NASA Technical Memorandum 78822

Summary of Southeastern Virginia Urban Plume Measurement Data for August 4 and 5, 1977

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Summary of Southeastern Virginia Urban Plume Measurement Data for August 4 and 5, 1977

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SUMMARY

Air quality data from the Southeastern Virginia Urban Plume Experiment conducted by the National Aeronautics and Space Administration on August 4 and 5, 1977, are presented. The purpose of the measurement program was to define the characteristics of the Southeastern Virginia urban plume with emphasis on the photo-oxidant species. The measurement area was a rectangle approximately 200 km by 60 km centered in the Hampton Roads area of Tidewater Virginia. Included in this area are the cities of Norfolk, Virginia Beach, Chesapeake, Newport News, and Hampton. The area is bounded on the north by Wallops Island, Virginia, and on the south by Elizabeth City, North Carolina. The major axis of the rectangle is oriented in the southwest-northeast direction. The data set presented includes aircraft measurements for ozone, nitrogen oxides, carbon monoxide, methane, and meteorological parameters such as dewpoint temperature. Surface level data for ozone are presented for 10 stations located throughout the test area. Comprehensive meteorological data from existing National Weather Service stations and special locations selected for the urban plume program are summarized. Meteorological data include surface observations of winds, temperature, solar insolation, and mixing-layer height as well as aloft observations of winds and temperature. The urban plume program was a combined effort of NASA Langley Research Center, NASA Wallops Flight Center, Virginia State Air Pollution Control Board Region VI, and Old Dominion University.

INTRODUCTION

The National Aeronautics and Space Administration (NASA) has for several years been developing remote sensors (refs. 1 to 5) for air pollution applications. The goal of many of these sensors is the detection, from satellite platforms, of pollutants in the lower troposphere. Included in each sensor development program is the application of the sensor and any associated technology to typical problems in the public sector. These applications usually entail operation of the sensor from aircraft platforms, thus providing a close simulation of satellite operation. The purpose of this evaluation phase is to obtain application experience with each sensor (prior to designing the satellite unit) and to allow user agencies (normally through joint programs with NASA) to witness the use of the sensor and thereby to allow for user suggestions about the design and final application of the sensor.

In preparation for these programs to check out remote sensors now under development, an airborne sampling program was conducted in August 1977 using in situ instruments to determine whether the urban plume of Southeastern Virginia is a suitable test area for application testing of remote sensors. Airborne in situ measurements of ozone (O_3), nitric oxide (NO), nitrogen oxides (NO_x), carbon monoxide (CO), methane (CH_4), and particulates were used to define the urban plume. Verification of the existence and definition of the

characteristics of this urban plume are a prerequisite to the design of experiments using maturing NASA remote sensing capability. The airborne program was coordinated with a program of the Virginia State Air Pollution Control Board conducted during the summer of 1977 (June to August) to evaluate surface level ozone concentrations in air masses as they are transported through the Southeastern Virginia region.

The purpose of this report is the documentation of the pertinent data collected during the test program. The measurement program is discussed briefly. Due to the massive quantity of data collected during the experiment, only those data, which in the editors' opinions, are directly pertinent to the program goals are presented. Data are presented without discussion. In each case the editors have made reasonable efforts to ensure that the data supplied by the various participating organizations and individual researchers are valid and within existing state-of-the-art data reduction techniques, accuracy, etc. A discussion of data accuracy and reduction for the numerous measurement techniques is beyond the scope of this report. Where possible, appropriate references are cited for the measurement techniques. Analysis is still being performed on the data sets and reference 6 describes one analysis of these data.

SYMBOLS AND ABBREVIATIONS

β_{scat}	aerosol scattering coefficient, m^{-1}
DACOM	Differential Absorption Carbon Monoxide Monitor
EDT	Eastern Daylight Time
LaRC	Langley Research Center
lidar	laser infrared radar
NASA	National Aeronautics and Space Administration
NOAA	National Oceanographic and Atmospheric Administration
NWS	National Weather Service
ODU	Old Dominion University, Norfolk, Virginia
ppb	parts per billion by volume
ppm	parts per million by volume
SAPCB	State Air Pollution Control Board Region VI
uv	ultraviolet
VIMS	Virginia Institute of Marine Science, Wachapreague, Virginia

VSAPCB Virginia State Air Pollution Control Board

X aircraft flight altitude, m

DESCRIPTION OF EXPERIMENT

Test Area

Location and topography.- The Southeastern Virginia area located approximately 36.8° N. and 76.4° W., in midlatitudes on the east coast has a climate which is temperate, rainy without a dry season, and has warm summers. It is centered around Hampton Roads which is one of the largest natural port areas in the world. The cities of Norfolk, Virginia Beach, and Chesapeake are located on the east and southeast sides of the area; Newport News and Hampton are on the northwest and north sides. (See fig. 1.) The northwest and southeast sides of Hampton Roads contain the larger population centers, whereas the southwestern and northeastern sides have relatively sparse populations. The most densely populated sections in the area are located southeast of Hampton Roads along the southern and eastern branches of the Elizabeth River.

The topography of the region is low and flat. For example, the average elevation above mean sea level of Norfolk is 5 m. To the southwest of the region lies the Dismal Swamp, which extends into North Carolina. As one goes westward, the terrain slopes imperceptibly upwards for approximately 240 km; here the land rises sharply into the Appalachians, with elevations averaging 1000 to 1200 m above mean sea level. Man has not altered the region's topography in any marked manner, as very few buildings even approach 100 m; the taller structures are located in the southwestern part of the city of Norfolk.

Climatology.- The effect of the Bermuda high on the air circulation in the Southeastern Virginia region in summer results in frequent southwest winds that are in evidence at all weather stations. Northwest winds, primarily an aftermath of cold fronts, are rare in the summer and when they occur are considerably weaker than their spring or winter counterparts. A sea breeze is well in existence; however, it does not extend too deeply inland as it is seldom felt at locations which are about 16 km inland. Diurnal changes are greatest in summer. A nightly gentle south through southwest prevailing wind is evident at all weather stations, and is caused by the coupling of the circulation around the Bermuda high and the night land breeze. Other wind directions during the summer are infrequent. Both day calms and night calms are frequent in summer; wind speeds average 4 m/sec during the day and 3 to 3.6 m/sec at night. For summer wind conditions in general, little difference exists between the individual months themselves or between individual months and the summer average.

Although it does not differ greatly from the two other summer months, the month of July deviates most from the average. In July the Bermuda high is strongest and produces a higher frequency of day and night southwest winds than occurs in June or August. Sea breezes are also slightly reduced in July since the warming coastal waters, together with the closer location of the Gulf

Stream, reduce the midday temperature contrasts between land and water. Although the frequency of northwest winds is low in June and August, it is reduced even more during July, the month of highest temperature. July has the lowest wind speeds both day and night of any month of the year. The June and August wind distributions are quite similar in both direction and speed and show spring and fall influences, respectively.

Selection rationale.- The Southeastern Virginia region possesses several features which make it a favorable site for urban plume studies. The area is flat with a mean elevation of 5 m above mean sea level. The major emission areas associated with its largest cities (Norfolk, Chesapeake, Virginia Beach, Newport News, and Hampton) are encompassed by a square measuring approximately 40 km by 40 km. This emission area is relatively isolated in terms of additional nearby urban sources, being bounded to the east by the Atlantic Ocean, to the north by the Chesapeake Bay and rural Eastern Shore, to the west by smaller scattered municipalities and rural farm land, and to the south by the Dismal Swamp. The 40- by 40-km emission area has many heavily traveled roads, numerous military bases, major shipping activities, several storage and refining sites for hydrocarbons, and moderate industrial activity. Depending on the direction of the predominant air flow at the time of measurements, the area can provide opportunities for study of (a) effect of urban area on ambient "clean" air, (b) composite effect of urban area and ambient "dirty" air, and (c) downwind characteristics of urban plume over emission-free area such as water and rural land masses.

Sampling Strategy

The meteorological condition selected for determining the characteristics of the Southeastern Virginia urban plume was flow from the southwest. Under this condition, incoming air to the region is readily characterized after having traveled typically 6 to 8 hours since having been influenced by emissions from a major urban (city) source. Similarly, for the southwest flow case, the air leaving the Norfolk (source) area travels 8 to 10 hours over a relatively emission-free area (counties of Mathews, Northampton, and Accomac). During this time the influence of Norfolk (urban) emissions on the air parcel can be studied without the complication of additional major emission sources.

The sampling area selected for study was a rectangle approximately 200 km by 60 km, with the major axis oriented along the desired southwest wind vector. (See fig. 2.) This sampling area was subdivided with six to seven flight legs perpendicular to the southwest air flow. These lettered (fig. 2) flight legs provided the flight paths over which the airborne data were obtained. Two aircraft, each equipped for monitoring different pollutant species, sampled the air on the various flight legs on each of the two test days, August 4 and 5, 1977. Sampling was performed from about 0900 to 1700 EDT on each day. Approximately 12 surface stations (see fig. 2) provided supporting data for the aircraft flights. The August 4 and 5 sampling program focused on ozone and its associated precursors although other effluents were measured. Aircraft monitored ozone, nitrogen oxides, hydrocarbons, carbon monoxide, and aerosols (scattering coefficient). Surface stations monitored ozone predominantly.

The sampling strategy for the test area was to determine by aircraft sampling the effluent concentrations both upwind (flight legs K → L and M → N) and downwind (flight legs A → B, C → D, and E → F) of the source area (Norfolk). From these data, the existence of the urban plume can be determined and an evaluation of the effect of an urban source on the downwind air quality can be made. Two aircraft, a Cessna 402 and a Douglas C-54, provided the sampling platforms. The Cessna monitored O_3, NO, NO_x, and aerosols (β_{scat}); the C-54 monitored CO continuously and took grab samples of CO and CH_4 for laboratory analyses. Figure 3 shows the sampling pattern designed for the C-54. This sampling pattern was performed on each flight leg flown by the C-54. Briefly, as shown in the figure, the C-54 made a constant-altitude sampling pass starting at the western point of each leg and flying along the leg to the eastern point. Flight altitude (defined as X in fig. 3) was selected to be below the mixing-layer height. Flight altitude X was selected prior to takeoff based on available mixing-layer measurements and was not varied in-flight. After the sampling aircraft reached the eastern point of the flight leg, it flew a descending (constant rate) flight from altitude X at the eastern point to a 460-m (1500-ft) altitude over the western point. At this time the C-54 proceeded to the next flight leg to repeat the pattern. Altitude (spirals) profiles of pollutants were made at times and locations selected by the flight crew based on available time, flight safety, etc. Figure 4 shows the sampling pattern used by the Cessna on each flight leg. The Cessna pattern consisted of two constant-altitude sampling passes: western point to eastern point at altitude X and eastern point to western point at a 460-m altitude. At both the eastern and western points of the flight leg a spiral (150 m/min) was made between the two altitudes. Flight altitude X was generally the same for both aircraft with each aircraft sampling different flight legs at the same time.

The actual flight parameters associated with the August 4 and 5 flights are shown in tables 1 and 2. Shown are the length of each flight leg, the start and stop times for the sampling pattern, and the flight altitude X.

The airborne sampling program which focused on ozone was coordinated with a program of the Virginia State Air Pollution Control Board (VSAPCB) that was designed to evaluate the ground-level ozone concentrations in air masses as they are transported through this region. The 12 ground stations operated by the VSAPCB provided data on the surface concentrations during the airborne data periods. The mixing-layer height was determined from measurements from the lidar operated at LaRC and from simultaneous radiosonde releases by the NOAA-NWS (at the Norfolk International Airport) and the NASA Wallops Flight Center. Additional meteorological data including synoptic data were available from the NWS network.

Measurement Systems

Meteorological data.- Meteorological data served two functions during the urban plume experiment: (1) source of the information from which the staff meteorologist forecast test conditions of southwest flow and high ozone production and (2) documentation of actual meteorology for the experiments

for assessment of results. Table 3 summarizes the available meteorological data including the source. The urban plume staff meteorologist was a local forecaster familiar with both program requirements and local meteorological features.

Surface ozone monitoring systems.- Figure 2 shows the location of those sites providing surface level ozone concentration in support of the August 4 and 5 flights. These sites were established and managed by the local SAPCB as part of a summer (June to August) program to evaluate surface ozone concentrations of air masses as the air mass moved through the Southeastern Virginia area. Table 4 shows the monitoring technique used and the organization responsible for the instrumentation for each site. Surface wind speed and direction data are also recorded at the indicated location. The VSAPCB also provided as part of their summer program, audits of each site to ensure instrumentation calibration. (See refs. 7 and 8 for a discussion of the ozone monitoring techniques.)

Aircraft monitoring systems.-

Douglas C-54: The Douglas C-54 monitoring instrumentation included the Differential Absorption Carbon Monoxide Monitor (DACOM) system for continuous CO measurements and stainless steel and glass container grab samples for laboratory analysis of CO and CH_4. Reference 9 discusses the DACOM system as flown on the C-54. The instrument is basically a laser system monitoring CO along a 10-m path located along the fuselage of the aircraft. Flight tests indicate about a 20-ppb sensitivity (noise level) for a 1-s integration time. Approximately 70 grab samples were taken in support of the August 4 and 5 missions. Each sample was analyzed in the laboratory for CO and CH_4 by Old Dominion University personnel using gas chromatographic techniques. The technique incorporates sample preconcentration with catalytic conversion of CO to CH_4 and subsequent flame ionization detection of these gases. The method has sufficient sensitivity and repeatability to obtain the concentrations of CH_4 and CO at ambient clean air levels. Reference 10 describes the measurement technique. All 70 samples were analyzed by August 12, 1977.

Cessna 402: The basic sampling configuration used in the Cessna 402 is described in reference 11. For the urban plume experiment, the Cessna was equipped to monitor O_3, NO, NO_x, aerosols (β_{scat}), and normal flight parameters including dewpoint. All measurement systems except that for O_3 are discussed in the reference. Ozone concentrations were measured with the chemiluminescent technique (commercially available). The ozone instrument was located in the rear passenger cabin (see ref. 11) and the air sampling system of the aircraft including nose inlet probe (that system described in ref. 11 for supplying sample air to the rear passenger cabin instrumentation) was lined with teflon tubing. Appropriate laboratory evaluation of the O_3 and NO/NO_x instruments, calibration procedure, and aircraft sampling hardware and procedures was performed. A discussion of that program is beyond the scope of this data report. Briefly, the laboratory program included investigation of pressure (altitude) effects on instrumentation sensitivity, effluent losses in the sampling lines, and calibration repeatability. Both the NO/NO_x

and O_3 instruments were calibrated using gas phase titration (ref. 12) traceable to a National Bureau of Standards nitrogen oxide standard. Absolute accuracies for both the NO/NO_x and O_3 instruments are believed to be better than ±10 percent.

DATA PRESENTATION

The data obtained during the August 4 and 5 urban plume experiment are summarized in this section. The data are presented in tabular or graphical format and in some cases in both formats. The data are presented without discussion and, where applicable, nonpertinent or redundant data have been omitted. As the introductory discussion indicated, the purpose of the paper and this section is to provide formal documentation of the urban plume data and, as such, to serve as the data base for analysis of the experiment.

Meteorological Data

Figure 5 shows the location of sites from which meteorological data are reported. The key of figure 5 shows the type of data collected at each location. Not shown in figure 5 are sites at Salisbury, Maryland (type 1 data); Cape Hatteras, North Carolina; Greensboro, North Carolina; and Charleston, South Carolina (the last three, type 2 data).

Surface observations.- Type 1 meteorological data (see fig. 5 key) are shown in tables 5 to 11. The source of these data is the National Weather Service network. Figures 6 and 7 show a data plot of the wind speed and direction from these stations for August 4 and 5. Table 12 shows additional surface wind speed and direction data as recorded at type 3 stations. Figure 8 shows the solar insolation data recorded at the LaRC site.

Aloft observations.- Tables 13 to 20 show, for August 4 and 5, the aloft data taken at the type 2 meteorological stations. The source of these data is the rawinsondes routinely released twice daily by the National Weather Service. Figures 9, 10, and 11 show the wind speed and direction data for the three sites closest to the Southeastern Virginia area (Wallops Island, Cape Hatteras, and Greensboro) for the release times of 0800 and 2000 EDT (August 4) and 0800 EDT (August 5). Only data for altitudes up to about 3 km are shown in the figures. Tables 21 to 26 show additional aloft data from sites at Wallops Island and Norfolk International Airport. On each day, release times at both locations were approximately 1030, 1300, and 1530 EDT. These releases were made by National Weather Service rawinsonde measurement teams and scheduled by NASA for direct support of the urban plume experiments.

Mixing-layer height observations.- Mixing-layer heights as determined from lidar data at the LaRC site are shown in table 27. The mixing layer was determined on an hourly basis from measurements of the aerosol-layer location.

Surface Level Ozone Data

Tables 28 and 29 show the surface ozone data recorded during the urban plume experiment. Each data point represents an hourly average at each site. Figures 12 and 13 are plots of the tabulated data. Each hourly average is plotted at the midpoint of the time interval.

Airborne Effluent Data

Douglas C-54 aircraft.- The results of the CO and CH_4 grab sample measurements are shown in table 30 (August 4) and table 31 (August 5). The time of day and the flight altitude at which each sample was taken are shown together with laboratory analysis of concentrations of CO and CH_4. Figures 14 to 17 show the location at which the samples were taken. In addition to the data in the tables, on each day an altitude profile over the LaRC site was taken. Figure 18 shows the grab sample results during these profiles. Each profile was flown from about 1230 to 1330 EDT each day.

The DACOM CO data obtained on board the C-54 aircraft are shown in figures 19 to 22. Only those data for the descending portion of the C-54 flight pattern (see fig. 3) are shown as the constant-altitude data for each leg was nearly identical to the descending leg. For figures 19 and 21, the data at the eastern point of each flight leg were taken at an altitude of about 600 m and the western point at 450 m with constant-descent-rate flight path between the end points of each leg. For figures 20 and 22 the data at the eastern point of each leg were taken at an altitude of about 900 m with a descending (constant rate) flight to an altitude of 450 m at the western point. DACOM data during the daily (1230 to 1330 EDT) altitude profiles at the LaRC site were invalid because of procedural problems.

Cessna 402 aircraft.- Tables 32 to 38 summarize the ozone data obtained during the constant-altitude portions of the Cessna flight plan. (See fig. 4.) Shown in each table are data for two flight altitudes (450 and 900 m) and the time of day over which each data set was obtained. The data are shown referenced to specific locations along each flight leg. These locations are identified as nautical miles and kilometers from the end points of the flight legs. Figures 23 to 26 are graphical displays of the 450-m-altitude data of the tables. Nitrogen oxide data for both days are shown in table 39. As a result of noise problems with the NO/NO_x instrument only the average NO and NO_x concentrations on each flight leg are reported. The ± values indicate the range of NO and NO_x variation for each leg. Figures 27 to 30 show ozone and dewpoint data taken during the aircraft spiral (fig. 4) portion of the flight plan.

While aerosol data (β_{scat}) from the onboard nephelometer are available for the same time periods as the O_3 data, the data are not reported herein. Figure 31 is shown to illustrate the type of results obtained from the nephelometer measurements. This figure shows a comparison of O_3 and β_{scat} for leg A' → B, 450-m altitude, and August 5. Additional β_{scat} data are available upon request from the editors.

CONCLUDING REMARKS

The data presented herein are not intended to be an all-inclusive documentation of the 1977 experimental program. This report does, however, present those data considered most pertinent to the program goals and serves as documentation of the data base for further analysis.

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TABLE 1.- AIRCRAFT SAMPLING FLIGHT PATH

ON AUGUST 4, 1977

(a) C-54

Flight leg	Length of leg, km	Approximate time, ETD		Altitude, X,[a] m
		Start	End	
B → A'	59	0855	0924	600
D → C	69	0931	0957	600
F → E	56	1004	1029	600
H → G	48	1035	1055	600
J → I	74	1105	1137	600
L → K	37	1150	1209	600
N → M	56	1216	1236	600
N → M	56	1555	1617	900
H → G	48	1633	1655	900
B → A'	59	1710	1732	900

[a]See figure 3 for definition of altitude X.

TABLE 1.- Concluded

(b) Cessna 402

Flight leg	Length of leg, km	Approximate time, ETD		Altitude, X,[a] m
		Start	End	
A' → B	59	0833	0906	900
E → F	56	0917	0947	900
G → H	48	0951	1018	900
I → J	74	1027	1101	900
K → L	37	1112	1132	900
M → N	56	1139	1207	900
M → N	56	1356	1424	900
K → L	37	1440	1550	900
I → J	74	1509	1544	900
G → H	48	1550	1616	900
E → F	56	1620	1648	900
A' → B	59	1657	1733	900

[a]See figure 4 for definition of altitude X.

TABLE 2.- AIRCRAFT SAMPLING FLIGHT PATH

ON AUGUST 5, 1977

(a) C-54

Flight leg	Length of leg, km	Approximate time, ETD		Altitude, X,[a] m
		Start	End	
B → A'	59	0855	0926	900
D → C	69	0941	1006	900
F → E	56	1015	1038	900
H → G	48	1047	1106	900
J → I	74	1113	1146	900
N → M	56	1220	1242	900
N → M	56	1608	1625	900
H → G	48	1643	1704	900
B → A'	59	1725	1742	900

[a]See figure 3 for definition of altitude X.

TABLE 2.- Concluded

(b) Cessna 402

Flight leg	Length of leg, km	Approximate time, ETD		Altitude, X,[a] m
		Start	End	
A' → B	59	0917	0948	900
E → F	56	1000	1029	900
I → J	74	1039	1117	900
M → N	56	1134	1202	900
K → L	37	1347	1407	900
G → H	48	1426	1455	900
C → D	69	1504	1534	900
A → B	96	1539	1621	900
R → S	44	1636	1703	900
A' → B	59	1715	1751	900

[a]See figure 4 for definition of altitude X.

TABLE 3.- SUMMARY OF METEOROLOGICAL DATA

Type of data	Number of locations	Frequency of data	Source
Surface observations Wind speed, direction Visibility Temperatures	8	4/day[a]	U.S. Coast Guard
Surface observations Wind speed, direction Visibility Temperatures	10	Hourly	National Weather Service
Aloft observations Wind speed, direction Temperatures	4	2/day	National Weather Service
Mixing-layer height	1	Hourly[b]	NASA

[a]Daylight hours only.
[b]Approximately from 0700 to 1700 EDT only.

TABLE 4.- SURFACE OZONE MONITORING SITES

Site	Ozone measurement technique	Responsible organization
Colerain[a]	uv absorption	VSAPCB
Great Bridge	uv absorption	ODU
Tidewater Community College	uv absorption	VSAPCB
ODU[a]	Chemiluminescence	ODU
Norfolk International Airport[a]	uv absorption	VSAPCB
Virginia School in Hampton[a]	uv absorption	VSAPCB
LaRC[a]	uv absorption	NASA
Milford[a]	uv absorption	VSAPCB
Cheriton	uv absorption	VSAPCB
VIMS[a]	uv absorption	VSAPCB
Painter	Electrochemical	VSAPCB
Wallops Flight Center[a]	uv absorption	NASA

[a]Measurements were made of surface wind speed and direction in addition to ozone.

TABLE 5.- SURFACE METEOROLOGICAL DATA FROM ELIZABETH CITY, N.C.

(a) August 4, 1977

Time of observation, EDT	Wind speed, m/s	Wind direction, deg	Visibility, km	Temperature, °C	
				Dry bulb	Dewpoint
0100					
0200					
0300					
0400					
0500					
0600	3	240	11	23	21
0700	5	250	16	23	21
0800	5	250	16	24	22
0900	5	240	16	26	21
1000	5	240	16	29	19
1100	6	250	16	29	21
1200	7	260	16	30	21
1300	5	240	16	30	23
1400	5	270	24	31	21
1500	6	220	24	31	21
1600	4	220	24	29	21
1700	5	230	24	29	21
1800	5	230	24	29	21
1900	3	230	24	28	21
2000	3	200	16	26	23
2100	0		11	25	23
2200					
2300					
2400					

TABLE 5.- Concluded

(b) August 5, 1977

Time of observation, EDT	Wind speed, m/s	Wind direction, deg	Visibility, km	Temperature, °C	
				Dry bulb	Dewpoint
0100					
0200					
0300					
0400					
0500					
0600	3	230	11	22	21
0700	5	240	11	24	23
0800	5	240	13	26	24
0900	6	240	13	28	24
1000	4	230	16	30	24
1100	7	230	16	31	24
1200	5	230	16	32	24
1300	5	240	16	32	25
1400	6	230	16	33	23
1500	6	230	16	33	23
1600	6	240	24	33	23
1700	6	230	24	33	23
1800	4	230	24	32	23
1900	3	220	24	30	24
2000	3	210	16	28	24
2100	3	220	11	28	24
2200					
2300					
2400					

TABLE 6.- SURFACE METEOROLOGICAL DATA FROM OCEANA, VA.

(b) August 4, 1977

Time of observation, EDT	Wind speed, m/s	Wind direction, deg	Visibility, km	Temperature, °C	
				Dry bulb	Dewpoint
0100	3	220	11	24	21
0200	2	220	11	24	20
0300	1	230	11	23	20
0400	1	250	11	23	20
0500	1	240	10	23	19
0600	2	240	10	23	20
0700	2	220	10	25	22
0800	2	230	11	26	22
0900	4	240	11	27	22
1000	3	250	11	27	21
1100	3	240	11	28	22
1200	4	220	11	29	22
1300	4	250	11	29	22
1400	5	250	11	31	21
1500	5	230	11	32	21
1600	3	100	11	29	24
1700	3	80	11	28	23
1800	2	90	11	28	23
1900	4	210	11	28	23
2000	3	210	11	28	22
2100	3	210	11	27	21
2200	3	230	11	27	21
2300	1	230	11	26	21
2400	3	230	11	26	21

TABLE 6.- Concluded

(b) August 5, 1977

Time of observation, EDT	Wind speed, m/s	Wind direction, deg	Visibility, km	Temperature, °C	
				Dry bulb	Dewpoint
0100	3	240	11	25	21
0200	2	220	11	25	21
0300	2	240	11	25	20
0400	2	230	11	24	19
0500	1	210	11	23	19
0600	2	220	11	24	20
0700	3	230	11	25	21
0800	4	230	11	26	21
0900	4	230	11	28	23
1000	3	240	11	29	23
1100	5	210	11	31	23
1200	5	220	11	32	22
1300	5	230	11	34	23
1400	4	240	11	33	23
1500	5	240	11	34	24
1600	4	230	11	34	24
1700	5	220	11	33	24
1800	4	200	11	32	24
1900	3	200	11	30	24
2000	3	210	11	29	23
2100	3	200	11	28	23
2200	4	180	11	28	21
2300	3	220	11	28	21
2400	3	210	11	27	21

TABLE 7.- SURFACE METEOROLOGICAL DATA FROM NORFOLK NAVAL AIR STATION, VA.

(a) August 4, 1977

Time of observation, EDT	Wind speed, m/s	Wind direction, deg	Visibility, km	Temperature, °C	
				Dry bulb	Dewpoint
0100	3	210	11	25	22
0200	6	200	11	24	21
0300	4	240	11	24	21
0400	3	210	11	24	21
0500	4	230	11	24	20
0600	4	240	10	24	21
0700	4	220	11	25	21
0800	5	200	11	26	21
0900	4	240	11	27	21
1000	4	270	11	28	20
1100	5	280	11	29	20
1200	5	260	11	29	20
1300	6	270	11	30	20
1400	6	280	11	32	21
1500	3	270	11	32	20
1600	3	270	11	32	20
1700	4	220	11	31	20
1800	4	210	11	31	21
1900	5	210	11	30	21
2000	4	200	11	29	22
2100	5	210	11	28	22
2200	4	220	11	27	21
2300	5	200	11	27	21
2400	5	210	11	27	21

TABLE 7.- Concluded

(b) August 5, 1977

Time of observation, EDT	Wind speed, m/s	Wind direction, deg	Visibility, km	Temperature, °C	
				Dry bulb	Dewpoint
0100	6	220	11	26	21
0200	5	230	11	26	20
0300	3	220	11	25	20
0400	5	220	11	25	21
0500	5	230	11	24	21
0600	6	230	11	25	21
0700	5	230	11	26	21
0800	4	230	11	28	21
0900	6	220	11	29	23
1000	6	230	11	31	22
1100	8	240	11	33	22
1200	5	240	11	34	21
1300	6	250	11	36	22
1400	7	240	11	36	21
1500	8	230	11	35	21
1600	6	240	11	34	21
1700	7	210	11	33	22
1800	7	210	11	32	24
1900	6	200	11	31	23
2000	5	190	11	29	23
2100	5	210	11	29	23
2200	4	200	11	28	23
2300	5	210	11	28	23
2400	6	220	11	28	22

TABLE 8.- SURFACE METEOROLOGICAL DATA FROM

LANGLEY AIR FORCE BASE, VA.

