

An Introduction to C-TOOLS

Version 4.0

<https://www.cmascenter.org/c-tools/>

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CMAS Webinar Series



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C-TOOLS Objectives

- ◆ Provide a broadly-accessible, quick and easy-to-use suite of tools for air quality screening analysis
- ◆ Enable the community user to explore local air quality impacts due to transportation-related sources (road and rail networks, ports, airports, energy facilities) in their region of interest
- ◆ Examine what-if scenarios of changes in emissions under varying activity conditions
- ◆ Enable comparison and contrasting of alternative emissions management scenarios
- ◆ Allow export of results to use in other applications
- ◆ Provide sufficient online support to users, including caveats and limitations

Concept of C-TOOLS

- ◆ C-TOOLS combine air dispersion models with evolving web-based and visualization technologies to provide an easy-to-access screening tool for community users
- ◆ C-TOOLS simulate dispersion of primary pollutants (CO, NO_x, SO₂, primary PM_{2.5} [including EC_{2.5}], and some air toxics: benzene, formaldehyde, acetaldehyde, acrolein) using meteorological conditions for the region of interest

C-TOOLS – Suite of Models

- ◆ The C-TOOLS suite is envisioned to include several modules:
 - ◆ **C-LINE** (roadway emissions)
 - ◆ **C-PORT** (more sources added: rail, port terminals, ships)
 - ◆ **C-AIRPORT** (adding aircraft and airport emissions sources)
 - ◆ **Other Modules upcoming**

History and Current Status (1 of 2)

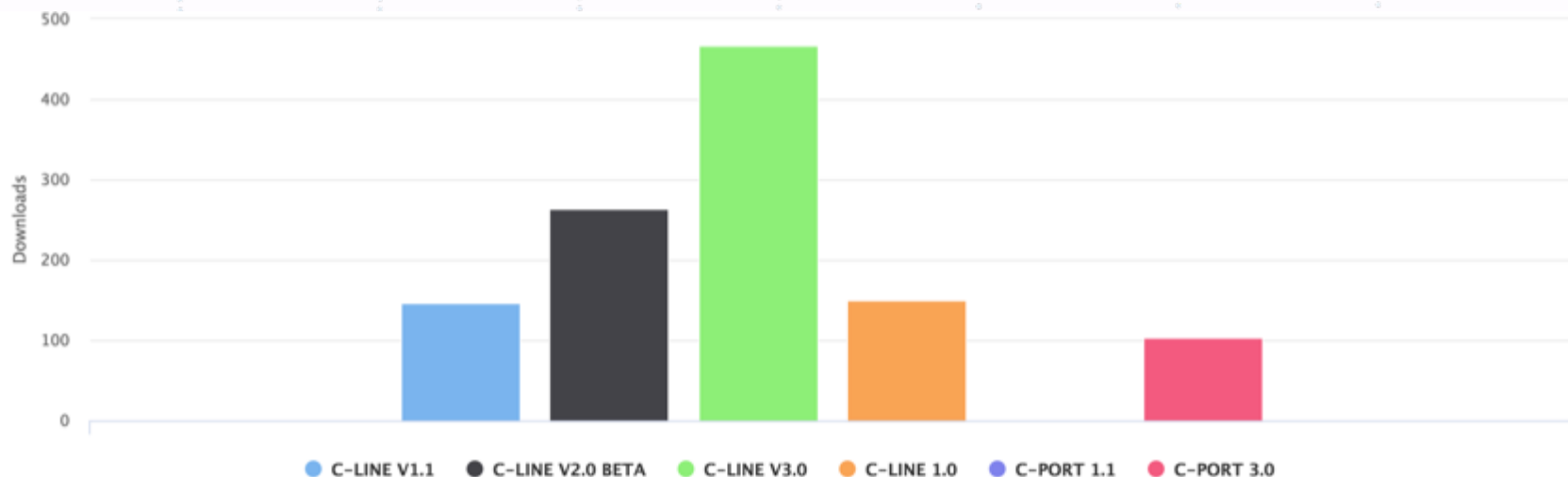
- ◆ C-LINE – peer reviewed, final and public
 - V1.0 released in Feb 2015
 - V1.1 released in Jul 2015
 - V2.0 Beta released in Nov 2015
 - V3.0 released in Jun 2016
 - V4.0 Beta released in May 2017
- ◆ C-PORT – peer reviewed, soon to be final and public
 - V1.1 Beta released in Feb 2015 (EPA only)
 - V2.0 Beta released in Nov 2015 (EPA only)
 - V3.0 Beta released in Oct 2016
 - V4.0 Beta released in May 2017

History and Current Status (2 of 2)

- ◆ C-AIRPORT – in development, using Los Angeles international airport (LAX) as prototype
 - V1.0 Alpha in September 2016 (EPA only)
 - V1.0 Beta in September 2017 (anticipated)
- ◆ Other Modules in the future
 - ◆ Specifics TBD



C-TOOLS Downloads via CMAS



The chart provides data on CMAS Software Download requests since 01/01/2015

Select a different date:

01/01/2015

Select model(s) to filter results by (optional):

☐ AMET ☐ BenMAP ☐ C-LINE ☐ C-PORT ☐ CMAQ ☐ CoST ☐ EMF_CoST ☐ FEST-C ☐
☐ I/O_API ☐ MCIP ☐ MCPL ☐ NetCDF ☐ PAVE ☐ R-LINE ☐ SMOKE ☐ Spatial_Allocator ☐
☐ Speciation_Tool ☐ VERDI

Submit

Product	Downloads since 01/01/2015
C-LINE V1.1	147
C-LINE V2.0 BETA	263
C-LINE V3.0	467
C-LINE 1.0	150
C-PORT 1.1	1
C-PORT 3.0	104



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C-TOOLS *What-if* Scenarios

- ◆ What will happen if diesel traffic doubles on a given roadway?
- ◆ How is near-road air quality affected due to a new road?
- ◆ How will air pollutant concentrations change due to
 - Changes in meteorological inputs such as wind direction?
 - Changes in AADT, speed, time of day, etc.?
 - Changes in emissions magnitudes?
- ◆ How will air pollutant concentrations change due to
 - Changes in activity at a single port terminal?
 - Increased/decreased activity at a rail yard?
 - Adding, moving or removing a source?
- ◆ Other?



