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1979 SOUTHEASTERN VIRGINIA URBAN PLUME STUDY, VOLUME I: DESCRIPTION OF EXPERIMENTS AND SELECTED AIRCRAFT DATA

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SUMMARY

The Southeastern Virginia Urban Plume Study (SEV-UPS) is part of the NASA continuing commitment to develop the technology to utilize remote-sensors and satellite platforms to monitor the Earth's environment and resources. SEV-UPS focuses on the application of specific remote sensors to the monitoring and study of specific air-quality problems. Results from each SEV-UPS measurement program enables NASA to assess the utilization of each sensor to the air-quality problem studied.

The 1979 SEV-UPS program was designed to evaluate and assess an airborne ozone remote sensor, the Laser Absorption Spectrometer, for monitoring ozone behavior in an aging urban plume. In addition to the remote-sensor evaluation and assessment objectives, other objectives of the 1979 program were to provide additional insight into ozone-precursor relationships in an aging urban plume and to compare similar measurements from different (surface, balloon, and aircraft) measurement platforms. To meet these objectives four groups of experiments were conducted:

1. Correlative data experiments designed to evaluate the accuracy, repeatability, and operational characteristics of the Laser Absorption Spectrometer remote sensor.

2. Air quality experiments designed to evaluate the utility of this remote sensor for the study of urban ozone problems.

3. Experiments designed to study air quality phenomena in Southeastern Virginia.

4. Experiments designed to compare measurement results of the various in situ measurement platforms.

The field program included monitoring from four aircraft, 12 surface stations, two tethered balloons, two radiosonde release sites, and numerous meteorological observation sites.

Volume I of the report discusses the design of each experiment conducted during the field program and presents an overview of the data obtained. The data overview consists of the results from one of the aircraft, the Langley chartered Cessna 402. This aircraft monitored O_3, NO_x, NO, B_{scat}, temperature, and dewpoint temperature. Volume II of the report gives a complete listing of the Cessna's data. The 1979 SEV-UPS data are reported in numerous reports. References are given on the availability of data from the other measurement platforms.

INTRODUCTION

The Southeastern Virginia Urban Plume Study (SEV-UPS) is part of the NASA continuing commitment to develop the technology to utilize remote-sensors and satellite platforms to monitor the Earth's environment and resources. SEV-UPS focuses on the application of specific remote sensors to the monitoring and study of specific air-quality problems. Results from each SEV-UPS measurement program enables NASA to assess the utilization of each sensor to the air-quality problem studied.

The SEV-UPS field measurement program (ref. 1) was conducted in Southeastern Virginia (1977, 1978, and 1979) to evaluate ozone remote sensors for tropospheric applications. The objectives of SEV-UPS are (1) to provide data to assess the accuracy, repeatability, and operational characteristics of ozone remote sensors for tropospheric air-quality measurements, and (2) to demonstrate the utility of these remote sensors in the study of air-quality phenomena. The SEV-UPS program includes not only field measurements to evaluate the sensors, but air-quality modeling and photochemical studies of the Southeastern Virginia area, both of which aid in demonstrating the usefulness of the remote sensor data.

The first phase of SEV-UPS was conducted in 1977 (ref. 2) when airborne and surface in situ measurements were used to characterize the production of ozone downwind of the urban complex for determining the suitability of Southeastern Virginia for the ozone remote sensor studies. These measurements revealed the characteristic ozone diurnal cycle at ground level with ozone concentration in an air parcel nearly doubling as the air parcel moved downwind of the populated areas and was advected over primarily rural agricultural areas. The second phase of SEV-UPS was conducted in the summer of 1978 (refs. 3 and 4) in which a preliminary evaluation of an ozone remote sensor, Laser Absorption Spectrometer (LAS), was performed. Based on the 1978 results, the LAS instrument and SEV-UPS measurement scenario were refined for evaluation of the remote sensor during SEV-UPS 1979.

The 1979 SEV-UPS field program was conducted in August with specific objectives:

(1) to provide correlative data to evaluate the accuracy, repeatability, and operational characteristics of the Laser Absorption Spectrometer (LAS) ozone remote sensor,

(2) to evaluate the utility of the LAS for the study of urban ozone problems,

(3) to provide additional insights into air-quality phenomena occuring in Southeastern Virginia, and

(4) to compare measurement results of the various in situ (surface, aircraft, and balloon) measurement platforms.

Participating in the program were the Langley Research Center, the Wallops Flight Center, the Jet Propultion Laboratory, and the Virginia State Air Pollution Control Board (Region VI). Measurement systems included 12 surface pollutant monitoring sites, four aircraft, two tethered balloons, two radiosonde release sites, and numerous surface meteorological observation sites.

Table I summarizes the major measurement platforms and the name identification used for discussion in this report. Figure 1 shows the test area and the location of fixed monitoring sites. The data from the 1979 measurement program are being reported in several reports. Already published is reference 5 covering the in situ O_3 measurements taken to satisfy objective 1 above and reference 6 covering the data from contractor aircraft.

Volume I of this report discussses the design of each experiment conducted during the 1979 field program and presents an overview of the data obtained. The data overview consists of that data from one of the four aircraft, the Langley chartered Cessna 402, hereafter referred to as the Langley aircraft. Volume II of the report gives a complete listing of the Langley aircraft data.

SYMBOLS AND ABBREVIATIONS

β_{scat} or $B_{(scat)}$	-	aerosol scattering coefficient, m^{-1}
DP or dp	-	dewpoint temperature, °C
e.d.t.	-	eastern daylight time
EPA	-	Environmental Protection Agency
Langley	-	Langley Research Center
LAS	-	laser absorption spectrometer
NASA	-	National Aeronautics and Space Administration
NO	-	nitric oxide, ppb
NO_x or NOX	-	nitrogen oxides, ppb
O_3 or 03	-	ozone, ppb
ppb	-	parts-per-billion, volume
RTI	-	Research Triangle Institute, NASA contractor
SAPCB	-	State Air Pollution Control Board
SEV-UPS	-	Southeastern Virginia Urban Plume Study
T	-	temperature, °C
THC	-	total hydrocarbon
UV	-	ultraviolet or UV absorption O_3 instrument
VOR	-	very high frequency ominidirectional range
wb	-	wet bulb temperature, °C

WD - wind direction, degrees from north

WS - wind speed, m/s

Z - altitude, m

DESCRIPTION OF TEST REGION

Location and Topography

The Southeastern Virginia area (figure 1), approximately 36.8 degrees N latitude and 76.4 degrees W longitude has a climate which is temperate, rainy without a dry season, and with warm summers. It is centered around the entrance to the Chesapeake Bay, commonly referred to as Hampton Roads, which is one of the largest natural port areas. The cities of Norfolk, Virginia Beach, and Chesapeake are located on the east and southeast sides of the area, and Newport News and Hampton, are on the northwest and north sides. The northwest, and southeast sides of Hampton Roads contain the large population centers, whereas the western and adjacent southern sides are relatively sparsely populated. The most densely populated sections are shown as shaded areas in figure 1.

The topography of the region is low and flat; as an example, the elevation above mean sea level of Norfolk is 5 meters. Southwest of the region lies the Dismal Swamp, which extends into North Carolina. As one goes westward, the terrain slopes upwards over a distance of approximately 240 kilometers; here the land rises sharply into the Appalachians, to elevations averaging 1 to 1.2 km above mean sea level. Man has not altered the region's topography in any marked manner as very few buildings even approach 100 meters; the taller structures are located in the southwestern part of the city of Norfolk.

Climatology (ref. 7)

The effect of the Bermuda high on the circulation in the Southeastern Virginia region in summer results in frequent southwest winds that are in evidence at all weather stations in the region. Northwest winds, since primarily an aftermath of cold fronts, are rare, and when they occur are considerably weaker than their spring or winter counterparts. A sea breeze frequently exists but does not extend too deeply inland as it is seldom felt at locations which are about 16 kilometers inland. A nightly gentle south through southwest prevailing wind is evident at all weather stations, and is due to the coupling of the circulation around the Bermuda high and the night land breeze. Other wind directions during the summer are infrequent. Both day and night calms are frequent in summer; wind speeds average 4 meters per second during the day, and 3 to 3.6 meters per second at night.

Selection Rationale

The Southeastern Virginia area possesses several unique features which make it a favorable site for both O_3 remote-sensor evaluation and studies of O_3 urban plume behavior. Besides the high frequency of southwest flow in the summer, ozone statistics over a period of several years show that for the months of July and August, surface O_3 concentrations (1 hour averages) frequently exceed 80 ppb, 60 to 90 hours per month at one or more surface stations in the region. This high frequency of prevailing wind direction combined with sizable O_3 concentrations provide some assurance that during a 2- to 4-week field program, numerous opportunities occur to apply the O_3 remote sensor to the monitoring of above ambient O_3 concentrations and to the study of representative ozone air-quality problems.

The major source area, the cities of Norfolk and Virginia Beach, is relatively isolated from other urban sources, being surrounded by water or primarily rural agricultural areas. This major source area combined with the other major cities in Southeastern Virginia (Chesapeake, Newport News, and Hampton) can be encompassed by an approximate 30 by 30 km square and considered as one isolated urban source. Depending on the direction of the predominant air flow at the time of measurements, the area can provide opportunities for study of the (1) effect of urban sources on ambient "clean" air, (2) composite effects of urban sources and ambient "dirty" air, (3) downwind aging characteristics of urban plumes over emission-free areas such as water and rural land masses, and (4) behavior of an aging urban plume in a coastal region.

DESCRIPTION OF EXPERIMENTS

Four general classes of experiments were performed during the 1979 SEV-UPS field program: (1) correlative data experiments for evaluation of the remote sensor, (2) air quality experiments for evaluating the utility of the remote sensor, (3) air-quality experiments to provide insight into O_3 urban plume behavior, and (4) experiments to compare in situ measurement systems. Selection of experiments for a given flight day was based on forecasted meteorology, experiment priority, and operational status of the instrument systems.

Correlative Data Experiments

Two experiments were designed to provide in situ O_3 data for evaluation of the accuracy, repeatability, and operational characteristics of the LAS remote sensor. The strategy of each experiment was to define a finite volume of the atmosphere (surface to 1.5 km altitude) and with in situ measurements, determine existing O_3 concentrations in that volume while the remote sensor made O_3 burden measurements. (The LAS measures total O_3 burden from the aircraft altitude to the Earth's surface. A description of the sensor is given in reference 8.) The two experiments, "Correlative Spiral" and "Correlative Box Face" differ only in the flight plan used by the in situ aircraft to measure existing O_3 concentrations. The "Spiral" experiment was conducted four times; the "Box Face," three times. Two aircraft were used in each experiment: the JPL remote-sensor aircraft and either the Langley or contractor aircraft for the in situ data. A detailed discussion of these experiments and the resulting data are given in reference 5.

Experiments To Evaluate Remote Sensor Utility

Two experiments were designed to evaluate the utility of the remote sensor in the study of ozone air-quality problems: "Urban Plume" and "Photochemical Box." Similar experiments were conducted in 1978 (ref. 3). Each of these experiments consisted of all day (0600 to 1700 e.d.t.) air-quality studies of O_3 and precursors in the Southeastern Virginia area. Each experiment was designed to demonstrate distinct advantages of remotely sensed data as compared to conventional in situ O_3 data, as well as to provide meaningful insight into O_3 photochemical behavior in an urban area. The experiments were designed to use all the measurement resources of table I. The experiments are discussed below including the designed flight plan for each aircraft. Deviations from the designed flight plans for Langley aircraft are discussed as the data are presented. Flight plan deviations of the other aircraft are discussed in their respective reports.

Urban plume experiment.- This experiment was designed to investigate the formation of ozone and ozone-precursor relationships downwind of the urban complex of Hampton Roads in an aging (1 to 5 hours) urban plume. Desired meteorological conditions are the Bermuda High and associated southwest flow (see climatology discussion) with concurrent bright, clear, and hot sunlit days. Under these conditions, incoming air to the region is readily characterized having traveled typically 6 to 8 hours since being influenced by emissions from a major urban source. Likewise, the southwest flow leaving the Hampton Roads area (source) travels 8 to 10 hours over relatively source-free (water and agricultural) areas, and during this time the influence of a single urban source (Hampton Roads) can be studied without the complication of additional major emission sources. For these conditions, the downwind plume contains sizeable O_3 concentrations (ref. 2) providing those conditions necessary to demonstrate the utility of the remote sensor for identifying and quantifying O_3-rich urban plumes.

Figure 2 shows the test region for the urban plume experiment, the sampling flight legs, and the supporting surface stations. The flight legs are for the prevailing southwest flow case. Flight plans were designed for other wind directions and are discussed, as required, in the data presentation section of the report. The urban plume experiment was performed three times during the August field program; two of these were with southwest winds. Table A-1 shows the scheduled flight times of the various aircraft for the flight legs of figure 2. In regard to the Langley aircraft, most sampling legs are constant altitude below the mixing-layer height. Spirals at specific locations to 1.0 km altitude provide data to define the mixing-layer location and vertical gradients of species in the atmosphere. Exact locations of the flight legs referenced to the local aeronautical navigational chart (ref. 9) are given in Appendix B for the urban plume and other experiments.

Photochemical box experiment.- This experiment was designed to evaluate the remote sensor for observing O_3 buildup in the near vicinity of an urban area. The strategy of the experiment is illustrated in figure 3. A box approximately 30- by 30-kilometers is centered on the major source area (city) of the region. Upwind, over the city, and downwind (approximately 1 hour air aging time) sampling legs are defined. Each flight leg is sampled hourly (constant altitude within the mixing layer) with vertical spirals at selected locations to define the top of the mixing layer. Sampling from 0600 to 1700 e.d.t., not only provides data for assessing the utility of the LAS to detect O_3 build-up, but also provides hourly data for future comparison with the hourly output of a single box photochemical model of the source area. The model then becomes an additional tool for studying the utility of ozone remote-sensor data. Desired meteorological conditions are those discussed for the urban plume experiment (southwest flow). The box experiment was conducted once during the field program and meteorological conditions dictated a flight plan based on westerly air flow. This flight plan is shown in figure 4 and table A-2. Wind shifts during the day resulted in a change of flight plans about midmorning. The changes in the flight legs for the afternoon portion of the experiment are discussed along with the presentation of the data.

Air Quality Experiments

Two experiments were conducted to study air-quality phenomena of interest in the Southeastern Virginia area.

Swamp characterization experiment.- This experiment was designed to define the levels of hydrocarbons emitted by the Great Dismal Swamp (south of Norfolk). The Langley and Wallops aircraft participated in the experiment. A flight plan (figure 5) was designed to sample the northern and southern boundaries of the swamp, to perform diagonal traverses across the swamp, and to perform spirals at selected locations within and outside of the swamp. Low level flight (0.15 km) was desired, starting at 0600 and ending at 1000 e.d.t., under conditions of low wind speeds (1 to 2 m/s). Spirals were flown to 1.5 km for definition of mixing layer and pollutant vertical profiles. The Wallops aircraft provided the basic hydrocarbon data; the Langley aircraft provided supporting O_3, NO, NO_x, B_{scat}, T, and dp data to aid in the description of atmospheric air quality. Table A-3 presents the flight schedule. The experiment was flown twice, once with both aircraft, and once with only the Wallops aircraft.

Coastal-inland plume experiment.- This experiment was designed to observe major differences in the behavior of an aging urban plume downwind of a coastal urban source (Norfolk) as compared to an inland source (Richmond) for similar meteorological conditions. The strategy of the experiment was to select a bright sunlit day (good O_3 generation) with southwest flow both in the Norfolk and Richmond areas, and sample both downwind and upwind (approximately 40 km) of each city in the 1030 to 1530 e.d.t. time period. Figure 6 and table A-4 describe the designed flight plan. The contractor aircraft flew the mission and the data are presented in reference 6. The experiment was flown once during the August field program.

In Situ Comparison Experiments

Comparison experiments were conducted: (1) to assess in situ measurement systems, (2) to compare similar measurements made from the various measurement platforms, and (3) to provide quality assurance data for the measurement program. These flights consisted of aircraft systems comparisons, aircraft-tethered balloon system comparisons, and aircraft-surface station system comparisons. The flights are in addition to other quality assurance tasks (calibration and audits) discussed in reference 6.

Aircraft system comparison flights.- These flights were designed to provide wing-tip-to-wing-tip comparison data among the various in situ aircraft. One flight was flown for comparison of the Langley and contractor aircraft data; a second, for comparison of the Langley and Wallops aircraft data. Figure 7 shows the location of the comparison flights. The flight plan consisted of a constant altitude (1.5 km) traverse of the indicated flight leg, a spiral at one end point of the leg to 0.15 km, and a constant altitude (0.15 km) reflight of the flight leg. Reference 5 presents the results of these comparisons, reference 6 tabulates the contractor aircraft data, and this report presents the Langley aircraft data.

Aircraft-tethered balloon system comparison.- The purpose of this flight was to provide in situ data with the Langley aircraft for evaluating the tethered balloons for measuring temperature, dewpoint, and ozone as a function of altitude. The location of the two tethered balloon sites is shown in figure 1. Balloon flight altitudes for the 1979 field program were limited to 1.5 km at Wallops and 0.6 km at the Naval Communication Center. The flight sequence of the aircraft at each balloon site was two spirals from about 0.15 to 1.5 km while the balloon was either in an ascending or descending mode. One comparison flight for each balloon site was made during the field program.

Aircraft-surface station system comparison.- This experiment was designed to provide low altitude aircraft data for comparison with the surface station data. Table II lists the surface sites and the aircraft platform used. The surface site locations are given in figure 1. Flight sequences consisted of 2 to 3 repetitive low-level (0.1 km or less) flights over or in the near vicinity of the surface station. Results of some of the comparisons are given in reference 5; contractor aircraft data, in reference 6, and Langley aircraft data, in this report.

DESCRIPTION OF THE LANGLEY AIRCRAFT INSTRUMENTS

Aircraft Instrument Systems

A brief description of the instrumentation systems of the Langley aircraft is given in this section. Instrumentation onboard the other aircraft is discussed in references 4, 6, 8, 10, and 11. The Langley aircraft, its design for air-quality sampling, instrumentation, and associated laboratory test programs are discussed in detail in references 2, 3, 5, 12, 13, and 14. The reader is referred to these references for a detailed description of the aircraft systems.

The Langley aircraft is a light, twin-engine, fixed-wing aircraft chartered by the NASA Langley Research Center for in situ air-quality studies. The aircraft, once received from the contractor, is outfitted by NASA for the designated air quality studies. Instruments are installed in both the nose baggage compartment and the passenger cabin area. The air-quality instruments for the aircraft have been studied in the laboratory under simulated flight conditions, investigating parameters of (1) instrument sensitivity, (2) instrument accuracy and precision, (3) instrument response time, (4) altitude (pressure) effects on instrument sensitivity, and (5) sample losses or modification in the air sample inlet system. Table I lists the measured parameters for the 1979 field program. Flight parameters for a sampling mission are 3 1/2 hours of data recording, a flight speed of 200 km/hr, ascent or descent rates of less than 150 m/min, and a total flight duration of 4 hours plus 30 minutes of fuel reserve.

All the instrumentation was calibrated prior to the SEV-UPS field program using EPA accepted practices. In addition, ozone and nitrogen oxides instruments were audited as part of the SEV-UPS quality assurance program. References 5 and 6 discuss the audit and calibration results as well as observed instrument problems. Two types of ozone instruments were installed in the Langley aircraft: chemiluminescent and UV absorption. As discussed in reference 5, operational problems were encountered with the UV absorption instrument. Consequently, no UV absorption O_3 data are presented.

Data Reduction/Accuracy

Data are recorded onboard the Langley aircraft as continuous analog signals on a magnetic tape system. Data processing at a ground-based station consists of digitizing the tape records at 10 records/second, averaging these records over a specified time period, and converting these averages to the appropriate engineering units. The data reported are 10-second averages tabulated or plotted at the mid-point of the averaging interval. The effect of the data averaging interval on the resolution of the data is illustrated for ozone in reference 3 for averaging periods of 1 to 90 seconds. For the nominal flight characteristics of the aircraft (200 km/hr and climb rates of 150 m/min), the 10-second averaging interval represents approximately 0.5 km spatial and 25 meters altitude resolution. The accuracy and precision of the aircraft data are shown in table III. Absolute accuracies are based on calibration rather than instrument uncertainties.

DATA RESULTS

The section gives an overview of the data obtained from each of the experiments conducted during the 1979 SEV-UPS August field program. The overview consists of a brief desription of existing meteorology during the experiments and a description of that data measured onboard the Langley aircraft. Other data (aircraft, surface station, meteorological, etc.) are discussed in separate reports: for example reference 6 and reference 15. The data overview is presented according to the experiment type and then in chronological order. Only representative data results are presented. A complete listing of the 10-second averaged data measured onboard the Langley aircraft is presented as Volume II of the report.

Experiments To Evaluate Remote Sensor Utility

Urban plume experiment of August 24, 1979. - The urban plume experiment of August 24 was flown as shown in figure 2 and table A-1 with the exception that as a result of electrical problems the remote-sensor aircraft did not participate. The meteorology of the test region was influenced by a high pressure cell off the coast of North Carolina (figure 8) resulting in south to southwest winds throughout the test area (figures 9 and 10). Wind speeds were nominally about 5 m/s up to 3 km altitude with some notable changes at certain locations, altitudes, and times of day. Table IV presents the actual flight times for the Langley aircraft. Selected data from spirals are shown in figures 11 through 13. Only O_3, NO_x, temperature, and dewpoint data for the ascent portion of the spirals are shown.

Composite plots of morning and afternoon effluent concentrations are shown in figures 14 through 17. The NO_x and B_{scat} peaks and corresponding O_3 depressions shown at the western edge of leg E-F are the result of the aircraft flightpath being just a few kilometers downwind of refinery and powerplant emissions at Yorktown, Virginia. The break in the data traces along legs A-B, E-F, and I-J indicates the location of the aircraft spirals. Most notable from the composite plots are:

1. The higher O_3 concentrations (legs E-F, G-H, and I-J) downwind of the source area in the afternoon (figure 16) as compared to the morning (figure 14).

2. The increase in NO_x concentrations over the source area (leg C-D) both morning and afternoon (figures 14 and 16).

3. The B_{scat} variations along leg C-D in the morning (figure 15).

Table V gives statistical averages and the associated standard deviations of the measured parameters for each of the constant altitude flight legs. The time sequence for the various flight legs should be considered in interpretation of composite plots like figures 14 through 17.

Urban plume experiment of August 25, 1979. - The experiment was conducted as shown in figure 2 and table A-1. Again, the remote-sensor aircraft did not participate, and it is noted that the test day was a Saturday. The high pressure cell centered over Ohio and Kentucky (figure 18) dominated the local weather resulting in southwest winds (figures 19 and 20) at speeds of 8 to 10 m/s up to about 3 km altitude. Wind speeds varied somewhat with location, altitude, and time of day. Table VI presents the actual flight sequence for the Langley aircraft.

Data from the ascent portion of the spirals are given in figures 21 through 23. Composite plots of morning and afternoon effluent concentrations are shown in figures 24 through 27. Again, the Yorktown emissions are seen in the data, as well as the O_3 plume in the afternoon (figure 26) downwind of the urban area. Table VII gives the statistical averages for the constant altitude flight legs.

Urban plume experiment of August 30, 1979. - This experiment was not flown exactly as shown in figure 2 and table II. Several deviations occurred:

1. While the initial flight schedules and plans for the aircraft were those of figure 2 and table A-1, meteorological observations around mid-morning (0900 e.d.t.) indicated a wind shift had occurred throughout the test area, and an alternate flight plan was assigned while each aircraft was on the ground between the morning and afternoon flights. The flight plan assigned was for a northwest flow and is shown in figure 28 and table A-5.

2. The contractor aircraft did not switch to the new flight plan for the afternoon flight.

3. The Langley aircraft terminated its afternoon flight after the spiral on leg G-H (figure 28) due to low fuel reserves.

Table VIII summarizes the actual flight sequence for aircraft 1.

The description of the meteorology associated with the experiment is complex, requires analysis of all available SEV-UPS meteorological data, and is beyond the scope of this data report. For this report, it suffices to state only that the wind shift occurred by mid-morning and was the result of the eastward movement of a high pressure cell located over western Virginia (figure 29). Wind direction data at the two sounding stations (figure 30) illustrate the complexity of the meteorology. Wind speeds were of the order of 3 to 8 m/s but varied substantially with location, altitude, and time of day.

Composite plots of the morning and afternoon O_3 and NO_x concentrations are shown in figures 31 and 32. The data show sizable O_3 and NO_x plumes. Conclusions as to the source or cause of these plumes should not be made without an extensive analysis of the entire SEV-UPS data for August 30. Because of the complexity of the data set, the authors have elected not to show additional data plots in this volume of the report.

Photochemical box experiment of August 31, 1979. - The experiment of August 31 was started early in the morning using the plan of figure 4 and table A-2. As was the case for the August 30 plume experiment, meteorological observations confirmed a wind shift around 0800 e.d.t. The flight plan of figure 4 and table A-2 (west wind) was changed to accommodate a northeast wind. The plan was changed at approximately 0900 e.d.t. while the Langley aircraft was sampling. The new flight plan is that of figure 33. The sampling schedule is that of table A-2. The remote-sensor aircraft did not fly the afternoon mission. Table IX presents the Langley aircraft actual flight schedule.

As was the case earlier, the meteorology associated with the experiment is complex and a detailed discussion is beyond the scope of this report. Basically the wind shift started to develop early in the morning, being approximately northeast by mid-morning. Passage of the low (figure 34) over North Carolina through the Virginia area caused the wind shift. Wind directions (figure 35) at 0200 e.d.t. were west to northwest but by 0800 were approaching northeast. Wind speeds were generally 3 to 5 m/s with some notable variations. Again, as a result of the complexity of the meteorology, only limited data are presented in this section. The data are presented as statistical averages (table X) for each of the constant altitude flight legs.

Air-Quality Experiments

Of the two experiments described in the "Description of Experiment" section of the report, the Langley aircraft participated in only one, the swamp characterization experiment of August 15, 1979. The experiment was conducted as described in figure 5 and table A-3. The actual flight sequence of the Langley aircraft was nearly identical to that of table A-3, differing at most by about 10 minutes. Winds for the test area were from the northerly direction (figure 36) at speeds of about 3 to 8 m/s.