(a) August 4, 1977

Time of observation, EDT	Wind speed, m/s	Wind direction, deg	Visibility, km	Temperature, °C	
				Dry bulb	Dewpoint
0100	4	240	11	26	22
0200	5	220	11	26	22
0300	5	240	11	26	21
0400	5	210	11	25	21
0500	3	230	11	25	21
0600	3	240	11	24	21
0700	5	240	11	26	21
0800	6	230	11	26	21
0900	5	230	11	27	20
1000	4	270	11	28	20
1100	5	260	11	29	20
1200	7	270	11	30	19
1300	7	230	11	31	20
1400	5	230	11	31	20
1500	4	230	11	32	20
1600	2	250	11	31	19
1700	3	290	11	31	20
1800	4	280	11	31	20
1900	1	250	11	30	20
2000	5	240	11	28	21
2100	3	210	11	28	22
2200	5	240	11	28	21
2300	4	220	16	27	21
2400	5	220	16	26	21

TABLE 8.- Concluded

(b) August 5, 1977

Time of observation, EDT	Wind speed, m/s	Wind direction, deg	Visibility, km	Temperature, °C	
				Dry bulb	Dewpoint
0100	5	230	16	27	21
0200	5	230	16	26	21
0300	5	240	16	26	21
0400	5	230	16	26	21
0500	4	230	16	26	21
0600	4	240	19	25	21
0700	5	240	16	26	21
0800	5	240	16	28	21
0900	6	250	16	29	22
1000	7	230	16	32	22
1100	7	250	16	33	21
1200	8	240	16	33	21
1300	9	240	16	34	21
1400	5	240	16	35	21
1500	7	230	16	36	21
1600	5	230	16	35	21
1700	8	230	16	34	21
1800	6	250	16	34	21
1900	4	230	16	32	21
2000	5	220	11	32	22
2100	4	220	11	31	22
2200	4	230	11	29	21
2300	6	230	16	29	21
2400	7	240	16	28	21

TABLE 9.- SURFACE METEOROLOGICAL DATA FROM PATRICK HENRY AIRPORT, VA.

(a) August 4, 1977

Time of observation, EDT	Wind speed, m/s	Wind direction, deg	Visibility, km	Temperature, °C	
				Dry bulb	Dewpoint
0100	7	280	11	26	20
0200	4	250	11	26	20
0300	4	250	11	26	19
0400	5	210	11	24	20
0500	4	250	11	24	20
0600	3	220	11	24	20
0700	4	230	16	24	20
0800	5	230	24	25	19
0900	6	230	32	27	19
1000	5	230	32	27	19
1100	5	270	32	28	19
1200	5	220	32	29	20
1300	8	230	32	29	19
1400	4	240	32	31	19
1500	4	260	32	31	19
1600	4	210	32	31	19
1700	4	230	32	31	19
1800	4	220	32	31	19
1900	3	180	24	28	21
2000	3	170	24	25	20
2100	3	200	24	26	20
2200	4	200	24	26	20
2300	4	230	24	27	19
2400	4	200	24	26	19

TABLE 9.- Concluded

(b) August 5, 1977

Time of observation, EDT	Wind speed, m/s	Wind direction, deg	Visibility, km	Temperature, °C	
				Dry bulb	Dewpoint
0100	6	220	24	26	20
0200	5	220	24	26	19
0300	6	220	24	26	19
0400	5	230	24	26	19
0500	6	220	24	25	19
0600	5	240	24	25	19
0700	5	240	24	26	19
0800	5	230	24	27	20
0900	5	230	24	29	21
1000	7	230	24	30	21
1100	6	220	19	32	21
1200	8	230	16	33	21
1300	6	250	16	34	21
1400	8	220	16	35	21
1500	7	220	16	36	21
1600	6	230	24	35	24
1700	8	220	24	34	23
1800	5	210	24	33	18
1900	5	210	24	32	18
2000	4	200	16	30	19
2100	5	220	16	29	19
2200	5	220	16	29	19
2300	6	210	16	29	19
2400	5	230	16	28	18

TABLE 10.- SURFACE METEOROLOGICAL DATA FROM WALLOPS FLIGHT CENTER, VA.

(a) August 4, 1977

Time of observation, EDT	Wind speed, m/s	Wind direction, deg	Visibility, km	Temperature, °C	
				Dry bulb	Dewpoint
0100					
0200					
0300					
0400					
0500	2	240	8	24	23
0600	4	220	8	24	23
0700	3	200	8	26	23
0800	4	230	8	28	23
0900	3	230	10	29	22
1000	4	240	11	31	20
1100	4	210	13	31	19
1200	3	210	16	31	20
1300	5	240	19	31	19
1400	4	240	16	32	21
1500	3	270	16	32	21
1600	2	240	16	31	20
1700					
1800					
1900					
2000					
2100					
2200					
2300					
2400					

TABLE 10.- Concluded

(b) August 5, 1977

Time of observation, EDT	Wind speed, m/s	Wind direction, deg	Visibility, km	Temperature, °C	
				Dry bulb	Dewpoint
0100					
0200					
0300					
0400					
0500	3	230	11	24	23
0600	3	230	13	24	23
0700	5	180	16	27	23
0800	3	240	16	29	24
0900	5	240	19	31	23
1000	7	230	24	32	23
1100	5	240	24	33	23
1200	8	230	19	33	23
1300	6	260	16	34	23
1400	5	240	16	35	23
1500	5	200	16	34	24
1600	5	180	16	33	25
1700					
1800					
1900					
2000					
2100					
2200					
2300					
2400					

TABLE 11.- SURFACE METEOROLOGICAL DATA FROM SALISBURY, MD.

(a) August 4, 1977

Time of observation, EDT	Wind speed, m/s	Wind direction, deg	Visibility, km	Temperature, °C	
				Dry bulb	Dewpoint
0100	3	180	11	24	24
0200	0		11	24	23
0300	0		11	24	23
0400	2	320	11	23	23
0500	0		11	23	23
0600	0		8	23	23
0700	3	200	8	25	25
0800	4	200	10	27	26
0900	4	250	10	29	22
1000	3	250	11	29	24
1100	5	200	11	31	23
1200	8	200	16	32	21
1300	6	220	16	31	22
1400	5	220	8	31	24
1500	5	210	8	31	23
1600	4	250	8	31	23
1700	4	200	8	31	23
1800	4	200	8	30	23
1900	4	170	8	28	23
2000	3	170	11	25	24
2100	3	170	11	25	24
2200	3	170	11	25	24
2300	3	170	16	24	24
2400	3	170	16	24	24

TABLE 11.- Concluded

(b) August 5, 1977

Time of observation, EDT	Wind speed, m/s	Wind direction, deg	Visibility, km	Temperature, °C	
				Dry bulb	Dewpoint
0100	0		16	24	24
0200	0		16	24	24
0300	0		16	24	24
0400	0		16	24	24
0500	2	230	16	24	24
0600	3	200	10	24	24
0700	4	220	10	27	26
0800	6	230	10	28	27
0900	5	210	10	30	27
1000	6	230	10	31	26
1100	6	220	10	32	26
1200	6	250	11	33	27
1300	5	240	11	33	27
1400	5	240	11	34	27
1500	6	210	11	34	25
1600	5	220	11	34	24
1700	3	200	11	32	25
1800	3	200	11	28	24
1900	3	200	11	29	24
2000	2	100	11	27	25
2100	0		11	26	24
2200	0		11	27	24
2300	3	190	11	27	25
2400	4	200	11	27	25

TABLE 12.- SURFACE WIND DATA

[WS = Wind speed, m/s; WD = Wind direction, deg]

(a) August 4, 1977

Time, EDT	Stations											
	Colerain		ODU		Norfolk International Airport		Virginia School at Hampton		VIMS		Milford	
	WS	WD	WS	WD	WS	WD	WS	WD	WS	WD	WS	WD
0 to 1	1.4	260	2.7	180	4	220	1.4	270	4.5	200	(a)	(a)
1 to 2	0	(a)	2.7	225	5	240	1.4	270	2.7	225	↓	↓
2 to 3	0	(a)	2.3	225	4.5	240	1.4	225	4.1	225		
3 to 4	1.4	250	.9	225	3	250	1.4	225	2.3	225		
4 to 5	.5	180	1.8	225	4	250	1.8	270	1.8	225		
5 to 6	.9	220	1.4	180	3.5	200	1.8	270	2.3	225		
6 to 7	.9	250	1.8	180	3	210	1.4	270	2.7	225		
7 to 8	3.2	250	2.7	180	4.5	220	1.8	225	3.2	245		
8 to 9	1.8	250	3.2	180	5.5	240	2.3	270	3.6	270		
9 to 10	1.8	250	3.2	180	5	230	1.8	225	2.7	245		
10 to 11	1.8	250	3.6	220	5.5	230	2.3	270	4.5	200		
11 to 12	1.8	250	3.6	260	6.5	240	2.7	270	4.5	225		
12 to 13	2.3	250	4.1	270	7	270	3.6	270	5.4	225		
13 to 14	2.3	250	3.6	270	4.5	290	3.2	270	4.5	245		
14 to 15	1.8	250	2.7	310	2.5	240	1.8	315	2.7	245		
15 to 16	1.3	250	1.8	290	4	260	1.4	270	3.6	245		
16 to 17	1.3	250	2.7	220	5.5	210	1.4	315	5.4	180		
17 to 18	1.8	250	2.3	210	4.5	240	1.8	270	4.5	180		
18 to 19	.9	250	3.2	200	6	220	1.4	270	4.1	180		
19 to 20	0	(a)	2.3	200	3.5	210	1.8	255	2.7	180		
20 to 21	0	(a)	2.3	190	3	210	1.4	225	3.2	180		
21 to 22	.9	240	1.4	190	3.5	220	1.4	225	3.2	180		
22 to 23	.9	250	1.4	200	4	220	1.4	225	1.8	200		
23 to 24	.9	250	2.7	210	4.5	230	1.8	225	1.8	225		

[a]Calm winds.

TABLE 12.- Concluded

(b) August 5, 1977

Time, EDT	Stations											
	Colerain		ODU		Norfolk International Airport		Virginia School at Hampton		VIMS		Milford	
	WS	WD	WS	WD	WS	WD	WS	WD	WS	WD	WS	WD
0 to 1	1.4	250	3.2	210	4.5	230	2.3	225	1.4	225	(a)	(a)
1 to 2	.9	240	2.3	240	5	240	1.8	225	1.8	225	(a)	(a)
2 to 3	.9	250	2.3	200	3.5	230	2.3	225	2.7	225	(a)	(a)
3 to 4	1.4	250	2.3	210	5.5	240	2.3	225	3.2	225	1.8	210
4 to 5	.9	250	2.3	210	4	230	2.3	225	2.3	225	1.8	210
5 to 6	.9	250	2.3	220	4	240	2.3	225	2.3	245	(a)	(a)
6 to 7	1.8	250	2.3	220	4.5	240	2.3	225	2.7	225	(a)	(a)
7 to 8	2.3	250	2.3	220	4.5	230	2.7	225	4.5	225	1.8	210
8 to 9	1.8	250	2.7	230	5.5	230	2.3	225	5.4	245	.9	210
9 to 10	2.3	250	4.5	260	5.5	250	2.3	225	6.8	245	.9	210
10 to 11	3.2	250	4.5	250	7.5	250	3.2	225	5.4	245	3.2	210
11 to 12	3.2	260	5	250	7	250	3.6	225	6.8	245	4.5	210
12 to 13	2.7	260	5	250	6.5	250	3.2	225	6.8	225	5.4	270
13 to 14	3.2	260	5.4	250	7.5	250	2.7	225	6.3	225	.9	210
14 to 15	2.3	260	5	250	7	230	3.2	225	6.3	225	3.6	210
15 to 16	2.3	260	4.5	210	6.5	240	3.6	225	4.5	220	1.8	210
16 to 17	2.7	260	4.5	220	8	230	3.6	225	5.4	220	1.8	210
17 to 18	1.8	260	3.6	200	6.5	220	2.3	225	5.4	240	.9	210
18 to 19	.9	260	3.6	200	6	220	2.3	225	3.6	260	.9	210
19 to 20	.9	240	3.6	200	4	220	2.3	225	2.7	260	(a)	(a)
20 to 21	.9	250	2.7	200	5	210	1.8	225	3.2	210	(a)	(a)
21 to 22	1.4	250	(a)	200	5	230	1.4	225	3.2	230	(a)	(a)
22 to 23	1.4	250	(a)	210	6	230	2.3	225	2.7	220	(a)	(a)
23 to 24	1.4	250	(a)	210	6.5	220	2.7	225	3.6	230	(a)	(a)

[a]Calm winds.

TABLE 13.- ALOFT METEOROLOGICAL DATA FROM WALLOPS ISLAND, VA., ON AUGUST 4, 1977

Altitude, m	Wind speed, m/s	Wind direction, deg	Temperature, °C	
			Dry bulb	Dewpoint
(a) 0800 EDT release				
4	2	205	24	22
186	4	219	24	22
1016	7	251	19	17
1237	7	243	18	11
1592	10	252	16	9
2689	13	245	8	6
3213	15	242	5	3
4376	14	243	-2	-3
4619	14	243	-2	-6
5106	15	242	-5	-6
(b) 2000 EDT release				
4	5	180	26	23
188	4	211	26	21
957	4	285	20	17
1362	7	281	19	15
1461	7	285	20	2
1602	7	285	20	-2
3236	8	252	7	1
3438	8	252	6	-5
4214	9	275	3	-27
5932	9	261	-9	-27

TABLE 14.- ALOFT METEOROLOGICAL DATA FROM WALLOPS ISLAND, VA.,

ON AUGUST 5, 1977

Altitude, m	Wind speed, m/s	Wind direction, deg	Temperature, °C	
			Dry bulb	Dewpoint
(a) 0800 EDT release				
4	4	205	24	22
199	7	235	25	22
360	9	265	25	21
1615	11	249	17	13
2250	12	262	15	3
3251	11	263	8	1
3895	12	264	2	-1
4330	13	262	0	-9
4515	14	255	-1	-8
4853	16	253	-4	-4
4992	16	256	-6	-6
5061	16	256	-6	-20
(b) 2000 EDT release				
4	5	180	27	23
179	6	210	31	22
1610	11	267	19	16
2181	12	282	14	13
2594	13	293	12	6
3246	10	287	8	1
3558	8	285	6	3
4057	9	272	4	-26
5254	12	271	-4	-18

TABLE 15.- ALOFT METEOROLOGICAL DATA FROM CAPE HATTERAS, N.C., ON AUGUST 4, 1977

Altitude, m	Wind speed, m/s	Wind direction, deg	Temperature, °C	
			Dry bulb	Dewpoint
(a) 0800 EDT release				
4	5	220	26	23
198	13	230	25	22
833	13	241	24	17
1612	9	251	18	12
2342	9	236	12	7
2483	10	233	12	7
2907	11	245	9	7
3243	13	250	8	2
4260	14	236	1	0
4837	18	231	-2	-5
5005	19	233	-3	-11
(b) 2000 EDT release				
4	3	210	28	25
131	3	210	26	24
201	7	207	24	22
615	6	219	23	20
1239	7	227	19	16
1614	6	248	17	12
1972	6	250	15	8
2909	7	271	9	4
3245	7	260	7	1
3351	7	260	6	1
4166	9	243	0	-9
4399	8	251	-2	-3
4638	9	355	-3	-13
4801	9	255	-4	-14
5023	9	248	-5	-9

TABLE 16.- ALOFT METEOROLOGICAL DATA FROM CAPE HATTERAS, N.C., ON AUGUST 5, 1977

Altitude, m	Wind speed, m/s	Wind direction, deg	Temperature, °C	
			Dry bulb	Dewpoint
(a) 0800 EDT release				
4	2	260	26	25
219	6	264	25	24
763	7	272	23	19
1635	7	257	17	11
1889	7	245	16	11
2087	7	249	15	8
2796	9	244	11	4
3269	9	242	7	1
3788	10	244	3	0
3837	10	244	3	-5
4064	9	244	2	-8
4231	8	240	1	-8
4440	8	240	0	-6
4723	9	240	-1	-4
4846	9	242	-2	-9
(b) 2000 EDT release				
4	2	260	26	25
219	6	264	25	24
763	7	272	23	19
1635	7	257	17	11
1889	7	245	16	11
2087	7	249	15	8
2796	9	244	11	4
3269	9	242	7	1
3788	10	244	3	0
3837	10	244	3	-5
4064	9	244	2	-8
4231	8	240	1	-8
4440	8	240	0	-6
4723	9	240	-1	-4
4846	9	242	-2	-9

TABLE 17.- ALOFT METEOROLOGICAL DATA FROM GREENSBORO, N.C.,

ON AUGUST 4, 1977

Altitude, m	Wind speed, m/s	Wind direction, deg	Temperature, °C	
			Dry bulb	Dewpoint
(a) 0800 EDT release				
275	2	230	19	18
684	7	241	20	17
991	7	244	20	13
1596	3	259	16	10
2121	2	281	13	8
2854	8	251	10	3
3224	11	255	7	2
3644	13	257	4	-6
3804	13	257	3	-3
4275	11	255	1	-29
5907	8	250	-9	-39
(b) 2000 EDT release				
275	5	180	31	21
392	5	180	27	19
1607	6	217	17	16
2790	8	254	10	10
2915	8	254	6	0
3063	8	253	6	0
3237	8	245	7	-1
3893	9	230	3	-5
4045	9	235	2	-3
4147	9	235	2	-8
4422	9	237	0	-10
4475	9	237	0	-7
5037	10	256	-4	-9

TABLE 18.- ALOFT METEOROLOGICAL DATA FROM GREENSBORO, N.C.,

ON AUGUST 5, 1977

Altitude, m	Wind speed, m/s	Wind direction, deg	Temperature, °C	
			Dry bulb	Dewpoint
(a) 0800 EDT release				
275	3	210	22	22
620	11	242	23	21
1623	13	241	19	13
2089	12	244	17	8
3263	12	241	8	3
3734	11	244	5	2
4411	11	262	1	-7
4885	13	252	-2	-7
5011	13	252	-2	-14
(b) 2000 EDT release				
275	5	230	31	18
411	8	234	30	18
849	8	229	26	16
1624	9	241	18	14
1828	8	246	17	14
2047	6	251	16	10
2753	4	271	11	6
2855	5	281	11	1
3261	6	280	9	2
3922	8	272	5	-6
4152	8	264	3	-1
4191	8	264	3	-7
4414	9	260	2	-7
4521	9	255	1	-2
4710	9	255	0	-9
4876	9	250	-1	-10

TABLE 19.- ALOFT METEOROLOGICAL DATA FROM CHARLESTON, S.C.,

ON AUGUST 4, 1977

Altitude, m	Wind speed, m/s	Wind direction, deg	Temperature, °C	
			Dry bulb	Dewpoint
(a) 0800 EDT release				
13	3	360	23	22
187	5	158	25	24
721	9	198	22	21
927	9	198	22	18
1601	8	195	18	14
1856	9	196	15	11
2171	8	197	15	7
3235	9	212	7	3
4183	10	195	1	-3
4512	11	178	0	-8
4993	10	165	-3	-10
(b) 2000 EDT release				
13	4	140	29	24
199	5	170	28	24
469	5	167	25	22
624	5	167	24	20
1328	4	176	20	15
1617	4	181	18	15
2501	7	173	12	9
3252	8	176	8	1
3467	8	170	7	-3
3973	4	180	3	0
4087	4	180	2	-3
4216	2	193	2	-1
4654	2	216	-1	-10
4860	4	226	-2	-8
4971	4	226	-2	-13

TABLE 20.- ALOFT METEOROLOGICAL DATA FROM CHARLESTON, S.C.,

ON AUGUST 5, 1977

Altitude, m	Wind speed, m/s	Wind direction, deg	Temperature, °C	
			Dry bulb	Dewpoint
(a) 0800 EDT release				
13	0	140	25	24
100	0	140	27	26
215	4	172	26	24
584	6	177	23	21
740	6	170	23	16
1629	6	142	18	5
2553	9	108	11	1
2820	6	113	11	-10
3259	5	127	10	-20
3720	5	138	7	-23
3984	4	142	6	-15
4035	4	142	5	-8
4112	2	166	5	-25
5133	5	184	-1	-31
(b) 2000 EDT release				
13	5	140	30	23
113	5	140	29	23
211	7	140	28	22
701	6	150	23	20
1194	6	148	21	8
1629	6	149	18	10
2083	2	122	16	1
2297	1	146	14	5
2547	1	146	13	-1
3268	3	197	10	-20
3880	2	240	6	-24
5045	4	238	0	-30

TABLE 21.- ALOFT METEOROLOGICAL DATA FROM SPECIAL RELEASE ON AUGUST 4, 1977, AT 1030 EDT

(a) Wallops Island site

Altitude, m	Wind speed, m/s	Wind direction, deg	Temperature, °C	
			Dry bulb	Dewpoint
3	3	250	30	23
250	1	247	25	19
500	1	253	23	18
750	1	248	21	18
1000	1.5	231	20	14
1250	2	223	18	11
1500	2	222	16	9
1750	2.5	216	15	8
2000	3	216	13	8
2250	3	226	10	9
2500	3	238	9	7
2750	2.5	242	8	5
3000	2	236	7	3
3250	1.5	240	6	1
3500	1.5	249	5	0
3750	2	250	4	-1
4000	2.5	253	3	-2
4250	3	258	1	-4
4500	3.5	262	0	-13
4750	4	261	-1	-21
5000	4.5	258	-3	-23

TABLE 21.- Concluded

(b) Norfolk International Airport site

Altitude, m	Wind speed, m/s	Wind direction, deg	Temperature, °C	
			Dry bulb	Dewpoint
7	5	200	30	24
250	1.5	229	25	19
500	1	244	22	18
750	2	244	21	16
1000	3	240	19	13
1250	3.5	237	18	12
1500	3	237	17	10
1750	3	240	16	9
2000	3.5	243	14	7
2250	4	245	13	5
2500	4	248	11	4
2750	4	251	10	3
3000	4	254	9	1
3250	4	256	8	0
3500	3.5	258	6	-2
3750	3.5	259	4	-3
4000	3.5	258	2	-9
4250	4	254	2	-18
4500	4.5	249	1	-23
4750	4.5	243	-1	-25
5000	5	240	-3	-26

TABLE 22.- ALOFT METEOROLOGICAL DATA FROM SPECIAL RELEASE ON AUGUST 4, 1977, AT 1300 EDT

(a) Wallops Island site

Altitude, m	Wind speed, m/s	Wind direction, deg	Temperature, °C	
			Dry bulb	Dewpoint
3	6	180	29	23
250	1.5	209	26	18
500	1	236	24	17
750	1	252	21	16
1000	1.5	253	19	15
1250	2.5	246	16	13
1500	3	241	16	10
1750	3	241	15	8
2000	2.5	246	14	6
2250	2	256	12	5
2500	2	269	11	3
2750	2.5	277	10	2
3000	2.5	277	9	0
3250	3	275	7	-4
3500	3	274	5	-5
3750	3.5	271	3	-5
4000	3.5	267	2	-10
4250	4	261	1	-18
4500	4	256	0	-22
4750	4	256	-1	-24
5000	3.5	262	-2	-25

TABLE 22.- Concluded

(b) Norfolk International Airport site

Altitude, m	Wind speed, m/s	Wind direction, deg	Temperature, °C	
			Dry bulb	Dewpoint
7	5	260	34	21
250	3	255	31	19
500	1.5	250	27	17
750	1	230	23	17
1000	1.5	237	20	16
1250	2.5	243	18	14
1500	3	249	18	10
1750	3	253	18	9
2000	3.5	256	15	6
2250	3.5	257	14	5
2500	3.5	259	12	4
2750	3	260	11	3
3000	3	261	10	2
3250	3	261	9	-1
3500	3.5	260	7	-3
3750	4	259	6	-13
4000	4	258	4	-8

TABLE 23.- ALOFT METEOROLOGICAL DATA FROM SPECIAL RELEASE ON AUGUST 4, 1977, AT 1530 EDT

(a) Wallops Island site

Altitude, m	Wind speed, m/s	Wind direction, deg	Temperature, °C	
			Dry bulb	Dewpoint
3	4.5	170	28	23
250	1	242	26	18
500	1	260	24	17
750	1.5	275	21	17
1000	2	286	20	13
1250	2	290	19	10
1500	2	287	18	9
1750	2	279	17	7
2000	2	273	16	4
2250	2	273	14	2
2500	2.5	272	12	2
2750	2.5	267	10	0
3000	3	263	8	0
3250	3	266	6	-1
3500	3	273	4	-4
3750	3.5	273	3	-7
4000	3.5	268	3	-17
4250	3.5	265	2	-24
4500	3	262	0	-26
4750	3	260	-1	-26
5000	3	257	-3	-27

TABLE 23.- Concluded

(b) Norfolk International Airport site

Altitude, m	Wind speed, m/s	Wind direction, deg	Temperature, °C	
			Dry bulb	Dewpoint
7	3.5	230	35	21
250	1.5	237	29	18
500	1	254	25	16
750	1	263	23	16
1000	1.5	262	20	15
1250	2	262	18	15
1500	2.5	260	16	14
1750	3	262	16	8
2000	3	266	15	8
2250	2.5	266	14	6
2500	2.5	263	12	4
2750	2.5	260	11	0
3000	2.5	261	9	-1
3250	3	260	7	-2
3500	3.5	256	4	-2
3750	3.5	252	2	-3
4000	4	252	2	-6
4250	4	254	1	-14
4500	4	256	0	-12
4750	4	256	-2	-13
5000	4.5	253	-4	-16

TABLE 24.- ALOFT METEOROLOGICAL DATA FROM SPECIAL RELEASE

ON AUGUST 5, 1977, AT 1030 EDT

(a) Wallops Island site

Altitude, m	Wind speed, m/s	Wind direction, deg	Temperature, °C	
			Dry bulb	Dewpoint
3	8.5	250	32	25
250	3.5	243	27	21
500	3	242	24	18
750	3.5	244	23	17
1000	3.5	248	22	15
1250	3.5	254	20	14
1500	3.5	258	18	12
1750	3.5	258	17	10
2000	3.5	256	15	9
2250	3.5	256	13	8
2500	3.5	257	12	5
2750	4	258	10	2
3000	4	258	9	0
3250	4	257	7	0
3500	4	257	5	-1
3750	3.5	257	3	-2
4000	3.5	260	2	-1
4250	3.5	262	1	-3
4500	4	260	-1	-4
4750	4	258	-3	-6
5000	4	260	-3	-9

TABLE 24.- Concluded

(b) Norfolk International Airport site

Altitude, m	Wind speed, m/s	Wind direction, deg	Temperature, °C	
			Dry bulb	Dewpoint
7	6	240	33	24
250	2.5	246	26	20
500	2	255	23	19
750	2.5	256	21	18
1000	3	254	21	16
1250	3.5	250	20	12
1500	3.5	247	18	10
1750	3.5	246	17	8
2000	3.5	246	15	7
2250	3.5	248	14	6
2500	3	250	12	5
2750	3	254	11	4
3000	3	258	9	1
3250	3.5	260	8	0
3500	3.5	260	6	-3
3750	3	260	4	-6
4000	3.5	260	2	-7
4250	3	260	0	-8
4500	3	261	-1	-8
4750	3	258	-2	-9
5000	3.5	238	-5	-16

TABLE 25.- ALOFT METEOROLOGICAL DATA FROM SPECIAL RELEASE ON AUGUST 5, 1977, AT 1300 EDT

(a) Wallops Island site

Altitude, m	Wind speed, m/s	Wind direction, deg	Temperature, °C	
			Dry bulb	Dewpoint
3	7.5	175	28	23
250	2.5	230	28	21
500	2	260	26	20
750	2	261	24	19
1000	2.5	256	22	18
1250	2.5	251	20	17
1500	3.5	253	18	13
1750	4	258	17	10
2000	4	263	15	8
2250	4	265	14	7
2500	4	265	12	6
2750	4.5	265	10	4
3000	4.5	264	9	2
3250	4.5	263	8	0
3500	4.5	263	6	-2
3750	4.5	262	4	-3
4000	4.5	260	2	-4
4250	4	258	1	-6
4500	3.5	259	0	-10
4750	3	265	-1	-14
5000	3	272	-2	-23

TABLE 25.- Concluded

(b) Norfolk International Airport site

Altitude, m	Wind speed, m/s	Wind direction, deg	Temperature, °C	
			Dry bulb	Dewpoint
7	7	260	36	23
250	3	245	29	19
500	2.5	244	25	18
750	2.5	245	23	17
1000	2.5	250	21	17
1250	2.5	257	19	17
1500	3	260	16	15
1750	3.5	259	16	6
2000	3.5	254	15	4
2250	3.5	250	13	2
2500	3	251	12	0
2750	3	257	10	-1
3000	3.5	261	8	-3
3250	3	260	7	-3
3500	3	258	5	-4
3750	3	257	3	-5
4000	3	258	1	-8
4250	3	259	0	-10
4500	3.5	260	-2	-12
4750	3.5	261	-3	-14
5000	3.5	261	-5	-22

TABLE 26.- ALOFT METEOROLOGICAL DATA FROM SPECIAL RELEASE

ON AUGUST 5, 1977, AT 1530 EDT

(a) Wallops Island site

Altitude, m	Wind speed, m/s	Wind direction, deg	Temperature, °C	
			Dry bulb	Dewpoint
3	5	170	28	24
250	2	225	30	21
500	2	237	28	20
750	2	243	25	18
1000	2	257	23	18
1250	2	266	20	17
1500	2.5	268	18	14
1750	3	267	17	10
2000	3.5	268	15	9
2250	4	270	13	7
2500	4	272	12	4
2750	4	274	11	1
3000	4.5	274	10	-3
3250	4.5	273	8	-2
3500	4.5	270	6	-2
3750	4.5	266	4	-3
4000	4	265	3	-8
4250	3.5	267	2	-14
4500	3.5	270	1	-19
4750	3	272	-1	-21
5000	3	275	-3	-18

