3.4 METEOROLOGICAL CONDITIONS ASSOCIATED WITH THE RAPID TRANSPORT OF CANADIAN WILDFIRE PRODUCTS INTO THE NORTHEAST DURING 5-8 JULY 2002

John R. Scala*, Christopher Hain, and Wayne M. MacKenzie, Jr.
Millersville University, Millersville, PA

Scott Bachmeier
CIMSS/SSEC, University of Wisconsin, Madison, WI

1. INTRODUCTION

Warm, and unusually dry conditions across central and eastern Canada during the summer of 2002 provided ideal antecedent conditions for widespread wildfire activity, particularly in late June across northern Saskatchewan, and early July across western, and central Quebec. At that time, the Quebec forest fire protection service stated that at least 85 fires triggered during the first few days of July burned more than 250,000 acres, principally in a region southeast of James Bay in western Quebec (Fig. 1). The fires generated a large amount of thick, dense smoke which was transported rapidly to the south. Residents of the large population centers of southern New England, the Northeast and the mid-Atlantic experienced a thick smoke pall (Fig. 2) characterized by low visibility, and an odor clearly identifiable as "pine." The wildfire products were transported southward from Quebec within an anomalously strong unidirectional flow accompanied by very little dilution. Although numerical forecasts 48 hours in advance were reasonably good with respect to the primary surface and upper air features, the importance of this flow regime in a region experiencing extensive wildfire activity was not recognized until the air quality degradation within the aforementioned large metropolitan areas was already occurring. It is the rapid transport mechanism which developed within the context of an unusual early summer synoptic pattern that is the subject of this study.

2. BACKGROUND

The Canadian wildfire events of early July 2002 occurred during an intensive observing period (IOP) of the Northeast Oxidant and Particle Study (NEOPS), a multi-year field campaign designed to investigate the evolution of pollution episodes in, and near urban regions (Ryan et al. 2003). Of particular interest to the present study are the range of in-situ data collected during the 6-7 July 2002 smoke episode in the Philadelphia area.

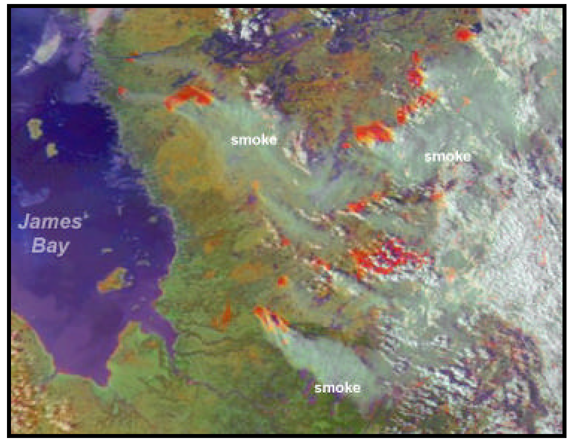

Fig. 1. NOAA-14 AVHRR 1km image taken at 2152 UTC 7 July 2003 of the Quebec fires during the height of the early July wildfire event (courtesy of NOAA).

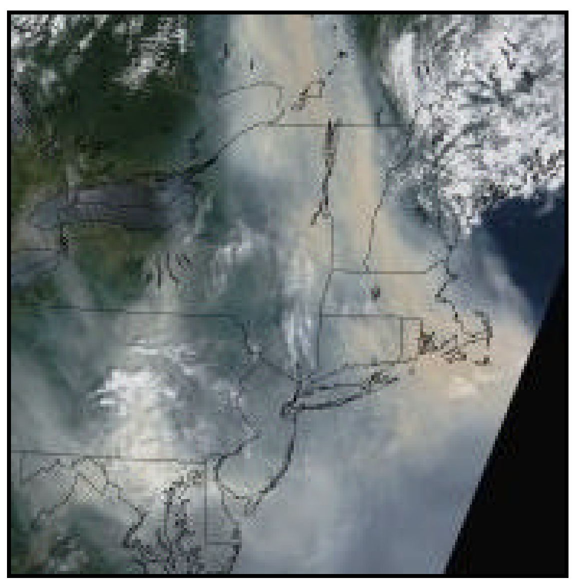

Fig.2. MODIS composite image of the northeastern U.S. for 7 July 2002 obtained 1629-1641 UTC.

* *Corresponding author address:* John R. Scala, Department of Earth Sciences, P.O. Box 1002, Millersville University, Millersville, PA 17551-0302; e-mail: John.Scala@millersville.edu

The suite of NEOPS instrumentation demonstrated the effect of the Quebec wildfire smoke plume on thelocal air quality (Clark et al. 2003).

The July 2002 NEOPS field effort (Philbrick et al. (2003) included the involvement of the Pennsylvania Department of Environmental Protection (DEP), the Federal Environmental Protection Agency's AIRNOW, Maryland's Department of the Environment, the Baltimore PM Supersite coordinated by the University of Maryland's Department of Chemistry.

