AN OVERVIEW OF THE LAKE MICHIGAN OZONE STUDY

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1. INTRODUCTION

The persistent, regional nature of the ozone nonattainment problem in the lower Lake Michigan area has necessitated a new air quality planning approach. During the past two decades, the lower Lake Michigan area, which includes portions of the States of Illinois, Indiana, Michigan, and Wisconsin (see Figure 1), has experienced violations of the National Ambient Air Quality Standard (NAAQS) for ozone (O3). Ambient exceedances have been measured on more than 30 days during some summers and have been as high as 250 parts per billion. In addition, exceedances frequently occur over a fairly large geographic area. Past regulatory efforts have focused on each State developing control plans to address the violations measured in the vicinity of specific urban areas. Despite these efforts, violations have continued. The failure to account for the transport of O3 and O3 precursors throughout the area may be an important reason why these control plans have not succeeded.

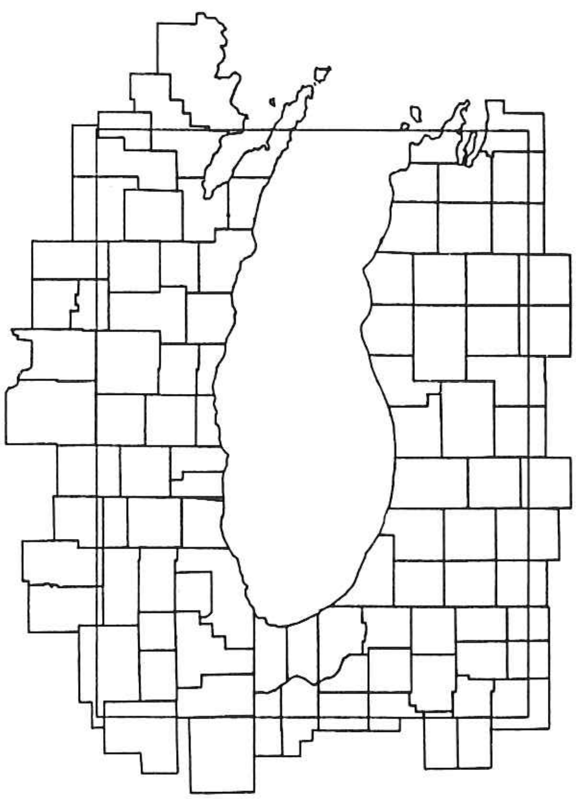

Figure 1. Lake Michigan Ozone Study Area

In 1988, in recognition of the need for a regional solution and in response to Notices of State Implementation Plan Deficiencies issued by the U. S. Environmental Protection Agency (USEPA) to all four Lake Michigan States, the States began a joint program to deal with the ozone problem. A scoping study was performed to improve understanding of the existing O3 problem, to identify an effective photochemical modeling tool, and to identify data collection efforts needed to support the application of a photochemical model (Haney, et al., 1989).

Independent of this joint State effort, USEPA and the States of Illinois and Wisconsin were engaged in litigation concerning O3 control in the Chicago area. In April 1987, over concerns about transport into southeast Wisconsin from the Chicago area, the State of Wisconsin filed suit against USEPA. On January 18, 1989, the U. S. District Court for the Eastern District of Wisconsin ordered USEPA to promulgate a Federal Implementation Plan (FIP) for O3 for the greater Chicago area within 14 months. USEPA, Illinois, and Wisconsin subsequently signed a settlement agreement in an attempt to resolve the litigation. On November 6, 1989, the Court vacated its prior order and ordered all further proceedings stayed pending performance of the settlement agreement. The settlement agreement calls for the use of a more sophisticated air quality model, allows more time for USEPA to promulgate a FIP using this model, and requires interim emission reductions while the modeling study is underway. USEPA and the four Lake Michigan States signed a Memorandum of Agreement (MOA) to establish a cooperative interstate and Federal effort (referred to as the Lake Michigan Ozone Study or LMOS) to support the more sophisticated photochemical grid modeling.

2. STUDY OVERVIEW

The LMOS is a multi-year, multi-million dollar study sponsored by the four Lake Michigan States and USEPA which will involve the collection of data bases (air quality, meteorology, and emissions), the development and evaluation of appropriate meteorological and photochemical models, and the establishment of a technically credible modeling system. Subsequent activities, such as control strategy assessments and attainment demonstrations, will also be necessary, but are beyond the scope of the current MOA.

