INSTITUTE FOR THE ENVIRONMENT

Technical Work Plan for Task Order PR-OAR-21-00981

"Air Quality Modeling Assessment Tools (AQMAT) Development"

U.S. EPA Contract No. 68HERD21A002

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Table of Contents

Version History

Version	Date	Comments
1	08/23/21	Initial version submitted to EPA
2	08/30/21	Revised version with corrected LOE table in Section 6
3	01/20/23	Revised version with updated Task 5 for Opt. Period 1

1 Introduction

1.1 Project Background

Over the last decade, EPA has engaged in the development of a series of air quality modeling assessment tools (AQMAT) to support air quality management and regulatory policy analysis, for example, the Modeled Attainment Test Software (MATS) and Environmental Benefits Mapping and Analysis Program (BenMAP). EPA has recently developed an enhanced and upgraded version of Software for Modeled Attainment Test-Community Edition (SMAT-CE) (https://www.epa.gov/scram/photochemical-modeling-tools) in replacing the legacy MATS. EPA has also developed and released a new version of BenMAP-Community Edition (BenMAP-CE) (http://www.epa.gov/air/benmap-ce.html) in replacing the legacy BenMAP. The software development team re-designed the legacy MATS and BenMAP into open-source and public community-owned tools, using a modern software language (C#) and geographic information system (GIS) under a user-friendly Graphical User Interface (GUI). The targeted users of SMAT-CE and BenMAP-CE include decision makers, policy analysts, and scientists among the Federal, State, and local air quality community as well as international community. The EPA will continue to update and improve the current versions of SMAT-CE and BenMAP-CE which will be released to the public community periodically.

Built upon the successful development of BenMAP-CE and SMAT-CE, EPA has also developed a series of modeling assessment tools to enhance its functions and strength for providing regulatory modeling support, including (1) a state-of-the-art model visualization and analysis tool (Model-VAT) to provide multi-scale and multi-model data graphical and statistical analysis capabilities, (2) a standalone "Data Fusion" Tool (DFT) to provide spatial field interpolation for fusing scattered monitoring data and gridded model data spatially together, and (3) a Response Surface Modeling – Visualization and Analysis Tool (RSM-VAT) to provide a near real-time assessment of air quality changes to emissions control. EPA also plans to develop new integrated air quality modeling assessment tools for supporting effective air quality assessment and management.

1.2 Task Order Background

In this work plan, the University of North Carolina at Chapel Hill's Institute for the Environment (UNC-IE) has responded to U.S. EPA Task Order (TO) PR-OAR-21-00981 issued under the Blanket Purchase Agreement contract 68HERD21A002. TO PR-OAR-21-00981, titled "Air Quality Modeling Assessment Tools (AQMAT) Development," is designed to assist EPA in developing and upgrading a suite of Air Quality Modeling Assessment Tools (AQMAT) for supporting regulatory modeling efforts. The work performed under TO PR-OAR-21-00981 will not duplicate any work that is being or has been performed under other task orders.

UNC-IE is the prime contractor on this task order and will be responsible for all work being done. We propose to use Southern China University of Technology (SCUT) as a sub-contractor on this work.

The sections of this document cover the various requirements specified in the Task Order for this effort:

- Section 2: A summary of the task order tasks
- Section 3: Quality Assurance Project Plan (QAPP)
- Section 4: The methods and technical approaches for all tasks/subtasks
- Section 5: The estimated schedule for completion of the TO deliverables
- Section 6: A listing of the proposed personnel for the TO

2 Task Order Task Summary

The work to be performed in TO PR-OAR-21-00981 is divided into the following tasks:

- Task 1: Task Order Administration
- Task 2: Support the development and improvement of EPA's "Flexible Air quality Scenario Tool – Community Edition" (FAST-CE) Tool
- Task 3: Support the development and improvements of EPA's NEXUS Multi-Pollutant Analysis Tool
- Task 4: Support the development and improvements of EPA's Existing Air Quality Modeling Assessment Tool
- Task 5: Support the upgrades of EPA's NEXUS Multi-Pollutant Analysis Tool

Details on the technical approach for addressing these tasks are discussed in Section 4. A complete list of deliverables with dates is shown in Table 5.1.

3 Quality Assurance Project Plan

We will develop a task order QAPP to provide a plan for obtaining, using, storing, and retrieving the type and quality of environmental data needed to support this task order. The QAPP will document how quality assurance (QA) and quality control (QC) activities are applied to environmental data operations to assure that the results obtained are of the type and quality needed and expected.

1. Within 30 days of the effective date of the TO, we will submit a draft QAPP in Microsoft Word format, divided by sections that describe the policies, organization, objectives, functional guidelines, and specific QA/QC activities designed to achieve the data quality requirements of the task order. The QAPP shall provide a level of detail and organization that is consistent with EPA QA/R5, EPA Requirements for Quality Assurance Project Plans which can found at https://www.epa.gov/quality/epa-qar-5-epa-requirements-quality-assuranceproject-plans. Specific tasks to be addressed by the QAPP are described in Task 1 of this task order. These are not necessarily all-inclusive; we will include any other tasks or implementable measures that are not mentioned but are necessary to optimize the quality or assess the uncertainty of the information that is produced. Additional guidance on developing the QAPP is available in EPA's Guidance for Quality Assurance Project Plans EPA QA/G-5 9 which can be found at https://www.epa.gov/sites/production/files/2015-06/documents/g5-final.pdf.
2. With consultation from the Quality Assurance Manager (QAM) or the Delegated Quality Assurance Officer (DQAO), the work required in this Task Order has been preliminarily determined to be classified as Category II by the TOCOR.
3. The TOCOR will review the quality documentation and provide comments to UNC-IE in writing within 4 weeks. EPA will provide comments to the submitted draft QAPP in writing or directly on a digital file. We will revise the QAPP and resubmit it to the EPA for approval within one week. The revised QAPP will be the official QAPP for the task order.
4. Incorporation of Standard Operating Procedures (SOPs) - When addressing the data acquisition elements in the task order QAPP, detailed copies of quality assurance methods and/or SOPs can be either included directly in the discussion, provided as attachments to the QAPP, or, if easily obtained and readily available to all project participants (e.g., American Society for Testing and Materials (ASTM) methods), cited within the discussion and included in the reference list. Detailed copies of the methods and/or SOPs must accompany the QAPP either in the text or as attachments. All SOPs referenced in each activity performed by UNC-IE will be submitted as part of the applicable QAPP. The SOPs shall be written to be consistent with EPA QA/G-6 titled Guidance for Preparing Standard Operating procedures (SOPs), which can found at https://www.epa.gov/quality/guidance-preparing-standard-operatingprocedures-epa-qag-6-march-2001.
5. QAPP Amendments – During the term of the contract, we will revise and maintain on file, with all previous revisions, an amended QAPP within 30 days of the following circumstances:
   a. The Agency modifies the contract.
   b. The Agency notifies UNC-IE of deficiencies in the QAPP document resulting from the Agency's review of our performance.
   c. We identify deficiencies resulting from their internal review of the QAPP document.
   d. Our organization, personnel, facility, equipment, policies, or procedures change.
   e. We identify deficiencies resulting from the internal review of our organization personnel, facility, equipment, policies or procedures.
6. Document Control - When the QAPP or any SOP is amended, all changes shall be clearly marked with a bar in the margin indicating where the change is found in the document, or by highlighting the change by underlining, bold printing, or using a different print font. The amended section pages shall have the date on which the changes were implemented. Any changes in the QAPP shall be submitted to the EPA Project Officer for approval before implementation.
7. QAPP and SOP Archival – We will maintain a master QAPP which incorporates the original QAPP and all subsequent amendments. We will provide a copy of the master QAPP (including the SOPs) and any of its attachments to the designated recipients within 14 days of a request.

Concerning software development, the QA requirements for this T.O. are as follows:

- Ensure that all software changes are tracked and stored within a source-code control system
- Ensure that the installed software versions meet EPA's priority requirements as discussed in meetings with the TOCOR
- Ensure that installed software versions and algorithms are tested and produce correct results given the specific combination of inputs
    - Provide documentation that describes the tests that were conducted and that confirms that correct results were achieved
- Ensure that the updated software versions use reasonable amounts of computer time, memory, and database connections
- We will apply best practices for software development such as source control, automated builds, automated bug-tracking, unit tests, and integration tests.
- Concerning any data preparation, to identify and eliminate errors we will perform quality control (QC) of the data prior to delivering data sets to the TOCOR.

4 Methods and Technical Approach

4.1 Task 1: Task Order Administration

Under this task, we will have conference calls with the TOCOR on a bi-weekly basis after approval of the task order to plan and review progress of this TO. We will have conference calls with the TOCOR on a monthly basis after approval of the task order to plan and review progress of this TO. We will provide status updates on each task and the EPA TOCOR will discuss any technical issues related to completing each task. The EPA TOCOR will provide UNC-IE with technical direction regarding the priority of the items for each task, including those that should be addressed by the next conference call. During the calls, we will provide status updates on the progress of active work items. Upon request, we will provide level-of-effort (LOE) estimates for implementing specific proposed work items.

We will submit monthly progress reports, provide labor category estimates of resources for each task and subtask in any provided cost estimate, review and quality assure all work products, and keep the TOCOR informed of any problems that may impede project performance or delivery dates, along with any corrective actions needed by UNC-IE or the TOCOR to solve such problems. We will include a description of the work performed on each task in each monthly report.

Task 1 Deliverables:

- Monthly reports– monthly after task order award, and project summary report
- QAPP Draft (within 30 days of receipt of task order)
- QAPP Final (within 7 days from receipt of EPA comments)

4.2 Task 2: Support the development and improvements of EPA's "Flexible Air quality Scenario Tool – Community Edition" (FAST-CE) Tool

Under the instruction of EPA, firstly, the UNC team (IE + SCUT) will improve the FAST-CE to provide a "meta data" function for FAST-CE cases and datasets, and also provide a function for O_3 and $PM_{2.5}$ Design Values (DVs) projection. Secondly, the UNC team will include RSM and/or DDM techniques under the FAST-CE, as well as develop EJ impact screening capabilities to include and display population-weighted and demographic data and develop capabilities to allow the link to the Global Climate Assessment Model (GCAM) energy scenarios and the Hemispheric-CMAQ applications. Lastly, the UNC team will update the correspondingly online User's Guides for the enhanced FAST-CE.

We will support EPA in debugging, managing the code, enhancing user-friendly GUI design and data V/A functions, and delivering improved FAST-CE installation package and their source code to EPA and user community as instructed.

We will build a comprehensive set of training materials and programs for improved FAST-CE, including "on-line User's Manual", and a public download website for information dissemination, sharing, and downloading of the enhanced FAST-CE.

Subtasks:

- Develop a beta version of FAST-CE with upgraded GUI and functions and online user's guide to be ready for public release; Build in a "meta data" function for identifying and organizing the FAST-CE cases and datasets,
- Develop capabilities under FAST-CE to project the O_3 and $PM_{2.5}$ Design Values (DVs) based on monitor data (e.g., SMAT-CE's "point" data) in addition to the current grid-based data and output the BenMAP-CE ready files,
- Extend the FAST-CE tool to include RSM and/or DDM techniques for better characterizing nonlinearity issues and evaluating Source Apportionment, DDM, and RSM methodologies under a common platform.
- Develop EJ impact screening capabilities under FAST-CE to include and display population-weighted and demographic data and deliver such information by region/sector/source,
- Develop capabilities to allow the FAST-CE to link to the Global Climate Assessment Model (GCAM) energy scenarios (e.g., "GCAM scenario builder" module) and the Hemispheric-CMAQ applications.

Development Tools and Platform:

- Development Environment: the Microsoft Visual Studio 2017 and .NET Framework version 4.6.1
- Programming Language: Microsoft Visual C#
- GIS: the open-source GIS tool DotSpatial

Main tasks to be developed or upgraded:

1. Develop a beta version of FAST-CE with upgraded GUI and functions and online user's guide to be ready for public release; Build in a "meta data" function for identifying and organizing the FAST-CE cases and datasets

    - Based on the current FAST-CE, we will continue to improve the FAST-CE GUI and functions, together with the updated online user's guide to be ready for public release according to EPA's suggestions and instruction.
    - With more and more cases and datasets building in the FAST-CE, we will develop a "Project Metadata & Model Info." module for identifying and organizing the FAST-CE cases and datasets to provide users with a better experience in using FAST-CE, as shown in Fig. 1. We will enhance this module by providing the following two functions: (1) Add/Edit Metadata, and (2) Model Info. When clicking the "Add/Edit Metadata" button, users will be allowed to add or edit "*.xml" files with metadata information of the following fields. Besides, when clicking the "Model Info." button, a "Source Contribution Modeling Information" window will pop up to provide the IOAPI data for the source contribution/apportionment modeling data info as shown in Fig. 1.
    - Current FAST-CE sometimes cannot detect problems in the users-provided input files but allow them to continue running and finish with strange results, which is confusing to users. To deal with such problems, we will further improve the errors detecting capability for input data in FAST-CE, and also provide more "error msg" or "warning" pop-up windows when input data files are not working or acceptable (Fig. 2).
    - We will fix the bugs that the FAST-CE often crashes or stops working when running several cases or running a single case with many scenarios.
    - We will build a new installation package into "My FAST-CE Files" similar to that in NEXUS.

1. Develop capabilities under FAST-CE to project the O_3 and $PM_{2.5}$ Design Values (DVs) based on monitor data (e.g., SMAT-CE's "point" data) in addition to the current grid-based data and output the BenMAP-CE ready files

    - SMAT-CE is a powerful tool to perform attainment tests for particulate matter ($PM_{2.5}$) and ozone (O_3), and regional haze (visibility) by predicting O_3 and $PM_{2.5}$ Design Values (DVs) metrics based on monitor data. In this subtask, we will migrate the algorithm of DVs from SMAT-CE into FAST-CE to provide a function for projecting the O_3 and $PM_{2.5}$ DVs based on monitor data, similar to the "point" data displayed in SMAT-CE as shown in Fig. 3
    - We will extend the "Monitor Point (DVs) & Projection Function" by providing the following functions:
        1. Include an option for inputting monitor point DVs data files.
        2. Provide a "Probe" function to show the value, i.e., when clicking a location, display the AQ value or grid cell value.
        3. Allow to configure the "size" and "color" of monitor points, similar to SMAT-CE and DFT.
        4. Allow to "Zoom-in" and "Zoom-out" map.
        5. Allow to "Compare" the difference between two selected scenarios.

6. Add a button "Output Contribute Table" to the "Right-click" menu with any projected scenario. Gray this button if the "Monitor point_DVs" function is not selected.

- We will further improve the Map module to include a "Difference Plot" function under the right-click menu, by which users can show the difference between two plots on display. Under this module. It also allows the "difference plot" to save to BenMAP-CE format and other formats (Fig. 4).
- We will also improve the Map module in FAST-CE to provide a function to output the BenMAP-CE ready file, by which users can output a series of BenMAP-CE format data files under the user-defined emission levels. The example of the BenMAP-CE ready file is shown in Fig. 5.

2. Extend the FAST-CE tool to include RSM and/or DDM techniques for better characterizing nonlinearity issues and evaluating Source Apportionment, DDM, and RSM methodologies under a common platform
   - Recently, several innovations have been made in RSM, especially in characterizing nonlinearity response to O_3 and $PM_{2.5,}$ as shown in Fig. 6. To extend FAST-CE with better-characterizing nonlinearity issues and evaluating Source Apportionment, we will continue to update and improve FAST-CE under EPA's instruction to include the latest RSM and/or DDM techniques under a common platform (Fig.6).
3. Develop EJ impact screening capabilities under FAST-CE to include and display population-weighted and demographic data and deliver such information by region/sector/source
   - EJSCREEN (EJ) is an environmental justice mapping and screening tool that provides EPA with a nationally consistent dataset and approach for combining environmental and demographic indicators. This tool provides demographic and environmental information for that user-specified geographic area. This information could help users identify areas with (1) minority and/or low-income populations;(2) potential environmental quality issues;(3) a combination of environmental and demographic indicators that is greater than usual. To expand FAST-CE with these EJ impact screening capabilities, we will develop an EJ/demographic module to input EJ data (Fig. 7) and provide a population-weighted and demographic data visualization function with air quality data under different emission reduction by region/sector/source in current "Map" module of FAST-CE as shown in Fig. 8
4. Develop capabilities to allow the FAST-CE to link to the Global Climate Assessment Model (GCAM) energy scenarios (e.g., "GCAM scenario builder" module) and the Hemispheric-CMAQ applications
   - The Global Climate Assessment Model (GCAM) is an integrated assessment model that links the world's energy, agriculture, and land-use systems with a climate model. The model is designed to assess various climate change policies and technology strategies for the globe over long time scales. This model also provides a user-friendly GCAM inputs files management function and support to project GHG and air pollution emissions for various U.S. scenarios. To rapidly assess different scenarios under FAST-CE, we will develop a link to Global Climate Assessment Model (GCAM) energy scenarios (e.g., "GCAM scenario builder" module) to accept the inputs from GCAM. Fig. 9 shows the key flow operation of this module.
   - For supporting Hemispheric-CMAQ applications, we will develop an input option for Hemispheric-CMAQ format data and build in a Hemispheric-CMAQ case in FAST-CE, as shown in Fig. 10.

Task 2 Deliverables:

- Delivery of upgraded interim and final versions of FAST-CE to EPA and user community – 12 months after task order award and as instructed and approved by EPA
- Delivery of updated interim and final versions on-line FAST-CE User's Guides of EPA's air quality modeling assessment tools to EPA and user community – 12 months after project starts and as instructed and approved by EPA

4.3 Task 3: Support the development and improvements of EPA's NEXUS Multi-Pollutant Analysis Tool

Under this task, the UNC team (IE + SCUT) will update the emissions data and the $PM_{2.5}$, O_3 and air toxics data and their health risk data used in NEXUS from 2014 to 2017 as suggested by EPA. Besides, the UNC team will upgrade the NEXUS to include EJ and demographic data, tribal areas, and climate indicators, as well as improve the screening, visualization, and analysis functions for them. SCUT will also develop summary and analysis capabilities for sector emissions and source category emissions and develop a prototype of the "Proximity and Spatial Analysis for Multi-Pollutant risks and EJ" module. Lastly, SCUT will update the correspondingly online User's Guides for the enhanced NEXUS.

We will support EPA in debugging, managing the code, enhancing user-friendly GUI design and data V/A functions, and delivering improved NEXUS installation package and their source code to EPA and user community as instructed.

We will build a comprehensive set of training materials and programs for improved NEXUS, including “on-line User’s Manual”, and a public download website for information dissemination, sharing, and downloading of the enhanced NEXUS.

Subtasks:

- Develop a beta version of NEXUS with upgraded GUI and functions and update the online user’s guide to be ready for public release,
- Update the emissions data and the $PM_{2.5}$, O_3 air toxics data and their health risk data used in NEXUS from 2014 to 2017,
- Develop sector emissions and source category emissions summary and analysis capabilities,
- Develop new screening capabilities for EJ and climate risks and include, visualize and analyze EJ and demographic data, tribal areas and climate indicators,
- Develop a prototype of “Proximity and Spatial Analysis for Multi-Pollutant risks and EJ” module; allow to identify individual sources/facilities within a specific region/area and extend to their sector groups at the national level (“zoom-out” to nationwide).

Development Tools and Platform

- Development Environment: the Microsoft Visual Studio 2017 and .NET Framework version 4.6.1
- Programming Language: Microsoft Visual C#
- GIS: GMAP.NET & the open-source GIS tool DotSpatial

Main tasks to be developed or upgraded

1. Develop a beta version of NEXUS with upgraded GUI and functions and update the online user’s guide to be ready for public release
   - Based on the previous NEXUS, we will continue to update NEXUS to a beta version by improving and enhancing GUI and functions, together with the online user’s guide to be ready for public release as suggested by EPA. The updated online user’s guide also supports jumping to the specified chapter by clicking the blue hyperlink of the module title. For example, click the title of “Data Viewer”, it will pop up a user guide and jump to the “Data Viewer” chapter, as shown in Fig.11.
2. Update the emissions data and the $PM_{2.5}$, O_3 air toxics data and their health risk data used in NEXUS from 2014 to 2017
   - As shown in Fig. 12, most of the current datasets used in NEXUS are still for 2014, which is possibly out of date. Therefore, we will continue to improve NEXUS to be compatible with emissions data and the $PM_{2.5}$, O_3 air toxics data and their health risk data from different years, for example, the GUI of the Data input module will be changed according to user-selected emission year, as shown in Fig. 13. Besides, we will also assist EPA to update the current 2014 datasets to the 2017 datasets provided by EPA, including emissions data and the $PM_{2.5}$, O_3 air toxics data and their health risk data.
   - We will improve the NEXUS to include $PM_{2.5}$, O_3, and air toxic data collected from air quality monitoring sites, and also allow users to display monitors under the “Map” module with a new “Show Monitor Data” function under the right-click menu as shown in Fig. 14.
   - Besides, users will be allowed to click a monitor location symbol on the map to view the DV trend plot of $PM_{2.5}$ or ozone for the selected monitor site as shown in Fig. 15.
3. Develop sector emissions and source category emissions summary and analysis capabilities
   - In the current NEXUS, the major emission sources module mainly focuses on facility emission analysis. To enhance/improve NEXUS, we will develop a sector emissions summary analysis module. Under this module, it will allow users to select major CBSAs/counties/states and provide source and sector emissions summary to support OAQPS’s “Sector Prioritization” project effort via providing two sub-modules:(1) Summary table, and (2) Summary plot. As shown in Fig. 16, the “Summary table” supports to display of emissions by specified sectors at selected regions first and then provides a function to output these data to Excel format tables. The summary plot allows users to display a plotting window for the top X sector group's score (calculated by frequency and rank of the sector).

- Besides, we will also develop a source category emissions analysis module in NEXUS. This module provides a similar table to the “Major Emission Sources” table, but instead of listing facility, listing “Source Categories” (Point, Non-point, Road, Non-road, and Event).

4. Develop new screening capabilities for EJ and climate risks and include, visualize and analyze EJ and demographic data, tribal areas and climate indicators

- NEXUS now can quickly identify top emitters of CAPs & HAPs. We will develop proximity screening capabilities to include EJ/demographic indicators (e.g., EJ Index, Supplementary Demographic Index.) and demographic data, as well as climate risks and indicators (e.g., Flood, Sea level rise, Fire, and Disease) and then add “EJ” indicators as one of the four key metrics (PM, O_3, AT & EJ) in the main page. Below are some key EJ indicators expressions:

$$\text{Demographic Index} = (\%\ \text{minority} + \%\ \text{low-income}) / 2 \tag{1}$$

where:

% minority= count of people of color individuals/ Population count for Block Group,

% low-income= count of low-income individuals / Population count for Block Group.

$$\begin{aligned}\text{EJ Index} = {} & (\text{Environmental Indicator}) \times (\text{Demographic Index for Block Group} - \\ & \text{Demographic Index for US}) \times (\text{Population count for Block Group})\end{aligned} \tag{2}$$

where:

Demographic Index for US= (count of people of color individuals for US + count of low-income individuals for US) / (Population count for US * 2).

$$\begin{aligned}\text{Supplementary Demographic Index} = {} & (\%\ \text{minority} + \%\ \text{low-income} \\ & + \%\ \text{less than high school education} + \%\ \text{linguistic isolation} \\ & + \%\ \text{individuals under age 5} + \%\ \text{individuals over age 64}) / 6\end{aligned} \tag{3}$$

where:

% individuals under age 5= count of individuals under age 5 / Population count for Block Group,

% individuals over age 64 = count of individuals over age 64 / Population count for Block Group,

% less than high school education = count of individuals age 25 or over with less than high school degree/ Population 25 years and over for Block Group,

% linguistic isolation = count of households in linguistic isolation / Households (for linguistic isolation) for Block Group.

