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OZONE FORMATION STUDY: INVENTORY PREPARATION PLAN

LOUISVILLE METRO AIR POLLUTION CONTROL DISTRICT

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ACRONYMS AND ABBREVIATIONS

AQM	Air Quality Model
BenMAP	Benefits Mapping and Analysis Program
BenMAP-CE	Benefits Mapping and Analysis Program – Community Edition
CAMD	Clean Air Markets
CAMx	Comprehensive Air Quality Model with Extensions
CB6r4	Carbon Bond version 6 revision 4
CO	carbon monoxide
CPRM	coarse particulate matter
CSA	Combined Statistical Area
FEDOOP	Federally Enforceable District Origin Operating Permits
FIPS	Federal Information Processing Standard
FPRM	primary others
HONO	nitrous acid
HRVOCs	highly reactive Volatile Organic Compounds
IN	Indiana
IPP	Inventory Preparation Plan
km	kilometers
KY	Kentucky
lb/hour	pounds per hour
LMA	Louisville Metro Area
Louisville NAA	Louisville-Jefferson County, Kentucky-Indiana ozone nonattainment area
Louisville MSA	Louisville-Jefferson County Kentucky-Indiana Metro Statistical Area
LMAPCD	Louisville Metropolitan Air Pollution Control District
MJO	Multi-jurisdictional Organizations
MOVES	Motor Vehicle Emission Simulator
MSA	metropolitan statistical area
NAA	ozone nonattainment area
NAQQS	National Ambient Air Quality Standard
NH3	ammonia
NOx	oxides of nitrogen
PM	particulate matter
$PM_{2.5}$	particulate matter with an aerodynamic diameter less than or equal to 2.5 microns
PM_{10}	particulate matter with an aerodynamic diameter less than or equal to 10 microns
PEC	primary elemental carbon
PNO_3	primary nitrate
POA	primary organic aerosol
POTW	Publicly Owned Treatment Works
ppb	parts per billion
ppm	parts per million
PSO_4	primary sulfate
QA	quality assurance
SCC	Source Classification Code
SIP	State Implementation Plan
SMOKE	Sparse Matrix Operator Kernel Emissions
SO_2	sulfur dioxide
SOx	sulfur dioxide
USEPA	United States Environmental Protection Agency
VOCs	Volatile Organic Compounds

1. INTRODUCTION

This document is an Emissions Inventory Preparation Plan (IPP) to compile a comprehensive 2016 base year emissions inventory of ozone precursors impacting ambient ozone levels in the Louisville Metro Area.

1.1 Background

On June 4, 2018, United States Environmental Protection Agency's (USEPA) designated a portion of the Louisville/Jefferson County – Elizabethtown – Madison, Kentucky-Indiana Combined Statistical Area (CSA) as Marginal nonattainment for the 2015 ozone National Ambient Air Quality Standard (NAAQS), effective August 3, 2018 (Federal Register Volume 83, Number 107, p. 25776). The 2015 ozone NAAQS is 0.070 parts per million (ppm). The annual fourth-highest daily maximum 8-hour concentration averaged over 3 years is not to exceed the 2015 ozone NAAQS. The Louisville CSA counties designated as nonattainment by USEPA for the 2015 ozone NAAQS included Bullitt, Jefferson, and Oldham in Kentucky (KY) and Clark and Floyd in Indiana (IN). The nonattainment designation was based on ozone design value[1] concentrations measured in 2014 through 2016 in the Louisville CSA (USEPA 2018a), when the Cannons Lane NCore monitoring site (site identifier 21-111-0067) had a 2014-2016 design value of 0.074 ppm. The USEPA completed a 5-factor analysis to determine the nonattainment area boundaries and classification for the Louisville, KY-IN nonattainment area (USEPA 2018a).