Potential Users and Applications

USERS	APPLICATION
Community Organizations	<ul style="list-style-type: none">• Target education/outreach to affected areas• Identify field sites for monitors• Provide context for local issues
Local Authorities	<ul style="list-style-type: none">• Preliminary scoping of alternative decision scenarios• Explore alternatives to mitigate risk (e.g. electrification, fleet turnover, ship speeds and types)• Publicize “greening” efforts
Other Federal Agencies (e.g., US Army Corps of Engineers)	<ul style="list-style-type: none">• Quantify direct, indirect, and cumulative impacts of decision alternatives• Weigh public trade-offs associated with port expansions
EPA Regions	<ul style="list-style-type: none">• Inform preliminary environmental reviews associated with Federal actions• Examine potential impacts to vulnerable populations• Identify options for exposure reduction and risk mitigation
EPA Program Offices	<ul style="list-style-type: none">• Screen locations and topics for further analysis• Provide initial assessment based on available emissions inventory• Consider alternatives in fuels and mobile source infrastructure• Examine ports in context of ambient pollution and other sources
International Partners	<ul style="list-style-type: none">• Examine effects of changes in mobile sources• Consider mobile sources in context of overall exposure

What C-TOOLS Models Are Not

- ◆ Not a regulatory or enforcement tool or a substitute for regulatory modeling with associated local emissions inventories
- ◆ Not appropriate to be used for meeting Clean Air Act requirements, including the development of State Implementation Plans (SIPs), conformity analyses, or other related regulatory modeling applications

What is C-LINE?

- ◆ C-LINE computes dispersion of primary mobile source pollutants using meteorological conditions for the region of interest and computes AQ concentrations corresponding to these selected conditions
- ◆ The dispersion routines used are in the analytical version of R-LINE
 - C-LINE provides a web-based platform
- ◆ Specific emissions for each road link are calculated by combining national database information on traffic volume (AADT) and fleet mix with emissions factors from the EPA's MOVES modeling system
- ◆ The user can modify the emissions for each road link by changing the traffic composition, speed, and/or volume
- ◆ Geographical Coverage: **Continental U.S.**, featuring a map-based interface similar to the widely used Google Maps

C-LINE: Emissions Inputs

- ◆ Activity data from U.S. DOT's Highway Performance Monitoring System (HPMS) 2013
- ◆ Assign speed from NEI-2011 county-level data by national functional class (NFC)
- ◆ Use link-specific AADT; If missing, compute average AADT values by county by NFC, and assign those averages to each road segment
- ◆ Onroad Emissions Factors (EFs) from MOVES-2014 for NEI-2011 V2
- ◆ County-specific EFs for all desired pollutants for 284 representative counties
- ◆ Emissions factors grouped based on: 4 road type categories, 16 vehicle speed bins, 24 vehicle/fuel type combinations based on fuel type and gross vehicle weight rating, and bins of ambient temperature (from -40 to 130 degF) based on the actual ambient temperature of counties simulated

C-LINE/C-PORT: Meteorological Inputs

- ◆ Use AERMET v13350 to create *.SFC files for each of > 800 NWS stations in the U.S.
- ◆ Dispersion can be done for representative short-term (1-hr) or long term (annual average)
- ◆ Hourly dispersion uses one of 5 *representative* conditions
 - Stable, Slightly Stable, Neutral, Slightly Convective, Convective
 - For each of summer (May-Sept) and winter (Nov-Mar) seasons
 - Optionally, user can input custom wind direction from GUI
- ◆ For annual runs, use the Meteorologically-weighted Averaging for Risk and Exposure (METARE) approach
 - See Chang et al, *Sci.Total Environ.* 2015



What is C-PORT?

- ◆ C-PORT builds upon C-LINE, for comparing and contrasting the relative impacts that alternative port activities may have on air pollution
 - ◆ Includes road, rail, ship and on-terminal emissions sources
- ◆ C-PORT is an easy-to-use, web-based tool for estimating the potential impacts of alternative planning scenarios and prioritizing follow-up actions (e.g., research into emissions reductions activities) at ports
- ◆ Geographical Coverage:
 - ◆ C-PORT currently includes data from 21 seaports mainly in the southeastern U.S., and 2 ports in the Pacific Northwest
 - ◆ Few additional ports to be added for V5.0



C-PORT: Emissions Inputs (1 of 2)

- ◆ EPA's NEI 2011 emissions are spatially allocated at the local scale
- ◆ Drayage, Cargo handling equipment, and all other “on-terminal” activities
 - Allocated to terminals and modeled as area sources
- ◆ Harbor craft
 - Class I,II ships allocated to the channels, and modeled as line sources
- ◆ Ocean going vessels
 - ***Ships at the terminal***: allocated to terminals and modeled as point sources
 - ***Ships underway***: allocated to shipping channels representing a path to the terminal from the sea (based on Army Corps of Engineers shipping lane segments with freight activity), and modeled as line sources with plume rise



C-PORT: Emissions Inputs (2 of 2)

◆ Rail

- Railroad emissions: allocated to railroads in ArcGIS and modeled as line sources
- Rail yard emissions: allocated to rail yard polygons in ArcGIS, modeled as area sources

◆ Non-mobile sources

- Facilities with latitude/longitude coordinates from NEI located within terminal boundaries are modeled as point sources

Dispersion Algorithms

Line sources:

