



User's Guide for C-LINE Version 3.0

C-LINE: Community Line Source Model

Version: 1.0

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1. Introduction to C-LINE

Near-road and near-source monitoring studies have established that busy roadways and large emission sources, respectively, may impact local air quality near the source. Reduced-form air quality modeling is a useful tool for examining what-if model runs of changes in emissions, such as those due to changes in traffic volume, fleet mix, or vehicle speed. Examining various modeling runs of air quality impacts in this way can identify potentially at-risk populations located near roadways, as well as the effects that a change in traffic activity may have on those populations.

The Community LINE Source Model (C-LINE) is a web-based modeling system that is available to a community user to estimate local air quality impacts from on-road mobile sources (i.e., vehicles operating on public roads). C-LINE uses a reduced-form modeling approach appropriate for a screening-level model. Input data include roads, the mix of vehicle types on each class of road, and annual average daily traffic (AADT) from national datasets. Modeling results are displayed to the user on a map.

The remainder of this section provides a general overview of C-LINE, lists references relevant to this work, and describes how to access C-LINE.

1.1. Overview

A team at the UNC's Institute for the Environment, in collaboration with the U.S. Environmental Protection Agency (EPA), is developing a series of community tools (C-TOOLS) to study the effects of various emissions sources on local air quality. Each tool is a modeling and visualization system that accesses inputs, performs calculations, produces graphical results, provides options to manipulate select input variables, and performs basic data analysis through an intuitive, web-based user interface.

C-LINE, which is the first member of the C-TOOLS, analyzes road and vehicular data for any relatively small area in the continental U.S. (CONUS). The Graphical User Interface (GUI) is built on a Google mapping platform that is served over the Internet to the user's web browser. The road data are derived from the TIGER/Line Shapefiles available from the U.S. Census Bureau and filtered to include highways, freeways, and principal arterials. Local and connector roads are not included in C-LINE's road network.

C-LINE operates in two phases: modeling and analysis. When modeling the user selects the modeling domain, optionally edits properties of roads and traffic, specifies the meteorological conditions and pollutants, and runs the model. When performing analyses, the user can view the results of a model run using *inspect mode* to see results at selected locations, display results for the Census block groups in the modeling domain, and display location and relevant information on air quality monitors. The user can also analyze the differences between two similar modeling runs (e.g., same modeling domain, pollutant, and metric).

C-LINE computes dispersion of primary criteria and select mobile source air toxic (MSAT) pollutants related to on-road mobile sources. (A primary pollutant is directly emitted by the emissions source.) Currently, these pollutants are CO (carbon monoxide), NO_x (nitrogen oxides), SO₂ (sulfur dioxide), PM_{2.5} (particulate matter with aerodynamic diameter less than 2.5 μm), D-PM_{2.5} (PM_{2.5} emitted by diesel vehicles), EC_{2.5} (elemental carbon portion of PM_{2.5}), OC_{2.5} (organic carbon portion of PM_{2.5}), benzene, formaldehyde, acetaldehyde, acrolein, and 1,3-butadiene.

Emissions for each road are calculated by combining national database information on traffic volume (AADT), fleet mix, and emissions factors from EPA's Motor Vehicle Emission Simulator model (MOVES-2010b). The user can modify the emissions for one or more roads by changing the traffic composition via the fleet mix, the speed, and/or the AADT.

Dispersion calculations combine the calculated emissions with the meteorological conditions for the region of interest to compute air quality concentrations for the selected location and time period. The dispersion routines are based on the analytical version of R-LINE that is described in Snyder, et al. (2013).

C-LINE calculates concentrations and human health risk for select pollutants. Concentrations may be calculated either for one hour of selected meteorological conditions or for an annual average of meteorological conditions for the selected locale. To compute annual averages, C-LINE uses the METeorologically-weighted Averaging for Risk and Exposure (METARE) approach described in Chang et al. (2015), wherein dispersion is modeled for 100 explicit hours and then a weighted average is computed using those explicit 100 hourly concentrations, and the frequency of occurrence of these conditions during the entire year. Cancer risk and non-cancer health effects may be estimated for toxic air pollutants using annual average concentrations.

1.2. References

Barzyk, Timothy M., Vlad Isakov, Saravanan Arunachalam, Akula Venkatram, Rich Cook, and Brian Naess. "A near-road modeling system for community-scale assessments of traffic-related air pollution in the United States." *Environmental Modelling & Software* 66 (2015): 46-56.

Chang, S.-Y. , W. Vizuite, A. Valencia, B. Naess, V. Isakov, T. Palma, M. Breen, S. Arunachalam (2015). A Modeling Framework for Characterizing Near-Road Air Pollutant Concentration at Community Scales, *Sci. Total Environ.*, 538:905-921.

Snyder, Michelle G., Akula Venkatram, David K. Heist, Steven G. Perry, William B. Petersen, and Vlad Isakov. "RLINE: A line source dispersion model for near-surface releases." *Atmospheric Environment* 77 (2013): 748-756.

1.3. Access to C-LINE

Access to C-LINE is granted to registered users of the CMAS Center. Go to the CMAS home page (<https://www.cmascenter.org/>) from a web browser and click "Log In" under the CMAS logo to navigate to the CMAS login page. Registered users must enter their email address and password, and press the *Submit* button. If you do not have a CMAS login, click the *Create One* link to the right of the login message. This link takes you to the Create a CMAS Account page at https://www.cmascenter.org/register/create_account.cfm. Fill in the form and then mark your preferences at the bottom of the form. When finished, click the *Create Account* button.

Once you have logged in to the CMAS Center, scroll down the page and look for the list of "Supported Products" on the CMAS home page. Click the link to "C-TOOLS" and then the "C-LINE" link. This action will display the primary information page for C-LINE. The login credentials are on the right side of the screen. Click the *Visit C-LINE* button and enter the login credentials (see Figure 1).

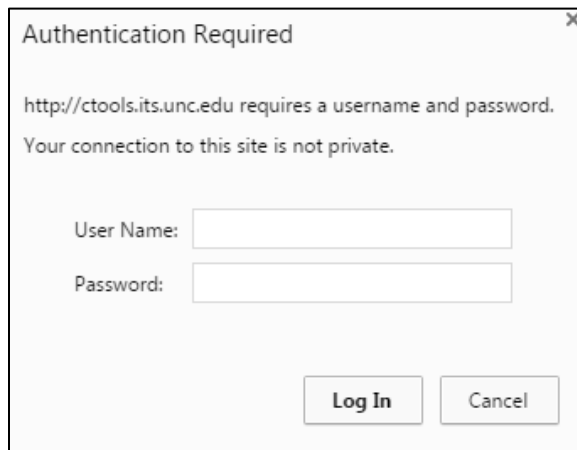
A screenshot of a web browser's authentication dialog box. The title bar reads "Authentication Required" with a close button (X) in the top right corner. The main text area contains the message: "http://ctools.its.unc.edu requires a username and password. Your connection to this site is not private." Below this text are two input fields: "User Name:" followed by a text box, and "Password:" followed by a password box. At the bottom right of the dialog are two buttons: "Log In" and "Cancel".

Figure 1. Enter your user name and password to access C-LINE.

The remaining sections of this document present the system requirements, a base-line analysis, editing inputs for an analysis, computing risk metrics, and managing model runs.

2. Software/Browser Requirements

The C-LINE application runs in any modern web browser and has been tested in Google Chrome, Firefox, and Safari. The most recent version of any browser is recommended. In order to use C-LINE, the browser must have JavaScript and cookies enabled. The recommended window size is at least 1200 by 800 pixels.

3. Base-Line Analysis

This section provides step-by-step instructions for performing a simple, base-line analysis. In this example, the urban area is Charleston, SC and the pollutant is NO_x.

Start by logging in to C-LINE (see section 1.3). Figure 2 illustrates the C-LINE main page.

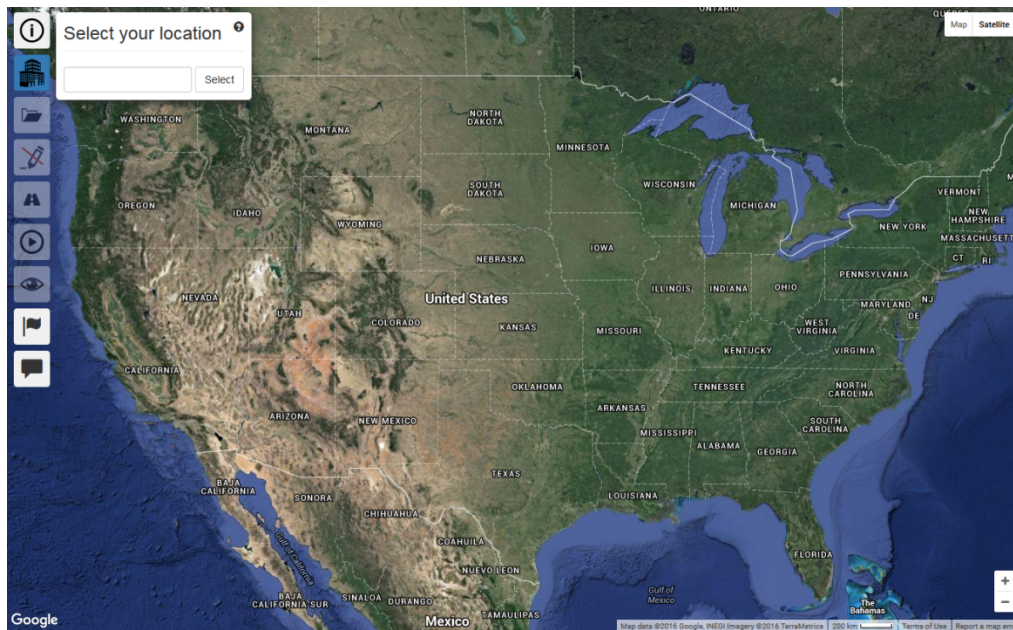


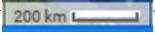
Figure 2. C-LINE's home screen showing satellite overlay with labels.


3.1. Overall Screen Layout

Some of the widgets are provided by the Google Maps interface. In the top-right corner of the map are two buttons labeled *Map* and *Satellite*. Figure 2 shows the satellite version of the map with labels turned on. If you want to remove the political boundaries and names from the map, hover your cursor over the *Satellite* button and uncheck Labels. Figure 3 shows the map version of the map, which includes country, province, and state political boundaries and names; major cities; and interstate highways. If you want to include the terrain features and remove the interstate highways, hover your mouse over the *Map* button and check Terrain.



Figure 3. Main screen showing map overlay.

The set of buttons in the bottom-right corner of the screen change the zoom level. Click + to zoom in and – to zoom out. Just to the left of the zoom buttons, at the very bottom of the screen, is the distance measure (). As you change the zoom level, both the distance measure segment and value may change. Also, you can click the distance measure to change between units of kilometers (km) and miles (mi).

Navigation tiles are positioned vertically along the left side of the screen (see Section 3.2). Click on a tile to display the related data selection and editing frame; click the tile again to hide its frame. Each of these screens has associated on-line help. Click the  icon for information on that frame, such as the one in the *Select your location* frame (see Figure 2 or Figure 3); click the icon when it appears next to a selection on the frame for information about that specific selection (see Figure 4). An example of a context-sensitive help box is shown in Figure 5.

