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THE 1974 OZONE EPISODE IN THE BALTIMORE-TO-RICHMOND CORRIDOR

by

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ABSTRACT

An ozone alert in July of 1974 in the Washington, D. C., area is examined in detail. Ozone data for 16 stations in the Baltimore-to-Richmond corridor are examined in conjunction with meteorological data for the alert period. Emphases are given to trajectories of the air between the surface and 1000 meters and the mixing height and winds aloft data of the air pollution forecasts of the National Weather Service. The investigation revealed: (1) the period with high ozone concentrations was one when synoptic scale stagnation at the surface and aloft prevailed most of the time together with high temperatures and abundant solar radiation; (2) despite overall stagnation over a very large region there were periods when 48-hour trajectories showed that ozone could have been transported from potential source areas as far as 1000 kilometers upwind; (3) that a) the Richmond-to-Baltimore corridor was at the southern and eastern periphery of a large area in the industrial eastern United States which had high ozone concentrations, and b) many of the distant potential source areas implicated in the trajectory analyses observed high ozone concentration; and (4) that any abatement strategy for this type of stagnation-ozone alert will have to take into account both local and distant sources.

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SECTION 1

INTRODUCTION

The Baltimore-to-Richmond corridor, which encompasses the nation's capital and includes a large population, is 250 kilometers (km) long. When the area experiences an air pollution alert it is a source for real concern to many people; causes of such an event should be determined so that similar episodes can be anticipated and possible corrective action taken before the alert occurs.

Reports[1,2] from the Washington, D. C., area indicate that the District experienced only one photochemical oxidant alert* in the summer of 1974. Montgomery County, Maryland, records[1] show that the alert occurred from July 8 through 11. The National Weather Service data[2] disclose that Air Stagnation Advisories (warnings that pollution problems might develop during the day) were issued for all 4 days. Since Advisories imply potential hazards for a large area, ozone data for all stations in the Richmond, Washington, and Baltimore areas were obtained for study.

Preliminary examination of the data confirmed that the high concentrations were widespread throughout the corridor and that the initial high concentrations actually occurred on the 7th (Sunday). Concurrent meteorological data were analyzed in detail to demonstrate the role of meteorology in the episode. Emphases were given to the synoptic situations, to trajectories[3] of the air between the surface and 1000 meters (m), and to the seldom evaluated mixing height and winds aloft data of the air pollution forecasts of the National Weather Service[2]. Finally, ozone data for stations in surrounding states were examined to delineate the area affected by large scale stagnation and to show the concentrations in areas upwind of the corridor cities, as implicated in the trajectory analyses.

*An alert is called when adverse meteorological conditions are predicted and photochemical oxidants exceed the 100 parts per billion (ppb) one-hour average standard of Maryland[1]. This 1974 alert was based on ozone measurements.

SECTION 2

CONCLUSIONS

On the basis of this study the following conclusions are drawn:

1. The meteorological conditions associated with the high concentrations of ozone in the Baltimore-to-Richmond corridor were those associated with ozone episodes in other areas of the country: stagnation at the surface and aloft; several days with relatively high temperatures; and intense solar radiation.

2. Many of the high concentrations of ozone during this stagnation period were associated with nearby (i.e., within several 10's of km of the receptors) upwind sources; local emissions were a major factor in the high concentrations much of the time.

3. The 48-hour trajectory analyses showed there were times during this widespread stagnation when air from as far away as 1000 km was transported to the Baltimore-to-Richmond corridor. The implications are that long range transport occurred in spite of the stagnation and that it contributed to the high concentrations observed on some days.

4. During this period the general area of high ozone concentrations, which approximately coincided with the stagnation area, extended from northern Tennessee and Virginia in the south, to Ohio in the northwest, and Massachusetts in the northeast. The Baltimore-to-Richmond corridor was on the southeastern edge of this region; many of the distant upwind areas implicated as possible sources of ozone and its precursors did experience high concentrations of ozone at the surface.

5. Inasmuch as long range transport readily occurred during this stagnation-ozone episode, an effective abatement strategy for this type of alert would require corrective action at distant as well as local sources.

SECTION 3

BACKGROUND INFORMATION AND METHODS

OZONE STATIONS, INSTRUMENTS, AND RECORDS

Ozone monitoring stations are generally operated by State and local agencies, with the State agency being responsible for providing the federal government with a near-complete and accurate record. In the District of Columbia, the Department of Environmental Services operates the instrumentation and is responsible for the records. The main ozone data used in this report came from 16 stations: the State of Virginia provided data for 2 stations in Richmond and 6 in the suburbs of Washington, D. C.; the District agency provided data for 1 station in the District; and the State of Maryland provided data for 4 stations in suburbs of Washington, 2 in Baltimore, and 1 in a Baltimore suburb. The locations of the stations are shown in Figure 1 and are identified in Table 1. About 10 separate agencies are responsible for operating these instruments. One station in Richmond uses an ultraviolet Dasibi instrument and all others use chemiluminescence instruments. Four Virginia stations record in micrograms per cubic meter ($\mu g/m^3$) and all others record in parts per million. The National Ambient Air Quality Standard (NAAQS) not to be exceeded more than once a year is 160 $\mu g/m^3$ or 80 parts per billion (ppb); in this report, when the NAAQS is violated, a concentration is called high. It should be noted that most of these stations are close to heavy traffic, the source of most local man-made ozone precursors[1]. The literature[4-6] indicates that peak ozone concentrations are not at the precursor source, but are displaced a considerable distance downwind. The ozone recorded at these stations is therefore reasonably attributed to upwind sources, both local (within several 10's of km of receptors) and distant (further away than local sources). In order to show the extent of the high ozone concentrations as well as the possibility for long-distant transport, the ozone data from 10 surrounding states are examined.

METEOROLOGY PREVIOUSLY ASSOCIATED WITH HIGH OZONE CONCENTRATIONS

Previous investigations have shown that a number of meteorological phenomena are associated with high ozone concentrations[4-5,7-34]. The phenomena mostly frequently associated with high concentrations are: low wind speeds or stagnation conditions[7-14] low mixing heights (shallow surface-based layers through which pollutants readily mix)[8,10,14-17]; intense solar radiation[4,8,9,11-14,18-20]; high temperatures[4,13,20-23]; heat waves[14,24-26]; and advection by surface winds and long-range transport winds aloft[4-5,27-34]. It has been suggested[1] that only one alert occured in the Washington area in 1974 because the area was more cloudy than usual during the months of June through September; in 1973, in the summer, cloudless skies and alerts were more frequent.

THE DIURNAL VARIATION OF OZONE CONCENTRATION AND THE ASSOCIATED METEOROLOGY

The typical diurnal variation of surface ozone concentrations, according to findings for 4 areas in the United States and one in Canada[14,22,35,36,23], is as follows: low at night and in the early morning hours; increasing rapidly starting 7 to 9 a.m. and peaking around 2 to 3 p.m.; and then declining rapidly through the remainder of the afternoon until the low nighttime values are first observed around 8 to 10 p.m.

Early investigators[7,8,18] described the high ozone concentrations as a local photochemical phenomenon. Solar radiation reacting with the precursors of ozone emitted by automobiles and industry brought about the high concentrations. In 1961[37] it was reported that the photochemical production of ozone exceeded ozone destruction (for example, by NO scavenging and surface uptake) from 2 to 7 hours after the photochemical reactions were initiated by irradiation. This timing readily accounted for the increases in concentrations starting in the morning, peaking in the early afternoon and then declining. After several hours of destruction exceeding production the low nighttime concentrations are observed. The relatively high concentratons of the daytime generally extended from a few km downwind from the sources to as many km as the surface winds advected the polluted layers in the daytime period. These relatively high daytime concentrations are thus local problems dependent on nearby emissions and surface advection on the day of the occurrence of the high concentration.