Fire detection and high resolution imaging of the Quebec smoke plume relied on the Moderate Resolution Imaging Spectrometer (MODIS). This instrument carries 36 spectral bands that range from .405 – 14.385 μm, with a spatial resolution of 250 m for two channels, 500 m for five channels and 1 km for 29 channels. MODIS is the first operational satellite sensor which is capable of measuring aerosol optical thickness at several wavelengths over land and ocean.

Long-range transport of Canadian wildfire plumes rich in carbon monoxide, ozone, and aerosols southward into the U.S. is a recognized source of regional air quality degradation. Low-level wind trajectories have been used in the past to document the source region, and distance traveled by a pollution plume (Peppler 2000; Hall et al. 1970). Wotowa and Trainer (2000) suggested the presence of fire emissions in regions of antecedent anthropogenic pollution is important enough to justify future study. The northeastern U.S. smoke event of 6-7 July 2002 further emphasized the potential danger to personal health posed by long-range transport of pollutants, particularly when the movement is rapid, and poorly anticipated.

3. SYNOPTIC REGIME

A high-latitude, high-amplitude flow regime was in place across much of Canada in early July 2002 while a broad 588 dm ridge which held most of the conterminous U.S. in a severe drought (Fig. 3). The North American large-scale pattern was marked by mid-level troughs over the Canadian Rockies, and southeast of James Bay separated by a ridge that extended northward from Manitoba to the western margin of Hudson Bay.

At the surface, thunderstorms triggered by an advancing surface cold front tied to the James Bay mid-level short-wave sparked fires in western, and central Quebec late on 2 July, and again on 3 July. Extensive cloudiness, and weak lower tropospheric wind fields prevented these fires from intensifying initially.

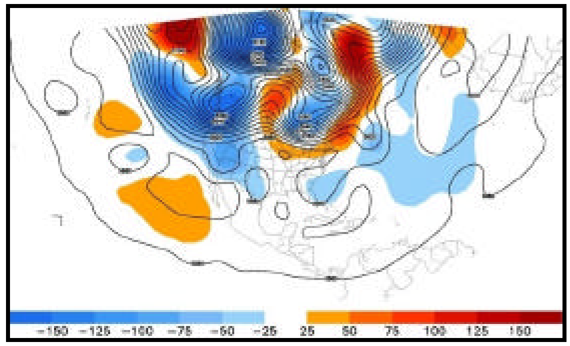

Fig. 3. Mean 24-hour 500 hPa heights and anomalies (in meters) centered on 12 UTC 5 July 2002 from NCEP Reanalysis data provided by NOAA-CIRES Climate Diagnostics Center.

A strong Pacific jet advancing through the base of the western mid- and upper-level trough initiated a downstream pattern amplification. A significant shortening of the wavelengths associated with the central Canadian ridge and Quebec trough resulted in a rather anomalous large-scale flow by 7 July 2002 (Fig. 4).

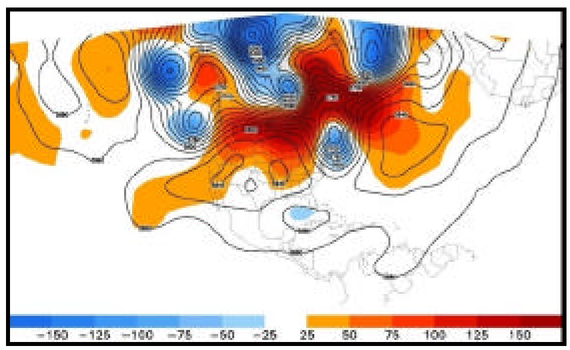

Fig. 4. Mean 24-hour 500 hPa heights and anomalies (in meters) centered on 12 UTC 7 July 2002 from NCEP Reanalysis data provided by NOAA-CIRES Climate Diagnostics Center.

The intensification of the myriad of smoldering fires across western and central Quebec on 5-6 July 2002, and subsequent long-range transport of the resultant smoke plume was a consequence of the juxtaposition of the high amplitude ridge over James Bay, and the closed 564 dm low over extreme eastern Maine (fig. 5). The deep unidirectional flow within this strengthening height gradient not only fanned the flames, but also assured the rapid transport of high concentrations of wildfire products into the northeastern U.S. Even a cursory glance of the MODIS image shown

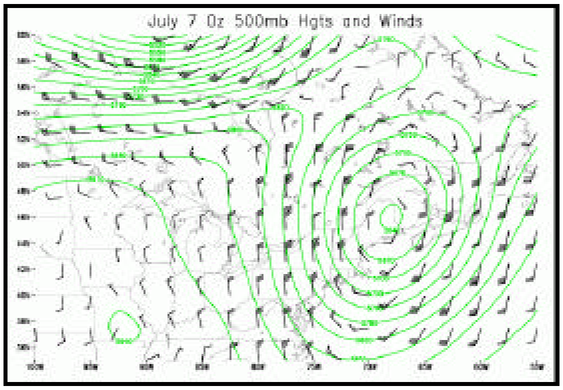

Fig. 5. 500 hPa heights and winds for 00 UTC 7 July 2002 from NCEP Reanalysis data provided by NOAA-CIRES Climate Diagnostics Center.

for 7 July 2002 (Fig. 2) reveals the magnitude of the smoke pall that resulted from this flow regime.

