MANE-VU Updated Q/d*C Contribution Assessment

MANE-VU Technical Support Committee

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Contents

Figures

Tables

Background and Introduction

The following analysis is a simplified method for estimating sulfate contributions to a receptor, known as the emissions over distance (Q/d) method. Q/d is largely accepted as a screening tool and continues to be as in the conclusion of a July 2015 report by an interagency air quality modeling work group.[1] NESCAUM previously employed this method in the *Contribution to Regional Haze in the Northeast and Mid-Atlantic United States*[2] and the *Contributions to Regional Haze in the Northeast and Mid-Atlantic United States: Preliminary Update Through 2007*[3].

This assessment primarily uses the methodology as in these previous two studies, any variances from the method are noted in the methods section below. MANE-VU states discussed various options for determining the largest contributors for opening discussions and employing further analysis; including, but not limited to, further CALPUFF modeling. A review of contribution analyses conducted by MANE-VU, including the previous two NESCAUM Q/d studies (CALPUFF analyses and REMSTAD analysis[2,3]) found similar results regardless of the method. It was decided the most cost effective tool for the first iteration of contribution analysis was the Q/d approach as the resource investment was less than the others and each method previously run provided similar ranking results.

Methods

The 2015 analysis was done using the ARC MAP ® software with some custom visual basic scripts; scripts are noted in Appendix B. The intent of this approach was to provide a simple exercise that could be repeated with little effort as the project evolved; to better test new methods and investigate new sources of haze; all while providing the data and illustrative graphics in a single effort.

The empirical formula that relates emission source strength and estimated impact is expressed through the following equation:

$$I = C_i \left(Q / d \right)$$

In this equation, the strength of an emission source, Q, is linearly related to the impact, I, that it will have on a receptor located a distance, d, away. As in the previous analysis, distances were computed using the Haversine function, using an earth radius of 6371 km[2]. The effect of meteorological prevailing winds can be factored into this approach by establishing the constant, C_i, as a function of the "wind direction sectors" relative to the receptor site.

By establishing a different constant for each wind direction sector, based on prior modeling results—in this case, CALPUFF results—are in effect "scaling" Q/d results by CALPUFF-calculated source impacts. The absolute impacts produced are then dependent on the CALPUFF results. The relative contributions, however, of each

[1] EPA, 2015. *Interagency Work Group on Air Quality Modeling Phase 3 Summary Report: Near-Field Single Source Secondary Impacts.* http://www3.epa.gov/ttn/scram/11thmodconf/IWAQM3_NFI_Report-07152015.pdf

[2] NESCAUM, 2006. *Contribution to Regional Haze in the Northeast and Mid-Atlantic United States.* http://www.nescaum.org/topics/regional-haze/regional-haze-documents

[3] NESCAUM, 2012. *Contributions to Regional Haze in the Northeast and Mid-Atlantic United States: Preliminary Update through 2007*. http://www.nescaum.org/topics/regional-haze/regional-haze-documents

source within a wind direction sector is established completely independent of the CALPUFF calculation, yielding a quasi-independent method of apportionment to add to the weight-of-evidence approach.

Discussion occurred as to whether the wind direction sectors changed to such an extent that updating the data with more recent data was necessary. A consensus of MANE-VU states determined that on average the directions of prevailing winds had not changed and thereby it was still acceptable to utilize the CALPUFF derived constants in the NESCAUM, 2002 analysis. These constants can be noted in Appendix A. As was done in the NESCAUM 2012 analysis state total emissions were evaluated from a source location of a population weight state centroid. Again little change was expected between the locations of the 2012 and 2015 estimated population densities thus the analysis was repeated with the locations of the centroids used in the NESCAUM 2012 study, also noted in detail in Appendix A.

The MANE-VU Class I areas with Interagency Monitoring of Protected Visual Environments (IMPROVE) monitors; Acadia, Brigantine, Great Gulf, Lye Brook & Moosehorn and several near-by Class I areas with IMPROVE monitors; Dolly Sods, James River Face and Shenandoah were used as receptors. The only new receptor in this analysis was the James River Face Wilderness area as it is in close enough in proximity to MANE-VU states it may be important receptor to MANE-VU states emissions (assumptions made to incorporate this receptor using the previous constants are explained in detail in Appendix B). See Figure 1 for locations of receptors analyzed in the 2015 analysis.

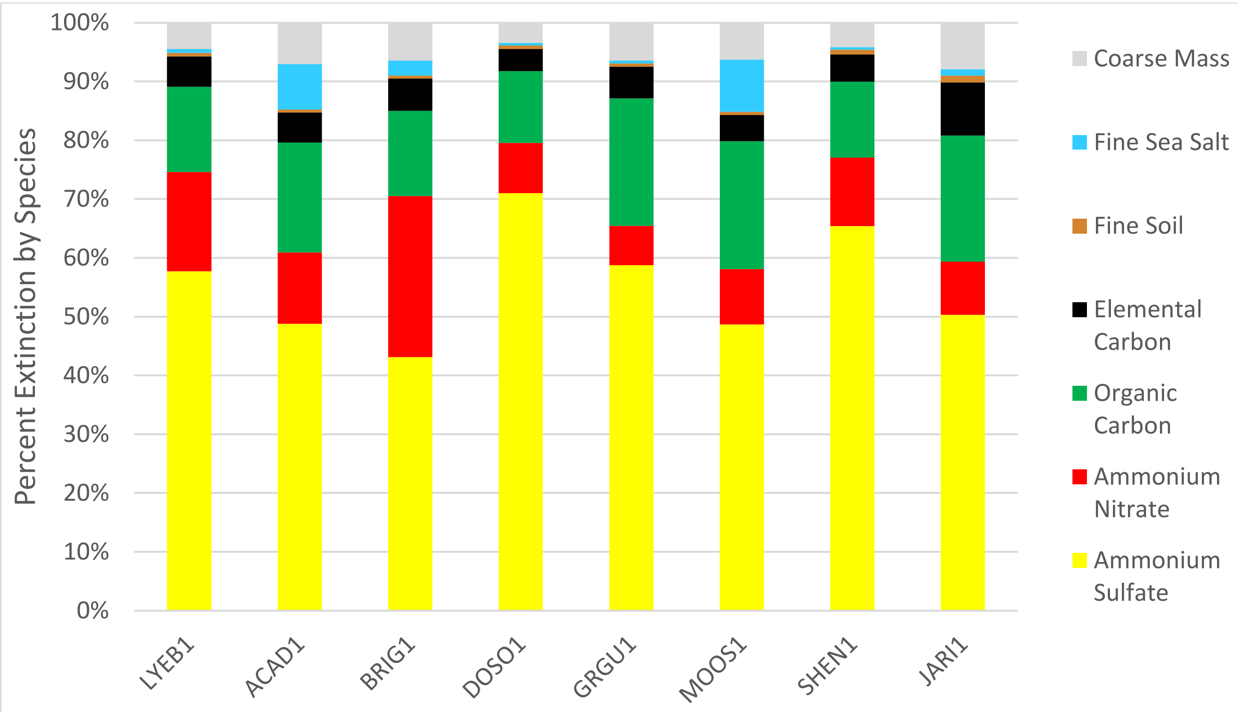
The geographic domain varied from the previous studies in that Canadian emissions were excluded this time. The remainder of the domain was the same and consistent with the regions modeling domain for other pollutant planning efforts.

Figure 1. Receptors for the 2015 $C_i(Q/d)$ Analysis

Sulfur dioxide (SO_2) emissions from 2011 NEI version 2 were summed for each state across all sectors with the exception of biogenic. This is consistent with the NESCAUM 2012 analysis. However, in the 2015 analysis additional experimental runs were done with volatile organic carbons (VOC), direct fine particulates ($PM_{2.5}$) and nitrogen oxides (NO_X). With the exception of $PM_{2.5}$ the same methodology was employed ($PM_{2.5}$ emissions were instead divided by distance squared, as Gaussian dispersion equation indicates is appropriate). A “step by step” documentation of this process can be found in Appendix B.

It was determined that the C_i's, originally derived for the SO_2 emissions, were not appropriate substitutions for these other pollutants; this was most evident in the resulting over estimation of the impact of NO_X at the Class I areas with this methodology. This, in addition with the visibility assessment which also showed the relative importance of sulfates compared to other pollutants in regards to light extinction at the IMPROVE sites analyzed (see Figure 2), led us to conclude that SO_2 was the most accurate and most relevant estimation for determining the impact of states' emissions to the visibility impairment of the MANE-VU Class I areas.

Figure 2. 2013-2014 Monitored Extinction on 20 Haziest Days, Expressed as Percentage of Extinction



In addition to exploring the other haze causing pollutants, the 2015 analysis also reviewed the point only portion of the 2011 NEI v2 emissions. The methodology for this is also outlined in appendix B and followed the same general principles. The C_i(Q/d) for the individual sources were summed for each state. The intent behind this analysis was to evaluate a possibly more accurate method, as Q/d is generally accepted for a screening tool for individual sources. In addition, this provided an understanding of the relative importance of a state's point only contribution to the total contribution of a state. Furthermore, the data from the point source analysis, prior to summation, is useful for later source specific control analyses.

The point analysis was run only with respect to SO_2 emissions. It was determined that it is also of value to run an additional analysis of the 2018 projected emissions for the point sources. The MARAMA α2 2018 was the base for the projected point inventory analysis. The 2018 analysis did not include the area and mobile sectors as the four-factor emissions inventory analysis determined that point sources were the overwhelming source of SO_2 emissions.[4]

[4] MANE-VU, 2015. *Recommendation on Sectors to Review as Part of the Four-Factor Analysis Based on an Emission Inventory Analysis of SO2 & NOX. Appendix B.,*

Results

State Population Weighted Centroid Analysis (State Totals & Comparison to 2012 Analysis)

For all of the analyses historical and current, Ohio was determined to be one of the top two contributors for all of the eight Class I areas reviewed. Pennsylvania also continues to be one of the top three for seven of the eight receptors. The majority of the top five contributors were very similar to the previous analysis, however significant reshuffling of the top five is apparent indicating the emissions reductions achieved were not equally applied among the neighboring states, see Table 1.

Table 1. Top Five Contributing U.S. States for Total State SO_2 Emissions over the Three Analyses

Class I Area (Receptor)	Rank	2002 Analysis (2002 emissions)	2012 Analysis (2007* emissions)	2015 Analysis (2011 emissions)
Acadia	1	Pennsylvania/Ohio	Pennsylvania	Ohio
	2		Ohio	Pennsylvania
	3	New York	Indiana	Indiana
	4	Indiana	Michigan	Michigan
	5	West Virginia/ Massachusetts	Georgia	Illinois
Brigantine	1	Pennsylvania	Pennsylvania	Pennsylvania
	2	Ohio	Maryland	Ohio
	3	Maryland	Ohio	Maryland
	4	West Virginia	Indiana	Indiana
	5	New York	West Virginia	Kentucky
Dolly Sods	1	New to 2007 analysis, no 2002 data	Pennsylvania	Ohio
	2		Ohio	West Virginia
	3		West Virginia	Pennsylvania
	4		Indiana	Indiana
	5		North Carolina	Kentucky
Great Gulf	1	Analysis not done	Pennsylvania	Ohio
	2		Ohio	Pennsylvania
	3		Indiana	Indiana
	4		Michigan	Michigan
	5		New York	Illinois
James River Face	1	New to analysis not available for earlier years		Ohio
	2			Pennsylvania
	3			Indiana
	4			Kentucky
	5			West Virginia
Lye Brook	1	Pennsylvania	Pennsylvania	Pennsylvania
	2	Ohio	Ohio	Ohio
	3	New York	New York	Indiana
	4	Indiana	Indiana	New York
	5	West Virginia	Michigan/West Virginia	Michigan
Moosehorn	1	Pennsylvania/ Ohio	Pennsylvania	Ohio
	2		Ohio	Indiana
	3	Indianan/New York	Indiana	Illinois
	4		Michigan	Michigan
	5	Michigan	Texas/Missouri/Illinois/West Virginia/New York	Texas
Shenandoah	1	Ohio	Pennsylvania	Ohio
	2	Pennsylvania	Ohio	Pennsylvania
	3	West Virginia	West Virginia	Indiana
	4	North Carolina	Maryland	West Virginia
	5	Maryland	Indiana	Virginia

Note: Cells with more than one source state/territory indicate equal values.
* The 2012 analysis uses 2008 NEI emissions, 2007 NPRI point source emissions and 2009 NPRI area and mobile source emissions. (See table 2-1 of the report NESCAUM, 2012)

Table 2, displays the quantitative contributions to the MANE-VU and neighboring Class I areas between the 2012 analysis (2007 emissions) and the 2015 (2011 emissions). Table 2. Comparison of State Emissions Contributions from 2007 Emissions and 2011 Emissions.

