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OPERATIONS SUMMARY FOR THE CONVECTION AND MOISTURE EXPERIMENT (CAMEX)

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Space Sciences Laboratory
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During the fall of 1993, NASA sponsored a field program called the Convection and Moisture Experiment (CAMEX) at Wallops Island, Virginia. CAMEX was a multi-disciplinary experiment design to measure the three-dimensional moisture fields over Wallops Island, and to characterize the multi-frequency radiometric signature of tropical convection over the Gulf Stream and southeastern Atlantic Ocean. This document summarizes the daily CAMEX activities, including ground and aircraft (NASA ER-2) operations, and includes "quick-look" summaries of data acquisition along with data examples provided by the various CAMEX PI's.

14. SUBJECT TERMS

CAMEX, AIRS, Remote Sensing, Water Vapor, Precipitation, Lightning, Aerosols, Meteorology, Multispectral Imagery, AMPR,EDOP, HIS, LIP, MAMS, MIR, MTS, Raman Lidar

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LIST OF ACRONYMS

AIR	Atmospheric Instrument Research (Inc.)
AIRS	Atmospheric Infrared Sounder
AMPR	Advanced Microwave Precipitation Radiometer
AMSU-A	Advanced Microwave Sounding Unit - A
CAMEX	Convection And Moisture EXperiment
CaPE	Convection and Precipitation/Electrification [experiment]
CLASS	Cross-Chain Loran Atmospheric Sounding System
COARE	Coupled Ocean Atmosphere Response Experiment
DAAC	Data Acquisition and Archive Center
DMSP	Defense Meteorological Satellite Program
EDOP	ER-2 Doppler Radar
EOS	Earth Observing System
GB-HIS	Ground Based HIS
GSFC	Goddard Space Flight Center
GMT	Greenwich Mean Time
HIS	High Resolution Interferometer Sounder
LIP	Lightning Instrument Package
MAMS	Multispectral Atmospheric Mapping Sensor
Meteosat	Meteorological Satellite
MIR	Millimeter Imaging Radiometer
MSFC	Marshall Space Flight Center
MTS	Millimeter-Wave Temperature Sounder
NASA	National Aeronautics and Space Administration
NCDC	National Climate Data Center
NOAA	National Oceanic and Atmospheric Administration
SPANDAR	S-band Radar
SSEC	Space Science Engineering Center (Univ. of Wisconsin)
SSM/I	Special Sensor Microwave/Imager
SSM/T-2	Special Sensor Microwave/Temperature Version 2
TOGA	Tropical Oceans, Global Atmospheres
USAF	United States Air Force
WFF	Wallops [Island] Flight Facility

TECHNICAL MEMORANDUM

OPERATIONS SUMMARY FOR THE CONVECTION AND MOISTURE EXPERIMENT (CAMEX)

SECTION I. INTRODUCTION

This report describes the activities during the Convection And Atmospheric Moisture Experiment (CAMEX), a NASA funded science experiment carried out at Wallops Island, VA from September 8, 1993 to October 7, 1993. CAMEX was a multi-disciplinary experiment designed to measure the three-dimensional moisture fields over the Wallops Flight Facility (WFF) and to characterize the multifrequency radiometric signature of tropical convection over the Gulf Stream and southeastern Atlantic Ocean.

For ease in relating CAMEX activities that occur on the same local day but different GMT days, it seemed convenient and beneficial to define a special CAMEX day. Each CAMEX day began at 1200 GMT and continued for 24 hours. Thus, all activities that occurred (begin) on the same local day have the same CAMEX day. Table 1 shows the relationship between the CAMEX days and the GMT and local (Wallops Island, VA) dates. CAMEX day 1 began at 1200 GMT, September 7, 1993, and ended at 1159 GMT, September 8, 1993; this date was chosen to coincide with the onset of the Raman lidar studies. The ER-2 arrived at Wallops on CAMEX day 6.

Table 1. Relationship between the 31 CAMEX experiment days and the GMT and local (Wallops Island, VA) dates

CAMEX DAY	LOCAL DAY	GMT DAY START	GMT DAY END
1	7-Sep	7-Sep	8-Sep
2	8-Sep	8-Sep	9-Sep
3	9-Sep	9-Sep	10-Sep
4	10-Sep	10-Sep	11-Sep
5	11-Sep	11-Sep	12-Sep
6	12-Sep	12-Sep	13-Sep
7	13-Sep	13-Sep	14-Sep
8	14-Sep	14-Sep	15-Sep
9	15-Sep	15-Sep	16-Sep
10	16-Sep	16-Sep	17-Sep
11	17-Sep	17-Sep	18-Sep
12	18-Sep	18-Sep	19-Sep
13	19-Sep	19-Sep	20-Sep
14	20-Sep	20-Sep	21-Sep
15	21-Sep	21-Sep	22-Sep
16	22-Sep	22-Sep	23-Sep
17	23-Sep	23-Sep	24-Sep
18	24-Sep	24-Sep	25-Sep
19	25-Sep	25-Sep	26-Sep
20	26-Sep	26-Sep	27-Sep
21	27-Sep	27-Sep	28-Sep
22	28-Sep	28-Sep	29-Sep
23	29-Sep	29-Sep	30-Sep
24	30-Sep	30-Sep	1-Oct
25	1-Oct	1-Oct	2-Oct
26	2-Oct	2-Oct	3-Oct
27	3-Oct	3-Oct	4-Oct
28	4-Oct	4-Oct	5-Oct
29	5-Oct	5-Oct	6-Oct
30	6-Oct	6-Oct	7-Oct
31	7-Oct	7-Oct	8-Oct

A. CAMEX Mission Resources

CAMEX resources included ER-2 data gathering missions using the instruments listed in Table 2, a Raman lidar operated at WFF, the Univ. of Wisconsin surface High Resolution Interferometer Sounder (called the GB-HIS), and a series of rawinsonde balloon launches from WFF and a Univ. of Wisconsin deployed CLASS site. In addition CAMEX was supported by the SPANDAR radar at the WFF and an ocean research vessel (the "Chessie") provided by Johns Hopkins Marine Research Center. The "Chessie" carried a tether-sonde system capable of profiling the lower atmosphere to 1 km.

Table 2. CAMEX ER-2 instruments

Instrument	PI, Institution	Discipline	Data Parameters
High Resolution Interferometer Sounder (HIS)	Smith, U. Wis.	Dynamics, AIRS	Temperature and moisture soundings
Advanced Microwave Precipitation Radiometer (AMPR)	Spencer, MSFC Hood, MSFC	Convection, SSM/T-2	High resolution, multifrequency sampling of precipitation
Millimeter Imaging Radiometer (MIR)	Wang, GSFC Racette, GSFC	Convection, SSM/T-2	Cloud structure, water vapor, cirrus ice particle size and distribution
Microwave Temperature Sounder (MTS)	Staelin, MIT Schwartz, MIT	Convection, SSM/T-2	Precipitation, temperature profiling
ER-2 Doppler Radar (EDOP)	Heymsfield, GSFC	Convection	Vertical air motion, precipitation, structure; and mass and heat budgets
Lightning Instrument Package (LIP)	Blakeslee, MSFC	Convection	Electrical fields and air conductivity
Multispectral Atmospheric Mapping Sensor (MAMS)	Jedlovec, MSFC Guillory, MSFC	Convection, AIRS	Cloud top temperatures, water vapor and intercomparisons

B. CAMEX Mission Objectives

The science objectives during CAMEX were as follows:

(1) Measurements of temperature, water vapor, clouds, precipitation, and electrical fields associated with tropical convection

(2) SSM/T-2 instrument validation and calibration

(3) Radiometric signatures of clear air and precipitation at high incidence angles

(4) High resolution vertical and horizontal measurement of the temperature and moisture field as well as top of the atmosphere radiances over WFF

(5) Indepth study of the low-level vertical temperature and moisture gradients and their relation to anomalous radar propagation.

The second and third objectives derived from a United States Air Force (USAF) request to underfly the DMSP F-11 satellite with the Millimeter Imaging Radiometer (MIR) and the Advanced Microwave Precipitation Radiometer (AMPR). The MIR and AMPR radiometric channels closely mirror those on the USAF's Special Sensor Microwave Temperature (SSM/T-2) and Special Sensor Microwave Imager (SSM/I). Underflights of the F-11 satellite were originally planned for the Tropical Oceans, Global Atmosphere-Coupled Ocean Atmosphere Response Experiment (TOGA COARE) but were rescheduled to coincide with CAMEX.

The fourth objective was designed to satisfy a requirement for very high quality "near top of the atmosphere" radiance spectra with associated temperature and water vapor profile ground truth. The data are necessary to validate and improve radiative transfer calculations over the spectral region to be observed by the EOS AIRS instrument.

The first three objectives closely mirror those of the NASA TOGA COARE program, and as such, CAMEX is an extension of NASA's TOGA COARE science efforts.

C. Facilities and Personnel

Program oversight and funding for CAMEX was provided by Ramesh Kakar, Code YS, NASA Headquarters. James Arnold, Marshall Space Flight Center (ES43), served as the field operations director and was responsible for coordination of support requirements with the WFF. The CAMEX project scientist was James Wang, Code 975, Goddard Space Flight Center, assisted by Vanessa Griffin and Robbie Hood, Marshall Space Flight Center (ES43). The ER-2 mission director was Jim Barrieaux, AMES Research Center. Judy Killmon and Joan Selby, Wallops Flight Facility, were the CAMEX focal points for support arrangements.

CAMEX was held at the NASA Wallops Island Flight Facility (WFF). WFF facilities support included hangar space for operations of the ER-2 and office space for the air crew, instrument teams, and project managers. WFF ground support included rawinsonde balloon launches at the direction of Francis Schmidlin, and SPANDAR radar support under the direction of Norris Beasley. Additional help was provided by the WFF weather, communications, radar tracking, and control facilities.

The Univ. of Wisconsin operated a CLASS mobile rawinsonde at the Chesser Farm about 3 miles west of Wallops Island. The Univ. of Wisconsin operated the GB-HIS a surface based high resolution interferometer from Wallops Island, collocated with the Raman lidar, operated by GSFC. Johns Hopkins Marine Research Center provided a small ocean-going research vessel, the "Chessie," to assist in measuring the lower atmospheric temperature and moisture profiles and the influence of temperature and moisture inversions on anomalous radar propagation. The "Chessie" was operated about 5 nm off shore east of Wallops Island, along a direct line extending from the CLASS site through the lidar site.

SECTION II. INSTRUMENT OVERVIEWS

There were seven instruments (listed in Table 2) onboard the ER-2 during CAMEX and two instruments provided ground truth. This section provides a short synopsis of each instrument's objectives and preliminary results along with samples of the data archive from each instrument. The sample data are provided for general interest only, and in most cases have not been quality controlled and should therefore not be used for scientific purposes. The actual data will be available from the instrument PI's and can be obtained by contacting them directly.

A. AMPR

1. **Instrument Description.** The Advanced Precipitation Microwave Radiometer (AMPR) is a four-channel scanning total power radiometer which measures the passive microwave signatures of the Earth's surface at 10.7, 19.35, 37.1, and 85.5 GHz. The AMPR is designed to fly aboard NASA's ER-2 high altitude aircraft platform.

2. **CAMEX Objectives**. The AMPR collected data during the CAMEX to accomplish several scientific goals.

(A) The first was to provide data to scientists of the Phillips Laboratory for calibration and validation of the DMSP SSM/I and SSM/T-2 sensors. An underflight of the SSM/T-2 F-11 satellite by the AMPR for comparison of the 91 GHz SSM/T-2 channel and the 85.5 GHz AMPR channel was planned. The sampling of a convective rain system by the AMPR at high incidence angle was also desired to simulate the characteristics the SSM/I. Since the AMPR scans +/- 45^{o} through nadir, this high incidence angle was to be accomplished by banking the ER-2 at a 20^{o} angle during data collection sorties.

(B) A second scientific objective of the AMPR data collection during CAMEX was to sample oceanic precipitation. New external calibration loads had been installed in the AMPR system in September 1992. Previously, oceanic precipitation data off the west and east coasts of Florida had been collected using older calibration loads. Tropical precipitation in the Pacific Ocean using the new calibration loads had also been sampled by the AMPR during the TOGA COARE. Oceanic rain data collected over U.S. coastal waters were needed to correlate the findings of the TOGA COARE Pacific Ocean data with the previous data collected using the old calibration loads.

3. **Preliminary Data**. The AMPR performed exceptionally well during CAMEX. Data were collected of tropical precipitation systems of varying size. Figure 1, Figure 2, and Figure 3 are examples of data collected during CAMEX during different atmospheric conditions. Instrument performance was nominal, with the exception of interference in the 10 GHz data due to the EDOP instrument. Data containing the interference were collected during two CAMEX flights to assist in post-mission analysis of the interference problem.

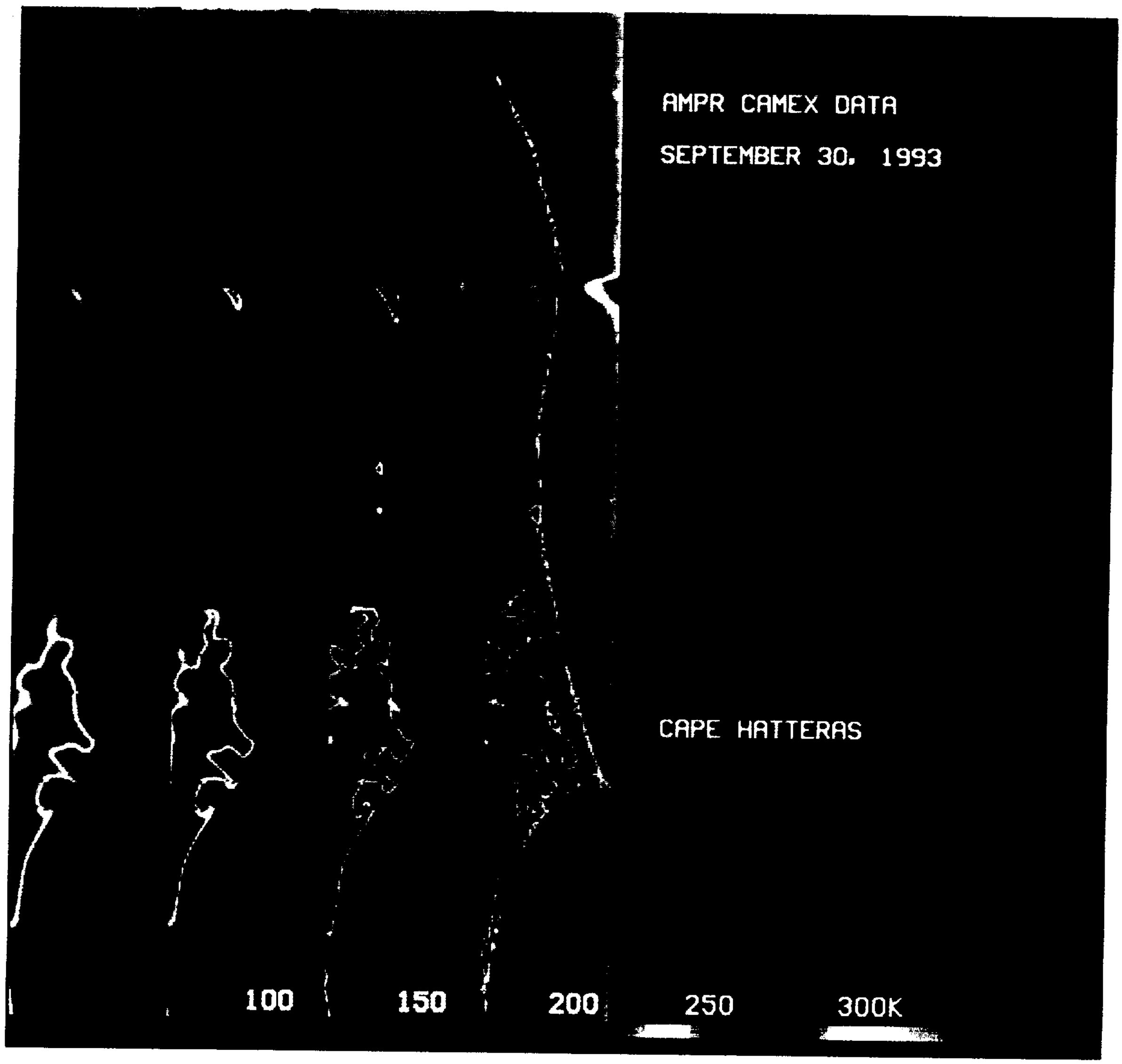

Figure 1. AMPR imagery of Cape Hatteras, September 30, 1993.

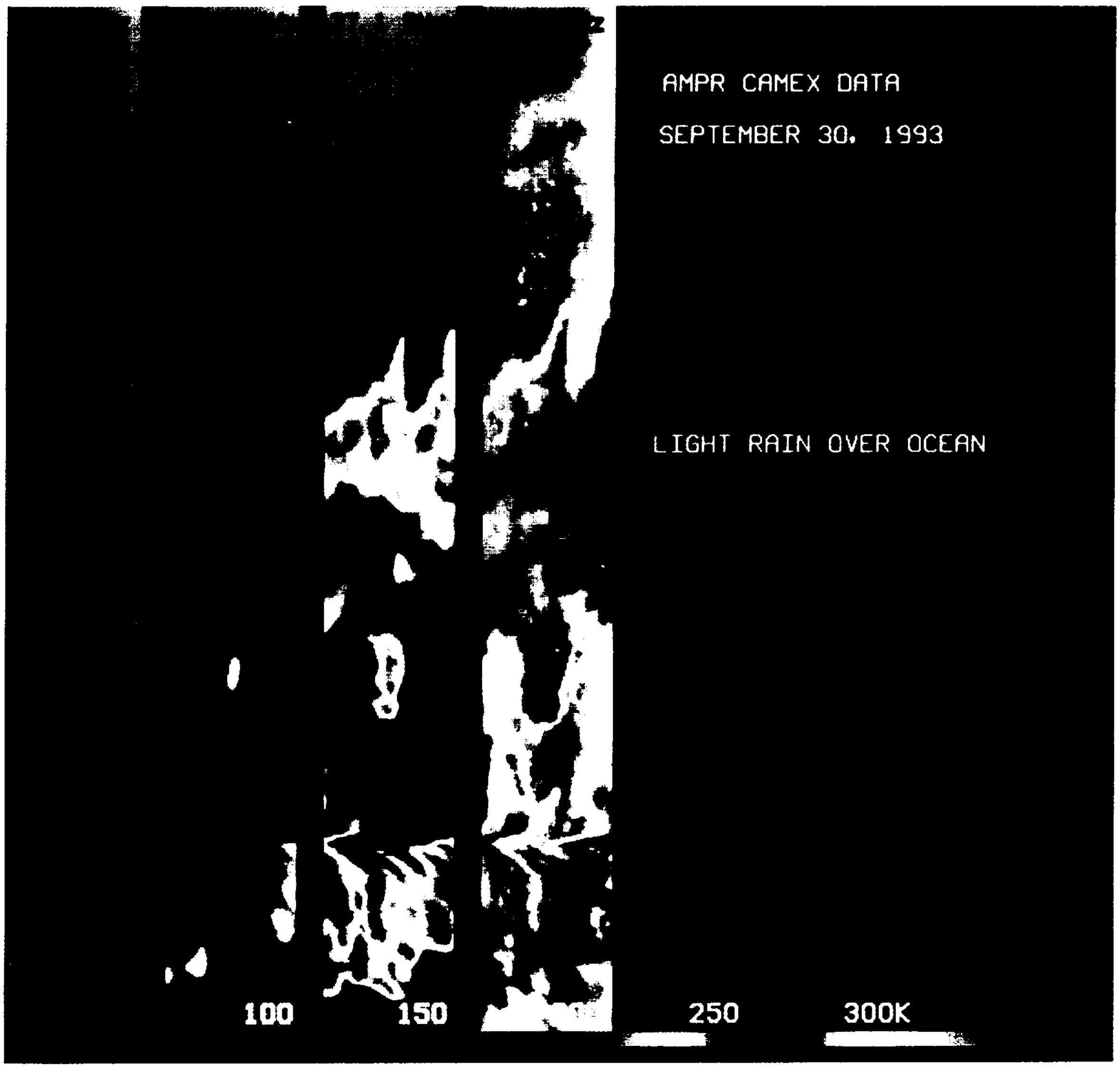

Figure 2. AMPR imagery of light rain over ocean, September 30, 1993.

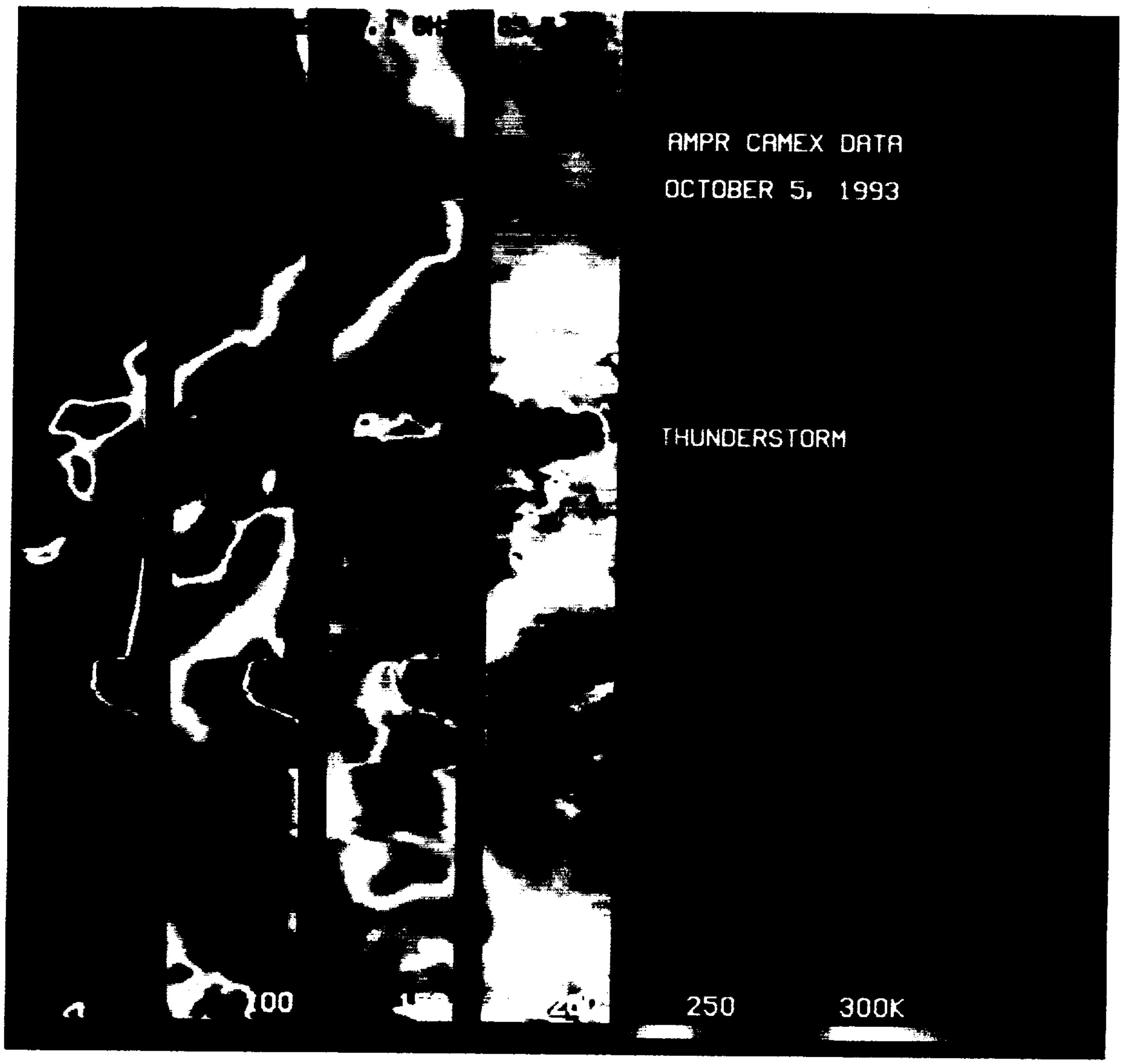

Figure 3. AMPR imagery of thunderstorm over ocean, October 5, 1993.

B. ER-2 Doppler Radar (EDOP)

1. **Instrument Description**. EDOP is an X-band fully-coherent pulsed-Doppler radar in the nose of the ER-2. It has two antennas: one nadir-pointing with pitch stabilization, and the other forward pointing. EDOP during CAMEX was configured to map time-height sections of reflectivity from the nadir and forward beams. The forward beam in addition measures linear depolarization ratio (LDR) which provides useful information on the cloud microphysical properties. The characteristics of EDOP are shown in Table 3.

Table 3. EDOP characteristics

Frequency	9.72 GHz
Wavelength	3.07 cm
Peak transmit power	20 kW
Pulse repetition frequency	2.2 or 4.4 kHz
Pulse widths/range resolution	0.25, 1.0 micro-sec/37.5, 150 m
Antenna beamwidths	2.9°

The data system for EDOP consists of data acquisition from three logarithmic (forward and nadir co-polarization reflectivity and forward cross-polarization reflectivity) and four linear (forward and nadir Doppler) channels. The CAMEX configuration collected raw data from the three reflectivity channels through most of the experiment, with the exception of the ferry flight (9/12/93) during which reflectivity processing was tested.

2. **EDOP CAMEX Objectives**. CAMEX provided the first EDOP measurements of precipitation. Thus, the main objective was to perform extended engineering flights to characterize the system performance. The end-to-end system performance could best be evaluated during data flights, where actual precipitation was probed. Issues such as the stability of the calibration with thermal changes of instrument, the performance of the antennas and data system, etc., were evaluated. Also, if possible, it was desired to perform a calibration flight over the ocean, using special calibration software which would preclude normal data collection. If the flights provided scientific quality data, the second goal was to study structure of precipitation systems using joint radar/microwave data with EDOP, MIR, and AMPR. These data would also be used to examine the TRMM precipitation retrieval algorithms.

3. **Preliminary Results.** Initial EDOP flights revealed that the radar interfered with the AMPR 10.6 GHz channel. To confirm the extent of interference, EDOP was

turned on and off during two of the flights. It was decided that EDOP would not fly on the more critical flights dealing with the SSM/T underpasses. On other flights, EDOP transmission was limited to the first few hours of the flight. All flights except the 10/3/93 flight produced data, although there was virtually no precipitation in the data. A problem with a part overheating in the radar caused data quality to be more questionable before 9/25/93 (i.e., 9/1/93 and 9/12/93).

4. **Data Collected During CAMEX**. The data flight on 10/5/93 resulted in excellent data from stratiform precipitation and weak showers near the Florida keys. The radar operated for approximately 2 hours and 40 minutes during this flight (see example in Figure 4), after which it was shut down to avoid AMPR interference. Figure 4 shows uncalibrated reflectivity data collected during this flight over stratiform rain with embedded cells. The surface return is evident at approximately 19 km and a bright band at about 5 km above the surface. A "mirror image" return occurs below the surface. The special calibration flight was not performed during the experiment and thus the absolute calibration of the data will be less accurate than if the ocean surface backscatter was used. The post-experiment EDOP calibration has provided radar reflectivities to better than a few dBZ; additional analysis of the ocean return will provide calibration accuracy to within +/- 1 dBZ.

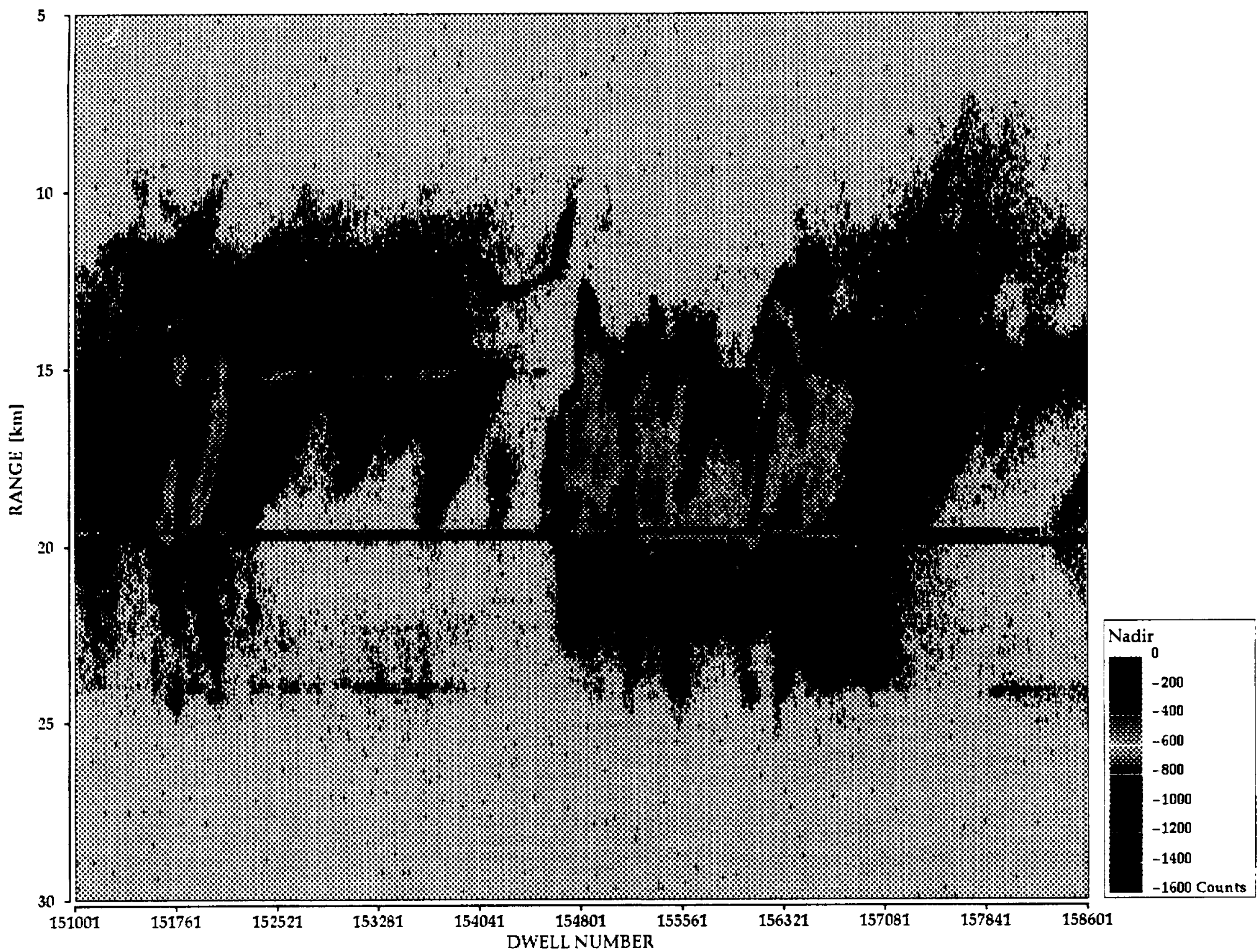

Figure 4. Example of EDOP uncalibrated reflectivity data collected from stratiform rain with embedded convective cells on October 5, 1993.

C. ER-2 and Ground-Based HIS

1. **Instrument Description**. The ER-2 HIS is a Michelson interferometer which measures the upwelling nadir radiance within 3.5 and 17 micron region of the spectrum with a spectral resolution of 3000. The upwelling radiance spectrum, defined by 4000 independent spectral elements, is observed every 6 sec, with a spatial resolution of 2 km (along the flight track of the ER-2). The instrument possesses an inflight calibration facility to provide absolute accuracies of better than 0.5 K and the instrument noise is about 0.25 K when viewing standard surface temperature scenes. Reduced noise level spectra are achieved by co-adding a time sequence of the 6-sec interval measurements.

The GB-HIS is a Michelson interferometer that measures downwelling zenith radiance within the 3-20 micron region of the spectrum with a spectral resolution of 1000 to 6000, depending on wavelength. The downwelling radiance spectrum is observed every few seconds but the data are co-added internally over several minutes to provide reduced noise level spectra. An automatic calibration facility enables calibrated radiance spectra to be produced in real time with a 10-min frequency and with an absolute accuracy better than 0.5 K. The noise level of the 10-min interval spectra is about 0.2 K for standard surface temperature source radiance conditions. The instrument and associated real time data processing system are designed to run in a totally unattended mode.

2. **CAMEX Objectives**

(A) To provide space and time coincident measurements of upwelling (at 20 km) and downwelling (with GB-HIS) spectra of infrared radiance with radiosonde and Raman lidar measurements of atmospheric temperature and moisture as needed to validate and improve spectroscopic variables and models used for radiative transfer calculations and remote sensing.

(B) To determine experimentally the temperature and water vapor profiling capability of current satellites, future satellite (as represented by prototype instruments on the NASA ER-2 aircraft), and ground-based active (Raman lidar) and passive (GB-HIS) systems.

(C) To demonstrate the ocean surface temperature and heat flux measurement advantages of high-spectral-resolution infrared sensors over the broadband sensors flown on contemporary satellites.

3. Preliminary Results

(A) Processing and Performance. All the ER-2 HIS and GB-HIS data have been processed into calibrated radiance spectra for the entire CAMEX period. The results confirm the in-field diagnosis of near perfect operation of both systems on all aircraft flight days, including the aborted missions. Figure 5 shows four atmospheric profiles calculated from GB-HIS data acquired during the CAMEX experiment. Figure 6 shows four CLASS soundings taken at the times of the GB-HIS data.

(B) Scientific Analysis. Intensive scientific investigations with the CAMEX interferometer, rawinsonde, and Raman lidar and NOAA satellite AVHRR and TOVS data are underway. Comparisons of observed aircraft and ground-based spectra with calculations from rawinsonde measurements have already been performed to reveal deficiencies of spectroscopic data files (e.g., HITRAN '91) and computational procedures. Preliminary retrievals from both aircraft and ground-based HIS data have been performed and compared to simultaneous rawinsonde data to reveal strengths and weaknesses in each observing approach and the methods used to invert the rawinsonde data into atmospheric profiles. A presentation of the first results of the CAMEX HIS observations was presented at the AIRS science team meeting held in Madison, WI on October 13, 1993.

(C) HIS Data Dissemination. Both ER-2 HIS and GB-HIS radiometric data are available for dissemination to the CAMEX HIS sponsors. Plans are to prepare a quality controlled aircraft and ground-based HIS and associated rawinsonde dataset for dissemination to the scientific community at large.

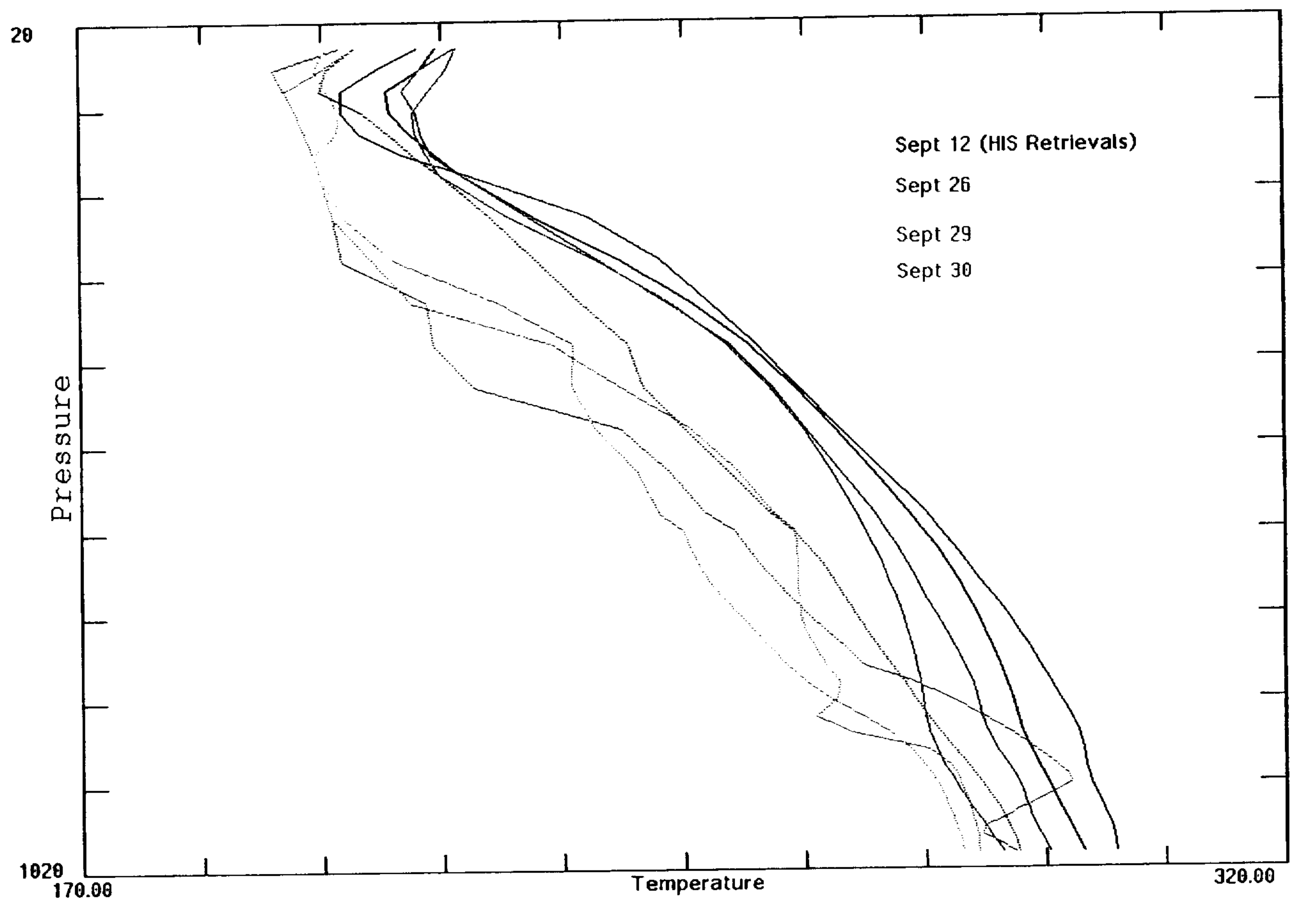

Figure 5. Ground-based HIS retrievals for Wallops Island on four CAMEX days.

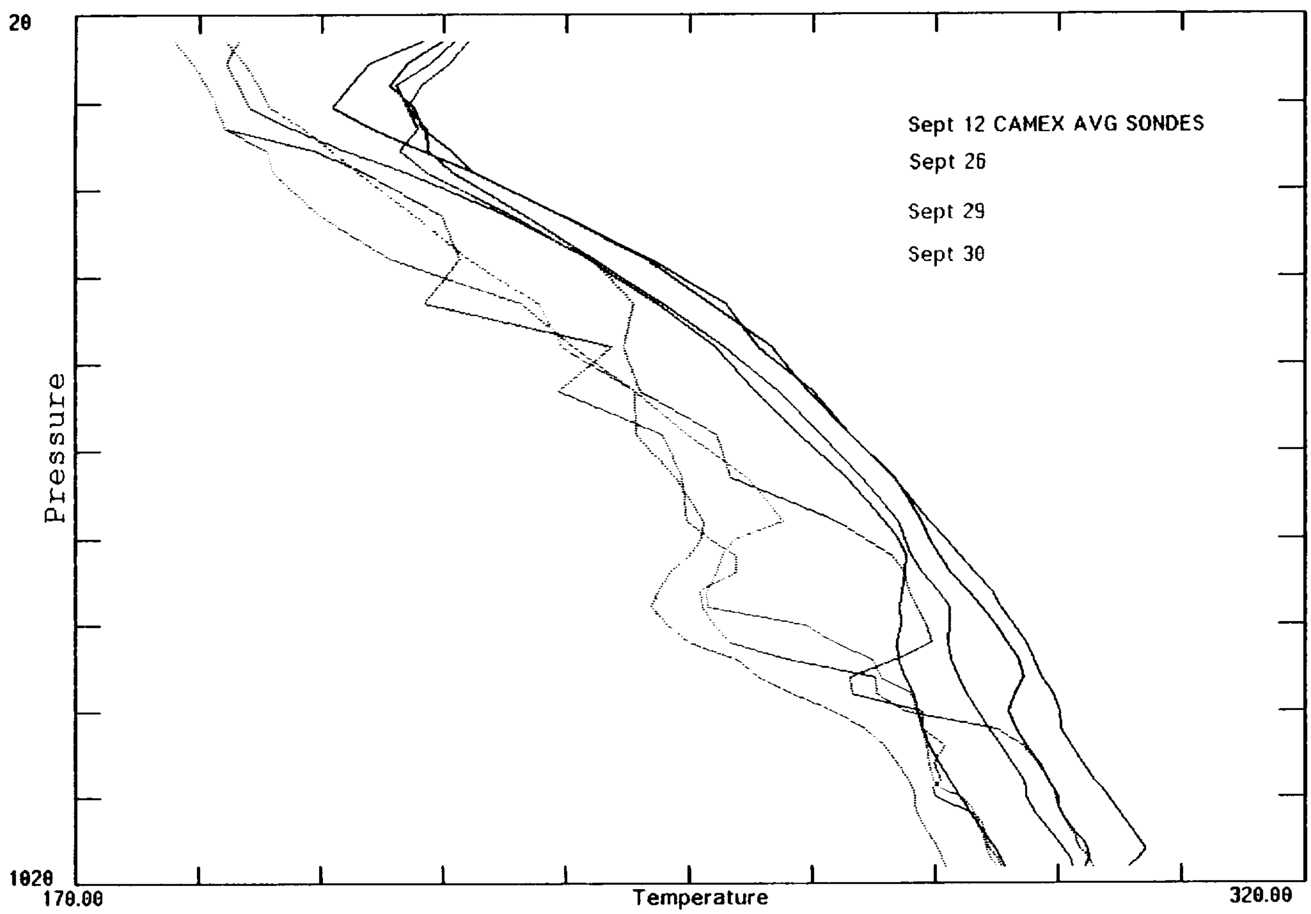

Figure 6. CLASS retrievals of atmospheric temperature and moisture on four days during CAMEX.

D. Lightning Instrument Package (LIP)

1. Instrument Description

(A) Instrument Components. The Lightning Instrument Package (LIP) consists of two electric field mills, conductivity probe, and data system. One of the field mills is installed on the upper Q-bay hatch cover and the second one is mounted on the lower E-bay hatch. The conductivity probe is integrated on the right-hand superpod nose cone. The LIP data system is mounted in a 19-inch vertical rack which is located in the aft portion of the ER-2 Q-bay. The ER-2 electric field mills and the conductivity probe are compact sensors, each weighing less than 5 lbs.

(B) Measurement Parameters and Characteristics. The electric field mills measured components of the electric field over a dynamic range exceeding 3 orders of magnitude (i.e., there are 3 gain channels, x1, x46 and x2116). Hence fair weather electric fields as well as large thunderstorm fields (e.g., 10-20 kV/m) could be measured. The field mills also provided a measurement of the electric charge on the aircraft. Abrupt electric field changes will be used to identify lightning discharges. The conductivity probe provided a measure of the air conductivity at the aircraft altitude. Conductivity contributions due to positive and negative ions were measured simultaneously. All measurements were recorded with a PC-based data system and archived on an Exabyte 8 mm tape drive. Data were continuously recorded throughout the duration of each mission.

2. CAMEX Objectives

(A) To develop and improve algorithms employing multi-sensor data for precipitation estimation. It has been widely recognized that storm electrification is connected closely to convective precipitation development. Therefore, we anticipated that lightning data could convey a great deal of information about the precipitation structure in a thunderstorm. This objective supported the scientific goals of TOGA COARE and the TRMM which will include a lightning sensor. Table 4 gives the measurement parameters sought during CAMEX along with their scientific uses.

(B) To investigate the structure, kinematics, and evolution of thunderstorms, and relate these to lightning. Lightning rates, distribution, and characteristics are all factors that may prove useful in devising quantitative algorithms, and these factors could be studied appropriately with the ER-2.

(C) To study the electric fields, currents, and charges in the vicinity of convective storms and determine the storm's contribution to the global electric circuit. It is widely believed that thunderstorms are the generators responsible for maintaining the global electric circuit. This hypothesis has been supported by measurements of the upward directed current above thunderstorms in the United States.

Table 4. Data products produced by ER-2 LIP system during CAMEX

Product:	Electric field components and aircraft self-charge
Period:	Continuous record, entire flight
Resolution:	10 Hz
Comments:	Total lightning (cloud-to-ground, intracloud) determined from electric field changes in the data. Data also provided information on the electrical structure in vicinity of thunderstorms. Maxwell, displacement, and conduction current densities derivable using the electric field and air conductivity measurements. The ER-2 dataset was complemented by the U.S. ground-based lightning location network.
Product:	Air conductivity
Period:	Continuous record, entire flight
Resolution:	10 Hz
Comments:	Simultaneous measurements provided of both polar components of the air conductivity (i.e., contributions from positive and negative ions). Storm electric conduction current densities derivable when used with electric field data.

3. **Preliminary Results**. LIP participated in 8 of the 9 ER-2 flights (not active on 9/30/93). Two of the fights (9/26/93 and 10/05/93) contained enough convective activity to produce lightning. Figure 7 shows an example of the approximate vertical field and aircraft self-charge above the storm on 9/26/93 from 1900 to 2130 GMT. The storm was located to the southeast of Cape Hatteras. Nine lightning flashes were detected during this time frame. Some of them are indicated by the letter "L." Air conductivity data were also collected during this time.

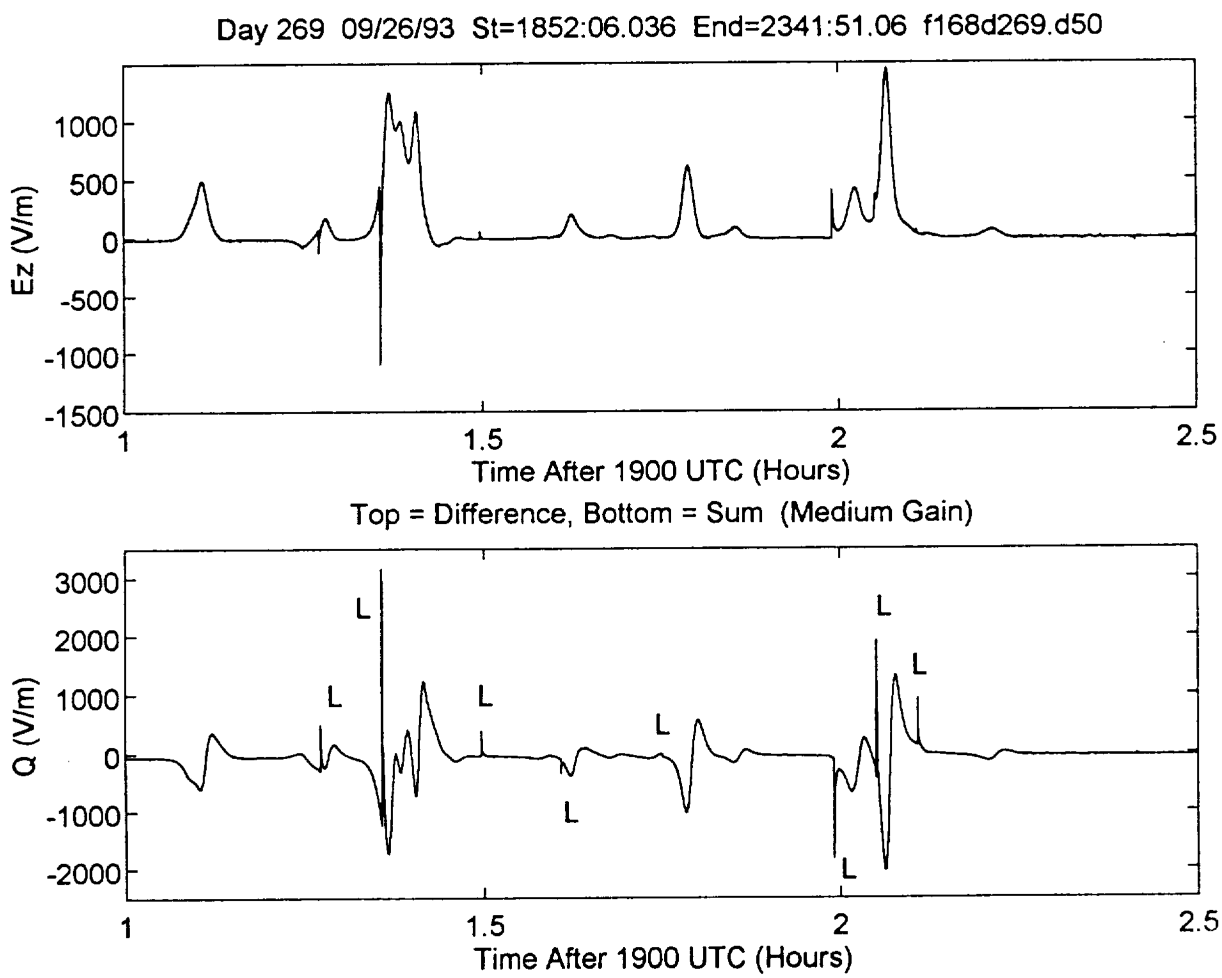

Figure 7. Vertical electric field and aircraft self-charge measurements from the LIP instrument flying above a thunderstorm on 9/26/93.

E. Multispectral Atmospheric Mapping Sensor (MAMS)

1. **Instrument Description**. In 1985, the MAMS was developed and flown to verify small-scale water vapor features observed in Visible Infrared Spin Scan Radiometer (VISSR) Atmospheric Sounder (VAS) imagery aboard the Geosynchronous Operational Environmental Satellites (GOES). MAMS is a multispectral scanner which measures reflected radiation from the Earth's surface and clouds in eight visible/near-infrared bands, and thermal emission from the surface, clouds, and atmospheric constituents (primarily water vapor) in four infrared bands. This aircraft sensor provided a unique opportunity to independently verify single-pixel variations observed in the VAS channels (Menzel et al., 1986). This verification continued for several years providing useful correlative measurements (Jedlovec et al., 1986a; Jedlovec, 1984).

2. **CAMEX Objectives**. The primary science objective with MAMS for CAMEX was the analysis of water vapor. In addition, MAMS flew in a support role during convection missions. To achieve these objectives, the ER-2 made several flights over Wallops Island, VA and the adjacent land and ocean.

3. **Preliminary Results**. Figure 8 shows MAMS imagery of Wallops Island during CAMEX. Data collected from MAMS will be used to identify: (A) mesoscale atmospheric moisture variations and (B) provide visible and infrared measurements of thunderstorms in support of the microwave and lightning investigations. The MAMS data will be used to characterize the structure of these features and to derive integrated water content (precipitable water) associated with these features. Quantitative analysis of the moisture variability associated with these features will be performed as well as intercomparisons of water vapor data sensed from the Raman lidar and rawinsondes. The MAMS 6.5 μm channel has been used to map variations in upper tropospheric water vapor associated with a variety of atmospheric disturbances (Menzel et al., 1986; Jedlovec, 1984; Jedlovec et al., 1986b). The split-window channels at 11 and 12 μm allow surface temperature estimations and the determination of total-integrated water content in a column of the atmosphere as discussed by Jedlovec (1990) and Guillory et al. (1993).

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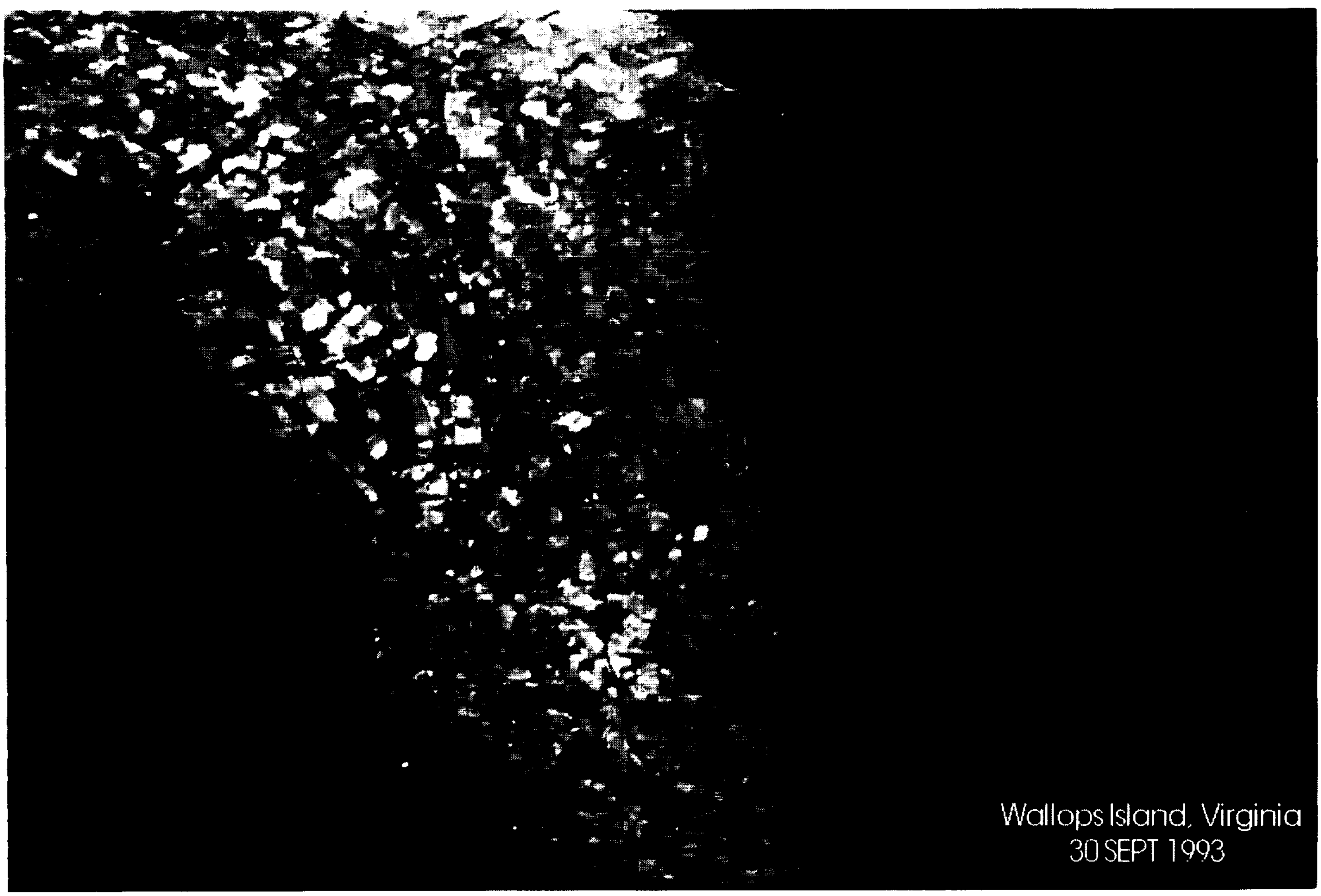

Wallops Island, Virginia
30 SEPT 1993

F. Millimeter Imaging Radiometer (MIR)

1. **Instrument Description**. MIR is a six-channel, mechanically scanned, total-power, imaging microwave radiometer that measures radiation at frequencies of 89, 150, 183.3±1, 183.3±3, 183.3±7, and 220 GHz. It has an angular resolution of about 3.5° at all frequencies. It is a cross-track scanner with an angular swath of about 100° centered at nadir. For every scan it also views heated (330 K) and cooled (250 K) external calibration targets resulting in a total frame time of about 3 sec. The radiometric signals and the measured physical temperatures from these calibration targets form the basis for the derivation of the scene brightness temperatures. The calibration accuracy is on the order of 1 K in the 250-300 K brightness temperature range. Based on the calibration data from bench testing in the laboratory environment, the measurement accuracy is estimated to be better than ±2 K at brightness temperature below 100 K. The temperature sensitivity (ΔT) is ≤1 K for all channels.

2. **CAMEX Objectives**. The objectives of the MIR CAMEX mission were: (A) measurements of water vapor profiles, (B) studies of 90-220 GHz microwave signatures associated with precipitation, (C) validation of the SSM/T-2 sensor aboard the DMSP's F-12 satellite, and (D) studies of microwave signatures at high incidence angles (e.g., ~60° to 70°). Some of the analysis work related to these objectives will be made with data from MIR as well as other sensors (e.g., AMPR, HIS, Raman lidar, etc.) aboard the same ER-2 aircraft or on the ground. The DMSP F-12 satellite data (SSM/T-2 and SSM/I) may also be used in the analysis.

3. **Preliminary Results**. MIR performed well during CAMEX, with a single exception being loss of about 1.5 hours of data toward the end of the flight on October 3, 1993 (CAMEX Flight 7). The electrical power to the system appeared to be turned off for no explainable reason. Minor interference was observed in the 220 GHz channel data in most of the flights when the ER-2 aircraft was in the neighborhood of the Wallops Flight Facility. This can be easily screened and will not present any problem in the data analysis. Figure 9 shows multifrequency MIR data of a small oceanic thunderstorm, acquired during CAMEX.

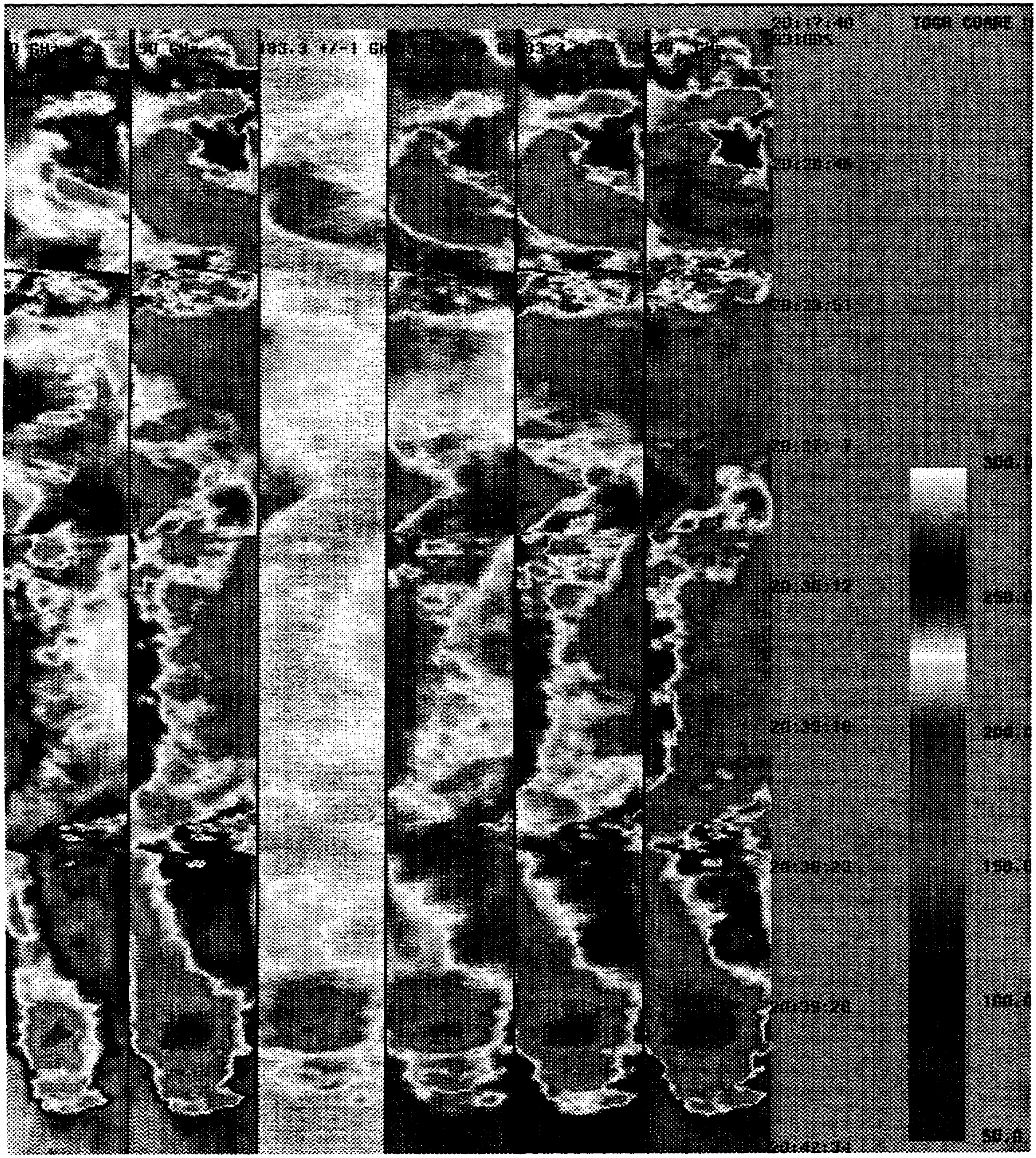


Figure 9. Sample of MIR multispectral imagery taken during CAMEX.

G. Millimeter-Wave Temperature Sounder (MTS)

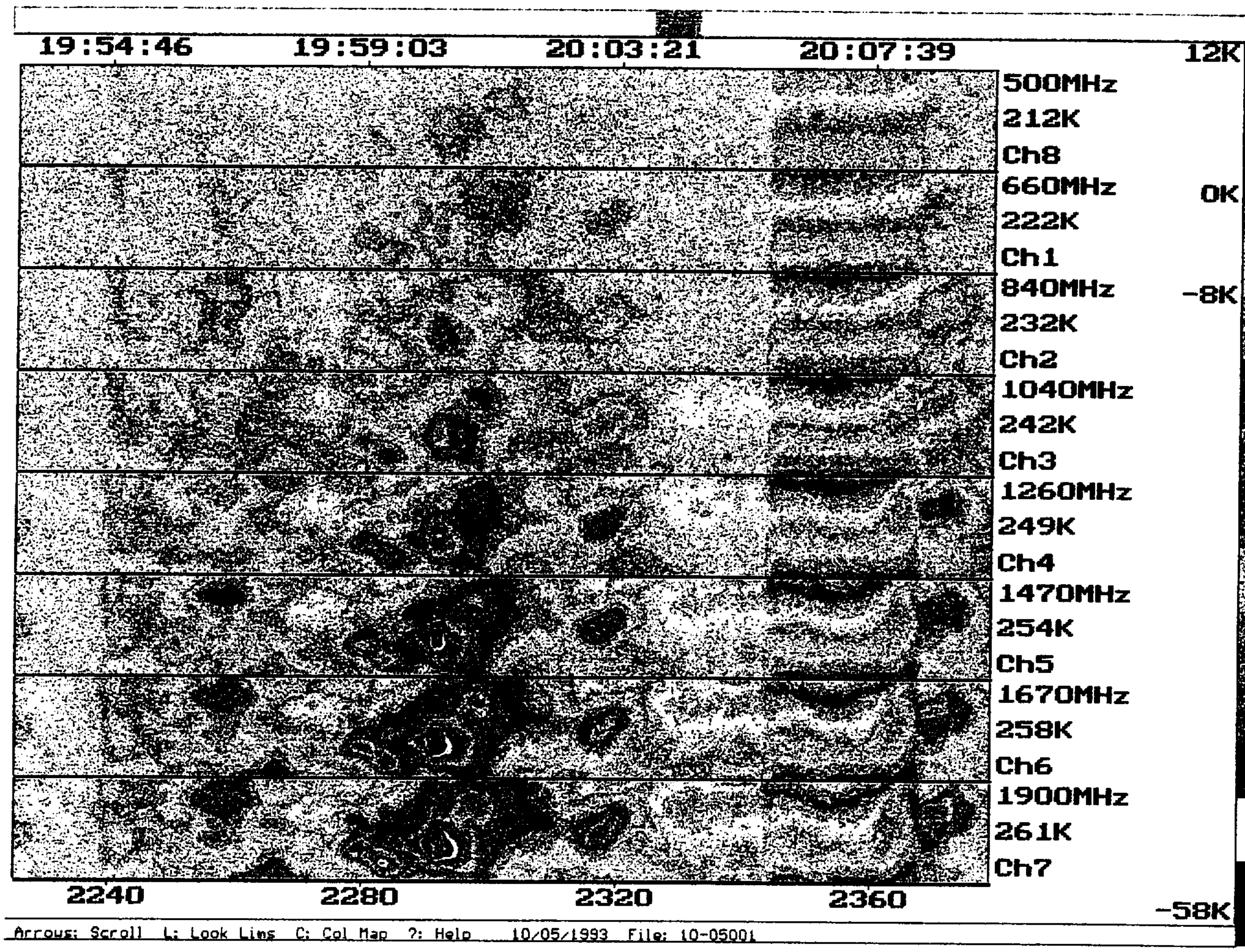
1. **Instrument Description**. The Massachusetts Institute of Technology's (MIT) Millimeter-Wave Temperature Sounder (MTS) is a dual-band microwave radiometer system for the measurement of atmospheric temperature and other phenomena affecting transmission in the microwave absorption bands of molecular oxygen. It is capable of either downward or upward viewing operation on the NASA ER-2 high-altitude aircraft, and also ground-based operation. The instrument has a scanhead installed in the aft cone of the ER-2 wing superpod, which houses the RF components and a video camera. IF amplifiers, synchronous detectors, integrators, power supplies, temperature controllers, video recorder, and microcomputer are housed in the midsection of the superpod.

