NOAA Technical Memorandum ERL ARL-176

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CONTENTS

Aircraft Measurements of Pollution Species Near Bermuda and the East Coast of the United States During CASE-WATOX

R.L. Gunter and J.F. Boatman

ABSTRACT. Chemical, meteorological, and aerosol measurements were made with the NOAA King Air C-90 aircraft during July 1988 near Bermuda and the east coast of the U.S. The study extended the 1985 and 1986 Western Atlantic Ocean Experiment (WATOX), and initiated coordinated aircraft and ship measurements, following the design of the Coordinated Air Sea Experiment (CASE), in which flights were planned to be made in the vicinity of the NOAA ship *Mt. Mitchell*. This report lists the objectives of the CASE-WATOX program; the instrumentation used, and the data obtained with the aircraft; a general outline of ship and aircraft coordination and instrumentation; and the aircraft data processing, quality and availability.

1. INTRODUCTION

Airborne and surface Western Atlantic Ocean Experiment (WATOX) chemical, meteorological, and aerosol measurements were conducted in 1985 in the central coastal region of the United States (Newport News, VA), and in 1986 in the northern coastal region (Boston, MA). In both years measurements were also made in the Bermuda Island area. Those WATOX measurements confirmed that pollutant transport away from the east coast of the United States is occurring in and above the marine boundary layer. Results showed that most of the sulfur transport off the east coast during offshore flow is in the marine boundary layer (Luria et al. 1987, 1988) and that the sulfur flux varies as a function of coastal segment (Galloway et al. 1984).

The Coordinated Air Sea Experiment (CASE) was designed to continue the WATOX observations and to supplement and confirm the earlier endeavors. Furthermore, it was designed to coordinate the air and sea measurements. During the 1985 and 1986 WATOX studies those measurements were not coordinated. CASE-WATOX measurements were conducted in 1988 near the central and southern portions of the U.S. east coast. The NOAA ship *Mt. Mitchell* remained in position between 125 and 250 km offshore for 5 days while four flights were made in its vicinity, then remained near the Island of Bermuda while four additional flights were made.

The aircraft scientific research for CASE-WATOX was directed jointly by the University of Virginia (Charlottesville, VA) and NOAA/Air Quality Group (Boulder, CO); the flights were conducted by the Air Quality Group. The following institutions were also involved in the planning and execution of the CASE-WATOX program and will be involved in the data analyses:

Atmospheric Environment Service (AES), Downsview, Ontario, Canada
Bermuda Biological Station (BBS), St. George's, Bermuda
Cooperative Institute for Research in the Environmental Sciences (CIRES), Boulder, CO

NOAA/Environmental Research Laboratory/Atlantic Oceanographic and Meteorological Laboratory (NOAA/ERL/AOML), Miami, FL
NOAA/ERL/Air Resources Laboratory (ARL), Air Quality Group, Boulder, CO
NOAA/Aircraft Operations Center (AOC), Miami, FL
University of Colorado at Denver, Denver, CO
University of Virginia, Charlottesville, VA
York University, Downsview, Ontario, Canada

This report includes the overall objectives of the CASE-WATOX program, a general outline of ship/aircraft coordination and instrumentation, the instrumentation used and the data obtained with the aircraft, and aircraft data processing, quality, and availability. Analysis and interpretation of both the ship and aircraft data will appear in later publications.

2. OBJECTIVES

The overall objective of CASE-WATOX was to assess the advection of pollution, mainly aerosols and sulfur and nitrogen species, away from the U.S. east coast. Each CASE-WATOX group had additional specific objectives.

2.1. Aerosol Analyses Group

This group was directed by H. Sievering, University of Colorado at Denver, and CIRES. The group's objectives (H. Sievering, personal communication, 1989) were the following:

- To assess trace-element sources and transport, and the role of sea-surface recycling on the precipitation signature of trace elements in marine rain.

- To differentiate the relative importance of natural and anthropogenic sources of major atmospheric constituents in aerosol over the North Atlantic Ocean.

- To assess, through aerosol black-carbon measurements as a tracer, the impact of combustion emissions on air masses.

- To analyze individual particles collected on shore (east coast), aboard ship, and from aircraft using Scanning Electron Microscopy/ X-Ray Emission Spectroscopy (SEMXES) to semi-quantitatively assess pathways for aerosol sulfate formation.

- To obtain aerosol-size distribution data, continuous SO_2 data, and size-segregated sulfate data to assess the contribution of several heterogeneous conversion pathways.

- To measure spatial and temporal variability in particulate-phase-concentrations of HCOOH and CH_3COOH.

2.2. Sulfur Dynamics Analyses Group

This group was directed by A. Pszenny, AOML. The group's objectives (A. Pszenny, personal communication, 1989) were the following:

- To examine the spatial and temporal variations in the concentrations of SO_2, non-sea-salt sulfate, and ancillary species and use the resulting data to investigate the causes of any observed diurnal concentration variations, the source regions influencing the North Atlantic atmosphere, and the rates of atmospheric transformation and deposition in this marine environment.

- To investigate mechanisms for the conversion of SO_2 to sulfate in North Atlantic marine atmospheric aerosols using data on spatial and temporal variations in the morphologies, size distributions, and chemical compositions of individual particles.

- To determine the contribution of heterogeneous conversion of SO_2 to observed concentrations of non-sea-salt sulfate in coarse-fraction aerosols in the marine boundary layer off the east coast of the United States.

- To reconcile apparent discrepancies in the sulfur budget in the remote North Atlantic marine boundary layer through multivariate statistical analyses of data for sulfur compounds, other chemical species, and meteorology.

- To critique a model for homogeneous and heterogeneous sulfur conversion, including natural and anthropogenic sulfate source terms, by applying data for sulfur compounds, other chemical species, and meteorology collected over the remote North Atlantic.

- To estimate rates of sulfur advection off the east coast of the United States during summer for comparison with data from previous winter-sampling periods.

- To differentiate the importance of natural and anthropogenic sources for non-sea-salt sulfur in the atmosphere over the North Atlantic Ocean.

- To gain insight into the oxidation pathways of dimethylsulfide (DMS) in the marine atmosphere by characterizing the distributions of DMS and the following proposed DMS oxidation products in the North Atlantic marine boundary layer: dimethylsulfoxide, dimethylsulfone, SO_2, methanesulfonic acid, and non-sea-salt sulfate.

- To constrain the net ocean-to-atmosphere release of DMS on the basis of measurements of DMS in headspace gases over flask incubations of natural phytoplankton communities collected in the North Atlantic region.

2.3. Nitrogen Dynamics Analyses Group

This group, directed by D. Hastie, York University, had the following objectives (D. Hastie, personal communication, 1989):

- To determine the time constant for nitrogen loss over the North Atlantic Ocean.
- To develop a climatology (in the sense of regular chemical conditions) for NO, NO_2, NO_y, Peroxyacetylnitrate (PAN), and O_3 over the North Atlantic Ocean.
- To improve our assessment of the degree of advection of nitrogen from the continent over the North Atlantic Ocean.
- To improve the nitrogen budget for the North Atlantic Ocean.
- To determine the amount of odd nitrogen available to initiate photochemistry.
- To determine the partitioning of nitrogen between active (NO, NO_2) and reservoir or sink species (NO_3, HNO_3, RNO_3).
- To determine whether the NO_3:HNO_3 ratio in the marine boundary layer over the North Atlantic Ocean is the same as that over the remote equatorial and southwestern Pacific Ocean (i.e., 1:1).
- To assess, by comparison with remote areas, the degree to which advection of pollutant odd nitrogen from surrounding continental areas enhances total nitrate concentrations over the North Atlantic Ocean.
- To assess the importance of organic nitrogen compounds, such as amines and amino acids, on the nitrogen budget of the North Atlantic Ocean.
- To try to reproduce previous observations of anomalously high ozone concentrations above the marine boundary layer and to correlate these with nitrogen measurements.
- To determine the importance of reservoir species, such as PAN, in supplying odd nitrogen to noncoastal areas of the North Atlantic Ocean.

3. DATA COLLECTION

3.1. Field Sites

Patrick Henry Field (PHF), in Newport News, VA was chosen as the east coast operational site for the aircraft for several reasons: (1) Trajectories suggested a marine-boundary-layer offshore-flow climatology for the CASE-WATOX timeframe. Additionally, flights needed to be conducted in cloud-free conditions, and the climatology of this region indicated optimum conditions. (2) The State of Virginia had a surface chemical and meteorological data collection site at Newport News, and agreed to make its data available to us. (3) Newport News provided for ship/aircraft pre-intensive coordination. The *Mt. Mitchell* was able to dock, and instruments were brought to the aircraft for intercomparison calibrations. (4) Costs for the experiment were less because PHF offered government contract fuel and hangaring rates. (5) Newport News was the site of the 1985 WATOX coastal intensive. Therefore, data collected under similar conditions can be collated and analyzed.

Bermuda Island was the end location for the flux measurements; however this site also offered surface data collection coordination, ship coordination, and duplication of the 1985 and 1986 WATOX projects.

3.2. Flight Plans

Table 1. CASE-WATOX flight dates and times

Date	Time (GMT) Begin	End	Date	Time (GMT) Begin	End
Newport News			Bermuda		
880717	1251	1733	880726	1151	1609
880718	1250	1718	880727(1)	1054	1502
880719	1405	1818	880727(2)	1700	2117
880721	1235	1653	880728	1125	1524

3.2.1. East Coast

Flights of approximately 4 hours duration were flown offshore in the vicinity of the *Mt. Mitchell*, which was stationed at about 35.50°N, 74.40°W. Each flight departed PHF at approximately 1300 GMT. Table 1 lists the dates and times of each flight; Figure 1 shows the east coast flight tracks. The first 2 hours of each flight (en route to the ship, and then back and forth over the ship) were in the free troposphere at approximately 2590 m (8500 ft), with a pass at 2285 m (7500 ft) and one at 760 m (2500 ft) at the end (for approximately 15 minutes each). The next 50-60 minutes of the flight were at 150 m (500 ft), back and forth near the ship, and one pass at 30 m (100 ft). The last 50-60 minutes of the flight was at 150 m (500 ft) en route to PHF. The flight tracks were designed to stay within 25 km (15 mi) on either side of the ship, weather permitting.

3.2.2. Bermuda

The *Mt. Mitchell* was stationed upwind of the island, at approximately 32.00°N, 63.30°W. Each flight departed Bermuda at approximately 1200 GMT, and lasted about 4 hours. Two flights were scheduled for 27 July, so the 1200 GMT

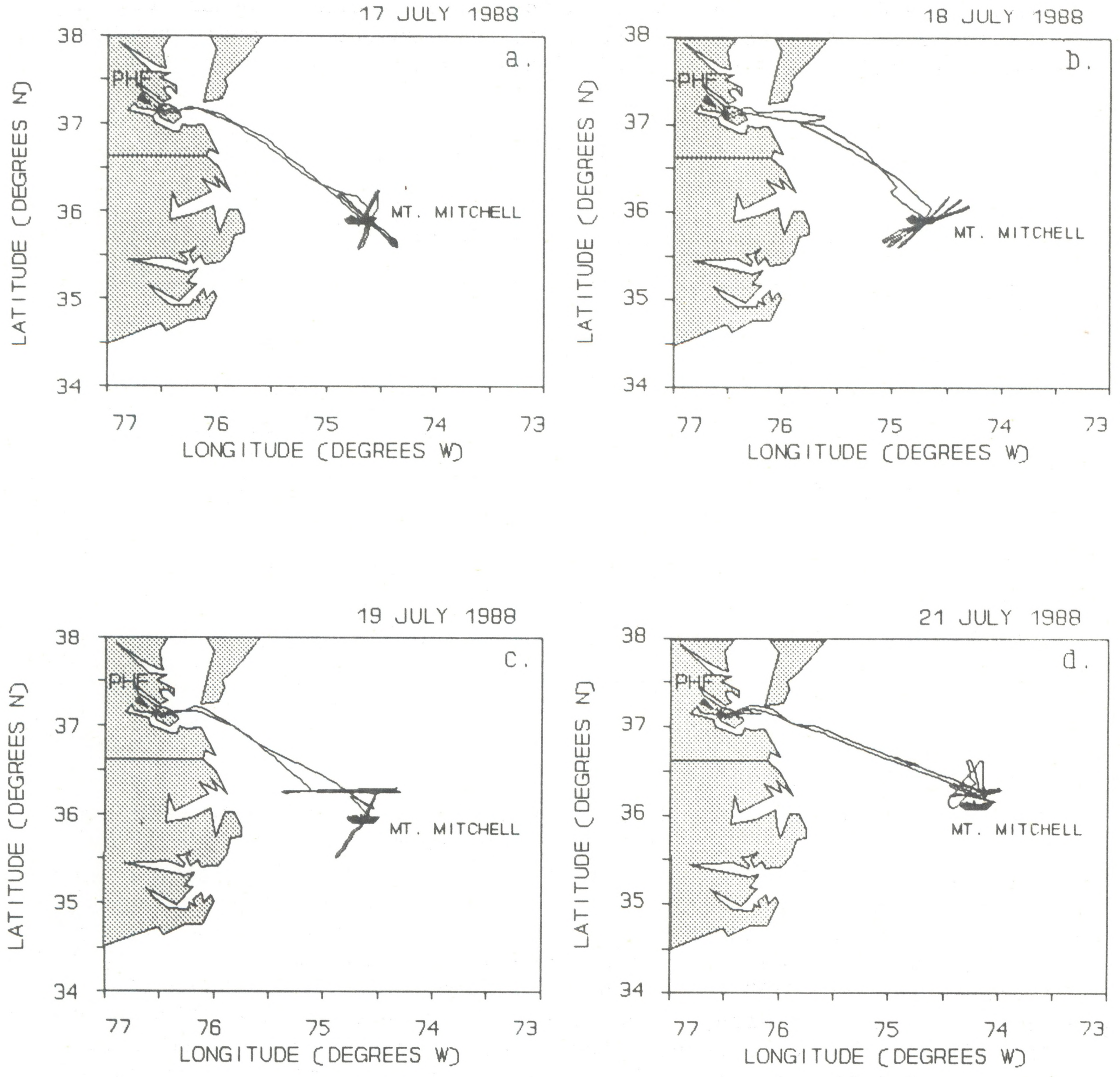

Figure 1. East coast flight tracks from Patrick Henry Field (PHF) Newport News, VA, to NOAA ship *Mt. Mitchell*.

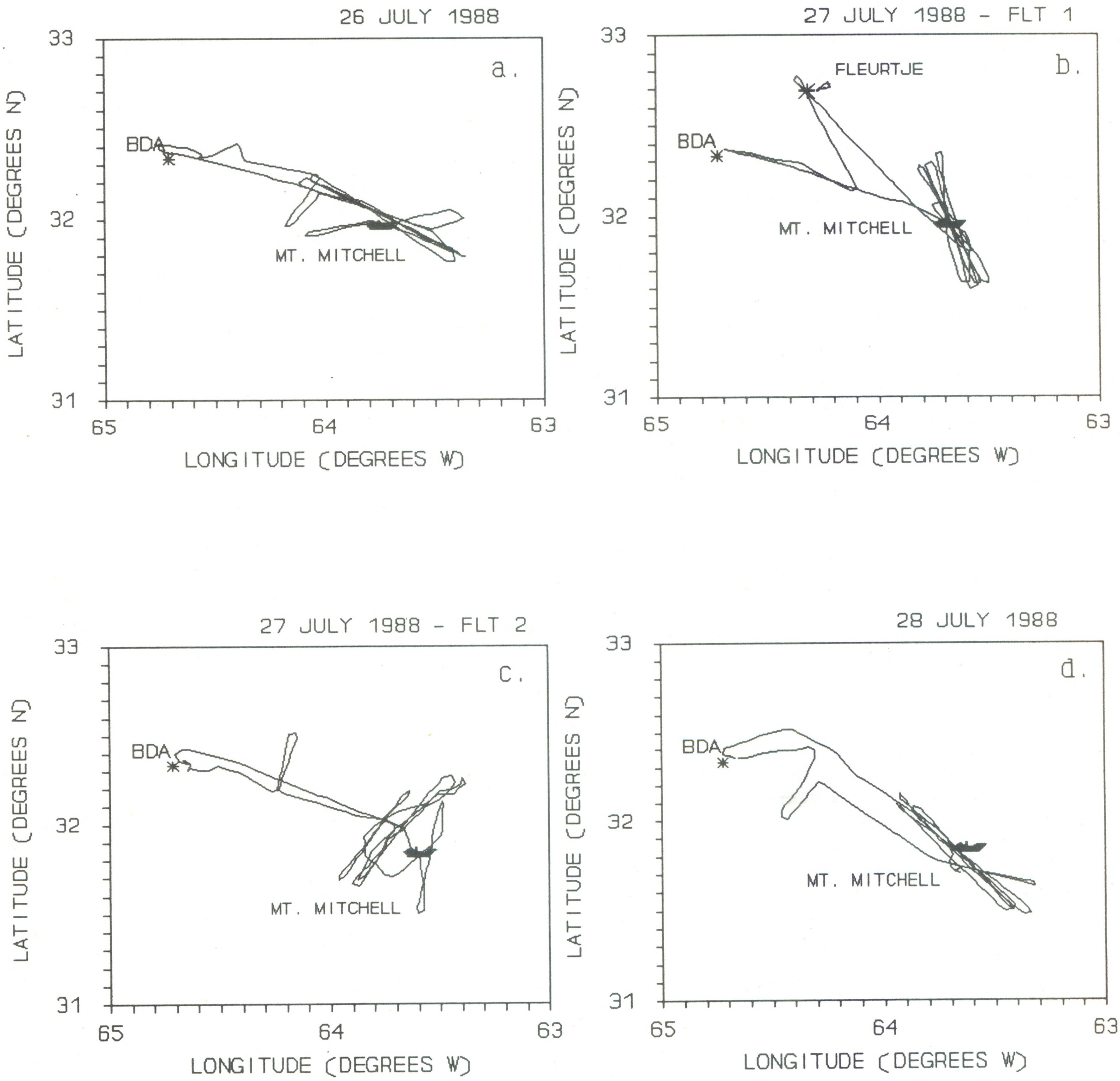

Figure 2. Flight tracks from Bermuda (BDA) to NOAA ship *Mt. Mitchell*.

departure time had to be adjusted slightly. Additionally, on 27 July, another ship (the *Fleurtje*), equipped with chemistry instrumentation, was stationed downwind of the island at 32.60°N, 64.30°W. The King Air diverted to make two 30-m (100 ft) flybys above that ship. Table 1 lists dates and times; Figure 2 shows the Bermuda flight tracks. As in Newport News, the first 2 hours of each flight were: 2590 m (8500 ft) for about 1.5 hours, then at 2280 m (7500 ft) and 760 m (2500 ft) (or below cloud base) for 15 minutes each. The last portion of each flight was at 150 m (500 ft) near the ship for approximately 1 hour, with a flyby at 30 m (100 ft), then at 150 m (500 ft) for about 1 hour en route to Bermuda.

3.3. Ship-Aircraft Coordination

The NOAA ship *Mt. Mitchell* was used for data collection in coordination with the NOAA King Air. The ship was equipped with chemical and meteorological instruments similar to those on the aircraft (see Table 5, Section 6). The flights nearshore east coast and Bermuda, were conducted near the ship. A low-level (30-m) flyby of the ship was conducted during each flight to provide further coordination with shipboard instruments. The aircraft was in radio contact with the *Mt. Mitchell* prior to takeoff. When the aircraft was airborne, the scientists on both ship and aircraft coordinated sampling times and flyby times, and were able to discuss weather conditions, ship location, instrumentation problems, and sample levels.

3.4. Daily Operations

Preparation time for the flights was approximately 3 hours. Daily calibrations were conducted on all instruments that required them. Weather forecasts were obtained from R. Artz, NOAA/ERL/ARL, and ship contact was established.

During flight, ship contact was established again once the aircraft was in range, and general information was exchanged such as current weather, instrument readings, and timing of the flyby.

After the flight, the Principal Investigators met for an informal debriefing of flight and scientific conditions. Post-flight debriefings included in-flight changes, if any, in-flight weather conditions, and instrument problems, if any. Selected instruments were calibrated. Pre-flight, in-flight, and post-flight log notes are presented in Appendix A.

