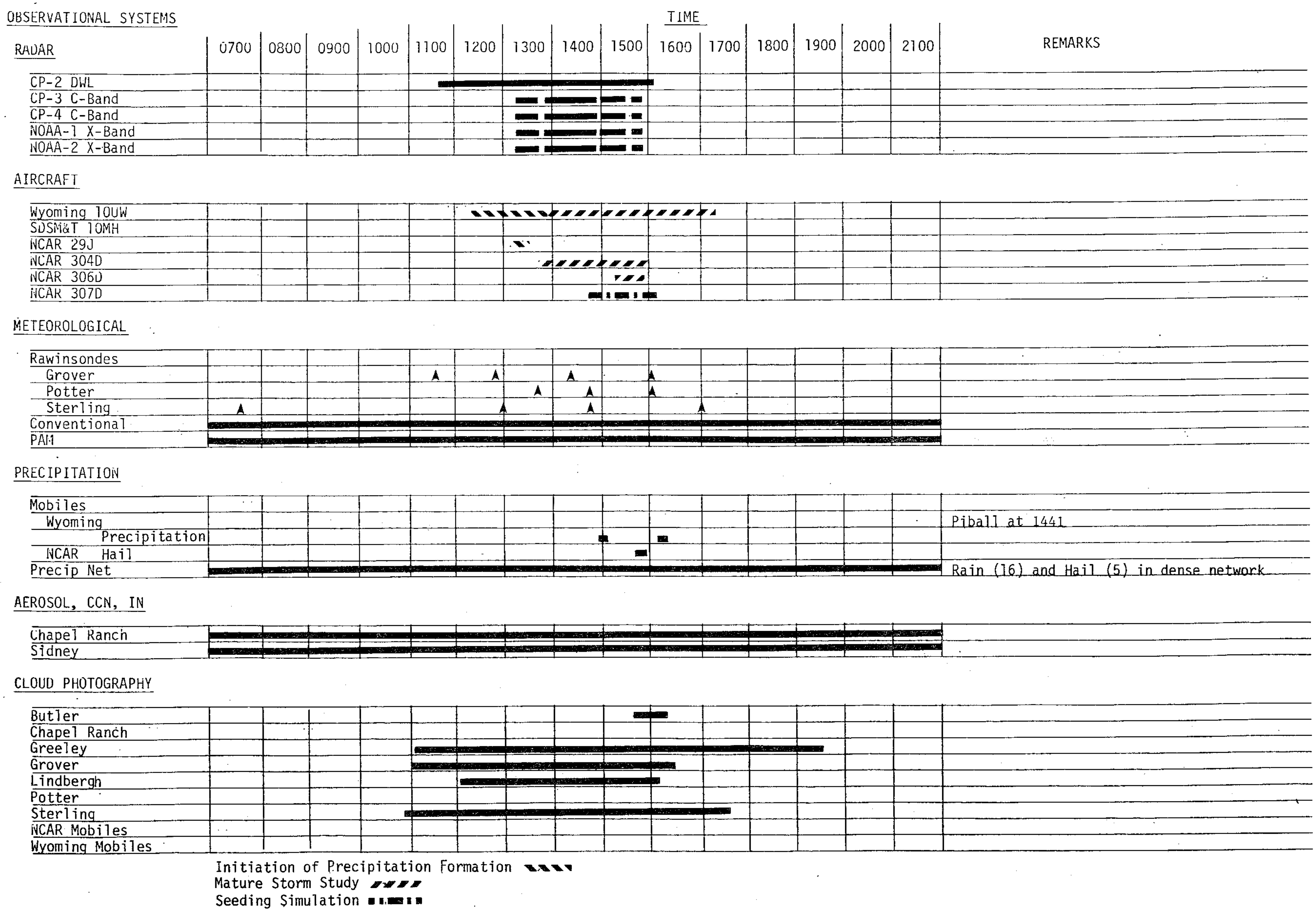


Figure 48.

Table 12.

OPERATIONS SUMMARY

July 1, 1976



July 2, 1976 15-20-42 MDT Max. dBZ 58.5

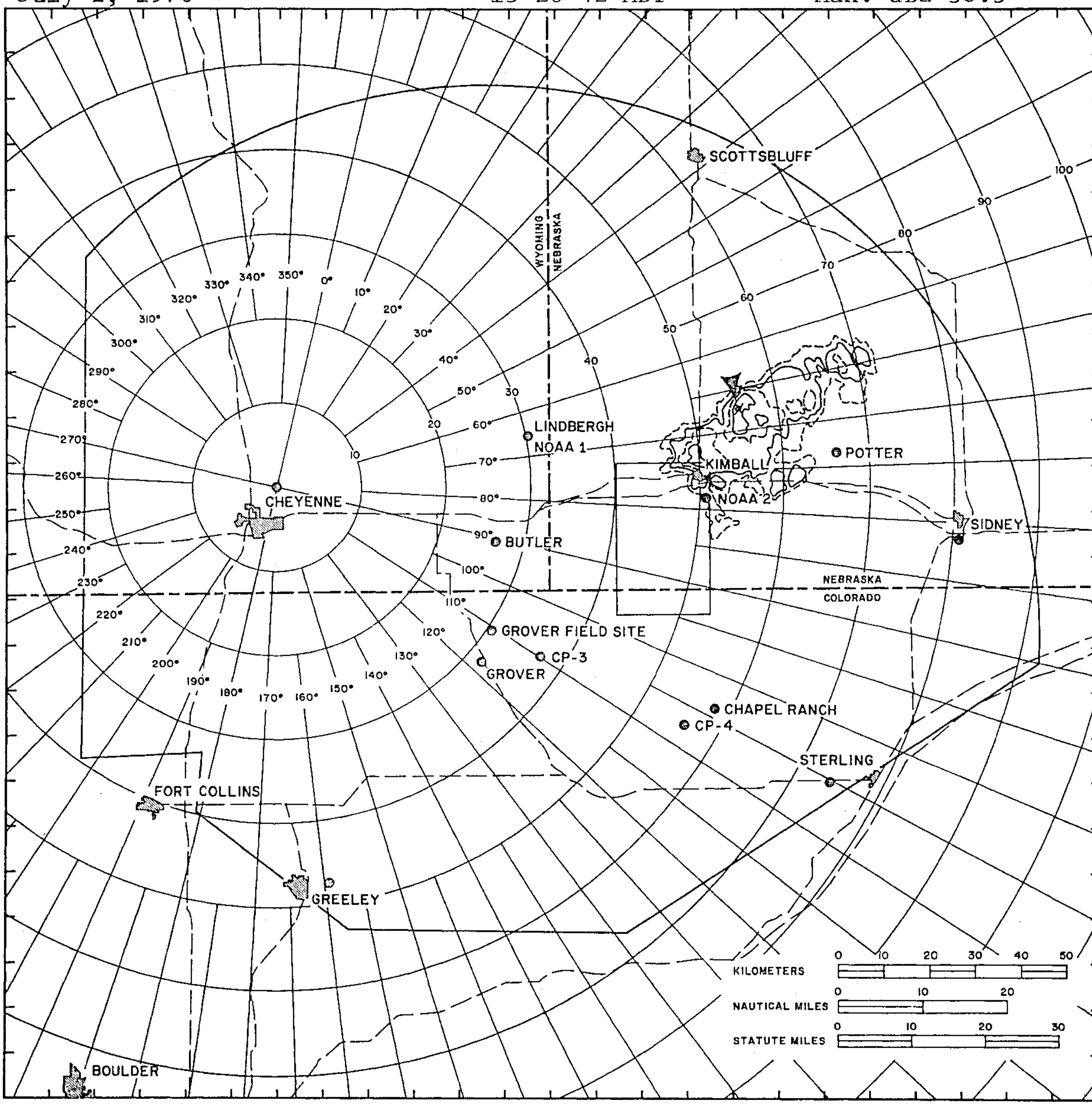


Figure 49.

July 2, 1976 16-55-24 MDT Max. dBZ 64.9

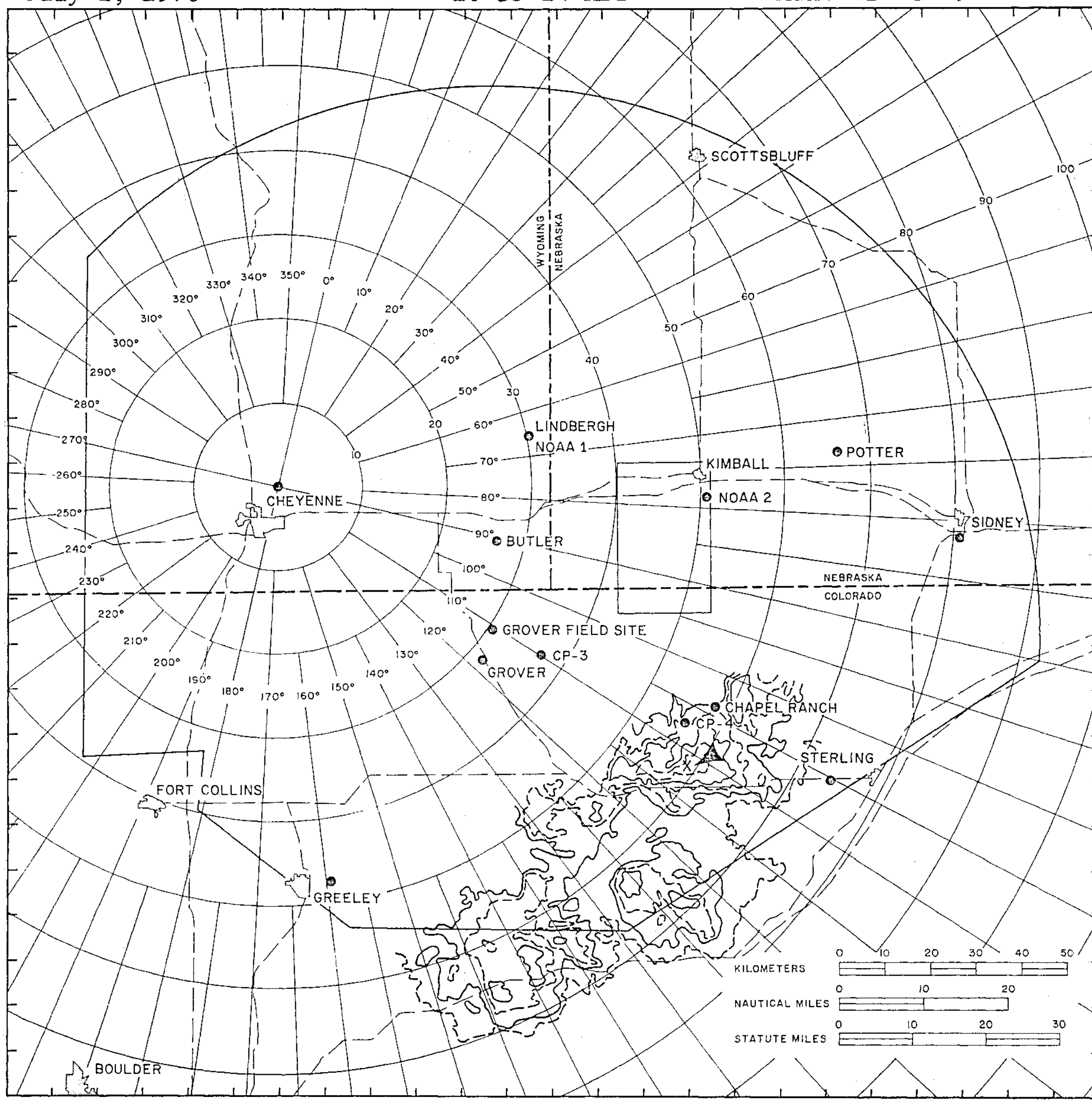


Figure 50.

Table 13.

OPERATIONS SUMMARY

July 2, 1976

OBSERVATIONAL SYSTEMS	0700	0800	0900	1000	1100	1200	1300	1400	1500	1600	1700	1800	1900	2000	2100	REMARKS
RADAR																
CP-2 DWL																
CP-3 C-Band																
CP-4 C-Band																
NOAA-1 X-Band																
NOAA-2 X-Band																
AIRCRAFT																
Wyoming 10UW																
SDSM&T 10MH																No M33 track
NCAR 29J																
NCAR 304D																
NCAR 306D																
NCAR 307D																
METEOROLOGICAL																
Rawinsondes																
Grover																
Potter																
Sterling																
Conventional																
PAM																
PRECIPITATION																
Mobiles																
Wyoming Precipitation																
NCAR Hail																
Precip Net																Rain (614) and Hail (82) in dense network
AEROSOL, CCN, IN																
Chapel Ranch																
Sidney																
CLOUD PHOTOGRAPHY																
Butler																
Chapel Ranch																
Greeley																
Grover																
Lindbergh																
Potter																
Sterling																
NCAR Mobiles																
Wyoming Mobiles																

Initiation of Precipitation Formation

Mature Storm Study

Nuclei Sampling

Seeding Simulation

July 4-5, 1976: Scheduled days off.

July 6, 1976: The sailplane investigated a growing cumulus congestus shown in Figure 51. The sailplane had a smooth climb to over 10 km at about 15 m/sec. There is good conventional radar data to support this case, but no multiple-Doppler data. Difficulties with the commercial power were experienced at NOAA1. Later the T-28 and Queen Air 304D were called for a possible Mature Storm Study, but the storm was in the decaying stage by the time the aircraft arrived. The T-28 made no penetrations because of the failure of the Grover tracking radar. Some data were collected by 304D.

July 7, 1976: The T-28 and Queen Airs 10UW, 304D and 306D collaborated on an investigation of the storm shown in Figure 52. The T-28 made two penetrations without tracking support from Grover. The storm was ideally located for observation by the Doppler radars. Rain and hail were observed in the dense network and several time-resolved hail collections were made by the mobile sampling teams.

July 8, 1976: The sailplane was the only aircraft used on this day. Several penetrations were made, one of which was of the storm shown in Figure 53 before the formation of the first radar echo. Some Doppler data were collected but this occurred after the termination of the sailplane's flight.

July 9, 1976: The sailplane and Queen Air 10UW conducted an investigation of the cloud identified in Figure 54. The cloud was weak and decaying. Some tri-Doppler radar data are available. Some light rain occurred in the dense network. This case is of marginal interest.

July 6, 1976 17-35-45 MDT Max. dBZ 51.2

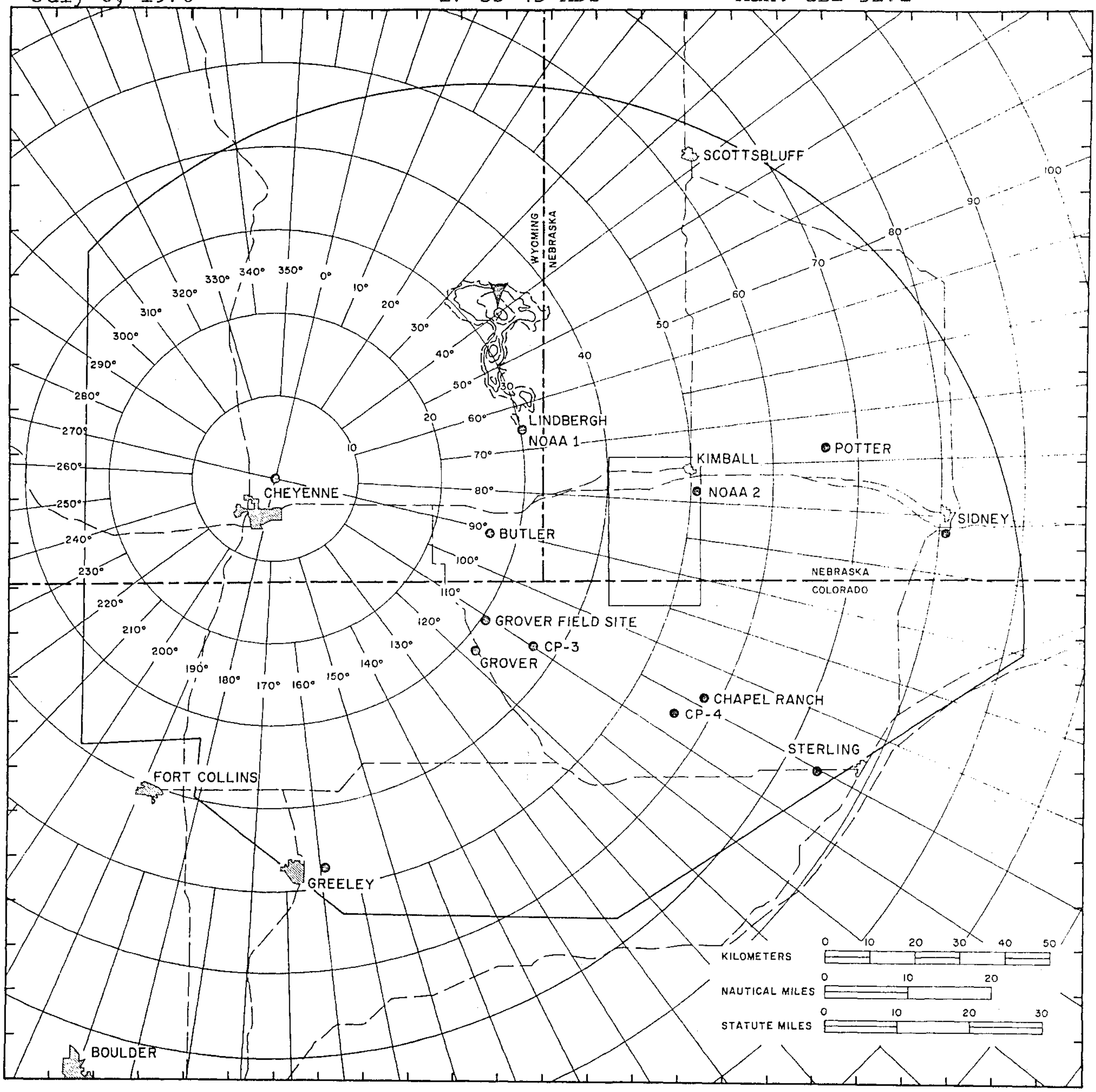
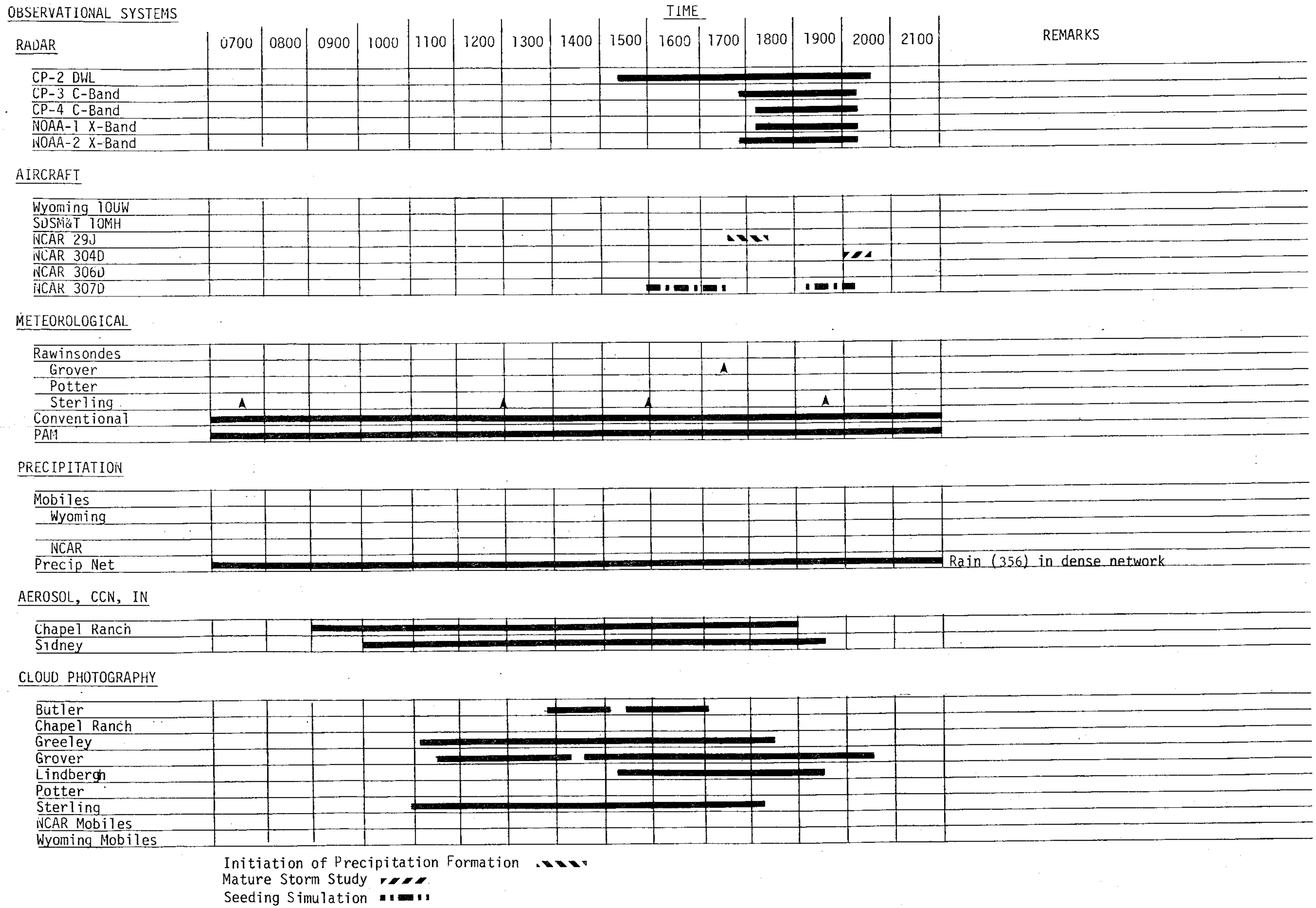


Figure 51.

Table 14.

OPERATIONS SUMMARY

July 6, 1976



July 7, 1976 17-17-17 MDT Max. dBZ 47.6

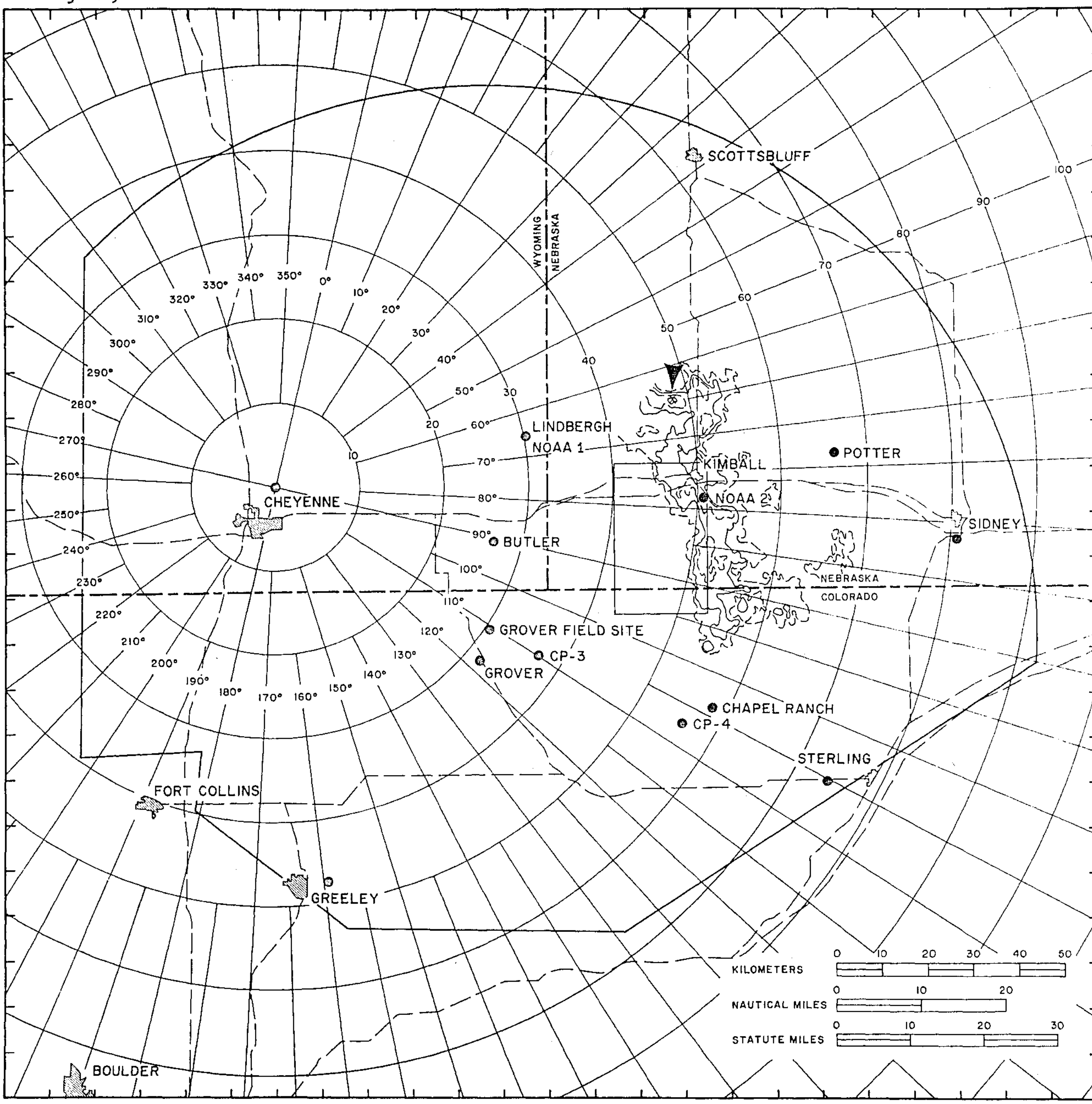


Figure 52.

Table 15.

OPERATIONS SUMMARY

July 7, 1976

OBSERVATIONAL SYSTEMS	0700	0800	0900	1000	1100	1200	1300	1400	1500	1600	1700	1800	1900	2000	2100	REMARKS
RADAR																
CP-2 DWL																
CP-3 C-Band																
CP-4 C-Band																
NOAA-1 X-Band																
NOAA-2 X-Band																
AIRCRAFT																
Wyoming 10UW																
SDSM&T 10MH																No M33 Track
NCAR 29J																
NCAR 304D																
NCAR 306D																
NCAR 307D																
METEOROLOGICAL																
Rawinsondes																
Grover																
Potter																
Sterling																
Conventional																
PAM																
PRECIPITATION																
Mobiles																
Wyoming																
NCAR																
Precip Net																Rain (541) and Hail (62) in dense network
AEROSOL, CCN, IN																
Chapel Ranch																
Sidney																
CLOUD PHOTOGRAPHY																
Butler																
Chapel Ranch																
Greeley																
Grover																
Lindbergh																
Potter																
Sterling																
NCAR Mobiles																
Wyoming Mobiles																

Mature Storm Study

Seeding Simulation

July 8, 1976 15-38-19 MDT Max. dBZ 35.7

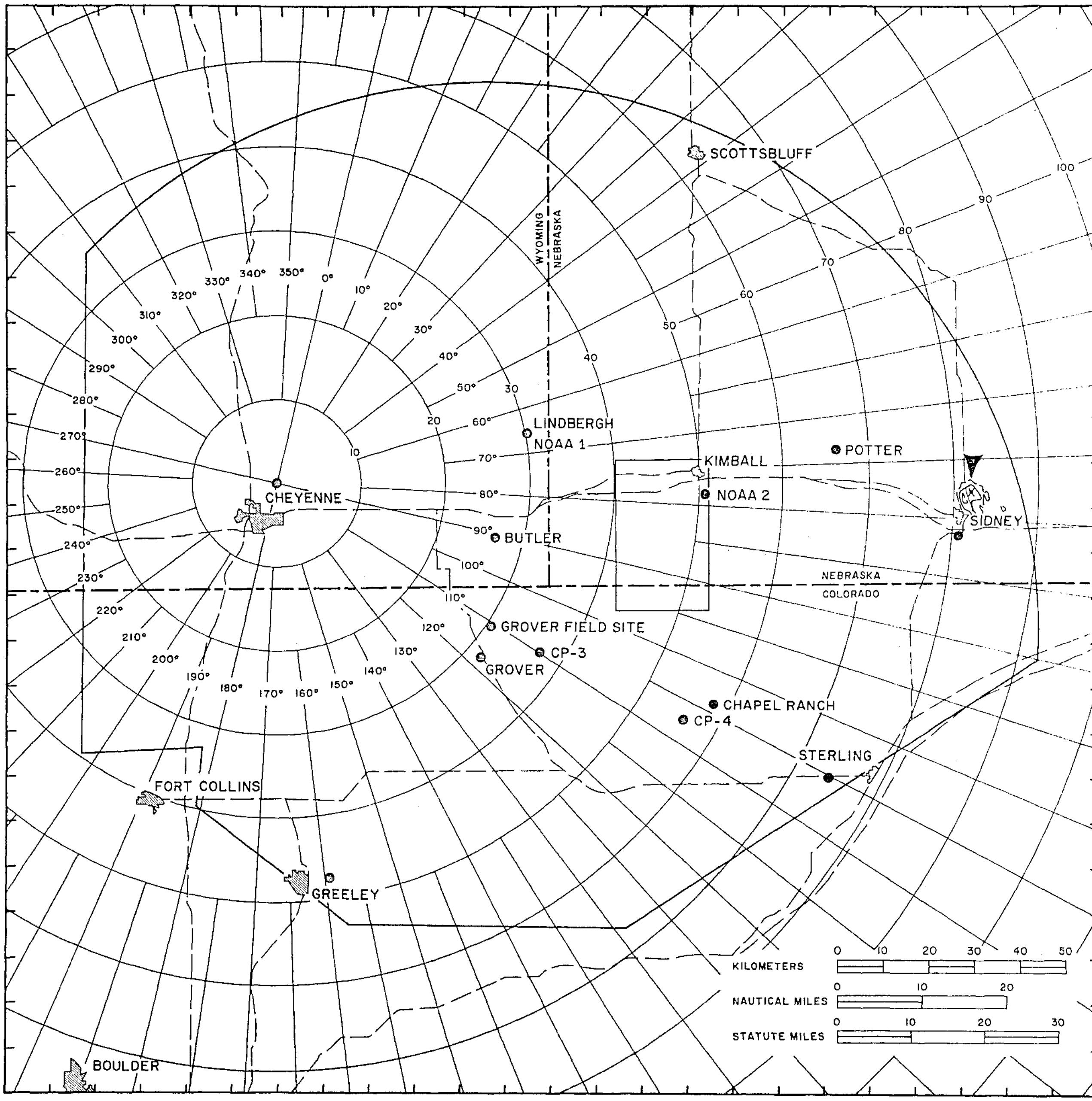


Figure 53.

Table 16.

OPERATIONS SUMMARY

July 8, 1976

OBSERVATIONAL SYSTEMS	TIME 0700	0800	0900	1000	1100	1200	1300	1400	1500	1600	1700	1800	1900	2000	2100	REMARKS
RADAR																
CP-2 DWL																
CP-3 C-Band																
CP-4 C-Band																
NOAA-1 X-Band																
NOAA-2 X-Band																
AIRCRAFT																
Wyoming 10UW																
SDSM&T 10MH																
NCAR 29J																
NCAR 304D																
NCAR 306D																
NCAR 307D																
METEOROLOGICAL																
Rawinsondes																
Grover																
Potter																
Sterling	▲						▲			▲						
Conventional																
PAM																
PRECIPITATION																
Mobiles																
Wyoming																
NCAR																
Precip Net																
AEROSOL, CCN, IN																
Chapel Ranch																
Sidney																
CLOUD PHOTOGRAPHY																
Butler																
Chapel Ranch																
Greeley																
Grover																
Lindbergh																
Potter																
Sterling																
NCAR Mobiles																
Wyoming Mobiles																

Initiation of Precipitation Formation

July 9, 1976 14-30-26 MDT Max. dBZ 49.8

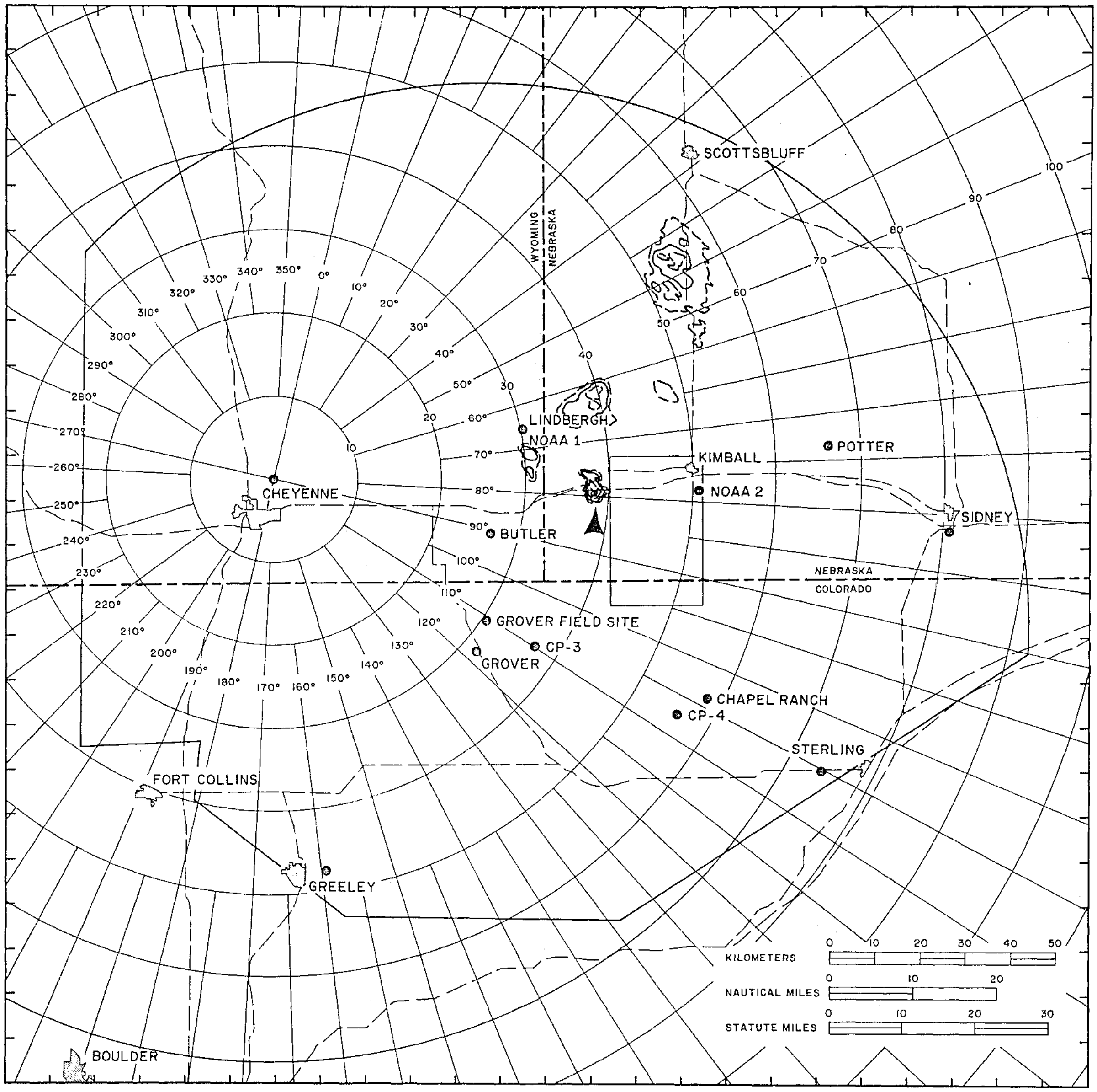


Figure 54.

Table 17.

OPERATIONS SUMMARY

July 9, 1976

OBSERVATIONAL SYSTEMS	0700	0800	0900	1000	1100	1200	1300	1400	1500	1600	1700	1800	1900	2000	2100	REMARKS
RADAR																
CP-2 DWL																
CP-3 C-Band																
CP-4 C-Band																
NOAA-1 X-Band																
NOAA-2 X-Band																
AIRCRAFT																
Wyoming 10UW																
SDSM&T 10MH																
NCAR 29J																
NCAR 304D																
NCAR 306D																
NCAR 307D																
METEOROLOGICAL																
Rawinsondes																
Grover																
Potter																
Sterling																
Conventional																
PAM																
PRECIPITATION																
Mobiles																
Wyoming																Piball at 1521
NCAR																
Precip Net																Rain (37) in dense network
AEROSOL, CCN, IN																
Chapel Ranch																
Sidney																
CLOUD PHOTOGRAPHY																
Butler																
Chapel Ranch																
Greeley																
Grover																
Lindbergh																
Potter																
Sterling																
NCAR Mobiles																
Wyoming Mobiles																

Initiation of Precipitation Formation

July 10-13, 1976: On July 10 through 13 no significant activity occurred. No radar data were collected and no aircraft missions were flown.

July 14, 1976: The sailplane and Queen Airs 10UW and 304D attempted to collaborate on an Initiation of Precipitation Formation Study but the sailplane never found good lift and landed at 1500 MDT. A Mature Storm Study was conducted with the T-28 and the three Queen Airs on the storm identified in Figure 55. The T-28 made five penetrations. Doppler radar data were collected. A few time-resolved precipitation collections were made. The only hail observed was small and this was recorded at 15 locations in the dense network.

July 15, 1976: No significant activity occurred. No radar data were collected and no aircraft missions were flown.

July 16, 1976: The sailplane was up but could not locate a suitable study cloud. The Grover radar did collect some data but none has been processed. No other aircraft missions were flown.

July 17, 1976: The sailplane was called out but never found a cloud worth being released into. The three Queen Airs later attempted an investigation of the rather weak storm shown in Figure 56. During the flight the emphasis was changed and all aircraft then concentrated on collecting aerosol, nuclei, and deuterium samples. The storm was also observed by the Doppler radars. A few time-resolved precipitation samples were made by the mobile sampling teams.