Aircraft spiral data at point LD (figure 5) are shown in figure 37. Over the 2 hour duration of the experiment, mixing layer height is seen to increase in the swamp area from about 0.5 km to about 0.8 km (see dewpoint data of figure 37). Table XI shows the statistical data for each of the constant altitude legs. Noteworthy features of the data are:

1. Ozone values (70 ppb) above the mixing layer (0.5 to 0.8 km) are higher than below the mixing layer (40 ppb). This observation is consistent based on the time of the experiment (little O_3 generation) and expected surface scavenging of O_3.

2. Standard deviations associated with the O_3 measurements are small.

3. Comparing the O_3 average of leg D-NCC to NCC-LD, a spatial variation of O_3 from the ocean inland to the swamp is suggested. A close examination of the D to NCC and NCC to LD data at about 0.2 km altitude (figure 38) indicates a general decrease in O_3 from the ocean to the swamp. More detailed data analysis is required to determine the significance of this observation.

In Situ Comparison Experiments

Aircraft comparison flights. - The data from the Langley aircraft for the comparison flights with the contractor and Wallops aircraft are given only in volume II of the report. The flight locations are shown in figure 7. Flights were either wing-tip-to-wing-tip with the other aircraft or within 2 minutes lag or lead time of the other aircraft. Flight conditions on August 15 were clear; for August 20, weather was overcast with heavy clouds at about 0.3 km. On August 20 flight at 1.5 km was in clear air while at 0.15 to 0.2 km, flight was in and out of clouds and misty rain. Statistical data for the constant altitude portion of the flights are presented in table XII.

Aircraft-tethered balloon flights. - The aircraft data for comparison with the tethered balloons are presented only in volume II. The flight plan was that discussed earlier. Weather for the flight was clear. The balloon at the communication center was operational at altitude while the aircraft spirals were made. The Wallops' balloon was tethered near the surface.

Aircraft-surface station flights. - The Langley aircraft data for comparison with selected surface stations are also given only in volume II. Sixty seconds of data are presented for each of three successive low-level passes of the surface stations. These low-level passes were generally either directly overhead (Chesapeake Light, for example) or within 2 to 3 km of the surface station location (Naval Air Station, for example). Weather conditions were clear and for the Langley site and Navy Communications Center site, flights were made on 2 days. The location of the surface sites are shown on figure 1.

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TABLE I. - MEASUREMENT PLATFORMS

a. Surface Pollutant Sites

Identification	Responsible Organization	Measurements
Wallops	NASA/Wallops	O_3, WS, WD
Wachapreague	SAPCB	O_3, WS, WD
Cheriton	SAPCB	O_3
Milford Haven	SAPCB	O_3
Langley (LaRC)	NASA/Langley	O_3, NO, NO_x, CH_4 THC, SO_2, CO, T, dp, WS, WD, solar insolation
Virginia School	SAPCB	O_3, CO, WS, WD
Tidewater College	SAPCB	O_3
Naval Air Station	RTI	O_3, NO, NO_x, CH_4 THC, SO_2, CO, T, WS, WD, solar insolation
Chesapeake Light	SAPCB	O_3, T, dp, WS, WS, solar insolation
Norfolk Agricultural Station	SAPCB & NASA/Langley	O_3, CO, CH_4 THC
Chesapeake Airport	SAPCB	O_3
Naval Communication Center	RTI	O_3, NO, NOx, CH_4 THC, SO_2, CO, T, dp, WS, WD, solar insolation

TABLE I. - Concluded.

b. Aircraft

Identification	Aircraft Type	Responsible Organization	Measurements
Langley Aircraft	Cessna 402	NASA/Langley	O_3, NO, NO_x, B_{scat}, T, dp, flight parameters
Contractor Aircraft	Piper Navajo B	RTI	O_3, NO, NO_x, SO_2, B_{scat}, CN, T, dp, flight parameters
Wallops Aircraft	Douglas C-54	NASA/Wallops and Langley	O_3, CO, CH_4, THC
Remote-Sensor Aircraft	Beech Queen Air	JPL	O_3 (in situ), O_3 (remote sensor)

c. Tethered Balloon

Identification	Responsible Organization	Altitude	Measurement
Wallops	NASA/Langley	0 to 0.6 km	O_3, T, wb, WS, WD
Naval Communication Center	NASA/Langley	0 to 1.5 km	O_3, T, wb, WS, WD

d. Sonde Releases

Identification	Responsible Organization	Measurement
Wallops	NASA/Wallops	T, dp, WS, WD, O_3
Naval Air Station	U.S. NAVY	T, dp, WS, WD

TABLE II. - SURFACE STATION SITES-AIRCRAFT COMPARISON

Surface Station	Langley Aircraft	Contractor Aircraft
Naval Communications Center	Aug. 15, Aug. 29	Aug. 29
Chesapeake Light	Aug. 15, Aug. 29	Aug. 29
Naval Air Station	Aug. 15	Aug. 29
Chesapeake Airport	-----	Aug. 29
Langley	Aug. 15	------

TABLE III. - LANGLEY AIRCRAFT INSTRUMENT ACCURACY

Parameter	Technique	Absolute Accuracy	Precision
temperature	resistance	0.5°C	0.1°C
dewpoint	cooled mirror	0.5°C	0.1°C
O_3	chemiluminescent	10% (5 ppb)[1]	2% (3 ppb)[1]
O_3	UV absorption	10% (5 ppb)[1]	2% (3 ppb)[1]
NO, NO_x	chemiluminescent	10% (5 ppb)[1]	3% (5 ppb)[1]
B_{scat}	light scattering	10%	2%

1 Whichever the larger (i.e., 2% of reading or 3 ppb)

TABLE IV - LANGLEY AIRCRAFT FLIGHT SCHEDULE FOR AUGUST 24, 1979 URBAN PLUME EXPERIMENT

Leg[1]	Time, e.d.t. (hrs. min. sec.) start	finish
AB*	08.26.50	09.13.20
FE*	09.28.10	10.09.50
CD[2]	10.17.10	10.33.20
CD	14.47.10	15.06.30
FE*	15.12.00	15.54.05
IJ*	16.11.20	17.00.40
HG	17.12.20	17.36.50

1 - * indicates spiral in the flight leg

2 - point D is at the coastline on leg C-D

TABLE V. - STATISTICAL DATA FOR CONSTANT ALTITUDE LEGS OF AUGUST 24, 1979
URBAN PLUME EXPERIMENT

Leg	Time[1] (e.d.t.)	Average ± Standard Deviation						
		Z (m)	T (C)	DP (C)	O_3 (ppb)	NO_x (ppb)	NO (ppb)	β_{scat}[2]
AB	0850	302 ± 13	22.1 ± .2	21.7 ± .7	52 ± 7	15 ± 1	15 ± 1	9.2 ± 1.7
CD	1025	307 ± 12	25.0 ± .3	21.7 ± .7	53 ± 4	19 ± 7	13 ± 2	10.1 ± 2.1
	1500	324 ± 16	28.0 ± 1	21.1 ± 1	70 ± 8	15 ± 4	11 ± 1	12.3 ± 1.3
EF	0950	306 ± 13	24.9 ± 3	21.7 ± 5	58 ± 4	15 ± 3	12 ± 2	12.4 ± 2.2
	1100	294 ± 62	22.1 ± 6.4	21.5 ± 1.1	65 ± 8	15 ± 7	12 ± 2	11.9 ± 3.3
	1530	335 ± 18	27.2 ± .7	21.2 ± .8	75 ± 12	14 ± 6	11 ± 3	12.5 ± 1.4
GH	1725	349 ± 22	26.9 ± .4	20.5 ± 1.3	67 ± 5	10 ± 2	10 ± 1	10.7 ± 2.4
IJ	1635	336 ± 16	26.6 ± .6	20.8 ± 1.1	80 ± 19	11 ± 2	11 ± 2	10.8 ± 2.0

1 - approximate time at mid-point of leg

2 - all values x 10^{-5}

TABLE VI - LANGLEY AIRCRAFT FLIGHT SCHEDULE FOR AUGUST 25, 1979 URBAN PLUME EXPERIMENT

Leg[1]	Time, e.d.t. (hrs. min. sec.) start	finish
AB*	08.35.40	09.23.10
FE*	09.36.50	10.20.00
CD	10.26.00	10.43.50
FE*	10.49.00	11.32.30
CD	14.32.50	14.51.30
FE*	14.56.30	15.38.30
IJ*	15.56.10	16.43.50
HG	16.59.30	17.22.50

1 - * indicates spiral in the flight leg

TABLE VII: STATISTICAL DATA FOR CONSTANT ALTITUDE LEGS OF AUGUST 25, 1979 URBAN PLUME EXPERIMENT

leg	time[1] (e.d.t.)	average ± standard deviation Z (m)	T (C)	DP (ppb)	O_3 (ppb)	NO_x (ppb)	NO (ppb)	β_{scat}[2] (m^{-1})
AB	0900	352 ± 5	25.1 ± .2	21.4 ± .8	39 ± 5	8 ± 1	9 ± 1	4.9 ± 1.1
CD	1030	297 ± 3	25.6 ± .6	22.4 ± .3	41 ± 4	13 ± 2	11 ± 1	7.5 ± 1.5
	1440	297 ± 5	29.4 ± .4	20.9 ± .4	54 ± 5	12 ± 2	11 ± 1	7.7 ± .8
EF	1000	296 ± 5	25.3 ± .4	22.7 ± .7	41 ± 6	14 ± 7	12 ± 9	7.4 ± 2.5
	1110	304 ± 7	25.9 ± .3	22.1 ± .3	47 ± 7	15 ± 12	11 ± 12	8.4 ± 3.8
	1150	307 ± 12	29.0 ± .6	21.0 ± .3	60 ± 14	12 ± 2	10 ± 2	8.0 ± 1.3
GH	1710	328 ± 2	28.3 ± .7	21.0 ± 9	57 ± 12	10 ± 2	10 ± 1	7.7 ± 1.0
IJ	1620	328 ± 13	27.8 ± .6	21.2 ± 1.1	58 ± 12	10 ± 2	10 ± 1	7.4 ± 2.4

1 - approximate time at mid-point of leg

2 - all values x 10^{-5}

TABLE IX - LANGLEY AIRCRAFT FLIGHT SCHEDULE FOR AUGUST 31, 1979
PHOTOCHEMICAL BOX EXPERIMENT

Leg[1]	time, e.d.t. (hrs. mins. sec.) start	finish
spiral F[1]	08.00.00	08.10.10
spiral A[1]	08.18.20	08.25.50
AB[1]	08.26.00	08.28.40
CD[1]	08.33.10	08.39.20
EF[1]	08.44.00	08.50.10
spiral F[1]	08.50.10	08.59.40
spiral A	09.19.50	09.29.30
AB	09.29.40	09.36.40
CD	09.41.10	09.47.40
EF	09.51.20	09.56.20
spiral F	09.56.20	10.04.00
spiral A	10.13.20	10.21.00
AB	10.24.00	10.31.10
CD	10.35.20	10.42.20
EF	14.15.00	14.19.40
spiral F	14.19.50	14.26.40
spiral A	14.19.50	14.26.40
AB	14.43.50	14.50.30
CD	14.54.30	15.01.50
EF	15.04.30	05.09.40
spiral F	15.09.50	15.16.30
spiral A	15.26.20	15.34.10
AB	15.34.20	15.40.40
CD	15.44.30	15.51.50
EF	15.44.30	15.51.50
spiral F	15.59.50	16.06.20

1 - flight plan of figure 4 and table A-2; all other legs flight plan of figure 33 and table A-2

TABLE X: STATISTICAL DATA FOR CONSTANT ALTITUDE LEGS OF AUGUST 31, 1979 PHOTOCHEMICAL BOX EXPERIMENT

a. flight plan of figure 4

leg	time[1] (e.d.t.)	average ± standard deviation						
		Z (m)	T (C)	DP (C)	O_3 (ppb)	NO_x (ppb)	NO (ppb)	β_{scat}[2] (m^{-1})
AB	0827	233 ± 64	26.1 ± 3	19.8 ± 1.1	68 ± 11	18 ± 5	12 ± 1	20.7 ± .8
CD	0836	284 ± 3	25.8 ± .1	20.3 ± .7	88 ± 6	15 ± 3	11 ± 1	21.0 ± 2.6
EF	0847	257 ± 47	25.8 ± .2	20.8 ± .3	91 ± 6	13 ± 3	10 ± 1	20.2 ± 1.8

b. flight plan of figure 33

leg	time[1] (e.d.t.)	average ± standard deviation						
		Z (m)	T (C)	DP (C)	O_3 (ppb)	NO_x (ppb)	NO (ppb)	β_{scat}[2] (m^{-1})
AB	0933	272 ± 40	24.8 ± .5	21.8 ± .9	60 ± 4	20 ± 7	11 ± 2	22.5 ± 2.7
	1027	293 ± 2	25.2 ± .3	20.6 ± 1	78 ± 5	16 ± 4	10 ± 2	21.4 ± 1.5
	1447	267 ± 40	25.9 ± .2	19.4 ± 9	120 ± 5	16 ± 2	11 ± 1	21.2 ± 2.7
	1537							
CD	0944	288 ± 2	25.3 ± .4	21.9 ± .4	66 ± 9	24 ± 4	12 ± 1	21.2 ± .9
	1039	296 ± 2	25.1 ± .2	22.1 ± 3	68 ± 5	21 ± 3	12 ± 2	22.7 ± .6
	1458	279 ± 3	26.8 ± .2	20.4 ± .5	122 ± 5	19 ± 3	10 ± 1	22.4 ± .8
	1547	293 ± 3	27.0 ± .3	20.1 ± .4	119 ± 6	19 ± 5	10 ± 1	22.6 ± 1.5
EF	0953	289 ± 2	25.8 ± .1	21.6 ± .4	81 ± 7	22 ± 9	10 ± 2	23.4 ± 4.7
	1417	284 ± 5	27.5 ± .2	20.0 ± .4	121 ± 4	19 ± 6	12 ± 1	25.8 ± .5
	1506	280 ± 7	27.6 ± .1	20.5 ± .5	119 ± 5	18 ± 4	10 ± 1	25.7 ± .8
	1557	295 ± 4	27.3 ± .2	20.3 ± .5	116 ± 4	18 ± 4	10 ± 1	24.1 ± .6

1 - approximate time at mid-point of leg

2 - all values x 10^{-5}

TABLE XI: STATISTICAL DATA FOR CONSTANT ALTITUDE LEGS OF AUGUST 15, 1979 SWAMP EXPERIMENT

leg	time[1] (e.d.t.)	Z (m)	T (C)	DP (C)	O_3 (ppb)	NO_x (ppb)	NO (ppb)	β scat[2] (m^{-1})
			average ± standard deviation					
LD-NCC	0700	1606 ± 2	13.7 ± .1	10.5 ± .1	71 ± 2	14 ± 1	12 ± 1	16 ± .8
NCC-B	0725	1711 ± 70	13.2 ± .5	9.5 ± 8	73 ± 2	14 ± 2	12 ± 1	17 ± .2
D-NCC	0810	248 ± 121	21.2 ± 1.1	16.8 ± .8	48 ± 3	17 ± 3	13 ± 1	14 ± .8
NCC-LC	0840	142 ± 38	20.7 ± .2	15.4 ± .4	36 ± 1	22 ± 2	13 ± 2	15 ± .5

1 - approximate time at mid-point of leg

2 - all values x 10^{-5}

TABLE XII: STATISTICAL DATA FOR AIRCRAFT COMPARISON FLIGHTS

a. Langley-Wallops Aircraft Flight (August 15, 1979)

leg	time[1] (e.d.t.)	Z (m)	average ± standard deviation T (C)	DP (C)	O_3 (ppb)	NO_x (ppb)	NO (ppb)	β scat[2] (m^{-1})
AB	1023	1572 ± 64	11.8 ± .3	-12.3 ± 2.4	54 ± 5	15 ± 1	15 ± 1	2.3 ± .6
Spiral B	1031	NA[3]	13.5 ± 3	5.5 ± 7.4	48 ± 2	18 ± 2	16 ± 2	5.3 ± 1.5
BA	1040	604 ± 5	14.3 ± .2	8.8 ± .4	46 ± 2	19 ± 2	16 ± 1	6.6 ± .6

1 - approximate time at mid-point of leg

2 - all values times 10^{-5}

3 - altitude range 118 to 1550 m

b. Langley-Contractor Aircraft Flight (August 20, 1979)

leg	time[1] (e.d.t.)	Z (m)	average ± standard deviation T (c)	DP (c)	O_3 (ppb)	NO_x (ppb)	NO (ppb)	β scat[2] (m^{-1})
AB	1117	1611 ± 29	15.4 ± .4	12.8 ± .7	86 ± 2	18 ± 1	17 ± 1	16.7 ± 2.5
Spiral B	1127	NA[3]	19.8 ± 2	17.9 ± 3	83 ± 5	21 ± 2	17 ± 1	19.5 ± 6.8
BA	1140	147 ± 18	24.0 ± .7	21.7 ± .4	88 ± 1	24 ± 2	17 ± 1	32.3 ± 3.3

1 - approximate time at mid-point of leg

2 - all values times 10^{-5}

3 - altitude range 180 to 1568 m

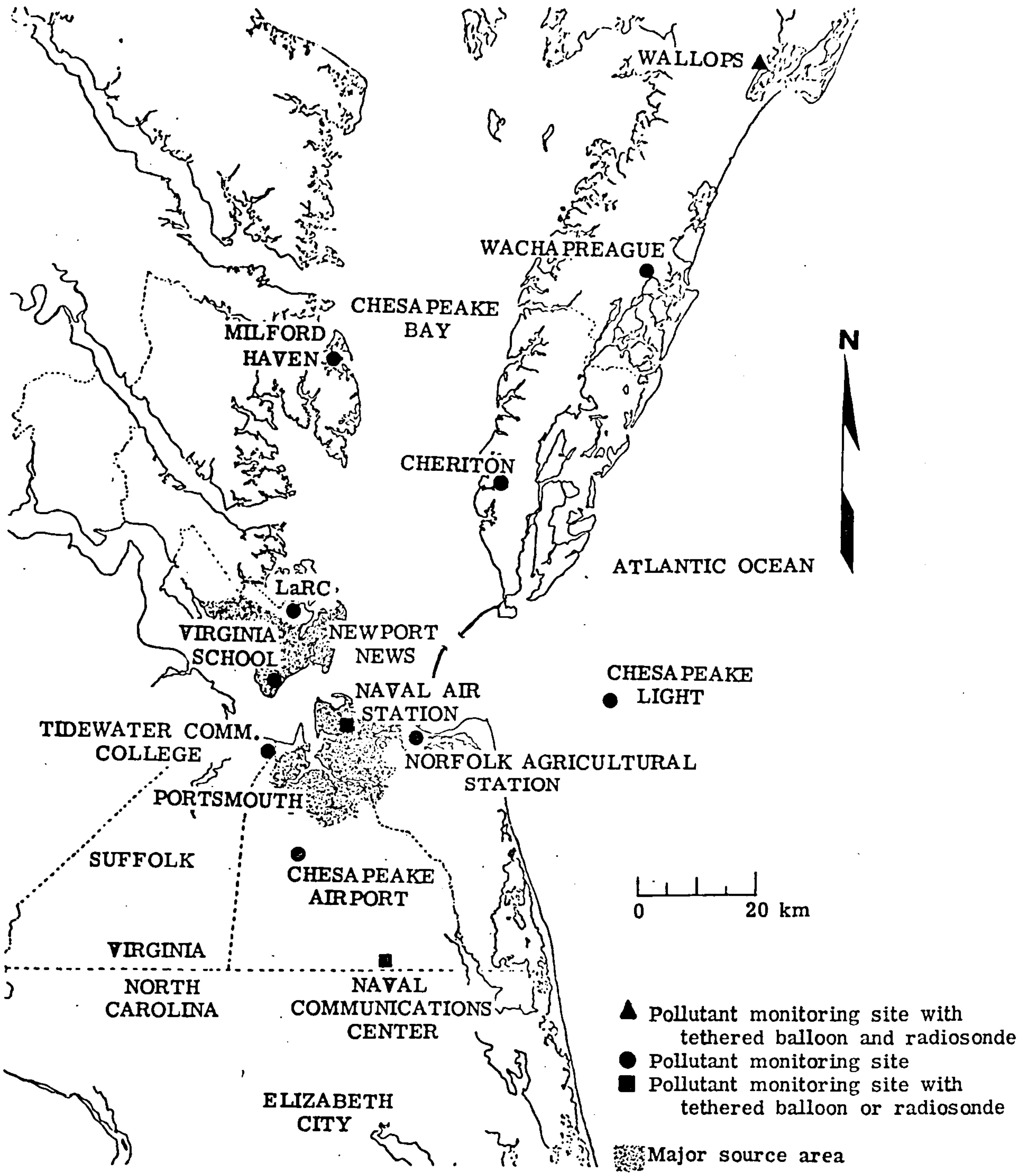


Figure 1. - Southeastern Virginia test area.

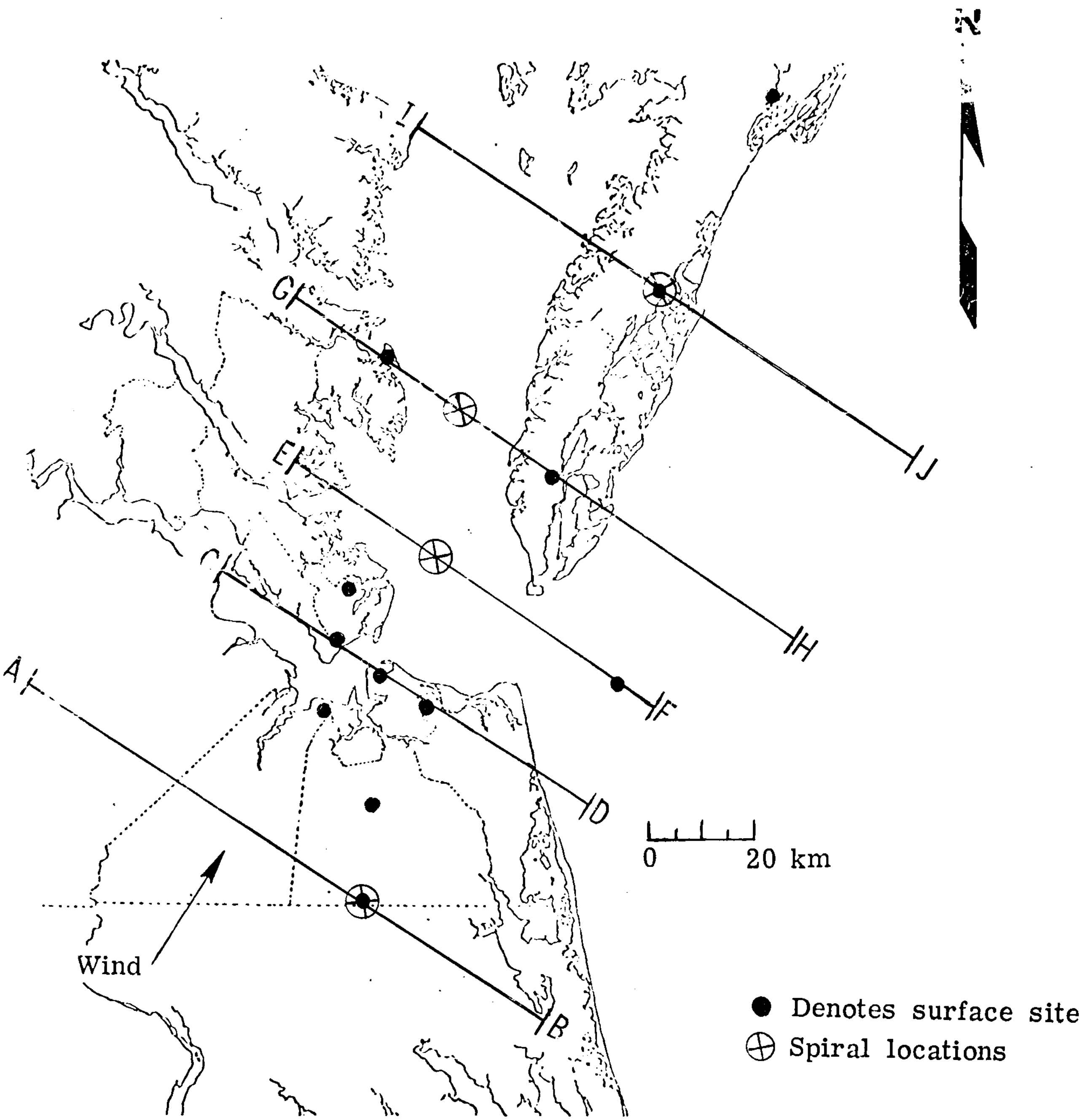


Figure 2. - Urban plume experiment flight legs; southwest flow case.

