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State-Level Nitrogen Source Attribution from CMAQ for the Chesapeake Bay TMDL Process to Support Air-Water Trading

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There is strong interest in air-water trading so states can get water quality credit

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The TMDL sets limits on the load that can be delivered from tributaries and the air to the Bay. The TMDL takes into account nitrogen deposition reductions from current national air rules (such as CAIR)

States may go beyond national CAA rules to meet local air quality standards

It is important to the costly, water-oriented TMDL process to take advantage of air emissions reductions that would occur in addition to national air rules

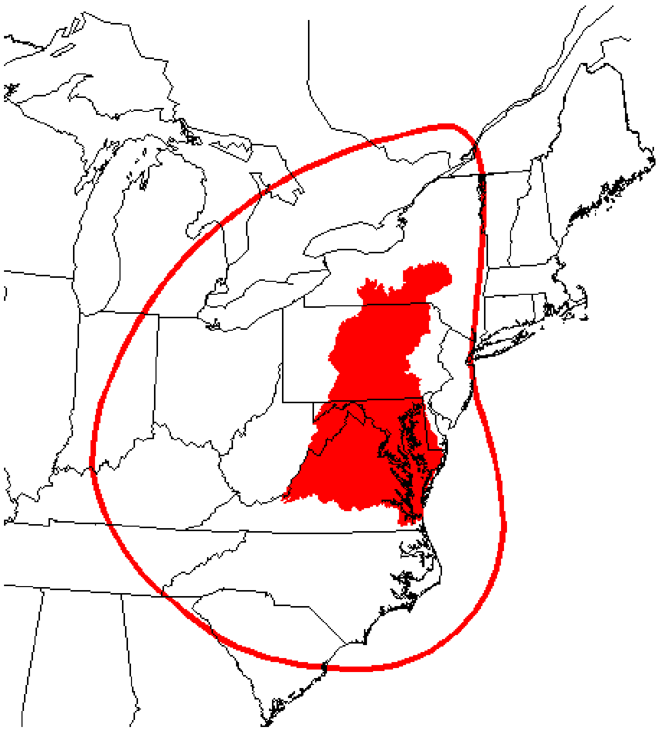
Because of the complex chemistry, transport and transformations, calculation of the incremental benefit needs an air quality model

We do not want to run the air quality model many times over (due to computational expense)

There is a special source attribution version of CMAQ (DDM-3D) that tracks the individual contribution of emissions by source or region, to the total deposition

Use CMAQ with DDM-3D Adapted for Deposition

- DDM-3D calculates in the forward sense: how a specific source or sources impacts the domain
- DDM-3D for deposition estimates the fraction of the total deposition attributed to emissions from a particular source type or region
- We track NO_X emissions (oxidized nitrogen) for a 2020 CAIR future
- We use the CMAQ DDM-3D version with 12km grids over the airshed domain
- We then create simplified state-level delta emissions–to-delta atmospheric deposition transfer coefficients by major source sectors within a state