Initial transport of the wildfire products into the northeastern U.S. occurred above the boundary layer (Clark et al. 2003) within a more northwesterly flow regime (Fig. 6). Total and backscatter coefficients from NEOPS in-situ data confirmed these aerosols remained well above the ground as the air transited across Philadelphia on 5 July 2002.

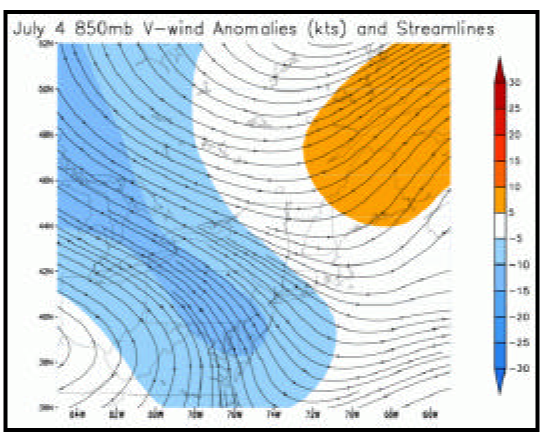

Fig. 6. 850 hPa streamlines and v-component anomalies for 00 UTC 4 July 2002 from NCEP Reanalysis data provided by NOAA-CIRES Climate Diagnostics Center.

The deepening of the eastern Maine closed mid-level low tightened the eastern Canadian height gradient while creating a unidirectional flow by 00 UTC 6 July (Fig. 7). The persistence of the deep northerly flow over the next 72 hours created a mechanism for rapid transport of smoke from the source region while minimizing its dilution with the ambient air. This transport pathway dissipated by 00 UTC 8 July 2002 as the eastern Maine closed low opened, and lifted into extreme eastern Canada (Fig. 8).

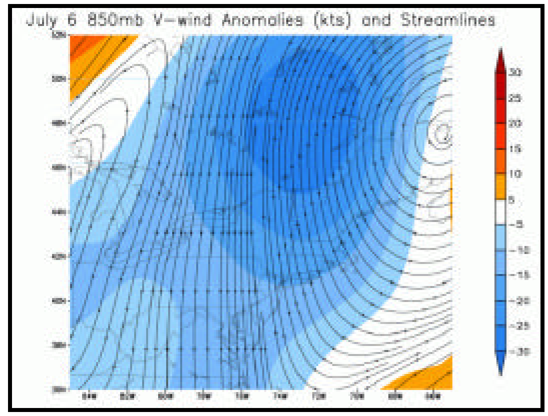

Fig. 7. 850 hPa streamlines and v-component anomalies for 00 UTC 6 July 2002 from NCEP Reanalysis data provided by NOAA-CIRES Climate Diagnostics Center.

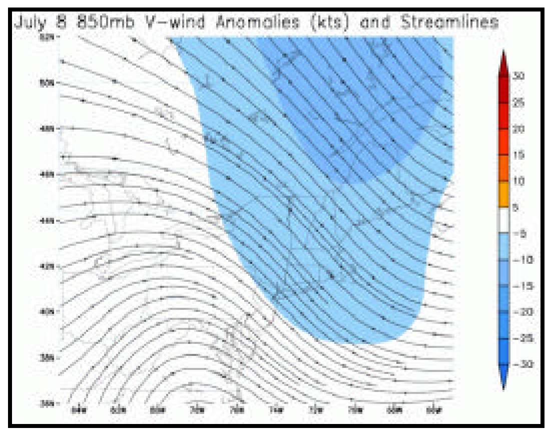

Fig. 8. 850 hPa streamlines and v-component anomalies for 00 UTC 8 July 2002 from NCEP Reanalysis data provided by NOAA-CIRES Climate Diagnostics Center.