July 14, 1976 15-07-58 MDT Max. dBZ 60.8

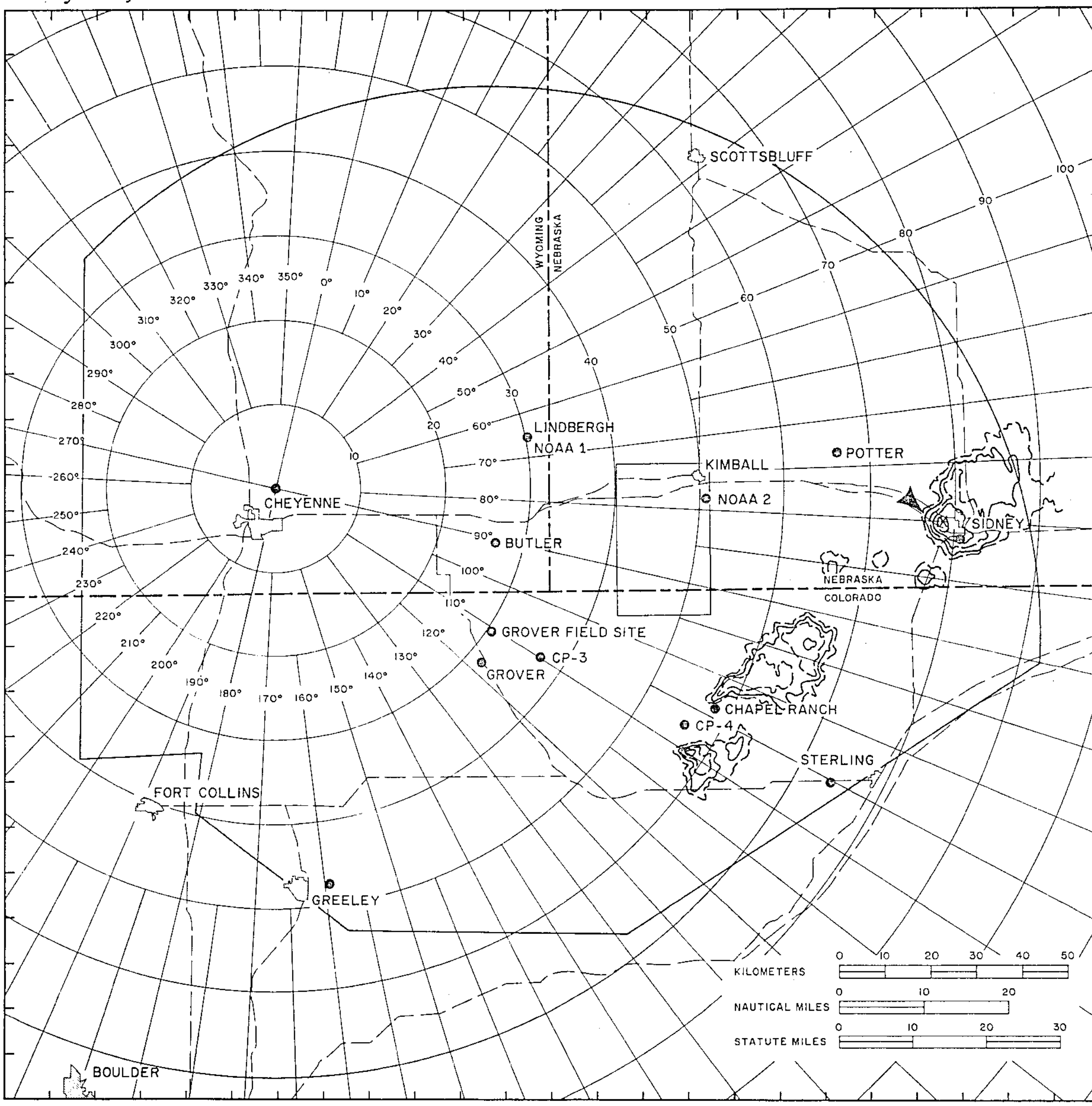


Figure 55.

Table 18.

OPERATIONS SUMMARY
July 14, 1976

OBSERVATIONAL SYSTEMS	0700	0800	0900	1000	1100	1200	1300	1400	1500	1600	1700	1800	1900	2000	2100	REMARKS
RADAR																
CP-2 DWL																
CP-3 C-Band																
CP-4 C-Band																
NOAA-1 X-Band																
NOAA-2 X-Band																
AIRCRAFT																
Wyoming 10UW																
SDSM&T 10MH																
NCAR 29J																
NCAR 304D																
NCAR 306D																
NCAR 307D																
METEOROLOGICAL																
Rawinsondes																
Grover					Λ		Λ	Λ	Λ							
Potter							Λ	Λ								
Sterling	Λ						Λ	Λ	Λ							
Conventional																
PAM																
PRECIPITATION																
Mobiles																
Wyoming Hail																
Precipitation																
NCAR Hail																
Precip Net																Rain (3) and Hail (7) in dense network
AEROSOL, CCN, IN																
Chapel Ranch																
Sidney																
CLOUD PHOTOGRAPHY																
Butler																
Chapel Ranch																
Greeley																
Grover																
Lindbergh																
Potter																
Sterling																
NCAR Mobiles																
Wyoming Mobiles																

Initiation of Precipitation Formation
Mature Storm Study
Seeding Simulation
Anomalous Propagation

July 17, 1976 17-20-26 MDT Max. dBZ 49.8

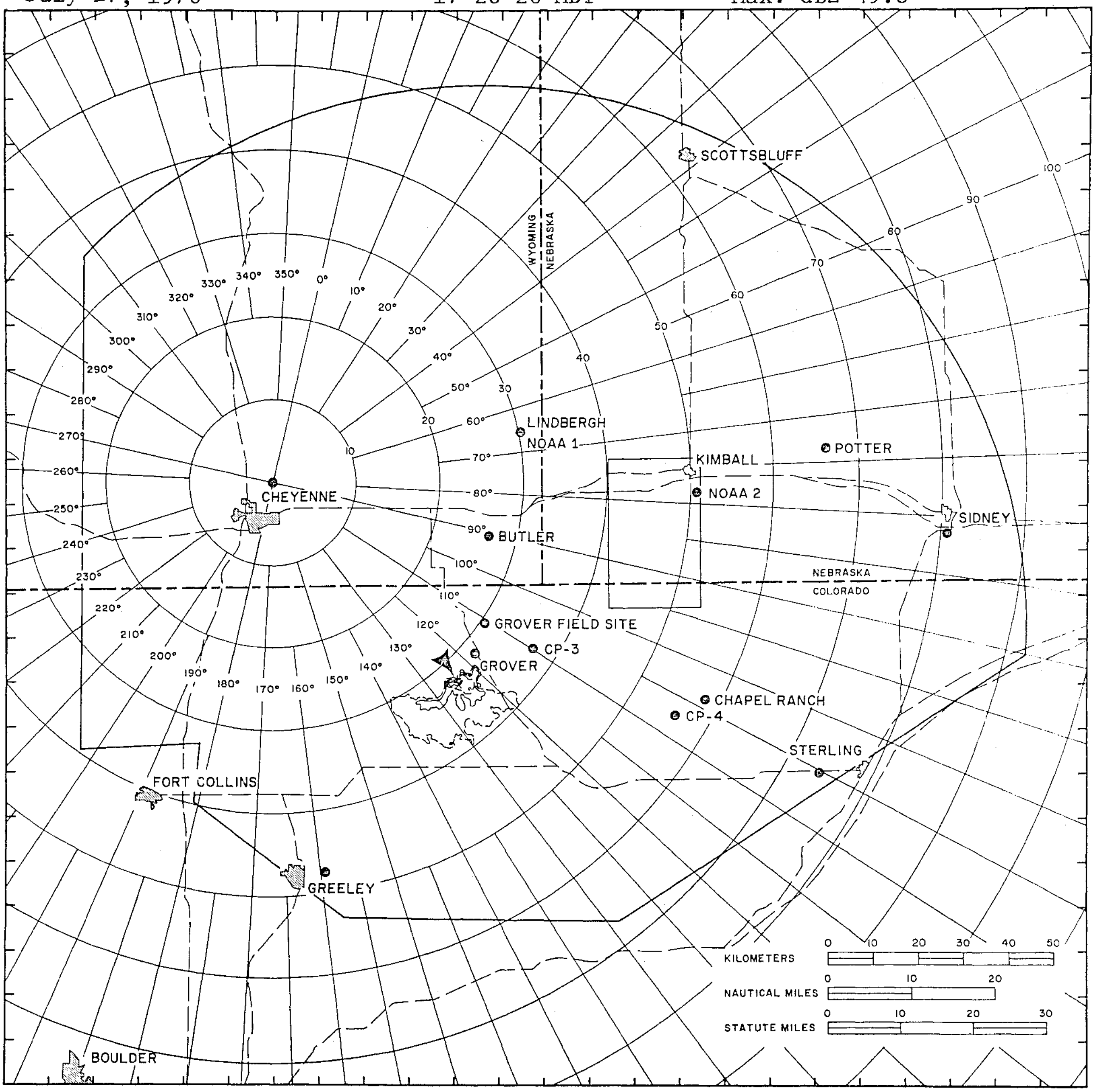
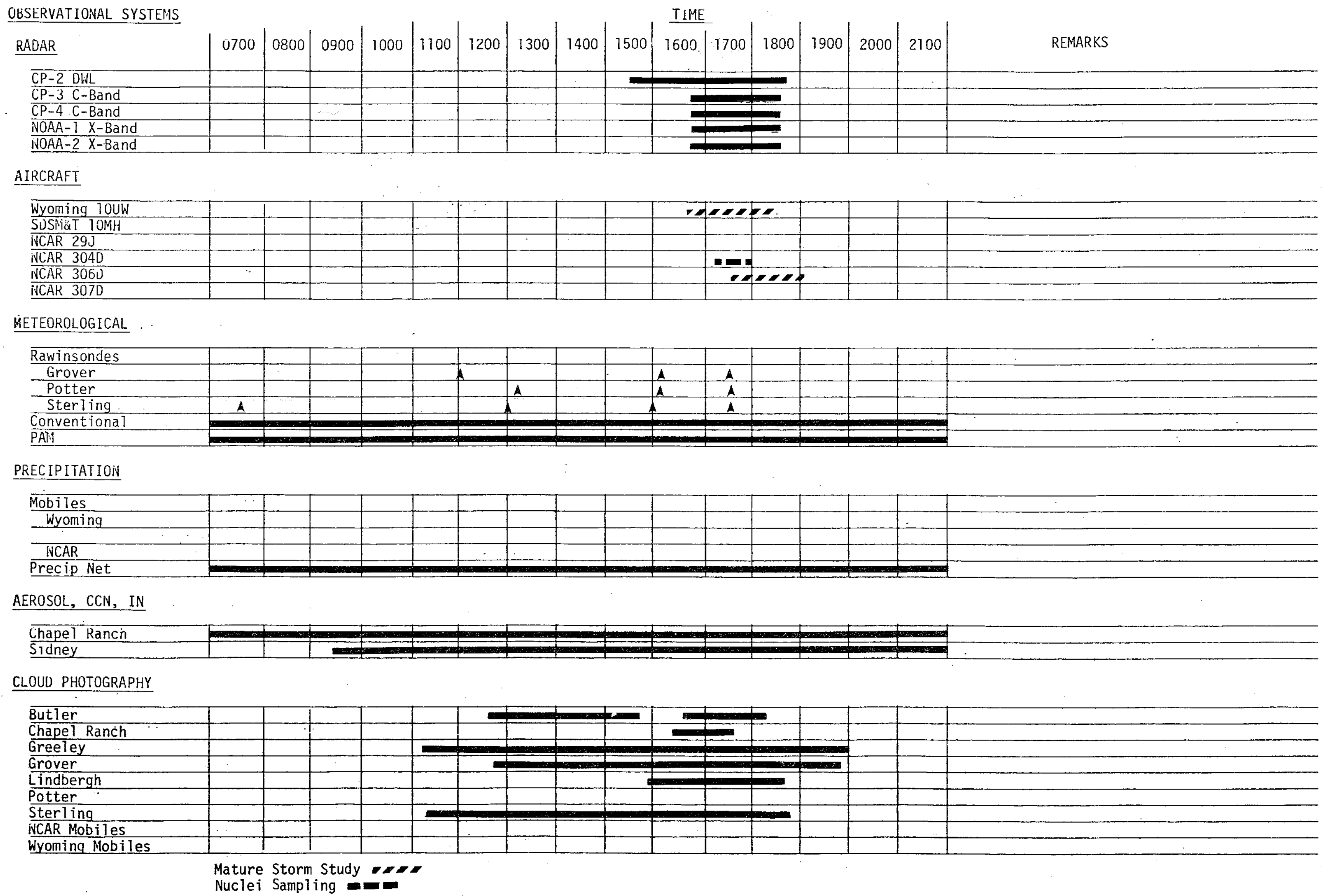


Figure 56.

Table 19.

OPERATIONS SUMMARY
July 17, 1976



July 18, 1976: The sailplane and Queen Airs 10UW and 304D were called for an Initiation of Precipitation Formation Study but the sailplane developed instrument problems and the investigation was cancelled. Later the T-28 and the three Queen Airs investigated the mature storm identified in Figure 57. The T-28 made three penetrations. The Doppler radars also collected data on this storm. Rain and hail (13 point samples) fell in the dense network. The surface meteorological data are poor because of the storm's location. No time-resolved precipitation samples were collected.

July 19, 1976: No significant activity occurred. No aircraft missions were flown. There were small weak echoes and widespread light rain in the area after 1800 MDT. No radar data for this day has been processed.

July 20, 1976: The T-28 and Queen Airs 304D and 306D conducted an investigation of the storm shown in Figure 58. The T-28 made five penetrations. The storm was observed by the Doppler radars. No hail was observed but light rain showers were fairly widespread throughout the area.

July 21, 1976: The T-28 and Queen Airs 304D and 306D conducted an investigation of the storm identified in Figure 59. The T-28 made six penetrations, four of which were through a new turret on the edge of the main cell with the expectation that it would grow to be the dominant system. This did not turn out to be the case. The Doppler radars collected data on the storm. Rain and hail were observed by the dense network. No time-resolved precipitation collections were made.

July 18, 1976 17-08-05 MDT Max dBZ 58.7

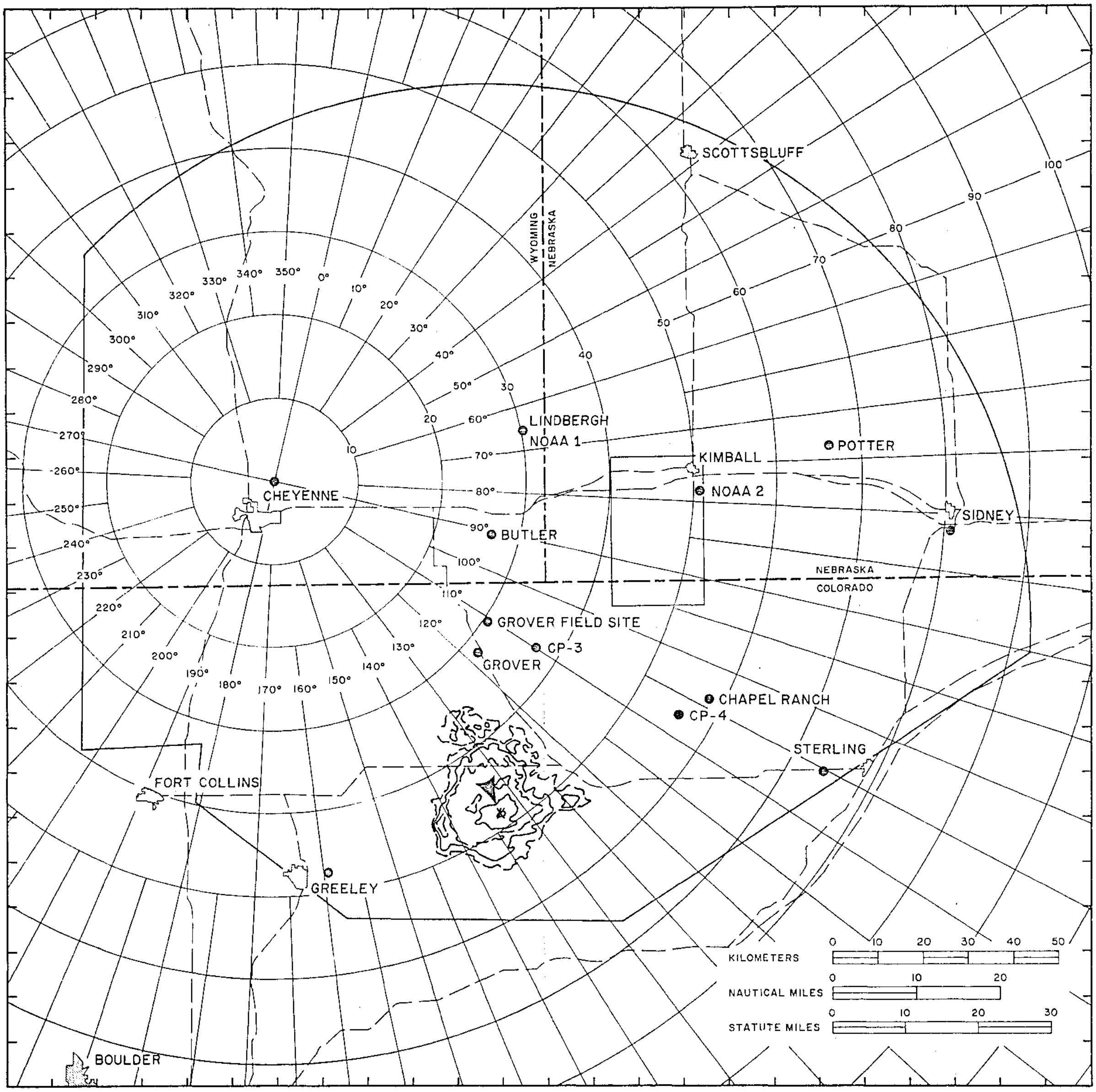


Figure 57.

Table 20.

OPERATIONS SUMMARY

July 18, 1976

OBSERVATIONAL SYSTEMS	0700	0800	0900	1000	1100	1200	1300	1400	1500	1600	1700	1800	1900	2000	2100	REMARKS
RADAR																
CP-2 DWL																
CP-3 C-Band																
CP-4 C-Band																
NOAA-1 X-Band																
NOAA-2 X-Band																
AIRCRAFT																
Wyoming 10UW																
SDSM&T 10MH																
NCAR 29J																
NCAR 304D																
NCAR 306D																
NCAR 307D																
METEOROLOGICAL																
Rawinsondes																
Grover						▲				▲	▲					
Potter						▲				▲	▲					
Sterling	▲						▲			▲	▲					
Conventional																
PAM																
PRECIPITATION																
Mobiles																
Wyoming																
NCAR																
Precip Net																Rain (193) and Hail (4) in dense network
AEROSOL, CCN, IN																
Chapel Ranch																
Sidney																
CLOUD PHOTOGRAPHY																
Butler																
Chapel Ranch																
Greeley																
Grover																
Lindbergh																
Potter																
Sterling																
NCAR Mobiles																
Wyoming Mobiles																

Initiation of Precipitation Formation

Mature Storm Study

Seeding Simulation

July 20, 1976 17-09-42 MDT Max. dBZ 55.8

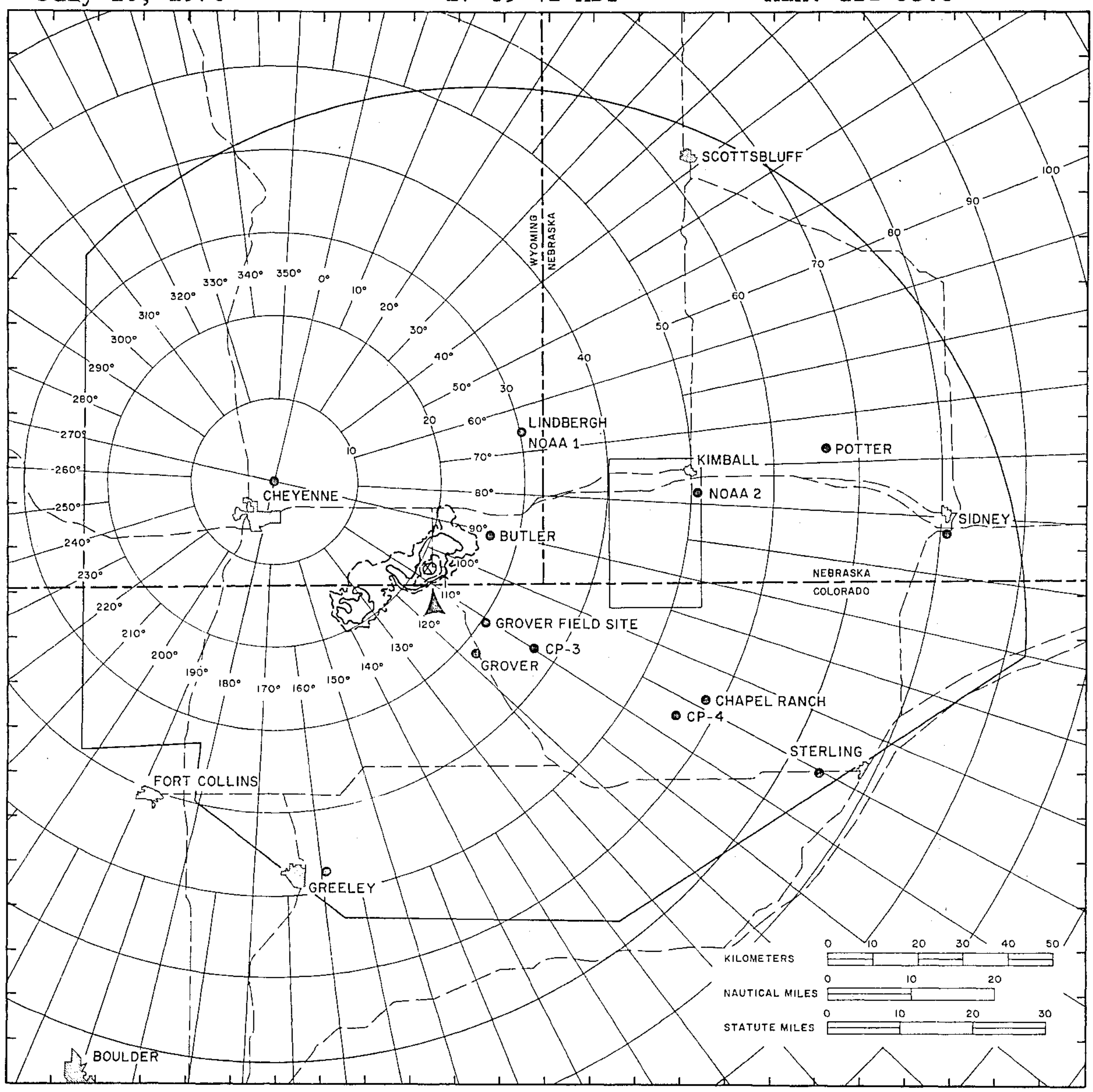


Figure 58.

Table 21.

OPERATIONS SUMMARY

July 20, 1976

OBSERVATIONAL SYSTEMS	TIME															
RADAR	0700	0800	0900	1000	1100	1200	1300	1400	1500	1600	1700	1800	1900	2000	2100	REMARKS
CP-2 DWL																
CP-3 C-Band																
CP-4 C-Band																
NOAA-1 X-Band																
NOAA-2 X-Band																
AIRCRAFT																
Wyoming 10UW																
SDSM&T 10MH																
NCAR 29J																
NCAR 304D																
NCAR 306D																
NCAR 307D																
METEOROLOGICAL																
Rawinsondes																
Grover																
Potter																
Sterling																
Conventional																
PAM																
PRECIPITATION																
Mobiles																
Wyoming Precipitation																
NCAR																
Precip Net																Rain (614) in dense network
AEROSOL, CCN, IN																
Chapel Ranch																
Sidney																
CLOUD PHOTOGRAPHY																
Butler																
Chapel Ranch																
Greeley																
Grover																
Lindbergh																
Potter																
Sterling																
NCAR Mobiles																
Wyoming Mobiles																

Mature Storm Study

Seeding Simulation

July 21, 1976 16-54-46 Max. dBZ 57.2

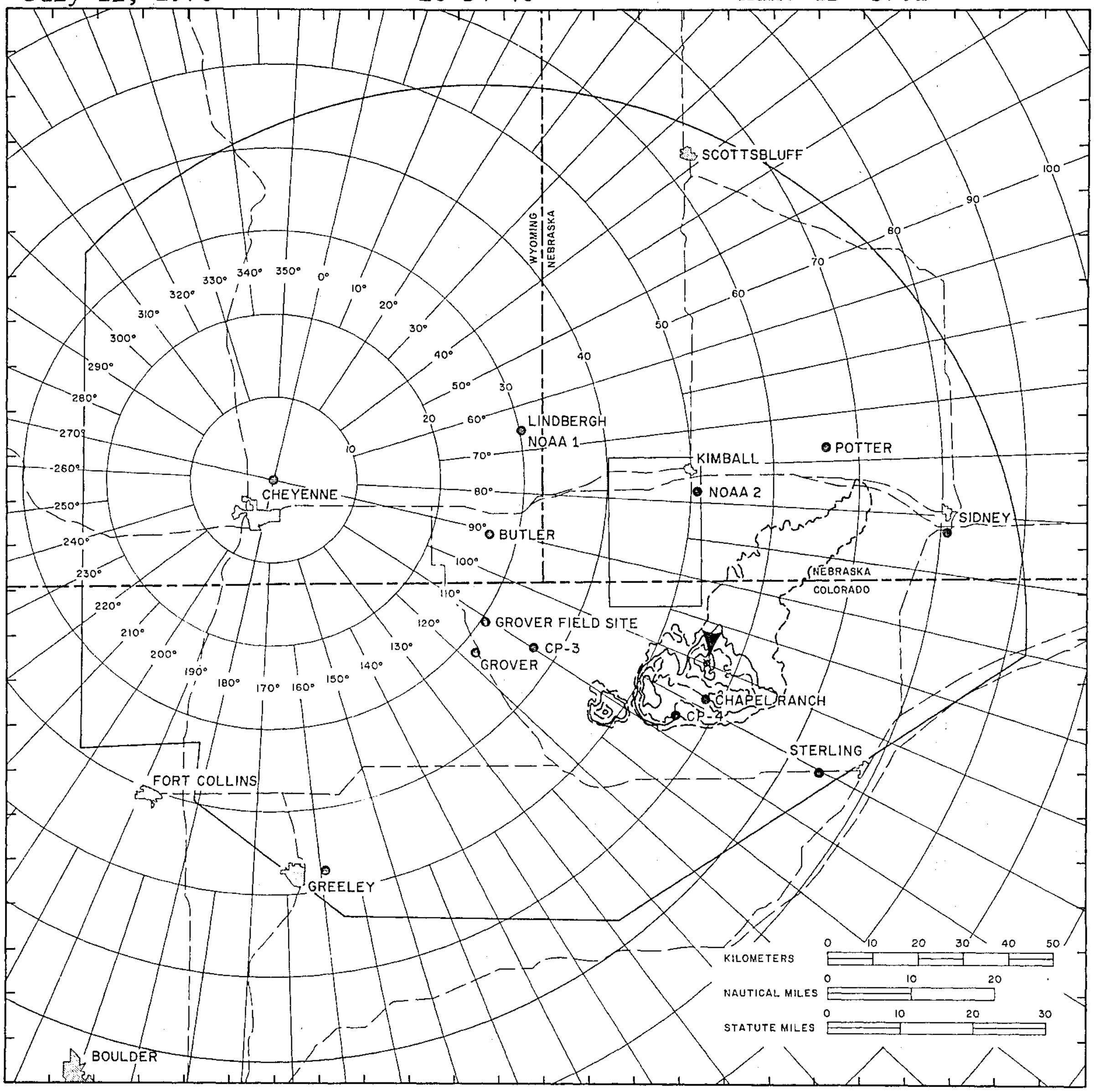


Figure 59.

Table 22.

OPERATIONS SUMMARY
July 21, 1976

OBSERVATIONAL SYSTEMS	0700	0800	0900	1000	1100	1200	1300	1400	1500	1600	1700	1800	1900	2000	2100	REMARKS
RADAR																
CP-2 DWL																
CP-3 C-Band																
CP-4 C-Band																
NOAA-1 X-Band																
NOAA-2 X-Band																
AIRCRAFT																
Wyoming 10UW																
SDSM&T 10MH																
NCAR 29J																
NCAR 304D																
NCAR 306D																
NCAR 307D																
METEOROLOGICAL																
Rawinsondes																
Grover																
Potter																
Sterling																
Conventional																
PAM																
PRECIPITATION																
Mobiles																
Wyoming																
Precipitation																
NCAR																
Precip Net																Rain (586) and Hail (31) in dense network
AEROSOL, CCN, IN																
Chapel Ranch																
Sidney																
CLOUD PHOTOGRAPHY																
Butler																
Chapel Ranch																
Greeley																
Grover																
Lindbergh																
Potter																
Sterling																
NCAR Mobiles																
Wyoming Mobiles																

Mature Storm Study
Seeding Simulation

<u>July 22, 1976</u>: The sailplane and Queen Air 306D investigated the cloud whose radar return is shown in Figure 60. This cloud subsequently developed into the small mature storm shown in Figure 61. During the developing stage the sailplane climbed from 5.5 km to over 8 km with good coordination with 306D and the Doppler radars. Later a Mature Storm Study was conducted on a storm located over the eastern portion of the area. The T-28 made six penetrations of which several were through the main updraft. Queen Air 306D also participated in this study. Later in the day, a second Initiation of Precipitation Formation Study was conducted by the sailplane and 306D. In this case the subject of the investigation was observed by the Grover radar and NOAA 1 and 2. Some rain and hail (8 point samples) were observed in the dense network. Several time-resolved precipitation and hail samples were also collected.

<u>July 23, 1976</u>: The sailplane and Queen Airs 10UW and 306D were called for an Initiation of Precipitation Formation Study but by the time they arrived the cloud shown in Figure 62 was dissipating. The aircraft remained in the area until 1745 MDT but no further opportunities developed. Some Doppler data were collected on the echo shown in Figure 62.

<u>July 24, 1976</u>: Weak cumulus congestus developed during the afternoon. Some radar data were collected but none has been processed. In the absence of suitable storm development a vertical profile nucleation and aerosol sampling mission was conducted using Queen Airs 10UW and 304D, the Wyoming mobiles and the field sites at Chapel Ranch and Sidney, Nebraska.

July 22, 1976 14-37-52 MDT Max. dBZ 46.7

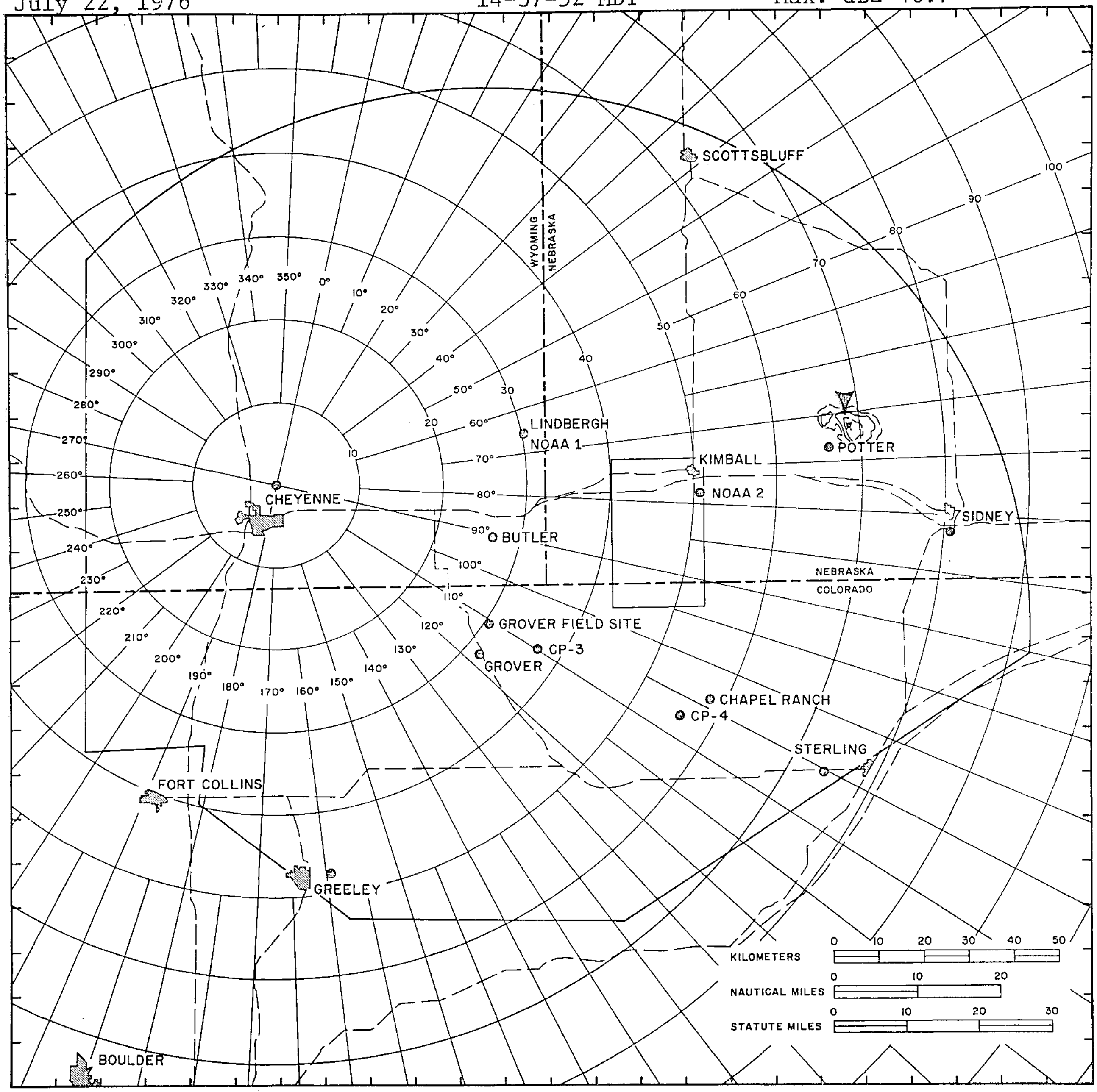


Figure 60.

July 22, 1976 16-32-17 MDT Max. dBZ 61.4

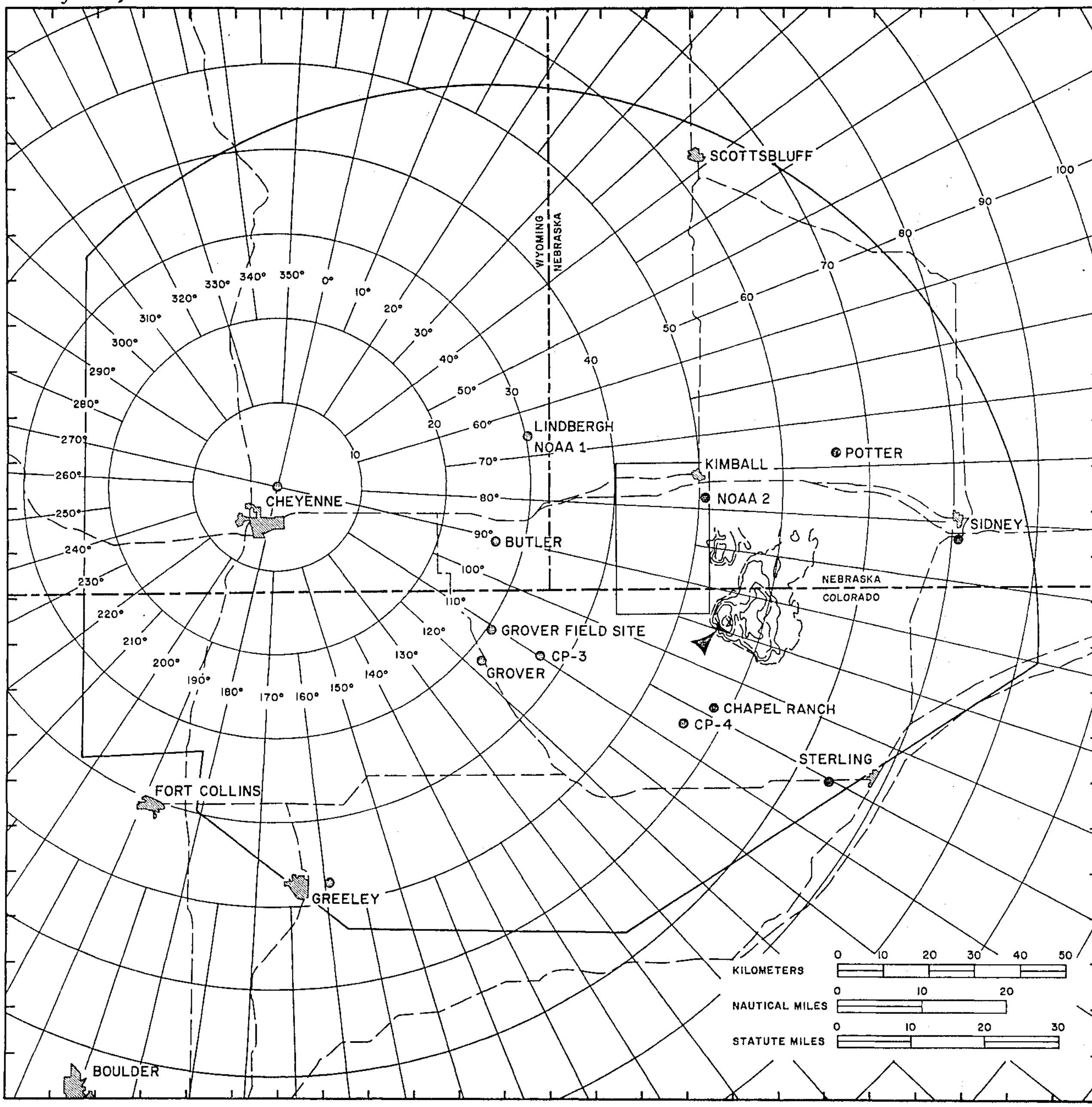
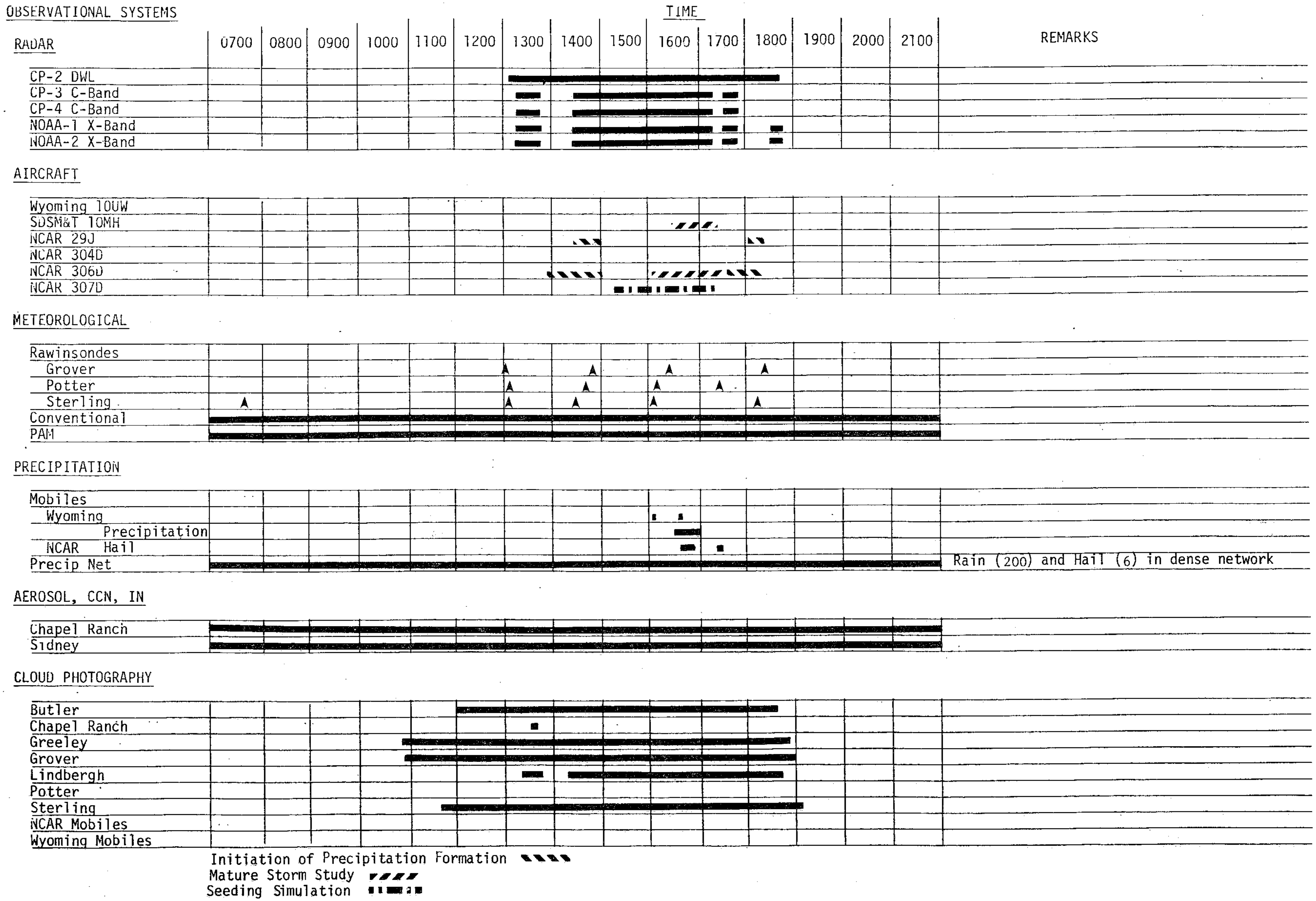


Figure 61.

