Future Modeling Platform Base Year Determination

Prepared by:

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- Dave Healy with the New Hampshire Department of Environmental Services for spending many hours helping with the processing of ozone and $PM_{2.5}$ data.

Thanks also to Martha Webster with the Maine Department of Environmental Protection for downloading ozone and $PM_{2.5}$ data from EPA's AQS database and creating maps for this report.

Executive Summary

In November 2012 Mid-Atlantic Northeast Visibility Union (MANE-VU) Directors charged the Executive Staff and the MANE-VU Technical Support Committee (TSC) to perform technical analyses in 2013 to determine the appropriate and most cost effective modeling base year for the next round of Regional Haze, $PM_{2.5}$ and Ozone State Implementation Plans (SIPs) and for more accurate multi-pollutant planning. The charge also called for the determination to take into account inventory development, meteorological and transport regimes as well as the most efficient use of state resources. The Base Year Workgroup was formed to complete this task.

The Base Year Workgroup analyzed Interagency Monitoring of Protected Visual Environments (IMPROVE) and certified Environmental Protection Agency (EPA) Air Quality System (AQS) data starting from the current 2007 modeling base year to 2012. The workgroup also analyzed meteorological data by season and meteorological conditions as well as the transport for ozone exceedance events in 2011. The focus region of the analyses was the Ozone Transport Region (OTR) but the workgroup also analyzed data for other regional planning areas in southern, mid-western and central states to see if all regional planning areas could have the same modeling base year. Preliminary results confirm that the current 2007 base year, 2010 and 2011 were the best candidate years to use for the future modeling platform base year. Since the MANE-VU Directors wanted a more recent year for future modeling, 2007 was eliminated. However, 2007 is confirmed to still be an appropriate base year for modeling currently being conducted for the 2008 Ozone NAAQS.

In making the final decision to use 2010 or 2011 as base years other factors were considered including:

- EPA guidance states that special consideration should be given to episodes with available “intensive databases” to ensure that aloft measurements and indicator and/or precursor species are available. During 2011, NASA conducted the DISCOVER-AQ project which could provide additional data to support modeling.
- Additionally, 2011 is the year for which states submitted their periodic National Emission Inventory (NEI) to EPA. Using a base year that allows the 2011 NEI to be employed in attainment modeling would allow for an already well developed inventory to be used with little additional cost (as compared to developing an inventory for a different base year). Also, the MANE-VU Commissioners’ charge to the workgroup placed emphasis on this factor.
- EPA has determined that 2011 will be the base year for the next round of transport modeling.
- It appears that other RPOs are planning on upgrading their modeling platforms to use a base year of 2011. Using a base year similar to other regions will allow for sharing of resources, collaboration on platform development, and higher quality emission inventories.

From the results of all analyses and other factors, 2011 is the best candidate base year for a future multi-pollutant modeling platform.

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1.0 Introduction

November 15, 2012 Charge to the Technical Support Committee for Work in 2013

The Mid-Atlantic Northeast Visibility Union (MANE-VU) directs the Executive Staff and the MANE-VU Technical Support Committee to perform technical analyses to help MANE-VU achieve substantial multi-pollutant emissions reductions in the most cost effective manner:

(1) Analysis of Updated Modeling Base Year.

A more recent year than 2007 will be necessary for use in the next round of Regional Haze SIPs, $PM_{2.5}$ SIPs, and Ozone SIPs, and for more accurate multi-pollutant planning. Given that inventory development takes several years to complete, the Committee should assess the appropriate base year for upcoming SIPs. The Technical Support Committee should review 2010, 2011, and 2012 as potential base years taking into account meteorological and transport regimes, as well as the most efficient use of state resources and coordination with other inventory efforts.

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The purpose of this report is to document data analyses for the determination of the base year for the next modeling platform. The platform is intended to be employed in multi-pollutant planning for the Ozone and Annual $PM_{2.5}$ NAAQS Regional Haze Rule SIP implementation timelines in Table 1. Analyses for other NAAQS iterations will continue to be completed using existing platforms.

TABLE 1: Implementation timelines

	Final NAAQS Date	Infrastructure SIP	Designations	SIPs Due	Attainment Dates
Ozone	2015*	2018*	2017*	2020*	2020* – 2037*
$PM_{2.5}$	Dec.2012	Dec.2015	Early 2015	Late2016	2021
Regional Haze	n/a	n/a	n/a	2018	2064

*Subject to change

Episode Selection

Factors that impact which base year should be selected for 8-hour Ozone , Annual $PM_{2.5}$ and Regional Haze modeling can be found in the EPA published document "Guidance on the Use of Models and Other Analyses for Demonstrating Attainment of Air Quality Goals for Ozone,

$PM_{2.5}$, and Regional Haze" in the section on episode selection. At a minimum, the following four criteria factors should be used to select time periods that are appropriate to model:

1) ***Simulate a variety of meteorological conditions:***
   a. ***8-Hour Ozone - Choose time periods which reflect a variety of meteorological conditions which frequently correspond with observed 8-hour daily maxima greater than the NAAQS at multiple monitoring sites.***
   b. ***Annual $PM_{2.5}$ - Choose time periods from each quarter which reflect the variety of meteorological conditions which represent average concentrations for that quarter and year***
   c. ***Regional Haze- Choose time periods which reflect the variety of meteorological conditions which represent visibility impairment on the 20% best and 20% worst days in the Class I areas being modeled.***
2) ***Model time periods in which observed concentrations are close to the appropriate baseline design value or visibility impairment.***
3) ***Model periods for which extensive air quality/meteorological data bases exist.***
4) ***Model a sufficient number of days so that the modeled attainment test applied at each monitor violating the NAAQS is based on multiple days (see section 14.1.1).***

Given the resources available for modeling, OTC will be conducting air quality modeling for a full year, so the question becomes whether or not the year to be modeled has the appropriate episodic conditions to meet these minimums proposed in the guidance.

Thresholds for Analysis

It should be noted that the current guidance is written for the older Ozone and $PM_{2.5}$ standards. When analyzing data to determine the base year for the next modeling platform, different thresholds were considered than those suggested in the current guidance. Considerations that need to be taken are as follows:

- **Ozone**
  The Ozone NAAQS are currently set at a value of 75 ppb, and were set at this level in 2008. The Clean Air Scientific Advisory Committee (CASAC) recommended in this previous evaluation that EPA consider values between 60 and 70 ppb. Since the Ozone NAAQS were last set in 2008, the Clean Air Act requires them to be reevaluated by 2013, at which point it is anticipated that EPA will set the Ozone NAAQS at a level in the recommended range from CASAC. Given the uncertainty as to what the level of the Ozone NAAQS will be when the future modeling platform is used, we recommend that Ozone NAAQS levels of 70 and 65ppb be analyzed, with priority going to 70ppb. Additionally, if one year is better for monitors that would be classified as moderate or

greater using a percentage above the standard, then that year would be given additional weighting. Final certified QA'd 2007-12 ozone data including flagged data from EPA's AQS database (May 6, 2013 download) were used in this report.

- **Annual Fine Particulate Matter ($PM_{2.5}$)**
  On December 14, 2012 EPA finalized an update to the $PM_{2.5}$ NAAQS. This revision update lowered the annual primary $PM_{2.5}$ NAAQS to 12 μg/m^3, while maintaining the 24-hour primary $PM_{2.5}$ NAAQS at 35 μ/m^3, the secondary $PM_{2.5}$ NAAQS at 15 μ/m^3, and the coarse PM standard also remained the same. Additionally, EPA will only designate nonattainment areas based on the updated annual primary $PM_{2.5}$ NAAQS so determinations of the base year for an updated modeling platform will be based solely on the year's meteorological impact on modeling the updated annual primary $PM_{2.5}$ NAAQS. Final certified QA'd 2007-12 FRM/FEM $PM_{2.5}$ data (pollutant code 88101) including flagged data from EPA's AQS database (May 6, 2013 download) were used in this report except for sites that have been identified not to be used for comparison with NAAQS.

- **Regional Haze**
  The regional haze program requires that improvements be made in visibility so that natural levels are achieved by 2064. The program uses the 20% worst and 20% best days (in deciviews) to determine progress. This analysis focuses on the 20% worst days. IMPROVE 2007-11 data from sites at Class I areas were used for this analysis. IMPROVE data for 2012 will not be available until late 2013 or early 2014. For 2012, 24-hour $PM_{2.5}$ concentrations from FRM/FEM sites closest to the IMPROVE sites were used as surrogates to identify the 20% worst days.

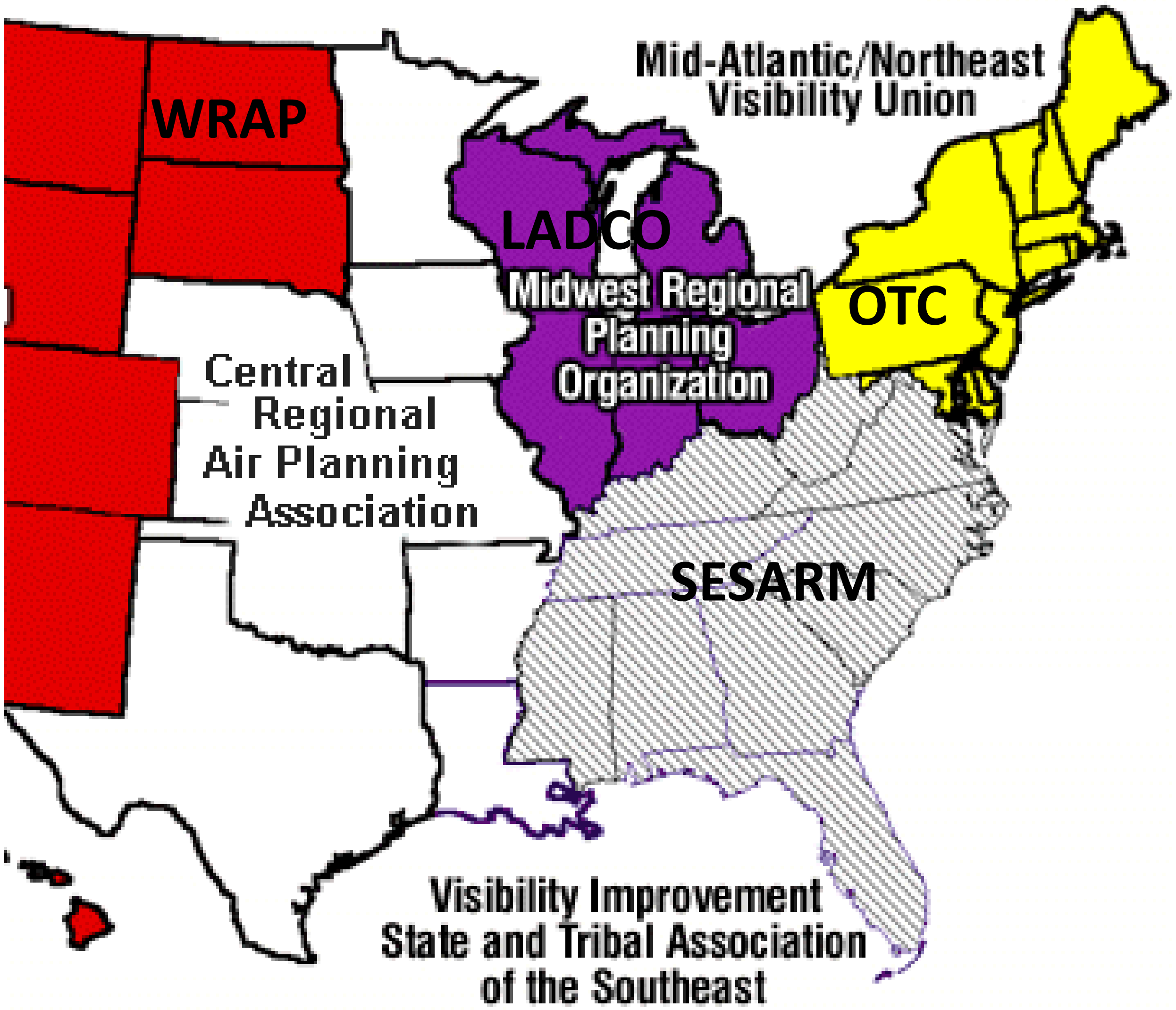
Analysis Years

It is important to consider data from several years when choosing an appropriate year for a base year to assure that the episodes within the year meet the requirements outlined in EPA guidance. It has been past practice for OTC/MANE-VU to review up to 5 years to determine the appropriate base year. Additionally, since SIP demonstrations would need to be complete by late 2016 for $PM_{2.5}$ any years later than 2012 could not be considered for that standard. Therefore, the years from 2007-2012 were considered. However, some years may be of relatively equal validity, in which case priority was given to more recent years.

Analysis Region

The primary focus of the analysis was on monitors within the Ozone Transport Region for Ozone plus nearby states for $PM_{2.5}$ and Regional Haze, since these monitors are the ones that will be used in an attainment demonstration or the 2018 Regional Haze SIP. Given that OTC is attempting to coordinate with nearby regions, analyzing adjacent regions in the inter-regional modeling domain (see Figure 1) in addition to the OTR was important to determine if OTC decisions should correspond with those of other RPOs. However, other RPO priorities for choosing a modeling base year may differ from ours so only the suitability of monitors in the OTR and Virginia carried a substantial weighting. Analyses for other regions will primarily be located in the Appendixes and more detailed factor analyses in this report will only be for the Ozone Transport Region.

Figure 1: Planning Organizations in the Inter-regional modeling domain



Meteorological Factors

Comparisons of surface temperature, 850mb temperature and heights, surface and upper air transport patterns, precipitation and soil moisture were analyzed. Also important transport patterns such as the presence of the nocturnal low level jet, bay breezes and transport into New England were considered. For ozone, the analysis was for the peak ozone season months of June to August. Meteorological analyses for $PM_{2.5}$ and Regional Haze are more complicated involving temperature inversions (especially in the winter), low mixing heights, dew point temperature and transport winds from source regions. For annual $PM_{2.5}$ and Regional Haze the analysis was for the entire year by meteorological season. Transport patterns and topography were used to combine nonattainment areas/Class I areas into as few analysis regions as necessary.

Other Factors

EPA guidance states that special consideration should be given to episodes with available "intensive databases" to ensure that aloft measurements and indicator and/or precursor species are available. During 2011 the DISCOVER-AQ project was conducted by NASA which could provide additional data to support modeling.

Additionally, 2011 corresponds to the year which states submitted their periodic National Emission Inventory to USEPA. Using a base year that allows the 2011 NEI to be employed in attainment modeling would allow for an already well developed inventory to be used with little additional cost (as compared to developing an inventory for a different base year). Also, the MANE-VU Commissioners' charge to the workgroup placed emphasis on this factor.

Finally, it appears that other RPOs and EPA are planning on upgrading their modeling platforms to use a base year of 2011. Using a base year similar to other regions will allow for sharing of resources, collaboration on platform development, and higher quality emission inventories.

These various factors should give additional weight when considering the use of 2011 as a base year.

2.0 Pollutant Monitoring Data Analyses

2.1 Ozone Analysis

Hourly 2007-12 ozone data (including flagged data) were downloaded from EPA's AQS database for all states east of the Rocky Mountains. Data handling conventions in 40 CFR 50 Appendix P were followed with changed cut points due to the level of the future potential standard. The final analyses were by counties so the Design Values and 4^{th} highs in a county reflect the maximum Design Values and 4^{th} highs of all the monitoring sites in that county. Maps of results are contained in Appendix A. Figures A-1 and A-10 show the resulting county 2010-12

Design Values for potential 65 ppb and 70 ppb 8-hour Ozone NAAQS in the large Inter-regional Modeling Domain. Potential nonattainment areas cover much of the domain including rural counties. Figures A-2 and A-7 zoom into the Ozone Transport Region (OTR) showing that the area of most concern to be able to meet a future standard continues to be the core of the OTR from Washington DC to coastal Southern New England with western areas in the OTR a second area of concern.

Since base year modeling will be for the entire ozone season the most important criteria factor in EPA's guidance to analyze is #4 – **"Model a sufficient number of days so that the modeled attainment test applied at each monitor violating the NAAQS is based on multiple days."** For this factor maps were created (see Appendix B) for each year showing the 4th highest 8-hour concentration and the number of days greater than the potential future NAAQS for all "violating" counties. For the OTR Figures B-25 to B-30 show results for counties with design values greater than 70 ppb. 2007 and 2010 are the years where most of the counties have at least 5 events. Figure 2a is a comparison of the ozone seasons in the OTR showing the percentage of counties for the potential future 70ppb NAAQS with more than 3 events, number of exceedance days and total number of county exceedance days. Results show that 2009 can be eliminated from base year consideration because only 35% of "violating" counties meet criteria factor #4. All other years have at least 85% of "violating" counties meeting the criteria factor with 2010 and 2012 having the highest percentages and thus being the best base year choices for the OTR when looking only at monitoring data. For 2011, 85% of the counties meet the criteria factor; however the remaining counties are in potential non-attainment areas that would most likely be classified as marginal not needing a modeling attainment demonstration.

After looking at OTR Ozone data analyses, the workgroup has determined that 2010, 2011 and 2012 are candidate base year choices. Another factor to consider is what other regional planning organizations (RPO's) may use for a base year. Figure 2b shows that 2010-12 are also potential base years for all combined RPO's. In fact other RPO's and EPA have already chosen 2011 for their base year. Other factors will be considered later in this report to determine the best base year for OTC/MANE-VU future multi-pollutant planning.