Lea[27] first reported that there could be a contribution from aloft to high concentrations of ozone at the surface and that this contribution could be associated with long-range transport. During the daytime, the upward currents of vertical mixing carry ozone and ozone precursors aloft. At night, when the vertical mixing is generally suppressed and restricted to a shallow layer near the surface, the ozone aloft remains intact while that at the surface is destroyed by reaction with fresh NO_x emissions and surface deposition. The diurnal variation of vertical mixing coupled with ozone aloft produces, at the surface, a variation in ozone concentration similar to that produced by photochemical reactions in the layers of air advected at the surface; at night and during the early morning hours no ozone is brought to the surface; as vertical mixing increases soon after sunrise there is a marked increase in the ozone brought to the surface; when vertical mixing reaches a maximum early in the afternoon ozone contained in the whole mixed layer is subject to downward vertical mixing and concentrations at the surface approach those in the layers aloft; after the maximum vertical mixing occurs the concentrations at the surface decrease as there is no fresh ozone from aloft being brought into the mixing layer. Thus, it is very difficult to separate the ozone concentrations associated with nearby (local) upwind emissions and those associated with long-range transport coupled with vertical mixing because each produces a similar pattern. A third, but rare, set of circumstances, complete stagnation in the layer aloft, with high concentrations brought upward on one day and downward the following day could also produce the same diurnal variation. However, there are relatively few conditions under which there is no wind movement in the mixing layer for periods as long as 24 hours (trajectories to be presented later will show that layers of air are frequently moved several hundred km in 24 hours during periods described as stagnant).

METEOROLOGICAL INPUTS

Daily weather data contained in the Local Climatological Data[38] for R. E. Byrd International Airport (Richmond), Washington National Airport, and Friendship International Airport near Baltimore were used to determine the following: the daily maximum and minimum temperatures, the prevailing wind direction and average speed for each quarter-day, the percent of possible sunshine for each day, and the weather (cloud conditions, obstructions to visibility, precipitation). Daily Weather Maps[39] were also reviewed to determine the air movement aloft, the locations of fronts, centers of high and low pressure, and areas of precipitation and to relate the wind speeds and directions to high ozone concentrations.

The National Weather Service records[2] on mixing heights and average wind speeds through these layers over the Washington area provide information on the vertical mixing as well as horizontal movement of the layer of air over the local area.

Trajectory analyses[3] were used to supplement the mixing height data of the local area by showing the likely paths of the layers of air prior to arrival in the local areas. The trajectory analyses are based on the wind data from the rawinsonde observations scheduled at 7 a.m. and 7 p.m. (all times are Eastern Standard) and the winds aloft observations at 1 a.m. and 1 p.m. each day. In the basic calculation, a point along the trajectory is determined every 3 hours and data within a radius of 300 nautical miles (556 km) are evaluted. The model includes a distance weighting factor (the closest observations receive the greatest weight), an alignment weighting factor (observations upwind and downwind receive the greatest weight) and a height weighting factor (the thicker the subpart of the trajectory layer which the wind represents, the greater the weight). Trajectory segments are linked together to produce a complete trajectory for a desired period of time. Trajectories are usually started from a source or receptor 4 times daily, 1 and 7 a.m. and 1 and 7 p.m. In this report, the trajectories for each receptor-city show the backward movements in 12-hour segments for ending times of 7 a.m. and 1 p.m. Obviously, these trajectories are approximations; they become progressively less reliable with each added segment. In this report the trajectories are limited to 48 hours. A point on a trajectory indicates the general area and not a specific location where the layer of air was located at an earlier time.

SECTION 4

RESULTS

OZONE DATA

The variations of the hourly ozone data for all 16 stations are shown in Figure 2. Although some data are missing, it is obvious that every location had high ozone concentrations on July 7 to 9. By July 10, there were no violations of the 160 $\mu g/m^3$ standard in the Baltimore area and concentrations were decreasing in Washington and peaking in Richmond. By July 11, only Richmond recorded violations of the standard.

OBSERVATIONS AT AIRPORTS

Pertinent weather observed at each airport is shown in Table 2. When compared to the normals, the maximum and minimum temperatures indicate that the temperatures were high on the first 4 days at all 3 stations. A heat wave prevailed during the 4-day period; the maxima averaged 3°C above the expected averages (July maxima averaged 31°C at all 3 airports). The wind directions varied locally and from airport to airport. On days of high concentrations the wind speeds occasionally reached 8 mps, but commonly were 4 mps or less. Overall, the winds were light and variable, indicating local stagnation. The weather and percent of sunshine showed a consistent pattern; the skies were predominantly clear and the amount of possible sunshine was relatively high. The main impedance to incoming solar radiation during the 5 days was haze.

MIXING HEIGHT DATA

Table 3 lists the mixing height data[2] for each day; July 6 is included because the low speed in the mixing layer may have contributed to the problem on July 7 (that is, the winds would not have moved ozone aloft out of the general area). The mixing heights of July 6 and 8 were relatively low and on the other days near average (the 1971-1972 average mixing height for July was 1760 m). The wind speeds appear to have been more significant than the mixing heights for the first 4 days because they were considerably less than the 5.4-mps average for July 1971-1972. The low speeds indicate that during the episode pollutants aloft may have remained in high concentrations above the three-city area.

SYNOPTIC WEATHER SITUATION

The Daily Weather Maps[39] disclosed that most of Niemeyer's[40] criteria for forecasting synoptic scale high air pollution potential and the criteria of Korshover[41] for determining that large scale stagnation had occurred (a post occurrence evaluation) were met. The primary criteria of the forecast and evaluation schemes are that the winds at the surface and aloft up to 500 mbs (about 5500 meters above mean sea level) be relatively weak. Both techniques included persistence criterion; the forecasts required conditions to continue for at least 36 hours; the evaluations only counted episodes that lasted at least 4 days. The minimum size area for a forecast was an area equivalent to a longitude-latitude square of 4 degrees on a side. The post analysis was based on longitude-latitude grid points at 2-degree intervals, but focused on the pressure pattern around anticyclone centers. Both schemes sought evidence of subsidence and an absence of precipitation and fronts. The surface and 500-mb maps for July 7 to 11 showed that the winds were relatively light as high pressure with weak pressure gradients was the dominant synoptic feature over the eastern part of the nation. Two examples of the surface maps are shown in Figure 3. On July 7, (Figure 3a), the first day with the high ozone concentrations in the corridor, the isobaric pattern was extremely weak over the eastern half of the country. A large fraction of stations in the area bounded by Illinois-Pennsylvania-Louisiana-Florida-Illinois recorded calm conditions at 7 a.m.; very few reported speeds as high as 3 mps. The stationary front just south of Pennsylvania was weak and dissipating as the area of high pressure immediately to its north amalgamated with the high centered along the Carolina coast. By July 9, (Figure 3b), the pressure distribution over the eastern states remained much like that on the 7th, except the gradient had increased slightly over the Great Lakes and had decreased over the southern Mississippi Valley. The front seen in southern Canada on July 9, moved into southern parts of New England, New York and Michigan on July 10 (position at 7 a.m.) and on July 11 pushed through the corridor.

The 500-mb charts, in concert with the sea-level charts, showed high heights (and pressure) and weak gradients over the eastern United States. One of the criteria[40] frequently employed in conjunction with other indicators of stagnation is that the winds be less than 12 mps at the 500-mb level. During this episode such speeds were exceeded only in the region north of our area of interest. Figure 4 shows the northern boundary of the region where the 500-mb winds were 12 mps or less, based on observations at 7 a.m. on each day of the episode. Clearly, winds aloft conducive to stagnation covered the eastern half of the nation except for the extreme northeast from July 7 to 10. The rapid southwestward movement of the area of stronger winds on the 11th was associated with the termination of the episode as the front shown in Figure 3b moved southward through the corridor.

TRAJECTORIES OF THE SURFACE-TO-1000 METER LAYERS

The mixing height data (Table 3) indicated that the afternoon well-mixed layers ranged from 1160 to 1990 meters thick. In the case of the trajectories, the conservative height of 1000 meters was employed; the bulk of the pollution in the atmosphere would be contained in that depth. Two trajectories for each day, for ending times of 7 a.m. and 1 p.m., and for Richmond, Washington and Baltimore are shown.

On July 7, as seen in Figure 5, the recent 24-hour movement was very slow (the recent 12-hour movement into each city averaged 1 mps) and the 48-hour movements covered 400 km or more (averaging about 2.3 mps or a little more). As to potential upwind sources, the air reaching Baltimore had passed over areas which were heavily populated and industrialized, while the air reaching Washington and Richmond had passed over areas with few potential sources.

