Maryland
Department of
the Environment

Larry Hogan, Governor
Boyd K. Rutherford, Lt. Governor

Ben Grumbles, Secretary
Horacio Tablada, Deputy Secretary

Implementation, Maintenance, and Enforcement of the 0.075 ppm 8-hour Ozone National Ambient Air Quality Standard State Implementation Plan §110(a)(2)(D)

MD 75 ppb Ozone Transport SIP

SIP Number: 18-05

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Prepared for:

U.S. Environmental Protection Agency

Prepared by:

Maryland Department of the Environment

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EXECUTIVE SUMMARY

Sections 110(a)(l) and (2) of the Clean Air Act (CAA) require all states to submit any necessary revisions to their State Implementation Plans (SIP) to provide for the implementation, maintenance and enforcement of any revised or new national ambient air quality standard (NAAQS). Such revisions are commonly referred to as "infrastructure SIPs."

This current SIP revision supplements MDE's previous submittal, further addressing the CAA §110(a)(2)(D)(i)(I) (i.e., good neighbor) requirements to demonstrate that emissions from sources in Maryland do not contribute significantly to nonattainment in, or interfere with maintenance by, any other state with respect to the 2008 ozone NAAQS. MDE's analysis of recent EPA modeling conducted for the updated transport rule[1], recent ozone monitoring data, and emission trends demonstrates that Maryland meets and exceeds its good neighbor requirements for the 2008 ozone NAAQS.

Maryland meets and exceeds the good neighbor obligations through state regulations and does not rely solely on federal programs to fulfill the requirements of §110(a)(2)(D)(i)(I). Due to the presence of nonattainment areas, Maryland has implemented numerous planning requirements designed to achieve compliance with the NAAQS. Maryland has previously complied with the requirements of §110 in its infrastructure SIPs, which have been approved by EPA. In doing so, Maryland, as a state, has implemented one of the country's most stringent set of emission controls in the country, aggressively regulating power plants, factories, and motor vehicles.

BACKGROUND

On March 27, 2008, the U.S. Environmental Protection Agency (EPA) promulgated a revised NAAQS[2] for ozone based on 8-hour average concentrations [73 FR 16436]. EPA revised the level of the 8-hour ozone NAAQS to 0.075 parts per million (ppm). EPA completed the designation process to identify nonattainment areas in July 2012[3] [77 FR 30088]. Pursuant to §110(a) of the CAA, states are required to submit infrastructure SIPs within three (3) years following the promulgation of new or revised NAAQS, or within a shorter period as EPA may prescribe. More specifically, §110(a)(1) provides the procedural and timing requirements for SIPs; and §110(a)(2) lists specific elements that states must meet for infrastructure SIP requirements related to new or revised NAAQS. These include basic SIP elements such as requirements for monitoring, basic program requirements and legal authority that are designed to assure attainment and maintenance of the NAAQS.

On December 31, 2012, Maryland submitted a plan to satisfy the requirements of §110(a)(2) of the CAA for the 2008 ozone NAAQS (2012 Ozone Infrastructure SIP). This submittal addressed the following infrastructure elements, or portions thereof: §§110(a)(2)(A), (B), (C), (D), (E), (F), (G), (H), (J), (K), (L), and (M) of the CAA. Earlier that year on August 21, 2012, in the EME Homer City decision[4], the U.S. Court of Appeals for the D.C. Circuit had found that a state was not required to submit a SIP pursuant to §110(a) which addresses §110(a)(2)(D)(i)(I) until EPA

[1] EPA, Air Quality Modeling Technical Support Document for the Final Cross-State Air Pollution Rule Update, August 2016. https://www.epa.gov/airmarkets/air-quality-modeling-technical-support-document-final-cross-state-air-pollution-rule
[2] See: https://www.gpo.gov/fdsys/granule/FR-2008-03-27/E8-5645
[3] See: https://www.gpo.gov/fdsys/pkg/FR-2017-04-18/pdf/2017-07770.pdf
[4] See: https://www.cadc.uscourts.gov/internet/opinions.nsf/.../$file/11-1302-1390314.pdf

has defined a state's contribution to nonattainment or interference with maintenance in another state. Maryland's 2012 Ozone Infrastructure SIP therefore did not include a component to address §110(a)(2)(D)(i)(I), and Maryland acknowledged in the SIP that this transport component of the infrastructure SIP would need to be updated.

On April 29, 2014[5], the EME Homer City decision was reversed by the Supreme Court of the United States (SCOTUS), which found that the CAA does not require that EPA quantify a state's obligation under that section before states are required to submit §110(a)(2)(D)(i)(I) SIPs. On November 17, 2014, EPA acted to approve all sections of the 2012 Ozone Infrastructure SIP except for §110(a)(2)(D)(i)(I) [79 FR 62010]. On April 12, 2016, Maryland submitted a letter to EPA informing them of the State's plans to submit an updated transport SIP for the 2008 Ozone NAAQS and to withdraw from consideration the portions of the 2012 Ozone Infrastructure SIP addressing §110(a)(2)(D) of the CAA.

Because of the SCOTUS decision, on July 21, 2016, EPA issued Findings of Failure to Submit a Section 110 State Implementation Plan for Interstate Transport for the 2008 National Ambient Air Quality Standards for Ozone [81 FR 47040] for Maryland, specifically that Maryland failed to submit a SIP to satisfy CAA §110(a)(2)(D)(i)(I). This finding of failure to submit established a 2-year deadline for EPA to promulgate a Federal Implementation Plan (FIP) that satisfies these requirements, unless the state submits (and the EPA approves) a satisfactory SIP prior the FIP promulgation.

EPA SIP GUIDANCE

On January 22, 2015, EPA issued partial guidance[6] (January 2015 guidance) to assist states with preparing SIP revisions to address the requirements of CAA §110(a)(2)(D)(i)(I) for the 2008 ozone NAAQS. The guidance discussed methodologies previously used to comply with CAA good neighbor requirements and presented new, preliminary EPA ozone modeling results[7] for 2018 based on emission reductions anticipated from previously adopted air pollution control programs. Consistent with the approach utilized during the development of the Cross-State Air Pollution Rule (CSAPR), EPA's preliminary modeling identified states that are projected to contribute at or above the screening threshold (i.e., 1% or more of the NAAQS) to nonattainment/maintenance concerns in other states in 2018.

Pursuant to EPA's guidance, those states whose modeled air quality impacts to at least one downwind nonattainment/maintenance monitor are greater than or equal to the screening threshold are required to take action to address transport. States whose air quality impacts to all downwind nonattainment/maintenance monitors are below the screening threshold have no additional emission reduction obligation for the 2008 NAAQS under the good neighbor provisions of CAA §110(a)(2)(D)(i)(I).

[5] See: https://www.supremecourt.gov/opinions/13pdf/12-1182_553a.pdf
[6] See: https://www.epa.gov/sites/production/files/2015-10/documents/goodneighborprovision2008naaqs.pdf
[7] See: https://www.epa.gov/sites/production/files/2015-11/documents/o3transportaqmodelingtsd.pdf

EPA's January 2015 guidance refers to a four-step process developed previously by EPA to address ozone transport:

1) Identify downwind air quality problems;
2) Identify upwind states that contribute enough (or are "linked") to those downwind air quality problems to warrant further review and analysis;
3) For states that are "linked", identify the emissions reductions necessary to prevent an identified upwind state from contributing significantly to those downwind air quality problems; and
4) Adopt permanent and enforceable measures needed to achieve identified emission reductions.

A complete good neighbor SIP revision should include an analysis, based on current data, of all four steps listed above.

As described below, *Maryland has examined the results of EPA's ozone transport modeling and analyzed recent ambient air monitoring data at key downwind sites to demonstrate that it complies with the requirements of CAA §110(a)(2)(D)(i)(I) for the 2008 ozone NAAQS.*

EPA OZONE TRANSPORT MODELING

In this SIP revision, Maryland will focus on several of the air quality modeling efforts which were considered during the SIP development, listed below. The modeling was completed by EPA to help states address the requirements of CAA §110(a)(2)(D)(i)(I) for both the 1997 and 2008 ozone NAAQS.

- Air Quality Modeling for the Cross-State Air Pollution Rule (CSAPR) (June 2011)
- Air Quality Modeling for the CSAPR Proposal (November 2015)
- Air Quality Modeling for the CSAPR Update (August 2016)
- Memo: Supplemental Information on Interstate Transport SIPs for the 2008 Ozone NAAQS (October 2017)

A brief description of each modeling platform is shown below.

Cross-State Air Pollution Rule Modeling

When developing the CSAPR, EPA used the Comprehensive Air Quality Model with Extensions (CAMx) version 5.3 to quantify the contribution of emissions from "upwind" states to 1997 8-hour ozone (0.08 ppm) nonattainment in "downwind" states ("downwind contribution")[8]. EPA's CAMx modeling included a 2012 "base case" with state-specific source apportionment runs to quantify each state's downwind contribution to other states' monitor(s), in projected 2012. Results showed Maryland being "linked" to two downwind maintenance receptors and no nonattainment receptors. The largest contribution to a downwind maintenance receptor was 2.70 ppb. However, this model run accounted for emission reductions from adopted national, regional

[8] EPA, Air Quality Modeling Final Rule Technical Support Document, June 2011. https://www.epa.gov/csapr/air-quality-modeling-final-rule-technical-support-document

and state control programs, but did not account for projected reductions due to the proposed CSAPR program or the CSAPR predecessor – Clean Air Interstate Rule (CAIR).

Cross-State Air Pollution Rule Proposal Modeling

EPA released air quality modeling[9] in November 2015 that projected ozone concentrations at individual monitoring sites in 2017 and estimated state-by-state contributions to those 2017 concentrations. The photochemical model simulations performed for this assessment used the CAMx version 6.11. The results of this updated modeling identified Maryland's largest downwind contribution to 8-hour ozone nonattainment and maintenance receptors (based on a proposed 2008 NAAQS of 0.075 ppm) as 2.07 ppb and 7.11 ppb, respectively. The modeling projected Maryland to be "linked" to three downwind 2017 nonattainment receptors and eight maintenance receptors.

Cross-State Air Pollution Rule Update Modeling

The final CSAPR Update air quality modeling[10] was released in August 2016. This model used the same 4-step framework to project ozone concentrations at individual monitoring sites in 2017 and estimate the state-by-state contributions, but updated several measures to reflect the newer 2008 ozone NAAQS (0.075 ppm) and in response to stakeholder comments and various court decisions.

The photochemical model simulations performed for this assessment used CAMx version 6.20, which did not include the impact of the Clean Power Plan (CPP) due to several uncertainties associated with measuring the effects of the CPP in 2017. The CSAPR Update modeling identified Maryland's largest downwind contribution to 8-hour ozone nonattainment and maintenance receptors as 2.12 ppb and 5.2 ppb, respectively [81 FR 74537], and projected Maryland to be "linked" to one downwind 2017 nonattainment receptor and seven maintenance receptors.

Maryland will be using this most recent CSAPR Update modeling to assess downwind contributions and address ozone transport under the 2008 ozone NAAQS.

Supplemental Information on the Interstate Transport SIPs for the 2008 Ozone NAAQS Modeling

On October 27, 2017, EPA issued a memo to provide supplemental information to states and the EPA Regional offices regarding the Interstate Transport SIPs for the 2008 ozone NAAQS modeling[11]. This information supports the development or review of SIPs which address

[9] EPA, Air Quality Modeling Technical Support Document for the 2008 Ozone NAAQS Cross-State Air Pollution Rule Proposal, November 2015. https://www.epa.gov/airmarkets/air-quality-modeling-technical-support-document-2008-ozone-naaqs-cross-state-air

[10] EPA, Air Quality Modeling Technical Support Document for the Final Cross-State Air Pollution Rule Update, August 2016. https://www.epa.gov/airmarkets/air-quality-modeling-technical-support-document-final-cross-state-air-pollution-rule

[11] Memo: Supplemental Information on Interstate Transport SIPs for the 2008 Ozone NAAQS. https://www.epa.gov/airmarkets/memo-supplemental-information-interstate-transport-sips-2008-ozone-naaqs

§110(a)(2)(D)(i)(I) of the CAA as it pertains to these NAAQS. The EPA chose 2023 as the analytic year, based on the time it would take to implement reductions from newly installed EGU controls, and performed nationwide photochemical modeling to identify nonattainment and maintenance receptors relevant to the 2008 ozone NAAQS.

The EPA used CAMx version 6.40 for modeling the updated emissions in 2011 and 2023. They used the recommended "3 x 3" grid cell approach for projecting design values for the updated 2023 modeling, and a modified version of this approach for monitoring sites located in coastal areas. When identifying areas with potential downwind air quality problems, the EPA's updated modeling used the same "receptor" definitions as those developed during the 2011 CSAPR rulemaking process and used in the 2016 CSAPR Update.

The EPA's 2023 updated modeling, using either the "3 x 3" approach or the alternative approach affecting coastal sites, indicates that there are no monitoring sites (outside of California) that are projected to have nonattainment or maintenance problems with respect to the 2008 ozone NAAQS in 2023.

In order to effectively utilize the modeling demonstration, MDE has identified five main items that need to be included in a Good Neighbor SIP prior to its approval:

- Use the 2023 modeling in a supplemental capacity for determining contribution, as 2023 is an inappropriate analytical year for assessment of significant contribution
- Complete the entire 4-Step process for addressing transport obligations
- Require the optimization of post-combustion controls at electric generating units (EGUs) as a simple, cost-effective near term strategy for NO_X reduction
- Require the reductions included in modeling for interstate transport SIP submittals to be permanent and enforceable and implemented as expeditiously as possible
- Require the optimization of post-combustion controls at EGUs on a daily basis, consistent with the way peak days are used to demonstrate attainment with the standards using measured ozone data

MARYLAND'S CONTRIBUTION TO DOWNWIND NONATTAINMENT AND MAINTENANCE RECEPTORS

As previously stated, EPA has conducted contribution modeling for the original CSAPR, the CSAPR Update Proposal, and the final CSAPR Update (June 2011, November 2015, and August 2016, respectively). A table detailing the results is shown below. EPA also conducted contribution modeling for the October 2017 supplemental information memo, but found the results may not be necessary for most states to develop good neighbor SIPs for the 2008 ozone NAAQS[12]. The outputs were not included in the final memo.

[12] October 2017 Memo and Supplemental Information on Interstate Transport SIPs for the 2008 Ozone NAAQS. https://www.epa.gov/airmarkets/october-2017-memo-and-supplemental-information-interstate-transport-sips-2008-ozone-naaqs

Table 1: Maryland's Projected Ozone Contributions to Nonattainment and Maintenance-Only Receptors based on Current and Historic Cross-State Air Pollution Rule Modeling

(Contributions shown in RED are to nonattainment receptors.)

DATE OF MODELING		June 2011 (80 ppb NAAQS)	November 2015 (75 ppb NAAQS)	August 2016 (75 ppb NAAQS)
PROJECTED YEAR		2012	2017	2017
PROJECTED MAXIMUM CONTRIBUTIONS (ppb)				
NONATTAINMENT RECEPTOR		0.00	2.07	2.12
MAINTENACE RECEPTOR		2.70	7.11	5.22
RECPTOR ID	**SITE ID**	**Contribution (ppb)**	**Contribution (ppb)**	**Contribution (ppb)**
Fairfield County, CT	090013007	N/A	2.07	2.11
Fairfield County, CT	090019003	N/A	1.83	2.12
Fairfield County, CT	090011123	2.30	N/A	N/A
Fairfield County, CT	090010017	N/A	1.34	1.61
New Haven, CT	090099002	2.70	1.55	1.60
Gloucester County, NJ	340150002	N/A	7.11	N/A
Middlesex County, NJ	340230011	N/A	2.35	N/A
Ocean County, NJ	340290006	N/A	2.01	N/A
Queens County, NY	360810124	N/A	2.15	N/A
Richmond County, NY	360850067	N/A	2.39	2.49
Suffolk County, NY	361030002	N/A	1.47	1.42
Philadelphia County, PA	421010024	N/A	5.10	5.22

Identifying "Linked" Nonattainment and Maintenance Receptors

Maryland is following the four step process outlined in the January 2015 guidance to demonstrate that it complies with the requirements of CAA section 110(a)(2)(D)(i)(I) for the

2008 ozone NAAQS. **Steps 1 and 2** involve identifying downwind receptors that are expected to have problems attaining or maintaining the 2008 ozone NAAQS. Maryland is utilizing the August 2016 CSAPR Update modeling to assess its impact on "linked" downwind states.

In the CSAPR Update, EPA identified a nonattainment receptor as a monitor that both currently measures nonattainment and the EPA projects will have a 2017 average design value that exceeds the NAAQS (i.e., 2017 average design values of 76 ppb or greater). Maintenance-only receptors include both: (1) sites with projected 2017 average design values above the NAAQS that are currently measuring clean data (i.e., 2013-2015 design values) and (2) sites with projected 2017 average design values below the level of the NAAQS, but with a projected 2017 maximum design value of 76 ppb or greater.[13]

As shown in the table above, the CSAPR Update modeling results showed Maryland to be "linked" to 2 nonattainment receptors and 5 maintenance-only receptors in Connecticut, New Jersey, New York, and Pennsylvania. The largest projected contribution for a nonattainment receptor in 2017 was 2.12 ppb at a monitor in Fairfield County, Connecticut and the largest contribution to a maintenance-only receptor was 5.22 ppb in Philadelphia County, Pennsylvania.

Maryland also examined the actual and projected values at key "linked" monitors to determine the likelihood of future compliance with the NAAQS. The tables below show EPA's actual historical monitoring data at receptors "linked" to Maryland from 2013 to 2016 as well as projected values at these sites from the both the CSAPR Update modeling and the October 2017 Supplemental Information Modeling.

Table 2: EPA's Ozone Design Value Reports from 2013 to 2016 at Monitors Linked to Maryland[14] (ppm)

Monitor	Site ID	2011-2013	2012-2014	2013-2015	2014-2016
Fairfield County, CT	090013007	0.089	0.084	0.083	0.081
Fairfield County, CT	090019003	0.087	0.085	0.084	0.083
Fairfield County, CT	090010017	0.083	0.082	0.081	0.080
New Haven, CT	090099002	0.089	0.084	0.078	0.076
Gloucester County, NJ	340150002	0.084	0.076	0.073	0.074
Middlesex County, NJ	340230011	0.079	0.074	0.072	0.074

[13] EPA, Air Quality Modeling Technical Support Document for the Final Cross-State Air Pollution Rule Update, August 2016. https://www.epa.gov/airmarkets/air-quality-modeling-technical-support-document-final-cross-state-air-pollution-rule

[14] EPA Ozone Design Value Reports, https://www.epa.gov/air-trends/air-quality-design-values#report

Monitor	Site ID	2011-2013	2012-2014	2013-2015	2014-2016
Ocean County, NJ	340290006	0.080	0.075	0.072	0.073
Queens County, NY	360810124	0.079	0.072	0.069	0.069
Richmond County, NY	360850067	0.078	0.073	0.074	0.076
Suffolk County, NY	361030002	0.081	0.073	0.072	0.072
Philadelphia County, PA	421010024	0.080	0.075	0.073	0.077

Table 3: Average and Maximum 2009-2013 and 2017 Base Case 8-Hour Design Values and 2013-2015 Design Values (ppb) at Projected Nonattainment Sites "Linked" to Maryland[15]

Monitor ID	State	County	Average Design Value 2009-2013	Maximum Design Value 2009-2013	Average Design Value 2017	Maximum Design Value 2017	2013-2015 Design Value
090019003	CT	Fairfield	83.7	87	76.5	79.5	84
090099002	CT	New Haven	85.7	89	76.2	79.2	78

Table 4: Average and Maximum 2009-2013 and 2017 Base Case 8-Hour Design Values and 2013-2015 Design Values (ppb) at Projected Maintenance-Only Sites "Linked" to Maryland[16]

Monitor ID	State	County	Average Design Value 2009-2013	Maximum Design Value 2009-2013	Average Design Value 2017	Maximum Design Value 2017	2013-2015 Design Value
090013007	CT	Fairfield	84.3	89	75.5	79.7	83
090010017	CT	Fairfield	80.3	83	74.1	76.6	81
360850067	NY	Richmond	81.3	83	75.8	77.4	74
361030002	NY	Suffolk	83.3	85	76.8	78.4	72
421010024	PA	Philadelphia	83.3	87	73.6	76.9	73

[15] Air Quality Modeling Technical Support Document for the Final Cross-State Air Pollution Rule Update. www.epa.gov/airmarkets/air-quality-modeling-technical-support-document-final-cross-state-air-pollution-rule

[16] Air Quality Modeling Technical Support Document for the Final Cross-State Air Pollution Rule Update. www.epa.gov/airmarkets/air-quality-modeling-technical-support-document-final-cross-state-air-pollution-rule

Table 5: Projected Ozone Design Values at Maryland "Linked" Sites Based on EPA's Updated 2023 Transport Modeling[17]

Monitor ID	State	County	2009-2013 Avg	2009-2013 Max	2023 "3x3" Avg	2023 "3x3" Max	2023 "No Water" Avg	2023 "No Water" Max
090019003	CT	Fairfield	83.7	87	72.7	75.6	73.0	75.9
090099002	CT	New Haven	85.7	89	71.2	73.9	69.9	72.6
090013007	CT	Fairfield	84.3	89	71.2	75.2	71.0	75.0
090010017	CT	Fairfield	80.3	83	69.8	72.1	68.9	71.2
360850067	NY	Richmond	81.3	83	71.9	73.4	67.1	68.5
361030002	NY	Suffolk	83.3	85	72.5	74.0	74.0	75.5
421010024	PA	Philadelphia	83.3	87	67.3	70.3	67.3	70.3

As can be seen in Table 5, using either the "3x3" approach or the "No Water" approach, none of the "linked" sites are expected to be violating the 75ppb NAAQS in 2023, and thus these areas are expected to attain the NAAQS. Demonstrating attainment of the NAAQS via a 2023 modeling exercise is insufficient reason to end the four-step evaluation. "Linked" sites must also maintain the standard. For these reasons, Maryland has continued the four-step evaluation to provide further evidence that no additional controls are required in the state.

IDENTIFICATION OF REQUIRED EMISSIONS REDUCTIONS

Identification of the necessary emissions reductions to prevent a 'linked" upwind state from contributing significantly to downwind air quality problems is outlined as **Step 3** in the four-step process. EPA analyses thus far have focused on the power sector because this is where the greatest amount of cost-effective reductions of nitrous oxides (NOx) can be achieved. Analyses conducted for CSAPR[18] and the CSAPR Update[19] determined state budgets for electric generating units (EGUs) that correspond to emission levels after accounting for operation of existing pollution controls, emission reductions available at a certain cost threshold, and any additional reductions required to address interstate ozone transport. According to the EPA, by conforming to these budgets, a state meets its good neighbor obligations under §110(a)(2)(D)(i)(I) for the respective ozone NAAQS[20].

[17] October 2017 Memo: Supplemental Information on Interstate Transport SIPs for the 2008 Ozone NAAQS. https://www.epa.gov/airmarkets/october-2017-memo-and-supplemental-information-interstate-transport-sips-2008-ozone-naaqs
[18] See: "Multi-Factor Analysis and Determination of State Emission Budgets" [76 FR 48208]
[19] https://www.epa.gov/sites/production/files/2017-05/documents/ozone_transport_policy_analysis_final_rule_tsd.pdf
[20] See: 76 FR 48208 (1997 NAAQS) and 80 FR 74504 (2008 NAAQS)

Cross-State Air Pollution Rule

EPA's Cross-State Air Pollution Rule (CSAPR) required twenty-five states to reduce NOx emissions to help downwind areas attain the 1997 8-hour Ozone NAAQS of 0.08 ppm, and address all upwind states' transport obligations under the 1997 ozone NAAQS [76 FR 48208]. This rule established a budget for NOx emissions from Maryland's EGUs which would address its good neighbor obligations for the 0.08 ppm standard.

Using the Integrated Planning Model (IPM), the EPA estimated the emissions that would occur within each state at ascending cost thresholds of emissions control. They determined the emission reductions that would be achieved in a state if all EGUs greater than 25 MW used all controls and reduction measures available at a particular cost threshold, and designed a series of IPM runs that imposed increasing cost thresholds for ozone-season NOx emissions. Based on this information and a subsequent multi-factor analysis, the EPA determined that $500/ton was the appropriate cost threshold for ozone-season NOx control at all covered states in the CSAPR rulemaking.

At this threshold, the ozone season emissions budget for all covered EGUs[21] in Maryland was determined to be 7,238 tons in 2012 and 7,540 tons in 2014. The budgets for all thresholds, including the base case, are shown in the table below.

Table 6: 2012 & 2014 Ozone Season NO_x EGU Emissions for Each State at Various Pollution Control Cost Thresholds per Ton of Reduction (Tons).

	Base Case Emission Levels		$500/ton		$1,000/ton		$5,000/ton	
State	**2012**	**2014**	**2012**	**2014**	**2012**	**2014**	**2012**	**2014**
Alabama	34,074	31,365	34,203	31,372	33,951	31,393	30,831	29,824
Arkansas	15,037	16,644	14,995	16,565	14,944	16,432	13,969	14,970
Florida	41,646	45,993	27,069	29,607	27,029	29,122	24,277	26,866
Georgia	29,106	19,293	28,185	18,331	28,033	18,323	25,413	17,569
Illinois	21,371	22,043	21,266	21,961	21,313	21,859	20,844	21,505
Indiana	46,877	46,086	46,123	46,471	46,190	46,174	42,769	41,374
Iowa	18,307	19,440	16,526	17,082	16,308	16,996	15,227	15,776
Kansas	16,126	13,967	13,502	10,849	13,502	10,730	12,030	9,506
Kentucky	37,588	35,296	36,687	34,957	36,221	34,573	33,548	32,483
Louisiana	13,433	13,924	13,435	13,910	13,451	13,910	13,301	13,728
Maryland	7,179	7,540	**7,238**	7,540	**7,235**	7,540	6,983	7,293
Michigan	25,989	28,037	26,058	26,250	25,771	26,180	25,381	25,168
Mississippi	10,161	11,212	10,164	11,212	10,153	11,212	9,106	9,592
Missouri	23,156	23,759	22,952	23,759	22,952	23,661	21,433	21,707
New Jersey	3,440	3,668	3,448	3,669	3,407	3,668	3,361	3,648
New York	8,336	9,031	8,329	9,035	8,420	8,910	8,039	8,525
North Carolina	22,902	20,169	22,904	20,182	22,642	19,997	21,240	18,949
Ohio	42,274	41,327	42,302	40,493	41,863	40,375	38,437	38,348
Oklahoma	31,415	31,723	21,574	22,059	20,998	21,328	20,009	19,456
Pennsylvania	52,895	54,217	52,626	54,134	52,444	53,842	49,279	49,444
South Carolina	15,145	16,586	15,108	16,351	14,946	15,958	13,594	14,745
Tennessee	15,505	12,141	15,512	12,126	15,486	12,126	14,715	11,613
Texas	64,711	65,492	63,081	64,341	62,872	64,448	60,419	62,453

[21] See: 40 CFR §97.404 and §97.504, CSAPR annual and ozone season NOx sources include all EGUs with fossil-fuel-fired boilers or stationary combustion turbines with a nameplate capacity of more than 25 MWe; with some exclusions for certain cogeneration units and solid waste incinerators.

Virginia	15,148	15,339	14,662	15,299	14,599	15,116	12,543	13,575
West Virginia	26,464	27,099	26,350	27,014	26,151	26,819	23,988	24,485
Wisconsin	15,876	16,048	13,971	14,134	13,928	14,035	12,412	12,897
Total	**654,161**	**647,439**	**618,267**	**608,702**	**614,807**	**604,728**	**573,150**	**565,498**

CSAPR Update

To reduce interstate emission transport under the authority provided in CAA §110(a)(2)(D)(i)(I), the CSAPR Update further limits ozone season NOx emissions from EGUs in 22 eastern states using the same framework as the original CSAPR [81 FR 74504]. Starting in May 2017, this rule has reduced ozone season nitrogen oxides (NO_X) emissions from power plants in 22 states in the eastern United States, including Maryland. These states were identified as contributing 1% or more of the 2008 Ozone NAAQS to downwind states.

For the 22 states identified in the CSAPR Update Rule, the EPA issued Federal Implementation Plans (FIPs) that generally provide updated CSAPR NOx ozone season emissions budgets for the affected electric generating units (EGUs) within these states, and that implement these budgets via modifications to the CSAPR NOx ozone season allowance program that was established under the original CSAPR. The FIPs require affected EGUs in each covered state to reduce emissions to comply with program requirements beginning with the 2017 ozone season.

For the updated NOx ozone season budgets for EGUs, the EPA found that an increased cost threshold of $1,400 per ton was appropriate, as it represents the level of maximum marginal NOx reduction with respect to cost, and also does not over-control upwind states' emissions.[22] This threshold of control requires that units turn on existing but idled selective catalytic reduction (SCR) controls and install additional state-of-the-art NOx combustion controls. The EPA determined that an achievable 2017 EGU NOx ozone season emissions rate for units with SCR is 0.10 lbs/MMBtu, and used this for budget-setting purposes. At the $1,400 per ton threshold, the ozone season NOx budget for Maryland is 3,828 tons, as shown in Table 7.

Table 7: Final 2017 EGU NOx Ozone Season Emission Budgets for the CSAPR Update Rule

State	CSAPR Update Rule Emission Budgets (Ozone Season NO_X tons)
Alabama	**13,211**
Arkansas	**9,210**
Illinois	**14,601**
Indiana	**23,303**
Iowa	**11,272**
Kansas	**8,027**
Kentucky	**21,115**
Louisiana	**18,639**
Maryland	**3,828**
Michigan	**17,023**
Mississippi	**6,315**

[22] *See* Cross-State Air Pollution Rule Update for the 2008 Ozone NAAQS, 81 FR 75404 (October 26, 2016).

Missouri	**15,780**
New Jersey	**2,062**
New York	**5,135**
Ohio	**19,522**
Oklahoma	**11,641**
Pennsylvania	**17,952**
Tennessee	**7,736**
Texas	**52,301**
Virginia	**9,223**
West Virginia	**17,815**
Wisconsin	**7,915**

PERMANENT AND ENFORCEABLE MEASURES TO ACHIEVE REQUIRED EMISSIONS REDUCTIONS

The January 2015 guidance identifies the adoption of permanent and enforceable emissions-reduction measures as **Step 4** in the process for addressing ozone transport. As stated previously, EPA has quantified the necessary emissions reductions needed to satisfy transport obligations by determining cost-effective EGU NOx budgets for affected upwind states during ozone season. Maryland has consistently implemented regulations that control EGU NOx emissions at levels more stringent than what is required by CSAPR and the CSAPR Update, including the Healthy Air Act and the Maryland NOx Rule.

The Healthy Air Act

In 2007, Maryland's Healthy Air Act (HAA)[23] set emission standards requiring total emission reductions from affected EGUs[24] equivalent to a 70% reduction from state-wide 2002 levels in 2009, and 75% in 2012. The act helps to address Maryland's emissions contribution to many downwind areas like PA, CT, NJ, and NY through its ozone-season NOx tonnage caps, set under COMAR 26.11.27 (*Emission Limitations for Power Plants*)., also known as the Healthy Air Act (HAA)[25]. This regulation requires emission reductions from power plants which, when compared to a 2002 emissions baseline, reduce total NOx emissions by 70% in 2009 and 75% in 2012. The regulation applies to fossil-fuel fired electric generating units: (1) Brandon Shores Units 1 and 2; C.P. Crane Units 1 and 2; (3) Chalk Point Units 1 and 2; (4) Dickerson Units 1, 2, and 3: (5) H.A. Wagner Units 2 and 3; and (6) Morgantown Units 1 and 2. The HAA helps to address Maryland's emissions contribution to many downwind areas like PA, CT, NJ, and NY by setting ozone season NOx tonnage caps. The HAA caps were based on Best Available Control Technology (BACT) rates for the affected EGUs. Maryland's HAA state cap budget (Table 8) compares with and supports the CSAPR budgets for NOx emissions (Table 6). The table below shows the current HAA tonnage limits for the affected units, which began January 1, 2012.

[23] Md. Environment Code Ann. §§2-1001—1005

[24] Affected EGUs specifically identified in Md. Environment Code Ann. §2-1001 (and COMAR 26.11.27.02) include Brandon Shores Units 1 and 2; C.P. Crane Units 1 and 2; Chalk Point Units 1 and 2; Dickerson Units 1, 2, and 3; H.A. Wagner Units 2 and 3; and Morgantown Units 1 and 2. R. Paul Smith Units 3 and 4 were originally included conditionally, though these are now closed.

Maryland ozone season NOx emissions regulated under the Healthy Air Act (Table 8) are lower than the results of the CSAPR 2012 IPM modeling at $500/ton and $1000/ton (Table 6). Therefore, at a minimum, Maryland has historically been controlling NOx emissions from electric generating units at a cost of twice the CSAPR threshold.