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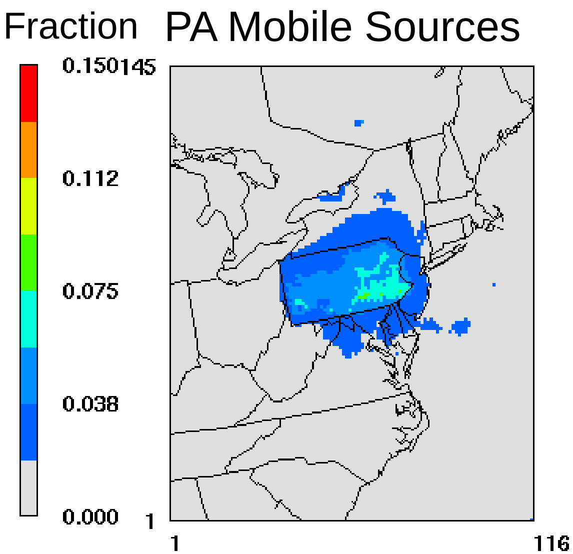
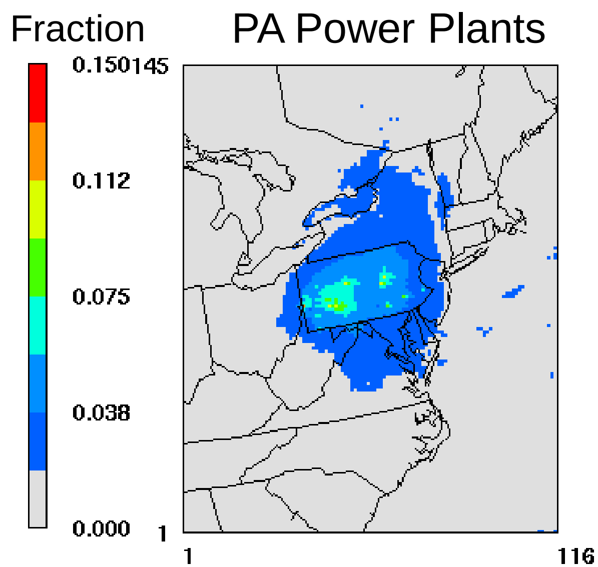
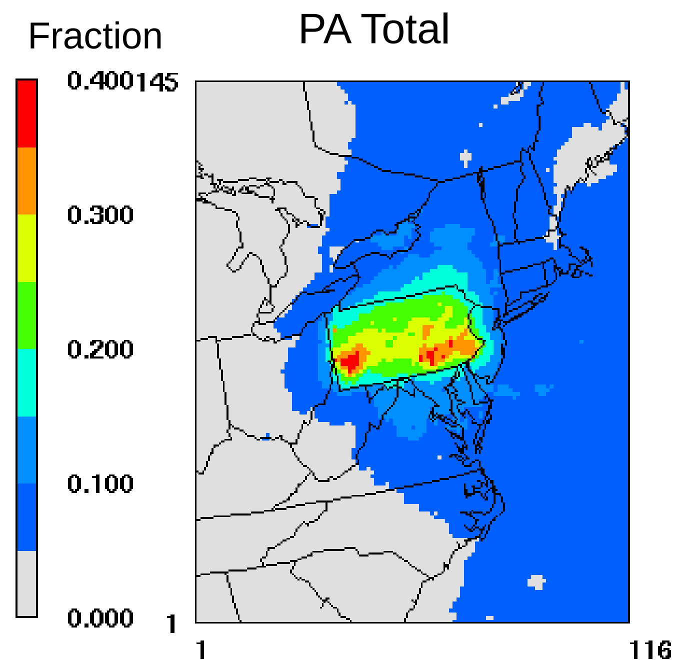
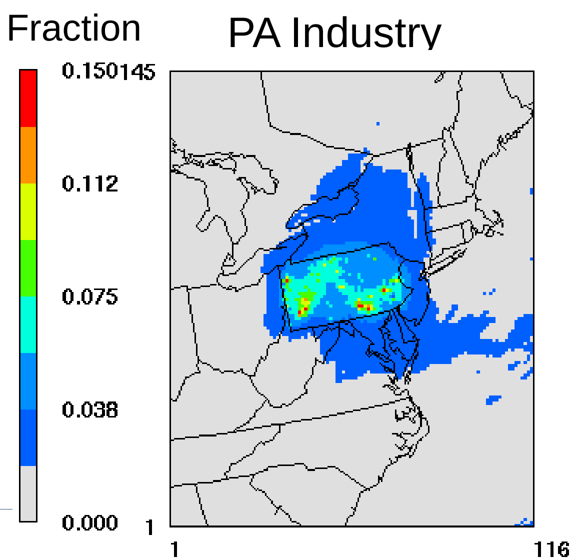
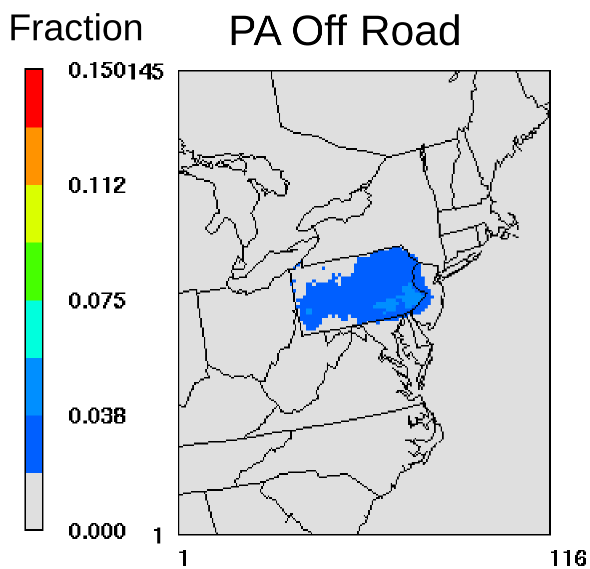
The states will be interested in fraction of deposition by key sectors (since rules will be by sector) for 2020 CAIR conditions











