Technical Guidance for Demonstration of Inter-Precursor Trading (IPT) for Ozone in the Nonattainment New Source Review Program

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Technical Guidance for Demonstration of Inter-Precursor Trading (IPT) for Ozone in the Nonattainment New Source Review Program

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1 Background

The EPA's implementing regulations at 40 CFR 51.165 and part 51 Appendix S allow air agencies to establish inter-precursor trading (IPT) provisions for ozone (O_3) as part of their Nonattainment New Source Review (NNSR) programs. *See* 40 CFR 51.165(a)(11)(i) and part 51 Appendix S section IV.G.5(i). O_3 IPT provisions allow any new or modified major stationary source, locating in an O_3 nonattainment area to satisfy the NNSR emissions offset requirements for O_3 with emissions reductions of volatile organic compounds (VOC) or nitrogen oxides (NO_X) interchangeably, subject to all statutory and regulatory offset requirements. This guidance and the supporting documents are not final agency actions and do not create any binding requirements on permitting authorities, permit applicants, the EPA, or the public. Further, this guidance applies only to IPT for the NNSR[1] program

The CAA recognizes that emissions of both VOC and NO_X contribute to ground-level O_3 and, as such, are considered precursors for O_3. In turn, the EPA's NNSR regulations identify both NO_X and VOC as precursors for O_3, and generally apply the control requirements for O_3 to both precursors in O_3 nonattainment areas. See 40 CFR 51.165(a)(xxxvii)(c)(1). However, emissions of NO_X and VOC are not considered interchangeable for all aspects of O_3 control. For example, in certain situations for purposes of meeting the CAA's reasonable further progress requirements, the NNSR requirements for O_3 in the CAA expressly require reductions in VOC emissions. Nevertheless, in NNSR permitting situations, with an appropriate technical demonstration, it is possible to define the relationship between emissions of VOC and NO_X to establish ratios for using NO_X decreases to offset VOC increases, or vice versa, that result in an equivalent or greater air quality benefit for O_3 in a particular O_3 nonattainment area.

This document provides technical guidance that can be used by both air agencies and permit applicants to estimate facility-specific impacts on O_3 for purposes of O_3 IPT by comparing the equivalency of NO_X and VOC precursor emission impacts on ground-level O_3. The air quality models and approaches for estimating single source O_3 impacts are consistent with those described in the most recent update to the Guideline on Air Quality Models (U.S. Environmental Protection Agency, 2017). Further, this document does not specifically provide guidance for inter-basin precursor trading, but may provide useful information for developing such a demonstration. Inter-basin precursor trading demonstrations will be reviewed on a case-by-case basis by the reviewing authority and be done in consultation with the appropriate Regional office.

2 O_3 formation in the atmosphere

Air pollutants formed through chemical reactions in the atmosphere are referenced as secondary pollutants. While some very small amount of ambient O_3 may result from the release of O_3 emissions from certain sources, ground-level O_3 is predominantly a secondary pollutant formed through photochemical reactions driven by emissions of NO_X and VOC. O_3 formation is a complicated nonlinear process that typically requires favorable meteorological conditions in addition to VOC and NO_X emissions (Seinfeld and Pandis, 2012). Clear skies (abundant levels of solar radiation) and stagnant air masses (low wind speeds) increase O_3 formation potential (Seinfeld and Pandis, 2012).

[1] It does not address guidance and policy for other programs such as general conformity, CAA § 110(l), Economic Incentive Program (non NNSR IPT related), Motor Vehicle Emissions Budget (MVEB for conformity, Reasonable Further Progress (RFP), Aggregate Commitments and Contingency Measures.

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 changes in ground-level O_3 concentrations are impacted by changes 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 O_3 formation is 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 NO to NO_2 in the presence of sunlight. In a NO_X-limited regime, O_3 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. and many urban centers tend to be VOC-limited (Seinfeld and Pandis, 2012). O_3 formation regimes vary across most areas due to the different mix of NO_X and VOC sources and also in time, meaning the precursors limiting O_3 formation can vary from day to day or even hour to hour in a given area.

3 Modeling systems for estimating single source O_3 impacts

Quantifying secondary pollutant formation requires simulating chemical reactions in a realistic chemical and physical environment. Chemical transport models (CTMs) treat atmospheric chemical and physical processes such as chemistry, deposition, and transport. Eulerian photochemical models are three-dimensional grid-based models that treat chemical and physical processes in each grid cell and use Eulerian diffusion and transport processes to move chemical species to other grid cells (McMurry et al., 2004). Photochemical models can provide a spatially and temporally dynamic and realistic chemical and physical environment for plume growth and chemical transformation (Baker and Kelly, 2014; Zhou et al., 2012). Publicly available and documented 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.

When using a photochemical grid model, specific source impacts can be isolated through the use of either source sensitivity or source apportionment approaches. The simplest source sensitivity approach (i.e., brute-force change to emissions) would be to simulate two sets of conditions, one with all existing emissions and one with the addition of a new source or a source of interest modified to reflect changes in operation (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 new or modified source. Another source sensitivity approach to differentiate the impacts of single sources on changes in model predicted air quality is the Decoupled Direct Method (DDM), which internally tracks the sensitivity of the emissions from a source through all chemical and physical processes within the modeling system (Dunker et al., 2002). Sensitivity coefficients relating source emissions to air quality levels are estimated during the model simulation and output at the grid resolution of the host model.

Some photochemical models have been instrumented with source apportionment capability, which enables the tracking of emissions from specific sources through chemical transformation, transport, and deposition processes to estimate a particular source's impact on predicted air quality levels (Kwok et al., 2015; Kwok et al., 2013). Source apportionment has been used to differentiate the impact from single sources on model predicted O_3 levels (Baker and Foley, 2011; Baker and Kelly, 2014; Baker et al., 2015). DDM has also been used to estimate O_3 impacts from specific sources (Baker and Kelly, 2014; Bergin et al., 2008; Cohan et al., 2005; Cohan et al., 2006; 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 and approaches to differentiate single source impacts (Baker and Kelly, 2014; Cohan et al., 2006; Kelly et al., 2015) has shown generally similar downwind spatial gradients and impacts.

4 Model application considerations for estimating O_3 IPT ratio

A modeling protocol is intended to communicate the scope of the analysis and generally includes (1) the types of analysis performed, (2) the specific steps taken in each type of analysis, (3) the rationale for the choice of modeling system and episode(s), (4) names of organizations participating in preparing and implementing the protocol, and (5) a complete list of model configuration options. For any IPT demonstration, EPA recommends permit applicants first consult with the appropriate air agency and the appropriate EPA Regional Office to develop a modeling protocol, and then conduct modeling consistent with the protocol. Elements of a modeling protocol for these purposes are outlined in "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, 2016b).

4.1 Model platform

The most recently submitted O_3 attainment demonstration modeling platform considered appropriate for the purposes of interprecursor trading demonstrations by the reviewing authority would be the best platform for a modeling demonstrtaion. This could include the last approved SIP demonstration, a more recent submission (even if not yet approved), 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. This approach of using the most recent SIP demonstration modeling will help support consistency and comparability between multiple demonstrations since the same modeling platform could be used by multiple applicants. Where multiple modeling platforms are available for a particular area, the platform that is considered to be the most reflective of the current atmosphere in that area would best account for growth in the area and the changing mix of sources. For instance, if an area has a SIP modeling platform with a baseline year or 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 area attainment demonstration modeling platform, a modeling platform that represents the current air quality and conforms to the specifications outlined for attainment demonstration modeling could be acceptable. The specifications for area attainment demonstration model platforms (e.g., horizontal grid spacing, vertical resolution, non-project source emission treatment, etc.) are detailed in the "Draft Modeling Guidance for Demonstrating Attainment of Air Quality Goals for O_3, PM2.5, and Regional Haze" (U.S. Environmental Protection Agency, 2014).

4.2 Episode selection

Meteorology is an important factor in the formation of many secondarily formed pollutants, both directly (e.g., ammonium nitrate formation under cool, humid conditions) and indirectly (e.g., warm temperatures and sunlight increase photochemistry and the availability of oxidants). A time period with meteorology generally conducive to the formation of O_3 is necessary. This means that time periods with elevated ambient O_3 at the source and receptors would be most relevant for an IPT demonstration. Since O_3 formation varies, even within a given area, an O_3 season or multiple well characterized O_3 episodes would be appropriate for modeling single source O_3 impacts to capture the variety of wind flows and O_3 formation regimes in a given area. Where multiple O_3 episode/season simulations are necessary for a single source assessment, it is not necessary they be consecutive. Multiple O_3 episodes may be necessary when a single O_3 episode does not have O_3 levels above the level of the NAAQS or if the single episode does not capture all of the typical O_3 formation regimes that are known in a particular area (U.S. Environmental Protection Agency, 2014, 2016b). Using modeled days much lower than the NAAQS may not be totally relevant for nonattainment related demonstrations such as interprecursor trading as the O_3 formation regime may be very different at those levels and not representative of how the atmosphere might change at higher O_3 levels.

4.3 Model domain and receptor placement

Model domains include locations considered "ambient air," which may be located throughout the entire nonattainment area for the IPT demonstration. Typically, the domain for an IPT demonstration will be consistent with an existing O_3 demonstration modeling platform. Receptor placement generally would include area just beyond beyond property owned or controlled by the project source and evenly placed throughout the nonattainment area. When a grid-based model is used to assess O_3 impacts, all grid cells intersecting the nonattainment area would be included in the IPT analysis to ensure the demonstration reflects impacts in the entire area.

4.4 Project and credit source emissions

Project source annual emissions reflecting the amount of Emission Reduction Credits (ERCs) would be most appropriate for the purposes to generating offsets under the CFR 51.165. In the uncommon situations where the project source would be emitting the vast majority of its actual emissions on a few days in a year an alternative emission rate may be used after consultation with the reviewing authority. Credit sources that are part of the baseline model platform scenario can be modeled based on post-construction conditions, and reflect the decrease in emissions sought for credit. If a credit source is not part of the baseline model platform scenario then the credit source can be modeled based on pre-shutdown conditions, which would be an increase in emissions from the baseline scenario.

4.5 Model evaluation

It is important to use a model evaluation approach that is universally applicable to any single source modeling system. Modeled O_3 estimates are typically compared to observation data to generate confidence that the modeling system is representative of local and regional air quality. For O_3 related projects, model estimates of O_3 are be compared with observations in both time and space (Simon et al., 2012; U.S. Environmental Protection Agency, 2014). Model performance metrics comparing observations and predictions are often used to summarize model performance. These metrics include, but are not limited to, mean bias, mean error, normalized mean bias, normalized mean error, and correlation coefficient (Simon et al., 2012). There are no specific levels of any model performance metric that indicate "acceptable" model performance. Model performance metrics are most useful when compared with other model applications of similar geographic areas and time of year to assess how well the model performs (Simon et al., 2012). Model performance for chemical transport models in the context of single source impact assessments for well characterized project sources is intended to provide confidence in the chemical environment of the source and does not provide specific information about the amount or directionality of possible error in modeled source impacts.

5 Approach for establishing a case-specific O_3 IPT ratio

Since O_3 formation can vary spatially and temporally, an IPT ratio tailored to the proposed facility's circumstances (involving the project and credit source(s) at known locations) will best reflect the conditions in that area. In these situations, applicants conduct modeling of the proposed source's post-construction conditions compared with the credit source(s) used for the emissions offset. This type of facility-specific air quality modeling is similar to a Tier 2 demonstration and procedures for using models for this purpose are outlined in "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, 2016b).

EPA recommends that methods used to model project and credit source impacts be consistent with guidance provided in "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, 2016b). Since the reactivity of specific VOCs make some more important for O_3 production, VOC emissions get speciated to match the VOC emissions expected to be released from the proposed source. The credit sources would be modeled such that operating conditions and locations reflect the credit sources before controls or retirement unless otherwise directed after consultation with the reviewing authority. It would not be appropriate to model the credit source emissions and stack release at the same location as the project source unless the project and credit sources are actually co-located in the post-construction scenario.

If the location and stack release characteristics of the credit emissions are not known, then a conservative approach must be taken in the technical demonstration to ensure protection of the air quality in the area. Conservative assumptions include stack parameters (e.g., low stack height), VOC speciation (e.g., VOC modeled as not highly reactive), and the "credit source" location, which could be considered by modeling the credit source at multiple locations in the area. The most conservative estimate from each of these modeled "credit sources" would represent a value most protective of an area when developing an IPT with the project source.

In situations where mobile source emissions may be allowed as credits, EPA believes the best technical approach would be to model those emissions using the location and emissions release characteristics of the specific project from which the credits originated. For instance, if a project was put into place to change roadways to significantly reduce emissions then that particular road segment would be the source of emissions.

6 General guidance for developing a case-specific IPT ratio for O_3 precursors

The general approach for developing an IPT demonstration is similar to that outlined for area-specific interpollutant trading for precursors of $PM_{2.5}$ (Fox, 2007; McCarthy, 2011). Illustrative examples using hypothetical sources are provided in the Appendix. Model simulations include impacts from both the project and credit sources are estimated. These impacts could be estimated in separate simulations or in a single simulation using source apportionment or other instrumented technique (e.g., higher-order DDM) that allows for differentiating source impacts. Here, the approach is described using the simplest approach where three separate scenarios would be modeled.

