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NASA Participation in the 1980 Persistent Elevated Pollution Episode/Northeast Regional Oxidant Study (PEPE/NEROS) Project: Operational Aspects

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CONTENTS

SUMMARY

The Environmental Protection Agency (EPA) conducted an extensive study of regional-scale air pollution in the Northeastern United States from July 10 to August 15, 1980. The study was a combined Persistent Elevated Pollution Episode (PEPE)/Northeast Regional Oxidant Study (NEROS) field experiment designed to further understand the formation and transport of visibility-reducing aerosols and to characterize regional-scale air masses and urban plumes. Measurements were made in the eastern section of the country, primarily in the Ohio River Valley region. Seven Federal agencies, elements of the Canadian and French governments, and numerous state organizations, universities, and contractors participated in the field experiment. Headquarters for the field experiment were located in Columbus, Ohio, and Baltimore, Maryland. The National Aeronautics and Space Administration (NASA) participation included obtaining measurements for the determination of mixing-layer height and ozone (O_3) profiles, primarily by using airborne remote sensor systems. These systems included the Ultraviolet Differential Absorption Lidar, the High Spectral Resolution Lidar, and the Laser Absorption Spectrometer. Other NASA systems consisted of the Microwave Atmospheric Remote Sensor, tethered balloons, an aircraft for making in situ measurements, and several photometer/transmissometer systems.

Contained in this report are a discussion of NASA's involvement in the field experiment, a description of the sensors employed, and a summary of the operational data for the various NASA systems. The report does not contain measurement data from the study.

INTRODUCTION

From July 10 to August 15, 1980, NASA participated in a study sponsored by the EPA to investigate regional-scale air pollution in the Ohio River Valley and other sections of the Eastern United States. This study was a combination of the Persistent Elevated Pollution Episode (PEPE) and Northeast Regional Oxidant Study (NEROS) experiments, with field headquarters located in Columbus, Ohio, and Baltimore, Maryland. NASA and EPA have a Memorandum of Understanding that provides NASA the opportunity to apply its remote sensing technology to the EPA-sponsored PEPE and NEROS experiments. The PEPE experiment focused on the formation and transport of visibility-reducing aerosols, and the NEROS experiment addressed regional-scale air-mass and urban-plume characterization with emphasis on model applications. Seven Federal agencies, participants from France and Canada, and numerous state organizations, universities, and contractors participated in the field experiment. Over 100 scientists, engineers, and technicians working with 12 aircraft and 12 surface systems were involved.

The principal role of NASA in the PEPE/NEROS experiment was to use NASA-developed remote sensing techniques to provide measurements for the determination of mixing-layer height and ozone (O_3) profiles on a regional scale. Participation in the program also provided an opportunity for further development,

testing, and evaluation of several "emerging" NASA airborne remote sensor systems. These systems were the Ultraviolet Differential Absorption Lidar (UV DIAL) and the High Spectral Resolution Lidar (HSRL), both flown aboard a Lockheed 188A Electra airplane, and the Laser Absorption Spectrometer (LAS), flown aboard a Beechcraft B80 Queen Air airplane. In situ correlative measurements for these systems were obtained by using a Cessna 402 airplane. Other NASA systems deployed during the study period were the Microwave Atmospheric Remote Sensor (MARS), two instrumented tethered balloons, and an array of photometers/ transmissometers.

The PEPE and NEROS experiment areas are shown in figure 1. Based on statistical meteorological data, the prolonged residence (1 to 2 days) of warm, moist air over a significant portion of the Northeastern United States would lead to a substantial accumulation of air pollutants during the period from mid-July to mid-August. Thus, this region was selected for study at this time.

This report documents NASA's involvement in the field study, including a brief description of the NASA sensor systems employed as well as the times and places of deployment. Discussion of non-NASA systems is not included.

Persistent Elevated Pollution Episode

The PEPE program was managed by the Regional Field Studies Office of the EPA Environmental Sciences Research Lab at Research Triangle Park, North Carolina. The 1980 PEPE experiment focused on the formation and transport of visibility-reducing aerosols, primarily in the Ohio River Valley with its high concentration of electric power plants burning fossil fuels. These power plants, along with the numerous other industries located in the region, emit huge quantities of sulfur dioxide (SO_2) and other gases into the atmosphere. These gases are believed to be major precursors in the formation of sulfate and nitrate aerosols which in turn are major components of the visibility-reducing hazes observed in the Northeastern United States during the summer months. A key element of the PEPE project was following a specific air mass for a period of several days (Lagrangian measurements) to provide data for mechanism studies as the pollutants in a moving air mass age and mix with freshly emitted pollutants along the path followed.

Northeast Regional Oxidant Study

The NEROS program was managed by the Meteorology Division of the EPA Environmental Sciences Research Lab at Research Triangle Park, North Carolina. The NEROS experiment was comprised of several separate studies to investigate characteristics of regional-scale air masses and urban plumes with emphasis on providing a data base for validation of EPA's regional oxidant model. Both Eulerian and Lagrangian studies were performed near Columbus, Ohio, and Baltimore, Maryland, in some cases involving the remnants of PEPE air masses as they migrated across the northeast corridor.

Participants

In addition to EPA and NASA, other major participants in the field experiment included the National Oceanic and Atmospheric Administration, Federal Aviation Administration, Tennessee Valley Authority, National Science Foundation, National Center for Atmospheric Research, Argonne National Laboratory, and the Canadian Ministry of the Environment. The role of each organization is discussed in reference 1. Several universities also participated in the field experiment and are involved in data interpretation and analysis. These include Ohio State University (OSU), the University of Minnesota, Washington University at St. Louis, the University of Washington, the New York University Medical Center, the University of Wisconsin, and Harvey Mudd College. Data analyses and scientific results are the responsibility of the individual investigators and are not discussed in this report.

NASA Participation

The major NASA commitment involved obtaining measurements for the determination of atmospheric mixing-layer height and O_3 profiles. In addition, this intensive field experiment program provided a vehicle for further development, testing, and evaluation of several emerging NASA remote sensor systems for future user-agency applications. These systems were the Langley Research Center (LaRC) Ultraviolet Differential Absorption Lidar (UV DIAL), University of Wisconsin High Spectral Resolution Lidar (HSRL), and the Jet Propulsion Laboratory (JPL) Laser Absorption Spectrometer (LAS). The UV DIAL and HSRL were flown aboard the Wallops Flight Center (WFC) Electra airplane and the LAS on the JPL Queen Air airplane. Correlative measurements for these systems were obtained using a Cessna 402 airplane instrumented with in situ sensors.

Other NASA sensors deployed during the field experiment were 12 photometer/transmissometer systems from the Goddard Space Flight Center (GSFC) and the University of Miami, the JPL ground-based Microwave Atmospheric Remote Sensor (MARS), and two LaRC tethered-balloon instrumentation systems. A brief description of these systems and their performance is included.

NASA field activities were coordinated by a project team from the LaRC Environmental Field Measurements Branch.

ACRONYMS AND SYMBOLS

CO_2	carbon dioxide
CRT	cathode ray tube
EDT	eastern daylight time
EPA	Environmental Protection Agency
GMT	Greenwich mean time

GSFC	Goddard Space Flight Center
GOES	Geostationary Operational Environmental Satellite
HSRL	High Spectral Resolution Lidar
JPL	Jet Propulsion Laboratory
LaRC	Langley Research Center
LAS	Laser Absorption Spectrometer
MARS	Microwave Atmospheric Remote Sensor
NASA	National Aeronautics and Space Administration
NASA 402	Cessna 402 airplane (under contract to LaRC)
NEROS	Northeast Regional Oxidant Study
N_2	nitrogen
NO_x	nitrogen oxide
OSU	Ohio State University
O_3	ozone
PEPE	Persistent Elevated Pollution Episode
PEPSIOS	Polyetalon Pressure Scanned Interferometric Optical Spectrometer
SCAMS	Scanning Microwave Spectrometer
SO_2	sulfur dioxide
UV	ultraviolet
UV DIAL	Ultraviolet Differential Absorption Lidar
VOR	VHF omnidirectional range
VTP	vertical temperature profile
WFC	Wallops Flight Center

FIELD OPERATIONS AND MISSION RESULTS

Field Operations

The nominal regions of interest for the combined field experiments are shown in figure 1. Field headquarters for the PEPE experiment was located on the campus of Ohio State University (OSU) in Columbus, Ohio. Dual field headquarters for NEROS were at Columbus, Ohio, and Baltimore, Maryland. Aircraft operations were centered at Don Scott Field, the OSU airport. Over 100 scientists, engineers, technicians, and support personnel representing the previously named organizations and their contractors were involved during peak measurement operations. Remote and in situ sensors aboard 12 airborne platforms and 12 fixed and/or mobile surface platforms were used. Field activities were directed by a contractor team headed by Environmental Measurements Incorporated and included Aerovironment, Inc., SRI International, and Washington University Technology Associates.

NASA field operations were coordinated by a LaRC project team stationed at the PEPE/NEROS field headquarters at OSU. (See fig. 2.) The long endurance (greater than 6 hr) and high cruising speed (170 to 330 knots) of the WFC Lockheed 188A Electra airplane, which contained the UV DIAL and HSRL remote sensors, permitted it to remain stationed at the WFC airport at Wallops Island, Virginia, rather than at the OSU airport where the other project aircraft were stationed. The JPL Beechcraft B80 Queen Air airplane (containing the LAS) was stationed at the OSU airport. The LaRC Cessna 402 airplane was stationed at the OSU airport from July 10 to July 26 and at the LaRC airport (Langley Air Force Base, Hampton, Virginia) for the remainder of the field experiment. All three airplanes were equipped with transceivers for direct communication among the principal investigators aboard each aircraft and with the field headquarters at OSU.

The two NASA tethered-balloon systems, which provided measurements of O_3 and particulates as well as meteorological parameters, were located at Croton, Ohio (a rural community approximately 56 km northeast of Columbus) and at the U.S. Army Proving Grounds in Aberdeen, Maryland. The JPL Microwave Atmospheric Remote Sensor (MARS) was located at the same site in Croton, Ohio. Finally, the GSFC photometer/transmissometer systems were positioned at nine locations across the Eastern United States.

Each of the seven major NASA scientific instrument systems used in the PEPE/NEROS experiment and the remote sensor aircraft platforms are briefly described. A schedule summarizing system participation is shown in figure 3. A list of personnel to contact for further information specific to a particular system is given after the appendixes. In the section entitled "Mission Results" the operational performance of each sensor system is discussed.

Remote sensor aircraft.- The UV DIAL and HSRL were flow aboard the WFC Electra airplane. This airplane has an airspeed range of 170 to 330 knots and a nominal endurance of 6 hr. Maximum altitude is 7600 m and minimum level altitudes are 150 m over water and 300 m over land. Maximum payload weight is 4500 kg. Payload space within the cabin is 16.8 m long by 2.2 m high by 2.5 m wide. Power available is 115 V, 3-phase, 400-cycle ac, with a maximum of 50 kW.

The JPL Queen Air airplane, which carried the LAS, has a sampling airspeed of 115 to 170 knots and a maximum endurance of 5 hr. Maximum sampling altitude is 3000 m. Minimum altitude is a function of sensor and safety requirements. Power available is 300 A at 28 V dc.

UV DIAL.- The airborne UV DIAL system consists of two frequency-doubled Nd:YAG lasers optically pumping two high-efficiency dye lasers which are in turn frequency doubled into the ultraviolet. The output of the pulsed dye lasers is tuned about an absorption line of the species (O_3, SO_2, or aerosol) of interest. The backscattered return signals are collected by a telescope, detected by photomultiplier tubes, digitized, and stored on high-speed magnetic tape. The UV DIAL data acquisition system provides real-time calculation of gas concentration profiles via a minicomputer which retrieves the digitized return signal from a high-speed magnetic-tape unit. A more complete description of the UV DIAL system is contained in reference 2.

HSRL.- The HSRL system was developed by the University of Wisconsin under contract to LaRC for the remote measurement of the optical properties of atmospheric aerosols. Specifically, the system measures the spatial distribution of the extinction coefficient by distinguishing the laser backscatter of aerosols from that of air.

The system is of the optically pumped oscillator/amplified dye-laser design. A superradiant nitrogen (N_2) UV laser operating at 337.1 nm is used to optically pump a dye laser which is beamed into the atmosphere. Backscatter is analyzed with a high-resolution, two-channel Fabry-Perot polyetalon spectrometer through a receiver telescope. One channel detects photons scattered by the aerosols and the other detects the spectrally broadened scatter from air (based on Doppler shifts). Suppression of solar background light is achieved with the Polyetalon Pressure Scanned Interferometer Optical Spectrometer (PEPSIOS). Interferometers are used to meet the spectral-resolution and flux-handling requirements of the receiver. The system has its own auxiliary light sources for alignment and calibration purposes. The associated data-acquisition system consists of a minicomputer, digital magnetic tape, floppy disk, and real-time graphic display screen with the necessary interactive software monitoring packages.

During operation, range-resolved measurements of optical-extinction cross section, scattering ratios, and the scattering phase function are obtained without additional assumptions when a temperature profile is known. Previously conducted evaluation test flights have provided continuous profiles of molecular- and aerosol-scattering properties from the Earth's surface to 1 km below the 4-km flight altitude.

LAS.- The LAS measures the vertical burden of O_3 between the aircraft and the ground. The LAS contains two CO_2 lasers, one on a strong absorption line of O_3 and the other on a weak line, both within the 9.5-um spectral region. Ozone burdens are determined by using Beer's law for an absorbing medium and the ratio of the laser power backscattered from the ground at the two wavelengths detected with heterodyne detection techniques. The LAS is currently capable of measuring ozone burdens with an accuracy of about 20 ppb-km and with a horizontal resolution of about 1 km. Vertical profiles can also be determined to some

extent by flying at several altitudes over the same flight track. Details of LAS operation and performance may be found in reference 3.

In situ aircraft measurements.- The purpose of the NASA in situ sensor aircraft during the PEPE/NEROS experiment was to provide correlative in situ data in support of the three NASA remote sensors (UV DIAL, HSRL, and LAS) being flown aboard other aircraft. The in situ sensor aircraft is a light, twin-engine Cessna 402 airplane chartered by LaRC and outfitted by NASA for air-quality measurements. The airplane has been in operation since 1974 and has been used in various NASA air-quality projects (refs. 4 and 5). Details of the airplane, its sampling systems, associated laboratory-instrument test programs, and instrumentation are available from references 4, 6, 7, and 8. For the PEPE/NEROS field experiment the primary aircraft measurements (and methods used to take them) were O_3 concentrations (chemiluminescence technique), light-scattering coefficients β_{scat} (nephelometer), air temperature (resistance probe), dew-point temperature (cooled-mirror technique), and flight parameters of altitude, heading, airspeed, and time. All instrumentation was calibrated using approved EPA or National Bureau of Standards procedures. The ozone instrument and nephelometer were audited on July 12, 1980, by the EPA PEPE/NEROS audit team and were within acceptable limits. Ozone and β_{scat} data are generally accurate to within 10 percent absolute (based on calibration), with a repeatability of 2 to 3 percent.

All data onboard the airplane were recorded continuously on magnetic tape. The magnetic tape was digitized and processed in the Langley Computer Complex. Further processing was done with a minicomputer, and data were reported as 10-s averages. The flight crew for each mission consisted of the pilot, a flight coordinator/principal investigator, and an instrument operator. Flight characteristics of the airplane during data collection were a forward flight speed of about 135 knots, ascent and descent rates of less than 150 m/min, and a flight time of 3 hr.

Tethered balloons.- Langley Research Center provided measurements of meteorological parameters and ozone profiles from instrumented tethered balloons at two sites: Aberdeen, Maryland, and Croton, Ohio. At the Maryland site, an instrumented balloon approximately 100 m^3 in volume, 12.2 m long, and 4.3 m in diameter with a payload-lift capability of 34.0 kg was used to obtain data at altitudes up to 1500 m.

The balloon at the Ohio site was approximately 4 m^3 in volume, 3.0 m long, and 1.2 m in diameter with a payload-lift capability of 2.3 kg. This balloon was used to obtain data at altitudes up to 900 m.

MARS.- The JPL mobile MARS system is a passive-microwave radiometer mounted on the roof of a van suitable for field operations. The instrument was used to infer the vertical temperature profile (VTP) of the Earth's tropospheric boundary layer based on measurements of the thermal emissions of atmospheric oxygen, water vapor, and liquid water.

The sensor system consists of two dual-channel sensor modules (similar to the Nimbus 6 Scanning Microwave Spectrometer (SCAMS)) reconfigured for 53.85/55.45-GHz and 22.20/31.60-GHz operation and combined with a 57.50-GHz single-

frequency angle scanning sensor. The MARS unit was controlled by a desk-top calculator and drove a video cathode ray tube (CRT) display for real-time viewing of VTP's. The unit was capable of providing data for 12 hr unattended. Measurements taken directly or inferred and parameters accessible through retrieval algorithms included mixing-layer thickness, potential temperature contrast of the overlying inversion layer, precipitable water vapor, and cloud liquid-water content, obtainable in both humid and overcast conditions.

Photometers/transmissometers.- As part of the satellite imagery studies at NASA Goddard Space Flight Center, Sun-scan photometers developed at the University of Miami were used to measure direct solar transmission and thereby obtain the total atmospheric aerosol optical thickness. These measurements were made with 12 instruments located at nine stations across the Eastern United States. The locations were: Columbus, Ohio; Pennsylvania State University at University Park, Pennsylvania; West Thornton, New Hampshire; GSFC, Greenbelt, Maryland; Albany, New York; Chicago, Illinois; Woods Hole Oceanographic Institute, Woods Hole, Massachusetts; Bedford, Massachusetts; and Miami, Florida.

Each photometer is similar to a photographic exposure meter with a very narrow viewing angle. Each has four spectral bands centered at 380 nm, 500 nm, 875 nm, and 945 nm. A silicon chip detects the incident energy as an observer scans the Sun with the photometer. A series of observations takes less than 1 min.

Measurements of aerosol optical thickness were made with an automated Sun-tracking transmissometer at the GSFC site. This unit has eight spectral bands within a range of 440.0 to 871.7 nm. Readout was manual and a series of observations through the eight bands took approximately 1 min.

Mission Results

Specific mission planning was done on a day-by-day basis at the field headquarters in Columbus. A NASA project-team coordinator was in residence at the field headquarters throughout the field-operations period and acted as the principal interface between the NASA project team and the EPA PEPE/NEROS experiment-team leaders.

Each day the principal participants or their representatives met and analyzed the meteorological forecast for the next day. A mission strategy was formulated using National Weather Service 24- and 48-hr predictions, data, maps, GOES imagery, the known presence (or absence) of pollutants, and the scientific objectives of interest. The participants were informed of the nominal mission scenario and the corresponding deployment schedule for each sensor. Participants were also informed as plans changed or delays occurred. In some cases, a mission was aimed at several scientific objectives and, when conditions dictated, multiple missions were carried out in a single day. Occasionally, multiple flights were necessary to accomplish a given mission.

A log containing a day-by-day account of NASA-related activities and the major events of each day of the experiment is included in appendix A.

The dates when the NASA sensor systems participated in the PEPE/NEROS field experiment are shown in figure 3. Supplementary information such as daily weather maps and satellite images for each day of the experiment are contained in figures B1 to B68 in appendix B. The voluminous amounts of data obtained are currently being analyzed by the various principal investigators who individually have the responsibility of publishing the results. The following is a brief discussion of sensor performance.

UV DIAL.- The UV DIAL was flown aboard the Electra airplane for 14 separate flights constituting 16 missions during the field experiment. Eleven missions were PEPE related and five were classified as NEROS missions. (Note from fig. 3 that the Aug. 5 and 7 flights had dual missions.) The Electra, which also contained the HSRL, logged 65 hr in support of the PEPE/NEROS experiment. Electra flight take-off and landing times are shown in the following table:

Date of flight	Electra flight times, EDT, for -	
	Take-off	Landing
July 18	1015	1440
July 24	1030	1530
July 25	0930	1410
July 31	1200	1620
July 31	2120	[a]0120
Aug. 2	0700	1300
Aug. 5	0920	1405
Aug. 7	1715	2220
Aug. 9	0505	1120
Aug. 10	0530	1050
Aug. 12	0605	1210
Aug. 13	1055	1430
Aug. 13	1510	1845
Aug. 13	2100	[b]0100

[a]Aug. 1.
[b]Aug. 14.

The flight data are tabulated in appendix C. Flight paths for each flight are shown in appendix C also. The UV DIAL provided high-spatial-resolution measurements of tropospheric O_3 (32 hr of data) and aerosols (42.5 hr of data) from which mixing-layer height can be determined.

HSRL.- The HSRL was also aboard the Electra during the 16 missions corresponding to the 65 hr of Electra flight time. The HSRL made aerosol measurements during 15 of those missions (18.5 hr of data). Again, the flight data and paths are presented in appendix C.

LAS.- The JPL LAS flying aboard the JPL Queen Air logged 16.5 hr of flight measurements during 3 weeks of participation in the field experiment. (See appendix D for tabulated flight data and a map of flight locations.) The major limiting factor to additional flight time was poor weather, which resulted in a limited number of missions being scheduled.

In situ aircraft measurements.- The purpose of the Cessna 402 airborne in situ sensor measurements was to provide correlative data for the remote sensors. Flight plans for the in situ sensor aircraft were designed specifically to obtain data at a point or along a short flight leg (20 to 40 km) as the remote sensor (flying in a PEPE/NEROS mission) overflew the correlative test area. In situ sensor data for most missions were in the altitude range of 150 to 2500 m (subject to flight restrictions). Appendix E gives the flight details associated with the various in situ measurement aircraft missions in tabular form. Also, the position of the in situ correlative measurements is indicated on the Electra flight-path plots included in appendix C (shown as a hatched area). A total of 20 hr of sampling were conducted, 4 hr in support of the LAS and 16 hr in support of the UV DIAL and HSRL sensors.

A problem did develop with the NASA system which supplies power to the instruments on the Cessna 402. The system incorporates four inverters which convert the aircraft 28-V dc to 110-V, 60-cycle ac. On July 17, an inverter failed. The failure resulted in an alternate aircraft being substituted for the NASA Cessna 402 on the July 18 mission. Subsequently, a rental inverter was obtained and installed, but on August 2 other inverter failures occurred. At that time a decision was made to disconnect the SO_2/NO_x instruments and all Cessna 402 missions thereafter collected only ozone and particulate data. This decision was based on the fact that the SO_2/NO_x measurements were incidental to the primary correlative-data measurements of O_3 and β_{scat}, and thus none of the principal measurement objectives were jeopardized.

Tethered balloons.- The 100-m^3-volume instrumented balloon located at Aberdeen, Maryland, was used to measure and record altitude, O_3 concentration, wet- and dry-bulb temperatures, wind speed and direction, and particle size from the Earth's surface to 1200 m and back. The ascent/descent rate was approximately 30 to 45 m/min.

Initially there was no facility available to house this balloon. On July 16, after operations were complete and the balloon was securely tied down, the system was subjected to a violent thunderstorm with swirling winds. A tail strut broke and punctured the balloon, resulting in the loss of data from July 17 to 23. A backup balloon having a ceiling of 1500 m was used from July 24 to August 7 and arrangements were made to house the balloon during future periods of hazardous weather. A total of 34 launchings resulted in 68 vertical meteorological and aerosol-size-distribution data profiles at the Aberdeen site. Table F1 in appendix F contains a summary of the tethered-balloon flight data at this site.

At the Croton site, the 4-m^3-volume balloon provided altitude, O_3 concentration, wet- and dry-bulb temperatures, and wind speed and direction data taken from July 16 to August 9. A total of 86 launchings yielded 157 profiles. The Croton tethered-balloon flight data are summarized in table F2.

The tethered-balloon data provided real-time information on events such as temperature inversions, O_3 buildup, and nocturnal jets at two sites. Additionally, aerosol size distributions were provided at the Aberdeen site throughout the experiment. Tethered-balloon flight times and altitudes for each day at both sites are shown in tabular form in appendix F.

MARS.- Field setup of the system began July 28 at the Croton, Ohio, site and the system became operational on August 6. Real-time temperature profiles were taken for a large part of the time from August 6 to August 10. On the evening of August 10, a severe rainstorm with wind and lightning hit the area and damaged the radiometer and computer interface system. The extent of the damage was such that the system could not be repaired in the field in time to continue participation in the experiment.

Photometers/transmissometers.- The photometer/transmissometer systems were coordinated by personnel from GSFC. All systems were operational during the entire PEPE/NEROS sampling period and the data are currently being analyzed.

CONCLUDING REMARKS

The National Aeronautics and Space Administration (NASA) has successfully applied the sensor systems described herein in an Environmental Protection Agency (EPA) field experiment to study the formation and transformation of air pollutants in regional air masses and urban plumes. The NASA involvement demonstrated how new remote sensor technology can contribute to the scientific understanding and measurement needs of user agencies.

The major NASA contribution was the first airborne remote measurements of atmospheric mixing-layer height and ozone layering on a regional scale. The Ultraviolet Differential Absorption Lidar developed at Langley Research Center (LaRC) flew 16 missions aboard the Wallops Flight Center Lockheed 188A Electra airplane to measure aerosol backscatter for mixing-height determination as well as ozone distribution in the mixing layer. Also onboard was the High Spectral Resolution Lidar, developed by the University of Wisconsin under contract to LaRC, which measured aerosol- and molecular-backscatter coefficients. The Laser Absorption Spectrometer developed by the Jet Propulsion Laboratory (JPL) provided 16.5 hr of total ozone-burden measurements. In addition, NASA made ground-based meteorological ozone measurements with the JPL Scanning Microwave System and the LaRC tethered-balloon systems. Airborne in situ measurements for remote sensor truth-data correlations were taken. Geostationary meteorological satellite imagery was used for real-time experiment planning.

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July 17, 1981

APPENDIX A

MISSION LOG - DAY-BY-DAY ACCOUNT OF ACTIVITIES

This appendix covers, on a daily basis, the operational period of the PEPE/NEROS experiment. The account is intented to be a chronicle documenting the events as they occurred and reflecting the extent of NASA's activities as copied from the daily log. All times referenced are eastern daylight time. In reading this appendix one may appreciate more fully the array of outside factors influencing the mission decisions (e.g., the dependence on weather) and the erratic circumstances inherent in a field experiment.

July 9, 10, and 11 were spent surveying the sites, establishing peripheral support requirements, and generally preparing for the experiment. The NASA 402 aircraft arrived in Columbus and started shakedown flights. During one of these flights the cabin air conditioner failed. A fuel-tank leak on the JPL Beechcraft B80 Queen Air airplane (which arrived on July 8) was discovered. However, short-duration flights continued and the fuel cell was replaced on July 11. The day-by-day mission log begins with the July 12 entry.

July 12 - The NASA 402 aircraft passed the EPA instrument audit with all instruments to be used in PEPE/NEROS experiments being well within EPA accepted tolerances.

The JPL Queen Air made no flight due to poor weather.

July 13 - No NASA mission was planned due to poor weather and the lack of a full complement of aircraft.

July 14 - The NASA 402 aircraft conducted a correlative measurements mission with the NASA JPL (LAS instrumented) Queen Air aircraft following a LAS checkout flight earlier in the day.

Tethered balloon crew arrived in Columbus, Ohio.

July 15 - The tethered balloon teams setup at both locations (Ohio and Maryland) and the NASA 402 performed a correlative flight with the LAS and UV-DIAL/HSRL aircraft. All systems performed satisfactorily.

July 16 - The large balloon was punctured in a violent thunderstorm at Aberdeen, Maryland. No NASA mission was planned for Columbus due to unfavorable weather.

July 17 - During a routine checkout flight the NASA 402 experienced an inverter failure. The NASA 402 returned to LaRC for checkout of inverters. The JPL Queen Air was not scheduled for a mission.

July 18 was the first full-up mission looking at what was termed a "mini PEPE" in the Ohio Valley. The NASA Electra was deployed in a straight-line pattern from Wallops (10:15 a.m. departure) to Lexington, Kentucky, north to Dayton, Ohio, and return to WFC at 2:40 p.m. Altitude for the flight was

nominal 10 000 ft (3048 m). Electra flight data and plots are presented in appendix B and the Electra flight times are presented in the text. Correlative O_3 measurements were made by an EPA contractor's aircraft since the NASA 402 was down because of the previous day's inverter failure.

Tetroon releases, coordinated with the overflight, were made from Botom Field Airport (in the Columbus area) to determine transport direction. The JPL Queen Air performed a 3-hour mission but without the NASA 402 to make correlative measurements.

July 19 and 20 - No NASA mission planned for July 19. A rental inverter was located in Chicago. The NASA 402 returned to Columbus on July 20. The JPL Queen Air flew two 2-hour missions on July 20.

July 21 - A NASA mission was planned to take advantage of the present weather situation (conducive to oxidant formation and transport into the Eastern United States). However, the mission was aborted due to rain in the Columbus area.

July 22 - It was still raining. No NASA missions were conducted.

July 23 - The last LAS flight was conducted as the Queen Air had to return to JPL due to previously scheduled missions. Correlative measurements were made with the NASA 402 aircraft. The Aberdeen tethered-balloon crew reported minor problems with their winch.

July 24 - A stagnation condition began developing in the Ohio area which could be the beginning of a PEPE. The full complement of available platforms was used with attention focused on the characterization of the Conesville, Ohio, power plant plume in a relatively clean air mass. A typical air parcel marked by a tetroon released near the power plant was studied over the next several days.

The Electra departed WFC at 10:30 a.m., flew to Pittsburgh, Pennsylvania, then to Indianapolis, Indiana, and returned to WFC at 3:30 p.m. The flight altitude was nominal 10 000 ft (3048 m). Correlative measurements were made by the NASA 402.

July 25 - Marked a continuation of the dual purpose mini-PEPE/Urban Plume studies. The Electra performed a regional characterization flight over central Ohio, departing WFC at 9:30 a.m. and returning at 2:10 p.m. Again, correlative measurements were provided by the NASA 402 aircraft.

July 26 and 27 - No NASA mission was scheduled due to a forecast of showers. The NASA 402 returned to LaRC July 26. The LAS crew returned to JPL.

July 28 - Thunderstorms precluded any mission possibility.

July 29 - No NASA missions scheduled. The rental inverter arrived in Columbus, Ohio, and was forwarded to LaRC to be installed in the NASA 402.

July 30 - No NASA mission was scheduled. EPA conducted an Urban Plume mission.

July 31 - There were two Electra missions conducted with correlative flights by the NASA 402 for each. The second mission was a nighttime correlative flight - the first nighttime correlative flight ever.

On the first mission, the Electra departed WFC at 12:00 noon and proceeded to Dulles airport, then to Atlantic City, New Jersey; to Hackettstown, New Jersey; to Poughkeepsie, New York; to Hampton, Long Island; Cape May, New Jersey; and returned to WFC, landing at 4:20 p.m.

On the second mission, the Electra departed WFC at 9:20 p.m. proceeded to Gordonsville, Virginia; Elmira, New York; Poughkeepsie, New York; and back to WFC (landing at 1:20 a.m. August 1). The Electra was observed passing overhead by the NASA 402 crew at approximately 9:45 p.m. at the Franklin, Virginia, VOR.

August 1 - No NASA missions were planned.

August 2 - Development of a PEPE over the southern coast of the United States with accompanying haze as indicated by the GOES satellite photographs (see GOES figure for August 2) prompted a southeastern mission for the Electra. The Electra departed WFC at 7:00 a.m. on a route that included Norfolk, Virginia; Edenton, North Carolina; Wilmington, North Carolina; Charleston, South Carolina; Savannah, Georgia; and Jacksonville, Florida, and return to WFC (landing at 1:00 p.m.). Haze conditions existed throughout the entire flight extending upward to nominally 12 500 ft (3810 m) and especially thick at 8000 ft (2438 m). During this flight the HSRL instrument worked well; however, the UV-DIAL collected data only for about 60 percent of the flight as the ozone laser malfunctioned as the Electra crossed the Virginia/Carolina border on the return leg of the mission. The NASA 402 made correlative measurements performing a spiral pattern from nearly surface level to 9500 ft (2895 m) at the Franklin VOR, Cape Charles and Chesapeake Light. Early during this flight the NASA 402 experienced another inverter failure so the ozone instrument was turned "off" leaving only the nephelometer and temperature and dewpoint instruments activated.

The Electra arrived at Franklin 30 minutes before the NASA 402 due to a mixup in communications.

August 3 - No NASA mission was scheduled.

August 4 - No NASA mission was scheduled.

Evidence provided on this date by Wyle contractors in solving the inverter failures problem indicated that for the high temperature experienced in the field (due possibly to the NASA 402 air conditioner failure) the inverters should be derated to 70-75 percent of their maximum power output. A decision was made to dispense with further NO_x measurements for all future missions since it appeared that a permanent fix would require some extended ground time. (All instruments must be "off loaded" from the aircraft to allow removal of the inverters.)

August 5 - Indications were that a southern PEPE existed in a triangular region from Savannah, Georgia, through Asheville, North Carolina, to Washington, D.C., and bounded by the east coast. EPA's emphasis had however shifted to the northeast corridor. An Electra mission starting from WFC through Franklin, Virginia; Williamston, North Carolina; Asheville, North Carolina; and Washington, D.C. assessed the PEPE and then proceeded to Cape May, New Jersey; Harrisburg, Pennsylvania; Wilkes-Barre, Pennsylvania, and Point Pleasants, New Jersey, to cover the northeast corridor. This was a 6 1/4 hour mission which extended the Electra's range somewhat. The NASA 402 conducted correlative measurements from 9:30 to 10:30 a.m. at the Franklin VOR in conjunction with the southern PEPE.

August 6 - The Aberdeen tethered balloon crew reported some curtailment of activities due to the inability of the air conditioner in the instrument hut to provide adequate cooling to the instrumentation. Daytime temperatures in excess of 100°F inside the instrument hut were by now commonplace.

A NASA mission was planned; however, the mission was aborted when the UV-DIAL ozone laser aboard the Electra failed. This occurred after the Electra was airborne. Nearly 2 1/2 hours of flight time was expended to try and clear up the problem, but to no avail. The proposed flight pattern would have been a PEPE mission over Bowling Green, Kentucky; Birmingham, Alabama; and Charleston, South Carolina, with NASA 402 correlative measurements at the Franklin VOR.

August 7 - The Electra flew a combined PEPE/NEROS mission (from 5:15 p.m. to 10:20 p.m.) over New York and Pennsylvania with NASA 402 correlative measurements in the vicinity of WFC. The NASA 402 then made additional independent air mass characterization measurements over southeastern Virginia.

August 8 - The planned PEPE/NEROS mission to Buffalo, New York, and the associated correlative measurements were canceled due to cloud build-up.

August 9 - The concensus was that the PEPE was growing and much more data would be needed to characterize it. There was also some evidence that a southern PEPE was building up. The Electra took off from WFC at 5:05 a.m. on a PEPE mission; however, ozone laser problems in the UV-DIAL developed resulting in only aerosol data being taken throughout the mission. The flight path covered Danville, Virginia, eastern Tennessee and eastern Kentucky, and back to eastern Virginia, landing at 11:20 a.m.

August 10 was much the same. The Electra took off at 5:30 a.m., flew to Danville, Virginia; then to northwest Alabama, to Mississippi, Memphis, Tennessee, and back to Virginia for correlative measurements with the NASA 402.

August 11 - No NASA mission was scheduled in order to allow the Electra crew a rest and to repair the ozone laser.

The NASA Microwave Atmospheric Remote Sensing system (MARS) had been struck by lightning and was no longer operational. This was also true of a number of the various ground instruments as the Columbus area had experienced a number of severe thunderstorms since the experiment began.

August 12 was spent examining the remnants of the subsiding PEPE. The Electra took off from WFC at 6:05 a.m. and flew a counterclockwise pattern including a swing approximately 100 nautical miles (185 km) out to sea off the New Jersey-Delaware coast. The NASA 402 took correlative data at Cape Charles from approximately 9:30 to 10:30 a.m. That afternoon the 402 returned to Columbus, Ohio.

August 13 - The NASA 402 staging out of Columbus conducted correlative flights with the Electra in what was called an "expanded urban plume." Three Electra missions were conducted; one each from 10:55 a.m. to 12:30 p.m.; 3:10 p.m. to 6:45 p.m.; and from 9:00 p.m. to 1:00 a.m. August 14. The NASA 402 made correlative flights with each of the first two but canceled on the third because of thunderstorm activity. These three missions were urban plume studies of three different urban areas. On the second mission five EPA officials flew on the Electra and observed first hand the UV-DIAL operation.

August 14 - No NASA mission was planned.

August 15 - No NASA mission was conducted due to poor weather.

August 16 - Experiment completed - all participants returned home.

APPENDIX B

DAILY WEATHER MAPS AND SATELLITE IMAGES

This appendix contains daily weather maps covering the period of July 14 to August 17, 1980, and satellite images for the period of July 14 to August 15, 1980. The maps were taken from the weekly series prepared by the National Meteorological Center of the National Weather Service. They were reproduced after the experiment was completed. However, during the experiment these maps came in real time to the field headquarters at Columbus via a facsimile printer (updated every 3 hr) from the National Weather Service. They provided the primary weather projections upon which the daily missions were planned. The maps provided herein represent the daily surface-station data for 0700 EDT on each day of the experiment and are included in order to allow the reader to get a feel for the meteorological conditions that prevailed during any decision-making time. Also, one can get a quick perception of the many frontal cells which propagated through the region during the experimental period by simply flipping through the maps in chronological order.

In addition to the surface weather features provided by the National Weather Service, GOES images were transmitted every half hour to the Columbus field headquarters, providing real-time information about cloud cover, haze buildup, frontal activity, and other information used for planning.

Included herein is one GOES image for each day of the experiment, which is a representative sampling of the information available to the mission planners. The images contain the date and the time of day in Greenwich mean time (GMT) at the upper margin. Note that not all images are for the same time. In some images atmospheric haze is clearly visible (e.g., Aug. 1) and trackable. Because of the loss of contrast in the photo reproduction process the atmospheric haze may not appear as evident in the photos contained herein as it does in the original GOES images.

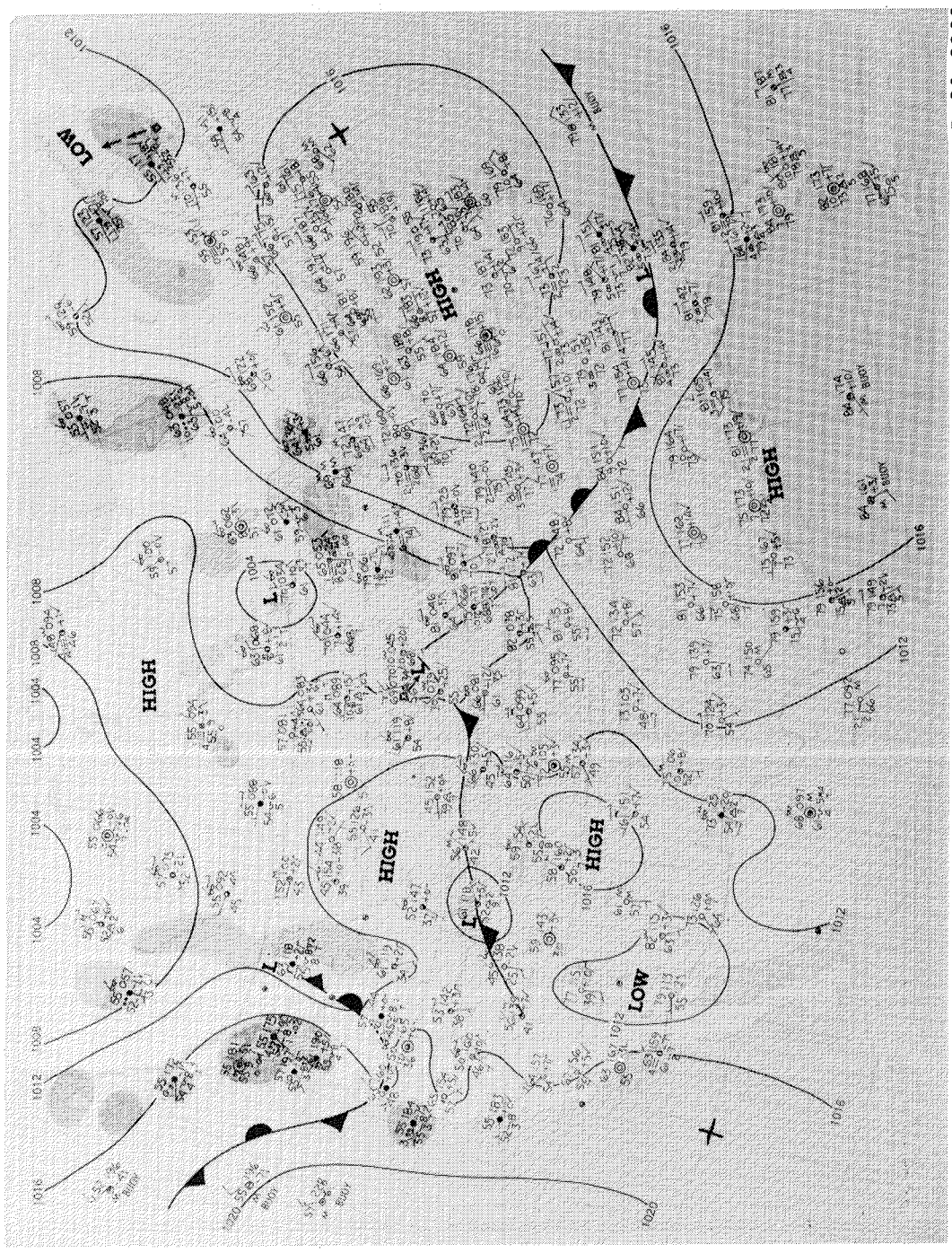
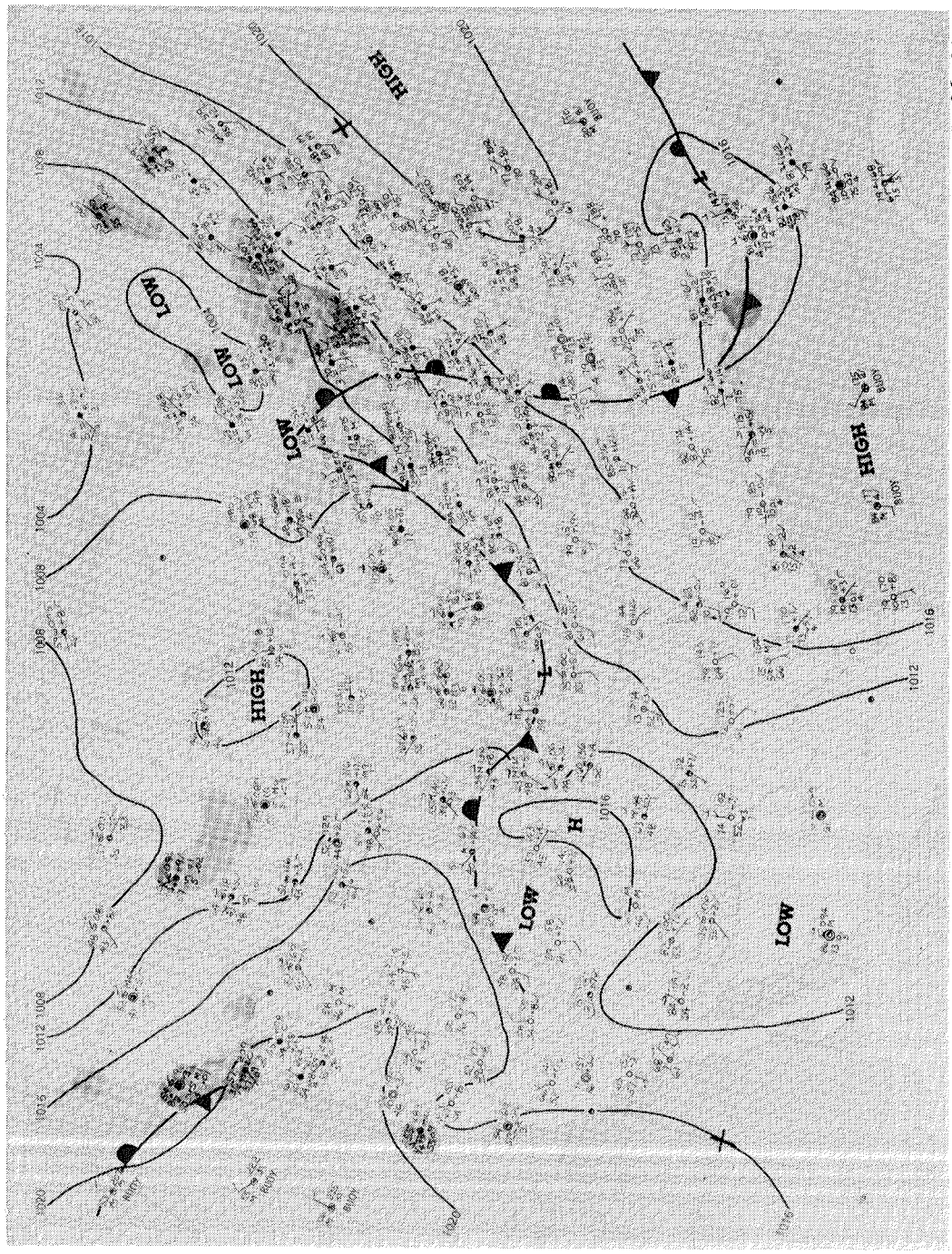
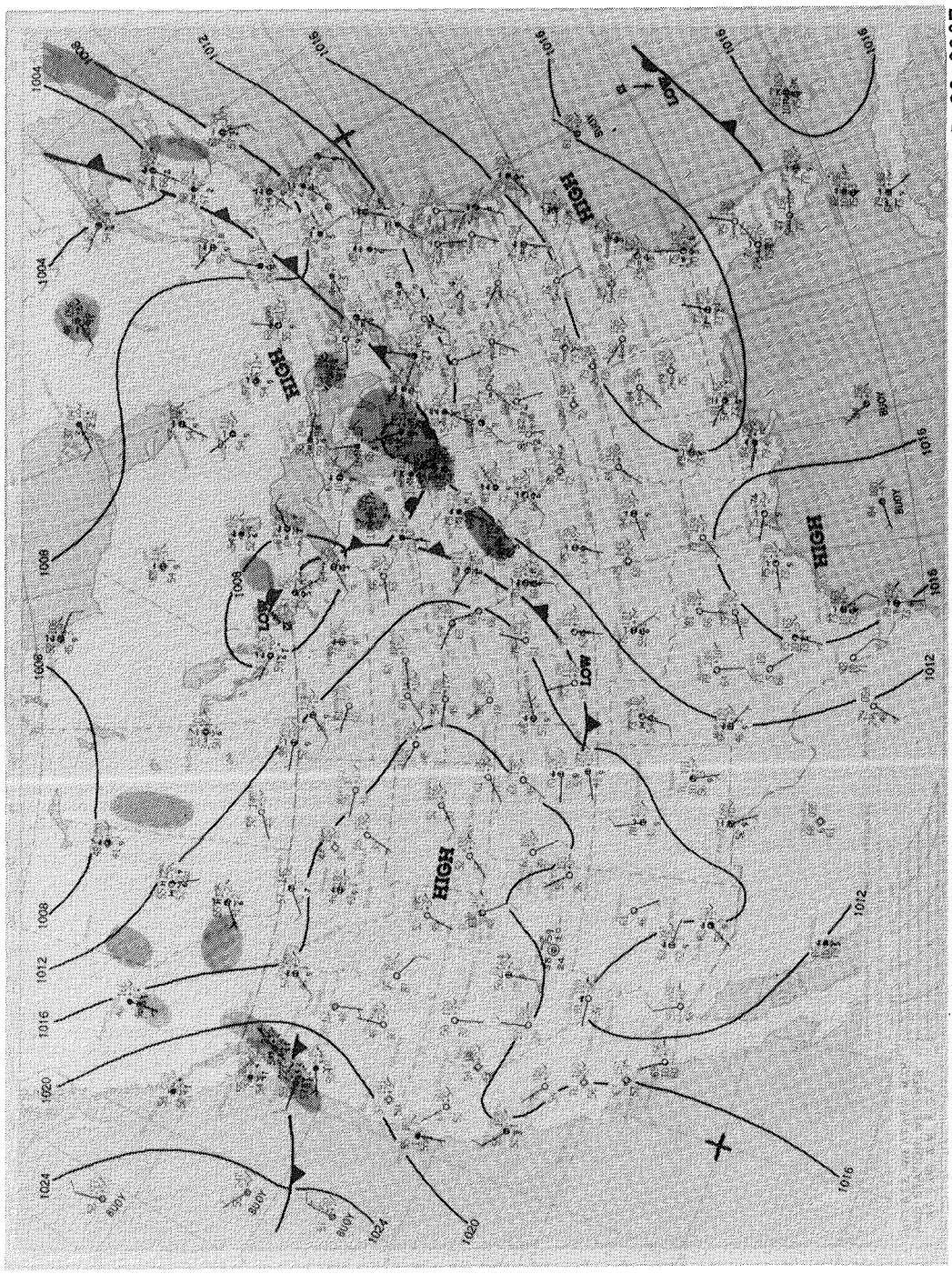


Figure B1.- Weather map for July 14, 1980.