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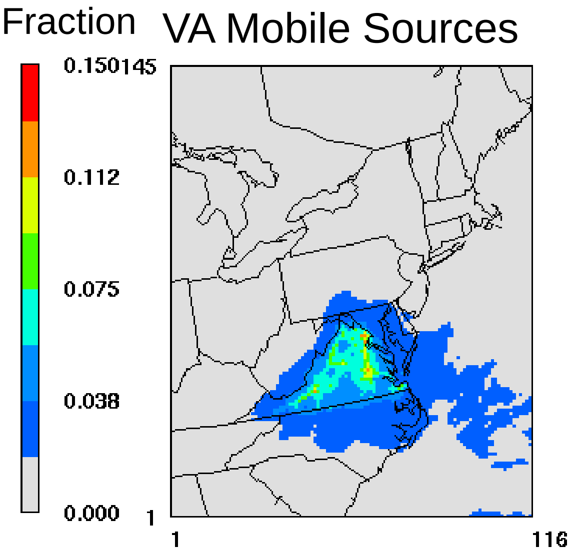

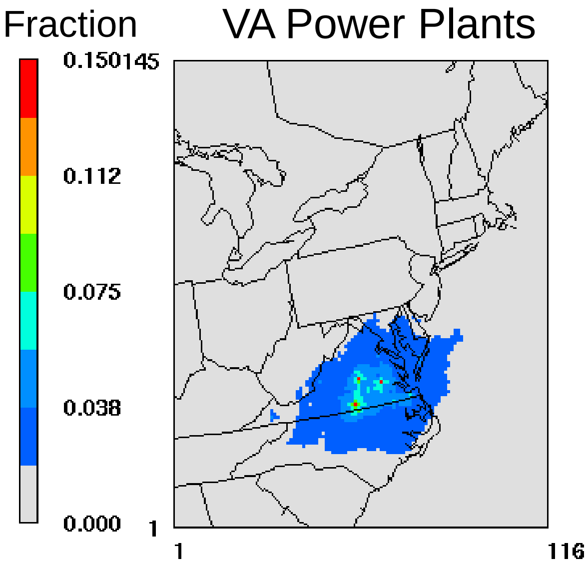

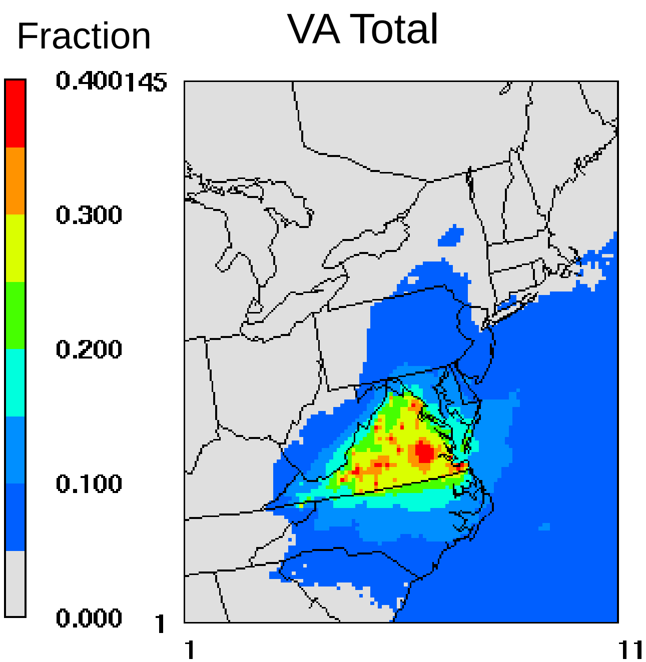

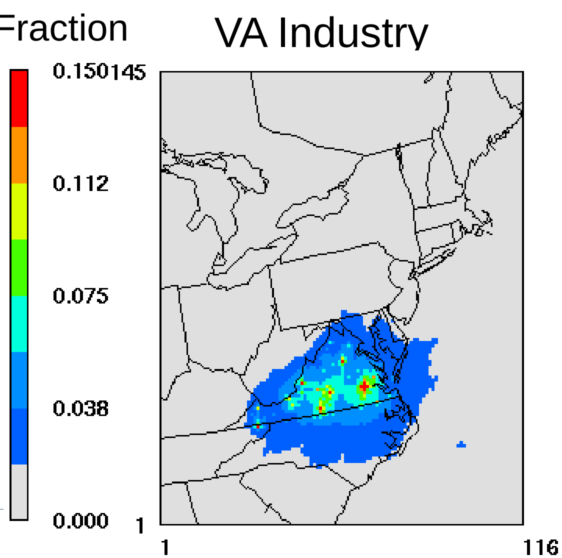

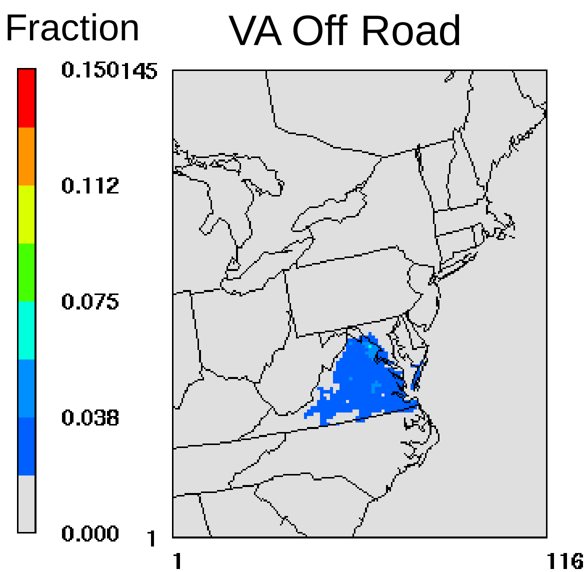

The emissions from watershed states account for a little over half of the deposition to the watershed