3.5. Synoptic Conditions

In Appendix B, the large-scale weather pattern is depicted for each CASE-WATOX flight day. The MSL pressure charts, and the 700-mb and 850-mb height analysis charts were created from NWS information (Rolph and Stunder, 1989). Isobaric back-trajectories to all locations were produced by the GMCC atmospheric trajectory model (Harris, 1982). The charts and trajectories used here are for a cursory explanation of the meteorology at the time of the flights. A complete meteorological analysis of the CASE-WATOX program will be presented by late 1989 (Stunder et al., 1989).

4. INSTRUMENTATION

The NOAA King Air (Beechcraft C-90) was used for the measurements described herein. The aircraft is owned and operated by the Aircraft Operations Center, NOAA, Miami, FL. It is equipped to measure aerosols, trace gases, and meteorological parameters (Wellman et al., 1989). Additionally, it is equipped with a LORAN navigational system (Advanced Navigation Inc.). The data-acquisition system aboard the aircraft is a Particle Measuring Systems, Model DAS-64, and is capable of recording 24 instrument outputs (14 fast analog and 10 slow analog channels), in addition to the Forward-Scattering Spectrometer Probe (FSSP) and the Active-Scattering Aerosol Spectrometer Probe (ASASP) data. Details of the data system are described by Wilkison and Boatman (1988).

Data are sampled every 0.5 seconds on the fast analog channels, and every 5 seconds on the slow analog channels. Data are recorded to tape every 5 seconds. Data were recorded on magnetic cartridge tapes using Algo Inc. recorder devices. There are two Algo systems: one for the instrumentation being recorded through the data acquisition system, and one for the LORAN data. Additionally, grab-sample data were recorded every 30 seconds on floppy diskettes (excluding LORAN data) as a backup in case of tape or tape recorder failure.

Instrumentation aboard the aircraft is a fairly standard package; however, instruments may be added or removed to meet specific research objectives. For CASE-WATOX, 11 of the 14 fast analog and 7 of the 10 slow analog channels were used for standard instrumentation. Two other instruments were installed (a Casella Impactor and an aerosol sampler from the Bermuda Biological Station); however, their sample flows were recorded only in the in-flight logbook, and not on the DAS-64. Below is a summary of the data collected:

Fast Analog		Slow Analog		Aerosol Data
1	Spare	1	Internal (no access)	FSSP
2	Spare	2	Internal (no access)	ASASP
3	H_2O_2 background	3	Photometer*	Casella impactor
4	H_2O_2 signal	4	1-in filter pack flow*	BBS sampler
5	Spare	5	90-mm filter pack flow	
6	Dynamic pressure	6	H_2O_2 flow A	**LORAN Data**
7	Temperature*	7	H_2O_2 flow B	
8	Dew point*	8	90-mm filter pack flow	Latitude*
9	NO_y status	9	NO_y range	Longitude*
10	Dew point (duplicate)	10	Spare	Heading
11	SO_2*			
12	Pressure*			
13	NO_y signal*			
14	Ozone*			

The asterisks indicate *Mt. Mitchell* comparable data; see also Table 5, Section 6.

Following is a description of the instrumentation used for CASE-WATOX. Each description includes the principle of operation, the algorithm used to convert to engineering units, the specifications (range and accuracy), and the calibration information.

4.1. K & K Inc.: H_2O_2 Analyzer

Principle of Operation: The system consists of a dual fluorimeter system with a wet chemical flow. In one channel, peroxidase enzyme catalyzes the reaction in which hydroperoxides form the fluorescent dimer of p-hydroxyphenylacetic acid (POPHA). Both H_2O_2 and organic hydroperoxide are measured; the peroxide concentration is directly proportional to the fluorescence intensity. In the second channel, H_2O_2 is selectively decomposed so that only organic hydroperoxides produce the fluorescence signal. This second channel acts as a background measurement. Output is in volts, and the following converts volts to H_2O_2 parts per billion by volume (ppbv):

H_2O_2 (ppbv) = h2fact * [(siga * bkth(2./flowa)) - (bkgda(2./flowb))],
where h2fact = calibration factor (standard H_2O_2 mixing ratio/voltage deflection for the standard)
siga = signal value minus the signal offset
bkth = breakthrough value (catalase efficiency)
bkgda = background value minus the background offset
flowa = flow for signal channel
flowb = flow for background channel.

Specifications: Range: 0-10 ppbv
Accuracy: 0.1 ppbv

Calibration: There was a daily pre-flight calibration using a 1.4 ppbv (2.93×10^{-7} M) and 2.8 ppbv (5.86×10^{-7} M) standard solution. A daily in-flight calibration was done using the 1.4 ppbv standard solution.

4.2. Tavis Transducer: Dynamic Pressure

Principle of Operation: This device consists of a pressure-sensing capsule with electronic signal conditioning. The transducer measures the difference between the static pressure port and the pitot tube. Output is in voltage, and is converted to millibars by the following:

Dyn Press (mb) = 51.81147 * volts + 9.83586

Specifications: Range: 0.236 to 4 pounds per square inch differential (psid)
Accuracy: 0.73%

Calibration: Calibration in the field is not necessary. The latest calibration was performed by the manufacturer on 19 November 1981. Calibration was verified during a Boulder Atmospheric Observatory (BAO) tower flyby on 30 May 1985.

4.3. Rosemount: Total Temperature Sensor

Principle of Operation: A sealed platinum resistance sensing element measures total air temperature. For stability and protection, the sealed element is surrounded by a gold-platinum alloy radiation shield, which, in turn, is surrounded by a stainless steel shield. The resistance is measured in volts, which are proportional to total temperature by the following algorithm:

T (°C) = recorded volts * (range/5 volts) + offset,
where the range is +40°C to -60°C, and the offset is -60°C.

Specifications: Range: +40° to -60°C
Accuracy: ≥ 0.995 (measured temperature to total temperature) (±0.25°C plus 0.5% of the magnitude of the temperature in degrees Celsius).

Calibration: Intercomparison calibrations are performed using the BAO 300-m tower and an additional temperature probe. These calibrations are performed annually if possible; however, the last calibration that was performed prior to the CASE-WATOX flights was 24 April 1986. A tower flyby on 13 October 1988 showed that the calibration was in good standing.

4.4. General Eastern: Dew Point Hygrometer

Principle of Operation: An incoming parcel of air is directed into the dew point hygrometer chamber and is cooled at constant pressure by contact with a thermoelectric cooling module with a mirrored surface. Condensation appears on the surface at a temperature slightly below that of the thermodynamic dew point of the air. The observed dew point will differ from the thermodynamic dew point depending on the nature of the condensing surface, the condensation nuclei, and the sensitivity of the condensate-detecting apparatus. When the dew on the mirrored surface is of a constant thickness, it is in equilibrium with the partial pressure of the water vapor in the air sample. At this point, the temperature of the mirror equals the dew point temperature. The voltage is proportional to the dew point according to the following algorithm:

T_d (°C) = recorded volts * (range/5.316 volts) + offset,
where the range is -75°C to +50°C, and the offset is -75°C.

Specifications: Range: -75° to +50°C
Accuracy: ±0.25°C at +50°C; ±1.0°C at -75°C

Calibration: Calibration was performed on the instrument on 25 November 1987 by the manufacturer prior to installation on the aircraft. Annual calibrations are performed using a portable calibration unit. System balance checks were performed periodically during the project to assure correctness of the instrument.

4.5. Thermo Environmental Instruments (TEI): NO_y Analyzer

Principle of Operation: This is a modified TEI NO_x instrument (see Delaney et al., 1982). Ambient air is sampled directly (NO mode) or through the NO_y to NO converter (NO_y mode). The chemiluminescence of NO and O_3 produce an intensity linearly proportional to the concentration of NO. The values (in ppbv) are derived by the following algorithm:

NO or NO_y (ppbv) = [volts(either NO or NO_y mode) - offset] * scaling factor,
where the scaling factor is a value of ppbv per volt.

Specifications: Range: 0-100 ppbv (range-selectable up to 10 parts per million (ppm)
Accuracy: 0.1 ppbv

Calibration: Prior to the field intensive, a four-point calibration was completed. In the field, a daily pre-flight and in-flight zero and span were performed.

4.6. Thermo Electron Corporation (TECO): SO_2 Analyzer

Principle of Operation: Pulsating ultraviolet (UV) light (230-190 nm) is focused through a narrow-band filter into a fluorescent compartment through which sample air passes. The UV light excites the SO_2 molecules, and they emit decay radiation that passes through another filter onto a photomultiplier tube (PMT). The amount of light energy impinging on the PMT is directly proportional in voltage to the amount of SO_2 in the sample:

SO_2 (ppbv) = so2max * (volts - vos)/(regs - vos),
where so2max = maximum SO_2(ppbv) during span with given calibration gas
vos = zero voltage offset
regs = pressure regression value (changes daily).

Specifications: Range: 0-200 ppbv (range selectable)
Accuracy: 0.1 ppbv

Calibration: Zero and span calibrations, on the low range (0-10 ppbv), were performed daily. Additionally, an in-flight span was performed from takeoff up to the highest altitude.

4.7. Rosemount Transducer: Static Pressure

Principle of Operation: The transducer consists of a precision capacitance pressure-sensing capsule with electronic signal conditioning. It measures the pressure from a static pressure port. Conversion from pounds per square inch absolute (psia) to millibars is through the following algorithm:

Pressure (mb) = volts * 68.95.

Specifications: Range: 0-15 psia
Accuracy: >±0.1% Full Scale Pressure (FSP)

Calibration: None required while in the field. An audit of the instrument performance was conducted during the BAO tower flyby 13 October 1988; no adjustment was necessary.

4.8. Thermo Electron Corporation (TECO): Ozone Analyzer

Principle of Operation: Concentration of ozone is directly related to the magnitude of the attenuation of light in the absorption cell, at 254 nm. Dual detectors monitor the changes in light intensity (both zero and sample), and an averaged intensity is calculated by the instrument using the Beer-Lambert Law: $I/I_o = \exp(-K\ell C)$,

where I = the light intensity of the ambient sample in the absorption cell
I_o = the light intensity measured with reference in the absorption cell
K = the absorption coefficient, a function of the gas and wavelength; for ozone at 254 nm it is 308 atm^{-1} cm^{-1} at standard conditions (0°C and 760 mm pressure)
ℓ = the length of the absorption cell (in cm)
C = the concentration (in ppm).

Each cell either measures I or I_o; when one cell is measuring I the other is measuring I_o, and vice versa. Concentration (in ppbv) is proportional to voltage using the following algorithm:

vd = (volts * 100) * ((1013.6/pressure) * (300/273.16)),
where vd is an interim step for density correction. Then the calibration correction is applied:

C (ppbv) = (vd * 1.02890) + 1.17713.

Specifications: Range: 0-0.5; 0-1 ppm
Accuracy: ±1.0 ppb

Calibration: An annual audit is performed using a National Institute of Standards and Technology (NIST) standard. The latest calibration was performed 11 February 1988.

4.9. LI-COR Photometer: Solar Radiation

Principle of Operation: A silicon photodiode measures solar radiation received from the whole sky (180° field of view). Through use of an amplifier, the volts are directly proportional to watts per square meter (Wm^{-2}).

Specifications: Range: 0.4-1.2 μm (peak at 0.95 μm)
Accuracy: ±5%

Calibration: No calibration is performed in the field. Calibration was performed by the manufacturer against an Eppley Precision Pyranometer. The calibration was performed under full-sun conditions at midday. Uncertainty of the calibration was ±5%; date of calibration was 25 April 1983.

4.10. Filter Pack Systems: Aerosol Composition

4.10.1. One 1-in-Diameter System

A one-inch Nuclepore filter pack system was used for all flights. The sample diameter of the filter was reduced to 0.50 cm by means of a Teflon mask. Filter handling and X-ray Fluorescence (XRF) analysis were provided by the University of Colorado. A mass flow meter (Kurz Inc.) monitored the flow; flows are in liters per minute. Calibration of the flow meter was performed 1 December 1986, with an audit of it in September 1988.

4.10.2. Two 90-mm-Diameter Systems

Two 90-mm filter pack systems were used during the flights; one for total flow sampling and one for separated flow samples. Filter handling and analysis were provided by the University of Virginia. Mass flow meters (Kurz Inc.) monitored the flows; output is in liters per minute. Both Kurz meters were calibrated in April 1988, prior to the flights; then one flow meter was audited in September 1988 and the other in November 1988.

4.11. Particle Measuring Systems (PMS) Active-Scattering Aerosol Spectrometer Probe (ASASP): Particle Size

Principle of Operation: A 632.8-nm He-Ne laser is used to size particles in the 0.12-3.12 μm range using a single channel, with 15 size bins. Air flow is directed and constrained to a 150-μm-diameter stream, providing isokinetic flow for sampling. Particles are detected and sized by the amount of light refracted by the collecting optics aperture.

Specifications: Range: 0.12-3.12 μm (15 bins)
Accuracy: 99% +

Calibrations: No calibration is done onsite; it is calibrated by the manufacturer. The last calibration was performed 13 January 1987.

4.12. Particle Measuring Systems (PMS) Forward-Scattering Spectrometer Probe (FSSP): Particle Size

Principle of Operation: This is a one-dimensional probe that measures a particle's diameter as each particle passes through the sample area. Particles are sized by measuring the amount of light scattered into the collecting optics aperture. There are four overlapping size ranges and each range is divided into 15 size intervals, providing 60 size channels in a 0.5-47 μm range; however, the instrument was set to Range 1, which measures 2-32 μm.

Specifications: Range: 2-32 μm (15 bins)
Accuracy: ±10% or ±2 μm (whichever is greater)

Calibrations: Performed by the manufacturer; last calibration was on 2 May 1988. No calibration is necessary while in the field.

4.13. Casella Cascade Impactor: Sulfate, Nitrate, Biomass Particle Concentrations

A four-stage cascade impactor designed to collect samples to determine sulfate, nitrate, and biomass particle concentrations was installed aboard the King Air. The stages of the impactor collect particles ≥ 5 μm, ≥ 2 μm to <5 μm, ≥ 0.7 μm to <2 μm, and ≥ 0.2 μm to <0.7 μm. See Quintana et al. (1988) for an explanation of sample preparation. No data were recorded on the DAS-64; flows were written in the in-flight log. Filter handling and analysis were provided by B. Kopcewicz, Polish Academy of Science, who was on assignment with NOAA/ARL.

4.14. Bermuda Biological Station (BBS) Sampler: Petroleum Hydrocarbons, Organochlorine

A Sierra-Misco pesticide sampler was modified for sampling petroleum hydrocarbons and organochlorine aboard the King Air. The sampler, sample preparation, and analysis were provided by K.S. Binkley, BBS. No data were recorded on the DAS-64; flow information was recorded in the in-flight log.

4.15. Advanced Navigation Inc. (ANI) Long-Range Navigation (LORAN) System: Latitude, Longitude, Heading

Principle of Operation: The LORAN system consists of a pulse-type radio system with ground-based transmitters. A receiver in the aircraft precisely measures signals from each ground station, thereby fixing a line of positions for tracking. Latitude, longitude, and heading are read directly from the LORAN; wind direction, and wind speed are calculated using LORAN input. Latitude and longitude are converted to decimal degrees; wind directions are in degrees, and wind speeds are in meters per second.

Specifications: Accuracy: Lat/Long--100 minutes
Heading--1.0°
Wind direction--1.0° (with 1-min averages)
Wind speed--1.0 ms^{-1} (with 1-min averages)

Calibration: None required; however, a check was made of the system over the BAO on 13 October 1988, and the LORAN accurately received the tower's position.

5. DATA PROCESSING

Data were verified on site by a post-flight look at the 30-s grab-sample files. The cartridge tapes were shipped overnight to Boulder for processing. A series of steps was involved in developing the final usable data:

1. The data (both DAS-64 and LORAN) were read back to a hard disk on an HP-1000 system.

2. An HP program designed specifically for the CASE-WATOX aircraft channel assignments was used to produce an averaged data file (user's choice of averaging time). This program integrates the LORAN data, so the final file has averaged chemical, meteorological, and position data.

3. The aerosol probe (ASASP and FSSP) data were processed separately, and an averaged file for each probe was produced.

4. Some data such as SO_2, NO/NO_y, H_2O_2, and filter-pack flows needed after-the-fact calibration coefficients applied. These data were initially analyzed for these adjustments, then were reprocessed with the correction factors.

The dataset for CASE-WATOX consists of 1-min and 10-s-averaged (one each per flight) ASASP and FSSP files; NO_y files; chemical, meteorological, and LORAN (CML) files.

In the ASASP final processed files, there are 19 columns of data:

Columns 1, 2. Beginning and ending times.

Columns 3-17. Bin values (particles cm^{-3} μm^{-1}). The bin number listed at the top of the columns is the value at the center of the bin (μm). The ASASP has only one range with 15 bins. Table 2 lists the ASASP bin sizes.

Column 18. Average mass (μg m^{-3}). The average concentration (particles cm^{-3} bin^{-1}) is converted to mass based on 2 g cm^{-3} density, then the average mass values are integrated across the bins.

Column 19. Average concentration (particles cm^{-3}). The value in each bin (particles cm^{-3} μm^{-1}) is converted to particles cm^{-3} bin^{-1}, then the average concentration values are integrated across the bins.

In the FSSP final processed files there are also 19 columns of data:

Columns 1, 2. Beginning and ending times.

Columns 3-17. Bin values (particles cm^{-3} μm^{-1}). The bin number listed at the top of the columns is the value at the center of the bin (μm). When the concentration is greater than 5.0 particles cm^{-3}, the value shifts to liquid water content (g m^{-3}) and displays in a different format. The FSSP may be set to auto-ranging or to an individual range. During CASE-WATOX, the instrument was on Range 1. Table 2 lists the FSSP bin sizes.

Column 18. Average mass (μg m^{-3}), based on 2 g cm^{-3} density, except when the value is shifted to liquid water, then the standard density of water (1 g cm^{-3}) is used. As with the ASASP, the values are integrated across the bins.

Column 19. Average concentration (particles cm^{-3}). Concentration values are converted as with the ASASP: Particles cm^{-3} μm^{-1} to particles cm^{-3} bin^{-1}, then integrated.

Table 2. ASASP and FSSP calibrated bin values

Channel	Size (μm)	Interval (μm)	Channel	Size (μm)	Interval (μm)
	ASASP-100X			FSSP	
1	0.120-0.145	0.025	1	2.00-4.00	2.00
2	0.145-0.195	0.050	2	4.00-6.00	2.00
3	0.195-0.270	0.075	3	6.00-8.00	2.00
4	0.270-0.370	0.100	4	8.00-10.00	2.00
5	0.370-0.495	0.125	5	10.00-12.00	2.00
6	0.495-0.645	0.150	6	12.00-14.00	2.00
7	0.645-0.820	0.175	7	14.00-16.00	2.00
8	0.820-1.020	0.200	8	16.00-18.00	2.00
9	1.020-1.245	0.225	9	18.00-20.00	2.00
10	1.245-1.495	0.250	10	20.00-22.00	2.00
11	1.495-1.770	0.275	11	22.00-24.00	2.00
12	1.770-2.070	0.300	12	24.00-26.00	2.00
13	2.070-2.395	0.325	13	26.00-28.00	2.00
14	2.395-2.745	0.350	14	28.00-30.00	2.00
15	2.745-3.120	0.375	15	30.00-32.00	2.00

The NO_y final data files have 7 columns of data: beginning time (of average); corresponding decimal time; corrected NO; corrected NO_y; calculated NO_2; zero value; and calibration value.

In the CML files, some data have been left in the raw voltage state; however, most have been converted (with calibrations) to engineering units. True air speed (TAS) is calculated and added to the processed CML files; each CML file has 30 columns in it. Table 3 lists the parameters that are in the final averaged CML data files.

6. DATA QUALITY

With the exception of one day (28 July) of the static pressure transducer failure, and some intermittent LORAN dropouts on six days, all instruments operated at 100%. A software problem that interfered with buffer storage caused random raw data dropout; however, not a significant amount. The values during that time have been averaged over the amount of data that existed in that time frame, and are accurate; however, the shorter the averaging time (i.e., 10 seconds), the greater amount of zeros. When a 1-min time frame is used, the data show no zeros for these short dropouts (which were usually less than 20 seconds). Some additional loss of in-flight data occurred at times when the cartridge tapes were changed (maximum 3 minutes). Table 4 shows the percentages of usable raw data per flight day. These percentages were obtained by including all possible losses.