On July 8, Figure 6, the 48-hour trajectories show the surface-to-1000 m layer moved with an average speed of 2 mps or less indicating stagnation was an important factor. Again, the air arriving in Richmond came from areas with a few potential sources. In contrast, the air arriving in Baltimore and Washington did come from potential source areas. Thus, stagnation both in the local area and at distant locations was associated with high concentrations in all 3 cities while long-range transport from potential source areas probably contributed to the problem in Baltimore and Washington.

On July 9, Figure 7, most of the slow movement shown by the 48-hour trajectories occurred with the July 7 and 8 winds; the most recent 12-hour flows were rapid (these flows averaged 10 mps coming into Baltimore and Washington and 8 mps coming into Richmond). Again, the flows showed that the air over Baltimore and Washington had prior movements over potential source areas while the air came into Richmond from areas with few sources. Stagnation in the local upwind areas appeared to be minor on this day, but stagnation at distant locations on prior days and long-range transport were associated with the high concentrations.

On July 10, Figure 8, most of the slow movement is traced back to the July 8 winds and the air arriving over Baltimore and Washington show a history of slow movement over the same distant areas; the most recent flows into all 3 cities averaged about 10 mps. Again, the Washington and Baltimore air had passed over areas with large numbers of potential sources while the Richmond air came from areas with few sources.

On July 11, Figure 9, there was rapid air movement into all 3 cities and no evidence of stagnation during the prior 48 hours. Only Richmond had violations of the ambient air standard and it was downwind of the Harrisburg-Baltimore-Washington region as well as areas to the northwest. It appeared that long-range transport rather than stagnation was associated with the high concentrations in Richmond.

THE TEMPORAL AND SPATIAL EXTENT OF THE HIGH OZONE CONCENTRATIONS

The temporal extent of this pollution episode for the Richmond-to-Baltimore corridor was July 7 to 11. In order to determine the spatial extent of the episode and whether upwind areas had high concentrations which could have contributed to high concentrations in the corridor, ozone data from the surrounding areas were sought. The data obtained were from more than 80 stations in 10 additional states extending from Tennessee and North Carolina in the south to Ohio and Massachusetts in the north. No data were available for West Virginia, and South Carolina. To conserve space, data for 42 representative stations were selected and are presented in Table 4. These stations gave complete coverage to the limits of all available data; each station which was omitted was very close to one which is listed and usually had a concentration about the same as the nearby station.

In order to show the beginning of the episode in this enlarged area, it was necessary to include data for July 6 (see Table 4); there were violations of the NAAQS at 17 of the 42 additional stations on July 6 (4 stations had violations on July 5). Excluding those stations which had violations on only one of the 6 days (July 6 to 11), it is concluded that the episode did extend almost to the far borders of Ohio and Massachusetts in the north and just into northern Tennessee and Virginia to the south.

The trajectories for Baltimore on July 7 and for Washington and Baltimore from July 8 through 10 (see Figures 5 through 8), show that air arriving in those cities came from areas which did have high ozone concentrations; upwind areas may have contributed to the high concentrations that were observed. The trajectories for Richmond for July 7 through 10 and those for Washington on July 7, however, did not show major source areas in the upwind direction.

SECTION 5

SUMMARY

In the investigation of high ozone concentrations in the Baltimore-to-Richmond corridor from July 7 to 11, 1974, the following were determined:

1. There was large scale stagnation during the period, and it generally extended west through north of the corridor. This stagnation was manifest in the surface, 500-mb, and mixing layer winds, in the sea-level pressure and 500-mb height patterns, and in the trajectory analyses.

2. The alert was associated with the meteorological phenomena typically associated with high concentrations of ozone: low wind speeds; several days with high temperatures and intense solar radiation. The mixing heights were not, however, very low during the episode.

3. Trajectory analyses indicated that in spite of wide-spread synoptic stagnation, some of the air arriving over Washington and Baltimore was associated with air from distant areas with potential sources. Examination of the ozone data from the surrounding area for the same period showed that high concentrations were a widespread phenomenon and that many of the implicated, distant upwind areas with potential sources actually observed high concentrations of ozone.

4. Any abatement strategy for this type of stagnation-ozone alert would have to include a plan for minimizing that part of the high concentrations resulting from long range transport and that part due to nearby sources.

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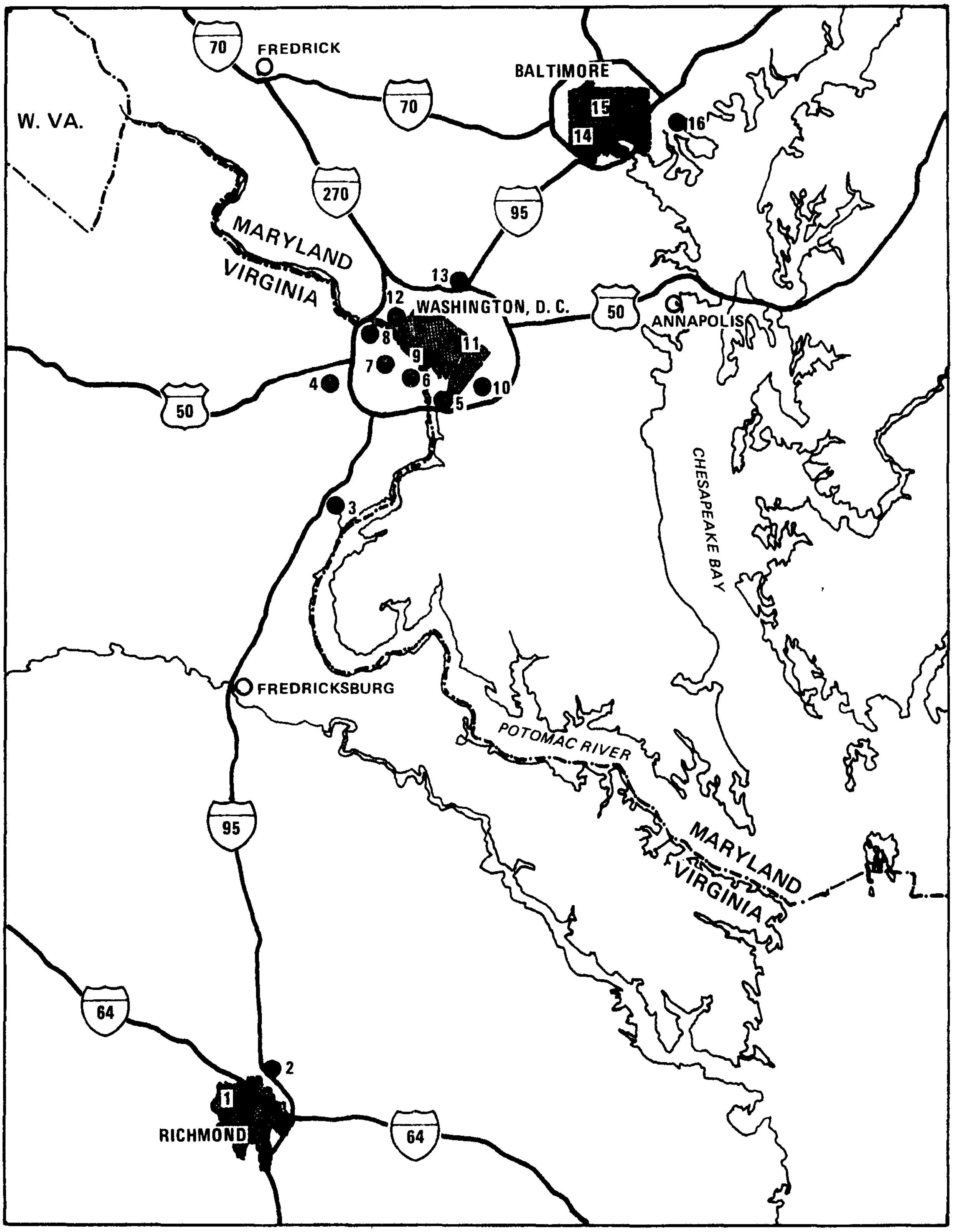

Figure 1. Locations of ozone monitoring stations.