	Acadia National Park		*Brigantine Wilderness Area*		*Dolly Sods Wilderness Area*		*Great Gulf Wilderness Area*		*James River Face*		*Lye Brook Wilderness Area*		*Moosehorn Wilderness Area*		*Shenandoah National Park*	
	2007*	2011	2007*	2011	2007*	2011	2007*	2011	2007*	2011	2007*	2011	2007*	2011	2007*	2011
Alabama	0.03	0.02	0.05	0.03	0.06	0.04	0.02	0.02	N/A	0.04	0.04	0.02	0.02	0.02	0.06	0.04
Arkansas	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	N/A	0.01	0.01	0.01	0.01	0.01	0.01	0.01
Connecticut	0.01	0.01	0.01	0.01	0.00	0.00	0.00	0.00	N/A	0.00	0.01	0.00	0.00	0.00	0.00	0.00
Delaware	0.01	0.00	0.08	0.03	0.01	0.00	0.01	0.00	N/A	0.00	0.01	0.00	0.01	0.00	0.02	0.00
DC	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	N/A	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Florida	0.03	0.01	0.04	0.01	0.03	0.01	0.01	0.00	N/A	0.02	0.02	0.01	0.01	0.00	0.04	0.02
Georgia	0.06	0.03	0.09	0.04	0.10	0.04	0.04	0.01	N/A	0.05	0.06	0.02	0.04	0.02	0.10	0.04
Illinois	0.04	0.04	0.05	0.03	0.06	0.05	0.04	0.03	N/A	0.04	0.04	0.03	0.04	0.04	0.05	0.04
Indiana	0.08	0.06	0.11	0.05	0.15	0.10	0.07	0.05	N/A	0.09	0.08	0.05	0.08	0.06	0.12	0.08
Iowa	0.02	0.01	0.01	0.01	0.02	0.01	0.01	0.01	N/A	0.01	0.01	0.01	0.02	0.01	0.02	0.01
Kansas	0.01	0.01	0.01	0.00	0.01	0.01	0.01	0.00	N/A	0.01	0.01	0.00	0.01	0.01	0.01	0.01
Kentucky	0.04	0.03	0.07	0.05	0.10	0.07	0.03	0.02	N/A	0.07	0.05	0.03	0.04	0.03	0.09	0.06
Louisiana	0.02	0.02	0.02	0.02	0.02	0.02	0.01	0.01	N/A	0.02	0.02	0.02	0.01	0.01	0.02	0.02
Maine	0.04	0.03	0.00	0.00	0.00	0.00	0.00	0.00	N/A	0.00	0.00	0.00	0.02	0.01	0.00	0.00
Maryland	0.05	0.02	0.20	0.06	0.12	0.03	0.03	0.01	N/A	0.02	0.05	0.01	0.03	0.01	0.15	0.04
Massachusetts	0.04	0.03	0.02	0.01	0.01	0.01	0.01	0.01	N/A	0.01	0.01	0.01	0.02	0.02	0.01	0.01
Michigan	0.07	0.04	0.06	0.03	0.09	0.04	0.06	0.04	N/A	0.04	0.07	0.04	0.07	0.03	0.08	0.04
Minnesota	0.01	0.01	0.01	0.00	0.01	0.01	0.01	0.00	N/A	0.01	0.01	0.01	0.01	0.00	0.01	0.01
Mississippi	0.01	0.00	0.01	0.01	0.01	0.01	0.00	0.00	N/A	0.01	0.01	0.01	0.00	0.00	0.01	0.01
Missouri	0.04	0.03	0.05	0.02	0.05	0.03	0.03	0.02	N/A	0.03	0.04	0.02	0.04	0.03	0.05	0.03
Nebraska	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	N/A	0.01	0.01	0.01	0.01	0.00	0.01	0.01
New Hampshire	0.03	0.02	0.01	0.01	0.00	0.00	0.01	0.01	N/A	0.00	0.01	0.01	0.02	0.01	0.01	0.00
New Jersey	0.01	0.01	0.07	0.01	0.01	0.00	0.01	0.00	N/A	0.00	0.01	0.00	0.01	0.00	0.01	0.00
New York	0.05	0.03	0.06	0.04	0.03	0.02	0.05	0.03	N/A	0.02	0.09	0.05	0.04	0.03	0.04	0.02
North Carolina	0.04	0.02	0.07	0.03	0.06	0.02	0.02	0.01	N/A	0.07	0.03	0.01	0.03	0.01	0.10	0.04
Ohio	0.13	0.11	0.19	0.12	0.43	0.29	0.12	0.10	N/A	0.15	0.16	0.12	0.11	0.08	0.32	0.21
Oklahoma	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	N/A	0.01	0.01	0.01	0.01	0.01	0.01	0.01
Pennsylvania	0.18	0.08	0.40	0.14	0.50	0.13	0.15	0.06	N/A	0.10	0.29	0.13	0.16	0.02	0.42	0.15
Rhode Island	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	N/A	0.00	0.00	0.00	0.00	0.00	0.00	0.00
South Carolina	0.02	0.01	0.04	0.02	0.03	0.01	0.01	0.01	N/A	0.03	0.02	0.01	0.02	0.01	0.04	0.02
Tennessee	0.03	0.01	0.05	0.02	0.07	0.03	0.02	0.01	N/A	0.03	0.04	0.02	0.03	0.01	0.06	0.03
Texas	0.04	0.03	0.05	0.04	0.05	0.04	0.03	0.02	N/A	0.04	0.04	0.03	0.03	0.03	0.05	0.04
Vermont	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	N/A	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Virginia	0.03	0.02	0.09	0.05	0.07	0.03	0.02	0.01	N/A	0.07	0.03	0.02	0.02	0.01	0.11	0.07
West Virginia	0.05	0.02	0.10	0.04	0.32	0.14	0.04	0.01	N/A	0.07	0.07	0.02	0.04	0.01	0.20	0.08
Wisconsin	0.02	0.02	0.02	0.01	0.03	0.02	0.02	0.02	N/A	0.02	0.02	0.02	0.02	0.01	0.02	0.02

2011 Point Source Analysis

The analysis was completed for the 2011 NEI v2 point inventory. Table 3, displays the top five ranks states with but the 2011 population weighted centroid SO_2 emissions and the point only SO_2 emissions in the C_i (Q/d) method. Highlighted cells indicate states that varied in their ranks between the analyses. Two of the eight Class I areas saw a significant difference in the rankings; Brigantine and Moosehorn. The relative quantities displayed in Table 3 also indicate that the point sources are still a significant portion of each state's contributions with respect to SO_2 emissions. Figure 3 and Figure 4 below clarify how the evaluation of the contributions by individual source or state total with population centroid approach can alter the results, using Brigantine as an example. The analysis when done by on an individual source places each source with in different vector constants, theoretically more accurate approach especially with the intent to consider individual source contributions in further analyses.

Table 3. Top Five Ranking Contributing States of Point Only and Population Weighted Centroid Methodology

2011 Point Top 5 Contributions			2011 Centroid Top 5 Contributions		
Receptor	State	Contribution	Receptor	State	Contribution
Acadia	OH	0.091941355	Acadia	Ohio	0.110722
	PA	0.065000429		Pennsylvania	0.076393
	IN	0.050261661		Indiana	0.056531
	MI	0.042254566		Michigan	0.043586
	IL	0.031767801		Illinois	0.035447
Brigantine	OH	0.143782214	Brigantine	Pennsylvania	0.144185
	PA	0.127168402		Ohio	0.122695
	IN	0.060995943		Maryland	0.062602
	KY	0.048691472		Indiana	0.054433
	TX	0.03855251		Kentucky	0.051057
Dolly Sods	OH	0.304332742	Dolly Sods	Ohio	0.285194
	PA	0.156460896		West Virginia	0.140909
	WV	0.121920177		Pennsylvania	0.13217
	IN	0.091857237		Indiana	0.096535
	KY	0.069838976		Kentucky	0.070214
Great Gulf	OH	0.073746721	Great Gulf	Ohio	0.097926
	PA	0.052415185		Pennsylvania	0.062172
	IN	0.045361066		Indiana	0.048236
	MI	0.035254865		Michigan	0.038705
	IL	0.027097205		Illinois	0.029948
James Face	OH	0.220751954	James Face	Ohio	0.148042
	PA	0.093719295		Pennsylvania	0.095895
	IN	0.084795405		Indiana	0.085382
	KY	0.06977157		Kentucky	0.070312
	VA	0.055890047		West Virginia	0.067112
Lye Brook	OH	0.114401027	Lye Brook	Pennsylvania	0.132424
	PA	0.098398004		Ohio	0.116413
	IN	0.051105607		Indiana	0.05447
	MI	0.044568087		New York	0.053722
	NY	0.032786194		Michigan	0.044304
Moosehorn	OH	0.08457113	Moosehorn	Ohio	0.079613
	PA	0.053933613		Indiana	0.057955
	IN	0.047024234		Illinois	0.036654
	MI	0.038105112		Michigan	0.030354
	IL	0.031793931		Texas	0.029351
Shenandoah	OH	0.223136587	Shenandoah	Ohio	0.205847
	PA	0.129388586		Pennsylvania	0.14796
	IN	0.07666613		Indiana	0.079393
	WV	0.063798543		West Virginia	0.079183
	KY	0.057891393		Virginia	0.068504

Figure 3. Wind Sector Constants and the State Total Emissions and the Locations

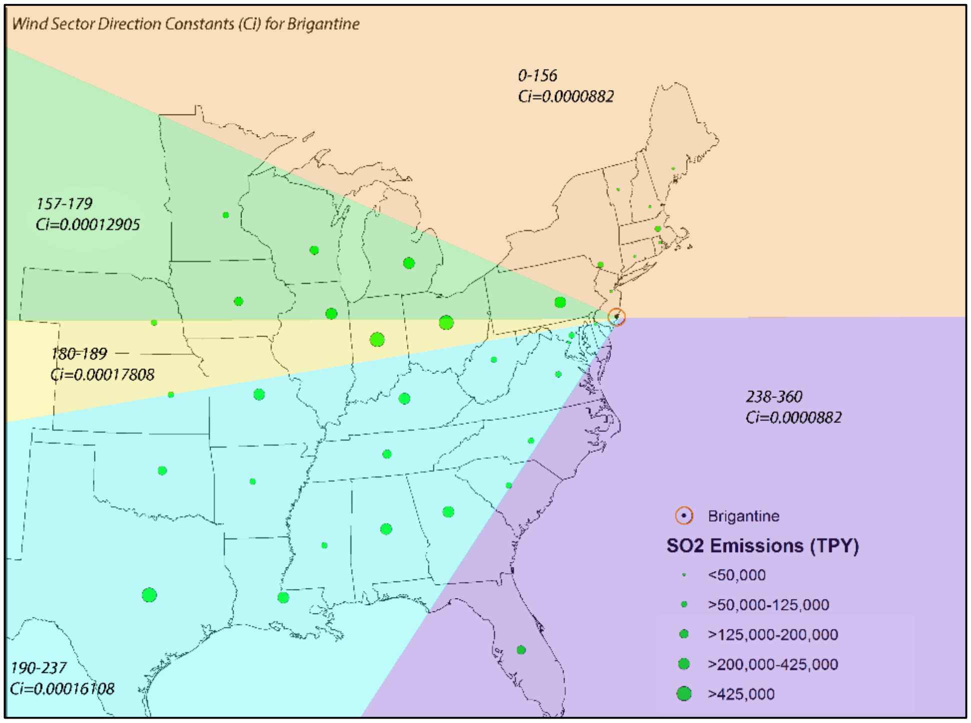
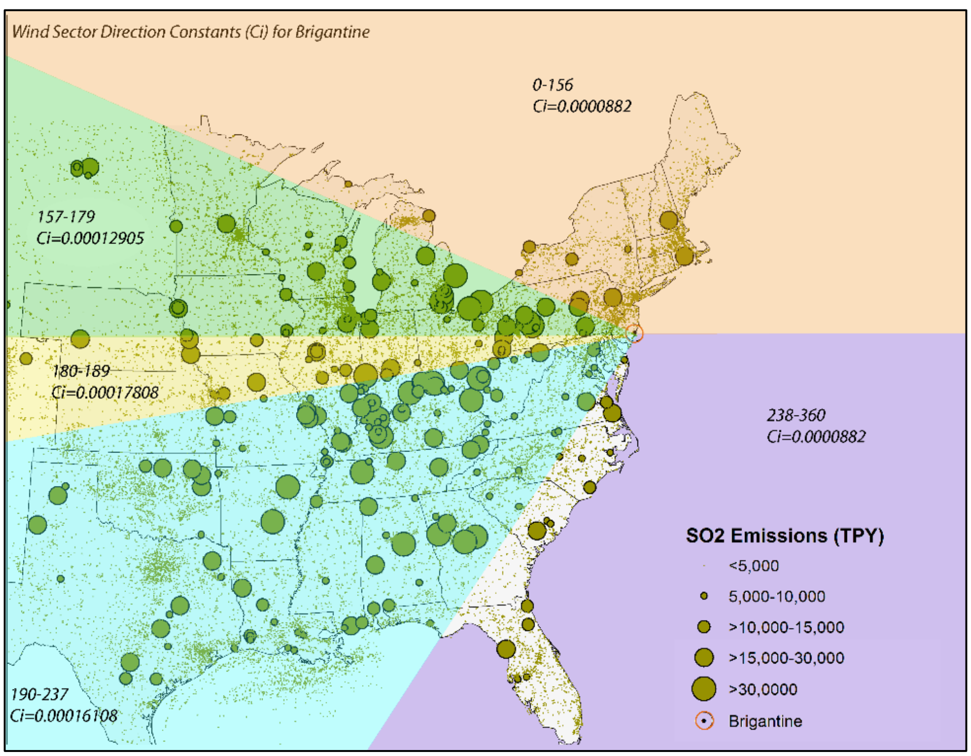


Figure 4. Wind Vectors Point Source Emissions and Their Locations (2011 Emissions)



Projected 2018 Point Source Analysis

The point contribution analysis was repeated for the point sector of the MARAMA α2 2018 inventory. The purpose of this analysis is to calculate a best estimate of with our most current understanding of the "start" year for the next regional haze SIP. Thereby reducing the efforts to further analyzed sources, which are known to significantly reduce emissions or no longer exist by 2018. The summation of the individual contributions by state resulted in an overall decrease in the total contributions by 2018 and the relative rankings did reshuffle for 2018, see Table 4 below.

Table 4. States with the Five Greatest Point Contributions in 2011 and Projected for 2018

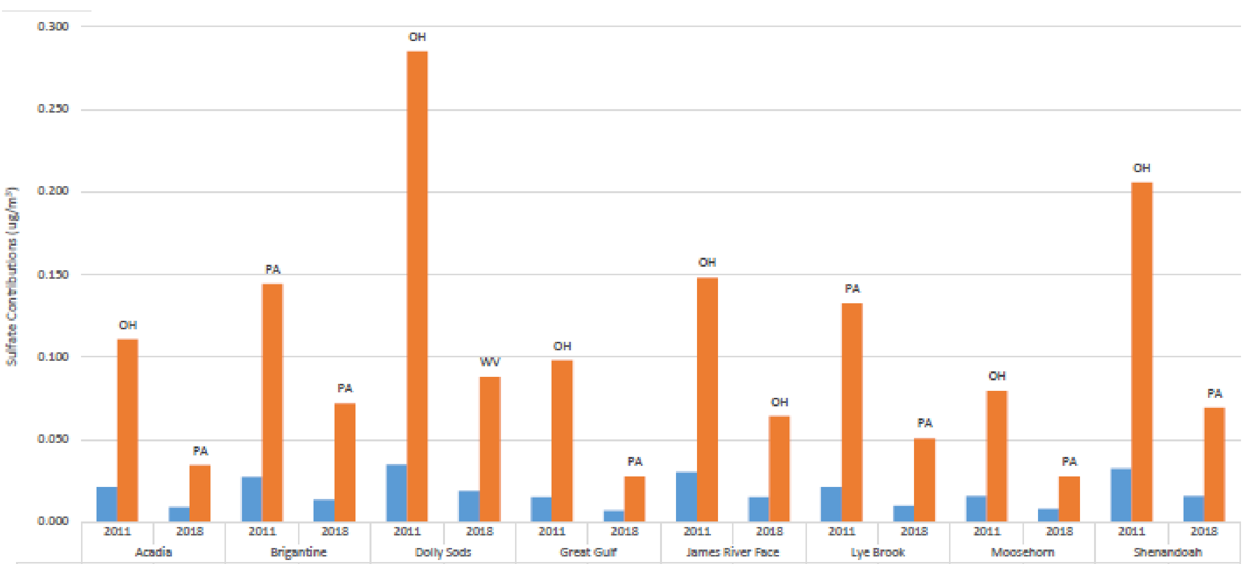
		2011*		2018*	
Receptor	**Rank**	**State**	**Contribution**	State	Contribution
Acadia	**1**	OH	0.091941355	PA	0.03442676
	2	PA	0.065000429	OH	0.030218026
	3	IN	0.050261661	TX	0.027290416
	4	MI	0.042254566	MO	0.022326675
	5	IL	0.031767801	IN	0.022200948
Brigantine	**1**	OH	0.143782214	PA	0.066174833
	2	PA	0.127168402	OH	0.043255256
	3	IN	0.060995943	TX	0.033915703
	4	KY	0.048691472	MD	0.033394815
	5	TX	0.03855251	IN	0.02723641
Dolly Sods	**1**	OH	0.304332742	WV	0.080326515
	2	PA	0.156460896	PA	0.079466227
	3	WV	0.121920177	OH	0.07326551
	4	IN	0.091857237	TX	0.034729442
	5	KY	0.069838976	KY	0.034046795
Great Gulf	**1**	OH	0.073746721	PA	0.028538138
	2	PA	0.052415185	OH	0.025792798
	3	IN	0.045361066	TX	0.02124918
	4	MI	0.035254865	IN	0.021009177
	5	IL	0.027097205	MO	0.01919794
James Face	**1**	OH	0.21967166	OH	0.059720444
	2	IN	0.088060923	PA	0.04587869
	3	PA	0.086371599	TX	0.03592808
	4	KY	0.072636643	KY	0.034641141
	5	VA	0.057416645	IN	0.033171851
Lye Brook	**1**	OH	0.114401027	PA	0.049709278
	2	PA	0.098398004	OH	0.035424463
	3	IN	0.051105607	TX	0.027899648
	4	MI	0.044568087	IN	0.022562486
	5	NY	0.032786194	MO	0.020612201
Moosehorn	**1**	OH	0.08457113	PA	0.028814579
	2	PA	0.053933613	OH	0.028212134
	3	IN	0.047024234	TX	0.026652076
	4	MI	0.038105112	MO	0.022926812
	5	IL	0.031793931	IN	0.020562191
Shenandoah	**1**	OH	0.223136587	PA	0.066894227
	2	PA	0.129388586	OH	0.058558198
	3	IN	0.07666613	WV	0.038467176
	4	WV	0.063798543	TX	0.032531606
	5	KY	0.057891393	IN	0.02970615

The Q/d contribution analysis showed a promising downward trend at all of the class I areas with IMPROVE monitors in MANE-VU, which is consistent with the ambient air quality measurements. Contributions decreased at all of the class I areas from 2011 to 2018, both the maximum and average state point source contributions were reviewed, See Figure 5. The contributions of the states with the largest point contributions remain fairly consistently in the top 5 through New York and Virginia do drop considerably in ranking when they were in the top 5 for 2011, See Figure 6.

