Contributions to Regional Haze in the Northeast and Mid-Atlantic United States:
Q/d Update with 2011 Emissions

Mid-Atlantic/Northeast Visibility Union (MANE-VU) Updated Contribution Assessment

DRAFT September 9, 2015

TABLE OF CONTENTS

1. INTRODUCTION

NESCAUM performed preliminary analyses to assess the contribution from states and regions on the visibility impairment on Class I areas in the MANE-VU region. NESCAUM designed the analyses to serve as updates to those performed for the report, *Contribution to Regional Haze in the Northeast and Mid-Atlantic United States* (NESCAUM, 2006). In that report, NESCAUM used a suite of analysis tools to assess the absolute and relative contribution of states for the 2002 baseline year.

This report is the second update and mimics distance the approach of the previous released in 2012 using emissions data through 2008. This report provides a baseline analysis by providing an initial assessment of the contributions from states in 2011.

2. SUPPORTING ANALYSES

2.1. Haze-associated pollutant emissions

This section explores the origin and quantity of haze-forming pollutants emitted in the eastern United States. The pollutants that affect fine particle formation, and thus contribute to regional haze, are sulfur oxides (SO_x), nitrogen oxides (NO_x), volatile organic compounds (VOCs), ammonia (NH_3), and directly emitted particles with an aerodynamic diameter less than or equal to 10 and 2.5 μm (i.e., primary PM_{10} and $PM_{2.5}$). The data analyzed in this update examined USEPA's National Emissions Inventory (NEI) to determine the contribution from different states.

2.2. Emissions Divided by Distance

This section provides methods and results for the emissions over distance (*Q/d*) approach.

This approach is described in the original analysis (NESCAUM, 2006), but a brief summary of methods is presented here.

The geographic domain of the sources included in the *Q/d* study consisted of states in four regional planning organizations: CENRAP, MANE-VU, MWRPO, and VISTAS. Emissions data were obtained from the USEPA's 2011 National Emissions Inventory (NEI) version 2, and consisted of point sources, nonpoint sources (or area sources), non-road sources, and on-road sources. Because regional 2018 emissions inventories were not yet available for the MANE-VU or other U.S. regions, NESCAUM used data from the 2011 NEI as a reasonable approximation, however the intent is to update again with the 2018 projections. The previous update included Canadian emissions, this was not included this time around.

Results were calculated for eight receptors: Acadia National Park, Brigantine Wilderness Area in the Forsythe National Wildlife Refuge, Dolly Sods Wilderness Area, Great Gulf Wilderness Area, James River Face Wilderness Area, Lye Brook Wilderness Area, Moosehorn Wilderness Area, and Shenandoah National Park. The locations used are presented in Appendix A. The James River Face Wilderness Area is a new addition to the analysis and was added because a MANE-VU state is considered a contributor to this Class I area.

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

[2] The Haversine function is an algorithm to calculate the distance between two points along the surface of a perfect sphere. It is discussed in greater detail in the previous report (NESCAUM, 2006).

The same values for C_i as were used in the previous analysis were used in this analysis, with the exception of James River Face since it was not previously used Shenandoah and Dolly Sods C_i values were tested. Therefore, this analysis essentially uses 2002 meteorology to process the 2011 estimated emissions. By using wind vector factors derived from 2002 meteorology, we have a common set of conditions to compare potential changes in relative contributions among upwind states between 2002, 2007 and 2011 looking at changes in emissions alone. The C_i constants are presented in Appendix A it should be noted that the wind vectors are relative to a counter-clock wise direction with east being equal to zero degrees. Appendix B contains the detailed directions for replicating or re-running the analysis and Appendix C is the full set of results exported into excel.

As with the previous analysis, to calculate the impact that each state had on a given receptor, the point, area and mobile source SO_2 emissions were summed across the entire state, and calculated the distance to the receptor site for those emission sources based on that state's geographic center, adjusted for population density. State population centers for 2010 were obtained from the U.S. Census Bureau (2011) for the 2012 report. In this way, we treated the area source emissions as a single point source located at the population-weighted center of each state, the latitude and longitudes used are presented in Appendix A and are the same as the 2012 report since the census data is still the most current.[1]

In the 2012 report states that contributed to any MANE-VU receptor above 0.10 $\mu g/m^3$ were noted as significant for SO_2 Q/d only. This threshold was selected as a starting point for discussion only and needs to be evaluated and decided by states with Class I areas. To ensure further reductions that are needed to meet the next 10 years goals, a new threshold is needed; 1% and 2% contribution of the monitored annual average ammonia sulfate concentrations are considered below see Figures 2-1(a)-(g).

The first round of regional haze SIPs focused primarily on SO_2 reductions due to the fact that these emissions were the primary drivers of poor visibility in the region. A review of the latest monitoring data from the Class I areas determined that sulfate continues to be the predominate driver of visibility degradation see Figure 1. Contributions of sulfur dioxide emissions were analyzed on a state total basis (with the exception of natural emissions)[1] provided in the graphics and table below. Table 2-1 shows the top 5 contributing states to the Class I areas in the region. Figures 2-1(a)-(g) show the corresponding Q/d rankings across a set of Northeast and Mid-Atlantic Class I areas in or near the MANE-VU region.

[1] March 21, 2012 Report: Contributions to Regional Haze in the Northeast and Mid-Atlantic United States: Preliminary through 2007

Figure 1. 2013-2014 Monitored Extinction on 20 Haziest Days, Expressed as Percentage of Extinction

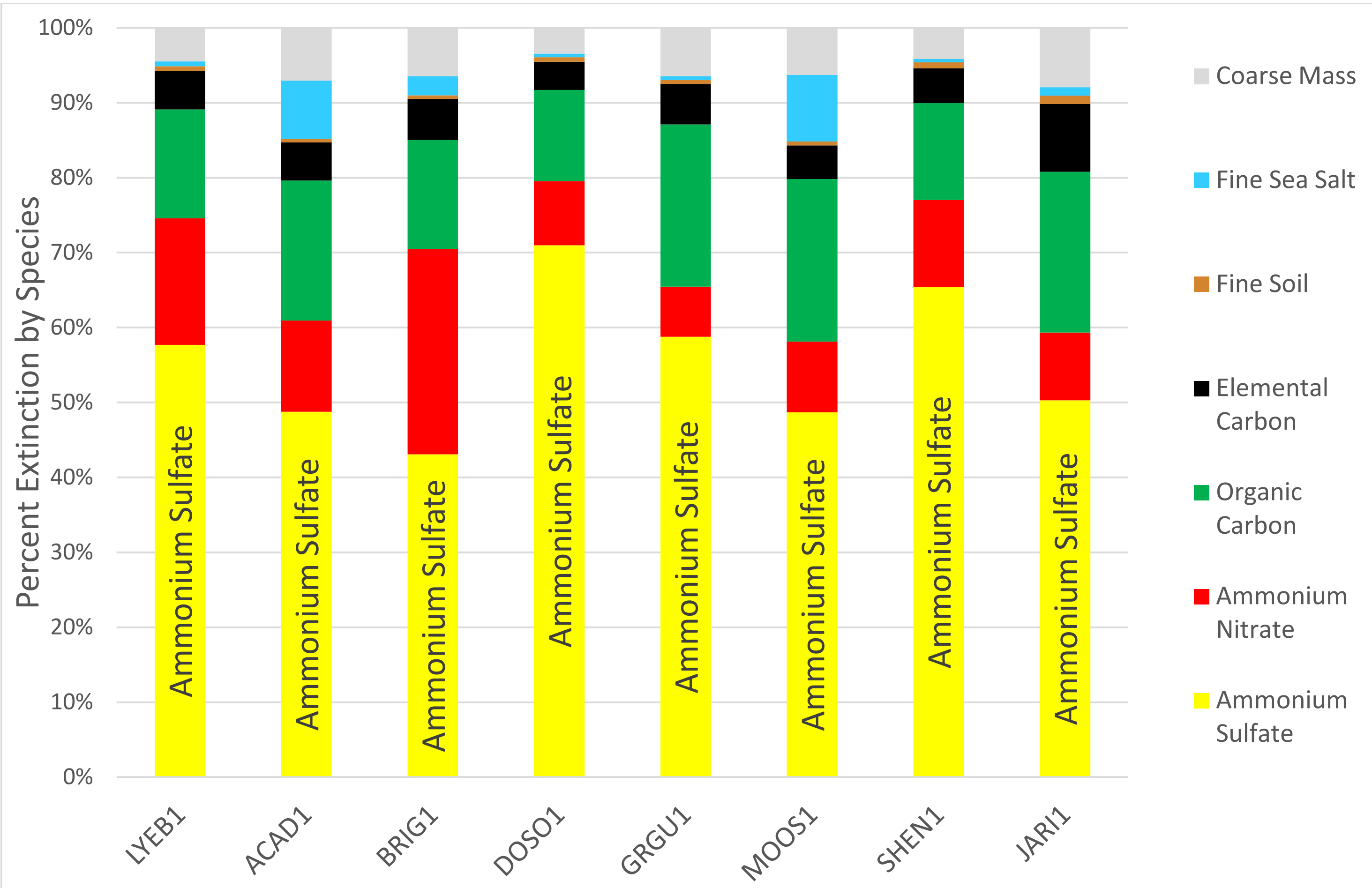
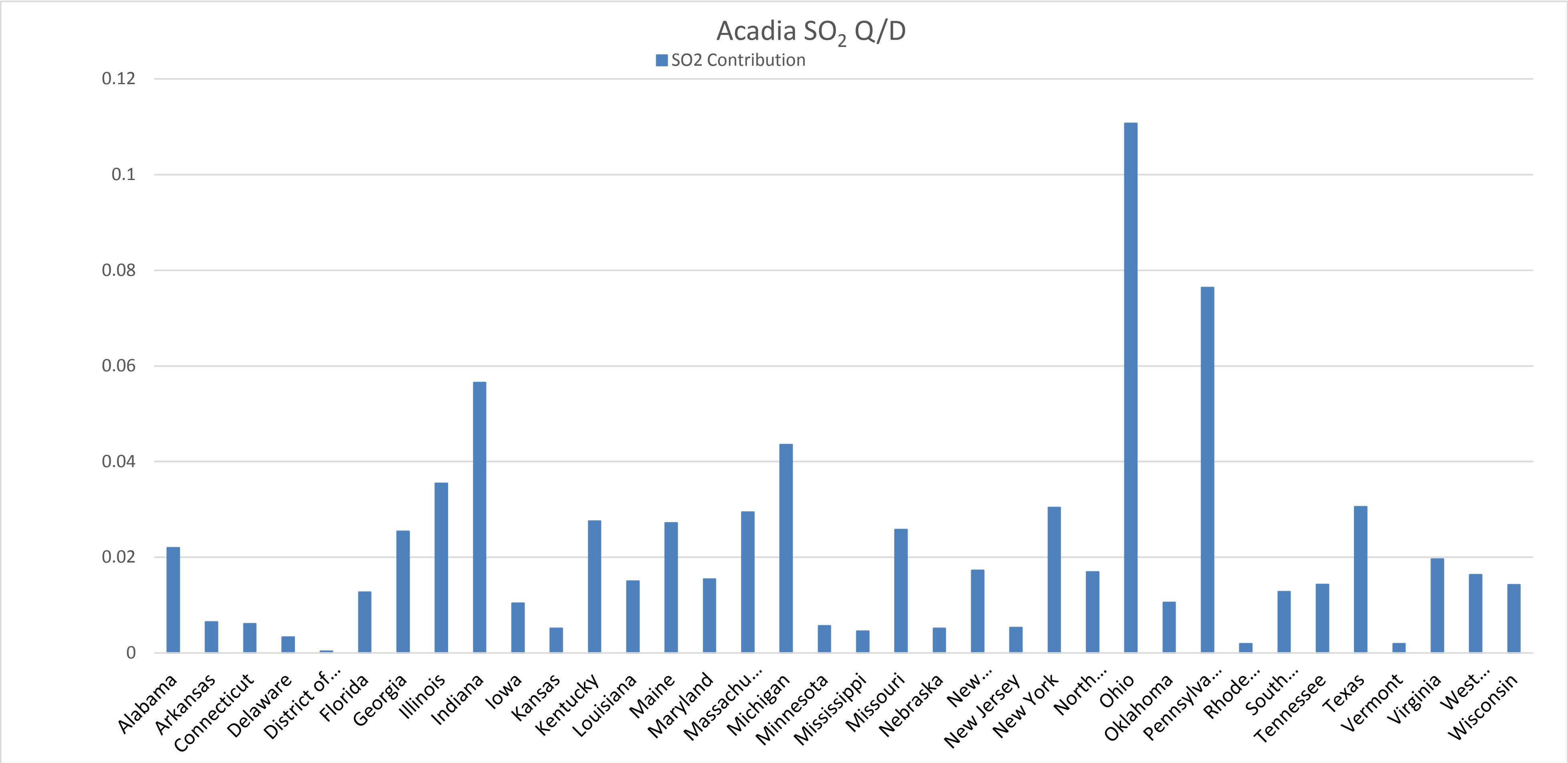