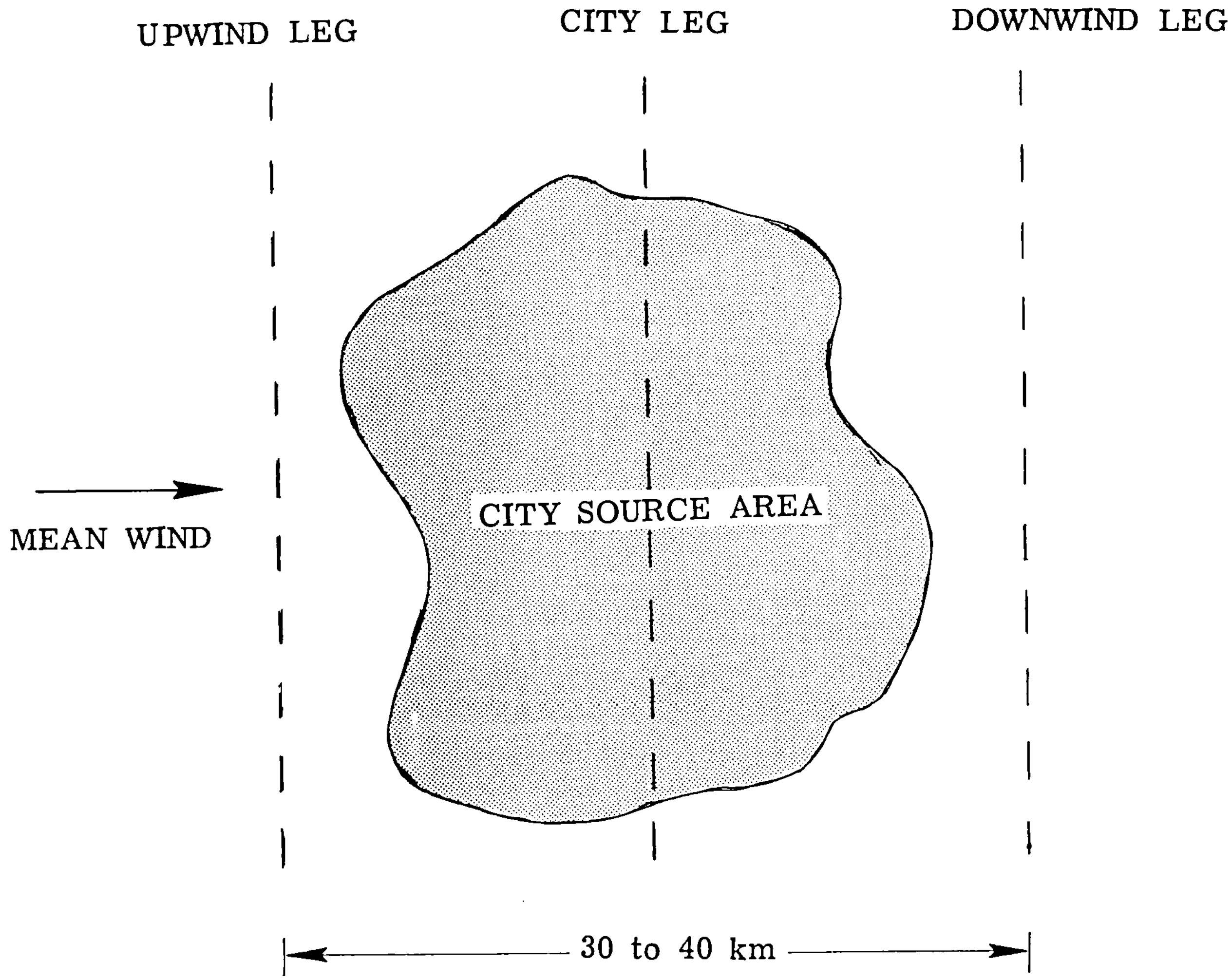


Figure 3. - Photochemical box experiment sampling strategy.

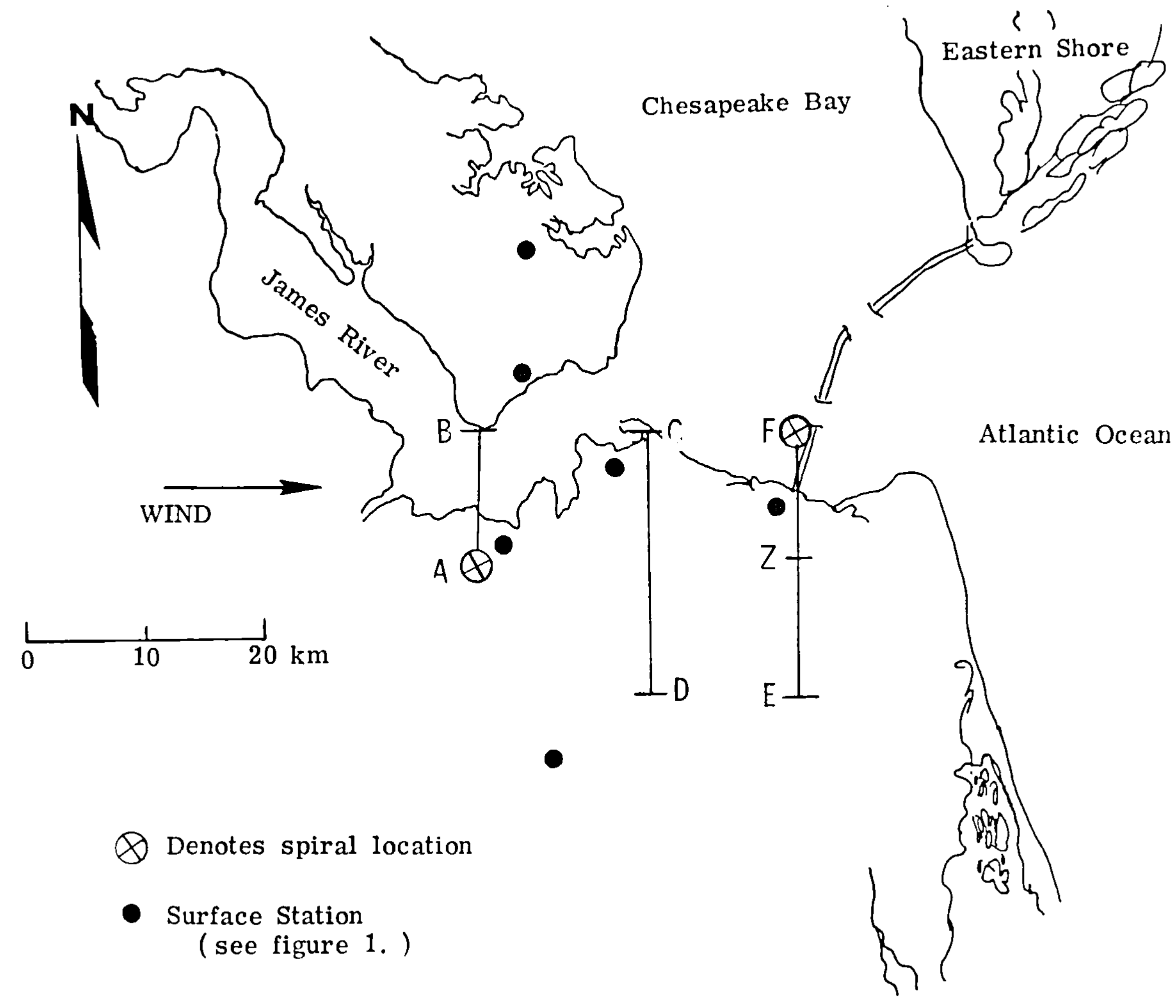


Figure 4. - Photochemical box experiment flight legs; west flow case.

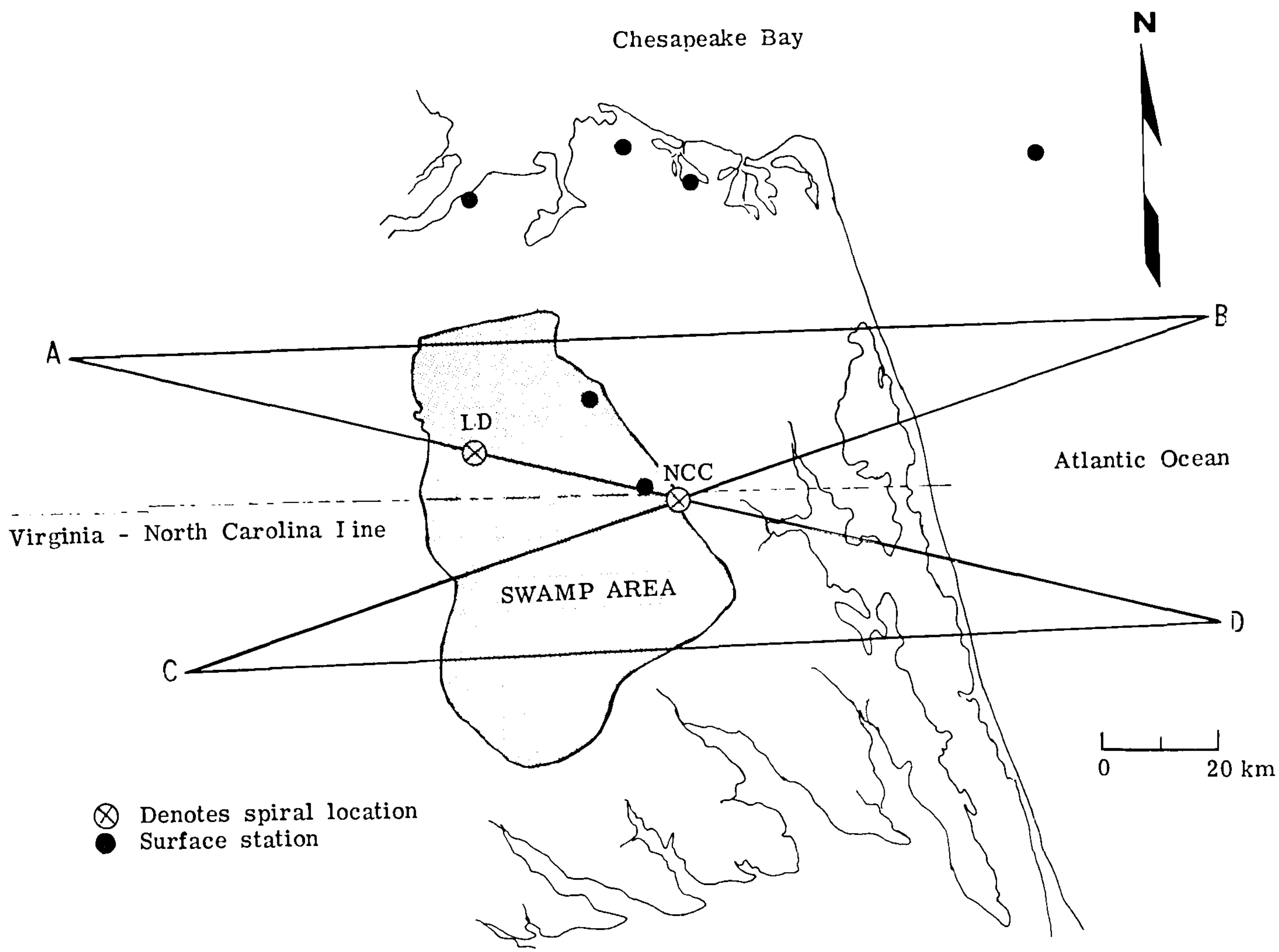


Figure 5. - Swamp characterization experiment flight legs.

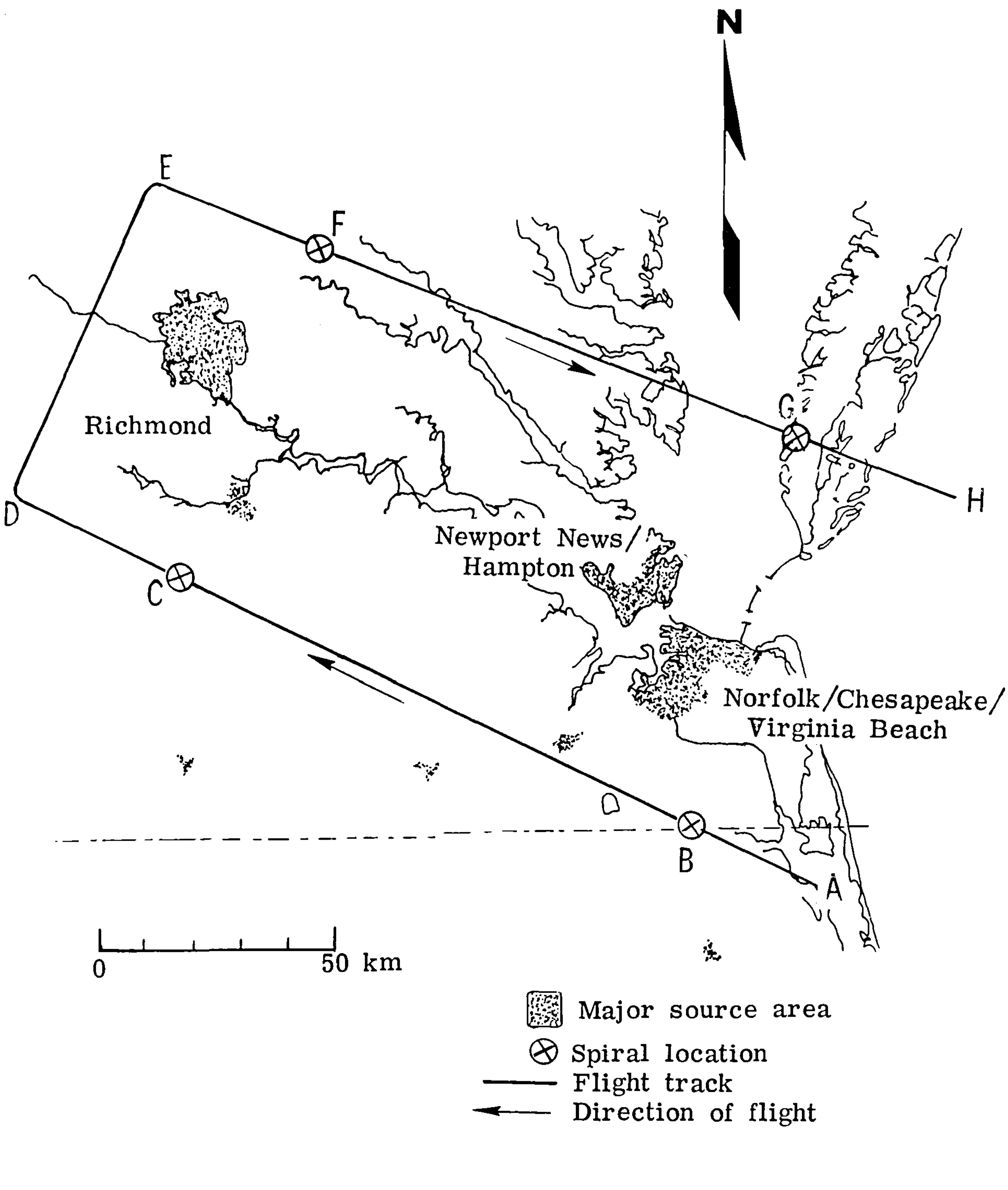


Figure 6. - Coastal-inland plume experiment flight legs.

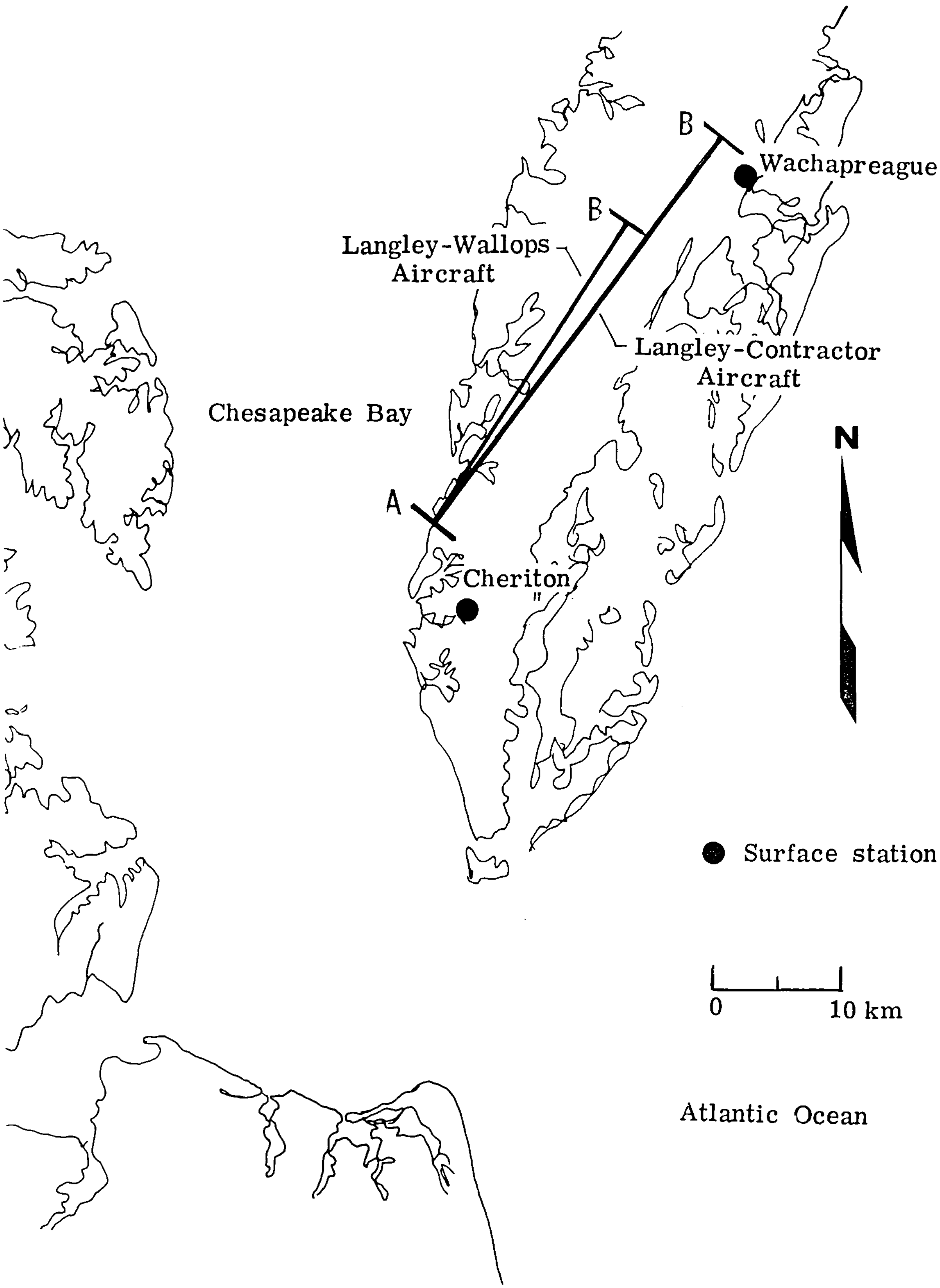


Figure 7. - Location of aircraft comparison flights.

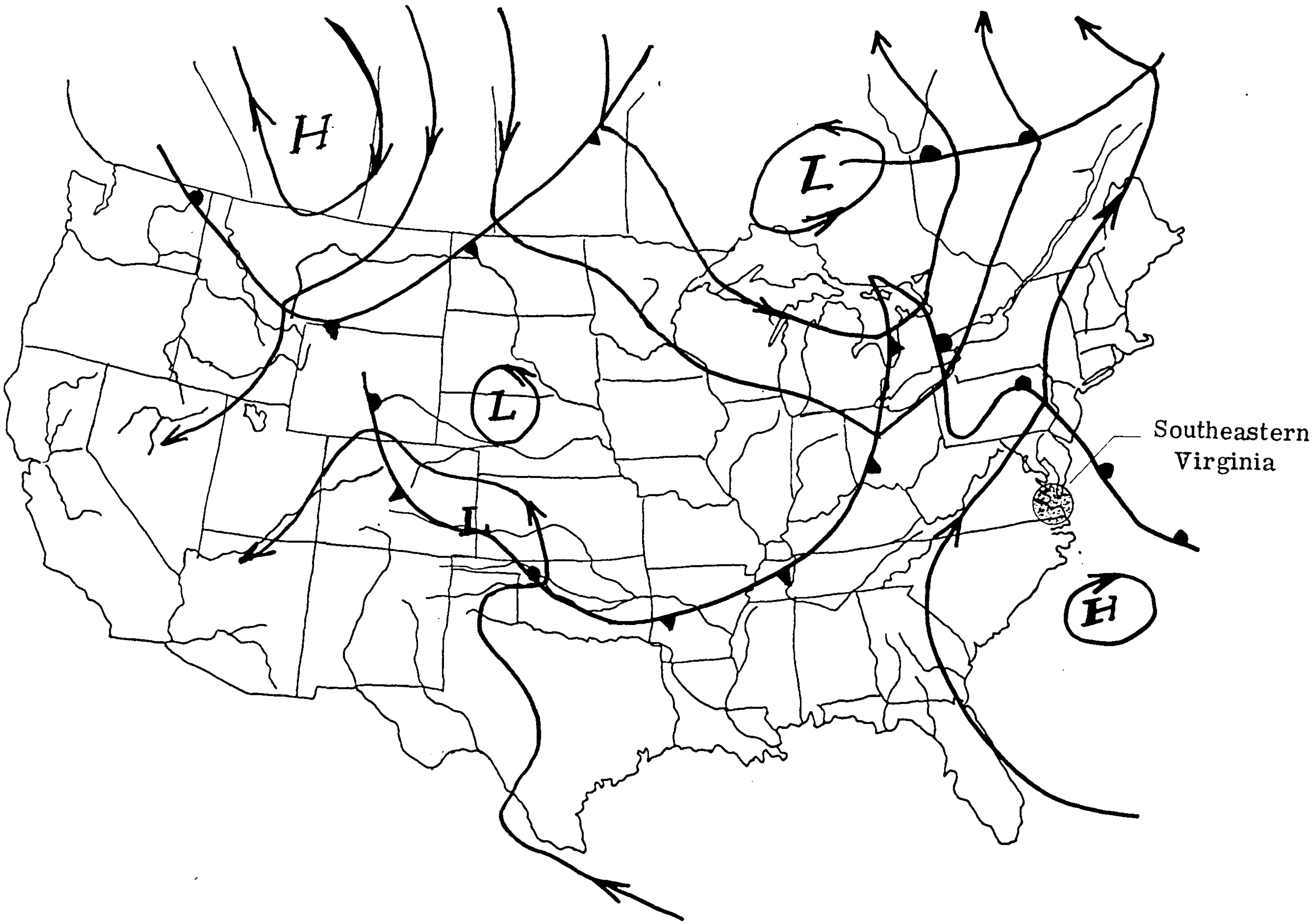
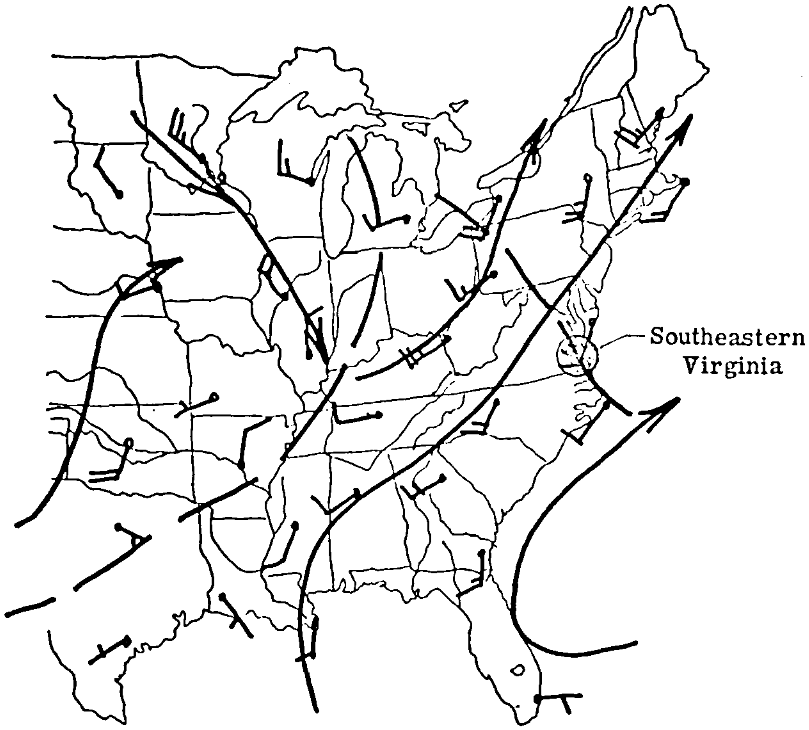
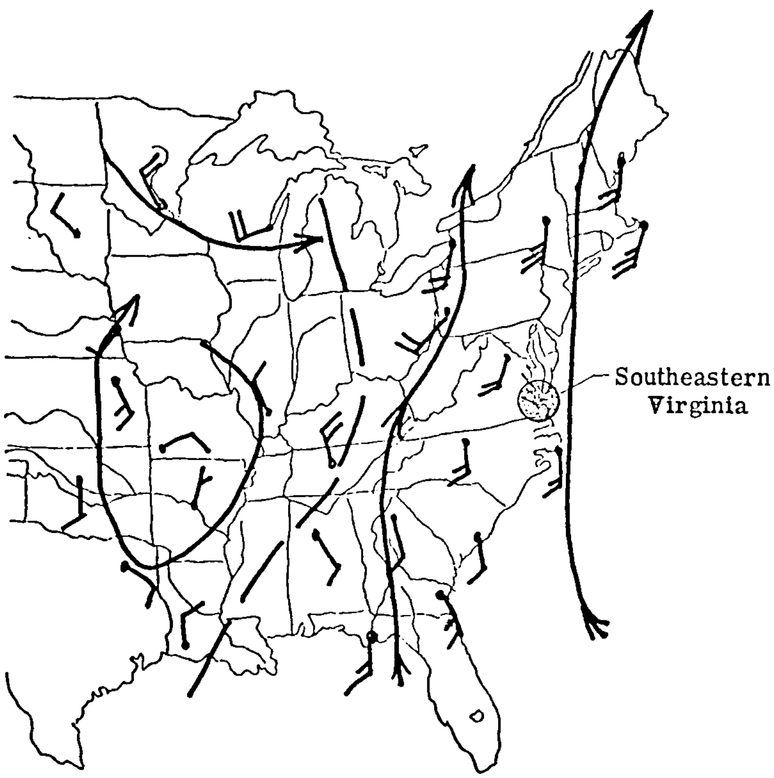


Figure 8. - Synoptic weather chart; 1200 e.d.t., August 24, 1979.