Table 23.

OPERATIONS SUMMARY

July 22, 1976



July 23, 1976 15-43-29 MDT Max. dBZ 46.6

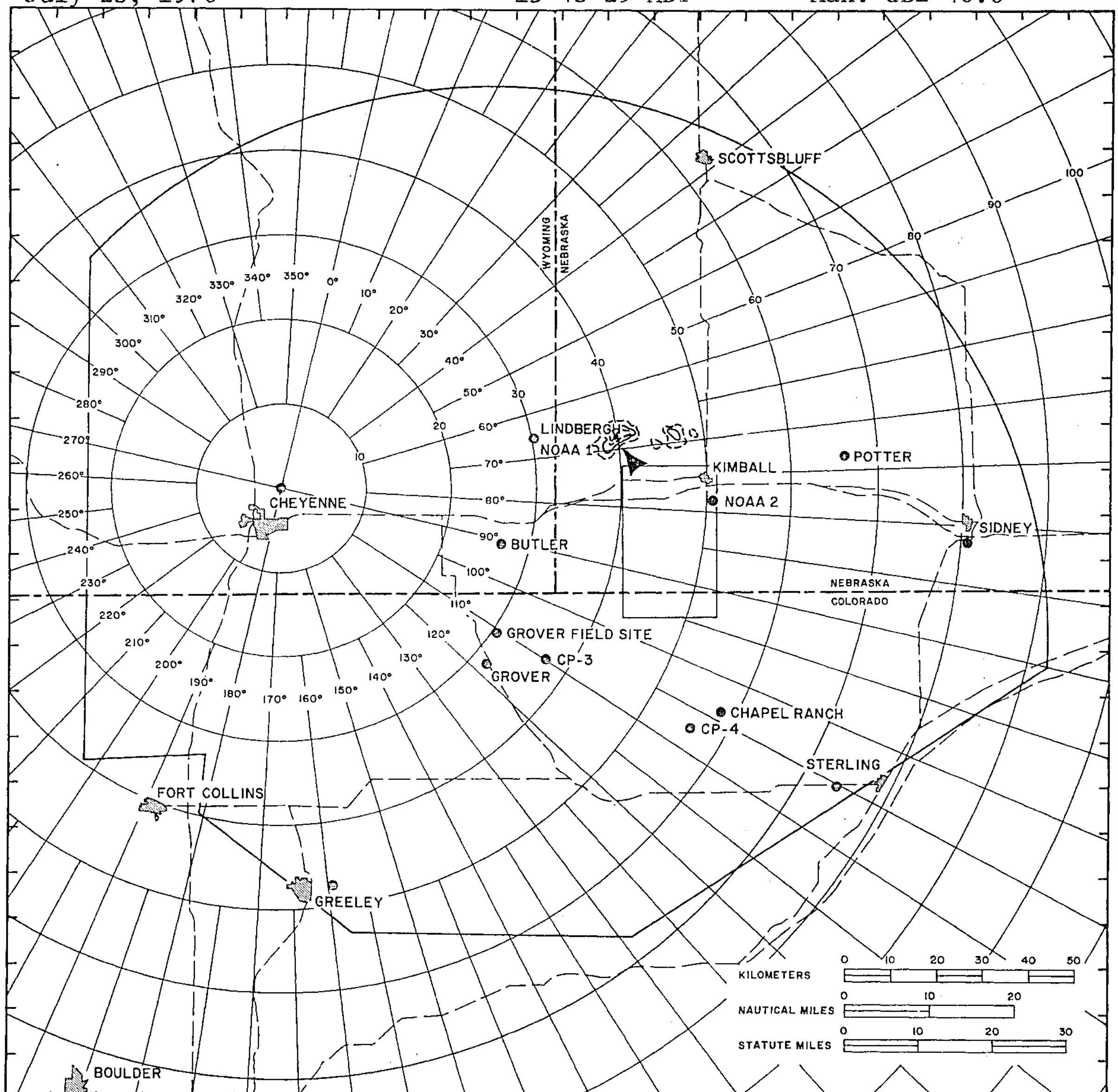


Figure 62.

Table 24.

OPERATIONS SUMMARY

July 23, 1976

OBSERVATIONAL SYSTEMS	0700	0800	0900	1000	1100	1200	1300	1400	1500	1600	1700	1800	1900	2000	2100	REMARKS
RADAR																
CP-2 DWL																
CP-3 C-Band																
CP-4 C-Band																
NOAA-1 X-Band																
NOAA-2 X-Band																
AIRCRAFT																
Wyoming 10UW																
SDSM&T 10MH																
NCAR 29J																
NCAR 304D																
NCAR 306D																
NCAR 307D																
METEOROLOGICAL																
Rawinsondes																
Grover																
Potter																
Sterling																
Conventional																
PAM																
PRECIPITATION																
Mobiles																
Wyoming																
NCAR																
Precip Net																Rain (17) and Hail (1) in dense network
AEROSOL, CCN, IN																
Chapel Ranch																
Sidney																
CLOUD PHOTOGRAPHY																
Butler																
Chapel Ranch																
Greeley																
Grover																
Lindbergh																
Potter																
Sterling																
NCAR Mobiles																
Wyoming Mobiles																

Initiation of Precipitation Formation

Seeding Simulation

July 25, 1976: The T-28 and Queen Airs 10UW, 304D and 306D conducted a coordinated research mission on the storm shown in Figure 63. Good conventional radar data and some Doppler data were collected on the storm. The Doppler data may be of poor quality because of the long range. Both hail and rain occurred in the dense precipitation network and several time-resolved hail samples were collected by the mobile sampling crews. Subsequently, an Initiation of Precipitation Formation Study was conducted on the cloud whose radar return is shown in Figure 64. There was no return at the start but during the course of the mission it developed into a fairly substantial rain shower. The sailplane ascended to about 25,000 feet while 10UW made repeated penetrations of the cloud at lower altitudes. Queen Airs 304D and 306D flew in the updraft and inflow regions. Doppler data were collected on this storm. Rain and hail occurred in the dense precipitation network and time-resolved hail samples were collected before and during the Mature Storm Study.

July 26, 1976: No significant activity occurred. No radar data were recorded and no aircraft missions were flown.

July 27, 1976: Three Initiation of Precipitation Formation Studies were conducted. Queen Airs 10UW and 304D combined on an unorganized storm in the vicinity of Sterling, Colorado. The sailplane and Queen Air 306D observed a cell about 30 km north of Grover (see Figure 65). This case is of interest since the investigations started early in the cloud's life cycle. The sailplane climbed to 7.5 km and then descended to 5.5 km in the cloud. The storm was close enough to Grover for good conventional radar data. Doppler coverage began late but there are data to support the later stages of the aircraft investigations. In the third case 10UW and 304D investigated new growth on the flanks of a larger storm from just prior to radar echo formation until it reached the moderately intense stage shown in Figure 66. Some light rain and hail occurred in the dense network. No time-resolved samples were collected.

July 25, 1976 18-04-16 MDT Max. dBZ 61.6

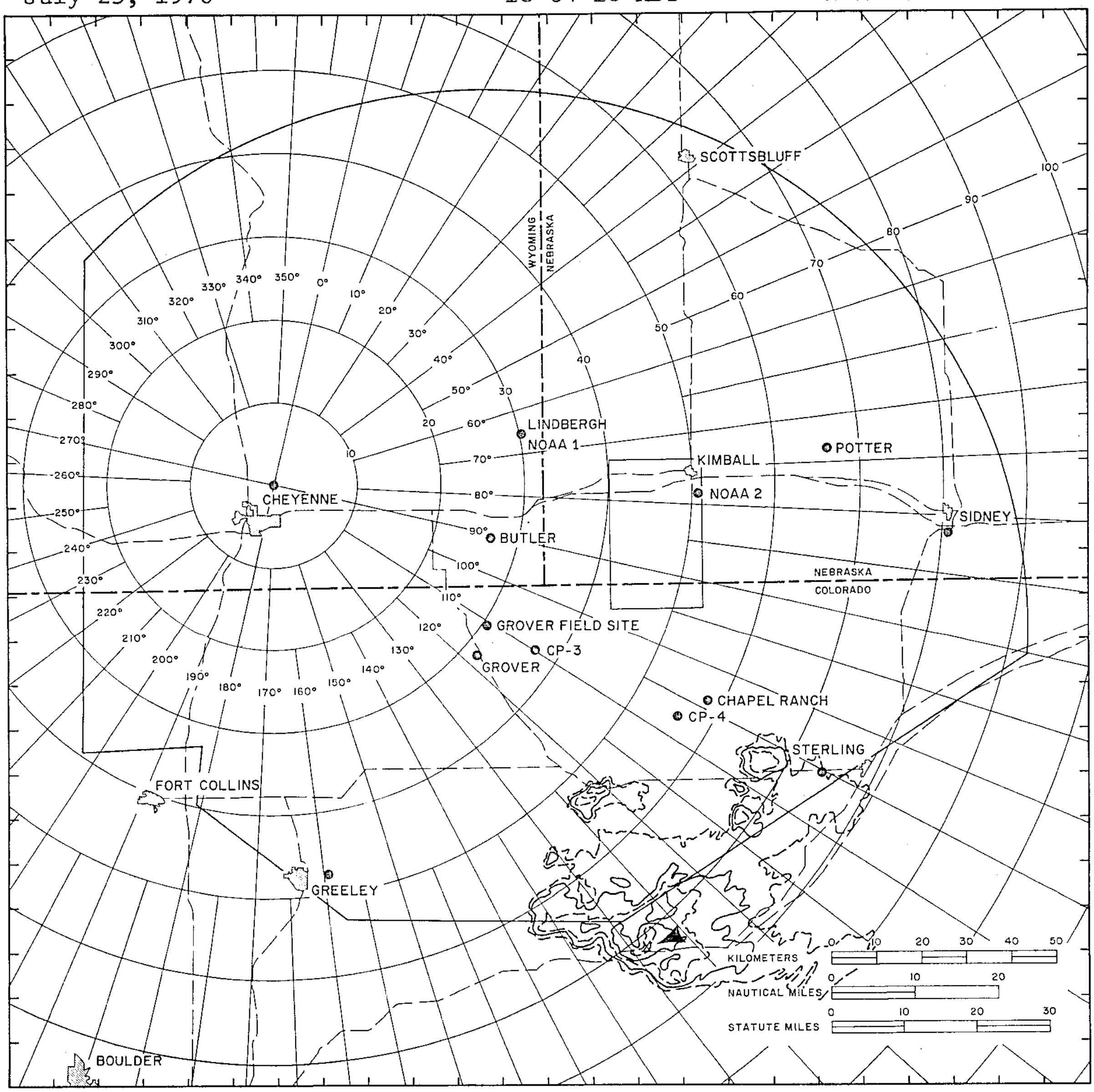


Figure 63.

July 25, 1976 19-19-22 MDT Max. dBZ 48.9

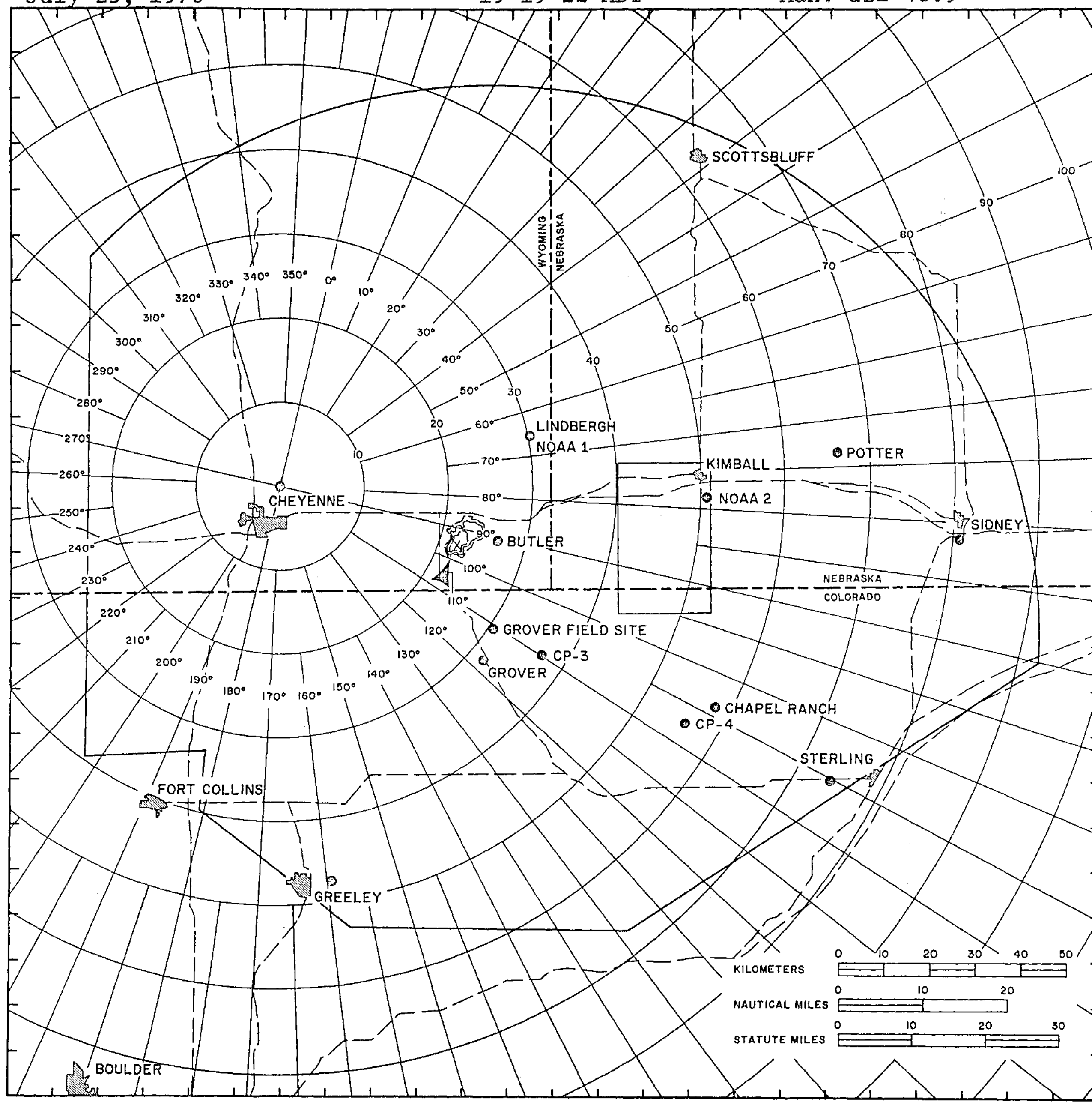


Figure 64.

Table 25.

OPERATIONS SUMMARY

July 25, 1976

OBSERVATIONAL SYSTEMS	0700	0800	0900	1000	1100	1200	1300	1400	1500	1600	1700	1800	1900	2000	2100	REMARKS
RADAR																
CP-2 DWL																CP-2 continued until 0225 MDT
CP-3 C-Band																
CP-4 C-Band																
NOAA-1 X-Band																
NOAA-2 X-Band																
AIRCRAFT																
Wyoming 10UW																
SDSM&T 10MH																
NCAR 29J																
NCAR 304D																
NCAR 306D																
NCAR 307D																
METEOROLOGICAL																
Rawinsondes																
Grover																
Potter																
Sterling																
Conventional																
PAM																
PRECIPITATION																
Mobiles																
Wyoming																
Precipitation																
NCAR Hail																
Precip Net																Rain (612) and Hail (84) in dense network
AEROSOL, CCN, IN																
Chapel Ranch																
Sidney																
CLOUD PHOTOGRAPHY																
Butler																
Chapel Ranch																
Greeley																
Grover																
Lindbergh																
Potter																
Sterling																
NCAR Mobiles																
Wyoming Mobiles																

Mature Storm Study

Initiation of Precipitation Formation

Seeding Simulation

July 27, 1976 16-59-50 MDT Max. dBZ 40.6

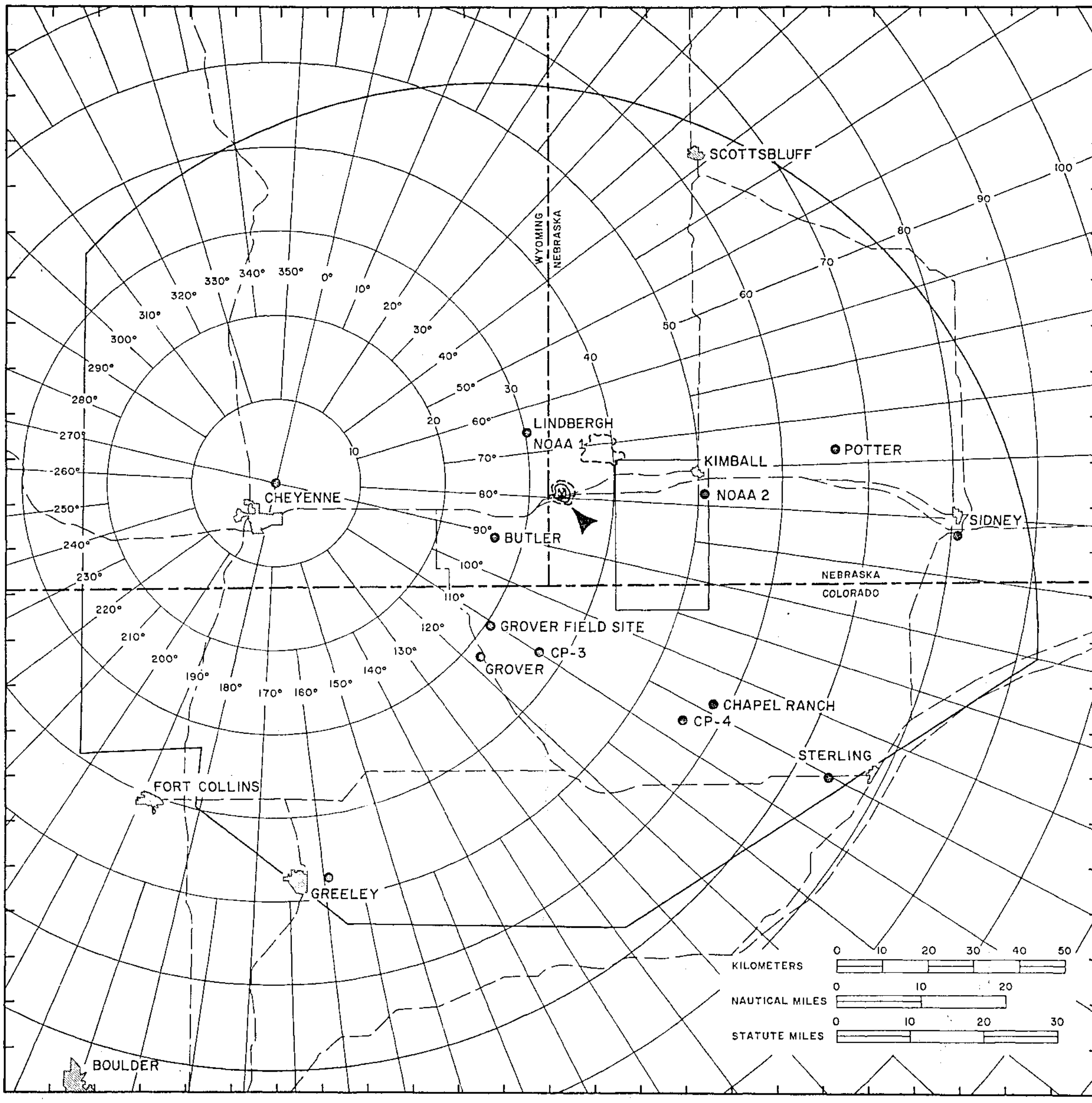


Figure 65.

July 27, 1976 17-48-24 MDT Max. dBZ 52.7

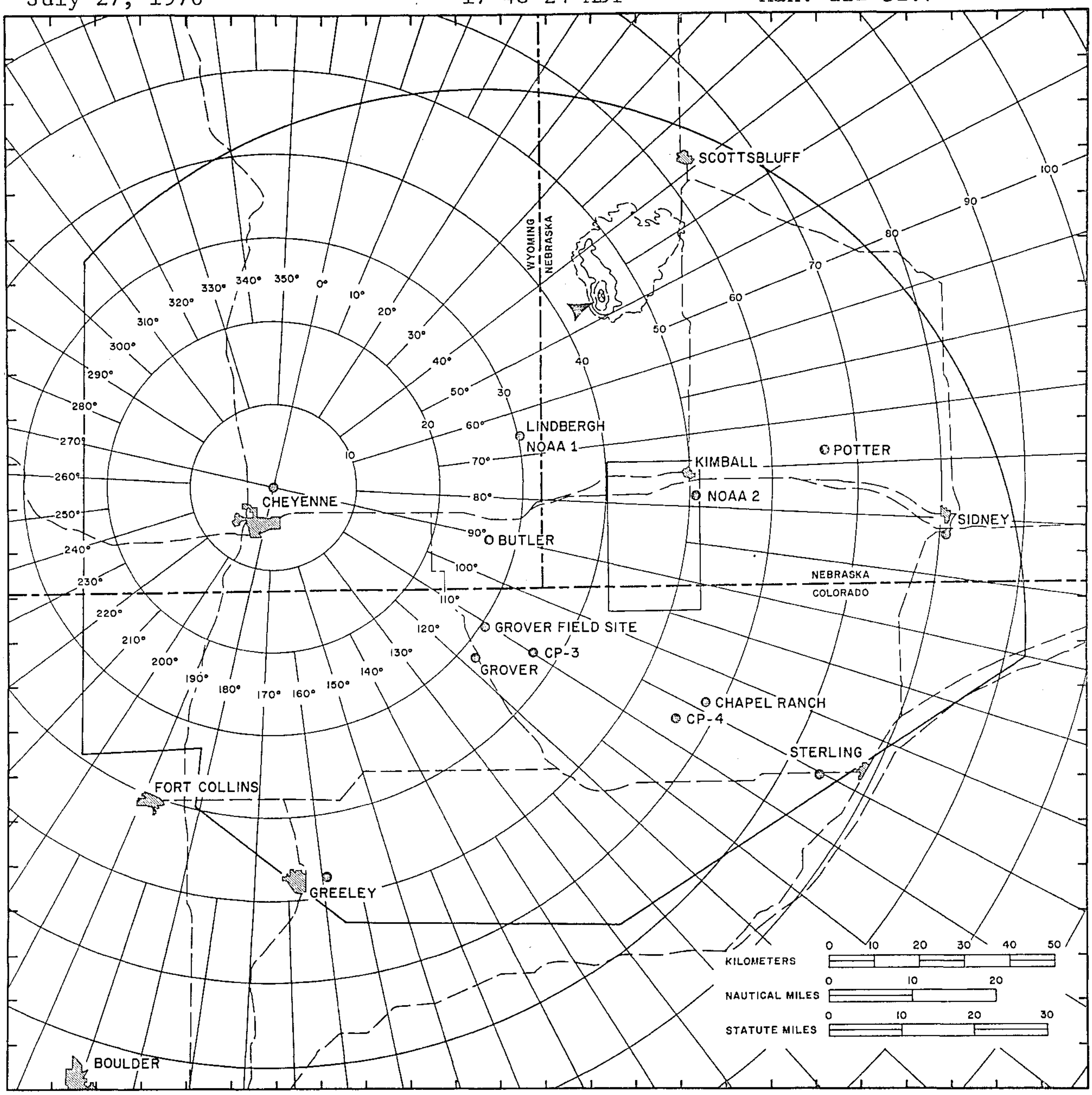
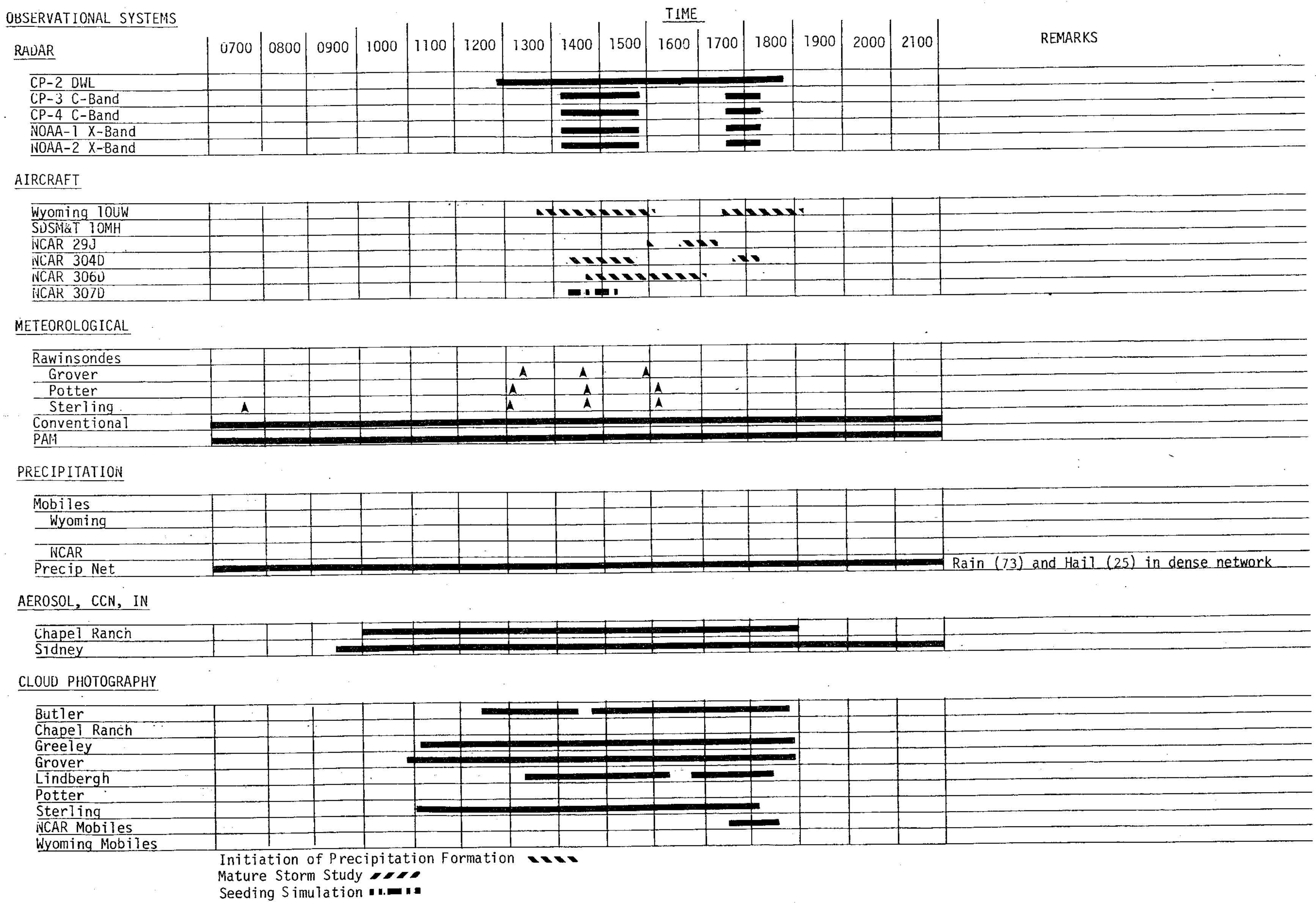


Figure 66.

Table 26.

OPERATIONS SUMMARY

July 27, 1976



July 28, 1976: No significant activity occurred. No radar data were collected and no aircraft missions were flown.

July 29, 1976: No significant activity occurred. Two aircraft missions were flown, one with Queen Air 304D for nuclei sampling and the second with Queen Air 306D to map a sharp moisture gradient to the east.

July 30, 1976: The T-28 and the three Queen Airs, 10UW, 304D and 306D, observed the storm shown in Figure 67. The storm was in a good location to be observed by the Doppler radars. The T-28 made three penetrations. The mobile sampling teams collected time-resolved precipitation samples, but no hail. Small hail was observed at 15 sites in the dense precipitation network.

July 31, 1976: The sailplane and Queen Air 10UW were called for an Initiation of Precipitation Formation Study but no suitable cloud occurred in the operating area. All activity was located west of the operating area as is shown in Figure 68. The day was called off at 1910 MDT thus ending the 1976 field season.

July 30, 1976 17-46-21 MDT Max. dBZ 50.7

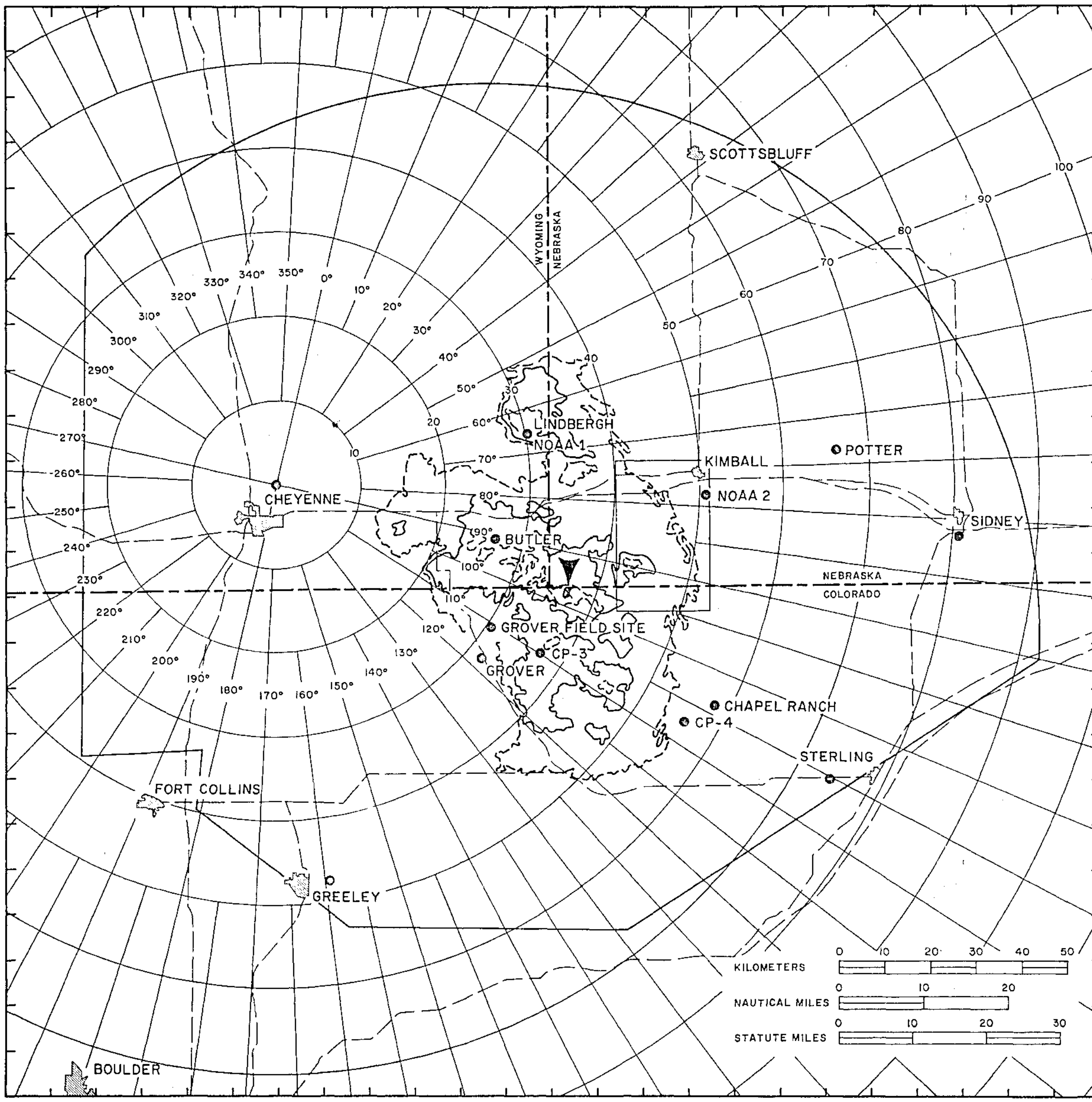


Figure 67.

Table 27.

OPERATIONS SUMMARY
July 30, 1976

OBSERVATIONAL SYSTEMS	0700	0800	0900	1000	1100	1200	1300	1400	1500	1600	1700	1800	1900	2000	2100	REMARKS
RADAR																
CP-2 DWL																
CP-3 C-Band																
CP-4 C-Band																
NOAA-1 X-Band																
NOAA-2 X-Band																
AIRCRAFT																
Wyoming 10UW																
SDSM&T 10MH																
NCAR 29J																
NCAR 304D																
NCAR 306D																
NCAR 307D																
METEOROLOGICAL																
Rawinsondes																
Grover																
Potter																
Sterling																
Conventional																
PAM																
PRECIPITATION																
Mobiles																
Wyoming Precipitation																
NCAR																
Precip Net																Rain (583) and Hail (15) in dense network
AEROSOL, CCN, IN																
Chapel Ranch																
Sidney																
CLOUD PHOTOGRAPHY																
Butler																
Chapel Ranch																
Greeley																
Grover																
Lindbergh																
Potter																
Sterling																
NCAR Mobiles																
Wyoming Mobiles																

Mature Storm Study

July 31, 1976 18-29-56 MDT Max. dBZ 64.1

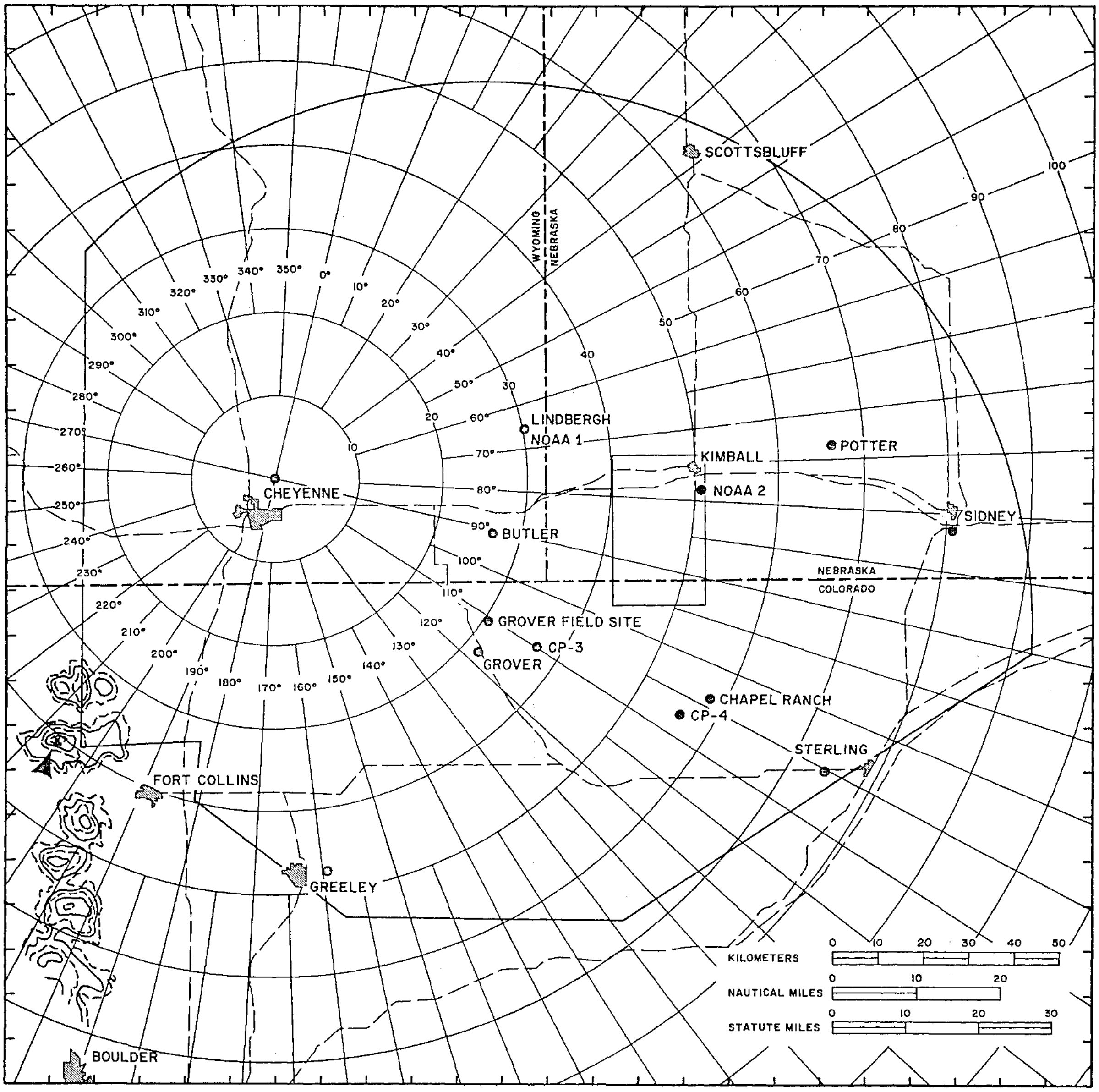


Figure 68.

