Appendix 2B

A Connecticut Perspective
On the Regional Ozone Problem

1.0 Introduction

Ozone pollution along the east coast of the United States has proved to be a difficult challenge. The meteorology, topography, population density and spatial pattern of emissions all contribute to the problem. The weather patterns can concentrate and transport ozone over hundreds of miles. Thus, it is a truly regional problem in need of regional solutions. Emission reductions from electric generating units (EGUs), mobile sources and other source categories need to occur. On behalf of the Ozone Transport Commission, the Northeast States for Coordinated Air Use Management (NESCAUM) produced a conceptual description of how ozone is formed and transported regionally in the eastern US. See Section 2 of the main body of this technical support document (TSD) for a summary of NESCAUM's report and Appendix 2A for a complete copy of the report.

The discussion below provides a Connecticut perspective on the regional ozone problem. The types of meteorological events that produce high ozone in Connecticut are described, using the hot summer of 2002 as an example. In addition, evidence is provided demonstrating the important role that upwind transport areas play in contributing to Connecticut's high ozone events.

2.0 Meteorological Regimes Producing High Ozone Days in 2002

Four meteorological regimes corresponding to four spatial patterns of ozone exceedances are identified for Connecticut from 2002 data. The frequency of ozone exceedances was unusually high in 2002 (i.e., 34 days with at least one monitor exceeding the 8-hour standard) due to the extremely hot summer,[1] but the patterns seen were characteristic of other years. The patterns identified are:

1. Inland-only exceedances (6 days);
2. Coastal-only exceedances (11 days);
3. Western boundary-only exceedances (8 days); and
4. Statewide exceedances (9 days).

All patterns feature hot air masses with 850 millibar (mb) and temperatures exceeding 13C. These temperatures aloft can correspond to inland surface temperatures of at least 85°F, with coastal temperatures typically in the 70°F's and low 80°F's along Long Island Sound (LIS). Generally, the winds aloft at 850 mb during ozone events are from the west-southwest (WSW) to west-northwest (WNW) and fairly strong (indicating transport). Surface geostrophic wind patterns (i.e., winds not influenced by mesoscale effects such as the seabreeze or leeside trough) vary from the south for inland-only exceedances (Pattern 1), the west for coastal-only exceedances (Pattern 2), south-southwest for western boundary exceedances (Pattern 3), and southwest for statewide exceedances (Pattern 4).

[1] There were 35 days with high temperatures ≥ 90 °F in 2002, as measured at Bradley International Airport, compared to the 30-year average of 17 days. Only 1983, with 38 days ≥ 90 °F, was hotter over the 30 years.

2.1 Pattern 1: Inland-Only Exceedances

For Pattern 1, ozone is brought in aloft from the west and mixed down during the day. Strong southerly surface winds bring in clean maritime air from off the Atlantic Ocean, with the coastal surface monitors reflecting that phenomenon. Figure 2.1 represents an example of a time series of the winds and an ozone map for June 21, 2002. The maritime front does not make it very far inland, leaving inland monitors influenced by the dirty air mass. A low level jet often sets up aloft overnight, transporting polluted air from the southwest. The synoptic weather pattern consists of a large warm sector with strong southerly surface winds. See Figures 2.2 and 2.3 for the surface and upper air charts for June 21, 2002.

FIGURE 2.1 CT PATTERN 1
INLAND EXCEEDANCES, STRONG MARINE INFLUENCE ON JUNE 21, 2002

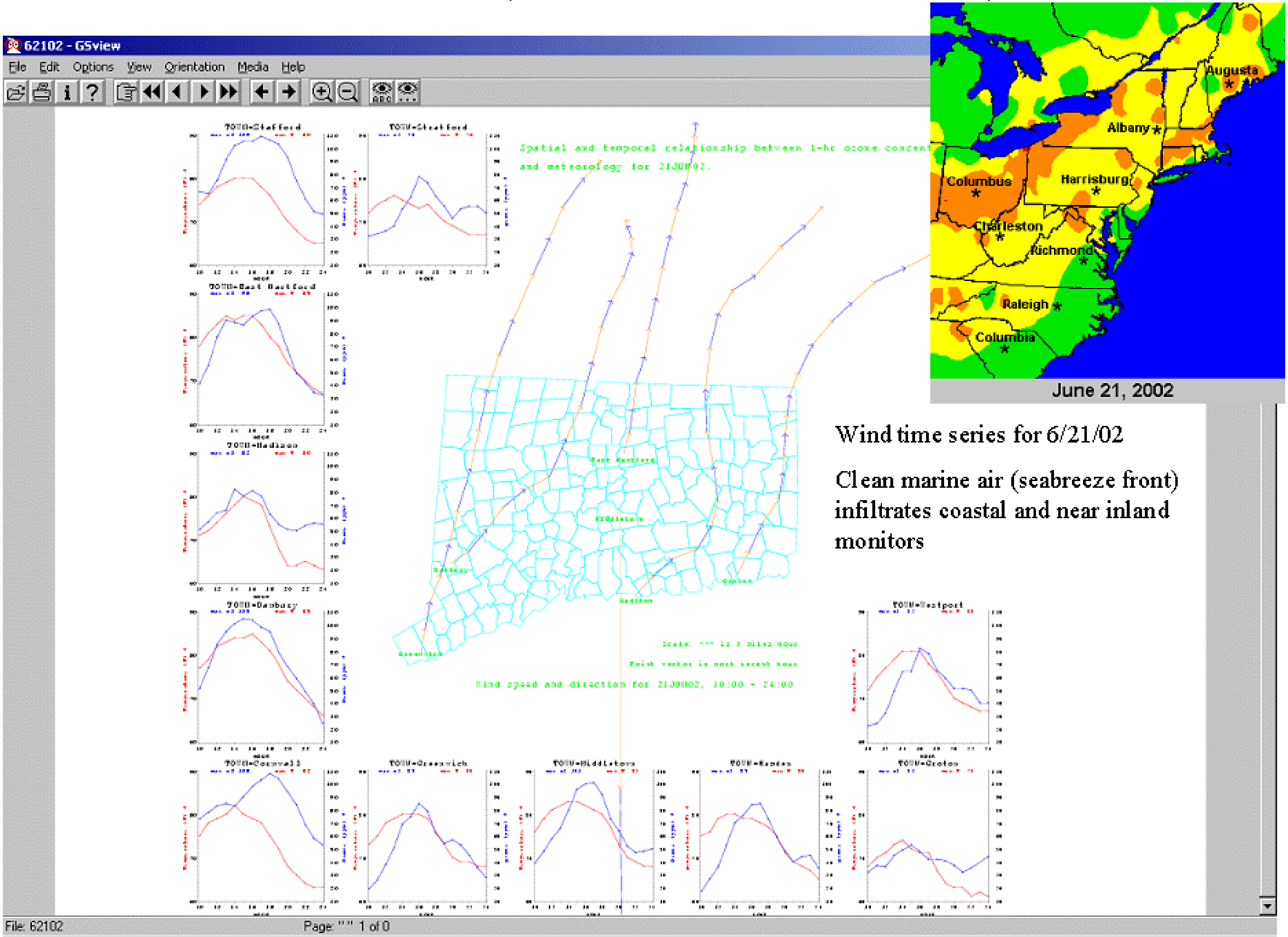
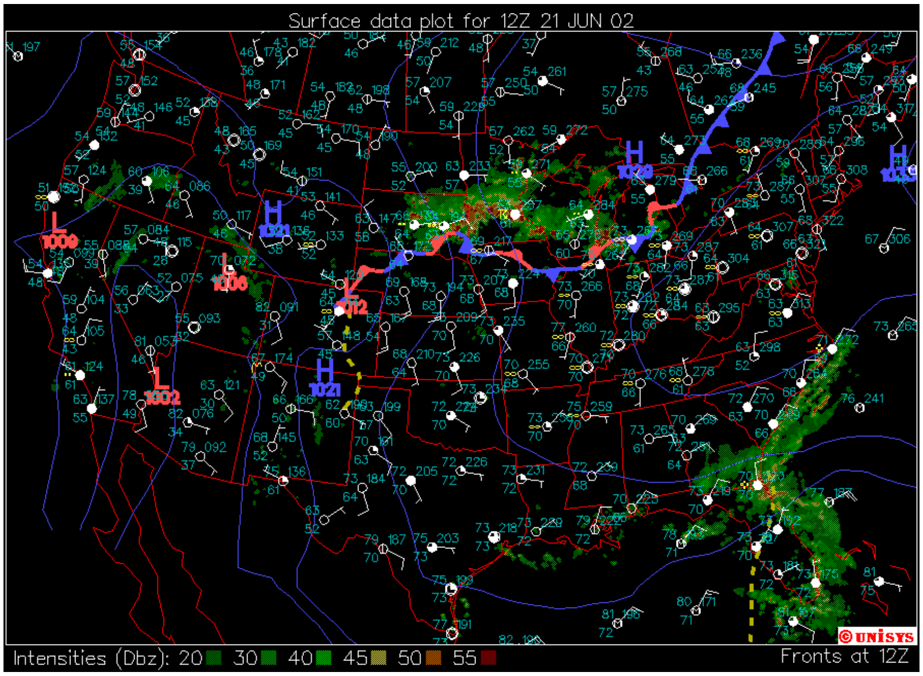
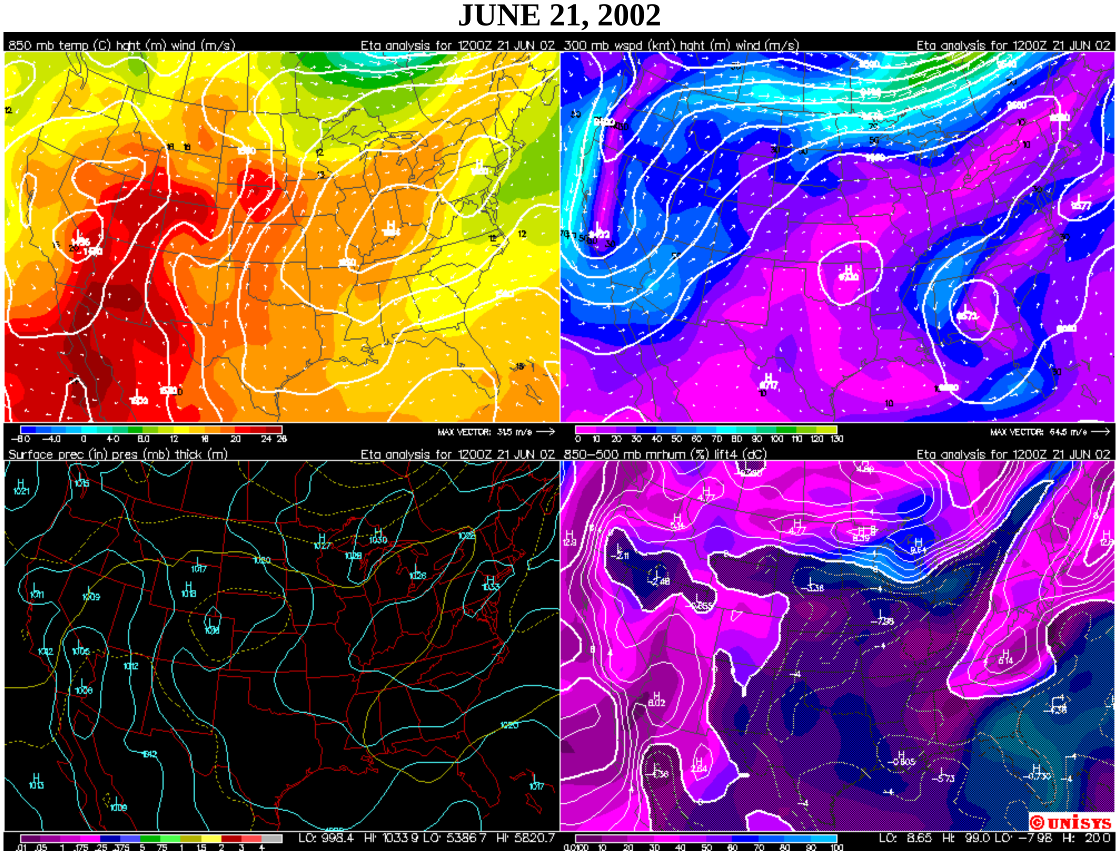


FIGURE 2.2 SURFACE METEOROLOGY ASSOCIATED WITH PATTERN 1 JUNE 21, 2002



Source: UNISYS, "UNISYS Weather Image and Map Archive" 2007. http://weather.unisys.com/archive/index.html

FIGURE 2.3 UPPER AIR METEOROLOGY ASSOCIATED WITH PATTERN 1 JUNE 21, 2002



Source: UNISYS, "UNISYS Weather Image and Map Archive" 2007. http://weather.unisys.com/archive/index.html

2.2 Pattern 2: Coastal-Only Exceedances

For Pattern 2, strong westerly surface winds transport pollutant laden air down LIS from west to east. (See Figure 2. upper left panel for forward trajectories for July 2, 2002). Ozone and its precursors are injected into the marine boundary layer (MBL) off the coast from New York and New Jersey. The MBL keeps the ozone highly concentrated by prohibiting vertical ventilation due to high stability. (See the lower left panel of Figure 2.4). The sea breeze has a southerly component to it, bringing the dirty air inland close to the shore. Inland, the wind is either west or WNW, prohibiting the maritime air from moving north and setting up a confluence/convergence zone further concentrating the ozone along the coast. The synoptic pattern is one of a cold front bearing down on the region from the west with strong west winds mixing down from aloft. (See Figure 2. for the surface chart, Figure 2.4, lower right panel for upper air chart). The exceedance pattern is a thin strip of concentrated ozone along the coast, as seen in Figure 2.4 (upper right panel).