Table 8: Healthy Air Act Tonnage Limits

Facility Name	Total Boilers	Generating Capacity, MWs[A]	Owner	Control Methods[B]	HAA Tonnage Limit (tons)	
					Annual	Ozone Season
Brandon Shores	Unit 1	685	Raven	LNB – OFA SCR	2,414	1,124
Brandon Shores	Unit 2	685	Raven	LNB – OFA SCR	2,519	1,195
C.P. Crane	Unit 1	190.4	Raven	LNB – OFA SNCR	686	284
C.P. Crane	Unit 2	209.4	Raven	LNB – OFA SNCR	737	317
H.A. Wagner	Unit 2	359	Raven	LNB – OFA SNCR	555	229
H.A. Wagner	Unit 3	414.7	Raven	LNB – OFA SCR	1,115	481
Chalk Point	Unit 1	659	NRG	LNB – OFA SCR	1,166	503
Chalk Point	Unit 2	659	NRG	LNG – OFA SACR	1,223	542
Dickerson	Unit 1	196	NRG	LNB – OFA SNCR	554	257
Dickerson	Unit 2	196	NRG	LNB – OFA SNCR	607	274
Dickerson	Unit 3	196	NRG	LNB – OFA SNCR	575	259
Morgantown	Unit 1	626	NRG	LNB – OFA SCR	2,094	868
Morgantown	Unit 2	626	NRG	LNB – OFA SCR	2,079	864
R. Paul Smith	Unit 3	28		Closed		
R. Paul Smith	Unit 4	88		Closed		
Total Ozone Season Tonnage Limit, All HAA Units						**7,197**

Notes:
[A] MWs = megawatts
[B] LNB - OFA = Low NOx Burner – Over Fired Air
SCR = Selective Catalytic Reduction
SNCR = Selective Non-Catalytic Reduction
SACR = Selective Auto-Catalytic Reduction

The Maryland NOx Rule

Phase I of COMAR 26.11.38 (*Control of NOx Emissions from Coal-Fired Electric Generating Units*), also known as the Maryland NOx Rule, became effective on May 1, 2015. This action

was part of a broader strategy to further reduce NOx emissions from coal-fired EGUs in the State by requiring owners and operators of affected EGUs to comply with the following measures:

- Submit a plan for approval by MDE and the EPA that demonstrates how the EGU will operate installed pollution control technology and combustion controls to minimize emissions;
- Beginning May 1, 2015, and during the entire ozone season whenever the EGU is combusting coal, operate and optimize the use of all installed pollution and combustion controls consistent with the technological limitations, manufacturers' specifications, good engineering, maintenance practices, and air pollution control practices to minimize emissions (as defined in 40 CFR §60.11(d));
- During the Ozone Season, meet a system-wide NOx emission rate of 0.15 lbs/MMBtu as a 30-day rolling average (an EGU located at an electric generating facility that is the only facility in Maryland directly or indirectly owned, operated, or controlled by the owner, operator, or controller of the facility is exempt from this obligation);
- Continue to meet the ozone season and annual NOx reduction requirements set forth in COMAR 26.11.27 (The Healthy Air Act);
- For EGUs equipped with a fluidized bed combustor, meet a NOx emission rate of 0.10 lbs/MMBtu as a 24-hour block average on an annual basis (instead of the three previous requirements); and
- For all affected EGUs, demonstrate compliance with the requirements and emission rates in the regulation in accordance with the prescribed procedures.

In order to meet the limits set by the Maryland NOx Rule, it is necessary for units to run their controls continuously. This satisfies the CSAPR Update requirement that units turn on idled existing SCRs. As shown in the table below, SCR units* in Maryland are required by the Maryland NOx Rule to run below the 0.10 lb/MMBtu rate that the EPA found to significantly and cost-effectively reduce NOx emissions.

Table 9: Required 24-Hour Block Average Unit Level NO_x Emission Rates

Affected Unit	**24-Hour Block Average NO_X Emissions Rate (lb/MMBtu)**
Brandon Shores	
Unit 1*	0.08
Unit 2* < 650 MWg ≥ 650 MWg	 0.07 0.15
C.P. Crane	
Unit 1	0.30
Unit 2	0.28
Chalk Point	
Unit 1 only*	0.07
Unit 2 only	0.33
Units 1 and 2 combined	0.20
Dickerson	
Unit 1 only	0.24

Affected Unit	24-Hour Block Average NO_X Emissions Rate (lb/MMBtu)
Unit 2 only	0.24
Unit 3 only	0.24
Two or more units combined	0.24
H.A. Wagner	
Unit 2	0.34
Unit 3*	0.07
Morgantown	
Unit 1*	0.07
Unit 2*	0.07

*SCR

Phase II of the Maryland NOx Rule, COMAR 26.11.38.04 (*Additional NOx Emission Control Requirements*), is designed to achieve further reductions by 2020 and requires the owner or operator of units that have not installed selective catalytic reduction (SCR) technology (H.A. Wagner Unit 2, C. P. Crane Units 1 and 2, Chalk Point Unit 2, and Dickerson Units 1, 2 and 3) to choose from the following:

Option 1: By June 1, 2020, install and operate an SCR control system that can meet a NOx emission rate of 0.09 lbs/MMBtu during the ozone season based on a 30-day rolling average;

Option 2: By June 1, 2020, permanently retire the unit;

Option 3: By June 1, 2020, switch fuel permanently from coal to natural gas and operate the unit on natural gas; or

Option 4: By June 1, 2020, meet a system-wide, daily NOx tonnage cap of 21 tons per day for every day of the ozone season or meet a system-wide NOx emission rate of 0.13 lbs/MMBtu as a 24-hour block average. The rate and the cap in option 4 are consistent with levels assuming SCR controls on all units. If option 4 is selected, deeper reductions starting in May 2016, 2018 and 2020 must also be achieved.

- 2016: Meet a 30-day system-wide rolling average NOx emission rate of 0.13 lbs/MMBtu during the ozone season.
- 2018: Meet a 30-day system-wide rolling average NOx emission rate of 0.11 lbs/MMBtu during the ozone season.
- 2020: Meet a 30-day system-wide rolling average NOx emission rate of 0.09 lbs/MMBtu during the ozone season.

Without option 4, the allowable 30-day system-wide rolling average NOx emission rate is 0.15 lbs/MMBtu during the ozone season. Option 4 also includes provisions to ensure that the reliability of the electrical system is maintained.

Additionally, COMAR 26.11.38.04E(1)(b) specifies that, beginning June 1, 2020, if the unit or units included in a system, as that system existed on May 1, 2015, is no longer directly or indirectly owned, operated, or controlled by the owner, operator, or controller of the system:

- The remaining units in the system shall meet a NOx emission rate of 0.13 lbs/MMBtu as determined on a 24-hour system block average and;
- Not later than May 1, 2020, the owner or operator of an affected electric generating unit shall not exceed a NOx 30-day system wide rolling average emission rate of 0.09 lbs/MMBtu during the ozone season.

Beginning June 1, 2020, if the unit or units included in a system, as that system existed on May 1, 2015, is no longer directly or indirectly owned, operated, or controlled by the owner, operator, or controller of the system may choose to: (a) meet the requirements of options 1-3 of this regulation or (b) meet a NOx emission rate of 0.13 lbs/MMBtu as determined on a 24-hour system wide block average and the requirements of §C(3) of this regulation.

Maryland projects the implementation of these new COMAR 26.11.38.04 requirements will (in combination with the Phase I requirements) result in an ozone season NOx reduction between 2,507 and 2,627 tons depending on the option chosen.

NRG, operator of the Chalk Point, Dickerson, and Morgantown generating stations, chose option 4 and the coal-fired units at these facilities were required to meet a 30-day rolling average NOx emission rate of 0.11 starting in May 1, 2018.

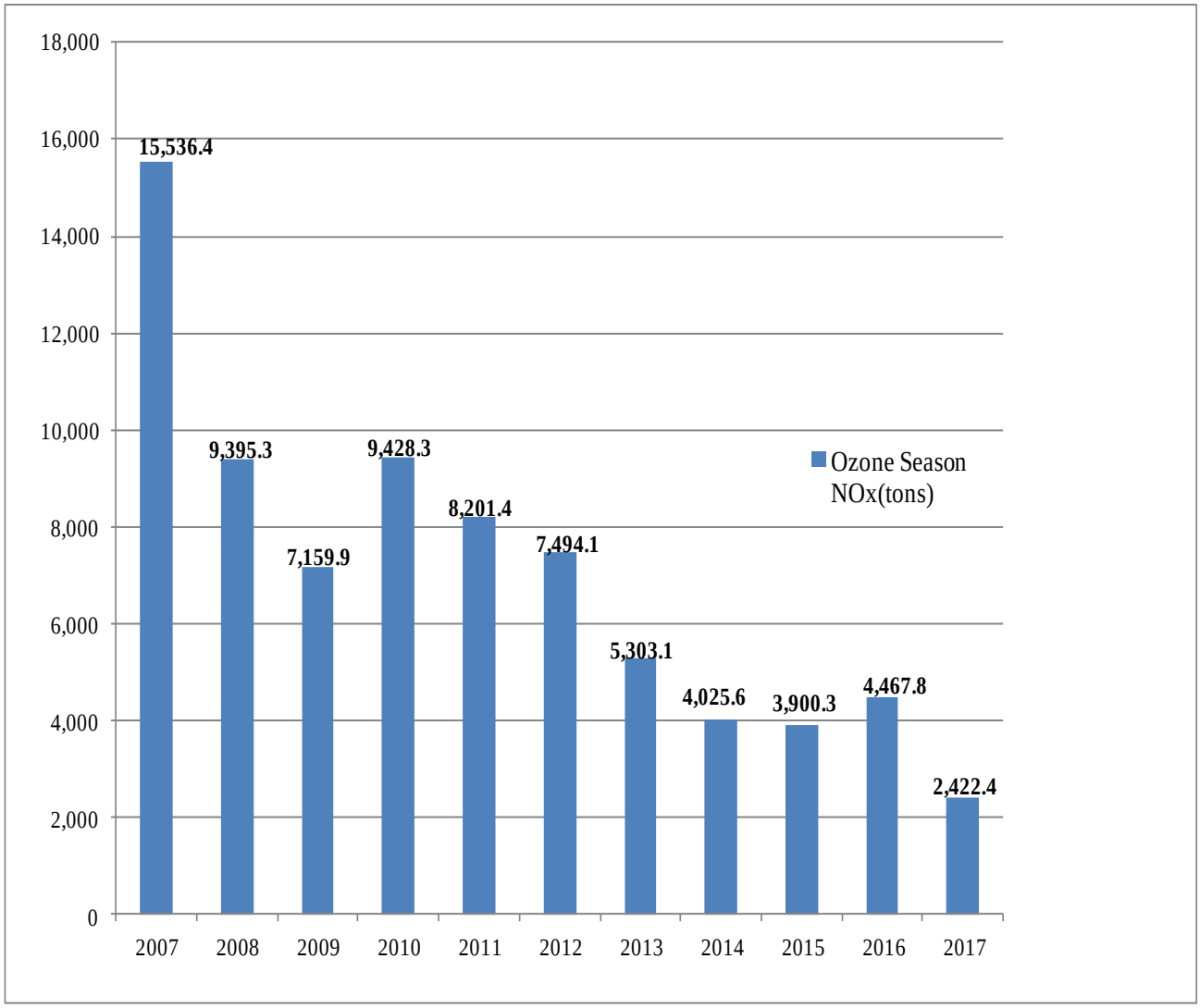
Brandon Shores and Herbert A. Wagner generating stations, both operated by Raven Power, are subject to requirements of COMAR 26.11.38.04E(1)(b). The coal-fired units at these facilities will meet a NOx emission rate of 0.13 lbs/MMBtu as determined on a 24-hour system block average June 1, 2020 and will also meet a 30-day system wide rolling average NOx emission rate of 0.09 lbs/MMBtu during the ozone season no later than May 1, 2020.

C.P. Crane, now operating under C.P. Crane, LLC after a sale in 2016, is required to choose from Options 1 through 3 for the units at the facility.

EGU NOx Emissions Trends in Maryland

The figure below demonstrates that Maryland has achieved significant ozone season EGU NOx emissions reductions in the past decade, which can be attributed to regulations like the HAA and the Maryland NOx Rule. The total reported EGU NOx emissions for the 2017 ozone season, 2,422.2 tons, is below the 3,828 ton CSAPR Update budget.

Figure 1: Maryland Ozone Season EGU NOx for CAMD Sources 2007-2017[26]



[26] EPA Air Markets Program Data. https://ampd.epa.gov/ampd/

ADDITIONAL EMISSONS-REDUCTION MEASURES

Maryland has regulated emissions from its mobile sector by implementing an enhanced vehicle emissions inspection and maintenance program (COMAR 11.14.08); Stage II gasoline pump controls (COMAR 26.11.24); Tier I and Tier II vehicle emissions standards (COMAR 26.11.20), including NLEV controls (COMAR 26.11.20.02), reformulated gasoline in on-road vehicles (COMAR 26.11.20.03), and heavy duty diesel engine controls (COMAR 26.11.20.06);the Clean Car Act of 2007 (CAL LEV) (COMAR 26.11.34); and evaporative test procedures (COMAR 26.11.22).

By being a Cal LEV state, Maryland has the toughest vehicle emission standards allowed by law. The Maryland Clean Car Program was adopted in 2007, after passage of the enabling legislation, as a strategy to reduce ozone-forming emissions and decrease the carbon footprint from the transportation sector. The program, which has stricter emission standards than the current federal standards, aims to improve air quality by reducing the emissions of NO_x and volatile organic compounds (VOCs) emanating from cars and light-duty trucks on a daily basis. Beginning with vehicle model year 2011, all cars and light-duty trucks sold in Maryland are required to meet these newer, more stringent standards which are expected to reduce VOCs and NOx emissions by approximately 3.55 and 5.18 *more* tons/day respectively by 2025, as compared to the Federal Tier II standards.

The State has also pursued significant regulation of industrial sources, including Distributed Generation (COMAR 26.11.26), Portland Cement Manufacturing Plants (COMAR 26.11.30.01, .02, .03, .07, and .08), Kraft Pulp Mills (COMAR 26.11.14.01; 26.11.14.02; 26.11.14.07 & 26.11.40), Yeast Manufacturing Plants (COMAR 26.11.19.17.17), Commercial Bakeries (COMAR 26.11.19.21.21), Iron and Steel Production (COMAR 26.11.10.01, .06, .07), Incinerators (COMAR 26.11.08.01, 26.11.08.02, 26.11.08.08-2, 26.11.08.07, 26.11.08.08), and Internal Combustion Engines at Natural Gas Pipeline Compression Stations (COMAR 26.11.29.02C(2)).

Maryland has implemented a substantial number of VOC rules targeted at printers, consumer products, portable fuel containers, and industrial coating, adhesive, and sealant operations. Pursuant to the requirements of 42 U.S.C. §7511a(b)(2), Maryland has implemented RACT controls for all source categories covered by a Control Technique Guideline (CTG) issued by EPA, and for all other "major" stationary sources emitting 25 tons per year or more of VOC or NOx (see Appendices for a listing of NOx and VOC regulations).[27] Many of these Maryland-specific regulations are presented in the tables below.

[27] Maryland RACT controls have been promulgated at COMAR 26.11.09.08 (Control of NOx emissions for Major Stationary Sources), COMAR 26.11.11 (Control of Petroleum Products Installations, Including Asphalt Paving and Asphalt Concrete Plants), COMAR 26.11.13 (Control of Gasoline and Volatile Organic Compound Storage and Handling), COMAR 26.11.19 (Volatile Organic Compounds from Specific Processes), COMAR 26.11.32 (Control of Emissions of Volatile Organic Compounds from Consumer Products), COMAR 26.11.33 (Architectural Coatings), and COMAR 26.11.35 (Volatile Organic Compounds from Adhesives and Sealants).

Table 10: VOC RACT Regulations

VOC STATE REGULATIONS	
COMAR Reference	**COMAR Title**
COMAR 26.11.06.06	Control of Volatile Organic Compound Emissions
COMAR 26.11.10.01, .06, .07	Control of Iron and Steel Production Installations
COMAR 26.11.11	Control of Petroleum Products Installations, Including Asphalt Paving and Asphalt Concrete Plants
COMAR 26.11.13.01, .03, .04, .05, and .08	Control of Gasoline and Volatile Organic Compound Storage and Handling
COMAR 26.11.14.01 and .06	Control of Emissions from Kraft Pulp Mills
COMAR 26.11.19	Volatile Organic Compounds from Specific Processes
COMAR 26.11.24	Stage II Vapor Recovery at Gasoline Dispensing Facilities

Table 11: NOx RACT Regulations

NOX STATE REGULATIONS	
COMAR Reference	**COMAR Title**
COMAR 26.11.09.08	Control of NO_x Emissions for Major Stationary Sources
COMAR 26.11.14.01; 26.11.14.02; 26.11.14.07 & 26.11.40	Control of NO_x Emissions from Kraft Pulp Mills
COMAR 26.11.29.02C(2)	Emission Reduction Requirements for Stationary Internal Combustion Engines at Natural Gas Pipeline Compression Stations
COMAR 26.11.30.01, .02, .03, .07, and .08	Emission Reduction Requirements for Portland Cement Manufacturing Plants

"On the Books/On the Way" Measures

<u>Area Source Controls</u>

- Federal Rules Affecting Area Sources
  - *Residential Wood Combustion* – This measure controls emissions from residential wood burning devices such as fireplaces and woodstoves.
- Federal MACT Rules
  - *Landfills MACT Standard* – These guidelines require landfills to install gas collection systems or to demonstrate that the landfill emits less than 50 metric tons/year of methane.

- *Reciprocating Engines RICE Standard* – These rules apply to any piece of equipment driven by a stationary reciprocating internal combustion engine located at a major source or area source of hazardous air pollutants *Ozone Transport Commission (OTC) 20*01 Model Rules
    - *ICI Boilers* – This rule establishes NOx emissions thresholds for industrial/commercial/institutional boilers. Emissions rate limits vary based upon the size of the boiler and how they are fired.
- OTC 2006
    - *Adhesive**s**/Sealants* – The purpose of this rule is to reduce VOC emissions from adhesives, sealants, and primers. This is achieved through sale and manufacture restrictions as well as restrictions that apply to commercial commercial/industrial applications.
    - *Architectural and Industrial Maintenance Coatings* – This rule controls VOC emissions from architectural coatings by placing a limit on any coating that is manufactured, blended, repackaged for sale, supplied, or sold in the jurisdiction of the state or local air pollution control agency.
    - *Asphalt Paving* – This rule limits the use of cutback asphalt during the ozone season and controls emissions from emulsified asphalt by providing allowable VOC content limits for various applications.
    - *Consumer Products* – This rule applies to any person who sells, supplies, offers for sale, or manufactures consumer products in an OTC state in order to controls VOCs.
    - *Mobile Equipment Repair and Refinishing* - This rule limits the concentration of solvents in auto refinishing coatings in order to reduce VOC emissions.
    - *Portable Fuel Containers* – This control measure establishes design and manufacturing specifications for portable fuel containers (PFCs) based on the California Air Resources Board (CARB) rules in order to control VOCs.
    - *Solvent Cleaning* – This rule applies emissions limits to all cold cleaning machines that process metal parts and contain more than one liter of VOC.
    - *ICI Boilers* – This rule establishes NOx emissions thresholds for industrial/commercial/institutional boilers. Emissions rate limits vary based upon the size of the boiler and how they are fired. The 2006 guidelines have undergone revision based on a more refined analysis.
    - *New, small Natural Gas-fired Boilers* – The provisions of this model rule limit NOx emissions from new natural gas-fired ICI and residential boilers, steam generators, and process heaters greater than 75,000 BTUs and less than 5.0 million BTUs.
    - *MANE-VU Low Sulfur Fuel Oil Strategy* – This strategy calls for the reduction of sulfur content of distillate oil to 0.05% sulfur by weight by no later than 2014, of #4 residual oil to 0.25-0.5% sulfur by weight no later than 2018, and of #6 residual oil no greater than 0.5% sulfur by weight by no later than 2018, and to reduce the sulfur content of distillate oil further to 15 ppm by 2018.

Non-EGU Point Source Controls

- Federal Rules Affecting Non-EGU Point Sources
    - *MACT Standards* – These standards set NOx emissions limits for non-EGU point sources. The standards call for the maximum degree of emissions reductions that are determined to be achievable.
    - *ICI Boilers* – This rule sets standards for the control of hazardous air pollutants from new and existing industrial, commercial, and institutional boilers and process heaters.
- OTC 2006 Model Rules
    - *Asphalt Plants* – This rule calls for NOx emission reductions through installation of low NOx burners and flue gas recirculation.
    - *Large Storage Tanks* – This model rule addresses high vapor pressure VOCs, such as gasoline, stored in large aboveground storage tanks. The OTC proposes five control measures in this rule: deck fittings, domes, roof landing controls, cleaning and degreasing, and inspection and maintenance.
    - *Cement Plants* – This rule requires existing cement kilns to meet a NOx emission rate of 3.88 lbs/ton clinker for a wet kiln, 3.44 lbs/ton clinker for a long dry kiln, 2.36 lbs/ton clinker for a pre-heater kiln, and 1.52 lbs/ton clinker for a pre-calciner kiln.
    - *Glass and Fiberglass Furnaces* – This rule establishes NOx emissions guidelines for glass furnaces. The guidelines vary based on the type of glass and the average time of the emissions rate.
    - *ICI Boilers* – This rule establishes NOx emissions thresholds for industrial/commercial/institutional boilers. Emissions rate limits vary based upon the size of the boiler and how they are fired. The 2006 guidelines have undergone revision based on a more refined analysis.

Mobile Source Controls

- *CALEV Programs* – These programs are "fleet average" programs, establishing fleet emission averages that decline with each passing year. Manufacturers meet this standard by selling a combination of vehicles that are certified to meet increasingly more stringent emissions standards.
- *Tier 3* – The program considers the vehicle and its fuel as an integrated system, setting new vehicle emissions standards and a new gasoline sulfur standard beginning in 2017.
- *Federal fuel economy (CAFE) standards* – These standards require vehicle manufacturers to comply with the federal gas mileage, or fuel economy, standards. CAFE values are obtained using the city and highway fuel economy test results and a weighted average of vehicle sales.
- *Heavy Duty Diesel Standards* – This rule ensures that heavy-duty trucks and buses run cleaner, by requiring that the sulfur concentration in highway diesel fuel must be no higher than 15 parts per million to enable to the use of advanced pollution controls.
- *Marine Diesel Standards* – These standards put stringent standards on exhaust emissions for large marine diesel engines. Beginning in 2011, Category 3 marine diesel engines were required to use current engine technology more efficiently with the use of engine timing, engine cooling, and advanced computer controls.

- *Emissions Control Area (ECA)* – This program applies stringent marine emissions standards and fuel sulfur limits to ships that operate in specially designated areas. The quality of the fuel that complies with the ECA standard changes over time.

Additional Maryland Voluntary/Innovative Control Measures

Maryland has also implemented the following programs that are listed as voluntary and innovative measures in recent attainment SIPs. MDE does not rely on any emission reductions projected as a result of implementation of these programs to demonstrate attainment, since actual air quality benefits are uncertain and hard to quantify. Nevertheless, these strategies do assist in the overall clean air goals in Maryland.

- *Regional Forest Canopy Program, Conservation, Restoration, and Expansion* – expanded tree canopy cover is an innovative voluntary measure proposed to improve the air quality in the Baltimore region
- *Clean Air Teleworking Initiative* – encourages teleworking on bad air days
- *High Electricity Demand Day (HEDD) Initiative* – On March 2, 2007, the OTC states and the District of Columbia agreed to a Memorandum of Understanding (MOU) committing to reductions from the HEDD source sector
- Transportation Measures:
    - Clean and efficient strategies such as diesel retrofits
    - Using CHART to improve traffic flow and reduce congestion caused by accidents
    - Truck Stop Electrification (TSE) to reduce diesel truck idling emissions
    - Bicycle/pedestrian enhancements, such as new and improved bicycle and pedestrian facilities, and programs to encourage pedestrians
    - MARC Station parking enhancements, refurbishment of MARC rolling stock, and locomotive retrofits
    - MTA and LOTS bus purchases
    - Bus service enhancements such as automatic vehicle locators (AVL), and next bus arrivals posted on electronic signs at stops and on the internet
    - Smart Card implementation for easier travel between transit modes
    - Port of Baltimore initiatives, such as crane retrofits, clean diesel in port vehicles, and hybrid port fleet vehicles
    - Clean Commute Month, including Bike to Work Day events
    - Electronic Toll Collection
    - Traffic Signal System Retiming
    - Ride Share and Maryland Commuter Tax Credit
    - Transit Oriented Development

Regional Greenhouse Gas Initiative (RGGI)

RGGI v CPP

Neither repeal nor implementation of the Clean Power Plan (CPP) will directly affect Maryland's EGU emissions controls, since Maryland is a participant in the Regional Greenhouse Gas

Initiative (RGGI)[28]. Under RGGI, Maryland *already* enforces a CO_2 cap which is structured to meet the CPP's requirements for a mass-based trading program covering new sources. Furthermore, the RGGI cap is much more stringent than the mass-based CPP goals, and so will achieve greater reductions in Maryland and regionally than the CPP would. Under the recently proposed RGGI amendments, Maryland's 2031 CO_2 budget will be approximately 12.2 million short tons, compared to its CPP goal of 14.5 million short tons[29]. Regionally, the nine RGGI states' combined budgets under RGGI will be 54.7 million short tons in 2031, compared to the states' aggregated CPP goal of 80.1 million short tons.

NOx Reductions from RGGI

Though RGGI is a CO_2 cap-and-invest program, the reduction activities necessary to meet its cap will significantly reduce NOx emissions. In the RGGI states' IPM modeling, which considered the effect of the proposed RGGI amendments and included the CSAPR Update Rule, Maryland EGUs' coal consumption decreased by 39% from 2017 through 2031.

CONCLUSION

This SIP revision addresses Maryland's good neighbor obligations under CAA §110(a)(2)(D)(i)(I), evaluating whether emissions from sources in Maryland contribute significantly to nonattainment in, or interfere with maintenance by, any other state with respect to the 2008 ozone NAAQS.

Maryland achieved significant reductions with the implementation of the Healthy Air Act, which controls coal-fired EGUs at levels below the emissions budgets set by CSAPR. Phase I of the Maryland NOx Rule reduced emissions further with new, more stringent control measures in 2015. Phase II of this regulation, effective in 2020, will build upon the Phase I controls, achieving even deeper cuts in EGU NOx emissions during ozone season.

Maryland has also adopted many additional emissions-reduction regulations for mobile, non-EGU, and area sources of NOx and VOC emissions. Maryland's participation in the Regional Greenhouse Gas Initiative will also provide NOx reductions. As demonstrated in this SIP revision, Maryland EGUs are currently emitting NOx emissions well below the 2017 season emissions budget established in the CSAPR Update.

The emissions reductions which have already been achieved, along with the future reductions expected from implemented regulations, demonstrate that Maryland has provided a full remedy to the good neighbor provision of the CAA, and will not cause or contribute to a "linked" downwind state's nonattainment, or interfere with its maintenance of the 2008 Ozone NAAQS. Furthermore, EPA's modeling for the October 2017 Supplemental Information Memo found that there are no monitoring sites outside of California that are projected to have nonattainment or maintenance problems with respect to the 2008 ozone NAAQS in 2023.

Based on the analyses described in this SIP revision, Maryland concludes that the State complies, and will remain in compliance with, the good neighbor provisions of CAA §110(a)(2)(D)(i)(I) for the 2008 ozone NAAQS.

[28] The CPP could indirectly affect Maryland's EGU emissions because the presence or absence of emissions controls in nearby states could influence Maryland's balance between in-state generation and imported power .

[29] final goal on an annual basis, with new source complement

WEIGHT OF EVIDENCE

Background/Summary

MDE and UMD performed numerous photochemical modeling scenarios to evaluate controls on electrical utilities and other sources of pollution and to demonstrate that regional NO_X and VOC control programs reduce ambient ozone concentrations. A complete report on the modeling scenarios is presented in Appendix C and D.

MDE's primary conclusions based on the results of the photochemical modeling and WOE analyses are:

1) A partial state remedy for SIP transport obligations under the Good Neighbor CAA provisions must include the optimization of controls at coal-fired electric generating facilities.
2) The optimization of controls at coal-fired electric generating stations is a cost effective control strategy for the reduction of nitrogen oxides emissions and the subsequent reductions in ozone concentrations.
3) The full implementation of OTC model rules across the OTR provides additional ozone benefits and should be addressed when considering a full remedy.

The following subsections of this document describe the procedures, inputs and results of the regional photochemical grid modeling sensitivity runs.

Objective

The objective of the photochemical modeling study is to enable the MDE to analyze the efficacy of various control strategies, and to demonstrate that the measures adopted fulfill Maryland's requirements under the Good Neighbor SIP provisions of the Clean Air Act.

The photochemical modeling was performed as part of an initiative under the auspices of the Departments of Atmospheric and Oceanic Science and Chemical and Biomolecular Engineering of the University of Maryland College Park (UMCP) and the Air and Radiation Administration (ARA) of the Maryland Department of the Environment (MDE).

A short description of the will result in attainment of the 8-hour ozone standard by the June 15, 2010 deadline for moderate nonattainment areas. The modeling exercise predicts future year 2009 and 2012 air quality conditions based on the worst observed ozone episodes in the base year 2002 and demonstrates the effectiveness of new control measures in reducing air pollution.

Modeling Platform and Configuration

The following discussion provides an overview of the air quality, meteorological, and emission modeling systems used for the analysis, as well as a description of model configuration and quality assurance procedures.

Episode Selection

Since it would be impractical to model every violation day, EPA has traditionally recommended targeting a select group of episode days for ozone attainment demonstrations. Such episode days should be (1) meteorologically representative of typical high ozone exceedance days in the domain, and (2) so severe that any control strategies predicted to attain the ozone NAAQS for that episode day would also result in attainment for all other exceedance days.

While EPA's suggested approach is perhaps feasible for isolated urban areas, such an approach is impractical in this case given the spatial extent of the regional ozone problem in the Northeast and the resulting size of the modeling domain. Also, selection of episodes from different years would require the generation of multiple meteorological fields and emissions databases, which would be an extremely difficult proposition given the modeling domain.

The 2011 ozone season had a significant number of exceedance days spread over numerous ozone episodes.

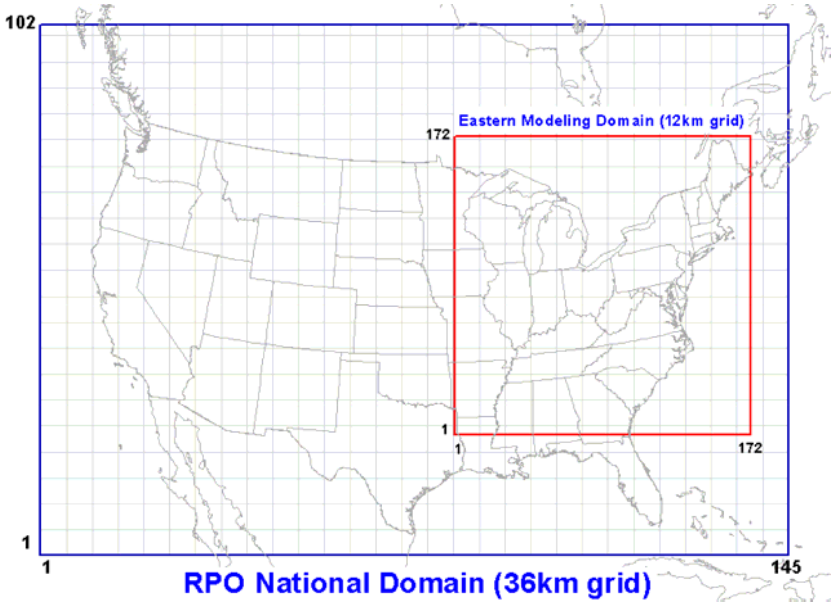
As a result, the MDE decided to investigate the appropriateness of modeling the entire 5-month ozone season. Results of that investigation demonstrate that 2011 episode days are (1) meteorologically representative of typical high ozone exceedance days in the domain, and (2) so severe that control strategies predicted to attain the ozone NAAQS for those episode days would likely also result in attainment for all other exceedance days. The total number of days examined for the complete ozone season far exceeds EPA recommendations and provides for better assessment of the simulated pollutant fields.

Modeling Domain

In defining the modeling domain, the following parameters should all be considered: location of local urban areas; the downwind extent of elevated ozone levels; the location of large emission sources; the availability of meteorological and air quality data; and available computer resources. In addition to the nonattainment areas of concern, the modeling domain should encompass enough of the surrounding area such that major upwind sources fall within the domain and emissions produced in the nonattainment areas remain within the domain throughout the day.

The areal extent of the OTR modeling domain (see Figure 8.2.2.1) is identical to the national grid adopted by the regional haze Regional Planning Organizations (RPOs), with a more refined "eastern modeling domain" focused on the eastern US and southeastern Canada. The placement of the eastern modeling domain was selected such that the northeastern areas of Maine are included. Based upon the existing computer resources, the southern and western boundaries of the imbedded region were limited to the area shown in Figure 8.2.2.1.

Figure 2: Weight of Evidence Modeling Domain



Horizontal Grid Size

As shown in Figure 2, the larger RPO national domain utilized a coarse grid with a 36-km horizontal grid resolution. The imbedded eastern modeling domain used a grid resolution of 12 km, resulting in 172 grids in both the east-west and north-south directions. More detailed descriptions regarding grid configurations are provided in Appendix 8C.

Vertical Resolution

The vertical structure of the air quality model is primarily defined by the vertical grid used in the meteorological modeling, which used a terrain-following coordinate system defined by pressure to create a total of 29 layers. The layer-averaging scheme adopted for the air quality modeling is designed to reduce the computational cost of the simulations, resulting in incorporation of 22 layers in the vertical, of which the lower 16 layers (approximately 3 km) coincide with those of the meteorological model. Layer averaging has a relatively minor effect on the model performance metrics when compared to ambient monitoring data. Appendix 8C contains the vertical layer definitions for the meteorological and air quality modeling domains.

Initial and Boundary Conditions

The objective of a photochemical grid model is to estimate the air quality given a set of meteorological and emissions conditions. When initializing a modeling simulation, the exact concentration fields are unknown in every grid cell for the start time. Therefore, photochemical grid models are typically started with clean conditions within the domain and allowed to stabilize before the period of interest is simulated. In practice this is accomplished by starting the model several days prior to the period of interest. For this application, the air quality modeling for 2002 began May 1, with the first 15 days assumed to be ramp-up days not used for performance evaluation or prediction purposes.