Table 28.

OPERATIONS SUMMARY

July 31, 1976

OBSERVATIONAL SYSTEMS	TIME															
RADAR	0700	0800	0900	1000	1100	1200	1300	1400	1500	1600	1700	1800	1900	2000	2100	REMARKS
CP-2 DWL																
CP-3 C-Band																
CP-4 C-Band																
NOAA-1 X-Band																
NOAA-2 X-Band																
AIRCRAFT																
Wyoming 10UW																
SDSM&T 10MH																
NCAR 29J																
NCAR 304D																
NCAR 306D																
NCAR 307D																
METEOROLOGICAL																
Rawinsondes																
Grover																
Potter																
Sterling																
Conventional																
PAM																
PRECIPITATION																
Mobiles																
Wyoming																
NCAR																
Precip Net																
AEROSOL, CCN, IN																
Chapel Ranch																
Sidney																
CLOUD PHOTOGRAPHY																
Butler																
Chapel Ranch																
Greeley																
Grover																
Lindbergh																
Potter																
Sterling																
NCAR Mobiles																
Wyoming Mobiles																

Initiation Precipitation Formation

V. DATA QUALITY

In this section a preliminary assessment is made of the quality of the observations collected during the summer field program. Summaries are presented for each aircraft, the Grover research radar (CP-2), the Doppler radars, the rawinsonde network, the mesometeorological network, time-lapse cloud photography, the mobile precipitation sampling teams, and the aerosol sites. As appropriate the type of observations are noted along with the period or the time. Except as noted, usable data is generally available for the time or periods presented in this section. Any known difficulties affecting the quality of the data are noted.

In addition to the above, the NOAA Wave Propagation Laboratory conducted a series of mesometeorological studies to take advantage of the extensive observations being made in the NHRE. Of the NOAA systems only information on the X-band Doppler radars are included in this section. Also no information is included on the ESIG Hail Crop Damage network since the reading of the hailpads is not as yet complete. The third system not included is the tethered balloon system operated by the Oregon State University. The balloon and the instrument package were lost early in the planned observational period and as a consequence, very little data were collected.

Aircraft.

The aircraft summaries are presented in Tables 29 through 34. The information includes the date and the flight period, the type of mission, the scientific observer, and the observational instruments aboard each aircraft. Any known difficulties that affected the quality or availability of the data are also noted.

Table 29.

SUMMARY OF THE OBSERVATIONS AVAILABLE FROM

NCAR Queen Air (N304D)

1976 NHRE Field Season

MISSION LEGEND:

PF - Precipitation Formation Study
MS - Mature Storm Study
AC - Interaircraft Comparisons
(1),(2) - Miscellaneous Operations - Defined in Footnote

DATE	FLIGHT PERIOD	MISSION	SCIENTIST ON BOARD	Data Time Base	Aircraft Position	Ambient Pressure	Temperature	Dew Point	Horizontal Wind	Vertical Wind	Turbulence	Time Lapse Photography	Membrane Filters	NCAR Ice Nucleus Counter	Aitken Particle Counter	CCN Bag Samples					REMARKS
5/27/76																					Tower fly-by, Haswell, Colorado
6/2	1910-1950	(1)	Foote	*	*	*	*	*	*	*	*	*		x	x						*Recorded data contains numerous bad records
	2017-2026	AC		*	*	*	*	*	*	*	*										
6/4	1740-1820	MS	Fankhauser	x	x	x	x	x	x	x	x	x	x	x	x	x					
	2000-2025	(2)	Fankhauser	x	x	x	x	x	x	x	x	x	x	x	x						
6/7	1645-1740	MS	Fankhauser	x	x	x	x	x	x	x	x	x	x	x	x						
	1748-1757	AC		x	x	x	x	x	x	x	x										
6/8	1013-1048	(3)	Langer	x	x	x	x	x	x	x	x	x	x	x	x	x					
	1400-1530	PF	Fankhauser	x	x	x	x	x	x	x	x	x	x	x	x	x					CCN sample set at 1805
	1744-1754	AC		x	x	x	x	x	x	x	x										
6/9	1530-1700	PF	Foote	x	*	x	x	x	*	*	*	x	x	x	x	x					*INS problems 1603-1700
	1750-1840	PF	Foote	x	x	x	x	x	x	x	x	x	x	x	x	x					
	1850-1900	AC		x	x	x	x	x	x	x	x										
6/18	1430-1515	(4)	Langer	x	x	x	x	x	x	x	x	x									
6/21	1620-1745	PF	Fankhauser	x	x	x	x	x	x	x	x	x	x	x	x	x					
	1900-1945	MS	Fankhauser	x	*	x	x	x	*	*	*	x	x	x	x	x					*INS problems after 1905
6/22	0935-1030	(3)	Langer	x	x	x	x	x	x	x	x	x	x	x	x	x					
	1539-1540	AC		x	x	x	x	x	x	x	x										
	1545-1615	MS	Foote	x	*	x	x	x	*	*	x	x		x	x	* x					*Also CCN flight in a.m. *INS problems 1533-1642
	1720-1800	MS	Foote	x	x	x	x	x	x	x	x	x	x	x							
6/26	1645-1715	PF	Fankhauser	x	*	x	x	x	*	*	*	x	x	x	x	x					*INS problems after 1655
	1716-1718	AC		x	x	x	x	x	*	*	*										*INS problems after 1655
6/30	1440-1515	PF	Fankhauser	x	x	x	x	x	x	x	x	x	x	x	x						
	1532-1534	AC		x	x	x	x	x	x	x	x										
6/30	1810-1910	MS	Fankhauser	x	x	x	x	x	x	x	x	x	x	x	x	x					
	1914-1923	AC		x	x	x	x	x	x	x	x										

(1) Aerosol, nuclei and water vapor collections
(2) IN, impactor slides during ferry from SNY to BJC
(3) Aircraft and ground aerosol intercomparison
(4) CCN counter test flight

Table 29. continued

SUMMARY OF THE OBSERVATIONS AVAILABLE FROM

NCAR Queen Air (N304D)

1976 NHRE Field Season

MISSION LEGEND:
PF - Precipitation Formation Study
MS - Mature Storm Study
AC - Interaircraft Comparisons
(1),(2) - Miscellaneous Operations - Defined in Footnote

DATE	FLIGHT PERIOD	MISSION	SCIENTIST ON BOARD	Data Time Base	Aircraft Position	Ambient Pressure	Temperature	Dew Point	Horizontal Wind	Vertical Wind	Turbulence	Time Lapse Photography	Membrane Filters	NCAR Ice Nucleus Counter	Aitken Particle Counter	CCN Bag Samples					REMARKS
7/1/76	1345-1500	MF	Foote/Dye	x	x	x	x	x	x	x	x	x	x	x	x						
7/2	1345-1415	(5)	Foote	x	x	x	x	x	x	x	x	x		x	x	x					
	1500-1545	PF	Foote	x	x	x	x	x	x	x	x	x	x		x	x					
	1625-1715	MS	Foote	x	x	x	x	x	x	x	x	x	x	x	x	x					
	1726-1731	AC	Foote	x	x	x	x	x	x	x	x										
	1800-1910	PF	Fankhauser	x	x	x	x	x	x	x	x	x	x	x	x	x					
	1922-1934	AC		x	x	x	x	x	x	x	x										
7/6	2000-2035	MS	Fankhauser	x	x	x	x	x	x	x	x	x	x	x	x						
7/7	1720-1745	MS	Fankhauser	x	x	x	x	x	x	x	x	x	x	x	x	x					
	1807-1816	AC		x	x	x	x	x	x	x	x										
7/14	1435-1615	MS	Foote	x	x	x	x	x	x	x	x	x	x	x	x	x					
	1616-1620	AC		x	x	x	x	x	x	x	x										
	1746-1754	AC		x	x	x	x	x	x	x	x										
7/17	1710-1800	(7)	Fankhauser	x	x	x	x	x	x	x	x	x	x	x	x	x					
	1904-1906	AC		x	x	x	x	x	x	x	x										
7/18	1600-1755	MS	Fankhuaser	x	x	x	x	x	x	x	x	x	x	x	x	x					
	1759-1801	AC		x	x	x	x	x	x	x	x										
7/20	0630-0644	AC		x	x	x	x	x	x	x	x										
	0734-0742	AC		x	x	x	x	x	x	x	x										Tower flyby, Grover Colorado
	1710-1750	MS	Fankhauser	x	x	x	x	x	x	x	x	x	x	x	x						
	1758-1807	AC		x	x	x	x	x	x	x	x										
7/21	1650-1810	MS	Fankhauser	x	x	x	x	x	x	x	x	x	x	x	x	x					
	1817-1825	AC		x	x	x	x	x	x	x	x										
7/24	1545-1705	(8)	Fankhauser	x	x	x	x	x	x	x	x	x	x	x	x						
7/25	1745-1835	MS	Fankhauser	x	x	x	x	x	x	x	x	x	x	x	x						
	1855-1903	AC		x	x	x	x	x	x	x	x										

(5) Filter samples, counters during ferry from BJC to SNY
(6) Aerosol, nucleus and deuterium sampling
(7) Aerosol and nuclei vertical profile sampling

Table 30.

SUMMARY OF THE OBSERVATIONS
AVAILABLE FROM

NCAR Queen Air (N306D)

1976 NHRE Field Season

MISSION LEGEND:
PF - Precipitation Formation Study
MS - Mature Storm Study
AC - Interaircraft Comparisons
(1),(2) - Miscellaneous Operations - Defined in Footnote

DATE	FLIGHT PERIOD	MISSION	SCIENTIST ON BOARD	Data Time Base	Aircraft Position	Ambient Pressure	Temperature	Dewpoint	Horizontal Wind	Vertical Wind	Time Lapse Photography	Membrane Filters	Impactor Slides	Aitken Particle Counter	CCN Bag Samples	Cyclone Aerosols					REMARKS
5/27/76																					Tower flyby, Haswell, Colorado
6/1/76	1734-1845	MS	Fankhauser	x	x	x	x	x	x			x	x	x		x					
6/2	1852-1944	MS	Fankhauser	x	x	x	x	x	x			x	x	x		x					
	2017-2026	AC																			
6/4	1720-1930	MS	Dye	x	x	x	x	x	x			x	x	x		x					
6/8	1601-1739	MS	Kelly	x	x	x	x	x	x	(a)	x	x	x	x		x					(a) Vertical wind will be computed using aircraft platform as a vertical motion sensor.
	1744-1754	AC																			
6/21	1821-1946	MS	Kelly	x	x	x	x	x	x		x	x	x	x		x					
6/22	1539-1540	AC																			
	1544-1712	MS	Fankhauser	x	x	x	x	x	x			x	x	x		x					
	1717-1721	AC																			
6/30	1830-1910	MS	Kelly	x	x	x	x	x	x			x	x	x		x					
	1914-1923	AC																			
7/1/76	1517-1555	MS	Kelly	x	x	x	x	x	x			x	x	x		x					
7/2	1629-1714	MS	Kelly	x	x	x	x	x	x		x	x	x	x		x					
	1726-1731	AC																			
7/7	1702-1753	MS	Kelly	x	x	x	x	x	x		x	x	x	x		x					
	1807-1816	AC																			
7/14	1445-1608	MS	Fankhauser	x	x	x	x	x	x			x	x	x	x	x					
	1746-1754	AC		x	x	x	x	x	x												
	1805-1815	(1)	Fankhauser	x	x	x	x	x	x												
	1832-1834	AC		x	x	x	x	x	x												
7/17	1730-1905	MS	Foote	x	x	x	x	x	x			x	x	x		x					
	1833-1835	AC		x	x	x	x	x	x												
7/18	1647-1756	MS	Kelly	x	x	x	x	x	x		x	x	x	x		x					

(1) Anomalous propagation mission

Table 30. continued

SUMMARY OF THE OBSERVATIONS AVAILABLE FROM

NCAR Queen Air (N306D)

1976 NHRE Field Season

MISSION LEGEND:

- PF - Precipitation Formation Study
- MS - Mature Storm Study
- AC - Interaircraft Comparisons
- (1),(2) - Miscellaneous Operations - Defined in Footnote

DATE	FLIGHT PERIOD	MISSION	SCIENTIST ON BOARD	Data Time Base	Aircraft Position	Ambient Pressure	Temperature	Dewpoint	Horizontal Wind	Vertical Wind	Time Lapse Photography	Membrane Filters	Impactor Slides	Aitken Particle Counter	CCN Bag Samples	Cyclone Aerosols					REMARKS
7/18	1759-1801	AC		x	x	x	x	x	x	(a)											(a) Vertical wind will be computed using aircraft platform as a vertical motion sensor.
7/8	1824-1833	AC		x	x	x	x	x	x												
7/20	0636-0644	AC		x	x	x	x	x	x												Tower flyby, Grover, Colorado
	0734-0742	AC		x	x	x	x	x	x												
	1644-1753	MS	Kelly	x	x	x	x	x	x		x	x	x	x	x	x					
	1758-1807	AC		x	x	x	x	x	x												
7/21	1635-1806	MS	Kelly	x	x	x	x	x	x		x	x	x	x	x	x					
	1817-1825	AC		x	x	x	x	x	x												
7/22	1350-1502	PF	Kelly	x	x	x	x	x	x		x	x	x	x	x	x					
	1605-1730	MS	Kelly	x	x	x	x	x	x		x	x	x	x		x					
	1735-1820	PF	Kelly	x	x	x	x	x	x		x	x	x	x	x	x					
7/23	1542-1748	PF	Kelly	x	x	x	x	x	x		x	x	x	x		x					
	1757-1759	AC		x	x	x	x	x	x												
7/25	1743-1836	MS	Kelly	x	x	x	x	x	x		x	x	x	x		x					
	1855-1902	AC		x	x	x	x	x	x												
	1907-1948	PF	Kelly	x	x	x	x	x	x		x	x	x	x	x	x					
7/27	1440-1704	PF	Kelly	x	x	x	x	x	x		x	x	x	x		x					
	1722-1724	AC																			
7/29	1430-1630	(2)	Kelly	*	*	*	*	*	*												*Recorder failure
7/30	1704-1712	AC																			
	1718-1904	MS	Kelly	x	x	x	x	x	x		x	x	x	x	x	x					

(2) Dewpoint mapping mission

Table 31.

SUMMARY OF THE OBSERVATIONS AVAILABLE FROM

NCAR Sabreliner (N307D)

1976 NHRE Field Season

MISSION LEGEND:

PF - Precipitation Formation Study
MS - Mature Storm Study
AC - Interaircraft Comparisons
(1),(2) - Miscellaneous Operations - Defined in Footnote

DATE	FLIGHT PERIOD	MISSION	SCIENTIST ON BOARD	Data Time Base	Aircraft Position	Ambient Pressure	Temperature	"Seeding" Passes Performed	35 mm Cloud Photographs Available	Time Lapse Photography	REMARKS
6/4/76	1956-2055	(1)	Biter	x	x(a)	x	x	No			(a)Aircraft position also available for all "seeding" events.
6/21	1904-2014			x	x	x	x	No	20	x	
6/22	1510-1650			x	x	x	x	Yes	16	*	*Approximately 20 minutes of film is usable.
6/30	1352-1531			x	x	x	x	Yes		*	*Camera jammed
7/1	1442-1607			x	x	x	x	Yes	12	x	
7/2	1348-1448			x	x	x	x	No		x	
7/6	1556-1730			x	x	x	x	Yes	29	x	
	1916-2010			x	x	x	x	No	10	x	
7/7	1552-1658			x	x	x	x	No	7	x	
7/14	1422-1620			x	x	x	x	Yes	40	x	
7/18	1546-1710			x	x	x	x	No	7	x	
7/20	1700-1744			x	x	x	x	No		x	
7/21	1603-1756			x	x	x	x	Yes	15	x	
7/22	1513-1718			x	x	x	x	Yes	20	x	
7/23	1526-1655			x	x	x	x	No	10	x	
7/25	1744-1848			x	x	x	x	Yes	10	x	
7/27	1415-1526			x	x	x	x	Yes	8	x	
7/30	1548-1726			x	x	x	x	Yes	11	x	

(1) All Sabreliner flights were for the purpose of determining the possibility of "on-top" seeding. Listed times are for the period of interest including take-off until the aircraft departed the research area.

Table 32.

SUMMARY OF THE OBSERVATIONS
AVAILABLE FROM

NOAA/NCAR Saiplane (9929J)

1976 NHRE Field Season

MISSION LEGEND:

PF - Precipitation Formation Study
MS - Mature Storm Study
AC - Interaircraft Comparisons
(1),(2) - Miscellaneous Operations - Defined in Footnote

DATE	FLIGHT PERIOD	MISSION	SCIENTIST ON BOARD	Date Time Base	Aircraft Position	Ambient Pressure	Temperature	Vertical Wind	Membrane Filters	Liquid Water Content	Ice Particle Sampling	Particle Camera	Forward Scattering Spectrometer Probe	Electric Field	REMARKS
6/21/76	1640-1750	PF	Toutenhoofd	x	x	x	x	x		x	x	x	x	x	
6/22	1520-1550	PF		x	x	x	x	x		x	x	x	x	x	
6/26	1650-1700	PF		x	x	x	x	x		x	x	x	x	x	
6/30	1440-1510	PF		x	x	x	x	x		x	x	x	x	x	
7/1	1310-1330	PF		x		x	x	x	x	x	x	x	x	x	
7/2	1520-1540	PF		x	x	x	x	x	x	x	x	x	x	x	
7/6	1735-1825	PF		x	x	x	x	x	x	x	x	x	x	x	
7/8	1440-1610	PF		x		x	x	x	x	x	x	x	x	x	
7/9	1340-1510	PF		x		x	x	x	x	x	x	x	x	x	
7/14	1420-1440	PF		x	x	x	x	x		x	x	x	x	x	
	1745-1754	AC													
7/22	1425-1500	PF		x	x	x	x	x		x	x	x	x	x	
	1805-1835	PF		x	x	x	x	x		x	x	x	x	x	
7/25	1855-1935	PF		x	x	x	x	x	x	x	x	x	x	x	
7/27	1600-1610	PF		x	x	x	x	x		x	x	x	x	x	
	1635-1720	PF		x	x	x	x	x		x	x	x	x	x	

Table 33.

SUMMARY OF THE OBSERVATIONS AVAILABLE FROM
Wyoming Queen Air (10UW)

1976 NHRE Field Season

MISSION LEGEND:

PF - Precipitation Formation Study
MS - Mature Storm Study
AC - Interaircraft Comparisons
(1),(2) - Miscellaneous Operations - Defined in Footnote

DATE	FLIGHT PERIOD	MISSION	SCIENTIST ON BOARD	Data Time Base	Aircraft Position	Ambient Pressure	Temperature	Dewpoint	Horizontal Wind	Vertical Wind	Turbulence	55 mm Cloud Photography	Membrane Filters	Impactor Slides (Dye's)	Aitken Particle Counter	Aerosol and CCN Bag Samples	Precip. Collections	J-W Liquid Water Content	Ice Particle Sampling Oil Hexan Slides	Soil Impactor	Cloud Gun Slides	Axially Scattering Spectrometer Probe	2-D Particle Spectrometer Probe	Electric Chart on Particles	R E M A R K S
6/1/76	1556-1731	PF	Vali, et al	x	x	x	x	x	x	x	x	x	x		x	x		x	x			x	x		
6/2	1816-1953	MS	Vali, et al	x	x	x	x	x	x	x	x	x		x	x		x	x				x	x	x	
6/3	1730-1823	(1)	Vali, et al	x	x	x	x	x	x	x	x				x			x				x	x	x	
6/4	0530-0730	(2)	Veal, et al	x	x	x	x	x	x	x	x				x			x				x	x		
	1647-1915	MS	Vali, et al	x	x	x	x	x	x	x	x	x		x	x	x	x	x		x	x	x	x	x	
	1955-2053	(3)	Vali, et al	x	x	x	x	x	x	x	x				x			x				x	x	x	
6/7	1619-1745	PF	Vali, et al	x	x	x	x	x	x	x	x	x		x	x	x	x	x	x		x	x	x	x	
	1748-1759	AC		x	x	x	x	x	x	x	x											x	x	x	
6/8	1415-1544	PF	Vali, et al	x	x	x	x	x	x	x	x	x	x	x	x		x	x	x		*	*	*	*	* Power failure, no data.
	1544-1619	PF	Vali, et al	*	*	*	*	*	*	*	*	x	*	*	*	*	x	*	*	*	x	x	x	x	
6/9	1544-1845	PF	Vali, et al	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x		x	x		
	1851-1859	AC		x	x	x	x	x	x	x	x											x	x		
6/10	1400-1510	(1)	Vali, et al	x	x	x	x	x	x	x	x	x			x			x			x	x	x	x	
	1657-1735	(3)	" "	x	x	x	x	x	x	x	x	x			x			x			x	x	x	x	
6/21	1547-1748	PF	Vali, et al	x	x	x	x	x	x	x	x	x	x	x	x			x	x						
	1900-2000	MS	" "	x	x	x	x	x	x	x	x	x	x	x	x	x		x	x			x	x	x	
	2003-2009	AC		x	x	x	x	x	x	x	x										x	x	x	x	
6/22	1442-1520	PF	Vali, et al	x	x	x	x	x	x	x	x	x	x		x			x	x	x		x	x	x	
	1520-1722	MS	" "	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x		x	x	x	x		
	1717-1721	AC	" "	x	x	x	x	x	x	x	x														
6/26	1559-1715	PF	" "	x	x	x	x	x	x	x	x	x	x		x			x	x			x	x		
	1716-1718	AC		x	x	x	x	x	x	x	x														
6/30	1410-1530	PF	Knight,Veal	x	x	x	x	x	x	x	x	x			x	x		x	x						
	1532-1534	AC		x	x	x	x	x	x	x	x														
	1840-1924	MS	Cooper	x	x	x	x	x	x	x	x				x			x							
	1914-1923	AC		x	x	x	x	x	x	x	x														

(1) Test flight
(2) Tower flyby
(3) Return to Laramie

Table 33. continued

SUMMARY OF THE OBSERVATIONS AVAILABLE FROM

Wyoming Queen Air (10UW)

1976 NHRE Field Season

MISSION LEGEND:

PF - Precipitation Formation Study
MS - Mature Storm Study
AC - Interaircraft Comparisons
(1),(2) - Miscellaneous Operations - Defined in Footnote

DATE	FLIGHT PERIOD	MISSION	SCIENTIST ON BOARD	Data Time Base	Aircraft Position	Ambient Pressure	Temperature	Dewpoint	Horizontal Wind	Vertical Wind	Turbulence	35mm Cloud Photography	Membrane Filters	Impactor Slides (Dye's)	Aitken Particle Counter	Aerosol & CCN Bag Samples	Precip. Collections	J-W. Liquid Water Content	Ice Particle Sampling/ Oil Hexan	Foil Impactor	Cloud Gun Slides	Axially Scattering Spectrometer Probe	2-D Particle Spectrometer Probe	Electric Chart on Particles	REMARKS
7/1/76	1219-1725	MS	Veal, et al	x	x	x	x	x	x	x	x	x			x	x	x	x	x		x	x	x		
7/2	1330-1413	PF	Bretherton,	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x		x	x	x		
			Veal																		x	x	x		
	1500-1720	MS	Vali	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x						
	1726-1732	AC		x	x	x	x	x	x	x	x										x	x	x	x	
7/3	1750-1920	PF	Vali, et al	x	x	x	x	x	x	x	x	x	x	x	x	x		x	x						
	1922-1932	AC		x	x	x	x	x	x	x	x										x	x	x	x	
7/7	1640-1805	MS	Firor, Veal	x	x	x	x	x	x	x	x	x	x		x	x		x	x						
	1807-1816	AC		x	x	x	x	x	x	x	x										x	x	x	x	
7/9	1356-1703	PF	Sand, et al	x	x	x	x	x	x	x	x	x	x			x		x	x		x	x	x	x	
7/14	1400-1620	PF	Sand, et al	x	x	x	x	x	x	x	x	x	x		x		x	x	x		x	x	x	x	
	1720-1830	MS	Sand, et al	x	x	x	x	x	x	x	x	x	x		x		x	x	x						
	1832-1834	AC	Sand, et al	x	x	x	x	x	x	x	x										x	x	x	x	
7/17	1640-1830	MS	Vali, et al	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x						
	1834-1836	AC		x	x	x	x	x	x	x	x														
	1904-1906	AC		x	x	x	x	x	x	x	x														
7/18	1505-1730	PF/MS	Vali, et al	x	x	x	x	x	x	x	x	x	x	x	x		x	x	x		x	x	x	x	
	1825-1834	AC		x	x	x	x	x	x	x	x														
7/20	0500-0719	(2)	Veal, et al	x	x	x	x	x	x	x	x				x			x				x	x		
7/23	1551-1755	PF	Foote, Veal	x	x	x	x	x	x	x	x	x		x	x			x	x		x	x	x		
	1758-1800	AC		x	x	x	x	x	x	x	x														
7/24	1511-1820	PF	Vali, et al	x	x	x	x	x	x	x	x	x	x		x	x		x	x			x	x		
	1910-2055	PF	Vali, et al	x	x	x	x	x	x	x	x	x	x		x			x	x			x	x	x	
7/25	1655-2019	MS/PF	Veal, et al	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x		x	x	x		
7/27	1340-1605	MS/PF	Veal, et al	x	x	x	x	x	x	x	x	x			x	x	x	x	x		x	x	x		
	1606-1613	AC		x	x	x	x	x	x	x															
	1722-1724	AC		x	x	x	x	x	x	x															

(2) Tower flyby

Table 33. continued

SUMMARY OF THE OBSERVATIONS AVAILABLE FROM

Wyoming Queen Air (10UW)

1976 NHRE Field Season

MISSION LEGEND:

PF - Precipitation Formation Study
MS - Mature Storm Study
AC - Interaircraft Comparisons
(1),(2) - Miscellaneous Operations - Defined in Footnote

DATE	FLIGHT PERIOD	MISSION	SCIENTIST ON BOARD	Data Time Base	Aircraft Potition	Ambient Pressure	Temperature	Dewpoint	Horizontal Wind	Vertical Wind	Turbulence	35 mm Cloud Photography	Membrane Filters	Impactor Slides (Dye's)	Aitken Particle Counter	Aerosol and CCN Bag Samples	Precip. Collections	J-W Liquid Water Content	Ice Particle Sampling/ Oil Hexane Slides	Cloud Gun Slides	Axially Scattering Spectrometer Probe	2-D Particle Spectrometer Probe	Electric Chart on Particles	REMARKS
7/27/76	1730-1923	PF	Veal, et al	x	x	x	x	x	x	x	x	x			x		x	x			x	x		
7/30	1704-1712	AC		x	x	x	x	x	x	x	x													
	1715-1918	MS	Cooper,et al	x	x	x	x	x	x	x	x	x	x	x	x		x	x	x	x	x	x		
	1945-2102	MS	Cooper,et al	x	x	x	x	x	x	x	x				x	x		x			x	x		
7/31	1700-1932	PF	Cooper,et al	x	x	x	x	x	x	x	x	x	x		x	x		x		x	x	x		
8/1	0730-1038	(4)	Veal, et al	x	x	x	x	x	x	x														

(4) Vertical motion calibration runs

Table 34.

SUMMARY OF THE OBSERVATIONS AVAILABLE FROM

SDSM&T T-28 (510MH)

1976 NHRE Field Season

MISSION LEGEND:
- PF - Precipitation Formation Study
- MS - Mature Storm Study
- AC - Interaircraft Comparisons
- (1),(2) - Miscellaneous Operations - Defined in Footnote

DATE	FLIGHT PERIOD	MISSION	SCIENTIST ON BOARD	Data Time Base	Aircraft Position	Ambient Pressure	Temperature	Calculated Vertical Wind	Calculated Turbulence	Cloud Photography	Foil Impactor	Particle Camera	Hail Spectrometer	Forward Scattering Spectrometer Probe	2-D Particle Spectrometer Probe	REMARKS
6/4/76	0540-0700	(1)	Killinger	*	x	x	x	x	x							*13 sec error
6/4	1738-1828	MS	Killinger	x	x(a)	x(a)	x	x	x	x	x	x		(b)	(b)	
6/8	1433-1544	PF	Killinger	x	(c)	(c)	(c)	(c)	(c)	x		x		x	x	
6/21	1816-1854	MS	Sand	x	x	x	x	x	x	x	x	x		x	x(d)	
6/22	1602-1657	MS	Killinger	x	x(a)	x	x	x	x	x	(b)		x	x(c)	x(d)	
6/30	1831-1850	MS	Killinger	x	(f)	(f)	(f)			x	x	(g)	(g)	(g)	(g)	
7/2/76	1656-1713	MS	Sand	x		x	x	x	x	x	x	x		x	x	Penetrations without M33 track
7/7	1715-1807	MS	Sand	x	x	x	x	x	x	x	x	x		x	x(h)	" " " "
7/14	1502-1535	MS	Killinger	x	x	x	x	x	x	x	x	x		x	x	
7/18	1710-1743	MS	Killinger	x	x	x	x	x	x	x	x		x	x	x	
7/20	0551-0631	(1)	Killinger	x	x	x	x	(i)	(i)	(i)						
	1709-1750	MS	Killinger	*	x	x	x	x	x	x	x			x	x	*Jumps in recorded time
7/21	1651-1732	MS	Killinger	x	x	x	x	x	x	x	x	x(j)		x	x	
7/22	1630-1723	MS	Killinger	x	x	x	x	x	x	x	x(k)	x	x	(g)x	(g)x	
7/25	1754-1834	MS	Killinger	x	x	x	x	x	x	x	x		x	x	x	
7/30	1743-1835	MS	Killinger	x	x	x	x	x	x	x	x	x		(g)x	(g)x	

(1) Tower flyby

(a) intermittent
(b) inoperative
(c) only data recorded is on Pertec tape
(d) bad images
(e) not correct
(f) problems with 9100 recorder
(g) Pertec recorder inoperative
(h) images too large
(i) lost voice recording at 0630
(j) frame count problems
(k) jammed with ice late in flight

Grover Research Radar.

The Grover research radar data summary is presented in Table 35 that follows. The table shows the date and period of operations for both DADS and MINA II. Notes in the remarks column show where the data recorded relates to other than meteorological phenomena such as calibration procedures and chaff tests. Also noted are those periods when radar data is not available because of difficulties such as power outages and tape recorder failures.

Table 35.

Summary of the CP-2 Radar Operations
During the 1976 NHRE Field Season

Date	Period: DADS	Period: MINA II	Remarks
May 20	1745 1830		Calibration
May 21		1631 1650	
May 25		1359 1457 1513 1648	
May 28		1721 1811	Chaff test
Jun 1	1358 1729	1348 1844	
Jun 2	1230 1935	1418 1729 1735 1755 1759 1930	Tape recorder problems
Jun 4	1631 2056 2114 2120	1600 1644 1711 2120	Power outage (alive 2056-2114) Tape recorder problems
Jun 6	1554 1813	1556 1821	
Jun 7	1424 1811	1426 1820	
Jun 8	1229 1918	1251 1918	
Jun 9	1359 1814	1402 1834	
Jun 10		1021 1047	Test tape
Jun 17	1421 1511	1308 1601	
Jun 21	1521 2020	1525 2010	
Jun 22	1323 1731	1225 1731	
Jun 26	1557 1734	1600 1715	
Jun 28	1312 1405	1314 1349	Chaff test
Jun 30	1315 1857	1321 1552 1712 1904	No weather
Jul 1	1141 1607	1141 1618	
Jul 2	1158 1810	941 1033 1159 1858	Calibration
Jul 3	1527 1805	1533 1821	
Jul 6	1527 2038	1529 1852 1902 2037	

Table 35. continued

Date	Period: DADS	Period: MINA II	Remarks
Jul 7	1330 1841	1331 1841	
Jul 8	1233 1657	1225 1628	
Jul 9	1222 1650	1217 1639	
Jul 14		1000 1138	Chaff test
	1246 1738	1242 1651 1702 1825	Tape recorder problems
Jul 16	1019 1055 1300 1501	1021 1052 1331 1655	Chaff test
Jul 17	1533 1839	1536 1843	
Jul 18	1337 1853	1353 1835	
Jul 20	1615 1853	1612 1842	
Jul 21	1505 1837	1512 1841	
Jul 22	1302 1848	1314 1851	
Jul 23	1316 1740	1327 1801	
Jul 24	1619 1712	1630 1706	Chaff test
Jul 25-26	1639 0229	1641 1658 1706 0230	Tape recorder problems
Jul 27	1255 1849	1304 1842	
Jul 28		1054 1129	X-band calibration
Jul 30	1451 2137	1451 1502 1712 2107	Tape recorder problems
Jul 31	1531 1902	1533 1901	

Doppler Radars.

A summary of the Doppler radar operations is set forth in Table 36. The information presented shows the time period and which of the four Doppler radars were operational on that particular day. The NCAR CP-4 was not operational until June 21, 1976, so that prior to that time, only tri-Doppler data are available. In addition, the volume or volumes scanned by the Doppler radars are also shown. These are given in a coordinate system centered at the Grover field site. The remarks section contains comments related to any difficulties experienced, the number of volume scans, and in some cases, the aircraft that observed that particular storm observed by the Doppler radars.

The only multiple-Doppler radar reduced is that being used in current, ongoing case studies. The quality of those remaining days is unknown.

Table 36.

Summary of Doppler Radar Operations During the 1976 NHRE Field Season

Date	Period	Operational Radars				Storm Positions Rel. to Grover			Remarks
		NOAA 1	NOAA 2	CP-3	CP-4	Azimuth Limits	Range Limits(km)	Time	
June 1	1613-1654	x	x	x		003-051	19-53	1613	Test setup
June 2	1906-1941	x	x	x		079-096	50-82	1914	
June 4	1626-1650			x					Cell near Greeley
	1650-2025	x	x	x		250-290 310-332	47-74 74-118	1650 1819	
June 7	1626-1827	x	x	x		064-084	78-110	1738	8-10 volume scans
June 8	1350-1511	x	x			270-324 246-008	35-80 5-52	1341 1506	
	1511-1819	x	x	x		242-030 034-258 134-186	11-56 3-42 22-43	1529 1654 1739	Same storm as above 15 vol scans with 3 radars
June 9	1605-1640	x	x	x		238-294	17-61	1558	
	1745-1837		x			084-096	107-131	1738	10UW and 304D worked storm
June 21	1615-1950	x	x		x	310-348 334-046 040-080 074-104	33-88 21-70 26-65 62-115	1607 1707 1757 1905	CP-4 operated but data irretrievable
June 22	1430-1810	x	x		x	032-094 000-110 028-102	6-30 13-75 8-70	1424 1456 1700	About 25 vol.scans
June 30	1348-1500			x		278-316	63-96	1336	Cell vicinity Laramie
	1510-1545		x	x	x	236-282	33-87	1532	Same cell as above
	1724-1904	x	x	x	x	004-154 352-172 114-162	2-44 6-48 15-47	1714 1750 1835	Cell dev. on gust front in quadrilateral
July 1	1319-1344	x	x	x	x	016-056	46-100	1310	5 vol. scans with 4 radars

Table 36. continued

Date	Period	Operational Radars: NOAA 1	NOAA 2	CP-3	CP-4	Storm Positions Rel. to Grover: Azimuth Limits	Range Limits (km)	Time	Remarks
	1354-1458	x	x	x	x	040-192 096-158	9-43 22-68	1350 1430	Some power problems with CP-3, CP-4. 10 vol. scans with 3 or more radars.
	1501-1530	x	x	x	x	156-230	16-75	1456	6 vol. scans with 3 or more radars.
	1538-1553	x	x	x	x	144-180	47-99	1527	
July 2	1513-1544	x	x	x	x	034-066	39-90	1502	5 vol. scans with at least 3 radars. Power problems at CP-3, NOAA 2.
	1622-1707	x	x		x	060-250	2-64	1613	
	1707-1730	x	x	x	x	030-090	12-48	1658	
July 3	1745-1833		x		x				Storm NE to E of Sidney.
July 6	1755-1815		x	x		356-024	33-60	1748	Power problems with NOAA 1.
	1817-1912	x	x	x	x	002-050	9-25	1810	Power bumps
	1912-2018	x	x	x	x	328-098	0-52	1912	Power surges and bumps
July 7	1605-1744	x	x	x	x	010-116 052-104	1-56 26-84	1553 1656	10UW, 304D and T-28 worked storm
July 8	1610-1622	x	x		x	118-160	15-38	1603	Sail plane worked cell.
July 9	1355-1405	x	x		x	322-002	15-34	1334	10UW and sailplane worked cell
	1428-1501	x	x		x	012-054	21-49	1436	
July 14	1323-1349	x	x	x	x	074-100	25-52	1314	
	1400-1410	x	x	x	x	052-078	70-121	1353	
	1421-1436	x	x	x	x	070-094	41-75	1418	Sailplane worked cell

Table 36. continued

Date	Period	Operational Radars NOAA 1	NOAA 2	CP-3	CP-4	Storm Positions Rel. to Grover Azimuth Limits	Range Limits(km)	Time	Remarks
	1455-1633	x	x	x	x	070-096	82-131	1603	Same as 2nd storm. T-28 worked this storm.
July 17	1646-1836	x	x	x	x	154-298 114-248	14-63 8-46	1640 1800	19 vol. scans. Chaff drop at 1811.
July 18	1527-1608	x	x	x	x	314-024	20-71	1546	10UW worked storm.
	1627-1716	x	x	x	x	054-180	18-39	1649	
	1722-1824	x	x	x	x	118-196	20-63	1716	All Q/A's and T-28 worked storm.
July 20	1718-1817	x	x	x	x	256-074	9-43	1719	Broad area of showers
July 21	1555-1729	x	x	x	x	064-126	20-71	1640	
	1734-1757	x	x	x	x	026-108	4-55	1741	
July 22	1320-1345	x	x	x	x	170-236	8-45	1313	5 vol. scans.
	1427-1541	x	x	x	x	052-128 080-208	4-39 8-41	1422 1526	13 vol. scans. Towplane cut chaff at 19 kft.
	1551-1720	x	x	x	x	068-108	34-71	1645	14 vol. scans.
	1737-1752	x	x	x	x	020-060	11-37	1729	
	1831-1844	x	x			306-340	12-33	1824	Sailplane worked cell
July 23	1534-1544	x	x	x	x	024-054	39-70	1529	No aircraft
July 24	1630-1647			x	x	070-088	26-40	1619	
July 25	1720-1738 1812-1832	x	x	x	x	114-117 124-182	30-81 52-102	1713 1806	CP-4 operational but irretrievable. T-28 worked the storm.
	1859-1959	x	x	x	x	318-010	18-41	1854	As above.
July 27	1403-1532	x	x	x	x	096-178 088-136	8-48 43-96	1356 1450	Cell worked by sailplane and 10UW.
	1532-1547	x	x	x	x	072-162	17-46	1526	

Table 36. continued

Date	Period	Operational Radars: NOAA 1	NOAA 2	CP-3	CP-4	Storm Positions Rel. to Grover: Azimuth Limits	Range Limits (km)	Time	Remarks
	1739-1826	x	x	x	x	000-032	65-105	1730	Cell worked by 304D, 10UW
July 30	1625-1902	x	x	x	x	226-300 000-360 056-160	23-64 0-44 11-58	1619 1725 1759	NOAA 1 down after 1837 due to lightning.