2.3 Pattern 3: Western Boundary-Only Exceedances

For Pattern 3, the maritime surface air invades the eastern two-thirds of Connecticut and keeps monitors in that portion of the state clean. However, for those monitors downwind of New York City (Greenwich, Danbury, and perhaps Cornwall) high ozone is measured. (See Figure 2.6 for an air quality map and wind time series for August 2, 2002). The SSW urban winds out of New York City cause exceedances at the western monitors, and the south to SSE maritime winds keep the rest of the state clean. In the case of August 2, 2002, a frontal system divided the state causing the wind to blow from different directions in different parts of the state. (See the surface chart in Figure 2.7.) The upper air charts in Figure 2.8 indicate weak flow aloft and no strong dynamics for weather systems. The temperatures aloft (at 850 mb) were very warm, promoting the formation of ozone.

2.4 Pattern 4: Statewide Exceedances

For Pattern 4, the flow at all levels is favorable for high ozone formation in all of Connecticut (and much of the OTR as well). Many or all of the mechanisms discussed in patterns 1-3 may be operating. Pattern 4 is a "classical" ozone pattern drawing ozone from the I-95 urban corridor both at the surface and at mid levels via the low level jet, as well as from the Midwest at upper levels. This convergence can produce some of the highest measured ozone levels in Connecticut. Figure 2.9, for August 12 and 13, 2002, reveals the following:

- The ozone map shows high ozone levels enveloping much of the OTR;
- Lowest level winds are out of the SSW, picking up ozone and precursor emissions from both the I-95 corridor of urban areas and a pool of ozone off the Atlantic Coast (see Section 3.2.3 of the TSD and Figure 2.2.2.4 in Section 2.2 of the TSD);
- Midlevel winds are lee of the Appalachians and the vertical profile indicate the existence of a nocturnal jet transporting ozone northeastward**;**
- Upper level winds are blowing from the west and WSW, the source region that includes numerous large coal burning power plants in Pennsylvania and the Ohio Valley; and
- Ozone concentrations reached unhealthy and very unhealthy (up to 126 ppb 8-hour average) levels for much of the state.

FIGURE 2.4 CT PATTERN 2
COASTAL EXCEEDANCES, JULY 2, 2002
FORWARD TRAJECTORIES, AQ MAP, SURFACE WIND TIME SERIES AND 850 MB ANALYSIS

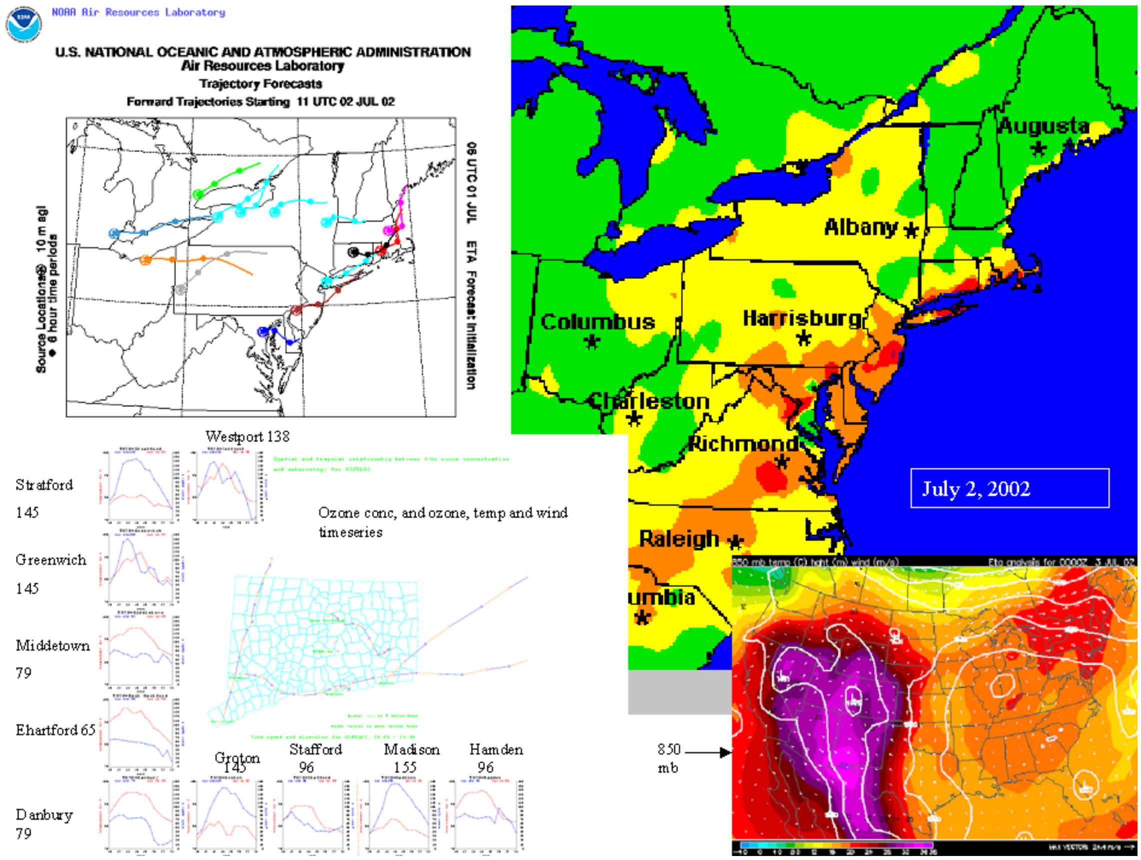
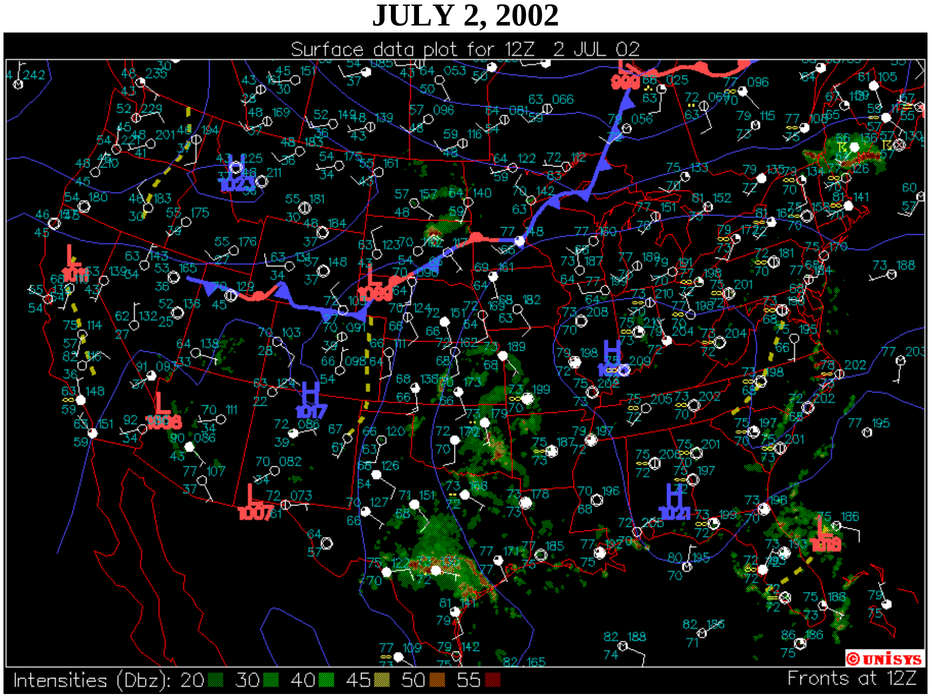


FIGURE 2.5. SURFACE METEOROLOGY ASSOCIATED WITH PATTERN 2 JULY 2, 2002



Source: UNISYS, "UNISYS Weather Image and Map Archive" 2007. http://weather.unisys.com/archive/index.html

FIGURE 2.6 CT PATTERN 3 AUGUST 2, 2002
EXCEEDANCES CONFINED TO THE SOUTHWEST CORNER OF THE STATE.
AIR QUALITY AND SURFACE TIME SERIES PLOTS