One radiometer is an eight-channel scanning spectrometer with its local oscillator centered on the 118.75 GHz oxygen line. It is a double-sideband superheterodyne system. The eight channels are derived from filters in the IF section, each approximately 200 MHz wide, which together cover the IF between 350 MHz and 2000 MHz. Thus each channel has two symmetrically placed pass bands, one on each side of the line. The resulting clear air temperature weighting functions for nadir viewing from 20 km peak successively from 13 km to the surface, as one chooses frequencies farther from the line center. This spectrometer has a stationary scalar feedhorn and subreflector with 7.5° beamwidth which view a step scanning mirror. The mirror directs energy from 14 positions, extending over a 95° swath below the aircraft, and also from two calibration targets, into the spectrometer. The integration time per spot is 224 ms, yielding approximately 0.5 K rms resolution per spot, and a scan of 16 spots lasts 5.5 sec.

The second radiometer is a single-channel, nadir (or zenith) viewing, double-sideband superheterodyne system. The antenna has a 10° beamwidth. The local oscillator is tunable, under computer control, from 52 to 54 GHz. A typical mode of operation time-shares three or four local oscillator frequencies, including as many of the AMSU-A frequencies as possible.

2. **CAMEX Objectives**. MTS measured atmospheric radiances in the 52-54 GHz and 119 GHz oxygen bands during CAMEX. The primary objective of these measurements was to support general CAMEX objectives with temperature sounding capabilities and imagery of convective cells at 119 GHz. The newly reconfigured 52-54 GHz radiometer was simultaneously operated in order to validate its calibration, with particular emphasis on the AMSU-A channels within its tuning range. An additional objective, which made use of MTS in an up-looking mode, was to test and validate recently revised oxygen-band transmittance algorithms. These tests will assist algorithm development for the NOAA and EOS satellites carrying AMSU-A.

3. **Preliminary Results**. In general, the instrument performed well throughout the deployment. Assessment of the data continues at MIT. Figure 10 shows MTS data collected over a thunderstorm off the east coast of Florida. The values displayed are brightness temperature deviations from adjacent clear-air values.



MTS imagery of a convective cell, 10-05-93, Florida Atlantic coast.
Values displayed are brightness temperature deviations from adjacent clear-air values.

Figure 10. MTS imagery of a convective cell on September 5, 1993, off Florida's coast.

H. Scanning Raman Lidar

1. **Instrument Description**. The NASA/GSFC Scanning Raman Lidar System was stationed at the building U-70 site 3 km inland of Wallops Island during the CAMEX campaign. The lidar is based on a XeF excimer laser (351 nm) operating at 400 Hz and 18 W. A 0.76-m telescope and large scan mirror provide the ability to acquire data from horizon to horizon in a single scan plane. During CAMEX, the scan plane of the lidar was aligned at 134° (magnetic). Photomultipliers acquired the Raman scattered signals from atmospheric water vapor (402 nm), nitrogen (382 nm), oxygen (372 nm), and the direct backscatter at the laser wavelength. The prime data products were 1-min profiles of water vapor mixing ratio and aerosol backscattering ratio. Other data products, which rely on additional data from radiosondes, included relative humidity, aerosol extinction, and temperature.

The lidar was housed in two environmentally controlled trailers. The larger of the two (12.8 m x 2.4 m x 3.0 m) housed the lidar instrument itself, while the smaller (10.4 m x 2.4 m x 3.0 m) housed personnel, and computer equipment for data acquisition and analysis.

2. **CAMEX Objectives**. The objectives of the Raman lidar program were to acquire water vapor and aerosol profiles of the lower troposphere over both land and ocean. To assist in this effort the Johns Hopkins/Applied Physics Laboratory's (APL) ocean research vessel was stationed off the coast of Wallops Island and operated a tether-sonde system to provide in situ measurements of the water vapor and temperature profiles. A secondary objective of the NASA and Johns Hopkins/APL research was to study enivronmental effects on anomalous propagation of radar waves transmitted by WFF's SPANDAR radar facility.

3. **Preliminary Results**. The lidar was operational for all requested CAMEX intensive observation periods without failure acquiring both vertical data and data at various angles over the land and the ocean. In addition, the lidar operated in conjunction with the APL ship-based tethersonde system. (Note that on one occasion the tethersonde system was operated on land along side the lidar system.) Figure 11 shows the water vapor mixing ratio data, and Figure 12 the aerosol scattering ratio data acquired on the vertical and at +/- 60° (- is toward the ocean, + is toward the land) on the night of September 14, 1993. Approximately 9 hours of data are shown over the given altitude ranges. (The altitude represented for the data acquired at an angle is determined by multiplying the range by the sine of the elevation angle where the angle is measured with respect to the vertical and the range is the distance along the laser propagation path.)

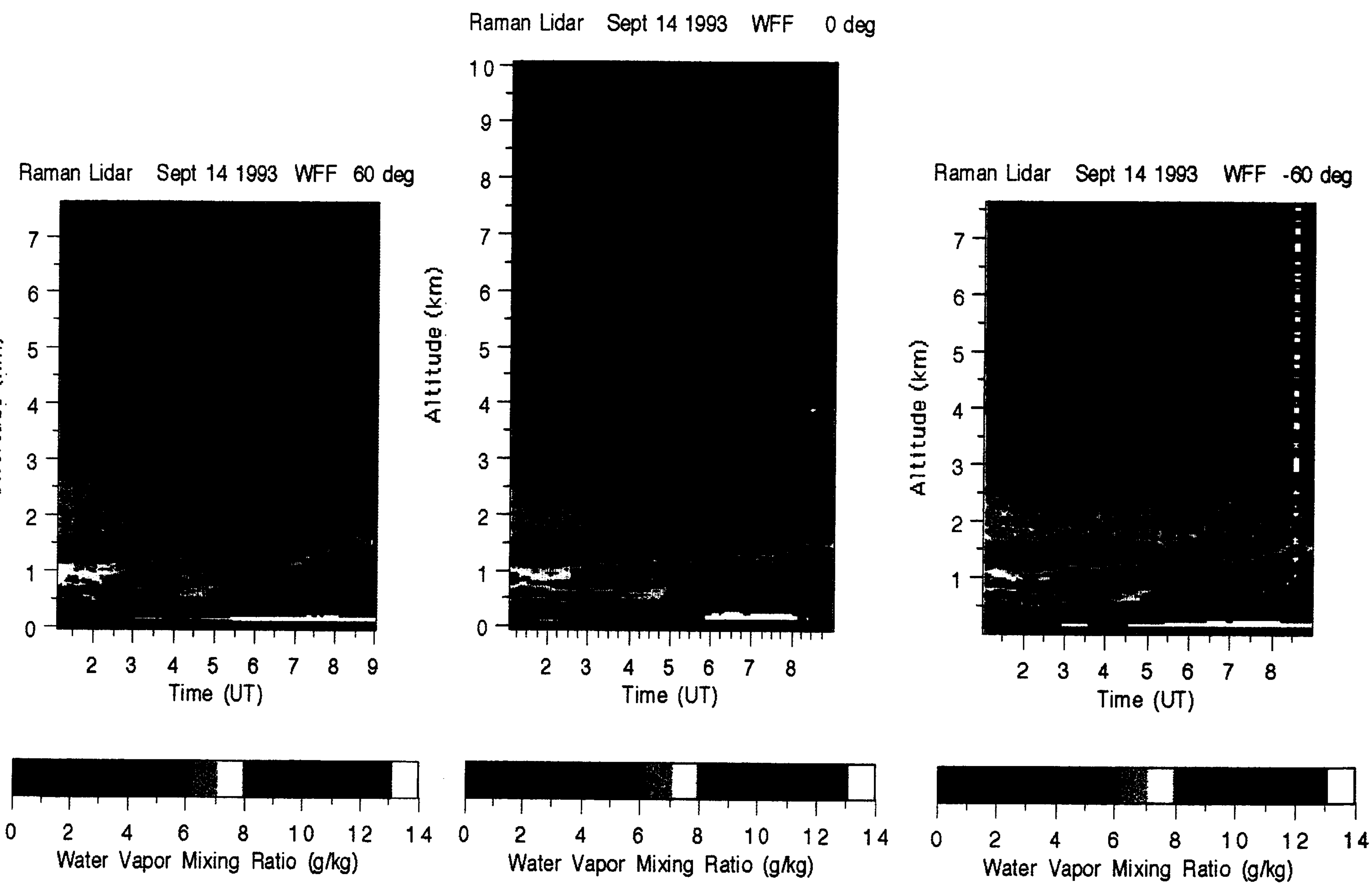


Figure 11. Raman lidar water vapor imagery at three angles (-60°, 0°, and +60°) acquired on September 14, 1993.

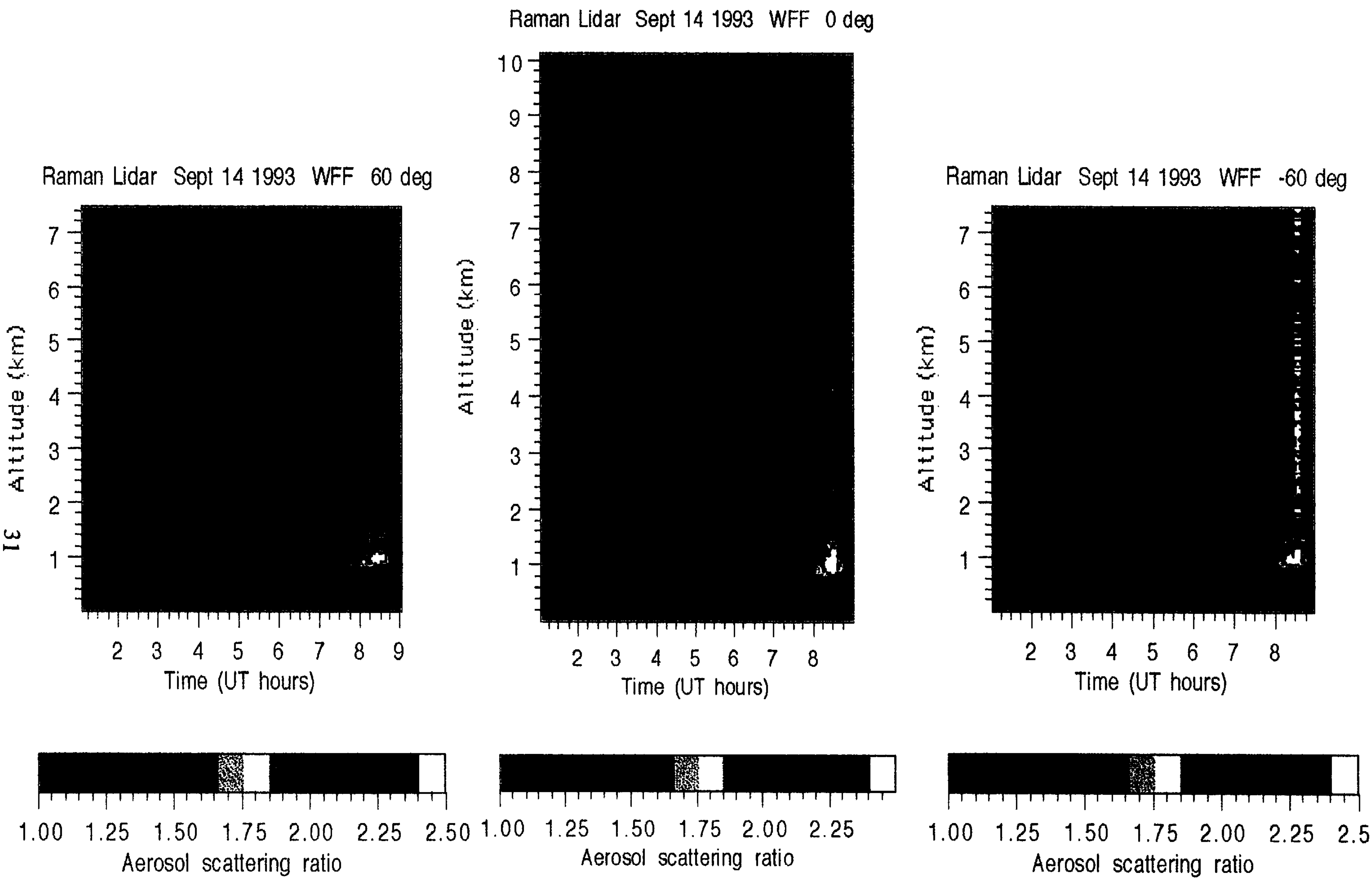


Figure 12. Raman lidar imagery of the aerosol scattering ratio at three angles (-60°, 0°, and +60°) acquired on September 14, 1993.

SECTION III. CAMEX ER-2 MISSION SUMMARIES

The eight ER-2 data collection flights were the primary goal of CAMEX. Table 5 gives an overview of the data flights, indicating which instruments were flown on each mission along with a very brief synopsis of the mission results. Because each ER-2 mission was characterized by different objectives, we have summarized each mission separately in Sections 3-A to 3-H. The ER-2 mission summaries, that begin on the next page, contain the ER-2 pilot's flight logs along with plots of the flight tracks. A surface analysis, along with afternoon Meteosat imagery and the 0000 GMT Wallops rawinsonde, are available for each ER-2 mission day in Section IV.

Table 5. CAMEX ER-2 flight summary

CAMEX FLIGHT	ER-2 SORTIE	DATE (local)	OBJECTIVE	INSTRUMENTS	PRIMARY	MISSION SUMMARY
1	93-165	9/15/93 T 2005Z L 2135Z	SSM/T-2	AMPR, LIP, MAMS, MIR, MTS, HIS	MIR, HIS, AMPR	Flight aborted shortly after takeoff due to pressurization problems with the Q-bay. Flight lasted 90 minutes.
2	93-166	9/19/93 T 2000Z L 2215Z	Convection	AMPR, LIP, MAMS, MIR, MTS, HIS	AMPR	Flight aborted 1 hour after take off due to partial failure in the aircraft hydraulic system. Flight duration was 2.3 hours.
3	93-167	9/25/93 T 1600Z L 1825Z	ER-2 Test Flight	AMPR, LIP, MAMS, MIR, MTS, HIS, EDOP	NONE	A short flight to test the ER-2 hydraulic system. All instruments collected data during the flight including EDOP. There was a failure in the MAMS recorder after 1 hour. Flight duration was 2.3 hours.
4	93-168	9/26/93 T 1900Z L 2340Z	Convection	AMPR, LIP, MAMS, MIR, MTS, HIS	AMPR	ER-2 overpasses (7) of isolated gulf-stream convection off North Carolina. Circle maneuver was performed but no precipitation was observed. HIS pattern flown over Wallops at end of mission. Flight duration was 4.67 hours.
5	93-169	9/28/93 T 0100Z L 0500Z	AIRS	AMPR, LIP, MAMS, MIR, MTS, HIS	HIS, MIR	AIRS mission flown over the Wallops Flight Facility. Most instruments worked well; however, the LIP instrument failed during the flight. Flight duration was 4 hours (Note: Julian day was 10/29/93.)
6	93-178	9/30/93 T 2000Z L 0220Z	SSM/T-2	MIR, HIS, AMPR, MTS, MAMS	MIR, AMPR	ER-2 flown under the DMSP F11 satellite and over coastal rawinsonde stations. HIS pattern flown over WFF at end of the mission. Flight duration was 6 hours.
7	94-001	10/3/93 T 2000Z L 0330Z	Convection	MIR, AMPR, HIS, MTS, LIP, MAMS, EDOP	AMPR	Convection flight in the Florida region. EDOP was onboard the ER-2 but failed on power up and was not recycled. Pilot flew several small thunderstorms. Circle maneuver was performed but no precipitation was observed. Flight duration was 7.5 hours.
8	94-002	10/5/93 T 1600Z L 2340Z	Convection	MIR, AMPR, HIS, MTS, LIP, MAMS, EDOP	AMPR	This was the best convection flight during CAMEX with several passes over deep convection in the South Florida area. EDOP had good coverage of storms, and lightning was observed by LIP. Circle maneuver flown over precipitation. Mission duration was 7.7 hours with 2.7 hours of storm observations.

A. CAMEX Flight 1

1. **Overview**

Mission:	Underflight of DMSP F11 Satellite
ER-2 Sortie:	93-165
Date:	September 15, 1993, CAMEX day 7
Takeoff:	2005 GMT (1605 local)
Duration:	1 hour and 30 minutes
Instruments:	AMPR, HIS, LIP, MAMS, MIR, and MTS
Key Instruments:	MIR, HIS

2. **Mission Objective**. The major objective of this flight was to validate and calibrate the SSM/T-2 sensor with data from the MIR instrument. The flight track selected (Figure 13) passed underneath the F11 orbit track and covered as many rawinsonde stations as possible along the coastline from South Carolina to Massachusetts.

3. **Mission Summary**. The ER-2 launched at 2005 GMT and flew north to 39° 45' N, 74° 40' W. Upon reaching this first weight point the pilot reported a failure in the Q-bay pressurization. The mission was aborted and the ER-2 returned to WFF arriving at 2135 GMT. Very little useful science data were acquired during this mission due to the length of the mission. Figure 14 contains the pilot's log for this mission.

4. **Ancillary data**. The surface HIS collected data the entire day and Raman lidar from 0100 to 0800 GMT. CLASS rawinsondes were launched at 2200 GMT, 0100 GMT, 0400 GMT, and 0700 GMT. Additional rawinsondes were launched by the WFF at 2200 GMT (Vaisala), 0100 GMT (Vaisala and AIR), and 0400 GMT (Vaisala and AIR).

5. **Aircraft Performance**. Because of the potential detrimental effects of low pressure on the instruments, the Mission Scientist decided to abort the mission after several unsuccessful attempts to pressurize the Q-bay.

6. **Instrument Performance**. The AMPR instrument performed well as did the MIR, although noise in the MIR data was attributed to the ascent and descent. The LIP recorded good data and the problems with the conductivity probe during the ferry flight were not present. The MAMS instrument performed well except for Channel 10 (11.1 μm). An analog-to-digital converter card was replaced after the flight. The HIS recorded clean data with an absence of the noise present in the previous flight. The MTS sensor had an in-flight failure 30 minutes after launch, and numerous attempts to recycle the MTS had no effect. No MTS data were collected after 2035 GMT.

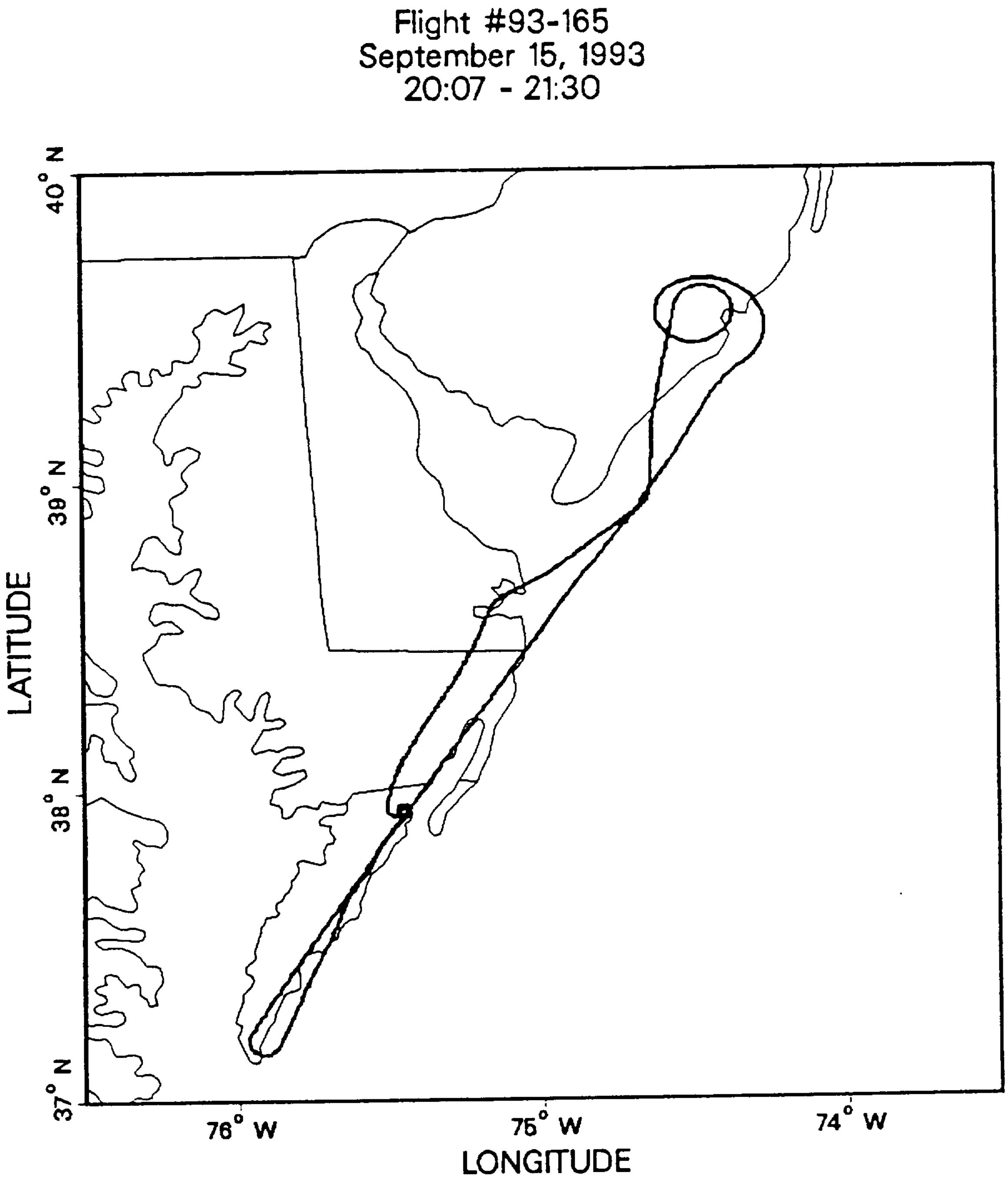


Figure 13. Flight track for CAMEX flight 1.

PILOT JV	SCHED T/O 1600 / 05	ALT CODE	
ACFT 709	ACTUAL T/O 1605	LOG NBR	
SORTIE NBR 97-165	LAND 2135	MISSION EQ	
DATE 15SEPT	FLT TIME 1.5		

WPT	TO	TCN	MAG CRSE / MAG HDG	DIST / TOT DIST	TIME / TOT TIME	ETA / ATA	ETA Z	FLIGHT NO
	END (51)		012	81	: / :15			SMYRNA
	ACY (23)		091	47	:07 / :22	2032		
	BOS 149 062 (74)		069	244	:37 / :59			
	BOS 099 107		063	86	:13 / 1:12			
	BOS 163 133		217	144	:36 / 1:48			2X360 Delay
	JFK 146 189 (106)		220	133	:20 / 2:08			
	ORF 111 064 113		251	224	:34 / 2:42			
	ORF 213 104		214	88	:13 / 2:55			
	CHS 62		246	256	:39 / 3:34			
	GSO 109		009	204	:31 / 4:05			SBY 186 02
E	37-56.0 (WAL 75 28.3		069	257	:38 / 4:43			
	SBY 082 047 (47)		01	58	:09 / 4:52			
A/C	37-50.45 37-35.5 / 75-29.3 75-00		270 / 134	185	:28 / 5:20			Delay 1430 70NM SBY
B/D	37-45 36-09.5 / 75-19 75-10		224 / 044	120	:25 / 5:45			
A/C			224 / 134	120	:27 / 6:12			APS —
	CRF / WAL				:35 / 6:45			
					: / :			
					: / :			

Figure 14. Pilot's flight log for CAMEX flight 1.

B. CAMEX Flight 2

1. **Overview**

Mission:	Convection
ER-2 Sortie:	93-166
Date:	September 19, 1993, CAMEX day 13
Takeoff:	2000 GMT (1600 local)
Duration:	2 hours and 15 minutes
Instruments:	AMPR, HIS, LIP, MAMS, MIR, and MTS
Key Instruments:	AMPR

2. **Mission Objective**. This flight was the first of a series of convection flights planned to study the multifrequency microwave signature of convective rain systems off the East Coast. Observations of Gulf Stream precipitation by the AMPR instrument are crucial for relating measurements taken during the CaPE program to observations of tropical thunderstorms in the Pacific warm pool region acquired during TOGA COARE.

A flight pattern was selected (Figure 15) to position the ER-2 over a line of convective precipitation over the Gulf Stream, off the coast of Virginia. GOES satellite imagery from 1600 GMT depicted a strong line of thunderstorms associated with a cold frontal boundary east of Wallops Island, VA. Two end points were selected to ensure the ER-2 flew over the most significant activity, while allowing for advection of the storms. An alternate flight pattern over ocean buoys and coastal rawinsonde sites was planned in the event the thunderstorms had dissipated or moved out of the operations area before the ER-2 reached the region.

3. **Mission Summary**. After a 2000 GMT launch, the ER-2 flew east to the designated flight operations area. Upon arrival at the first way point (36° 30' N, 71° 30' W) at 2044 GMT, the pilot reported there were no thunderstorms present in the designated flight area. The Mission Scientist requested the pilot fly the alternate pattern. While making a turn to start the alternate flight plan, the pilot detected an aircraft hydraulics failure and aborted the mission. The ER-2 arrived back at WFF at 2215 GMT. Little useful science data were acquired during this mission due to the shortened length of the mission and the lack of convection, although there may be good calibration data over clear ocean from many of the instruments. Figure 16 contains the pilot's log for this flight.

4. **Ancillary data**. The surface HIS started collecting data from 1800 GMT. The Raman lidar collected data from 0100 to 0530 GMT. CLASS rawinsondes were launched at 2300 GMT, 0100 GMT, and 0400 GMT. Additional rawinsondes were launched from the Wallops Flight Facility at 2200 GMT (VIZ, Vaisala, and AIR), 0100 GMT (VIZ and Vaisala), and 0400 GMT (VIZ, Vaisala, and AIR).

5. **Aircraft Performance**. The mission was aborted 60 minutes after takeoff because of a failure in the hydraulics system.

6. **Instrument Performance**. The AMPR instrument performed satisfactorily with minor noise observed in the 10 GHz channel starting at 2132 GMT. The LIP instrument had no major problems although data from the field-mil on the top of the aircraft continued to be slightly noisy. The MAMS collected good data with only minor RF noise in the IR channels, and the HIS and MIR also performed well. The MTS operated nominally in the downward looking position, but had oscillation in the three highest channels during descent.

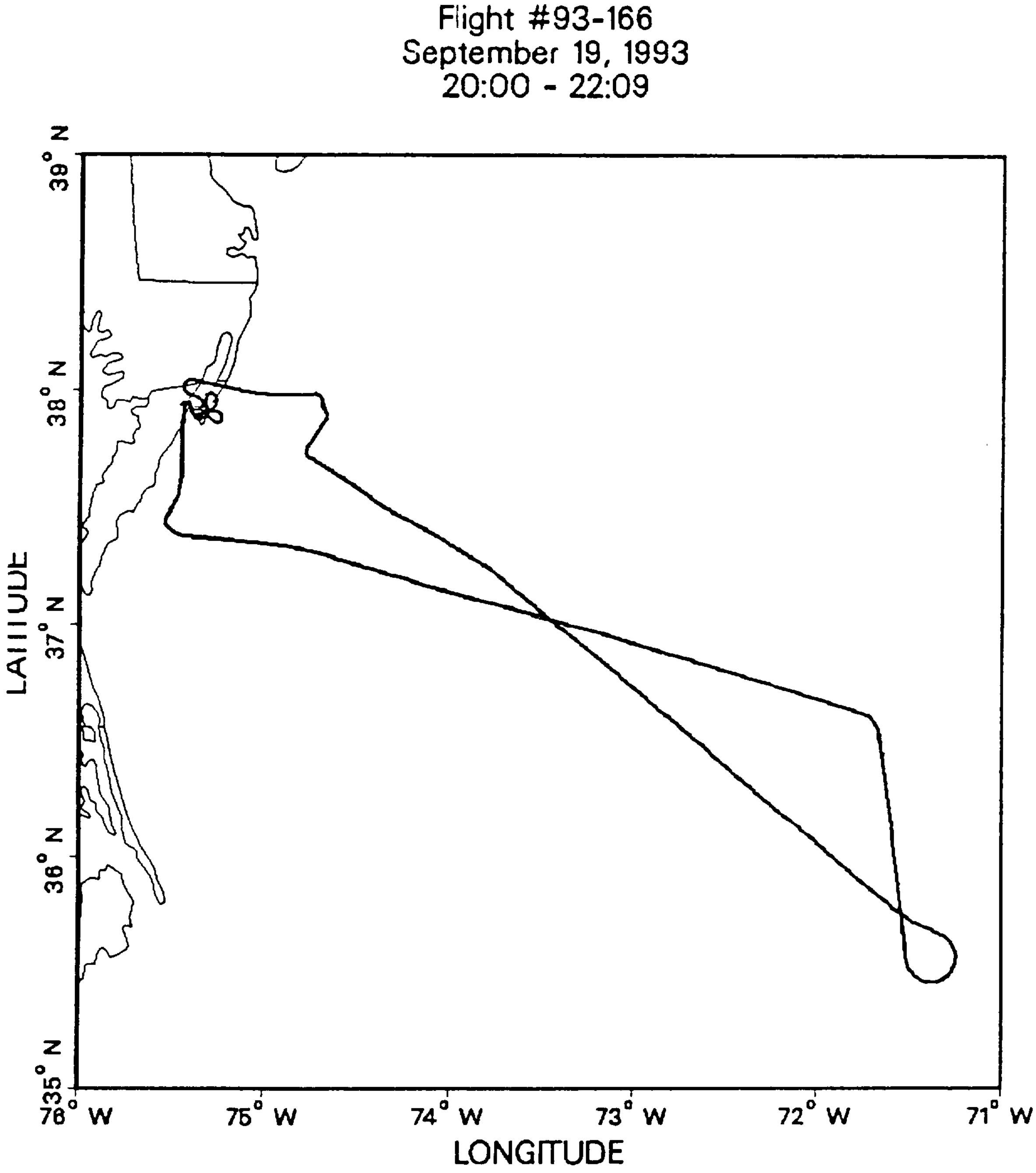
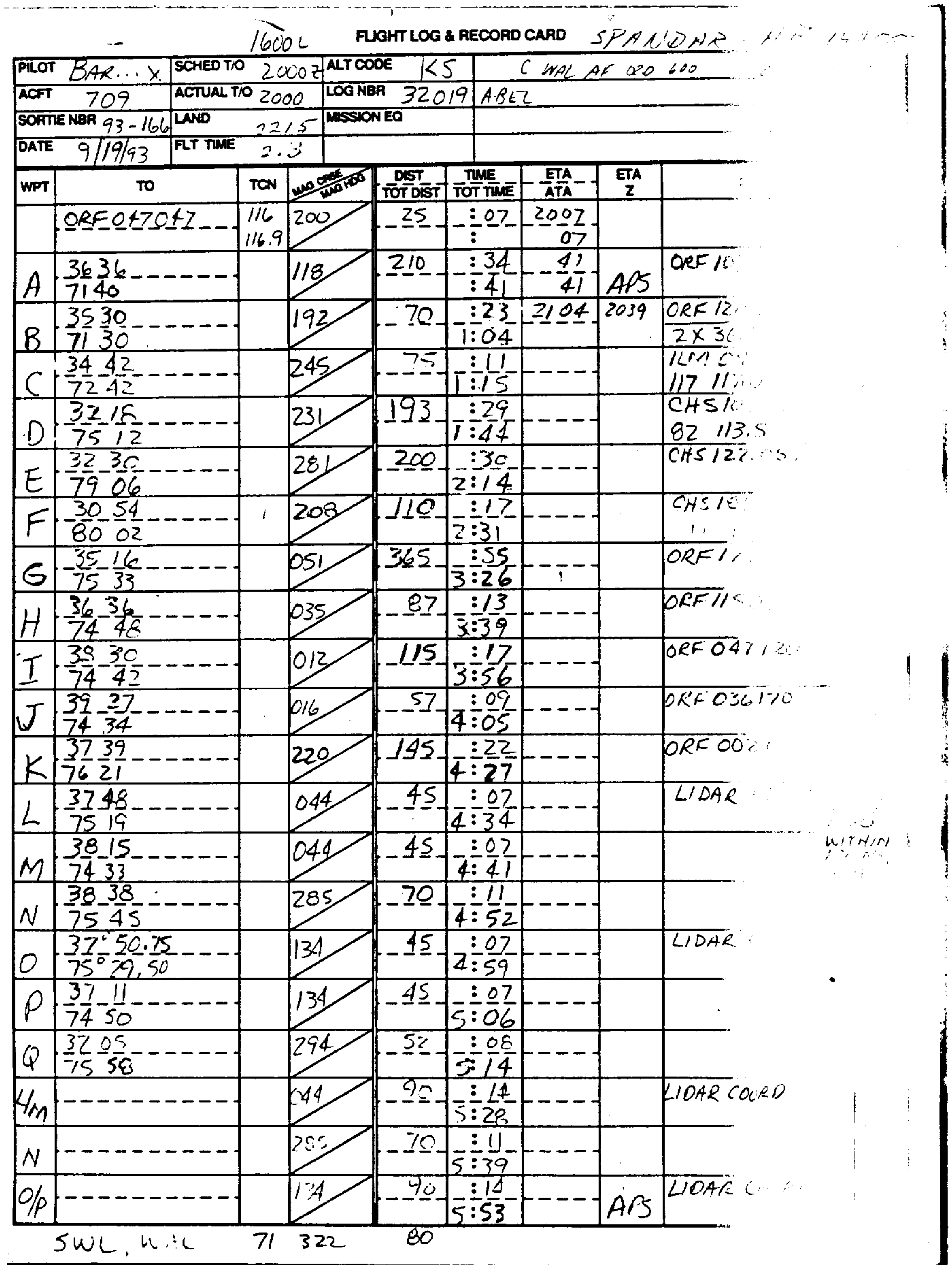


Figure 15. ER-2 flight track for CAMEX flight 2.



1600L FLIGHT LOG & RECORD CARD SPANDAR

PILOT	BAR...X	SCHED T/O	2000Z	ALT CODE	KS — C WAL AF 020 600
ACFT	709	ACTUAL T/O	2000	LOG NBR	32019 ABEL
SORTIE NBR	93-166	LAND	2215	MISSION EQ	
DATE	9/19/93	FLT TIME	2.3		

WPT	TO	TCN	MAG CRSE / MAG HDG	DIST / TOT DIST	TIME / TOT TIME	ETA / ATA	ETA Z	
	ORF 047047	116 / 116.9	200	25	:07 / :	2007 / 07		
A	3636 / 7140		118	210	:34 / :41	41 / 41	APS	ORF 1
B	3530 / 7130		192	70	:23 / 1:04	2104	2039	ORF 12 / 2X 3
C	34 42 / 72 42		245	75	:11 / 1:15			ILM C / 117 11
D	32 18 / 75 12		231	193	:29 / 1:44			CHS 1 / 82 113.5
E	32 30 / 79 06		281	200	:30 / 2:14			CHS 127
F	30 54 / 80 02		208	110	:17 / 2:31			CHS 1
G	35 16 / 75 33		051	365	:55 / 3:26			ORF 1
H	36 36 / 74 48		035	87	:13 / 3:39			ORF 11
I	38 30 / 74 42		012	115	:17 / 3:56			ORF 047 1
J	39 27 / 74 34		016	57	:09 / 4:05			ORF 036170
K	37 39 / 76 21		220	145	:22 / 4:27			ORF 00
L	37 48 / 75 19		044	45	:07 / 4:34			LIDAR
M	38 15 / 74 33		044	45	:07 / 4:41			WITHIN
N	38 38 / 75 45		285	70	:11 / 4:52			
O	37° 50.75 / 75° 29.50		134	45	:07 / 4:59			LIDAR
P	37 11 / 74 50		134	45	:07 / 5:06			
Q	37 05 / 75 58		294	52	:08 / 5:14			
L/M			044	90	:14 / 5:28			LIDAR COORD
N			285	70	:11 / 5:39			
O/P			134	90	:14 / 5:53		APS	LIDAR

SWL, WAL 71 322 80

Figure 16. Pilot's flight log for CAMEX flight 2.

C. CAMEX Flight 3

1. Overview

Mission:	ER-2 Test Flight (after repair of hydraulic system)
ER-2 Sortie:	93-167
Date:	September 25, 1993, CAMEX day 19
Takeoff:	1610 GMT (1210 local)
Duration:	2 hours and 15 minutes
Instruments:	AMPR, EDOP, HIS, LIP, MAMS, MIR, and MTS
Key Instruments:	None

2. <u>Mission Objective</u>. The objective of this 2-hour flight was to check out the functioning of the aircraft after the hydraulic system was repaired. The flight also provided a good opportunity to examine the performance of all instruments. The flight path covered both ocean and land (Figure 17).

3. <u>Mission Summary</u>. The aircraft launched from WFF and headed south and southeast to way point (36° N, 75° W) over the ocean, and then to another way point (37° 30' N, 77° 20' W) over land before returning to WFF. A pass over the lidar site at 20-km altitude was made before the aircraft descended and landed around 1815 GMT. It was cloudy during the entire flight. Figure 18 shows the pilot's log for this flight.

4. <u>Ancillary Data</u>. Univ. of Wisconsin GB-HIS collected data from 1400 GMT to 0000 GMT. A CLASS rawinsonde was launched at 1700 GMT near the time of the aircraft overpass.

5. <u>Aircraft Status</u>. Aircraft performance was nominal during the 2-hour mission, and the crew certified that the airplane was ready to resume normal operations.

6. <u>Instrument Status</u>. All channels from AMPR worked well; the interference from EDOP at 10 GHz channel was still present, of course. Most of the MIR data were somewhat noisy because a major portion of the flight was spent on ascending and descending, and MIR needed some time to reach stabilization. HIS acquired a good dataset, but the spectra from 1731 to 1743 GMT needed to be reprocessed because of the false mirror position indication in housekeeping data. Some segments of LIP data were noisy; there was no clear correlation with the EDOP operation. MTS had a successful upward-looking flight. MAMS collected good data; however, there was a bad spot on tape around 1707 GMT and post analysis could not recover the missing data. EDOP had a good flight. The efforts to improve the system in the past few days had paid off apparently, as the noise present in the previous flights had disappeared.

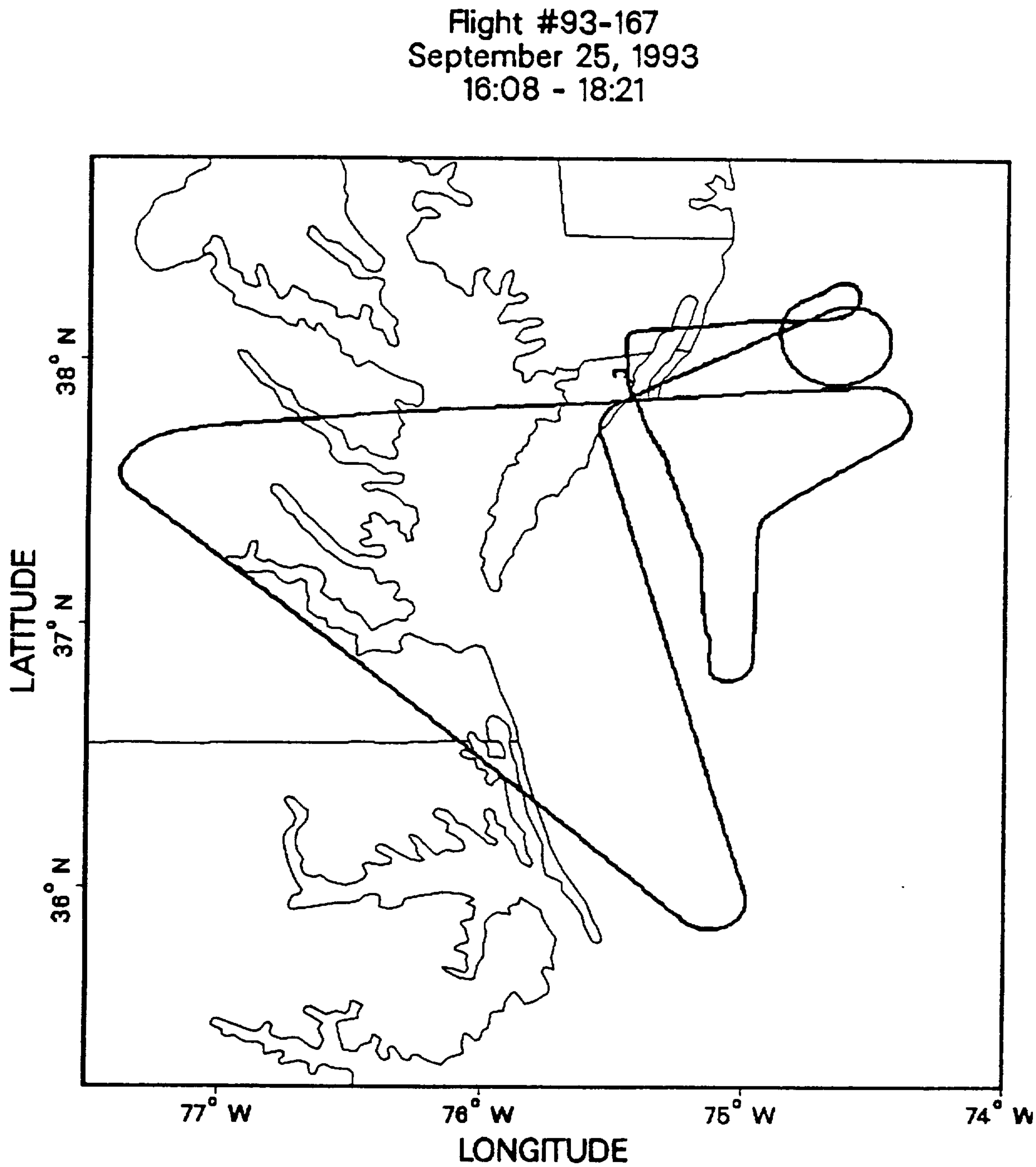


Figure 17. ER-2 flight track for CAMEX flight 3.

FLIGHT LOG & RECORD CARD

PILOT JV	SCHED T/O 1600	ALT CODE	
ACFT 709	ACTUAL T/O 1610	LOG NBR [illegible]	
SORTIE NBR 93-117	LAND 1825	MISSION EQ	
DATE [illegible]	FLT TIME 2.3	CAMEX	

WPT	TO	TCN	MAG CRSE / MAG HDG	DIST / TOT DIST	TIME / TOT TIME	ETA / ATA	ETA Z	FLIGHT NOTES
	SWL (71)		010	7	:3 / :			
	EVC (51)		008	70	:14 / :17			smyrna
A	37-51 / 75-29		193	160	:16 / :33	1641		[illegible]
B	36-55 / [illegible]		177	113	:26 / :59	57 / 58		[illegible]
C	37-32 / 77-20		332	160	:24 / 1:23	1722 / 1722		RIC (50)
D	32-50.7 / 75-29.5		094	100	:15 / 1:39	37 / 1736		
??.	CRF 063/130		094	45	:7 / 1:45	42		
	ORF [illegible]				:30 / 2:15			
					: / :			
					: / :			
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Figure 18. Pilot's flight log for CAMEX flight 3.

D. CAMEX Flight 4

1. **Overview**.

Mission:	Convection Flight
ER-2 Sortie:	93-168
Date:	September 26, 1993, CAMEX day 20
Takeoff:	1900 GMT (1500 local)
Duration:	4 hours and 40 minutes
Instruments:	AMPR, HIS, LIP, MAMS, MIR, and MTS
Key Instruments:	AMPR

2. **Mission Objective**. The objective of this mission was to collect multifrequency data over Gulf Stream convection, within the acquisition range of the SPANDAR radar at Wallops, using the three passive microwave sensors onboard (AMPR, MTS, MIR). Observations of convection during CAMEX by the AMPR will help scientists relate the observations of thunderstorms during CaPE to those acquired during TOGA COARE (the calibration hardware for AMPR was rebuilt between the two experiments). A cold front that had moved off the East Coast north of Wallops was producing shallow rainfall over the Atlantic City area and there were more significant thunderstorms well to the east and southeast of Wallops Island. An alternate objective was to observe any precipitation outside SPANDAR's effective range. The flight track for the ER-2 is shown in Figure 19.

3. **Mission Summary**. The ER-2 launched at 1900 GMT and flew northward to the first way point (39° 31' N, 73° 08' W). By the time of his arrival at way point 1 (1930 GMT) the precipitation over the ocean in the region had ended, and the Mission Scientist requested the ER-2 switch to the alternate flight plan calling for flight legs over precipitation northeast and east of Cape Hatteras, NC. At 2025 GMT the ER-2 pilot reported he was over an area of thunderstorms from 32° to 34° N and 73° to 74° W. He began flying repeated passes over these storms. Although, the storms were outside the effective range of the SPANDAR radar, the storms were observable on the Cape Hatteras weather radar and the East Coast lightning detection network indicated the storms were electrified. The ER-2 made five passes over storms and the times and locations as noted by the pilot were:

2004-2009 GMT	36° 51' N, 72° 04' W to 36° 24' N, 72° 27' W
2015-2039 GMT	35° 48' N, 72° 41' W to 34° 09' N, 75° 14' W
2046-2049 GMT	34° 26' N, 74° 57' W to 34° 43 N, 74° 44' W
2050-2053 GMT	34° 50' N, 74° 42' W to 35° 09' N, 74° 36' W
2100-2115 GMT	35° 00' N, 75° 40' W to 35° 58' N, 72° 15' W

After 2115 GMT, the storms began to dissipate and the Mission Scientist requested the pilot return to WFF Before his return, the pilot executed two 360° turns at with 20° bank (one left turn and one right turn); however, there was no precipitation in the area selected by the pilot for the turns. Upon arrival over Wallops at 2214 GMT the ER-2 flew the Raman lidar ground pattern (Figure 21) one time prior to landing at 2340 GMT. The Raman lidar was not operating during this flight, but the Univ. of Wisconsin GB-HIS was collecting data. The pilot's log for this mission is shown in Figure 20.

4. **Ancillary Data**. A CLASS rawinsonde was launched at 2200 GMT near the time of the aircraft overpass. The GB-HIS was operating from 1600 GMT until 1200 GMT.

5. **Aircraft Status**. The ER-2 performed nominally during the mission.

6. **Instrument Status**. The AMPR performed well with some noise in the 85 GHz channel and minor RF interference in 19 GHz and 37 GHz channels. The AMPR data indicated the pilot flew over several small convective cells, all less than 20 km in diameter. A preliminary look at the data collected during the 360° maneuvers indicated no precipitation was present. MAMS collected good data; however, some RF noise was apparent, as well as a possible absolute calibration problem. The LIP instrument collected a good dataset and detected lightning in some of the cells. Data from the top field mill did not contain the noise seen in the earlier missions. The HIS and MTS collected great datasets; although there was an 80 second glitch in the MTS data shortly after ascent. The MIR also collected excellent observations of small rain cells.

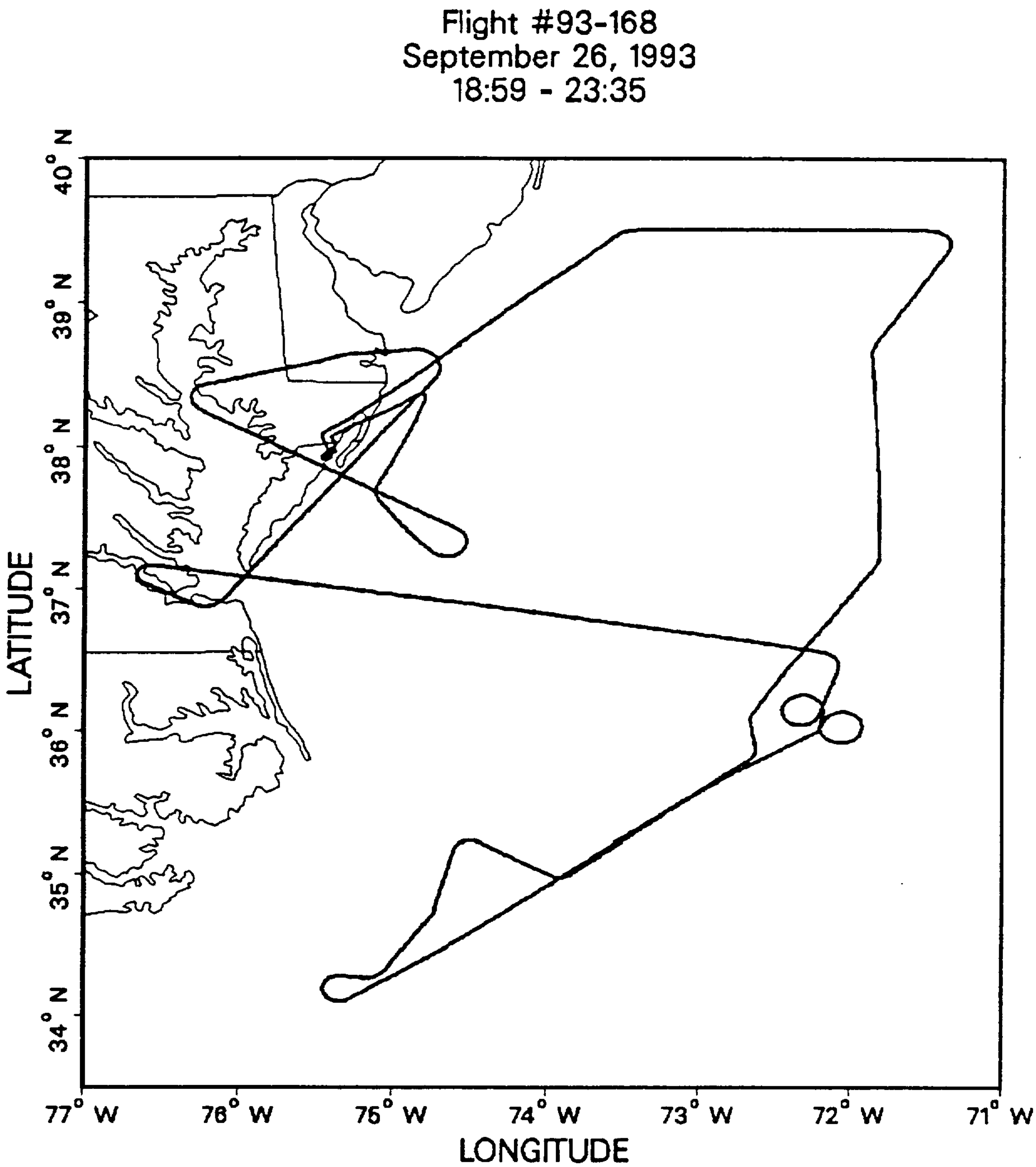


Figure 19. ER-2 flight track for CAMEX flight 4.

1500 L FLIGHT LOG & RECORD CARD [illegible]

PILOT BAR[illegible]	SCHED T/O 1900 Z	ALT CODE KS	
ACFT 709	ACTUAL T/O 1900	LOG NBR 32629	SPENCER
SORTIE NBR 93-168	LAND 2340	MISSION EQ	
DATE 9/26/93	FLT TIME 4+40	CAMEX	

WPT	TO	TCN	MAG CRSE / MAG HDG	DIST / TOT DIST	TIME / TOT TIME	ETA / ATA	ETA Z	FLIGHT NOTES
	SWL	71 112.4	010	10	:03 :	1903 04		
AA	SIE 080065 3930 7330	95 114.8	057	125	:23 :26	27 25	APS	OUT @ 1910
BB	SIE 093/163 3930 7120		103	100	:15 :41	40 39		-TRW
CC	3850 7120		193	46	:07 :48			2004 Z - 2009 36°53' 36°24 72°04' 72°27
DD	3850 7330		283	100	:15 1:03			2015 Z - 2039 Z 35°[illegible] 34 09 72°41 75 14
EE	3810 7330		193	46	:07 1:10			2046 Z - 2049 Z 34°[illegible] 34°43 74°57 74°44
FF	3810 7120		103	100	:15 1:25			2050 Z - 2053 Z 34°50 35° 0[illegible] 74°[illegible] 74° 36
GG	3730 7120		193	46	:07 1:32			2100 Z - 2114½ Z [illegible] 35°58 [illegible] 73°15
HH	3730 7330		283	100	:15 1:47			
II	3650 7330		193	46	:07 1:54			
JJ	3650 7120		103	100	:15 2:09			
	2 X 360° TURNS				:12 2:21			NEAR 36°N - 72°W 2115½-21[illegible](R) 2122-2126(L)
NN	37°50.75 75°29.50			90	: :			X PATTERN
BB					: 0:47	1931	2214 2227	3705 3828 7558 7445 044°
KK	SWL/125/130 3708 7300		227	170	:25 1:12	2004		~~3719 [illegible]~~ ~~[illegible]~~
LL	ORF 120 165 3547 7306	115 115.9	194	80	:12 1:24			~~3839~~ ~~7345~~
MM	SAY/135 118 3053 7924	74 112.7	235	430	1:05 2:29			~~[illegible]~~
LL			057	450	1:08 3:37			
KK			014	80	:12 3:49			~~3813~~ ~~3721~~ ~~7617~~ ~~7440~~
NN	45 NM PAST 37°50.75 75°29.50		296	185	:28 4:17		2242 2255	3816 3728 134° AAA/BBB 7617 7440
	SWL WAL				:28 4:45		APS	IN 2255 (3+15)

Figure 20. Pilot's flight log for CAMEX flight 4.

E. CAMEX Flight 5

1. Overview

Mission:	Special Flight for the AIRS Project
ER-2 Sortie:	93-169
Date:	September 29, 1993, CAMEX day 22
Takeoff:	0100 GMT (2100 local, September 28, 1993)
Duration:	4 hours
Instruments:	AMPR, HIS, LIP, MAMS, MIR, and MTS
Key Instruments:	HIS, MIR

2. **Mission Objective**. The objective of the "AIRS" mission is to achieve very high quality "Near Top of the Atmosphere" radiance spectra with associated temperature and water vapor profile ground truth to validate and improve radiative transfer calculations over the spectral regions to be observed by the EOS AIRS instrument. The major spectroscopic issue to be studied was the water vapor continuum and associated absorption line shape approximations. Secondary issues were CO_2 line strengths and half widths and the shortwave N_2 continuum.

The University of Wisconsin is supporting this study with ER-2 aircraft HIS spectra of upwelling radiance at aircraft altitude, downwelling radiance spectra observed at the surface with a ground-based HIS (called the GB-HIS), and CLASS rawinsondes from the Chesser farm. Other supporting data are WFF rawinsondes, Raman lidar water vapor profiles, and MAMS multispectral imagery and derived integrated water content (precipitable water).

3. **Mission Summary**. The flight consisted of multiple passes along two perpendicular lines over the Raman lidar site, one parallel to the coast of the Wallops Island, and another perpendicular to it (Figure 21). The total on-station time at the aircraft altitude of 20 km was 3 hours. The entire ER-2 flight track is shown on Figure 22. The pilot's log for the AIRS mission is shown in Figure 23.

4. **Ancillary Data**. The GB-HIS (Univ. of Wisconsin) operated for a full 24 hours during CAMEX day 22, including the complete mission time. The Raman lidar collected data from 0030 to 0500 GMT. The Univ. of Wisconsin launched CLASS sondes at 2200, 0100, and 0400 GMT. The WFF launched AIR and Vaisala rawinsondes at 2200, 0100, and 0400 GMT, and an ozone sonde at 0100 GMT.

5. **Aircraft Status**. The aircraft-sensor interface box was accidentally damaged during the EDOP integration process (no fault of EDOP). Therefore, EDOP was pulled off the aircraft at the last moment, and the takeoff time was postponed for 1 hour while

the aircraft crew repaired to the electrical system. The LIP instrument had a physical hardware failure, apparently resulting from the electrical system damage.

6. **Instrument Status**. HIS acquired a very good dataset during the flight. MIR also had a good flight and the data at all channels looked great. MTS was looking upward during this flight, and a very clean dataset was collected. AMPR acquired a great dataset for the duration of the entire flight. Unfortunately, MAMS experienced a tape system failure resulting in no data being collected. LIP had a major hardware failure at the start of the flight, apparently related to the problems encountered during the EDOP integration.

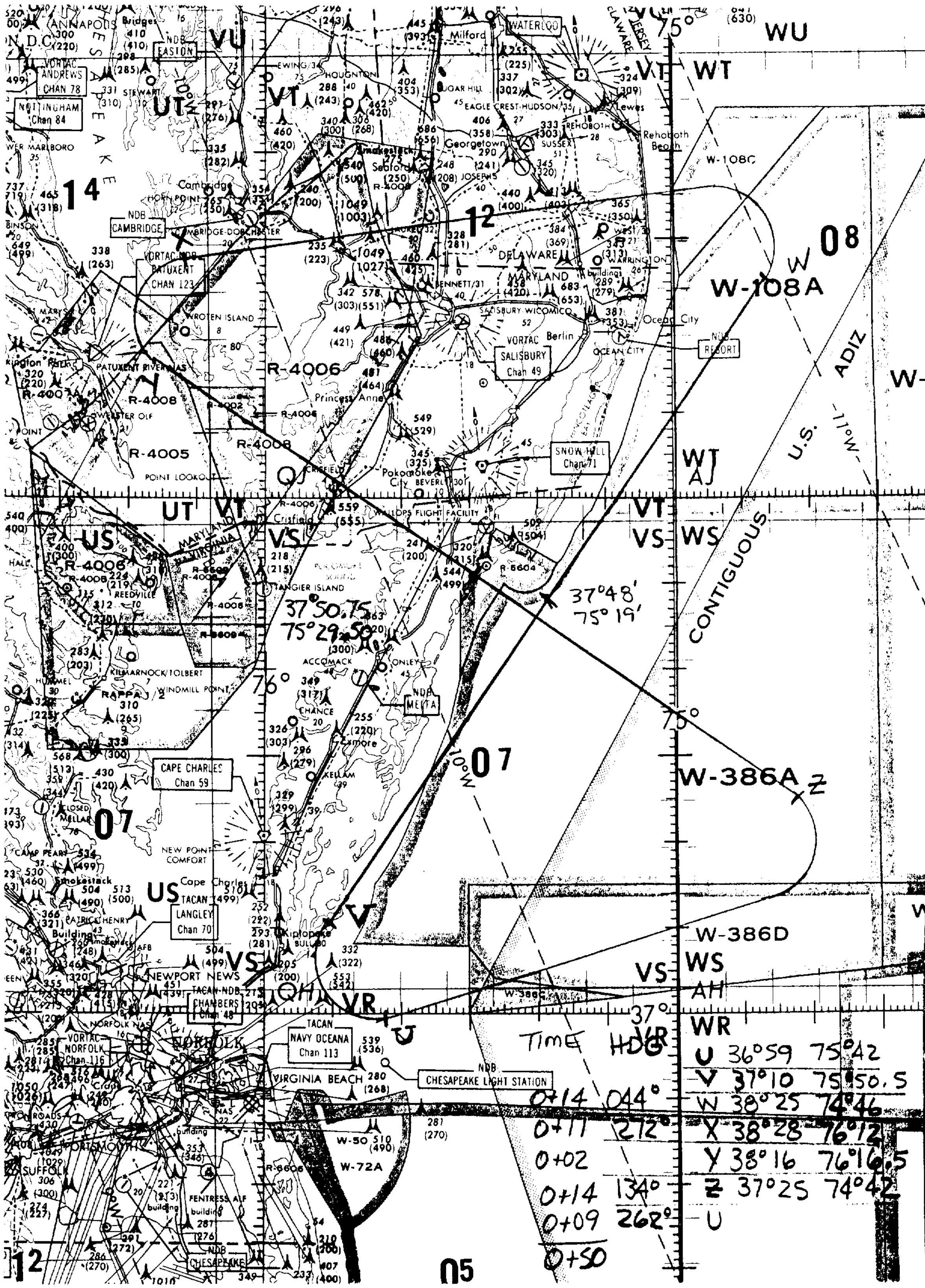


Figure 21. HIS-AIRS ground track pattern.