TABLE 26.- Concluded

(b) Norfolk International Airport site

Altitude, m	Wind speed, m/s	Wind direction, deg	Temperature, °C	
			Dry bulb	Dewpoint
7	6	250	36	23
250	3	236	31	19
500	2	241	28	18
750	2	253	25	17
1000	2	254	22	16
1250	2	256	20	16
1500	2.5	259	18	15
1750	3	262	16	11
2000	3	262	16	7
2250	3	262	14	5
2500	3	264	12	4
2750	2.5	267	11	3
3000	2.5	270	9	2
3250	2.5	270	7	1
3500	2.5	268	5	-1
3750	2.5	265	3	-4
4000	2.5	263	2	-5
4250	3	263	1	-7
4500	3	264	-1	-8
4750	3	265	-3	-16
5000	3	267	-3	-20

TABLE 27.- MIXING-LAYER HEIGHTS

AT LaRC SITE, LIDAR DATA

Time, EDT	Mixing-layer height, m
(a) August 4, 1977	
0800	300 to 400
1000	750
1100	825
1130	870
1300	990
1400	1050
1500	1080
1600	1110
(b) August 5, 1977	
0800	1140
1000	1320
1100	1320
1130	960
1300	1320
1400	1320

TABLE 28.- SURFACE OZONE HOURLY AVERAGE CONCENTRATION ON AUGUST 4, 1977

Time, EDT	Surface ozone hourly average concentration, ppb, at -									
	Colerain	ODU	Norfolk International Airport	Virginia School at Hampton	Tidewater Community College	LaRC	VIMS	Milford	Wallops Flight Center	Painter
0 to 1	31	9	5	10	15	43	29	28	43	14
1 to 2	26	18	5	10	10	40	23	32	42	24
2 to 3	26	18	11	15	5	33	17	32	40	14
3 to 4	21	21	16	10	5	40	17	32	23	24
4 to 5	21	18	11	15	5	37	23	37	24	29
5 to 6	26	18	5	15	10	38	29	30	25	29
6 to 7	21	6	0	5	15	30	17	28	25	14
7 to 8	21	3	0	10	10	33	29	28	22	24
8 to 9	26	12	11	20	10	26	34	32	33	34
9 to 10	31	24	27	25	15		46	37	38	43
10 to 11	41	33	43	35	20		57	51	50	
11 to 12	41	43	48	35	35	64	63	55	57	
12 to 13	45		54	35	45	64	68	60	61	
13 to 14	50		48	30	40	62	80	69	64	144
14 to 15	55	43	48	35	35	65	80	79	64	144
15 to 16	55	49	48	40	35	67	85	83	79	134
16 to 17	55	46	54	35	35	68	91	88	91	120
17 to 18	50	46	38	35	40	68	80	93	97	115
18 to 19	50	43	32	35	45	62	74	79	92	101
19 to 20	45	40	27	30	40	63	57	60	64	82
20 to 21	31	40	11	25	35	54	51	46	58	72
21 to 22	16	30	5	20	30	43	51	55	50	53
22 to 23	41	21	0	15	20	37	46	46	43	34
23 to 24	11	15	0	15	20	41	40	28	43	24

TABLE 29.- SURFACE OZONE HOURLY AVERAGE CONCENTRATION ON AUGUST 5, 1977

Time, EDT	Surface ozone hourly average concentration, ppb, at -									
	Colerain	ODU	Norfolk International Airport	Virginia School at Hampton	Tidewater Community College	LaRC	VIMS	Milford	Wallops Flight Center	Painter
0 to 1	31	18	5	15	15	37	34	32	42	19
1 to 2	26	18	11	15	15	40	23	32	35	14
2 to 3	21	15	11	15	15	36	23	28	28	14
3 to 4	26	21	5	15	10	35	23	23	23	29
4 to 5	21	6	5	10	10	36	23	18	21	29
5 to 6	21	6	0	10	10	32	23	18	20	29
6 to 7	16	6	0	5	5	28	23	23	21	14
7 to 8	11	6	0	5	5	18	23	28	21	19
8 to 9	16	9	16	10	0	18	34	32	26	29
9 to 10	21	27	38	20	5	26	51	46	35	43
10 to 11	36	46	48	30	15	31	63	55	49	53
11 to 12	50	27	48	30	25		68	51	56	58
12 to 13	50	30	48	35	25	59	80	60	60	72
13 to 14	55	40	48	35	25	61	80	60	64	72
14 to 15	60	30	38	35	30	57	85	65	72	86
15 to 16	65	24	38	35	20	69	85	69	83	91
16 to 17	65	24	32	35	30	63	91	65	92	96
17 to 18	60	24	38	30	30	60	80	60	84	82
18 to 19	55	27	38	30	35	60	68	55	76	86
19 to 20	45	33	27	35	40	60	57	51	70	67
20 to 21	50	21	11	25	35	57	46	46	64	58
21 to 22	45	12	0	15	35	57	46	42	53	48
22 to 23	41	9	5	15	25	57	40	42	30	43
23 to 24	31	9	11	15	20	47	34	42	27	38

TABLE 30.- DOUGLAS C-54 AIRCRAFT GRAB SAMPLE DATA

FOR CO/CH_4 ON AUGUST 4, 1977

Sample	Time of sample, hours EDT	Flight altitude, m	Concentration, ppm	
			CO	CH_4
1	0847	610	0.1	1.5
2	0847	610	2.1	1.4
3	0847	610	2.4	1.4
4	0900	518	.2	1.5
6	0945	518	.1	1.5
7	1030	518	.2	1.6
8	1051	518	.1	1.4
9	1129	518	(a)	(a)
10	1205	518	.1	1.5
12	1231	549	.1	1.5
26	1612	823	.1	1.4
27	1650	762	.2	1.5
28	1651	686	.2	1.4
29	[b]1710	686	.3	1.4
30	1735	914	.2	1.6
31	1736	914	.2	1.6
32	1737	914	(a)	(a)

[a]No data.
[b]Estimated time.

TABLE 31.- DOUGLAS C-54 AIRCRAFT GRAB SAMPLE DATA

FOR CO/CH_4 ON AUGUST 5, 1977

Sample	Time of sample, hours EDT	Flight altitude, m	Concentration, ppm	
			CO	CH_4
33	0929	686	0.2	1.6
34	1000	701	.1	1.5
35	1011	914	.2	1.5
36	1011	914	.2	1.5
37	1011	914	7.8	1.5
38	1032	671	(a)	(a)
39	1102	686	.1	1.5
40	1137	686	.1	1.5
41	1209	686	.1	1.6
42	1236	686	.1	1.5
43	1236	686	.5	1.5
61	[b]1600	671	.1	1.6
62	[b]1645	701	.1	1.7
63	1736	701	.1	1.7

[a]No data.
[b]Estimated time.

TABLE 32.- CESSNA 402 OZONE DATA IN ppb FOR LEG A' → B

Location[a]		August 4, 1977, at time, EDT, of -				August 5, 1977, at time, EDT, of -			
		0833 to 0906		1657 to 1733		0917 to 0948		1715 to 1751	
n. mi.	km	Ozone, ppb, at altitude, m, of -							
		450	900	450	900	450	900	450	900
0	0	80	77	154	139	78	54	107	97
1	1.85	81	79	154	129	82	55	107	107
2	3.70	81	77	160	134	79	63	103	106
3	5.56	82	75	148	139	79	59	102	105
4	7.41	85	73	149	139	80	57	102	100
5	9.26	83	77	151	138	76	49	104	106
6	11.11	78	73	150	137	76	60	102	99
7	12.96	78	71	162	137	77	64	102	101
8	14.82	77	73	160	129	75	61	101	105
9	16.67	70	78	162	129	83	61	100	99
10	18.52	75	75	156	132	87	61	97	101
11	20.37	76	71	156	135	85	62	100	103
12	22.22	76	76	144	135	83	59	100	106
13	24.08	77	74	147	134	87	59	98	100
14	25.93	78	68	144	134	82	61	95	98
15	27.78	76	73	152	132	95	65	91	95
16	29.63	81	65	153	135	94	62	93	92
17	31.48	84	65	148	132	95	66	94	94
18	33.34	84	70	117	132	94	68	93	94
19	34.19	81	67	126	133	89	64	93	89
20	37.04	73	66	135	133	90	60	95	93
21	38.89	74	69	123	134	86	59	95	92
22	40.74	75	71	114	136	80	60	91	88
23	42.60	75	69	115	126	85	53	89	92
24	44.45	72	70	112	126	84	58	86	92
25	46.30	75	68	116	132	81	56	86	95
26	48.15	73	69	114	126	77	62	90	95
27	50.00	80	68	114	120	75	57	85	91
28	51.86	83	70	112	116	83	55	86	89
29	53.71	77	69	113	117	89	52	93	84
30	55.56	76	68	114	112	91	49	99	85
31	57.41	77	66	115	100	81	57	96	88
32	59.26	76	66	110	94	75	50	97	92

[a]Location given in nautical miles and kilometers; 0 n. mi. = Point A'; 32 n. mi. = Point B.

TABLE 33.- CESSNA 402 OZONE DATA IN ppb FOR LEG E → F

Location[a]		August 4, 1977, at time, EDT, of -				August 5, 1977, at time, EDT, of -	
		0917 to 0947		1620 to 1648		0100 to 1029	
n. mi.	km	Ozone, ppb, at altitude, m, of -					
		450	900	450	900	450	900
0	0	65	79	85	97	78	73
1	1.85	65	78	85	96	85	74
2	3.70	65	77	94	107	79	77
3	5.56	72	73	85	109	80	80
4	7.41	67	78	92	106	79	77
5	9.26	74	77	94	100	77	80
6	11.11	68	77	96	91	76	80
7	12.96	74	75	84	91	78	80
8	14.82	74	75	91	82	78	72
9	16.67	74	74	88	78	76	48
10	18.52	78	77	90	82	76	53
11	20.37	74	76	93	82	76	51
12	22.22	70	76	95	78	77	56
13	24.08	68	77	96	81	81	55
14	25.93	67	77	97	82	87	58
15	27.78	77	76	96	87	83	61
16	29.63	74	74	87	85	90	59
17	31.48	70	75	85	81	82	59
18	33.34	59	75	90	81	80	59
19	35.19	63	69	96	84	81	54
20	37.04	69	72	96	77	80	64
21	38.89	75	72	104	79	82	64
22	40.74	71	72	109	90	84	67
23	42.60	75	71	112	89	85	73
24	44.45	76	70	112	100	86	71
25	46.30	76	71	119	106	84	75
26	48.15	77	73	121	110	84	73
27	50.00	74	71	124	106	81	73
28	51.86	73	74	118	100	84	73
29	53.71	74	67	111	105	82	74
30	55.56	73	72	111	110	78	73

[a]Location given in nautical miles and kilometers;
0 n. mi. = Point E; 30 n. mi. = Point F.

TABLE 34.- CESSNA 402 OZONE DATA IN ppb FOR LEG G → H

Location[a]		August 4, 1977, at time, EDT, of -				August 5, 1977, at time, EDT, of -	
		0951 to 1018		1550 to 1616		1426 to 1455	
n. mi.	km	Ozone, ppb, at altitude, m, of -					
		450	900	450	900	450	900
0	0	71	69	85	83	89	89
1	1.85	73	69	82	80	87	88
2	3.70	74	69	84	83	84	88
3	5.56	73	72	84	80	86	88
4	7.41	72	74	83	79	84	83
5	9.26	73	74	85	81	82	83
6	11.11	75	74	85	81	80	82
7	12.96	76	71	85	81	83	82
8	14.82	79	73	84	81	79	75
9	16.67	80	73	86	79	78	76
10	18.52	74	72	85	81	79	77
11	20.37	81	74	89	79	80	77
12	22.22	83	74	91	78	78	74
13	24.08	80	72	85	79	79	73
14	25.93	82	75	83	79	76	75
15	27.78	79	70	86	81	79	76
16	29.63	76	77	83	84	78	74
17	31.48	76	76	89	84	82	71
18	33.34	76	77	93	84	82	69
19	35.19	72	76	97	89	83	73
20	37.04	74	77	96	90	86	80
21	38.89	71	76	101	91	80	80
22	40.74	69	77	102	95	83	75
23	42.60	79	77	102	97	76	72
24	44.45	69	75	102	93	77	71
25	46.30	60	76	99	91	80	71
26	48.15	67	80	101	97	78	70

[a]Location given in nautical miles and kilometers;
0 n. mi. = Point G; 26 n. mi. = Point H.

TABLE 35.- CESSNA 402 OZONE DATA IN ppb FOR LEG I → J

Location[a]		August 4, 1977, at time, EDT, of -				August 5, 1977, at time, EDT, of -	
		1027 to 1101		1509 to 1544		1039 to 1117	
n. mi.	km	Ozone, ppb, at altitude, m, of -					
		450	900	450	900	450	900
0	0	74	65	82	70	76	66
1	1.85	80	69	82	75	74	68
2	3.70	79	70	87	78	71	55
3	5.56	83	72	81	76	68	64
4	7.41	88	72	86	79	65	52
5	9.26	88	74	86	78	68	61
6	11.11	80	75	87	76	68	63
7	12.96	86	74	83	78	60	62
8	14.82	80	72	84	75	65	62
9	16.67	80	72	86	80	69	54
10	18.52	78	70	87	79	74	60
11	20.37	71	73	87	79	77	68
12	22.22	75	75	92	86	80	58
13	24.08	71	75	97	88	74	60
14	25.93	67	74	92	83	77	69
15	27.78	68	73	88	86	74	59
16	29.63	74	72	83	86	71	59
17	31.48	70	72	81	85	68	61
18	33.34	69	75	76	79	71	53
19	35.19	70	73	79	74	67	61
20	37.04	72	76	78	74	72	62
21	38.89	73	73	78	72	70	61
22	40.14	72	75	80	73	71	60
23	42.60	70	75	82	74	73	58
24	44.45	68	73	78	75	71	72
25	46.30	64	77	79	72	74	61
26	48.15	70	77	76	71	72	64
27	50.00	67	77	79	71	73	63
28	51.86	69	79	76	75	79	58
29	53.71	66	76	79	70	77	63
30	55.56	63	80	75	72	76	76
31	57.42	63	78	77	73	79	76
32	59.27	66	79	77	72	74	70
33	61.12	66	77	79	69	77	72
34	62.98	65	79	77	68	75	72
35	64.83	70	78	77	72	74	71
36	66.68	69	77	75	71	78	74
37	68.53	65	80	80	71	76	72
38	70.38	68	81	77	75	79	72
39	72.24	64	79	75	73	74	72
40	74.09	72	81	75	72	71	73

[a]Location given in nautical miles and kilometers;
0 n. mi. = Point I; 40 n. mi. = Point J.

TABLE 36.- CESSNA 402 OZONE DATA IN ppb FOR LEG K → L

Location[a]		August 4, 1977, at time, EDT, of -				August 5, 1977, at time, EDT, of -	
		1112 to 1132		1440 to 1500		1347 to 1407	
n. mi.	km	Ozone, ppb, at altitude, m, of -					
		450	900	450	900	450	900
0	0	67	65	74	66	64	60
1	1.85	68	67	76	69	68	60
2	3.70	73	65	74	72	71	58
3	5.56	66	67	76	71	72	58
4	7.41	67	67	76	69	75	62
5	9.26	68	67	74	70	76	67
6	11.11	68	71	72	71	78	61
7	12.96	75	73	76	66	85	67
8	14.82	73	73	75	70	78	69
9	16.67	70	72	74	67	76	68
10	18.52	68	71	77	71	76	65
11	20.37	61	72	76	70	74	61
12	22.22	66	74	80	69	70	60
13	24.08	65	76	82	70	71	60
14	25.93	56	72	83	79	68	60
15	27.78	58	69	88	75	63	54
16	29.63	59	71	87	81	62	50
17	31.48	69	72	84	76	61	49
18	33.34	66	70	80	80	65	55
19	35.19	67	68	78	76	65	48
20	37.04	68	68	69	68	67	55

[a]Location given in nautical miles and kilometers;
0 n. mi. = Point K; 20 n. mi. = Point L.

TABLE 37.- CESSNA 402 OZONE DATA IN ppb FOR LEG M → N

Location[a]		August 4, 1977, at time, EDT, of -				August 5, 1977, at time, EDT, of -	
		1139 to 1207		1356 to 1424		1134 to 1202	
n. mi.	km	Ozone, ppb, at altitude, m, of -					
		450	900	450	900	450	900
0	0	76	64	71	65	81	63
1	1.85	69	71	72	68	77	59
2	3.70	73	68	72	65	76	67
3	5.56	67	58	73	61	78	58
4	7.41	69	62	70	64	78	66
5	9.26	66	62	75	62	77	60
6	11.11	68	66	75	62	76	62
7	12.96	62	63	75	63	76	65
8	14.82	62	65	75	65	71	69
9	16.67	64	67	75	64	73	71
10	18.52	63	60	75	65	77	66
11	20.37	65	68	75	62	76	64
12	22.22	63	76	70	64	79	66
13	24.08	65	69	71	62	85	61
14	25.93	65	71	69	64	80	63
15	27.78	66	73	68	62	82	69
16	29.63	65	63	64	61	84	51
17	31.48	66	63	63	60	93	64
18	33.34	68	66	63	57	86	80
19	35.19	69	63	62	55	89	81
20	37.04	60	60	68	55	93	74
21	38.89	70	63	64	53	90	63
22	40.74	65	72	63	54	85	80
23	42.60	69	74	66	55	87	94
24	44.45	72	72	63	57	85	86
25	46.30	75	78	66	43	83	90
26	48.15	72	84	67	51	93	88
27	50.00	69	71	70	51	83	86
28	51.86	74	66	67	42	84	85
29	53.71	66	63	68	42	80	70
30	55.56	72	62	67	46	78	69

[a]Location given in nautical miles and kilometers;
0 n. mi. = Point M; 30 n. mi. = Point N.

TABLE 38.- CESSNA 402 OZONE DATA FOR LEGS A → B, C → D, and R → S

ON AUGUST 5, 1977

Location		Leg[a] A → B at time, EDT, of -		Leg[b] C → D at time, EDT, of -		Leg[c] R → S at time, EDT, of -	
		1539 to 1621		1504 to 1534		1636 to 1703	
n. mi.	km	Ozone, ppb, at altitude, m, of -					
		450	900	450	900	450	900
0	0	108		104	94	132	114
1	1.85	114		109	100	133	111
2	3.70	102		106	102	126	114
3	5.56	111		106	107	124	114
4	7.41	107		103	107	135	120
5	9.26	113		107	102	131	117
6	11.11	120		102	107	122	116
7	12.96	113		97	104	125	112
8	14.82	119		98	108	128	109
9	16.67	125		93	101	120	111
10	18.52	123		98	103	121	109
11	20.37	117		98	101	122	112
12	22.22	119		95	99	121	109
13	24.08	117		96	101	125	115
14	25.73	114		93	96	124	107
15	27.78	122		96	93	127	119
16	29.63	119		91	95	126	116
17	31.48	112		91	93	130	117
18	33.34	113		89	98	125	119
19	35.19	109		82	99	123	114
20	37.04	105	101	83	95	125	113
21	38.89	108	102	86	92	121	113
22	40.74	104	100	85	91	119	109
23	42.60	109	103	92	91	119	110
24	44.45	108	94	86	78	112	111
25	46.30	108	104	93	81		
26	48.15	113	99	87	79		
27	50.00	120	101	98	77		
28	51.56	132	102	99	75		
29	53.71	128	107	105	97		
30	55.56	118	102	109	102		
31	57.41	122	104				
32	59.26	115	104				
33	61.12	115	109				
34	62.98	107	124				
35	64.83	108	119				
36	66.68	109	127				
37	68.53	112	133				
38	70.38	108	119				
39	72.24	107	115				
40	74.09	108	108				
41	75.94	104	106				
42	77.79	102	103				
43	79.65	102	107				
44	81.50	99	105				
45	83.35	100	101				
46	85.20	102	101				
47	87.05	100	99				
48	88.91	97	102				
49	90.76	102	96				
50	92.61	107	97				
51	94.46	95	98				
52	96.32	100	96				

[a]0 n. mi. = Point A; 20 n. mi. = Point A'; 52 n. mi. = Point B.
[b]0 n. mi. = Point C; 30 n. mi. = Point D.
[c]0 n. mi. = Point R; 24 n. mi. = Point S.

TABLE 39.- AIRCRAFT DATA FOR NO/NO_x

(a) August 4, 1977

Flight leg	Time, EDT	Altitude, m	Average concentration, ppb, for leg	
			NO	NO_x
A → B	0833	910	40 ± 6	44 ± 6
	0849	460	34 ± 4	54 ± 6
E → F	0917	910	26 ± 4	36 ± 4
	0931	460	30 ± 6	44 ± 6
G → H	0951	910	26 ± 6	38 ± 6
	1003	460	30 ± 8	44 ± 10
	1550	910	18 ± 6	30 ± 8
I → J	1026	910	24 ± 8	36 ± 10
	1043	460	26 ± 4	36 ± 10
	1509	910	24 ± 8	32 ± 8
	1525	460	26 ± 6	30 ± 10
K → L	1112	910	26 ± 4	30 ± 6
	1440	910	24 ± 4	30 ± 4
	1449	460	20 ± 10	36 ± 8
M → N	1355	910	30 ± 4	34 ± 4
	1411	460	32 ± 8	40 ± 8

TABLE 39.- Concluded

(b) August 5, 1977

Flight leg	Time, EDT	Altitude, m	Average concentration, ppb, for leg	
			NO	NO_x
A → B	0916	910	34 ± 4	40 ± 6
	0930	460	34 ± 6	44 ± 6
	1539	910	20 ± 6	30 ± 8
	1554	460	20 ± 10	26 ± 8
	1714	910	20 ± 12	24 ± 14
	1729	460	18 ± 10	24 ± 10
C → D	1504	910	22 ± 8	32 ± 10
	1517	460	22 ± 8	36 ± 14
E → F	0959	910	25 ± 6	34 ± 8
	1013	460	24 ± 8	40 ± 10
G → H	1426	910	26 ± 8	34 ± 12
	1438	460	24 ± 10	34 ± 12
I → J	1039	910	24 ± 10	34 ± 8
	1056	460	24 ± 8	42 ± 10
K → L	1348	910	-------	-------
	1357	460	30 ± 6	36 ± 8
M → N	1134	910	24 ± 10	36 ± 12
	1147	460	24 ± 8	42 ± 8
R → S	1636	910	20 ± 10	24 ± 12
	1648	460	20 ± 8	24 ± 10

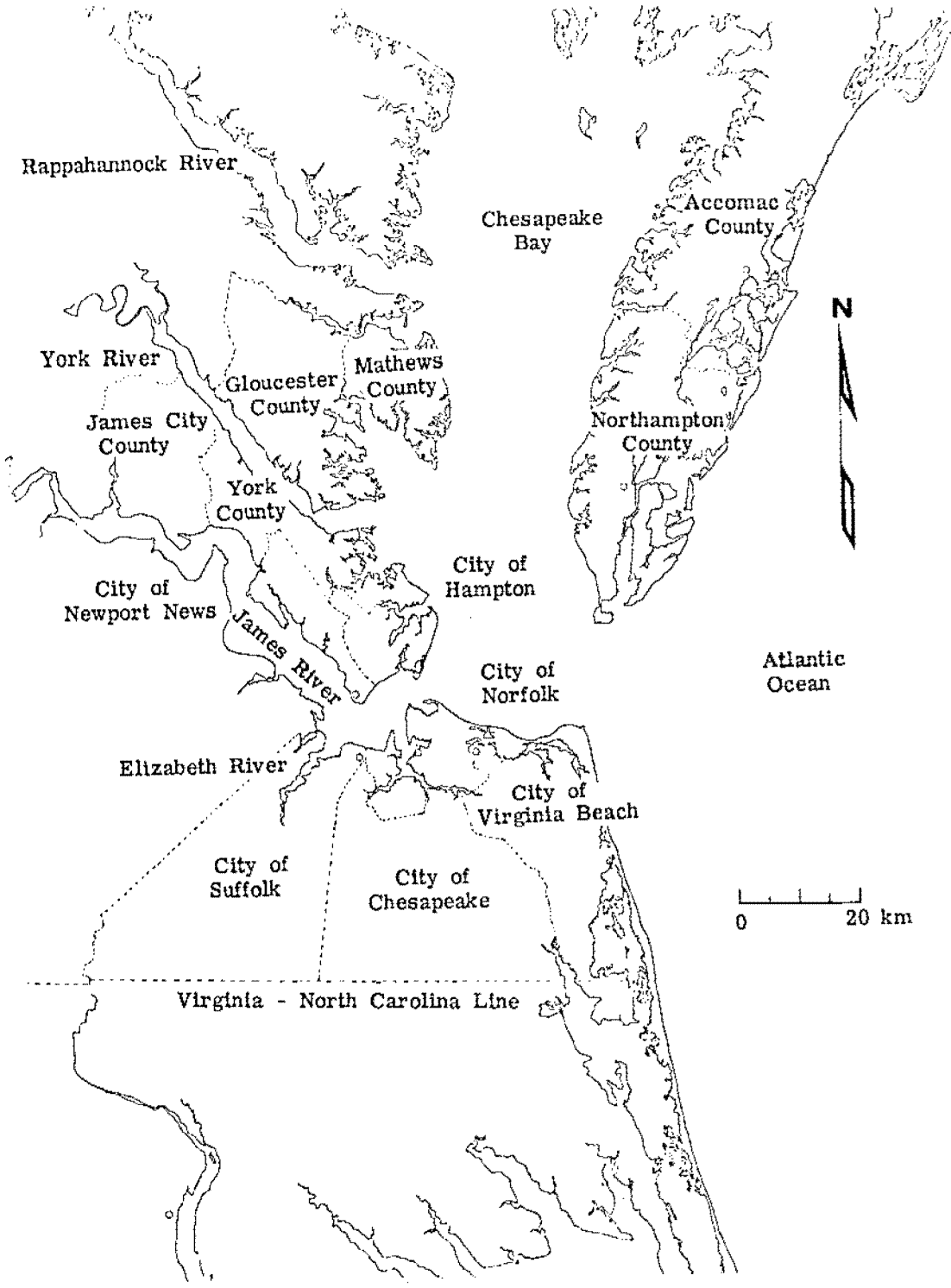

Figure 1.- Southeastern Virginia urban plume study area.

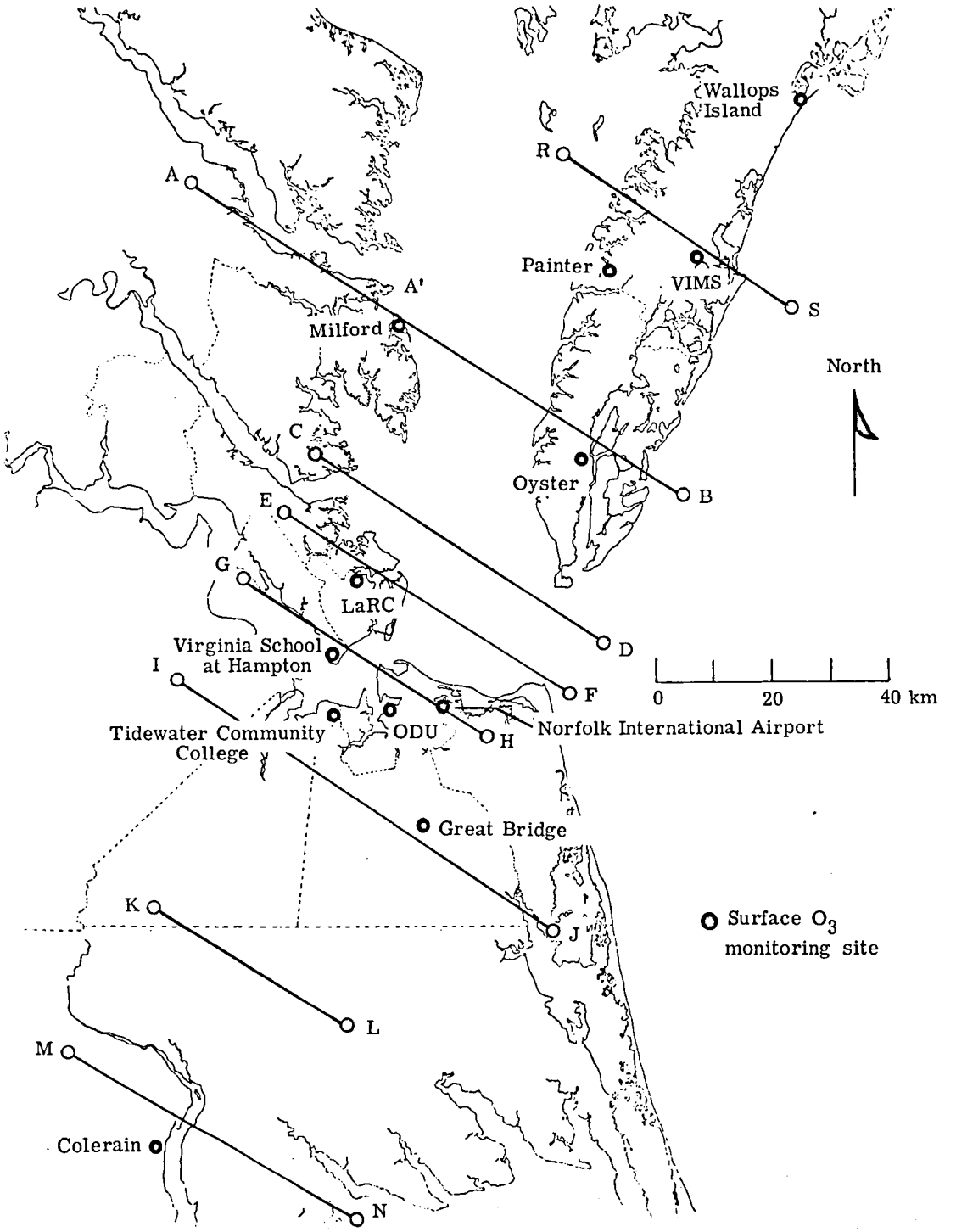

Figure 2.- Monitoring sites and flight legs.

