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Project Summary

Ozone Plumes from Small Cities and Ozone in High Pressure Weather Systems

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The report describes the results from a five-week study to investigate ozone transport in urban plumes of small cities and the behavior of ozone in a moving high pressure system traversing the eastern half of the United States. The study was a collaborative effort involving research groups from Battelle-Columbus, the EPA Environmental Sciences Research Laboratories and Washington State University. The results show that small cities do affect ambient ozone levels and under photochemically reactive conditions can produce measurable ozone in downwind plumes. Studies of a moving high pressure system revealed a vertical multilayer structure for ozone. The origin of some of these layers appeared to be stratospheric air injected into the troposphere during cyclogenesis in northern Canada. The upper layer of ozone, found between 10,000 and 15,000 feet MSL, was observed to cover nearly the entire eastern half of the United States.

This Project Summary was developed by EPA's Environmental Sciences Research Laboratory, Research Triangle Park, NC, to announce key findings of the research project that is fully documented in a separate report of the same title (see Project Report ordering information at back).

Introduction

This report presents the results of a field investigation of ozone (O_3) distribution and transport. The program focused on the formation and transport of O_3 in urban plumes of large and small cities, and the behavior of O_3 in a high pressure weather system traversing the eastern half of the U.S. The program involved detailed ground-level and aircraft monitoring studies, and the analysis and interpretation of the resulting data. This study builds upon earlier investigations of O_3 transport in the Ohio Valley and New England.

The issue of O_3/precursor transport has caused much controversy, and this program was directed at providing additional information on various aspects of the controversy. Specifically, we have investigated the contribution of smaller cities to the downwind O_3 burden and the long-range transport of O_3 associated with a high pressure system.

Objectives

The overall objective of the program was to determine the propensity of air masses to generate and transport O_3 over long distances. Specific goals of the project were:

- To investigate the transport of O_3 and precursors from urban areas, and especially to determine whether smaller cities contribute measurably to the downwind O_3 burden.
- To study the behavior of O_3 associated with high pressure weather systems.
- To improve current understanding of O_3 variations with altitude, with an emphasis on obtaining more data at higher altitudes (up to 20,000 feet mean sea level (MSL)).

Project Description

Field experiments were conducted in July and August, 1977 in the midwestern U.S. Both ground-level and airborne monitoring were conducted and measurements were made from two ground sites and two twin-engine research planes. Ground-level measurements were taken at a site near St. Louis and at the Civic Memorial Airport in Bethalto, Illinois, where aircraft operations were also based. The location of the airport in relation to St. Louis and other urban areas is noted in Figure 1. The variables monitored by aircraft include O_3, oxides of nitrogen (NO_x), nitric acid ($HONO_2$), nitrate (NO_3^-), fluorocarbon-11, C_2 to C_{10} hydrocarbons, temperature, and dew-point temperature. Ground-level measurements included O_3, nitric oxides, NO, NO_x, peroxyacetyl nitrate, PAN, $HONO_2$, fluorocarbon-11, nonmethane hydrocarbons (NMHC), methane (CH_4), carbon monoxide (CO), total suspended particulates (TSP), NO_3^-, sulfate ($SO_4^=$), ammonium (NH_4^+), carbon (C), hydrogen (H), nitrogen (N), temperature, relative humidity, radiation intensity, wind speed and wind direction. The study was a collaborative effort involving Battelle-Columbus Laboratories, EPA-ESRL, who provided detailed hydrocarbon analyses of aircraft samples, and Washington State University (WSU), with whom we coordinated many aircraft operations.