Air quality and meteorological data will be collected during the summers of 1990 and 1991 using routine and non-routine sampling. Although the existing (routine) monitoring network includes numerous air quality (O_3, oxides of nitrogen [NO_x], and carbon monoxide [CO]), and meteorological monitors, it is not adequate for the purpose of developing and testing a photochemical grid model (e.g., there is a sparsity of data on the eastern shore of the Lake and along the boundary, and an absence of data aloft and over the Lake). Thus, enhancement of the surface network and some special (non-routine) sampling is necessary.

The non-routine monitoring platforms, which will be deployed on forecasted high O_3 days (i.e., intensive sampling days), will likely include aircraft, ships, tetroons, tracers, volatile organic compound (VOC) and carbonyl sampling, and various vertical profiling systems (e.g., radiosondes, tethersondes, radar wind profilers, and acoustic sounders). Quality assurance and information management contractors will be responsible for assessing the validity of, and archiving, the field data. Another contractor will analyze the field data to characterize the spatial and temporal distribution of air quality levels and associated meteorological conditions on intensive sampling days, and develop a conceptual model of the processes responsible for the formation and transport of O_3 in the LMOS area (Bowne and Shearer, 1990).

A comprehensive inventory of sources of O_3 precursor emissions (VOC, NO_x, and CO) will be prepared for point, area, and mobile sources. The inventory will be compiled on a geographic information system to facilitate data processing and manipulation (e.g., speciating, gridding, and allocating the data for input into the photochemical grid model). The four States will be responsible for supplying a base inventory for anthropogenic sources, for performing initial quality assurance checks, and providing updated information for 1990 and 1991. A contractor will be responsible for developing the biogenic emissions, for combining the four State inventories into a single inventory, for updating the base data to reflect 1990 and 1991 conditions, and for speciating, gridding, and allocating the inventory. A separate contractor will perform additional quality assurance checks. Current information on land use classifications, which will be used to estimate biogenic emissions and to grid certain area source categories, will be developed through analysis of recent satellite imagery.

The LMOS modeling effort will focus on the evaluation and application of an existing photochemical grid model (such as the Urban Airshed Model) with some enhancements to address the basic modeling needs of the Lake Michigan area. These model enhancements include the incorporation of a prognostic meteorological model, improved horizontal and vertical resolution (e.g., variable grid sizes), and nested gridding.

The complexity of meteorological conditions over and near Lake Michigan, particularly the lake breeze circulations on the western shore of the Lake (where the highest O_3 levels have been measured historically) and the unique conditions which develop over the Lake (e.g., intense low level conduction inversions, formation of low level jets, and high humidities) necessitate the use of a prognostic meteorological model. Considerable effort is required to evaluate a prognostic model, to provide data assimilation, and to combine this meteorological model with the photochemical grid model.

Improved treatment of spatial resolution is necessary in view of the sharp differences in emission densities and tight concentration gradients along the western shore of the Lake, which demand resolution on the order of 1-2 km, and the large spatial extent of the study area and uniform land use type covering broad areas (e.g., the Lake), which allow resolution on the order of 10 km or more. Improved vertical resolution is important to deal with the differences in atmospheric structure over the Lake, over the land in the lake breeze circulation zone, and farther inland. Nesting may be necessary to achieve the small scale resolution needed in some areas and to facilitate future applications of the model for sub-areas in the LMOS domain.

To demonstrate that the meteorological/photochemical modeling system is capable of providing reliable concentration estimates, the modeling system must be evaluated using ambient measurements. The basic evaluation procedures (i.e., statistical measures and acceptance criteria) will be defined in the modeling protocol. Diagnostic analyses (testing of the input data) and sensitivity analyses (testing of the models' response to changes in input data) will be performed as part of the performance evaluation.

3. 1990 FIELD PROGRAM

The 1990 field program was a preliminary study to provide data and experience needed to plan and perform the more extensive field program in 1991. It was not intended to provide a complete data set for model development or evaluation; this will be the purpose of the 1991 field program. The 1990 field program was also designed, however, to improve understanding of the complex meteorological conditions in the LMOS area and the transport of O_3 and O_3 precursors into the LMOS area (Lyons, et al., 1989).