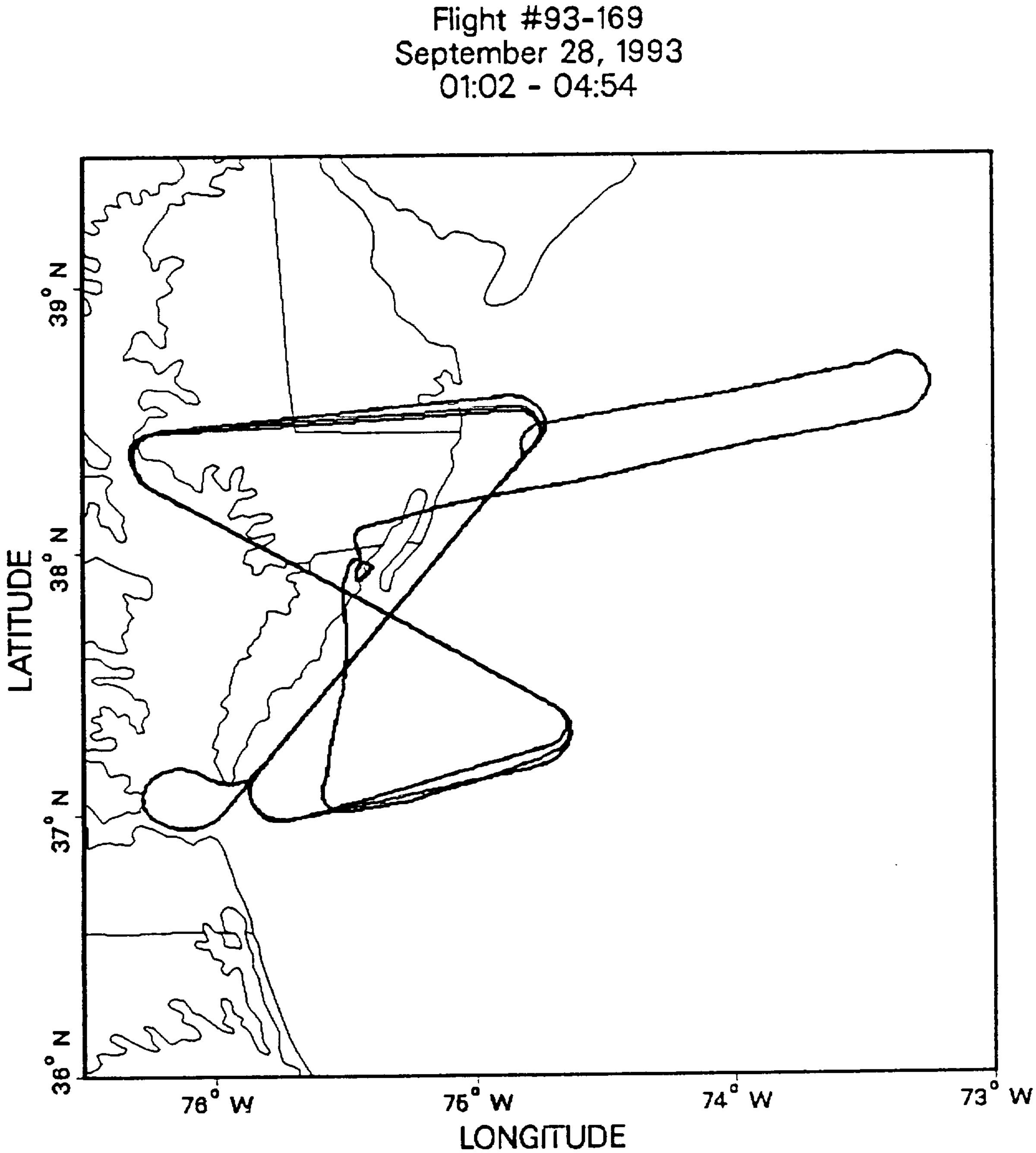


Figure 22. ER-2 flight track for CAMEX flight 5.

JT JAN	SCHED T/O 2100 / 0100Z	ALT CODE KS	Giant Killer 350.0 / 118.12
T 709	ACTUAL T/O 0100	LOG NBR 32029	SPANDAR 324.3 / 121.95
TIE NBR 93-169	LAND 0500	MISSION EQ CAMEX	A.R. [illegible] 129.9
E 85-0+ (Local)	FLT TIME 4.0		

TO	TCN	MAG CRSE / MAG HDG	DIST / TOT DIST	TIME / TOT TIME	ETA / ATA	ETA Z	FLIGHT NOTES
SWL			07	:03 :03			
SWL 085 100		085	100	:18 :21			APS DELAY ? SWL[illegible]
38-25 74-46		074	64	:10 :31	 0136		
37-10 75-50.5		224	90	:14 :45	0150 51		
		044	125	:19 1:04	0210 213		
38 28 76 12		272	75	:11 1:15	24 25		
38-16 37-25 76-11.5 74-42		134	105	:16 1:31	41 0240		
36-59 [illegible]		263	62	:09 1:40	49 50		
		044	106	:16 1:56	0306 0306		
		272	75	:11 2:07	12 17		
		134	105	:16 2:23	33 32		
		263	62	:9 2:32	41 42		
		044	106	:16 2:48	58 58		
		272	75	:11 2:59	0409 09		
		134	121	:16 3:15	25 24		CRF
SWL / [illegible]				:30 3:45	 55		
				:			
				:			

Figure 23. Pilot's flight log for CAMEX flight 5.

F. CAMEX Flight 6

1. **Overview**

Mission:	SSM/T-2 Under flight
ER-2 Sortie:	93-178
Date:	September 30, 1993, CAMEX day 24
Takeoff:	2000 GMT (1600 local)
Duration:	6 hours and 20 minutes
Instruments:	MIR, AMPR, MTS, HIS, and MAMS
Key Instruments:	MIR, AMPR

2. **Mission Objective**. The major objectives of this flight were (A) to validate/calibrate the SSM/T-2 channels with the MIR measurements and (B) to study the microwave signatures at high incidence angles (up to 65°) over ocean areas under clear and cloudy conditions in the frequency range of AMPR and MIR.

3. **Mission Summary**. The flight path was designed to cover as many rawinsonde stations as possible, within the region of coverage by the SSM/T-2, along the coastline of the eastern shore from the Carolinas to Massachusetts. Over the ocean areas the aircraft also flew over some buoy sites that provided measurements of sea surface temperature and near-surface humidity and air temperature. Toward the end, two perpendicular passes over the Lidar site in the Wallops Island were conducted before landing. Figure 24 shows the flight track for this mission.

The aircraft flew over rawinsonde stations located at Atlantic City, Chatham, Cape Hatteras, Charleston, Greensboro, and Wallops, and buoy sites 44005, 44008, 44004, 44014, and 44009. Two 360° turns, left and right, were flown in the neighborhood of the buoy site 44008 at 2140 GMT. The weather in the region of coverage during the flight period was mostly clear over land and (probably) partly cloudy over the oceans. The wind condition at the time of aircraft takeoff was north to northeasterly from 10 to 15 knots. At the time of landing the wind was expected to be northerly and less than 10 knots. The nighttime temperature was in the low 40's (°F). The pilot's log for this mission is shown in Figure 25.

4. **Ancillary Data**. The Univ. of Wisconsin operated the GB-HIS for 24 hours during CAMEX day 24. The Raman lidar collected data from 0030 to 0500 GMT. The Univ. of Wisconsin personnel launched CLASS sondes at 2200, 0100, and 0400 GMT. The WFF launched rawinsondes at 2200 (Vaisala and AIR), 0100 (Vaisala), and 0400 GMT (Vaisala and AIR), and also launched an ozone sonde at 0100 GMT.

5. **Aircraft Summary**. The aircraft performance was nominal during the flight; however, there was a failure in the flight navigation recorder near the end of the flight.

6. **Instrument Summary**. MIR had a very good flight and a clean dataset was acquired. AMPR also collected a great dataset during the entire flight, as did the HIS. MTS acquired a clean dataset throughout. MAMS collected good data. The HIS lost their navigation data in the last one-third of the flight, though the navigation data were available in the data stream of the other instruments. The LIP instrument was undergoing repairs caused by the electrical problems during the previous flight, and did not fly on this mission.

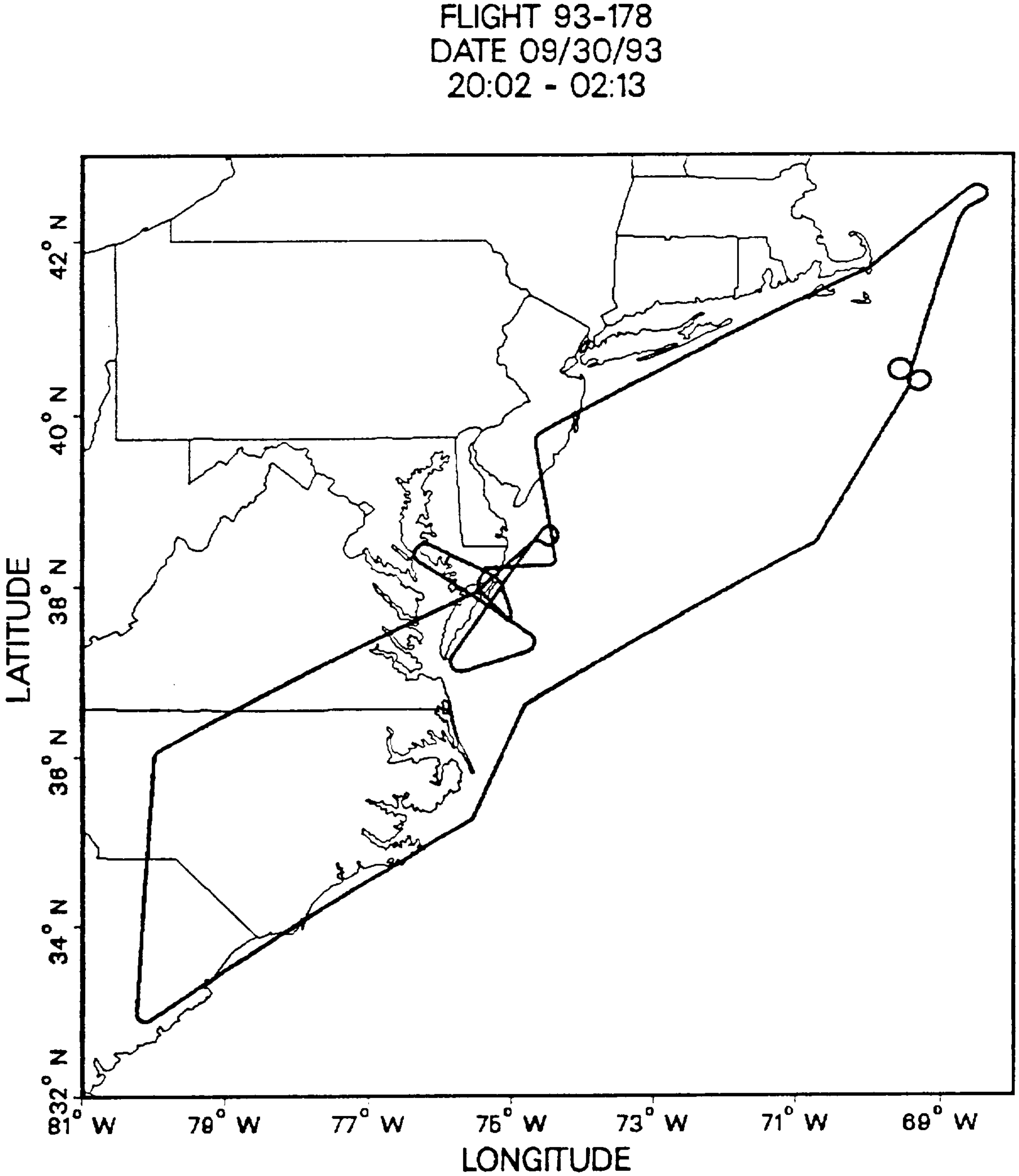


Figure 24. ER-2 flight track for CAMEX flight 6.

PILOT BAR..., X	SCHED T/O 2000 Z	ALT CODE KS	GIANT KILLER 350.0/118.12
ACFT 709	ACTUAL T/O 2000	LOG NBR 32012	SPANDAR 326.3 /121.95
SORTIE NBR 93-178	LAND 0220	MISSION EQ CAMEX	AIRPIIK 129.9
DATE 9/30/93	FLT TIME 6+20	SPINHIRNE	

WPT	TO	TCN	MAG CRSE / MAG HDG	DIST / TOT DIST	TIME / TOT TIME	ETA / ATA	ETA Z	FLIGHT NOTES
	SWL	71 112.4	010	09	:03 :03	2003 05		
A	39°45 74°40	81 113.4	030	110	:20 0:23	25 34		CYN 260012 COYLE
B	41°40 69°58	109 116.2	071	242	:36 0:59	2110 07	2050 APS	ACK 020025 NANTUCKET
C	42°36 68°36		065	84	:13 1:12	20 19		ACK054 100 BOTH
D	40°30 69°24		219	150	:34 1:46	53 55	2 360°s	AIRIMAIN PRIMARY
E	38°30 70°42	106 115.9	222	136	:20 2:06	2215 15		JFK 193192
F	36°36 74°48	116 116.9	251	224	:34 2:40	49 49		CRF 116070
G	35°16 75°33	117 117.0	213	85	:13 2:53	2302 02		ILM 071127 WILMINGTON
	CHS	82 113.5	245	265	:40 3:33	42 42		
	GSO	109 116.2	011	200	:30 4:03	0012 11		
H	37°56 75 29		070	240	:36 4:39	47 45		SWL 170006
I	38°30 74°42		059	50	:08 4:47	53 53		IFR DELAY 1+00 WITHIN 80 NM SWL
W/V	38°25 37°10 74°46 75°50.5		222°		:21 5:08	0114 15		HIS PRIMARY OR MIR
J	37°13 74°47		052		:09 5:17	24 24		APS 4+50
Z/Y	37°25 38°16 74°42 76°16.5		314		:15 5:32	39 40	0140 APS	LIGHT TURB
	SWL/WAL				:30 6:02	0210		
					:			
					:			
					:			
					:			
					:			

OMH-4

Figure 25. Pilot's flight log for CAMEX flight 6.

G. CAMEX Flight 7

1. **Overview**

Mission:	Convection
ER-2 Sortie:	94-001
Date:	October 03, 1993, CAMEX day 27
Takeoff:	2000 GMT (1600 local)
Duration:	7 hours 30 minutes
Instruments:	MIR, AMPR, EDOP, LIP, MTS, HIS, and MAMS
Key Instruments:	AMPR

2. **Mission Objective**. The major objective of this flight was to continue multifrequency microwave radiometer measurements of tropical convection in the Southeastern U.S., using AMPR, MIR, and MTS. In addition, a secondary objective was EDOP measurements of precipitation over an ocean background. Due to lack of precipitation off the coast of Virginia, a flight path was selected to fly over convection in the coastal waters off the Florida Peninsula. GOES imagery from 1600 GMT indicated there were active areas of convection west of Tampa, near Ft. Meyers, and east of Daytona. Figure 26 shows the ER-2 flight track for CAMEX flight 7.

3. **Mission Summary**. After launch at 2000 GMT the pilot proceeded to the first way point (35° 07' N, 74°11' W) due east of Cape Hatteras where a large convective complex was observed on the satellite imagery. After a pass over convection in this region, the ER-2 flew to the Daytona area and the pilot requested a location of the most active convection from the air traffic control center. The ER-2 was directed to an area of convection west of Ft. Meyers, FL. Arriving in the area at 2220 GMT, the ER-2 made several short passes over convection in this region. The dates and times the ER-2 was over deep convective as recorded by the pilot were:

2224-2226 GMT	25°18' N, 81°26' W
2232-2234 GMT	25°33' N, 81°56' W
2246-2247 GMT	25°31' N, 81°47' W
2259-2301 GMT	25°43' N, 81°47' W
2344 GMT	25°36' N, 82°27' W
2152 GMT	26°21' N, 82°11' W
2159 GMT	26°23' N, 82°07' W

The ER-2 performed two 360° turns from 0001 to 0015 GMT (Oct. 4), but the post-flight analysis indicated the aircraft was not in an area with precipitation. Figure 27 shows the pilot's log for this flight.

4. **Ancillary Data**. The Univ. of Wisconsin operated the GB-HIS for 24 hours during CAMEX day 27. The Raman lidar collected data from 0000 GMT to 0500 GMT. CLASS sondes were launched at 2200, 0100, and 0400 GMT. WFF launched rawinsondes at 2200 (AIR, Vaisala, and VIZ), 0100 (Vaisala), and 0300 GMT (AIR, Vaisala, and VIZ), and an ozone sonde at 0100 GMT.

5. **Aircraft Summary**. The aircraft performance was nominal during the flight. The navigation recorder (which was replaced) worked well.

6. **Instrument Summary**. The AMPR collected excellent data during the flight, with the exception of some minor noise in the 19 GHz channel. The EDOP transmitter failed to start when switched on, and at the instructions of the Mission Scientist, the EDOP was not recycled. Thus, the instrument collected no data during the flight. The MAMS instrument worked well, and was able to receive the navigation data through the RS-232 channel for the first time during the experiment. The LIP instrument had a failure early in the mission, but recycled properly and collected good data. Preliminary post-flight analysis of the LIP data indicated that while there were significant electrical fields in the areas of active convection, no obvious lightning signals were present. The MTS instrument worked well, recording clean data, although there was some gain instability. The HIS sensor also worked well. MIR had a failure and did not record any data the last 90 minutes of the flight. The cause of the MIR failure could not be located.

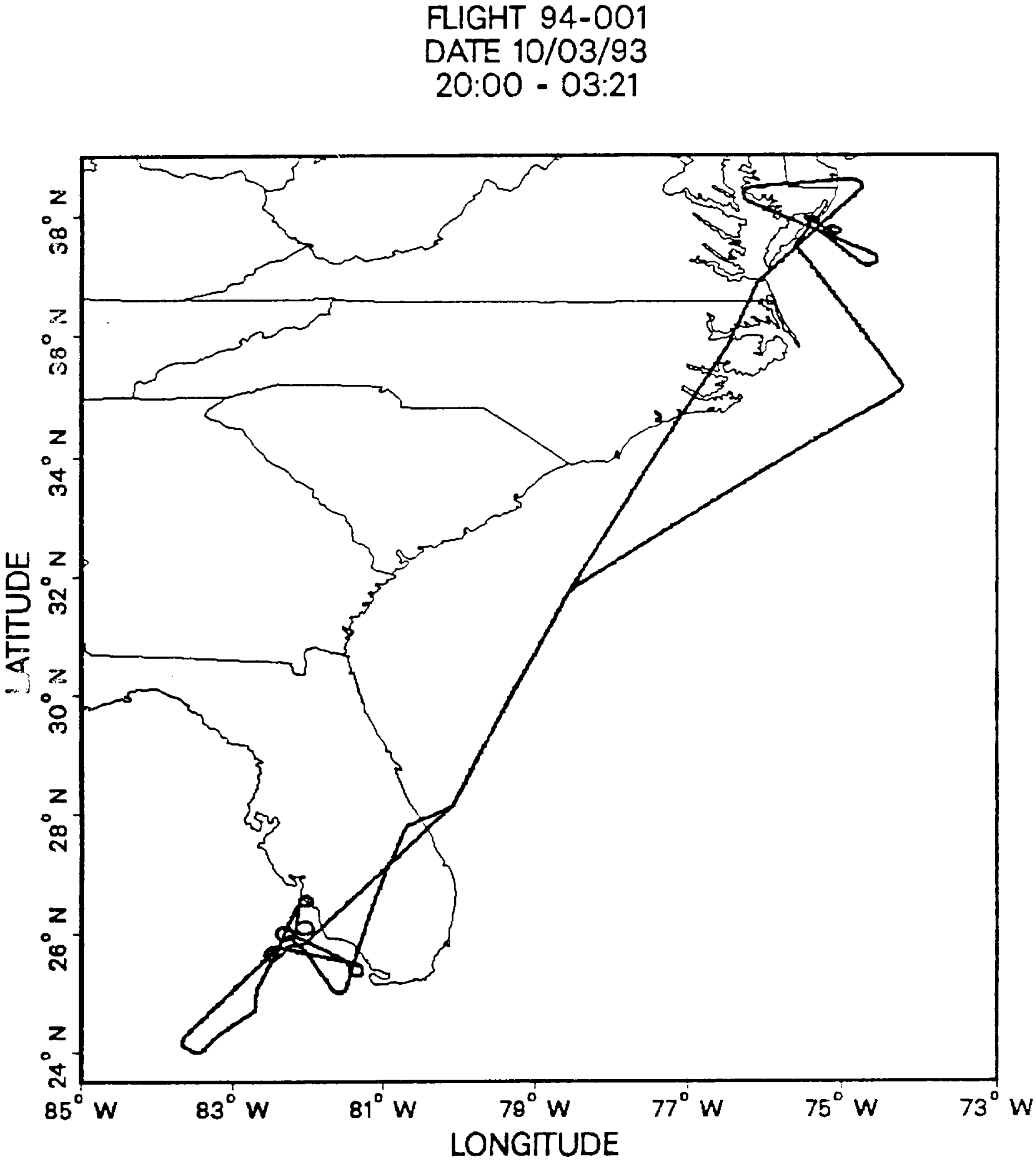
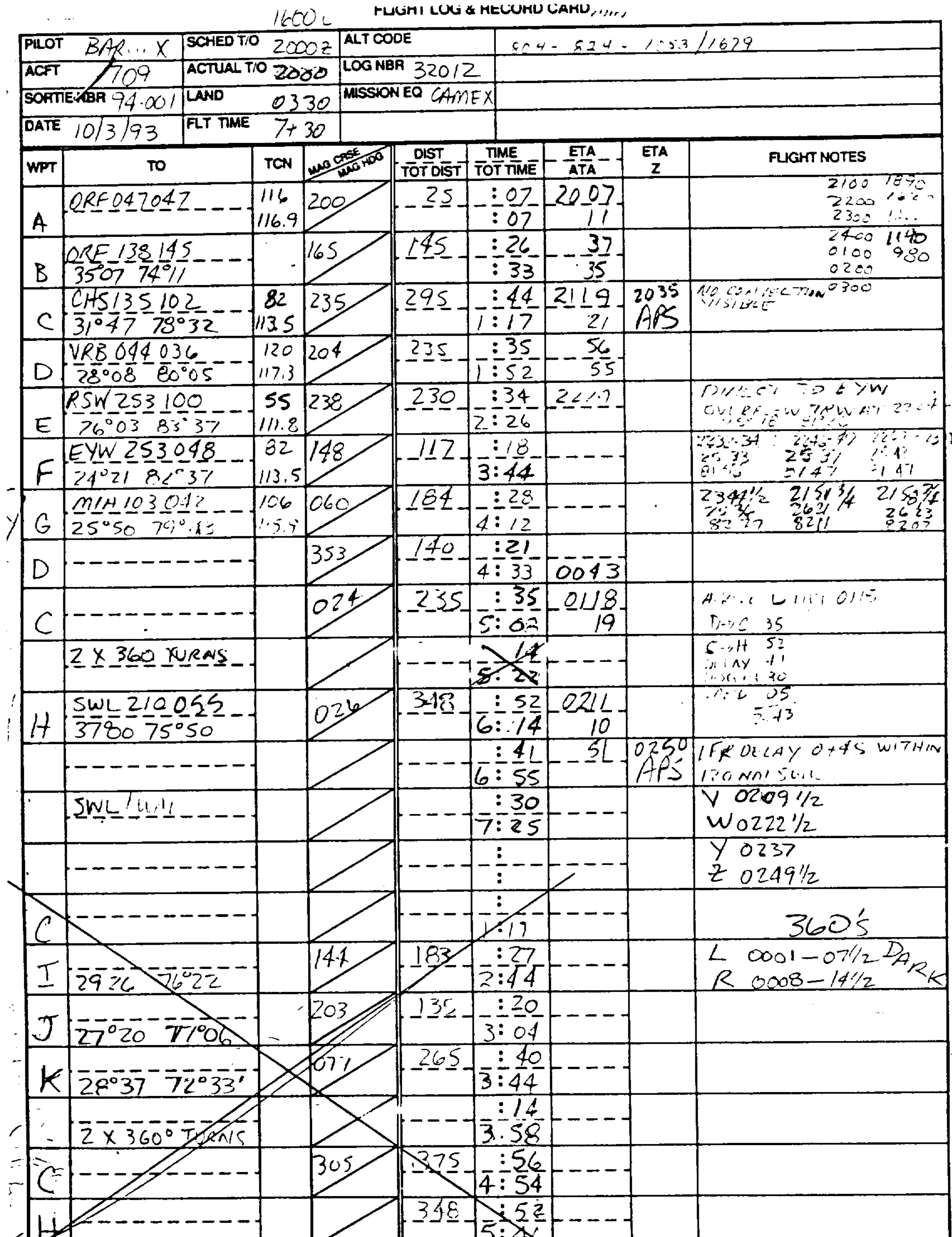


Figure 26. ER-2 flight track for CAMEX flight 7.



1600 L

FLIGHT LOG & RECORD CARD

PILOT	BAR... X	SCHED T/O	2000Z	ALT CODE	904-824-1053/1629
ACFT	709	ACTUAL T/O	2000	LOG NBR	32012
SORTIE NBR	94-001	LAND	0330	MISSION EQ	CAMEX
DATE	10/3/93	FLT TIME	7+30		

WPT	TO	TCN	MAG CRSE / MAG HDG	DIST / TOT DIST	TIME / TOT TIME	ETA / ATA	ETA Z	FLIGHT NOTES
A	ORF 047047	116 / 116.9	200	25	:07 / :07	2007 / 11		2100 1890 / 2200 [illegible] / 2300 [illegible]
B	ORF 138 145 / 3507 74°11		165	145	:26 / :33	37 / 35		2400 1140 / 0100 980 / 0200
C	CHS 135 102 / 31°47 78°32	82 / 113.5	235	295	:44 / 1:17	2119 / 21	2035 APS	NO CONNECTION 0300 VISIBLE
D	VRB 044 036 / 28°08 80°05	120 / 117.3	204	235	:35 / 1:52	56 / 55		
E	RSW 253 100 / 26°03 83°37	55 / 111.8	238	230	:34 / 2:26	22[illegible]		DIRECT TO EYW [illegible]
F	EYW 253 048 / 24°21 82°37	82 / 113.5	148	117	:18 / 3:44			[illegible]
G	MIA 103 042 / 25°50 79°[illegible]	106 / [illegible]	060	184	:28 / 4:12			2344½ 2151¾ 2158¾
D			353	140	:21 / 4:33	0043		
C			024	235	:35 / 5:08	0118 / 19		[illegible] 0115 / [illegible] 35
	2 X 360 TURNS				~~14~~ / ~~5:22~~			C-H 52 / DELAY 41 / [illegible] 30 / [illegible] 05 / 5:43
H	SWL 210 055 / 3780 75°50		026	348	:52 / 6:14	0211 / 10		
					:41 / 6:55	51	0250 APS	IFR DELAY 0+45 WITHIN 120 NM SWL
	SWL / [illegible]				:30 / 7:25			V 0209½ / W 0222½
								Y 0237 / Z 0249½
C					1:17			360's
I	2926 7622		144	183	:27 / 2:44			L 0001–07½ DARK / R 0008–14½
J	27°20 71°06		203	135	:20 / 3:04			
K	28°37 72°33'		071	265	:40 / 3:44			
	2 X 360° TURNS				:14 / 3:58			
C			305	375	:56 / 4:54			
H				348	:52 / 5:46			

IFR DELAY + DESCENT

OMH-4

Figure 27. Pilot's flight log for CAMEX flight 7.

H. CAMEX Flight 8

1. Overview

Mission:	Convection
ER-2 Sortie:	94-002
Date:	October 05, 1993, CAMEX day 29
Takeoff:	1600 GMT (1200 local)
Duration:	7 hours and 40 minutes
Instruments:	MIR, AMPR, EDOP, LIP, MTS, HIS, and MAMS
Key Instruments:	AMPR

2. **Mission Objective**. The major objectives of this flight were to continue multifrequency microwave radiometer measurements of tropical convection in the Southeastern U.S., using AMPR, MIR, and MTS, and collect EDOP measurements of precipitation over an ocean background. A secondary objective was to study the interference in the AMPR data caused by the EDOP, comparing the interference patterns over land and ocean backgrounds. A flight path was selected to fly over convection in the coastal waters off the Florida Peninsula, and an earlier launch time was set to maximize daylight observations. Satellite imagery from 1200 GMT indicated there were active areas of convection south of Key West and east of Miami. To ensure the pilot flew over the most significant precipitation, a radio-contact schedule was established and the pilot was given hourly position fixes of convection in south Florida.

3. **Mission Summary**. The ER-2 launched at 1600 GMT and flew south down along the east coast. During the transit flight the mission scientist studied the current satellite and radar imagery, concluding that the most significant convection was a line of thunderstorms south of the Florida Keys from 24° 25' N, 80° 37' W to 24° 52' N, 82° 04' W. The pilot was given these positions and proceeded to the area, arriving at 1832 GMT. The pilot made three passes over the convection before turning the EDOP transmit off to allow for interference-free data collection by the AMPR. After one more pass over the storms the pilot was directed to a developing line of storms north of Miami. This line of storms was aligned east-west from Lake Okeechobee to about 60 miles offshore of West Palm Beach. The ER-2 made repeated passes over these storms. The pilot completed two 360° turns from 2017 to 2030 GMT, and post-flight analysis of the AMPR data indicated that precipitation was observed during the banked turns. The times and locations for the passes over deep convection as noted by the pilot were:

1833-1840 GMT	24° 26' N, 80° 44' W to 24° 03' N, 81° 23' W
1848-1852 GMT	24° 13' N, 81° 17' W to 24° 22' N, 80° 57' W
1852-1917 GMT	24° 27' N, 80° 52' W to 27° 04' N, 79° 58' W
2014-2017 GMT	27° 32' N, 80° 00' W to 27° 12' N, 80° 01' W
2038-2041 GMT	26° 20' N, 80° 25' W to 26° 09' N, 80° 45' W
2050-2057 GMT	26° 06' N, 80° 56' W to 26° 26' N, 80° 13' W

The ER-2 made at least three other passes for which incomplete data were noted by the pilot. Figure 28 shows the ER-2 flight path during this mission. The pilot's log for this flight is shown in Figure 29.

4. **Ancillary Data**. The Raman lidar collected data from 0030 to 0500 GMT (6 Oct.); however, this was after the ER-2 had landed. The GB-HIS collected data for the entire 24 hours of CAMEX day 29. CLASS sondes were launched at 2200 GMT, 0100 GMT, and 0400 GMT. WFF launched rawinsondes at 2200 GMT (VIZ and Vaisala), 0100 GMT (Vaisala and AIR), and 0400 GMT (VIZ, Vaisala, and AIR), and an ozone sonde at 0100 GMT.

5. **Aircraft Performance**. The ER-2 performance was nominal during the mission.

6. **Instrument Performance**. This was the best convection flight during CAMEX. The thunderstorms as observed by the AMPR were the largest and most active seen. The LIP collected good data including observations of lightning during several of the passes. The EDOP performed very well, and collected excellent data on the storms south of the Florida Keys before being turned off at 1920 GMT. The EDOP measured the tops of the thunderstorms at 12 km. The MIR worked well, seeing numerous rain cells as did the MTS. The HIS also collected a great dataset.

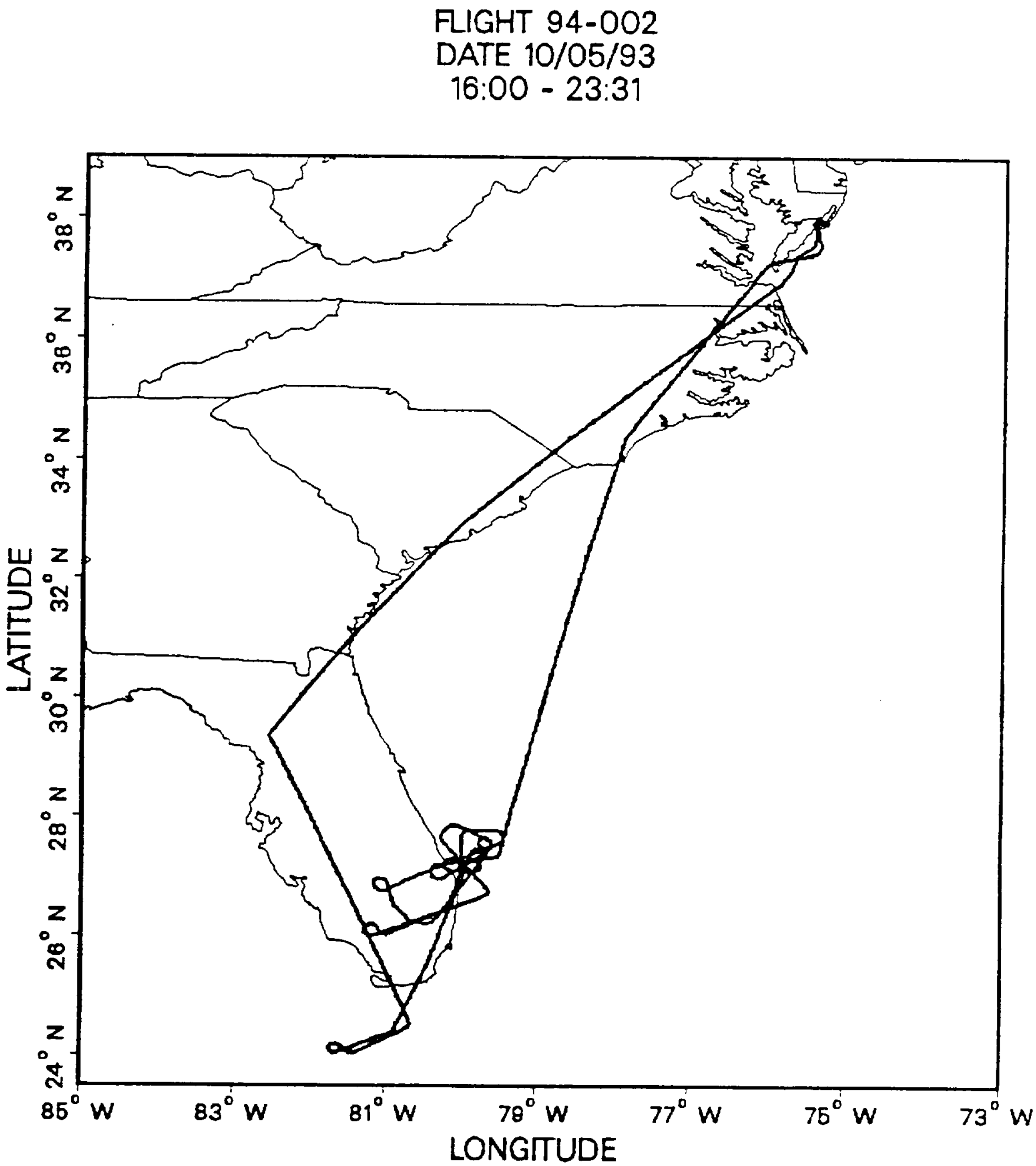


Figure 28. ER-2 flight track for CAMEX flight 8.

PILOT BAR... X	SCHED T/O 1600	ALT CODE	804-824-1053/1679 1330 TO 1730
ACFT 709	ACTUAL T/O 1600	LOG NBR 32012	
SORTIE NBR 94-002	LAND 2340	MISSION EQ CAMEX	
DATE 10/5/93	FLT TIME 7+40		

T	TO	TCN	MAG CRSE / MAG HDG	DIST / TOT DIST	TIME / TOT TIME	ETA / ATA	ETA Z	FLIGHT NOTES
	ORF 047 047	116 116.9	200	25	:08 :08	1608 09		
	CHS	82 113.5	225	350	:55 1:03	1704 09	1645 APS	
	SSI	35 109.8	217	175	:26 1:29	35 28		
A	PIE 256052 27°40 83°38	111 116.4	211	230	:35 2:04	1803		
B	EYW 335058 25°26 82°17	82 113.5	150	160	3:24 5:28			N-2-EPOD IFR DELAY 2 x 360°'s 3+00 WITHIN 120NM RSW
C	MIA 083040 26°03 79°47	106 115.9	075	145	:22 5:50			
D	OMN 160062 28°24 80°36	73 112.6	344	150	:23 6:13			ILM 015° 510NM 1+17
E	OMN 153043 28°42 80°41		348	20	:03 6:16			
	ILM	117 117.0	028	370	:56 7:12	2242 39		50L 20S
B/D			036	125	:19 7:31	58 58	2300 APS	APS 6+15
	SWL/WAL		036	120	:29 8:00			
					:			
F	24°25 80° 37				:	1832		1833½ — 1840 10 NM PAST TRW 24 26 2403 80 44 81 23
G/H	2648 2740 8057 7934				:			1848½ — 1851½ TURN TO NNE 24 13 24 22 81 17 80 57
				2104 2652	~:2110 :00PS			1852½ — 1917 TURNS 1902½-a 24 27 27 04 80 52 79 58
				7942	:			1933 — 1938½
				2121 2727	-:2124 2:7 13			1953 — 2006 G 2733 7930
				7939	7:9 56			2014 — 2017 2 2732 2712 360's 80 00 80 01
				2130¾ 2713	-:2136½ :27 19			2038 — 2041 2620 2609 8025 8045
				8018	:79 35			2050½ — 2057 2606 2626 8056 8019
					:			2101 2638 7946

OMI

Figure 29. Pilot's flight log for CAMEX flight 8.

SECTION IV. DAILY SUMMARIES

Table 6 provides a synopsis of the CAMEX program with the significant activities listed for each day of the experiment. Table 7 shows the Wallops Island weather observation for each day (starting on September 12) during CAMEX. The remaining pages of this section document each day of the CAMEX field operations. Each daily summary (see Section I for a description of the CAMEX day) includes (if available) an experiment summary, a copy of the NOAA *Daily Weather Map*, Meteosat imagery (a sample of visible, IR, or water vapor), and a plot of the 0000 GMT Wallops Island rawinsonde. Although CAMEX operations did not occur on every day, the summary for each day is here included for continuity. As mentioned in Section II, the imagery and plots are included in this section for the purpose of providing an overview of CAMEX. The data have not been processed or quality controlled in any fashion. To acquire scientific quality data, you can contact the appropriate agencies.

Table 6. CAMEX operations schedule

CAMEX Day	Calendar Day	Significant Events
1	Tues, 7 Sept	Raman lidar operations begin
2	Wed, 8 Sept	
3	Thur, 9 Sept	Lidar
4	Fri, 10 Sept	
5	Sat, 11 Sept	ER-2 integration flight at ARC
6	Sun, 12 Sept	ER-2 ferry flight to WFF GB-HIS deployed First CLASS sondes launched
7	Mon, 13 Sept	Lidar and GB-HIS operated First WFF rawinsondes launched
8	Tues, 14 Sept	GB-HIS
9	Wed, 15 Sept	ER-2 flight - aborted due to pressurization problem GB-HIS and Lidar
10	Thur, 16 Sept	GB-HIS
11	Fri, 17 Sept	GB-HIS
12	Sat, 18 Sept	No activity
13	Sun, 19 Sept	ER-2 flight - aborted due to hydraulic system failure Lidar and GB-HIS
14	Mon, 20 Sept	
15	Tues, 21 Sept	Johns Hopkins Research Vessel, "Chessie," deployed Lidar and GB-HIS
16	Wed, 22 Sept	Lidar, GB-HIS, and "Chessie"
17	Thur, 23 Sept	Lidar, GB-HIS, and "Chessie"
18	Fri, 24 Sept	GB-HIS
19	Sat, 25 Sept	ER-2 maintenance test flight GB-HIS
20	Sun, 26 Sept	ER-2 convection flight (5 hour) GB-HIS
21	Mon, 27 Sept	GB-HIS
22	Tues, 28 Sept	ER-2 AIRS flight (4 hour) Lidar, GB-HIS, and "Chessie"
23	Wed, 29 Sept	Lidar, GB-HIS, and "Chessie"
24	Thur, 30 Sept	ER-2 SSM/T-2 flight (7 hour) Lidar and GB-HIS
25	Fri, 1 Oct	GB-HIS
26	Sat, 2 Oct	GB-HIS
27	Sun, 3 Oct	ER-2 convection flight (7.5 hour) Lidar and GB-HIS
28	Mon, 4 Oct	Lidar and GB-HIS
29	Tues, 5 Oct	ER-2 convection flight (7 hour) Lidar and GB-HIS
30	Wed, 6 Oct	ER-2 instruments off-loaded GB-HIS and Lidar shut down
31	Thur, 7 Oct	ER-2 ferry flight back to ARC (only MTS onboard)

Table 7. Weather summary for Wallops Island during CAMEX

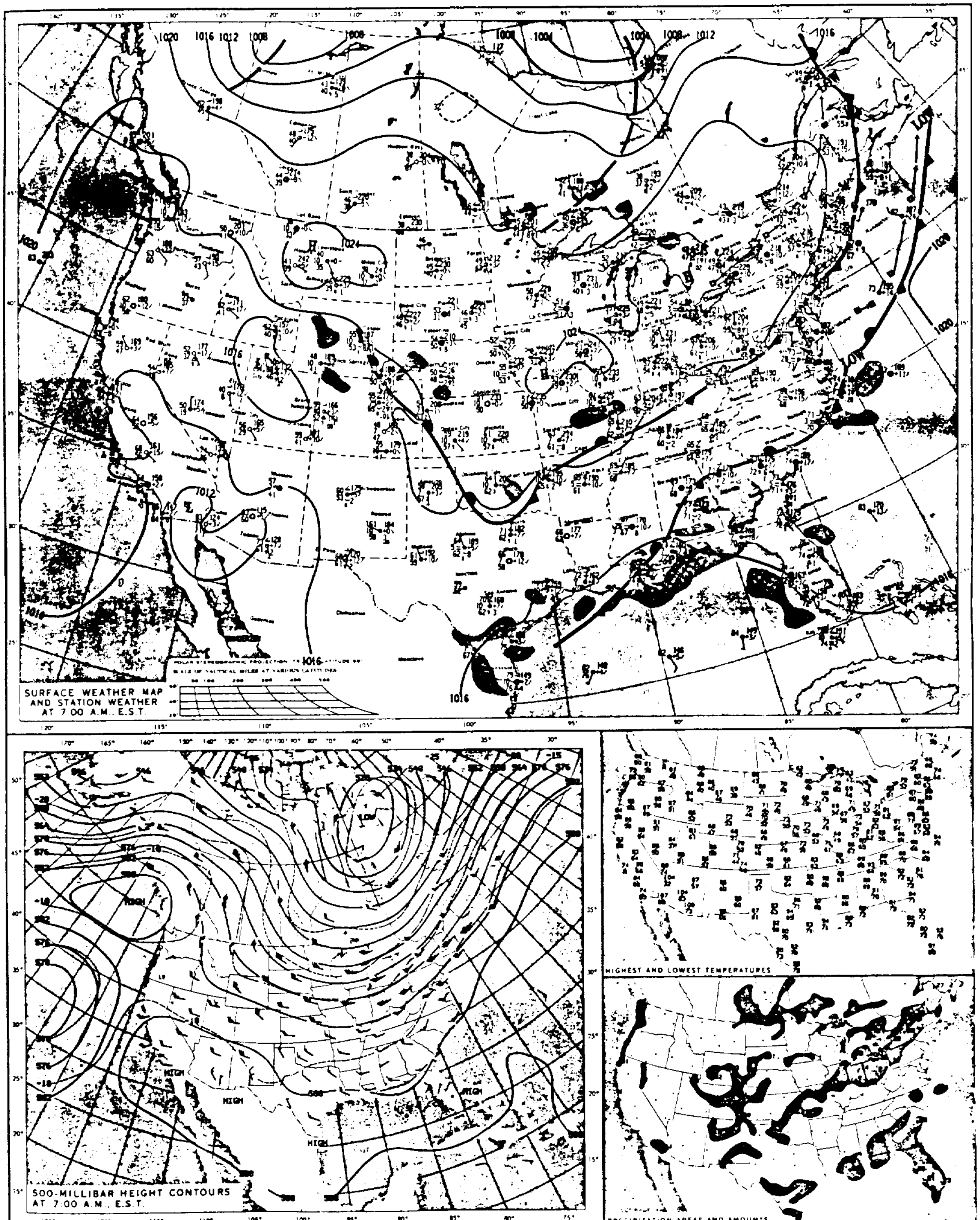
Date	Max T (F)	Td (F)	Weather	Minimum Ceiling
9/12/93	75			
9/13/93	81	62		
9/14/93	81	64		250
9/15/93	88	70		
9/16/93	79	70	F H	M7
9/17/93	74	69	F	M3
9/18/93	76		F R	
9/19/93	75		F	
9/20/93	70	49		M55
9/21/93	74	66	R L F	M8
9/22/93	74	59	F	M5
9/23/93	76	62	F H	140
9/24/93	73	53	F H	M21
9/25/93	73		F R	
9/26/93	86		F R H	
9/27/93	78	70	R F	M5
9/28/93	69	47		
9/29/93	70	42		
9/30/93	61	38	RW F	M40
10/1/93	65	47		
10/2/93	72			
10/3/93	69		Trace R	
10/4/93	77	44		
10/5/93	67	38		
10/6/93	67	44		250
10/7/93	73	60		250
10/8/93	69	64	R	130

CAMEX FLIGHT DAY 1 - ACTIVITY

				CAMEX Experiment Schedule for CAMEX Operations Day 1																					
				Julian Day 9/07/93											Julian Day 9/08/93										
TIME (GMT Hour)	12	13	14	15	16	17	18	19	20	21	22	23	0	1	2	3	4	5	6	7	8	9	10	11	12
ER-2 Instruments																									
AMPR																									
EDOP																									
HIS																									
LIP																									
MAMS																									
MIR																									
MTS																									
Ground Sensors																									
Raman Lidar														X	X										
HIS																									
Johns Hopkins/APL Ship																									
CLASS Sonde																									
Rawinsonde																									
VIZ																									
Vaisala																									
AIR																									
Ozone Sonde																									

CAMEX FLIGHT DAY 1 - SYNOPTIC CHARTS

TUESDAY, SEPTEMBER 7, 1993

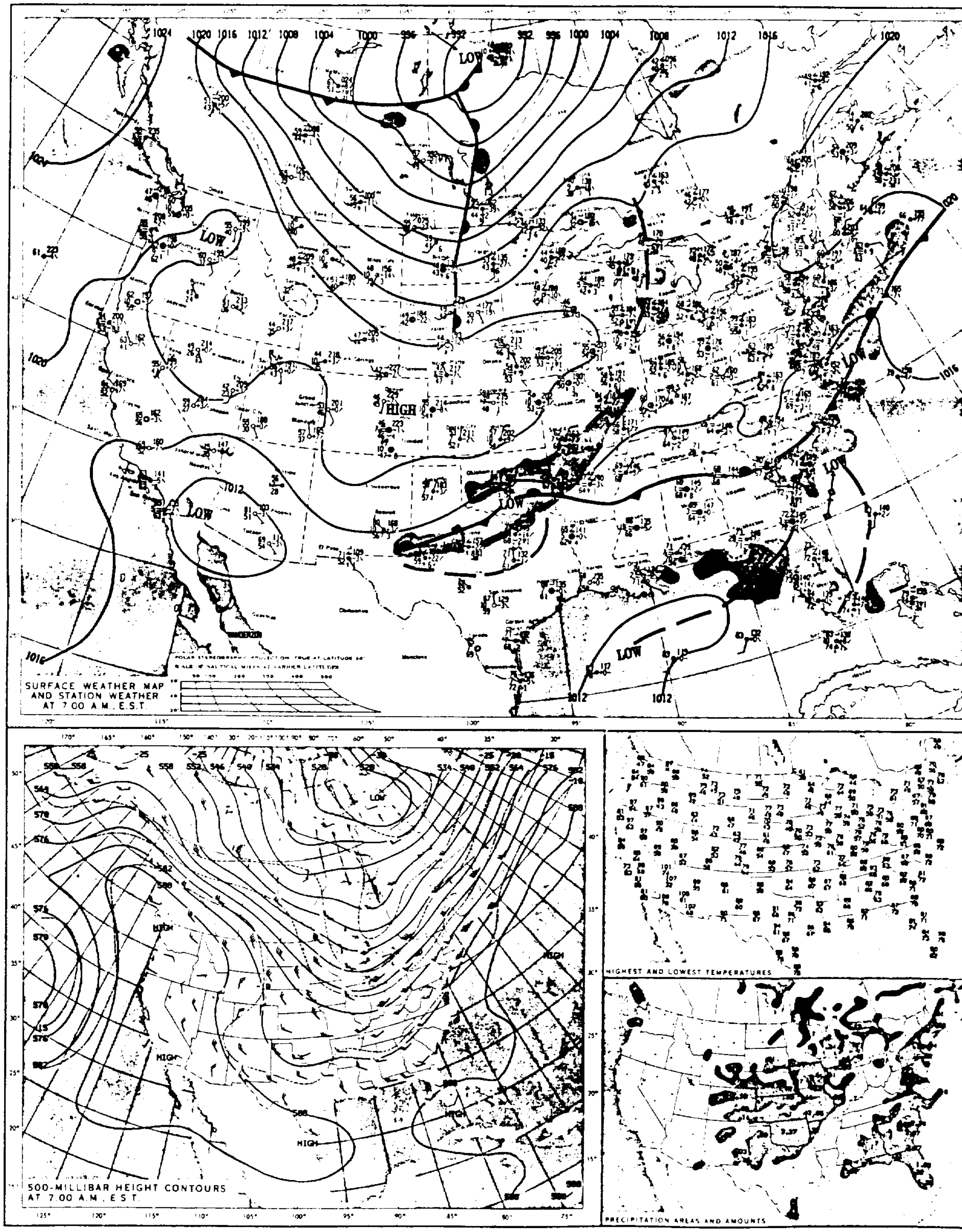


CAMEX FLIGHT DAY 2 - ACTIVITY

CAMEX Experiment Schedule for CAMEX Operations Day 2																									
				Julian Day 9/08/93												Julian Day 9/09/93									
TIME (GMT Hour)	12	13	14	15	16	17	18	19	20	21	22	23	0	1	2	3	4	5	6	7	8	9	10	11	12
ER-2 Instruments																									
AMPR																									
EDOP																									
HIS																									
LIP																									
MAMS																									
MIR																									
MTS																									
Ground Sensors																									
Raman Lidar																									
HIS																									
Johns Hopkins/APL Ship																									
CLASS Sonde																									
Rawinsonde																									
VIZ																									
Vaisala																									
AIR																									
Ozone Sonde																									

CAMEX FLIGHT DAY 2 - SYNOPTIC CHARTS

WEDNESDAY, SEPTEMBER 8, 1993

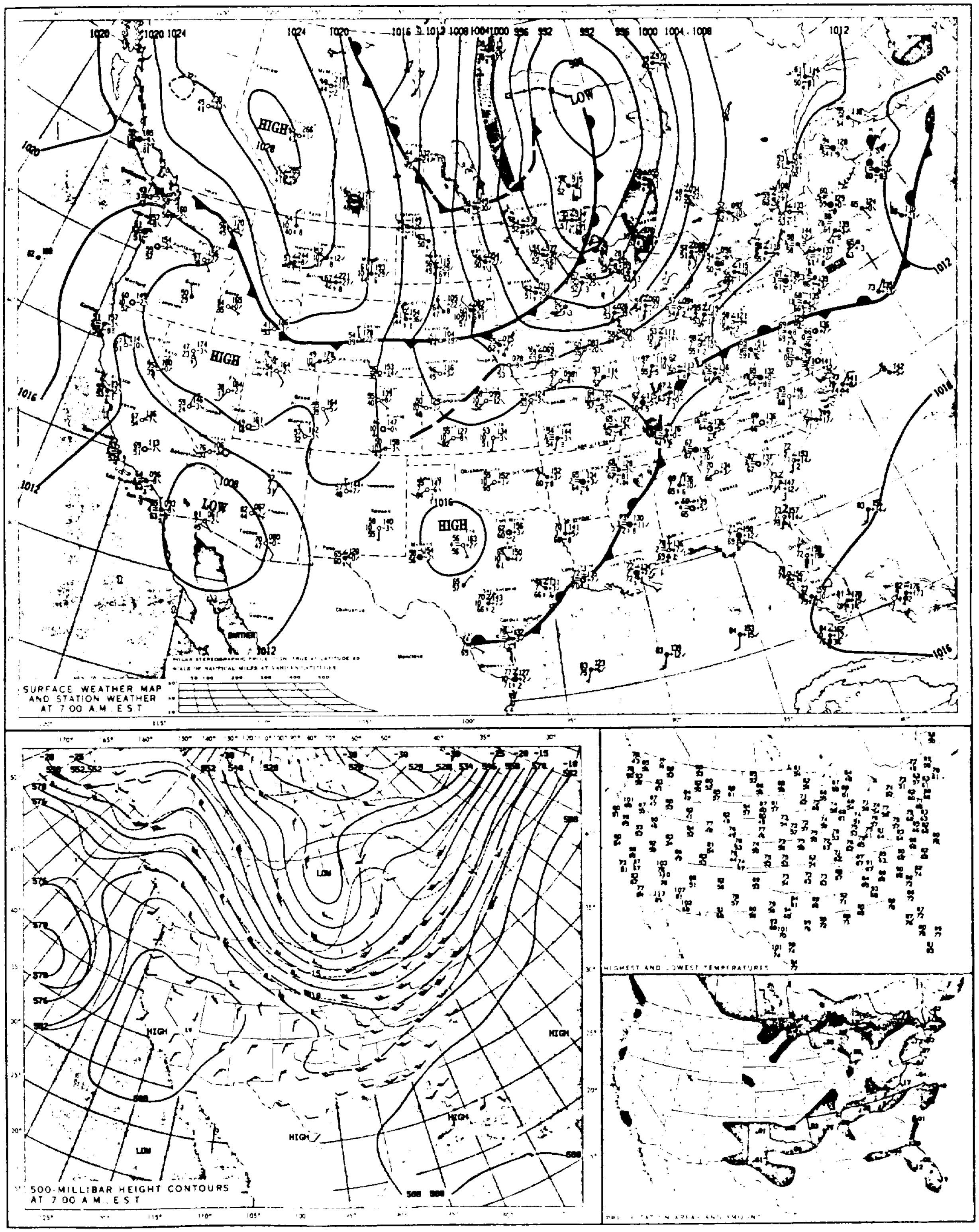


CAMEX FLIGHT DAY 3 - ACTIVITY

				CAMEX Experiment Schedule for CAMEX Operations Day 3																					
				Julian Day 9/09/93												Julian Day 9/10/93									
TIME (GMT Hour)	12	13	14	15	16	17	18	19	20	21	22	23	0	1	2	3	4	5	6	7	8	9	10	11	12
ER-2 Instruments																									
AMPR																									
EDOP																									
HIS																									
LIP																									
MAMS																									
MIR																									
MTS																									
Ground Sensors																									
Raman Lidar														X	X										
HIS																									
Johns Hopkins/APL Ship																									
CLASS Sonde																									
Rawinsonde																									
VIZ																									
Vaisala																									
AIR																									
Ozone Sonde																									

CAMEX FLIGHT DAY 3 - SYNOPTIC CHARTS

THURSDAY, SEPTEMBER 9, 1993

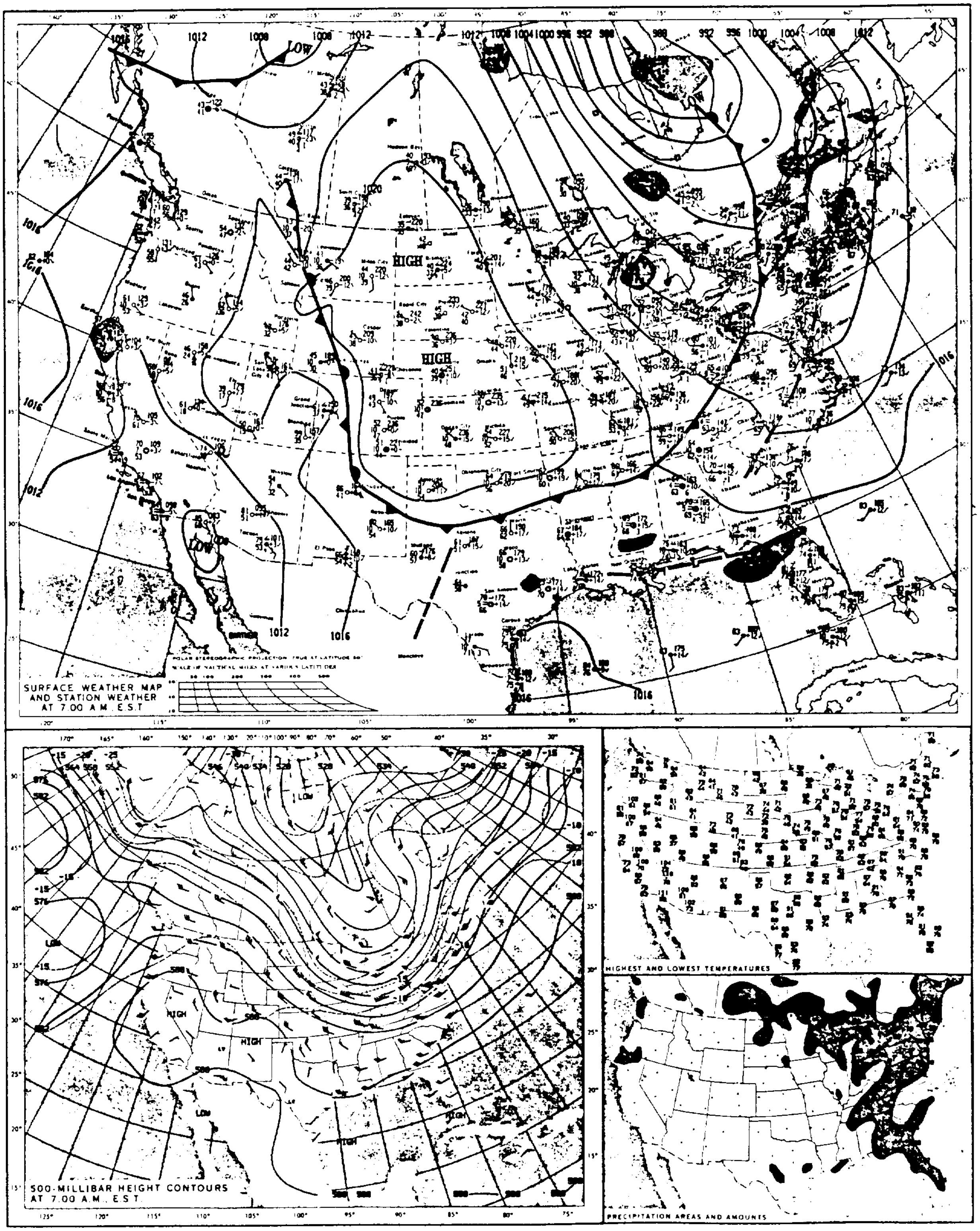


CAMEX FLIGHT DAY 4 - ACTIVITY

				CAMEX Experiment Schedule for CAMEX Operations Day 4																					
				Julian Day 9/10/93											Julian Day 9/11/93										
TIME (GMT Hour)	12	13	14	15	16	17	18	19	20	21	22	23	0	1	2	3	4	5	6	7	8	9	10	11	12
ER-2 Instruments																									
AMPR																									
EDOP																									
HIS																									
LIP																									
MAMS																									
MIR																									
MTS																									
Ground Sensors																									
Raman Lidar																									
HIS																									
Johns Hopkins/APL Ship																									
CLASS Sonde																									
Rawinsonde																									
VIZ																									
Vaisala																									
AIR																									
Ozone Sonde																									

CAMEX FLIGHT DAY 4 - SYNOPTIC CHARTS

FRIDAY, SEPTEMBER 10, 1993

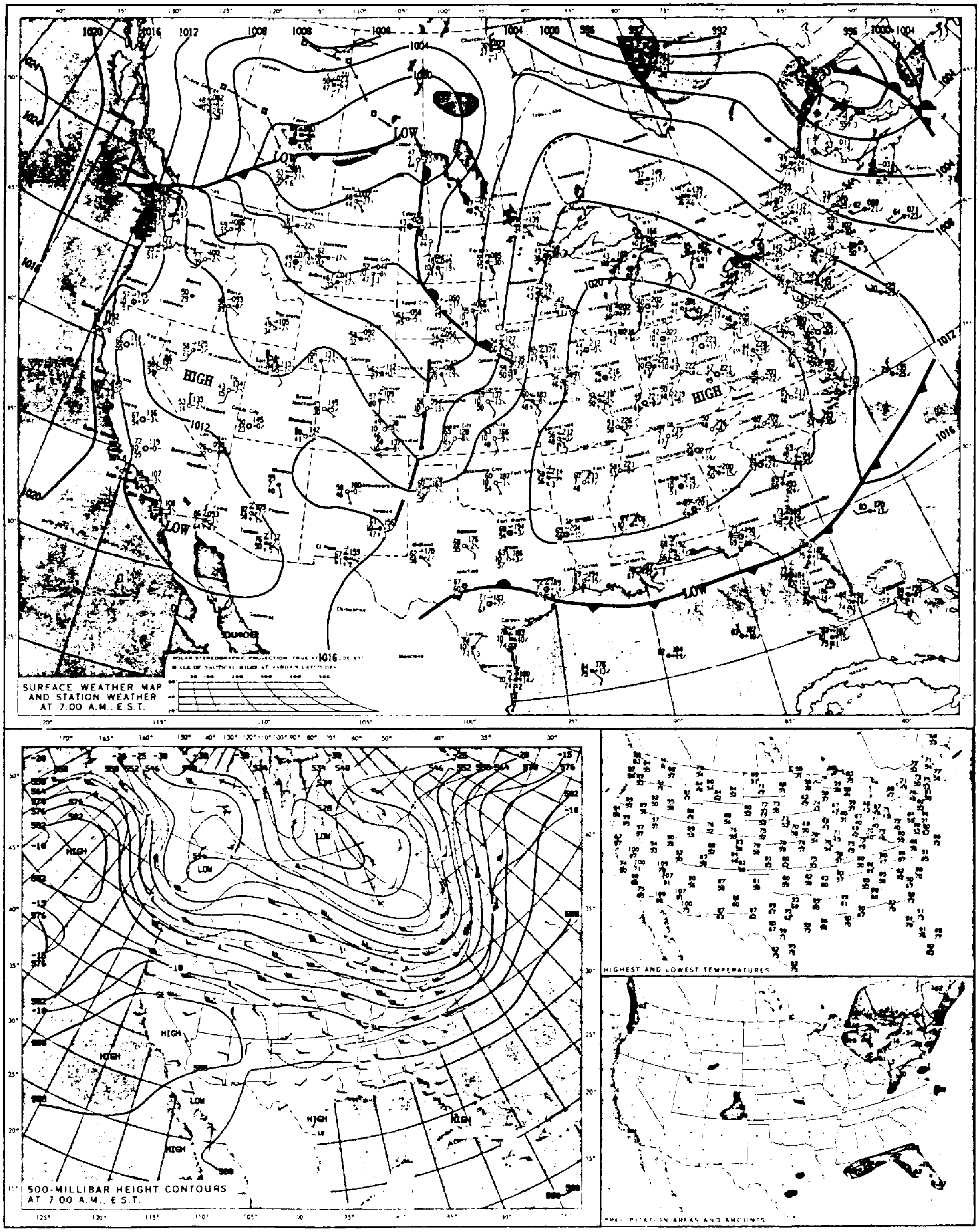


CAMEX FLIGHT DAY 5 - ACTIVITY

				CAMEX Experiment Schedule for CAMEX Operations Day 5																					
				Julian Day 9/11/93											Julian Day 9/12/93										
TIME (GMT Hour)	12	13	14	15	16	17	18	19	20	21	22	23	0	1	2	3	4	5	6	7	8	9	10	11	12
ER-2 Instruments																									
AMPR																									
EDOP																									
HIS																									
LIP																									
MAMS																									
MIR																									
MTS																									
Ground Sensors																									
Raman Lidar																									
HIS																									
Johns Hopkins/APL Ship																									
CLASS Sonde																									
Rawinsonde																									
VIZ																									
Vaisala																									
AIR																									
Ozone Sonde																									