Table 2-1. Top 5 2011 SO_2 CALPUFF-scaled emissions over distance impacts (µg/m^3) at Northeast and Mid-Atlantic Class I areas

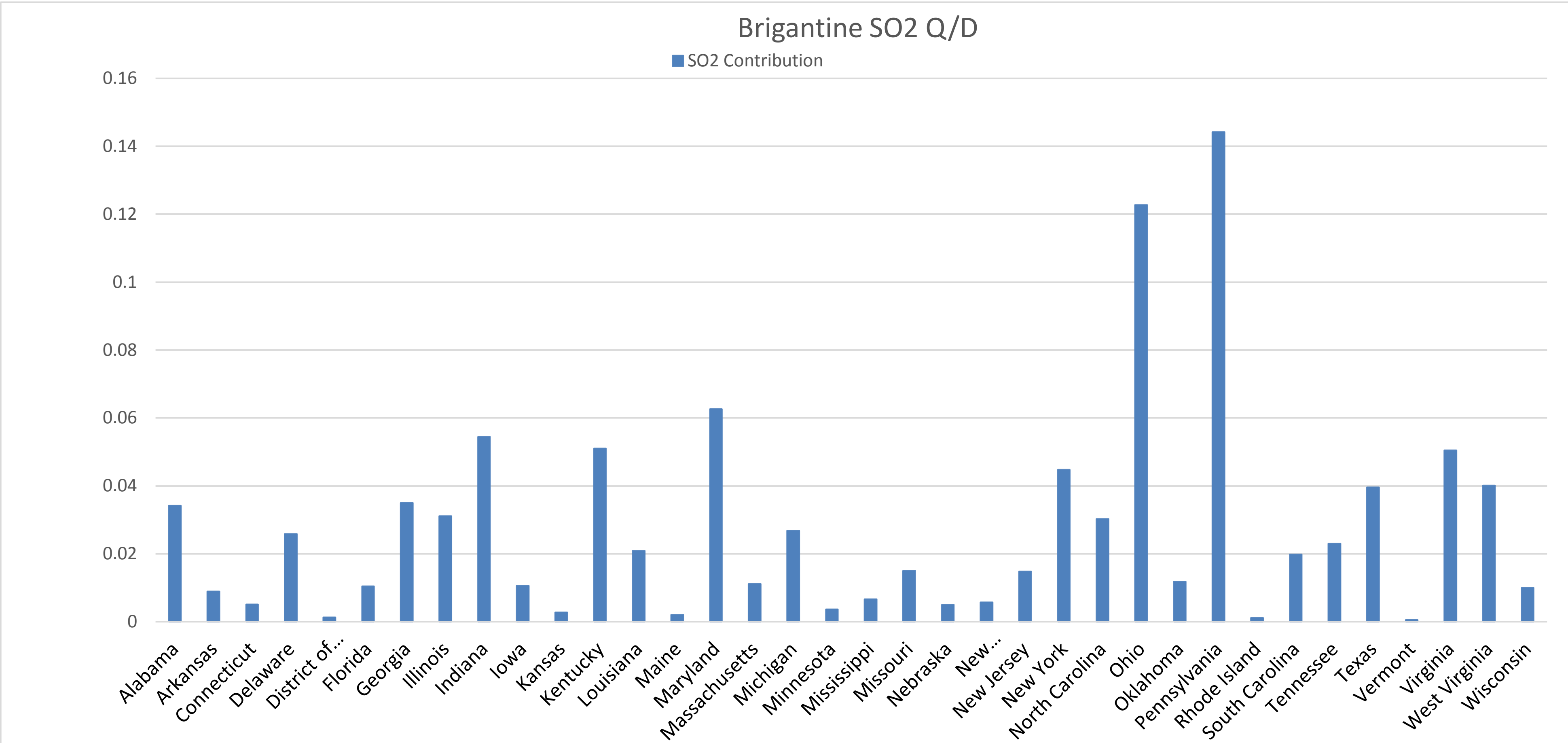
Receptor	State	Contribution			
Acadia	Ohio	0.110722			
	Pennsylvania	0.076393			
	Indiana	0.056531			
	Michigan	0.043586			
	Illinois	0.035447			
Brigantine	Pennsylvania	0.144185			
	Ohio	0.122695			
	Maryland	0.062602			
	Indiana	0.054433			
	Kentucky	0.051057			
Dolly Sods	Ohio	0.285194			
	West Virginia	0.140909			
	Pennsylvania	0.13217			
	Indiana	0.096535			
	Kentucky	0.070214			
Great Gulf	Ohio	0.097926			
	Pennsylvania	0.062172			
	Indiana	0.048236			
	Michigan	0.038705			
	Illinois	0.029948			
James Face	Ohio	0.209511	<Shen	Ohio	0.21814
	Pennsylvania	0.095895	Dolly>	West Virginia	0.09889
	West Virginia	0.094978		Indiana	0.0889
	Indiana	0.085382		Pennsylvania	0.08838
	Kentucky	0.070312		Kentucky	0.07321
Lye Brook	Pennsylvania	0.132424			
	Ohio	0.116413			
	Indiana	0.05447			
	New York	0.053722			
	Kentucky	0.033723			
Moosehorn	Ohio	0.079613			
	Indiana	0.057955			
	Illinois	0.036654			
	Michigan	0.030354			
	Texas	0.029351			
Shenandoah	Ohio	0.205847			
	Pennsylvania	0.14796			
	Indiana	0.079393			
	West Virginia	0.079183			
	Virginia	0.068504			

Figure 2-1 Ranked state percent summed contributions to Class I area Receptors in NE region based on 2011 emissions divided by distance (Q/d) results