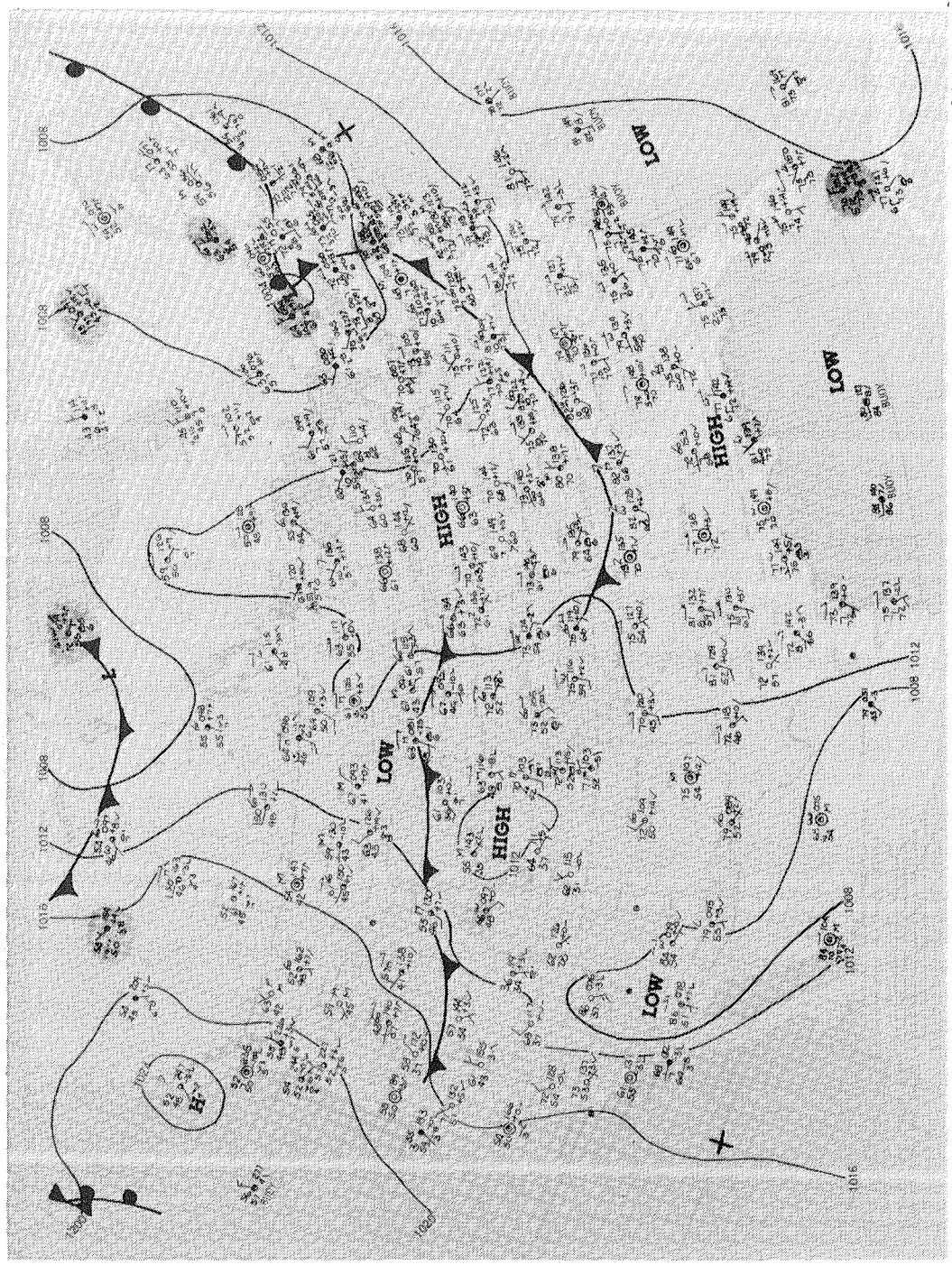
L-80-8911

Figure B2.- Weather map for July 15, 1980.



L-80-8907

Figure B3.- Weather map for July 16, 1980.



L-80-8908

Figure B4.- Weather map for July 17, 1980.

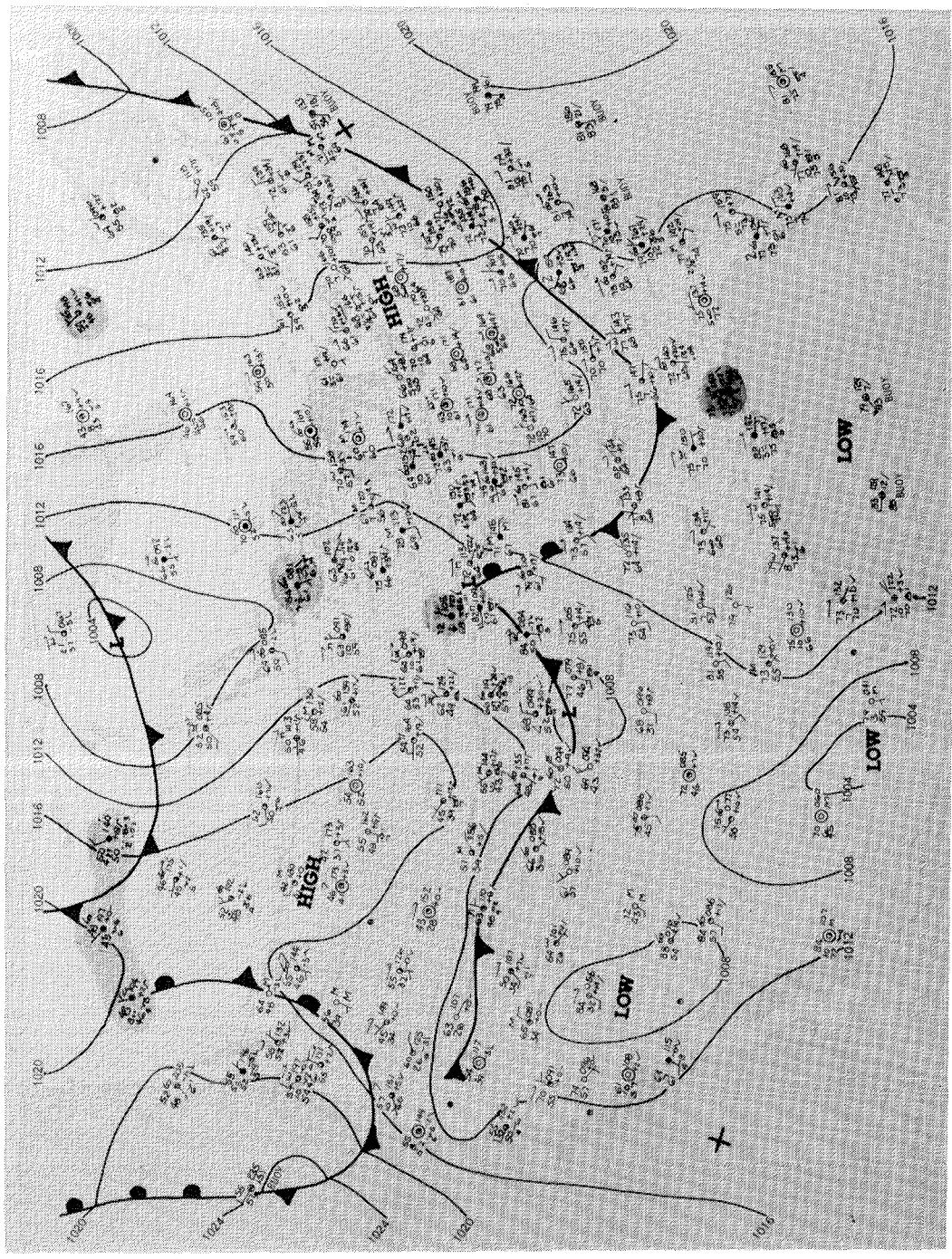


Figure B5.- Weather map for July 18, 1980.

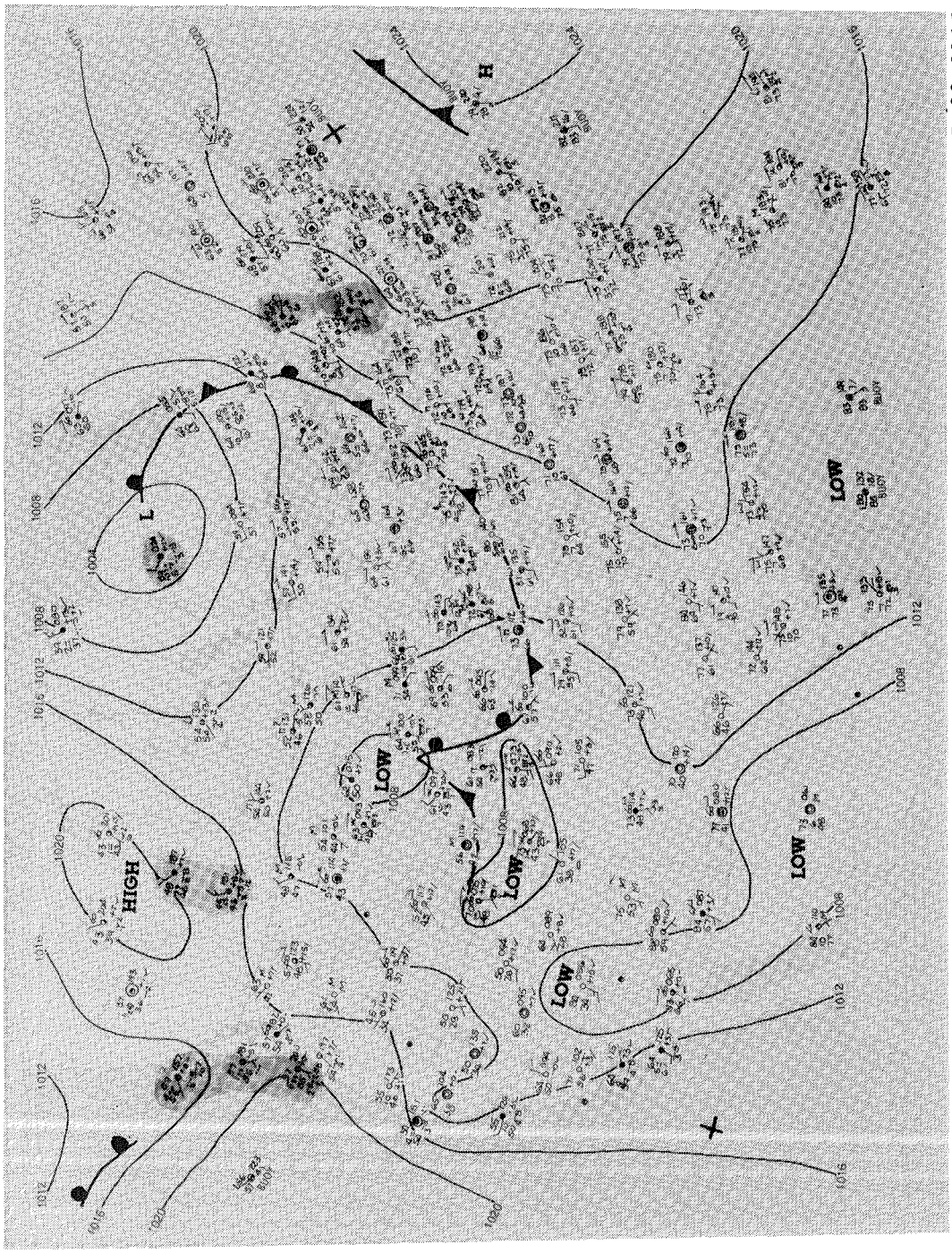
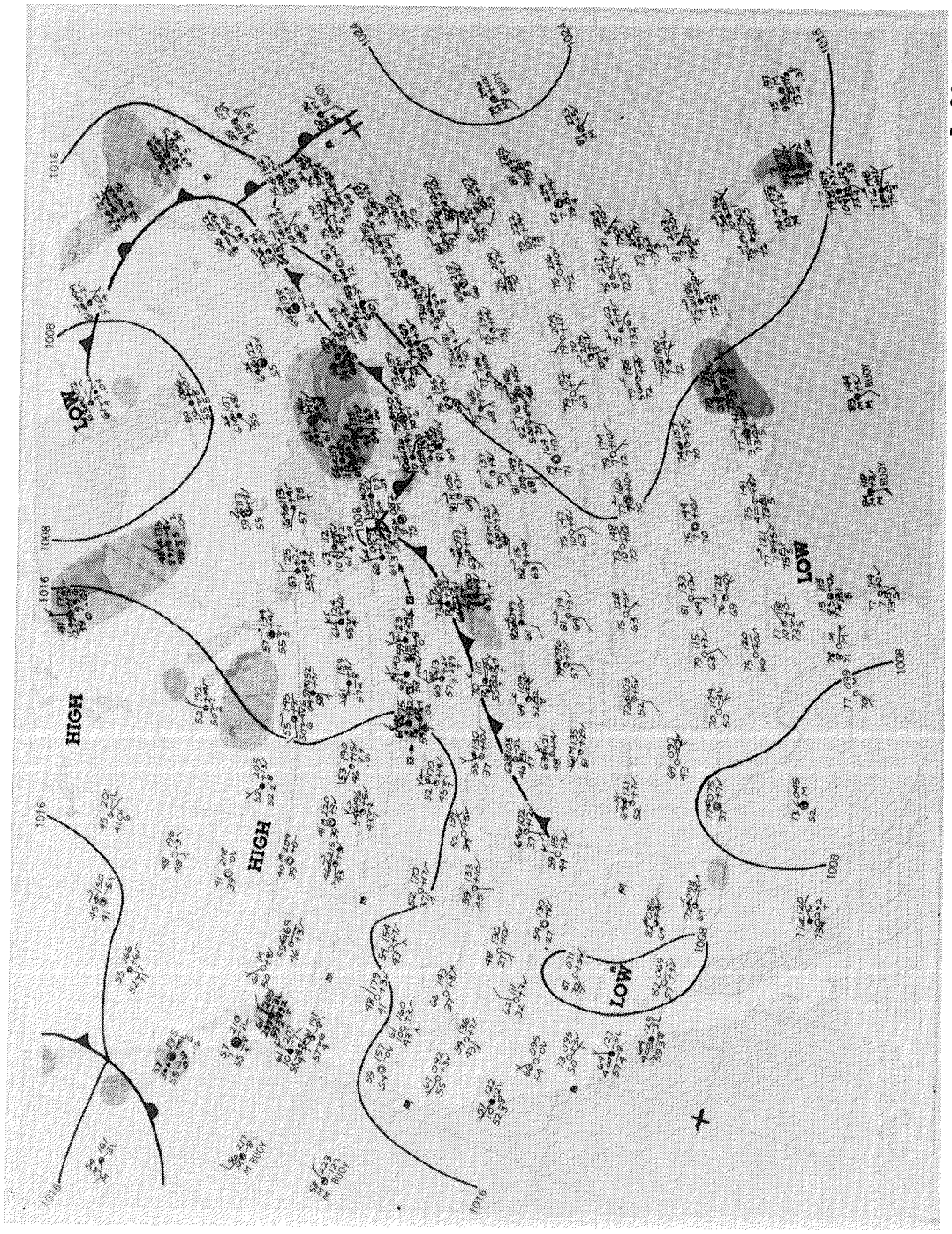


Figure B6.- Weather map for July 19, 1980.



L-80-8904

Figure B7.- Weather map for July 20, 1980.

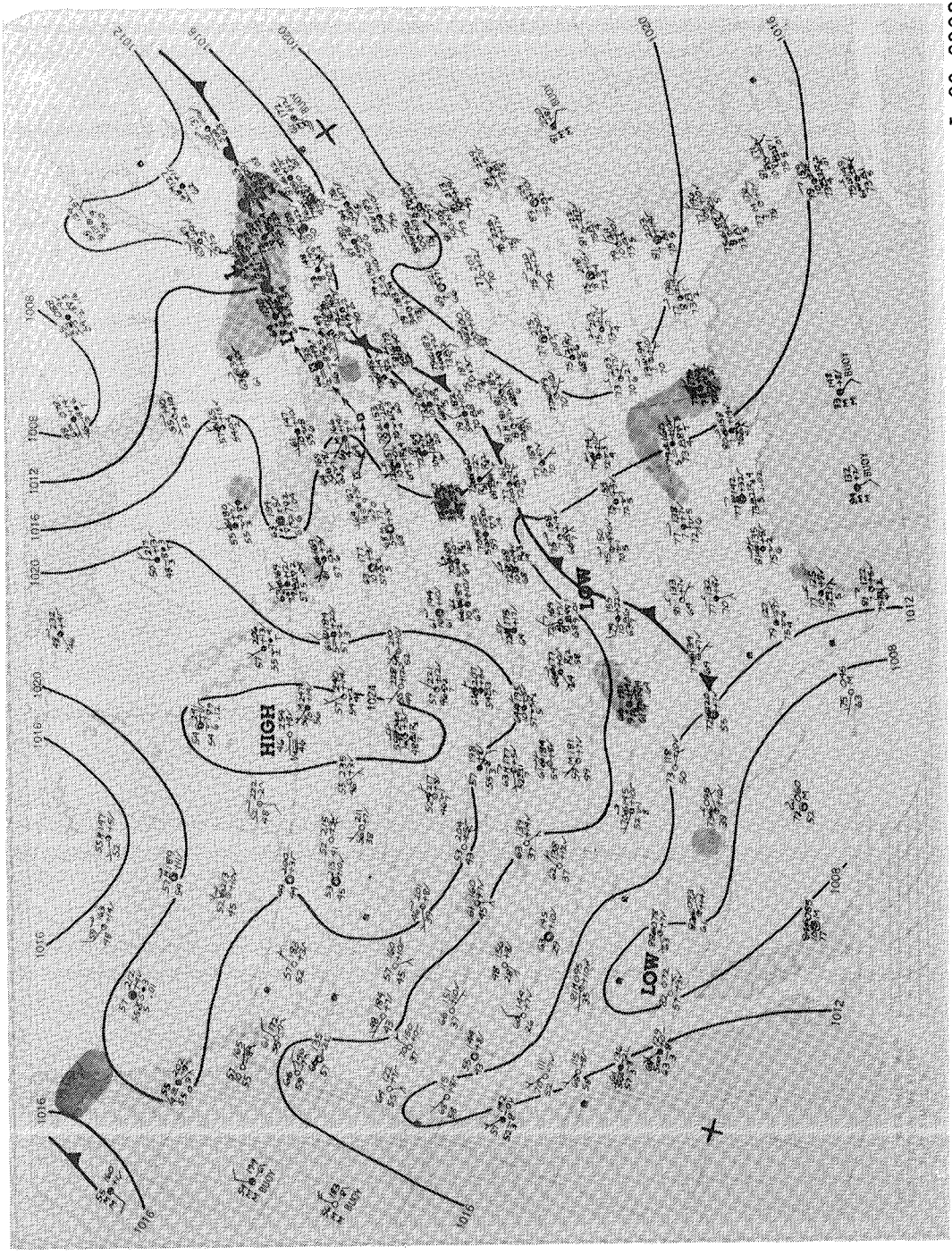
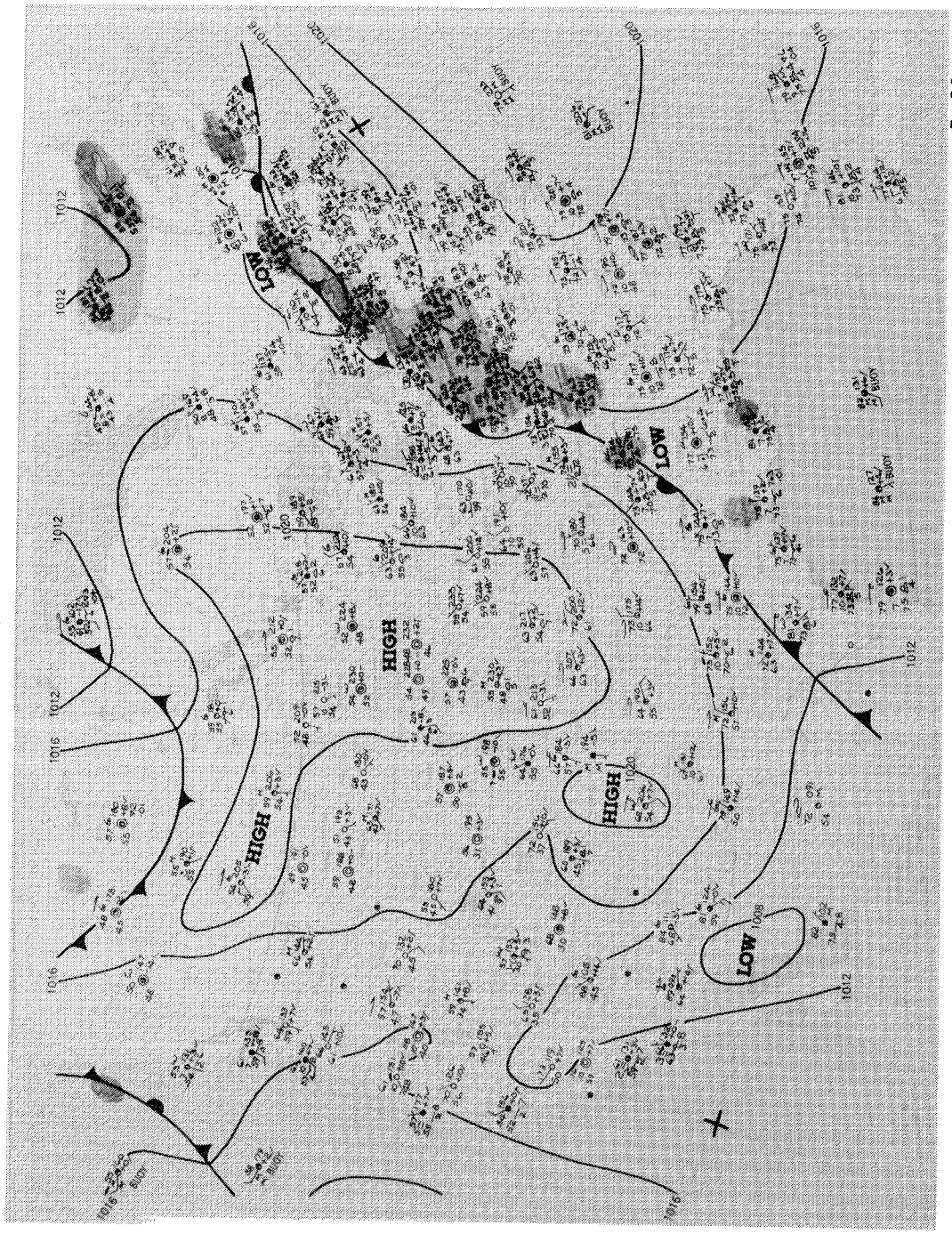
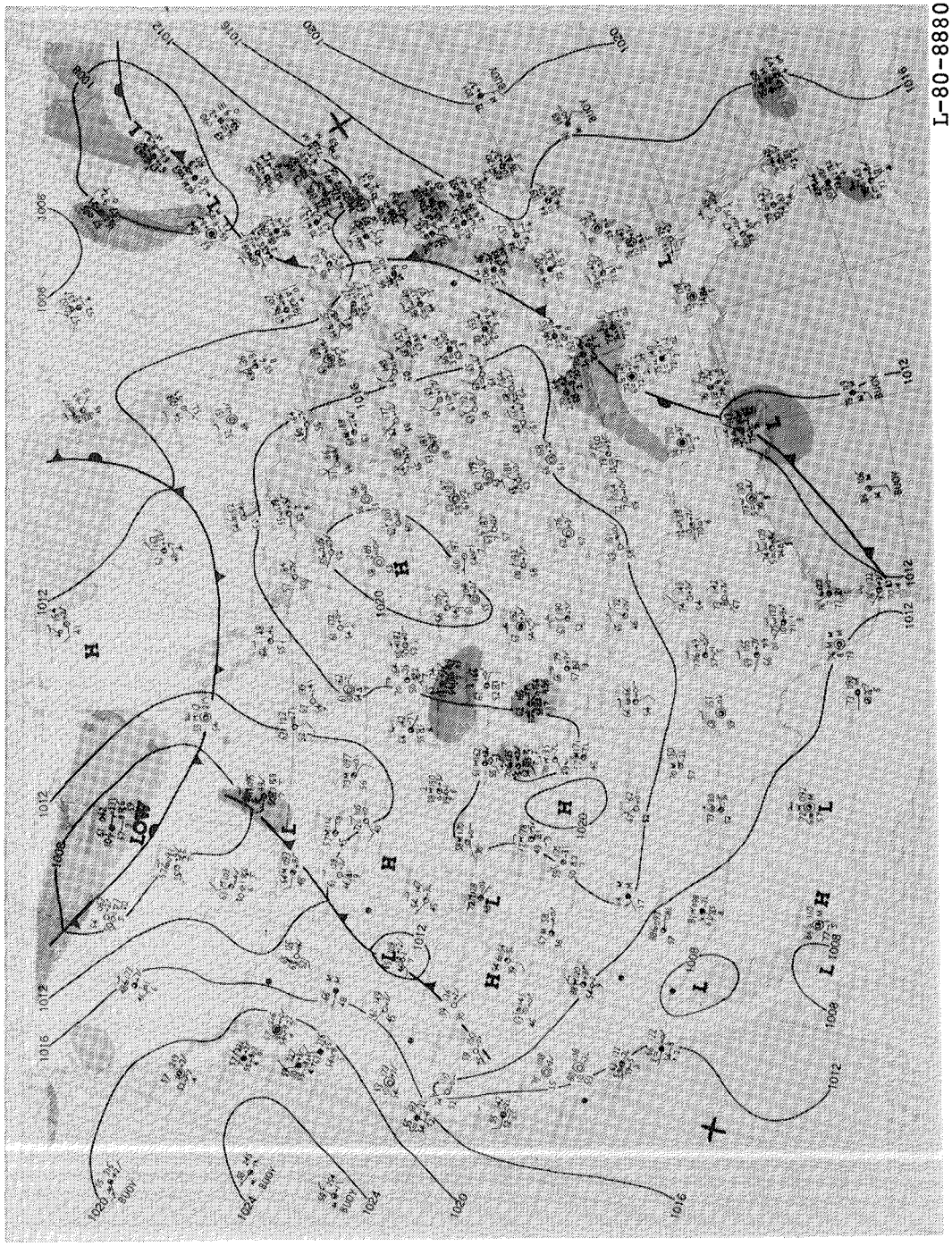


Figure B8.- Weather map for July 21, 1980.



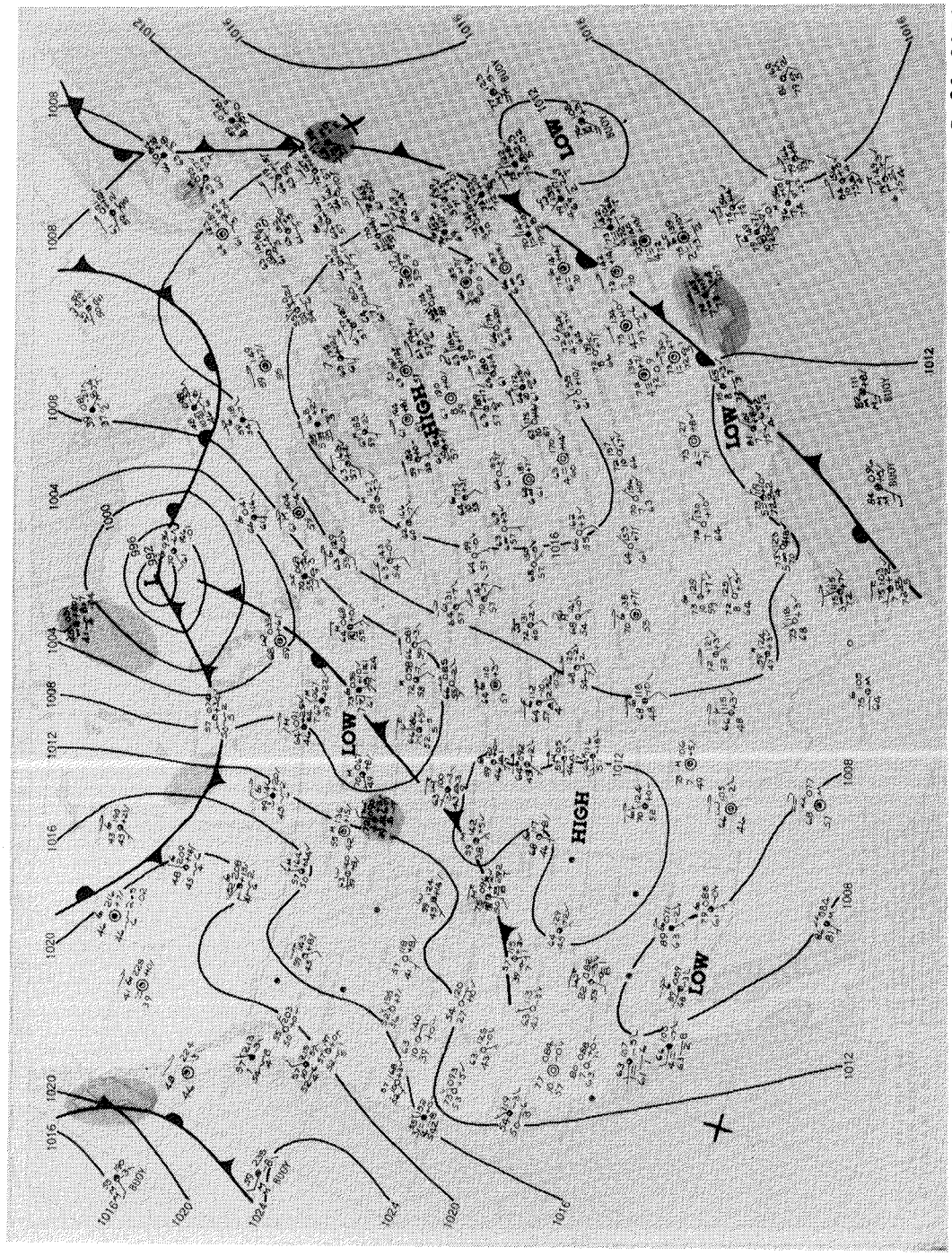
L-80-8881

Figure B9.- Weather map for July 22, 1980.



L-80-8880

Figure B10.- Weather map for July 23, 1980.



L-80-8878

Figure B11.- Weather map for July 24, 1980.

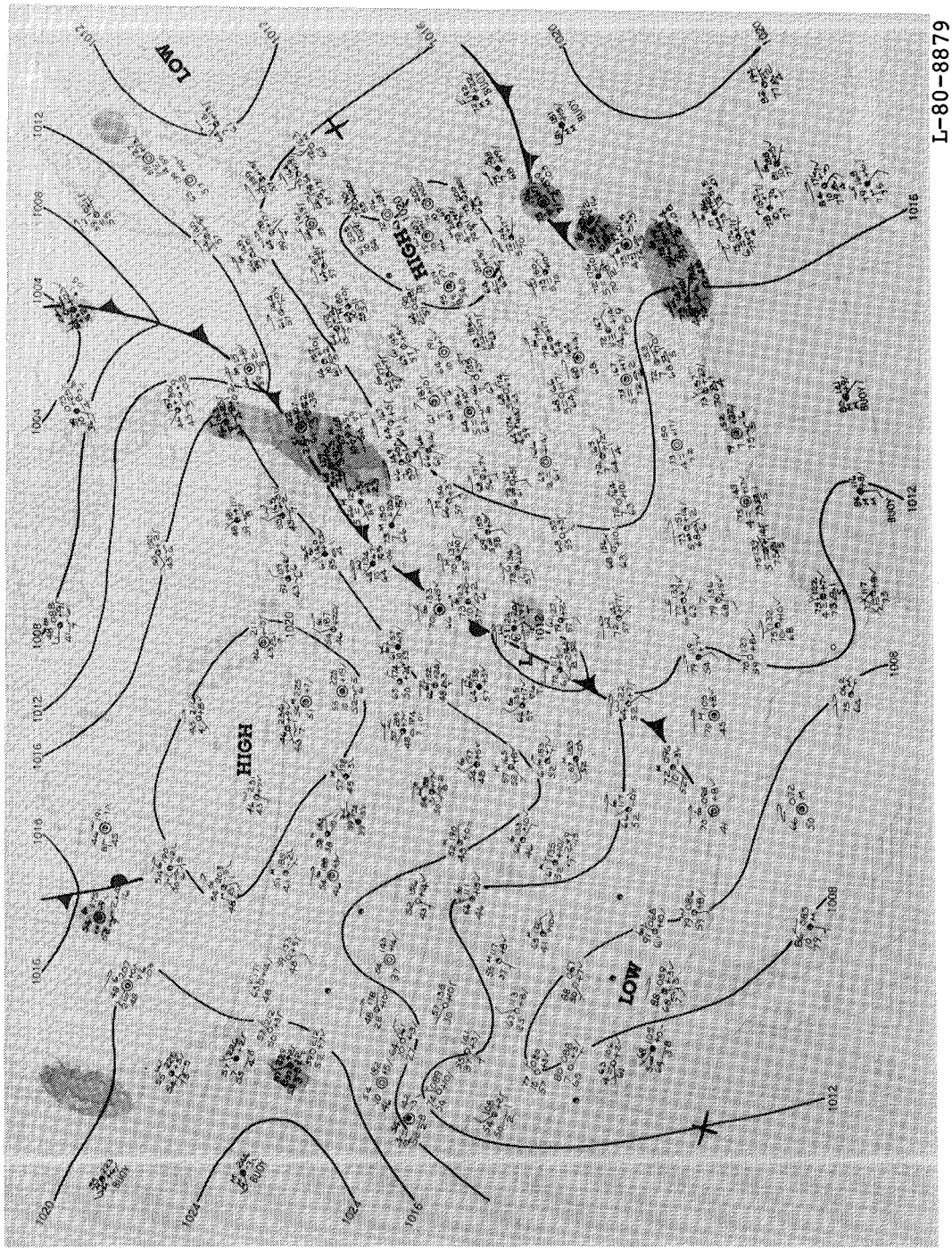


Figure B12.- Weather map for July 25, 1980.

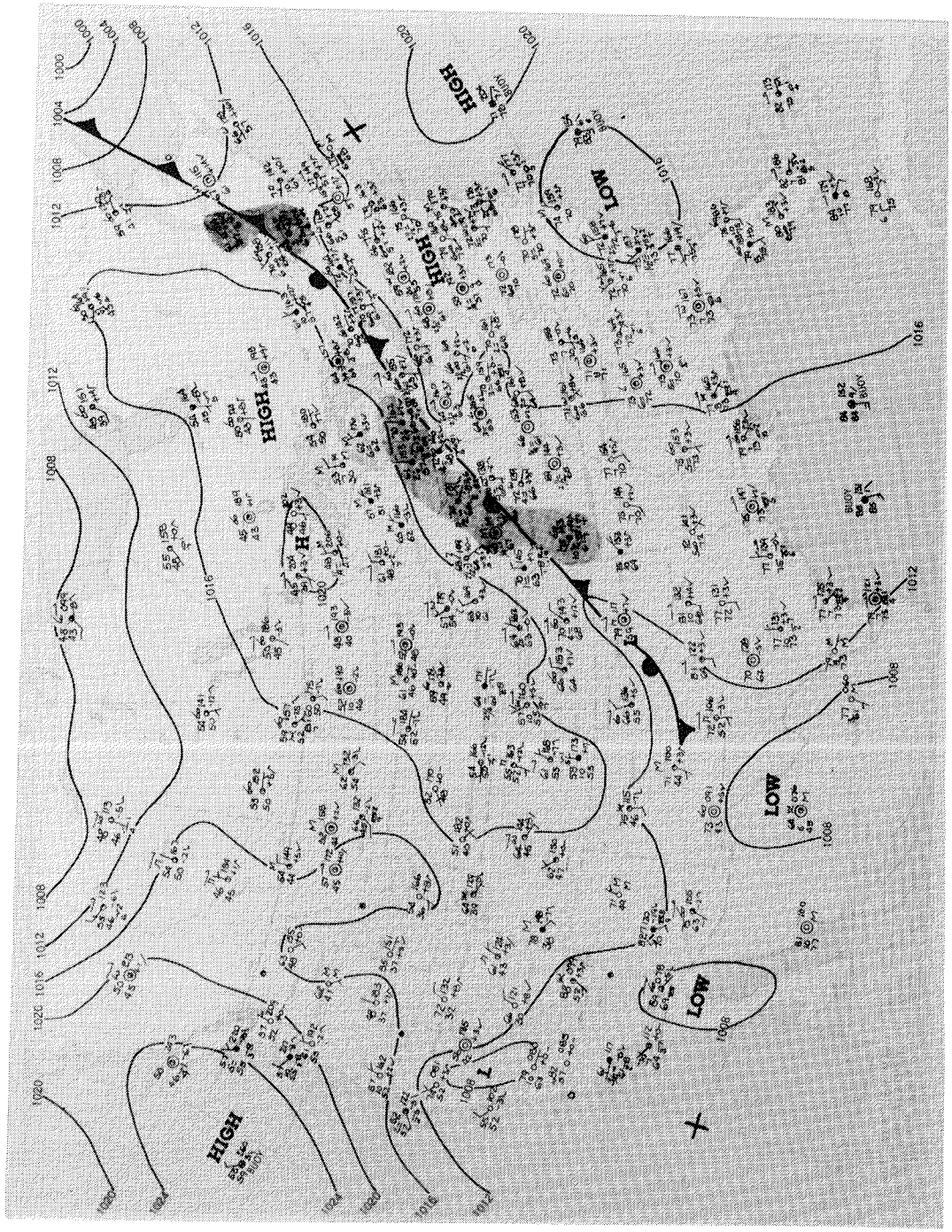
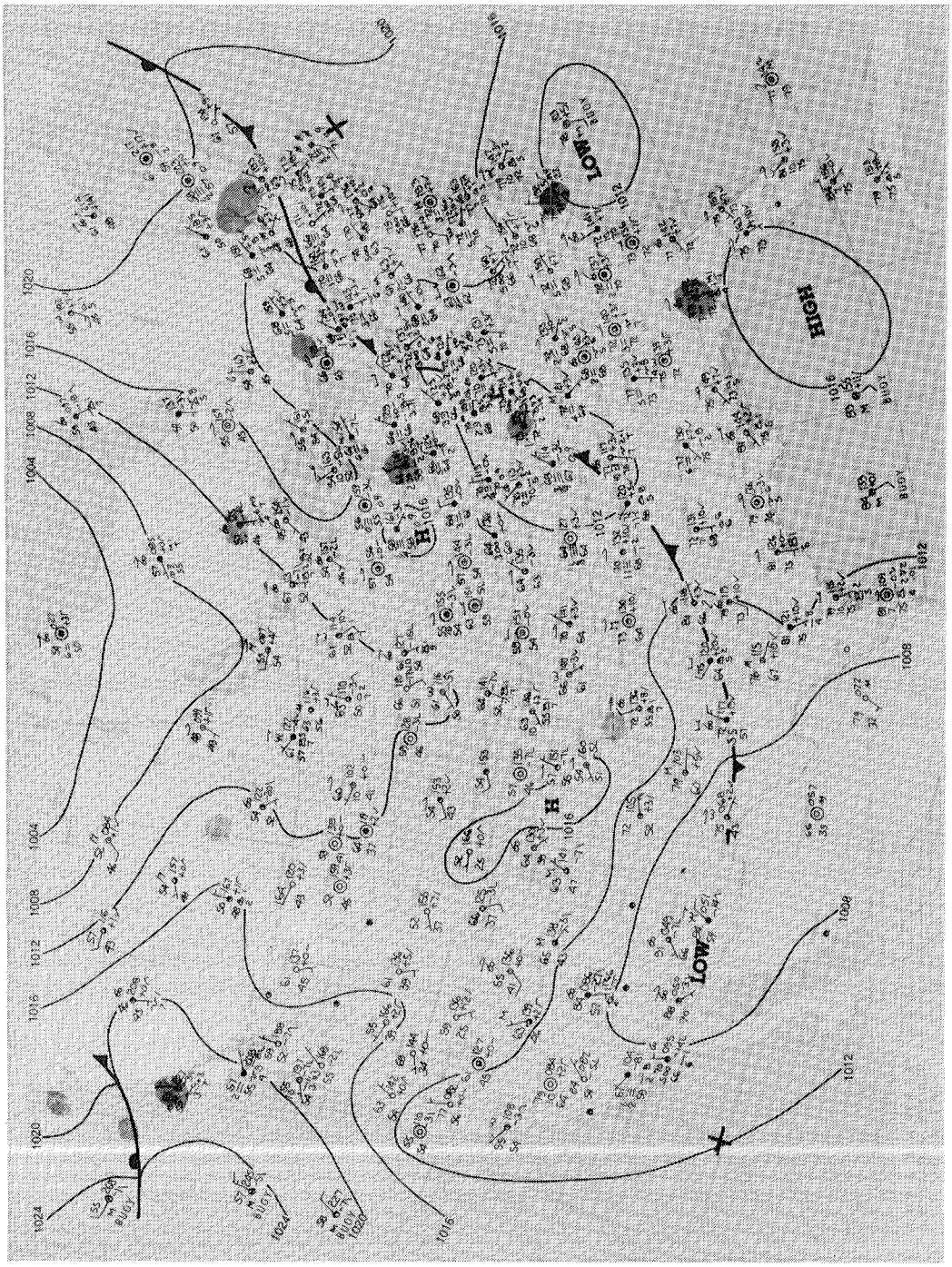
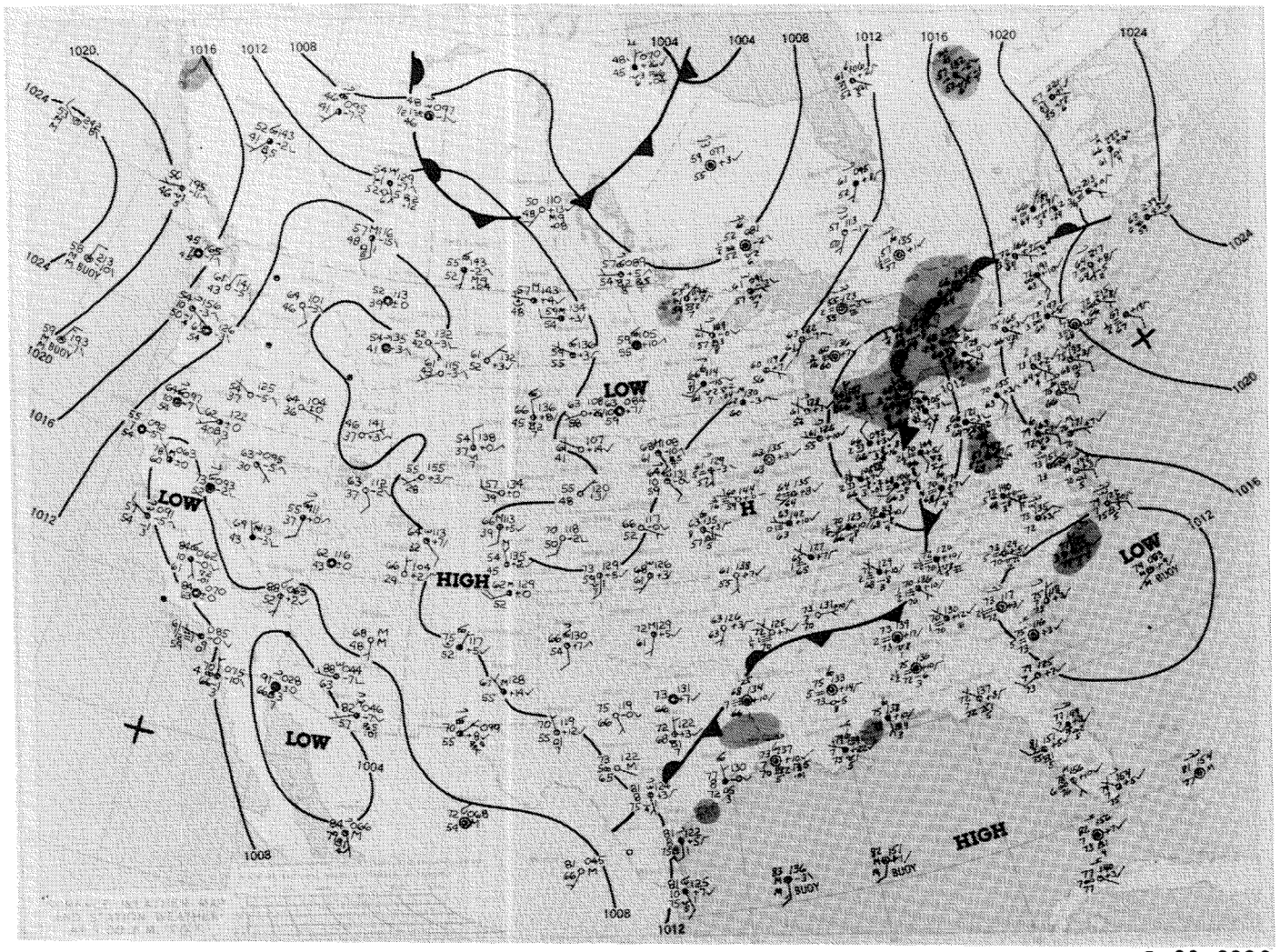


Figure B13.- Weather map for July 26, 1980.



L-80-8910

Figure B14.- Weather map for July 27, 1980.



L-80-8890

Figure B15.- Weather map for July 28, 1980.