CAMEX FLIGHT DAY 5 - SYNOPTIC CHARTS

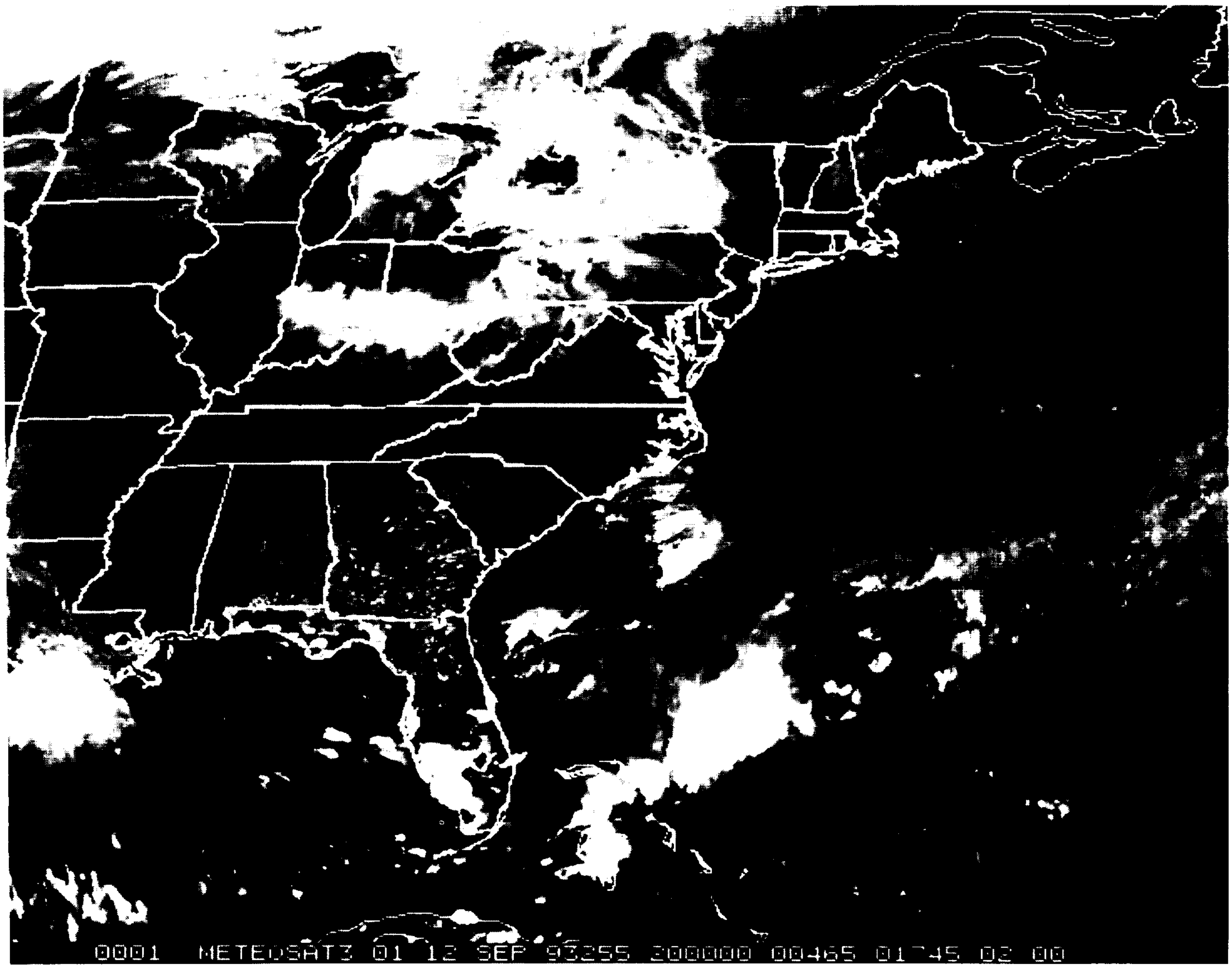
SATURDAY, SEPTEMBER 11, 1993



CAMEX FLIGHT DAY 6 - ACTIVITY

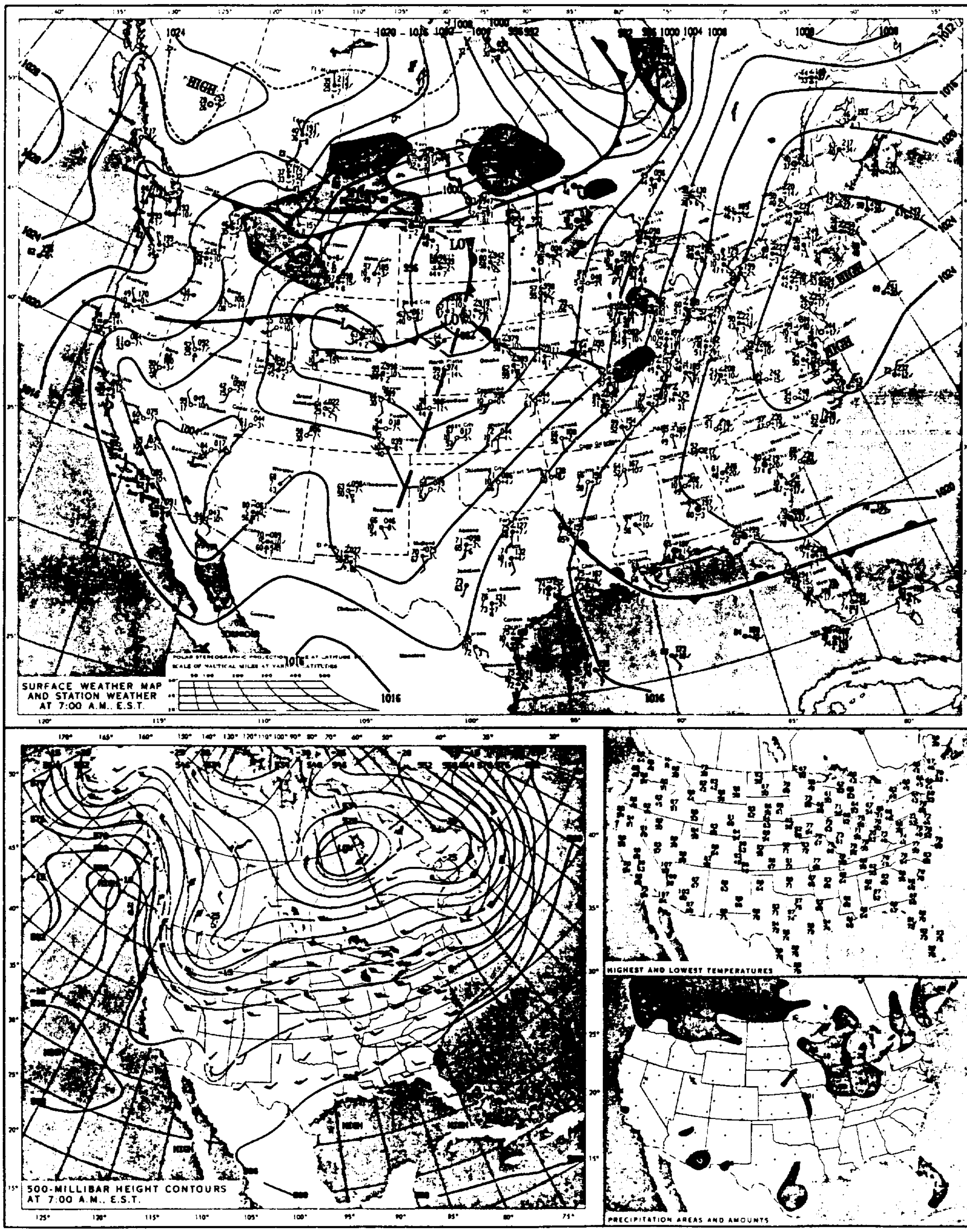
				CAMEX Experiment Schedule for CAMEX Operations Day 6																				
				Julian Day 9/12/93											Julian Day 9/13/93									
TIME (GMT Hour)	12	13	14	15	16	17	18	19	20	21	22	23	0	1	2	3	4	5	6	7	8	9	10	11	12
ER-2 Instruments																									
AMPR									X	X	X	X	X	X	X										
EDOP									X	X	X	X	X	X	X										
HIS									X	X	X	X	X	X	X										
LIP									X	X	X	X	X	X	X										
MAMS									F	F	F	F	F	F	F										
MIR									X	X	X	X	X	X	X										
MTS									X	X	X	X	X	X	X										
Ground Sensors																									
Raman Lidar													X	X	X	X									
HIS								X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
Johns Hopkins/APL Ship																									
CLASS Sonde									X					X		X									
Rawinsonde																									
VIZ																									
Vaisala																									
AIR																									
Ozone Sonde																									

CAMEX FLIGHT DAY 6 - SATELLITE IMAGERY



CAMEX FLIGHT DAY 6 - SYNOPTIC CHARTS

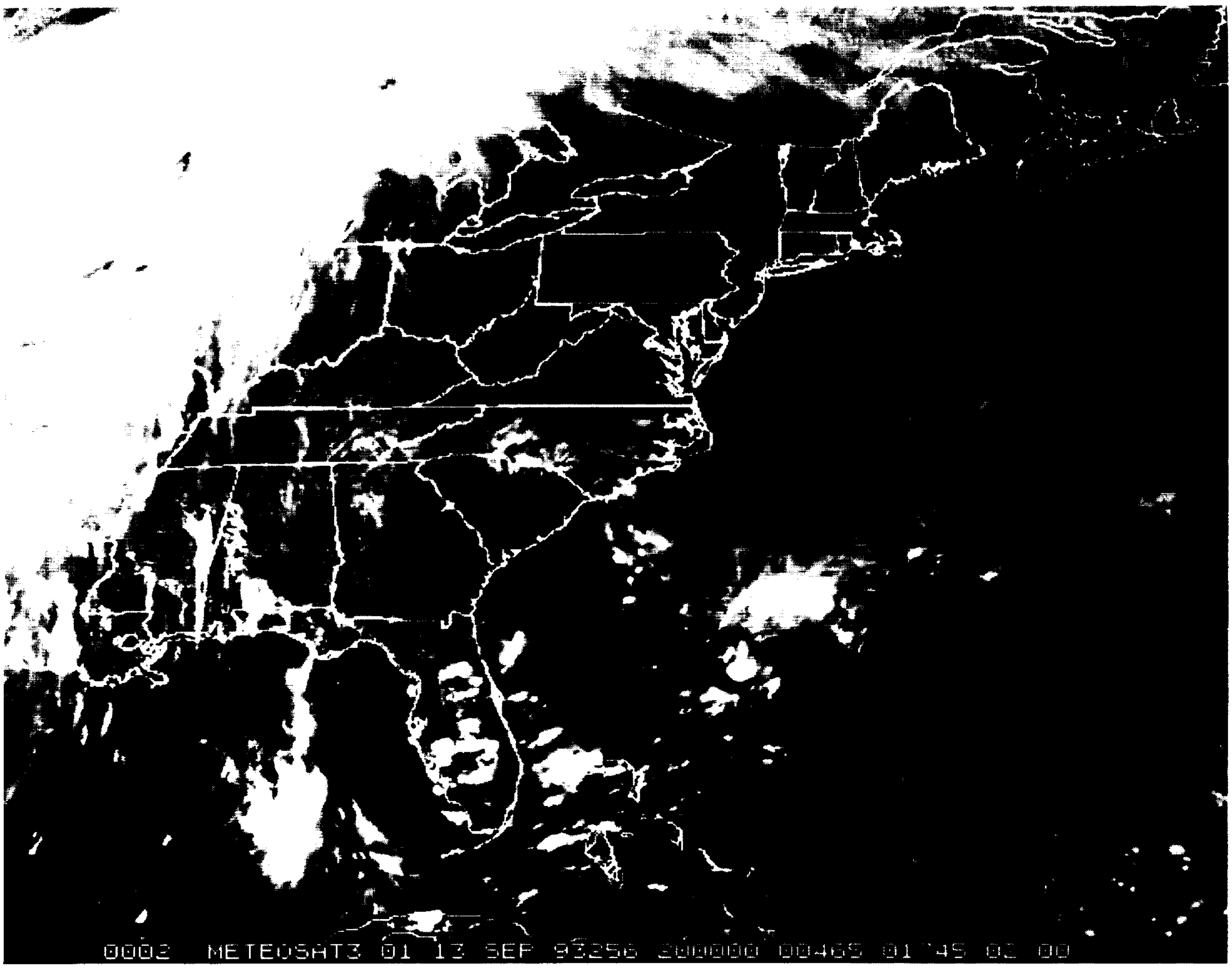
SUNDAY, SEPTEMBER 12, 1993



CAMEX FLIGHT DAY 7 - ACTIVITY

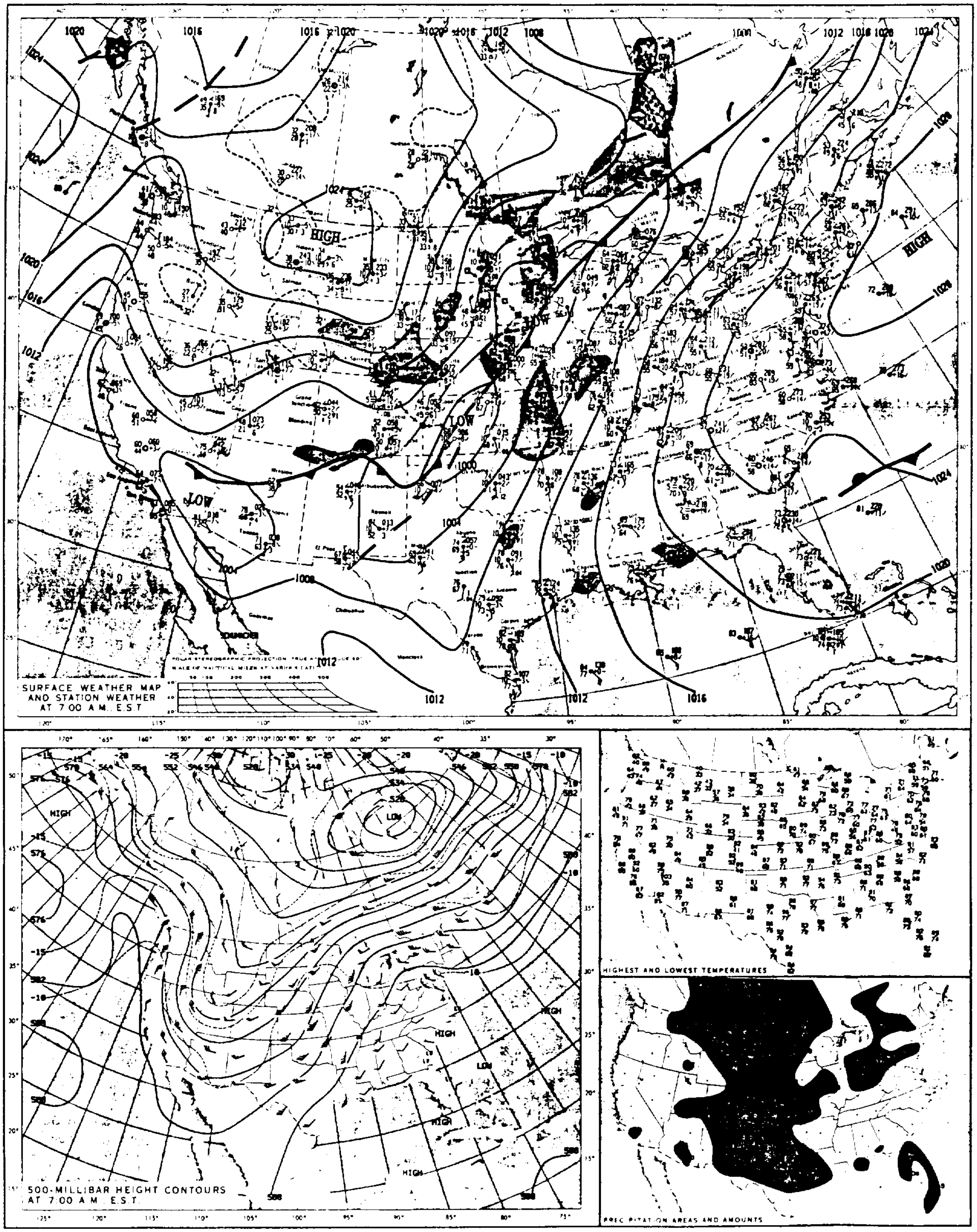
				CAMEX Experiment Schedule for CAMEX Operations Day 7																					
				Julian Day 9/13/93												Julian Day 9/14/93									
TIME (GMT Hour)	12	13	14	15	16	17	18	19	20	21	22	23	0	1	2	3	4	5	6	7	8	9	10	11	12
ER-2 Instruments																									
AMPR																									
EDOP																									
HIS																									
LIP																									
MAMS																									
MIR																									
MTS																									
Ground Sensors																									
Raman Lidar														X	X	X	X	X	X	X	X				
HIS	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
Johns Hopkins/APL Ship																									
CLASS Sonde											X			X			X			X					
Rawinsonde																									
VIZ																									
Vaisala											X			X			X								
AIR														X			X								
Ozone Sonde																									

CAMEX FLIGHT DAY 7 - SATELLITE IMAGERY

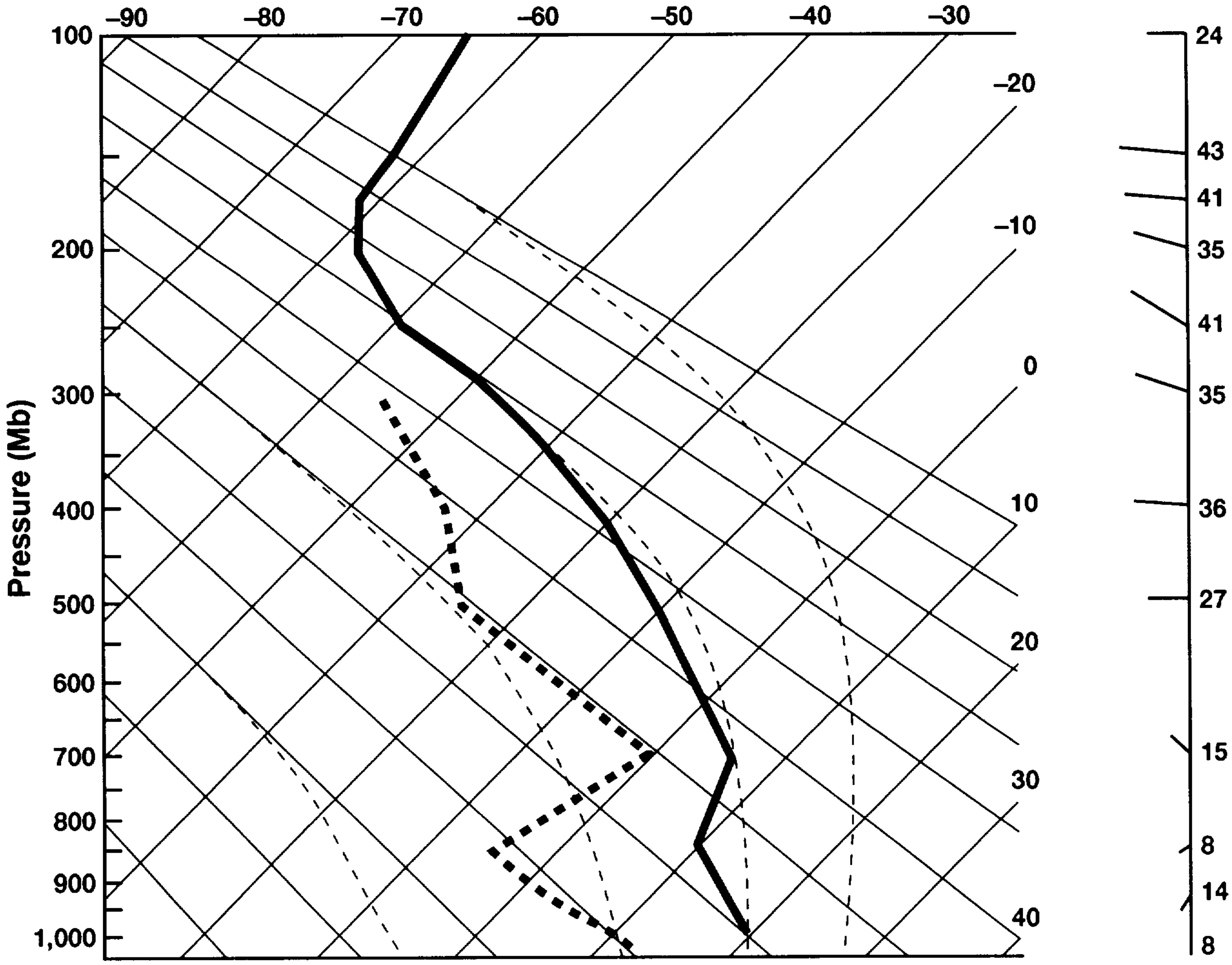


CAMEX FLIGHT DAY 7 - SYNOPTIC CHARTS

MONDAY, SEPTEMBER 13, 1993



CAMEX FLIGHT DAY 7 - WALLOPS RAWINSONDE

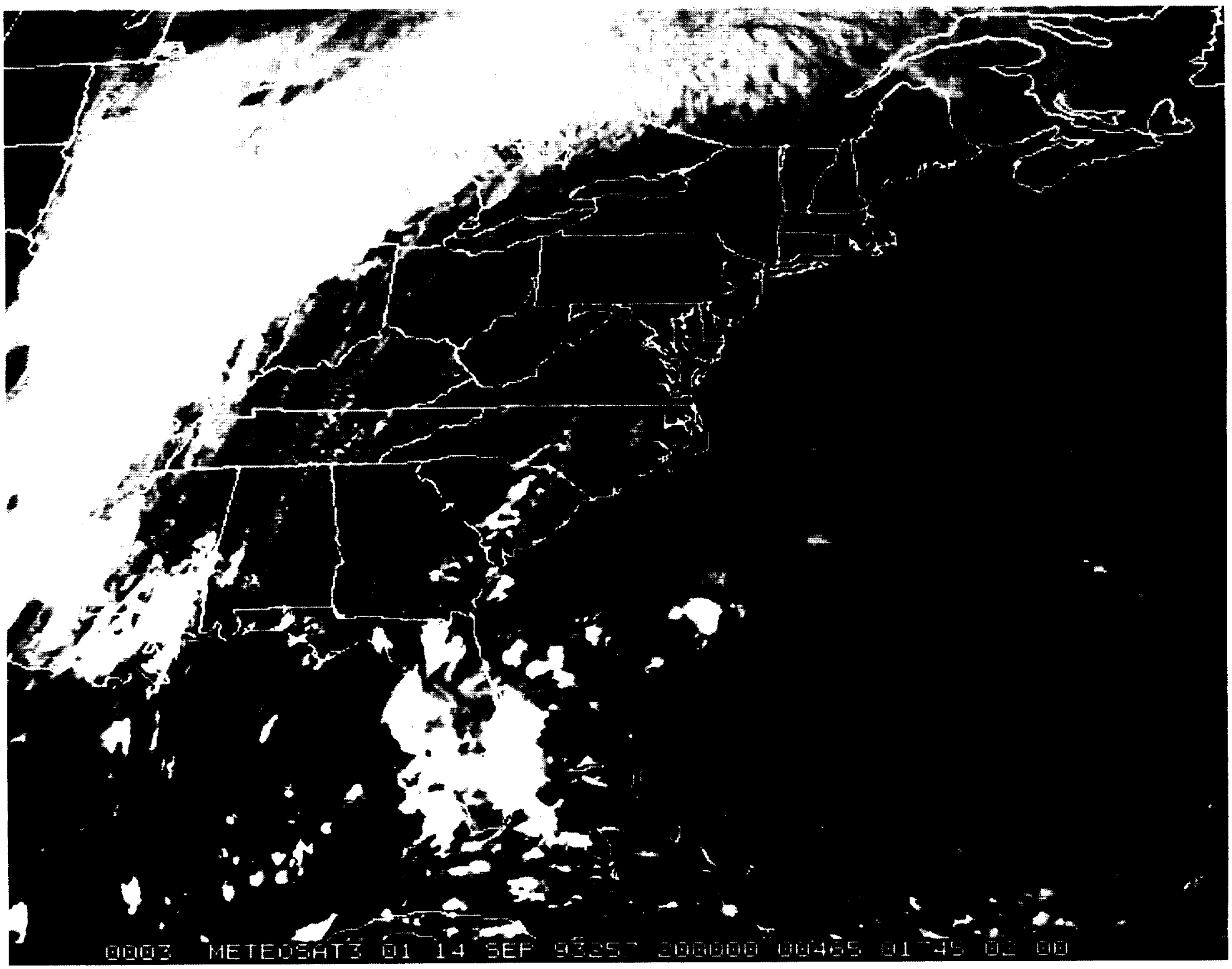


GMT	ID	TOTAL	EQUIP	FMAX	CVT	L.I.	KINX	PW
130,000	72,402	25		0		11	8	22

CAMEX FLIGHT DAY 8 - ACTIVITY

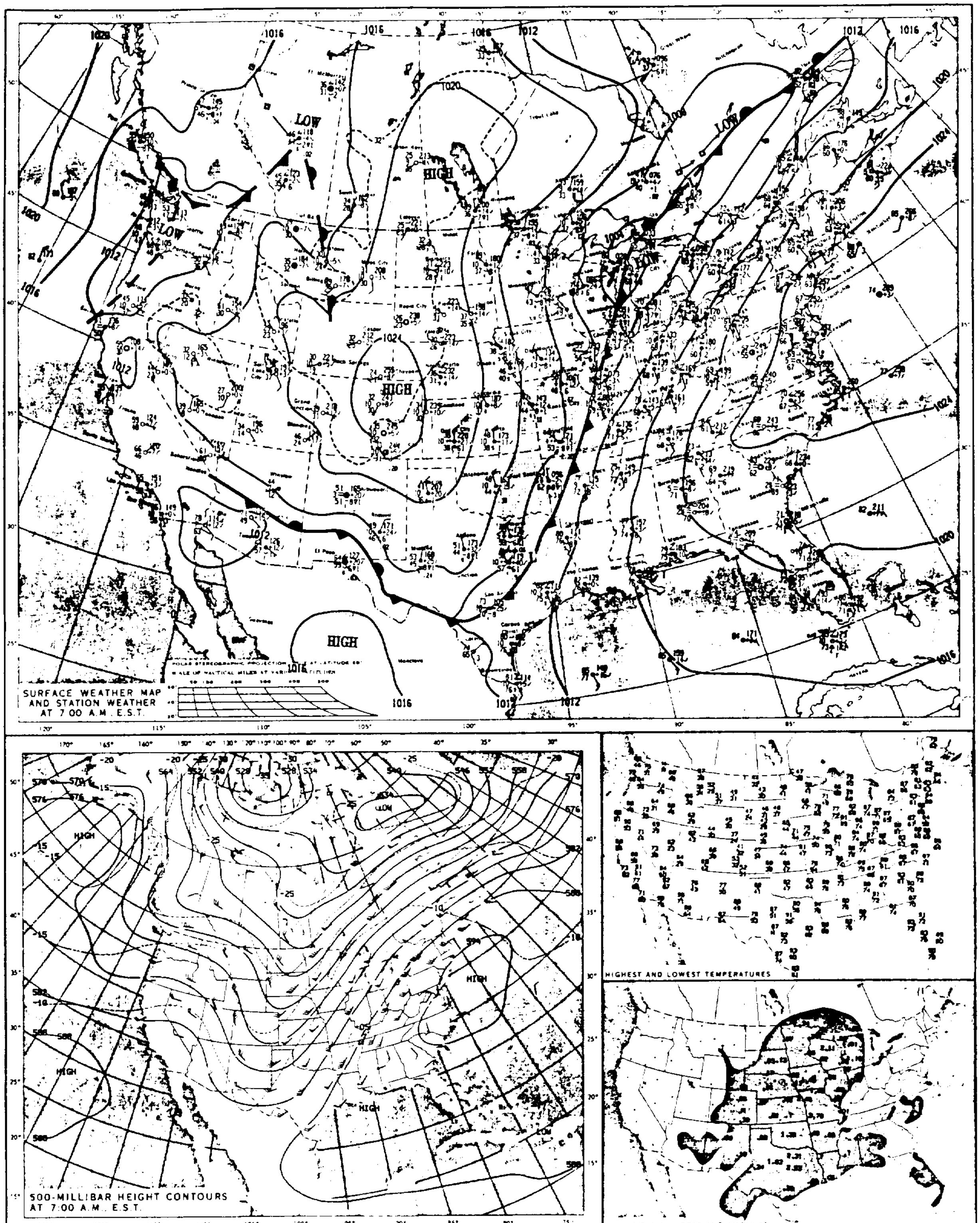
CAMEX Experiment Schedule for CAMEX Operations Day 8																									
				Julian Day 9/14/93												Julian Day 9/15/93									
TIME (GMT Hour)	12	13	14	15	16	17	18	19	20	21	22	23	0	1	2	3	4	5	6	7	8	9	10	11	12
ER-2 Instruments																									
AMPR																									
EDOP																									
HIS																									
LIP																									
MAMS																									
MIR																									
MTS																									
Ground Sensors																									
Raman Lidar																									
HIS	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
Johns Hopkins/APL Ship																									
CLASS Sonde																									
Rawinsonde																									
VIZ																									
Vaisala																									
AIR																									
Ozone Sonde																									

CAMEX FLIGHT DAY 8 - SATELLITE IMAGERY

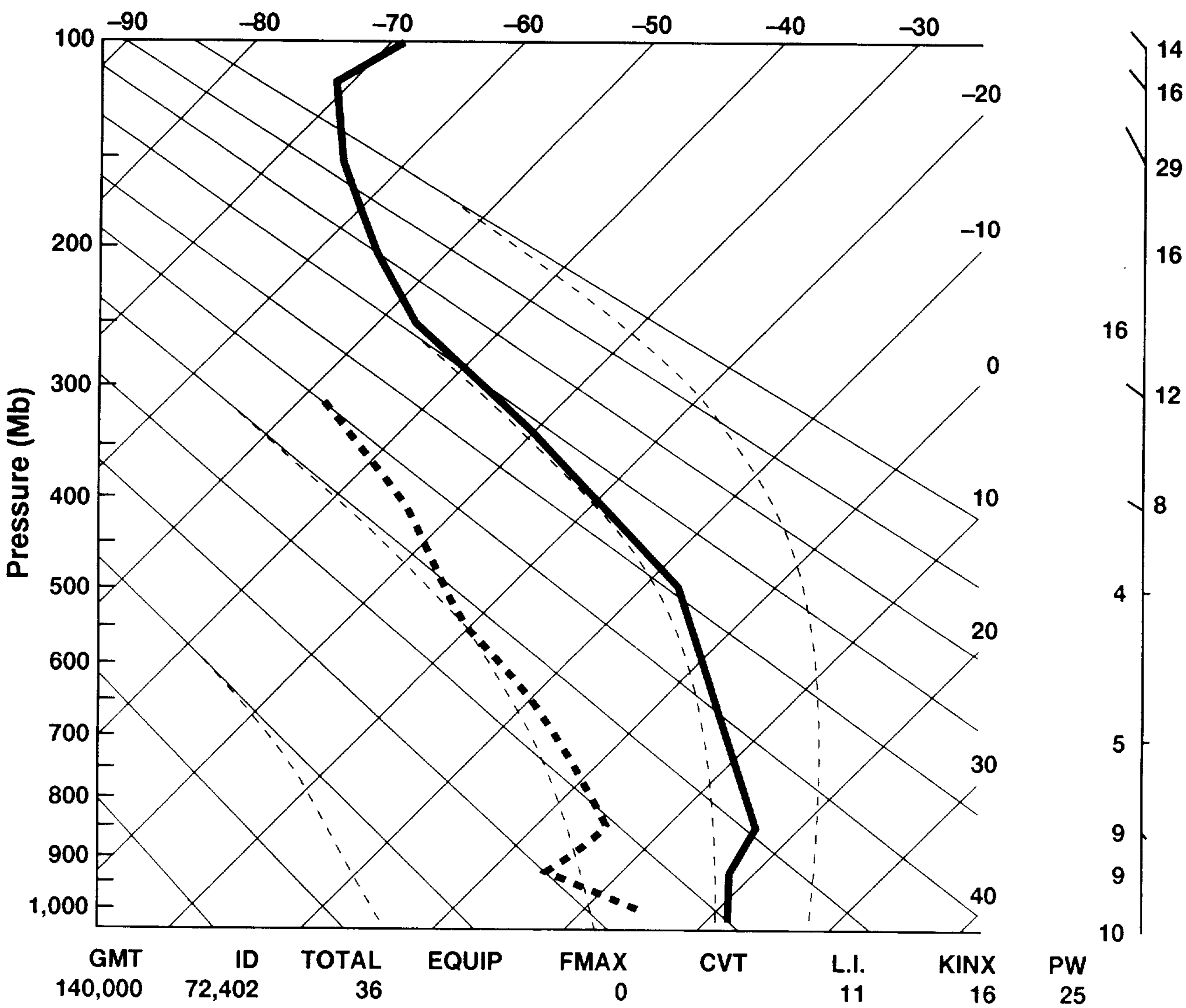


CAMEX FLIGHT DAY 8 - SYNOPTIC CHARTS

TUESDAY, SEPTEMBER 14, 1993



CAMEX FLIGHT DAY 8 - WALLOPS RAWINSONDE

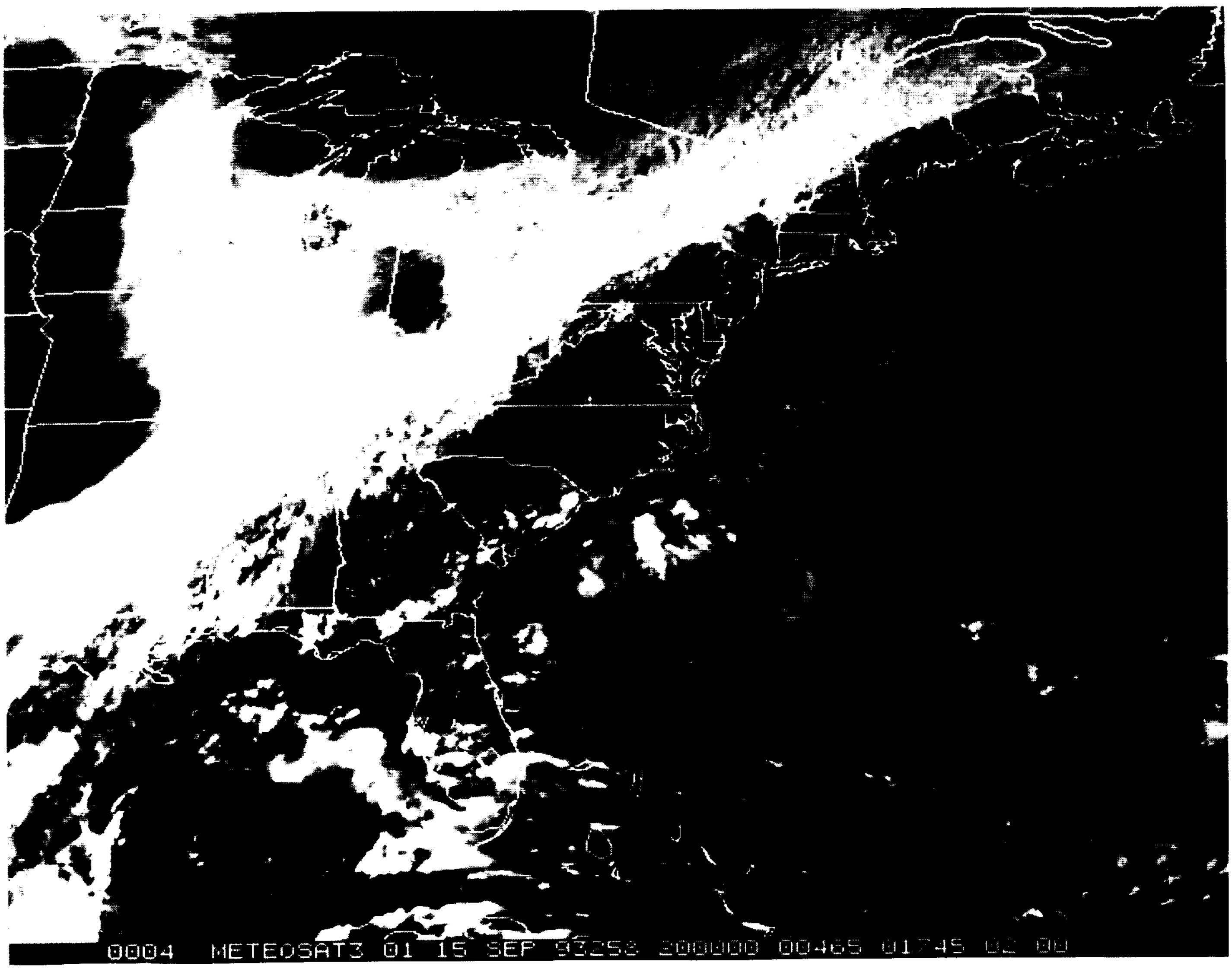


CAMEX FLIGHT DAY 9 - ACTIVITY

CAMEX Experiment Schedule for CAMEX Operations Day 9

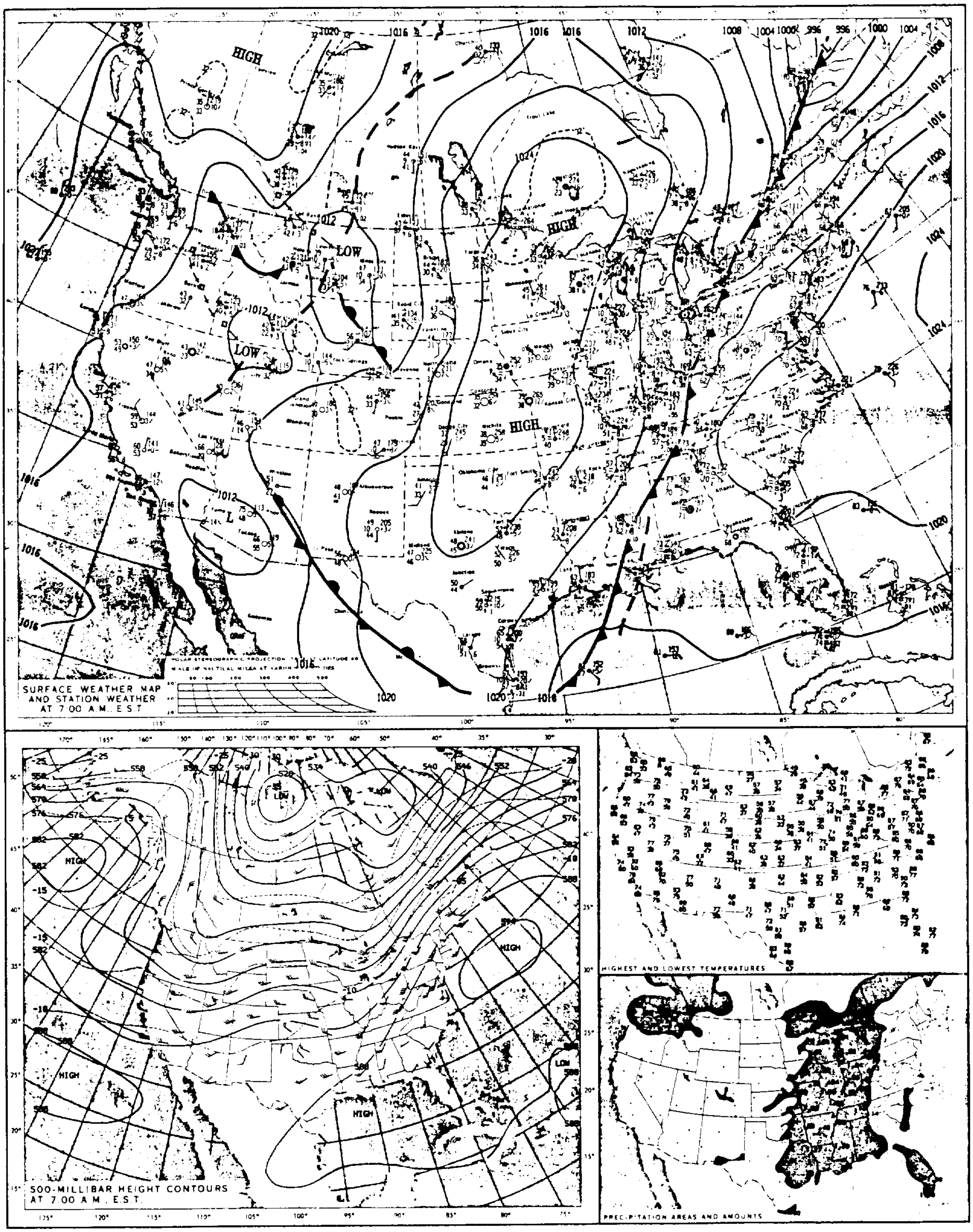
				Julian Day 9/15/93												Julian Day 9/16/93									
TIME (GMT Hour)	12	13	14	15	16	17	18	19	20	21	22	23	0	1	2	3	4	5	6	7	8	9	10	11	12
ER-2 Instruments																									
AMPR									X	X															
EDOP																									
HIS									X	X															
LIP									X	X															
MAMS									X	X															
MIR									X	X															
MTS									X	X															
Ground Sensors																									
Raman Lidar													X	X	X	X	X	X							
HIS	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
Johns Hopkins/APL Ship																									
CLASS Sonde									X		X			X			X								
Rawinsonde																									
VIZ											X						X								
Vaisala											X			X											
AIR											X			X											
Ozone Sonde																									

CAMEX FLIGHT DAY 9 - SATELLITE IMAGERY

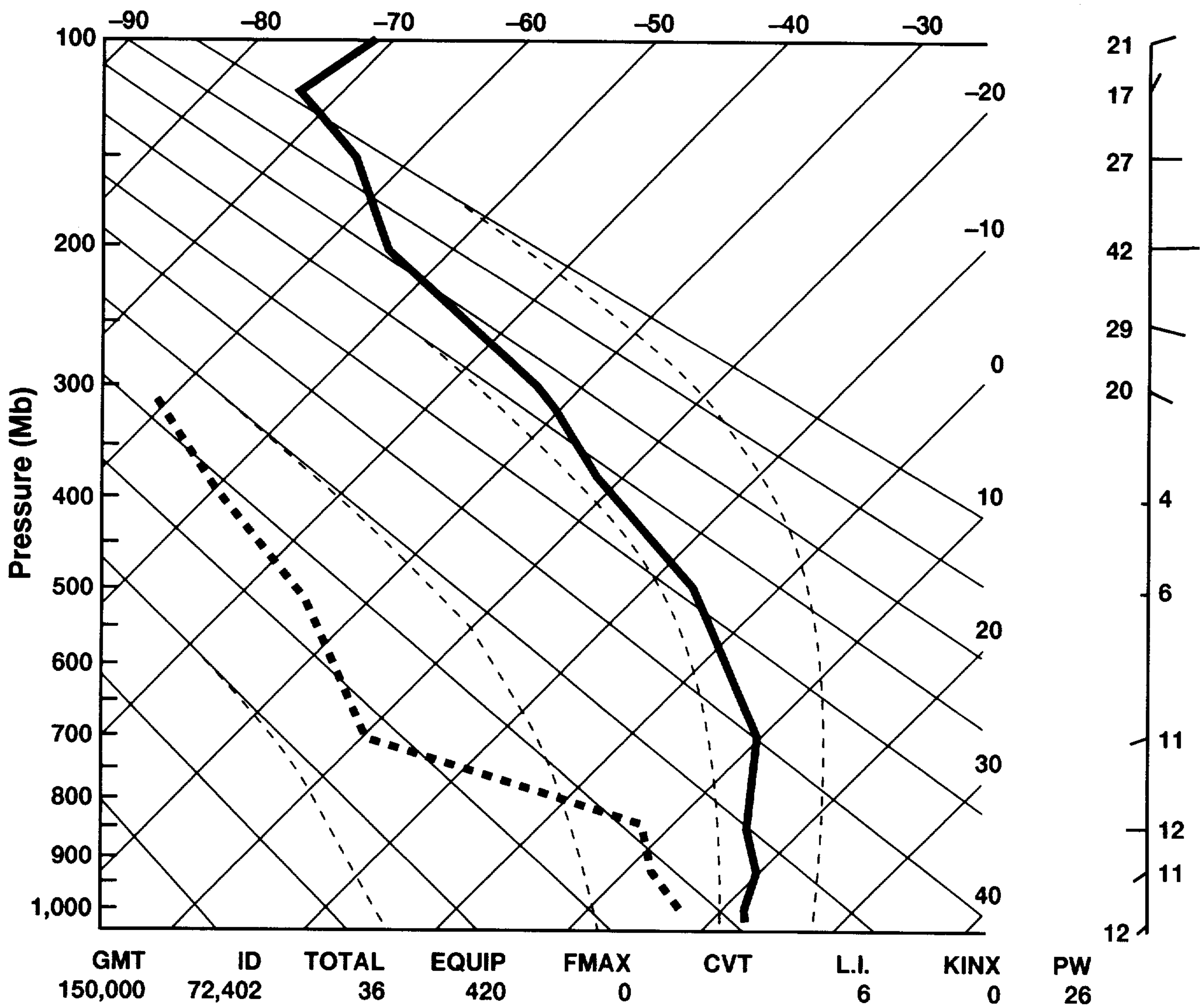


CAMEX FLIGHT DAY 9 - SYNOPTIC CHARTS

WEDNESDAY, SEPTEMBER 15, 1993



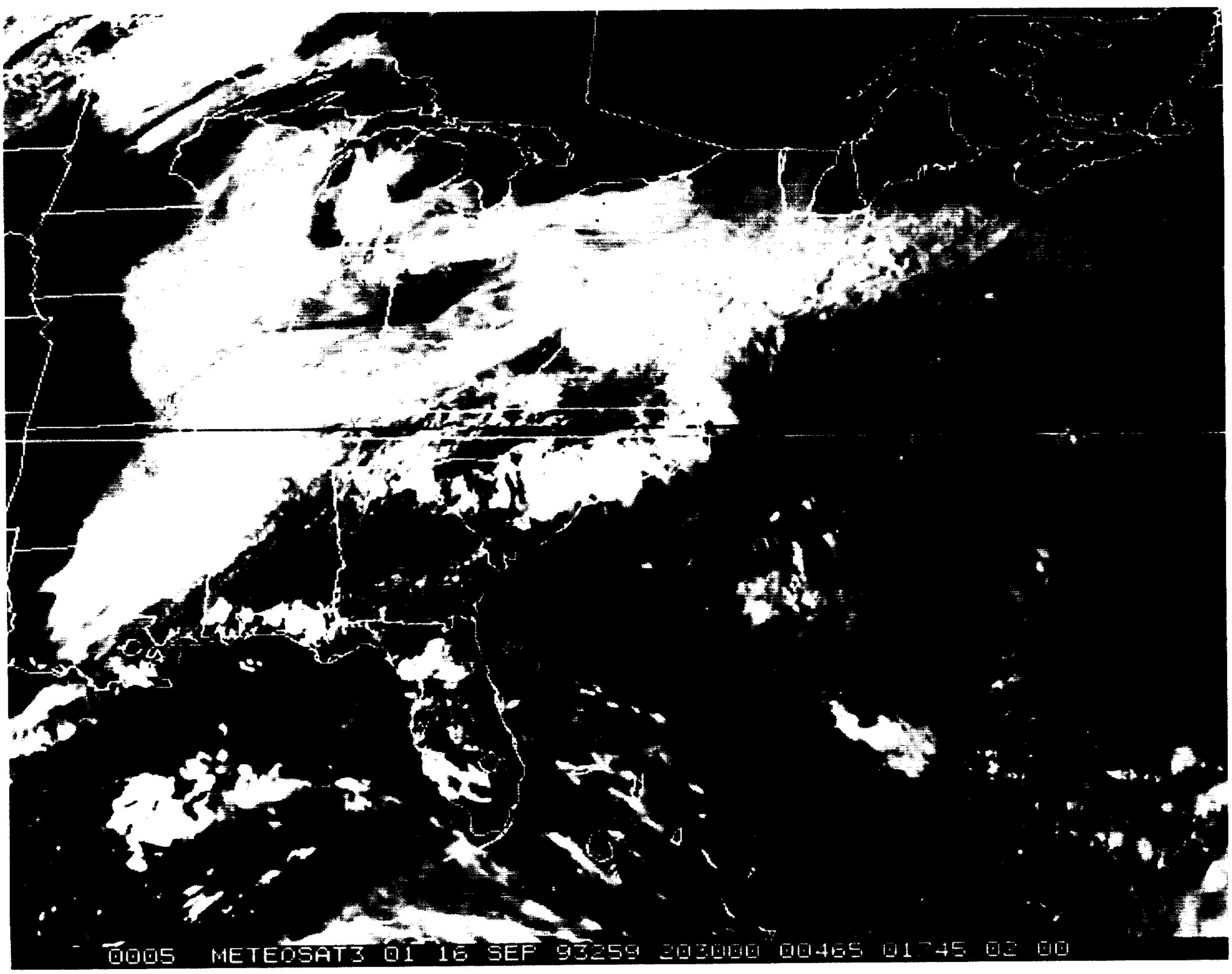
CAMEX FLIGHT DAY 9 - WALLOPS RAWINSONDE



CAMEX FLIGHT DAY 10 - ACTIVITY

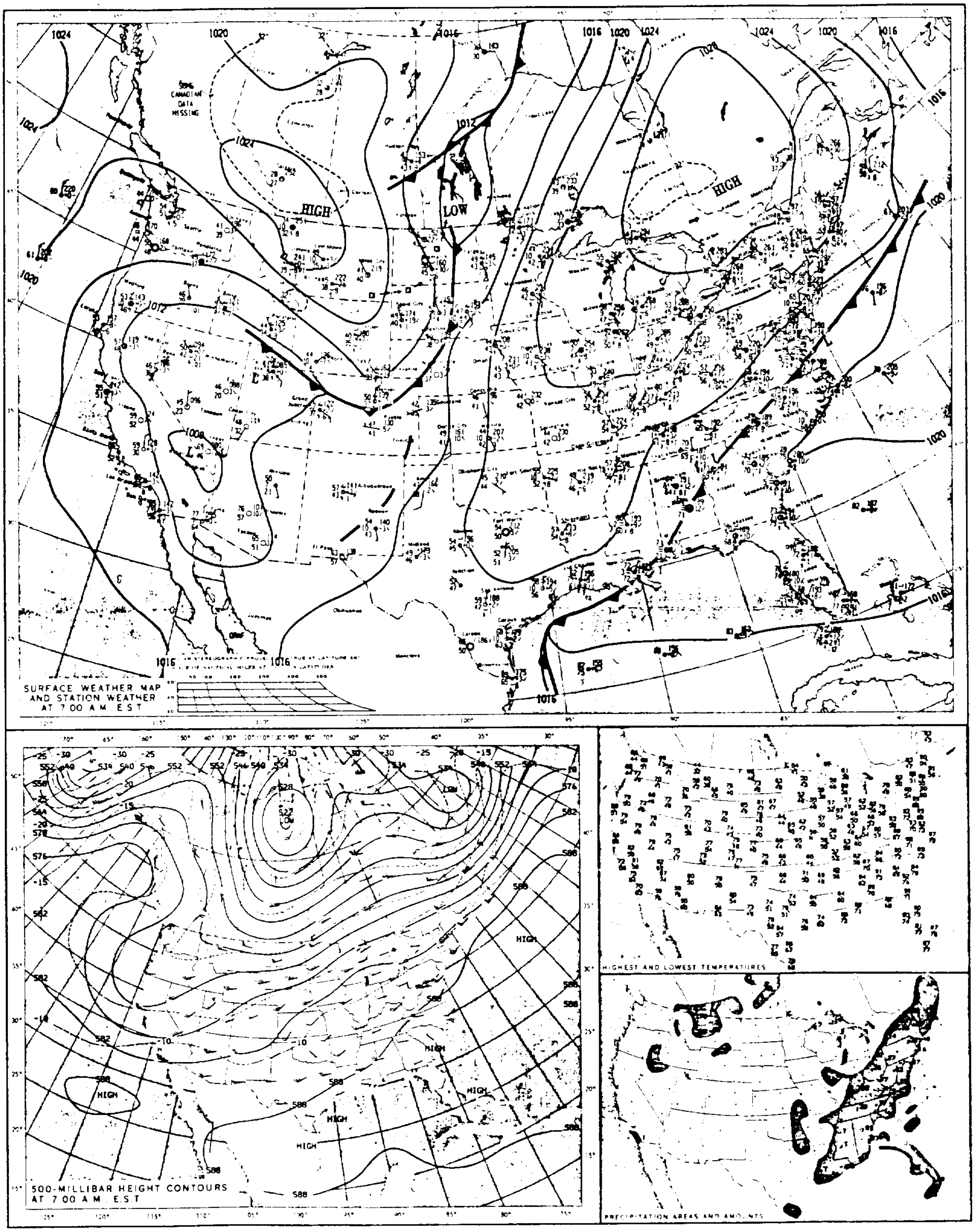
				CAMEX Experiment Schedule for CAMEX Operations Day 10																					
				Julian Day 9/16/93											Julian Day 9/17/93										
TIME (GMT Hour)	12	13	14	15	16	17	18	19	20	21	22	23	0	1	2	3	4	5	6	7	8	9	10	11	12
ER-2 Instruments																									
AMPR																									
EDOP																									
HIS																									
LIP																									
MAMS																									
MIR																									
MTS																									
Ground Sensors																									
Raman Lidar																									
HIS	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
Johns Hopkins/APL Ship																									
CLASS Sonde																									
Rawinsonde																									
VIZ																									
Vaisala																									
AIR																									
Ozone Sonde																									

CAMEX FLIGHT DAY 10 - SATELLITE IMAGERY

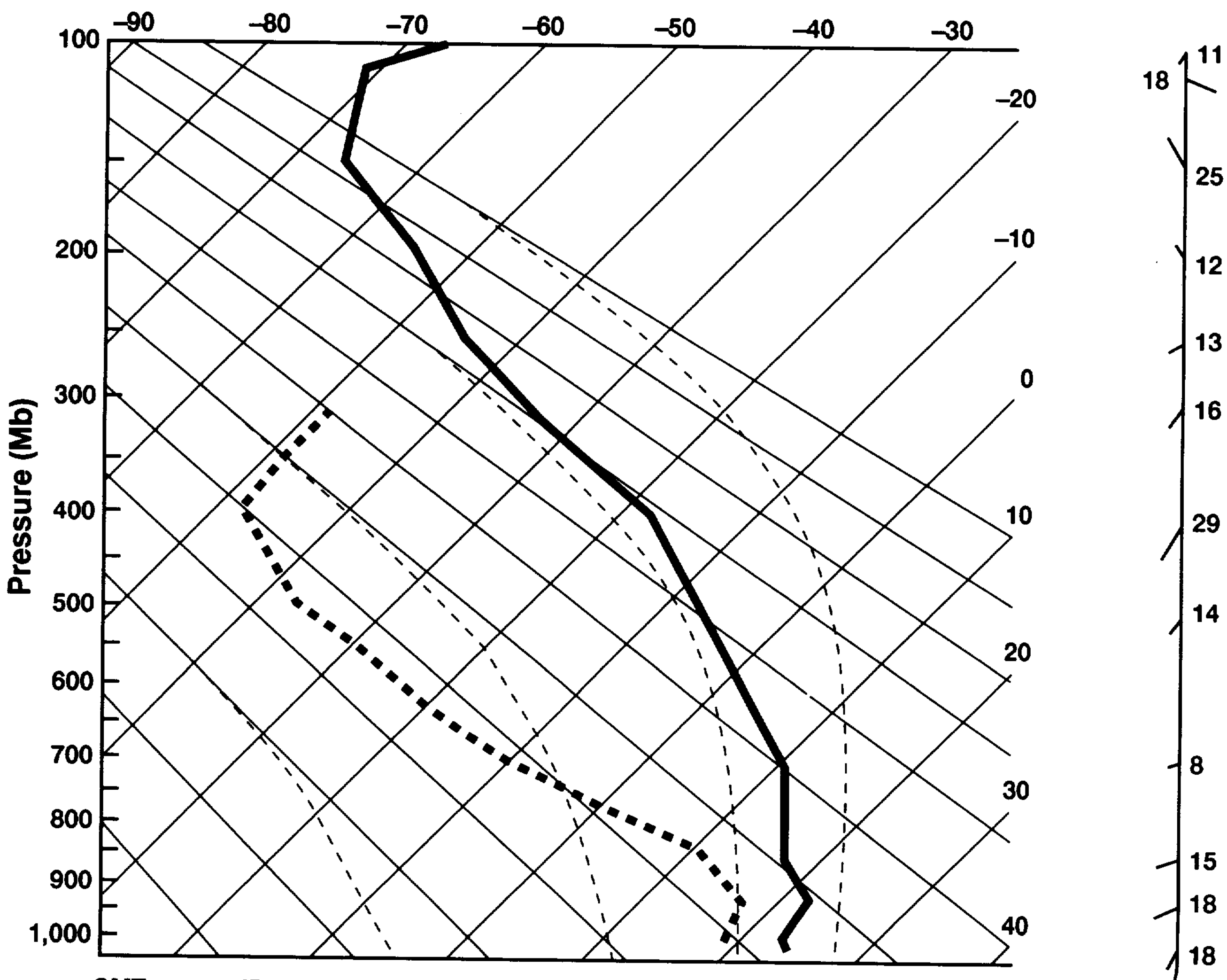


CAMEX FLIGHT DAY 10 - SYNOPTIC CHARTS

THURSDAY, SEPTEMBER 16, 1993



CAMEX FLIGHT DAY 10 - WALLOPS RAWINSONDE



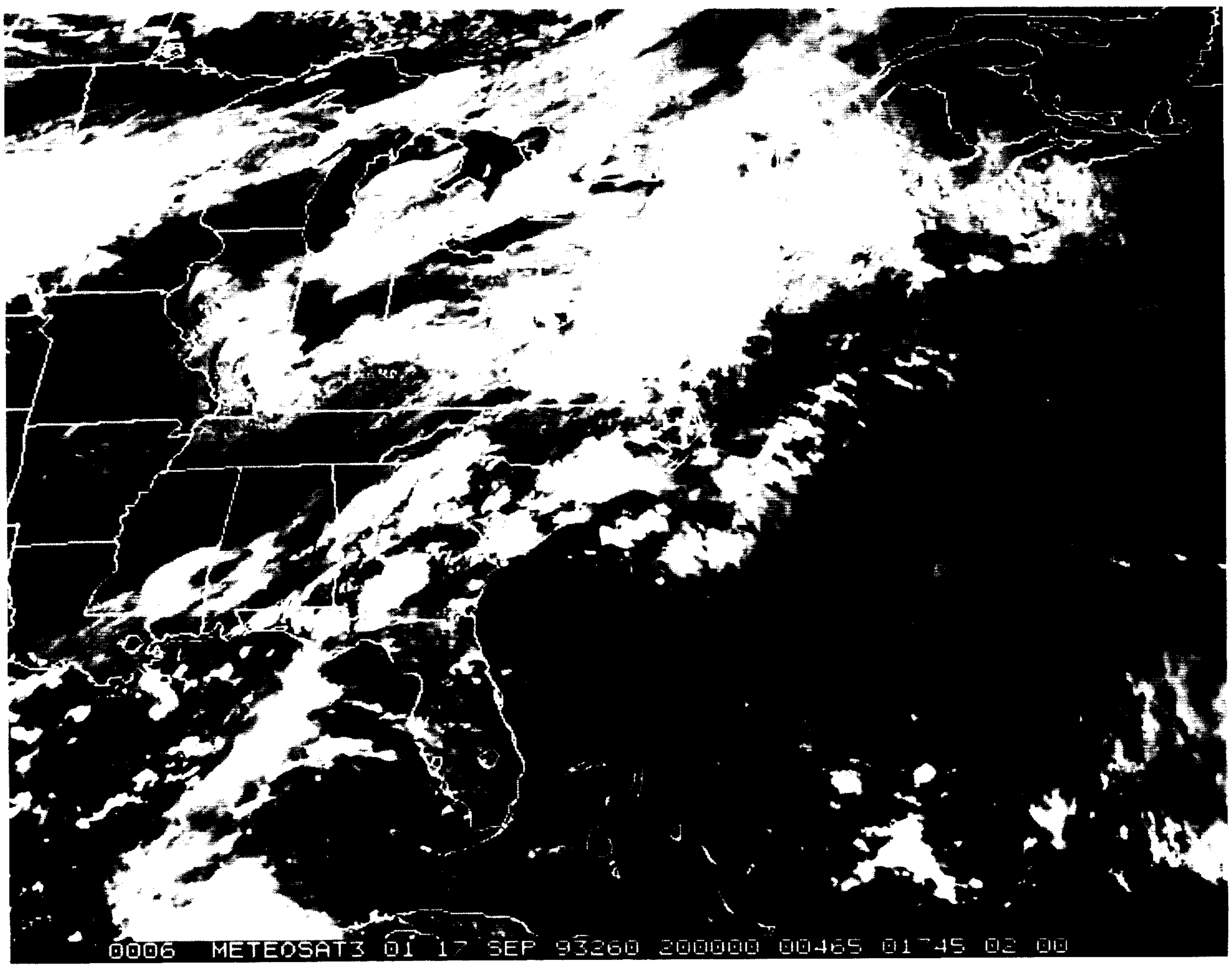
GMT	ID	TOTAL	EQUIP	FMAX	CVT	L.I.	KINX	PW
160,000	72,402	41	250	0	32	0	13	33