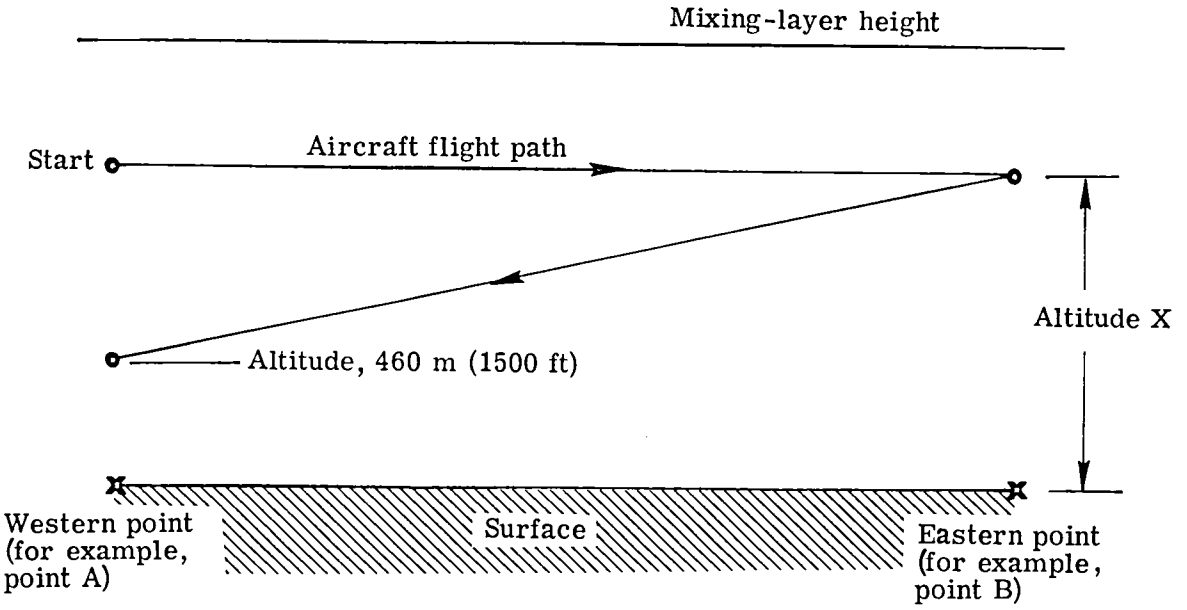

Figure 3.- Douglas C-54 sampling pattern.

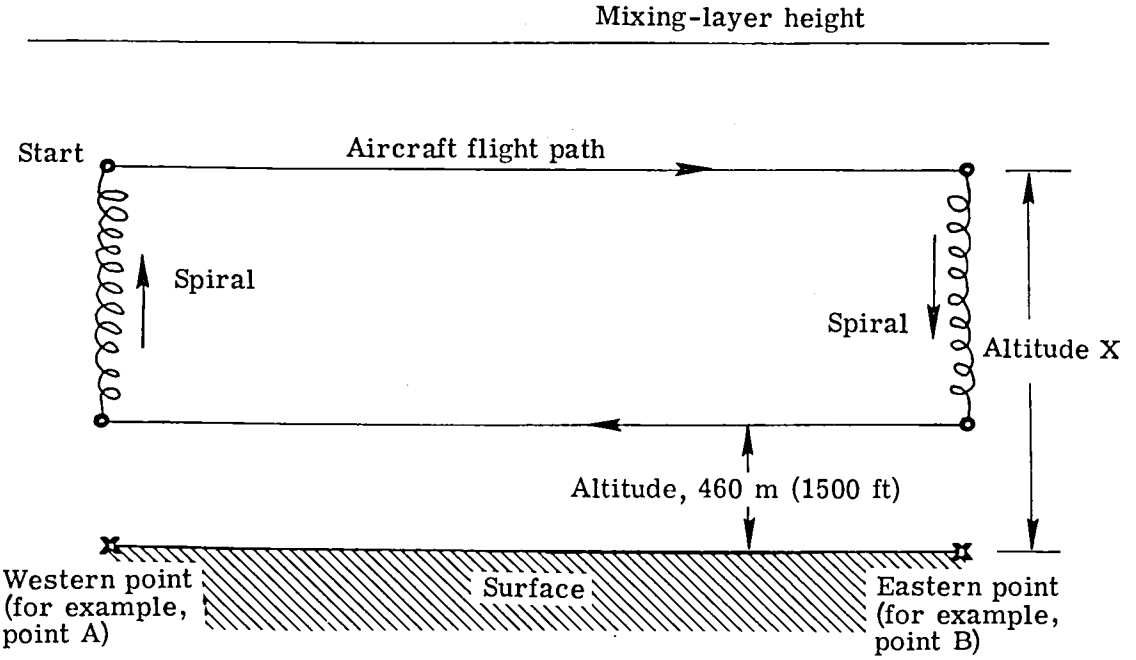

Figure 4.- Cessna 402 sampling pattern.

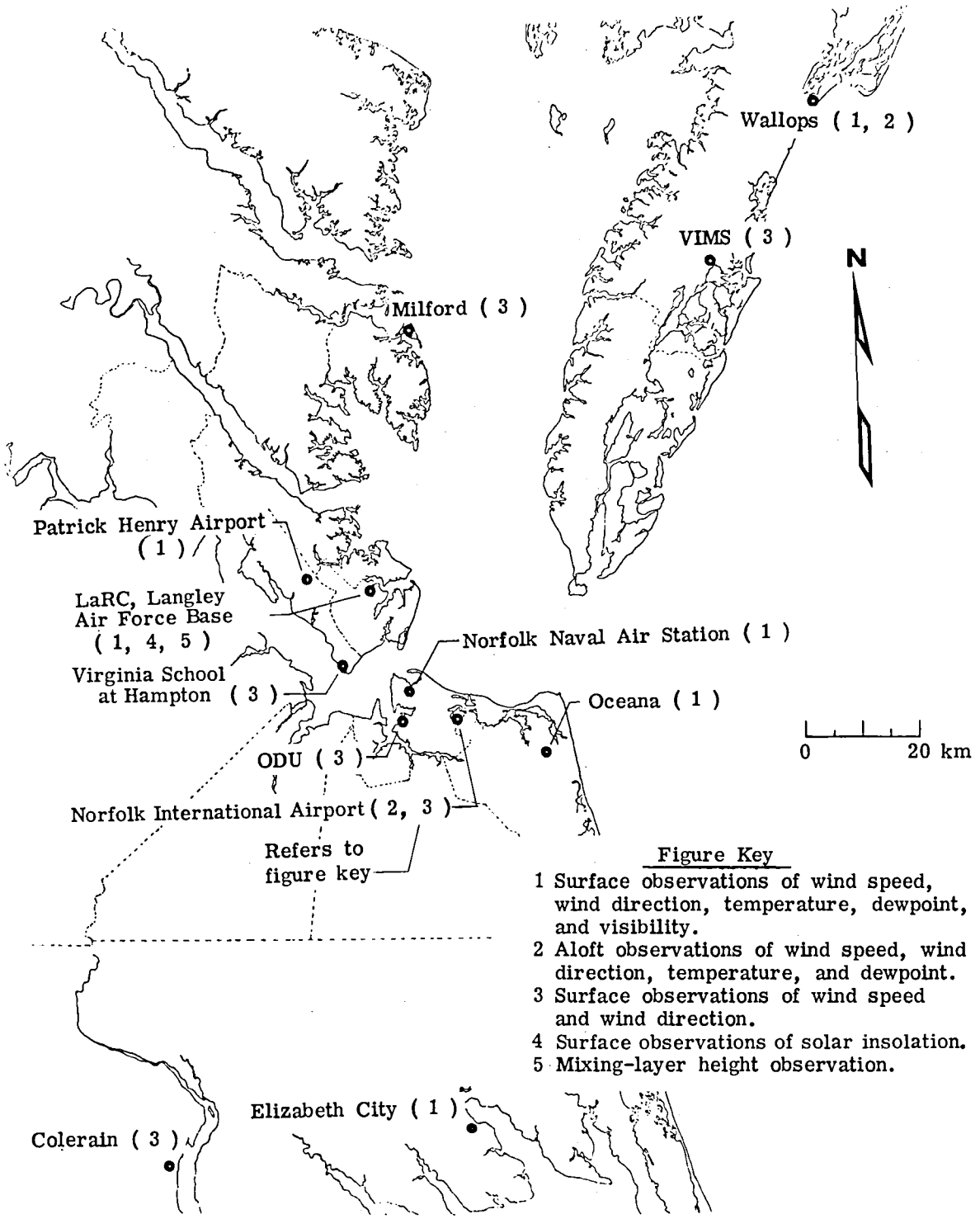

Figure 5.- Meteorological data sites.

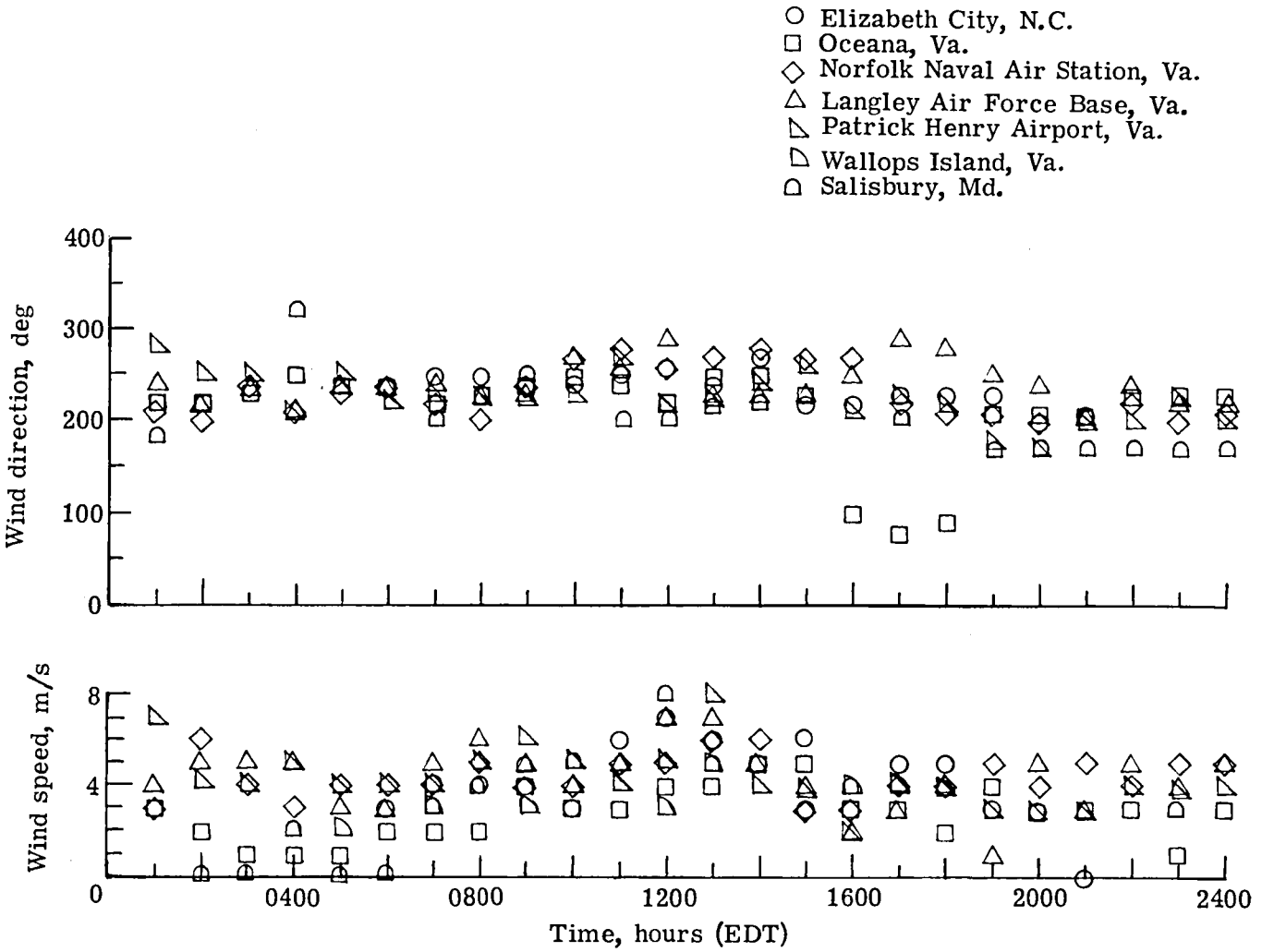

Figure 6.- Surface wind hourly averaged data from National Weather Service, August 4, 1977.

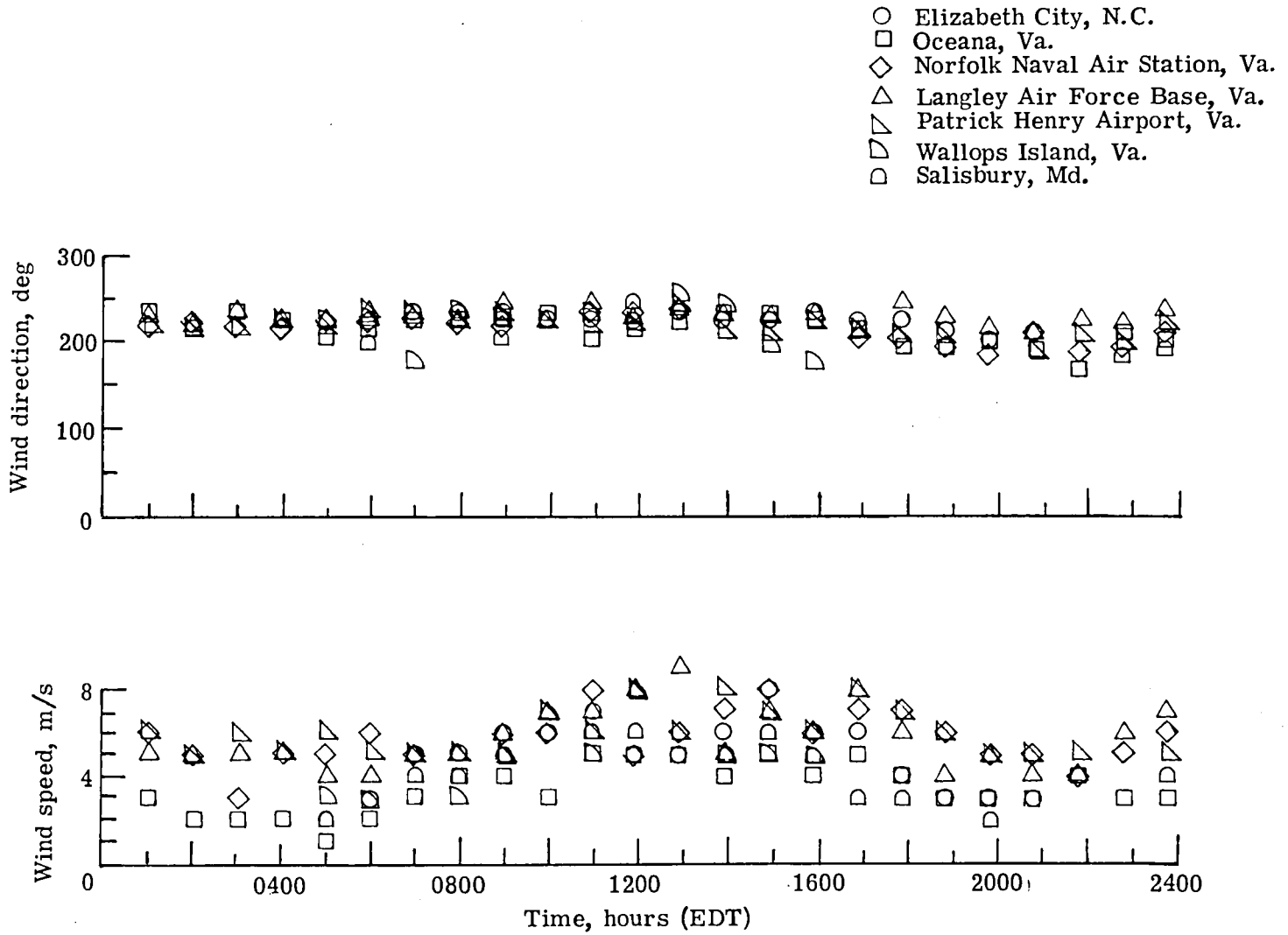

Figure 7.- Surface wind hourly averaged data from National Weather Service, August 5, 1977.

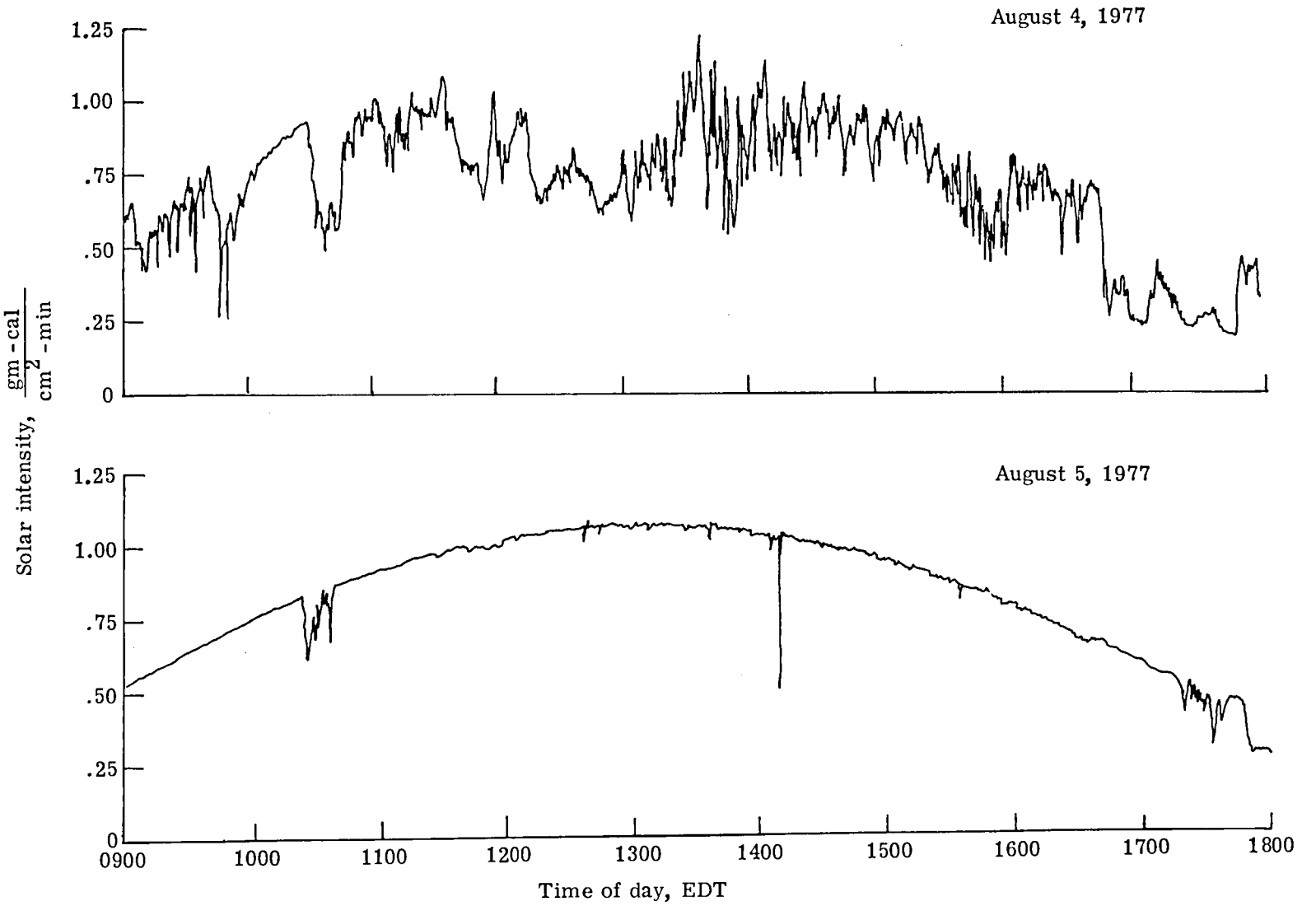

Figure 8.- Solar insolation data; Langley Air Force Base site.

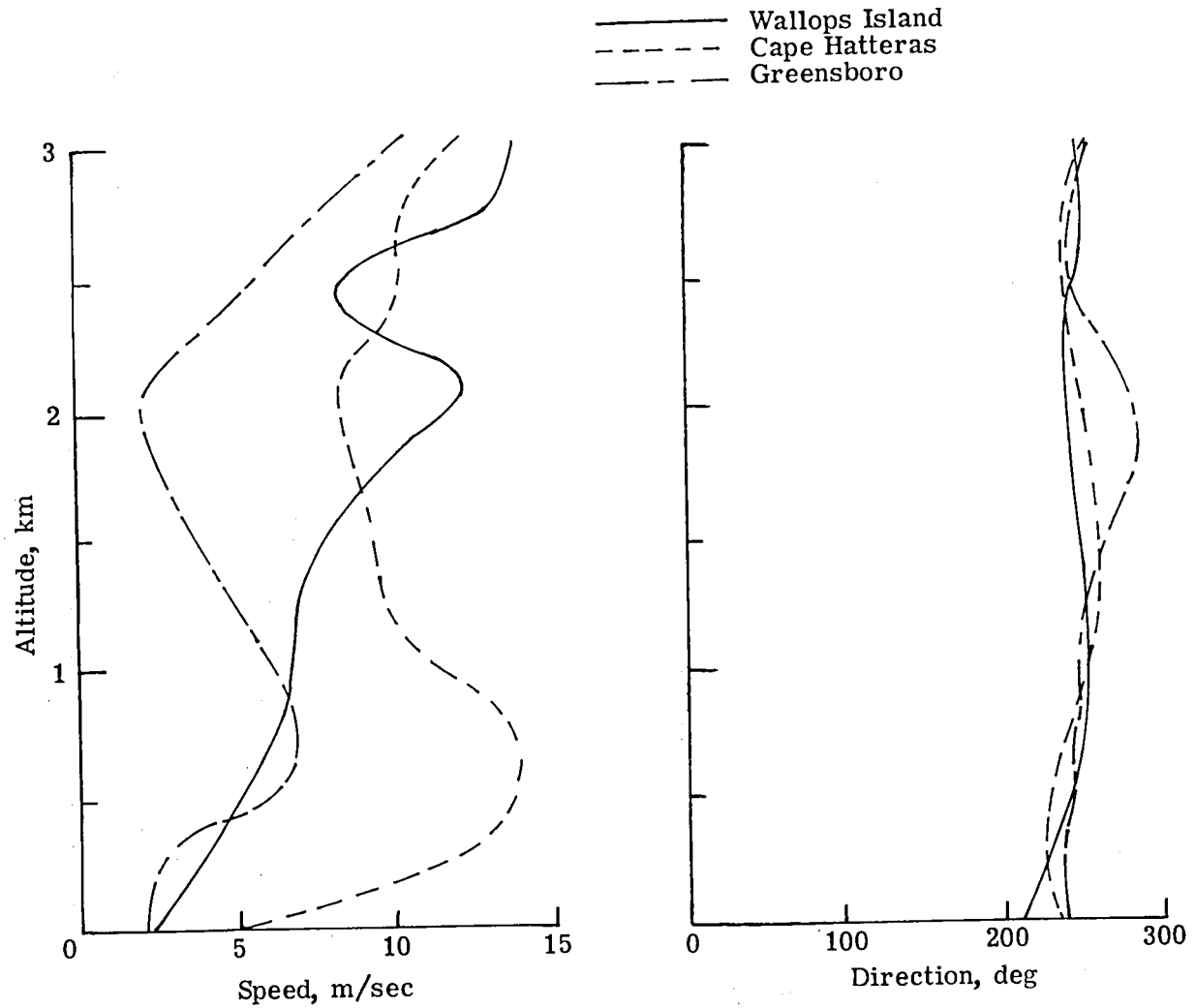

Figure 9.- Winds aloft data from release at 0800 EDT on August 4, 1977.

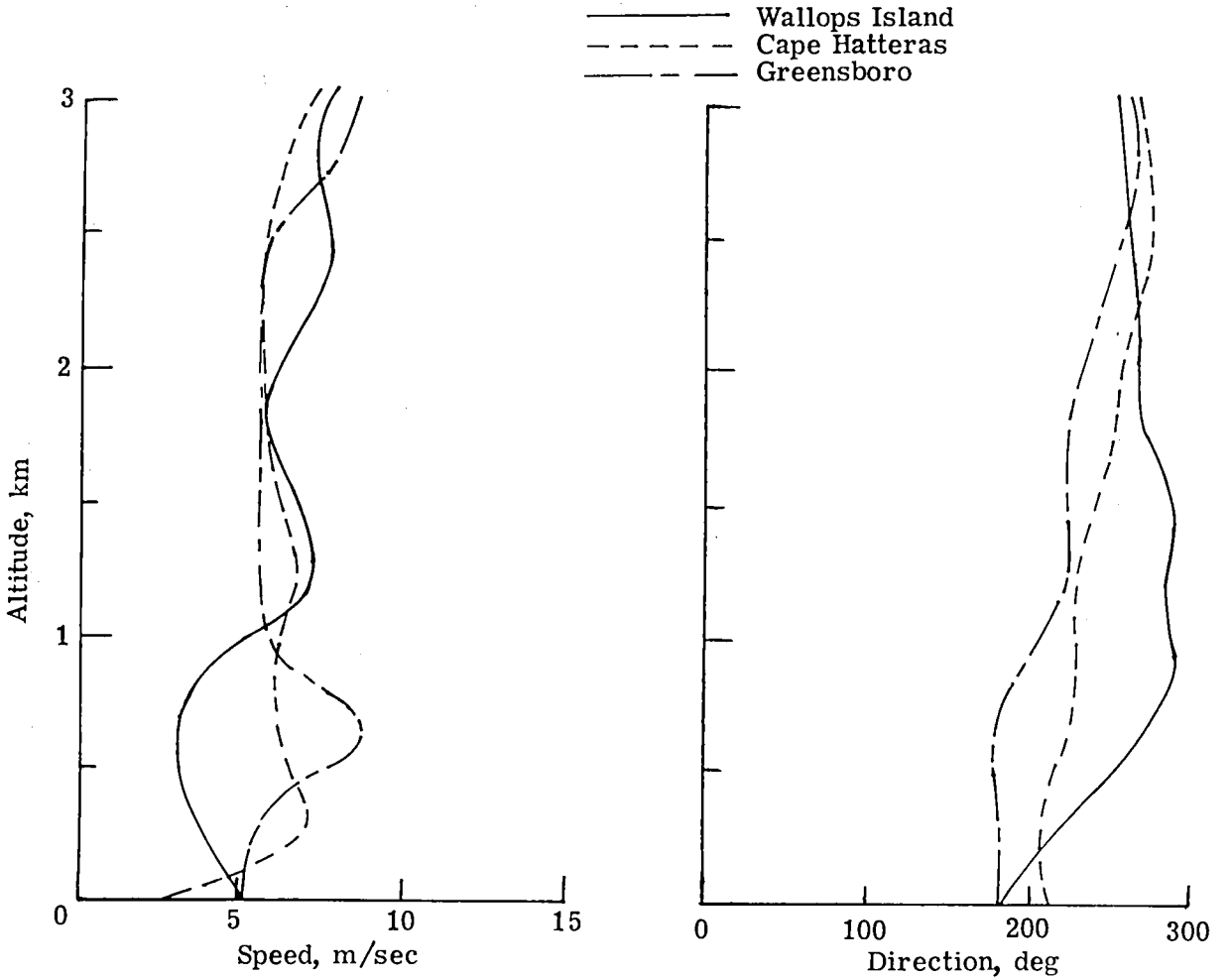

Figure 10.- Winds aloft data from release at 2000 EDT on August 4, 1977.