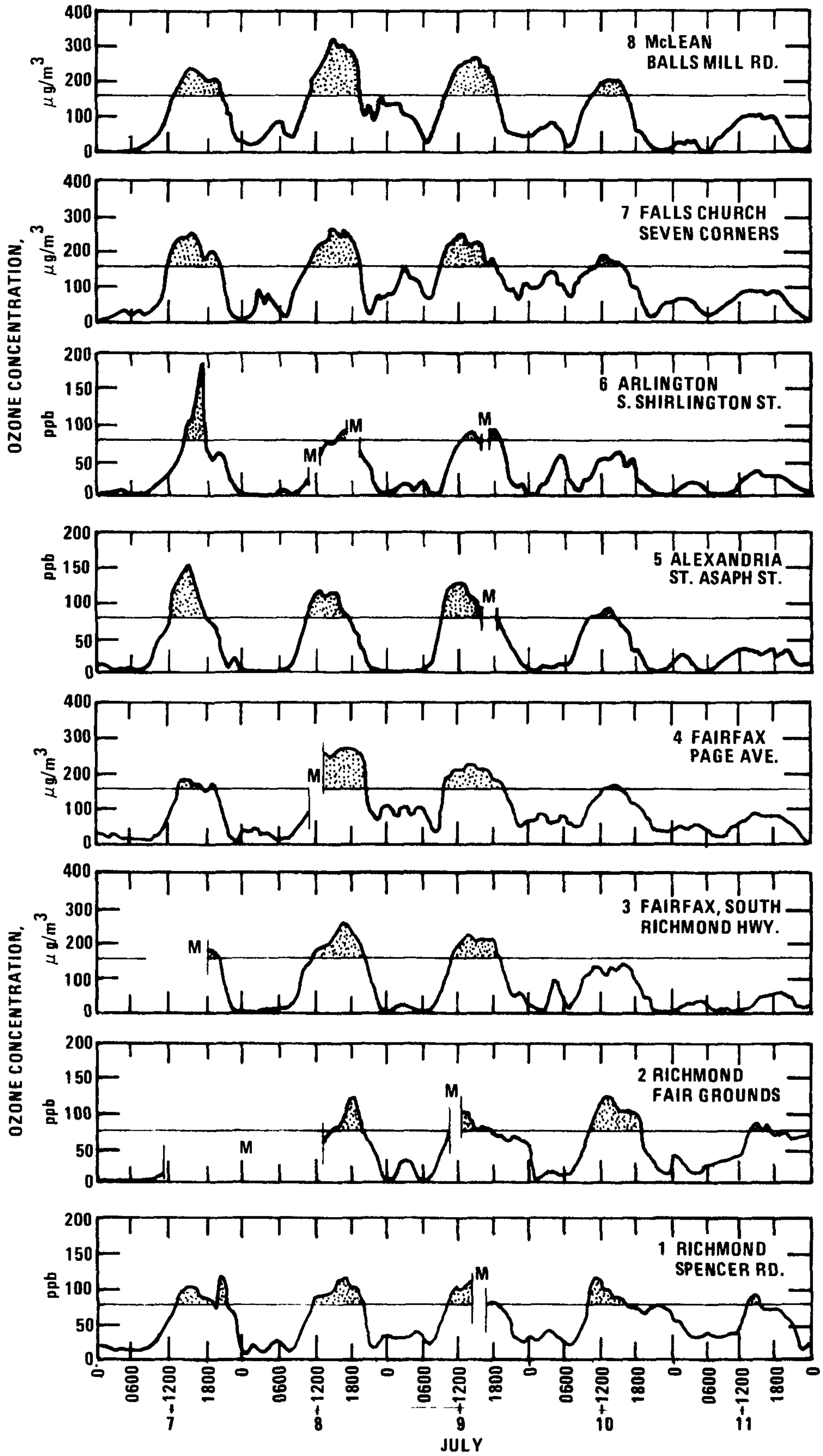

Figure 2. Ozone concentrations at 16 stations, July 7-11, 1974.

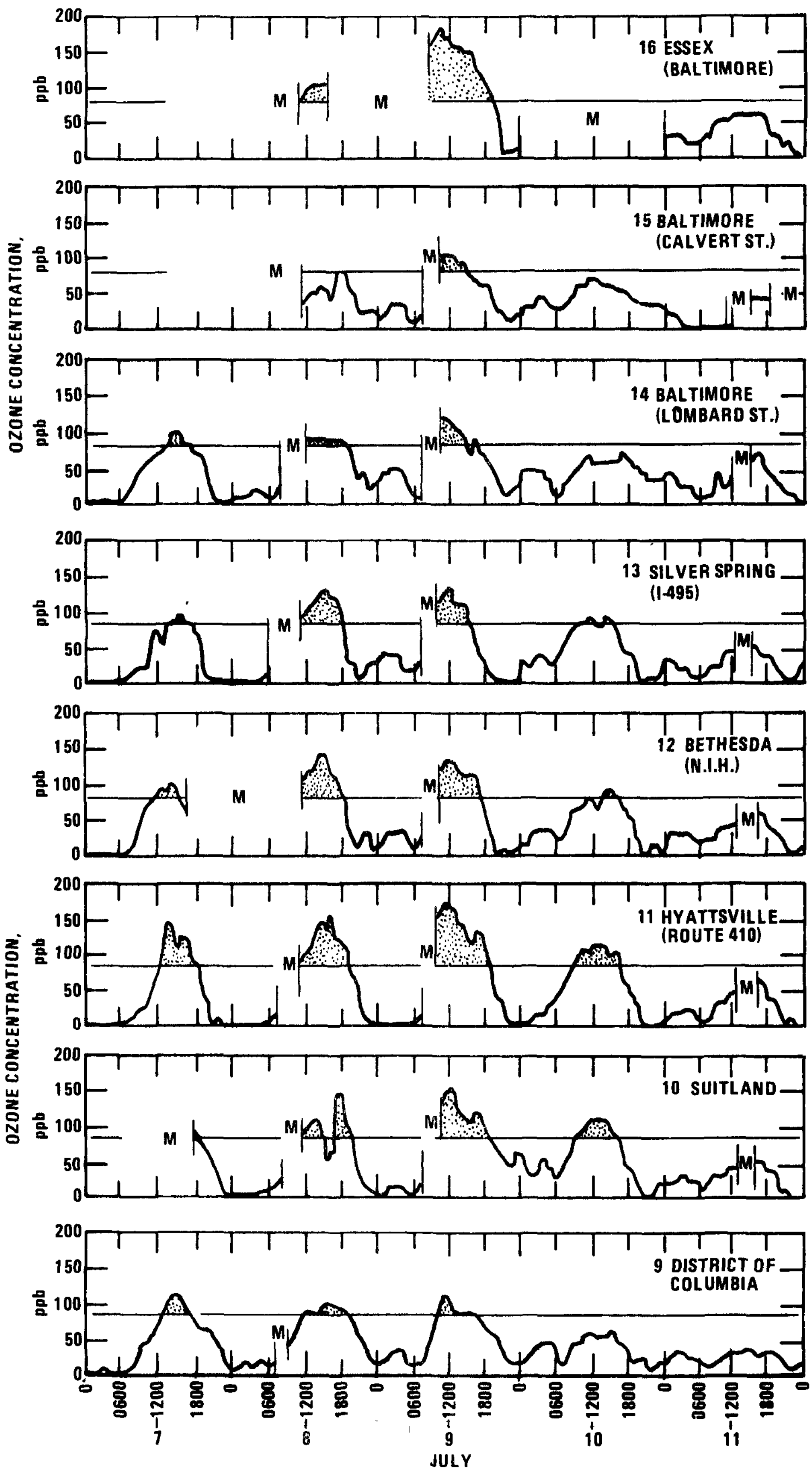

Figure 2 (Continued). Ozone concentrations at 16 stations, July 7-11, 1974.