1) A baseline scenario where project source is operating at pre-construction conditions and credit source(s) reflect actual conditions (e.g., not operating or operating at pre-construction conditions);

2) A project source scenario, which is the same as the baseline scenario except the project source is operating at post-construction conditions; and

3) A credit source scenario, which is the same as the baseline scenario except the credit source(s) is operating at post-construction conditions if included in the baseline scenario or operating at pre-closure conditions if not included in the baseline scenario.

Hereafter, scenario 1 will be referred to as the "baseline scenario", scenario 2 will be referred to as the "project source scenario" and scenario 3 will be referred to as the "credit source scenario".

In order to establish that the proposed increase in emissions is comparable to the reductions from the credit source(s) for an O_3 IPT ratio, the modeled results of the project source scenario and the credit source scenario would be compared in grid cells or receptors within the nonattainment area using NAAQS relevant averaging times (e.g. daily maximum 8-hr average) where the model is predicting elevated O_3 (U.S. Environmental Protection Agency, 2016b). The general steps for estimating project and credit source sensitivities over an area follow.

First, estimate the modeled maximum daily 8-hr O_3 (MDA8) at each receptor for each simulation day of each of the baseline, project source, and credit source scenarios.

Second, estimate project source impacts by subtracting the project source scenario MDA8 values for each receptor and modeled day from the corresponding baseline scenario MDA8 values. If the credit source was not part of the baseline scenario, then estimate the credit source impacts by subtracting the credit source scenario MDA8 values for each receptor and modeled day from the corresponding baseline scenario MDA8 values. If the credit source was in the baseline scenario and was modeled with emission reductions matching the credit emissions amount, then subtract the baseline scenario MDA8 values from the credit source scenario MDA8 values at each receptor and modeled day.

Third, match the MDA8 values estimated by the baseline (step 1) and project source (step 2). Next, match baseline (step 1) and credit source scenarios (step 2) for each receptor and model simulation day.

Fourth, remove receptor-day pairings where either the project source or credit source impacts are negative (i.e., a disbenefit to air quality). Situations in which the increased emissions from the project or credit source result in a negative contribution are not included in the calculation of an O_3 IPT ratio. Next, remove receptor-day pairings where source contribution is < 1 ppt. Additionally, receptor-day pairings where the baseline modeled MDA8 is less than a specific value may be removed where appropriate and technically justified (e.g. 65 ppb or other episode-specific/appropriate value to emphasize impacts on days where the model predicts relatively elevated O_3 levels). A lower threshold may be necessary in some situations where there are few modeled days in the area at that level which means a slightly lower threshold may be needed to develop a robust respresentation of impacts. If modeled O_3 levels are low throughout the episode then that episode is not appropriate for this type of demonstration. Selecting modeled receptor-days with elevated O_3 is important for NNSR demonstrations since the relationship between the project and credit source is most relevant for O_3 levels closer to the level of the NAAQS. Using modeled days where levels are half or lower than the NAAQS for instance may not be relevant because the O_3 formation regime may be very different at those levels and not representative of how the atmosphere might change at higher O_3 levels.

Fifth, for each modeled day, sum the project source contributions over all receptors (grid cells) meeting the criteria in step 4 of this process. Then sum the credit source contributions over all receptors (grid cells) meeting the criteria in step 4 of this process. Since emissions sensitivity will vary spatially, it would not be fully protective of the air quality in a given area to only consider impacts at monitor locations.

Sixth, sum the daily impacts over all days in the episode or modeling period for both the project and credit sources. The ratio of the episode or modeling period summed impacts represents the relative impacts of the project and credit sources on O_3 in that particular area. It is unlikely that the impacts will be exactly the same (i.e., a 1-to-1 relationship) so this ratio provides information about how much additional (or less) credit emissions may be needed to offset the change in project source emissions.

Before selecting a specific O_3 IPT value, conduct quality assurance of the resulting ratio and evaluate the appropriateness given the nature of O_3 precursor emissions sources and chemical formation in the area of interest. This evaluation will likely require area-specific emissions inventory information and observed ambient data for O_3 and O_3 precursors. One way to provide confidence in the modeled impacts would be to qualitatively determine whether the impacts conform to the conceptual understanding of the NO_X and/or VOC limited formation across the area. This means that in an area that is NO_X limited the introduction of VOC emissions would not lead to as much O_3 formation as the introduction of new NO_X emissions and vice versa in VOC limited areas. Another option for quality assurance may be comparison with other single source modeling done for that area or similar areas to support Tier 1 PSD demonstration tools (U.S. Environmental Protection Agency, 2016a).

A narrative that shows that the increased emissions sought by the applicant for the project source will not adversely impact a particular population in the area either through indirect chemical reactions forming O_3 disproportionally in that area or that increased exposure to the precursor itself or toxic components (e.g., formaldehyde) will not lead to adverse health effects in the area is an important element of an IPT demonstration. For example, a hypothetical situation where a new refinery or paint coating facility in an urban core area seeking NO_X credits to offset increased VOC emissions. This result may not cause violations of the O_3 NAAQS, but may result in increased exposure to air toxics in the urban core area.

If there are questions about applying these steps, air agencies can contact their Regional Office for further technical consultation.

7 Area Specific O_3 IPT ratios

The previous section (Section 6 above) provided guidance on developing case-specific IPT ratios for O_3 precursors. This section provides an approach for generating area-specific, i.e., “default” O_3 IPT ratios, which involves an analysis of the existing technically credible O_3 attainment demonstration (or similar quality) modeling data, emission inventory data, and ambient monitor data to determine whether an area or sub-sections in an area could be characterized as either NO_X or VOC limited for O_3 formation. Ambient data would typically include co-located NO_X and VOC measurements to determine the relationship between these O_3 precursors for an area. In addition to considering ambient and modeling data, emissions information is considered useful when determining whether an area’s O_3 formation is

NO_X or VOC limited. This determination may be easier for smaller metropolitan areas that do not have large NO_X emissions sources (e.g. industrial point sources, transportation, etc.) and that do have large regional VOC sources (e.g., biogenic VOC) or large highly reactive VOC sources.

This section provides information about how NO_X and VOC single-source impacts on downwind O_3 could be used to estimate an IPT ratio protective for a given area. Depending on the size of the nonattainment area, the prescribed area within which offsets need to be obtained may be smaller than the total nonattainment area, i.e., a defined sub-area, in order for emissions precursors to have a similar impact on O_3. However, even if there is some variation in impacts within an entire nonattainment area, the ratio would be developed to be conservative enough to address any IPT used anywhere in the area as an alternative to generating sub-area ratios.

Since emissions sensitivities typically vary across an area, an area-specific O_3 IPT ratio would be most protective for an area when based on refined modeling that follows the approach outlined for a NNSR credit demonstration in this guidance. However, rather than modeling a specific post-construction scenario for existing project source facilities, the approach for this purpose involves modeling multiple hypothetical sources with varying emission rates and stack release characteristics typical of sources in the area or region. These sources would need to be located in different parts of the area to account for differences in sensitivities that may be possible when considering air quality impacts of sources located in different parts of the area. The overall approach for hypothetical source impact assessment would be generally similar to that provided for a tier 1 demonstration tool such as MERPs (U.S. Environmental Protection Agency, 2016a). Choices made for the number, placement, and type (emission levels and stack release characteristics) of hypothetical sources are important and EPA recommends selection be done in consultation with the permitting authority. Multiple hypothetical sources would be modeled in a particular area and the impacts from each would be compared then the most conservative ratio selected as the default ratio for that area.

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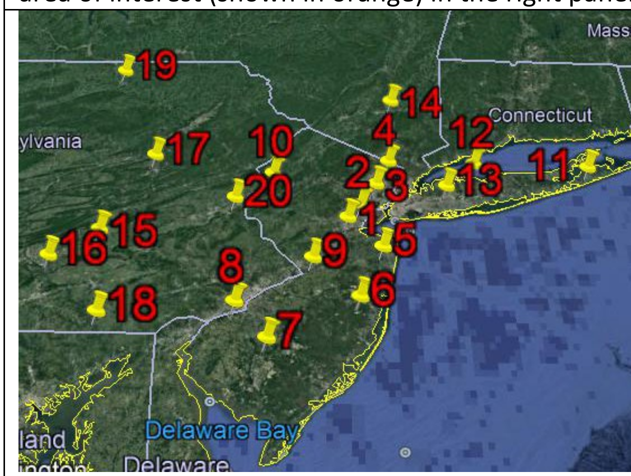
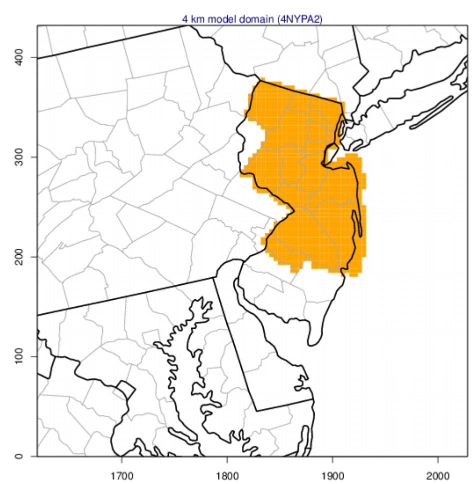
APPENDIX A. Illustrative example of a hypothetical project and credit source O_3 interprecursor trading scenario (example 1)

The following example is intended only to provide an illustrative example of how model results for specific sources could be used in the framework provided in this guidance document toward estimating equivalency in terms of O_3 formation to inform an IPT ratio.

Multiple hypothetical sources were modeled for a high O_3 period in the northeast U.S. during July 2011. This hypothetical example considers source 4 the project source and source 2 the credit source (see Figure 1 left panel). The project source is seeking to offset 500 tpy of NO_X emissions with 500 tpy of VOC emissions from the credit source. MDA8 O_3 impacts from both the project and credit source were estimated for each day of the July 2011 episode using the CMAQ model applied with 4 km sized grid cells and 35 layers to resolve the vertical atmosphere from the surface to the tropopause. The extent of the 4 km model domain and area of interest for this hypothetical demonstration are shown in Figure 1 (right panel).

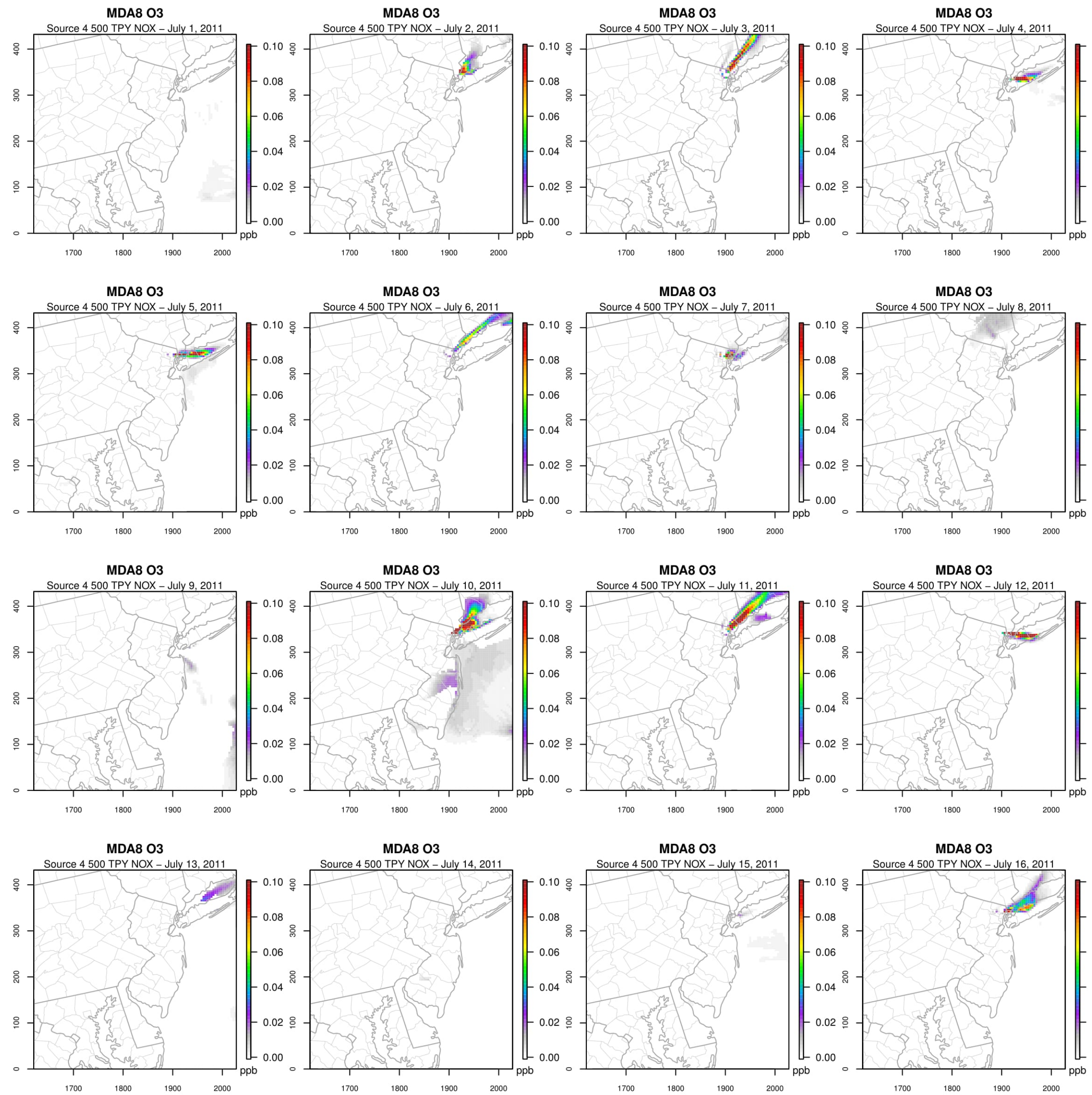
Figure 1. Hypothetical sources used in this analysis (4 and 2). The model domain and hypothetical area of interest (shown in orange) in the right panel.