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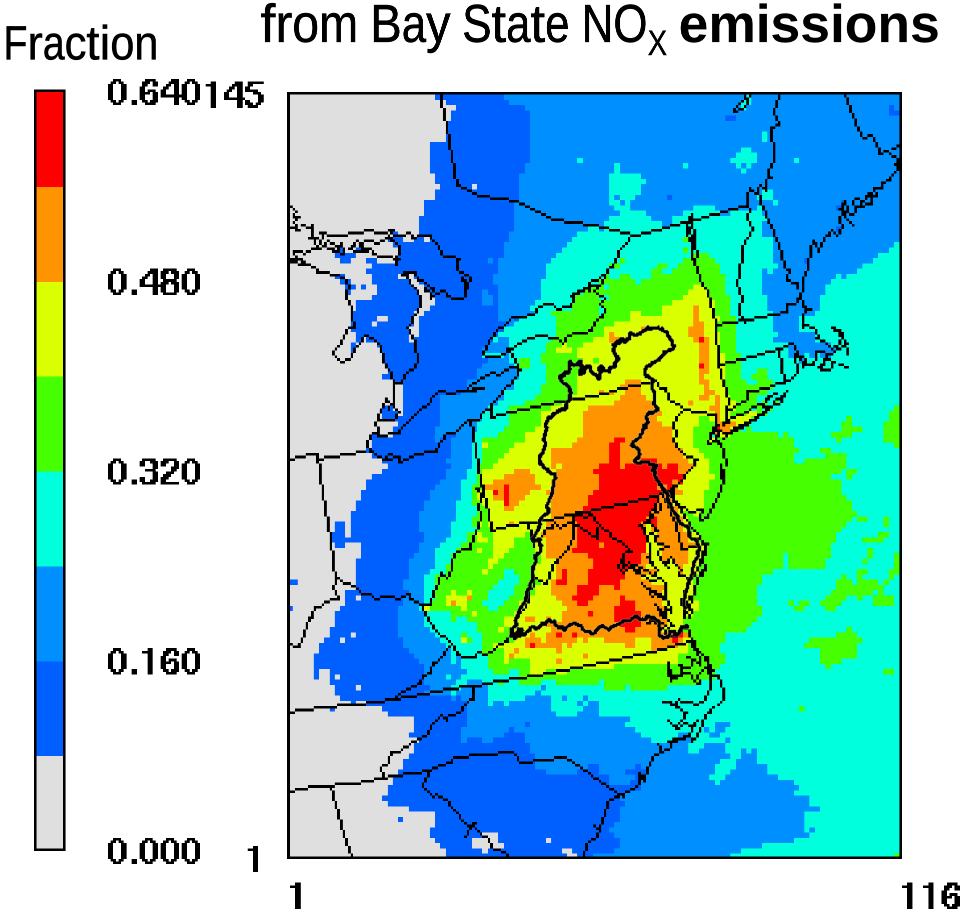
6 Bay States+DC
Fraction of Ox-N Deposition Derived from Bay State NO_X **emissions**



2020 State Attribution to Chesapeake Bay Watershed (12km)	
State	%
New York	5.5
Pennsylvania	16.3
Maryland	8.7
Virginia	15.0
Delaware	1.1
West Virginia	5.2
D.C.	0.5
6 States+DC Combined	52.5

State Contribution (2020 CAIR)