Electric Generating Units (EGUs) that report emissions to the Clean Air Markets Division (CAMD) as a whole still account for the majority of the sulfate contributions to all of the Class I Areas examined (approximately 70% in all cases). Other point sources and non-reporting EGUs (small EGUs) produce the bulk of the remaining contribution. Emissions from oil and gas, refueling, and ethanol point sources have negligible impacts on the monitored Class I areas. Details as to the magnitude and relative importance of 2018 projected emissions from each point source sector can be observed in

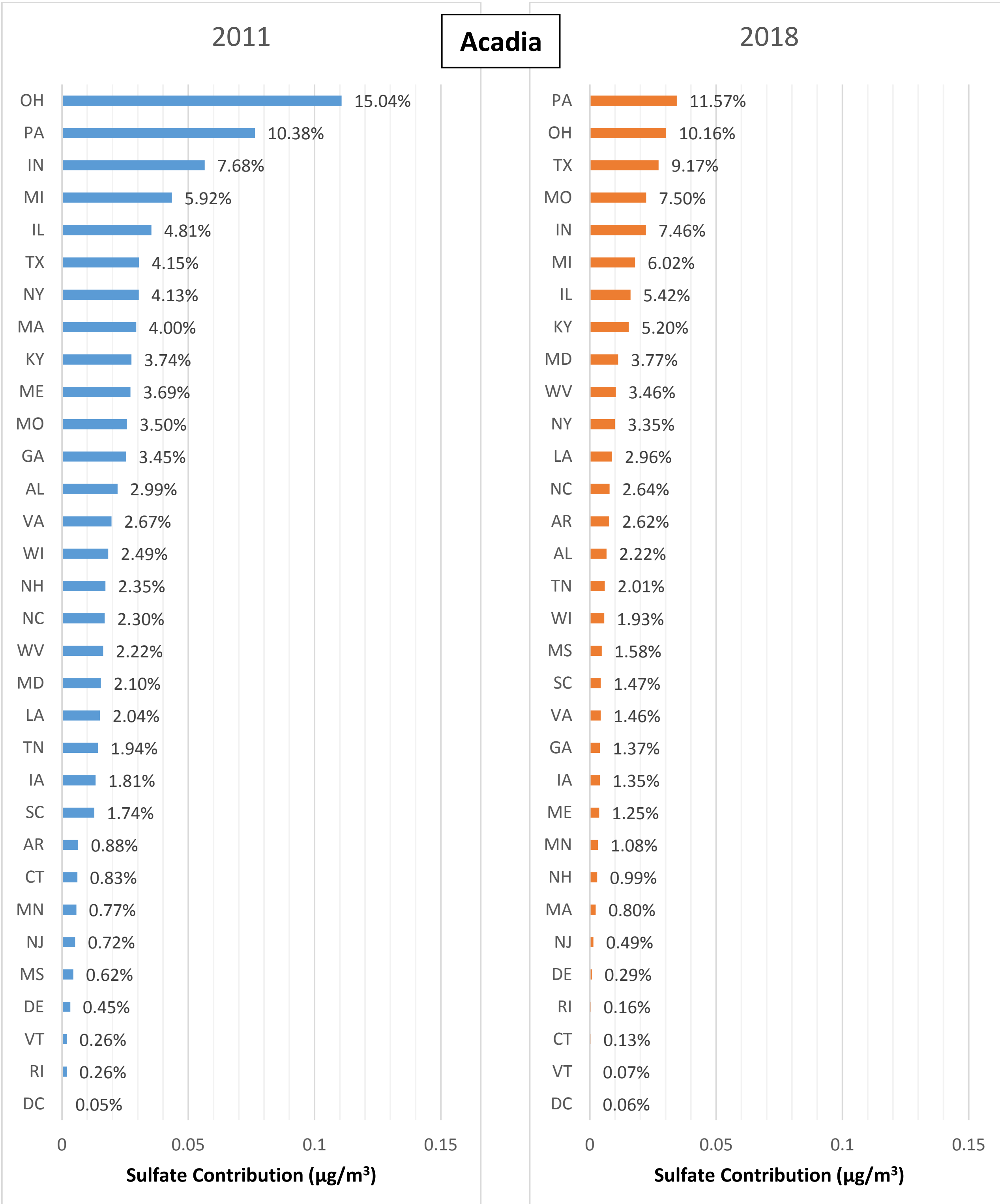
Figure 7 and Figure 8, respectively. Figure 9 emphasizes the outsized role of coal EGUs on impact, since nine of the top ten EGU SCCs in terms of projected 2018 impact are from coal powered EGUs (the other SCC in the top ten is associated with oil powered EGUs).

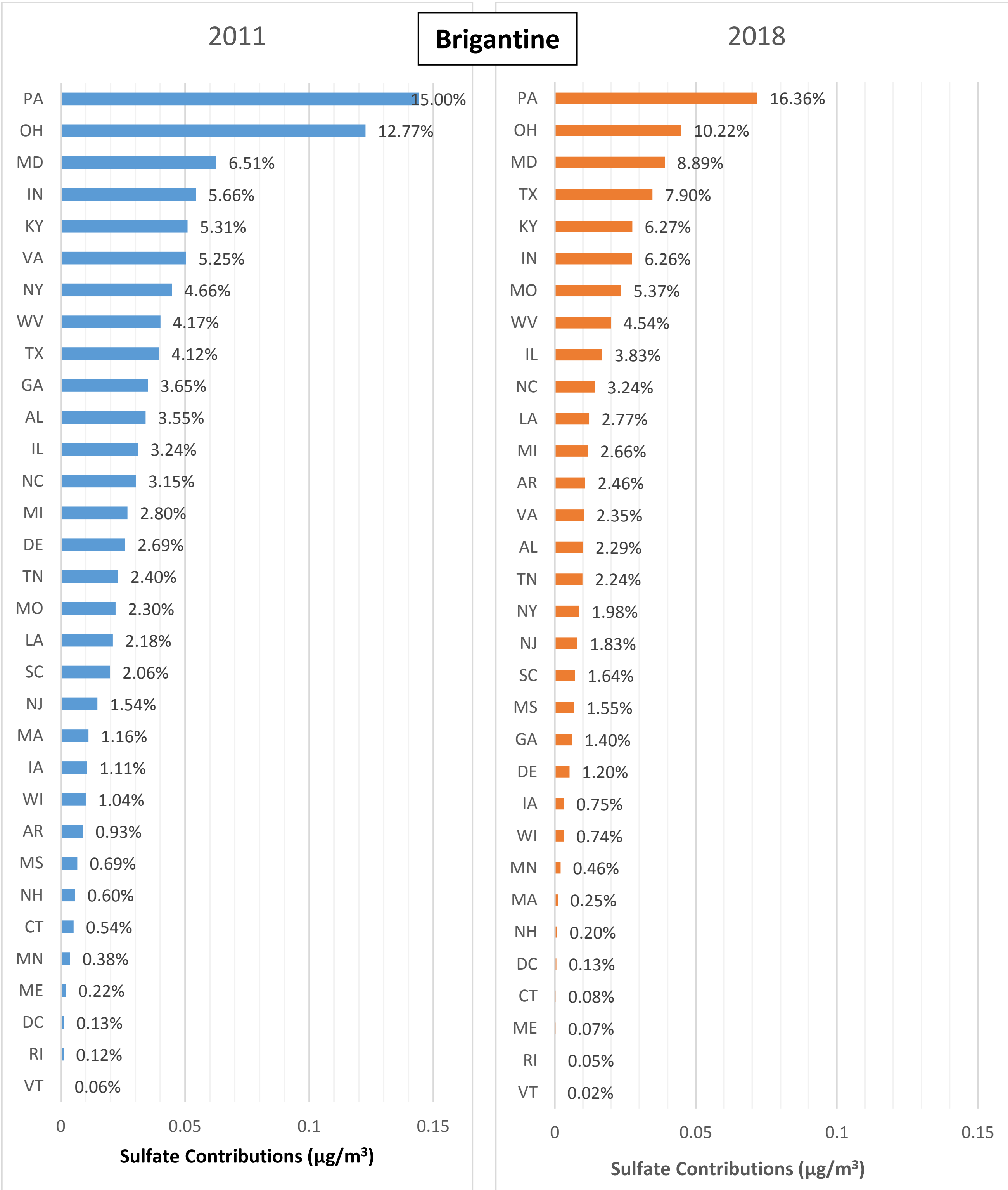
Figure 5: Average and maximum state point source contribution to monitored class I areas for 2011 and 2018