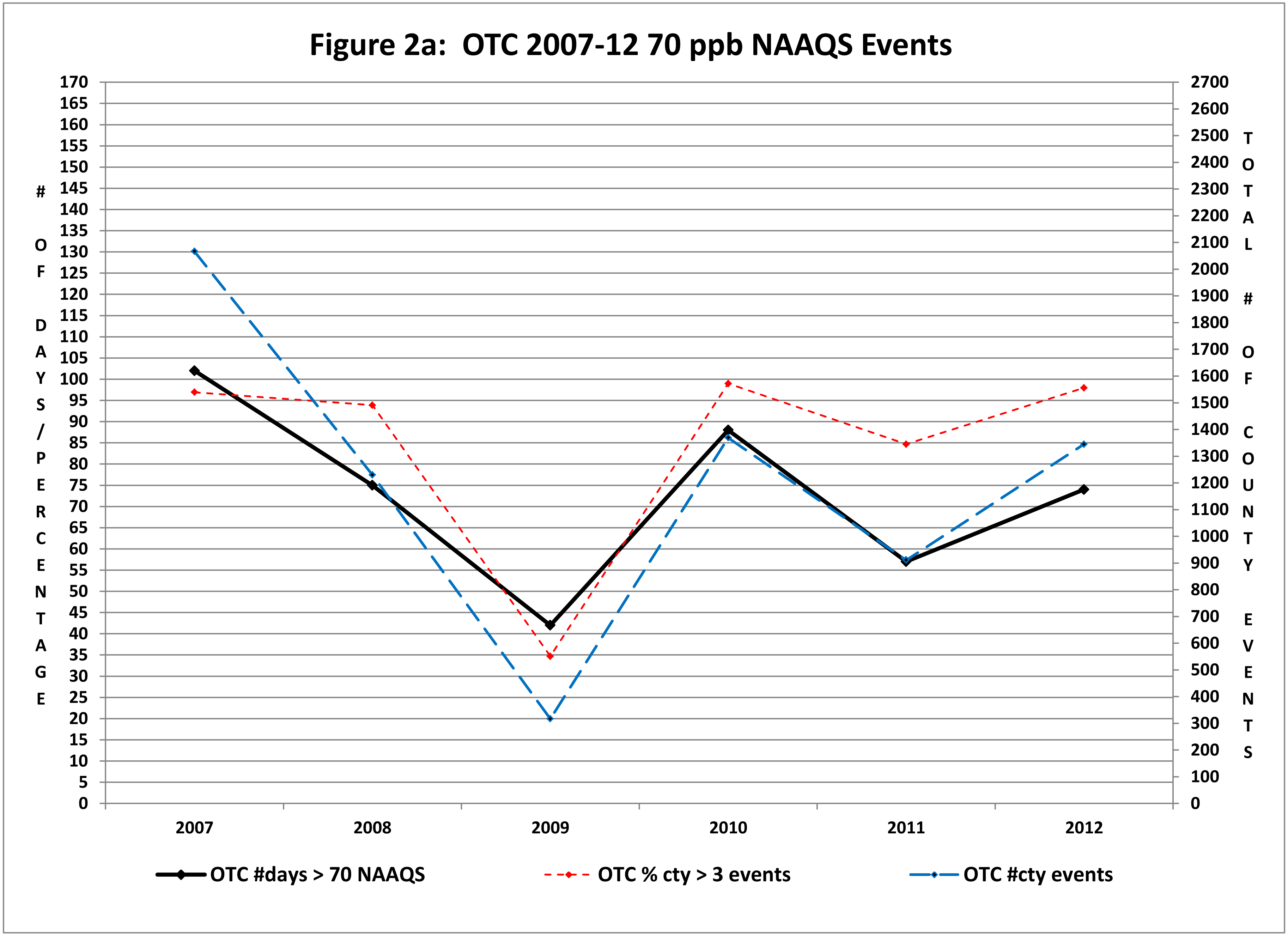


Figure 2a: OTC 2007-12 70 ppb NAAQS Events
OF DAYS / PERCENTAGE
TOTAL # OF COUNTY EVENTS
2007
2008
2009
2010
2011
2012
OTC #days > 70 NAAQS
OTC % cty > 3 events
OTC #cty events

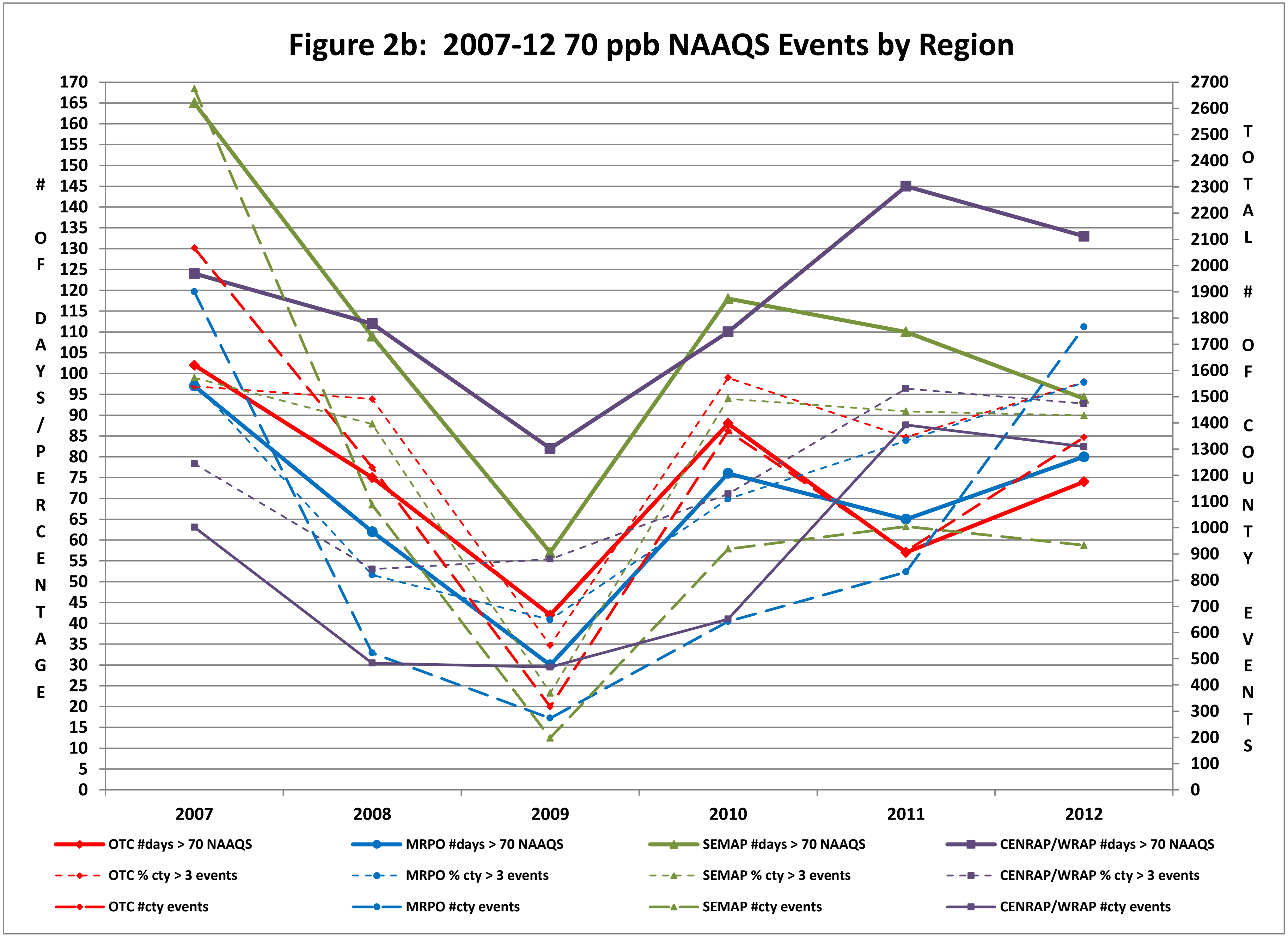


Figure 2b: 2007-12 70 ppb NAAQS Events by Region
OF DAYS / PERCENTAGE
TOTAL # OF COUNTY EVENTS
170
165
160
155
150
145
140
135
130
125
120
115
110
105
100
95
90
85
80
75
70
65
60
55
50
45
40
35
30
25
20
15
10
5
0
2700
2600
2500
2400
2300
2200
2100
2000
1900
1800
1700
1600
1500
1400
1300
1200
1100
1000
900
800
700
600
500
400
300
200
100
0
2007
2008
2009
2010
2011
2012
OTC #days > 70 NAAQS
MRPO #days > 70 NAAQS
SEMAP #days > 70 NAAQS
CENRAP/WRAP #days > 70 NAAQS
OTC % cty > 3 events
MRPO % cty > 3 events
SEMAP % cty > 3 events
CENRAP/WRAP % cty > 3 events
OTC #cty events
MRPO #cty events
SEMAP #cty events
CENRAP/WRAP #cty events

2.2 $PM_{2.5}$ Analysis

Hourly 2007-12 $PM_{2.5}$ data (including flagged data) were downloaded from EPA's AQS database for all states east of the Rocky Mountains. Data handling conventions in 40 CFR 50 Appendix N were followed. The final analyses shown in Appendix C and Appendix D were by counties so the Design Values, annual and seasonal values in a county reflect the maximum values of all the monitoring sites in that county. Figure C-1 shows the resulting 2010-12 annual Design Values for all counties in the large inter-regional domain. For the OTR only counties in Pennsylvania were violating the annual $PM_{2.5}$ NAAQS. The remaining analyses in Appendix C and D focus in on only those counties violating the NAAQS. Table 2 shows the 2010-12 annual $PM_{2.5}$ design values for violating counties in the OTR. Table 3 shows for those violating counties 2007-12 annual and seasonal (meteorological seasons) averages and percentage of days with 24-hour averages greater than the 12.0 $\mu g/m^3$ Annual $PM_{2.5}$ NAAQS. Figures C-2 to C-31 and Figures D-1 to D-30 also show the same for the OTR and other violating counties in the inter-regional domain. Results show that winter and summer seasons are the worst, with concentrations significantly being reduced for most counties during the summer season and half of those counties having 2012 summer and annual averages less than 12.0 $\mu g/m^3$. Results also show that, except for 2012, there are more than 25% of days over the NAAQS in each season of the year for all violating counties in the OTR thus 2011 is the best candidate base year for annual $PM_{2.5}$ NAAQS modeling.

Table 2: OTR Violating Counties $PM_{2.5}$ Annual NAAQS 2010-12 Design Values

State	CBSA	RPO	County Name	**Annual 2010-12 PM2.5 Design Values ($\mu g/m^3$)**
Pennsylvania	Allentown-Bethlehem-Easton, PA-NJ	OTC	Northampton	**13.2**
Pennsylvania	Johnstown, PA	OTC	Cambria	**12.3**
Pennsylvania	Lancaster, PA	OTC	Lancaster	**12.1**
Pennsylvania	Philadelphia-Camden-Wilmington, PA-NJ-DE-MD	OTC	Chester	**12.3**
Pennsylvania	Philadelphia-Camden-Wilmington, PA-NJ-DE-MD	OTC	Delaware	**12.9**
Pennsylvania	Philadelphia-Camden-Wilmington, PA-NJ-DE-MD	OTC	Philadelphia	**13.3**
Pennsylvania	Pittsburgh, PA	OTC	Allegheny	**14.8**
Pennsylvania	Pittsburgh, PA	OTC	Westmoreland	**12.7**

Table 3: OTR Annual $PM_{2.5}$ NAAQS 2007-12 Annual and Seasonal Comparisons

CBSA	PA COUNTY NAME	Annual Average (µg/m³)						% of Annual # days > 12.0µg/m³					
		2007	2008	2009	2010	2011	2012	2007	2008	2009	2010	2011	2012
Allentown-Bethlehem-Easton, PA-NJ	**Northampton**	**13.31**	**12.26**	**11.90**	**13.72**	**14.46**	**11.45**	**45.5%**	**40.6%**	**40.8%**	**49.7%**	**54.3%**	**43.0%**
Johnstown, PA	**Cambria**	**14.42**	**13.86**	**11.87**	**11.93**	**13.43**	**11.57**	**55.6%**	**56.6%**	**41.0%**	**42.6%**	**50.6%**	**40.4%**
Lancaster, PA	**Lancaster**	**15.40**	**13.93**	**12.19**	**11.72**	**12.01**	**12.59**	**58.1%**	**52.6%**	**42.9%**	**39.8%**	**40.4%**	**46.4%**
Philadelphia-Camden-Wilmington, PA-NJ-DE-MD	**Chester**	**14.07**	**13.68**	**14.07**	**13.79**	**13.23**	**9.78**	**52.2%**	**47.1%**	**54.2%**	**52.2%**	**47.1%**	**28.5%**
Philadelphia-Camden-Wilmington, PA-NJ-DE-MD	**Delaware**	**14.72**	**13.93**	**12.35**	**13.34**	**12.79**	**M**	**55.6%**	**53.6%**	**47.6%**	**49.0%**	**46.3%**	**M**
Philadelphia-Camden-Wilmington, PA-NJ-DE-MD	**Philadelphia**	**14.32**	**13.52**	**11.30**	**11.32**	**13.15**	**16.02**	**54.8%**	**55.5%**	**41.6%**	**40.5%**	**54.8%**	**71.0%**
Pittsburgh, PA	**Allegheny**	**18.88**	**17.00**	**15.02**	**16.34**	**14.00**	**14.29**	**66.6%**	**63.0%**	**58.4%**	**64.4%**	**59.8%**	**54.1%**
Pittsburgh, PA	**Westmoreland**	**15.26**	**12.67**	**13.52**	**13.95**	**M**	**10.58**	**50.4%**	**40.4%**	**49.3%**	**53.3%**	**M**	**34.2%**

CBSA	PA COUNTY NAME	Winter Season Average (µg/m³)						% of Winter # days > 12.0µg/m³					
		2007	2008	2009	2010	2011	2012	2007	2008	2009	2010	2011	2012
Allentown-Bethlehem-Easton, PA-NJ	**Northampton**	**13.60**	**13.84**	**12.82**	**12.77**	**16.20**	**13.09**	**50.6%**	**43.8%**	**44.9%**	**42.2%**	**59.1%**	**47.3%**
Johnstown, PA	**Cambria**	**12.48**	**13.30**	**12.22**	**12.42**	**17.38**	**11.90**	**44.8%**	**53.3%**	**37.5%**	**40.0%**	**68.4%**	**40.7%**
Lancaster, PA	**Lancaster**	**17.50**	**16.03**	**13.33**	**14.28**	**15.18**	**14.94**	**71.4%**	**58.6%**	**50.0%**	**45.7%**	**56.7%**	**58.2%**
Philadelphia-Camden-Wilmington, PA-NJ-DE-MD	**Chester**	**15.82**	**M**	**13.81**	**13.79**	**15.39**	**10.91**	**65.2%**	**M**	**47.6%**	**45.3%**	**63.9%**	**37.5%**
Philadelphia-Camden-Wilmington, PA-NJ-DE-MD	**Delaware**	**16.45**	**14.71**	**12.52**	**13.99**	**15.26**	**14.39**	**76.0%**	**57.1%**	**47.1%**	**44.4%**	**63.2%**	**62.5%**
Philadelphia-Camden-Wilmington, PA-NJ-DE-MD	**Philadelphia**	**15.06**	**14.05**	**12.77**	**12.76**	**14.80**	**15.45**	**61.1%**	**54.9%**	**54.4%**	**38.9%**	**72.2%**	**72.5%**
Pittsburgh, PA	**Allegheny**	**13.95**	**13.97**	**15.12**	**16.26**	**15.36**	**13.21**	**58.9%**	**62.6%**	**60.2%**	**61.1%**	**65.6%**	**54.9%**
Pittsburgh, PA	**Westmoreland**	**11.62**	**12.16**	**14.12**	**13.45**	**M**	**9.76**	**42.3%**	**33.3%**	**50.7%**	**56.1%**	**M**	**30.7%**

CBSA	PA COUNTY NAME	Spring Season Average (µg/m³)						% of Spring # days > 12.0µg/m³					
		2007	2008	2009	2010	2011	2012	2007	2008	2009	2010	2011	2012
Allentown-Bethlehem-Easton, PA-NJ	**Northampton**	**9.68**	**10.51**	**10.38**	**10.96**	**11.36**	**10.82**	**27.6%**	**35.9%**	**28.3%**	**34.8%**	**38.0%**	**51.1%**
Johnstown, PA	**Cambria**	**12.74**	**13.58**	**11.28**	**10.52**	**10.75**	**9.84**	**37.0%**	**54.8%**	**39.5%**	**36.3%**	**34.6%**	**33.7%**
Lancaster, PA	**Lancaster**	**13.40**	**12.69**	**12.00**	**9.67**	**9.95**	**11.98**	**45.2%**	**41.9%**	**40.4%**	**35.2%**	**26.1%**	**48.9%**
Philadelphia-Camden-Wilmington, PA-NJ-DE-MD	**Chester**	**12.67**	**12.30**	**10.74**	**10.48**	**10.80**	**8.39**	**48.0%**	**48.0%**	**29.1%**	**37.1%**	**31.0%**	**17.7%**
Philadelphia-Camden-Wilmington, PA-NJ-DE-MD	**Delaware**	**12.10**	**12.75**	**12.62**	**12.57**	**11.21**	**9.46**	**41.4%**	**42.3%**	**50.0%**	**50.0%**	**33.7%**	**25.3%**
Philadelphia-Camden-Wilmington, PA-NJ-DE-MD	**Philadelphia**	**11.57**	**11.72**	**11.07**	**9.70**	**9.19**	**13.67**	**40.4%**	**45.7%**	**37.0%**	**35.9%**	**27.2%**	**54.3%**
Pittsburgh, PA	**Allegheny**	**16.56**	**15.13**	**12.90**	**14.90**	**12.48**	**14.05**	**56.5%**	**52.2%**	**46.7%**	**54.3%**	**53.3%**	**42.9%**
Pittsburgh, PA	**Westmoreland**	**13.50**	**11.38**	**10.62**	**13.05**	**11.97**	**10.52**	**35.5%**	**39.3%**	**33.3%**	**51.6%**	**36.9%**	**30.4%**