On December 6, 2018, the USEPA finalized the Implementation Rule for the 2015 ozone NAAQS, which includes State Implementation Plan (SIP) requirements (Federal Register Volume 83 Number 234, p. 62998). Areas classified as Marginal nonattainment, such as the Louisville KY-IN nonattainment area, have 3 years from the date of designation to attain the standard (i.e., August 3, 2021 for the Louisville, KY-IN nonattainment area). If an ozone monitor in the Louisville, KY-IN nonattainment area exceeds the 2018 ozone NAAQS during the 2018-2020 ozone season, the area could be reclassified to the more stringent "Moderate" nonattainment level. Moderate nonattainment levels have additional SIP requirements, including a requirement to demonstrate attainment by the future attainment date using an air quality model.

In order to better understand ozone precursor emissions and ozone formation processes in the Louisville/Jefferson County area, LMAPCD is undertaking this Ozone Formation Study. Ozone is formed in the atmosphere through a set of complex nonlinear photochemical reactions involving oxides of nitrogen (NOx) and Volatile Organic Compounds (VOCs) in the presence of sunlight. Ozone formation within LMA has previously been characterized as being either NOx-limited or VOC-limited (radical-limited); for example, typically earlier in the day ozone formation is limited by the rate of radical initiation so is more VOC (radical)-limited and by the afternoon, when photochemical reactions are greatest, ozone formation tends to be more NOx-limited. The level of precursor limitation can also vary greatly across an urban area. For example, in areas with high NOx emissions (such as urban downtowns where mobile source emissions predominate or downwind of large NOx point sources) ozone formation may be more VOC-limited, while a few km away in the suburbs ozone formation may be more NOx-limited. Beyond a certain ratio of VOC to NOx, however, further NOx

[1] A design value is the monitored concentration reported in the form of the NAAQS. For both the 2008 and the 2015 ozone NAAQS, the design value is the 3-year average of the annual forth highest daily maximum 8-hour average ozone concentration.

reductions may act to increase ozone formation through radical initiated reactions of VOC and subsequent photochemical reactions that produce ozone, the so-called NOx disbenefit.

Louisville/Jefferson County has a unique heterogenous source mixture. While Louisville/Jefferson County has conditions like many other urban areas containing an urban core surrounded by suburban and rural areas, the industrial sources in the county are highly diverse, both from the perspective of industrial activities (such as power generation, automotive manufacturing, chemical manufacturing, commercial product manufacturing, petroleum terminals, sewage treatment, landfills, etc.), as well as air quality emissions. Furthermore, some areas, such as Rubbertown, have a high density of highly reactive VOCs (HRVOCs) while other areas have relatively large distances between NOx emissions sources or low reactivity VOCs.

A photochemical model is the best tool to assess spatial and temporal variations in ozone formation, as found in Louisville/Jefferson County, and analyze the sensitivity of ozone formation to NOx versus VOC precursors. Photochemical models are also the USEPA recommended tool for ozone modeling (USEPA 2018a). In order to better understand the ozone formation processes contributing to elevated periods of ozone in Louisville/Jefferson County, ozone modeling will be conducted with an existing air quality model (AQM) with an existing air quality database.

Emissions inputs will be refined based on LMAPCD information to better represent the unique source characteristics and emissions profiles in Louisville/Jefferson County, as described in Louisville Metropolitan Air Pollution Control District Emissions Inventory Quality Assurance Project Plan (Ramboll 2019) and this Inventory Preparation Plan. The emissions inputs generated specifically for the Louisville Ozone Formation Study will be used in combination with other publicly available data in an AQM to assess:

1. The extent to which areas and periods of elevated ozone in Louisville, KY-IN nonattainment area is NOx-limited or VOC-limited, and
2. For VOC-limited areas/periods, the ozone formation potential of VOC emissions.

This information can inform voluntary ozone reduction measures to attain compliance with the ozone NAAQS by the Marginal attainment date (August 3, 2021) as well as inform potential future control strategies should the area be reclassified to Moderate. Model results can also be used to assess health effects using the USEPA Environmental Benefits Mapping and Analysis Program – Community Edition (BenMAP-CE) model (AAI 2018).