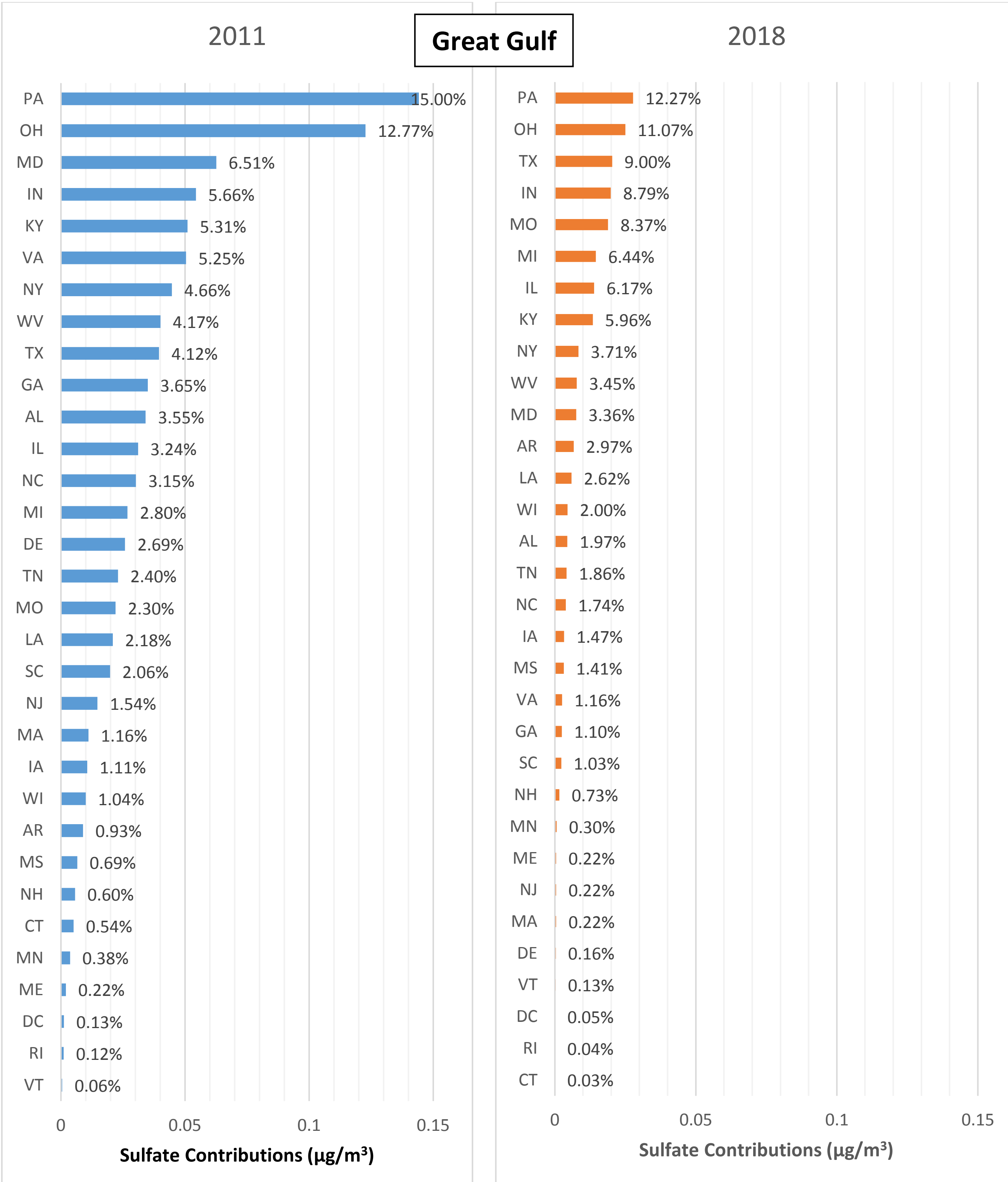


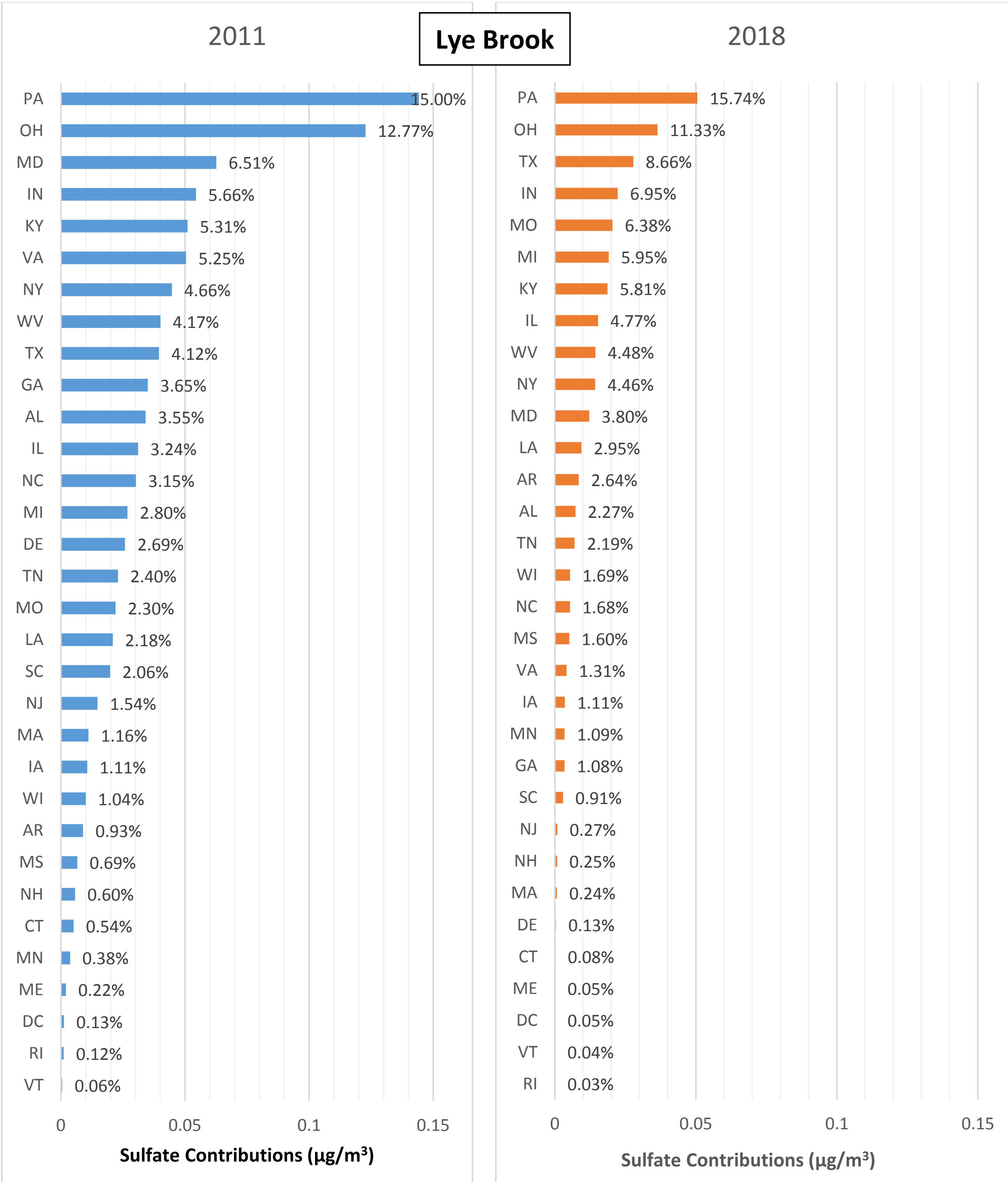
	Acadia 2011	Acadia 2018	Brigantine 2011	Brigantine 2018	Dolly Sods 2011	Dolly Sods 2018	Great Gulf 2011	Great Gulf 2018	James River Face 2011	James River Face 2018	Lye Brook 2011	Lye Brook 2018	Moosehorn 2011	Moosehorn 2018	Shenandoah 2011	Shenandoah 2018
Average	0.0214235	0.0092969	0.0275686	0.0137088	0.0346418	0.0187993	0.0151724	0.0070634	0.0302113	0.0151743	0.0212774	0.0100431	0.0157828	0.0079349	0.0322890	0.0157888
Max	0.1107220	0.0344268	0.1441850	0.0717839	0.2851940	0.0879930	0.0979260	0.0277355	0.1480420	0.0640868	0.1324240	0.0505901	0.0796130	0.0277739	0.2058470	0.0692504

Figure 6. Total point contributions (and percent of total contribution in labels) for 2011 actual and 2018 projections for state in OTC modeling domain.


Acadia
2011
OH 15.04%
PA 10.38%
IN 7.68%
MI 5.92%
IL 4.81%
TX 4.15%
NY 4.13%
MA 4.00%
KY 3.74%
ME 3.69%
MO 3.50%
GA 3.45%
AL 2.99%
VA 2.67%
WI 2.49%
NH 2.35%
NC 2.30%
WV 2.22%
MD 2.10%
LA 2.04%
TN 1.94%
IA 1.81%
SC 1.74%
AR 0.88%
CT 0.83%
MN 0.77%
NJ 0.72%
MS 0.62%
DE 0.45%
VT 0.26%
RI 0.26%
DC 0.05%
0
0.05
0.1
0.15
Sulfate Contribution (µg/m³)
2018
PA 11.57%
OH 10.16%
TX 9.17%
MO 7.50%
IN 7.46%
MI 6.02%
IL 5.42%
KY 5.20%
MD 3.77%
WV 3.46%
NY 3.35%
LA 2.96%
NC 2.64%
AR 2.62%
AL 2.22%
TN 2.01%
WI 1.93%
MS 1.58%
SC 1.47%
VA 1.46%
GA 1.37%
IA 1.35%
ME 1.25%
MN 1.08%
NH 0.99%
MA 0.80%
NJ 0.49%
DE 0.29%
RI 0.16%
CT 0.13%
VT 0.07%
DC 0.06%
0
0.05
0.1
0.15
Sulfate Contribution (µg/m³)


Brigantine
2011
PA 15.00%
OH 12.77%
MD 6.51%
IN 5.66%
KY 5.31%
VA 5.25%
NY 4.66%
WV 4.17%
TX 4.12%
GA 3.65%
AL 3.55%
IL 3.24%
NC 3.15%
MI 2.80%
DE 2.69%
TN 2.40%
MO 2.30%
LA 2.18%
SC 2.06%
NJ 1.54%
MA 1.16%
IA 1.11%
WI 1.04%
AR 0.93%
MS 0.69%
NH 0.60%
CT 0.54%
MN 0.38%
ME 0.22%
DC 0.13%
RI 0.12%
VT 0.06%
0
0.05
0.1
0.15
Sulfate Contributions (μg/m³)
2018
PA 16.36%
OH 10.22%
MD 8.89%
TX 7.90%
KY 6.27%
IN 6.26%
MO 5.37%
WV 4.54%
IL 3.83%
NC 3.24%
LA 2.77%
MI 2.66%
AR 2.46%
VA 2.35%
AL 2.29%
TN 2.24%
NY 1.98%
NJ 1.83%
SC 1.64%
MS 1.55%
GA 1.40%
DE 1.20%
IA 0.75%
WI 0.74%
MN 0.46%
MA 0.25%
NH 0.20%
DC 0.13%
CT 0.08%
ME 0.07%
RI 0.05%
VT 0.02%
0
0.05
0.1
0.15
Sulfate Contributions (μg/m³)


Great Gulf
2011
PA 15.00%
OH 12.77%
MD 6.51%
IN 5.66%
KY 5.31%
VA 5.25%
NY 4.66%
WV 4.17%
TX 4.12%
GA 3.65%
AL 3.55%
IL 3.24%
NC 3.15%
MI 2.80%
DE 2.69%
TN 2.40%
MO 2.30%
LA 2.18%
SC 2.06%
NJ 1.54%
MA 1.16%
IA 1.11%
WI 1.04%
AR 0.93%
MS 0.69%
NH 0.60%
CT 0.54%
MN 0.38%
ME 0.22%
DC 0.13%
RI 0.12%
VT 0.06%
0
0.05
0.1
0.15
Sulfate Contributions (µg/m³)
2018
PA 12.27%
OH 11.07%
TX 9.00%
IN 8.79%
MO 8.37%
MI 6.44%
IL 6.17%
KY 5.96%
NY 3.71%
WV 3.45%
MD 3.36%
AR 2.97%
LA 2.62%
WI 2.00%
AL 1.97%
TN 1.86%
NC 1.74%
IA 1.47%
MS 1.41%
VA 1.16%
GA 1.10%
SC 1.03%
NH 0.73%
MN 0.30%
ME 0.22%
NJ 0.22%
MA 0.22%
DE 0.16%
VT 0.13%
DC 0.05%
RI 0.04%
CT 0.03%
0
0.05
0.1
0.15
Sulfate Contributions (µg/m³)


Lye Brook
2011
PA 15.00%
OH 12.77%
MD 6.51%
IN 5.66%
KY 5.31%
VA 5.25%
NY 4.66%
WV 4.17%
TX 4.12%
GA 3.65%
AL 3.55%
IL 3.24%
NC 3.15%
MI 2.80%
DE 2.69%
TN 2.40%
MO 2.30%
LA 2.18%
SC 2.06%
NJ 1.54%
MA 1.16%
IA 1.11%
WI 1.04%
AR 0.93%
MS 0.69%
NH 0.60%
CT 0.54%
MN 0.38%
ME 0.22%
DC 0.13%
RI 0.12%
VT 0.06%
0
0.05
0.1
0.15
Sulfate Contributions (μg/m³)
2018
PA 15.74%
OH 11.33%
TX 8.66%
IN 6.95%
MO 6.38%
MI 5.95%
KY 5.81%
IL 4.77%
WV 4.48%
NY 4.46%
MD 3.80%
LA 2.95%
AR 2.64%
AL 2.27%
TN 2.19%
WI 1.69%
NC 1.68%
MS 1.60%
VA 1.31%
IA 1.11%
MN 1.09%
GA 1.08%
SC 0.91%
NJ 0.27%
NH 0.25%
MA 0.24%
DE 0.13%
CT 0.08%
ME 0.05%
DC 0.05%
VT 0.04%
RI 0.03%
0
0.05
0.1
0.15
Sulfate Contributions (μg/m³)

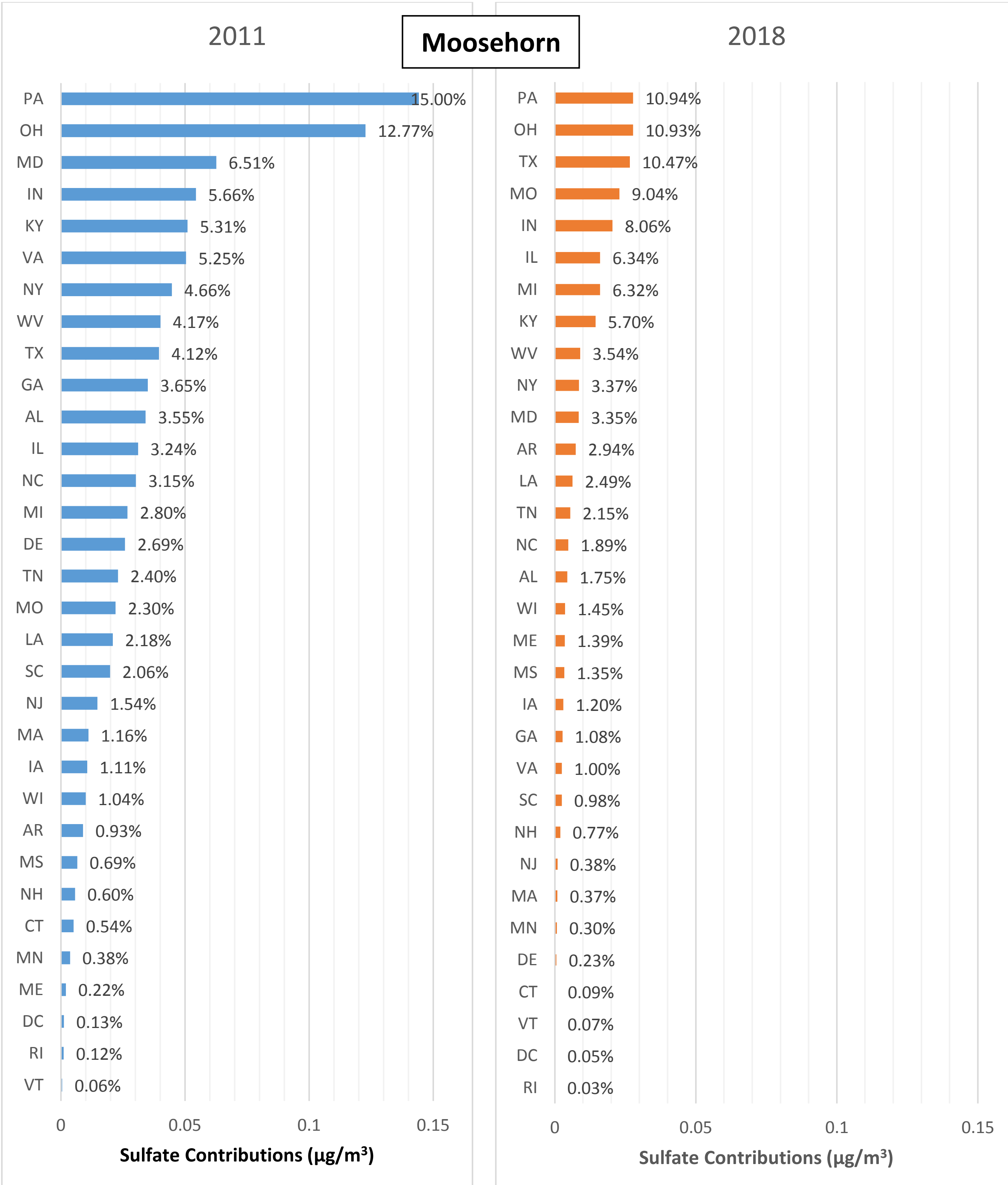

Moosehorn
2011
PA 15.00%
OH 12.77%
MD 6.51%
IN 5.66%
KY 5.31%
VA 5.25%
NY 4.66%
WV 4.17%
TX 4.12%
GA 3.65%
AL 3.55%
IL 3.24%
NC 3.15%
MI 2.80%
DE 2.69%
TN 2.40%
MO 2.30%
LA 2.18%
SC 2.06%
NJ 1.54%
MA 1.16%
IA 1.11%
WI 1.04%
AR 0.93%
MS 0.69%
NH 0.60%
CT 0.54%
MN 0.38%
ME 0.22%
DC 0.13%
RI 0.12%
VT 0.06%
0
0.05
0.1
0.15
Sulfate Contributions (µg/m³)
2018
PA 10.94%
OH 10.93%
TX 10.47%
MO 9.04%
IN 8.06%
IL 6.34%
MI 6.32%
KY 5.70%
WV 3.54%
NY 3.37%
MD 3.35%
AR 2.94%
LA 2.49%
TN 2.15%
NC 1.89%
AL 1.75%
WI 1.45%
ME 1.39%
MS 1.35%
IA 1.20%
GA 1.08%
VA 1.00%
SC 0.98%
NH 0.77%
NJ 0.38%
MA 0.37%
MN 0.30%
DE 0.23%
CT 0.09%
VT 0.07%
DC 0.05%
RI 0.03%
0
0.05
0.1
0.15
Sulfate Contributions (µg/m³)