4. DISCUSSION

The delivery of Canadian wildfire products to the metropolitan corridor of the northeastern, and northern mid-Atlantic regions of the U.S. occurred in waves or pulses of thick smoke, rather than a continuous plume. This transport behavior is most likely a consequence of the physical nature, and distribution of the more than 85 wildfires present, as well as the attributes of the temporal evolution of the flow trajectories in which the smoke was transported. Clark et al. (2003) indicated the initial movement of smoke was well above the boundary layer. However, downward isentropic glide from central Quebec southward after 5 July 2002 is a reasonable expectation given the rising heights within the high amplitude ridge across the Great Lakes, and development of the closed low over eastern Maine. Backscatter in-situ observations reveal the dramatic incursion of thick smoke into the Philadelphia area during the afternoon of 6 July 2002 (Clark et al. 2003). Nearly coincident MODIS imagery reveals the leading edge of a discontinuous plume of smoke as it moved across the Canadian border into the northeastern U.S. on 6 July 2002 (Fig. 9).

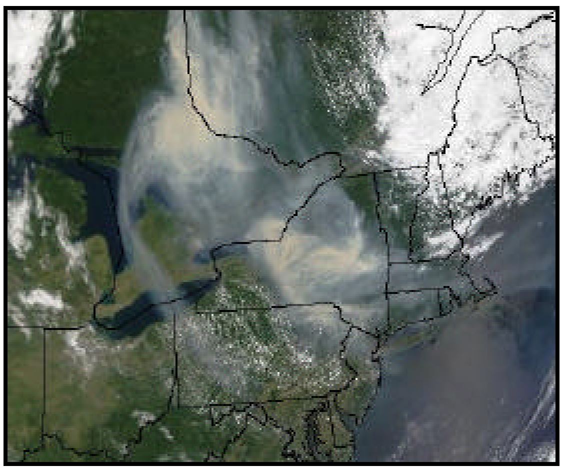

Fig. 9. Terra MODIS composite image of eastern Canada and the northeastern U.S. for 6 July 2002 obtained 1546-1553 UTC.

Aerosol index data from the NASA Earth Probe Total Ozone Mapping Spectrometer instrument corroborate the intensity of the smoke pall that descended over Philadelphia, New York, and Boston, and the episodic behavior of the event.

The high amplitude pattern which developed over Canada in early July 2002 was well forecast by the suite of short-term numerical models. However, the coincident nature of extensive wildfire activity, and a mechanism for fire intensification accompanied by the rapid transport of thick smoke caught most forecasters by surprise. The descending pall posed a short-term, yet significant health risk to millions of inhabitants of the northeastern U.S.

Recognition of the importance of identifying local air quality conditions which could pose a health risk led to the implementation of daily forecasts of ozone concentration for the mid-Atlantic region during the warm season, mid-May to mid-September (Ryan et al. 2000). The 6-7 July 2002 smoke event suggests that accurate numerical forecasts of the synoptic pattern when combined with local air quality estimates may not be adequate if the attributes of the larger-scale source regions are not identified, and accounted for. The post-September 11 environment heightens the critical value of such information.

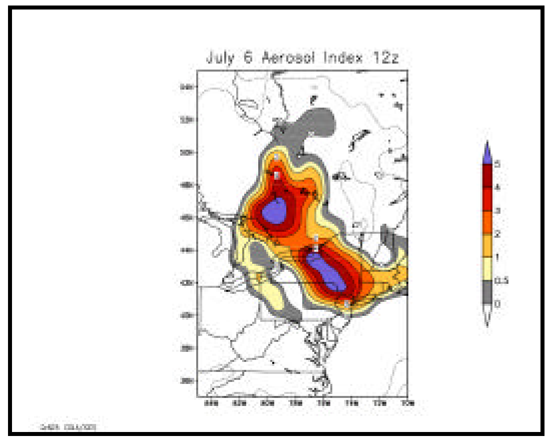

Fig. 10. Aerosol index for 12 UTC 6 July 2002 obtained from NASA/GSFC EPTOMS Ozone Mapping Spectrometer instrument (courtesy of NASA/GSFC TOMS Ozone Processing Team).

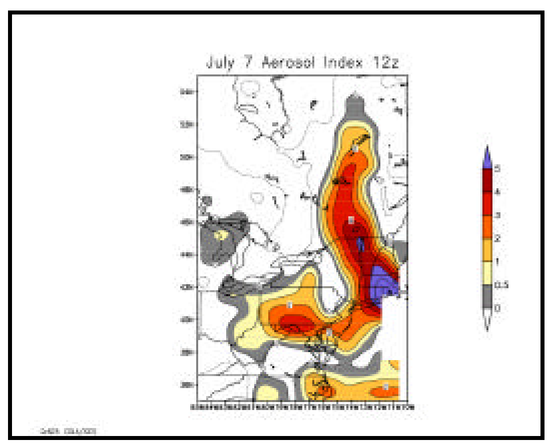

Fig. 11. Aerosol index for 12 UTC 8 July 2002 obtained from NASA/GSFC EPTOMS Ozone Mapping Spectrometer instrument (courtesy of NASA/GSFC TOMS Ozone Processing Team).

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