1.2 Louisville-Jefferson County Unique Source Composition

Louisville-Jefferson County Kentucky-Indiana Metro Statistical Area (Louisville MSA) has a unique source mix comprised of a variety of industrial source sectors, mobile sources and biogenic emissions. The locations and magnitudes of NOx and VOC emissions sources from the industrial sector are shown in Figure 1 for the Louisville MSA based on the 2014 NEI (USEPA 2018b). As shown in the figure, some sources emit both NOx and VOC, but several geographic areas, such as Rubbertown, the NOx and VOC emissions are not correlated.

Of further relevance for this study is that the VOC emissions sources often have unique and temporally varied composition. The VOC composition is a critical component of this study for the accurate assessment of ozone sensitivity to NOx versus VOC and the VOC ozone formation potential. Available data from the USEPA Air Toxics Monitoring Project funded via Regional Applied Research Effort (RARE) may be particularly useful for this study to assess the quality of the speciated VOC emissions inventory and inform emissions inventory development efforts.

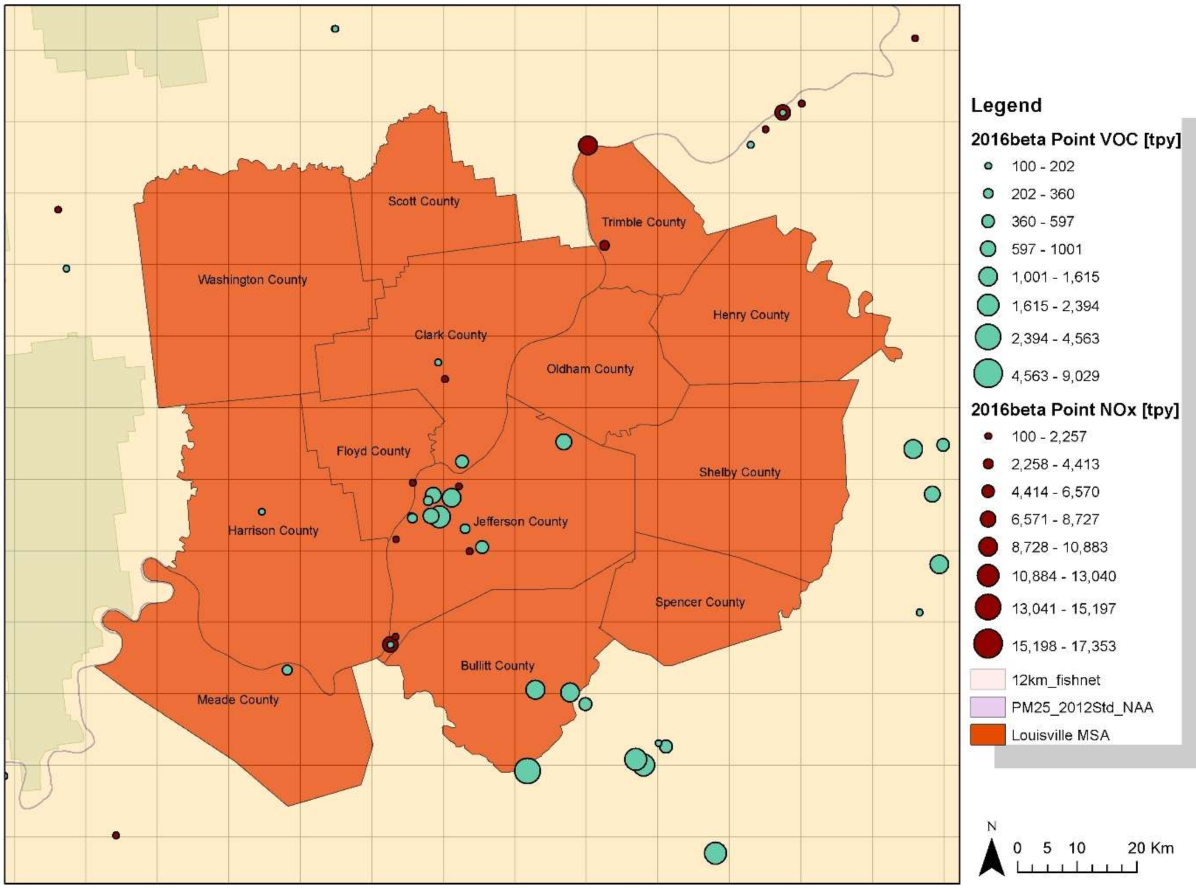

Figure 1. NOx and VOC emissions sources in the vicinity of Louisville MSA.

1.3 Inventory Scope

The 2016beta inventory developed by the USEPA will form the framework of the modeling emissions for the Louisville Ozone Formation Study. The USEPA emissions data will be updated for key inventory sources to better represent the Louisville MSA, wherever feasible. The scope of the emissions inventory updates includes the following characteristics:

- Pollutants: The pollutants included in the emissions inventory are as follows:
  - Ozone precursors: nitrogen oxides (NOx), volatile organic compounds (VOC), and CO;
  - Primary PM_{10} and $PM_{2.5}$; and
  - Precursors of PM_{10} and $PM_{2.5}$: NOx, sulfur dioxide (SOx), VOC, and ammonia (NH_3).
- Time Frame and Temporal Resolution: The base year inventory to be developed is for calendar year 2016. In addition to annual inventories, estimates will also be provided for ozone season monthly emissions for on-road sector. The ozone season is March 1 through October 31.