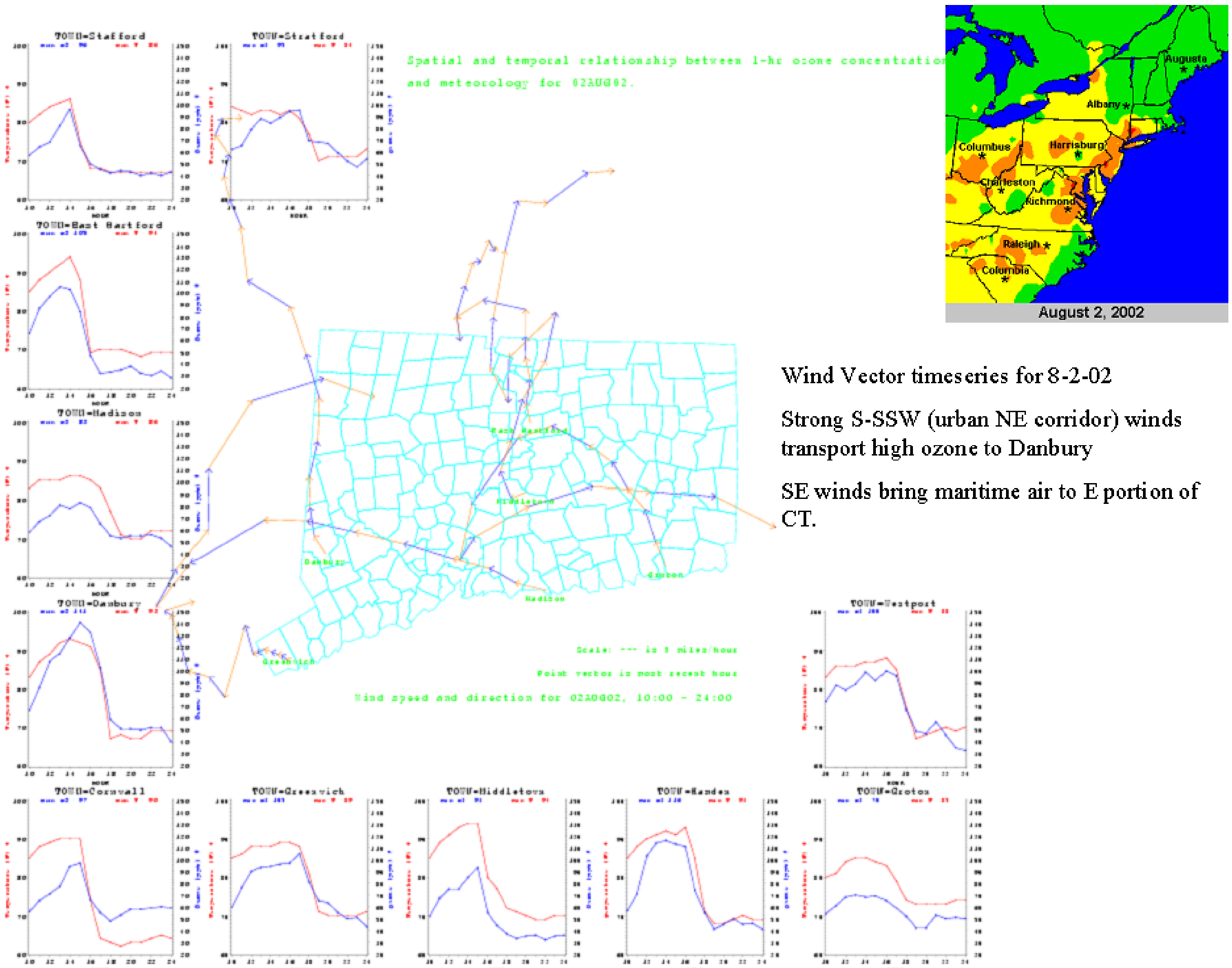


Figure 2.7 PATTERN 3
Surface Chart for August 2, 2002

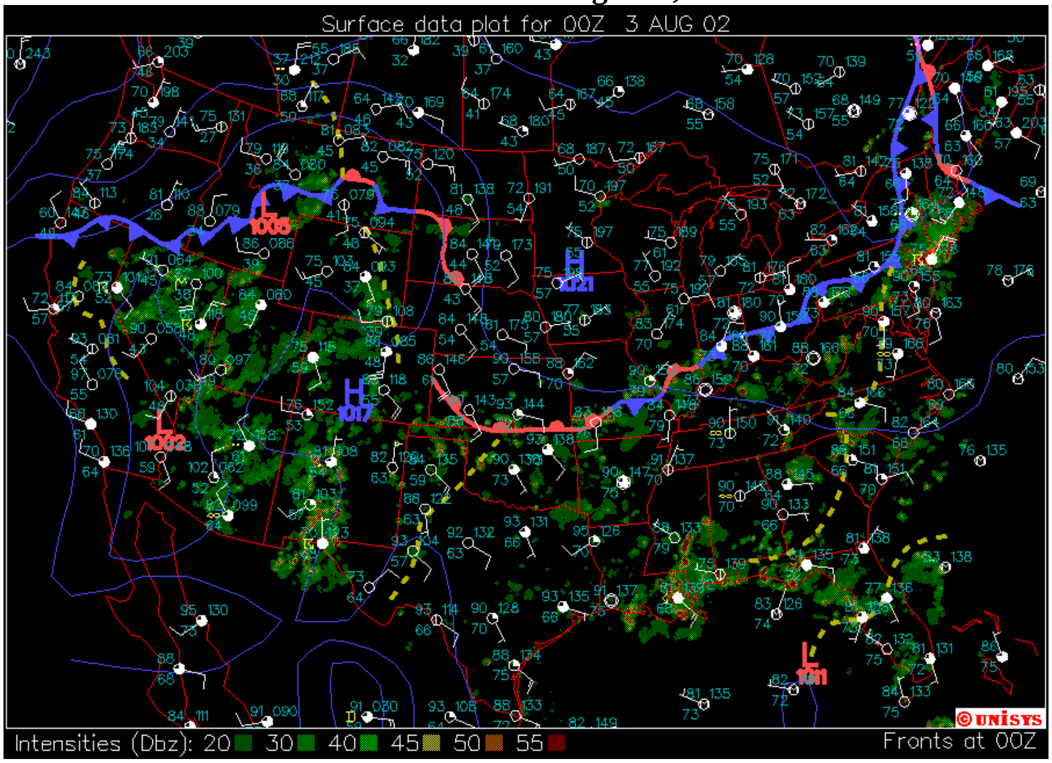
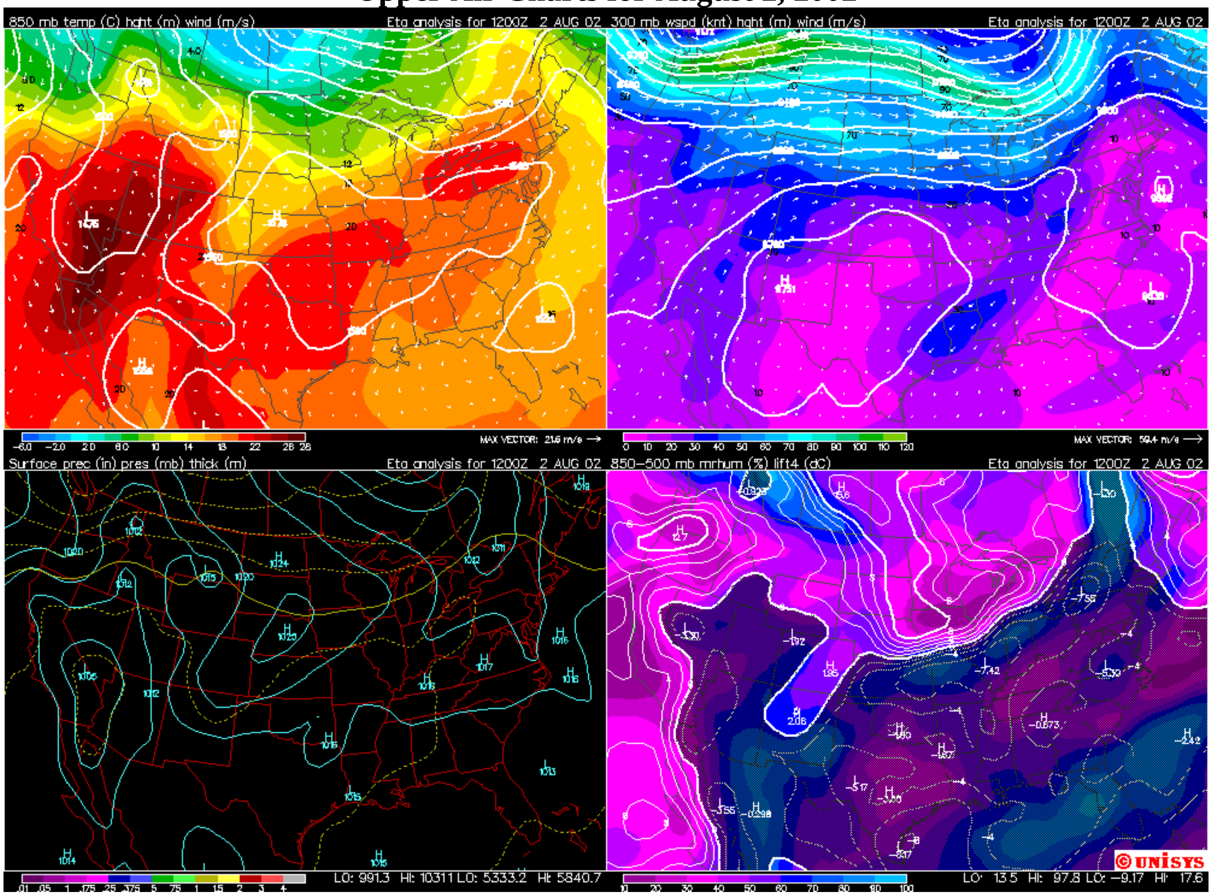


Figure 2.8 PATTERN 3
Upper Air Charts for August 2, 2002



Source: UNISYS, "UNISYS Weather Image and Map Archive" 2007. http://weather.unisys.com/archive/index.html

FIGURE 2.9 CT PATTERN 4
EXCEEDANCES IN ENTIRE STATE (AND THROUGHOUT OTR)
AIR QUALITY, VERTICAL PROFILE AND 3-D TRAJECTORY MAPS

A Worst Case Day in Connecticut

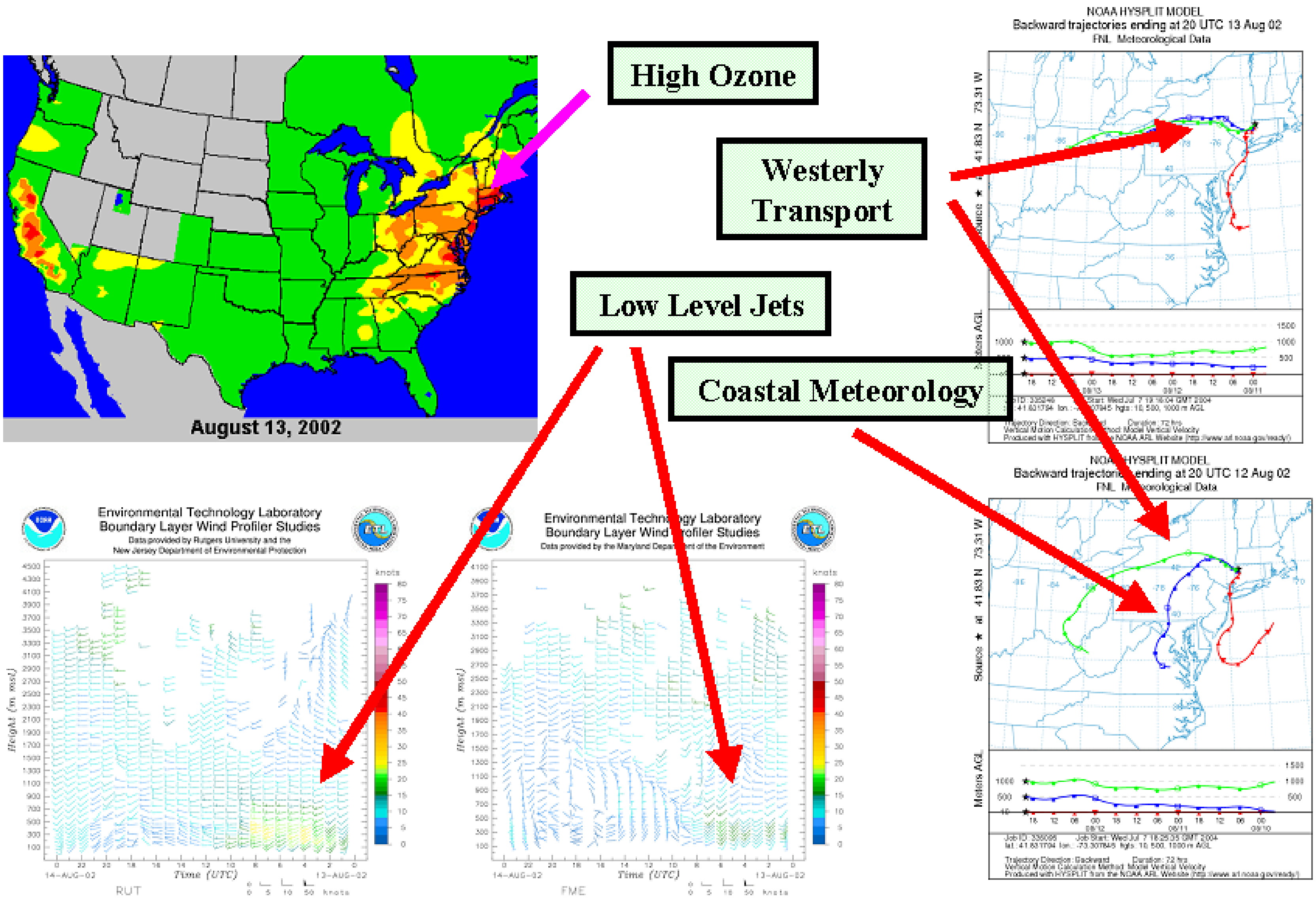
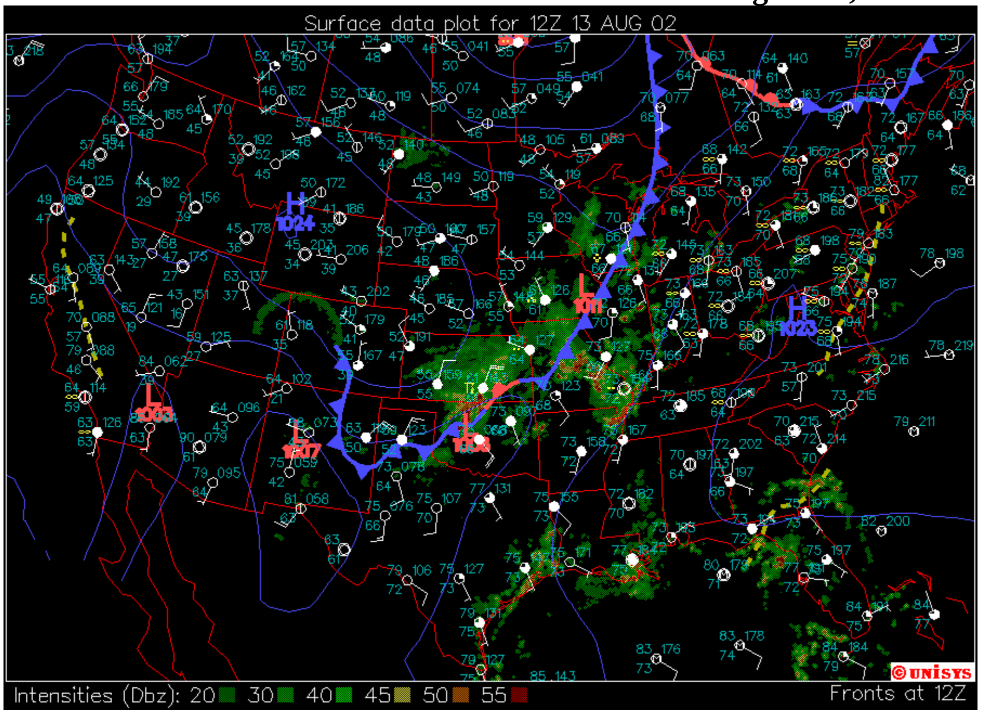