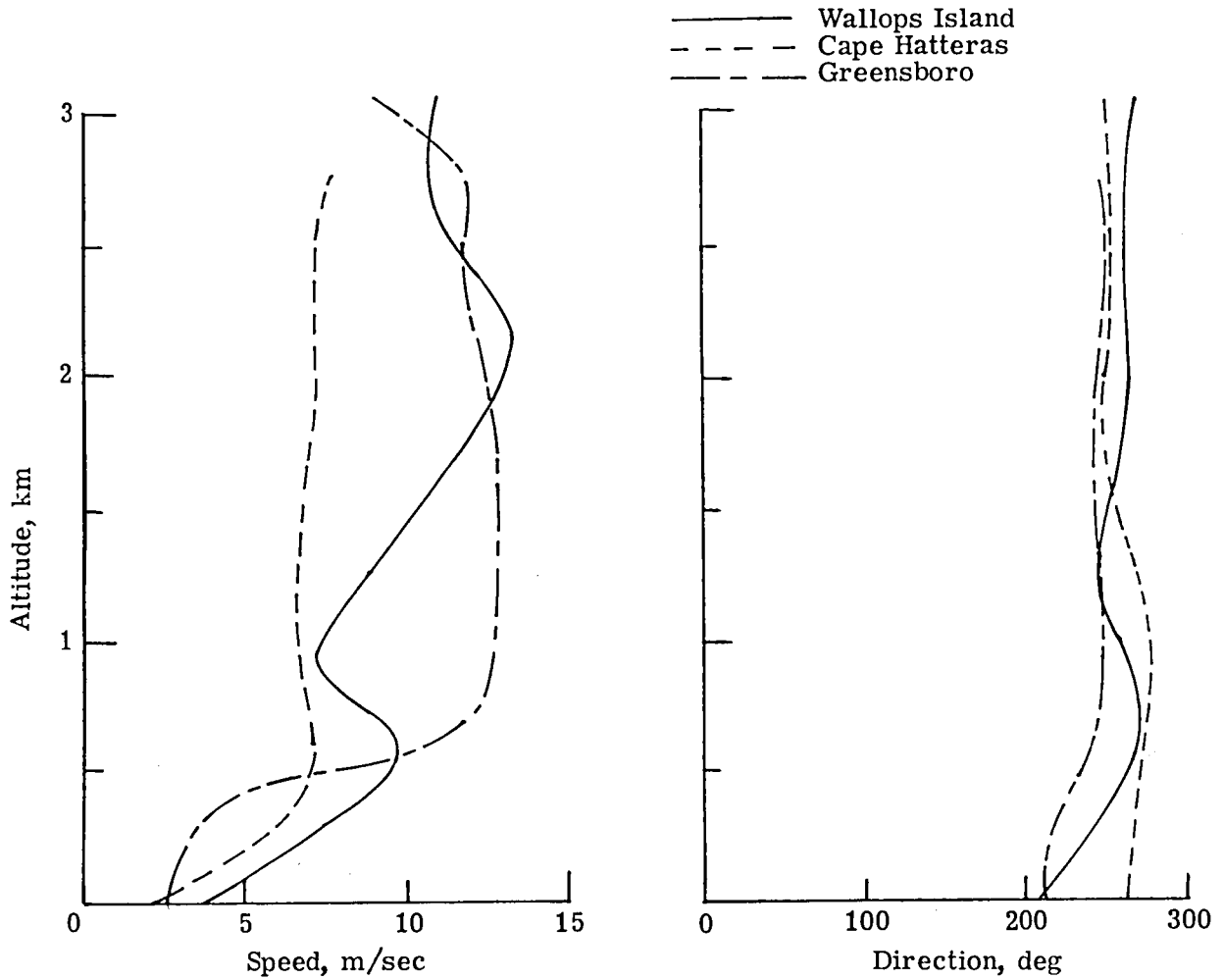

Figure 11.- Winds aloft data from release at 0800 EDT on August 5, 1977.

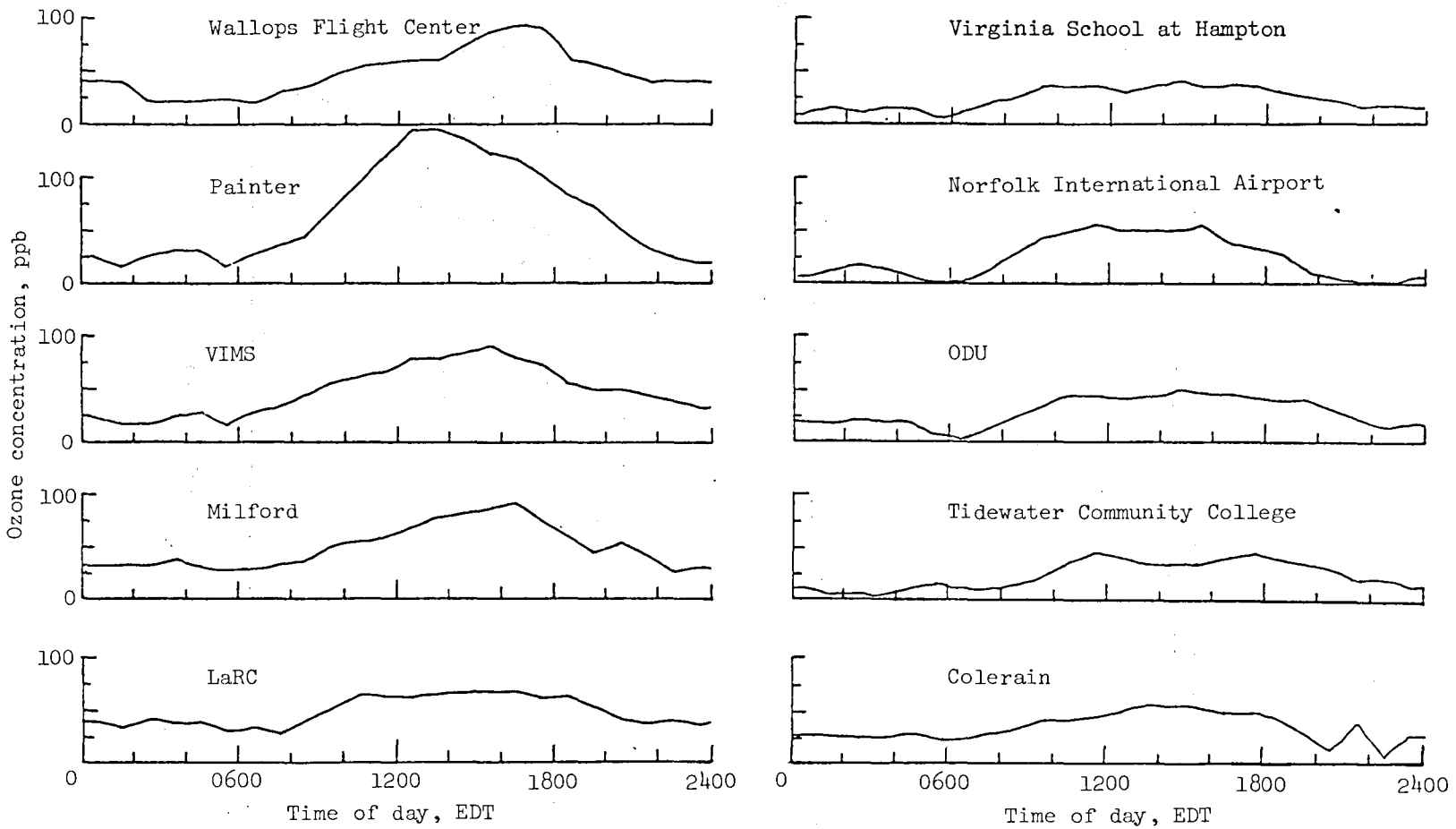

Figure 12.- Hourly ozone data; August 4, 1977.

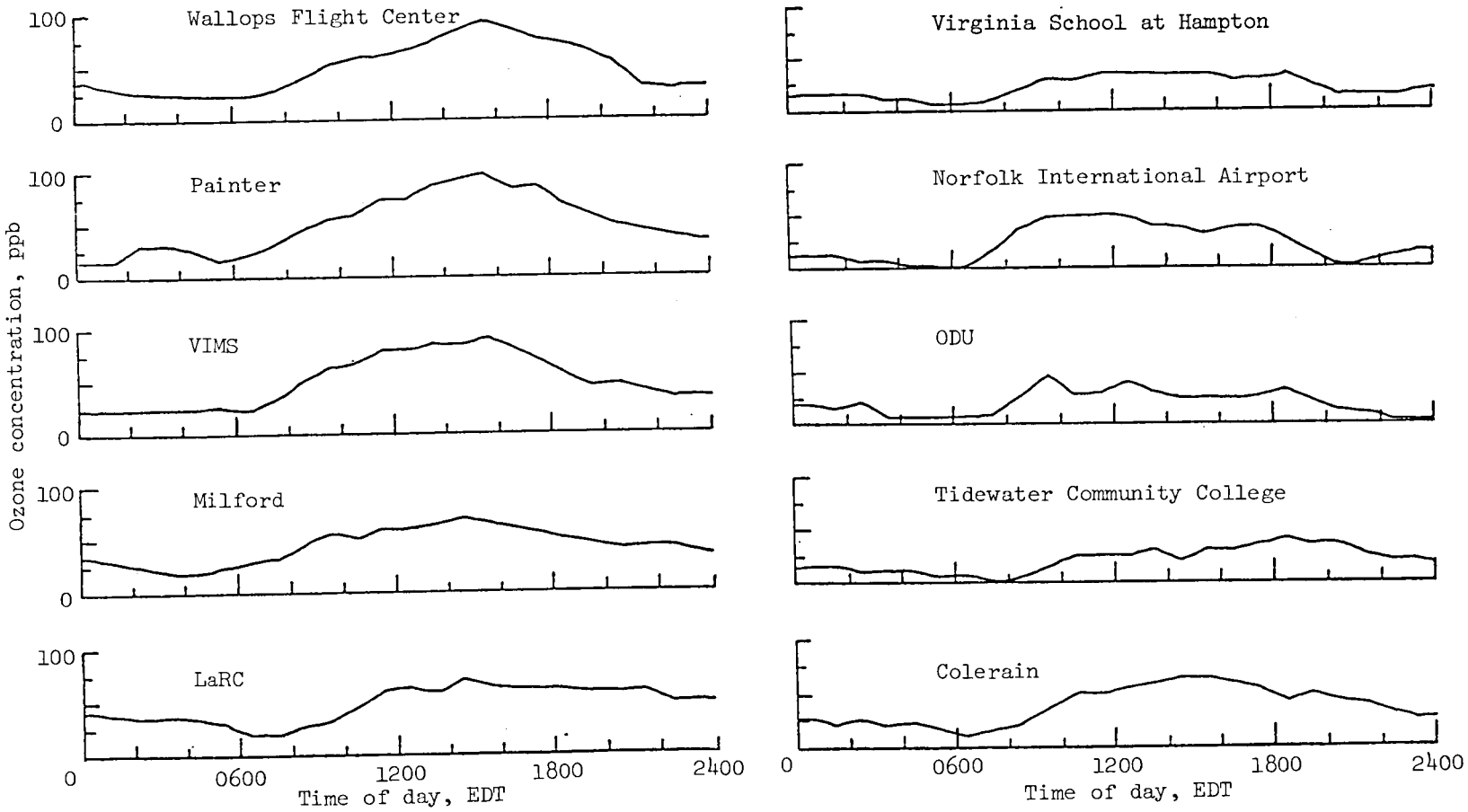

Figure 13.- Hourly ozone data; August 5, 1977.

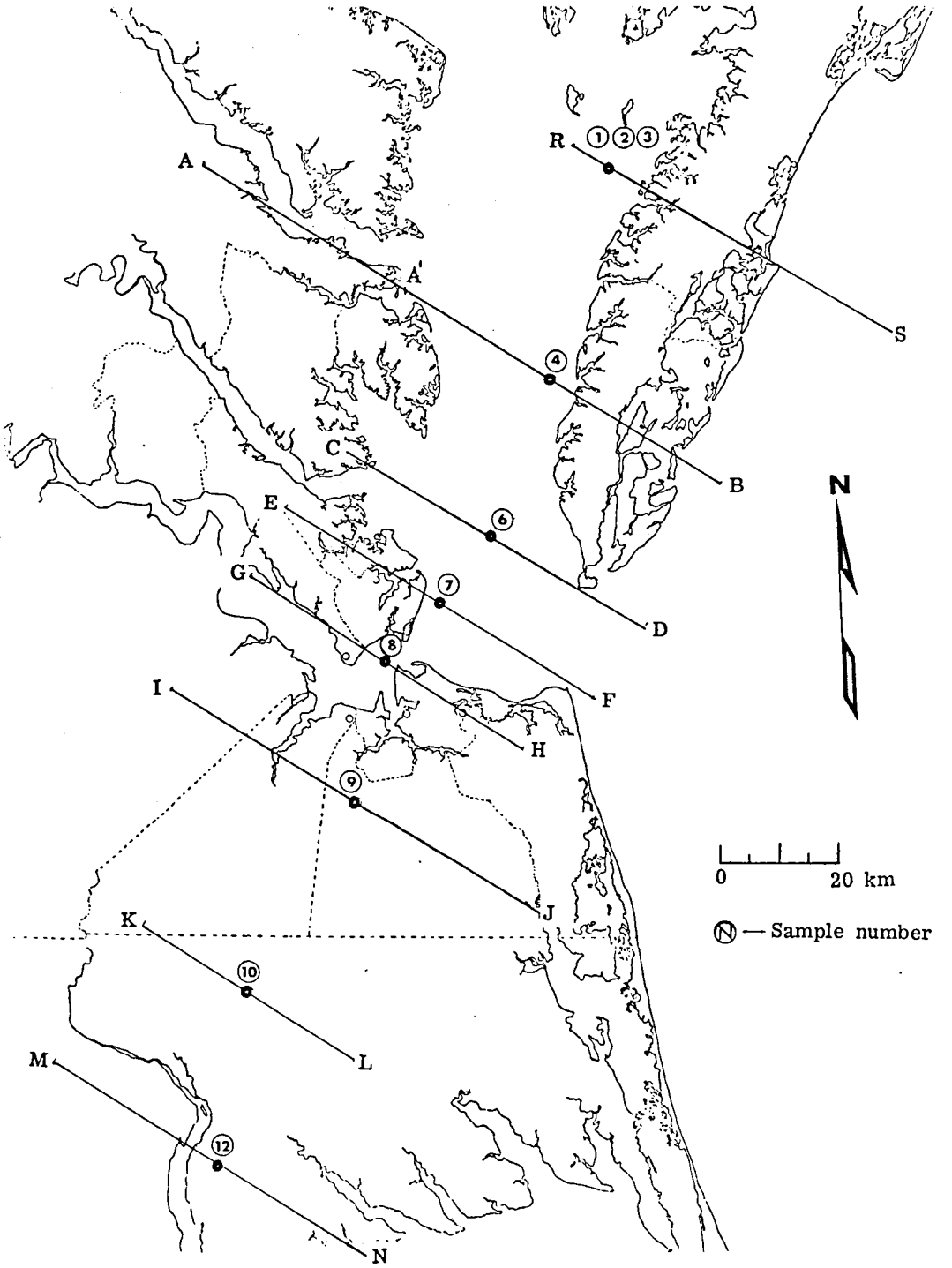

Figure 14.- Location of grab sample measurements for CO/CH_4; morning flight of August 4, 1977.

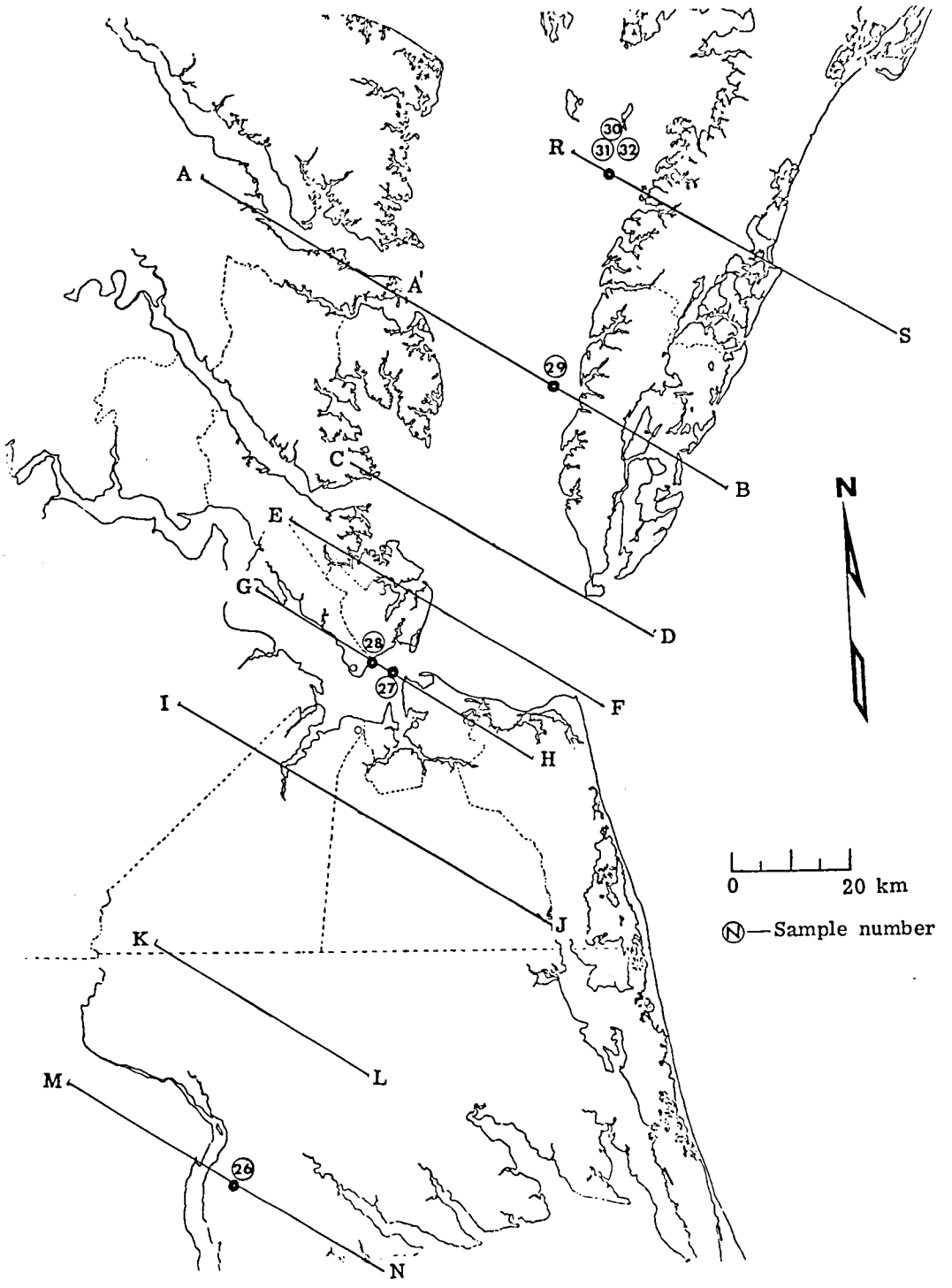

Figure 15.- Location of grab sample measurements for a CO/CH_4; afternoon flight of August 4, 1977.

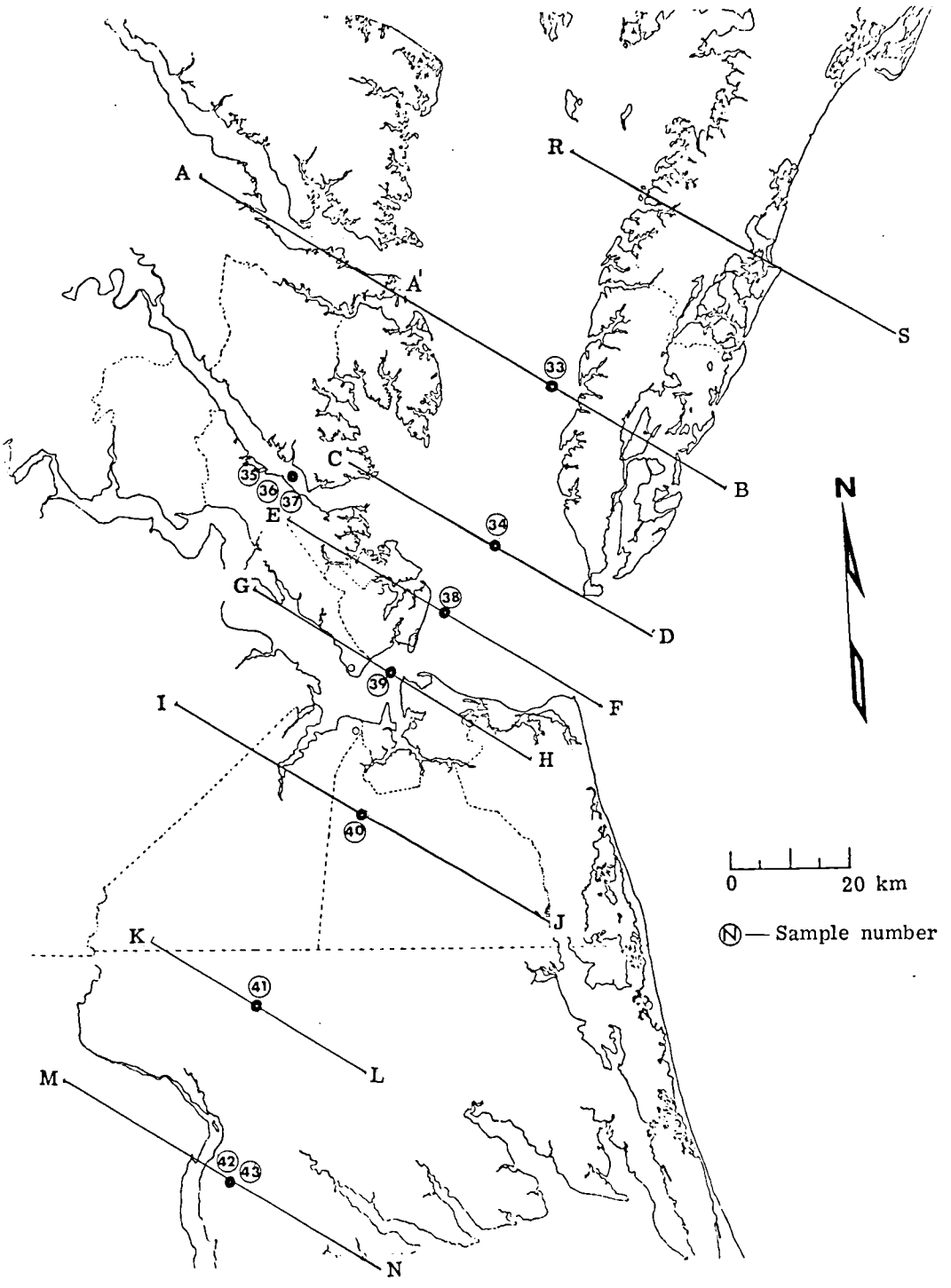

Figure 16.- Location of grab sample measurements for CO/CH_4; morning flight of August 5, 1977.

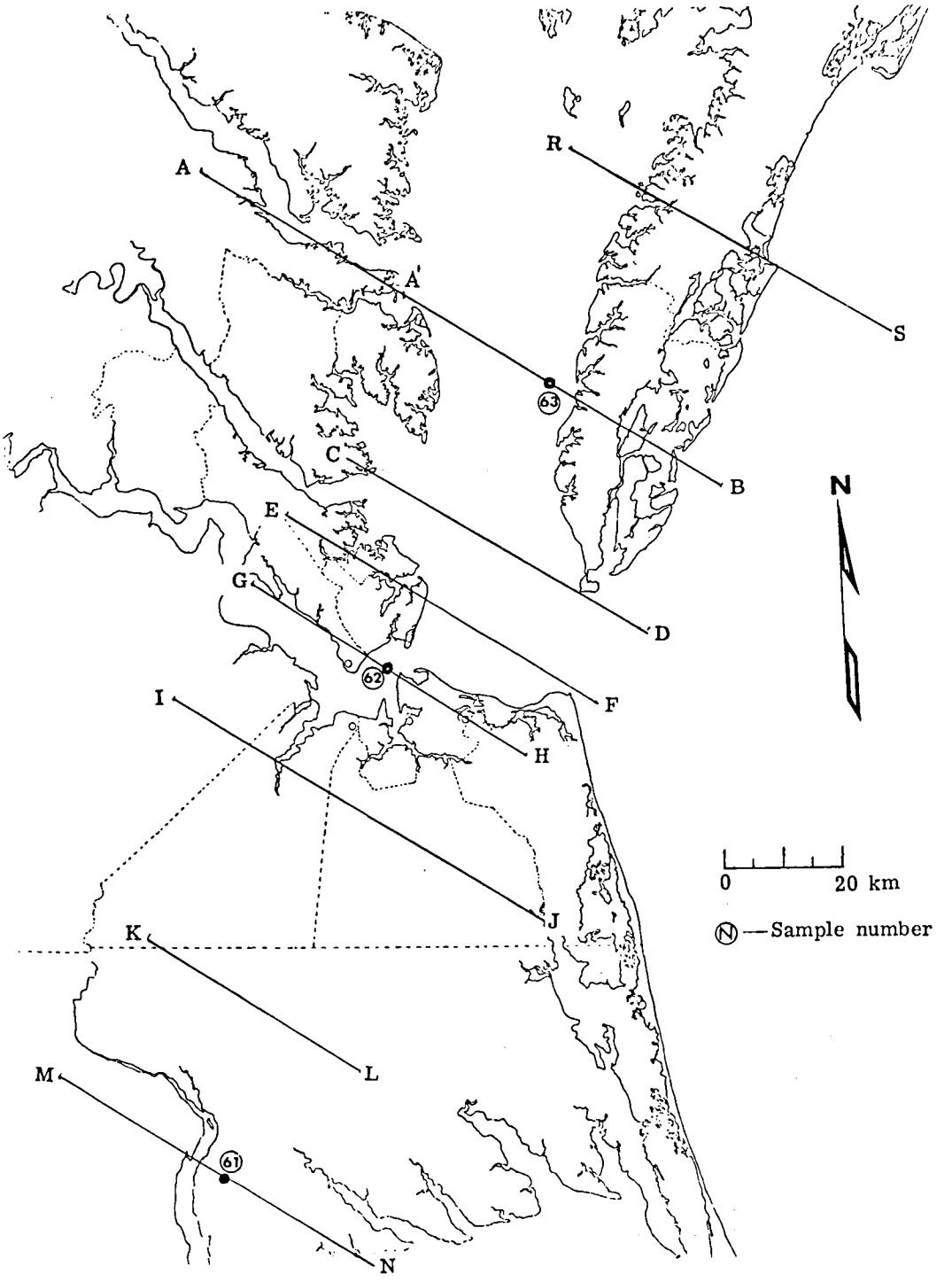

Figure 17.- Location of grab sample measurements for CO/CH_4; afternoon flight of August 5, 1977.

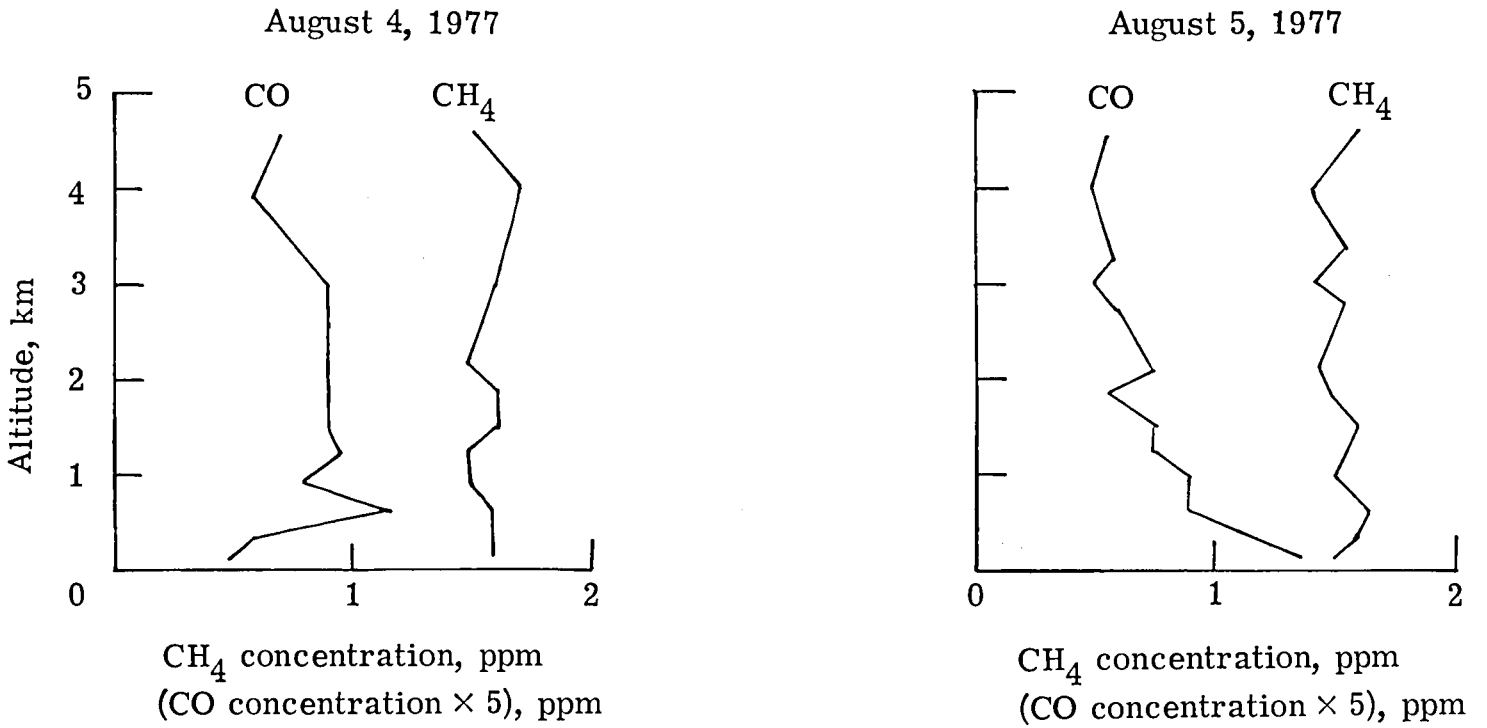

Figure 18.- Altitude profile for Douglas C-54 over site at Langley Air Force Base (1230 to 1330 EDT) during grab sample measurements for CO/CH_4.