Table 3. Processed parameter files

For CASE-WATOX: 17-28 July 1988, Newport News and Bermuda

No.	Parameter	Unit	Accuracy	Response Time	Precision	Comments
1	Begin time	hhmmss	----	----	----	From tape
2	End time	hhmmss	----	----	----	From tape
3	Spare	----	----	----	----	----
4	Spare	----	----	----	----	----
5	H_2O_2 background	mV	0.1 mV	2.5 min	0.1 mV	H_2O_2 instrument
6	H_2O_2 signal	mV	0.1 mV	2.5 min	0.1 mV	H_2O_2 instrument
7	H_2O_2	ppbv	0.1 ppbv	----	0.1 ppbv	Flow corrected; not time corrected
8	Dynamic pressure	mb	0.1 mb	1 s	0.1 mb	Pitot tube and static pressure port
9	Temperature	°C	0.1°C	1 s	0.1°C	Wire
10	Dew point	°C	1.0°C	5 s	0.1°C	Cooled mirror
11	NO_y status	mV	----	----	----	NO_y sample mode indicator
12	Dew point	°C	1.0°C	5 s	0.1°C	Duplication for backup purposes
13	SO_2	ppbv	0.1 ppbv	1 min	0.1 ppbv	Pulsed fluorescence
14	Pressure	mb	0.5 mb	1 s	0.1 mb	Static pressure
15	NO_y signal	mV	1.0 mV	30 s	1.0 mV	Raw voltages
16	Ozone	ppbv	0.5 ppbv	1 s	0.1 ppbv	UV photometric detection
17	Latitude	deg-min	100 min	1 s	----	LORAN-C
18	Longitude	deg-min	100 min	1 s	----	LORAN-C
19	TAS	ms^{-1}	1.0 ms^{-1}	1 s	0.1 ms^{-1}	Computed value
20	Heading	deg	1.0°	1 s	1.0°	Gyrocompass
21	Wind direction	deg	1.0°	60 s	0.1°	Computed value
22	Wind speed	ms^{-1}	1.0 ms^{-1}	60 s	0.1 ms^{-1}	Computed value
23	Solar radiation	Wm^{-2}	----	----	----	Short-wave sun photometer
24	Filter flow	slpm*	0.1 lpm	1 s	0.1 lpm	1-in filter pack
25	Filter flow	slpm*	0.1 lpm	1 s	0.1 lpm	90-mm filter pack (total)
26	H_2O_2 flow A	slpm*	----	----	----	H_2O_2 airflow for signal
27	H_2O_2 flow B	slpm*	----	----	----	H_2O_2 airflow for background
28	Filter flow	slpm*	0.1 lpm	1 s	0.1 lpm	90-mm filter pack (separator)
29	NO_y range	V	----	----	----	NO_y range indicator
30	Spare	----	----	----	----	----

*slpm is standard liters per minute.

Table 4. Percentage of usable raw data

Date	Fast and Slow Analog Channels	LORAN
880717	97.58	97.23
880718	98.07	98.88
880719	98.42	100.00
880721	98.00	100.00
880726	98.06	94.06
880727(1)	97.71	99.33
880727(2)	98.32	93.86
880728	98.10 and 65.20*	99.47

*All instruments except the pressure transducer operated correctly during the flight. The 65.20% is the amount of usable raw data from the pressure transducer.

In the processed CML data files, latitude, longitude, heading, wind speed, and wind direction are all incorrect whenever there is a LORAN malfunction. On 28 July, when the pressure transducer malfunctioned, temperature, SO_2, pressure, ozone, and true air speed are incorrect data during those times. However, for 28 July, we created a raw data file with corrected pressures for the dropout times to have a more accurate picture of the other variables. The pressures were estimated by using the flight pressures from the three previous days. Because of the fairly static high-pressure system Bermuda was under at the time, we feel it was an accurate estimation of in-flight pressures. All files (raw and processed, corrected raw and corrected processed) exist, and the corrected file is only used as an estimate. Users are given the corrected files as part of the data set; the uncorrected files are available on request, as well as the values used to correct them.

In the processed NO_y files, NO values for all flights are at detection limits or less than detection limits; NO_y data are good for all eight flights.

7. DATA AVAILABILITY

Processed aircraft data files (CML, ASASP and FSSP probe data, and NO_y) are available in standard ASCII files on either 9-track magnetic reel tape, or on 360-kilobyte or 1.2-megabyte floppy diskettes. Copies of all original King Air flight tapes, and all programs, graphs and printouts, are maintained by NOAA/ERL/ARL/GMCC/Air Quality Group, Boulder, CO.

Requests for aircraft data may be directed to R.L. Gunter, NOAA/ERL/ARL/GMCC, Air Quality Group, Mail Code R/E/AR4, 325 Broadway, Boulder, CO 80303. Commercial phone number, (303) 497-5130; FTS, 320-5130.

Table 5 lists only the comparable data and agency responsible for the data for the King Air/*Mt. Mitchell* coordinated data-taking sessions (17-28 July 1988). Data available from the *Mt. Mitchell* are more extensive. Requests for ship-coordinated data may be directed to A.A.P. Pszenny, NOAA/AOML/Ocean Chemistry Division, 4301 Rickenbacker Causeway, Miami, FL 33149. Commercial phone number, (305) 526-1388; FTS, 350-1388.

Table 5. Ship-aircraft comparable data

Parameter	Collection Method	Archived Location
Temperature	Hourly values entered in ship's log	AOML
Dew point	Hourly values entered in ship's log	AOML
Pressure	Hourly values entered in ship's log	AOML
SO_2	Filter pack data	AOML
NO_y:		
NO_x	NO_x instrument aboard *Mt. Mitchell*	York Univ.
NO_x	NO_x instrument aboard *Mt. Mitchell*	AOML
PAN	Instrument aboard *Mt. Mitchell*	AOML
Ozone	Instrument aboard *Mt. Mitchell*	AOML
Solar radiation	Photosynthetic wavelengths	AOML
Latitude	Hourly values entered in ship's log	AOML
Longitude	Hourly values entered in ship's log	AOML
Wind direction	Hourly values entered in ship's log	AOML
Wind speed	Hourly values entered in ship's log	AOML

8. ACKNOWLEDGMENTS

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APPENDIX A: Pre-flight, In-flight, and Post-flight Log Notes.

17 July, 1988
Data Flight #1 - Newport News, VA
Pilot, Tom Gates; Co-Pilot, Roger Morris; Scientist, Joe Boatman

PRE-FLIGHT:

All pre-flight data are archived on diskettes (30-second grab sample file).

053000 SO_2 on --> NO_x on (cooling)
062000 NO_x nearly cooled down (0.05 range); SO_2 0 check = 0.7 V; span = 5.3 V = 7 ppbv
062300 Starting NO_x 0 & cal
064000 Circuit #4 on
064300 SO_2 on zero; span = 6.1 V
065200 NO_x zero = 2.2 V; circuit #4 0.05 range
065400 NO_x 0 = 1.98 V; SO_2 0 = 0.8 V; 0.05 range
065600 Range on NO_x to 0.5; 0 = 0.23 V
065900 Circuit #4 off (NO_x), 0 reading = 0.20 V
070100 NO_x = 0.19
070400 NO gas on, T #3 = 10.0 sccm
070500 NO_x range to 0.05; LAT 35∘55, LONG 74∘40'; 6 mi ; winds 200/17 - 3-5 ft. waves - scattered low clouds - no swell - marine strato Cu

Go to GMT time

TSI - Parzyck 612-490-2848
Floating 0, 0.13 -> 0.15 voltage on all channels - earlier +0.4
Today positive again
Rick Artz, Bob McBeth - no LORAN data; temp data ok - new class software doesn't work - not possible to code data - no transmission possible

072700 NO_x NO signal = 8.65
073400 NO signal = 5.0 V at T #3 = 5
073900 NO to zero - circuit #4 on - range = 0.5
074100 0 value = 0.13 V circuit #4 off
074800 NO_x zero = 0.102 V with circuit #4 off

NOTE: All pre-flight calibrations were recorded, and are archived on diskettes (30-second grab sample file).

IN-FLIGHT:

[GMT]
124630 Start engines
125027 Algos on - off loadpoint
1252 SO_2 offscale on ground
1253 SO_2 on span (some trouble! too hot?)
1302 NO_x zero air off
130245 Takeoff
1310 Pumps (90 mm) on - purging
131159 BBS installed & pump on at 8500 ft - 1" of water pressure reading

131459	Herman's filter #A-01 on, flow rate = 3.8 lpm
131614	Cassella on pack #1; max flow available = 16 lpm
1328	90 mm filter #41 on, flow = 310 lpm; SO_2 = 0.3 ppbv; 8500 ft; T = 14.2°C; T_{dp} = -1.4°C; winds 210/18 knots; clear skies/hazy below
1333	ASASP pump just turned on (oops!)
1334	All systems looking good
1338	Flask #373 exposed 8500 ft
1343	Cassella 16 lpm; BBS - 1" H_2O
1344	All systems ok
1345	Adj H_2O_2 flow slightly to 2 lpm
1347	H_2O_2 shows very low concentration - maybe 0.1 or 0.2 ppbv
1348	O_3 = 67 ppbv; SO_2 = 1.2 ppbv; T = 13.9; T_d = -10.5
1349	A few scattered buildups about 30 mi ahead - no threat - high bases
1352	NO_x cal sequence begun
1358	NO zeroing
1400	Turned on NO Cal gas - in contact & above ship
1403	NO_x span constant - going to zero
1407	Stable NO_x zero achieved - back to NO_x sample
1411	Zeroing SO_2
1417	Return to SO_2 sample ≈1.5 volts offset - I entered 0.6 V offset on the ground - should subtract another 0.9 V from the SO_2 ppbv screen for correct SO_2 conc. - this doesn't apply to the recorded data
1418	Ship sited at 12 o'clock and 7 mi
1428	H_2O_2 on zero
1441	Algo tape #1 changed to #2
1447	H_2O_2 now on sample - zero & cal were weird - I think I zeroed it but no span
1451	Kurz 90 mm - 275 lpm; 25 mm 3.9 lpm
1452	Down to 5500'
1457	At 5500 ft
1501	Preparing for filter changes - #42 will be a blank - #A02 will also be blank
1504	90 mm flow off; Herm's pump off
1524	Down to 500 ft near ship
1525	90 mm both on; SO_2 = 1.4 ppbv; 500 ft; T = 26.1; T_d = 23.6; #43 on total #44 on separator
1532	Pump overheated - back on; 252 lpm; 3140 mV separated
1535	25 mm filter blank A-02; 25 mm filter A-03 started - 5.1 lpm
1542	Cassella changed
1543	Pump for Cassella on - flow to 17
1544	Breaker kicked on 90 mm again - put more cool air on it - running now - flow: total = 237, sep. 3118
1547	Flask #345 exposed - 35°36.6/74°42.2 LAT/LONG; T = 26.1; T_d = 23.1 500 ft
1617	Preparing to change 90 mm filters at 1620 - filters #45 & #46 will be blanks on the total & separated, respectively.
1622	90 mm off
1643	90 mm back on - #47 TOTAL & #48 SEP; SO_2 = 1.4 ppbv; 500 ft. AGL; T = 27; T_d = 23.9; SW winds
1647	Flask #720 exposed - 36°27.8/75°15.1; winds 200/26 knots; T = 27.4; T_d = 23.4; 500 ft
1709	Flask #771 - 37°02.7/35°56.5 lat/long; T = 24.9; T_d = 22.1; clear; 500 ft

1712 25 mm off
1714 Cassella off
1715 BBS off
1720 90 mm off

POST-FLIGHT:

No post-flight calibrations were performed after this flight.

18 July, 1988
Data Flight #2 - Newport News, VA
Pilot, Roger Morris; Co-Pilot, Tom Gates; Scientist, Laureen Gunter

PRE-FLIGHT:

A pre-flight calibration of SO2, H2O2 and NOx were performed: data are archived on a diskette (30-second grab sample file).

IN-FLIGHT:

[GMT]
124100 Engine start
124300 Taxi-out
124500 SO_2 to span (span gives 6.7 ppbv chan 2)
125000 DAS & LORAN tapes on - DR2 - ASASP on - FSSP on R1
125700 ASASP pump on - cleared for T/O
125800 T/O
130000 @ 2000' - extremely hazy!!!
130300 @ 5000 ft - flushing all FP systems - installing BBS
130700 BBS installed - having to stay @ 6500 - clouds - can't go up
131000 Can see to go up now - going to 8500
131100 Casella on - 17 lpm; BBS on - 1.75" H_2O
131200 Stopping flushing of 90 mm & 1"
1313 @ 8500'; +12°C; BBS now @ 1.50" H_2O
131600 90 mm FP on #51 - flow 301 lpm; HS #A-05 - flow 3.9 lpm
131700 SO_2 to sample - zero air off - SO_2 cyl off
132000 H_2O_2 to cal (red button)
132500 NO_x to zero first
132900 NO cyl on - zero stable going to span
133500 NO_x to zero
134000 NO_x to sample - zero air off
134100 Having to turn around or go down - never mind - we have been cleared to go straight - just took a little jog to the S
134500 Flask #760 - 36°08 LAT/74°55 LONG; +12°C; winds 255/20; 8500' haze, clouds below/above - 17 mi from ship - in clear layer now
1351 Contact with Mt. Mitchell - 35°53/74°40 position (theirs) winds 205/22; 5 mi vis - we're 3 1/2 mi N/NW of Mt. Mitchell

1353 Over Mt. Mitchell now - turning around; BBS still 1.5; Casella 17 lpm; O_3 = 57; SO_2 1.0 ppbv; H_2O_2 ≈2 ppbv; flow on 90 mm now 272 lpm; HS's = 3.8
141100 Cirrus above - haze below - line of CU's to the south/southeast 3 mi from ship
142100 Flask #752 - 36°01/74°23; +12°C; winds 188/16; 8500'; clouds above and below - haze below
142400 Turning to west - heading back to ship
143000 Casella still @ 17 lpm; BBS still @ 1.5" H_2O
144000 End DAS tape #1 (Tk/Tm'd - not ET'd) - begin DAS tape #2
144500 Descending according to flight plan
144600 FP 90 mm #51 off - flow 271 lpm; HS A-05 off - flow 3.7 lpm
144700 FP 90 mm #52T-BLANK - on descent; HS A-04 BLANK
145000 @ 5500'
145600 Descending to 2500'
145900 Casella #1 off - 17 lpm flow; zero check on #2 - ok
150000 @ 2500'; SO_2 4.7
150400 Casella #2 on - 17 lpm flow; BBS 1.6" H_2O; @ 2500'
150500 Descending to 500 - on descent SO_2 decreased
150830 @ 500; SO_2 @0.7 - total only
150900 FP 90 mm #53 on - flow 342 - total; FP 90 mm #54 - BLANK; 500'; HS #A-06 on - flow 5.0 lpm
151500 Flask #1129 - 35°57/74°35; +26°C; winds 231/27; 500'; hazy - choppy water
152200 BBS 1.8" H_2O; Casella ≈18 lpm; 90 mm #53 now 329 lpm
153300 90 mm pump off - C.B. popped - air cond. apparently off again
153400 Pump off again
153500 On
153600 Off again!! won't hold
154000 90 mm pump back on - flow 341 lpm - A.C. seems a little cooler now - Tom turned it off & on several times - maybe the pump will stay cool
155000 Flask #1144 - 36°10/74°29; +25.9°C; winds 236/25; 500'; hazy all around; T_d 23.9
155030 90 mm pump off again - didn't notice when it went off
155100 Pushed the CB back on - flow 343 lpm
155700 SO_2 only 0.6-0.7 so only total 90 mm going on next leg
155900 90 mm #53 off - flow 339; HS #A-06 still on - flow 5.0
160100 90 mm #55T - BLANK
160600 Lined up descent to 100' over Mt. Mitchell - we'll be to the south side of it going SW -> NE
160800 Past Mt. Mitchell; SO_2 0.6; O_3 15.9
161000 FP 90 mm #56 on - flow 377 - having trouble keeping pump on - 1 min later it popped the CB - won't hold
161500 Closed up FP - will have to let pump cool a bit - will restart
162000 FP 90 mm #56 on again - let's hope it holds
162200 Pump off - won't hold - will have to let it cool longer
162500 Flask #132 - 36°25/74°59; +27.1°C; T_d 22.4; winds 222/25; 500'; hazy
163000 Begin FP 90 mm #56 again - pump was able to cool some - keep your fingers crossed Sheryl; SO_2 = 2.4 ppbv
163400 End DAS tape #2
163500 Begin DAS tape #3
163800 Casella 17 lpm; BBS 1.7" H_2O; 90 mm total 333 lpm; HS 1" 5.5 lpm SO_2 = 3.1; getting closer to shore - winds 218/16

164100 Pump off - 90 mm
164300 Back on - flow 334
164500 Pump off - it is just too too hot
164700 Back on - if it goes again its coming off!!!
165000 SO_2 5.4 - winds 200/4
165100 #56 90 mm pump gone off again - end this
165200 #57 90 mm BLANK (TOT); HS #A-06 still on; SO_2 now 6.0 ppbv
170000 HS #A-06 off - flow 5.6 lpm; pilots are in control now
170000 Casella #2 off - flow 17 lpm; BBS off 1.7" H_2O
170100 Ascending and RTB'ing
170200 Removing BBS sampler
171700 Landed
171800 Alt/F10 - leaving most on for grd cals

POST-FLIGHT:

No post-flight calibrations were performed after this flight.

19 July, 1988
Data Flight #3 - Newport News, VA
Pilot, Tom Gates; Co-Pilot, Roger Morris; Scientist, Laureen Gunter

PRE-FLIGHT:

A pre-flight calibration of SO_2, H_2O_2 and NO_x were performed: data are archived on a diskette (30-second grab sample file).

IN-FLIGHT:

[GMT]
135500 Engine start
135900 SO_2 to span
140400 NO_x tylan #4 to 0.0
140500 DAS & LORAN on - DR2 - ASASP on - FSSP on - R1
1406 NO_x range chg to 0.10
1407 Up to 0.20 (on NO_x)
140800 ASASP pump on - taxi out - cleared for T/O
141000 Takeoff
141100 NO_x range back to 0.05
141200 Cloud layer at 2000'-2200' - lite clouds and blue sky above - not as hazy as yesterday
141430 @ 5K - flushing FP systems - installing BBS sampler
141800 @ 8500'
142000 FP 90 mm #61 - BLANK - total
142300 Casella #1 on - flow 17 lpm; BBS on flow 1" H_2O
142400 90 mm #62 on - total - flow 291 lpm; HS's A07 on - flow 4.3; winds 256/23; SO_2 1.0 ppbv; T = 11.7; T_d = 11.7
142500 SO_2 to sample

143000 H_2O_2 to cal (red button)
143200 Zero NO_x box
143600 Span NO_x box
144100 Zero NO_x box
144600 End NO_x "stuff"
144900 Ship is 20 mi south - right now we can't get closer cause of active TAC - 36∘15N boundary
145200 Crud layer right below us
145800 Sci msg from ship - see adj page

MSG FROM SHIP:

Pmb	alt	T	Td	RH	WD	WD
920mb	9.17m	2.1∘	16.1∘	73%	238	$15.6 ms^{-1}$
840	16.86	18.9	2.7	35	235	7.6
750	26.48	12.1	4.2	57	220(est)	10.0(est)

dry layer @840-820mb
sfc radar conc are @ at remote marine backgrd levels
aerosol filters exposed overnite only faintly colored suggesting very clean air
Mt Mitchell position: 35°54'.8" N/74°40'.9" W winds 225/20 vis about 5 miles
END OF SHIP MSG

150000 Doing ≈E/W tracks line of CU's to south and east
151400 Flask #1253 - 36∘17/74∘27; +12.1∘C; winds 212/27; T_d = -4.1∘C clear above - clouds to south - dirty haze below
152100 BBS flow ≈.9" H_2O; 90 mm - 272 lpm; Casella - 17 lpm; 1" - 4.1 lpm
153100 Flask #_______ - 36∘15/74∘58; +11.6∘C; winds 243/15; 8500'; T_d = 5.2 clear above - cruddy haze below
154200 Going to 5500' and finish up FP's
154430 @ 5500'; flow on 90 mm up to 287; 1" - 4.4; T = 18.2; T_d = +1.3; flow check: casella - 17 lpm; SO_2 = 0.6; BBS - 1" H_2O
155000 End DAS tape #1 - begin DAS tape #2 - TK/TM'd not ET
155400 90 mm #62 off - 285 lpm; HS #A-07 off - 4.3 lpm
155430 Descend to 2500 - casella #1 off
155800 @ 2500 for 5 min
160300 Descending to 500' - zero check on casella #2 ok
160400 90 mm #64 - filter out couldn't use
160600 @ 500' - 5 mi NE of Mt. Mitchell; SO_2 = 0.7
160700 90 mm #63 - BLANK total; 90 mm #65 - BLANK sep; HS's #A-08 - BLANK
161100 90 mm #66 - filter out couldn't use

NOTE: Can we use the 2 90mm's - #64 and #66 as cabin blanks? (the ones with the filters out).