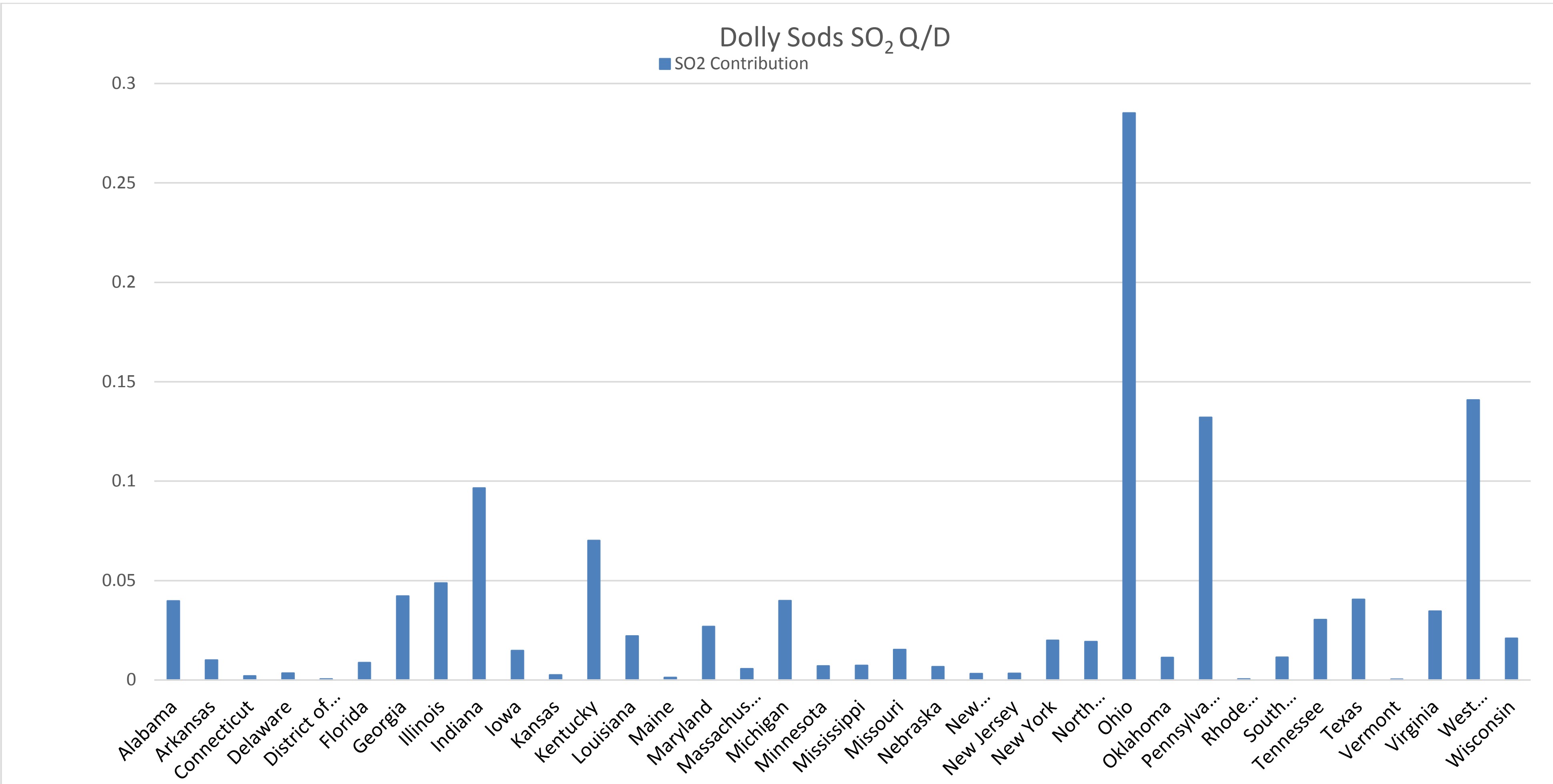
(a)Acadia



(b)Brigantine

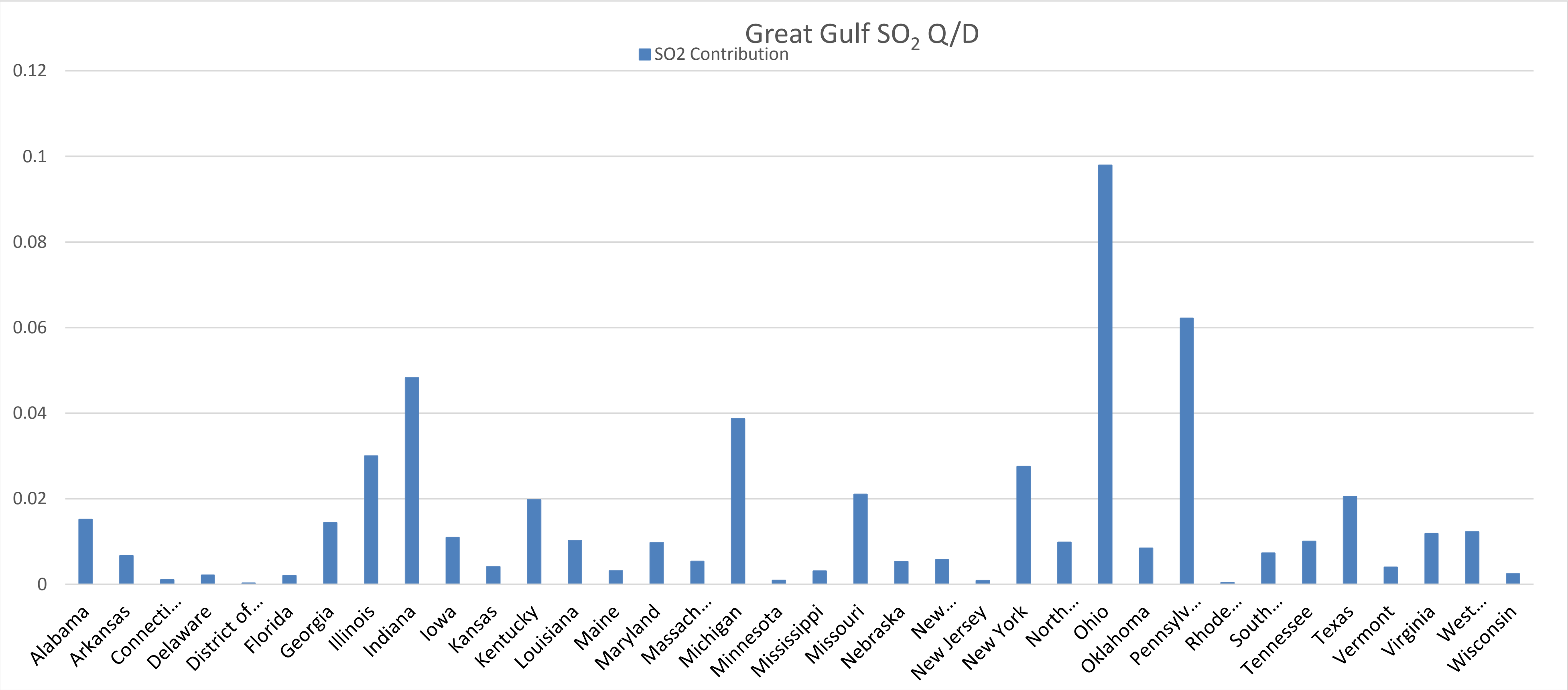


(c)Dolly Sods



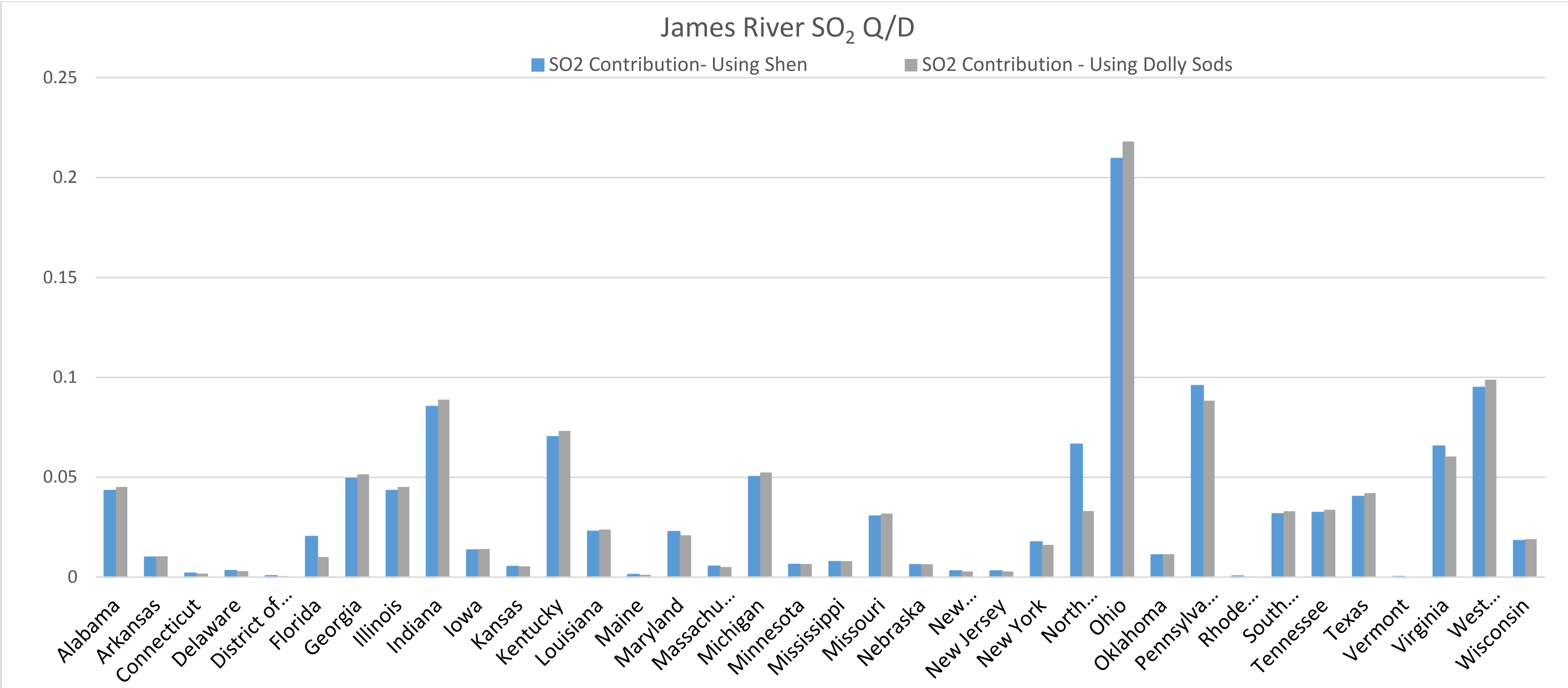
Dolly Sods SO_2 Q/D
SO2 Contribution
0.3
0.25
0.2
0.15
0.1
0.05
0
Alabama
Arkansas
Connecticut
Delaware
District of...
Florida
Georgia
Illinois
Indiana
Iowa
Kansas
Kentucky
Louisiana
Maine
Maryland
Massachus...
Michigan
Minnesota
Mississippi
Missouri
Nebraska
New...
New Jersey
New York
North...
Ohio
Oklahoma
Pennsylva...
Rhode...
South...
Tennessee
Texas
Vermont
Virginia
West...
Wisconsin

