UNITED STATES ENVIRONMENTAL PROTECTION AGENCY
RESEARCH TRIANGLE PARK, NC 27711

APR 3 0 2019

OFFICE OF
AIR QUALITY PLANNING
AND STANDARDS

MEMORANDUM

SUBJECT: Guidance on the Development of Modeled Emission Rates for Precursors (MERPs) as a Tier 1 Demonstration Tool for Ozone and PM$_{2.5}$ under the PSD Permitting Program

FROM: Richard A. Wayland, Director Richard A. Wayland
Air Quality Assessment Division

TO: Regional Air Division Directors

The Environmental Protection Agency (EPA) is providing the attached *Guidance on the Development of Modeled Emission Rates for Precursors (MERPs) as a Tier 1 Demonstration Tool for Ozone and PM$_{2.5}$ under the PSD Permitting Program* in final form. This guidance reflects the EPA's recommendations for how air agencies conduct air quality modeling and related technical analyses to satisfy compliance demonstration requirements for ozone and secondary PM$_{2.5}$ under the Prevention of Significant Deterioration (PSD) permitting program.

This document is not binding and does not change or substitute for provisions of the Clean Air Act (CAA) or CAA regulations, nor is it a regulation or final agency action itself. As the term "guidance" indicates, it provides recommendations on compliance demonstration tools that may be used together with other relevant information in satisfying air quality modeling requirements for PSD permitting. Thus, it does not impose enforceable requirements on any party. In addition, the guidance may not apply to a particular situation based upon the circumstances. Permitting decisions by the EPA or an air agency regarding a PSD permit application are made based on the applicable statutory and regulatory provisions and the relevant permitting record.

A detailed framework is provided in this document that permit applicants may choose to use, subject to review by the appropriate permitting authority, to estimate single source impacts on secondary pollutants under the first tier (Tier 1) approach put forth in EPA's *Guideline on Air Quality Models* (Appendix W to 40 CFR part 51). For Tier 1 assessments, it is generally expected that applicants would use existing empirical relationships between precursors and secondary impacts based on modeling systems appropriate for this purpose as detailed in relevant EPA guidance. We are providing this guidance document for consideration and use by permitting authorities and permit applicants on a case-by-case basis under the PSD program in assessing the effects of precursors of PM$_{2.5}$ and ozone.

This document also presents the EPA's modeling of hypothetical single source impacts on ozone and secondary $PM_{2.5}$ to illustrate how this framework can be implemented by stakeholders. The modeling relationships and illustrative MERPs presented here, in some cases, may provide relevant technical information to assist or inform an applicant in providing a Tier 1 demonstration and also as a template for permit applicants and/or state or local agencies to develop information relevant to a specific area or source type.

If there are any questions regarding this guidance, please contact George Bridgers of EPA's Air Quality Modeling Group at (919) 541-5563 or *bridgers.george@epa.gov*.

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Attachment

Guidance on the Development of Modeled Emission Rates for Precursors (MERPs) as a Tier 1 Demonstration Tool for Ozone and $PM_{2.5}$ under the PSD Permitting Program

EPA-454/R-19-003
April 2019

Guidance on the Development of Modeled Emission Rates for Precursors (MERPs) as a Tier 1 Demonstration Tool for Ozone and $PM_{2.5}$ under the PSD Permitting Program

U.S. Environmental Protection Agency
Office of Air Quality Planning and Standards
Air Quality Assessment Division
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Contents

EXECUTIVE SUMMARY

EPA finalized revisions to the *Guideline on Air Quality Models* (the "*Guideline,*" published as Appendix W to 40 CFR part 51) that recommend a two-tiered approach for addressing single-source impacts on ozone (O_3) and secondary particulate matter less than 2.5 microns in diameter ($PM_{2.5}$) (U.S. Environmental Protection Agency, 2017a). The first tier (or Tier 1) involves use of appropriate and technically credible relationships between emissions and ambient impacts developed from existing modeling studies deemed sufficient for evaluating a project source's impacts. The second tier (or Tier 2) involves more sophisticated case-specific application of chemical transport modeling (e.g., with an Eulerian grid or Lagrangian model).

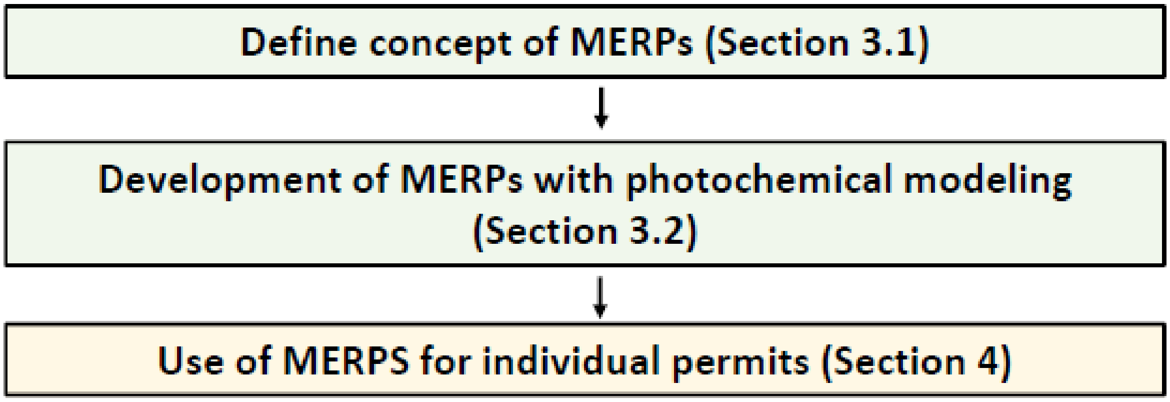
As EPA introduced in the preamble to the 2015 proposed revisions to the *Guideline*, Modeled Emission Rates for Precursors (MERPs) can be viewed as a type of Tier 1 demonstration tool under the Prevention of Significant Deterioration (PSD) permitting program that provides a simple way to relate maximum downwind impacts with a critical air quality threshold (e.g., a significant impact level or SIL) (U.S. Environmental Protection Agency, 2018). The purpose of this document is to provide a framework for permitting authorities and permit applicants on how air quality modeling can be used to develop relationships between precursors and maximum downwind impacts for the purposes of developing a technically credible Tier 1 demonstration tool.

A conceptual understanding of an area's emission sources and which precursor emissions limit the formation of secondary pollutants such as O_3 and $PM_{2.5}$ is useful for interpreting modeled and monitored impacts due to changes in emissions to that area. O_3 formation is a complicated, nonlinear process that depends on meteorological conditions in addition to volatile organic compounds (VOC) and nitrogen oxides (NO_x) concentrations (Seinfeld and Pandis, 2012). Warm temperatures, clear skies (abundant levels of solar radiation), and stagnant air masses (low wind speeds) increase O_3 formation potential (Seinfeld and Pandis, 2012). In the case of $PM_{2.5}$, or fine PM, total mass is often categorized into two groups: primary (i.e., emitted directly as $PM_{2.5}$ from sources) and secondary (i.e., $PM_{2.5}$ formed in the atmosphere by precursor emissions from sources). $PM_{2.5}$ organic carbon is directly emitted from primary sources and also formed secondarily in the atmosphere by reactions involving VOCs. $PM_{2.5}$ sulfate, nitrate, and ammonium are predominantly the result of chemical reactions of the oxidized products of sulfur dioxide (SO_2) and NO_X emissions and direct ammonia (NH_3) emissions (Seinfeld and Pandis, 2012).

A Tier 1 demonstration tool, as described in the *Guideline,* consists of technically credible air quality modeling that relates precursor emissions and secondary pollutant impacts from specific or hypothetical sources (U.S. Environmental Protection Agency, 2017a). Existing credible air quality modeling generally may include single source modeling based on an approved State Implementation Plan (SIP) demonstration, a more recent submitted but not yet approved SIP demonstration, or modeling not used to support a SIP demonstration but considered representative of the current air quality in the area and of sufficient quality that is comparable to a model platform supporting a SIP demonstration.

Figure ES-1 illustrates the framework for MERPs as a Tier 1 demonstration tool. This framework is the organizing flow of this guidance and sequences from the concept of a MERP, how MERPs can be developed from either existing EPA modeling or other credible sources, and then how that information can be credibly used for a source impact analysis and, if necessary, a cumulative impact analysis.

Figure ES-1. Framework for MERPs as a Tier 1 demonstration tool.



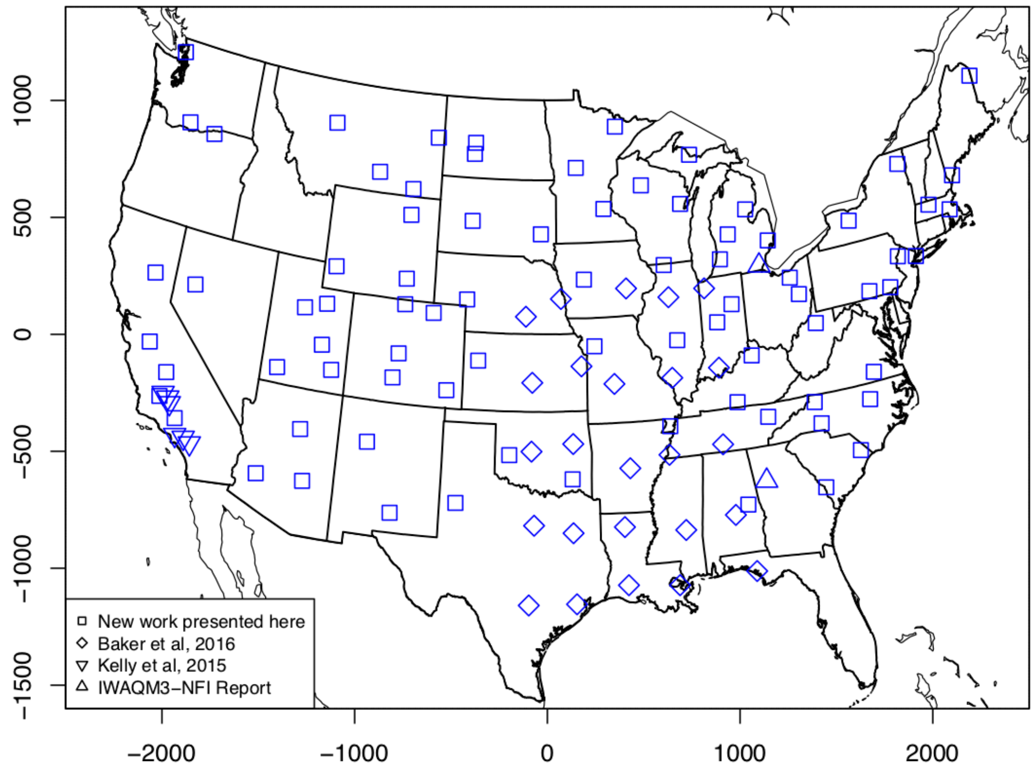
Properly supported MERPs provide a straightforward way to relate modeled downwind impacts with an air quality threshold that is used to determine if such an impact causes or contributes to a violation of the appropriate National Ambient Air Quality Standard (NAAQS). To derive a MERP value for the purposes of a PSD compliance demonstration, the model predicted relationship between precursor emissions from hypothetical sources and their modeled downwind impacts can be combined with the appropriate SIL value using the following equation:

$$\text{Eq 1.}\quad \text{MERP} = \text{appropriate SIL value} \times \frac{\text{Modeled emission rate from hypothetical source}}{\text{Modeled air quality impact from hypothetical source}}$$

MERPs can be derived using any air quality threshold of concern (“critical air quality threshold”) and are not necessarily dependent on SILs. In practice, MERPs are intended to be used with SILs as analytical tools for PSD air quality analyses. For $PM_{2.5}$, the modeled air quality impact of an increase in precursor emissions from the hypothetical source is expressed in units of μg/m^3. For O_3, the modeled air quality impact is expressed in ppb.

As stated in the preamble to the 2017 final revisions to the *Guideline* (U.S. Environmental Protection Agency, 2017a), the EPA believes that use of photochemical models for the purpose of developing MERPs is scientifically appropriate and practical to implement. In this guidance document, EPA presents existing and new photochemical modeling of hypothetical single source impacts on downwind O_3 and secondary $PM_{2.5}$. This modeling was configured, applied, and post-processed consistent with EPA single source modeling guidance (U.S. Environmental Protection Agency, 2016a). The locations of hypothetical sources included here are shown in Figure ES-2. The single source impacts detailed in this section are collected from various past and more recent photochemical grid model-based assessments. More than 100 locations were modeled with hypothetical source emissions and are presented here.

Figure ES-2. Hypothetical sources modeled for downwind secondary air quality impacts included in this assessment.



The relationships shown here for these hypothetical sources are not intended to provide an exhaustive representation of all combinations of source type, chemical, and physical source environments but rather to provide insightful information about secondary pollutant impacts from hypothetical single sources in different parts of the U.S. Based on these annual photochemical model simulations, the maximum impacts for daily $PM_{2.5}$, annual $PM_{2.5}$ and daily maximum 8-hr average O_3 are provided for each modeled source described in Appendix Table A-1 in an Excel spreadsheet on EPA's Support Center for Regulatory Atmospheric Modeling (SCRAM) website. It is expected that the information in the Excel spreadsheet will be updated over time as newer modeling is done consistent with EPA's single source modeling guidance (U.S. Environmental Protection Agency, 2016a).

Based on these photochemical modeling data, EPA recommends that the permit applicant in consultation with the appropriate reviewing authority follow a three-step process:

1) Identify a representative hypothetical source (or group of sources for an area) from EPA's modeling results (as described in Section 3.2.1).

    - ✓ If a representative hypothetical source is not available, then consider whether any of these derived MERP values available for the geographic location of the project source may be appropriate to use. Alternatively, one can consider conducting photochemical modeling (as described in Section 3.2.2) to derive a source- or area-specific value.

2) Acquire the source characteristics and associated modeling results for the hypothetical source(s).

3) Apply the source characteristics and photochemical modeling results from Step 2 above with the appropriate SIL to the MERP equation for comparison with the project emission rate.

Section 4 provides details on the use of MERPs for PSD compliance demonstrations for: 1) source impact analysis, 2) $PM_{2.5}$ increment analysis, and 3) cumulative impact analysis. It also provides illustrative examples that show how existing EPA hypothetical source modeling can be used to support a Tier 1 demonstration.

For $PM_{2.5}$, based on EPA modeling presented here and recommended $PM_{2.5}$ SILs, the illustrative MERPs for NO_X as a precursor to daily $PM_{2.5}$ range from 1,073 tons per year (tpy) to over 100,000 tpy, while the illustrative MERPs for sulfur dioxide (SO_2) as a precursor to daily $PM_{2.5}$ range from 188 tpy to over 27,000 tpy. The illustrative MERPs for NO_X as a precursor to annual $PM_{2.5}$ range from 3,182 tpy to over 700,000 tpy, while the illustrative MERPs for SO_2 to annual $PM_{2.5}$ range from 859 tpy to over 100,000 tpy. For this assessment, the illustrative MERPs are generally lower for SO_2 than NO_X reflecting that SO_2 tends to form $PM_{2.5}$ more efficiently than NO_X.

For O_3, based on EPA modeling presented here and recommended O_3 SIL, the illustrative MERPs for NO_X as a precursor to daily maximum 8-hr O_3 range from 125 tpy to over 5,000 tpy, while the illustrative MERPs for VOC as a precursor to daily maximum 8-hr O_3 range from 1,049 tpy to over 140,000 tpy. For this assessment, illustrative MERPs for NO_X tend to be lower than VOC which suggests most areas included in this assessment are more often NO_X limited rather than VOC limited in terms of O_3 formation.

1. Background

EPA finalized revisions to the *Guideline on Air Quality Models* (the "*Guideline,*" published as Appendix W to 40 CFR part 51) that recommend a two-tiered approach for addressing single-source impacts on ozone (O_3) and secondary particulate matter less than 2.5 microns in diameter ($PM_{2.5}$) (U.S. Environmental Protection Agency, 2017a). The first tier (or Tier 1) involves use of appropriate and technically credible relationships between emissions and ambient impacts developed from existing modeling studies deemed sufficient for evaluating a project source's impacts. The second tier (or Tier 2) involves more sophisticated case-specific application of chemical transport modeling (e.g., with an Eulerian grid or Lagrangian model). This guidance document is intended to provide a detailed framework that applicants may choose to apply, in consultation with the appropriate permitting authority, to estimate single-source impacts on secondary pollutants under the first-tier approach put forth in the *Guideline* (i.e., Sections 5.3.2.b and 5.4.2.b).

For Tier 1 assessments, EPA generally expects that applicants would use existing empirical relationships between precursors and secondary impacts based on modeling systems (e.g., chemical transport models) appropriate for this purpose. The use of existing credible technical information that appropriately characterizes the emissions to air quality relationships will need to be determined on a case-by-case basis. Existing credible air quality modeling would generally include single source modeling based on an approved State Implementation Plan (SIP) demonstration, a more recent submitted but not yet approved SIP demonstration, or modeling not used to support a SIP demonstration but considered representative of the current air quality in the area and of sufficient quality that is comparable to a model platform supporting a SIP demonstration. The applicant should describe how the existing modeling reflects the formation of O_3 or $PM_{2.5}$ in that geographic area. Information that could be used to describe the comparability of two different geographic areas include average and peak temperatures, humidity, terrain, rural or urban nature of the area, nearby local and regional sources of pollutants and their emissions (e.g., other industry, mobile, biogenic), and ambient concentrations of relevant pollutants where available.

As EPA introduced in the preamble to the 2015 proposed revisions to the *Guideline*, Modeled Emission Rates for Precursors (MERPs) can be viewed as a type of Tier 1 demonstration tool under the Prevention of Significant Deterioration (PSD) permitting program that provides a simple way to relate maximum downwind impacts with a critical air quality threshold (e.g., a significant impact level or SIL) (U.S. Environmental Protection Agency, 2018). EPA had initially planned to establish generally applicable MERPs through a future rulemaking. However, after further consideration, EPA believes it is preferable for permit applicants and permitting authorities to consider site-specific conditions when deriving MERPs and to allow for the development and application of locally and regionally appropriate values in the permitting process. Thus, instead of deriving generally-applicable MERP values, the EPA is providing this guidance document for consideration and use by permitting authorities and permit applicants on a permit specific basis.

This guidance is relevant for the PSD program and focuses on assessing the ambient impacts of precursors of $PM_{2.5}$ and O_3 for purposes of that program. The MERP framework may be used to describe an emission rate of an individual precursor that is expected to result in a change in the level of ambient O_3 or $PM_{2.5}$, as applicable, that would be less than a specific air quality threshold for O_3 or $PM_{2.5}$ that a permitting authority adopts and chooses to use in determining whether a projected impact causes or contributes to a violation of the NAAQS for O_3 or $PM_{2.5}$, such as the SILs recommended by EPA. In the context of the PSD program, precursors to O_3 include volatile organic compounds (VOC) and nitrogen oxides (NO_X) and precursors to $PM_{2.5}$ generally include sulfur dioxide (SO_2) and NO_X. MERPs relate emissions of a specific precursor of O_3 or $PM_{2.5}$ to ambient impacts of O_3 or $PM_{2.5}$ and do not provide a single demonstration for all NAAQS pollutants.

If approved by the permitting authority as a $PM_{2.5}$ Tier 1 demonstration tool for a PSD source in a $PM_{2.5}$ attainment or unclassifiable area, a finding that projected increases in the $PM_{2.5}$ precursor emissions of NO_X and/or SO_2 from a project are below the respective MERPs may be part of a sufficient demonstration that the project will not cause or contribute to violation of the applicable NAAQS (hereafter "demonstration of compliance" or "compliance demonstration"). Similarly, for the O_3 NAAQS, an appropriate Tier 1 demonstration may include a finding that the projected increases in O_3 precursor emissions of NO_X and/or VOC are below the respective MERPs.

For situations where project sources are required to assess multiple precursors of $PM_{2.5}$ or of O_3, EPA recommends that the impacts of multiple precursors should be estimated in a combined manner for comparison to the appropriate SIL such that the sum of precursor impacts would be lower than the SIL in a demonstration of compliance. Examples of combining precursor impacts are provided in Section 4 of this document. Further, where project sources are required to assess both primary $PM_{2.5}$ and precursors of secondary $PM_{2.5}$, EPA recommends that applicants combine the primary and secondary impacts to determine total $PM_{2.5}$ impacts as part of the PSD compliance demonstration. An example of combining primary and secondary impacts is provided in Section 4 of this document.

The purpose of this document is to provide a framework for using air quality modeling to develop relationships between precursors and maximum downwind impacts for the purposes of developing and using MERPs as a Tier 1 demonstration tool. We provide hypothetical single source impacts on O_3 and secondary $PM_{2.5}$ to illustrate how this framework can be implemented by permit applicants. The relationships presented here in some cases may provide relevant technical information to assist or inform an applicant in providing a first-tier demonstration for their specific permit situation and as a template for stakeholders and/or state or local agencies to develop information relevant to a specific area or source type. Based on the EPA modeling conducted to inform these illustrative MERPs provided here, such values will vary across the nation reflecting different sensitivities of an area's air quality level to changes in levels of precursor emissions thereby providing an appropriate technical basis for evaluating the impacts of these precursors to $PM_{2.5}$ and O_3 formation because they reflect the regional or local atmospheric conditions for particular situations.

This document is not a final agency action and does not reflect a final determination by the EPA that any particular proposed source with emissions below an illustrative MERP value developed by EPA (or a MERP developed by another party using methods recommended by EPA) will not cause or contribute to a violation of an O_3 or $PM_{2.5}$ NAAQS or $PM_{2.5}$ PSD increments. A determination that a proposed source does not cause or contribute to a violation can only be made by a permitting authority on a permit-specific basis after consideration of the permit record. The illustrative MERP values identified by the EPA have no practical effect unless and until permitting authorities decide to use those values in particular permitting actions. This guidance document does not require the use, nor does it require acceptance of the use, of this framework or any result using this framework by a permit applicant or a permitting authority. Permit applicants and permitting authorities retain the discretion to use other methods to complete a first-tier assessment under Sections 5.3.2.b and 5.4.2.b of the Guideline and to require additional information from a permit applicant to make the required air quality impact demonstration. This guidance document does not create any binding requirements on EPA, permitting authorities, permit applicants, or the public.

Subsequent sections of this document include information about O_3 and secondary $PM_{2.5}$ formation in the atmosphere, a conceptual description of MERPs, information about developing MERPs using photochemical modeling, using MERPs for individual permit demonstrations, and several illustrative examples of using MERPs to support hypothetical permit applications.

2. O_3 and Secondary $PM_{2.5}$ Formation in the Atmosphere

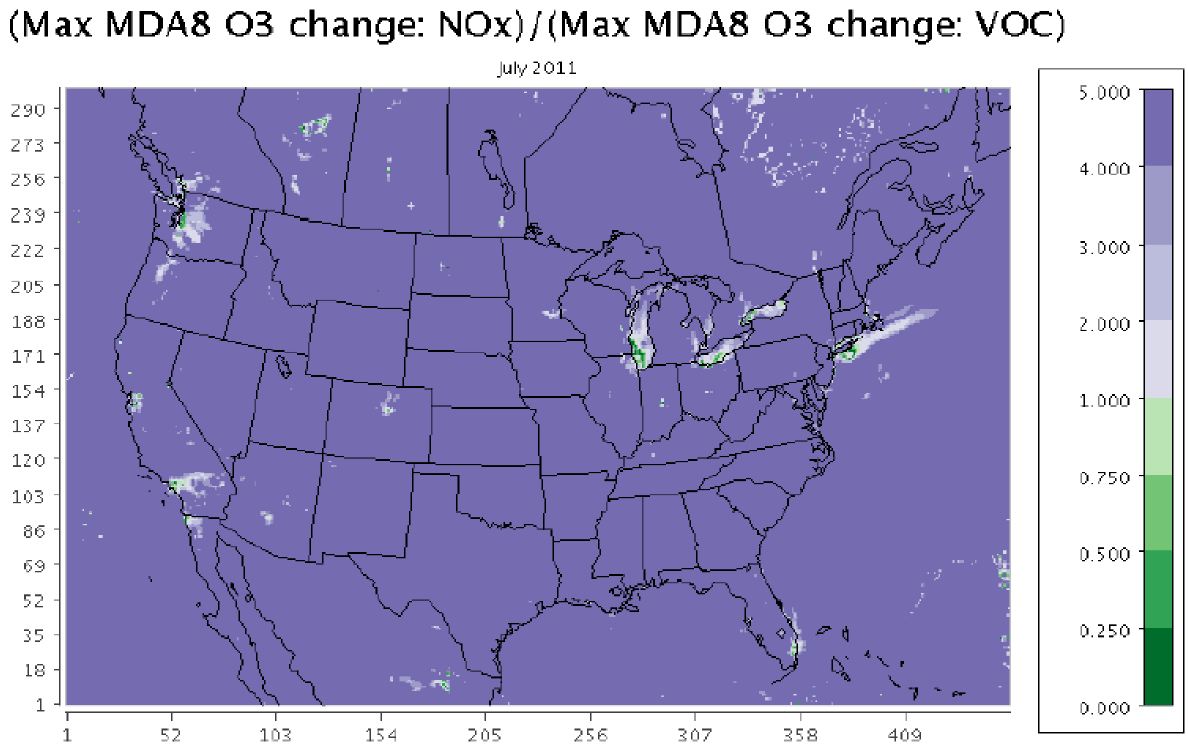
A conceptual understanding of an area's emissions sources and which precursor emissions limit the formation of secondary pollutants such as O_3 and $PM_{2.5}$ is useful for interpreting modeled and ambient impacts due to changes in emissions in that area. The formation regime favoring a particular precursor may vary seasonally, day to day, and by hour of the day. It is important to understand how the atmosphere will respond to changes in emissions to make informed decisions about how changes in emissions from a source might impact ambient pollutant levels. Typically, reductions in emissions of primary pollutants or precursors of secondary pollutants result in some level of reduction in ambient pollutant concentrations.