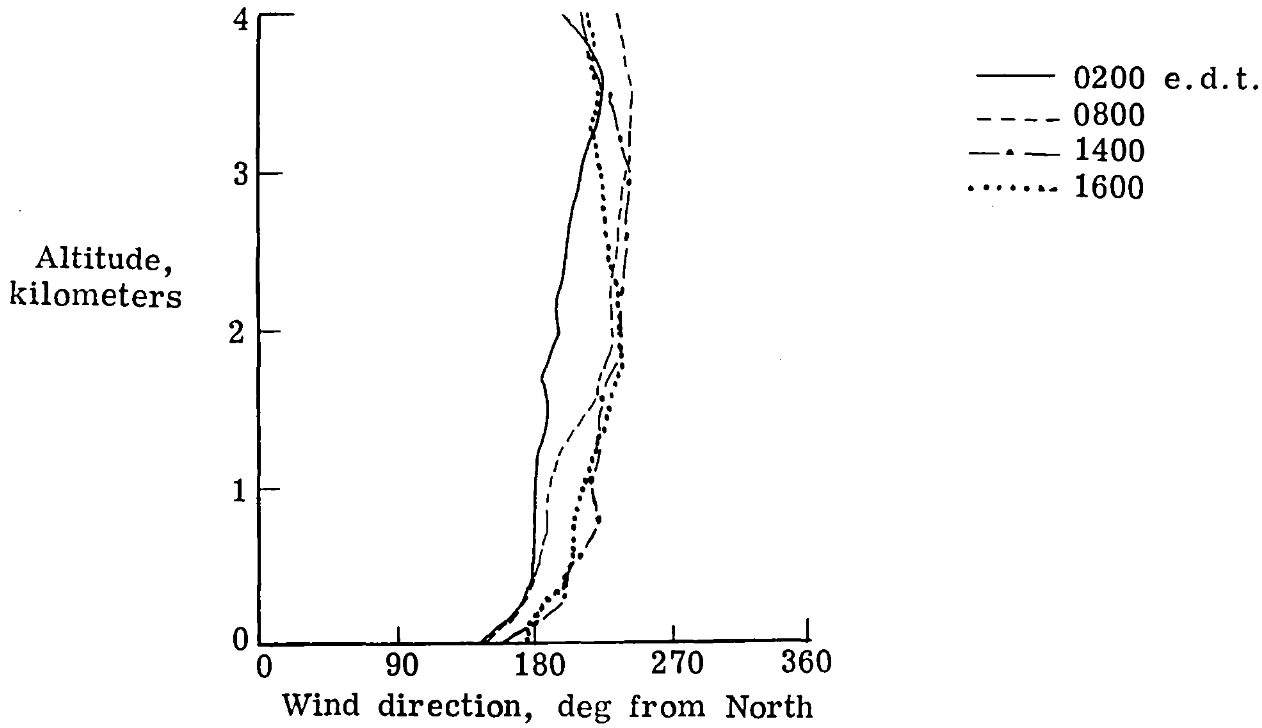


a.) 0800 e.d.t.

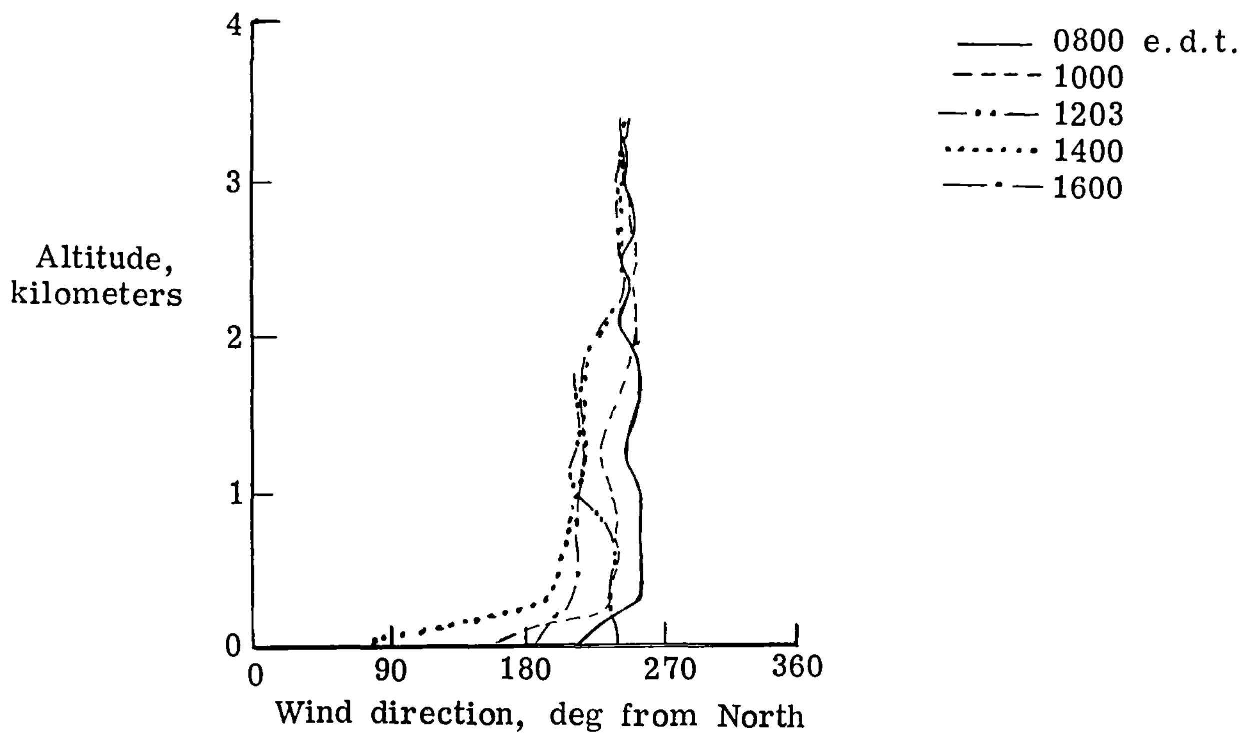


b.) 2000 e.d.t.

Figure 9. - 500-millibar wind flow charts; August 24, 1979.



a.) Wallops Island, Virginia



b.) Naval Air Station; Norfolk, Virginia

Figure 10. - Wind direction as a function of altitude; August 24, 1979.

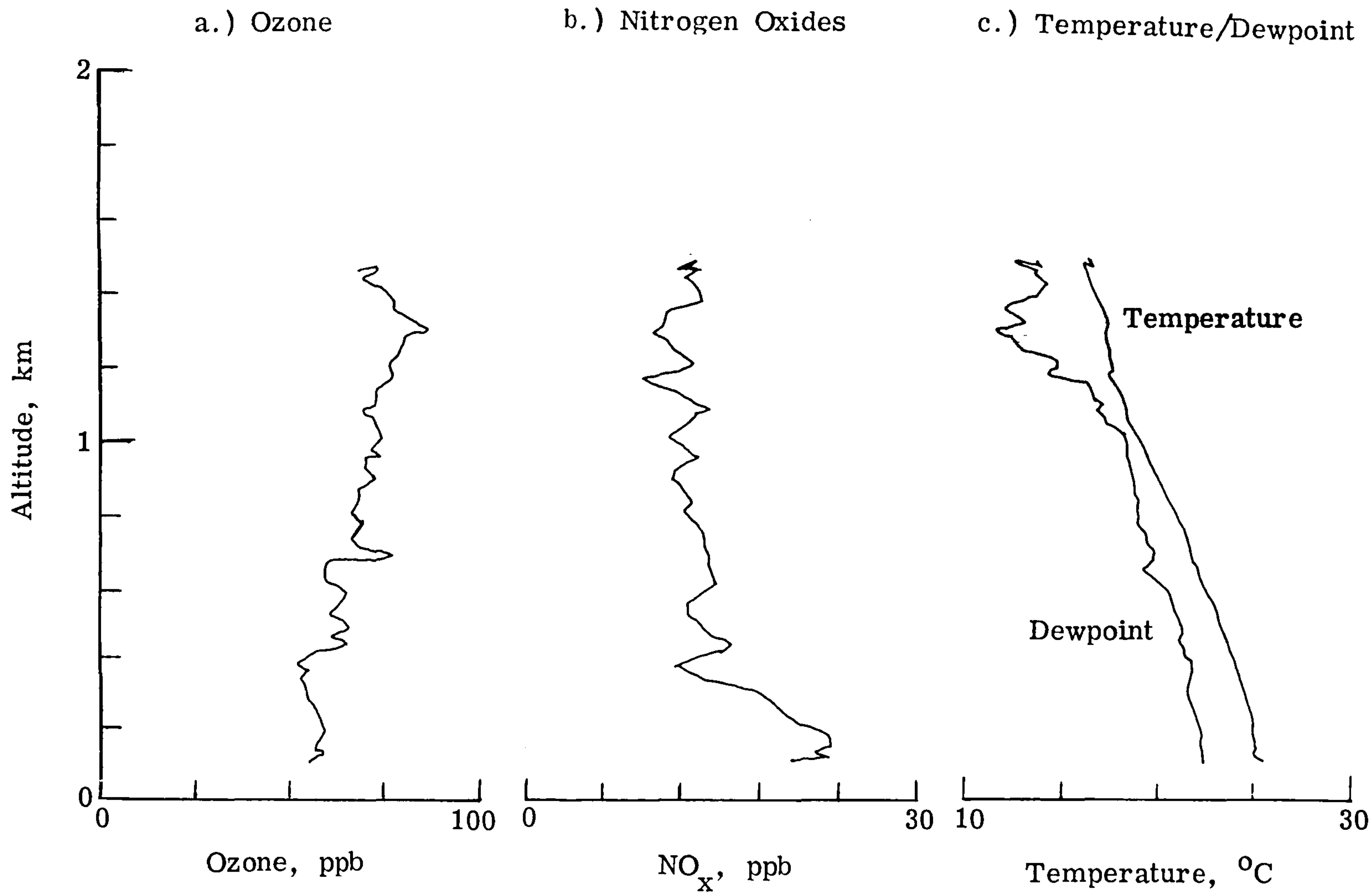


Figure 11. - Spiral data on leg EF; 0945 e.d.t., August 24, 1979.

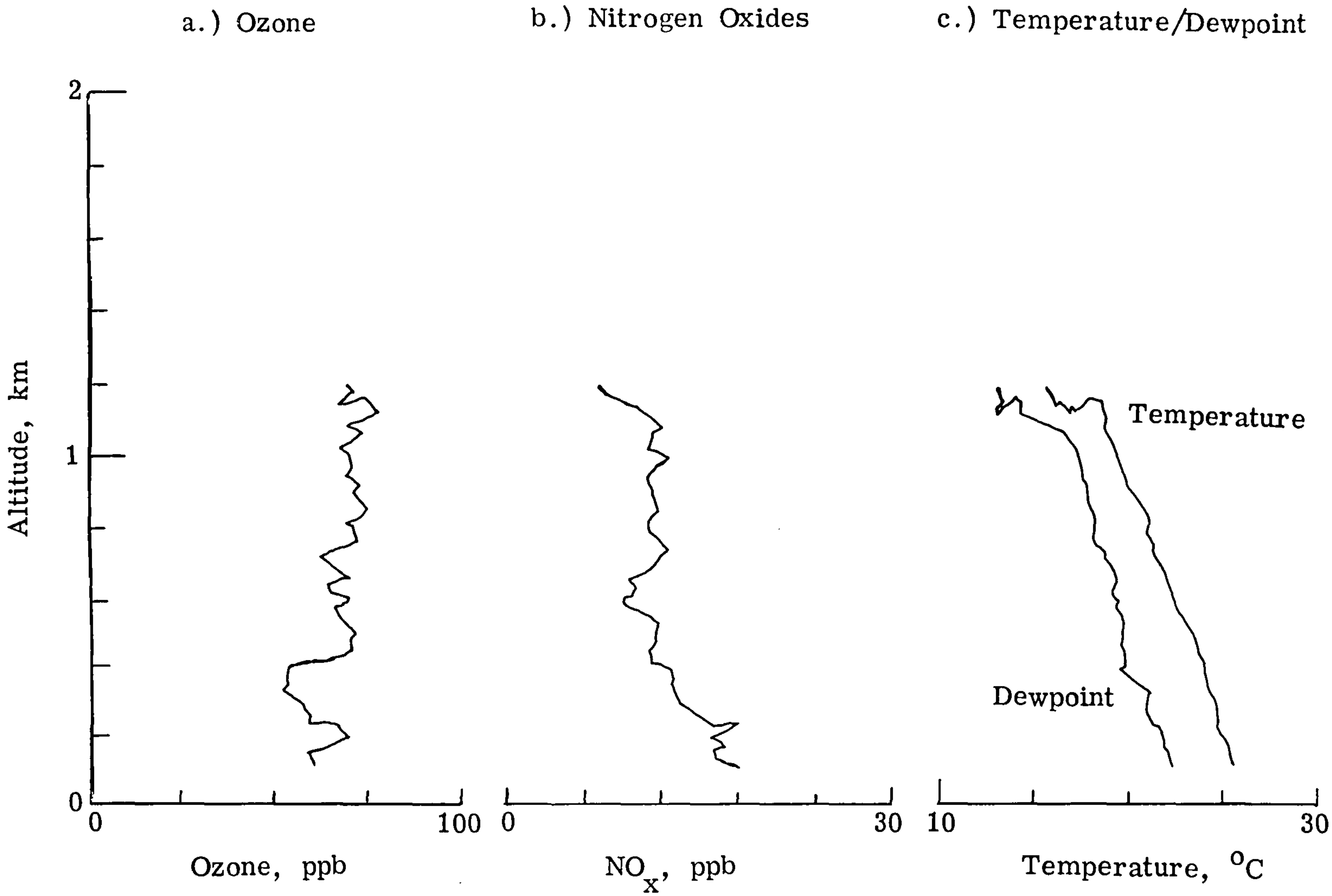


Figure 12. - Spiral data on leg EF; 1100 e.d.t., August 24, 1979.

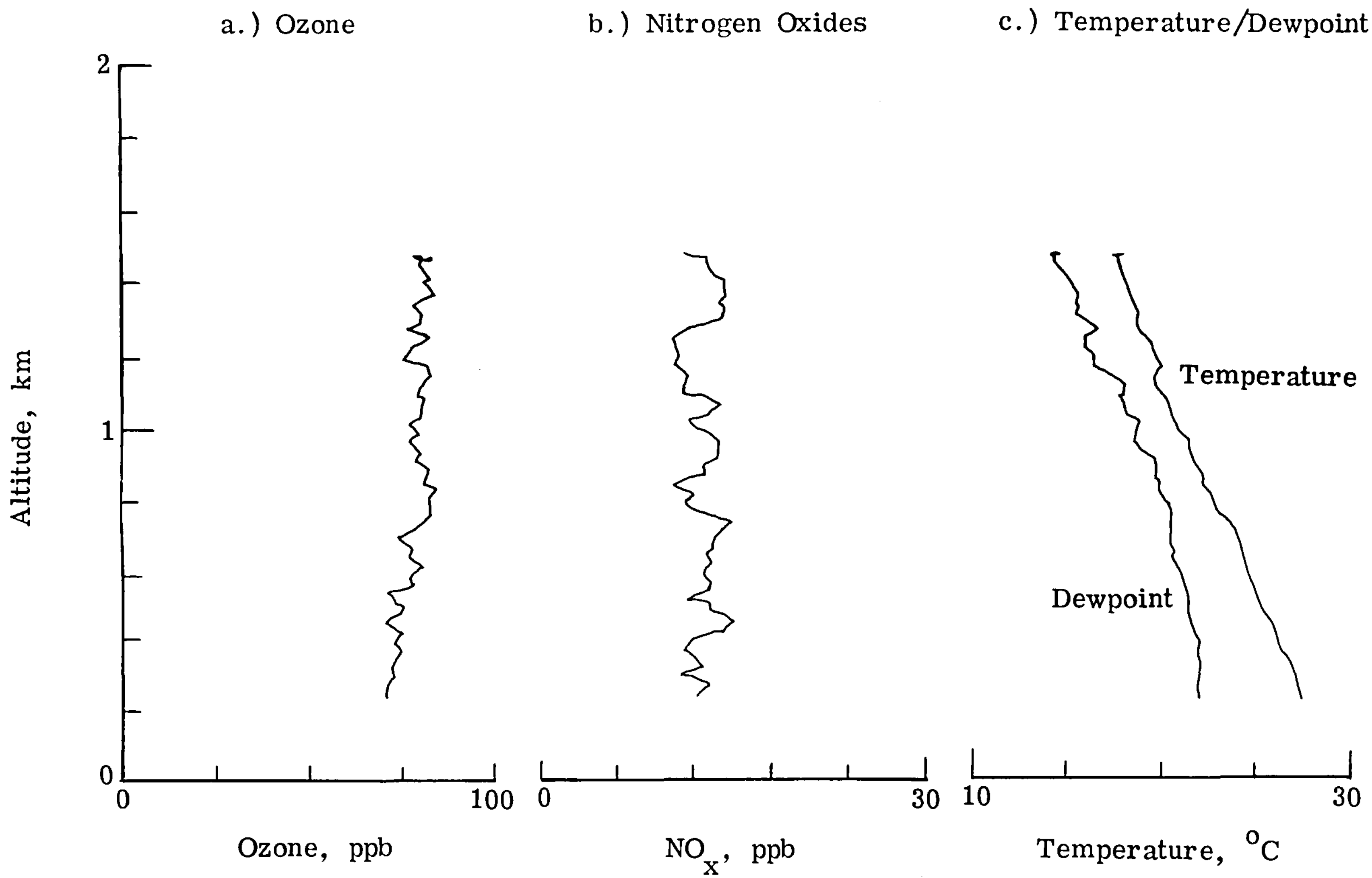


Figure 13. - Spiral data on leg EF; 1530 e.d.t., August 24, 1979.

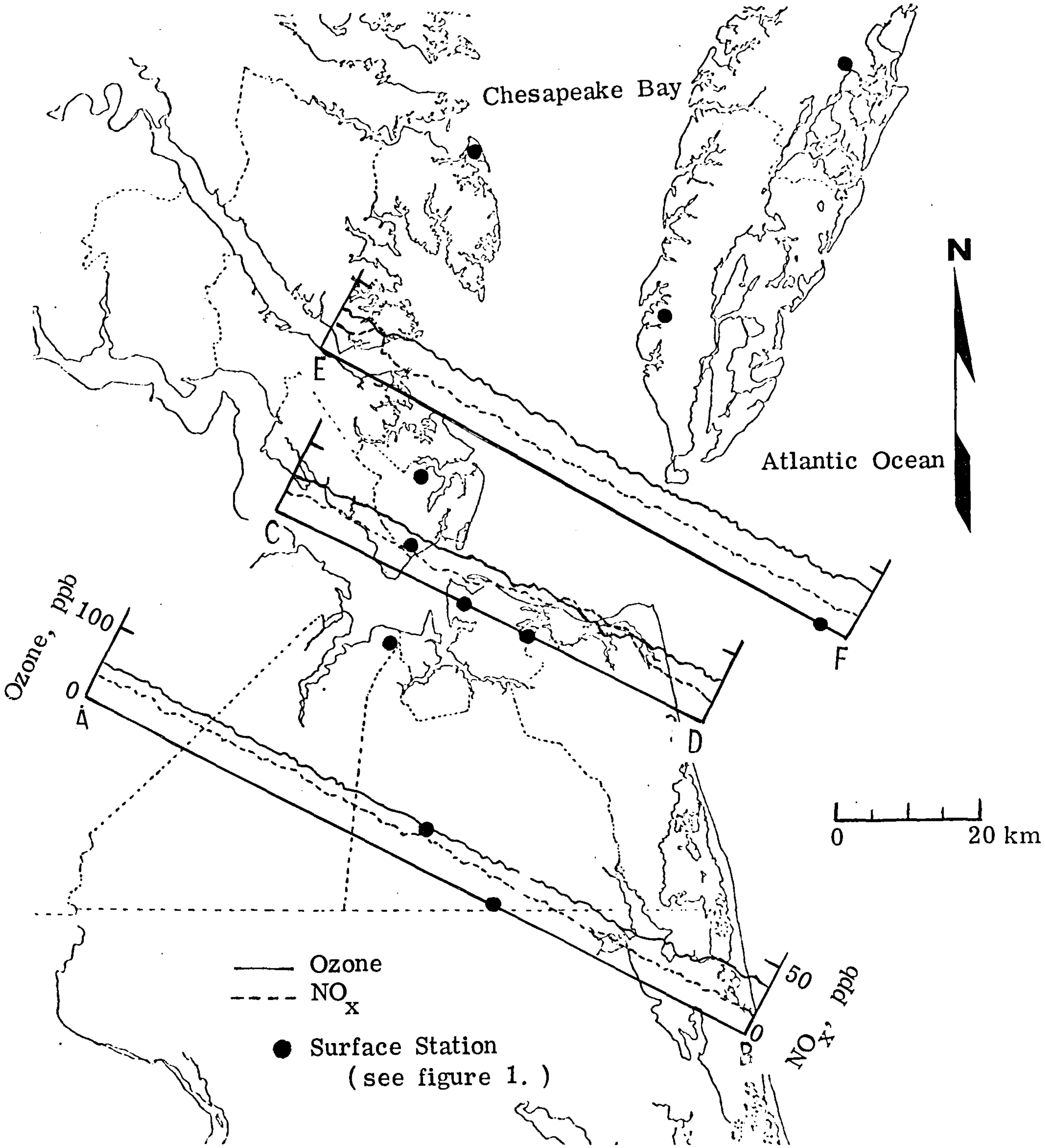


Figure 14. - Ozone and nitrogen oxides data (0.3 km altitude); morning of of August 24, 1979.

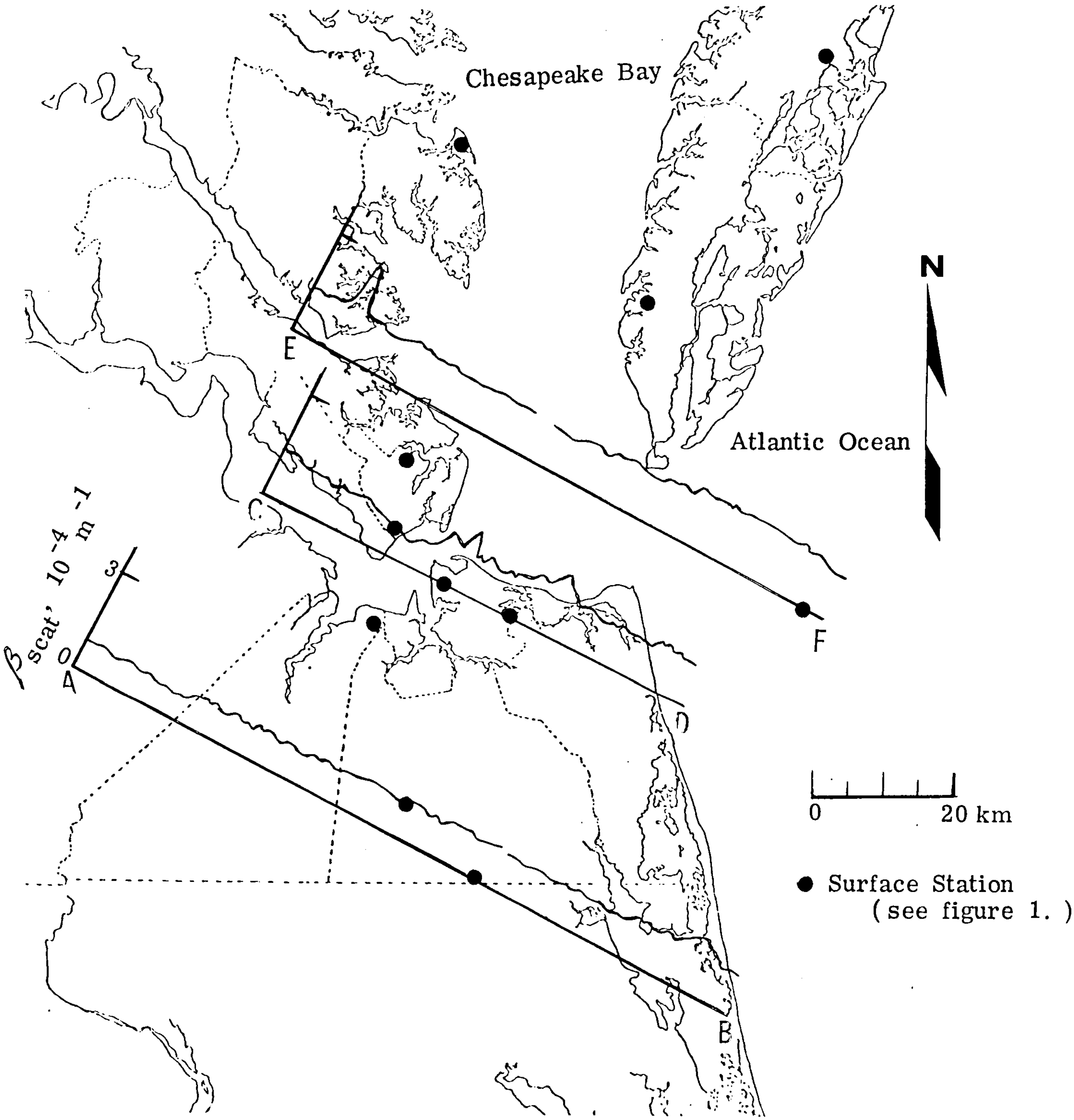


Figure 15. - β_{scat} data (0.3 km altitude); morning of August 24, 1979.