Table 3 (cont.): OTR Annual $PM_{2.5}$ NAAQS 2007-12 Annual and Seasonal Comparisons

CBSA	PA COUNTY NAME	Summer Season Average (µg/m³)						% of Summer # days > 12.0µg/m³					
		2007	2008	2009	2010	2011	2012	2007	2008	2009	2010	2011	2012
Allentown-Bethlehem-Easton, PA-NJ	**Northampton**	**17.79**	**15.14**	**14.09**	**17.00**	**19.16**	**11.35**	**63.4%**	**53.4%**	**59.8%**	**72.5%**	**80.4%**	**42.4%**
Johnstown, PA	**Cambria**	**19.96**	**16.51**	**13.99**	**15.16**	**15.92**	**14.16**	**79.2%**	**67.7%**	**56.5%**	**64.1%**	**67.8%**	**57.5%**
Lancaster, PA	**Lancaster**	**17.40**	**15.89**	**13.82**	**13.59**	**12.99**	**12.02**	**71.0%**	**62.1%**	**59.1%**	**54.0%**	**47.3%**	**46.7%**
Philadelphia-Camden-Wilmington, PA-NJ-DE-MD	**Chester**	**M**	**16.82**	**16.94**	**18.25**	**15.68**	**10.46**	**M**	**69.0%**	**73.9%**	**77.9%**	**62.2%**	**32.1%**
Philadelphia-Camden-Wilmington, PA-NJ-DE-MD	**Delaware**	**19.21**	**16.23**	**14.35**	**16.32**	**14.40**	**M**	**66.7%**	**67.7%**	**64.2%**	**70.8%**	**57.1%**	**M**
Philadelphia-Camden-Wilmington, PA-NJ-DE-MD	**Philadelphia**	**17.69**	**18.06**	**12.56**	**13.82**	**14.72**	**18.55**	**69.2%**	**79.3%**	**53.3%**	**63.0%**	**57.6%**	**84.8%**
Pittsburgh, PA	**Allegheny**	**23.74**	**20.52**	**16.22**	**20.90**	**16.72**	**15.57**	**79.3%**	**79.3%**	**75.0%**	**85.9%**	**72.3%**	**67.4%**
Pittsburgh, PA	**Westmoreland**	**21.68**	**16.41**	**17.56**	**18.74**	**19.32**	**12.53**	**69.0%**	**64.3%**	**74.7%**	**80.2%**	**85.9%**	**47.8%**
		Fall Season Average (µg/m³)						**% of Fall # days > 12.0µg/m³**					
		2007	**2008**	**2009**	**2010**	**2011**	**2012**	**2007**	**2008**	**2009**	**2010**	**2011**	**2012**
Allentown-Bethlehem-Easton, PA-NJ	**Northampton**	**12.65**	**9.73**	**10.35**	**14.23**	**11.93**	**10.63**	**41.8%**	**29.7%**	**31.0%**	**49.5%**	**39.6%**	**31.1%**
Johnstown, PA	**Cambria**	**13.39**	**12.12**	**9.87**	**9.60**	**9.53**	**10.08**	**64.3%**	**50.0%**	**29.7%**	**29.7%**	**31.8%**	**28.2%**
Lancaster, PA	**Lancaster**	**13.21**	**11.28**	**9.31**	**9.51**	**9.94**	**11.43**	**44.4%**	**48.0%**	**24.2%**	**25.6%**	**31.9%**	**31.9%**
Philadelphia-Camden-Wilmington, PA-NJ-DE-MD	**Chester**	**12.31**	**10.47**	**14.86**	**13.10**	**10.40**	**9.37**	**50.0%**	**29.6%**	**63.9%**	**48.4%**	**31.6%**	**25.3%**
Philadelphia-Camden-Wilmington, PA-NJ-DE-MD	**Delaware**	**11.52**	**11.49**	**10.03**	**10.42**	**10.56**	**M**	**40.7%**	**44.4%**	**30.8%**	**30.2%**	**33.0%**	**M**
Philadelphia-Camden-Wilmington, PA-NJ-DE-MD	**Philadelphia**	**12.63**	**10.66**	**8.91**	**9.17**	**14.52**	**16.47**	**48.4%**	**41.8%**	**22.0%**	**24.2%**	**62.6%**	**72.5%**
Pittsburgh, PA	**Allegheny**	**21.33**	**18.35**	**15.82**	**15.49**	**14.09**	**14.39**	**71.4%**	**57.8%**	**51.2%**	**56.0%**	**48.9%**	**50.6%**
Pittsburgh, PA	**Westmoreland**	**14.08**	**10.48**	**11.85**	**10.72**	**12.48**	**9.47**	**55.2%**	**25.0%**	**37.4%**	**28.6%**	**41.4%**	**27.5%**

M = Less than 75% data recovery rate

2.3 Regional Haze Analysis

Regional haze 2007-11 data from IMPROVE monitoring sites were downloaded from the Federal Land Manager Database (FED) for all Class I areas in the large inter-regional Domain (see Figure 3). Procedures in Chapter 2 of EPA's "Guidance for Tracking Progress under the Regional Haze Rule" were followed to calculate the results in this report. Important 20% worst day statistics that were calculated included annual and seasonal (meteorological seasons) deciviews and percentage of the number of worst days in a season. Table 4 contains a detailed summary of the results for the 20% worst visibility days for all Class I areas in Virginia, West Virginia and the MANE-VU region. Maps of results for all Class I areas in the large modeling domain are in Appendix E and Appendix F. Because 2012 IMPROVE data is not yet available, data from surrogate $PM_{2.5}$ FEM/FRM monitoring sites were also analyzed to determine 2007-12 20% worst $PM_{2.5}$ concentration days. Table 4 2012 data only includes the percentage of 20% worst $PM_{2.5}$ concentration days for a comparison with the 2007-11 IMPROVE results. Results of the full surrogate analyses for Class I areas in Virginia, West Virginia and the MANE-VU region are in Table 5. Maps of the full surrogate analyses results for all Class I areas in the large modeling domain are in Appendix G and Appendix H.

Figure 3: U.S. Modeling Domain with Class 1 Areas

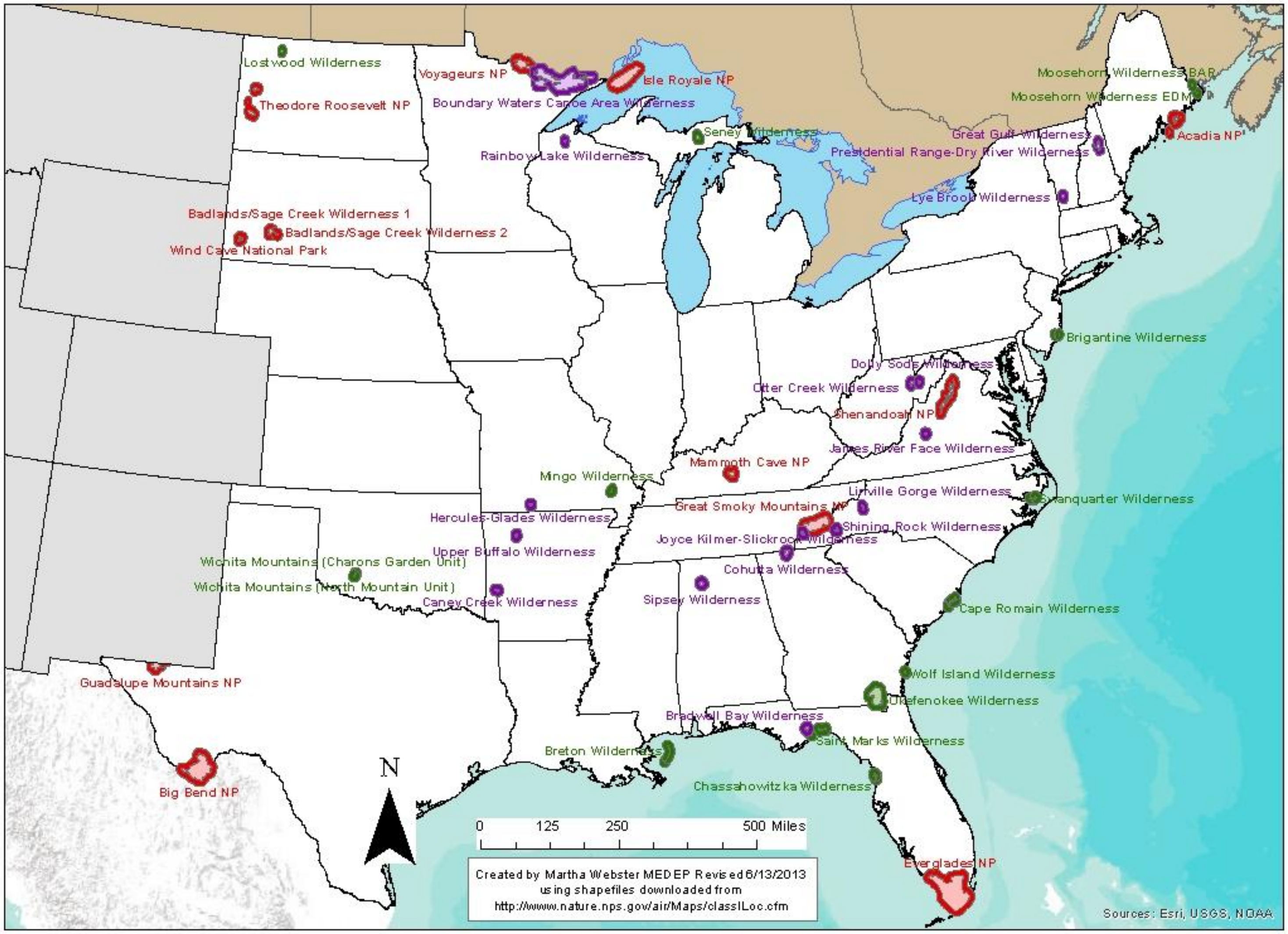


Table 4: MANE-VU, VA and WVA Regional Haze 20% Worst Visibility Day Analysis

Class I Area Coverage	Year	20% Worst DV	WINTER %	SPRING %	SUMMER %	FALL %	WINTER DV	SPRING DV	SUMMER DV	FALL DV
MANE-VU RPO										
Acadia National Park	2007	21.74490	12.5%	29.2%	37.5%	20.8%	19.84	20.33	24.25	20.37
ACAD1	2008	20.20503	4.0%	12.0%	64.0%	20.0%	26.53	20.21	20.42	18.25
	2009	18.93400	20.0%	28.0%	36.0%	16.0%	18.13	18.64	20.35	17.26
	2010	18.16314	12.5%	16.7%	50.0%	20.8%	14.92	17.67	18.47	19.78
	2011	18.80460	25.0%	4.2%	37.5%	33.3%	18.24	17.56	19.29	18.84
23-009-0103 McFarland Hill $PM_{2.5}$	2012		**12.5%**	**25.0%**	**45.8%**	**16.7%**				
Moosehorn NWR	2007	19.24372	13.0%	30.4%	39.1%	17.4%	17.86	18.19	20.94	18.31
Roosevelt Campobello IP	2008	18.72864	16.7%	20.8%	54.2%	8.3%	18.02	17.50	19.41	18.79
MOOS1	2009	17.71455	25.0%	29.2%	29.2%	16.7%	16.99	17.11	20.02	15.82
	2010	17.09115	16.7%	12.5%	54.2%	16.7%	14.51	17.16	16.95	20.08
	2011	17.06954	21.7%	0.0%	43.5%	34.8%	16.82	---	17.10	17.19
23-009-0103 McFarland Hill $PM_{2.5}$	2012		**12.5%**	**25.0%**	**45.8%**	**16.7%**				
Great Gulf Wilderness	2007	21.34845	8.7%	21.7%	43.5%	26.1%	17.99	20.50	22.56	21.16
Presidential Range-Dry River Wilderness	2008	16.77740	4.5%	27.3%	40.9%	27.3%	15.54	15.89	17.38	16.97
GRGU1	2009									
	2010									
	2011	18.95670	28.6%	9.5%	42.9%	19.0%	16.54	18.64	20.84	18.49
33-001-2004 Laconia $PM_{2.5}$	2012		**16.7%**	**16.7%**	**41.7%**	**25.0%**				
Lye Brook Wilderness	2007	25.25052	4.8%	19.0%	52.4%	23.8%	19.60	22.99	26.13	26.26
LYBR1	2008									
	2009	18.43730	9.5%	42.9%	38.1%	9.5%	18.95	17.26	20.41	15.34
	2010	19.88139	13.0%	30.4%	52.2%	4.3%	16.08	17.12	21.64	29.48
	2011	19.47054	10.0%	15.0%	35.0%	40.0%	16.85	18.07	21.91	18.51
Bennington 50-003-0004 $PM_{2.5}$	2012		**27.3%**	**36.4%**	**18.2%**	**18.2%**				
Brigantine Wilderness	2007	26.90959	17.4%	17.4%	56.5%	8.7%	25.72	25.47	27.74	26.77
BRIG1	2008									
	2009	24.25019	20.8%	33.3%	37.5%	8.3%	23.73	23.91	24.83	24.29
	2010	25.21601	28.0%	12.0%	40.0%	20.0%	25.65	23.61	25.84	24.32
	2011	25.77788	21.7%	13.0%	65.2%		25.31	25.44	26.00	
Brigantine 34-001-0006 $PM_{2.5}$	2012		**16.7%**	**8.3%**	**50.0%**	**25.0%**				

Table 4 (cont.): MANE-VU, VA and WVA Regional Haze 20% Worst Visibility Day Analysis

Class I Area Coverage	Year	20% Worst DV	WINTER %	SPRING %	SUMMER %	FALL %	WINTER DV	SPRING DV	SUMMER DV	FALL DV
VISTAS RPO										
Shenandoah NP	2007	28.79225		20.8%	62.5%	16.7%		27.84	29.13	28.71
SHEN1	2008	25.64841	4.0%	8.0%	68.0%	20.0%	23.41	22.74	26.56	24.17
	2009	21.81040	8.3%	16.7%	58.3%	16.7%	19.23	21.05	22.43	21.68
	2010	23.43899	13.0%	17.4%	52.2%	17.4%	21.84	21.53	24.82	22.40
	2011	23.42390	8.3%	12.5%	75.0%	4.2%	20.40	22.24	23.70	27.99
Page Co 51-139-0004 $PM_{2.5}$	2012		**36.0%**	**4.0%**	**36.0%**	**24.0%**				
James River Face Wilderness	2007	28.47256	4.2%	20.8%	58.3%	16.7%	27.37	28.10	28.52	29.04
JAR1	2008	25.51637	16.7%	12.5%	50.0%	20.8%	26.56	23.15	26.14	24.60
	2009	22.93128	16.7%	12.5%	50.0%	20.8%	22.52	21.82	23.41	22.78
	2010	23.86366	25.0%	8.3%	58.3%	8.3%	23.83	22.99	24.13	22.99
	2011	24.29448	20.8%	12.5%	62.5%	4.2%	24.00	22.36	24.61	26.82
Lynchburg 51-680-0015 $PM_{2.5}$	2012		**4.3%**	**26.1%**	**56.5%**	**13.0%**				
Dolly Sods Wilderness	2007	29.51565	0.0%	20.8%	54.2%	25.0%	---	29.09	30.27	28.23
Otter Creek Wilderness	2008	25.38667	0.0%	12.5%	66.7%	20.8%	---	23.58	25.56	25.93
DOSO1	2009	22.16685	0.0%	8.3%	79.2%	12.5%	---	21.69	22.20	22.31
	2010	23.94369	8.3%	25.0%	58.3%	8.3%	22.17	22.46	24.89	23.56
	2011	24.43501	4.2%	16.7%	70.8%	8.3%	21.56	23.03	24.73	26.15
Morgantown 54-061-0003 $PM_{2.5}$	2012		**8.3%**	**16.7%**	**58.3%**	**16.7%**				

% =percentage of 20% worst days in a season

DV = deciview

2012 $PM_{2.5}$ Surrogate Regional Haze site

Highest for each year

unacceptable data recovery rate

Table 5: MANE-VU, VA and WVA Regional Haze $PM_{2.5}$ Surrogate 20% Worst Visibility Day Analysis