Secondary $PM_{2.5}$ and O_3 are closely related to each other in that they share common sources of emissions and are formed in the atmosphere from chemical reactions with similar precursors (U.S. Environmental Protection Agency, 2017a). Air pollutants formed through chemical reactions in the atmosphere are referred to as secondary pollutants. For example, ground-level O_3 is predominantly a secondary pollutant formed through photochemical reactions driven by emissions of NO_x and VOCs in the presence of sunlight. O_3 formation is a complicated nonlinear process that depends on meteorological conditions in addition to VOC and NO_x concentrations (Seinfeld and Pandis, 2012). Warm temperatures, clear skies (abundant levels of solar radiation), and stagnant air masses (low wind speeds) increase O_3 formation potential (Seinfeld and Pandis, 2012).

O_3 Formation

O_3 formation may be limited by either NO_X or VOC emissions depending on the meteorological conditions and the relative mix of these pollutants. When O_3 concentrations increase (decrease) because of increases (decreases) in NO_X emissions, the O_3 formation regime is termed "NO_X limited." Alternatively, the O_3 formation regime is termed "VOC limited" when ambient ozone concentrations are very sensitive to changes in ambient VOC. The VOC-limited regime is sometimes referred to as "radical-limited" or "oxidant-limited" because reactions involving VOCs produce peroxy radicals that can lead to O_3 formation by converting nitric oxide (NO) to nitrogen dioxide (NO_2) in the presence of sunlight. In a NO_X-limited regime, ozone decreases with decreasing NO_X and has very little response to changes in VOC. The NOx-limited formation regime is more common in rural areas of the U.S. where high levels of biogenic VOC exist and relatively few man-made, or anthropogenic, NOx emissions occur. O_3 decreases with decreasing VOC in a VOC-limited formation regime. The O_3 formation regime for some urban areas in the U.S. is locally VOC-limited during daytime hours due to large NO_X emissions from mobile and industrial sources and relatively smaller amount of biogenic and anthropogenic VOC emissions. Additional information on O_3 formation regimes based on modeling (U.S. Environmental Protection Agency, 2017b) and satellites (Chang et al., 2016; Duncan et al., 2010; Jin et al., 2017) are available elsewhere. An example is shown in Figure 2-1.

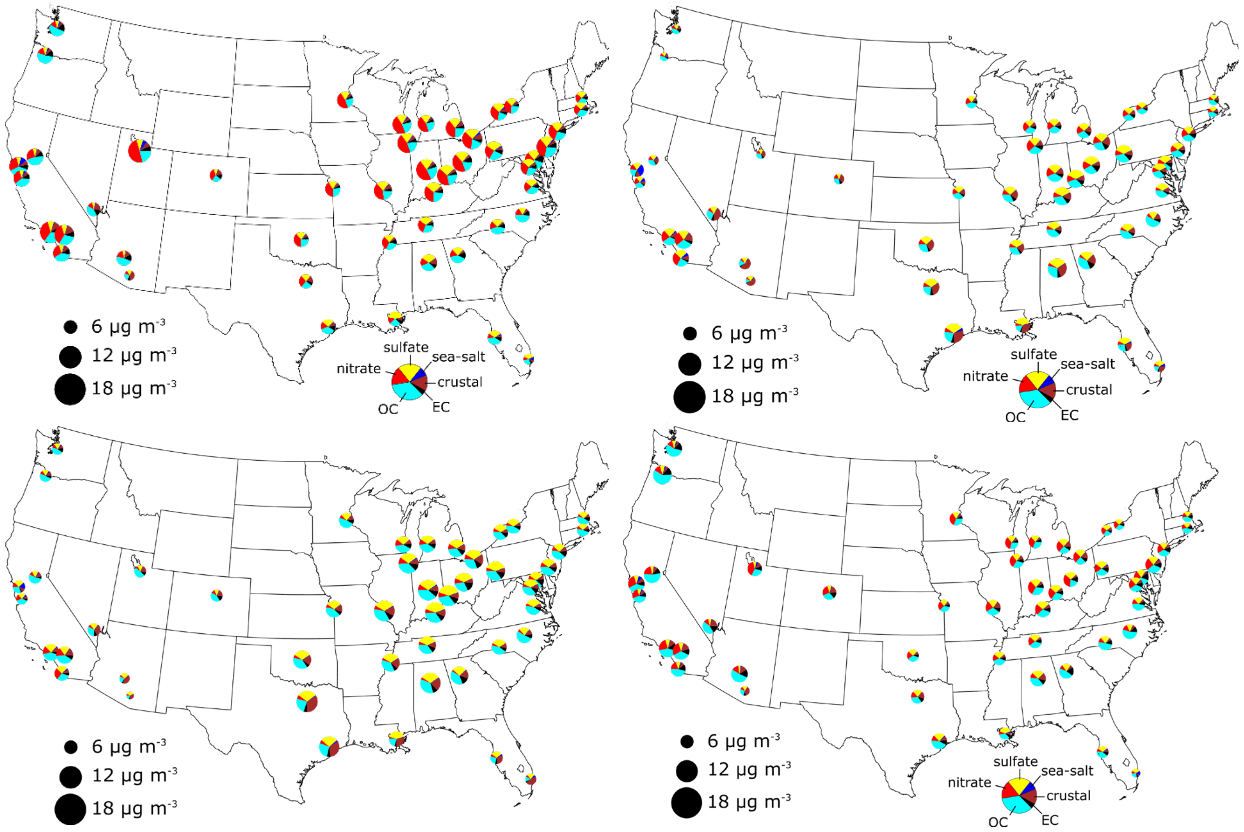
Figure 2-1. The ratio of the change in monthly peak daily maximum 8-hr (MDA8) O_3 from the 50% reduction in NO_X to the change in monthly peak MDA8 O_3 from a 50% reduction in VOC.
Note: Ratios greater than one (shown in purple) indicate that ozone was reduced more effectively by similar percentage reductions in NO_X emissions than reductions in VOC emissions. Ratios less than one (shown in green) indicate that ozone was reduced more effectively by similar percentage reductions in VOC emissions than reductions in NO_X emissions.
Source: https://www.epa.gov/sites/production/files/2017-05/documents/national_modeling.advance.may_2017.pdf



$PM_{2.5}$ Formation

In the case of $PM_{2.5}$, or fine PM, total mass is often categorized into two groups: primary (i.e., emitted directly as $PM_{2.5}$ from sources) and secondary (i.e., $PM_{2.5}$ formed in the atmosphere by precursor emissions from sources). The ratio of primary to secondary $PM_{2.5}$ varies by location and season. In the U.S., $PM_{2.5}$ is dominated by a variety of chemical components: sulfate, nitrate, ammonium, organic carbon (OC), elemental carbon (EC), crustal elements, sea-spray constituents, and oxidized metals. $PM_{2.5}$ EC, crustal elements, and sea spray are directly emitted into the atmosphere from primary sources. $PM_{2.5}$ OC is directly emitted from primary sources but is also formed secondarily in the atmosphere by reactions involving VOCs. $PM_{2.5}$ sulfate, nitrate, and ammonium are predominantly the result of chemical reactions of the oxidized products of SO_2 and NO_X emissions and direct NH_3 emissions (Seinfeld and Pandis, 2012). Figure 2-2 shows the average composition by season (spring, summer, fall and winter) for $PM_{2.5}$ data collected during 2013-15. In the eastern United States, sulfate is high in the spring (March-May) and summer (July-September). Nitrate is most evident in the Midwest and western cities and highest during the winter. Organic mass (OM) is a large component throughout the year.

Figure 2-2. Average composition by season for $PM_{2.5}$ data collected during 2013-15.
Note: Quarter 1 (top left), quarter 2 (top right), quarter 3 (bottom left), and quarter 4 (bottom right).



Sulfur dioxide emissions are oxidized in the atmosphere and form sulfuric acid, which has a very low vapor pressure and tends to exist in the particulate phase. Particulate sulfuric acid reacts with NH_3 to form ammonium bisulfate and ammonium sulfate. Aqueous phase reactions are also an important pathway for particulate sulfate formation. SO_2 dissolves into cloud and fog droplets and is oxidized to sulfate via reaction pathways involving hydrogen peroxide, O_3, and other oxidants. Since sulfate is essentially non-volatile under atmospheric conditions, sulfate formed in clouds persists as particulate sulfate after the cloud evaporates. Sulfur dioxide emission reductions lead to reductions in particulate sulfate. The process is not completely linear, especially when aqueous phase production is significant, and so changes in SO_2 emissions may not result in the same proportion of change in $PM_{2.5}$ sulfate concentration.

Emissions of NO_X are chemically transformed to nitric acid (HNO_3) through gas-phase and heterogeneous reactions. Nitric acid may condense onto particles to form particulate nitrate depending on the conditions. Condensation of HNO_3 onto particles is favored by low temperature, high relative humidity, and relatively less acidic conditions associated with high levels of NH_3 and particulate cations. HNO_3 formation may be oxidant or NOx-limited, and $PM_{2.5}$ ammonium nitrate formation may be limited by the availability of either nitric acid or NH_3 or by meteorological conditions. When $PM_{2.5}$ ammonium nitrate is limited by the availability of NH_3, the formation regime is termed "ammonia-limited," and the formation regime is termed "nitric acid-limited" when the opposite situation exists (Stockwell et al., 2000). In general, a decrease in NO_X emissions will result in a decrease in $PM_{2.5}$ nitrate concentration (Pun et al., 2007). Since $PM_{2.5}$ ammonium nitrate formation is preferred under low temperature and high relative humidity conditions and in the presence of NH_3, ammonium nitrate concentrations tend to be greater during colder months and in areas with significant NH_3 emissions. NO_X emission changes during warm temperatures may result in less change in ambient $PM_{2.5}$ compared to cold months due to HNO_3 staying in the gas rather than particle phase due to higher temperatures. Additionally, NO_X emission changes in places with very little or no ambient ammonia may result in little change in ambient $PM_{2.5}$ ammonium nitrate.

3. Framework for Developing MERPs as a Tier 1 Demonstration Tool

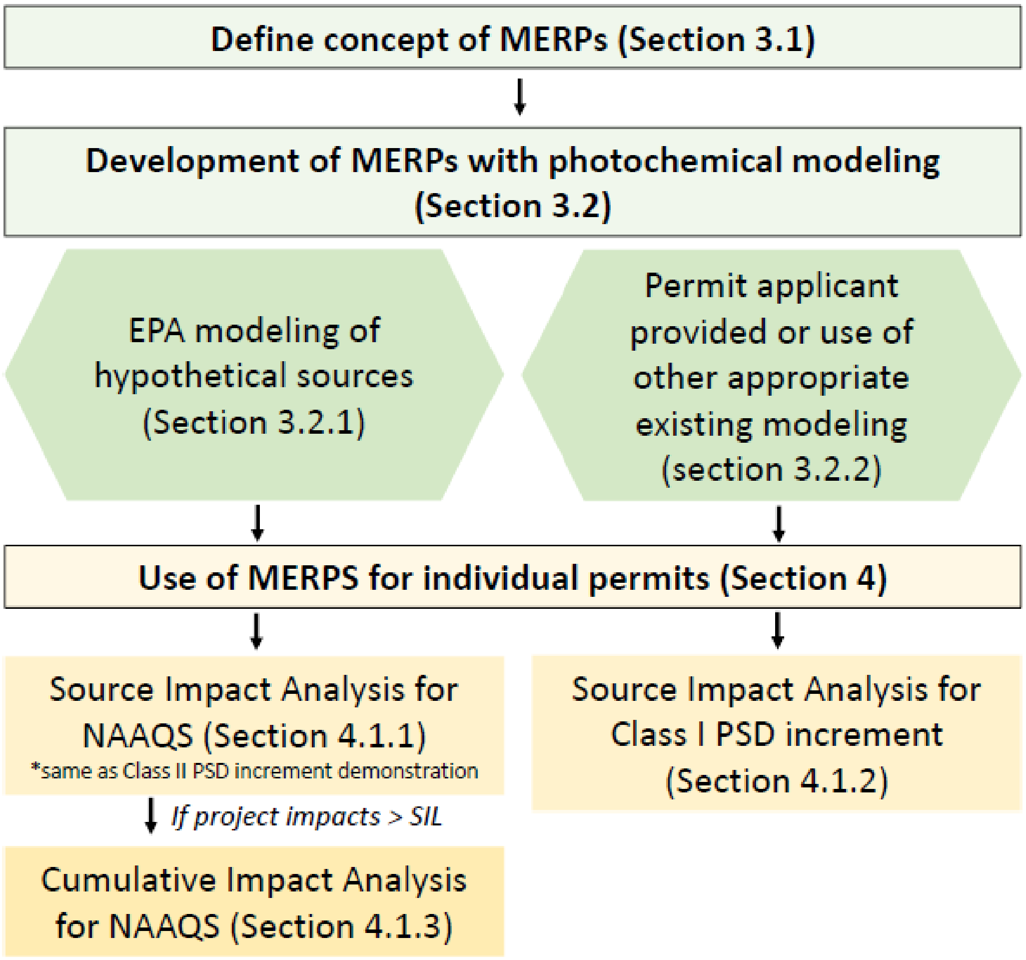
A Tier 1 demonstration tool as described in the *Guideline* consists of technically credible air quality modeling done to relate precursor emissions and peak secondary pollutant impacts from specific or hypothetical sources (U.S. Environmental Protection Agency, 2017a). With appropriate supporting information, permit applicants may use existing appropriate air quality modeling as part of an assessment of air quality impacts from a proposed new or modified source under the PSD permitting program. Permit applicants should provide a narrative explanation describing how project source emissions relate to the information provided as part of their Tier 1 demonstration. It should be made clear how the chemical and physical environments modeled as part of an existing set of information included in their Tier 1 demonstration are relevant to the geographic area of the project and key receptors.

As detailed below, this framework for developing MERPs focuses on use of photochemical modeling to relate the modeled air quality impacts and a critical air quality threshold (e.g., appropriate SIL value) to estimate a MERP for comparison with the project source emissions. However, a similar screening approach would be to adjust the modeled air quality impacts based on the relationship between the modeled and project source emissions to then compare the resulting air quality impact with the appropriate SIL.

Existing credible air quality modeling generally may include single source modeling based on an approved SIP demonstration, a more recent submitted but not approved SIP demonstration, or modeling not used to support a SIP demonstration but considered representative of the current air quality in the area and of sufficient quality that is comparable to a model platform supporting a SIP demonstration. The specifications for single source demonstration model platforms (e.g., horizontal grid spacing, vertical resolution, non-project source emission treatment, etc.) are detailed in the 2016 EPA guidance document "Guidance on the use of models for assessing the impacts of emissions from single sources on the secondarily formed pollutants O_3 and $PM_{2.5}$" (U.S. Environmental Protection Agency, 2016a).

Figure 3-1 illustrates the EPA's framework for MERPs as a Tier 1 demonstration tool. This framework is intended to show how the elements and concepts described in this document relate to each other and where more information is provided in this document about each step of the process. This flow diagram shows how MERPs can be developed from either existing EPA modeling or another source of data and how that information can be credibly used for a source impact analysis and, if necessary, a cumulative impact analysis. In this framework, the source impact analysis for the $PM_{2.5}$ NAAQS may also satisfy Class II PSD increment since the recommended EPA SILs are the same.

Figure 3-1. EPA's framework for MERPs as a Tier 1 Demonstration Tool.



3.1. Definition of MERPs as a Tier 1 Demonstration Tool

Properly-supported MERPs provide a simple way to relate modeled downwind impacts with an air quality threshold that is used to determine if such an impact causes or contributes to a violation of the appropriate NAAQS. In the discussion that follows and in reported results in computing MERP values, we use the EPA's recommended SIL values for O_3 and $PM_{2.5}$ as the relevant air quality threshold (U.S. Environmental Protection Agency, 2018). Consistent with EPA's SILs guidance, to the extent a permitting authority elects to use a SIL to help quantify a level of impact that does not cause or contribute to a violation of the O_3 and/or $PM_{2.5}$ NAAQS or $PM_{2.5}$ PSD increment(s), such values will need to be justified on a case-by-case basis. To derive a MERP value for the purposes of a PSD compliance demonstration, the model predicted relationship between precursor emissions from hypothetical sources and their downwind modeled impacts can be combined with the appropriate SIL value using the following equation:

$$\textbf{Eq. 1} \quad \text{MERP} = \text{appropriate SIL value} \times \frac{\text{Modeled emission rate (tpy) from hypothetical source}}{\text{Modeled air quality impact from hypothetical source}}$$

For $PM_{2.5}$, the modeled air quality impact of an increase in precursor emissions from the hypothetical source is expressed in units of $\mu g/m^3$. For O_3, the modeled air quality impact is expressed in ppb. As discussed in Section 4, these modeled impacts would reflect the maximum downwind impacts for $PM_{2.5}$ and O_3. The SIL value is expressed as a concentration for $PM_{2.5}$ (in $\mu g/m^3$) and mixing ratio for O_3 (in ppb). Consistent with the air quality model application used here to predict a change in pollutant concentration, MERPs are expressed as an annual emissions rate (in this case as tons per year).

3.2. Development of MERPs through Photochemical Modeling

As stated in the preamble to the 2017 revisions to the Guideline (U.S. Environmental Protection Agency, 2017a), the EPA believes that use of photochemical models for estimating single source secondary pollutant impacts is scientifically appropriate and practical to implement. Publicly available and fully documented Eulerian photochemical grid models such as the Comprehensive Air Quality Model with Extensions (CAMx) (Ramboll ENVIRON, 2016) and the Community Multiscale Air Quality (CMAQ) (Byun and Schere, 2006) model treat emissions, chemical transformation, transport, and deposition using time and space variant meteorology. These modeling systems simulate primarily emitted species and secondarily formed pollutants such as O_3 and $PM_{2.5}$ (Chen et al., 2014; Civerolo et al., 2010; Russell, 2008; Tesche et al., 2006). Even though single source emissions are injected into a grid volume, photochemical transport models have been shown to adequately capture single source impacts when compared with downwind in-plume measurements (Baker and Kelly, 2014; Baker and Woody, 2017; Zhou et al., 2012). Where set up appropriately for the purposes of assessing the air quality impact of single sources to ambient levels of primary and secondarily formed pollutants, photochemical grid models could be used with a variety of approaches to estimate these impacts. These approaches generally fall into the categories of source sensitivity (how air quality changes due to changes in emissions) and source apportionment (what air quality impacts are related to certain emissions).

The simplest source sensitivity approach, commonly referred to as a brute-force change to emissions, would be to simulate two sets of conditions, one with all emission sources and a subsequent simulation with all emission sources and the post-construction characteristics of the new source or modification being the only difference from the original baseline simulation (Cohan and Napelenok, 2011). The difference between these model simulations provides an estimate of the air quality change related to the change in emissions from the project source. In addition to the brute force approach, some photochemical models have been “instrumented” with techniques that allow tracking of air quality impacts from the emissions of a particular sector or source. One sensitivity approach is the decoupled direct method (DDM), which tracks the sensitivity of an emission source through all chemical and physical processes in the modeling system (Dunker et al., 2002). Sensitivity coefficients relating source emissions to air quality are estimated during the model simulation and output at the resolution of the host model. Unlike the brute force approach, a second simulation is not necessary when using DDM, although additional resources are required as part of the initial baseline simulation when DDM is applied.

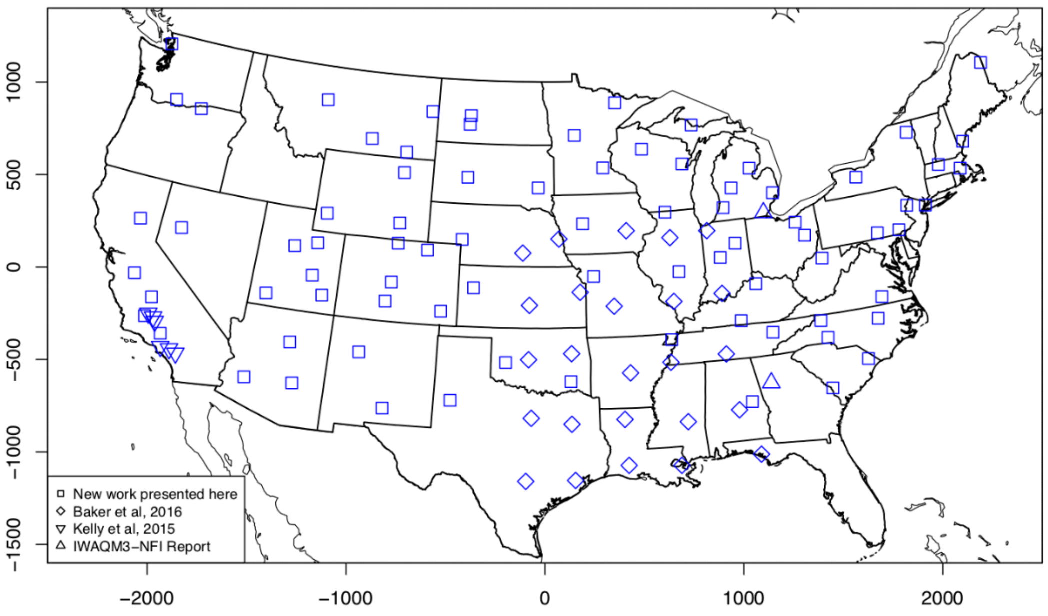
Some photochemical models have been instrumented with source apportionment capabilities which tracks emissions from specific sources through chemical transformation, transport, and deposition processes to estimate source-specific impacts to predicted air quality at downwind receptors (Kwok et al., 2015; Kwok et al., 2013). Source apportionment has been used to differentiate the air quality impact from single sources on model predicted O_3 and $PM_{2.5}$ (Baker and Foley, 2011; Baker and Kelly, 2014; Baker and Woody, 2017). DDM has also been used to estimate O_3 and $PM_{2.5}$ impacts from specific sources (Baker and Kelly, 2014; Bergin et al., 2008; Kelly et al., 2015) as well as the simpler brute-force sensitivity approach (Baker and Kelly, 2014; Bergin et al., 2008; Kelly et al., 2015; Zhou et al., 2012). Limited comparison of single source impacts between models (Baker et al., 2013) and approaches to differentiate single source impacts (Baker and Kelly, 2014; Kelly et al., 2015) show generally similar downwind spatial gradients and impacts.

Near-source in-plume aircraft based measurement field studies provide an opportunity to evaluate model estimates of (near-source) downwind transport and chemical impacts from single stationary point sources (ENVIRON, 2012b). Photochemical grid model source apportionment and source sensitivity simulation of single-source downwind impacts compare well against field study primary and secondary ambient in-plume measurements (Baker and Kelly, 2014; Baker and Woody, 2017; ENVIRON, 2012b). This work indicates photochemical grid models using source apportionment or source sensitivity approaches provide meaningful estimates of single source impacts.

3.2.1. EPA Single Source Photochemical Modeling for O_3 and Secondary $PM_{2.5}$

This section presents a summary of EPA photochemical modeling of hypothetical single source impacts on downwind O_3 and secondary $PM_{2.5}$. The locations of hypothetical sources modeled are shown in Figure 3-2. A total of 113 locations were modeled. The single source impacts detailed in this section were collected from various past and recent photochemical grid model-based assessments. The resulting relationships were based on photochemical modeling studies that estimated single source impacts in California (Kelly et al., 2015), the Detroit and Atlanta urban areas (U.S. Environmental Protection Agency, 2016b), and at rural and suburban locations in the central and eastern United States (Baker et al., 2016). Additional photochemical modeling was conducted by EPA consistent with the approach described in Baker et al., 2016 for hypothetical sources in the western, central, and eastern U.S. to provide broader geographic coverage across the nation.

Figure 3-2. Location of hypothetical sources modeled for downwind secondary air quality impacts included in EPA's assessment.