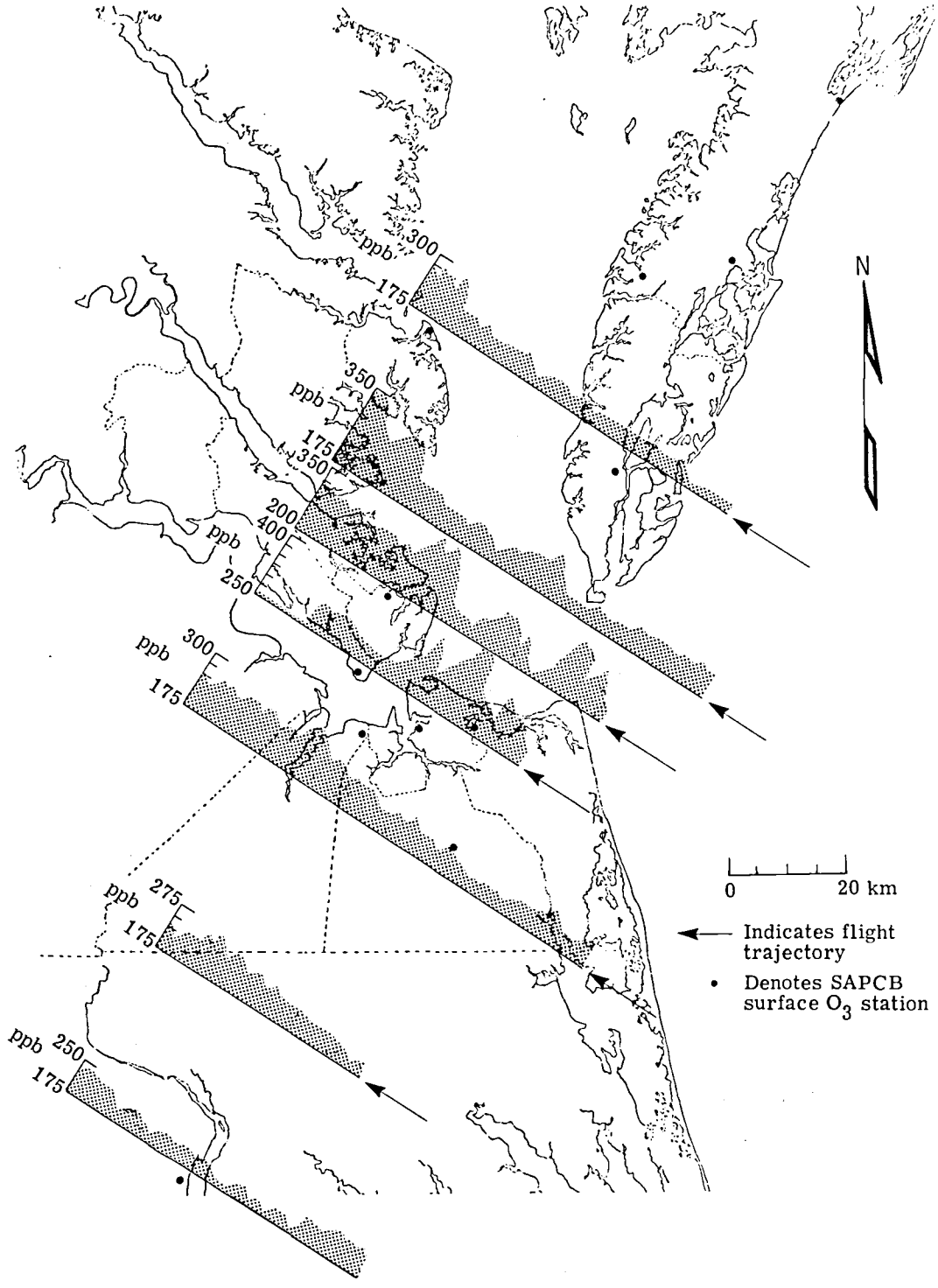

Figure 19.- DACOM CO data from morning flight of August 4, 1977.

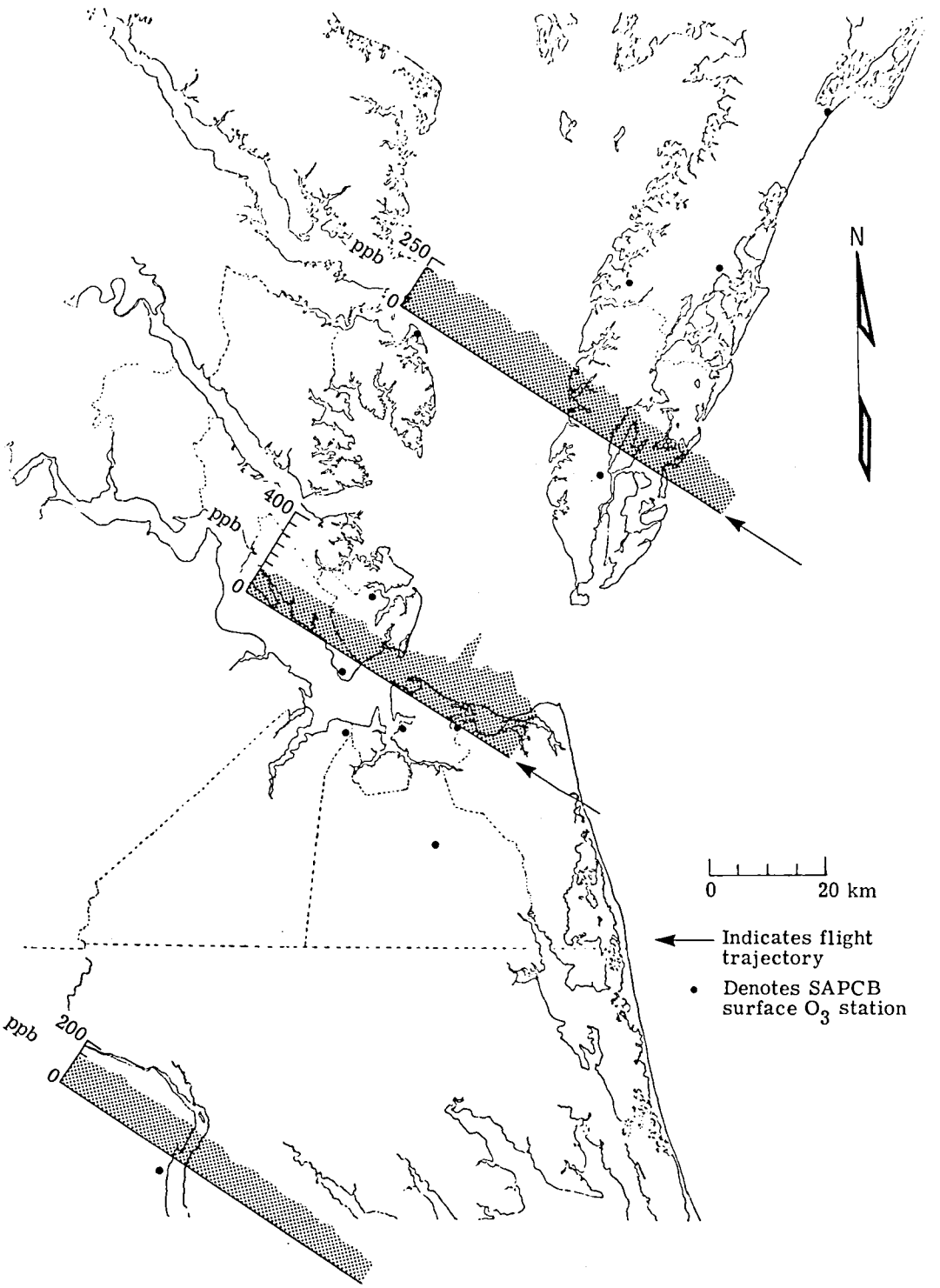

Figure 20.- DACOM CO data from afternoon flight of August 4, 1977.

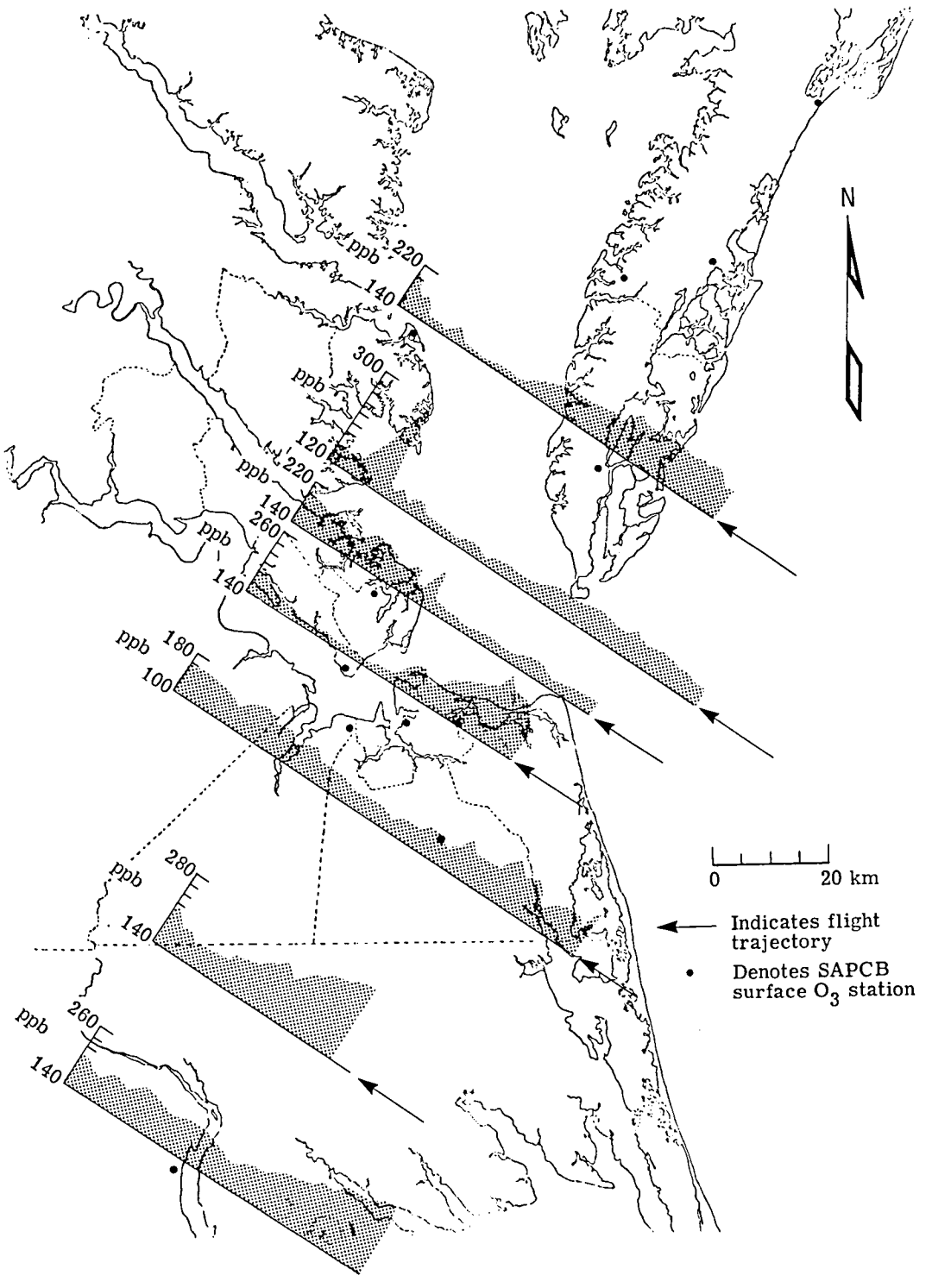

Figure 21.- DACOM CO data from morning flight of August 5, 1977.

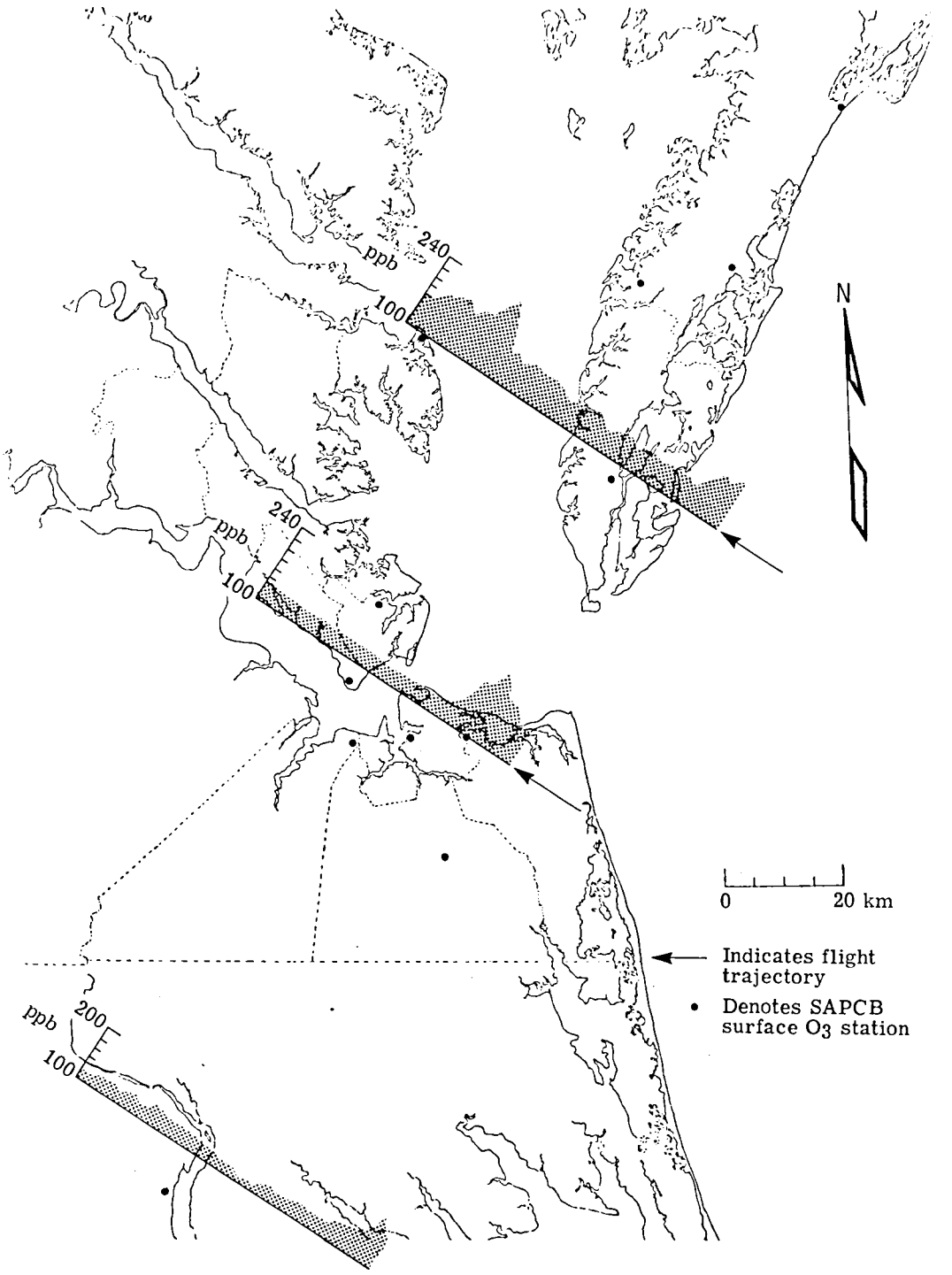

Figure 22.- DACOM CO data from afternoon flight of August 5, 1977.

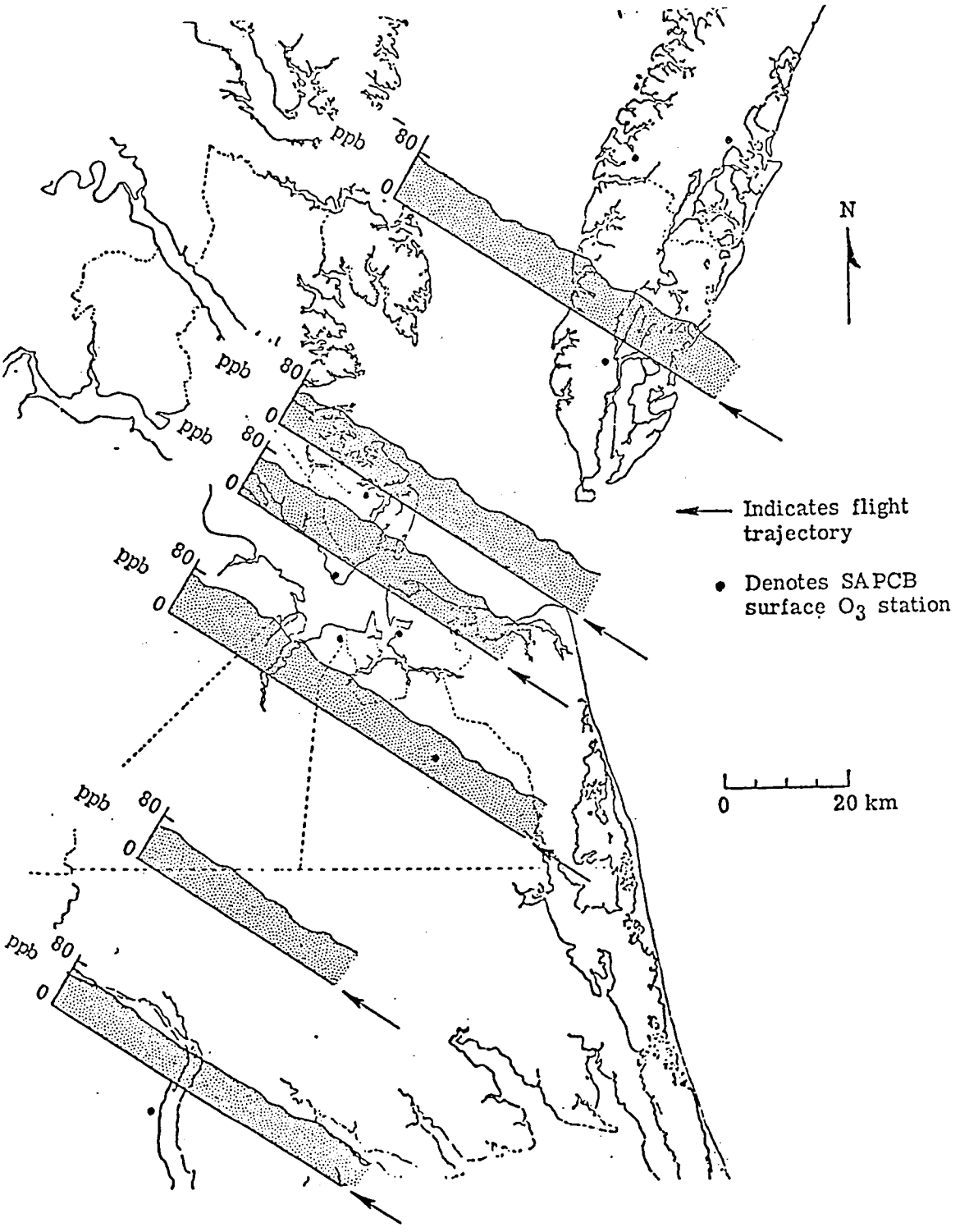

Figure 23.- Ozone data from morning flight of August 4, 1977, at 450-m altitude.

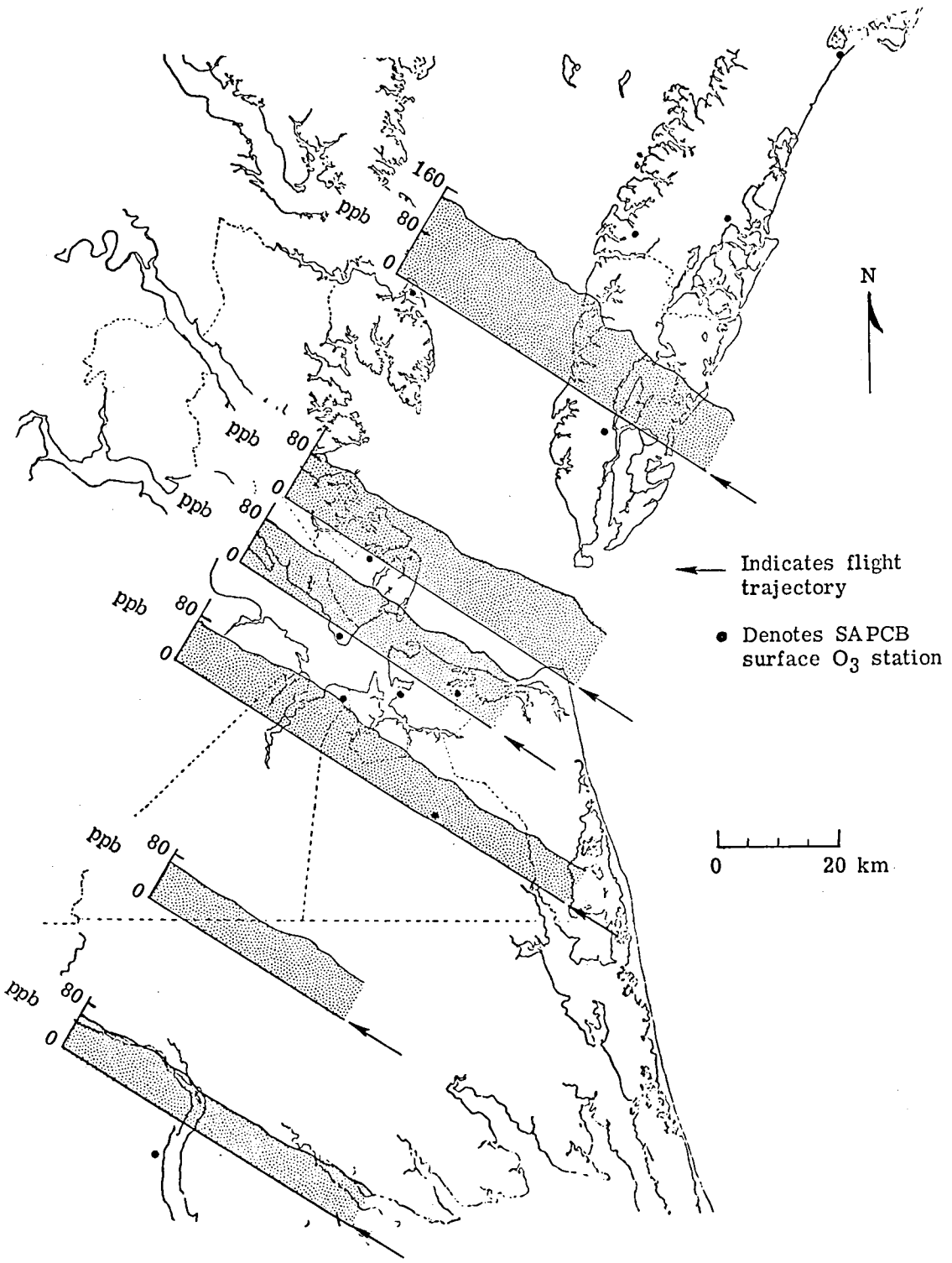

Figure 24.- Ozone data from afternoon flight of August 4, 1977, at 450-m altitude.

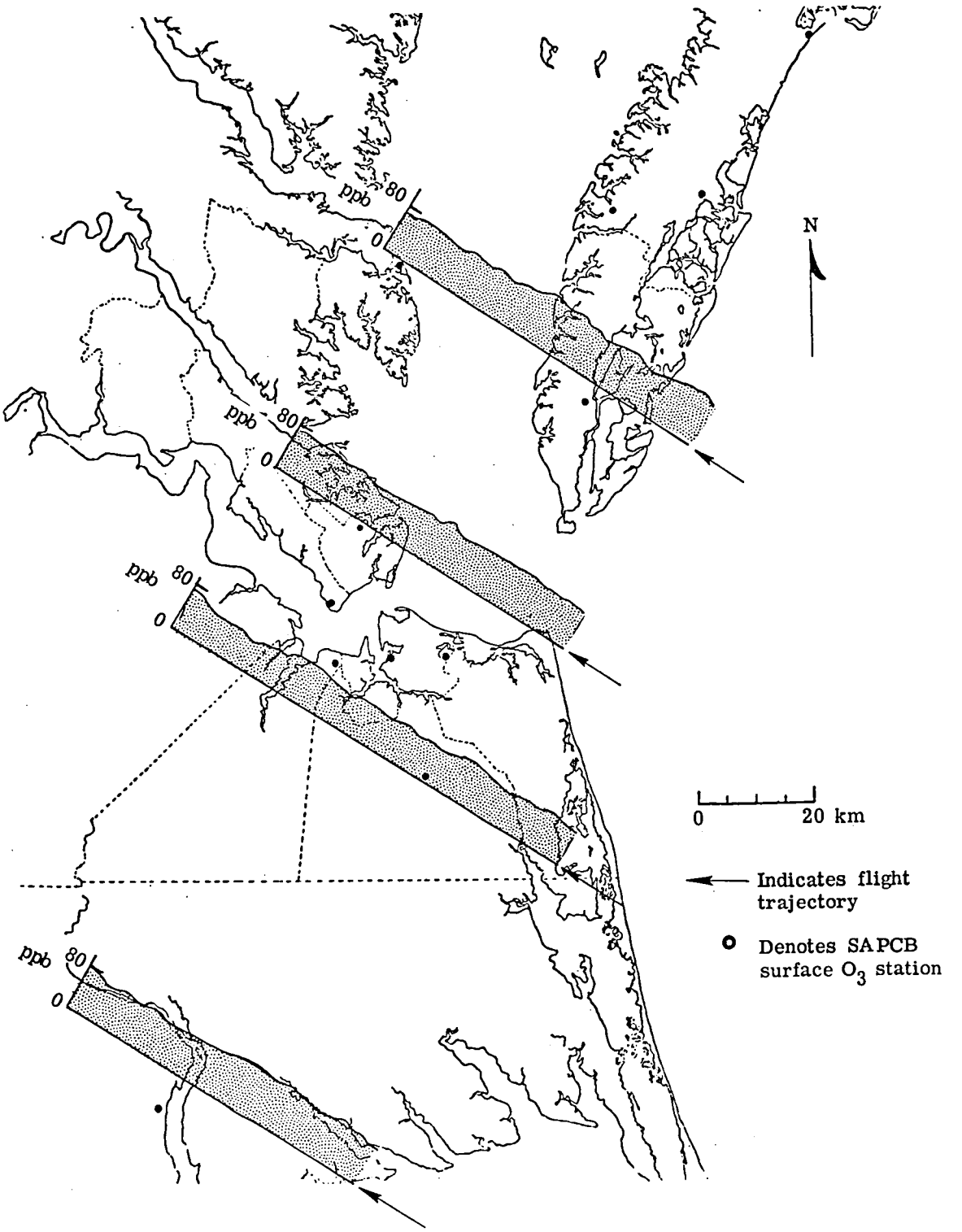

Figure 25.- Ozone data from morning flight of August 5, 1977, at 450-m altitude.

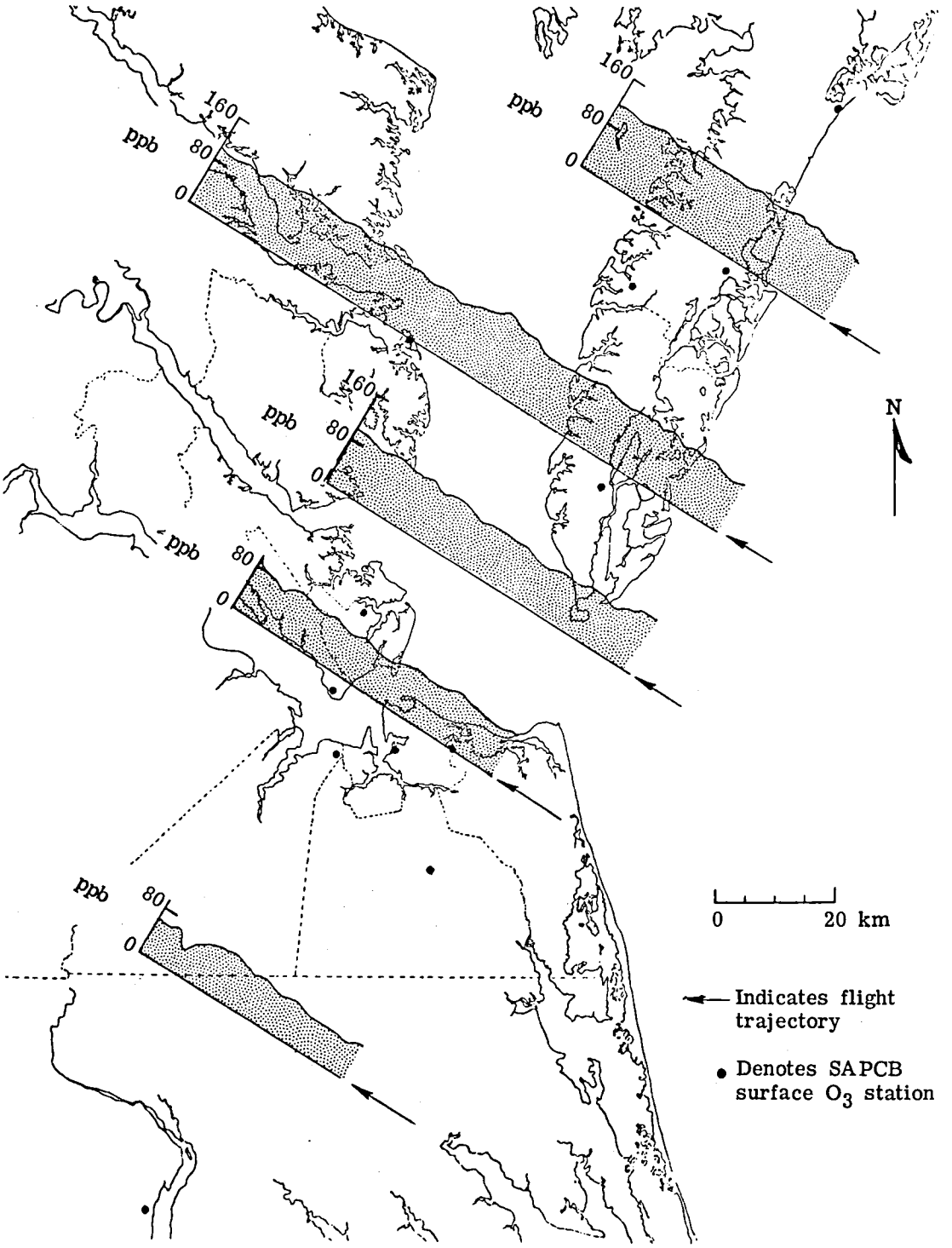

Figure 26.- Ozone data from afternoon flight of August 5, 1977, at 450-m altitude.