Roadways,
Railways



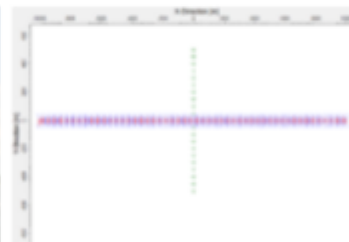
Area sources

Drayage,
Cargo handling



Line sources with plume rise

Ships underway



Point sources

Ships at the terminal,
On-terminal stacks



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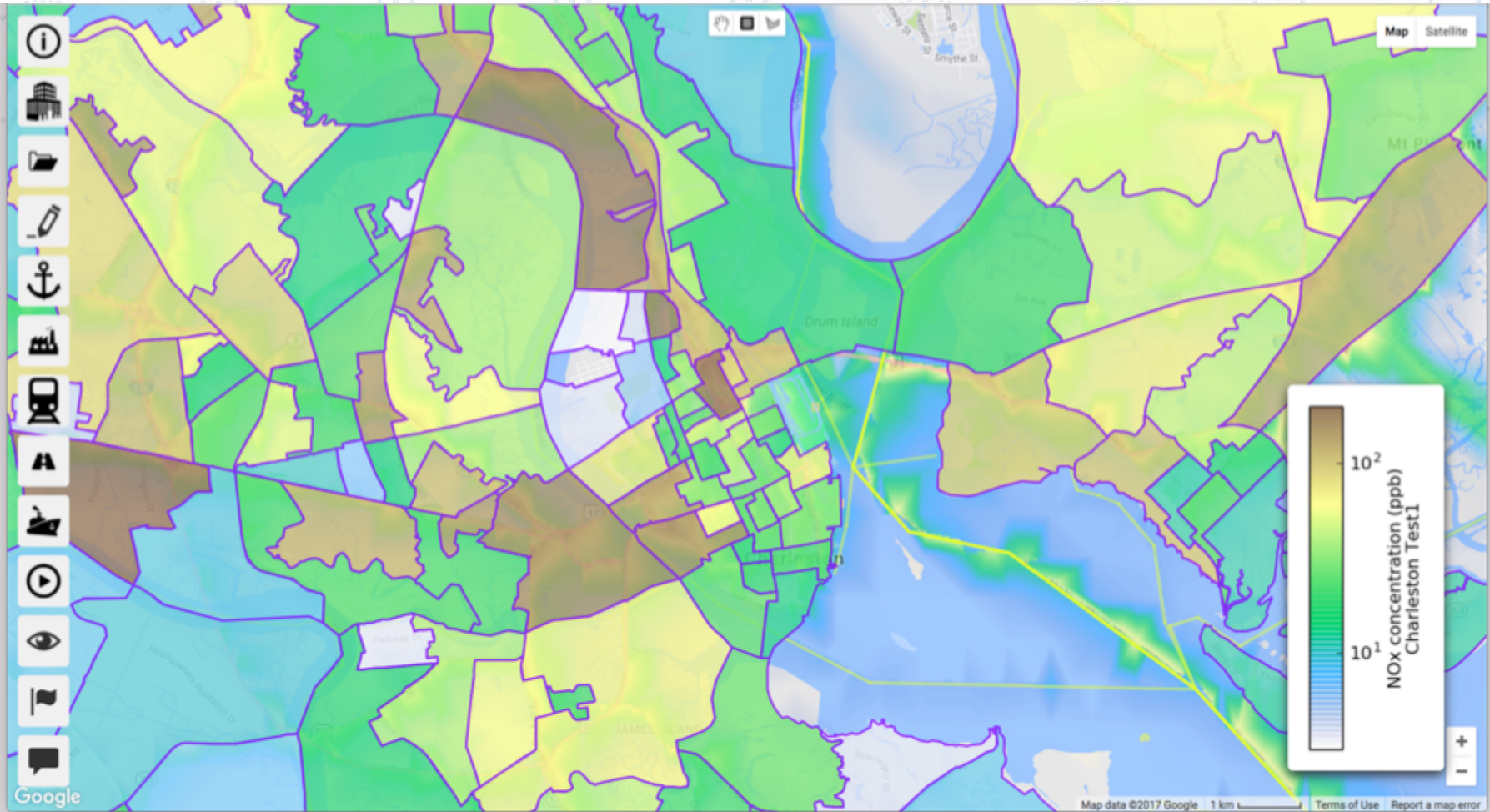
C-PORT



C-PORT: Source Apportionment



C-PORT: Census Block Overlay



New Features in C-LINE V4.0 Beta

- ◆ Ability to compute NO_2 for onroad sources
 - Using 4th order polynomial regression of NO_2/NO_x ratios from U.S. near-road sites
- ◆ Migrate from MOVES-2010 to MOVES-2014 for 2011 emissions factors
 - MOVES-2014 Emissions Factors are lower than MOVES-2010 for all pollutants
- ◆ Migrate from TIGER to DOT's HPMS for traffic network data
 - BTS National Transportation Data Atlas, 2013
 - HPMS has better coverage for primary roads, but comes at a cost to the dispersion runtimes
 - 8.5x increase in road-links in HPMS compared to TIGER

New Features in C-LINE and C-PORT V4.0 Beta

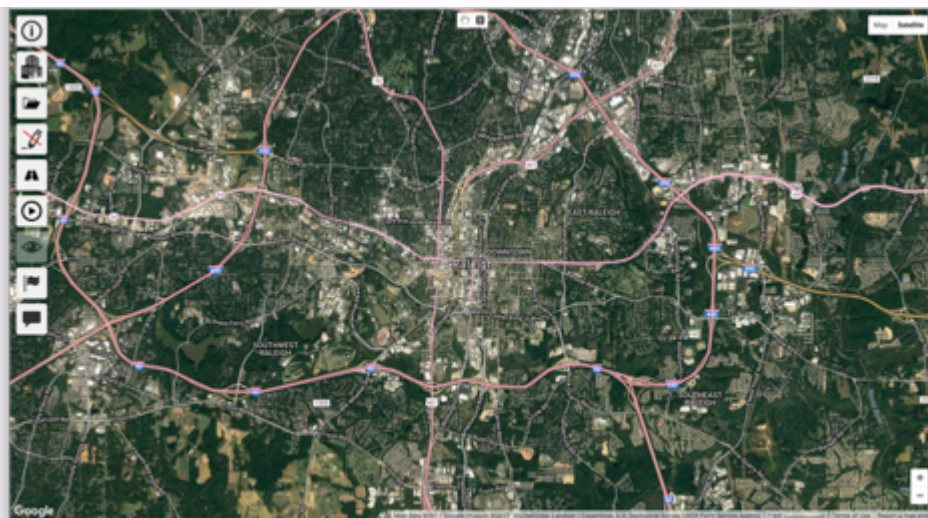
- ◆ Incorporated feedback from external peer review conducted in Spring 2017
- ◆ Ability to upload custom input data for all source types through GUI
 - Road, Rail, Ship, Point and Terminal sources
- ◆ Ability to add custom but pre-processed meteorological data to backend
- ◆ For annual averages, ability to include background concentration from EPA's AQS data, and allow user to change value if necessary for view domain
- ◆ Ability to select multiple pollutants in single model execution
- ◆ Distinguish between “Background” and “non-Background” designated sites in AQS, during overlay
- ◆ Show locations of meteorological stations as overlay, along with WMO and ICAO IDs for global network of stations