Figure 7: Impact on Class 1 Areas by Point Sectors

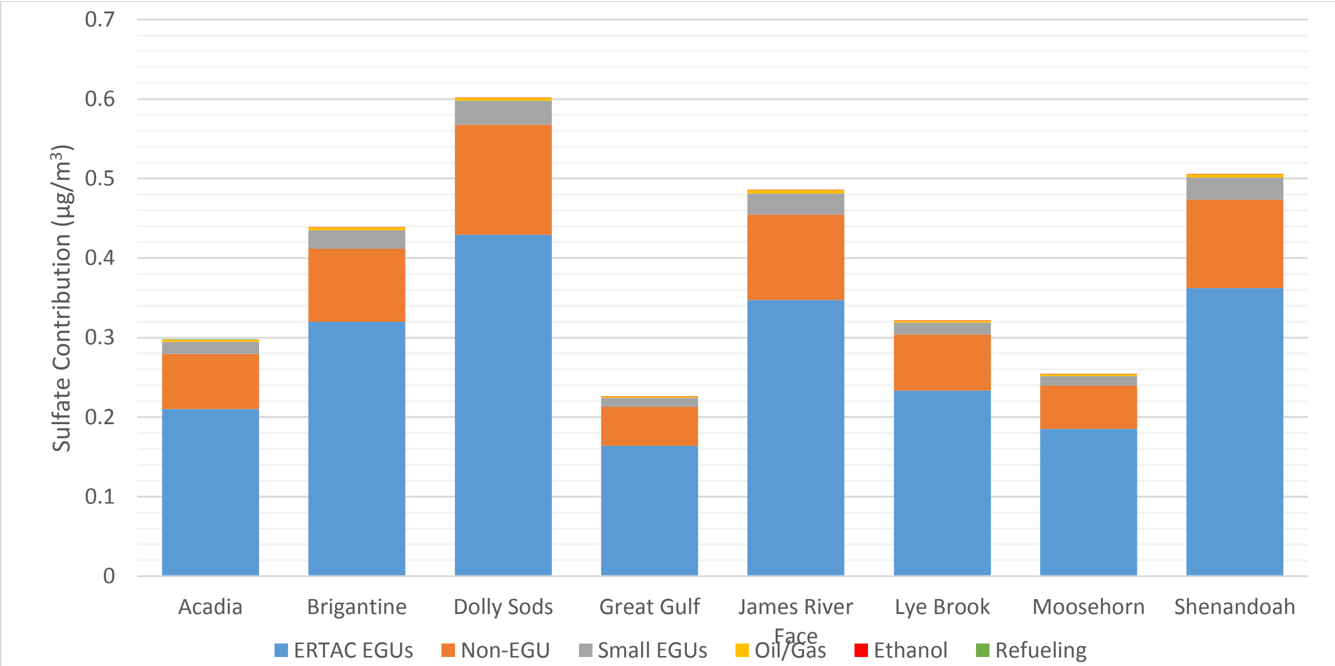


Figure 8: Relative Impact on Class 1 Areas by Point Sectors

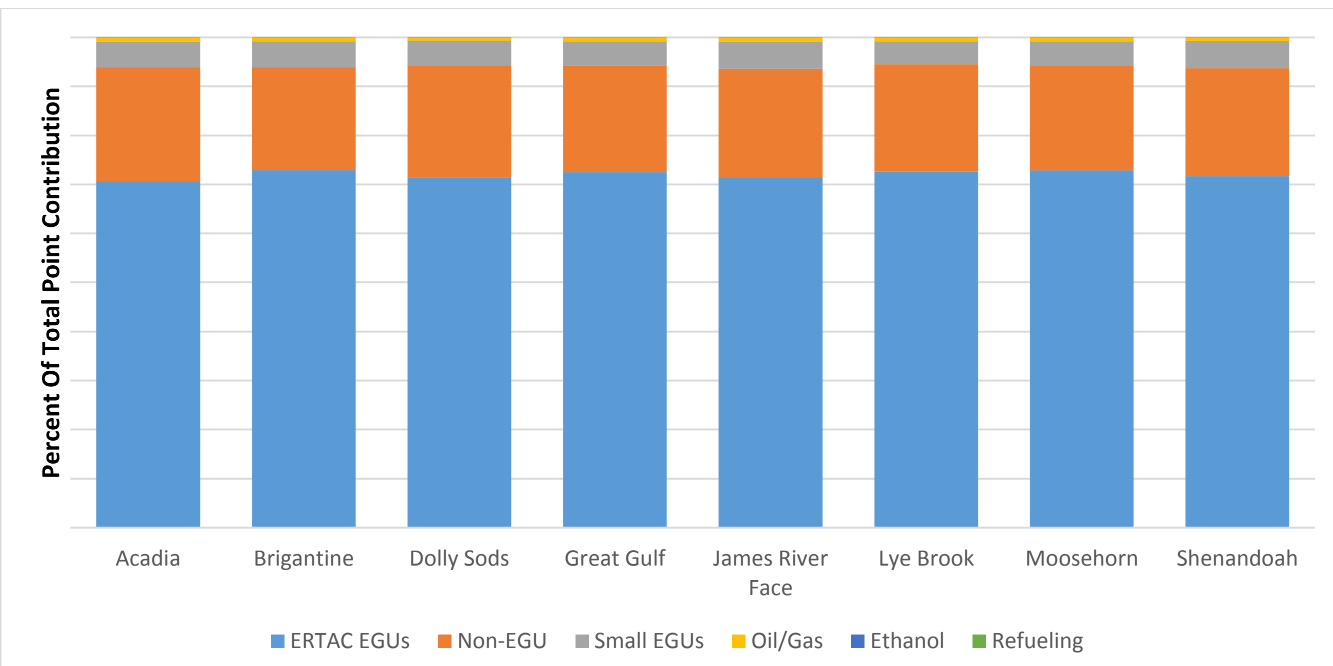
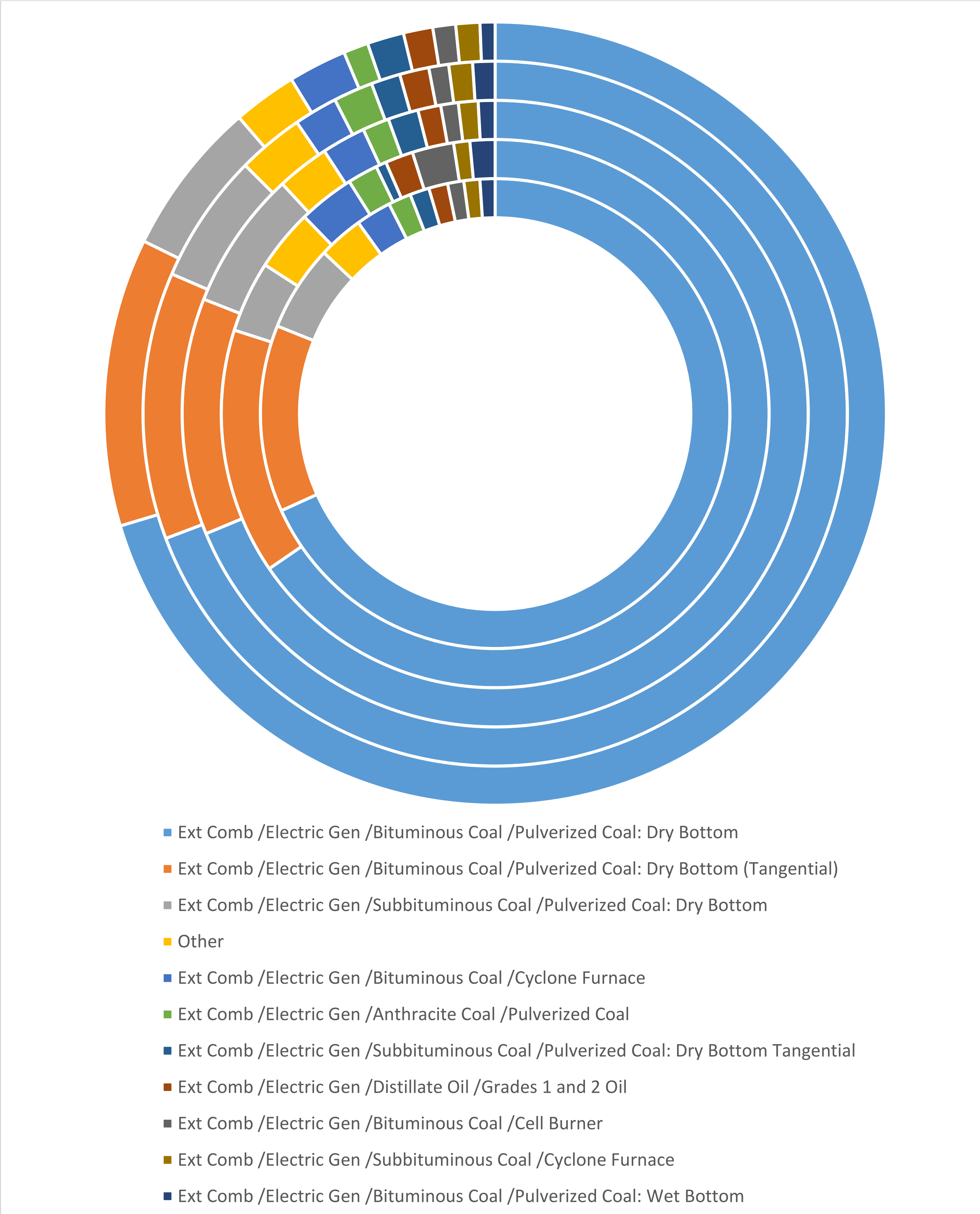


Figure 9: Relative Impact of EGU Point Source SCCs on Acadia, Brigantine, Great Gulf, Lye Brook, and Moosehorn (inner to outer)

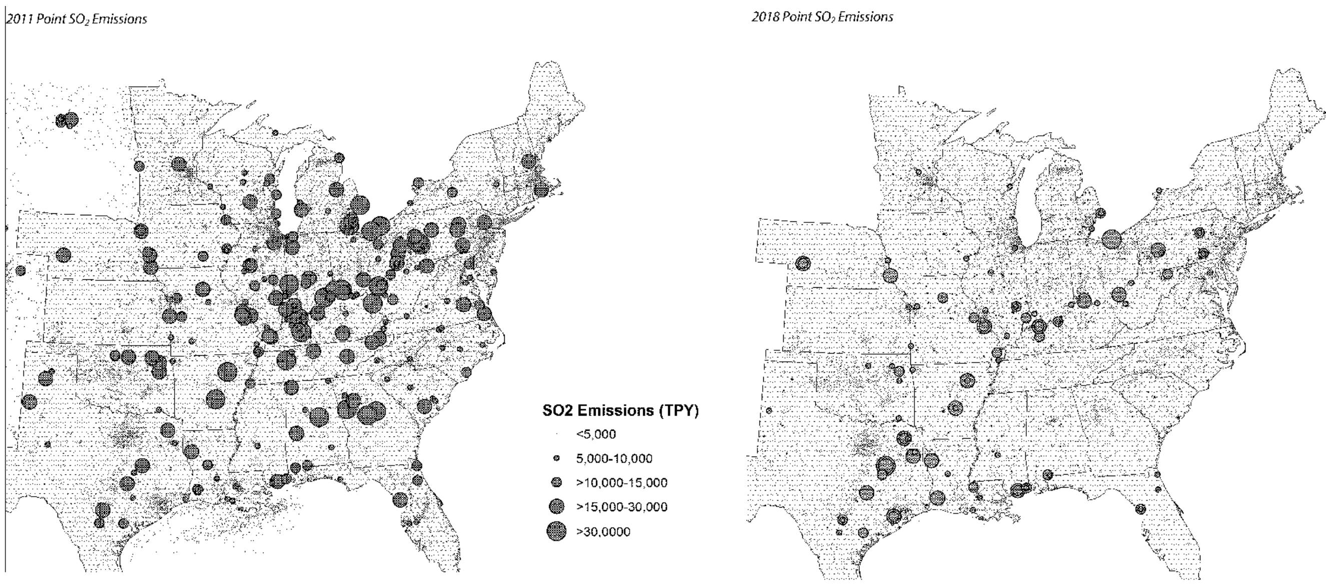

Ext Comb /Electric Gen /Bituminous Coal /Pulverized Coal: Dry Bottom
Ext Comb /Electric Gen /Bituminous Coal /Pulverized Coal: Dry Bottom (Tangential)
Ext Comb /Electric Gen /Subbituminous Coal /Pulverized Coal: Dry Bottom
Other
Ext Comb /Electric Gen /Bituminous Coal /Cyclone Furnace
Ext Comb /Electric Gen /Anthracite Coal /Pulverized Coal
Ext Comb /Electric Gen /Subbituminous Coal /Pulverized Coal: Dry Bottom Tangential
Ext Comb /Electric Gen /Distillate Oil /Grades 1 and 2 Oil
Ext Comb /Electric Gen /Bituminous Coal /Cell Burner
Ext Comb /Electric Gen /Subbituminous Coal /Cyclone Furnace
Ext Comb /Electric Gen /Bituminous Coal /Pulverized Coal: Wet Bottom

Conclusions

The 2015 analyses; 2011 state total emissions, 2011 point emissions and the 2018 point emissions, each provide a unique insight to the contribution of each state and source sector the MANE-VU and neighboring class I areas. This report is the summary and is a starting point for the states in the region to assess their contributions to each neighboring class I area and for the class I areas state to further address the appropriate next steps in tandem with the other analyses available.

The summary of the results presented above illuminated two approaches a geographic approach and source sector approach. Geographically, all three of the 2015 analyses resulted in two top contributors, Ohio and Pennsylvania. The remaining state rankings varied by class I area and by analysis type (total emissions vs. point only emissions). The source sector approach, determined that EGUS (more specifically coal EGUs) still dominated the contributions. While emissions have and are projected to decrease in 2018, see Figure 10 , further work is needed to accomplish to visibility goals for 2064 and the resulting near term goals for the next ten-year planning cycle.

Figure 10. 2011 and 2018 Point Emissions



Appendix A - Inputs to the emissions over distance approach

Table A-1. Geographic coordinates used for "center of state" locations

State	Latitude	Longitude		State	Latitude	Longitude
Alabama	33.008097	-86.756826		Mississippi	32.590954	-89.579514
Arkansas	35.14258	-92.655243		Missouri	38.423798	-92.198469
Connecticut	41.497001	-72.870342		Nebraska	41.1743	-97.315578
Delaware	39.358946	-75.556835		New Hampshire	43.154858	-71.461974
District of Columbia	38.91027	-77.014468		New Jersey	40.43181	-74.432208
Florida	27.822726	-81.634654		New York	41.501299	-74.620909
Georgia	33.376825	-83.882712		North Carolina	35.543075	-79.658232
Illinois	41.286759	-88.390334		Ohio	40.455191	-82.773339
Indiana	40.149246	-86.259514		Oklahoma	35.598464	-96.836786
Iowa	41.946066	-93.036629		Pennsylvania	40.456756	-77.00968
Kansas	38.464949	-96.462812		Rhode Island	41.753609	-71.450869
Kentucky	37.824499	-85.248467		South Carolina	34.025176	-81.011022
Louisiana	30.722814	-91.508833		Tennessee	35.80809	-86.359136
Maine	44.29995	-69.736482		Texas	30.905244	-97.365594
Maryland	39.140769	-76.797763		Vermont	44.094874	-72.816417
Massachusetts	42.272291	-71.36337		Virginia	37.810313	-77.81116
Michigan	42.873187	-84.203434		West Virginia	38.795594	-80.731308
Minnesota	45.203555	-93.571903		Wisconsin	43.721933	-89.018997

Table A-2. Geographic coordinates used for Class I area locations

Class I Area	Area Abbreviation	Latitude	Longitude
Acadia National Park	ACAD	44.3771	-68.2612
Moosehorn Wilderness Area	MOOS	45.1259	-67.2661
Great Gulf Wilderness Area	GRGU	44.3082	-71.2177
Brigantine Wilderness Area	BRIG	39.465	-74.4492
Lye Brook Wilderness Area	LYBR	43.1481	-73.1267
Shenandoah National Park	SHEN	38.5228	-78.4347
Dolly Sods Wilderness Area	DOSO	39.1069	-79.4262