Class I Area Coverage	Year	Annual average	20% Worst average	WINTER %	SPRING %	SUMMER %	FALL %	WINTER average	SPRING average	SUMMER average	FALL average
MANE-VU RPO											
Acadia National Park	2007	5.83293	12.61765	0.0%	29.4%	58.8%	11.8%	---	10.84	14.11	9.60
ACAD1	2008	5.05765	10.77059	5.9%	11.8%	76.5%	5.9%	18.60	9.10	10.63	8.10
	2009	4.10990	8.88095	4.8%	23.8%	52.4%	19.0%	9.50	8.22	9.75	7.15
	2010	4.33967	10.18000	4.0%	16.0%	68.0%	12.0%	7.30	8.98	9.96	14.00
$PM_{2.5}$ Surrogate 2007-12 site	2011	4.91017	9.87500	20.8%	4.2%	37.5%	37.5%	8.94	8.20	10.81	9.64
23-009-0103 McFarland Hill $PM_{2.5}$	2012	4.69746	8.85000	12.5%	25.0%	45.8%	16.7%	8.27	8.75	9.52	7.60
Moosehorn NWR	2007	5.83293	12.61765	0.0%	29.4%	58.8%	11.8%	---	10.84	14.11	9.60
Roosevelt Campobello IP	2008	5.05765	10.77059	5.9%	11.8%	76.5%	5.9%	18.60	9.10	10.63	8.10
MOOS1	2009	4.10990	8.88095	4.8%	23.8%	52.4%	19.0%	9.50	8.22	9.75	7.15
	2010	4.33967	10.18000	4.0%	16.0%	68.0%	12.0%	7.30	8.98	9.96	14.00
$PM_{2.5}$ Surrogate 2007-12 site	2011	4.91017	9.87500	20.8%	4.2%	37.5%	37.5%	8.94	8.20	10.81	9.64
23-009-0103 McFarland Hill $PM_{2.5}$	2012	4.69746	8.85000	12.5%	25.0%	45.8%	16.7%	8.27	8.75	9.52	7.60
Great Gulf Wilderness	2007	6.77500	13.40000	14.3%	7.1%	50.0%	28.6%	9.95	15.90	13.11	15.00
Presidential Range-Dry River Wilderness	2008	6.12295	10.79231	23.1%	23.1%	46.2%	7.7%	14.33	9.03	9.87	11.00
GRGU1	2009	6.04833	12.37500	16.7%	25.0%	41.7%	16.7%	14.05	9.20	14.94	9.05
	2010	5.40492	12.53077	7.7%	15.4%	61.5%	15.4%	7.90	13.85	13.63	9.15
$PM_{2.5}$ Surrogate 2007-12 site	2011	5.99123	11.57500	33.3%	16.7%	41.7%	8.3%	10.10	12.20	12.76	10.30
33-001-2004 Laconia $PM_{2.5}$	2012	6.67719	13.22500	16.7%	16.7%	41.7%	25.0%	13.20	15.40	12.80	12.50
Lye Brook Wilderness	2007	8.27692	19.13333	8.3%	25.0%	50.0%	16.7%	16.90	16.25	20.23	21.28
LYBR1	2008	7.33000	13.95000	33.3%	12.5%	45.8%	8.3%	12.66	11.20	15.85	12.75
	2009	6.45167	12.35417	37.5%	29.2%	20.8%	12.5%	12.43	10.77	14.78	11.77
	2010	6.92500	15.53333	25.0%	16.7%	45.8%	12.5%	16.67	12.73	15.98	15.37
$PM_{2.5}$ Surrogate 2007-12 site	2011	7.06226	14.47727	36.4%	9.1%	50.0%	4.5%	15.25	11.95	14.67	11.20
Bennington 50-003-0004 $PM_{2.5}$	2012	6.72430	12.20455	27.3%	36.4%	18.2%	18.2%	11.47	12.11	14.58	11.13
Brigantine Wilderness	2007	10.86989	22.71579	10.5%	5.3%	78.9%	5.3%	17.50	18.20	23.76	22.00
BRIG1	2008	10.23093	19.57500	20.0%	15.0%	65.0%	0.0%	15.33	18.40	21.15	---
	2009	7.93952	14.79200	24.0%	32.0%	36.0%	8.0%	13.65	14.45	15.34	17.10
	2010	8.42857	16.82800	24.0%	12.0%	52.0%	12.0%	18.17	14.80	17.08	15.07
$PM_{2.5}$ Surrogate 2007-12 site	2011	8.68246	17.01304	21.7%	4.3%	73.9%	0.0%	15.22	14.60	17.68	---
Brigantine 34-001-0006 $PM_{2.5}$	2012	7.59160	13.56667	16.7%	8.3%	50.0%	25.0%	11.48	13.10	14.80	12.65

Table 5 (cont.): MANE-VU, VA and WVA Regional Haze $PM_{2.5}$ Surrogate 20% Worst Visibility Day Analysis

Class I Area Coverage	Year	Annual average	20% Worst average	WINTER %	SPRING %	SUMMER %	FALL %	WINTER average	SPRING average	SUMMER average	FALL average
VISTAS RPO											
Shenandoah NP	2007	12.53898	23.33333	16.7%	25.0%	41.7%	16.7%	22.63	22.73	23.89	23.55
SHEN1	2008	10.47119	18.53750	16.7%	20.8%	45.8%	16.7%	18.20	15.98	20.36	17.05
	2009	8.82328	15.70833	45.8%	20.8%	25.0%	8.3%	17.26	14.80	13.92	14.80
	2010	10.24016	17.87917	50.0%	4.2%	37.5%	8.3%	18.62	17.10	17.40	16.00
$PM_{2.5}$ Surrogate 2007-12 site	2011	8.67143	16.05000	37.5%	8.3%	50.0%	4.2%	15.47	17.15	15.83	21.80
Page Co 51-139-0004 $PM_{2.5}$	2012	8.32167	13.92400	36.0%	4.0%	36.0%	24.0%	14.77	14.00	13.87	12.73
James River Face Wilderness	2007	13.22632	24.16522	8.7%	21.7%	56.5%	13.0%	22.50	22.48	24.95	24.67
JAR1	2008	10.02881	17.70800	12.0%	16.0%	60.0%	12.0%	19.50	14.45	18.60	15.80
	2009	8.38115	14.32400	28.0%	20.0%	44.0%	8.0%	13.16	11.82	15.47	18.35
	2010	9.80427	16.68750	16.7%	16.7%	54.2%	12.5%	16.13	14.65	17.72	15.67
$PM_{2.5}$ Surrogate 2007-12 site	2011	8.38393	14.84783	21.7%	21.7%	47.8%	8.7%	13.86	13.42	15.54	17.10
Lynchburg 51-680-0015 $PM_{2.5}$	2012	7.60348	12.96957	4.3%	26.1%	56.5%	13.0%	10.40	12.80	13.41	12.27
Dolly Sods Wilderness	2007	14.79661	28.26667	4.2%	20.8%	58.3%	16.7%	23.60	27.10	28.85	28.85
Otter Creek Wilderness	2008	12.60598	21.80417	8.3%	16.7%	54.2%	20.8%	19.70	18.85	22.85	22.30
DOSO1	2009	10.74758	18.35833	26.4%	9.7%	50.0%	13.9%	17.65	17.81	18.93	18.01
	2010	11.31695	19.17917	12.5%	16.7%	66.7%	4.2%	19.00	18.05	19.69	16.00
$PM_{2.5}$ Surrogate 2007-12 site	2011	10.63884	19.70400	16.0%	16.0%	56.0%	12.0%	16.20	17.65	21.24	19.93
Morgantown 54-061-0003 $PM_{2.5}$	2012	8.84602	14.68333	8.3%	16.7%	58.3%	16.7%	13.50	13.60	15.06	15.03

% =percentage of 20% worst days in a season
Average = $PM_{2.5}$ concentration average (µg/m³)

Summer is the worst season for visibility for most of the years at sites in and near the MANE-VU region. As shown in the $PM_{2.5}$ results, visibility during the 20% worst days has also been steadily improving and given that 2011 is a periodic inventory year, 2011 would be the best candidate base year for Regional Haze planning.

3.0 METEOROLOGICAL ANALYSIS

Meteorological conditions conducive to ozone formation include high temperatures both at the surface and aloft, mostly clear skies and winds from ozone precursor (NO_x and VOC) regions. Meteorological conditions conducive to elevated $PM_{2.5}$ and Regional Haze are more complicated involving temperature inversions, low mixing heights, dew point temperature and transport winds from source regions. In the OTR, $PM_{2.5}$ and Regional Haze levels are primarily higher during the summer and winter months. During the summer this is due to smoke from forest fires especially during drought conditions and is also primarily due to more formation of sulfates which more readily forms with higher relative humidity and dew point temperatures. During the winter $PM_{2.5}$ and regional haze levels are highest during temperature inversions and with lower mixing heights trapping pollution near the surface.

Analyses of surface and 850mb temperature anomalies, precipitation anomalies and short term drought anomalies by meteorological season for 2007-2012 were completed to see if any of the years were too extreme or were not meteorologically conducive to formation of ozone, $PM_{2.5}$, or regional haze. Anomalies as used in this report are departures from 30-year (1981-2010) averages for the meteorological parameters. Figure 4 and Appendix I Figures I-1 to I-6 show the 2007-12 surface temperature anomalies for the peak months of the ozone season, Figures I-7 to I-12 show the 850 mb transport level temperature anomalies, Figure 5 and Figures I-13-18 show the precipitation anomalies and Figure 6 shows the short term drought index anomalies. From those analyses 2008 and 2009 can be eliminated as a choice for a base year because both surface and transport level temperatures were the least conducive to ozone formation. For the OTR, 2010 was a drier (more ozone conducive) year than 2011 but for many other regions 2011 was drier than 2010.

For Regional Haze and $PM_{2.5}$ analyses of surface temperature, precipitation and short term drought anomalies conditions for meteorological seasons of the year were done with results in Appendix I. Summer months (June – August) meteorological conditions were discussed earlier and Figure 9 and Figure I-37 further summarize anomalies for the OTR. For the winter months (January, February and December) Figure 7 and Figure I-25 show both 2010 and 2011 had average conditions. Figure 8 and Figure I-31 show results for spring months (March – May) and Figure 10 and Figure I-43 show results for the fall months (September – November) with more mixed results. Since Regional Haze and $PM_{2.5}$ conditions are worse in the winter and summer months, 2010 and 2011 can be used for base years as meteorological conditions during those seasons were not too extreme.

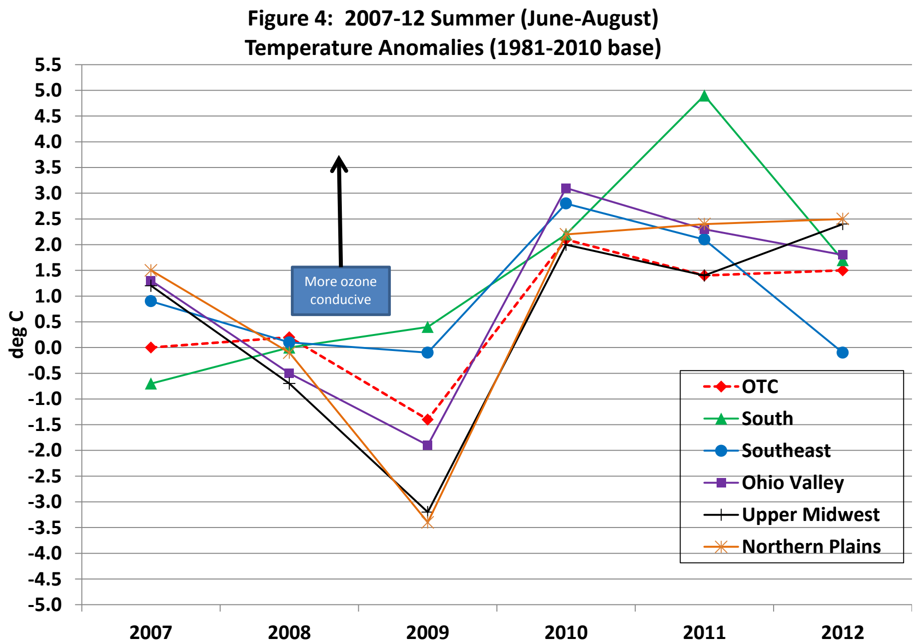


Figure 4: 2007-12 Summer (June-August)
Temperature Anomalies (1981-2010 base)
deg C
More ozone conducive
OTC
South
Southeast
Ohio Valley
Upper Midwest
Northern Plains
2007
2008
2009
2010
2011
2012

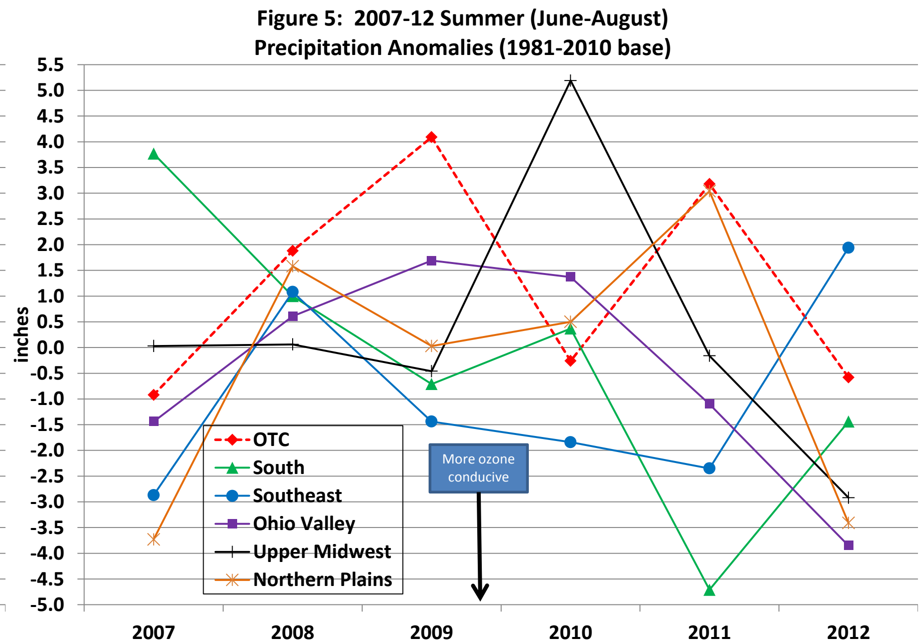


Figure 5: 2007-12 Summer (June-August)
Precipitation Anomalies (1981-2010 base)
inches
More ozone conducive
OTC
South
Southeast
Ohio Valley
Upper Midwest
Northern Plains
2007
2008
2009
2010
2011
2012

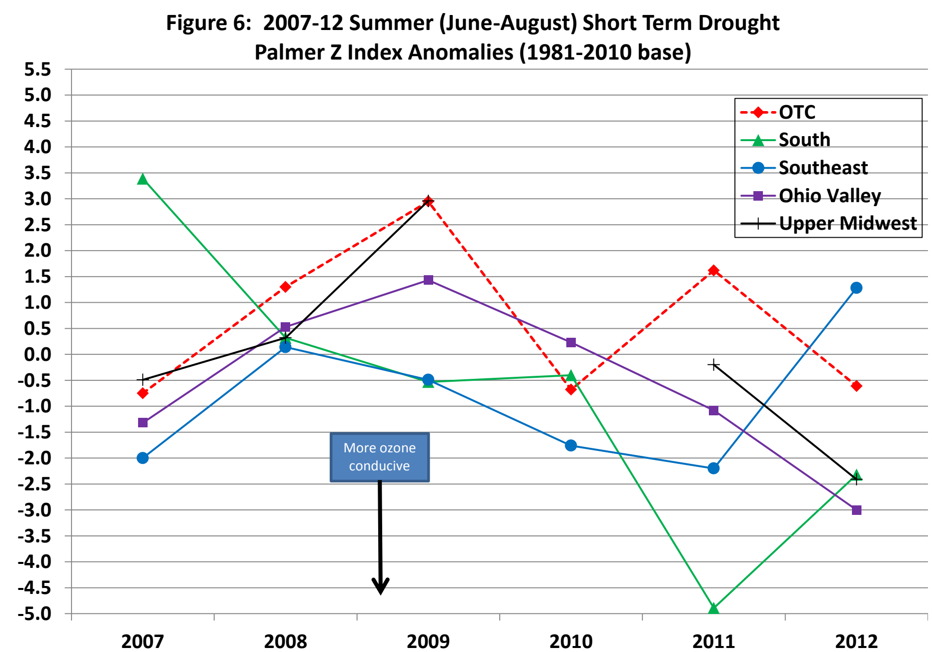


Figure 6: 2007-12 Summer (June-August) Short Term Drought
Palmer Z Index Anomalies (1981-2010 base)
More ozone conducive
OTC
South
Southeast
Ohio Valley
Upper Midwest
2007
2008
2009
2010
2011
2012

Figure 7: OTR 2007-12 Winter (Jan, Feb and Dec) Temp, Precip and Short Term Drought Palmer Z Index Anomalies (1981-2010 base)

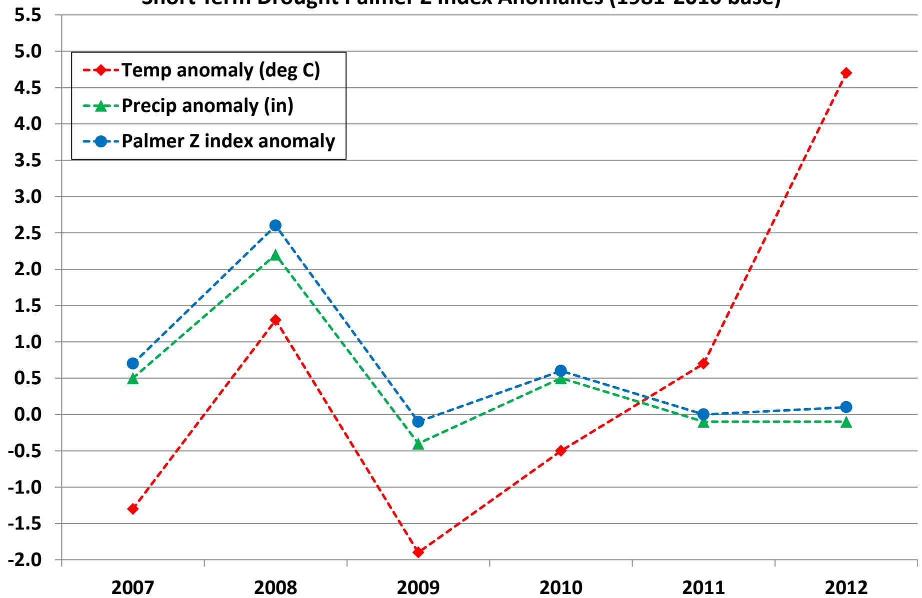


Figure 8: OTR 2007-12 Spring (March - May) Temp, Precipitation and Short Term Drought Palmer Z Index Anomalies (1981-2010 base)