(d)Great Gulf

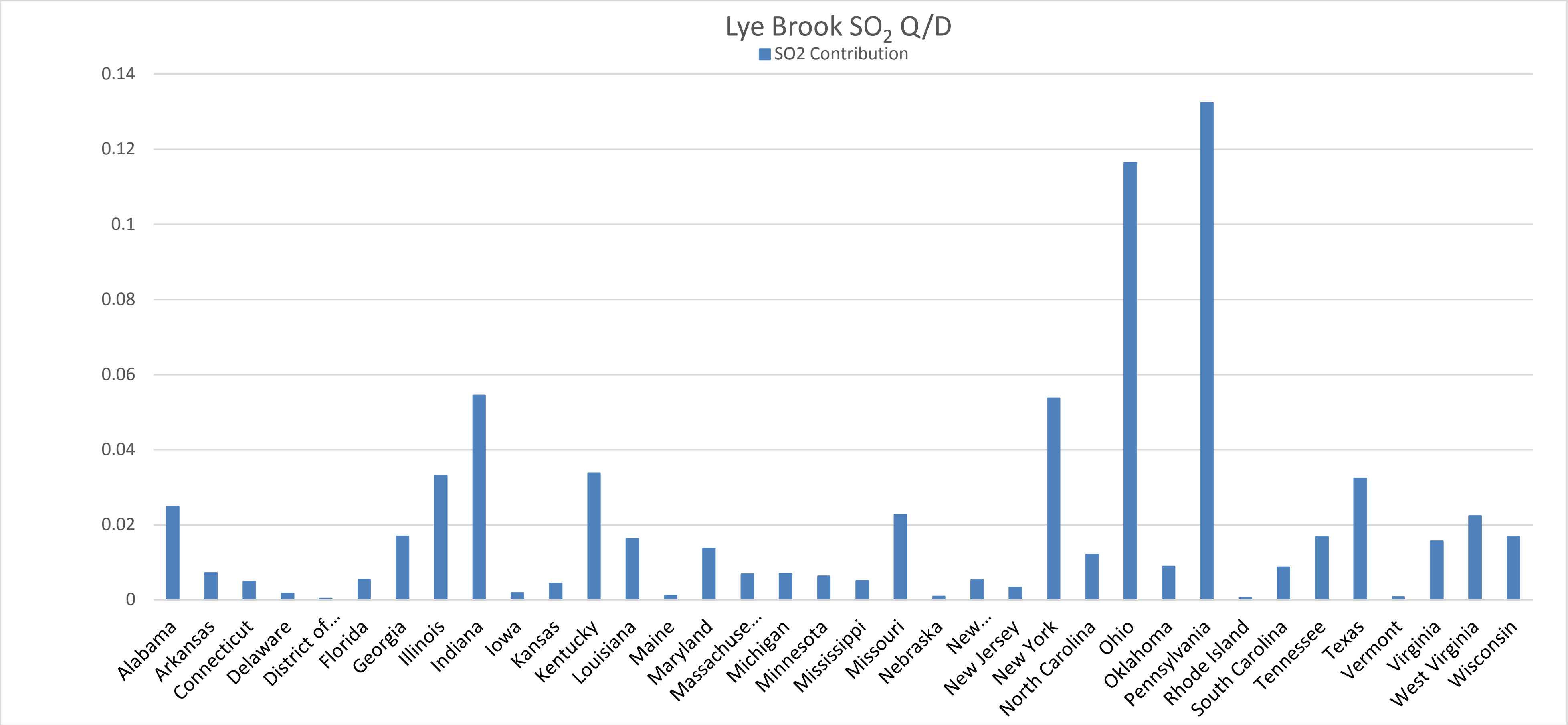


Great Gulf SO_2 Q/D
SO2 Contribution
0.12
0.1
0.08
0.06
0.04
0.02
0
Alabama
Arkansas
Connecti...
Delaware
District of...
Florida
Georgia
Illinois
Indiana
Iowa
Kansas
Kentucky
Louisiana
Maine
Maryland
Massach...
Michigan
Minnesota
Mississippi
Missouri
Nebraska
New...
New Jersey
New York
North...
Ohio
Oklahoma
Pennsylv...
Rhode...
South...
Tennessee
Texas
Vermont
Virginia
West...
Wisconsin

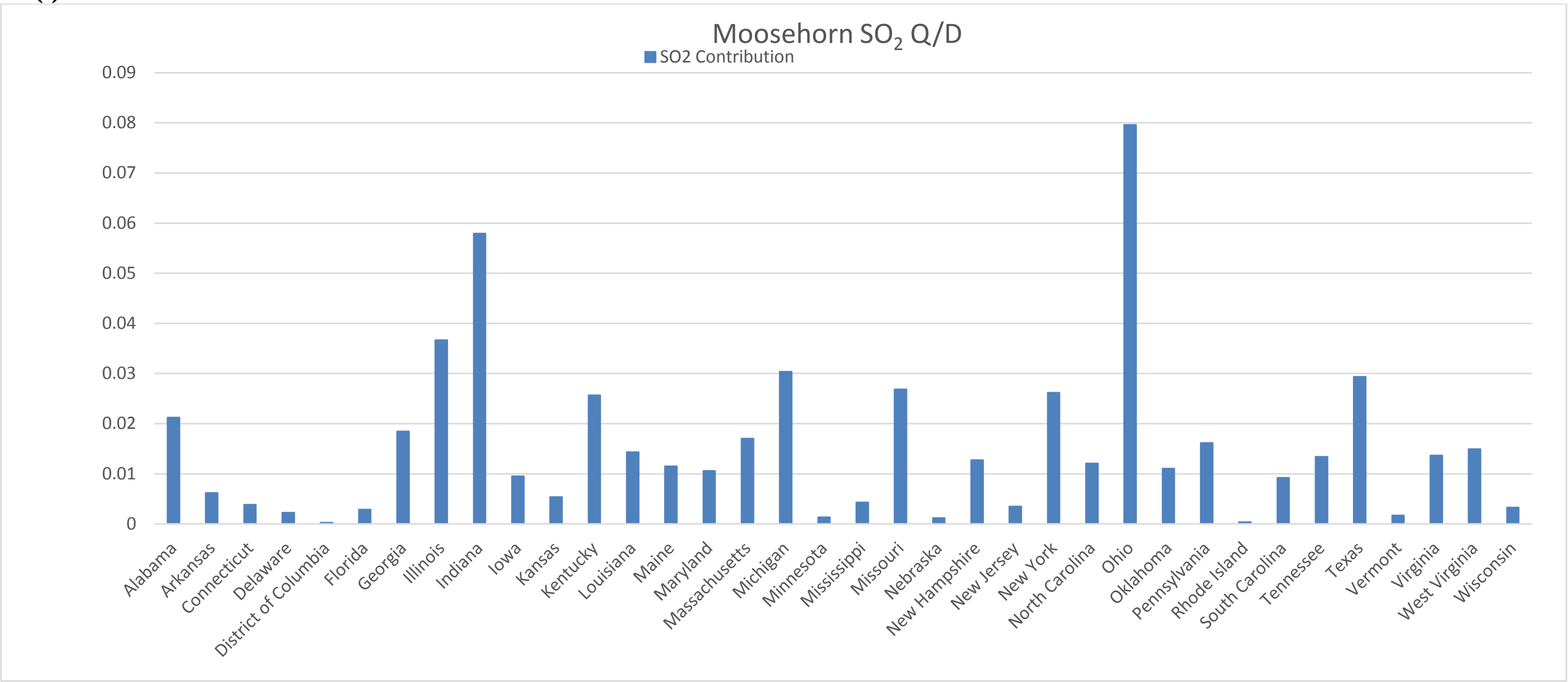
(e)James River Face



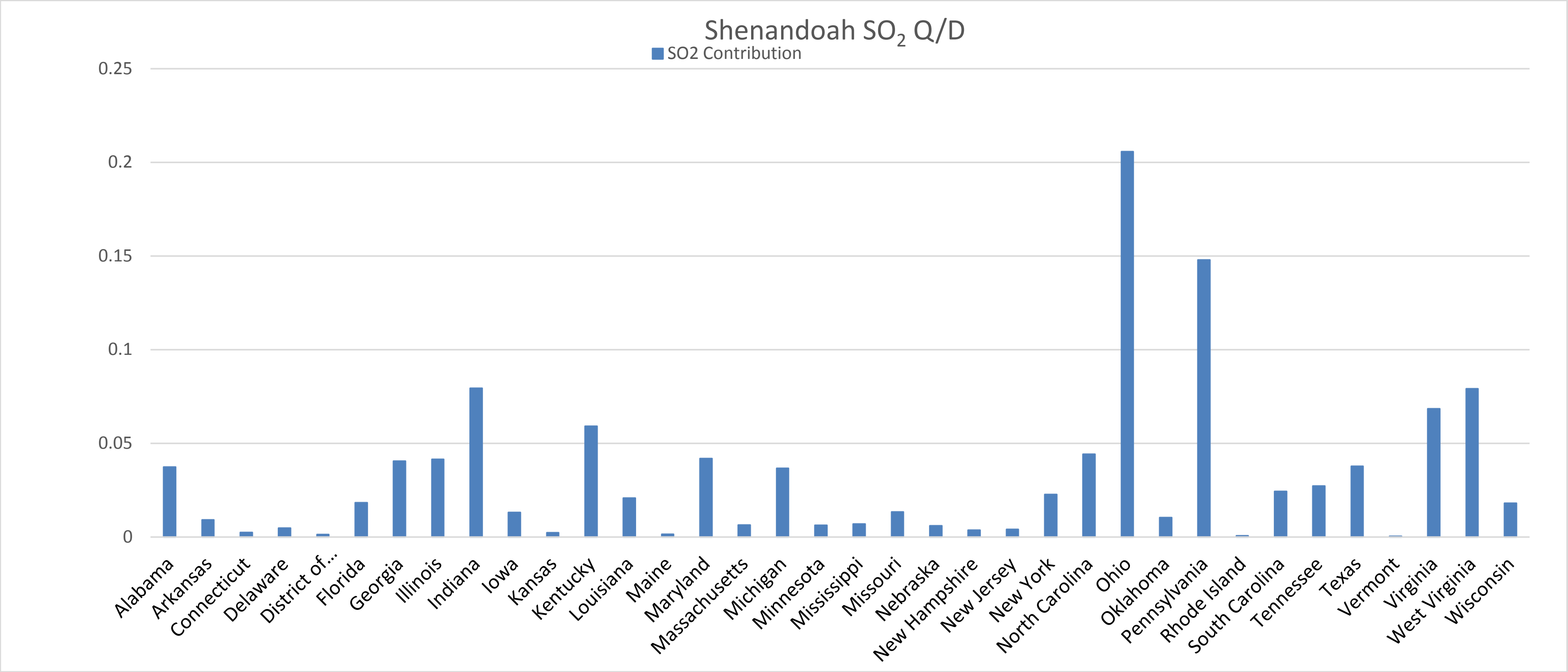
(f)Lye Brook


Lye Brook SO_2 Q/D
SO2 Contribution
0.14
0.12
0.1
0.08
0.06
0.04
0.02
0
Alabama
Arkansas
Connecticut
Delaware
District of...
Florida
Georgia
Illinois
Indiana
Iowa
Kansas
Kentucky
Louisiana
Maine
Maryland
Massachuse...
Michigan
Minnesota
Mississippi
Missouri
Nebraska
New...
New Jersey
New York
North Carolina
Ohio
Oklahoma
Pennsylvania
Rhode Island
South Carolina
Tennessee
Texas
Vermont
Virginia
West Virginia
Wisconsin

(f)Moosehorn


Moosehorn SO2 Q/D
SO2 Contribution
0.09
0.08
0.07
0.06
0.05
0.04
0.03
0.02
0.01
0
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

(g)Shenandoah



Appendix A: Inputs to the emissions over distance approach

Appendix A: Inputs to the emissions over distance approach

This appendix presents inputs used in the emissions over distance approach (*Q/d*).