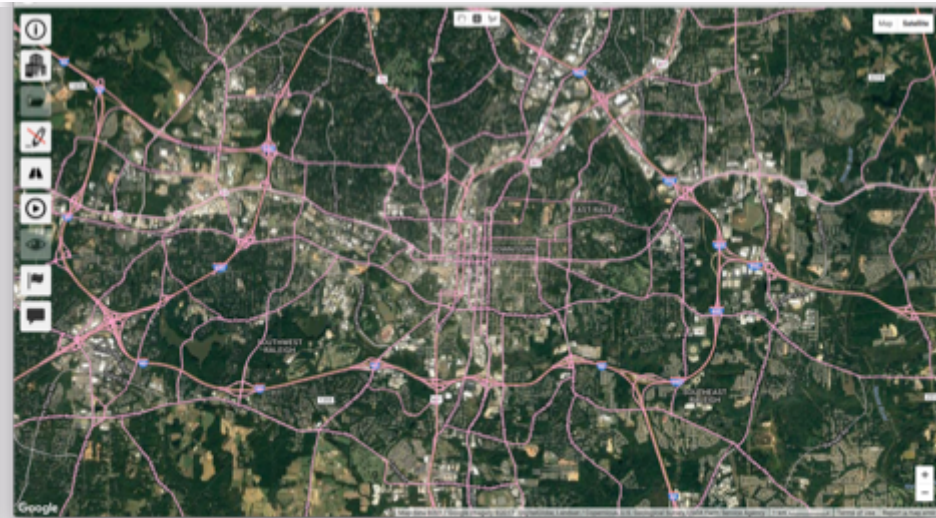
Other Updates in V4.0 Beta

- ◆ Improved quality of concentration plots for representative short-term (1-hr) simulations, using a high resolution receptor network
 - ◆ Varies by zoom level
- ◆ Add caption and scenario description on each mapped output
- ◆ Add background column to list of model runs
- ◆ Few bug-fixes in dispersion code
- ◆ Streamlining of overall workflow and data processing to enhance user experience
- ◆ Ability to calculate cancer and non-cancer risk no longer supported