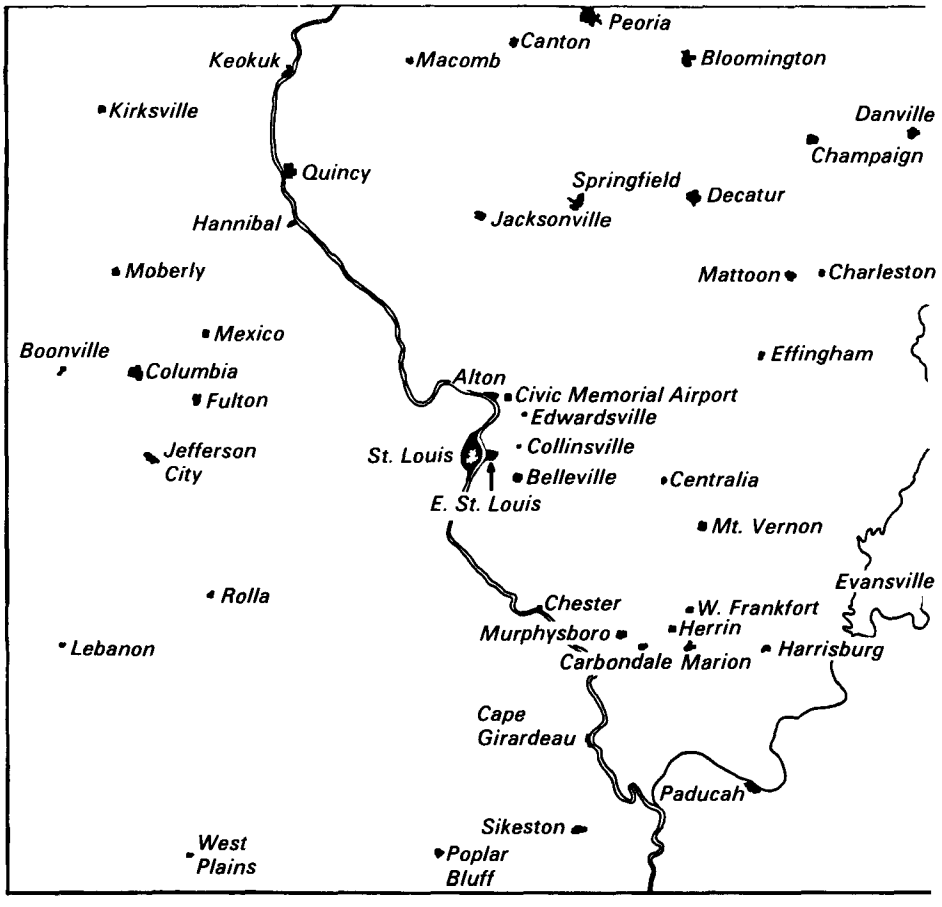

Figure 1. Location of mobile labs and Civic Memorial Airport in the St. Louis area.

Results

The field investigation of atmospheric O_3 distribution and transport focused on the formation and transport of O_3 in urban plumes of large and small cities, and the behavior of O_3 in a high pressure weather system traversing the eastern U.S. Both ground-level and airborne monitoring were employed, and a comparison of the ozone monitors aboard the two aircraft showed agreement within 2.5 percent. The project report describes the experimental aspects of the field program and interpretation of the data as they relate to the program objectives. A succinct summary of the study findings follows.

- The St. Louis urban area generates an O_3 plume with O_3 concentrations approaching 300 ppb under stagnated conditions.
- Smaller cities (populations $\leq$ 100,000) generate a measurable O_3 plume under photochemically reactive conditions. The additional O_3 in the plumes is related to the cities' precursor emissions An isopleth diagram of the O_3 plume from Springfield, Illinois on August 3, 1977 is shown in Figure 2.
- During the study of O_3 and precursors in a high pressure weather system, O_3 concentrations near the surface increased steadily over the three days that it took the high to cross the eastern U.S. Figure 3 shows the area covered by the High Pressure Weather System Study, the aircraft flight tracks, and mixing-layer O_3 concentrations. During flights over rural areas, O_3 concentrations of 30 to 40 ppb were observed on the first day over Wisconsin, 70 to 90 ppb on the second day over Ohio, and $>$ 100 ppb on the third day over Pennsylvania.
- During the studies in a high pressure weather system traversing the eastern U.S., several layers rich in O_3 were observed in vertical profiles. The upper layer of O_3, which was found between 10,000 and 15,000 feet MSL, was observed to cover nearly the entire eastern half of the U.S. (from Wisconsin to Virginia). Such a pervasive tropospheric O layer has not been reported previously. The source of this O_3 layer was demonstrated to be the stratosphere
- Analysis of vertical profile results and rawindsonde data during the high pressure system study suggests that the pervasive O_3 layer observed over the eastern U.S. at 10,000 to 15,000 feet MSL resulted from an injection of stratospheric air into the troposphere during cyclogenesis in northern Canada several days before our observations over the U.S. If this is the case, then the persistence of O_3 in this elevated layer must be at least 3 to 4 days.
- The O_3 was injected into the troposphere along a stable frontal layer The injection was limited in time so that the O_3 remained as a finite layer when it later appeared above the surface high pressure area in the Midwest. The O_3 in the frontal layer did not extend to the ground in the Midwest and thus there was no rise in O_3 at the surface marking the