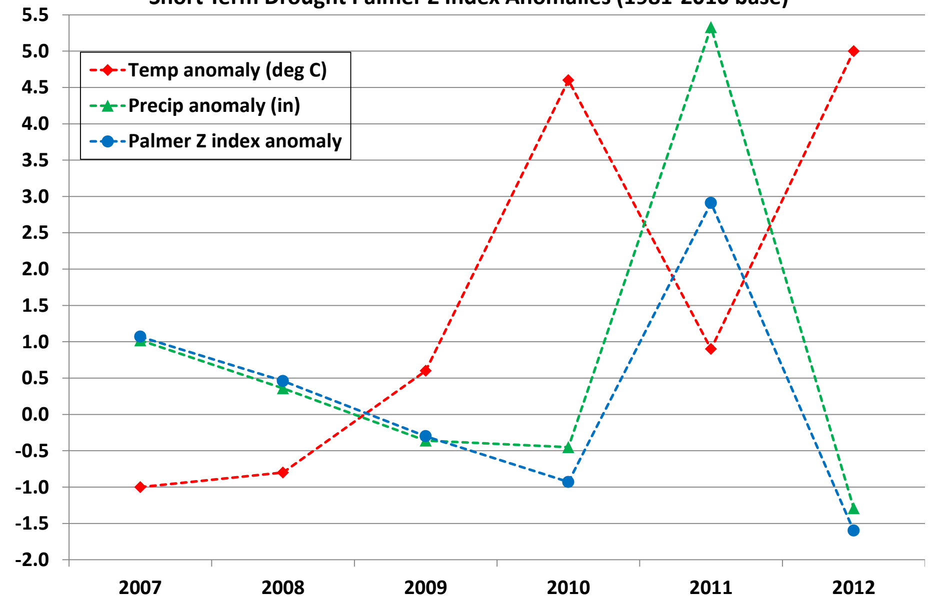


Figure 9: OTR 2007-12 Summer (June-August) Temp, Precipitation and Short Term Drought Palmer Z Index Anomalies (1981-2010 base)

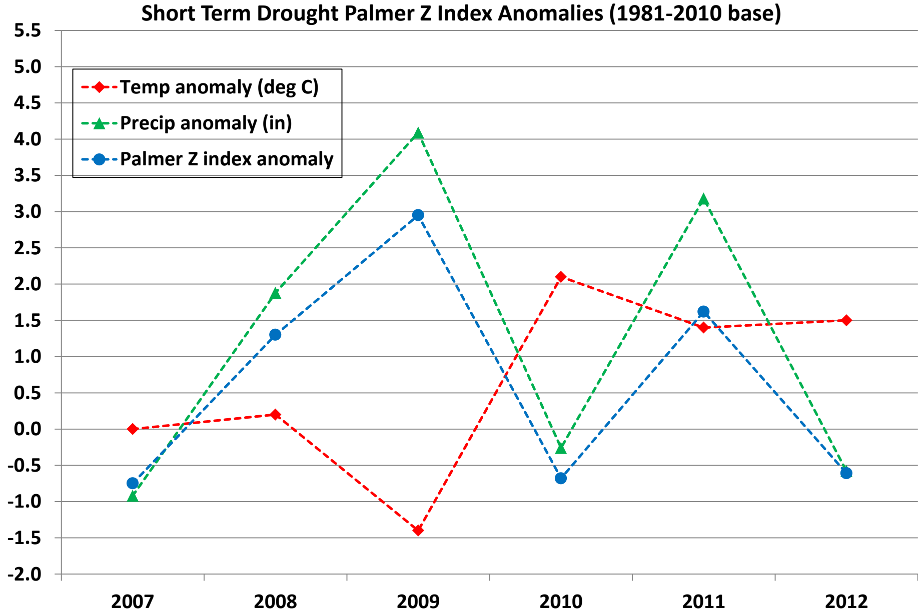
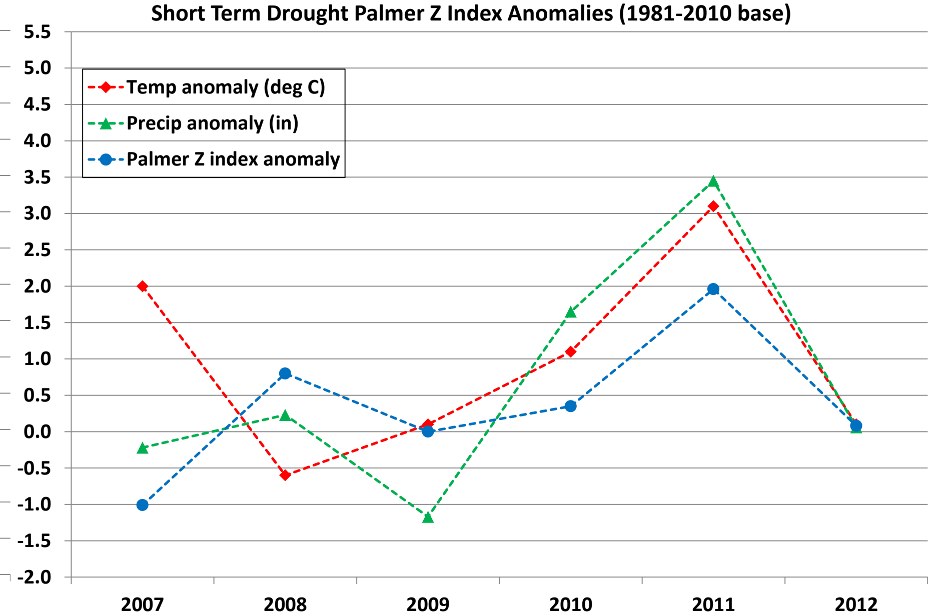


Figure 10: OTR 2007-12 Autumn (Sept - Nov) Temp, Precipitation and Short Term Drought Palmer Z Index Anomalies (1981-2010 base)



4.0 Other Factors

From previous data and meteorological analyses in this report, 2011 is the best candidate base year for future Regional Haze and annual $PM_{2.5}$ NAAQS modeling using EPA's guidance criteria factors. For the future Ozone NAAQS 2007, 2010 and 2011 are candidate base years and the following factors were used to help solidify the final base year decision.

- EPA guidance states that special consideration should be given to episodes with available "intensive databases" to ensure that aloft measurements and indicator and/or precursor species are available. During 2011 the DISCOVER-AQ project was conducted by NASA which could provide additional data to support modeling.
- Additionally, 2011 corresponds to the year which states submitted their periodic National Emission Inventory to USEPA. Using a base year that allows the 2011 NEI to be employed in attainment modeling would allow for an already well developed inventory to be used with little additional cost (as compared to developing an inventory for a different base year). Also, the MANE-VU Commissioners' charge to the workgroup placed emphasis on this factor.
- EPA has determined that 2011 will be the base year for the next round of transport modeling.
- It appears that other RPOs are planning on upgrading their modeling platforms to use a base year of 2011. Using a base year similar to other regions will allow for sharing of resources, collaboration on platform development, and higher quality emission inventories.

These various factors give additional strong weight of evidence to choose 2011 as a base year.

5.0 2011 Ozone Season Event Analysis

To solidify that 2011 is the best candidate base year for future Ozone NAAQS modeling, analyses in this section looked at exceedance events in the OTR to make sure there are a sufficient number of events and a variety of wind flow patterns to represent a typical year for modeling for areas in the OTR that may be classified moderate (or higher) nonattainment for a future Ozone NAAQS.

The entire OTR experienced high ozone in 2011. Weather patterns were similar to other severe years such as 2007, with some minor variations. As can be seen below in Figures 11 and 12, the composite flow patterns are similar with the Bermuda High building westward across the Southeastern U.S.

Figure 11: 2007 850mb summer composite flow pattern

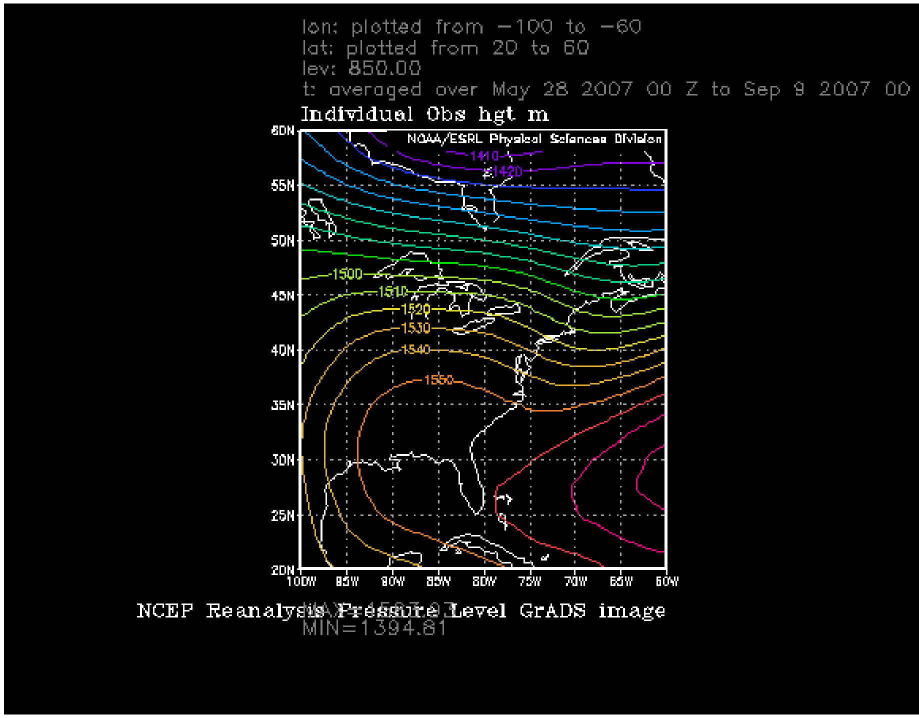
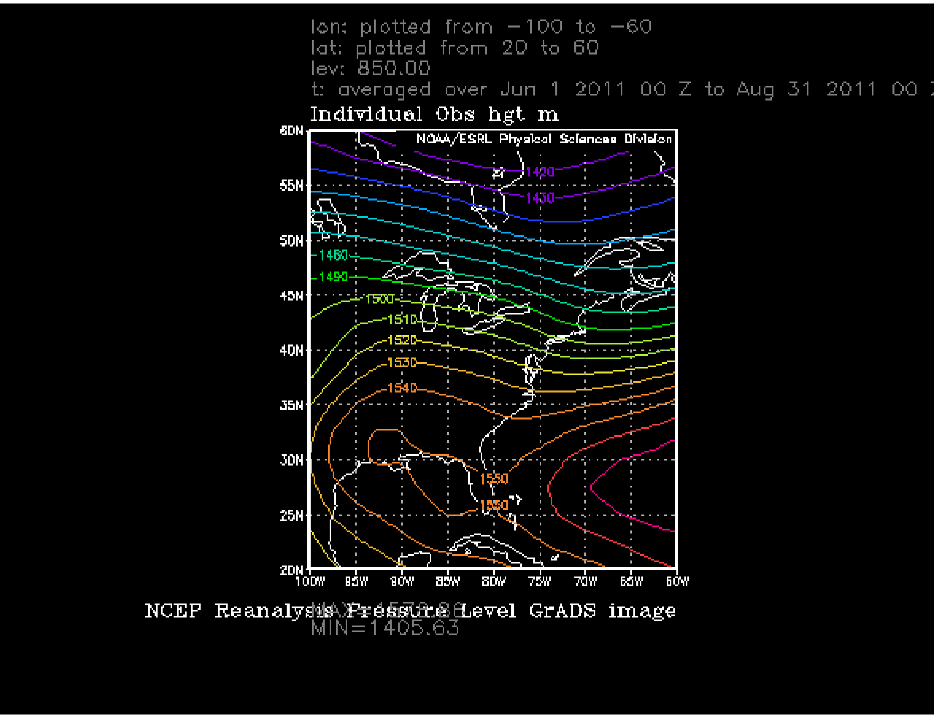


Figure 12: 2011 850mb summer composite flow



It is possible in 2015 that the 8-hour Ozone NAAQS will be at 70 ppb or lower as recommended by CASAC. Using EPA certified AQS monitored data the following number of exceedance days occurred in 2011 for areas in the OTR for a 70 ppb standard:

- Vermont: **1** (1 if the 8-hour Ozone NAAQS was reduced to 65 ppb)
- New Hampshire: **5** (11 if the 8-hour Ozone NAAQS was reduced to 65 ppb)
- Maine: **10** (19 if the 8-hour Ozone NAAQS was reduced to 65 ppb)
- Massachusetts: **15** (27 if the 8-hour Ozone NAAQS was reduced to 65 ppb)
- Rhode Island: **11** (22 if the 8-hour Ozone NAAQS was reduced to 65 ppb)
- Connecticut: **20** (27 if the 8-hour Ozone NAAQS was reduced to 65 ppb)
- New York: **32** (47 if the 8-hour Ozone NAAQS was reduced to 65 ppb)
- New Jersey: **29** (45 if the 8-hour Ozone NAAQS was reduced to 65 ppb)
- Pennsylvania: **38** (58 if the 8-hour Ozone NAAQS was reduced to 65 ppb)

- Delaware: **25** (39 if the 8-hour Ozone NAAQS was reduced to 65 ppb)
- Maryland: **46** (64 if the 8-hour Ozone NAAQS was reduced to 65 ppb)
- Washington DC: **16** (31 if the 8-hour Ozone NAAQS was reduced to 65 ppb)
- Northern Virginia: **23** (38 if the 8-hour Ozone NAAQS was reduced to 65 ppb)

Note that there are no counties with Design Values greater than the potential future 70 ppb NAAQS in New Hampshire and Vermont (see Figure A-7) and no counties with Design Values greater than the potential future 65 ppb NAAQS in Vermont (see Figure A-2). For other states in the OTR the following guidance factor is being met: "**Model a sufficient number of days so that the modeled attainment test applies at each monitor violating the NAAQS are based on multiple days**". More detailed breakdowns by county are in Appendix B where Figure B-29 shows the number of exceedances for the potential future 70 ppb NAAQS and Figure B-5 shows the number of exceedances for the potential future 65 ppb NAAQS.

Attainment demonstration guidance requires a variety of exceedance patterns to make sure a broad area of source regions is included in the modeling. 2011 had the required pattern variability. Specifically, there were 3 types of patterns resulting in ozone exceedances in the OTR:

- Cut off low southern exceedances: July 1-3
- Progressive warm-front-cold front systems: June 7-9, July 5-7 and July 11-12
- Bermuda high: July 17-24

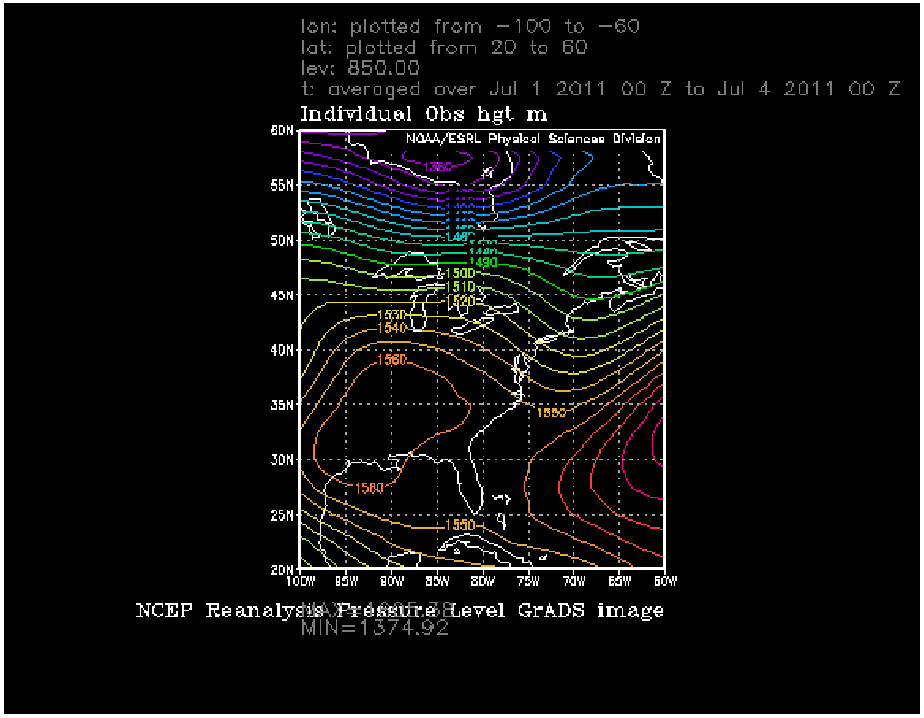
Each of the sections below (with more detailed maps in Appendix J) examined these cases in detail. Included are air quality maps from EPA AIRNOW, surface and upper air charts from ESRL/NOAA archives, UNISYS archives, and HYSPLIT back trajectories. To simplify the analysis, only three receptor areas were used

- Northern New England
- Connecticut
- Maryland

5.1 Cut Off Low

Cut off lows of this sort are not conducive to formation of ozone and represent cooler air as it did north of southeast Pennsylvania July 1-3. The composite 850mb flow for this event (see Figure 13 below) was a trough and not a ridge as is more typical for ozone events. Very warm air was pushed south over Maryland and south as the cut off low stubbornly hung on off the Northeastern US coast, blocking warm air from moving north but trapping it in the south. This is an unusual situation where ozone arrives from the north. However, eastern Pennsylvania has a multitude of mobile and stationary combustion sources and plentiful biogenic, highly ozone reactionary VOCs to form ozone.