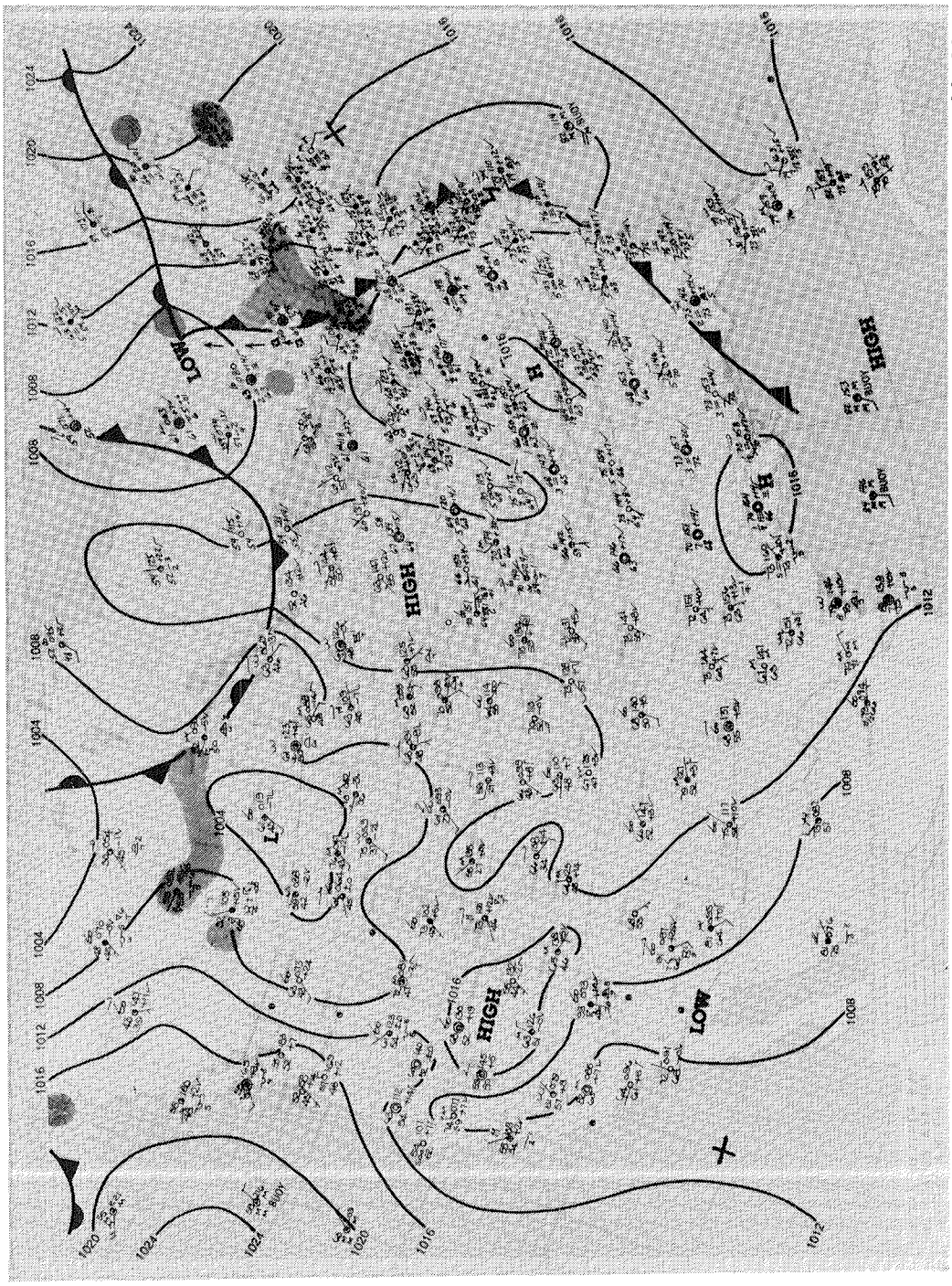
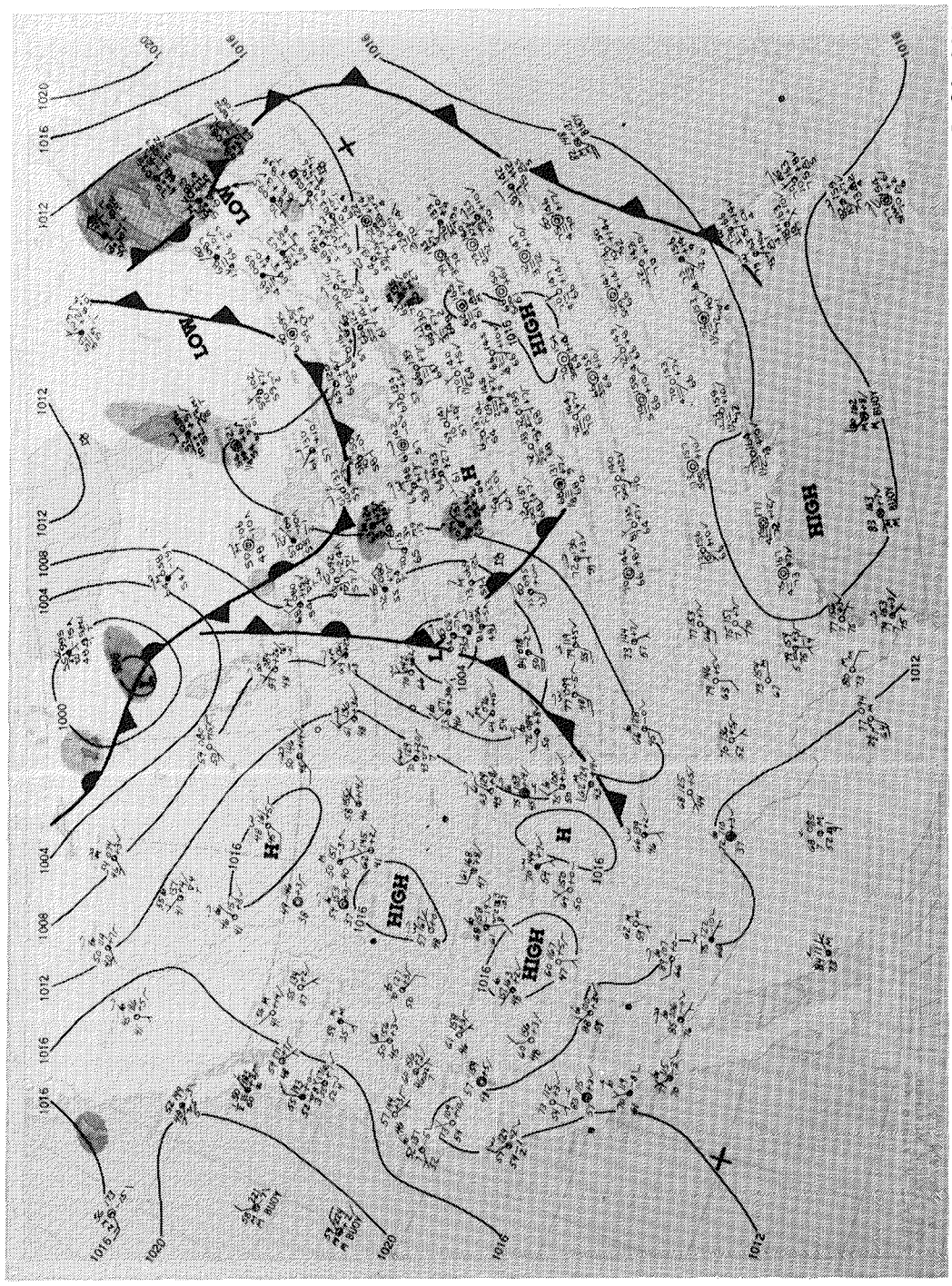


Figure B16.- Weather map for July 29, 1980.



L-80-8887

Figure B17.- Weather map for July 30, 1980.

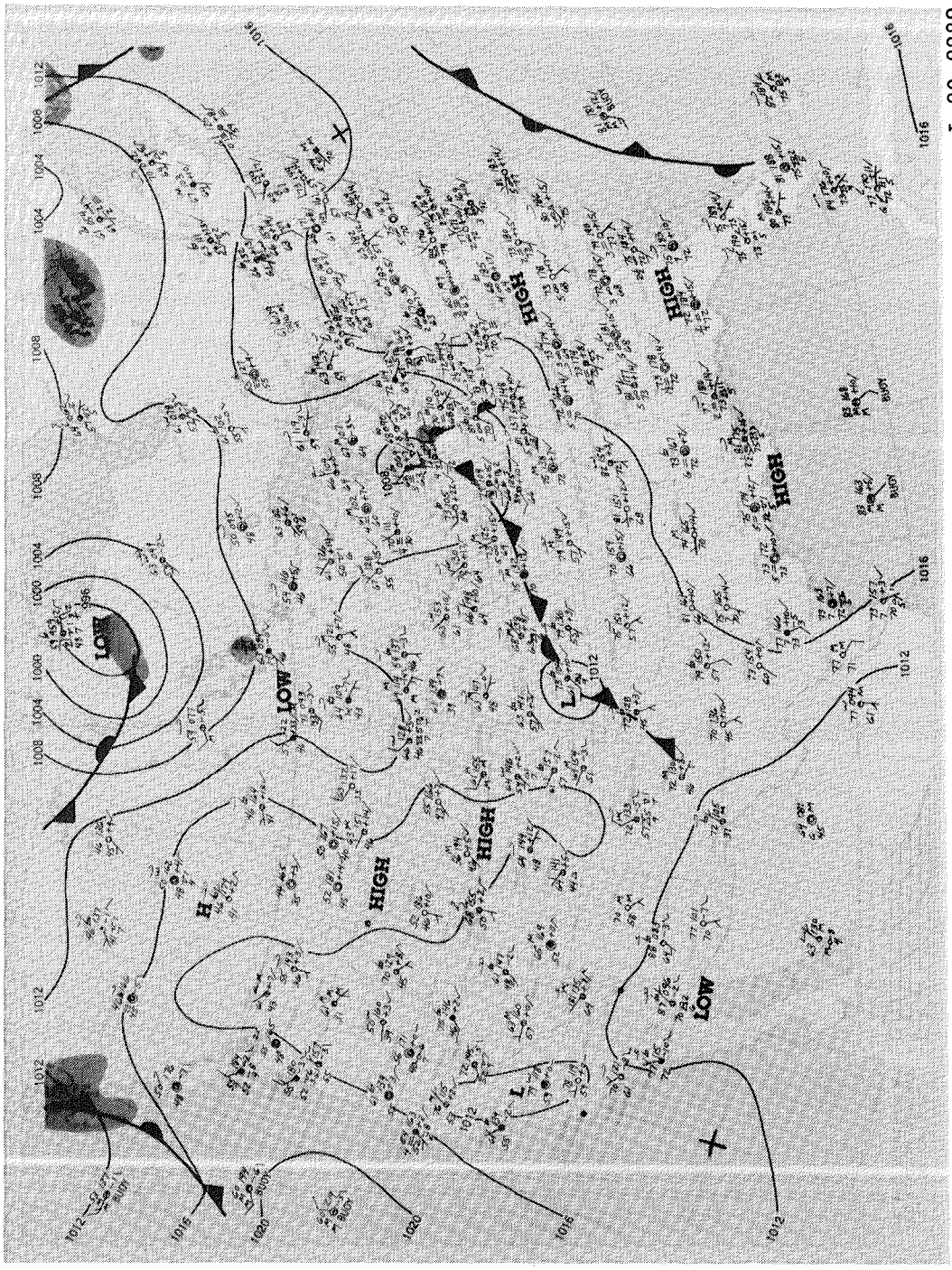


Figure B18.- Weather map for July 31, 1980.

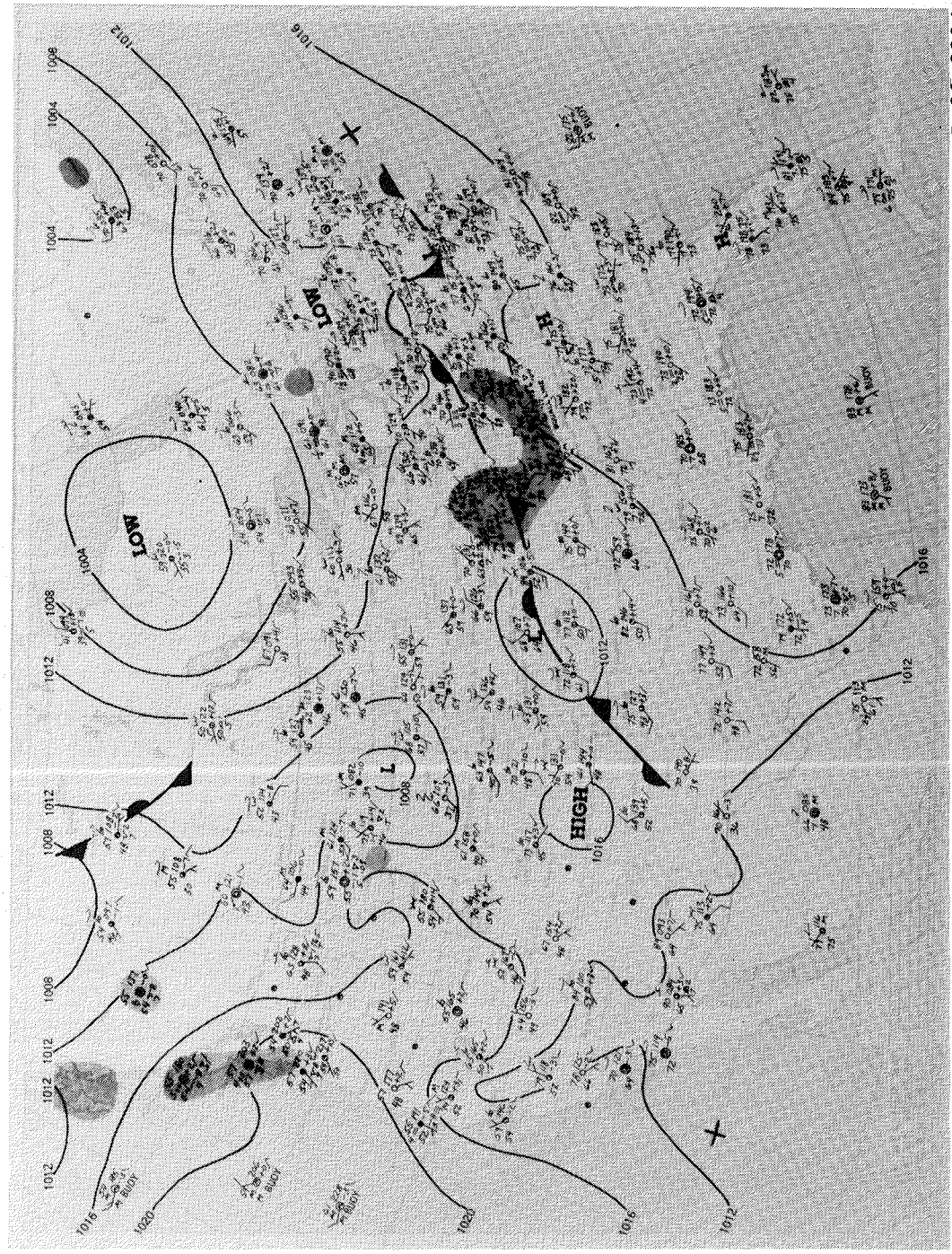
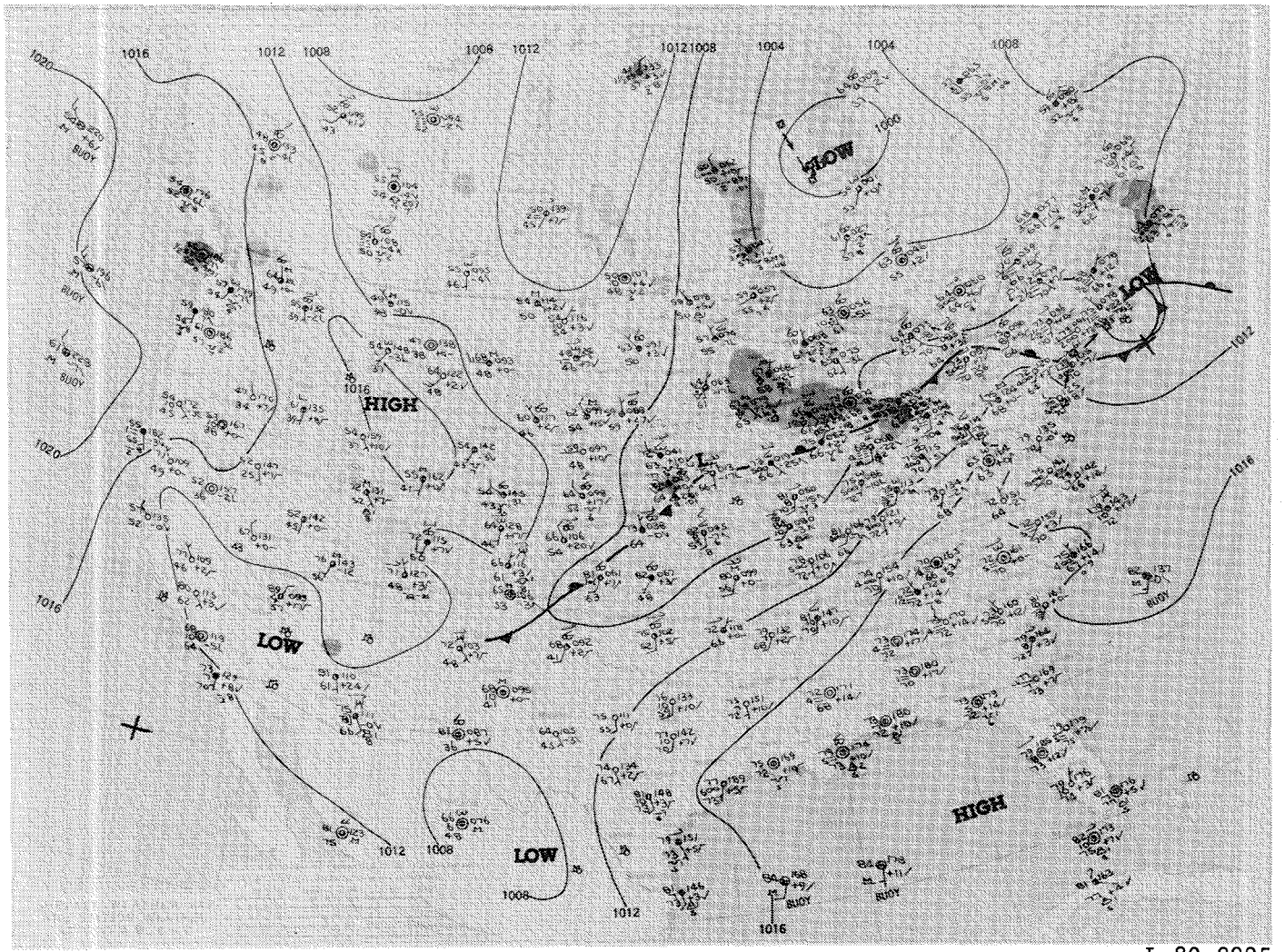


Figure B19.- Weather map for August 1, 1980.



L-80-8885

Figure B20.- Weather map for August 2, 1980.

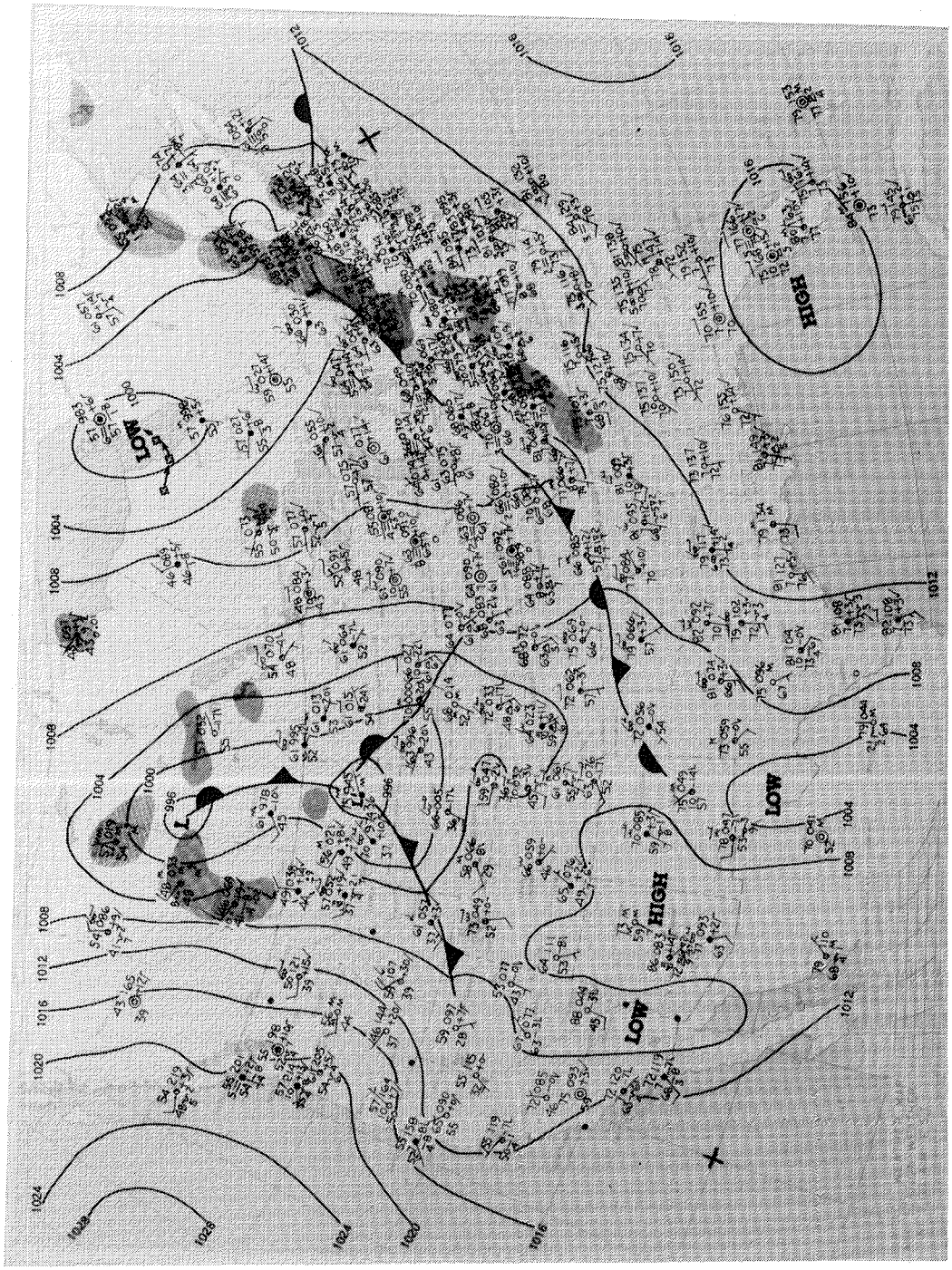


Figure B21.- Weather map for August 3, 1980.

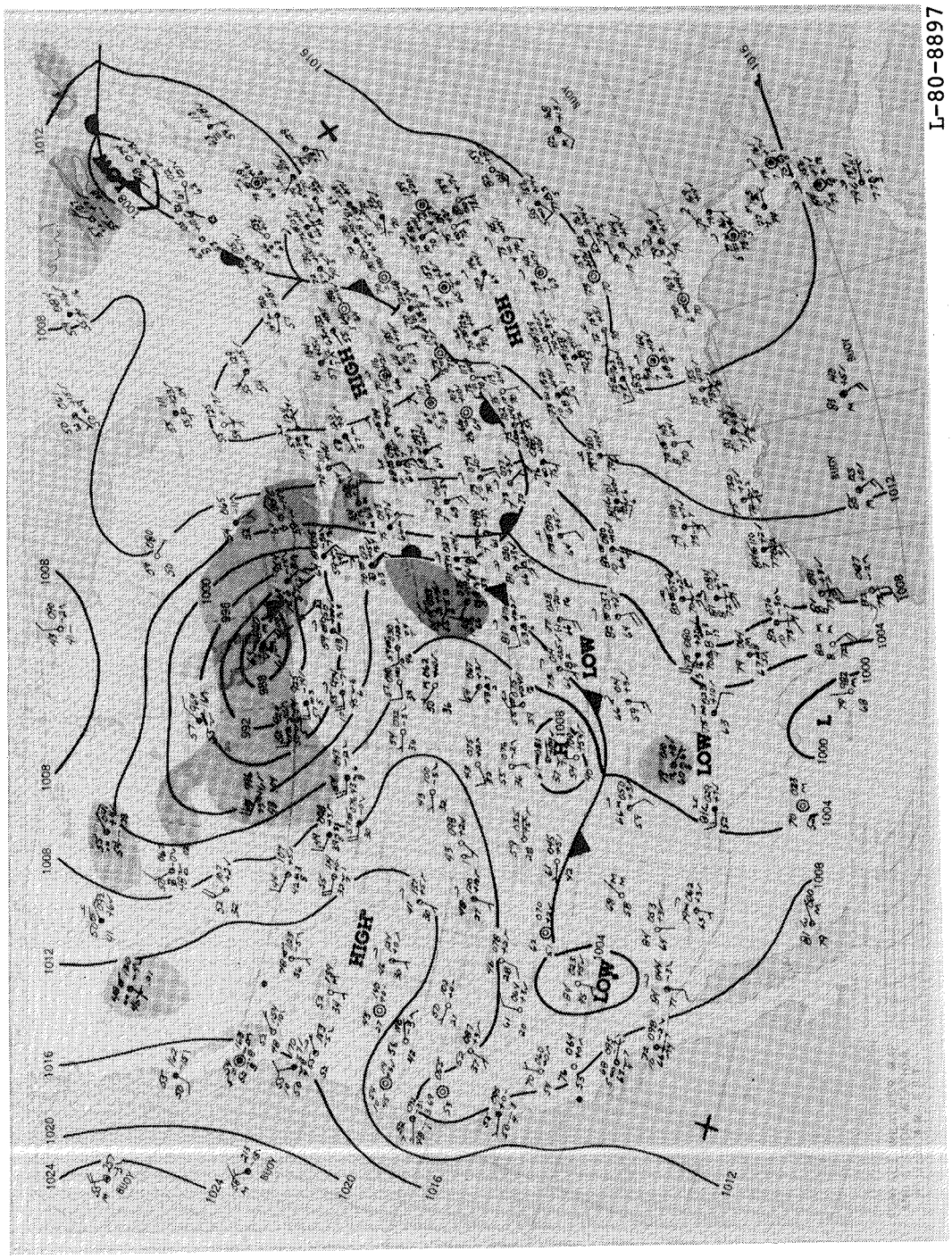


Figure B22.- Weather map for August 4, 1980.

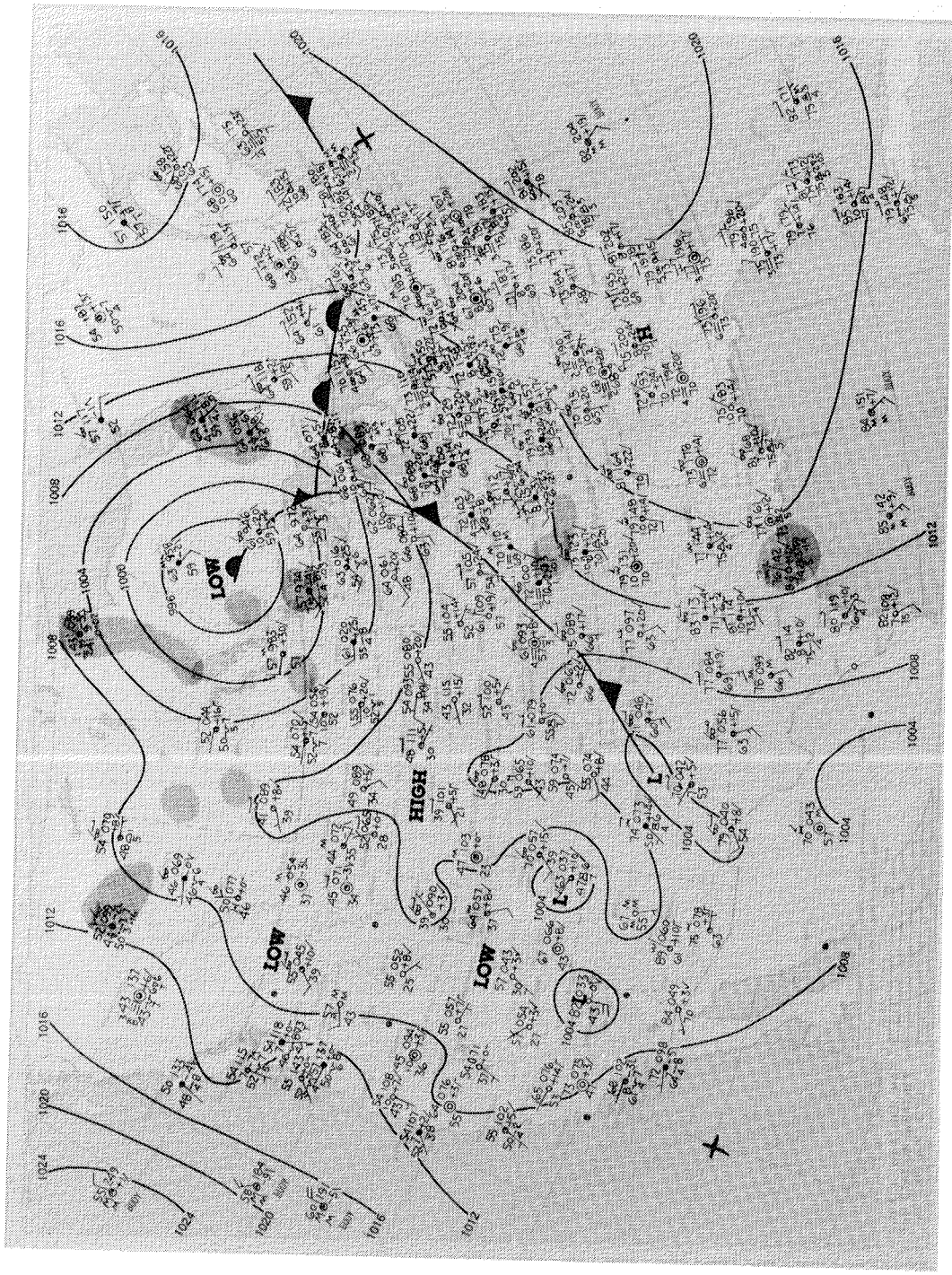


Figure B23.- Weather map for August 5, 1980.

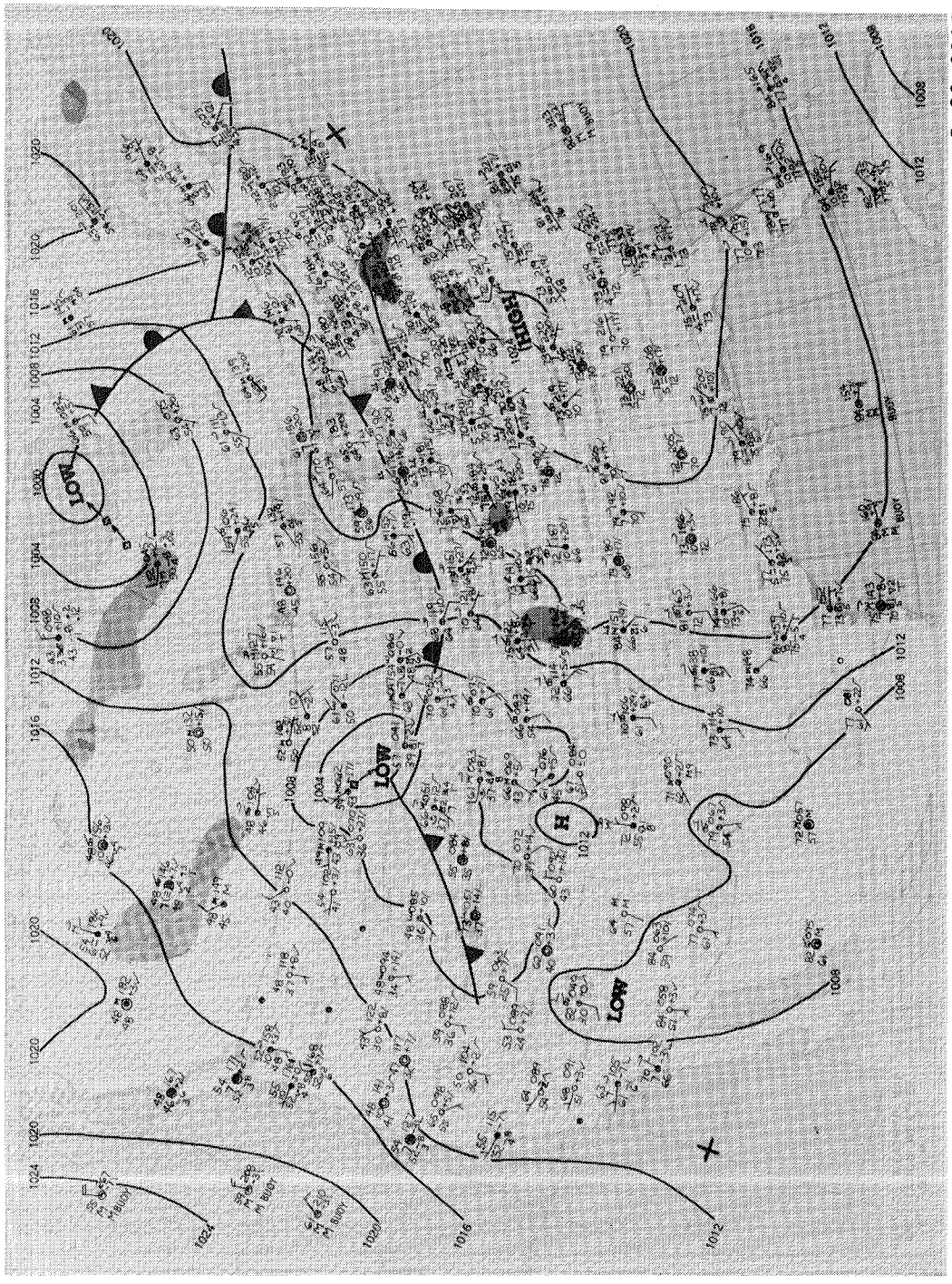


Figure B24.- Weather map for August 6, 1980.

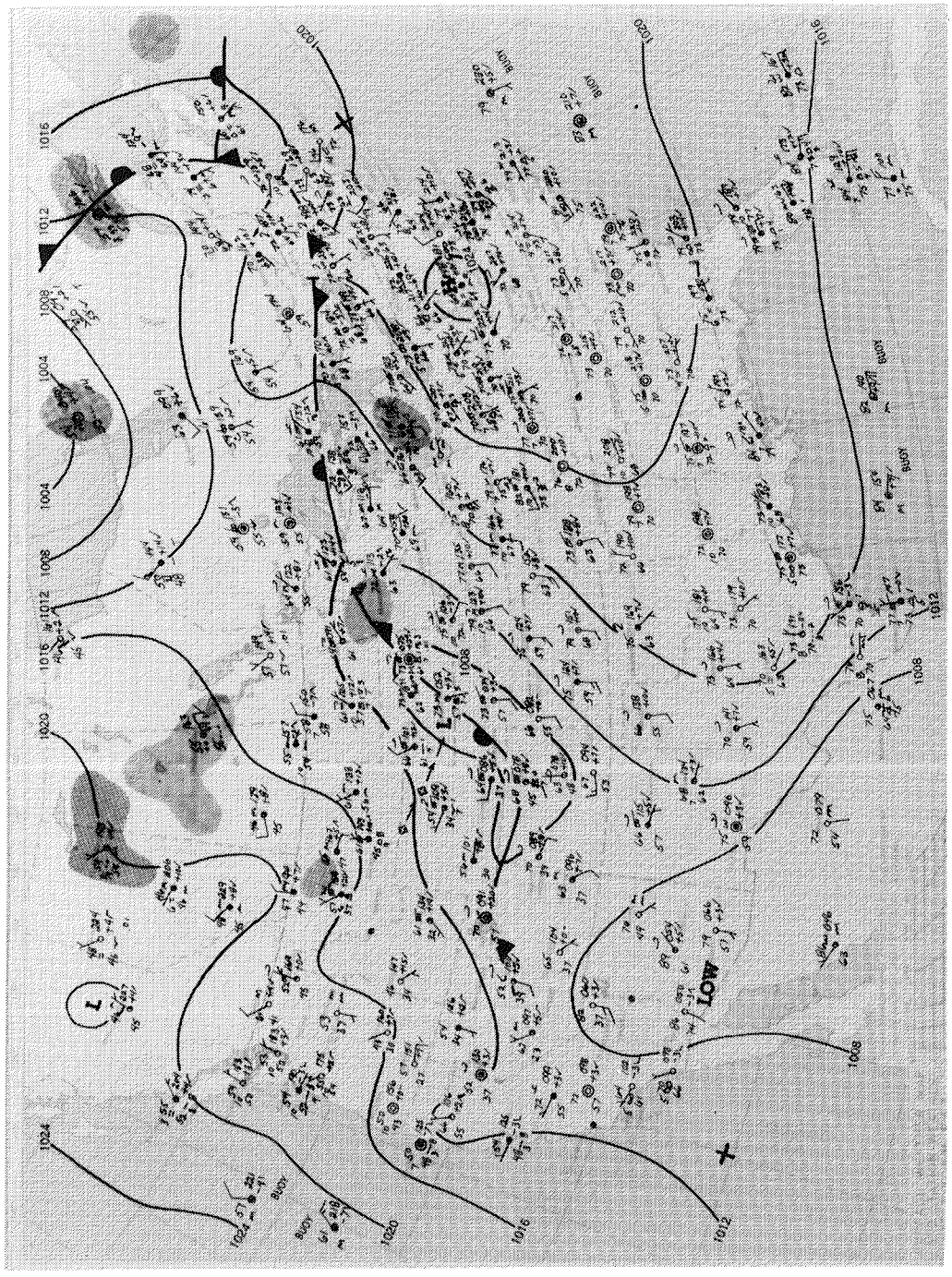


Figure B25.- Weather map for August 7, 1980.

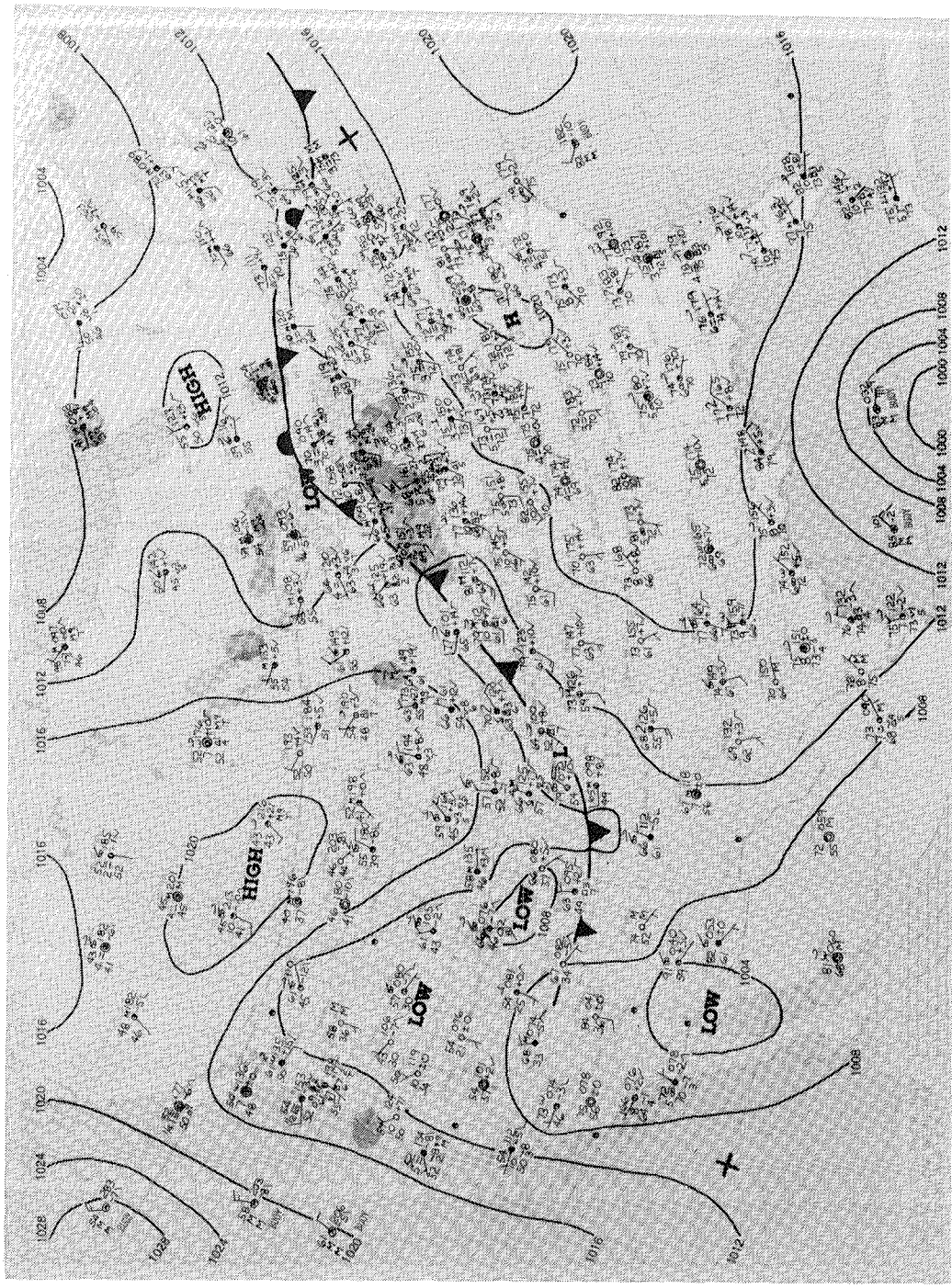
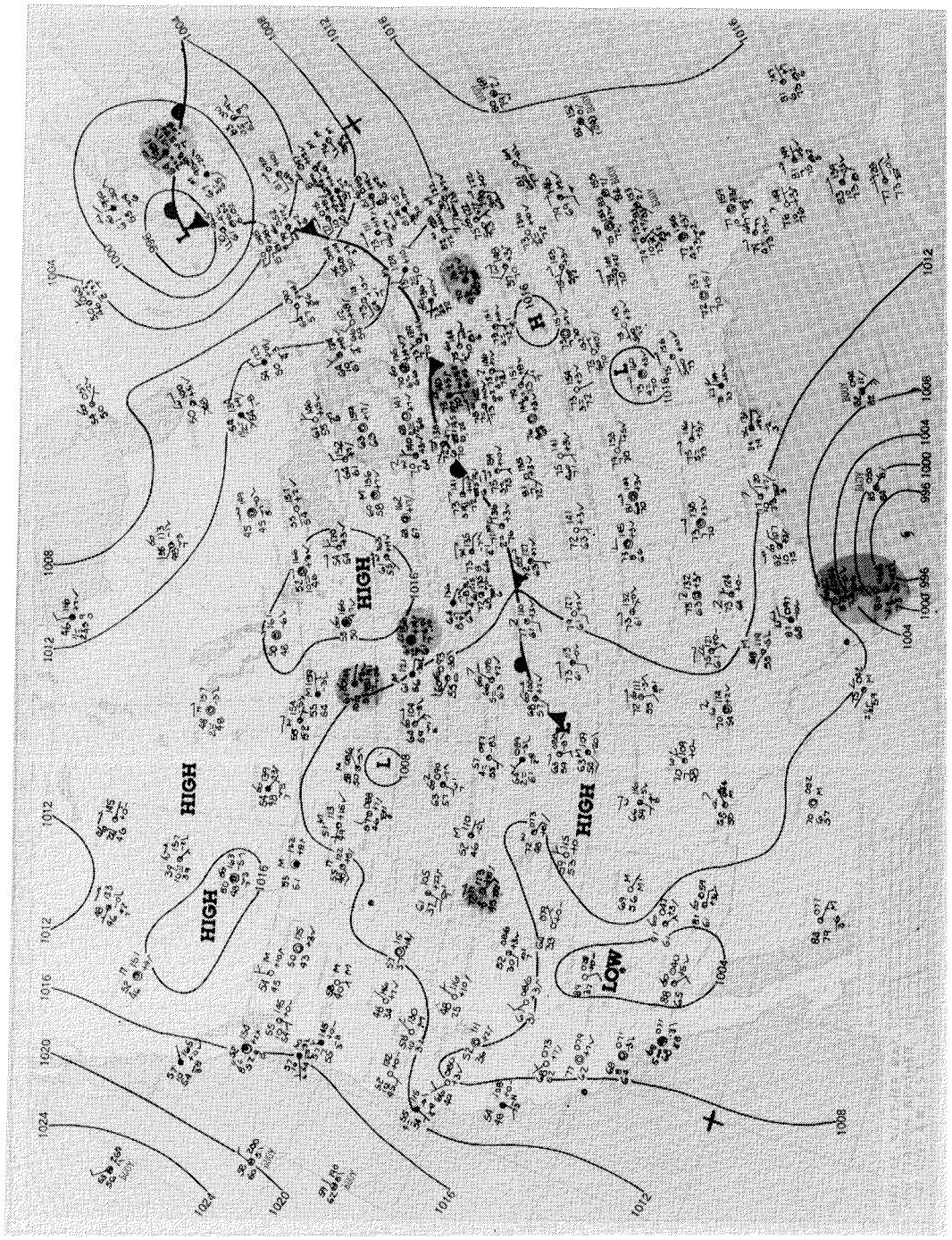


Figure B26.- Weather map for August 8, 1980.



L-80-8876

Figure B27.- Weather map for August 9, 1980.

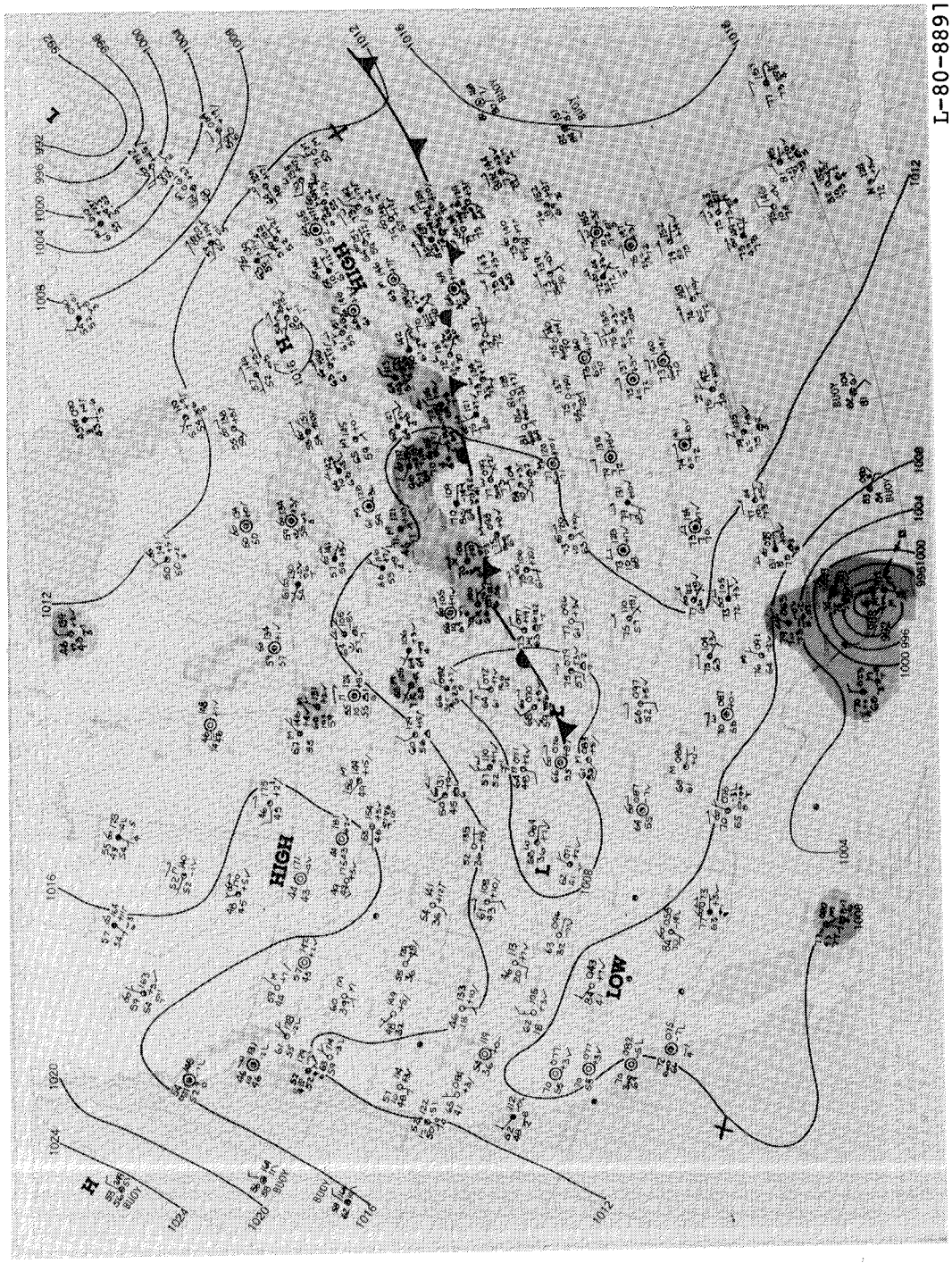
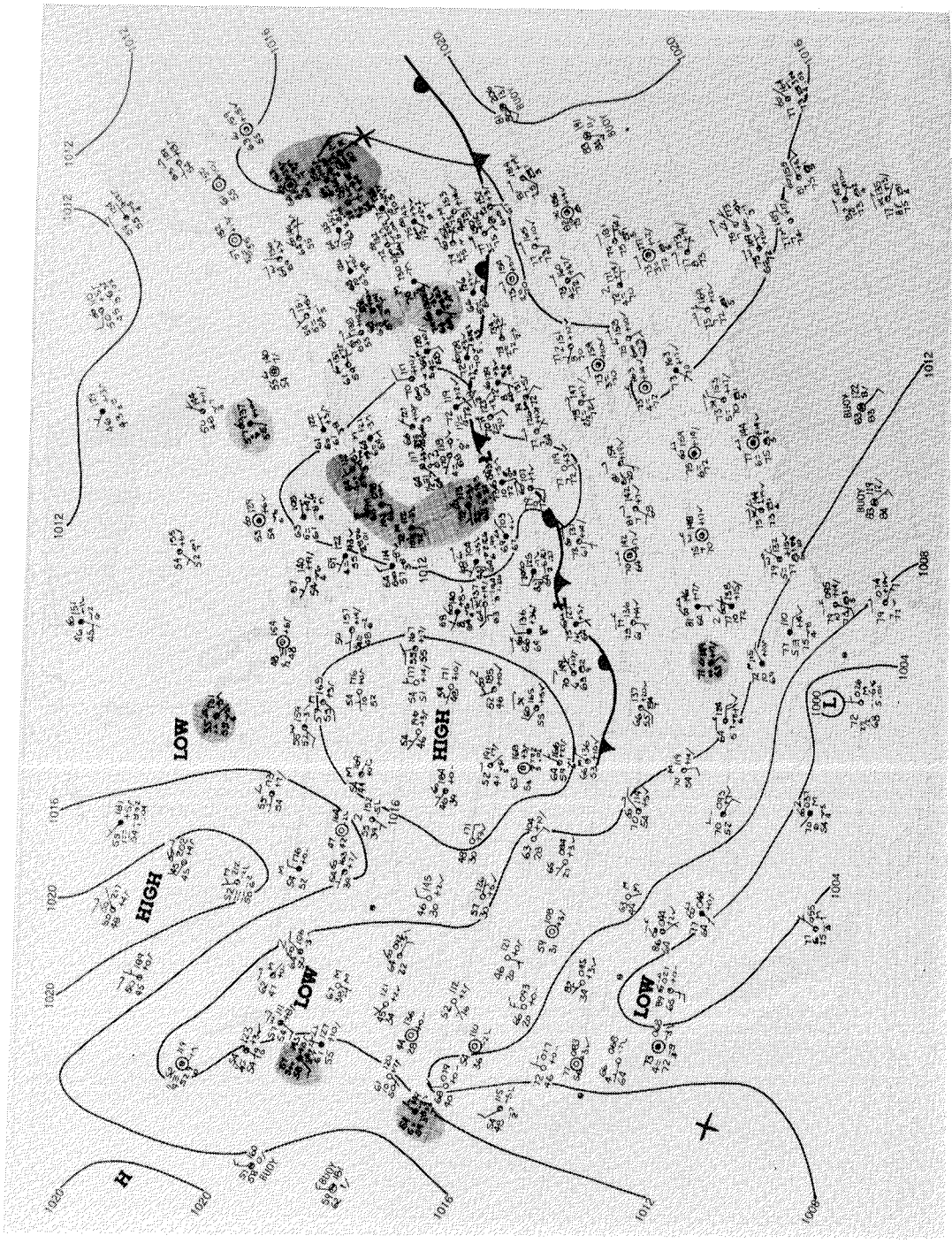


Figure B28.- Weather map for August 10, 1980.