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

State	Latitude	Longitude
Alabama	33.008097	-86.756826
Arkansas	35.14258	-92.655243
Connecticut	41.497001	-72.870342
Delaware	39.358946	-75.556835
District of Columbia	38.91027	-77.014468
Florida	27.822726	-81.634654
Georgia	33.376825	-83.882712
Illinois	41.286759	-88.390334
Indiana	40.149246	-86.259514
Iowa	41.946066	-93.036629
Kansas	38.464949	-96.462812
Kentucky	37.824499	-85.248467
Louisiana	30.722814	-91.508833
Maine	44.29995	-69.736482
Maryland	39.140769	-76.797763
Massachusetts	42.272291	-71.36337
Michigan	42.873187	-84.203434
Minnesota	45.203555	-93.571903
Mississippi	32.590954	-89.579514
Missouri	38.423798	-92.198469
Nebraska	41.1743	-97.315578
New Hampshire	43.154858	-71.461974
New Jersey	40.43181	-74.432208
New York	41.501299	-74.620909
North Carolina	35.543075	-79.658232
Ohio	40.455191	-82.773339
Oklahoma	35.598464	-96.836786
Pennsylvania	40.456756	-77.00968
Rhode Island	41.753609	-71.450869
South Carolina	34.025176	-81.011022
Tennessee	35.80809	-86.359136
Texas	30.905244	-97.365594
Vermont	44.094874	-72.816417
Virginia	37.810313	-77.81116
West Virginia	38.795594	-80.731308
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
James River Face Wilderness Area	JARI	37.6266	-79.5125
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 (C_i)
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
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

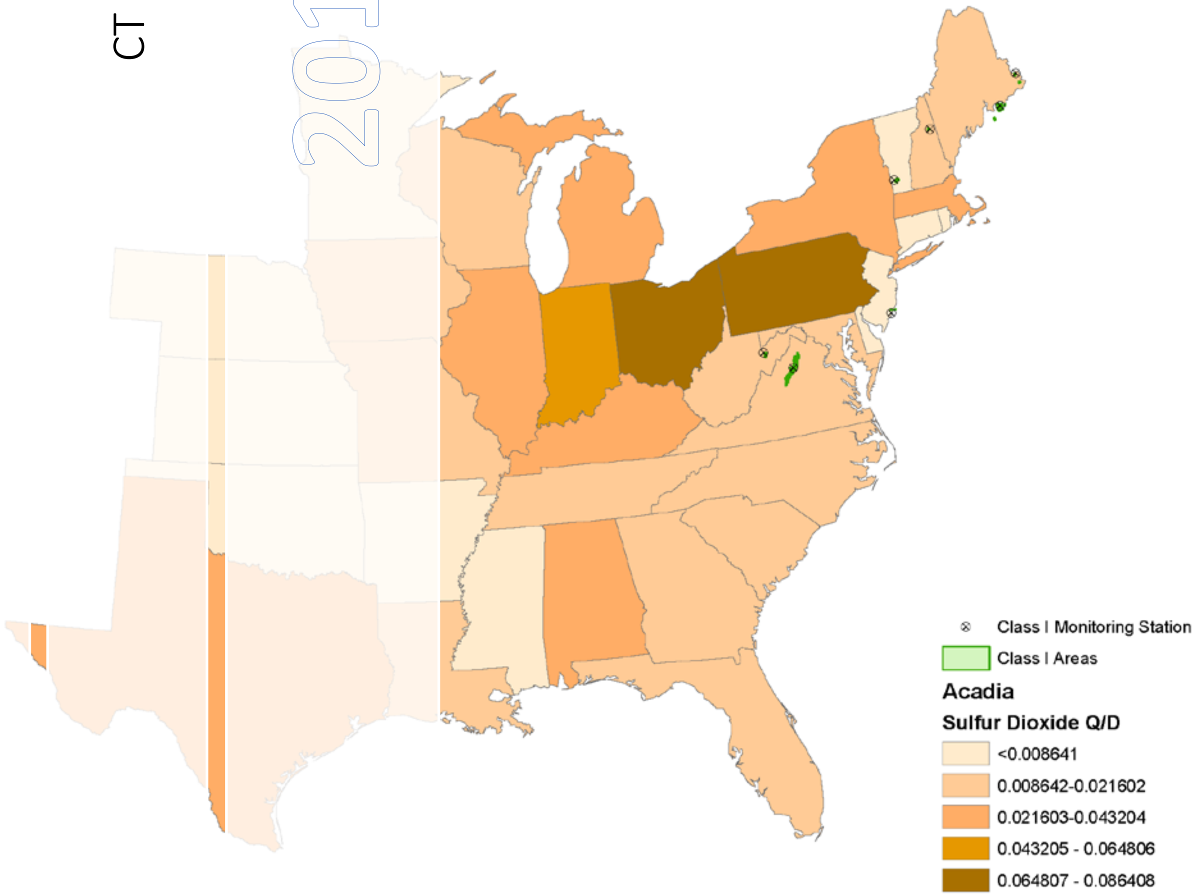
Class I Area Abbreviation	**Minimum Angle**	**Maximum Angle**	**Constant (C_i)**
MOOS	197	209	0.00015967
MOOS	210	211	0.00003842
MOOS	212	212	0.00016344
MOOS	213	215	0.00012298
MOOS	216	225	0.00015147
MOOS	225	360	0.00003842
SHEN	0	133	0.00009164
SHEN	134	280	0.00012969
SHEN	281	311	0.00006097
SHEN	312	360	0.00006097

Note: Above angles are measured in degrees counterclockwise, with east equal to zero degrees. Also note James River Face Wilderness was run twice once using Dolly Sods Ci values and once using Shenandoah values.

Q/d in ARC Map Step by Step Instructions

CT DEEP

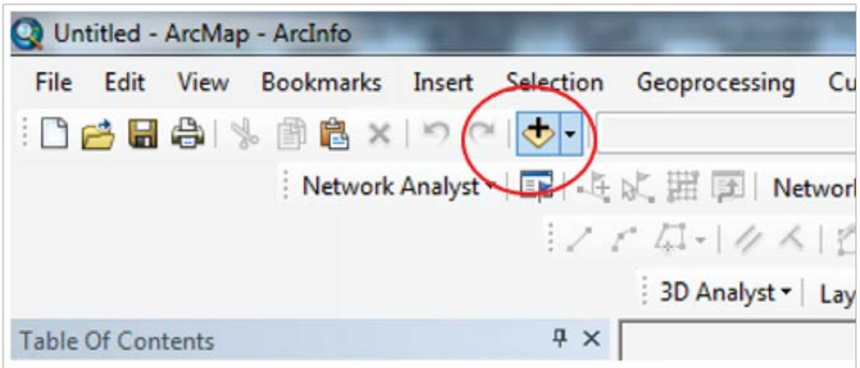
2015



Outlined in the attached pages is the step by step instructions for the Q/d analysis as performed in ARC Map.

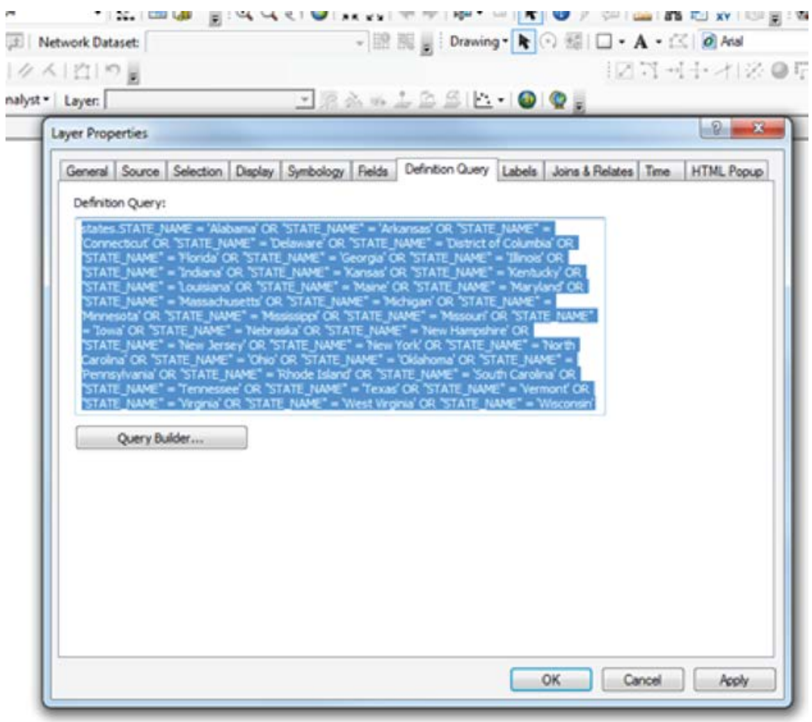
Q/d in ARC Map Step by Step Instructions

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.

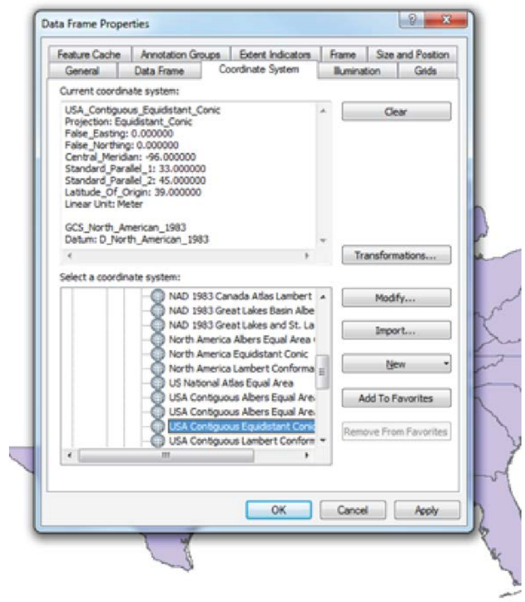


    b. Set definition query to limit view to the states you wish to anlayze. For the 2015 Q/D up date this list of states was used. – Doing this step will save you from memory limits and speed up the calculation steps later on.