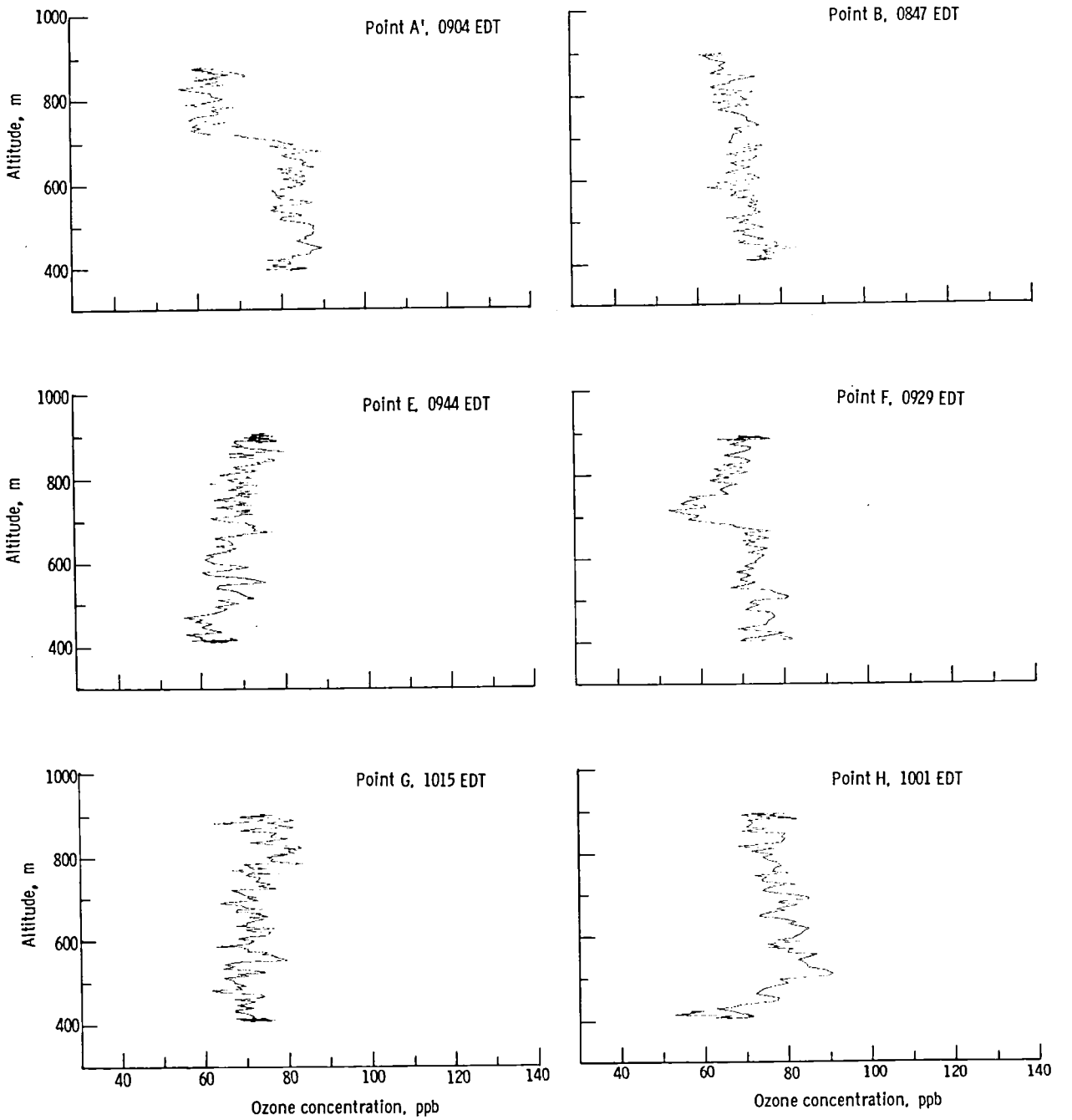

Figure 27.- Ozone altitude profiles for August 4, 1977.

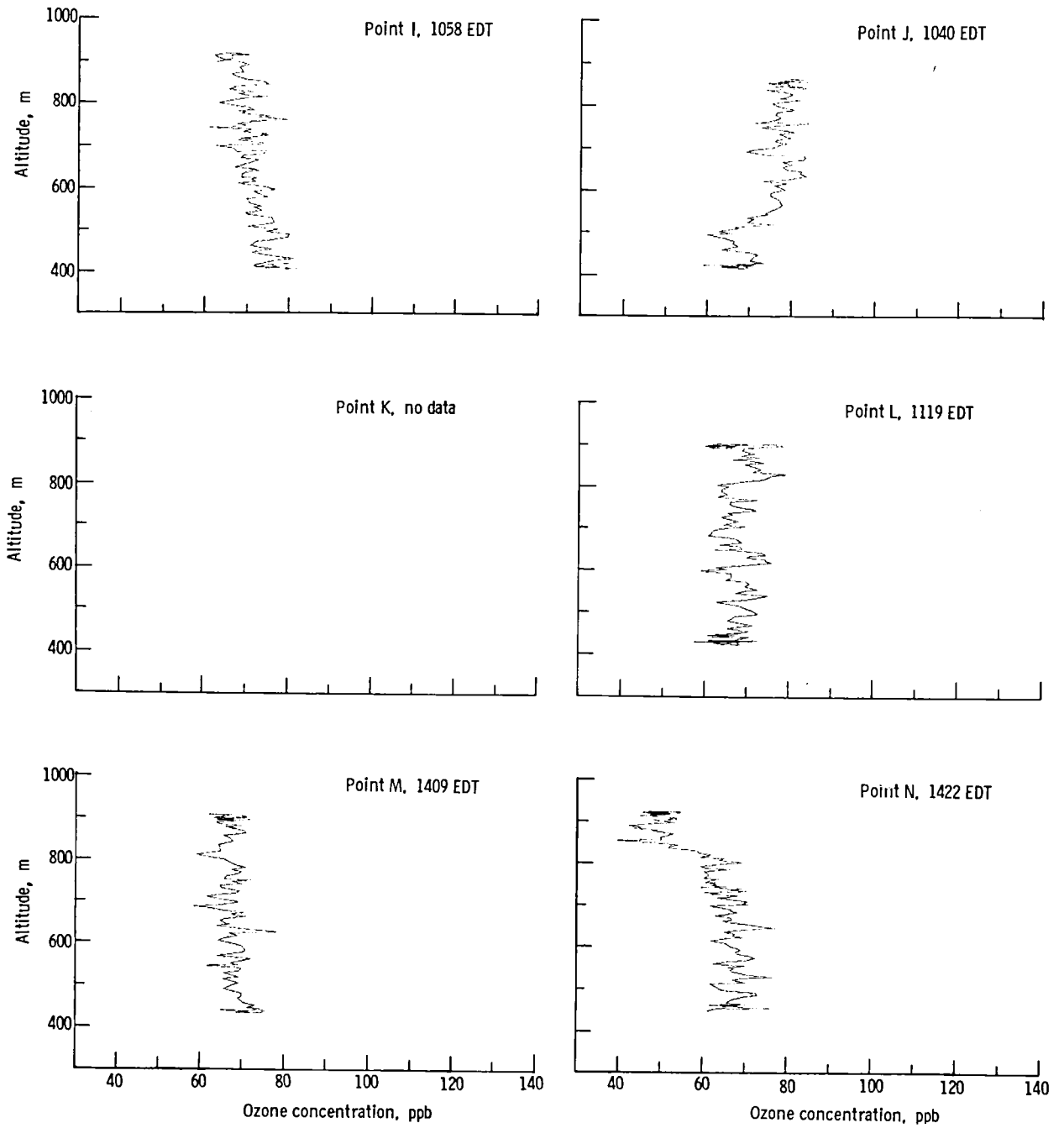

Figure 27.- Continued.

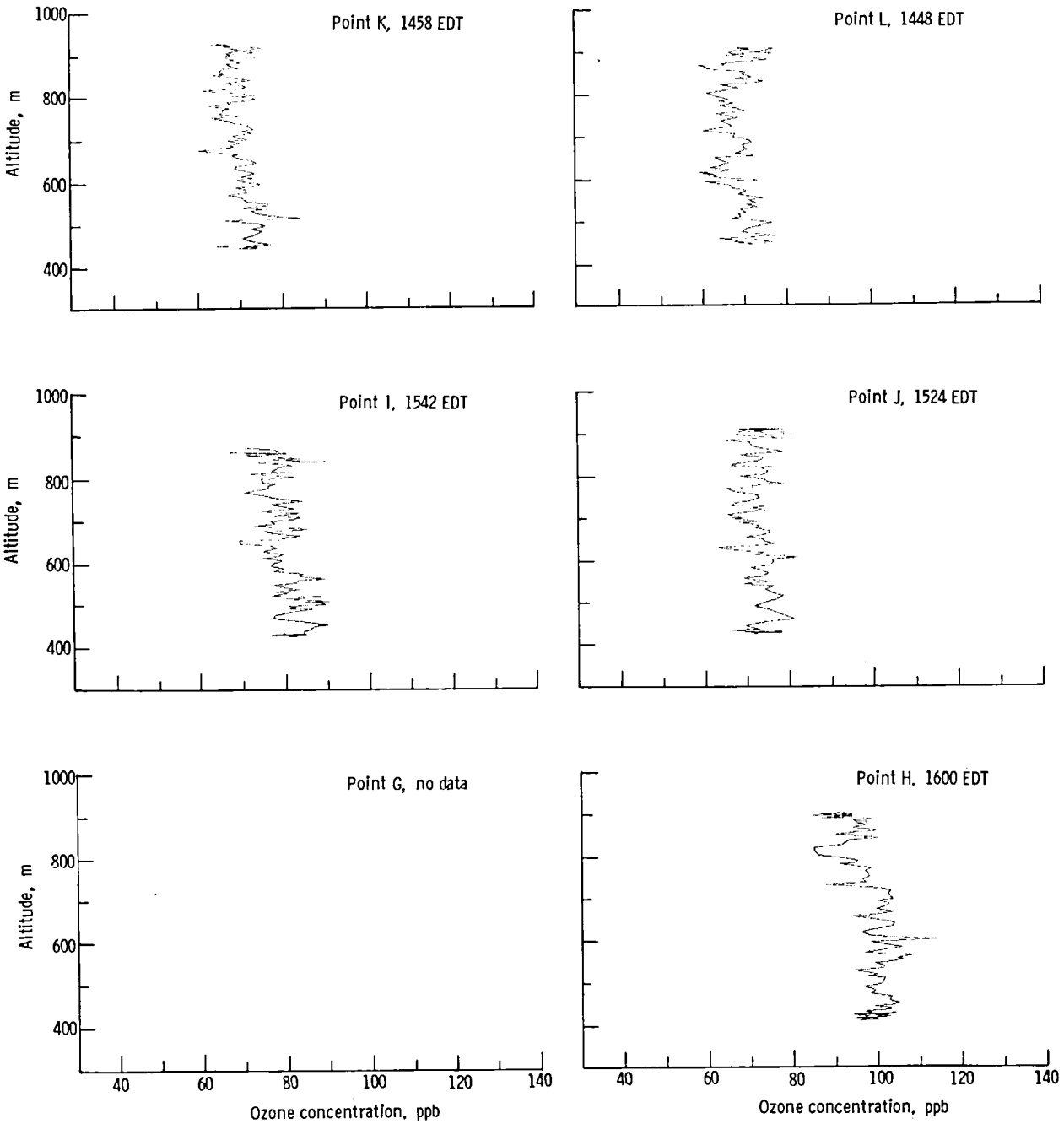

Figure 27.- Concluded.

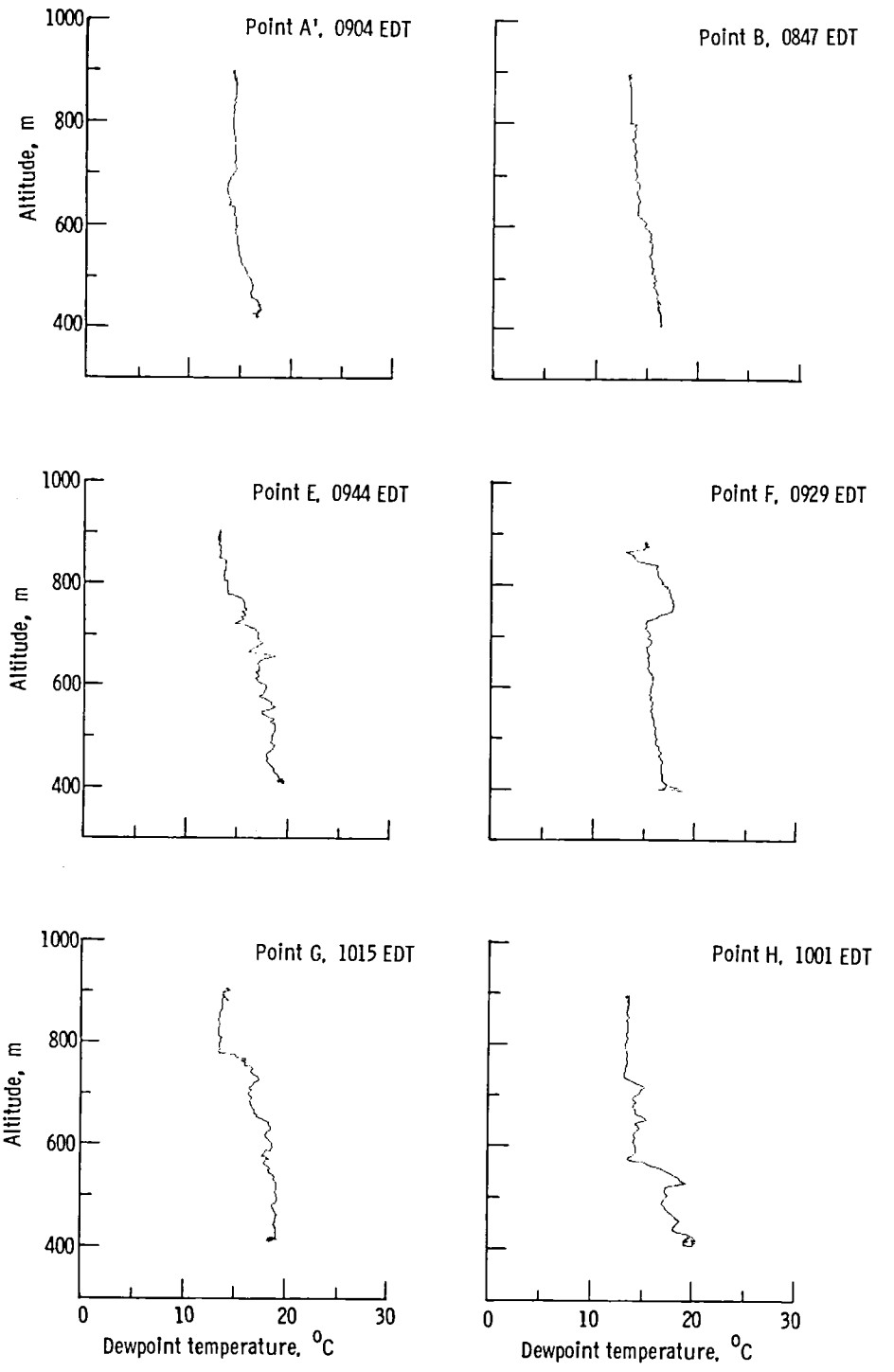

Figure 28.- Dewpoint altitude profiles for August 4, 1977.

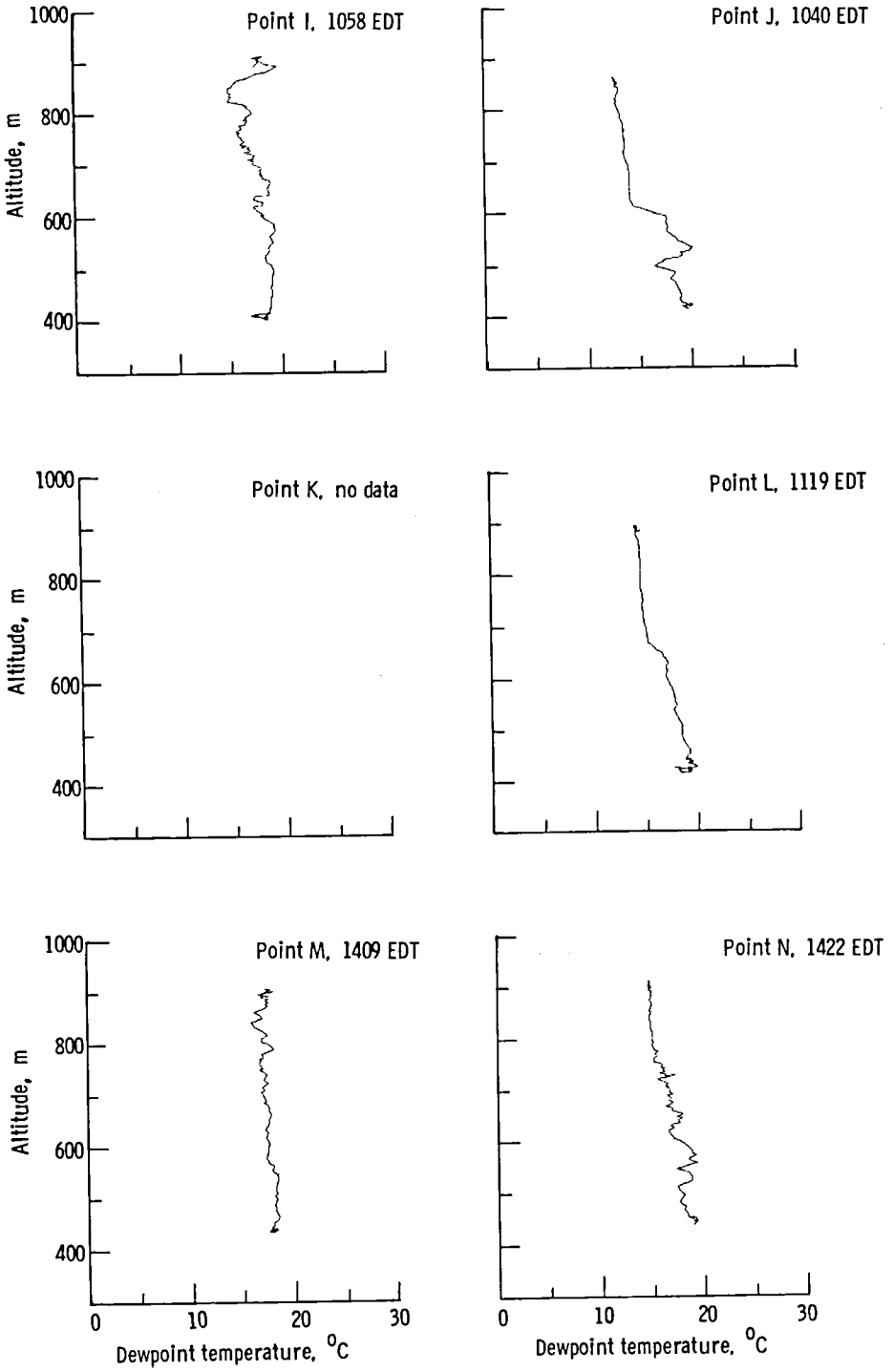

Figure 28.- Continued.

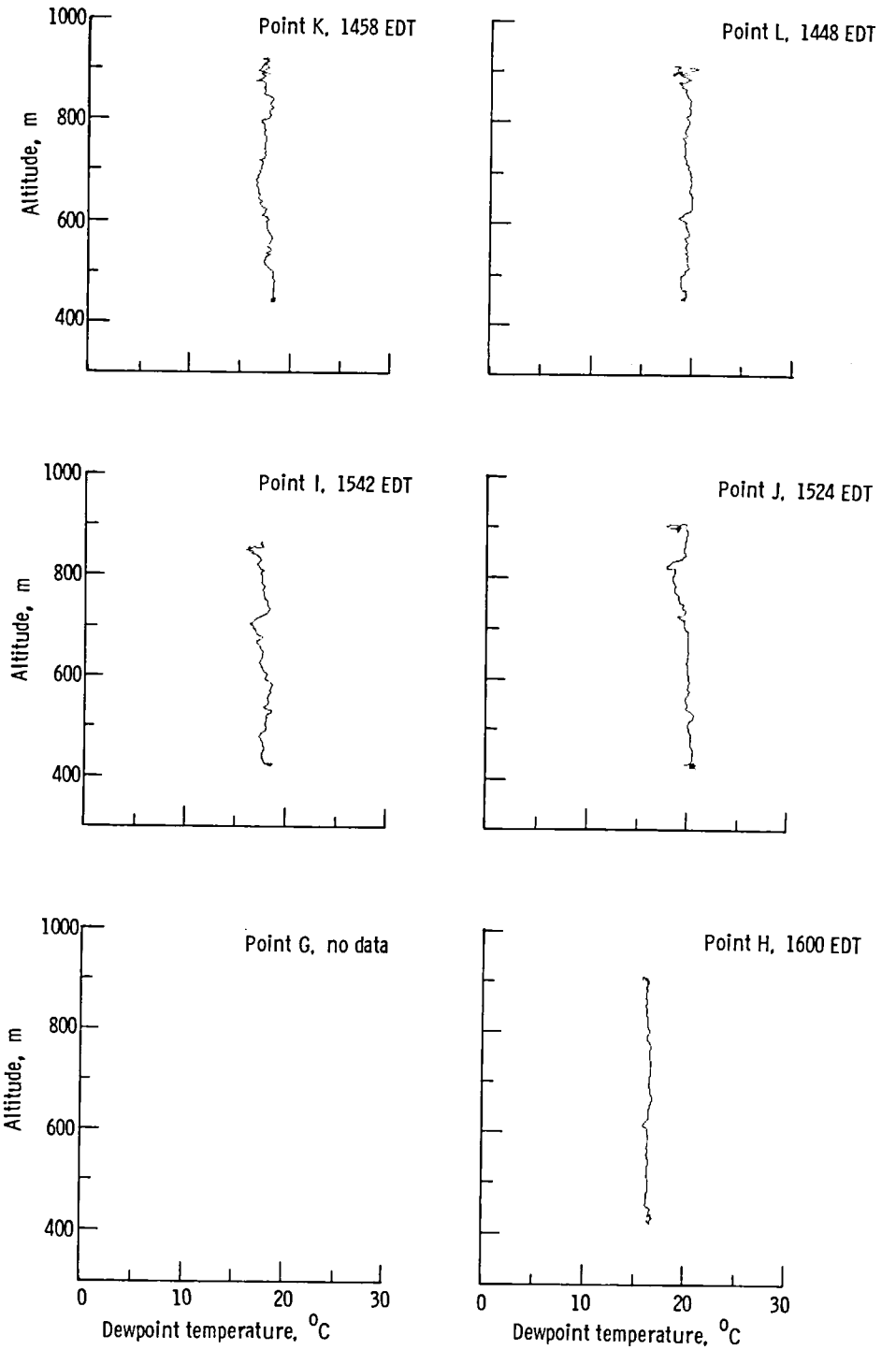

Figure 28.- Concluded.

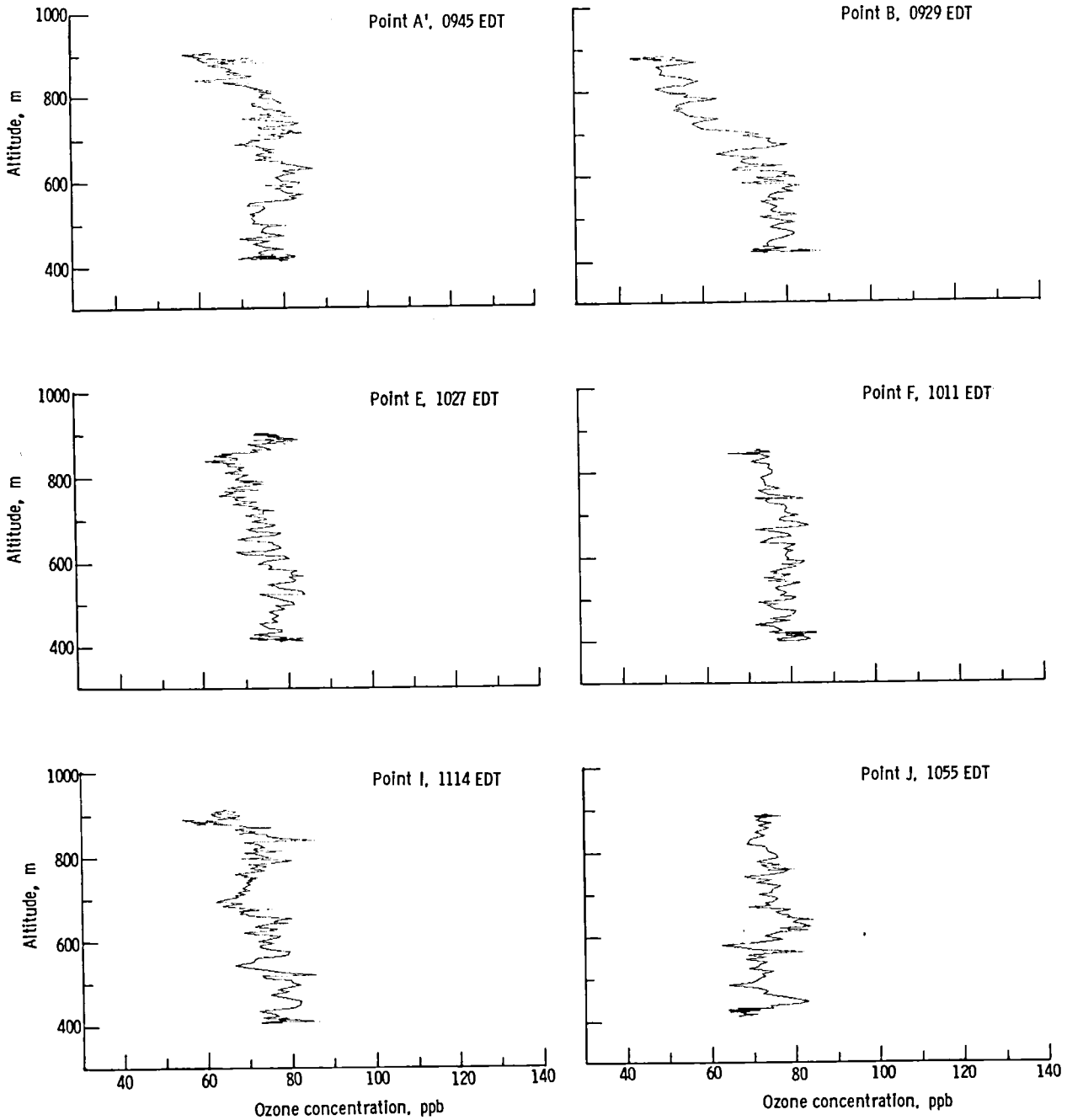

Figure 29.- Ozone altitude profiles for August 5, 1977.

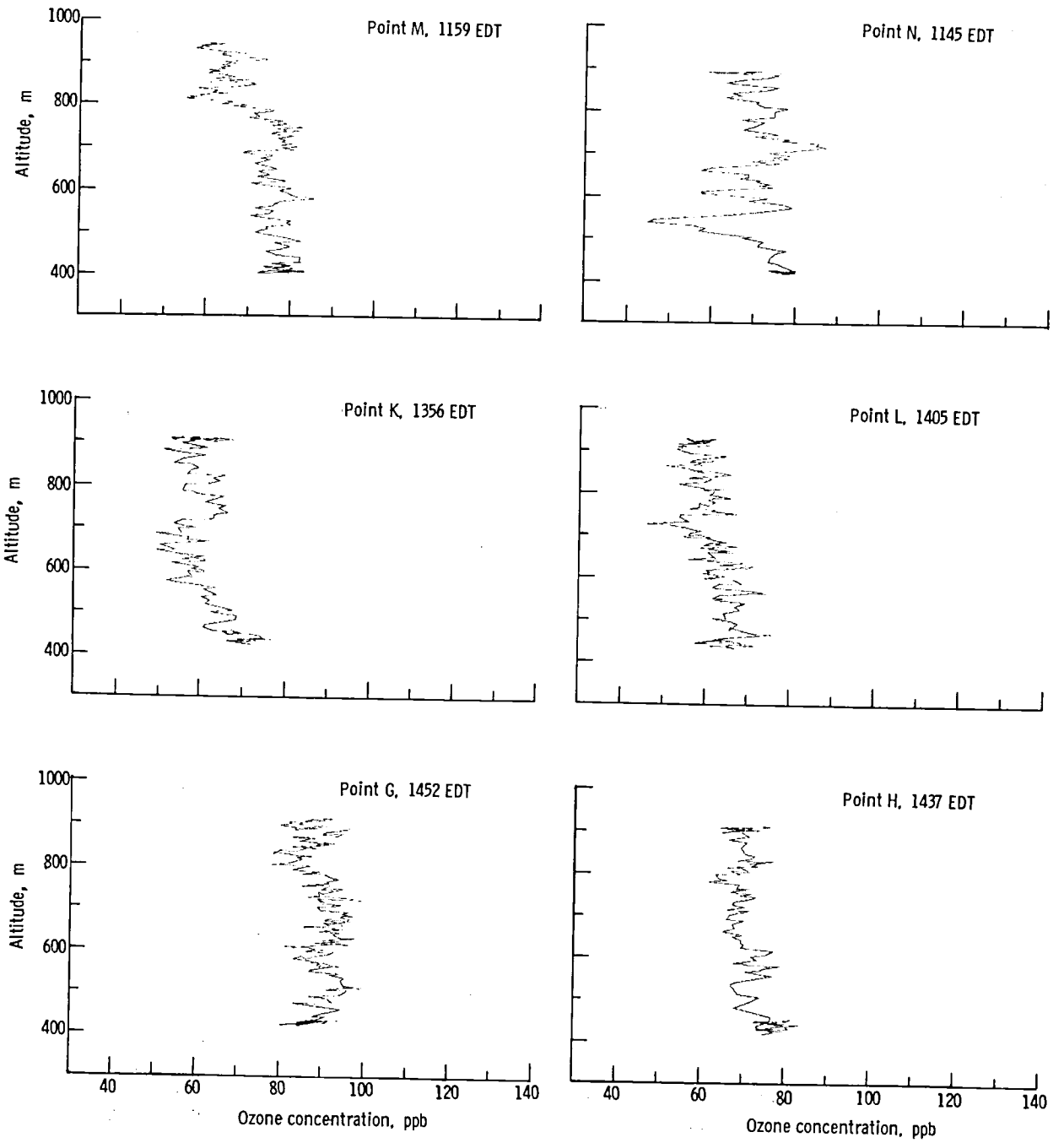

Figure 29.- Continued.