161300 90 mm T flow 236 lpm; #68 S flow 3.12 V; HS #A-09 on - flow 5.4 lpm; SO_2 = 0.6; 500'; T = 25.9; T_d = 22.8
161400 Casella #2 on adj flow at 17 lpm; BBS on - 1" H_2O - maybe 1.09 - jerky little needle
162500 Flask #1190 - 35∘33/74∘51; T = +26.1∘C; winds 211/28; 500'; T_d = +22.5∘C lite haze - clear above - clouds to S
163008 Noticed flow on 1" HS's #A-09 jumped up to 27.4 lpm - something must have happened to the filter inside - going to look at it

163200 HS #A-09 filter has a big hole right in the center - I don't have another to replace it so I just turned his pump off
164200 Flask #1255 - 36∘14/74∘31; +25.6∘C; winds 197/22; 500'; T_d 23.3∘C light haze - cirrus above
170300 90 mm off #67 T - 234 lpm; 68 S - 3.1 V
170800 100' flyby Mt. Mitchell
171000 " " " " "
171200 90 mm #69 T on - flow 254 lpm; 70 S on - flow 3.59 V SO_2 = 0.7; T = +25.9; T_d = +22.7; BBS still 1" H_2O; Casella 17 lpm
173500 End DAS tape #2 - TK/TM'd - begin DAS tape #3
174400 SO_2 = 0.7; T = 27.8; T_d = 21.1; TOT 90mm - 238 lpm; SEP 90mm - 3.39 V
180200 90 mm off - 69T and 70S
180300 Casella off 17 lpm; BBS off - 1" H_2O
180400 Going up and home
181800 Landed - ASASP off - FSSP off - leaving most on
181900 Tapes out - TK/TM'd

POST-FLIGHT:

No post-flight calibrations were performed after this flight.

21 July, 1988
Data Flight #4 - Newport News, VA
Pilot, Roger Morris; Co-Pilot, Tom Gates; Scientist, Laureen Gunter

PRE-FLIGHT:

TELEPHONE CONVERSATION WITH MT MITCHELL PRIOR TO FLIGHT:
Clouds East and South - Clear N and W - 10 mi vis; waves 3-5 ft; wind 205/12 knots; 36∘12'/74∘12' (ship's position); 0.6 knots speed moving NNE now. EAA might be fixable. Won't know until tonight. SO_2 below detection limits.

Calibration data are archived on a diskette (30-second grab sample file).

IN-FLIGHT:

[GMT]
122500 Engine start
122900 Taxi-out - SO_2 to span - ASASP on - FSSP on R1
123500 DAS & LORAN on - DR2 - NO_x tylon 4 to zero
123900 ASASP pump on - cleared for T/O
124000 T/O - keeping low going out - under cloud layers - looks good from here offshore
124700 @ 5000 - flushing FP & flask systems
125100 @ 8500
1254 Casella on - flow 17 lpm;
BBS on - flow 0.5" H_2O - why so low?;
this fought me today!! ('bout won too!)

1255 90 mm #71 - BLANK; 8500′

125700 90 mm #72 - TOTAL on - flow 280 lpm; T = +11.1; T_d = 5.4; winds 216/36

130000 SO_2 to sample - cyl off - zero air off

130300 HS #A-10 on - flow 4.4 lpm

1318 Relatively lots of ships in water today - seas are calm - nice blue skies - mix of clouds - quite nice out here today - clean air too.

132800 Heading E - coming into building CU's - heavier cloud decks - lightening - not quite to ship yet

133300 Ship is ≈5 mi ahead of us - wx may prevent us from flying E past them - we're looking for a hole thru

133600 Turning E - can't go thru - dark & ominous

133900 Flask #1177 - 36∘16/74∘00; T = +10.8∘C; winds 210/40; 8500′; T_d = 5.7∘C; clouds all around - mixed layers

134300 H_2O_2 to span

134800 NO_x to zero - its really zero - can't see anything on graph

135200 NO_x to span

135700 NO_x to zero - there will be a peak on the dive to zero - I accidentally shut off zero air pump prematurely but then right back on

140200 NO_x to sample

140700 BBS still 0.5" H_2O; Casella still 17 lpm; 90 mm #72 278 lpm; HS #A-10 4.2 lpm; T = +10.8∘C; T_d = +6.1∘C; winds 222/31

141000 Flask #1162 - 36∘17/74∘21; +10.8∘C; winds 222/31; 8500′; - clouds above and around - mixed - we're in between layers

141430 Descending to 5500 - BBS will need new reading - so will FP's

141800 @ 5500′ - this puts us into some heavier clouded areas

142000 End DAS tape #1 - not ET'd - begin DAS tape #2 - TK/TM'd

142300 Casella 17 lpm; BBS 0.5" H_2O; 90 mm #72 - 290 lpm; HS #A10 - 4.7 lpm

142700 90 mm #72 off - 291 lpm; 1" #A-10 off - 4.7; desc to 2500

142800 HS #A-11 - BLANK

143100 @ 2500′; SO_2 = 0.6 ppbv

143300 BBS 0.6" H_2O; Casella 17 lpm - had to be adjusted

143630 Descending to 500′

143920 @ 500′

144000 90 mm #73 TOT on - BLANK; #74 SEP on - BLANK

144500 90 mm #75 TOT on - flow 245 lpm; #76 SEP on - flow 3.24 V; HS #A-12 on - flow 5.4 lpm; BBS 0.75" H_2O; SO_2 = 0.7; Casella adj to 17 lpm; T = +26∘C; T_d = +23.8∘C

144800 N/S tracks now due to wx - light rain occasionally - we're diverting when that happens

145300 H_2O_2 to zero

151300 Flask #1148 - 36∘33/74∘12; winds 210/25; 500′; T = +26C; clouds above and around; hazy to sea; T_d = 22.4; SO_2 = 5 ppbv

153500 90 mm #75 & 76 off; 1" flow went to 28?; 90 mm - 242 lpm TOT; 90 mm - 3.31 V SEP; HS's off - don't know when flow went high - will put another on after 100′ pass

153530 Going to 100′ for pass

153600 BBS still 0.75; SO_2 = 0.5

153800 Flyby @ 100′ - clear - good pass

154530 FP 90 mm #77 TOT on - 252 lpm; 78 SEP on - 3.69 V; HS #A-13 on - flow 5.1

1554 Flask #1176 - 36∘33/74∘43; winds 200/28; 500′; T = +26∘C; T_d = 20.7∘C; clear below to sea - blue skies - mixed clouds above

161000 End DAS tape #2 - TK/TM'd not ET - Begin DAS tape #3

161400 BBS still 0.75" H_2O; Casella 17 lpm; T flow 90 mm - 239 lpm; S flow 90 mm - 3.37 V; T = 26°C; T_d = 21.4°C; SO_2 = 0.6
161500 H_2O_2 to zero
162700 Passing by navy ship within 1 mile - crossed her bow
163000 Crossing in front of carrier - 2 planes in vic - now 3 - they just launched one
163500 FP 90 mm #77 T off - flow 239 lpm; 78 S off - flow 3.45 V; HS #A-13 also blew filter!!! flow inc to 20+ lpm; SO_2 = 0.8
1640 90 mm #79 T - BLANK; #80 S - BLANK; 500'
164700 Casella off; BBS off
164900 NO_x to zero
1650 Really choppy & bumpy - hard to do anything
165300 Landed
165400 TK/TM' DAS tape - some inst off - LORAN power cart needed on ground for post flight cals

POST-FLIGHT:

Post-flight calibration data were recorded at the end of the in-flight 30-second grab sample file (archived on diskette).
NOTE ABOUT CASELLA: Only one casella exposed, forgot to change to #2 at altitude change.

26 July, 1988
Data Flight #5 - Bermuda
Pilot, Roger Morris; Co-Pilot, Tom Gates; Scientist, Laureen Gunter

PRE-FLIGHT:

25 July, 1988 - Bermuda
[GMT]
1412 Contacted Mt Mitchell - they forecast their 26 July ship position to be 32° N/63°50' W. Advised them that aircraft takeoff time est to be 1100Z. WX: overcast midlevel - calm sea and winds.

NOTE to Roger Morris: use 8802.6 HF radio-up.

All pre-flight calibration data are archived on diskette (30-second grab sample file).

[GMT]
0918 H_2O_2 lamp on - solutions loaded
0919 NO_x vacuum pump on - 0.05 range - ~6.00
0938 NO_x ozonizer on
0941 O_3 on
0950 H_2O_2 - A & B at 0.34 for std #1, zero offset 0.06
0952 SO_2 zero 0.6 ppb (stable 20 min)
0953 NO_x zero mode 2.86 V

0957 NO_x - zero air 2.57 V; H_2O_2 - A = 0.337 - B = 0.336 - zero offset 0.06; SO_2 at 6.2 V on cal
1000 NO_x - on NO_x mode zero air - 2.81-2.70-->2.49 V
1003 H_2O_2 - catalase in chan B - HVA = 525; HVB = 481; lamp 4.64
1004 NO_x - 10 sccm; NO - CAL - 1.53 lpm air
1007 SO_2 - at 7.3 V
1010 NO_x - zero mode interrupted CAL - turned zero off - NO at 8.01 V prior
1012 SO_2 at 7.7 V; O_3 at 7 ppb
1015 NO at 7.69 V
1018 NO at 7.67 - NO_x mode on
1020 H_2O_2 zero offset - A = 0.068; B = 0.067; NO_x = 7.73 V on CAL; SO_2 at 8.0 V
1028 H_2O_2 A = 0.32; B = 0.08 for Std #1; NO_x = 7.65
1038 NO at 7.26 V - NO cal off - NO_x mode off
1043 NO at 1.43 for zero air - zero mode on
1045 H_2O_2 A = 1.038; B = 0.285
1046 NO at 1.43 on zero mode
1050 SO_2 at 8.5 V; H_2O_2 ambient thru filter A = 0.12; B = 0.08
1054 SO_2 on zero (left SO_2 flowing to span port)
1101 SO_2 at 0.8 V on zero air

H_2O_2 pre-flight calibrations:

Time [Decimal GMT]	Cals Bkgd	Sig	(std-zero) Δ	CF	BKthru
9.5	0.063	0.065			zero
9.7	0.338	0.343	0.270	6.300	std #1, no cat.
9.86	0.076	0.064			zero
9.93	0.035	0.337			std #1, no cat.
10.30	0.063	0.067			zero w/ catalase
10.37	0.107	0.330	0.263	6.468	16.7 std #1
10.46	0.066	0.069			zero
10.54	0.106	0.325	0.256	6.645	15.6 std #1
10.62	0.068	0.071			zero
10.67	0.103	0.322	0.251	6.773	13.9% std 1
10.74	0.285	1.039	0.968	X	std 2 off scale

CF 6.500; BKthru = 1.16
BKthru too high, add more catalase to solution!
File: 880726G.WR1 on CW#2 disk

SO_2 Cal: zero 0.7 V, 28 sccm SO_2 6.81 ppb 8.5 V, zero (after) 0.8 V.

Δ = 7.7 V for 6.81 ppb (0.884 ppb/volt)
NO_x 10 sccm NO-CAL 7.25 V, zero mode, zero air, NO 1.33 V, NO_x 1.56 V
Δ = 5.92 for 8.51 ppb (1.437 ppb/volt)

IN-FLIGHT:

[GMT]

113500 Engine start
114200 Taxi-out - delay in getting clearance
114700 SO_2 to span - FSSP on - R1; ASASP on
115100 DAS & LORAN on - DR2
115300 Bleed air warning lite on - checking out to see if its a "no-go" item
115800 ASASP pump on - cleared
115900 T/O
120300 Thru ≈3K' top of MBL maybe - small layer as we go up and out
120500 Flushing FP systems & flask
120700 Installing BBS sampler
120900 @ 8500' - going for SE/NW tracks
121300 90 mm FP #81 (TOT) on - flow 288 lpm; BBS on - flow 0.5" H_2O
121500 HS's #A-14 on - flow 4.2 lpm
1217 H_2O_2 to cal (red button)
1218 SO_2 to sample
1222 Over ship now - Herman spoke to us - wanted flyby time
1228 NO_x to zero - 1.16 V - changed as we turned, went down - now higher 1.18 V
123600 NO_x to span 6.018 V
124200 NO_x to zero 1.0 V - why the change
125000 NO_x to sample
130000 Flask #1319 - 32°00/63°44; +12°C; winds 266/24; 8500'; T_d = -14°C clear above clouds below - building CU's; SO_2 = 0.9 ppbv; O_3 = 84 ppbv; 90 mm flow (T) - 269 lpm; HS #A-14 - 4.1 lpm; BBS = 0.5"
133200 Descending to 5500'
133600 @ 5500'; 90 mm flow (T) - 292 lpm; HS #A-14 - flow 4.5 lpm; BBS = 0.6"; H_2O; SO_2 = 0.8 ppbv; O_3 = 29 ppbv
134000 End DAS tape #1 - TK/TM'd - begin DAS tape #2
134300 90 mm #81 off (T) - flow 290 lpm; HS #A-14 off - flow 4.6 lpm; descending to 2500'
134430 90 mm #82 BLANK (T)
134500 HS #A-14 off (for real) - forgot to switch it when I said I was
134830 @ 2500' - clear above - clouds around - building CU's - 30 mi vis
135400 Descending to 500'
135630 @ 500'; T = +25C; T_d = +20.3°C; heading W
135700 90 mm #83 (T) on - flow 242 lpm; #84 (S) on - flow 3.09 V HS's #A-15 on - flow 4.8 lpm; SO_2 = 0.6 ppbv; O_3 = 17 ppbv
1401 Mt. Mitchell's position 31°58N/63°42W; winds 140/8 - they say
140600 H_2O_2 to zero
141900 HS's #A-15 just blew (or maybe a few min ago - don't know) trying another - he's down 2 blanks as it is
142400 Spoke with Herman - some of his filters blowing also - he suggested cut down on high alt filters - try to get good samples in MBL - ask Dennis to cut down on flow if he can
142600 Started HS #A-16 - flow 5.1
142700 A/C not working very well - pilots shutting it off for a bit to defrost
143900 Flask - no label - 31°58/63°39; +25.3°C; winds 0/10; 500'; lite & variable winds; T_d = 20.8°C; clear above lite clouds around

144300 90 mm T #83 - flow 242 lpm; S #84 - flow 3.24 V; HS #A-16 - 5.4 lpm; BBS 0.7" H_2O; SO_2 0.6 ppbv; O_3 = 17 ppbv

144700 90 mm #83, #84 off

145000 90 mm #85 - BLANK T; 90 mm #86 BLANK S

145638 Descending to 100' for flyby; SO_2 = 0.6

145800 @ 100'; SO_2 = 0.7/0.6; BBS 0.75" H_2O; HS #A-16 5.7 lpm

150030 Flyby @ 100' - calm seas - blue skies - CU's around - great day out here; T = +26.6°C; T_d = 21.5°C

150100 Back up to 500'

150300 90 mm #87 (T) on - flow 239 lpm; 88 (S) on - flow 3.41 V

150800 Aircraft's LORAN out

151800 Deviate a little - rain - LORAN still out

152000 BBS flow 0.6" H_2O maybe 0.65; 90 mm #87 T - 240 lpm; #88 S - 3.35 V HS #A-16 - 5.5 lpm; SO_2 0.7 ppbv; O_3 = 15.6

152300 LORAN back on

153000 End DAS tape #2 - begin DAS tape #3

155300 90 mm #87 T off - 240 lpm; #88 S off - 3.4 V

155520 90 mm #89 - BLANK (T); #90 - BLANK (S)

1556 HS #A-16 off

155630 BBS off

160300 NO_x & SO_2 to zero

160800 Landed

160900 TK/TM'd alt F10 tapes - O_3 off - T_d off - probes - leaving chem on for post cals

POST-FLIGHT:

NOTE: LORAN out intermittently during the flight.
Also, lots of Hexane smell when I installed the BBS sampler.
The pilots complained a lot.

[GMT]

163300 SO_2 ambient (no air); NO_x on zero mode; H_2O_2 - 2 pt cal started

163500 new zero air to both SO_2 and NO_x - 1.35 V on zero air mode (NO_x)

163900 SO_2 - 1.1 V; NO_x - zero air 1.34; H_2O_2 (2 pt cal) zero A = 0.169, B = 0.181

164000 SO_2 - 1.1 V; NO_x - zero 1.30 - NO on; H_2O_2 - Std #1: A = 0.341, B = 0.209

164200 SO_2 - 1.1 V; NO_x - 6.06 and rising; H_2O_2 - Std #1: A = 0.352, B = 0.211

164400 SO_2 - 1.1 V; NO_x - 6.06; H_2O_2 - Std #2: A = 0.695 and rising,B = 0.260

164600 SO_2 - 6.3 V cal; NO_x - 5.92; H_2O_2 - Std #2: A = 0.716, B = 0.258

164800 SO_2 - 7.7 V with new procedure; NO_x - 5.80 and NO_x off

165100 SO_2 - 7.8 V; NO_x - 1.20 on zero air; H_2O_2 - ambient

165300 SO_2 - 7.7 V; NO_x mode on

165500 SO_2 - 7.9 V; NO_x - 1.21 (NO_x mode and zero air); H_2O_2 - 2 pt cal zero A = 0.172, B = 0.20

165800 SO_2 - 8.0 V; NO_x - NO - CAL on 5.27 V; H_2O_2 - Std. #1: A = 0.347, B = 0.214

170100 SO_2 - 7.9 V; NO_x - 5.70; H_2O_2 - Std. #2: A = 0.671, B = 0.264

170300 NO_x - now to NO_x mode - 5.66 V; H_2O_2 - A = 0.698, B = 0.266

170500 SO_2 - 1.1 V; NO_x - 5.74 V

170600 SO_2 - 0.9 V; NO_x - 5.73 V
170800 0.9 V; NO_x - 5.67 V; H_2O_2 - off!

27 July, 1988, Flight 1
Data Flight #6 - Bermuda
Pilot, Tom Gates; Co-Pilot, Roger Morris; Scientist, Laureen Gunter

PRE-FLIGHT:

NOTE: 1430Z rendezvous with Fleurtje at 32∘40'/64'20' - do 100 ft pass
Pre-flight calibration data are archived on diskette (30-second grab sample file).