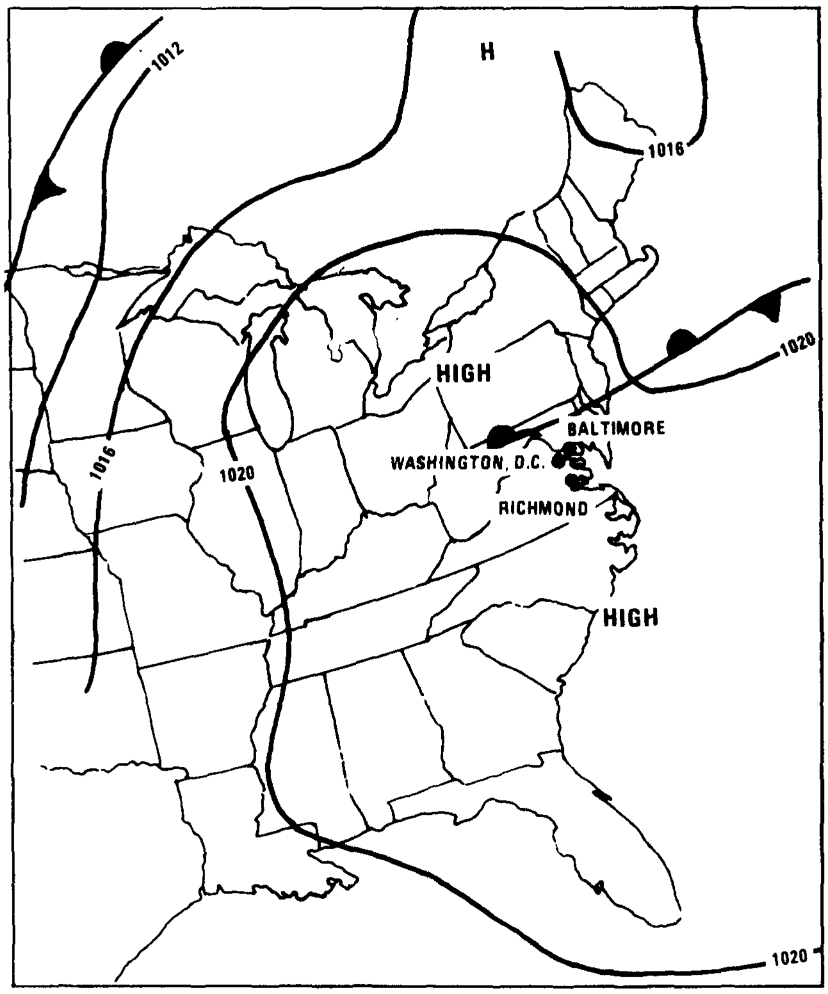

Figure 3a. Surface Weather Map, 7:00 a.m., E.S.T., July 7, 1974.

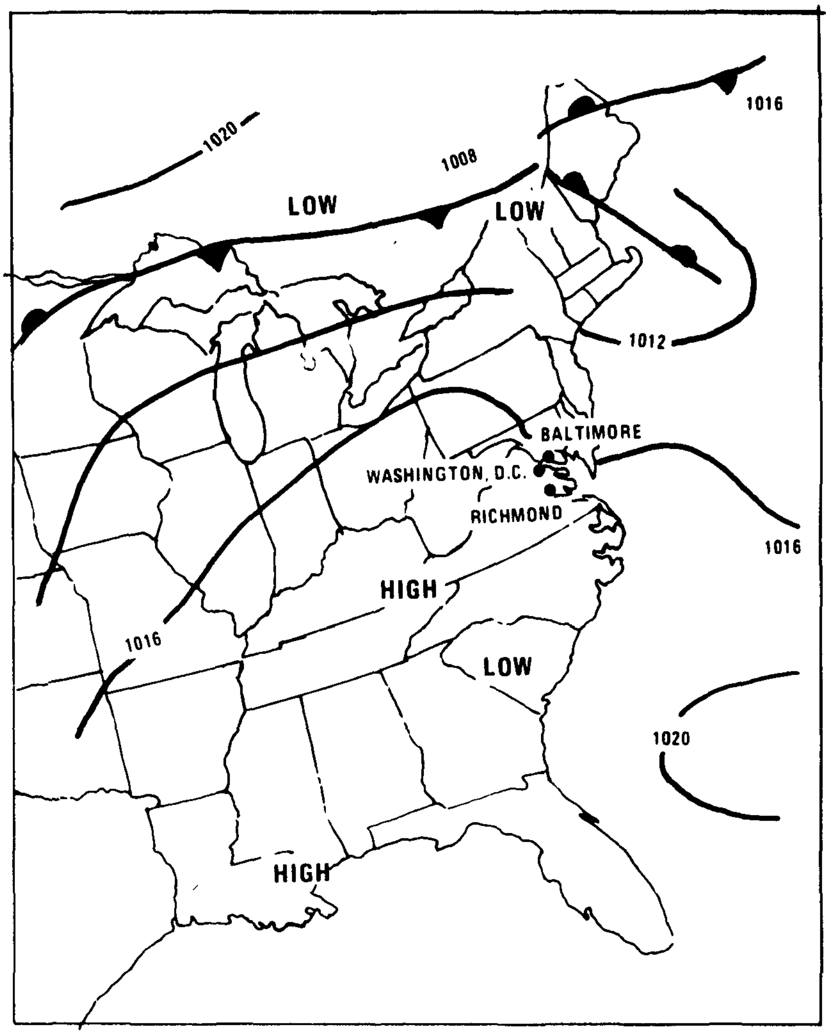

Figure 3b. Surface Weather Map, 7:00 a.m., E.S.T., July 9, 1974.

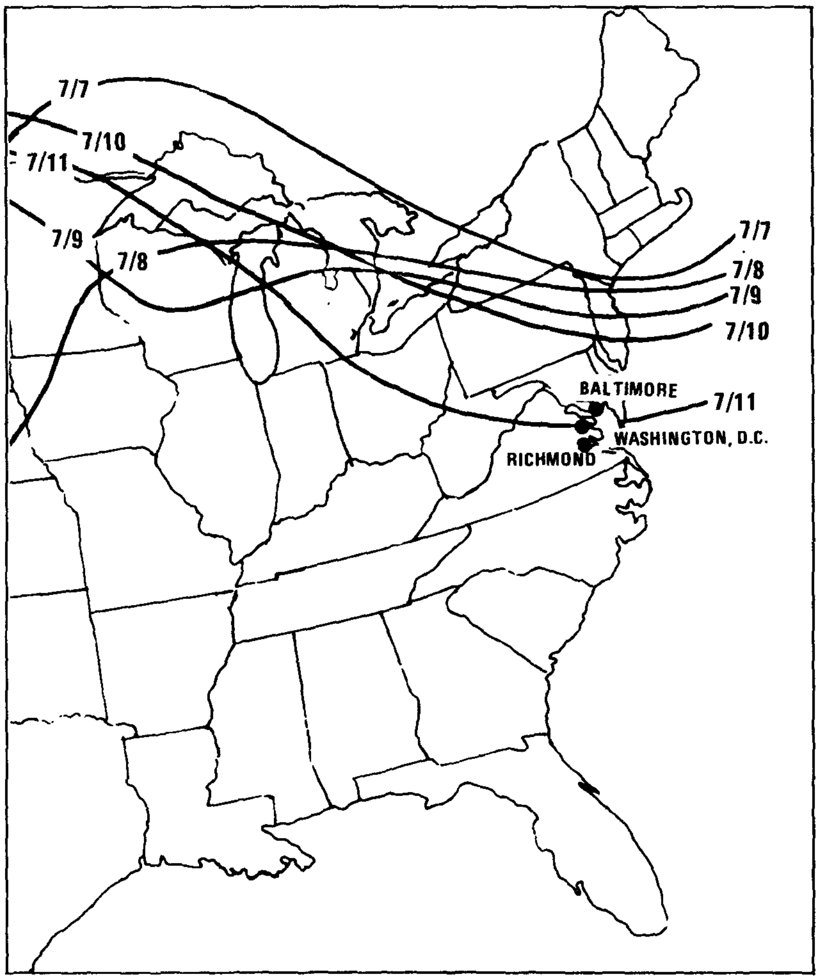

Figure 4. 12 mps contour, 500 mb height, 7:00 a.m., July 7-11, 1974. (Weaker winds to south.)