L-80-8903

Figure B29.- Weather map for August 11, 1980.

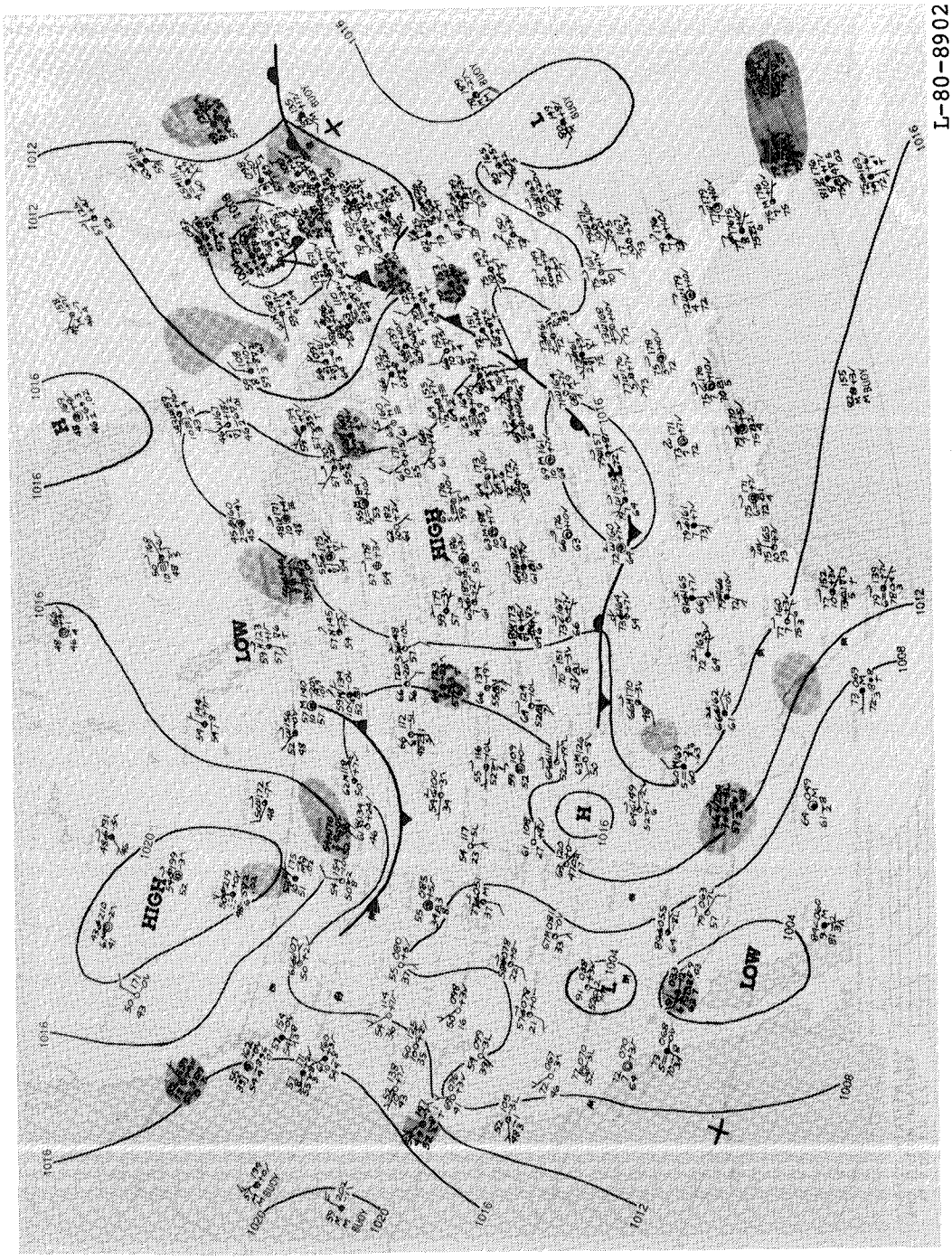


Figure B30.- Weather map for August 12, 1980.

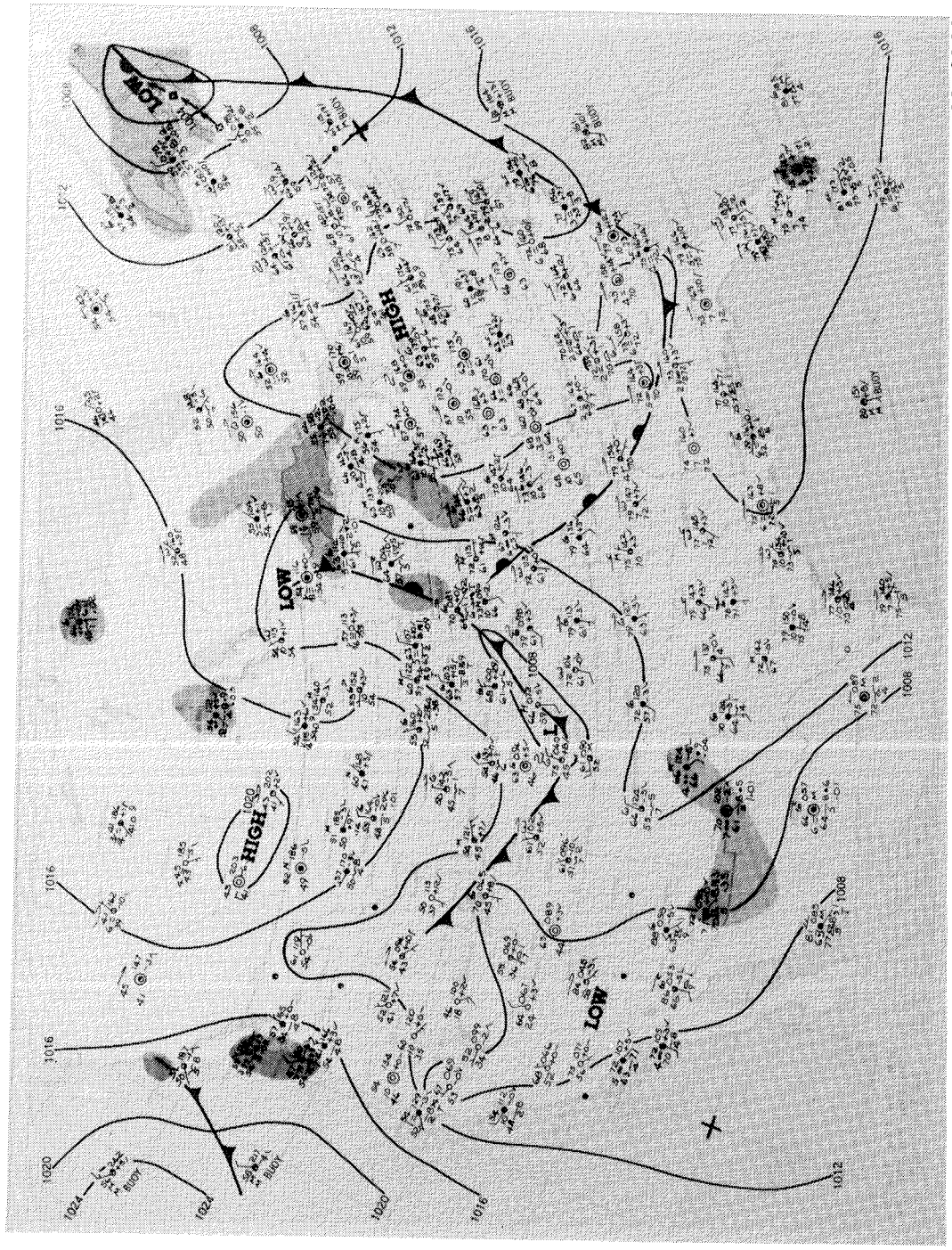


Figure B31.- Weather map for August 13, 1980.

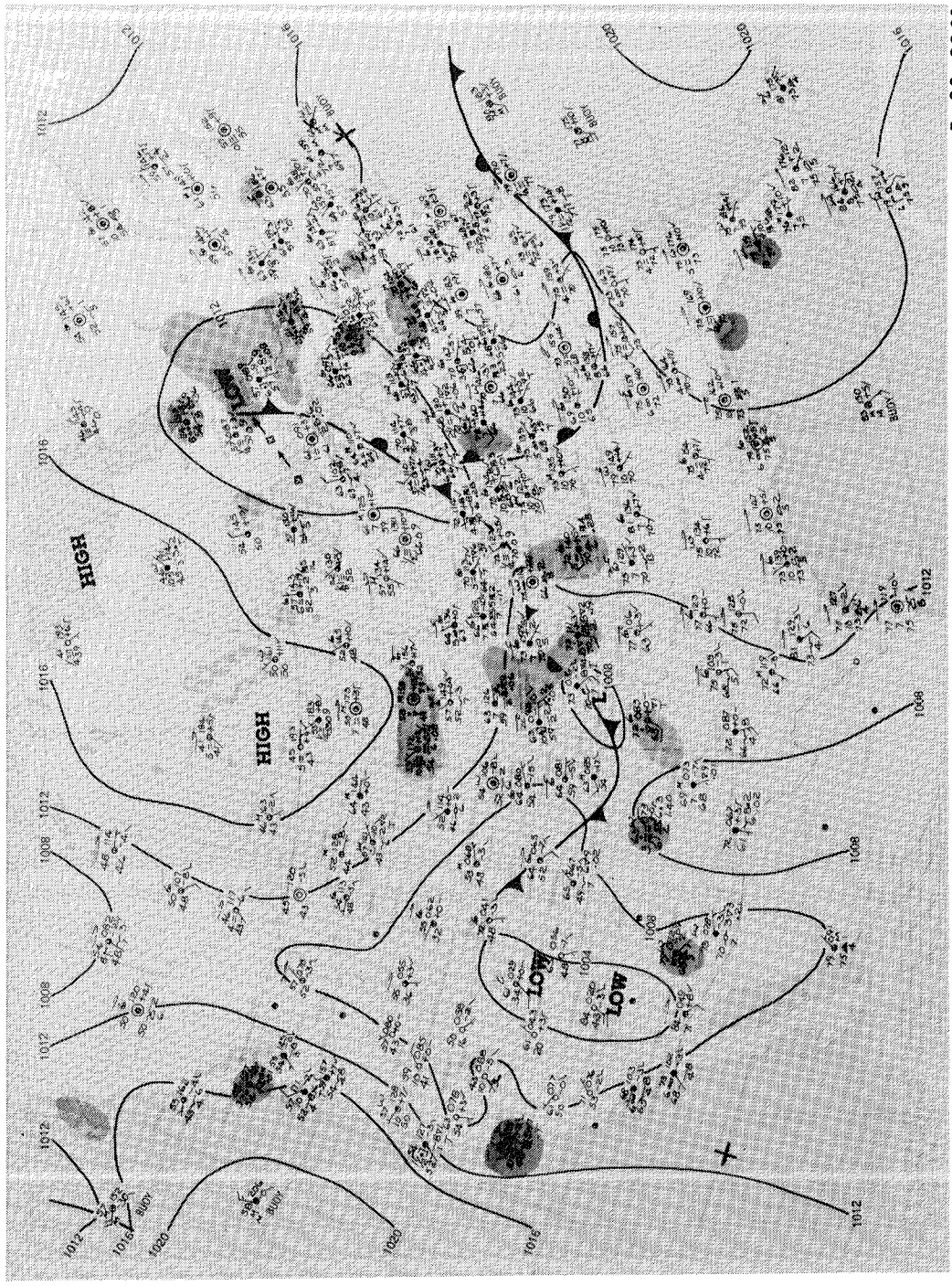


Figure B32.- Weather map for August 14, 1980.

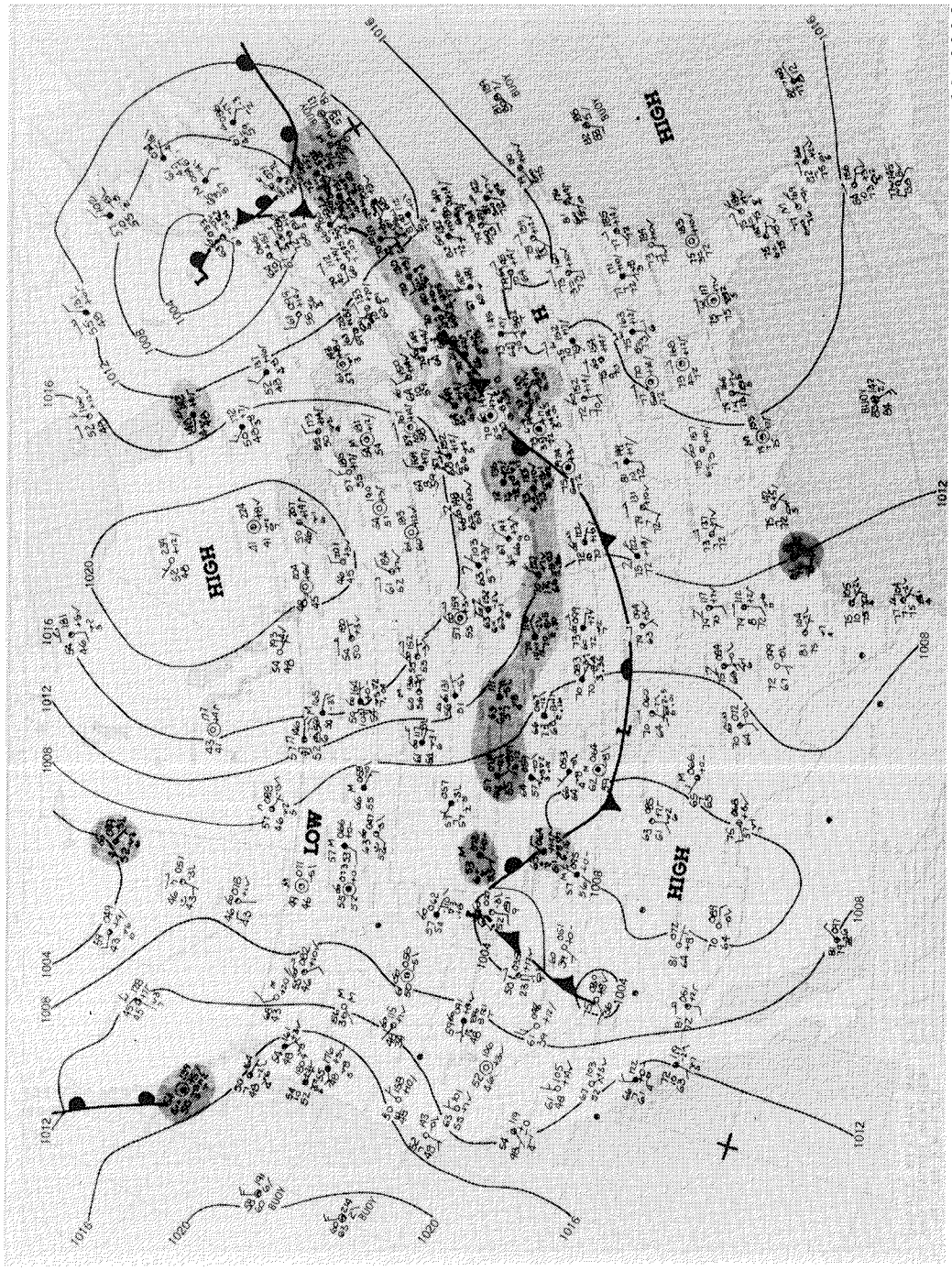
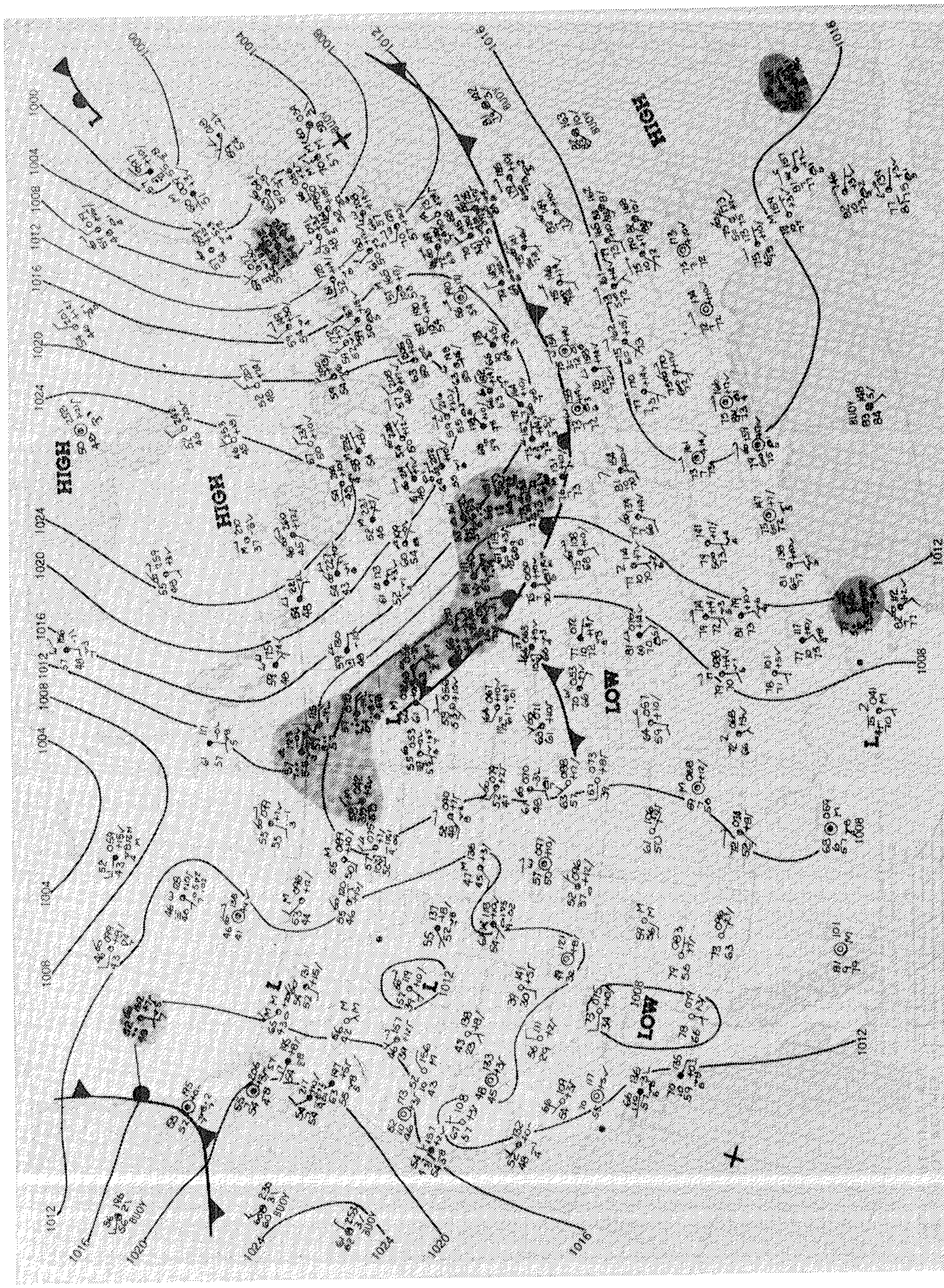


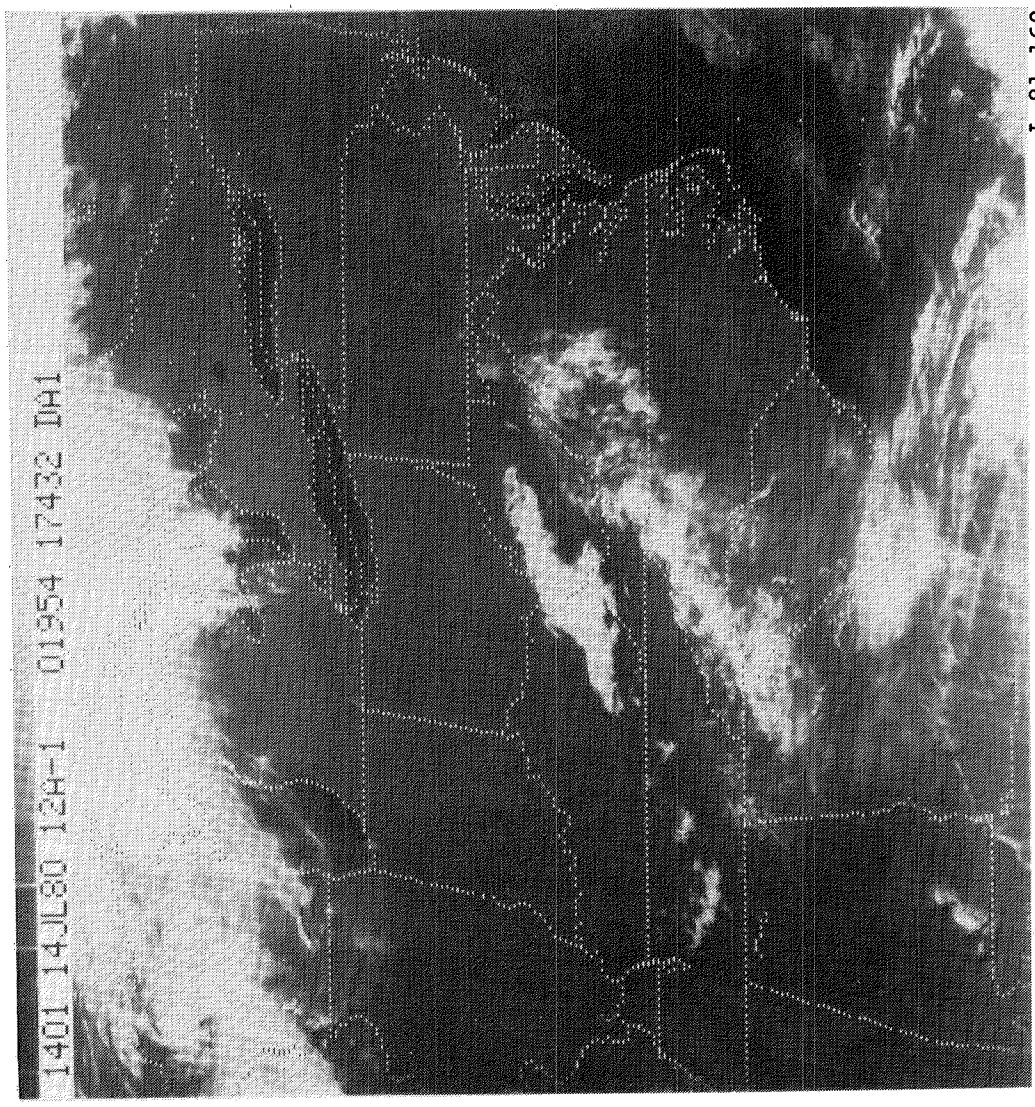
Figure B33.- Weather map for August 15, 1980.



L-80-8899

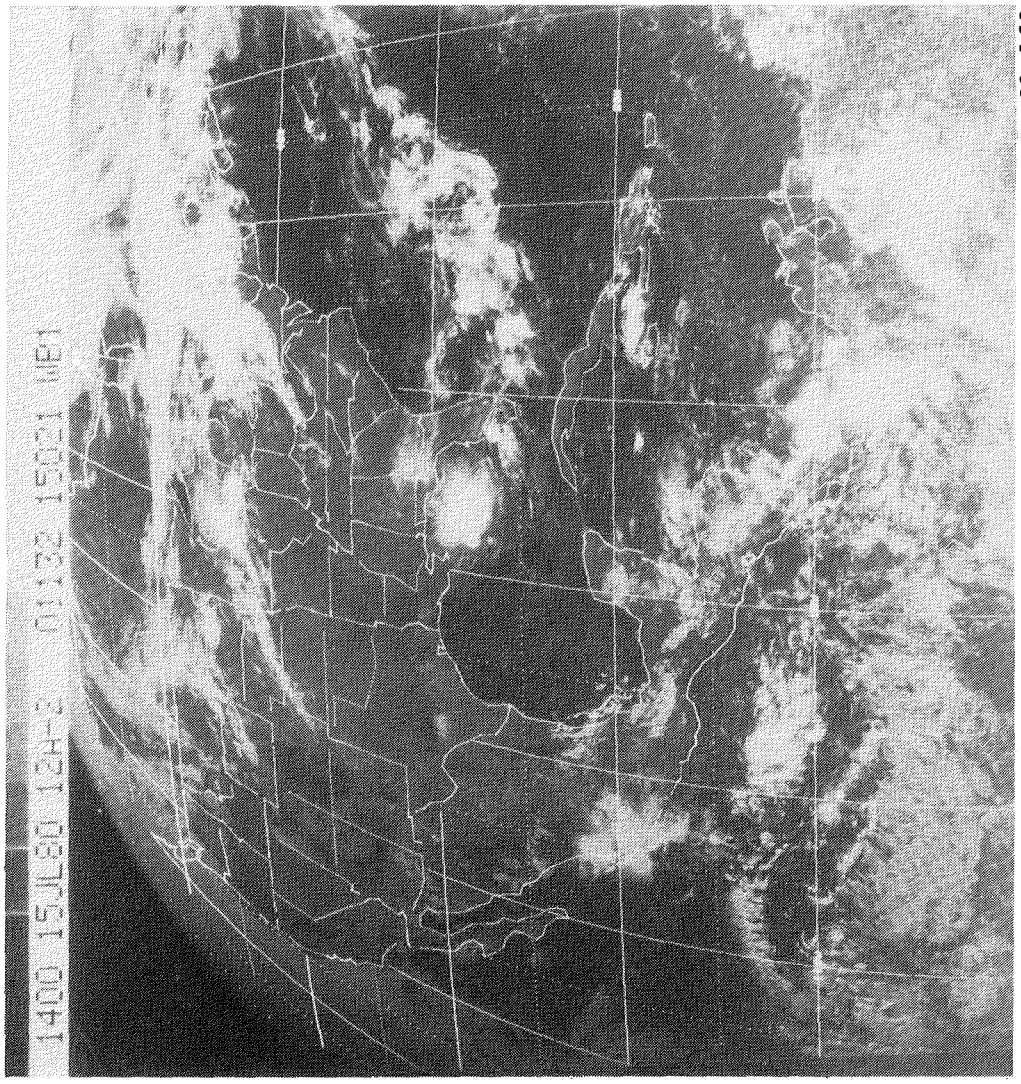
Figure B34.- Weather map for August 16, 1980.

Figure B35.- Weather map for August 17, 1980.



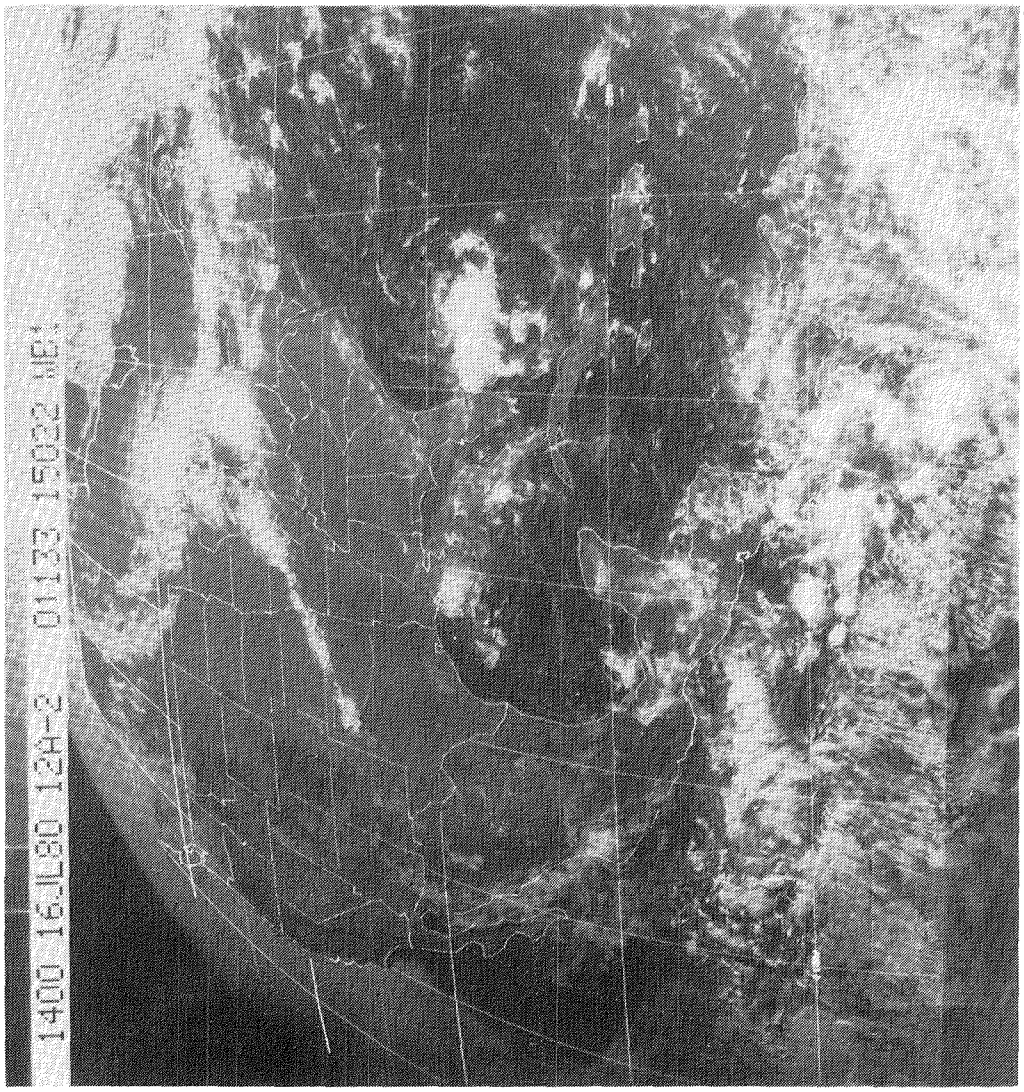
L-81-168

Figure B36.- GOES image for July 14, 1980.



L-81-169

Figure B37.- GOES image for July 15, 1980.



L-81-170

Figure B38.- GOES image for July 16, 1980.

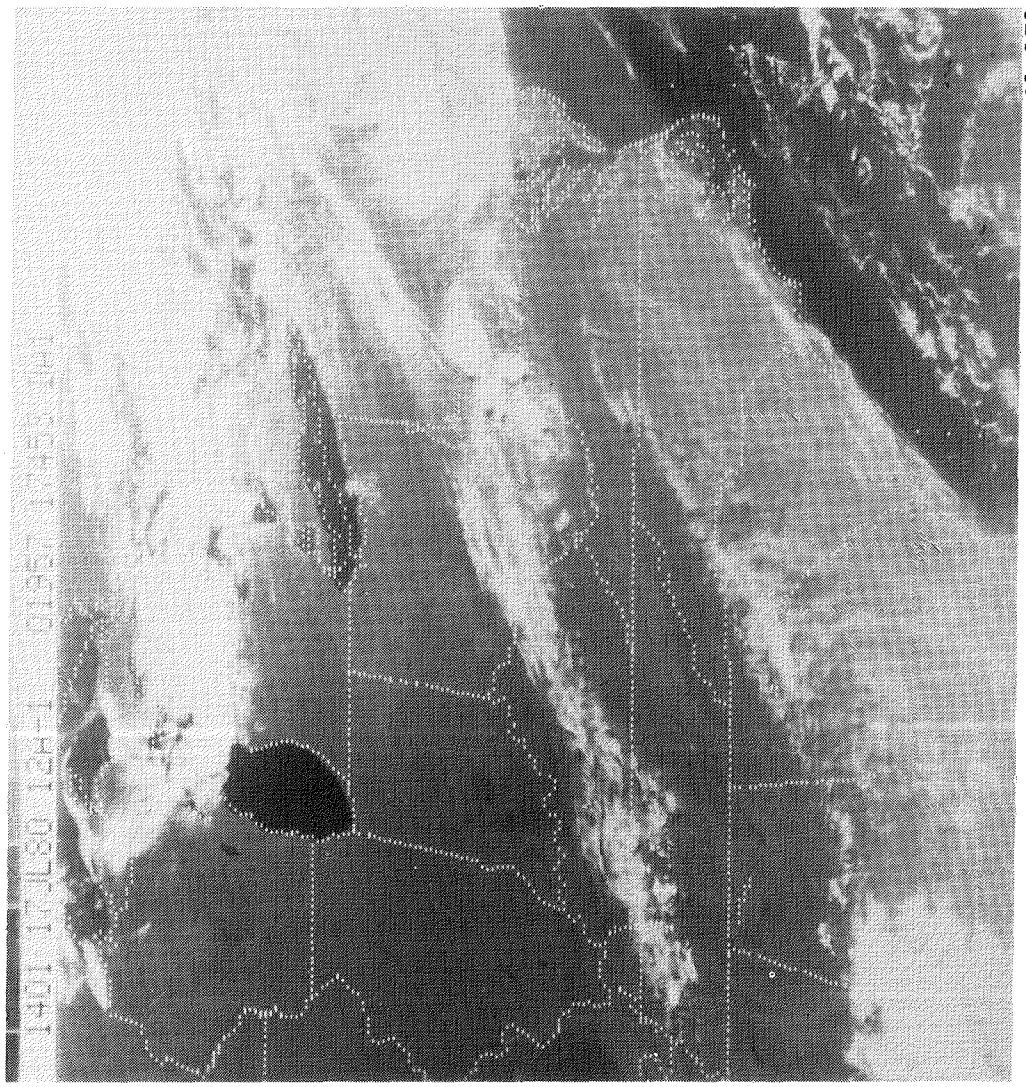


Figure B39.- GOES image for July 17, 1980.

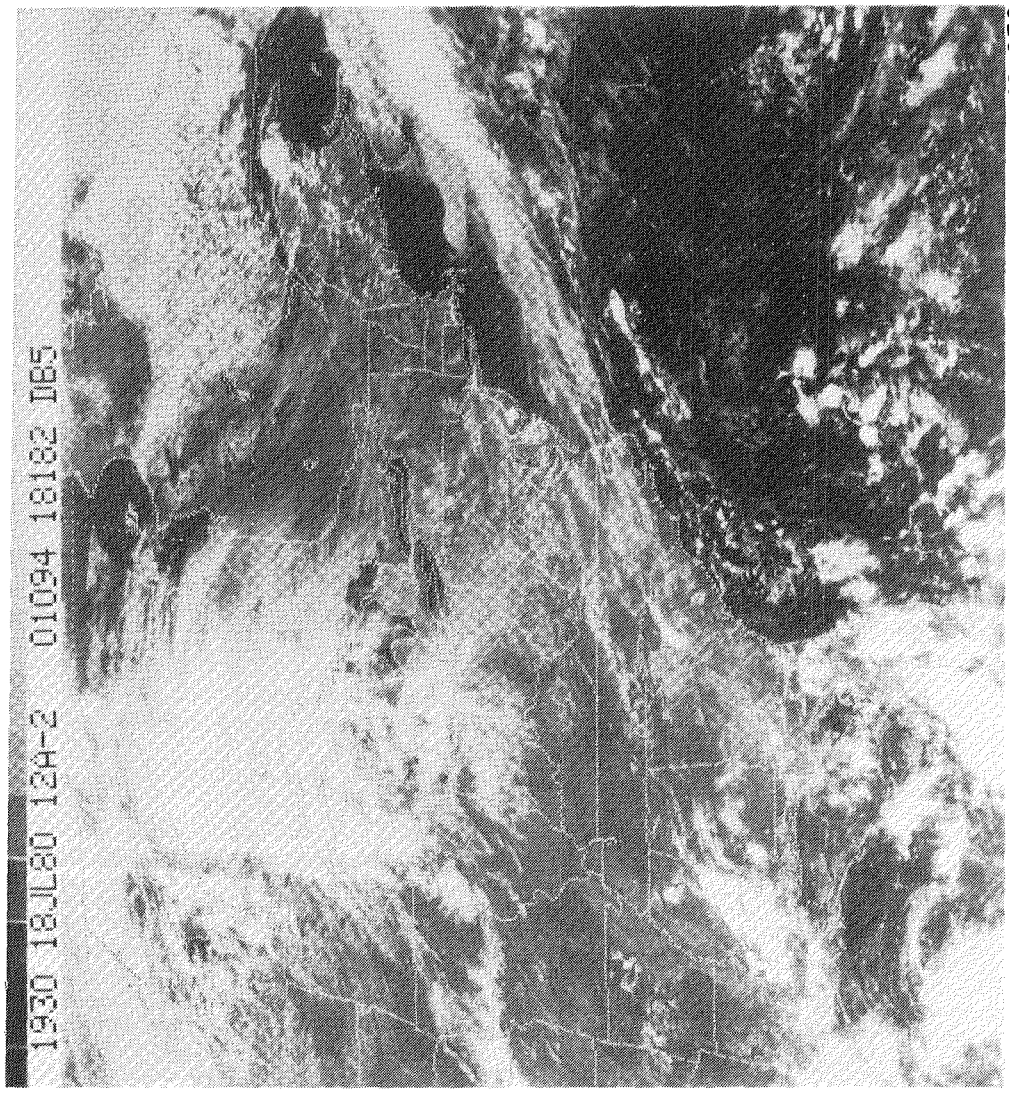


Figure B40.- GOES image for July 18, 1980.

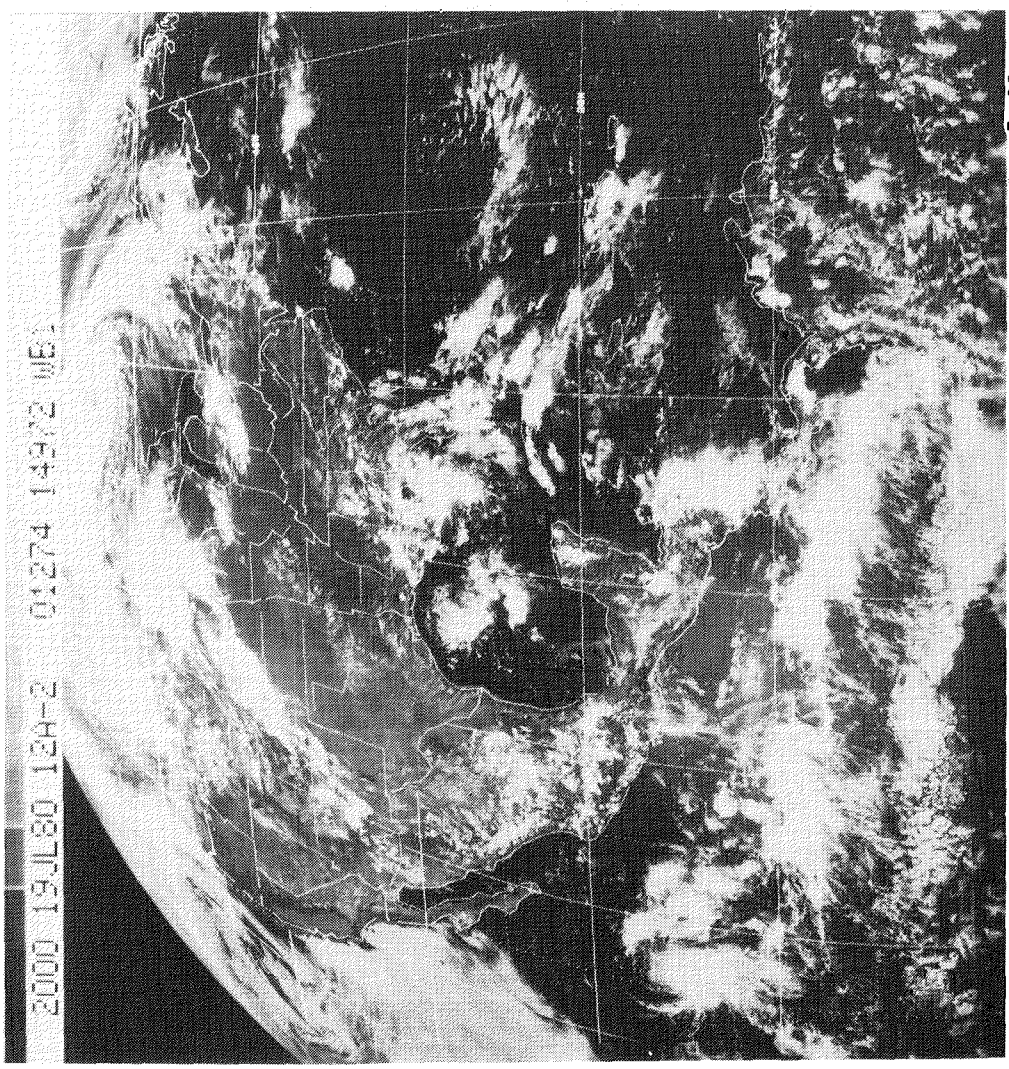


Figure B41.- GOES image for July 19, 1980.

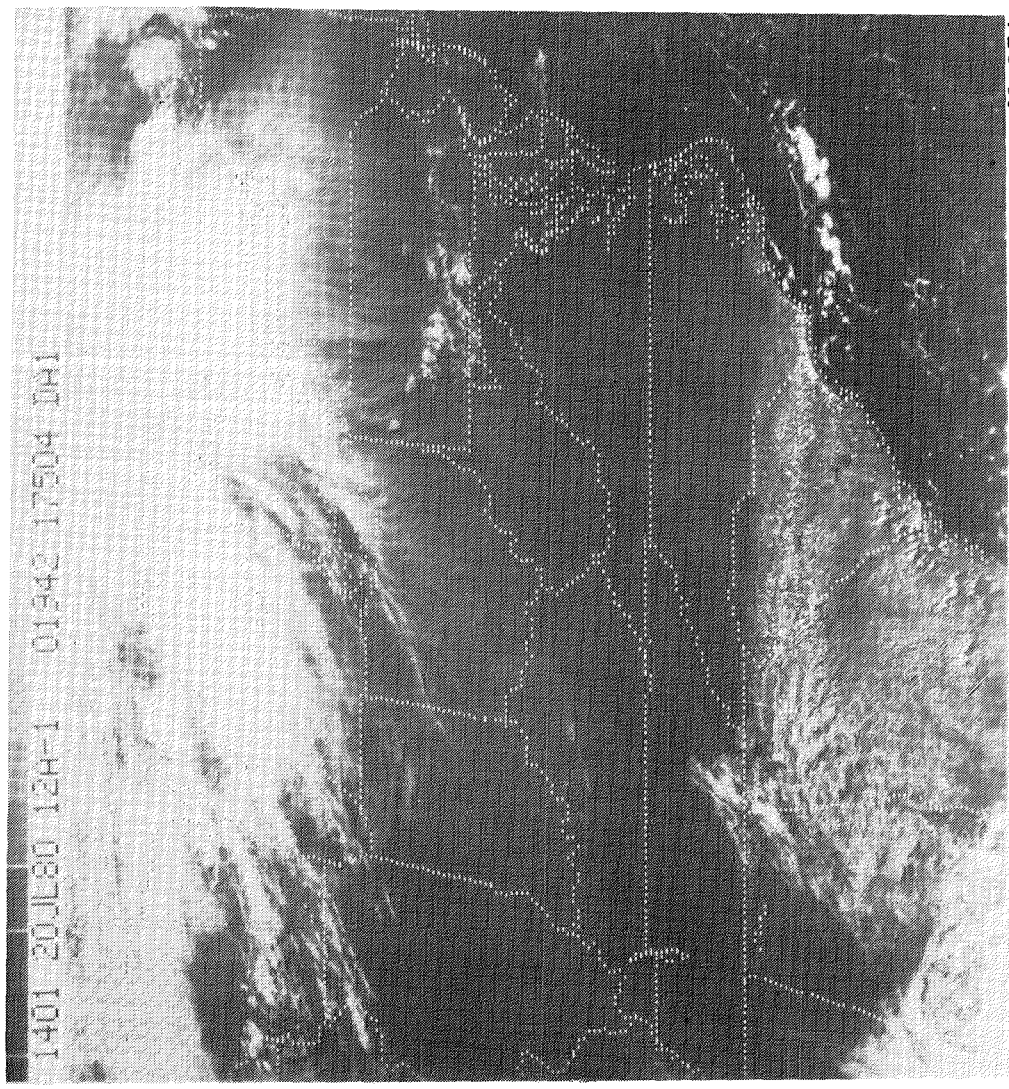


Figure B42.- GOES image for July 20, 1980.