- Emissions Source Type: The inventory will be updated for industrial point sources within Louisville/Jefferson County, non-point area sources within Louisville/Jefferson County, and on-road mobile sources within five counties in the Louisville/Jefferson County MSA.

2. EMISSIONS DATA SOURCES

The USEPA and Multi-jurisdictional Organizations (MJOs) are co-developing a 2016 Air Quality Modeling (AQM) platform. The 2016beta Emissions Modeling Platform (EMP) is the first product from the National Emissions Inventory Collaborative that includes a full suite of base year (2016) and future year inventories, ancillary emissions data, and scripts and software for preparing the emissions for air quality modeling[1]. Details on the 2016beta platform development is available on its wiki[2].

The 2016beta inventory will form the frame work of the modeling emissions for the Louisville Ozone Formation Study. The USEPA has developed model-ready emissions based on the 2016beta inventories for the 12-km CONUS2 domain embedded in an expanded 36-km US3 domain, both of which are shown in Figure 2.

2.1 On-road Mobile Emissions

Ramboll will incorporate on-road emissions generated by the LMAPCD into the final 2016 base year emissions inventory. The LMAPCD will develop 2016 on-road inventory data for five counties of the LMA: Bullitt, Jefferson and Oldham counties in KY and Floyd and Clark counties in IN and provide them to Ramboll. The emissions data will be generated with MOVES2014b (USEPA, 2014a,b,c) in inventory mode for the 8 ozone months (March through October). The inventory data will consist of monthly total emissions by Source Classification Code (SCC) for the five counties.

Ramboll will evaluate LMAPCD-provided county-level emissions against what USEPA has in their 2016 Modeling Platform. For this Platform, the USEPA generated on-road mobile emissions directly on the 12-km model grids rather than county-level totals using SMOKE-MOVES processing approach. The gridded emissions will be summarized by county using 12-km grid cells masking approach and compared against the LMAPCD emissions by month to help with QA/QC of new onroad emissions. The purpose is to make sure that there are no glaring errors in the new emissions. After the satisfactory review of the new on-road emissions, Ramboll will process the on-road emissions with SMOKE using weekly and diurnal temporal profiles from the 2016beta platform.