TIGER vs. HPMS for Road Network

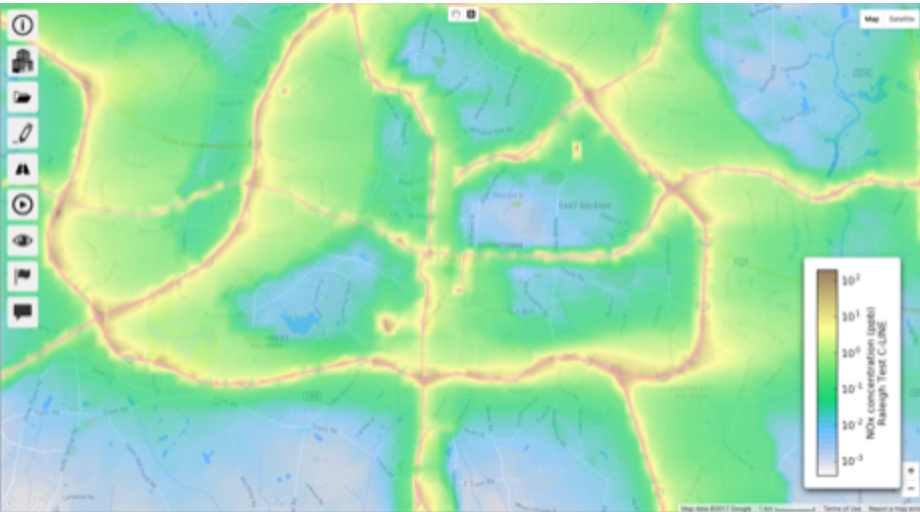


TIGER



HPMS

C-LINE V3.0 vs. V4.0 Beta

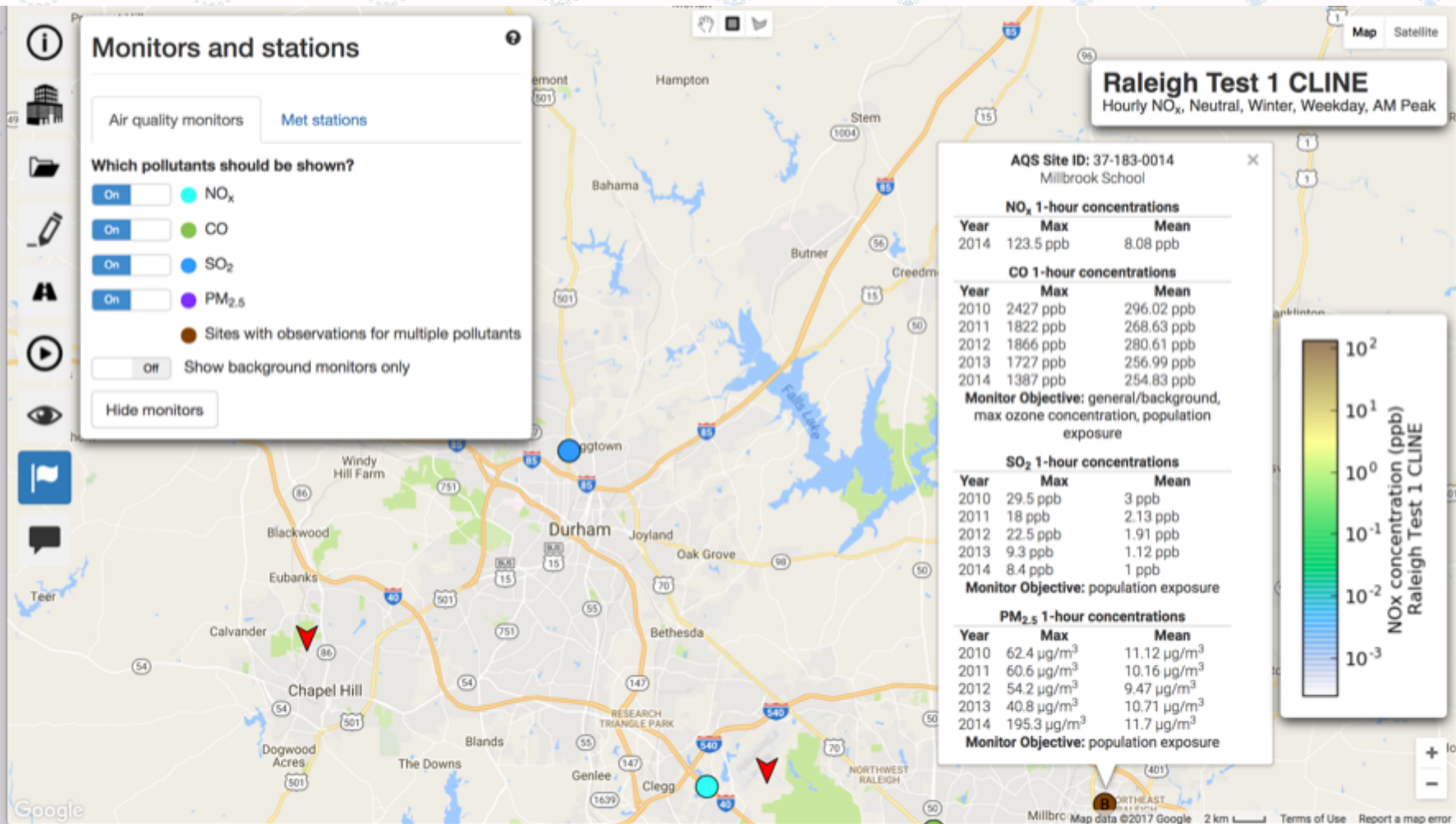


V3.0

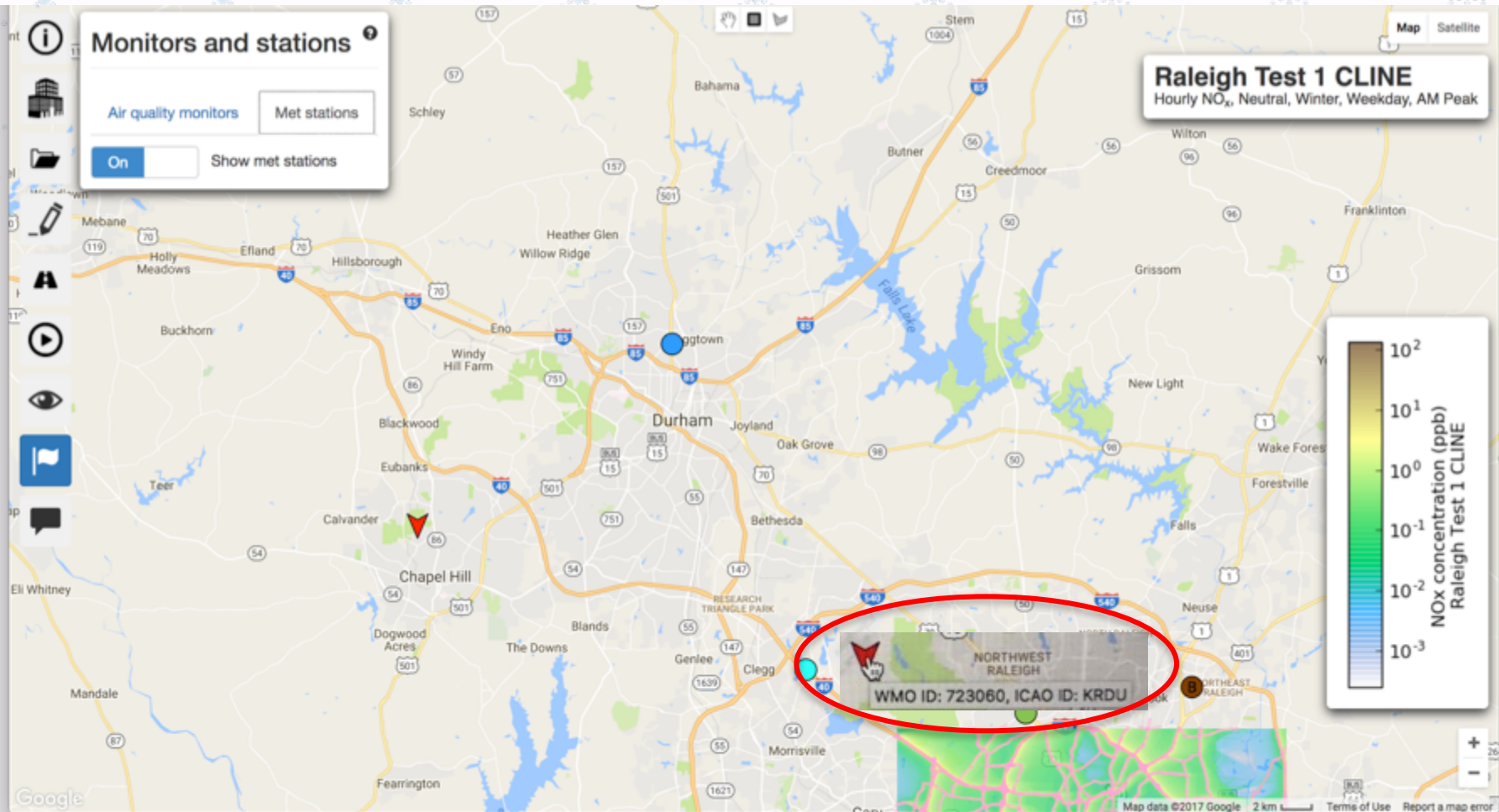


V4.0 Beta

New Feature: AQS Overlay with Background Sites Distinction



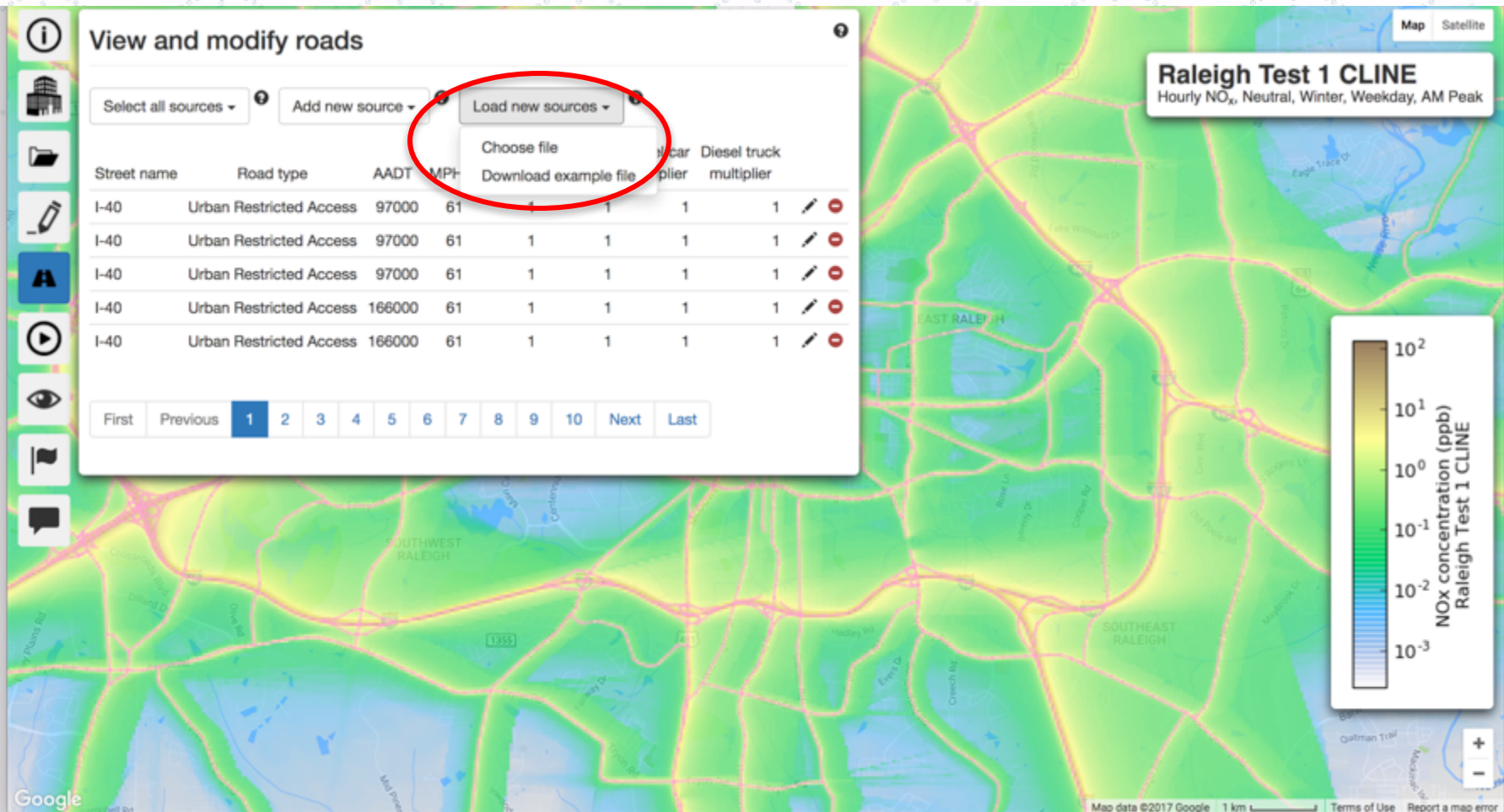
New Feature: Meteorological Stations Overlay



New Sources added by User

- ◆ C-LINE and C-PORT have option for user to add their own emissions sources via GUI
 - For each source type, the system finds the 10 nearest sources of same type (area, point, line, etc.), using nearest neighbor algorithm
 - Compute simple mean of these 10 sources
 - Provide this mean as first order estimate for modeling
 - If user has better estimate based upon local knowledge, GUI provides option to change as necessary
- ◆ Motivation of this feature is to provide user option to add their own sources, but the emissions estimates are left to the user's discretion if the default estimate is not suitable

New Feature: Upload Custom Sources





View and modify area sources

All emissions values given in tons/year.

Select all sources

Add new source

Load new sources

Facility

Gulfport Railway

Port of Gulfport E

View and modify area

View

All emis

Select

Emiss

Name

Gulfport

View and modify point sources

View and n

All emissions value

Select all sources

Railway owner