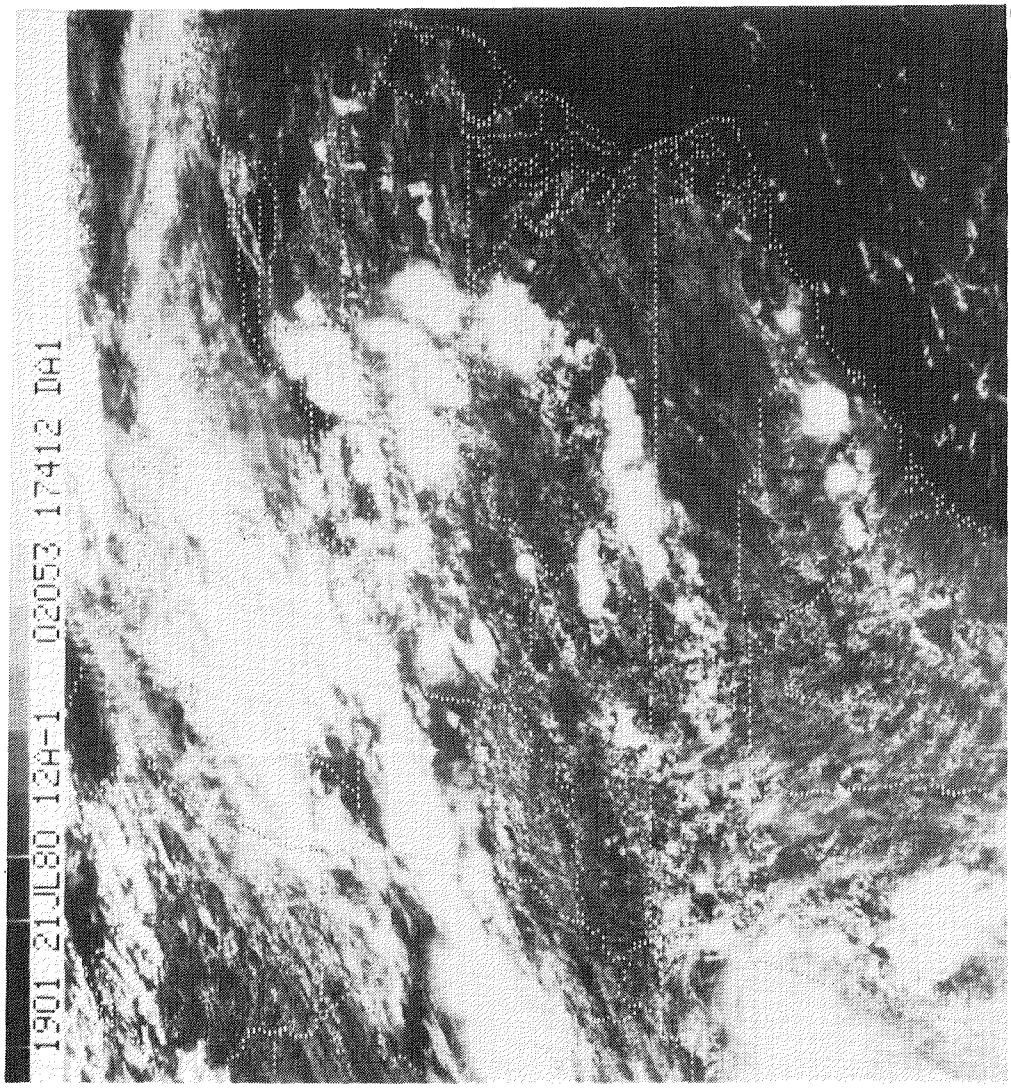
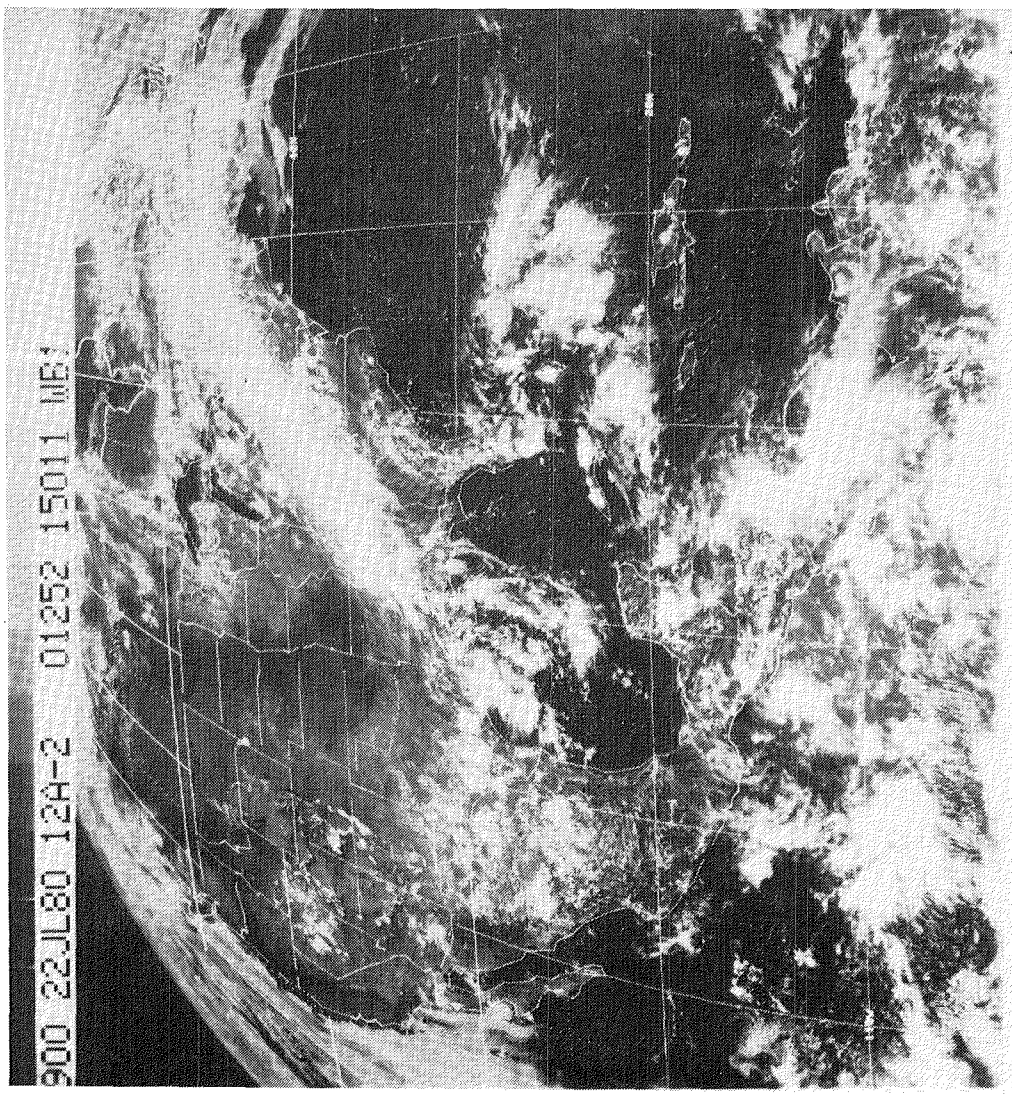
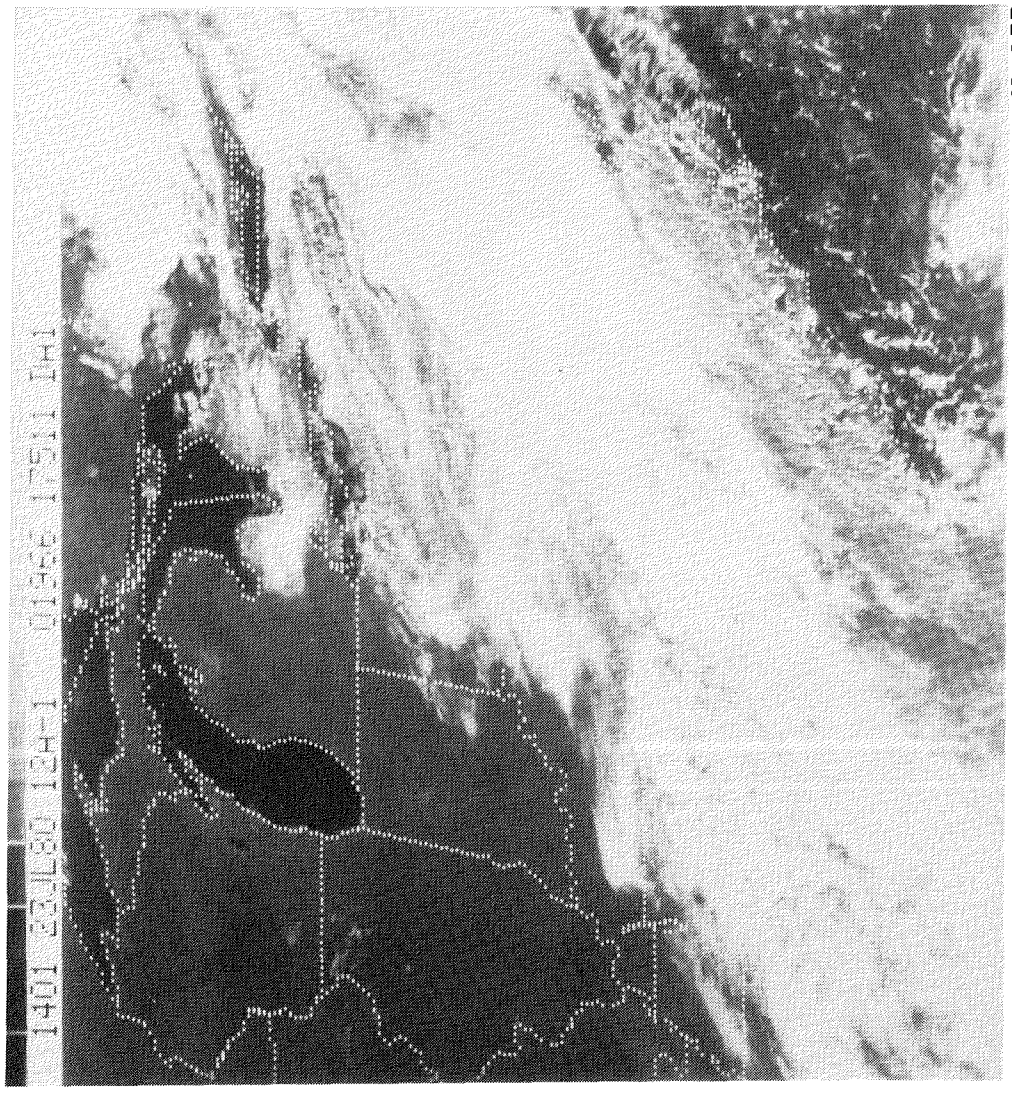


Figure B43.- GOES image for July 21, 1980.



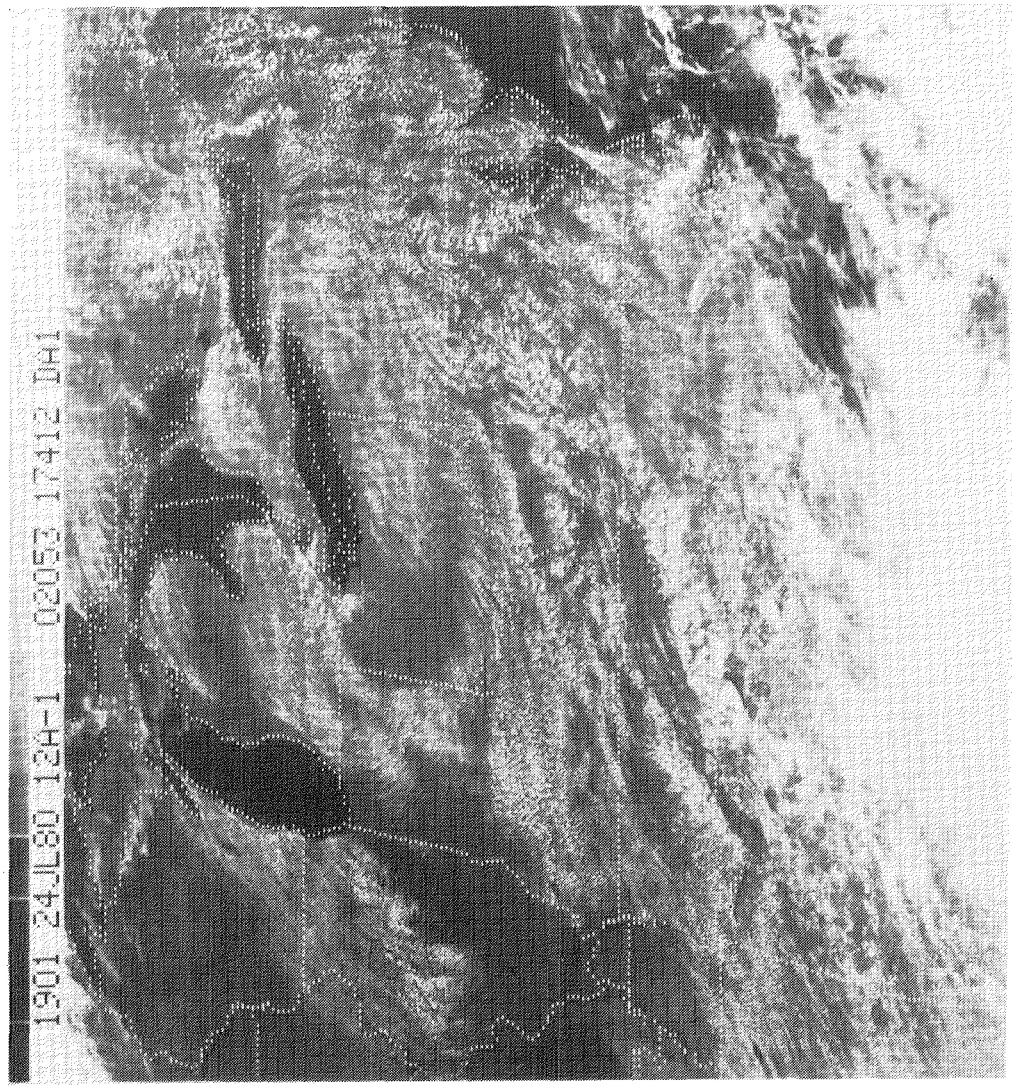
L-81-176

Figure B44.- GOES image for July 22, 1980.



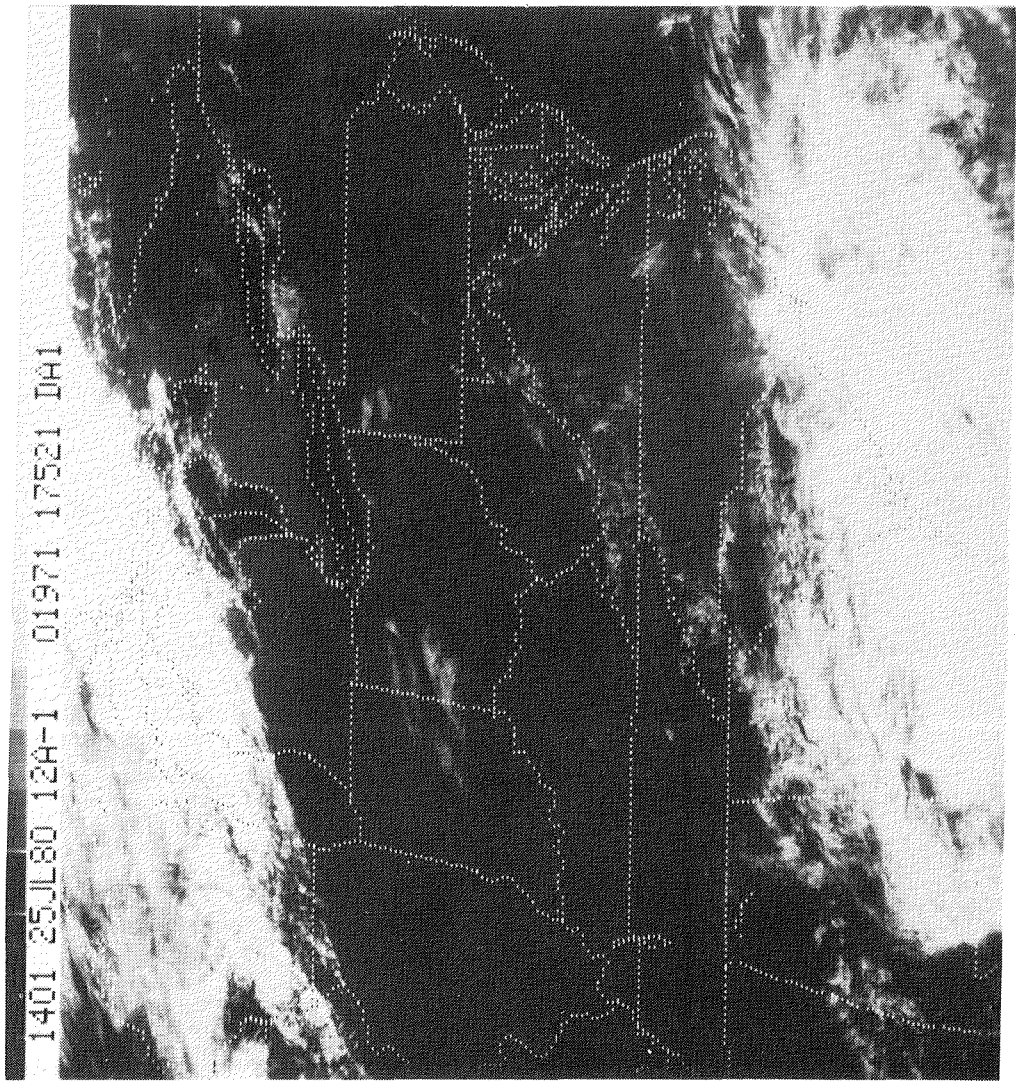
L-81-177

Figure B45.- GOES image for July 23, 1980.



L-81-178

Figure B46.- GOES image for July 24, 1980.



L-81-179

Figure B47.- GOES image for July 25, 1980.

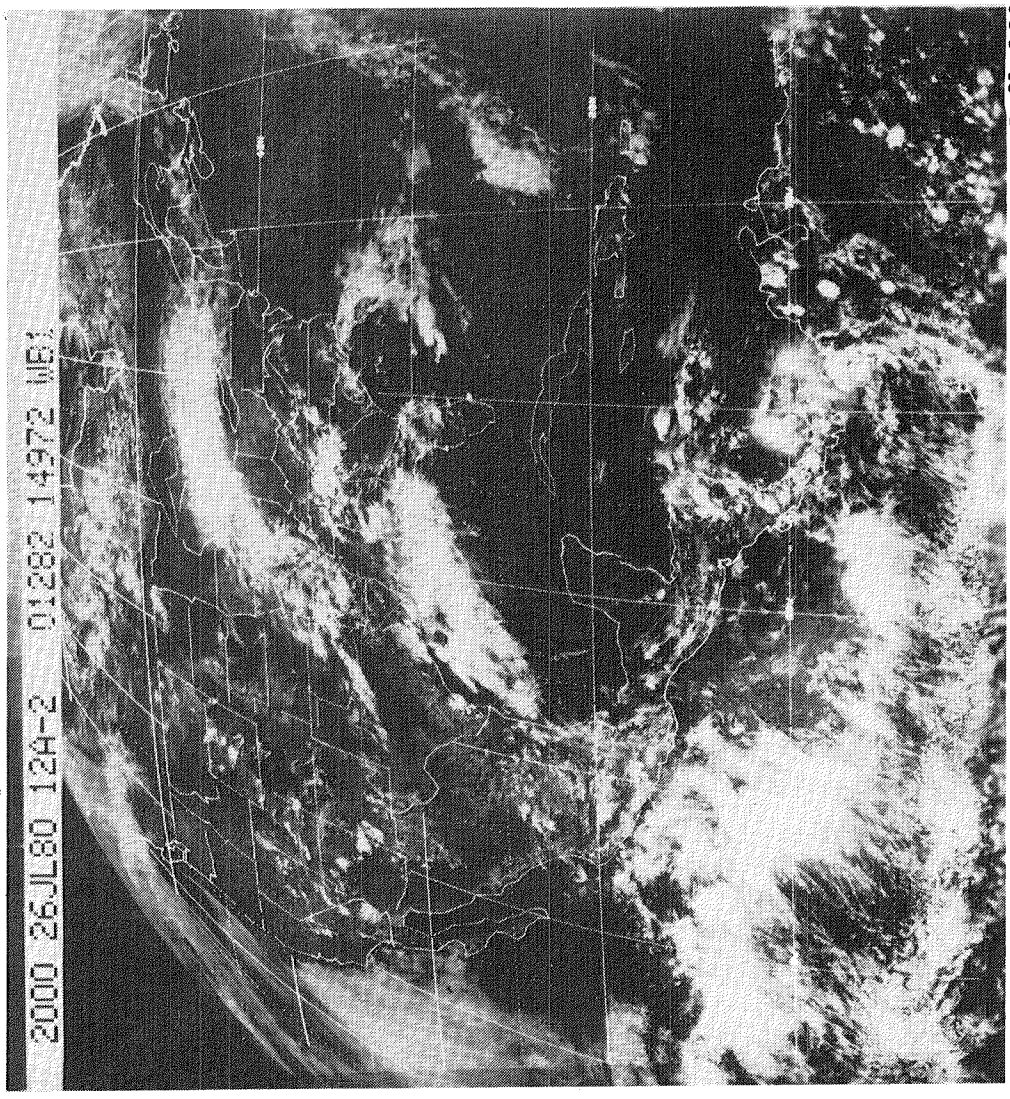
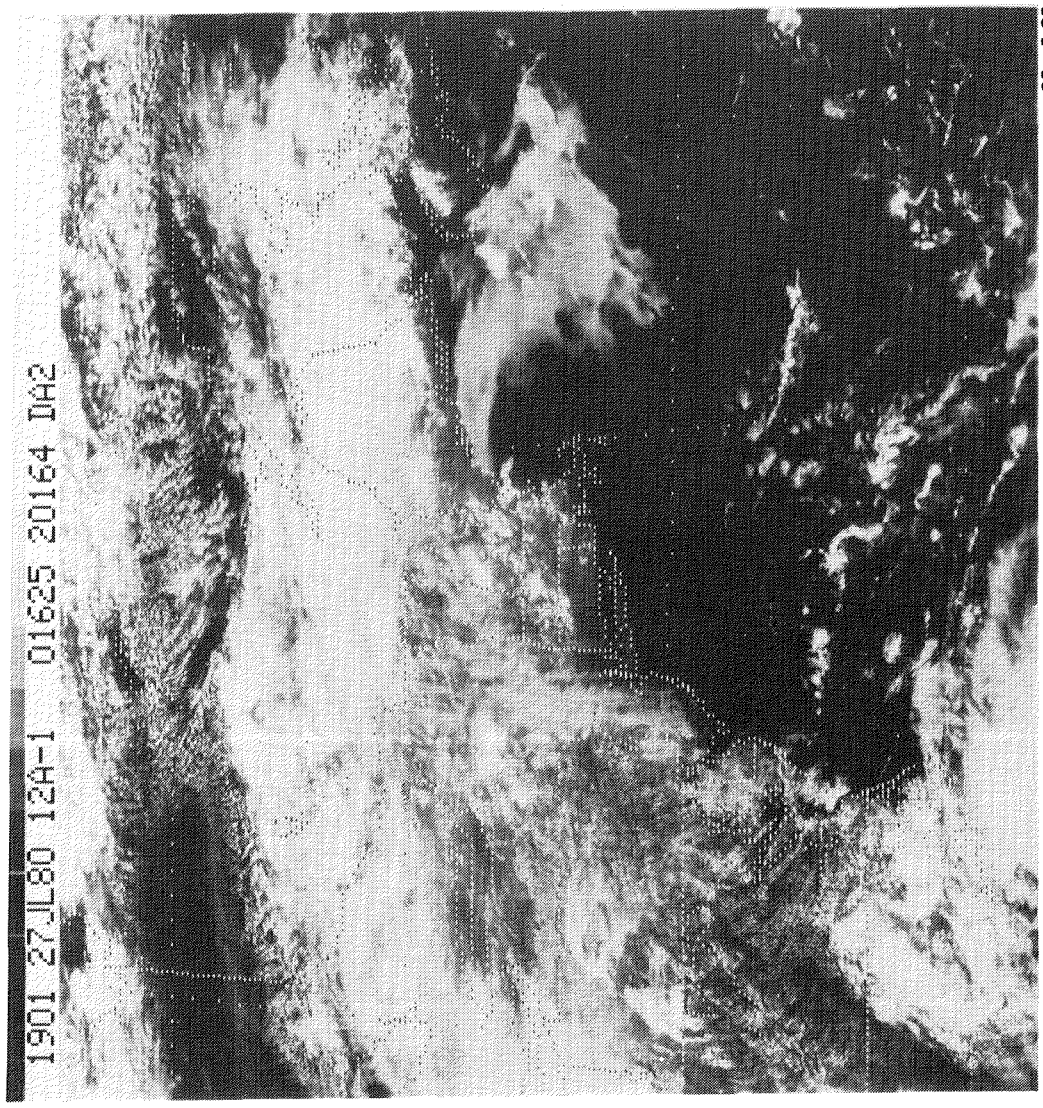
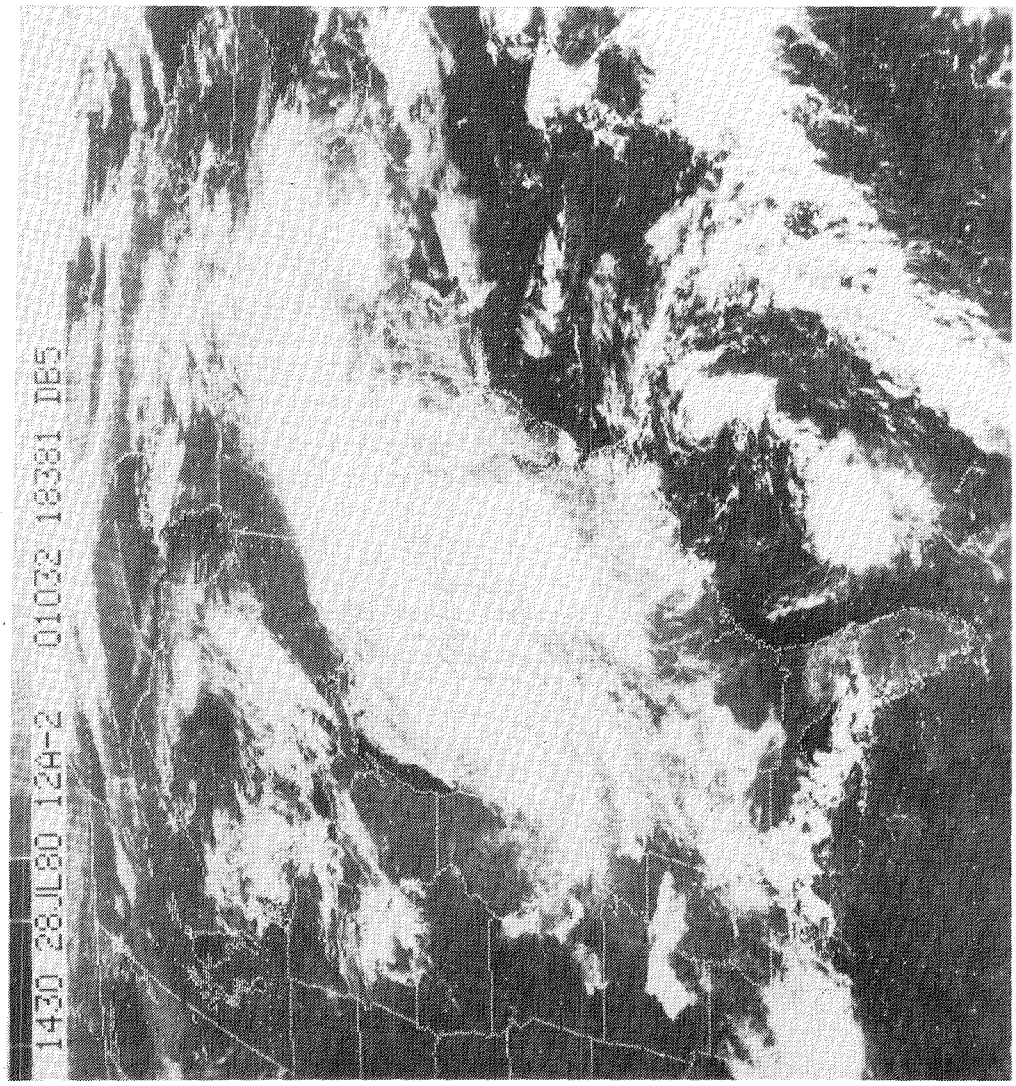


Figure B48.- GOES image for July 26, 1980.



L-81-181

Figure B49.- GOES image for July 27, 1980.



L-81-182

Figure B50.- GOES image for July 28, 1980.

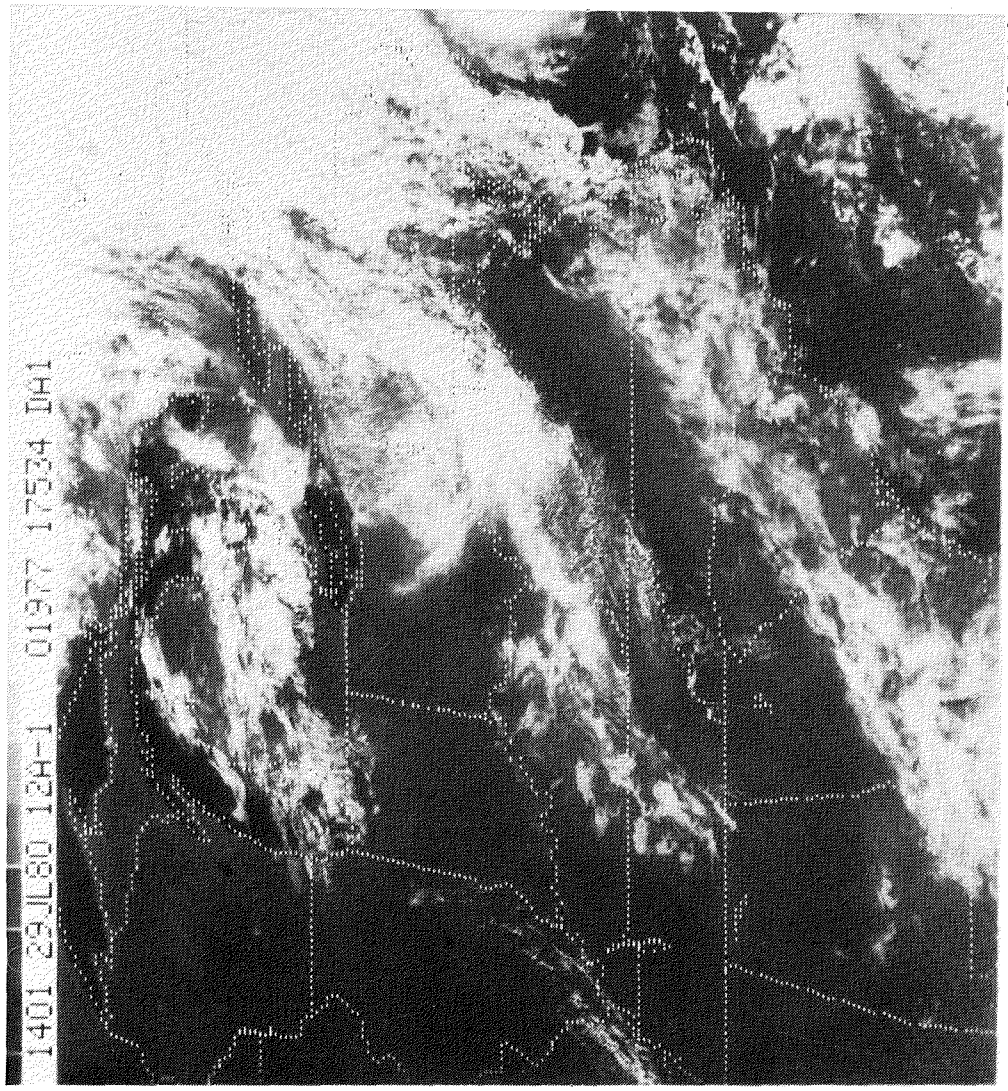


Figure B51.- GOES image for July 29, 1980.

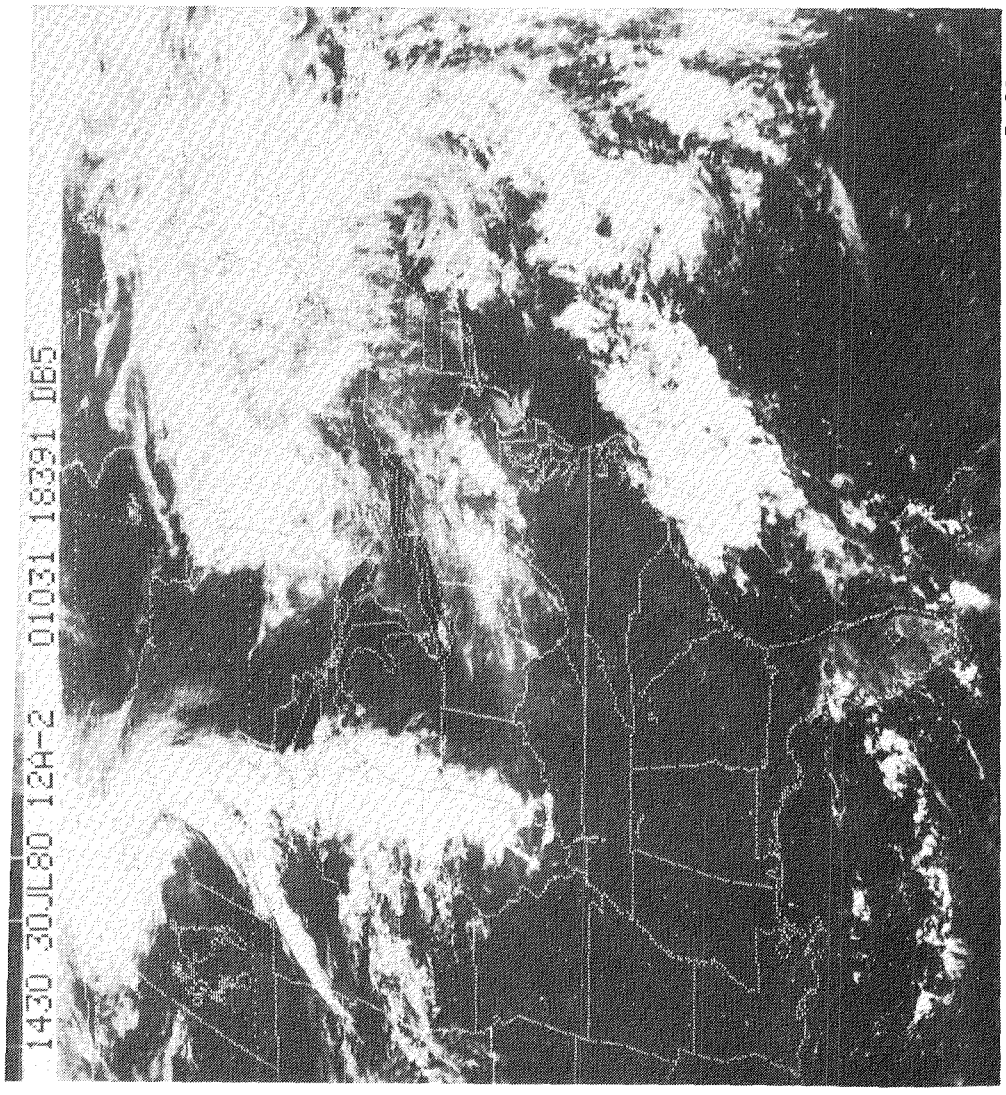
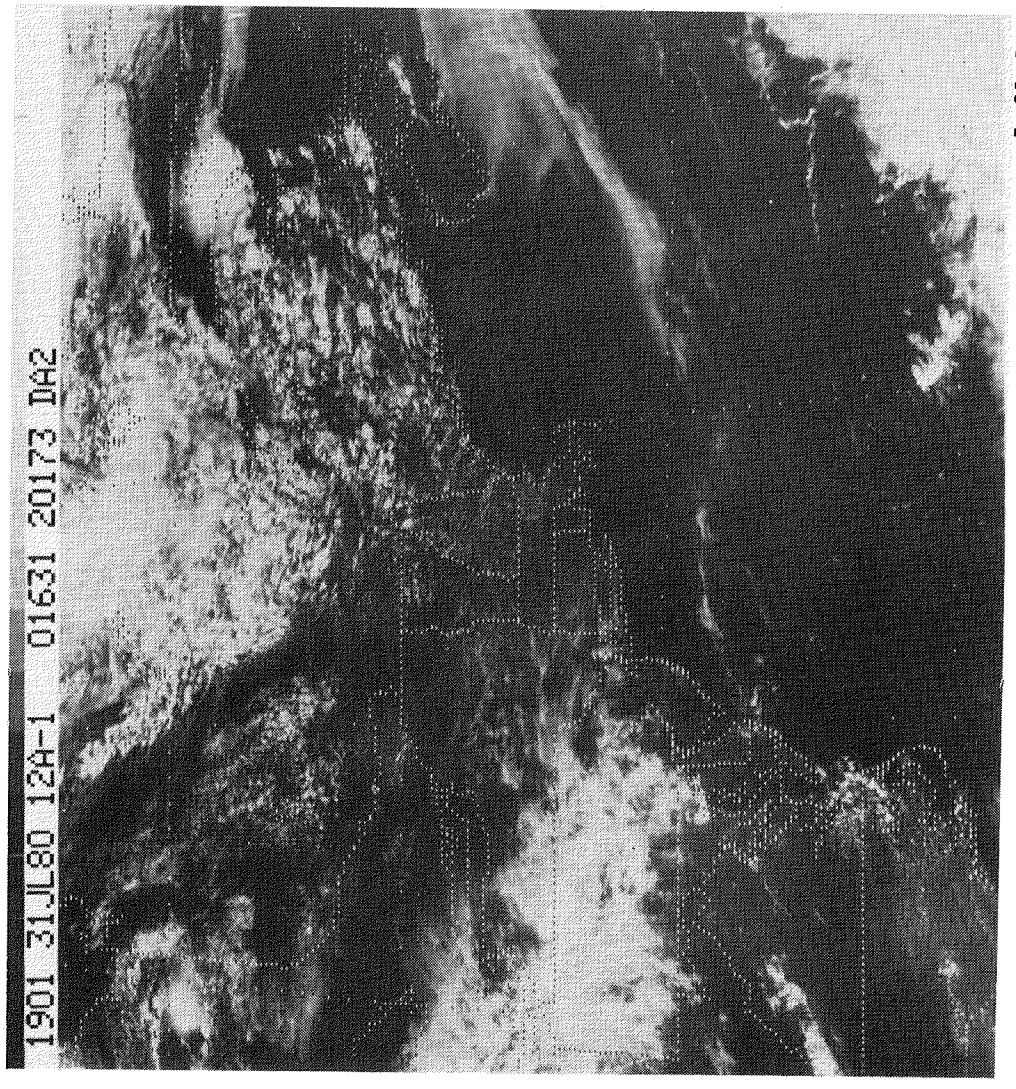


Figure B52.- GOES image for July 30, 1980.



L-81-185

Figure B53.- GOES image for July 31, 1980.

L-81-186

Figure B54.- GOES image for August 1, 1980.

Figure B55.- GOES image for August 2, 1980.

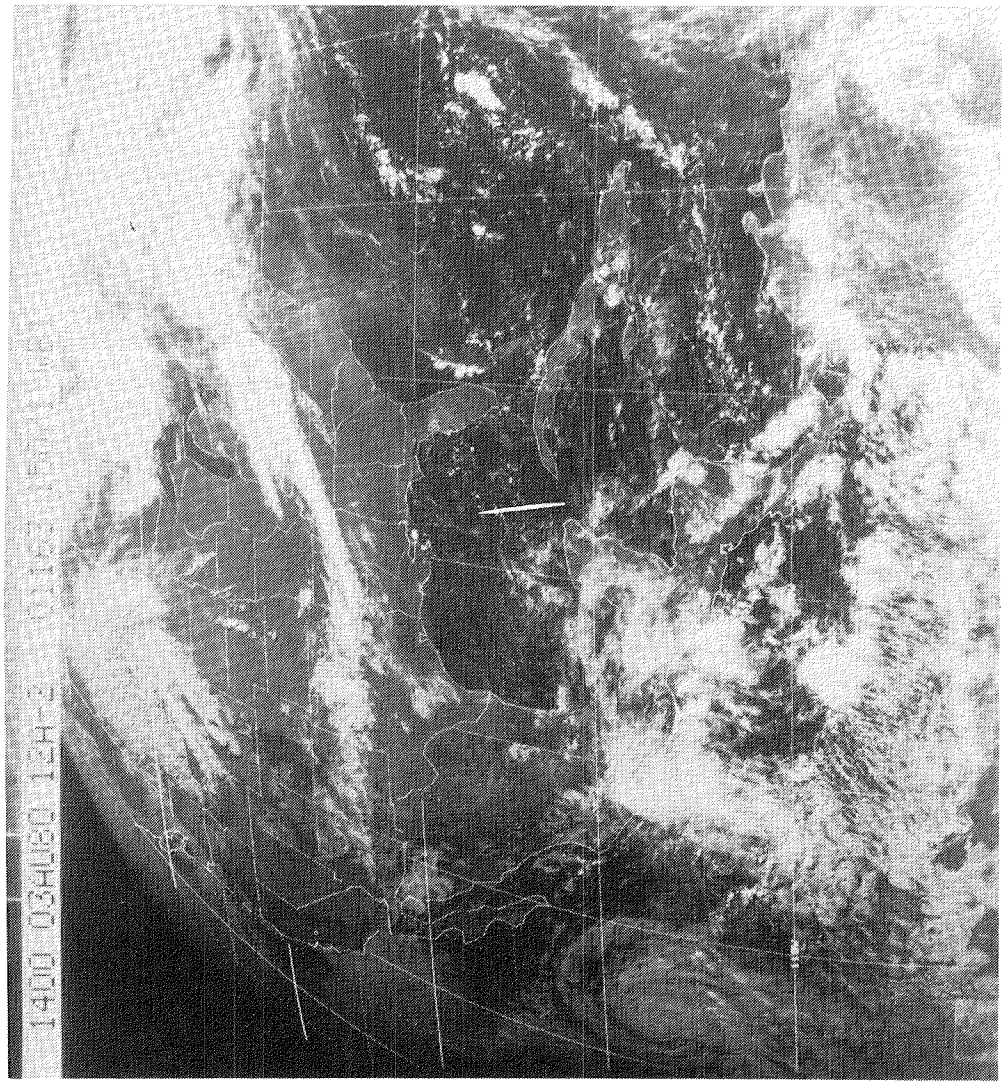
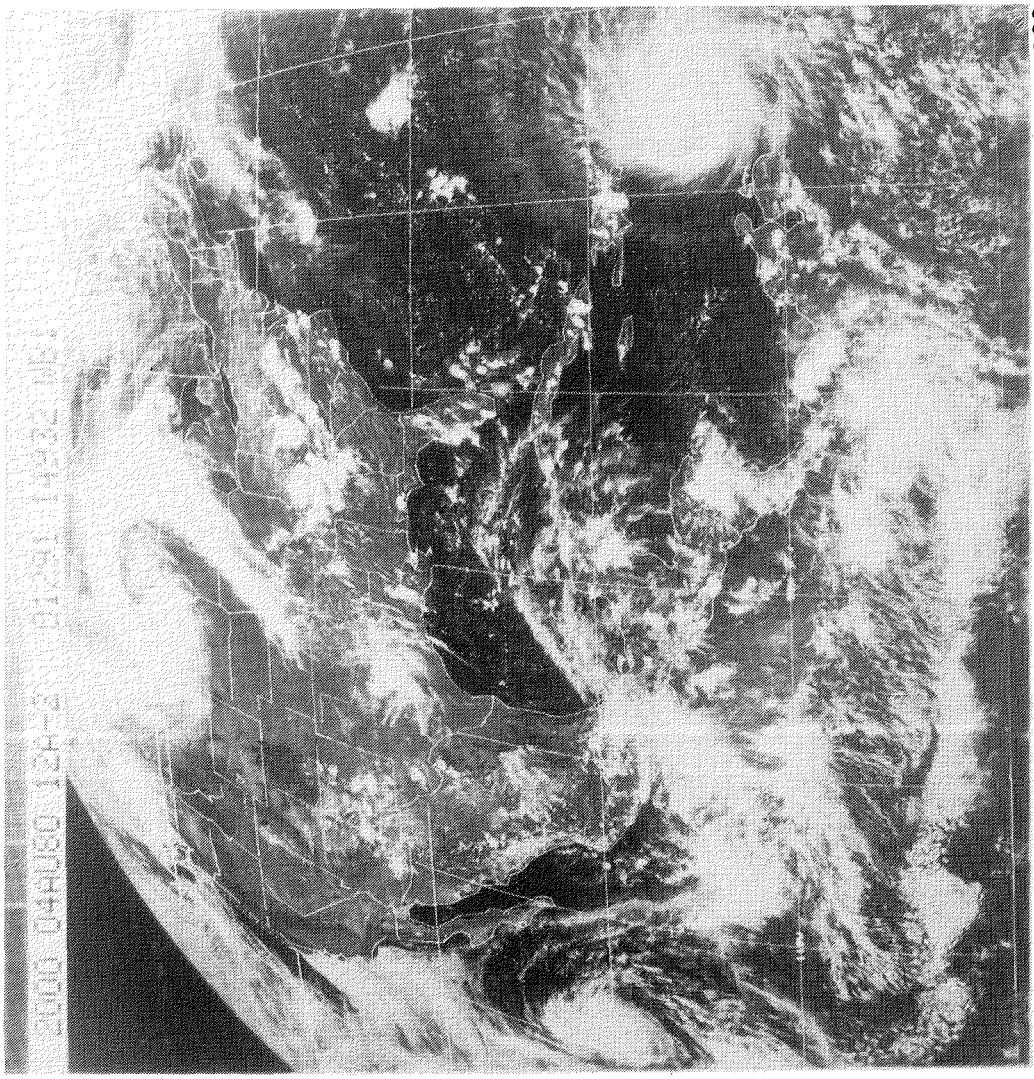
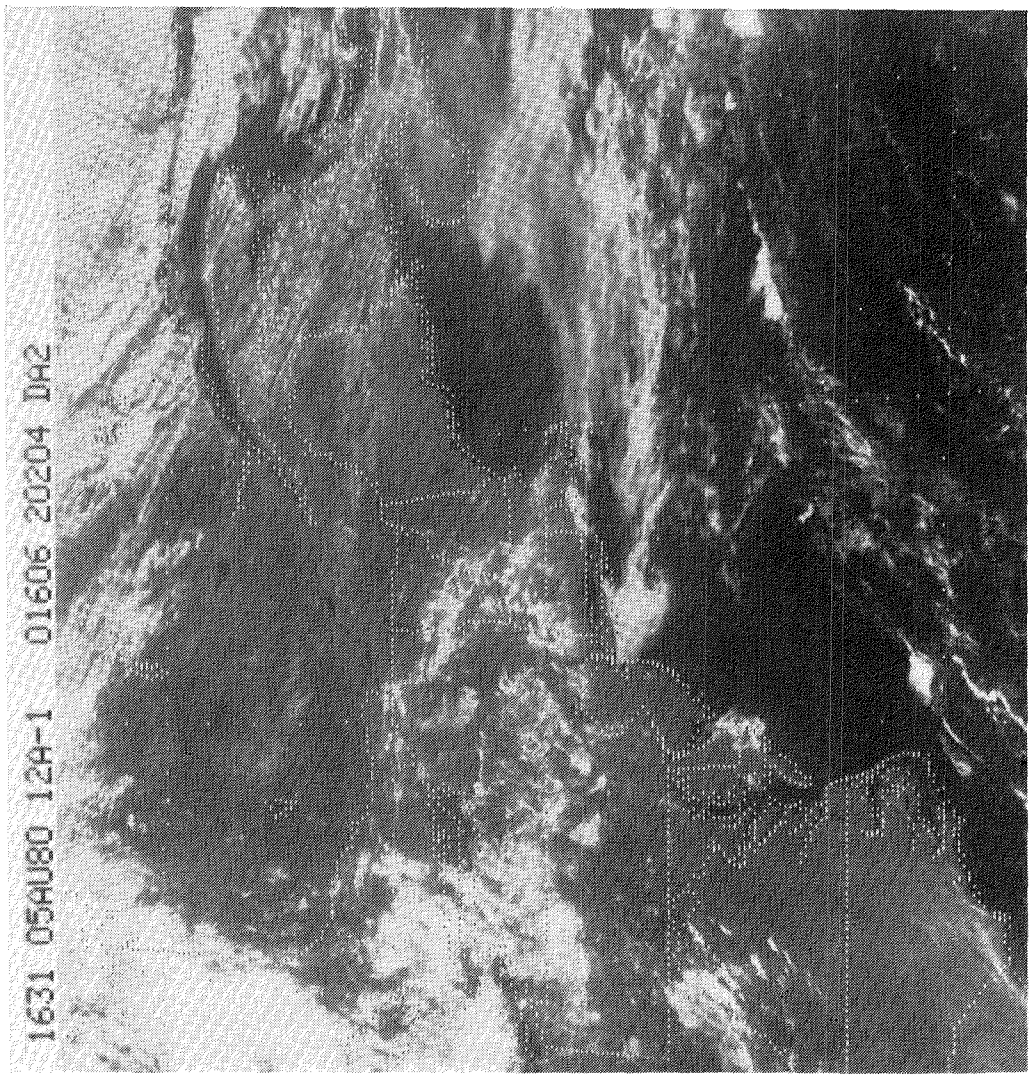


Figure B56.- GOES image for August 3, 1980.



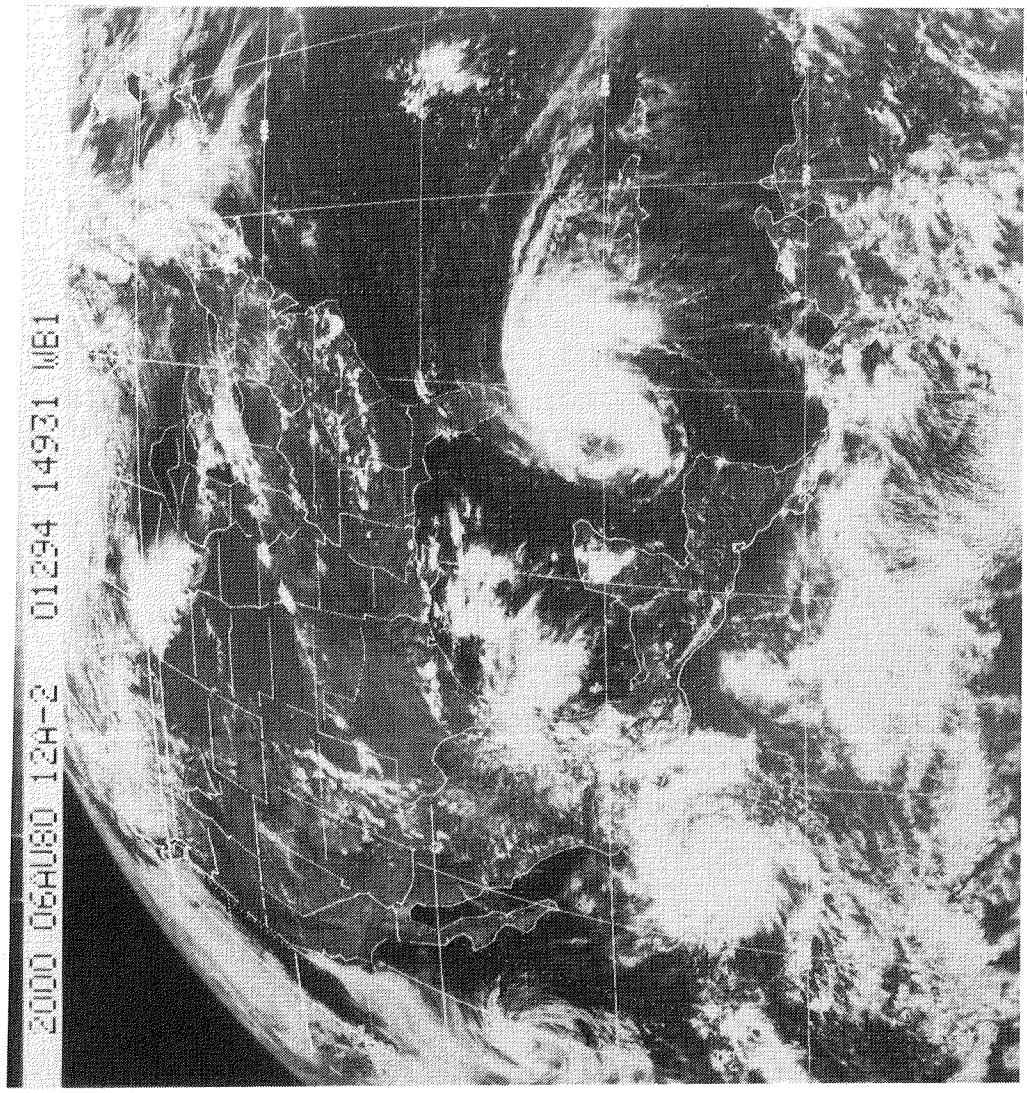
L-81-189

Figure B57.- GOES image for August 4, 1980.



L-81-190

Figure B58.- GOES image for August 5, 1980.



L-81-191

Figure B59.- GOES image for August 6, 1980.