The 1990 field program consisted of four parts: (1) intensive air quality and meteorological measurements in a 2-dimensional data plane (2DDP), (2) air quality and meteorological monitoring along the boundaries of the study area, (3) continuation and enhancement of the States' existing air quality and meteorological monitoring networks, and (4) special studies involving tetroons, and VOC and carbonyl sampling and analysis. Non-routine sampling platforms were employed during two events: July 2-4 and July 16-19. A pictorial presentation of the 1990 monitoring activities is provided in Figure 2.

The purpose of the 2DDP, which is indicated in Figure 2, was to focus the limited 1990 monitoring resources in a specific area to study certain aspects of the O_3 problem (i.e., flux of O_3 in a north-south direction, and lake/land breeze flow effects) in some detail. Sampling in the 2DDP consisted of vertical profiles (using tethersondes or radiosondes) and surface measurements of air quality and meteorological data over land and over the Lake (by ships), and air quality

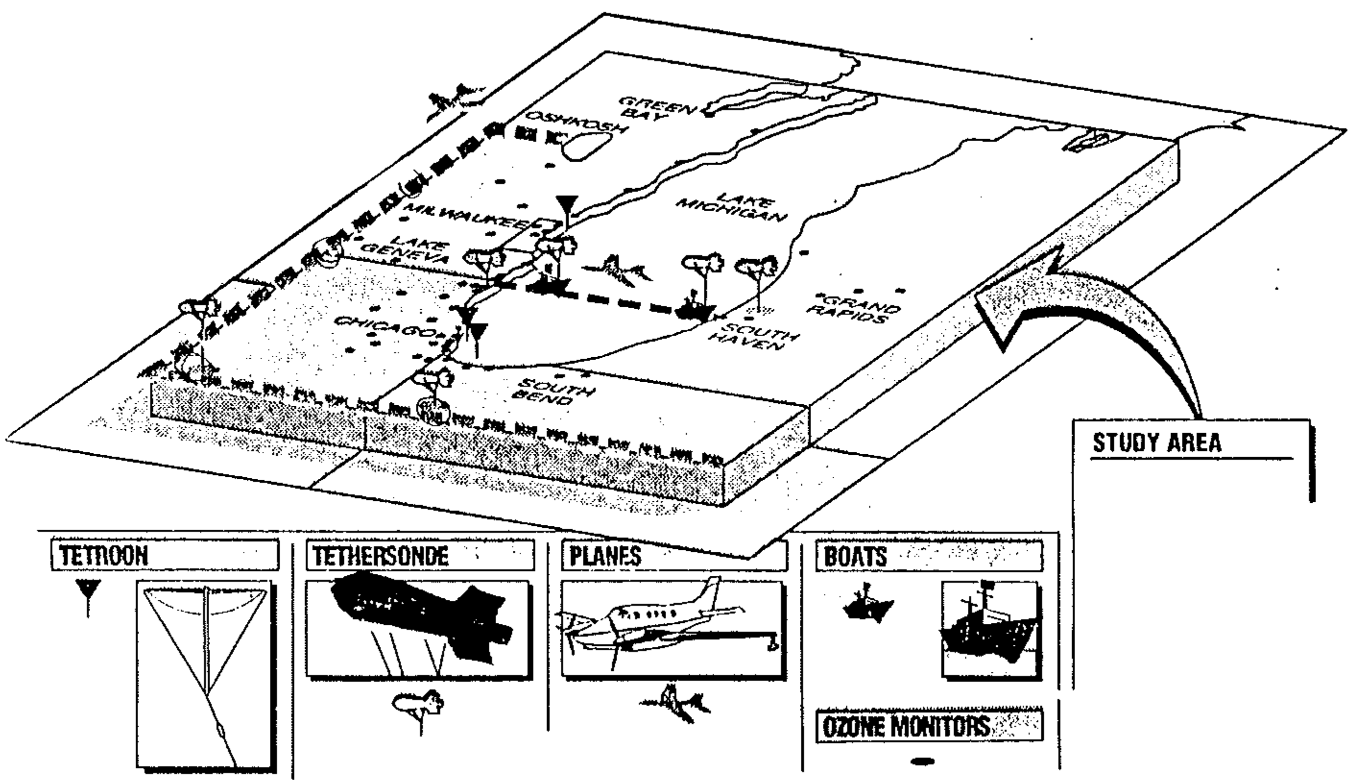

Figure 2. Monitoring Activities During the 1990 Field Program
(courtesy Dorothea Taylor, Milwaukee Sentinel)

and meteorological data collected by aircraft. To provide information on transport into the area, vertical profiles (using tethersondes or radiosondes) and surface measurements of air quality and meteorological data, and aircraft measurements of air quality and meteorological data were made along the boundary of the LMOS domain. Enhancement of existing monitoring networks consisted only of adding two sites along the eastern end of the 2DDP in Michigan. The two special studies consisted of using tetroons launched from 3 shoreline sites as a visual tracer of air flow, and collecting and analyzing hourly samples of VOC and carbonyl at 3 locations (Chicago, rural boundary site, and rural 2DDP site) on 2 days to provide information on diurnal variations and spatial differences in speciation (ENSR, 1990).

