6.4 THE INFLUENCE OF CANADIAN WILDFIRES ON AIR QUALITY IN PHILADELPHIA PA DURING NE-OPS-DEP

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1. INTRODUCTION

On 6-7 July 2002 a nearly stationary upper level circulation over Maine produced an extended fetch of northerly flow that transported smoke into the mid-Atlantic and New England regions from wildfires 1500 kilometers north of Philadelphia, PA, where an air quality study was being conducted. Continuous measurements of trace gases (CO, SO_2, O_3, $NO/NO_2/NO_X$), fine particle mass from three ambient samplers (TEOM, CAMM, and RAMS), EC/OC, b-scattering coefficients and $PM_{2.5}$, and conventional meteorological data were being collected at the surface, while a tethered balloon and RASS profiler documented aloft distributions of $PM_{2.5}$, virtual temperature, and wind velocity. The measurement campaign was part of the Northeast Oxidant and Particle Study (NE-OPS), an investigation of meteorological and chemical processes that control the evolution of air pollution events in near-urban environments. NEOPS is part of the North American Research Strategy for Tropospheric Ozone (NARSTO), and the site is located at the Samuel Baxter Water Treatment Plant 18 km northeast of center city Philadelphia. Intensive observing campaigns (IOPs) have been carried out at this location during the summer seasons of 1998, 1999 and 2001. In July 2002, a continuation of this project was conducted under the sponsorship of the Pennsylvania Department of Environmental Protection (PA-DEP).

2. SYNOPTIC OVERVIEW

A large area of upper level cyclonic circulation centered over Maine, coupled with a high amplitude ridge extending across the Hudson Bay (Fig. 1), created a 1500 km fetch of northerly flow coincident with the intensification of wildfires covering a broad area from southwest of Quebec, north toward the La Grande Riviere. The smoke began to canvass the Philadelphia area late on July 5th, but remained well above the boundary layer (~ 4000 m). At the surface, scattering coefficients and trace gas concentrations remained low, and visibility high (10 SM), characteristic of the clear, relatively unpolluted air mass advected in from the northern Midwest and across the Great Lakes. The slow moving northeastward progression of the upper level low eventually changed the parcel trajectories from WNW on the 5 July to Northerly by 6 July, resulting large-scale descent of the smoke plume (Fig. 3), and a rapid modification of the boundary layer properties beginning at 1400 EDT.

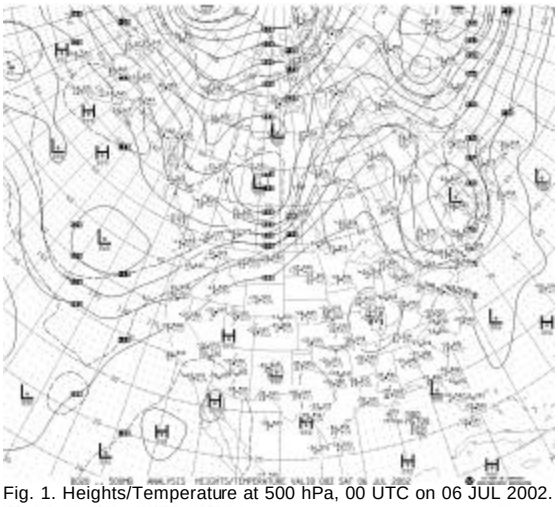

Fig. 1. Heights/Temperature at 500 hPa, 00 UTC on 06 JUL 2002.

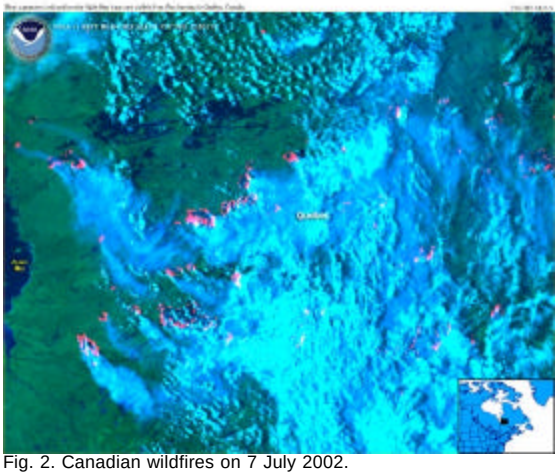

Fig. 2. Canadian wildfires on 7 July 2002.

Large-scale difluence on 7 July over the mid-Atlantic region resulted in a spreading of the smoke plume from PA, south to NC, to well off the Atlantic coast (Fig. 4). The slow moving synoptic pattern maintained the transport of smoke into the Philadelphia area through July 7th and remained

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through the morning hours of July 8th, before moving off the coast later in the day.