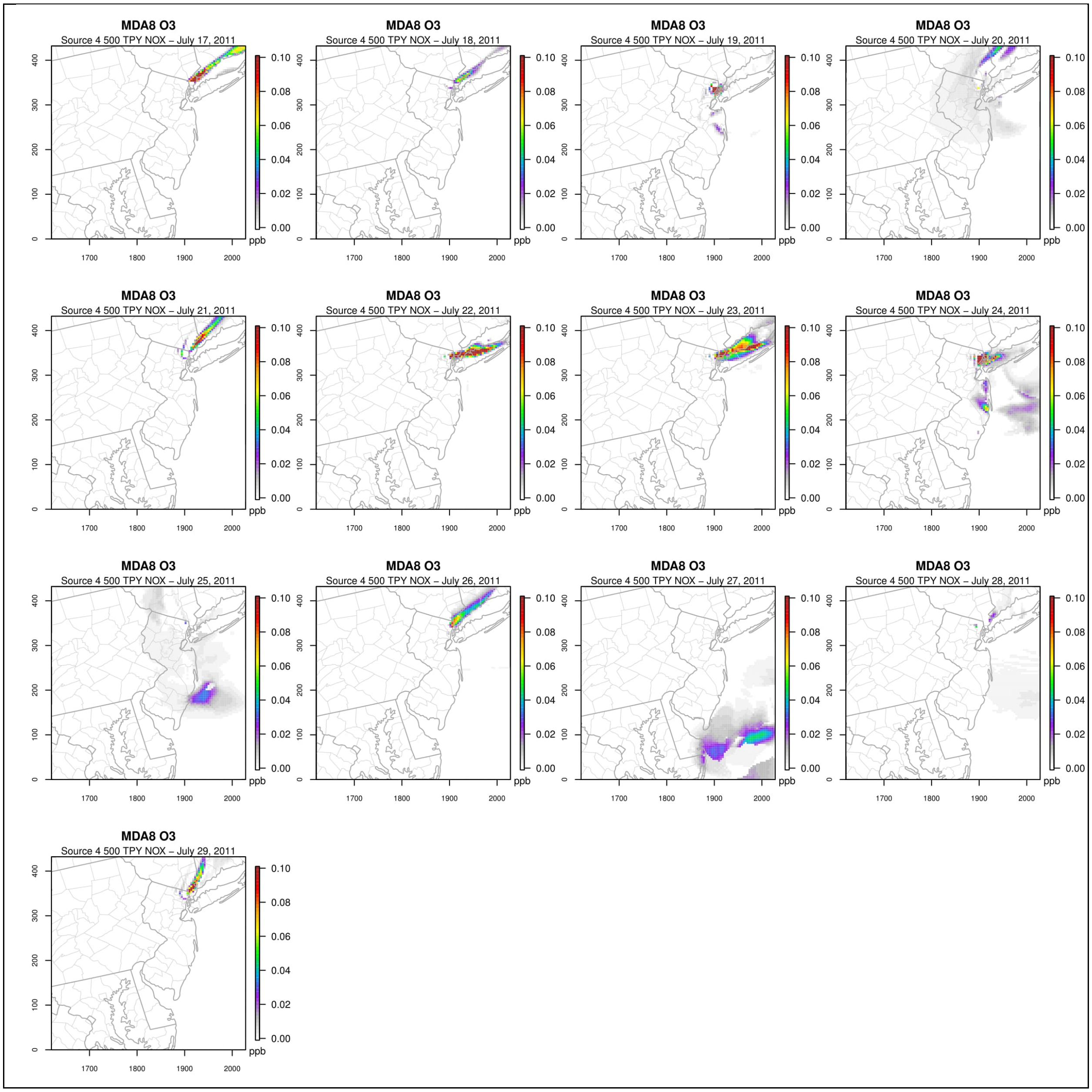




Daily absolute impacts for the project source are shown in Figure 2 and credit source in Figure 3.

Figure 2. MDA8 O_3 impacts for source 4 (project source) for 500 tpy of NOX.




MDA8 O3
Source 4 500 TPY NOX – July 17, 2011
MDA8 O3
Source 4 500 TPY NOX – July 18, 2011
MDA8 O3
Source 4 500 TPY NOX – July 19, 2011
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Source 4 500 TPY NOX – July 20, 2011
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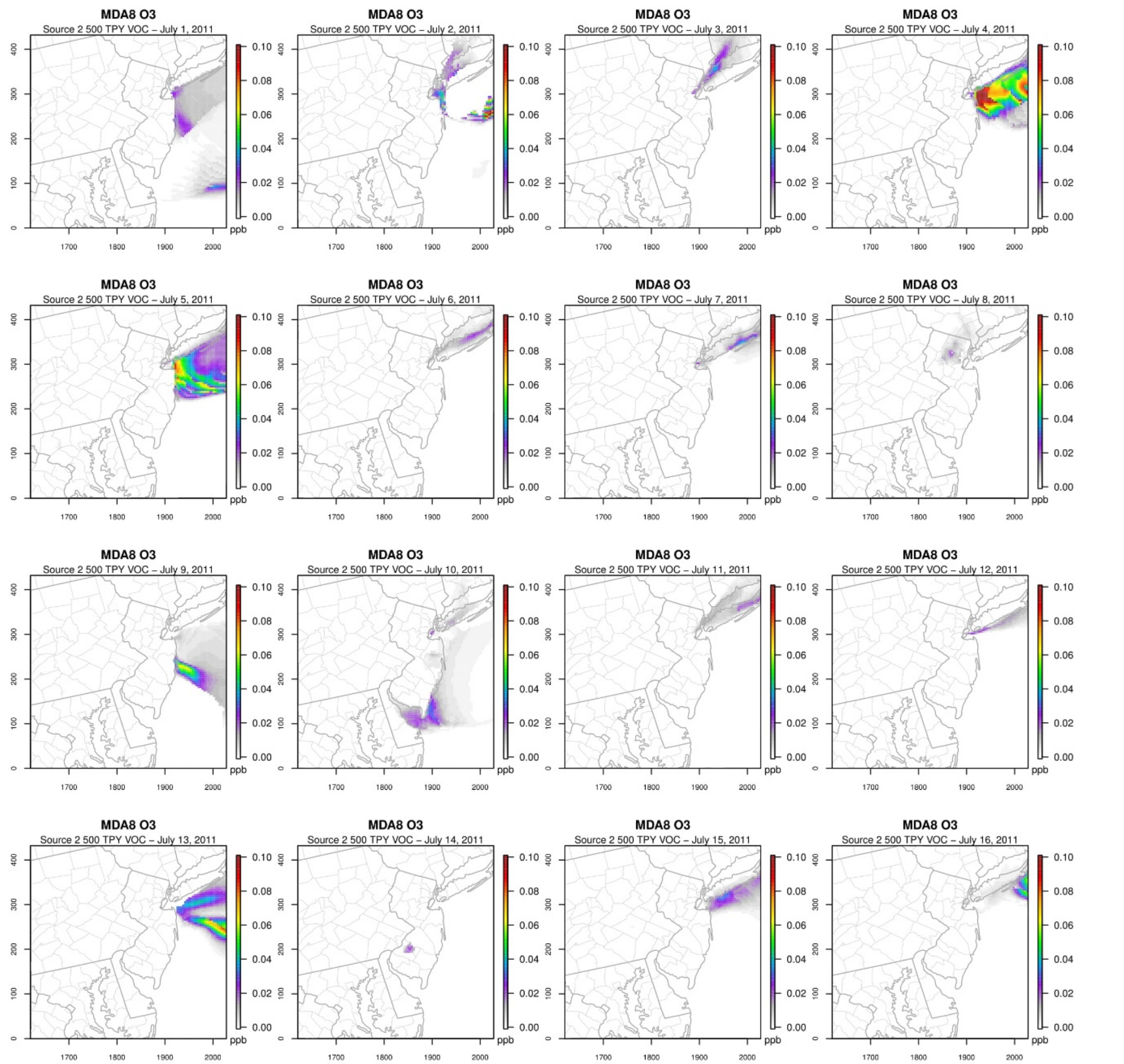
Source 4 500 TPY NOX – July 22, 2011
MDA8 O3
Source 4 500 TPY NOX – July 23, 2011
MDA8 O3
Source 4 500 TPY NOX – July 24, 2011
MDA8 O3
Source 4 500 TPY NOX – July 25, 2011
MDA8 O3
Source 4 500 TPY NOX – July 26, 2011
MDA8 O3
Source 4 500 TPY NOX – July 27, 2011
MDA8 O3
Source 4 500 TPY NOX – July 28, 2011
MDA8 O3
Source 4 500 TPY NOX – July 29, 2011
0.10
0.08
0.06
0.04
0.02
0.00
ppb
0
100
200
300
400
1700
1800
1900
2000

Figure 3. MDA8 O_3 impacts for source 2 (credit source) 500 tpy of VOC.