Figure 13: July 1-3 2011 850mb composite flow pattern



Appendix J Figures J-16, 21 and 26 show the daily peak AQI- ozone in these cases (note the exceedances were all in the southern part of the OTR), Appendix J Figures J-18, 20, 23, 25, 28 and 30 show the requisite 850mb temperatures > 12 deg C. Appendix J Figures J-17, 19, 22, 24, 27 and 29 show the slow eastward progression of the surface moving system. Figure 14 shows the location of major electric generating units (EGU's) and their high electricity demand day NO_x emissions on July 21, 2011. Figure 15 below shows HYSPLIT 72-hour back trajectories for level 1 (10 meters(m)), level 2 (500 m), and level 3 (1500 m) heights from Maryland monitors during this event overlaid with major EGU combustion sources that operate on hot high demand days (exceedance days criteria was 75ppb on these maps). Exceedances were measured on all three days at multiple Maryland, Pennsylvania and northern Virginia locations. All of the trajectories passed over major source regions (cities major EGUs and their ton/day emissions are part of a GIS layers on the map).

Figure 14: 2011 (July 21) High Electricity Demand Day CAMD Eastern US NOx Emissions From Major Electric Generating Units (EGU)

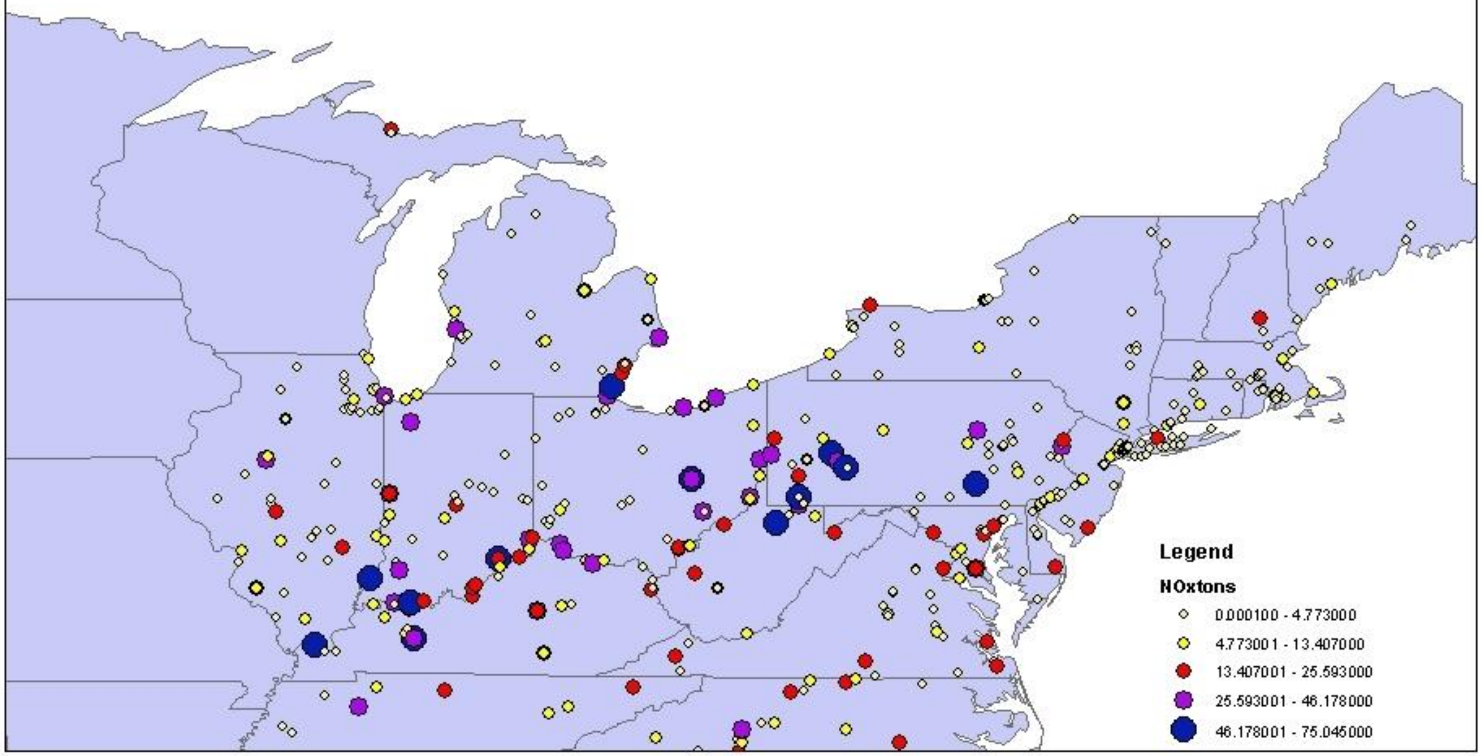
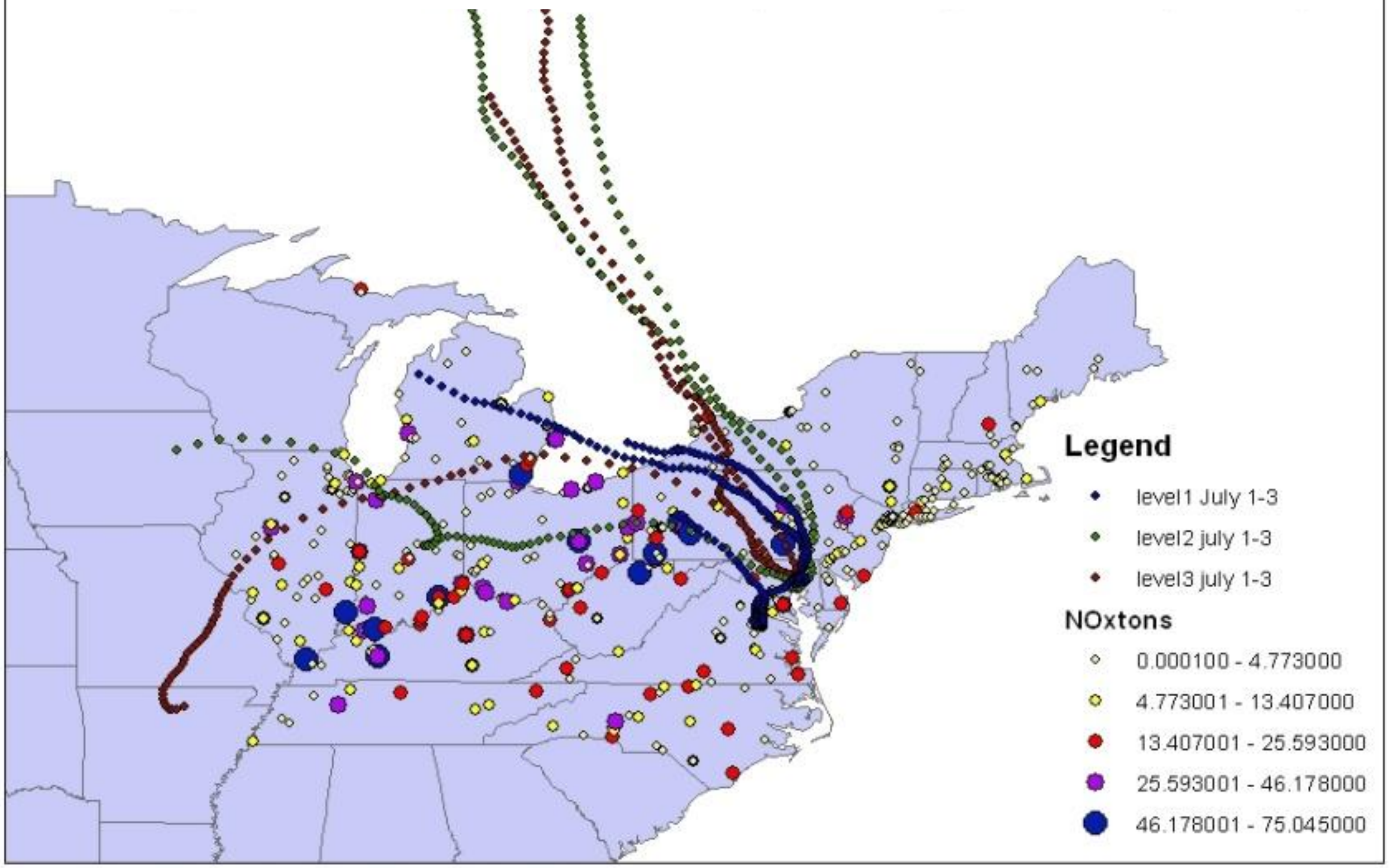


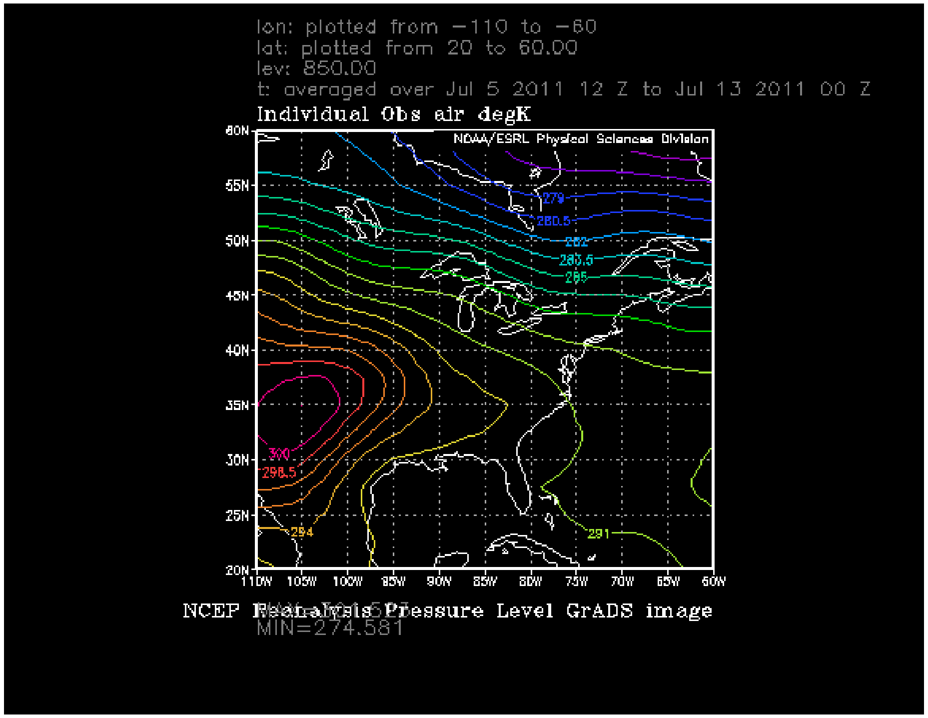
Figure 15: 10, 500 and 1500m 72-hr back trajectories during 7/1-3/2011 ozone events in Maryland



5.2 Progressive Warm/Cold Front Systems

A fairly strong 300mb jet stream across the Northern part of the OTR was guiding a series of systems across the region between July 5-12. The composite 860mb flow for this period (Figure 16 below) shows strong transport flow across the north and weaker flow across the south

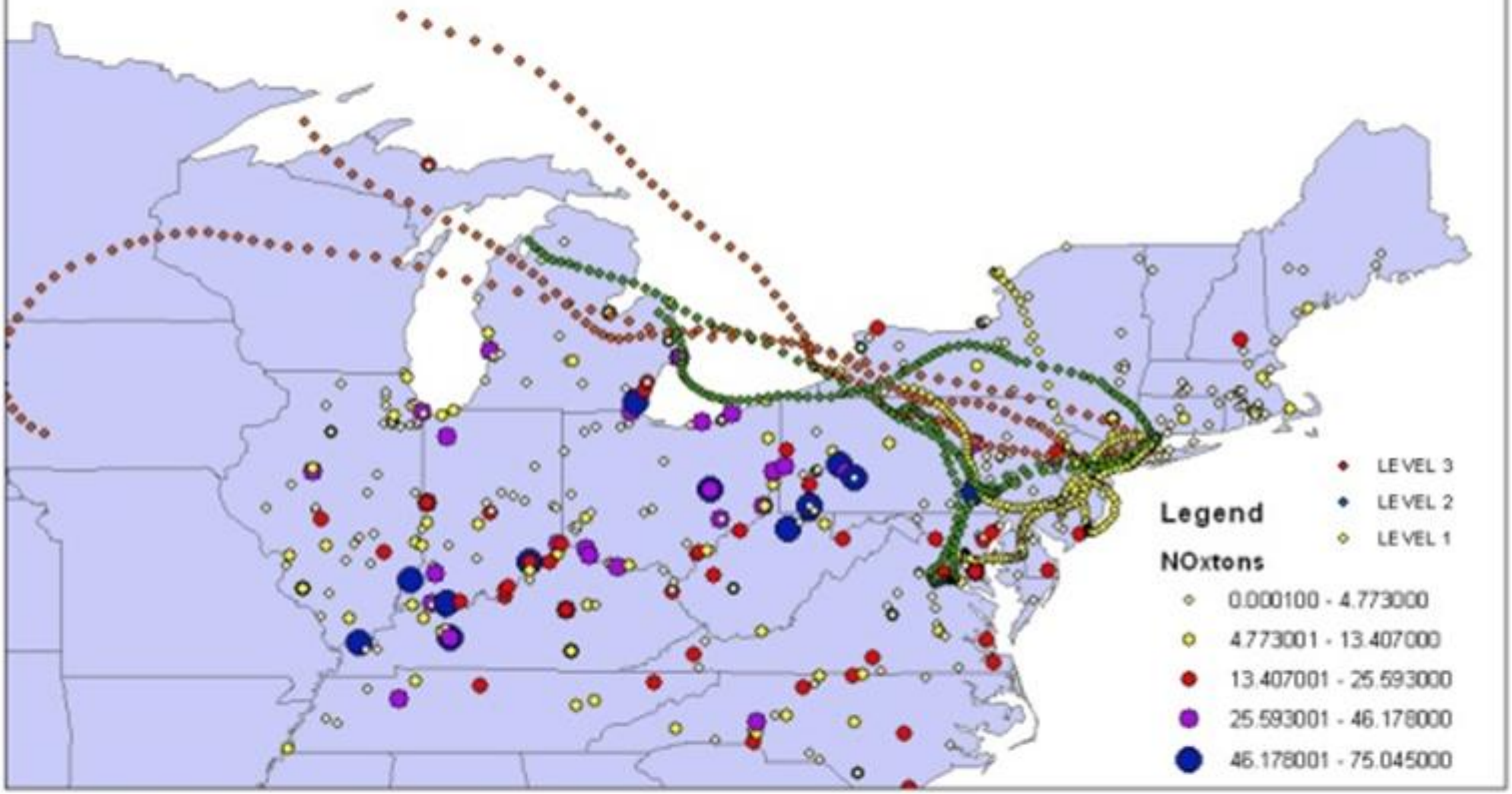
Figure 16: July 5-12 2011 850mb composite flow pattern

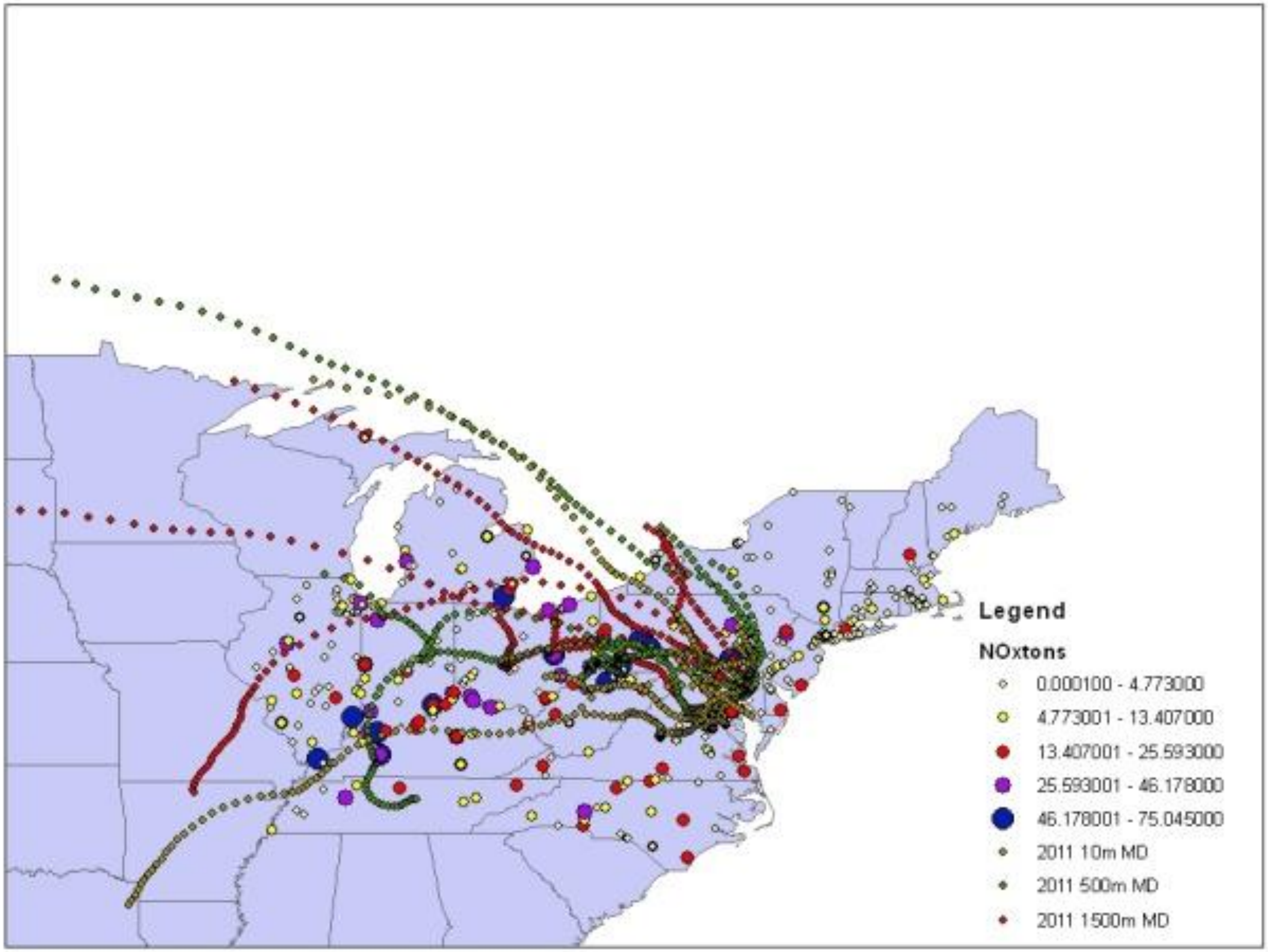


The pattern for the exceedances on event days July 5-7 and July 11-12 are seen in Appendix J Figures J-31, 36, 41, 46 and 51. The jet stream is steering a series of frontal systems across the area during the 7/5-12 period. 850 mb temperatures (See Appendix J Figures J-33, 35, 38, 40, 43, 45, 48, 50, 53 and 55) of 20+ deg C are hot enough to create ozone. The surface charts (See Appendix J Figures J-32, 34, 37, 39, 42, 44, 47, 49, 52 and 54) show the procession of frontal systems from 7/5-12/2011. The highest ozone precedes the cold frontal passage. Elevated ozone levels start showing up in the south on the 5th, moves up to Connecticut on the 6th and 7th , cleaner air between systems causes lower ozone from the 8th-10th , then races up to Connecticut on the 11th before finally exiting off the Delmarva shore on the 12th.