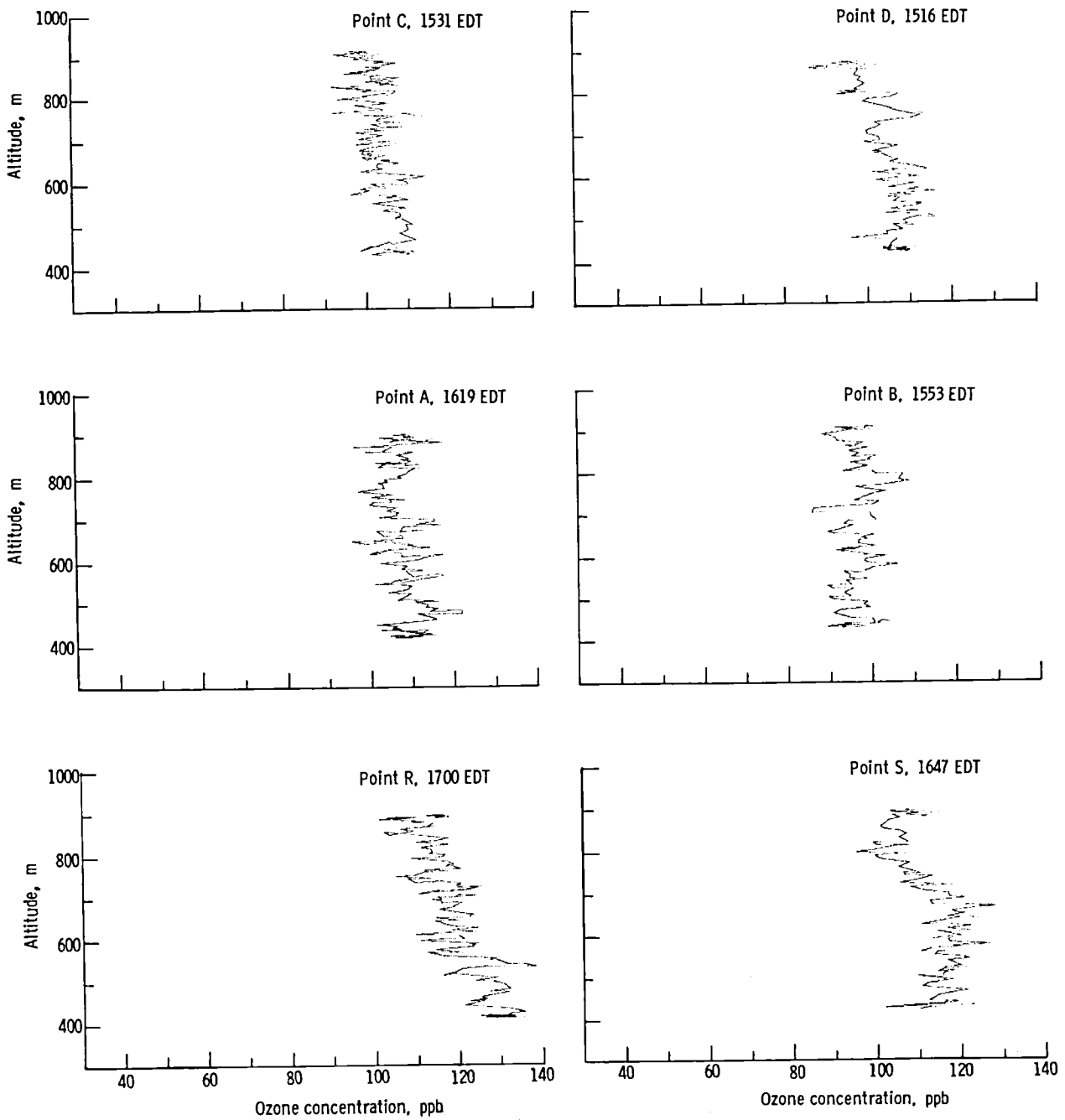

Figure 29.- Continued.

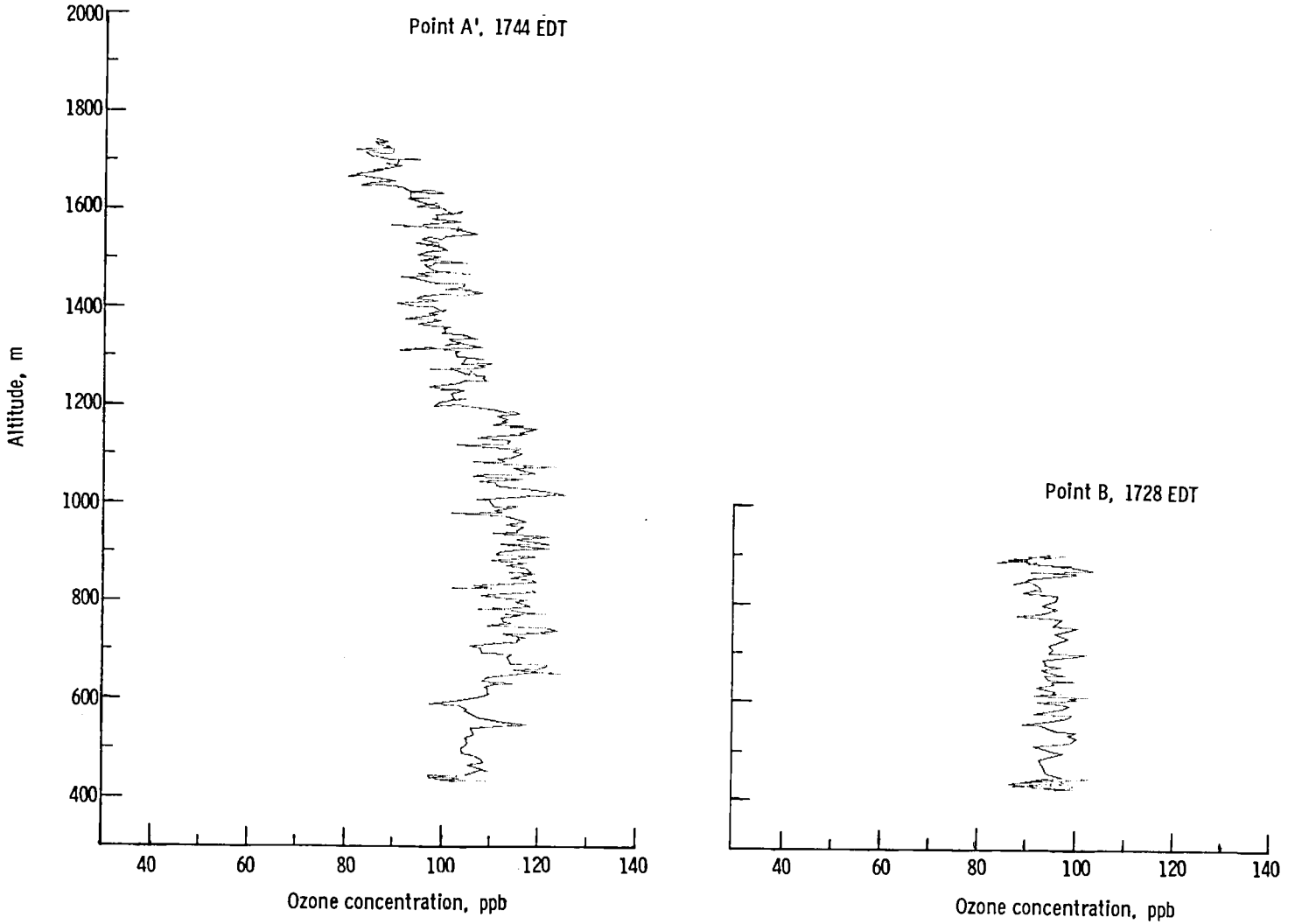

Figure 29.- Concluded.

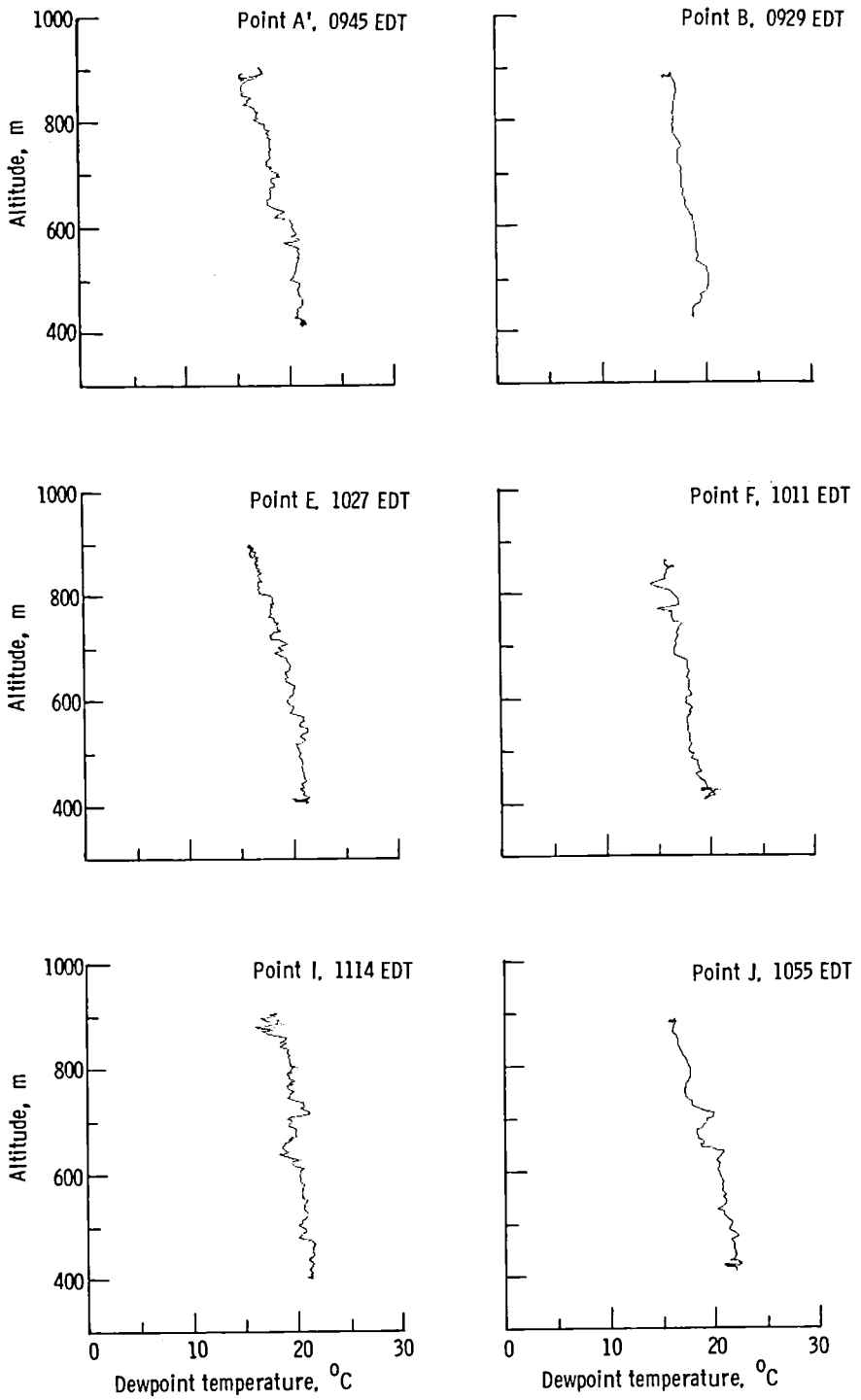

Figure 30.- Dewpoint altitude profiles for August 5, 1977.

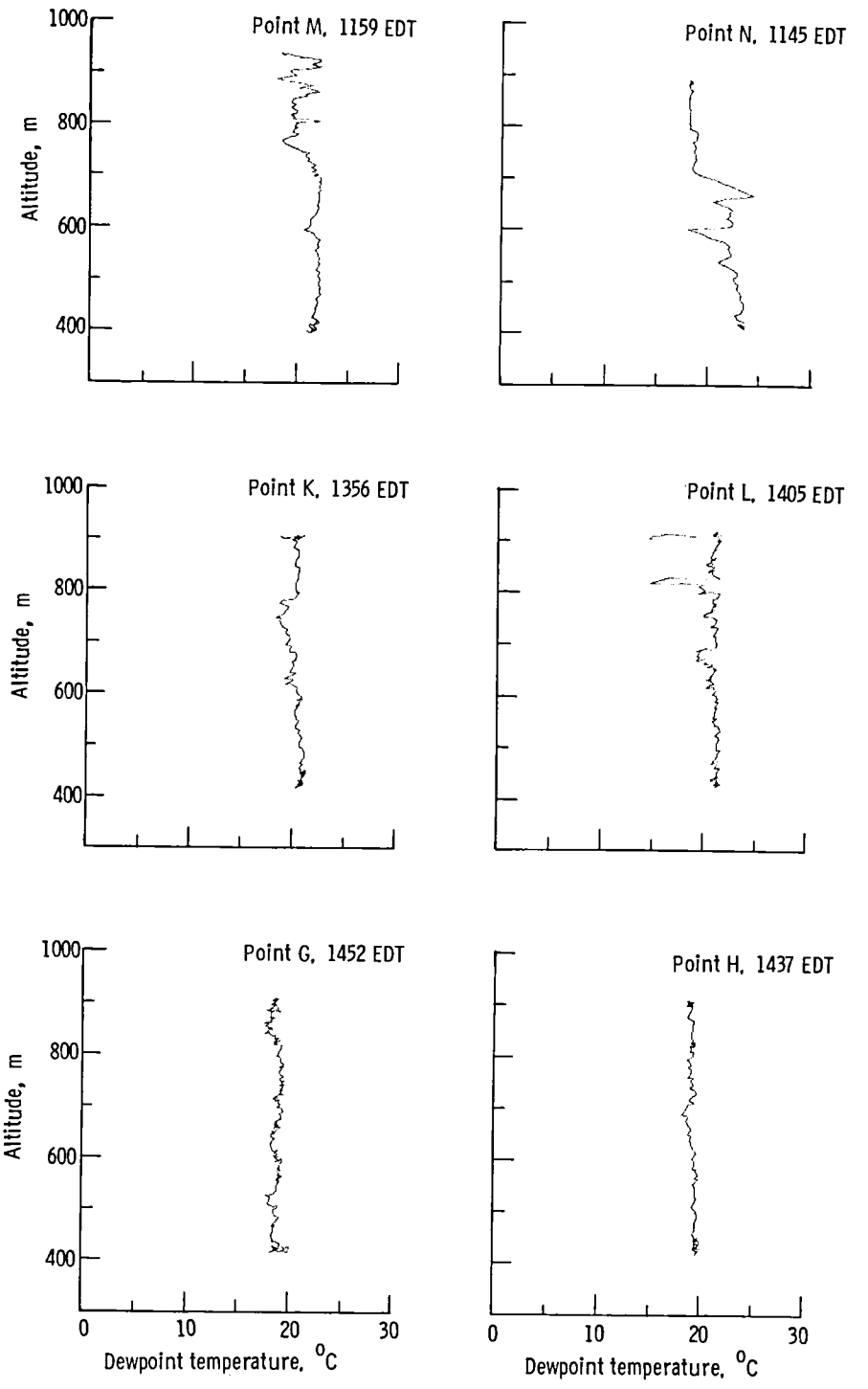

Figure 30.- Continued.

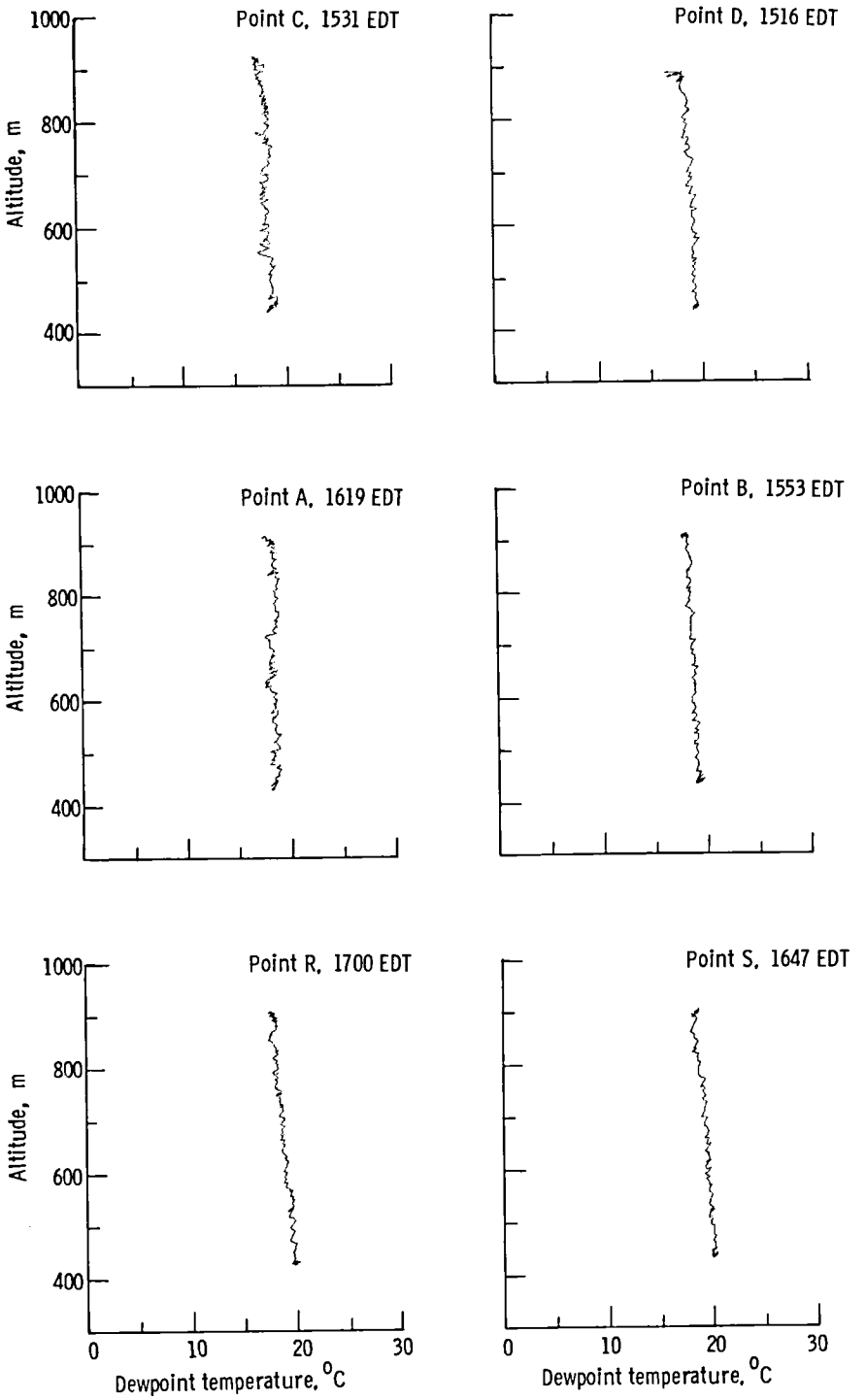

Figure 30.- Continued.

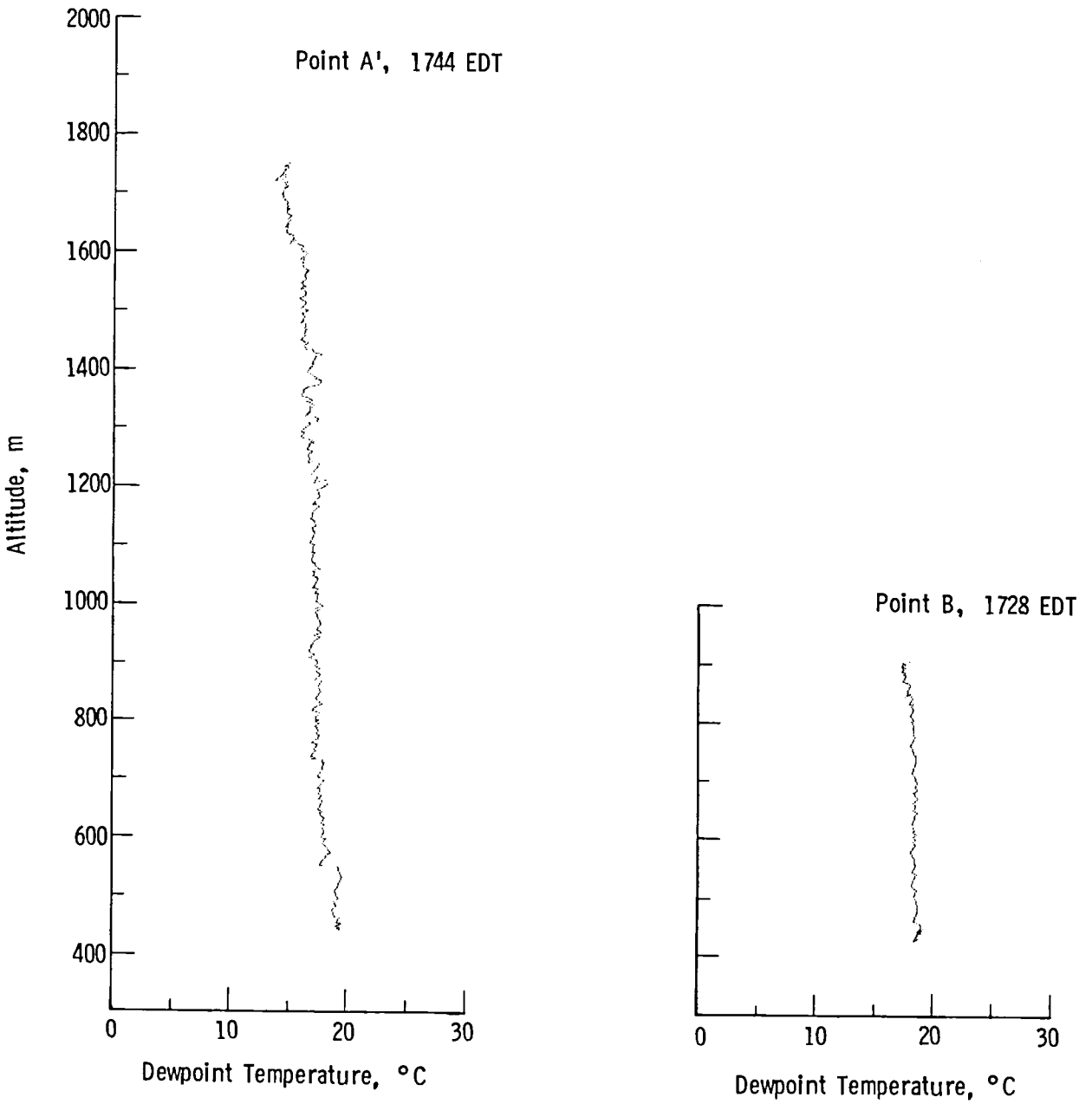

Figure 30.- Concluded.

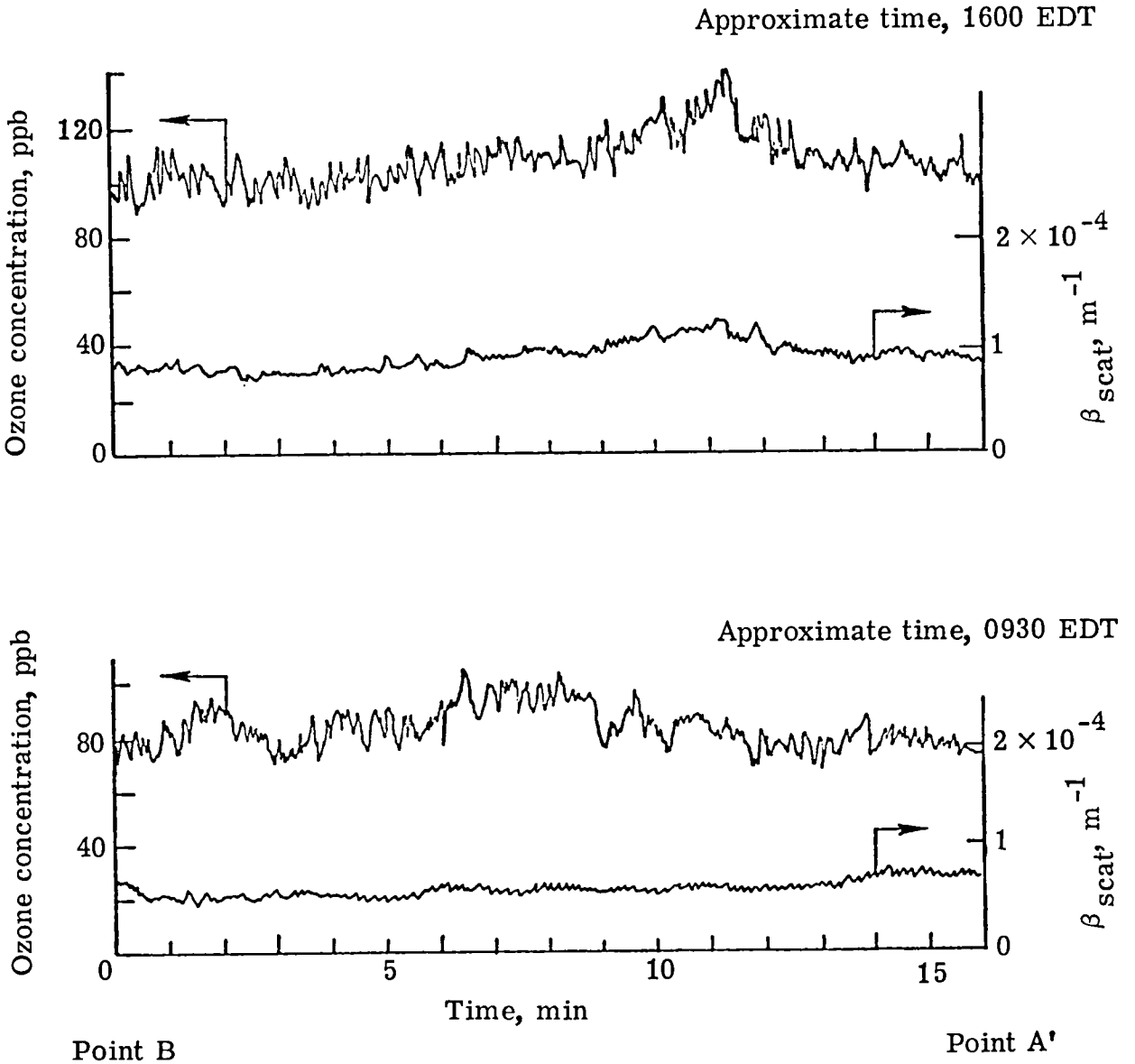

Figure 31.- Comparison of ozone and β_{scat} for flight leg A' → B (450-m altitude); August 5, 1977.

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15. Supplementary Notes

16. Abstract

Air quality data from the Southeastern Virginia Urban Plume Experiment conducted by the National Aeronautics and Space Administration during August 4 and 5, 1977, are presented. The purpose of the measurement program was to define the characteristics of the Southeastern Virginia urban plume with emphasis on the photooxidant species. The measurement area was a rectangle approximately 200 km by 60 km centered in the Hampton Roads area of Tidewater Virginia. This area includes the cities of Norfolk, Virginia Beach, Chesapeake, Newport News, and Hampton. The data set presented includes aircraft measurements for ozone, nitrogen oxides, carbon monoxide, methane, and meteorological parameters such as dewpoint temperature. Surface level data for ozone are presented for 10 stations located throughout the test area. Comprehensive meteorological data from existing National Weather Service stations and special locations selected for the urban plume program are summarized. Meteorological data include surface observations of winds, temperature, solar insolation, and mixing-layer height as well as aloft observations of winds and temperature. The urban plume program was a combined effort of the NASA Langley Research Center, NASA Wallops Flight Center, Virginia State Air Pollution Control Board Region VI, and Old Dominion University.

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