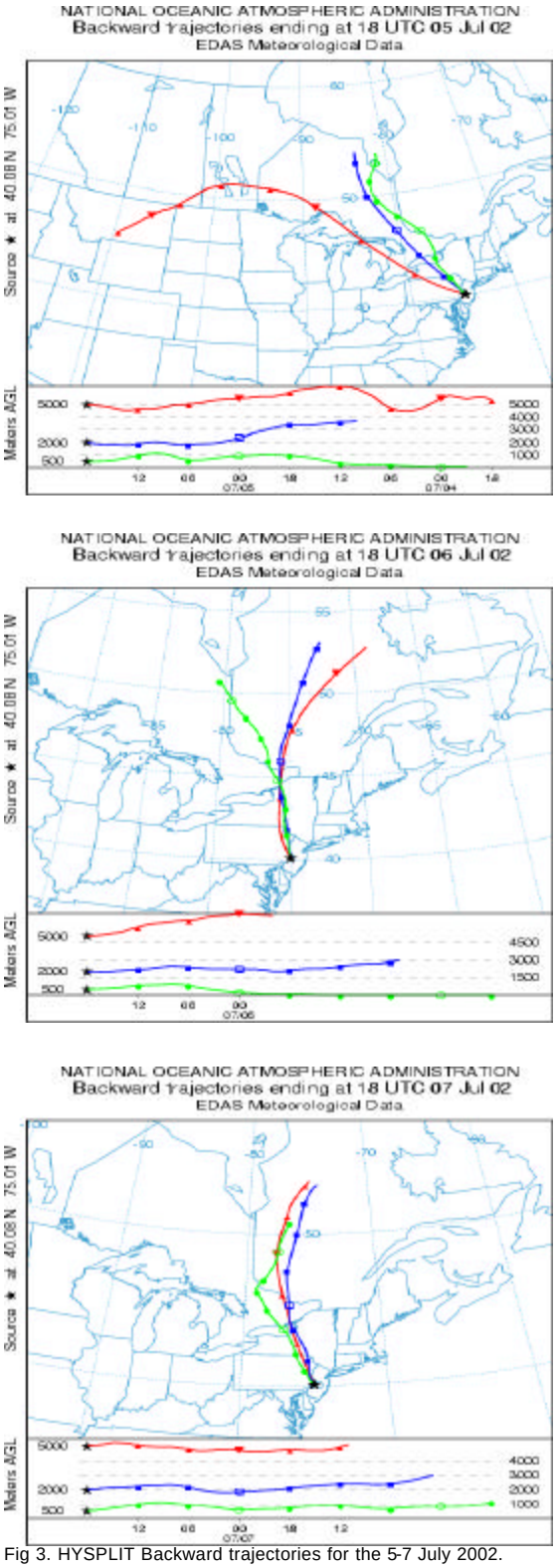

Fig 3. HYSPLIT Backward trajectories for the 5-7 July 2002.

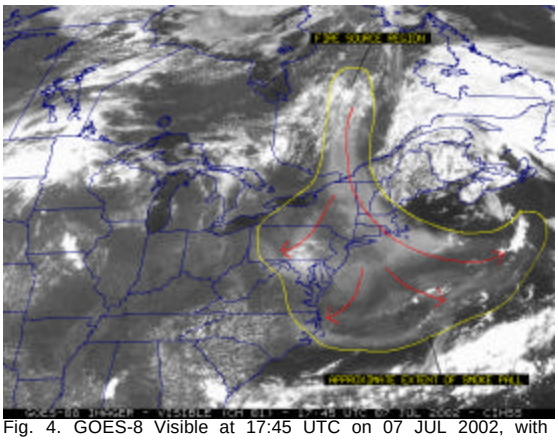
Fig. 4. GOES-8 Visible at 17:45 UTC on 07 JUL 2002, with estimated trajectories superimposed.

3. EFFECTS ON LOCAL AIR QUALITY

The smoke plume radically altered the local atmospheric and air quality conditions around Philadelphia. A northerly wind direction will generally correlate with lower trace gas concentrations in the Philadelphia area because of the paucity of significant upstream sources. O_3, NO_X, and SO_2 concentrations for 6-7 July shown in Figs. 5-7, confirm the intrusion of less polluted air into the region.