The winds move pollutants into, out of, and within the domain. The model handles the movement of pollutants within the domain and out of the domain. An estimate of the quantity of pollutants moving into the domain is needed. These are called boundary conditions. To estimate the boundary conditions for the modeling study, three-hourly boundary conditions for the outer 36-km domain were derived from an annual model run performed by researchers at Harvard University using the GEOS-Chem global chemistry transport model. The influence of boundary conditions was minimized by the 15-day ramp-up period, which is sufficient to establish pollutant levels that are encountered in the beginning of the ozone episode.

Meteorological Model Selection and Configuration

The Pennsylvania State University/National Center for Atmospheric Research (PSU/NCAR) Mesoscale Meteorological Model (MM5) was selected to produce meteorological data fields for the modeling analysis. MM5 is a non-hydrostatic, prognostic meteorological model routinely used for urban-scale and regional-scale photochemical regulatory modeling studies. Based on model validation and sensitivity testing, the MM5 configurations provided in Appendix 8D were selected. Results of the NYSDEC's detailed performance evaluation of the MM5 modeling used in conjunction with the OTC platform are provided in Appendices 8E and 8F.

Emissions Inventory and Model Selection and Configuration

MARAMA Alpha Version 2 emissions inventories formed the basis for the development of various screening attainment scenarios. The v2 emissions are an update to the v1 emissions, which used the EPA provided NEI2011v2 inventories as a basis. Output from the updated Biogenic Emission Inventory System (BEIS) model was made available in early 2016. The updated biogenic emissions from BEIS v3.61 have been included in some of the more recent CMAQ simulations.

The ERTAC EGU Forecast Tool was used to grow base year hourly EGU air emissions inventories into future projection years hourly EGU air emissions inventories for air quality impact assessment on both an annual and episodic peak basis. The tool uses base year hourly USEPA Clean Air Markets Division (CAMD) data, fuel specific growth rates, and other information to estimate future emissions. To explore the impacts of NOx from EGUs on 2018 Maryland ozone concentrations, a series of runs were performed where NOx emissions rates from coal-fired power plants were adjusted.

Air Quality Model Selection and Configuration

EPA's Models-3/Community Multi-scale Air Quality (CMAQ) modeling system was selected for the demonstration primarily because it is a "one-atmosphere" photochemical grid model capable of addressing ozone at regional scale. EPA considers CMAQ to be one of the preferred models for regulatory modeling applications, citing the model in its ozone modeling guidance.

CMAQ Platforms

1. "Latest Chemistry" CMAQ – This platform uses the latest EPA/ORD chemistry algorithm (CB6R2) not yet available for CMAQ. This new chemistry is consistent with what has been built into CAMX. The University of Maryland has tested a new chemistry algorithm for CMAQ based on the discover AQ/MA field study. When this algorithm has been run next to CAMX, it has produced similar results. There have been fewer modeling runs with this platform, but they have built upon the results from the CMAQ base runs.

2. "Best Science" CMAQ – This platform is designed to make the model work in a way that best fits the data and research on how ozone is actually created and how ozone transport works. "Best Science" improves chemistry and also adjusts model inputs so that model performance is more accurate aloft, consistent with discover AQ/MA. Key assumptions of this platform include the most recent chemistry from the University of Maryland, the latest biogenic inventory, and a 50% reduction in mobile NOx. This platform allows Maryland to better understand transport and to fix what appear to be underestimated benefits from EGU strategies in almost all other current modeling platforms.

Analysis of Scenarios 4A, 4B, 4D, 4OTC3, 4MD1

MDE chose five modeling scenarios for further analysis. The scenarios were designed to illustrate the ozone reduction potential and effectiveness of specific control programs.

Control Strategies and Scenarios 4A, 4B, 4D, 4OTC3, 4MD1

In order to understand the basis of the modeling scenarios, an understanding of the control strategies that were applied in the different model runs is necessary. Table 12 below highlights the control programs MDE used in the modeling scenarios.

Table 12: Maryland Modeling Control Measures

Maryland Modeling Control Measures	Description
"On the Books"/"On the Way"	Over 40 control programs; generally older federal programs that continue to generate deeper reductions as they phase in or as fleets turn over
Optimized EGUs	All coal fired units in selected eastern states running existing controls in the summertime consistent with NO_X emissions rates measured in earlier years, applies to PA, VA, NC, TN, KY, WV, OH, IN, IL, MI, CT, NJ, NY & DE

Tier 3	Federal program that lowers the sulfur content in gasoline to 10 ppm. Lowering the sulfur content of gasoline allows pollution control equipment on cars and trucks to operate more effectively and can significantly reduce oxides of nitrogen (NOx) and other emissions from gasoline-powered vehicles.
New OTC and MD Measures	Nine new Ozone Transport Commission (OTC) model reduction programs for mobile sources and other sources implemented in just the OTC states as well as additional EGU and mobile source reductions just in MD. These measures include: Aftermarket Catalysts, On-Road Idling, Nonroad Idling, HD I&M, Enhanced SMARTWAY, Ultra Low NO_X Burners, Consumer Products, AIM, and Auto Coatings.

Table 13 provides an estimate of the emission reductions that each control measure provided.

Table 13: Maryland Modeling Control Measures

Maryland Modeling Control Measures	Regional Reductions (tons per year)	Regional Reductions (tons/day)
"On the Books"/"On the Way"	Base Case	Base Case
Optimized EGUs	60,577 (NOx)	165 (NOx)
Tier 3	Reflected in MOVES data output	
MD Measures	1,876 (NOx)	5 (NOx)

New OTC Model Control Measures	Regional Reductions (tons per year)	Regional Reductions (tons per day)
Aftermarket Catalysts	14,983 (NOx) 3,390 (VOC)	41 (NOx) 9 (VOC)
On-Road Idling	19,716 (NOx) 4,067 (VOC)	54 (NOx) 11 (VOC)
Nonroad Idling	16,892 (NOx) 2,460 (VOC)	46 (NOx) 7 (VOC)
Heavy Duty Inspection & Maintenance	9,326 (NOx)	25 (NOx)
Enhanced SMARTWAY	2.5%	
Ultra Low NOx Burners	3,669 (NOx)	10 (NOx)
Consumer Products	9,729 (VOC)	26 (VOC)
Architectural Industrial Maintenance (AIM)	25,506 (VOC)	72 (VOC)
Auto Coatings	7,711 (VOC)	21 (VOC)

Table 14 below provides a description of each modeling scenario run and a comment on the purpose of the modeling run.

Table 14: Modeling Scenario Description and Purpose

RUN	DESCRIPTION	COMMENT
4B	EGU sector run at the worst rate recorded in CAMD after the installation of the control device	Truly represents a "worst case". Mixes and matches worst rates for the controlled unit from different years
4A	2017/2018 Future Base Case With Tier 3 – OTB/OTW OTC controls – Optimized EGUs	Base Case
4D	4A with SCR-like reductions at all remaining uncontrolled coal-fired EGUs	Designed to get the maximum additional benefit associated with SCRs on all remaining uncontrolled coal-fired units
4OTC3	4A with all OTC measures added in the OTC states	Designed to look at total incremental benefit from OTC VOC measures.
4MD1	4A with MD new NOx regulations Phase 1 Optimized EGUs	Designed to identify the additional benefit from Phase 1 of the MD NOx regulation. Optimized SCRs at all MD coal-fired units.

Table 15 below provides a listing of the specific control scenarios that were applied to each modeling scenario run.

Table 15: Modeling Scenarios and the Corresponding Applied Control Strategies

Run	CONTROL MEASURES					
	Optimized EGUs	OTB/OTW	Tier 3	SCR applied to Uncontrolled Units	MD New NOx Regulation	OTC Measures
4B		X	X			
4A	X	X	X			
4D	X	X	X	X		
4OTC3	X	X	X			X
4MD1	X	X	X	X	X	

Results of the Modeling Simulations

The modeling scenarios show that the Maryland monitors achieve the largest reductions in ozone concentration when large regional ozone precursor reduction programs are enacted

The largest reduction in ozone concentration comes from the optimization of post-combustion controls at coal-fired electric generating units.

The best modeling results at the Maryland monitors are produced when a combination of regional and local control measures are enacted such as a combination of EGU optimization and on-road mobile source control programs.

Table 16: Modeling Scenarios and the Corresponding Design Values

			MODELING SCENARIO				
Site	**DV 2011**	**DV 2018**	**4B**	**4A**	**4D**	**4OTC3**	**4MD1**
Davidsonville	83	72.3	73.2	71.7	71.3	71.7	70.2
Padonia	79	70.8	71.9	69.9	69.3	69.9	68.7
Essex	80.7	74.3	75	73.8	73.5	73.7	72.7
Calvert	79.7	72.3	73.1	71.6	71.3	71.6	70.2
South Carroll	76.3	68.3	69.9	67.1	66.4	67.1	66.6
Fair Hill	83	74.6	75.7	73.5	73	73.5	72.4
S.Maryland	79	70.4	71.6	69.5	69	69.6	68.5
Blackwater	75	67.3	68.2	66.7	66.3	66.7	66.1
Frederick Airport	76.3	68.1	69.9	66.7	65.9	66.7	66.2
Piney Run	72	61.7	63.6	60.2	57.3	60.2	60.2
Edgewood	90	82.1	82.9	81.5	81.2	81.5	80.1
Aldino	79.3	70.7	71.6	69.9	69.5	69.9	68.4
Millington	78.7	70.5	71.5	69.6	69.1	69.6	68.4
Rockville	75.7	66.5	67.6	65.7	65.2	65.7	64.7
HU-Beltsville	79	68.4	69.4	67.7	67.3	67.8	66.5
PG Equest.	82.3	71.8	72.8	71.1	70.7	71.1	69.8
Beltsville	80	69.6	70.4	69	68.5	68.9	67.5
Hagerstown	72.7	64.3	65.8	63.2	62.3	63.2	62.8
Furley	73.7	67.5	68.2	67	66.8	67	66.1

4B to 4A	Shows what optimization does not including MD
4A to 4D	Shows what adding SCRs to Uncontrolled units does
4A to 4OTC3	Shows what adding OTC Measures does
4D to 4MD1	Shows what adding MD NOx reg will do

Conclusions to the Modeling Analysis

1) Large regional ozone precursor reduction programs are essential for areas to attain and maintain the standard.
2) A partial state remedy for SIP transport obligations under the Good Neighbor CAA provisions must include the optimization of controls at coal-fired electric generating facilities.
3) The optimization of controls at coal-fired electric generating stations is a cost effective control strategy for the reduction of nitrogen oxides emissions and the subsequent reductions in ozone concentrations.
4) The optimization of controls must establish enforceable permit limits for NO_X at each coal-fired electric generating unit.
5) The full implementation of OTC model rules across the OTR provides additional ozone benefits and should be addressed when considering a full remedy.

APPENDICES

Appendix A: Maryland NOx RACT Regulations under the 8-Hour Ozone NAAQS

Source Category	Basis for RACT Control	Code of Maryland Regulations (COMAR) Citation	Summary of Applicable RACT Standards	EPA Latest SIP Approval or MDE Latest SIP Revision[30]	State Effective Date	Requirements at least as stringent as RACT level for the 2008 Ozone NAAQS?
Fuel-Burning Equipment Located at Major Sources – General Requirements and Conditions	1. Summary of NO_x Control Technologies and their Extent of Application, USEPA February 1992; 2. State Implementation Plans; General Preamble for the Implementation of Title I of the Clean Air Act Amendments of 1990; 3. USEPA Memorandum Subject: De Minimis Values for NO_x RACT, from G.T. Helms, Ozone Policy and Strategies Group, dated 1/1/1995; and 4. Alternative Control Techniques (ACT) Document, NO_x Emissions from Industrial/Commercial/Institutional (ICI) Boilers (EPA-453/R-94-022).	26.11.09.08A&B MDE confirms that there are no additional sources at this time seeking alternative standards and that MDE continues to rely on any alternative standards that have been previously approved into the SIP.	NOx RACT standards apply to tangentially or wall-fired fuel-burning units, based on fuel: Gas only- 0.20 pounds of NO_x per Million Btu per hour (lb/MMBTU) Gas/Oil: 0.25 lb/MMBTU Coal (dry bottom): 0.38 lb/MMBTU/hr Coal (wet bottom): 1.0 lb/MMBTU/hr	3/28/2018, 83 FR 13192	11/24/2003	Yes. This provision fully implements NOx RACT controls over the targeted sources. It was approved by EPA as RACT under the 1997 ozone standard. After EPA's approval there has been no significant change in RACT control technology for the covered sources.

[30] Because SIP 15-04 was the last amend a Section of Regulation .08, the overall COMAR 26.11.09.08 Control of NOx Emissions from Major Sources approval date matches the approval of SIP 15-04

Fuel-Burning Equipment with a Rated Heat Input Capacity of 250 MMBtu/hr or Greater	1. Summary of NO_x Control Technologies and their Extent of Application, USEPA February 1992; 2. State Implementation Plans; General Preamble for the Implementation of Title I of the Clean Air Act Amendments of 1990; 3. USEPA Memorandum Subject: De Minimis Values for NO_x RACT, from G.T. Helms, Ozone Policy and Strategies Group, dated 1/1/1995; and 4. Alternative Control Techniques (ACT) Document, NO_x Emissions from Industrial/Commercial/Institutional (ICI) Boilers (EPA-453/R-94-022).	26.11.09.08C	NOx standards applicable by type of unit and/or fuel. Coal Tangentially fired: 0.70 lb/MMBTU (for high heat release units); 0.45 lb/MMBTU (all other units) Cyclone: 0.70 lb/MMBTU/hr from May 1 to September 30, and 1.5 lb/MMBTU for the reaminder of the year. Cell burner: 0.6 lb/MMBTU Wall fired: 0.80 lb/MMBTU (for high heat release units); 0.50 lb/MMBTU (all other units) Oil fired or gas/oil fired: 0.30 lb/MMBTU	3/28/2018, 83 FR 13192	3/3/2014	Yes. This provision fully implements NOx RACT controls over the targeted sources. It was approved by EPA as RACT under the 1997 ozone standard. After EPA's approval there has no significant change in RACT control technology for the covered sources. In addition, Maryland has adopted more stringent NOx emissions limits in COMAR 26.11.38 for several of the units in this category, which is also certifying as RACT.
Fuel-Burning Equipment with a Rated Heat Input Capacity of Less than 250 MMBtu/hr and Greater than 100 MMBtu/hr	1. Summary of NO_x Control Technologies and their Extent of Application, USEPA February 1992; 2. State Implementation Plans; General Preamble for the Implementation of Title I of the Clean Air Act Amendments of 1990;	26.11.09.08D	For coal fired fuel-burning equipment: The installation and operation of the affected unit in accordance with the manufacturer's specifications, combustion modifications, or other	3/28/2018, 83 FR 13192	11/11/2002	Yes. This provision fully implements RACT NOx controls over the targeted sources. It was approved by EPA as RACT under the 1997 ozone standard. After EPA's approval there has been no updated ACT and no significant change in

	3. USEPA Memorandum Subject: De Minimis Values for NO_x RACT, from G.T. Helms, Ozone Policy and Strategies Group, dated 1/1/1995; and 4. Alternative Control Techniques (ACT) document, NO_x Emissions from Industrial/Commercial/Institutional (ICI) Boilers (EPA-453/R-94-022).		technologies to meet an emission rate of 0.65 lb/MMBTU. For all other: compliance with 26.11.09.08B(1)(c).			RACT control technology for the covered sources.
Fuel-Burning Equipment with a Rated Heat Input Capacity of 100 MMBtu/hr or Less	1. Summary of NO_x Control Technologies and their Extent of Application, USEPA February 1992; 2. State Implementation Plans; General Preamble for the Implementation of Title I of the Clean Air Act Amendments of 1990; 3. USEPA Memorandum Subject: De Minimis Values for NO_x RACT, from G.T. Helms, Ozone Policy and Strategies Group, dated 1/1/1995; 4. Alternative Control Techniques (ACT) document, NO_x Emissions from Industrial/Commercial/Institutional (ICI) Boilers (EPA-453/R-94-022).	26.11.09.08E	Applicable NOx RACT standards include: Performing a combustion analysis for each installation at least once each year and optimizing combustion based on the analysis.	3/28/2018, 83 FR 13192	9/18/2000	Yes. This provision fully implements NOx RACT controls over the targeted sources. It was approved by EPA as RACT under the 1997 ozone standard. After EPA's approval there has been no significant change in RACT control technology for the covered sources.

Space Heaters	1. Summary of NO_x Control Technologies and their Extent of Application, USEPA February 1992; 2. State Implementation Plans; General Preamble for the Implementation of Title I of the Clean Air Act Amendments of 1990; 3. USEPA Memorandum Subject: De Minimis Values for NO_x RACT, from G.T. Helms, Ozone Policy and Strategies Group, dated 1/1/1995; and 4. Alternative Control Techniques (ACT) document, NO_x Emissions from Industrial/Commercial/Institutional (ICI) Boilers (EPA-453/R-94-022).	26.11.09.08F	Applicable NOx RACT standards include: Developing an operating and maintenance plan to minimize NO_x emissions based on the recommendations of equipment vendors and other information including the source's operating and maintenance experience; implementing the operating and maintenance plan.	3/28/2018, 83 FR 13192	9/18/2000	Yes. This provision fully implements NOx RACT controls over the targeted sources. It was approved by EPA as RACT under the 1997 ozone standard. After EPA's approval there has been no significant change in RACT control technology for the covered sources.
Fuel-Burning Equipment with a Capacity Factor of 15 Percent or Less	1. Alternative Control Techniques document: NOx Emissions from Industrial/Commercial/Institutional (ICI) Boilers, EPA-453/R-94-022, March 1994; 2. Alternative Control Techniques Document: NOx Emissions from Stationary Gas Turbines, US EPA, EPA-453/R-93-007, January 1993; 3. NESCAUM Stationary	26.11.09.08G(1)	Applicable NOx RACT standards include: Providing certification of the capacity factor of the equipment to the Department in writing; for fuel-burning equipment that operates more than 500 hours during a calendar year, performing a	3/28/2018, 83 FR 13192	9/18/2000	Yes. This provision fully implements NOx RACT controls over the targeted sources. It was approved by EPA as RACT under the 1997 ozone standard. After EPA's approval there has been significant change in RACT control technology for the covered sources.

	Source Committee Recommendation on NOx RACT for Industrial Boilers, Internal Combustion Engines and Combustion Turbines 9/18/1992; 40 4. NESCAUM Status Report on NOx Controls for Gas Turbines, Cement Kilns, Industrial Boilers, Internal Combustion Engines, December 2000; 5. USEPA Summary of NOx Control Technologies and their Availability and Extent of Application, February 1992; and 6. USEPA Summary of State/Local NOx Regulations for Stationary Sources, 2004.		combustion analysis and optimize combustion at least once annually.			
Combustion Turbines with a Capacity Factor Greater than 15 Percent	1.Alternative Control Techniques document: NOx Emissions from Industrial/Commercial/Institutional (ICI) Boilers, EPA-453/R-94-022, March 1994; 2. Alternative Control Techniques Document: NOx Emissions from Stationary Gas Turbines, US EPA, EPA-453/R-93-007, January 1993; 3. NESCAUM Stationary Source Committee Recommendation on NOx	26.11.09.08G(2)	To meet an hourly average NO_x emission rate of not more than 42 ppm when burning gas or 65 ppm when burning fuel oil (dry volume at 15 percent oxygen).	3/28/2018, 83 FR 13192	9/18/2000	Yes. This provision fully implements NOx RACT controls over the targeted sources. It was approved by EPA as RACT under the 1997 ozone standard. After EPA's approval there has been no significant change in RACT control technology for the covered sources.

	RACT for Industrial Boilers, Internal Combustion Engines and Combustion Turbines 9/18/1992; 40 4. NESCAUM Status Report on NOx Controls for Gas Turbines, Cement Kilns, Industrial Boilers, Internal Combustion Engines, December 2000; 5. USEPA Summary o f NOx Control Technologies and their Availability and Extent of Application, February 1992; and 6. USEPA Summary of State/Local NOx Regulations for Stationary Sources, 2004.					
Hospital, Medical, and Infectious Waste Incinerators (HMIWI)	EPA's 2009 revision to 40 CFR Part 60, Subpart Ec, and "Standards of Performance for Hospital/Medical/Infectious /Waste Incinerators." EPA approved regulations on 11/28/2016 [81 FR 85457] (as part of 111(d)/State Plan)	26.11.08.01, 26.11.08.02, 26.11.08.08-2	NO_x emissions from hospital, medical, and infectious waste incinerators as defined in COMAR 26.11.08.01B may not exceed NO_x emission standards in COMAR 26.11.08.08-2B(1) (190 ppm 24-hour average for small and medium HMIWIs and 140 ppm 24-hour average for large HMIWIs) as applicable.	This regulation is being submitted to EPA for SIP approval.	4/2/2012	Yes. This provision fully implements NOx RACT controls over the targeted sources.

Municipal Waste Combustors (MWC)	1.EPA's 2007 Standards of Performance for New Stationary Sources and Emission Guidelines for Existing Sources: Large Municipal Waste Combustors 2. Federal Plan for Small Municipal Waste Combustion Units Constructed on or Before August 30, 1999, 40 CFR 62 Subpart JJJ EPA approved regulations on 12/26/2017 [82 FR 60872] (as part of 111(d)/State Plan)	26.11.08.01, 26.11.08.02, 26.11.08.07, 26.11.08.08	NO_x emissions from municipal waste combustors may not exceed 24- hour average NO_X emissions of 205 ppmv. A person may not operate a municipal waste combustor that has a burning capacity of 35 tons or more per day and less than or equal to 250 tons per day that was constructed on or before August 30, 1999 which results in violation of the provisions of 40 CFR 62 Subpart JJJ.	This regulation is being submitted to EPA for SIP approval.	2/15/2016	Yes. This provision fully implements NOx RACT controls over the targeted sources.
Glass Melting Furnaces	EPA's NSPS for Glass Plants (40 CFR 60, subpart CC) and NESHAP for area source Glass Plants (40 CFR 63, subpart SSSSSS)	26.11.09.08I	Optimization of combustion by performing daily oxygen tests and maintaining excess oxygen at 4.5 percent or less.	3/28/2018, 83 FR 13192	7/20/2015	Yes. This provision fully implements NOx RACT controls over the targeted sources. It was approved by EPA as RACT under the 1997 ozone standard. After EPA's approval there has been no significant change in RACT control technology for the covered sources.

Industrial Furnaces and Other Miscellaneous Installations that Cause Emissions of NO_x	Alternative Control Techniques document: NOx Emissions from Industrial/Commercial/Institutional (ICI) Boilers, EPA-453/R-94-022, March 1994	26.11.09.08J	NOx RACT standards for any installations other than fuel-burning equipment include: Maintaining good operating practices as recommended by the equipment vendor to minimize NO_x emissions; and burning only gas in each installation, where gas is available, during the period May 1 through September 30 of each year.	3/28/2018, 83 FR 13192	9/18/2000	Yes. This provision fully implements NOx RACT controls over the targeted sources. It was approved by EPA as RACT under the 1997 ozone standard. After EPA's approval there has been no significant change in RACT control technology for the covered sources.
Kraft Pulp Mills (Prior to 3/3/2014 Kraft Pulp Mills NOx RACT was found under 26.11.09.08C(2)(h))	Federal standards for NOx emissions from boilers at pulp and paper facilities (Alternative Control Techniques document: NOx Emissions from Industrial/Commercial/Institutional (ICI) Boilers, EPA-453/R-94-022, March 1994)	26.11.14.01; 26.11.14.02; 26.11.14.07 & 26.11.40	NOx RACT standards applicable to any fuel burning equipment at Luke Kraft pulp mill. During the period May 1 through September 30 of each year: 0.70 lb/MMBTU and NOx ozone season emission cap of 656 tons. During the period October 1 through April 30 of each year: 0.99 lb/MMBTU, 30 day rolling average.	7/17/2017, 82 FR 32641 (26.11.14) SIP #18-03 for 26.11.40 & 26.11.14.07 was submitted to EPA for approval on 5/17/18	26.11.14 - 5/9/2016 26.11.40 - 4/23/18	Yes. This provision fully implements NOx RACT controls over the targeted sources. It was approved by EPA as RACT under the 1997 ozone standard (as COMAR 26.11.09.08C(2)(h)) and although re-codified, the control requirements remain the same.. After EPA's approval there has been no significant change in RACT control technology for the covered sources. The new action in SIP #18-03 removes 95 NOx allowances under 26.11.14.07.

Portland Cement Manufacturing Plants	EPA's 2004 Alternative Control Techniques (ACT) for NOx Emission from Cement Manufacturing	26.11.30.01, .02, .03, .07, and .08	NOx RACT standards applicable to a cement kiln at a Portland cement manufacturing plant: On or after April 1, 2017: For dry long kilns: 3.4 lb of NOx/ton of clinker For pre-calciner kilns: 2.4 lb of NOx/ton of clinker Both of Maryland's cement plants are now of the pre-calciner type kiln.	3/28/2018, 83 FR 13192	7/20/2015	Yes. This provision fully implements NOx RACT controls over the targeted sources. The original NOx control requirements were approved by EPA into the SIP and determined adequate as RACT under the 1997 ozone standard as COMAR 26.11.09.08H(1)&(2). Recent regulatory amendments reflect more stringent RACT level of control than previously adopted as RACT under 1997 ozone standard.
Natural Gas Compression Station Engines	EPA's 1993 Alternative Control Techniques for Stationary Reciprocating Internal Combustion Engines	26.11.29.02C(2) (Prior to 7/20/2015 Internal Combustion Engines at NG Pipeline Stations NOx RACT was found under 26.11.09.08I)	Applicable NOx RACT standards depend on the types and size of engine.	3/28/2018, 83 FR 13192	7/20/2015	Yes. This provision fully implements NOx controls over the targeted sources. The original NOx control requirements were approved by EPA into the SIP and determined adequate as RACT under the 1997 ozone standard as COMAR 26.11.09.08I and although re-codified, the control requirements remain the same. After EPA's approval there has been no significant change in RACT control technology for the covered sources.

Additional NOx RACT requirements for Coal-Fired EGUs		26.11.38 EPA SIP-Approved Version		5/30/2017, 82 FR 24546	8/31/2015	Maryland has adopted more stringent NOX limits for coal-fired electric generating units (EGUs) with a capacity greater than or equal to 25 MW. This subset of fuel-burning equipment is regulated under the SIP-approved version of COMAR 26.11.38. See Section 2.3.1 of this document for details. This regulation requires the lowest emission limitations that the covered sources are capable of meeting by the application of control technology that is reasonably available considering current technological and economic feasibility. The Department determines that these requirements satisfy the current RACT requirements under the 2008 ozone NAAQS.

Appendix B: Maryland VOC RACT Regulations under the 8-Hour Ozone NAAQS

Maryland Regulation	Rule Applicability and Requirements	Latest SIP # Date Adopted Date EPA Approved
COMAR 26.11.06 **Regulation .06** General Emission Standards, Prohibitions, and Restrictions Volatile Organic Compounds	Applies to VOC emitting installations above 20 pounds per day. Emissions are required to be controlled by 85% or more.	SIP # 99-07 Adopted 4/11/1995 Approved 2/27/2003
COMAR 26.11.10 **Regulations .01, .06, .07** Control of VOCs from Iron and Steel Production Installations	Establishes a standard for VOC emissions from the sinter plant. Requires installation of a CEM system, use of a "good management practices" manual. COMAR 26.11.19.02G requires major VOC sources to comply with RACT. There is one integrated steel mill in Maryland. Its total VOC emissions exceed the major source threshold	SIP# 01-01 Adopted 12/5/2000 Approved 11/7/01
COMAR 26.11.11 Control of Petroleum Products Installations, including Asphalt Paving and Asphalt Concrete Plants	Applies to the manufacture, mixing, storage, use, and application of cutback and emulsified asphalts. Restricts cutback asphalt during the ozone season without approval.	SIP# 93-05 Adopted 3/26/93 Approved 1/6/95
COMAR 26.11.13 **Regulation .01B(4)** amended definition of "Gasoline"	Applies to sources that store and handle JP-4, a jet fuel.	SIP # 98-07 Adopted 7/18/97 Approved 12/22/98
COMAR 26.11.13 **Regulations .01B(6-1), (13)** Definitions of "Marine Vessel" and "Vapor Control System"	Defines "Marine vessel" and "vapor control system".	SIP# 07-12 Adopted 9/12/07 Approved 7/18/08

Maryland Regulation	Rule Applicability and Requirements	Latest SIP # Date Adopted Date EPA Approved
COMAR 26.11.13 **Regulation .03A** Large Storage Tanks - Closed Top Tanks	Applies to gasoline liquid storage tanks with fixed roofs and with capacity of 40,000 gallons or greater. Covers sealing standards for a covered storage tank, openings, connection between roof edge and tank wall and vents.	SIP# 91-02 Adopted 3/9/1991 Approved 11/29/1994
COMAR 26.11.13 **Regulation .03 B** Large Storage Tanks - Open Top tanks	Applies to gasoline storage tanks with external floating roofs and with capacity of 40,000 or greater. Incorporates sealing standards for a storage tank, including its openings, its connection roof and tank wall, all seal closure devices, vents, and emergency roof drains.	SIP# 91-01B Recodification only from 10.18 to 26.11 on 7/1/87 Approved 11/3/92
COMAR 26.11.13 **Regulation .04 A** Loading Operations – Bulk Gasoline Terminals	Applies to all the loading racks at any bulk gasoline terminal that deliver liquid product into gasoline tank trucks. A vapor collection and control system designed to collect and destroy the organic compound liquids or vapors displaced from gasoline tank trucks during product loading is required and various other equipment and operational requirements are also included.	SIP# 93-05 Adopted 3/26/1993 Approved 1/6/1995

Maryland Regulation	Rule Applicability and Requirements	Latest SIP # Date Adopted Date EPA Approved
COMAR 26.11.13 **Regulation .04 B** Loading Operations – Bulk Gasoline Plants	Applies to all unloading, loading, and storage operations at bulk gasoline plants. Requires the use of vapor balance, and sets standards for equipment and work practices.	SIP# 81-01 Adopted 4/8/1981 Approved 5/11/1982
COMAR 26.11.13 **Regulation .04 C** Loading Operations – Small Storage Tanks	Applies to storage tanks with capacity greater than 2000 gallons but less than 40,000 gallons and requires Stage I vapor recovery.	SIP# 93-05 Adopted 3/26/1993 Approved 1/6/1995
COMAR 26.11.13 **Regulation .04 C** Loading Operations – Small Storage Tanks	Increases the gasoline storage tank capacity affected by Stage I vapor recovery from the previous 250 gallon capacity to greater than 2,000 gallons.	SIP # 98-06 Adopted 7/18/97 Approved 9/2/98
COMAR 26.11.13 **Regulation .05** Gasoline Leaks from Tank Trucks	Applies to gasoline tank trucks and requires compliance with standards for vapor-tightness.	SIP# 93-02 Adopted 1/18/1993 Approved 9/7/1994
COMAR 26.11.13 **Regulation .08** Control of VOC Emissions from Marine Vessel Loading	Requires owners or operators of barge loading facilities in the Baltimore/Washington areas to reduce captured VOC vapors by 90 percent if emissions from the barge loading are ≥ 25 TPY. In rest of State, controls are required if emissions are ≥ 50 TPY.	SIP# 07-12 Adopted 9/12/07 Approved 7/18/08
COMAR 26.11.14 **Regulations .01 and .06** Control of VOC Emissions from Kraft Pulp Mills	Establishes RACT standards for VOC emissions from several process installations at MD's one mill including the condensate steam stripper, the digester blow tank system, the evaporators, brown stock washers, bleach rooms and paper machines, recovery boilers, smelt dissolving tanks, and other miscellaneous operations.	SIP# 01-11 Adopted 9/25/01 Approved 11/7/01

Maryland Regulation	Rule Applicability and Requirements	Latest SIP # Date Adopted Date EPA Approved
COMAR 26.11.19 **Regulations .01B(4) and .02 G** **Control of Major Stationary Sources of Volatile Organic Compounds.** Maryland's generic major source VOC RACT regulation	Applies to all major stationary sources not subject to any VOC emission standard in COMAR 26.11.11, 26.11 .13, or Regulations .02 - .31 of COMAR 26.11.19.	SIP # 95-14 Adopted 4/13/1995 5/13/98
COMAR 26.11.19 **Regulation .02 I** Good Operating Practices, Equipment Cleanup, and VOC Storage.	Applies to all installations located at premises that are subject to any VOC requirement in COMAR 26.11.19. Requires sources to implement such things as**:** training of operators on good operating and maintenance procedures to minimize VOC emissions; storing VOC or VOC-containing materials in closed containers; using available spray gun cleaning and application technology to eliminate or minimize VOC emissions; and equipping VOC storage tanks with conservation vents and vapor balance systems.	SIP# 01-14 Adopted 11/6/01 Approved 2/3/03
COMAR 26.11.19 **Regulation .03** Automotive Light Duty Truck Coating	Apply to automobile or light-duty truck assembly plants, and any can, coil, paper, fabric, or vinyl coating unit. Establish coating VOC content limits specific to operations.	SIP# 98-01 Adopted 8/18/1997 Approved 11/5/1998
COMAR 26.11.19 **Regulation .04** Can Coating	Apply to automobile or light-duty truck assembly plants, and any can, coil, paper, fabric, or vinyl coating unit. Establish coating VOC content limits specific to operations.	SIP# 91-01B Recodification only from 10.18 to 26.11 on 7/1/87 Approved 11/3/92
COMAR 26.11.19 **Regulation .05** Coil Coating	Apply to automobile or light-duty truck assembly plants, and any can, coil, paper, fabric, or vinyl coating unit. Establish coating VOC content limits specific to operations.	SIP# 91-01B Recodification only from 10.18 to 26.11 on 7/1/87 Approved 11/3/92