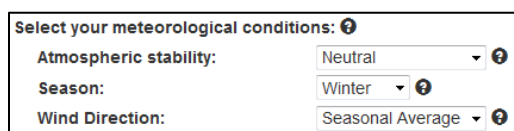
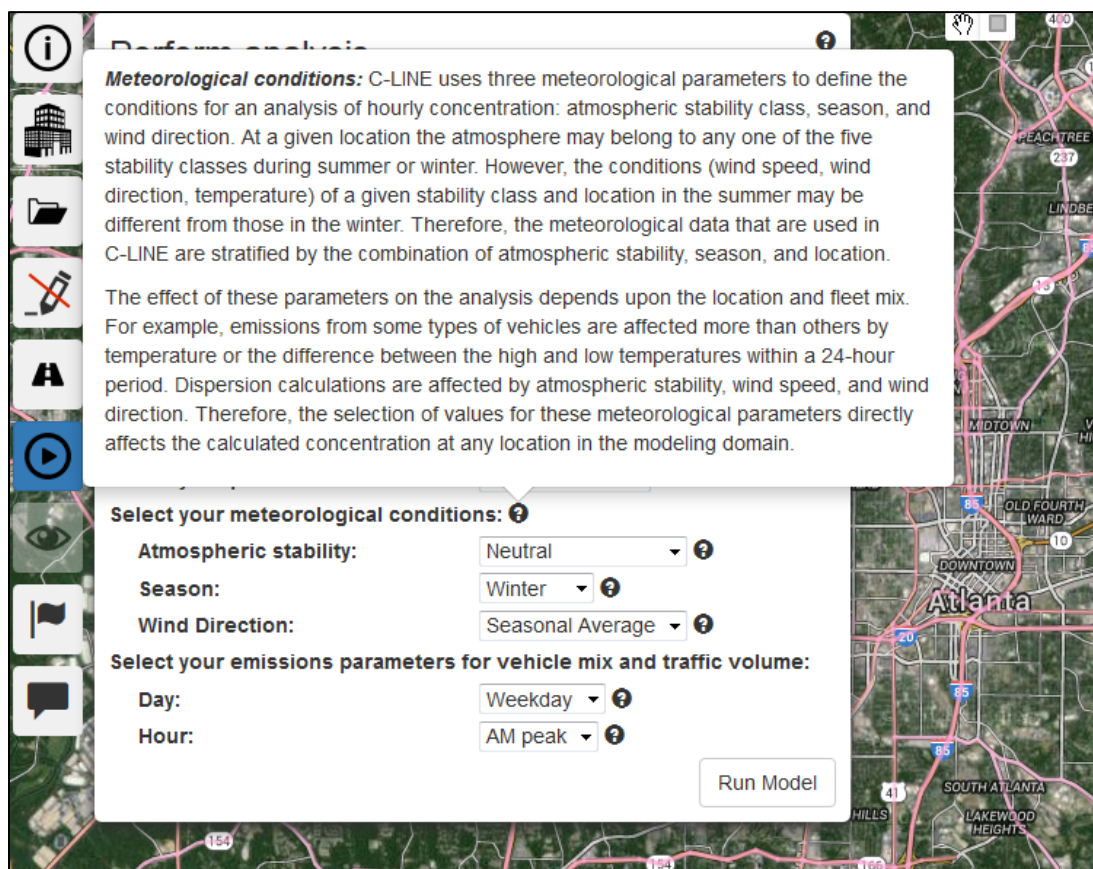


Figure 4. Example of item-specific help topics.



Meteorological conditions: C-LINE uses three meteorological parameters to define the conditions for an analysis of hourly concentration: atmospheric stability class, season, and wind direction. At a given location the atmosphere may belong to any one of the five stability classes during summer or winter. However, the conditions (wind speed, wind direction, temperature) of a given stability class and location in the summer may be different from those in the winter. Therefore, the meteorological data that are used in C-LINE are stratified by the combination of atmospheric stability, season, and location.

The effect of these parameters on the analysis depends upon the location and fleet mix. For example, emissions from some types of vehicles are affected more than others by temperature or the difference between the high and low temperatures within a 24-hour period. Dispersion calculations are affected by atmospheric stability, wind speed, and wind direction. Therefore, the selection of values for these meteorological parameters directly affects the calculated concentration at any location in the modeling domain.

Select your meteorological conditions:

Atmospheric stability: Neutral

Season: Winter

Wind Direction: Seasonal Average


Select your emissions parameters for vehicle mix and traffic volume:

Day: Weekday

Hour: AM peak

Run Model

Figure 5. Example of context-sensitive help box.

Two widgets appear in the top center of the screen when a map of road segments or modeling results is displayed. These are a *hand* and a *box* (). The default widget is the hand. It can be used in several ways. To select a single roadway segment, carefully move the hand until it changes to look like it is pointing at the desired segment; click your left mouse button to select the segment and it will appear in red in the *View and modify roads* frame. Click on other road segments to add them to your selection. To pan the map, place the hand and click (or click and hold) your left mouse button to change the hand to a fist; move your mouse to pan the map and then click the left mouse button again to stop panning.

The *box* widget facilitates selecting multiple road segments in one operation. Clicking on the square widget changes your cursor to a plus sign (+). Move your cursor to one corner of the geographic area that you want to select; click your left mouse button to start the selection process. A rectangle is displayed on the screen as you move your mouse. Position your cursor at the opposite corner of the rectangle and click your left mouse button to end the selection process. All the road segments within the rectangle are selected and shown in red in the *View and modify selected roads* frame.













When looking at the table of road segments, you can use your shift key to select a list of road segments or your control key to select individual road segments.

3.2. Navigation Tiles

The tiles shown down the left-hand side of the screen provide navigation to the various parts of C-LINE. The following table shows the list of tiles and an overview of each.

Table 1. Navigation tiles and how to use them.

Tile	Description
	<i>About C-LINE.</i> Display overview information about C-LINE, including its purpose, calculations, and references.
	<i>Select your location.</i> Enter the name of a geographic location in the continental U.S. that Google Maps recognizes (e.g., Charleston, SC; Spokane, WA). WARNING: Any unsaved edits will be lost.
	<i>View results.</i> Load the results of a model run or of a comparative analysis.
	<i>Edit mode.</i> Toggle edit mode to select individual road segments and then modify their characteristics. NOTE: The red line shows that edit mode is OFF.
	<i>View and modify roads.</i> Selected roads are shown in red. You can change the AADT, average vehicular speed (mph), and the fleet mix on one or more selected road segments.
	<i>Perform analysis.</i> Select the type of analysis, pollutant, atmospheric conditions, and time period for the traffic data. Provide a name for your model run and submit it for calculation.
	<i>Visualization options.</i> Turn on inspect mode to see results at specific locations on the map. Toggle census block groups as a map overlay. Press the <i>Clear overlay</i> button to turn off your results and return to your base map.
	<i>Air quality monitors.</i> Turn on locations of air quality monitors that have observed concentrations for one or more pollutants modeled in C-LINE.
	<i>Cancel adding new source.</i> Tile appears when drawing a new source on the map. Press this tile to undo adding the new source.
	<i>Give feedback about C-LINE.</i> Answer a brief survey to provide feedback about C-LINE to its development team.

To hide the frame associated with a tile, click the tile again. The frame then disappears, allowing you to see more of your map.

3.3. Select a Location

Enter the name of the city for your analysis. Note that C-LINE does not prevent you from entering a city outside the United States, such as Beijing. The selected city and its road network from Google Maps will be displayed for you. However, if this location is outside the CONUS, C-LINE will not have any road segments to display and will not activate its other tiles (see Figure 6).

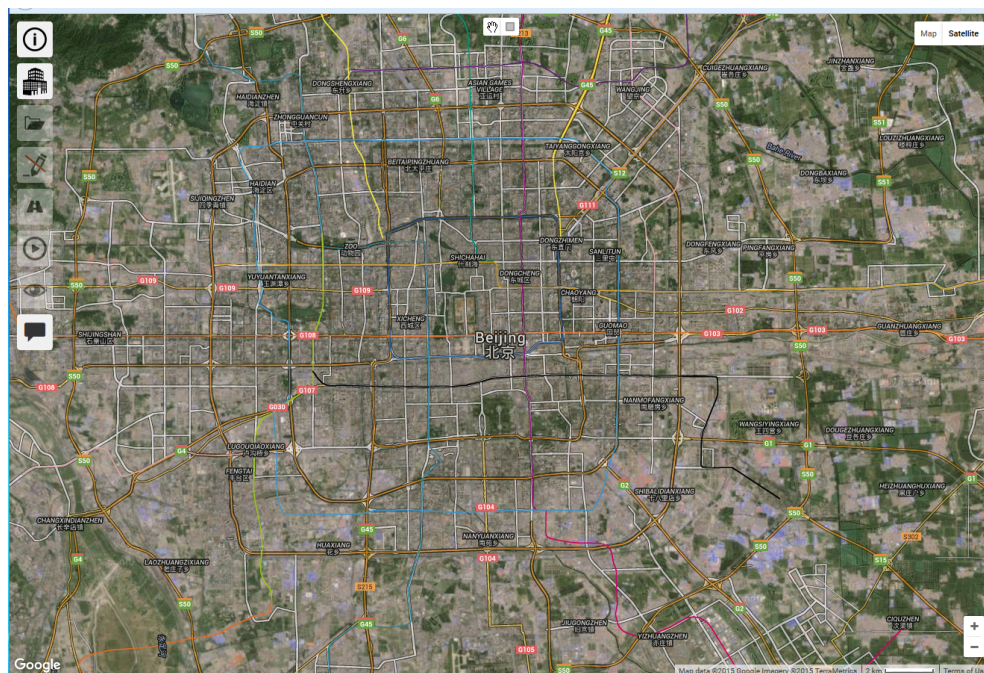


Figure 6. Example of a city outside CONUS selected in C-LINE.

For this sample analysis enter **Charleston, SC** and press *Enter* or the *Select* button. C-LINE then pans the map to be centered on Charleston and adjusts the zoom level for an analysis (see Figure 7). The road segments that are in C-LINE for the selected area are shown in pink. You can adjust the zoom level to display your region of interest. If you zoom out too far, the road segments disappear from the map and you no longer see pink roads. Zoom back in until the road segments appear again. If they do not appear, go to the *Select your location* tile and select your location again to reset the map.

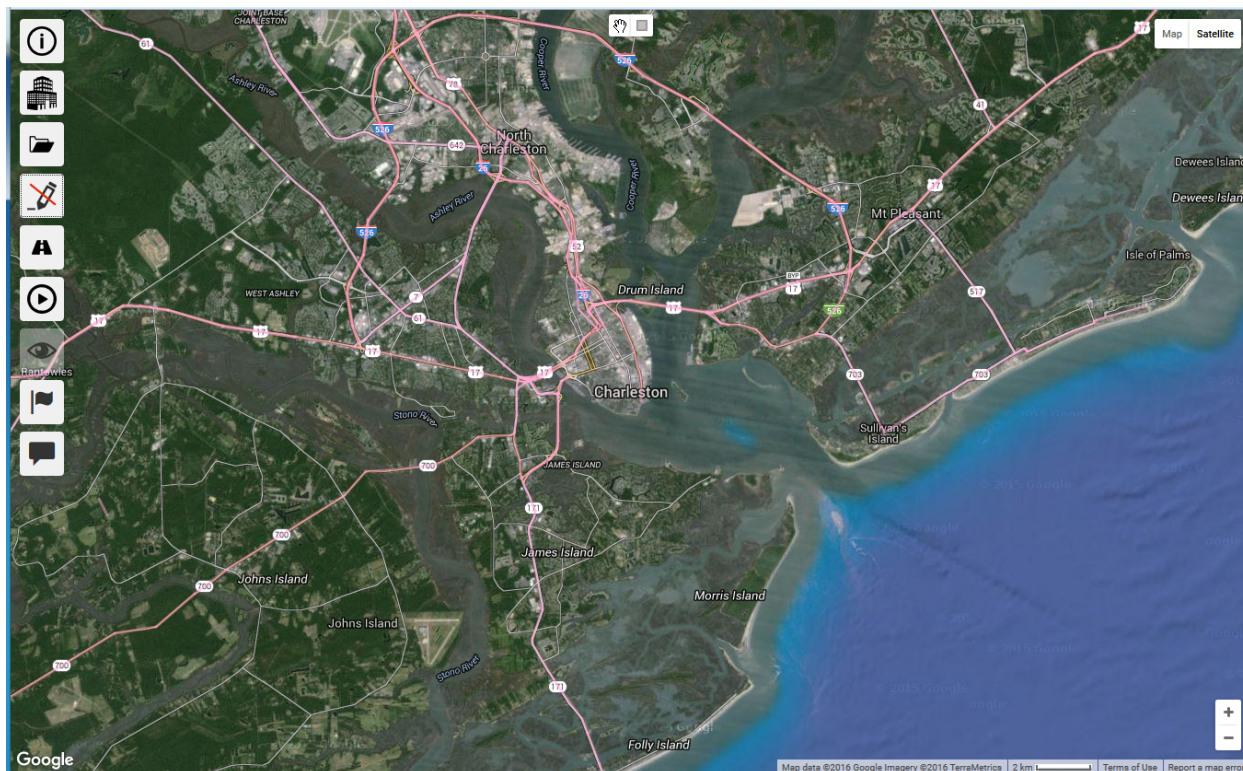


Figure 7. Selected location: Charleston, SC.

3.4. Perform a Baseline Analysis

First, decide the type of analysis you want to perform. C-LINE can perform many types of analyses, as listed below. All meteorological data have been preprocessed into categories based on statistical frequency of a variety of factors, including temperature, wind speed and direction, and atmospheric stability. This method supports annual analyses without the need to perform dispersion calculations for every hour of a year. It also allows fast lookup of typical (median) values and information related to a combination of atmospheric stability, season, and wind direction.

