Summary of 2002 North-East Oxidant and Particle Study

Purpose: **To understand the physical and chemical processes that occur during periods of elevated ozone and fine particle concentrations over Philadelphia.**

University Participants: Penn State – C. Russell Philbrick, William Ryan
Millersville – Richard Clark
Clarkson – Philip Hopke
Drexel – Stephen McDow

Site: Northeast Philadelphia
Study Duration: Late June through early August 2002
Measurements: Ozone, fine Particulate Matter (PM) and other trace gases, meteorological variables

Trace Gases-

1. Vertical profiles of ozone and water vapor using PSU Raman Lidar.
2. Suite of API analyzers and on-site calibrators to measure CO, O_3, SO_2, and $NO/NO_2/NO_X$ by Millersville University.
3. Aloft ozone concentration profiles using Millersville University's tethered atmospheric sounding system (TASS) between the surface and 300 meters.
4. Air toxics and minor species composition of particulate matter using GC/MS laboratory analysis of filters gathered at the site and measured at the laboratories of Drexel University.

Particulates-

1. PSU Raman Lidar vertical profiles of optical extinction at visible and ultraviolet wavelengths.
2. Millersville University tethered balloon profiles of PM using laser diode particle nephelometers and impaction sampling on Personal Environmental Monitors (PEMs, SKC Inc.).
3. Clarkson University particulate properties using CAMMS, RAMS, Sunset Labs OC/EC, HSPH SO_4, aethalometer, and nephelometer.
4. Millersville University nephelometer (TSI model 3563) total scatter and backscatter at three wavelengths.
5. Particle filter samples analyzed at Drexel University using laboratory techniques for toxics and minor constituents.

Meteorological Variables-

1. PSU Radar/RASS vertical profiles of wind velocity (surface to 4.5 km) and virtual temperature (surface to 2.5 km).

2. PSU Raman Lidar vertical profiles of water vapor and temperature.
3. Meteorological variables (Temp, pressure, mixing ratio, wind speed and direction) as a function of height between the surface and 300 meters using Millersville University's tethered balloon.
4. Continuous measurements of meteorological variables recorded from a 10-meter tower.

Study Importance-

- Understanding the key processes that contribute to air pollution episodes in the Philadelphia region:
    - The 8-hr ozone design values in the Philadelphia region are among the highest on the east coast.
    - A need to understand these processes in order to develop effective control strategies for ozone and fine particulates.
    - The collection of meteorological data is used to determine how well synoptic-scale models are replicating the local atmospheric circulation.
    - An understanding of how local atmospheric circulation affects air-pollution levels.
- Study period occurred during a key time:
    - 2002 will be the base year for future attainment demonstrations.
    - Ozone attainment demonstrations will use 2002 air pollution episodes.
    - Regional OTC modeling will include 2002 episodes.
    - Other intensive measurements taken in New York and Baltimore regions.

Other Study Items-

- Other summer intensive studies were done in 1998, 1999 and 2001.
- Created a database of vertical and horizontal ozone and fine particulate measurements in the Philadelphia region.
- Included aloft and surface measurements to get a better understanding of processes that contribute to elevated ozone and fine particulates.

Synopsis of University Investigations:

Part 2 - Penn State University (Remote Sensing Applications)

- Atmospheric measurements show Low Level Jets (LLJs) precede many of the pollution events during the study.
- Weak synoptic features generally occur during pollution events.
- Aloft transport is important during pollution events: it holds a reservoir of nighttime ozone aloft that eventually mixes down during the daytime hours, thereby increasing surface concentrations.
- Atmospheric and pollution dynamics aloft are missed by surface instruments.

Part 3 - Penn State University (Regional Scale Meteorology/Forecasting)

- PM2.5 and ozone episodes are generally well correlated.
- PM2.5 concentrations generally peak during episodes with westerly winds (transport).
- LLJs are present during a majority of pollution episodes: nearly 75% of ozone episodes (>100 ppb) have a LLJ associated with them.
- LLJs are observed at other profilers in Baltimore and northern NJ.
- LLJs are important transport features along the coastal plain, but their extent westward is unknown.
- Current atmospheric models have difficulty fully resolving these features, and have trouble simulating core wind speeds and core size.
- Regional extent of these LLJs is unknown due to limited profiler network.

Part 4 - Millersville University (Boundary Layer Meteorology)

- Ozone transported aloft overnight can rapidly mix down to the surface after sunrise.
- In some cases, this rapid mix down can account for 30-50% of the ozone measured at the surface.
- Sea-breeze fronts were observed in the Philadelphia region: typically, sea-breeze fronts significantly decrease ozone concentrations and can increase PM2.5 concentrations.
- LLJs were observed during the overnight hours when skies are generally clear and synoptic forcing is weak.
- Peak winds in these LLJs can reach 15 m/s. Wind directions are from the south to southwest, often turning to the west before dawn.
- LLJs can transport pollutants along the northeast corridor and regions west of the corridor.
- Horizontal extent of the LLJ is unknown.
- Mechanical mixing can cause overnight LLJ to mix down to the surface ("bursting") and cause surface ozone to increase 20-30 ppb.

Part 5 - Clarkson University (Measurements of Chemical Species in PM2.5)

- High sulfate concentrations correlated well with the haze episodes.
- Organic Carbon (OC) did not correlate well with haze events.
- Observed sulfate concentrations roughly doubled during haze events.
- Elemental Carbon (EC) shows a strong diurnal pattern, possibly related to local automobile traffic patterns (peaks occurring during rush hour).
- Black Carbon (BC) is well correlated with local traffic patterns. BC patterns vary little over the weekends. Weekday BC concentrations are roughly 3 times higher than weekend BC concentrations.

- Back trajectories for haze events correlate well with areas of the Midwest (similar to findings by other studies).
- OC shows no diurnal pattern.
- Potential Source Contribution Function (PSCF) maps:
    - Includes Canadian Forest fires
    - Sulfate-Lower Ohio River Valley
    - $PM_{2.5}$-Western PA, Lower Ohio River Valley, Northern Quebec
    - B_{scat}-Western PA, Lower Ohio River, Eastern TX, LA
    - OC-Northern Quebec, western PA
    - EC-Northern Quebec, Western PA, portions of the Midwest

Part 6 - Drexel University (PM Sources Based on Laboratory Analysis)

- The organic component of PM can either be directly emitted as particles (primary organic particles), or it can be formed through atmospheric chemical reactions (secondary organic particles).
- This study used gas chromatography-mass spectrometry to examine the organic component of PM.
- This type of analysis can yield information about the relative contribution of anthropogenic and biogenic sources and the relative importance of primary and secondary formation to the organic PM being analyzed.
- Combining information about wind direction with the data from the analysis of samples taken during an air pollution episode can yield insight into the origin of the organic PM during that episode.
- Analysis of the summer organic PM in Philadelphia revealed relatively constant levels of primary organic PM, punctuated by episodes of high levels of secondary organic PM during ozone events.
- While secondary organic PM levels may spike during air pollution events, the relatively constant contribution of primary organic PM may make a greater contribution to annual average PM levels.