Maryland Regulation	Rule Applicability and Requirements	Latest SIP # Date Adopted Date EPA Approved
COMAR 26.11.19 **Regulation .06** Large Appliance Coating	Requires use of compliant coatings with a VOC content of less 2.8 lbs/gal.	SIP# 91-01B Recodification only from 10.18 to 26.11 on 7/1/87 Approved 11/3/92
COMAR 26.11.19 **Regulation .07** Paper, Fabric, Vinyl, and Other Plastic Parts Coating	Apply to automobile or light-duty truck assembly plants, and any can, coil, paper, fabric, or vinyl coating unit. Establish coating VOC content limits specific to operations.	SIP# 99-04 Adopted 8/6/1997 & 8/4/1998 Approved 1/14/2000
COMAR 26.11.19 **Regulation .07-1** Solid Resin Decorative Surface Manufacturing	Requires control of 75 % emissions from solid resin decorative surface manufacturing operation with the help of a control device.	SIP# 99-02 Adopted 5/20/1998 Approved 6/17/1999
COMAR 26.11.19 **Regulation .08** Metal Furniture Coating	Requires use of compliant coatings with a VOC content of less than 3.0 lb/gal.	SIP# 91-01B Recodification only from 10.18 to 26.11 on 7/1/87 Approved 11/3/92
COMAR 26.11.19 **Regulation .09** Control of VOC Emissions from Cold and Vapor Degreasing	Requires controls on vapor degreasing operations and applies to a person who uses a VOC degreasing material for use in cold or vapor degreasing.	SIP# 95-09 Adopted 5/12/1995 Approved 8/4/1997
COMAR 26.11.19 **Regulation .10** Flexographic and Rotogravure	This regulation applies to any packaging rotogravure, publication rotogravure, or flexographic printing process at a facility. The rule establishes the limits of VOC contents in coatings and inks used in the covered facilities, and specify standards for control devices for various printing processes.	SIP# 95-11 Adopted 5/5/1995 Approved 9/2/1997

Maryland Regulation	Rule Applicability and Requirements	Latest SIP # Date Adopted Date EPA Approved
COMAR 26.11.19 **Regulation .11** Lithographic Printing	Applies to offset lithographic printing, including heatset and non-heatset web, non-heatset sheet-fed, and newspaper facilities. A 90 percent reduction of VOC emissions (by weight) from the press dryer exhaust vent of heatset printing operations, limits the alcohol content in fountain solutions, and establishes standards for cleaning printing equipment.	SIP# 95-11 Adopted 5/5/1995 Approved 9/2/1997
COMAR 26.11.19 **Regulation .12** Dry Cleaning Installations	Applies to petroleum dry cleaning facilities that consume 6000 gallons or more petroleum solvent per year. The rule establishes emission limits or reduction requirements for emissions, inspection, repair and reporting requirements for dryers, filtration systems and other equipment.	SIP# 91-03 Adopted 7/24/1991 Approved 9/7/1994
COMAR 26.11.19 **Regulation .13** Miscellaneous Metal Coating	Applies to any miscellaneous metal parts coating operation, and allows coatings with a VOC content in the range of 3.0 to 4.3 lb/gal.	SIP# 91-02 Adopted 3/9/1991 Approved 11/29/1994
COMAR 26.11.19 **Regulation .13-1** Aerospace Coating Operations	Applies to aerospace coating operations and emission limits for coating types range from 1.3 to 3.5 pounds per gallon. For over 50 specialty coatings the standards go up to 10 lbs/gal.	SIP# 01-10 Adopted 9/25/2001 Approved 11/7/2001
COMAR 26.11.19 **Regulation .13-2** Brake Shoe Coating Operations	Applies to brake shoe coating operations establishes coating standards and equipment cleanup standards and requires high transfer efficiency methods for application of coating.	SIP# 99-03 Adopted 8/4/1998 Approved 6/17/1999

Maryland Regulation	Rule Applicability and Requirements	Latest SIP # Date Adopted Date EPA Approved
COMAR 26.11.19 **Regulation .13-3** Control of Volatile Organic Compounds from Structural Steel Coating Operations	Coating standards are established for structural steel operations which can only be exceeded from November to March by 20 %. Minimizes VOC emissions from cleaning solvents.	SIP# 99-01 Adopted 6/5/1998 6/17/1999
COMAR 26.11.19 **Regulation .14** Manufacture of Synthesized Pharmaceutical Products	Establishes standards for the control of emissions from reactor, distillation operation, crystallizer centrifuge and vacuum dryer. Control efficiency of 90 percent or more. Vapor balance systems are also required.	SIP# 91-02 Adopted 3/9/1991 Approved 11/29/1994
COMAR 26.11.19 **Regulation .15** Paint, Resin and Adhesive and Adhesive Application	Applies to honeycomb core installation, footwear manufacturing and spiral tube winding and impregnating. Adhesive and resin standards are established for these operations.	SIP# 93-02 Adopted 1/18/1993 Approved 11/30/1993
COMAR 26.11.19 **Regulation .16** Control of VOC Equipment Leaks	Applies to operations that are subject to the requirements in COMAR 26.11.19 and without specific leak management	SIP# 91-03 Adopted 7/24/1991 Approved 9/7/1994
COMAR 26.11.19 **Regulation .17** Control of Volatile Organic Compounds Emissions from Yeast Manufacturing	Applies to yeast manufacturing installation at a premises that has a potential to emit 25 tons or more per year of VOC. Sets emission standards based on the type of yeast fermenter. Requires continuous monitoring and reporting.	SIP# 05-09 Adopted 8/23/2005 Approved 3/31/2006
COMAR 26.11.19 **Regulation .18** Control of Volatile Organic Compound Emissions from Screen Printing and Digital Imaging.	Applies to screen printing operations on different substrates. The standards vary according to the substrate, type of printing and inks. Digital imaging and control device option is also included in the regulation.	SIP# 02-04 Adopted 5/9/2002 Approved 1/15/2003

Maryland Regulation	Rule Applicability and Requirements	Latest SIP # Date Adopted Date EPA Approved
COMAR 26.11.19 **Regulation .19** Control of Volatile Organic Compound Emissions from Expandable Polystyrene Operations	Applies to expandable polystyrene operations and control efficiency of 85 % is required for emissions from pre-expander or combustion in a fire box.	SIP# 00-09 Adopted 9/11/2000 Approved 5/7/2001
COMAR 26.11.19 **Regulation .20** Control of Landfill Gas Emissions from Municipal Solid Waste Landfill	Applies to existing MSW landfills that have a design capacity equal to or greater than 2,750,000 tons and 3,260,000 cubic yards of MSW. Gas collection and control system is required if the emissions are calculated to be greater than 55 tons per year.	111(d)# 99-09 Adopted 2/5/1998 and 3/2/1999 Approved 9/8/1999
COMAR 26.11.19 **Regulation .21** Control of Volatile Organic Compounds from Bakery Ovens	Applies to an oven that has the potential to emit 25 tons or more. Controls are required based on predictive factors of 80 % or greater. The regulations also have provisions for the review and approval of innovative control technology.	SIP# 95-10 Adopted 6/9/1995 Approved 10/15/1997
COMAR 26.11.19 **Regulation .22** Control of Volatile Organic Compounds from Vinegar Generators	Applies to vinegar generation operation with emissions greater than 20 lbs/day. A scrubber-absorber system is required at 85 % or greater efficiency.	SIP# 98-09 Adopted 7/15/1997 Approved 9/23/1999
COMAR 26.11.19 **Regulation .23** Control of VOC Emissions from Vehicle Refinishing	Applies to vehicle refinishing operations. Establishes coating , cleaning solvent and equipment standards	SIP# 95-03 Adopted 5/1/1995 Approved 8/4/1997
COMAR 26.11.19 **Regulation .24** Control of VOC Emissions from Leather Coating	Applies to a person who owns or operates a leather coating operation at a premises with actual VOC emissions of 20 pounds or more per day. Establishes coating standard and provides alternative means of compliance by controlling 85 % or more emissions.	SIP# 98-08 Adopted 7/15/1997 Approved 9/23/1999

Maryland Regulation	Rule Applicability and Requirements	Latest SIP # Date Adopted Date EPA Approved
COMAR 26.11.19 **Regulation .25** Control of Volatile Organic Compounds From Explosives and Propellant Manufacturing.	Applies to existing equipment at a premise that has a potential to emit 25 tons or more of VOC per year from all explosives and propellant manufacturing equipment. Establishes control efficiency requirement of 85% or more overall.	SIP# 98-18 Adopted 7/15/1997 Approved 1/26/1999
COMAR 26.11.19 **Regulation .26** Control of Volatile Organic Compound Emissions from Reinforced Plastic Manufacturing	Applies to reinforced plastic manufacturing operations if VOC emissions are 20 pounds or more per day. Requires the use of low styrene resin, high efficiency application equipment and low voc cleaning solvents.	SIP# 98-15 Adopted 7/18/1997 Approved 8/19/1999
COMAR 26.11.19 **Regulation .27** Control of Volatile Organic Compound Emissions from Marine Vessel Coating Operations	Applies to marine vessel coating operations. Establishes over 20 coating standards, cleanup and record keeping requirements.	SIP# 98-17 Adopted 9/12/1997 Approved 9/5/2001
COMAR 26.11.19 **Regulation .28** Control of Volatile Organic Compound Emissions from Bread and Snack Food Drying Operations	Applies to bread drying operation that has a potential to emit VOC emissions of 25 tons or more per year. Requires control of 85 % efficiency with the help of a scrubber or an alternative control device.	SIP# 00-11 Adopted 9/11/2000 Approved 5/7/2001
COMAR 26.11.19 **Regulation .29** Control of Volatile Organic Compound Emissions from Distilled Spirits Facilities	Applies to a distilled spirits facility that has a total potential to emit VOCs of 25 tons or more per year. Requires standards to be met for emptying barrels, cleaning of filters and filling of barrels.	SIP# 01-12 Adopted 9/25/2001 Approved 11/7/2001
COMAR 26.11.19 **Regulation .30** Control of Volatile Organic Compound Emissions from Chemical Production and Polytetrafluoroethylene Installations	Applies to an organic chemical production installation or an inorganic chemical production installation with VOC emissions of 20 pounds or more per day. For emissions above 100 lbs/day, 90 % controls are required. Good operating practices apply if the emissions are less than 100 lbs/day.	SIP# 08-02 Adopted 3/17/2008 Pending EPA Action

Maryland Regulation	Rule Applicability and Requirements	Latest SIP # Date Adopted Date EPA Approved
COMAR 26.11.19 **Regulation .31** Control of Volatile Organic Compound Emissions from Medical Device Manufacturing	Applies to medical device manufacturing installations that emit, or have the potential to emit, 100 pounds or more VOC/day that engage in the production of hypodermic products syringes, catheters, blood handling and other medical devices.	SIP# 06-04 Adopted 5/11/2006 Approved 1/11/2007
COMAR 26.11.24 Stage II Vapor Recovery at Gasoline Dispensing Facilities	Applies to facilities with average monthly throughput of 10,000 gallons or more. Requires regular inspection and testing of Stage II systems and includes record keeping and reporting.	SIP# 02-03 Adopted 3/14/2002 Approved 5/7/2003

Appendix C: Maryland WOE Modeling Runs

Run	Description	Comment
4A1	2017/2018 Future Base Case Without Tier 3 – OTB/OTW with Optimized EGUs – No Tier 3	The purpose of this run is to identify incremental additional benefit from Tier 3 (4A1 – 4A)
4A2	2017/2018 Future Base Case Without Optimized EGUs – OTB/OTW with Tier 3 – No Optimized EGUs	The purpose of this run is to identify incremental additional benefit from Optimized EGUs (4A2 – 4A)
4A	2017/2018 Future Base Case Without Tier 3 – OTB/OTW with Tier 3 and Optimized EGUs	This is the 2017/2018 Future base case
4B	4A with EGUs run at worst rates seen in all CAMD data	Mixes and matches worst rates from different years – Truly represents a worst case
4C	4A with EGUs run at real rates seen in 2011 or 2012 – from CAMD data	Intended to represent what really did happen in a real year in the recent past.
4D	4A with SCR like reductions at all remaining post-2017/2018 uncontrolled EGUs	Designed to get the maximum additional benefit associated with SCRs on all remaining units
4E	4A with all of the post 2017/2018 retired units running at best rates from earlier years	Designed to identify the benefit of the Post 2017/2018 shutdowns
4OTC1	4A with OTC AMC, On- and Off-Road Idling added in just OTC states	Designed to look at the big three OTC NOx Mobile Source Strategies
4OTC2	4A with OTC AMC, On- and Off-Road Idling, and all other OTC mobile measures added in Just OTC states	Designed to look at total benefit from OTC Mobile measures
4OTC3	4A with All OTC VOC measures added in just OTC states	Designed to look at total incremental benefit from OTC VOC measures
4OTC	4A with all OTC measures added in just OTC states	Designed to look at total benefit from OTC Mobile measures in OTC states
4OTC4	4OTC with all OTC measures added in all states in the domain	Designed to look at additional benefit from OTC measures expanded to all of East Coast
4OTC5	4OTC with just OTC AMC and all OTC VOC measures added in all states in the domain	Designed to look at additional benefit from OTC measures that could be “EPA Asks” expanded to all of East Coast
4MD1	4OTC with new MD requirements for 2015 to 2017/2018.	Designed to identify the additional benefit from MD 2015 RACT. Optimize controls at SCRs, run SNCRs and optimize SNCR performance
4MD2	4MD1 with new MD requirements for 2020	Designed to identify the additional benefit from MD 2020 Step. SCRs at all units - optimized
4MD3 (Also	4MD1 with rough (small) cut from MDE cutting edge mobile efforts	Designed to identify the additional incremental (small) benefit from MD mobile

4ATT1)	(EV, ZEV, MPO partnerships)	efforts
4Beta1	4ATT1 with just NTR	See BETA benefits from just NTR
4Beta2	4ATT1 with just mobile	See BETA benefits from just mobile cuts
4Beta	4ATT1 in Beta mode	See BETA benefits from full Beta package
4ATTW	4MD3 with Optimized EGUs in contributing states to Sheboygan WI from 1/22 EPA GNS Guidance	Designed to see if 4ATT1 with optimized EGUs in states contributing to Sheboygan brings that monitor into attainment
4ATTC1	4MD3 with an additional 10% generic NOx reduction in CT, NY, NJ,	Designed to see if 4ATT1 with a surrogate for a "NAA local strategy" to help CT/NY/NJ brings that area into attainment.
4ATTC2	4MD3 with an additional 10% generic NOx reduction in just NY	Designed to see if 4ATT1 with a surrogate for a "focused local strategy" to help CT/NY/NJ brings that area into attainment.
4ATTC	4MD3 with an additional 10% generic NOx reduction in CT, NY, NJ, PA, DE, NOVA. If the emissions decrease from 4MD3 is less than 10% in MD – bump MD reductions up to 10% as well.	Designed to see if 4ATT1 with a surrogate for a "broader local strategy" to help CT/NY/NJ brings that area into attainment.
4WOE1	4ATT1 with 111D benefits added in across the East	What might 11D do to help?
4WOE2	4ATT1 with EE/RE benefits in MD added in	What additional small benefit might we get from EE/RE in MD
4WOE3	4ATT1 with 1% additional NOx reduction from mobile in Baltimore and DC from Beyond Conformity Partnerships	What additional small benefit might we get from voluntary partnerships with MPOs through smart transportation planning
4WOE4	4ATT1 with enhanced urban tree canopy benefits	Mimic previous work. How do trees help?
4WOE	4ATT1 with all of the above	Total potential benefit if all non-traditional stuff works out.

Appendix C1: MARAMA 2011 Alpha 2 Inventory and Projections

The following introduction section from MARAMA's *Technical Support Document Emission Inventory Development for the 2011, 2018 and 2028 for the Northeastern U.S. Alpha2 Version* summarizes the inventory used in Maryland's modeling base case. Full documentation and emissions files can be found at http://www.marama.org/technical-center/emissions-inventory/2011-inventory-and-projections.

1. INTRODUCTION

The Mid-Atlantic Regional Air Management Association (MARAMA) is coordinating the development of Northeastern regional emissions inventories for air quality modeling. This Technical Support Document (TSD) describes the development of a comprehensive Northeastern regional emission inventory for 2011 and emission projections for 2018 and 2028[31] . State, Local, and Tribal (S/L/T) air agencies may use these inventories to address State Implementation Plan (SIP) requirements for attaining national ambient air quality standards (NAAQS) for ozone and fine particles, to evaluate progress towards long-term regional haze goals, and to support a single integrated, one-atmosphere air quality modeling platform.

Key inventory attributes include:

- Base Year: 2011
- Projection Years: 2018 and 2028
- Source Category Sectors: electric generating unit (EGU) point sources, other point sources, nonpoint sources, nonroad mobile sources included in the NONROAD model, other nonroad sources (aircraft, locomotives, commercial marine vessels), onroad mobile sources included in the MOVES model, fire events, and biogenic sources
- Pollutants: ammonia (NH3), carbon monoxide (CO), oxides of nitrogen (NOx), filterable plus condensable particles with diameter less than or equal to 10 and 2.5 micrometers (PM10 and PM25), sulfur dioxide (SO2), and volatile organic compounds (VOC)
- Temporal Resolution: Annual
- Geographic Area: 15 jurisdictions in the Northeastern U.S. (CT, DC, DE, MA, MD, ME, NC, NH, NJ, NY, PA, RI, VA, VT, WV); additional states, Canadian provinces, and offshore sources are included in the complete modeling inventory for the Northeastern domain, however, this detailed documentation is only for the states in the Northeastern US in this document.

The guiding philosophy behind the development of the 2011 inventory was to rely as much as possible on the collaborative work performed by the S/L/T air agencies and the U.S. Environmental Protection Agency (EPA) in developing a 2011-based Modeling Platform. The EPA's 2011 Modeling Platform consists of emissions inventory data, supporting data, and methods used to process the 2011 National Emissions Inventory (NEI) and related data into a form useful for air quality modeling. EPA compiles the NEI primarily using data submitted by S/L/T agencies via the Emissions Inventory System (EIS). These S/L/T agencies collaborated

[31] MARAMA intends to develop a 2017 inventory in response to the court ruling that resulted in the 2008 NAAQS attainment deadlines being moved up by one year.

extensively with EPA to avoid duplication of effort, use consistent data and methodologies, avoid duplication between categories, ensure completeness and improve data quality.

S/L/T agencies and EPA continue to refine the 2011 Modeling Platform. EPA released Version 1 of the 2011 NEI (referred to as 2011NEIv1) on November 27, 2013. EPA published extensive documentation and asked S/L/T agencies and stakeholders to provide any necessary updates to the inventory or the model inputs used to develop mobile source emission inventories. EPA addressed comments and released a preliminary Version 2 (NEI2011v2) for most stationary source categories in October 2014. They then updated this preliminary Version 2 and provided updated files to MARAMA in December 2014.

For the 2018 and 2028 inventories, the guiding philosophy was to use a combination of S/L/T data and methods for projecting emissions from stationary sources and to rely on EPA's 2018/2028 Modeling Platform for mobile source emission projections. EPA released NEI2018v1 on January 14, 2014. EPA developed emission projections for EGUs using the Integrated Planning Model (IPM). Over the past few years, S/L/T agencies have developed an alternative EGU modeling approach under the direction of the Eastern Regional Technical Advisory Committee (ERTAC). Northeastern S/L/T agencies plan to use the ERTAC tool for forecasting EGU emissions to substitute for EPA IPM-based forecasts. In earlier versions of the NEI2011, EPA used a "no-growth" approach that essentially flat-lines future year emissions for many nonEGU point and nonpoint stationary source categories. Northeastern S/L/T agencies prefer to use growth and control factors developed by MARAMA within the Emission Modeling Framework (EMF) tool to project emissions as a better representation of future year emissions.

EPA has now adopted the MARAMA state-supplied growth factors for most categories.[32] For mobile sources, the Northeastern S/L/T agencies have coordinated with EPA in developing the model inputs that EPA uses with the NONROAD and MOVES models to project future emissions. The development of the 2011 inventory and emission projections is an iterative process. Northeastern S/L/T agencies have developed this ALPHA2 version of the 2011/2018/2028 inventories using the best data currently available. Figure 1 summarizes the data sources used for each source sector of the ALPHA2 inventory. Figure 1 shows the date when MARAMA received each of the files used in this inventory. Updates to the inventory made by USEPA after that point are not reflected in this inventory. MARAMA and S/L/T agencies may develop future versions of the Northeastern regional emission inventory when significant revisions are necessary.

[32] One exception is Oil and Gas sources where USEPA used a uniform approach across all states.

Figure 1: Data Sources for 2011, 2018 and 2028 Inventories by Source Sector

MARAMA Sector	Source for 2011 Inventory	Source for 2018 Inventory	Source for 2028 Inventory
Point - ERTAC EGUs	ERTAC V2.3 with growth factors set at 1.0 for NOx and SO2. State provided emission rates for other pollutants	ERTAC V2.3 for NOx and SO2, with state provided emission rates for other pollutants	ERTAC V2.3 for NOx and SO2, with state provided emission rates for other pollutants
Point – Small EGUs	NEI2011v2	NEI2011v2 projected to 2018 using growth and control factors within the EMF tool	NEI2011v2 projected to 2028 using growth and control factors within the EMF tool
Point – Aircraft Engines, Ground Support Equipment, Auxiliary Power Units	NEI2011v2	NEI2011v2 projected to 2018 using FAA growth factors within the EMF tool	NEI2011v2 projected to 2018 using FAA growth factors within the EMF tool
Point - Other Sources	NEI2011v2	NEI2011v2 projected to 2018 using growth and control factors within the EMF tool	NEI2011v2 projected to 2028 using growth and control factors within the EMF tool
Nonpoint – Area Sources	NEI2011v2	NEI2011v2 projected to 2018 using growth and control factors within the EMF tool	NEI2011v2 projected to 2028 using growth and control factors within the EMF tool
Nonroad – Commercial Marine Vessels and Railroad Locomotives	NEI2011v2	NEI2011v2 projected to 2018 using growth and control factors within the EMF tool	NEI2011v2 projected to 2028 using growth and control factors within the EMF tool
Nonroad – NONROAD Model	NEI2011v1 NONROAD Model	NEI2018v1 NONROAD Model	NEI2025v2 NONROAD Model
Onroad – MOVES Model	NEI2011v2 MOVES Model	NEI2018v2 MOVES Model	NEI2025v2 MOVES Model
Fire Events	NEI2011v2	NEI2011v2 (using 2011 inventory for 2018)	NEI2011v2 (using 2011 inventory for 2028)
Biogenic	EPA BEIS	EPA BEIS (using 2011 inventory for 2018)	EPA BEIS (using 2011 inventory for 2018)
Canadian Sources	Canada 2010	Applied the average change in emissions that is expected to occur in the Eastern modeling domain between 2011 and 2018 by pollutant and sector	Applied the average change in emissions that is expected to occur in the Eastern modeling domain between 2011 and 2028 by pollutant and sector

Appendix C2: Optimized EGU Analysis for Coal-Fired Units Equipped With SCR and SNCR Post-Combustion Controls

Modeling Scenario 4A is designed to determine the maximum benefit of coal-fired units with SCR or SNCR post-combustion controls running the installed controls efficiently every day of the ozone season. NOx is reduced at all coal-fired units that are equipped with SCR or SNCR in the following states: IL, IN, KY, MI, NC, OH, TN, VA, WV, PA, NY, NJ, CT & DE. The controlled rate is reflective of each unit's lowest ozone season average emission rate as reported to CAMD between 2005 and 2014.

The lowest ozone season average emission rate was selected as it represents a rate that the unit has demonstrated it can achieve while fully optimizing the installed controls. The average rate was selected, as opposed to the absolute lowest daily or hourly value, in order to account for a range of operating parameters including start-up, shut-down, high and low capacity operation and times where the SCR or SNCR may not have been fully optimized. The result is a flexible but readily achievable and sufficiently stringent emission rate.

The lowest ozone season average emission rate between 2005-2014 was selected for all units with SCR and SNCR controls If a unit installed a SCR or SNCR in 2005 or a later year, the data collection period was narrowed to the first ozone season in the year following the installation to 2014. If a unit was identified as installing control in 2014 or a future year, the emission rate identified as indicative of that control running in 2018 was selected. If a unit was identified as installing a control in 2014 or a future year, but has performed at a lower rate than the 2018 rate, then the lower rate was used. Also, if a unit with an existing control was identified as having a 2018 emission rate lower than its past best demonstrated ozone season average rate, that lower rate was used.

A reduction percentage was calculated for each unit by dividing the best ozone season average emission rate by the 2018 reference case ozone season average emission rate. Applying that reduction percentage to the 2018 reference case ozone season average emission reduces the 2018 ozone season average emission rate to each units best controlled ozone season emission rate. Because the ozone season emission rate in ERTAC EGU is constant across the ozone season, the reduction percentage can be applied to the mass.

Scenario 4A realized a 36% reduction in ozone season NOx from optimizing SCR and SNCR controls on coal-fired units. 2018 ozone season NOx from these units was reduced from 167,746 tons to 107,769 tons. The 60,577 ton reduction in ozone season equates to a 396 ton per day NOx benefits. The NOx benefits per state are outlined in the table below:

State	Reference Case 2018 Ozone Season NOx Mass (Tons)	Scenario 4A 2018 Ozone Season NOx Mass (Tons)	Ozone Season NOx Mass Benefit (Tons)
Connecticut	N/A – no coal-fired units with SCR or SNCR		
Delaware	351.32	230.82	-120.50
Illinois	8,959.81	7,976.52	-983.29
Indiana	25,627.47	18,036.05	-7,591.42
Kentucky	14,255.19	7,837.57	-6,417.63
Michigan	4,844.12	2,734.14	-2,109.97
New Jersey	1,446.85	1,350.02	-96.83
New York	1,517.22	1,438.48	-78.74
North Carolina	19,626.33	11,022.93	-8,623.40
Ohio	24,454.04	15,280.64	-9,173.40
Pennsylvania	37,017.21	21,084.13	-15,933.08
Tennessee	6,687.48	5,819.64	-867.84
Virginia	6,481.34	5,572.80	-908.54
West Virginia	16,447.85	8,805.70	-7,672.14
Total	**167,746.23**	**107,169.43**	**-60,576.80**

Unit level reductions are available upon request.

Appendix C3: Uncontrolled EGU Emission Reductions Analysis

Modeling Scenario 4D includes all assumptions about optimized SCRs (Scenario 4A), plus SCR like reductions at all remaining post 2017/2018 coal-fired EGUs that are not equipped with SCR or SNCR post-combustion controls. It is designed to get the maximum additional benefit associated with SCR's on all remaining coal-fired units.

From Scenario 4A, ozone season NOx is reduced at all coal-fired units that are not controlled by SCR or SNCR by the year 2018 in the following states: IL, IN, KY, MI, NC, OH, TN, VA, WV, PA, NY, NJ, CT & DE. The controlled rate is reflective of all remaining uncontrolled coal-fired units receiving SCR controls.

To calculate the reduction percentage, the Scenario 4A best ozone season average NOx emission rates for units already controlled by SCR were averaged by state. For states with uncontrolled units that do not have units with SCR controls, a SCR controlled best ozone season average emission ate was calculated by averaging all of the Scenario 4A NOx emission rates across all of the affected states. The table below indicates what rates were applied to uncontrolled coal-fired units in each affected state:

State	ERTAC 2.3 SCR Best Ozone Season Average Emission Rate
Connecticut	0.0721 lb/mmBtu*
Delaware	N/A – no uncontrolled units
Illinois	0.0605 lb/mmBtu
Indiana	0.0838 lb/mmBtu
Kentucky	0.0595 lb/mmBtu
Michigan	0.0585 lb/mmBtu
New Jersey	N/A – no uncontrolled units
New York	0.1200 lb/mmBtu
North Carolina	0.0610 lb/mmBtu
Ohio	0.0728 lb/mmBtu
Pennsylvania	0.1245 lb/mmBtu
Tennessee	N/A – no uncontrolled units
Virginia	0.0500 lb/mmBtu
West Virginia	0.0523 lb/mmBtu

*State does not have units with SCR controls. Scenario 4D rate is an average of Scenario 3A rates across all SCR units in all affected states.

A reduction percentage was calculated for each unit by dividing the average SCR controlled best ozone season average emission rate by the 2018 ozone season average emission rate in Scenario 4A. Note that for the uncontrolled units, there is no difference between the reference case rate and the Scenario 4A rates as the uncontrolled units were not impacted by Scenario 4A.

For units in 2018 that had a lower ozone season average emission rate than the state averaged SCR controlled emission rate, the lower 2018 emission rate was used, and no change was made to that unit.

Applying that reduction percentage to the 2018 ozone season average emission rate in Scenario 4A reduces the 2018 ozone season average emission rate to a potential best SCR controlled ozone season emission rate. Because the ozone season emission rate in ERTAC EGU is constant across the ozone season, the reduction percentage can be applied to the mass.

Scenario 4D realized a 60% reduction in ozone season NOx from adding SCR controls to coal-fired units without post-combustion controls. 2018 ozone season NOx from these units was reduced from 65,313 tons to 19,369 tons. The 45,944 ton reduction in ozone season equates to a 300 ton per day NOx benefits. The NOx benefits per state are outlined in the table below:

State	**Scenario 4A 2018 Ozone Season NOx Mass (Tons)**	**Scenario 4D 2018 Ozone Season NOx Mass (Tons)**	**Ozone Season NOx Mass Benefit (Tons)**
Connecticut	193.3	97.77	-95.26
Delaware	N/A – no uncontrolled units		
Illinois	8,287.56	4,228.75	-4,058.81
Indiana	7,682.04	2,927.95	-4,754.09
Kentucky	20,162.23	3,900.63	-16,261.60
Michigan	12,044.39	2,872.03	-9,172.35
New Jersey	N/A – no uncontrolled units		
New York	784.84	784.84	0.00
North Carolina	858.72	169.81	-688.91
Ohio	6,911.00	2,058.89	-4,852.11
Pennsylvania	1,281.93	1,220.95	-60.89
Tennessee	N/A – no uncontrolled units		
Virginia	1,323.33	192.88	-1,130.45
West Virginia	5,783.72	914.60	-4,869.12
Total	**65,312.79**	**19,369.10**	**-45,943.69**

Unit level reductions are available upon request.

Appendix C4: Tier 3 On-Road Mobile Emission Reductions Analysis

The U.S. EPA finalized a rule[33] designed to reduce air pollution from passenger cars and trucks. Starting in 2017, Tier 3 sets new vehicle emissions standards and lowers the sulfur content of gasoline, considering the vehicle and its fuel as an integrated system.[34]

- The Tier 3 vehicle standards reduce both tailpipe and evaporative emissions from passenger cars, light-duty trucks, medium-duty passenger vehicles, and some heavy-duty vehicles.

- The Tier 3 gasoline sulfur standard will make emission control systems more effective for both existing and new vehicles, and will enable more stringent vehicle emissions standards. Removing sulfur allows the vehicle's catalyst to work more efficiently. Lower sulfur gasoline also facilitates the development of some lower-cost technologies to improve fuel economy and reduce greenhouse gas (GHG) emissions, which reduces gasoline consumption and saves consumers money.

- The tailpipe standards include different phase-in schedules that vary by vehicle class but generally phase in between model years 2017 and 2025. In addition to the gradual phase-in schedules, other flexibilities include credits for early compliance and the ability to offset some higher-emitting vehicles with extra-clean models.

- The fuel sulfur standards include an averaging, banking, and trading (ABT) program that will allow refiners and importers to spread out their investments through an early credit program and rely on ongoing nationwide averaging to meet the sulfur standard. EPA is also finalizing flexibilities such as the ability to carry over credits from Tier 2 to Tier 3 and hardship provisions for extenuating circumstances, as well as flexibility provisions for small businesses (small manufacturers of Tier 3 vehicles and small refiners), small volume manufacturers, and small volume refineries.

These Tier 3 standards will address public health issues that exist currently and are projected to continue in the future as requested in a May 21, 2010 Presidential memorandum.

- Over 149 million Americans are currently experiencing unhealthy levels of air pollution which are linked with adverse health impacts such as hospital admissions, emergency room visits, and premature mortality. Motor vehicles are a particularly important source of exposure to air pollution, especially in urban areas.

- The vehicle emission standards combined with the reduction of gasoline sulfur content will significantly reduce motor vehicle emissions, including nitrogen oxides (NOX),

[33] https://www.epa.gov/regulations-emissions-vehicles-and-engines/final-rule-control-air-pollution-motor-vehicles-tier-3
[34] https://nepis.epa.gov/Exe/ZyPDF.cgi/P100HVZV.PDF?Dockey=P100HVZV.PDF

volatile organic compounds (VOC), direct particulate matter (PM2.5), carbon monoxide (CO) and air toxics.

- Compared to current standards, the non-methane organic gases (NMOG) and nitrogen oxides (NOX), presented as NMOG+NOX, tailpipe standards for light-duty vehicles represent approximately an 80% reduction from today's fleet average and a 70% reduction in per-vehicle particulate matter (PM) standards. The heavy-duty tailpipe standards represent about a 60% reduction in both fleet average NMOG+NOX and per vehicle PM standards. EPA is also extending the regulatory useful life period during which the standards apply from 120,000 miles to 150,000 miles.

The Tier 3 onroad mobile emissions reductions are reflected in the MOVES model output files.

Appendix C5: Maryland NOx Regulation Requirements

On November 20, 2015, MDE submitted a regulation as a SIP revision for EPA approval and incorporation into the Maryland SIP. The revision consists of Maryland regulation COMAR 26.11.38—Control of NO_X Emissions from Coal-Fired Electric Generating Units. The regulation, effective in August 2015, establishes NO_X emission standards and additional monitoring and reporting requirements for coal-fired EGUs.

COMAR 26.11.38 defines the affected units for the regulation as Brandon Shores Units 1 and 2, C.P. Crane Units 1 and 2, Chalk Point Units 1 and 2, Dickerson Units 1, 2, and 3, H.A. Wagner Units 2 and 3, Morgantown Units 1 and 2, and Warrior Run. The regulation requires an affected EGU to minimize NOX emissions by operating and optimizing the use of all installed pollution controls and combustion controls during all times that the unit is in operation while burning coal. For demonstrating compliance with this requirement, the owner or operator is required to submit a plan to MDE and EPA for approval that summarizes the data to be collected to show that each affected EGU is operating its installed controls.