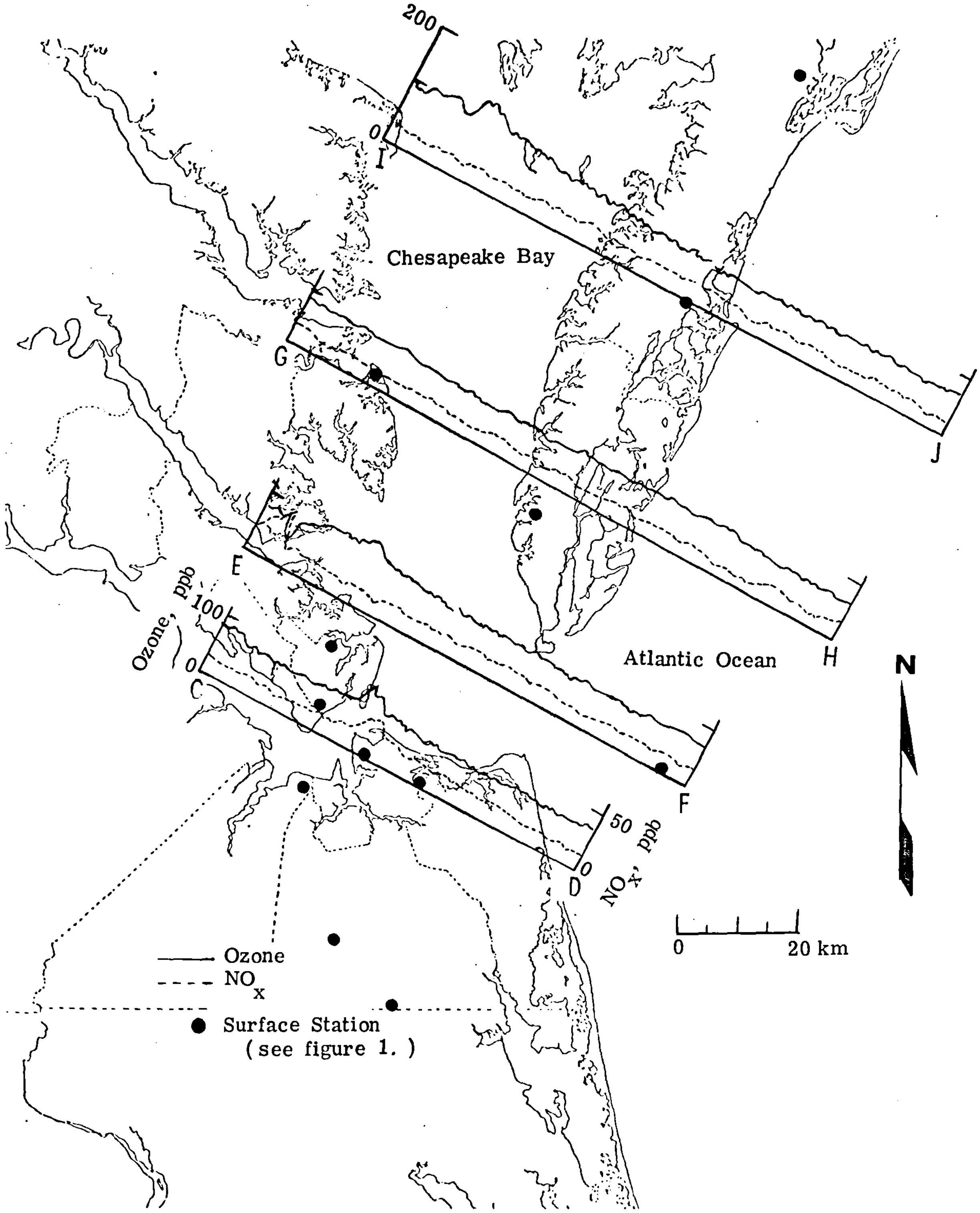


Figure 16. - Ozone and nitrogen oxides data (0.3 km altitude); afternoon of August 24, 1979.

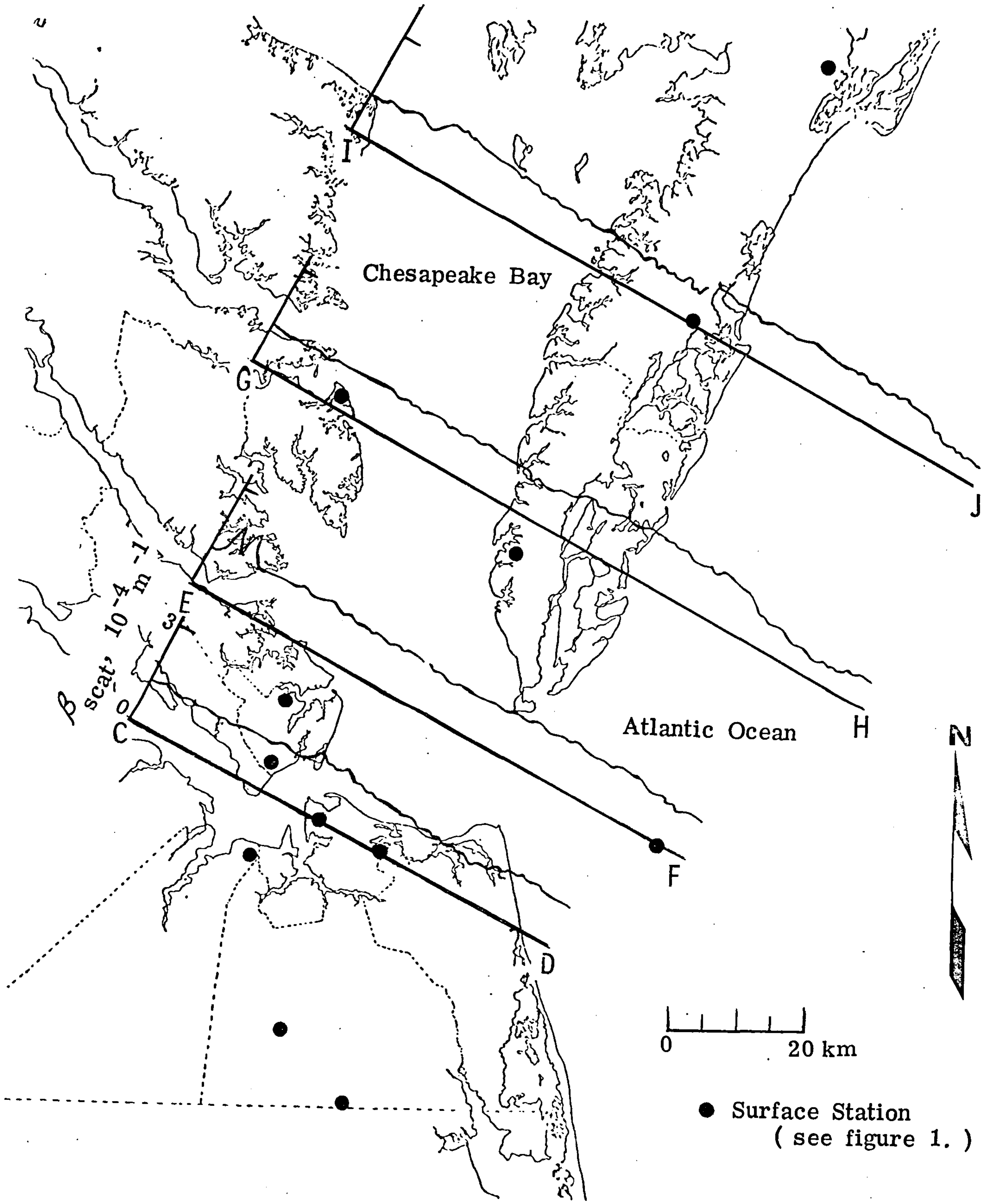


Figure 17. - β_{scat} data (0.3 km altitude); afternoon of August 24, 1979.

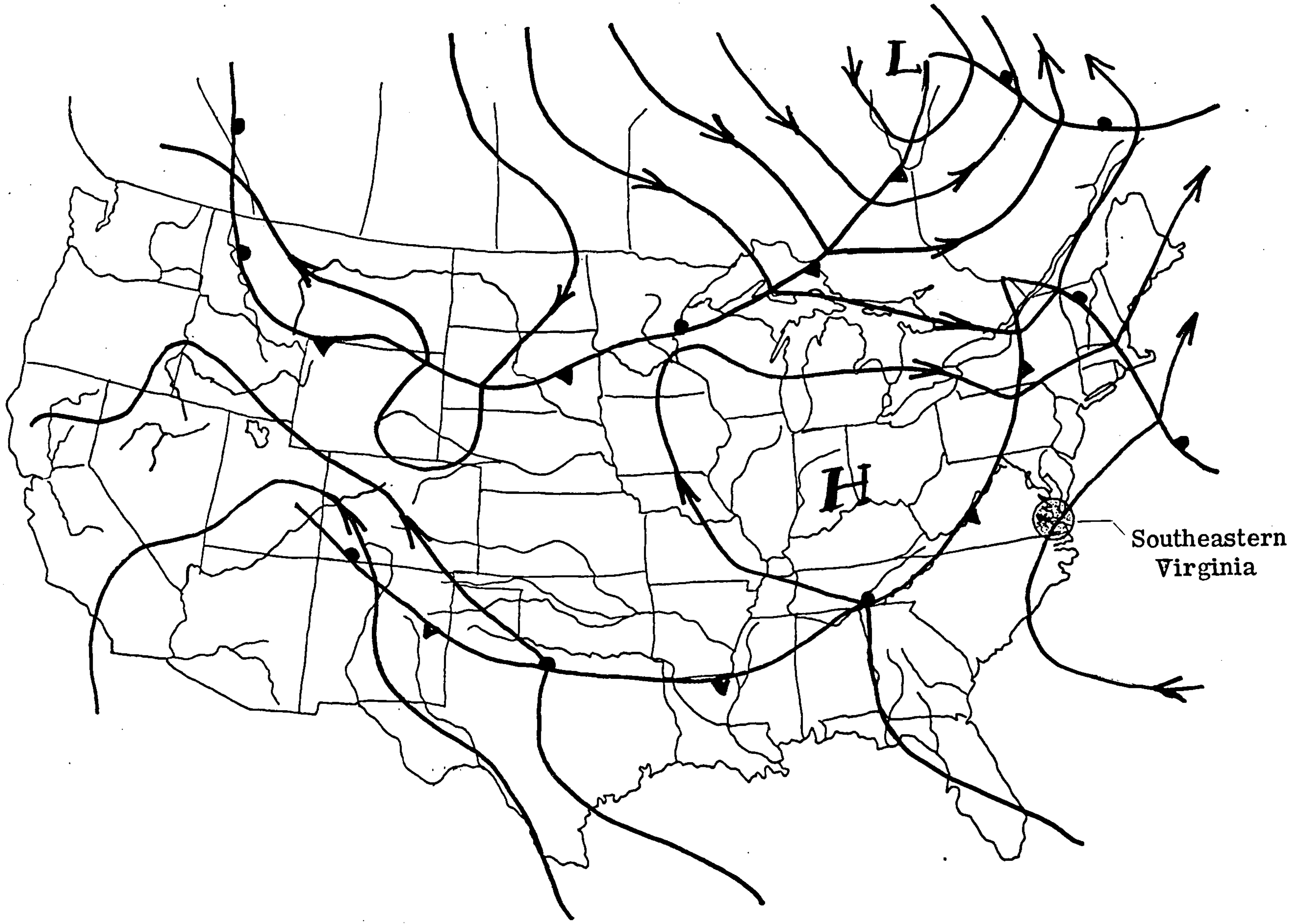
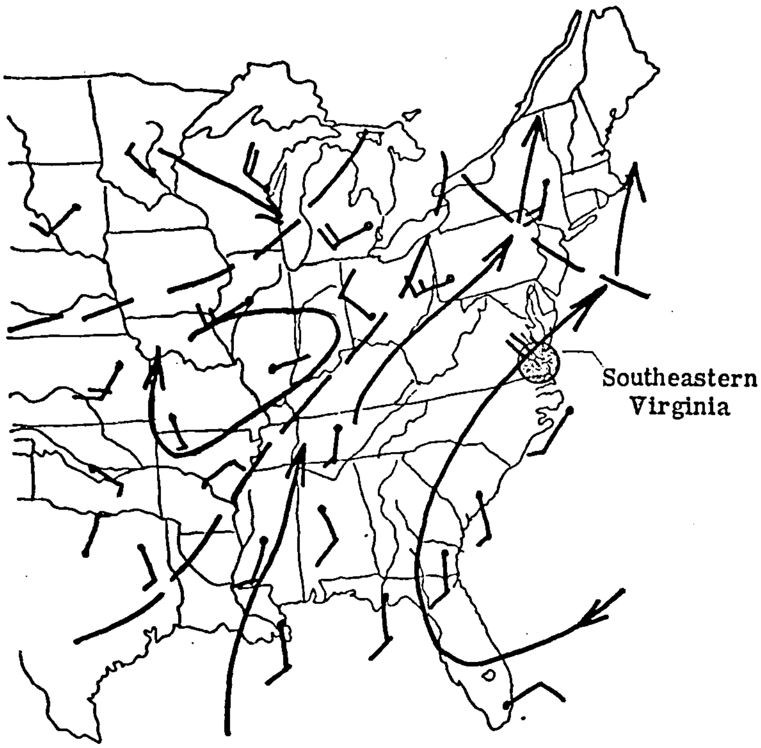
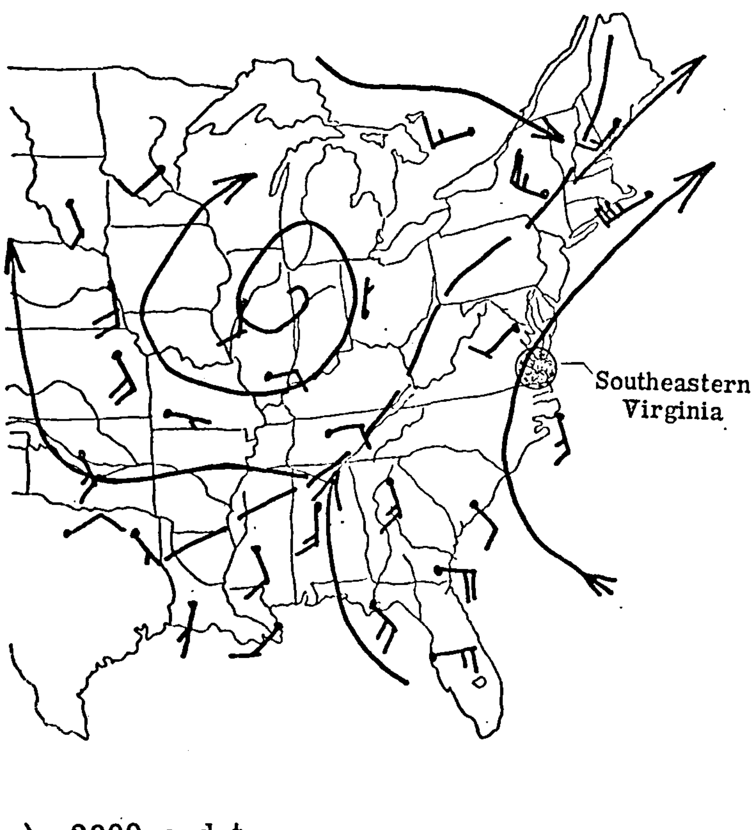


Figure 18. - Synoptic weather chart; 0800 e.d.t., August 25, 1979.

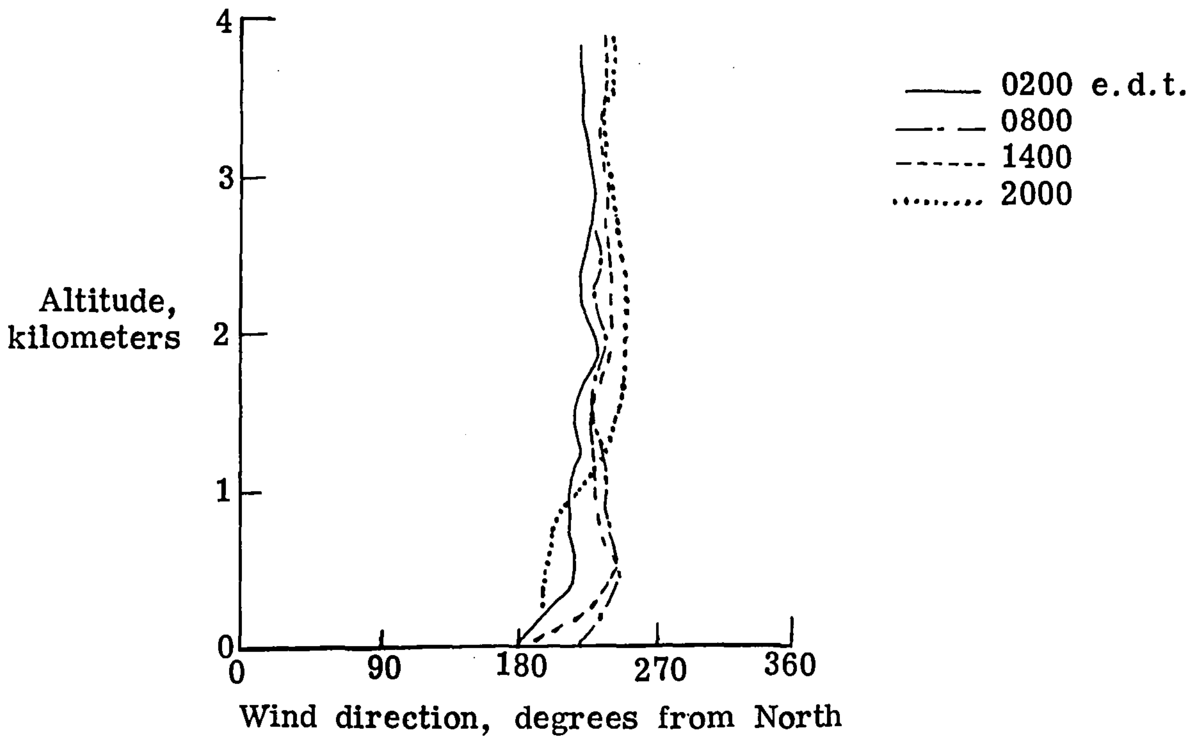


a.) 0800 e.d.t.

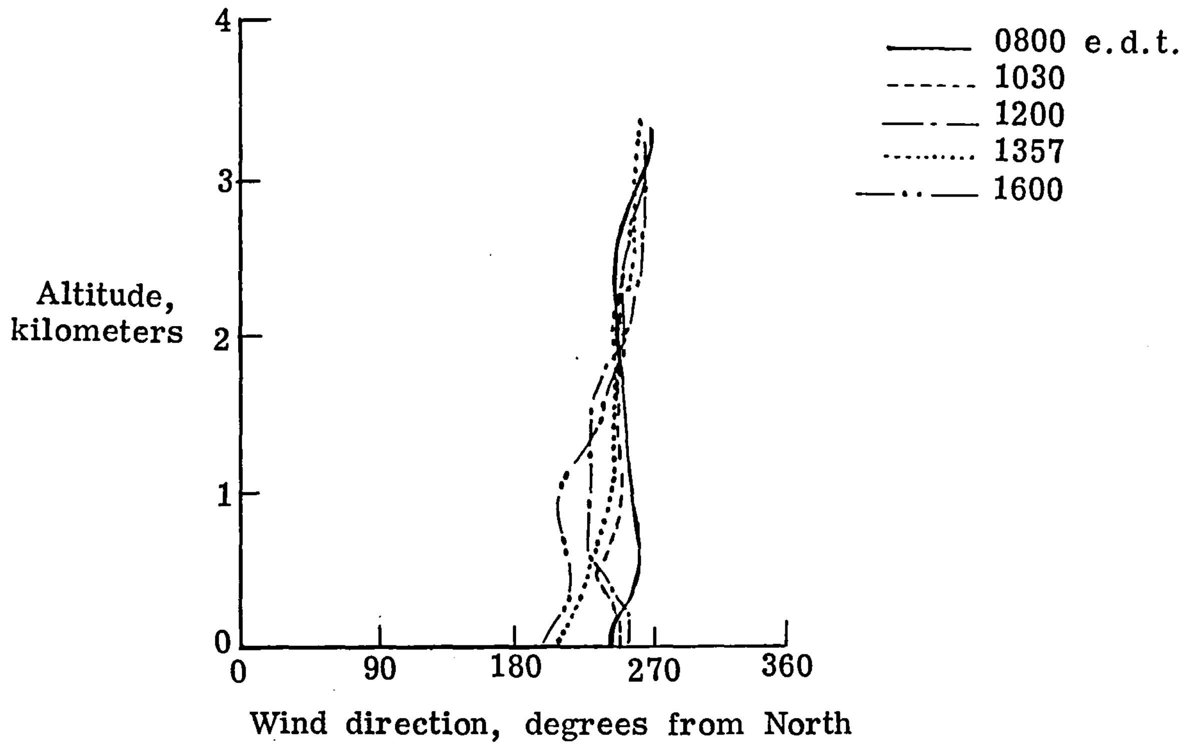


b.) 2000 e.d.t

Figure 19. - 500-millibar wind flow charts; August 25, 1979.



a.) Wallops Island, Virginia



b.) Naval Air Station; Norfolk, Virginia

Figure 20. - Wind direction as a function of altitude; August 25, 1979.

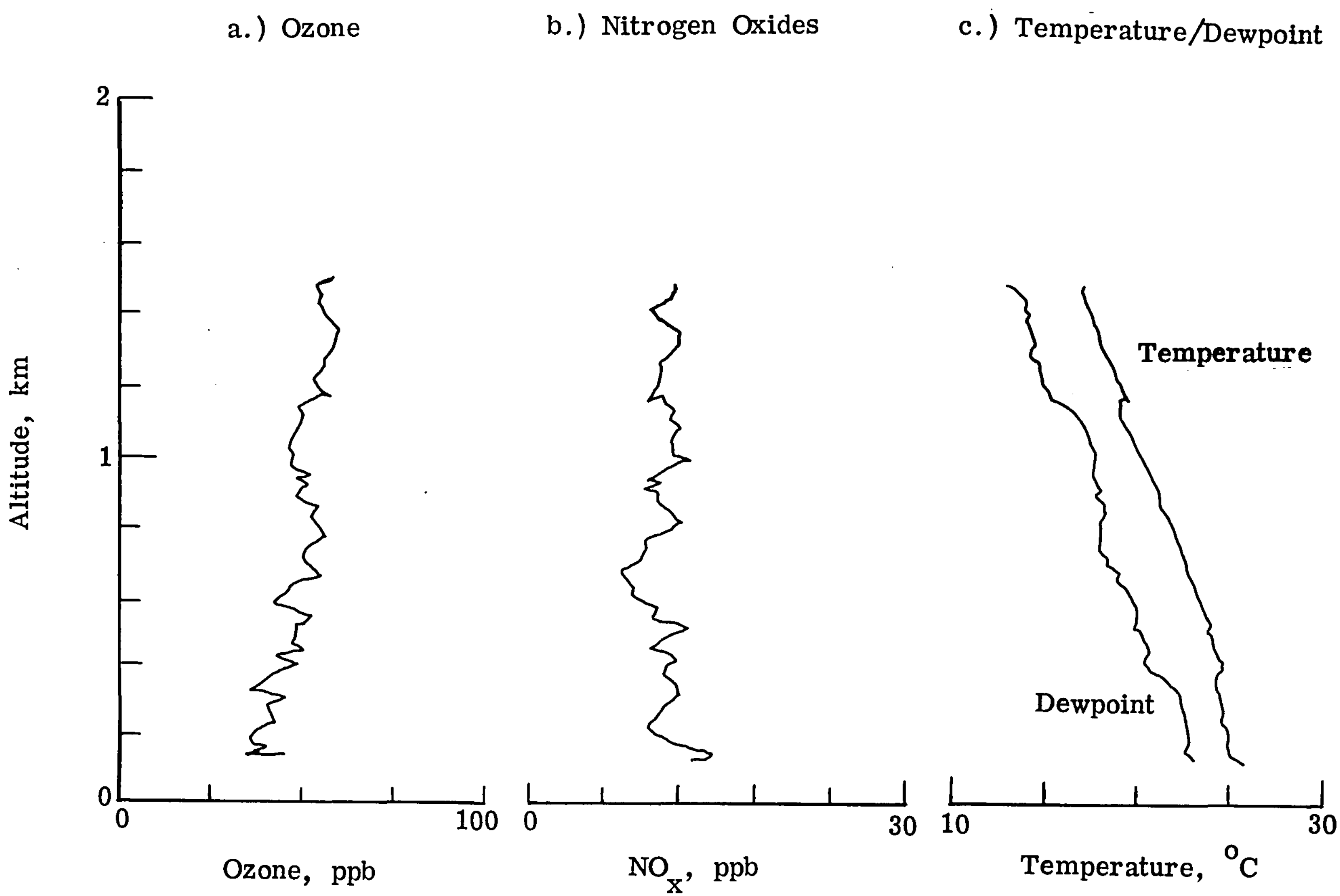


Figure 21. - Spiral data on leg EF; 0955 e.d.t., August 25, 1979.

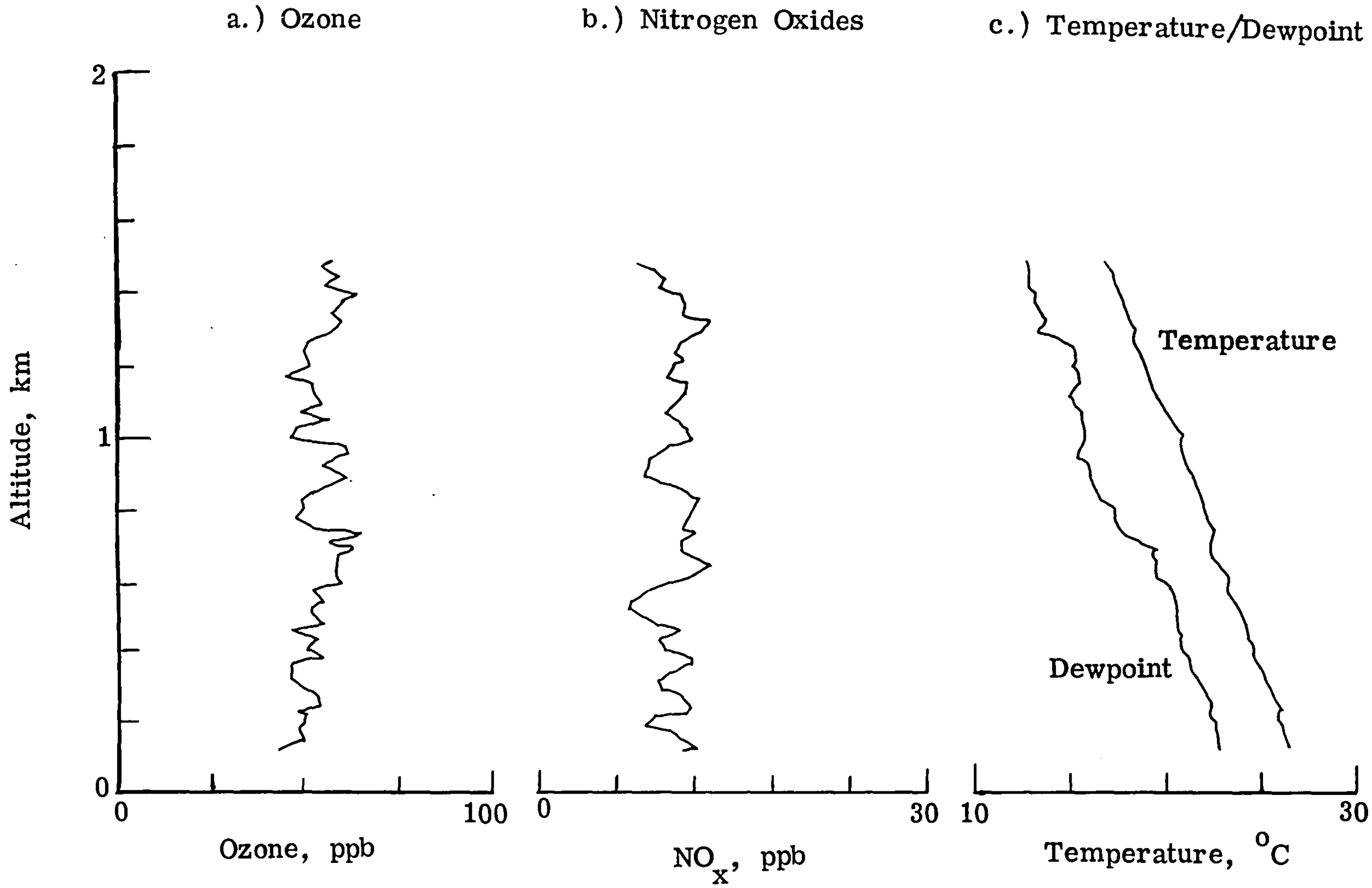


Figure 22. - Spiral data on leg EF; 1105 e.d.t., August 25, 1979.