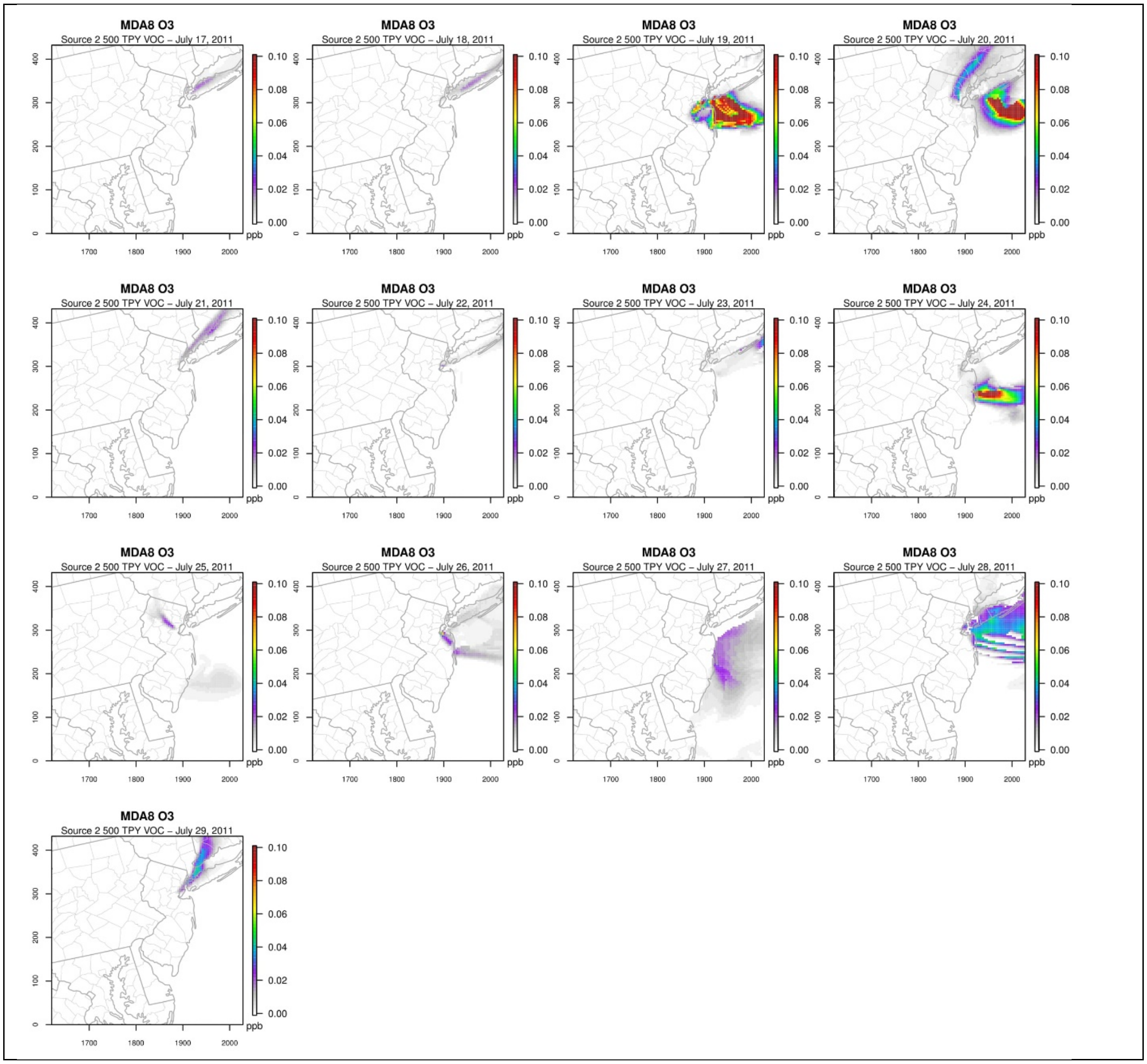
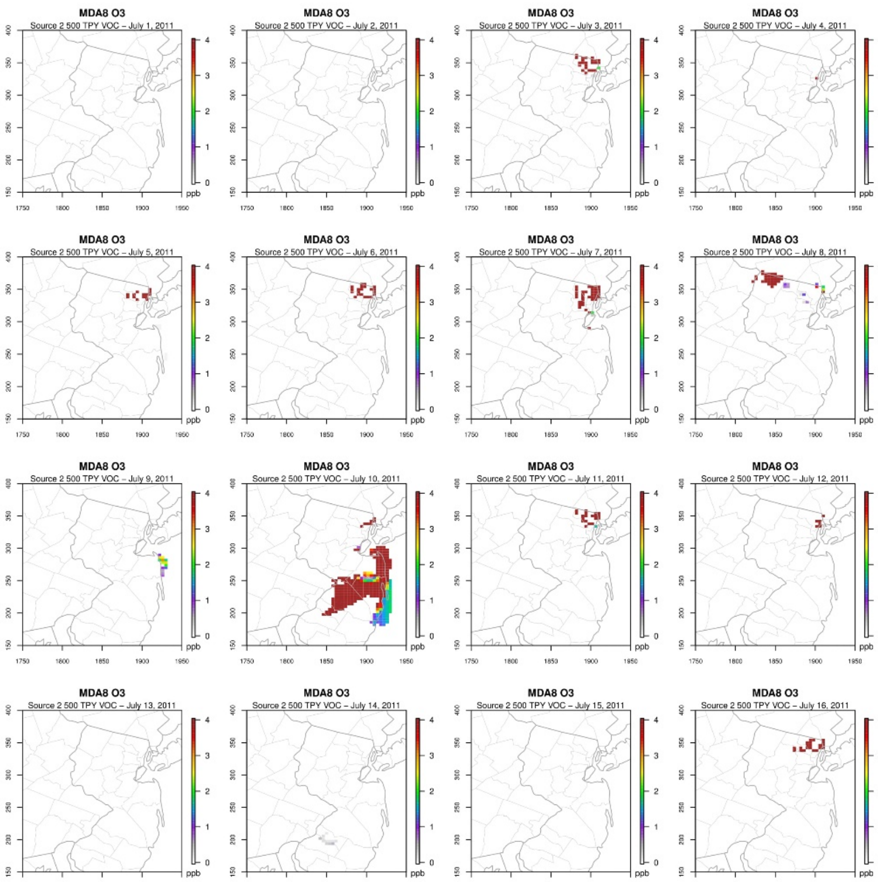
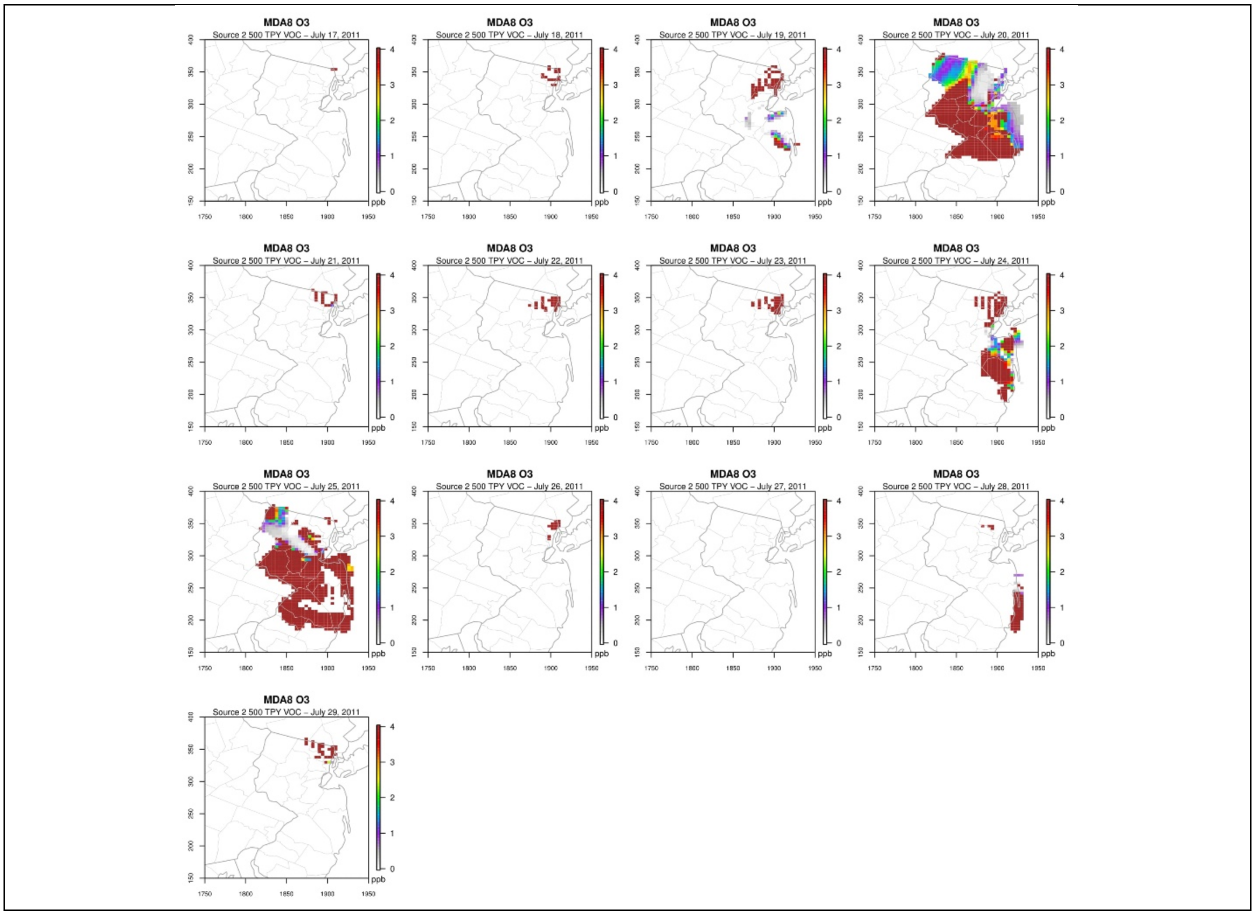

MDA8 O3
Source 2 500 TPY VOC – July 17, 2011
MDA8 O3
Source 2 500 TPY VOC – July 18, 2011
MDA8 O3
Source 2 500 TPY VOC – July 19, 2011
MDA8 O3
Source 2 500 TPY VOC – July 20, 2011
MDA8 O3
Source 2 500 TPY VOC – July 21, 2011
MDA8 O3
Source 2 500 TPY VOC – July 22, 2011
MDA8 O3
Source 2 500 TPY VOC – July 23, 2011
MDA8 O3
Source 2 500 TPY VOC – July 24, 2011
MDA8 O3
Source 2 500 TPY VOC – July 25, 2011
MDA8 O3
Source 2 500 TPY VOC – July 26, 2011
MDA8 O3
Source 2 500 TPY VOC – July 27, 2011
MDA8 O3
Source 2 500 TPY VOC – July 28, 2011
MDA8 O3
Source 2 500 TPY VOC – July 29, 2011
ppb

Figure 4 shows the ratio of MDA8 O_3 project to credit source impacts where multiple conditions are satisfied. First, only impacts greater than 1 ppt are shown; second, only impacts are shown where the baseline bulk model O_3 prediction was greater than 60 ppb; third, only impacts are shown where the grid cell intersects the area of interest (shown in Figure 1 as the orange colored cells).

Figure 4. Ratio of project source to credit source impacts where multiple conditions are satisfied.





Daily metrics relating MDA8 project and credit source impacts are shown in Table 1. These impacts are based on episode days and grid cells meeting multiple criteria. First, only impacts greater than 1 ppt are shown; second, only impacts are shown where the baseline bulk model O_3 prediction was greater than 60 ppb; third, only impacts are shown where the grid cell intersects the area of interest (shown in Figure 1 as the orange colored cells). For each day, the ratio is provided of the sum of project source impacts divided by the sum of credit source impacts over all cells meeting the criteria detailed above. The number of cells meeting the criteria is also provided along with that value being expressed as the percentage of all cells in the area of interest (the total number of cells examined for this analysis). The number of cells used in the analysis varies due to varying O_3 production in the area of interest from day to day during this period of time. At the bottom of Table 1, the ratio represents the ratio of episode total impacts and is not the average of the daily ratios.

Table 1. Project and credit source daily impacts, number of cells used, and the percentage of cells used in the area of interest.

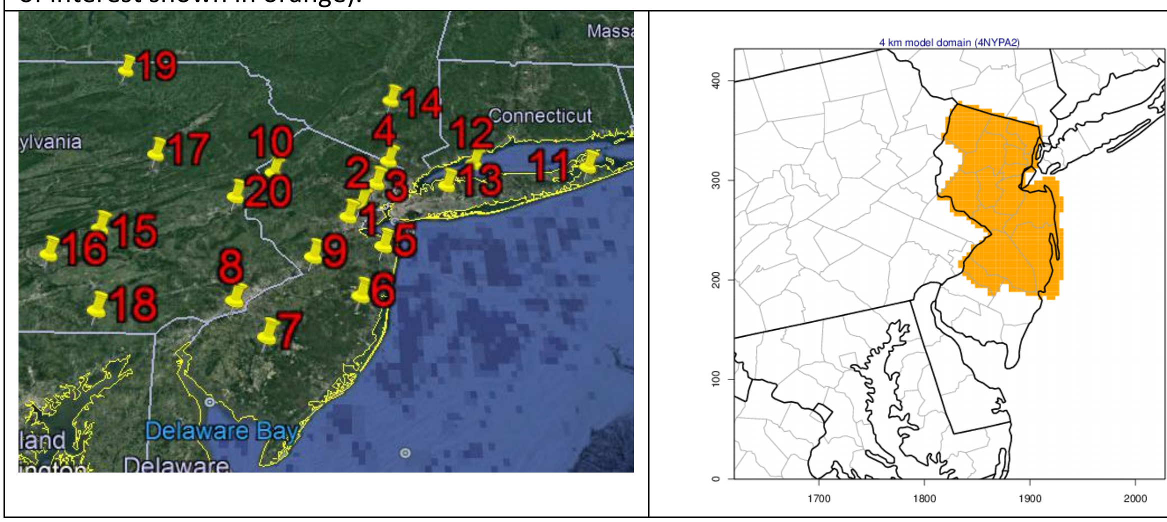
Episode Day	Sum of Project Source MDA8 O3 Impacts (ppb)	Sum of Credit Source MDA8 O3 Impacts (ppb)	Ratio of project to credit source impacts	Number of cells used for project source impact sum	Project source impacted cells divided by total cells in area of interest x 100	Number of cells used for credit source impact sum	Credit source impacted cells divided by total cells in area of interest x 100
1	0	1.35	0	1	0.1	88	8.7
2	0	1.23	0	0	0	57	5.6
3	0.51	0.37	1.4	26	2.6	33	3.2
4	0	3.19	0	1	0.1	64	6.3
5	0.53	2.8	0.2	50	4.9	93	9.2
6	0.19	0.13	1.5	21	2.1	20	2
7	1.72	0.15	11.5	39	3.8	28	2.8
8	0.12	1.22	0.1	46	4.5	190	18.7
9	0.12	1.09	0.1	14	1.4	61	6
10	3.44	0.77	4.5	310	30.5	196	19.3
11	0.48	0.18	2.7	20	2	28	2.8
12	0.25	0.07	3.6	6	0.6	5	0.5
13	0	0.19	0	0	0	9	0.9
14	0.05	0.34	0.1	12	1.2	21	2.1
15	0	0.26	0	0	0	31	3.1
16	0.43	0.07	6.1	21	2.1	21	2.1
17	0.09	0	Inf	2	0.2	0	0
18	0.16	0.06	2.7	16	1.6	16	1.6
19	3.55	10.09	0.4	119	11.7	241	23.7
20	2.53	3.14	0.8	828	81.5	401	39.5
21	0.34	0.21	1.6	21	2.1	30	3
22	1.33	0.06	22.2	26	2.6	19	1.9
23	1.04	0.07	14.9	33	3.2	26	2.6
24	6.18	2.61	2.4	249	24.5	225	22.1
25	2	1.06	1.9	757	74.5	178	17.5
26	0.66	1.29	0.5	16	1.6	105	10.3
27	0	1.39	0	0	0	93	9.2
28	0.16	1.66	0.1	64	6.3	90	8.9
29	0.52	0.32	1.6	30	3	27	2.7
Sum	**26.4**	**35.37**	**0.746**				

APPENDIX B. Illustrative example of a hypothetical project and credit source O_3 interprecursor trading scenario (example 2)

The following example is intended only to provide an illustrative example of how model results for specific sources could be used in the framework provided in this guidance document toward estimating equivalency in terms of O_3 formation to inform an IPT ratio.