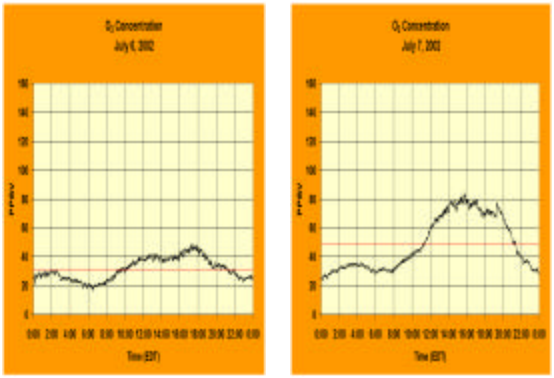
Fig 5. Surface O_3 concentrations on July 6 – 7, 2002.

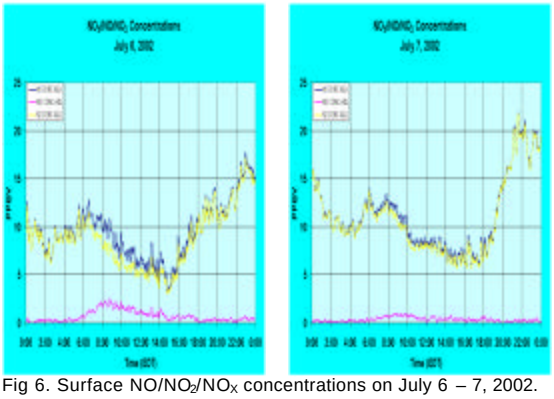
Fig 6. Surface $NO/NO_2/NO_X$ concentrations on July 6 – 7, 2002.

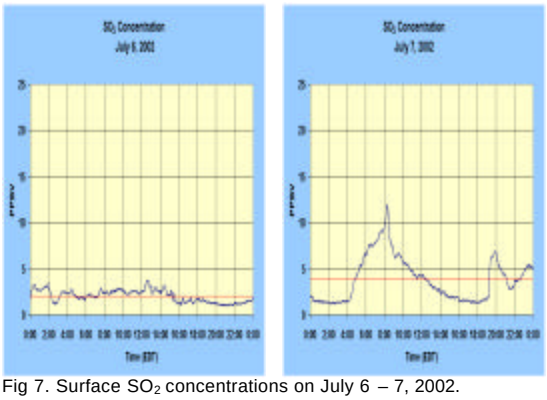

Fig 7. Surface SO_2 concentrations on July 6 – 7, 2002.

Considering that 6-7 July fell on a weekend, high concentrations of O_3 due to anthropogenic precursors and fine particles were not expected, especially in association with northerly flow and moderate wind speeds between 4 – 7 m/s. There is some evidence of an I-95 influence in the NO_X time trace on both days, and slight enhancements in O_3 concentrations resulting from the oxidation of NO_2, but concentrations remained largely representative of an unpolluted air mass.

However, as the boundary layer developed and smoke, heretofore confined to the free troposphere, began to mix down, CO concentrations, b_{scat} coefficients, and $PM_{2.5}$ exhibited rapid increases commencing at 1400 EDT on 6 July. In addition to turbulent mixing, downward transport was enhanced by quasi-geostrophic descent along isentropic surfaces on the western flank of the upper level low (see Figs. 1 & 3). Within one hour after the onset of this event, visibility had fallen to less than 1 SM. Contrary to forecasts that called for a sustained period of dry continental air, relative humidity remained elevated at 60% even as temperatures on both days peaked at 32 C.

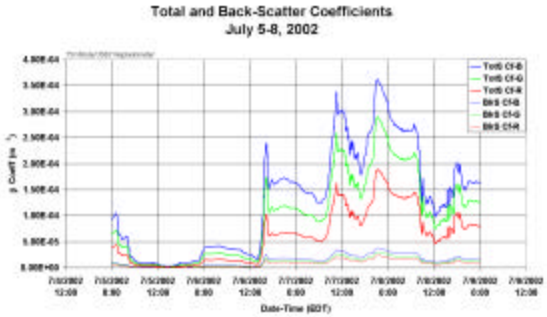

Fig 8. Total and backscattering coefficients for 5-7 July 2002. Note the onset of the smoke event at 1400 EDT on 6 July and the sustained levels of particle scattering through 1000 EDT on 8 July.

A tethered balloon was deployed during the smoke event to carry a laser-diode nephelometer to an altitude of 300 m. Laser nephelometry serves as a proxy indicator of $PM_{2.5}$ concentration by measuring the scattering produced by particles less than 2.5 μm in diameter. Larger particles are deposited on an impaction slide prior to entering the scattering chamber. The nephelometer (DustTrak©) measures scattering due to the total hydrated aerosol. (Intercomparisons with RAMS and TEOM have shown the nephelometer to yield concentrations approximately three times higher than the corresponding concentrations of dry $PM_{2.5}$ mass.) Laser-diode nephelometry is a valuable measure of the particulate effects on haze and, with a sampling frequency of 1 min^{-1}, is especially useful in comparing trends and variability. Six vertical profiles of $PM_{2.5}$ were obtained between 1020 – 1618 EDT on 7 July (~ 1 profile/hour). Each profile consisted of a 20-minute ascent, 20-minute time series at 300 m, followed by 20-minute descent.