CAMEX FLIGHT DAY 11 - ACTIVITY

CAMEX Experiment Schedule for CAMEX Operations Day 11

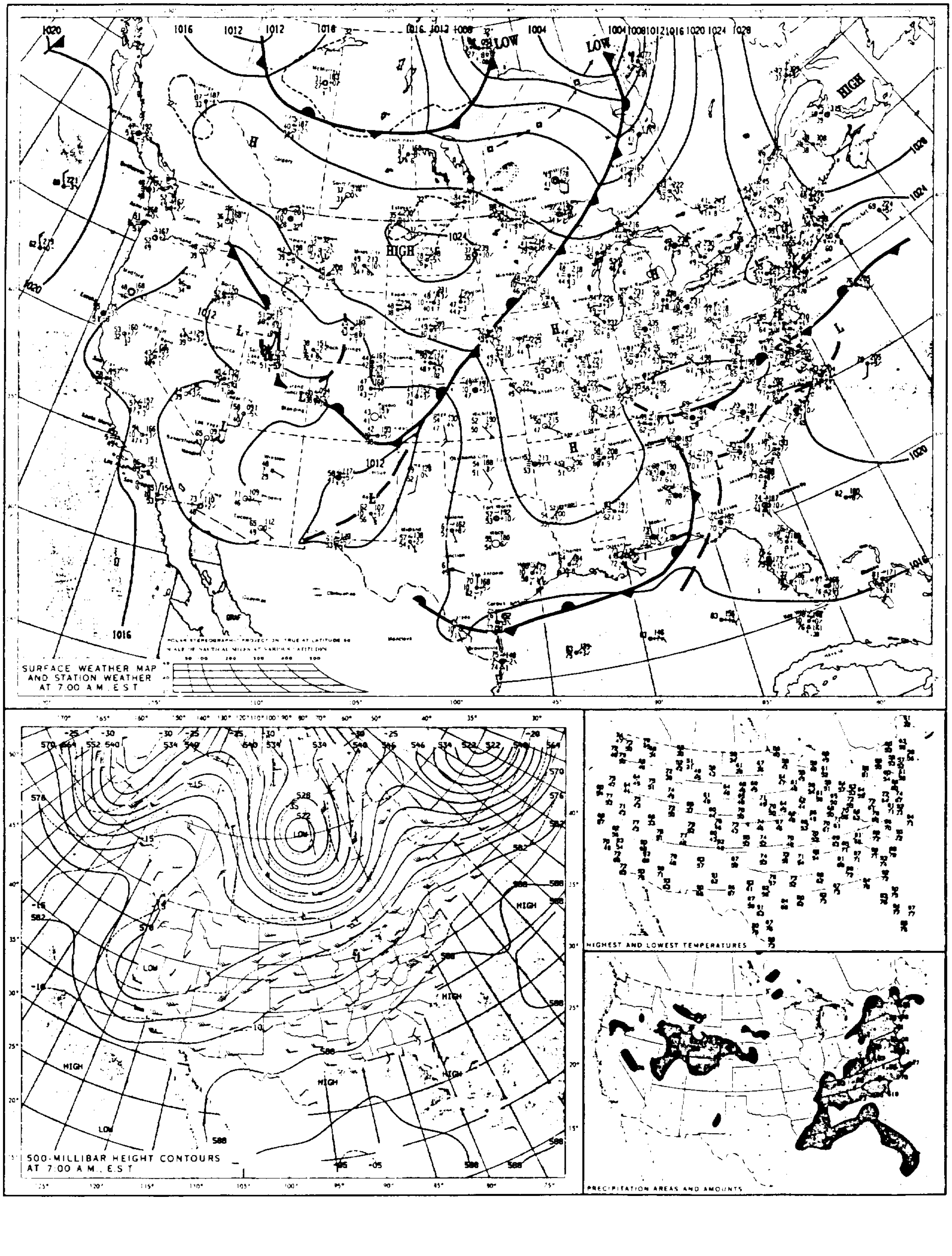
	Julian Day 9/17/93												Julian Day 9/18/93												
TIME (GMT Hour)	12	13	14	15	16	17	18	19	20	21	22	23	0	1	2	3	4	5	6	7	8	9	10	11	12
ER-2 Instruments																									
AMPR																									
EDOP																									
HIS																									
LIP																									
MAMS																									
MIR																									
MTS																									
Ground Sensors																									
Raman Lidar																									
HIS	X	X	X	X	X																				
Johns Hopkins/APL Ship																									
CLASS Sonde																									
Rawinsonde																									
VIZ																									
Vaisala																									
AIR																									
Ozone Sonde																									

CAMEX FLIGHT DAY 11 - SATELLITE IMAGERY

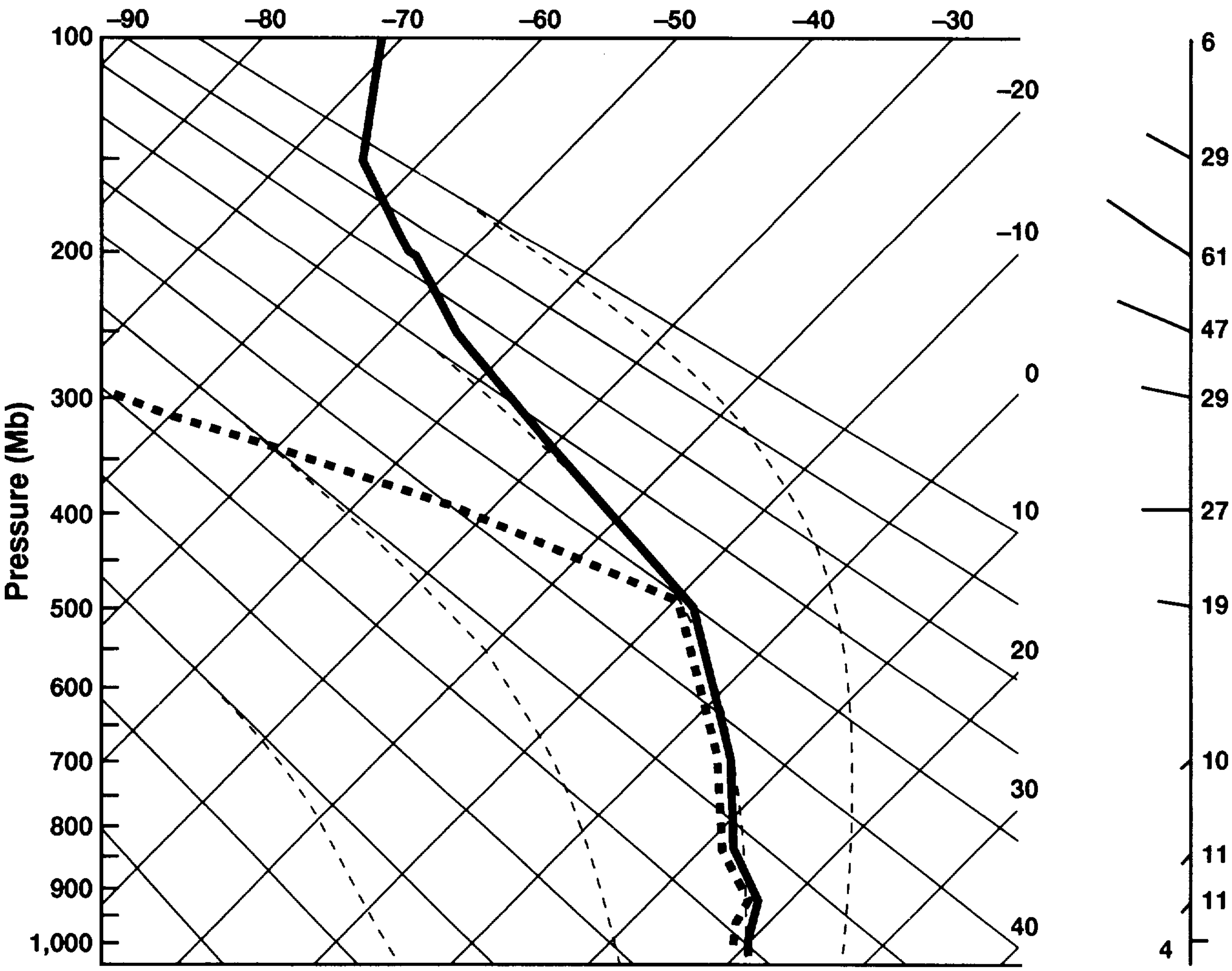


CAMEX FLIGHT DAY 11 - SYNOPTIC CHARTS

FRIDAY, SEPTEMBER 17, 1993



CAMEX FLIGHT DAY 11 - WALLOPS RAWINSONDE

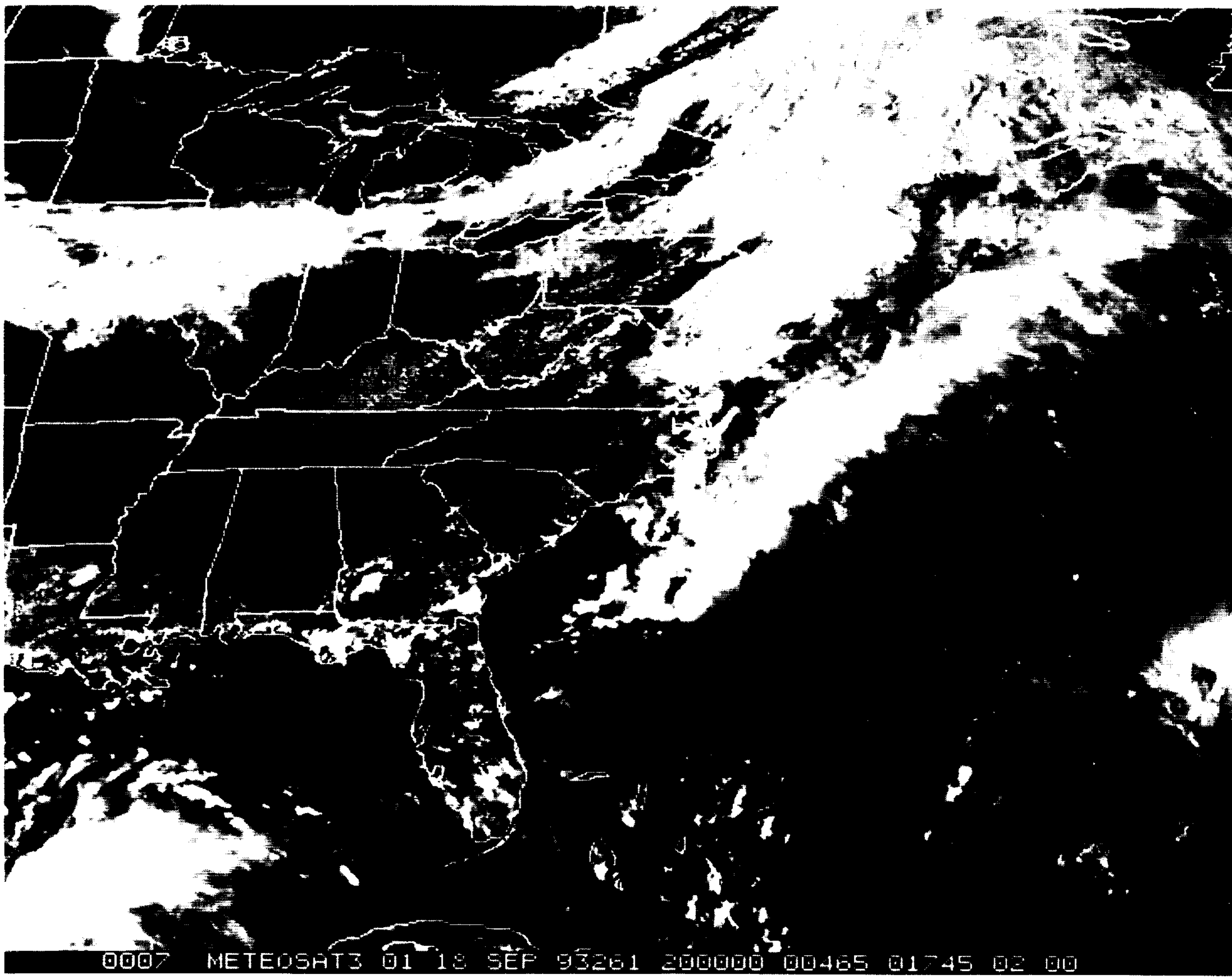


GMT	ID	TOTAL	EQUIP	FMAX	CVT	L.I.	KINX	PW
170,000	72,402	41	304	0	22	1	32	48

CAMEX FLIGHT DAY 12 - ACTIVITY

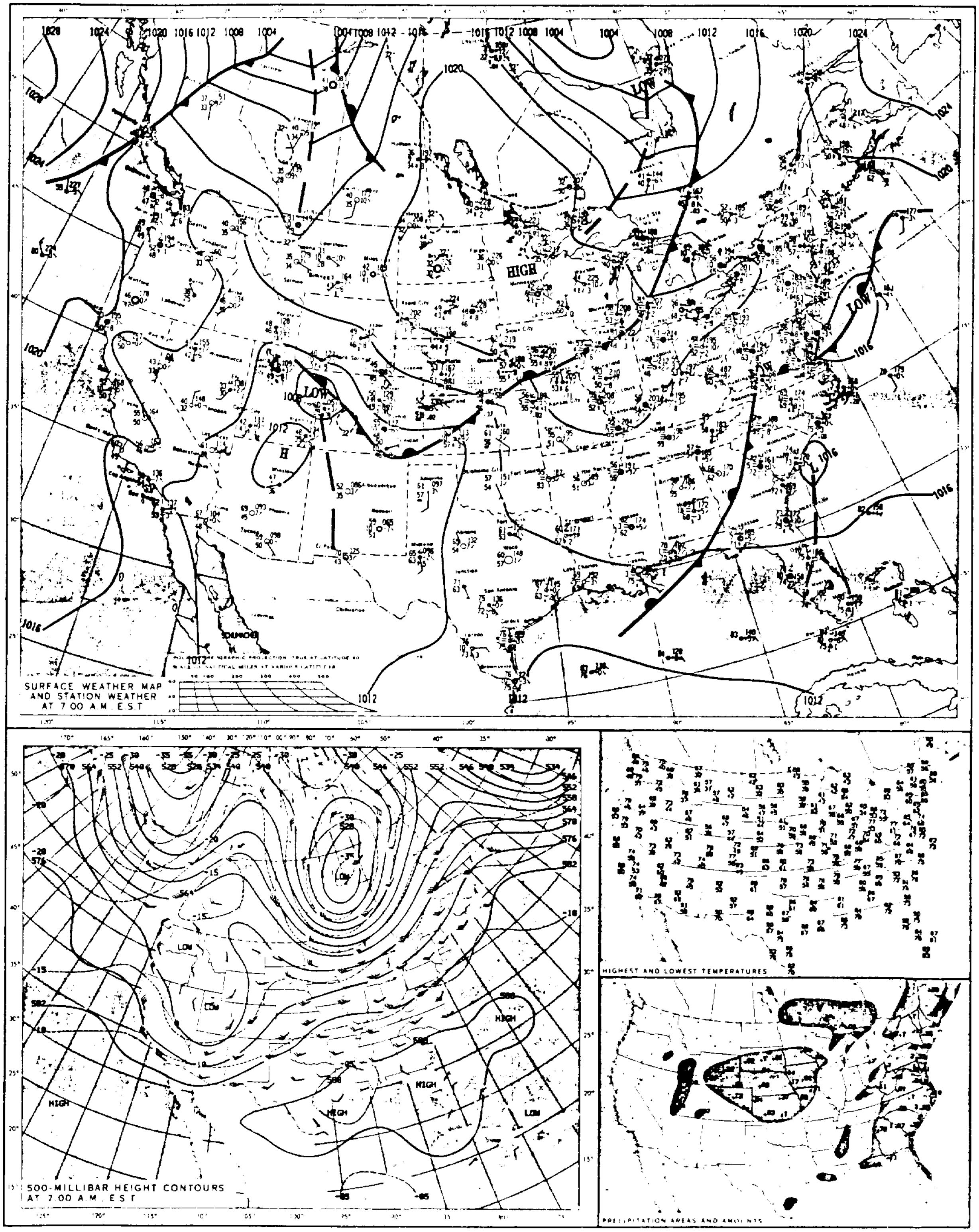
	CAMEX Experiment Schedule for CAMEX Operations Day 12																								
				Julian Day 9/18/93												Julian Day 9/19/93									
TIME (GMT Hour)	12	13	14	15	16	17	18	19	20	21	22	23	0	1	2	3	4	5	6	7	8	9	10	11	12
ER-2 Instruments																									
AMPR																									
EDOP																									
HIS																									
LIP																									
MAMS																									
MIR																									
MTS																									
Ground Sensors																									
Raman Lidar																									
HIS																									
Johns Hopkins/APL Ship																									
CLASS Sonde																									
Rawinsonde																									
VIZ																									
Vaisala																									
AIR																									
Ozone Sonde																									

CAMEX FLIGHT DAY 12 - SATELLITE IMAGERY

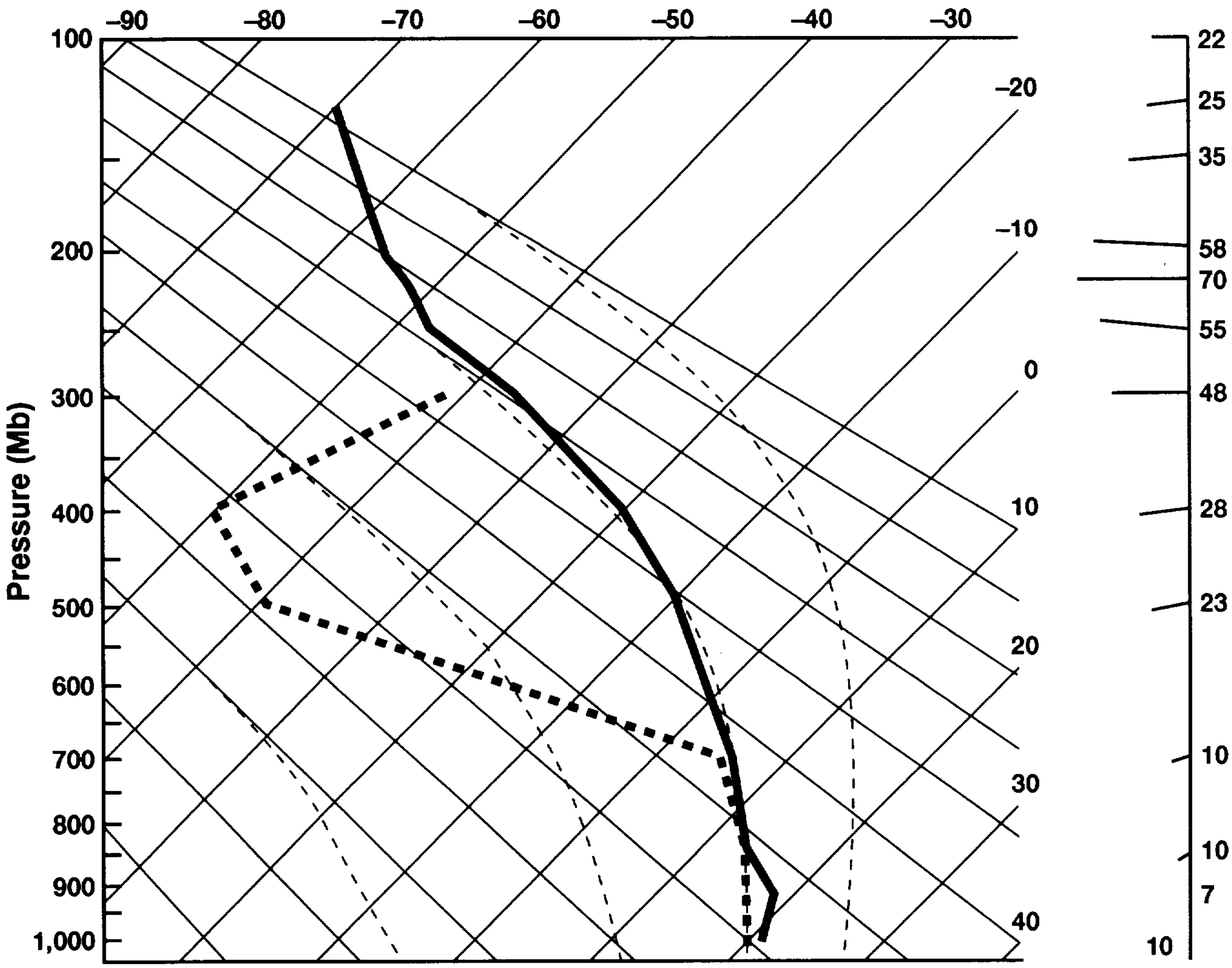


CAMEX FLIGHT DAY 12 - SYNOPTIC CHARTS

SATURDAY, SEPTEMBER 18, 1993



CAMEX FLIGHT DAY 12 - WALLOPS RAWINSONDE

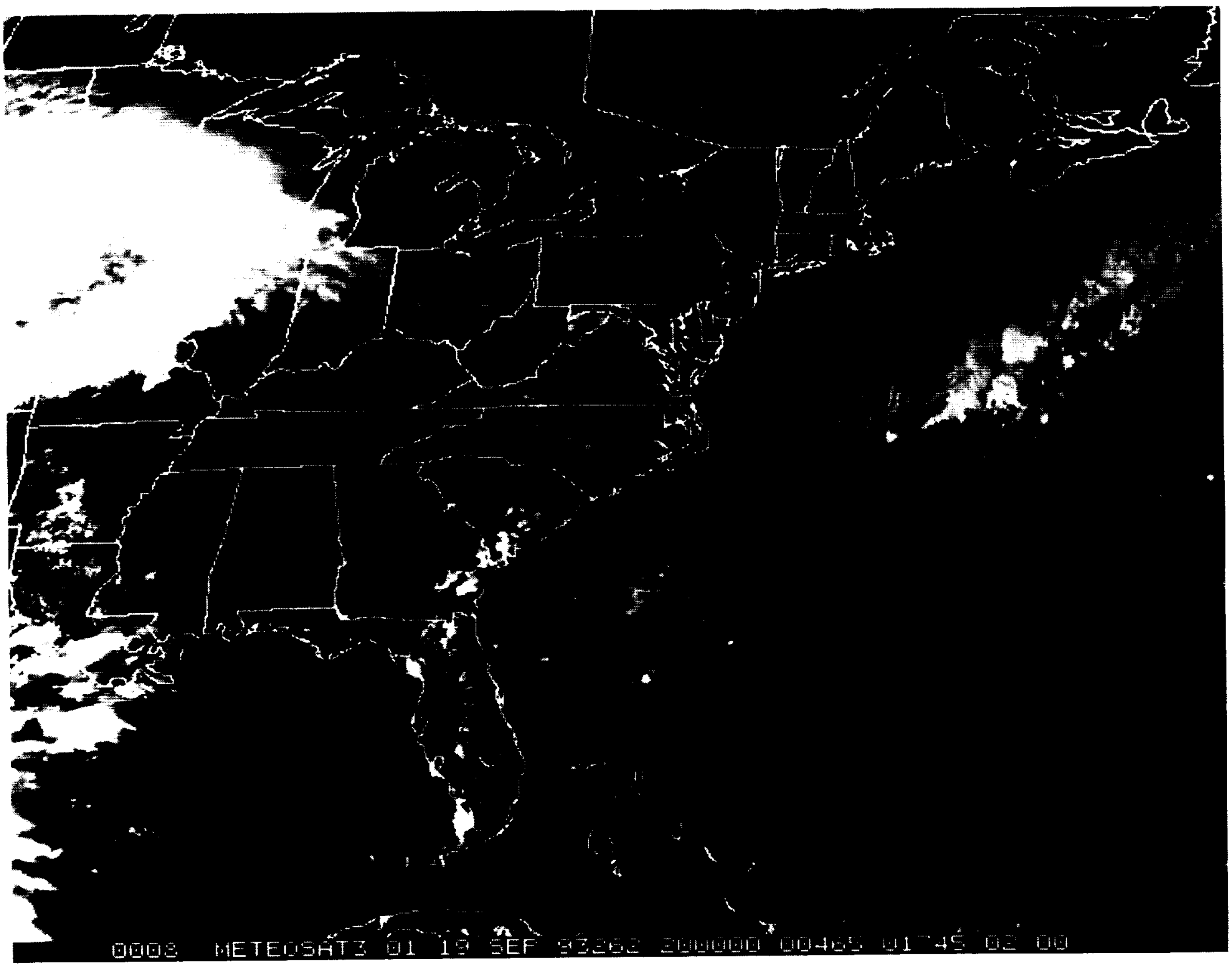


GMT	ID	TOTAL	EQUIP	FMAX	CVT	L.I.	KINX	PW
180,000	72,402	45	264	0	27	0	35	44

CAMEX FLIGHT DAY 13 - ACTIVITY

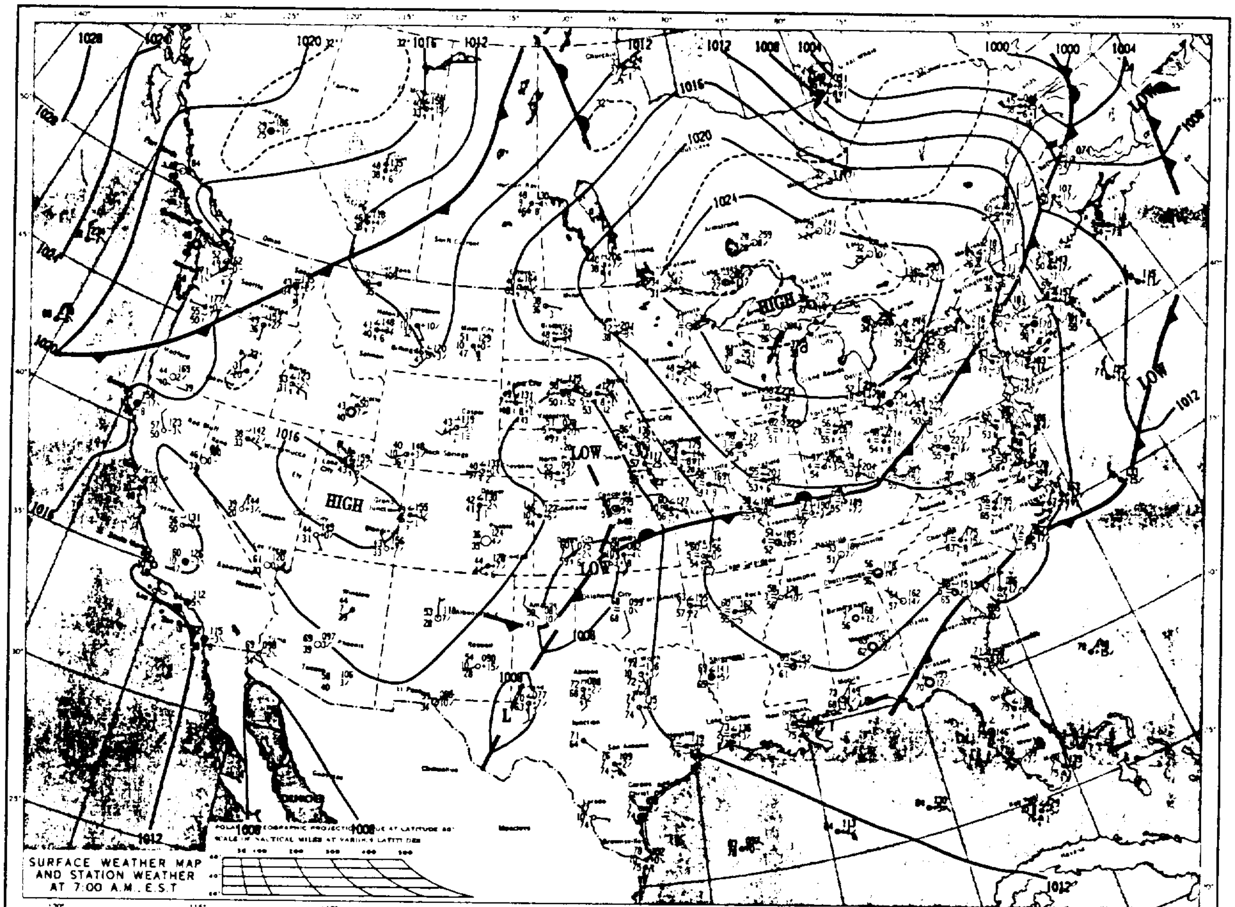
CAMEX Experiment Schedule for CAMEX Operations Day 13																									
				Julian Day 9/19/93											Julian Day 9/20/93										
TIME (GMT Hour)	12	13	14	15	16	17	18	19	20	21	22	23	0	1	2	3	4	5	6	7	8	9	10	11	12
ER-2 Instruments																									
AMPR									X	X	X														
EDOP																									
HIS									X	X	X														
LIP									X	X	X														
MAMS									X	X	X														
MIR									X	X	X														
MTS									X	X	X														
Ground Sensors																									
Raman Lidar														X	X	X	X	X							
HIS							X	X	X	X	X	X	X	X	X	X	X								
Johns Hopkins/APL Ship																									
CLASS Sonde												X		X			X								
Rawinsonde																									
VIZ											X			X			X								
Vaisala											X			X			X								
AIR											X						X								
Ozone Sonde																									

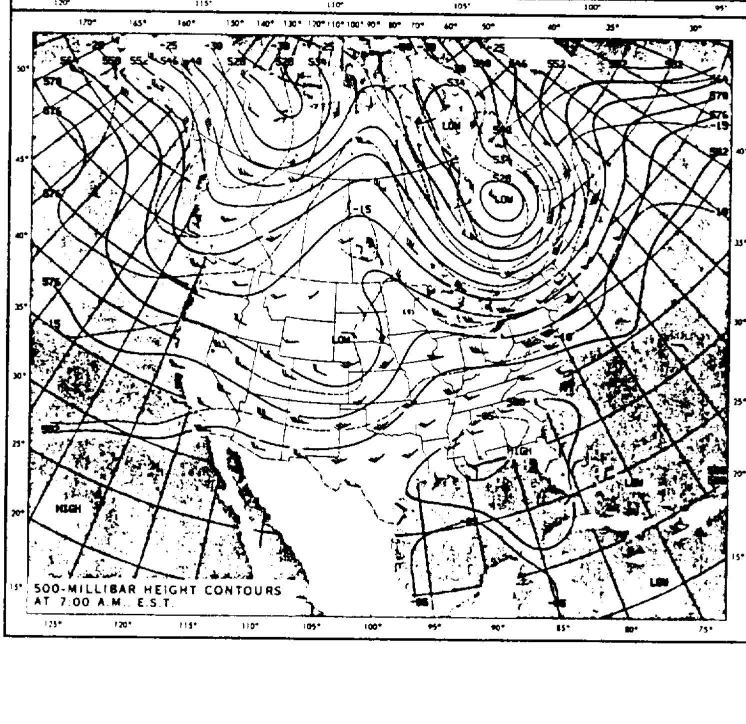
CAMEX FLIGHT DAY 13 - SATELLITE IMAGERY

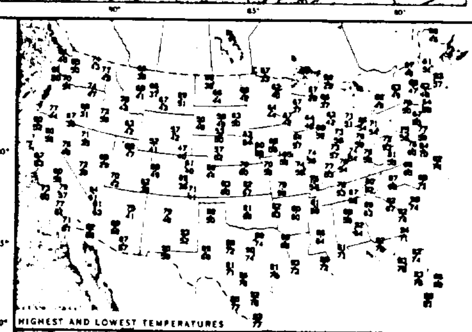


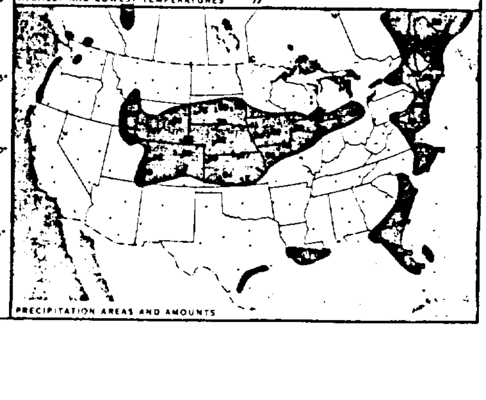
CAMEX FLIGHT DAY 13 - SYNOPTIC CHARTS

SUNDAY, SEPTEMBER 19, 1993

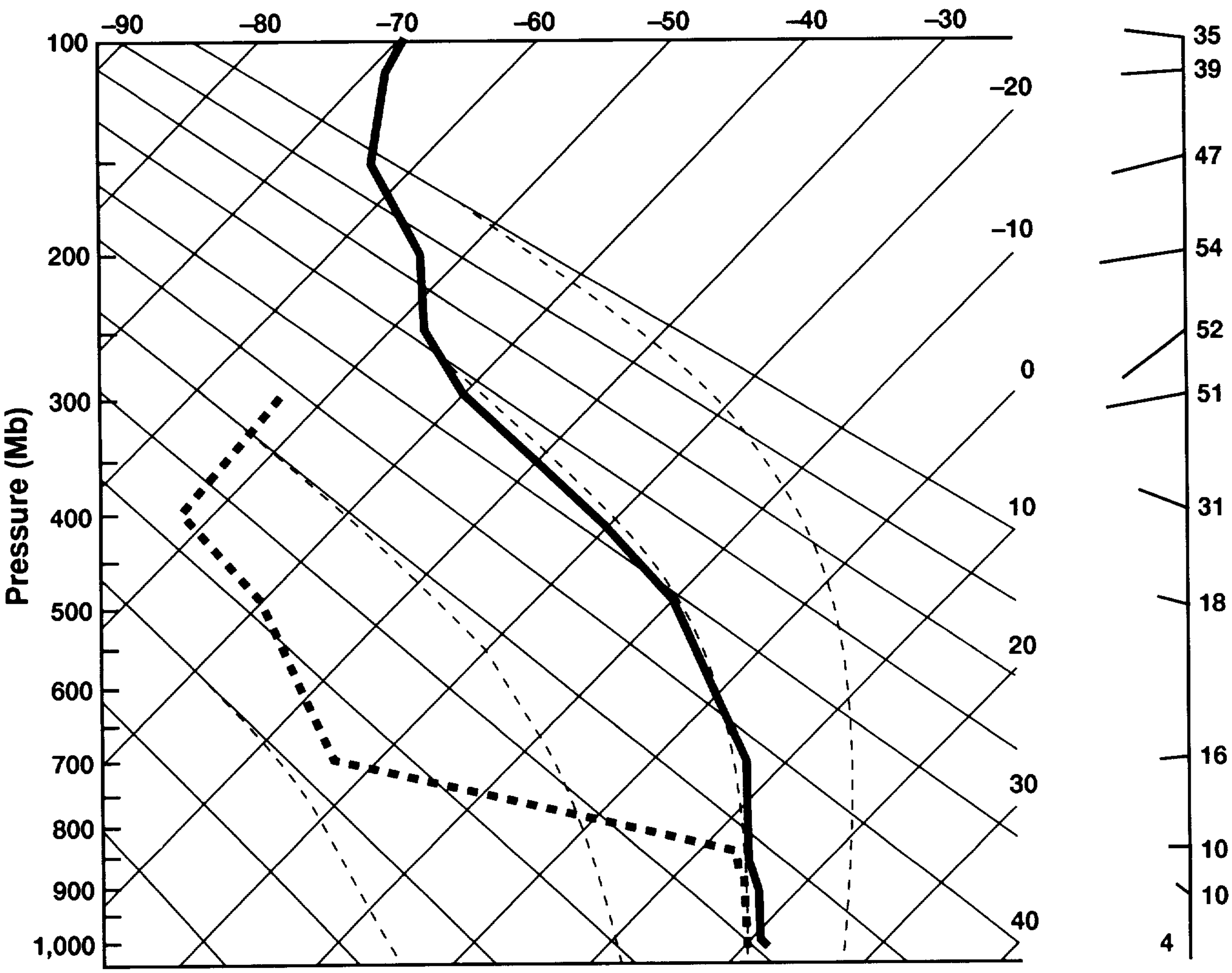








CAMEX FLIGHT DAY 13 - WALLOPS RAWINSONDE

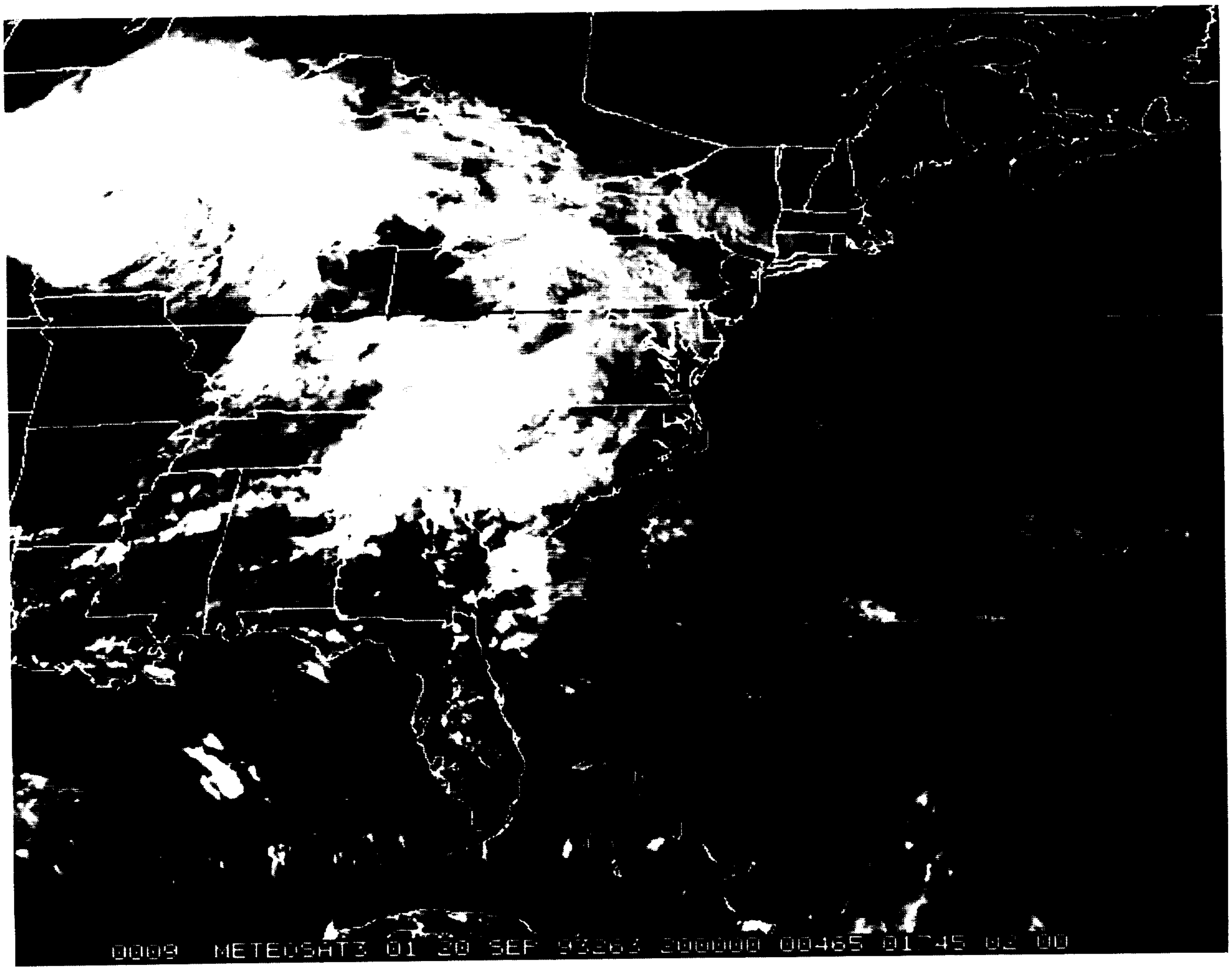


GMT	ID	TOTAL	EQUIP	FMAX	CVT	L.I.	KINX	PW
190,000	72,402	44	264	0	23	0	5	31

CAMEX FLIGHT DAY 14 - ACTIVITY

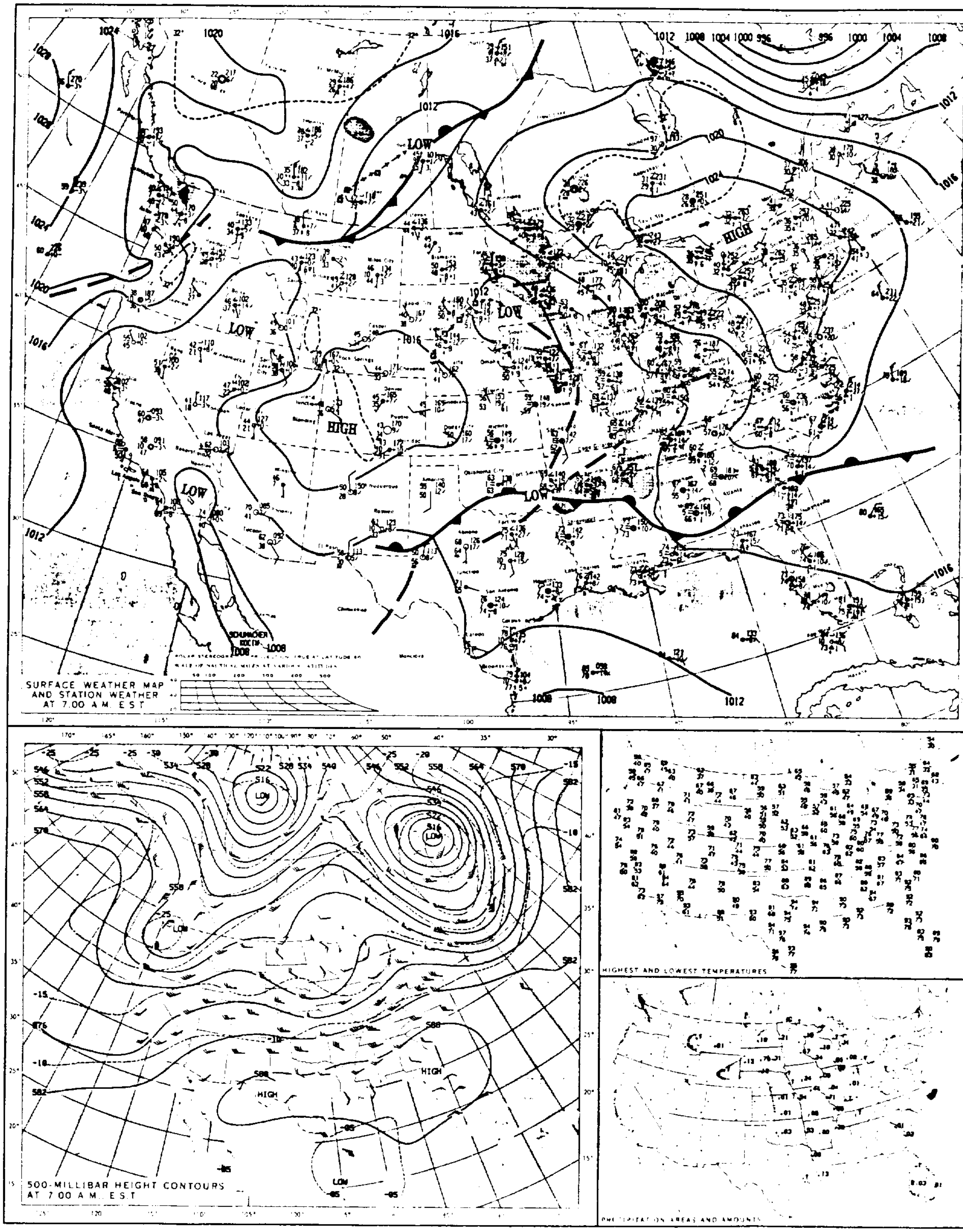
				CAMEX Experiment Schedule for CAMEX Operations Day 14																					
				Julian Day 9/20/93											Julian Day 9/21/93										
TIME (GMT Hour)	12	13	14	15	16	17	18	19	20	21	22	23	0	1	2	3	4	5	6	7	8	9	10	11	12
ER-2 Instruments																									
AMPR																									
EDOP																									
HIS																									
LIP																									
MAMS																									
MIR																									
MTS																									
Ground Sensors																									
Raman Lidar																									
HIS																									
Johns Hopkins/APL Ship																									
CLASS Sonde																									
Rawinsonde																									
VIZ																									
Vaisala																									
AIR																									
Ozone Sonde																									

CAMEX FLIGHT DAY 14 - SATELLITE IMAGERY

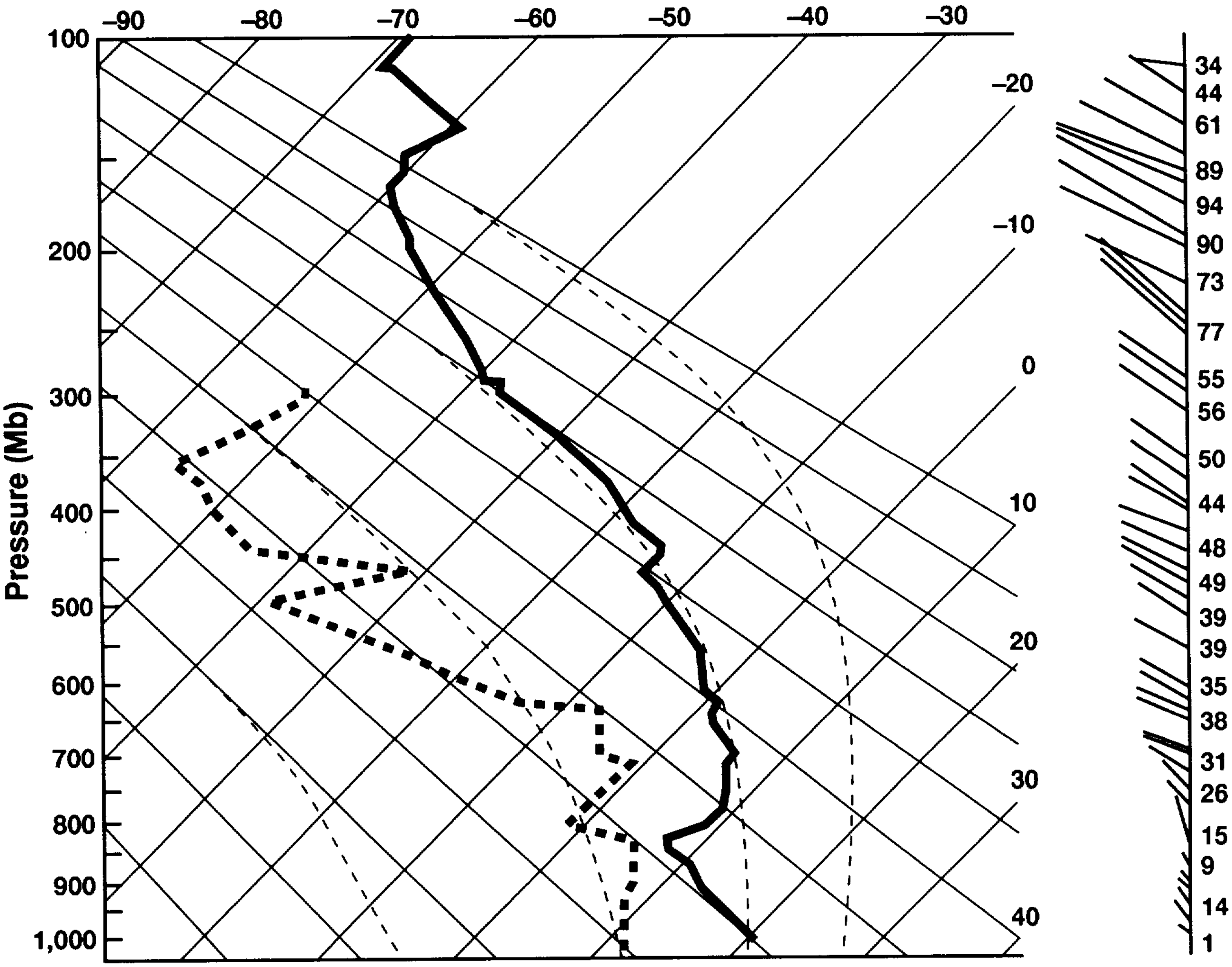


CAMEX FLIGHT DAY 14 - SYNOPTIC CHARTS

MONDAY, SEPTEMBER 20, 1993



CAMEX FLIGHT DAY 14 - WALLOPS RAWINSONDE



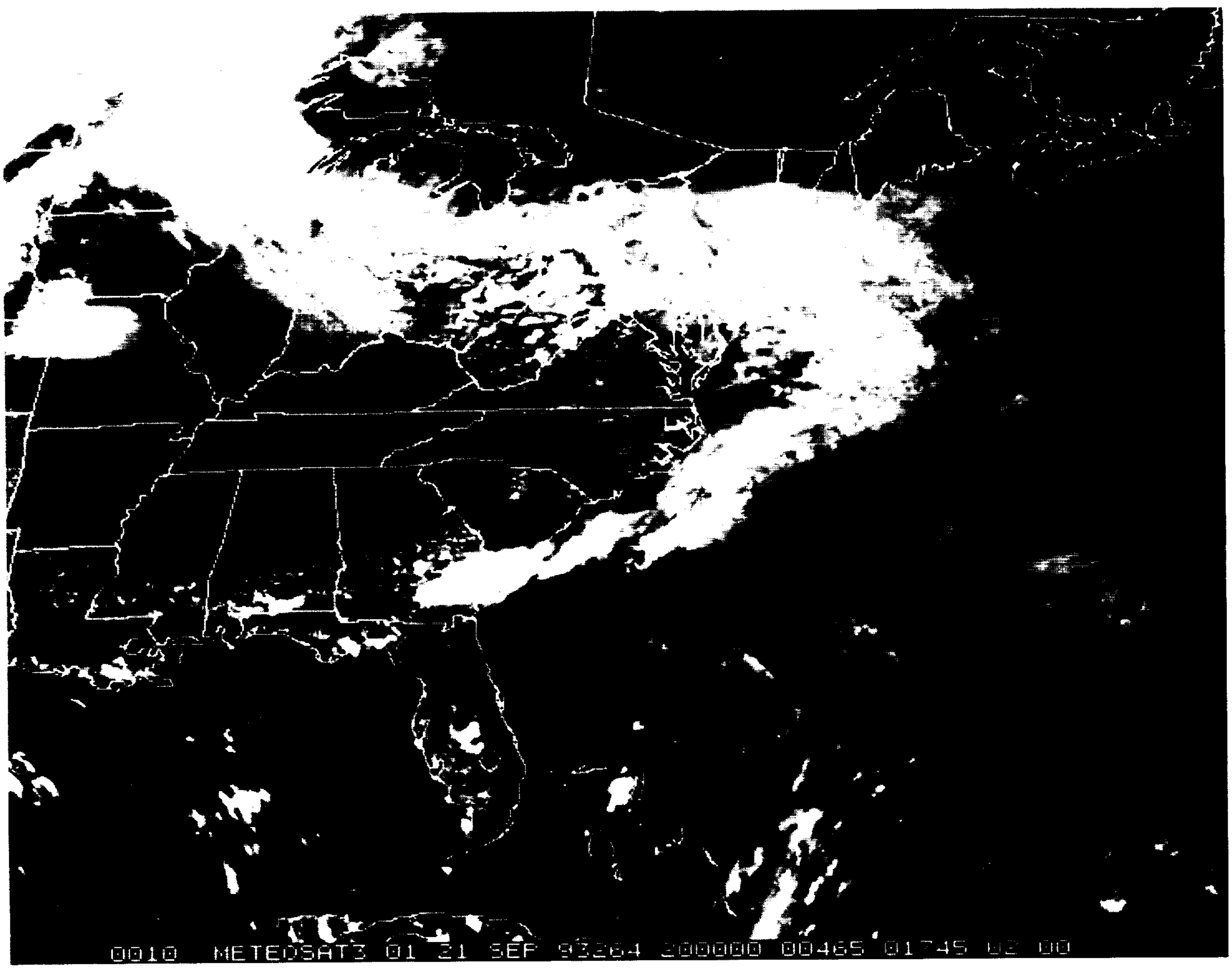
GMT	ID	TOTAL	EQUIP	FMAX	CVT	L.I.	KINX	PW
140,000	72,402	33	599	0		9	13	23

CAMEX FLIGHT DAY 15 - ACTIVITY

CAMEX Experiment Schedule for CAMEX Operations Day 15

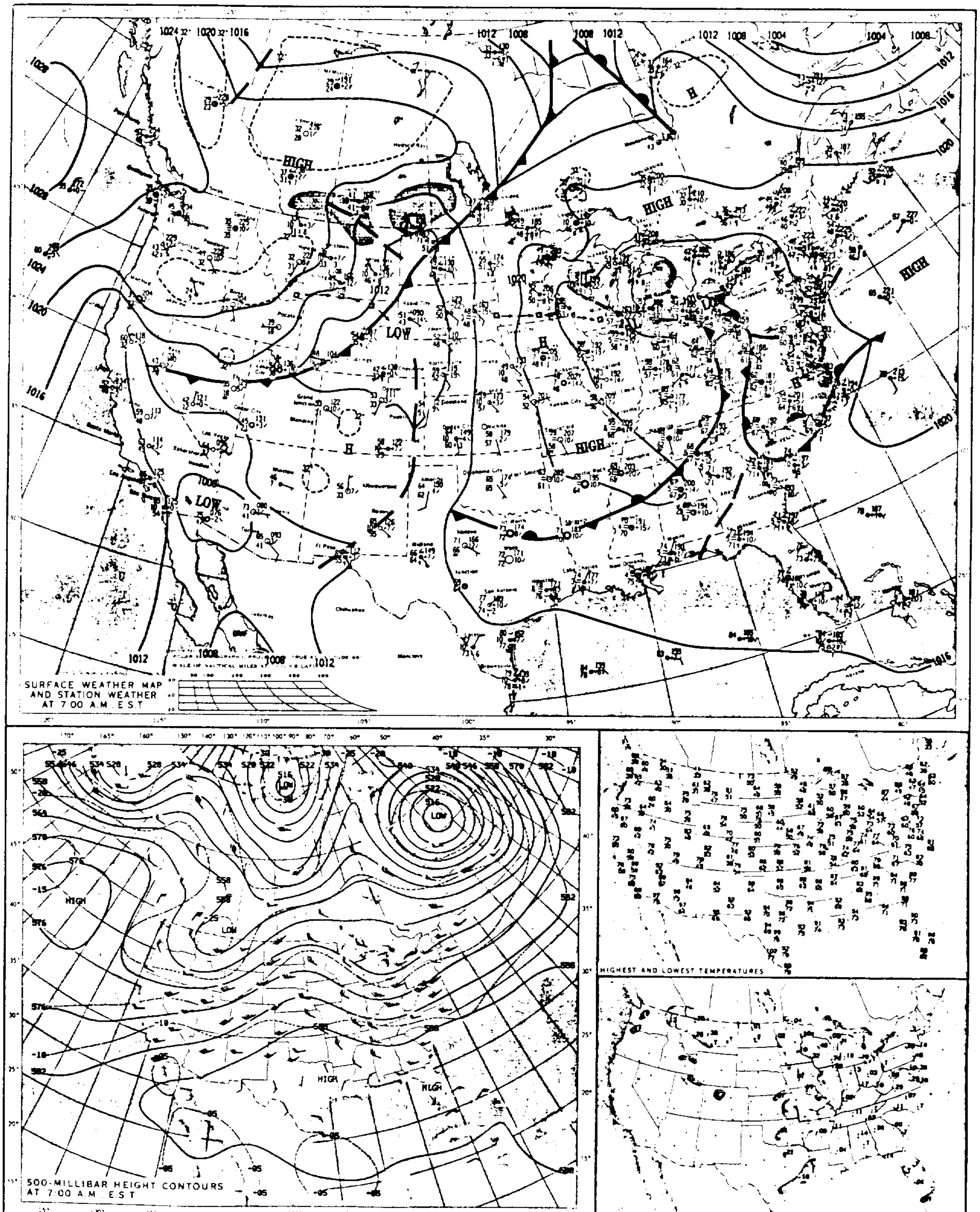
				Julian Day 9/21/93												Julian Day 9/22/93									
TIME (GMT Hour)	12	13	14	15	16	17	18	19	20	21	22	23	0	1	2	3	4	5	6	7	8	9	10	11	12
ER-2 Instruments																									
AMPR																									
EDOP																									
HIS																									
LIP																									
MAMS																									
MIR																									
MTS																									
Ground Sensors																									
Raman Lidar													X	X	X										
HIS					X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
Johns Hopkins/APL Ship											X	X	X	X	X	X	X								
CLASS Sonde														X											
Rawinsonde																									
VIZ																									
Vaisala																									
AIR																									
Ozone Sonde																									

CAMEX FLIGHT DAY 15 - SATELLITE IMAGERY

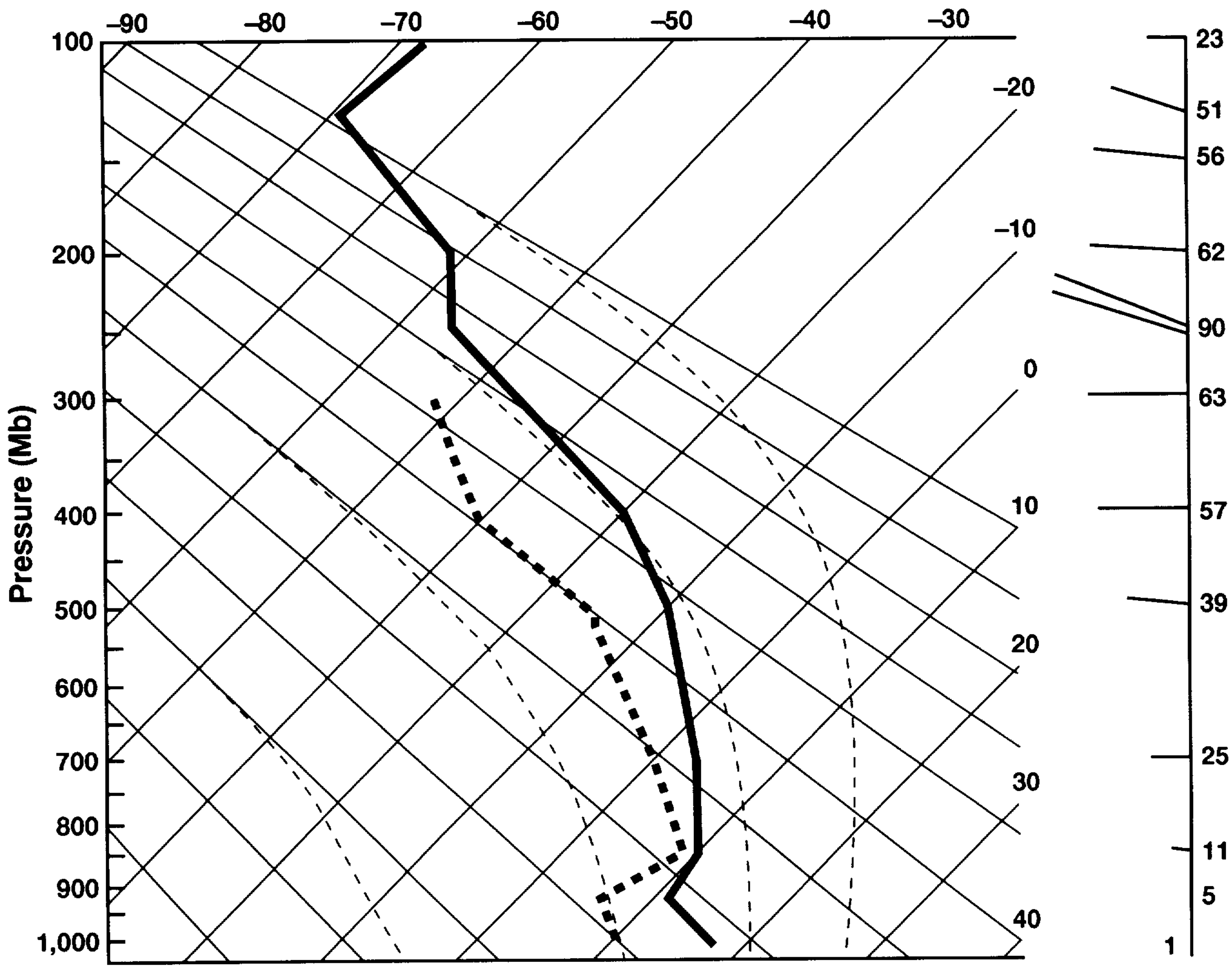


CAMEX FLIGHT DAY 15 - SYNOPTIC CHARTS

TUESDAY, SEPTEMBER 21, 1993



CAMEX FLIGHT DAY 15 - WALLOPS RAWINSONDE



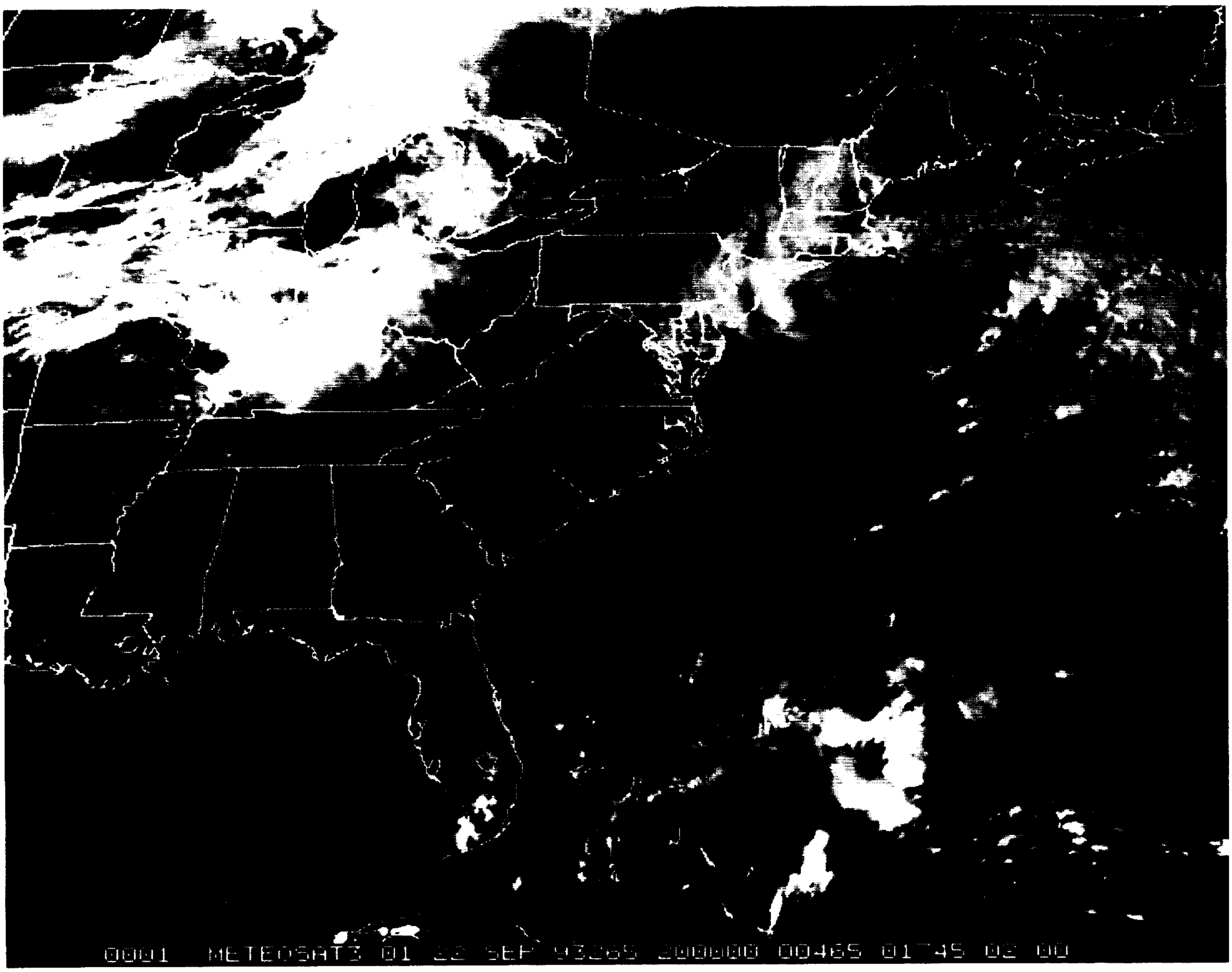
GMT	ID	TOTAL	EQUIP	FMAX	CVT	L.I.	KINX	PW
210,000	72,402	40		0	32	12	26	30