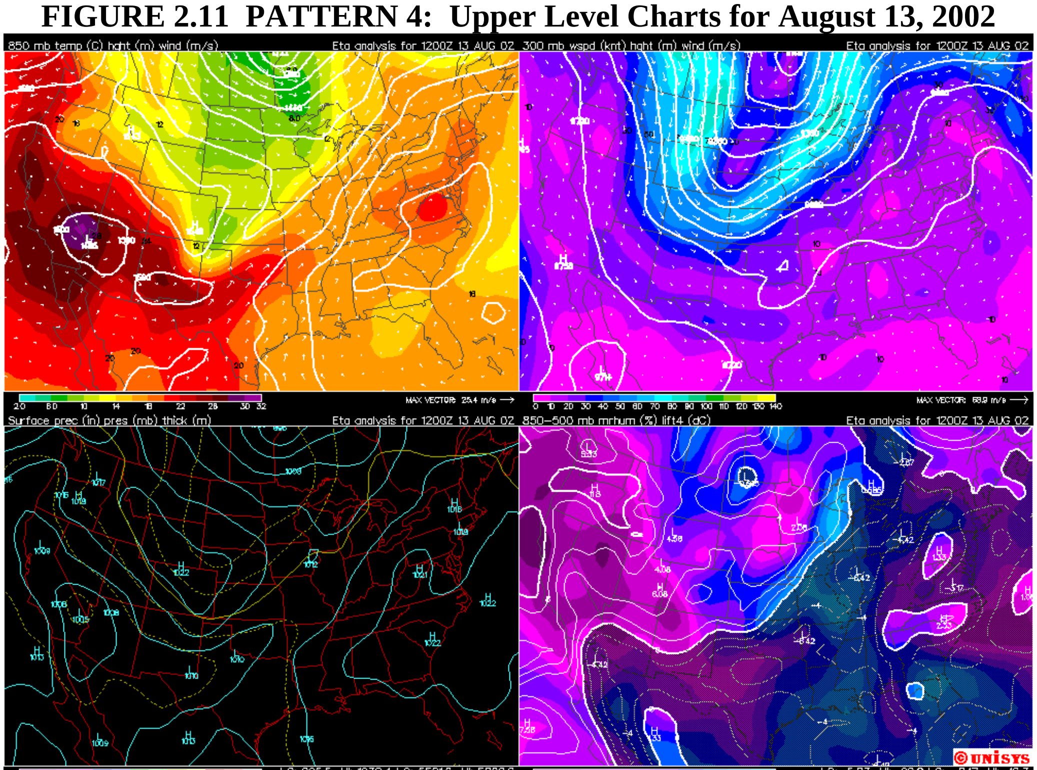
Figure 2.10 shows the surface weather features for August 13, 2002. Of note is the familiar high pressure to the south, pumping SW winds into Connecticut. Figure 2.11 shows a ridge at all levels of the atmosphere with westerly winds at transport level and hot temperatures approaching 20C at 850 mb, translating to mid-to-upper 90°F's at the surface.

FIGURE 2.10 PATTERN 4: Surface Chart for August 13, 2002



Source: UNISYS, "UNISYS Weather Image and Map Archive" 2007. http://weather.unisys.com/archive/index.html

FIGURE 2.11 PATTERN 4: Upper Level Charts for August 13, 2002



Source: UNISYS, "UNISYS Weather Image and Map Archive" 2007. http://weather.unisys.com/archive/index.html

3.0 Evidence of Transport

Although emissions from sources in Connecticut do contribute significantly to the state's poor air quality events, substantial upwind help is needed to reduce ozone in the state to healthy levels. Current emission reduction programs such as the NO_X SIP call have been effective at reducing ozone in Connecticut, primarily because they reduce ozone that is transported to the state by large power plants upwind that emit significant amounts of NO_X. This section presents evidence from modeling, air quality and meteorological analyses regarding the transport of ozone and ozone precursor emissions into Connecticut from upwind areas.

3.1 Modeling Evidence of Ozone Transport

Modeling conducted by the New Hampshire Department of Environmental Services (NHDES) for the states of the Ozone Transport Region (OTR) and by EPA in support of the Clean Air Interstate Rule (CAIR) illustrates the overwhelming level of ozone transport affecting Connecticut.

NHDES CALGRID Zero-Out Modeling

The California Photochemical Grid Model (CALGRID) was run by the NHDES to provide OTR states with additional information to inform policy decisions related to candidate control strategies. The CALGRID model is not considered to be a SIP-quality modeling tool and has a tendency to predict higher ozone levels than the SIP-quality CMAQ modeling system. Nonetheless, CALGRID analyses are less resource-intensive to produce than CMAQ analyses and can provide useful information on the relative contributions of source areas and the relative effectiveness of control strategies.

NHDES conducted CALGRID runs using meteorology simulations for the July 7 to July 21 and July 31 to August 16 periods of 2002. Base case runs used emissions representing the 2009 beyond-on-the-way (BOTW) control scenario. Comparison runs removed anthropogenic emissions for entire states (i.e., "zero-out" runs) to estimate the relative contribution of each state to the transport problem.

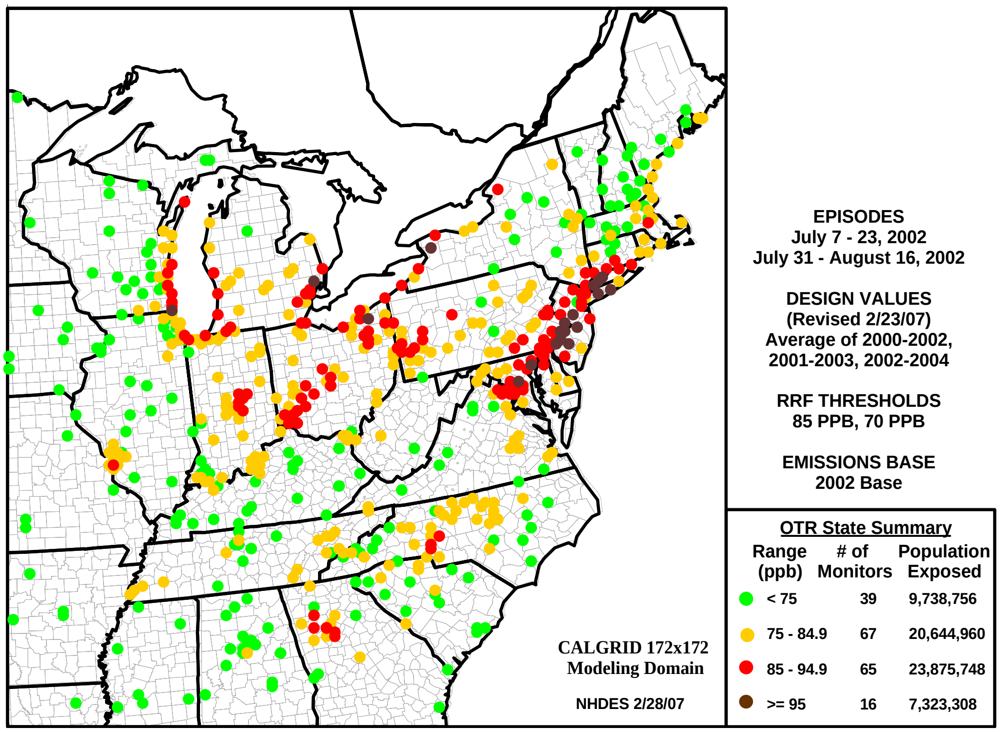
Figure 3.1 depicts CALGRID results based on zero-out runs for Connecticut sources. Even with no in-state anthropogenic emissions in 2009, the conservative CALGRID model predicts that Connecticut's coastal and boundary monitors would exceed the air quality standard due to overwhelming transport from sources outside the state. Connecticut's own contribution at these key monitors is predicted to be less than 15 ppb, indicating that transport from upwind out-of-state areas accounts for more than 80% of predicted peak ozone levels in Connecticut.

Figures 3.2 through 3.4 provide estimates of near-field transport into Connecticut, based on CALGRID zero-out runs for three nearby upwind states (New York, New Jersey and Pennsylvania, respectively). When contributions are summed for Connecticut's key coastal and boundary monitors, as much as 35 ppb can be attributed to these three nearby upwind states for the periods modeled. Given how close Connecticut is to full attainment in 2009 according to the SIP-quality CMAQ modeling (see Section 8.4 of the TSD), additional regional emission reduction measures in these states, such as the high electric demand day (HEDD) initiative (see Section 8.5.5 of the TSD), would provide greater confidence regarding projected attainment.

Figure 3.1 CALGRID Connecticut Zero-Out Run, Concentration and Difference Plot (2009 BOTW-CT ZEROUT)

Future Design Values for 8-Hour Ozone

R005: 2009 BOTW, Zero Out Anthropogenic Emissions in CT



Episode Maximum 8-Hour Ozone Difference Concentrations
2009 BOTW minus 2009 BOTW, Zero Out Anthropogenic Emissions in CT
July 6 - 23 and July 30 - August 16, 2002

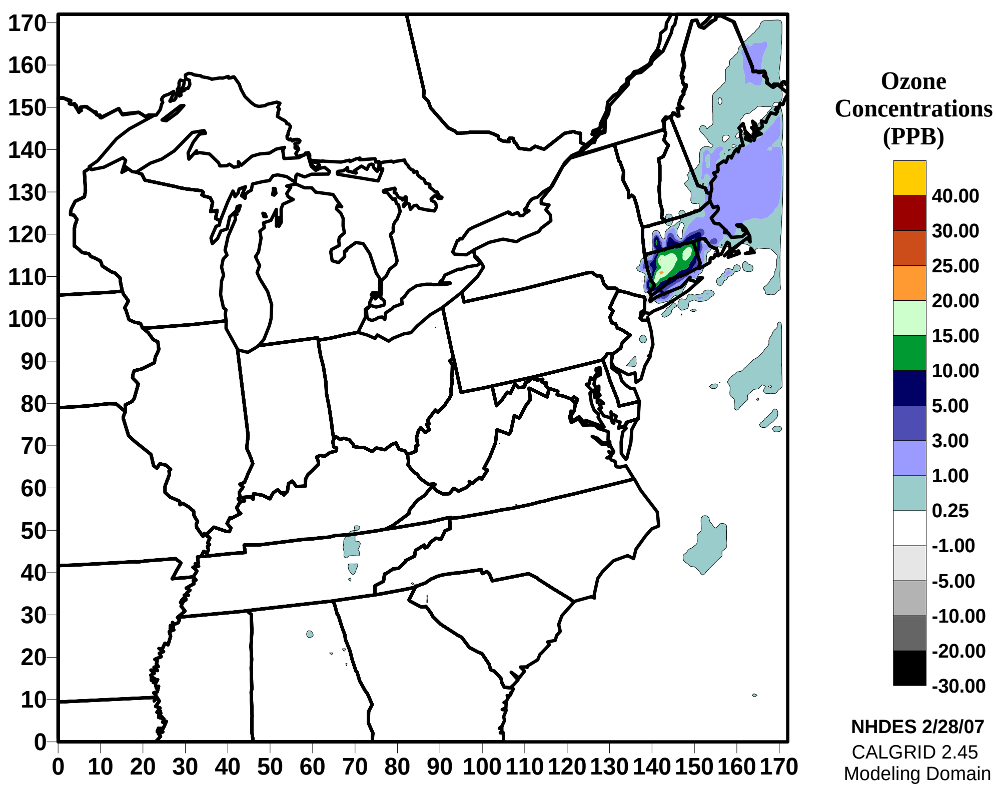


Figure 3.2 CALGRID NY Zero-Out Run, Difference Plot
(2009 BOTW-NY ZEROUT)
Episode Maximum 8-Hour Ozone Difference Concentrations
2009 BOTW minus 2009 BOTW, Zero Out Anthropogenic Emissions in New York
July 6 - 23 and July 30 - August 16, 2002