To demonstrate compliance with the requirement to optimize controls, MDE established 24-hour block emissions levels for each coal-burning EGU based on historical emissions data. During the ozone season, EGU owners are required to provide a daily report for any unit that exceeds its 24-hour emissions level. The report requires specific operating data and an explanation of any exceedances of the 24-hour level. A detailed discussion of the requirements of regulation COMAR 26.11.38 may be found in the EPA technical support document (TSD) prepared in support of this proposed rulemaking.[35]

The 14 affected units at the seven plants that are subject to COMAR 26.11.38 have all installed controls as a result of programs requiring NO_X reductions by previous regulatory requirements such as the NO_X SIP Call (65 FR 57356, October 27, 1998), the Clean Air Interstate Rule (CAIR) (70 FR 25162, May 12, 2005), the Cross State Air Pollution Rule (CSAPR) (76 FR 48208, August 8, 2011), and Maryland's Healthy Air Act (HAA). All of the affected units have either selective catalytic reduction (SCR), selective non-catalytic reduction (SNCR), or selective alternative catalytic reduction (SACR).

EPA found that the submittal strengthens the Maryland SIP. COMAR 26.11.38 imposes NO_X emissions limits on units subject to the regulation which are expected to lower NO_X emissions within the State. The NO_X emissions limits plus the operation and optimization of the existing NO_X controls whenever the units are in operation will help Maryland's attainment and maintenance of the 2008 ozone NAAQS.

[35] https://www.regulations.gov/contentStreamer?documentId=EPA-R03-OAR-2016-0238-0005&contentType=pdf

Appendix C6: Additional OTC Measures Documentation

Additional OTC control measures were also included as a modeling scenario. These control measures included aftermarket catalysts, on-road idling, nonroad idling, heavy duty diesel inspection and maintenance, enhanced SMARTWAY, ultra low NO_X burners, commercial and consumer products, architectural and industrial maintenance coatings, and motor vehicle refinishing/line coatings.

OTC Measure – Aftermarket Catalysts

SCC Affected: All On-Road Mobile
Percent Reduction: 2.9% NOx; 0.64% VOC
Multiplier: 0.971 NOx; 0.9936 VOC
State/Counties Controls Applied To: Entire OTC

OTC Measure – On-Road Idling

SCC Affected: All On-Road Mobile
Percent Reduction: 5.6% NOx; 1.2% VOC
Multiplier: 0.944NOx; 0.988 VOC
State/Counties Controls Applied To: Entire OTC

OTC Measure – NonRoad Idling

SCC Affected: All Non-Road Mobile
Percent Reduction: 11.0% NOx; 1.6% VOC
Multiplier: 0.89 NOx; 0.984 VOC
State/Counties Controls Applied To: Entire OTC

OTC Measure – Heavy Duty I & M

SCC Affected: All On-Road Mobile
Percent Reduction: 2.7% NOx
Multiplier: 0.973 NOx
State/Counties Controls Applied To: Entire OTC

OTC Measure – Smartways

SCC Affected: All On-Road Mobile
Percent Reduction: 2.3% NOx
Multiplier: 0.977 NOx
State/Counties Controls Applied To: Entire OTC

OTC Measure – Consumer Products

SCC Affected:

2460000000	Consumer Products, All Products
2465000000	Consumer Products, All Products
2460100000	Consumer Products, Personal Care Products
2460200000	Consumer Products, Household Products
2460400000	Consumer Products, Auto Aftermarket Products
2460500000	Consumer Products, Coatings
2460600000	Consumer Products, Adhesives and Sealants
2460800000	Consumer Products, FIFRA Products
2460900000	Consumer Products, Misc. Products

Percent Reduction: 4.8% (Includes Brake Cleaner Reduction)
Multiplier: 0.952
State/Counties Controls Applied To: ENTIRE OTC except Delaware

OTC Measure – Architectural and Industrial Maintenance Coatings

SCC Affected:

2401001000	Surface Coating /Architectural Coatings /Total: All Solvent Types
2401002000	Surface Coating /Architectural Coatings - Solvent-based /Total: All Solvent Types
2401003000	Surface Coating /Architectural Coatings - Water-based /Total: All Solvent Types
2401008000	Surface Coating /Traffic Markings /Total: All Solvent Types
2401100000	Surface Coating /Industrial Maintenance Coatings /Total: All Solvent Types
2401102000	Surface Coating /Industrial Maintenance Coatings /All Solvent Types
2401200000	Surface Coating /Other Special Purpose Coatings /Total: All Solvent Types

Percent Reduction: Varies by SCC
Multiplier: Varies by SCC

SCC	Percent Reduction	Multiplier
2401001000	0.324	0.676
2401002000	0.324	0.676
2401003000	0.324	0.676
2401008000	0.097	0.903
2401100000	0.000	1.000
2401102000	0.000	1.000
2401200000	0.1526	0.8474

State/Counties Controls Applied To: ENTIRE OTC except Delaware

OTC Measure – Motor Vehicle Refinishing/Line Coating

SCC Affected:

2401005000	Auto Refinishing - All Solvent Types
2401005500	Auto Refinishing - Surface Preparation Solvents
2401005600	Auto Refinishing - Primers
2401005700	Auto Refinishing - Top Coats
2401005800	Auto Refinishing - Clean Up Solvents

Percent Reduction: 35.0%
Multiplier: 0.65
State/Counties Controls Applied To: ENTIRE OTC except Delaware

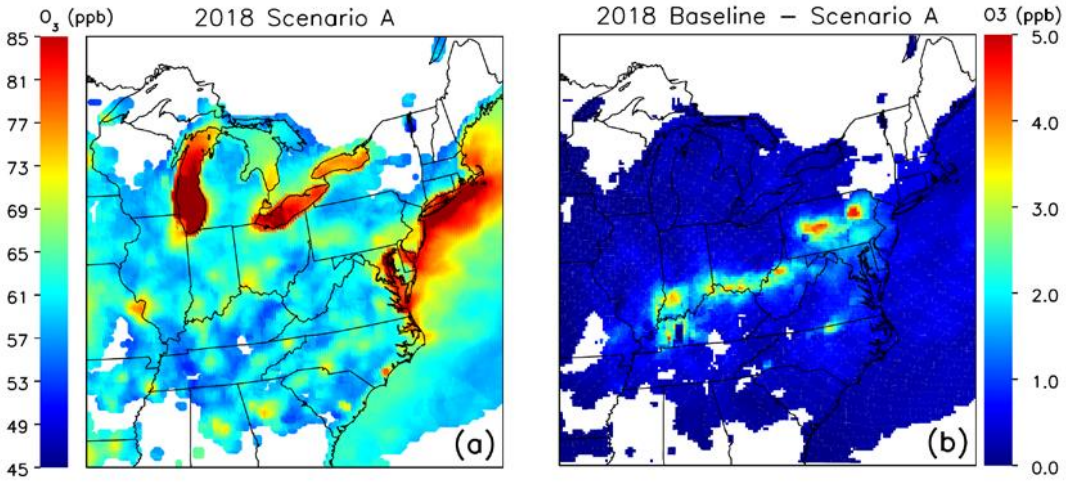
Appendix D: UMCP Air Quality Modeling Final Report

Final Report FY2016

To the Maryland Department of the Environment
Phone: (410) 537-3242
Fax: (410) 537-3391

For contract entitled

Air Pollution in Maryland – RAMMPP



Russell Dickerson, PI, Dale Allen, Timothy Canty, Hao He, Xinrong Ren, Ross Salawitch, and Da-Lin Zhang
Department of Atmospheric and Oceanic Science
College Park, Maryland 20742
301.405.5364

Sheryl Ehrman
Department of Chemical and Biomolecular Engineering
The University of Maryland

August 31, 2016
(PO #: U00P5401103)

Cover Image

Left (a) Average 8-hour maximum surface ozone for the July 2018 Scenario A (historically best power plant NOx emission rates) run. Regions shown in red-orange to red exceed 75 ppb. Right (b) Difference plot between model surface 8-hour ozone concentrations from the 2018 Baseline and 2018 Scenario A runs showing the potential improvement from optimal operation of existing NOx control equipment (Vinciguerra et al., 2016).

Synopsis

The Departments of Atmospheric and Oceanic Science and Chemical and Biomolecular Engineering of the University of Maryland College Park (UMCP) are currently undertaking a project to assist the Air and Radiation Management Administration (ARMA) of the Maryland Department of the Environment (MDE), in photochemical modeling and observational studies of ozone, regional haze, and fine particulate matter in the Baltimore-Washington region and to provide modeling, measurements, air quality analysis, and other technical support to evaluate controls on the utilities and other sources of pollution under the new air quality standards. The primary source of information and results for the aircraft measurement component of the Regional Atmospheric Measurement, Modeling, and Prediction Program (RAMMPP) is the improved website, at URL: http:/www.atmos.umd.edu/~rammpp. Detailed reports or power point presentations on each deliverable item have been submitted via quarterly meetings throughout the year in electronic form to Mr. Michael Woodman at MDE. This report represents work done on a project July 1, 2015 - June 30, 2016.

FY2016 (July 1, 2015 to June 30, 2016) RAMMPP Highlights

For the Good Neighbor SIP due in 2016, extensive numerical simulations using CMAQ and CAMx were undertaken in FY 2016; numerous policy-relevant papers were submitted or published. These concern primarily the regional nature of ozone in the Mid Atlantic States. These peer-reviewed publications help inform the Weight of Evidence report.

- Model runs with CMAQ demonstrated that running SCR and SNCR NOx control devices at optimal rates would have a substantial favorable impact on O_3, up to 5 ppb, in the eastern US [*Vinciguerra et al., 2016]*.
- Use of satellite data to evaluate emissions and CTM numerical simulation was investigated and helped demonstrate the regional nature of NO_2 and thus ozone production [*Krotkov et al*., 2016].
- Numerical simulations with CAMx CB6r2 [*Goldberg et al*., 2016] showed impacts on alkyl nitrates (NTR) similar to the fix applied by *Canty et al*. [2015].
- CAMx model simulations also demonstrated that applying the best science increases by ~30% the role of power plants in Maryland's ozone formation.
- We submitted a paper on use of a tethersonde to study the bay breeze in Maryland [*Mazzuca et al*., 2016b].
- A paper on the impact of the Healthy Air Act appeared in the journal Earth's Future [*He et al.*, 2016].
- Vehicular emissions of NOx appear to be overestimated in the EPA NEI for 2011 as was discovered in RAMMPP [*Anderson et al.,* 2014] and since supported by model studies see http://acmg.seas.harvard.edu/presentations.html and *Travis et al*. [2016].
- Extensive modeling with CMAQ and CAMx demonstrates that Edgewood will be challenged to achieve attainment in 2018, but the Weight of Evidence provides support for a more optimistic outlook.
- Improvements to the emissions and chemical mechanisms of the models increase the role of interstate transport of ozone and precursors.

Contents

1. Management

Key Personnel: Russell Dickerson

MDE: Michael Woodman

As outlined in the contract, UMD organized and held bi-weekly conference calls and quarterly meetings. Major quarterly half-day meetings were held at MDE and were well attended. Copies of PowerPoint presentations were submitted. In order to keep MDE better informed of progress and problems, tables of specific tasks were set up at the beginning of the fiscal year, and tracked throughout the year. All objectives were met, except where an agreed upon alternative was provided. Weekly (Thursday morning) modeling update calls were held with MDE, MARAMA, EPA and other States. Weekly summaries of new, relevant publications were provided. Tim Canty participated in OTC calls. UMD principal investigators provided presentations concerning the science of photochemical smog, PM2.5, haze and policy relevant science as well as participated in conference calls with institutions including:

- AGU
- AMS
- MARAMA
- EPA & CMAS
- EPRI
- NOAA/ARL
- NASA/AQAST
- NASA/AURA
- NIST

2. Modeling, dynamical

Personnel: Da-Lin Zhang, Dale Allen, Doyeon Ahn, Jonathan Hansford, and Ross Salawitch

Tasks (Questions to be addressed):
1) Model the meteorology over the Washington/Baltimore area with the Weather Research and Forecasting (WRF) model with resolution of 4 km or better. Determine if these data better replicate what is occurring along The Chesapeake Bay and whether the higher resolution fields impact the results found with CMAQ.

The WRF model was not run at 4 km resolution during the summer of 2011; however, the 4-km North American Mesoscale (NAM) was run and fields are available for analysis of meteorological fields. All CMAQ runs were conducted with 12km WRF runs as requested.

Fluxes of CH_4, CO_2, and CO are being estimated for the Baltimore and Washington metropolitan areas using 4-km and 12-km meteorological fields from the NAM model as part of the 2015 FLAGG-MD campaign. The flux calculations are being done using two different methods, an "intersections" method and a "minimum downwind" method. Both methods require estimates of the pollution-enhanced (downwind) and background (upwind) concentrations and use these values and HYSPLIT backward trajectories to estimate the fluxes. In the "intersections" method, a HYSPLIT backward trajectory is computed starting at each of the aircraft measurements downwind of the region and is connected to an aircraft measurement upwind of the region, which is assumed to be the background. In the "minimum downwind" method, the minimum of all the data points downwind of the region is used as the background for all data points, and the aircraft measurements are used to determine the perpendicular wind speed. The "minimum downwind" approach is believed to give an upper estimate of the flux while the "intersections" method requires an upwind measurement to be available along the back trajectory.

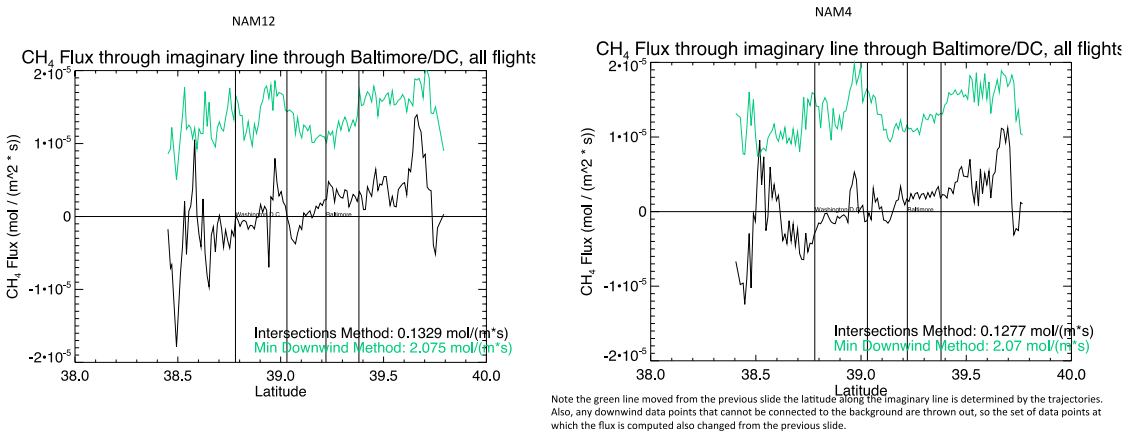


Figure 2B1. Showing 4-km and 12-km estimates of the CH_4 flux from the upwind and wings methods.

Figure 2B1 shows 4-km and 12-km estimates of the CH_4 flux from these two methods as a function of the latitude at which the back trajectories intersect the Baltimore and DC region for all flights for which upwind values are found. Fluxes from the "minimum downwind" method exceed fluxes from the "intersection" method by over a factor of ten, while differences due to resolution are minimal. For this particular problem, the method used to estimate the fluxes is much more important than the resolution of the meteorological fields used to calculate the fluxes.

3. Chemical Transport and Emissions Modeling

Key Personnel:
MDE: Michael Woodman,
UMD: Tim Canty, Hao He, Daniel Goldberg, Tim Vinciguerra

Tasks

1) *Will Maryland attain the 8-hour ozone NAAQS?*
   SMOKE and CMAQ runs will be completed to support MDE's modeling efforts as it relates to OTC activities for SIP development. MDE will require a minimum of 5 modeling runs of 1 month each and 2 modeling runs for the entire ozone season (April – October). Three of five runs with existing or separately supplied SMOKE emissions and two with additional details from new SMOKE runs. Additional modeling runs will contingent on revising this contract.

2) *Compare ozone simulated with CAMx with CB05 to CAMx with CB6r2 and predicted 2018 values.*
3) *Quantify the effect proper representation of maritime emissions has on local and regional ozone. These results will be folded into improvements to the CMAQ framework to better represent long-range transport.*

4) *The Box model (or CAMx) will be used as a screening tool to answer the questions such as:*
   a) *How does or will CMAQ/CB05 or CAMx CB6r2 respond to changes in emissions?*
      i) *What is the ozone at upwind monitoring sites (e.g., Piney Run) with reduced EGU and/or vehicular NOx?*
      ii) *What is the ozone at a receptor (e.g., Essex or Edgewood) with reduced NOx and anthropogenic VOC's?*
   b) *What were the benefits of specific regulations?*
      i) *This modeling will be completed by adjusting the box model's O_3 precursor initial conditions, emissions, and chemistry to match the observed changes in concentration resulting from on the books and on the way pollutant reductions. The change in maximum 8 hr ozone will be calculated and attributed to the regulation in question.*
   c) *What role do pollutants from outside the domain (i.e. Boundary Conditions) play in local air quality?*
      i) *UMD will continue to investigate how the boundary conditions used to constrain the models are developed*
   d) *Are regional or national EPA regulations on mobile or stationary sources necessary?*
      i) *UMD will correct the reactions (such as photolysis of alkyl nitrates or formation of HONO) and emissions to match observed concentrations. Then calculate the ozone production efficiency (OPE) with improvised chemistry and compare it to observed OPE. This will provide insight into how to best run CMAQ.*

5) *How best to accomplish source apportionment modeling to demonstrate pollutant transport into Maryland?*
    a) *UMD will continue to do CAMx modeling to determine a state's contribution to Maryland's ozone problem*
6) *Test modifications to the chemical mechanisms used in the air quality models and modifications to the emissions inventory based on analysis of ground based, aircraft, and satellite. Take steps to quantify how much surface O_3 has been reduced in Maryland resulting from the NOx SIP call using a mix of models and measurements.*

Description of Model Framework and Emissions

For the screening air quality modeling presented here meteorological output from the Weather Research and Forecasting (WRF) model representing July 2011 was used in all baseline and attainment strategy simulations. MARAMA Alpha Version 2 emissions inventories formed the basis for the development of various screening attainment scenarios. The v2 emissions are an update to the v1 emissions, which used the EPA provided NEI2011v2 inventories as a basis. Both the Community Multi-scale Air Quality model (CMAQ) and the Comprehensive Air Quality model with Extension (CAMx) were used. Output from the updated Biogenic Emission Inventory System (BEIS) model was made available in early 2016. The updated biogenic emissions from BEIS v3.61 have been included in some of the more recent CMAQ simulations.

To explore the impacts of NOx from EGUs on 2018 Maryland ozone concentrations, a series of runs were performed where NOx emissions rates from coal-fired power plants were adjusted in states surrounding Maryland (Figure 3.1). **Scenario 4A**, NOx rates were reduced to match the lowest historic rates observed during the years of 2005-2014. Alternatively, EGU NOx rates were increased to the highest historic (2005-2014) rates for **Scenario 4B**. For **Scenario 4C**, NOx rates were increased to match rates observed during the 2011 ozone season. Finally, **Scenario 4D** explored the impacts of additional NOx reductions by assuming installation of SCR controls on uncontrolled units. These scenarios (called "Scenario 4" series) are summarized in Table 3.1.

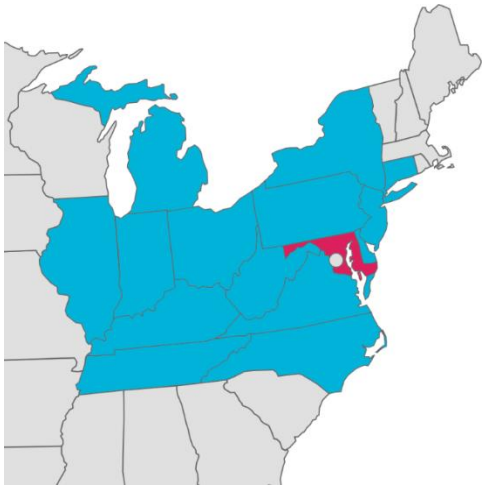


Figure 3.1. NOx rates were adjusted for coal-fired EGUs in the blue-colored states for Scenarios 4A, 4B, 4C, and 4D.

Table 3.17: Emissions adjustments for the Scenario 4 series of model runs

Scenario	Emissions Adjustment
4A	EGU NOx rates reduced to match lowest rates observed between 2005-2014, OTB/OTW with Tier 3
4B	4A, EGU NOx rates increased to highest rates —Based on CAMD data (2005-2014)
4C	4A, EGU NOx rates matched observed rates for 2011—Based on CAMD data
4D	4A, with SCR like reductions at all remaining post-2017/2018 uncontrolled EGUs

Using Scenario 4A as a starting point, further tests were performed to understand potential impacts of additional Ozone Transport Commission (OTC) regulations enacted within the OTC states (Figure 3.2) (i.e. the "4OTC scenarios"). **Scenario 4OTC1** applied aftermarket catalysis (AMC) and onroad and nonroad idling reductions. In addition to these reductions, **Scenario 4OTC2** also included heavy duty I&M and Smartways reductions to mobile sources. **Scenario 4OTC3** considered VOC reductions from area sources such as consumer products, refinishing, and surface coatings. The mobile reductions from Scenario 4OTC2 and the area VOC reductions from Scenario 4OTC3 were combined for **Scenario 4OTC**. These emissions are summarized in Table 3.2.

Figure 3.2. OTC reductions were applied the colored regions shown for Scenarios 4OTC1, 4OTC2, 4OTC3, and 4OTC.

Table 3.18: Emissions adjustments for the 4OTC Scenario series of model runs

Scenario	Emissions Adjustment
4OTC1	4A with OTC After Market Catalysts (AMC), On- and Off-Road Idling reductions, OTC states only
4OTC2	4A with OTC AMC, On- and Off-Road Idling, and all other OTC mobile measures (heavy duty I&M and Smartways reductions), OTC states only
4OTC3	4A with All OTC VOC measures (from area sources such as consumer products), OTC states only
4OTC	4A with all OTC measures, OTC states only (4OTC2 + 4OTC3)
4OTC4	4OTC with all OTC measures applied to all states in the domain
4OTC5	4OTC with just OTC AMC and all OTC VOC measures applied to all states in the domain

Reductions based on control measures in Maryland only were considered and added to the reductions used in Scenario 4OTC (so-called "4MD" scenarios). **Scenario 4MD1** includes reducing NO_x emissions from Maryland coal-fired units to 2018 ozone season optimized rates (Phase 1). **Scenario 4MD3 (ATT-1)** builds off of 4MD1 and includes reductions from cutting-edge mobile efforts (EV, ZEV, MPO). Three regulatory scenarios were also considered for NO_x emissions from Maryland coal-fired EGUs. **Scenario 4MD2-D** assumed a 0.11 lb./mmBtu 30-day rolling cap for Raven and NRG systems, **Scenario 4MD2-A** assumed a fuel switch from coal to natural gas, and **Scenario 4MD2-B** assumed a 21 ton-per-day, system-wide mass cap, as well as a 0.09 lb./mmBtu 30-day rolling cap (Phase 2).

"**Science Runs**" were also performed that incorporated changes to the model framework based on analysis of data acquired during NASA field missions and satellite observations. These simulations included a 50% reduction of onroad mobile NO_x emissions [*Anderson et al.*, 2014] and a tenfold increase to alkyl nitrate photolysis rates in CMAQ [*Canty et al.*, 2015b] (Canty et al, 2015). Biogenic emissions generated using BEIS 3.6 were upgraded using BEIS 3.61, which

incorporates revisions to land use data, canopy model, and vegetation representation. Some simulations only included changes to alkyl nitrate chemistry. Science runs were performed for the 2011 and 2018 MARAMA Alpha Version 2 baselines, Scenarios 4 and 4OTC series, and 4MD3. Some simulations were performed where only the chemistry of alkyl nitrates was changed. Changes to the model framework necessitated re-running the 2011 simulation.

Table 3.3: Emissions adjustments for the 4MD Scenario series of model runs

Scenario	Emissions Adjustment
4MD1	EGU NOx rates for Maryland coal power plants reduced to match 2018 ozone season optimized rates (Phase 1)
4MD3 (ATT-1)	4MD1 and MDE cutting edge mobile efforts (EV, ZEV, MPO partnerships)
4MD2-A	Complete fuel switch from coal to natural gas for Maryland EGUs (Phase 2)
4MD2-B	21 ton-per-day, system-wide mass cap, as well as a 0.09 lb/mmBtu 30-day rolling cap
4MD2-D	0.11 lb/mmBtu 30-day rolling cap for Raven and NRG systems

A simulation that investigated the role that EGU peaking units play on bad air quality days was also performed where emissions were modified on a unit by unit basis.

Model Run Duration Summary

Full Ozone Season: 2
Single "July" Month: 40

Scenario 4 Attainment Series:

When developing strategies to inform the policies that will be used to improve air quality, it is important that the regulatory air quality model best represent the actual state of the atmosphere. UMD, through this contract, and leveraging additional funds from federal sources has analyzed ground based, aircraft, and satellite data to probe the veracity of the chemical mechanisms used on CMAQ and CAMx. The knowledge acquired from these studies has led to important modifications to the "baseline" model framework. We identify the "science" runs, which include a 50% reduction in NO_x emissions from onroad mobile sources and a decrease in the lifetime of the family of chemicals called alkyl nitrates (NTR). The "NTR only" simulations include just the modification to the NTR lifetime. Throughout this document, we will present images of average maximum 8-hr O_3. The values of O_3 were determined following the EPA guidance for calculating relative reduction factors. It is important to note that, when changes were made to the model framework, these changes were applied to both the 2011 base year and 2018 future year simulations.

Figures 3.3 and 3.4 indicate how the empirically motivated model improvements affect calculated ozone for both 2011 and 2018, respectively. Model output from an "off the shelf"

baseline simulation are displayed in the left hand panels. The middle panels show that calculated O_3 increases when the lifetime of NTR is decreased. In the baseline version of the model, NTR has a lifetime of 10 days, which makes this species a long term reservoir for NO_2. Decreasing the lifetime to 1 day not only increases NO_2 but also increases VOCs created by the decomposition of NTR. When combined with a 50% reduction in mobile NO_x emissions, calculated surface O_3 decreases.

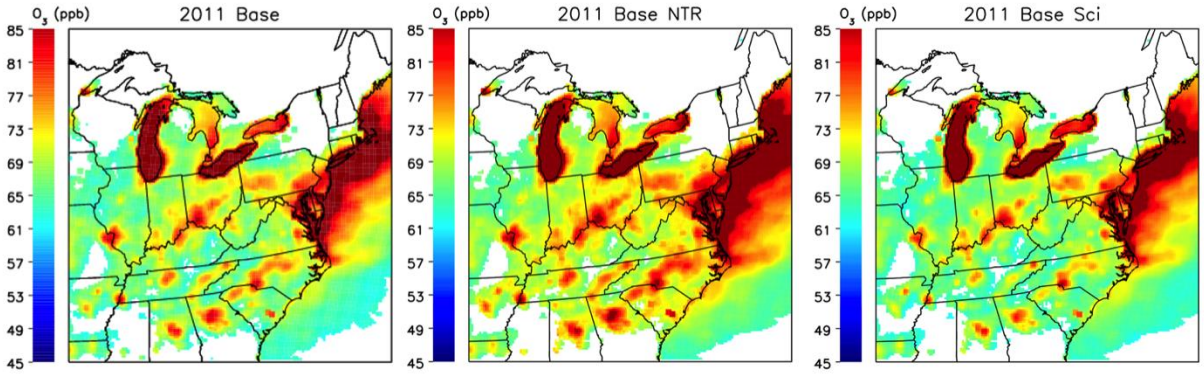


Figure 3.3. Average maximum 8hr O_3 for July 2011 baseline model simulation (left panel); simulation where the lifetime of NTR has been decreased (middle panel), NTR lifetime is decreased and onroad mobile NO_x has been decreased by 50%.

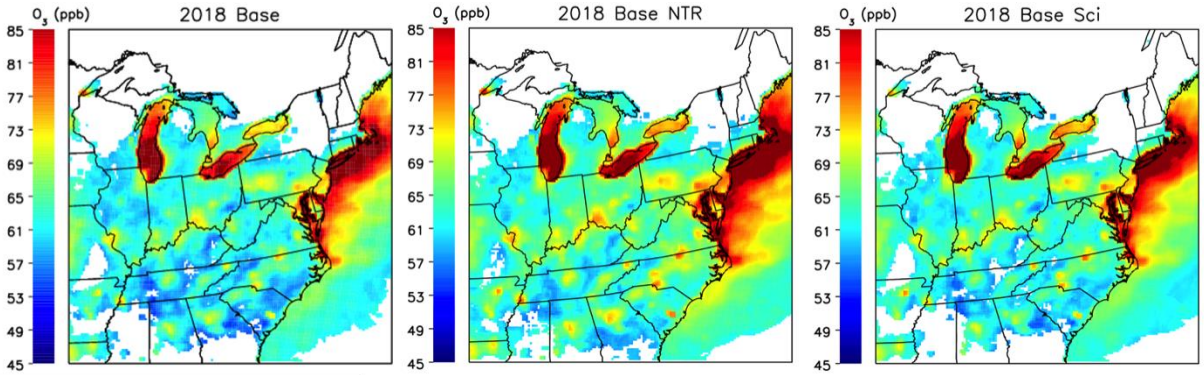


Figure 3.4. Same as Figure 3.3 except all simulations are for July 2018,

To calculate the 2018 model design values, the 2011 observed design values are multiplied by the relative reduction factor (RRF). The RRF is the ratio of average maximum 8hr ozone from 2018 divided by the same quantity for 2011. The RRF is, essentially, a measure of the effectiveness of a control strategy. It is NOT an indication of the change in absolute value of ozone between model scenarios. In some cases 2011 and 2018 model ozone is quite low. However, the relative change in ozone is small. For instance, if onroad emissions of NO_x were reduced by 50% in the 2011 and 2018 simulations, any further reductions in mobile NO_x will not

lead to significant additional decreases in O_3. The attainment strategy is not as effective when mobile NO_x sources are small. This would yield an RRF that is large and, consequently, a large 2018 model design value. The design values for the 2018 baseline, NTR, and Science runs is shown in Table 3.4.

The "science" model framework, which is our best representation of the actual atmosphere, suggests that O_3 in Maryland would be higher in 2018 than compared to a standard, baseline model simulation of 2018. Below, we show similar results for the scenario 4 series of model simulations. Figure 3.5 shows results from the baseline, NTR, and Science runs as applied to scenario 4A. Figure 3.6 is the same as Figure 3.5 except model results are for Scenario 4B. Figures 3.7 and 3.8 show baseline and NTR results for scenario 4C and 4D, respectively.

Table 3.4 Observed design values in Maryland for 2011 and calculated design values for a July 2018 baseline simulation; a model run where the lifetime of alkyl nitrates has been decreased by factor of 10 (NTR); and a model run where, in addition to the NTR modifications, onroad NOx is reduced by 50% (Science). Red shaded boxes indicate O3 levels above the 75 ppb standard. Values in red text are above 75 ppb but, when truncated, will satisfy attainment.

