Investigations of Ozone and Particulate Matter Air Pollution in the Northeast

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Introduction. During summer 1998, the NARSTO-NE-OPS (North American Research Strategy for Tropospheric Ozone - North East - Oxidant and Particle Study) pilot study was conducted in Philadelphia. This research has involved a consortium of investigators from several universities and government laboratories (see Table 1). Several were involved in preparation of the Philadelphia field measurement site and participated in a measurement campaign during a two week period in August 1998.[1] The primary purposes of the pilot study were to evaluate the site and compare instrument platforms. However, the 21-22 August 1998 measurements included a significant pollution event, during which substantial increases in both ozone (concentration 125 ppb) and air borne particulate matter ($PM_{2.5}$ 65 $\mu g/m^3$) were observed. During the summer of 1999, extended measurements were carried out over a two-month period that captured data on several air pollution episodes, some of which recorded the highest O_3 in Philadelphia during the past decade. Techniques which were used during the investigation included a wide range of instruments that measured the surface layer and boundary layer properties.

Methods. The advanced research techniques brought into the field for data collection during the NE-OPS project included Raman lidar, tethersonde balloons, recently developed instruments to obtain ground based particle/chemical samples using Harvard SPH instruments (TEOMS, HEADS and HV-TOX), and the latest aircraft sampling techniques on the DOE-G1 aircraft (chemistry and particle characterization). The Raman lidar has proven to be a useful tool for providing time sequences of vertical profiles of ozone, temperature, water vapor and optical extinction.[2-4] Profiles of the surface layer to 300 meters were obtained by Millersville University using tethersondes for ozone, temperature, water vapor, wind velocity and fine particle concentration.[5] The regional distributions of particulate matter, chemical species and meteorology were obtained using the University of Maryland instrumented aircraft[6] and the DOE-G1 instrumented aircraft. The latest techniques for measuring the particulate matter properties were used by Harvard SPH,[7] Drexel University and Brigham Young University. The contributions of the researchers participating in the project are shown in Table 1.

Site preparation for the summer intensive at the Baxter Water Treatment Plant began on 15 June 1999 and the site was fully operational from 28 June to 19 August, 1999. The particulate matter samplers and the ozone and chemical measurements were made by Harvard SPH and NOx/ NOy chemistry by Harvard Engineering and Applied Scinces continuously during the project. Profiles of ozone, meteorological parameters and optical extinction were obtained each day with PSU lidar, except for the period July 18-21. Measurements were made by Millersville University using the 2 tether balloons during intensive periods and other interesting periods. The smaller tether balloon (5 kg capacity) measured profiles of meteorological properties and ozone from surface to 300 meters and obtained a total of 430 profiles. A larger tether balloon (50 kg capacity) was used to suspend $PM_{2.5}$ filter samplers, continuous optical scattering instrument for $PM_{2.5,}$ and VOC canisters at several altitudes between the surface and 300 meters. The NE-OPS Radar/RASS sounder, obtained from EPRI with support of MARAMA, was placed into operation at the Philadelphia site on 23 July and operated throughout the program. Analysis of dynamical fields using the data from this instrument and two other sounders from ANL and PNNL was carried out by Argonne National Laboratory. Particulate matter samples were collected each day by Drexel University for GC/MS

analysis of minor species. The University of Maryland provided of CO and UV radiation measurements at the site and conducted instrumented flights with Cessna and Aztec aircrafts.[6] Brookhaven National Lab made 19 regional flights using the instrumented DOE-G1 aircraft between 25 July and 11 August. The Pacific Northwest National Lab (PNNL) released 61 radiosonde balloons and 10 ozonesonde balloons between 23 July and 10 August from the Philadelphia site. PNNL setup and operated a Radar/RASS sounder at West Chester, PA (about 30 miles west) from 23 July through 11 August. The Argonne National Lab (ANL) operated a mobile chemistry laboratory and a Radar/SODAR sounder at Centerton NJ (about 30 mi south) during the period 24 July through 11 August. At the Centerton site, ANL also released 56 radiosondes balloons. During the period 2-30 July, Brigham Young University used three instruments to measure the volatile and semi-volatile mass and species of particles.