Atlanta and Detroit both include a single hypothetical source modeled at 4 km horizontal grid resolution for an entire year. The California sources were also modeled at 4 km but only include a sub-set of an entire year meaning the maximum impact from those hypothetical sources may not be realized as part of that study design. The western, central, and eastern U.S. sources were modeled at 12 km horizontal grid resolution for the entire year of 2011. It is possible that the maximum impacts from each of these hypothetical sources may not have been realized using a single year of meteorology and that another year with more conducive meteorology for secondary formation of O_3 and/or $PM_{2.5}$ might be more appropriate and result in greater downwind impact. As shown, we define the following source types throughout the continental U.S. that reflect different release heights and multiple emissions rates:

- Source release type "L" refers to sources modeled with surface level emissions releases: stack height of 10 m, stack diameter of 5 m, exit temperature of 311 K, exit velocity of 27 m/s, and flow rate of 537 m^3/s.
- Source release type "H" refers to sources modeled with tall stack emissions releases: stack height of 90 m, stack diameter of 5 m, exit temperature of 311 K, exit velocity of 27 m/s, and flow rate of 537 m^3/s.

Hypothetical sources for this assessment include impacts based on multiple emission rates and emitted with a near-surface release or tall stack. Information about each hypothetical source modeled is provided in Appendix A.

The relationships shown here for these hypothetical sources are not intended to provide an exhaustive representation of all combinations of source type, chemical, and physical source environments but rather to provide insightful information about secondary pollutant impacts from single sources in different parts of the U.S. The maximum impacts for daily $PM_{2.5}$, annual $PM_{2.5}$ and daily maximum 8-hr average O_3 are shown in the following sub-sections for the hypothetical sources modeled for an entire year and do not include sources modeled for an episode.

Tables showing the maximum impacts for sources modeled with annual simulations are provided in an Excel spreadsheet on EPA's SCRAM website. Impacts for each source include the maximum daily $PM_{2.5}$ impacts, maximum annual $PM_{2.5}$ impacts, and maximum daily 8-hr O_3 impacts over annual simulations. Emissions are shown in tpy and release height in meters. VOC speciation used for these assessments is shown in Table 3-1. More information about these hypothetical sources and how the model output was processed to generate maximum impacts are described in more detail in (Baker et al., 2016).

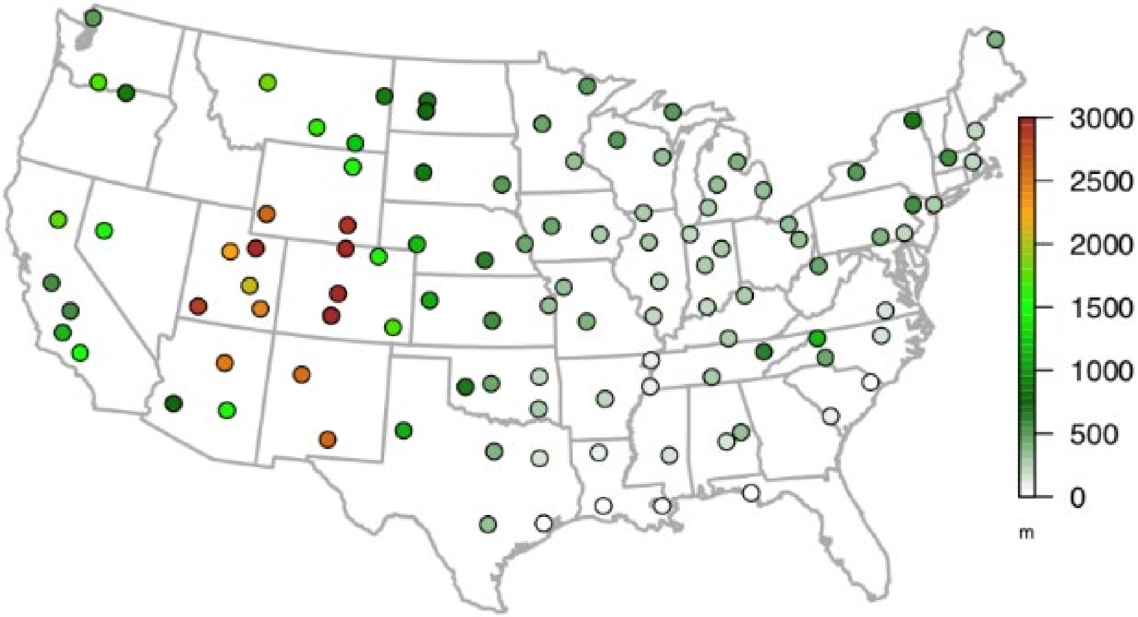
Table 3-1. Assumed VOC speciation for hypothetical sources presented here.

Carbon bond specie	Fraction	Carbon bond specie	Fraction
ALD2	0.0152	MEOH	0.0054
ALDX	0.0155	NVOL	0.0008
ETH	0.0324	OLE	0.1143
ETHA	0.0094	PAR	0.4057
ETOH	0.0090	TERP	0.0170
FORM	0.0757	TOL	0.1148
IOLE	0.0088	UNR	0.1080
ISOP	0.0007	XYL	0.0674

Additional information has been provided for each source to facilitate qualitative comparison between hypothetical sources with project sources. The additional information includes the terrain within 50 km of the source and maximum grid cell percent urban landcover within 50 km of the source to provide some additional information about nearby orography and whether the source is in proximity to population centers. This additional information is illustrated in Figure 3-3.

The spreadsheet also includes the climate zone where the source is located as shown in Figure 3-4. These regional classifications are used to aggregate impacts in summarizing modeling results in subsequent sections.

Figure 3-3. Maximum terrain height (top) and fractional urban coverage (bottom) within 50 km of each of the hypothetical sources modeled.



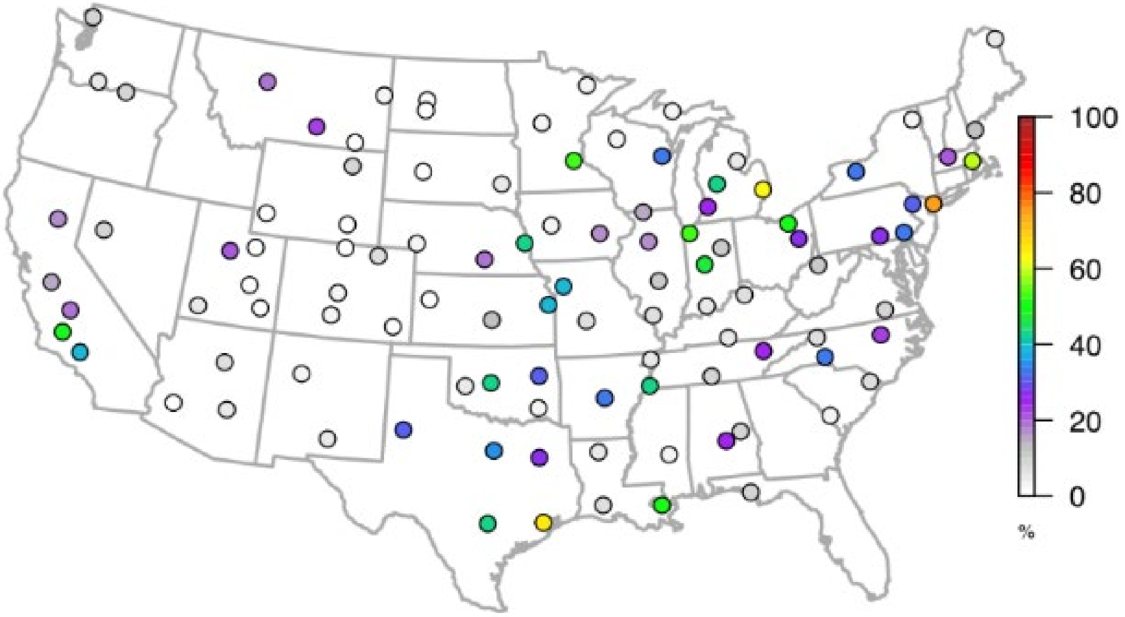
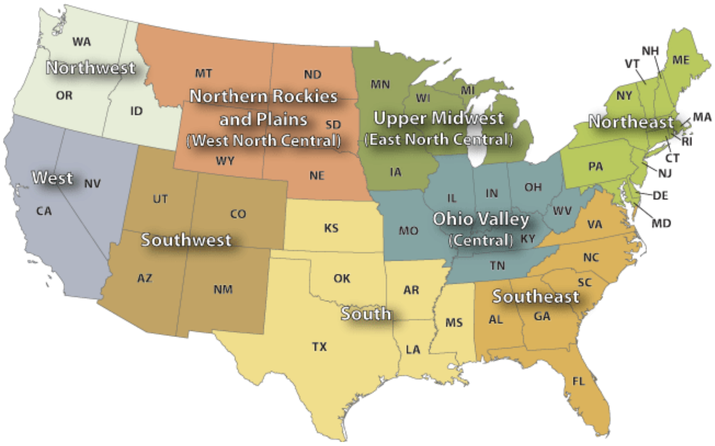


Figure 3-4. NOAA climate zone map with number of hypothetical source locations modeled in each climate zone.
Source: https://www.ncdc.noaa.gov/monitoring-references/maps/us-climate-regions.php



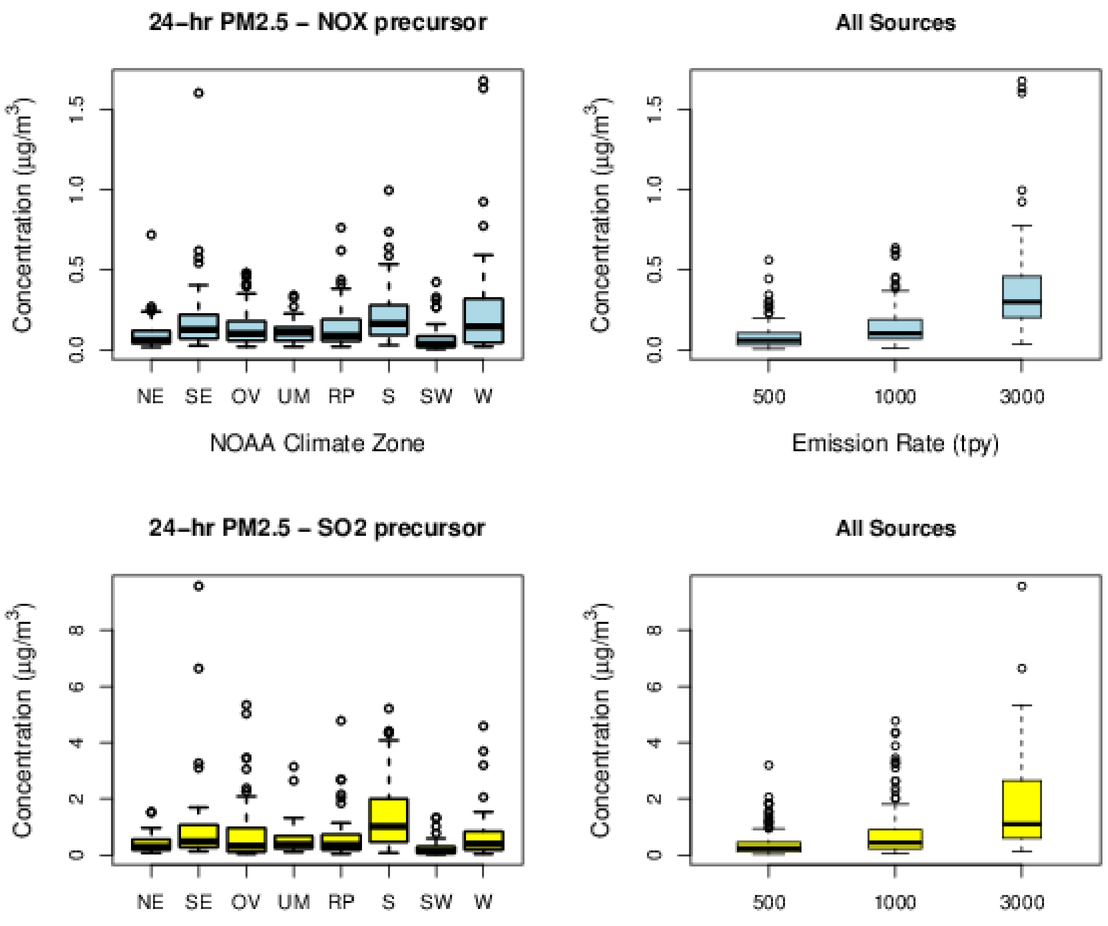
Climate Zone	Sources
Northeast	10
Southeast	9
Ohio Vally	19
Upper Midwest	12
Rockies/Plains	14
South	17
Southwest	15
West	6
Northwest	3

3.2.1.1. EPA Modeled Impacts: Annual and Daily PM2.5

The maximum daily average $PM_{2.5}$ sulfate ion from SO_2 emissions and maximum daily average $PM_{2.5}$ nitrate ion from NO_X emissions are shown in Figure 3-5 by emission rate and area. Downwind maximum $PM_{2.5}$ impacts generally increase as rates of precursor emissions increase. However, differences in chemical (e.g. NO_X/VOC ratio, NH_3 concentrations) and physical (e.g., terrain and meteorology) regimes among these hypothetical sources result in differences in downwind impacts even for similar types of sources. Differences in maximum impacts can also be seen between the different areas and studies. One such example is described in Section 3.2.1.3 of this document.

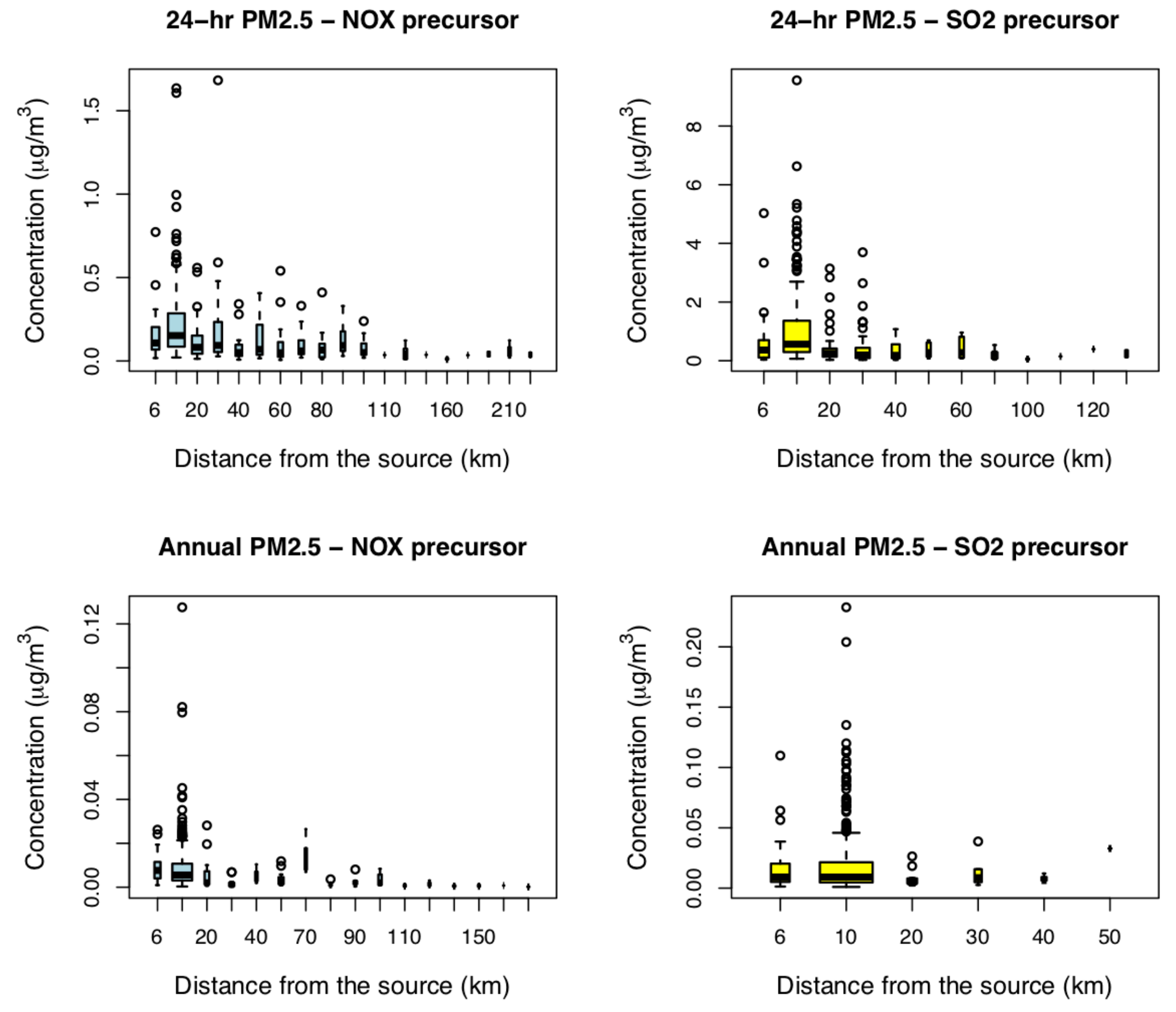
Figure 3-5. Maximum daily average $PM_{2.5}$ nitrate ion impacts from NO_X emissions and $PM_{2.5}$ sulfate ion impacts from SO_2 emissions.

Note: These impacts are from multiple modeling studies estimating downwind impact from hypothetical sources. The distribution shown for each climate zone represents multiple emission rates.



The distance from the source of maximum daily and annual average secondary $PM_{2.5}$ impact is shown in Figure 3-6. Peak impacts tend to be in close proximity to the source. For NO_X precursor, the peak 24-hour $PM_{2.5}$ impacts are typically within 20 to 50 kilometers, while peak annual average $PM_{2.5}$ impacts are typically within 20 kilometers of the source. For SO_2 precursor, the peak 24-hour $PM_{2.5}$ impacts are shown to be mostly within 10 to 40 kilometers, while peak annual average $PM_{2.5}$ impacts are largely within 20 kilometers. These peak impacts become less common as distance from the source increases. Figure 3-7 shows maximum annual average impacts from SO_2 emissions on modeled $PM_{2.5}$ sulfate ion and NO_X emissions on modeled $PM_{2.5}$ nitrate ion. Downwind impacts tend to increase as emissions of precursors increase. Also, impacts vary from area to area.

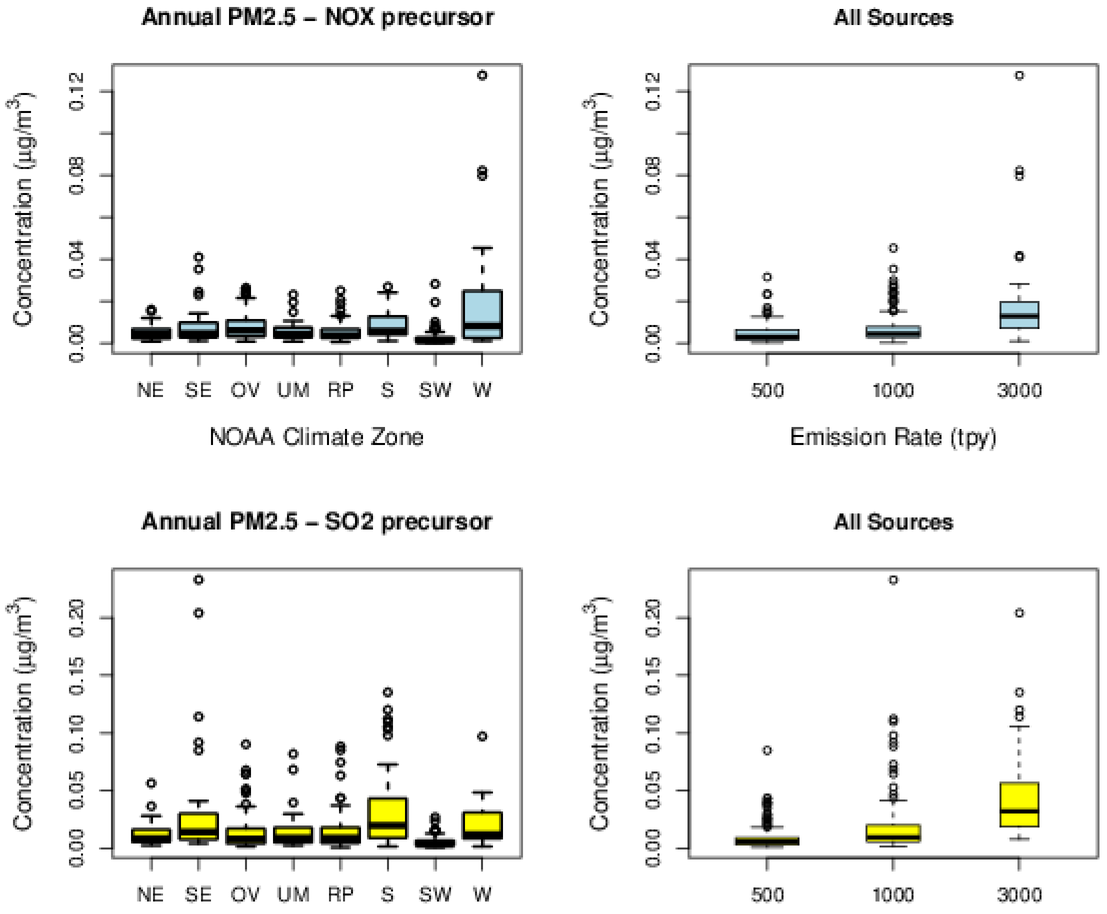
Figure 3-6. Maximum daily and annual average secondary $PM_{2.5}$ nitrate ion impacts from NO_X emissions and $PM_{2.5}$ sulfate ion impacts from SO_2 emissions shown by distance from the source.



The tendency for secondary $PM_{2.5}$ to be larger near the source is important when considering how to use impact estimates to inform different types of permit demonstrations. For NAAQS demonstrations, peak impacts tend to be near the source. Class I impacts are likely to be further downwind of the project source, so a near-source impact estimate would typically not be as relevant.

Figure 3-7. Maximum annual average secondary $PM_{2.5}$ nitrate ion impacts from NO_X emissions and $PM_{2.5}$ sulfate ion impacts from SO_2 emissions.

Note: These impacts are from multiple modeling studies estimating downwind impact from hypothetical sources. The distribution shown for each climate zone represents multiple emission rates.

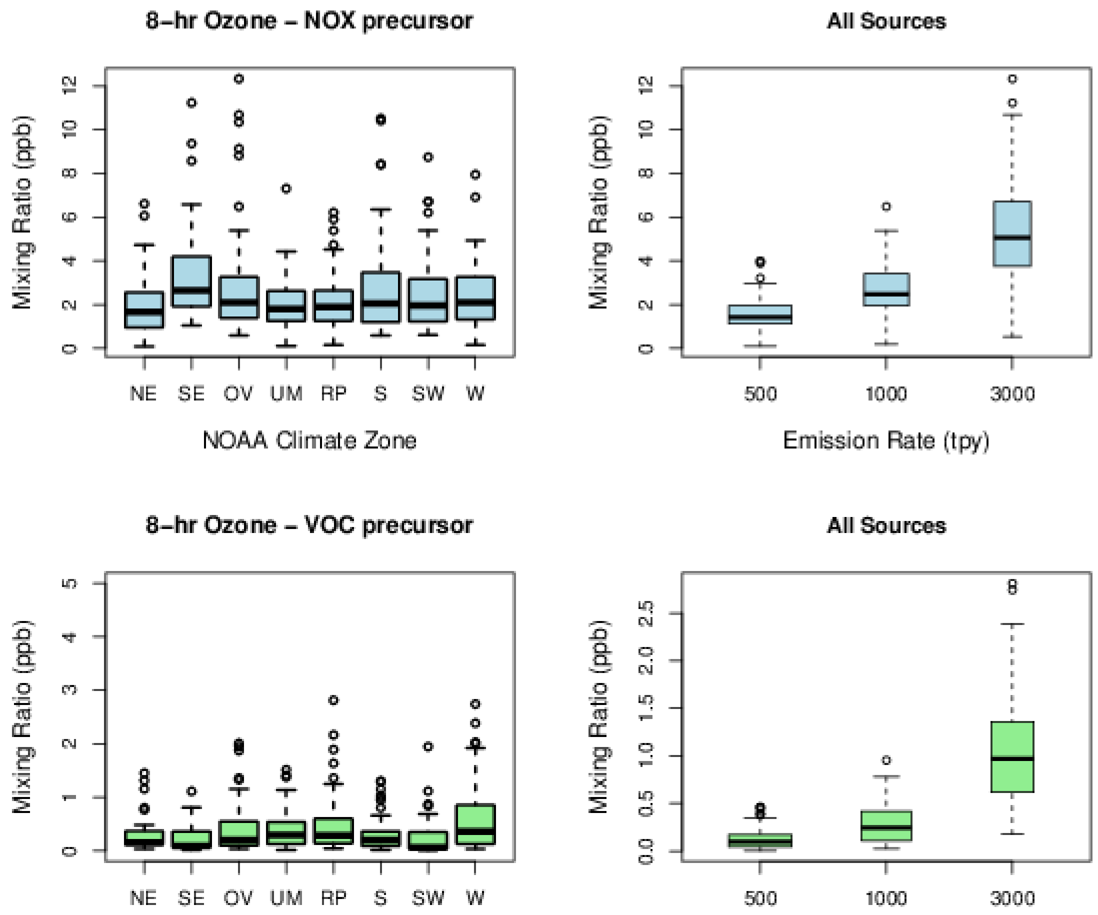


3.2.1.2. EPA Modeled Impacts: 8-hour Ozone

Maximum 8-hr O_3 impacts are shown in Figure 3-8 compared to single source precursor emission rates. These relationships are based on photochemical modeling studies that estimated single source impacts in California (Kelly et al., 2015), the Detroit and Atlanta urban areas (U.S. Environmental Protection Agency, 2016b), and at rural and suburban locations in the central and eastern United States (Baker et al., 2016). Additional modeling was conducted consistent with the approach described in Baker et al., 2016 for hypothetical sources in the western and eastern U.S. to provide broader geographic coverage of the U.S.