Site	DV 2011	DV 2018	2018 NTR	2018 Science
Davidsonville	83	72.3	73.4	74.3
Padonia	79	70.8	71.5	72.3
Essex	80.7	74.3	74.5	74.8
Calvert	79.7	72.3	73.0	74.4
South Carroll	76.3	68.3	68.8	70.3
Fair Hill	83	74.6	**75.3**	76.7
S.Maryland	79	70.4	71.3	72.3
Blackwater	**75**	67.3	68.2	69.3
Frederick Airport	76.3	68.1	69.0	70.1
Piney Run	72	61.7	62.5	62.9
Edgewood	90	82.1	82.7	83.8
Aldino	79.3	70.7	71.5	72.7
Millington	78.7	70.5	71.3	72.5
Rockville	**75.7**	66.5	67.2	67.5
HU-Beltsville	79	68.4	69.3	69.8
PG Equest.	82.3	71.8	72.9	73.7
Beltsville	80	69.6	70.3	71.5
Hagerstown	72.7	64.3	65.1	66.0
Furley	73.7	67.5	67.8	68.2

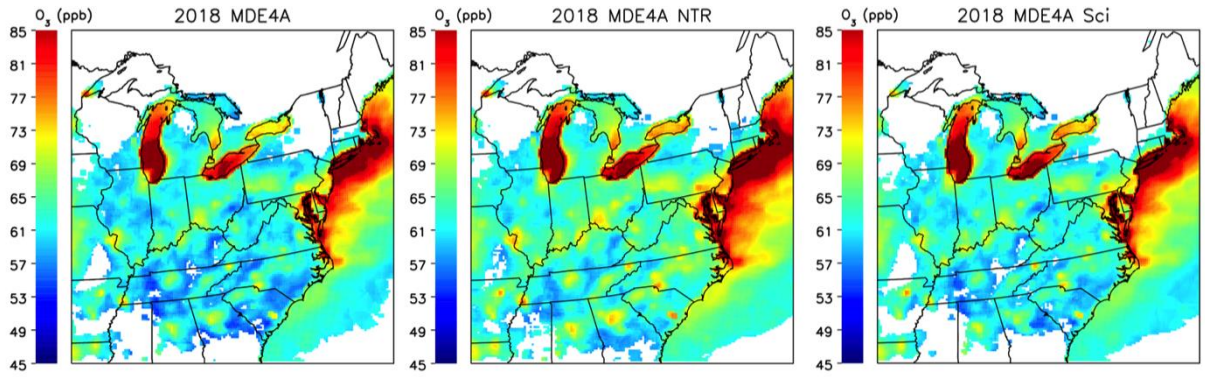


Figure 3.5: Same as Figure 3.4 except all simulations are for July 2018, Scenario 4A

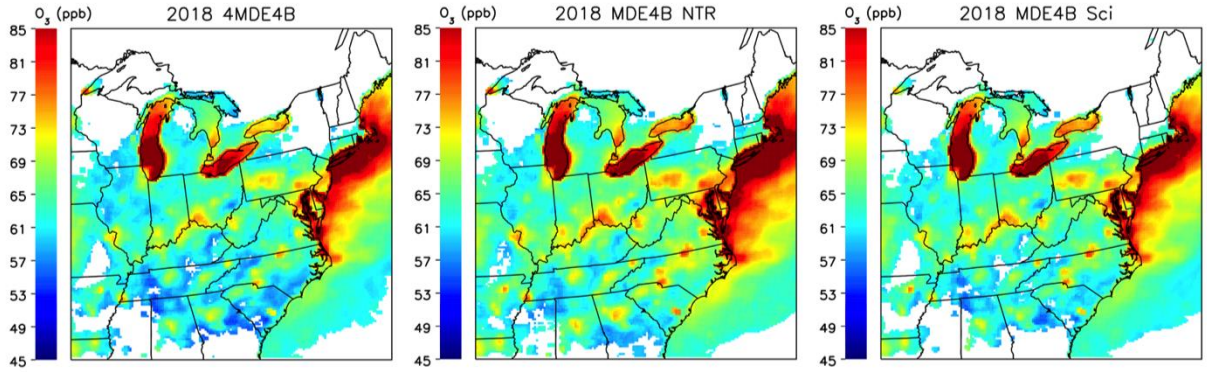


Figure 3.6. Same as Figure 3.4 except all simulations are for July 2018, Scenario 4B

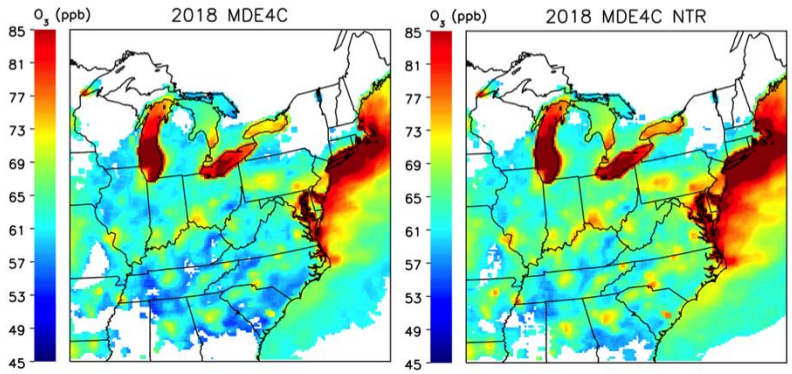


Figure 3.7. Same as Figure 3.4 except baseline and NTR simulations are for Scenario 4C

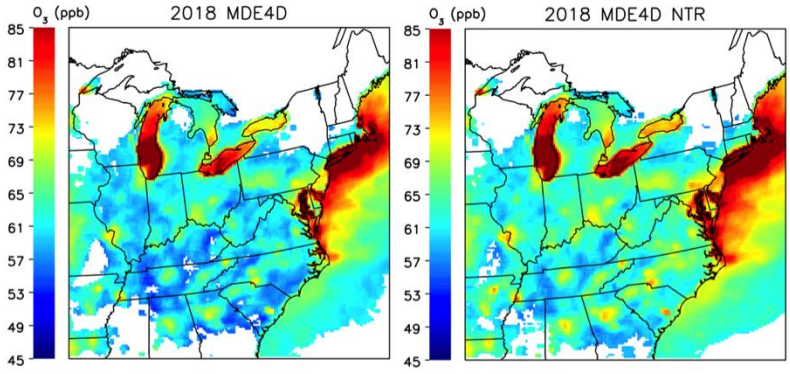


Figure 3.8. Same as Figure 3.7 except baseline and NTR simulations are for Scenario 4D

Table 3.5 Observed 2011 design values in MD and calculated design values for the Scenario 4 series of model simulations. Red shaded boxes indicate O_3 levels above the 75 ppb standard. Values in red text are above 75 ppb but, when truncated, will satisfy attainment.

Site	DV 2011	DV 2018	2018 NTR	4A	4A NTR	4A Sci	4B	4B NTR	4B Sci	4C	4C NTR	4D	4D NTR
Davidsonville	83	72.3	73.4	71.7	72.8	73.5	73.2	74.2	75.4	72.4	73.5	71.3	72.3
Padonia	79	70.8	71.5	69.9	70.5	71.2	71.9	72.6	73.4	70.9	71.6	69.3	67.0
Essex	80.7	74.3	74.5	73.8	74.0	74.2	75.0	75.2	75.5	74.4	74.6	73.5	73.7
Calvert	79.7	72.3	73.0	71.6	72.3	73.6	73.1	73.8	75.3	72.3	73.0	71.3	72.1
South Carroll	76.3	68.3	68.8	67.1	67.7	68.9	69.9	70.4	72.0	68.5	69.0	66.4	67.0
Fair Hill	83	74.6	75.3	73.5	74.2	75.4	75.7	76.1	77.8	74.5	75.1	73.0	73.7
S.Maryland	79	70.4	71.3	69.5	70.5	71.3	71.6	72.4	73.7	70.6	71.4	69.0	70.0
Blackwater	75	67.3	68.2	66.7	67.7	68.6	68.2	69.0	70.1	67.5	68.3	66.3	67.3
Frederick Airport	76.3	68.1	69.0	66.7	67.6	68.6	69.9	70.6	71.9	68.3	69.2	65.9	66.9
Piney Run	72	61.7	62.5	60.2	61.1	61.4	63.6	64.3	64.8	61.8	62.6	57.3	58.3
Edgewood	90	82.1	82.7	81.5	82.1	83.1	82.9	83.5	84.6	82.2	82.8	81.2	81.8
Aldino	79.3	70.7	71.5	69.9	70.8	71.8	71.6	72.4	73.7	70.7	71.6	69.5	70.4
Millington	78.7	70.5	71.3	69.6	70.5	71.5	71.5	72.2	73.5	70.5	71.2	69.1	70.0
Rockville	75.7	66.5	67.2	65.7	66.4	66.5	67.6	68.2	68.7	66.7	67.3	65.2	65.8
HU-Beltsville	79	68.4	69.3	67.7	68.7	69.0	69.4	70.2	70.9	68.6	69.4	67.3	68.2
PG Equest.	82.3	71.8	72.9	71.1	72.1	72.8	72.8	73.8	74.9	72.0	73.0	70.7	71.7
Beltsville	80	69.6	70.3	69.0	69.7	70.7	70.4	71.1	72.5	69.7	70.3	68.5	69.3
Hagerstown	72.7	64.3	65.1	63.2	64.0	64.7	65.8	66.5	67.7	64.5	65.3	62.3	63.2
Furley	73.7	67.5	67.8	67.0	67.3	67.7	68.2	68.4	68.9	67.7	67.9	66.8	67.1

Table 3.5 summarizes the year 2018 model design values for these various simulations. We note that none of the attainment strategies meant to simulate EGU emissions in 2018 attain the 75 ppb standard for average 8-hr O_3.

Scenario 4OTC Attainment Series: Where the scenario 4 model runs investigated power plant emissions, the 4OTC series focused on additional regulations within the OTC states. These simulations are based off of Scenario 4A. Scenario 4OTC (Figure 3.9) includes controls on aftermarket catalysts, regulation of onroad and off-road idling, and VOC measures such as controls on consumer products.

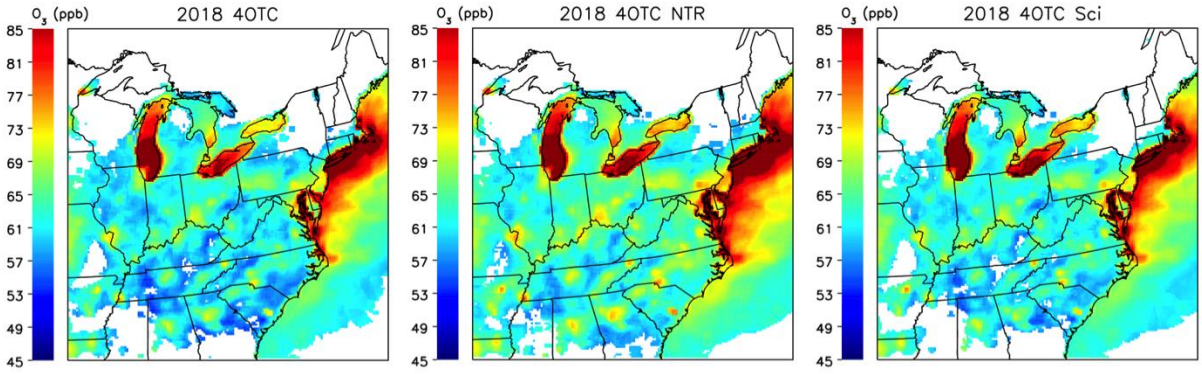


Figure 3.9. Same as Figure 3.4 except all simulations are for July 2018, Scenario 4OTC

The difference between the science model framework and the baseline 4OTC simulations is seen in Figure 3.10, left panel. Though mobile NO_x emissions have decreased surface O_3 is still greater in the Science framework. This is due to the increase in VOCs caused by the decrease in NTR lifetime. By subtracting the O_3 fields calculated from the NTR run from the Science run, we can isolate the effect of decreasing mobile NOx emissions (Fig. 3.10, right panel). As expected, there is a precipitous decrease in surface O_3 when the only difference between the models is a 50% reduction in onroad NO_x.

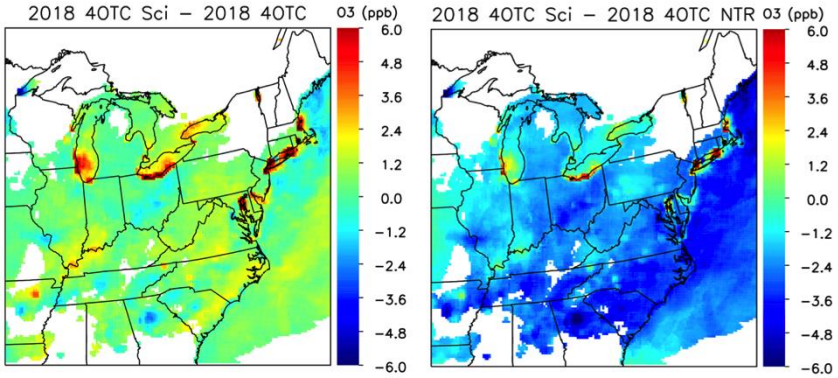


Figure 3.10. Difference between 4OTC Science and 4OTC baseline model runs (Left). Difference between 4OTC Science and 4OTC NTR model runs (Right).

Scenario 4OTC1 (Figure 3.11) only includes aftermarket catalysts, regulation of onroad and off-road idling. Scenario 4OTC2 (Figure 3.12) includes emissions reductions used for 4OTC1 plus additional mobile measures within the OTC. Scenario 4OTC3 (Figure 3.13) only includes control measures on VOCs from sources such as consumer products. In the 4OTC4 model simulations (Figure 3.14), all OTC measures are applied to the entire modeling domain. Scenario 4OTC5 (Figure 3.15) applies reductions based on aftermarket catalysts and VOCs measures across the domain. This is an attempt to highlight the impact of the idling and other efforts to control mobile emissions included in 4OTC4.

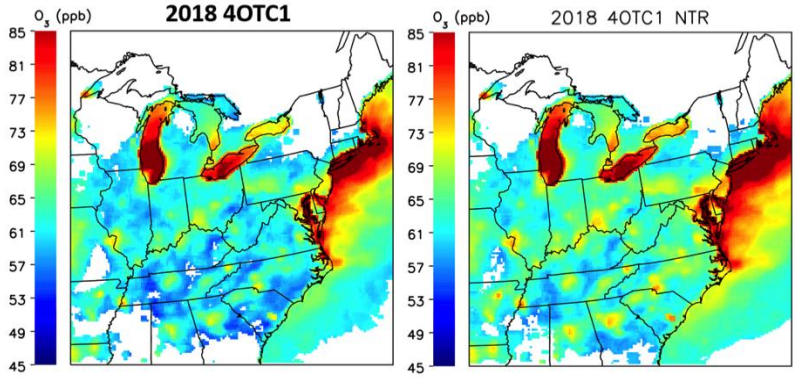


Figure 3.11. Same as Figure 3.7 except baseline and NTR simulations are for Scenario 4OTC1

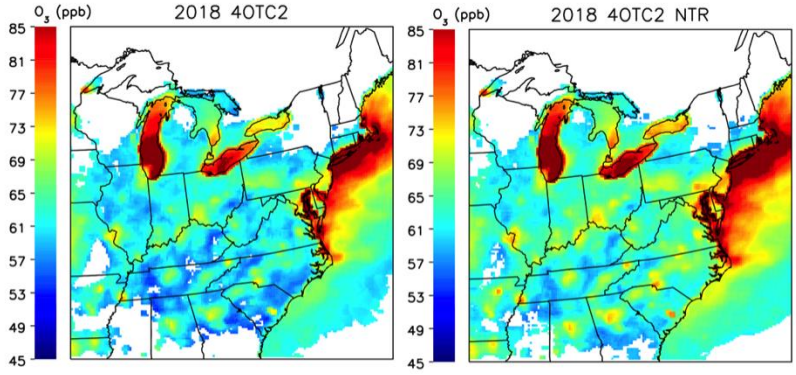


Figure 3.12. Same as Figure 3.7 except baseline and NTR simulations are for Scenario 4OTC2

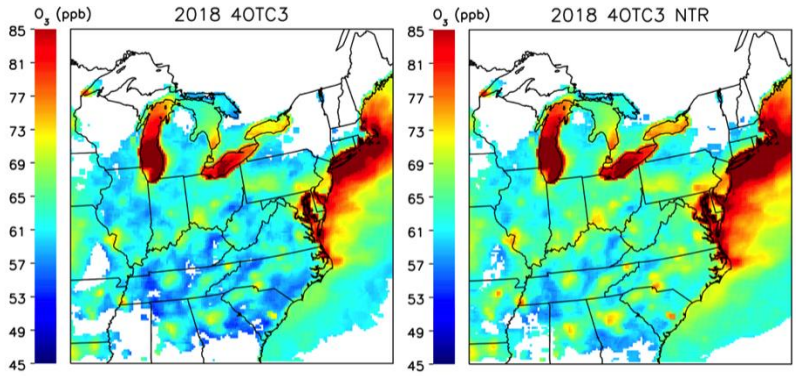


Figure 3.13. Same as Figure 3.7 except baseline and NTR simulations are for Scenario 4OTC3

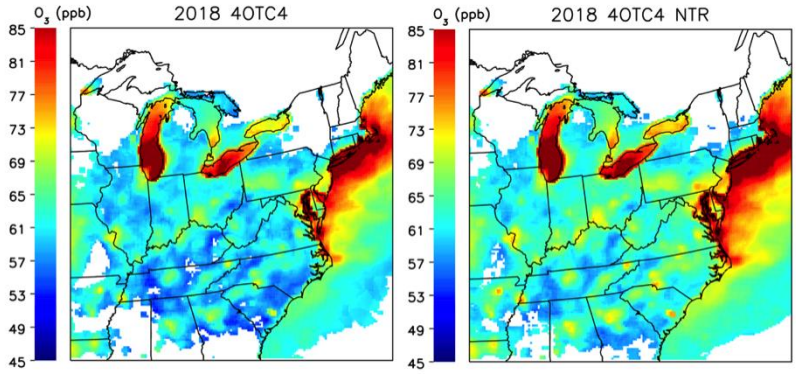


Figure 3.14. Same as Figure 3.7 except baseline and NTR simulations are for Scenario 4OTC4

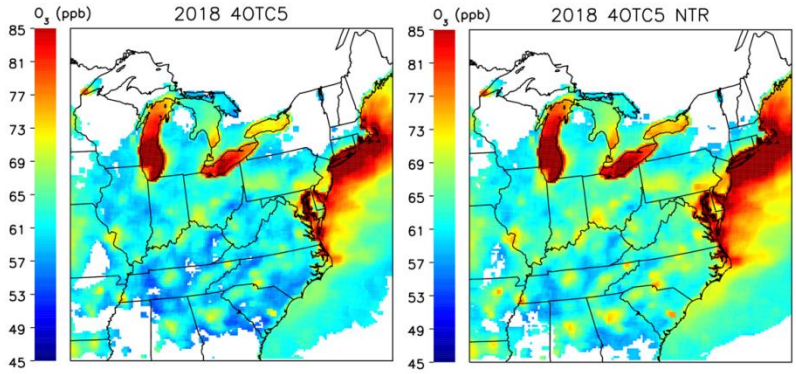


Figure 3.15. Same as Figure 3.7 except baseline and NTR simulations are for Scenario 4OTC5

How the results of these model simulations propagate through to the calculated 2018 models design values for Maryland is shown in Tables 3.6 and 3.7. As with the scenario 4 series of runs, none of the 4OTC models place the Edgewood monitor into attainment.

Table 3.6: Observed design values in Maryland for 2011 and calculated design values for the Scenario 4OTC, 4OTC1, and 4OTC2 series of model simulations. Red shaded boxes indicate O_3 levels above the 75 ppb standard. Values in red text are above 75 ppb but, when truncated, will satisfy attainment.

County	Site	DV 2011	DV 2018	DV 2018 NTR	4 OTC	4OTC NTR	4OTC SCI	4OTC 1	4OTC 1 NTR	4OTC 2	4OTC 2 NTR
Anne Arundel	Davidsonville	83	72.3	73.4	70.5	71.6	72.5	70.8	71.9	70.5	71.7
Baltimore	Padonia	79	70.8	71.5	69.1	69.8	70.5	69.3	70.0	69.1	69.8
Baltimore	Essex	80.7	74.3	74.5	73.0	73.2	73.3	73.2	73.4	73.0	73.2
Calvert	Calvert	79.7	72.3	73.0	70.8	71.6	73.0	71.0	71.8	70.8	71.6
Carroll	South Carroll	76.3	68.3	68.8	66.7	67.2	68.6	66.8	67.3	66.7	67.2
Cecil	Fair Hill	83	74.6	**75.3**	72.8	73.5	74.8	73.0	73.7	72.8	73.5
Calvert	S.Maryland	79	70.4	71.3	69.0	69.9	70.8	69.1	70.0	69.0	69.9
Cambridge	Blackwater	**75**	67.3	68.2	66.2	67.1	68.1	66.3	67.3	66.2	67.2
Frederick	Frederick Airport	76.3	68.1	69.0	66.3	67.2	68.3	66.4	67.4	66.3	67.2
Garrett	Piney Run	72	61.7	62.5	60.2	61.1	61.3	60.2	61.1	60.2	61.1
Harford	Edgewood	90	82.1	82.7	80.7	81.3	82.2	80.9	81.5	80.7	81.3
Harford	Aldino	79.3	70.7	71.5	68.9	69.8	70.9	69.1	70.0	68.9	69.8
Kent	Millington	78.7	70.5	71.3	68.9	69.7	70.9	69.1	69.9	68.9	69.8
Montgomery	Rockville	**75.7**	66.5	67.2	64.8	65.5	65.7	65.0	65.7	64.8	65.5
PG	HU-Beltsville	79	68.4	69.3	66.6	67.6	67.9	66.9	67.9	66.6	67.6
PG	PG Equest.	82.3	71.8	72.9	70.0	71.2	71.9	70.3	71.4	70.0	71.2
PG	Beltsville	80	69.6	70.3	67.7	68.6	69.7	68.1	68.9	67.7	68.6
Washington	Hagerstown	72.7	64.3	65.1	62.8	63.7	64.4	62.9	63.8	62.8	63.7
Baltimore City	Furley	73.7	67.5	67.8	66.3	66.5	66.8	66.5	66.8	66.3	66.6

Table 3.7: Observed design values in Maryland for 2011 and calculated design values for the Scenario 4OTC3, 4OTC4, and 4OTC5 series of model simulations. Red shaded boxes indicate O_3 levels above the 75 ppb standard. Values in red text are above 75 ppb but, when truncated, will satisfy attainment.

County	Site	DV 2011	DV 2018	DV 2018 NTR	4OTC3	4OTC3 NTR	4OTC4	4OTC4 NTR	4OTC5	4OTC5 NTR
Anne Arundel	Davidsonville	83	72.3	73.4	71.7	72.7	70.1	71.3	71.5	72.5
Baltimore	Padonia	79	70.8	71.5	69.9	70.5	68.7	69.4	69.7	70.3
Baltimore	Essex	80.7	74.3	74.5	73.7	74.0	72.8	73.0	73.6	74.0
Calvert	Calvert	79.7	72.3	73.0	71.6	72.3	70.5	71.3	71.5	72.2
Carroll	South Carroll	76.3	68.3	68.8	67.1	67.7	66.2	66.7	66.9	67.5
Cecil	Fair Hill	83	74.6	**75.3**	73.5	74.2	72.3	73.1	73.3	74.0
Calvert	S.Maryland	79	70.4	71.3	69.6	70.5	68.4	69.3	69.4	70.3
Cambridge	Blackwater	**75**	67.3	68.2	66.7	67.7	65.7	66.6	66.6	67.5
Frederick	Frederick Airport	76.3	68.1	69.0	66.7	67.6	65.7	66.7	66.5	67.5
Garrett	Piney Run	72	61.7	62.5	60.2	61.1	59.6	60.5	60.1	61.0
Harford	Edgewood	90	82.1	82.7	81.5	82.1	80.3	81.0	81.4	82.0
Harford	Aldino	79.3	70.7	71.5	69.9	70.8	68.5	69.5	69.7	70.6
Kent	Millington	78.7	70.5	71.3	69.6	70.4	68.5	69.4	69.4	70.3
Montgomery	Rockville	**75.7**	66.5	67.2	65.7	66.4	64.3	65.1	65.5	66.2
PG	HU-Beltsville	79	68.4	69.3	67.8	68.7	66.2	67.2	67.5	68.4
PG	PG Equest.	82.3	71.8	72.9	71.1	72.2	69.6	70.8	70.9	72.0
PG	Beltsville	80	69.6	70.3	68.9	69.7	67.4	68.2	68.7	69.4
Washington	Hagerstown	72.7	64.3	65.1	63.2	64.0	62.3	63.2	63.0	63.9
Baltimore City	Furley	73.7	67.5	67.8	67.0	67.3	66.1	66.4	67.0	67.2

Scenario 4MD Attainment Series: These simulations investigate power plant controls in Maryland. These scenarios add controls to Maryland EGUs to the 4OTC model framework.

The 4MD1 model run includes 2018 ozone season optimized EGUs (Phase 1) in Maryland. While O_3 decreases are most noticeable in MD (Figure 3.16), benefits are also expected downwind. Differences are only shown when O_3 changes by more than 0.05 ppb.

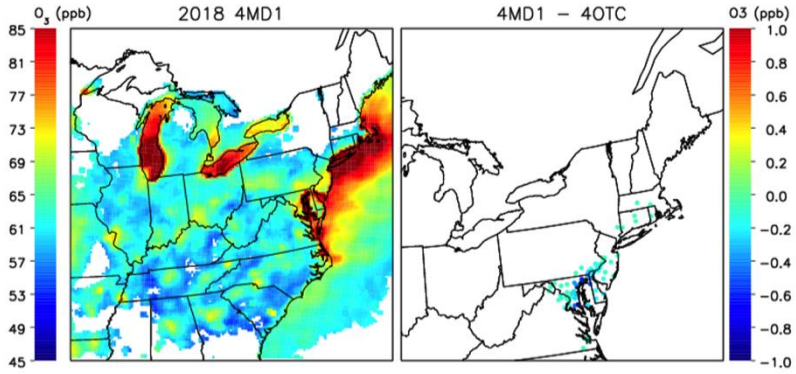


Figure 3.16. Average maximum 8hr O_3 for July 2011 for the 4MD1 attainment CMAQ run (left panel). The expected difference in O_3 between the 4MD1 and 4OTC runs at the location of surface monitoring sites.

The 4MD2A scenario builds on 4MD1 and assumes a fuel switch from coal to natural gas (Figure 3.17).

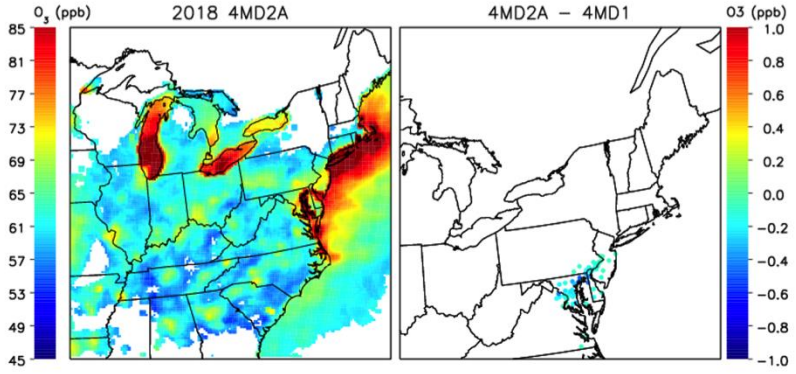


Figure 3.17. Average maximum 8hr O_3 for July 2011 for the 4MD2A attainment CMAQ run (left panel). The expected difference in O_3 between the 4MD2A and 4MD1 runs at the location of surface monitoring sites.

In scenario 4MD2B, a 21 ton-per-day NOX, system-wide mass cap was applied as well as a 0.09 lb./mmBtu 30-day rolling cap to the Raven and NRG systems. Benefits are noticeable downwind of Maryland as far as Massachusetts (Figure 3.18).

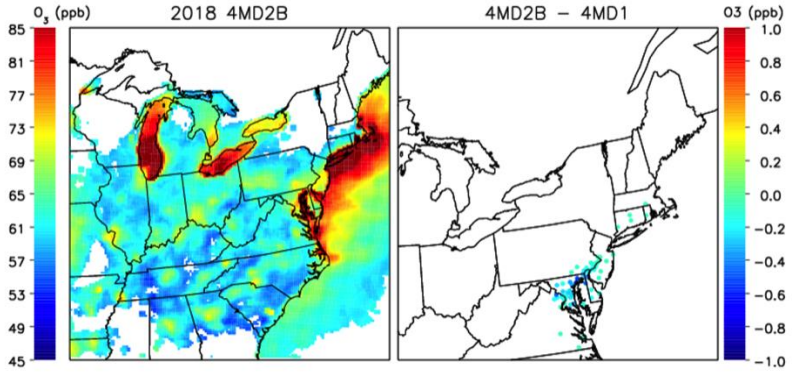


Figure 3.18. Average maximum 8hr O_3 for July 2011 for the 4MD2B attainment CMAQ run (left panel). The expected difference in O_3 between the 4MD2B and 4MD1 runs at the location of surface monitoring sites.

Scenario 4MD2D assumed a 0.11 lb./mmBtu 30-day rolling cap for Raven and NRG power stations. These controls have a highly localized effect (Figure 3.19).

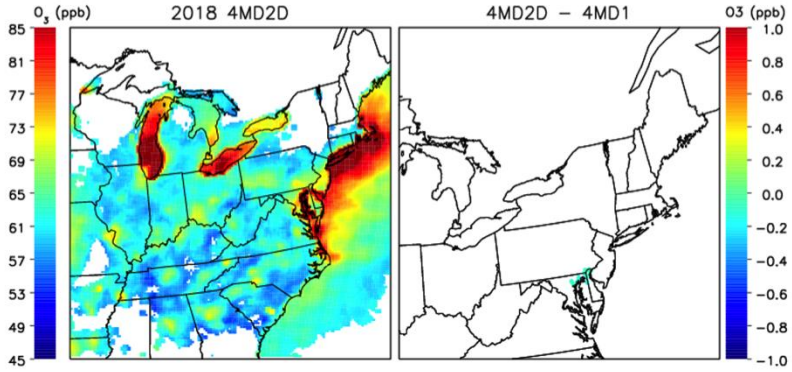


Figure 3.19. Average maximum 8hr O_3 for July 2011 for the 4MD2D attainment CMAQ run (left panel). The expected difference in O_3 between the 4MD2D and 4MD1 runs at the location of surface monitoring sites.

When reductions from cutting-edge mobile efforts are included (Figure 3.20), there is very little effect on surface ozone.

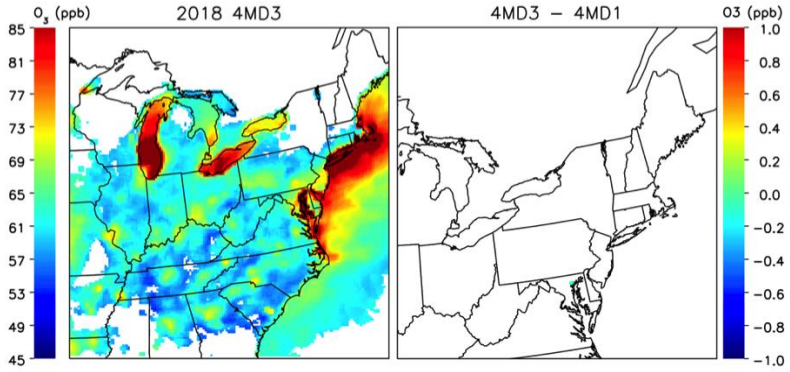


Figure 3.20. Average maximum 8hr O_3 for July 2011 for the 4MD3 attainment CMAQ run (left panel). The expected difference in O_3 between the 4MD3 and 4MD1 runs at the location of surface monitoring sites.

Calculated design values in Maryland for July 2018 based on these various simulations are shown in Table 3.8.

Table 3.8: Observed design values in Maryland for 2011 and calculated design values for the Scenario 4MD, July model simulations. Red shaded boxes indicate O_3 levels above the 75 ppb standard. Values in red text are above 75 ppb but, when truncated, will satisfy attainment.

County	Site	DV 2011	DV 2018	4OTC	4MD1	4MD2-A	4MD2-B	4MD2-D	4MD3
Anne Arundel	Davidsonville	83	72.3	70.5	70.2	70.0	70.0	70.2	70.2
Baltimore	Padonia	79	70.8	69.1	68.7	68.4	68.3	68.6	68.7
Baltimore	Essex	80.7	74.3	73.0	72.7	72.4	72.4	72.6	72.6
Calvert	Calvert	79.7	72.3	70.8	70.2	67.0	69.9	70.2	70.2
Carroll	South Carroll	76.3	68.3	66.7	66.6	66.5	66.5	66.6	66.6
Cecil	Fair Hill	83	74.6	72.8	72.4	72.0	72.0	72.3	72.3
Calvert	S.Maryland	79	70.4	69.0	68.5	68.3	68.2	68.5	68.5
Cambridge	Blackwater	75	67.3	66.2	66.1	66.0	66.0	66.1	66.0
Frederick	Frederick Airport	76.3	68.1	66.2	66.2	66.0	65.9	66.2	66.2
Garrett	Piney Run	72	61.7	60.2	60.2	60.2	60.2	60.2	60.2
Harford	Edgewood	90	82.1	80.7	80.1	79.7	79.7	80.0	80.1

Harford	Aldino	79.3	70.7	68.9	68.4	68.0	68.0	68.3	68.4
Kent	Millington	78.7	70.5	68.9	68.4	68.0	68.0	68.3	68.4
Montgomery	Rockville	75.7	66.5	64.8	64.7	64.5	64.4	64.7	64.7
PG	HU-Beltsville	79	68.4	66.6	66.5	66.4	66.4	66.5	66.5
PG	PG Equest.	82.3	71.8	70.0	69.8	69.6	69.5	69.8	69.7
PG	Beltsville	80	69.6	67.7	67.5	67.3	67.2	67.5	67.5
Washington	Hagerstown	72.7	64.3	62.8	62.8	62.8	62.8	62.8	62.8
Baltimore City	Furley	73.7	67.5	66.3	66.1	65.9	65.9	66.0	66.1

Biogenic Emissions Update

Biogenic emissions play an integral role in O3 production with isoprene being the most important VOC in our region. The 2007 modeling platform used biogenic output from the Model of Emissions of Gases and Aerosols from Nature (MEGAN). The 2011 platform uses the Biogenic Emission Inventory System (BEIS) model to generate biogenic emissions. Previously, UMD ran the "scenario 3" series of attainment runs that included BEIS v3.14. The simulations performed for this contract included BEIS v3.6 and BEIS 3.61. Figure 3.21 shows the emissions of isoprene at the surface on July 22, 2011 as determined by BEIS v3.6 and 3.61 and MEGAN v2.10.

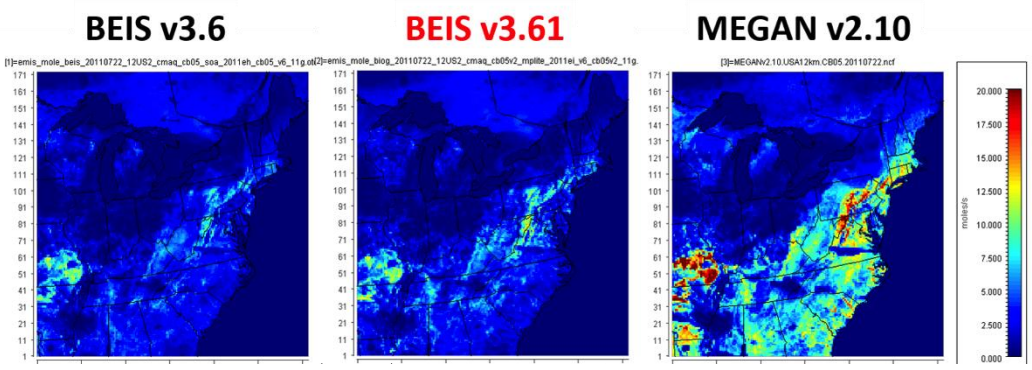


Figure 3.21 Surface isoprene emissions for July 22, 2011 as generated by the BEIS v3.6 (left panel), BEIS v3.61 (center panel), and MEGAN v2.10 (right panel).