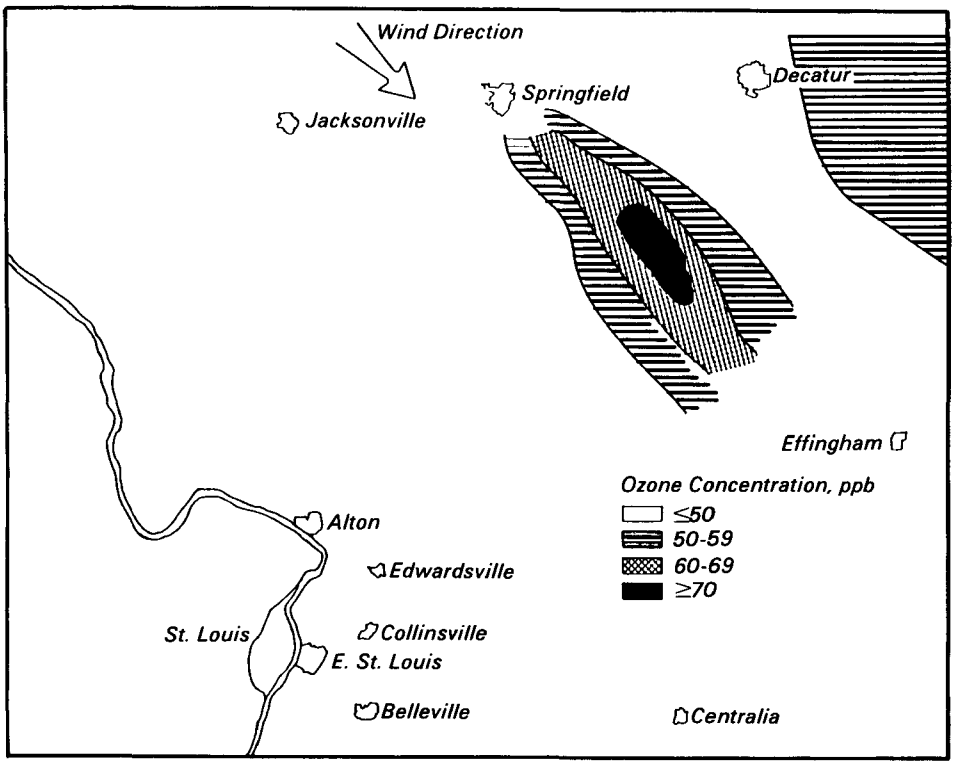

Figure 2. Ozone isopleths downwind of Springfield, Illinois, on August 3, 1977.

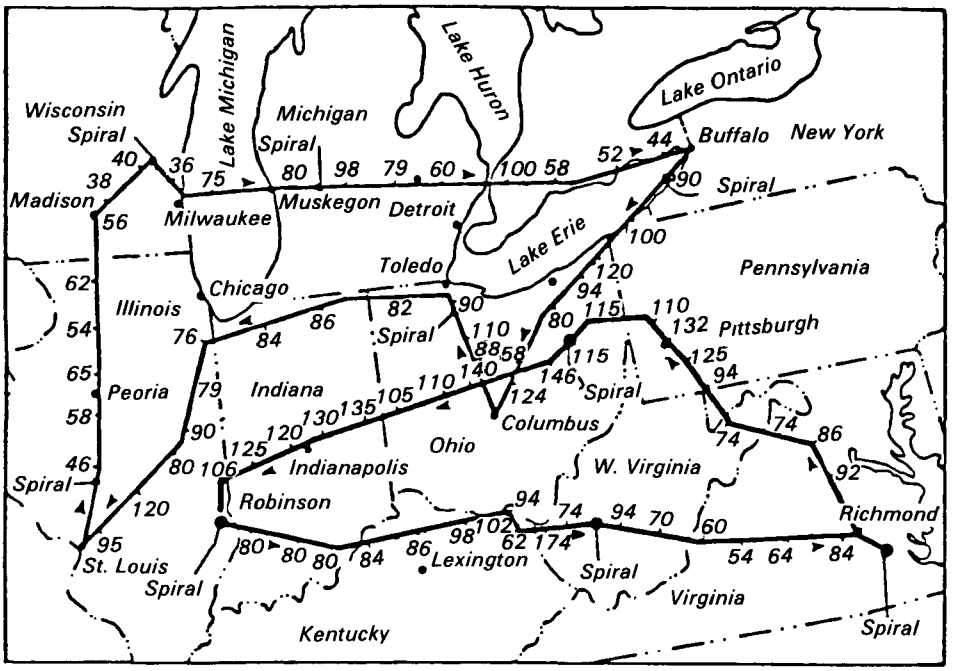

Figure 3. O_3 concentrations (ppb) along the paths of the Washington State University and Battelle's Columbus Laboratories cross-country flights between July 22 and July 24. (Sites of spiral soundings are shown.)

frontal passage. The frontal stable layer was also the subsidence inversion overlying the high pressure area. On the backside of the high pressure area, the stratospheric O_3 within this inversion layer could be distinguished from the anthropogenic O_3 which filled the layer from the ground to the base of the inversion.

- Observations made during the cross-country traverse of this July high pressure area led to the conclusion that layers of stratospheric O_3 with concentrations in excess of the surface ambient standard can be found in the troposphere above a high pressure area, but that the O_3 in these layers has no direct effect on the surface concentrations in the Midwest during the summer.

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***William A. Lonneman** is the EPA Project Officer (see below).*

The complete report, entitled "Ozone Plumes from Small Cities and Ozone in High Pressure Weather Systems," (Order No. PB 84-120 807; Cost: $19.00, subject to change) will be available only from:

National Technical Information Service
5285 Port Royal Road
Springfield, VA 22161
Telephone: 703-487-4650

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