Vehicular emissions are a function of many factors including speed, diurnal temperature range, engine load, age distribution of vehicles, and types of vehicles. These and other factors are input to the MOVES vehicle emissions model to calculate emissions factors. To reduce execution time required for a C-LINE simulation, the MOVES model has been executed for a wide range of conditions and its results are available as supporting tables for C-LINE's calculations.

Figure 8 shows all the selections that can be made for a C-LINE simulation. The following list of analyses includes the required selections in the *Perform analysis* frame. Note that the risk calculations (for cancer and non-cancer) are computed from annual average concentrations.

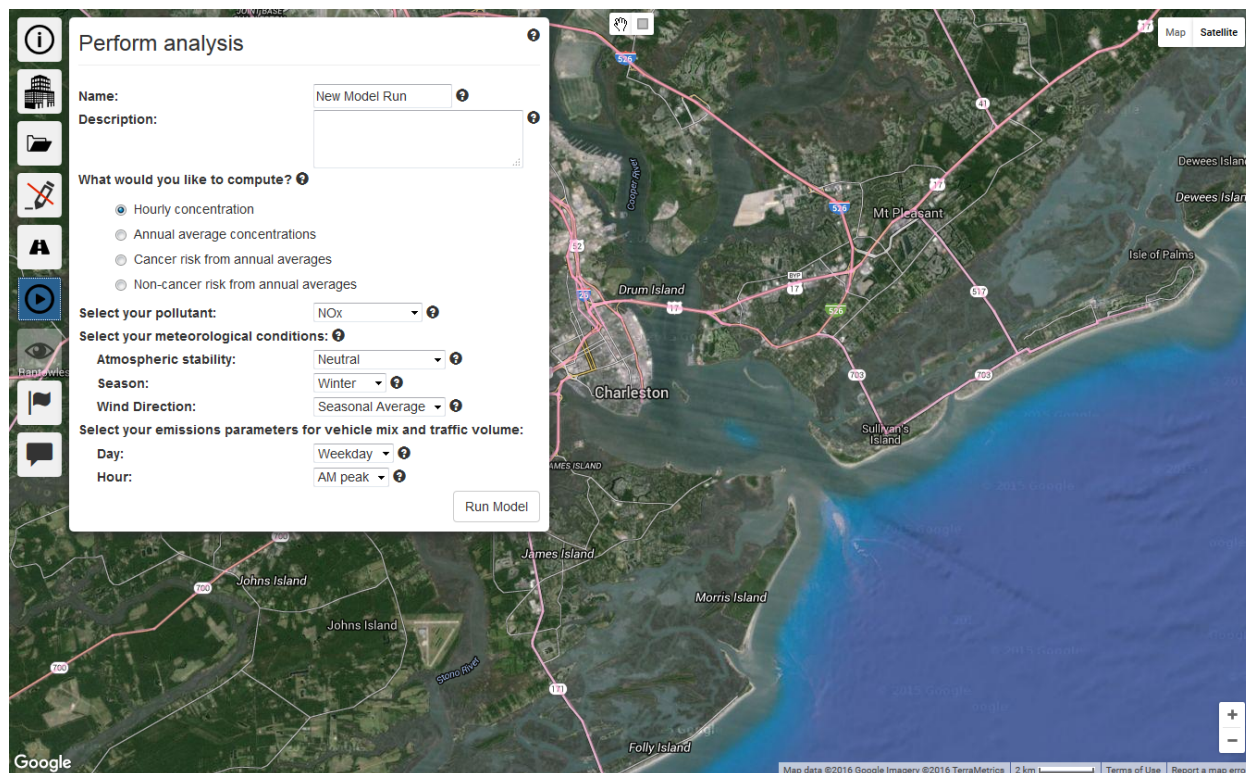


Figure 8. *Perform analysis* frame for base-line simulation of Charleston, SC.

- Hourly concentrations: Figure 8 shows default values for meteorological conditions and vehicle selections.
 - Atmospheric stability: Select one item from the following list from lower to higher turbulence: stable, slightly stable, neutral, slightly convective, and convective.
 - Season: The two selections are winter and summer.
 - Wind direction: Select *Seasonal Average* for the average wind direction corresponding to the season you selected. Alternatively, select one of the sixteen compass directions (South to North, SSW to NNE, SW to NE, etc.).
 - Day: Select weekday (Monday through Friday) or weekend (Saturday and Sunday). Selection affects the traffic pattern (number and types of vehicles) to be modeled.
 - Hour: Select one of four possible time periods related to traffic patterns: AM peak (morning rush period), mid-day (daytime period between rushes), PM peak (afternoon rush period), and off peak (nighttime period between rushes).
- Annual average concentrations: None of the five selections listed for hourly concentrations is available for annual average concentrations. Instead, each set of conditions and its frequency of occurrence in the modeling domain are used to calculate the annual average concentrations.
- Cancer risk from annual averages: NOTE: The risk estimates are preliminary and subject to change. C-LINE users are advised to use these estimated risks with caution. When this option is selected, the list of pollutants is changed to include only those that have associated cancer risk (i.e., benzene, formaldehyde, acetaldehyde, and 1,3-butadiene).

- Non-cancer risk from annual averages: The risk estimates are preliminary and subject to change. C-LINE users are advised to use these estimated risks with caution. When this option is selected, the list of pollutants is changed to include only those that have associated non-cancer risk (i.e., benzene, formaldehyde, acetaldehyde, acrolein, and 1,3-butadiene).
- The risk factors for cancer and non-cancer are consistent with the methods used in the EPA's National Air Toxics Assessment (NATA)¹.

For this baseline analysis, select to compute annual average concentrations for the pollutant NO_x. Name the model run "Charleston annual base NO_x". Enter the description "annual average concentrations for NO_x, default roads and emissions, Charleston, SC". Then click the *Run Model* button (see Figure 9).

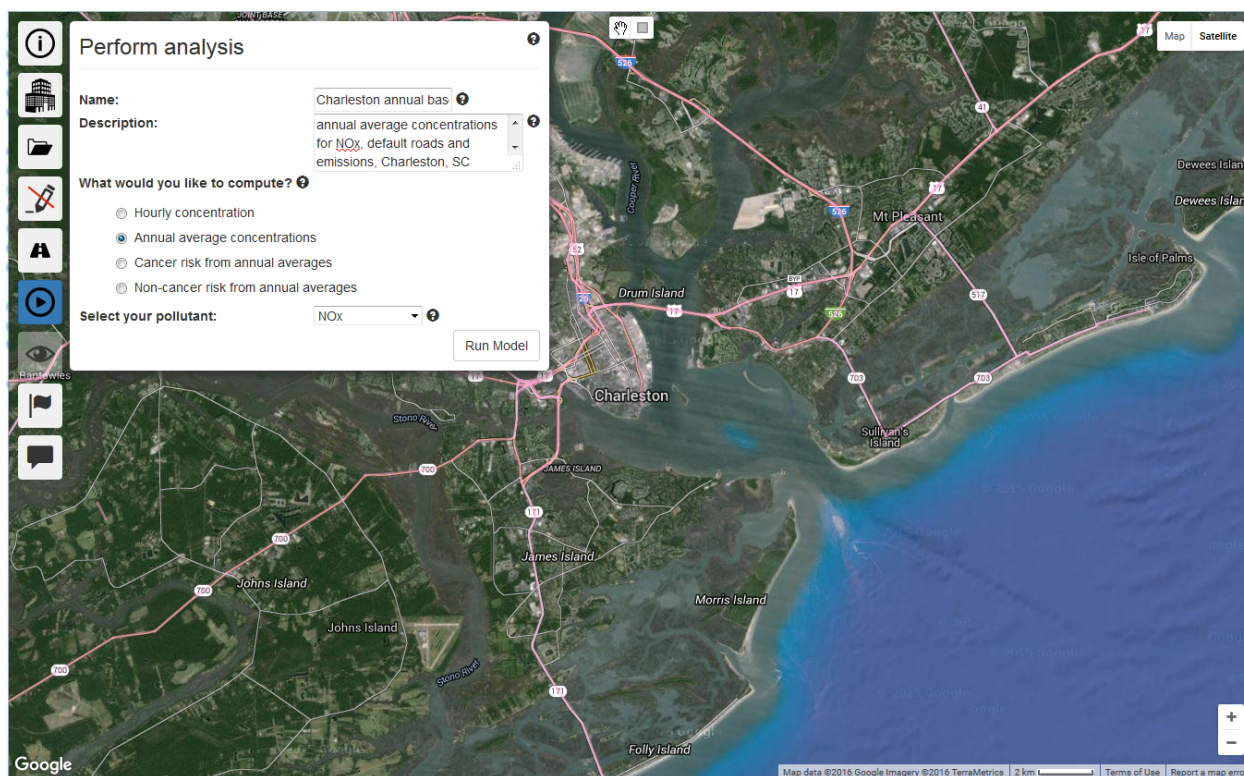


Figure 9. Selections in *Perform analysis* frame showing base-line selections.

3.5. View the Baseline Results

Click the *View results* tile to open its associated frame. Note that it has two tabs. Select the *Model Runs* tab and click the *Refresh* button. Your base-line model run then appears as the top line in your list (see Figure 10). If the status shows *running* instead of *completed*, periodically press the *Refresh* button. NOTE: C-LINE's status for runs and comparisons does not automatically update.

¹ <https://www.epa.gov/national-air-toxics-assessment/nata-overview>

View results									
Model Runs		Comparisons							
Refresh									
Name	Pollutant	Values	Stability	Season	Wind	Day	Hour	Status	Last Updated
Charleston annual base NOx	NOx	Annual	N/A	N/A	N/A	N/A	N/A	completed	Apr 8, 2016 5:09 pm
Charleston, SC defaults	NOx	Hourly	Neutral	Winter		Weekday	AM Peak	completed	Apr 8, 2016 2:58 pm

Figure 10. View Results frame, Model Runs tab showing completed base-line model run.

When the run is complete, click the blue eye (👁) on the right-hand side of that run's status line. The annual average concentration results are then displayed on the map (see Figure 11).

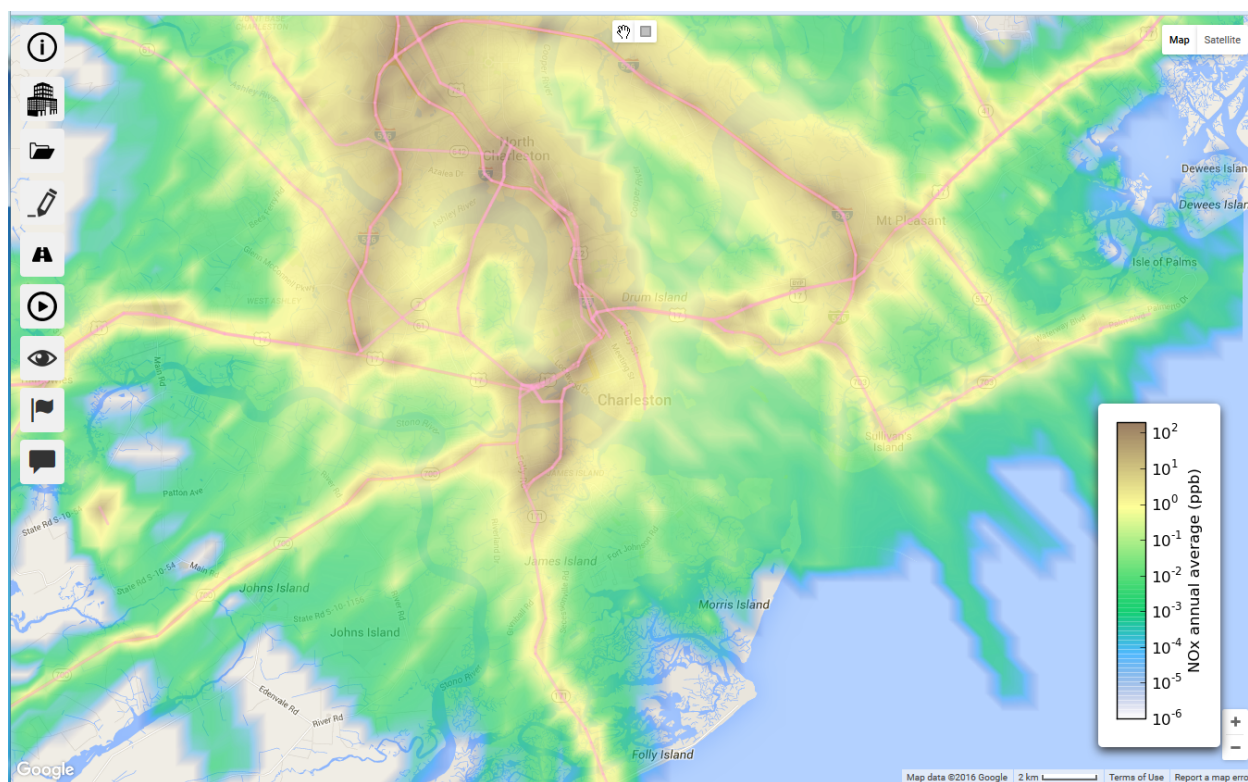


Figure 11. NO_x annual average concentrations (ppb) for Charleston, SC base-line scenario.