DRI M33 Radar.

The DRI M33 radar was operated continuously throughout the field season. Two purposes were served by this system. The first was to maintain a 24-hour surveillance of the operating area and the second was to track the penetrating aircraft. Time-lapse scope photography was used to record S-band reflectivities. Tracking data are available from DADS. A tabulation of this data is not presented in this section.

Rawinsonde Observations.

The summary of the 1976 rawinsonde observations, see Table 37, shows the date, station and the time of release of each sounding. Those soundings which contain questionable, missing, doubtful, or corrected data are identified. It should also be noted that the format used in presenting the rawinsonde data is similar to previous years. One change is the addition of a plot of the sonde elevation angles below 20° versus time. This is to serve as a caution to the user of wind data computed from low elevation angles.

Table 37.

Summary of 1976 NHRE Rawinsonde Observations

Period of Operation: 24 May through 31 July 1976

Station	Location	Equipment
Sterling (STK)	½ mile east of Sterling Airport, Sterling, Colorado	RD65A
Grover (GRO)	NHRE Field Hdqs., 3½ miles N of Grover, Colorado	RD65A
Potter (POT)	6 miles N of Potter, Nebraska	GMD-1

Codes for questionable, missing, doubtful or corrected data:

A - Winds doubtful due to tracking difficulties.
B - Winds missing.
C - Humidity baseline questionable - trace usually appears high.
D - Temp baseline corrected 5C - also affects humidity baseline.
E - Temp questionable - usually surface.
F - Humidity questionable - usually surface.

Date	Station	Release Time (MDT)	Flag
5/24	STK	0748	
5/25	STK	0735	
	STK	1310	
	STK	1555	
5/26	STK	0735	
	GRO	1401	
	POT	1420	
	STK	1627	
5/27	STK	0740	
	STK	1310	
	POT	1450	
	STK	1629	
5/28	STK	0838	
	STK	1310	A (above 600 mb)
	STK	1628	A (below 745 mb)
5/29	STK	0741	
	STK	1306	
	STK	1611	
5/30	STK	0825	
	STK	1309	
	STK	1611	
5/31	STK	0815	
	STK	1310	
	STK	1605	
6/01	STK	0735	
	STK	1304	
	STK	1600	
6/02	STK	0735	
	STK	1314	
	GRO	1315	
	POT	1345	C
	GRO	1450	
	POT	1525	
	STK	1605	
	STK	1923	

Table 37. continued

Date	Station	Release Time (MDT)	Flag
6/03	STK	0735	
	GRO	1340	A (below 700 mb)
	GRO	1702	
	STK	1709	
6/04	STK	0752	
	GRO	1351	
	STK	1553	
	GRO	1719	
	STK	1736	
	POT	1850	
	STK	1857	
	GRO	1922	
	POT	2020	
	STK	2020	
6/05	STK	0740	
	STK	1255	
	STK	1600	
6/06	STK	0740	
	STK	1310	
	STK	1605	
	POT	1652	
	GRO	1706	
6/07	STK	0735	
	STK	1305	
	GRO	1443	
	POT	1600	C
	STK	1610	
	POT	1738	C
	STK	1743	
6/08	STK	0735	
	STK	1258	
	GRO	1410	
	POT	1530	C
	GRO	1531	
	STK	1540	
	GRO	1727	
	POT	1730	C
	STK	1730	
6/09	STK	0745	
	STK	1301	
	POT	1600	C
	GRO	1603	
	STK	1603	
	POT	1756	C
	STK	1815	
6/10	STK	0739	
	STK	1305	
6/11	STK	0740	
	STK	1306	F
	STK	1610	F
6/12	STK	0735	
	STK	1302	
	STK	1605	
6/13	STK	0735	
	STK	1315	E,F
	STK	1606	F
6/14	STK	0750	
6/15	STK	1620	
6/16	STK	1610	F
6/17	STK	0735	
	STK	1304	F
6/18	STK	0818	
	STK	1308	
	GRO	1621	
6/19	STK	0735	
	POT	1346	
	STK	1635	
6/20	STK	0735	
	POT	1300	C
	STK	1320	F
	GRO	1555	
6/21	STK	0735	
	STK	1259	
	GRO	1433	
	STK	1605	
	GRO	1618	
	STK	1735	
	GRO	1744	
	STK	1910	
	GRO	1912	

Table 37. continued

Date	Station	Release Time (MDT)	Flag
6/22	STK	0735	
	POT	1330	
	STK	1330	A (below 700 mb)
	GRO	1439	F
	POT	1450	E
	STK	1518	
	POT	1603	
	GRO	1604	
6/23	STK	0735	
	STK	1315	
6/24	NO DATA COLLECTED		
6/25	STK	0735	
6/26	STK	0745	
	STK	1255	
	GRO	1616	
6/27	STK	0733	
	STK	0928	
	STK	1035	
	STK	1302	
	STK	1603	
6/28	STK	0732	
	STK	1305	A
	STK	1410	
	STK	1605	
6/29	STK	0745	No data above 650 mb
	POT	1304	
	STK	1310	
	GRO	1321	
6/30	STK	0737	
	GRO	1305	
	STK	1308	
	POT	1345	
	GRO	1435	
	STK	1556	
	POT	1601	C
	GRO	1611	
	GRO	1728	
	POT	1730	
	STK	1738	
7/01	STK	0732	
	GRO	1134	
	GRO	1249	
	STK	1259	
	POT	1342	
	GRO	1423	
	STK	1444	
	POT	1445	
	STK	1600	
	POT	1603	
	GRO	1604	
7/02	STK	0730	
	GRO	1146	
	POT	1300	E
	STK	1302	
	GRO	1305	
	GRO	1425	
	STK	1430	
	POT	1432	
	POT	1548	
	STK	1605	
	GRO	1617	
7/03	STK	0735	
	STK	1307	F (below 850 mb)
	GRO	1310	
	POT	1313	
	STK	1559	
	GRO	1607	
	POT	1615	
	POT	1730	D
	STK	1735	
	GRO	1738	
7/04	NO DATA COLLECTED		
7/05	NO DATA COLLECTED		
7/06	STK	0735	
	STK	1258	
	STK	1558	
	GRO	1728	
	STK	1939	
7/07	STK	0737	
	GRO	1256	
	STK	1305	
	POT	1318	D
	POT	1600	
	STK	1600	
	GRO	1730	
	STK	1732	
	POT	1748	

Table 37. continued

Date	Station	Release Time (MDT)	Flag
7/08	STK	0737	
	STK	1304	
	STK	1605	
7/09	STK	0735	
	GRO	1305	C
	GRO	1436	
	STK	1556	C
7/10	STK	0730	
	STK	1300	
7/11	NO DATA COLLECTED		
7/12	NO DATA COLLECTED		
7/13	STK	0735	
	STK	1307	
	POT	1519	D
	STK	1607	
7/14	STK	0733	
	GRO	1133	
	STK	1300	
	POT	1304	
	GRO	1313	
	STK	1431	
	GRO	1435	
	POT	1445	
	GRO	1558	
	STK	1558	
7/15	STK	0758	
	STK	1305	
	GRO	1424	
7/16	STK	0735	
	GRO	1127	
	POT	1301	
	STK	1302	
7/17	STK	0735	
	GRO	1203	C (trace appears low)
	STK	1300	
	POT	1311	D
	STK	1601	
	POT	1605	D
	GRO	1608	
	GRO	1731	C
	STK	1735	
	POT	1738	
7/18	STK	0735	
	GRO	1255	
	POT	1259	
	STK	1305	
	STK	1604	
	GRO	1608	
	POT	1610	
	GRO	1739	
	STK	1740	
	POT	1742	
7/19	STK	0735	
	POT	1312	
	GRO	1424	
7/20	STK	0735	
	STK	1258	
	STK	1559	
	POT	1607	
	GRO	1636	
7/21	STK	0735	
	STK	1302	
	POT	1316	
	GRO	1330	
	POT	1604	
	STK	1605	
	GRO	1619	
	POT	1737	
	STK	1738	
7/22	STK	0740	
	GRO	1303	
	STK	1305	
	POT	1308	
	STK	1431	
	POT	1445	
	GRO	1454	
	STK	1605	
	POT	1608	
	GRO	1627	
	POT	1730	
	STK	1818	
	GRO	1827	
7/23	STK	0740	
	STK	1304	
	POT	1341	
	GRO	1425	
	STK	1439	
	GRO	1607	
	STK	1610	
	POT	1620	

Table 37. continued

Date	Station	Release Time (MDT)	Flag
7/24	STK	0740	
	GRO	1157	
	STK	1302	
7/25	STK	0740	
	GRO	1302	C (trace appears low)
	STK	1304	
	POT	1304	
	STK	1605	
	GRO	1729	
	POT	1730	
	STK	1739	
	STK	1856	
7/26	STK	0740	
	STK	1259	
	POT	1307	
	GRO	1310	
	STK	1559	
	GRO	1745	
7/27	STK	0740	
	GRO	1130	
	STK	1305	
	POT	1305	
	GRO	1321	
	GRO	1435	
	STK	1440	
	POT	1440	
	GRO	1553	
	STK	1610	F
	POT	1610	
7/28	STK	0740	
	STK	1306	
	GRO	1406	
	STK	1600	
7/29	STK	0740	
	POT	1300	
	STK	1305	
	POT	1630	
7/30	STK	0735	
	GRO	1438	
	POT	1444	
	STK	1601	F
	GRO	1606	
	POT	1625	
	POT	1745	
	STK	1814	F
	GRO	1815	
	POT	1858	
7/31	STK	0740	
	GRO	1252	
	POT	1318	B
	STK	1320	
	STK	1602	

Mesometeorological and PAM Networks.

The mesometeorological and PAM data are of general good quality. The major difficulty occurs in the measurement of humidity in the conventional network. This arises from the standard instrument error of $\pm$ 3% in measuring relative humidity. Also, the 1976 field program was the first field deployment of the PAM system and as such, it was considered as the final field evaluation of the system. Tables summarizing these observations are not included since these systems operated on a 24-hour-per-day basis for all operational periods.

Time-Lapse Cloud Photography.

The tabulation of data related to time-lapse cloud photography is shown in Table 38. The data presented includes the location, the roll number for the day, the direction toward which the camera was pointing, and the period during which photographs were taken. In addition, in the remarks section, discrepancies and the frame or footage counts are noted.

It should also be noted that each of the four mobile precipitation sampling teams were equipped to take time-lapse cloud photographs. Information on this data is included later in this section.

Table 38.

1976 Time-Lapse Photography

Date	Location	Roll #	Direction	Time	Remarks, Frame/Footage Count
18 May	Greeley	1	NE		experimental roll, no clock or other information
20 May	Grover	1	NW	1421-1735	film may have run out
21 May	Greeley	2	NE	1200-1730	data board set up ~1605-2325 frames
	Grover	2	NE	1107-1844	3394 frames
24 May	Greeley	3	NE	1245-2000	3241 frames
25 May	Greeley	4	NE	1223-1920	3410 frames
	Grover	3	W, NE, SE	1102-1811	2860 frames
26 May	Greeley	5	NE	1220-1915	3034 frames
27 May	Greeley	6	NE		film jammed--no footage this date
	Grover	4	SE	1213-1710	2640 frames
28 May	Greeley	7	NE	1126-1910	no frame count
	Grover	4	SW, E	1302-1656	1270 frames
	Sterling	1	NW		film jammed--no footage this date
29 May	Greeley	8	NE	1123-1915	3228 frames
	Sterling	2	NW	1100-1800	2914 frames
30 May	Greeley	9	NE	1057-1556	2125 frames (dark)
	Sterling	3	NW	1233-1756	2364 frames
31 May	Greeley	10	NE	1145-2000	3018 frames
	Sterling	4	NW		film jammed--no footage this date

Table 38. continued

Date	Location	Roll #	Direction	Time	Remarks, Frame/Footage Count
1 June	Greeley	11	NE		Camera broke--no film this date
	Grover	5	NE	1351-1740	2601 frames
	Sterling	5	NW		film jammed--no footage this date
2 June	Greeley	12	NE	1129-1915	3449 frames
	Grover	6	NW	1113-1758	3900 frames
	Sterling	6	NW	1241-1919	3980 frames
3 June	Greeley	13	NE	1055-1950	2988 frames
	Sterling	7	NW	1144-1859	3711 frames
4 June	Greeley	14	NE	1110-1540	1633 frames
	Grover	Wisc.	W, NW, SE	1726-1935	30 feet
	Sterling	8	NW	1400/2003	3705 frames (dark)
	SE of Gro.	Wisc.	NW	1800-1840	26 feet
5 June	Greeley	15	NE	1222-1920	3333 frames
	Grover	Wisc.	NW, W	1555(?)-1722	Not recorded
	Sterling	9	NW	1113-1818	3264 frames
	Butler	Wisc.	SW	1513-1755	44 feet
6 June	Greeley	16	NE	1105-1900	3048 frames
	Grover	6	SW, NW	1632-1747	220 frames
	Grover	Wisc.	NW	1305-1608	68 feet
	Sterling	10	NW	1050-1800	3739 frames
	Butler	Wisc.	NW, N(?)	1345-1537	Not recorded

Table 38. continued

Date	Location	Roll #	Direction	Time	Remarks, Frame/Footage Count
7 June	Greeley	17	NE	1023-2000	4000 frames
	Grover	7	VAR	1241-1815	3423 frames
	Grover	Wisc.	VAR	1230-1746	84 feet
	Sterling	11	NW	1022-1858	4000 frames
	Butler	Wisc.	W, SE, NE	1335-1839	63 feet
8 June	Greeley	18	NE	1114-2000	3561 frames
	Grover	Wisc.	NW, W, SW	1227-1312 1327-1801	8 feet 55 feet (2 rolls)
	Sterling	12	NW	1045-1825	3944 frames
	Lindbergh	1	NW, SW	1045-1819	2872 frames
	Chapel	1	SW, SE	1707-1830	(8mm)
	Butler	Wisc.	NE, NW, W	1333-1445 1606-1633	35 feet
9 June	Greeley	19	NE	1103-1945	4000 frames
	Grover	Wisc.	NW, SE, E	1100-1421 1440-1630 1814-1911	45 feet 32 feet (2 rolls)
	Sterling	13	NW	1046-1955	4000 frames
	Lindbergh	2	SW, SE, S	1300-1806	2054 frames
	Chapel	2	E	1625-1707	753 frames
	Butler	Wisc.	W, SE, NW	1228-1643 1715-1816	53 feet
10 June	Greeley	20	NE	1100-2000	3906 frames
	Grover	Wisc.	SW, NW, ENE	1003-1356	68 feet
	Sterling	14	NW	1246-1740	2923 frames
	Lindbergh	2	SE	1532-1601	206 frames
	Butler	Wisc.	NW, SW, NE	1215-1700	47 feet

Table 38. continued

Date	Location	Roll #	Direction	Time	Remarks, Frame/Footage Count
11 June	Sterling	15	NW	1246-1724	3124 frames
12 June	Greeley	21	NE	1140-2000	3642 frames
	Sterling	16	NW	1027-1725	3751 frames
13 June	Greeley	22	NE	1117-1940	3719 frames
	Sterling	17	NW	1037-1740	3639 frames
	Lindbergh	2	W	1215-1300	350 frames
	Butler	Wisc.	W	1650-1657	1 ft.
14 June	Greeley	23	NE	1121-1903	3336 frames
	Sterling	18	NW	1036-1744	3622 frames
15 June	Greeley	24	NE	1102-1954	3736 frames
	Sterling	19	NW	1353-1743	2295 frames
16 June	Greeley	25	NE	1115-1915	3547 frames
	Sterling	19	NW	1217/1535	1685 frames
17 June	Greeley	26	NE	1104-1945	3274 frames
	Sterling	20	NW	1033-1805	2883 frames
18 June	Greeley	27	NE	1100-1900	3235 frames
19 June	Greeley	28	NE	1105-1900	3534 frames
	Sterling	21	NW	1138-1744	3104 frames
	Butler	Wisc.	NW	1358-1524	12 ft.
20 June	Greeley	29	NE	1103-1900	3214 frames
	Grover	Wisc.	S, SW	1232-1535	29 ft.
	Sterling	22	NW	1008-1539	2646 frames
	Lindbergh	3	NW	1327-1516	1831 frames

Table 38. continued

Date	Location	Roll #	Direction	Time	Remarks, Frame/Footage Count
21 June	Greeley	30	NE	1108-1910	3818 frames
	Grover	Wisc.	NW, E	1257-1832 1847-2004	69 ft. 14 ft. (2 rolls)
	Sterling	23	NW		Film jammed--no footage this date.
	Chapel	2	NW, N	1440/ 1703	2836 frames
	Lindbergh	3	S, SW, SE	1229-1941	1204 frames
	Butler	Wisc.	NW, SE	1329-1740 1758-1935	75 ft.
22 June	Greeley	31	NE	1115-1910	2966 frames
	Grover	8	S	1441-1650 1753-1812	N/R
	Grover	Wisc.	VAR	1141-1300 1447-1625	30 ft.
	Sterling	25	NW	1115-1922	3737 frames
	Lindbergh	4	NW, S, SW	1236-1805	2137 frames
	Chapel	3	NW, N	1520-1815	(8mm)
	Butler	Wisc.	N	1519-1529	4 ft.
23 June	Greeley	32	NE	1106-1530	2078 frames
	Grover	Wisc.	NW	1254-1559	85 ft.--some cine speed
	Sterling	26	NW	1239-1601	976 frames
	Butler	Wisc.	NW	1333-1509	32 ft.
26 June	Greeley	33	NE	1115-2000	3952 frames
	Grover	8	NW	1407-1733	N/A
	Grover	Wisc.	S, SW	1321-1737	80 ft.
	Sterling	26	NW	1224-1550	1862 frames

Table 38. continued

Date	Location	Roll #	Direction	Time	Remarks, Frame/Footage Count
26 June (cont.)	Chapel	3	NW	1620-1755	N/A (8mm)
	Butler	Wisc.	WNW	1342-1457 1523-1703	23 ft. 30 ft. (2 rolls)
27 June	Greeley	34	NE	1104-2000	3454 frames
	Grover	Wisc.	NW	1444-1601	20 ft.
	Sterling	27	NW	1153-1750	3528 frames
	Butler	Wisc.	SW, SE	1447-1618 1655-1823	54 ft.
28 June	Greeley	35	NE	1221/1903	3130 frames
	Grover	Wisc.	SE	1459-1705	40 ft.
	Sterling	28	NW	1146-1750	2521 frames
	Butler	Wisc.	SW	1540-1740	37 ft.
29 June	Greeley	36	NE	1106-1900	3363 frames
	Grover	Wisc.	SW	1159-1440	46 ft.
	Sterling	29	NW	1057-1430	Film ran out
	Sterling	30	NW	1435-1555	893 frames
30 June	Greeley	37	NE, E	1139-2000	3659 frames.
	Grover	9	W, NW	1144-1809	3747 frames
	Grover	10	S	1830-1904	188 frames
	Grover	Wisc.	SE, SW	1157-1507 1545-1637 1934-2030	100 ft.
	Sterling	29	NW	1100-1901	3846 frames
	Lindbergh	4	W, SE	1315-1828	1878 frames
	Chapel	3	NW	1140-1232 1245-1620	N/A (8mm)
	Butler	Wisc.	NW	1316-1623	38 ft.

Table 38. continued

Date	Location	Roll #	Direction	Time	Remarks, Frame/Footage Count
1 July	Greeley	38	NE	1105-1930	3694 frames
	Grover	10	NW, W	1101-1601	∿2000 frames
	Grover	Wisc.	NE	1353-1418	7 ft.
	Sterling	30	NW	1054-1729	3399 frames
	Lindbergh	5	SW, SE	1202-1607	1730 frames
	Butler	Wisc.	NE	1538-1615	8 ft.
2 July	Greeley	39	NE	1103-1944	3653 frames
	Grover	10	W, NE, SE	1035-1620	Film ran out
	Grover	Wisc.	SSW, N	1054-1135 1219-1246 1420-1457	17 ft.
	Sterling	31	NW	1050-1756	3724 frames
	Lindbergh	5	VAR	1210-1727	1203 frames
	Chapel	4	W, NW	1316-1645	(8mm)
	Butler	Wisc.	SW, NE	1241-1332	16 ft.
3 July	Greeley	40	NE	1210-2000	3627 frames
	Grover	Wisc.	NW, NE, E	1250-1851	74 ft.
	Sterling	32	NW	0943-1830	Film ran out
	Lindbergh	5	SE, E	1526-1832	910 frames
	Chapel	5	N, NE	1553-1841	(8mm)
	Butler	Wisc.	SW, NE	1247-1350 1554-1825	57 ft.
6 July	Greeley	41	NE	1109-1855	3691 frames
	Grover	11	NW, N	1522-2035	N/A
	Grover	Wisc.	SW, NW	1133-1419 1436-1718 1800-1802	65 ft.

Table 38. continued

Date	Location	Roll #	Direction	Time	Remarks, Frame/Footage Count
6 July (cont.)	Sterling	33	NW	1057-1814	4000 frames
	Lindbergh	6	W, SW, S	1520-1930	1622 frames
	Chapel	5	NW	1646-1830	2847 frames
	Butler	Wisc.	NW, SW	1345-1509 1532-1704 1732-1752	35 ft. 33 ft. (2 rolls)
7 July	Greeley	42	NE	1105-1900	3347 frames
	Grover	11	N, NE	1628-1810	818 frames
	Grover	Wisc.	NW, ESE	1225-1428	30 ft.
	Sterling	34	NW	1216-1825	3406 frames
	Lindbergh	6	SW, S, SE	1300-1800	1462 frames
	Chapel	6	NE	1650-1748	1036 frames
	Butler	Wisc.	W, SE	1255-1330 1405-1502	21 ft.
8 July	Greeley	43	NE	1055-1858	3801 frames
	Grover	12	VAR	1220-1637	1940 frames
	Grover	Wisc.	SW, NE	1139-1212 1244-1449 1513-1537	50 ft.
	Sterling	35	NW	1104-1743	3601 frames
	Lindbergh	6	SE	1250-1349 1450-1508	460 frames
	Chapel	6	SW, SE	1327-1418 1429-1445	1015 frames
	Butler	Wisc.	SE, E, SE	1220-1449 1517-1624	45 ft. 18 ft. (2 rolls)

Table 38. continued

Date	Location	Roll #	Direction	Time	Remarks, Frame/Footage Count
9 July	Greeley	44	NE	1104-1900	3463 frames
	Grover	12	NW	1058-1445	2096 frames
	Grover	12	NE	1520-1607	445 frames
	Grover	Wisc.	NE	1226-1522	50 ft.
	Sterling	36	NW	1114-1744	3263 frames
	Lindbergh	7	VAR	1113-1540	1208 frames
	Butler	Wisc.	E, NE	1222-1404	31 ft.
10 July	Greeley	45	NE	1040-2005	3141 frames
	Grover	13	W	1056-1157 1459-1542	715 frames
	Grover	Wisc.	SW, E	1317-1337	5 ft.
	Sterling	37	NW	1143-1515	2130 frames
	Butler	Wisc.	SW, SE	1416-1446 1523-1536	12 ft.
11 July	Greeley	46	NE	1104-2010	3943 frames
12 July	Greeley	47	NE	1100-1920	3830 frames
	Grover	Wisc.	NW	1347-1700	49 ft.
	Butler	Wisc.	NW	1420-1617	38 ft.
13 July	Greeley	48	NE	1103-1900	3863 frames
	Grover	Wisc,	NW, W	1438-1711	30+ ft.
	Sterling	38	NW	1044-1750	3855 frames
	Butler	Wisc.	NW, SW	1500-1708	39 ft.

Table 38. continued

Date	Location	Roll #	Direction	Time	Remarks, Frame/Footage Count
14 July	Greeley	49	NE	1119-1857	3050 frames
	Grover	13	NW, E	1136-1552	2889 frames
	Grover	14	E	1620-1745	1039 frames
	Grover	Wisc.	NE	1157-1802	100 ft.
	Sterling	39	NW, N	1145-1804	3402 frames
	Lindbergh	7	E, SE	1310-1705	1443 frames
	Chapel	6	VAR	1145-1322	1553 frames, film ran out
	Butler	Wisc.	NE	1220-1559 1608-1732	61 ft. 21 ft. (2 rolls)
15 July	Greeley	50	NE	1102-1856	3459 frames
	Sterling	40	NW	1033-1552	2707 frames
16 July	Greeley	50	NE	1102-1956	3916 frames
	Grover	Wisc.	NW, E, NE	1311-1406 1452-1611	21 ft.
	Sterling	41	NW	1103-1545	2552 frames
	Butler	Wisc.	NW, NE	1345-1359 1611-1641	13 ft.
17 July	Greeley	52	NE	1115-2000	3674 frames
	Grover	14	W, SW	1554-1849	3102 frames
	Grover	Wisc.	NW, NE	1244-1600	31 ft.
	Sterling	42	NW	1118-1850	3976 frames
	Lindbergh	8	SW, S	1553-1838	870 frames
	Chapel	7	W	1627-1735	917 frames
	Butler	Wisc.	W, S	1236-1541 1636-1819	63 ft.

Table 38. continued

Date	Location	Roll #	Direction	Time	Remarks, Frame/Footage Count
18 July	Greeley	53	NE	1105-2000	4000 frames
	Grover	14	NW	1341-1520	927 frames
	Grover	?	VAR	1544-1858	1064 frames
	Grover	Wisc.	NW, N	1333-1546	20 ft.
	Sterling	43	NW, SW	1111-1830	3775 frames
	Lindbergh	8	SW, S	1448-1830	990 frames
	Butler	Wisc.	W, NW, E	1405-1525 1723-1726	26 ft.
19 July	Greeley	54	NE	1104-1903	3546 frames
	Grover	Wisc.	NW NE	1315-1435 1525-1640	25 ft. 24 ft. (2 rolls)
	Sterling	44	NW	1055-1627	2748 frames
	Lindbergh	8	SSE	1410-1520	2260 frames
	Butler	Wisc.	NW, NE	1358-1500 1552-1632	19 ft.
20 July	Greeley	55	NE	1100-1854	4000+ frames
	Grover	15	SW	1550-1613	1125 frames
	Sterling	45	NW	1104-1748	3660 frames
21 July	Greeley	56	NE	1115-1901	3167 frames
	Grover	15	SE	1411-1440 1520-1735	∿1511 frames
	Grover	16	NE	1807-1848	363 frames
	Grover	Wisc.	NE	1415-1519 1545-1647 1843-1910	41 ft.
	Sterling	46	NW	1049-1814	4071 frames
	Lindbergh	8	S, SE	1448-1828	1220 frames

Table 38. continued

Date	Location	Roll #	Direction	Time	Remarks, Frame/Footage Count
21 July (cont.)	Chapel	7	NW	1646-1832	1875 frames
	Butler	Wisc.	SE, E, NE	1307-1337 1515-1652 1744-1849	54 ft.
22 July	Greeley	57	NE	1052-1852	3801 frames
	Grover	16	VAR	1155-1816	3530 frames
	Grover	Wisc.	NW NW, NE, SE	1055-1225 1241-1900	28 ft. 100 ft. (2 rolls)
	Sterling	47	NW	1140-1906	4037 frames
	Lindbergh	9	VAR	1321-1342 1422-1843	1906 frames
	Chapel	7	W	1332-1337	95 frames
	Butler	Wisc.	NW, NE, SE	1159-1835	100 ft.
23 July	Greeley	58	NE	1106-1955	4000+ frames
	Grover	17	VAR	1254-1625 1638-1804	2567 frames
	Grover	Wisc.	SW, NE	1257-1715	55 ft.
	Sterling	48	NW	1156-1747	3145 frames
	Lindbergh	9	SE	1410-1618 1516-1617	469 frames
	Butler	Wisc.	SE, SW, NE	1252-1627	66 ft.
24 July	Greeley	59	NE	1015-1955	3668 frames
	Grover	18	VAR	1258-1925	Film ran out
	Grover	Wisc.	NW, E	1400-1520	33 ft.
	Sterling	49	NW	1113-1552	2648 frames

Table 38. continued

Date	Location	Roll #	Direction	Time	Remarks, Frame/Footage Count
25 July	Greeley	60	NE	1145-2000	2894 frames
	Grover	Wisc.	E, W	1247-1417 1451-1948	21 ft. 81 ft. (2 rolls)
	Sterling	50	NW	1112-1855	4000+ frames
	Lindbergh	9	E, SE, SW	1601-1947	1619 frames
	Chapel	8	N	1659-1952	(8mm)
	Butler	Wisc.	SW, SE, E	1402-1600 1627-1936	34 ft. 55 ft. (2 rolls)
26 July	Greeley	61	NE	1138-1857	3460 frames
	Grover	Wisc.	NW NE	1308-1408 1605-1425	18 ft. 36 ft. (2 rolls)
	Sterling	51	NW	1048-1829	Film ran out
	Butler	Wisc.	ESE	1500-1630 1737-1840	40 ft.
27 July	Greeley	62	NE	1106-1855	3659 frames
	Grover	19	VAR	1052-1852	3845 frames
	Grover	Wisc.	NE	1239-1313 1340-1709 1738-1823	64 ft.
	Sterling	52	NW	1100-1804	4090 frames
	Lindbergh	10	S, SE, E	1322-1618 1645-1828	1843 frames
	Butler	Wisc.	ESE, NE	1228-1425 1444-1849	99 ft.
28 July	Greeley	63	NE	1105-1900	3411 frames
	Grover	Wisc.	SE	1735-1845	20 ft.
	Sterling	53	NW	1055-1819	4081 frames
	Lindbergh	10	SE	1828-1839	89 frames

Table 38. continued

Date	Location	Roll #	Direction	Time	Remarks, Frame/Footage Count
28 July (cont.)	Butler	Wisc.	NW, SE	1426-1520 1653-1907	32 ft.
29 July	Greeley	64	NE	1055-1855	3881 frames
	Grover	Wisc.	NE	1455-1520	Not recorded
	Sterling	54	NW	1120-1717	2676 frames
	Butler	Wisc.	SE	1530-1645	11 ft.
30 July	Greeley	65	NE	1114-1855	3520 frames
	Grover	Wisc.	NW, SE	1201-1638	76 ft.
	Sterling	55	NW	1138-1821	4078 frames
	Lindbergh	10	S	1618-1817	856 frames
	Chapel	8	W, N	1747-1920	(8mm)
	Butler	Wisc.	NW, NE	1332-1410	10 ft.
31 July	Greeley	66	NE	1121-1950	3613 frames (dark)
	Grover	Wisc.	VAR SE, E	1355-1415 1514-1635	66 ft.
	Sterling	56	NW	1200-1903	3737 frames
	Lindbergh	10	S, SW	1652-1757	479 frames
	Butler	Wisc.	NE, SE	1540-1659	25 ft.

Precipitation Network.

Information related to the precipitation network is set forth in Table 39. The table shows the type of instruments and the number of measurements of hail and rain for each day of the season. It should be noted that this table combines data from the dense precipitation network and those sites which were established for evaluating improvements in the hail/rain separator.

Additional precipitation data were recorded at each of the meso-meteorological and PAM sites.

Table 39.

Number of Instruments of Each Type Measuring Hail or Rain

Date	Hailpad	Hailcube	Hail/Rain Separator*		Wedge Rain Gauge	Weighing Rain Gauge
			Hail	Rain		
May						
21				1		
22				21(5)		
23				20(4)		1
24				18(2)		
25	122	31	5(3)	23(5)		2
26				7(1)		
27					70	
28				1	24	
29	69	27	1	27(7)	507	82
30	322	46	7(1)	26(7)	493	88
31				1		1
June						
1				3	38	
2	11	30	1	16(3)	192	37
3					8	
4	72	18		16(3)	217	24
5					1	1
6						
7						
8				1	2	2
9				1	47	1
10						
11					2	1
12						
13						
14				1		
15						
16						
17				21(4)	617	55
18				16(3)	533	41
19				2(1)		6
20						
21	7	3		5(1)	333	21
22	498	83	11(4)	29(10)	623	101
23				21(3)	538	22
24					2	
25					15	
26						
27						
28						
29						
30	7	4		5(1)	44	7
July						
1		5		8(1)	16	18
2	43	39	2	28(8)	614	95
3				11(3)		1
4				4(2)	1	1
5	150	27	1	11(3)	349	32
6				11(2)	356	41
7	53	9		16(5)	541	49
8				2	2	4
9				2	37	7
10				2(1)		
11						
12					2	
13						
14		7		3(1)	3	5
15						3
16						
17						
18	3	1		12(1)	193	51
19				16(2)	338	37
20				21(5)	614	80
21	21	10		27(4)	586	82
22	1	5		8	200	22
23	1			3(1)	17	4
24					2	1
25	67	17	1	31(8)	612	96
26				18(4)	312	32
27	15	10		9(1)	73	26
28						
29						1
30	6	9		26(8)	583	90
31				25(9)		36
August						
1				31(8)	572	110

* Parenthetical numbers give numbers of pairs of collocated separators, at which both separators measured hail or rain.

Mobile Precipitation Sampling Teams.

Both the NCAR and the University of Wyoming mobile teams were equipped to collect time-resolved hail samples and time-lapse cloud photograhs as time and opportunity permitted. In addition to the above, the University of Wyoming teams also measured precipitation, aerosols, winds aloft, and selected meteorological parameters.

The times and the locations (Cheyenne coordinates) of the mobile sampling teams observations are shown in Tables 40 and 41 that follow.

Table 40.

Hail Collections — NCAR Vehicles

— Summer 1976 —

Date	Time	Cheyenne Coordinates ° m	Data
June 2	1717:01 - 1718:09	120° - 39	Hail-Catcher*
	1734:39 - 1735:27	127° - 31	" "
	1727:32 - 1732:15	122° - 47	" "
	1111:45 - 1351:00	Grover site NW-W-N	Time-Lapse
4	1809:30 - 1847:30	099° - 08 NW-N	Time-Lapse
	1928:20 - 2006:00	102° - 23	Hail-Catcher
6	1736:30 - 1804:30	123° - 28 NW	Time-Lapse
7	1706:15 - 1745:18	082° - 34 E	Time-Lapse
	1655:15 - 1811:00	Stoneham NE	" "
8	1643:45 - 1655:30	127° - 31	Hail-Catcher
		132° - 34	Hail-Ground
		129° - 40.5	" "
		131° - 40	" "
	1638:30 - 1655:00	133° - 22	Hail-1 min samples
	1645:00 - 1658:30	137° - 31	Hail-Catcher
		130° - 42	Hail-Ground
		127° - 44	" "
21	1730:39 - 1731:12	92° - 20	Hail-Catcher
22	1621:20 - 1646:05	91° - 41	Hail-Catcher
		96° - 45	Hail-Ground
		86° - 40	" "
		92° - 37	" "
		98° - 30	" "
	1633:00 - 1647:04	092° - 41	Hail-Catcher
26	1631:00 - 1722:00	122° - 28 N-NW-W	Time-Lapse
30	1752:46 - 1800:43	100° - 44	Hail-Catcher
	1354:00 - 1455:20	291° - 18 W-NW	Time-Lapse
	1539:00 - 1611:00	291° - 18	" "
July 1	1550:30 - 1556:40	126° - 66	Hail-Catcher
2	1607:00 - 1640:08	127.5° - 44	Hail-Catcher
	1715:11 - 1717:30	115° - 58	" "
	1730	115° - 58	Hail-Ground
		111° - 60	" "
		109° - 60	" "
	1616:42 - 1629:19	124° - 46	Hail-Catcher
	1709:00 - 1712:00	116° - 57	" "
	1722:10 - 1731:51	115° - 57	" "

*Hail-Catcher is time-resolved

Table 40. continued
Hail Collections — NCAR Vehicles
— Summer 1976 —

Date	Time	Cheyenne Coordinates ° m	Data
July 7	1631:36 - 1637:07	90° - 41	Hail-Catcher
14	1441:43 - 1450:30	77° - 71	Hail-Catcher
	1526:12 - 1529:52	81° - 81	" "
	1451:00 - 1452:20	102° - 54	" "
	1454:25 - 1455:54	101° - 55	" "
	1500:45 - 1502:30	102° - 56	" "
22	1610	77° - 65	Hail-Ground
	1644:21 - 1652:30	096° - 58	Hail-Catcher
	1727:25 - 1729:23	104° - 66	" "
		105° - 66	Hail-Ground
		103° - 69	" "
25	1725:41 - 1726:31	123° - 53	Hail-Catcher
	1800:58 - 1809:02	126° - 67	" "
27	1740:00 - 1826:00	78° - 39 N-NE	Time-Lapse

Table 41.