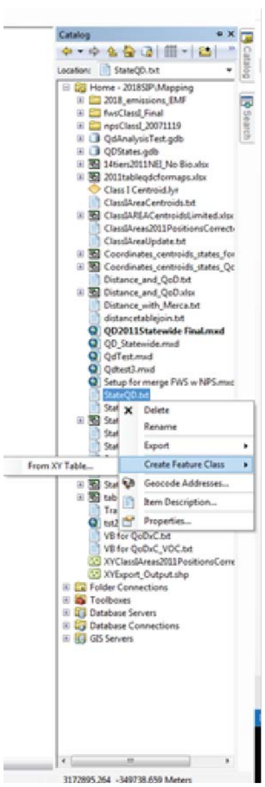
Alabama
Arkansas
Connecticut
Delaware
District of Columbia
Florida
Georgia
Illinois
Indiana
Iowa
Kansas
Kentucky
Louisiana
Maine
Maryland
Massachusetts
Michigan
Minnesota
Mississippi
Missouri
Nebraska
New Hampshire
New Jersey
New York
North Carolina
Ohio
Oklahoma
Pennsylvania
Rhode Island
South Carolina
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 NH_3, SO_2, NOX, PM2.5 primary and VOC emissions totals[1] for each state (minus biogenic/natural totals) and a shape file was made from this appendix.

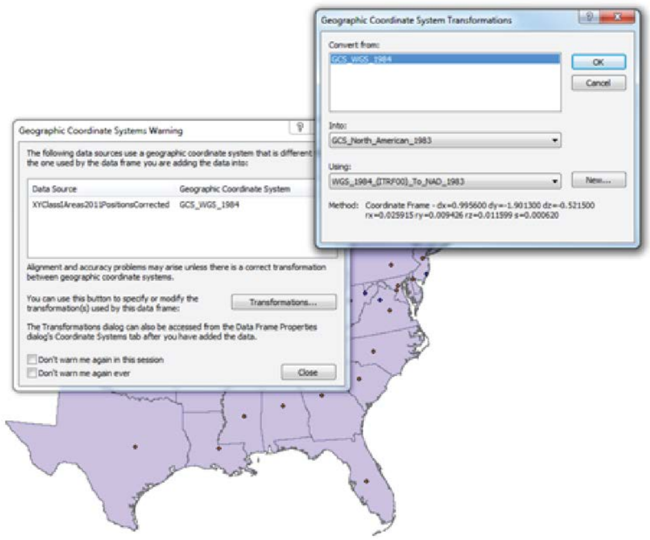
b. To create shapefile from csv or excel:

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

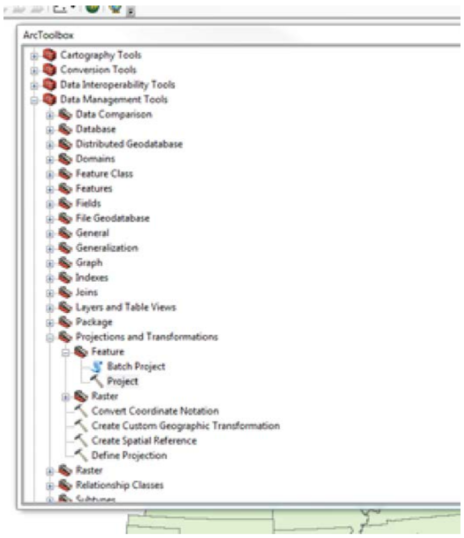
ii. Identify the coodinate system- the coordinates in appendix A are WGS 84.

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

c.
d. 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.

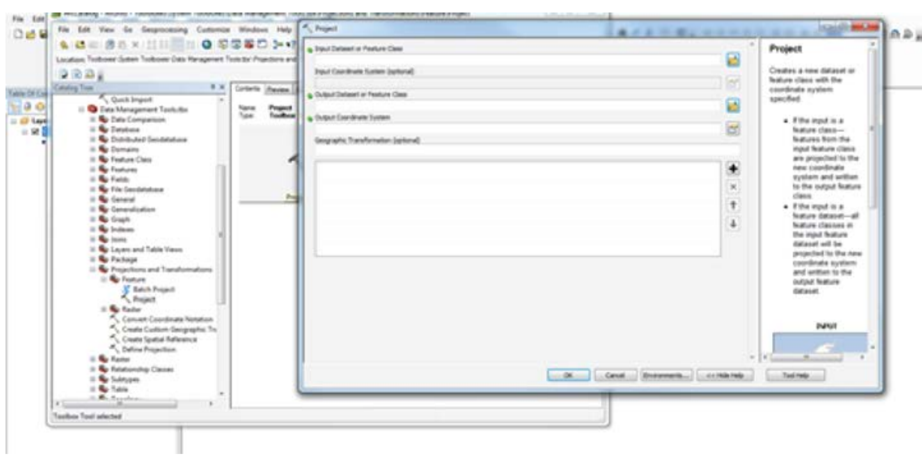


4. This takes the shape file which is in WGS84 and places it in the correct NAD 83 position; now you must convert your shapfiles to the NAD83 datum so that the distance will result in meters and not the angle from the center of the earth (degrees).



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

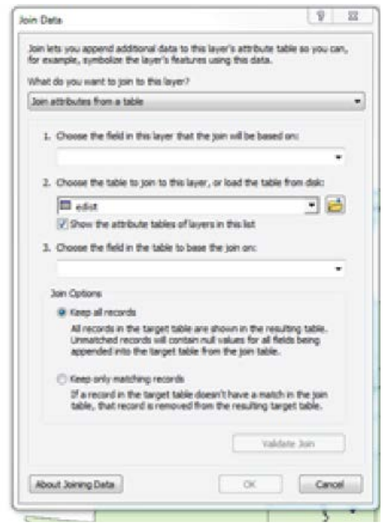
6. Select one of your features (State Centroids with Emissions or the Park Monitors) as the Input Data Set. Select output coordinate system to be the best for calculating distance. In this case we used USA Contiguous Equidistant Conic.prj. (If including Canada in furture I would suggest selecting North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



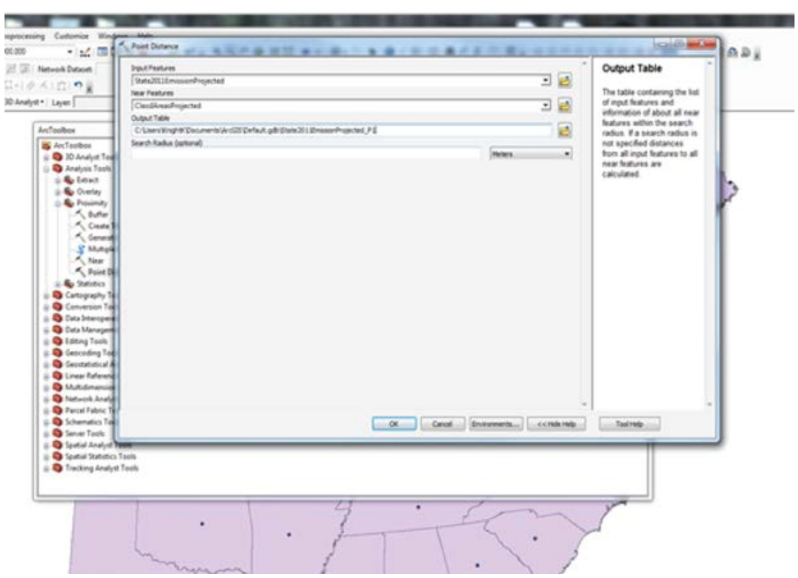
7. To ensure your transformation took check the units in the lower right , if you are in NAD 83 projected they should be in meters not DD. If it did not take go into data management tools and

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.

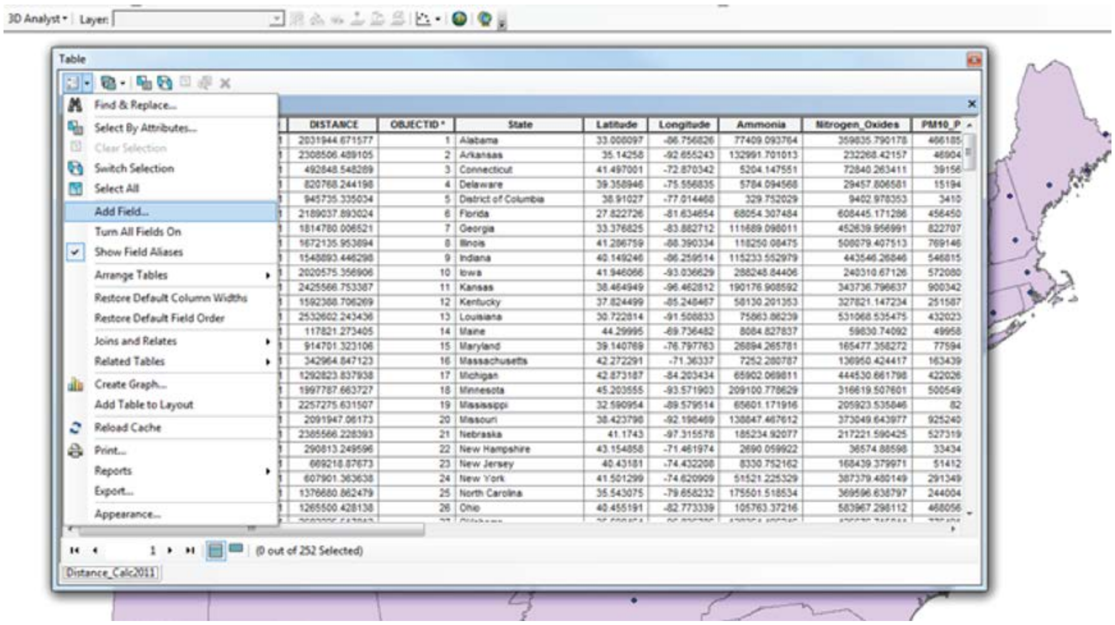


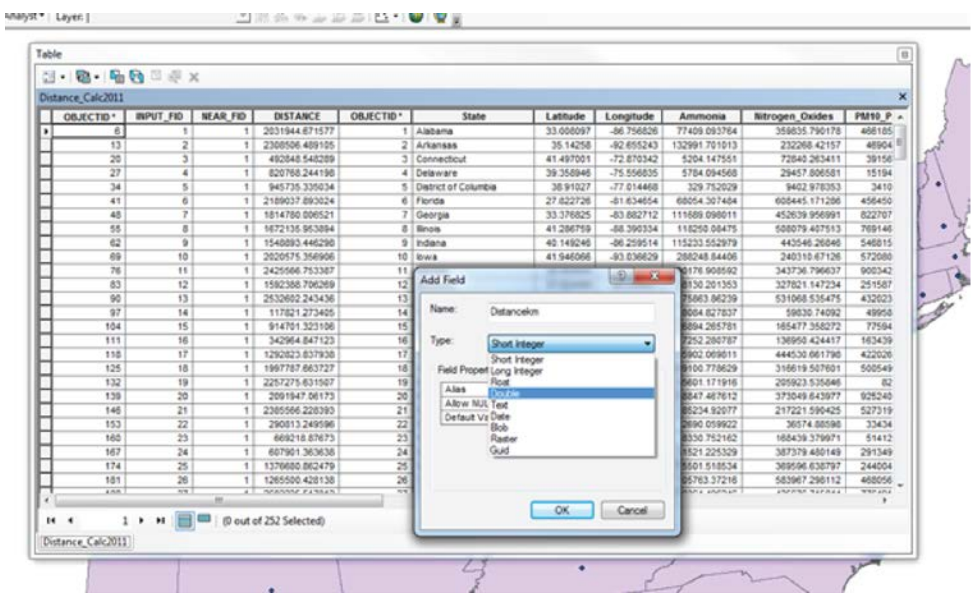
9. Do a quick does this make sense check- by joining the features and new output table to get the context. Right click on your newly created distance table select Joins and Relates and then Join. Your input feature was your states. First Select the States feature for box 2. Box 1 is choices of columns 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