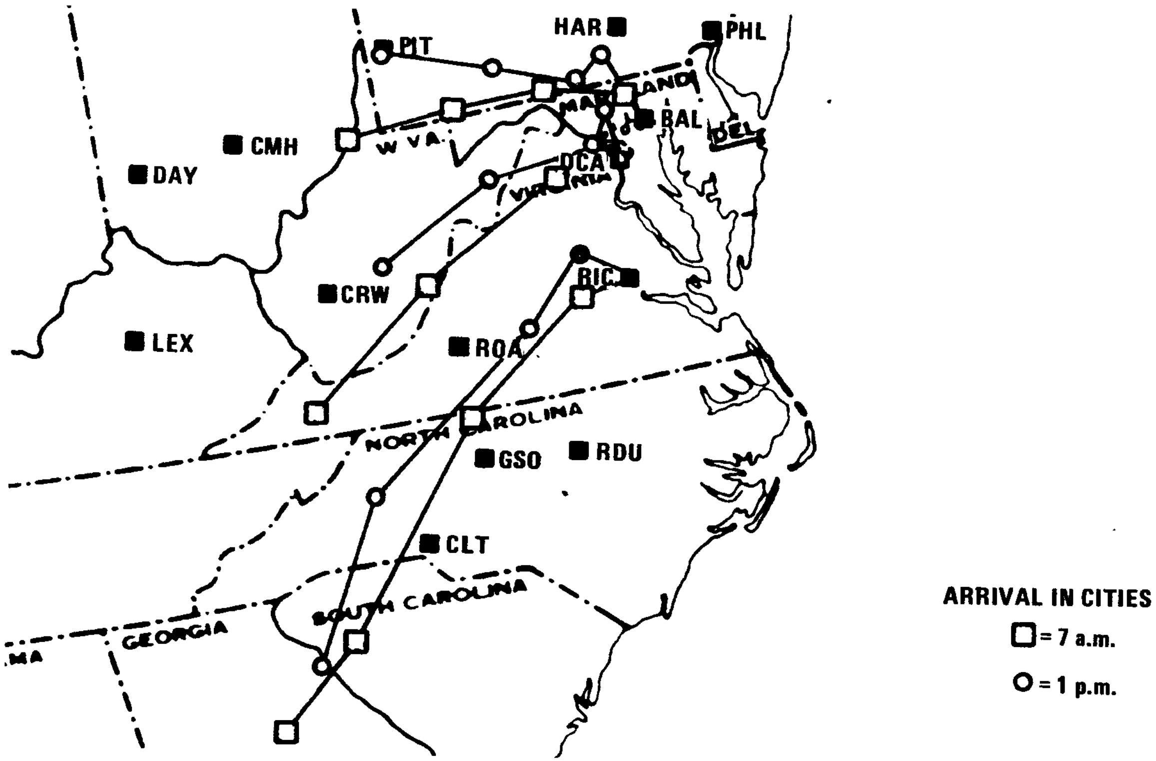

Figure 5. Forty-eight-hour trajectories (12-hour increments) of layer from surface to 1000 meters, July 7, 1974.

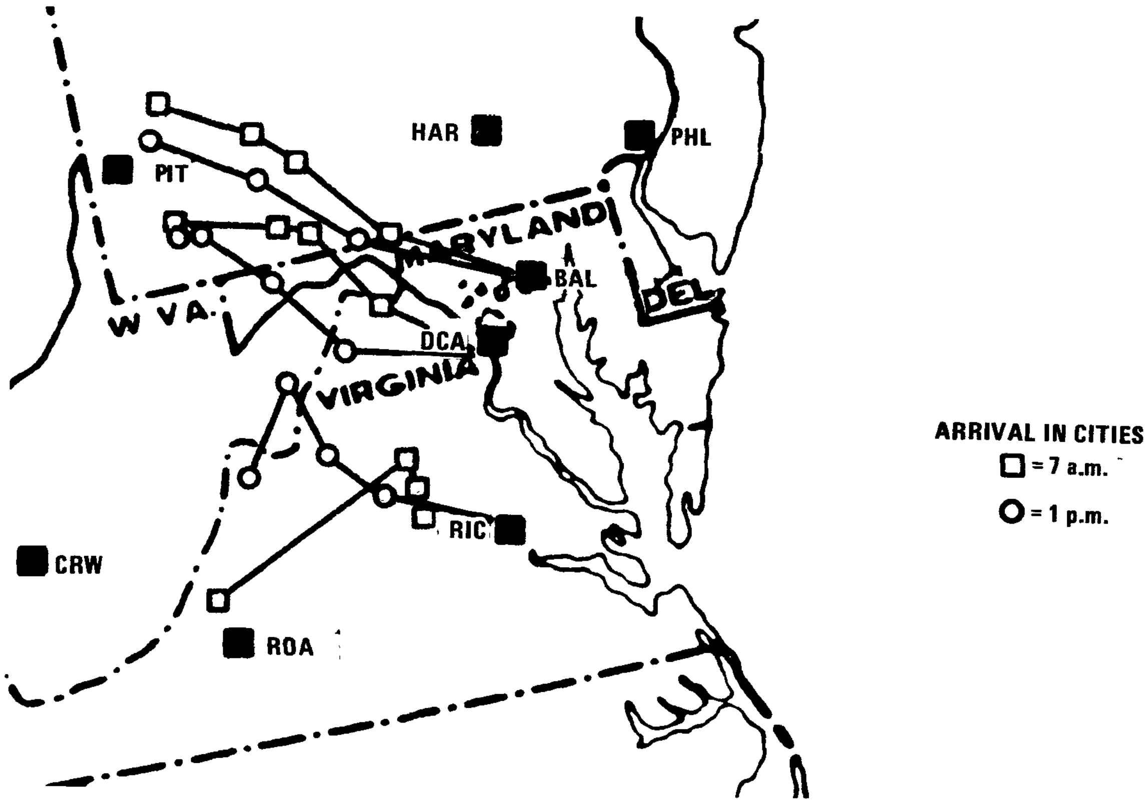

Figure 6. Forty-eight-hour trajectories (12-hour increments) of layer from surface to 1000 meters, July 8, 1974.

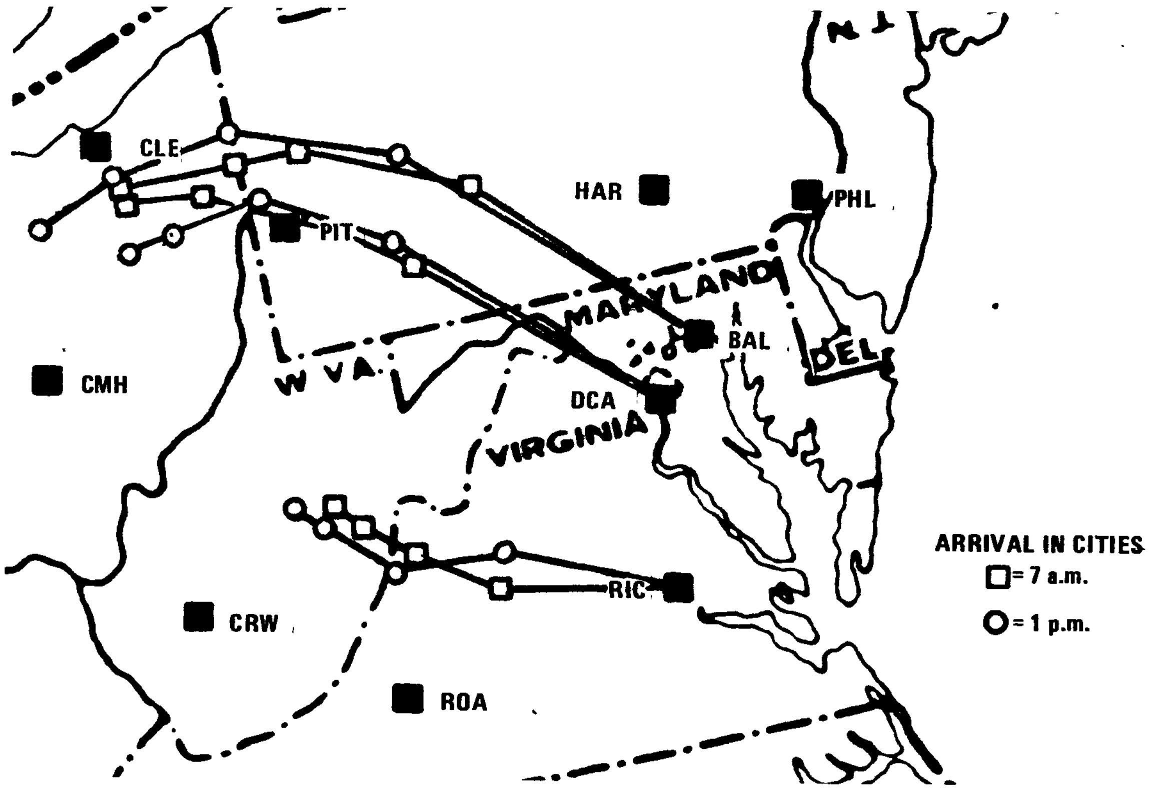

Figure 7. Forty-eight-hour trajectories (12-hour increments) of layer from surface to 1000 meters, July 9, 1974.