Just to the right of the blue eye is a blue cloud widget (☁). Select this widget to download a shapefile of the census block groups with the concentration in each. A shapefile is generated for all model runs that compute the metrics annual concentration, cancer risk, and non-cancer risk. The relevant attributes associated with each polygon are the Name (block group identifier), State_Name, Road_Conc (concentration or risk value for that polygon), and Total_Conc (same as Road_Conc). As shown in the legend in Figure 11, the concentration units are ppb.

The results of the model run are displayed using a logarithmic scale. The legend in the lower right hand corner shows the color range for the minimum through maximum values calculated. For all model

run types, the minimum value that can be displayed is 10^{-6} . The actual minimum displayed depends upon the smallest values calculated in the model run.

The maximum value displayed depends upon the type of model run. Calculated values above pollutant-specific maximums are displayed in dark brown. For hourly and annual average model runs, a pollutant-specific maximum is used, based on ranges at or near the EPA's National Ambient Air Quality Standard (NAAQS) for criteria pollutants, or the EPA's Reference Concentration (RfC) for air toxics. Model runs that calculate cancer risk use a maximum value of 100 per million, while non-cancer risk has a maximum hazard quotient (HQ) of 1.

3.6. Visualization Options

When viewing the results of your analysis click the *Visualization options* tile, which looks like a human eye, to display the *Visualization options* frame (see Figure 12). You have three types of functionality on this frame: inspect mode, census block groups, and clear overlay.

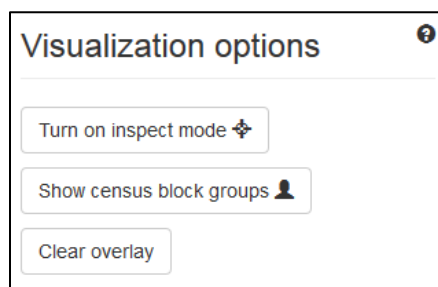


Figure 12. Visualization options frame when viewing scenario results.

Inspect mode displays the concentration at one or more selected locations on your map. To access this feature, click the *Turn on inspect mode* button. You can then click on one or more locations of interest. C-LINE will display the coordinates of the location in (latitude, longitude) degrees and the concentration. NOTE: The concentration is interpolated from surrounding locations where the model calculated the concentration, not calculated by the dispersion model at that location when you click on it.

Figure 13 shows an example results screen of a C-LINE run. Inspect mode was used on two locations. If you want to turn off one of the boxes, just click its X in its top right-hand corner. If you want to dismiss all of the boxes and end inspect mode, open the *Visualization options* frame again and click the *Turn off inspect mode* button.

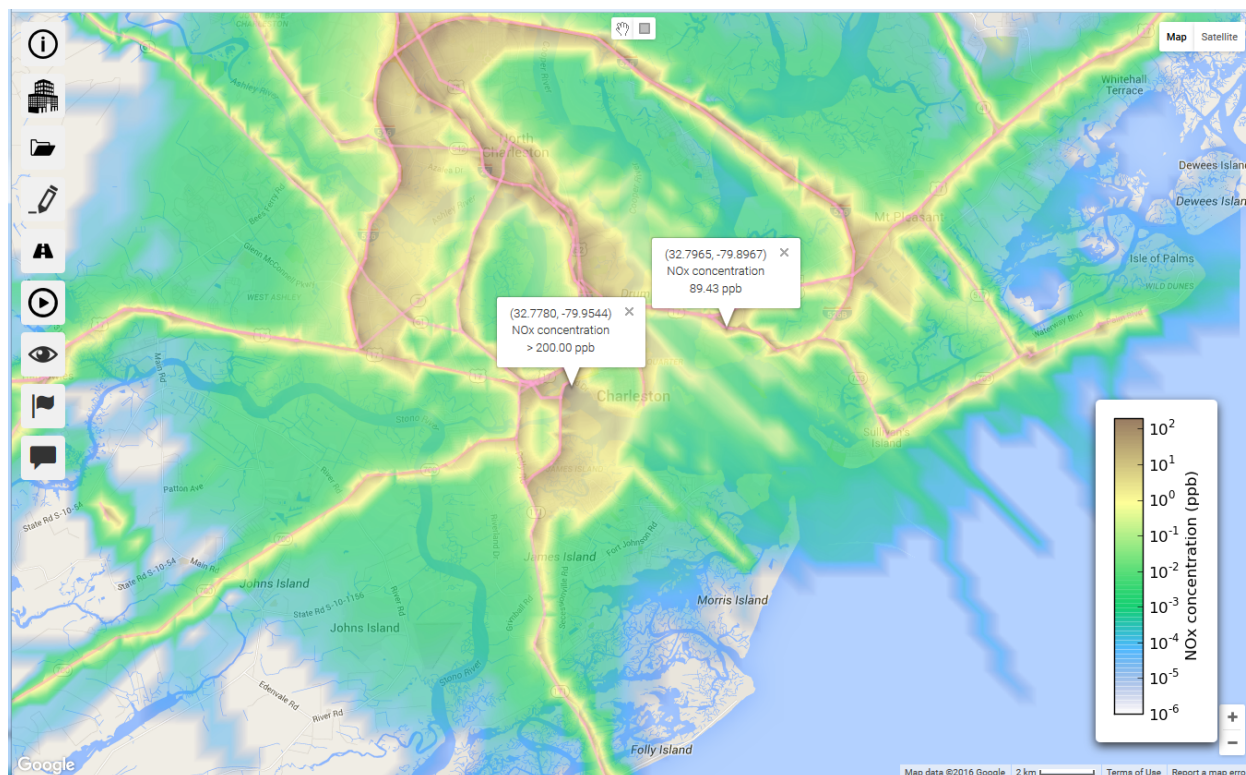


Figure 13. Inspect mode showing concentrations at two selected locations.

Click the *Show census block groups* button to overlay the boundaries of the 2010 census block groups on your modeling domain. This version of C-LINE does not provide any additional information about individual census block groups. However, you can turn on inspect mode and then click within a census block group of interest to see concentration values of interest. When you are finished with the census block groups, open the *Visualization options* frame again and click the *Hide census block groups* button.

When you are finished working with the results on your map, open the *Visualization options* frame and click the Clear overlay button. This removes the map of your modeling results, values from inspect mode, and census block group boundaries. The *Visualization options* tile is also deactivated.

3.7. Air Quality Monitors

Select the tile *Air quality monitors* to locate air quality monitors that may be available in your modeling domain (Figure 14). Select the types of monitors that you want to display (e.g., NO_x monitor if you are modeling NO_x). Note the colors that designate each of the four pollutants; brown indicates that more than one pollutant is monitored at that site. Click the *Show monitors* button to display the monitors on your map.

Air quality monitors

Which pollutants should be shown?

☒ NO_x

☒ CO

☒ SO₂

☒ PM_{2.5}

☐ Sites with observations for multiple pollutants

Show monitors

Figure 14. Air quality monitors by pollutant measured.

Figure 15 shows two monitors in the greater Atlanta region. The monitor designated by a bright blue circle is for SO₂ only. It is on the AQS network of monitors and recorded the given maximum and mean 1-hr concentrations of SO₂ for the years 2010 through 2014. The monitor designated by a brown circle has observations for four pollutants: NO_x, CO, SO₂, and PM_{2.5} as 1-hr concentrations. The PM_{2.5} monitor does not have data for 2010. Also note that the button on the air quality monitors frame has now changed to *Hide monitors*; click that button to remove the monitors from the map.

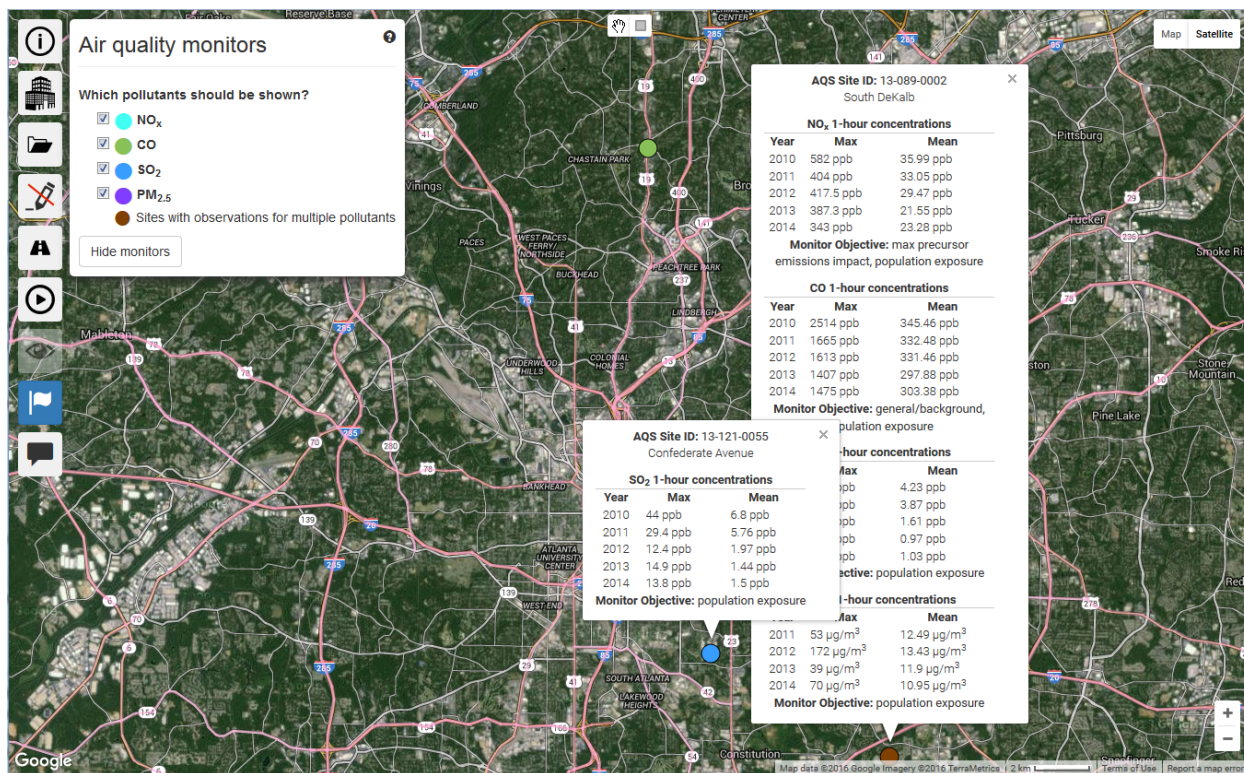


Figure 15. Air quality monitors in greater Atlanta, GA with pop up boxes showing annual statistics.

4. Changes to Inputs for Comparative Analyses

A comparative analysis compares the concentration field from a base-line analysis (old) to an analysis with a different concentration field (new) throughout the modeling domain. Users must use the same modeling domain, which is defined by its geographic center and extent, pollutant, and metric for both old and new analyses.

Because the concentration field is calculated by C-LINE using on-road mobile emissions, the **new** analysis needs to change some of the emissions input values for an annual metric. For the hourly concentrations metric, users can change either emissions or meteorological conditions. The following input changes affect the results produced by a C-LINE model run.

- Change the traffic (AADT)
- Change the average speed (mph)
- Change the vehicle mix (see Section 4.4)
- Edit a single road segment
- Edit multiple road segments
- Add a new road segment
- Remove a road segment
- Select different meteorological conditions

The remainder of this section presents the *View and modify roads* frame, provides details on these seven methods to change on-road mobile emissions, illustrates examples of the two types of comparative analyses available in C-LINE, and discusses the legend box.

4.1. *View and modify roads* Frame

Click the *View and modify roads* tile to display its associated frame. Figure 16 shows all of the data elements for roads. Users cannot change the street name column.