Fraction of kg-N contributed to tributary deposition by state

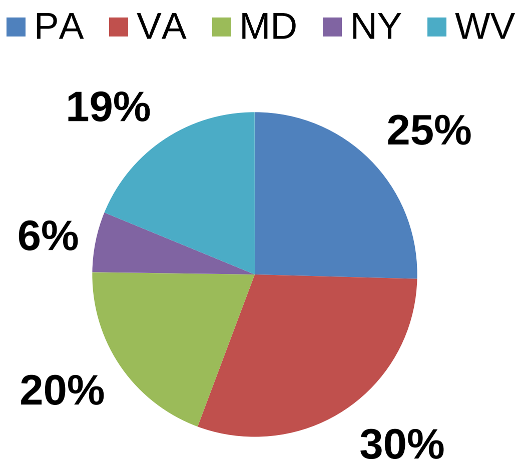
State	Potomac AFL	SusquehannaAFL	James AFL		Potomac AFL	Susquehanna AFL	James AFL
	fraction	fraction	fraction		kg-N Dep	kg-N Dep	kg-N Dep
PA	0.135	0.234	0.076		1,550,493	7,264,605	596,921
VA	0.160	0.065	0.278		1,845,927	2,022,897	2,190,683
MD	0.103	0.064	0.050		1,189,608	1,999,316	390,278
NY	0.032	0.082	0.024		365,609	2,548,684	185,847
WV	0.099	0.044	0.063		1,144,380	1,363,908	492,872
Total Tributary N Deposition (kg-N)					11,521,959	31,090,112	7,880,591

AFL = Above the Fall Line

State Contribution (2020 CAIR)

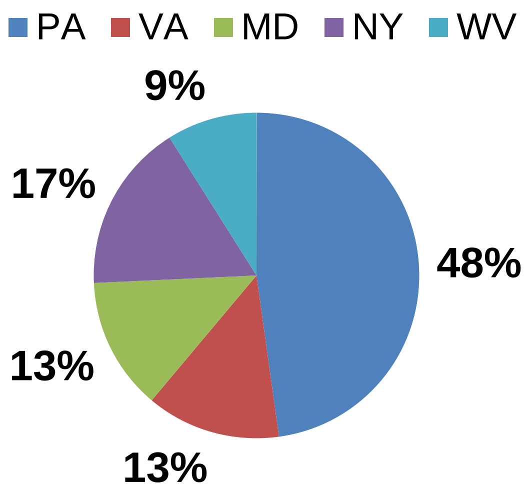
Fraction of kg-N contributed to tributary deposition by state normalized to 5-State total

Potomac AFL Deposition



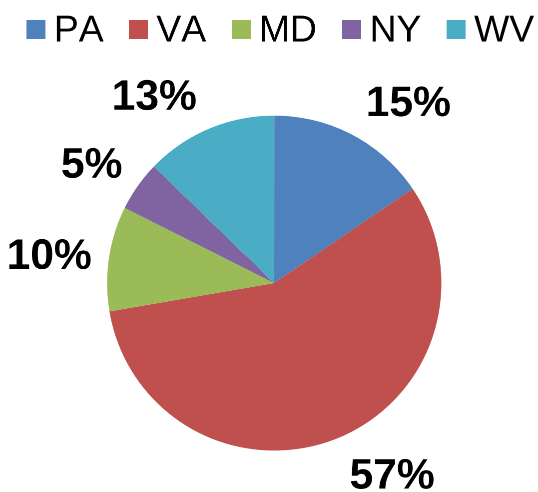
Load = 6.1 x 10^6 kg-N
= 53% of total load