CAMEX FLIGHT DAY 16 - ACTIVITY

CAMEX Experiment Schedule for CAMEX Operations Day 16

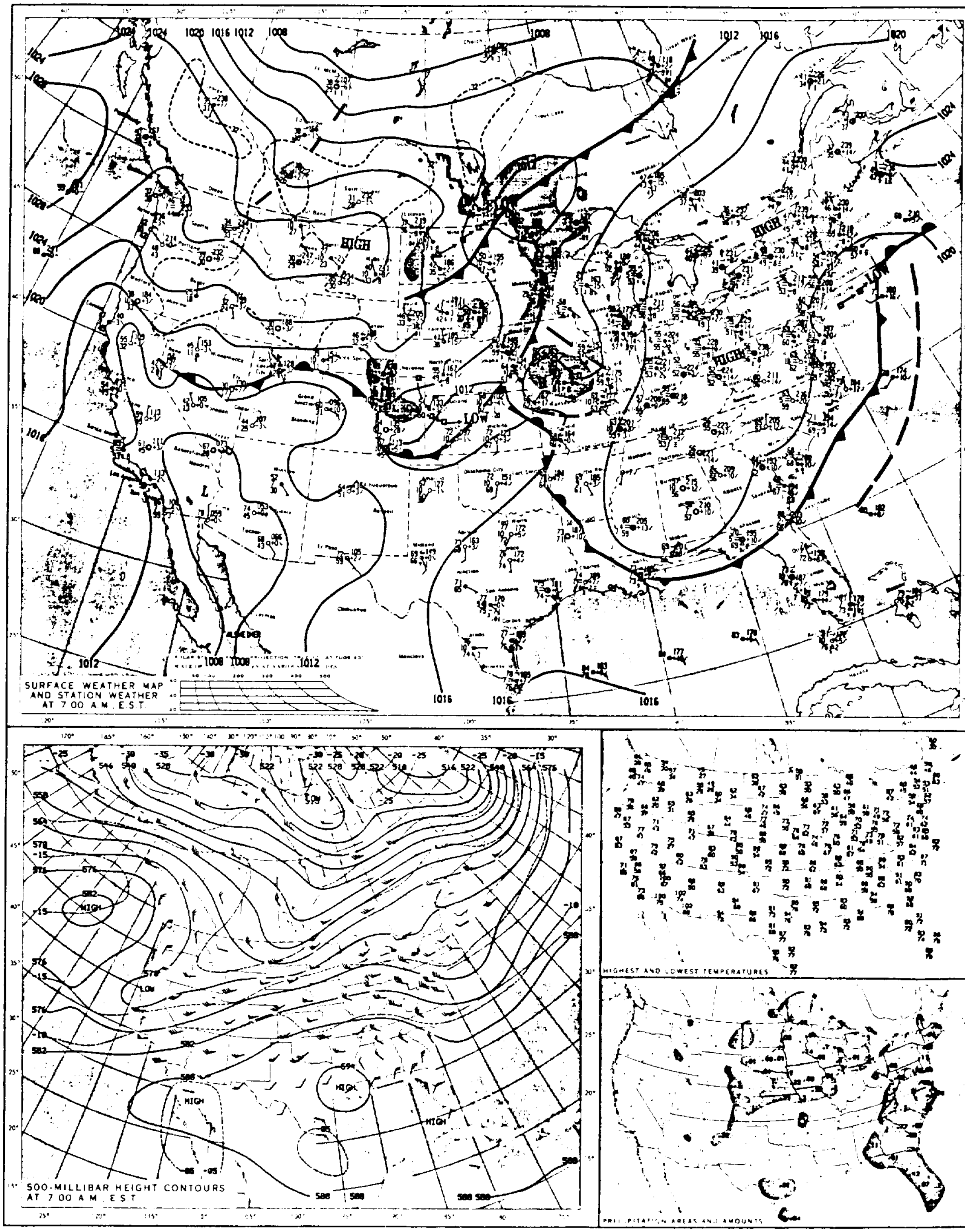
	Julian Day 9/22/93												Julian Day 9/23/93												
TIME (GMT Hour)	12	13	14	15	16	17	18	19	20	21	22	23	0	1	2	3	4	5	6	7	8	9	10	11	12
ER-2 Instruments																									
AMPR																									
EDOP																									
HIS																									
LIP																									
MAMS																									
MIR																									
MTS																									
Ground Sensors																									
Raman Lidar													X	X	X	X	X								
HIS	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
Johns Hopkins/APL Ship											X	X	X	X	X	X	X								
CLASS Sonde											X														
Rawinsonde																									
VIZ																									
Vaisala											X			X			X								
AIR														X			X								
Ozone Sonde																									

CAMEX FLIGHT DAY 16 - SATELLITE IMAGERY

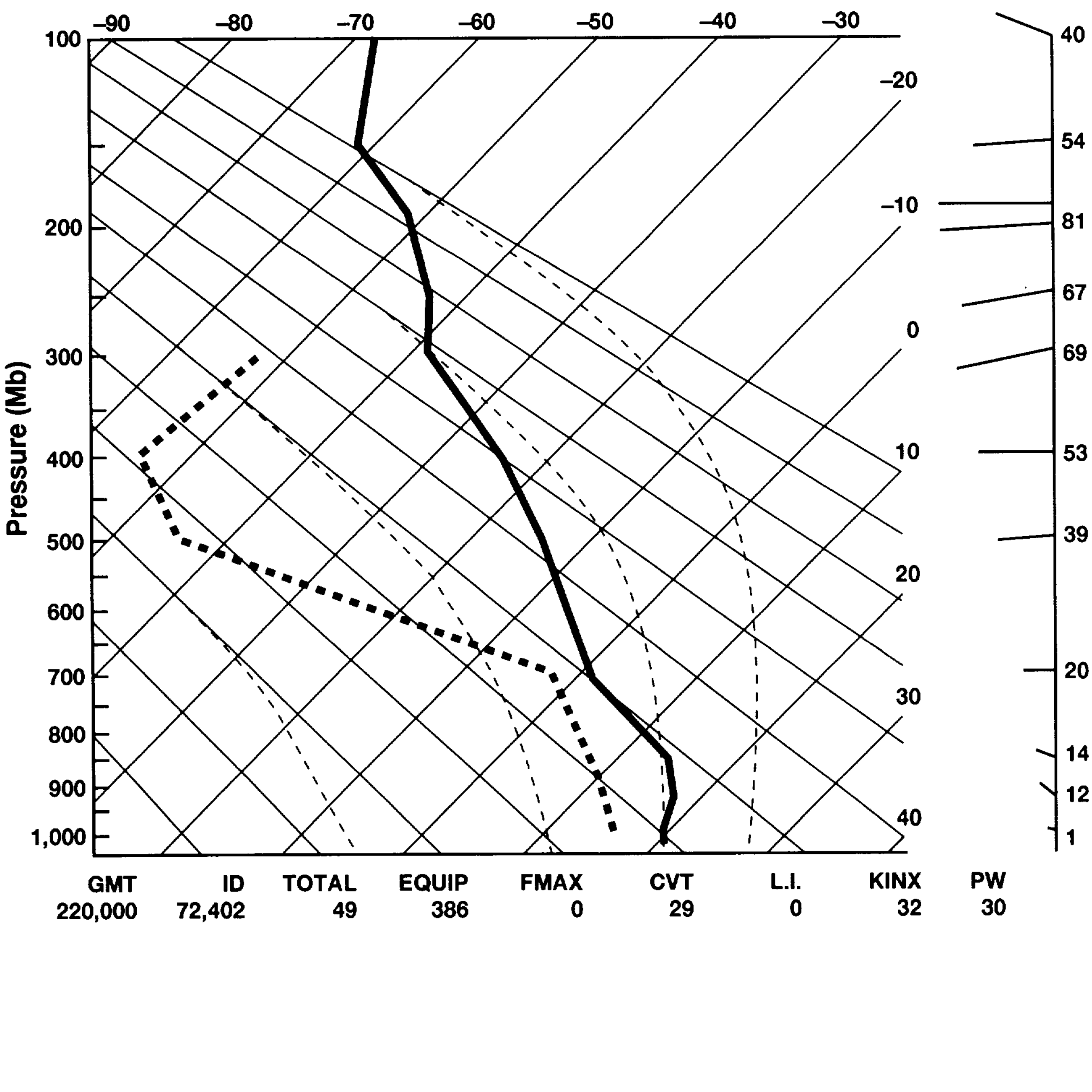


CAMEX FLIGHT DAY 16 - SYNOPTIC CHARTS

WEDNESDAY, SEPTEMBER 22, 1993



CAMEX FLIGHT DAY 16 - WALLOPS RAWINSONDE



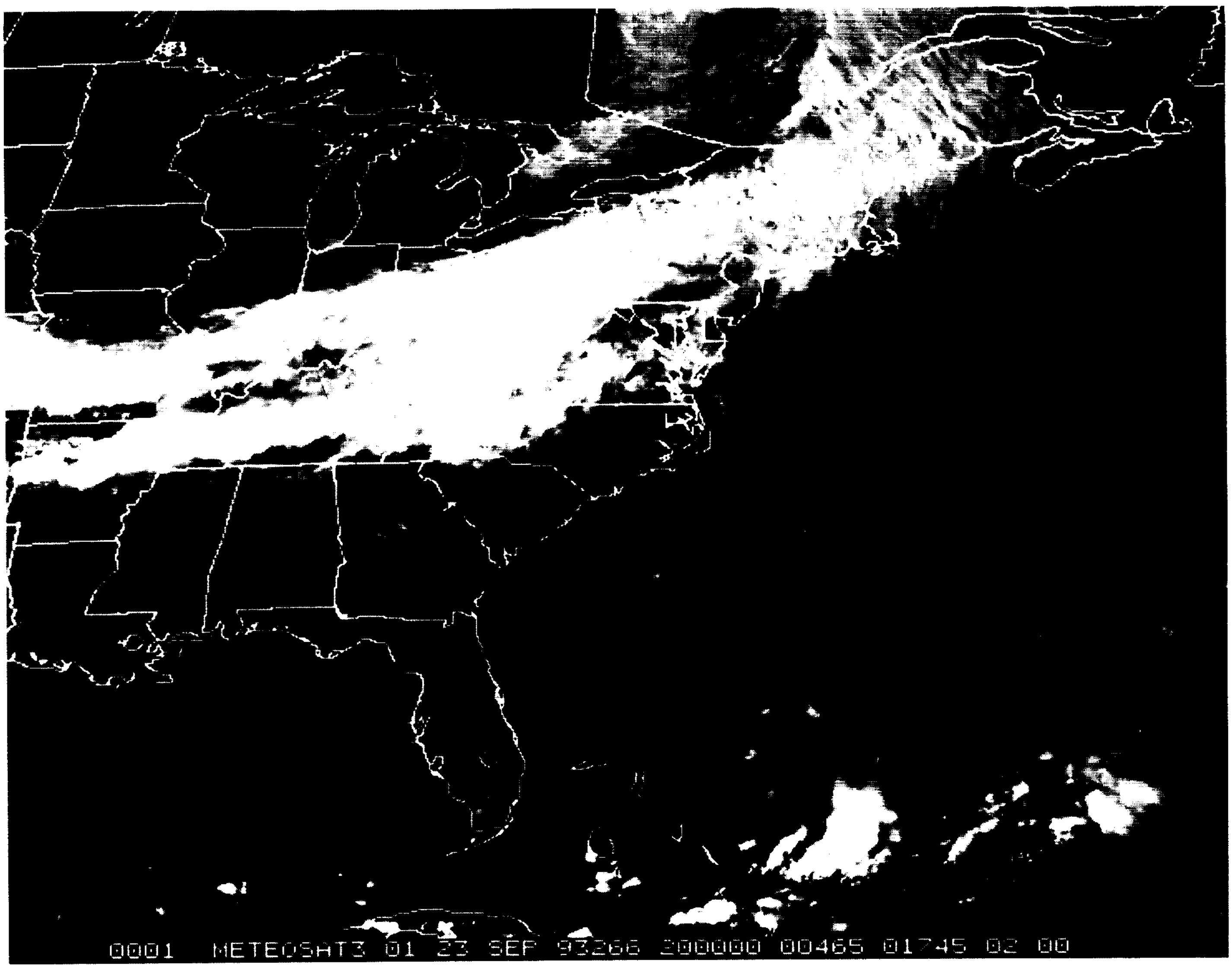
GMT	ID	TOTAL	EQUIP	FMAX	CVT	L.I.	KINX	PW
220,000	72,402	49	386	0	29	0	32	30

CAMEX FLIGHT DAY 17 - ACTIVITY

CAMEX Experiment Schedule for CAMEX Operations Day 17

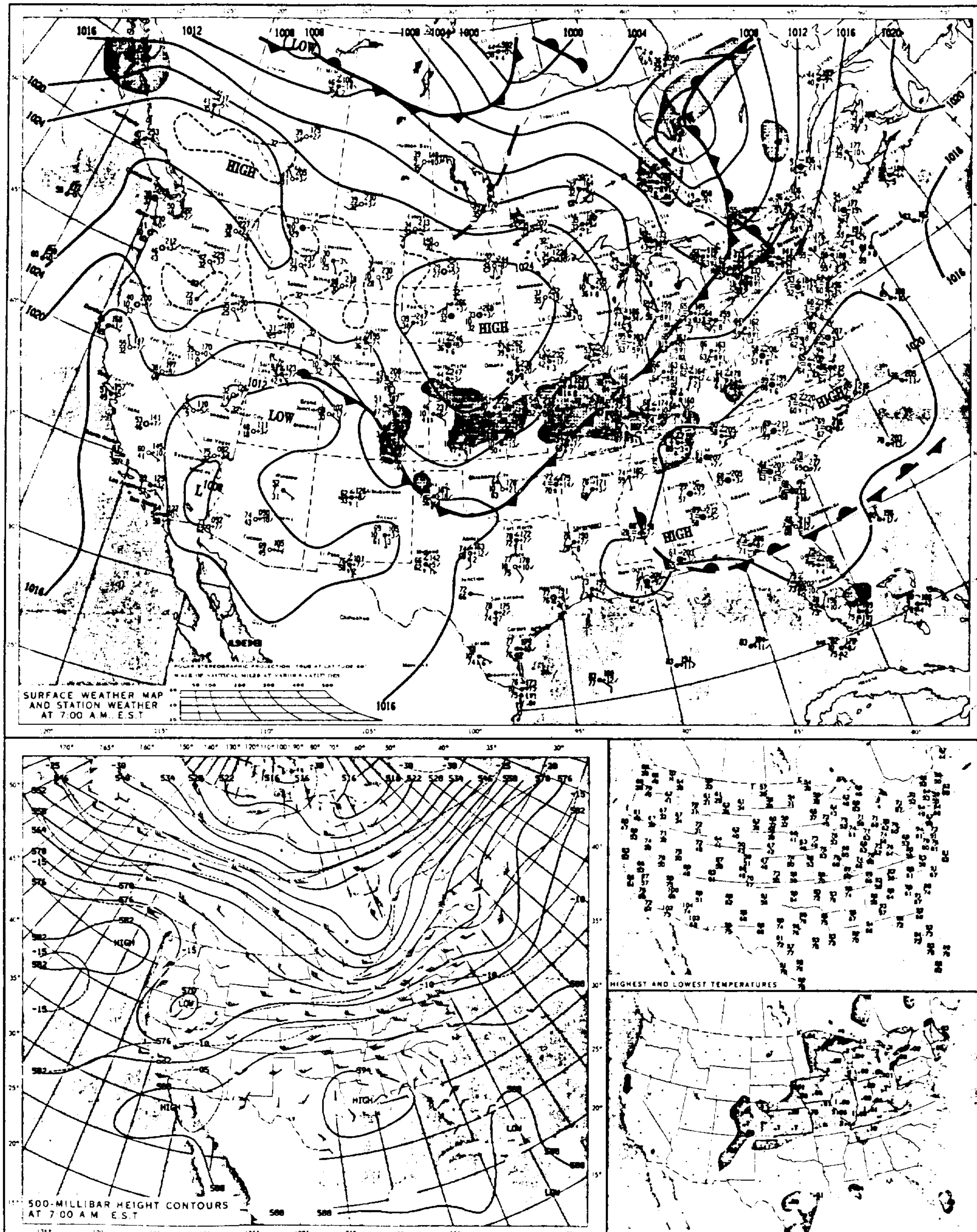
	Julian Day 9/23/93												Julian Day 9/24/93												
TIME (GMT Hour)	12	13	14	15	16	17	18	19	20	21	22	23	0	1	2	3	4	5	6	7	8	9	10	11	12
ER-2 Instruments																									
AMPR																									
EDOP																									
HIS																									
LIP																									
MAMS																									
MIR																									
MTS																									
Ground Sensors																									
Raman Lidar														X	X	X	X								
HIS	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
Johns Hopkins/APL Ship											X	X	X	X	X	X	X								
CLASS Sonde													X				X								
Rawinsonde																									
VIZ																									
Vaisala						X																			
AIR							X																		
Ozone Sonde																									

CAMEX FLIGHT DAY 17 - SATELLITE IMAGERY

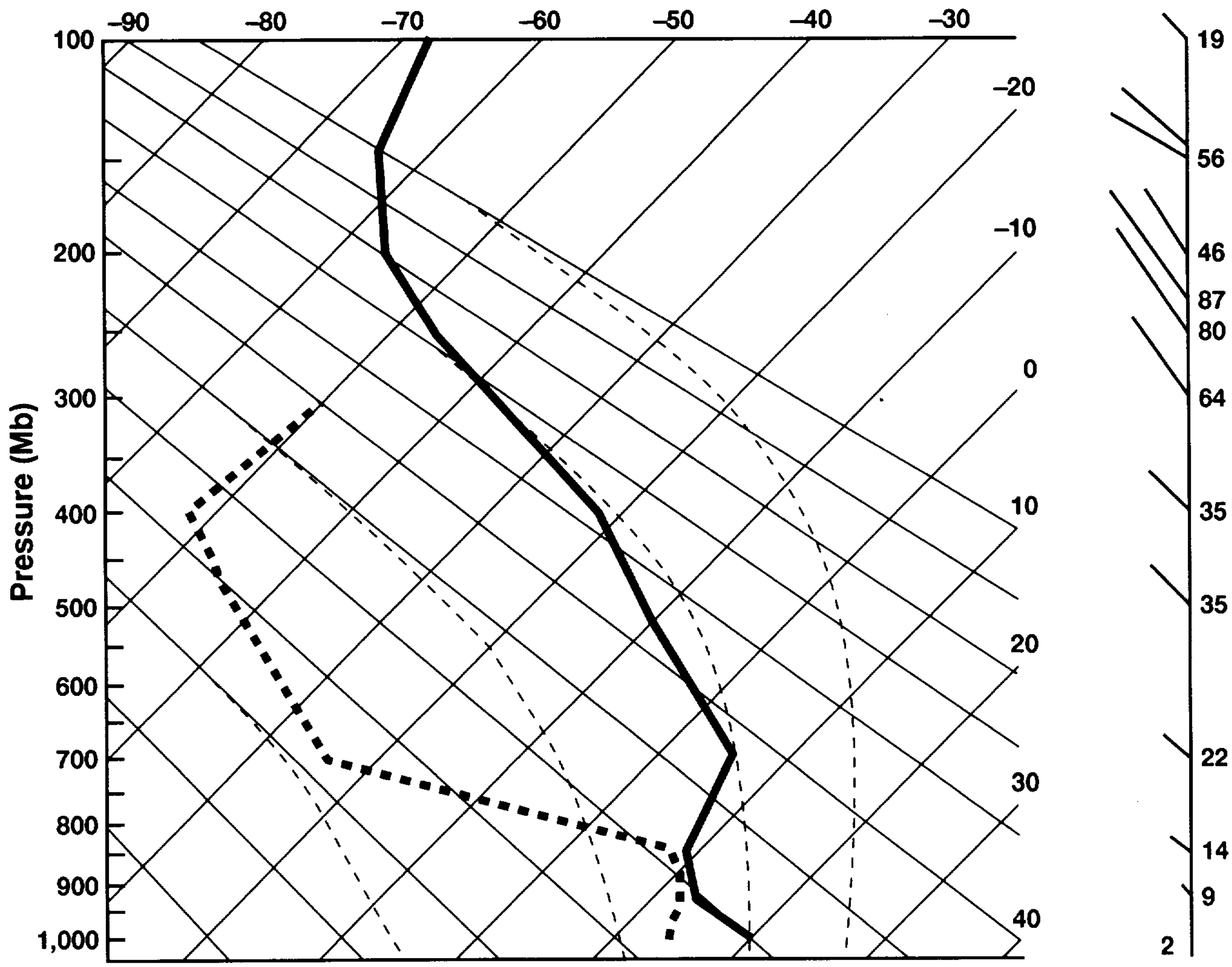


CAMEX FLIGHT DAY 17 - SYNOPTIC CHARTS

THURSDAY, SEPTEMBER 23, 1993



CAMEX FLIGHT DAY 17 - WALLOPS RAWINSONDE

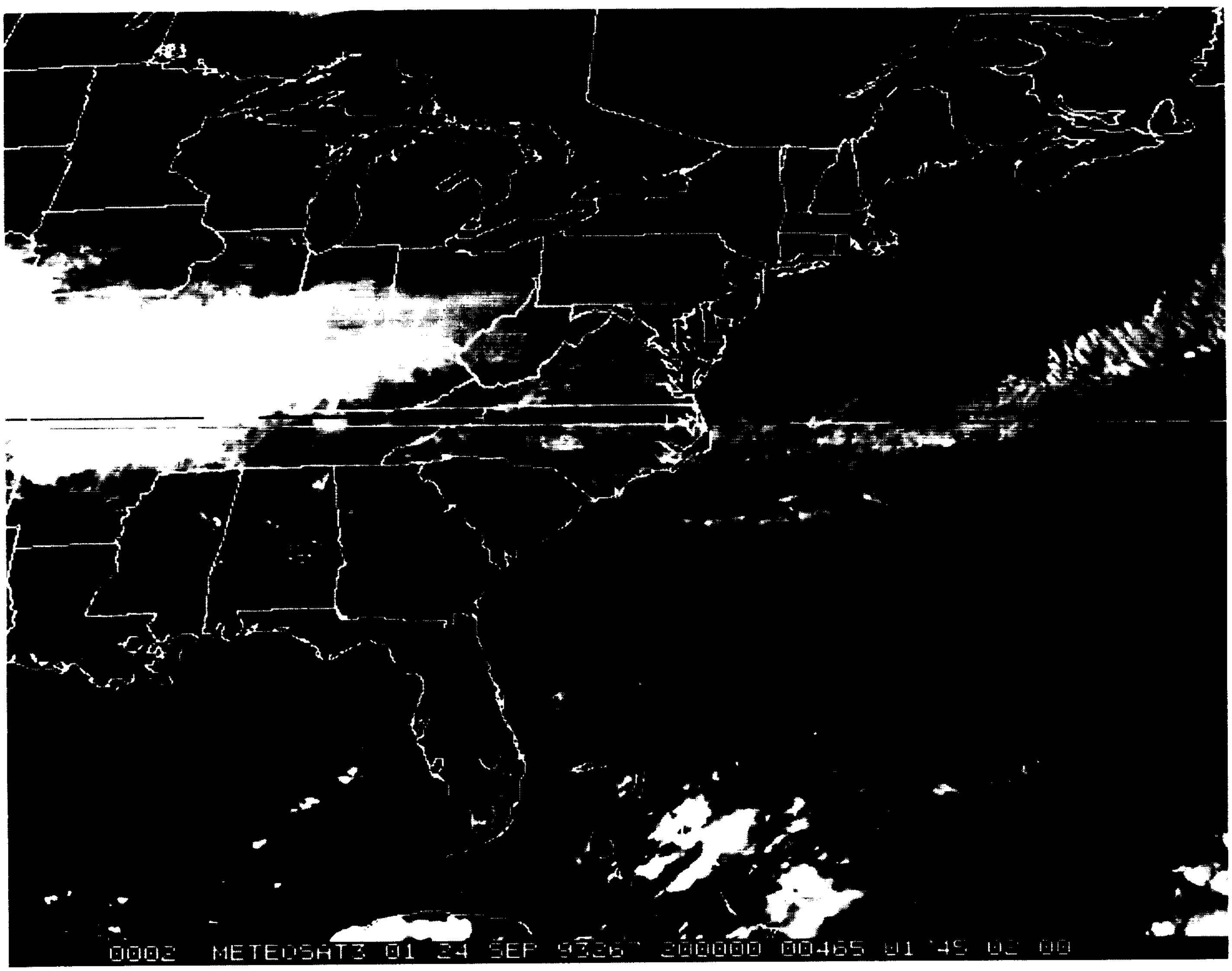


GMT	ID	TOTAL	EQUIP	FMAX	CVT	L.I.	KINX	PW
230,000	72,402	39	483	0	21	4	–2	23

CAMEX FLIGHT DAY 18 - ACTIVITY

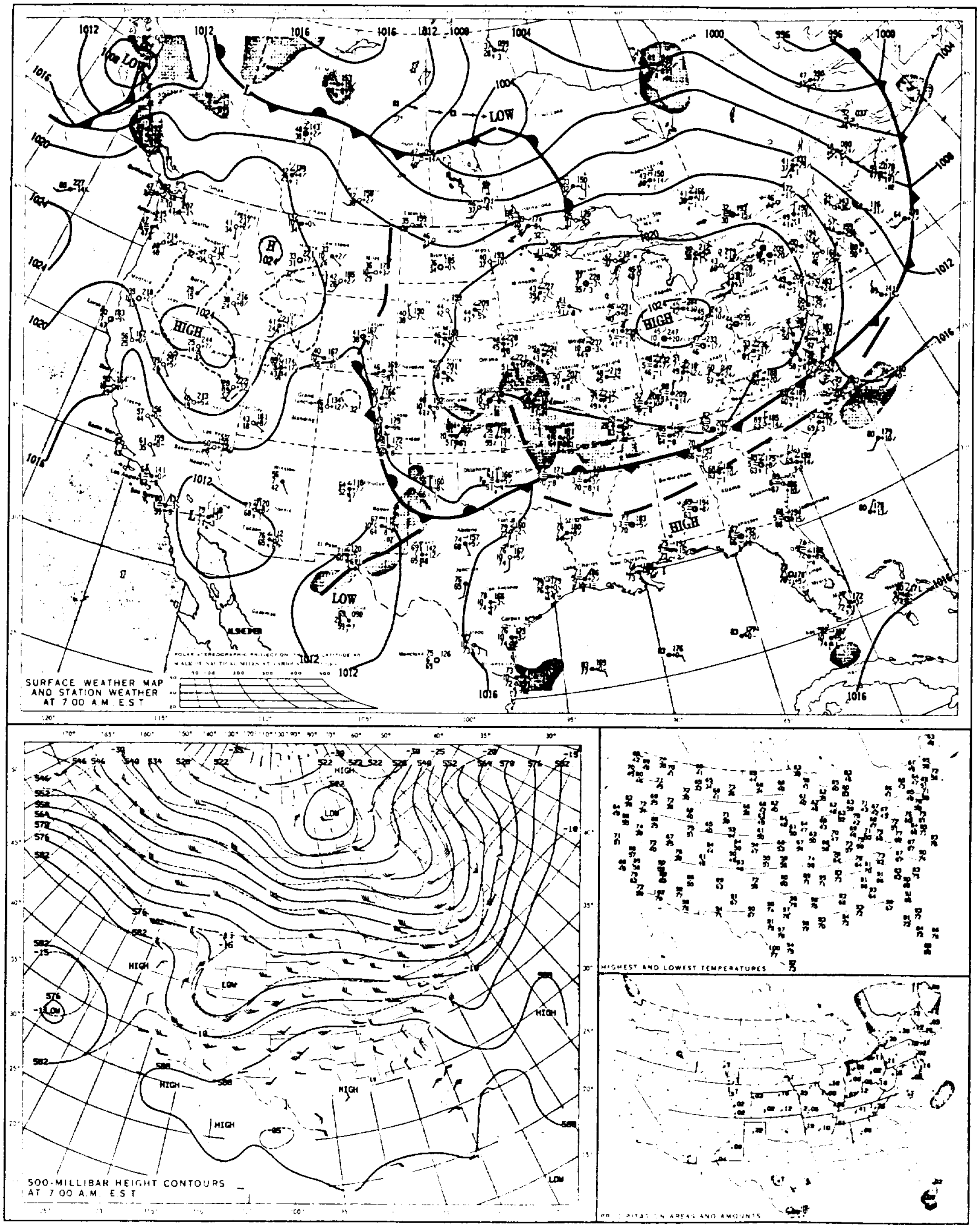
				CAMEX Experiment Schedule for CAMEX Operations Day 18																					
				Julian Day 9/24/93											Julian Day 9/25/93										
TIME (GMT Hour)	12	13	14	15	16	17	18	19	20	21	22	23	0	1	2	3	4	5	6	7	8	9	10	11	12
ER-2 Instruments																									
AMPR																									
EDOP																									
HIS																									
LIP																									
MAMS																									
MIR																									
MTS																									
Ground Sensors																									
Raman Lidar																									
HIS	X	X	X	X	X	X	X	X	X	X	X	X													
Johns Hopkins/APL Ship																									
CLASS Sonde																									
Rawinsonde																									
VIZ																									
Vaisala																									
AIR																									
Ozone Sonde																									

CAMEX FLIGHT DAY 18 - SATELLITE IMAGERY

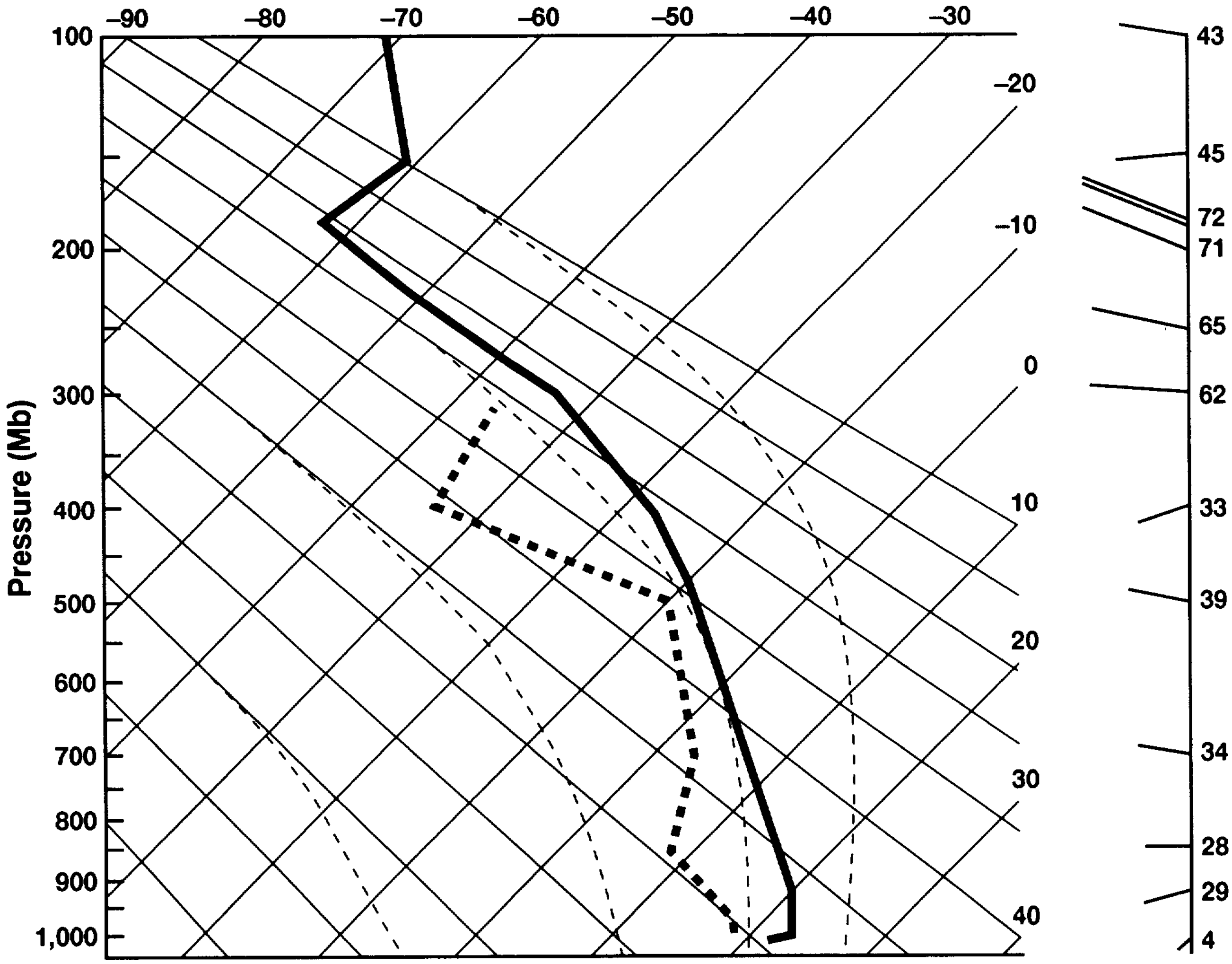


CAMEX FLIGHT DAY 18 - SYNOPTIC CHARTS

FRIDAY, SEPTEMBER 24, 1993



CAMEX FLIGHT DAY 18 - WALLOPS RAWINSONDE



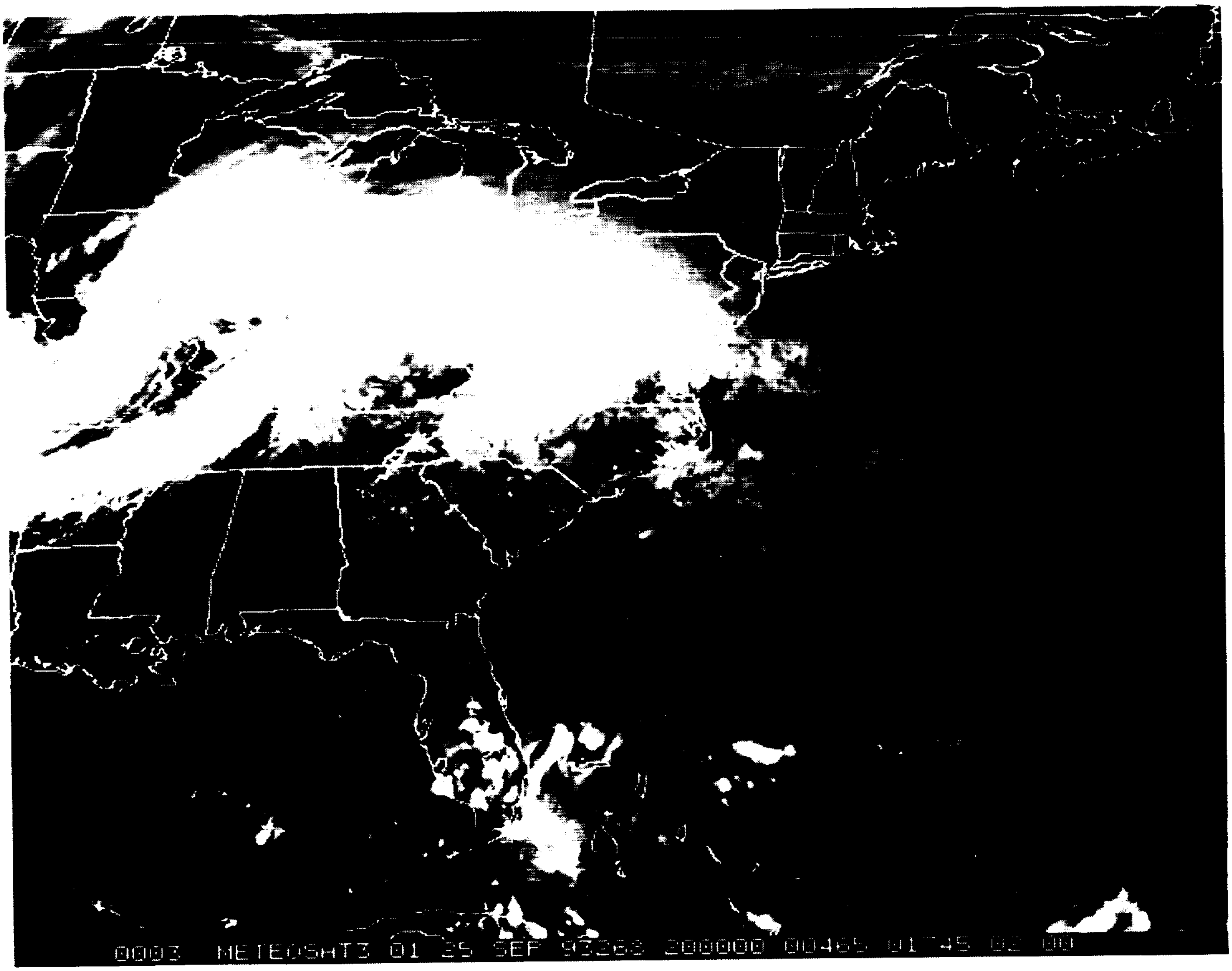
GMT	ID	TOTAL	EQUIP	FMAX	CVT	L.I.	KINX	PW
240,000	72,402	41	361	0	32	1	28	40

CAMEX FLIGHT DAY 19 - ACTIVITY

CAMEX Experiment Schedule for CAMEX Operations Day 19

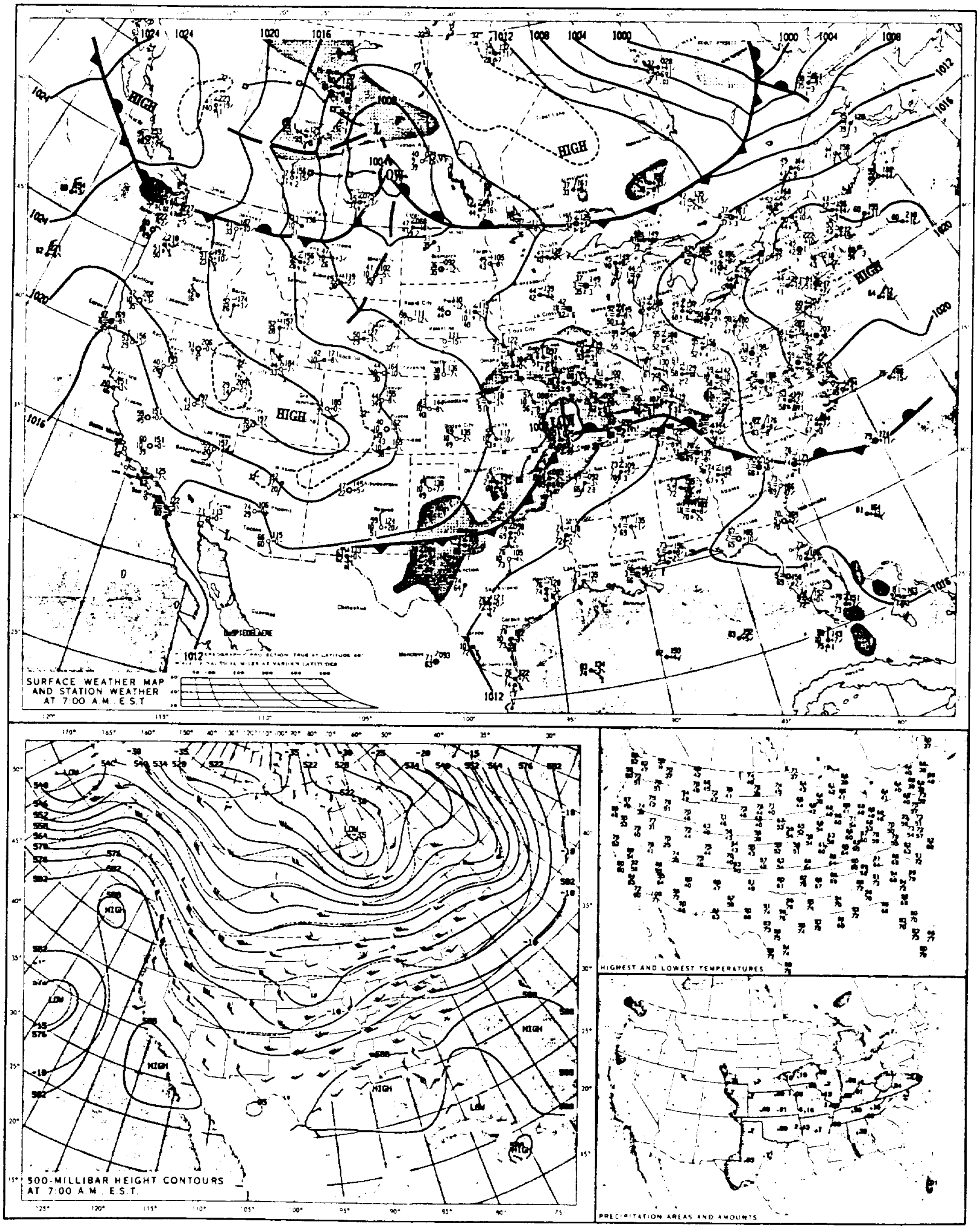
	Julian Day 9/25/93												Julian Day 9/26/93												
TIME (GMT Hour)	12	13	14	15	16	17	18	19	20	21	22	23	0	1	2	3	4	5	6	7	8	9	10	11	12
ER-2 Instruments																									
AMPR					X	X	X																		
EDOP					X	X	X																		
HIS					X	X	X																		
LIP					X	X	X																		
MAMS					X	F	F																		
MIR					X	X	X																		
MTS					X	X	X																		
Ground Sensors																									
Raman Lidar																									
HIS			X	X	X	X	X	X	X	X	X	X													
Johns Hopkins/APL Ship																									
CLASS Sonde						X																			
Rawinsonde																									
VIZ																									
Vaisala																									
AIR																									
Ozone Sonde																									

CAMEX FLIGHT DAY 19 - SATELLITE IMAGERY

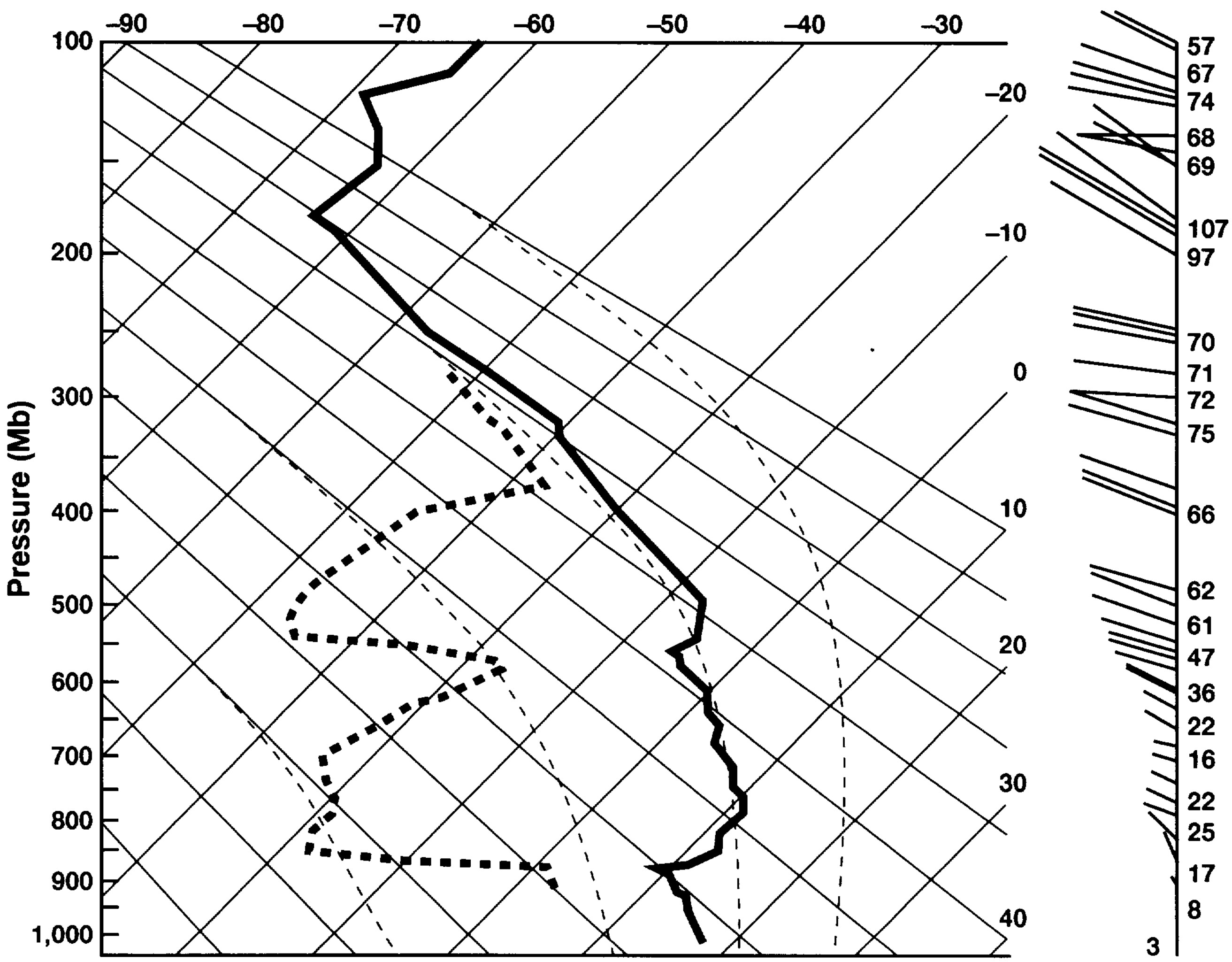


CAMEX FLIGHT DAY 19 - SYNOPTIC CHARTS

SATURDAY, SEPTEMBER 25, 1993



CAMEX FLIGHT DAY 19 - WALLOPS RAWINSONDE

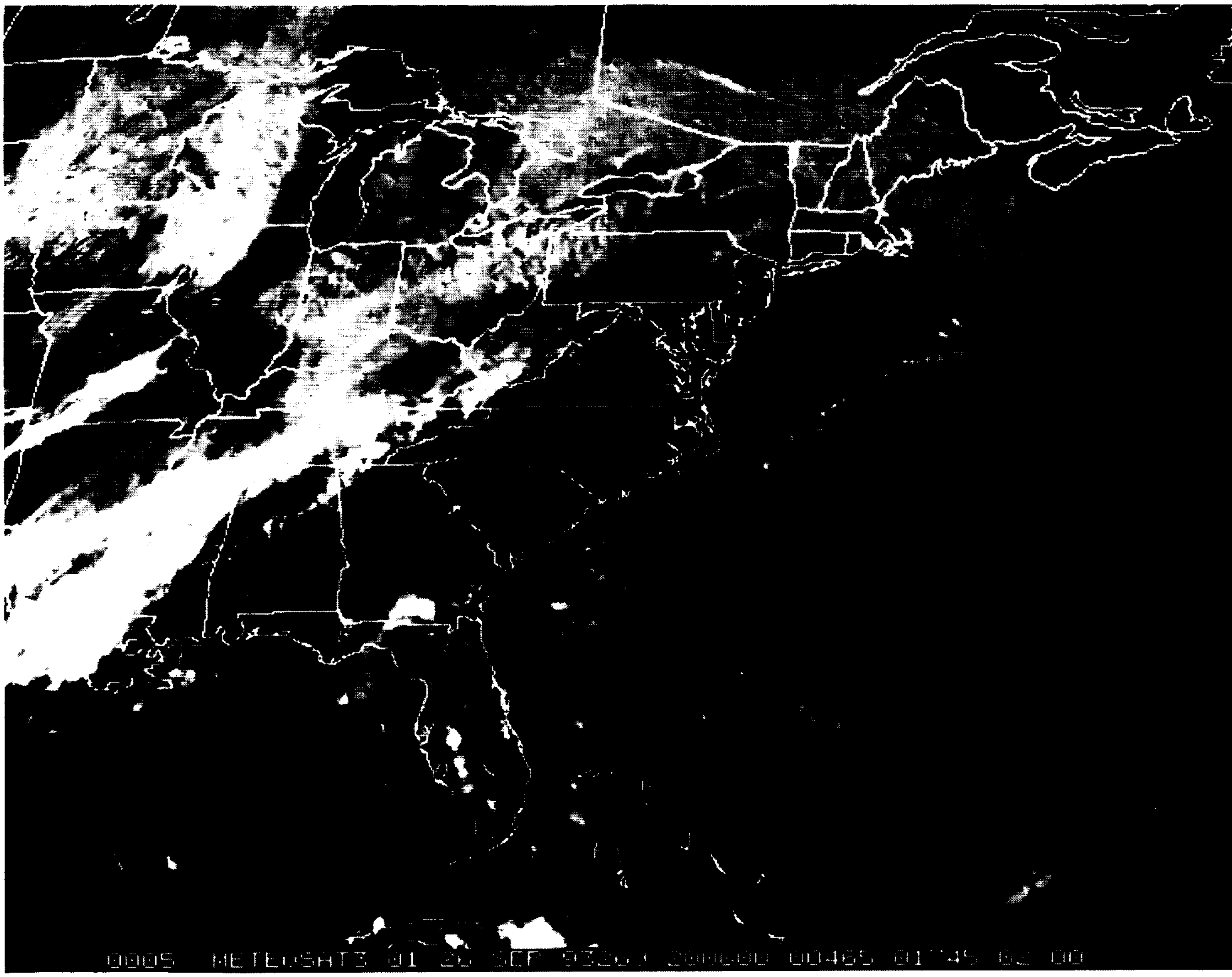


GMT	ID	TOTAL	EQUIP	FMAX	CVT	L.I.	KINX	PW
250,000	72,402	7		0		15	-30	13

CAMEX FLIGHT DAY 20 - ACTIVITY

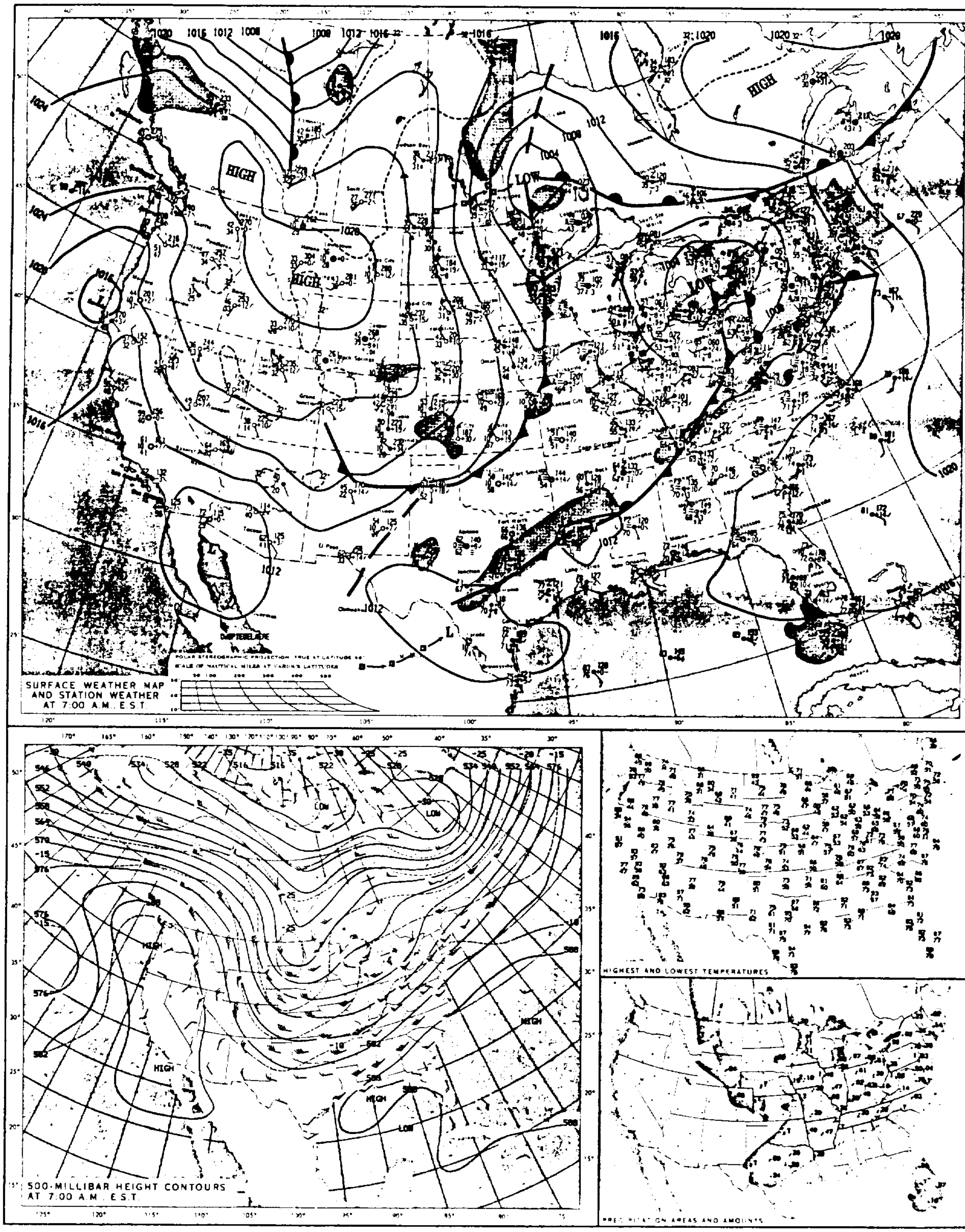
				CAMEX Experiment Schedule for CAMEX Operations Day 20																				
				Julian Day 9/26/93											Julian Day 9/27/93									
TIME (GMT Hour)	12	13	14	15	16	17	18	19	20	21	22	23	0	1	2	3	4	5	6	7	8	9	10	11	12
ER-2 Instruments																								
AMPR								X	X	X	X	X													
EDOP																									
HIS								X	X	X	X	X													
LIP								X	X	X	X	X													
MAMS								X	X	X	X	X													
MIR								X	X	X	X	X													
MTS								X	X	X	X	X													
Ground Sensors																									
Raman Lidar																									
HIS					X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
Johns Hopkins/APL Ship																									
CLASS Sonde											X														
Rawinsonde																									
VIZ																									
Vaisala																									
AIR																									
Ozone Sonde																									

CAMEX FLIGHT DAY 20 - SATELLITE IMAGERY

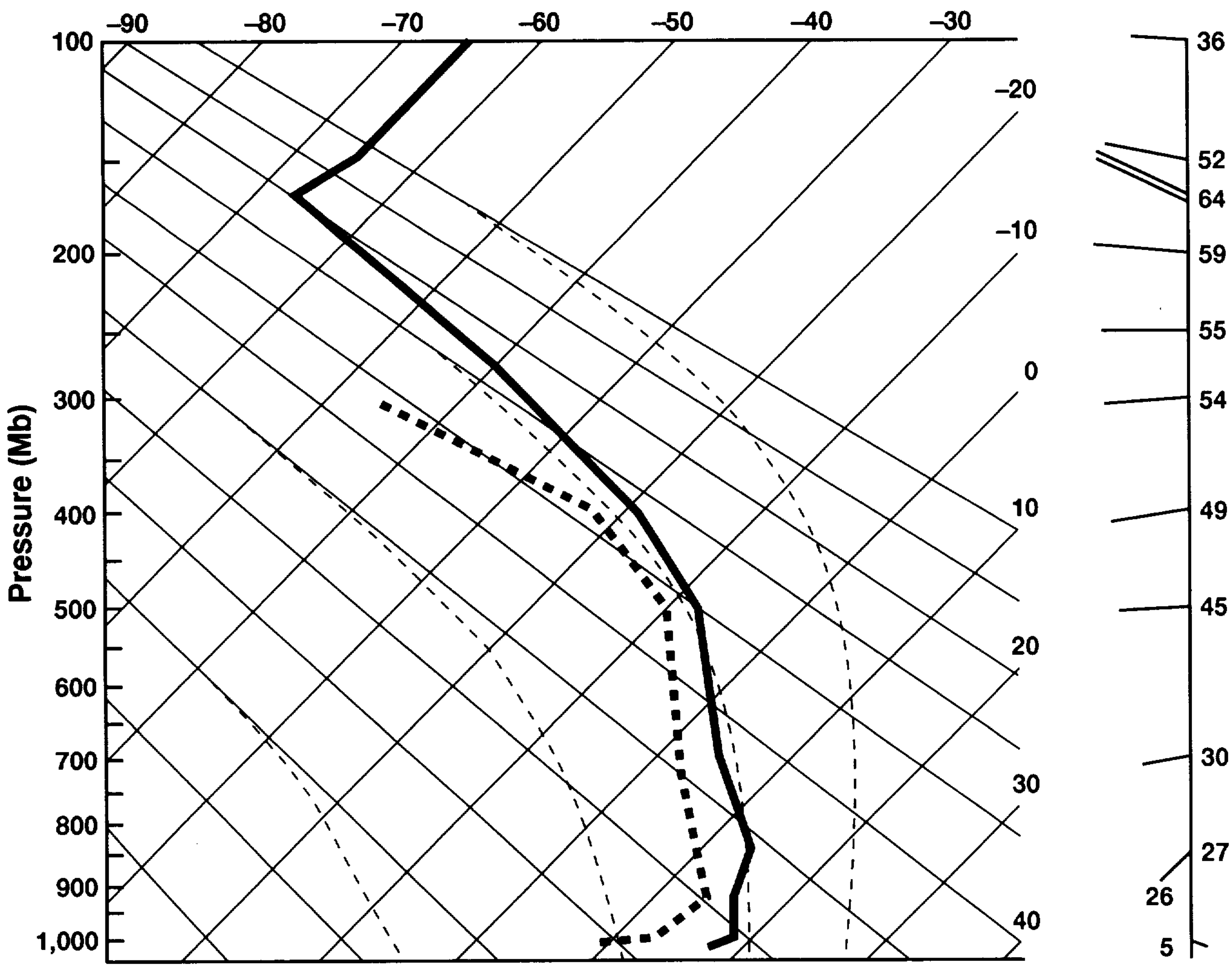


CAMEX FLIGHT DAY 20 - SYNOPTIC CHARTS

SUNDAY, SEPTEMBER 26, 1993



CAMEX FLIGHT DAY 20 - WALLOPS RAWINSONDE



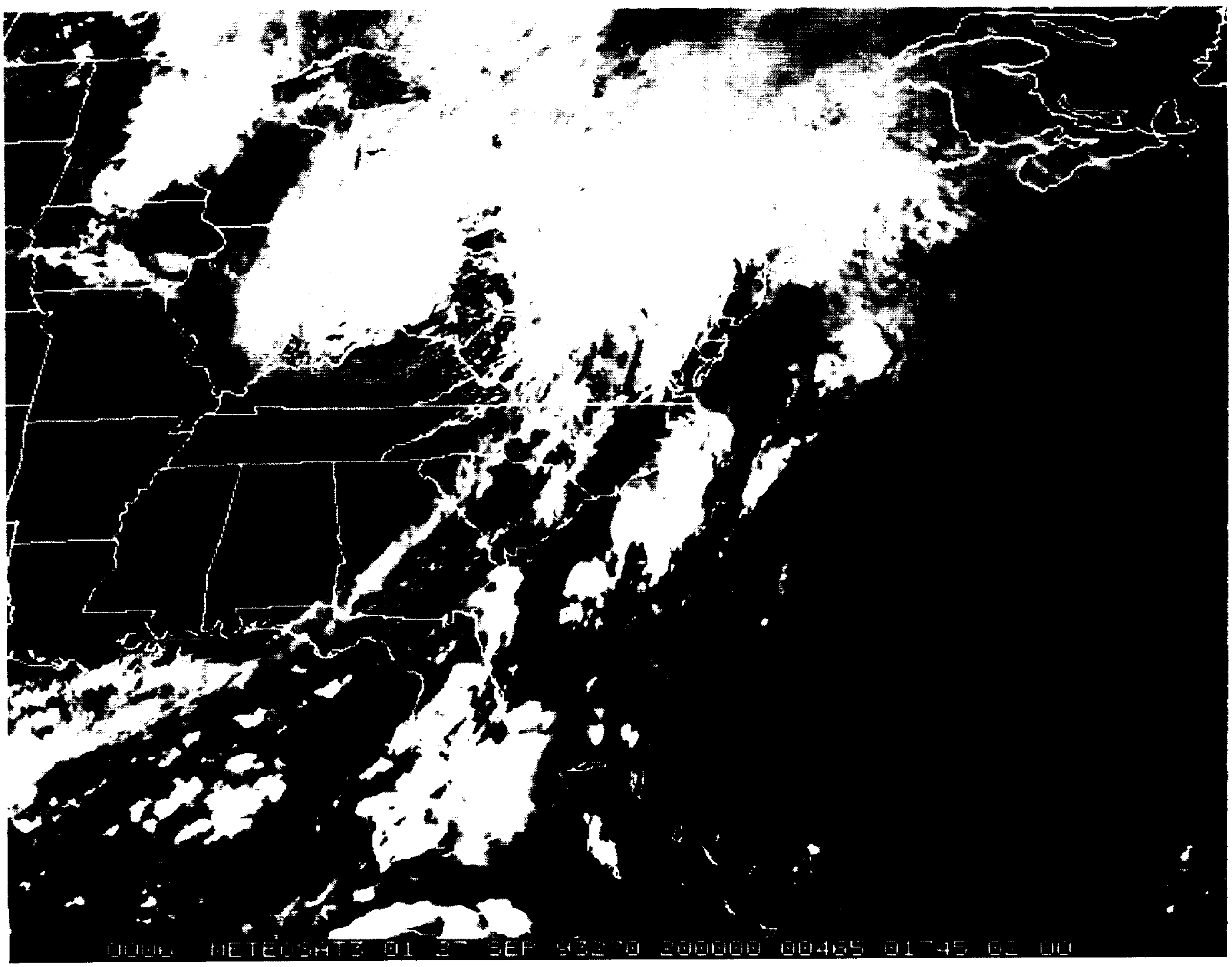
GMT	ID	TOTAL	EQUIP	FMAX	CVT	L.I.	KINX	PW
260,000	72,402	40	529	0	31	7	29	38