View and modify roads							
Select all sources		Add new source ▼					
Street name	AADT	MPH	Gas car multiplier	Gas truck multiplier	Diesel car multiplier	Diesel truck multiplier	
21st Ave	19618	38	1	1	1	1	 
41st Ave	19618	38	1	1	1	1	 
Ashley River Rd	12722	44	1	1	1	1	 
Ashley River Rd	19618	38	1	1	1	1	 
Ashley River Rd	19618	38	1	1	1	1	 
<div> First Previous 1 2 3 4 5 6 7 8 9 10 Next Last </div>							

Figure 16. View and modify roads frame.

Use the *Select all sources* button to select all road segments at once. Once the user has selected one or more road segments, they are shown in the table in red; a new button *Unselect all sources* then appears between the *Select all sources* and the *Add new source* buttons.

4.2. Change the Traffic (AADT)

AADT is the annual average daily traffic volume (number of vehicles) on a road segment. Users can increase or decrease the AADT by using the up/down arrows or by deleting the old value and typing in a new one.

Several types of studies may require a change in the AADT. You may need to look at general growth in traffic across the modeling domain or in a section of the domain. Examples of growth to expect include: a new subdivision, school, office complex, or sports arena to be built in one area. A new highway could be built or widened to handle increased traffic flow. Users may need to compare the effects of several potential routes for a major thoroughfare during a planning phase and may need to shut down a major roadway for repairs and move the traffic to alternate routes.

4.3. Change the Average Speed (MPH)

Miles per hour (mph) represents the average speed on the road segment. Speed is one factor used to determine emissions for each vehicle type on a road segment. Although emissions are partially determined by average speed, the calculation is not sufficiently sensitive to warrant making changes to average speed on the order of 1 mph. For example, the difference in vehicular emissions is very small when comparing 36 and 37 mph. Therefore, C-LINE uses a binning approach to calculating vehicular emissions.

Emissions are calculated in 5-mph bins. This means that the assigned speed is rounded to the nearest 5-mph (e.g., 33 - 37 are all assigned the 35-bin, 38-42 are all assigned the 40-bin). The bins are 0, 5, 10, 15, 20, 25, 30, 35, 40, 45, 50, 55, 60, 65, 70, and 75 mph.











4.4. Change the Vehicle Mix

C-LINE uses four vehicle classes: gasoline car, gasoline truck, diesel car, and diesel truck. The vehicle mix represents the percentage of each of the vehicle classes on the road for the specified time period. The vehicle mix was obtained from a national vehicle emissions dataset. The default vehicle mix is determined for each road class in each county in your modeling domain. As shown in Figure 16, *All road segments*, start with “1” as the multiplier for each of these four vehicle classes, indicating that the default vehicle mix is to be used.

Adjust the vehicle mix by changing the multipliers. For example, to decrease the gasoline cars by 50%, put 0.5 in the ‘Gas car multiplier’ box. This multiplier value would decrease the number of gasoline cars and would increase the number of all other types of vehicles (i.e., gasoline trucks, diesel cars, and diesel trucks) to keep AADT constant.





4.5. Edit a Single Road Segment

Select a road segment by clicking it on the map or in the *View and modify roads* frame. Refer to section 3.1 for more details on using the *hand* widget. Figure 17 shows how one selected road segment is displayed in red in the table; its color is also changed from pink to red on the map.

Select all sources			Unselect all sources			Add new source ▾	
Street name	AADT	MPH	Gas car multiplier	Gas truck multiplier	Diesel car multiplier	Diesel truck multiplier	
Folly Rd	19618	38	1	1	1	1	 
Folly Rd	19618	38	1	1	1	1	 
Folly Rd	19618	38	1	1	1	1	 
Folly Rd	19618	38	1	1	1	1	 
Folly Rd	19618	38	1	1	1	1	 












First Previous 6 7 8 9 10 11 12 13 14 15 Next Last

Figure 17. *View and modify roads* frame with one selected road segment.

Click the black pencil icon () on the right side of the selected road segment; this action starts edit mode. Figure 18 illustrates the *View and modify roads* frame while changes are being made to the one selected road segment. The pencil changes to a green check () ; press this icon when you are finished editing the line. After changing something on a line, a blue circular arrow () appears on that line; press this icon to revert your changes back to their original values. If you want to delete a road segment from your analysis, press the red icon () on the far right side of that segment.

View and modify roads

Select all sources
Unselect all sources
Add new source



Street name	AADT	MPH	Gas car multiplier	Gas truck multiplier	Diesel car multiplier	Diesel truck multiplier	
Folly Rd	19618	38	1	1	1	1	 
Folly Rd	19618	38	1	1	1	1	 
Folly Rd	19618	38	1	0.7	1	1.5	  
Folly Rd	19618	38	1	1	1	1	 
Folly Rd	19618	38	1	1	1	1	 

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Figure 18. *View and modify roads* frame showing one road segment being edited.

Note how the vehicle distribution has been changed in Figure 18. Every road segment begins with all the vehicle type multipliers set to 1, signifying that C-LINE will use the preset distribution for that road class and county. But this road segment has been changed to decrease the proportion of gasoline trucks and to increase the proportion of diesel trucks. The AADT has not been changed, so the number of vehicles will not change. Also note that the name of the road segment is now shown in blue, indicating that at least one value associated with this road segment has been changed.

4.6. Edit Multiple Road Segments

C-LINE provides several methods to select multiple road segments to edit as a group. To make the same change to all road segments in the modeling domain, use the *Select all sources* button on the *View and modify roads* frame (see Figure 16). Section 3.1 provides instructions on using the *hand* widget to select individual road segments or the *box* widget to select a geographic grouping of road segments. To deselect a link, find it in the table and click the black check mark () on the right side of that link (see Figure 19). The red icon () on the far right side of a road segment deletes that segment from the analysis, whereas the black check mark only removes that segment from the group of road segments being edited.

View and modify selected roads

Select all sources

Unselect all sources

Add new source ▾

Street name	AADT	MPH	Gas car multiplier	Gas truck multiplier	Diesel car multiplier	Diesel truck multiplier	
Folly Rd	19618	38	1	1	1	1	
Folly Rd	19618	38	1	1	1	1	
Folly Rd	19618	38	1	1	1	1	
Folly Rd	19618	38	1	1	1	1	
Folly Rd	19618	38	1	1	1	1	

<<

<

1

2

3

4

>

>>

AADT multiplier	MPH change	Gas car multiplier	Gas truck multiplier	Diesel car multiplier	Diesel truck multiplier
<input type="text" value="1"/>	<input type="text" value="0"/>	<input type="text" value="1"/>	<input type="text" value="1"/>	<input type="text" value="1"/>	<input type="text" value="1"/>

Apply Multipliers

Reset Sources

Figure 19. View and modify selected roads frame with multiple road segments selected.

Note how the widgets for changing values are now located at the bottom of the frame. Any change a user makes now affects all the selected road segments whether or not they appear on the current frame. Also, users cannot change the AADT or the mph values to a specific value; those changes are relative to the existing values.

- **AADT multiplier:** This is a factor to be applied to the AADT of all selected road segments. To decrease the AADT, use a multiplier less than one. To increase the AADT, use a multiplier greater than one. If a user does not wish to change the AADT, set the multiplier to one.
- **MPH change:** This is a value to be added to the mph value for each selected road segment. Use the up and down arrows to change the average speed in increments of 5 mph. Use a positive value to increase the average speed, a negative value to decrease the average speed, and zero for no change to speed.
- **Vehicle type multipliers:** Information on these multipliers is discussed above (see Section 4.4). Note that these multipliers will be applied to all selected road segments regardless of road type and county.

When edits to this group of road segments are complete, press the *Apply Multipliers* button.

NOTE: This button applies the mph change, as well as the values for the five multiplier widgets.

To discard changes, press the *Reset Sources* button.

4.7. Add a New Road Segment

This section describes how to add a new road segment (i.e., a source in C-LINE) to a modeling domain. Figure 16 through Figure 19 show the *View and modify roads* frames for several types of edits. Each of those figures shows the button *Add new source*.

First, click the *Add new source* button at the top of the *View and modify roads* frame. The drop-down list shows the four road classes supported in C-LINE (see Figure 20). Roads are categorized as *urban* or *rural* and then as functional classes within each of those. If a road segment is within a city limit, categorize it as *urban*; otherwise it is *rural*. The highest functional class is *interstate*. Because C-LINE does not support the *freeway* class for *rural*, the next functional class is *freeway* for *urban* and *principal arterial* for *rural*. The functional classifications are documented by the U.S. Department of Transportation, Federal Highway Administration, “Highway Functional Classification Concepts, Criteria and Procedures” available from www.fhwa.dot.gov/planning/processes/statewide/related/highway_functional_classifications/fcauab.pdf.

Street name	AA			Truck multiplier	Diesel car multiplier	Diesel truck multiplier		
21st Ave	19618	44	1	1	1	1		
41st Ave	19618	44	1	1	1	1		
Ashley River Rd	12722	44	1	1	1	1		
Ashley River Rd	19618	38	1	1	1	1		
Ashley River Rd	19618	38	1	1	1	1		

Navigation: First Previous **1** 2 3 4 5 6 7 8 9 10 Next Last

Figure 20. Add new source drop-down list.

- Select **urban freeway**. The frame then disappears and the cursor changes into a plus sign (+). Also, note that a tile *Cancel adding new source* with a red X is added to the tiles list.
- Click the starting point of the new road segment and the number of times needed to define the road as a series of straight line segments. After clicking the end of the last line segment, move the cursor to the *Cancel adding new source* tile and click it.
- The cursor changes back to a hand. Point the cursor to any part of the new road segment and click to select it. That road segment is displayed in red on the map.
- The *View and modify roads* frame then appears again and the new road segment is shown in red as the last road in the list (see Figure 21).



When you finish drawing a new road, you can double-click the end of the last line segment.

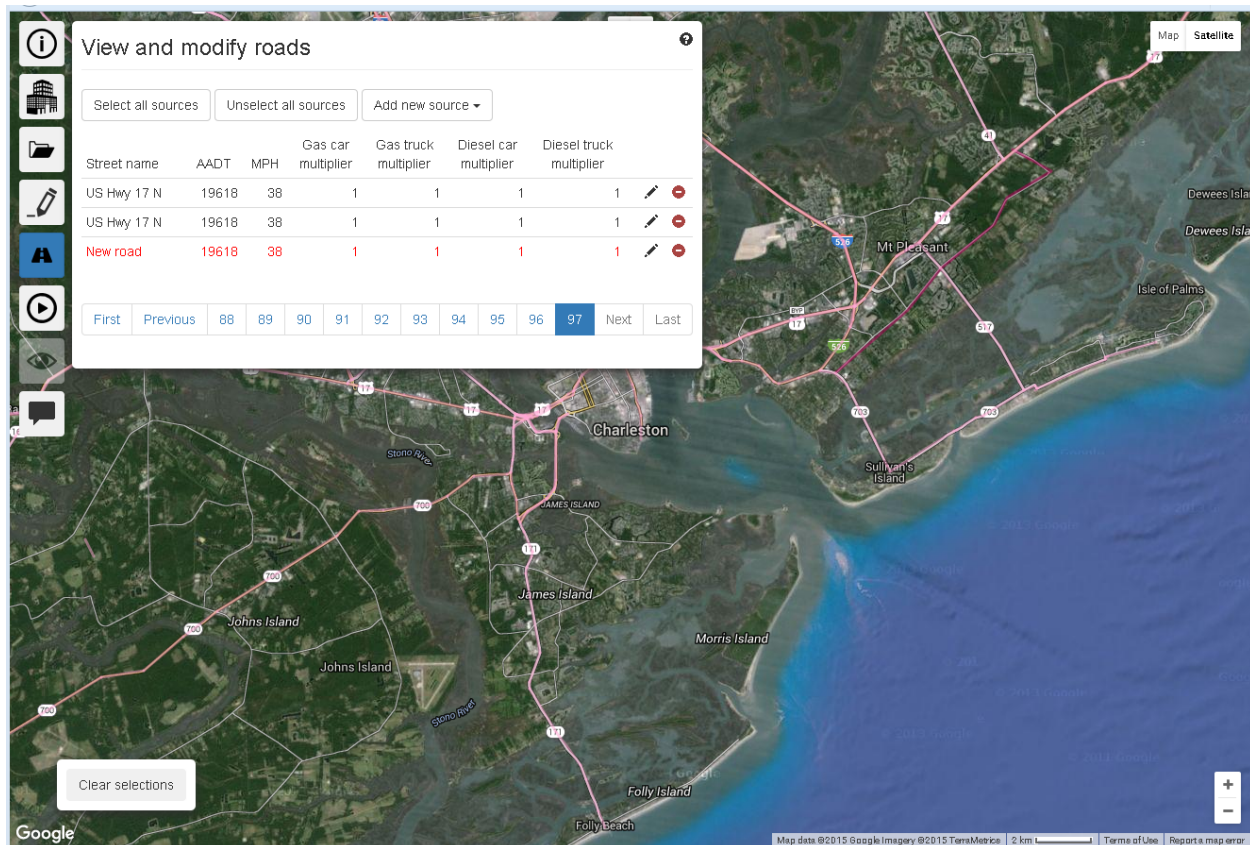


Figure 21. View and modify roads frame with new road segment in red and also in red on the map.