Table 1. List of Investigators in the NARSTO-NE-OPS program

Penn State University - C.R. Philbrick (PI)
Program management, lidar remote sensing, optical scattering, structure and dynamics

Millersville University - R. D. Clark
Boundary layer meteorology, tethersonde measurements

Harvard University

Harvard School Public Health - P. Koutrakis, G. Allen, J. Lawrence, J. M. Wolfson, V. Hatch
Atmospheric gas and aerosol chemistry measurements and analysis, PM_1, $PM_{2.5}$, PM_{10}, aerosol-size, EC/OC, sulfate, nitrate, toxics

Engineering and Applied Science - S. C. Wofsy, J. W. Munger
NO, NO_y measurements, Regional Reference Site at Harvard Forest

University of Maryland - R. Dickerson, B. Doddridge
Instrumented small aircraft, UV flux and CO measurements, atmospheric chemistry

State University of New York - S. T. Rao, V. Mohnen, I. Zurbenko, S. Porter, K. Civerolo
Analysis and model calculations of polluted air masses

Rutgers University Environmental and Occupational Health - P. Georgopoulos and M. Lazaridis
Emissions inventories and chemistry modeling, particular experience in Philadelphia area

Brookhaven National Laboratory - L. Newman, P. Daum, L. Kleinman, J. Lloyd, Y-N. Lee
Highly instrumented DOE-G1 aircraft measurements of chemistry and aerosol properties

Philadelphia Air Management Services Laboratory - W. Miller
Several measurement sites in Philadelphia, PAMS site

Drexel University - S. McDow
Trace species measurements of filter samples using GC/MS and other techniques

Brigham Young University - D. Eataugh
Measurement of particle volatile mass component and identification of volatile species

Pacific Northwest National Lab - C. Doren, J. Allwine, C. Berkowitz, J. Fast
Rawinsondes at Philadelphia, RASS at West Chester, Ozonesondes at Philadelphia site

Argonne National Lab - R. Coulter, J. Gaffney, N.A. Marley
Rawinsondes, RASS, Sodar and Chemistry Laboratory at Centerton NJ

North Carolina A&T State University - D. Dunn
Remote sensing with lidar and sodar

North Carolina State University - H. Hallen
Laser remote sensing, particle optical properties measurements

Results. During 1998, one major air pollution event occurred while the pilot study was in progress. The event has provided an interesting opportunity to examine the development of an event that was associated with transport of a polluted air mass into the region and subsequent downward mixing by the planetary boundary layer.[4,5] Table 2 provides a summary of the pollution events contained in the present data set, which includes both the 1998 and 1999 field campaigns. A more detailed meteorological description for the events has been prepared by W. Ryan at http://www.meto.umd.edu/~ryan/summer99.htm.

Table 2. A summary of the intensive observational periods during 1998 and 1999

	Dates	Comments
Summer 1998 - 7-22 August 1998 - Pilot study to prepare site and evaluate instruments		
	21-22 Aug	Sudden ozone and PM event with vertical mixing of transported material
Summer 1999 - 28 June - 20 August 1999		
1	3-5 July	Ozone event limited in magnitude (120 ppb) and duration by strong winds (10 m/s at 850 mb), depth of PBL, variation in local emissions due to traffic change, UMD A/C
2	8-10 July	Weak cold front oscillation north/south, frontal passage effects, ozone and PM event enhanced in boundary layer as front approached
3	16-21 July	Major ozone event, UMD aircraft
4	23-24 July	Limited regional ozone, very strong stable boundary layer, wind shift, RASS and sondes
5	27 J/1 Aug	West flow brings increase ozone on 27th, regional convection limits ozone on 28th ,31st has high ozone, DOE-G1 and UMD aircraft, ozone 162 ppb surface-180 ppb aloft
6	11-13 Aug	Recirculation event, 125 ppb on 12th followed by storm on night of 13th
7	15-17 Aug	Standard ozone event but did not last to produce build up of ozone, UMD Aztec aircraft

Conclusions. The first set of combined measurements, clearly showing the importance of transported aged materials in development of a significant pollution event, was obtained during the pilot study of the NE-OPS project in Philadelphia over a two week period in August 1998. The unique set of measurements from vertical profiles obtained with lidar, tethersondes and aircraft spirals clearly shows the incursion of processed precursor materials in an aloft layer, which was transported into the region, and then mixed downward to the surface by the rising daytime convective boundary layer. The transported material appears to be important in the initiation of an ozone and particulate matter pollution event on 21 August 1998. Vertical profiles of the ozone, aerosol extinction, water vapor and other meteorological parameters were obtained continuously over a period of three days. These time sequence profiles clearly show the advection of an aloft layer of polluted air into the region followed by entrainment into the daytime convective mixed layer and subsequent transport to the surface. The measurements of this first depiction of the meteorological control of a pollution event are providing a useful case study. Time sequences of ozone and aerosol (PM) profiles obtained during the NE-OPS project pilot study between the surface and 3 km show the importance of the surface layer (first 100 meters) dynamics in determining the actual pollution hazard for the regional population. During the two week period of the pilot study, hazardous levels of ozone were observed several times existing above the surface layer. The intensity of vertical transport, and presence of surface layer gases that can destroy ozone, can result in differences in human exposure. Examination of these several days of data demonstrates that the local surface exposure depends upon the development of convective activity, wind-shear driven transport, and presence of surface gaseous species. The results show the importance in measuring the vertical structure to understand the population exposure at the surface.

References.

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