UNIVERSITY OF WYOMING MOBILES - NHRE 1976

	COLLECTION SAMPLES			RECORDED DATA				PHOTOS	
	HAILSTONES (catcher)	PRECIPITATION (bags)	AEROSOLS (filters)	RAINDROP DIST (distrometer)	RAIN ACCUML. (wedge)	WIND ALOFT (pibal)	MET. PARAM. (strip chart)	TIME LAPSE	STILL
June 1				√					
2	√	√	√	√	√	√	√		√
3			√				√	√	
4	√	√	√	√	√	√	√		√
5			√				√		√
6			√				√	√	√
7			√				√	√	√
8	√	√	√	√	√		√		√
9		√	√				√		
10			√				√		√
11			√				√		
12									
13			√				√		
14			√				√		
15									
16									
17			√				√		√
18									
19			√				√		
20			√				√		
21		√	√	√			√		√
22	√	√	√	√			√		√
23			√				√		
24									
25									

Table 41. continued

UNIVERSITY OF WYOMING MOBILES - NHRE 1976

	COLLECTION SAMPLES			RECORDED DATA				PHOTOS	
	HAILSTONES (catcher)	PRECIPITATION (bags)	AEROSOLS (filters)	RAINDROP DIST. (distrometer)	RAIN ACCUM. (wedge)	WIND ALOFT (pibal)	MET. PARAM. (strip chart)	TIME LAPSE	STILL
June 26								√	
27			√				√		
28			√				√		
29			√			√	√		√
30	√	√	√	√			√		√
July 1				√	√	√	√		√
2	√	√	√				√		√
3			√				√		
4									
5									
6			√				√		
7	√		√				√		√
8			√				√	√	√
9			√			√	√		√
10			√				√		
11									
12									
13			√				√		
14	√	√	√				√		√
15									
16			√				√		
17			√				√		√
18		√	√	√			√		√
19			√				√		
20		√	√	√	√		√		√

Table 41. continued

UNIVERSITY OF WYOMING MOBILES - NHRE 1976

	COLLECTION SAMPLES			RECORDED DATA				PHOTOS	
	HAILSTONES (catcher)	PRECIPITATION (bags)	AEROSOLS (filters)	RAINDROP DIST (distrometer)	RAIN ACCUM. (wedge)	WIND ALOFT (pibal)	MET. PARAM. (strip chart)	TIME LAPSE	STILL
July 21		√	√	√	√		√		√
22	√	√	√	√	√		√	√	√
23			√				√		
24			√			√	√		√
25	√		√	√			√		√
26			√				√		
27			√				√	√	√
28			√				√		
29			√				√		
30		√	√	√	√		√		√
31			√				√		√

Table 41. continued

1976 NHRE

WYOMING VEHICLE DATA COLLECTIONS

Hailstone Collections

Date	Time	Location	Sample Numbers
2 June	1825	CYS 107°/57.5	H101, 102
4 June	1920-1944	CYS 141°/39	H103, 104, 105, 106
8 June	1452-1505	CYS 116°/12	H107, 108, 109, 110
	1639-1704	CYS 130°/32	H111, 112, 113, 114, 115
	1734-1738	CYS 129°/43	H118
	1631-1700	CYS 129°/29	H1-H8
	1722	CYS 131°/33	H9, 10
	1803-1823	CYS 132°/34	H11-H19
22 June	1625-1644	CYS 93°/41	H20-H26
	1610-1617	CYS 83°/39	H116
	1624-1704	CYS 85°/39.5	H119-H125
	1653-1812	CYS 76°/39	H126
30 June	1738-1747	CYS 118°/48	H117, 127, 128
	1749-1804	CYS 100°/44	H27-H30
2 July	1703-1715	CYS 124°/64	H31, 32
	1731-1740	CYS 128°/71	H33-H35
	2000	CYS 125°/66	H36-H39
	1657-1727	CYS 124°/65	H129-H145
7 July	1619-1621	CYS 93°/41.5	H147
	1624-1629	CYS 91°/41	H146, 148, 149
14 July	1526-1535	CYS 82°/81	H41-H43
	1453-1456	CYS 78°/74	H40
	1441-1445	CYS 100°/53	H150
22 July	1606-1608	CYS 82°/62	H151
	1637-1638	CYS 85°/68	H152
25 July	1809-1814	CYS 131°/68	H153, 154
	1817-1823	CYS 131°/67	H155, 156

Table 41. continued

Precipitation Bag Samples

Date	Time	Location	Sample Numbers
2 June	1819-1836	CYS 106°/56	101-103
4 June	1913-1954	CYS 141°/39	104-106
8 June	1735-1740	CYS 129°/43	113-115
	1453-1525	CYS 116°/12	107-110
	1640-1706	CYS 130°/32	111, 112
	1435-1501	CYS 93°/12	1-3
	1638-1703	CYS 129°/29	4-9
9 June	1632-1644	CYS 119°/26	116-118
21 June	1647-1701	CYS 55°/21	10
22 June	1623-1650	CYS 93°/41	11-14
	1611-1626	CYS 83°/39	119-121
	1627-1700	CYS 85°/39.5	124-129
30 June	1747-1759	CYS 100°/44	15-17
1 July	1609-1623	CYS 127°/68	21-23
	1455-1510	CYS 116°/57	18-20
2 July	1704-1748	CYS 124°/65	131-141
	1706-1712	CYS 124°/64	24-25
14 July	1434-1447	CYS 100°/53	142-144
18 July	1800-1825	CYS 116°/54	145-147
20 July	1717-1801	CYS 130°/22	148-150
21 July	1722-1750	CYS 107°/57	29-31
	1638-1651	CYS 94°/52	26-28
22 July	1638-1700	CYS 96°/57	32-37
30 July	1708-1715	CYS 116°/32	152, 155, 156
	1746-1808	CYS 100°/37	157-159

Table 41. continued

Raindrop Distrometer Measurements

Date	Time	Location	Run No.
1 June	1609-1621	CYS 63°/40	137
2 June	1812-1828	CYS 109°/58	138
	1821-1837	CYS 106°/56	130
4 June	1931-1958	CYS 141°/39	131
8 June	1429-1456	CYS 93°/12	139
	1504-1514	CYS 116°/12	132
9 June	1634-1643	CYS 119°/26	133
21 June	1647-1656	CYS 55°/21	140
22 June	1637-1707	CYS 83°/38	134
30 June	1749-1811	CYS 100°/44	141
1 July	1611-1621	CYS 127°/68	142
18 July	1759-1808	CYS 124°/65	135
20 July	1718-1747	CYS 130°/22	136
21 July	1731-1749	CYS 107°/57	143
22 July	1641-1700	CYS 96°/57	144
25 July	1829-1846	CYS 131°/67	145
30 July	1751-1820	CYS 100°/37	146

Table 41. continued

Aerosol Filter Samples

Date	Time	Location	Sample No.
2 June	0940-0955	Grover*	M1-3
3 June	0940-0957	Grover	M9-11
4 June	0957-1021	Grover	M12-14
5 June	1000-1025	Grover	M4-6
6 June	0945-1005	Grover	M15, 16, 31
7 June	1000-1015	Grover	M7, 8, 25
8 June	1010-1025	Grover	M26-28
9 June	0952-1012	Grover	M17-19
10 June	1000-1015	Grover	M29, 30, 34
11 June	0912-0932	Grover	M20-22
13 June	1002-1016	Grover	M37-39
14 June	1000-1019	Grover	M23, 24, 32
17 June	0955-1008	Grover	M35, 36, 47
19 June	0953-1012	Grover	M33, 40, 41
20 June	1335-1350	Grover Radar	M48-50
	1652-1706	Grover	M51-53
21 June	1316-1335	Grover	M42-44
22 June	1303-1317	Grover	M54-56
23 June	1259-1317	Grover	M45, 46, 66
27 June	1303-1322	Grover	M67-69
28 June	1259-1313	Grover	M57-59
29 June	1306-1324	Grover	M70-72
	1655-1713	Grover	M73-75
30 June	1312-1326	Grover Radar	M60-62
2 July	1305-1323	Grover	M76-78
3 July	1311-1325	Grover	M63-65
6 July	1309-1327	Grover	M90-92
7 July	1308-1322	Grover	M82-84
8 July	1300-1318	Grover	M93-95
9 July	1300-1313	Grover	M85-87
10 July	1251-1308	Grover	M96, 97, 104

Table 41. continued

Aerosol Filter Samples (continued)

Date	Time	Location	Sample No.
13 July	1309-1323	Grover	M88, 89, 110
14 July	1254-1312	Grover	M79-81
16 July	1312-1326	Grover	M111-113
17 July	1304-1322	Grover	M99-101
18 July	1810-1824	CYS 116°/54	M114, 115, 124
	1303-1317	Grover	M107-109
19 July	1302-1316	Grover	m125-127
20 July	1256-1314	Grover	M98, 102, 103
21 July	1308-1325	Grover	M105, 106, 135
22 July	1308-1322	Grover	M128-130
23 July	1303-1321	Grover	M136-138
24 July	1548-1723	CYS 112°/38	M134, 139-146
	1548-1745	CYS 113°/41	M116-123, 150-153
	1254-1308	Grover	M131-133
26 July	1307-1321	Grover	M154-156
27 July	1301-1317	Grover	M169-171
28 July	1245-1259	Grover	M157-159
29 July	1657-1714	Grover	M175-177
	1252-1308	Grover	M172-174
30 July	1256-1310	Grover	M160, 164, 165
31 July	1251-1307	Grover	M178-180
25 July	1306-1324	Grover	M166-168

*Grover = Tenney Ranch

Table 41. continued

Pibal Tracks

Date	Time	Location
2 June	1443	Pine Bluffs, Wyoming
	1610	3 mi N of Grover Radar
4 June	1755	CYS 121°/27.5
1 July	1441	CYS 116°/57
9 July	1521	CYS 95°/47
24 July	1535	CYS 112°/38
	1638	CYS 113°/41

Time-Lapse Photography

Data	Time	Location	Direction* Camera Pointed
3 June	1510-1700	CYS 118°/31	S, SW, W
6 June	1735-1805	CYS 155°/48	330°
7 June	1655-1745	CYS 78°/38	100°-80°
	1653-1745	CYS 77°/49.5	110°-92°
26 June	1602-1722	CYS 150°/21	330°, 345°, 360°
8 July	1430-1520	CYS 127°/70	30°, 70°, 75°
22 July	1404-1442	CYS 110°/25	160°, 115°, 120°
27 July	1820-1835	CYS 78°/39	45°, 75°

* = magnetic compass direction from camera

Aerosols.

Aerosol measurements were made at two fixed sites, the Chapel Ranch near Stoneham, Colorado, and the Sidney, Nebraska Airport, and by the three Queen Air aircraft, 10UW, 304D, and 306D. The types of aerosol measurements and the periods or times of point observations are set forth in Tables 42 and 43 . Among the instruments used were the Royce Aerosol Counter, the G.E. Condensation Nucleus Counter, the Allee Cloud Condensation Nucleus Counter, membrane filters, a Cyclone for collecting large particles, and aircraft bag samples.

Table 42.

Royce Aerosol Counter - Chapel Ranch Site, 1976

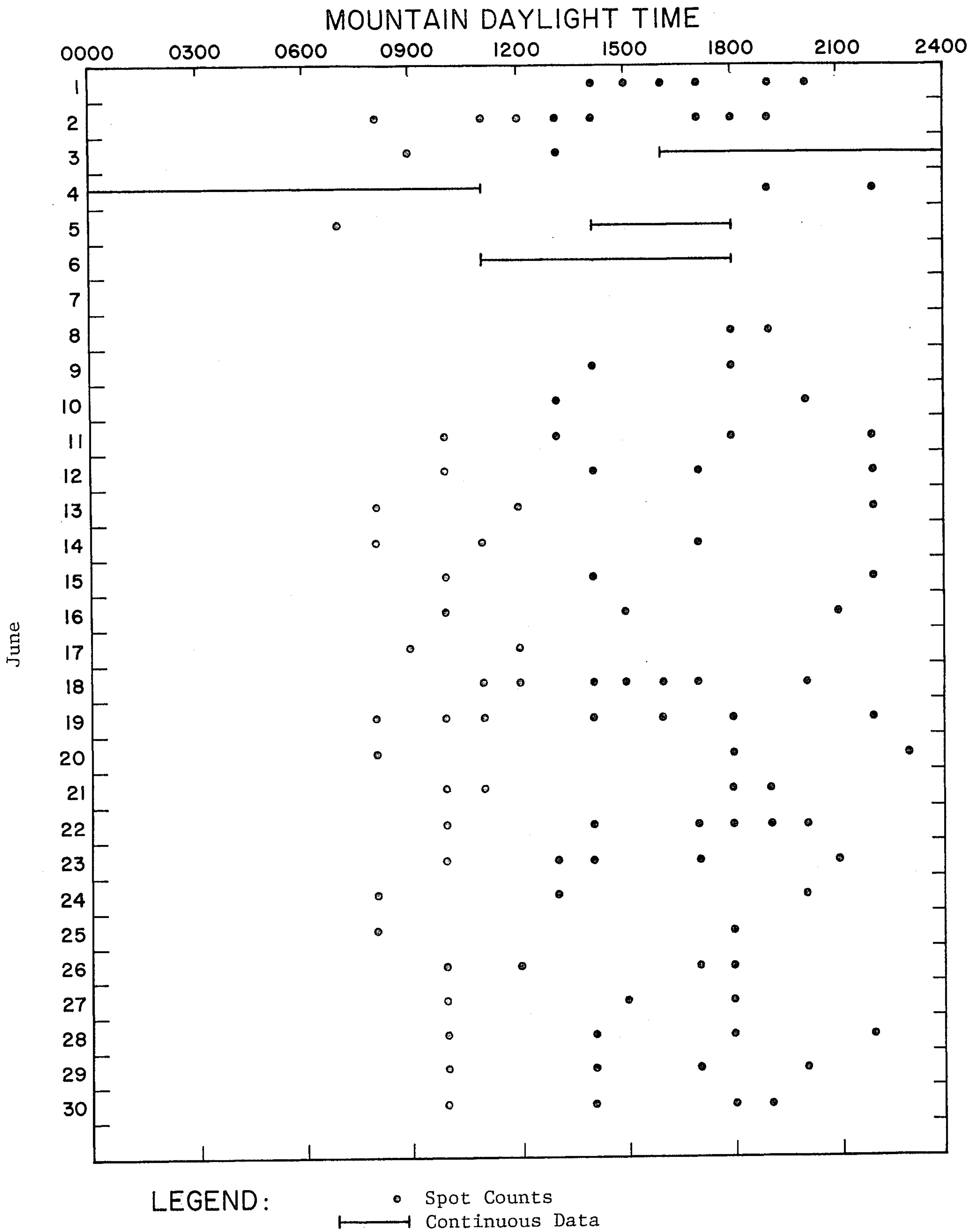


Table 42. continued

Royce Aerosol Counter - Chapel Ranch Site, 1976

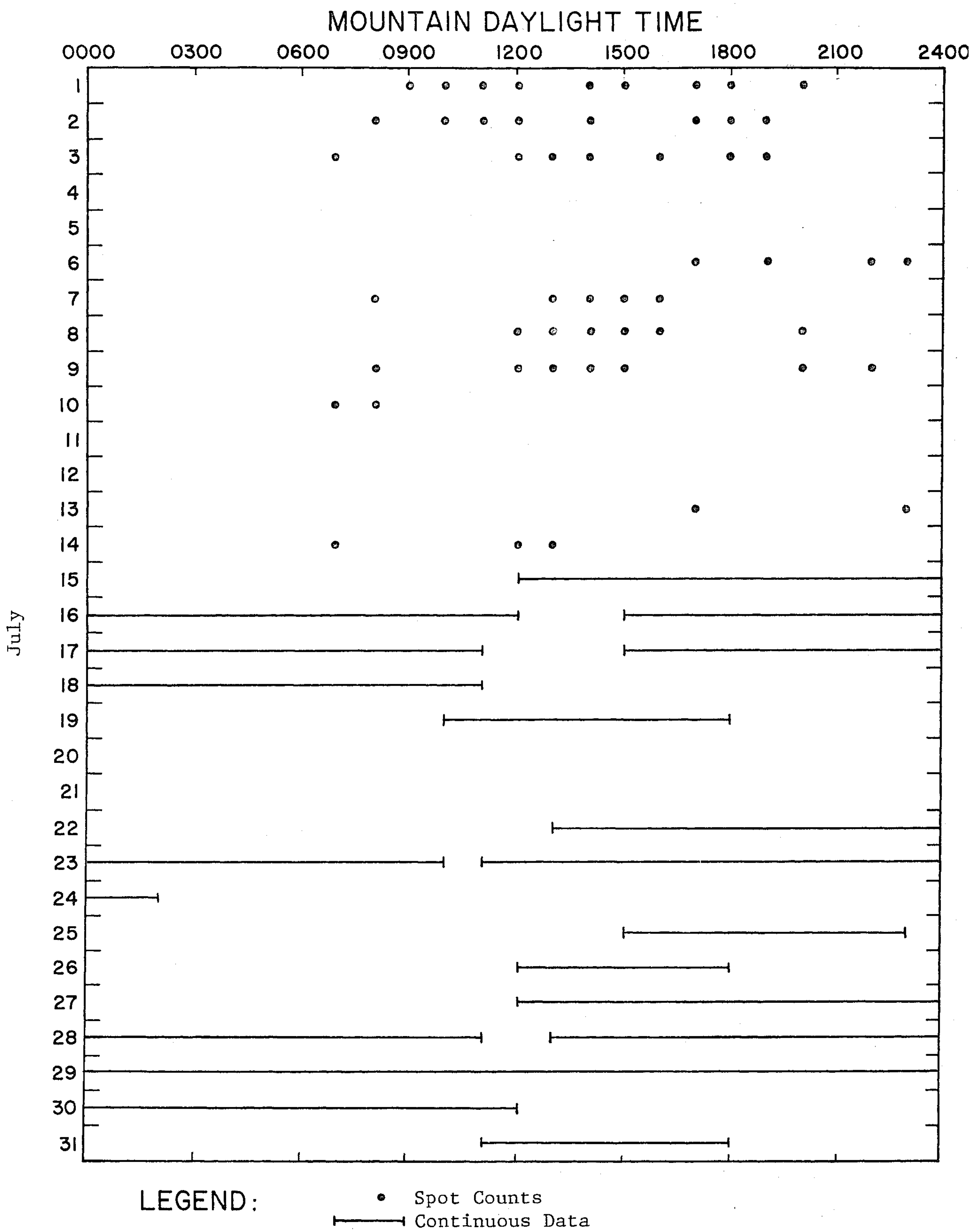


Table 42. continued

Aitken Particles from G. E. Condensation Nucleus Counter
Chapel Ranch Site, 1976

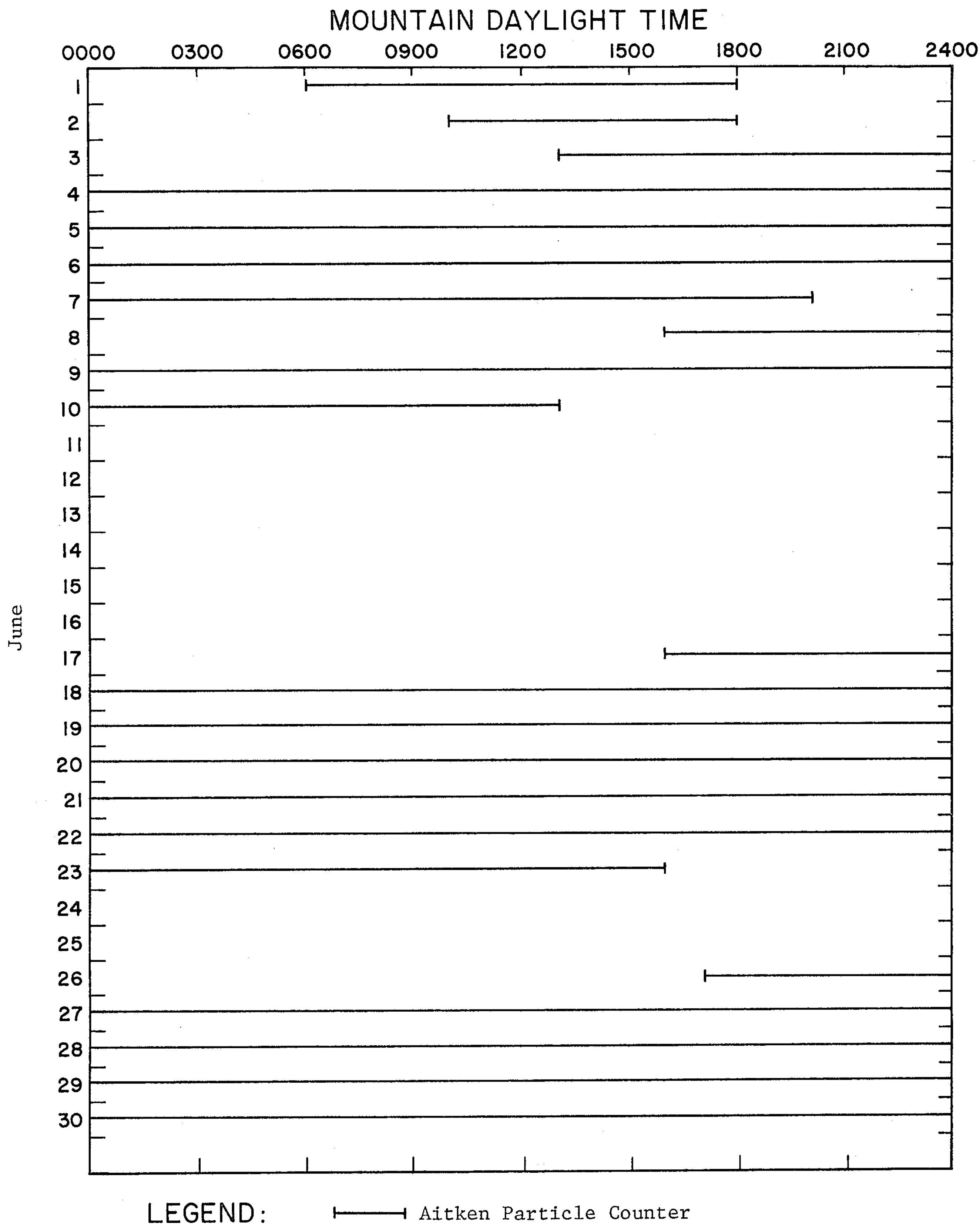


Table 42. continued

Aitken Particles from G.E. Condensation Nucleus Counter
Chapel Ranch Site, 1976

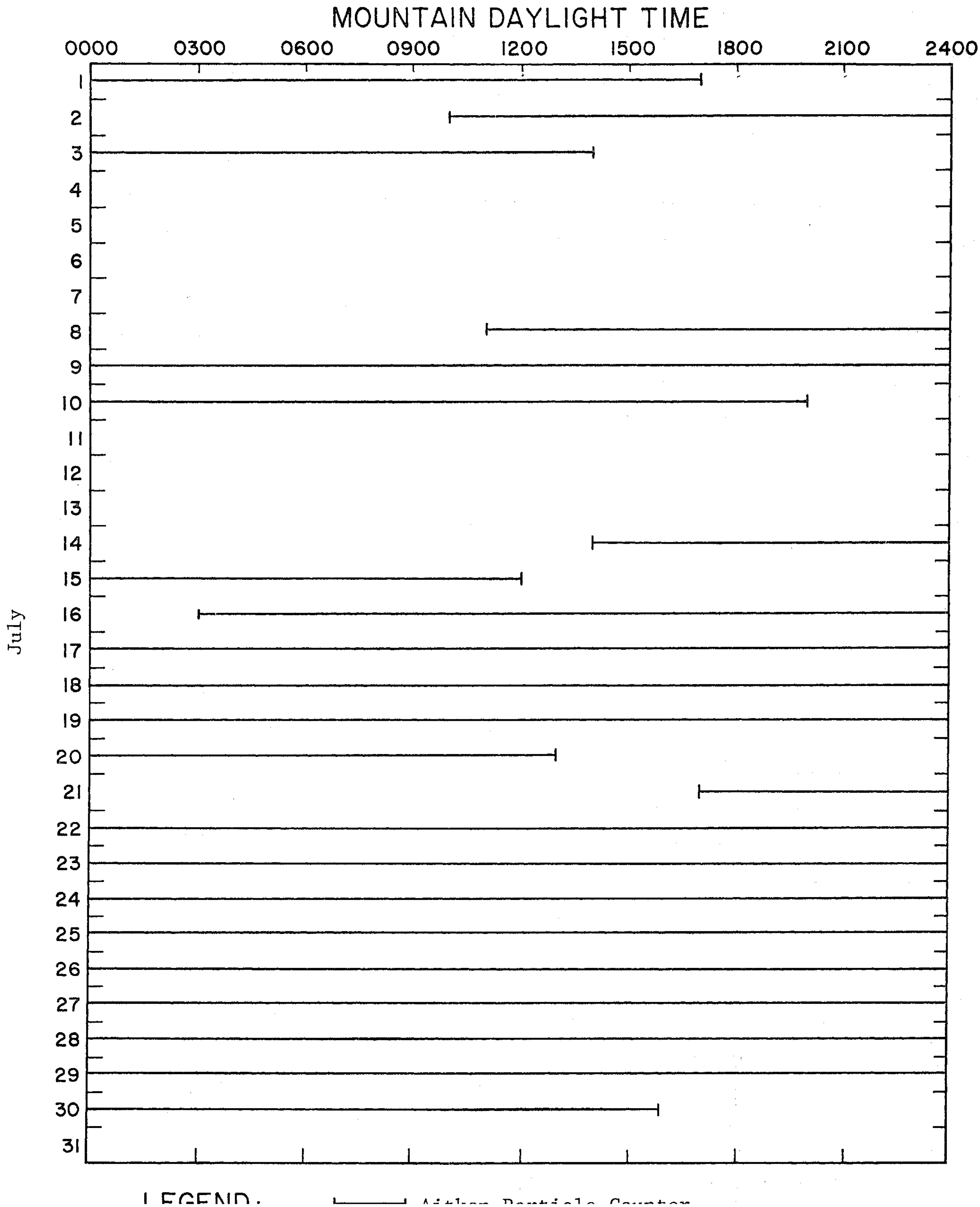


Table 42. continued

Condensation Nuclei from Allee Cloud Condensation Nucleus Counter - Chapel Ranch Site, 1976

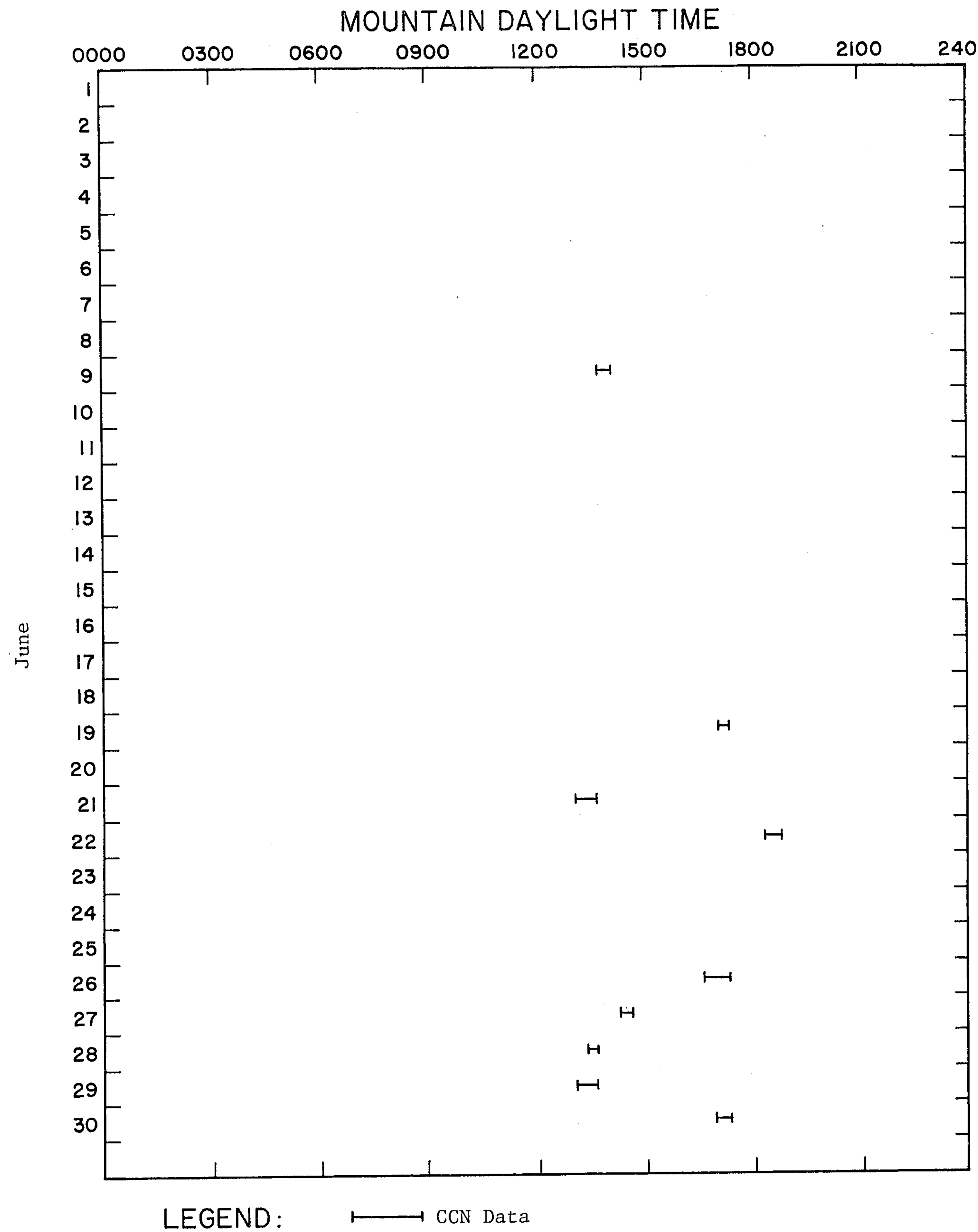


Table 42. continued
Condensation Nuclei from Allee Cloud
Condensation Necleus Counter - Chapel Ranch Site, 1976