Click the pencil icon to edit the new source line. Edit the value for *Street name* so the new roads do not all have the name “New road”. C-LINE assigned the AADT based on the user’s road classification. In this example, the road is named “703-517”, the AADT is set to “5000”, and the *Diesel truck multiplier* is changed to “0” (see Figure 22). Click the green check mark icon to save these changes for that road segment.

View and modify roads

Select all sources Add new source

Street name	AADT	MPH	Gas car multiplier	Gas truck multiplier	Diesel car multiplier	Diesel truck multiplier
US Hwy 17 N	19618	38	1	1	1	1
US Hwy 17 N	19618	38	1	1	1	1
703-517	5000	38	1	1	1	1

First Previous 88 89 90 91 92 93 94 95 96 97 Next Last

Figure 22. Add new road segment.

4.8. Remove a Road Segment

Users can easily remove one or more road segments from a model run. **WARNING:** Once removed from the model run, the road segments cannot be put back in. Follow these steps.

- Start edit mode.
- Select one or more road segments. They will be shown in red on the map and as a group of red selected roads in the *View and modify selected roads* frame.
- Make certain the selected road segments are meant to be removed.
- Click the *Delete source* icon at the right end of each segment.

WARNING: If the browser brings up a dialog box asking if you want to prevent the current page from bringing up more dialog boxes, click *Okay* to allow C-LINE to bring up the dialog boxes; otherwise, you will not be able to delete more of your selected roads and you may need to reset your C-LINE session (see Figure 23).

Are you sure you want to delete this source?

OK Cancel

Figure 23. Click OK to delete the selected source, or Cancel to not delete the source.

Figure 24 shows the C-LINE screen when the *box* widget was used to select the road segments of Rte. 171 on James Island down to Folly Beach. The selected road segments are shown in red on the map and as the selected roads in the table. Delete each road segment and confirm deletion of each.

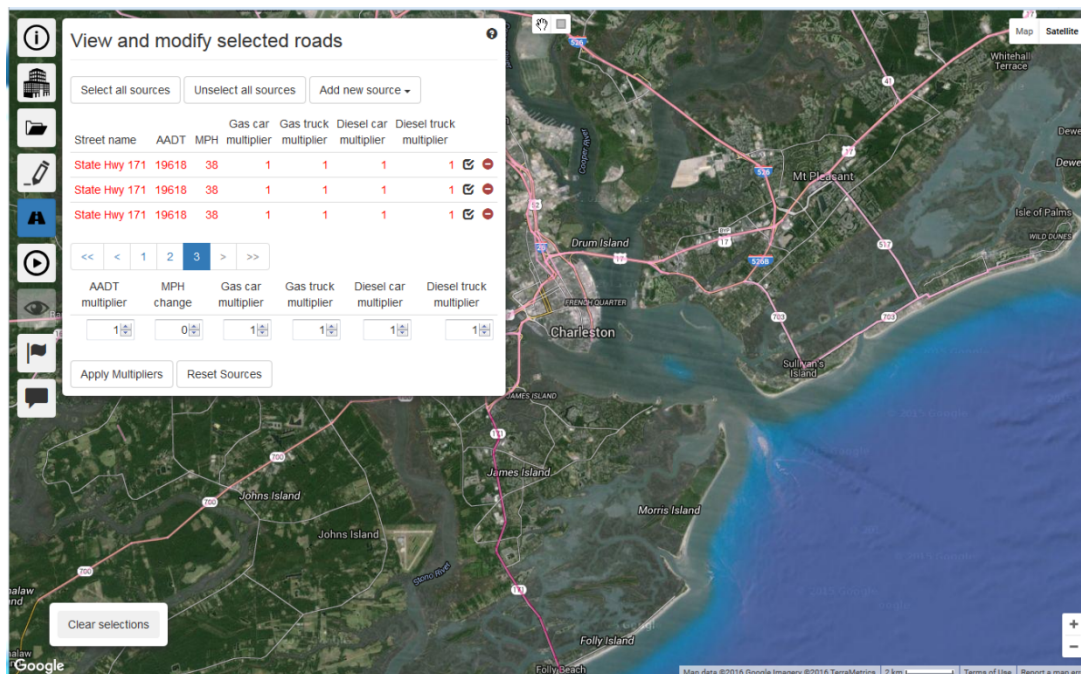
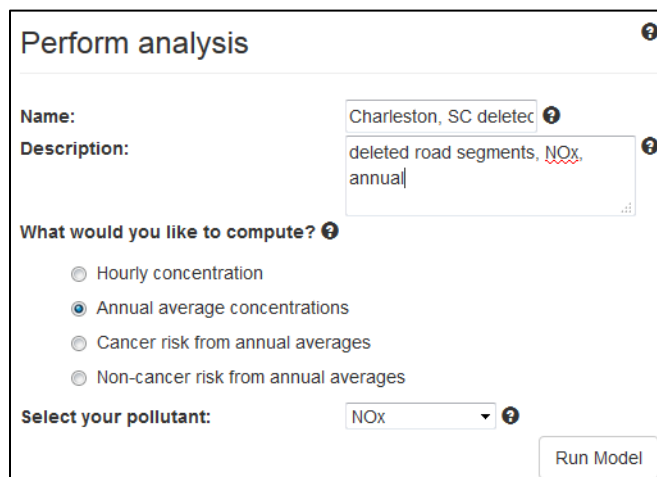


Figure 24. Selected road segments shown on map and *View and modify selected roads* frame.

After you finish deleting these road segments, click the *Perform analysis* tile, and then change the *Name* to “Charleston deleted 171 to coast”. Click the *Run Model* button.

4.9. Select Different Meteorological Conditions

C-LINE can simulate a range of meteorological conditions as shown in Figure 8 and discussed in Section 3.4. Figure 25 shows the Perform Analysis frame when hourly concentrations are not selected. Because human health risks are computed using annual average concentrations, all meteorological conditions occurring at the selected site are used in the calculations. Users are not able to select specific meteorological conditions for human health risk computations.



The image shows a web-based form titled "Perform analysis". It contains several input fields and a "Run Model" button. The "Name:" field has the text "Charleston, SC deletec". The "Description:" field has the text "deleted road segments, NOx, annual". The "What would you like to compute?" section has four radio button options: "Hourly concentration", "Annual average concentrations" (which is selected), "Cancer risk from annual averages", and "Non-cancer risk from annual averages". The "Select your pollutant:" dropdown menu is set to "NOx". There are help icons (question marks) next to the "Name:", "Description:", and "Select your pollutant:" fields. A "Run Model" button is located at the bottom right of the form.

Perform analysis

Name: Charleston, SC deletec

Description: deleted road segments, NOx, annual

What would you like to compute?

- ☐ Hourly concentration
- ☒ Annual average concentrations
- ☐ Cancer risk from annual averages
- ☐ Non-cancer risk from annual averages

Select your pollutant: NOx

Run Model

Figure 25. *Perform Analysis* frame for annual meteorological conditions.

The results of this annual analysis are shown in Figure 26. Note that the legend shows “NO_x annual average (ppb)” indicating that the analysis was on an annual time basis and computed concentrations in units of ppb for the pollutant NO_x.

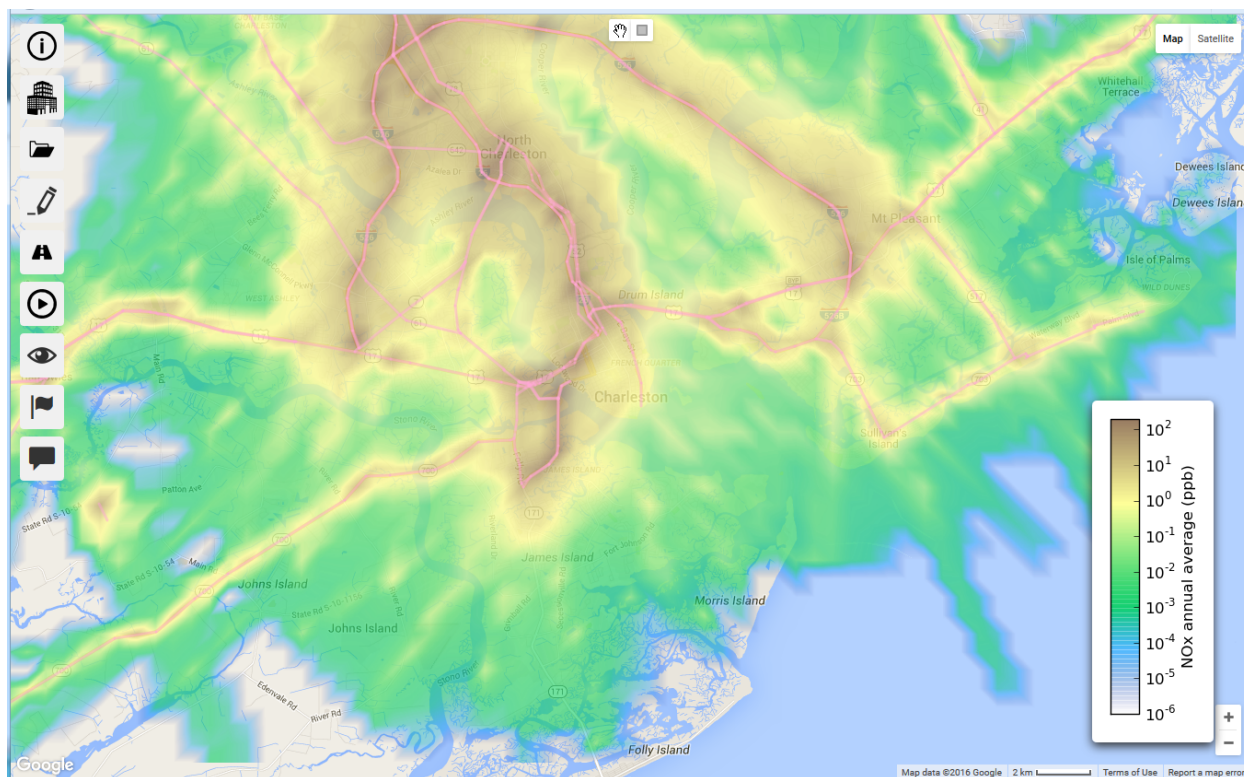


Figure 26. Results of annual average concentration scenario for Highway 171 deleted to coast for NO_x .

Figure 27 shows modeled NO_x concentrations for 1 hour of weekday AM peak traffic under neutral atmospheric stability in the winter months using the seasonal average wind direction. Note that the legend shows “ NO_x concentration (ppb)” indicating that the analysis was on an hourly time basis and computed concentrations in units of ppb for the pollutant NO_x . The individual parameters that determined the meteorological conditions and the vehicular emissions are not included in the results map.