CAMEX FLIGHT DAY 21 - ACTIVITY

CAMEX Experiment Schedule for CAMEX Operations Day 21

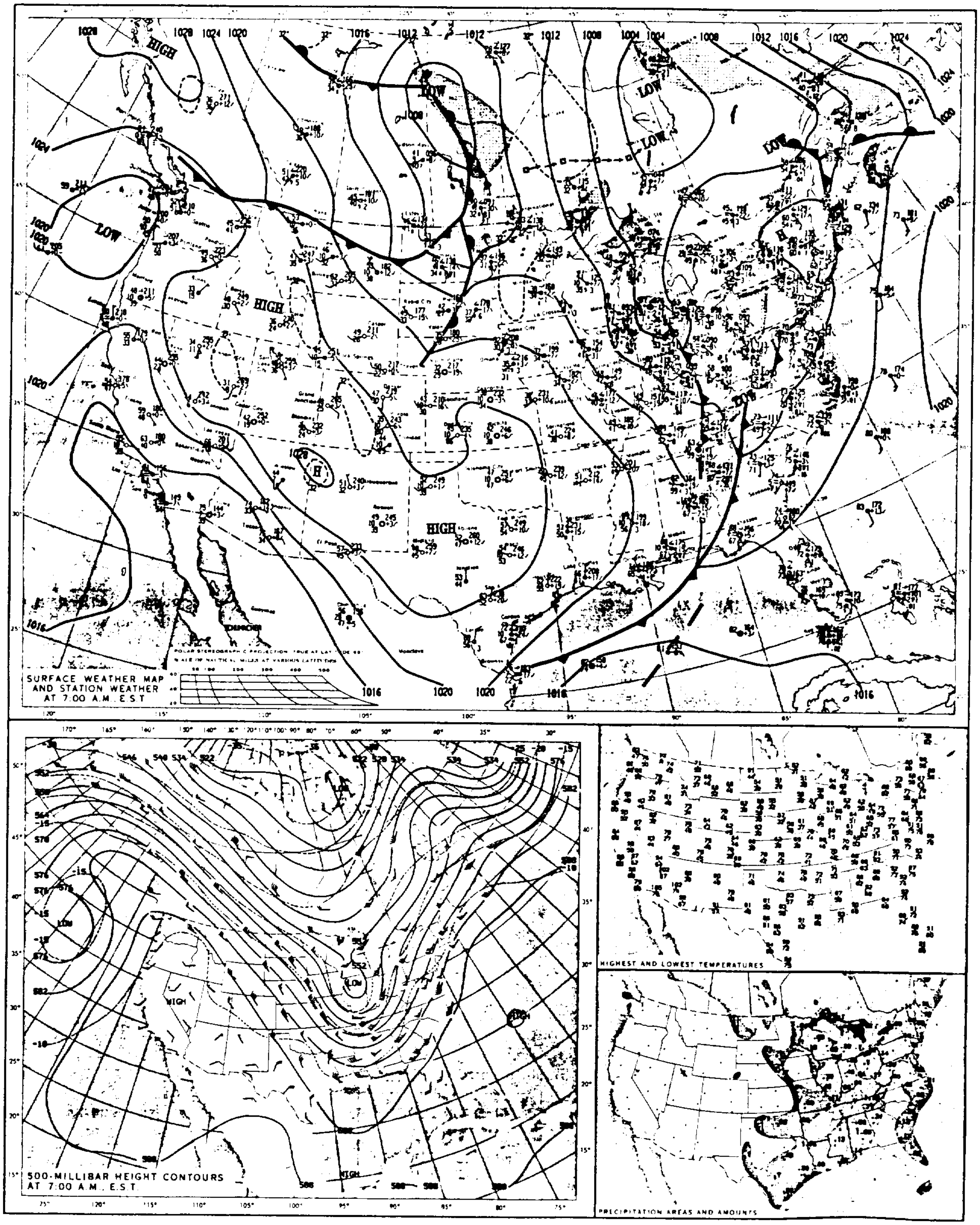
				Julian Day 9/27/93												Julian Day 9/28/93								
TIME (GMT Hour)	12	13	14	15	16	17	18	19	20	21	22	23	0	1	2	3	4	5	6	7	8	9	10	11	12
ER-2 Instruments																								
AMPR																								
EDOP																								
HIS																								
LIP																								
MAMS																								
MIR																								
MTS																								
Ground Sensors																								
Raman Lidar																								
HIS	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
Johns Hopkins/APL Ship																								
CLASS Sonde																								
Rawinsonde																								
VIZ																								
Vaisala			X																					
AIR																								
Ozone Sonde																								

CAMEX FLIGHT DAY 21 - SATELLITE IMAGERY

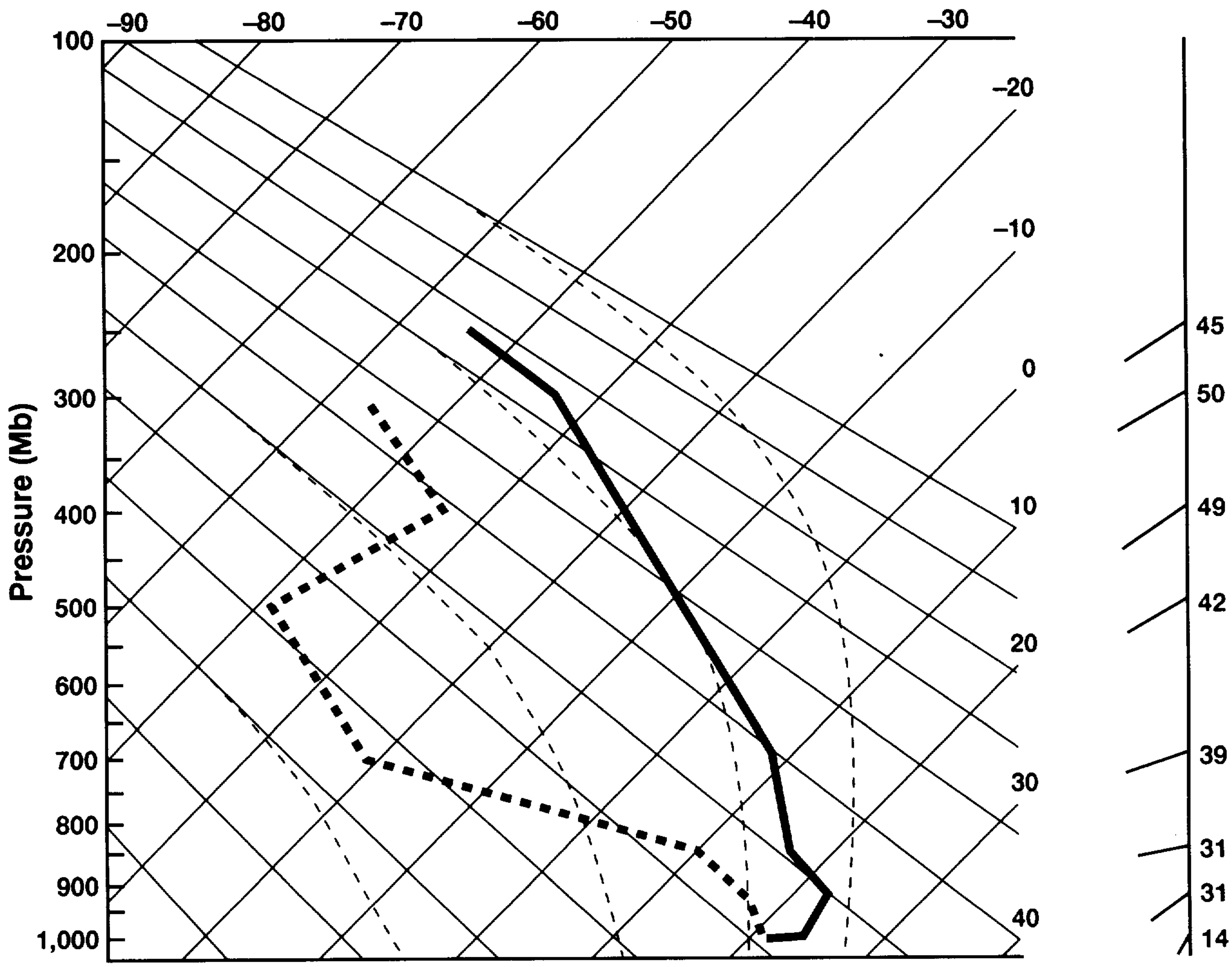


CAMEX FLIGHT DAY 21 - SYNOPTIC CHARTS

MONDAY, SEPTEMBER 27, 1993



CAMEX FLIGHT DAY 21 - WALLOPS RAWINSONDE



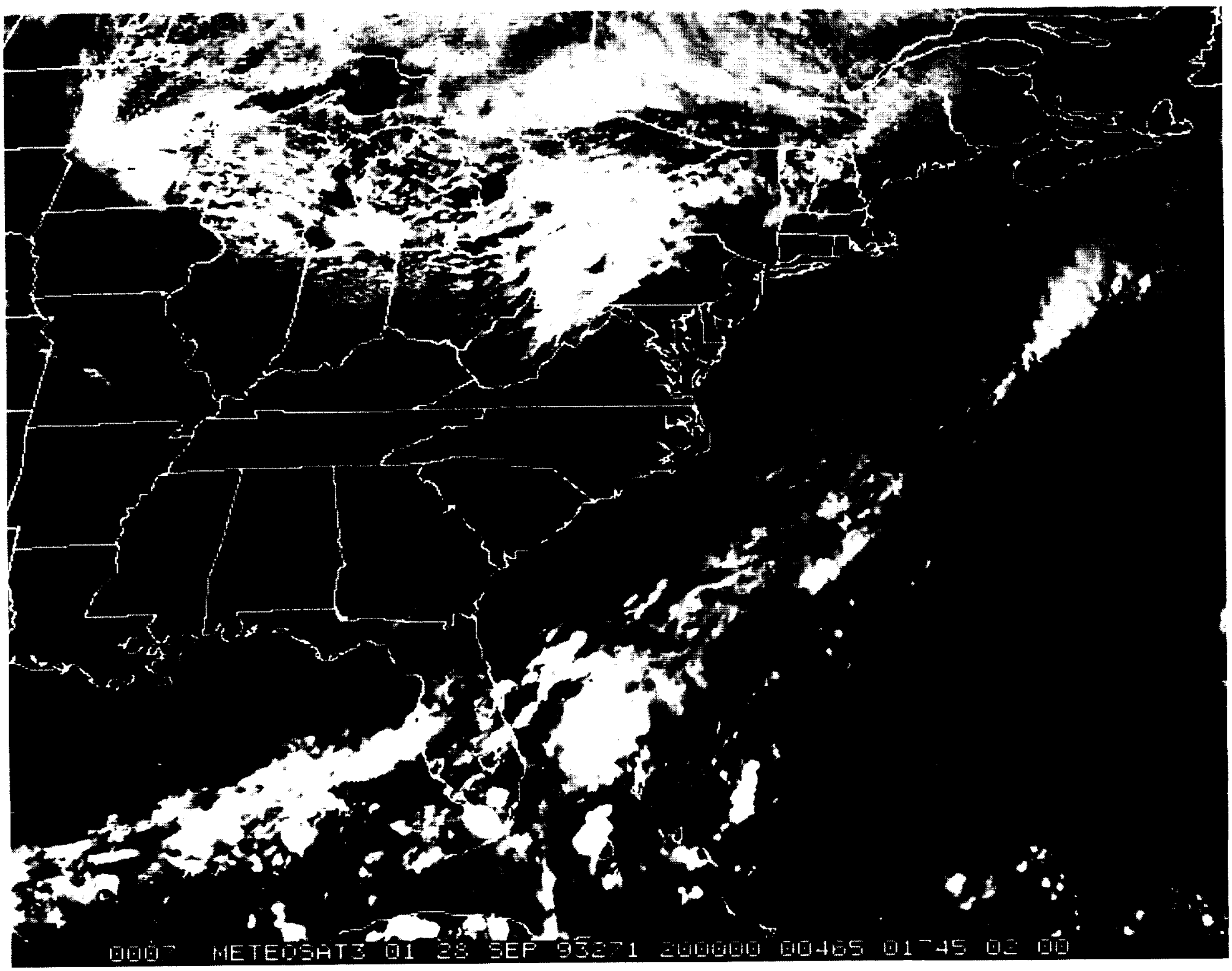
GMT	ID	TOTAL	EQUIP	FMAX	CVT	L.I.	KINX	PW
270,000	72,402	261	0	0	32	–3	6	30

CAMEX FLIGHT DAY 22 - ACTIVITY

CAMEX Experiment Schedule for CAMEX Operations Day 22

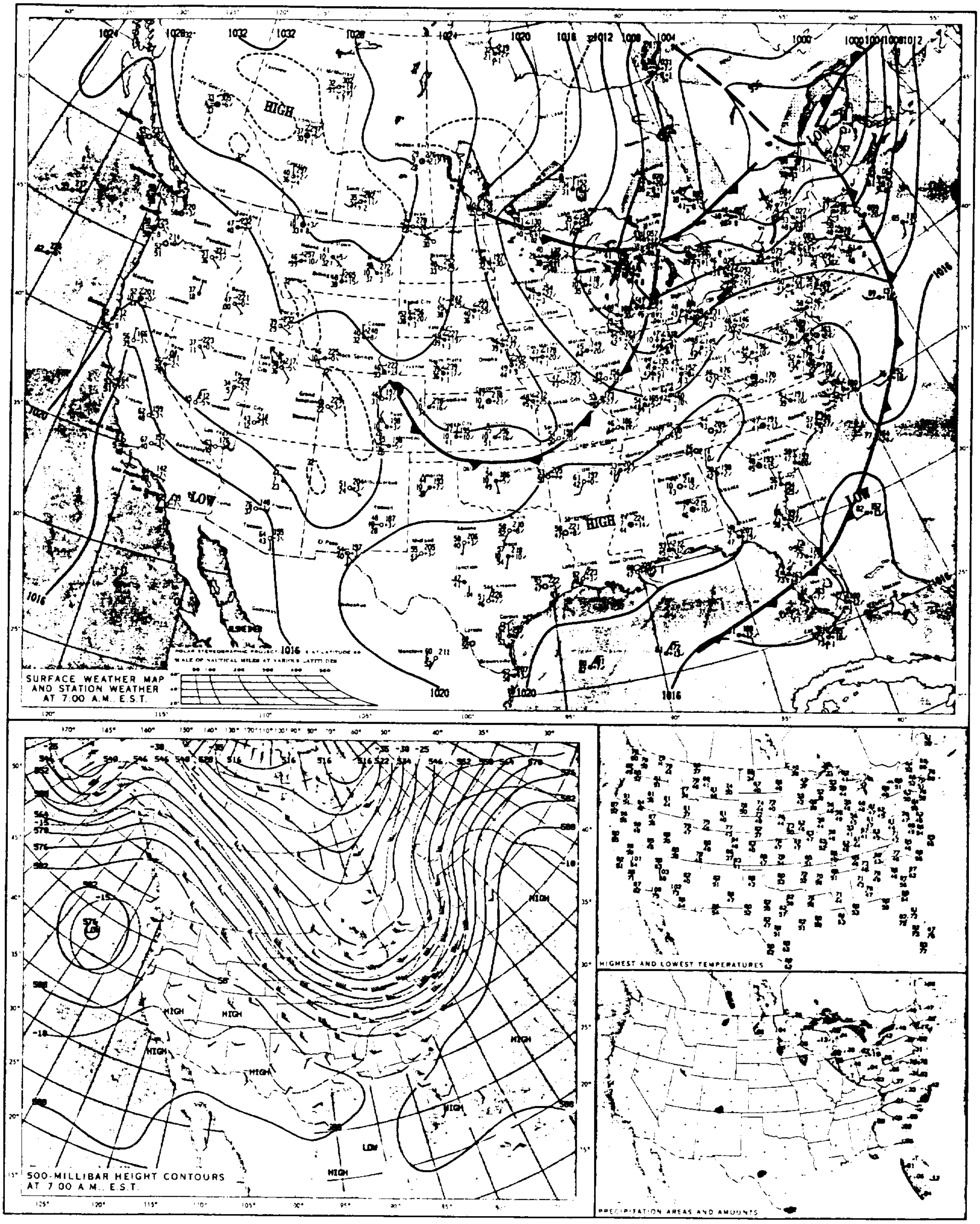
				Julian Day 9/28/93												Julian Day 9/29/93									
TIME (GMT Hour)	12	13	14	15	16	17	18	19	20	21	22	23	0	1	2	3	4	5	6	7	8	9	10	11	12
ER-2 Instruments																									
AMPR														X	X	X	X								
EDOP																									
HIS														X	X	X	X								
LIP														F	F	F	F								
MAMS														F	F	F	F								
MIR														X	X	X	X								
MTS														X	X	X	X								
Ground Sensors																									
Raman Lidar													X	X	X	X	X								
HIS	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
Johns Hopkins/APL Ship											X	X	X	X	X	X	X								
CLASS Sonde											X			X			X								
Rawinsonde																									
VIZ							X																		
Vaisala											X			X			X								
AIR											X			X			X								
Ozone Sonde														X											

CAMEX FLIGHT DAY 22 - SATELLITE IMAGERY

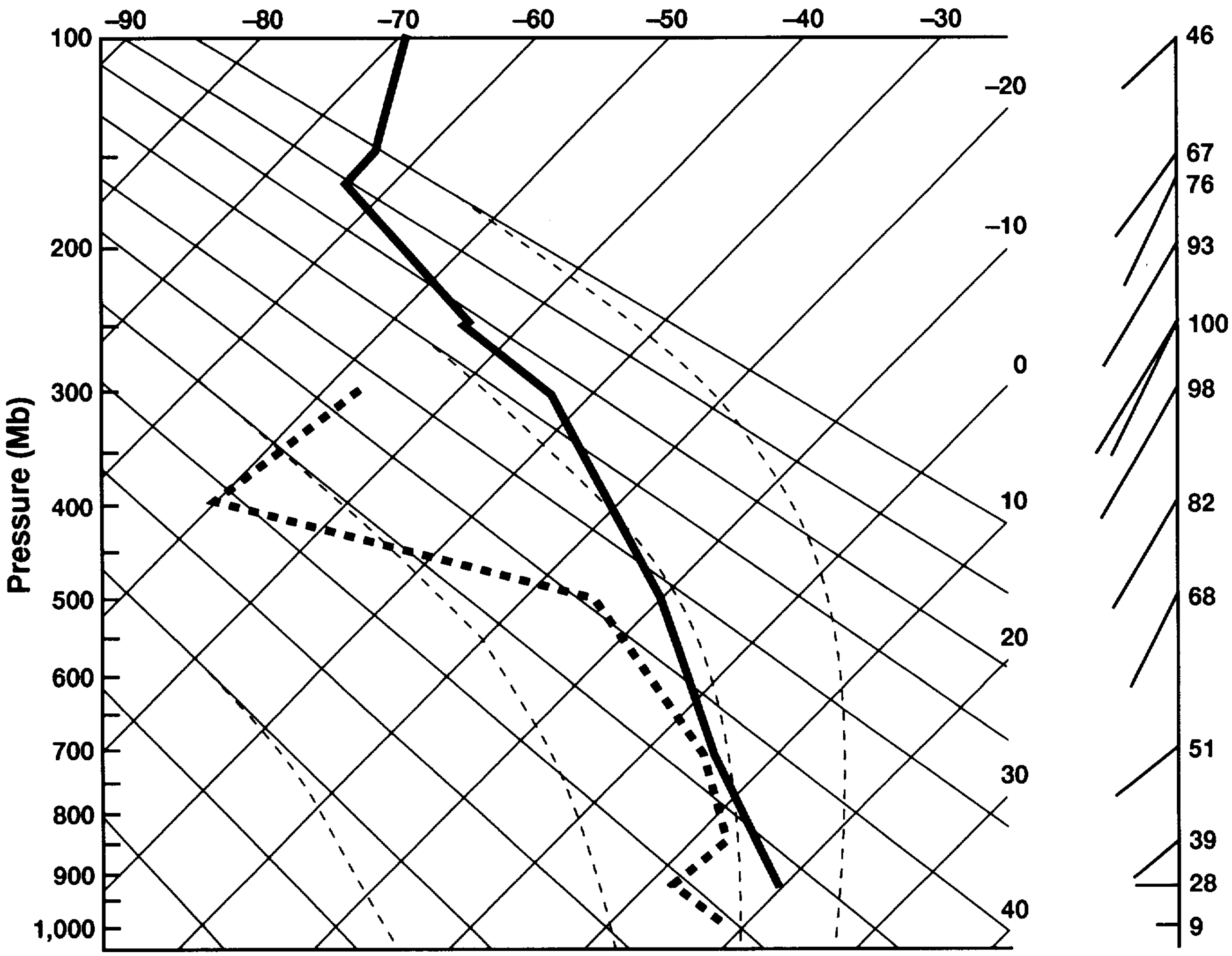


CAMEX FLIGHT DAY 22 - SYNOPTIC CHARTS

TUESDAY, SEPTEMBER 28, 1993



CAMEX FLIGHT DAY 22 - WALLOPS RAWINSONDE



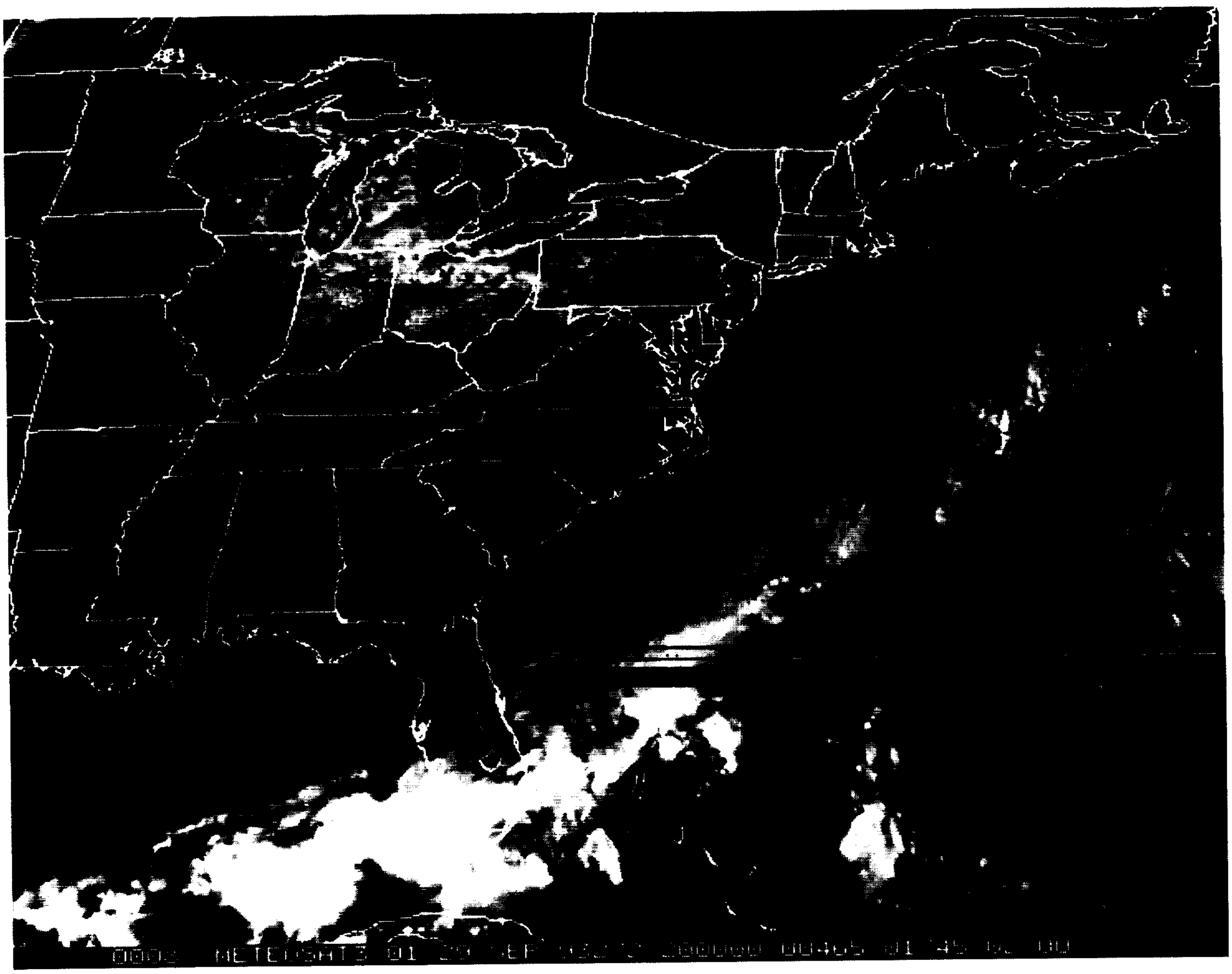
GMT	ID	TOTAL	EQUIP	FMAX	CVT	L.I.	KINX	PW
280,000	72,402	48	405	0	30	2	37	41

CAMEX FLIGHT DAY 23 - ACTIVITY

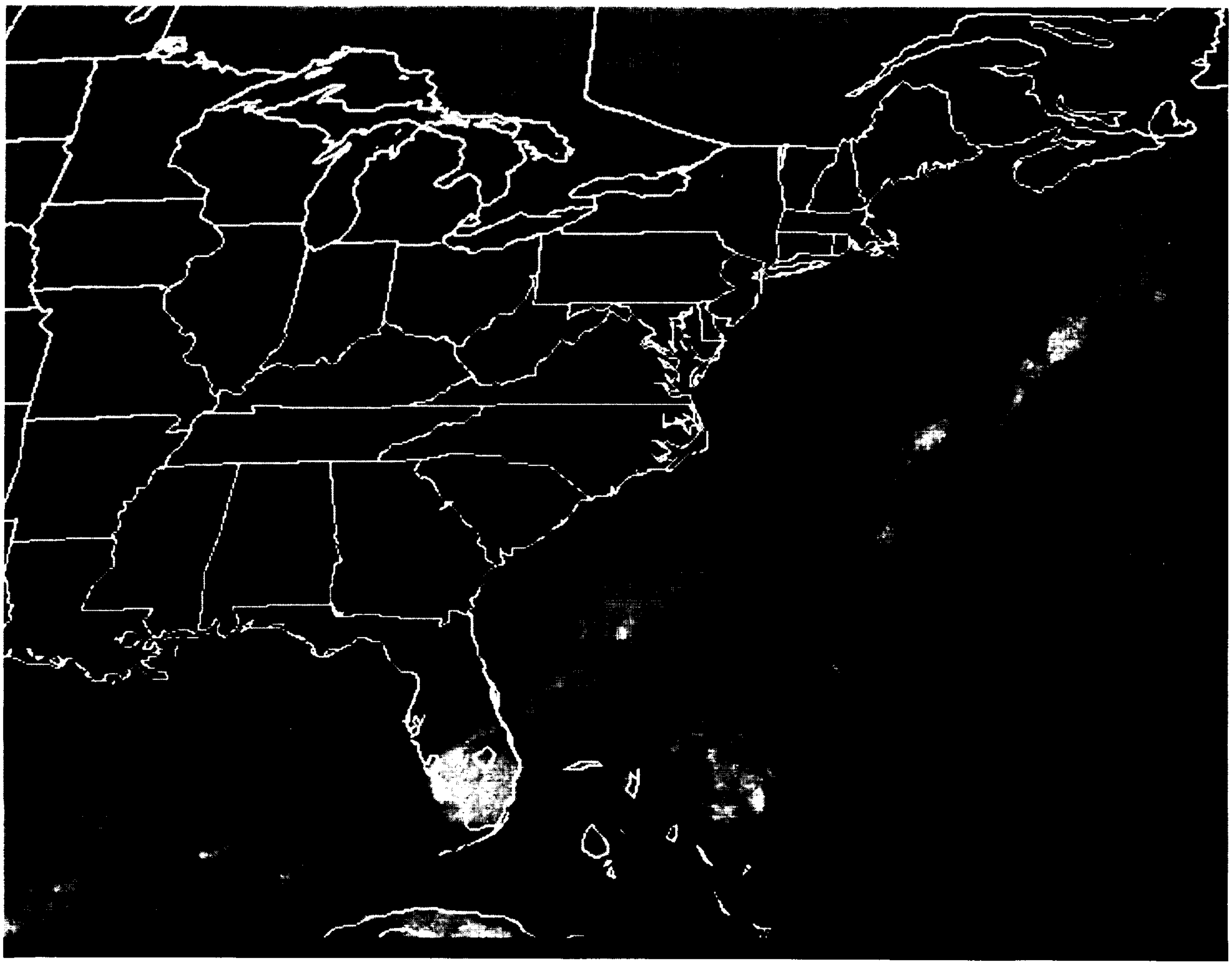
CAMEX Experiment Schedule for CAMEX Operations Day 23

	Julian Day 9/29/93												Julian Day 9/30/93												
TIME (GMT Hour)	12	13	14	15	16	17	18	19	20	21	22	23	0	1	2	3	4	5	6	7	8	9	10	11	12
ER-2 Instruments																									
AMPR																									
EDOP																									
HIS																									
LIP																									
MAMS																									
MIR																									
MTS																									
Ground Sensors																									
Raman Lidar													X	X	X	X	X								
HIS	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
Johns Hopkins/APL Ship																									
CLASS Sonde											X			X			X								
Rawinsonde																									
VIZ											X														
Vaisala											X			X		X									
AIR					X						X			X		X									
Ozone Sonde																									

CAMEX FLIGHT DAY 23 - SATELLITE IMAGERY-VISIBLE

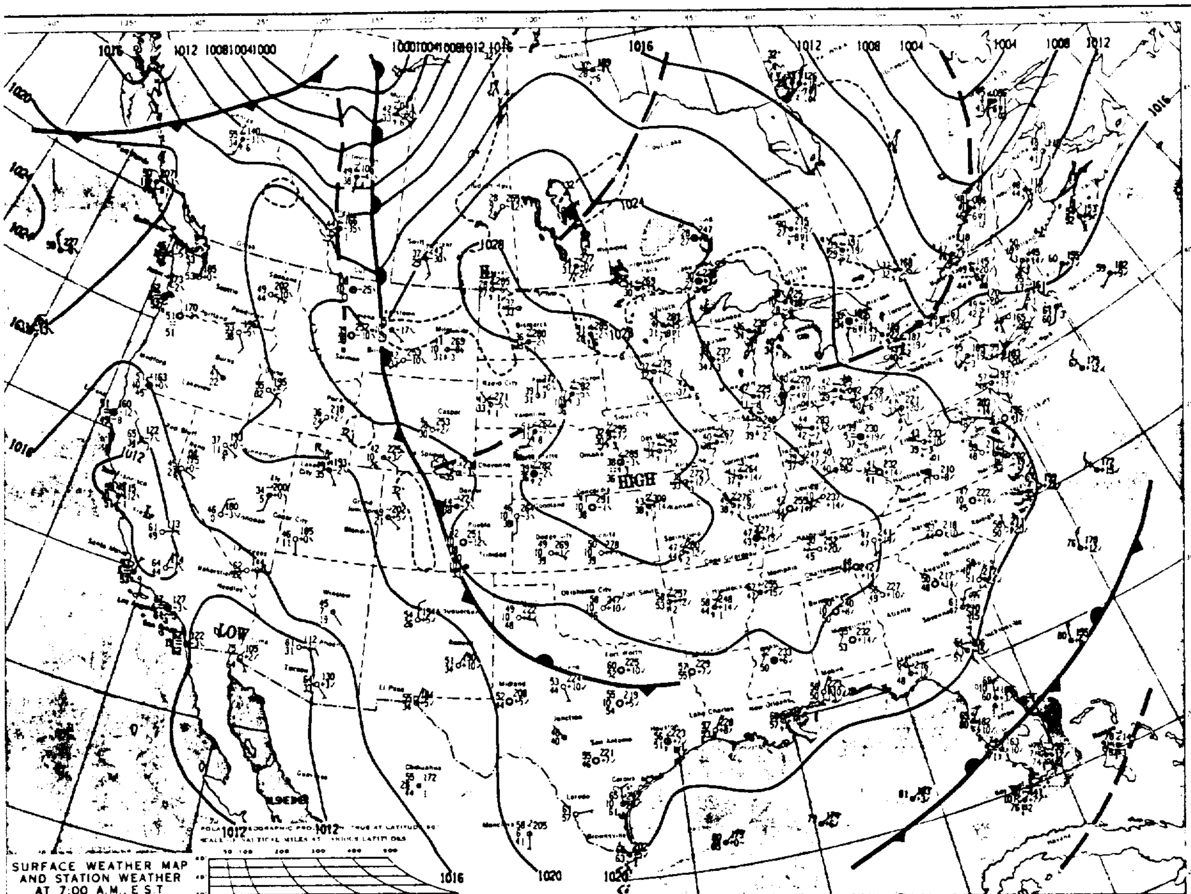


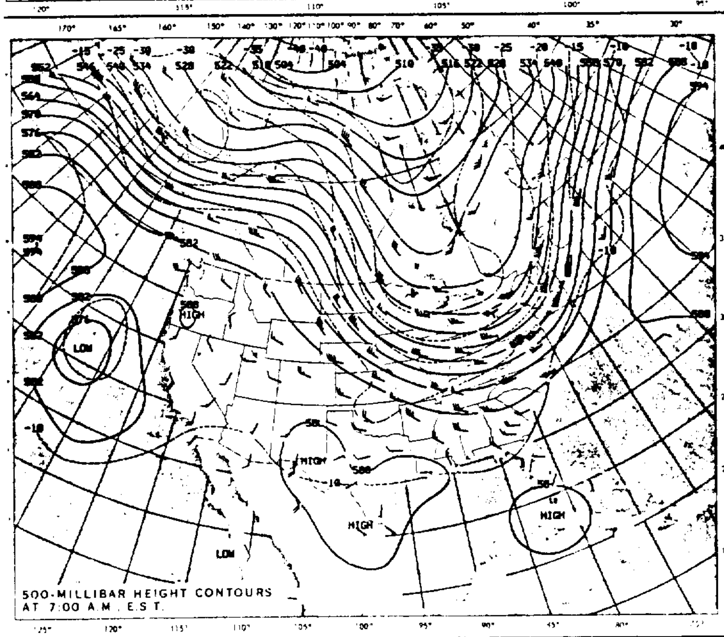
CAMEX FLIGHT DAY 23 - SATELLITE IMAGERY-WATER VAPOR

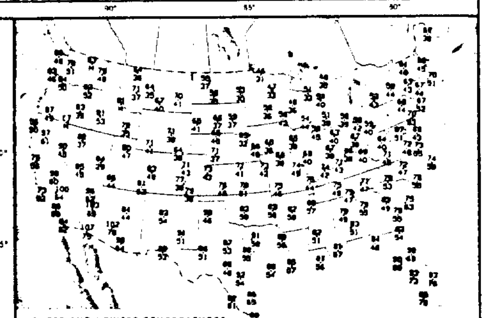


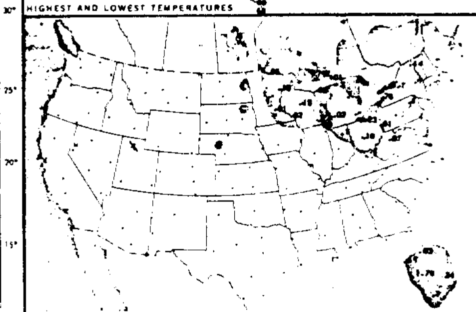
CAMEX FLIGHT DAY 23 - SYNOPTIC CHARTS

SEPTEMBER 29, 1993

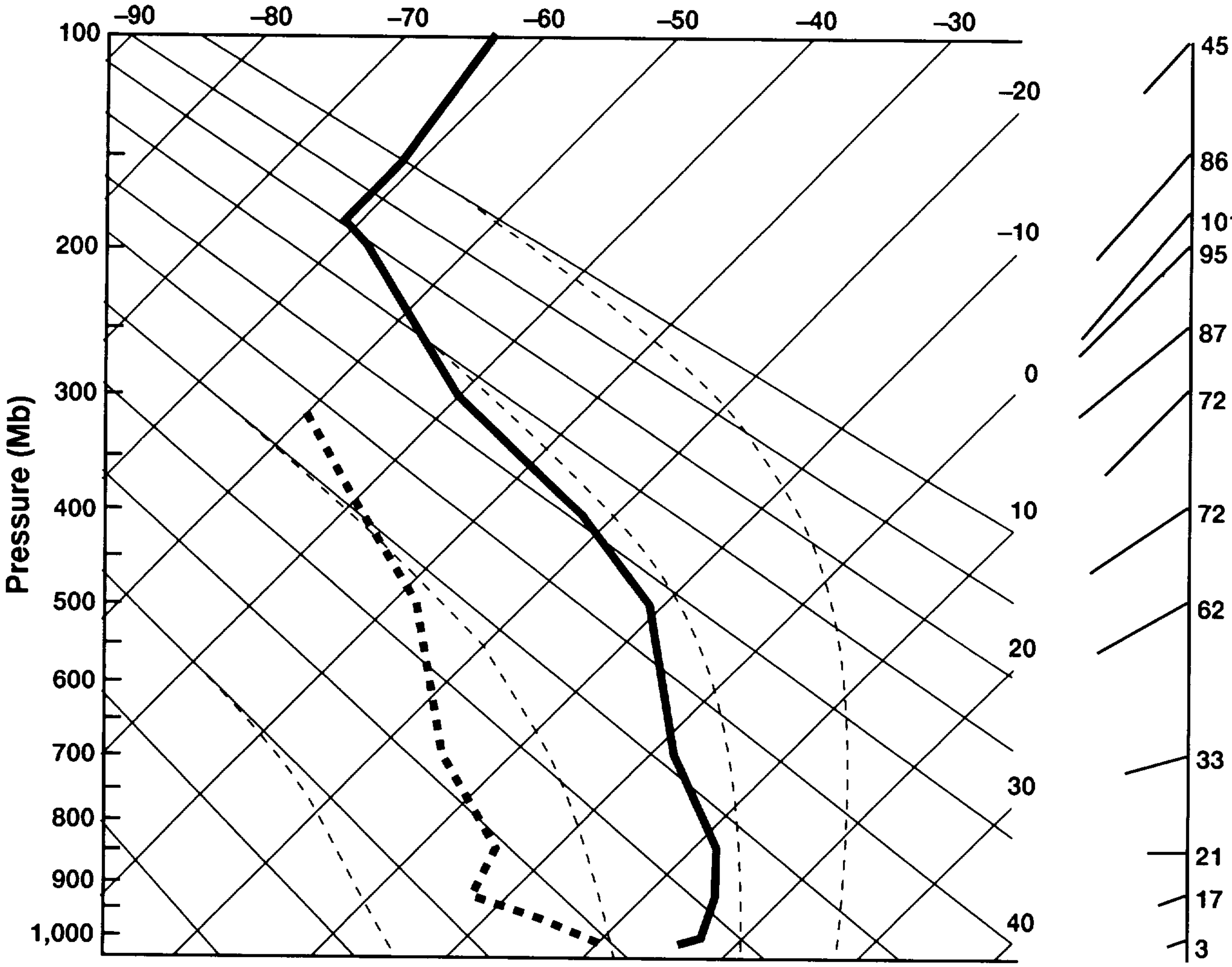








CAMEX FLIGHT DAY 23 - WALLOPS RAWINSONDE

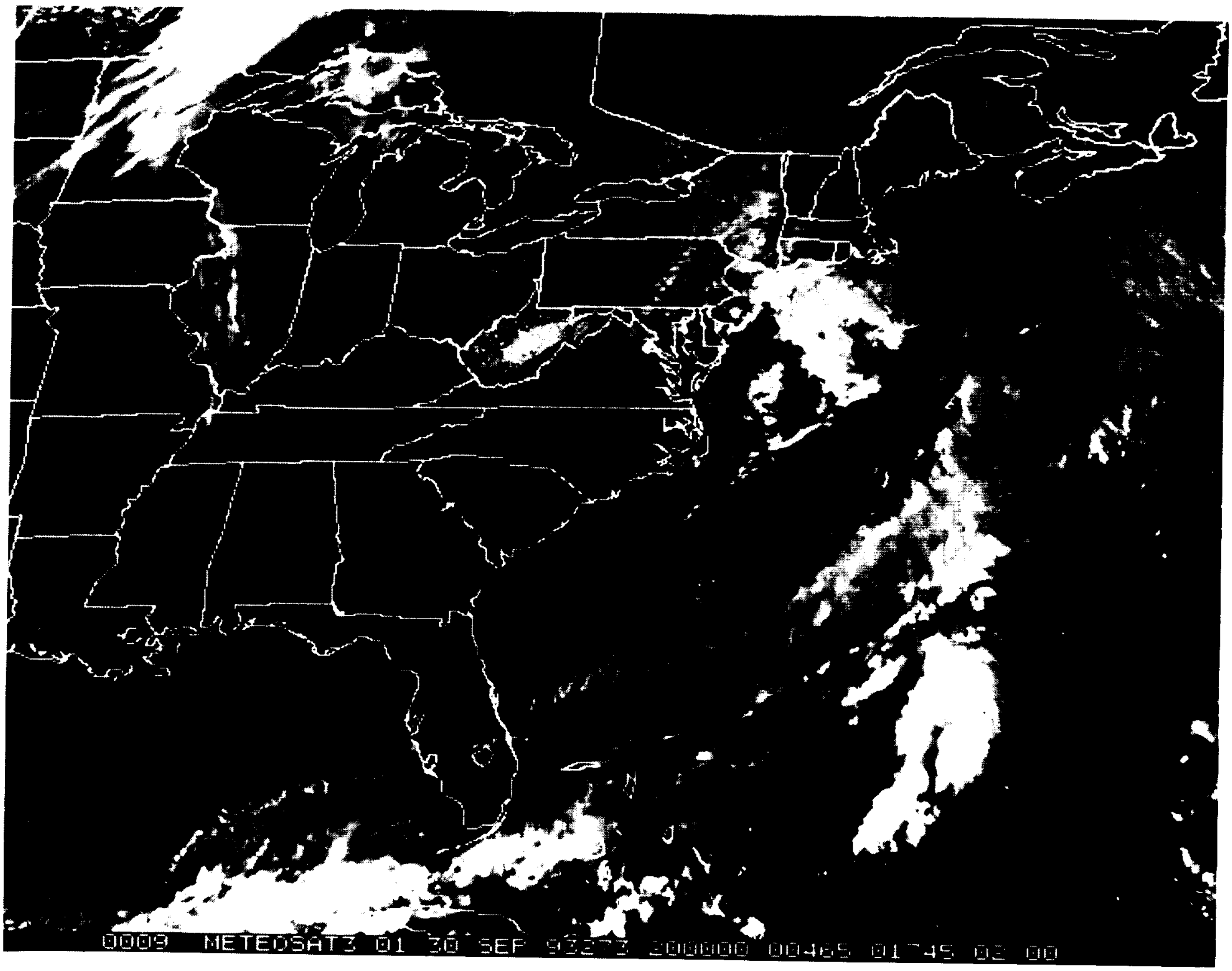


GMT	ID	TOTAL	EQUIP	FMAX	CVT	L.I.	KINX	PW
290,000	72,402	29		0		13	1	13

CAMEX FLIGHT DAY 24 - ACTIVITY

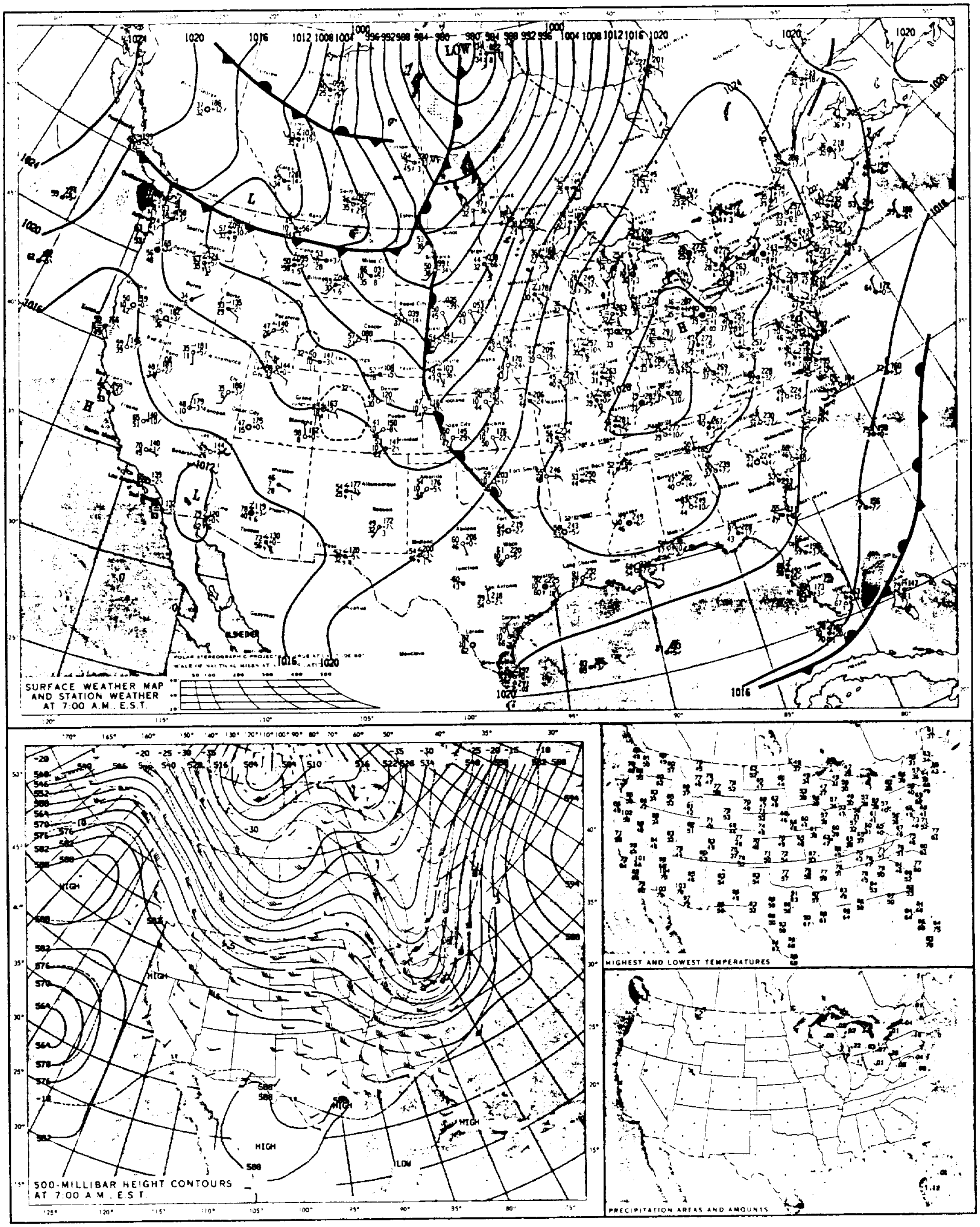
				CAMEX Experiment Schedule for CAMEX Operations Day 24																					
				Julian Day 9/30/93												Julian Day 10/01/93									
TIME (GMT Hour)	12	13	14	15	16	17	18	19	20	21	22	23	0	1	2	3	4	5	6	7	8	9	10	11	12
ER-2 Instruments																									
AMPR									X	X	X	X	X	X	X										
EDOP																									
HIS									X	X	X	X	X	X	X										
LIP																									
MAMS									X	X	X	X	X	X	X										
MIR									X	X	X	X	X	X	X										
MTS									X	X	X	X	X	X	X										
Ground Sensors																									
Raman Lidar													X	X	X	X	X								
HIS	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
Johns Hopkins/APL Ship																									
CLASS Sonde											X			X			X								
Rawinsonde																									
VIZ																									
Vaisala											X			X			X								
AIR											X	·					X								
Ozone Sonde														X											

CAMEX FLIGHT DAY 24 - SATELLITE IMAGERY

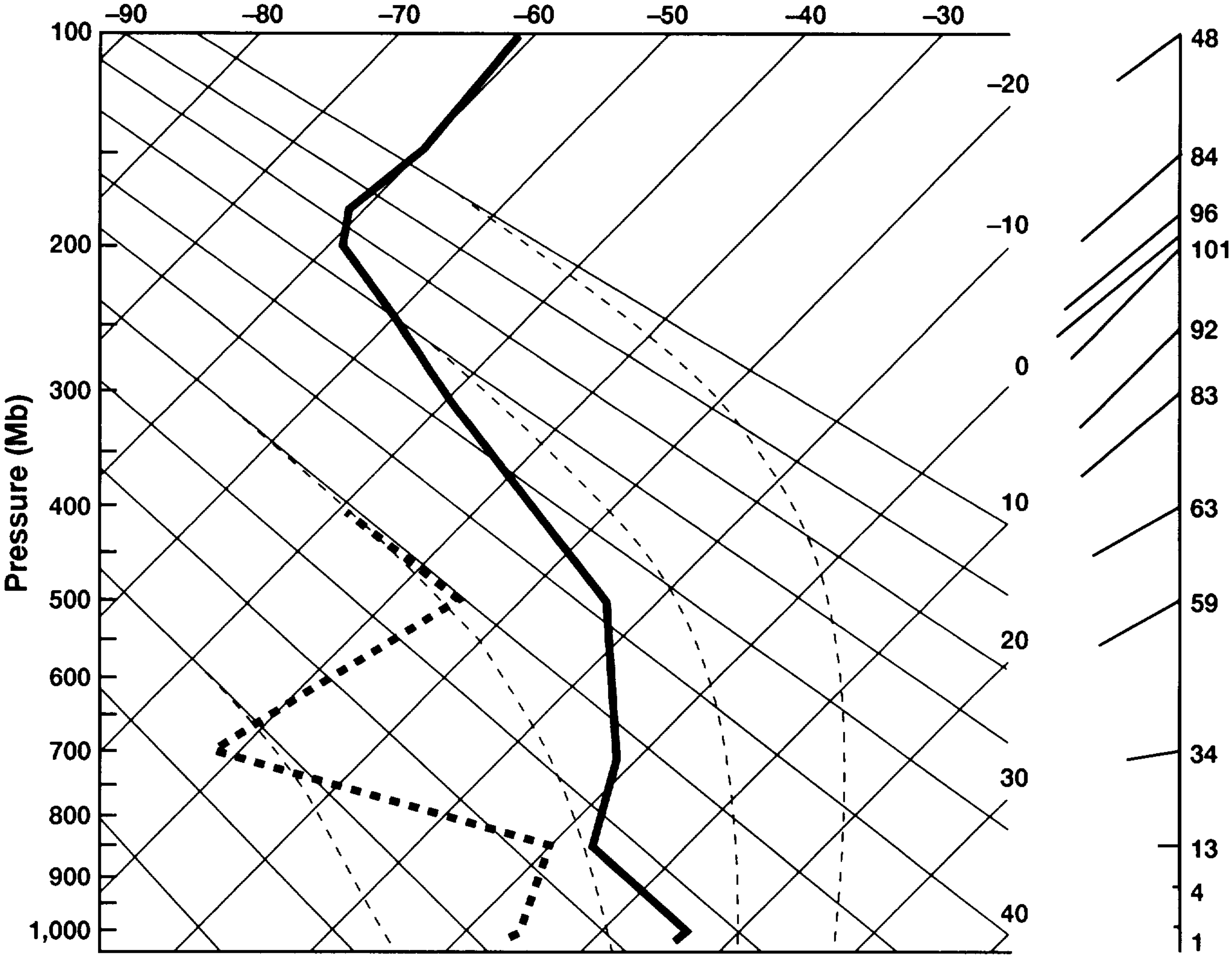


CAMEX FLIGHT DAY 24 - SYNOPTIC CHARTS

THURSDAY, SEPTEMBER 30, 1993



CAMEX FLIGHT DAY 24 - WALLOPS RAWINSONDE

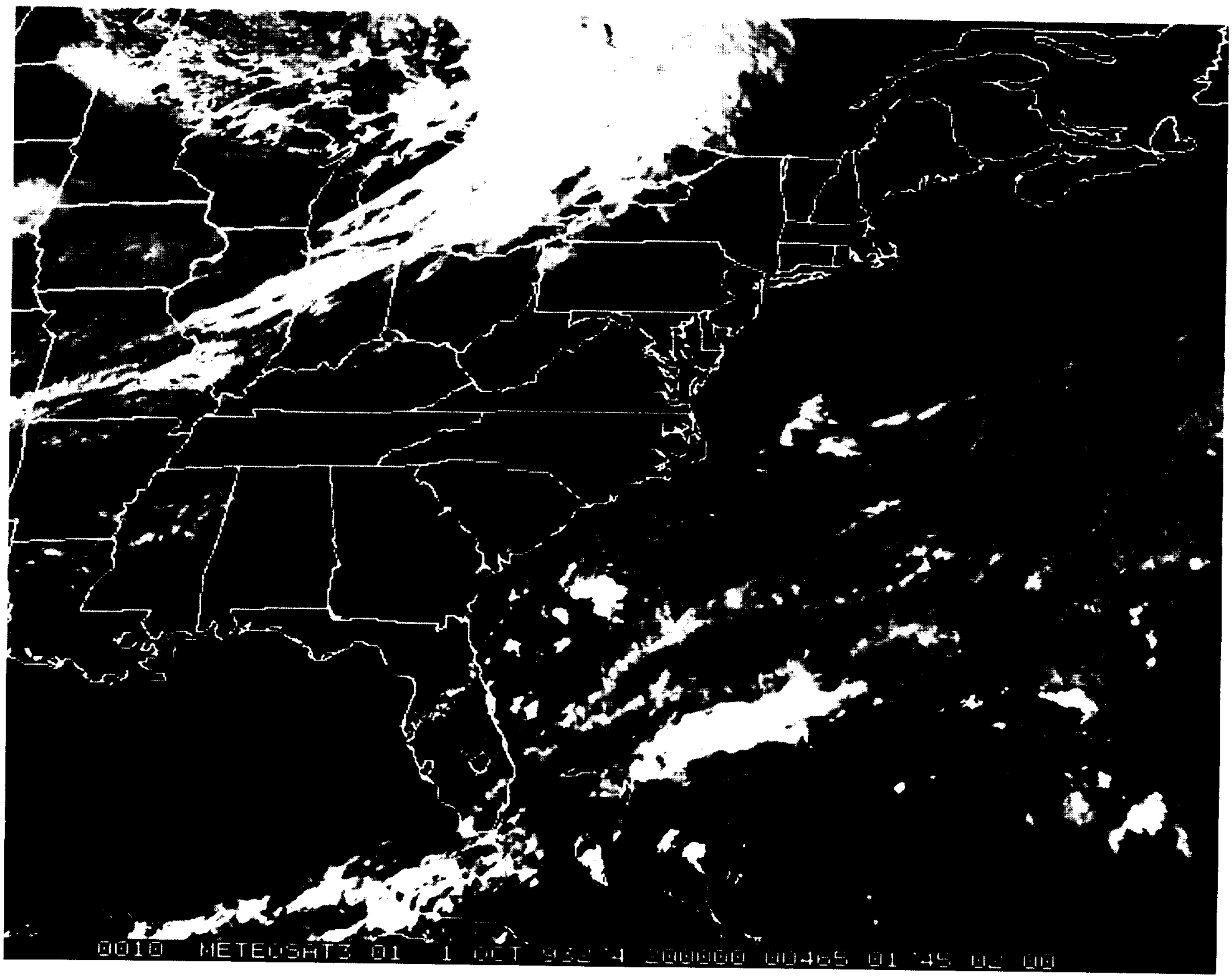


GMT	ID	TOTAL	EQUIP	FMAX	CVT	L.I.	KINX	PW
300,000	72,402	32		0	26	13	–13	13

CAMEX FLIGHT DAY 25 - ACTIVITY

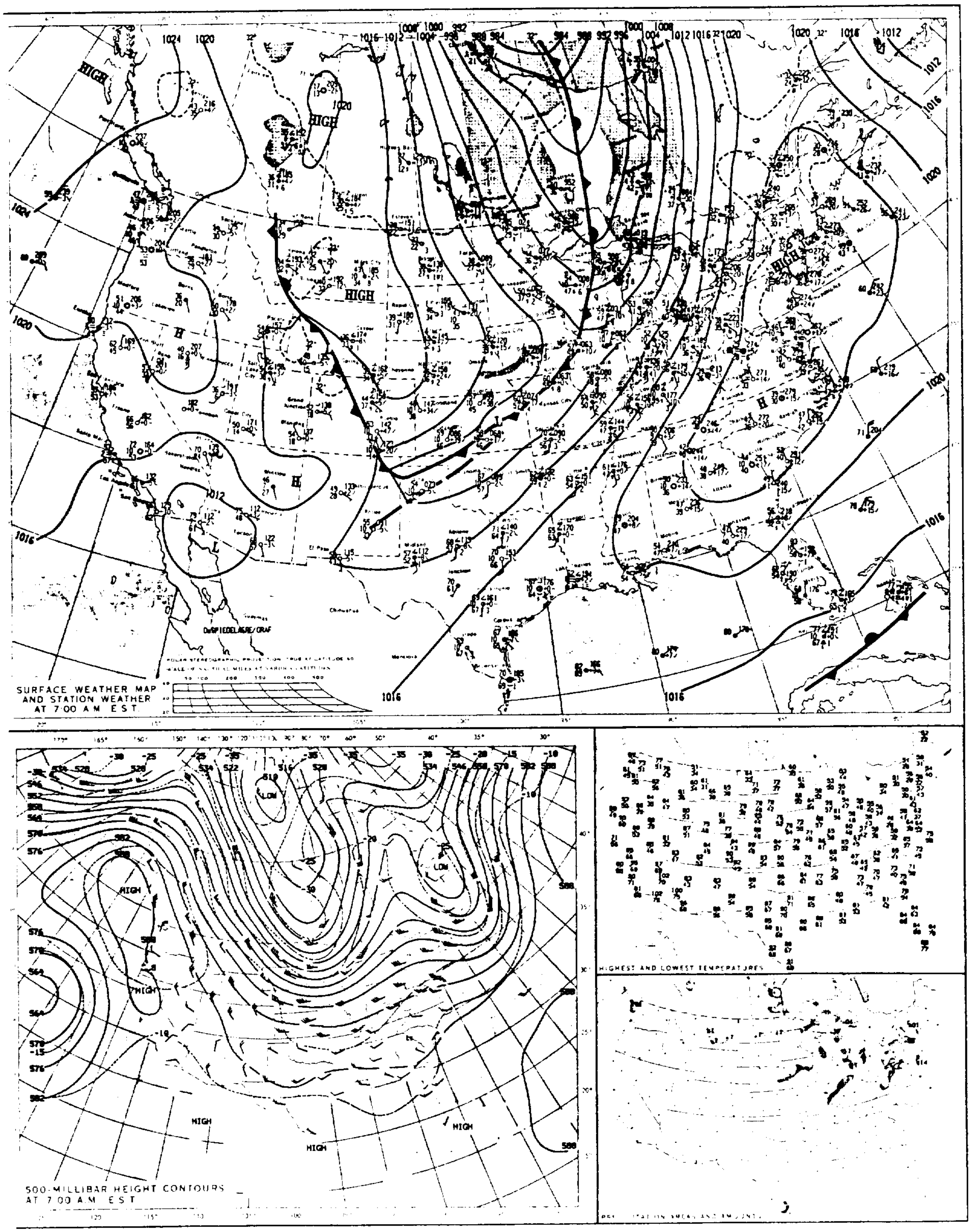
				CAMEX Experiment Schedule for CAMEX Operations Day 25																					
				Julian Day 10/01/93												Julian Day 10/02/93									
TIME (GMT Hour)	12	13	14	15	16	17	18	19	20	21	22	23	0	1	2	3	4	5	6	7	8	9	10	11	12
ER-2 Instruments																									
AMPR																									
EDOP																									
HIS																									
LIP																									
MAMS																									
MIR																									
MTS																									
Ground Sensors																									
Raman Lidar																									
HIS	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
Johns Hopkins/APL Ship																									
CLASS Sonde																									
Rawinsonde																									
VIZ																									
Vaisala																									
AIR																									
Ozone Sonde																									

CAMEX FLIGHT DAY 25 - SATELLITE IMAGERY

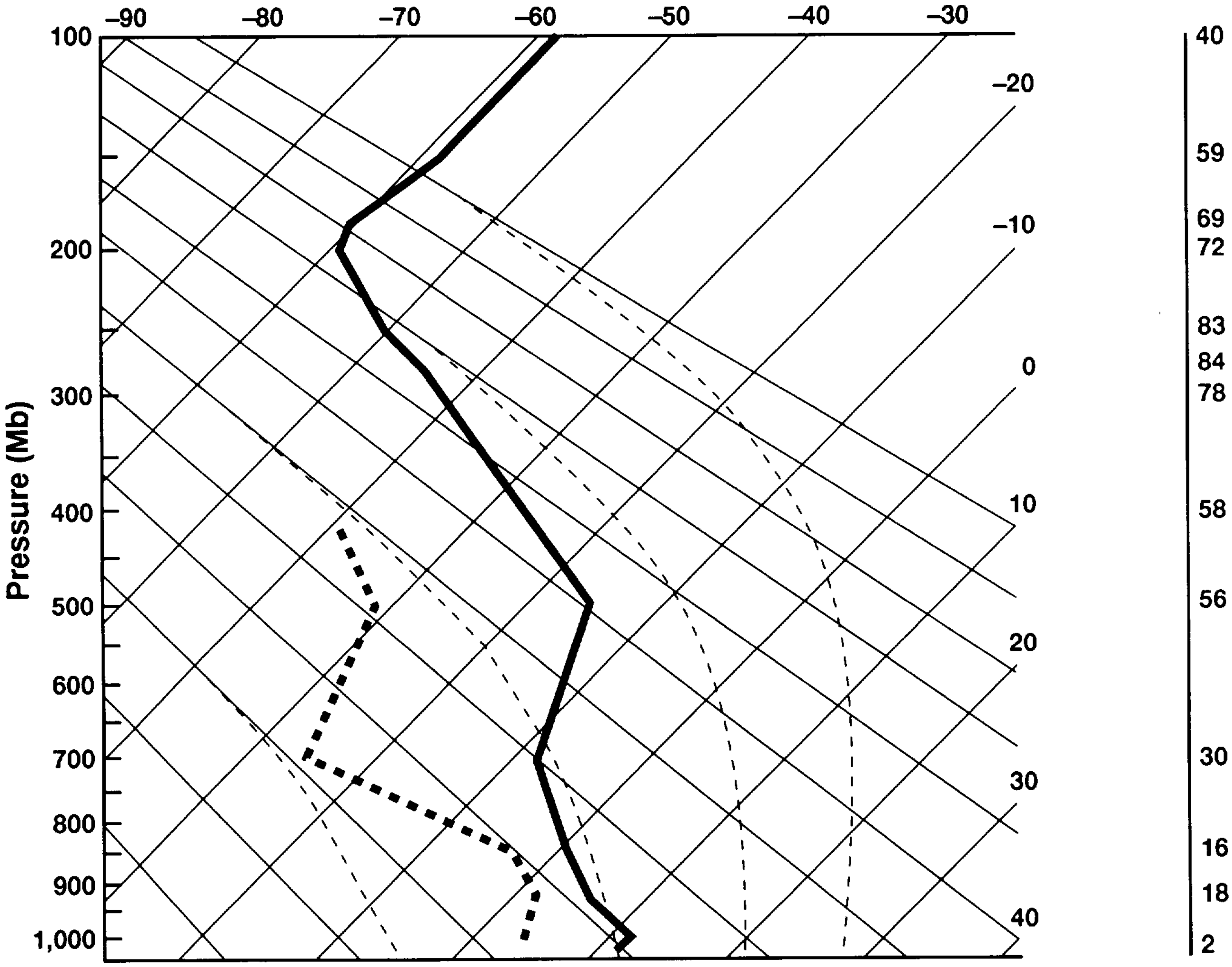


CAMEX FLIGHT DAY 25 - SYNOPTIC CHARTS

OCTOBER 1, 1993



CAMEX FLIGHT DAY 25 - WALLOPS RAWINSONDE



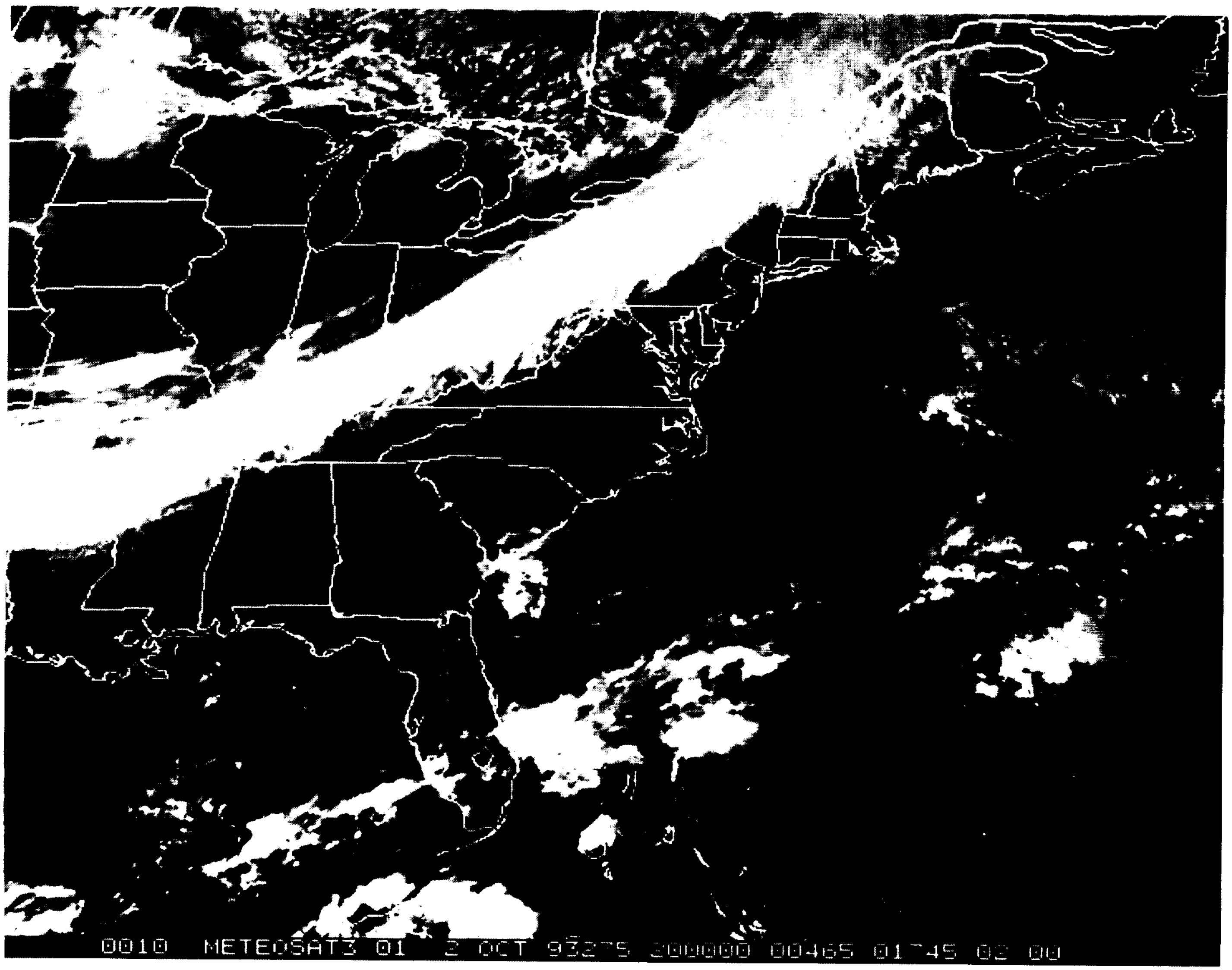
GMT	ID	TOTAL	EQUIP	FMAX	CVT	L.I.	KINX	PW
100,000	72,402	27		0	15	15	–5	12