- We will also develop new screening capabilities for EJ, climate risks, and tribal areas, as well as upgrade the NEXUS to support visualization and analysis of EJ, climate risks, and tribal areas indicators, such as support to overlay on map (Fig. 18) and visualize with a bar chart, which is similar to EJSCEEN Reports (Fig. 19).

5. Develop a prototype of “Proximity and Spatial Analysis for Multi-Pollutant risks and EJ” module; allow to identify individual sources/facilities within a specific region/area and extend to their sector groups at the national level (“zoom-out” to nationwide)

- NEXUS now can be used to quickly identify top emitters NO_x, SO_2, $PM_{2.5}$, and heavy metal & VOCs HAPs near EJ areas of interest but is still lack in proximity and spatial analysis for multi-pollutant risks, EJ indicators, and climate risks together**.** To extend this analysis ability of NEXUS, we will develop a prototype of the “Proximity and Spatial Analysis for Multi-Pollutant risks and EJ” module, which can be applied to individual sources/facilities within a specific geographic area or sector groups at the national level. This new module will also equip NEXUS with multi-pollutant and climate risks and EJ analysis capabilities with a higher resolution (census tract and/or block group level). Three capabilities will be developed under this new module, including (1) “Proximity Analysis”, (2) “Graphical & Tabular Analysis”, (3) “Spatial Analysis”, as shown in Fig. 20.
- Under “Proximity Analysis”, it supports spatial analysis for multi-pollutant risk and EJ analysis for a selected industrial source (local) and its sector group (“zoom-out” to nationwide) as well as a selected monitoring site (or any census tract center). Users will be allowed to set a flexible “Radius of Impact” (e.g., 1 ~ 50 km) for a selected facility or monitoring site and create a summary table or chart for multi-pollutant risk and EJ analysis as shown in Fig. 21.

- We will also extend this module by providing a window to switch the location by clicking the marker icon, as shown in Fig. 22. Users are allowed to (1) select a point by clicking on the map, (2) or input a location, (3) or select a monitor site or facility from the drop-down control.
- Besides, we will also extend the "Proximity Analysis" by providing a legend configuration module, in which users can change the size, color, and title of the legend (Fig. 23).
- Under "Graphical & Tabular Analysis", the summary table or chart will help to cross-examine the potential linkages of multi-pollutant risks ($PM_{2.5}$, O_3, and Air toxics), demographic and socio-economic data (population, minority group, low income, etc.), and Climate risks as shown in Table 1 and Fig. 24. We will also extend the tool to provide plots/charts based on the selected table attributes when a facility is selected.
- We will provide "Spatial analysis" (map) functions for MP risks and EJ indicators as shown in Fig. 25.
- Besides, we will develop the new module to allow "zoom-in" and "zoom-out" actions as shown in Fig. 26. Both actions can be started after selecting a source/facility. The "zoom-out" function will extend the map to national wide and display all facilities with the same "Sector group" which are color-classified by the point value of MP. The "zoom-in" function will bring the map back to facility level and focus on the selected facility.

Task 3 Deliverables:

- Delivery of upgraded interim and final versions of NEXUS to EPA and user community – 12 months after task order award and as instructed and approved by EPA
- Delivery of updated interim and final versions on-line NEXUS User's Guides of EPA's air quality modeling assessment tools to EPA and user community – 12 months after project starts and as instructed and approved by EPA.

4.4 *Task 4: Support the development and improvements of EPA's Existing Air Quality Modeling Assessment Tool*

Under the instruction of EPA, the UNC Team (IE + SCUT) will update EPA's existing air quality modeling assessment tools. Firstly, SCUT will develop the new "deep machine-learning" RSM (DeepRSM) capabilities under RSM-VAT and conduct a pilot DeepRSM case study for the USA. Secondly, SCUT will upgrade the DFT to provide configuration options for the Downscaler data fusion technique and functions to output the data fusion results as well as upgrade the Model-VAT with the improved formula, timestamp, and remote access functions. Lastly, we will update the corresponding online User's Guides for the enhanced RSM-VAT and DFT.

We will support EPA in debugging, managing the code, and delivering improved RSM-VAT, DFT, and Model-VAT installation package and their source code to EPA and user community as instructed.

We will build a comprehensive set of training materials and programs for improved RSM-VAT and DFT, including "on-line User's Manual", and provide a public download website for information dissemination, sharing, and downloading of the enhanced RSM-VAT and DFT.

Subtasks:

- Develop the new "deep machine-learning" RSM (DeepRSM) capabilities under RSM-VAT; Conduct a pilot DeepRSM case study over a selected USA domain as instructed by EPA,
- Upgrade the DFT to provide configuration options for Downscaler data fusion technique and output both the non-grid based (GIS shapefile) data fusion results as well as the grid-based results,
- Upgrade the Model-VAT with the improved formula, timestamp and remote access functions.

Development Tools and Platform

- Development Environment: the Microsoft Visual Studio 2017 and .NET Framework version 4.6.1
- Programming Language: Microsoft Visual C#
- GIS: the open-source GIS tool DotSpatial

Main tasks to be developed or upgraded

2. Develop the new "deep machine-learning" RSM (DeepRSM) capabilities under RSM-VAT; Conduct a pilot DeepRSM case study over a selected USA domain as instructed by EPA

- In the current version of RSM-VAT, pf-RSM is the latest available method which requires at least 20 case numbers of CTM simulation for one region. But it still means a heavy computational burden if there are multiple regions. The pf-RSM has other disadvantages such as the polynomial functions are fitted individually for each spatial grid cell and therefore ignore the moderate degree of spatial correlation that is common among air pollutants. The functions are fitted solely based on simulated O_3 and $PM_{2.5}$ concentrations without considering the concentrations of related chemical species. To address these issues, Tsinghua University research team has updated the RSM to deep-learning-based response surface model (DeepRSM). This DeepRSM can characterize the response of O_3 and $PM_{2.5}$ concentrations to the full range of emission changes using a deep CNN with a carefully designed architecture and training method. As shown in Fig. 27, a trained DeepRSM model only required 2 CTM simulations (i.e., the concatenated baseline and clean condition indicators) for creating a single-region RSM. And it demonstrates the transferability to different time periods and spatial domains, which means a trained DeepRSM model is expected to be suitable for RSM fitting for different regions and time periods.

- Moreover, DeepRSM can well represent collinearity between O_3 and $PM_{2.5}$ concentrations and the moderately correlated indicators, and also preserve important spatial features of pollutants through the network.
- The previous studies suggested that the nonlinear response of O_3 and $PM_{2.5}$ concentrations to precursor emission controls can be represented by a set of polynomial functions (i.e., pf-RSM). The polynomial functions fitted by DeepRSM have a similar format to that fitted by pf-RSM, and their structure is expressed as follows

$$\Delta conc = \sum_{i=1}^{n} X_i \times (E_{NOx})^{a_i} \times (E_{SO2})^{b_i} \times (E_{NH3})^{c_i} \times (E_{VOCs})^{d_i} \quad (4)$$

where Δconc is the response of the O_3 and $PM_{2.5}$ concentrations (i.e., change relative to the baseline concentration) calculated from a polynomial function of four variables (E_{NOx}, E_{SO2}, E_{NH3}, E_{VOCs},); E_{NOx}, E_{SO2}, E_{NH3}, and E_{VOCs}, are the ratios of emission changes relative to baseline emissions for NO_X, SO_2, NH_3, and VOC, respectively; and ai, bi, ci, and di represent the nonnegative integer powers of E_{NOx}, E_{SO2}, E_{NH3}, and E_{VOCs}, respectively. X_i (the coefficient of term i) is determined by fitting the polynomial function with pf-RSM or DeepRSM for each spatial grid cell. The difference between the two methods is that DeepRSM predicts the coefficients with a carefully designed and well-trained deep CNN using 2 CTMs as the input (Fig. 28), while pf-RSM fit the polynomial function using 20 CTMs as the input.

- Based on the study above, we will develop the new DeepRSM capabilities under RSM-VAT to allow creating RSM with the trained DeepRSM model, as well as upgrade the "Visualization & Analysis" module and the "QA & Validation" module to support the analysis for the new DeepRSM results.
- Under the instruction from EPA, we will also conduct a pilot DeepRSM case study over a selected USA domain.

3. Upgrade the DFT to provide configuration options for Downscaler data fusion technique and output both the non-grid based (GIS shapefile) data fusion results as well as the grid-based results
   - In the previous DFT, the results for Downscaler data fusion technique are based on the "Identity" option. In this subtask, we will upgrade the DFT configuration options to include "Log" and "Square root" options for Downscaler data fusion technique under the instruction from EPA, as shown in Fig. 29.
   - We will develop a function for outputting both the non-grid based (GIS shapefile) and the grid-based data fusion results (Fig. 30).
4. Upgrade the Model-VAT with the improved formula, timestamp and remote access functions
   - We will improve the "formula" functions under the Model-VAT to provide more built-in functions. For example, using the aggregate function Max({[1]O3}) to create a new variable that is the maximum MDA8 ozone concentration from another variable that has MDA8 values on each day from May through September.
   - We will further improve the functions under the Model-VAT as suggested by EPA, such as convert the timestamp in 12-hour AM/PM format to military (24-hour) time and upgrade the remote access functions.

Task 4 Deliverables:

- Delivery of upgraded versions of existing air quality modeling assessment tools to EPA and user community – 12 months after task order award and as instructed and approved by EPA
- Delivery of updated on-line User's Guides of EPA's existing air quality modeling assessment tools to EPA and user community – 12 months after project starts and as instructed and approved by EPA

4.5 *Task 5: Support the upgrades of EPA's NEXUS Multi-Pollutant Analysis Tool*

The objectives of this NEXUS development and improvements project task include the following:

1. Develop a web-based version of NEXUS for EPA's website deployment and IT security clearing to be ready for public release,
2. Update NEXUS with AQ data and MP risk data based on EPA's new 2018 and 2019 MP modeling platform,
3. Develop a prototype to automate regional packets reporting and address Beta Testing Team's critical needs as instructed by EPA,

4. develop new climate risk indicators as 5th screening metric,
5. update EJ and demographic data based on most updated EJScreen 2.x census tract-level data, and
6. develop new capabilities for displaying and analyzing the meteorological and satellite data.

We will assist EPA in carrying out the subtasks listed below to meet these aforementioned objectives. EPA will first review and test the NEXUS interim versions submitted by the project team, including the online User's Guides, and then approve the final version delivered to EPA.

Under the instruction of the EPA, the UNC team (IE + SCUT) will first develop a web-based version of NEXUS, and deploy it on EPA's website or cloud server environment. We will develop the following functions in this version of NEXUS:

1. automate the regional packets reporting functions,
2. new climate risk indicators as the 5^{th} screening metric, and
3. new capabilities for displaying and analyzing the meteorological data.

Secondly, SCUT will update NEXUS data, including AQ data and MP risk data based on EPA's new 2018 and 2019 MP modeling platform, and EJ/demographic and climate risk data based on new census tract-level data released by EJScreen 2.x.

Lastly, the UNC team (IE + SCUT) will update the correspondingly online User's Guides for the enhanced NEXUS.

We will support EPA in debugging, managing the code, enhancing user-friendly GUI design and data V/A functions and delivering improved NEXUS installation package and their source code to EPA and user community as instructed.

We will build a comprehensive set of training materials and programs for upgraded NEXUS, including "online User's Manual" and "Quick Start Guide", training programs and workshops for international applications, and a public download website for information dissemination, sharing, and downloading of the enhanced NEXUS.

Subtasks:

- Develop a web-based version of NEXUS to be ready for EPA's website deployment and IT security clearance; Deploying and testing NEXUS on EPA's website or cloud server environment; Assist EPA in testing and debugging NEXUS and ensure the application is compliant with EPA's security policies; Update the online user's manual and quick tutorial guide to be ready for public release,
- Update NEXUS with AQ data and MP risk data based on EPA's new 2018 and 2019 MP modeling platform; Perform QA by comparing with previous 2017 MP data,
- Develop a prototype to automate the regional packets reporting functions and address Beta Testing Team's critical needs as instructed by EPA,
- Develop new climate risk indicators as 5th screening metric under main page and proximity analysis module, including indicators such as heat index and extreme temperature related mortality/stressor indices, wildfire vulnerability, flood, sea level rise, etc.,
- Update EJ/demographic and climate risk data based on new census tract-level data released by EJScreen 2.x,
- Develop new capabilities for displaying and analyzing the meteorological data such as wind roses plot and NO_2 satellite data to supplement fused O_3 and $PM_{2.5}$ data layer.

Development Tools and Platform

- Development Tools and Platform for client NEXUS
  - Development Environment: Microsoft Visual Studio 2022 and .NET Framework version 4.6;
  - Programming Language: C#;
  - GIS: the open-source GIS tool DotSpatial;

- Development Tools and Platform for web-based NEXUS
  - Development Environment: Microsoft Visual Studio 2022 and Visual Studio Code;
  - Programming Language: C# and JavaScript;
  - GIS: the open-source GIS server GeoServer;
  - Third party library: OpenLayers

Main tasks to be developed or upgraded

Develop a web-based version of NEXUS to be ready for EPA's website deployment and IT security clearance; Deploying and testing NEXUS in EPA's website or cloud server environment; Assist EPA in testing and debugging NEXUS and ensure the application is compliant with EPA's security policies; Update the online user's manual and quick tutorial guide to be ready for public release

The current NEXUS is developed under C/S (Client/Server) architecture. C/S architecture is a popular software design due to its strong interaction, high efficiency in processing a large number of datasets and high secure access mode. The application requires installation in the end-user computer and provides a user-interface (UI) that handles what the application feels and looks like and how it interacts with end-use. However, the disadvantages of it are also obvious. The overall executable of the current NEXUS is a very large file to install and set up, and it works in a narrow application area, usually used in Local Area Network (LAN) and has high maintenance costs (e.g., an upgrade occurs, all client programs need to change), which seriously limits its use on the internet. To address these issues, we will develop a web-NEXUS based on B/S (browser/Server) architecture under the instruction of EPA, which is easy to access via a web browser. Under B/S architecture, the program can be directly placed on the Wide Area Network (WAN); therefore, the end-users do not need to install individual software repeatedly and the web-NEXUS support multi-platform (e.g., Windows, Linux, and Mac OS) to access. Besides, once the web-NEXUS is updated and released in the server, all the users could access the latest version by visiting the weblink var internet, indicating its ease of ability to expand and maintain.

Below are the details for the development of web-based NEXUS:

1. Develop a web-based version of NEXUS to be ready for EPA's website deployment and IT security clearance
   - We will develop a protype of web-based NEXUS including the following four modules: Set-up standard module, Major Emission Sources, Monitor Sites/Data, and Proximity Analysis.
     i. Set-up standard module
        This module is helpful to identify the areas experiencing multi-pollutant air quality issues or other risks, including the high ozone, particle pollution, air toxics cancer risk, environment injustice, and also the climate risks. Under this module, users can choose and set up standard values of concentrations and risks for the selected pollutants or indicators (e.g., EJ/Demographics), which will be applied to the map to identify the areas above the set-up thresholds. The draft interface design of web-NEXUS is shown in Fig. 31 .
     ii. Major Emission Sources
        This module allows users to select pollutants of interest and then show the corresponding sorting results of pollutant sources (e.g., Top 10 pollutant sources), as an example shown in Fig. 32. The sorting results make sense in identifying the sources of most importance to selected pollutants and further recognizing the multi-pollutant nature of emissions sources, which can eventually provide scientific decision support to make more informed "co-control" strategies. As shown in Fig. 32, it will include the functions of "Major Point Sources", "Source Category Emissions", "Top X Emission Sources" and "Sector Emission Summary", which is similar to current NEXUS.
     iii. Monitor Sites/Data
        Similar to the monitor sites/data in current NEXUS, as shown in Fig. 33, this module will include $PM_{2.5}$, O_3, and air toxic data collected from air quality monitoring sites and also allow users to display monitors under the "Map" module with a new "Show Monitor Data" function. Besides, users are also allowed to click a monitor location symbol on the map to view the DV trend plot of $PM_{2.5}$ or ozone for the selected monitor site.
     iv. Proximity Analysis
        This module provides proximity and spatial analysis capabilities which are similar to current NEXUS. It especially supports spatial analysis for multi-pollutant risk and EJ & climate risk analysis for a selected industrial source (local) and its sector group as well as a selected monitoring site (or any census tract center). Users will be allowed to set a flexible "Radius of Impact" (e.g., 1 ~ 50 km) for a selected facility or monitoring site and create a summary table or chart for multi-pollutant risk and EJ & climate risk analysis. Fig. 34~Fig. 35 are examples for this module in web-based NEXUS.
2. Deploying and testing NEXUS in EPA's website or cloud server environment
   We will work with EPA to determine the best option for hosting the NEXUS web application deployment using
     i. Amazon Web Services (see details at: https://aws.amazon.com/blogs/devops/building-an-end-to-end-kubernetes-based-devsecops-software-factory-on-aws/),

ii. hosting on cloud.gov (see details at: https://cloud.gov/docs/deployment/deployment/), or other services that may be available.

Based on the chosen platform and its requirements, the UNC team will be able to develop a plan for deploying updates to the NEXUS application, in consultation with the EPA TOCOR and the EPA IT team.

3. Assist EPA in testing and debugging NEXUS and ensure the application is compliant with EPA's security policies
   - The UNC team (IE + SCUT) will be responsible for the following actions:
     i. Testing and debugging NEXUS
     ii. Keep our application compliant with security policies
     iii. Communicate any critical timeframes or issues that arise to NCC
     iv. Be open to NCC suggestions of technology improvements at an enterprise-level
     v. Keep ISSOs, ISOs, and IMOs informed of any changes to the application owner or application configuration
     vi. Keep any application owner-purchased licensing renewed to ensure no issues with security patching
     vii. Stay aware of end-of-life policies for technologies and keep the application compliant
4. Update the online user's manual and quick tutorial guide to be ready for public release
   - We will update all training materials, including the "online user's manual" and "quick tutorial guide" for the web-based version of NEXUS, which are similar to these for the client NEXUS (Fig. 37).
5. Update NEXUS with AQ data and MP risk data based on EPA's new 2018 and 2019 MP modeling platform; Perform QA by comparing with previous 2017 MP data
   - Most of the current datasets used in NEXUS are possibly out of date as time goes on. Therefore, we will continue to improve NEXUS to be compatible with AQ data and MP risk data based on EPA's new 2018 and 2019 MP modeling platforms as suggested by EPA, so that the data could be more accurate, which was conducive to better statistics and analysis, and the analysis results could be more in line with the actual situation.
   - Before integrating the updated MP dataset into NEXUS, we will conduct a series of comparisons suggested by EPA. Below is an example for MP dataset comparisons (Fig. 38).
6. Develop a prototype to automate the regional packets reporting functions and address Beta Testing Team's critical needs as instructed by EPA
   - Based on the latest NEXUS, we will continue to develop a prototype to automate the regional packet reporting functions and address Beta Testing Team's critical needs as instructed by EPA. This function will integrate the charts/tables into NEXUS so that users can quickly view or output the key information (e.g., AQ Risk & EJ Indicators, Source/Sector Emissions, and Monitor Sites/Data) of the selected areas. It will allow users to select multiple regions, including State, County, and Tract (Fig. 39) and support to generate a series of charts or reports according to user's selection.
   - AQ Risk & EJ Indicators

     The AQ Risk & EJ Indicators module will support to create a chart or table for the AQ risk ($PM_{2.5}$, Ozone, Air Toxic) and EJ (Demographic index, low-income, people of color, etc.) data of the selected areas or selected sites within specified radius (Fig. 40). This chart/table calculates summaries of multi-pollutant risks and EJ data by population-weighting the values of those census tracts within selected areas. Ambient concentrations are summarized by equal-weighting of the tract values.
   - Source/Sector Emissions

     The Source/Sector Emissions module has three sub-modules.
     i. The "Top X Emission Sources" module (Fig. 41) filters the pollutant emission sources by providing selections of pollutant, facility, or source category for the selected areas, and displays the filtering results in the chart and table.
     ii. The "Source Category Emissions" module (Fig. 42) supports to display the source category emissions (including "Point", "Non-Point", "On-Road", "Non-Road", and "Event") in table or pie chart for selected areas.
     iii. The "Sector Emission Summary" module (Fig. 43) provides source and sector emissions summaries for selected areas. And users are allowed to select one or more pollutants of interest (e.g., NO_x, $PM_{2.5}$, SO_2, VOC, CO_2e, PM_{10}, NH_3, GAS & VOC HAPs, etc.) to display or output.
   - Monitor Sites/Data
     i. This module displays monitor data of the selected areas on the window and allows users to view the trend plot of pollutants for the selected monitor site (Fig. 44).

7. Develop new climate risk indicators as the 5th screening metric under main page and proximity analysis module, including indicators such as heat index and extreme temperature related mortality/stressor indices, wildfire vulnerability, flood, sea level rise, etc.
    - NEXUS now has proximity screening capabilities to include $PM_{2.5}$, Ozone, Air Toxics, and EJ/demographic indicators. To further enrich the proximity screening capabilities of NEXUS, we will add climate risk as 5th screening metric under the main page and proximity analysis module as suggested by EPA based on the latest version of the NEXUS. Fig. 45 displays the draft design of these functions. It includes the following indicators:
        i. Heat index and extreme temperature related mortality/stressor indices
        ii. Wildfire Hazard Potential
        iii. Drought
        iv. 100 Year Flood Plain
        v. Coastal Flood Hazard
        vi. Sea Level Rise
8. Update EJ/demographic and climate risk data based on new census tract-level data released by EJScreen 2.x
    - To keep pace with EJScreen 2.x, we will update NEXUS with EJ/demographic and climate risk data based on new census tract-level data released by EJScreen 2.x, mainly including MINORPCT(% people of color), LOWINCPCT(% low income), LESSHSPCT(% less than high school education), LINGISOPCT(% linguistically isolated), UNDER5PCT(% under age 5) and OVER64PCT(% over age 64), as shown in Fig. 46.
9. Develop new capabilities for displaying and analyzing the meteorological data such as wind roses plot and NO_2 satellite data to supplement fused O_3 and $PM_{2.5}$ data layer
    - To utilize the tool with the capability to assess monitor siting, we will develop the meteorological data analysis function (e.g., including wind roses plot for selected monitor site) in NEXUS as suggested by EPA. As shown in Fig. 47, users are allowed to display a wind rose plot for selected monitoring site by clicking the site on map.
    - Besides, we will also incorporate the satellite NO_2 as the 3rd "AQ Concentration" option in addition to existing "Fused O_3" & "Fused $PM_{2.5}$" under the "Proximity analysis" module as suggested by EPA, as shown in Fig. 48.

Task 5 Deliverables:

- Delivery of upgraded interim and final versions of NEXUS, including the web-based NEXUS version, to EPA and user community – 12 months after task order award and as instructed and approved by EPA
- Delivery of updated interim and final versions on-line NEXUS User's Guides and Quick Tutorial Guide to EPA and user community

5 Task Order Deliverables Schedule

Table 5-1 illustrates the estimated schedule for the task order's deliverables.

Table 5-1: Deliverables schedule

Deliverable	Projected completion date
Task 1: Task Order Administration	
QAPP Draft	Within one month of the effective date of the TO
QAPP Final	Within 7 days of EPA comments
Monthly report and project summary report	Monthly report after task order award and project summary report at the end of project
Task 2: Support the development and improvements of EPA's "Flexible Air quality Scenario Tool – Community Edition" (FAST-CE) Tool	
Delivery of upgraded interim and final versions of FAST-CE to EPA and user community	12 months from TO award
Delivery of updated interim and final versions on-line FAST-CE User's Guides of EPA's air quality modeling assessment tools to EPA and user community	12 months from TO award
Task 3: Support the development and improvements of EPA's NEXUS Multi-Pollutant Analysis Tool	
Delivery of upgraded interim and final versions of NEXUS to EPA and user community	12 months from TO award
Delivery of updated interim and final versions on-line NEXUS User's Guides of EPA's air quality modeling assessment tools to EPA and user community	12 months from TO award
Task 4: Support the development and improvements of EPA's Existing Air Quality Modeling Assessment Tool	
Delivery of upgraded versions of existing air quality modeling assessment tools to EPA and user community	12 months from TO award
Delivery of updated on-line User's Guides of EPA's existing air quality modeling assessment tools to EPA and user community	12 months from TO award
Task 5: Support the upgrades of EPA's NEXUS Multi-Pollutant Analysis Tool	
Delivery of upgraded interim and final versions of NEXUS, including the web-based NEXUS version, to EPA and user community – 12 months after task order award and as instructed and approved by EPA	12 months from TO award
Delivery of updated interim and final versions on-line NEXUS User's Guides and Quick Tutorial Guide to EPA and user community	12 months from TO award

6 Staff Resources

This section lists the technical staff to be used during this TO.