Downwind maximum 8-hr O_3 impacts generally increase as rates of precursor emissions increase. However, differences in chemical (e.g., NO_X/VOC ratio, radical concentrations) and physical (e.g., terrain and meteorology) regimes among these hypothetical sources result in differences in downwind impacts even for similar types of sources.

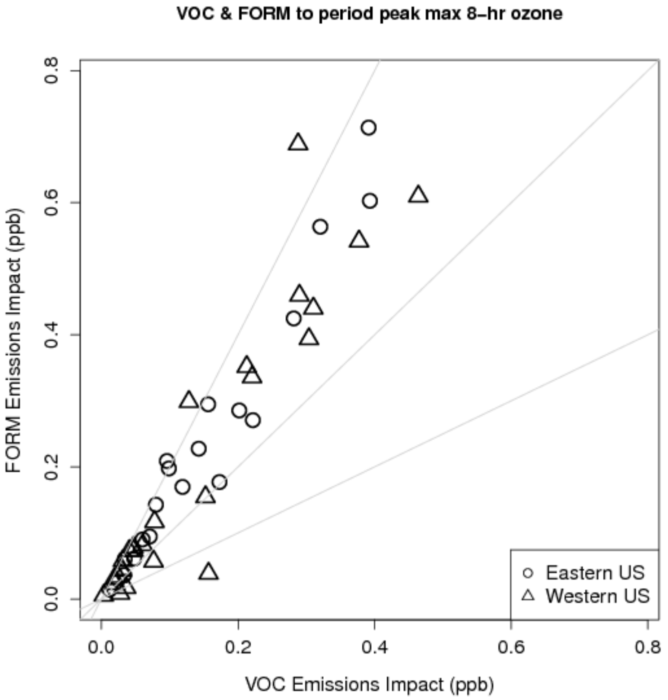
Figure 3-8. Maximum 8-hr ozone impacts from NO_X emissions and from VOC emissions.
Note: These impacts are from multiple modeling studies estimating downwind impact from hypothetical sources. The distribution shown for each climate zone represents multiple emission rates.



Each of the hypothetical source impacts modeled as part of EPA's assessment used a typical industrial assumption for speciation of VOC emissions (see Table 3-1 for VOC speciation profile). To better understand the influence of VOC speciation, as a sensitivity analysis, EPA modeled a set of hypothetical sources with near-surface releases in the western and eastern U.S. with an alternative VOC emissions speciation that assumed 100% of the VOC emissions were emitted as formaldehyde to provide a more reactive profile than typically used. Figure 3-9 shows a comparison of the downwind maximum daily 8-hr average O_3 impacts using the typical VOC profile compared with impacts where these same sources are modeled with formaldehyde-only VOC emissions. For both sets of emissions scenarios, a total of 500 tpy of VOC was emitted, the only difference being the VOC speciation. The formaldehyde only simulations for these sources generally resulted in higher downwind O_3 impacts than the simulations of hypothetical sources with VOC speciation shown in Table 3-1. The increases in impacts are typically between 1.5 and 2 times higher (Figure 3-9).

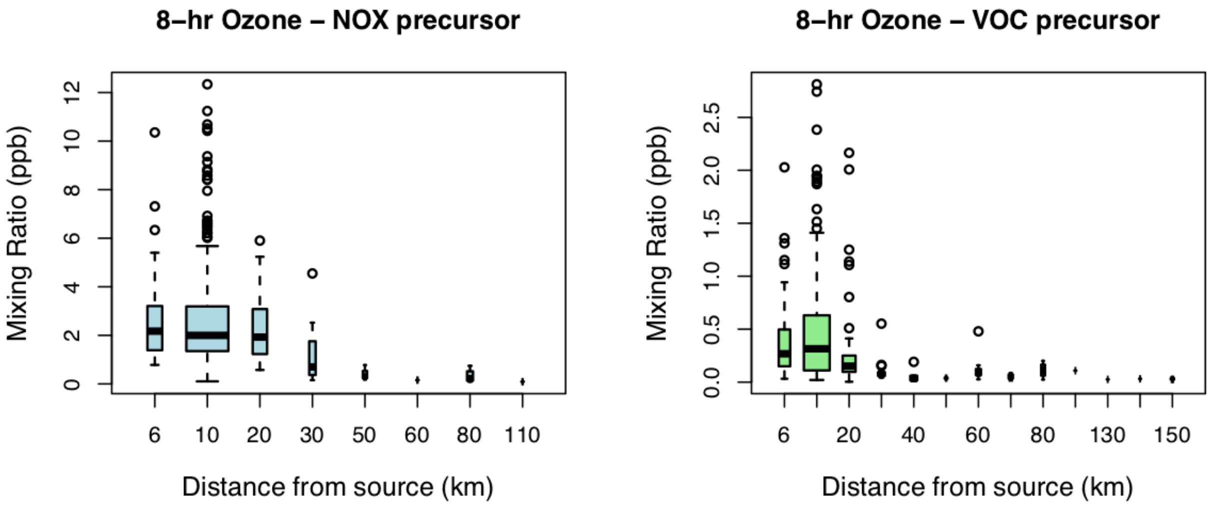
Since VOC reactivity can be important, some areas may want to develop separate VOC to O_3 relationships using typical VOC profiles and VOC profiles that may be more reflective of certain types of sources that exist in that area or are anticipated to operate in that area in the future.

Figure 3-9. Maximum 8-hr ozone impacts from 500 tpy of near-surface VOC emissions using a typical industrial VOC speciation profile and assuming all VOC emissions are formaldehyde.
Note: these impacts are for the eastern and western U.S. hypothetical sources presented here and do not include information from any other studies.



The distance from the source of the maximum daily 8-hr average O_3 impacts are shown in Figure 3-10. Like maximum daily $PM_{2.5}$ impacts, maximum daily 8-hr average O_3 impacts tend to be in close proximity to the source and are less frequent as distance from the source increases. This is particularly notable where distance from the source exceeds 50 km.

Figure 3-10. Maximum 8-hr ozone impacts from NO_X emissions and from VOC emissions by distance from the source.
Note: These impacts are from multiple modeling studies estimating downwind impact from hypothetical sources.



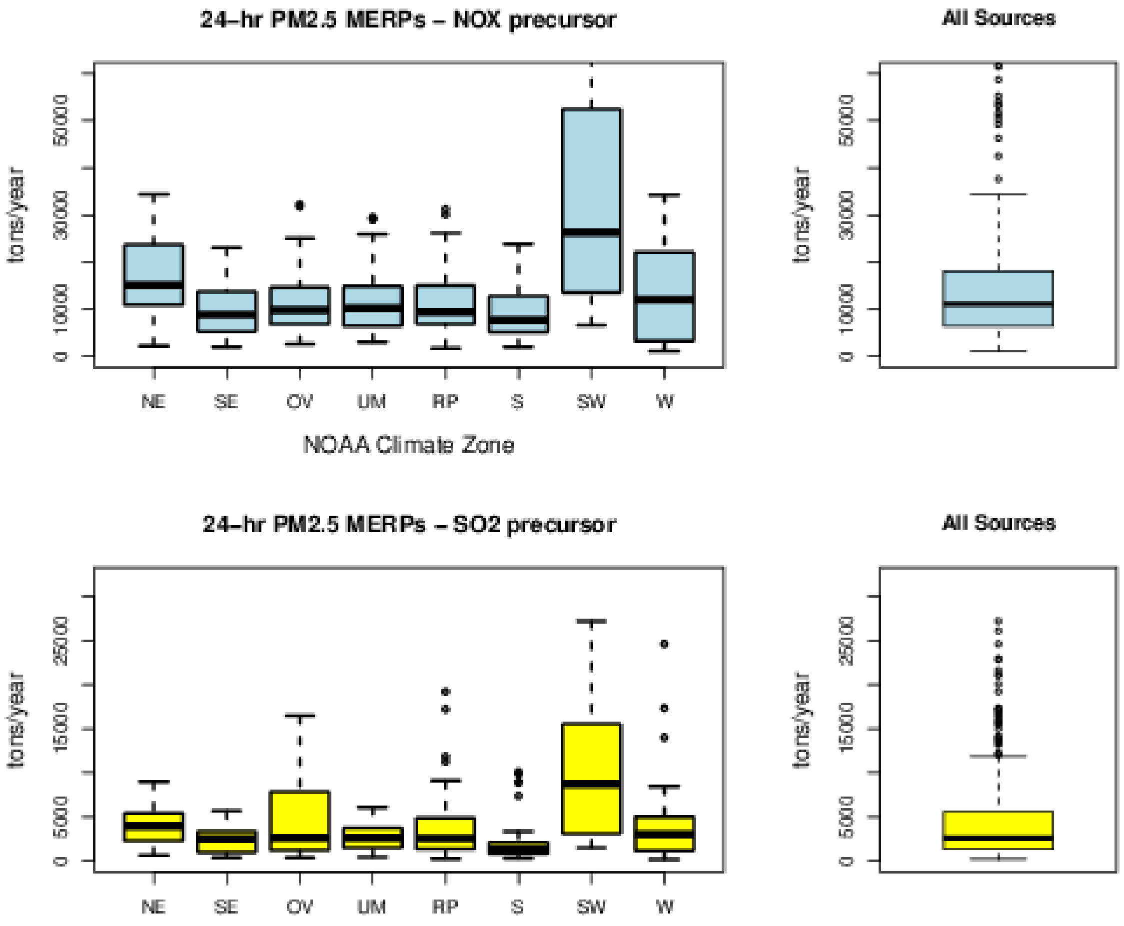
3.2.1.3. EPA Illustrative MERPs: Annual and Daily PM2.5

The hypothetical single source modeling presented here was used to develop illustrative MERPs based on equation 1 and the EPA recommended SIL. Based on the EPA's photochemical modeling results across all hypothetical sources presented above and detailed in Appendix A of this document, Figure 3-11 shows NO_X to annual maximum daily average $PM_{2.5}$ nitrate ion and SO_2 to annual maximum daily average $PM_{2.5}$ sulfate ion MERPs that illustrate the range of potential values for these sources and time period. Neither $PM_{2.5}$ sulfate nor $PM_{2.5}$ nitrate was assumed to be neutralized by ammonium. For this illustrative example, consistent with EPA's SILs guidance (U.S. Environmental Protection Agency, 2018), the EPA recommended 24-hour $PM_{2.5}$ NAAQS SILs value of 1.2 $\mu g/m^3$ was used to estimate daily average $PM_{2.5}$ MERPs.

The illustrative MERPs for NO_X to daily $PM_{2.5}$ range from 1,073 tpy to over 100,000 tpy, while the illustrative MERPs for SO_2 to daily $PM_{2.5}$ range from 188 tpy to over 27,000 tpy for the hypothetical sources modeled and presented here based on the selected air quality threshold. The variation from source to source is related to different chemical and meteorological environments around the source that range in terms of conduciveness toward secondary $PM_{2.5}$ formation.

Similarly, based on EPA's photochemical modeling results of hypothetical sources, Figure 3-12 shows NO_X to maximum annual average $PM_{2.5}$ nitrate ion and SO_2 to maximum annual average $PM_{2.5}$ sulfate ion MERPs to illustrate the range of potential values for these sources and this time period. Neither $PM_{2.5}$ sulfate nor $PM_{2.5}$ nitrate were assumed to be neutralized by ammonium.

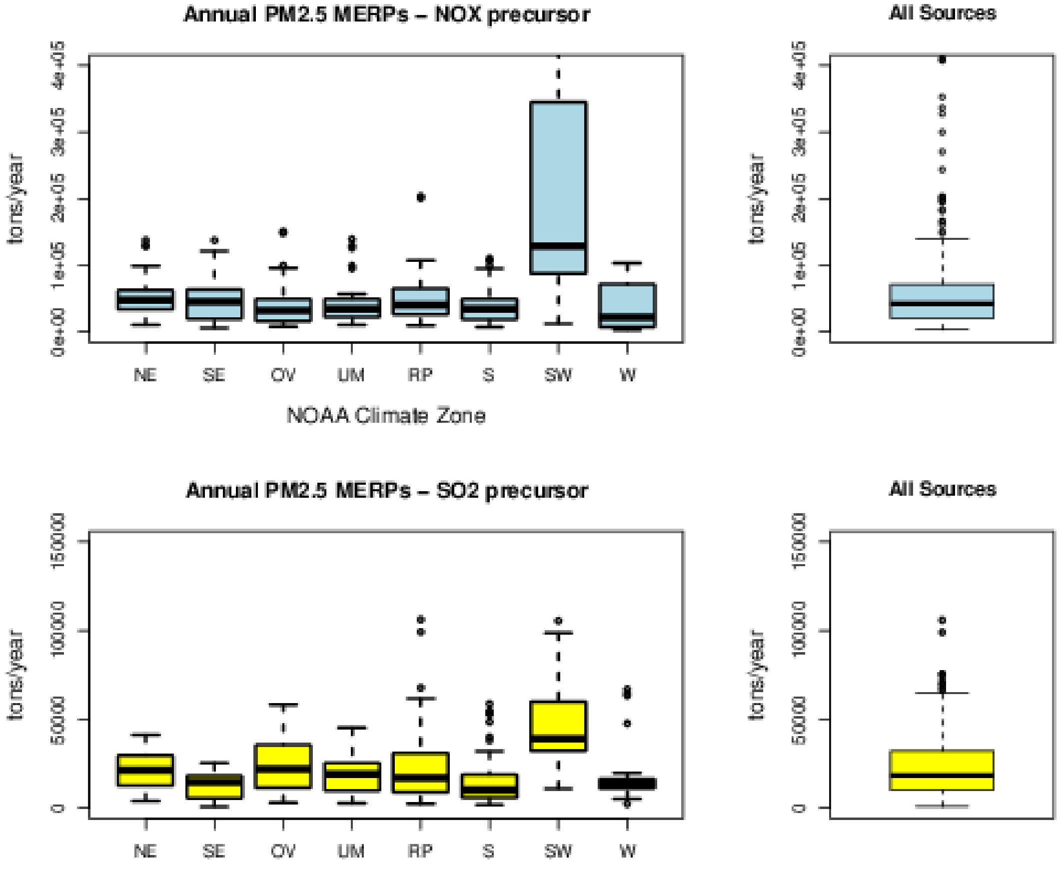
Figure 3-11. NO_X and SO_2 daily average $PM_{2.5}$ MERPs estimated from single source hypothetical emissions impacts on $PM_{2.5}$ nitrate ion and $PM_{2.5}$ sulfate ion respectively.
Note: Daily $PM_{2.5}$ MERPs derived here based on EPA recommended 24-hour $PM_{2.5}$ NAAQS SIL value of 1.2 µg/m^3 and neither $PM_{2.5}$ sulfate nor nitrate is assumed to be neutralized by ammonia.



For this illustrative example, consistent with EPA's SILs guidance, the EPA recommended annual $PM_{2.5}$ NAAQS SILs value of 0.2 µg/m^3 was used to estimate annual average $PM_{2.5}$ MERPs. The illustrative MERPs for NO_X to annual $PM_{2.5}$ range from 3,182 tpy to over 700,000 tpy, while the illustrative MERPs for SO_2 to annual $PM_{2.5}$ range from 859 tpy to over 100,000 tpy for the hypothetical sources presented here based on the selected air quality threshold. The variation from source to source is related to different chemical and meteorological environments around the source that range in terms of conduciveness toward secondary $PM_{2.5}$ formation.

Figure 3-12. NO_X and SO_2 annual average $PM_{2.5}$ MERPS shown by geographic region.

Note: Annual $PM_{2.5}$ MERPs derived here based on EPA recommended annual $PM_{2.5}$ NAAQS SIL value of 0.2 µg/m^3 and neither $PM_{2.5}$ sulfate nor nitrate is assumed to be neutralized by ammonia.



As shown, the illustrative MERPs are generally lower for SO_2 than NO_X meaning that SO_2 tends to form $PM_{2.5}$ more efficiently than NO_X. This is consistent with the conceptual model of secondary $PM_{2.5}$ formation in many parts of the United States reflecting that the $PM_{2.5}$ sulfate ion has a lower vapor pressure than $PM_{2.5}$ nitrate ion and tends to stay in the particulate phase in a greater range of meteorological conditions.

The distribution of illustrative MERPs for both SO_2 and NO_X to daily $PM_{2.5}$ are shown to vary between regions of the United States. This is expected since the chemical (e.g., oxidants, neutralizing agents) and physical (e.g., terrain) environments vary regionally in the United States. Figure 3-13 shows the lowest MERP at each hypothetical source location for daily (left panels) and annual (right panels) $PM_{2.5}$ from SO_2 (top panels) and NO_X (bottom panels) emissions. These plots show broad regional patterns in $PM_{2.5}$ formation potential which are generally related to regions with conducive meteorology, available neutralizing agents, and other emission sources competing for these neutralizing agents.

Figure 3-13. Lowest MERP value at each hypothetical source location for daily (left panels) and annual (right panels) $PM_{2.5}$ from SO_2 (top panels) and NO_X (bottom panels) emissions.

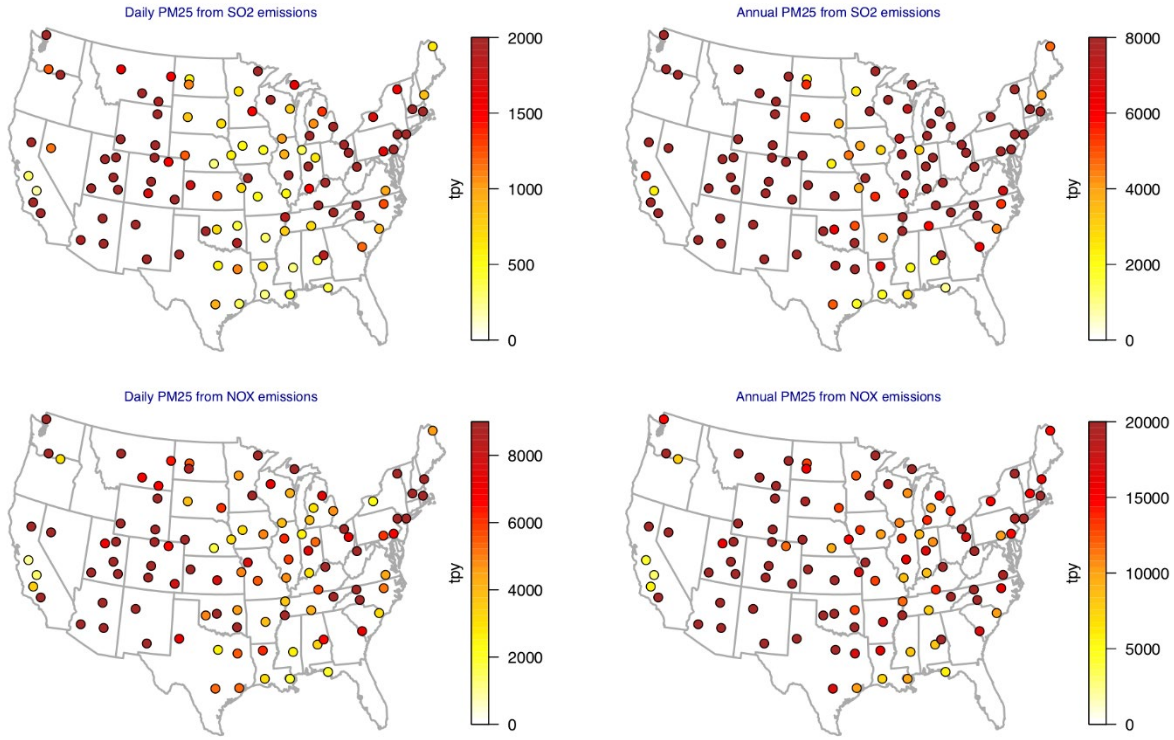


Figure 3-13 also shows that sometimes there are notable differences in $PM_{2.5}$ formation potential for sources in close proximity. Again, these differences are related to differences in local to regional mix of pollution, terrain, and meteorology. This also shows that spatial interpolation between these hypothetical sources would not always provide a realistic representation of model response to the introduction of new precursor emissions.

One interesting example of sources in close proximity with different $PM_{2.5}$ formation potential for sulfate and nitrate are the two hypothetical sources in western North Dakota. These sources are in fairly close proximity but are situated by very different types of emissions sources (e.g., large complex of industrial sources, animal operations). Figure 3-14 shows the location of these sources relative to modeled monthly average ammonia concentration and annual NO_2 emissions from the oil and gas sector.

Figure 3-14. Monthly average ammonia concentrations estimated by CAMx for July 2011 and annual total NO_2 emissions from the oil and gas sector based on the 2011 National Emission Inventory.

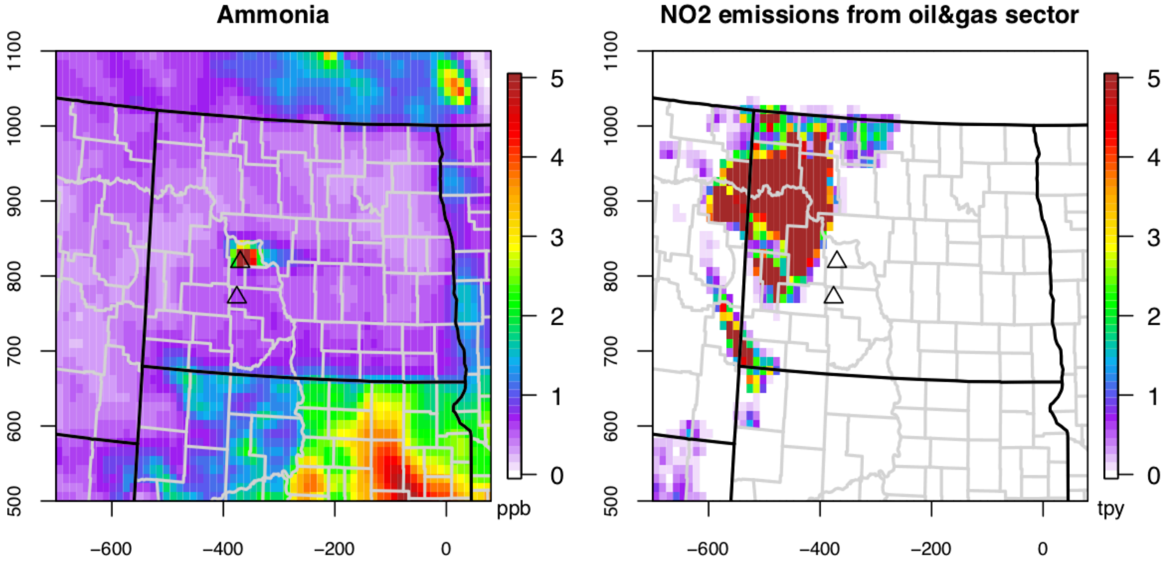
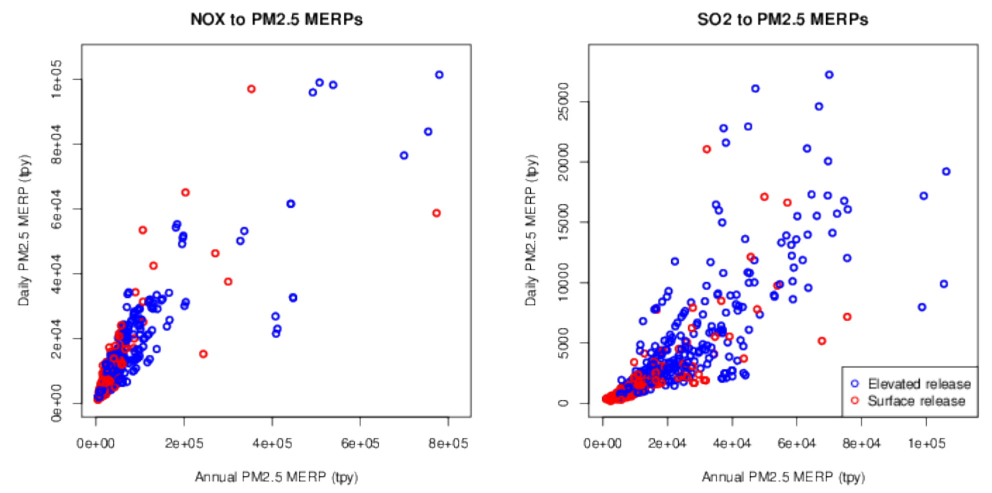


Figure 3-14 shows that the northern source is in very close proximity to a very large ammonia source which provides a readily available neutralizing agent for $PM_{2.5}$ formation when weather conditions are favorable. However, when winds are out of the north the southern source is in closer proximity to ammonia emissions located to the south in South Dakota. Further, the northern source is closer to the Bakken shale which is an area of high emissions that can provide oxidants for secondary chemical production and compete for neutralizing agents like ammonia.