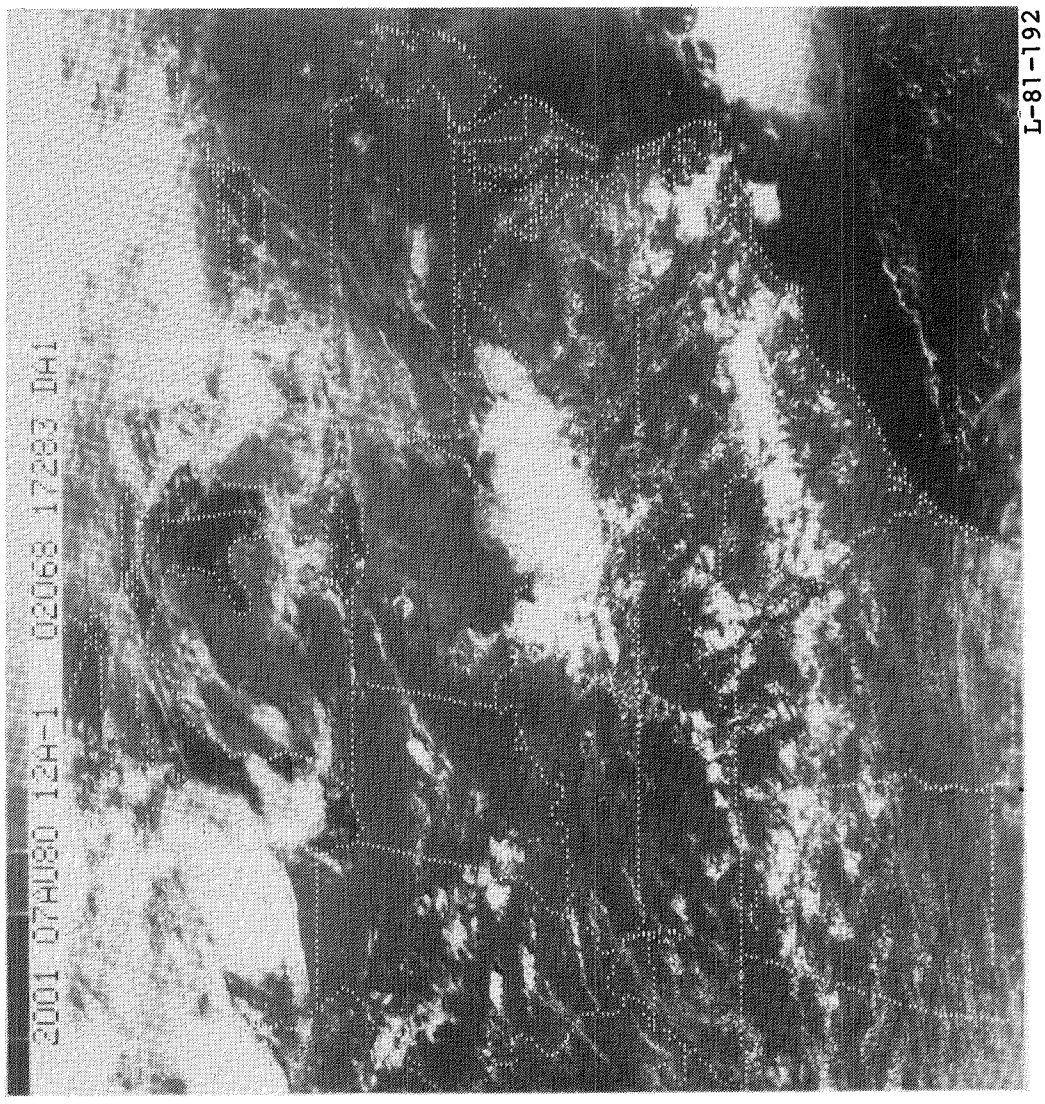
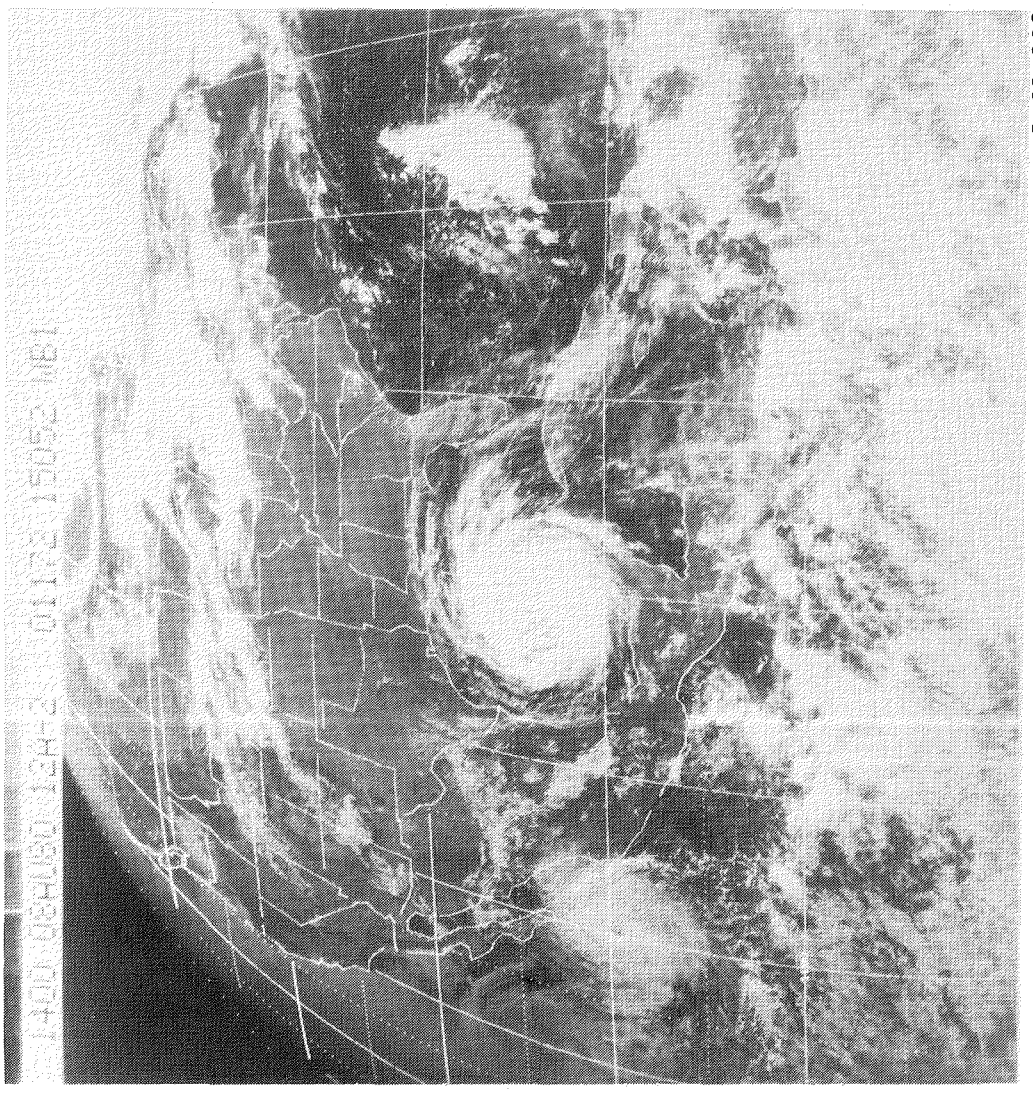


Figure B60.- GOES image for August 7, 1980.



L-81-193

Figure B61.- GOES image for August 8, 1980.

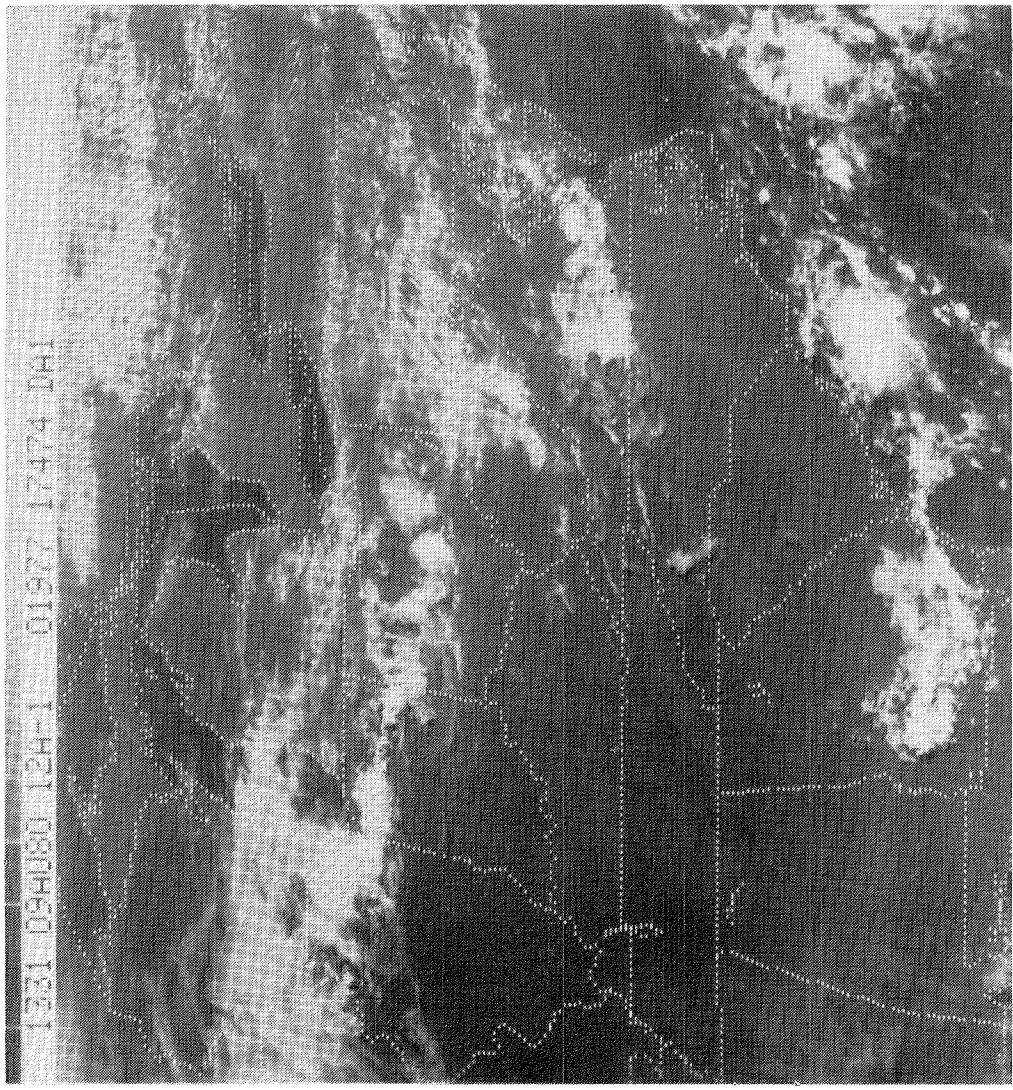
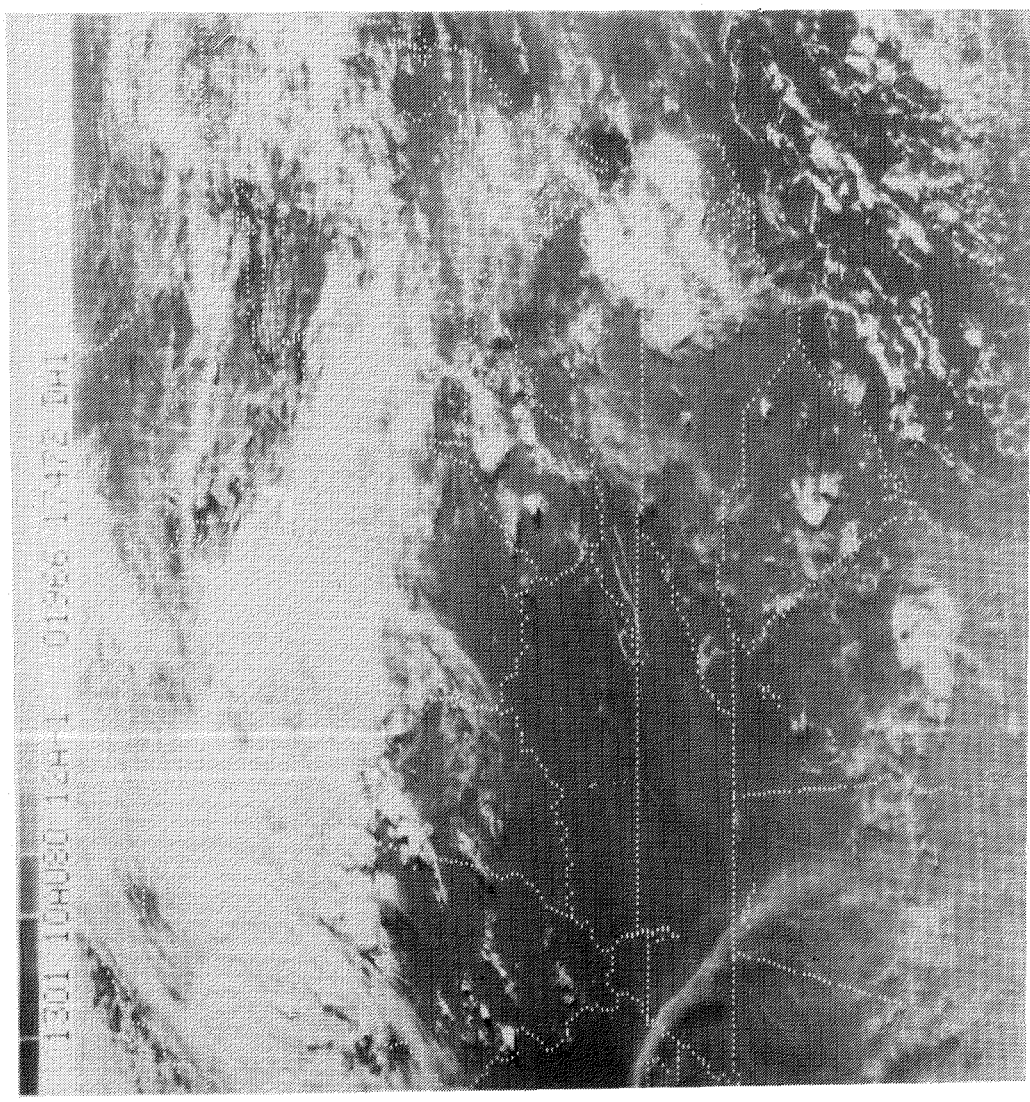
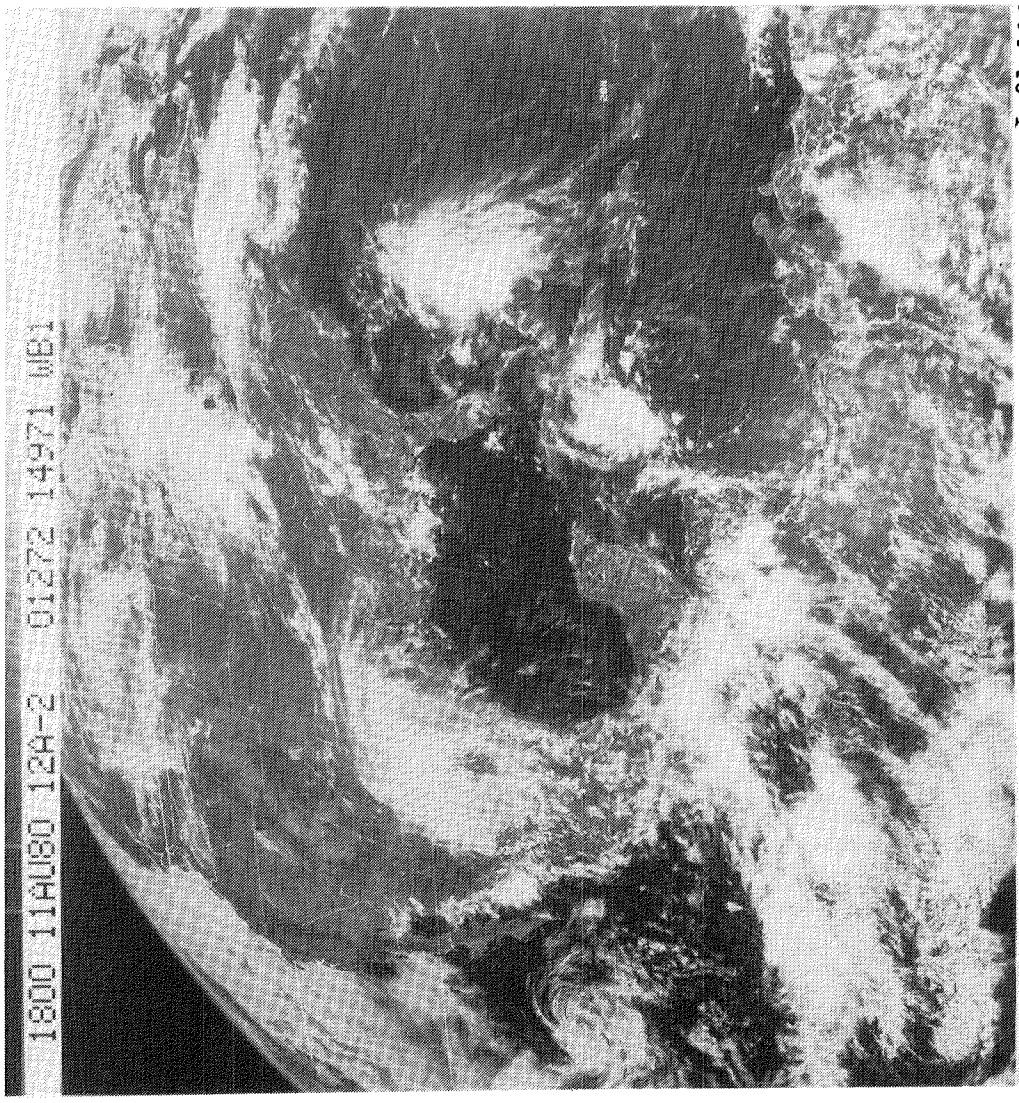


Figure B62.- GOES image for August 9, 1980.



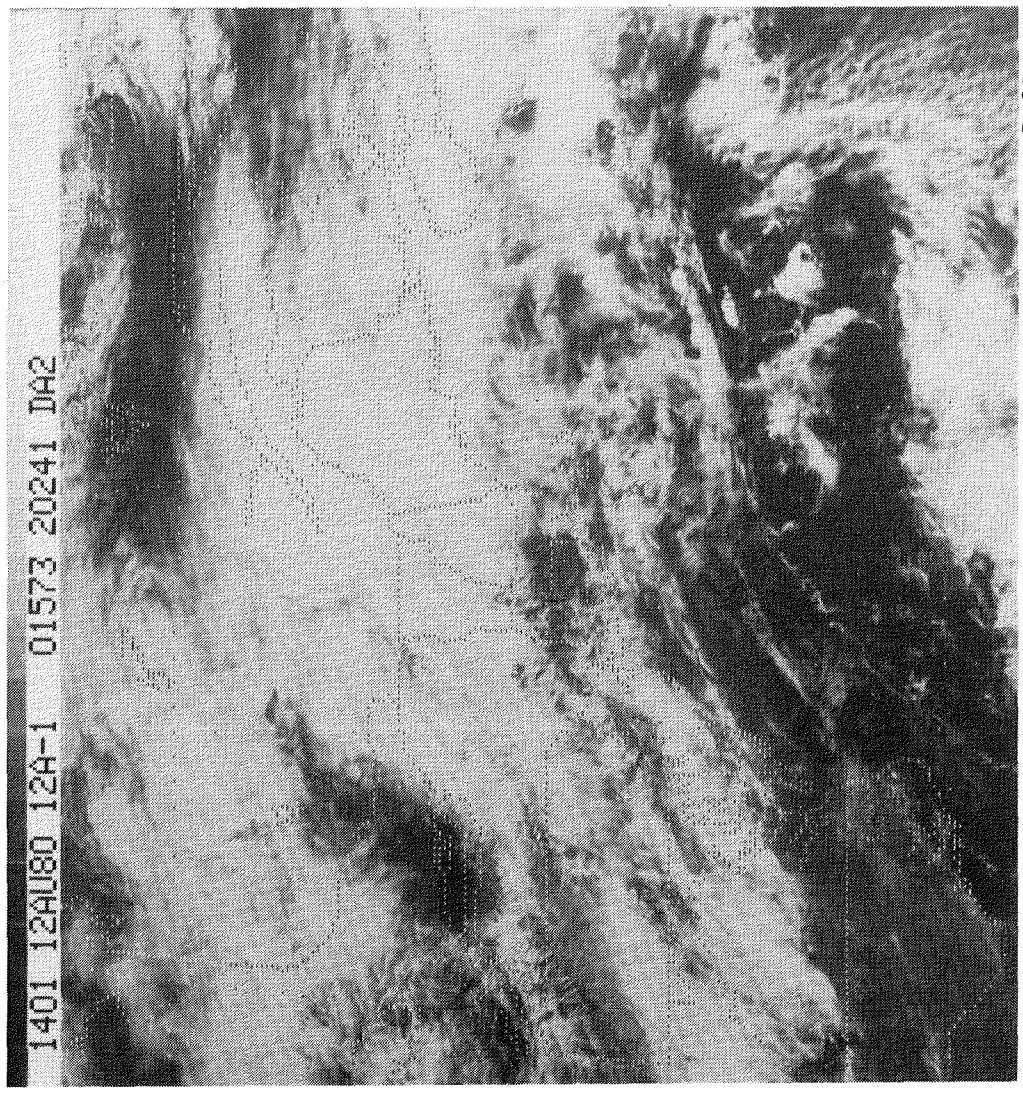
L-81-195

Figure B63.- GOES image for August 10, 1980.



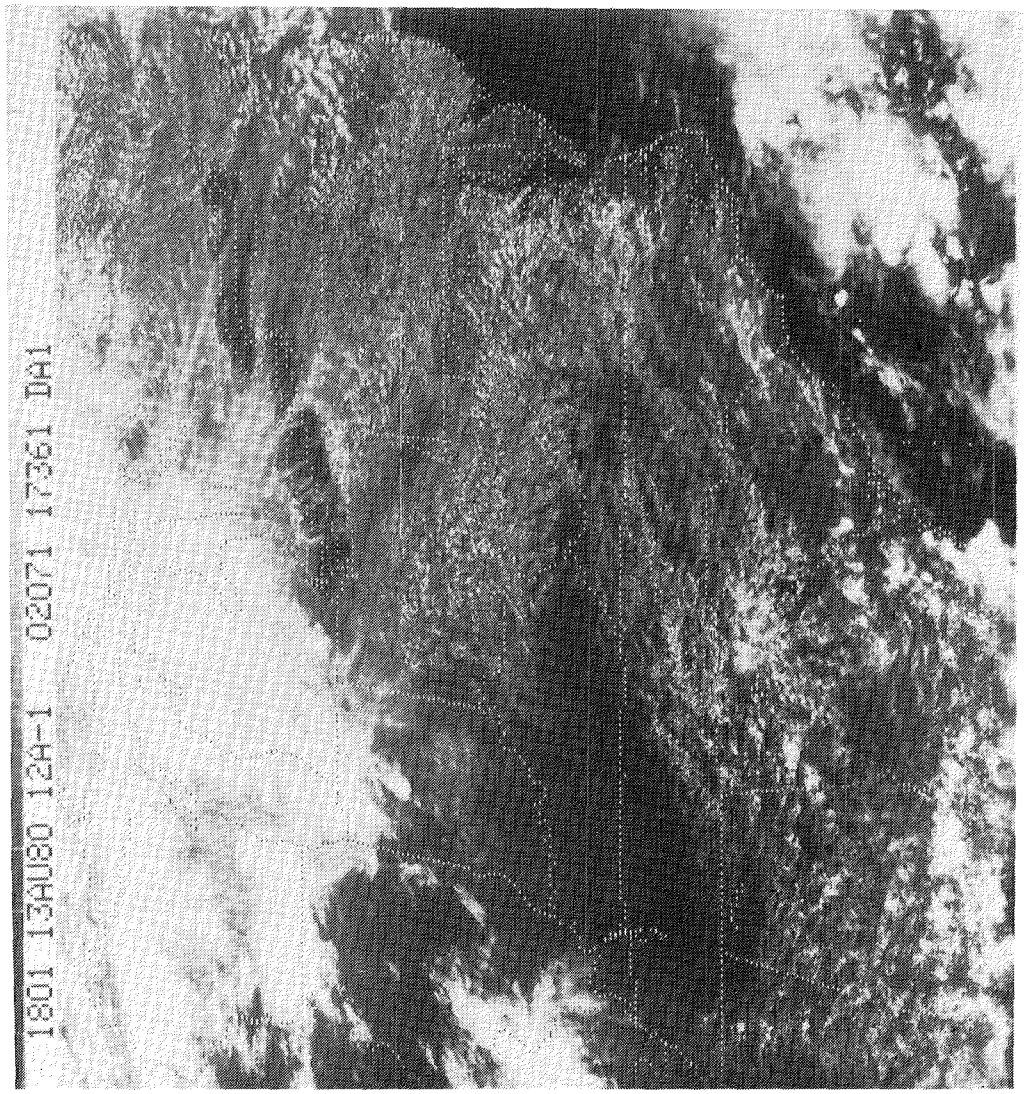
L-81-196

Figure B64.- GOES image for August 11, 1980.



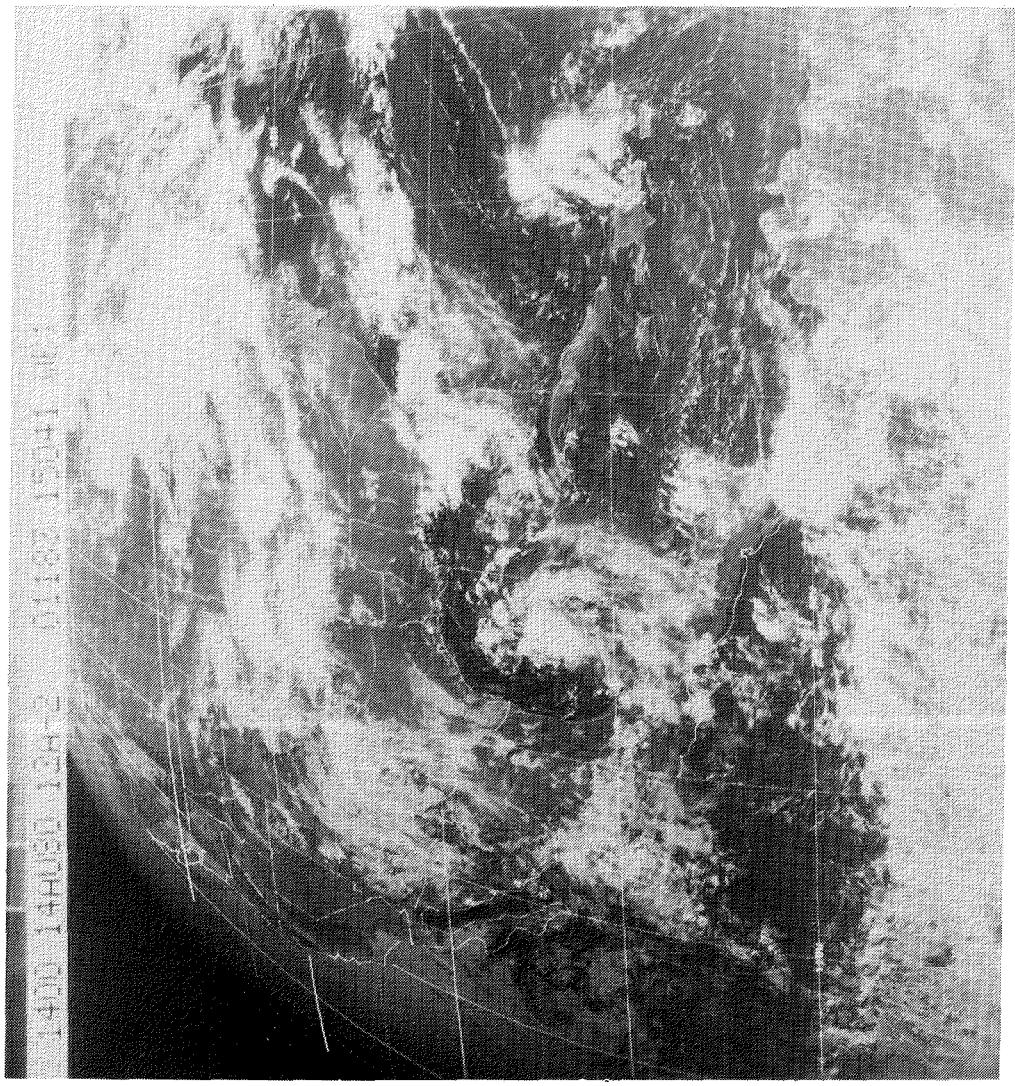
L-81-197

Figure B65.- GOES image for August 12, 1980.



L-81-198

Figure B66.- GOES image for August 13, 1980.



L-81-199

Figure B67.- GOES image for August 14, 1980.

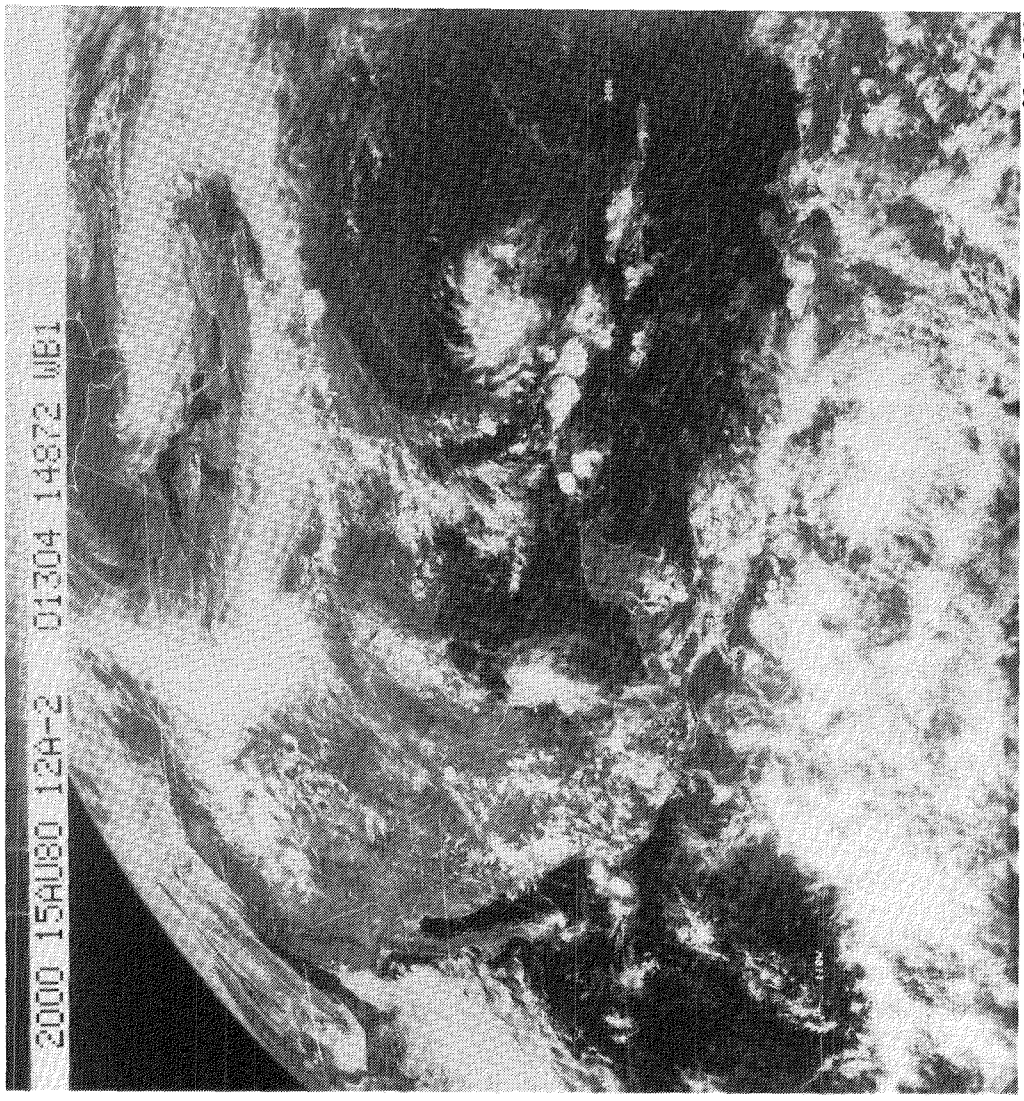


Figure B68.- GOES image for August 15, 1980.

APPENDIX C

ELECTRA FLIGHT DATA AND FLIGHT PATHS

Position data for the Lockheed 188A Electra airplane are given in table C1 to C11 in this appendix. The data are given (generally) in 5-min intervals and include geodetic coordinates (and/or VOR position), time (EDT), altitude (to mean sea level), and ground speed. (Note: The position data were obtained from two sources: (1) VOR bearing and distance as provided from the pilot's cabin, in which case it was logged and later converted to position latitude and longitude denoted in the table as a two-digit degree entry and a two-digit minute entry rounded to the nearest minute, and (2) read out directly from an onboard loran C navigation system and so logged as a two-digit degree entry, a two-digit minute entry, and a two-digit second entry.) Also tabulated are the indicated ground speed, altitude, and some general comments regarding, among other things, the existing meteorological conditions. Since the data presented are taken directly from the flight log, a missing entry simply means no entry was made. Similarly, the comments reflect direct entries in the log.

The positions have been displayed pictorially on maps and are shown in this appendix as the Electra flight paths (figs. C1 to C14). The daily take-off and landing times for the Electra airplane for each flight are given in the text. The plots were made from the actual flight latitude and longitude coordinates read from the loran C navigation system onboard the airplane or as determined from the VOR magnetic bearing and distance relayed from the pilot. The data were taken at 5-min intervals (generally) and generally every other point was plotted. Each flight is shown on a map of the United States with the data of the flight. Arrows show the direction of flight and ticks on the hour and half hour denote the progression of time, with the time of the first tick noted. All times are eastern daylight time. The plotted flight paths represent only that portion of the flight during which the mission was in a data-taking mode.

Hatched areas denote the location of the Cessna 402 correlative-data measurements being taken in conjunction with that Electra flight. (Not all flights had correlative flights.) Times for the Cessna 402 can be obtained from the data tabulated in Appendix E. Further synchronization can be gleaned in some cases from the comments contained in the Electra flight data tabulated in this appendix and from comments contained in the day-by-day account of activities from the mission log in appendix A.

APPENDIX C

TABLE C1.- ELECTRA FLIGHT DATA FOR JULY 18, 1980

Time, EDT	Latitude	Longitude	VOR (station)	Magnetic bearing	Distance, km	Aircraft altitude, m	Aircraft ground speed, m/s	Comments
1030	37°17.00'	75°48.76'				3200	162	
1035	37°21.06'	76°02.58'				3200	107	
1040	37°31.41'	76°25.79'				3200	114	
1045						3200		
1050	37°39'	78°37'	GVE	119	81	3200	112	
1055	37°51.50'	77°36.65'	GVE	115	46	3200	121	
1100	37°56.98'	78°00.64'	GVE	111	6	3200	123	
1105	37°56.65'	78°34.83'	GVE	271	26	3505	114	
1110	37°54.07'	78°54.19'	GVE	272	70	3810		
1115			GVE	271	100	3810	130	
1120	37°50.02'	79°42.06'	GVE	270	138	3810		
1125	37°47.38'	80°07.23'	GVE	270	179	3810	121	
1130	37°46.67'	80°36.20'	GVE	273		3566	123	No DME
1135	37°47.19'	80°57.81'				3200	131	
1140	37°45.27'	81°38.30'	BKW/CRW*	272/170		3200	136	
1145	37°46.45'	81°45.63'	BKW/CRW*	276/187		3200	131	
1150	37°49.01'	82°21.77'	LEX	095	198	3200	120	
1155	37°49.71'	82°36.21'	LEX	094	164	3200	124	
1200	37°51.65'	83°02.95'	LEX	096	123	3200	128	
1205	37°54.76'	83°27.47'	LEX	094	88	3200	128	
1210	37°57.47'	83°53.01'	LEX	089	50	3200	126	
1215	37°56.61'	84°18.56'	LEX	093	14	3200	125	
1220	38°06.15'	84°29.96'	LEX	355	17	3200	123	
1225	38°26.93'	84°28.61'	LEX	360	56	3200	120	
1230	38°45.07'	84°27.14'	DAY	185	138	3200	125	
1235	39°10'	84°25'	DAY	182	94	3200		
1240	39°30'	84°26'	DAY	185	57	3200		
1245	39°47'	84°24'	DAY	183	27	3353		
1250	40°01'	84°19'	DAY	088	11	3505		
1255	39°54'	84°04'	DAY	104	50	3048		
1300	39°52'	83°48'	DAY	101	88	2896		
1305	39°47'	83°32'	DAY	102	128			
1310								
1315	39°33'	81°01'	CKB	287	115	3109		
1320	39°29'	80°49'	CKB	288	83	3505		
1325						3505		

*Denotes two VOR bearings with location determined by the intersection.

TABLE C1.- Concluded

Time, EDT	Latitude	Longitude	VOR (station)	Magnetic bearing	Distance, km	Aircraft altitude, m	Aircraft ground speed, m/s	Comments
1330	39°16'	80°45'	AIR	173	85	3505		
1335	39°08'	80°29'	AIR	153	110	3505		
1340						3505		
1345	39°05'	78°45'	FRR	270	78	3505		
1350	38°55'	78°31'	FRR	247	50	3505		
1355						3505		
1400	38°47'	77°08'	PXT	298	117	3505		
1405						3505		
1410	38°30'	76°52'	OTT	315	29	3505		
1415	38°32'	76°03'	SWL	302	99	3505		

APPENDIX C

TABLE C2.- ELECTRA FLIGHT DATA FOR JULY 24, 1980

Time, EDT	Latitude	Longitude	VOR (station)	Magnetic bearing	Distance, km	Aircraft altitude, m	Aircraft ground speed, m/s	Comments
1130	39°50'	79°00'	MMJ	130	125			
1135	39°59'	79°44'	MMJ	130	87	3200	112	
1140	40°12'	79°56'	MMJ	130	51			
1145	40°29'	80°16'						Changing VOR
1150	41°37'	79°50'	MMJ	257	29			
1155	40°10'	81°00'	MMJ	262	71			
1200	40°28'	80°50'	MMJ	268	87			
1205	40°15'	81°45'	TVT	132	39			
1210	40°13'	82°07'	TVT	179	27		114	
1215	40°11'	82°22'	TVT	230	47		91	
1220								
1225	39°50'	83°00'	ZZV	270	104	3231		
1230	30°42'	82°57'	ZZV	260	156			
1235	39°31'	83°09'	ZZV	255	189			
1240	39°10'	84°50'	ABB	060	130			
1245	38°59'	85°02'	ABB	063	96			
1250	38°43'	85°13'	ABB	076	61			
1255	38°32'	84°58'	LEX	312	94	3200		
1300	38°15'	85°00'	ABB	114	44			
1305	38°08'	85°14'	LEX	280	108			
1310	38°15'	84°56'	LEX	295	73			
1315	38°15'	84°47'	LEX	305	54			
1320	38°17'	84°34'	LEX	340	39			
1325	38°22'	84°19'	LEX	027	49			
1330	38°25'	83°59'	LEX	054	84			
1335								No Data
1340								"
1345								No Data
1350								"
1355	38°58'	81°06'	EKN	272	144	3200	106	
1400	38°50'	80°38'	EKN	267	112			
1405	38°50'	80°39'	EKN	264	81			
1410	38°52'	80°18'	EKN	261	30	4115		
1415	39°08'	79°33'	EKN	072	81			

TABLE C2.- Concluded

Time, EDT	Latitude	Longitude	VOR (station)	Magnetic bearing	Distance, km	Aircraft altitude, m	Aircraft ground speed, m/s	Comments
1420	38°48'	79°48'	EKN	105	44			
1425	38°56'	78°53'	LDN	275	98			
1430	38°44'	78°38'	LDN	258	63			
1435	38°39'	78°25'	LDN	231	38			
1440	38°36'	78°09'	LDN	166	28			
1445	38°56'	76°44'	SBY	291	185			
1450	38°38'	76°22'	SBY	285	126		113	
1455	38°29'	76°00'	SBY	282	72			
1500	38°35'	76°03'	SBY	290	81			
1505	38°40'	75°43'	SBY	321	46			

TABLE C3.- ELECTRA FLIGHT DATA FOR JULY 25, 1980

Time, EDT	Latitude	Longitude	VOR (station)	Magnetic bearing	Distance, km	Aircraft altitude, m	Aircraft ground speed, m/s	Comments
1000	38°48.78'	77°01.20'				3200	125	Over D.C.
1005	38°55.35'	77°25.90'					126	Over Dulles
1010	39°05.07'	77°48.96'					126	
1015	39°13.61'	78°12.59'					124	
1021	39°20.65'	78°44.59'					117	
1025	39°23.72'	79°02.82'					124	
1030	39°26.91'	79°28.66'					131	
1035	39°35.15'	79°52.55'						Over Morgantown
1040	39°51.78'	80°07.16'					128	
1045	40°07.29'	80°25.06'					126	
1050	40°20.37'	80°45.06'					126	Over Wheeling
1055	40°33.35'	81°05.75'					125	
1100	40°45.17'	81°26.03'					114	
1105	40°49.38'	81°48.36'					105	
1110	40°50.15'	82°09.14'						
1115	40°49.50'	82°02.54						Circling
1120	40°46.92'	82°01.26'						
1125	40°48.60'	82°05.80'						
1130	40°52.59'	82°28.62'					119	Over Mansfield
1135	40°38.20'	82°35.87'					121	
1140	40°18.02'	82°35.60'					116	
1145	40°03.49'	82°45.91'						Over Port Columbus Int. Airport
1150	39°53.07'	83°06.95'					120	
1155	39°43.64'	83°28.83'					119	
1200	39°34.35'	83°51.13'					120	
1205	39°21.15'	84°12.90'				3200	133	
1210			CVG					Over VOR
1215	38°57.52'	84°32.09'					130	
1220	38°53.51'	84°05.05'					139	Over Ohio River
1225	38°49.12'	83°36.94					139	
1230	38°44.41'	83°08.54'					138	

TABLE C3.- Concluded

Time, EDT	Latitude	Longitude	VOR (station)	Magnetic bearing	Distance, km	Aircraft altitude, m	Aircraft ground speed, m/s	Comments
1235	38°41.55'	82°36.78'				3505	137	
1240	38°45.53'	82°13.21'					135	Over river at Henderson
1245	38°45.12'	82°02.55'					126	Circling
1250	38°53.10'	81°48.59'					135	Passing through plume
1255	38°56.13'	82°03.27'						Over plume
1300	38°54.50'	81°42.96'						Back on course
1305	38°55.63'	81°13.00'					137	
1310	38°56.59'	80°35.12'					140	Climbing
1315	38°54.44'	80°18.26'				4115	137	
1320	38°53.29'	79°48.76'					145	
1325	38°47.71'	79°20.00'					148	
1330	38°42.12'	78°50.76'					142	
1335	38°40.32'	78°21.10'					147	
1340	38°38.54'	77°51.00'					147	
1345	38°34.12'	77°21.14'					146	Descending
1350	38°29.34'	76°50.22'				2896	142	
1355	38°24.83'	76°23.34'					134	

APPENDIX C

TABLE C4.- ELECTRA FLIGHT DATA FOR JULY 31, 1980

(a) First flight

Time, EDT	Latitude	Longitude	VOR (station)	Magnetic bearing	Distance, km	Aircraft altitude, m	Aircraft ground speed, m/s	Comments
1315	38°08.72'	75°41.50'				3810	127	
1320	38°17.80'	76°05.04'					129	
1325	38°30.03'	76°26.92'					129	
1330	38°41.56'	76°49.26'					130	
1335	38°50.75'	77°13.35'					129	
1341	38°57.56'	77°19.92'				4115	138	
1345	39°02.47'	76°57.03'				4115	146	
1350	39°08.51'	76°27.87'					155	
1355	39°13.58'	75°59.51'					133	
1400	39°17.71'	75°32.81'					129	Passed over NASA 402
1405	39°21.78'	75°06.47'					128	
1410	39°31.08'	74°34.03'					108	
1415	39°41.29'	74°35.99'				4115	108	
1420	39°59.03'	74°38.68'					116	
1422	40°06.56'	74°39.42'					120	
1425	40°18.81'	74°41.18'						
1430	40°37.57'	74°45.86'					121	
1435	40°54.27'	74°39.95'					133	
1440	41°09.04'	74°16.92'					132	
1445	41°24.07'	73°59.92'				3505	124	Over Hudson River
1450	41°40.73'	73°43.49'					130	
1455	41°28.35'	73°20.17'					136	
1500	41°15.52'	72°56.46'					134	Over Long Island Sound
1505	41°02.88'	72°32.86'					135	
1510	40°46.93'	72°29.59'					121	
1515	40°32.98'	72°49.97'				3505	121	
1520	40°20.37'	73°07.39'				3505	123	
1525	40°06.61'	73°26.55'				3505	124	
1530	39°52.47'	73°45.02				3505	126	
1535	39°38.33'	74°03.82'				3505	123	
1540	39°25.28'	74°23.44'				3505	127	
1545	39°10.29'	74°41.24'				3505	123	
1550	38°53.35'	74°55.34'				3505	126	
1555	38°35.98'	75°09.06'				3505	127	
1600	38°17.23'	75°20.83'				3505	120	

TABLE C4.- Concluded

(b) Second flight

Time, EDT	Latitude	Longitude	VOR (station)	Magnetic bearing	Distance, km	Aircraft altitude, m	Aircraft ground speed, m/s	Comments
2140	37°22.49'	76°17.65'				4420	136	
2145	37°26.91'	76°45.02'				4420	143	
2150	37°29.36'	77°14.04'				4420	141	
2155	37°34.85'	77°40.91'				4420	137	
2200	37°38.47'	78°08.59'				4420	138	
2205	37°43.90'	78°39.20'				4420	134	
2210	37°52.40'	78°59.73'				4420	135	
2215	38°10.62'	79°02.99'				4115	137	
2220	38°33.64'	78°58.38'				4115	144	
2225	38°55.11'	78°59.17'				4115	133	
2230	39°17.54'	78°59.88'				4115	144	
2235	39°40.67'	78°55.61'				4115	146	
2240	40°04.15'	78°51.91'				4115	147	
2245	40°28.16'	78°47.34'				4115	146	
2252			JST	010	76			Out of track
2255	41°14.48'	78°39.18'						
2302	42°16.36'	79°38.46'						
2307	43°35'	78°36'	BUF	005	73			
2312	43°18'	78°39'	BUF	000	41			
2315	43°03'	78°39'	BUF	000	14			
2331								No data
2349	42°52'	74°19'	ALB	280	80		159	
2355	42°42'	73°56'	ALB	250	22			
2400	42°22'	73°52'	ALB	193	43			
0010								Over Kingston
0020	40°58'	73°57'	COL	22	80		151	
0026	40°26'	74°07'	COL	22	15		141	
0028								Passing COL at 7500'
0030	40°10'	74°13'	COL	210	19		131	
0040								Over Atlantic City, N.J. VOR
0041	39°09'	74°44'	SWL	40	161			
0048	38°47'	75°04'	SWL	35	98		139	
0053	38°29'	75°11'	SWL	40	61		137	
0100	38°05'	75°27'	SWL	50	4			

TABLE C5.- ELECTRA FLIGHT DATA FOR AUGUST 2, 1980

Time, EDT	Latitude	Longitude	VOR (station)	Magnetic bearing	Distance, km	Aircraft altitude, m	Aircraft ground speed, m/s	Comments
0725	36°29.32'	75°47.15'				3505	135	
0730	36°19.16'	75°38.28'					131	0734 made turn at RBX
0736	35°53.62'	75°41.32'				3505	108	
0740						3505	105	Out of track
0746	35°51.49'	76°23.92'				3505		
0750	35°49.37'	76°40.56'				3505	120	0749 turn at EDE
0755	35°31.45'	76°50.86'				3505	125	
0800	35°15.64'	76°55.66'					123	0830 turn at EWN
0805	34°55.87'	77°09.23'					116	
0810	34°41.03'	77°24.20'				3810	117	
0815	34°28.06'	77°40.06'				3810	113	0815 turn at ILM
0820	34°14.19'	77°51.27'				3810		Over water
0825	33°45.84'	77°52.31'					104	
0830	33°29.50'	77°47.39'					129	
0835	33°08.68'	77°46.54'					125	
0840	32°48.78'	77°45.46						
0845								0844 turn at OLDEY 108 radial
0850								92 miles off Charleston, S.C.
0855	32°36.29'	98°39.02'					129	
0900	32°40.39'	79°00.29'					126	
0905	32°45.19'	79°23.98'					127	
0910	32°50.49'	79°47.29'					129	0909 over land
0915	32°48.81'	80°10.14'					126	0913 turn at CHS
0920	32°37.31'	80°29.24'						0924 over Beaufort Marine Corp.
0925	32°24.09'	80°49.21'					127	