6.1 UNC-IE Technical Staff

Sarav Arunachalam (BPA Program Manager 2) will serve as the overall Project Manager on this TO. He will be the primary point of contact on this TO with the EPA. He will provide overall technical expertise on this task and will also liaison with the proposed subcontractor South China Institute of Technology (SCUT) in the performance of the proposed work.

Liz Adams (Subject Matter Expert 3) will assist installing the AQMAT tool on UNC's Virtual Computing Cluster (VCL) for testing and with documentation.

Catherine Seppanen (Subject Matter Expert 3) will assist with reviewing/implementing the web-based NEXUS on the UNC/EPA server and liaison with the EPA IT team to ensure that all security protocols are followed as needed.

Bin Cheng (Scientist 2) will assist with testing the web-based NEXUS and the enhanced NEXUS and reviewing/refining the documentation and user's guide.

Erin Valentine (Analyst 2) will assist with preparing and technical editing of the monthly reports before submission to the EPA.

6.2 Subcontractor Technical Staff

South China University of Technology proposes the following staff for this TO.

Yun Zhu..................................Subject Matter Expert 3
Zhenhua Zhu............................Subject Matter Expert 3
Shicheng Long..........................Subject Matter Expert 2
Wenwei Yang...........................Subject Matter Expert 2
Jingyin Li.................................Scientist 2
Mengmeng Zhang....................Scientist 2
Ziyi Liu....................................Scientist 2
Xuehao Yan.............................Scientist 1
Hui Yuan..................................Scientist 1

6.3 *Level of Effort*

Title:	**PR-OAR-21-00981, "Air Quality Modeling Assessment Tools (AQMAT) Development"**
Institution:	**The University of North Carolina at Chapel Hill**
Department:	**Institute for the Environment**
Project Period:	**September 13, 2021 - September 12, 2024**

Task No.	Task Description	Labor Category	Base Period Hours	Option I LOE Hours	Option II LOE Hours	All Period Total Hours
Task 1	Task Order Administration	Analyst 2	24	48	48	120
		Project Manager 1	8	-	8	16
		Project Manager 2	24	36	36	96
		Task 1 Subtotal	**56**	**84**	**92**	**232**
Task 2	Support the development and improvements of EPA's "Flexible Air quality Scenario Tool – Community Edition" (FAST-CE) Tool	Scientist 1	233	36	74	343
		Scientist 2	256	152	118	526
		Analyst 2	4	4	4	12
		Subject Matter Expert 2	396	197	154	747
		Subject Matter Expert 3	135	110	52	297
		Task 2 Subtotal	**1,024**	**499**	**402**	**1,925**
Task 3	Support the development and improvements of EPA's NEXUS Multi-Pollutant Analysis Tool	Scientist 1	234	60	156	450
		Scientist 2	284	207	184	675
		Analyst 2	4	4	4	12
		Subject Matter Expert 2	434	345	246	1,025
		Subject Matter Expert 3	170	195	82	447
		Task 3 Subtotal	**1,126**	**811**	**672**	**2,609**
Task 4	Support the development and improvements of EPA's Existing Air Quality Modeling Assessment Tool	Scientist 1	88	78	338	504
		Scientist 2	108	253	368	729
		Analyst 2	4	4	4	12
		Subject Matter Expert 2	150	430	600	1,180
		Subject Matter Expert 3	52	217	209	478
		Task 4 Subtotal	**402**	**982**	**1,519**	**2,903**
Task 5	Support the upgrades of EPA's NEXUS Multi-Pollutant Analysis Tool	Scientist 1	-	170	-	170
		Scientist 2	-	458	-	458
		Analyst 2	-	8	-	8
		Project Manager 2	-	23	-	23
		Subject Matter Expert 2	-	962	-	962
		Subject Matter Expert 3	-	682	-	682
		Task 5 Subtotal	**-**	**2,303**	**-**	**2,303**
All Tasks Grand Total		Scientist 1	555	344	568	1,467
		Scientist 2	648	1,070	670	2,388
		Analyst 2	36	68	60	164
		Project Manager 1	8	-	8	16
		Project Manager 2	24	59	36	119
		Subject Matter Expert 2	980	1,934	1,000	3,914
		Subject Matter Expert 3	357	1,204	343	1,904
		Grand Total	**2,608**	**4,679**	**2,685**	**9,972**

Appendix A: Tables and Figures

Figures

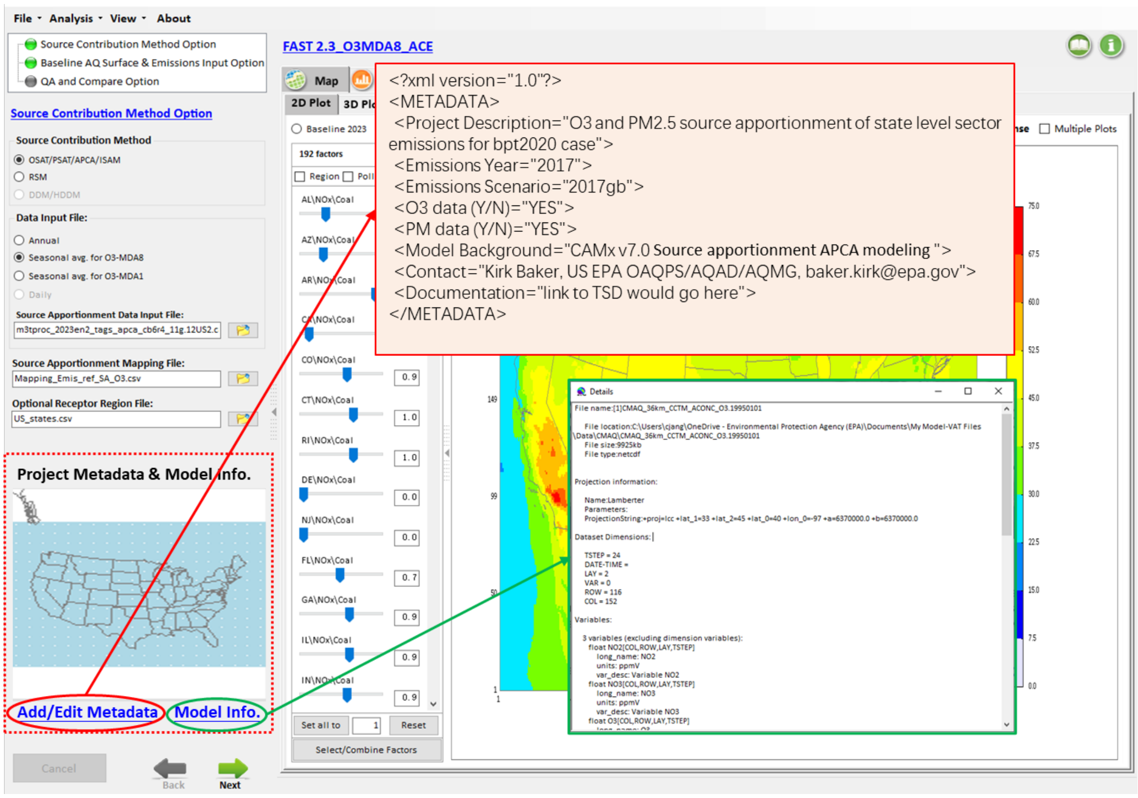


Fig. 1 The draft design of the “Metadata” function

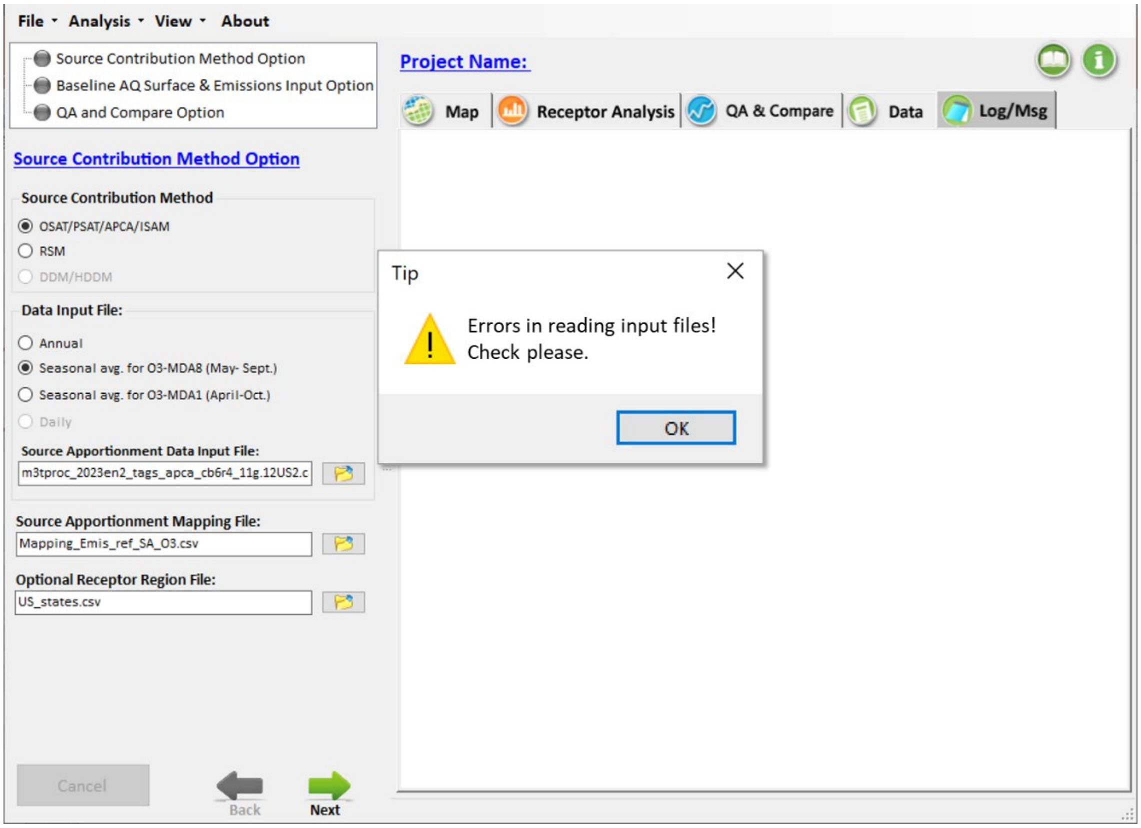


Fig. 2 Draft design of the warming pop-up window

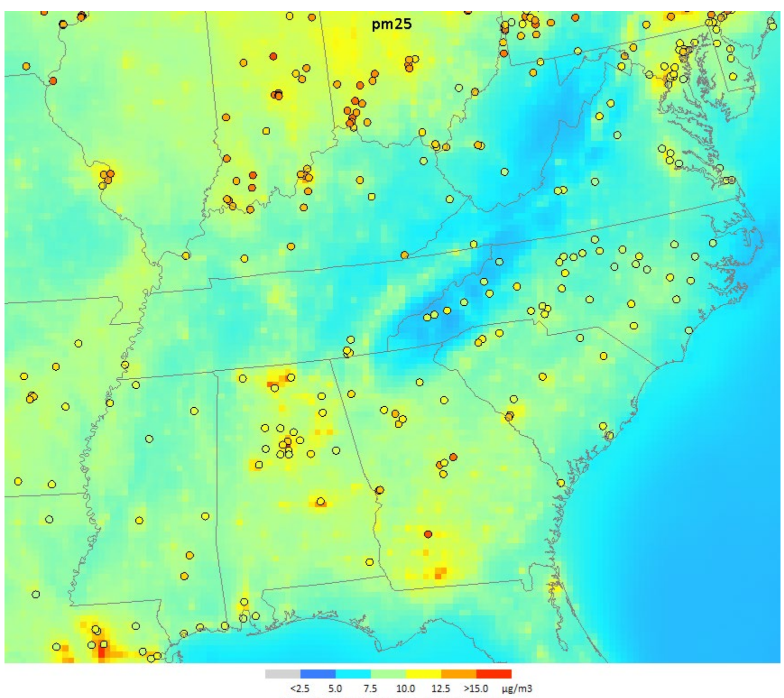


Fig. 3 Project the O_3 and $PM_{2.5}$ Design Values (DVs) based on monitor data

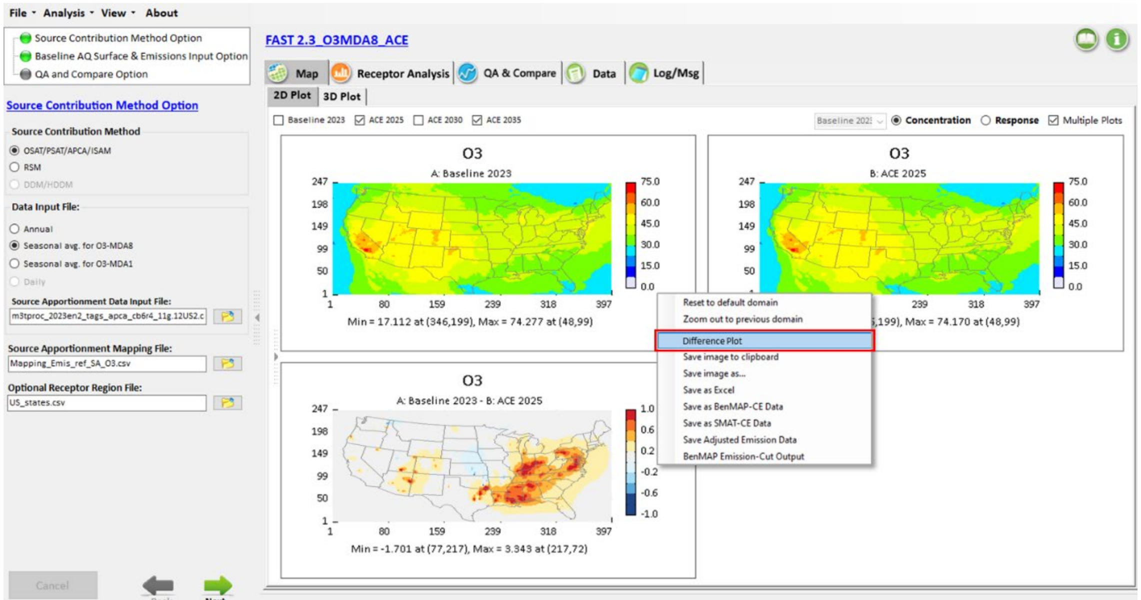


Fig. 4 The "Different Plot" function under the Map module

	A	B	C	D	E	F
1	Column	Row	Metric	Seasonal Metric	Statistic	Values
2	1	1	D24HourMean	QuarterlyMean	Mean	0.03044
3	2	1	D24HourMean	QuarterlyMean	Mean	0.03031
4	3	1	D24HourMean	QuarterlyMean	Mean	0.01949
5	4	1	D24HourMean	QuarterlyMean	Mean	0.01467
6	5	1	D24HourMean	QuarterlyMean	Mean	0.01546
7	6	1	D24HourMean	QuarterlyMean	Mean	0.01681
8	7	1	D24HourMean	QuarterlyMean	Mean	0.01188
9	8	1	D24HourMean	QuarterlyMean	Mean	0.00916
10	9	1	D24HourMean	QuarterlyMean	Mean	0.01159

Fig. 5 Example of the BenMAP-CE ready file

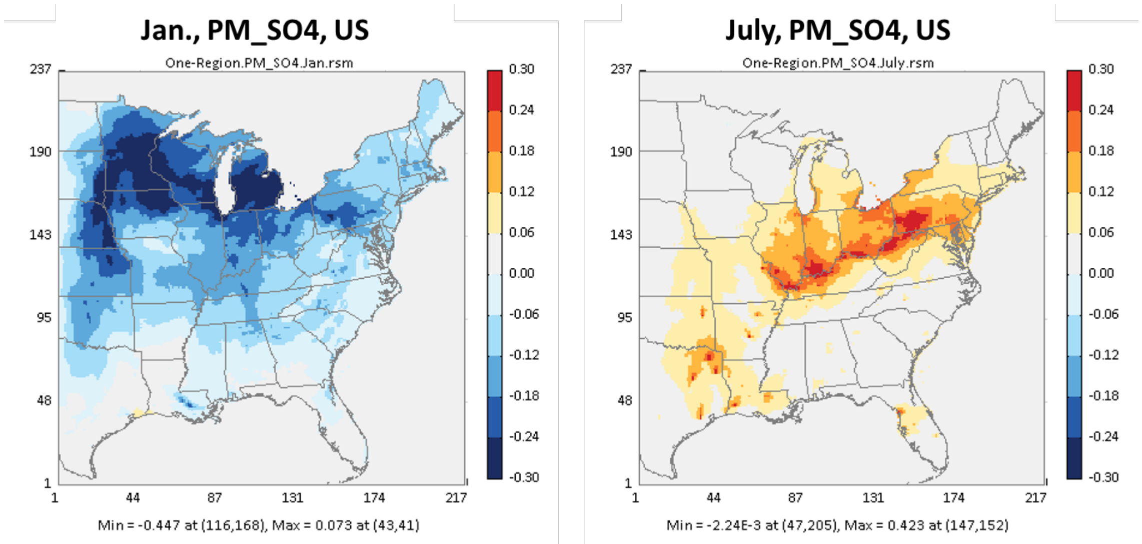


Fig. 6 Example of RSM Response for SO_4^{2-} under all man-made NOx 100% reduction in January and July