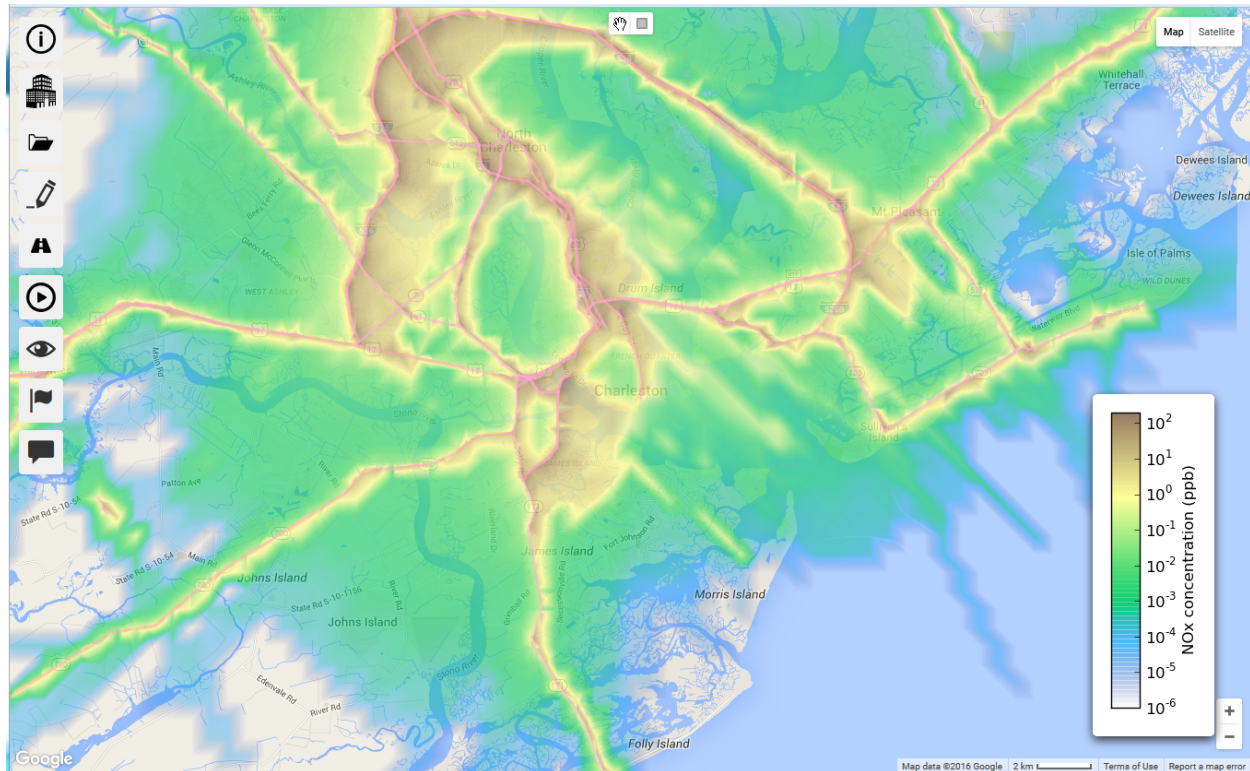


Figure 27. Results of hourly concentration scenario, neutral stability, winter, AM peak for NO_x .

Visually compare Figure 26 and Figure 27 showing annual and hourly results, respectively. Hourly concentrations are mostly to one side of the emissions sources, which are located on the roads, but annual concentrations are more spread around the emissions sources. In addition, the annual concentrations deleted the road to the coast from the model run, making the concentrations from its emissions apparent for the hourly model run, but missing in the annual model run.

Figure 28 shows the selections for another hourly analysis. This one is for the stable atmospheric stability class during the winter season when the wind is blowing from the North to the South.

Perform analysis

Name:

ton NOx hrly stable N-S

Description:

Charleston, SC; winter, stable, wind N-S

What would you like to compute?

☒ Hourly concentration

☐ Annual average concentrations

☐ Cancer risk from annual averages

☐ Non-cancer risk from annual averages

Select your pollutant:

NOx

Select your meteorological conditions:

Atmospheric stability:

Stable

Season:

Winter

Wind Direction:

North to South

Select your emissions parameters for vehicle mix and traffic volume:

Day:

Weekday

Hour:

AM peak

Run Model

Figure 28. Define an analysis for a different set of hourly conditions.

Note that there are two methods to select the wind direction. Either use the Wind Direction drop-down box or click the arrow widget to the right of that box. Each time you click the arrow widget, the arrow shifts to the next wind direction in clockwise order. Figure 29 shows the results of this simulation.



The model run with all of your selections and customized road segments is saved when you click *Run Model*.

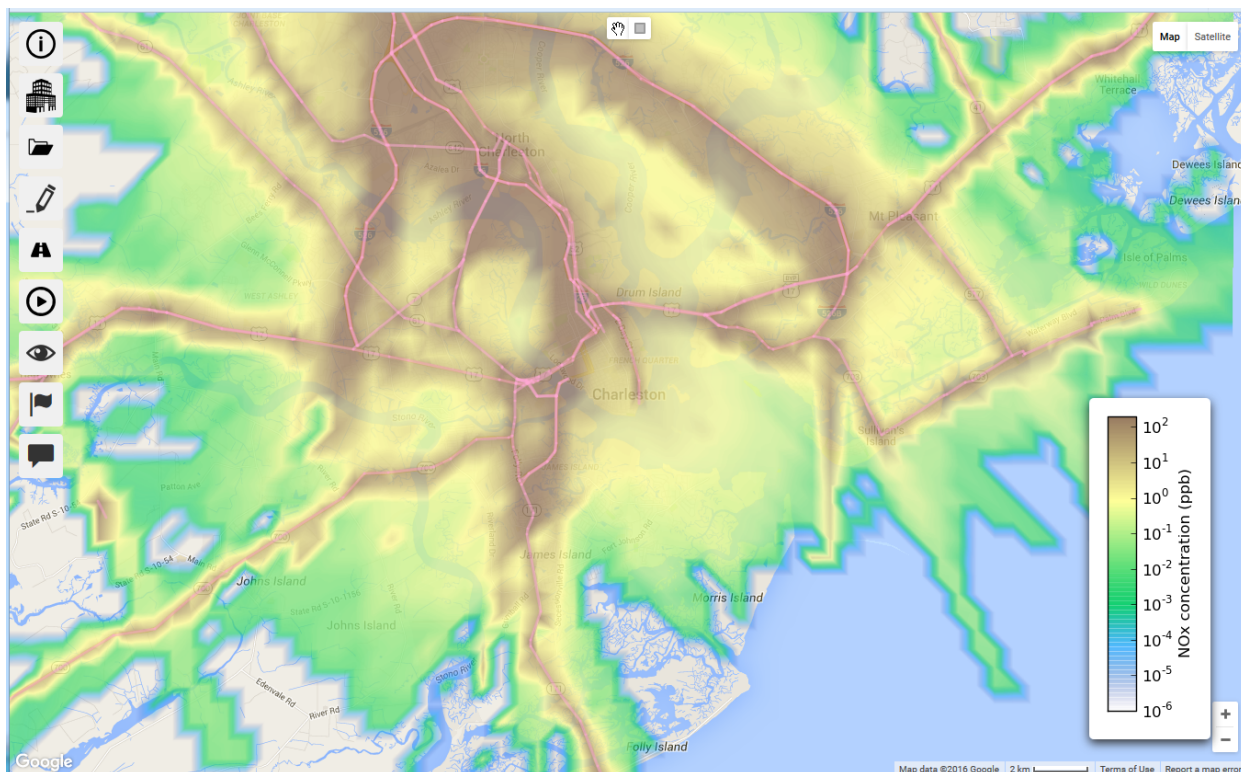


Figure 29. Concentrations of NO_x for hourly, stable, winter conditions, weekday, AM Peak, with the wind blowing from North to South.

4.10. Compare Model Runs – Raw Difference

This example compares the raw differences between two model runs. This means that the actual differences in concentration values throughout the modeling domain are mapped. To perform this analysis, load a single model run into C-LINE. This example uses default roads, vehicle mixes, AADT, weekday, and AM peak traffic volume for Charleston, SC. Meteorological conditions are the *stable* atmospheric stability class during the *winter* season. The sole difference between the two model runs is *wind direction*: North-to-South and South-to-North. Those model runs are named “Charleston NO_x hrly stable N-S” and “Charleston NO_x hrly stable S-N”, respectively.

Go to the *View Results* frame and select the *Comparisons* tab. Select the *Raw Difference* mode, as shown in Figure 30. Note that both your base and new model runs must have been saved using different names. C-LINE calculates raw differences as (New – Base); in this example differences are calculated as concentrations with winds blowing from the south, minus concentrations with winds blowing from the north.

The screenshot shows the 'View results' interface with the 'Comparisons' tab selected. A 'Refresh' button is visible. Below it is a table with columns: Base Run, New Run, Mode, Status, and Last Updated. Two rows are shown, both with a status of 'completed' and a timestamp of 'May 2, 2016 4:25 pm' and 'May 2, 2016 4:24 pm' respectively. The first row has a blue eye icon, and the second has a red eye icon. Below the table is a 'Create New Comparison' section with dropdowns for Mode (Raw Difference), New Model Run (Charleston NOx hrly stable S-N), and Base Model Run (Charleston NOx hrly stable N-S). A 'Submit' button is at the bottom right.

Base Run	New Run	Mode	Status	Last Updated
Charleston, SC defaults	Charleston, SC defaults	Relative Difference	completed	May 2, 2016 4:25 pm
Charleston, SC defaults	Charleston, SC defaults	Raw Difference	completed	May 2, 2016 4:24 pm

Create New Comparison

Mode: Raw Difference

New Model Run: Charleston NOx hrly stable S-N

Base Model Run: Charleston NOx hrly stable N-S

Submit

Figure 30. View Results frame, Comparisons tab for Raw Difference mode.

To see the results of your raw difference model run, click the Refresh button to see your most recent C-LINE runs (Figure 31).

The screenshot shows the 'View results' interface with the 'Comparisons' tab selected. A 'Refresh' button is visible. Below it is a table with columns: Base Run, New Run, Mode, Status, and Last Updated. One row is shown with a status of 'completed' and a timestamp of 'May 2, 2016 6:18 pm'. The row has a blue eye icon and a red eye icon.

Base Run	New Run	Mode	Status	Last Updated
Charleston NOx hrly stable N-S	Charleston NOx hrly stable S-N	Raw Difference	completed	May 2, 2016 6:18 pm

Figure 31. View Results frame for a Comparison analysis.

When the Status shows **completed** for your Raw Difference model run, click the blue eye widget (👁) to display your map. Figure 32 shows the results from this model run. Note that brown colors indicate higher concentrations in the new model run (wind from the south) and blue colors indicate lower concentrations (wind from the north) (i.e., higher concentrations when the wind was from the north). The results for the raw difference comparison are displayed using a logarithmic scale. The logarithm of the magnitude of the difference is computed, and then the original sign of the difference is applied.

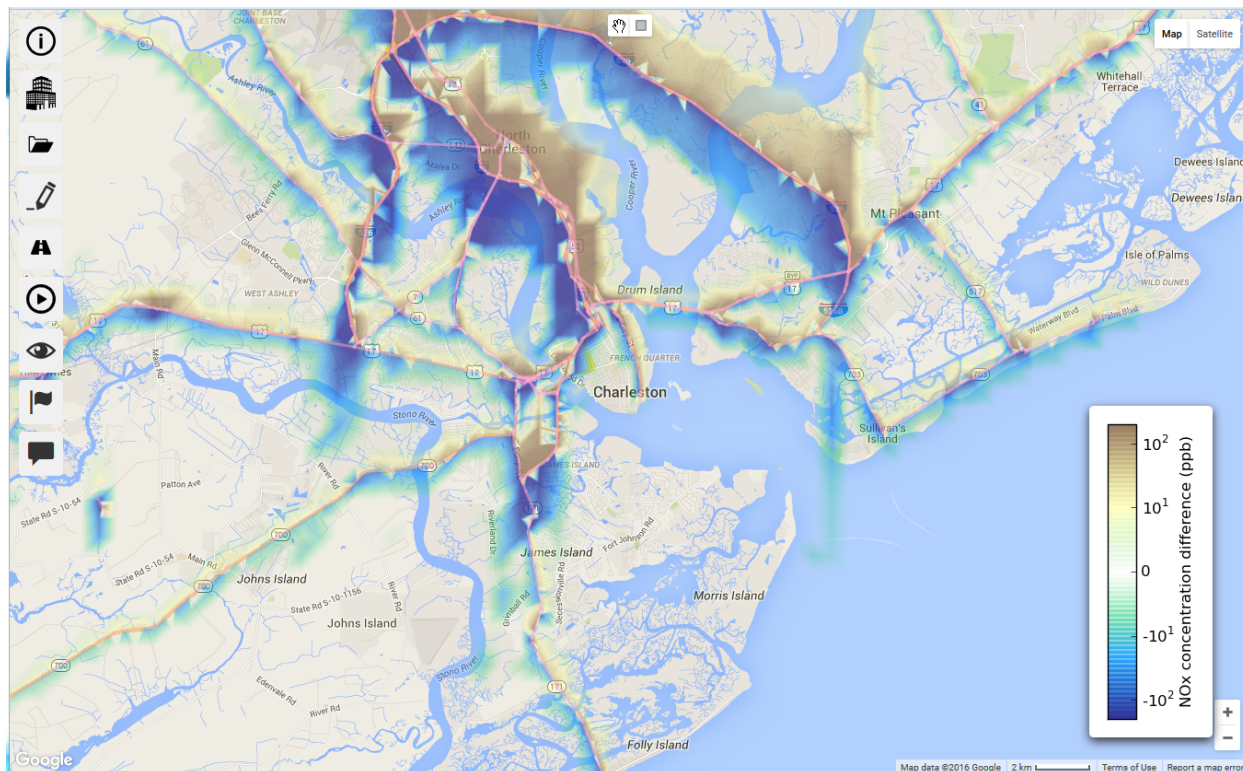


Figure 32. Example comparison analysis showing *Raw Difference* mode.