2.2 Non-point Emissions

Ramboll will revise the USEPA 2016 non-point emissions for Jefferson County based on synthetic minor source emissions supplied by LMAPCD and incorporate the revisions with the final 2016 base year emissions inventory. Specifically, the LMAPCD will provide Jefferson county emissions from sources permitted through federally enforceable district origin operating permits (FEDOOP). Ramboll will isolate the SCC codes in the non-point source emissions file that correspond with the LMAPCD-supplied emissions and update the non-point emissions file for those SCC codes. Non-point source emissions are typically estimated using a top-down approach with county-level activity data and not easy to reconcile with individual source-specific inventory. Therefore, only select SCC with a complete county emission inventory from the LMAPCD will be updated. The proposed source categories to be updated is provided below:

- Bulk Gas Terminals/Plants

1 National Emissions Inventory Collaborative (2019). 2016beta Emissions Modeling Platform. Retrieved from http://views.cira.colostate.edu/wiki/wiki/10197.

2 http://views.cira.colostate.edu/wiki/wiki/9169

- Waste Disposal: Publicly Owned Treatment Works (POTW)
- Graphic Arts
- Industrial Natural Gas Combustion
- Land Clearing Debris

The LMAPCD will develop revised estimates for the Land Clearing Debris using the BlueSky Playground tool (https://tools.airfire.org/playground/v3/emissionsinputs.php?) based on permitted agricultural fires for 2016 (87 acres) in Jefferson County because the USEPA 2016 estimate seems unrealistically high.

Ramboll will conduct the SMOKE runs replacing the 2016beta non-point emissions from USEPA with data supplied by LMAPCD. The resulting non-point emissions will be reviewed and quality assured by generating plots and tables of emissions. The revised non-point emissions will be re-merged with the rest of the model-ready emissions inventory using SMOKE.