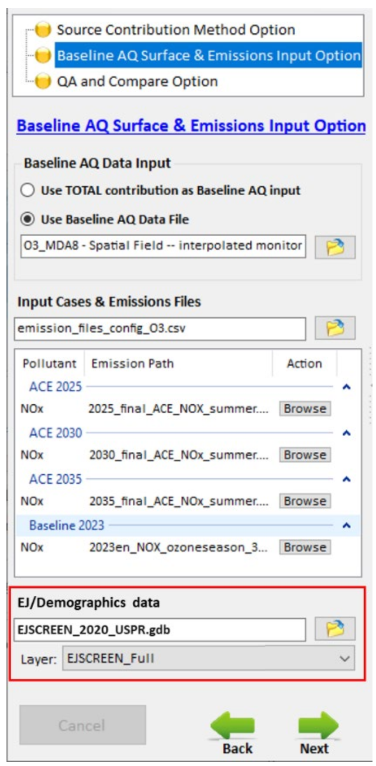


Fig. 7 Draft design of the EJ/demographic data input option

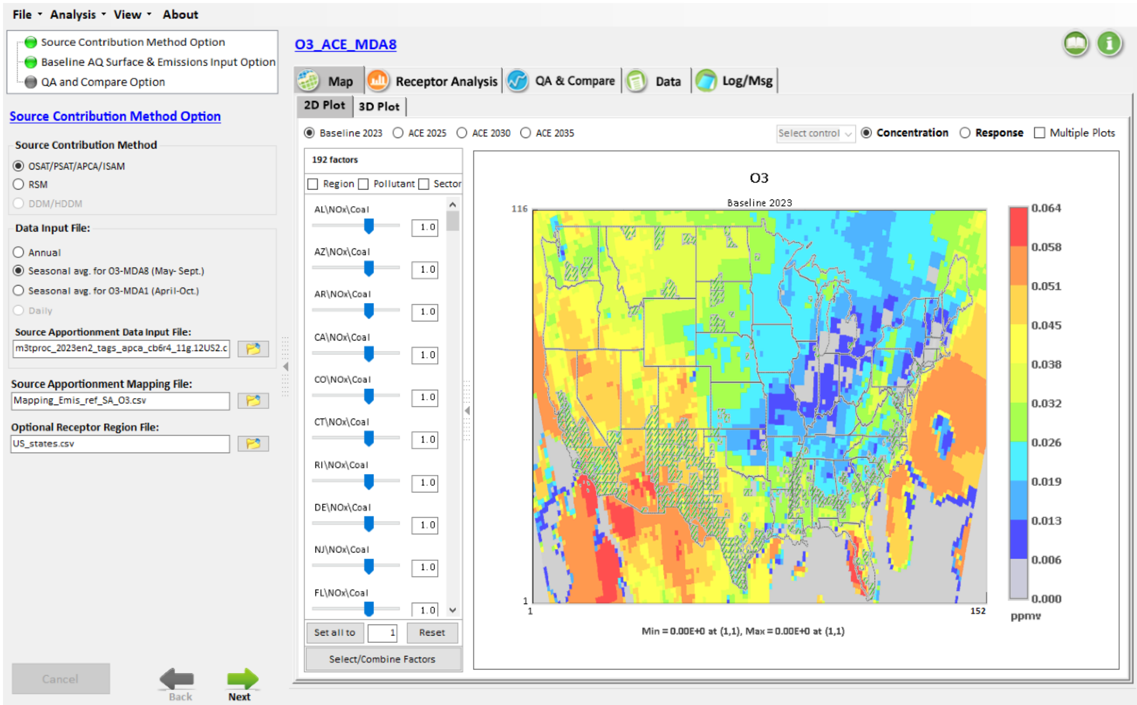


Fig. 8 Draft design of the "Map" module with EJ/demographic data display

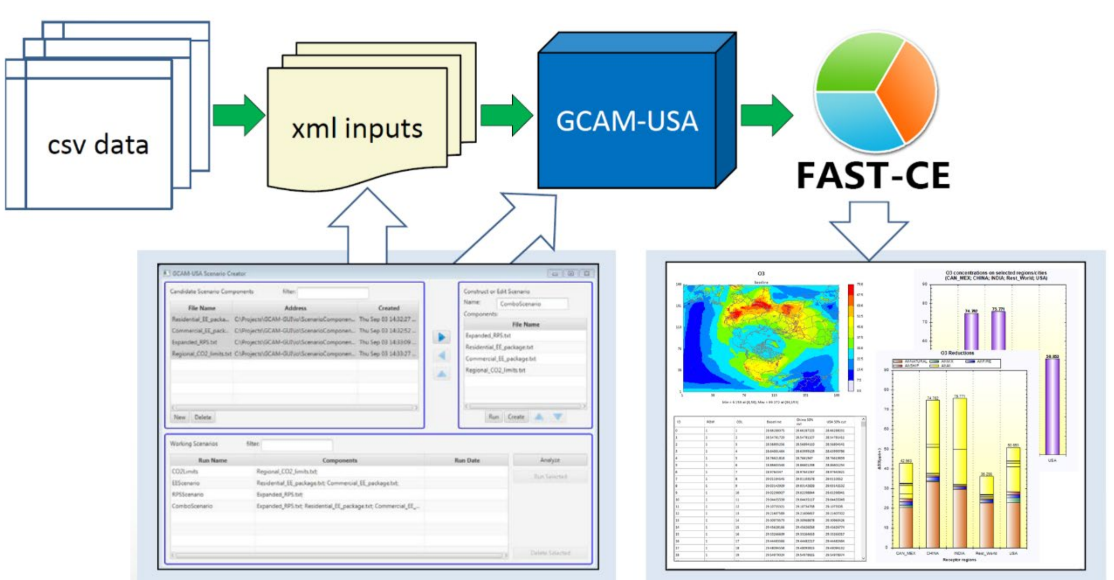


Fig. 9 key flow operation of the "GCAM scenario builder" module

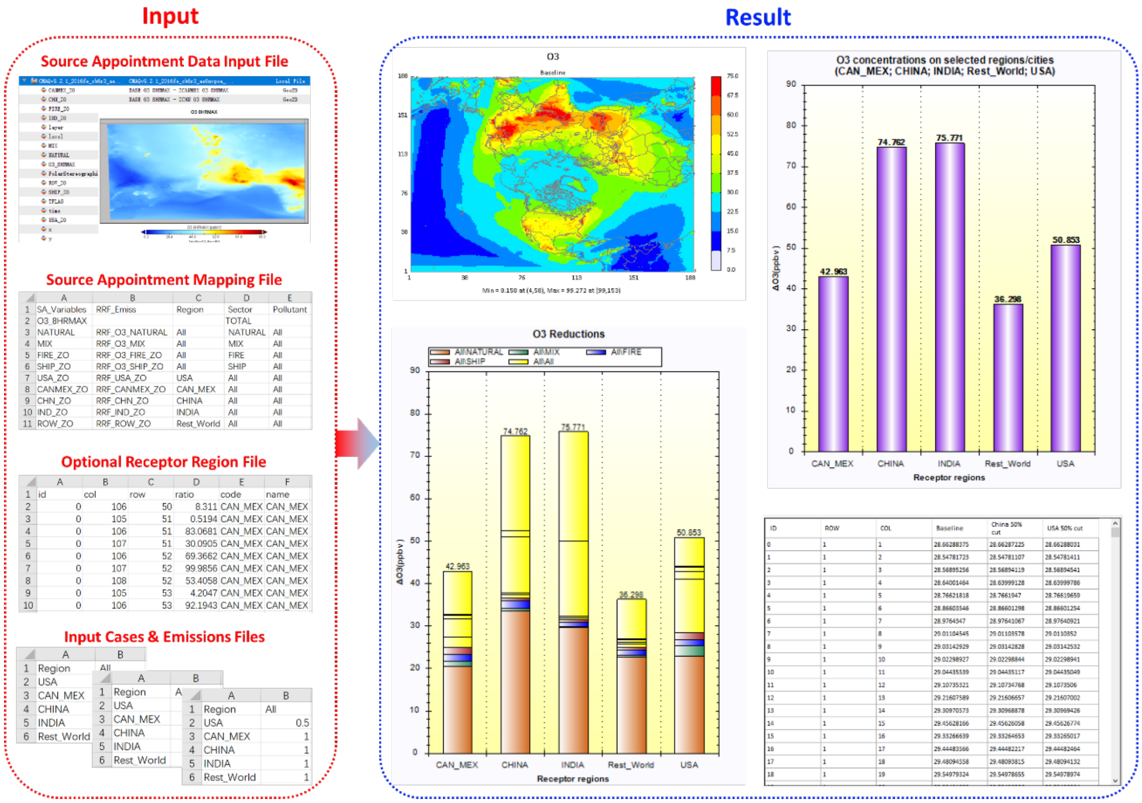


Fig. 10 Hemispheric-CMAQ applications in FAST-CE

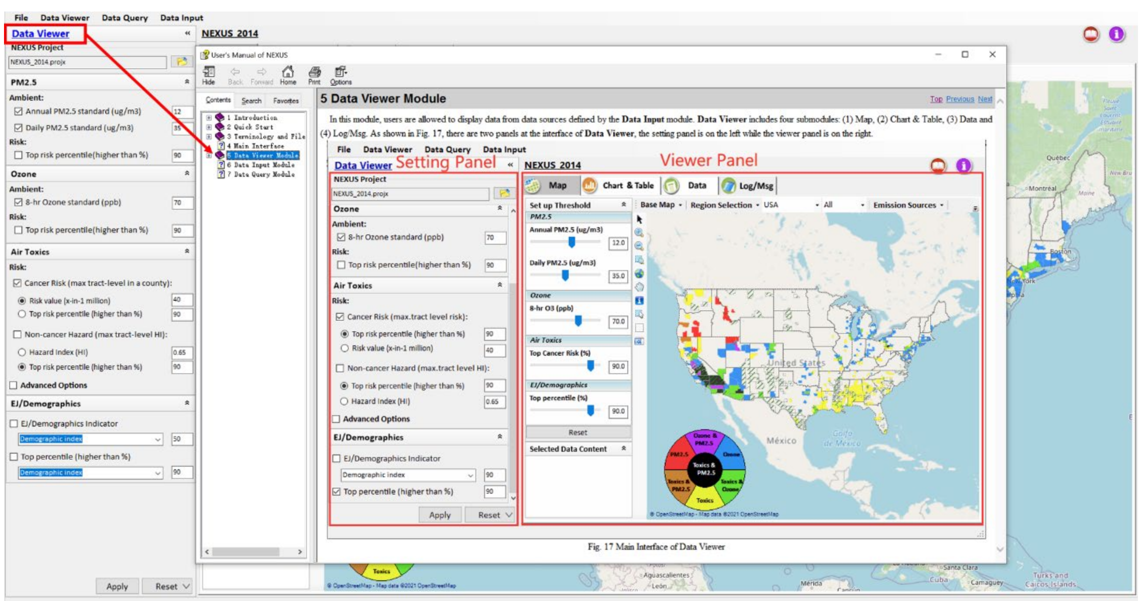


Fig. 11 User's manual for the NEXUS

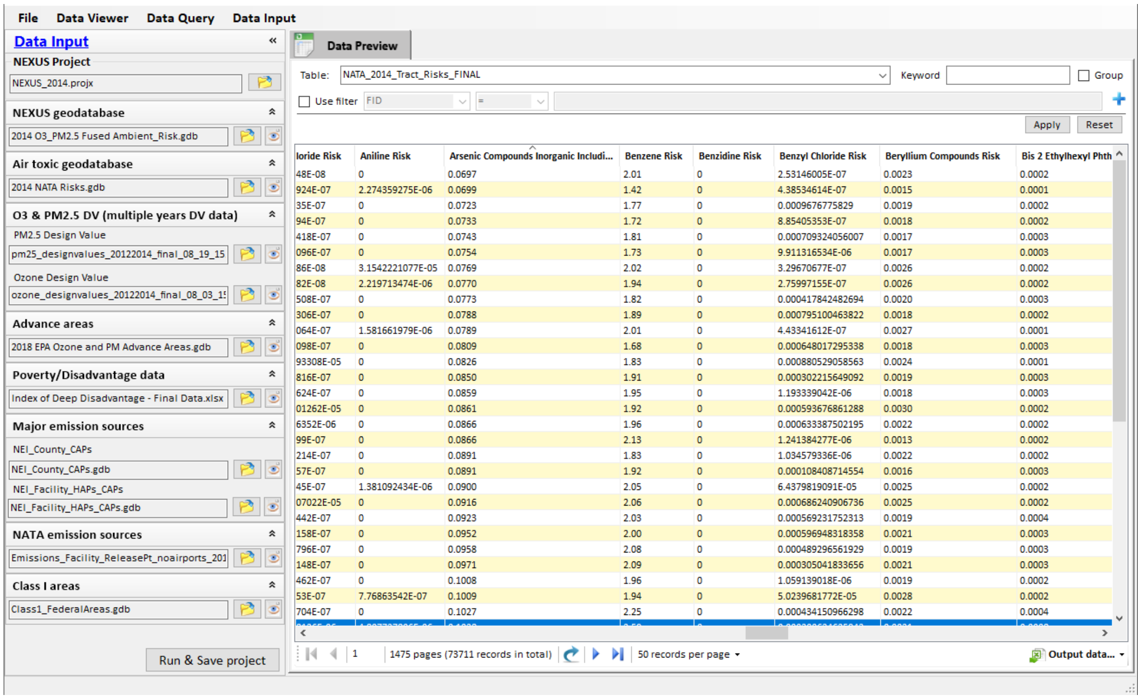


Fig. 12 The "Data Input" module of NEXUS

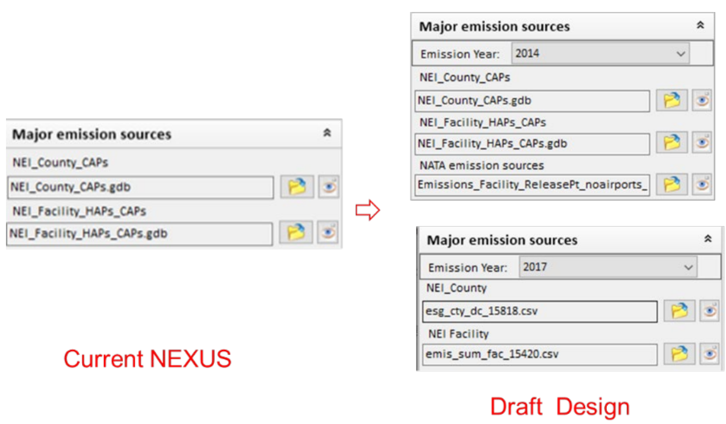


Fig. 13 Draft design for supporting emission data from different years.

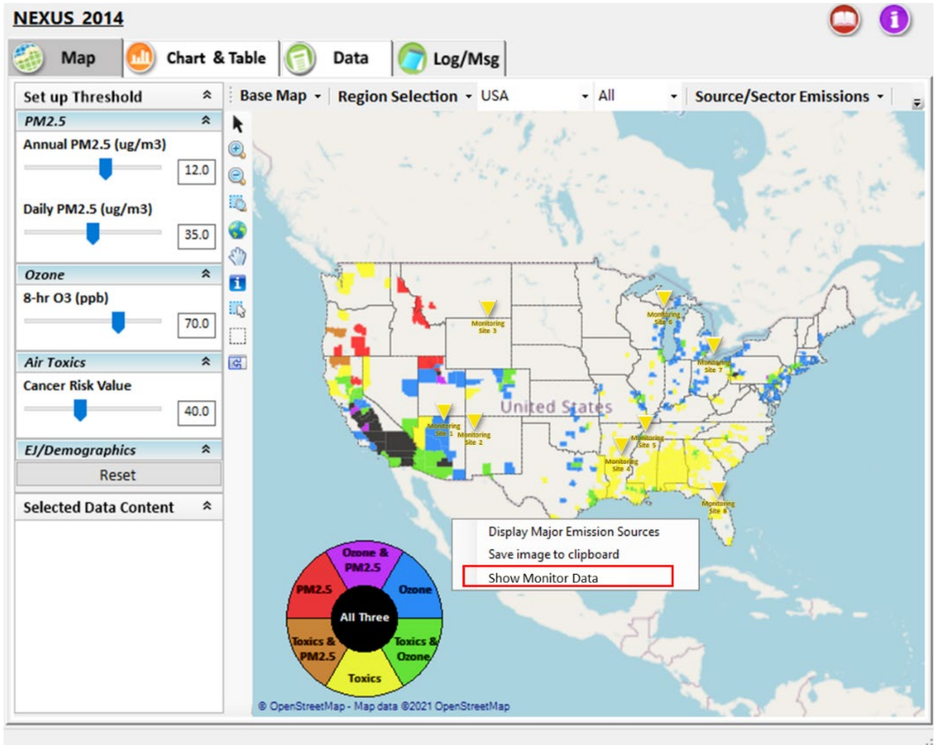


Fig. 14 The "Show Monitor Data" function under the "MAP" module

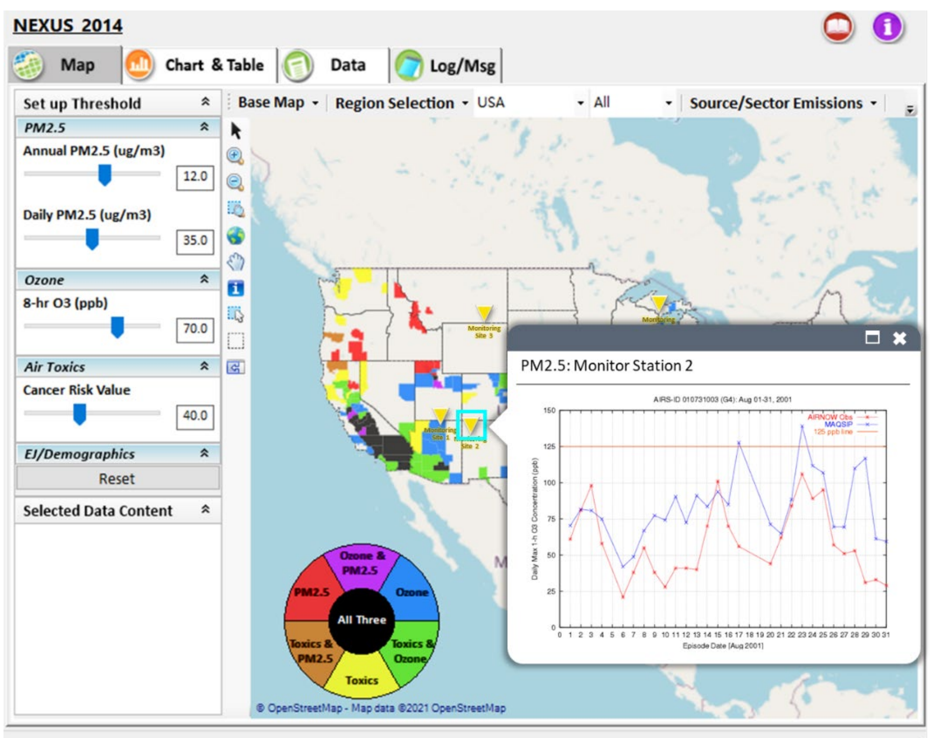


Fig. 15 Example of showing the air quality trend of the selected monitor site

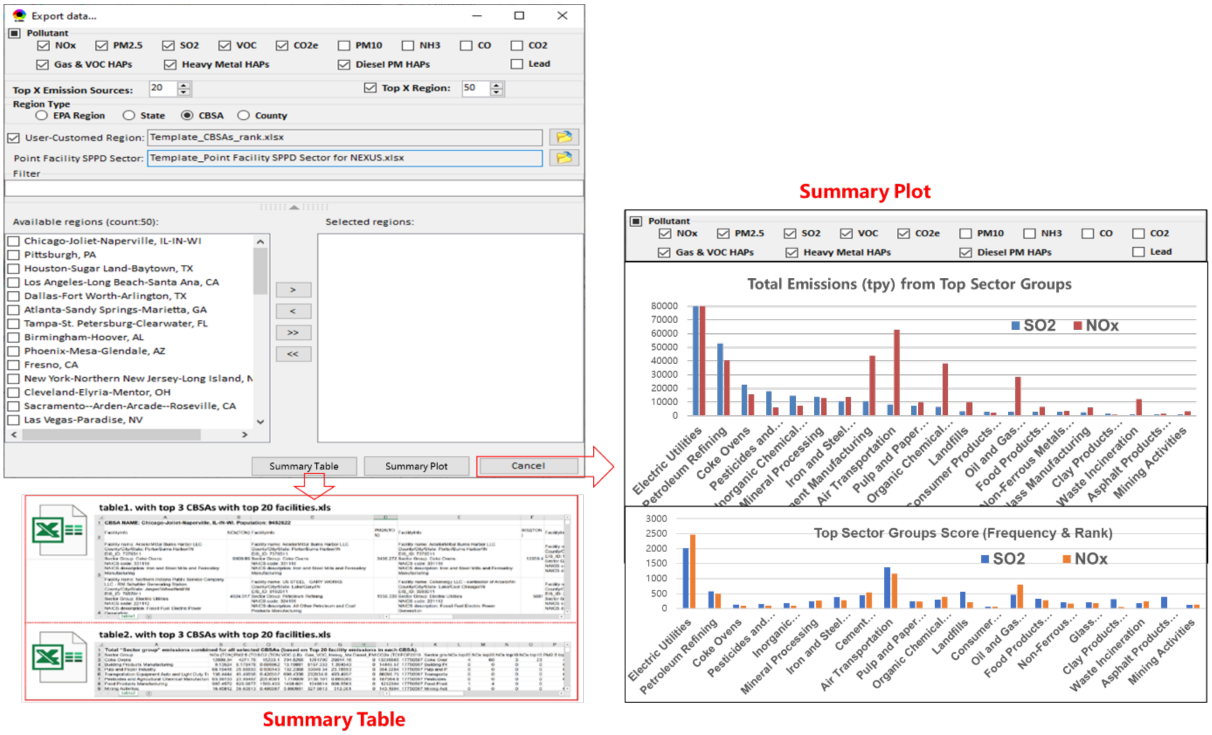


Fig. 16 Draft design of the "Sector Emissions Summary" function

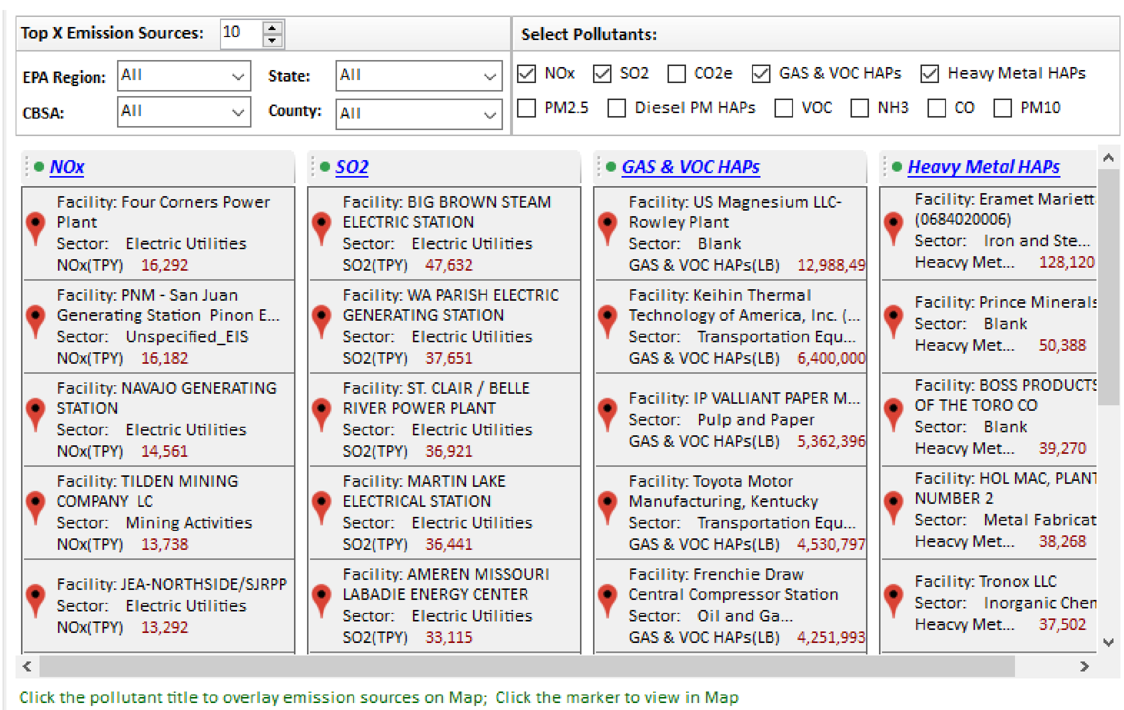


Fig. 17 Draft design of source category emissions table

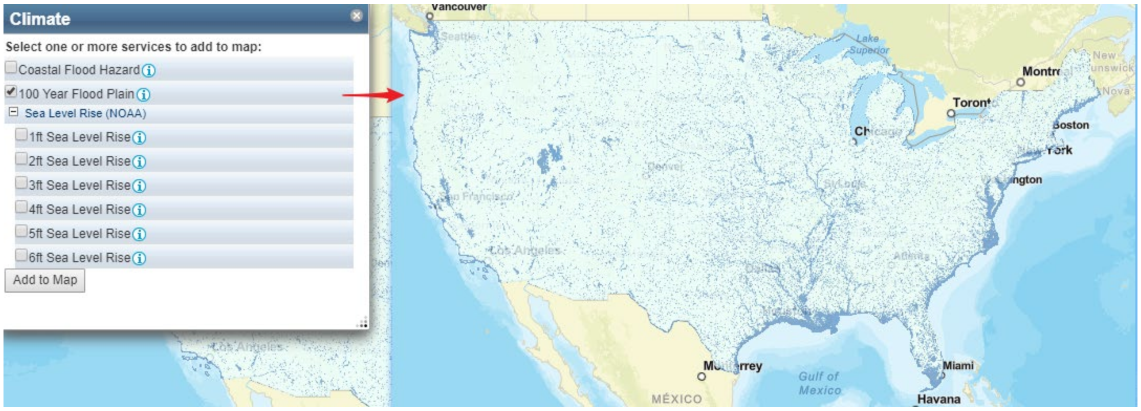


Fig. 18 Draft design of overlaying climate indicators on the map.