Time [ADT]	
~ 4:45 am	NO_x & H_2O_2
5:00	SO_2 on - no zero available
5:46	H_2O_2 on - lamp - zero air on!
5:48	NO_x vacuum on

Time [GMT]	SO_2		NO_x	H_2O_2
8:51	zero air	0.6 V	zero air ozonizer on- response	no catalase - balance
8:52	SO_2 - CAL	7.7 V&up		
8:58	" "	7.4 V	zero air - NO 2.63 V	zero A = 0.69 B = 0.069
9:03	" "	7.5 V	2.24 V & down	start std #1
9:08	" "	7.7 V	1.85	
9:12	" "	7.8 V	1.60	std #1 A = 0.301 B = 0.294
9:15	" "	7.9 V	1.46	
9:17	" "	8.0 V	1.42	zero A = 0.070 B = 0.070
9:21	" "	8.0 V	1.29	std #1 A = 0.301 B = 0.302
9:24	" "	8.1 V	1.21	switch to catalase
9:30	O_3 TECO turned on			
9:30		8.3 V	1.12	
9:33			NO - CAL on - 5.67	
9:34		8.3 V	0.3 - 10 sccm 5.78 V switch to zero mode	zero w/cat A = 0.064 B = 0.063
9:37		8.4 V	5.57	adj. zero
9:39		8.3 V	switch to zero mode 5.50	
9:42	return to zero		0.99 V	

9:44	0.9 V	switch to NO_x mode 0.95	
9:46	0.7 V	5.50	std #1 A = 0.288 B = 0.064
9:48	0.7 V	NO-CAL off 5.40	
9:50	0.7 V		
9:52	SO_2 CAL - too high	zero air 0.81	start std #2 A = 0.482, B = 0.068
9:55	purge w/air - return to SO_2 - CAL	0.80	A = 0.480, B = 0.068
9:56	4.1 V	switch NO-CAL 0.81	start 2 pt cal
9:57	9.1 V	5.42	
10:00	8.9 V	5.27	ambient thru trap A = 0.92 B = 0.072
10:01	8.9 V	5.31	
10:04	8.7 V	5.26	
10:10	8.7 V	NO_x mode\5.28	
10:11	return to zero air		2 pt CAL hungup
10:13		5.25	
10:16	0.7 V	timer on; return to zero air	chrontrol re-programmed
10:17		zero mode & zero air, 0.74 V	
10:18	0.8 V	0.71	
10:21	0.8 V	0.79 DAS off	

T/O ~8 am local [ADT]
Replaced zero air dryer just before take-off

IN-FLIGHT:

[GMT]
104600 Engine start
105000 SO_2 to span
105400 DAS & LORAN on - DR2 - FSSP on range 1 - ASASP on
105530 ASASP pump on
105630 T/O
110600 Dry layer @ 8K - was relatively moist all the way up
110700 @ 8500'; BBS on - flow 0.5
110730 90 mm #91 (T) - BLANK; SO_2 = 1 ppbv
111200 SO_2 to sample - zero air off - cyl off
111300 90 mm #93 (T) on - flow 279 lpm; HS #A-17 on - flow 3.9 lpm
112130 H_2O_2 to cal (red button) - was in reset mode - had to hit run then cal
112400 NO_x to zero
112600 31°55'/63°37' - Mt. Mitchell position; winds 140/6; 1027 mb
112900 NO_x zero stable @ 546 mV - NO_x to span - not responding at all - check cyl to make sure its open - it was

113345 Finally it responded and signal is going up - pretty weird
113700 NO_x span stable @ 5.15 V
113730 Going to zero (NO_x)
114300 Zero won't settle down - it goes down and is stable for about 1 min then increases
114600 NO_x to sample
120000 Flask #1264 - 31∘58/63∘39; +12∘C; winds 352/11; T_d = -5.5∘C; clear above, haze and small CU's below; 8500'; SO_2 = 0.9 ppbv; O_3 = 57 ppbv
120200 Mt. Mitchell switching over to talk to Fluertje - we'll monitor also
123000 Descending to 5500'
123300 @ 5500'; 90 mm #93 (T) - flow 293 lpm; HS #A-17 - flow 4.2 lpm; BBS 0.6" H_2O; SO_2 est 0.5 ppbv
124100 End DAS tape #1 - begin DAS tape #2
124300 90 mm #93 off; HS #A-17 off; descending to 2500' - can't - clouds
124700 @ 1800' (pressure altitude based on BDA altimeter) - just below cloud bases - 2200' radar alt.; BBS = 0.75" H_2O
125200 Descending to 500'
125400 @ 500'
125500 90 mm #92 (T) on - flow 241 lpm; #94 (S) on - flow 2.86 V; HS #A-18 on - flow 5.4 lpm; BBS 0.76" H_2O; SO_2 est 0.6 -0.7 ppbv; O_3 = 19 ppbv
134000 Flask #1228 - 31∘53/63∘39; +25.6∘C; winds 003/4 - light & variable T_d = +21.1∘C; clear above and below; 500'
134500 90 mm #92 T off - 233 lpm; #94 S off - 3.19 V; HS #A-18 still on 5.4 lpm
134830 90 mm #95 T - BLANK; #96 S - BLANK
134900 Descending to 100'; BBS 0.75
135000 @ 100'
135200 Flyby
135300 Up to 500'
135400 @ 500'
135600 90 mm #97 T on - flow 241 lpm; #98 S on - flow 3.17 V
135700 Heading to Fluertje
141000 No radio contact with tall ship
141800 Fluertje in sight - still no radio contact on freq given
142100 Descending to 100'
142200 @ 100'
142500 Flyby - O_3 20.6 ppbv; SO_2 est. 0.6-0.7 - no radio contact
142600 Up to 500' then swing by them again at 100' then up
143200 Flyby #2 - still no radio contact
143300 End DAS tape #2 - begin DAS tape #3
144600 90 mm #97 T off - 244 lpm; #98 S off - 3.27 V; HS #A-18 off - 5.7 lpm
144930 90 mm #99 T - BLANK; #100 S - BLANK; 500' - HS #A-19 - BLANK
145200 BBS off
1453 Up & RTB
145800 SO_2 & NO_x to zero air
150130 Landed
150200 All off - complete power down

POST-FLIGHT:

No post-flight calibrations were done after this flight.

27 July, 1988, Flight 2
Data Flight #7 - Bermuda
Pilot, Roger Morris; Co-Pilot, Tom Gates; Scientist, Laureen Gunter

PRE-FLIGHT:

Calibration information are recorded and archived on 30-second grab sample files.

new silica gel drying trap
15:40 power restored to instruments

Time [GMT]	SO_2	NO_x	H_2O_2
15:50	0.8 V zero air	4.23 V dark current on 0.50 range	both std #1 & #2 are 1.7 ppb
15:55	0.8 V zero air		
15:56	bleed 3 sccm SO_2 thru SPAN	5.3 V on 0.20 range	zero A = 0.051 B = 0.055
15:58	SO_2 - CAL, 28 sccm 6.0 V	3.9 V on 0.20 range	A = 0.054, B = 0.0508
16:00	8.1 V on SO_2 - CAL	3.5 V on 0.20	
16:03	7.9 V	2.63	
16:07	7.9 V	7.1 V on 0.05	std #1 A = 0.295 B = 0.054
16:10	8.0 V	6.2 V on 0.05	A = 0.296, B = 0.052
16:14	8.4 V	5.0 V on 0.05	zero A = 0.057, B = 0.052
16:17	8.4 V	ozonizer ON	std #1 A = 0.298, B = 0.058
16:19	8.3 V	5.3 on 0.05 range	A = 0.295, B = 0.056
16:20		zero mode	
16:22	8.4 V	4.79 V - still too high - more cooling!	
16:24	8.4 V	4.52 V	
16:26	8.4 V - switch to zero	4.25 - NO - CAL now ON	
Note: lot of aircraft traffic			
16:28	4.7 V		std #2 A = 0.257 B = 0.057
16:29	2.0 V	3.77 V	A = 0.257 B = 0.057

16:31	2.3 V	3.79 V still on zero mode	ambient A = 0.335 B = 0.136
16:32	1.4 V	NO mode	
16:33	1.2 V	8.28 V NO - CAL	
16:34	1.1 V	8.15	
16:36	1.1 V	8.02	
16:37	1.0 V	8.00	zero A = 0.059 B = 0.055
16:38	1.0 V	7.87 V NO - CAL	A = 0.058 B = 0.055
16:42	1.5 V go to SO_2 CAL	3.01 zero air only	
16:47	8.7 V	2.73 V	
16:48	8.8 V	2.67	

T/O ~ 2:00 pm local [ADT]

IN-FLIGHT:

[GMT]

165900 Engine start - SO_2 is on span already

170000 DAS & LORAN on - DR2 - FSSP on R1 - ASASP on

170630 Cleared for T/O - ASASP pump on

170730 T/O

171000 Cloud base ≈2K

171200 Tops ≈3.5K - cirrus above

171300 Installing BBS pump - not on yet - 4500′

171400 Flushing FP systems - ≈5500′

171500 Dirty layer at ≈7000′ - more clouds S now

171700 @ 8500′

171800 90 mm #101 (T) on - flow 295 lpm; HS #A-20 on - flow 4.3 lpm

171900 BBS on flow 0.5" H_2O - no hexane smell at all

172200 SO_2 to sample - NO_x to sample - zero air pump off - SO_2 off

172700 H_2O_2 to cal (red button)

173500 NO_x to zero - sample tube in

174300 Going between 1.62 V to 1.74 V sometimes 1.5

174500 NO_x to span

175000 NO_x is dropping?? going to zero levels almost - NO is on!! highest level was about 6 V - what is going on??

175200 NO_x is climbing back up on its own??!! up to 5.8 ± 0.2 V

175400 NO_x to zero - 1.32 ± 0.02 V

175800 NO_x to sample - zero air pump off - sample tube in

175900 Heading 055 lots of clouds and layering all around - clear above - high cirrus - 32∘06/63∘34; T = +12.2; T_d = -7.9; winds 185/15; SO_2 = 0.4; O_3 = 55

181000 Lost LORAN

181700 Should be about over ship - still no LORAN - but need to take flask

181800 Flask #1187 - est 31∘55/63∘39; T = +11.5∘C; winds 180/10 - light and variable; T_d = 7.0; 8500′; 140 radial at 57 DME for BDA VOR; 12 mi from ship 020 heading

182600 Mt. Mitchell getting rain right now

182700 LORAN back on

182900 Clouds around us ≈12K tops
183000 Descending to 5500′
183330 @ 5500′ - T = +15.2; T_d = +12.4; BBS = 0.6" H_2O;
90 mm #101 T - 288 lpm; HS #A-20 = 4.7 lpm
184300 End DAS tape #1 - TK/TM'd - begin DAS tape #2
184800 90 mm #101 off; HS #A-20 off
185000 90 mm #102T - BLANK; 8500′
185100 Descending to 2500 or < cloud base
185600 @ 1800′ - just below cloud base - 31°51/63°36 Mt. Mitchell position
winds 160/7; 1027.5 mb
190100 Descending to 500′
190330 @ 500′
190400 90 mm #103 T - BLANK; #104 S - BLANK
190800 90 mm #105 T on - flow 241 lpm; #106 S on - flow 3.03 V; HS #A-21 on -
flow 4.1 lpm; SO_2 jumping around 0.2-0.3; cloudy and hazy;
BBS 0.75" H_2O
191800 Rain showers in vicinity - SO_2 and O_3 levels have really dropped if
offset is correct; SO_2 = 0.1 ppbv; O_3 = 14 ppbv; H_2O_2 = 0.5 ppbv;
leaving T & S FP's on however
192400 H_2O_2 to zero
193000 Going around rain area trying to get closer to ship
193100 Winds 060/14 - choppy ride - lite & irritating; T = 24.5°C; T_d = 20.4
193530 31°49/63°34 - new position of Mt. Mitchell - winds 120/3
193800 Light rain
195800 90 mm #105 T off - 239 lpm; # 106 S off - 3.1 V; HS #A-21 still on -
4.2 lpm
2000 Descending to 100′
2002 @ 100′; BBS 0.75; O_3 = 13.4; SO_2 0.1-0.2 - if offset correct not sure
200500 Flyby @ 100′
200600 Up to 500′
200700 @ 500′
200800 90 mm #107 T on - flow 250 lpm; #108 S on - flow 3.5 V - decided to
run T & S because of uncertainty in SO_2 offset
202300 Flask #1100 - 31°48/63°36; +25°C; winds 085/14; broken clouds above
T_d = +21.4°C; haze below; 500′
203000 End DAS tape #2 - TK/TM - begin DAS tape #3
2032 Rain all around - deviating out of it
2058 90 mm #107 T off - flow 237 lpm; #108 S off - flow 3.37 V; HS #A-21
off - flow 4.4 lpm
2059 SO_2 & NO_x to zero - NO_x sample tube in
210330 90 mm #109 T - BLANK; #110 S - BLANK; HS #A-22 - BLANK
210400 BBS off
211730 Landed
211800 All off - complete

<u>POST-FLIGHT:</u>

No post-flight calibrations were performed after this flight.

28 July, 1988
Data Flight #8 - Bermuda
Pilot, Tom Gates; Co-Pilot, Roger Morris; Scientist, Laureen Gunter

PRE-FLIGHT:

Pre-flight data are archived on diskette (30-second grab sample files).

Time [GMT]	SO_2	NO_x	H_2O_2
8:55	small SO_2 bleed thru SPAN, zero air to SO_2 & NO_x, 0.6 V	4.45 V cooling	lamp & pump on!
9:03	0.6 V	3.36 V vacuum pump on	to zero mode
9:13	0.6 V	O_3 on - 2.3 V	zero no catalase A = 0.061 B = 0.061
9:19	0.6 V	2.39 V on zero air switch to zero mode	
9:24	SO_2 - CAL		
9:27	7.9 V	1.87 V - switch to zero air done	std #1 A = 0.274 B = 0.27
9:31	7.4 V	1.63 V	catalase now in B
9:33	7.4 V	1.55/NO_x mode on-zero air	
9:37	7.5 V	1.51 V - NO_x mode	
9:40	7.5 V	1.52/NO mode on	zero A = 0.065 B = 0.065
9:42	7.7 V	1.31 V/NO - CAL	zero A = 0.065 B = 0.067
9:44	7.7 V	5.56 - NO - CAL	
9:52	7.8 V	5.53 V/NO_x on w/ NO - CAL	std #1 A = 0.263 B = 0.066
9:54	7.7 V	5.49 V - NO_x CAL	
9:56	7.8 V	5.44 V/NO CAL mode on	zero A = 0.063 B = 0.065
9:58	7.9 V	5.40	
10:01	7.9 V	5.32 V & NO - CAL off zero air only	std #1 A = 0.259 B = 0.070
10:03	8.0 V	0.71 V/ on zero air	
10:05	7.9 V	0.64 V on zero air	zero/start a std #2 CAL A = 0.063 B = 0.069
10:07	8.0 V	0.59 V/NO_x mode on	
10:09	7.9 V	0.69	
10:11	8.1 V	0.69	
10:14	8.0 V	0.58/switch to zero mode on NO	A = 0.463 B = 0.073

10:18	7.9 V	0.45 V on zero mode/ NO	
10:19	8.0 V	0.42	zero 0.079, 0.076
10:20	8.0 V	0.41	
10:21	zero/w/ bleed of SO_2 to SPAN	0.42/zero mode off	
10:22	1.1 V & dropping	0.38 zero air on NO mode	
10:24	0.7 V	0.37	
10:27	0.7 V	0.36/NO - CAL at 10 sccm	std #1 A = 0.263 B = 0.075
10:29	0.7 V	4.67	
10:30		4.88 V	std #2 A = 0.414 B = 0.081
10:32	0.7 V	4.74	A = 0.452 B = 0.081

Zero air system off - change dryer & NO_x trap

10:42	back on air - 0.8 V	4.75	
10:43	Ozone TECO turned on		
10:45	zero 0.7/switch to SO_2 CAL	4.72/ & CAL off	H_2O_2 ready!
10:48	8.9 V	timer started	
10:49	8.6 V	zero mode NO_x 0.24 V	
10:56	8.4 V	zero air/NO 0.22 V	
10:58	8.4 V	0.23	
11:00	8.3 V	0.19	

Stop DAS
Take off - ~8:30 am local [ADT] - problem with pressure transducer - SO_2 on SPAN for takeoff.

<u>IN-FLIGHT:</u>

[GMT]

111000	Engine start - trouble with pressure transducer - water
112300	Taxi-out now - still not working - maybe it will straighten out
112500	DAS & LORAN tapes on - DR2
112700	ASASP pump on
112800	T/O
113000	Pressure changing on T/O - was a constant 1076 mb
1132	3K' - 930 mb
1135	BBS on - 6500' - flow 0.6
113700	90 mm #111 T on - flow 283 lpm; @ 8500'; SO_2 = 0.4 ppbv; O_3 = 33.1
113800	SO_2 to sample - zero off - SO_2 cyl off; NO_x to sample also - tube out
114000	HS #A-23 on - flow 4.0 lpm
114200	Flow on BBS @ 8500' - 0.55 - 0.6
114300	Pressure transducer seems ok now - we're @ 8500'; Pmb = 750; numerous clouds/haze all around

114600 Clearing as we head south - the ship says they're in good weather - Mt. Mitchell position 31∘47/63∘39 - winds 130/10 - 1028 mb
115600 H_2O_2 to cal (red button)
120000 NO_x to zero - sample tube in
120600 NO_x zero = 0.13-0.14 V
120900 NO_x going to span - delayed cause of msg

MSG FROM SHIP:
msg from Alex for BBS: Doug Whelpdale: Brian Martin fell and injured his ankle - may have to stay in Bermuda - maybe can't do leg 2 - Steve Melnichuk may have to replace him - ship leaving again Sunday morning
END OF SHIP MESSAGE

121330 NO_x span @ 4.6-4.7 V
121500 Going to zero (NO_x)
122230 NO_x zero @ 0.104 V - 0.11 V
122300 NO_x going to sample - tube out
124100 BBS 0.6" H_2O; 90 mm #111 T - 278 lpm; HS #A-23 - 3.8 lpm; SO_2 = 0.5 ppbv; O_3 = 29.8 ppbv
124400 Flask #1236 - 31∘48/63∘38; winds 284/7; T = +10.4∘C; T_d = +1.7∘C; clear above - haze & clouds below; @8500'
125500 Descending to 5500'
125700 @ 5500'
125800 Msg from Herm

MSG FROM SHIP:
msg to J.Ray, D.Wellman - SO_2 was going to be intercompared; however, it is <det limits. Herman believes that we don't need another comparison - he doesn't have time (he and Glenn) to come along - he'll let the instrument go @ 1000-1100. Tom Carcy's NO_x has only been working the last day or two (NO only). Whelpdale's NO_2 maybe cal? - has been working somewhat
END OF SHIP MESSAGE

130700 90 mm #111 T off - flow 289 lpm; HS #A-23 off - flow 4.2 lpm
130830 90 mm #112 T - BLANK
130900 Descending to 2500' or <cloud base
131400 @ 1500' radar alt - just below cloud base; BBS = 0.75"
131800 End DAS tape #1 - begin DAS tape #2
131900 Descending to 500'
132100 90 mm #113 T on 241 lpm; #114 S on - 3.15 V; SO_2 = 0.3 ppbv; O_3 = 3.3
132100 Also @ 500'
132300 HS #A-24 on - flow 4.9
133000 H_2O_2 to zero
133030 BBS = 0.75" H_2O
135200 Flask #767 - 31∘46/63∘37; +26∘C; winds 127/28 1st reading; T_d = +21.5∘C; winds now 112/12 - winds shifted; 500' - we may have polluted the ship - clear above and below - clouds off in the distance
141100 90 mm #113 T off - 236 lpm; #114 S off - 3.31 V; HS #A-24 still on
141330 90 mm #115 T - BLANK; #116 S - BLANK
141430 Descending to 100'

141530 @ 100'; BBS 0.76-0.77" H_2O; SO_2 = 0.3 ppbv; 1" FP - 5.1 lpm; O_3 = 12.6
141800 Flyby - winds 209/9 - may not be correct - can't be
141830 Up to 500'
142100 90 mm #117 T on - 261 lpm; #118 S on - 3.54 V; SO_2 = 0.3 ppbv
150000 End DAS tape #2 - TK/TM'd - begin DAS tape #3
150800 SO_2 & NO_x to zero - NO_x tube in
151100 90 mm #117 T off - 239 lpm; #118 S off - 3.47 V; HS #A-24 off - 5.2 lpm
151400 90 mm #119 T - BLANK; #120 S - BLANK
151500 BBS off - 0.75" H_2O
151700 RTB
152500 Landed
152600 Power on landing - not shutting all down - only tapes, T_d, probes

POST-FLIGHT:

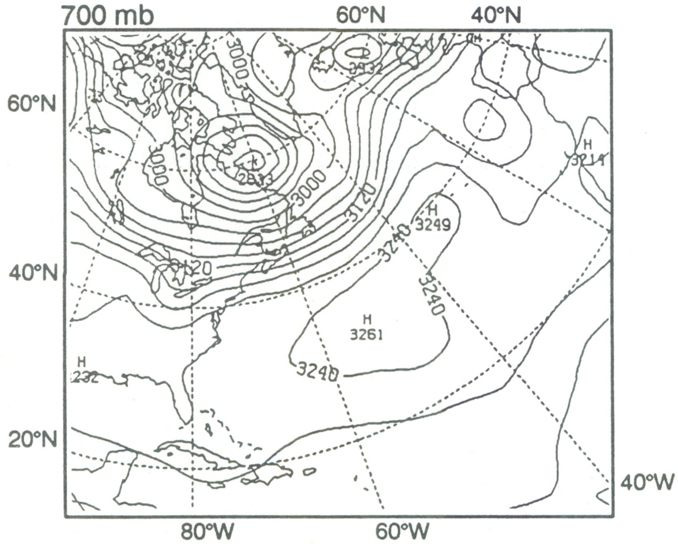
SO_2 cylinder: 1700 psi; NO cylinder: 1700 psi
SO_2 (ppb) #2; NO_x status #9; NO_x range slow G