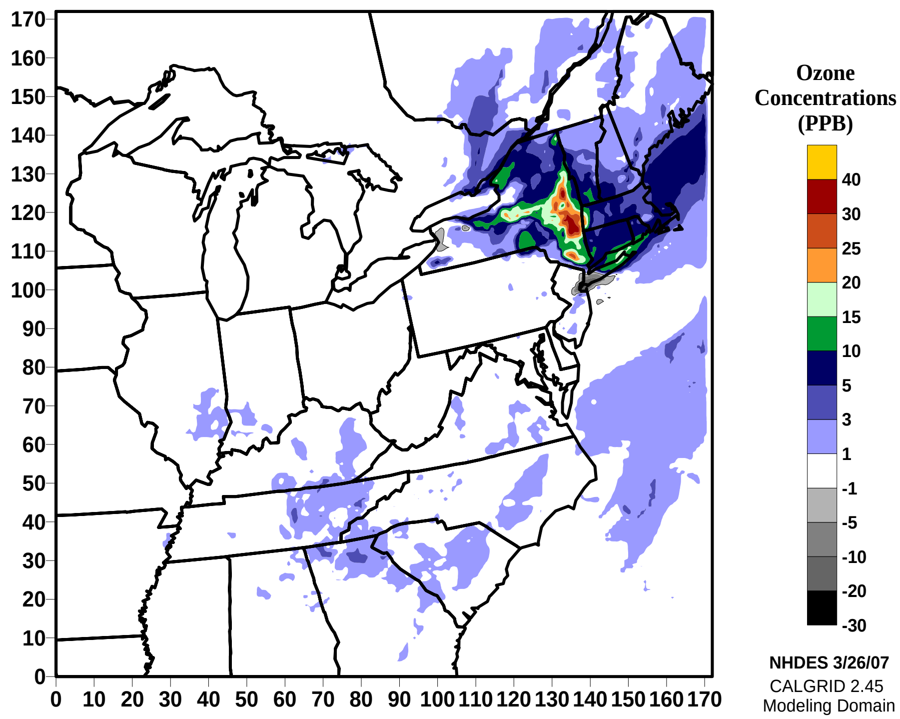


FIGURE 3.3 CALGRID NJ Zero-Out Run, Difference Plot
(2009 BOTW-NJ ZEROUT)
Episode Maximum 8-Hour Ozone Difference Concentrations
2009 BOTW minus 2009 BOTW, Zero Out Anthropogenic Emissions in New Jersey
July 6 - 23 and July 30 - August 16, 2002

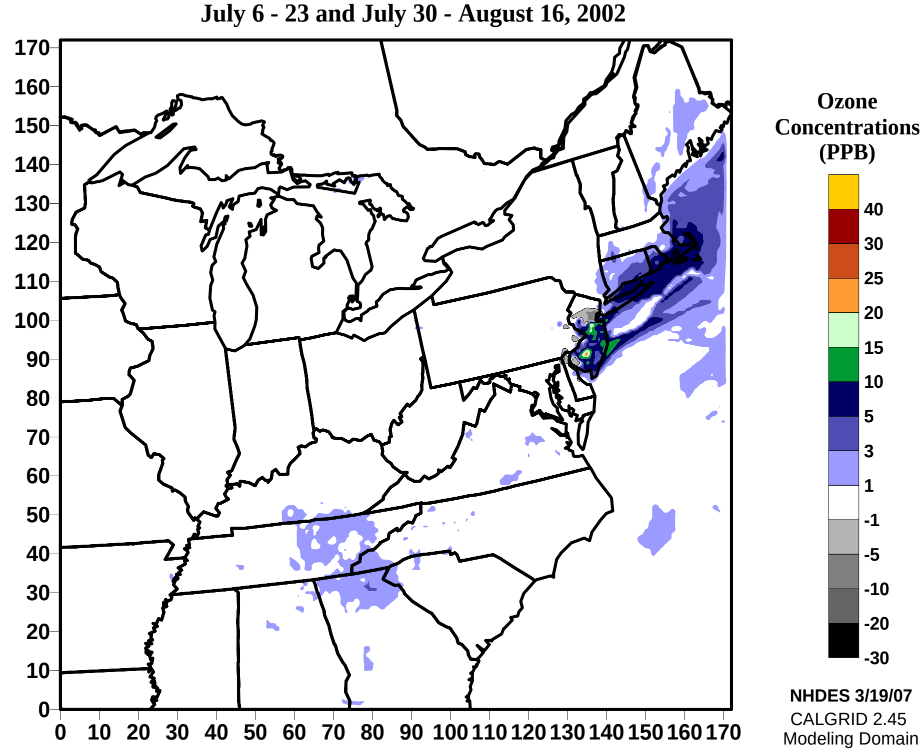
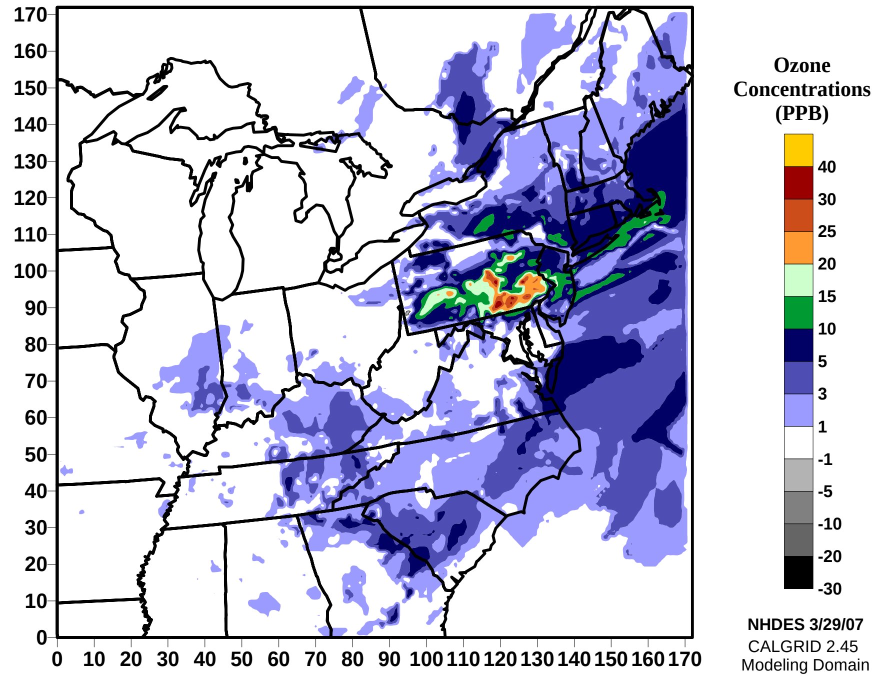


FIGURE 3.4 CALGRID PA Zero-Out Run, Difference Plot
(2009 BOTW-PA ZEROUT)
Episode Maximum 8-Hour Ozone Difference Concentrations
2009 BOTW minus 2009 BOTW, Zero Out Anthropogenic Emissions in Pennsylvania
July 6 - 23 and July 30 - August 16, 2002



EPA CAIR Modeling

EPA's CAIR program is intended to reduce interstate transport of ozone using market-based incentives targeted at electric generating units (EGUs). As more fully described in Connecticut's recent SIP revision satisfying Section 110(a)(2)(D) requirements,[2] EPA's modeling analysis[3] for CAIR identified eight upwind states as contributing significantly to 8-hour ozone NAAQS nonattainment in Connecticut (i.e., NY, PA, NJ, OH, VA, MD/DC, WV, MA). EPA's analysis concluded that transport from upwind states contributes, on average, 95% of projected 2010 ozone levels in New Haven County and 93% in Middlesex County. Connecticut is the only state subject to transport exceeding 90% of projected 2010 ozone levels; this illustrates the unique and overwhelming influence upwind emissions have on Connecticut's prospects for achieving timely attainment. EPA's CAIR modeling estimates that almost two-thirds of the transport affecting Connecticut results from emissions from the three states of New York, Pennsylvania and New Jersey.

Despite EPA's stated goals for the CAIR program, the modeling predicts that improvements due to CAIR will be inconsequential in Connecticut when compared to the overwhelming levels of transport from upwind areas that cannot be addressed by in-state controls. EPA's modeling predicts that CAIR will result in no more than a 0.4 ppb improvement in Connecticut's ozone

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[2] "Revision to Connecticut's State Implementation Plan: Meeting the Interstate Air Pollution Transport Requirements of Clean Air Act Section 110(a)(2)(D)(i)"; Submitted to EPA on March 13, 2007; See: http://www.ct.gov/dep/lib/dep/air/regulations/proposed_and_reports/revsipsec110appendix.pdf.

[3] "Technical Support Document for the Final Clean Air Interstate Rule: Air Quality Modeling"; US EPA OAQPS; March 2005; See: http://www.epa.gov/cleanairinterstaterule/pdfs/finaltech02.pdf.

levels in 2010 (0.8 ppb in 2015), amounting to far less than one percent of the transport affecting the state. These results suggest that the levels of transport after CAIR implementation will remain large enough that the prospects for 2009 attainment may be in jeopardy without additional upwind emission reductions from such programs as the HEDD initiative being pursued by several Northeast states. Results also indicate that upwind states will continue to contribute significantly to any residual nonattainment remaining in Connecticut in 2009, highlighting the need for EPA to ensure that the remaining significant contributions are properly addressed in the ozone attainment demonstrations submitted by states upwind of Connecticut.

3.2 Air Quality and Meteorological Evidence of Ozone Transport

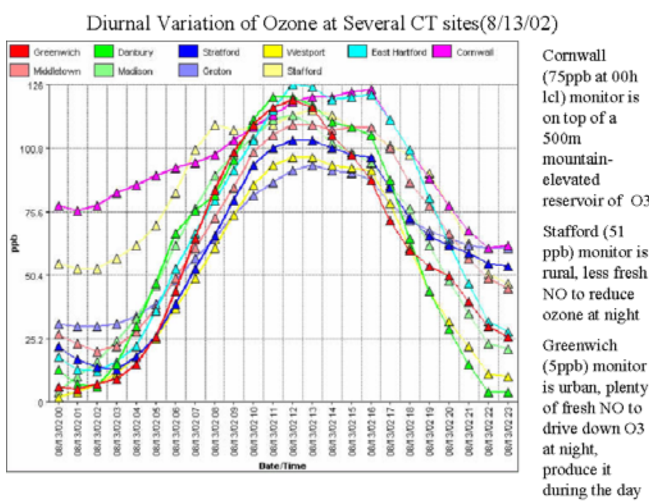
As described below, analyses of air quality and meteorological data provide further evidence of the nature and degree of ozone transport affecting Connecticut.

3.2.1 Aloft Transport of Ozone

Ozone exceedances measured in the afternoon at Connecticut's low elevation, inland monitors are often preceded by high ozone levels occurring earlier in the day at the upwind, high elevation site in Cornwall (Mohawk Mountain, or Cornwall). The Cornwall site's rural location atop the 1600-foot Mohawk Mountain, is not affected by emissions that can titrate ozone and is typically subject to higher winds than at low altitude sites. These factors allow Mohawk Mountain to be used as a good indicator of ozone transport to Connecticut that occurs aloft.