CAMEX FLIGHT DAY 26 - ACTIVITY

CAMEX Experiment Schedule for CAMEX Operations Day 26

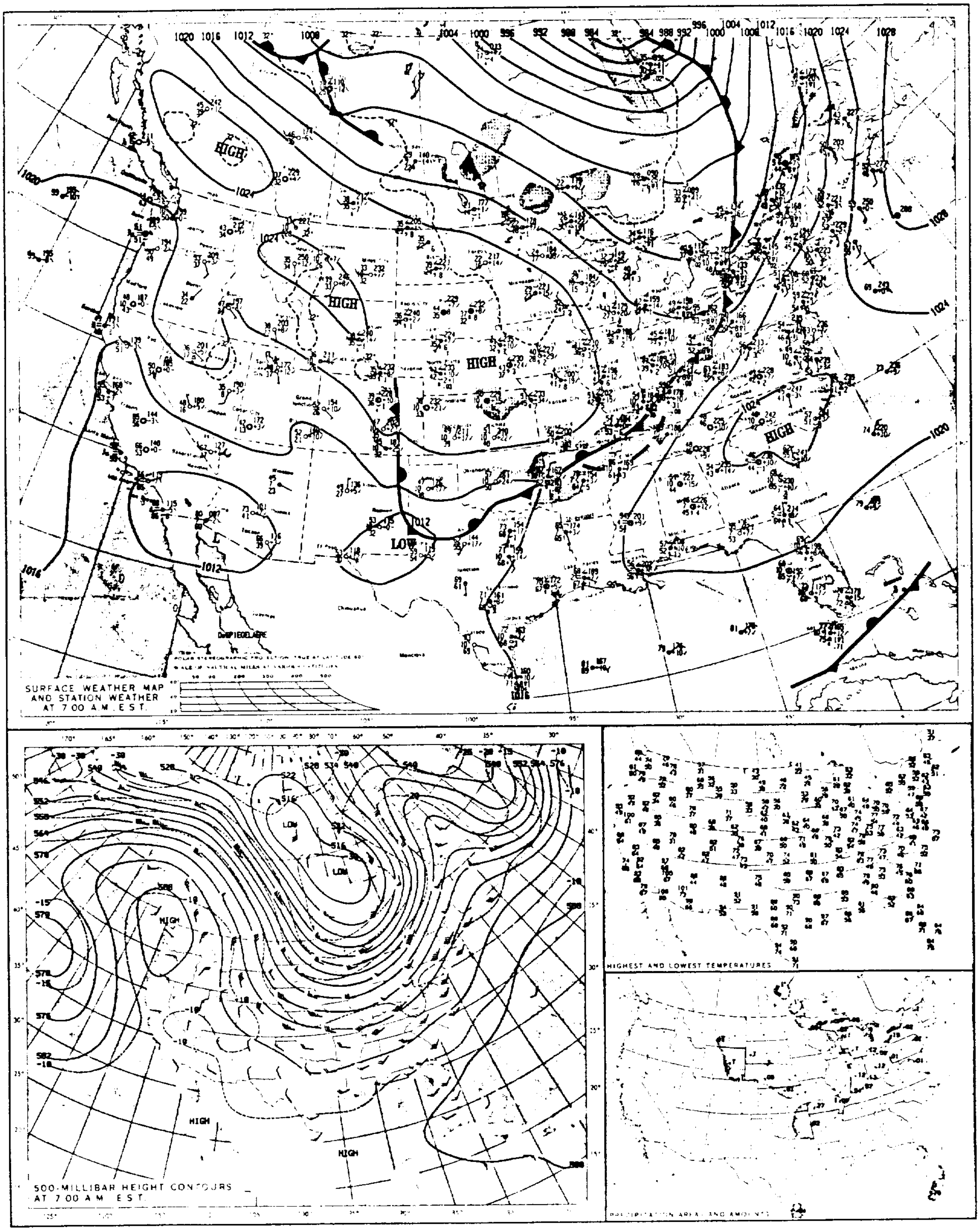
	Julian Day 10/02/93												Julian Day 10/03/93												
TIME (GMT Hour)	12	13	14	15	16	17	18	19	20	21	22	23	0	1	2	3	4	5	6	7	8	9	10	11	12
ER-2 Instruments																									
AMPR																									
EDOP																									
HIS																									
LIP																									
MAMS																									
MIR																									
MTS																									
Ground Sensors																									
Raman Lidar																									
HIS	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
Johns Hopkins/APL Ship																									
CLASS Sonde																									
Rawinsonde																									
VIZ																									
Vaisala																									
AIR																									
Ozone Sonde																									

CAMEX FLIGHT DAY 26 - SATELLITE IMAGERY

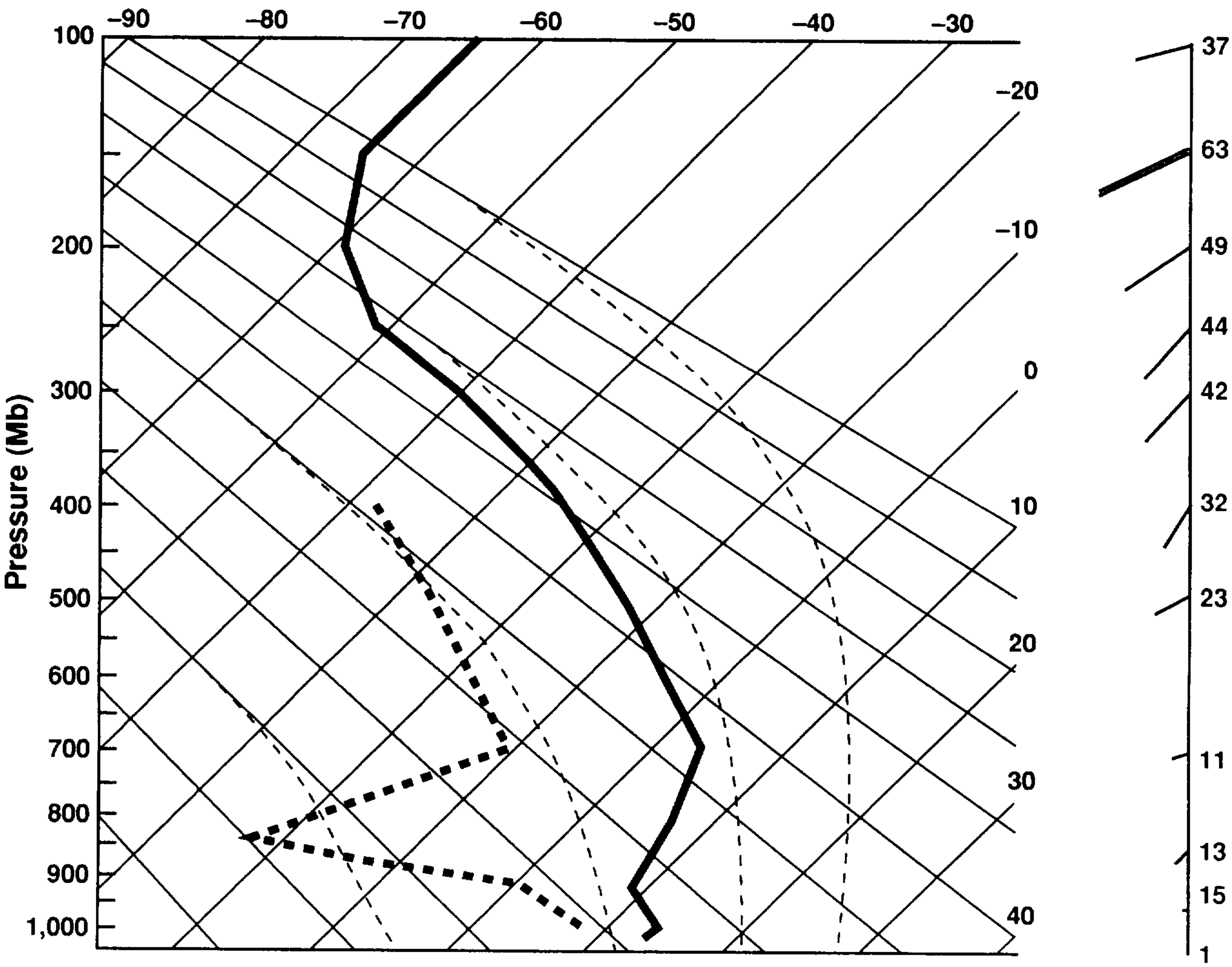


CAMEX FLIGHT DAY 26 - SYNOPTIC CHARTS

SATURDAY, OCTOBER 2, 1993



CAMEX FLIGHT DAY 26 - WALLOPS RAWINSONDE

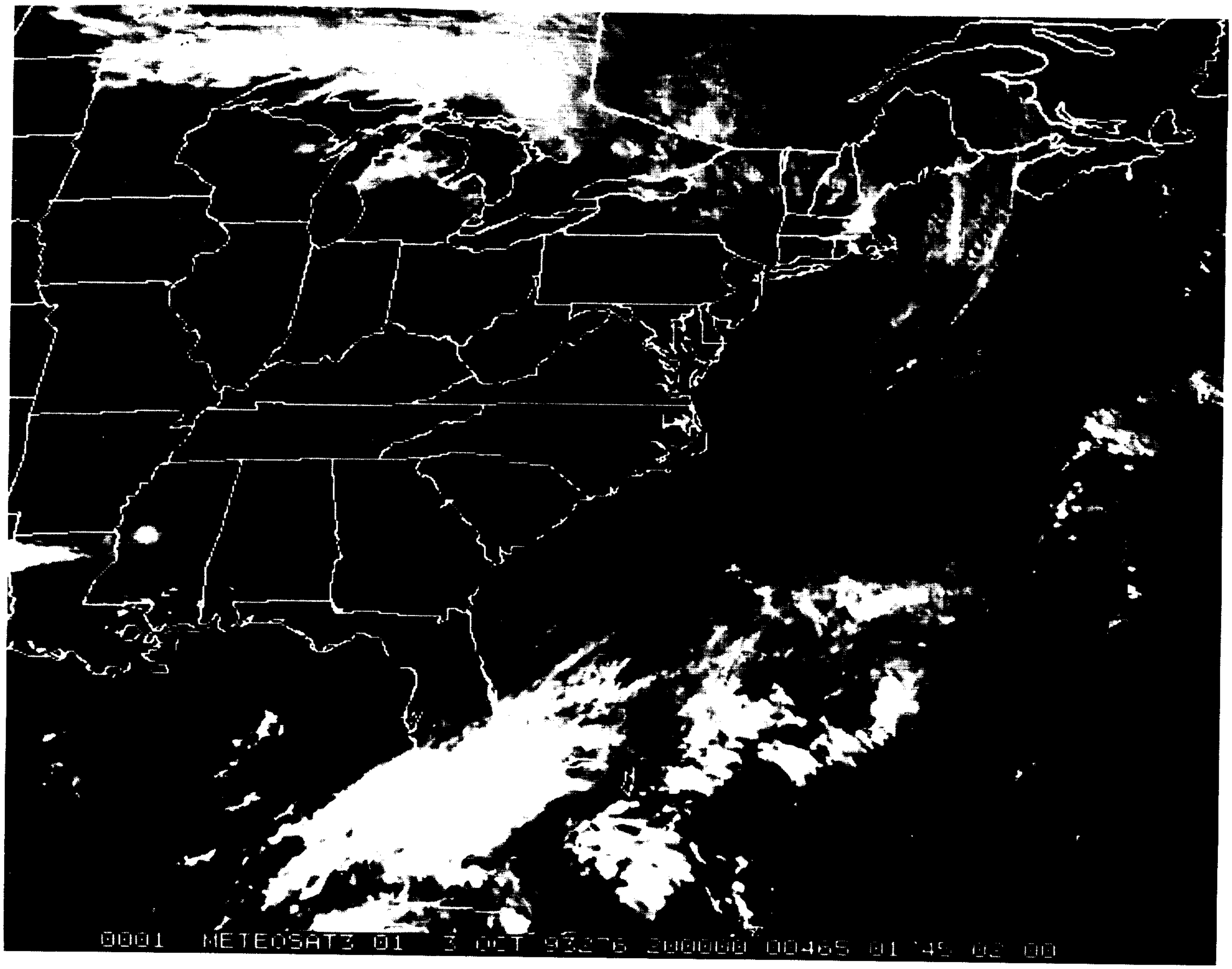


GMT	ID	TOTAL	EQUIP	FMAX	CVT	L.I.	KINX	PW
20,000	72,402	13		0		13	-15	13

CAMEX FLIGHT DAY 27 - ACTIVITY

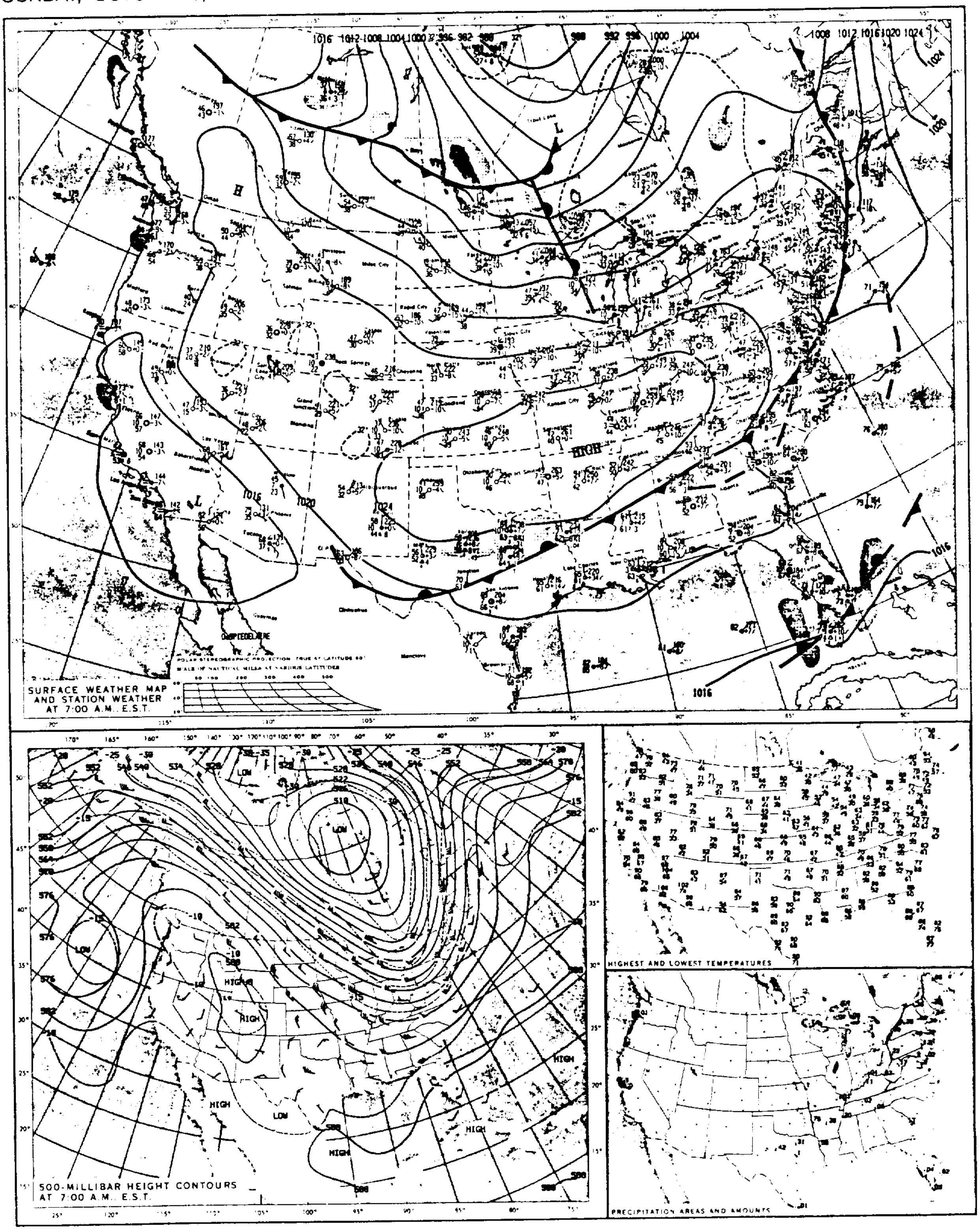
				CAMEX Experiment Schedule for CAMEX Operations Day 27																					
				Julian Day 10/03/93											Julian Day 10/04/93										
TIME (GMT Hour)	12	13	14	15	16	17	18	19	20	21	22	23	0	1	2	3	4	5	6	7	8	9	10	11	12
ER-2 Instruments																									
AMPR									X	X	X	X	X	X	X	X									
EDOP									F	F	F	F	F	F	F	F									
HIS									X	X	X	X	X	X	X	X									
LIP									X	X	X	X	X	X	X	X									
MAMS									X	X	X	X	X	X	X	X									
MIR									X	X	X	X	X	F	F	F									
MTS									X	X	X	X	X	X	X	X									
Ground Sensors																									
Raman Lidar													X	X	X	X	X								
HIS	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
Johns Hopkins/APL Ship																									
CLASS Sonde											X			X			X								
Rawinsonde																									
VIZ											X					X									
Vaisala											X			X		X									
AIR											X					X									
Ozone Sonde														X											

CAMEX FLIGHT DAY 27 - SATELLITE IMAGERY

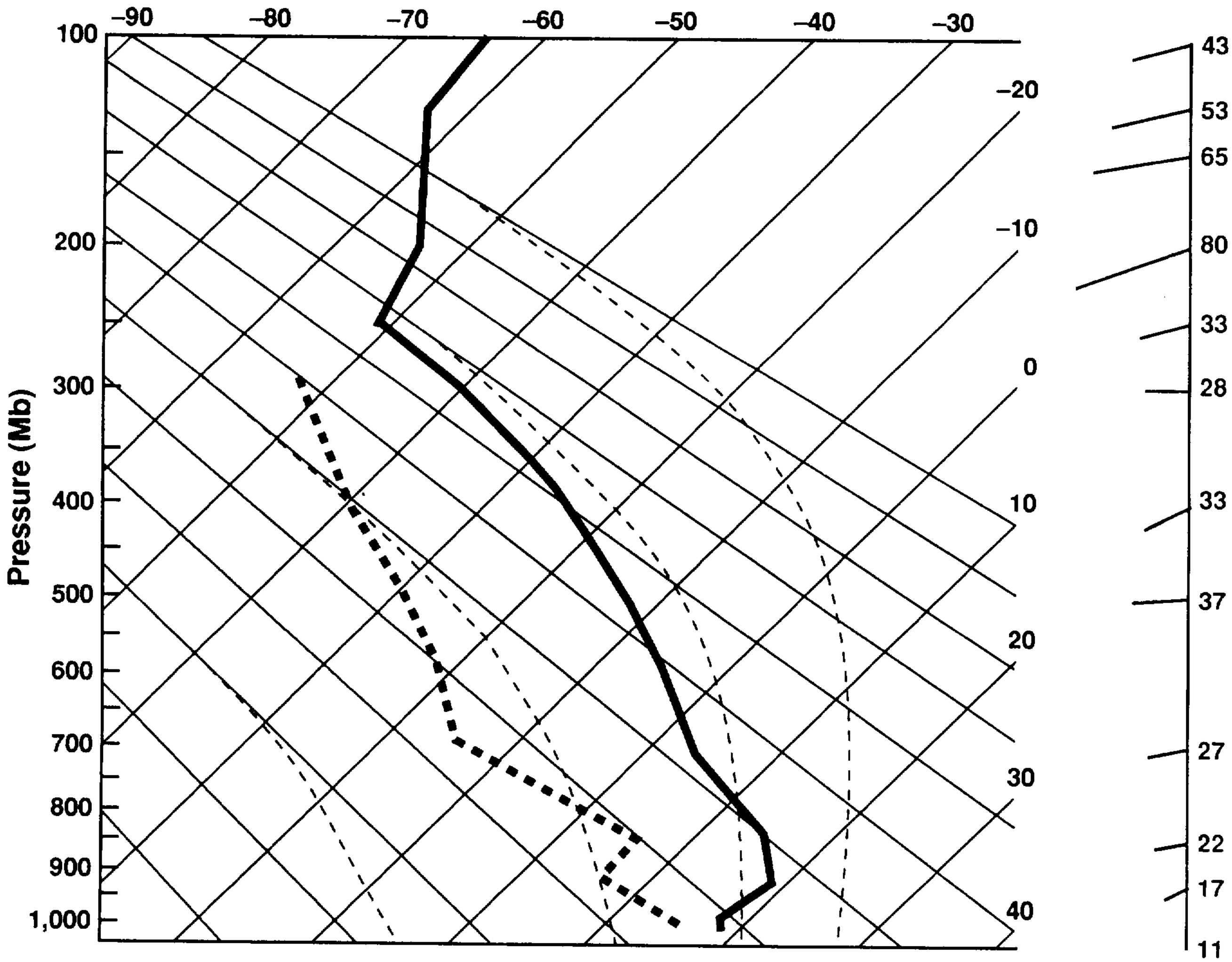


CAMEX FLIGHT DAY 27 - SYNOPTIC CHARTS

SUNDAY, OCTOBER 3, 1993



CAMEX FLIGHT DAY 27 - WALLOPS RAWINSONDE



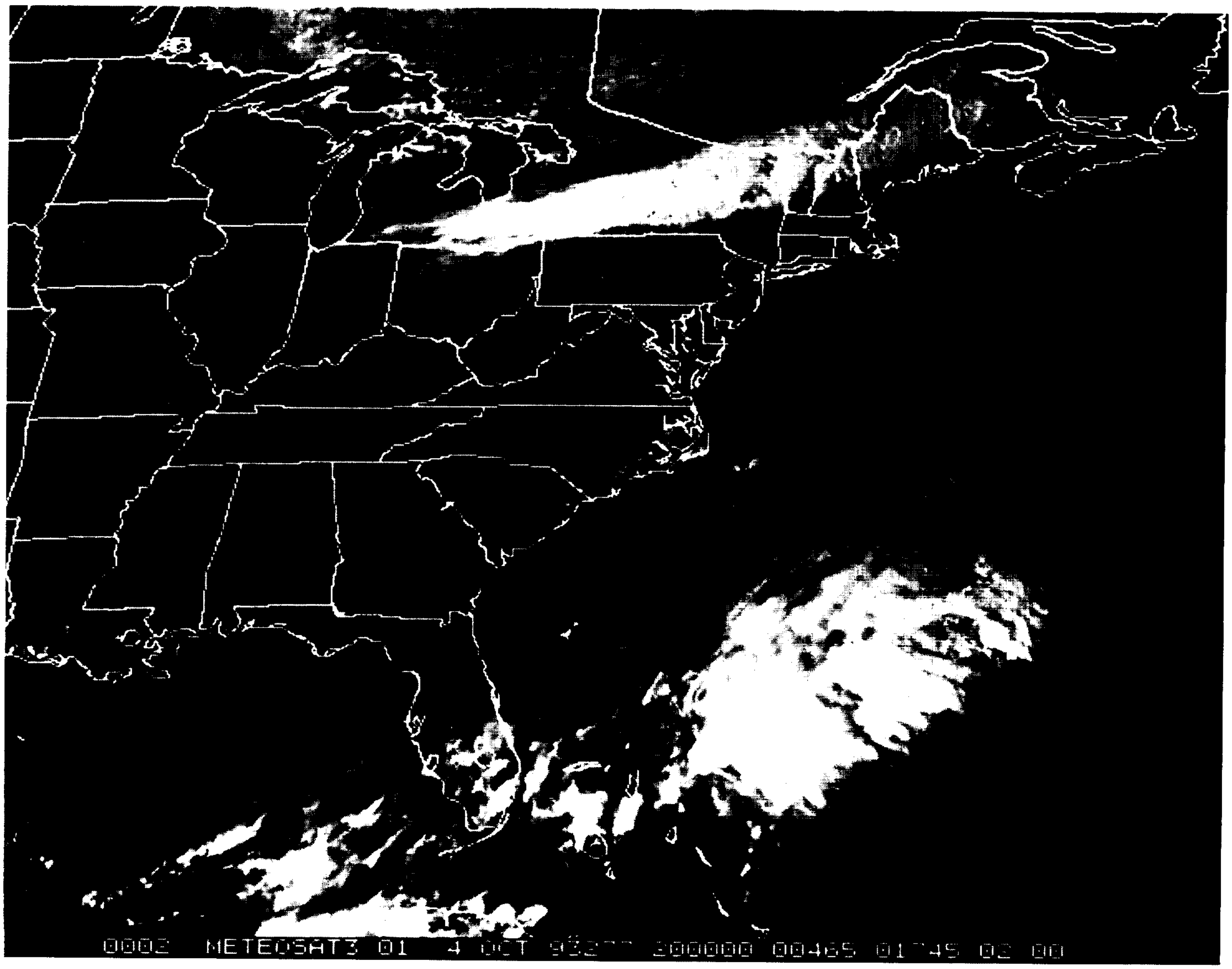
GMT	ID	TOTAL	EQUIP	FMAX	CVT	L.I.	KINX	PW
30,000	72,402	47	475	0	33	4	16	22

CAMEX FLIGHT DAY 28 - ACTIVITY

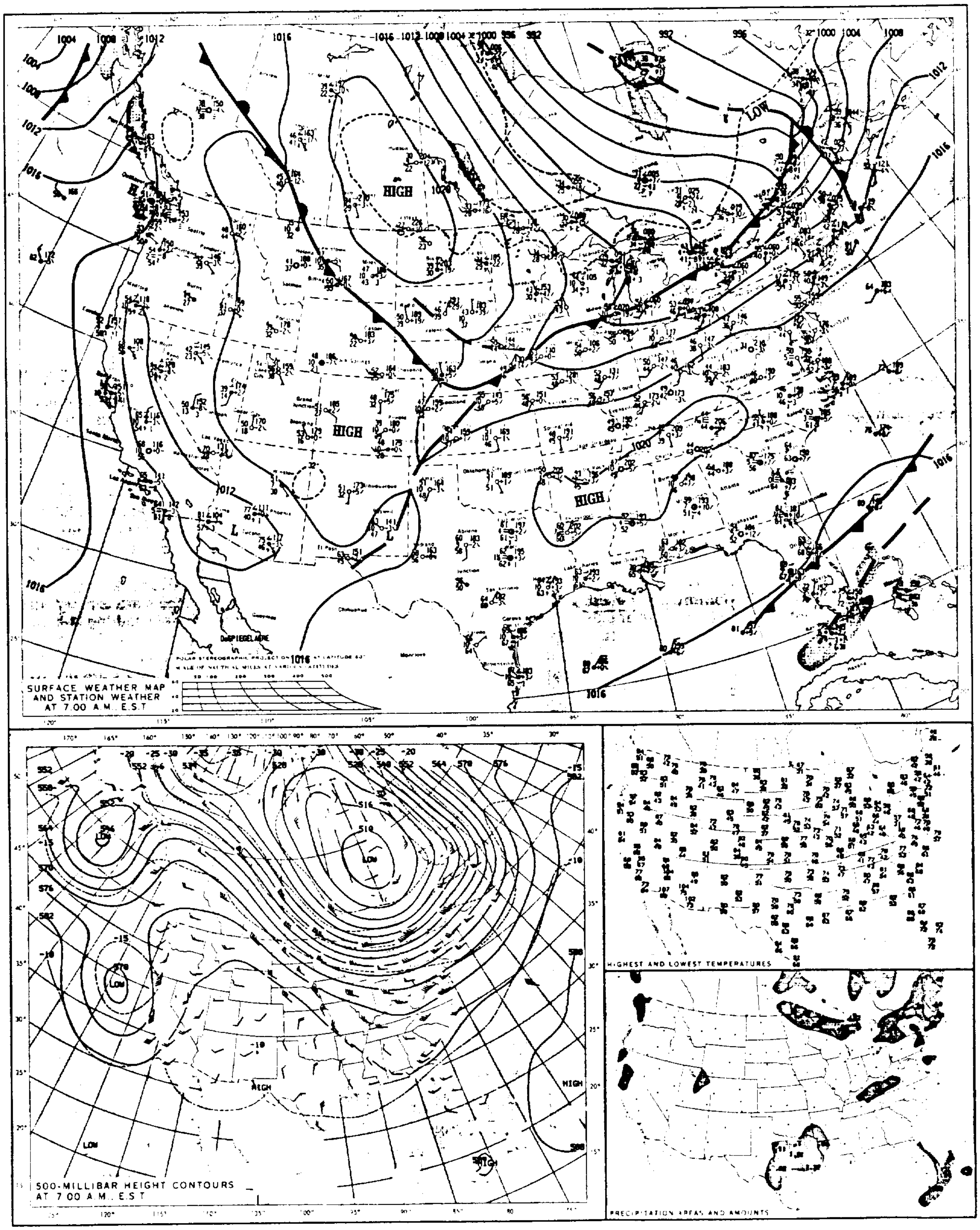
CAMEX Experiment Schedule for CAMEX Operations Day 28

				Julian Day 10/04/93												Julian Day 10/05/93									
TIME (GMT Hour)	12	13	14	15	16	17	18	19	20	21	22	23	0	1	2	3	4	5	6	7	8	9	10	11	12
ER-2 Instruments																									
AMPR																									
EDOP																									
HIS																									
LIP																									
MAMS																									
MIR																									
MTS																									
Ground Sensors																									
Raman Lidar													X	X	X	X	X								
HIS	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
Johns Hopkins/APL Ship																									
CLASS Sonde											X			X			X								
Rawinsonde																									
VIZ											X						X								
Vaisala											X			X			X								
AIR											X			X			X								
Ozone Sonde																									

CAMEX FLIGHT DAY 28 - SATELLITE IMAGERY



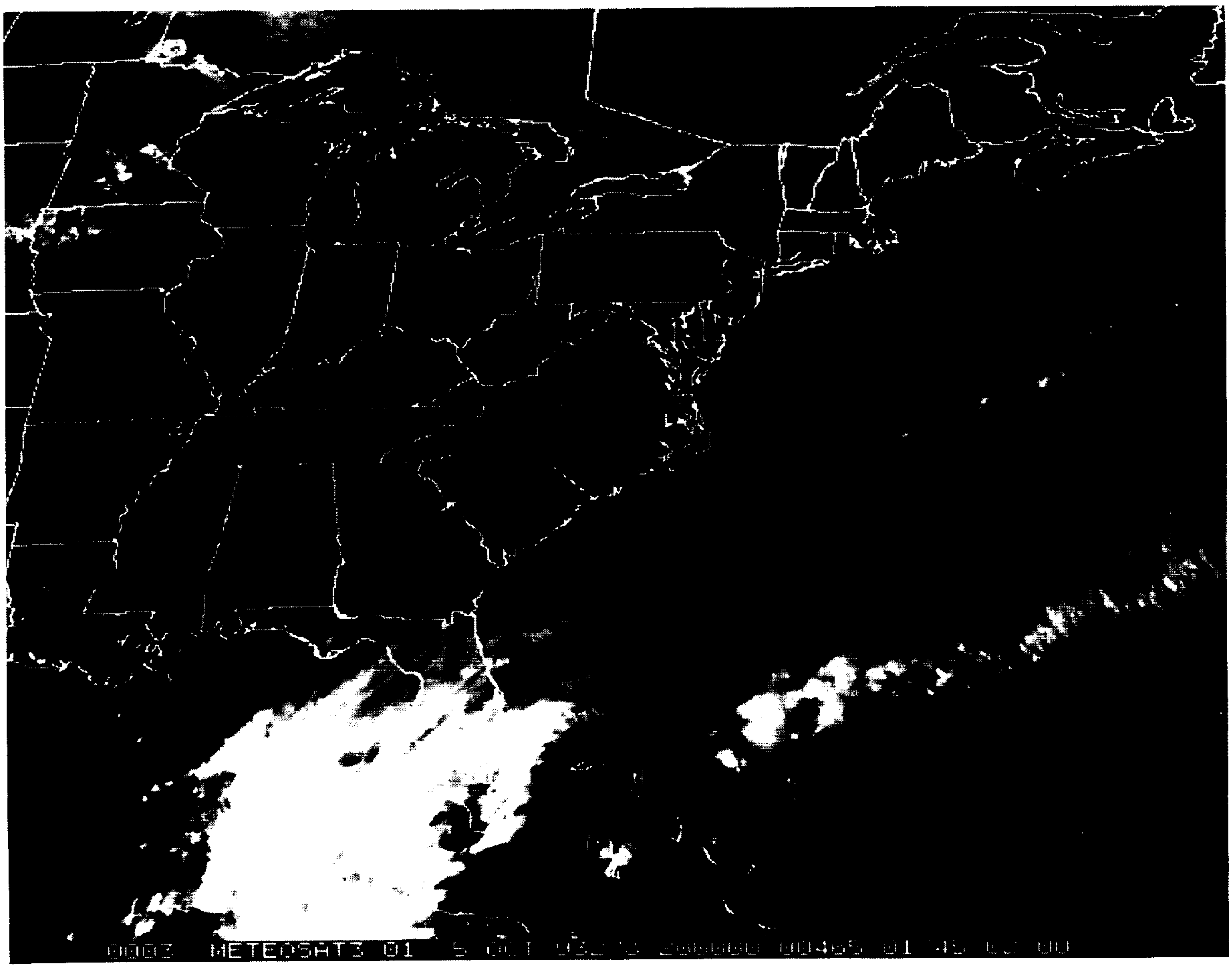
CAMEX FLIGHT DAY 28 - SYNOPTIC CHARTS



CAMEX FLIGHT DAY 29 - ACTIVITY

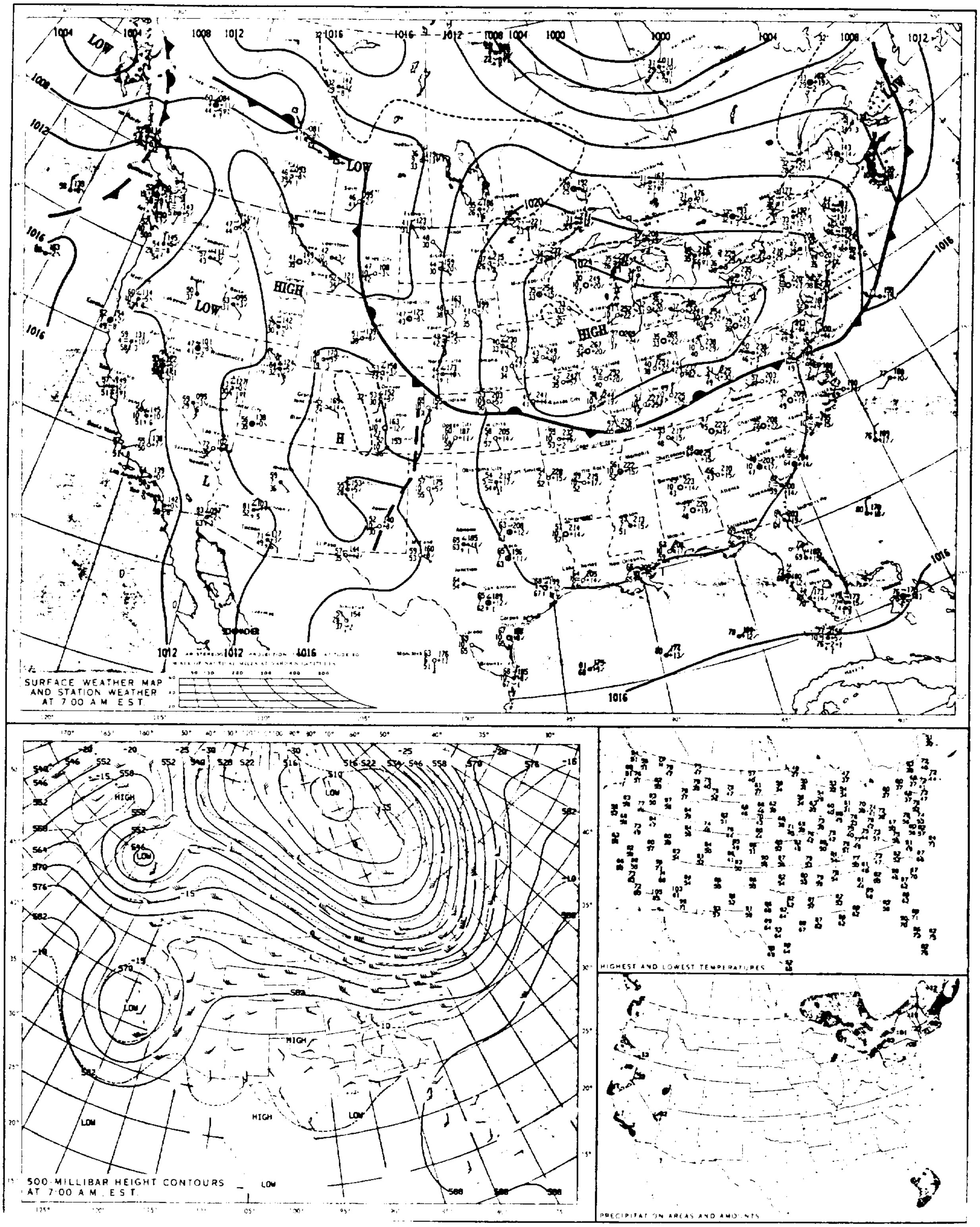
				CAMEX Experiment Schedule for CAMEX Operations Day 29																					
				Julian Day 10/05/93												Julian Day 10/06/93									
TIME (GMT Hour)	12	13	14	15	16	17	18	19	20	21	22	23	0	1	2	3	4	5	6	7	8	9	10	11	12
ER-2 Instruments																									
AMPR					X	X	X	X	X	X	X	X													
EDOP					X	X	X	X																	
HIS					X	X	X	X	X	X	X	X													
LIP					X	X	X	X	X	X	X	X													
MAMS					X	X	X	X	X	X	X	X													
MIR					X	X	X	X	X	X	X	X													
MTS					X	X	X	X	X	X	X	X													
Ground Sensors																									
Raman Lidar													X	X	X	X	X								
HIS	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
Johns Hopkins/APL Ship																									
CLASS Sonde											X			X			X								
Rawinsonde																									
VIZ											X						X								
Vaisala											X			X			X								
AIR														X			X								
Ozone Sonde														X											

CAMEX FLIGHT DAY 29 - SATELLITE IMAGERY

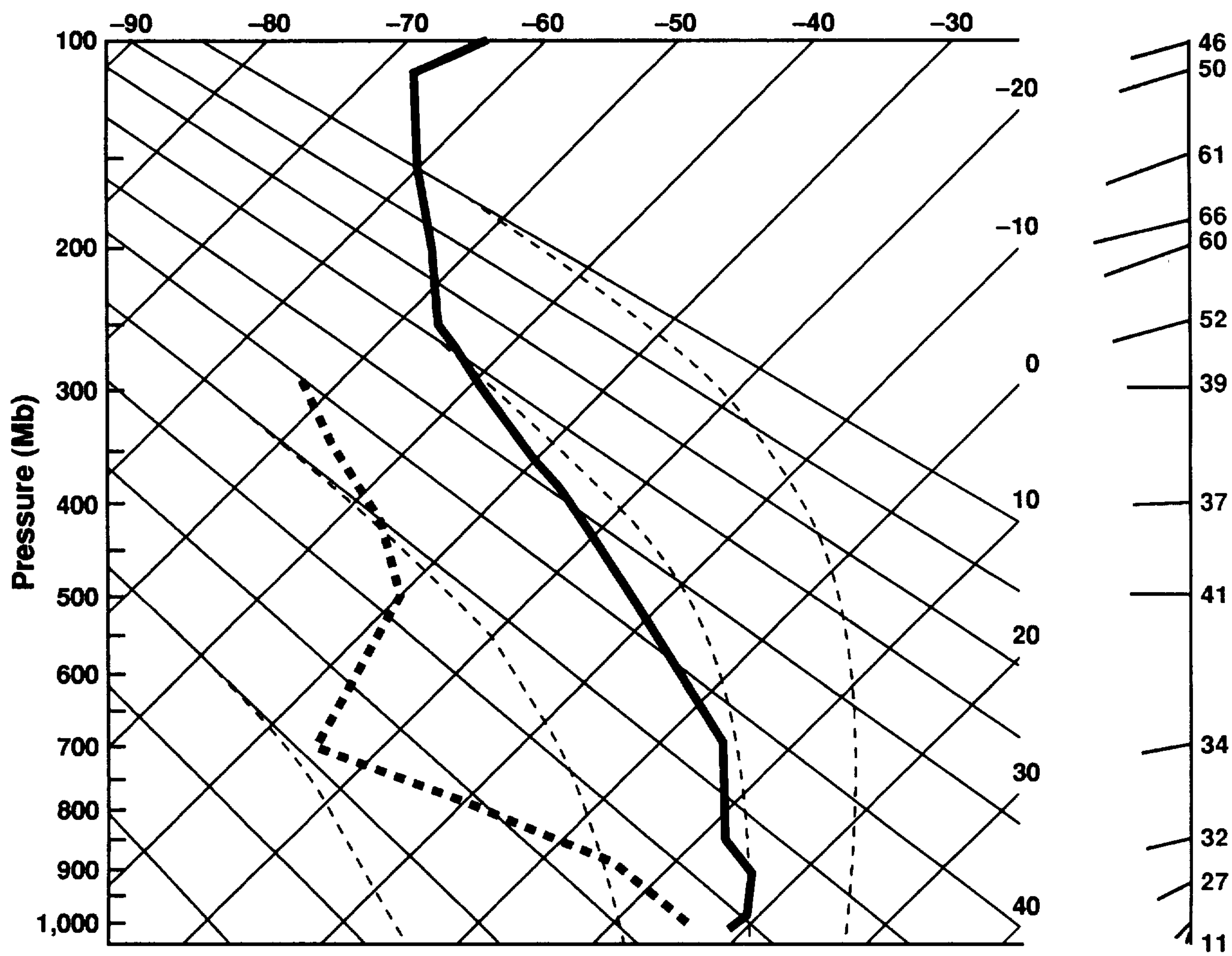


CAMEX FLIGHT DAY 29 - SYNOPTIC CHARTS

TUESDAY, OCTOBER 5, 1993



CAMEX FLIGHT DAY 29 - WALLOPS RAWINSONDE



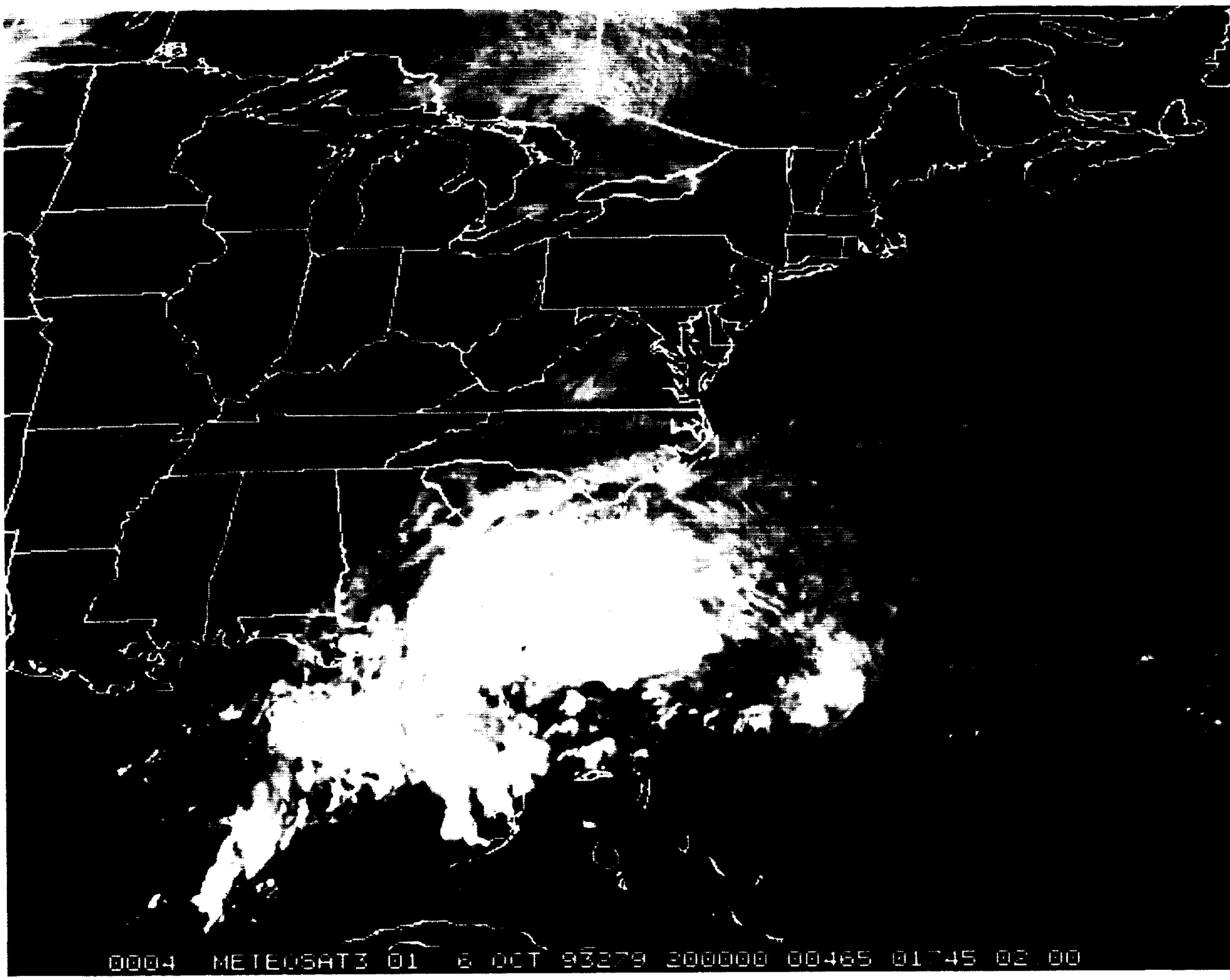
GMT	ID	TOTAL	EQUIP	FMAX	CVT	L.I.	KINX	PW
50,000	72,402	36	450	0	28	3	–7	18

CAMEX FLIGHT DAY 30 - ACTIVITY

CAMEX Experiment Schedule for CAMEX Operations Day 30

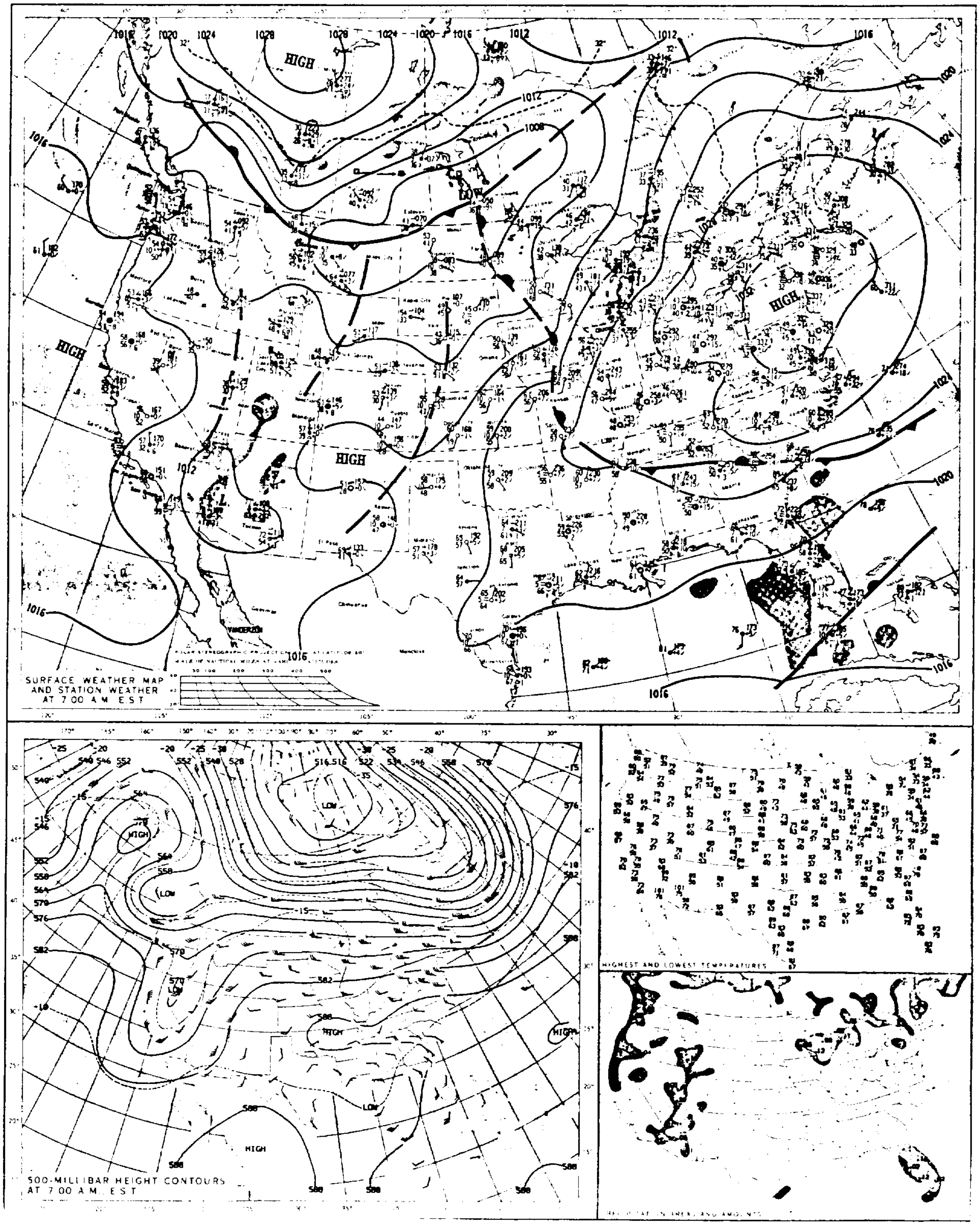
				Julian Day 10/06/93												Julian Day 10/07/93									
TIME (GMT Hour)	12	13	14	15	16	17	18	19	20	21	22	23	0	1	2	3	4	5	6	7	8	9	10	11	12
ER-2 Instruments																									
AMPR																									
EDOP																									
HIS																									
LIP																									
MAMS																									
MIR																									
MTS																									
Ground Sensors																									
Raman Lidar																									
HIS	X	X																							
Johns Hopkins/APL Ship																									
CLASS Sonde																									
Rawinsonde																									
VIZ																									
Vaisala																									
AIR																									
Ozone Sonde																									

CAMEX FLIGHT DAY 30 - SATELLITE IMAGERY

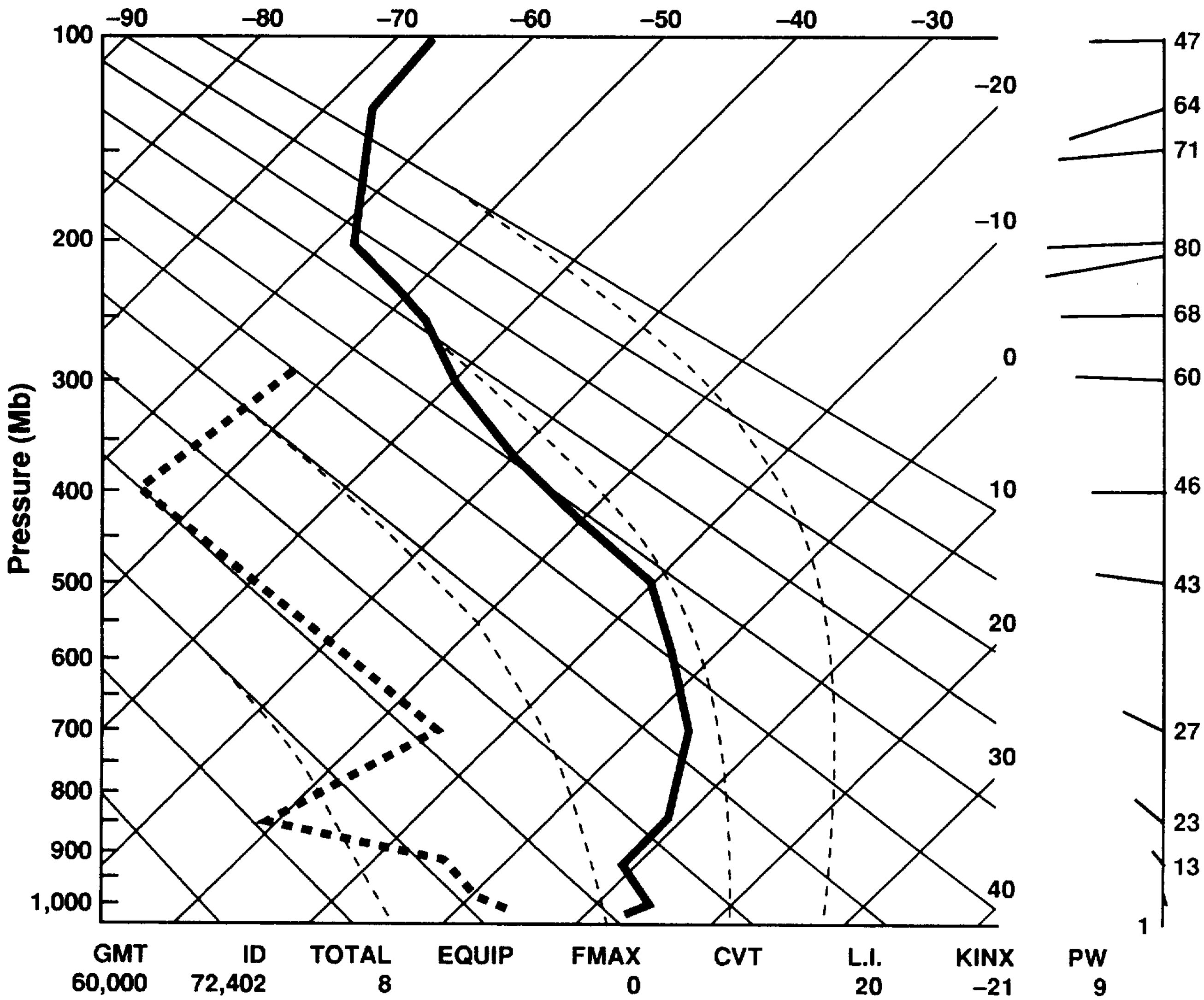


CAMEX FLIGHT DAY 30 - SYNOPTIC CHARTS

WEDNESDAY, OCTOBER 6, 1993



CAMEX FLIGHT DAY 30 - WALLOPS RAWINSONDE

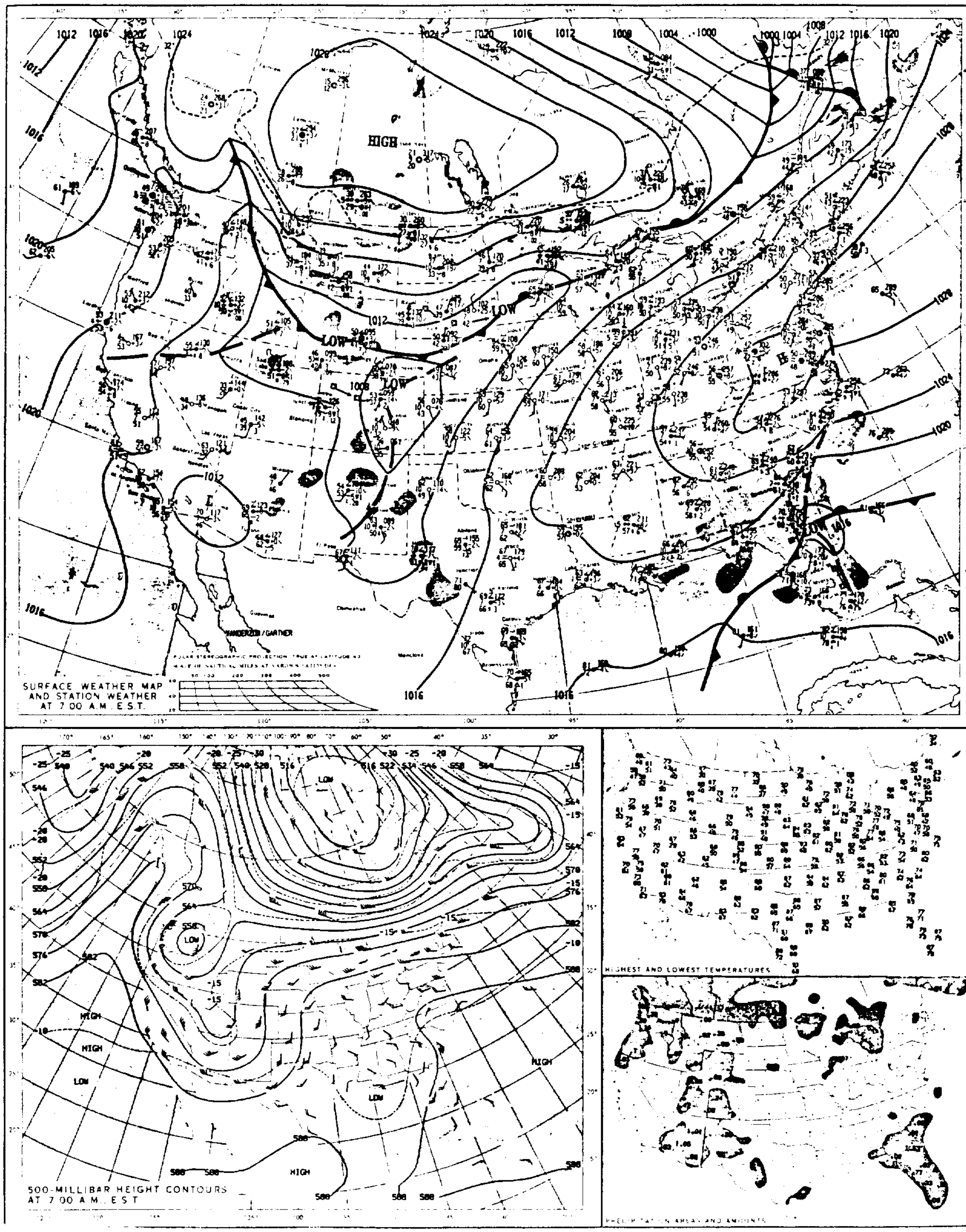


CAMEX FLIGHT DAY 31 - ACTIVITY

				CAMEX Experiment Schedule for CAMEX Operations Day 31																					
				Julian Day 10/07/93											Julian Day 10/08/93										
TIME (GMT Hour)	12	13	14	15	16	17	18	19	20	21	22	23	0	1	2	3	4	5	6	7	8	9	10	11	12
ER-2 Instruments																									
AMPR																									
EDOP																									
HIS																									
LIP																									
MAMS																									
MIR																									
MTS			X	X	X	X	X	X	X																
Ground Sensors																									
Raman Lidar																									
HIS																									
Johns Hopkins/APL Ship																									
CLASS Sonde																									
Rawinsonde																									
VIZ																									
Vaisala					X																				
AIR																									
Ozone Sonde																									

CAMEX FLIGHT DAY 31 - SYNOPTIC CHARTS

THURSDAY, OCTOBER 7, 1993



SECTION V. CAMEX DATA ACCESS

Unlike TOGA COARE, NASA has no plans for a CAMEX data archive center. CAMEX data will be available on request from the CAMEX PI's. Each PI is individually responsible for the quality control of their data, and therefore, the date the datasets will be available may differ significantly. Although Marshall will acquire much of the ancillary and ground-truth data for our own research, we do will not have a complete archive of either, so CAMEX researchers should acquire ancillary data through the normal channels (i.e., from SSEC, National Climate Data Center, or the Earth Observing System Distributed Archive and Acquisition Centers). The ground-truth data will be available from the respective instrument PI's. Table 8, shown on the next page, gives the address, telephone numbers, and E-Mail for each of the CAMEX PI's.

Table 8. CAMEX data contacts

Instrument	PI	Address
AMPR	Ms. Robbie Hood	ES-43 Marshall Space Flight Center Huntsville, AL 35812 Ph: (205) 544-5407 Fax: (205) 544-5760 E-Mail: RHOOD@NASAMAIL.MSFC.NASA.GOV
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APPROVAL

OPERATIONS SUMMARY FOR THE CONVECTION AND MOISTURE EXPERIMENT (CAMEX)

By

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This report has been reviewed for technical accuracy and contains no information concerning national security or nuclear energy activities or programs. The report, in its entirety, is unclassified.

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