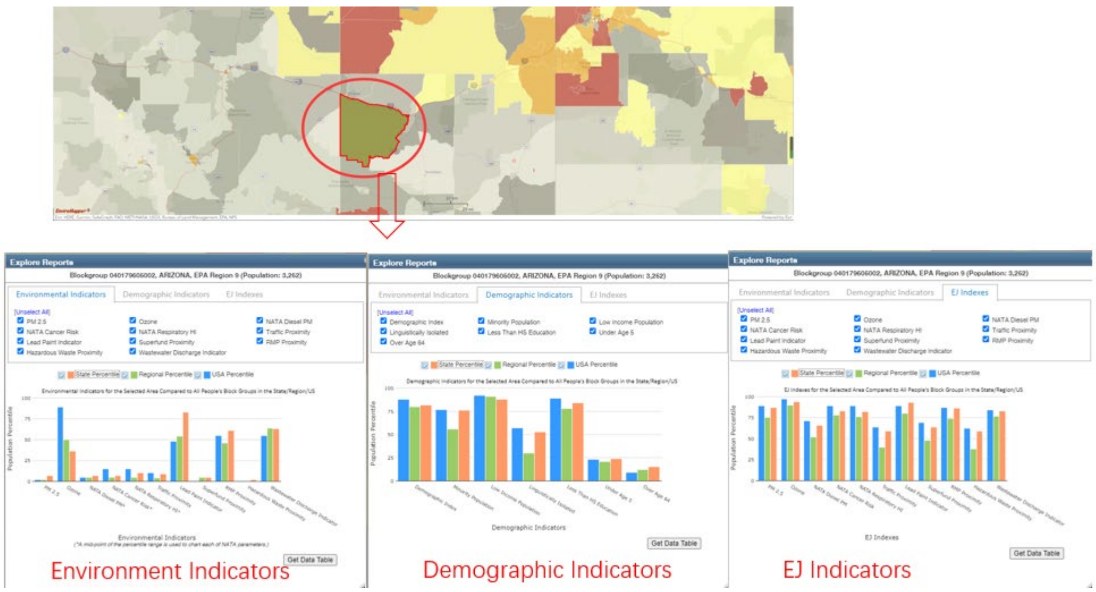


Fig. 19 Visualization and analysis functions for EJ/demographic data under the NEXUS

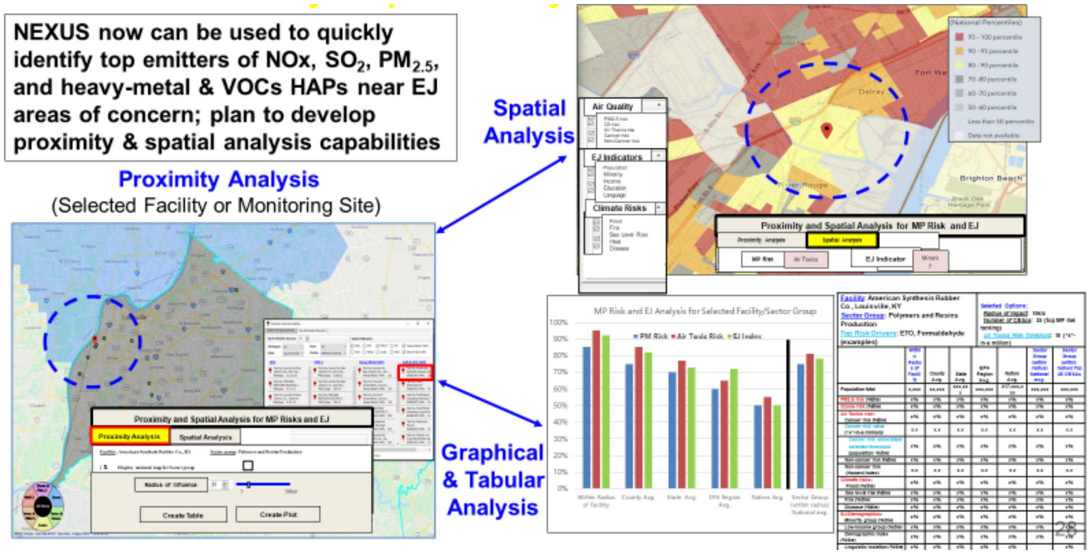


Fig. 20 Draft design of the "Proximity and Spatial Analysis for Multi-Pollutant risks and EJ" module

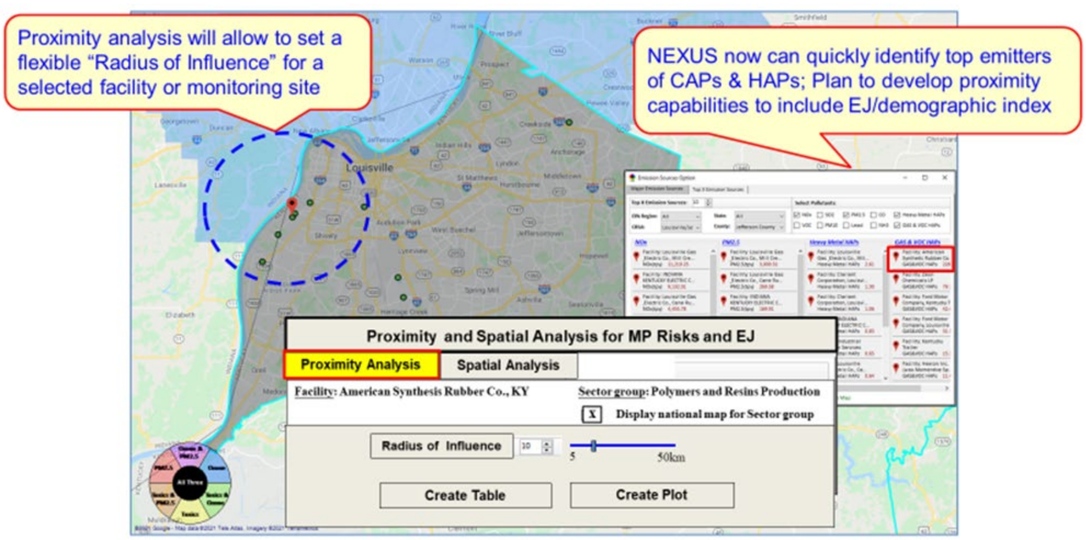


Fig. 21 The draft design of the "Proximity Analysis" function

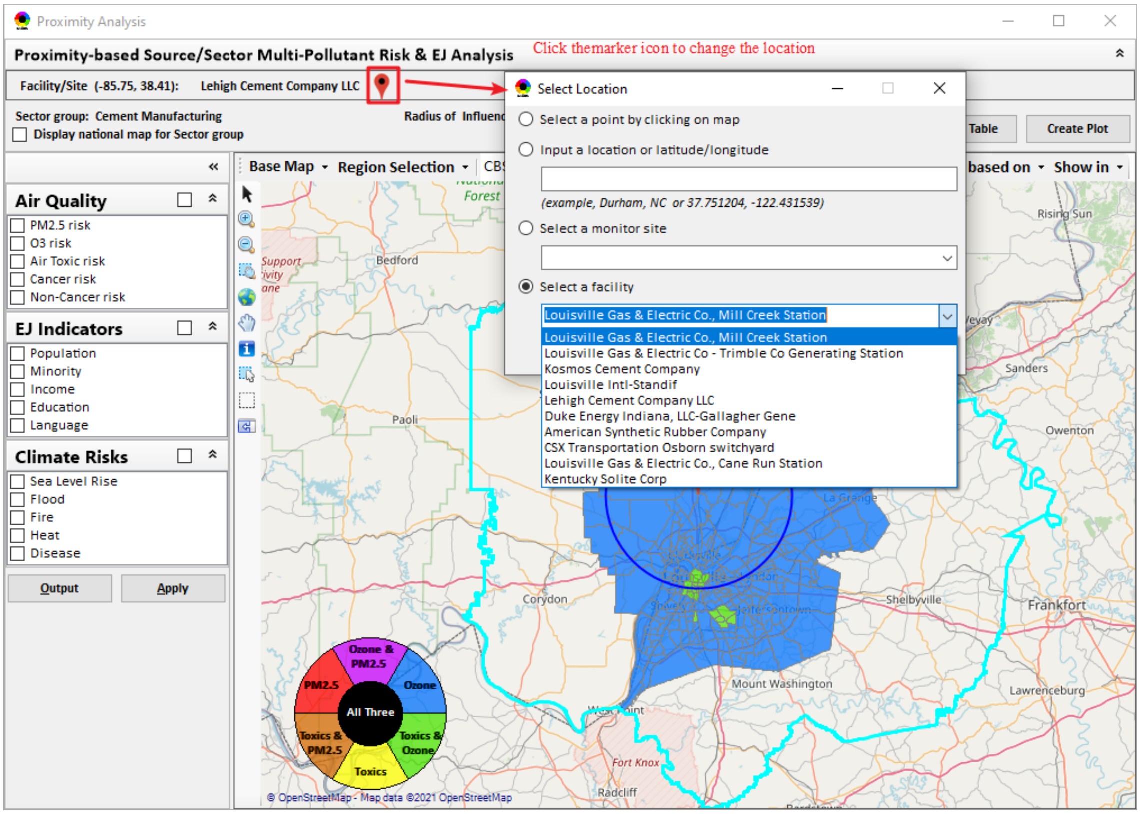


Fig. 22 Example for "Select location"

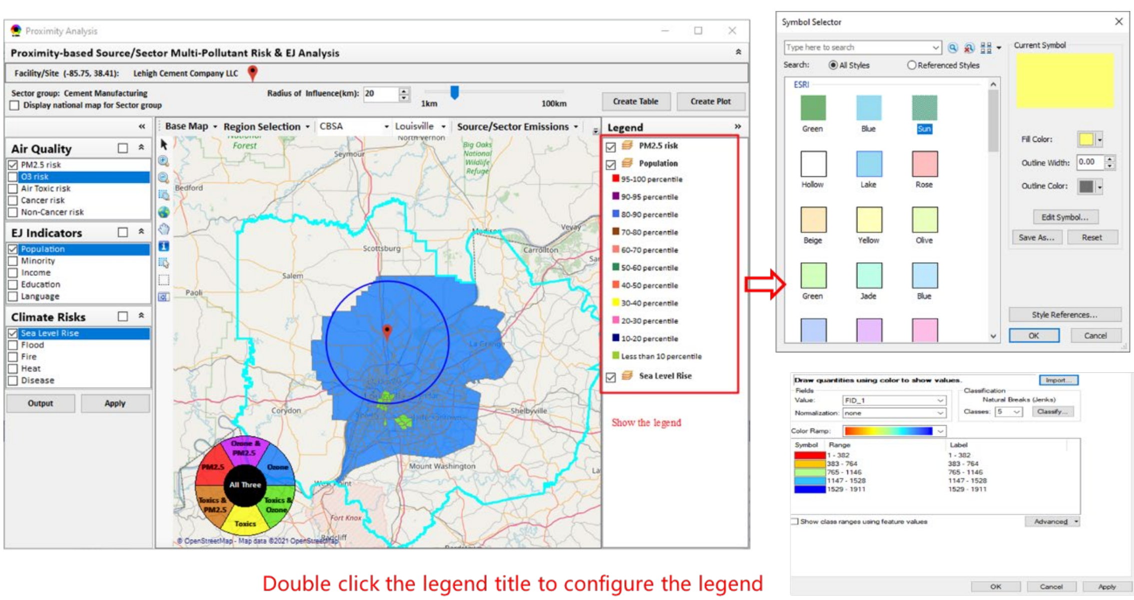


Fig. 23 Draft design of Legend Configuration module

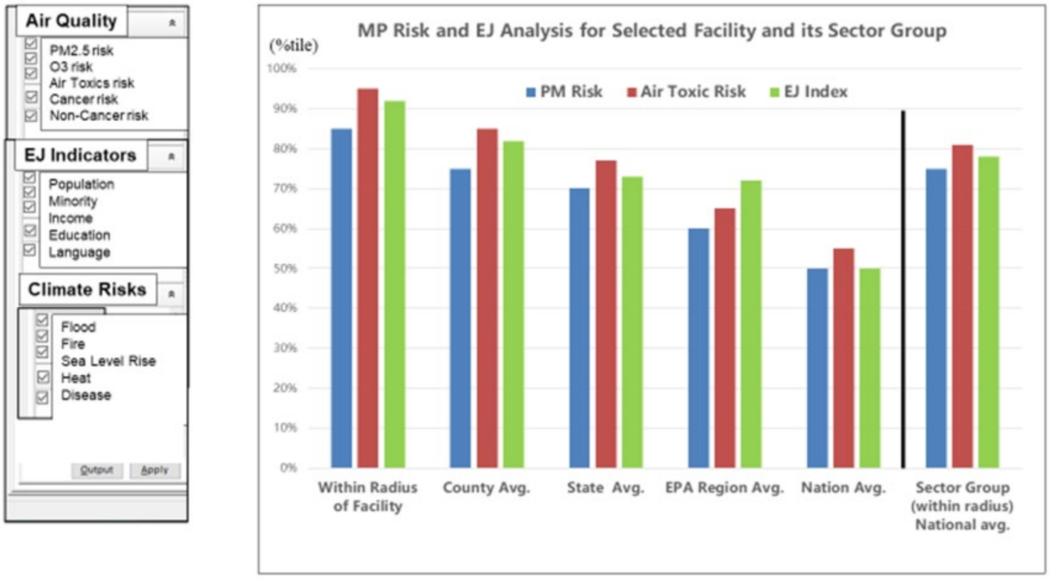


Fig. 24 Example summary chart for "Spatial Analysis"

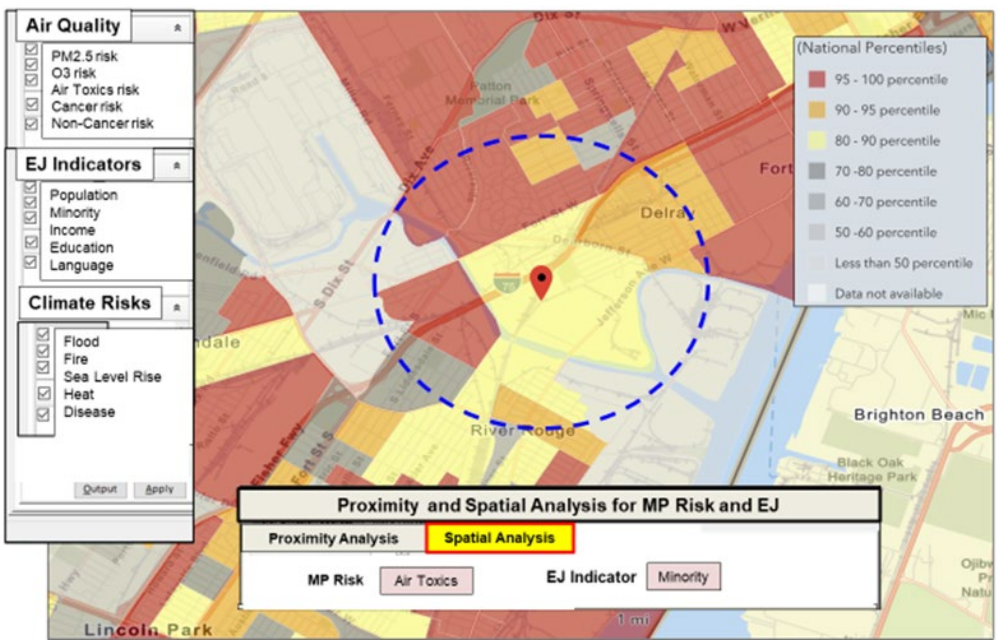


Fig. 25 The draft design of the "Spatial Analysis" function

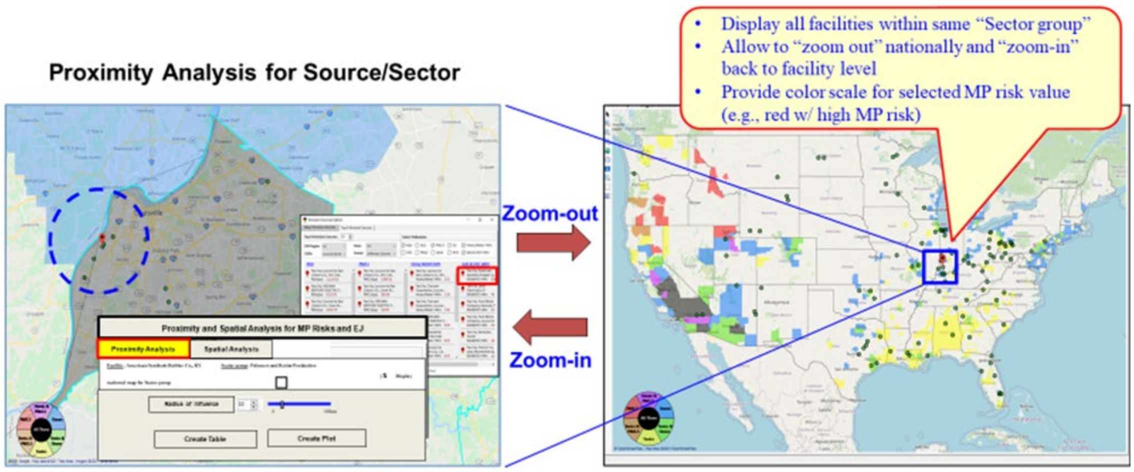


Fig. 26 The "zoom-in" and "zoom-out" functions under the "Proximity and Spatial Analysis for Multi-Pollutant risks and EJ" module

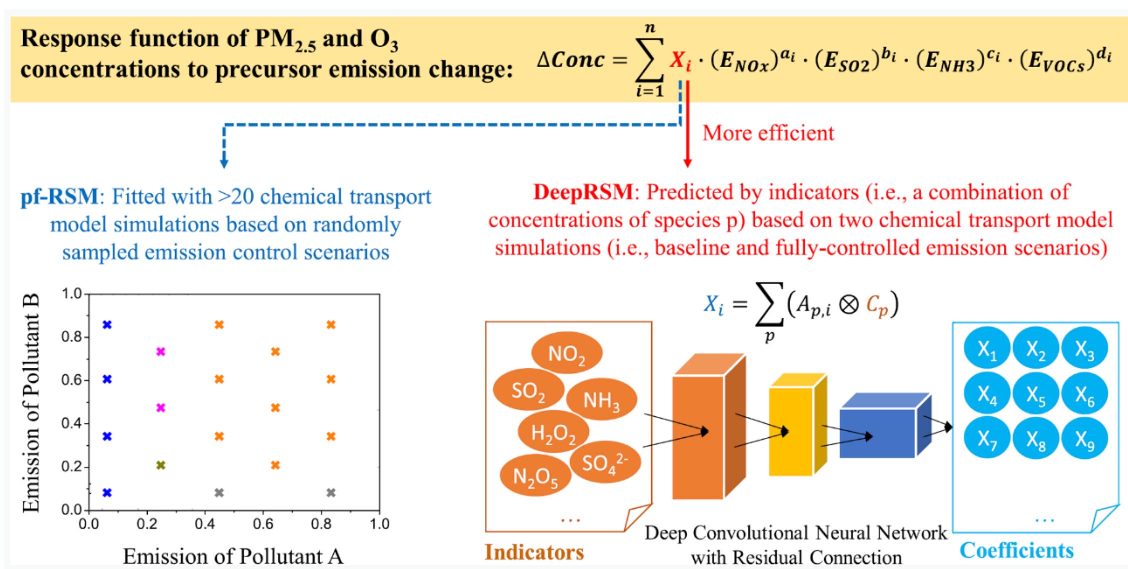


Fig. 27 Conceptual framework of pf-RSM and DeepRSM methods

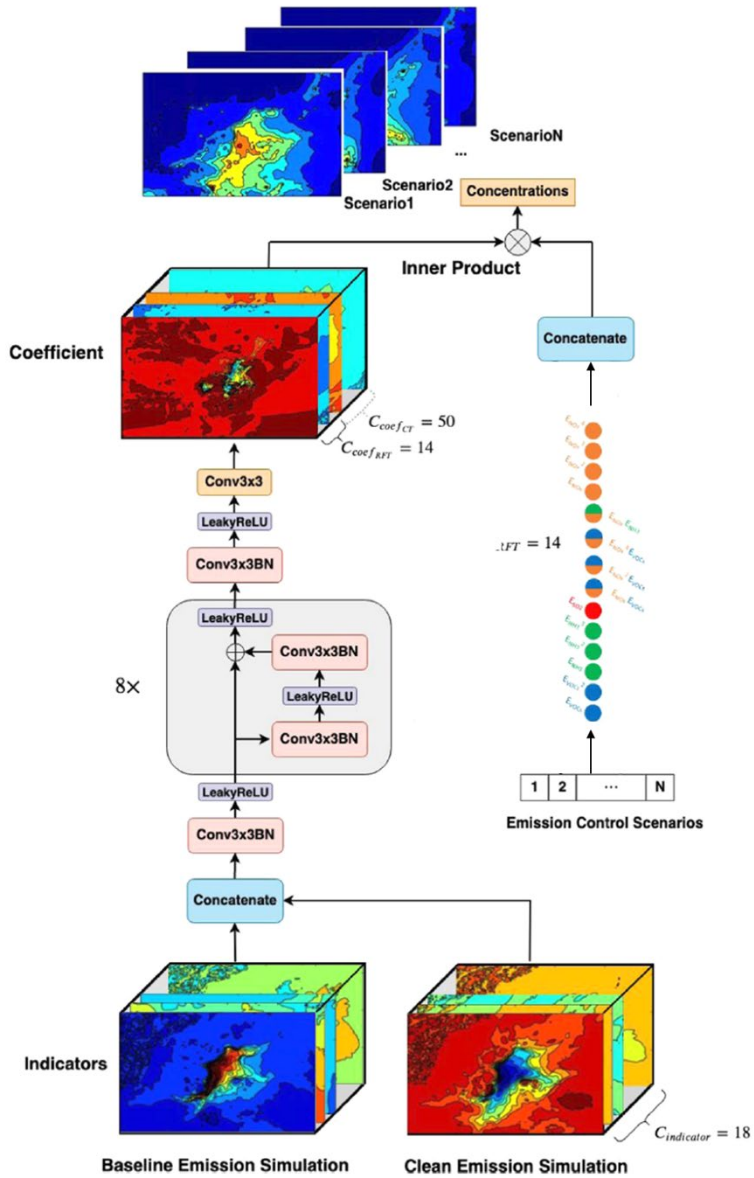


Fig. 28 CNN flow of the DeepRSM with optimized polynomial structure for predicting the air quality response functions