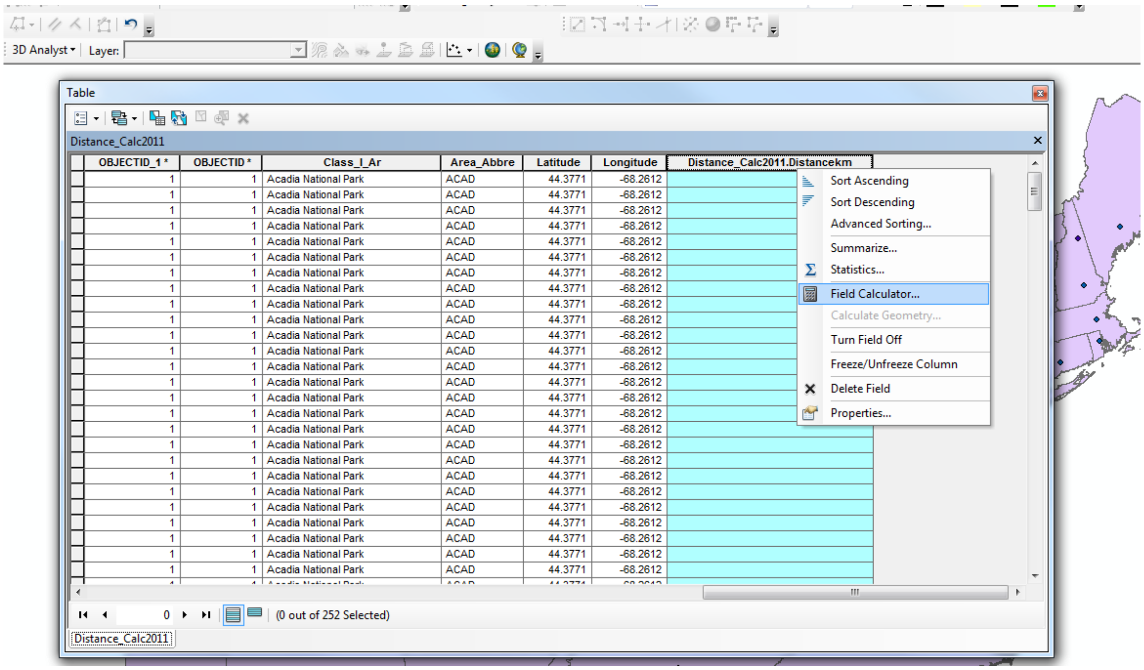


Table
Distance_Calc2011
OBJECTID_1 *
OBJECTID *
Class_I_Ar
Area_Abbre
Latitude
Longitude
Distance_Calc2011.Distancekm
Sort Ascending
Sort Descending
Advanced Sorting...
Summarize...
Statistics...
Field Calculator...
Calculate Geometry...
Turn Field Off
Freeze/Unfreeze Column
Delete Field
Properties...
(0 out of 252 Selected)

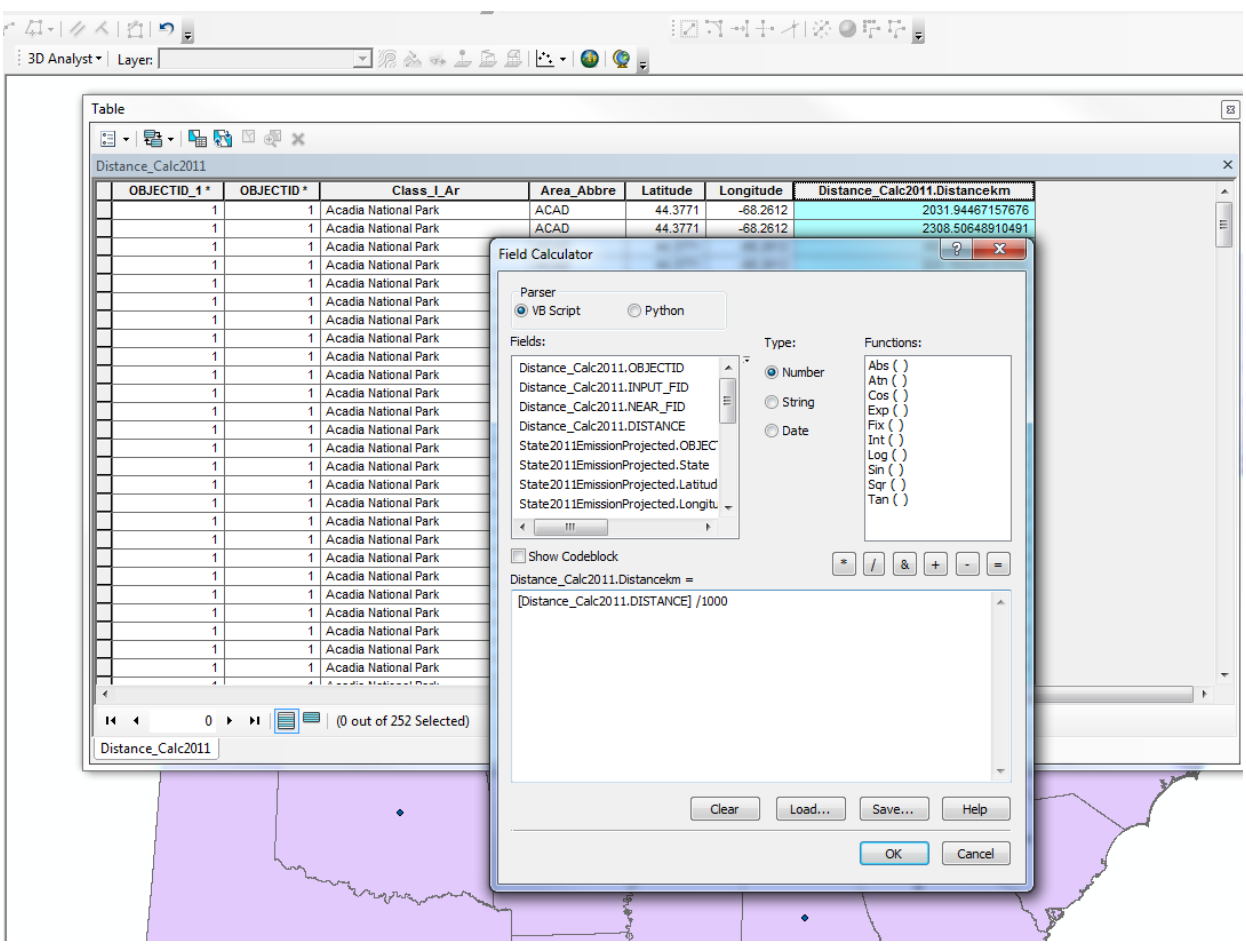


Table
Distance_Calc2011
Field Calculator
Parser
VB Script
Python
Fields:
Distance_Calc2011.OBJECTID
Distance_Calc2011.INPUT_FID
Distance_Calc2011.NEAR_FID
Distance_Calc2011.DISTANCE
Type:
Number
String
Date
Functions:
Abs ( )
Atn ( )
Cos ( )
Exp ( )
Fix ( )
Int ( )
Log ( )
Sin ( )
Sqr ( )
Tan ( )
Show Codeblock
Distance_Calc2011.Distancekm =
[Distance_Calc2011.DISTANCE] /1000
Clear
Load...
Save...
Help
OK
Cancel
(0 out of 252 Selected)

12. Calculate the wind vector that the state falls in for each Class I monitor
    a. Create new field in state table (type=double)
    b. 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.