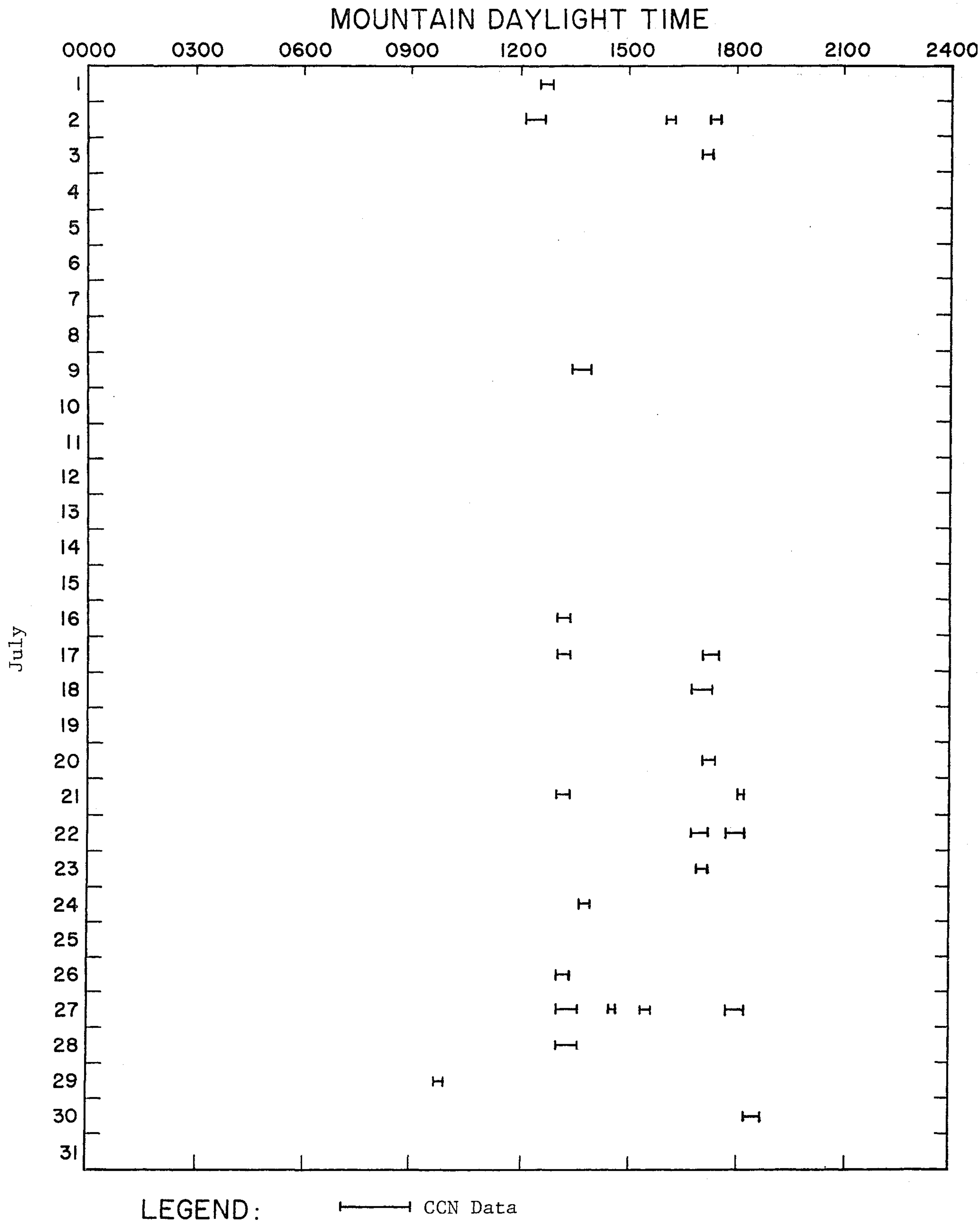


Table 42. continued

Ice Nuclei Deposited on Membrane Filters, 1976; 306D

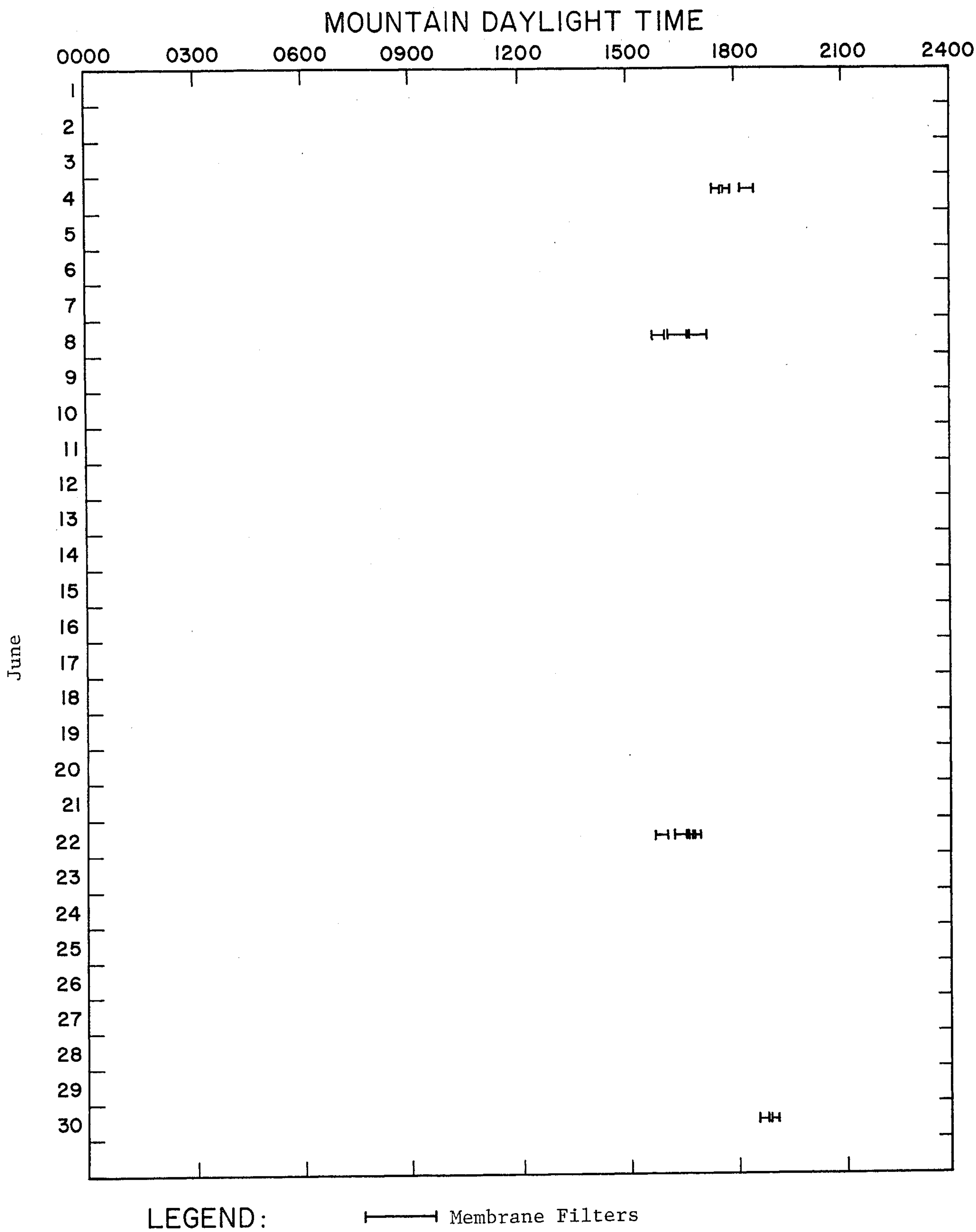


Table 42. continued

Ice Nuclei Deposited on Membrane Filters, 1976; 306D

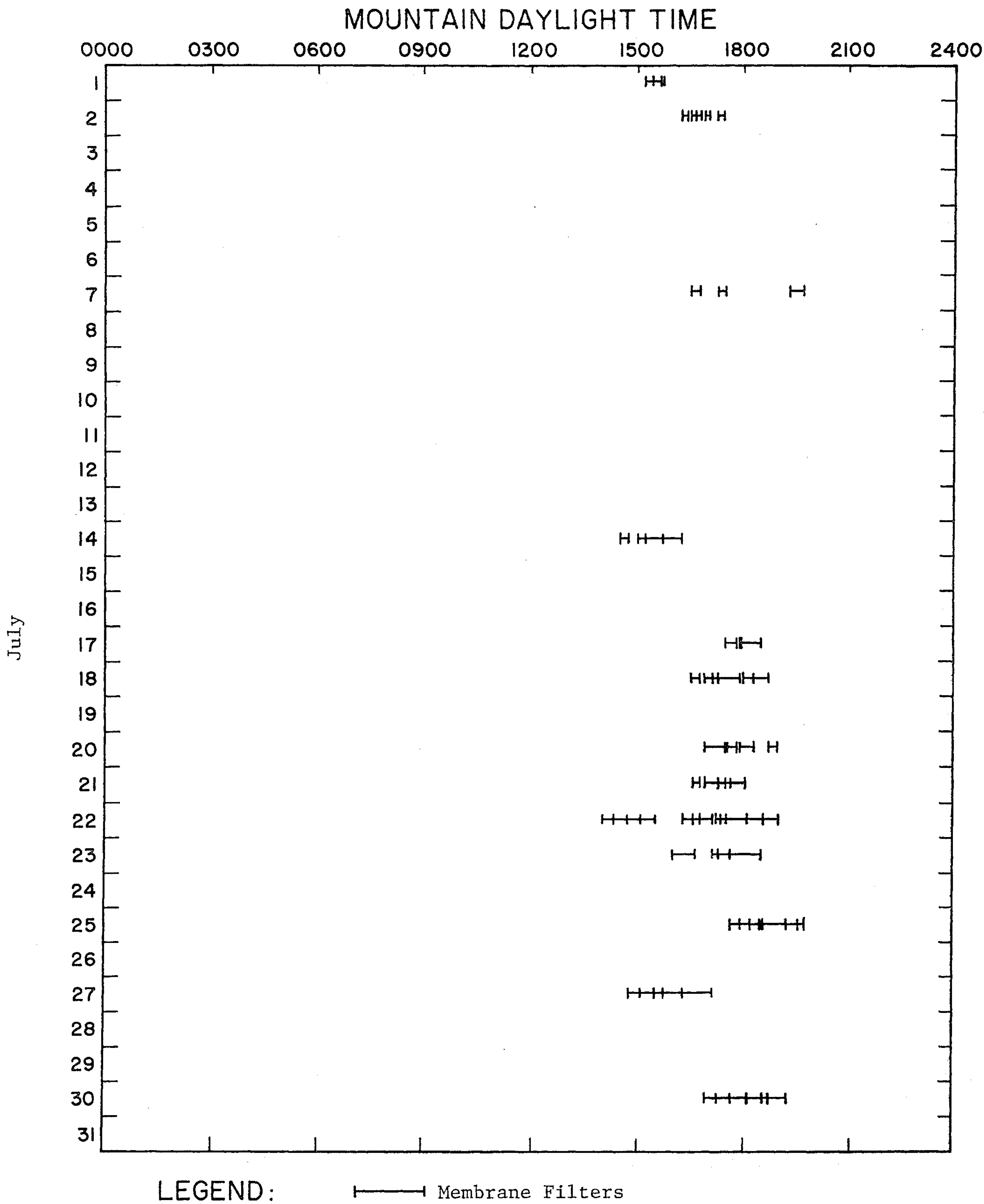


Table 42. continued

Large Particles Collected in Cyclone, 1976; 306D

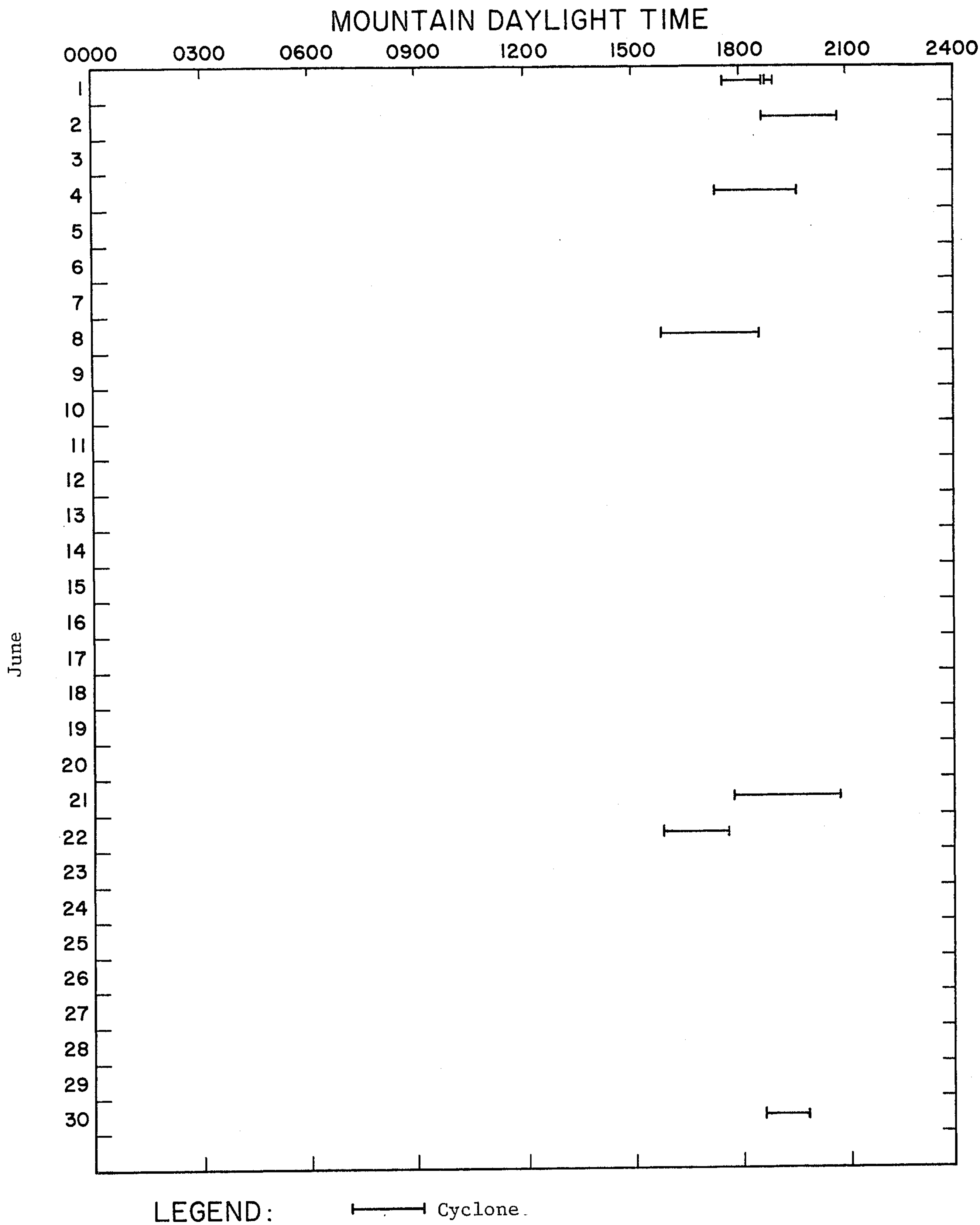


Table 42. continued

Large Particles Collected in Cyclone, 1976; 306D

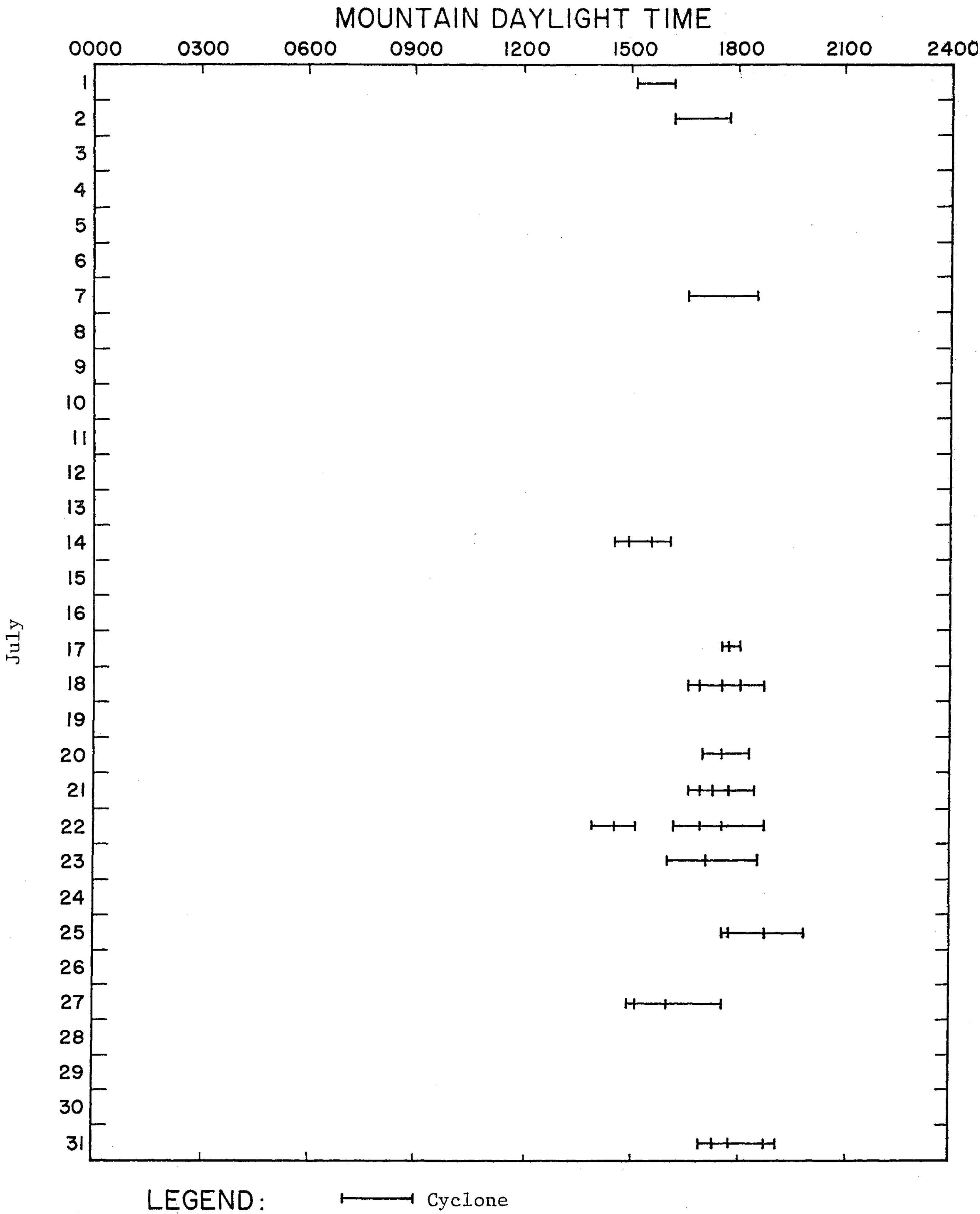


Table 42. continued

NCAR Ice Nucleus Counter and Membrane Filter Data, 1976; 304D

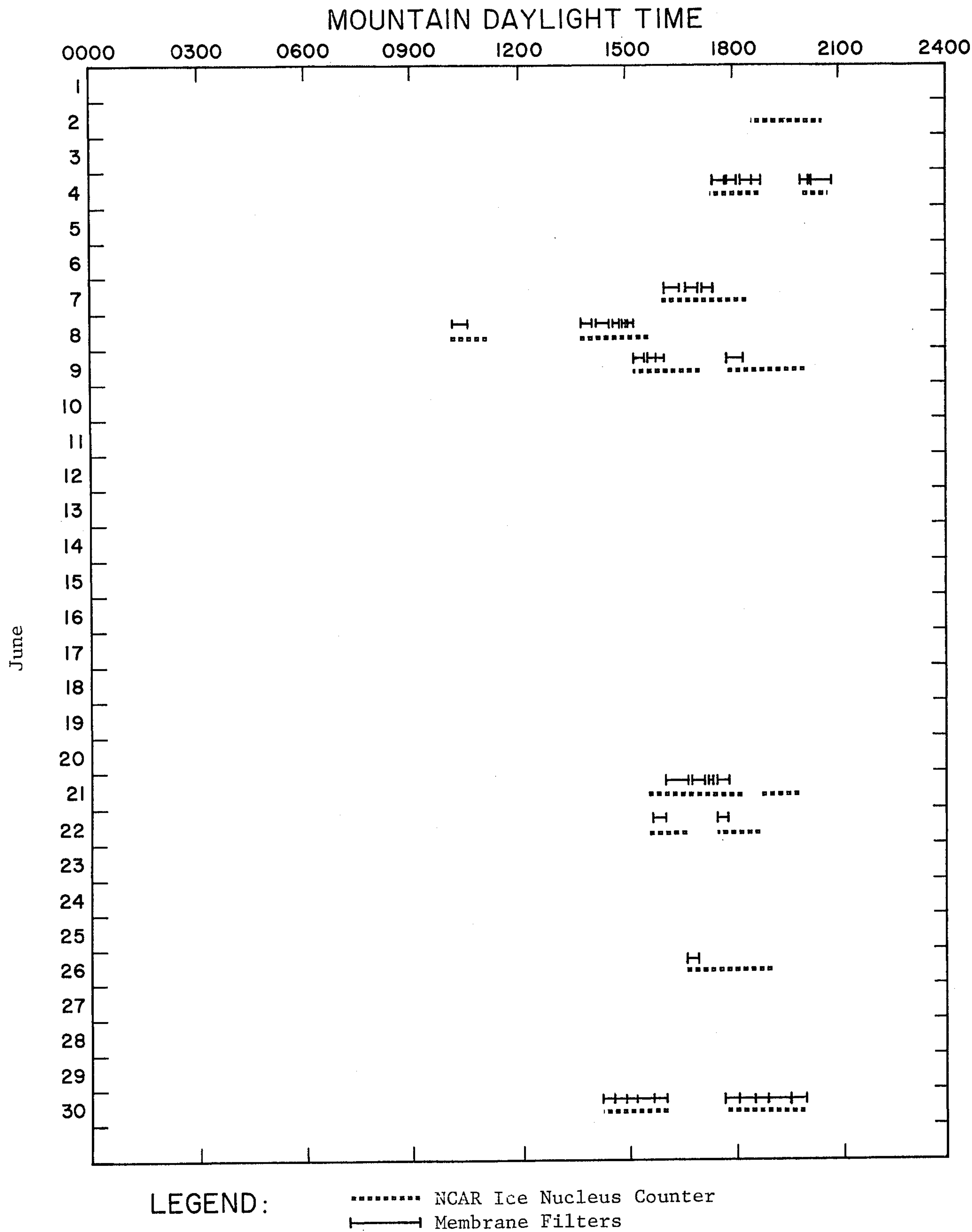
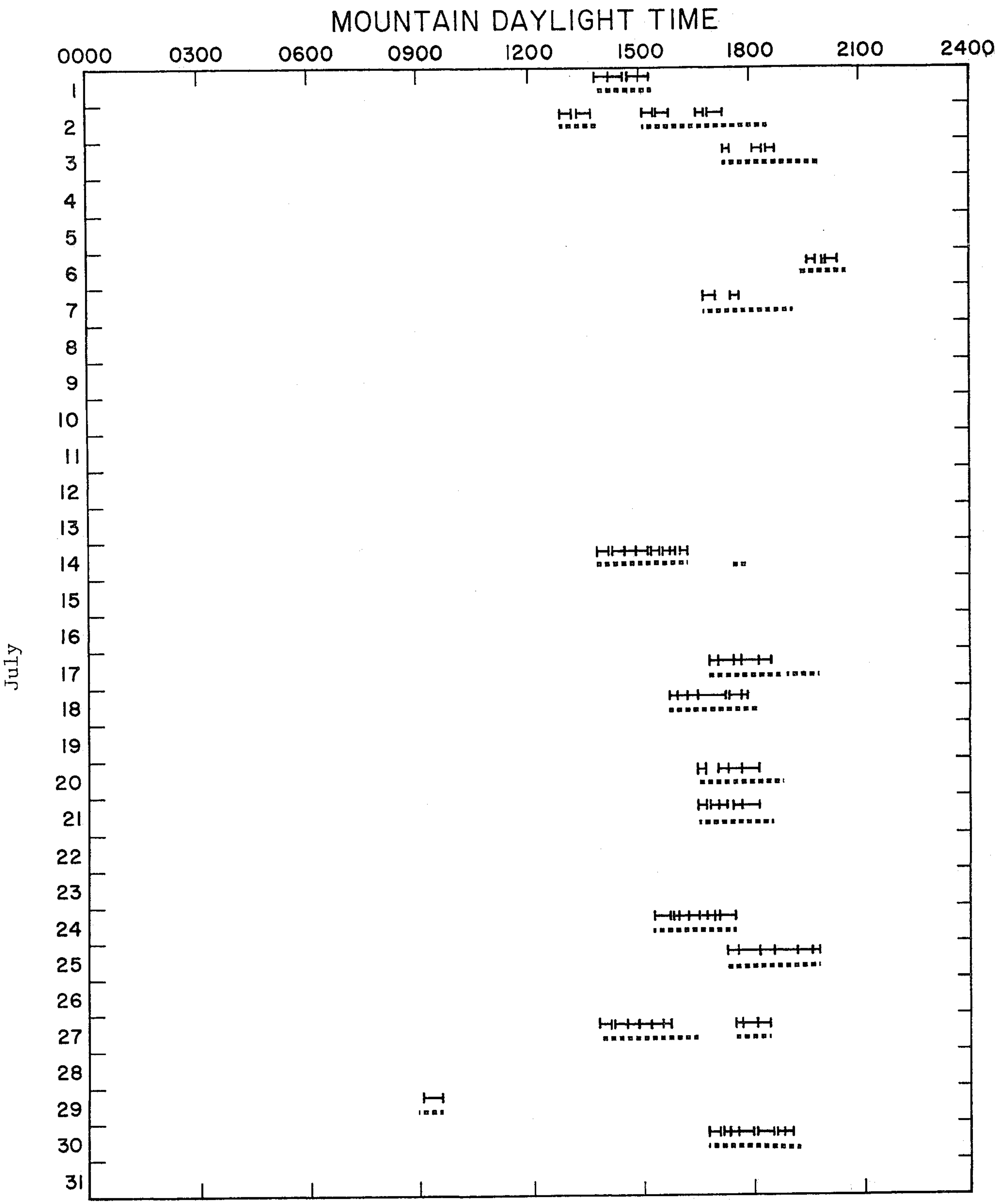


Table 42. continued

NCAR Ice Nucleus Counter and Membrane Filter
Data, 1976; 304D



LEGEND: NCAR Ice Nucleus Counter
Membrane Filters

Table 42. continued

Condensation Nuclei Using the Aitken Particle Counters, 1976 - 304D and 306D

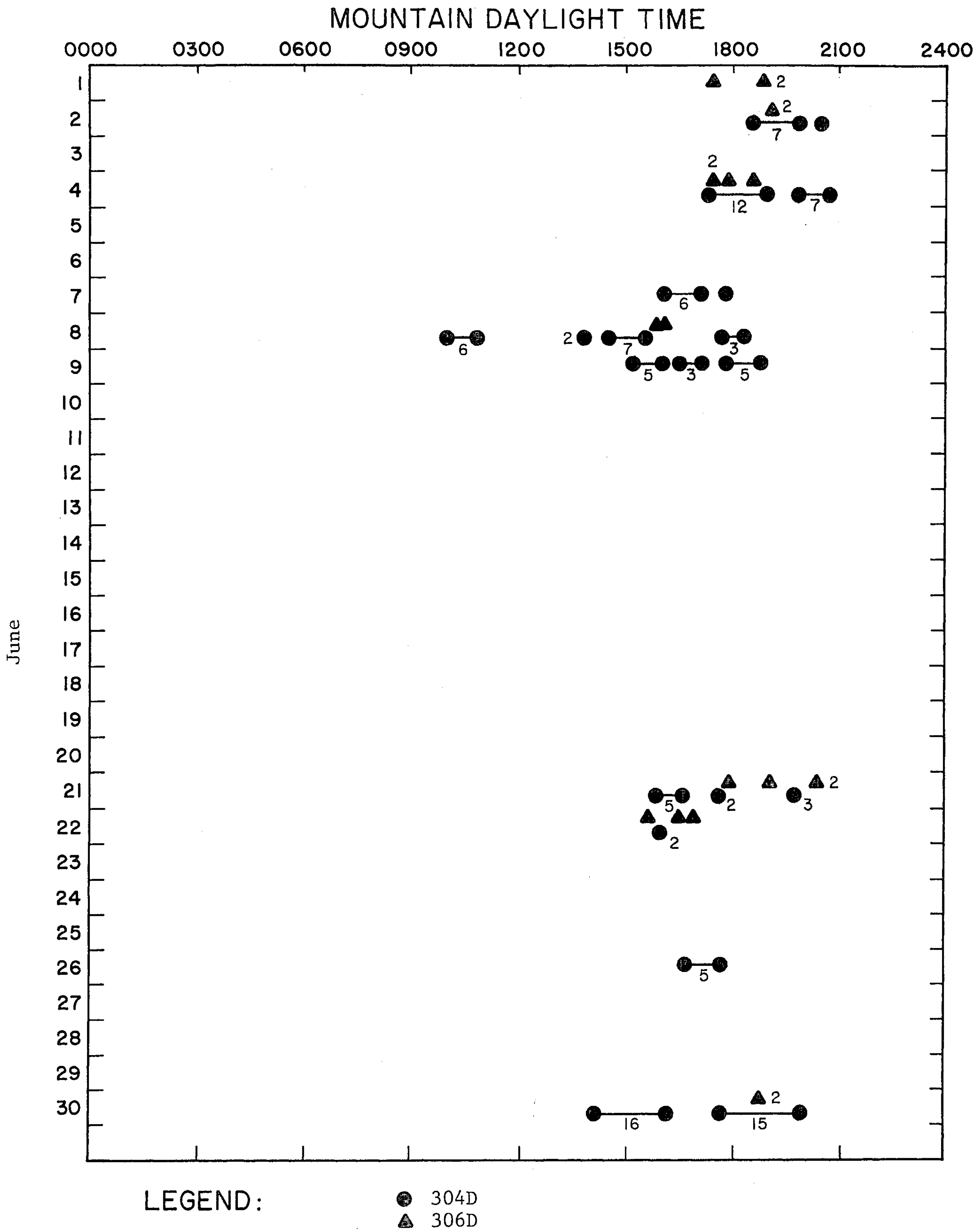


Table 4.2. continued

Condensation Nuceli Using the Aitken Particle Counters, 1976 - 304D and 306D

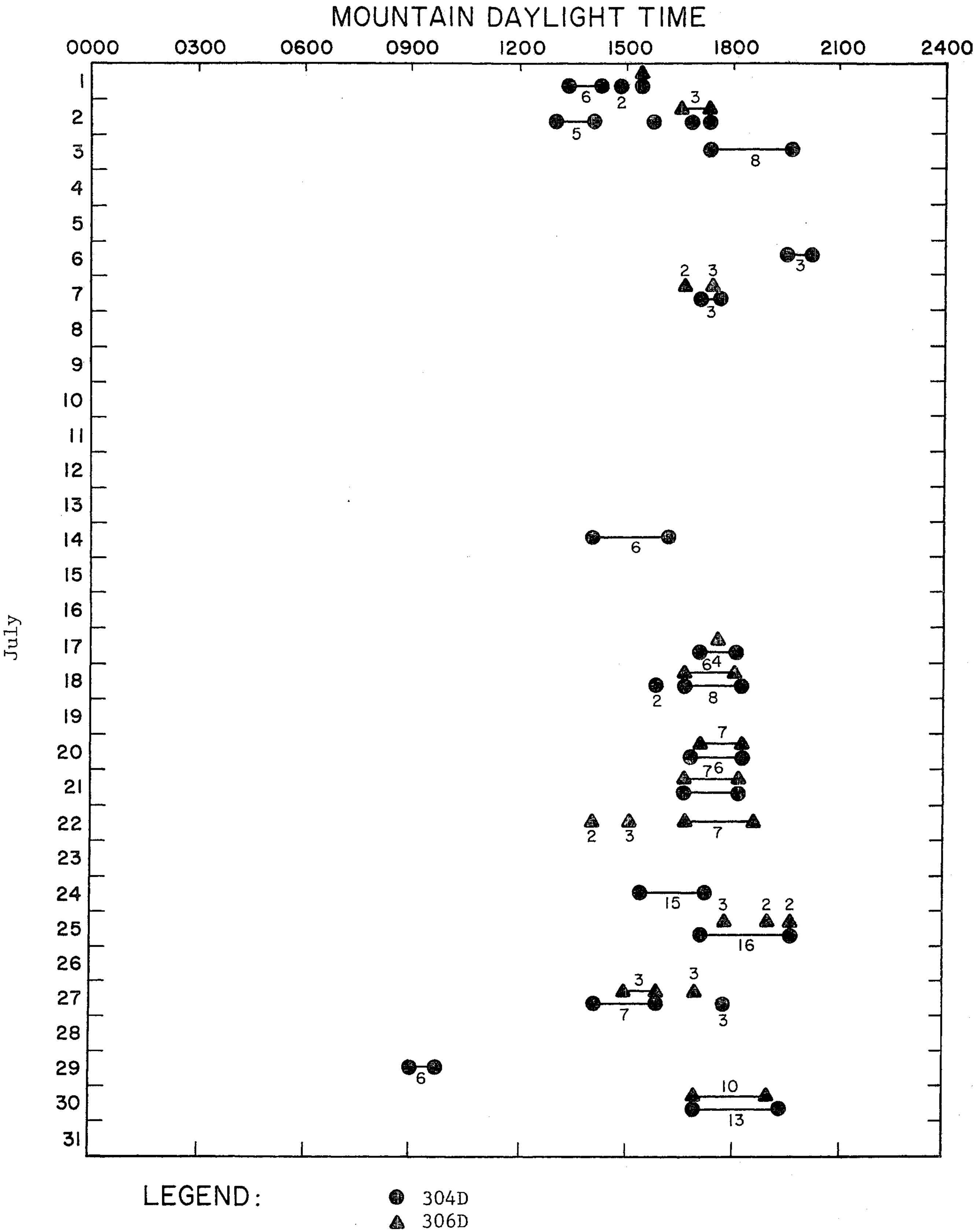


Table 42. continued

NCAR Ice Nucleus Counter and
Membrane Filter Data, 1976 - Chapel Ranch Site

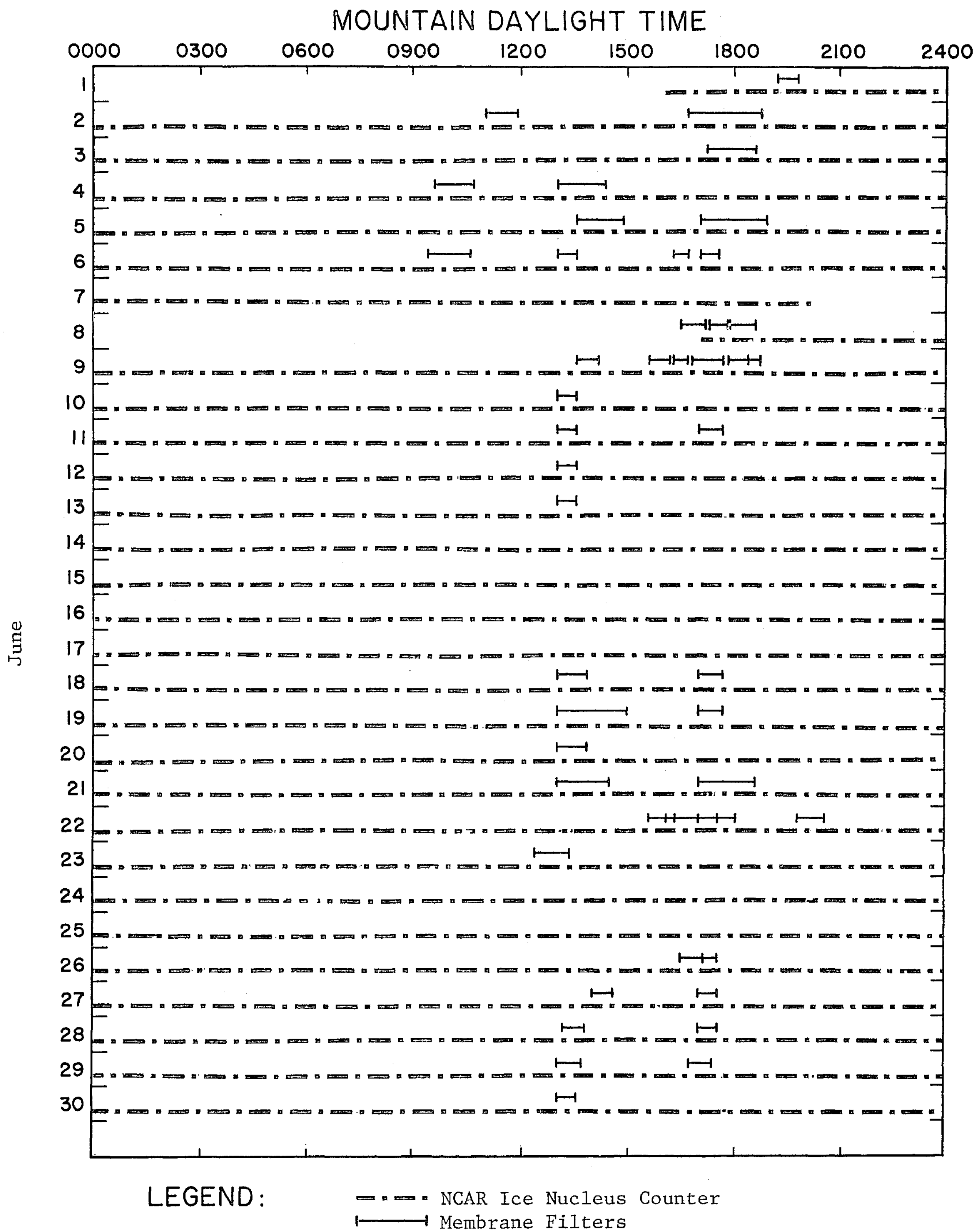


Table 42. continued

NCAR Ice Nucleus Counter and
Membrane Filter Data, 1976 - Chapel Ranch Site

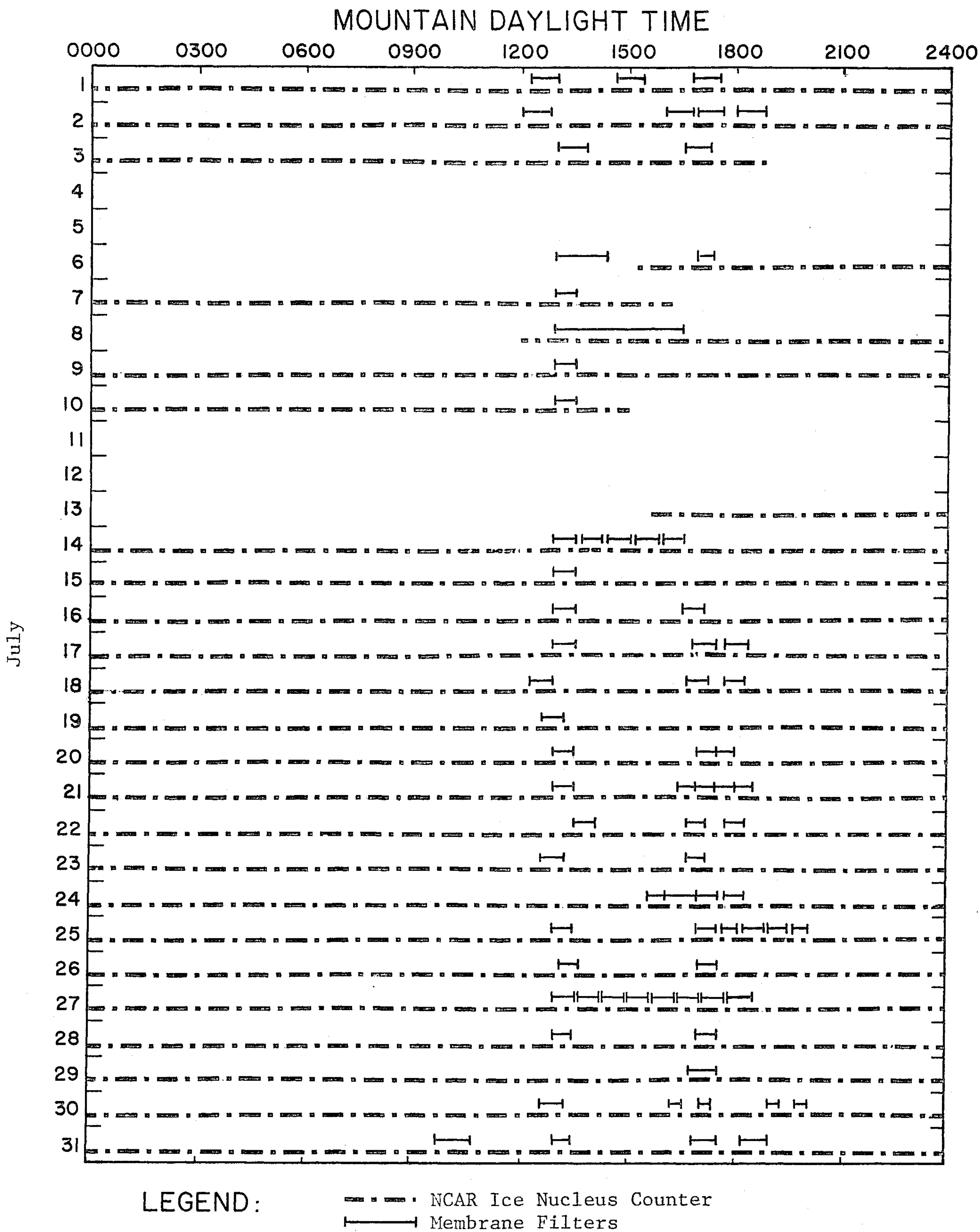
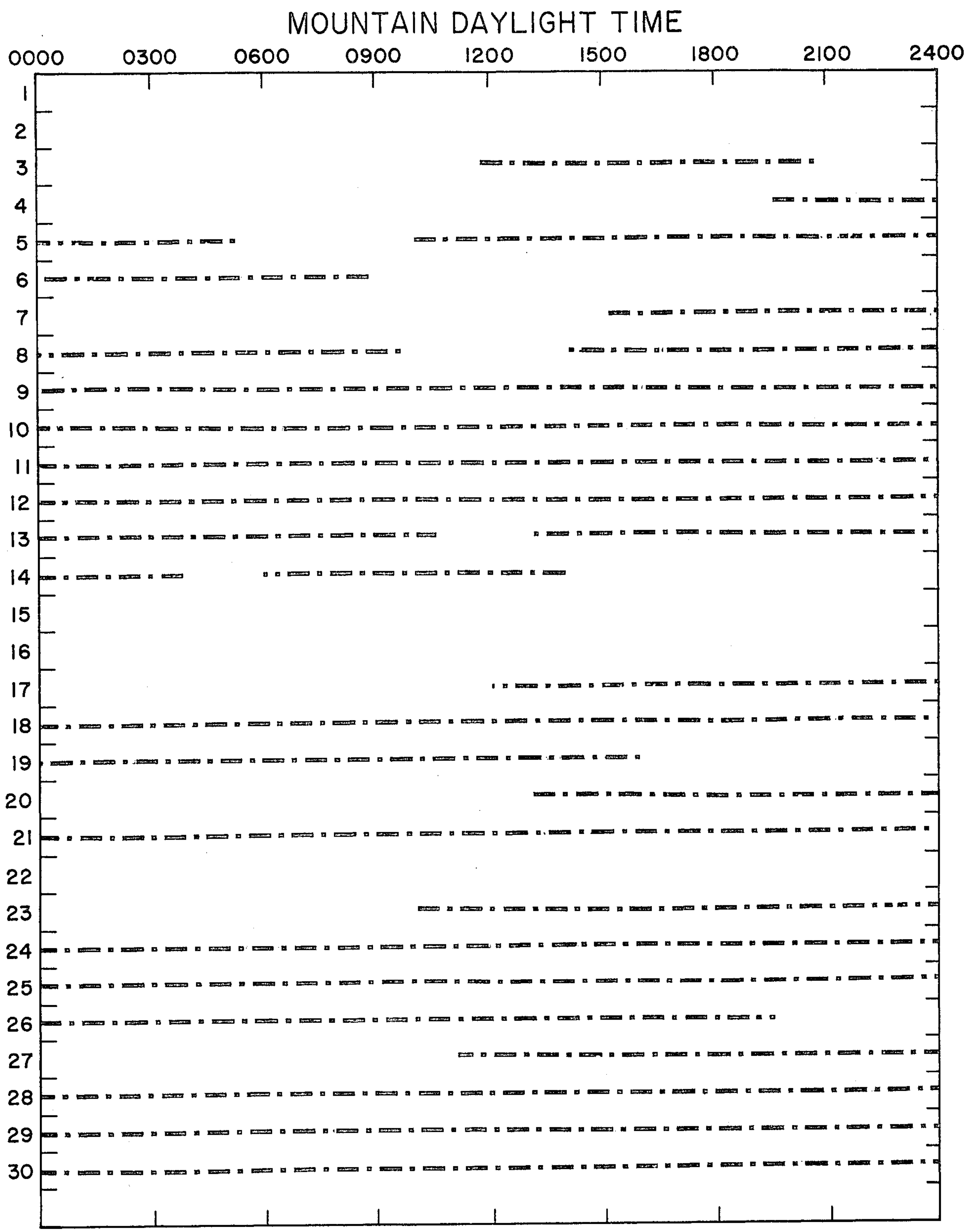