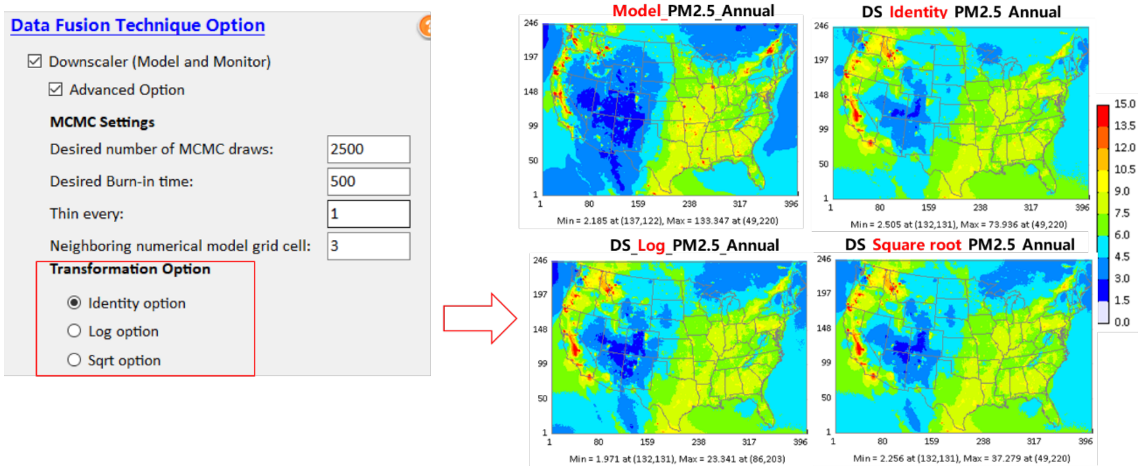


Fig. 29 Draft Design of configuration options for DS

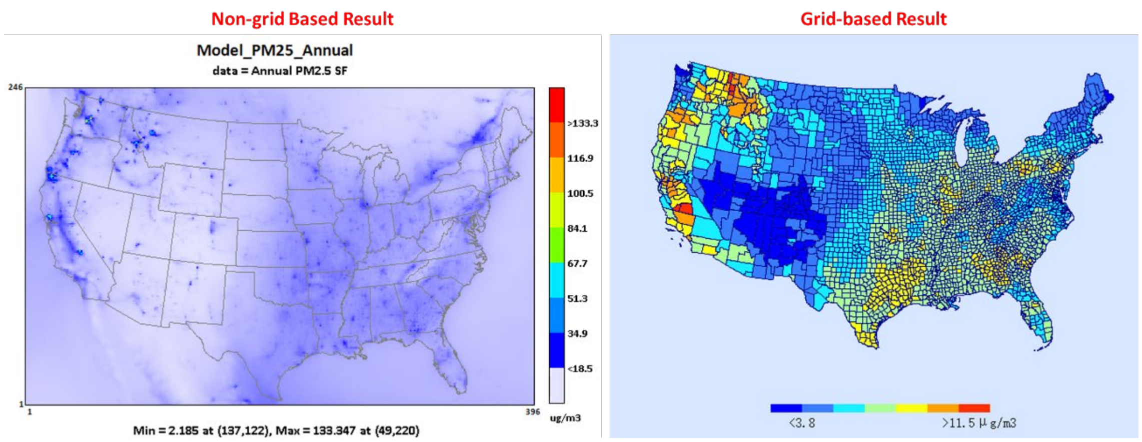


Fig. 30 Non-grid based and grid-based data fusion result

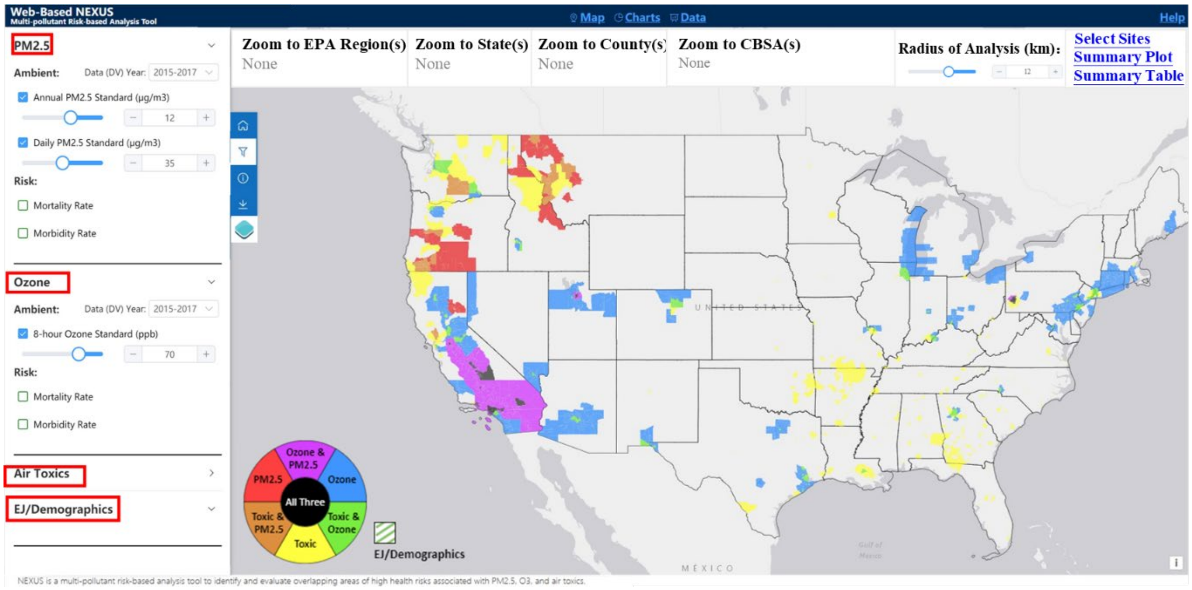


Fig. 331 Example of set-up standard module in protype of web-NEXUS

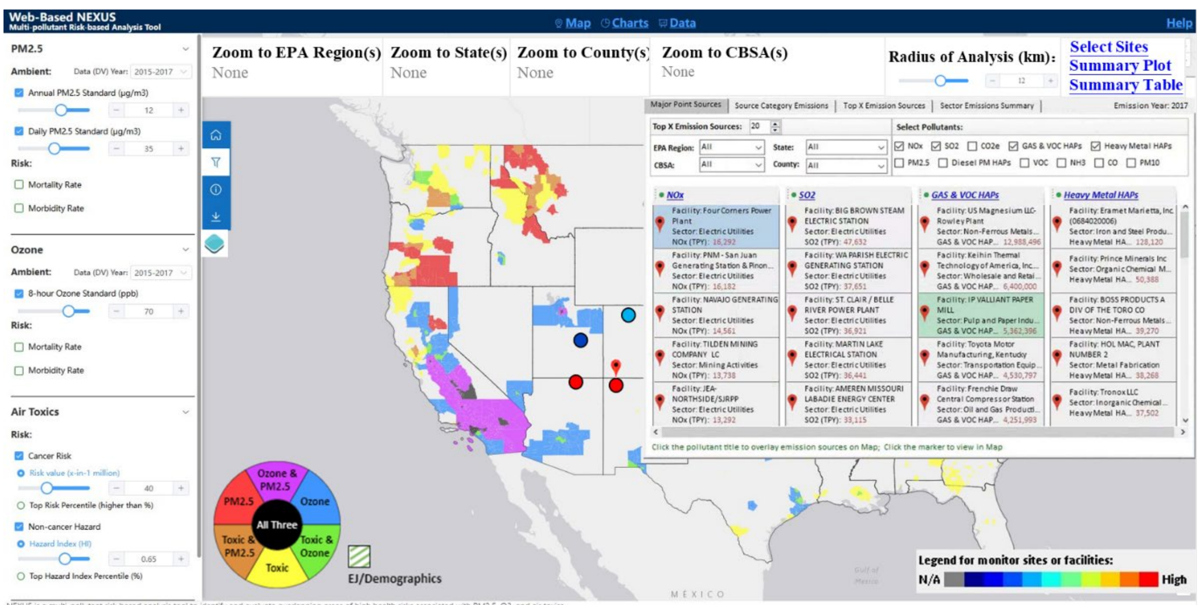


Fig. 332 Example of "Emission Sources" Window in protype of web-NEXUS

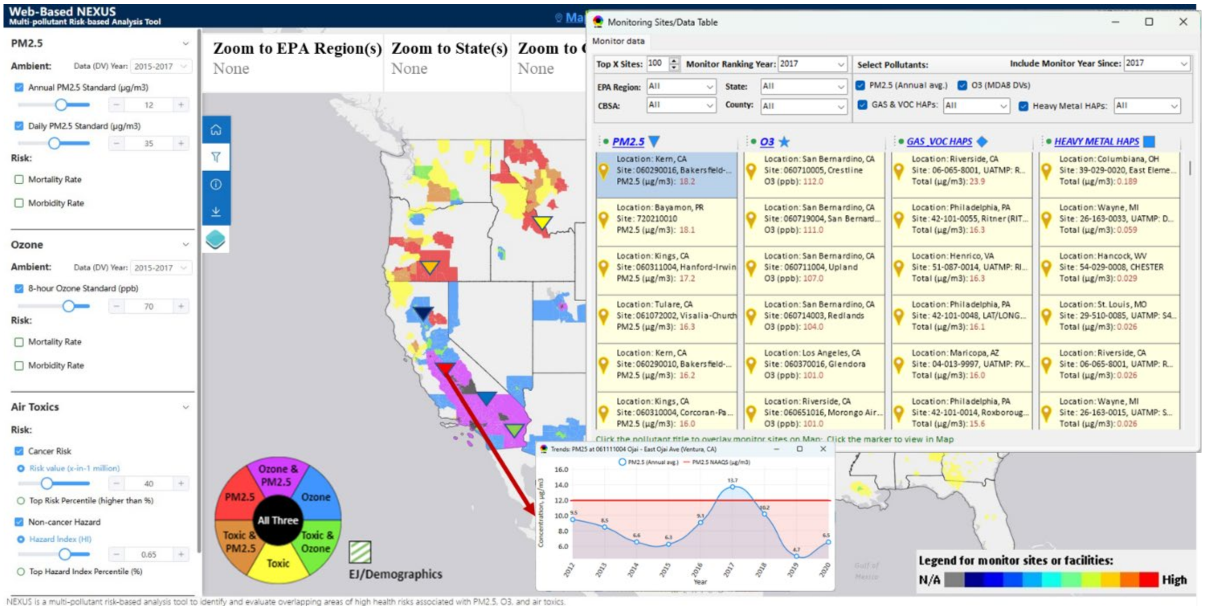


Fig. 333 Example of "Monitor Sites/Data Table" Window in protype of web-NEXUS

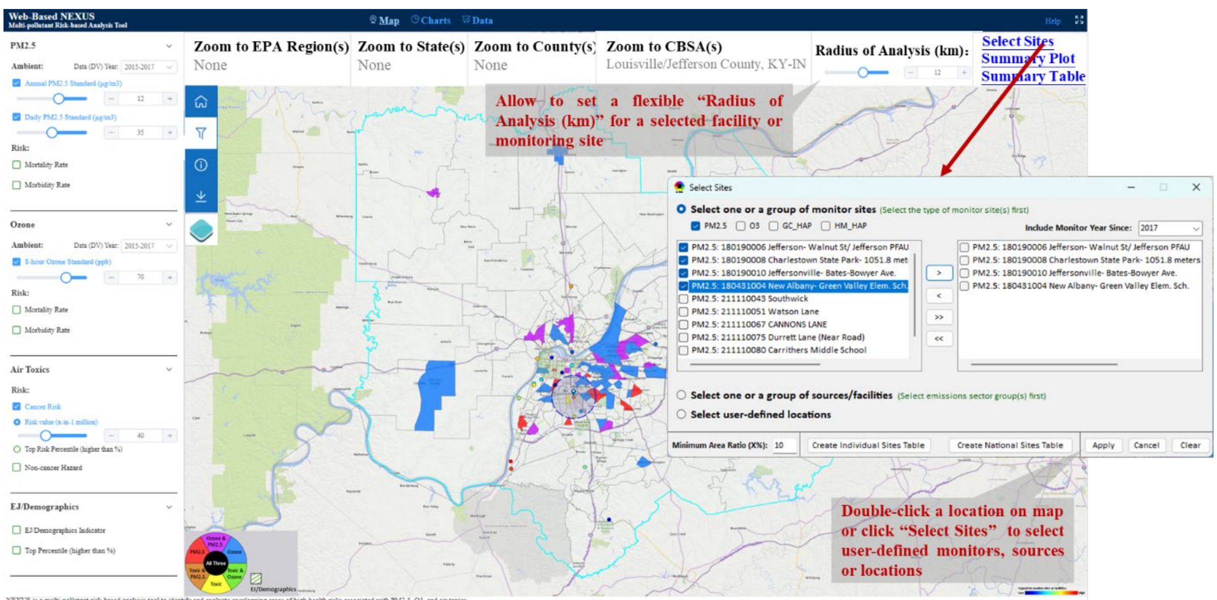


Fig. 334 Example of spatial analysis for a selected industrial source/monitoring site/location in Proximity Analysis Module

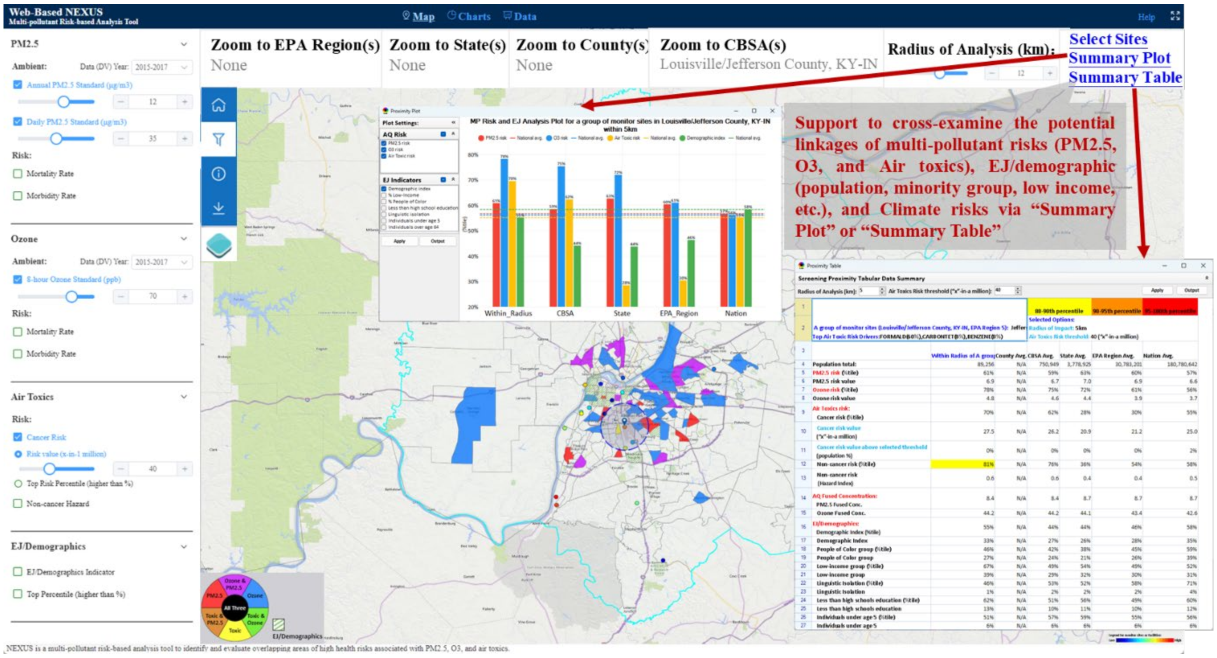


Fig. 335 Example of summary table/plot analysis in Proximity Analysis Module

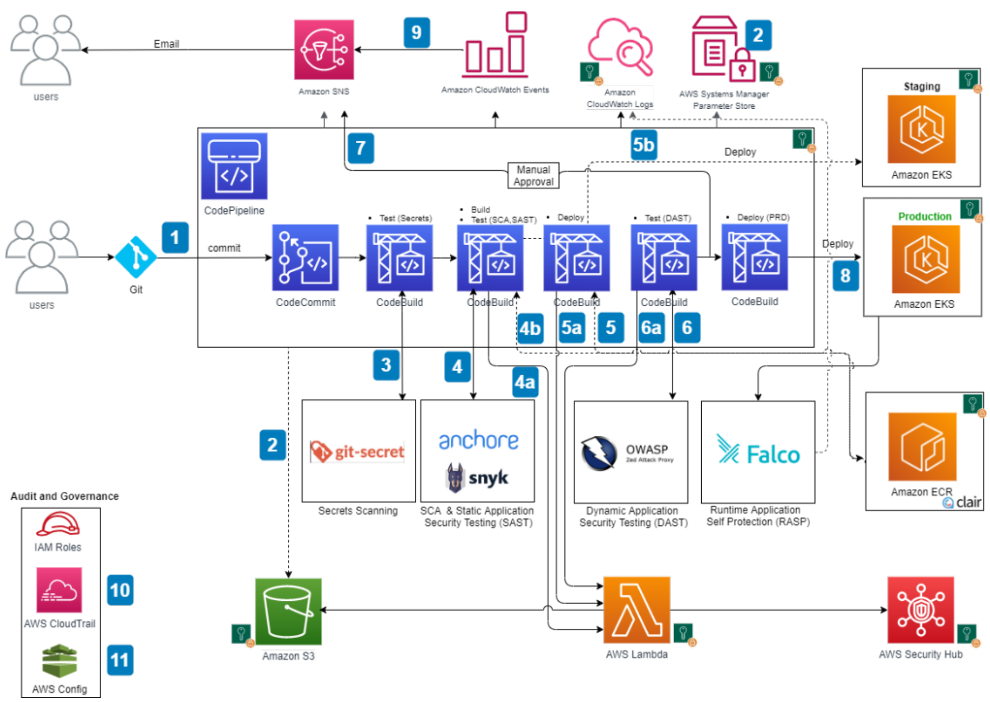


Fig. 336 The architecture of DevSecOps hosted in AWS

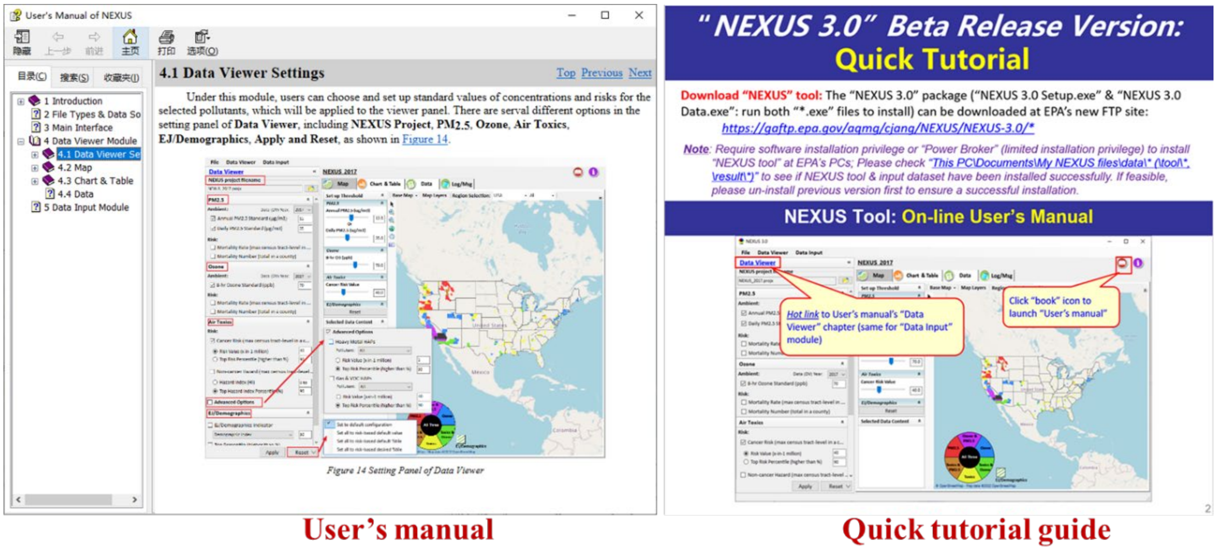


Fig. 337 Example of User's manual and Quick tutorial guide

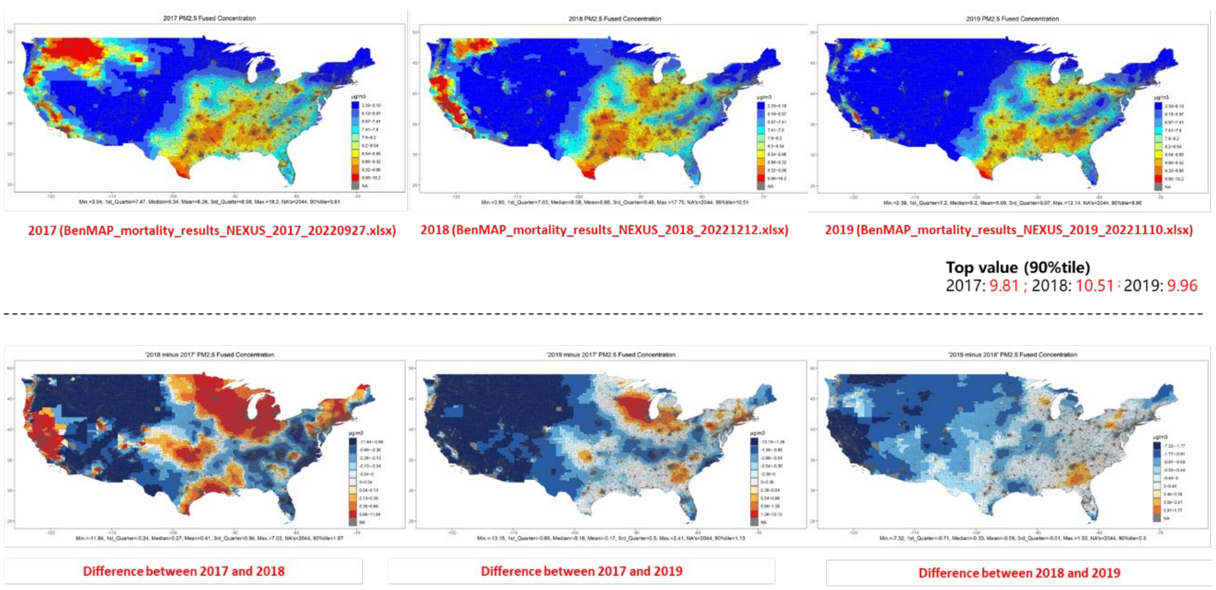


Fig. 338 Comparison of $PM_{2.5}$ fused concentration between 2017 vs. 2018 vs. 2019 data

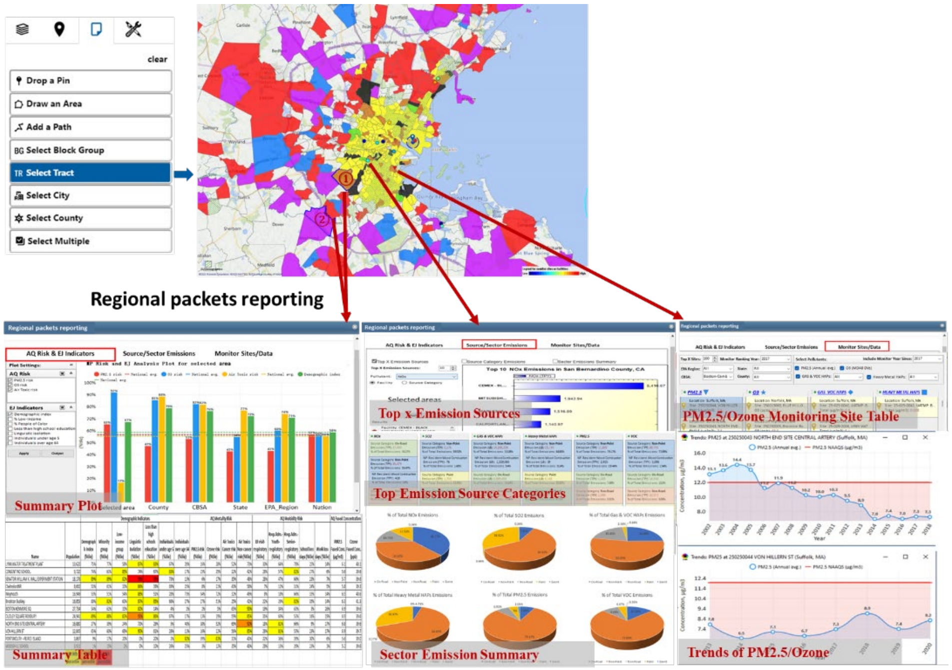
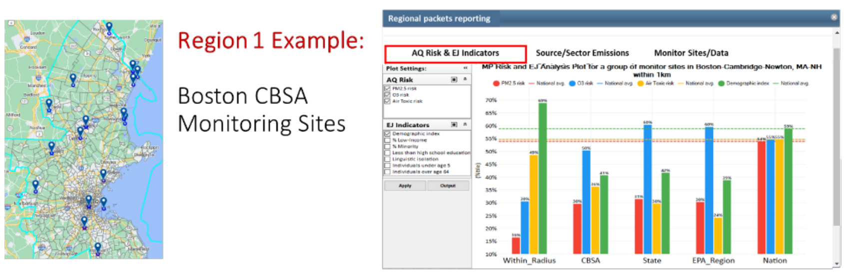


Fig. 339 Example of selecting multiple regions and outputting charts/reports



		Demographic Indicators							AQ Mortality Risk				AQ Morbidity Risk					AQ Fused Concentration	
Name	Population	Demographic Index (%tile)	Minority group (%tile)	Low-income group (%tile)	Linguistic Isolation (%tile)	Less than high schools education (%tile)	Individuals under age 5 (%tile)	Individuals over age 64 (%tile)	PM2.5 risk (%tile)	Ozone risk (%tile)	Air Toxics Cancer risk (%tile)	Air Toxics Non-cancer risk (%tile)	ER visit-respiratory (%tile)	Hosp.Adm.-Youth-respiratory (%tile)	Hosp.Adm.-Senior-respiratory (%tile)	School loss days (%tile)	Work loss days (%tile)	PM2.5 Fused Conc. (µg/m3)	Ozone Fused Conc. (ppb)
250090005	22,187	89%	89%	82%	98%	95%	60%	16%	7%	19%	34%	45%	29%	47%	73%	23%	7%	5.7	39.6
LYNN WATER TREATMENT PLANT	13,620	75%	77%	58%	87%	83%	67%	20%	16%	28%	52%	73%	30%	64%	78%	25%	14%	6.1	40.1
SITE LOCATED OFF PARKING LOT 2.	6,666	3%	12%	11%	0%	16%	14%	75%	26%	44%	19%	30%	24%	30%	66%	31%	5%	5.6	40.0
NEWBURYPORT HARBOR ST PARKING LOT	4,300	1%	2%	11%	0%	8%	13%	87%	37%	58%	20%	34%	23%	59%	71%	31%	5%	5.6	40.0
CONSENTINO SCHOOL.	9,720	74%	63%	85%	74%	67%	83%	17%	15%	35%	32%	42%	28%	57%	82%	27%	6%	5.6	39.6
USEPA REGION 1 LAB	8,613	60%	65%	40%	86%	64%	17%	53%	19%	46%	38%	47%	8%	16%	41%	25%	4%	5.6	39.2
inactive military resv	6,590	3%	20%	6%	0%	2%	72%	59%	14%	36%	27%	38%	8%	9%	32%	33%	2%	5.8	39.7
BLUE HILL OBSERVATORY	3,810	15%	42%	3%	35%	20%	14%	78%	75%	91%	40%	55%	13%	4%	87%	10%	17%	6.7	41.0
Brockton Buckley	16,853	80%	82%	63%	87%	85%	66%	27%	27%	51%	25%	42%	22%	29%	82%	35%	14%	6.3	41.3
BOSTON LONG ISLAND	535	97%	78%	100%	0%	97%	0%	1%	8%	4%	32%	43%	17%	91%	29%	3%	12%	6.6	40.0
DUDLEY SQUARE ROXBURY	24,941	89%	88%	83%	91%	86%	67%	17%	13%	19%	59%	85%	35%	69%	53%	16%	19%	6.9	39.6
330150012	5,298	1%	4%	6%	37%	7%	17%	96%	53%	78%	20%	34%	26%	23%	31%	26%	4%	5.6	39.3
SOUTH ROAD BRENTWOOD	5,940	12%	1%	40%	0%	37%	61%	24%	5%	16%	20%	28%	24%	22%	21%	23%	2%	5.3	38.9
PORTSMOUTH - PEIRCE ISLAND	3,867	9%	17%	20%	0%	20%	2%	82%	59%	83%	31%	43%	22%	36%	39%	30%	6%	5.6	39.0
SEACOAST SCIENCE CENTER	5,298	1%	4%	6%	37%	7%	17%	96%	53%	78%	20%	34%	26%	23%	31%	26%	4%	5.6	39.3
MOOSEHILL SCHOOL	3,931	1%	15%	2%	0%	10%	26%	25%	3%	12%	35%	40%	28%	13%	20%	23%	1%	5.2	39.6
SOUTHWEST CORNER OF SKYHAVEN AIRPORT	4,872	20%	9%	45%	0%	52%	33%	70%	44%	54%	18%	13%	22%	24%	25%	18%	4%	5.8	37.8
	80-90th percentile	90-95th percentile	95-100th percentile																