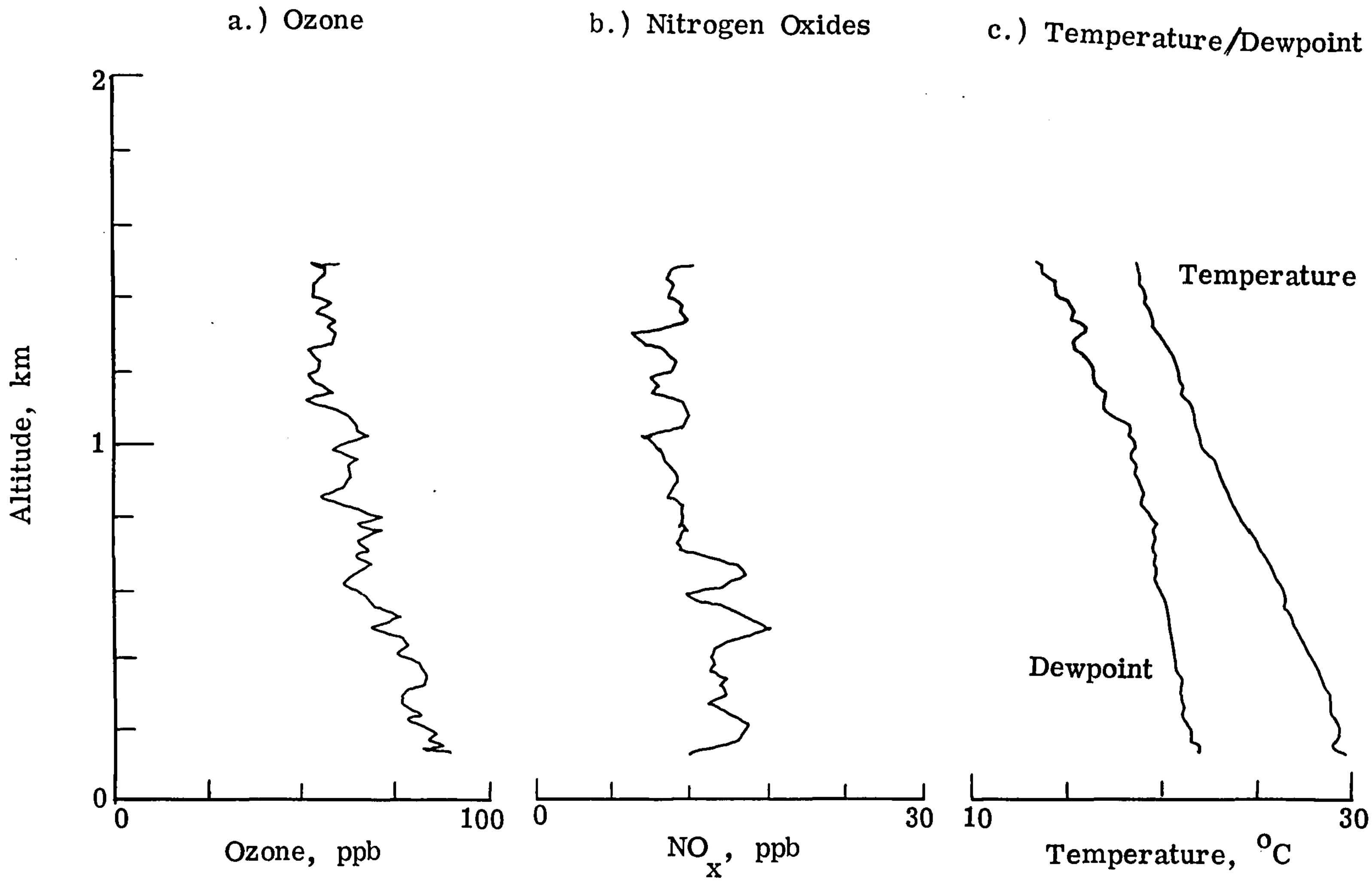


Figure 23. - Spiral data on leg EF; 1530 e.d.t., August 25, 1979.

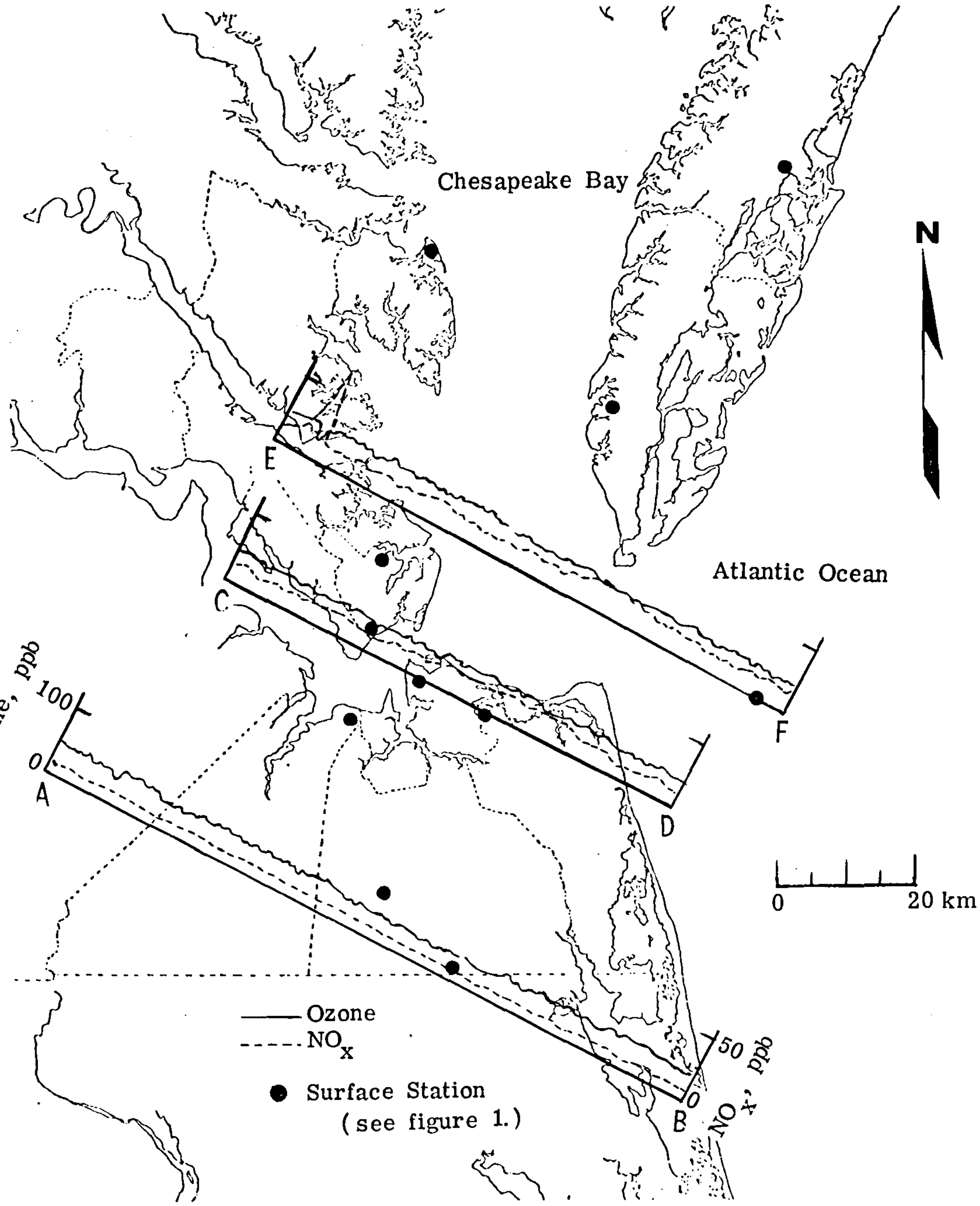


Figure 24. - Ozone and nitrogen oxides data(0.3 km altitude); morning of of August 25, 1979.

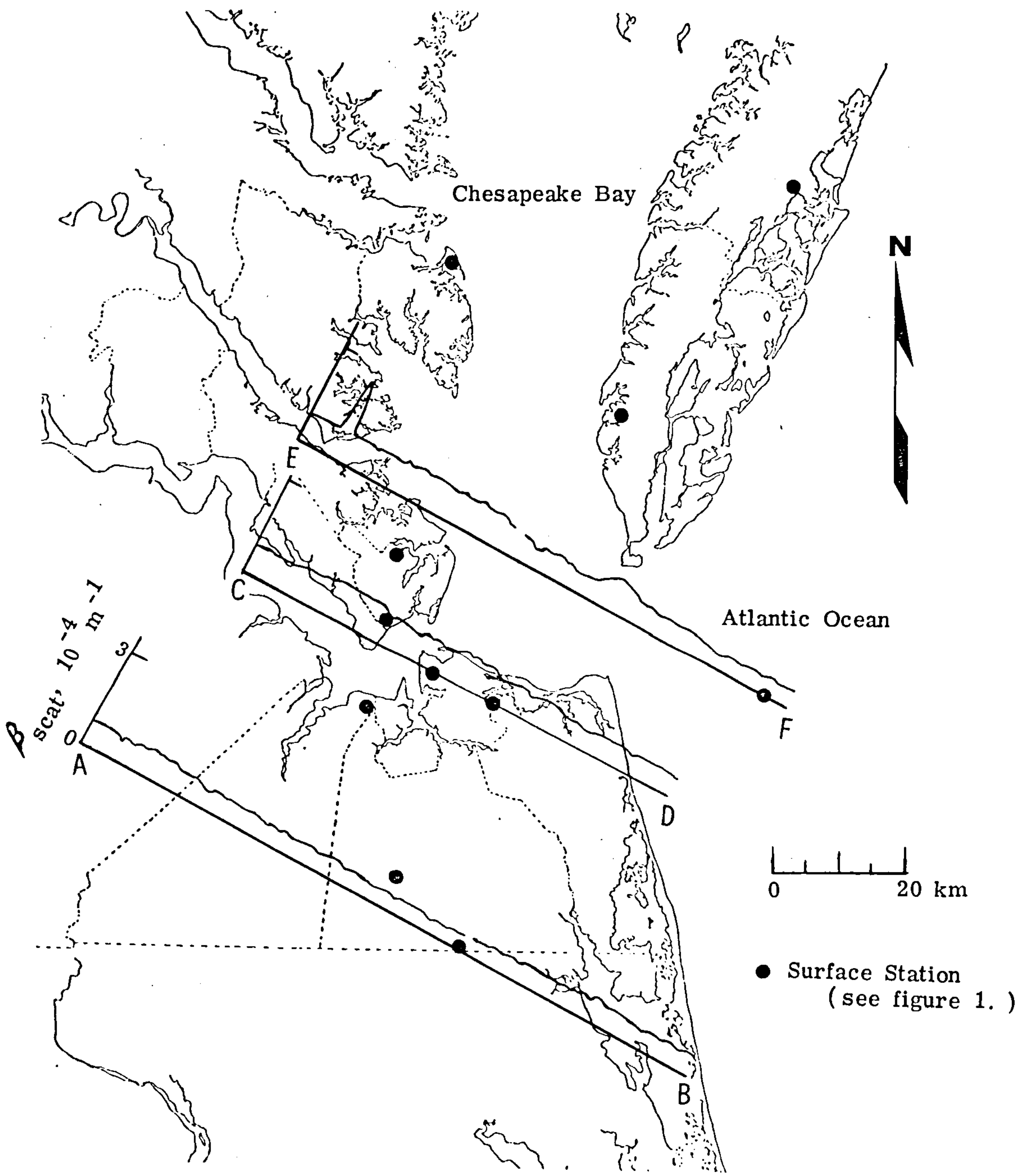


Figure 25. - β_{scat} data(0.3 km altitude); morning of August 25, 1979.

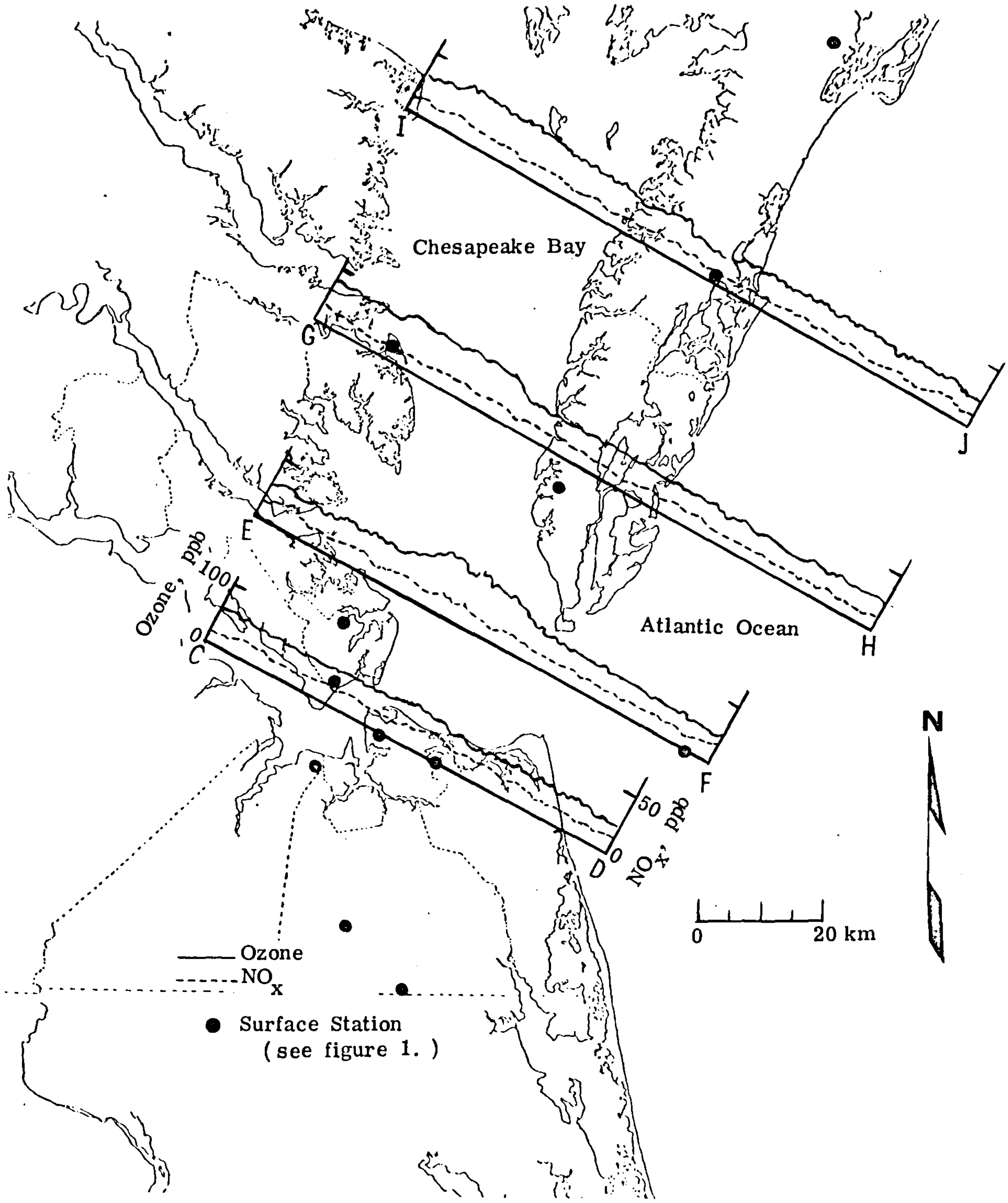


Figure 26. - Ozone and nitrogen oxides data(0.3 km altitude); afternoon of August 25, 1979.

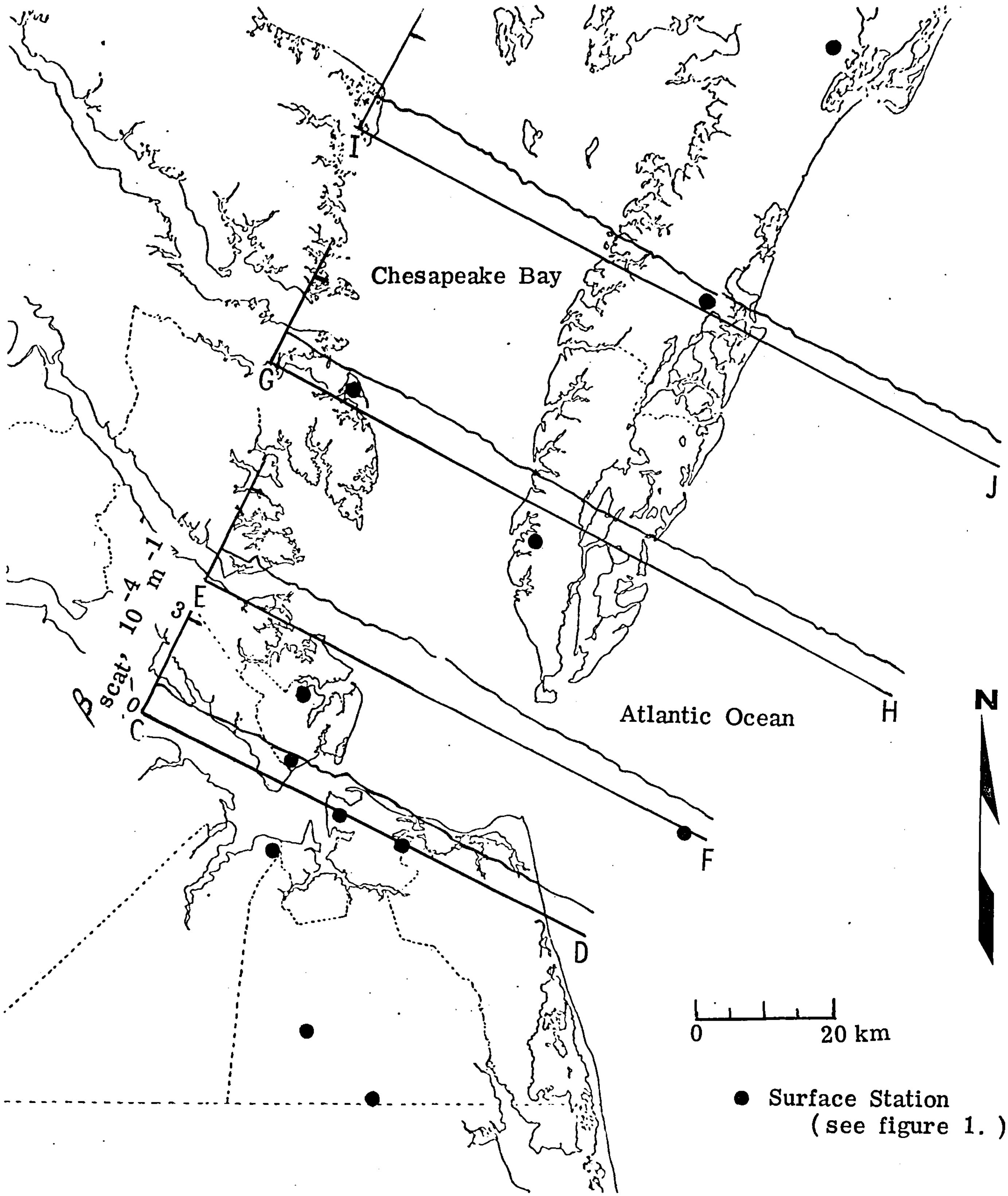


Figure 27. - β_{scat} data(0.3 km altitude); afternoon of August 25, 1979.

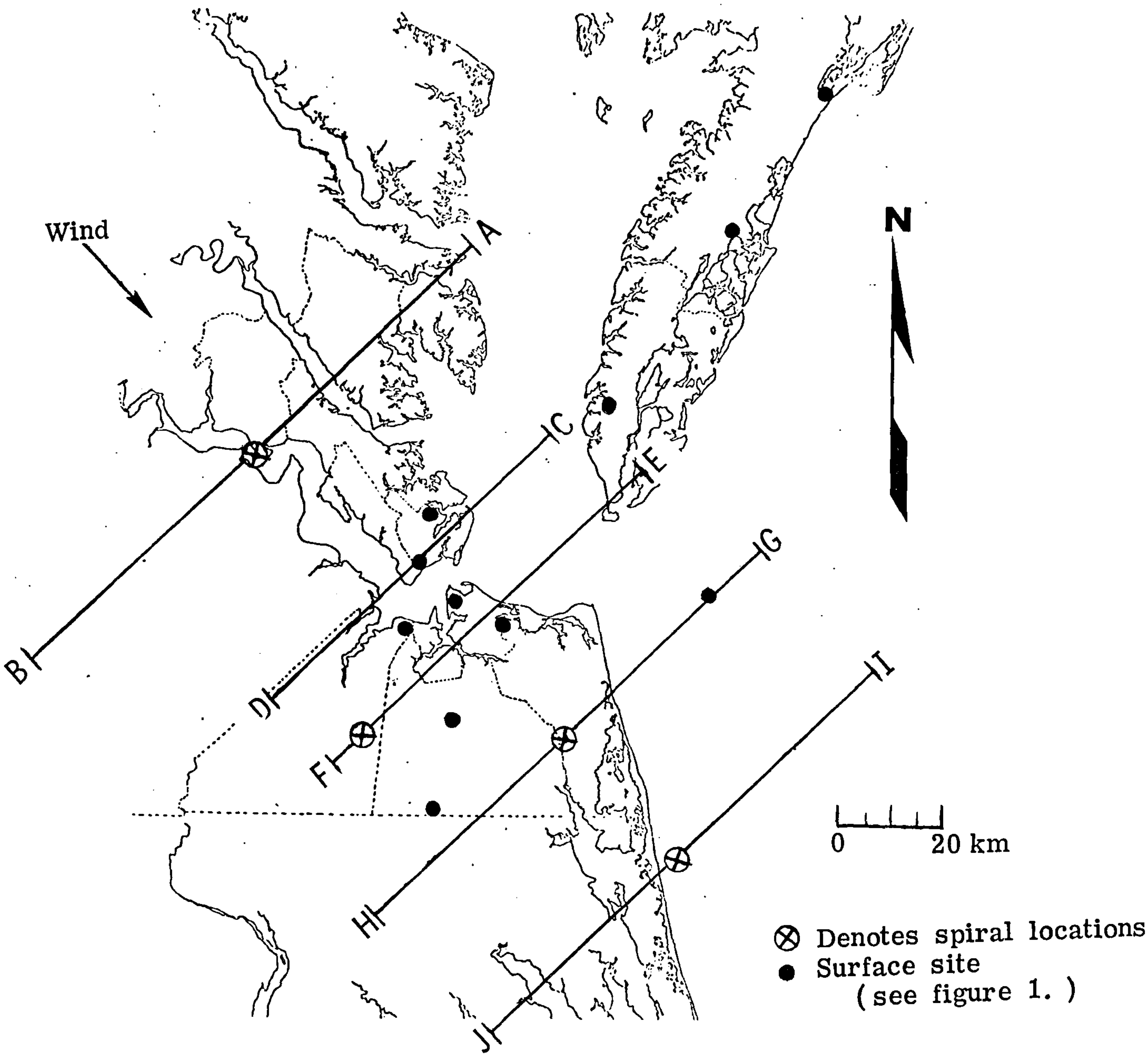


Figure 28. - Urban plume experiment flight legs; northwest flow case, afternoon of August 30, 1979.