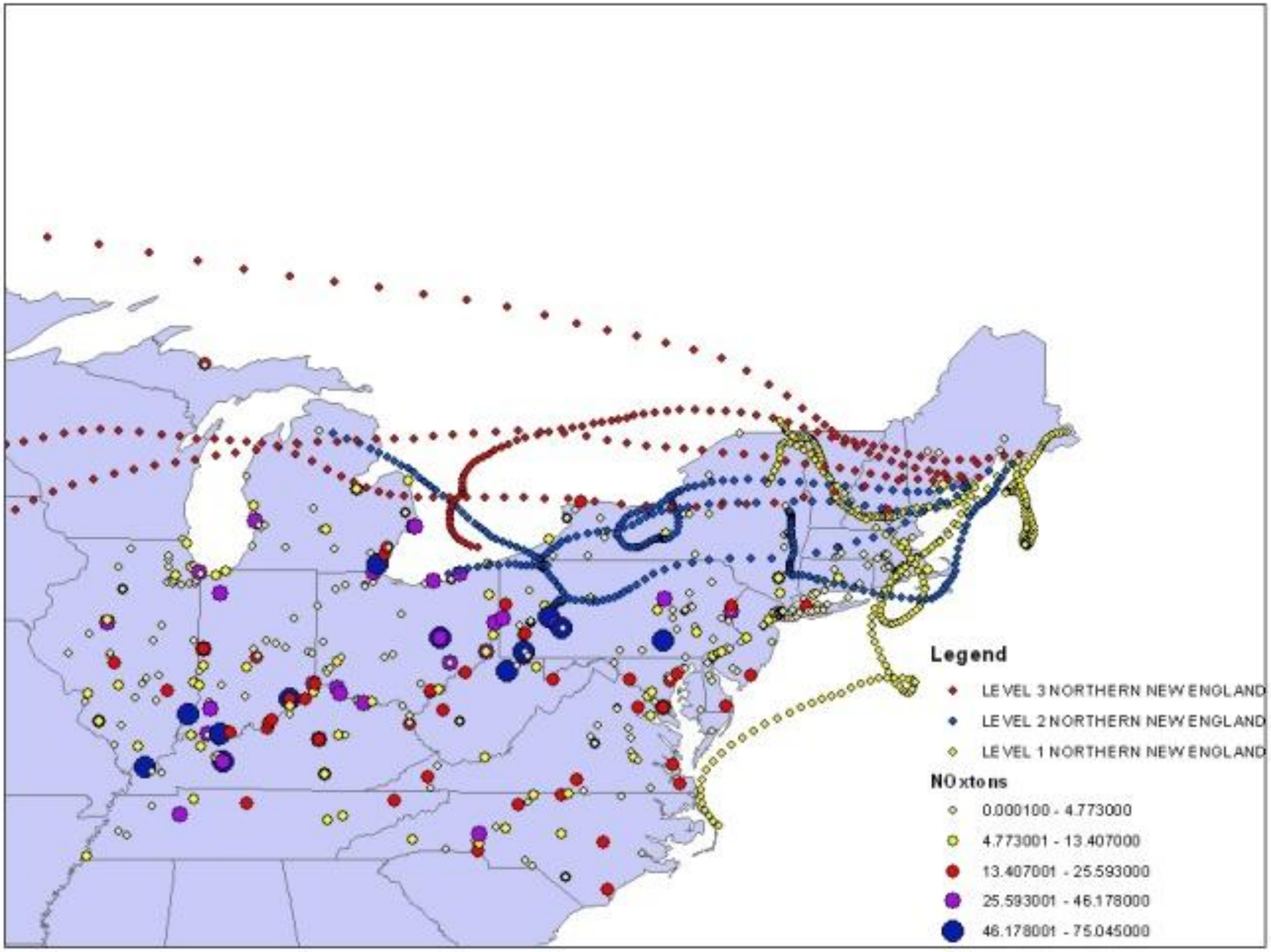
Figures 17-19 show HYSPLIT 72-hour back trajectories for level 1 (10 m), level 2 (500 m), and level 3 (1500 m) heights from monitors in Maryland, Connecticut and Northern New England recording exceedances (> 75 ppb) July 5-7 and July 11-12. For Maryland, trajectories covered the cities of Baltimore, Washington DC , Philadelphia and the power plants of PA and the Ohio River Valley, For Connecticut, trajectories covered urban areas of Connecticut, New York and New Jersey as well as power plants in Eastern Pennsylvania. For coastal Maine, low level trajectories were over the Gulf of Maine from Boston and Providence.

Figure 17: 10, 500 and 1500m 72-hr back trajectories during 7/5-13/2011 ozone events in Connecticut





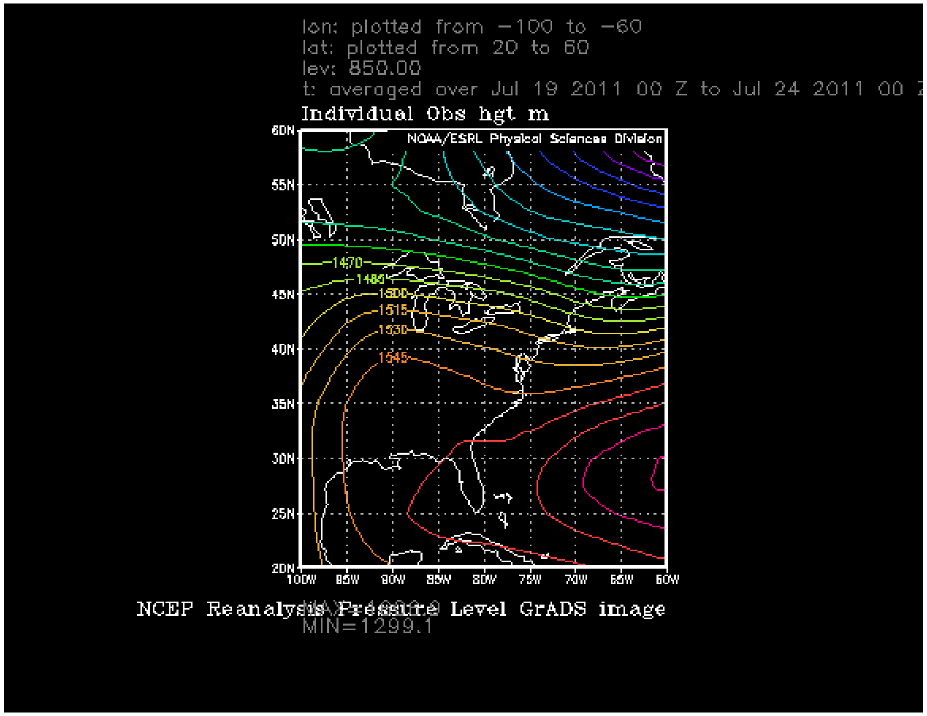
Legend
NOxtons
0.000100 - 4.773000
4.773001 - 13.407000
13.407001 - 25.593000
25.593001 - 46.178000
46.178001 - 75.045000
2011 10m MD
2011 500m MD
2011 1500m MD


Legend
LEVEL 3 NORTHERN NEW ENGLAND
LEVEL 2 NORTHERN NEW ENGLAND
LEVEL 1 NORTHERN NEW ENGLAND
NOxtons
0.000100 - 4.773000
4.773001 - 13.407000
13.407001 - 25.593000
25.593001 - 46.178000
46.178001 - 75.045000

5.3 Bermuda High

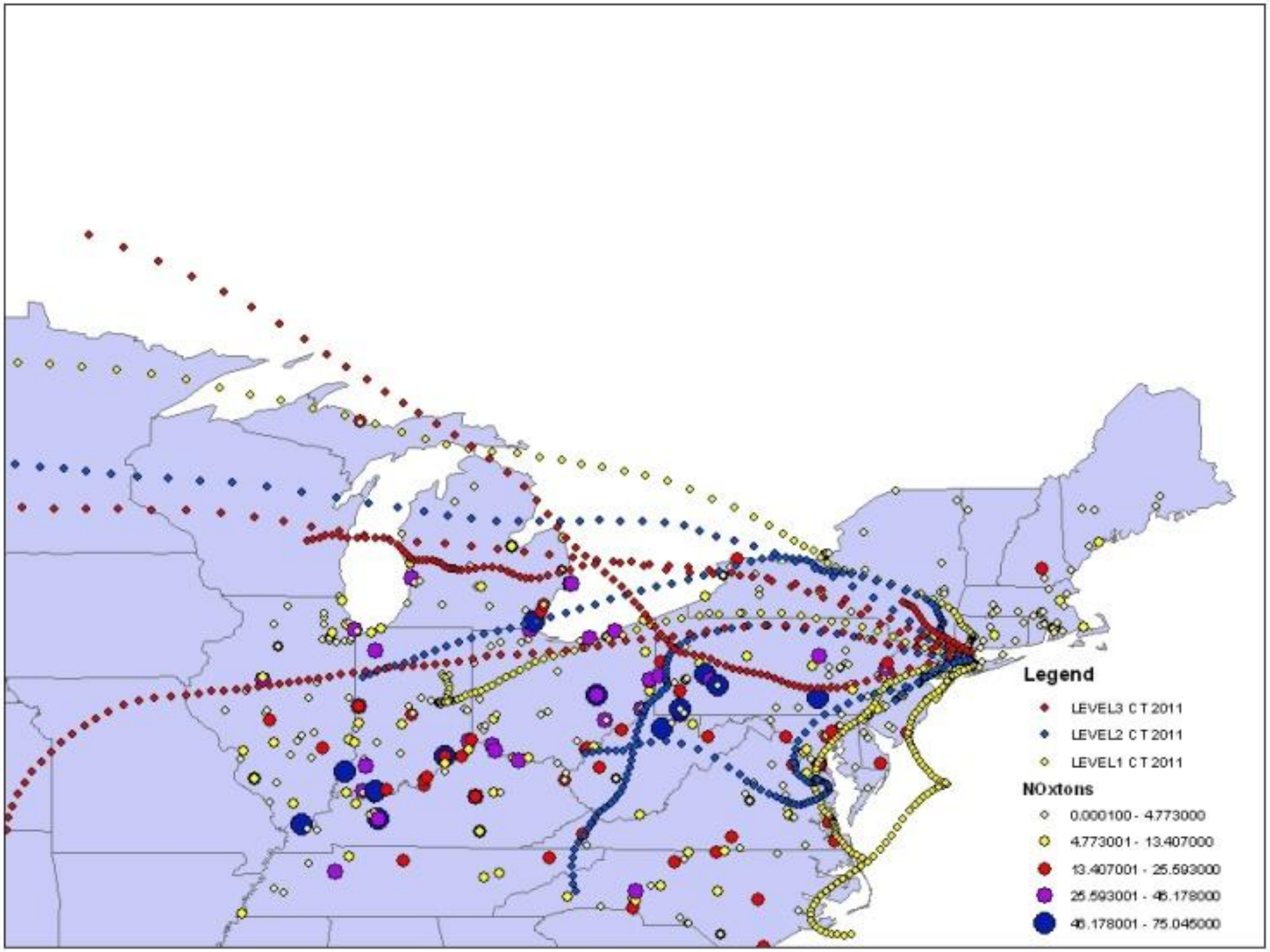
The period between July 17-24 is a classic eastern midsummer heat wave that produces a lot of ozone along the east coast. High pressure builds westward across the southeastern US inducing a weak westerly flow at low levels and an 850mb flow pattern that reaches far into the hot interior of the US. The composite 850mb flow pattern for this period is shown in Figure 20 below. The jet stream retreats far to the north blocking off the supply of cold air and moisture for progressive weather systems.

Figure 20: July 18-23 2011 850mb composite flow pattern

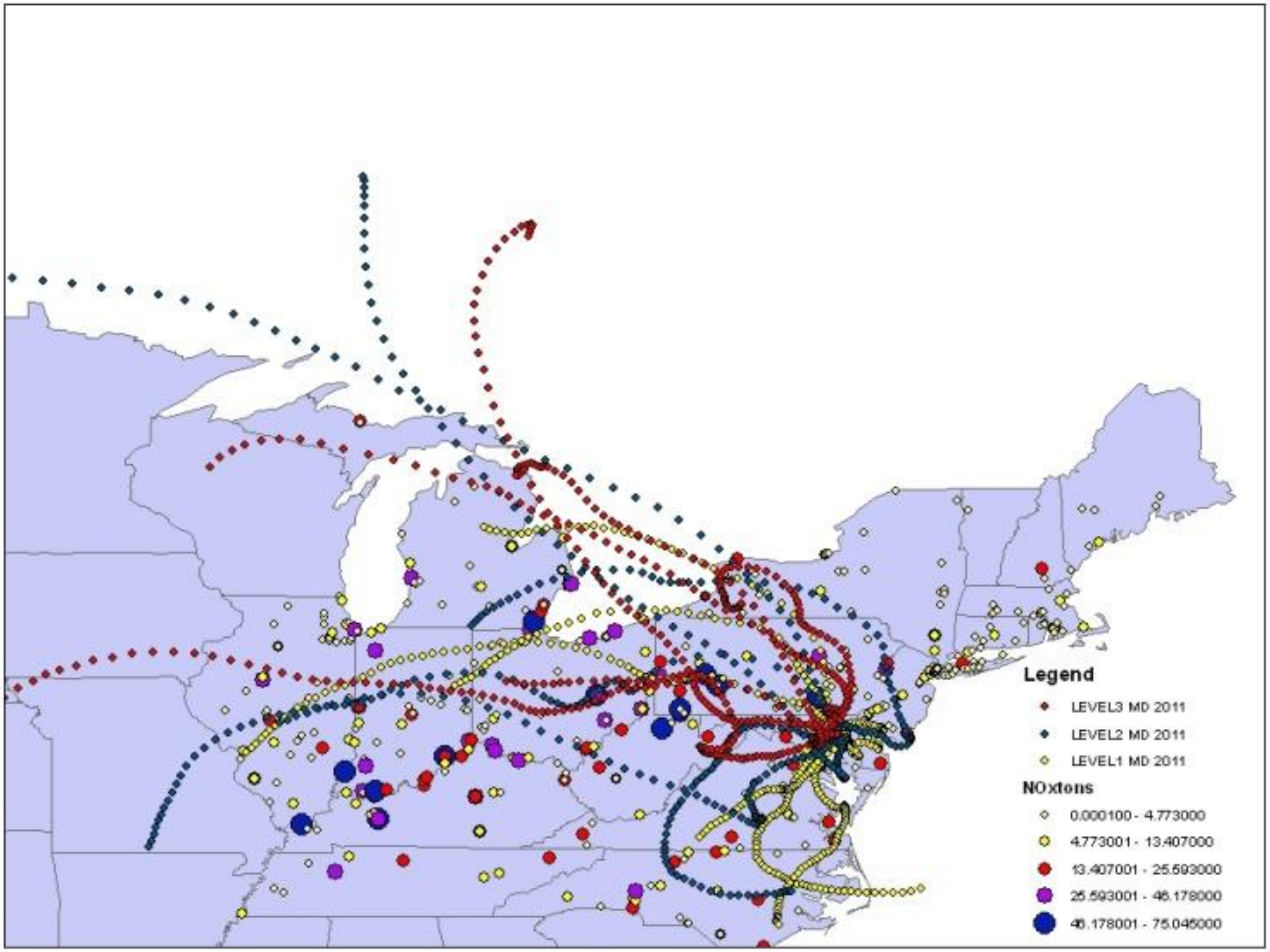


The spatial pattern for the exceedances on event days is seen in the Appendix J Figures J-56, 61, 66, 71, 76, 81, 86 and 91. Ozone exceedances start on July 17 in Western New York and moves to the eastern seaboard for the next seven days. The jet stream retreats to the north allowing the heat north and suppressing frontal system formation in the US. The 850 mb temperature increases from 16 to over 20 deg C during the period (See Appendix J Figures J-58, 60, 63, 65, 68, 70, 73, 75, 78, 80, 83, 85, 88, 90, 93 and 95). With the warmer air locking the cooler air to the north, frontal systems are few and weak, with little wind shift or temperature contrast across them (See Appendix J Figures J-57, 59, 62, 64, 67, 69, 72, 74, 77, 79, 82, 84, 87, 89, 92 and 94).