TABLE C5.- Concluded

Time, EDT	Latitude	Longitude	VOR (station)	Magnetic bearing	Distance, km	Aircraft altitude, m	Aircraft ground speed, m/s	Comments
0930	32°10.26'	81°06.12'					124	Turn over Savannah, Ga.
0935								No data
0940	31°24.78'	81°21.54'						
0946	31°06.21'	81°26.61'					134	
0950	30°48.99'	81°30.50'					128	
0955	30°28.67'	81°33.24'					126	Turn over Jacksonsville, Fla.
1000	30°37.04'	81°26.81'				4115	130	
1005	30°56.42'	81°17.90'				4115	129	
1010	31°15.00'	81°06.91'				4115	127	
1015	31°33.27'	80°54.79'					129	
1020	31°51.73'	80°42.54'				4724	125	
1025	32°10.87'	80°30.07'					134	
1030	32°29.80'	80°17.71'				3810	133	Descending to 12 500
1035	32°48.79'	80°04.69'				3810	135	Turn at Charleston descending to 12 500
1040	33°09.82'	80°13.01'				3810	148	
1045	33°29.99'	80°27.30'					137	Turn at VAN ascending
1050	33°47.47'	80°14.78'				4115	132	
1055	34°06.42'	80°01.74'				4115	137	
1100	34°26.78'	79°51.54'				4115	136	
1105	34°47.31'	79°43.42'				4115	126	
1110	35°07.87'	79°37.02'				4115	131	
1115	35°28.38'	79°43.39'					132	
1120	35°48.17'	79°52.44'					126	Turn at Greensboro, 1123
1125	36°06.78'	79°47.62'					142	
1130	36°14.63'	79°20.44'				4115	136	
1135	36°22.79'	78°53.58'				4115	127	
1140	36°28.80'	78°26.51'				4115	152	Changed lower chain
1145	36°34.16'	77°56.97'				4115	138	
1150	36°36.40'	77°32.74'				4115	131	
1155	36°40.60'	77°06.94'				4115	128	
1200	36°46.04'	76°36.94'					131	Descending

TABLE C6.- ELECTRA FLIGHT DATA FOR AUGUST 5, 1980

Time, EDT	Latitude	Longitude	VOR (station)	Magnetic bearing	Distance, km	Aircraft altitude, m	Aircraft ground speed, m/s	Comments
0955								Over Franklin
1111								Over Charlotte
1115								No data
1120	35°42'	81°11'	BZM	158	21	3505		
1125	35°59'	81°11'	BZM	035	15	3505	106	
1130	36°12'	80°55'	BZM	049	57	3505	123	
1135	36°30'	80°04'	LYH	234	143	3505	131	
1140	36°43'	79°43'	LYH	228	90	3505	131	
1145	36°57'	79°31'	LYH	229	52	3505	136	
1153						3505		Over Lynchburg airport
1155	37°34'	78°42'	GVE	237	93	3505	129	
1202	37°43'	78°26'	GVE	231	52	3505	134	
1207	37°57'	78°12'	GVE	226	10	4115	124	
1215	39°38'	77°06'	ADW	340	98	4115		
1220	39°52'	77°16'	HAR	222	55	4115	136	Over Alexandria
1241	39°36'	77°01'	HAR	179	28	4115	131	
1247	40°36'	76°30'	AVP	238	143	4115		Over Harrisburg
1255	40°51'	76°06'	AVP	232	78	4176	138	
1257	41°59'	75°10'	COL	303	174	4145	134	Turned southeast
1305	40°49'	74°49'	COL	300	112	4145	134	
1310	40°36'	74°36'	COL	296	73	4145	132	
1315	40°26'	74°21'	COL	294	31			
1320						3810		Turned over Columbus
1327	39°42'	74°28'	SIE	036	83	3810		

TABLE C7.- ELECTRA FLIGHT DATA FOR AUGUST 7, 1980

Time, EDT	Latitude	Longitude	VOR (station)	Magnetic bearing	Distance, km	Aircraft altitude, m	Aircraft ground speed, m/s	Comments
1824	38°07.76'	75°31.78'				3200	130	
1829	38°26.38'	75°34.68'				3200	133	
1834	38°40.12'	75°54.51'				3200	129	
1839	38°55.19'	76°13.01'				3200	121	
1844	39°16.34'	76°15.42'				3200	134	
1849	39°37.99'	76°17.63'				3200	134	
1854	39°59.73'	76°18.17'				3200	136	
1859	40°21.55'	76°17.37'				3200	136	
1904	40°43.26'	76°15.74'				3200	135	
1909	41°09'	76°20'	BGM	195	117	3200	130	
1914	41°26'	76°17'	BGM	195	83	3200	130	
1919	41°46'	76°11'	BGM	190	44	3810	129	Ascending to 12 500
1924	42°07'	76°09'	BGM	190	4	3810	139	
1929	42°29'	76°05'	BGM	014	37	3810	138	
1934	42°55'	76°15'	ART	195	119	3810	144	
1937	43°11'	76°09'	ART	189	87	3810		
1940	42°48'	76°25'	ELM	050	120	3810		
1945	42°39'	76°36'	ELM	045	89	3810	134	
1950	42°28'	76°50'	ELM	035	50	3810	126	
1955	42°12'	76°58'	ELM	042	15	3200	129	Descending to 10 500
2000	41°51'	77°07'	ELM	208	31	3200	127	
2005	41°34'	77°14'	ELM	208	67	3200	131	
2010	41°08'	77°31'	THS	025	148	3810	131	Ascending to 12 500
2015	40°47'	77°39'	THS	025	106	3810	146	
2020	40°23'	77°47'	THS	027	56	3810	144	
2025			THS	027	17	3810	144	
2030	39°42.45'	78°01.43'					139	
2035	39°20.31'	78°06.52'					138	
2040	39°13'	78°24'	TON	183	170	3810		
2045	39°32'	78°29'	TON	190	135	3810		
2050	39°58'	78°26'	TON	190	87	3810	139	
2055	40°15.86'	78°19.58'					137	

TABLE C7.- Concluded

Time, EDT	Latitude	Longitude	VOR (station)	Magnetic bearing	Distance, km	Aircraft altitude, m	Aircraft ground speed, m/s	Comments
2100	40°37.86'	78°22.10'					138	
2105	40°59.81'	78°24.06'					140	
2110								No data
2115	41°29'	78°03'	ELZ	186	69	3505		
2121	41°10'	77°54'	ELZ	172	104	3505	134	
2125	40°56.60'	77°23.63'					157	
2130	40°36.17'	77°13.32'					144	
2135	40°06.64'	76°55.67'					140	
2140	39°54.28'	76°47.11'					141	
2145	39°35.37'	76°30.73'					141	
2150	39°15.81'	76°14.72'					145	
2155	38°55.91'	75°58.50'					144	
2200	38°36.30'	75°42.66'					145	

TABLE C8.- ELECTRA FLIGHT DATA FOR AUGUST 9, 1980

Time, EDT	Latitude	Longitude	VOR (station)	Magnetic bearing	Distance, km	Aircraft altitude, m	Aircraft ground speed, m/s	Comments
0733	37°53.66'	75°29.20'				4420	164	
0738	37°32.36'	75°47.73'				4420	163	
0743	37°17.38'	76°13.11'				4420	157	
0748	37°06.74'	76°41.47'				4420	159	
0753	37°00.12'	77°12.85'				4420	160	
0758	36°51.55'	77°43.31'				4420	160	
0803	36°43.18'	78°14.21'				3810	162	
0808	36°37.21'	78°47.16'				3810	157	
0813	36°37.60'	79°17.65'				3810	151	
0820	36°36'	79°40'	SBV	265	092	3810	156	
0825	36°26.36'	80°29.56'				3810	157	
0830	36°16.31'	81°01.04'				3810	155	
0835	36°08.71'	81°29.20'				3810	149	
0840	36°01.70'	81°58.52'				3810	153	
0850	36°02.49'	82°54.87'				3810	158	
0855	36°01.56'	83°25.02'				3810	157	
0900			TYS			3810	156	Over Knoxville, Tenn.
0905	35°39'	84°35'	HCH	106	056	3810	139	
0910	35°23.87'	84°48.30'				3505	161	
0918	35°50.64'	84°56.93'				3505	168	
0923	36°14.32'	84°52.67'				3505	148	
0928	36°38.56'	84°47.63'				3505	147	
0933	37°02.86'	84°41.03'				3505	154	
0938	37°28.04'	84°31.34'				3505	152	
0943	37°51.01'	84°30.30'				3505	152	
0948	37°57.02'	84°02.46'				3505	163	
0953	37°57.52'	83°30.92'				4115	149	
0958	37°58.13'	82°58.82'				4115	160	
1005	37°55'	81°45'	BKW	280	90	4115	164	
1012	37°45.62'	81°26.38'				4115	164	
1017	37°44.68'	80°55.68'				4115	162	
1022	37°42.78'	80°22.96'				4115	160	
1027	37°41.47'	79°49.48				4115	162	
1032	37°37.86'	79°16.98'				4115	165	
1037	37°29.34'	78°45.44'				4115	165	
1042	37°30.54'	78°13.98'				4115	156	
1047	37°31.96'	77°42.26'				4115	159	
1052	37°32.49'	77°10.22'				4115	158	
1057	37°35.79'	76°38.65'				4115	155	

APPENDIX C

TABLE C9.- ELECTRA FLIGHT DATA FOR AUGUST 10, 1980

Time, EDT	Latitude	Longitude	VOR (station)	Magnetic bearing	Distance, km	Aircraft altitude, m	Aircraft ground speed, m/s	Comments
0555	36°53.76'	76°48.73'					140	
0600	37°00.86'	77°10.21'				5944	131	
0605	36°54.15'	77°36.69'				6157	129	
0610	36°47.41'	78°01.37'				6553	138	
0615	36°42.60'	78°29.94'				6706	153	
0620	36°40.57'	79°01.80'				6706	160	
0625								No data
0630	36°28.84'	80°02.71'				6706	149	
0635	36°25.44'	80°34.18'				6248	166	
0643								No data
0647	36°26.60'	81°53.16'				4877	174	Descending to 16 000
0652	36°23.75'	82°27.55'				5243	177	
0700	36°01.80'	83°14.20'				4877	150	
0706	35°54.68'	83°51.83'				5486	170	
0710	35°50.64'	84°17.32'				5486	160	
0716	35°35.03'	84°49.10'				5486	159	
0720	35°27.82'	83°12.32'				5486	162	
0725	35°21.54'	85°42.63'				5486	156	
0730	35°12.79'	86°12.23				5486	160	
0735	35°03.21'	86°41.52'				5486	161	
0740	34°52.21'	87°09.56'				5547	160	
0745	34°41.21'	87°38.87'				5547	165	
0750	34°41.32'	88°11.43'				5547	162	
0755	34°41.58'	88°43.20'				5547	165	
0800	34°43.33'	89°15.20'				5791	164	Turn at HLI at 0803 Descending to 19 000
0805	34°49.96'	89°43.26'				5791	177	
0810	35°13.61'	89°29.12'				5791	160	
0815	35°39.24'	89°25.19'				5791	160	
0820	36°05.33'	89°20.59'				5791	159	
0825	36°28.56'	89°12.70'				5791	155	
0830	36°24.88'	88°42.43'				5791	158	
0835	36°17.87'	88°12.13'				5791	158	
0840	36°13.89'	87°40.76'				5791	158	
0845	36°15.41'	87°09.29				5791	156	
0850	36°19.50'	86°37.15'				5791	165	

TABLE C9.- Concluded

Time, EDT	Latitude	Longitude	VOR (station)	Magnetic bearing	Distance, km	Aircraft altitude, m	Aircraft ground speed, m/s	Comments
0855	36°27.03'	86°04.01'				5791	170	
0900	36°30.73'	85°31.09'				5791	173	Over LVT
0905	36°36.13'	84°57.36'				5791	170	
0910	36°34.77'	84°22.29'				5791	169	
0915	36°34.06'	83°48.99'				5791	171	
0920	36°33.92'	83°14.82'				5791	170	
0925	36°36.15'	82°14.04'				5791	167	
0930	36°35.42'	82°07.63'				5791	165	
0935	36°46.50'	81°38.02'				5791	164	
0940	36°55.54'	81°06.85'				5791	166	
0945	37°06.11'	80°36.10'				5791	169	
0950	37°10.47'	80°02.61'				5791	167	
0955	37°15.69'	79°27.89'				5791	167	
1000	37°18.00'	78°54.12'				5791	168	
1005	37°20.81'	78°20.25'				5791	169	
1010	37°32.06'	77°49.35'				5791		
1015	37°27.95'	77°15.14'					156	Descending
1020	37°26.99'	76°42.48						

TABLE C10.- ELECTRA FLIGHT DATA FOR AUGUST 12, 1980

Time, EDT	Latitude	Longitude	VOR (station)	Magnetic bearing	Distance, km	Aircraft altitude, m	Aircraft ground speed, m/s	Comments
0650	38°18.47'	75°21.81'				5334	140	
0655	38°38.16'	75°01.71'				5334	143	
0700	38°56.97'	74°52.38'				5334	140	
0706	39°03.17'	74°42.37'				5334	140	
0710	38°52.62'	74°27.60'				5334	141	
0715	38°37.11'	74°05.87'				5334	142	
0720	38°20.36'	73°45.89'				5334	140	
0725	38°04.13'	73°26.52'				5334	135	
0730	37°52.10'	73°12.70'				5334	140	Turning
0735	37°48.15'	72°44.54'				5334	137	
0741	38°11.30'	72°24.58'				5334	144	
0746	38°31.19'	72°17.54'				5334		
0750	38°48.67'	72°10.31'				5334		
0755	39°07.05'	72°14.92'				5334	111	
0800	39°20.88'	72°28.10'				5334	115	
0805	39°31.05'	72°47.04'				5334	109	
0810	39°47.40'	72°57.90'				5334	137	
0815	40°09.16'	72°58.76'				5029	133	
0820	40°25.17'	73°15.62'				5029	123	
0825	40°35.69'	73°37.70'				5029		
0830	40°37.47'	74°00.27'				5029	111	
0835								No data climbing
0840	40°35.79'	74°47.59'				5334	126	
0845	40°38.87'	75°14.01'				5334	126	
0850	40°30.82'	75°39.34'				5334	122	
0855	40°26.23'	76°04.03'				5334	117	
0900	40°21.29'	76°28.16'				5334	119	
0905	40°17.01'	76°53.35'				5334	116	
0910	40°09.79'	77°14.29'				5334	127	Turning at Harrisburg
0915	39°50.60'	77°24.73'				5334		
0920	39°28.54'	77°26.29'				5334	139	
0925	39°05.59'	77°27.61'				5334	134	Over Dulles at 0927
0930	38°44.83'	77°28.22'				5334	129	
0935	38°24.06'	77°34.75'				5334	129	
0940	38°03.54'	77°40.53'				4724	138	
0945	37°41.48'	77°47.48'				4724	134	Turning at FAR
0950	37°28.88'	77°32.30'				4724	146	

TABLE C10.- Concluded

Time, EDT	Latitude	Longitude	VOR (station)	Magnetic bearing	Distance, km	Aircraft altitude, m	Aircraft ground speed, m/s	Comments
0955	37°25.45'	77°04.36'				4724	138	
1000	37°45.03'	76°51.74'				4724	140	
1005	38°05.80'	76°41.16'				5334	138	Climbing to 17 500
1010	38°26.60'	76°30.34'				5334	153	
1015	38°45.19'	76°09.49'				5334	156	
1020	38°33.44'	75°44.58'				5334	150	
1025	38°14.99'	75°29.14'				5334	133	
1030	37°55.29'	75°34.76'				5334	129	
1035	37°37.13'	75°52.31'				5334	131	
1040	37°17.77'	76°02.41'				5334	130	
1045	36°57.59'	76°08.88'				5334	127	
1050	36°41.12'	76°23.55'				5334	126	
1055	36°27.72'	76°42.23'				5334	123	
1100	36°11.92'	76°56.94'				5334	131	
1105	35°52.25'	77°05.77'				5334	128	
1110	35°35.55'	77°19.62'				3505	124	
1115	35°22.69'	77°36.02'				3505	149	Turning at Kinston Descending to 11 500
1120	35°34.39'	77°20.37'				3505	128	
1125	35°52.42'	77°05.39'				3505	141	
1130	36°11.28'	76°54.03'				3505	133	
1135	36°28.04'	76°38.66'				3505	134	
1140	36°42.87'	76°18.88'				3505	136	
1145								Over Norfolk

APPENDIX C

TABLE C11.- ELECTRA FLIGHT DATA FOR AUGUST 13, 1980

(a) First flight

Time, EDT	Latitude	Longitude	VOR (station)	Magnetic bearing	Distance, km	Aircraft altitude, m	Aircraft ground speed, m/s	Comments
1135	37°47.43'	78°46.14'				5029	146	
1140	37°52.15'	79°15.51'				5029	148	
1145	37°59.14'	79°47.52'				5029	146	
1150	38°05.07'	80°13.90'				5029	146	
1155	38°12.56'	80°43.11'				5029	148	
1200	38°18.54'	81°11.75'				5029	147	
1205	38°23.76'	81°42.00'				5029	148	Over Charleston
1210	38°28.15'	82°11.00'				5029	148	Over Power Plant Plume
1215	38°35.24'	82°41.18'				3810	155	Over YRK at 1218 Descending to 12 500
1220	38°40.62'	83°07.06'				3810	113	
1225	38°46.34'	83°36.27'				3810	152	
1230	38°53.86'	84°00.68'				3810	154	Over Ohio River 1231
1235	39°01.80'	84°38.35'				3810	153	
1242						3810		Lost track over York, Pa.
1245								No data; turned at RID
1250						3810		Lost track
1255						3810		Lost track; turned at ROD at 1254
1301						3810	158	Lost track over Springfield at 1300
1305						3810		Lost track
1310	40°13.34'	83°18.34'				3810		
1315	40°08.04'	82°41.15'				3810	177	
1320	40°00.99'	82°04.42'				3810	177	Over APE at 1316
1325	40°09'	82°06'	ZZV	316	037	3810	137	

TABLE C11.- Continued

(a) Concluded

Time, EDT	Latitude	Longitude	VOR (station)	Magnetic bearing	Distance, km	Aircraft altitude, m	Aircraft ground speed, m/s	Comments
1327	40°14.69'	82°24.63'				3810	153	
1330	40°20.67'	82°40.71'				3810	153	
1335	40°35.82'	83°06.57'				3810	154	
1340	40°51.08'	83°32.29'				3810	153	Turned at FDY
1345	40°59.04'	83°20.28'				3810	152	
1350	40°43.03'	82°49.14'				3810	187	
1355	40°27.57'	82°15.48'						
1400	40°13.26'	81°38.09'					159	
1405	40°09.25'	82°06.48'					157	
1410								No data
1415	39°48.34'	83°04.08'					157	Over Port Columbus Airport at 1413

APPENDIX C

TABLE C11.- Continued

(b) Second flight

Time, EDT	Latitude	Longitude	VOR (station)	Magnetic bearing	Distance, km	Aircraft altitude, m	Aircraft ground speed, m/s	Comments
1615	39°33.85'	82°51.90'				3810		
1620	39°45.71'	83°18.16'				3810	157	
1625	40°00.69'	83°38.10'				3810	155	
1630	40°16.69'	84°02.87'				3810	162	Turned over Rosewood VOR for APC
1635	40°15.06'	83°34.52'				3810	183	Over Scioto River at 1638
1640	40°10.01'	82°56.81'				3810	180	Turned at APE for ZZV
1645	40°04.59'	82°20.43'				3810	180	Turned at ZZV for FDY
1652	40°03.42'	82°03.33'					180	
1655	40°09.22'	82°20.66'					154	
1700	40°27.75'	82°42.54'					153	
1705	40°39.54'	83°10.58'					154	
1710	40°52.50'	83°36.92'					149	Turned at FDY to MFD
1715	40°57.00'	83°32.34'						
1720	40°48.42'	83°04.97'					181	Turned back from clear area
1726	40°42.26'	83°22.56'					181	
1730	40°54.73'	83°46.94'					181	Turned at FDY at 1732
1736	40°55'	82°50'	MFD	278	037		181	
1740			MFD				181	Over MFD turning to CTW
1747	40°30'	81°43'	CTW	311	046			
1750								Turned to Briggs over CTW
1753	40°22'	81°26'	CTW	25	017			
1800			BSV					Turned at BSV at 1758
1805			CLE	132	044			Over plume at 1801
1810	41°05'	81°56'						Over Lake Erie
1815								No data
1824								Returning to Columbus

TABLE C11.- Concluded

(c) Third flight

Time, EDT	Latitude	Longitude	VOR (station)	Magnetic bearing	Distance, km	Aircraft altitude, m	Aircraft ground speed, m/s	Comments
2220	39°12'	23°16'	ROD	137	167	3200	134	
2225						3200	134	No data
2230	39°51'	83°47'	ROD	143	061	2591	134	Descending to 8500
2235						2591	134	No data
2240	40°12'	83°58'				2286	134	No data Descending to 7500
2245	40°11'	83°58'	ROD	134	015	2591	134	Ascending to 8500
2250						3353	134	Ascending to 11 000
2255	40°01'	82°15'	PKB	297	143	3353	134	Turned over ROD
2300	39°44'	81°55'	PKB	293	085	2743	134	Descending to 9000
2305	39°35'	81°41'	PKB	289	046	2743	159	
2310						2743	159	Turned over PKB
2315	39°37'	81°29'	PKB	323	024	3048	159	Ascending to 10 000
2320	38°58'	81°04'	BUZ	140	069	3048	159	
2325	38°35'	80°55'	BUZ	145	117	3048	159	
2330	38°23'	80°41'	BUZ	140	154	3048	159	
2335						3353	159	Over BUZ Ascending to 11 000
2340	40°49'	81°48'	AIR	302	169	3353	159	
2345	40°31'	81°32'	AIR	298	119	3353	172	
2350	40°15'	81°14'	AIR	293	067	3353	172	
2355	40°00'	80°52'	AIR	260	007	5791	172	Climbing to 19 000
2400	39°55'	80°43'	AIR	123	019		172	Still climbing
2406	39°53'	79°05'	FRR	305	156	5578	172	and climbing
2410	39°34'	78°44'	FRR	305	093		172	
2415	39°21'	78°29'	FRR	305	050			Descending

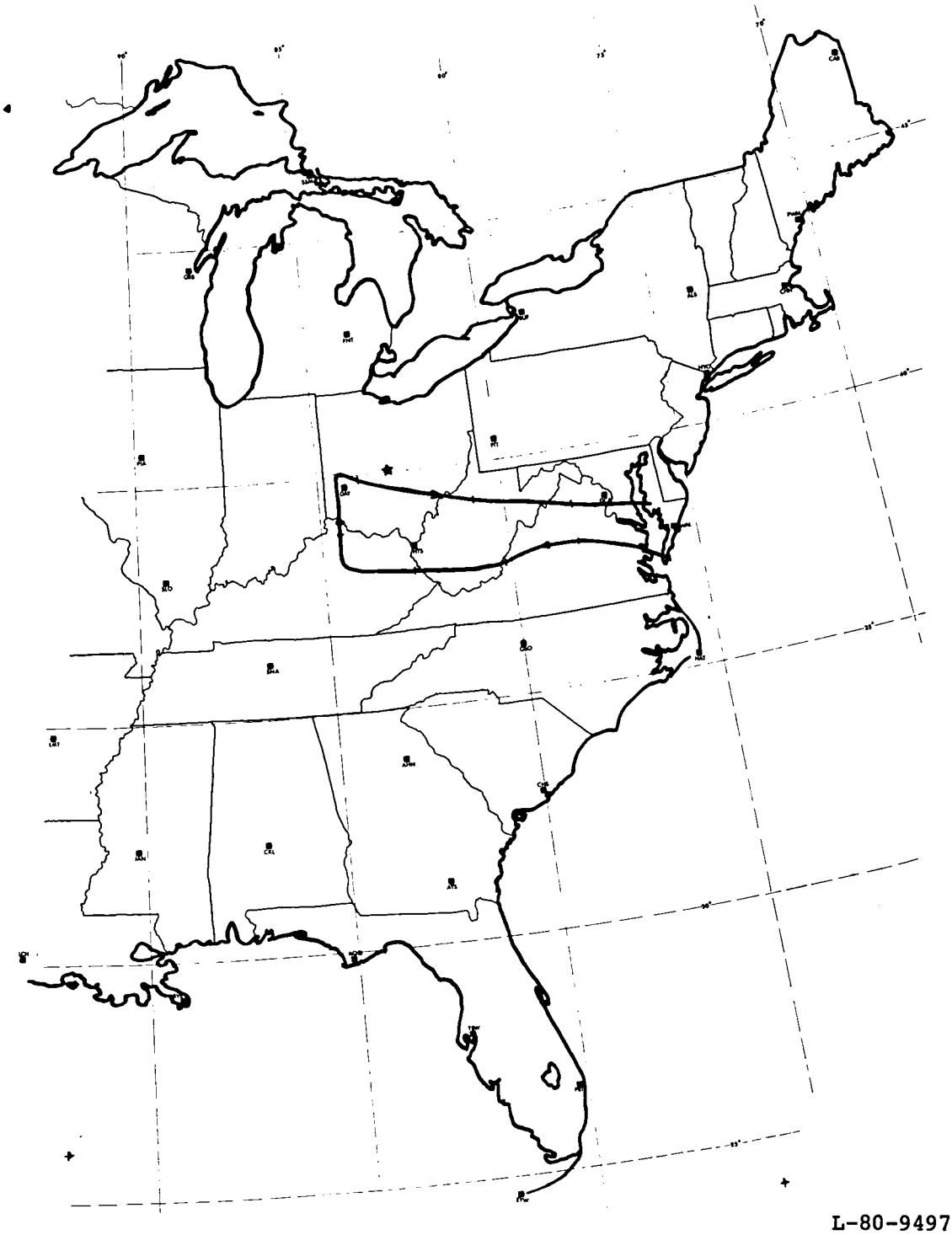
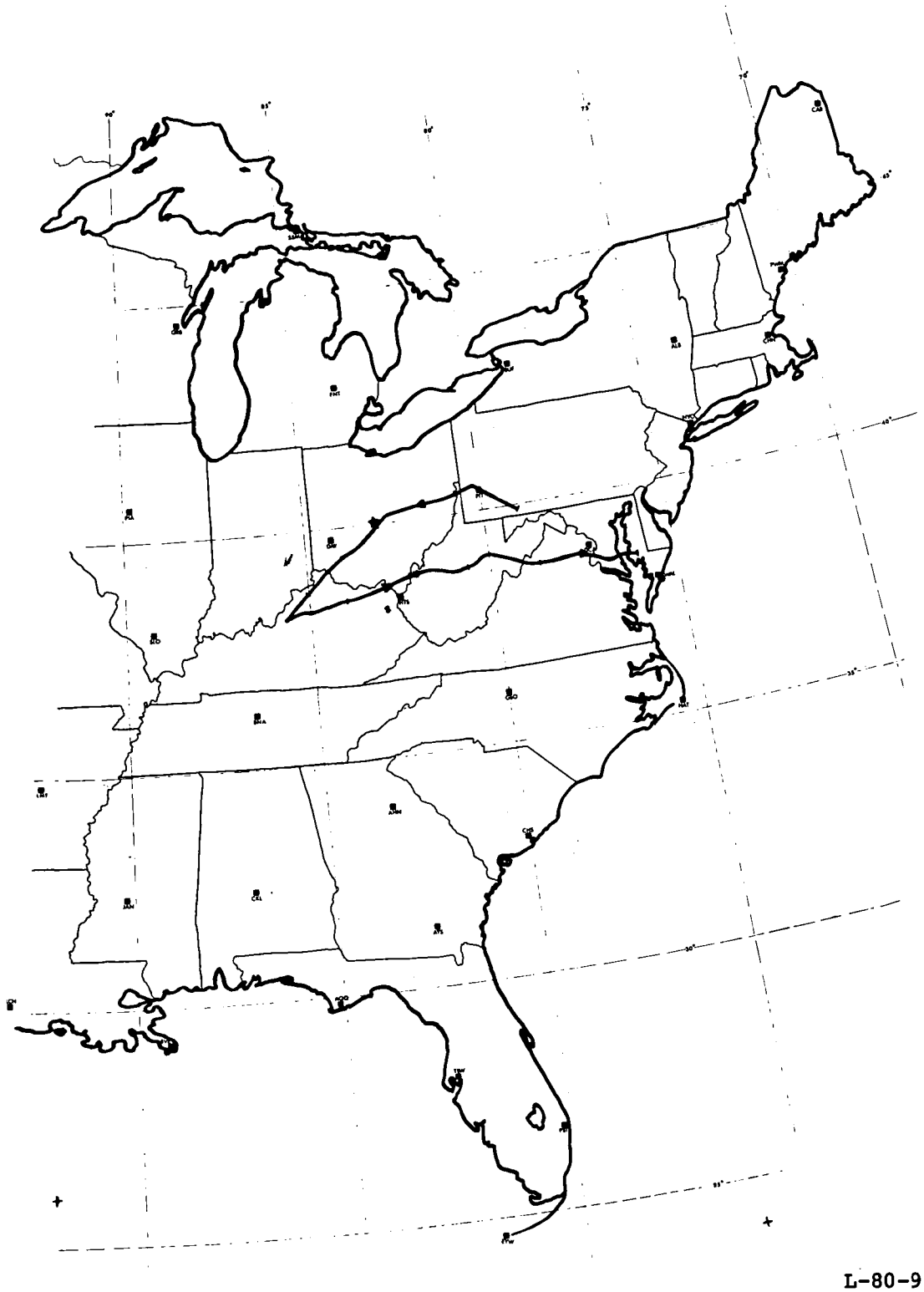
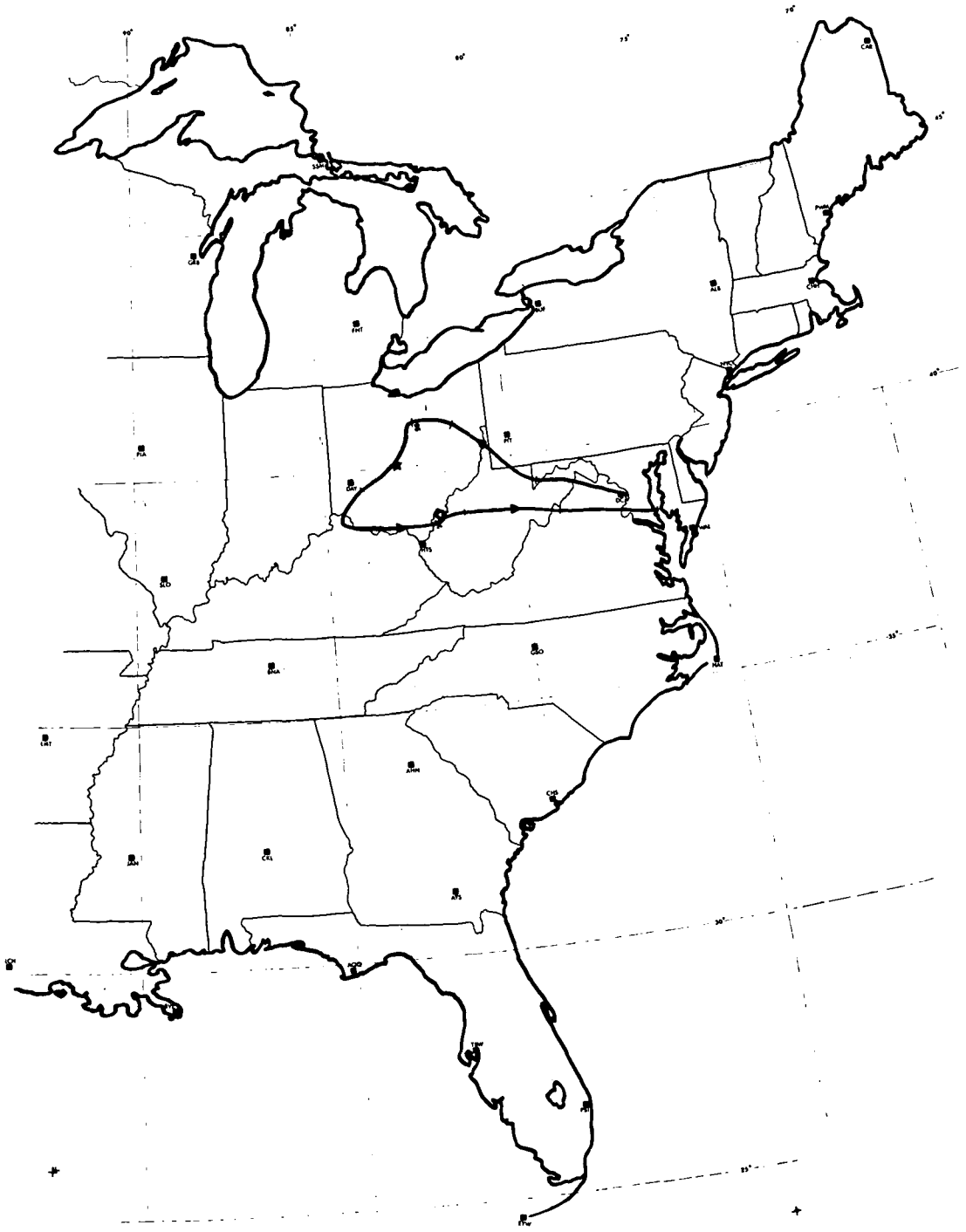


Figure C1.- Electra flight path for July 18, 1980. First tick at 1030.



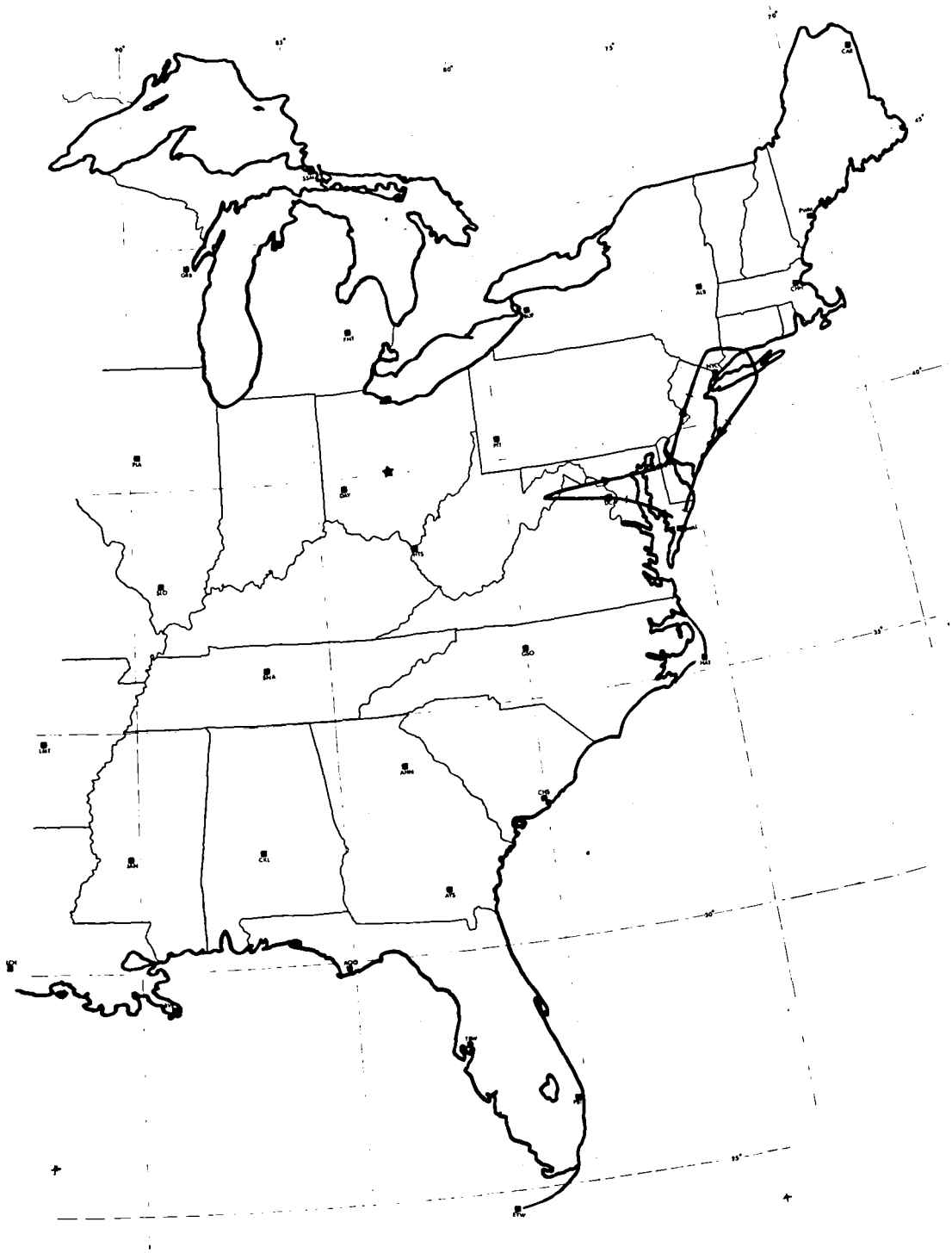
L-80-9503

Figure C2.- Electra flight path for July 24, 1980. First tick at 1130.



L-80-9502

Figure C3.- Electra flight path for July 25, 1980. First tick at 1200.



L-80-9498

Figure C4.- Electra flight path for July 31, 1980 (afternoon flight). First tick at 1330.

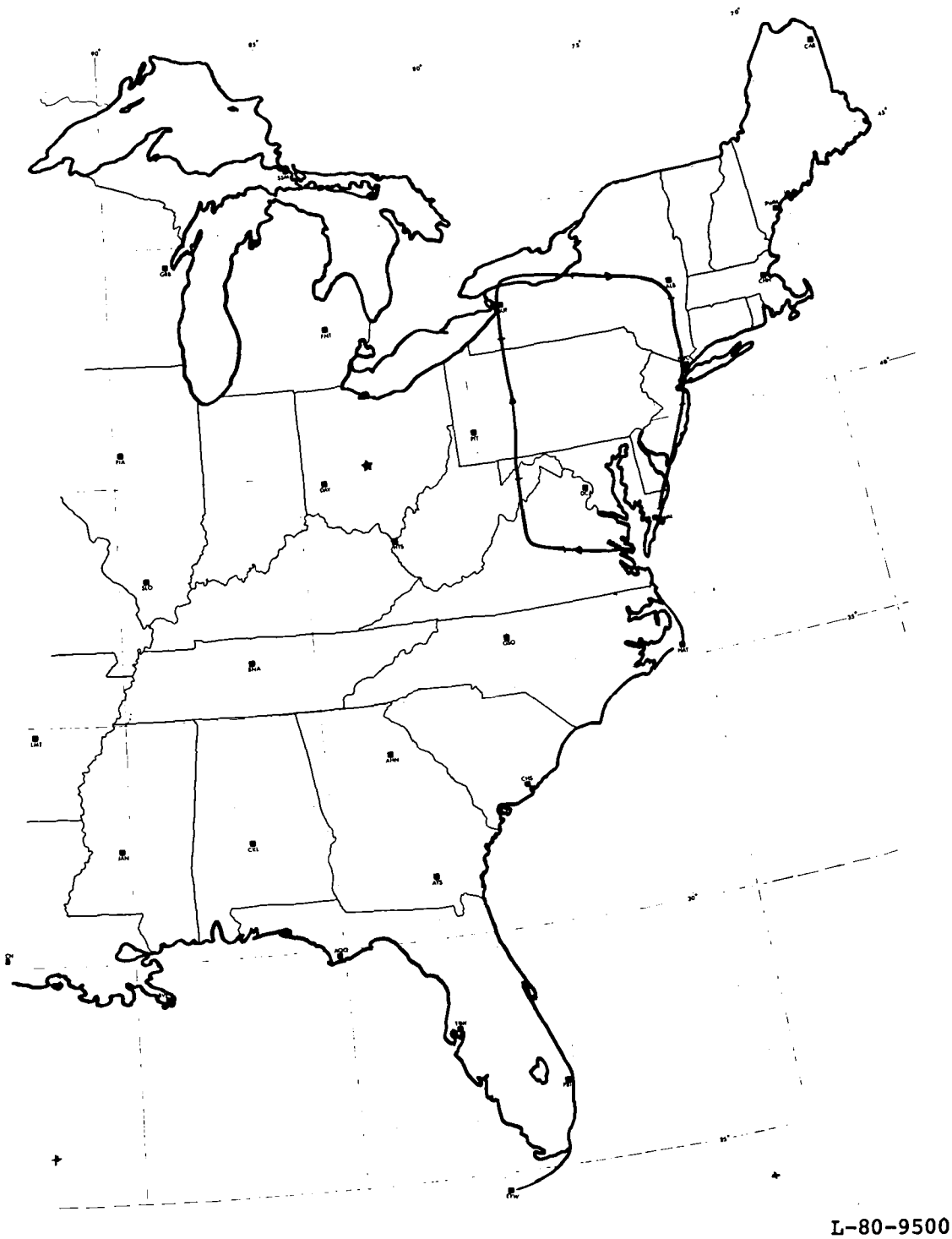
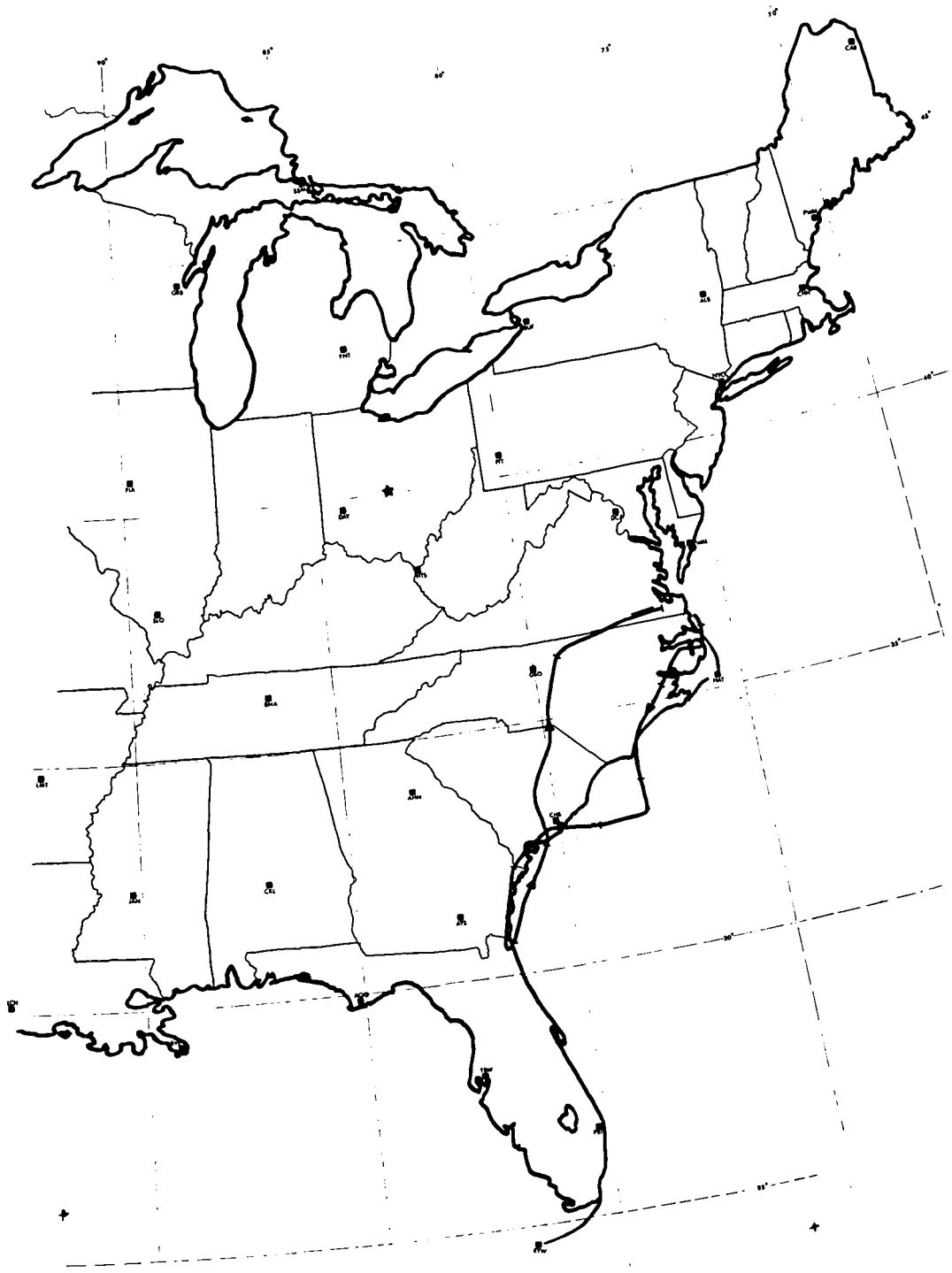


Figure C5.- Electra flight path for July 31, 1980 (night flight).
First tick at 2200.



L-80-9501

Figure C6.- Electra flight path for August 2, 1980. First tick at 0730.

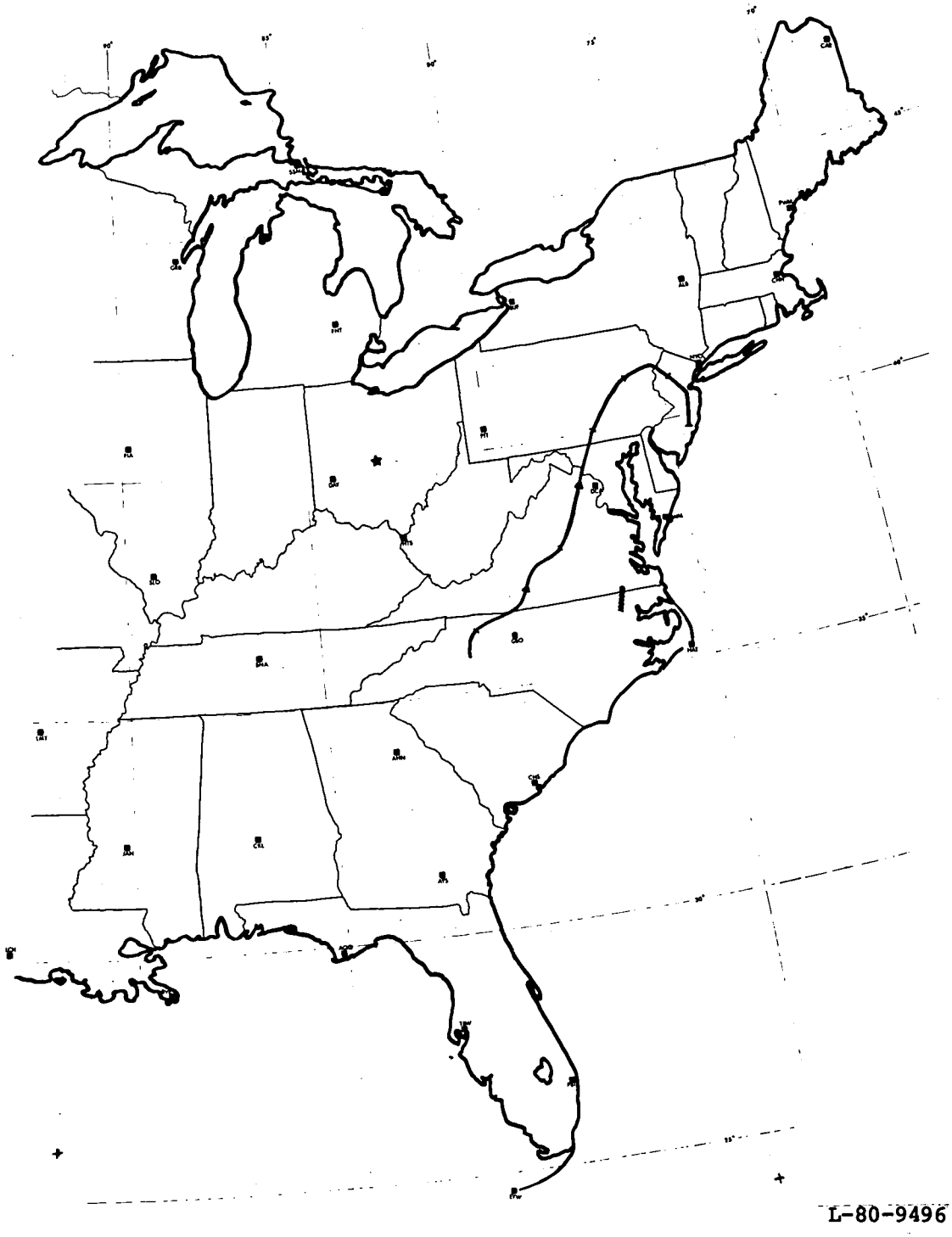
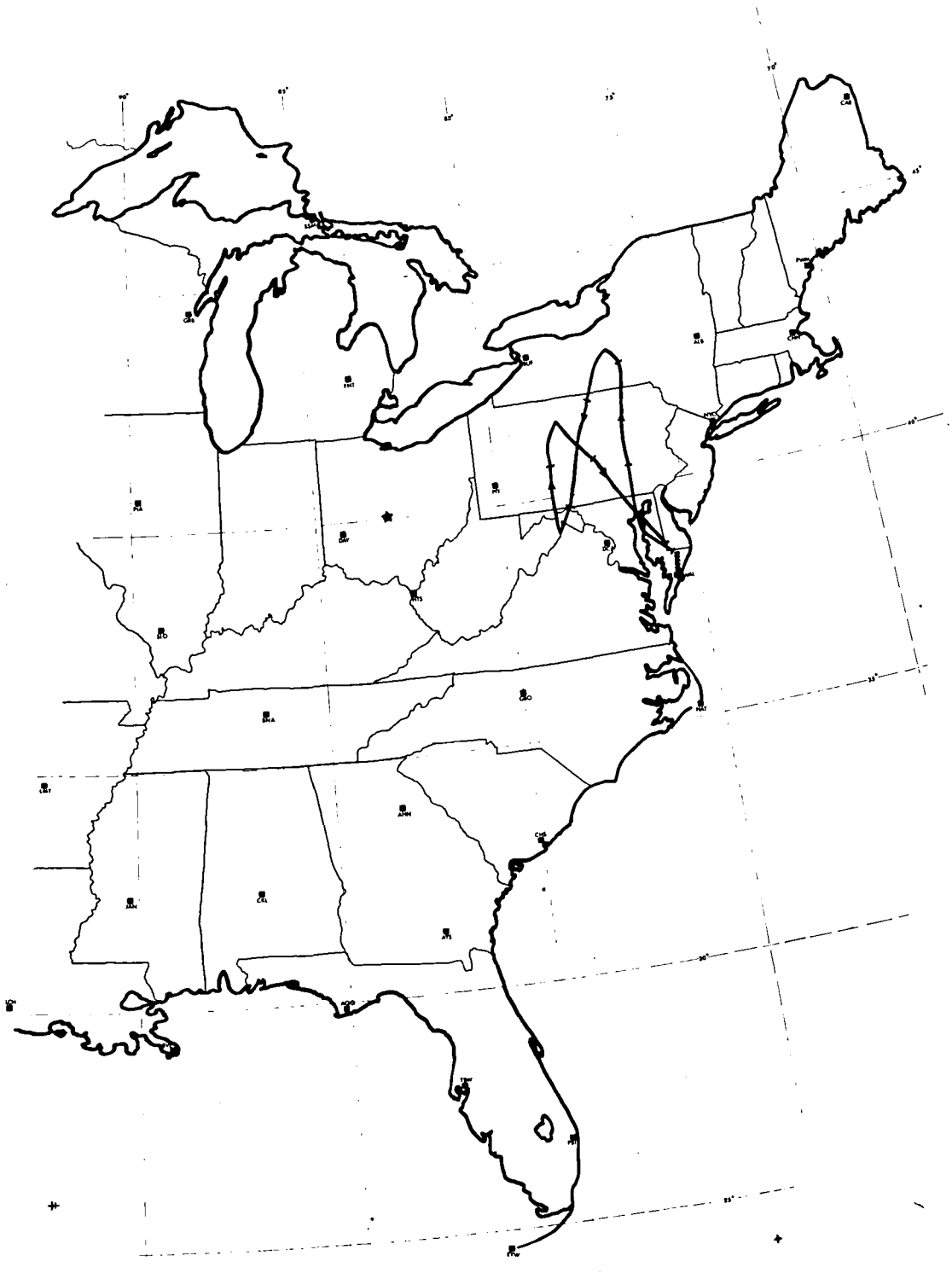


Figure C7.- Electra flight path for August 5, 1980. First tick at 1130.