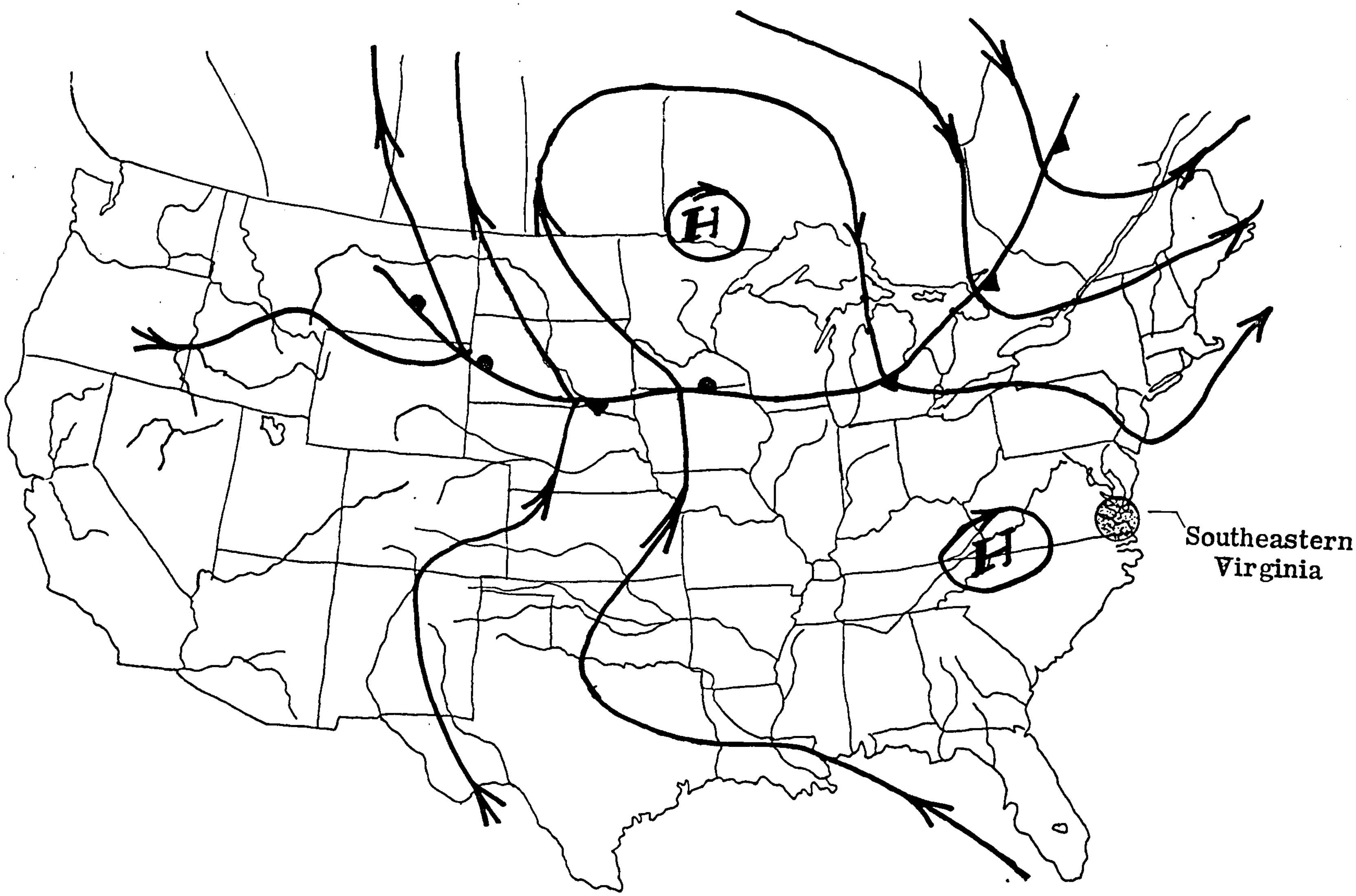
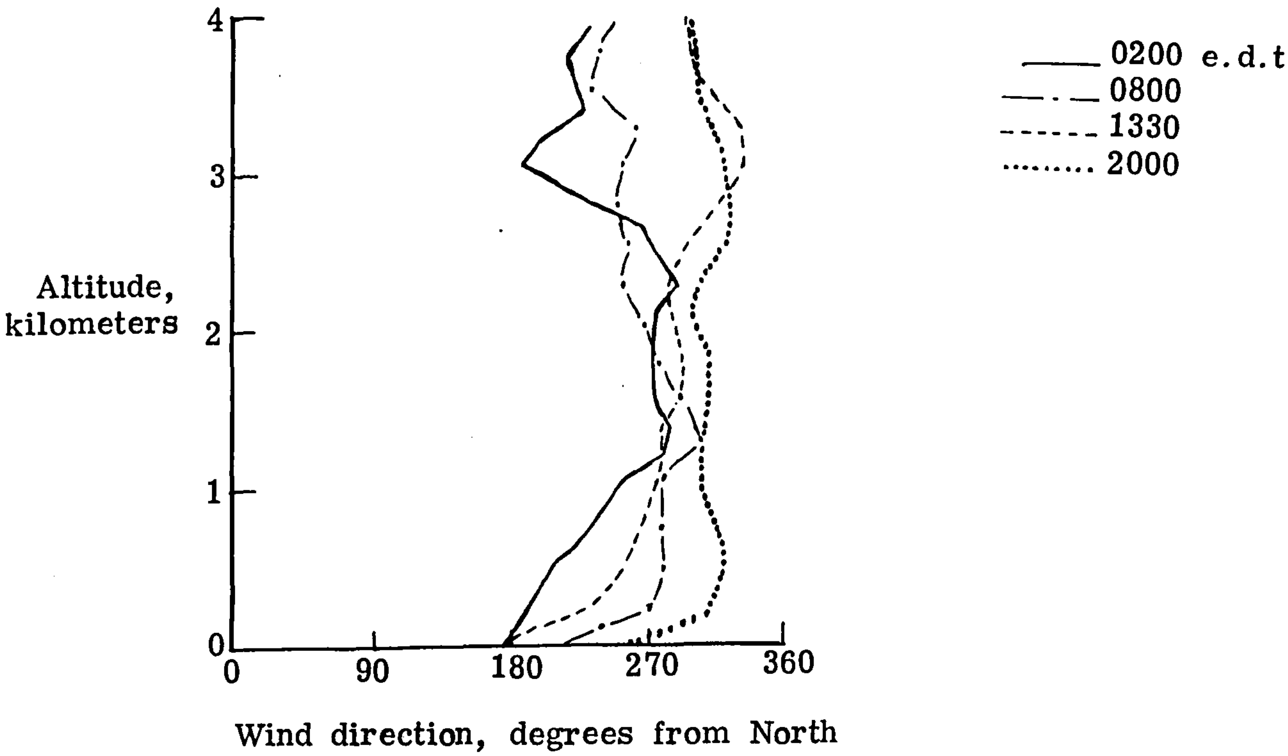
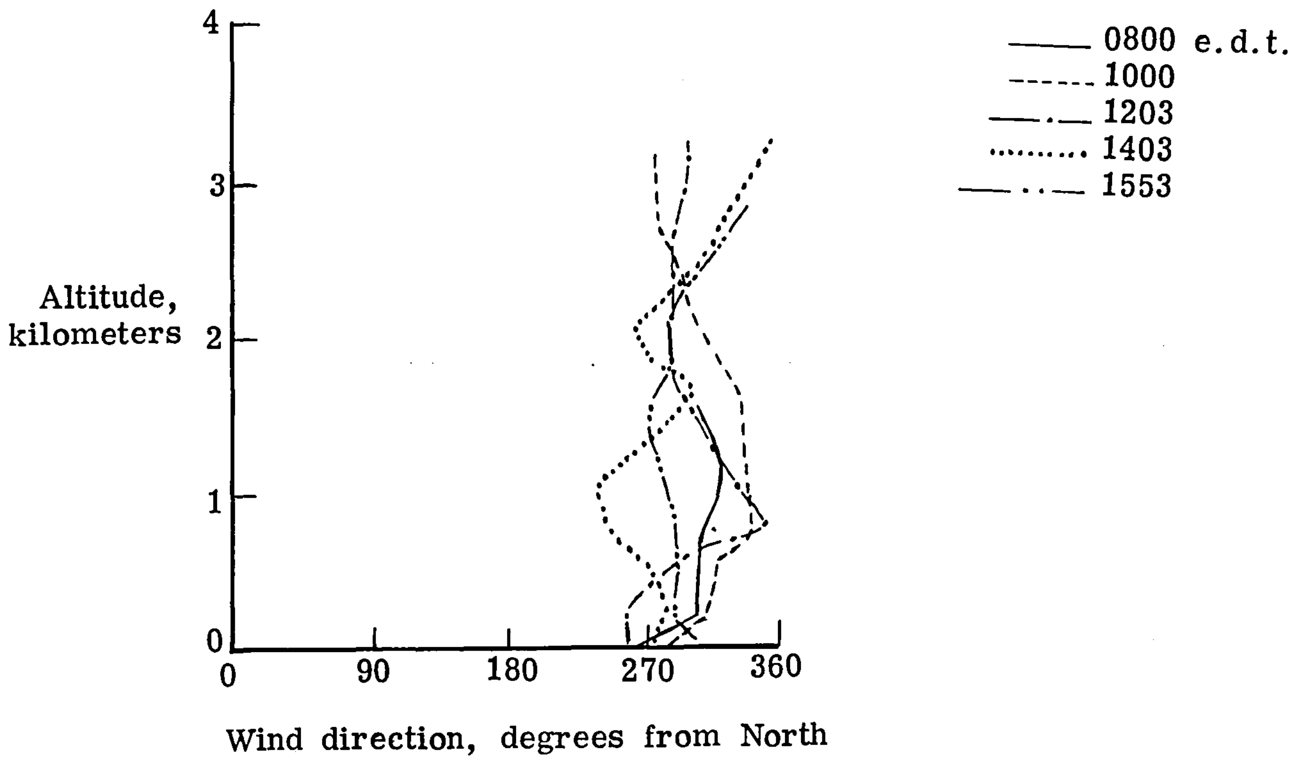


Figure 29. - Synoptic weather chart; 1100 e.d.t., August 30, 1979.



a.) Wallops Island, Virginia



b.) Naval Air Station; Norfolk, Virginia

Figure 30. - Wind direction as a function of altitude; August 30, 1979.

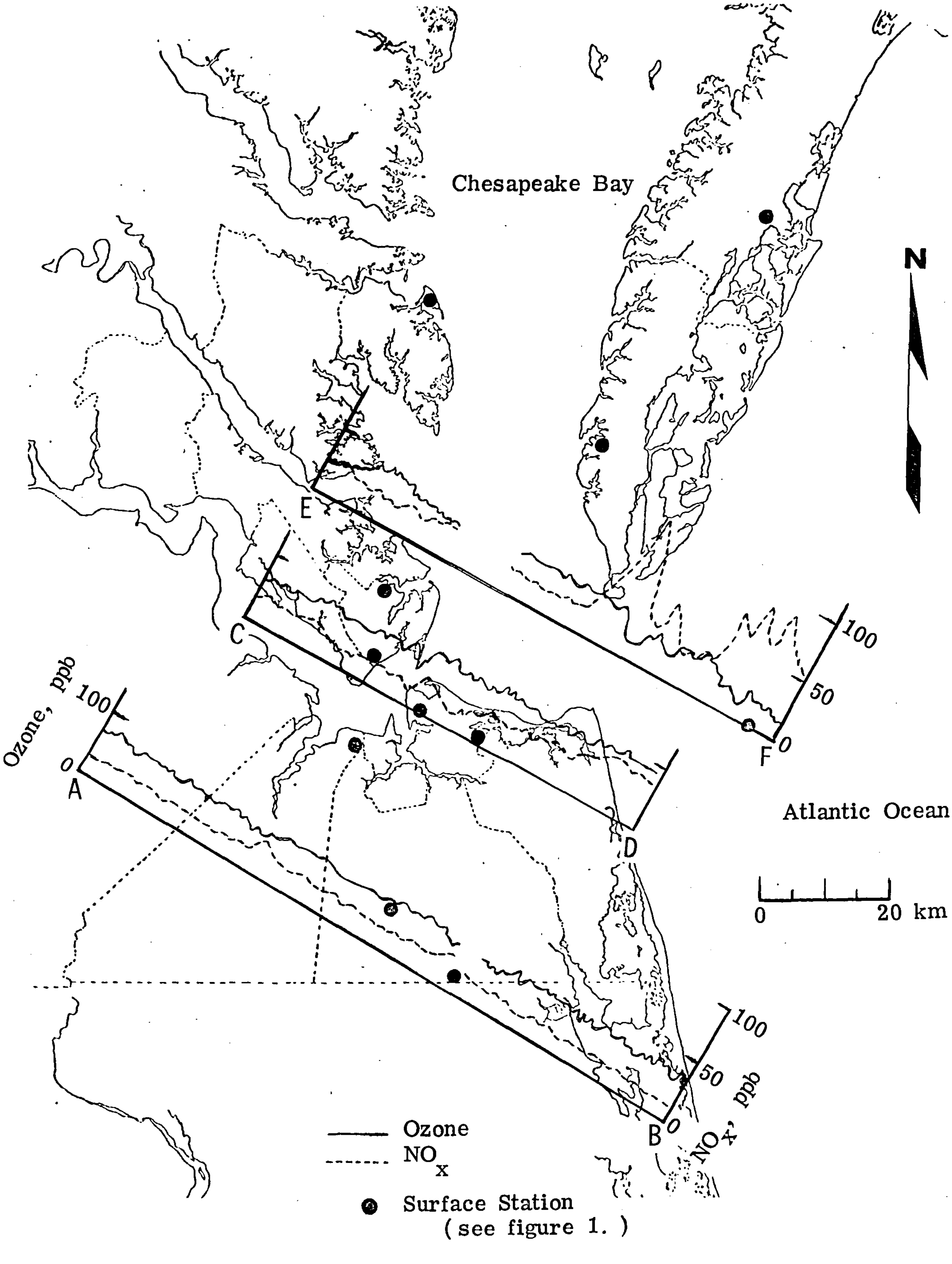


Figure 31. - Ozone and nitrogen oxides data(0.3 km altitude); morning of of August 30, 1979.

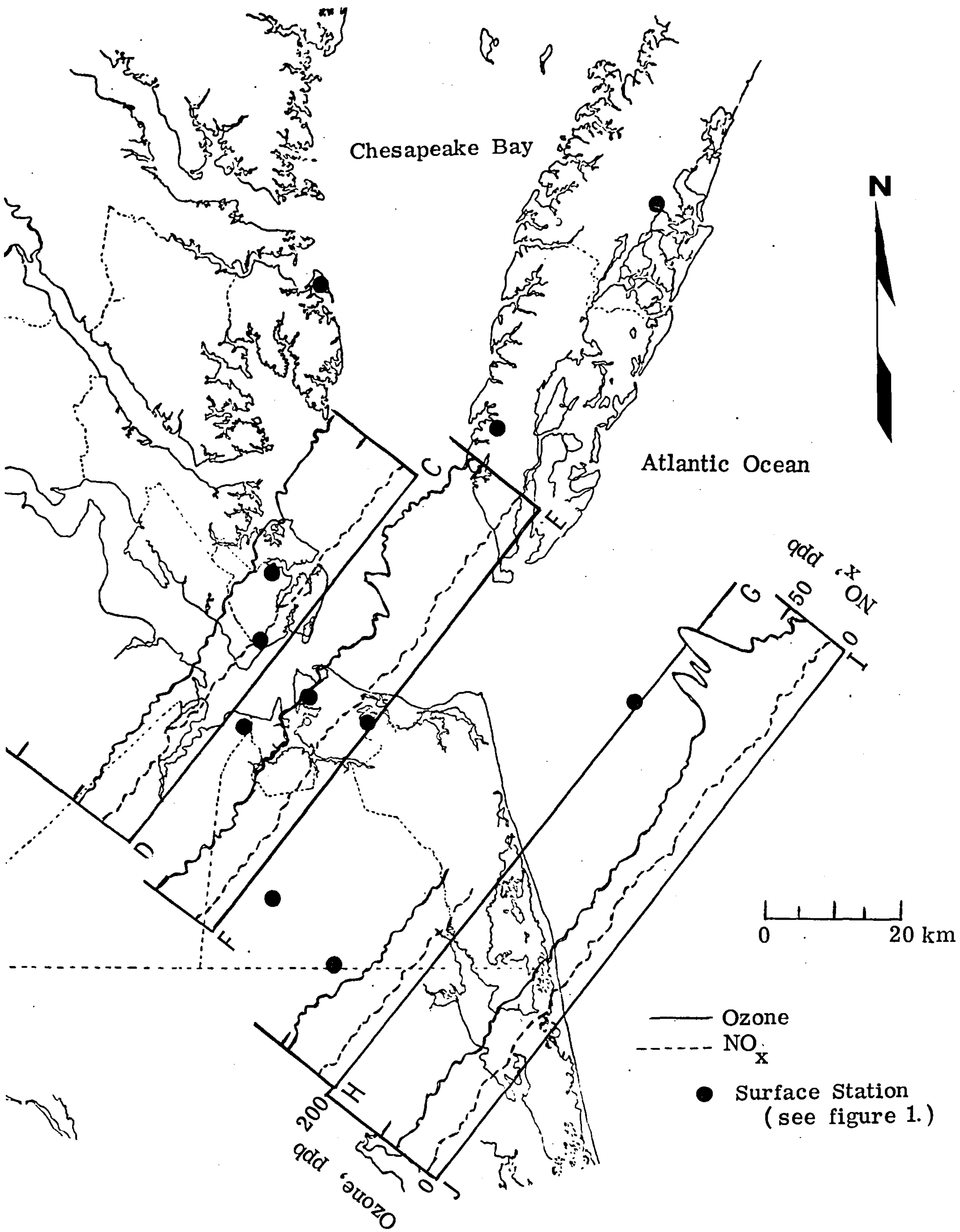


Figure 32. - Ozone and nitrogen oxides data(0.3 km altitude); afternoon of August 30, 1979.

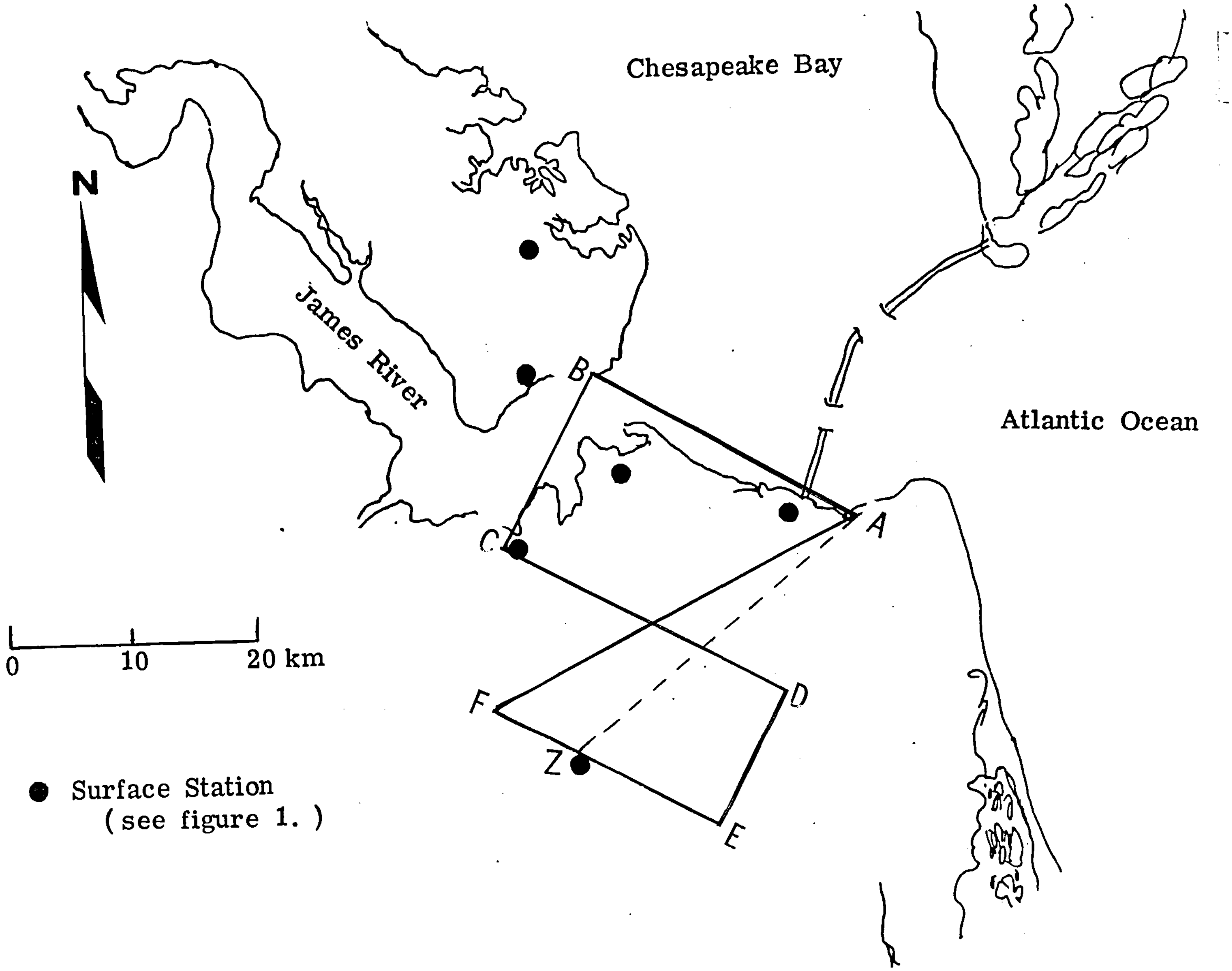


Figure 33. - Photochemical box experiment flight legs; northeast flow case, afternoon of August 31, 1979.

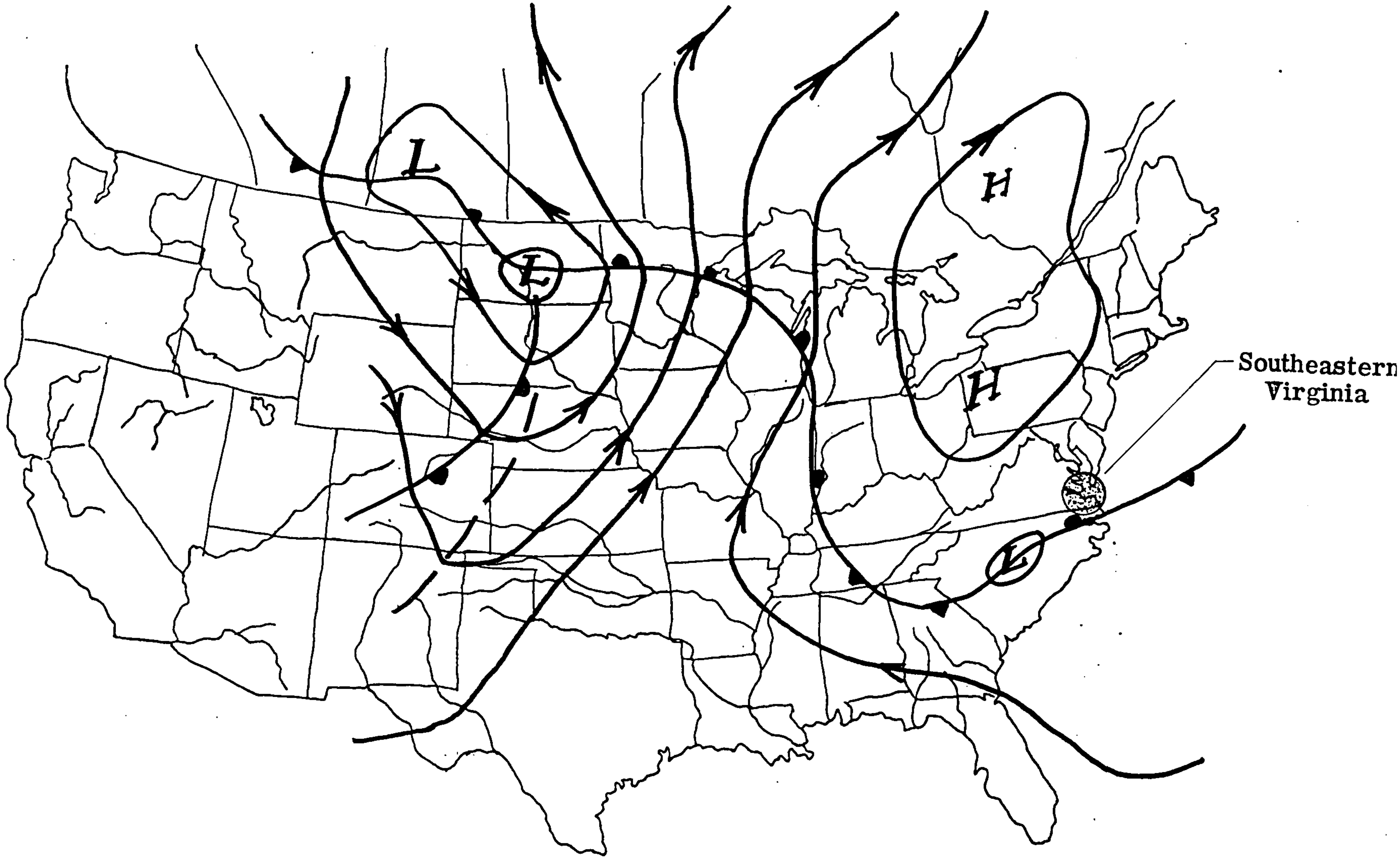
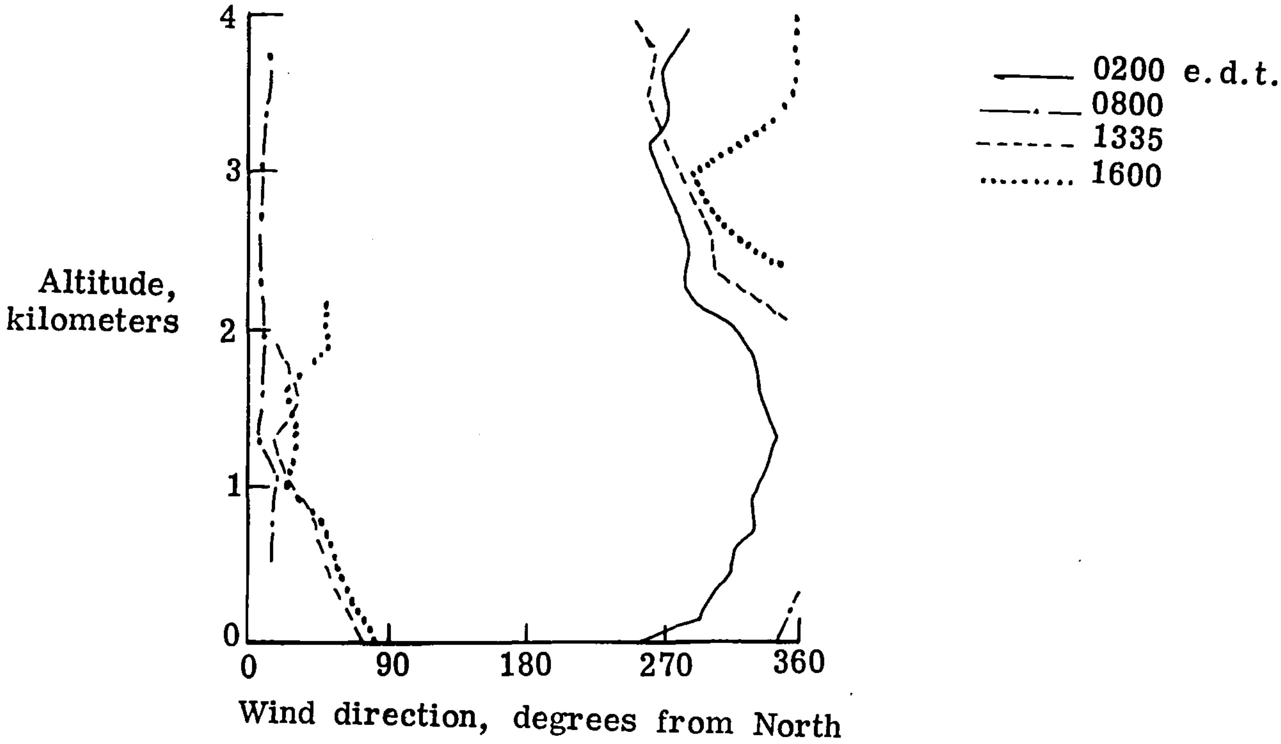
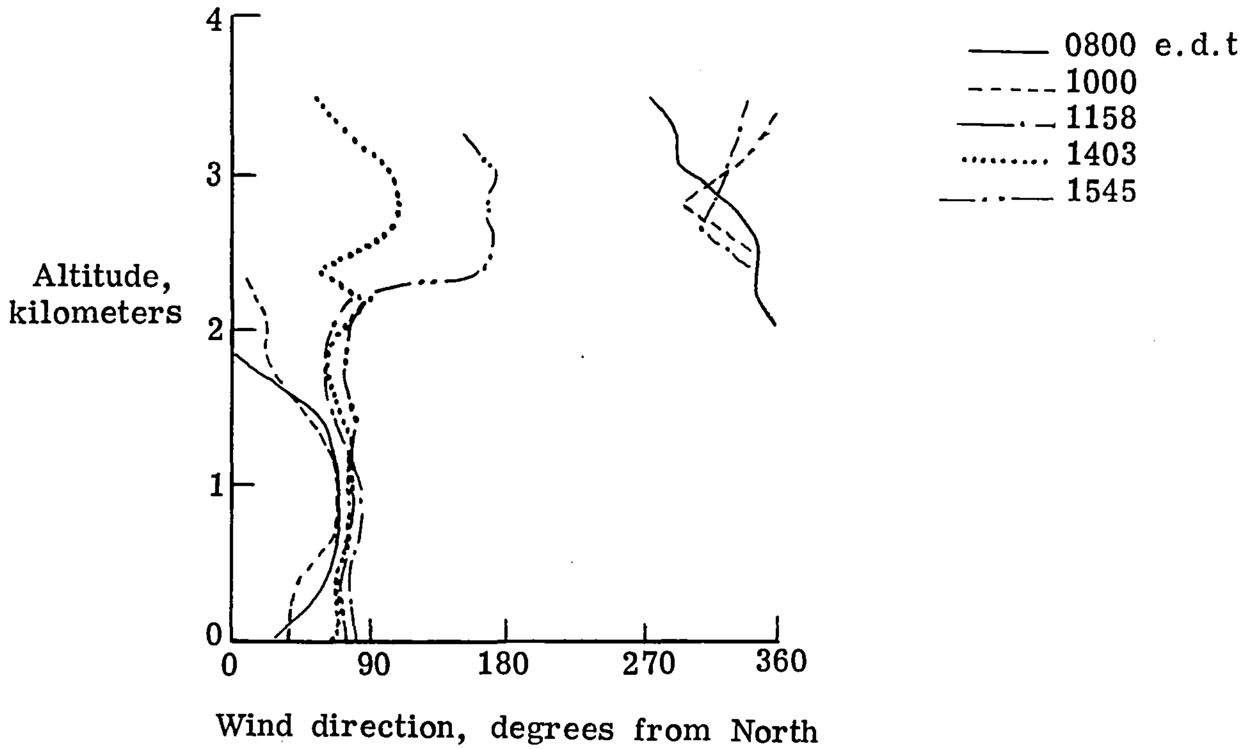


Figure 34. - Synoptic weather chart; 1400 e.d.t., August 31, 1979.