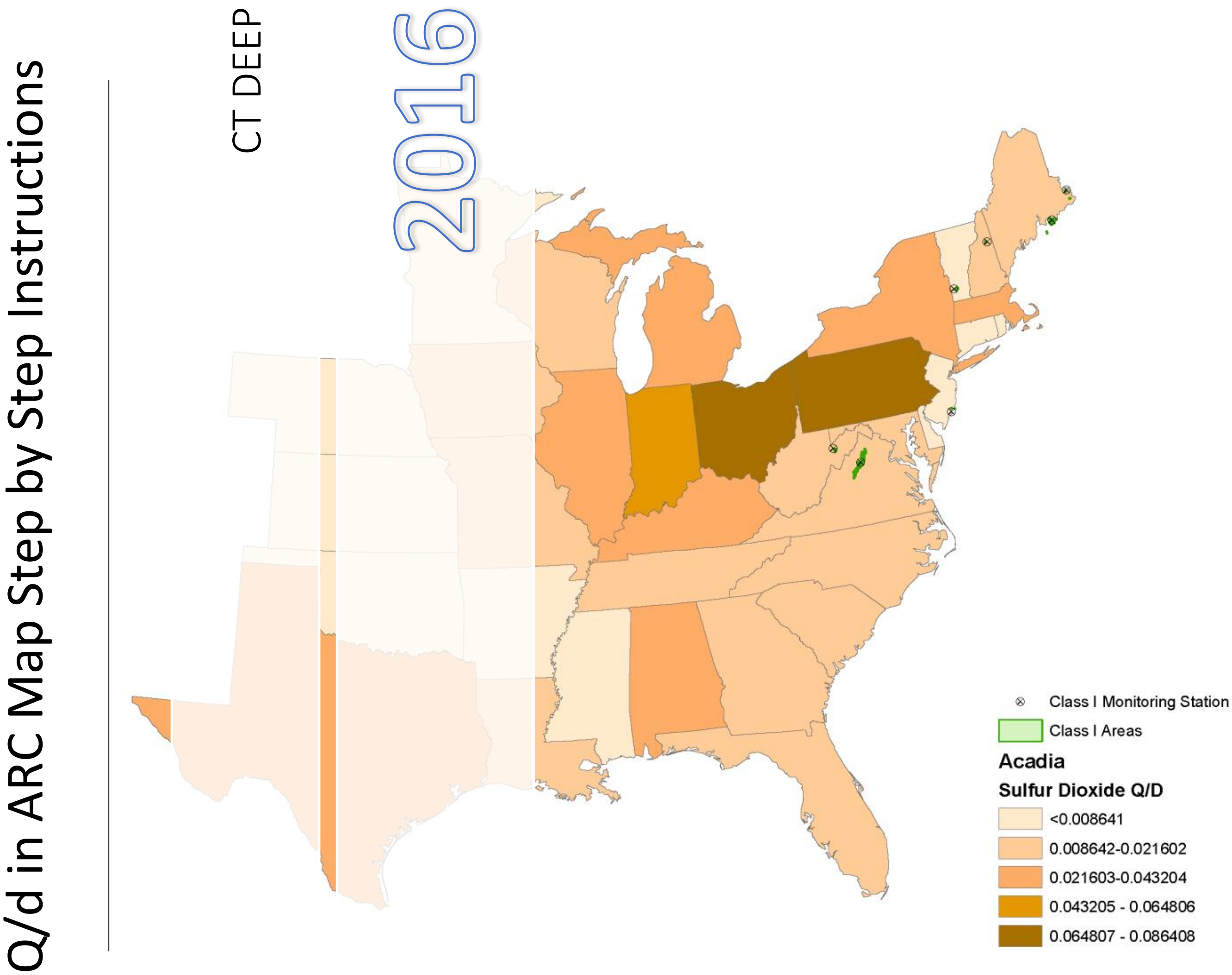
Table A-3. Wind direction sector constants

Class I Area Abbreviation	Minimum Angle	Maximum Angle	Constant (*Ci*)
ACAD	0	171	0.00016071
ACAD	172	197	0.00020593
ACAD	198	216	0.00016071
ACAD	217	226	0.00019667
ACAD	227	360	0.00016071
DOSO	0	140	0.00008446
DOSO	141	254	0.00013503
DOSO	255	355	0.00006458
DOSO	356	360	0.00006458
BRIG	0	33	0.0000882
BRIG	34	156	0.0000882
BRIG	157	179	0.00012905
BRIG	180	189	0.00017808
BRIG	190	237	0.00016108
BRIG	238	360	0.0000882

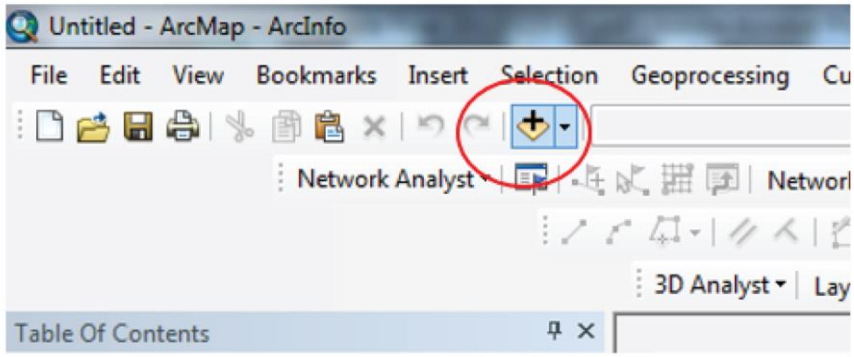
Class I Area Abbreviation	Minimum Angle	Maximum Angle	Constant (*Ci*)
GRGU	0	170	0.00002371
GRGU	171	203	0.00014956
GRGU	204	236	0.00009968
GRGU	237	289	0.00002371
GRGU	290	360	0.00002371
LYBR	0	143	0.00002303
LYBR	144	225	0.00014575
LYBR	226	240	0.00010289
LYBR	241	299	0.00005815
LYBR	300	360	0.00002303
MOOS	0	173	0.00003842
MOOS	174	184	0.00015274
MOOS	185	196	0.00022409
MOOS	197	209	0.00015967
MOOS	210	211	0.00003842
MOOS	212	212	0.00016344
MOOS	213	215	0.00012298
MOOS	216	225	0.00015147
MOOS	225	360	0.00003842
SHEN	0	133	0.00009164
SHEN	134	280	0.00012969
SHEN	281	311	0.00006097
SHEN	312	360	0.00006097

Note: Above angles are measured in degrees counterclockwise, with east equal to zero degrees.

Appendix B - Q/d in ARC Map Step by Step Instructions

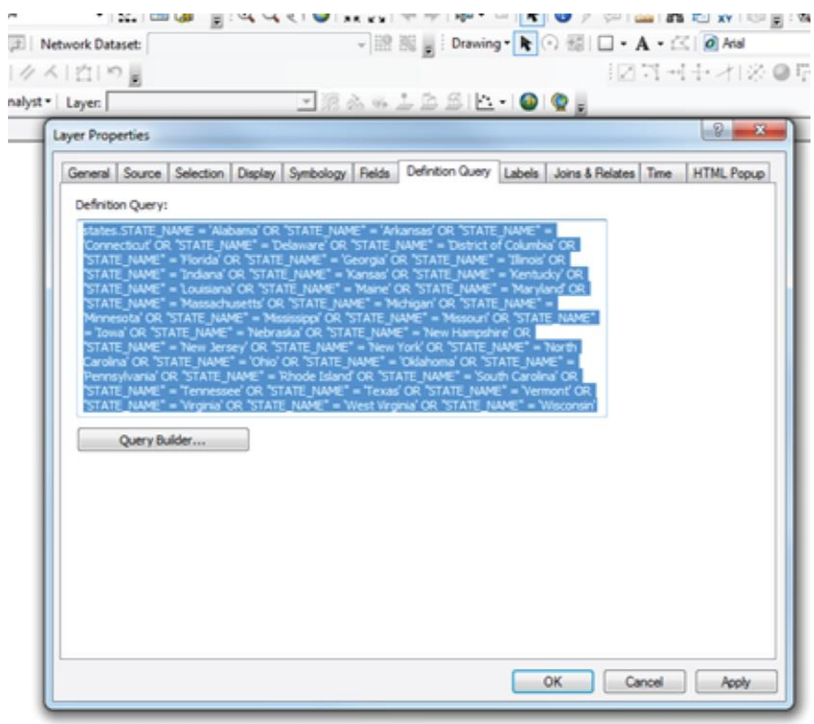


1. In new map import state out line shape file. The most up to date shape file can be downloaded at https://www.census.gov/geo/maps-data/data/tiger-line.html
    a. To import select the add data button circled below.

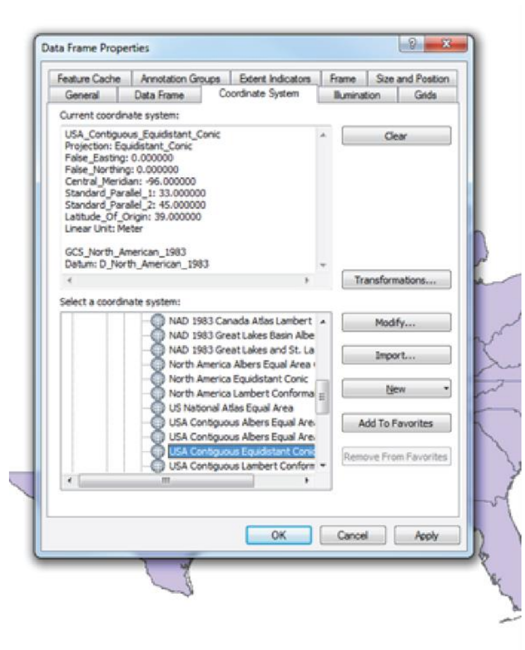


    b. Set definition query to limit view to the states you wish to anlayze. For the 2015 Q/D up date this list of states was used. – Doing this step will save you from memory limits and speed up the calculation steps later on.

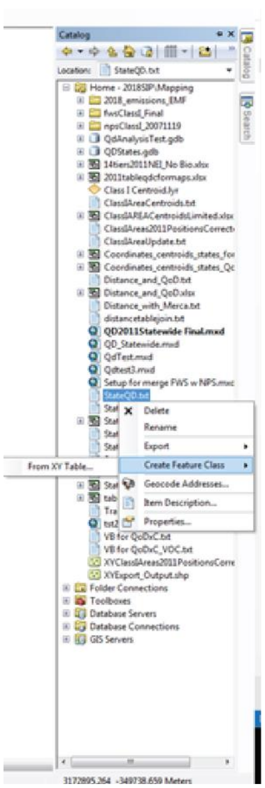
Alabama
Arkansas
Connecticut
Delaware
District of Columbia
Florida
Georgia
Illinois
Indiana
Iowa
Kansas
Kentucky
Louisiana
Maine
Maryland
Massachusetts
Michigan
Minnesota
Mississippi
Missouri
Nebraska
New Hampshire
New Jersey
New York
North Carolina
Ohio
Oklahoma
Pennsylvania
Rhode Island
South Carolina
Tennessee
Texas
Vermont
Virginia
West Virginia
Wisconsin



2. Set the projection for the map
    a. Right click in the map and select Data Frame Properties.
    b. Select the Coordinate System Tab
    c. Select a projection in the projected folder. Depending on your area there may be a different projection that is best suited to your area, but make sure to use one that represents distances correctly, if you do not your distance calculation could be signifigantly skewed. For the purposes of the 2015 Q/d the region USA contigious Equidistant conical. This best represented the states selected and preserved the quality of the distances.



3. Select the add data button again and import the population weighted state centroids.



a. You can calculate geographic centroids through the calculate geometery when adding a field in the polygons of interests table. For the 2015 update this was not done and centroids were used from Appendix A of the Contributions to Regional Haze in the Northeast and Mid-Atlantic United States: Preliminary Update Through 2007, this table was pasted into excel file with state total NH3, SO2, NOX, PM2.5 primary and VOC emissions totals[5] for each state (minus biogenic/natural totals) and a shape file was made from this appendix.

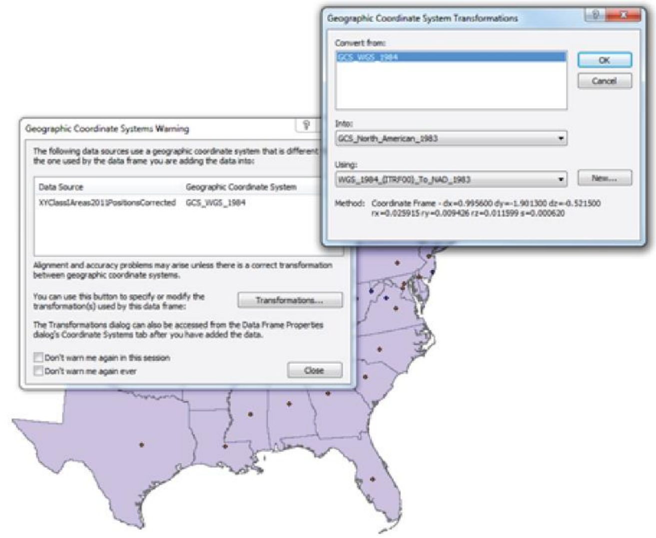
b. To create shapefile from csv or excel:

i. Right click on file in the catalog list select create feature class then select from xy table

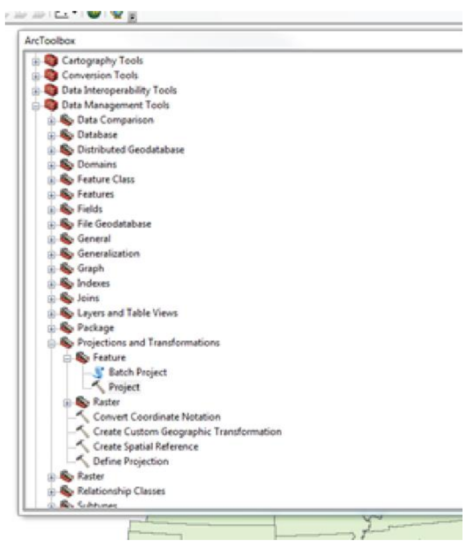
ii. Identify the coodinate system- the coordinates in appendix A are WGS 84.

[5] NEI 2011 version 2 (April, 2015 download)

c. Import new shapefile into the map and check the transformation is correct WGS 1984 into North american 1983 is what was used.- Repeat with Class I area monitors coordinates.

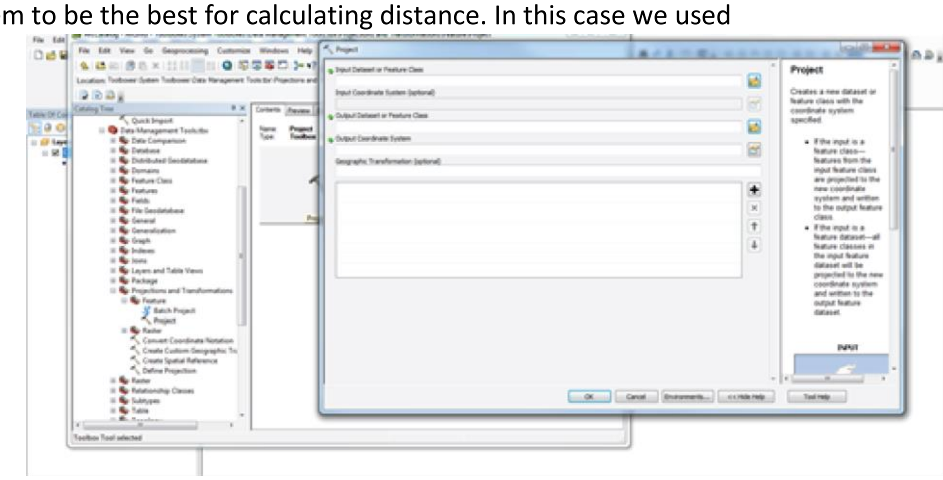


4. This takes the shape file which is in WGS84 and places it in the correct NAD 83 position; now you must convert your shapfiles to the NAD83 datum so that the distance will result in meters and not the angle from the center of the earth (degrees).