L-80-9499

Figure C8.- Electra flight path for August 7, 1980. First tick at 1830.

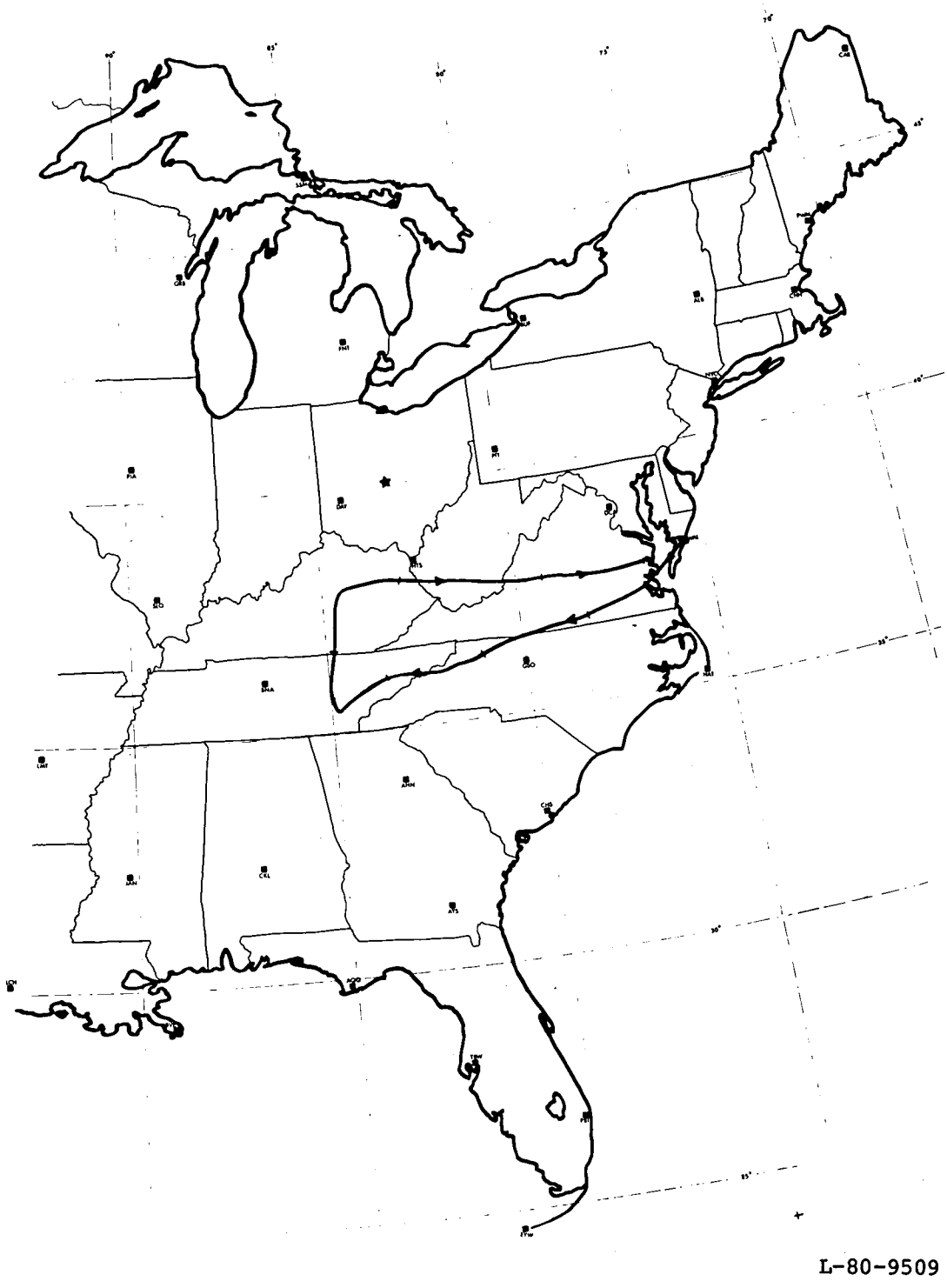
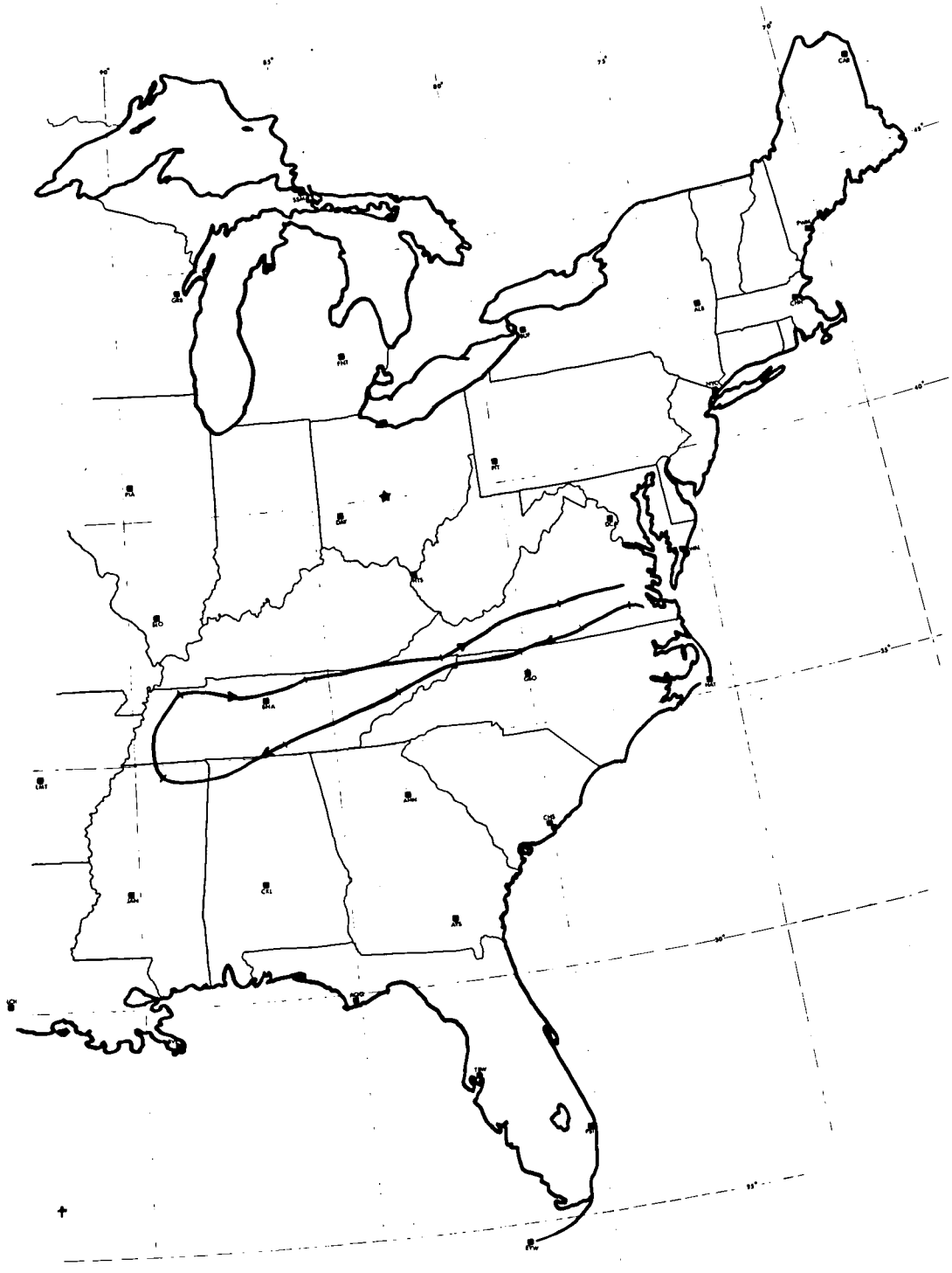
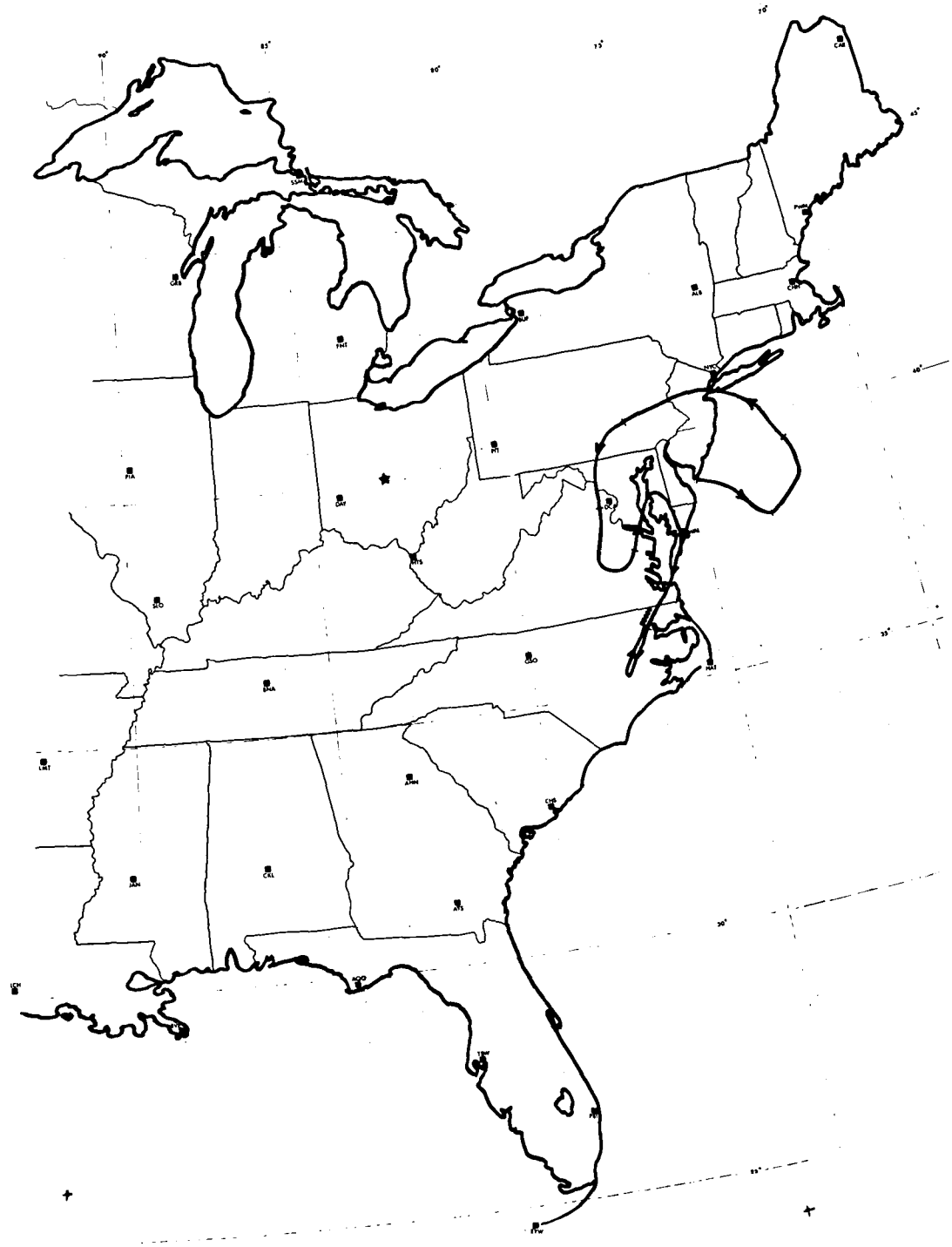


Figure C9.- Electra flight path for August 9, 1980. First tick at 0730.



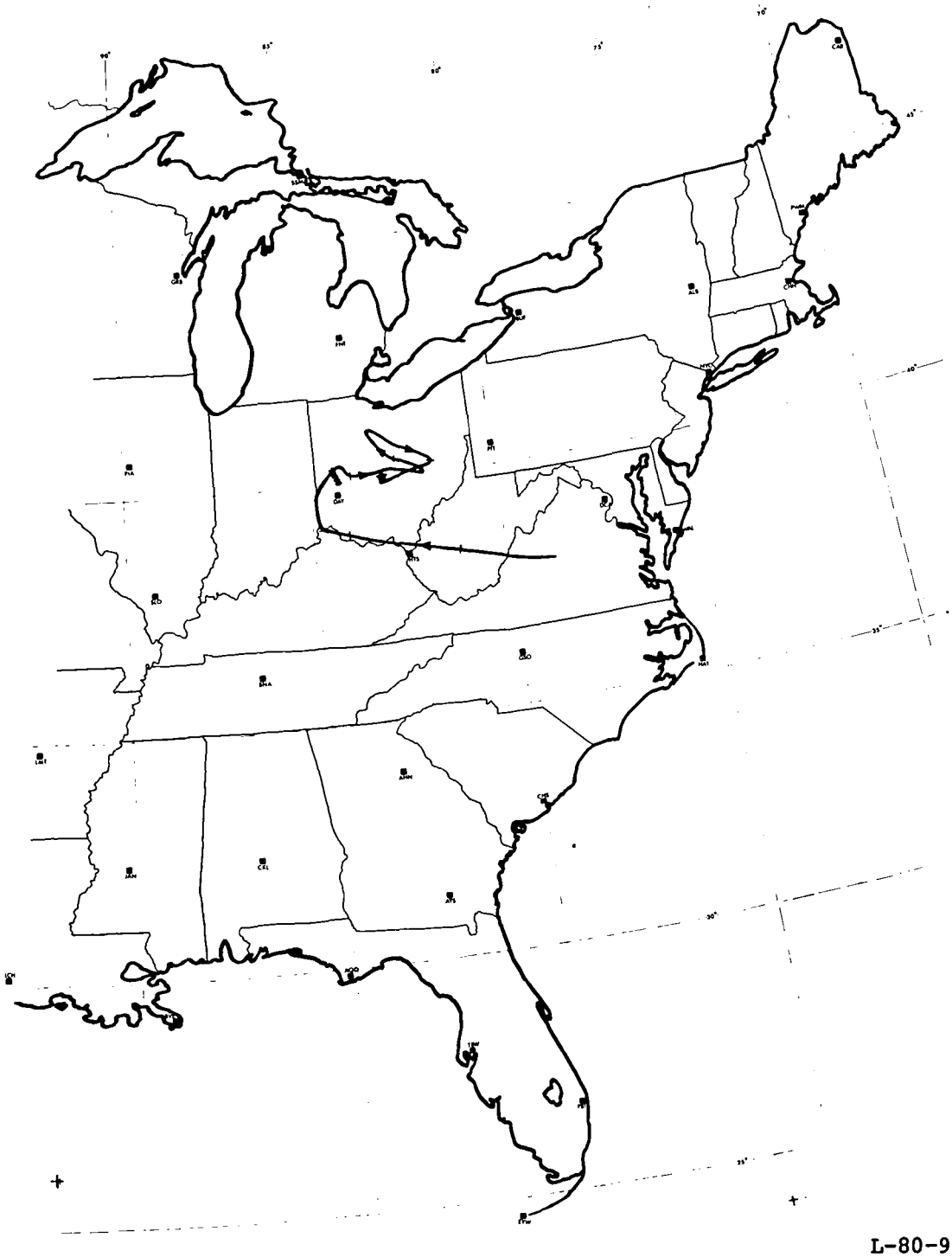
L-80-9506

Figure C10.- Electra flight path for August 10, 1980. First tick at 0600.



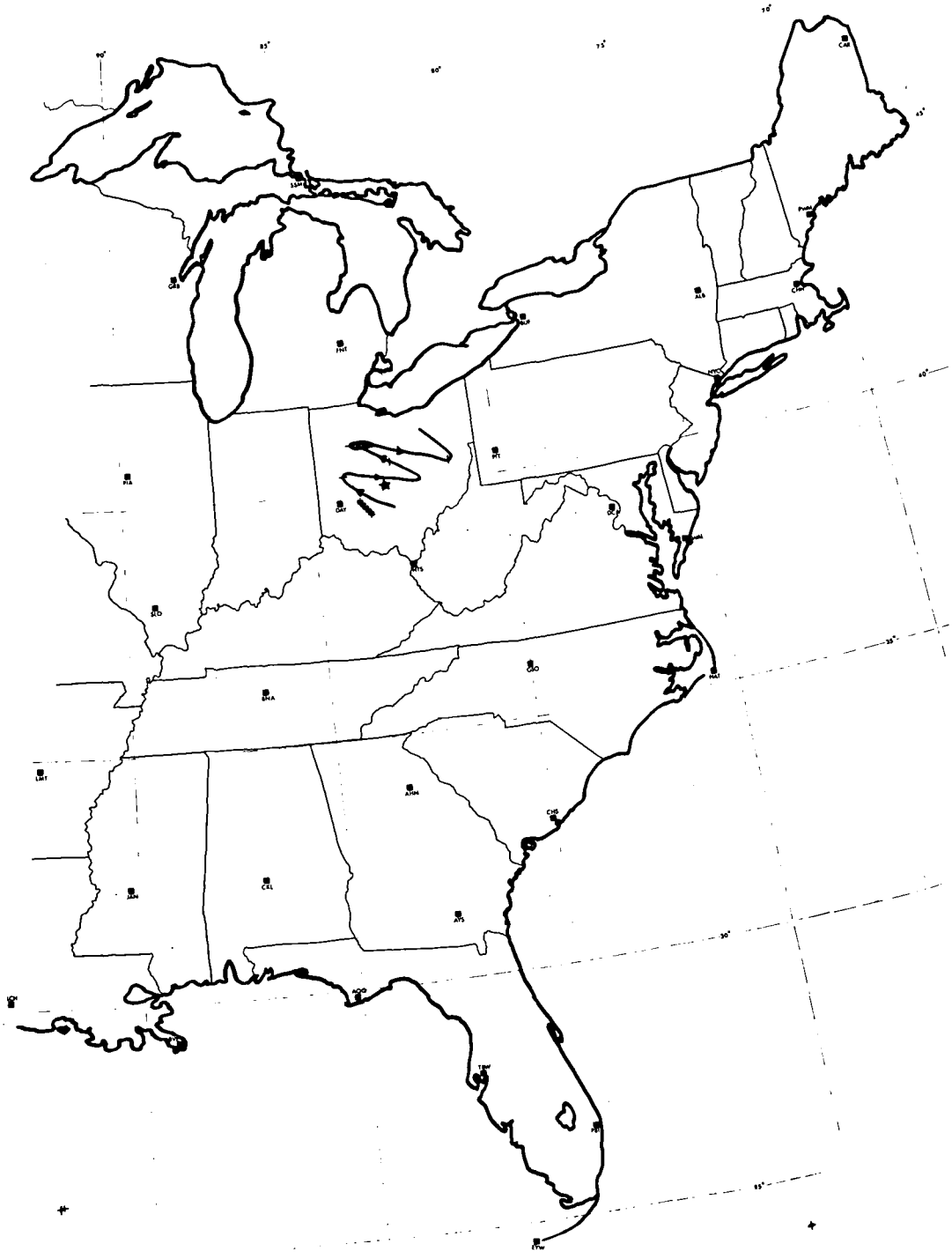
L-80-9505

Figure C11.- Electra flight path for August 12, 1980. First tick at 0700.



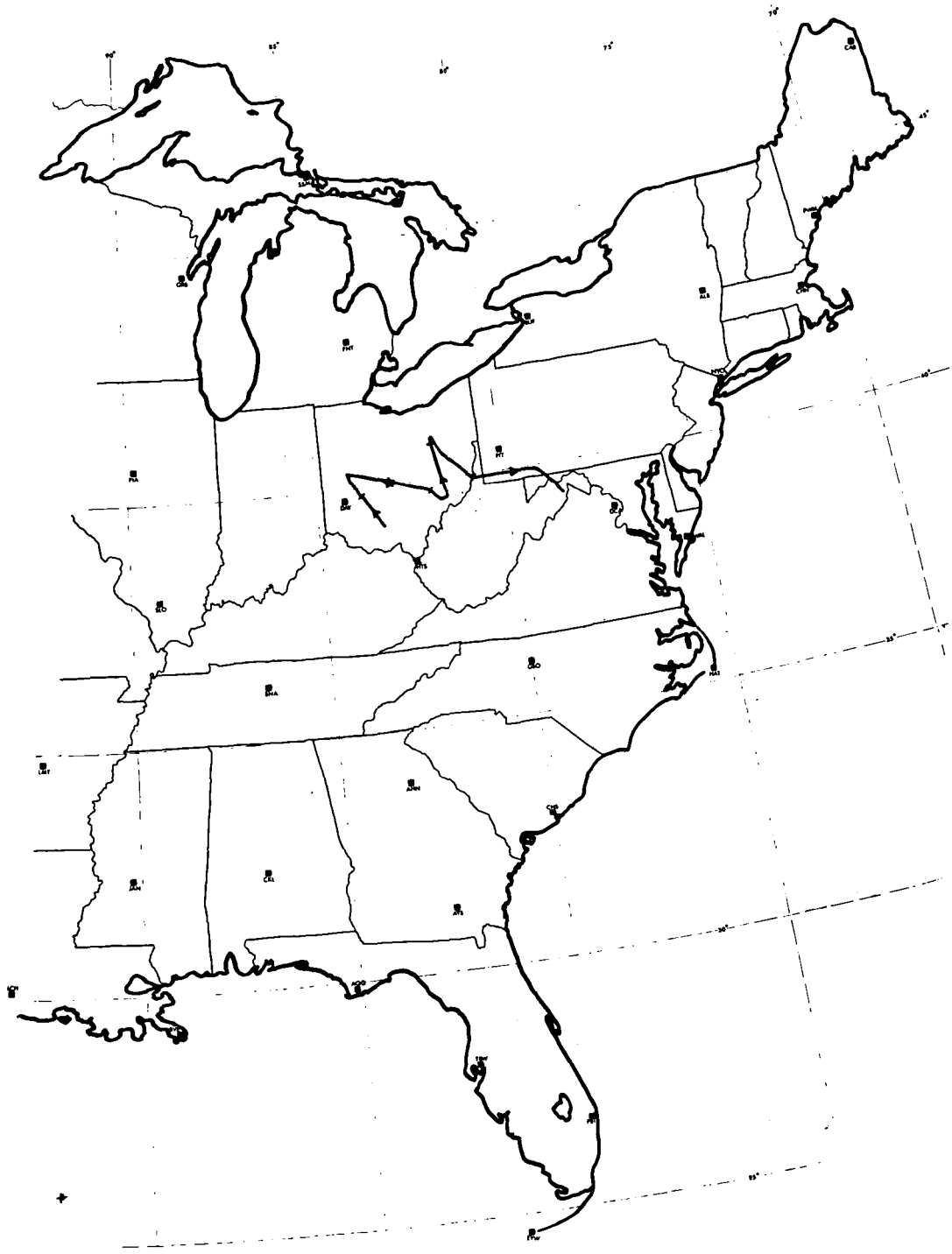
L-80-9508

Figure C12.- Electra flight path for August 13, 1980 (first flight). First tick at 1200.



L-80-9507

Figure C13.- Electra flight path for August 13, 1980 (second flight). First tick at 1630.



L-80-9504

Figure C14.- Electra flight path for August 13, 1980 (third flight). First tick at 2230.

APPENDIX D

JPL QUEEN AIR FLIGHT DATA

The JPL Beechcraft B80 Queen Air airplane flight data, keyed to the map in figure D1 of this appendix, are shown in table D1.

TABLE D1.- QUEEN AIR FLIGHT DATA

Date	Time, EDT	Location (keyed to fig. D1)	Altitude, m	Comments
July 11	1100	A-B	1000	S of Columbus*
July 14	1100	C-D	750 and 1300	N of OSU airport
July 14	1500	E-F	750, 1000, and 1300	W of OSU airport*
July 15	1100	G-H	1000	SW of Columbus*
July 18	1400	I-J-K	1000	SE of Lancaster**
July 18	1500	L-M	1000	SW of Columbus
July 20	1000	N-P-Q	1000	SW of Columbus
July 20	1100	R-S-T	1000	NE of Columbus
July 20	1400	U-V-W	1000	SE of Mansfield
July 20	1500	X-Y-Z	1000	SE of Ashland
July 23	1100	AA-BB		W of OSU airport*

*Joint flight with NASA Cessna 402 in situ measurement aircraft.
**Joint flight with WFC Electra airplane carrying UV DIAL and HSRL.

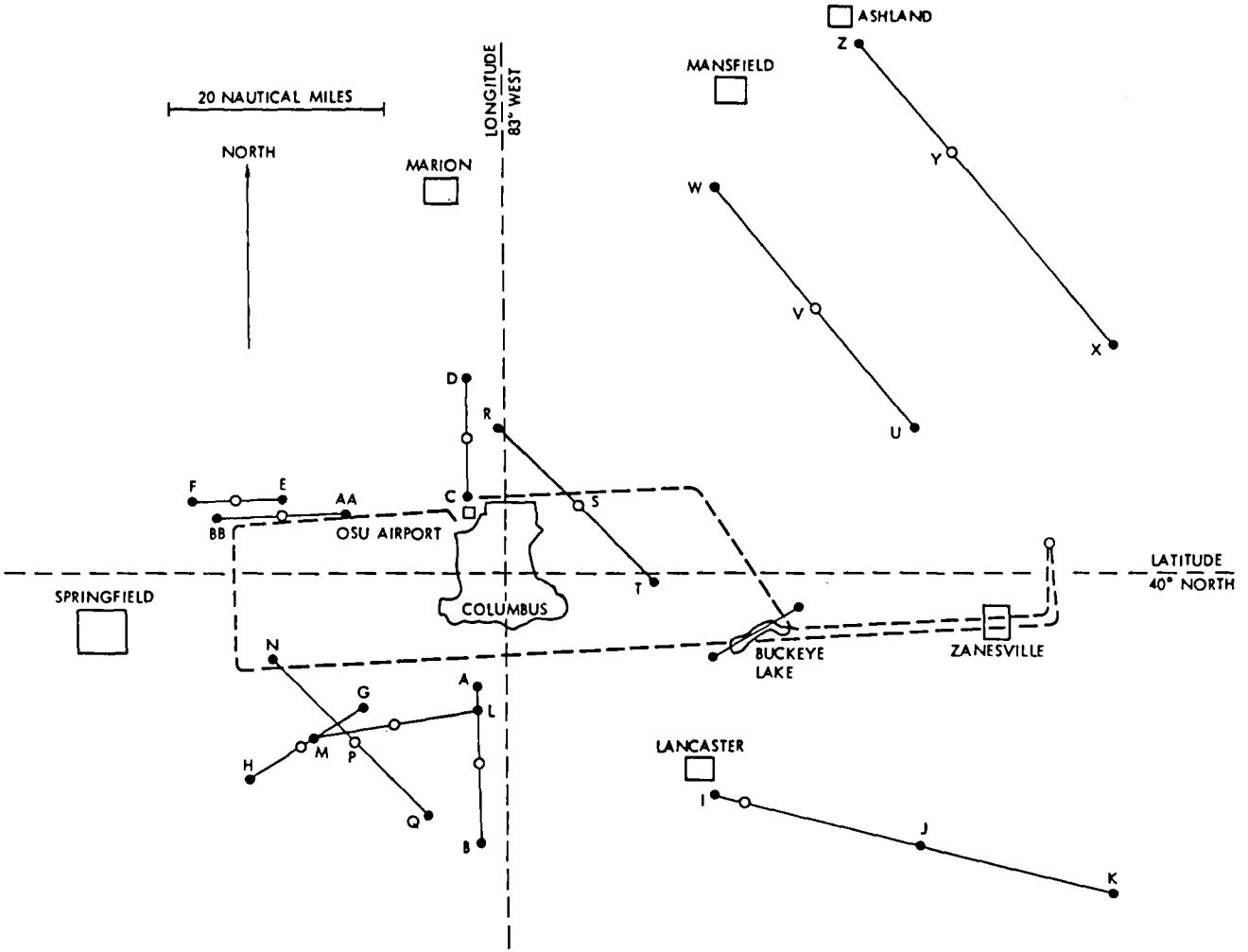


Figure D1.- Flight paths for JPL Beechcraft B80 Queen Air airplane.

APPENDIX E

FLIGHT DATA FOR IN SITU MEASUREMENT AIRCRAFT

Table E1 presents the time, date, and location data for the NASA Cessna 402 in situ measurement aircraft flights. Also denoted are the flight pattern, straight line or single location (point), the length of the flight leg, and the remote sensor system the correlative measurements were supporting. The locations for days when Electra missions were flown are shown pictorially on figures C1 to C14.

TABLE E1.- FLIGHT DATA FOR NASA CESSNA 402 IN SITU MEASUREMENT FLIGHTS

Date	Data location, VOR radial/km	Data time (EDT)	Correlation type	Remote sensor participating in correlation
July 11	York VOR 360/123.3 York VOR 360/103.7	1040 to 1200	30-km flight leg	LAS
July 14	Appleton 270/74.0 Appleton 270/88.8	1440 to 1540	15-km flight leg	LAS
July 15	Appleton 240/72.2 Appleton 240/94.4	0950 to 1030	22-km flight leg	LAS
July 23	Appleton 267/74.0 Appleton 267/37.0	1020 to 1110	37-km flight leg	LAS
July 24	Newcomb 0/0 Henderson 90/3.7	1200 to 1400	Point (2)	UV DIAL + HSRL
July 25	Mansfield 101/38.8 Henderson 90/3.7	1120 to 1310	Point (2)	UV DIAL + HSRL
July 31	Kenton 270/61.1 Kenton 292/14.8	1320 to 1430	26-km flight leg	UV DIAL + HSRL
July 31	Harcum 103/27.7 Harcum 296/27.7	2100 to 2210	28-km flight leg	UV DIAL + HSRL
Aug. 2	Franklin 260/33.3 Franklin 80/25.9	1200 to 1320	33-km flight leg	UV DIAL + HSRL
Aug. 5	Franklin 197/57.4 Franklin 197/14.8	0930 to 1110	43-km flight leg	UV DIAL + HSRL
Aug. 6	Franklin 280/7.4 Franklin 280/62.9	1240 to 1400	55-km flight leg	UV DIAL + HSRL (Flight canceled)
Aug. 7	Snow Hill 170/7.4 Snow Hill 350/29.6	1740 to 1850	37-km flight leg	UV DIAL + HSRL
Aug. 9	Cape Chas. 40/38.8	1030 to 1100	Point	UV DIAL + HSRL
Aug. 12	Coefield 52/18.5 Coefield 232/18.5	1030 to 1220	37-km flight leg	UV DIAL + HSRL
Aug. 13	Rosewood 203/7.4 Rosewood 203/37.0	1210 to 1330	27-km flight leg	UV DIAL + HSRL
Aug. 13	Rosewood 137/124.0 Rosewood 137/87.0	1620 to 1700	37-km flight leg	UV DIAL + HSRL

APPENDIX F

TETHERED-BALLOON FLIGHT DATA

Tethered-balloon flight data at both test locations are presented in tables F1 and F2 in this appendix.

TABLE F1.- TETHERED-BALLOON FLIGHT DATA FOR ABERDEEN, MARYLAND, SITE

Date	No. of profiles	Time, EDT	Maximum altitude, m
July 24	4	1136 to 2209	1280
July 25	12	0724 to 2153	1240
July 26	4	1135 to 1413	1210
July 28	4	0829 to 1249	1310
July 29	2	1506 to 1700	1060
July 30	8	0520 to 1725	1120
July 31	6	0707 to 1422	1500
Aug. 1	2	0807 to 0955	0910
Aug. 4	4	1019 to 1658	1360
Aug. 5	6	0548 to 1326	1470
Aug. 6	8	0539 to 1223	1370
Aug. 7	8	0419 to 1037	1020

TABLE F2.- TETHERED-BALLOON FLIGHT DATA FOR CROTON, OHIO, SITE

Date	No. of profiles	Time, EDT	Maximum altitude, m
July 16	4	1557 to 1718	650
July 17	2	1216 to 1314	690
July 18	14	0546 to 1237	700
July 20	2	0600 to 0824	180
July 21	8	0538 to 1134	600
July 23	8	0552 to 1206	600
July 24	8	0548 to 1158	600
July 25	7	0702 to 1231	620
July 26	6	0812 to 1003	600
July 29	6	1026 to 1615	630
July 30	16	0606 to 2358	600
Aug. 1	9	1644 to 2321	600
Aug. 4	11	0555 to 1054	700
Aug. 6	22	0601 to 1420	600
Aug. 7	26	0557 to 2236	600
Aug. 8	6	0631 to 1030	600
Aug. 9	2	0558 to 0656	600

CONTACTS FOR SENSOR SYSTEMS

For information relative to details of a specific sensor system or its operation, contact the following people:

INSTRUMENT	CONTACT
UV DIAL	Dr. Edward V. Browell NASA Langley Research Center Hampton, Virginia 23665 (804) 827-2576 or FTS 928-2576
HSRL	Dr. Scott T. Shipley NASA Langley Research Center Hampton, Virginia 23665 (804) 827-2576 or FTS 928-2576
LAS	Michael S. Shumate Jet Propulsion Laboratory California Institute of Technology 4800 Oak Grove Drive Pasadena, California 91103 (213) 354-2016 or FTS 792-2016
In situ measurement aircraft	George L. Maddrea, Jr. NASA Langley Research Center Hampton, Virginia 23665 (804) 827-2486 or FTS 928-2486
Tethered balloons	Otto Youngbluth, Jr. NASA Langley Research Center Hampton, Virginia 23665 (804) 827-3645 or FTS 928-3624
MARS	Bruce Gary Jet Propulsion Laboratory California Institute of Technology 4800 Oak Grove Drive Pasadena, California 91103 (213) 354-3198 or FTS 792-3198
Photometers/ Transmissometers	Dr. Robert S. Frazer NASA Goddard Space Flight Center Greenbelt, Maryland 20771 (301) 344-9008 or FTS 88 344-9008

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6. Gregory, G. L.: Selected In Situ Airborne Pollutant Measurement Techniques Applicable to the Power Plant Plume Problem. Environmental and Climatic Impact of Coal Utilization, Jag J. Singh and Adarsh Deepak, eds., Academic Press, Inc., 1980, pp. 147-182.

7. Gregory, Gerald L.; and Wagner, H. Scott, eds.: Summary of Southeastern Virginia Urban Plume Measurement Data for August 4 and 5, 1977. NASA TM-78822, 1979.

8. White, J. H.; Strong, R.; and Tommerdahl, J. B.: Altitude Characteristics of Selected Air Quality Analyzers. NASA CR-159165, 1979.

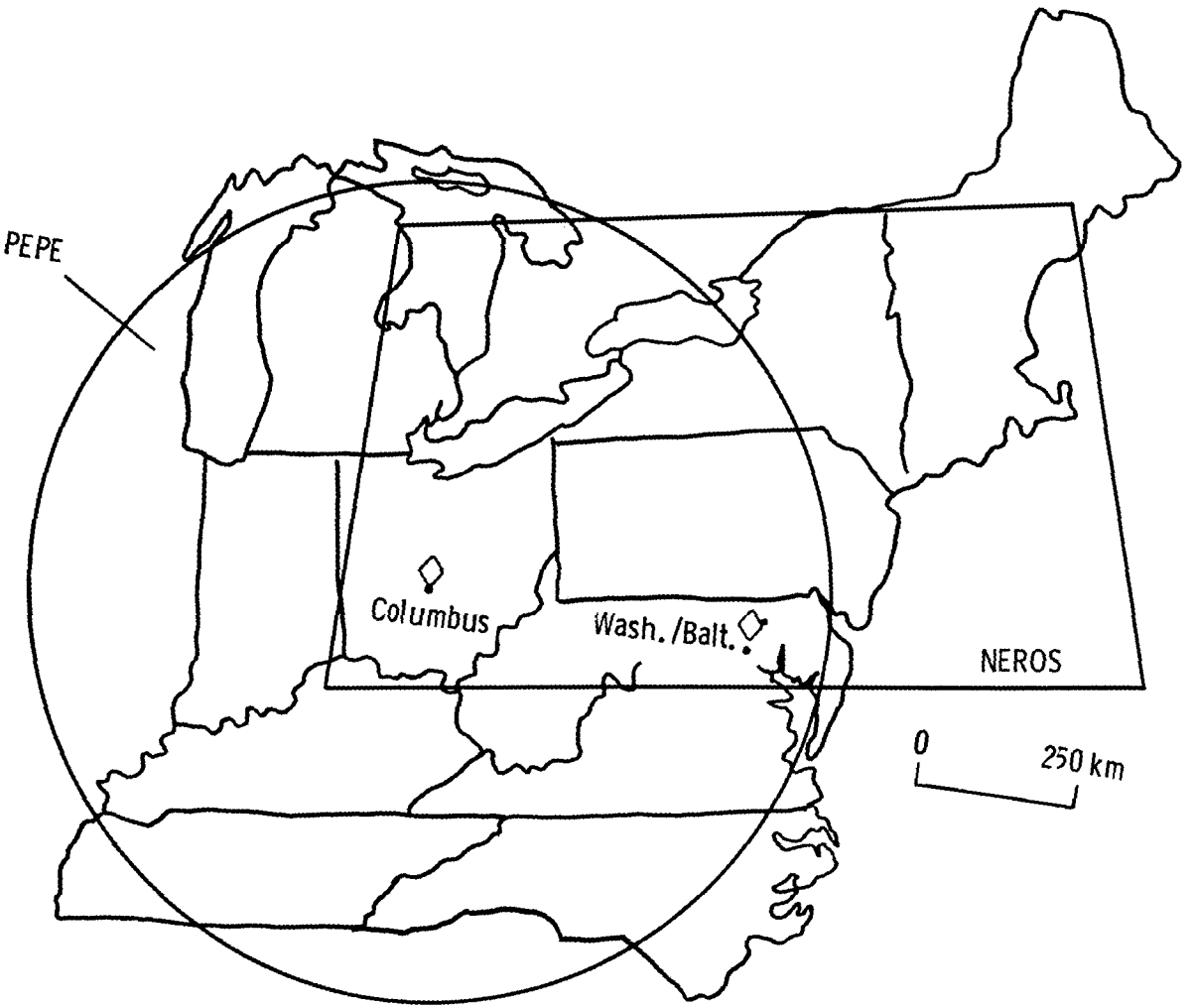

Figure 1.- Experiment areas for 1980 PEPE/NEROS field study.

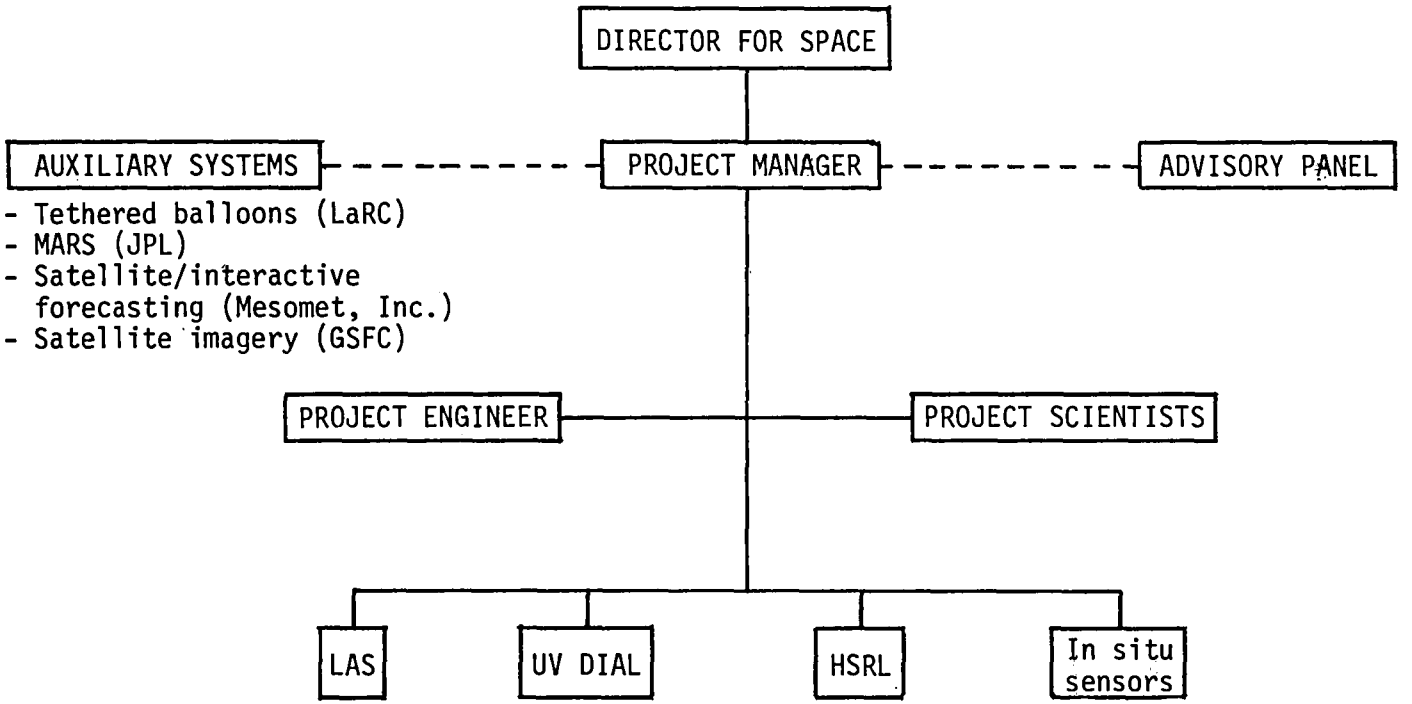

Figure 2.- NASA organization for 1980 PEPE/NEROS experiment.

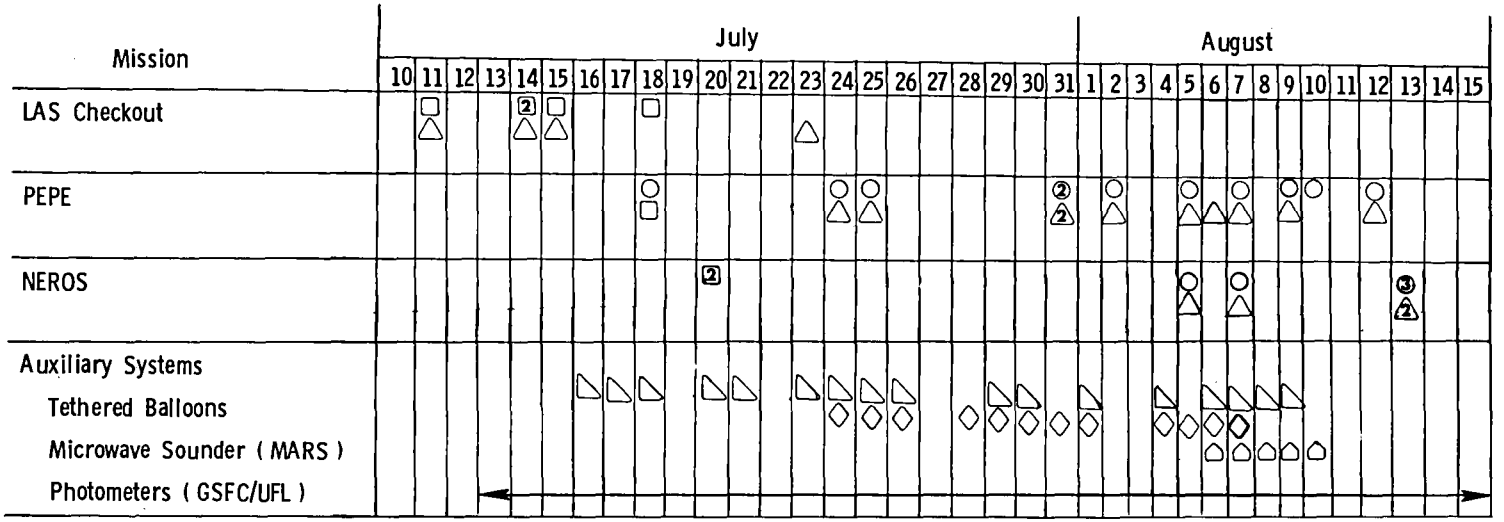

Figure 3.- Schedule of 1980 PEPE/NEROS experiment sensor participation.

1. Report No.	2. Government Accession No.	3. Recipient's Catalog No.
NASA TM-83170		

4. Title and Subtitle	5. Report Date
NASA PARTICIPATION IN THE 1980 PERSISTENT ELEVATED POLLUTION EPISODE/NORTHEAST REGIONAL OXIDANT STUDY (PEPE/NEROS) PROJECT: OPERATIONAL ASPECTS	September 1981
	6. Performing Organization Code: 146-20-10-30
7. Author(s): G. L. Maddrea, Jr., and R. J. Bendura	8. Performing Organization Report No.: L-14584
	10. Work Unit No.
9. Performing Organization Name and Address: NASA Langley Research Center, Hampton, VA 23665	11. Contract or Grant No.
	13. Type of Report and Period Covered: Technical Memorandum
12. Sponsoring Agency Name and Address: National Aeronautics and Space Administration, Washington, DC 20546	14. Sponsoring Agency Code

15. Supplementary Notes

16. Abstract

The Environmental Protection Agency (EPA) conducted an extensive study of regional-scale air pollution in the Northeastern United States from July 10 to August 15, 1980. The study was a combined Persistent Elevated Pollution Episode (PEPE)/Northeast Regional Oxidant Study (NEROS) field experiment designed to further understand the formation and transport of visibility-reducing aerosols and to characterize regional-scale air masses and urban plumes. Measurements were made primarily in the Ohio River Valley region. Seven Federal agencies, elements of the Canadian and French governments, and numerous state organizations, universities, and contractors participated in the field experiment. The National Aeronautics and Space Administration (NASA) participation included obtaining measurements for the determination of mixing-layer height and ozone (O_3) profiles by using airborne remote sensor systems such as the Ultraviolet Differential Absorption Lidar, the High Spectral Resolution Lidar, and the Laser Absorption Spectrometer. Other NASA systems included the Microwave Atmospheric Remote Sensor, tethered balloons, an in situ measurements aircraft, and several photometer/transmissometer systems. This report discusses NASA's involvement in the field experiment, describes the sensors used, and summarizes the operational data for the various NASA systems. The report does not contain measurement data from the study.

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