BEIS v3.61 includes improvement to canopy representation and higher resolution land use data based on satellite retrievals from the Moderate Resolution Imaging Spectroradiometer (MODIS) satellite instrument. The effect this has on average maximum 8hr ozone between two baseline

simulations for 2011 is shown in Figure 3.22. Most rural areas within the domain experience a decrease in surface ozone. This is not the case for many urban regions where ozone rises when BEIS 3.61 is used to generate biogenic emissions.

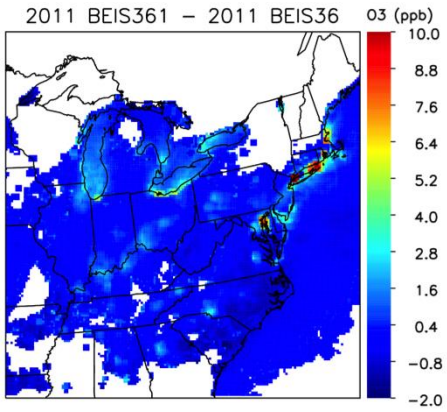


Figure 3.22. The difference in averaged maximum 8hr ozone for July 2011 between two baseline model simulations where biogenic emissions were calculate using either BEIS 3.6 or BEIS 3.61.

Differences in surface O_3 for 2018 baseline simulations using either of the BEIS products show similar patterns. Design value for 2018 for these model runs are provided in Tables 3.9 and 3.10. The use of the updated BEIS output has a modest impact on the relative change in O_3 for Maryland. Simply put, the relative change in ozone does not vary much regardless of which biogenics model is used. More significant changes in surface O_3 occur at some of the problem attainment and maintenance monitors when biogenic emissions are improved (Table 3.10) with the largest differences in NY and CT.

Table 3.9 Observed design values in Maryland for 2011 and calculated design values for a July 2018 baseline simulation that uses the prior version of BEIS (v3.6) and a July 2018 simulation the uses BEIS v3.61. Red shaded boxes indicate O_3 levels above the 75 ppb standard. Values in red text are above 75 ppb but, when truncated, will satisfy attainment.

County	Site	DV 2011	DV 2018 BEIS v3.6	DV 2018 BEIS v3.61
Anne Arundel	Davidsonville	83	72.3	71.9
Baltimore	Padonia	79	70.8	70.5
Baltimore	Essex	80.7	74.3	73.5
Calvert	Calvert	79.7	72.3	72.4
Carroll	South Carroll	76.3	68.3	68.3
Cecil	Fair Hill	83	74.6	74.6
Calvert	S.Maryland	79	70.4	70.5
Cambridge	Blackwater	75	67.3	67.6
Frederick	Frederick Airport	76.3	68.1	68.2
Garrett	Piney Run	72	61.7	61.5
Harford	Edgewood	90	82.1	81.9
Harford	Aldino	79.3	70.7	70.7
Kent	Millington	78.7	70.5	70.5
Montgomery	Rockville	75.7	66.5	66.1
PG	HU-Beltsville	79	68.4	68.0
PG	PG Equest.	82.3	71.8	71.4
PG	Beltsville	80	69.6	69.0
Washington	Hagerstown	72.7	64.3	64.2
Baltimore City	Furley	73.7	67.5	67.3

Table 3.10 Observed design values at attainment and maintenance monitors for 2011 and calculated design values for a July 2018 baseline simulation that uses the prior version of BEIS (v3.6) and a July 2018 simulation the uses BEIS v3.61. Red shaded boxes indicate O3 levels above the 75 ppb standard. Values in red text are above 75 ppb but, when truncated, will satisfy attainment.

County, State	AQS #	Design Value 2011	DV 2018 BEIS v3.6	DV 2018 BEIS v3.61
Attainment Problems - 2018				
Harford, MD	240251001	90.0	82.1	81.9
Fairfield, CT	090013007	84.3	77.9	76.5
Fairfield, CT	090019003	83.7	85.4	83.0
Suffolk, NY	361030002	83.3	81.1	77.5
Maintenance Problems - 2018				
Fairfield, CT	090010017	80.3	81.0	75.8
New Haven, CT	090099002	85.7	77.6	77.1
Camden, NJ	340071001	82.7	73.0	73.1
Gloucester, NJ	340150002	84.3	75.3	75.3
Richmond, NY	360850067	81.3	78.3	78.6
Philadelphia, PA	421010024	83.3	75.1	74.2

3b CAMx Model Simulations

D. Goldberg et al.

Model Set-Up

The studies described here focus on month-long simulations of July using CAMx version 6.10 with 35 vertical layers and 12 km horizontal resolution. The baseline simulation was conducted for July 2011, using emissions and meteorological fields prepared for the summer of 2011. We also present simulations conducted using projected emissions for July 2018 based on July 2011 meteorology, and a modified "Beta" inventory in which NO_x emissions from mobile sources were decreased by 50% (Anderson *et al.*, 2014). Biogenic emissions prepared using the MEGAN model were used instead of BEIS. The overall effect of this change is a non-uniform increase in isoprene emissions from biogenic sources. The model domain covers the area depicted in Figure 3b1, split into 12 km x 12 km grid cells (not shown).

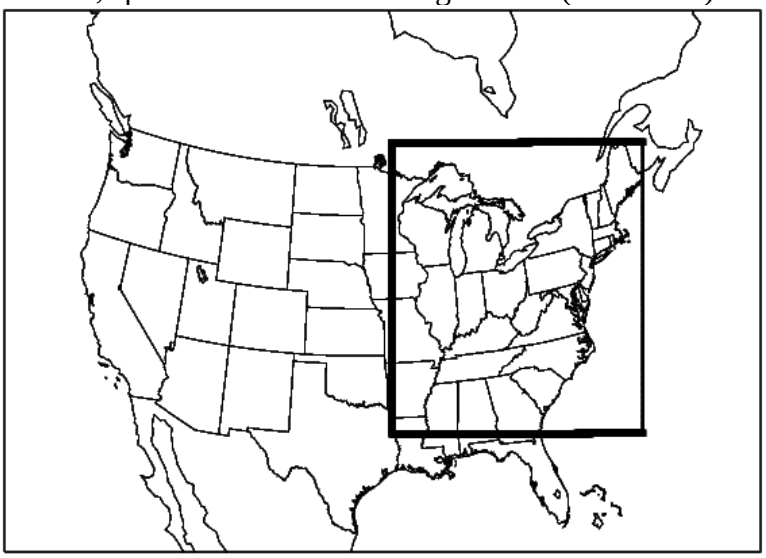


Figure 3b.1. CAMx v6.10 model domain as denoted by the dark black line, 12 km horizontal resolution

Prediction of 2018 Ozone Design Values

Previous annual reports have addressed the model biases of CAMx in simulating ozone; biases for simulating mean monthly maximum daily averaged 8-hour ozone (MDA8) ozone are less than 2 ppb across Maryland during July 2011. However, model biases on any one particular day can exceed 15 ppb [2015 report].

Ozone design values are predicted to decrease across Maryland – some locations may see greater decreases than others – by 2018. Predicted 2018 ozone design values are denoted in Table 3b.1. In 2018, ten monitoring sites are predicted to exceed the 70-ppbv NAAQS threshold. The source receptor at Edgewood, MD is still the only location in Maryland to exceed the old 75 ppbv NAAQS. Edgewood is projected to be at 82.4 ppbv using CAMx and 82.1 ppbv using CMAQ.

Table 3b.1. Observed Ozone Design Values for 2011 and model design values for 2018. 2018 Design values are projected based on CAMx v6.10 and CMAQ v5.02 simulations with version 2 NEI emissions.

Maryland Monitoring Location	County	Observed 2011 DV (ppb)	CAMx 2018 Version 2 Emissions Baseline (ppb)	CMAQ 2018 Version 2 Emissions Baseline (ppb)
Davidsonville	Anne Arundel	83.0	72.4	72.3
Padonia	Baltimore	79.0	71.6	70.8
Essex	Baltimore	80.7	74.4	74.3
Calvert	Calvert	79.7	72.9	72.3
South Carroll	Carroll	76.3	68.2	68.3
Fair Hill	Cecil	83.0	74.8	74.6
Southern Maryland	Charles	79.0	70.8	70.4
Frederick Airport	Frederick	76.3	68.4	68.1
Piney Run	Garrett	72.0	62.9	61.7
Edgewood	Harford	90.0	82.4	82.1
Aldino	Harford	79.3	72.3	70.7
Millington	Kent	78.7	70.9	70.5
Rockville	Montgomery	76.3	68.1	66.5
HU-Beltsville	Prince George's	79.0	69.0	68.4
PG Equestrian Center	Prince George's	82.3	71.8	71.8
Hagerstown	Washington	72.7	65.0	64.3
Furley	Baltimore City	73.7	68.4	67.5

Anthropogenic Precursor Culpability Assessment (APCA)

We use the Anthropogenic Precursors Culpability Assessment (APCA) software to attribute ozone to different source regions and source sectors. APCA is similar to the Ozone Source Apportionment Tool (OSAT) software in its ability to attribute ozone to particular sources, but a shortcoming of the OSAT software is its inability to attribute ozone in anthropogenic/biogenic interactions to the controllable (i.e., anthropogenic) source. For example, if biogenic VOCs react with NO_x in a NO_x–saturated production environment to create ozone (e.g., downtown Baltimore), OSAT would determine that the non-controllable biogenic VOCs are responsible. While this may be true from a scientific perspective, this masks the real reason why ozone was produced: NO_x concentrations were large. Instead, the APCA software attributes anthropogenic/biogenic interactions to the controllable, anthropogenic source. Biogenic VOCs are only responsible for ozone production when reacting with biogenic sources from NO_x.

Using APCA, instead of OSAT, causes more ozone formation to be attributed to anthropogenic sources and less to biogenic sources, as shown in 3b. 2. In the left side panel, we use OSAT to attribute ozone to different source sectors. During the late morning (~11 AM) approximately 15 ppbv of ozone is attributed to biogenic sources. In the right side panel, we use APCA. During the late morning (~11 AM) only 2 ppbv of ozone is attributed to biogenic sources. At this location, we can presume that environmental conditions during the late morning

are NO_x-saturated and that OSAT attributes ozone to the biogenic source. When switching to APCA we show a better conceptual representation of the anthropogenic sources responsible for the ozone formation. It is also important to denote that calculations of total ozone (i.e. the top of bar) and boundary condition ozone (i.e., black bar) are not affected by the probing strategy utilized.

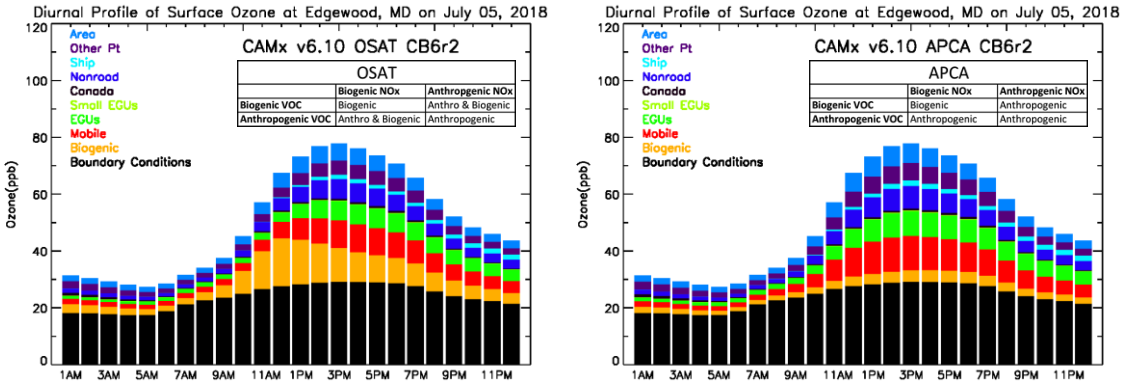
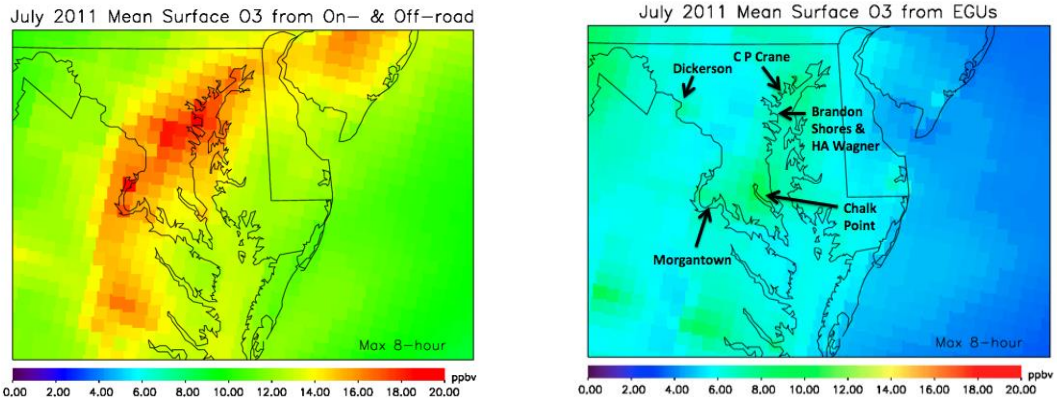


Figure 3b.2. Diurnal pattern of ozone source attribution at the Edgewood, MD site for the July 5, 2018 projected scenario using (left) OSAT and (right) APCA.

APCA is particularly useful in calculating ozone attribution to grouped source sectors. In Figure 3b.3, we show APCA ozone attribution to on-road and off-road mobile sources (i.e., cars and trucks), electricity generating units (EGUs), non-road mobile sources (i.e., construction vehicles, farm equipment, recreational marine, etc.), and large marine vessels (C3 marine).



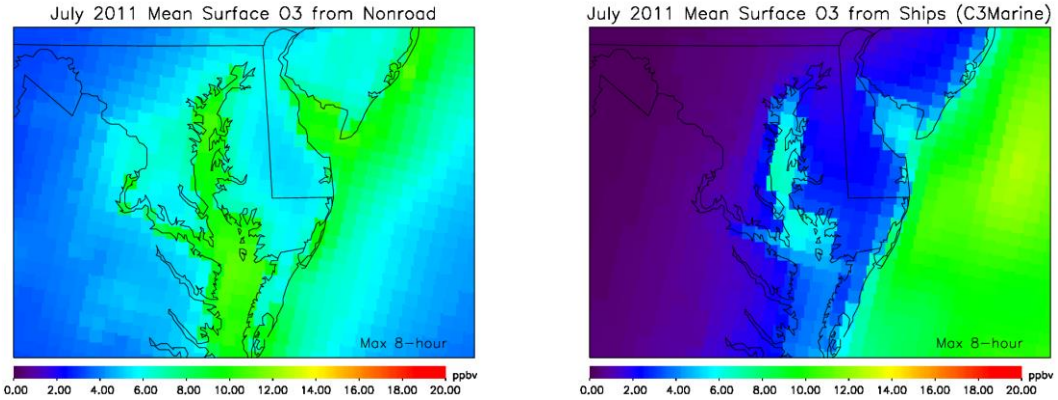


Figure 3b.3. APCA source attribution from the baseline simulation for mean 8-hour maximum ozone during July 2011 for the following source sectors: (top left) on- and off-road mobile sources, (top right) electricity generating units, (bottom left) nonroad mobile sources, and (bottom right) large marine vessels.

Ozone Transport Patterns

The Cross-State Air Pollution Rule (CSAPR) says that any state contributing more than 1% to a downwind monitor in a different state must reduce their emissions so that the monitor will achieve attainment of the ozone NAAQS. In Figure 3b.4 we show states responsible for pollution at the Edgewood, MD monitor; the states vary by transport pattern. For example, on westerly transport days, Pennsylvania is the second largest individual state (behind Maryland) contributing to the ozone problem at Edgewood. However, on southerly transport days, Virginia is the second largest contributor.

This analysis is particularly important for states that are near the 1% contribution threshold. For example, during the summer of 2011, the state of North Carolina did not contribute more than 1% towards pollution at Edgewood, but on days with southerly winds, North Carolina's contribution well exceeds the 1% contribution threshold. By constraining meteorology in future year scenarios, we assume perhaps incorrectly that wind patterns in future years remain identical to the baseline year (in this case 2011).

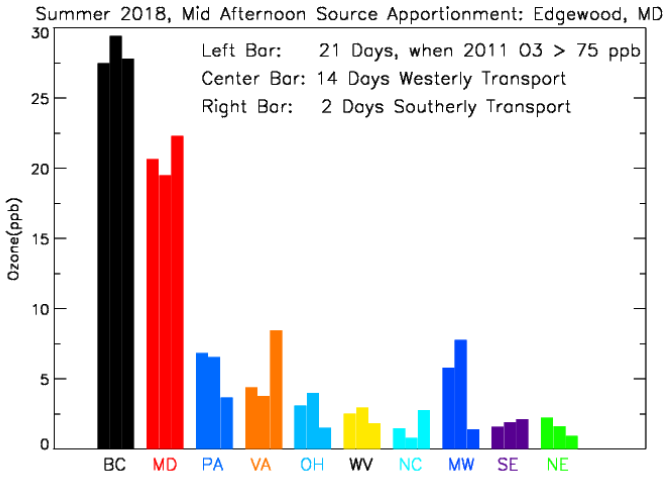


Figure 3b.4. Mid-afternoon source apportionment for ozone at Edgewood, MD from CAMxv6.10 for days when 2011 ozone exceeded 75 ppbv. The left bars show the average of all 21 days, the center bars show the average of 14 days with westerly transport, and the right bars show the average of 2 days with southerly transport.

Updated "Beta" Model Platform

We also performed CAMx simulations on an updated model platform, which uses an updated emission inventory and an updated chemical mechanism [e.g., Canty et al., [2015]). Anderson et al. [2014] shows evidence for a large overestimate in the 2011 NOx national emissions inventory (NEI). There is strong scientific basis to link the overestimate in the NO_x emissions inventory to mobile source emissions since they represent more than 50% of the NO_x emissions inventory. We keep emissions from EGUs identical to the baseline simulation because the NEI is developed from observed Continuous Emissions Monitoring System (CEMS) data. There is also strong scientific evidence showing that the BEISv3.6 biogenic emission simulator underestimates isoprene emissions [Goldberg et al., 2016]. We therefore update biogenic emissions to an inventory using MEGAN v2.1 [Guenter et al., 2012]. Lastly we update the gas-phase chemical mechanism from an outdated version, CB05 [Yarwood, 2005], to a more recent version, CB6r2 [Hildebrandt-Ruiz and Yarwood, 2014].

Figure 3b.5 depicts ozone attributed to emissions from individual states (denoted by color) as well as from various source sectors (each histogram). Results are shown for both the (left) baseline and (right) Beta simulations for the ten worst air quality days in July 2011 at Edgewood, Maryland. We have chosen to focus on Edgewood (the location shown as the filled circle in Figure 7) because this site causes the Baltimore region to be in moderate non-attainment of the 2008 NAAQS for ozone [EPA, 2014].

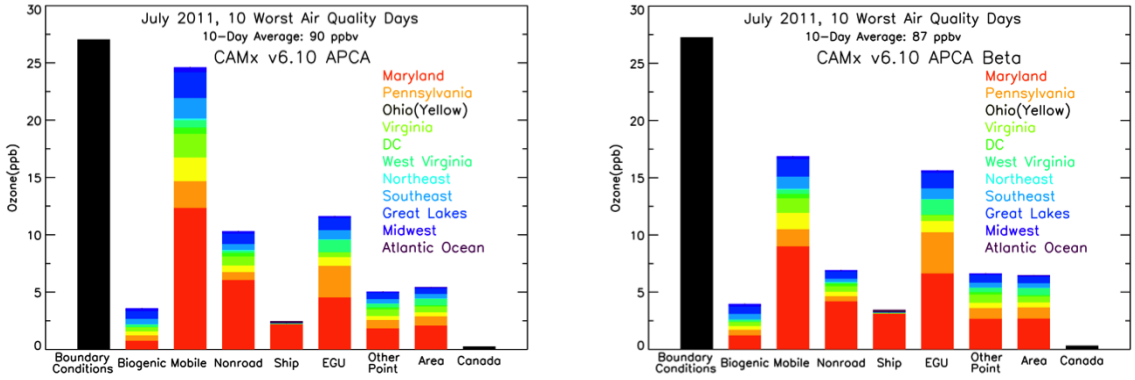


Figure 3b.5. Ozone attributed to source sectors separated by state during the ten worst air quality days in July 2011 at 2 PM local time at the Edgewood, MD monitoring site which is located 30 km east-northeast of Baltimore for the (left) baseline simulation and (right) updated chemistry and emissions scenario.

In the baseline simulation (Figure 3b.5, left) – generated from the 2011 NEI – on-road sources are responsible for the largest portion (24.6 ppbv) of total surface ozone. Ozone attributed to electric generating units (EGUs) accounts for the second largest single sector (11.6 ppbv) during the ten worst air quality days at Edgewood. The NEI indicates EGUs are responsible for 14% of total NO_x emissions, and 11% within the state of Maryland.

In the Beta simulation (Figure 3b5, right) more ozone is attributed to EGUs and less ozone to mobile sources. While on-road mobile sources are still the primary individual source sector contributing to surface ozone, they are responsible for 7.7 ppbv less ozone compared to the baseline simulation: 24.6 ppbv to 16.9 ppbv, a drop of 31.4%. Ozone attributed to non-road sources also shows a similar percentage drop. Despite identical emissions of NO_x from EGUs in the two simulations, electricity generation is responsible for 4.0 ppbv more ozone in the Beta run, increasing from 11.6 to 15.6 ppbv, a 34.6% increase. The ozone attributed to EGU emissions shows a large increase because CB6r2 gas-phase chemistry has faster photolysis of NO_2 than CB05 and increased modeled HO_2 and RO_2 concentrations driven by greater biogenic emissions from MEGAN v2.1. This implies greater ozone production efficiency, a topic to be treated in a separate paper. For the Beta simulation, EGUs and on-road mobile sources are now responsible for roughly the same fraction of surface ozone in Maryland. The change in surface ozone attribution to on-road mobile and EGU sources for the baseline compared to the Beta simulation is similar throughout the eastern United States for July 2011 (Figure 3b.6).

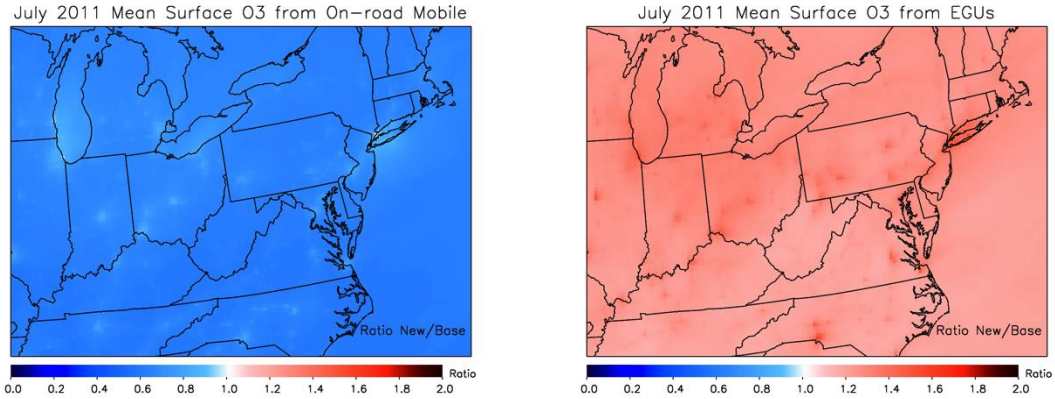


Figure 3b.6. The fractional change in surface ozone from on-road mobile sources (left) and Electricity Generation Units [EGUs] (right) during July 2011 due to the change from the baseline model to the updated "Beta" model. Cool (warm) colors show where the change led to a decrease (increase) in the importance of each source.

The overestimate of NO_y and underestimate of HCHO for the baseline simulation [Goldberg et al., 2016] suggests that ozone in the original model framework may be produced in a more VOC-limited ozone production regime than occurs in the actual atmosphere, even though NO_x remains the key pollutant. We use an OSAT simulation to calculate the amount of ozone formed in NO_x-limited and VOC-limited environmental conditions. Figure 3b.7 shows the percentage of ozone production attributed to a NO_x-limited ozone regime. In the baseline simulation, 65 – 85% of ozone in the Baltimore vicinity is attributed to a NO_x-limited environment.

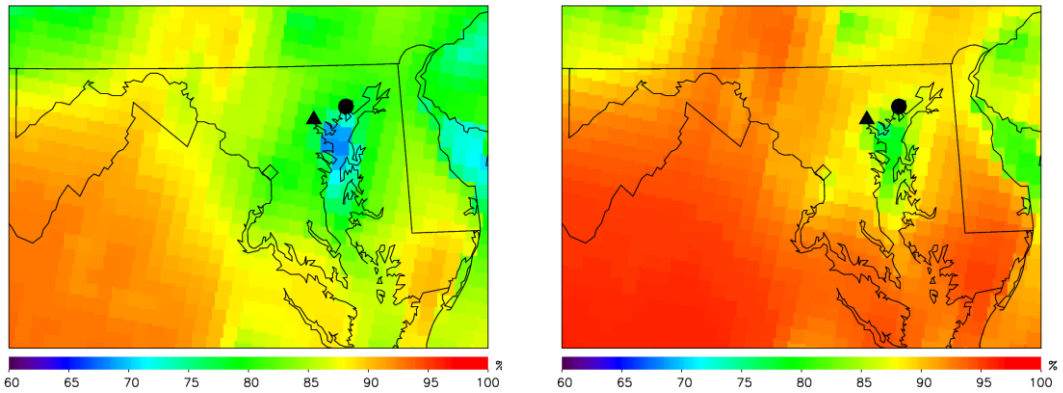


Figure 3b.7. Percentage of ozone formed in a NO_x–limited production regime during July 2011 daytime mean (8 AM – 8 PM local time) at each model grid point in the (left) baseline simulation and (right) updated chemistry and emissions scenario.

The updated Beta simulation uniformly shows more ozone production in a NO_x-limited regime. The biggest differences occur over the Chesapeake Bay. The Beta simulation shows 80 – 95% of ozone is produced in a NO_x-limited environment in the Baltimore vicinity. Instead of being in the "transition region" – the region on the EKMA diagram in which ozone production occurs due to both VOC and NO_x

limitation – the area is now squarely in a region of NO_x-limited ozone production. This is consistent with observed changes in ozone resulting from NO_x emission reductions [Gilliland et al., 2008].

Additional information

Please see Goldberg et al. [2015], Goldberg et al. [2016] and Goldberg Dissertation [2015] for further details.

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4. Measurements

RAMMPP-Measurements Accomplishments Report 2015
Xinrong Ren, Gina Mazzuca, Dolly Hall, and Russell R. Dickerson

Highlights

- A box model based on Regional Atmospheric Chemistry Mechanism Version 2 (RACM2) was used to study ozone production and its sensitivity to NOx and VOC during DISCOVER-AQ 2011 in Baltimore/Washington.
- In Baltimore/Washington, for most of time periods, ozone production was in the NOx sensitive regime, while the highest ozone production occurred in the morning in the VOC sensitive regime when NOx levels were high.
- $P(O_3)$ ranged from 0 to 50 ppb hr^{-1} and showed NOx dependence as we would expect.
- Limited flights (funded separately) to and from the Marcellus oil and natural gas operation area to the west of Maryland show the transport of air pollution into Maryland.

Overview

Understanding the non-linear relationship between ozone production and its precursors is critical for the development of an effective ozone (O_3) control strategy. Despite great efforts undertaken in the past decades to address the problem of high ozone concentrations, our understanding of the key precursors that control tropospheric ozone production remains incomplete and uncertain. Atmospheric ozone levels are determined by emissions of ozone precursors, atmospheric photochemistry, and dispersion. A major challenge in regulating ozone pollution lies in comprehending its complex and non-linear chemistry with respect to ozone precursors, i.e., nitrogen oxides (NOx) and volatile organic compounds (VOCs) that varies with time and location (Figure 4.1). Understanding of the non-linear relationship between ozone production and its precursors is critical for the development of an effective ozone control strategy.

Sensitivity of ozone production to NOx and VOCs represents a major uncertainty for oxidant photochemistry in urban areas. Depending on physical and chemical conditions, the production of ozone can be either NOx-sensitive or VOC-sensitive due to the complexity of these photochemical processes. Therefore, effective ozone control strategies rely heavily on the accurate understanding of how ozone responds to reduction of NOx and VOC emissions, usually simulated by photochemical air quality models. However, those model-based studies have inputs or parameters subject to large uncertainties that can affect not only the simulated levels of ozone but also the ozone dependence on its precursors.

In this work, we provide an investigation of spatial and temporal variations of ozone production and its sensitivity to NOx and VOCs to provide a scientific basis to develop a non-uniform emission reduction strategy for O_3 pollution control in urban and suburban areas such as the Baltimore metropolitan area. Observations made during the Deriving Information on Surface Conditions from COlumn and VERtically Resolved Observations Relevant to Air Quality (DISCOVER-AQ) campaign in Maryland in July 2011 were used. This field campaign is well

suited due to the comprehensive air sampling performed over a large spatial (urban and suburban areas in and around Baltimore) and temporal (entire month of July 2011) range.

4.1. Ozone production Scenarios and Sensitivity

During the day, the photochemical O_3 production rate is essentially the production rate of NO_2 molecules from HO_2 + NO and RO_2 + NO reactions [Finlayson-Pitts and Pitts, 2000]. The net instantaneous photochemical O_3 production rate, $P(O_3)$, can be written approximately as the following equation:

$$P(O_3) = k_{HO_2+NO}[HO_2][NO] + \sum k_{RO_{2i}+NO}[RO_{2i}][NO] - k_{OH+NO_2+M}[OH][NO_2][M] - P(RONO_2)$$
$$-k_{HO_2+O_3}[HO_2][O_3] - k_{OH+O_3}[OH][O_3] - k_{O(^1D)+H_2O}[O(^1D)][H_2O] - L(O_3 + alkenes) \quad (1)$$

where the *k term*s are the reaction rate coefficients and RO_{2i} is the concentration of individual organic peroxy radicals. The negative terms in Eq. (1) correspond to the reaction of OH and NO_2 to form nitric acid, the formation of organic nitrates, $P(RONO_2)$, the reactions of OH and HO_2 with O_3, the photolysis of O_3 followed by the reaction of $O(^1D)$ with H_2O, and O_3 reactions with alkenes. Ozone is additionally destroyed by dry deposition.

The dependence of O_3 production on NO_x and VOCs can be categorized into two typical scenarios: NO_x sensitive and VOC sensitive (Figure 4.1). The method was used to evaluate the O_3 production sensitivity using the ratio of L_N/Q, where L_N is the radical loss via the reactions with NO_x and Q is the total primary radical production. Because the radical production rate is approximately equal to the radical loss rate, this L_N/Q ratio represents the fraction of radical loss due to NO_x. It was found that when L_N/Q is significantly less than 0.5, the atmosphere is in a NO_x-sensitive regime, and when L_N/Q is significantly greater than 0.5, the atmosphere is in a more VOC-sensitive regime. Note that the contribution of organic nitrates impacts the cut-off value for L_N/Q to determine the ozone production sensitivity to NO_x or VOCs and this value may vary slightly around 0.5 in different environments.

An observation-constrained box model with the Regional Atmospheric Chemistry Mechanism Version 2 (RACM2) was used to simulate the oxidation processes in Maryland during DISCOVER-AQ 2011. Measurements made on the P-3B were used as input to constrain the box model. From the box model results, the ozone production rate and its sensitivity to NO_x and VOCs were calculated allowing us to calculate ozone production efficiency at different locations and at different times of day.

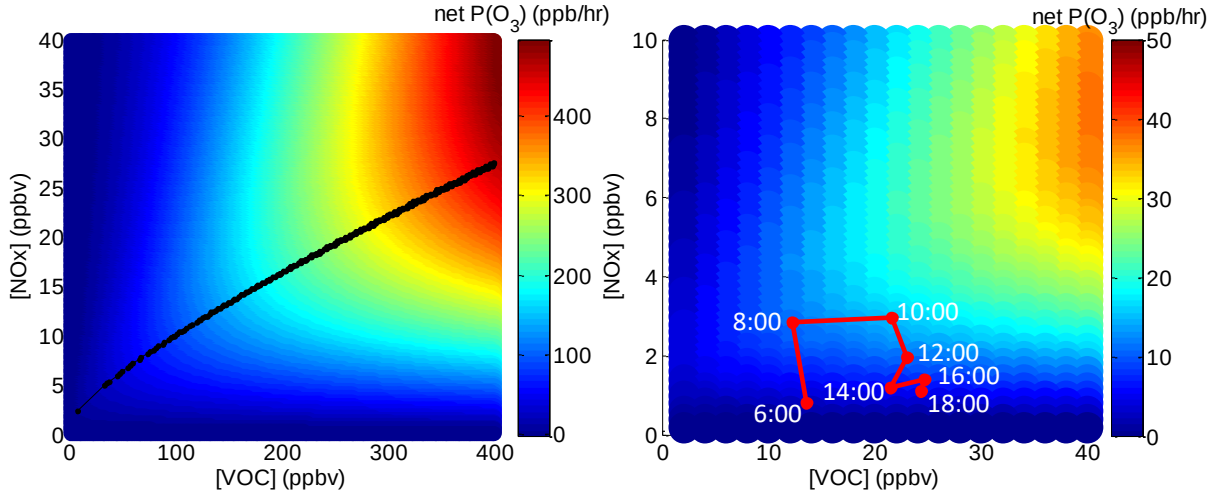

Figure 4.1. *Left:* ozone production empirical kinetic modeling approach (EKMA) diagram using a box model results with NOx levels varying from 0-40 ppbv and VOC levels from 0-400 ppbv while the mean concentrations of other species and the speciation of NOx and VOCs observed during DISCOVER-AQ in Maryland in 2011 were used to constrain the box model. This diagram clearly shows the sensitivity of ozone production to NOx and VOCs in Maryland. The black line shows the maximum P(O3) at given [NOx] and [VOC]. Right: a zoom-in P(O_3) EKMA diagram with NOx levels varying from 0-10 ppbv and VOC levels from 0-40 ppbv. The red linked dots shows the NOx and VOC levels measured on the NASA P-3B during DISCOVER-AQ 2011 at different times (local standard time) of day.