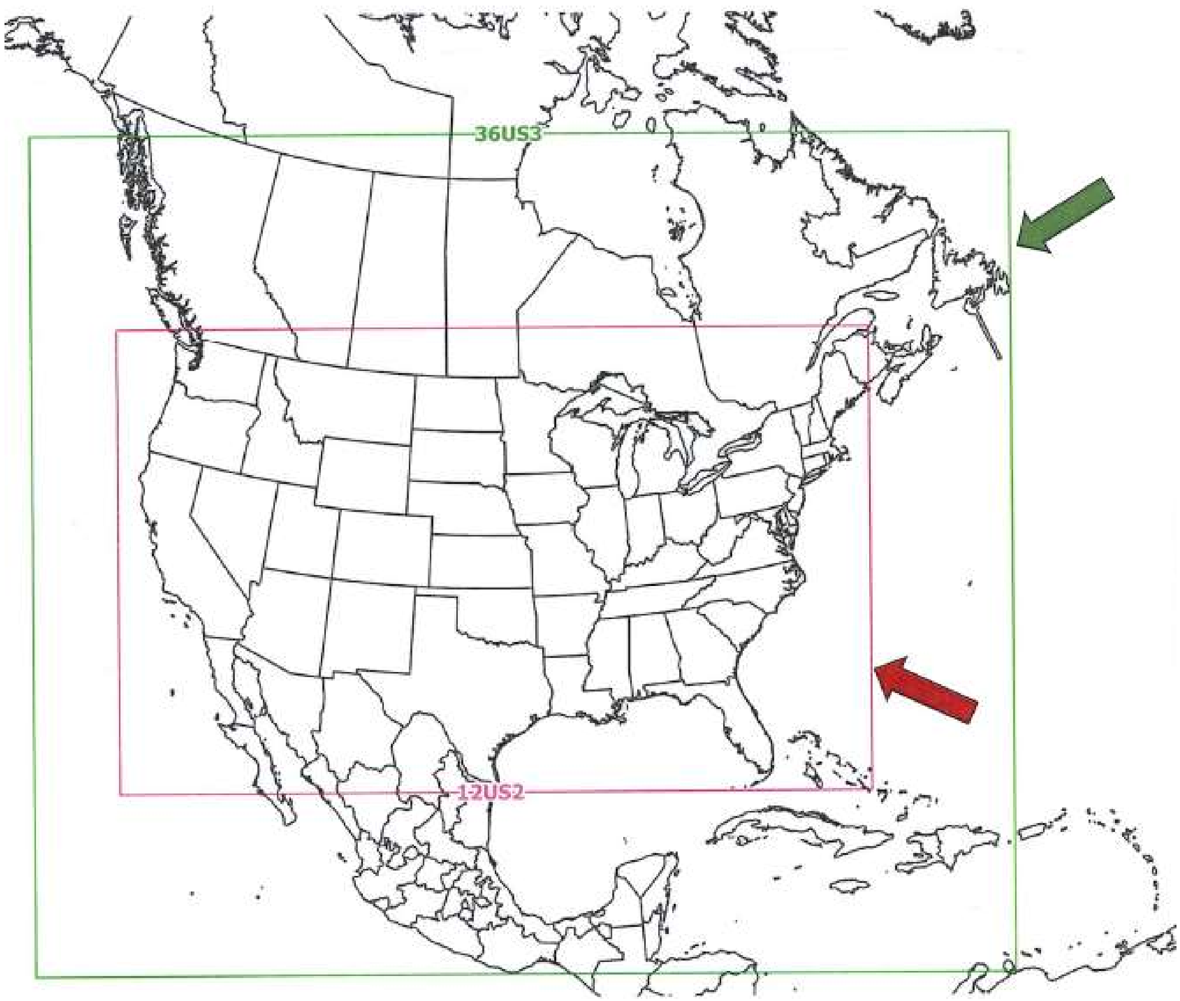

Figure 2. 12-km (12US2/CONUS2) and 36-km (36US3) domains used in the 2016 modeling platform.

3. DEVELOPMENT OF MODEL-READY EMISSIONS

AQMs require a complete suite of all emissions (anthropogenic and biogenic) within the analysis areas as well as background emissions transported into the area. Error! Reference source not found. summarizes the emission models and sources of emissions data to be used in the Louisville Ozone Formation Study. The Louisville Ozone Study CAMx modeling will use a 12/4-km nested grid structure as shown in Figure 3.

The updated inventory sectors will be processed using the SMOKE system (CMAS, 2018a) and merged with the 12-km Midwest domain emissions. During emissions processing, annual emissions inventories will be speciated to model species, temporally allocated to hourly emissions, and spatially allocated to grid cells as follows.

Spatial Allocation: SMOKE uses spatial surrogates to spatially distribute emissions to modeling grid cells. Spatial surrogates are generated by overlaying the AQM modeling grid on maps of geospatial indicators appropriate to each source category (e.g., housing units).

Temporal Allocation: We will process the on-road emissions using weekly and diurnal temporal profiles from the USEPA 2016beta platform. SMOKE will be used to allocate minor point source and non-point annual emissions to months and across the diurnal cycle to account for seasonal, day-of-week, and hour-of-day effects. SMOKE will also be used to process event emissions.

Chemical Speciation: The emissions inventories will include the following pollutants: CO, NOx, VOC, NH_3, SO_2, PM_{10}, and $PM_{2.5}$. The CB6r4 photochemical mechanism with active local methane emissions will be used for the CAMx modeling. We will use SMOKE to convert inventoried VOC emissions into the CB6r4 mechanism-specific model species used in CAMx. Chemical speciation profiles will be assigned to inventory sources using cross-referencing data that match the profiles and inventory sources using country/state/county (FIPS) and SCCs. The team will use VOC and PM speciation profiles from the 2016beta platform. SMOKE also will apply source-specific speciation profiles convert inventoried NOx emissions to NO, NO_2, and nitrous acid (HONO) components. PM emissions will also be speciated to model species, namely primary organic aerosol (POA), primary elemental carbon (PEC), primary nitrate (PNO_3), primary sulfate (PSO_4), primary others (FPRM), and coarse PM (CPRM or $PM_{10-2.5}$).