Figure 3.5 shows the diurnal variation of 8-hour ozone at all Connecticut monitors on August 13, 2002. The magenta line at Cornwall indicates that ozone levels on the evening of August 12, 2002 start off 50-75 ppb higher than at all other monitors in the state. During the day, as ozone levels begin to rise, vertical mixing brings the high ozone aloft to lower levels, and all monitors develop a similar hourly ozone distribution. An example of this mixing phenomenon is seen for New Haven, Connecticut (urban site) in Figures 3.6 and 3.7. Note the low levels of ozone at the surface on the morning profile, and the well-mixed higher ozone throughout the vertical column in the afternoon profile. Transported ozone aloft is mixed down to increase ozone at the surface.

Figure 3.5 Diurnal Variation of 8-Hour Ozone in CT on August 13, 2002



Source: Blumenthal D.L., Lurmann F.W., Kumar N., Dye T.S., Ray S.E., Korc M.E., Londergan R., and Moore G.(1997); Assessment of transport and mixing and OTAG model performance for Northeast U.S. ozone episodes. Summary of results. Report prepared for Ozone Transport Assessment Group, Air Quality Analysis Workgroup by Sonoma Technology, Inc., Santa Rosa, CA, and Earth Tech, Concord, MA, STI-996133-1710/1716-S, March 1997.

Figure 3.6 Morning Vertical Profile of Ozone*

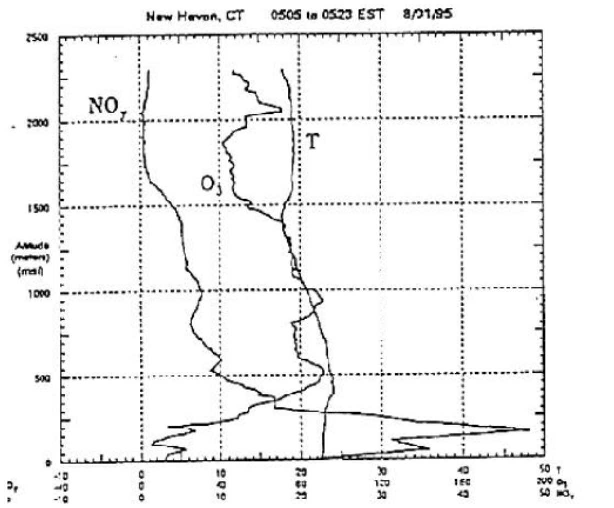
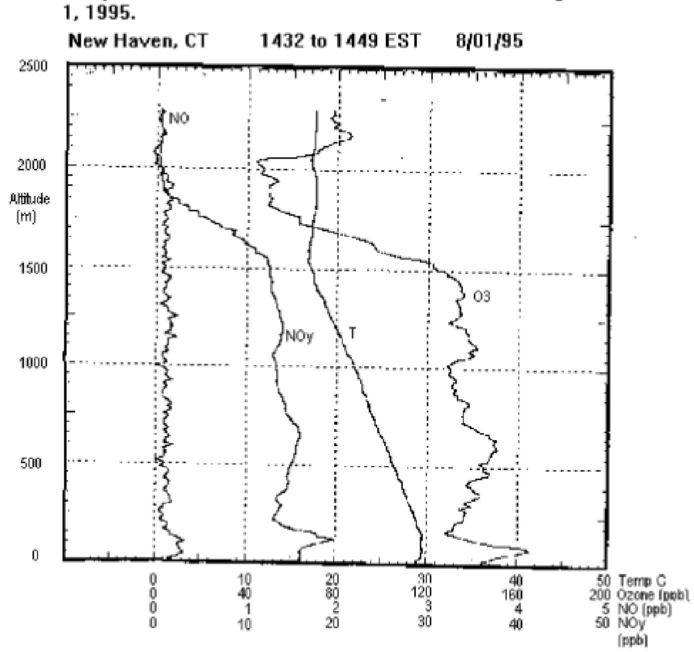


Figure 4-4. Ozone, Temperature and NOy Vertical Profiles for August 1, 1995, Early Morning Flights.

Figure 3.7 Afternoon Vertical Profile of Ozone*

Figure 4-5. Vertical Distribution of Ozone, NO, NOy and Temperature at New Haven, CT on the Afternoon of August 1, 1995.

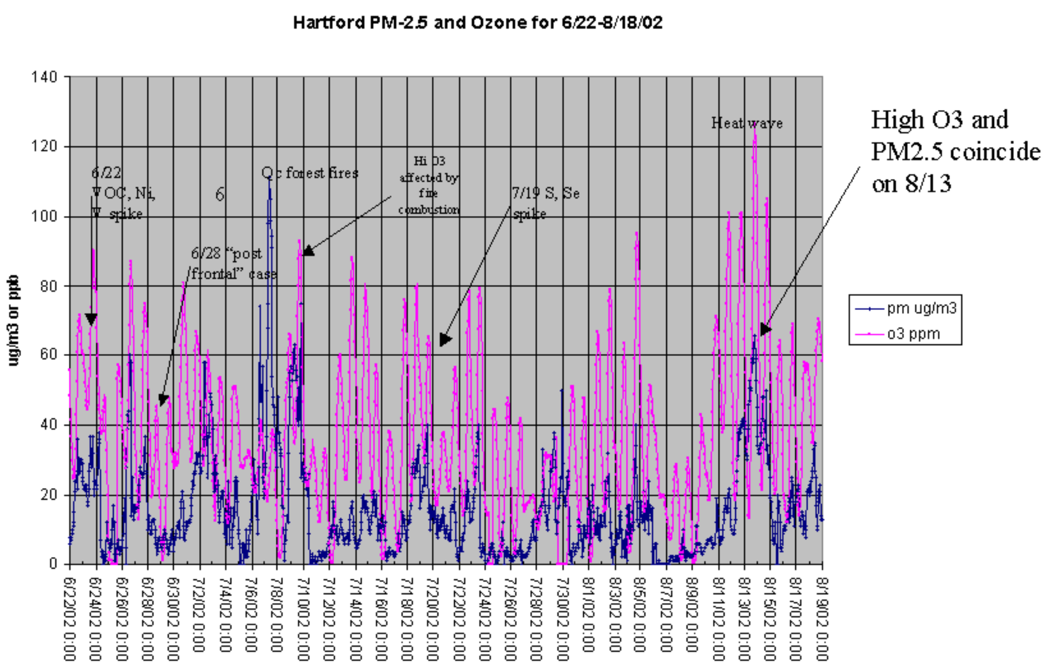


Source: Figures 3.6 and 3.7 are from Blumenthal D.L., Lurmann F.W., Kumar N., Dye T.S., Ray S.E., Korc M.E., Londergan R., and Moore G.(1997); Assessment of transport and mixing and OTAG model performance for Northeast U.S. ozone episodes. Summary of results. Report prepared for Ozone Transport Assessment Group, Air Quality Analysis Workgroup by Sonoma Technology, Inc., Santa Rosa, CA, and Earth Tech, Concord, MA, STI-996133-1710/1716-S, March 1997.

3.2.2 Transport Determined Using Tracer Species

In the summer, high ozone levels are often accompanied by high levels of fine particulate matter ($PM_{2.5}$), as shown in the example in Figure 3.8. During these events, the $PM_{2.5}$ is usually dominated by high levels of sulfate, which typically originate from large Midwestern coal burning power plants. These plants produce significant emissions of NO_X and SO_X. As these emissions move downwind, much of the NO_X is transformed to ozone and much of the SO_X combines with available ammonium to form ammonium sulfate, the most abundant $PM_{2.5}$ species on those days. Ammonium sulfate is highly hygroscopic and leads to air masses with appreciable haze, detectable by visibility measurements and satellite images. These and other tools make it possible to use high $PM_{2.5}$ and sulfate levels as potential tracer species for ozone.

Figure 3.8 Time Series of Ozone and $PM_{2.5}$

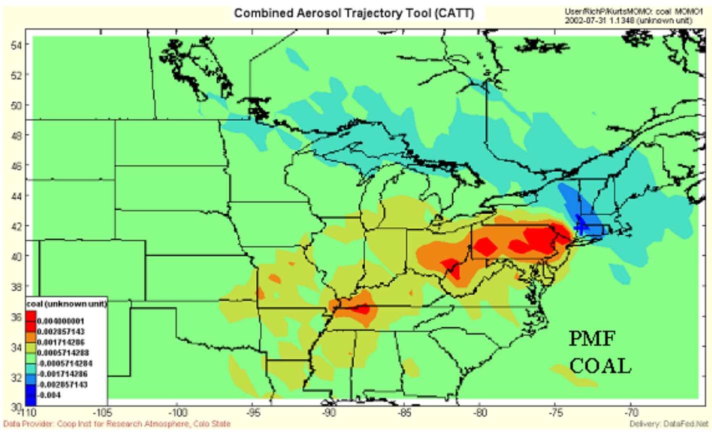


The Combined Aerosol Trajectory Tool[4] (CATT) is a relational database and query system allowing access to multiple measured aerosol and receptor model data sets along with gridded trajectory data. This resource facilitates pairing wind trajectories with aerosol data to help identify the location of sources of air pollutants that impair visibility. The results also provide useful insights into sources contributing to regional levels of $PM_{2.5}$ and as described above, ozone.

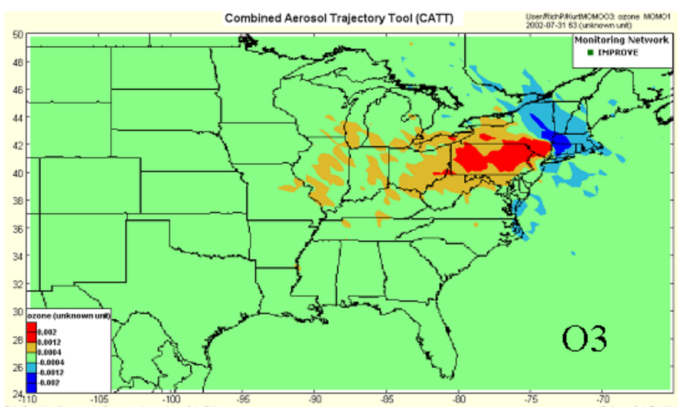
[4] Husar, R; "Combined Aerosol Trajectory Tool"; http://www.datafed.net/projects/CATT/CATT_Links.htm http://www.marama.org/visibility/NationalRPO/Presentations/Plenary/Husar%20-%20CATT%20&%20FASTNET%20Intro.pdf; 2007.

Using the CATT, high ozone and sulfate days were paired with their air mass source region. Incremental probability plots such as Figure 3.9 depict the likely source regions for high ozone and high sulfate. The incremental probability compares the number of trajectory passes through a grid cell, both the total and the number of events, when the target species (ozone or sulfate) is above a set threshold. The ratio of the two is taken and red choropleths are plotted where the ratio is high. Or, put another way, the cell is colored red when the probability is high that a back trajectory passed through a particular grid cell when the receptor concentration was high.

Figure 3.9 Source Regions of High Ozone and Sulfate



Mohawk Mt. Incremental probability plots for "PMF coal" and ozone. The high probability of high ozone in CT and trajectories passing through the red areas is high. These are regions of coal burning EGUs.



The target species on Figure 3.9 are ozone and a combination of species called "PMF coal". The Positive Matrix Factorization (PMF) model is a receptor model that breaks an observation of speciated PM into its source constituents.[5] A combination of constituents might be identified as coal combustion, oil combustion, wood smoke, crustal, industrial smelter, municipal waste combustion, etc. based on the ratio of indicator species. For coal burning plants, a ratio of sulfate, organic carbon, elemental carbon, selenium and many other species make up a unique profile for that source.

[5] Paatero, P; " Introduction to PMF - positively constrained factor analysis with individual weighting of matrix element"; ftp://rock.helsinki.fi/pub/misc/pmf/PMFINTRO.PDF; 2007

For Mohawk Mountain most trajectories on high ozone and high PMF coal days pass through Pennsylvania and the Ohio Valley, a region with many, large, coal-burning EGUs. This is noted by the coinciding red areas on the two plots, which suggest that the ozone transported to Mohawk Mountain was, in part, formed by the same sources' emitting the SO_X (later transformed to sulfate), probably coal burning EGUs.