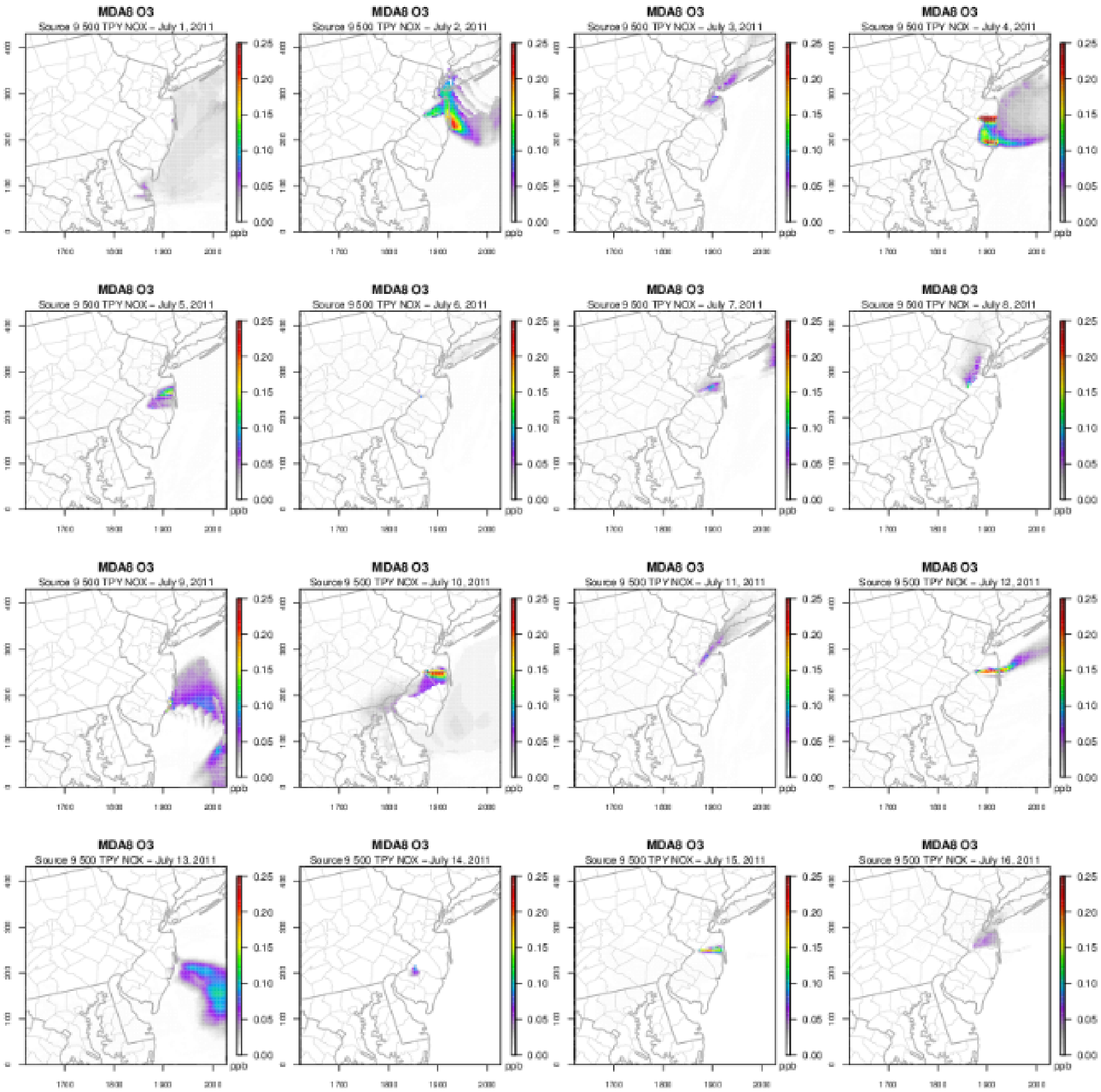
Multiple hypothetical sources were modeled for a high O_3 period in the northeast U.S. during July 2011. This hypothetical example considers source 9 the project source and source 1 the credit source (see Figure 1 left panel). The project source is seeking to offset 500 tpy of NO_X emissions with 500 tpy of VOC emissions from the credit source. MDA8 O_3 impacts from both the project and credit source were estimated for each day of the July 2011 episode using the CMAQ model applied with 4 km sized grid cells and 35 layers resolved the vertical atmosphere from the surface to the tropopause. The extent of the 4 km model domain and area of interest for this hypothetical demonstration are shown in Figure 1 (right panel).

Figure 1. Hypothetical sources used in this analysis (9 and 1) the model domain and hypothetical area of interest shown in orange).



Daily absolute impacts for the project source are shown in Figure 2 and credit source in Figure 3. Source impacts are only shown where modeled bulk MDA8 O_3 was greater than 60 ppb.

Figure 2. MDA8 O_3 impacts for source 9 (project source) for 500 tpy of NO_X.



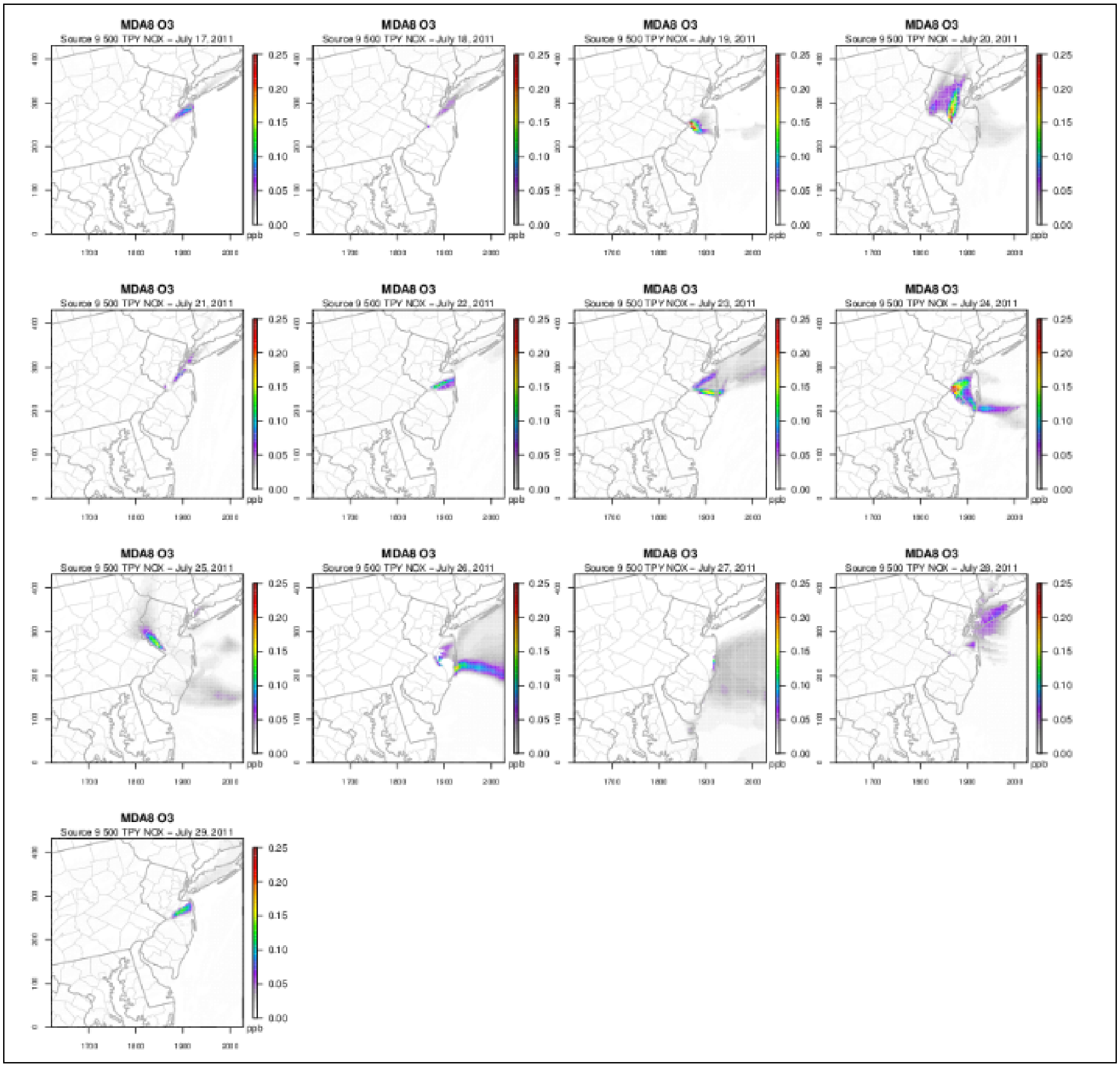
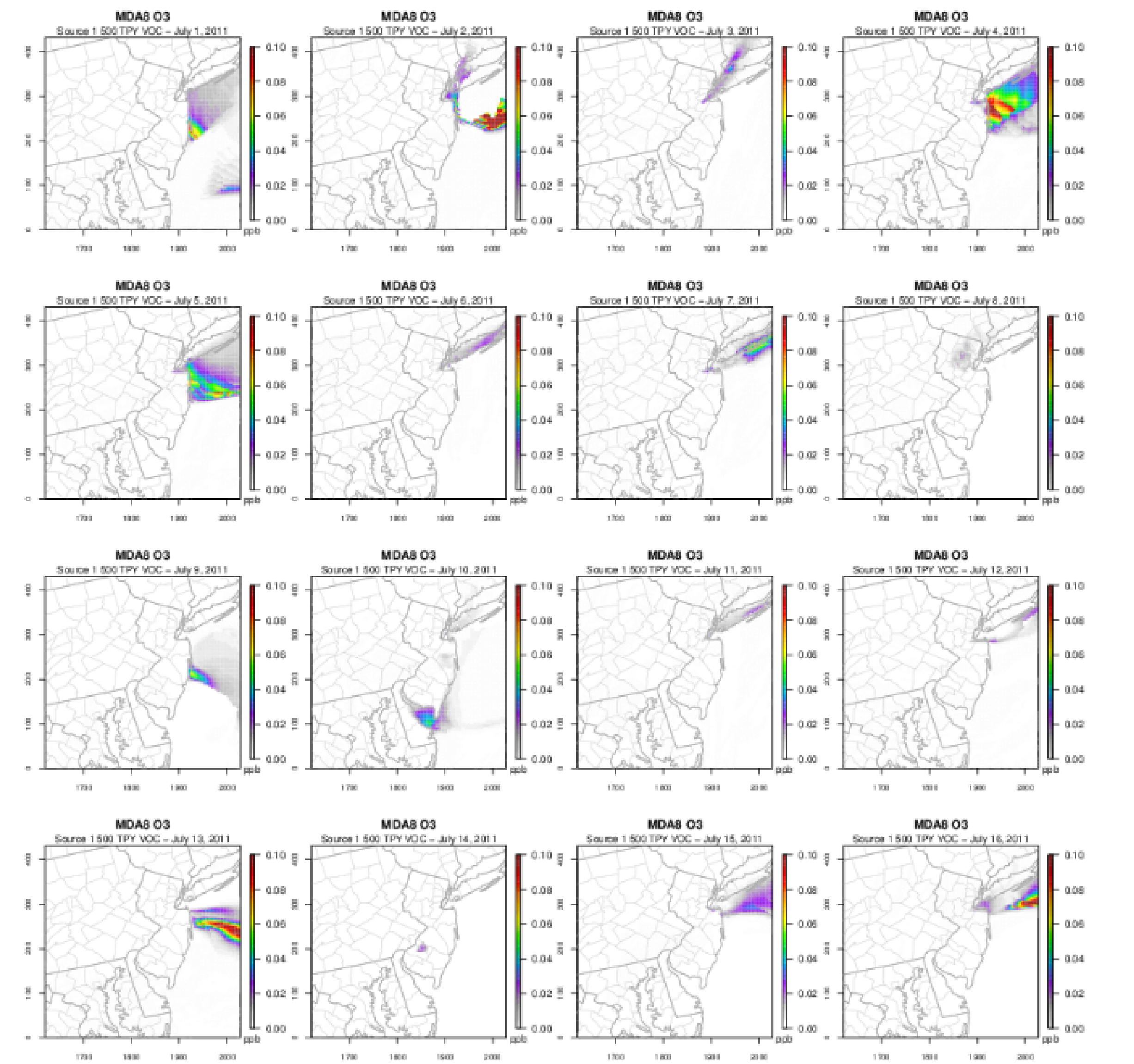

MDA8 O3
Source 9 500 TPY NOX – July 17, 2011
MDA8 O3
Source 9 500 TPY NOX – July 18, 2011
MDA8 O3
Source 9 500 TPY NOX – July 19, 2011
MDA8 O3
Source 9 500 TPY NOX – July 20, 2011
MDA8 O3
Source 9 500 TPY NOX – July 21, 2011
MDA8 O3
Source 9 500 TPY NOX – July 22, 2011
MDA8 O3
Source 9 500 TPY NOX – July 23, 2011
MDA8 O3
Source 9 500 TPY NOX – July 24, 2011
MDA8 O3
Source 9 500 TPY NOX – July 25, 2011
MDA8 O3
Source 9 500 TPY NOX – July 26, 2011
MDA8 O3
Source 9 500 TPY NOX – July 27, 2011
MDA8 O3
Source 9 500 TPY NOX – July 28, 2011
MDA8 O3
Source 9 500 TPY NOX – July 29, 2011
ppb

Figure 3. MDA8 O_3 impacts for source 1 (credit source) 500 tpy of VOC. Note scales are different between Figure 2 and Figure 3.