Quality Assurance: The QA capabilities in SMOKE will be used to generate standard and custom reports for checking the emissions modeling process. SMOKE generates diagnostic files and summary reports which need to be carefully reviewed for error and warning messages.

Table 1. Summary of Sources for 2016 Base Case Emissions.

Emissions Component	Configuration/Data Sources	Details
Model	SMOKE	https://www.cmascenter.org/smoke. Latest version is SMOKE V4.6 released in September 2018.
Oil and Gas	USEPA/MJO 2016beta emissions	USEPA/MJO 2016beta inventory: http://views.cira.colostate.edu/iwdw/RequestData/Default.aspx?pid=USEPA_2016
Area	Reconciled non-point emissions for Jefferson County and 2016beta non-point emissions for rest of the domain	USEPA/MJO 2016beta inventory: http://views.cira.colostate.edu/iwdw/RequestData/Default.aspx?pid=USEPA_2016
On-Road Mobile	MOVES2014b for 5 counties of the LMA and SMOKE-MOVES for rest of the domain	http://www.epa.gov/otaq/models/moves/
EGU	2016 Continuous Emissions Monitor data for NO_x and SO_2	Clean Air Markets (CAMD) http://ampd.epa.gov/ampd/
Other Points (non-EGU)	USEPA/MJO 2016beta emissions	USEPA/MJO 2016beta inventory: http://views.cira.colostate.edu/iwdw/RequestData/Default.aspx?pid=USEPA_2016
Off-Road Mobile	USEPA/MJO 2016beta emissions	USEPA/MJO 2016beta inventory: http://views.cira.colostate.edu/iwdw/RequestData/Default.aspx?pid=USEPA_2016
Fugitive Dust	USEPA/MJO 2016beta emissions	USEPA/MJO 2016beta inventory: http://views.cira.colostate.edu/iwdw/RequestData/Default.aspx?pid=USEPA_2016
Ammonia Emissions	USEPA/MJO 2016beta emissions	USEPA/MJO 2016beta inventory: http://views.cira.colostate.edu/iwdw/RequestData/Default.aspx?pid=USEPA_2016
Biogenic Sources	SMOKE-BEIS with 2016 meteorological data	Biogenic Emission Inventory System, version 3.61 (BEIS3.61) within SMOKE
Fires	2016 US BlueSky fires	2016 US BlueSky framework
Temporal Adjustments	Seasonal, monthly, day, hour	Based on collected information for the base case emissions.

Emissions Component	Configuration/Data Sources	Details
Chemical Speciation	CB6r4	Revision 4 of Carbon Bond 6 chemical mechanism
Gridding	Spatial Surrogates based on land use and other geospatial data sources	Use spatial surrogates from the 2016beta EMP
Emission Controls	Source Category Specific	MOVES and the USEPA inventory include effect of "on the books" regulations as assessed by USEPA.
Quality Assurance	QA Tools in SMOKE; spatial plots; Summary reports	