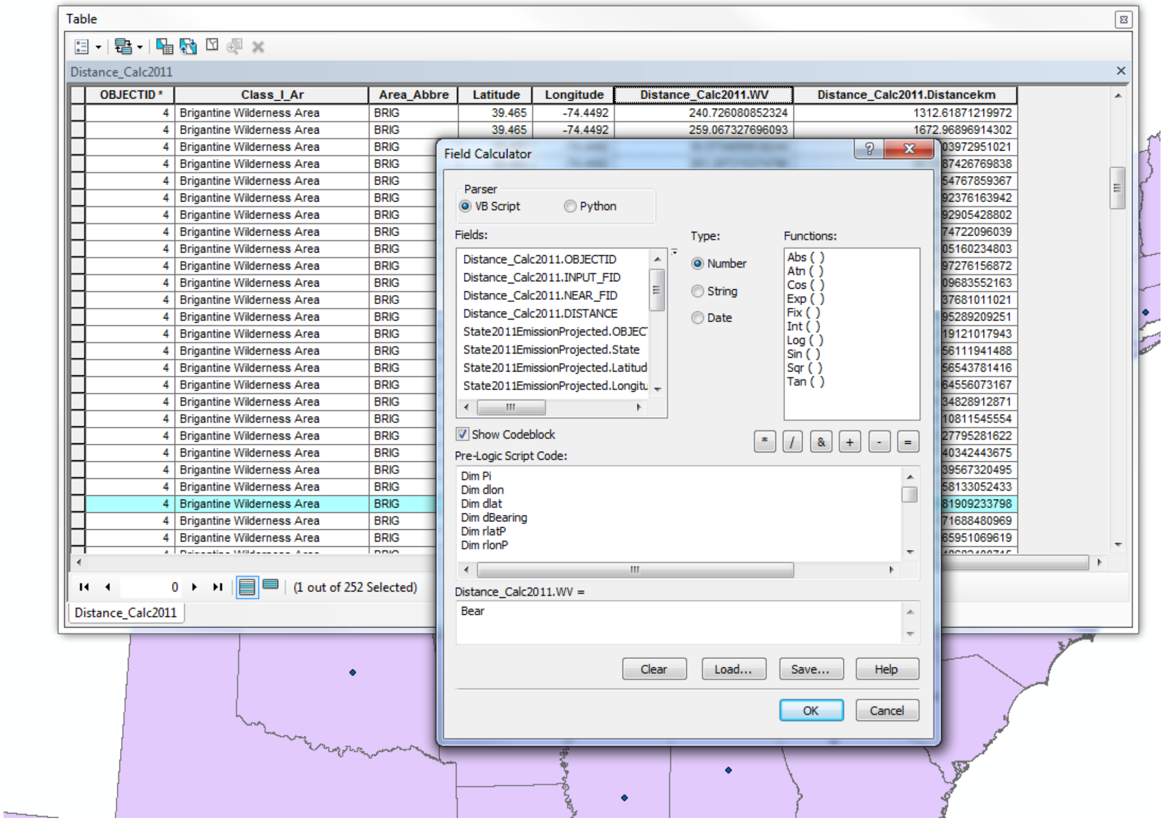
```
Dim Pi
Dim dlon
Dim dlat
Dim dBearing
Dim rlatP
Dim rlonP
Dim rlatS
Dim rlonS
Dim Xr
Dim Yr
Pi=4 * Atn ( 1 )
dlon=( ([Longitude] * (Pi/180))-( [Longitude_1] *(Pi/180)))
dlat=(( [Latitude] *(Pi/180))-( [Latitude_1] *(Pi/180)))
rlatP= [Latitude_1] *(Pi/180)
rlonP= [Longitude_1] *(Pi/180)
rlatS= [Latitude] *(Pi/180)
rlonS= [Longitude] *(Pi/180)
Yr=Cos (rlatP) * Sin ( rlatS ) - Sin ( rlatP ) * Cos ( rlatS ) * Cos (
dlon )
Xr=Sin ( dlon ) * Cos ( rlatS )

If dlon>0 AND dlat>0 then
dBearing=(90*Pi/180)-Atn(Yr/Xr)

ElseIf dlon>0 AND dlat<0 then
dBearing=(90*Pi/180)+Abs(Atn(Yr/Xr))
Elseif dlon<0 AND dlat<0 then
dBearing=(Pi)+Atn(Xr/Yr)
ElseIf dlon<0 AND dlat>0 then
dBearing=(270*Pi/180)+Abs(Atn(Yr/Xr))
Else
dBearing=0
End If

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

13. 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



14. Add another field (type=double) 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 to apply the correct Ci. The Ci were developed with this counter clockwise, see image below for the Acadia example. Add this script in the field calculator to account for this. Open in notepad first and replace the appropriate title of your bearing column (replacing [Distance_Calc2011.WV] with your title)

dim WVE

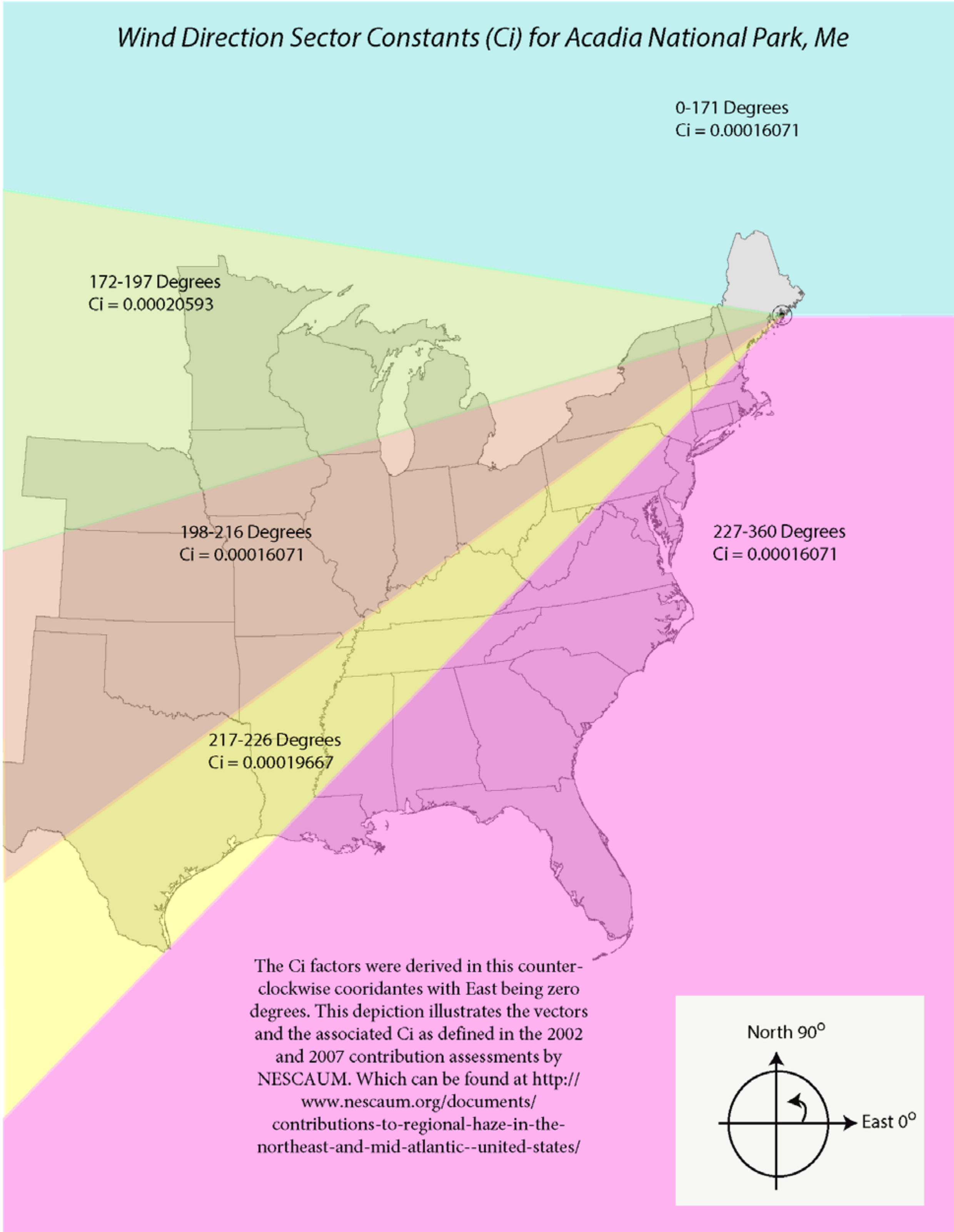
If [Distance_Calc2011.WV] < 90 then

WVE=90 - [Distance_Calc2011.WV]

Else

WVE=360 - [Distance_Calc2011.WV]- 90

End If

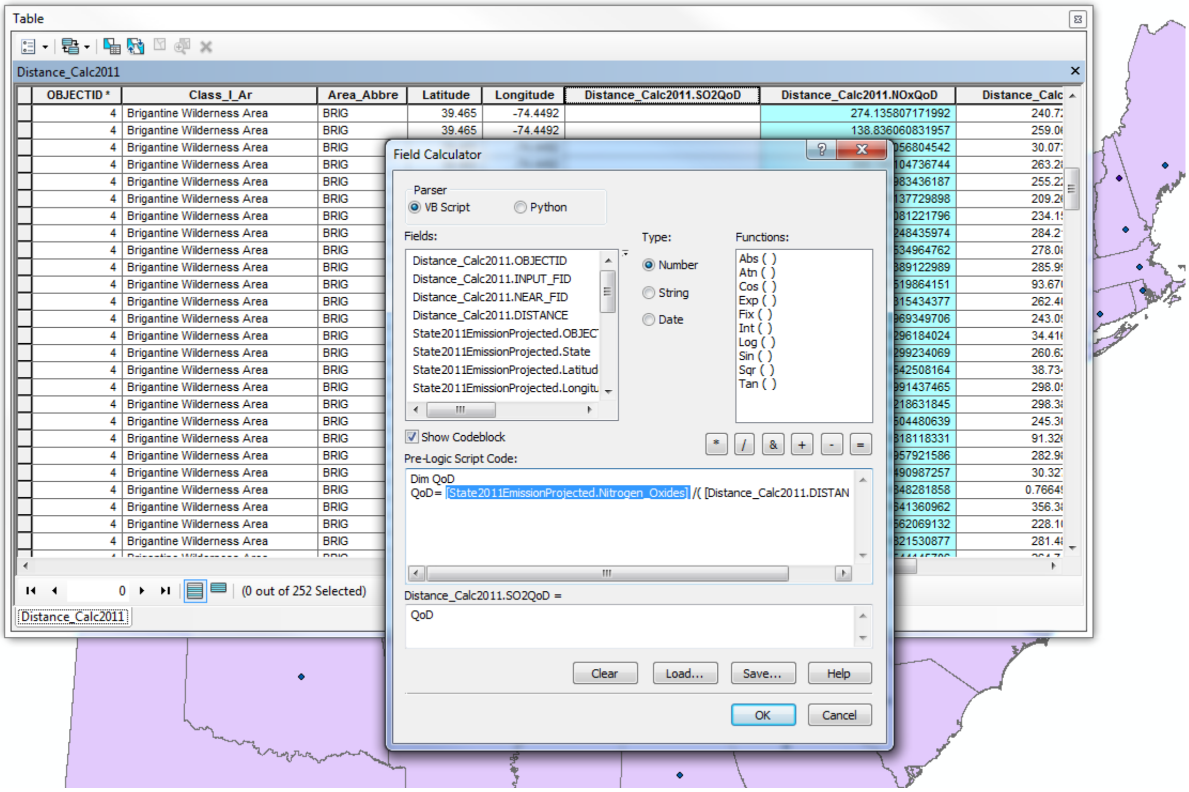

Wind Direction Sector Constants (Ci) for Acadia National Park, Me
0-171 Degrees
Ci = 0.00016071
172-197 Degrees
Ci = 0.00020593
198-216 Degrees
Ci = 0.00016071
227-360 Degrees
Ci = 0.00016071
217-226 Degrees
Ci = 0.00019667
The Ci factors were derived in this counter-clockwise cooridantes with East being zero degrees. This depiction illustrates the vectors and the associated Ci as defined in the 2002 and 2007 contribution assessments by NESCAUM. Which can be found at http://www.nescaum.org/documents/contributions-to-regional-haze-in-the-northeast-and-mid-atlantic--united-states/
North 90°
East 0°

15. 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 corrected created in step 14.

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



16. Final step export table to CSV for charts (can do in ARC map as well but more workable format for large group in excel)