Fig. 40 Example of the AQ Risk & EJ Indicators module

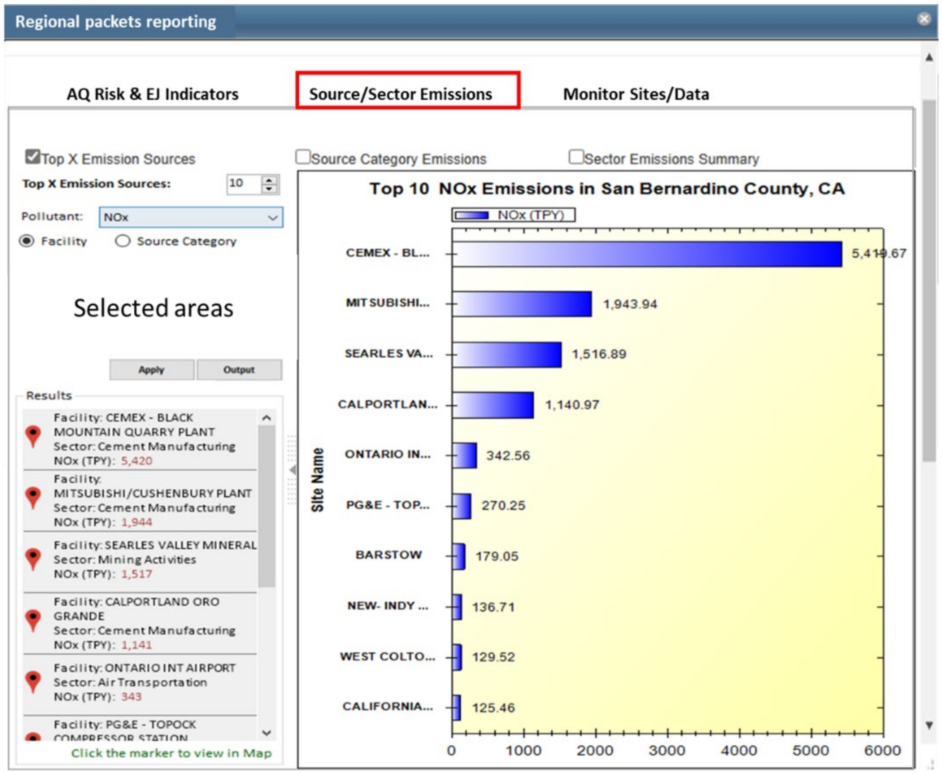


Fig. 41 Example of "Top X Emission Sources" in Source/Sector Emissions module

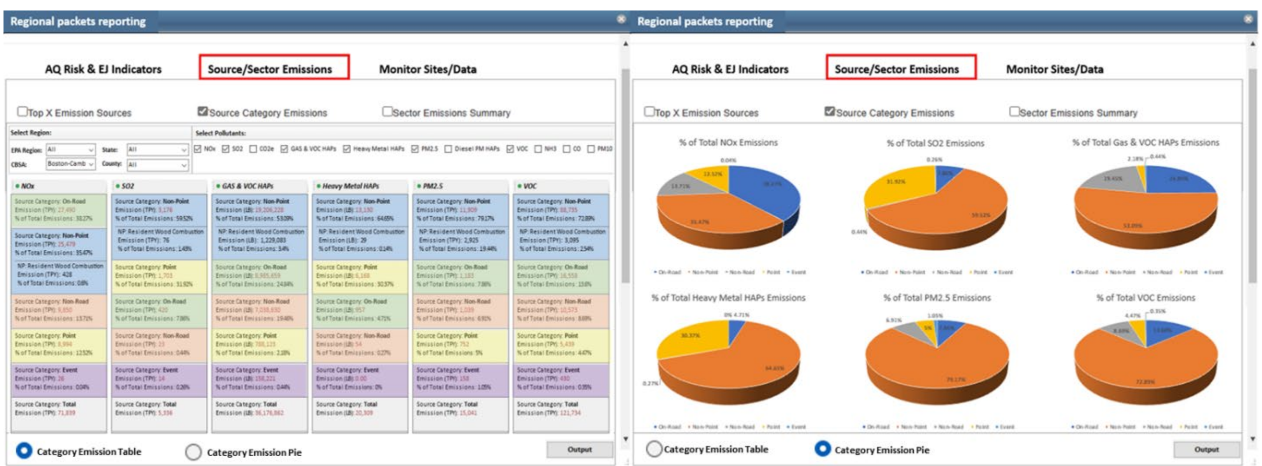
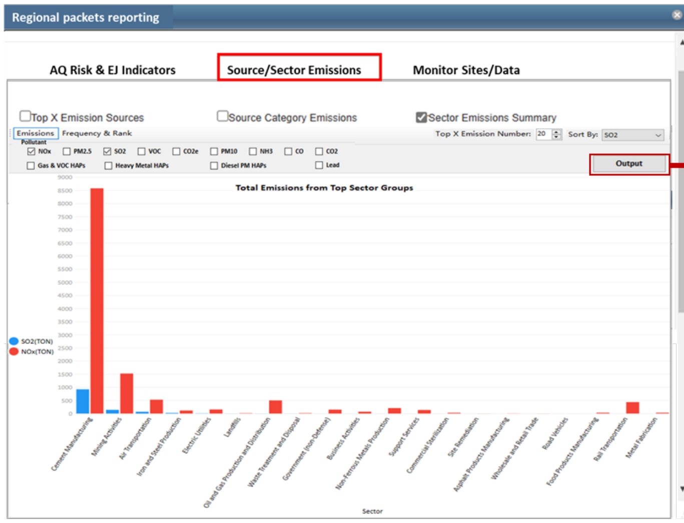


Fig. 42 Example of "Source Category Emissions" in the Source/Sector Emissions module



Total "Sector group" emissions combined for all selected CBSAs (based on Top 20 facility emissions in each CBSA).

Sector Group	NOx (TON)	PM2.5 (TON)	SO2 (TON)	VOC (TON)	Gas_VOC_HAPs (LB)	Heavy_Metal_HAPs (LB)	Diesel_PM_HAPs (TON)	CO2e (TON)
Electric Utilities	1521.79	235.79	697.06	108.77	121233.15	1309.28	0.00	9740700.403
Waste Incineration	2731.19	19.39	368.67	20.30	157.25	258.46	0.00	1889911.942
Air Transportation	1720.02	63.80	224.33	523.09	265983.07	2790.38	2.68	569992.1296
Landfills	1070.30	22.40	146.51	31.76	37470.45	7.41	0.00	894801.6732
Asphalt Products Manufacturing	66.18	77.59	69.05	66.10	287.09	585.09	0.00	0
Business Activities	530.89	47.62	35.10	39.96	19091.79	59.27	0.00	315914.7884
Clay Products Manufacturing	4.09	6.54	26.81	0.34	7700.00	0.00	0.00	0
Organic Chemical Manufacturing	80.75	5.63	21.57	69.26	74963.03	133.82	0.00	0
Construction and Related Industries	91.79	7.08	19.84	4.67	3123.81	14.28	0.00	81976.10418
Waste Treatment and Disposal	48.35	20.15	19.17	21.37	5514.00	29.76	0.00	0
Commercial Sterilization	223.13	11.62	18.07	29.44	4865.06	18.38	0.00	0
Government (non-Defense)	72.55	2.98	17.82	7.99	1578.86	6.23	0.00	0
Food Products Manufacturing	81.97	22.00	11.80	146.65	2106.82	5.74	0.00	0
Transportation Equipment Aerospace Industry	151.76	18.15	9.37	69.39	3434.23	563.37	0.00	100229.8844
Pharmaceuticals Production	46.02	14.65	3.23	59.60	29965.29	11.58	0.00	83484.34409
Road Vehicles	10.10	0.30	1.73	2.13	88.89	0.68	0.00	0
Wholesale and Retail Trade	19.72	23.27	1.43	250.41	8242.31	58.17	0.00	0
Mineral Processing	36.68	52.84	1.28	39.60	2683.78	12.17	0.00	84823.04629
Crop Production	6.38	0.16	1.08	0.50	35.86	0.13	0.00	0
Plastic and Metal Parts Manufacturing	37.16	3.10	1.07	30.06	11388.91	110.89	0.00	0
Metal Fabrication	16.05	5.06	1.05	217.48	96.53	10.22	0.00	0
Electronics and Computer Manufacturing	42.09	1.58	1.00	39.75	1317.19	4.79	0.00	24006.82548
Petroleum Products Distribution	6.30	0.16	0.97	308.01	20180.84	0.91	0.00	0
Consumer Products (Cleaning, Photographic, etc.)	18.49	0.73	0.95	2.71	874.16	2.81	0.00	44835.02994
Textiles and Apparel Manufacturing	36.97	3.18	0.77	28.66	14926.76	1.59	0.00	29965.4146
Transportation Equipment Ship/Boat Building & Repa	9.09	2.14	0.73	17.01	8291.32	0.01	0.00	0
Pulp and Paper Industry	12.37	7.20	0.68	174.88	113509.12	4.32	0.00	0
Research and Development	35.27	2.22	0.62	25.36	2789.66	8.29	0.00	0
Non-Ferrous Metals Production	15.03	17.59	0.55	2987.89	17668.11	87.24	0.00	55906.09769
Oil and Gas Production and Distribution	187.52	8.78	0.41	53.42	1302.93	18.53	0.00	59742.96624
Mining Activities	3.08	28.97	0.32	0.82	1.80	1.02	0.00	0
Paper Products Manufacturing	6.87	7.16	0.05	14.43	272.67	0.80	0.00	0
Furniture Manufacturing	1.53	9.77	0.05	15.16	133.36	4.89	0.00	0

Fig. 43 Example of "Sector Emissions Summary" in the Source/Sector Emissions module

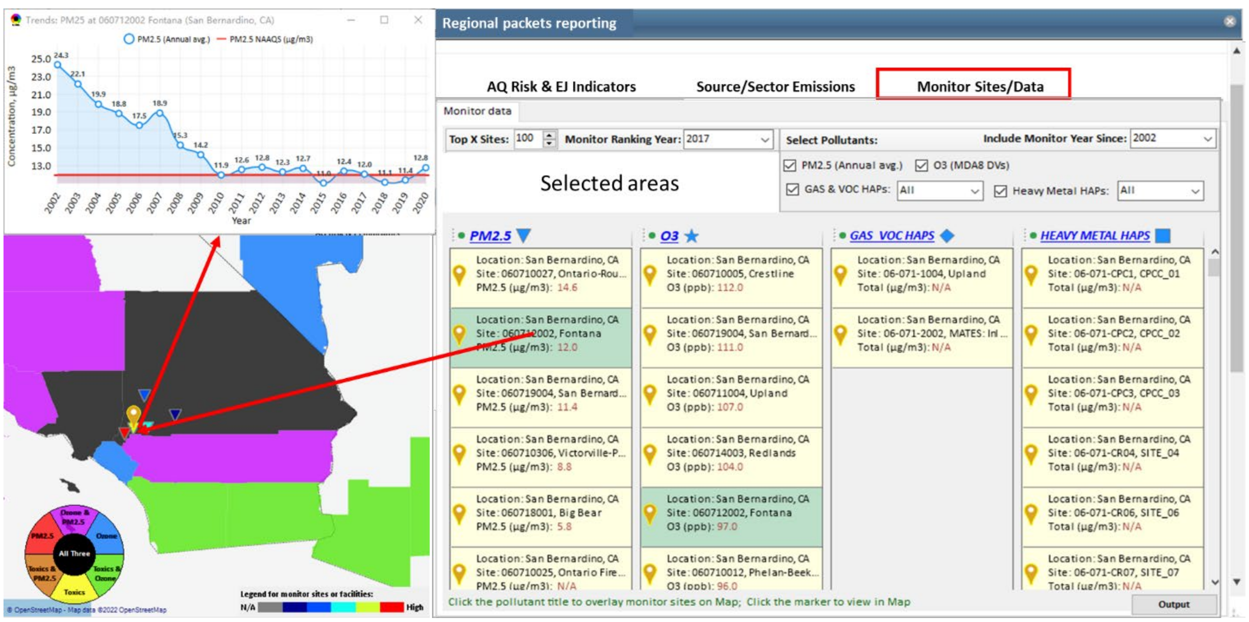


Fig. 44 Example of the Monitor Sites/Data module

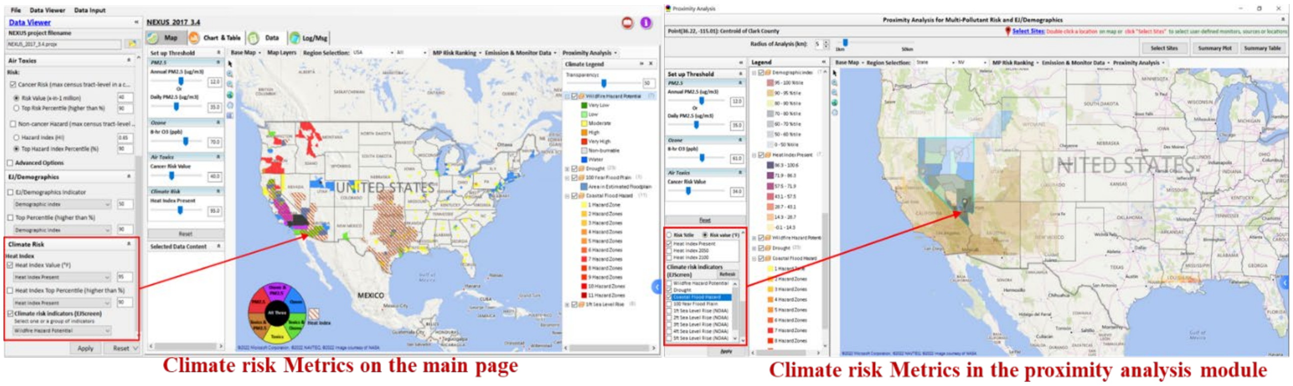


Fig. 45 Example for Climate risk Metric on the main page and proximity analysis module

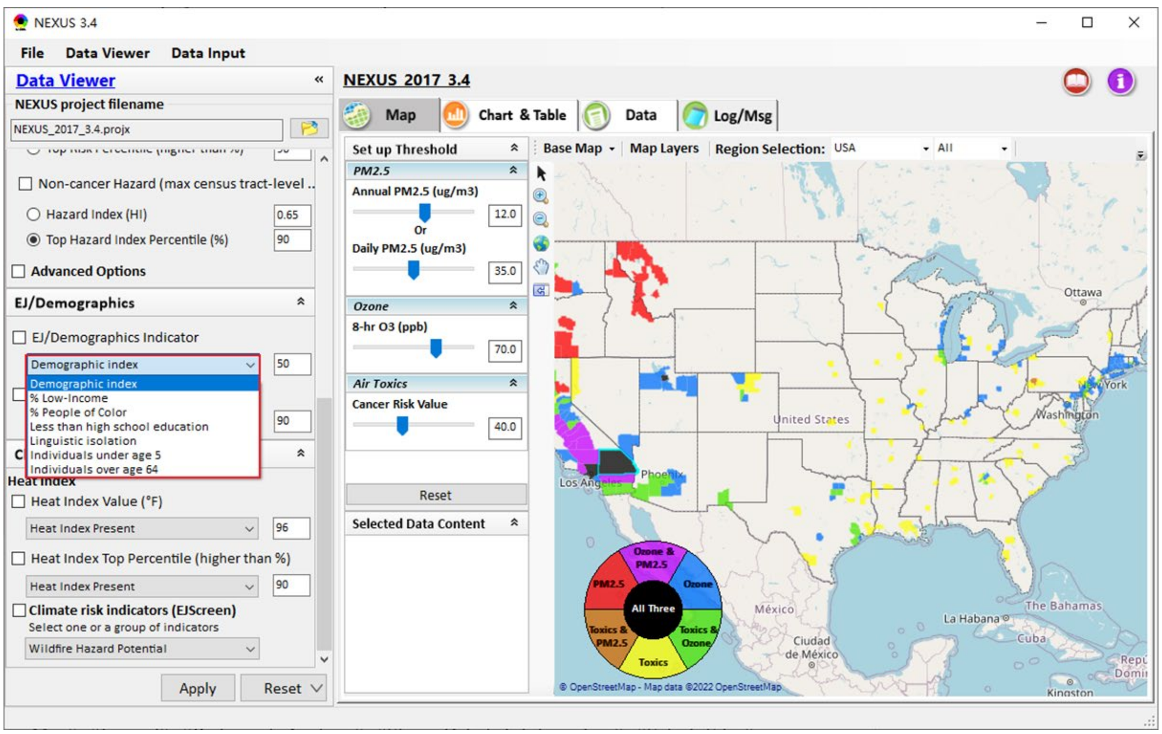


Fig. 46 Example of updated EJScreen data

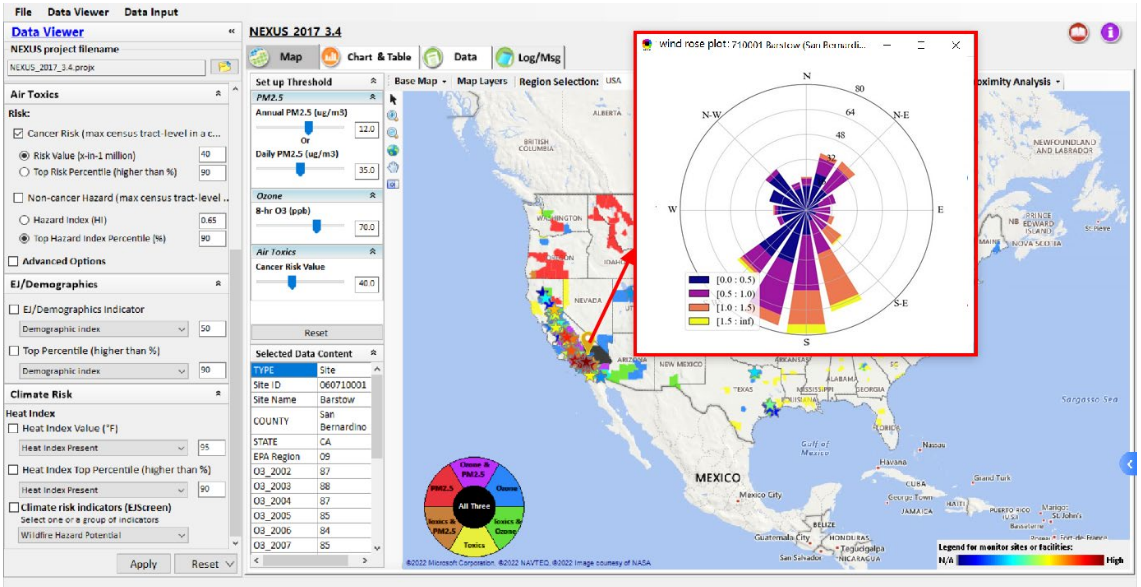


Fig. 47 Example for wind roses plot

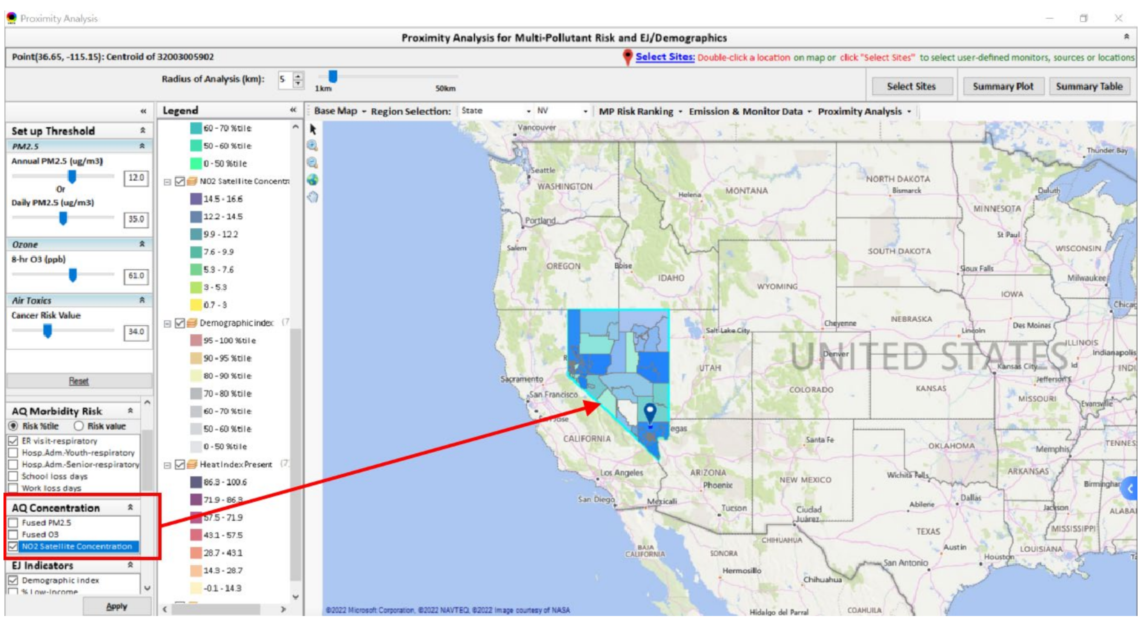


Fig. 48 Example for NO_2 satellite data in the proximity analysis module

Table 1 Example summary table for "Spatial Analysis"

<u>Facility</u>: American Synthesis Rubber Co., Louisville, KY **<u>Sector Group</u>: Polymers and Resins Production** **<u>Top Risk Drivers</u>: ETO, Formaldehyde**	**Selected Options:** **<u>Radius of Impact</u>: 10km** **<u>Number of CBSAs</u>: 25 (top MP risk ranking)** **<u>Air Toxics Risk threshold</u>: 10 ("x"-in-a million)**

	Within Radius of Facility	**County Avg.**	**State Avg.**	**EPA Region Avg.**	**Nation Avg.**	**Sector Group (within radius) National avg.**
Population total	x,xxx	xx,xxx	xxx,xxx	xxx,xxx	xxx,xxx	xxx,xxx
PM2.5 risk (pop. weighted conc.)	x	x	x	x	x	x
Ozone risk (pop. weighted conc.)	x	x	x	x	x	x
Air Toxics risk: Cancer risk value ("x"-in-a million))	x.x	x.x	x.x	x.x	x.x	x.x
Cancer risk value above selected threshold (population)	x,xxx	xx,xxx	xx,xxx	xx,xxx	xx,xxx	xx,xxx
Non-cancer risk (Hazard Index)	x.x	x.x	x.x	x.x	x.x	x.x
Climate risks: Flood (%)	x%	x%	x%	x%	x%	x%
Sea level rise (%)	x%	x%	x%	x%	x%	x%
Fire (%)	x%	x%	x%	x%	x%	x%
Disease (%)	x%	x%	x%	x%	x%	x%
EJ/Demographics Minority group (%)	x%	x%	x%	x%	x%	x%

Low-income group (%)	x%	x%	x%	x%	x%	x%
Demographic Index (%)	x%	x%	x%	x%	x%	x%
Linguistic Isolation (%)	x%	x%	x%	x%	x%	

Appendix B: Resumes / Biosketches

UNC Staff Resumes

Arunachalam, Sarav	BPA Program Manager 2
Adams, Elizabeth	Subject Matter Expert 3
Catherine Seppanen	Subject Matter Expert 3
Bin Cheng	Scientist 2
Valentine, Erin	Analyst 2

Sarav Arunachalam, BPA Program Manager 2

THE UNIVERSITY *of* NORTH CAROLINA *at* CHAPEL HILL

Education

- Ph.D. Chemical Engineering, Rutgers, the State University of New Jersey, New Brunswick, NJ, 1998
- M.S. Chemical Engineering, Rutgers, the State University of New Jersey, New Brunswick, NJ, 1993
- B.Tech. Chemical Engineering, Anna University, Chennai, INDIA, 1989

Registrations and Certifications

Faculty of the Year (**2008**), FAA Partnership for Air Transportation Noise and Emissions Reduction (PARTNER) Centers of Excellence

U.S. EPA Certificate of Appreciation (**1996**), Contributions to the Evaluation of the Draft Guidance for Using Models to Demonstrate Attainment of the O3 NAAQS)

Ozone Transport and Assessment Group (OTAG), Certificate of Appreciation (**1996**) (for

Contribution to Modeling performed for OTAG), Chair, OTAG Policy Decisions Group

U.S. EPA Blue Ribbon Paper Award (**2013**) Contributions in Improving Simulation of Air Pollution Near Roadways "Estimating near-road pollutant dispersion: a model intercomparison"

U.S. EPA Scientific and Technological Achievement Award (**2014**) "Advancements in NearRoad Dispersion Modeling"

Professional Association Memberships

2019 – Current: Air Quality Research Team, Google Inc.