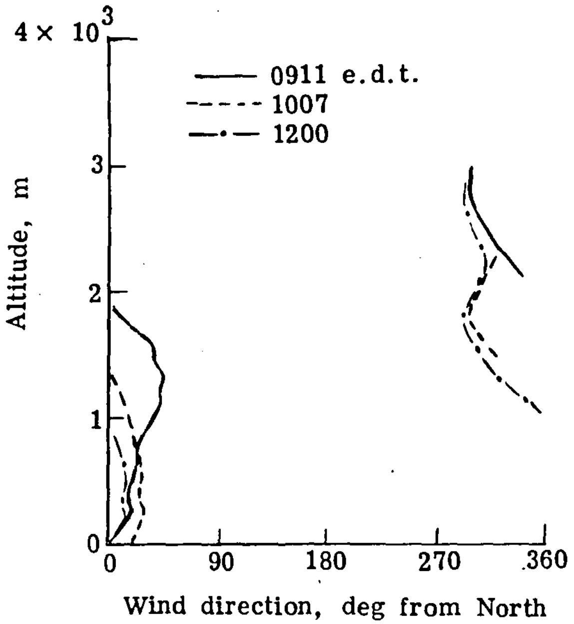


a.) Wallops Island, Virginia

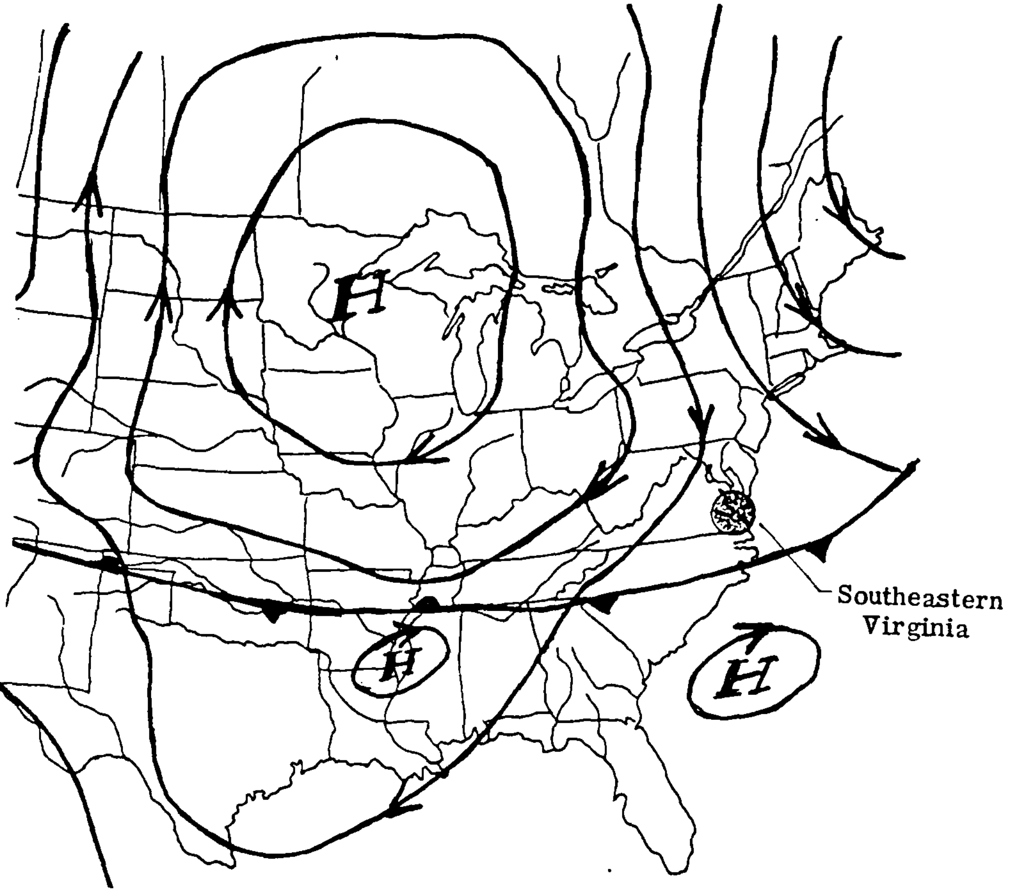


b.) Naval Air Station; Norfolk, Virginia

Figure 35. - Wind direction as a function of altitude; August 31, 1979.



a.) Wind direction as a function of altitude; Wallops Island, Virginia August 15. 1979



b.) Synoptic weather chart; 1400 e.d.t., August 15. 1979

Figure 36. - Meteorology; August 15, 1979.

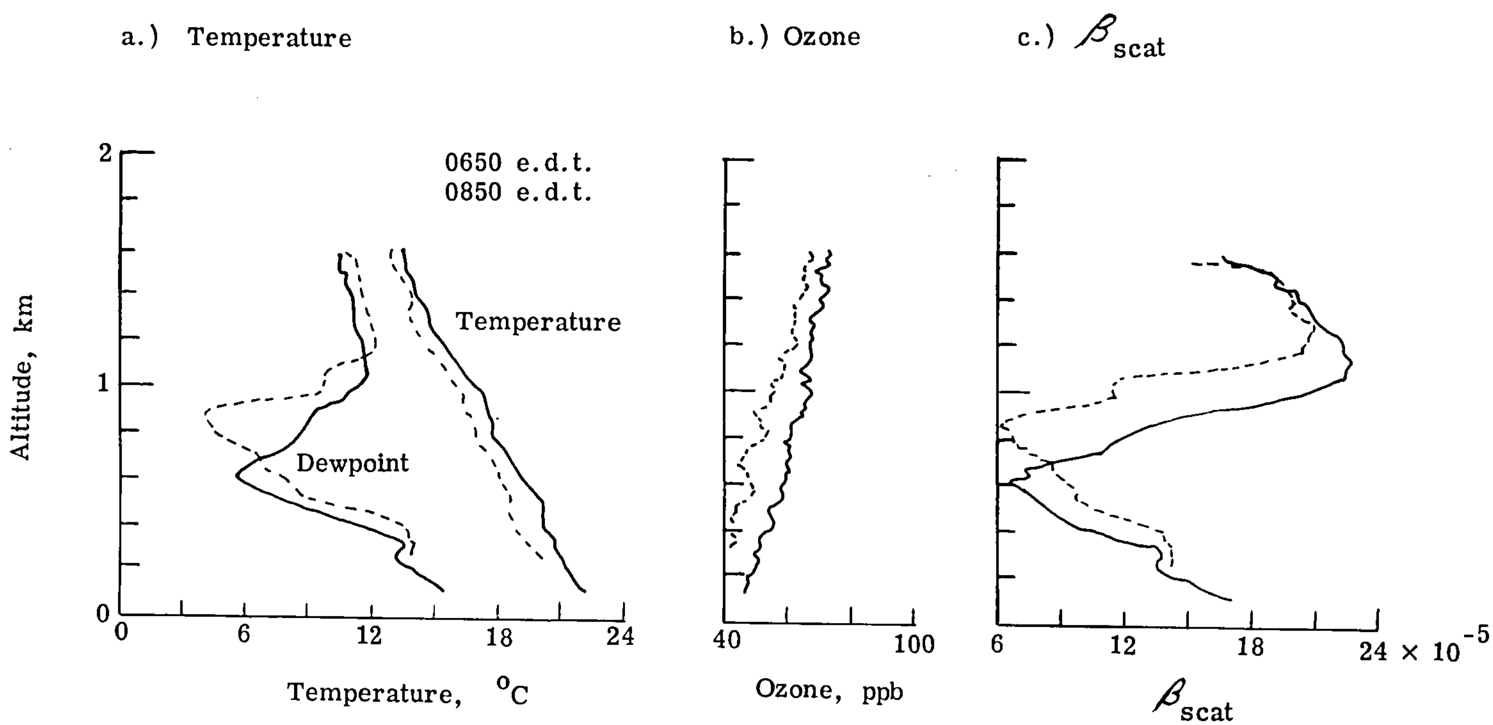


Figure 37. - Spiral data at location LD; swamp experiment, August 15, 1979.

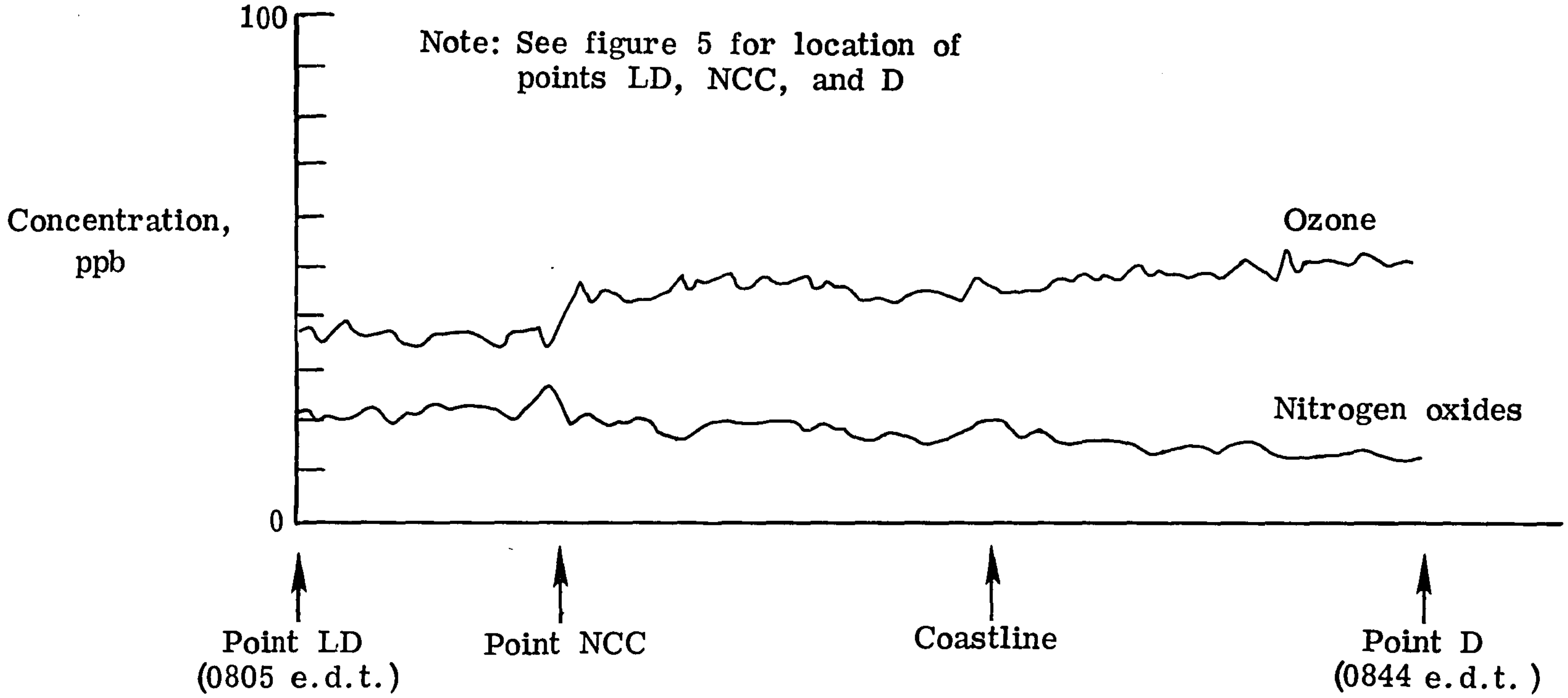


Figure 38. - Constant altitude (0.2 km) data for leg LD to D; swamp experiment, August 15, 1979.

APPENDIX A

FLIGHT PLAN SCHEDULES

TABLE A-1. - URBAN PLUME FLIGHT SCHEDULES

Time, e.d.t.	Flight Leg[1,2] Langley Aircraft	Contractor Aircraft	Wallops Aircraft	Remote-Sensor Aircraft
0545-0630		AB*		
0630-0715			AB*	
0645-0700		DC		
0715-0800		AB*		
0725-0740			DC	
0750-0830			AB*	
0815-0830		DC		
0830-0920	AB*			
0840-0855			DC	
0900-0920			EF	
0925-0940			DC	
0930-1010	FE*			
1020-1035	CD			
1030-1050				EF
1050-1130	FE*			
1100-1120				DC
1100-1150		AB*		
1130-1200				GH
1130-1215			AB*	
1200-1215		DC		
1225-1240			DC	
1225-1305		EF*		
1245-1320			EF*	
1315-1405		HG*		
1330-1345			DC	
1350-1430			EF*	
1400-1430				JI
1430-1450	CD			
1440-1505				GH
1455-1545	FE*			
1520-1540				FE
1605-1650	IJ*			
1703-1731	HG			

1 flight legs are constant altitude (except as specified in footnote 2); aircraft assigned altitudes varied with meteorological conditions; nominal altitudes: Langley and contractor aircraft, 0.3 km; Wallops aircraft, 0.45 km; remote-sensor aircraft, 0.75 km.

2 Flight legs with * include spiral at location shown on figure 2 for that leg; nominal altitude range of spiral is 0.15 km to 1.5 km; spiral consist of descent to 0.15 km, ascent to 1.5 km, and descent to assigned altitude.

TABLE A-2. - PHOTOCHEMICAL BOX FLIGHT SCHEDULE

Time, e.d.t.	Flight Leg[1,2]			
	Langley Aircraft	Contractor Aircraft	Wallops Aircraft	Remote-Sensor Aircraft
0450-0500			Spiral A	
0500-0510		Spiral A	AB	
0510-0520		AB	CD	
0525-0530		CD	EF	
0535-0545		EF	Spiral F	
0545-0555		Spiral F		
0555-0605			Spiral A	
0605-0610		Spiral A	AB	
0615-0625		AB	CD	
0630-0635		CD	EF	
0640-0650		EF	Spiral F	
0650-0700		Spiral F		
0700-0710			Spiral A	
0710-0720		Spiral A	AB	
0720-0730		AB	CD	
0735-0745		CD	EF	
0745-0755		EF	Spiral F	
0755-0805	Spiral F	Spiral F		
0815-0825	Spiral A			
0825-0835	AB			
0840-0845	CD			
0850-0900	EF			
0900-0910	Spiral F			
0920-0930	Spiral A			
0930-0940	AB			AB
0945-0950	CD			CD
0955-1005	EF			EF
1005-1015	Spiral F			
1015-1025				BZ
1025-1035	Spiral A			ZA
1035-1045	AB			AB
1050-1055	CD			CD
1100-1110		EF		EF
1110-1120		Spiral F		
1120-1130			Spiral A	
1130-1140		Spiral A	AB	
1140-1150		AB	CD	
1155-1200		CD	EF	
1205-1215		EF	Spiral F	
1215-1225		Spiral F		

TABLE A-2. - Concluded.

Time, e.d.t.	Flight Leg[1,2] Langley Aircraft	Contractor Aircraft	Wallops Aircraft	Remote-Sensor Aircraft
1225-1235			Spiral A	
1235-1245		Spiral A	AB	
1245-1255		AB	CD	
1255-1305		CD	EF	
1310-1320		EF	Spiral F	
1320-1330		Spiral F		
1325-1335			Spiral A	
1340-1350		Spiral A	AB	
1350-1400		AB	AB	
1400-1410		CD	EF	
1410-1420	EF		Spiral F	EF
1425-1435	Spiral F			
1435-1445				BZ
1445-1455	Spiral A			ZA
1455-1505	AB			AB
1510-1515	CD			CD
1520-1530	EF			EF
1530-1540	Spiral F			
1540-1550				BZ
1550-1600	Spiral A			ZA
1600-1610	AB			
1615-1620	CD			
1625-1635	EF			
1635-1645	Spiral F			

1 Flight legs are constant altitude; aircraft assigned altitudes varied with meteorological conditions; nominal altitudes: Langley and contractor aircraft, 0.3 km; Wallops aircraft, 0.45 km; and remote-sensor aircraft, 0.75 km.

2 Spiral normally consists of descent to 0.15 km, ascent to 1.5 km, and descent to assigned altitude.

TABLE A-3: SWAMP EXPERIMENT FLIGHT SCHEDULE

Time, e.d.t.	Flight Leg[1] Langley Aircraft	Wallops Aircraft
0600-0610		Spiral LD
0610-0625		LD to A
0615-0635	Spiral LD	
0630-0705		A to B
0635-0640	LD to NCC[2]	
0640-0705	Spiral NCC	
0705-0725	NCC to B[2]	Spiral B
0725-0755	Spiral B	B to C
0735-0745	B to D[3]	
0745-0755	Spiral D	
0755-0840	D to LD*	
0800-0830		C to D
0835-0930		D to A*
0840-0850	Spiral LD	

1 Constant altitude flight (typically 0.3 km); * indicates spiral in the flight leg; spirals nominally 0.15 to 1.5 km altitude

2 Constant altidude flight at 1.5 km

3 Constant ascent rate; 0.15 km at B to 1.5 km at D

TABLE A-4: COASTAL-INLAND URBAN PLUME COMPARISON EXPERIMENT FLIGHT SCHEDULE

Time, e.d.t	Contractor Aircraft Flight Legs[1]
1130-1240	leg A to D[2]
1250-1350	leg E to H[3]

1 Constant altitude flight at approximately 0.5 km

2 Leg includes spiral (0.5 to 1.5 km) at B and C (figire 6)

3 Leg includes spiral (0.5 to 1.5 km) at F and G (figure 6)

TABLE A-5 - URBAN PLUME FLIGHT SCHEDULE:
NORTHWEST FLOW, AFTERNOON ONLY (AUGUST 30)

time, e.d.t.	flight plan[1] Langley Aircraft[2]	Contractor Aircraft[2]	Wallops Aircraft[2]	Remote-Sensor Aircraft
1100 - 1150		AB*		
1130 - 1215			AB*	
1200 - 1215		DC		
1225 - 1305		EF*		
1225 - 1240			DC	
1245 - 1320			EF*	
1315 - 1405		HG*		
1330 - 1345			DC	
1350 - 1425			EF*	
1400 - 1430				JI
1430 - 1450	CD			
1440 - 1505				GH
1455 - 1545	FE*			
1520 - 1540				FE
1605 - 1650	IJ*			
1705 - 1730	HG			

1 Flight legs are constant altitude (except as specified in footnote 2); aircraft assigned altitudes varied with meteorological conditions; nominal altitudes: Langley and contractor aircraft, 0.3 km; Wallops aircraft, 0.45 km; remote-sensor aircraft, 0.75 km.

2 Flight legs with * include spiral at location shown on figure 30 for that leg; nominal altitude range of spiral is 0.15 km to 1.5 km; spiral consist of descent to 0.15 km, ascent to 1.5 km, and descent to assigned altitude.

APPENDIX B

LOCATION OF FLIGHT LEGS

Several flight plans have been discussed in the body of the report and each shown pictorially on a map of the test area. In this appendix, the location of the various legs will be referenced to the local aeronautical chart (reference 9 of the text). These locations are referenced in terms of heading and distance from a VOR station shown on the reference chart. Distances are given in nautical miles, the engineering unit commonly used in aircraft navigation. Some locations will be referenced to specific geographical locations shown on the navigational chart.

APPENDIX B

TABLE B-1: FLIGHT LEG LOCATIONS, URBAN PLUME EXPERIMENT

A. Southwest flow (figure 2)

Station	VOR Navigational Reference	Radial/distance (deg./n. mile)
A	Franklin	50/ 8.6
B	Elizabeth City	65/16.2
C	Norfolk	305/21.6
D	Norfolk	125/16.2
E	Cape Charles	258/25.9
F	Cape Charles	159/30.8
G	Cape Charles	305/23.2
H	Cape Charles	125/30.8
I	Cape Charles	345/31.3
J	Cape Charles	90/36.7

B. Northwest flow (figure 28)

Station	VOR Navigational Reference	Radial/distance (deg./n. mile)
A	Cape Charles	316/20.5
B	Franklin	0/ 7.8
C	Cape Charles	231/10.8
D	Franklin	95/17.3
E	Cape Charles	166/10.8
F	Norfolk	225/21.6
G	Cape Charles	136/27
H	Elizabeth City	335/ 7.6
I	Cape Charles	136/37.8
J	Elizabeth City	105/4.8

APPENDIX B

TABLE B-2: FLIGHT LEG LOCATIONS, PHOTOCHEMICAL BOX EXPERIMENT

A. West flow (figure 4)

Station	VOR Navigational Reference	Radial/distance (deg./n. mile)
A	Norfolk	267/10.8
B	Norfolk	297/12.1
C	Norfolk	330/ 5.2
D	Norfolk	212/ 8.3
E	Norfolk	342/ 8.3
F	Norfolk	48/ 5.5
Z	Norfolk	122/ 4.1

B. Northeast flow (figure 33)

Station	VOR Navigational Reference	Radial/distance (deg./n. mile)
A	Norfolk	90/6.2
B	Norfolk	142/90
C	Norfolk	272/ 9.7
D	Norfolk	167/ 6.9
E	Norfolk	187/12.4
F	Norfolk	238/13.0
Z	Norfolk	223/11.4

APPENDIX B

TABLE B-3: FLIGHT LEG LOCATIONS, SWAMP EXPERIMENT (figure 5)

Station	VOR Navigational Reference	Radial/distance (deg./n. mile)
A	Franklin	0/0
B	Franklin	95/73
C	Coefield	0/0
D	Coefield	92/67
LD	Franklin	111/27
NCC	Franklin	111/37

TABLE B-4: FLIGHT LEG LOCATIONS, COASTAL-INLAND PLUME COMPARISON EXPERIMENT (figure 6)

Station	VOR Navigational Reference	Radial/distance (deg./n. mile)
A	Elizabeth City	53/15.1
B	Elizabeth City	354/18.4
C	Richmond	210/28.1
D	Richmond	247/35.1
E	Richmond	335/25.4
F	Richmond	30/15
G	Cape Charles	120/ 1.6
H	Cape Charles	120/27

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15. Supplementary Notes

16. Abstract The Southeastern Virginia Urban Plume Study SEV-UPS is part of NASA's continuing commitment to develop the technology to utilize remote sensors and satellite platforms to monitor the Earth's environment and resources. SEV-UPS focuses on the application of specific remote sensors to the monitoring and study of specific air-quality problems. The objectives of SEV-UPS are to provide data to assess the accuracy, repeatability, and operational characteristics of ozone remote sensors for tropospheric air-quality measurements, and to demonstrate the utility of these sensors in the study of air-quality phenomena. The 1979 SEV-UPS field program was conducted during August 1979 with specific objectives: (1) to provide correlative data to evaluate the Laser Absorption spectrometer ozone remote sensor, (2) to demonstrate the utility of the sensor for the study of urban ozone problems, (3) to provide additional insights into air-quality phenomena occuring in Southeastern Virginia, and (4) to compare measurement results of various in situ measurement platforms.

The August field program included monitoring from 12 surface stations, four aircraft, two tethered balloons, two radiosonde release sites, and numerous surface meteorological observation sites. The subject report discusses the design of each experiment conducted to meet the above objectives and presents an overview of the data obtained. The data overview consists of the results from one of the aircraft, the Langley chartered Cessna 402. The aircraft monitored O_3, NO, NO_x, B_{scat}, temperature, and dewpoint temperature. The report references the availability of that data from the other measurement platforms. Volume II of the report is a listing of the data measured onboard the Langley chartered Cessna.

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