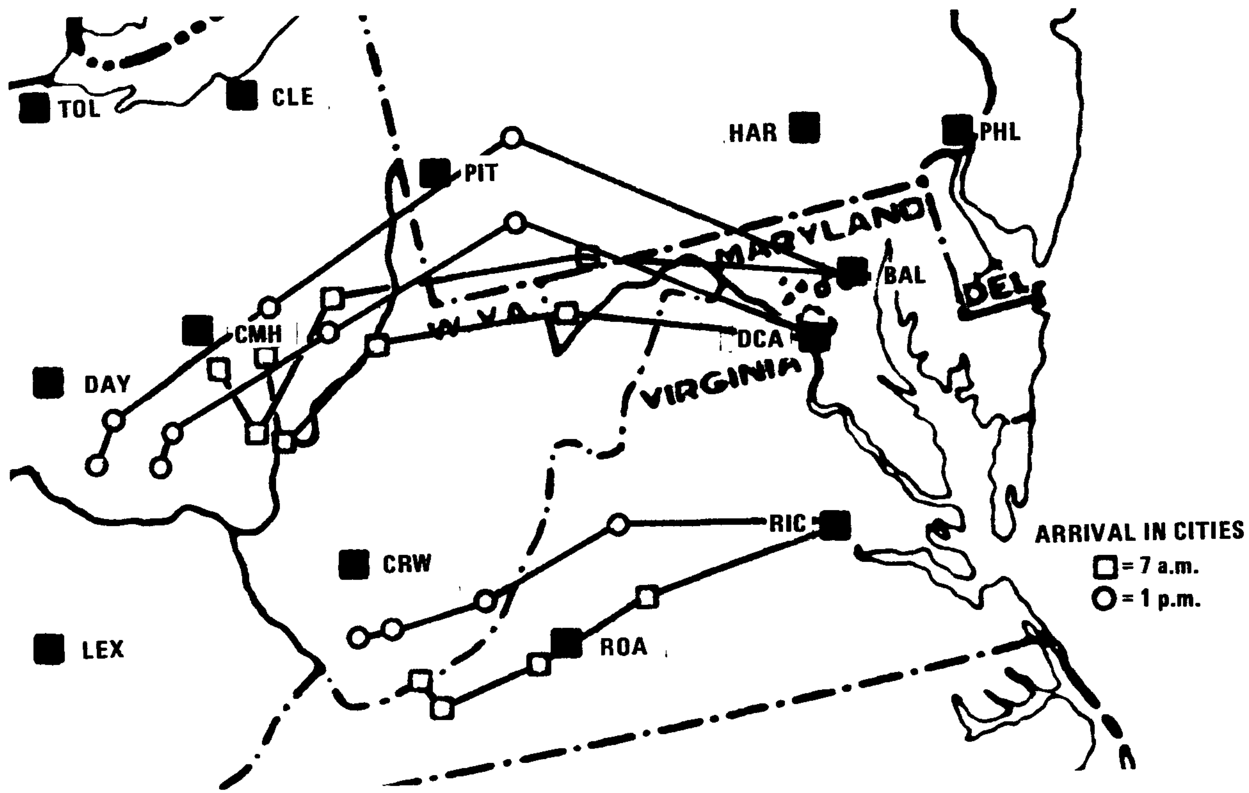

Figure 8. Forty-eight-hour trajectories (12-hour increments) of layer from surface to 1000 meters, July 10, 1974.

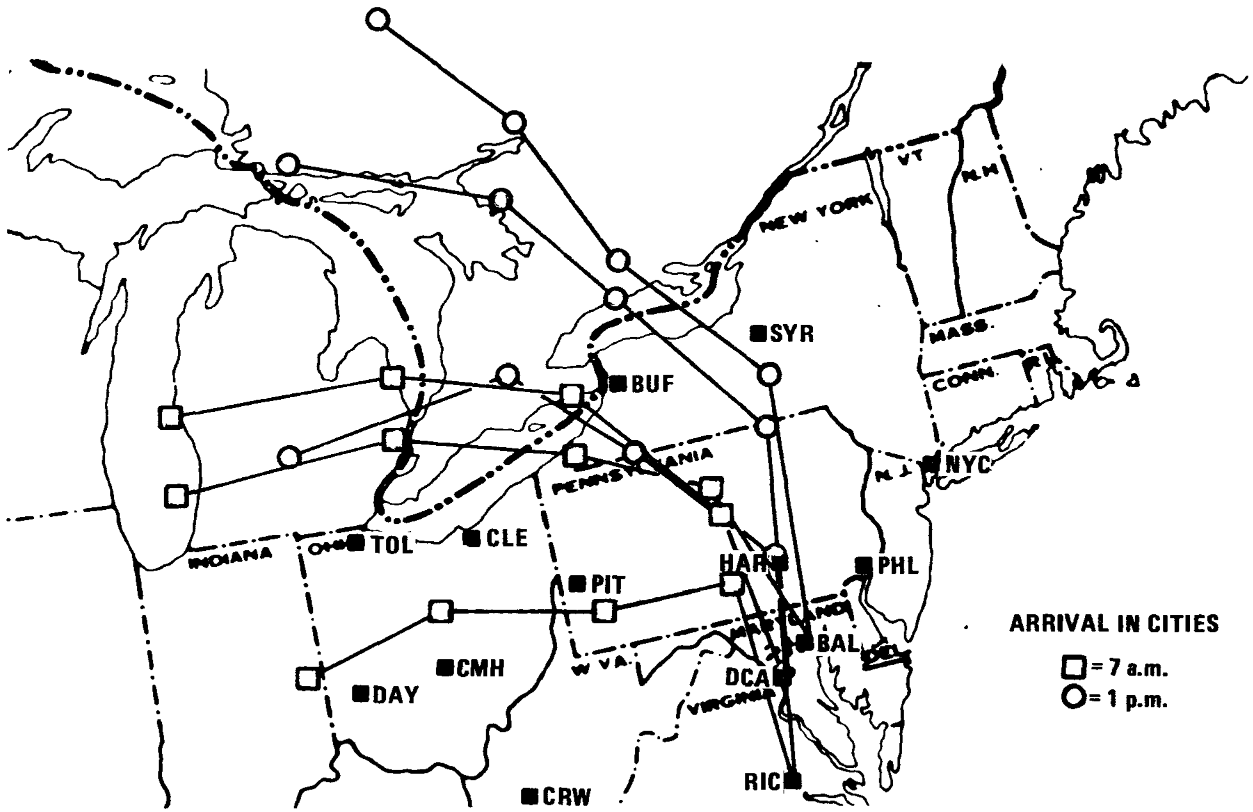

Figure 9. Forty-eight-hour trajectories (12-hour increments) of layer from surface to 1000 meters, July 11, 1974.