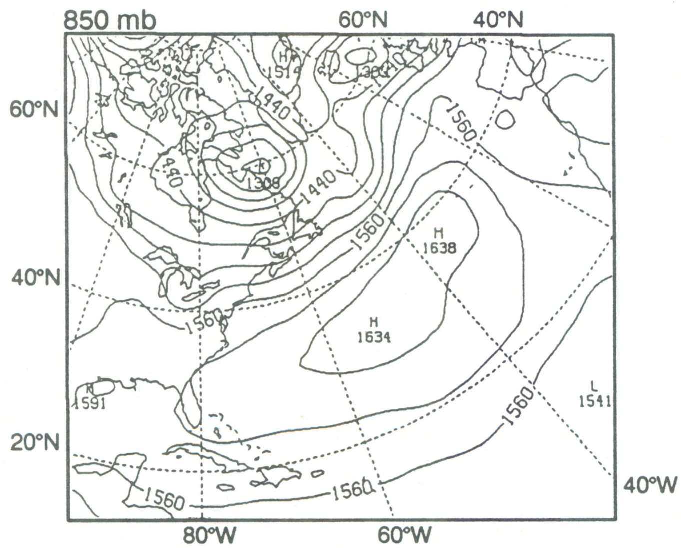
Time [GMT]	SO_2	NO_x	H_2O_2
15:34	zero - 1.0 V 28 sccm	zero air 1.13 V	ambient A = 0.137 B = 0.101
15:42	SPAN - 10.0 V	zero air 1.07 NO - CAL, 10 sccm	#1 new solutions 1.7 ppb, #2 3.4 ppb
15:45	8.8 V	NO - CAL 5.17 V	flows A = 209 B = 203
15:47	8.7 V	5.00	A = 0.094 B = 0.024
15:50	(O_3 = 9.9) 8.6 V	4.90 V	A = 0.089 B = 0.023
15:51	8.6 V	4.79 V	A = 0.089 B = 0.023
15:53	8.6 V	4.84 V	
15:54	8.5 V	NO_x mode & NO - CAL 5.28 V	
15:56	(O_3 = 7.7) 8.4 V	4.88	
15:58	(O_3 = 11.2) 8.5 V	4.89	
16:00	(O_3 = 10.2) 8.4 V	4.83 zero mode & zero air - 2.87 spike	std #1 A = 0.278 B = 0.023
16:02	(O_3 = 11.2) 8.5 V	0.924	A = 0.286 B = 0.023
16:04	8.5 V	0.91	std #2 A = 0.089 B = 0.023
16:05	8.5 V, Δ = 7.4	0.898	A = 0.474 B = 0.023
16:07	SO_2 CAL at 14.0 sccm 7.7 V	zero air only, 1.11 spike & down	A = 0.463 B = 0.025
16:09	5.2 V, Δ = 14.0	0.88	

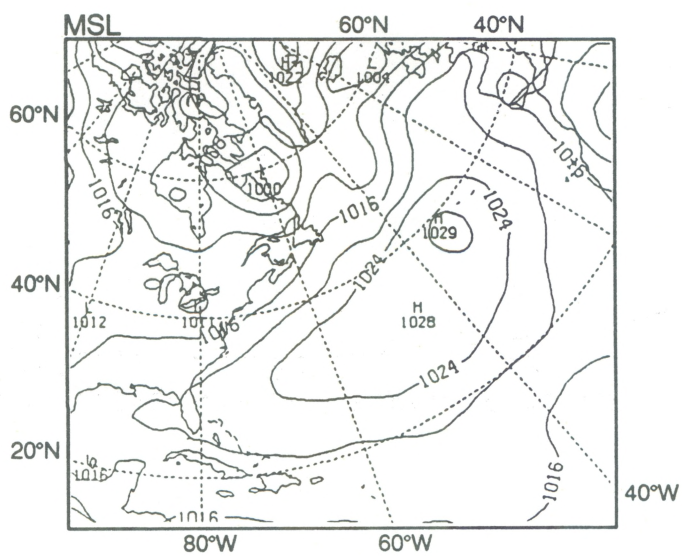
16:11	5.2 V	0.86	
16:12	5.0 V	0.85	zero A = 0.095 B = 0.023
16:14	(O_3 = 11.0) 4.9 V	NO - CAL at 17.0 sccm, 6.34 and up	A = 0.091 B = 0.023
16:16	5.0 V	7.04 V	
16:18	5.1 V	7.08 V	std #1 A = 0.286 B = 0.024
16:20	5.0 V	7.05	A = 0.288 B = 0.025
	to zero air now		
16:21	2.4 V	7.10	std #2 A = 0.470 B = 0.023
16:22	1.1 V	7.09/NO off/ zero air only	
16:24	1.0 V		
16:27	1.0 V	0.76 V	H_2O_2 off - unload solution
16:31	1.0 V	0.71	rinse with DI
		zero mode & zero air	water
16:34	1.0 V	0.65	zero trap on O_3
16:36	1.0 V	0.65	2.4 V O_3
16:39	1.0 V	0.65	2.4 O_3
16:44	1.0 V	0.59	2.4170800 SO_2

APPENDIX B: Synoptic Conditions for Each Flight: MSL pressure charts and 850-mb and 700-mb height analysis charts, and airmass trajectories

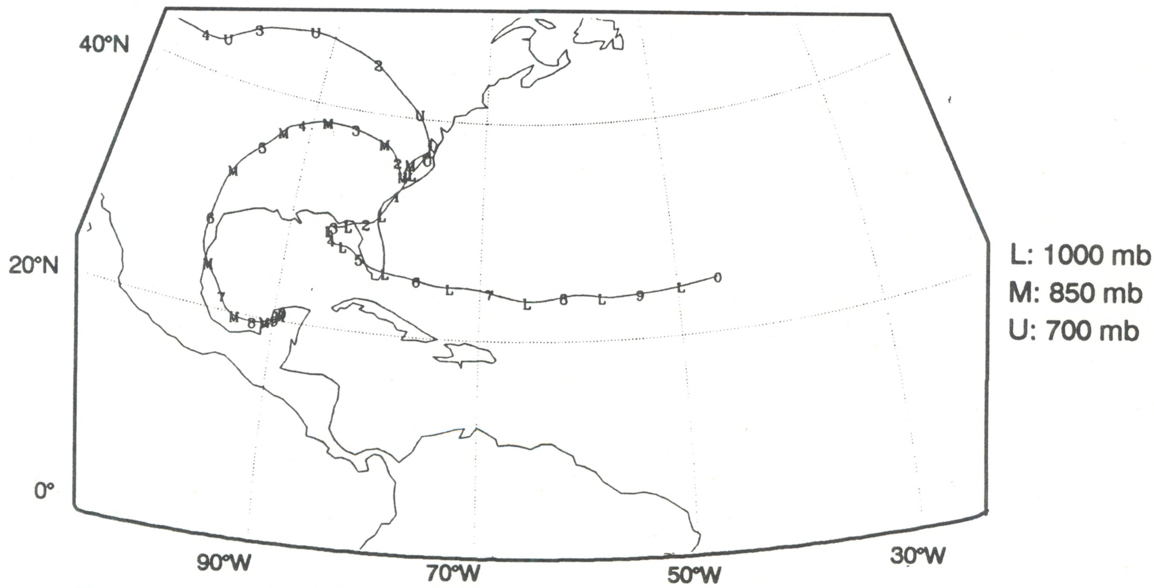
Flight #1
Newport News, VA
880717
All charts valid: 1200Z



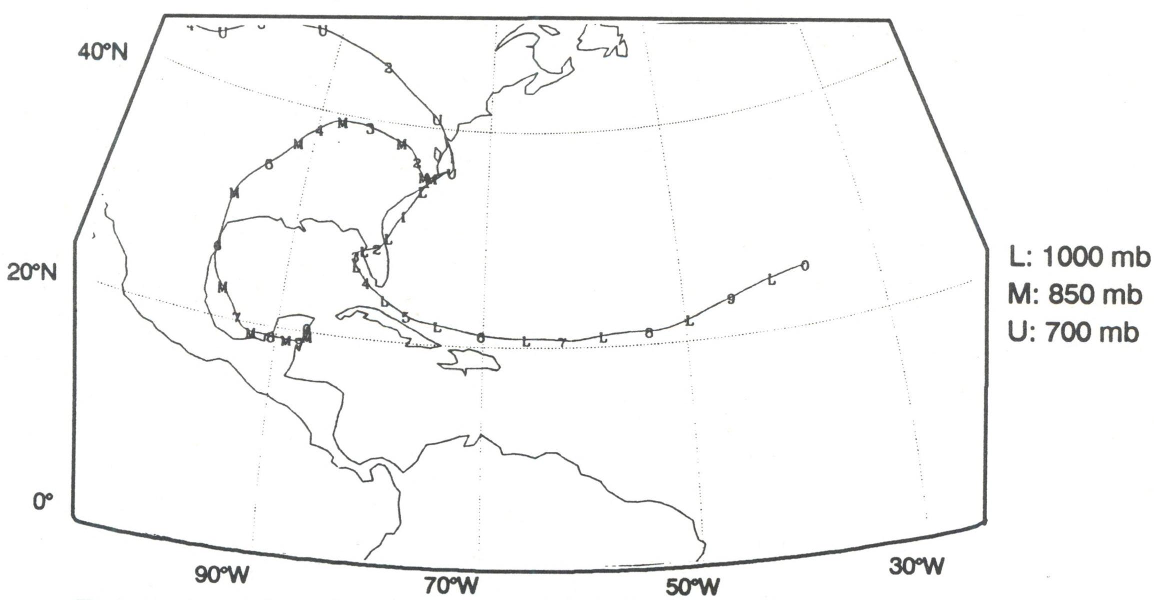




Flight #1, Newport News, VA 880717

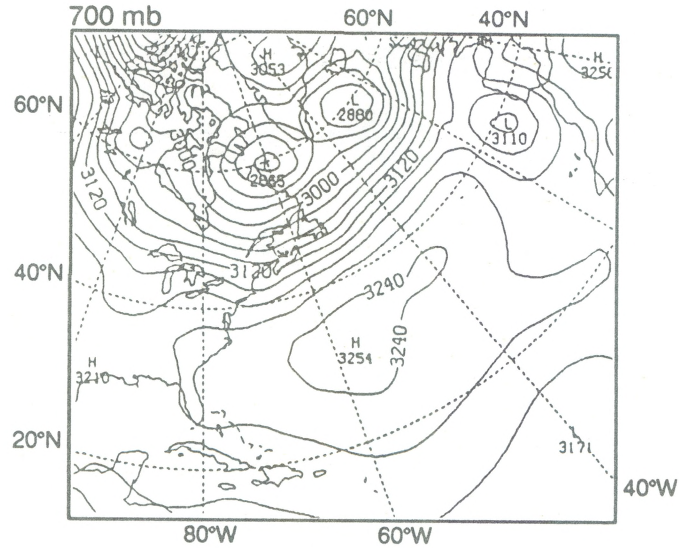


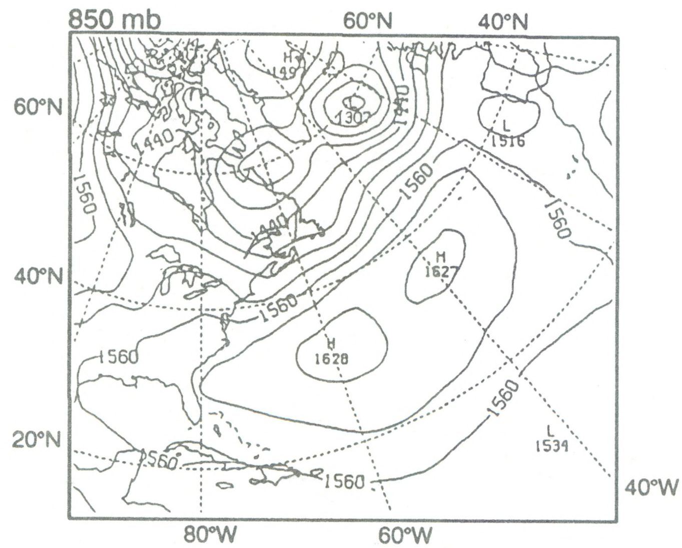
Trajectories to PHF (37.08°N,76.30°W) valid 1200Z

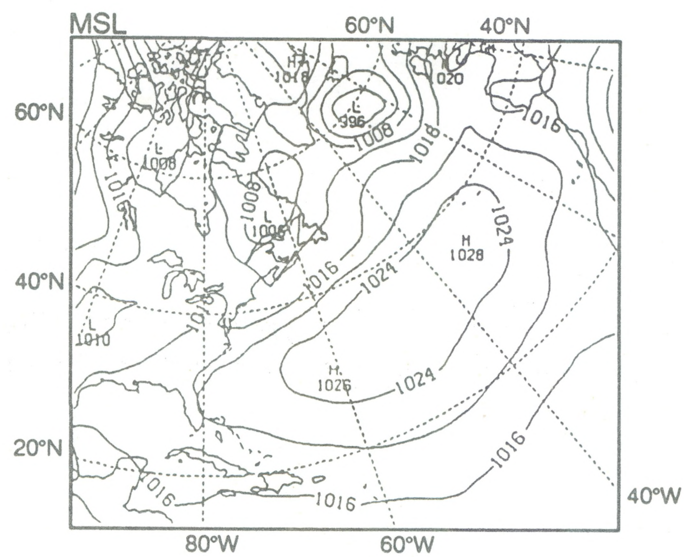


Trajectories to Mt Mitchell (east coast) (35.50°N,74.40°W) valid 1200Z

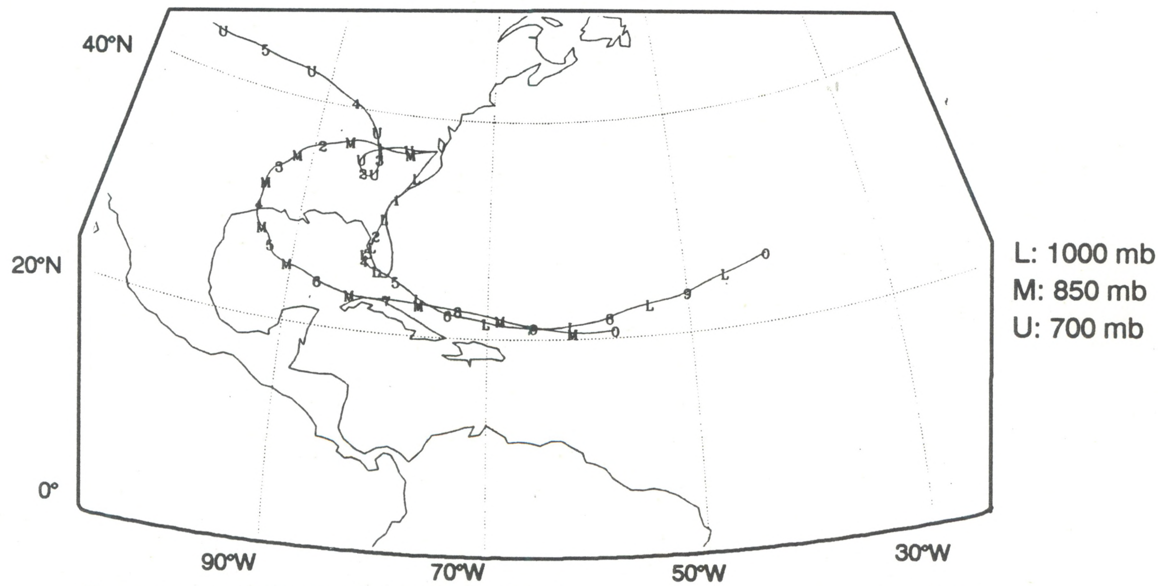
Flight #2
Newport News, VA
880718
All charts valid: 1200Z



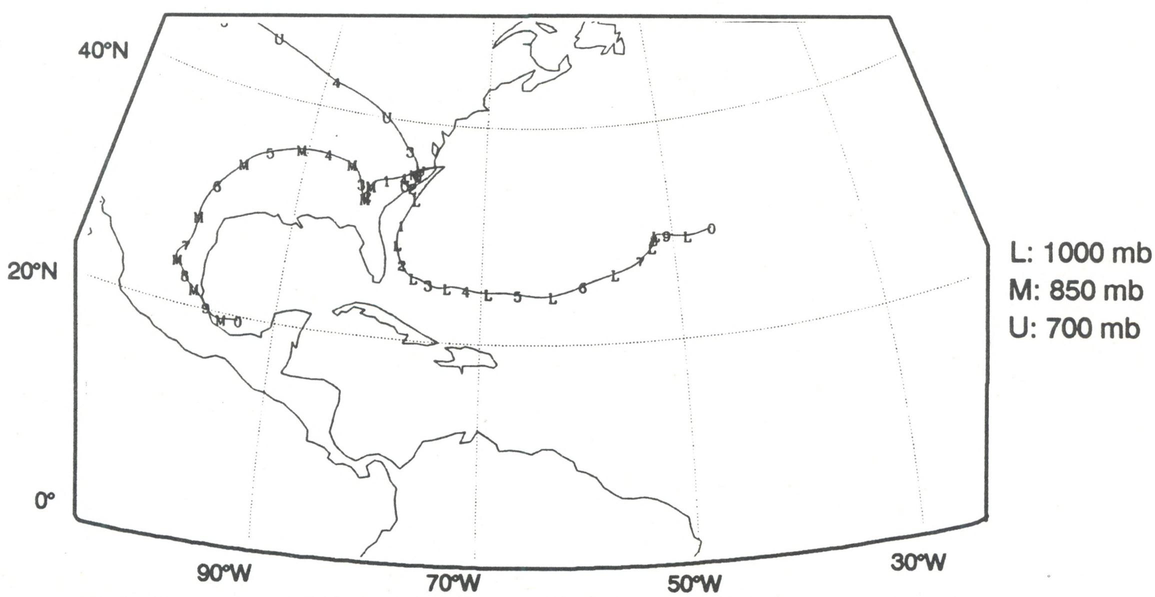




Flight #2, Newport News, VA 880718

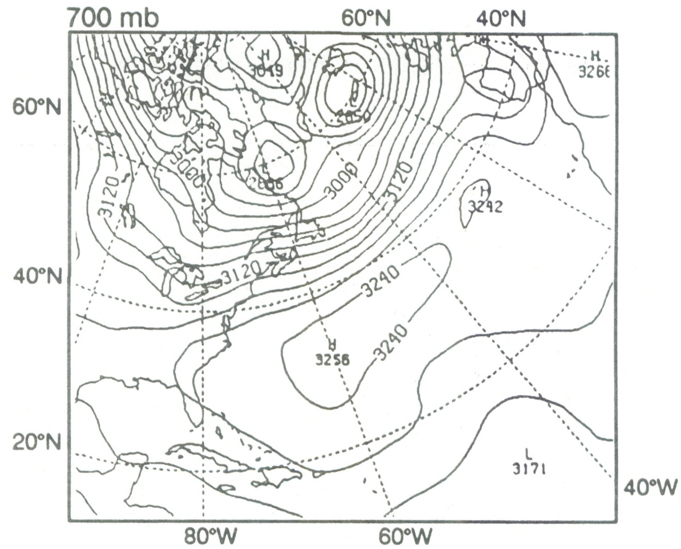


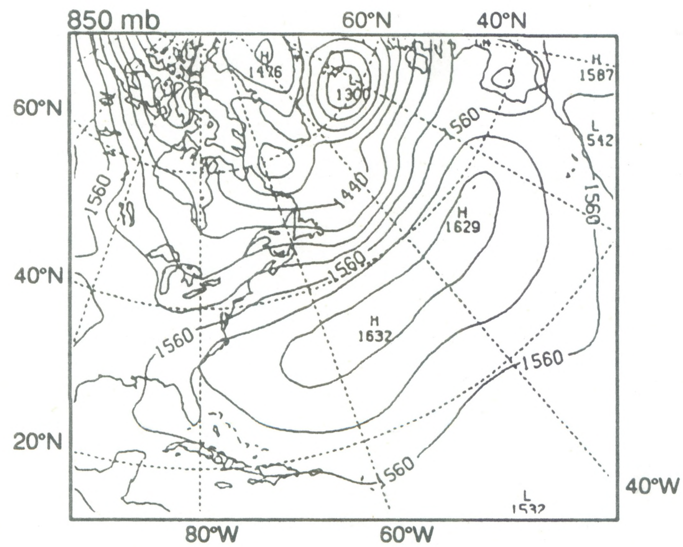
Trajectories to PHF (37.08°N,76.30°W) valid 1200Z