Susquehanna AFL Deposition



Load = 15.2 x 10^6 kg-N
= 49% of total load

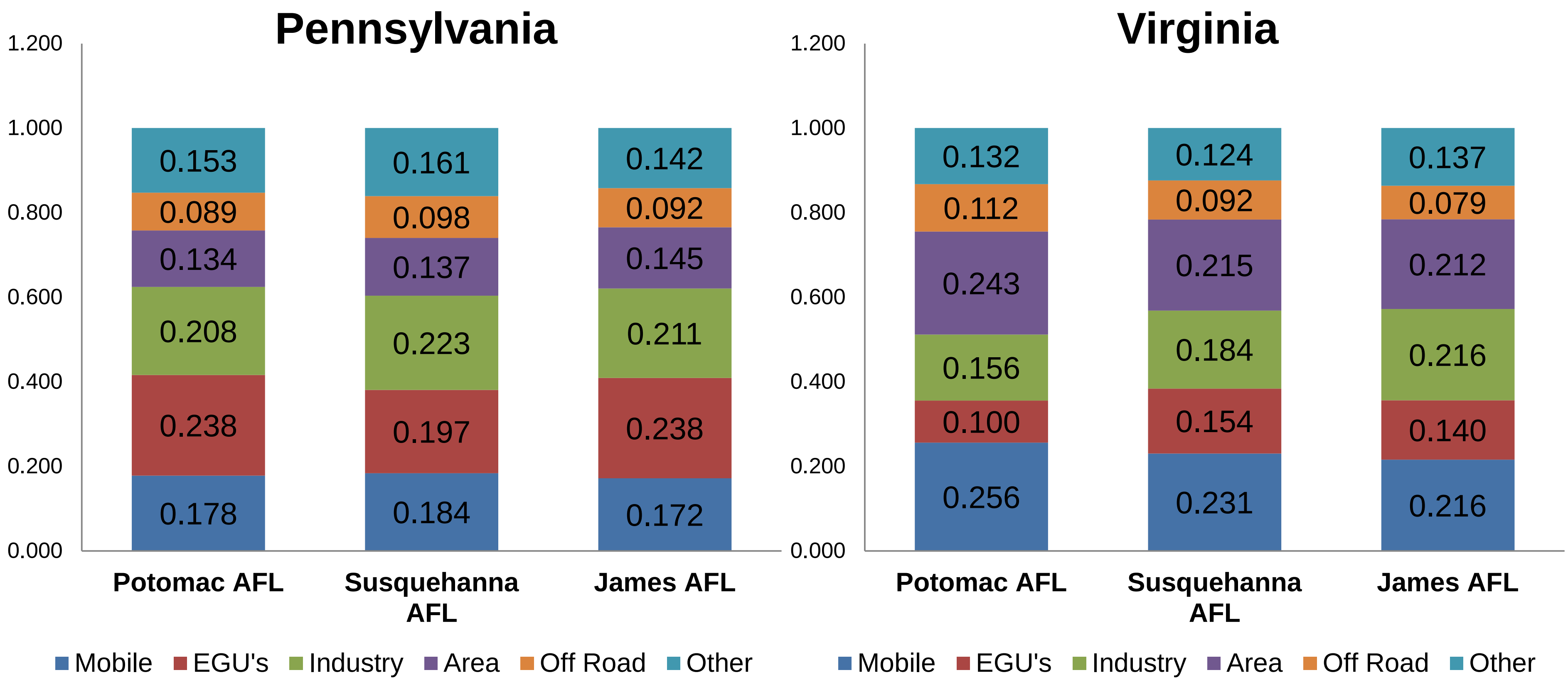
James AFL Deposition



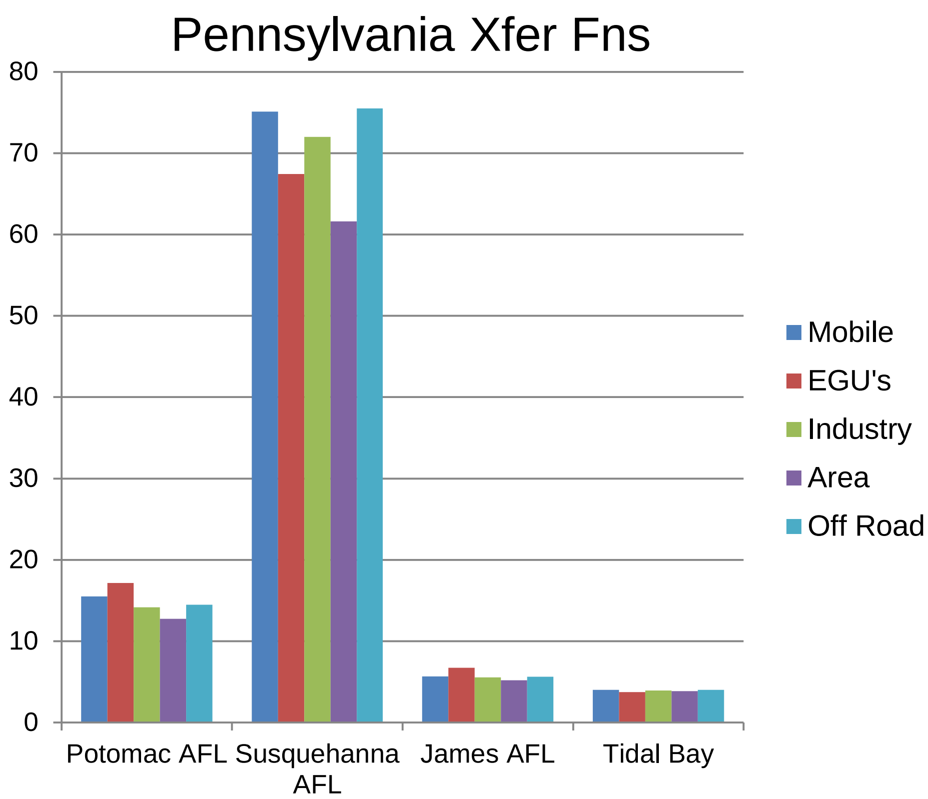
Load = 3.9 x 10^6 kg-N
= 49% of total load