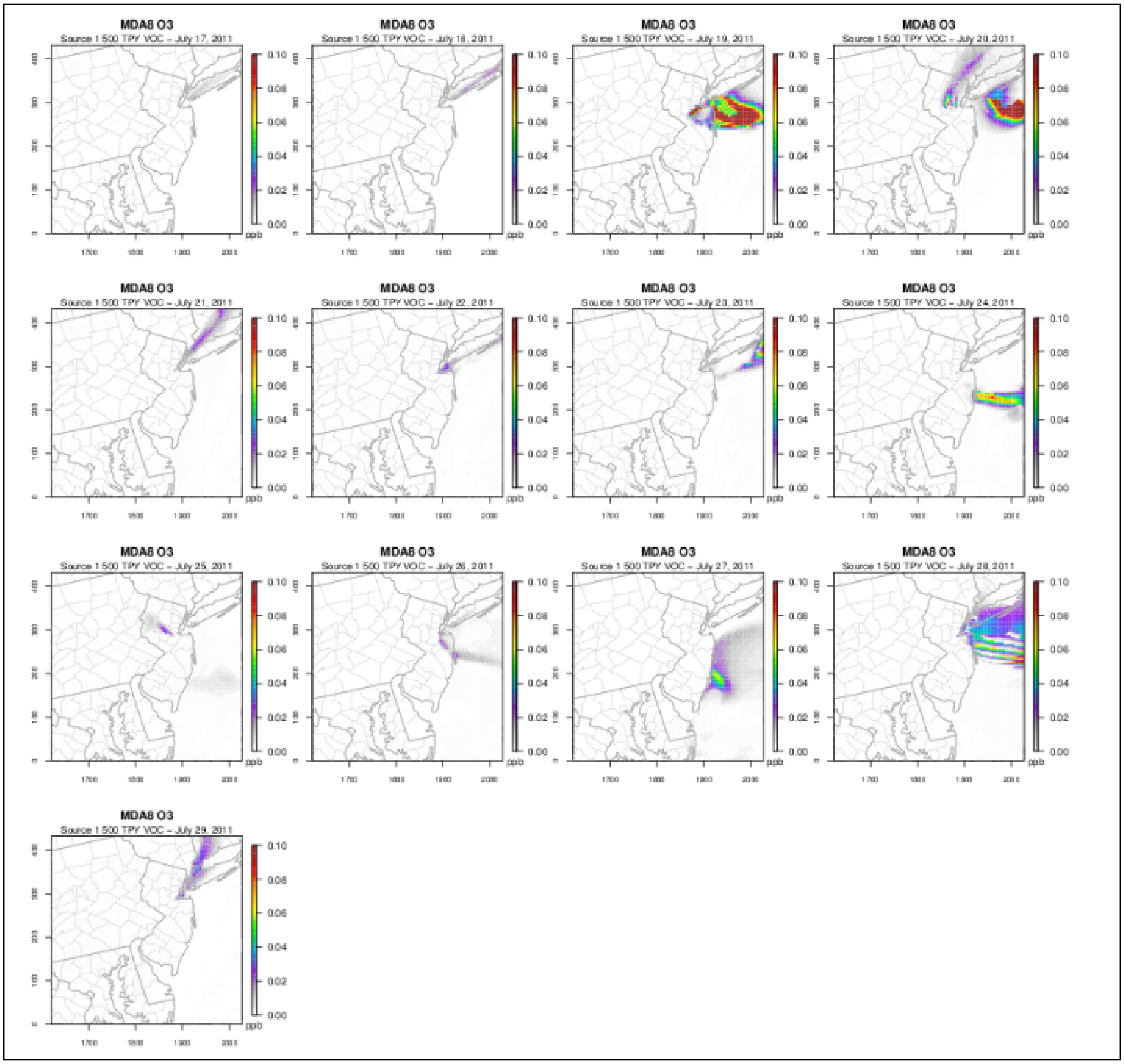
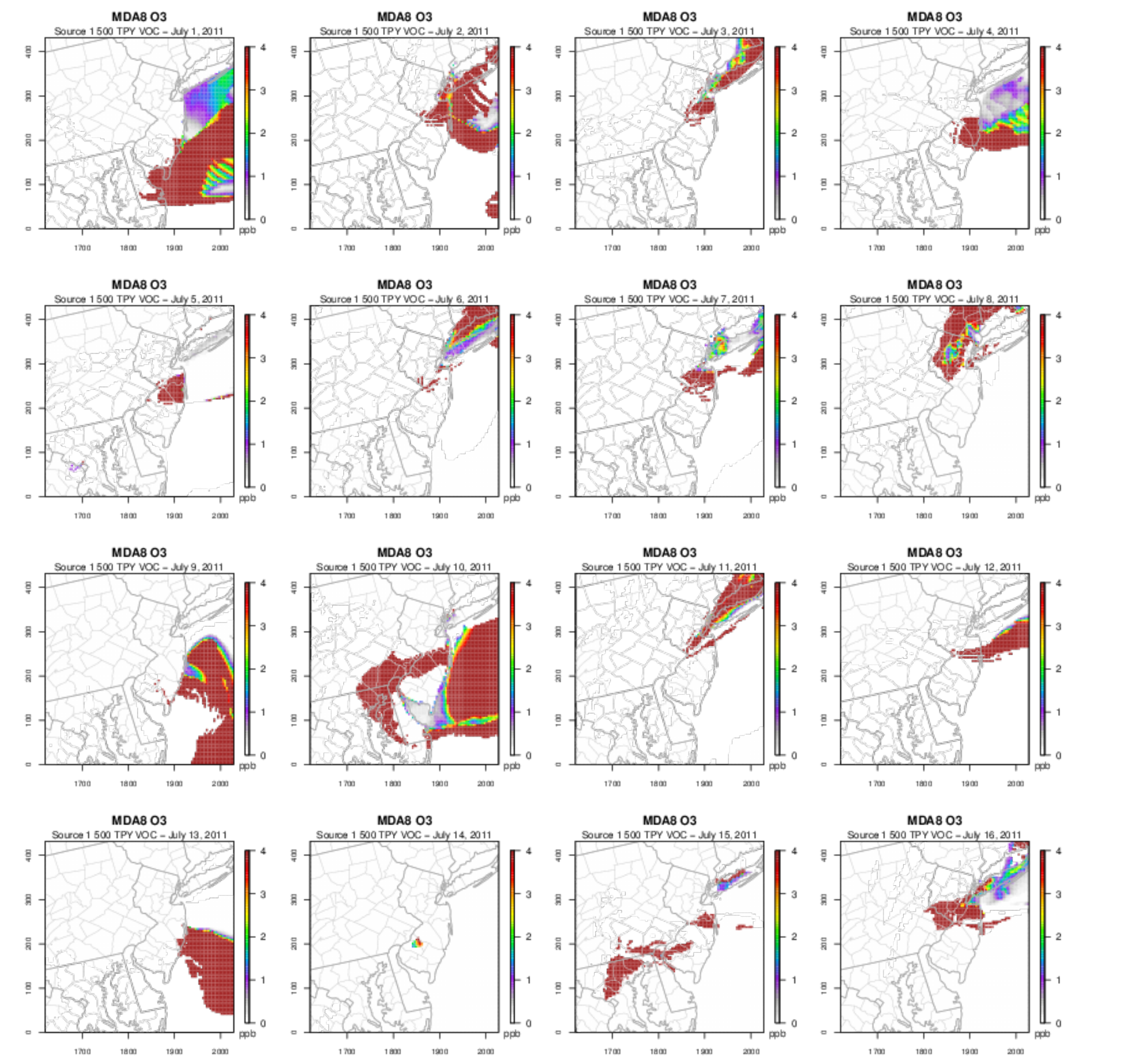


Figure 4 shows the ratio of the differences in impacts between sources. In Figure 4, the modeled impacts were not subset based on any particular criteria.

Figure 4. Ratio of project source to credit source MDA8 O_3 impacts.



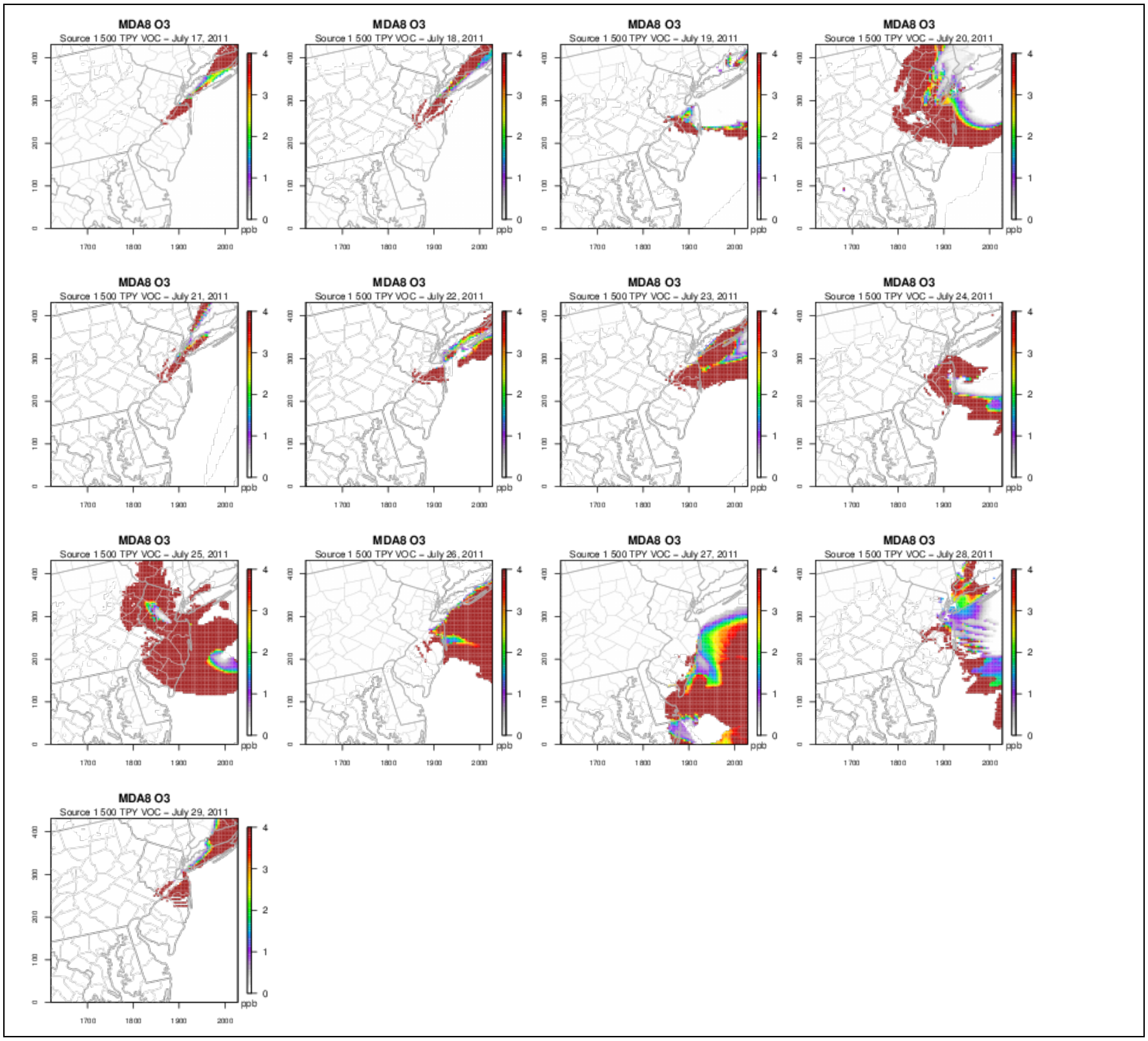
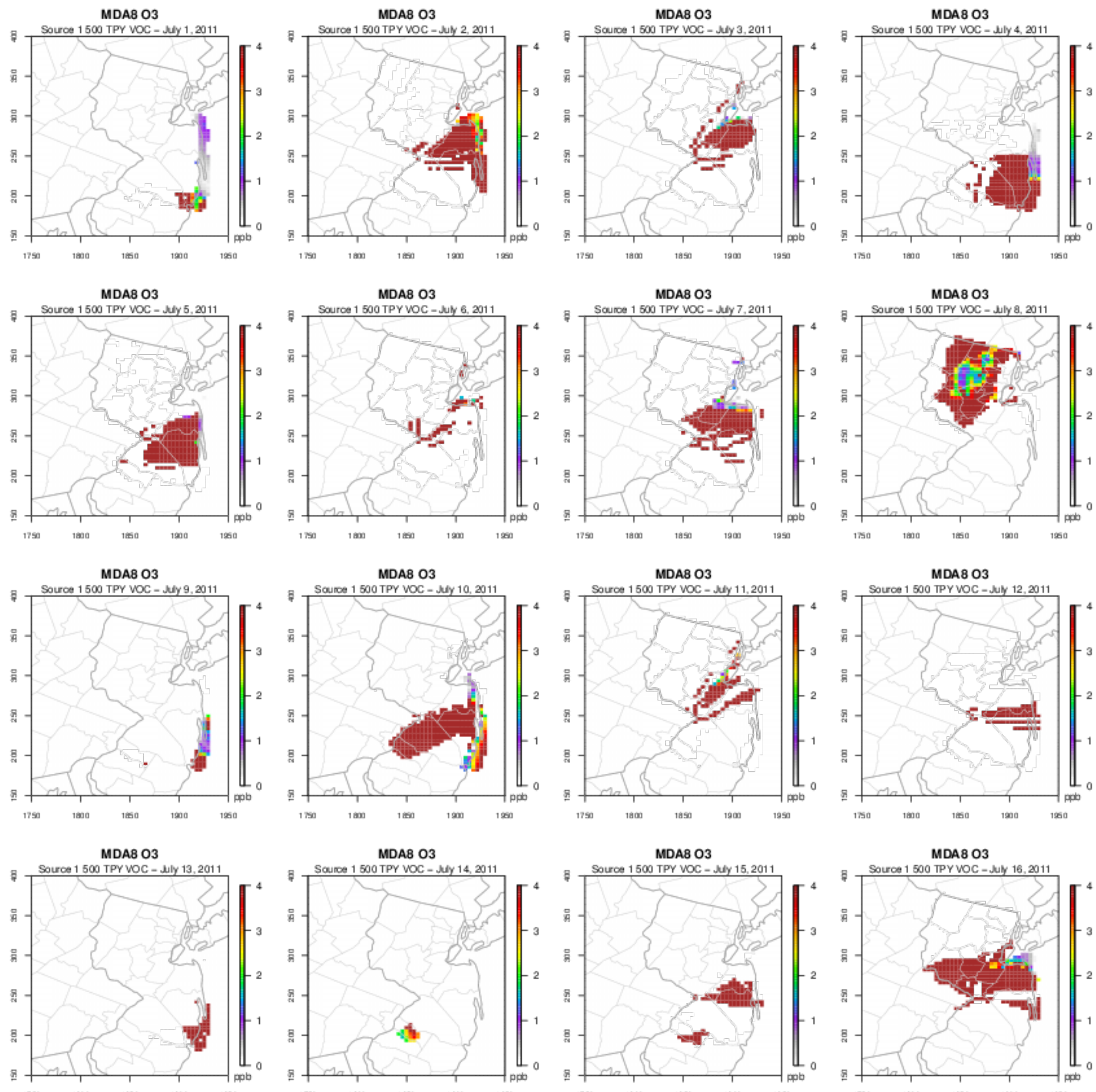
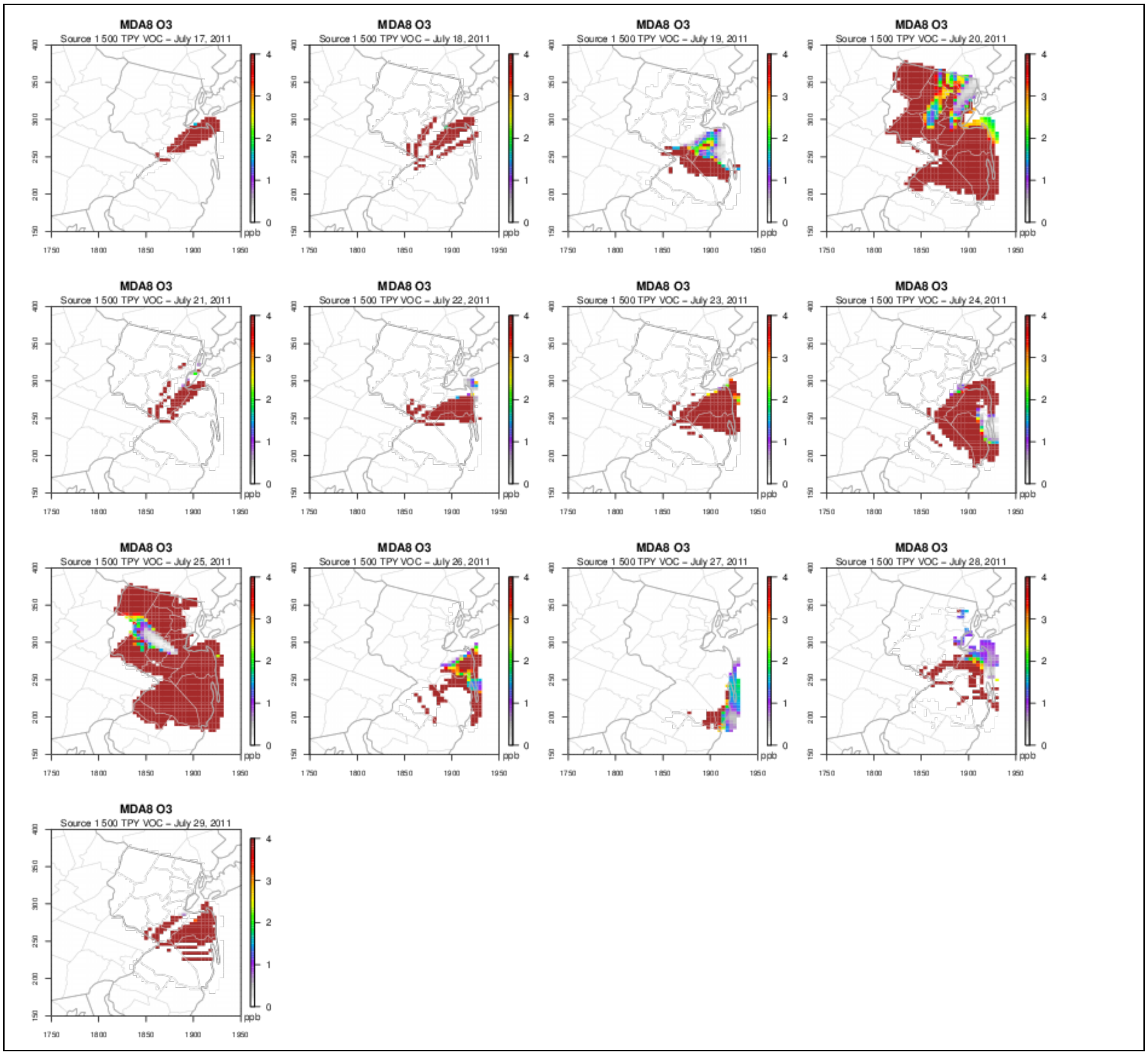