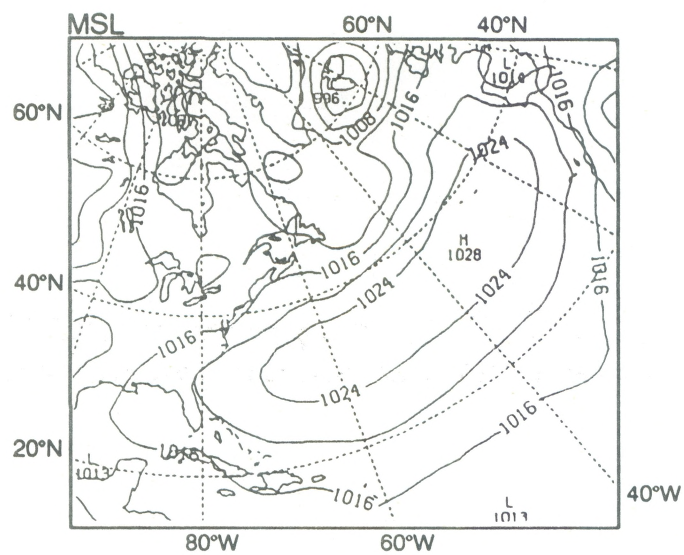


Trajectories to Mt Mitchell (east coast) (35.50°N,74.40°W) valid 1200Z

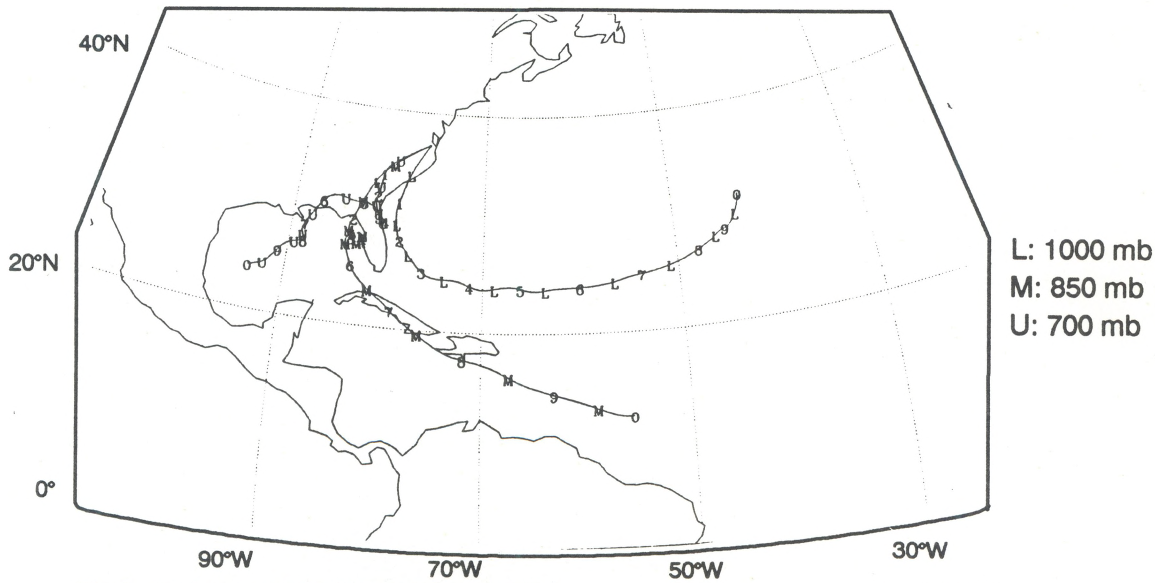
Flight #3
Newport News, VA
880719
All charts valid: 1200Z



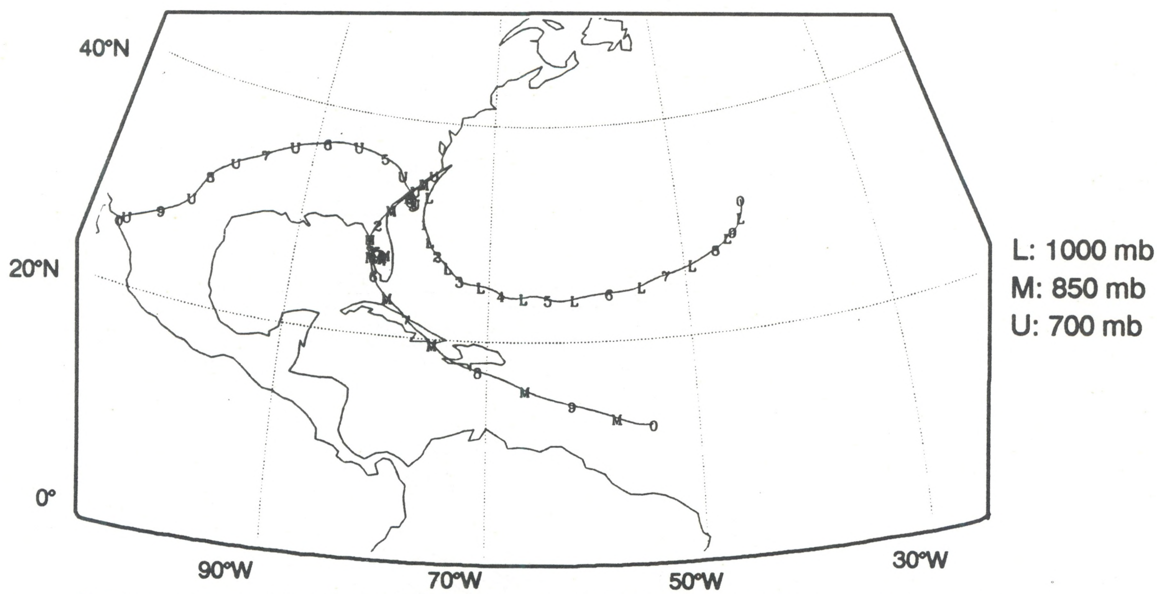




Flight #3, Newport News, VA 880719

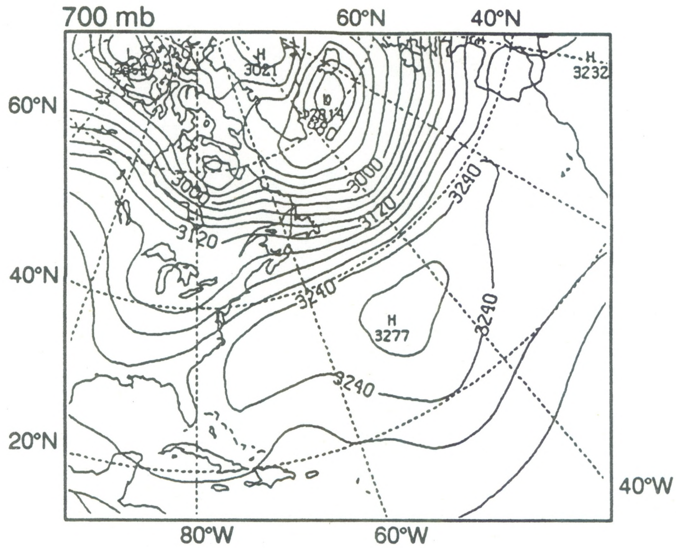


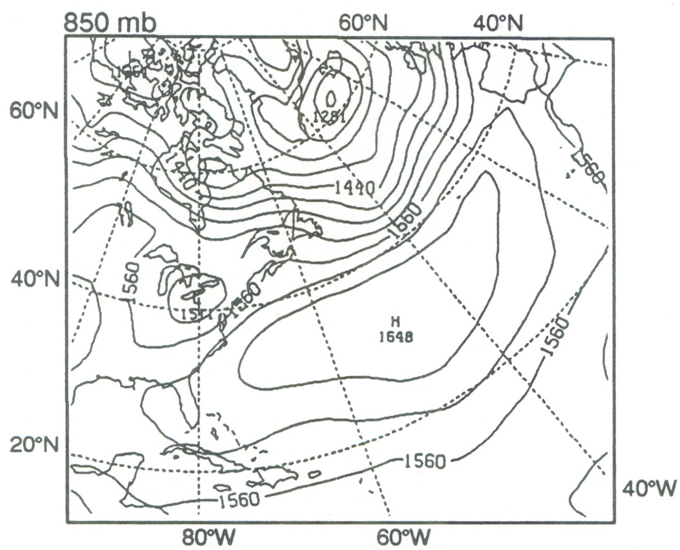
Trajectories to PHF (37.08°N,76.30°W) valid 1200Z

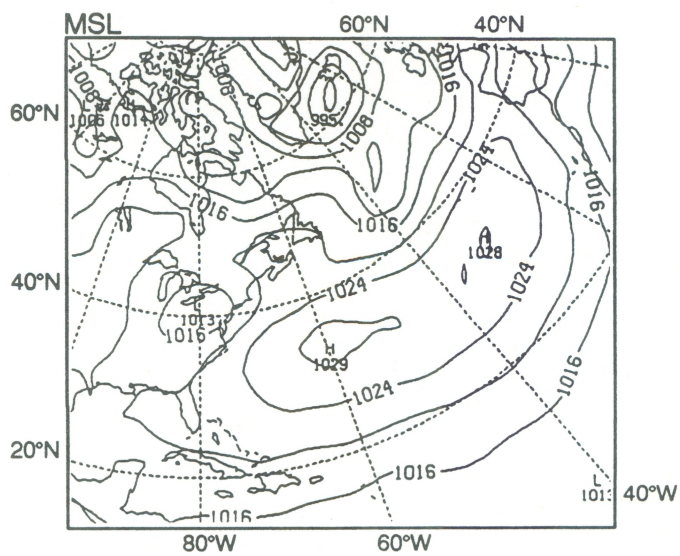


Trajectories to Mt Mitchell (east coast) (35.50°N,74.40°W) valid 1200Z

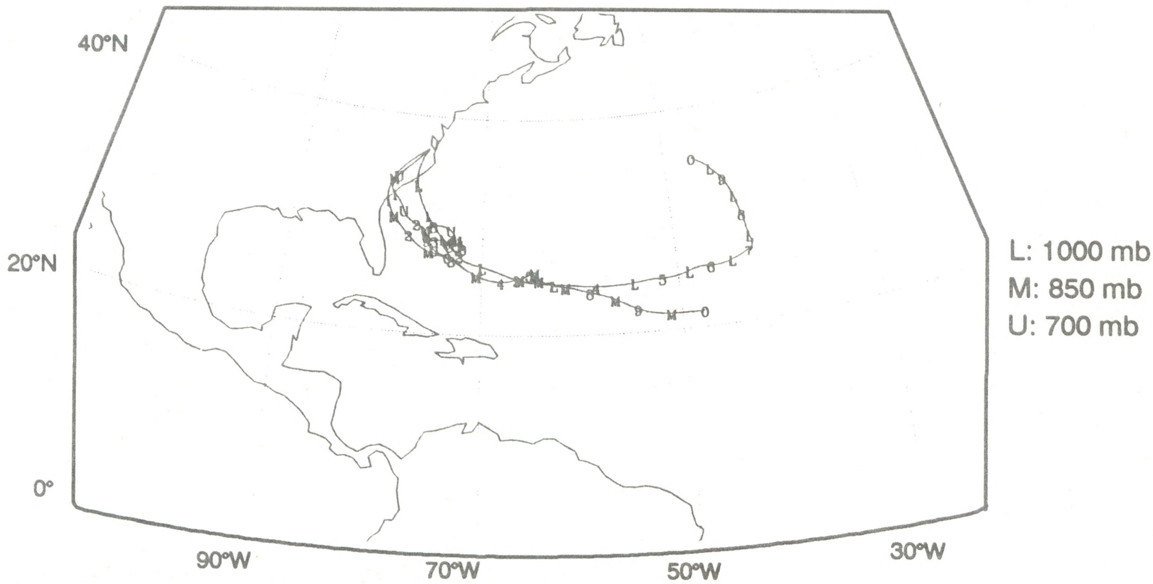
Flight #4
Newport News, VA
880721
All charts valid: 1200Z



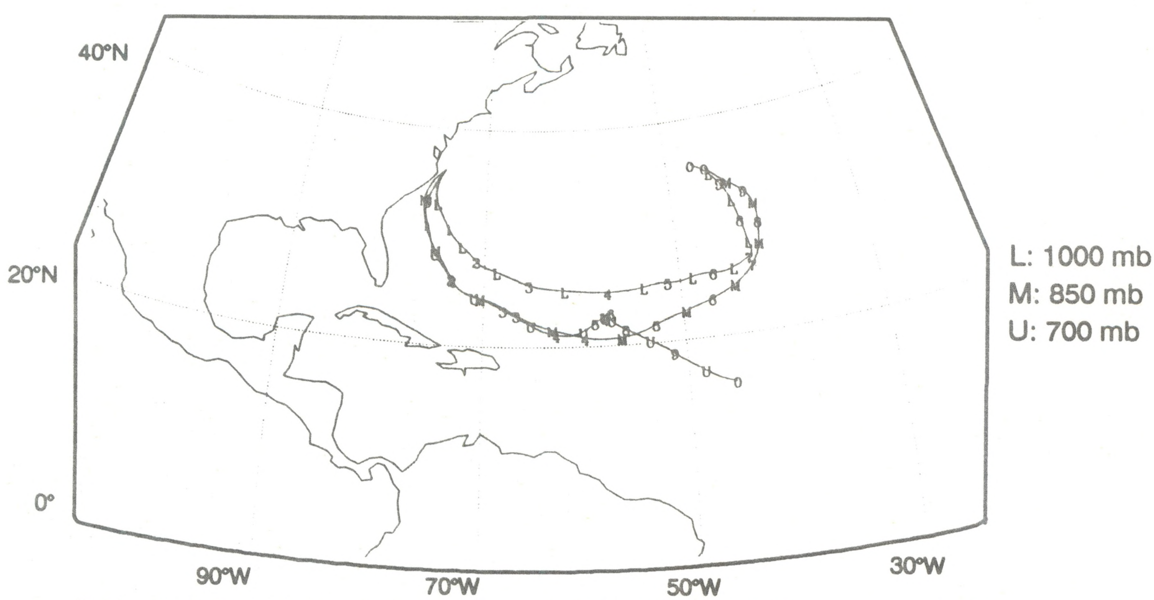




Flight #4, Newport News, VA 880721

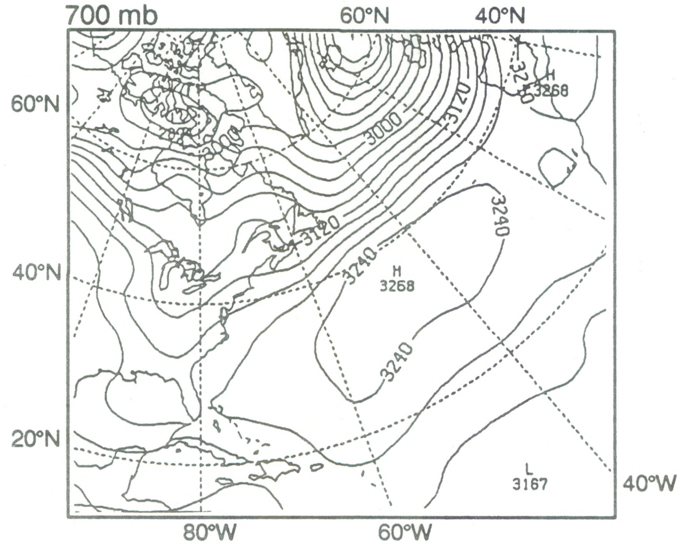


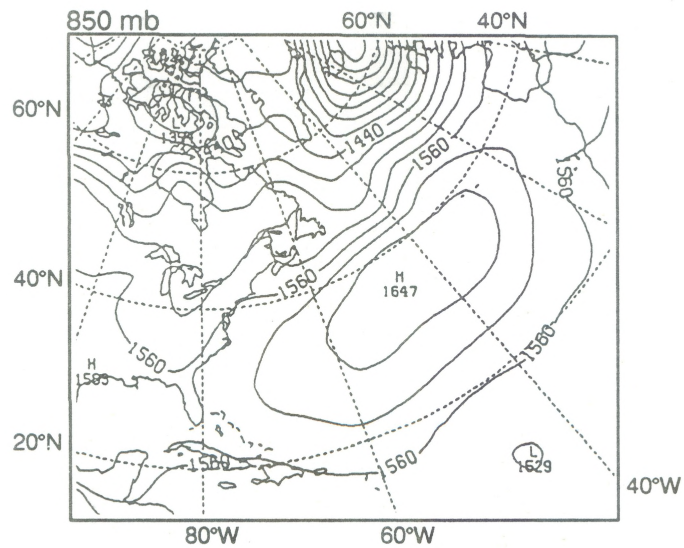
Trajectories to PHF (37.08°N,76.30°W) valid 1200Z

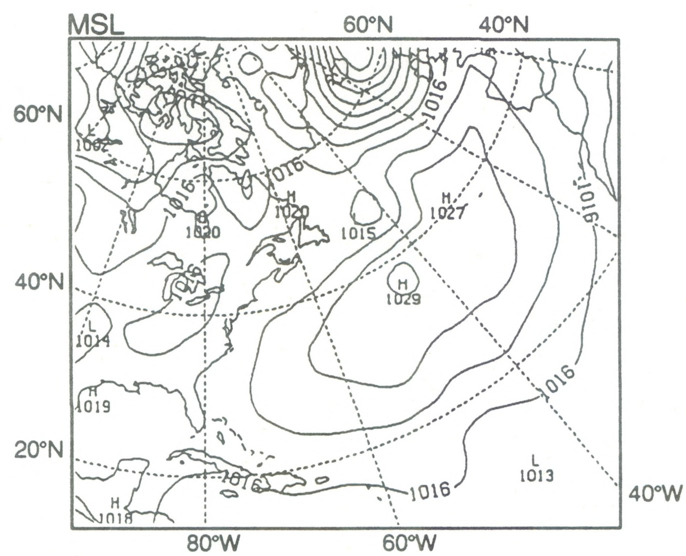


Trajectories to Mt Mitchell (east coast) (35.50°N,74.40°W) valid 1200Z

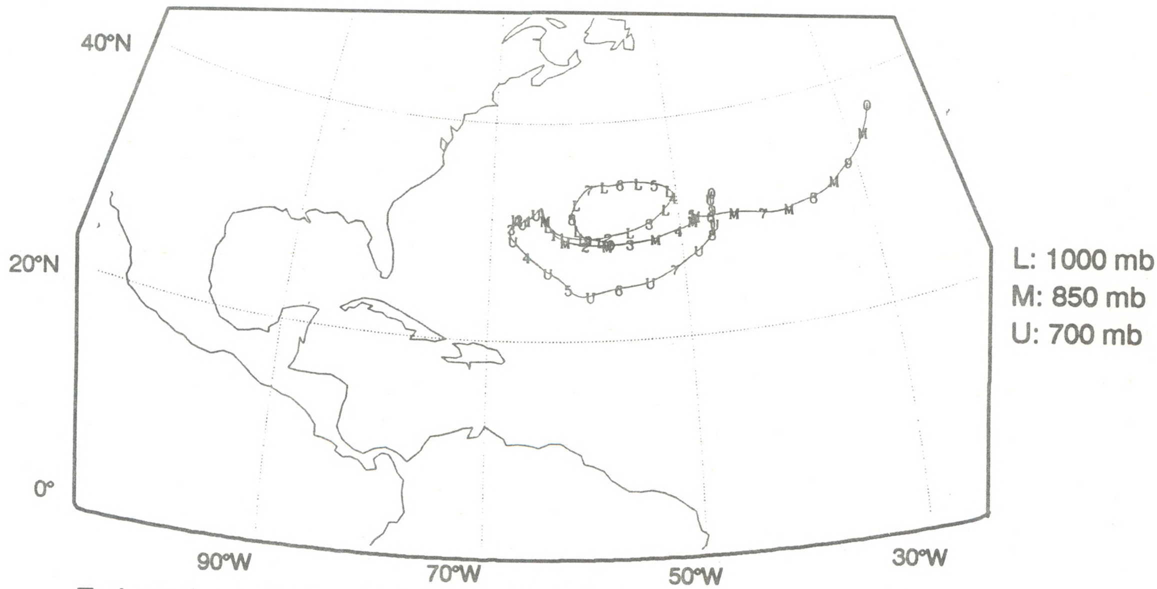
Flight #5
Bermuda
880726
All charts valid: 1200Z