During the 4-week study window, the only exceedance of the O3 NAAQS was recorded on July 4 at one site in southwest Michigan (see Figure 3). This figure, which reflects the highest 1-hour concentrations observed on July 4 at all land-based sites, also indicates the large spatial extent of elevated ozone concentration in the lower Lake Michigan area.

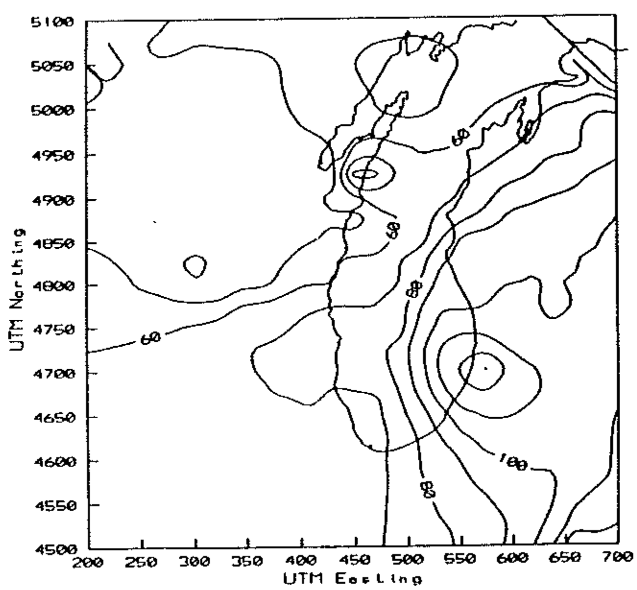

Figure 3. Peak Ozone Levels, July 4, 1990

Overall, the study was successful in providing testing and experience with specialized measurement systems, and in improving the ability of the four States (and many contractors) to work together to collect and archive a large data base. The field experience gained during the 1990 program will valuable in planning the 1991 program. A few observations on the 1990 program are worth noting:

(1) The time frame for planning (i.e., about 6 months) was much too short, as expected. Particular problems included the unavailability of ships for part of the program and last minute changes in the vertical profiling systems due to disapproval by the Federal Aviation Administration (FAA) of waivers to fly the tethered balloons anywhere in the Chicago area and elsewhere above 150 m.

(2) The planned 1-week set-up period did not happen. More time and incentives are needed in 1991 to ensure that all groups are on-site and that all equipment is fully tested in advance.

(3) Communications suffered at times. Likely improvements for 1991 include a radio system for ship-to-shore communications, hardwired telephones at each monitoring site, and fax machines at airports.

(4) Tethersondes did not prove as useful as initially thought. In addition to the FAA restriction noted above, high winds prevented their use on certain days. Other techniques (in situ and remote sensing) will be considered for 1991.

(5) Some flexibility in the flight plans should be provided to account for weather conditions. For example, the flight path may need to be altered somewhat depending on the wind directions and the flight schedule may need to be changed (i.e., more air time in the early afternoon) if severe weather is forecast for later in the day.

REFERENCES

Bowne, N.E., and D.L. Shearer, 1990, "Lake Michigan Ozone Study (LMOS) Workplan", ENSR Consulting and Engineering, Glastonbury, Connecticut.

ENSR Consulting and Engineering, 1990, "Lake Michigan Ozone Study Field Program and Operations Plan for the 1990 Summer Measurements", Glastonbury, Connecticut.

Haney, J.L., S.G. Douglas, L.R. Chinkin, D.R. Souten, C.S. Burton, and P.T. Roberts, 1989, "Ozone Air Quality Scoping Study for the Lower Lake Michigan Air Quality Region", Systems Applications, Inc., San Rafael, California.

Lyons, W.A., R.A. Pielke, and C.S. Keen, 1989, "Contributions Towards the Design of the Summer 1990 Preliminary Lake Michigan Ozone Study Field Program", R*SCAN Corporation, Minneapolis, Minnesota.