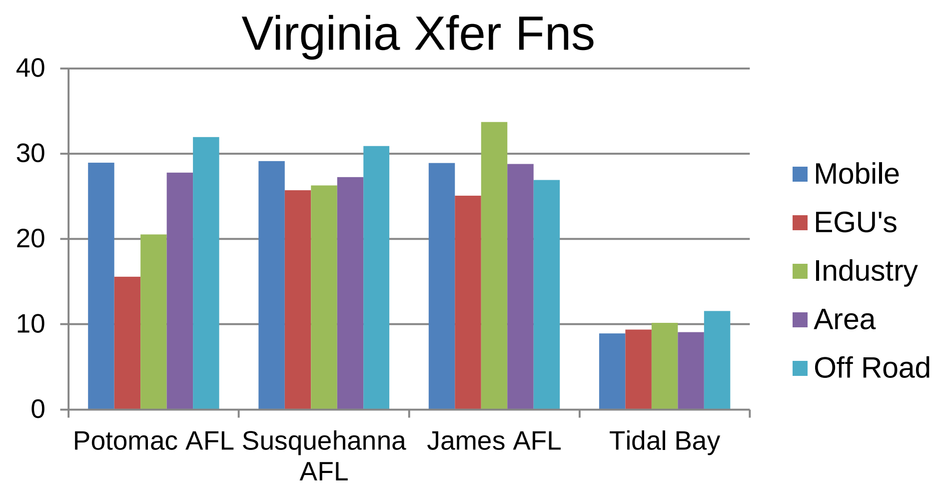
State Sector (2020 CAIR)

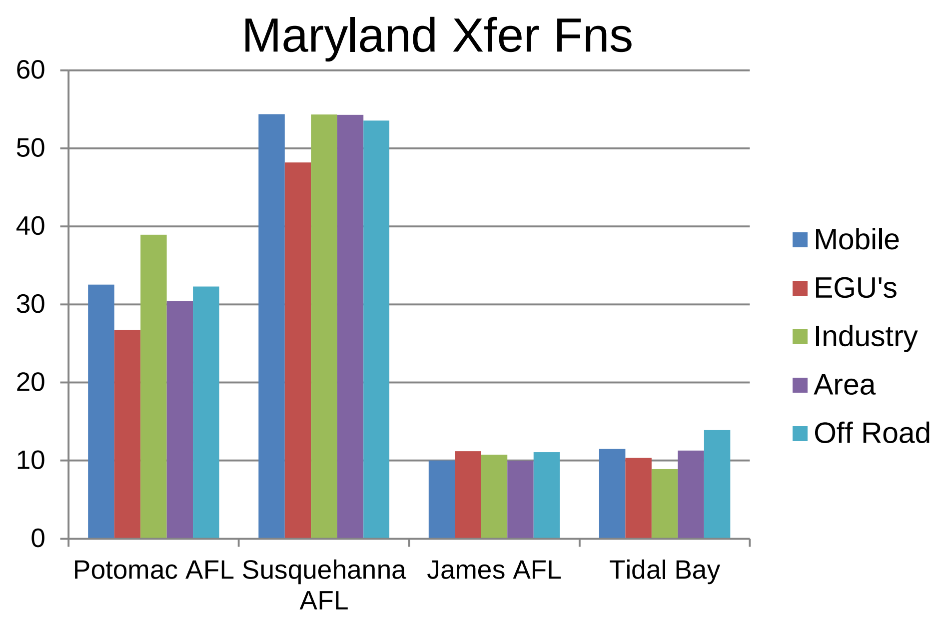
Relative fraction of kg-N contributed to tributary deposition by state emission sectors: Normalized to 1.0



Divide deposition by emissions to create a deposition transfer function by state and sector = kg-N deposition / ton-N emissions







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Divide by emissions to create a deposition transfer function by state and sector which is then multiplied by a load transfer function from the watershed model

Deposition Transfer Function
Pennsylvania

PA	Potomac AFL	SusquehannaAFL	James AFL	Tidal Bay		State-Sector Emissions
Sector	Xfer Fn*	Xfer Fn*	Xfer Fn*	Xfer Fn*		tons-N
Mobile	15.52	75.09	5.68	4.01		17,742.0
EGU's	17.18	67.42	6.75	3.76		21,183.9
Industry	14.19	72.00	5.56	3.93		22,552.1
Area	12.76	61.62	5.22	3.87		16,170.5
Off Road	14.48	75.51	5.62	4.04		9,373.2
*Xfer Fn = kg-N deposition/ton-N emissions						

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For Perspective: What impact would Pennsylvania Diesel Rule NO_X emission reductions have?