Figure 5 shows the ratio of MDA8 O_3 project to credit source impacts where multiple conditions are satisfied. First, only impacts greater than 1 ppt are shown; second, only impacts are shown where the baseline bulk model O_3 prediction was greater than 60 ppb; third, only impacts are shown where the grid cell intersects the area of interest (shown in Figure 1 as the orange colored cells).

Figure 5. Ratio of project source to credit source impacts where multiple conditions are satisfied.





Daily metrics relating MDA8 project and credit source impacts are shown in Table 1. These impacts are based on episode days and grid cells meeting multiple criteria. First, only impacts greater than 1 ppt are shown; second, only impacts are shown where the baseline bulk model O_3 prediction was greater than 60 ppb; third, only impacts are shown where the grid cell intersects the area of interest (shown in Figure 1 as the orange colored cells). For each day, the ratio is provided of the sum of project source impacts divided by the sum of credit source impacts over all cells meeting the criteria detailed above. The number of cells meeting the criteria is also provided along with that value being expressed as the percentage of all cells in the area of interest (the total number of cells examined for this analysis). The number of cells used in the analysis varies due to varying O_3 production in the area of interest from day to day during this period of time. At the bottom of Table 1, the ratio represents the ratio of episode total impacts and is not the average of the daily ratios.

Table 1. Project and credit source daily impacts, number of cells used, and the percentage of cells used in the area of interest.

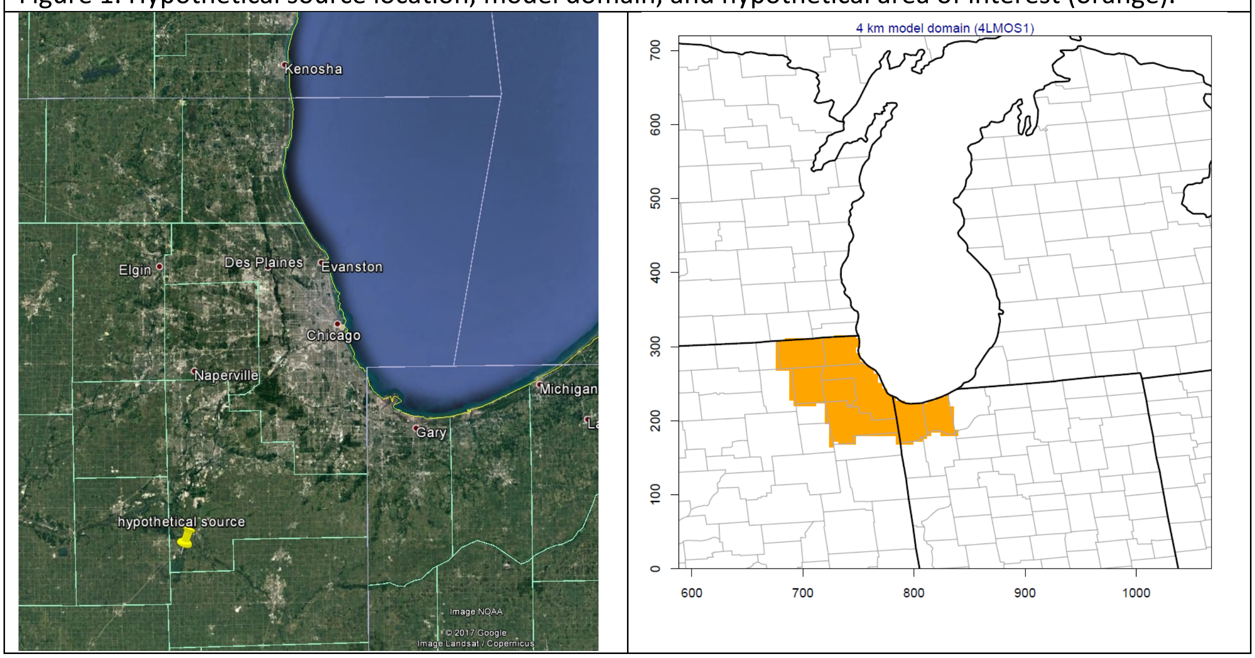
Episode Day	Sum of Project Source MDA8 O3 impacts (ppb)	Sum of Credit Source MDA8 O3 impacts (ppb)	Ratio of project to credit source impacts	Number of cells used for project source impact sum	Project source impacted cells divided by total cells in area of interest	Number of cells used for credit source impact sum	Credit source impacted cells divided by total cells in area of interest
1	1.5	2.86	0.5	111	10.9	101	9.9
2	17.07	1.83	9.3	213	21	74	7.3
3	3.19	0.4	8	140	13.8	37	3.6
4	25.89	5	5.2	247	24.3	120	11.8
5	8.06	2.97	2.7	209	20.6	123	12.1
6	0.45	0.2	2.2	53	5.2	37	3.6
7	4.02	0.54	7.4	197	19.4	59	5.8
8	7.57	1.47	5.1	341	33.6	223	21.9
9	2.42	1.14	2.1	54	5.3	60	5.9
10	16.4	0.69	23.8	297	29.2	194	19.1
11	2.04	0.18	11.3	97	9.5	25	2.5
12	5.55	0.22	25.2	71	7	27	2.7
13	0.74	0.13	5.7	48	4.7	16	1.6
14	1.06	0.32	3.3	21	2.1	21	2.1
15	3.87	0.32	12.1	95	9.4	35	3.4
16	4.94	0.73	6.8	322	31.7	72	7.1
17	3.58	0.01	358	89	8.8	5	0.5
18	2.22	0.09	24.7	106	10.4	22	2.2
19	7.63	8.8	0.9	196	19.3	231	22.7
20	25.15	3.89	6.5	879	86.5	322	31.7
21	2.05	0.25	8.2	80	7.9	29	2.9
22	5.02	0.71	7.1	132	13	66	6.5
23	9.58	0.31	30.9	199	19.6	65	6.4
24	18.42	1.6	11.5	339	33.4	160	15.7
25	9.73	1.03	9.4	940	92.5	148	14.6
26	6.93	1.22	5.7	166	16.3	128	12.6
27	2.81	2.17	1.3	109	10.7	93	9.2
28	3.15	2.72	1.2	188	18.5	137	13.5
29	4.74	0.31	15.3	156	15.4	31	3.1
Sum	205.78	42.11	4.9				

APPENDIX C. Illustrative example of a hypothetical project and credit source O_3 interprecursor trading scenario (example 3)

The following example is intended only to provide an illustrative example of how model results for specific sources could be used in the framework provided in this guidance document toward estimating equivalency in terms of O_3 formation to inform an IPT ratio.

A hypothetical source was modeled for a short July 1-10, 2013, time-period in the Chicago/Lake Michigan area. For this example, MDA8 O_3 impacts from both the project and credit source (co-located) were estimated for each day of the July 1-10, 2013, time-period using the CMAQ model applied with 4 km sized grid cells and 35 layers resolved the vertical atmosphere from the surface to the tropopause. The extent of the 4 km model domain and area of interest for this hypothetical demonstration is shown in Figure 1 (right panel).

Figure 1. Hypothetical source location, model domain, and hypothetical area of interest (orange).



This hypothetical example considers the project source and the credit source to be co-located. The project source is seeking to offset 500 tpy of NOx emissions with 500 tpy of VOC emissions from the credit source. Daily absolute O_3 impacts from the project source are shown in Figure 2 and daily absolute O_3 impacts from the credit source are shown in Figure 3. Spatial plots subset with criteria related to baseline model predicted O_3 show source impacts where modeled bulk MDA8 O_3 was greater than 30 ppb. A value of 30 ppb was selected for this hypothetical example because this period of time did not include many days with elevated O_3. In a real-world situation, O_3 episodes would be selected such that the time period in that area experienced elevated O_3 levels. Multiple model predicted MDA O3 thresholds were used as part of this example to illustrate how the relationship between source impacts can vary at different O_3 levels and those impacts are shown in Table 2 of this Appendix section. The level of 30 ppb should not be used in actual demonstrations.