Therefore, depending on meteorology, these sources will often have different potential for $PM_{2.5}$ production given their proximity to other industrial emissions sources and ammonia emissions sources. Figure 3-15 shows illustrative MERPs estimated for modeled sources for the daily and annual average forms of the $PM_{2.5}$ NAAQS.

Figure 3-15. Illustrative $PM_{2.5}$ MERPs for NO_X (left panel) and SO_2 (right panel) estimated from single source hypothetical emissions impacts on $PM_{2.5}$ nitrate ion and $PM_{2.5}$ sulfate ion respectively. Note: Daily average $PM_{2.5}$ MERPs are directly compared with annual average $PM_{2.5}$ MERPs.



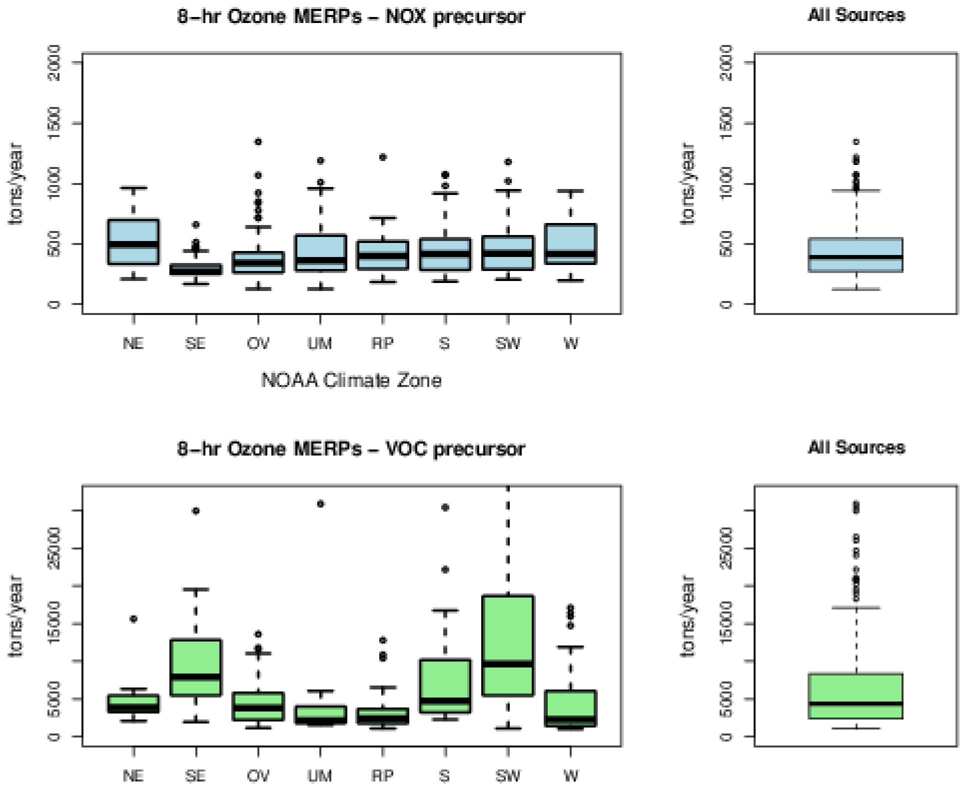
3.2.1.4. EPA Illustrative MERPs: 8-hour Ozone

The hypothetical single source modeling presented here was used to develop illustrative MERPs based on equation 1 and the EPA recommended SIL. Figure 3-16 shows illustrative MERPs for NO_X and VOC to daily maximum 8-hr average O_3 to illustrate the variability between regions/studies for the hypothetical sources included in this assessment. The modeled impacts reflect the highest annual 8-hr O_3 impacts from various hypothetical sources presented in this assessment (Baker et al., 2016; Kelly et al., 2015; U.S. Environmental Protection Agency, 2016b). The hypothetical source impacts presented here were not intended to capture O_3 formation associated with winter time cold pool events and are not appropriate for situations where peak impacts would be expected during these meteorological conditions.

Based on EPA's SILs guidance (U.S. Environmental Protection Agency, 2018), the recommended 8-hour O_3 NAAQS SIL of 1.0 ppb was used for this illustrative example. The illustrative VOC MERPs are based on single source VOC impacts on downwind daily maximum 8-hr O_3, while the illustrative NO_X MERPs are based on single source NO_X impacts on downwind daily maximum 8-hr O_3. The illustrative MERPs for NO_X to daily maximum 8-hr O_3 range from 125 tpy to over 5,000 tpy, while the illustrative MERPs for VOC to daily maximum 8-hr O_3 range from 1,049 tpy to over 140,000 tpy for the hypothetical sources presented here.

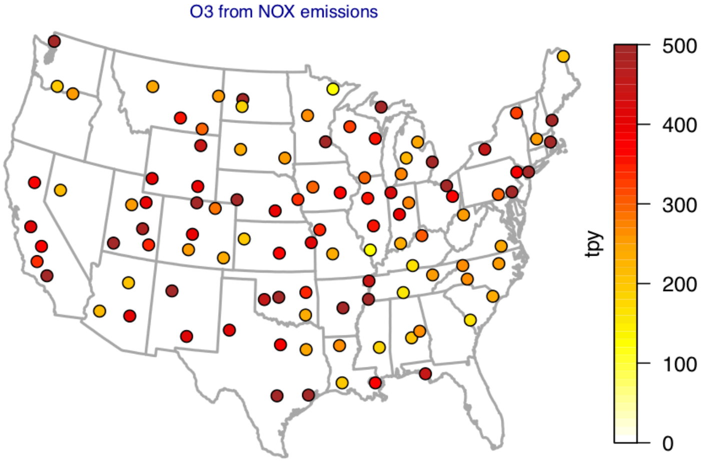
For this assessment, illustrative MERPs for NO_X tend to be lower than VOC which suggests most areas included in this assessment are often more NO_X limited rather than VOC limited in terms of O_3 formation regime. This finding is consistent with the information provided in Section 2. The distribution of illustrative MERPs for both NO_X and VOC are shown to vary between areas modeled as part of this assessment. Similar to $PM_{2.5}$, this is expected since the chemical (e.g., oxidants) and physical (e.g., terrain) environments vary regionally in the United States. The area-to-area availability of oxidants will determine whether O_3 production is NO_X or VOC limited which will be an important factor in how much an emissions source of NO_X or VOC will impact O_3 production.

Figure 3-16. NO_X (top panels) and VOC (bottom panels) MERPs estimated from single source hypothetical emissions impacts on daily maximum 8-hr O_3.
Note: 8-hr O_3 MERPs derived here based on EPA recommended 8-hour O_3 NAAQS SIL value of 1.0 ppb

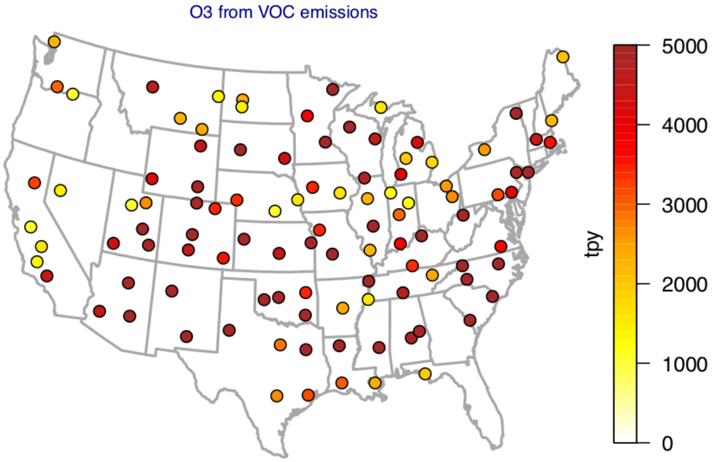


The lowest MERP value for each of the hypothetical source locations is shown for NO_X (top) and VOC (bottom) in Figure 3-17. This shows that even within geographic areas there are sometimes notable differences in O_3 production potential for these precursors. Some broader patterns do emerge such as VOC emissions having less potential for O_3 formation in areas rich in regional VOC such as the southeast and intermountain west. Differences are also sometimes seen for sources located in fairly close proximity, which is related to local scale differences in emissions and meteorology. Figure 3-3 provides additional information about each of the hypothetical sources to help interpret conceptual differences in O_3 formation that may be related to terrain or proximity to urban areas.

Figure 3-17. Lowest MERP value for each hypothetical source location for O_3 from NO_X (top panel) and VOC (bottom panel) emissions.



O3 from NOX emissions



O3 from VOC emissions

3.2.2. Use of Other Photochemical Modeling to Develop MERPs for O_3 and Secondary $PM_{2.5}$

Given the spatial variability in illustrative MERPs for each precursor for $PM_{2.5}$ and O_3, stakeholders choosing to develop their own Tier 1 demonstration tool will need to conduct air quality modeling. Therefore, the air quality modeling should be consistent with the type of modeling system, model inputs, model application and estimation approach for O_3 and secondary $PM_{2.5}$ recommended in the *Guideline* and the "Guidance on the use of models for assessing the impacts from single sources on secondarily formed pollutants ozone and $PM_{2.5}$" (U.S. Environmental Protection Agency, 2016a). The chosen modeling system should be applied with a design scope similar to that shown in this document where multiple hypothetical single sources with varying emission rates and stack release parameters are simulated for a period that includes meteorology conducive to the formation of O_3 and/or secondary $PM_{2.5}$. A modeling protocol should be developed and shared with the EPA Regional office that details the planned approach for developing MERPs based on photochemical modeling to ensure a sound technical basis for development of a suitable Tier 1 demonstration tool.

There is no minimum number of hypothetical sources to include in developing a MERPs Tier 1 demonstration tool, but the benefit of including more hypothetical sources is that more information is available for future sources to use in predicting secondary pollutant impacts from their post-construction emissions. Permitting authorities or permit applicants should examine existing recent (e.g., last 5 to 10 years) permit applications in that area to determine what types of emission rates and stack characteristics (e.g., surface and elevated release) should be reflected in the hypothetical project sources included in the model simulations. These model simulations should include a credible representation of current or post-construction conditions around the project source and key receptors.

Existing regulatory modeling platforms can be used to minimize resource burden. The most recently submitted regulatory demonstration (e.g., O_3 or $PM_{2.5}$ attainment demonstration, Regional Haze SIP demonstration) modeling platform considered appropriate for the purposes of permit related single source secondary impact demonstrations by the reviewing authority could provide a platform for development of a MERPs Tier 1 demonstration tool. This could include the last approved SIP demonstration, a more recent submitted but not yet approved SIP demonstration, or modeling not used to support a SIP demonstration but considered representative of the current air quality in the area and of sufficient quality that is comparable to a model platform supporting a SIP demonstration.

Where multiple appropriate modeling platforms are available for a particular area, the platform that is considered to be the most reflective of the current atmosphere in a particular area should be used for the demonstration to account for growth in an area and the changing mix of sources. For instance, if an area has a SIP modeling platform with a baseline year of 2011 and projected future year of 2018 and the current year is 2018, then the projected future year may better represent air quality in that area.

For areas that do not have an existing regulatory demonstration modeling platform, a new modeling platform that represents the current air quality and conforms to the specifications outlined for attainment demonstration modeling could be acceptable. The specifications for permit related demonstration model platforms (e.g., horizontal grid spacing, vertical resolution, non-project source emission treatment) are detailed in the "Guidance on the use of models for assessing the impacts from single sources on secondarily formed pollutants ozone and PM2.5" (U.S. Environmental Protection Agency, 2016a).

These platforms should be assessed for reasonableness with respect to predictive capability compared to ambient data to ensure that single sources are modeled in a realistic chemical and physical environment.

3.2.2.1. Developing Area Specific MERPs

Photochemical modeling conducted for an area by a source, a governmental agency, or some other entity that is deemed sufficient may be adequate for air agencies to conduct permit related demonstrations and also or alternatively leading to the development of area-specific MERPs.

8-hr Ozone: The general framework for such developmental efforts for O_3 should include the following steps:

1) Define the geographic area(s)
2) Conduct a series of source sensitivity simulations with appropriate air quality models to develop a collection of modeled O_3 impacts associated with emissions of O_3 precursors (i.e., VOC and NO_X) from typical industrial point sources within the area of interest.
3) Extract the highest daily 8-hr average modeled impact related to each hypothetical source anywhere in the domain from each model simulation (U.S. Environmental Protection Agency, 2016a).
4) Calculate the MERP estimate(s) using Equation 1.
5) Conduct quality assurance of the resulting MERP estimate(s) and evaluate the interpretation and appropriateness given the nature of O_3 precursor emissions sources and chemical formation in the area of interest. This evaluation will likely require emissions inventory data, observed ambient data for O_3 and precursors, a comparison of baseline total model predictions against ambient data, and qualitative comparison to MERPs estimated here and elsewhere.

Daily $PM_{2.5}$: The general framework for such developmental efforts for daily $PM_{2.5}$ should include the following steps:

1) Define the geographic area(s)
2) Conduct a series of source sensitivity simulations with appropriate air quality models to develop a collection of modeled $PM_{2.5}$ impacts associated with emissions of $PM_{2.5}$ precursors (i.e., SO_2 and NO_X) from typical industrial point sources within the area of interest.
3) Extract the highest daily 24-hr average modeled impact related to each hypothetical source anywhere in the domain from each model simulation (U.S. Environmental Protection Agency, 2016a).
4) Calculate the MERP estimate(s) using Equation 1.
6) Conduct quality assurance of the resulting MERP estimate(s) and evaluate the interpretation and appropriateness given the nature of $PM_{2.5}$ precursor emissions sources and chemical formation in the area of interest. This evaluation will likely require emissions inventory data, observed ambient data for $PM_{2.5}$ and precursors, a comparison of baseline total model predictions against ambient data, and qualitative comparison to MERPs estimated here and elsewhere.

Annual $PM_{2.5}$: The general framework for such developmental efforts for annual $PM_{2.5}$ should include the following steps:

1) Define the geographic area(s)
2) Conduct a series of source sensitivity simulations with appropriate air quality models to develop a collection of modeled $PM_{2.5}$ impacts associated with emissions of $PM_{2.5}$ precursors (i.e., SO_2 and NO_X) from typical industrial point sources within the area of interest.
3) Extract the highest annual average modeled impact related to each hypothetical source anywhere in the domain from each model simulation (U.S. Environmental Protection Agency, 2016a).
4) Calculate the MERP estimate(s) using the Equation 1.
7) Conduct quality assurance of the resulting MERP estimate(s) and evaluate the interpretation and appropriateness given the nature of $PM_{2.5}$ precursor emissions sources and chemical formation in the area of interest. This evaluation will likely require emissions inventory data, observed ambient data for $PM_{2.5}$ and precursors, a comparison of baseline total model predictions against ambient data, and qualitative comparison to MERPs estimated here and elsewhere.

If there are questions about what steps are appropriate in each instance or how to apply the steps described above, air agencies should contact their Regional office modeling contact for further technical consultation.

4. Application of the MERPs to Individual Permit Applications

The *Guideline* recommends a two-tiered approach for addressing single-source impacts on O_3 or secondary $PM_{2.5}$ (U.S. Environmental Protection Agency, 2017a) with the first tier involving use of appropriate and technically credible relationships between emissions and ambient impacts developed from existing modeling studies deemed sufficient for evaluating a project source's impacts. Consistent with the recommendations in EPA's *Guideline*, the appropriate tier for a given application should be selected in consultation with the appropriate reviewing authority (paragraph 3.0(b)) and after reviewing EPA guidance. This section describes how applicants might choose, in consultation with the appropriate permitting authority, to use MERPs in estimating single-source impacts on secondary pollutants under the first-tier approach (i.e., sections 5.3.2.b and 5.4.2.b of the *Guideline*).

The use of MERPs as a Tier 1 demonstration tool can be based on either (1) EPA photochemical modeling with the source-specific value for a representative hypothetical source (as described in Section 3.2.1) or (2) the source- or area-specific value derived from a more similar hypothetical source modeled by a permit applicant or permitting authority (as described in Section 3.2.2). In some situations, the most conservative (lowest) MERP value across a region/area could be considered representative. The relevant geographic area could range from a county or airshed to a state or multi-state region. The selection of this geographic area may be determined in consultation with the appropriate reviewing authority and technical justification should be provided in the modeling protocol and/or permit-related documentation.

EPA recommends that the permit applicant follow a three-step process as shown in Figure 4-1.

1) Identify a representative hypothetical source (or group of sources for an area) from EPA's modeling as detailed in Appendix Table A-1 or the Excel spreadsheet available on SCRAM. If a representative hypothetical source is not available, then consider whether an EPA derived MERP value available for the broader geographic area of the project source may be adequately representative and thus appropriate to use (see Table 4-1). Alternatively, one can consider conducting photochemical modeling (as described in Section 3.2.2) to derive appropriate information to derive a source- or area-specific value.

   The permit applicant should provide the appropriate permitting authority with a technically credible justification that the source characteristics (e.g., stack height, emissions rate) of the specific project source described in a permit application and the chemical and physical environment (e.g., meteorology, background pollutant concentrations, and regional/local emissions) near that project source are adequately represented by the selected hypothetical source(s).

2) Acquire the source characteristics and associated modeling results for the hypothetical source(s). If using EPA modeling, then access these data from the on-line spreadsheet on

EPA's SCRAM website. If using other modeling, then access these data from the relevant input and output files.

3) Apply the source characteristics and photochemical modeling results from Step 2 to the MERP equation with the appropriate SIL value to assess the project source impacts.

   Section 4.1 provides several example PSD permit application scenarios that illustrate how to use source characteristics and photochemical modeling results to derive a MERP Tier 1 demonstration tool. In general, for situations where the project source emits only one precursor for O_3 or secondary $PM_{2.5}$ (and no primary $PM_{2.5}$ emissions), the project source emissions for that precursor can be compared directly to the appropriate MERP value for that precursor to determine if the applicable SIL is exceeded or not. For situations where project sources are required to assess multiple precursors, EPA recommends that the project source impacts on O_3 or secondary $PM_{2.5}$ reflect the sum of air quality changes resulting from each of those precursors for comparison to the EPA recommended SIL. Further, where project sources are required to assess both primary $PM_{2.5}$ and precursors of secondary $PM_{2.5}$, EPA recommends that applicants combine the primary and secondary impacts to determine total $PM_{2.5}$ impacts as part of the PSD compliance demonstration. In such cases, the project source impacts associated with their direct $PM_{2.5}$ emissions should be assessed through dispersion modeling.

At the start of this process, EPA recommends that the permit applicant consult with the appropriate reviewing authority in developing a modeling protocol (per Section 9 of the *Guideline*) and that both parties confirm, at that time, the appropriateness of using these modeling results for the permitting situation. As part of the protocol, the permit applicant should include a narrative that provides a technical justification that the existing information or planned photochemical modeling is appropriate for the project source(s).

Derived from EPA modeling results, Table 4-1 summarizes the distribution of illustrative MERPs values across climate zones showing the lowest, highest and median values. Consistent with Step 1 outlined above, the most conservative (lowest) illustrative MERP value may, in some cases, be considered adequately representative to characterize the responsiveness of ozone or secondary $PM_{2.5}$ to precursors emitted in a region or area and then be considered for the Tier 1 demonstration in an individual permit application. Climate zones are only used here to summarize the MERPs values for the reader. EPA recommends that the permit applicant consult with the appropriate reviewing authority to determine the relevant geographic area and/or hypothetical source from which to select a representative MERP value.

Figure 4-1. EPA recommended multi-step process for use of MERPs in PSD compliance demonstrations.

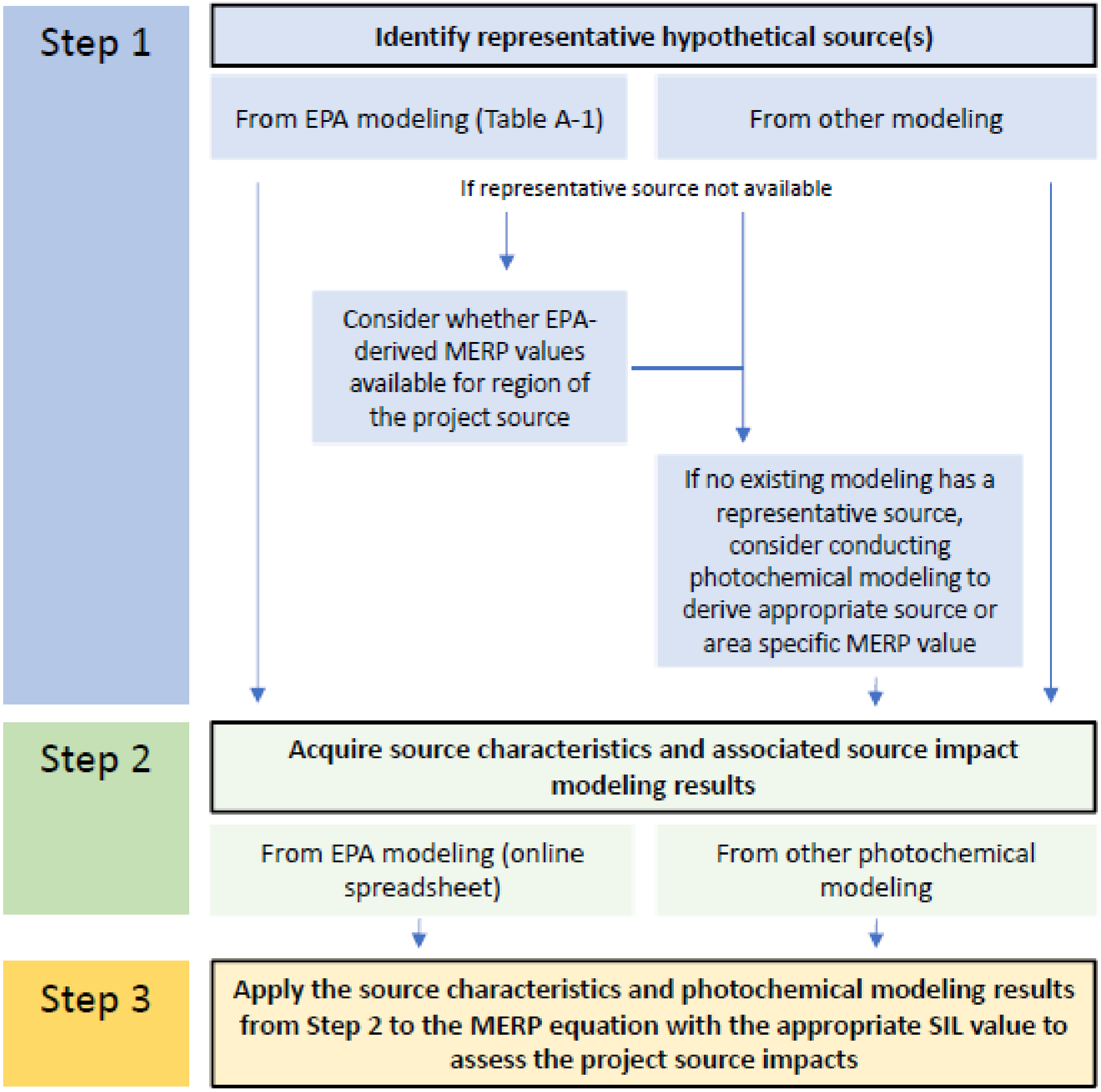


Table 4-1. Lowest, median, and highest illustrative MERP values (tons per year) by precursor, pollutant and climate zone.

Note: illustrative MERP values are derived based on EPA modeling and EPA recommended SILs from EPA's final SILs guidance (U.S. Environmental Protection Agency, 2018).