2019 – Current: Advisory Board, Clean Air Carolina

2019 – Current: Chair, AMS Committee on Meteorological Aspects of Air Pollution (CMAAP)

American Geophysical Union

2020 – Current Editor, Atmosphere, Frontiers in Future Transportation Reviewer for NASA, EPA, and over 15 Leading Scientific Journals

Work Experience in the environmental field – Years (27)

2017 – present Deputy Director, Institute for the Environment, UNC Chapel Hill, NC

2009 – 2017 Research Associate Professor, University of North Carolina at Chapel Hill, NC

2003 – 2009 Research Assistant Professor, University of North Carolina at Chapel Hill, NC

1999 – 2002 Research Scientist, MCNC Environmental Programs, RTP, NC

1998 – 1999 Research Scientist, Bureau of Air Quality Planning, NJDEP, Trenton, NJ

1997 – 1998 Post-doctoral Research Fellow, Rutgers University, Piscataway, NJ

Summary of work experience relevant to the SOW

- Program Manager on EPA Contracts EPD12044 and EPW16023, where coordinated activities related to emissions inventory analyses and preparation of data for multiple modeling and analyses tasks including the development of AMET
- Program Manager on EPA Contracts EPD12044 and EPW16023 where coordinated activities related to the development of SMOKE, EMF and CoST, including the Sample Task Order described in this response
- Program Manager on EPA Contracts EPD12044 and EPW16023 where coordinated and served as lead air quality modeler for projects involving the development and application of multiple models including WRF, CMAQ, AERMOD, R-LINE, CALPUFF, SCICHEM, CTOOLS, WRF-CMAQ; Developed applications of Hemi-CMAQ and Response Surface Models for aviation and EGUs
- As PI on projects funded by FAA, EDF, Barr Foundation, etc. led CMAQ-DDM based modeling to assess primary and secondary sensitivities for individual source sectors including aircraft emissions, oil and gas, onroad transportation, etc.
- Program Manager on EPA Contracts EPD12044 and EPW16023 where coordinated the development of numerous tools including support for AMET, TracMyAir, Odor Explorer, etc.
- Led Data Fusion and inverse modeling for refining emissions inputs for the KC-TRAQS study
- Developed a series of web-based screening level models including C-LINE, C-PORT
- As PI on projects led multiple emissions processing tools including EDMS2Inv, AEDTProc, SMOKE-MOVES, etc.
- Program Manager on EPA Contracts EPD12044 and EPW16023 where coordinated the development of various datasets for the EPA including surrogates, speciation and temporal profiles for multiple model platforms in current and future years
- Program Manager on EPA Contracts EPD12044 and EPW16023 and others where led training of air quality models for a global user community, support and outreach through the globally renowned CMAS Center since 2002 (> 10,000 users) with active user support through a coordinated help desk, and developed numerous TSDs for the EPA and state agencies

Relevant Professional Presentations or Publications

- 72 peer-reviewed publications, 40 invited presentations
- 160 Conference presentations, 41 Technical reports

See full list at https://ie.unc.edu/people/arunachalam/

Elizabeth Adams, Subject Matter Expert 3

THE UNIVERSITY *of* NORTH CAROLINA *at* CHAPEL HILL

Education

- M.S.P.H., Environmental Science and Engineering; University of North Carolina, Chapel Hill, NC, 1993
- M.S., Chemistry, University of North Carolina, Chapel Hill, NC, 1989
- B.S., Chemistry, State University of New York, Stony Brook, NY, 1987

Registrations and Certifications

- Data Analysis Tools for High Resolution Air Quality Satellite Datasets, NASA's Applied Remote Sensing Training Program (ARSET), Jan 17 –Jan 22, 2018

Professional Association Memberships

- American Geophysical Union
- American Meteorological Society
- Air & Waste Management Association
- American Chemical Society

Work Experience in the environmental field - Years (15)

Ms. Adams is an atmospheric modeler with over 15 years of experience in the areas of air quality modeling and analysis. She has provided applications support for air quality modeling projects including testing and documentation to prepare software releases of the following products:
CMAQ, WRF-CMAQ, VERDI, SMOKE, CoST/EMF, Spatial Allocator and ABaCAS tools.

Summary of work experience relevant to the SOW (Task 1, Task 3, Task, 4, Task 6)

- Ms. Adams compiled and ran the benchmark case for the WRF-CMAQ coupled model to compare the model output for different compilers (gnu versus intel), and to confirm an issue with running using gnu compilers and I/O API 3.2. Ms. Adams used and modified VERDI and R scripts to generate base versus sensitivity plots, and uploaded those plots to the UNC Dataviewer site, a web-browser tool that allows user control and viewing of comparison plots.
- SMOKE Modeling. 2018 – 2019 Downloaded and installed the NEI2014v7.0 platform package and ran scripts to generate CMAQ model ready emissions. Client: KNRF
- Ms. Adams performed base minus zero out runs for an annual 12km CONUS domain and three short-term 4km domains covering four power plants located in the southeastern United States to determine impacts on secondary pollutants (MDA8 ozone, daily and annual average $PM_{2.5}$ sulfate and nitrate) and daily and annual average primary $PM_{2.5}$.
- Ms. Adams performed annual CMAQ modeling for two resolutions (36km and 12km) for historical case using boundary conditions from the GISS model, using AMET to postprocess and analyze the outputs. Client: Joint Fire Science Program (JFSP)
- Ms. Adams developed c-shell batch scripts to run the CALPUFF/POSTUTIL/CALPOST/POSTCALPOST suite of models for two different

visibility methods, and 2 different background concentrations, for 2001, 2002, 2003, and the combined 2001-2003 years for BART and Regional Progress Analysis modeling for Arizona Regional Haze Federal Implementation Plans.

- Ms. Adams assisted with the analysis of the Multi-pollutant Electric Generating Unit Response Surface Model using CMAQ (EGU-RSM) on UNC's HPC server.
- Ms. Adams performed GEOS2CMAQ modeling to generate boundary conditions from the Goddard Earth Observing System-Chemistry (GEOSChem) Model, and generated R plots to view the concentrations at each of the four boundaries for each variable.
- Ms. Adams performed CMAQ modeling for the Rocky Mountain Atmospheric Nitrogen and Sulfur (RoMANS) project on 36km, 12km, and 4km grid. Instrumented CMAQ to perform Process Analysis runs for the 12km domain for the period and region of interest. Client: National Aeronautics and Space Administration (NASA)
- Ms. Adams performed CMAQ v5.3.1 model pre-release testing on multiple processors and compilers on UNC's compute servers, performed AMET v1.4 testing, and provided documentation and release information on Github and the CMAS Center Website for CMAQ v5.3.1, AMET v1.4 and CMAQ v5.2-DDM-3D and previous releases.
- Ms. Adams updated the CMAS software clearinghouse website to provide the latest releases of VERDI, a Java program for visualizing air quality, meteorology and emissions data, including providing the User Guide, updating html pages, FAQs, and bug fixes for each software release.
- Ms. Adams downloaded and installed software on UNC Virtual Computing Lab Windows 10 images that were connected to using Microsoft Remote Desktop. Ms. Adams reviewed and used track changes to recommend edits to the quick start guide and user manual documentation for the FAST-CE 1.4, RSM-VAT 2.1, SMAT-CE 1.7, MODEL-VAT 1.7 and Data Fusion Tool 1.9 tools.
- Ms. Adams provides support to the CMAS Center User Discourse Forum by answering user issues and providing best practice tips for diagnosing and reporting user errors. Contributes debug and compiler tutorials for users in markdown on the CMAQ Github site.
- Ms. Adams uploaded datasets (NEI Platform Data, MCIP, and CMAQ annual and benchmark datasets) from EPA to the Google Drive and CMAS Data Warehouse and assisted with creating data download instructions for users and descriptive metadata and data object identifiers using UNC Dataverse. Client: U.S. EPA
- Ms. Adams installed and maintains the Community Multiscale Air Quality (CMAQ) and the Sparse Matrix Operator Kernel Emissions (SMOKE) software, data and ancillary software on the Amazon Web Services (AWS) Elastic Compute Cloud (EC2) and UNC's Sakai Learning Management System, and provides user support for the SMOKE and CMAQ training courses.
- Ms. Adams provides support for the CMAS Center Webinar Series, assisting the invited speaker with preparations and addressing technical issues.

Catherine Seppanen, M.S.

Education

- MS, Biomedical Engineering, Duke University, NC, 2000
- BSE, Biomedical Engineering, Tulane University, LA, 1999

Work Experience in the Environmental Field – Years (22)

Summary of Work Experience

Catherine Seppanen has more than 20 years of experience in software development, supporting emissions and air quality modeling through model implementation, web and mobile application development, and technology integration. Her development expertise includes a wide range of programming languages (Python, Perl, Java, JavaScript, Swift, Kotlin, Fortran) and various web development, database, and cloud technologies (PostgreSQL, PostGIS, MySQL, Angular, iOS, Android, Amazon Web Services, Google Maps).

Development of the Zip code Air Pollution Policy Assessment, NYC (ZAPPA) web application

- Developed a web-based screening tool to allow users to estimate the benefits to public health from policies that address air pollutant emissions in New York City and more broadly in New York State. Integrated the Community Air Quality Tools (C-TOOLS) dispersion model with CO-Benefits Risk Assessment Health Impacts Screening and Mapping Tool (COBRA) in an easy-to-use, interactive web application. Responsible for full stack web development, data ingestion, and model integration.

Support for EPA's Emissions Modeling Framework (EMF) and Control Strategy Tool (CoST)

- Ongoing software updates and technical support for a Java-based client-server system supporting EPA's emissions modeling efforts. Periodic updates to the CoST control measures database and cost equations, used to estimate the air pollution emissions reductions and economic costs associated with future-year control scenarios.

Development of TracMyAir iOS app

- Ongoing development of an iOS application for estimating personal air pollution exposure based on the user's locations throughout the day, activity levels, and indoor and outdoor environments. Integrates with various data services for local weather, near real time air pollution levels (including low cost PurpleAir sensors), and Apple Watch exercise data.

Development of OdorExplore iOS and Android apps

- Ongoing development of mobile applications promoting citizen science allowing users to report local environmental odors.

Development of the C-TOOLS suite of web applications. Developed a series of web applications using the C-TOOLS reduced-form dispersion model to model and visualize localized air quality, including emissions from vehicles, ports, shipping, railways, and airports.

Relevant Professional Publications

Breen, M., C. Seppanen, Vladilen Isakov, S. Arunachalam, M. Breen, J. Samet, AND H. Tong. Development of TracMyAir Smartphone Application for Modeling Exposures to Ambient PM2.5 and Ozone. International Journal of Environmental Research and Public Health. Molecular Diversity Preservation International, Basel, Switzerland, 16(18):3468, (2019). https://doi.org/10.3390/ijerph16183468

Sorte, Sandra & Arunachalam, Saravanan & Naess, Brian & Seppanen, Catherine & Rodrigues, Vera & Valencia, Alejandro & Borrego, Carlos & Monteiro, Alexandra. (2019). Assessment of source contribution to air quality in an urban area close to a harbor: Case-study in Porto, Portugal. Science of The Total Environment. 662. 10.1016/j.scitotenv.2019.01.185.

Arunachalam, Saravanan & Naess, Brian & Seppanen, Catherine & Valencia, Alejandro & Brandmeyer, Jo & Venkatram, Akula & Weil, Jeffrey & Isakov, Vlad & Barzyk, Timothy. (2019). A new bottom-up emissions estimation approach for aircraft sources in support of air quality modelling for community-scale assessments around airports. International Journal of Environment and Pollution. 65. 43. 10.1504/IJEP.2019.101832.

Bin Cheng, Ph.D., B.Eng.

Education

- Ph.D. (2013-2018) in Biological and Agricultural Engineering from North Carolina State University, Durham, NC, USA
  - Air Quality – Formation of Secondary Inorganic $PM_{2.5}$
- Bachelor of Engineering (2009-2013) in Agricultural Structure Environment and Energy Engineering from China Agricultural University, Beijing, China

Registrations and Certifications

- American Geophysical Union (AGU) 2020-2022
- American Society of Agricultural and Biological Engineers 2014-2022
- Association of Overseas Chinese Agricultural, Biological, and Food Engineers 2014-2022

Work Experience in the Environmental Field – Years (9)

Summary of Work Experience

- Post-doctoral Research Associate (April 2022 to Present) at Institute for the Environment, University of North Carolina at Chapel Hill, Chapel Hill, North Carolina, USA
- ORISE Postdoctoral Research Fellow (March 2019 to March 2022) at U.S. Environmental Protection Agency, RTP, North Carolina, USA
- Teaching Assistant (August 2013 to December 2018) at North Carolina State University, Raleigh, North Carolina, USA
- Research Assistant (March 2013 to December 2018) at North Carolina State University, Raleigh, North Carolina, USA

Relevant Professional Presentations or Publications

Publications

Akter, S., Liu, Y., **Cheng, B.**, Classen, J., Oviedo, E., Wang-Li, L. (2022). Impacts of Air Velocity Treatments under Summer Condition: Part II–Heavy Broiler's Behavioral Response. *Animals*. XX: XXX.

Akter, S., **Cheng, B.**, West, D., Liu, Y., et al. (2022). Impacts of Air Velocity Treatments under Summer Condition: Part I–Heavy Broiler's Surface Temperature Response. *Animals*. 12: 328.

Cheng, B., Alapaty, K., Zartarian, V., Poulakos, A., et al. (2021). PFAS Exposure Science: Current Knowledge, Information Needs, Future Directions. *International Journal of Environmental Science & Technology*.

Cheng, B., Wang-Li, L., Meskhidze, N., et al. (2021). Partitioning of NH_3-NH_4^+ in the Southeastern U.S. *Atmosphere*. 12: 1681.

Hu, F., **Cheng, B.**, Wang-Li, L. (2021). Characteristics of Particulate Matter Emissions from Swine and Poultry Production Houses in the United States. *Transactions of the ASABE*. 64 (5): 1569−1579.

Cheng, B., Shiv Kumar, A. P., Wang-Li, L. (2021). Inverse AEROMOD and SCIPUFF Dispersion Modeling for Farm Level PM_{10} Emission Rate Assessment. *Transactions of the ASABE*. 64 (3):801−817.

Cheng, B., Wang-Li, L., Classen, J., et al. (2021). Spatial and Temporal Variations of Atmospheric Chemical Condition in the Southeastern U.S. *Atmospheric Research*. 248:105190.

Cheng, B., Wang-Li, L., Meskhidze, N., et al. (2019). Spatial and Temporal Variations of $PM_{2.5}$ Mass Closure and Inorganic $PM_{2.5}$ in the Southeastern U.S. *Environmental Science & Pollution Research*. 26:33181–33191.

Cheng, B., Wang-Li, L. (2018). Spatial and Temporal Variations of $PM_{2.5}$ in North Carolina. *Aerosol and Air Quality Research.* 19:698–710.

Cheng, B., Wang-Li, L. (2018). Responses of Secondary Inorganic $PM_{2.5}$ to Precursor Gases in an Ammonia Abundant Area in North Carolina. *Aerosol and Air Quality Research.* 19:1126–1138.

Jiang, C., Zhao, S., Cheng, Y., **Cheng, B.**, et al. (2013). The Effect of Oxygen Condition in Micro/Nano-bubble Water on Leafy Vegetables Seed Germination. *Northern Horticulture.* 02:28–30.

Liu, L., Wu, S., Guo, J., **Cheng, B.**, et al. (2011). Adsorption of Ammonia Nitrogen in Effluent from Pig Manure Biogas Plant by Zeolite. *Journal of Agro-Environment Science.* 30:2130–2135.

Erin Valentine, Analyst 2

Education

- M.A. Women and Gender Studies, Arizona State University, AZ 2018
- B.A. Print/Online Journalism, Elon University, NC 2015

Registrations and Certifications

- Certified Scrum Master, Scrum Alliance, February 2022

Professional Association Memberships

- Council of Science Editors
- International Society for Managing and Technical Editors
- Coalition for Diversity and Inclusion in Scholarly Communications
- National Women's Studies Association

Work Experience in Project Management – Years (4)

2021–present	Research Project Coordinator, Institute for the Environment, UNC – Chapel Hill
2018–2021	Managing Editor of *Journal of Human Lactation*, *Mucosal Immunology*, and *Reproductive Sciences*

Summary of Work Experience

- Managed day-to-day operation of multiple international projects simultaneously
- Provided consistent communication and training materials to team members to ensure understanding of goals and expectations across organization
- Created protocols and templates to assist in consistent performance and deliverables
- Tracked milestones and provided weekly, monthly, and yearly reports of progress
- Audited workflows and instituted new systems for more streamlined and efficient function
- Ensured consistency of branding across multiple platforms
- Acted as point of contact for multiple vendors to meet deadlines with a successful product
- Technical/copy editing on various project deliverables and workplans

South China University of Technology (SCUT) Staff Bio-sketches

Yun Zhu	Professor
Zhenhua Zhu	Senior Project Manager
Shicheng Long	Project Manager
Wenwei Yang	Project Manager
Jingyin Li	Research Assistant I
Mengmeng Zhang	Research Assistant I
Ziyi Liu	Research Assistant I
Xuehao Yan	Research Assistant II
Hui Yuan	Research Assistant II

Yun Zhu, Professor (Subject Matter Expert 3): Ph.D. (2001) and M.S. (1998) Environmental Engineering, South China University of Technology (SCUT). Dr. Zhu is a SCUT full professor and the group lead of Environmental Simulation & Information Laboratory at School of Environment and Energy. After obtaining doctorate graduation in 2001, he had worked for more than 4 years as a department manager at a software company (Guangzhou city information research institute Co., Ltd.), and then came back to SCUT. Dr. Zhu has nearly 20 years of working experience in the fields of air quality simulation, air pollution control policies, and health impact evaluation, environmental management information systems, and air pollution control decision support system development. He has been responsible for 101 projects (total funding more than $9,500,000), which are supported by the U.S. EPA, National Nature Science Foundation of China, Ministry of Science and Technology of the People's Republic of China, Ministry of Ecology and Environment of the People's Republic of China, Department of Science and Technology of Guangdong Province, Department of Ecology and Environment of Guangdong Province, etc. He has published over 80 Peer-reviewed journal publications and gotten 29 software copyrights issued by the National Copyright Administration of China. A series of air quality management regulation tools used by the U.S. EPA are developed and continually maintained by Dr. Zhu's team, include RSM-VAT, BenMAP-CE, SMAT-CE, Model-VAT, DFT, FAST-CE, and NEXUS. They can be downloaded at the website http://abacas.see.scut.edu.cn/abacas/Software.aspx.`

Zhenhua Zhu, Senior Project Manager (Subject Matter Expert 3): M.S. (2011) and B.S (2008) Environmental Engineering, South China University of Technology (SCUT). Mr. Zhu joined the Environmental Simulation & Information Laboratory as a postgraduate student from 2008 to 2011. He developed a series of systems such as the management system for motor vehicle exhaust testing, the GIS-based management system for hazardous waste transportation, and the atmospheric environmental information management system. After graduating in 2011, he was hired by Guangzhou Communication Information Construction Investment and Operation Co. Ltd. as the project manager to develop and maintain the management system for hazardous goods transportation of Guangzhou. In 2016, Mr. Zhu joined Guangzhou Urban Environmental Cloud Information Technology R&D Co.ltd as a senior project manager. Mr. Zhu has more than 12 years of development experience in management and decision support systems. He has been collaborating with Dr. Zhu on developing and improving the functionalities of the air quality management regulation tools (e.g., BenMAP-CE, RSM-VAT, etc.).

Shicheng Long, Project Manager (Subject Matter Expert 2): M.S. (2015) and B.S (2012) Environmental Engineering, South China University of Technology (SCUT). Mr. Long joined the Environmental Simulation & Information Laboratory as a postgraduate student from 2012 to 2015. As one of the key programmers, he developed a series of systems such as RSM-VAT, SMAT-CE, etc. He joined Guangzhou Urban Environmental Cloud Information Technology R&D Co. ltd as a project manager in 2016. Mr. Long has more than 9 years of development experience in the air quality modeling system and the air quality management decision support system.

Wenwei Yang, Project Manager (Subject Matter Expert 2): M.S. (2017) and B.S. (2014) Environmental Engineering, South China University of Technology (SCUT). Mr. Yang joined the Environmental Simulation & Information Laboratory as a postgraduate student from 2014 to 2017. As one of the key programmers, he developed a series of systems such as Model-VAT, DFT, etc. He joined Guangzhou Urban Environmental Cloud Information Technology R&D Co. Ltd as a project manager. Mr. Yang has more than 7 years of development experience in the air quality modeling system and the air quality management decision support system.

Jingyin Li, Ph.D. student (P2): M.S. (2022), B.S. (2016) Environmental Engineering, South China University of Technology (SCUT). Mr. Li joined Guangzhou Urban Environmental Cloud Information Technology R&D Co. Ltd as a software development engineer after graduating (B.S.) in July, 2016. Four years later, he joined the Environmental Simulation & Information Laboratory as a M.S. student in 2020, and then as a Ph.D. student in 2022. Mr. Li is one of the key programmers for developing RSM-VAT, FAST-CE, DFT, Model-VAT, and NEXUS.

Mengmeng Zhang, Ph.D. student (P2): M.S. (2020) and B.S. (2017) Environmental Engineering, South China University of Technology (SCUT). Ms. Zhang joined the Environmental Simulation & Information Laboratory as a Ph.D. student in 2021. She is one of the key programmers for developing RSM-VAT and SMAT-CE, and also very familiar with the air quality simulation system (WRF-CMAQ) and the machine learning algorithm.

Ziyi Liu, Ph.D. student (P2): M.S. (2021) and B.S. (2018) Environmental Engineering, South China University of Technology (SCUT). Mr. Wang joined the Environmental Simulation & Information Laboratory as a Ph.D. student in 2021. He is one of the key programmers for developing FAST-CE, and also very familiar with the air quality simulation system (WRF-CMAQ).

Xuehao Yan, Postgraduate student (P1): B.S (2021) Environmental Engineering, South China University of Technology (SCUT). Mr. Yuan joined the Environmental Simulation & Information Laboratory as a postgraduate student in 2021. He has joined the development work of FAST-CE.

Hui Yuan, Postgraduate student (P1): B.S (2021) Environmental Engineering, South China University of Technology (SCUT). Mr. Yuan joined the Environmental Simulation & Information Laboratory as a postgraduate student in 2021. He has joined the development work of NEXUS.