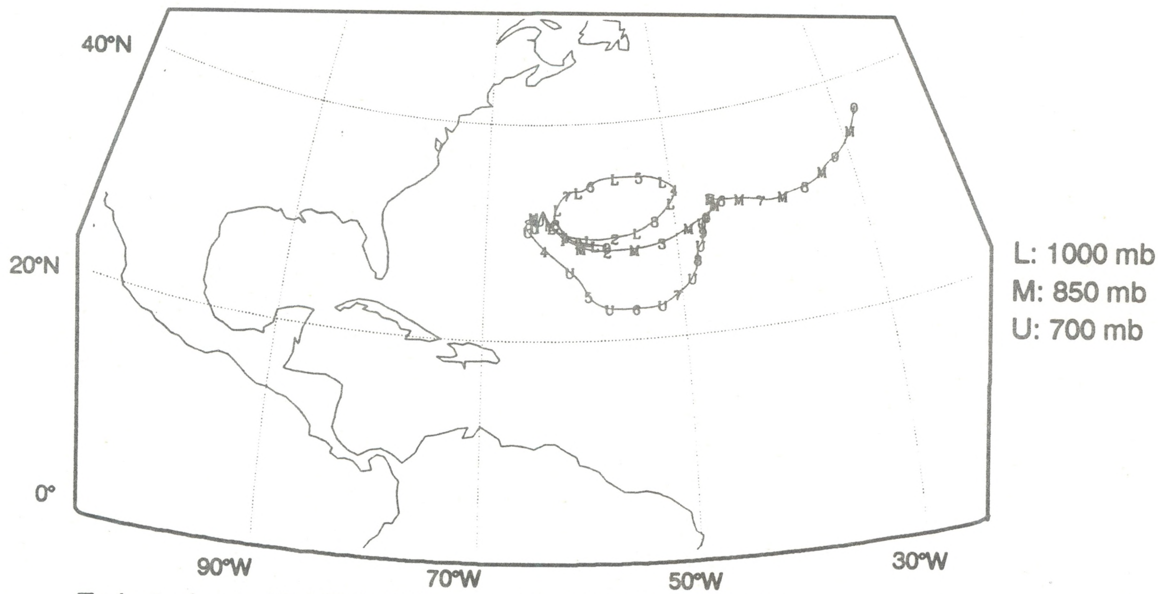




Flight #5, Bermuda 880726

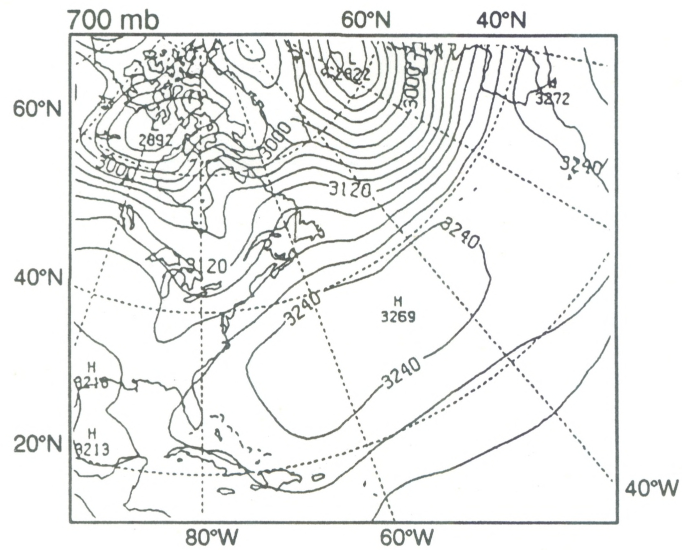


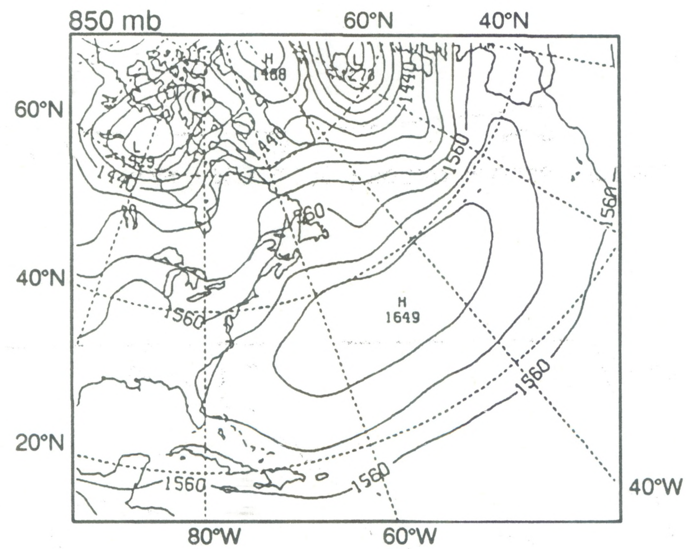
Trajectories to Bermuda (32.37°N,64.69°W) valid 1200Z

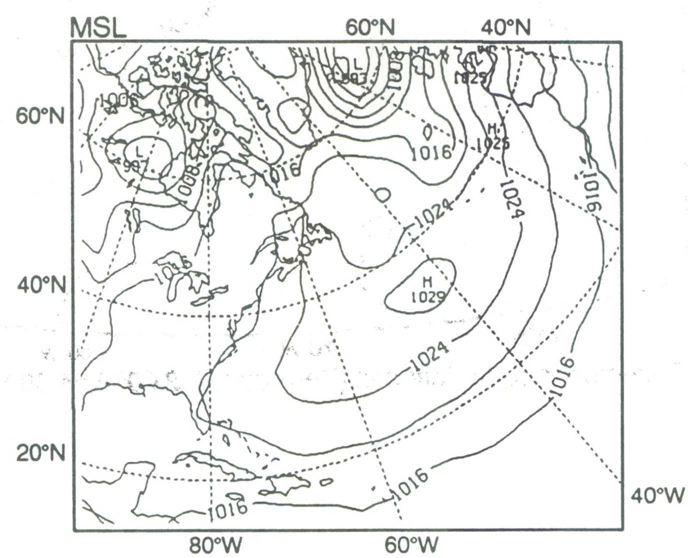


Trajectories to Mt Mitchell (Bermuda) (32.00°N,64.00°W) valid 1200Z

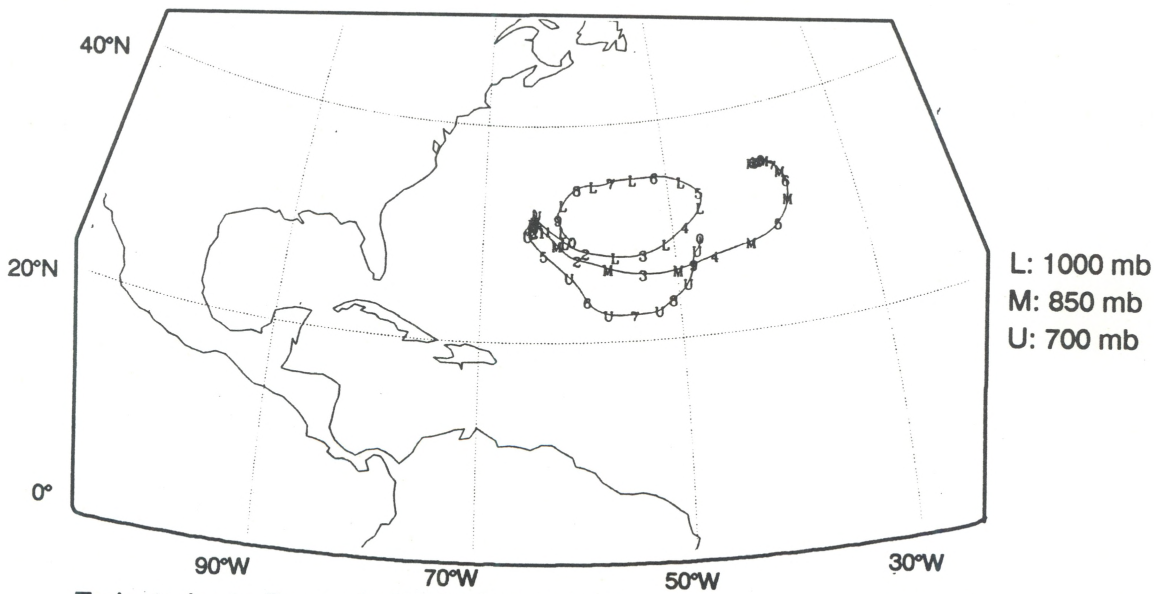
Flights #6 and #7
Bermuda
880727
All charts valid: 1200Z



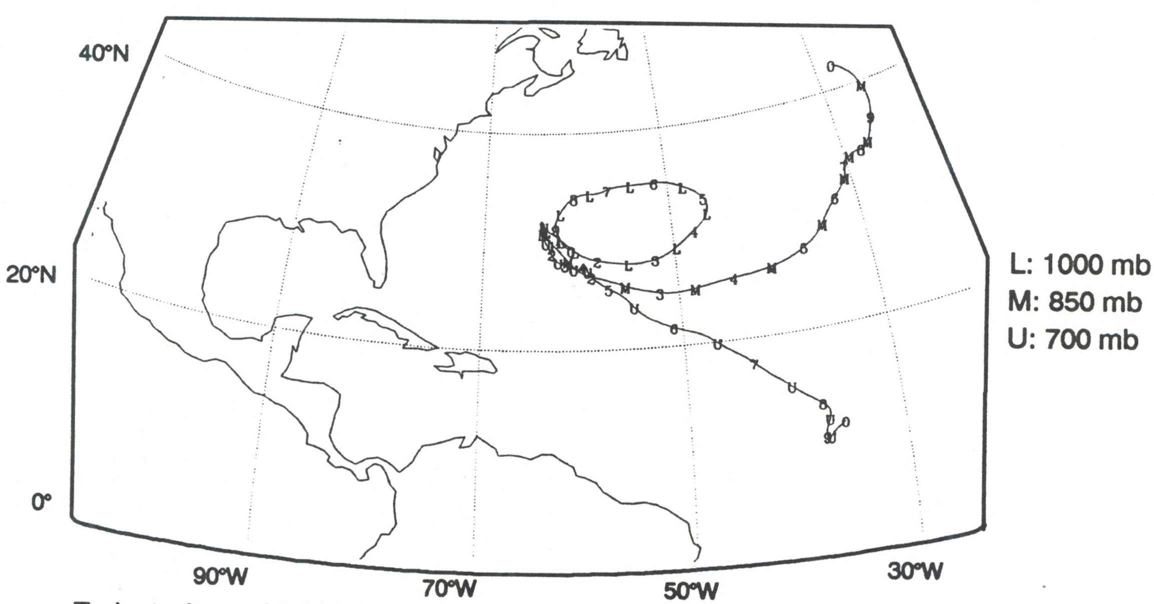




Flights #6 and #7, Bermuda 880727



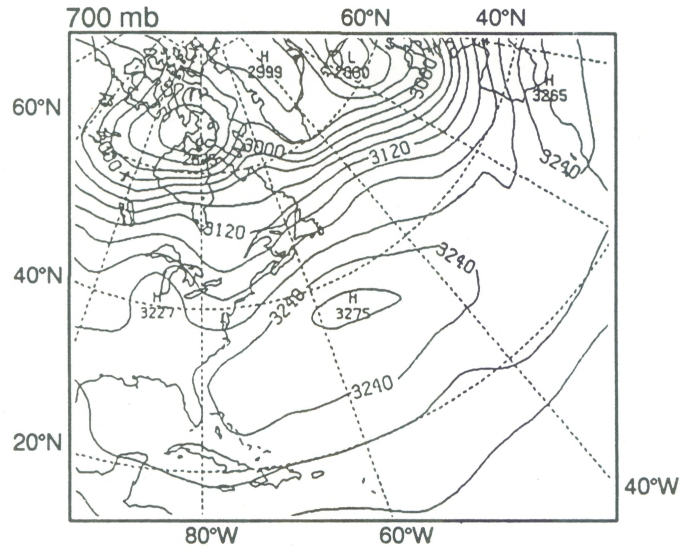
Trajectories to Bermuda (32.37°N,64.69°W) valid 1200Z



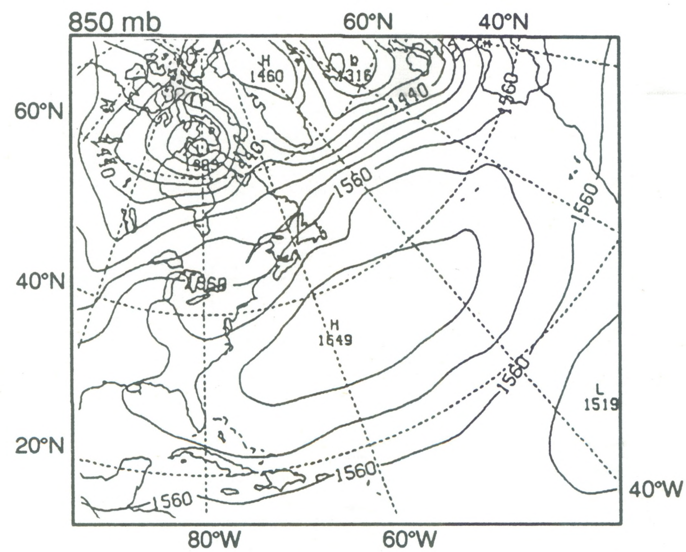
Trajectories to Mt Mitchell (Bermuda) (32.00°N,64.00°W) valid 1200Z

Flight #8
Bermuda
880728
All charts valid: 1200Z

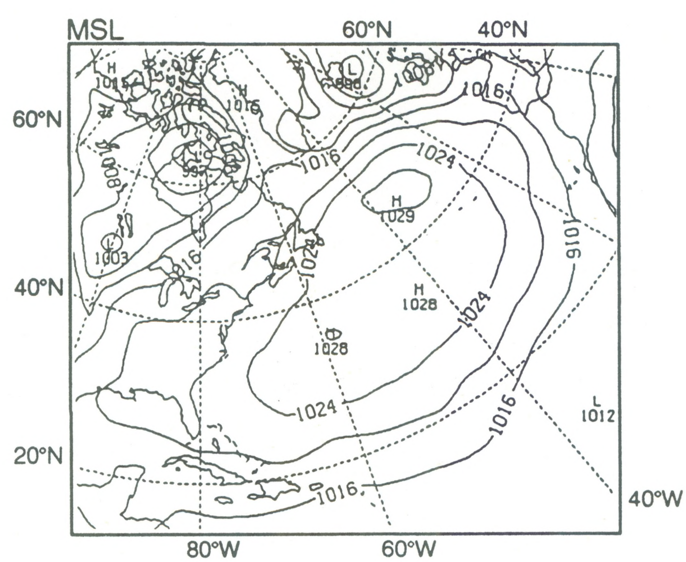
700 mb



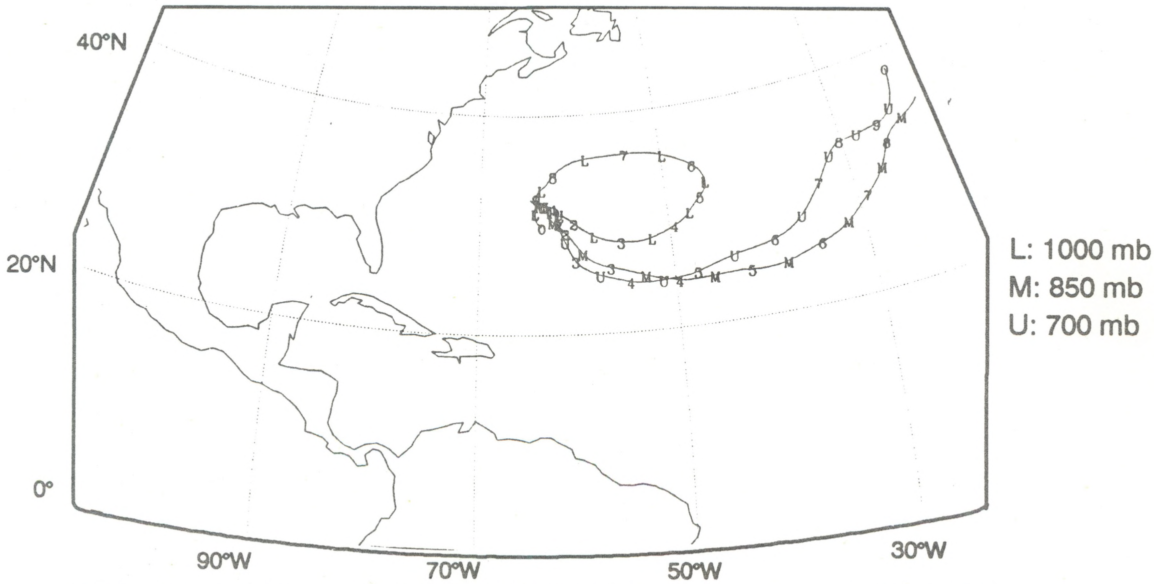
850 mb



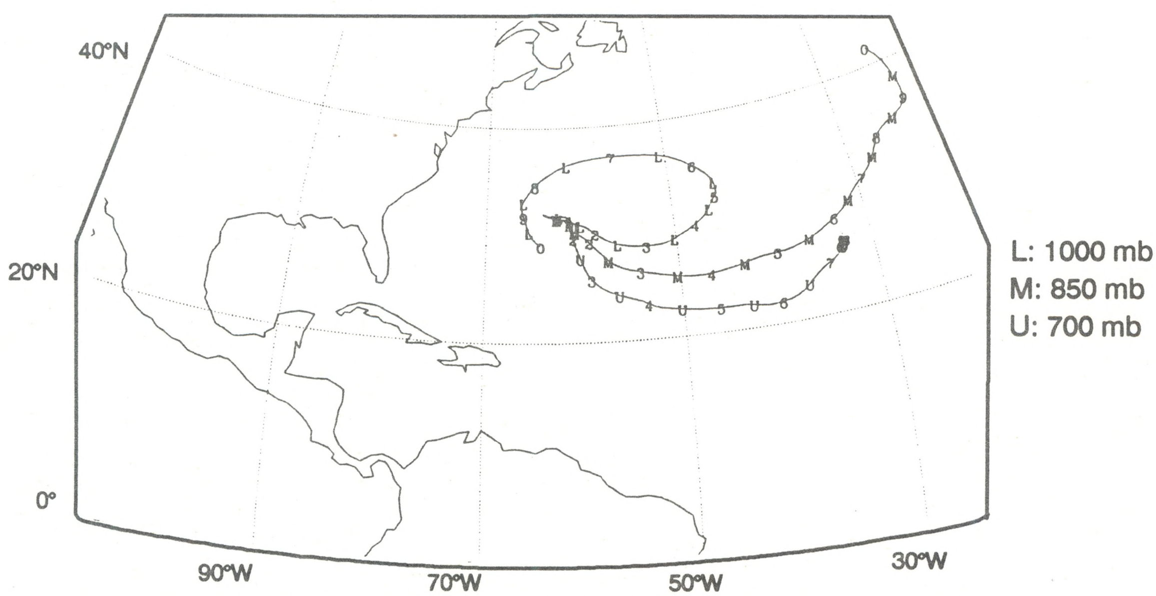
MSL



Flight #8, Bermuda 880728



Trajectories to Bermuda (32.37°N,64.69°W) valid 1200Z



Trajectories to Mt Mitchell (Bermuda) (32.00°N,64.00°W) valid 1200Z