	8-hr O_3 from NO_X			8-hr O_3 from VOC		
Climate Zone	Lowest	Median	Highest	Lowest	Median	Highest
Northeast	209	495	5,773	2,068	3,887	15,616
Southeast	170	272	659	1,936	7,896	42,964
Ohio Valley	126	340	1,346	1,159	3,802	13,595
Upper Midwest	125	362	4,775	1,560	2,153	30,857
Rockies/Plains	184	400	3,860	1,067	2,425	12,788
South	190	417	1,075	2,307	4,759	30,381
Southwest	204	422	1,179	1,097	10,030	144,744
West	218	429	936	1,094	1,681	17,086
Northwest	199	373	4,031	1,049	2,399	15,929

	Daily PM2.5 from NO_X			Daily PM2.5 from SO_2		
Climate Zone	Lowest	Median	Highest	Lowest	Median	Highest
Northeast	2,218	15,080	34,307	623	3,955	8,994
Southeast	1,943	8,233	23,043	367	2,475	5,685
Ohio Valley	2,570	10,119	32,257	348	3,070	16,463
Upper Midwest	2,963	10,043	29,547	454	2,482	6,096
Rockies/Plains	1,740	9,389	31,263	251	2,587	19,208
South	1,881	8,079	24,521	274	1,511	10,112
Southwest	6,514	26,322	101,456	1,508	8,730	27,219
West	1,073	8,570	34,279	188	2,236	24,596
Northwest	3,003	11,943	20,716	1,203	3,319	8,418

	Annual PM2.5 from NO_X			Annual PM2.5 from SO_2		
Climate Zone	Lowest	Median	Highest	Lowest	Median	Highest
Northeast	10,142	47,396	137,596	4,014	21,353	41,231
Southeast	5,679	45,076	137,516	859	14,447	25,433
Ohio Valley	7,625	31,931	150,868	3,098	23,420	58,355
Upper Midwest	10,011	33,497	139,184	2,522	17,997	45,113
Rockies/Plains	9,220	39,819	203,546	2,263	16,939	106,147
South	7,453	41,577	110,478	1,781	11,890	58,612
Southwest	11,960	128,564	779,117	10,884	38,937	105,417
West	3,182	29,779	103,000	2,331	11,977	66,773
Northwest	7,942	21,928	71,569	11,276	15,507	18,263

4.1. Illustrative MERP Tier 1 Demonstrations for Example PSD Permit Scenarios

In this section, several example PSD permit application scenarios are presented to illustrate how modeled emissions and secondary pollutant impacts from EPA's modeling of hypothetical sources (described in Section 3.2.1) could be used to derive a MERP Tier 1 demonstration tool (as described in Section 3.1) for a given location. Some of these examples demonstrate how to account for multiple precursor impacts on secondary $PM_{2.5}$ formation. One scenario (i.e., scenario D) reflects a situation where a project source emits both primary $PM_{2.5}$ and precursors to secondary $PM_{2.5}$. In those situations, applicants should consult the appropriate sections of the *Guideline* (U.S. Environmental Protection Agency, 2017a) and related permit modeling guidance for information about estimating primary PM2.5 impacts**.** As illustrated in these examples, representative MERPs for each precursor may be developed based on either the most conservative (lowest) value across a region/area or the source-specific value derived from a more similar hypothetical source modeled by a permit applicant, permitting authority, or EPA.

For multiple areas, Table 4.1 shows an example of the most conservative (i.e., lowest) illustrative MERP for each precursor and NAAQS across all sources and studies. These illustrative values in Table 4.1 are based on the EPA modeling of hypothetical sources described in Section 3.2.1. For reference at the individual source level, the maximum predicted downwind impacts for each of the hypothetical sources modeled with annual simulations are provided in the Excel spreadsheet available on EPA's SCRAM website.

4.1.1. Source Impact Analysis: O_3 and $PM_{2.5}$ NAAQS

The following section provides examples of developing a suitable Tier 1 demonstration tool for each precursor and secondary pollutant as part of a PSD source impact analysis for the O_3 and $PM_{2.5}$ NAAQS. Where only a single precursor of O_3 or $PM_{2.5}$, and no direct $PM_{2.5}$, is emitted by the project source, then the MERP for that precursor may be directly applied. For situations where project sources are required to assess multiple precursors of $PM_{2.5}$ or of O_3, EPA recommends that the impacts of multiple precursors should be estimated in a combined manner for comparison to the appropriate SIL such that the sum of precursor impacts would be lower than the SIL in a demonstration of compliance. Further, where project sources are required to assess both primary $PM_{2.5}$ and precursors of secondary $PM_{2.5}$, EPA recommends that applicants combine the primary and secondary impacts to determine total $PM_{2.5}$ impacts as part of the PSD compliance demonstration. In such cases, the project source impacts associated with their direct $PM_{2.5}$ emissions should be assessed through dispersion modeling.

In this assessment, the maximum downwind impact from each source is chosen over the length of the model simulation period and matched with the annual emission rate. The maximum impact is selected since a single year of meteorology (or less in some instances) is used to generate these relationships. Additional or alternative meteorological patterns may result in different impacts in some areas. The following illustrative examples are intended to show how MERP values may be used in specific PSD permit air quality demonstrations.

Scenario A: Single precursor assessment for $PM_{2.5}$ and additive O_3 impacts

In this scenario, a PSD permit applicant with a proposed increase in emissions of 0 tpy of primary $PM_{2.5}$, 130 tpy of VOC, 72 tpy of NO_X, and 0 tpy of SO_2 located in the upper midwest region.

O_3 analysis: The project source is not located in an area with unusual circumstances regarding complex terrain, proximity to very large sources of either NO_X or VOC, or meteorology. Thus, the climate zone may be defined as the relevant geographic area such that the lowest MERPs from Table 4-1 for the upper midwest region could be considered representative and chosen for comparison with the project emissions rather than selecting a particular hypothetical source from this same climate zone. In practice, EPA recommends that the permit applicant consult with the appropriate reviewing authority to determine the relevant hypothetical source and geographic area from which to select representative MERP values.

The NO_X emissions of 72 tpy and VOC emissions of 130 tpy from the project source are well below the lowest (most conservative) MERP values for NO_X as an O_3 precursor (i.e., 125 tpy) and VOC as an O_3 precursor (i.e., 1,560 tpy), respectively, of all sources modeled by EPA in the upper midwest region, as shown in Table 4-1. In this case, air quality impacts for each O_3 precursor from this source would be expected to be below the EPA recommended 8-hour O_3 SIL.

However, for this example, EPA recommends that the NO_X and VOC precursor impacts on 8-hr daily maximum O_3 be considered together to determine if the project source's air quality impact would exceed the O_3 SIL. In such a case, the project source's emissions increase can be expressed as a percent of the MERP for each precursor and then the percentages can be summed. A value less than 100% indicates that the EPA recommended 8-hour O_3 SIL will not be exceeded when considering the combined impacts of these precursors on 8-hr daily maximum O_3.

Example calculation for additive precursor impacts on 8-hr daily maximum O_3:

> (72 tpy NO_X from source/125 tpy NO_X 8-hr daily maximum O_3 MERP) + (130 tpy VOC from source/1,560 tpy VOC 8-hr daily maximum O_3 MERP) = .58 + .08 = .66 * 100 = 66%

A value less than 100% indicates that the O_3 SIL would not be exceeded when considering the combined impacts of these precursors. Thus, the project level O_3 impacts associated with both NO_X and VOC precursor emissions from this source would be expected to be below the EPA recommended 8-hour O_3 SIL.

$PM_{2.5}$ analysis: The project source is not located in an area with unusual circumstances regarding complex terrain, proximity to very large sources of pollutants that impact atmospheric chemistry (i.e., NO_X, SO_2, NH_3) or meteorology. Thus, similar to the O_3 analysis above, the climate zone may be defined as the relevant geographic area such that the lowest MERPs from Table 4-1 for the upper midwest region could be considered adequately representative and chosen for comparison with the project emissions rather than selecting a particular hypothetical source from this same region. EPA recommends that the permit applicant consult with the appropriate reviewing authority to determine the relevant hypothetical source and geographic area from which to select representative MERP values.

The project source emits no direct $PM_{2.5}$ nor SO_2 so the demonstration focuses only on the NO_X emissions increase of 72 tpy, which is well below the lowest (most conservative) MERP value in the upper midwest region for NO_x as a precursor for the daily and annual $PM_{2.5}$ NAAQS shown in Table 4-1, i.e., 2,963 tpy and 10,011 tpy respectively. In this case, air quality impacts of $PM_{2.5}$ from this source are expected to be below the EPA recommended 24-hour and annual $PM_{2.5}$ SILs.

Scenario B: Single precursor assessment for O_3 impacts and additive secondary $PM_{2.5}$ impacts

In this scenario, a facility with a proposed increase in emissions of 0 tpy of primary $PM_{2.5}$, 0 tpy of VOC, 220 tpy of NO_X, and 75 tpy of SO_2 located in the southeast region.

O_3 analysis: The project source is not located in an area with unusual circumstances regarding complex terrain, proximity to very large sources of either NO_X or VOC, or meteorology. The project source does not emit VOC so the demonstration focuses only on the NOx emission increase of 220 tpy, which is greater than the lowest (most conservative) NO_X MERP for 8-hr O_3 in the southeast region (i.e., 170 tpy). Thus, for this example, even though the project source's surrounding environment does not raise an obvious regional feature that would influence downwind O_3 impacts, it is likely more appropriate to use a specific hypothetical source in the same region or other appropriate geographic area for comparison.

A comparable hypothetical source is identified to be representative of this source (e.g., southeast region source located in Tallapoosa County, Alabama with elevated emissions release). Here, equation 1 is used with the modeled emissions rates and air quality impact information from this hypothetical source. Since multiple hypothetical sources were modeled at this location with an elevated release, the source with the lowest MERP was selected for comparison with the project source, i.e.,

> MERP for selected representative hypothetical source (tpy) = 1.0 ppb * (500 tpy /1.528 ppb) = 327 tpy

In this case, based on EPA modeling results for a representative hypothetical source, the project source emissions are less than the calculated NO_X to 8-hr O_3 MERP such that air quality impacts of O_3 from this source would be expected to be less than the EPA recommended 8-hour O_3 SIL.

$PM_{2.5}$ analysis: The project source is not located in an area with unusual circumstances regarding complex terrain, proximity to very large sources of pollutants that impact atmospheric chemistry (i.e., NO_X, SO_2, NH_3) or meteorology. Thus, the climate zone may be defined as the relevant geographic area such that the lowest MERPs from Table 4-1 for the southeast region could be considered adequately representative and chosen for comparison with the project emissions rather than selecting a particular hypothetical source from this same region. In practice, EPA recommends that the permit applicant consult with the appropriate reviewing authority to determine the relevant hypothetical source and geographic area from which to select representative MERP values.

For this example, both the NO_X emissions of 220 tpy and SO_2 emissions of 75 tpy are well below the lowest (most conservative) daily $PM_{2.5}$ MERP values of any source modeled in the southeastern region, i.e., 1,943 tpy for NO_X and 367 tpy for SO_2 respectively. These emission rates are also well below the annual $PM_{2.5}$ MERP values of any source modeled in the southeastern region (see Table 4-1).

However, for this example, EPA recommends that the NO_X and SO_2 precursor impacts to both daily and annual average $PM_{2.5}$ are considered together to determine if the project source's air quality impact on $PM_{2.5}$ would exceed the $PM_{2.5}$ SILs. In this case, the project source's emissions increase can be expressed as a percent of the MERP for each precursor and then the percentages can be summed. A value less than 100% indicates that the EPA recommended daily or annual $PM_{2.5}$ SIL would not be exceeded when considering the combined impacts of these precursors on daily or annual $PM_{2.5}$.

Example calculation for additive secondary impacts on daily $PM_{2.5}$:

> (220 tpy NO_X from source/1,943 tpy NO_X daily $PM_{2.5}$ MERP) + (75 tpy SO_2 from source/367 tpy SO_2 daily $PM_{2.5}$ MERP) = .11 + .20 = .31 * 100 = 31%

Example calculation for additive secondary impacts on annual $PM_{2.5}$:

> (220 tpy NO_X from source/5,679 tpy NO_X annual $PM_{2.5}$ MERP) + (75 tpy SO_2 from source/859 tpy SO_2 annual $PM_{2.5}$ MERP) = .04 + .09 = .13 * 100 = 13%

A value less than 100% indicates that the $PM_{2.5}$ SIL would not be exceeded when considering the combined impacts of these precursors on daily or annual $PM_{2.5}$. Thus, in this case, the air quality impacts of $PM_{2.5}$ from precursor emissions of NO_X and SO_2 from this source would be expected to be less than the EPA recommended daily and annual $PM_{2.5}$ SILs.

Scenario C: Single precursor assessment for O_3 and additive $PM_{2.5}$ impacts

In this scenario, a facility with a proposed increase in emissions of 0 tpy of primary $PM_{2.5}$, 0 tpy of VOC, 920 tpy of NO_X, and 259 tpy of SO_2 located in the Rockies region.

O_3 analysis: The project source is not located in an area with unusual circumstances regarding complex terrain, proximity to very large sources of either NO_X or VOC, or meteorology. The project source does not emit VOC so the demonstration focuses only on the NOx emission increase of 920 tpy, which is greater than the lowest (most conservative) NO_X MERP for 8-hr O_3 in the Rockies region (i.e., 184 tpy). Thus, for this example, even though the project source's surrounding environment does not raise an obvious regional feature that would influence downwind O_3 impacts, it is likely more appropriate to use a hypothetical source for comparison.

A comparable hypothetical source is identified to be representative of this source (e.g., Rockies region in Iron County, Utah with elevated release). Here, equation 1 is used with the modeled emissions rates and air quality impact information from the selected comparable source. Since multiple hypothetical sources were modeled at this location with an elevated release, the source with the most similar emission rate was selected for comparison with the project source, i.e.,

> MERP for selected representative hypothetical source (tpy) = 1.0 ppb * (1000 tpy / 1.314 ppb) = 761 tpy

In this case, based on EPA modeling results for a representative hypothetical source, the project source emissions are greater than the calculated NO_X to 8-hr O_3 MERP such that air quality impacts of O_3 from this source are expected to exceed the EPA recommended 8-hour O_3 SIL. Given that the NO_X emissions from this project source are expected to have air quality impacts that exceed the O_3 SIL, a cumulative impact analysis would be the next step in this scenario. More information for this type of demonstration is provided in Section 4.1.3.

$PM_{2.5}$ analysis: The project source is not located in an area with unusual circumstances regarding complex terrain, proximity to very large sources of pollutants that impact atmospheric chemistry (i.e., NO_X, SO_2, NH_3) or meteorology. The NO_X emissions of 920 are below the lowest (most conservative) daily and annual $PM_{2.5}$ MERP value of any source modeled in the Rockies region (i.e., 1.740 tpy and 9,220 tpy respectively), while the SO_2 emissions of 259 tpy are slightly higher than the lowest daily $PM_{2.5}$ MERP value of any source modeled in the Rockies region (i.e., 251 tpy for daily and 2,263 tpy for annual). Thus, for this example, even though the project source's surrounding environment does not raise an obvious regional feature that would influence downwind secondary $PM_{2.5}$ impacts, it is likely more appropriate to use a hypothetical source for comparison.

A hypothetical representative source is identified to be representative of this source (e.g., Rockies region in Iron County, Utah) and has a 1,000 tpy elevated release NO_X MERP for daily $PM_{2.5}$ of 25,754 tpy and SO_2 MERP for daily $PM_{2.5}$ of 7,515 tpy, which are both much larger than the increase in emissions of the project source such that the source's impact on daily $PM_{2.5}$ would be expected to be less than the EPA recommended daily $PM_{2.5}$ SIL. The same hypothetical source has a NO_X MERP for annual $PM_{2.5}$ of 166,670 tpy and SO_2 MERP for annual $PM_{2.5}$ of 37,997 tpy, which are both much larger than the increase in emissions of the project source such that the source's impact on annual $PM_{2.5}$ would be expected to be less than the

EPA recommended annual $PM_{2.5}$ SIL. However, for this example, EPA recommends that the NO_X and SO_2 precursor contributions to both daily and annual average $PM_{2.5}$ are considered together to determine if the project source's air quality impact of $PM_{2.5}$ would exceed the $PM_{2.5}$ SILs. In this case, the project source's emissions increase can be expressed as a percent of the MERP for each precursor and then the percentages can be summed.

Example calculation for additive secondary impacts on daily $PM_{2.5}$:

> (920 tpy NO_X from source/25,754 tpy NO_X daily $PM_{2.5}$ MERP) + (259 tpy SO_2 from source/7,515 tpy SO_2 daily $PM_{2.5}$ MERP) = .036 + .034 = .07 * 100 = 7%

Example calculation for additive secondary impacts on annual $PM_{2.5}$:

> (920 tpy NO_X from source/166,670 tpy NO_X annual $PM_{2.5}$ MERP) + (259 tpy SO_2 from source/37,997 tpy SO_2 annual $PM_{2.5}$ MERP) = .006 + .007 = .013 * 100 = 1.3%

A value less than 100% indicates that the $PM_{2.5}$ SIL would not be exceeded when considering the combined impacts of these precursors on daily or annual $PM_{2.5}$. Thus, in this case, the air quality impacts of $PM_{2.5}$ from precursor emissions of NO_X and SO_2 from this source would be expected to be less than both the EPA recommended daily and annual $PM_{2.5}$ SILs.

Scenario D: NO_X and SO_2 precursor assessment for additive secondary $PM_{2.5}$ impacts along with direct $PM_{2.5}$

In this scenario, a facility with a proposed increase in emissions of 250 tpy of primary $PM_{2.5}$, 0 tpy of VOC, 220 tpy of NO_X, and 75 tpy of SO_2 located in the southeast region. This scenario is like Scenario B above, except that EPA recommends that in assessing $PM_{2.5}$ the primary $PM_{2.5}$ emissions be accounted for along with the secondary impacts of $PM_{2.5}$ precursor emissions as part of the Tier 1 demonstration.

O_3 analysis: See scenario B above.

$PM_{2.5}$ analysis: Same as Scenario B as to $PM_{2.5}$ precursors. The combined impacts of the proposed increases in $PM_{2.5}$ precursor emissions of NO_X and SO_2 would not exceed the EPA recommended daily or annual $PM_{2.5}$ SILs.

However, for this example, EPA recommends that the primary $PM_{2.5}$ impacts be added to the secondary impacts for a full account of total $PM_{2.5}$ impacts in comparison to the daily and annual $PM_{2.5}$ SILs. The primary $PM_{2.5}$ impacts should be estimated using AERMOD or an approved alternative model as outlined in the *Guideline* (U.S. Environmental Protection Agency, 2017a) and consistent with EPA guidance for combining primary and secondary impacts of $PM_{2.5}$ for permit program assessments.

In this scenario, a representative secondary $PM_{2.5}$ impact for this source is added to the appropriately estimated primary $PM_{2.5}$ impacts. The highest ambient impact at any receptor for primary $PM_{2.5}$ should be divided by the daily or annual $PM_{2.5}$ SIL values to estimate the primary impact calculated as a percentage of the SIL value and then added to the previously calculated secondary impacts.

For the daily $PM_{2.5}$ NAAQS, a peak primary $PM_{2.5}$ impact from AERMOD in this scenario is estimated to be 0.41 $\mu g/m^3$. Compared with a 1.2 $\mu g/m^3$ SIL for daily $PM_{2.5}$ means that the primary impact is 34% of the SIL. When this primary impact is summed with the secondary impacts of 31% the total is 65% which is below 100% suggesting this source impact is below the EPA recommended daily $PM_{2.5}$ SIL.

For the annual $PM_{2.5}$ NAAQS, annual average primary $PM_{2.5}$ impact from AERMOD is estimated to be 0.11 $\mu g/m^3$ for the scenario above. Compared with a 0.2 $\mu g/m^3$ SIL for annual $PM_{2.5}$ means that the primary impact is 55% of the SIL. When this primary impact is summed with the secondary impacts of 13% the total is 68% which is below 100% suggesting this source impact is below the EPA recommended annual $PM_{2.5}$ SIL.

Accounting for spatial correlation of primary and secondary impacts: As a variant on this scenario, for the daily $PM_{2.5}$ NAAQS, if the peak primary $PM_{2.5}$ impact from AERMOD is estimated to be 0.90 $\mu g/m^3$ for the above scenario, then the percent primary contribution to the SIL would be 75%. When summed with the secondary contribution of 31%, the total source impact exceeds 100% and, therefore, is greater than the EPA recommended daily $PM_{2.5}$ SIL. In this case, the spatial nature of the primary and secondary $PM_{2.5}$ impacts of the project source may be resolved in a more detailed manner to gain a better estimate of the project source impact for comparison to the $PM_{2.5}$ SILs. Primary impacts tend to be higher in closer proximity of the source, whereas secondary impacts can be higher further downwind (beyond the property fence line). For example, the primary and secondary $PM_{2.5}$ impacts could be resolved at varying distances from the source (e.g., within 5-10 km, between 10 and 25 km, and between 25 and 50 km) and then combined at each distance range for a comparison with the EPA recommended $PM_{2.5}$ SILs. If the more spatially resolved assessment still finds combined percentages above 100%, then a cumulative impact analysis would be the next step for this demonstration. More information for this type of demonstration is provided in Section 4.1.3.

4.1.2. Source Impact Analysis: Class 1 PSD Increment for $PM_{2.5}$

This section provides information for single source permit demonstrations for PSD increment of $PM_{2.5}$ at Class I areas. According to 40 CFR 51.166(c)(1) and 52.21(c), an allowable PSD increment based on an annual average may not be exceeded, and the allowable PSD increment for any other time period may be exceeded once per year at any one location. Currently there is no PSD increment for O_3 so no PSD increment demonstration for O_3 is necessary. The $PM_{2.5}$ PSD increment SIL values recommended by EPA for Class II and III areas are the same as the recommended $PM_{2.5}$ NAAQS SIL values so no separate PSD increment demonstration is needed for Class II and III areas.

The hypothetical model results provided in this document represent peak impacts for secondary $PM_{2.5}$, which are typically within 50 km from the source (see section 3.2.1). These impacts may not be applicable for PSD increment demonstrations at Class I area receptors that may be far downwind (beyond 50 km) of the project source. As stated in the *Guideline*, AERMOD is the preferred dispersion model for estimating primary $PM_{2.5}$ impacts from single sources for distances up to 50 km. Currently, there is no preferred modeling system for estimating long range transport impacts (i.e., beyond 50 km). The *Guideline* establishes a screening approach for such assessments (U.S. Environmental Protection Agency, 2017a).

The screening approach for the primary $PM_{2.5}$ component of a PSD Class I area demonstration beyond 50 km could include AERMOD estimates at or about 50 km from the project source (Section 4.2.c.i of the *Guideline*) or a second level assessment based on modeling primary PM2.5 that does not include plume-depleting processes to ensure a conservative estimate (Section 4.2.c.ii of the *Guideline*). The *Guideline* suggests a Lagrangian or comparable modeling system would be appropriate for a second level assessment. Photochemical grid models have been shown to demonstrate similar skill to Lagrangian models for long range pollutant transport when compared to measurements made from multiple mesoscale field experiments (ENVIRON, 2012a; U.S. Environmental Protection Agency, 2016c). EPA modeled a subset of the hypothetical sources shown in Figure 3-2 with tracking of primary $PM_{2.5}$ contribution (N=36) using the CAMx model applied without chemistry. A table of maximum daily average and maximum annual average primary $PM_{2.5}$ impacts by emission rate are shown in Table 4-2. This table is intended to provide illustrative information about peak downwind primary $PM_{2.5}$ impacts at distances beyond 50 km and where agreed to by the appropriate reviewing authority may provide relevant information to support Tier 1 PSD Class I increment demonstrations.

Table 4-2. Maximum daily average and maximum annual average primary $PM_{2.5}$ impacts at 100, 200, and 300 km from modeled hypothetical source.

Emission Rate (tpy)	Distance from source (km)	Highest Daily Average Concentration (μg/m^3) - tall stack	Highest Daily Average Concentration (μg/m^3) - surface release	Highest Annual Average Concentration (μg/m^3) - tall stack	Highest Annual Average Concentration (μg/m^3) - surface release
100	300	0.0117	0.0123	0.0008	0.0009
100	200	0.0223	0.0212	0.0016	0.0015
100	100	0.0537	0.0445	0.0070	0.0049
150	300	0.0180	0.0184	0.0012	0.0013
150	200	0.0328	0.0311	0.0024	0.0022
150	100	0.0807	0.0632	0.0102	0.0073
500	300	0.0610	0.0625	0.0044	0.0045
500	200	0.1167	0.1095	0.0087	0.0078
500	100	0.2717	0.2536	0.0379	0.0238
1000	300	0.1186	0.1217	0.0087	0.0089
1000	200	0.2300	0.2161	0.0175	0.0157
1000	100	0.5445	0.5009	0.0731	0.0477

Single source impacts on secondary $PM_{2.5}$ tend to decrease as distance from the source increases (Baker et al., 2016), which means peak source impacts presented in previous sections to inform a $PM_{2.5}$ NAAQS air quality assessment may not provide relevant information for the spatial scales involved between project sources and Class I areas. Given that project source impacts will be lower at greater distances (see also Figure 3.6), the illustrative MERPs listed in Section 4 would not usually be relevant (unless the source and Class I area were in close proximity), so applicants should follow the screening approach described in this section for a Tier 1 demonstration of compliance with the Class I PSD increment for $PM_{2.5}$.