Illinois Central RR	0.1420	0.0197	1.3936e-3	4.2008e-3	0	7.1544e-5	6.5750e-4	1.1126e-3		
Illinois Central RR	0.3244	0.0451	3.1831e-3	9.5950e-3	0	1.6341e-4	1.5018e-3	2.5414e-3		
Illinois Central RR	0.3462	0.0481	3.3970e-3	0.0102	0	1.7440e-4	1.6028e-3	2.7122e-3		
Illinois Central RR	0.5704	0.0793	5.5971e-3	0.0169	0	2.8735e-4	2.6408e-3	4.4688e-3		
Illinois Central RR	0.2021	0.0281	1.9831e-3	5.9779e-3	0	1.0181e-4	9.3566e-4	1.5834e-3		

View and modify roads

Select all sources

Add new source

Load new sources

Street name Road type AADT MPH multiplier multiplier multiplier multiplier

Harrison County NFC=1 Urban Restricted Access 47716 38 1 1 1 1

Harrison

Harrison

Harrison

Harrison

First

View and modify ships in transit

All emissions values given in tons/year.

Select all sources

Add new source

Load new sources

Emissions

Stack parameters

Facility	NO _x	CO	SO ₂	PM _{2.5}	EC _{2.5}	OC _{2.5}	PM ₁₀	Benz	Form	Acro
BAYOU BERNARD, MS	6.0591	1.2316	0.0745	0.1942	0.1498	0.0342	0	2.5475e-3	3.7127e-6	3.0322e-4
BAYOU BERNARD, MS	4.1210	0.8377	0.0506	0.1321	0.1019	0.0233	0	1.7327e-3	2.5251e-6	2.0623e-4
BAYOU BERNARD, MS	2.7927	0.5677	0.0343	0.0895	0.0690	0.0158	0	1.1742e-3	1.7112e-6	1.3975e-4
BAYOU BERNARD, MS	3.4285	0.6969	0.0421	0.1099	0.0847	0.0193	0	1.4415e-3	2.1008e-6	1.7157e-4
BAYOU BERNARD, MS	5.3494	1.0874	0.0657	0.1715	0.1322	0.0302	0	2.2491e-3	3.2778e-6	2.6770e-4