TABLE 1. OZONE STATIONS AND LOCATIONS

	Station	Location
1.	Richmond	Spencer Road
2.	Richmond	State Fair Grounds
3.	Fairfax South	Richmond Highway
4.	Fairfax	Page Avenue
5.	Alexandria	St. Asaph Street
6.	Arlington	South Shirlington Street
7.	Falls Church	Seven Corners
8.	McLean	Balls Mill Road
9.	Washington	New Jersey Avenue, NW
10.	Suitland	Suitland Road
11.	Hyattsville	Route 410
12.	Bethesda	National Institute of Health
13.	Silver Spring	I-495
14.	Baltimore	Lombard Street
15.	Baltimore	Calvert Street
16.	Essex	Woodward Drive

TABLE 2. ATMOSPHERIC CONDITIONS DURING EPISODE

Date Station-Weather	July 7	July 8	July 9	July 10	July 11
Baltimore					
Max T*(°F/°C)	90/32	94/34	96/36	95/35	81/27
Min T (°F/°C)	68/20	66/19	70/21	72/22	64/18
Prevailing WD[a]	WNW NNE NW W	W NNW NNW W	W WNW WNW W	WSW W WNW W	NNW N NNW N
Avg. Speed (mps)	3 2 4 2	3 4 5 3	3 4 4 4	4 6 5 6	5 8 6 5
% Sunshine	78	92	77	64	89
Weather	Clear[b]	Clear	Clear, hazy	Clear, hazy, rain in evening	Clear
Washington					
Max T (°F/°C)	92/33	95/35	96/36	94/34	84/29
Min T (°F/°C)	73/23	70/21	72/22	75/24	70/21
Prevailing WD	SW ENE NE W	W N N W	SW NE WNW SW	WSW NW NW SW	N N N NNE
Avg. Speed (mps)	2 2 3 3	2 3 3 4	1 3 4 3	3 5 5 2	5 7 5 6
% Sunshine	67	93	84	67	83
Weather	Clear, hazy	Clear, hazy	Clear, hazy	Clear, hazy rain in evening	Clear
Richmond					
Max T (°F/°C)	88/31	94/34	97/36	96/36	87/31
Min T (°F/°C)	69/21	67/19	67/19	68/20	64/18
Prevailing WD	SW WSW ESE SSE	C** WNW NE SW	SW NW WSW SSW	S WSW WNW WSW	NW NE N NNE
Avg. Speed (mps)	2 3 3 2	3 2 3	2 1 2 3	2 3 3 2	2 5 4 4
% Sunshine	66	95	97	79	82
Weather	Partly cloudy	Clear, hazy	Clear, foggy, hazy	Clear, hazy	Clear

[a] WD, Avg. Speed = Wind direction and speed for each consecutive quarter day, speed in meters per second (mps)
[b] Clear = Thin clouds or scattered or less obscuring clouds
* T = Temperature
**C = Calm

TABLE 3. MIXING HEIGHT DATA, WASHINGTON AREA, JULY 6-11, 1974

Parameter \ Data	July 6	July 7	July 8	July 9	July 10	July 11
Afternoon mixing height m	1160	1830	1280	1690	1990	1850
Average direction[a]	200°	350°	250°	300°	330°	360°
Average speed[a] mps	2.3	2.6	2.8	4.2	5.7	8.3

[a] Directions and speeds are averages for mixing layer.

TABLE 4. MAXIMUM OZONE CONCENTRATIONS (PPB) IN CITIES SURROUNDING THE STUDY AREA

Station \ Date	July 6	July 7	July 8	July 9	July 10	July 11
Connecticut						
Greenwich	70	*90*	*130*	*130*	*90*	40
Groton	*82*	*95*	*101*	*114*	53	38
Hartford	46	64	*87*	*98*	72	27
New Haven	76	*88*	*93*	*130*	74	19
Stamford	*110*	*119*	*124*	*133*	*83*	46
Kentucky						
McCarken County (Paducah)	80	70	70	70	70	40
Massachusetts						
Boston	27	65	57	*87*	40	22
Fall River	33	M	*83*	*118*	65	36
Fitchburg	37	60	51	*94*	41	32
Worchester	44	*82*	66	*100*	M	32
New Jersey						
Ancora	*144*	*154*	*166*	*184*	*138*	52
Asbury	52	*102*	*112*	*89*	67	51
Bayonne	*94*	79	80	*100*	*84*	40
Trenton	64	58	69	*93*	59	21
New Yörk						
Babylon	*111*	*169*	*113*	*127*	*104*	43
Buffalo	*158*	*87*	*147*	*138*	77	38
New York	*114*	*101*	*106*	*116*	*99*	49
Niagara	*118*	*90*	*150*	*140*	*100*	55
Rochester	48	*82*	*125*	*103*	30	26
Syracuse	45	*104*	*110*	*98*	34	32

(continued)

TABLE 4. MAXIMUM OZONE CONCENTRATIONS (PPB) IN CITIES SURROUNDING THE STUDY AREA

Station \ Date	July 6	July 7	July 8	July 9	July 10	July 11
North Carolina						
Asheville	25	35	35	45	45	45
Charlotte	29	55	*83*	52	76	63
Ohio						
Cleveland	30	*145*	80	75	60	M
Columbus	*95*	*125*	*150*	*95*	*90*	80
Dayton	64	49	76	54	57	44
Morgan County	*111*	*121*	*129*	*99*	*81*	60
Wilmington	*114*	78	M	*133*	*132*	*82*
Youngstown	*112*	*185*	*192*	*140*	*112*	68
Pennsylvania						
Allentown	*91*	*100*	*115*	*180*	*125*	65
DuBois	76	*137*	*163*	*156*	*115*	71
Harrisburg	*100*	*97*	*123*	*138*	*118*	49
Johnstown	60	*135*	*203*	*152*	*122*	50
Philadelphia	*110*	*115*	*110*	*165*	*115*	M
Reading	*94*	*131*	*126*	*201*	*135*	43
Scranton	68	69	*87*	*116*	75	50
York	*98*	*95*	*110*	*144*	*110*	48
Tennessee						
Kingsport	52	60	67	65	75	65
Memphis	65	60	*95*	40	60	75
Morgan County	30	50	70	50	50	70
Sumner County	67	80	*160*	*85*	*108*	78
Virginia						
Hampton	10	50	*130*	60	55	75
Norfolk	20	55	*150*	M	80	80

Notes: No data for West Virginia and South Carolina stations for these dates.
Italics show violations of Federal Standard.
M = Missing

TECHNICAL REPORT DATA

(Please read Instructions on the reverse before completing)

1. REPORT NO. EPA-600/4-78-016	2.	3. RECIPIENT'S ACCESSION NO.
4. TITLE AND SUBTITLE THE 1974 OZONE EPISODE IN THE BALTIMORE-TO-RICHMOND CORRIDOR		5. REPORT DATE February 1978
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15. SUPPLEMENTARY NOTES

*On assignment from the National Oceanic and Atmospheric Administration, U.S. Department of Commerce.

16. ABSTRACT

An ozone alert in July of 1974 in the Washington, D. C., area is examined in detail. Ozone data for 16 stations in the Richmond-to-Baltimore corridor are examined in conjunction with meteorological data for the alert period. Emphases are given to trajectories of the air between the surface and 1000 meters and the mixing height and winds aloft data of the air pollution forecasts of the National Weather Service. The investigation revealed: (1) the period with high ozone concentrations was one when synoptic scale stagnation at the surface and aloft prevailed most of the time together with high temperatures and abundant solar radiation; (2) despite overall stagnation over a very large region there were periods when 48-hour trajectories showed that ozone could have been transported from potential source areas as far as 1000 kilometers upwind; (3) that a) the Richmond-to-Baltimore corridor was at the southern and eastern periphery of a large area in the industrial eastern United States which had high ozone concentrations, and b) many of the distant potential source areas implicated in the trajectory analyses observed high ozone concentration; and (4) that any abatement strategy for this type of alert, even though associated with stagnation, will have to take into account both local and distant sources.

17. KEY WORDS AND DOCUMENT ANALYSIS

a. DESCRIPTORS	b. IDENTIFIERS/OPEN ENDED TERMS	c. COSATI Field/Group
* Air pollution * Ozone * Meteorological data Evaluation	Baltimore-to-Richmond Area	13B 07B 04B

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