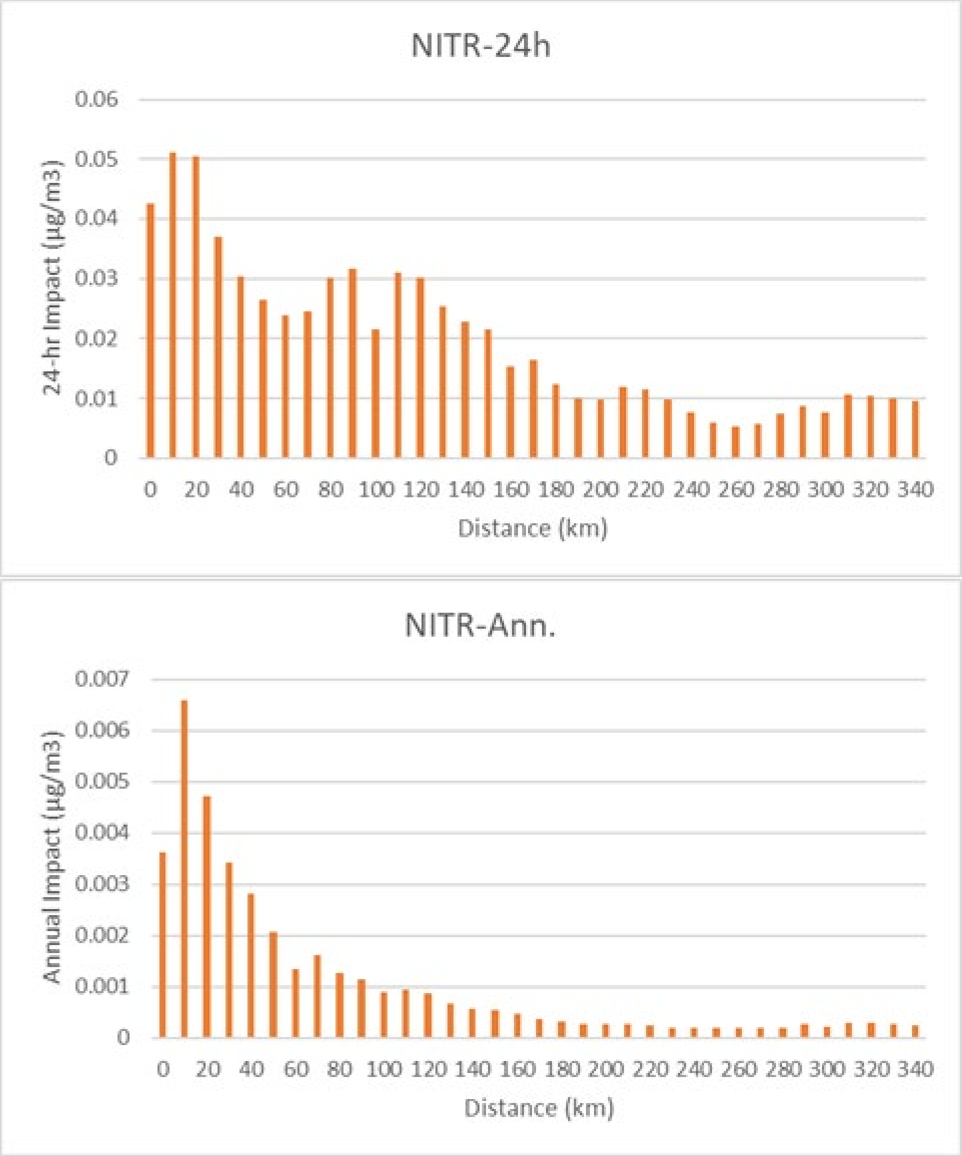
The hypothetical source impact information generated as part of the illustrative examples shown here or other credible existing single source modeling could provide information relevant for Class I SIL screening demonstrations. Rather than using the peak impact, the entirety of modeled information available for a specific project source (if available) or hypothetical source (such as but not limited to the sources modeled as part of this document) could be used to provide an estimate of secondary $PM_{2.5}$ impacts at distances further downwind.

Consistent with the long-range transport (LRT) screening approach in the *Guideline*, the initial screening step would be to select one or more of the hypothetical sources modeled as part of the illustrative assessment provided in this document that are found to be similar to the project source. Then, modeled maximum secondary $PM_{2.5}$ impacts at or greater than 50 km would be used in combination with primary $PM_{2.5}$ impacts estimated with AERMOD at 50 km downwind of the source for comparison to the EPA recommended $PM_{2.5}$ Class I SIL value. Information about using AERMOD to support a LRT demonstration for primary pollutants is provided elsewhere (U.S. Environmental Protection Agency, 2016d).

If the results of the initial screening step show an exceedance of the $PM_{2.5}$ Class I SIL value, a second more refined screening step would involve selecting the highest modeled secondary $PM_{2.5}$ impact at or less than the downwind distance of the Class I area relative to the project source. That value would be combined with primary $PM_{2.5}$ impacts estimated with AERMOD at 50 km downwind and compared with the EPA recommended $PM_{2.5}$ Class I SIL. Another option for this screening step would also involve selecting the highest modeled secondary $PM_{2.5}$ impact at or near the downwind distance of the Class I area relative to the project source but include an estimate of primary $PM_{2.5}$ impacts estimated with a chemical transport model (e.g., Lagrangian or photochemical model) at or less than the downwind distance of the Class I area relative to the project source.

An illustrative example of this type of a screening demonstration for Class I $PM_{2.5}$ increment would be a 3,000 tpy NO_X project source that emits near the surface in the northeast U.S. This project source does not emit SO_2 so secondary formation of $PM_{2.5}$ sulfate ion does not need to be considered in addition to $PM_{2.5}$ nitrate formation from the NO_X emissions. The nearest Class I area is ~300 km downwind of the project source. Multiple hypothetical sources (3 for this particular example) with ground-level emission release characteristics near the project source were examined for annual and 24-hr average $PM_{2.5}$ nitrate impacts at or greater than 50 km and at or near 300 km downwind of the source in any direction. Figure 4-2 shows the peak hypothetical source impacts from 500 tpy of emissions at ~50 km downwind on $PM_{2.5}$ nitrate for daily $PM_{2.5}$ is 0.032 µg/m^3 and annual $PM_{2.5}$ is 0.002 µg/m^3. As shown, at approximately 310 km from the project source, the peak hypothetical source impacts on $PM_{2.5}$ nitrate for daily $PM_{2.5}$ would be 0.01 µg/m^3 and 0.0003 µg/m^3 for annual $PM_{2.5}$ (see Figure 4-2).

Figure 4-2. Modeled peak daily average (top) and annual average (bottom) $PM_{2.5}$ nitrate ion impacts from a hypothetical 500 tpy surface level source of NO_X emissions by distance downwind of the source.



The hypothetical source NO_X emission rate is 500 tpy and the project source emission rate is 3,000 tpy. Impacts from the 500 tpy hypothetical sources are linearly scaled (increased in this example) to be better representative of the project source emission rate. For example, the daily $PM_{2.5}$ nitrate impacts at 50 km downwind would be adjusted to 0.192 µg/m^3: 0.032 µg/m^3 *

3000 tpy/500 tpy = 0.192 µg/m^3. The annual $PM_{2.5}$ nitrate impacts at 300 km downwind would be adjusted to 0.0018 µg/m^3: 0.0003 µg/m^3 * 3000 tpy/500 tpy = 0.0018 µg/m^3.

As part of the initial screening step, the project source impact of 0.192 µg/m^3 for daily $PM_{2.5}$ at 50 km downwind is added to its primary impact estimated with AERMOD at 50 km for comparison with the EPA recommended 24-hr $PM_{2.5}$ Class I area SIL of 0.27 µg/m^3. Assuming the primary impacts are below 0.078 µg/m^3, the project source could include this screening demonstration in its PSD application. Otherwise, the project source would move on to the second step with more refined screening demonstration based on 0.01 µg/m^3 impacts per 500 tpy NO_X at 300 km distance downwind, i.e., 0.01 µg/m^3 * 3000 tpy/500 tpy = 0.06 µg/m^3 of $PM_{2.5}$ nitrate.

This estimate of secondary contribution at the distance of the Class I area from the project source would then be added to the primary impacts modeled with AERMOD at 50 km and be compared with the EPA recommended $PM_{2.5}$ Class I SIL. If the sum of the more refined secondary contribution paired with the primary $PM_{2.5}$ contribution exceeds the SIL, the next step in the screening demonstration would utilize an estimate of primary $PM_{2.5}$ using a chemical transport model (e.g., Lagrangian or photochemical model) that can be paired with the secondary impact at 300 km downwind (as shown above). In situations where the screening demonstration does not show downwind impacts of $PM_{2.5}$ at Class I areas below the SIL, then a more refined approach to estimate the impacts from their project source based on methods suggested for Tier 2 demonstrations may be considered prior to conducting a cumulative impact analysis.

4.1.3. Cumulative Impact Analysis: O_3 and $PM_{2.5}$ NAAQS

As detailed in Section 9 of the *Guideline*, for situations where the project source is not able to demonstrate compliance through the source impact analysis, a cumulative impact analysis can be conducted that accounts for the impacts from the project source, impacts from nearby sources (as appropriate), and monitored background levels. The cumulative impacts are then compared to the NAAQS to determine whether the project source could cause or contribute to a NAAQS exceedance.

The following section provides examples of developing a suitable Tier 1 demonstration tool for each precursor and secondary pollutant for the purposes of a cumulative impact analysis. Where only a single precursor of O_3 or $PM_{2.5}$ necessitates a demonstration, then a direct application of this approach would be appropriate. For situations where project sources are required to assess multiple precursors of $PM_{2.5}$ or of O_3, EPA recommends that the impacts of multiple precursors should be estimated in a combined manner for comparison to the appropriate SIL such that the sum of precursor impacts would be lower than the SIL in a demonstration of compliance. Further, where project sources are required to assess both primary $PM_{2.5}$ and precursors of secondary $PM_{2.5}$, EPA recommends that applicants combine the primary and secondary impacts to determine total $PM_{2.5}$ impacts as part of the PSD compliance demonstration. In such cases, the project source impacts associated with their direct $PM_{2.5}$ emissions should be assessed through dispersion modeling. The examples below include each of these situations.

The Tier 1 demonstration approach detailed in Section 3 of this document can be modified for use in a cumulative impact assessment. Here, existing relevant single source modeled impacts can be estimated and then added to the appropriate background contribution for comparison to the NAAQS. The MERP equation (Eq. 1) can be rearranged such that instead of calculating a modeled emission rate based on a critical air quality threshold such as a SIL value, a project specific impact would be estimated. Equation 2 shows how a project source impact would be the product of the relevant hypothetical source air quality impact relative to emissions scaled either upwards or downwards to the emission rate of the project.

$$\text{Eq. 2} \quad \text{Project Impact} = \text{Project emission rate} \times \frac{\text{Modeled air quality impact from hypothetical source}}{\text{Modeled emission rate from hypothetical source}}$$

For simplicity in these examples, nearby and background levels are represented by the design value from a representative monitor. In this situation, the cumulative assessment would include the sum of equation 2 and that monitored design value.

$$\text{Eq. 3} \quad \text{Projected Design Value with Project} = \text{Project Impact (Eq. 2)} + \text{Monitored Design Value}$$

If equation 3 results in an air quality level less that the NAAQS, then there is no NAAQS violation for which the source could cause or contribute to. However, if equation 3 results in an air quality level greater than the NAAQS, then the permit applicant should consult with the reviewing authority to determine the next step in the demonstrating project source impact at the location of the NAAQS violation. This may necessitate more refined modeling to reconcile project source impacts and monitored design values to complete the second phase of the cumulative impact analysis.

The following illustrative examples are intended to show how existing modeling information may be used in specific permit demonstrations.

Scenario A: Single precursor assessment for O_3 and additive secondary $PM_{2.5}$ impacts

In this scenario, a facility with a proposed increase in emissions of 0 tpy of primary $PM_{2.5}$, 0 tpy of VOC, 600 tpy of NO_X, and 3,100 tpy of SO_2 located in the southeast region.

<u>O_3 source impact analysis</u>: The project source is not located in an area with unusual circumstances regarding complex terrain, proximity to very large sources of either NO_X or VOC, or meteorology. However, the NO_X emissions of 600 tpy are larger than the lowest (most conservative) NO_X MERP for 8-hr O_3 in the southeast region (i.e., 170 tpy). Thus, even though the project source's surrounding environment does not raise an obvious regional feature that would influence downwind O_3 impacts, it is likely more appropriate to use a hypothetical source

in the same region or other appropriate geographic area for comparison. In practice, EPA recommends that the permit applicant consult with the appropriate reviewing authority to determine the relevant hypothetical source and geographic area from which to select representative MERP values.

A comparable hypothetical source is identified to be representative of the project (e.g., southeast region source located in Tallapoosa County, Alabama with elevated emissions release). Since multiple hypothetical sources were modeled at this location with an elevated release, the source with the lowest MERP was selected for comparison with the project source. The project source does not emit VOC so a MERP approach addressing only NO_X emission is sufficient in this example. For this example, equation 2 was used to estimate air quality impacts using the hypothetical source information rather than equation 1 because this form of the Tier 1 demonstration approach more clearly fits into the subsequent cumulative assessment.

Project source impact (ppb) = 600 tpy * (1.528 ppb / 500 tpy) = 1.83 ppb

In this case, based on EPA modeling results for a representative hypothetical source, air quality impacts of O_3 from this project source would be expected to exceed the EPA recommended 8-hour O_3 SIL.

O_3 cumulative impact analysis: For the cumulative impact analysis, the impact estimated with equation 2 in the source impact analysis was used with an estimate of nearby source impacts and background O_3, which was a nearby monitor design value. The representative monitor near the project source has a design value of 65 ppb.

Projected Design Value with Project Source (ppb) = 1.83 ppb + 65 ppb = 66.83 ppb

When the source impact is combined with the nearby monitor design value using equation 3, the projected value is below the level of the O_3 NAAQS of 70 ppb.

$PM_{2.5}$ source impact analysis: The project source is not located in an area with unusual circumstances regarding complex terrain, proximity to very large sources of pollutants that impact atmospheric chemistry (i.e., NO_X, SO_2, NH_3) or meteorology. Both the NO_X and SO_2 emissions are below the lowest (most conservative) daily and annual $PM_{2.5}$ MERP values of any source modeled in the southeast region. The SO_2 emissions are not very far below the most conservative MERP relating SO_2 emissions to daily PM2.5 impacts. Thus, for simplicity in this example, even though the project source's surrounding environment does not raise an obvious regional feature that would influence downwind secondary $PM_{2.5}$ impacts, it is likely more appropriate to use a specific hypothetical source in the same region or other appropriate geographic area for comparison. In practice, EPA recommends that the permit applicant consult with the appropriate reviewing authority to determine the relevant hypothetical source and geographic area from which to select representative MERP values.

A comparable hypothetical source is identified to be representative of this project (e.g., southeast region source located in Tallapoosa County, Alabama with elevated emissions release) and has a source derived NO_X MERP for 24-hr $PM_{2.5}$ of 12,686 tpy and SO_2 MERP for 24-hr PM2.5 of 2,593 tpy. This hypothetical source has a derived NO_X MERP for annual $PM_{2.5}$ of 116,399 tpy and SO_2 MERP for annual PM2.5 of 21,106 tpy.

For this example, EPA recommends that the NO_X and SO_2 precursor impacts on both daily and annual average $PM_{2.5}$ are considered together to determine if the project source's air quality impact of $PM_{2.5}$ would exceed the $PM_{2.5}$ SILs. In this case, the project source's emissions increase can be expressed as a percent of the MERP for each precursor and then the percentages can be summed. A value less than 100% indicates that the EPA recommended $PM_{2.5}$ SILs would not be exceeded when considering the combined impacts of these precursors on daily and annual $PM_{2.5}$.

Example calculation based on equation 1 for additive precursor impacts on daily $PM_{2.5}$:

> (600 tpy NO_X from source/12,686 tpy NO_X daily $PM_{2.5}$ MERP) + (3,100 tpy SO_2 from source/2,593 tpy SO_2 daily $PM_{2.5}$ MERP) = .05 + 1.20 = 1.21 * 100 = 121%

Example calculation based on equation 1 for additive precursor impacts on annual $PM_{2.5}$:

> (600 tpy NO_X from source/116,399 tpy NO_X annual $PM_{2.5}$ MERP) + (3,100 tpy SO_2 from source/21,106 tpy SO_2 annual $PM_{2.5}$ MERP) = .005 + .147 = .15 * 100 = 15%

A value less than 100% indicates that the EPA recommended $PM_{2.5}$ SIL would not be exceeded when considering the combined impacts of these precursors on daily or annual $PM_{2.5}$. Thus, in this case, the air quality impacts of $PM_{2.5}$ from precursor emissions of NO_X and SO_2 from this source would be expected to be above the daily $PM_{2.5}$ SIL and less than the annual $PM_{2.5}$ SIL.

$PM_{2.5}$ cumulative impact analysis: For the cumulative impact analysis on daily $PM_{2.5}$ impacts, equation 2 is used with the modeled emissions rates and air quality impact information from this representative hypothetical source with an elevated release. Since multiple hypothetical sources were modeled at this location with an elevated release the source with the lowest MERP was selected for comparison with the project source.

> Source nitrate impact ($\mu g/m^3$) = 600 tpy * (0.047 $\mu g/m^3$ / 500 tpy) = 0.056 $\mu g/m^3$
> Source sulfate impact ($\mu g/m^3$) = 3,100 tpy * (0.891 $\mu g/m^3$ / 3,000 tpy) = 0.921 $\mu g/m^3$

A representative monitor near the project source has a 24-hour $PM_{2.5}$ design value of 14 $\mu g/m^3$.

> Projected Design Value with Project Source ($\mu g/m^3$) = 0.056 $\mu g/m^3$ + 0.921 $\mu g/m^3$ + 14 $\mu g/m^3$ = 14.98 $\mu g/m^3$

When the source impact is combined with the nearby monitor design value using equation 3, the projected value is below the level of the daily $PM_{2.5}$ NAAQS of 35 $\mu g/m^3$.

Scenario B: Additive demonstration for O_3 and secondary $PM_{2.5}$ with primary $PM_{2.5}$ impacts

In this scenario, a facility with a proposed increase in emissions of 500 tpy of primary $PM_{2.5}$, 62 tpy of VOC, 920 tpy of NO_X, and 259 tpy of SO_2 located in the western region.

<u>O_3 source impact analysis</u>: The project source is not located in an area with unusual circumstances regarding complex terrain, proximity to very large sources of either NO_X or VOC, or meteorology. However, the NO_X emissions of 920 tpy are larger than the lowest (most conservative) NO_X MERP for 8-hr O_3 in the western region of the U.S. Thus, even though the project source's surrounding environment does not raise an obvious regional feature that would influence downwind O_3 impacts, it is likely more appropriate to use a specific hypothetical source in the same region or other appropriate geographic area for comparison. In practice, EPA recommends that the permit applicant consult with the appropriate reviewing authority to determine the relevant hypothetical source and geographic area from which to select representative MERP values.

A comparable hypothetical source is identified to be representative of this source (e.g., western (Rockies) region in Iron County, Utah with elevated release). Here, equation 1 is used with the modeled emissions rates and air quality impact information from the selected comparable source. Since multiple hypothetical sources were modeled at this location with an elevated release the source with the MERP with the most similar emission rate was selected for comparison with the project source, i.e.,

1. NO_X MERP for selected representative hypothetical source (tpy) = 1.0 ppb * (1000 tpy / 1.314 ppb) = 761 tpy
2. VOC MERP for selected representative hypothetical source (tpy) = 1.0 ppb * (500 tpy / 0.0407 ppb) = 12,275 tpy
3. Combining impacts from both NO_X and VOC: (920/761 + 62/12,275) * 100 = 121%

In this case, based on modeling results for a representative hypothetical source, the project source emissions are greater than the calculated 8-hr O_3 MERP such that air quality impacts of O_3 from this source are expected to exceed the EPA recommended 8-hour O_3 SIL.

<u>O_3 cumulative impact analysis</u>: For the cumulative impact analysis, equation 2 is used with the modeled emissions rates and air quality impact information from this representative hypothetical source with an elevated release. Since multiple hypothetical sources were modeled at this location with an elevated release the source with the most similar emission rate was selected for comparison with the project source.

Source impact from NO_X (ppb) = 920 tpy * (1.314 ppb / 1000 tpy) = 1.208 ppb
Source impact from VOC (ppb) = 62 tpy * (0.0407 ppb / 500 tpy) = 0.005 ppb

A representative monitor near the project source has a design value of 62 ppb.

Projected Design Value with Project Source (ppb) = 1.213 ppb + 62 ppb = 63.213 ppb

When the source impact is combined with the nearby monitor design value using equation 3, the projected value is below the level of the O_3 NAAQS.

PM$_{2.5}$ source impact analysis: The project source is not located in an area with unusual circumstances regarding complex terrain, proximity to very large sources of pollutants that impact atmospheric chemistry (i.e., NO_X, SO_2, NH_3) or meteorology. However, the NO_X emissions of 920 are marginally below the lowest (most conservative) daily and annual PM$_{2.5}$ MERP value of any source modeled in the continental U.S., while the SO_2 emissions of 259 tpy are slightly higher than the lowest daily PM$_{2.5}$ MERP value of any source modeled in the western U.S. region.

Thus, for simplicity in this example, even though the project source's surrounding environment does not raise an obvious regional feature that would influence downwind secondary PM$_{2.5}$ impacts, it is likely more appropriate to use a hypothetical source in the same region or other appropriate geographic area for comparison. In practice, EPA recommends that the permit applicant consult with the appropriate reviewing authority to determine the relevant hypothetical source and geographic area from which to select representative MERP values.

A hypothetical source is identified to be representative of this source (e.g., western (Rockies) region in Iron County, Utah). Since multiple hypothetical sources were modeled at this location with an elevated release the source with the lowest MERP was selected for comparison with the project source. The 1,000 tpy MERP was chosen for NO_X and the 500 tpy MERP for SO_2 impacts. Both reflect elevated emissions release.

For this example, EPA recommends that the NO_X and SO_2 precursor contributions to both daily and annual average PM$_{2.5}$ are considered together to determine if the project source's air quality impact of PM$_{2.5}$ would exceed the EPA recommended PM$_{2.5}$ SILs. In this case, the project source's emissions increase can be expressed as a percent of the MERP for each precursor and then the percentages can be summed.

Example calculation for additive precursor impacts on daily PM$_{2.5}$:

(920 tpy NO_X from source/25,754 tpy NO_X daily PM$_{2.5}$ MERP) + (259 tpy SO_2 from source/6,386 tpy SO_2 daily PM$_{2.5}$ MERP) = 0.04 + 0.04 = 0.08 * 100 = 8%

Example calculation for additive precursor impacts on annual PM$_{2.5}$:

(920 tpy NO_X from source/166,670 tpy NO_X daily PM$_{2.5}$ MERP) + (259 tpy SO_2 from source/33,561 tpy SO_2 daily PM$_{2.5}$ MERP) = 0.0055+ 0.0077 = 0.013 * 100 = 1.3%

The emissions rates for both NO_X and SO_2 are much lower than the daily and annual $PM_{2.5}$ MERP based on the modeling results for a representative hypothetical source. However, for purposes of illustration in this hypothetical example, an assumption is made that primary $PM_{2.5}$ modeling with AERMOD (daily impact assumed to be 1.8 $\mu g/m^3$ and annual impact assumed to be 0.02 $\mu g/m^3$) showed an exceedance of the EPA recommended daily (but not annual) $PM_{2.5}$ SIL so that a cumulative impact analysis example is presented below for the daily form of the NAAQS. Note that no AERMOD simulations were done to relate primary $PM_{2.5}$ emissions and downwind impacts; the levels of impact used here are purely to support this illustrative example. When considering primary and secondary impacts for the annual form of the NAAQS, the source's impact would be expected to be less than the EPA recommended $PM_{2.5}$ SIL.

$PM_{2.5}$ cumulative impact analysis: For the cumulative impact analysis, equation 2 is used with the modeled emissions rates and air quality impact information from this representative hypothetical source with an elevated release.

Source nitrate impact ($\mu g/m^3$) = 920 tpy * (0.047 $\mu g/m^3$ / 1000 tpy) = 0.043 $\mu g/m^3$
Source sulfate impact ($\mu g/m^3$) = 259 tpy * (0.094 $\mu g/m^3$ / 500 tpy) = 0.049 $\mu g/m^3$

A representative monitor near the project source has a daily $PM_{2.5}$ design value of 11 $\mu g/m^3$. A hypothetical downwind primary $PM_{2.5}$ impact from other analysis for this source was determined to be 1.8 $\mu g/m^3$, which is included in the CIA together with the secondary impact analysis.