Table 42. continued

NCAR Ice Nucleus Counter Data, 1976 - Sidney, Nebraska Site



LEGEND: NCAR Ice Nucleus Counter

Table 42. continued
NCAR Ice Nucleus Counter Data, 1976
Sidney Nebraska Site

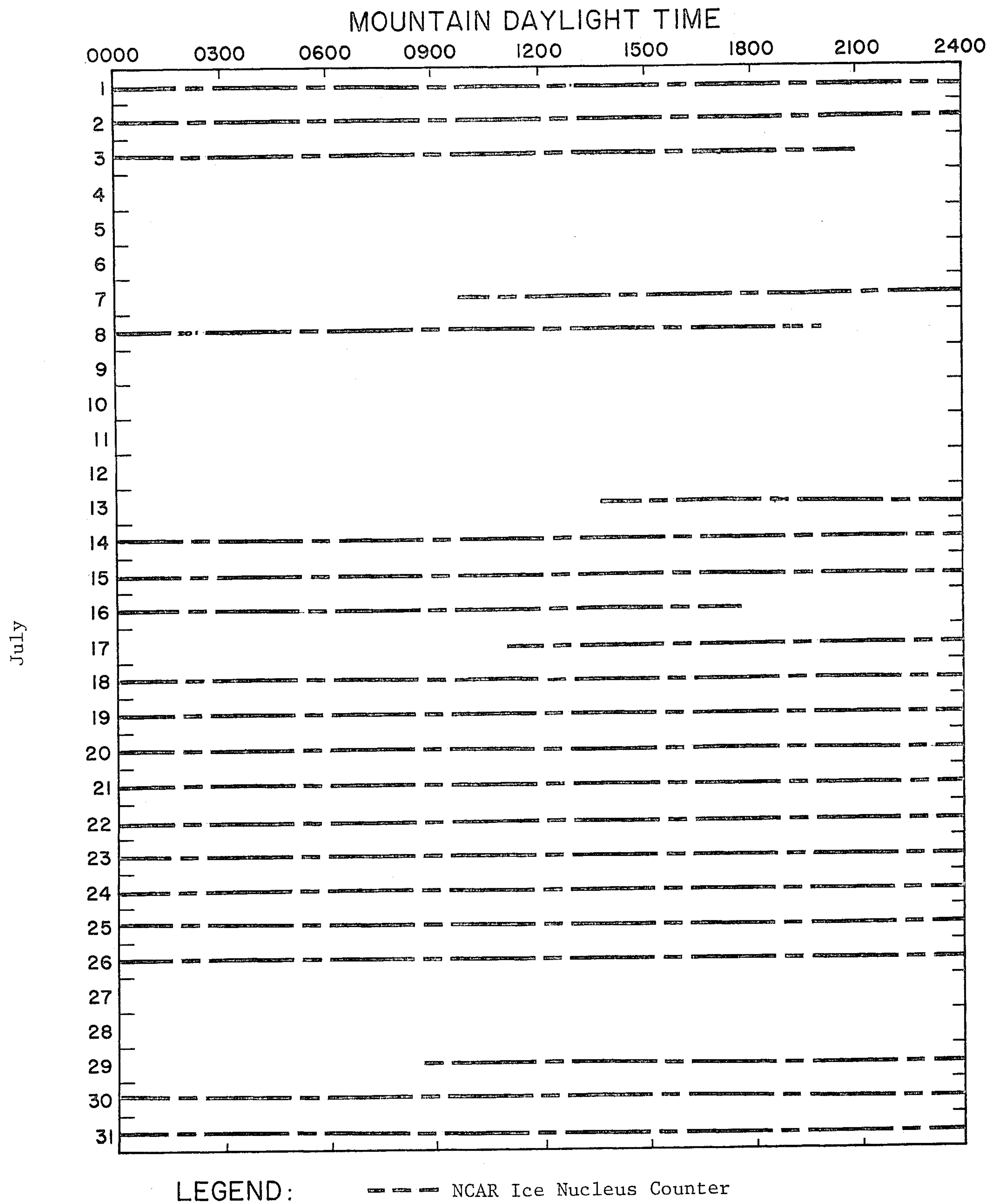
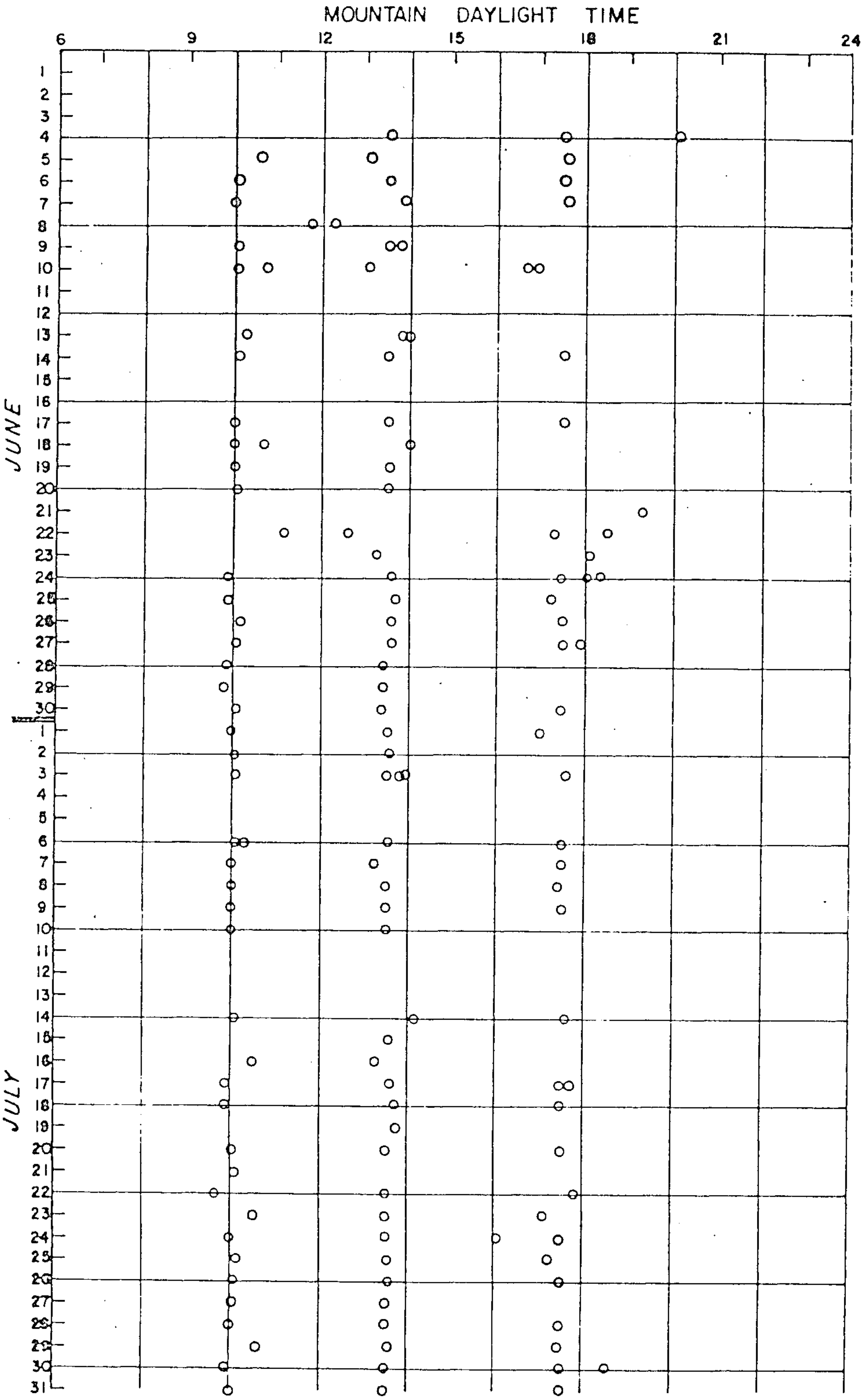


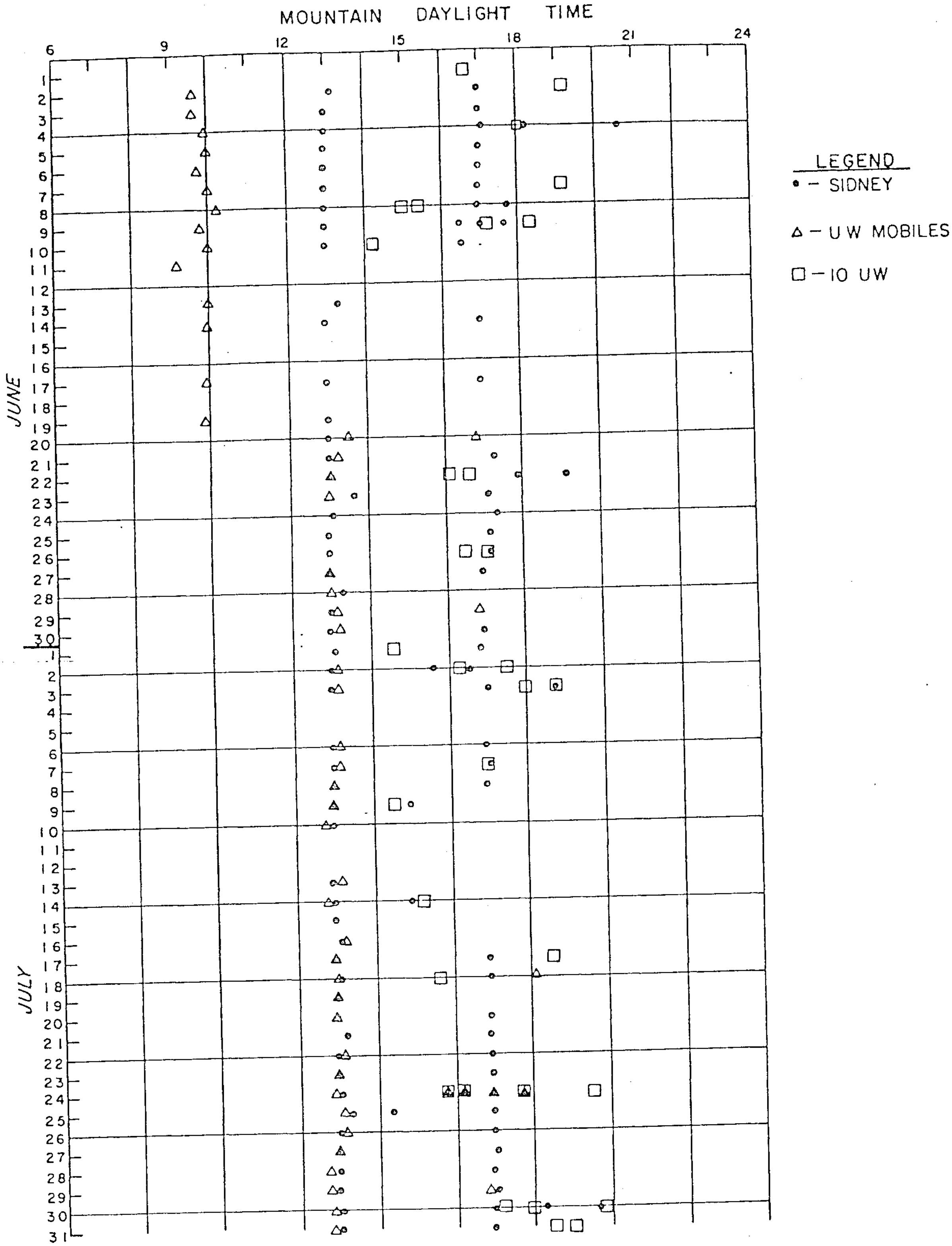
Table 43.



CCN SAMPLES-SURFACE AIR 1976

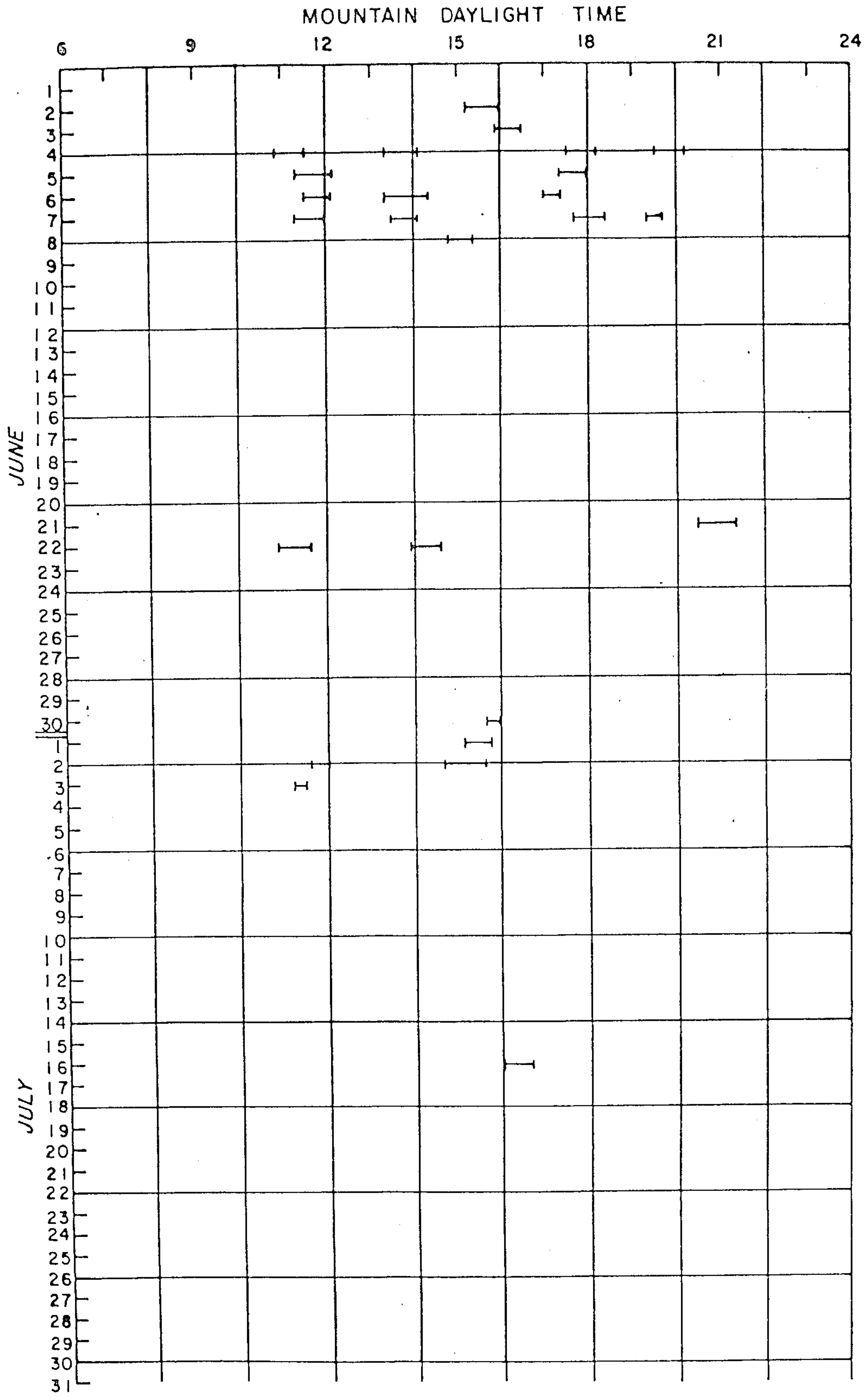
SIDNEY

Table 43. continued



MEMBRANE FILTER SAMPLES FOR
ICE NUCLEUS MEASUREMENTS 1976

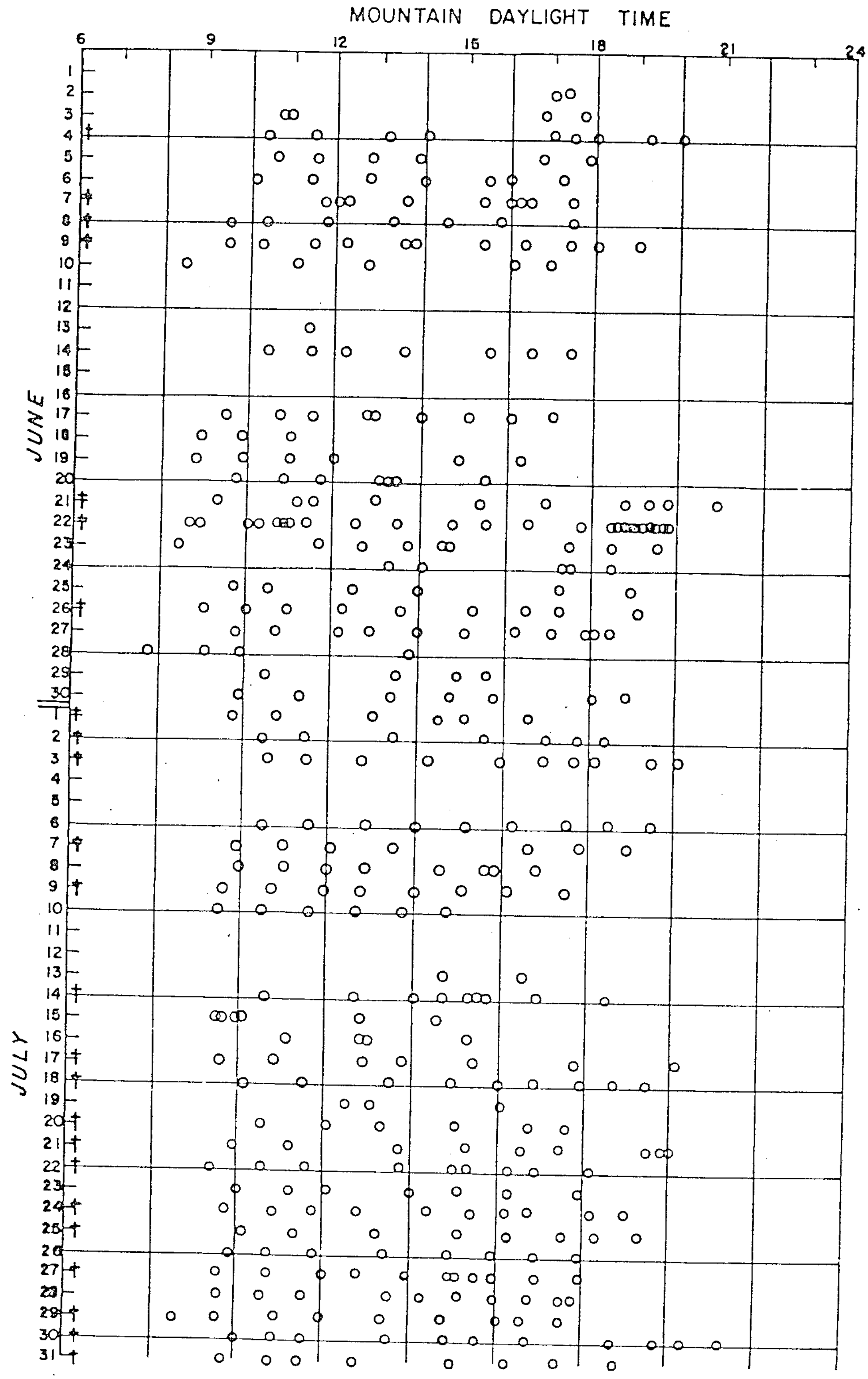
Table 43. continued



DFC OPERATION 1976

SIDNEY

Table 43. continued



AEROSOL SIZE SPECTRA 1976

SURFACE AIR

†*Aircraft bag samples were also taken on these days*

VI. DATA AVAILABILITY

The purpose of this section is to summarize the data components indicating the typical data formats and to whom the requests should be addressed. It is expected that most requests for data will be filled within a two-week period. Those requests that require additional computer processing may take longer. In this event, the person requesting the data will be notified as to when it is expected that the request can be filled. It should also be remembered that some of the more specialized data may be made available only after consultation so that the data are not employed inappropriately.

Nominal charges may be made for reproducing microfilm, magnetic tape, etc. These charges will also vary depending upon the type of data and the magnitude of the request.

Table 44.

Data Components	Typical Data Formats	Address Request To
Aircraft		
NCAR Queen Air 304D NCAR Queen Air 306D	Listing at observed and derived parameters on magnetic tape and microfilm plots as a function of time of the parameters as well as plots of aircraft tracks. A tabulation of aerosol and nucleus measurements is also available for 304D.	James Fankhauser NCAR, P. O. Box 3000 Boulder, CO 80307
NCAR Sabreliner 307D	Listing of observed and derived parameters on magnetic tape and microfilm plots as a function of time of the parameters as well as plots of aircraft tracks.	Cleon Biter NCAR, P. O. Box 3000 Boulder, CO 80307
NCAR Sailplane 29J	Microfilm plots of observed parameters. Cloud Particle Camera data on original film.	Peter Johnson NCAR, P. O. Box 3000 Boulder, CO 80307
Wyoming Queen Air 10UW	Listing of observed and derived parameters on magnetic tape and microfilm plots as a function of time of the parameters as well as plots of aircraft tracks. A tabulation of aerosol and nucleus measurements.	William A. Cooper Atmos. Sci. Dept. U. of Wyoming P. O. Box 3038, Univ. Sta. Laramie, WY 82071
SDSM&T T-28	Microfilm listings of data recorded on the PMS recording system. Data recorded on the SDSM&T system available on magnetic tape and hard copy. Cloud Particle Camera data on original film.	Paul L. Smith, Jr. Institute of Atmos. Sci. South Dakota School of Mines & Technology Rapid City, S. D. 57701
Radars		
Grover - DADS	Contoured PPI's in standard format on microfilm and copies of original magnetic data tapes. CAPPT's and vertical sections are available for selected days.	Ronald Rinehart NCAR, P. O. Box 3000 Boulder, CO 80307
Grover - MINA II	Contoured maps of S- and X-band reflectivities in standard format on microfilm are available for selected days. Copies of magnetic tapes.	Ronald Rinehart NCAR, P. O. Box 3000 Boulder, CO 80307
M33 Aircraft Track	Microfilm listing of aircraft position and plotted track. Aircraft tracks cannot be superimposed on DADS contoured PPI's.	Cleon Biter NCAR, P. O. Box 3000 Boulder, CO 80307

Table 44. continued

Data Components	Typical Data Formats	Address Request To
Radars - continued		
APTC Aircraft Track	Microfilm listing of position and plotted aircraft track.	Cleon Biter NCAR, P. O. Box 3000 Boulder, CO 80307
NOAA X-Band Dopplers and NOAA C-Band Dopplers	Mean Doppler velocities and reflectivities from each radar recorded on magnetic tape. These are combined to produce multiple Doppler velocity fields for selected case studies.	
M33 Scope Photography	Copies of original film.	Richard W. Sanborn NCAR, P. O. Box 3000 Boulder, CO 80307
Rawinsondes	Microfilm listings of data according to stations with plotted skew-T diagrams. Data also available on magnetic tapes.	Charles Wade NCAR, P. O. Box 3000 Boulder, CO 80307
Conventional Mesonet	Xerox copies of state parameters and wind data selected cases fully reduced.	James Fankhauser NCAR, P. O. Box 3000 Boulder, CO 80307
Portable Automated Mesonet (PAM)	Data available on magnetic tape; selected cases on microfilm and magnetic tape.	James Fankhauser NCAR, P. O. Box 3000 Boulder, CO 80307
Cloud Photography	Copies of original film.	Richard W. Sanborn NCAR, P. O. Box 3000 Boulder, CO 80307
Precipitation		
Belfort Gages	Digitized one-minute amounts on magnetic tape. On microfilm are available listing of one-minute amounts, reproduction of the original charts and a map of one-minute amounts and specified totals.	Alexis Long NCAR, P. O. Box 3000 Boulder, CO 80307
Wedge Gages	Daily totals on magnetic tape. On microfilm are listings of daily totals and a map of daily totals.	Alexis Long NCAR, P. O. Box 3000 Boulder, CO 80307

Table 44. continued

Data Components	Typical Data Formats	Address Request To
Precipitation - continued		
Hail/Rain Separators	Digitized hail and rain one-minute amounts will be available on magnetic tape. On microfilm will be available listings of one-minute amounts and maps of one-minute amounts and specified totals.	Alexis Long NCAR, P. O. Box 3000 Boulder, CO 80307
Hailpads	On magnetic tape will be hailstone size distributions and derived hailfall parameters, e.g., hail mass and hail K.E. for each paid and each day. This information will also be available on microfilm. Some of the derived parameters will be available in map form.	Alexis Long NCAR, P. O. Box 3000 Boulder, CO 80307
Hailcubes	For each pad from each cube there will be available on magnetic tape and microfilm the same information as available for each ordinary hailpad.	Alexis Long NCAR, P. O. Box 3000 Boulder, CO 80307
Mobiles		
NHRE Hail Chase Mobiles	Annotated hailstone photographs.	Nancy Knight NCAR, P. O. Box 3000 Boulder, CO 80307
Wyoming Mobile Meteorological Systems	Strip charts of observed parameters. Tabulations of aerosol and nucleus measurements and pilot balloon observations.	Gabor Vali, Atmos. Sci. Dept. U. of Wyoming P. O. Box 3038, U. Sta. Laramie, WY 82071
Aerosols		
NHRE Aerosol System	Tabulation of aerosol and nucleus measurements.	Gerhard Langer NCAR, P. O. Box 3000 Boulder, CO 80307
Wyoming Aerosol Systems	Tabulation of aerosol and nucleus measurements.	Gabor Vali, Atmos. Sci. Dept. U. of Wyoming P. O. Box 3038, U. Sta. Laramie, WY 82071

VII. SUMMARY

By and large the summer 1976 field program went very much according to plan. Only two meaningful deviations occurred. First, it was planned to use X-band chaff extensively in the first echo studies to gain more air flow information from the Doppler data. It was thought that X-band chaff would not contaminate the S-band reflectivity measurements, which were also a necessary part of the study. Chaff tests early in the season revealed that X-band chaff does contaminate S-band data, and plans to use the chaff were cancelled. Second, seeding trials were planned as a part of the first echo studies. The seeding was to be done with an acetone burner mounted on the towplane. This required a special towplane which unfortunately was disabled at the start of the season. Seeding could not be done from the only available replacement. Consequently, the seeding experiments were not carried out. Aside from these two aspects, the 1976 operations were remarkably close to those envisaged in writing the plan for the summer experiment.

The analysis of the 1976 data is well underway. The specific research tasks are shown in Table 45. The tasks include the analysis of data from three sources:

1) pre-1976 NHRE data emphasizing the suppression program and using the data base compiled for the Report on the Randomized Seeding Experiment and several excellent T-28 flights in 1975;

2) 1976 field data; and

3) data from other hail suppression programs.

The objective of this research, in which the 1976 data plays a major role, is the preparation of a report on the characteristics of thunderstorms studied during the National Hail Research Experiment.

References

Final Report, National Hail Research Experiment Randomized Seeding Experiment 1972-1974. December 1976. Volumes I through V.

Table 45.

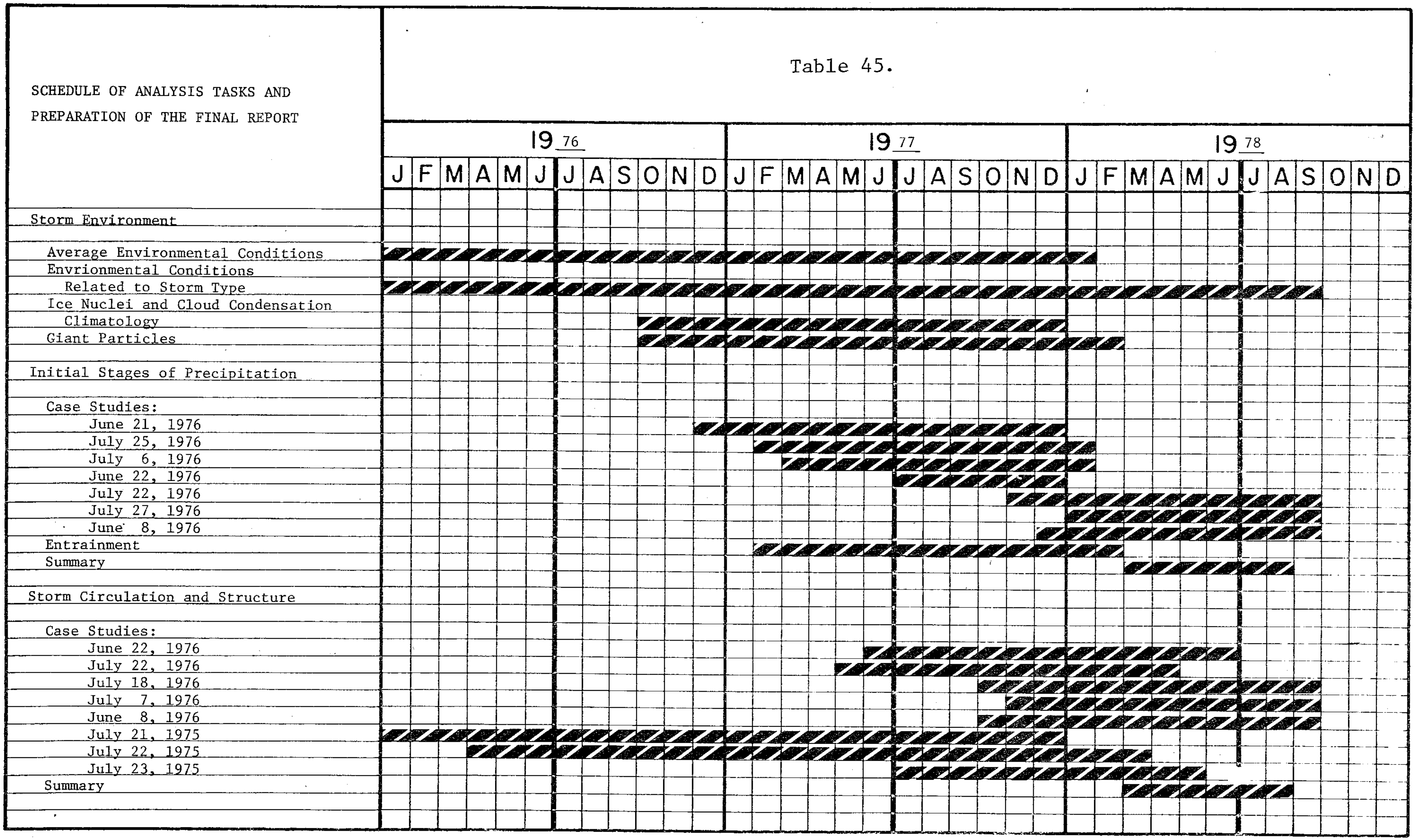
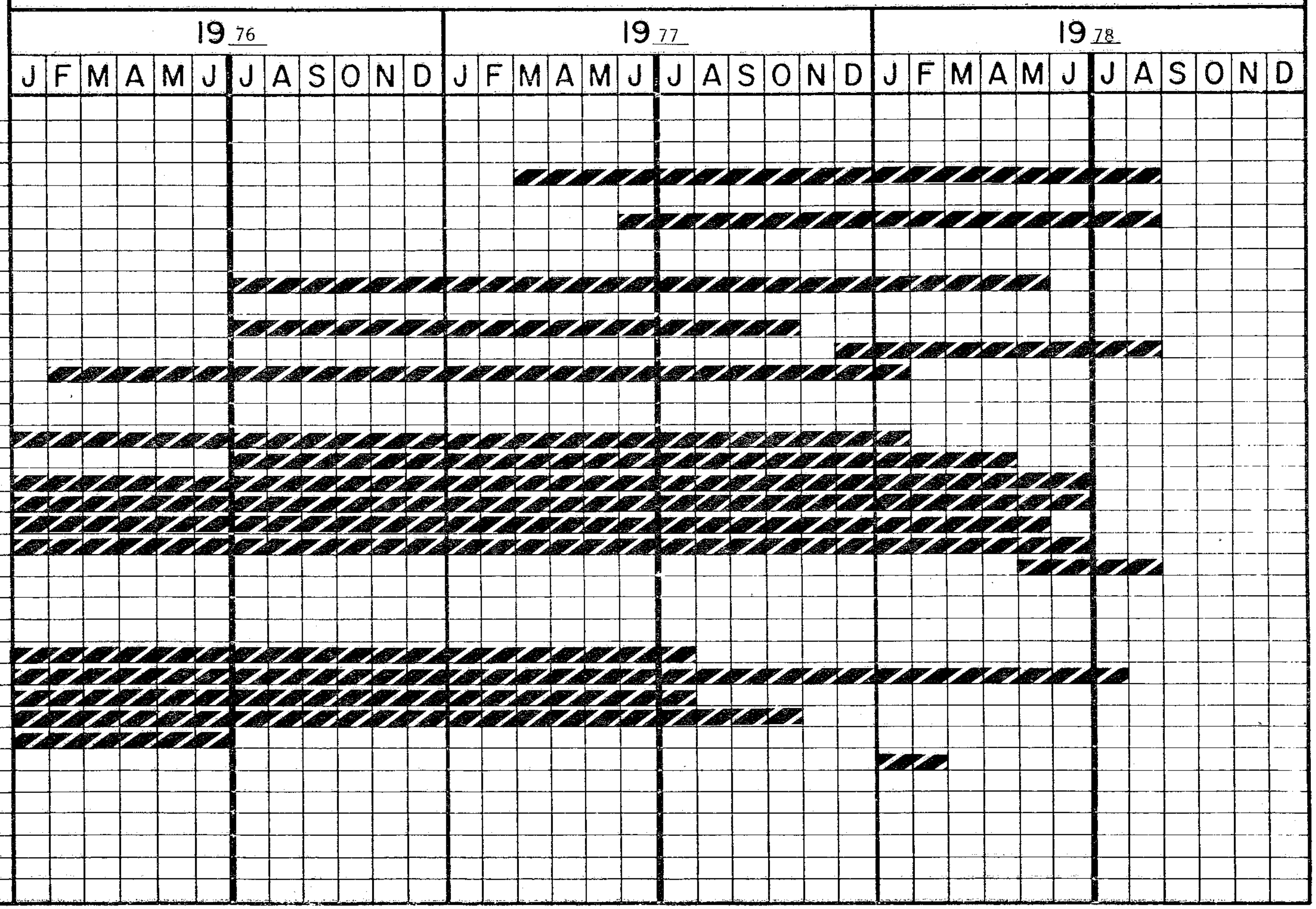

SCHEDULE OF ANALYSIS TASKS AND
PREPARATION OF THE FINAL REPORT
Table 45.
1976
1977
1978
J F M A M J J A S O N D J F M A M J J A S O N D J F M A M J J A S O N D
Storm Environment
Average Environmental Conditions
Envrionmental Conditions
Related to Storm Type
Ice Nuclei and Cloud Condensation
Climatology
Giant Particles
Initial Stages of Precipitation
Case Studies:
June 21, 1976
July 25, 1976
July 6, 1976
June 22, 1976
July 22, 1976
July 27, 1976
June 8, 1976
Entrainment
Summary
Storm Circulation and Structure
Case Studies:
June 22, 1976
July 22, 1976
July 18, 1976
July 7, 1976
June 8, 1976
July 21, 1975
July 22, 1975
July 23, 1975
Summary

Table 45. continued

SCHEDULE OF ANALYSIS TASKS AND PREPARATION OF THE FINAL REPORT



Modification of Precipitation Processes

- Update Seeding Experiment Report
- Survey of Other Hail Suppression Projects
- Results Related to the Conduct of Precipitation Modification Experiments
- Seeding Methods
  - Analysis On-top Seeding Trails
  - Recommendations
- Surface Network Design
- Covariates, Predictors and Classification Variables
  - Embryos
  - Nuclei
  - Meteorological Analysis
  - Surface Measurements
  - Radar Observations
  - Radar Detection of Hail and Rain
- Summary

Societal Aspects

- Economic Evaluation
- Hail Crop Damage
- Downwind Effects
- Ecological Effects
- Social Factors
- Summary

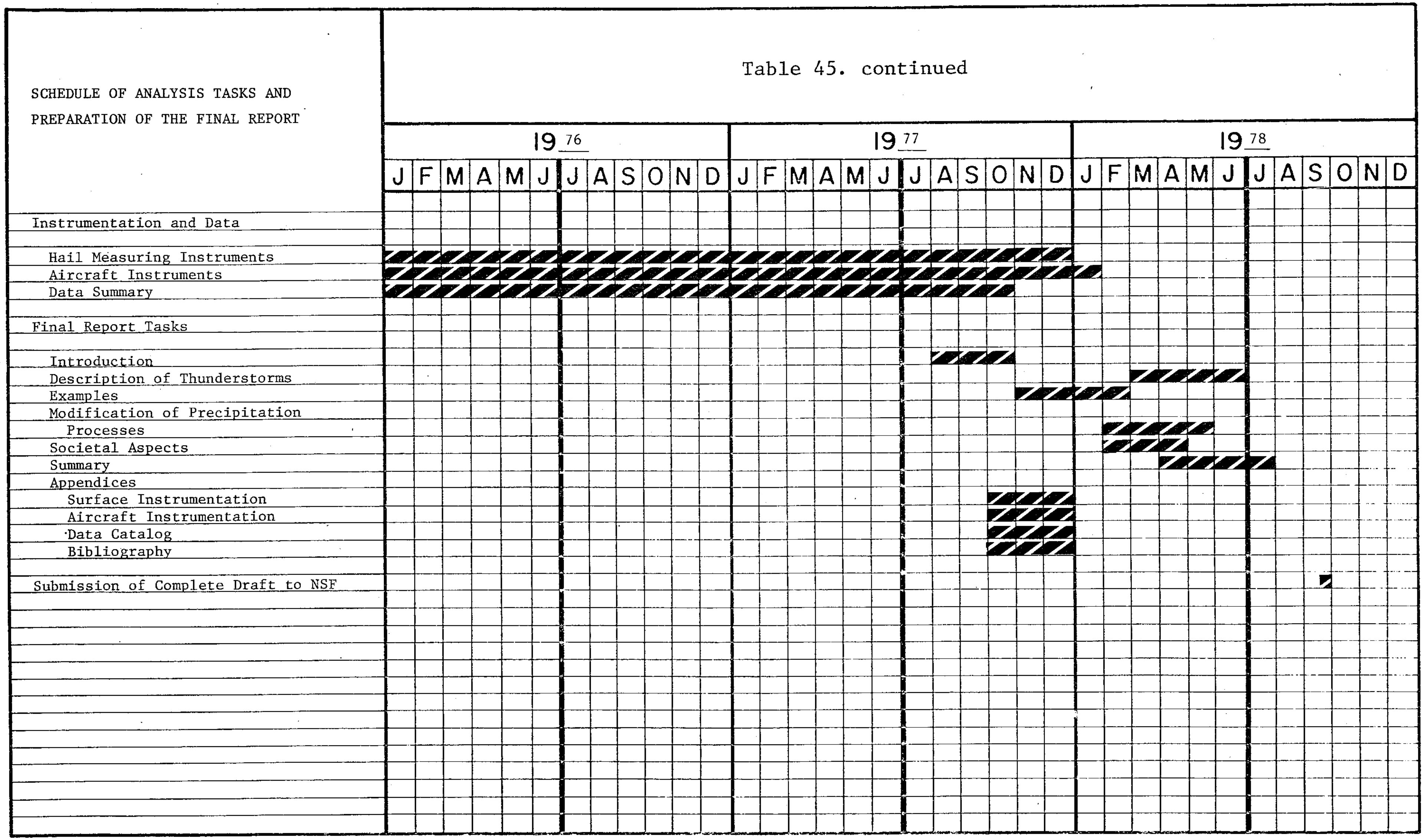


Table 45. continued
SCHEDULE OF ANALYSIS TASKS AND
PREPARATION OF THE FINAL REPORT
19 76
19 77
19 78
J F M A M J J A S O N D
J F M A M J J A S O N D
J F M A M J J A S O N D
Instrumentation and Data
Hail Measuring Instruments
Aircraft Instruments
Data Summary
Final Report Tasks
Introduction
Description of Thunderstorms
Examples
Modification of Precipitation
Processes
Societal Aspects
Summary
Appendices
Surface Instrumentation
Aircraft Instrumentation
Data Catalog
Bibliography
Submission of Complete Draft to NSF

The National Hail Research Experiment Summer 1976 Summary Report - Link Page

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