5. To convert each shapefile to the projection needed open Data Management Tools>Projections and Transformations>Feature>Project (see image at left)

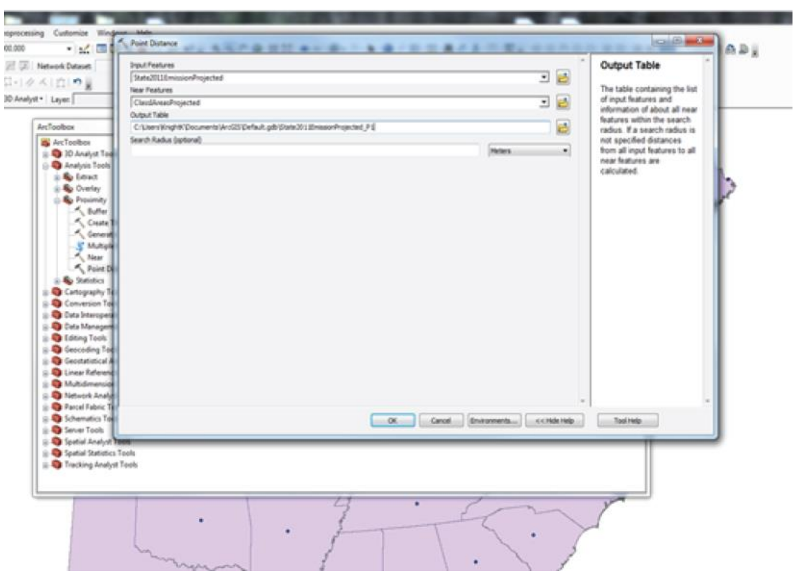
6. Select one of your features (State Centroids with Emissions or the Park Monitors) as the Input Data Set. Select output coordinate system to be the best for calculating distance. In this case we used USA Contiguous Equidistant Conic.prj. (If including Canada in furture I would suggest selecting North America Equidistant Conic) Repeat for the other feature.



7. To ensure your transformation took check the units in the lower right , if you are in NAD 83 projected they should be in meters not DD. If it did not take go into data management tools and projections and retry the projection. Use this tool to project the geometric layer into a projected.

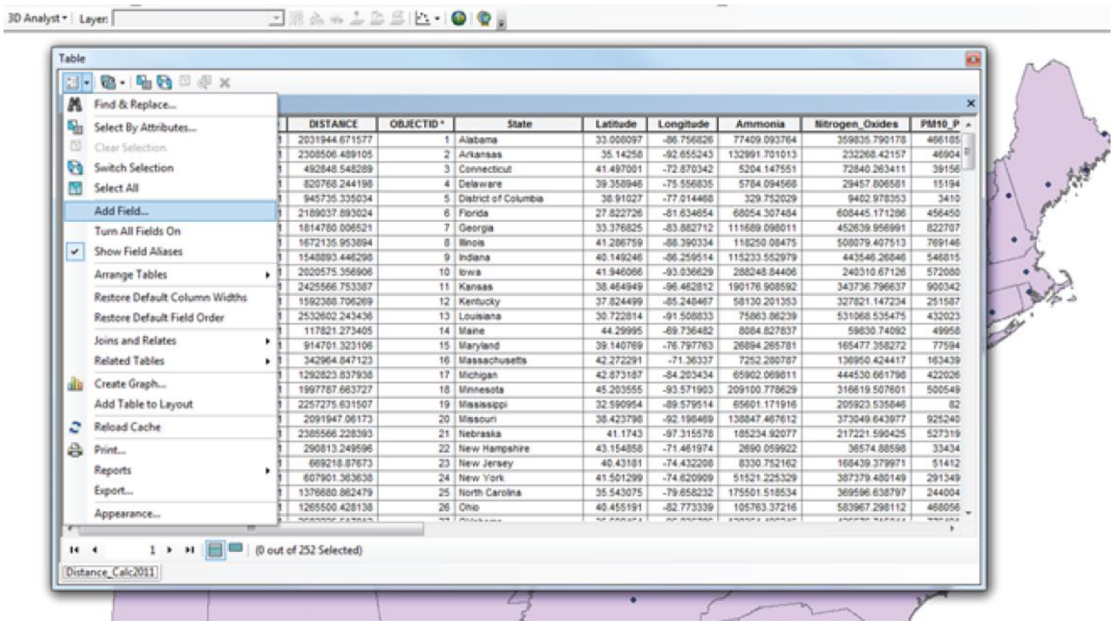
8. Calculate distance
    a. Open Arc tool box and select analysis tools and proxmity tool set. The input feature was state centroids. Make sure to use the newly create shape file that is projected into the flat projection not your WGS 84 file.

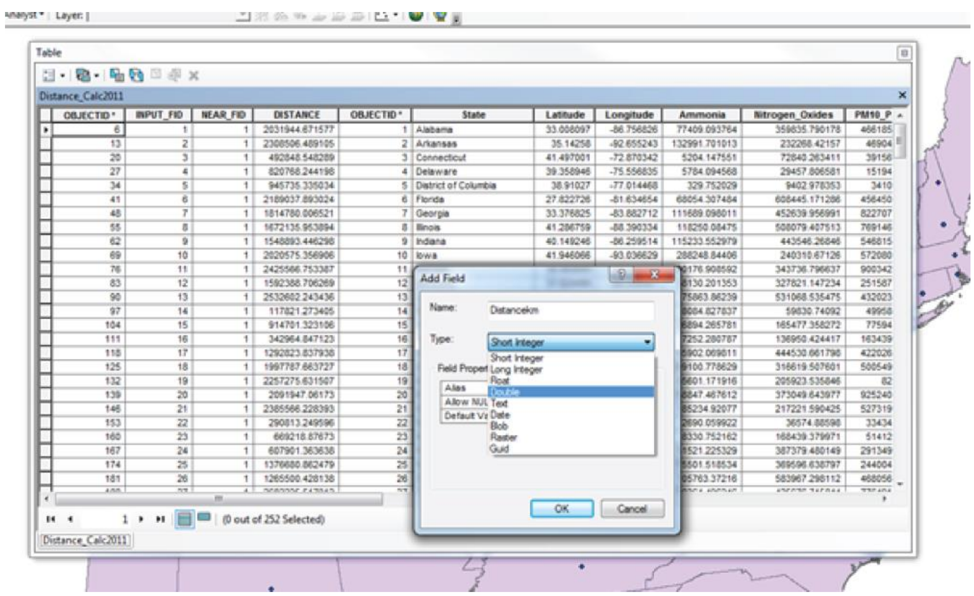
9. Do a quick does this make sense check- by joining the features and new output table to get the context. Right click on your newly created distance table select Joins and Relates and then Join. Your input feature was your states. First Select the States feature for box 2. Box 1 is choices of columns from your new distance table input_FID is the state tables object ID select this column and Object Id should auto populate for selection three if it doesn't select it. Then select validate join. Then select ok. It will tell you the number of joins created this will enable you to notice an error immediately. Too many , too little? Often this is result of formating error. You will need to edit the layer to match the format of one of those columns to match the other. Which you choose to edit doesn't matter as long as they are the same and retain all their digits.
10. Repeat the join for the parks but this time use Near FID column to match the object ID in the parks shapefile.

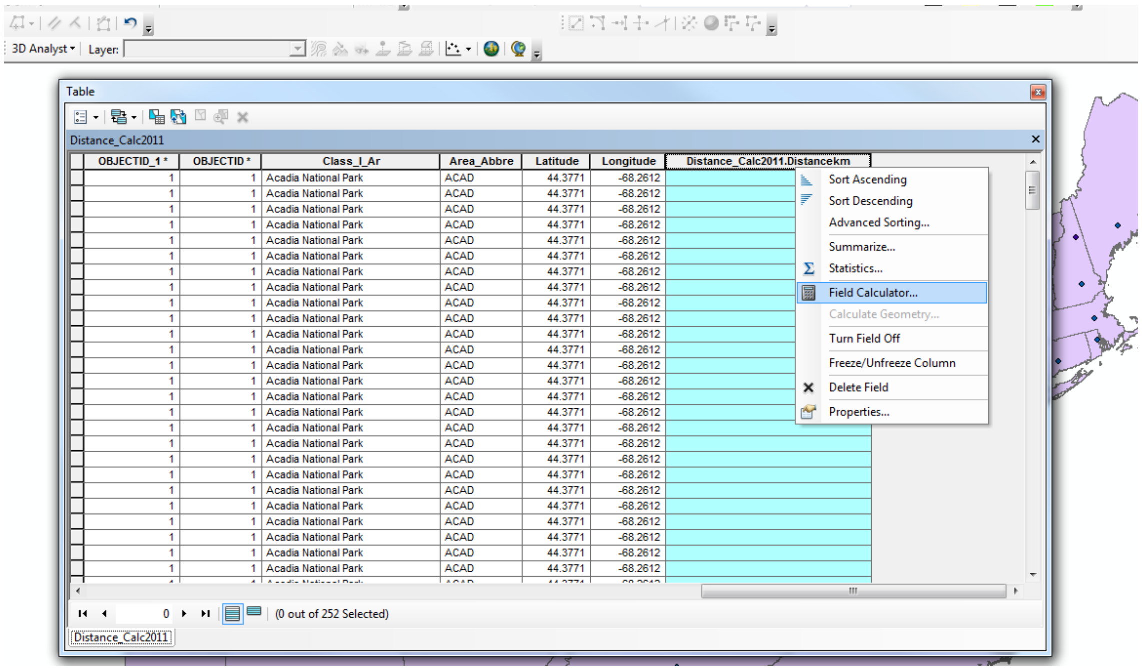


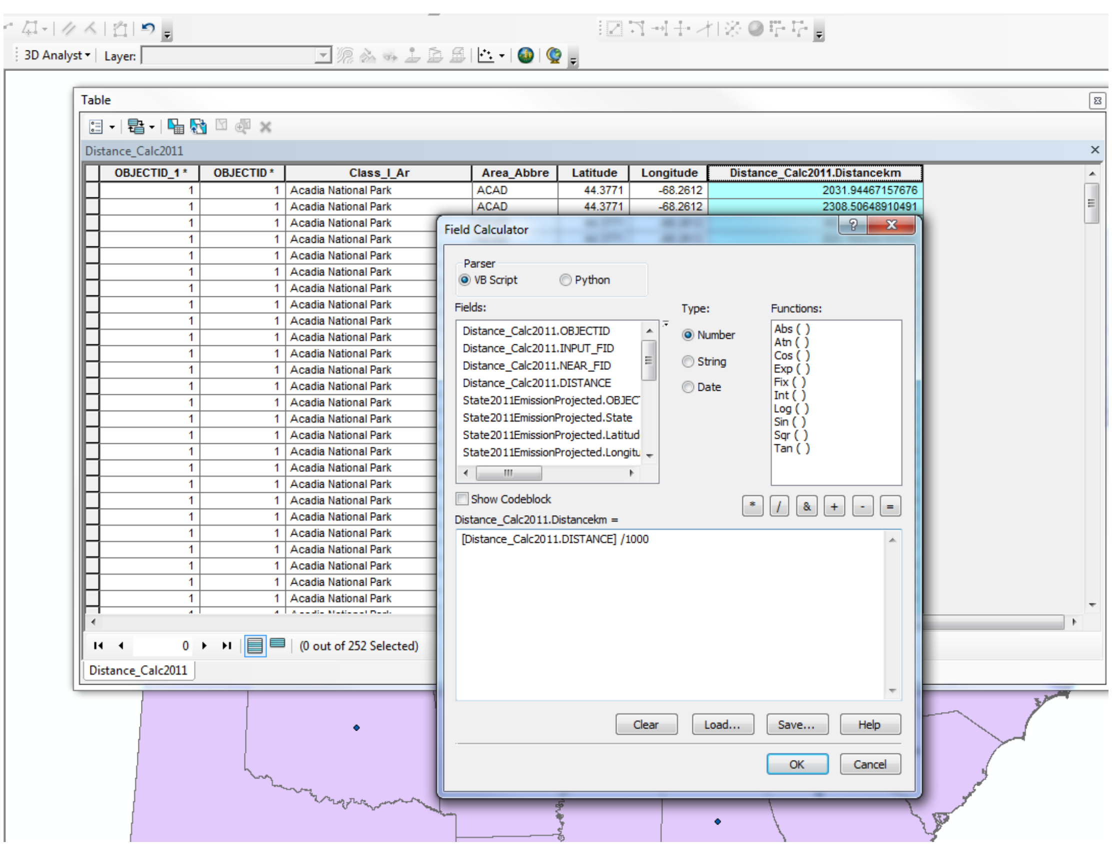
11. Distance is output in m recalculate in km
    a. Add new field to newly created distance table.
    b. Title it and field type should be double

c. Right click new column and select field calculator and insert equation [distance]/1000









12. Calculate the wind vector that the state falls in for each Class I monitor

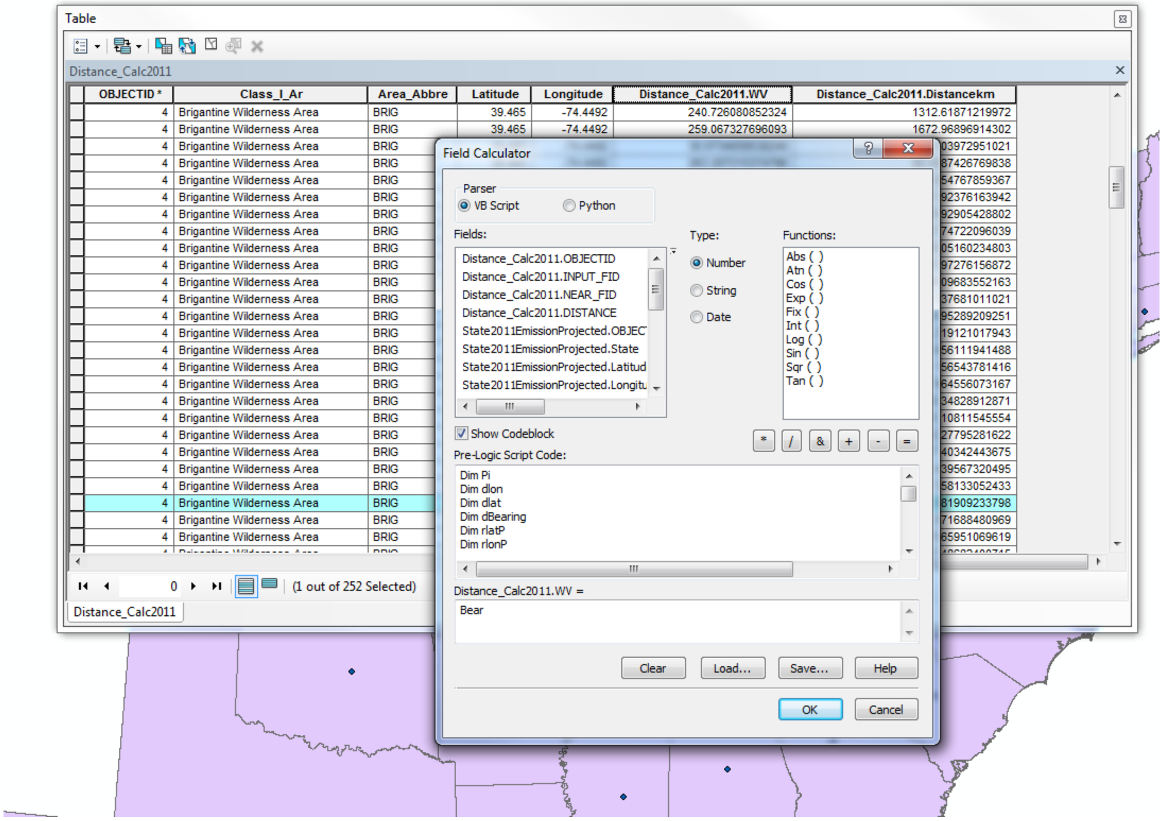
    a. Create new field in state table (type=double)