4.11. Compare Model Runs – Relative Difference

Use the same steps to perform a Relative Difference as those described for a Raw Difference in Section 4.10. On the *Perform Analysis* frame, shown in Figure 30, select *Relative Difference* from the **Mode** drop-down list. The Relative Difference is calculated as a percentage based on the following equation.

$$\text{Relative Difference (\%)} = (\text{New} - \text{Base}) / \text{Base} \times 100$$

Figure 33 shows the relative difference in NO_x concentrations between the new and the base model runs. Note that the range in the legend is -100% to +100%. All relative differences outside this range are mapped as though they were at the appropriate extreme value.

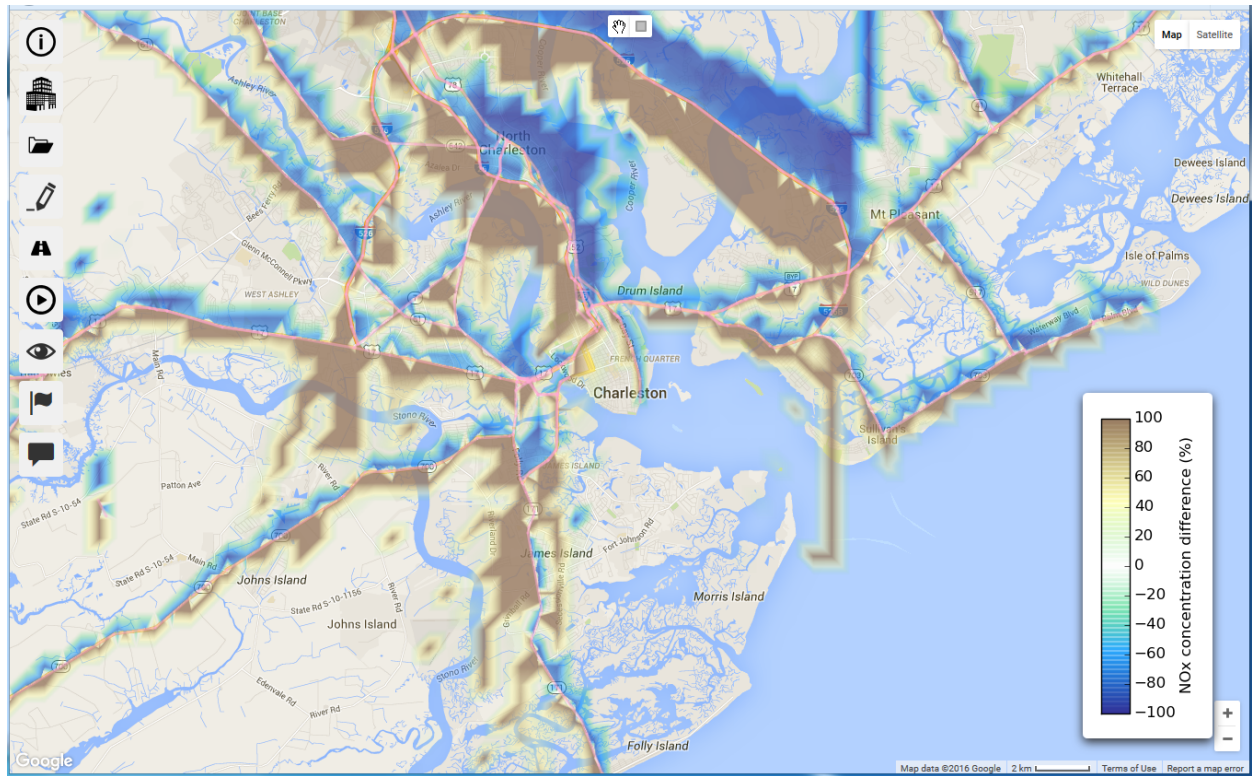


Figure 33. Example comparison analysis showing *Relative Difference* mode.

4.12. Visualization Options

The visualization options for comparative model runs are the same as those for regular model runs (see Figure 12, section 3.6).

5. Risk Metrics

C-LINE computes cancer risk and non-cancer risk from annual average concentrations. However, not all of the pollutants supported in C-LINE have human health benchmarks for chronic exposure from inhalation. The list of pollutants for which cancer risk may be computed is benzene, formaldehyde, acetaldehyde, and 1,3-butadiene. The list of pollutants for non-cancer risk is benzene, formaldehyde, acetaldehyde, acrolein, and 1,3-butadiene.

NOTE: The risk estimates are preliminary, subject to change, and should be used with caution.

5.1. Cancer Risk from Annual Average Concentrations

C-LINE uses the standard calculation for cancer risk from chronic exposure via inhalation pathway, and then converts the results to a basis of one million people. The human health risk factor is the Unit Risk Factor (URF) for inhalation, which has units of $(\mu\text{g}/\text{m}^3)^{-1}$. Concentration is calculated in units $\mu\text{g}/\text{m}^3$. C-LINE then employs a conversion factor (10^6) to calculate incidence per million people, as shown in the following equation.

$$\text{Cancer Risk per million people} = \text{URF} \times \text{Concentration} \times 10^6$$

Figure 34 shows the estimated incidences of cancer from benzene due to inhalation from an annual baseline concentration calculation in C-LINE.

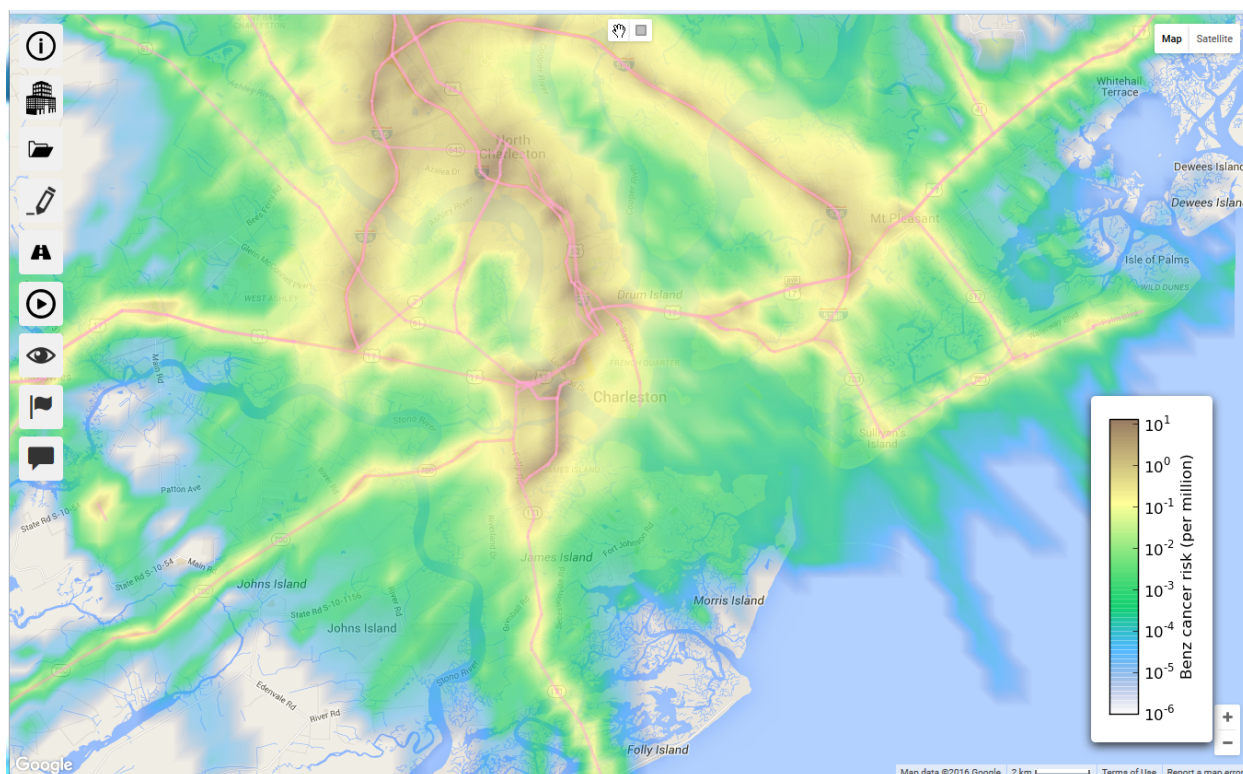


Figure 34. Estimated cancer risk (incidence per million people) due to chronic inhalation of benzene.

5.2. Non-cancer Risk from Annual Average Concentrations

C-LINE uses the standard calculation for hazard quotient (HQ), or non-cancer health effects, from chronic exposure via the inhalation pathway, and then converts the results to a basis of one million people. The human health hazard factor is the Reference Concentration (RfC) for inhalation, which has units of (mg/m³). Concentration is calculated in the units µg/m³. C-LINE converts between mg and µg.

$$\text{HQ per million people} = \text{Concentration} / \text{RfC}$$

Figure 35 shows the estimated hazards from benzene due to inhalation from an annual baseline concentration calculation in C-LINE.

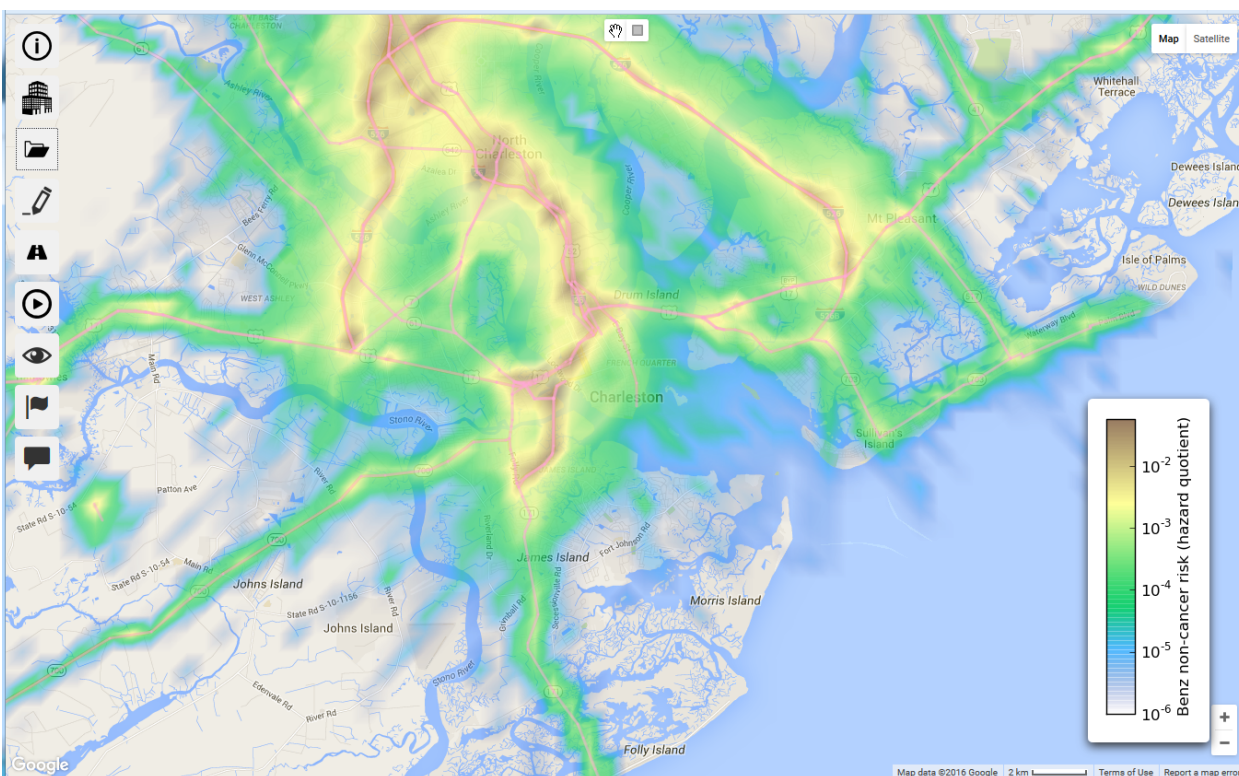



Figure 35. Estimated hazard quotient (incidence per million people) due to chronic inhalation of benzene.

6. User Feedback

By clicking on the  icon at the bottom left of the C-LINE system's navigation menu, the user is directed to an interactive short survey with a few questions, and ability to provide comments. We encourage all users of the C-LINE system to use this feature to provide feedback for future enhancements.