Profiles typical of this event are shown in Fig. 9 to illustrate the extremely high magnitudes of $PM_{2.5}$ concentrations observed on 7 July. Concentrations of $PM_{2.5}$ between 0.3 - 0.6 mg/m^3 were observed in a highly variable vertical distribution. This should be compared with concentrations between 0.06 – 0.2 mg/m^3 observed on days with deleterious air quality or haze.

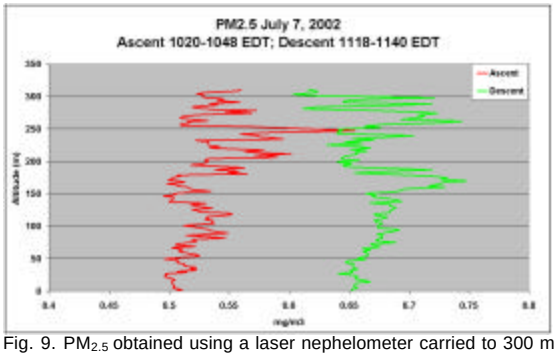

Fig. 9. $PM_{2.5}$ obtained using a laser nephelometer carried to 300 m by a tethered balloon. Concentrations are three times higher than those observed during a haze event.

$PM_{2.5}$ dry mass and EC/OC were measured by the Clarkson University group using TEOM and the Sunset Labs OC/EC instrument. Their results, shown in Fig. 10, also document an increase in

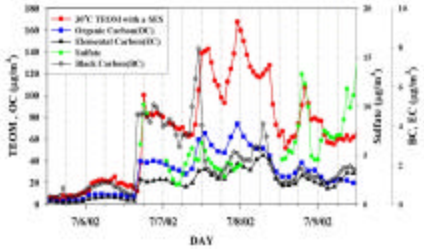

Fig. 10. Dry $PM_{2.5}$, OC, EC, total carbon, BC, and sulfate obtained by Clarkson University for the period 1200 EDT 4 July through 1200 EDT 9 July.

$PM_{2.5}$, OC, EC, and BC concurrent with the increases b_{scat} seen in Fig. 8. Commencing with an increase in PM and carbon (~ factors of 5-8) shortly after 1200 EDT on 6 July, high levels of particles were observed at the site through the morning hours of 8 July 2002 as the parcel

trajectories continued to track from Quebec to the mid-Atlantic region.

4. DISCUSSION AND CONCLUSIONS

The high concentrations of $PM_{2.5}$ contributed to the most significant haze event observed during the four-summer NE-OPS field intensives, and helped set the stage for a Code Red O_3 episode on 8-9 July (Ryan, 2002). At the Philadelphia, PA NE-OPS site, the smoke event began abruptly with an initial incursion of smoke particles around 1400 EDT on 6 July. The leading edge of the smoke plume was responsible for total scattering coefficients at three wavelengths increasing by two orders of magnitude in about 30 minutes, accompanied by a rapid decline in visibility. b-scattering coefficients remained elevated overnight as moderate wind speeds maintained a well-mixed boundary layer. On 7 July, sustained by moderate northerly winds, sufficient daytime heating, and continued transport of smoke from Canada, scattering coefficients increased to magnitudes 300 times greater than on clear days, and $PM_{2.5}$ to values 3-10 times higher than days with haze. Clarkson University's TEOM measurements exhibited the same trend in $PM_{2.5}$ dry, and their Sunset Lab instrument documented similar increases in organic and elemental carbon. Trace gases had little influence on particle concentrations and haze since their concentrations remained low throughout the 2-day episode. Some monitors in NJ did report elevated O_3 concentrations, but this was not the case in Philadelphia.

The preliminary results presented here provide key insights into the degradation of an otherwise clean, dry, continental air mass due to the injection of smoke from wildfires. The 6-7 July smoke event provides an interesting study of the effects of particles on the degradation of air quality and visibility without being contaminated by the influence of high criteria gas concentrations and their precursors.

Acknowledgements

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References

Ryan, W. F., C. R. Philbrick, and R. D. Clark, 2002: *Summary of meteorological conditions during the Northeast Oxidant and Particulate Study (NE-OPS-DEP) July 2002 intensive observing period.* (These proceedings). AMS 2003, Long Beach, CA.