Figure 2. MDA8 O_3 impacts from the project source emitting 500 tpy of NOx. *Note scales are different between Figure 2 and Figure 3.*

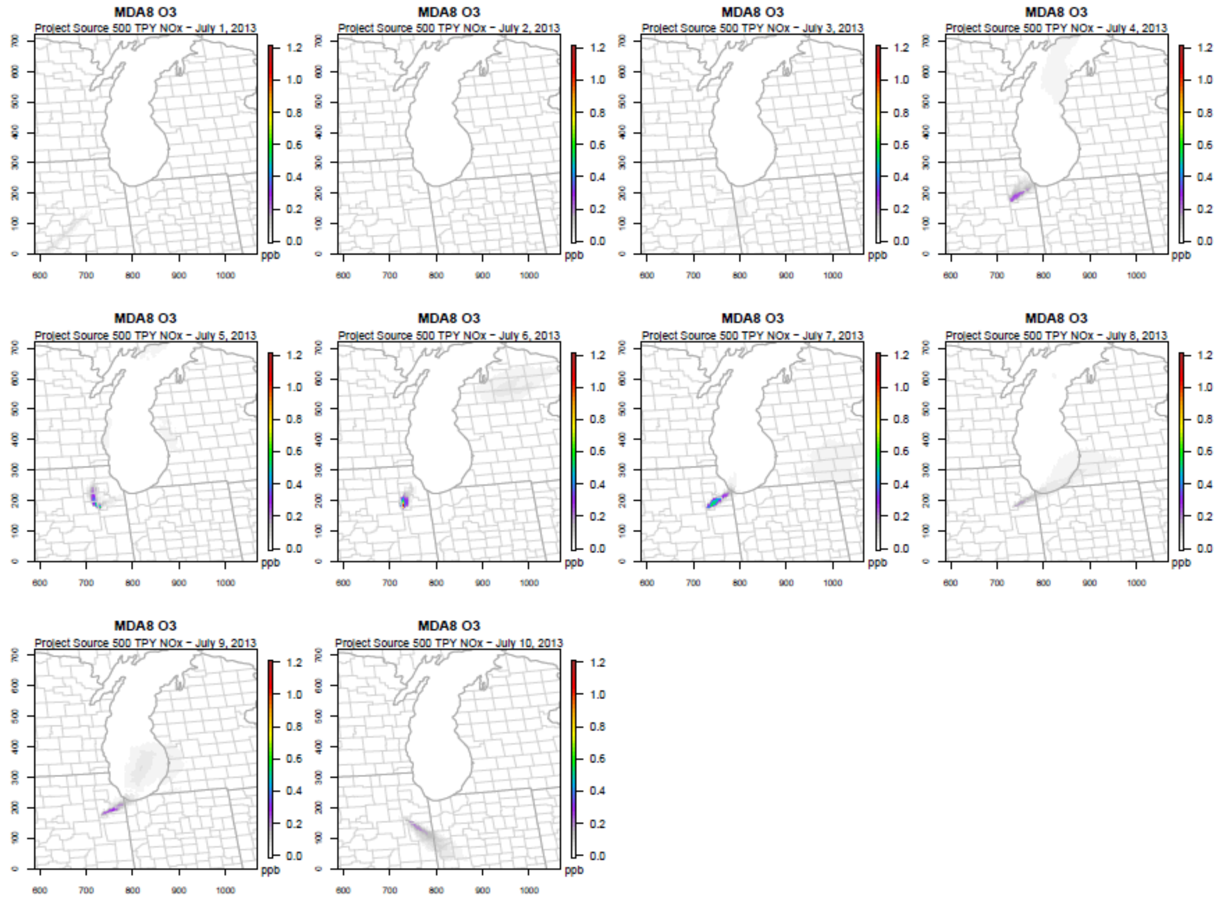


Figure 3. MDA8 O_3 impacts from the credit source emitting 500 tpy of VOC. *Note scales are different between Figure 2 and Figure 3.*

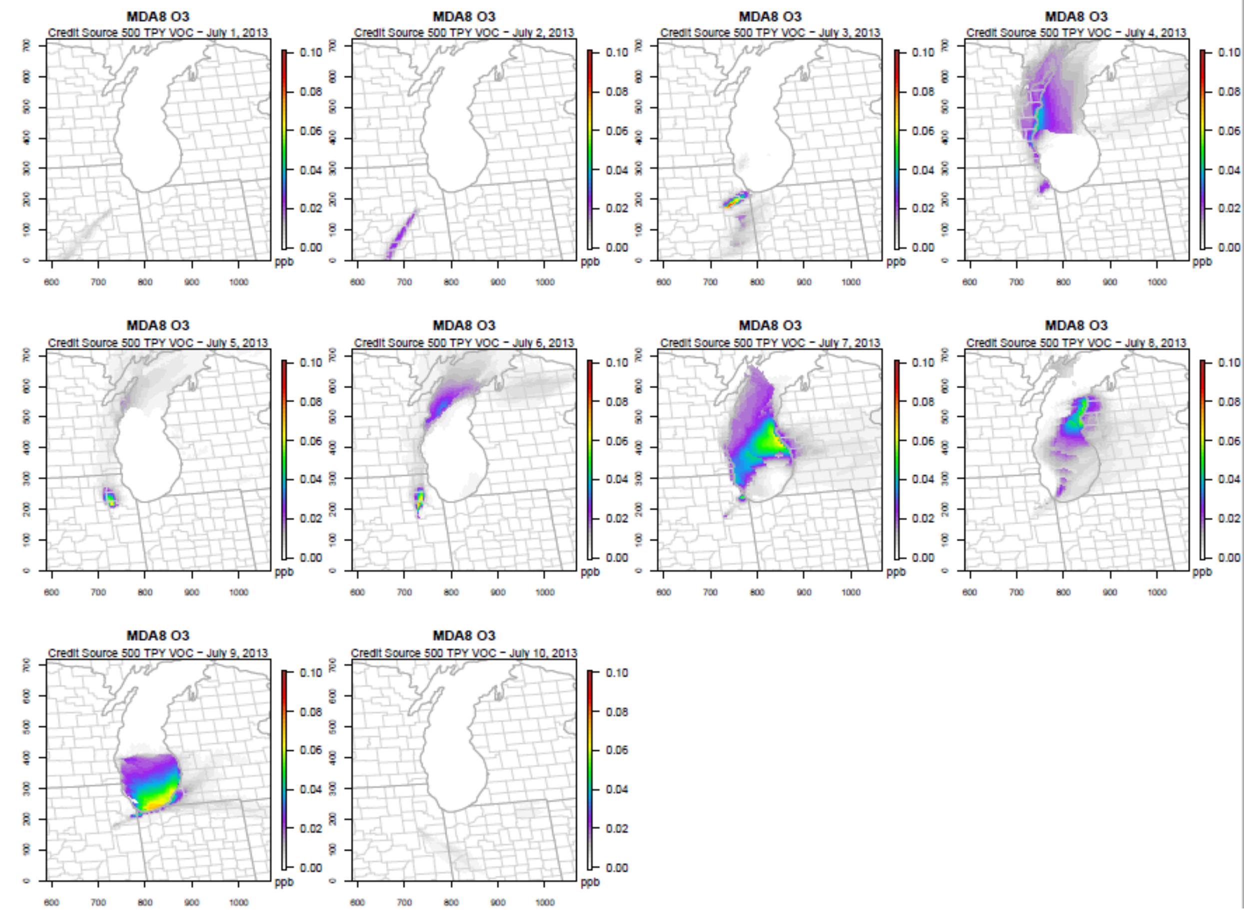
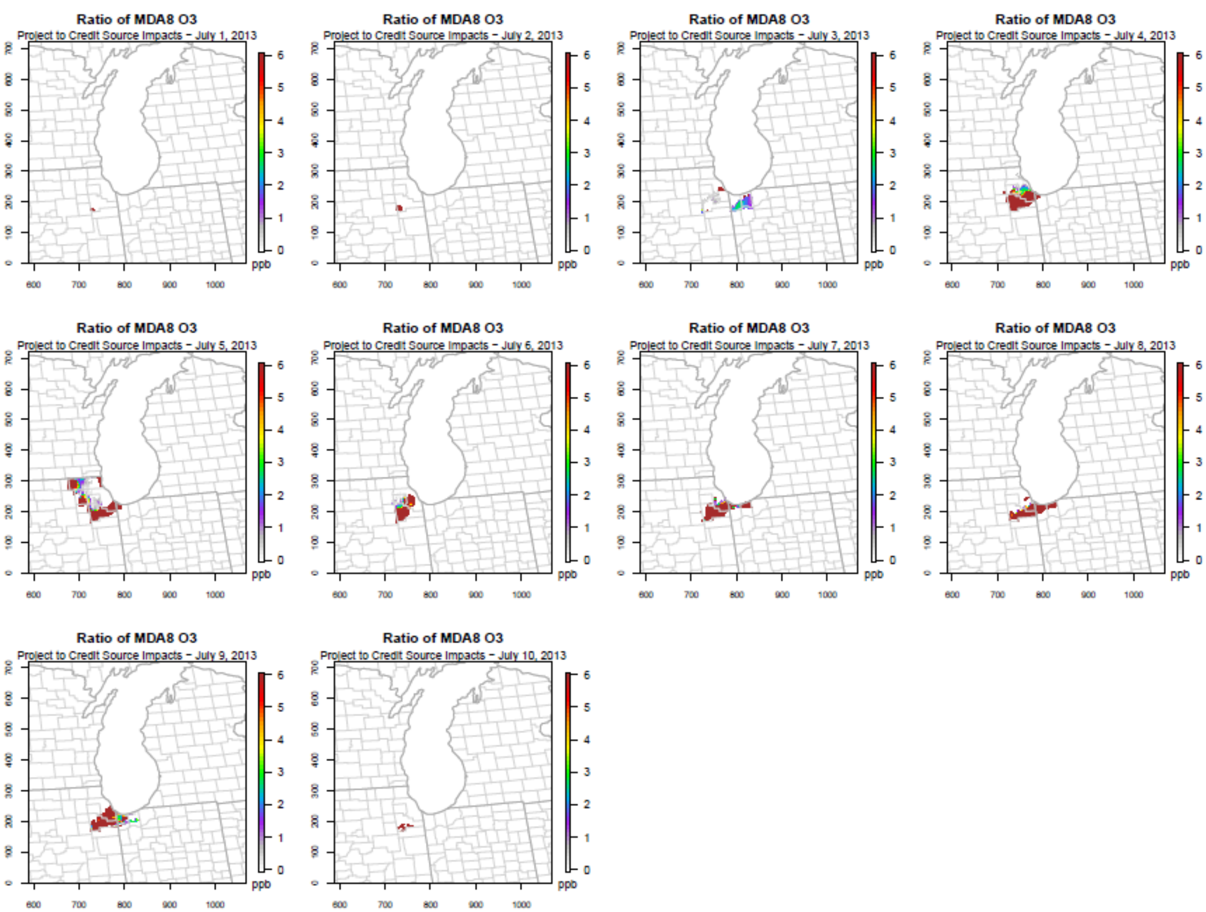


Figure 4 shows the ratio of MDA8 project source O_3 impacts to credit source O_3 impacts where multiple conditions are satisfied. First, only impacts greater than 1 ppt are shown; second, only impacts are shown where the baseline bulk model O_3 prediction was greater than 30 ppb; third, only impacts are shown where the grid cell intersects the area of interest (shown in Figure 1 as the orange colored cells).

Figure 4. Ratio of project source to credit source O_3 impacts where multiple conditions are satisfied.



Daily metrics relating MDA8 project and credit source O_3 impacts are shown in Table 1. These impacts are based on episode days and grid cells meeting multiple criteria. First, only impacts greater than 1 ppt are shown; second, only impacts are shown where the baseline bulk model O_3 prediction was greater than 30 ppb; third, only impacts are shown where the grid cell intersects the area of interest (shown in Figure 1 as the orange colored cells). For each day, the ratio is provided of the sum of project source O_3 impacts divided by the sum of credit source O_3 impacts over all cells meeting the criteria detailed above. The number of cells meeting the criteria is also provided along with that value being expressed as the percentage of all cells in the area of interest (the total number of cells examined for this analysis). The number of cells used in the analysis varies due to varying O_3 production in the area of interest from day to day during this period of time. At the bottom of Table 1, the ratio represents the ratio of episode total impacts and is not the average of the daily ratios. Table 2 presents an illustrative sensitivity analysis of the ratio of sums of O_3 impacts at various baseline bulk model O_3 cutoffs**.**

Table 1. Ozone impacts from the hypothetical project source and credit source and ratio analysis

Episode Day	Sum of Project Source MDA8 O3 Impacts (ppb)	Sum of Credit Source MDA8 O3 Impacts (ppb)	Ratio of project to credit source O3 impacts	Number of cells used for project source impact sum	Project source impacted cells divided by total cells in area of interest x 100	Number of cells used for credit source impact sum	Credit source impacted cells divided by total cells in area of interest x 100
1	0.02	0.02	1	4	0.5	4	0.5
2	0.12	0.03	4	7	0.9	3	0.4
3	1.47	4.94	0.3	161	19.7	340	41.7
4	20.92	1.92	10.9	255	31.2	237	29
5	17.95	4.43	4.1	422	51.7	357	43.8
6	22.05	4.69	4.7	171	21	317	38.8
7	25.16	1.7	14.8	197	24.1	181	22.2
8	9.82	0.61	16.1	173	21.2	156	19.1
9	15.61	1.98	7.9	218	26.7	240	29.4
10	0.09	0.01	9	13	1.6	4	0.5
sum	**113.21**	**20.33**	**ratio of sums 5.57**				

Table 2. Sensitivity analysis of the ratio of summed ozone impacts to changes in the baseline bulk model O_3 cutoff.

baseline bulk model O_3 cutoff (ppb)	ratio of sums
0	5.57
10	5.57
20	5.57
30	5.57
40	5.64
45	5.17
50	2.20
60	0.43

United States Environmental Protection Agency	Office of Air Quality Planning and Standards Air Quality Assessment Division Research Triangle Park, NC	Publication No. EPA-454/R-18-004 May, 2018