First

Previous

1

2

Next

Last

View and modify ships in transit

Applications to Date

◆ C-LINE

- Portland, Oregon

◆ C-PORT

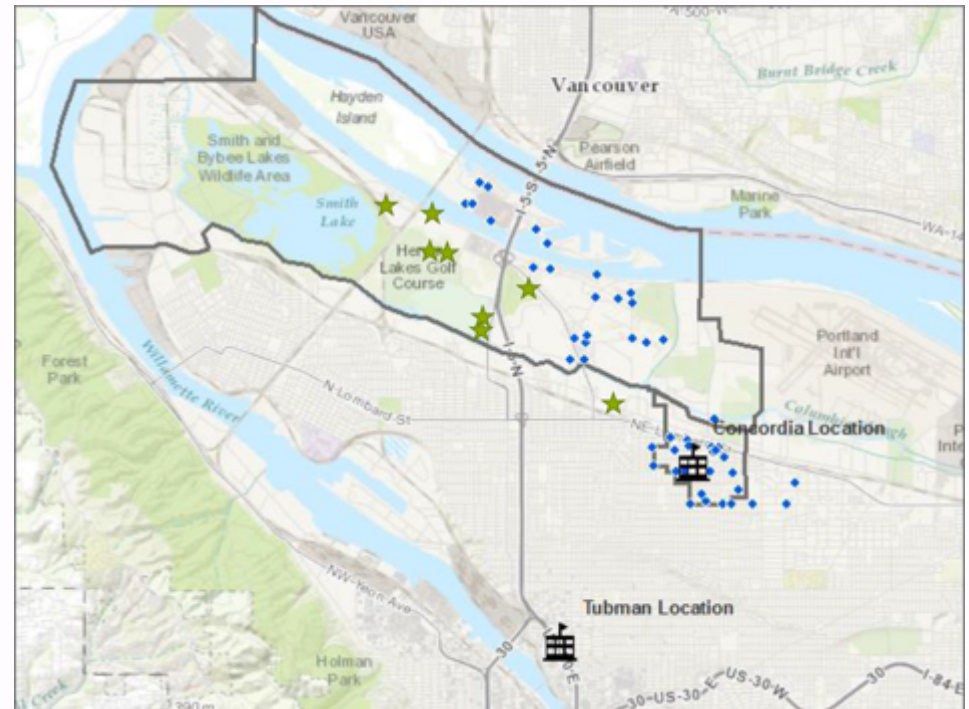
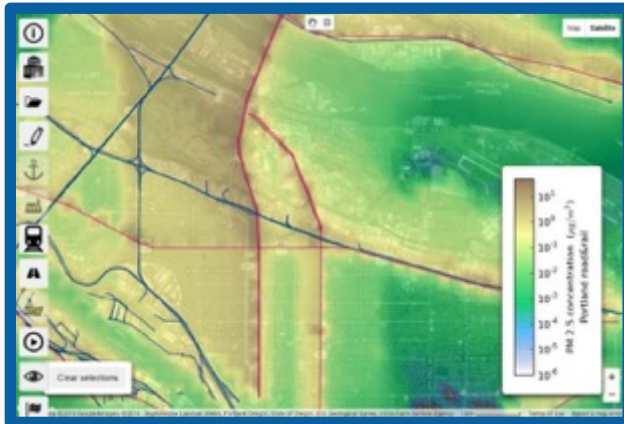
- Charleston, South Carolina
- Argentine Railyard in Kansas City (KC-TRAQS)
- Iron-bound District of Newark, New Jersey
- Mobile, Alabama
- Porto, Portugal

C-LINE Application in Portland, OR



Part of the EPA R10 Making a Visible Difference (MVD) ...project in N/NE Portland: Engaging Communities, Using Citizen Science to Assess and Address Children's Environmental Health from Transit and Air Pollution

- Using C-LINE to **identify potential locations for monitoring** in N/NE Portland study area.
- Examine and **evaluate various scenarios**



C-PORT Application in Kansas City



Part of the Kansas City TRansportation and Local-scale Air Quality Study (KC-TRAQS)

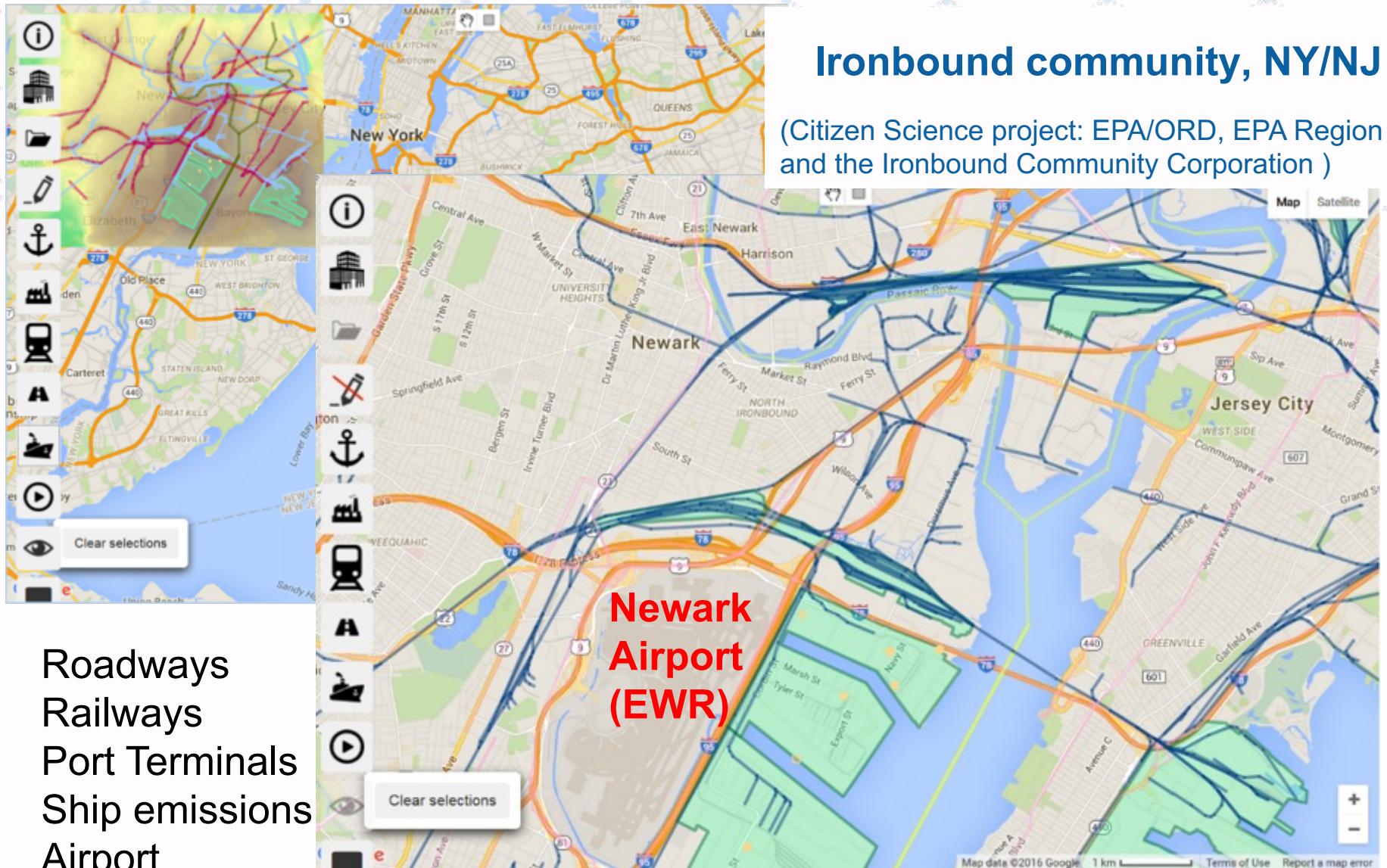
- to characterize the spatial and temporal impact of local air pollution sources on the Argentine (KS) community
- utilize citizen science-based sensor packages and modeling tools in a real-world field study, and
- provide tools to the Argentine (KS) community to aid in the assessment of the significance of measurements