Figures 21-22 show HYSPLIT 72-hour back trajectories for level 1 (10 m), level 2 (500 m), and level 3 (1500 m) heights from monitors in Connecticut and Maryland recording exceedances (> 75 ppb) July 17-24. These two maps show the meteorology by capturing the major sources during the ozone events. Ozone transport is evident for all receptor regions.



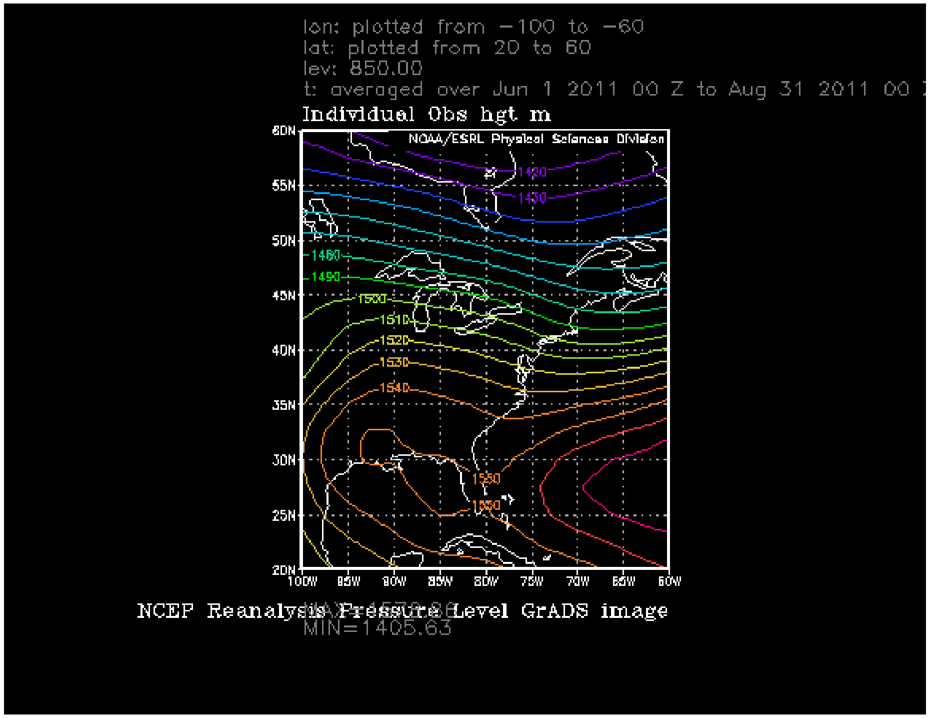
Legend
LEVEL3 C T 2011
LEVEL2 C T 2011
LEVEL1 C T 2011
NOxtons
0.000100 - 4.773000
4.773001 - 13.407000
13.407001 - 25.593000
25.593001 - 46.178000
46.178001 - 75.045000

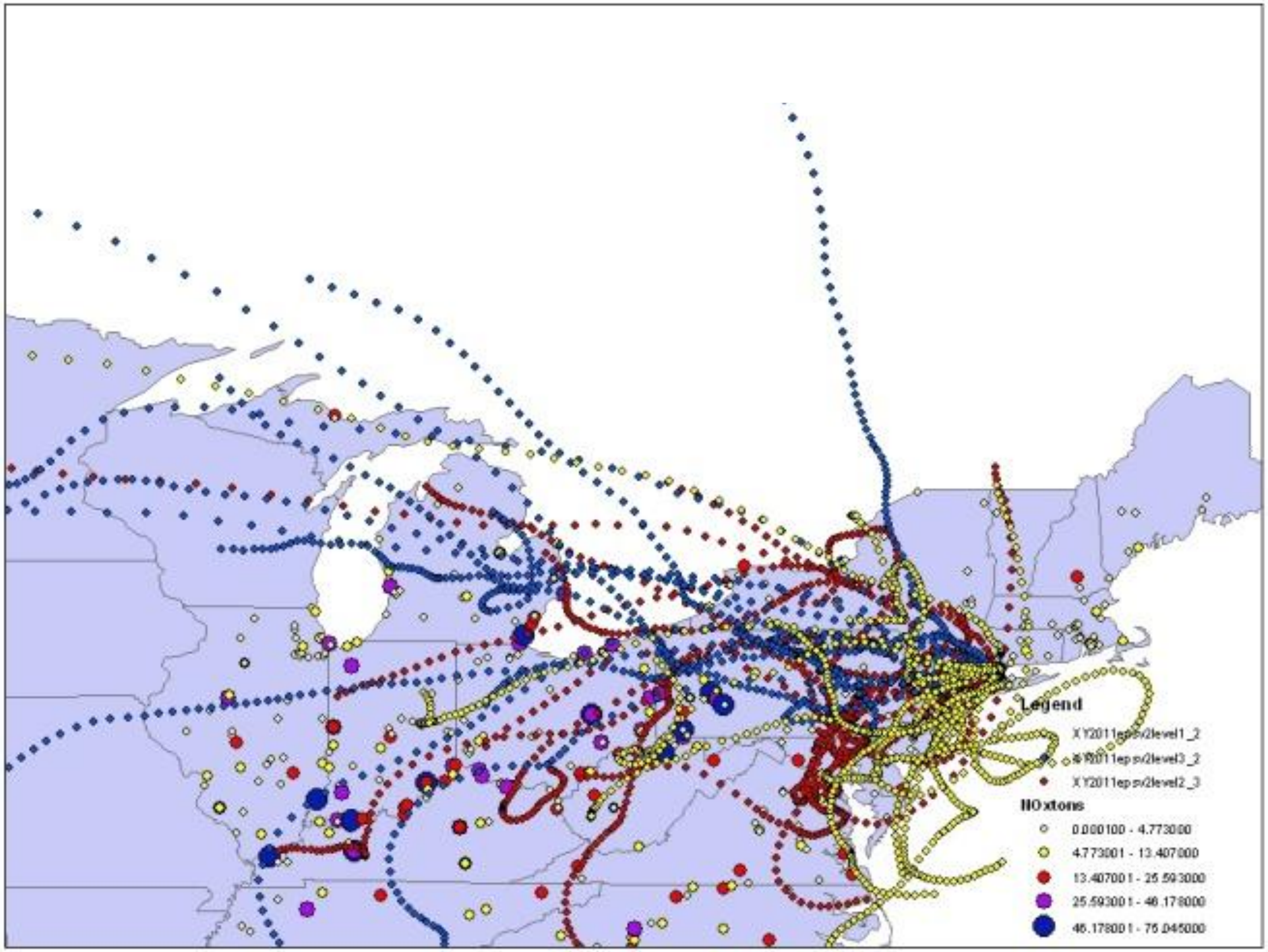

Legend
LEVEL3 MD 2011
LEVEL2 MD 2011
LEVEL1 MD 2011
NOxtons
0.000100 - 4.773000
4.773001 - 13.407000
13.407001 - 25.593000
25.593001 - 46.178000
46.178001 - 75.045000

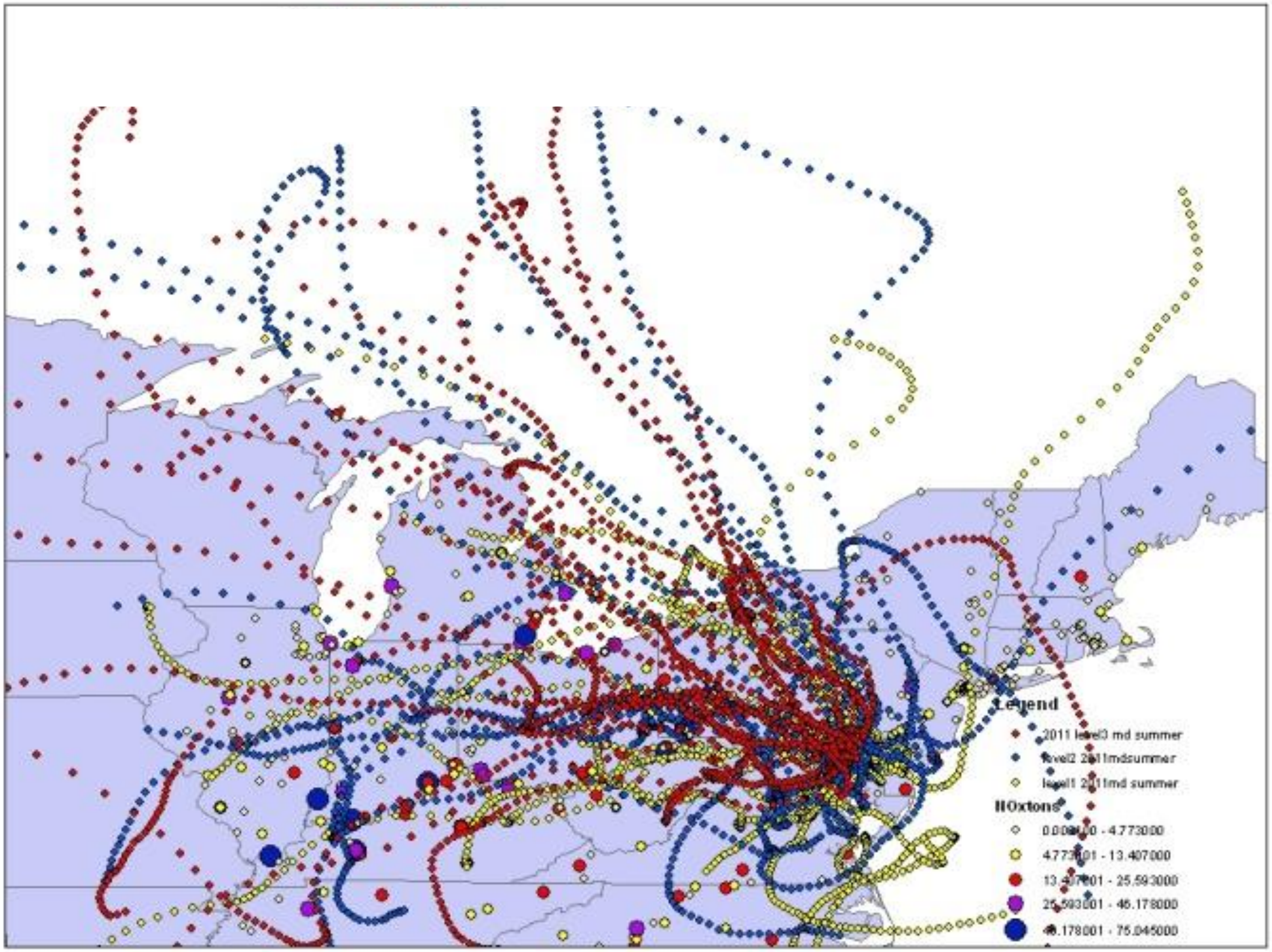
5.4 Summary

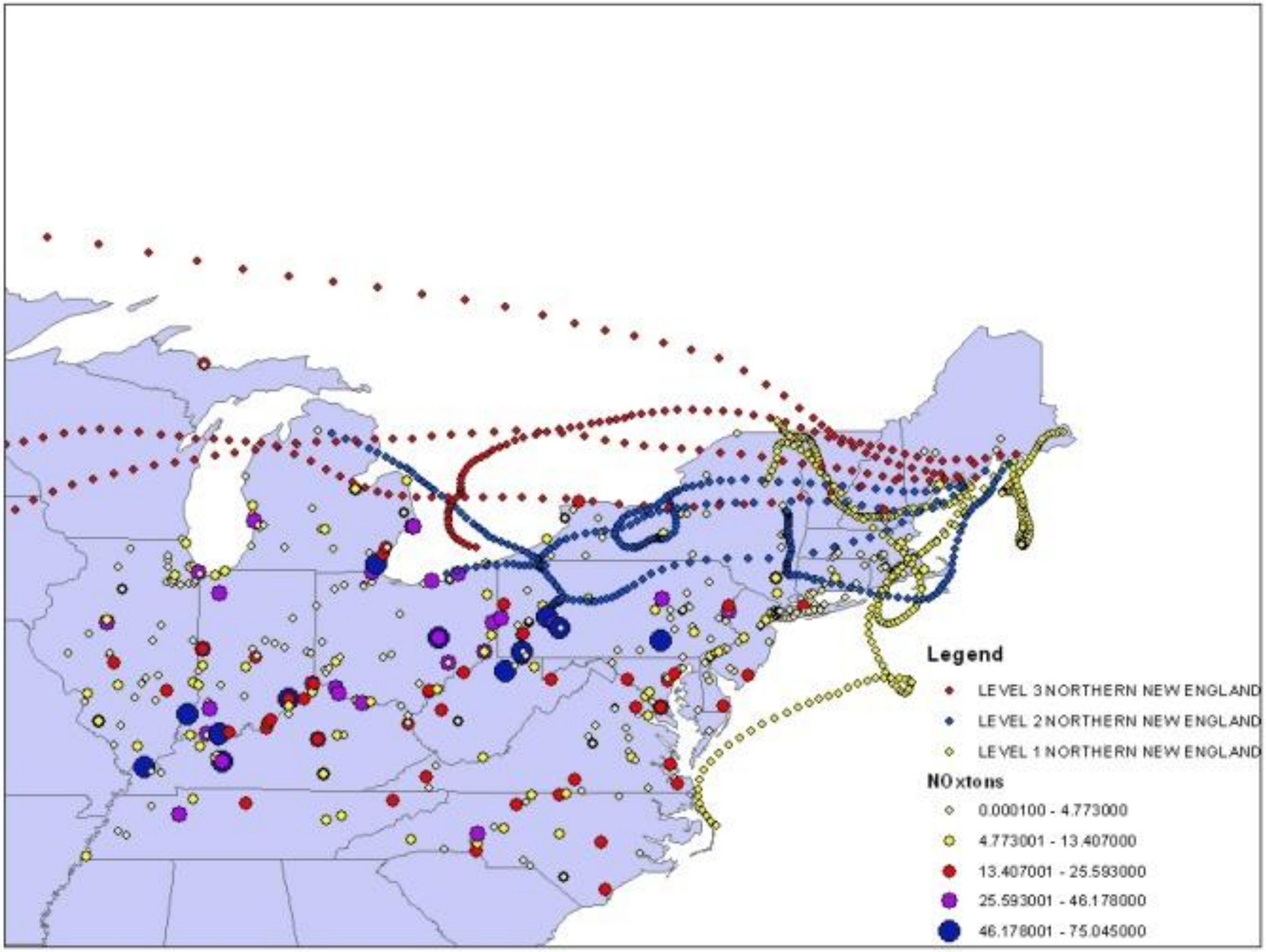
The evidence presented here should be compelling enough to choose 2011 as the base year for future ozone SIP modeling. The slight ridging in the 850 mb composite in Figure 23 and NW flow in the OTR reflect a ridge and a very warm summer condition across the Midwest. The HYSPLIT back trajectory maps, Figures 24-26, reflect this WNW flow and cause upper level sources in Canada, Western, NY and the Boston-Providence area (via sea breezes from the Gulf of Maine) to affect Northern New England. Southern Ontario, the southern tier of New York, Pennsylvania, Ohio, Michigan and the I-95 corridor from Connecticut south to Virginia affect Connecticut and the New York City CMSA. For Baltimore, DC, and Philadelphia, sources from southern Ontario, Western New York, Pennsylvania, Ohio, West Virginia and the I-95 corridor from Philadelphia south affect the Mid-Atlantic States.

Figure 23: May 31 to August 30, 2011 850mb composite flow pattern




Legend
XY2011epsv2level1_2
XY2011epsv2level3_2
XY2011epsv2level2_3
NOxtons
0.000100 - 4.773000
4.773001 - 13.407000
13.407001 - 25.593000
25.593001 - 46.178000
46.178001 - 75.045000


md summer
11mdsummer
11md summer
NOxtons
4.773000
13.407000
13.407001 - 25.593000
46.178000
75.045000



Legend
LEVEL 3 NORTHERN NEW ENGLAND
LEVEL 2 NORTHERN NEW ENGLAND
LEVEL 1 NORTHERN NEW ENGLAND
NOx tons
0.000100 - 4.773000
4.773001 - 13.407000
13.407001 - 25.593000
25.593001 - 46.178000
46.178001 - 75.045000

6.0 Conclusions / Recommendation

Analyses of monitored data and meteorological data confirm that 2007 is still a good base year for current modeling projects. For the OTR, 2010, 2011 and 2012 are the candidate base years to model for future ozone NAAQS planning and because levels are dropping steadily, 2011 is the best base year for future Regional Haze and annual $PM_{2.5}$ NAAQS planning. More detailed analyses including transport patterns of 2011 ozone events in the OTR confirms that 2011 would be a good base year. Finally, all other factors including periodic emission inventory, research data availability and other RPO and EPA base year decisions for future modeling efforts give weight to using 2011 as a base year. The final recommendation from the Base Year Workgroup is that 2011 is the best candidate base year for a multi-pollutant (Ozone, Regional Haze and $PM_{2.5}$) future modeling platform allowing for the most efficient use of state resources.

7.0 References

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National Weather Service Weather Prediction Center Surface Analysis Archive Website http://www.hpc.ncep.noaa.gov/html/sfc_archive.shtml#CONUS

National Weather Service DIFAX Weather Map Archive (850mb) http://archive.atmos.colostate.edu/data/misc/QHUA04/

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