4.2. Photochemical O_3 Production Rate

Figure 4.2 shows the net ozone production rate, net P(O_3), calculated using the box model results along the P-3B flight track for all flight days during the Maryland deployment of DISCOVER-AQ. There are several P(O_3) hotspots over the Baltimore and Washington area. This is expected because of relatively large emissions of NO_x and VOCs from this area, where the highest P(O_3) was observed – up to ~50 ppbv hr^{-1}.

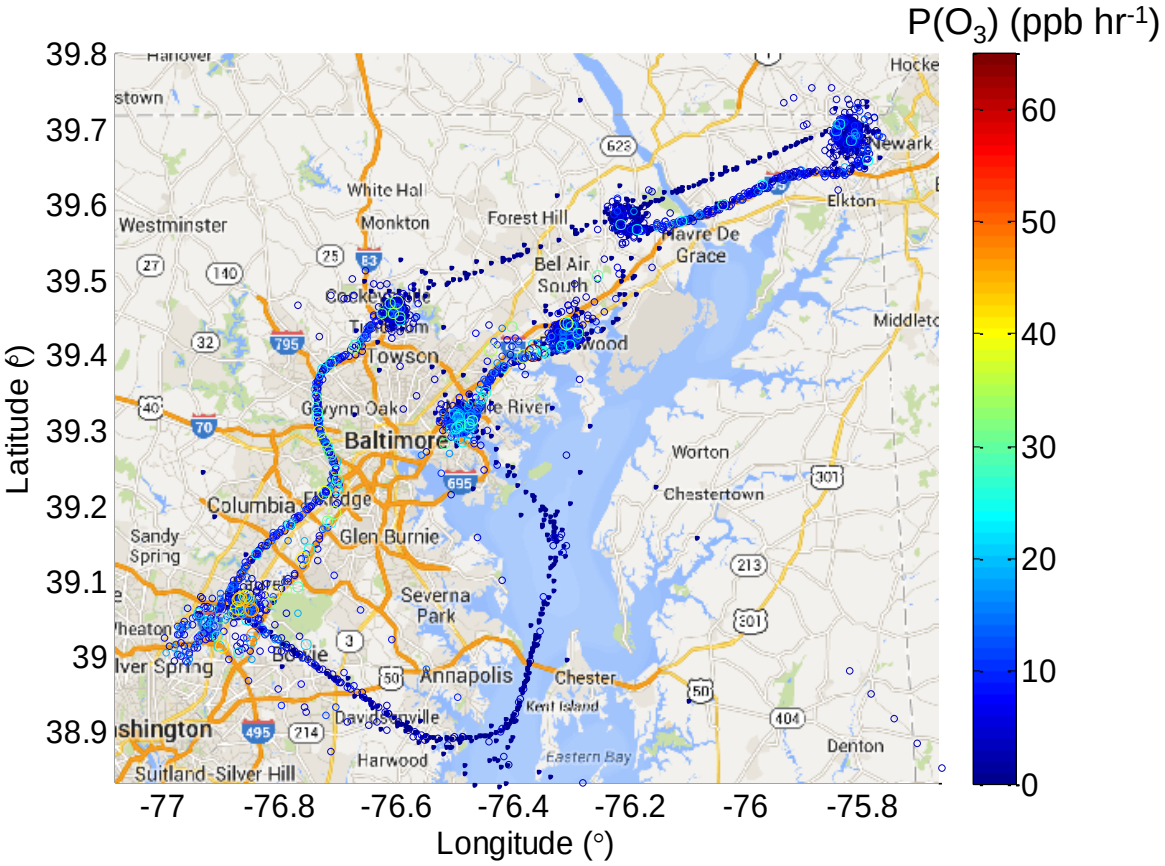

Figure 4.2. P(O3): Net ozone production rate, net $P(O_3)$ calculated using the box model results along the P-3B flight track during DISCOVER-AQ in Maryland in 2011. The size of dots is proportional to $P(O_3)$.

In the diurnal variations of $P(O_3)$, a broad peak in the morning with significant $P(O_3)$ in the afternoon was obtained on ten flight days during DISCOVER-AQ in Maryland (Figure 4.3). The majority data points are in blue, meaning the $P(O_3)$ in the NOx sensitive region. There are a few data points with red/orange color meaning $L_N/Q > 0.5$ (i.e., in the VOC sensitive regime) in the morning with high $P(O_3)$. The diurnal variation of L_N/Q indicates that $P(O_3)$ was mainly VOC sensitive in the early morning and then transitioned towards the NO_x sensitive regime later

in the day (Figure 4.3).

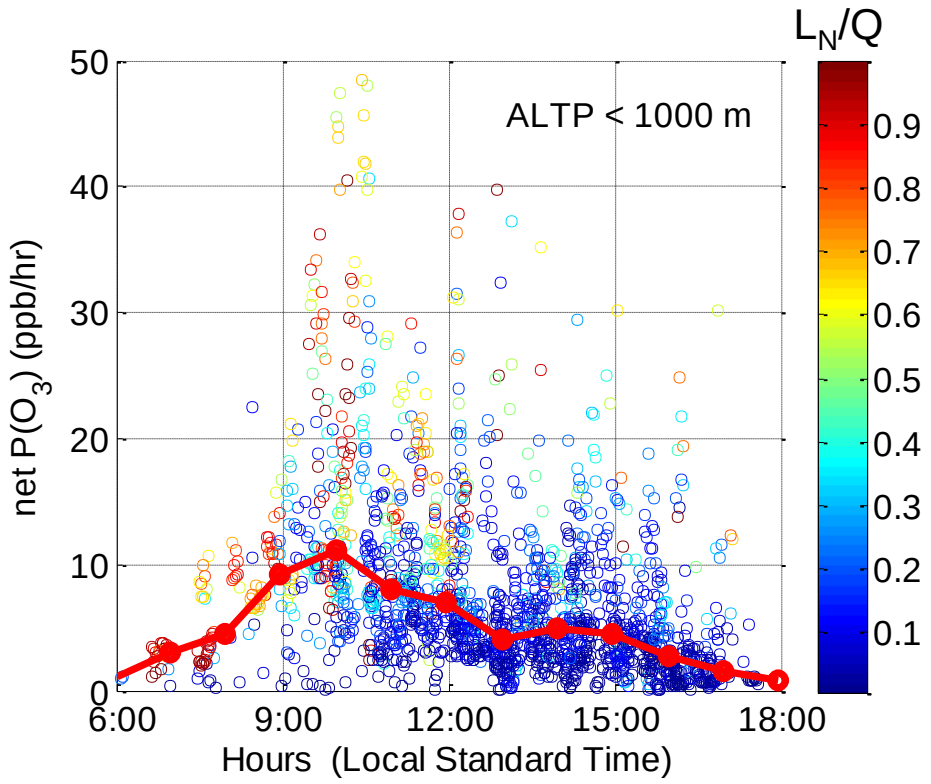

Figure 4.3. Diurnal variation of ozone production rate colored with the indicator L_N/Q on ten flight days during DISCOVER-AQ in Maryland in 2011. The solid red circles represent the median values in hourly bins of $P(O_3)$. Data are limited with the pressure altitude less than 1000 m to represent the lowest layer of the atmosphere.

The dependence of $P(O_3)$ on the NO mixing ratio ([NO]) shows that when [NO] is less than ~1000 pptv, ozone production increases as the [NO] increases, i.e., $P(O_3)$ is in NOx sensitive regime. When the NO mixing ratio is greater than ~1-2 ppbv, ozone production levels off, i.e., $P(O_3)$ is in a NOx saturated regime (Figure 4.4). It was also found that at a given NO mixing ratio, a higher production rate of HO_x results in a higher ozone production rate.

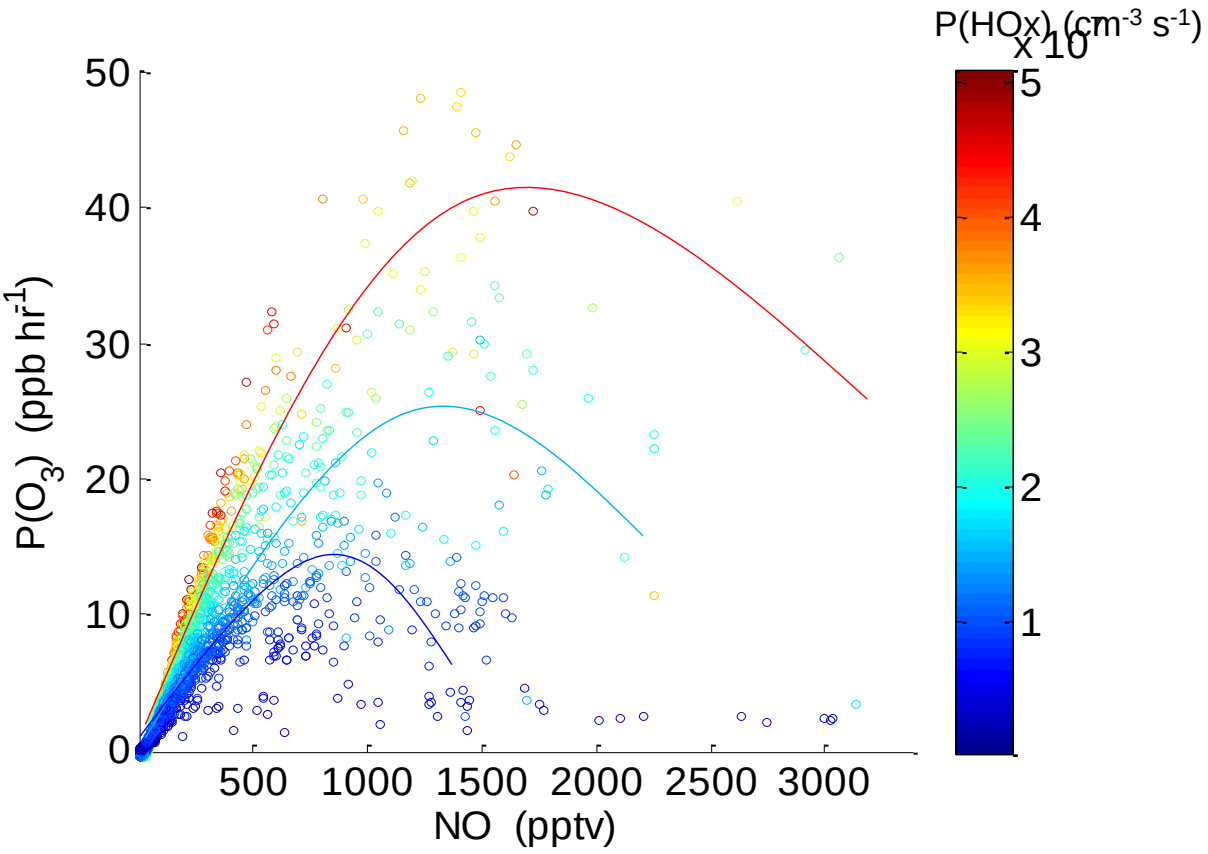

Figure 4.4. Ozone production as a function of NO mixing ratio. Individual data points are the 1-minute averages and are colored with the production rate of HOx (= OH + HO_2) during DISCOVER-AQ in Maryland in 2011. The colored lines represent the dependence of $P(O_3)$ as function of NO at different P(HOx) levels.

4.3. Photochemical O_3 Production Sensitivity

Figure 4.5 shows the indicator L_N/Q of ozone production sensitivity along the P-3B flight track for all flight days during the Maryland deployment. $P(O_3)$ was mainly VOC-sensitive over the Baltimore metropolitan and its surrounding urban areas due to large NO_x emissions. Over areas away from the center of the city with relatively low NO_x emissions, $P(O_3)$ was usually NOx-sensitive.

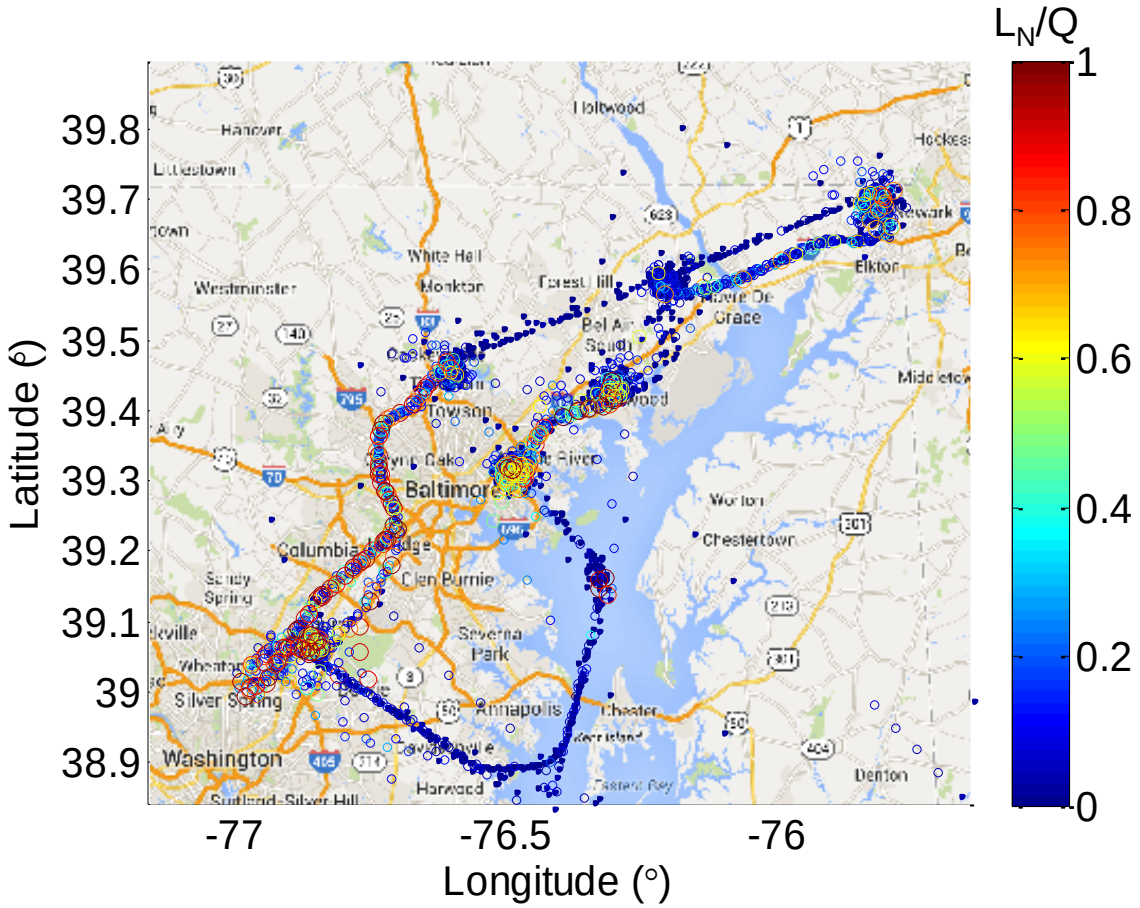

Figure 4.5. Ozone production sensitivity indicator, LN/Q, along the P-3B flight track during DISCOVER-AQ in Maryland in 2011. $P(O_3)$ is VOC-sensitive when $L_N/Q > 0.5$, and NOx-sensitive when $L_N/Q < 0.5$.

High $P(O_3)$ in the morning was mainly associated with VOC sensitivity due to high NO_x levels in the morning (points in the red circle in Figure 4.6). Although $P(O_3)$ was mainly NO_x sensitive in the afternoon between 12:00 and 17:00 Eastern Standard Time, EST (UTC-5 hours), there were also periods and locations when $P(O_3)$ was VOC sensitive, e.g., the points with LN/Q > 0.5 between 12:00 and 17:00 (EST) in Figure 4.6.

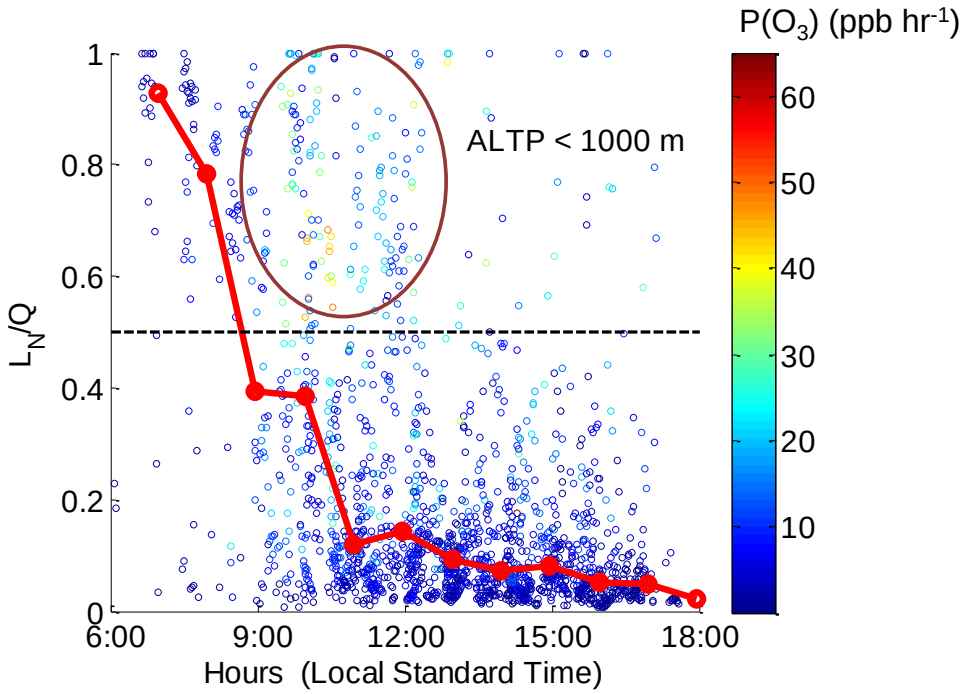

Figure 4.6. Diurnal variations of the indicator L_N/Q of ozone production rate sensitivity colored with ozone production rate and median hourly bins of L_N/Q shown in solid red circles below 1000 m during DISCOVER-AQ in Maryland in 2011.

4.4. Tasks and Deliverables

The results from the analysis of measurements and box model results have been presented at every RAMMPP quarterly meeting. This report serves as the final written report.

Task 1: *Report with analysis of aircraft data and other measurements showing pollution transport into Maryland and local production.*

In August/September 2015, we conducted three flights over the oil and natural gas operations in the Marcellus Shale area in Southwest Pennsylvania and northern West Virginia with support from MDE and NSF on methane emissions from the oil and natural gas production and the climate impact; see also Chang et al., *Atmos. Environ.*, in press 2016. On the way to and from the oil and natural gas operation area, we were able capture air pollution transport into Maryland from the west (Figure 4.7). We think good locations to measure aloft SO_2, NO_2, $PM_{2.5}$, SOA, and ozone are the upwind area of Baltimore/Washington (e.g., near the western MD border) and the downwind area of Baltimore/Washington (e.g., over the Bay and Eastern Shore) in prevailing west flow. A good way to characterize the aloft air pollutants is to measure various vertical profiles in these two upwind and downwind areas. We will continue profiling in the flights to be conducted in summer 2016.

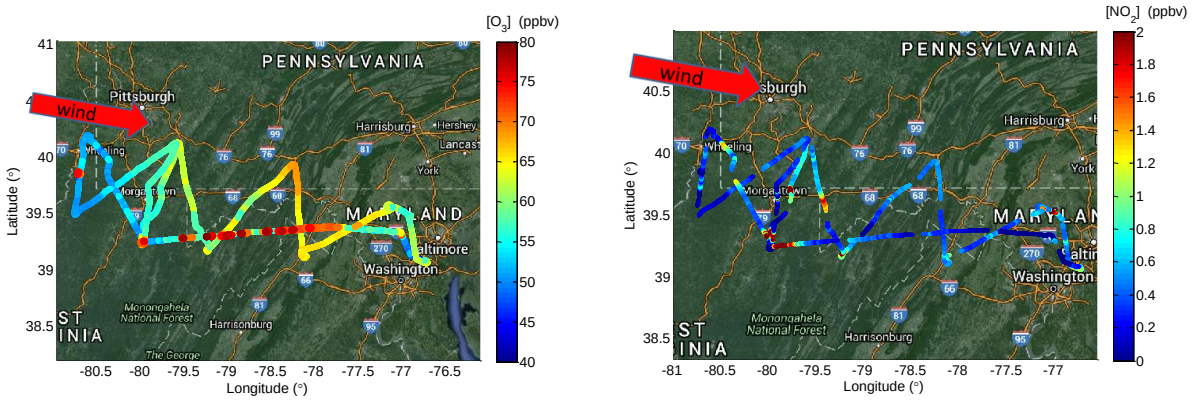

Figure 4.7. Ozone (left) and NO_2 (right) mixing ratios observed along the flight path during a fracking flight on September 14, 2015.

4.5 Evaluation of VOC's in the Baltimore Washington Area
Sayantan Sahu, GRA

Summary: Most analyses indicate biogenic isoprene, C_5H_8, is the dominant VOC for ozone formation in Maryland and the mid Atlantic States. But anthropogenic VOCs play a role especially in urban centers. We examine VOC and CO measurements from the Essex, MD site to evaluate the emissions inventories. If we detect substantial differences between observations and inventories, ozone production in models that use the inventories may be influenced. Based on the data available to us we see prodigious amounts of methane (and ethane) in the atmosphere in the Baltimore-Washington region. We attempt to find whether this methane is from fracking operations upwind in southwestern Pennsylvania, from leakage in the natural gas pipelines, or another source such as livestock, waste treatment plants, wetlands, and termites. We also try to assess the inherent uncertainties in VOC emissions inventories. Since these emission inventories are fed into air quality models, any uncertainty in the inventories can impact the output from the model.

Data sources: PAMS hourly VOC data during the months of June, July, August; cans collected during the FLAGG-MD campaign (in the Baltimore-Washington region) in February 2015 and during the fracking flights in August-September 2015.

Glossary of terms as partitioned in CB05:

Toluene = all monoalkyl aromatics
Xylene = all polyalkyl aromatics
Paraffin = all compounds with C-C
Olefins = compounds with terminal C=C
Internal olefins = compounds with internal C=C

Key findings:

<u>February 2015 FLAGG-MD campaign over Baltimore/Washington</u>

1. Based on the cans collected during the campaign, the ethane to methane ratio is 3.2%. The ethane content in the natural gas pipelines of BGE is ~8.6% (J. Quinn personal communication).
2. The isopentane to pentane ratio in the region from the cans is approximately 2.2% indicating that C5 hydrocarbons in region are predominantly from vehicles.
3. Correlation plots of the VOCs with CO shows appreciable correlation indicating that the sources are co-located.

<u>Fracking flights August-September 2015 over SW Pennsylvania</u>

4. The ethane to methane ratio from the cans is around 2.4%. One plausible reason for the lower ratio than the Baltimore region is coal mining, which releases substantial amounts of methane but no appreciable ethane.
5. The isopentane to pentane ratio is 0.99 from the cans in the fracking flights, much lower than that observed over Baltimore/Washington, indicating that this region is impacted strongly by natural gas operations.
6. The correlation plots of the VOCs with CO, CH_4 show good correlations suggesting co-location of sources.
7. Elevated concentrations of NO_2, methane, and ethane were observed around the same spots indicating that the spots were associated with fracking operations.

Evaluation of emission inventories using PAMS hourly VOC data

We plot the ratio of VOC over CO against the VOC concentration. The rationale behind such plots is at high concentrations of shorter-lived species the ratio will asymptotically approach the emissions ratio. We compare this with the modeled emission ratio from SMOKE. The modeled emissions ratio is obtained from grid cells of varying sizes. The SMOKE files used were driven by BEIS 3.6.

8. Ethane is grossly underestimated in the emissions inventory. The underestimation increases from 2011 to 2015 where it is a factor of ~25. There is almost no difference between the ratios from various grid cells. C_2H_6:CO approaches 3% at Essex. The ethane to CO ratio (for volume mixing ratios) in Los Angeles is 1.51% from [*Warneke et al.*, 2012] indicating another unrecognized source of ethane in addition to tailpipe emissions at Essex, MD.
9. Benzene emissions are also underestimated by a factor ~2 both in 2011 and 2015.
10. Toluene emissions predicted reasonably well by SMOKE within 20% (Figure 4.5.1).
11. Xylene emissions are underestimated by 55% as compared to 33% in 2011. The xylene concentrations have declined in the time period 2011-2015.
12. Paraffin emissions are underestimated by ~50% in 2015 as compared to 35% in 2011.
13. Internal olefins are overestimated by a factor ~4 whereas olefins are overestimated by more than factor of 4 in 2011 and 2015.
14. Isoprene emissions are overestimated by a factor of 15 in 2015, but this is a product of the site – vehicles dominate for CO emissions but contribute minimally to C_5H_8 emissions. When using SMOKE files driven with the latest biogenic BEIS 3.6.1, the overestimation increases to 20. The factors are almost the same for the year 2011. Substantial difference exists between the ratios from the various grid cells.

Implications: As we see from above that the emission of VOC categories are either underestimated or overestimated by various factors. We would like to see the potential impacts of altering the emissions of VOC categories on ozone production and PM2.5, known to have detrimental effects on human health.

There exist notable discrepancies between the various reported values of ethane and methane content in the fracking regions. We plan to look deeper into the data from each can collected in the fracking region and see whether it is in the vicinity of a coalmine or fracking well.

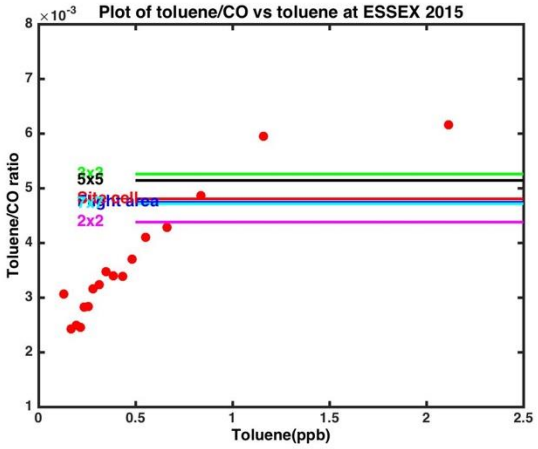

Figure 4.5.1: Plot of toluene to CO ratio as a function of toluene concentration. The red dots show observed concentrations from ESSEX in 2015. The various colored lines denote the modeled ratio from SMOKE across grid cells of varying sizes. For high toluene concentrations, the observed concentration asymptotically approaches (within 20%) the modeled ratios indicating that toluene emissions in SMOKE are reasonable.

4.6 Analysis of Ambient Measurements at two Near-Road Sites within the Baltimore-Washington Region: Impact of Meteorology
Dolly L. Hall, GRA

Objective: Quantify the temperature dependence of emission rates with measurements taken at two near-road (NR) sites.

For this study we analyzed ambient carbon monoxide (CO) and nitrogen oxide (NO_x) measurements at two NR sites within the Baltimore-Washington Region to evaluate the impact of meteorology and fleet distribution on the CO to NO_x emission ratio. The two sites investigated are the MDE NR site along I-95 in Howard County and a NR site along I-295 located in Washington D.C. The purpose of using these two sites is that I-295 does not allow trucks on the road segment at which the NR monitoring site is located, whereas the I-95 NR site allows trucks. Thus, the local emissions of CO and NO_x at each site are also affected by differences in the fleet distribution. Meteorology may impact emissions since ambient air is mixed with fuel in vehicle engines, so the temperature and humidity of the ambient air may affect exhaust emissions. Modeled vehicular emissions are generated by the EPA MOtor Vehicle Emission Simulator (MOVES) model, which includes a temperature dependence for emission rates of exhaust pollutants including CO and NO_x. The purpose of this analysis is to verify the temperature dependence of the MOVES model with these NR measurements to ensure that air quality models represent actual atmospheric composition.

The comparison period chosen in this study is June-November 2015 as both sites have measurements for this period. From June to November the average ambient CO concentration at the I-95 (I-295) NR site was 301.6±111.0 ppb (426.7±269.5 ppb) and the average NO_x concentration was 34.54±25.14 ppb (34.11±32.20 ppb), whereas for only 8:00-20:00 the average CO was 303.1±111.0 ppb (382.2±223.8 ppb) and the average NO_x was 28.16±19.45 ppb (27.86±24.99 ppb). The June-November $\Delta CO/\Delta NO_x$ emission ratio (calculated as the linear best-fit line for the data) was ~8.6 mol/mol for the I-295 NR site and ~4.9 mol/mol for the I-95 NR site. This difference in emission ratio for the two NR sites is likely due to fleet distribution differences, as I-295 does not allow trucks. Diesel emissions of NO_x are higher than those from spark-ignited engines and this could explain why a lower emission ratio is observed where trucks are allowed. We have also analyzed the diurnal pattern of fleet distribution from a traffic counter located 5 miles north of the I-95 NR Site and compared this analysis to ambient CO and NO_x measurements from the I-95 site. In general, spark-ignited vehicles make up over 90% of the total traffic volume for 10/16-12/31/2015 and reach their lowest point at night with a trough between 2 and 3 AM. The highest fraction of diesel vehicles (diesel vehicles/total vehicles) occurs at night between midnight and 4 AM, and this is also when the ambient CO/NO_x ratio is lowest.

To estimate the portion of ambient CO and NO_x that is due to vehicular emissions, we chose a background for each time period that is a constant and represented by the 5^{th} percentile of the data. With this definition of background there appears to be a positive trend between the emission ratio and temperature (Figure 4.6.1). For June-November, $\Delta CO/\Delta NO_x$ increases by ~60% (from ~5 mol/mol to ~8 mol/mol) at the I-95 site, and by ~67% (from ~7.5 mol/mol to ~12.5 mol/mol) at the I-295 site. This method sometimes overestimates the background as some

emissions ratios are negative. Thus, we are continuing to search for a time-dependent method of calculating the background to better represent actual conditions. We also need to filter out measurements that were taken during rain events as the CO and NO_x concentrations measured then would not reflect actual vehicular emissions.

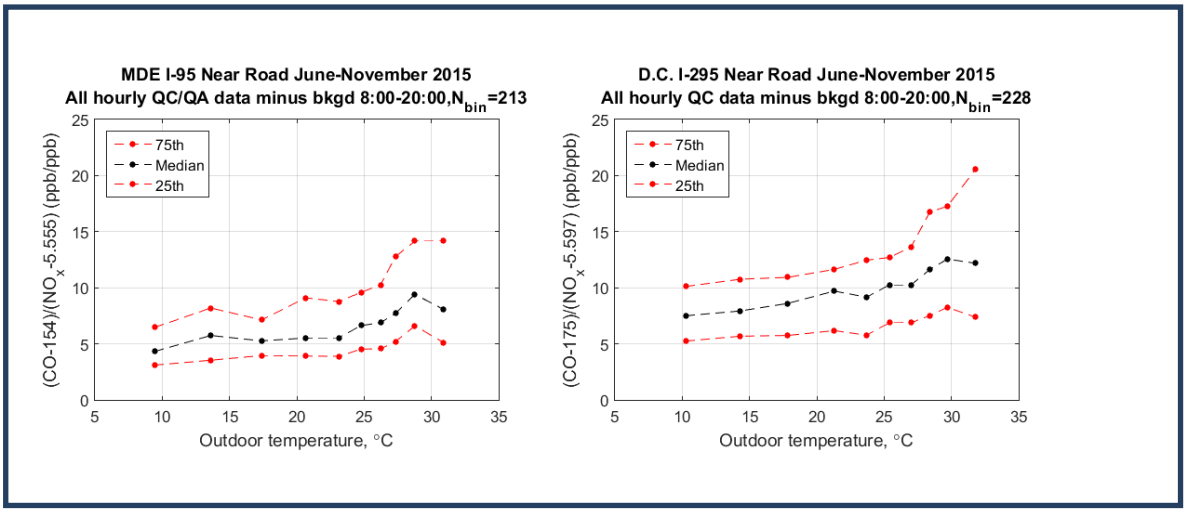

Figure 4.6.1. Temperature dependence of CO/NOx at roadside sites.

These preliminary data appear to confirm the hypothesis that the CO:NOx ratio of vehicular emissions rises with rising ambient temperature. This could help explain the disagreement between the EPA NEI and the in situ measurements of NASA's DISCOVER-AQ (Anderson et al., 2014).

5. Bibliography

[*Aburn et al.*, 2015; *Anderson et al.*, 2014; *Brent et al.*, 2014; *Brioude et al.*, 2013; *Canty et al.*, 2015a; *Doraiswamy et al.*, 2009; *Flynn et al.*, 2014; *Fujita et al.*, 2012; *Gilliland et al.*, 2008; *Goldberg et al.*, 2014; *Goldberg et al.*, 2015; *Goldberg et al.*, 2016; *Guenther et al.*, 2012; *He et al.*, 2016; *He et al.*, 2014; *Krotkov et al.*, 2016; *Loughner et al.*, 2014; *Mazzuca et al.*, 2016a; *Mazzuca et al.*, 2016b; *Schneising et al.*, 2014; *Solazzo et al.*, 2013; *Thompson et al.*, 2015; *Travis*, 2016; *Vinciguerra et al.*, 2015; *Vinciguerra et al.*, 2016; *Warneke et al.*, 2012; *Warner et al.*, 2015; *Yang et al.*, 2014; *Yarwood et al.*, 2005; *Yu et al.*, 2012; *Zhou et al.*, 2013]

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