3.2.3 Sea Breeze and Maritime Effects on Transport

Air masses over coastal waters provide another pathway for pollutants transported into Connecticut. Two examples, one traveling from the New York City/New Jersey/Eastern Pennsylvania region via Long Island Sound to Connecticut and the second from the Philadelphia area via the Atlantic Ocean to Connecticut, illustrate this phenomena.

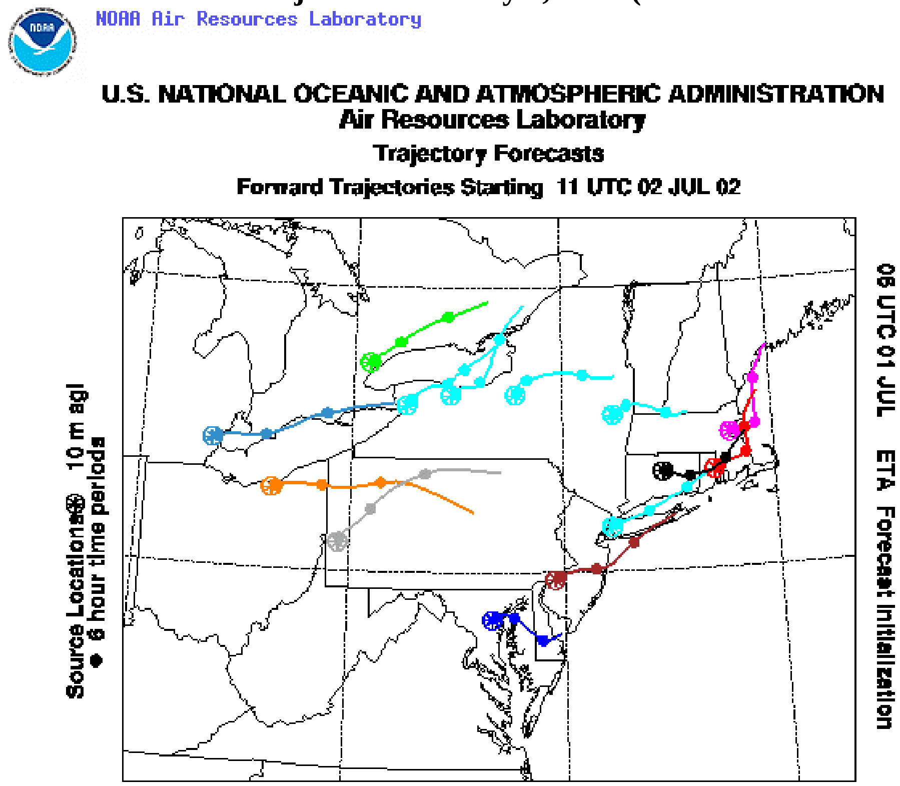
Figure 3.10 shows the forecasted forward trajectory originating in New York City on July 2, 2002 (light blue line), verifying the probable air mass path. The cold water acted to stabilize the lowest layer of the atmosphere, keeping mixing heights low, and concentrating pollutants. In the Long Island Sound (LIS) example (light blue line), strong geostrophic-synoptic westerly winds blew the ozone plume from the western to the eastern end of LIS on July 2, 2002. The ozone and ozone precursor plume originated in New York City/New Jersey/Eastern Pennsylvania and moved eastward. As the plume traversed east down Long Island Sound, the edges of the plume were blown inland by the sea breeze and detected by the coastal monitors. Figure 3.11 shows how closely the high concentration plume, shown in red and orange, hugged the coast, with a sharp concentration gradient inland (air quality in northern Connecticut is "good"). Figure 3.12 represents hourly still frames from an animation showing the progression of the ozone plume and each station's wind data every hour. The ozone plume (red circles) moved east with time as the sea breeze winds (southerly component) pulled ozone ashore. Note the wind at Madison was from the west, coinciding with the shore orientation at that point. (The monitor is on a peninsula that juts out into LIS.)

An Atlantic Ocean example occured on the same day. Figure 3.10 shows the forecasted forward trajectory out of Philadelphia (brown line). The plume blew across central New Jersey, out over the Atlantic and up towards eastern Long Island, southeast Connecticut, coastal Rhode Island and beyond. This second plume signature from July 2, 2002 resulted in the high concentration swath over eastern Long Island and coastal southern New England, as shown in Figure 3.11.

A second over-water scenario occurred on August 13, 2002. A pool of ozone moved just off the east coast as seen in the haze/smog plume in the satellite photo in Figure 3.13. The extended north-south (N-S) orientation is visible against the blue ocean on the far left side of the photo. Figure 3 is a re-projected image involving two separate satellite passes. It also shows the haze/ozone pool's orientation relative to major pollution sources and 3-level back trajectories for the period preceding the time of the image. This "pool" of ozone was oriented N-S off the coast and the low level back trajectory in Figure 3.15 is similarly oriented. The Bermuda high pressure weather system picked up this pool of ozone and transported it in concentrated form northward across the cold waters to CT. As seen in the ozone map in Figure 3.15, widespread ozone occurred from North Carolina through New England.

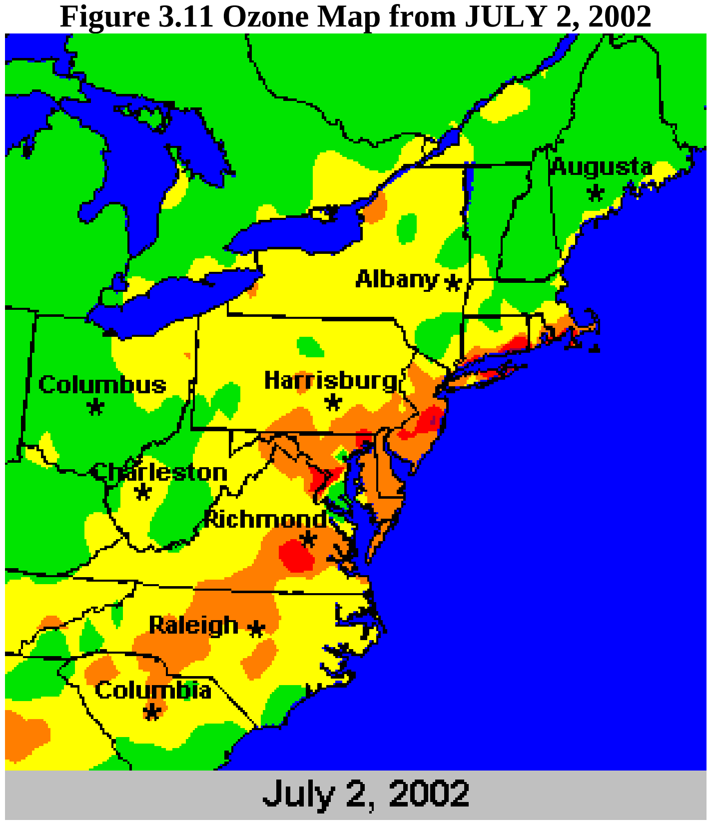
It is unusual for an Atlantic maritime air mass to result in high ozone for Connecticut. As seen in Figure 3.16, the $PM_{2.5}$ and ozone concentration peaks were in phase, verifying that the haze plume was also rich with ozone. Sulfate on the previous day was also high at the Mohawk Mountain site, suggesting that the visibility reduction seen on the satellite photo was due to residual sulfate aerosol from Midwestern power plants, accompanied by NO_X that contributed to ozone levels.

Figure 3.10 Forward Trajectories on July 2, 2002 (Sea Breeze Effect Day)



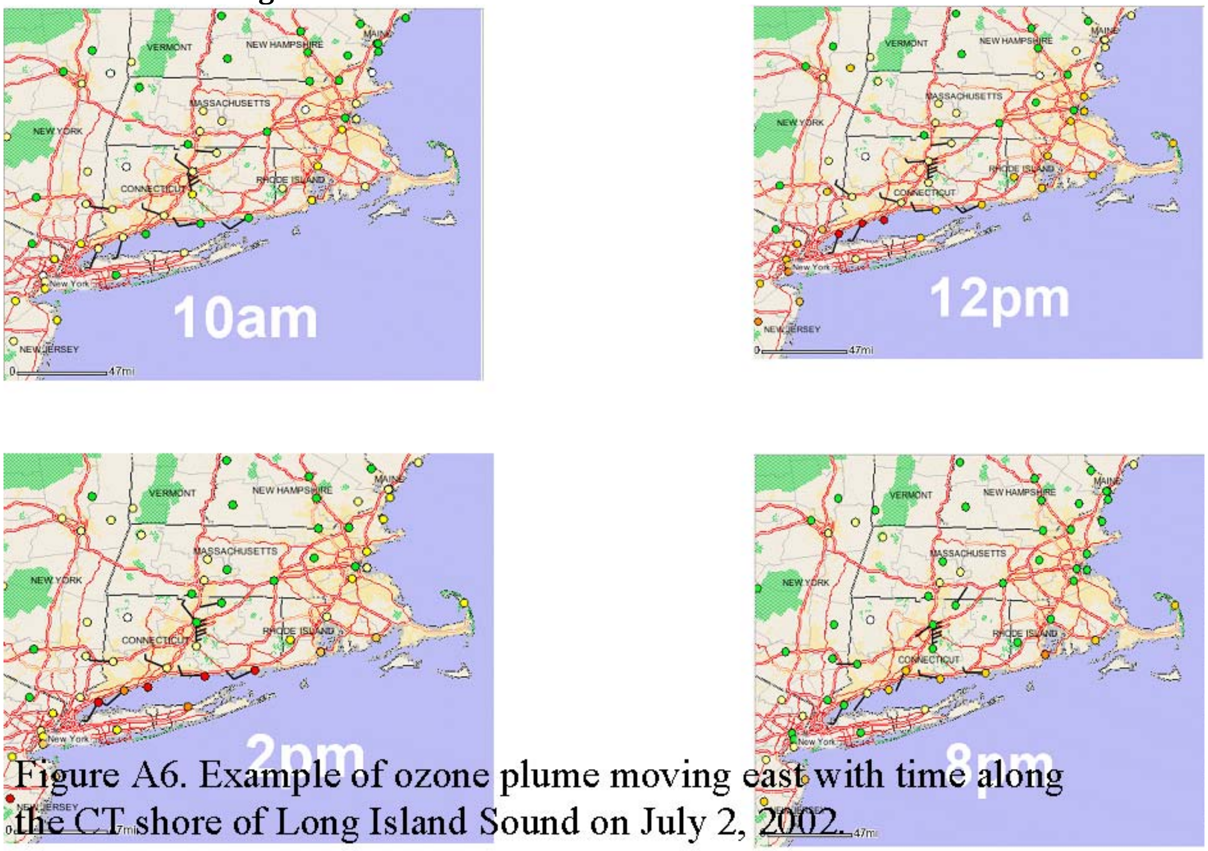
Source: Draxler, R.R. and Rolph, G.D., 2003; HYSPLIT (HYbrid Single-Particle Lagrangian Integrated Trajectory) Model; Accessed via NOAA ARL READY Website (http://www.arl.noaa.gov/ready/hysplit4.html); NOAA Air Resources Laboratory, Silver Spring, MD.