Estimated reduction: 736 tons NO_X = 224.1 tons-N (0.3045 conversion)

Impact of PA State-wide Diesel Rule NO_X Emission Reduction					
	PA Mobile Xfer Fn	ΔKg-N Deposition (x 224.1)	% Trib. Deposition	Δkg-N load Delivered (x0.1107)	Δlb-N load Delivered (x 2.2)
Potomac AFL	15.52	3,478	0.030%	385	847
Susquehanna AFL	75.09	16,828	0.054%	1,863	4,098
James AFL	5.68	1,273	0.016%	141	310
Tidal Bay	4.01	898.6	0.022%	99.5	219

Summary

- There is not a simple relationship between air emission reductions and reductions of deposition to different tributaries because the deposition comes from many sources and only a fraction comes from emissions from within (each of) the Bay states

- A sophisticated air quality model can be used to create realistic, simplified equations approximating the complex relationship of an incremental emissions change in a state (or specified geographic region) to an incremental deposition change in designated tributaries

- These simplified equations can be used in the TMDL process to facilitate air-water trading and open up the possibility to take credit for additional air reductions required to meet human health standards and enhance efficiency and cost-effectiveness of the TMDL process

- We learned we have to be careful in how DDM-3D is applied: Oxidized-N deposition budgets need to be internally complete, because some nonlinearities are not accounted for.

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Thank You

Questions?

Divide by emissions to create a deposition transfer function by state and sector which is then multiplied by a load transfer function from the watershed model

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Deposition Transfer Function
Virginia

VA	Potomac AFL	SusquehannaAFL	James AFL	Tidal Bay		State-Sector Emissions
Sector	Xfer Fn*	Xfer Fn*	Xfer Fn*	Xfer Fn*		tons-N
Mobile	28.95	29.14	28.89	8.93		16,299.4
EGU's	15.57	25.72	25.09	9.37		12,094.5
Industry	20.53	26.28	33.73	10.18		14,071.9
Area	27.78	27.25	28.79	9.07		16,229.5
Off Road	31.96	30.89	26.93	11.57		6,377.5
*Xfer Fn = kg-N deposition/tons-N emissions						

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Divide by emissions to create a deposition transfer function by state and sector which is then multiplied by a load transfer function from the watershed model

Deposition Transfer Function
Maryland

MD	Potomac AFL	SusquehannaAFL	James AFL	Tidal Bay		State-Sector Emissions
Sector	Xfer Fn*	Xfer Fn*	Xfer Fn*	Xfer Fn*		tons-N
Mobile	32.56	54.37	10.00	11.51		7,862.6
EGU's	26.71	48.17	11.20	10.34		6,897.7
Industry	38.94	54.34	10.77	8.92		5,425.8
Area	30.41	54.31	9.97	11.27		6,566.5
Off Road	32.31	53.54	11.07	13.92		4,454.6
*Xfer Fn = kg-N deposition/tons-N emissions						

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Divide by emissions to create a deposition transfer function by state and sector which is then multiplied by a load transfer function from the watershed model

New York

NY	Potomac AFL	Susquehanna AFL	James AFL	Tidal Bay		State-Sector Emissions
Sector	Xfer Fn*	Xfer Fn*	Xfer Fn*	Xfer Fn*		tons-N
Mobile	4.13	29.62	2.08	1.96		18,910.0
EGU’s	4.02	31.16	1.95	1.74		10,272.1
Industry	4.20	29.54	2.09	1.93		9,771.3
Area	3.84	24.04	2.00	1.90		26,730.0
Off Road	4.14	26.31	2.23	1.90		13,624.5
*Xfer Fn = kg-N deposition/tons-N emissions						

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State Sector (2020 CAIR)

Fraction of kg-N contributed to tributary deposition by state sector

Pennsylvania

PA	Potomac AFL	SusquehannaAFL	James AFL		Potomac AFL	Susquehanna AFL	James AFL
Sector	fraction	fraction	fraction		kg-N Dep	kg-N Dep	kg-N Dep
Mobile	0.024	0.043	0.013		275,306	1,332,309	100,768
EGU's	0.032	0.046	0.018		364,042	1,428,125	143,063
Industry	0.028	0.052	0.016		320,053	1,623,787	125,404
Area	0.018	0.032	0.011		206,285	996,399	84,390
OffRoad	0.012	0.023	0.007		135,743	707,746	52,711
Total Tributary N Deposition (kg-N)					11,521,959	31,090,112	7,880,591

EGU's = Electric Generating Units = Power Plants

AFL = Above the Fall Line

State Sector (2020 CAIR)

Fraction of kg-N contributed to tributary deposition by state sector

Virginia

VA	Potomac AFL	SusquehannaAFL	James AFL		Potomac AFL	Susquehanna AFL	James AFL
Sector	fraction	fraction	fraction		kg-N Dep	kg-N Dep	kg-N Dep
Mobile	0.041	0.015	0.060		471,826	474,996	470,942
EGU's	0.016	0.010	0.039		188,292	311,048	303,410
Industry	0.025	0.012	0.060		288,941	369,853	474,632
Area	0.039	0.014	0.059		450,885	442,198	467,259
OffRoad	0.018	0.006	0.022		203,834	197,004	171,777
Total Tributary N Deposition (kg-N)					11,521,959	31,090,112	7,880,591

EGU's = Electric Generating Units = Power Plants

AFL = Above the Fall Line