Projected Design Value with Project Source ($\mu g/m^3$) = 0.043 $\mu g/m^3$ + 0.049 $\mu g/m^3$ + 11 $\mu g/m^3$ + 1.8 $\mu g/m^3$ = 12.89 $\mu g/m^3$

When the project source primary impact (from AERMOD) and secondary impacts (from MERP equation) are combined with the nearby monitor design value using equation 3, the projected value is below the level of the daily $PM_{2.5}$ NAAQS.

5. References

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Appendix A. Hypothetical Sources Included in the EPA's Modeling Assessment

Table A-1. Complete list of EPA modeled hypothetical sources presented in this document. A list of emission rates and stack height combinations modeled for each domain are provided in Table A-2. The "Max Nearby Urban (%)" column provides the highest percentage urban landcover in any grid cell near (within 50 km) the source. Source locations are shown in Figures A-1, A-2, A-3, and A-4.

FIPS	State	County	Domain	Source	Latitude	Longitude	Max Nearby Terrain (m)	Max Nearby Urban (%)
1001	Alabama	Autauga	12EUS2	4	32.522	-86.550	179	25
1123	Alabama	Tallapoosa	12EUS3	19	32.848	-85.809	306	10
4005	Arizona	Coconino	12US2	36	35.428	-111.270	2483	7.4
4007	Arizona	Gila	12WUS1	14	33.469	-110.789	1592	4.3
4012	Arizona	La Paz	12WUS1	17	33.400	-113.408	757	0.9
5119	Arkansas	Pulaski	12EUS2	13	34.724	-92.275	235	32.2
6029	California	Kern	12WUS1	26	35.356	-119.508	1195	49.1
6037	California	Los Angeles	12WUS1	21	34.696	-118.414	1528	39.9
6047	California	Merced	12WUS1	25	37.274	-120.708	547	14.6
6063	California	Plumas	12WUS1	24	39.920	-121.263	1773	17.5
6107	California	Tulare	12WUS1	20	36.324	-119.404	566	18.1
8011	Colorado	Bent	12WUS1	4	37.685	-102.994	1698	1.4
8069	Colorado	Larimer	12WUS1	8	40.841	-105.826	3288	0.5
8093	Colorado	Park	12US2	31	38.919	-105.990	3535	2.2
8109	Colorado	Saguache	12WUS1	9	37.965	-106.234	3374	2.7
8109	Colorado	Saguache	12WUS1	9	37.965	-106.234	3374	2.7
8123	Colorado	Weld	12WUS1	3	40.621	-104.037	1609	6.2
12005	Florida	Bay	12EUS2	5	30.269	-85.700	55	9.8
17021	Illinois	Christian	12US2	16	39.509	-89.092	209	11.6
17145	Illinois	Perry	12EUS2	7	38.078	-89.547	194	6.8
17155	Illinois	Putnam	12EUS2	6	41.200	-89.446	243	16.4
17177	Illinois	Stephenson	12US2	15	42.455	-89.606	296	14.4
18011	Indiana	Boone	12US2	11	40.009	-86.574	290	47.3
18037	Indiana	Dubois	12EUS2	2	38.255	-86.724	224	4.4
18053	Indiana	Grant	12EUS3	17	40.623	-85.589	285	10.3
18127	Indiana	Porter	12EUS2	1	41.380	-87.185	235	52.3
19027	Iowa	Carroll	12US2	20	42.092	-94.693	435	3.9
19095	Iowa	Iowa	12EUS2	11	41.674	-92.060	295	17.3
20091	Kansas	Johnson	12EUS2	17	38.746	-94.949	325	38.8
20109	Kansas	Logan	12US2	26	38.909	-101.173	1121	1.6
20155	Kansas	Reno	12EUS2	22	38.121	-97.899	542	12.7

21009	Kentucky	Barren	12EUS3	18	36.828	-85.830	269	4.5
21187	Kentucky	Owen	12US2	33	38.536	-84.707	279	7.4
22001	Louisiana	Acadia	12EUS2	15	30.241	-92.616	16	6.5
22061	Louisiana	Lincoln	12EUS2	14	32.476	-92.711	97	5.8
22071	Louisiana	Orleans	12EUS2	10	30.092	-89.879	10	50.4
23003	Maine	Aroostook	12EUS3	1	46.772	-67.850	365	4.6
23031	Maine	York	12EUS3	2	43.367	-70.580	237	13.3
25011	Massachusetts	Franklin	12EUS3	4	42.582	-72.459	583	21.6
25021	Massachusetts	Norfolk	12EUS3	3	42.139	-71.234	224	60
26099	Michigan	Macomb	12EUS3	11	42.822	-82.872	317	63.9
26103	Michigan	Marquette	12EUS3	15	46.570	-87.395	518	4
26117	Michigan	Montcalm	12EUS3	16	43.319	-85.368	309	42.8
26129	Michigan	Ogemaw	12US2	5	44.164	-84.069	382	4.4
26159	Michigan	Van Buren	12US2	10	42.410	-86.027	273	25.3
27037	Minnesota	Dakota	12US2	19	44.785	-93.311	339	52.4
27137	Minnesota	St Louis	12US2	13	47.913	-92.331	485	2.8
27159	Minnesota	Wadena	12US2	18	46.401	-95.086	464	2.2
28129	Mississippi	Smith	12EUS2	9	32.177	-89.345	142	2.3
29029	Missouri	Camden	12EUS2	12	38.014	-93.006	378	6.2
29155	Missouri	Pemiscot	12US2	17	36.223	-89.851	104	5.1
29177	Missouri	Ray	12US2	21	39.504	-94.135	305	39
30013	Montana	Cascade	12US2	28	47.367	-111.447	1803	18.1
30075	Montana	Powder River	12WUS1	7	45.299	-105.895	1238	0.6
30083	Montana	Richland	12WUS1	6	47.367	-104.447	862	2.3
30111	Montana	Yellowstone	12WUS1	11	45.786	-108.207	1641	22.2
31001	Nebraska	Adams	12EUS2	21	40.673	-98.327	655	18.2
31055	Nebraska	Douglas	12EUS2	16	41.364	-96.155	424	43.3
31101	Nebraska	Keith	12US2	25	41.247	-102.006	1197	2.1
32001	Nevada	Churchill	12WUS1	19	39.941	-118.748	1599	9.2
34041	New Jersey	Warren	12US2	2	41.017	-75.000	577	31.2
35031	New Mexico	Mc Kinley	12US2	32	35.368	-107.382	2577	3.6
35035	New Mexico	Otero	12WUS1	10	32.757	-105.767	2618	4.4
36005	New York	Bronx	12EUS3	5	40.819	-73.909	273	75.4
36019	New York	Clinton	12US2	1	44.477	-73.836	889	3.2
36051	New York	Livingston	12EUS3	7	42.877	-77.603	532	34
37009	North Carolina	Ashe	12EUS3	13	36.301	-81.374	1168	6.9
37109	North Carolina	Lincoln	12US2	8	35.439	-81.154	457	32.1
37127	North Carolina	Nash	12US2	4	35.922	-78.187	123	22.1
38057	North Dakota	Mercer	12WUS1	1	47.287	-101.879	719	1.8
38059	North Dakota	Morton	12WUS1	2	46.861	-101.925	799	1
39103	Ohio	Medina	12US2	6	41.238	-81.813	344	51.7
39157	Ohio	Tuscarawas	12EUS3	12	40.541	-81.396	356	26.9
40017	Oklahoma	Canadian	12EUS2	23	35.463	-97.913	473	43.1

40101	Oklahoma	Muskogee	12EUS2	18	35.751	-95.507	236	30.4
40127	Oklahoma	Pushmataha	12US2	22	34.390	-95.567	294	2.5
40149	Oklahoma	Washita	12US2	27	35.311	-99.187	662	4.4
41049	Oregon	Morrow	12WUS1	18	45.790	-119.475	894	8.2
42001	Pennsylvania	Adams	12EUS3	8	40.009	-77.111	364	26.9
42029	Pennsylvania	Chester	12US2	3	39.940	-75.822	188	32.2
45005	South Carolina	Allendale	12EUS3	14	32.973	-81.407	84	2.2
45051	South Carolina	Horry	12EUS3	10	34.083	-79.187	33	7.1
46055	South Dakota	Haakon	12US2	23	44.287	-101.879	842	1.4
46097	South Dakota	Miner	12US2	24	43.861	-97.425	535	5.4
47001	Tennessee	Anderson	12US2	12	36.079	-84.149	611	25.4
47055	Tennessee	Giles	12EUS2	3	35.291	-86.897	286	8.4
47157	Tennessee	Shelby	12EUS2	8	35.124	-90.002	117	42.4
48187	Texas	Guadalupe	12EUS2	25	29.553	-97.991	349	43.8
48201	Texas	Harris	12EUS2	20	29.592	-95.418	41	64.7
48213	Texas	Henderson	12EUS2	19	32.314	-95.556	155	27.6
48367	Texas	Parker	12EUS2	24	32.610	-97.736	384	35.7
48445	Texas	Terry	12WUS1	5	33.369	-102.146	1112	31.9
49013	Utah	Duchesne	12WUS1	12	40.407	-110.618	3395	0.9
49015	Utah	Emery	12US2	35	38.804	-110.630	2090	0.6
49021	Utah	Iron	12WUS1	16	37.608	-113.092	2870	5.5
49037	Utah	San Juan	12WUS1	13	37.905	-109.899	2450	0.2
49049	Utah	Utah	12WUS1	15	40.110	-111.936	2235	21.7
51053	Virginia	Dinwiddie	12EUS3	9	36.919	-77.707	133	9
53039	Washington	Klickitat	12WUS1	23	45.938	-121.191	1699	4.9
53057	Washington	Skagit	12WUS1	22	48.466	-122.559	497	9.6
54017	West Virginia	Doddridge	12US2	7	39.299	-80.633	454	10.4
55107	Wisconsin	Rusk	12US2	14	45.596	-90.768	482	2.3
55115	Wisconsin	Shawano	12US2	9	44.733	-88.263	309	32.2
56001	Wyoming	Albany	12US2	30	41.829	-105.857	2898	0.3
56005	Wyoming	Campbell	12US2	29	44.299	-105.895	1532	8.1
56023	Wyoming	Lincoln	12US2	34	41.905	-110.326	2585	1.3

Table A-2. A list of emission rates and stack release height combinations modeled for each domain. A complete list of hypothetical sources in each domain are provided in Table A-1. Figures showing the location of specific sources by domain are provided in Figures A1-A4.

				NAAQS & Precursors Modeled		
Geographic Region	**# hypothetical sources within the region**	**Release Type**	**Emission Rate (tpy)**	**8-hr O3**	**Daily PM2.5**	**Annual PM2.5**
12EUS3 (eastern US)	18	H	3000	NOX, VOC	NOX, SO2	NOX, SO2
	18	H	1000	NOX, VOC	NOX, SO2	NOX, SO2
	18	H	500	NOX, VOC	NOX, SO2	NOX, SO2
	18	L	500	NOX, VOC	NOX, SO2	NOX, SO2
12EUS2 (central US)	25	H	3000	NOX, VOC	NOX, SO2	NOX, SO2
	25	H	1000	NOX, VOC	NOX, SO2	NOX, SO2
	25	L	1000	VOC	NOX, SO2	NOX, SO2
	25	H	500	NOX	NOX, SO2	NOX, SO2
	25	L	500	NOX, VOC	NOX, SO2	NOX, SO2
12WUS1 (western US)	26	H	3000	NOX, VOC	NOX, SO2	NOX, SO2
	26	H	1000	NOX, VOC	NOX, SO2	NOX, SO2
	26	H	500	NOX, VOC	NOX, SO2	NOX, SO2
	26	L	500	NOX, VOC	NOX, SO2	NOX, SO2
12US2 (contiguous US)	36	H	1000	NOX	NOX, SO2	NOX, SO2
	36	H	500	NOX	NOX, SO2	NOX, SO2
	36	L	500	NOX, VOC	NOX, SO2	NOX, SO2

Figure A-1. Hypothetical source locations for the eastern U.S. (12EUS3) domain.

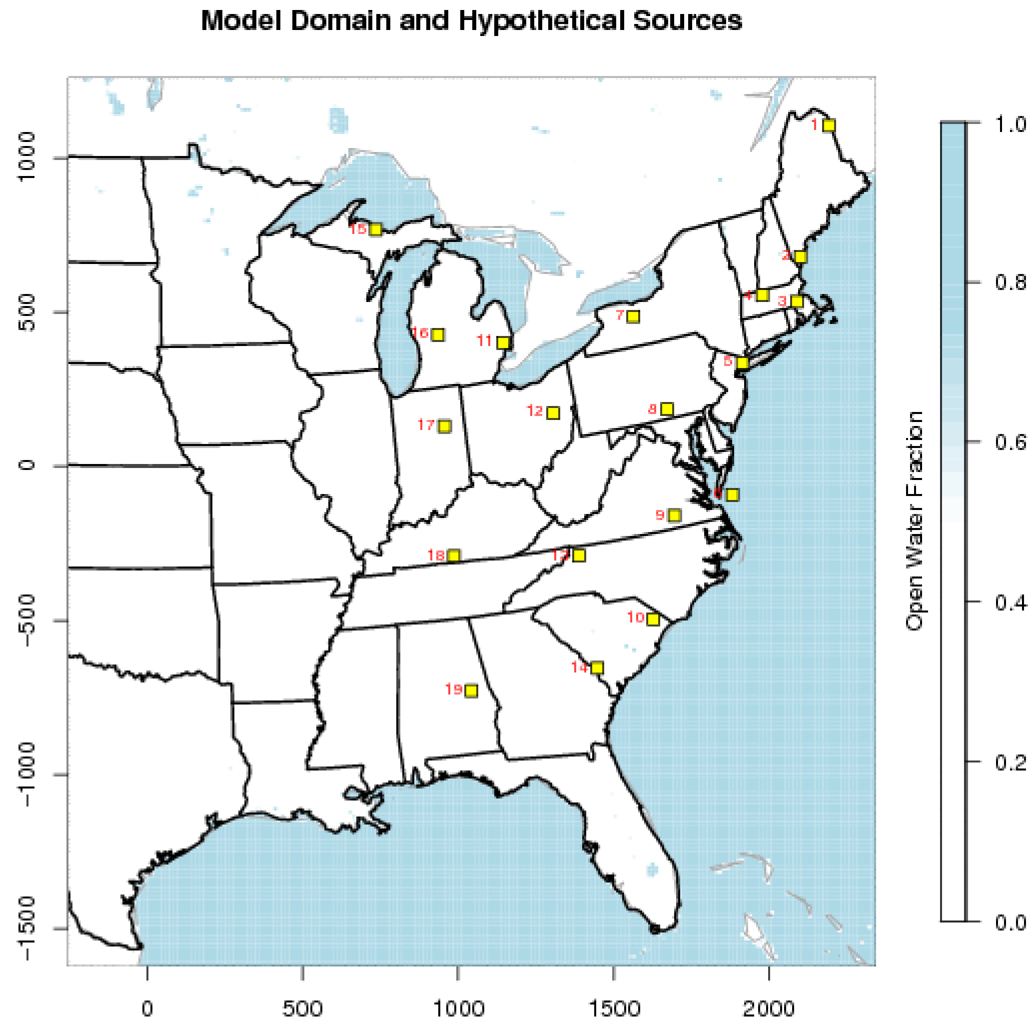


Figure A-2. Hypothetical source locations for the central U.S. (12EUS2) domain.

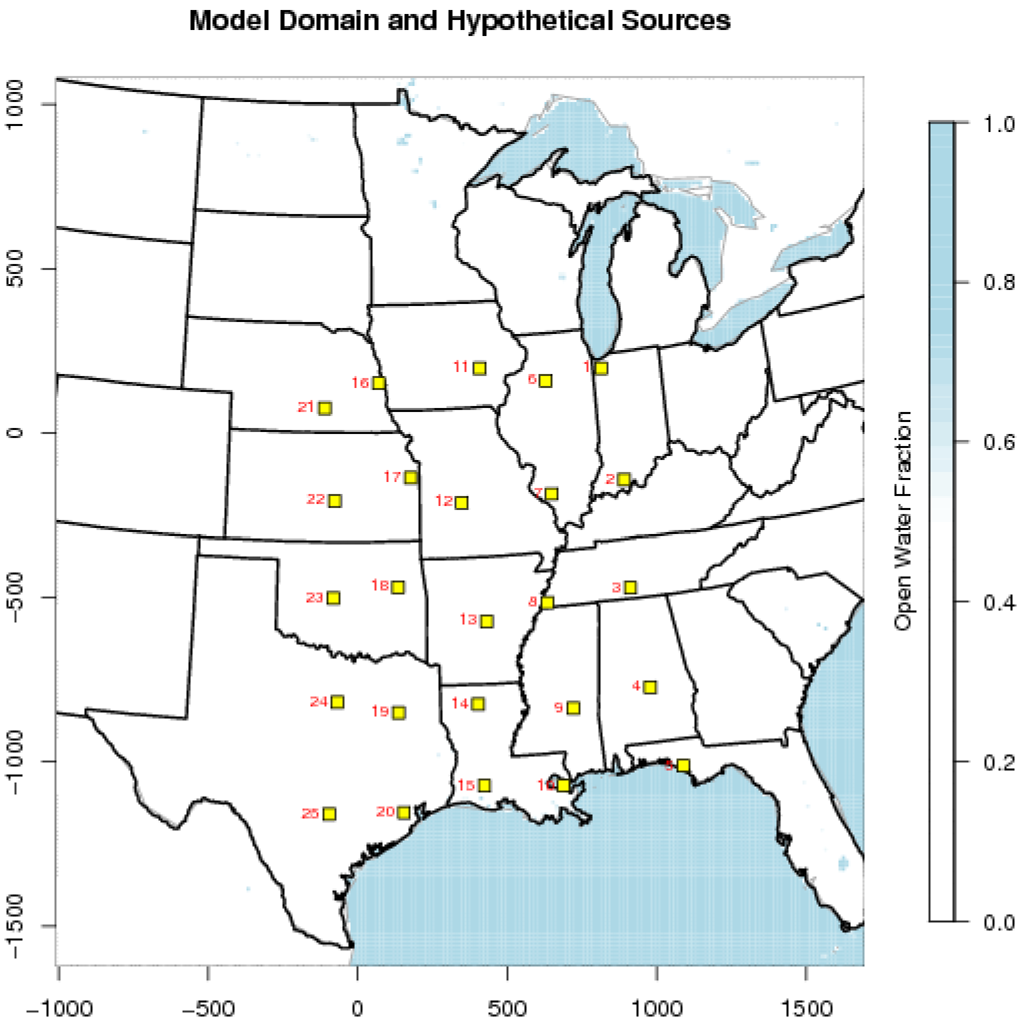


Figure A-3. Hypothetical source locations for the western U.S. (12WUS1) domain.

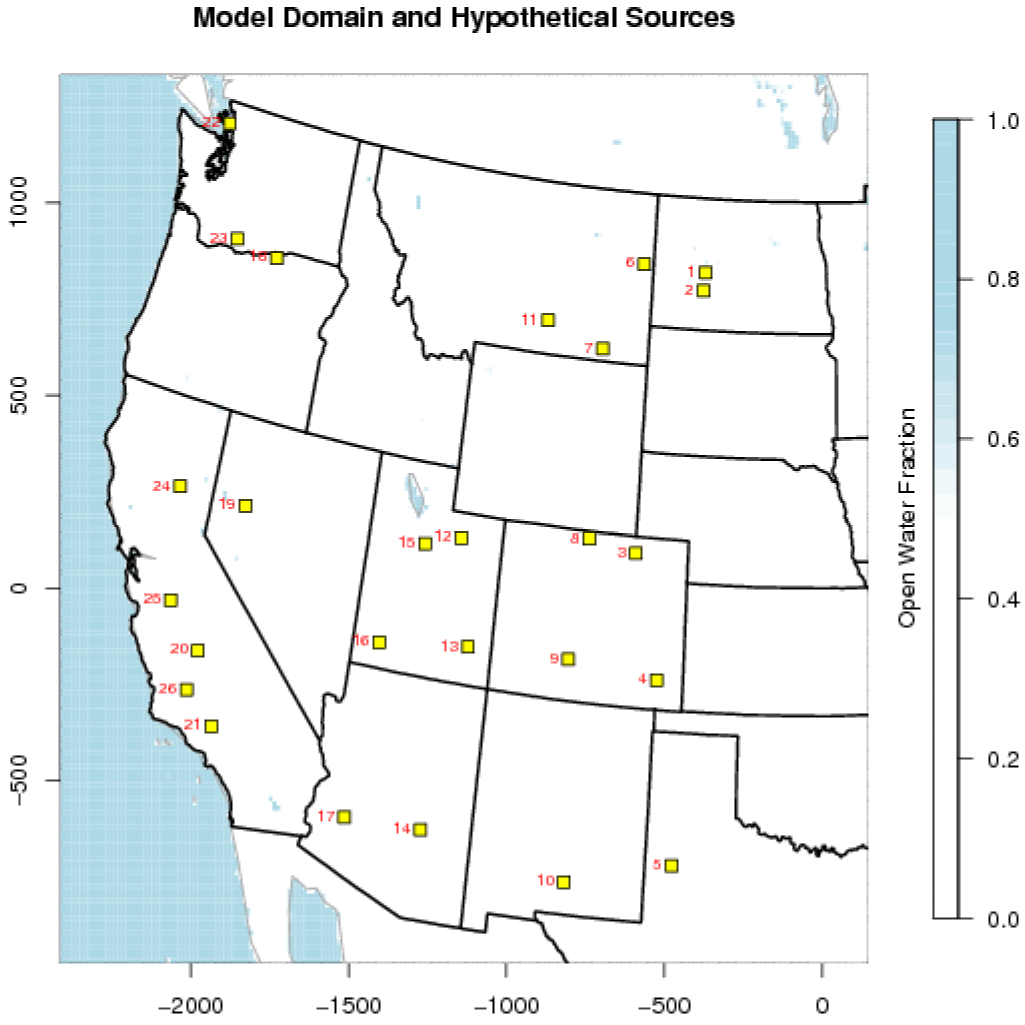
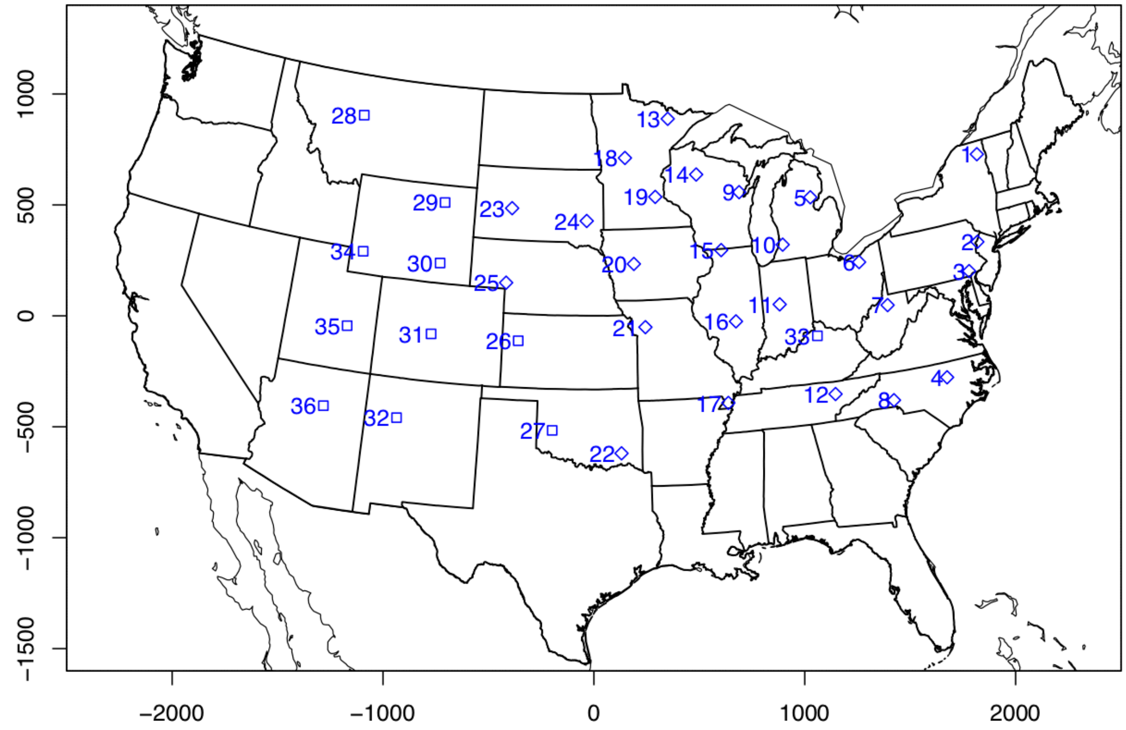


Figure A-4. Hypothetical source locations for the contiguous U.S. (12US2) domain.



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Office of Air Quality Planning and Standards
Air Quality Assessment Division
Research Triangle Park, NC

Publication No. EPA-454/R-19-003
April 2019