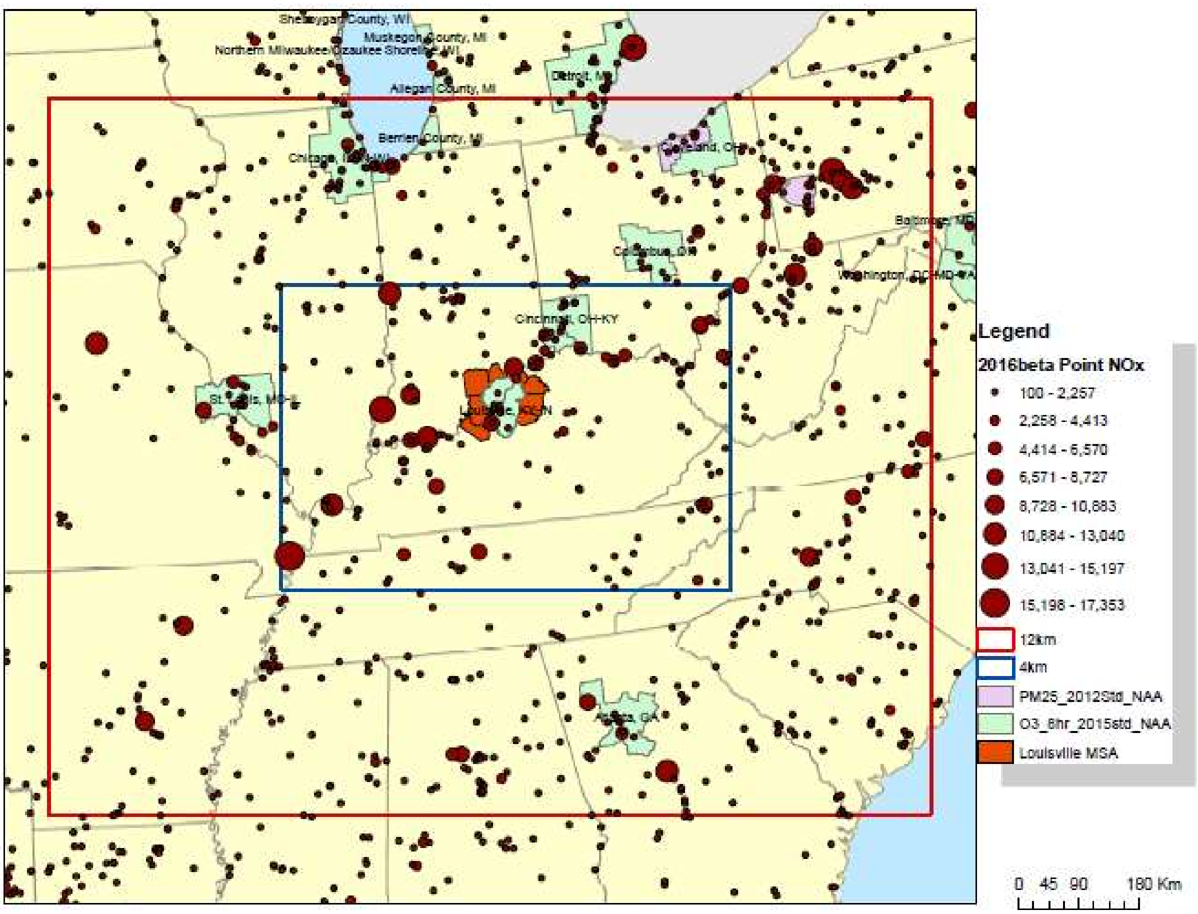

Figure 3. Map of proposed 12/4-km flexi-nested CAMx modelling domains for the Louisville Ozone Study.

All pre-merged emissions components will be merged together to generate the final CAMx-ready two-dimensional gridded low-level (layer 1) and point source emission inputs. The CAMx photochemical grid model requires two types of emissions files, as described below, for every episode day; both types are FORTRAN binary files.

Surface-level two-dimensional emissions: This file contains all sources other than elevated point sources that have no or little plume rise, so are emitted directly into the lowest (surface) layer of the model. SMOKE outputs gridded, speciated, hourly emissions files (one for each day) for each source category. The component emissions are then merged together into one surface layer emissions file.

Elevated point source emissions: This file typically consists of emissions from major stationary point sources and includes stack parameters for each source so that plume rise may be calculated within CAMx. SMOKE outputs speciated hourly point source emissions files with stack parameters in an ASCII format that are converted into FORTRAN binary format that is readable by CAMx. If multiple point source files are produced for one day they are merged together into one file.

The surface-level file is a gridded file that is matched to a specific modeling grid. Therefore, we will generate CAMx model-ready emission files for the 12 km modeling domain shown in

Figure 3. The elevated point source file is independent of the modeling grid, because it contains horizontal (x, y) coordinates for each point source, and includes all point sources in the 12 km modeling grid.

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