13. Load or select code book and write an equation for calculating bearing from Class I area to state. For the 2015 update this code was written. Should your column titles be different than Longitude, Latitude, Latitude_1, and longitude_1 it is easiest to open the script file in note pad first and do a find and replace to rename each appropriately as your columns are named in your files. Because the Ci from appendix A of the ["Contributions to Regional Haze in the Northeast and Mid-Atlantic United States: Preliminary Update Through 2007"]() Uses the due east coordinate as 0 degrees and in a counter clockwise direction your bearing will need to be slide 90 degrees and rotated should you want to QA with respect to a north heading. The Ci were developed with this counter clockwise (radian quadrants), see image below for the Acadia example. The equation below puts these in that quadrant system and this result will be the one you apply your Ci value to.

```
Dim Pi
Dim SlatR
Dim SlonR
Dim PlatR
Dim PlonR
Dim dlon
Dim X
Dim Y
Dim Dx
Dim Dy
Dim Bear
Dim Bearing
Pi=4*Atn(1)
SlatR= [FaciProjecEastSO2.latitude_m]*(Pi/180)
SlonR= [FaciProjecEastSO2.longitude_]*(Pi/180)
PlatR= [ClassIProjected.Latitude]*(Pi/180)
PlonR= [ClassIProjected.Longitude]*(Pi/180)
dlon=SlonR-PlonR
X=Sin(dlon)*Cos(SlatR)
Y=Cos(PlatR)*Sin(SlatR)-Sin(PlatR)*Cos(SlatR)*Cos(dlon)
If X>0 AND Y>0 then
Bear=Atn(Y/X)
ElseIf X<0 AND Y>0 then
Bear=Pi+Atn(Y/X)
ElseIf X<0 ANd Y<0 then
Bear=Pi+Atn(Y/X)
ElseIf X>0 AND Y<0 then
Bear=2*PI+Atn(Y/X)
Else
Bear=9999
End If

Bearing=Bear*(180/Pi)
```

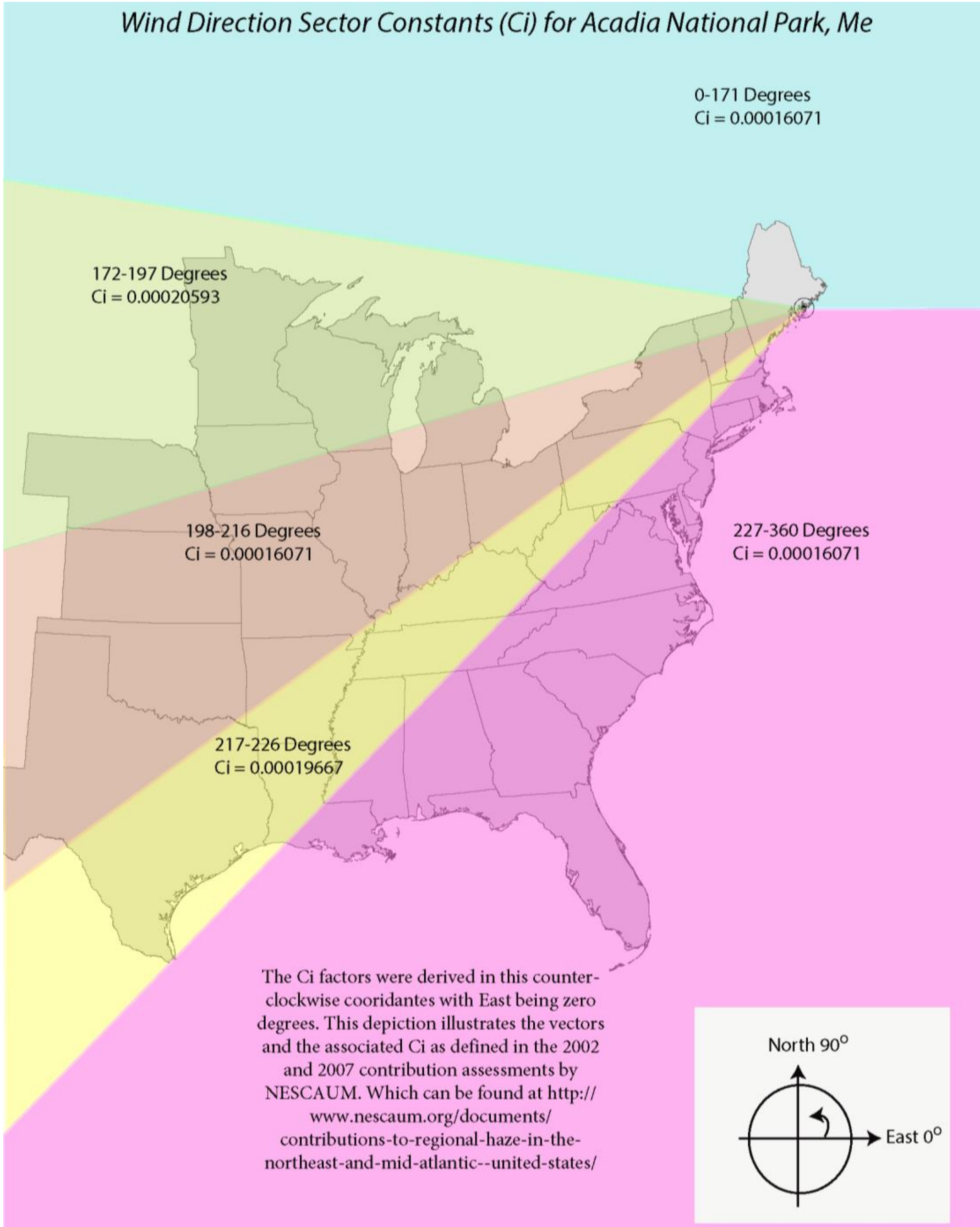
14. Then add new field (again type is double). Q/d Right click and select field calculator and divide emissions by distance in km repeat until each desired Q/d is done. Note – with primary pollutants like PM2.5 use d^2



15. Optional Step for QA Check: Add another field (type=double) dim WVE

```
If [Distance_Calc2011.WV] < 90 then
WVE=90 - [Distance_Calc2011.WV]
Else
WVE=360 - [Distance_Calc2011.WV]- 90
End If
```

This column will have comparable angles to what you think of as a heading w North being zero, easier to quickly eye ball errors.



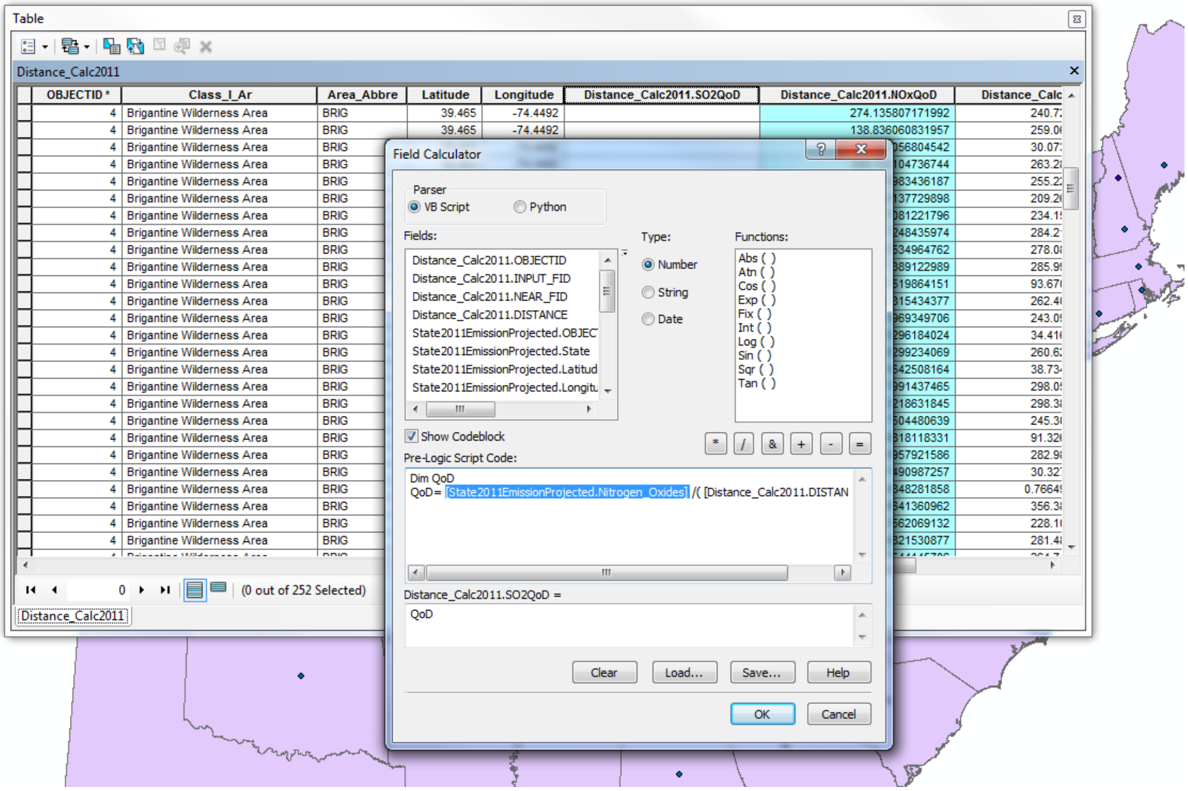
16. Add another field (type=double) and calculate Q/d*C depending on vector calculated earlier. The below scipt was used for 2015 update. Repeated for other pollutants if desired, this study experimented with the other precursors of PM2.5 but in the end found these results to be unreliable and not a priority and were therefore removed. Again easiest way to replace column titles is to open the scrip in Note pad first and find and replace all of that name with the appropriate column names. Remember to use the azimuth created in step 13.
    a. Adding recptors- For the 2015 study the James River Face Wilderness Area was added. This was done to be thorough in considering where MANE-VU states may contribute to. To do so the constants were needed and Dolly Sods and Shenandoah were substituted

to see what made the most sense. Therefore the script below was run twice, once as JARI with SHEN's if then statements and once with JARI with the DOLLY if then statements. Code below illustrates the Shenadoah (SHEN) run.

```
Dim QDC
If [Area_Abbreviation] ="ACAD" then
If [Azimuth] >=171.5 AND [Azimuth] <197.45 then
QDC=[VOCQoD] *0.00020593
ElseIf [Azimuth] >=216.5 AND [Azimuth] <226.5 then
QDC= [VOCQoD] *0.00019667
Else
QDC= [VOCQoD] *0.00016071
End If
Else
If [Area_Abbreviation] = "DOSO" then
If [Azimuth] <140.5 then
QDC= [VOCQoD] *0.00008446
ElseIf  [Azimuth] >=140.5 AND [Azimuth] <254.5 then
QDC= [VOCQoD] *0.00013503
Else
QDC= [VOCQoD] *0.00006458
End If
Else
If [Area_Abbreviation] = "BRIG" then
If [Azimuth] <156.5 then
QDC= [VOCQoD] *0.0000882
ElseIf  [Azimuth] >=156.5 AND [Azimuth] <179.5 then
QDC= [VOCQoD] *0.00012905
ElseIf  [Azimuth] >=179.5 AND [Azimuth] <189.5 then
QDC= [VOCQoD] *0.00017808
ElseIf  [Azimuth] >=189.5 AND [Azimuth] <237.5 then
QDC= [VOCQoD] *0.00016108
Else
QDC= [VOCQoD] *0.0000882
End If
Else
If [Area_Abbreviation] = "GRGU" then
If [Azimuth] <171 then
QDC= [VOCQoD] *0.00002371
ElseIf  [Azimuth] >=170.5 AND [Azimuth] <203.5 then
QDC= [VOCQoD] *0.00014956
ElseIf  [Azimuth] >=203.5 AND [Azimuth] <236.5 then
QDC= [VOCQoD] *0.00009968
Else
QDC= [VOCQoD] *0.00002371
End If
Else
If [Area_Abbreviation] = "LYBR" then
If [Azimuth] <143.5 then
QDC= [VOCQoD] *0.00002303
ElseIf  [Azimuth] >=143.5 AND [Azimuth] <225.5 then
QDC= [VOCQoD] *0.00014575
ElseIf  [Azimuth] >=225.5 AND [Azimuth] <240.5 then
QDC= [VOCQoD] *0.00010289
ElseIf  [Azimuth] >=240.5 AND [Azimuth] <299.5 then
QDC= [VOCQoD] *0.00005815
Else
QDC= [VOCQoD] *0.00002303
End If
```

```
Else
If [Area_Abbreviation] = "MOOS" then
If [Azimuth] <173.5 then
QDC= [VOCQoD] *0.00003842
ElseIf  [Azimuth] >=173.5 AND [Azimuth] <184.5  then
QDC= [VOCQoD] *0.00015274
ElseIf  [Azimuth] >=184.5 AND [Azimuth] <196.5 then
QDC= [VOCQoD] *0.00022409
ElseIf  [Azimuth] >=196.5 AND [Azimuth] <209.5 then
QDC= [VOCQoD] *0.00015967
ElseIf  [Azimuth] >=209.5 AND [Azimuth] <211.5 then
QDC= [VOCQoD] *0.00003842
ElseIf   [Azimuth] >=211.5 AND [Azimuth] <212.5 then
QDC= [VOCQoD] *0.00016344
ElseIf  [Azimuth] >=212.5 AND [Azimuth] <215.5 then
QDC= [VOCQoD] *0.00012298
ElseIf  [Azimuth] >=215.5 AND [Azimuth] <225.5 then
QDC= [VOCQoD] *0.00015147
Else
QDC= [VOCQoD] *0.00003842
End If
Else
If [Area_Abbreviation] = "SHEN" then
If [Azimuth] <133.5 then
QDC= [VOCQoD] *0.00009164
ElseIf  [Azimuth] >=133.5 AND [Azimuth] <280.5  then
QDC= [VOCQoD] *0.00012969
Else
QDC= [VOCQoD] *0.00006097
End If
Else
If [Area_Abbreviation] = "JARI" then
If [Azimuth] <133.5 then
QDC= [VOCQoD] *0.00009164
ElseIf  [Azimuth] >=133.5 AND [Azimuth] <280.5  then
QDC= [VOCQoD] *0.00012969
Else
QDC= [VOCQoD] *0.00006097
End If
Else

QDC=0
End If
End If
End If
End If
End If
End If
End If
```



17. Final step export table to CSV for charts (can do in ARC map as well but more workable format for large group in excel)
18. If these steps are applied to individual sources; then summation for each point by state can be done easily in excel via the pivot table function. This was the case for the 2015 q/d point analysis.