Figure 3.11 Ozone Map from JULY 2, 2002



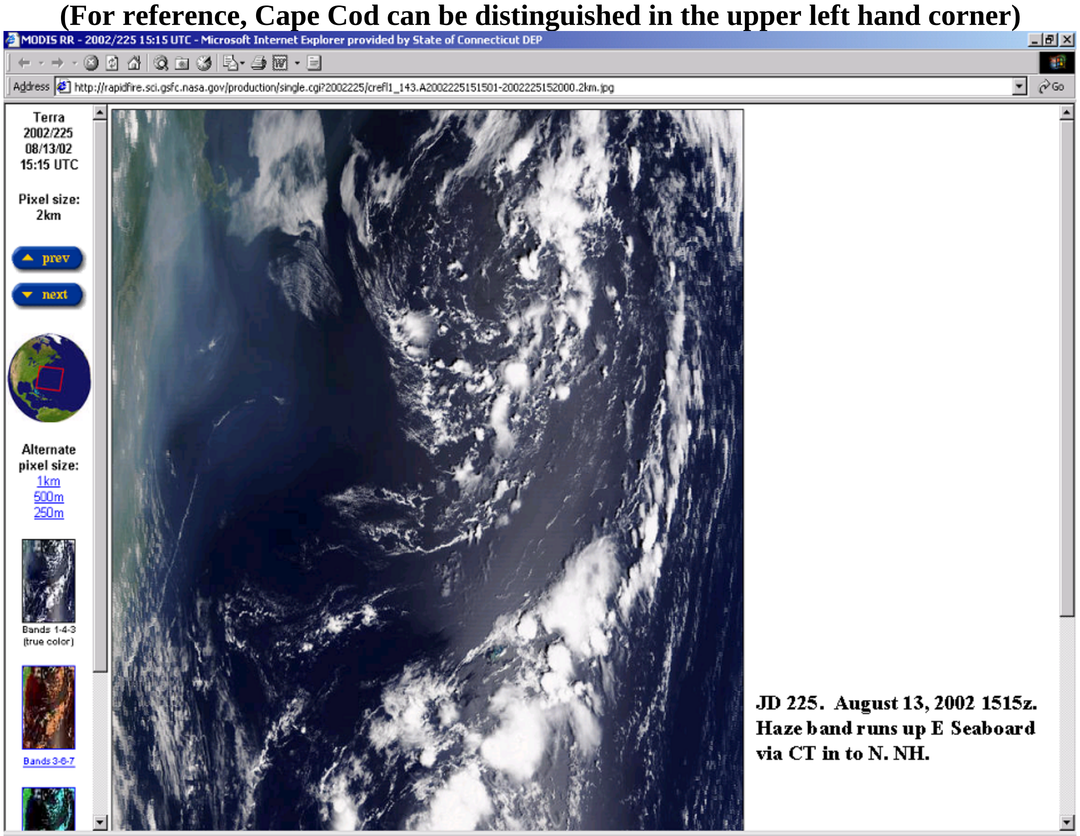
Source: EPA AIRNOW Air Quality Map Archive;
http://airnow.gov/index.cfm?action=airnow.displaymaps&StateID=8&Pollutant=OZONE

Figure 3.12 Sea Breeze Effect on CT Coastal Monitors



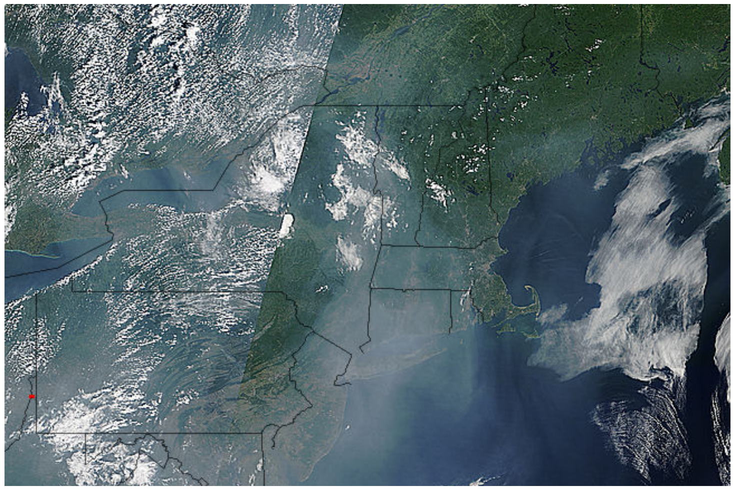
Note 1. Progression of 1hr values > 125 red dots, 85-124 orange dots, 2. wind barbs pointing toward sound (onshore breeze)

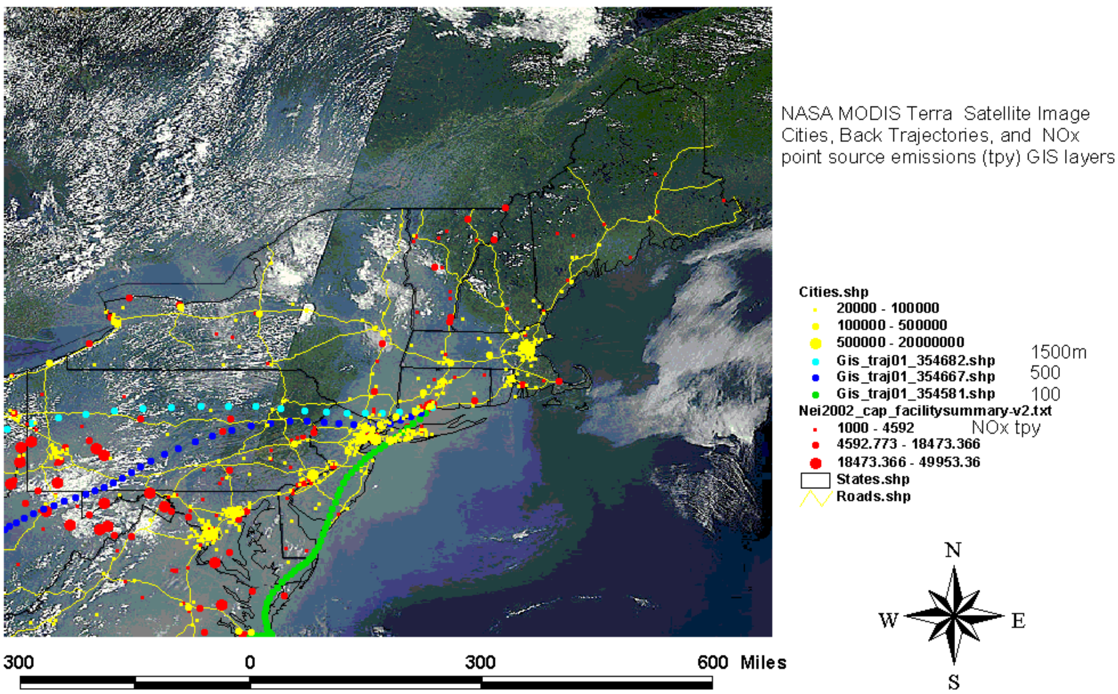
Figure 3.13 Satellite Image of Haze/Ozone Over the Eastern US and Adjacent Waters. (For reference, Cape Cod can be distinguished in the upper left hand corner)



Source: NASA; "MODIS Real-Time Rapid Response System" http://rapidfire.sci.gsfc.nasa.gov/realtime/?calendar.

Figure 3.14 NASA Re-Projected Images of Figure 3.13





Geo-referenced activity and inventory data (on top of the satellite images presented above) demonstrating the relationship between observed pollution and upper level winds (driving weather patterns from West to East), mid-level winds (tracking back to major point sources), and lower level winds (tracking back to major population centers along the East Coast).

]Figure 3.15 August 13, 2002, Ozone Map, Back Trajectories and Vertical Wind Profiles

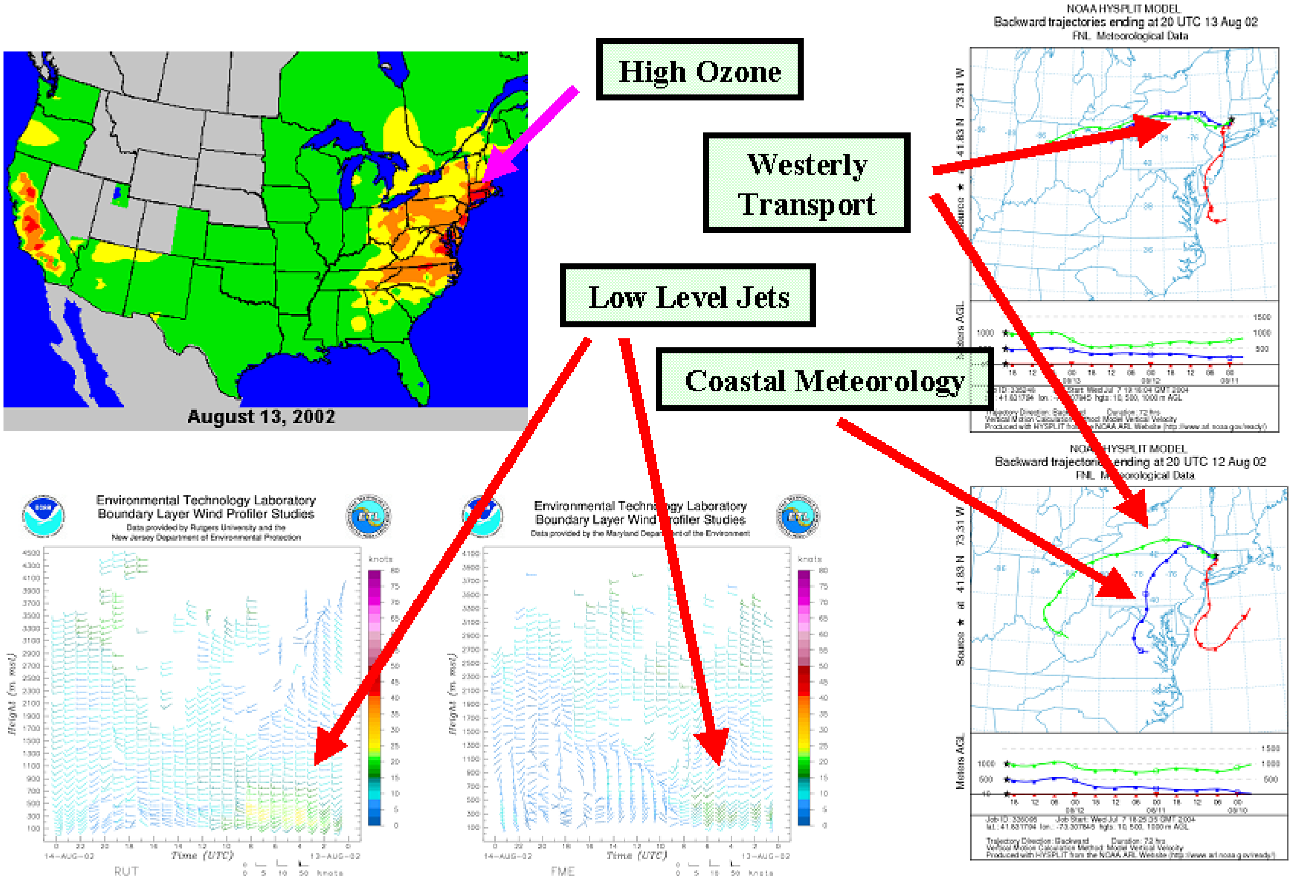
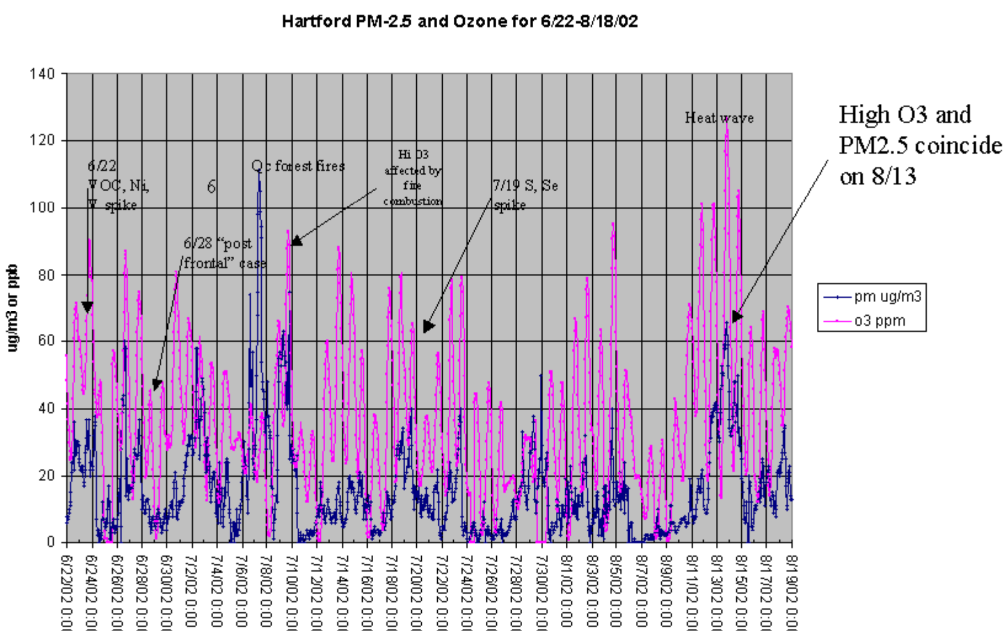


Figure 3.16 Times Series of Ozone and $PM_{2.5}$ at Hartford, CT (June 23 – August 19, 2002)



Figure