C-PORT Application in Newark, NJ

Ironbound community, NY/NJ

(Citizen Science project: EPA/ORD, EPA Region 2 and the Ironbound Community Corporation)



- Roadways
- Railways
- Port Terminals
- Ship emissions
- Airport

C-PORT Application in Porto, Portugal



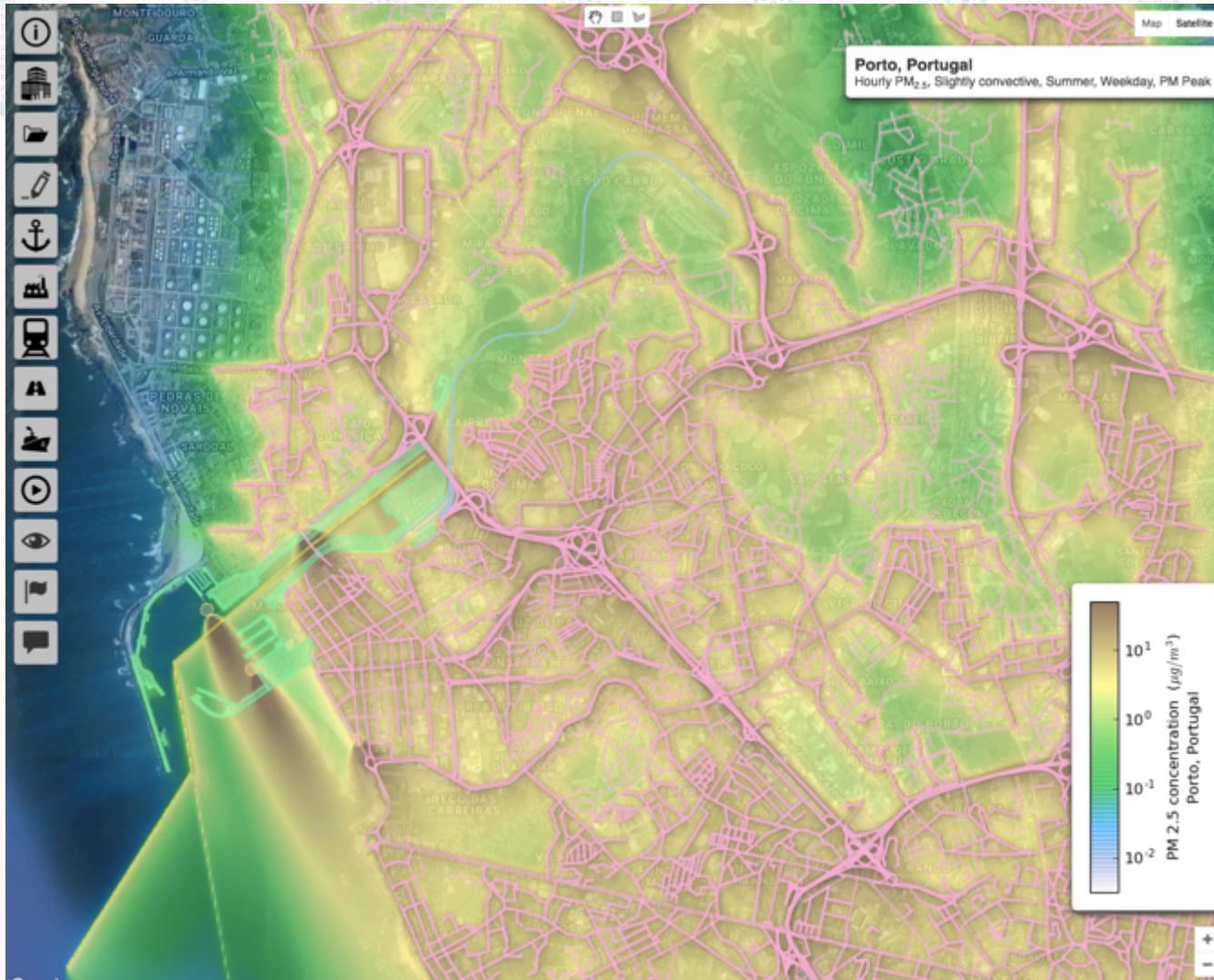
Part of the AIRSHIP project (<http://airship.web.ua.pt>),
...A three-year research project funded by the Foundation for Science and Technology to assess the impact of maritime transport emissions on urban/coastal air quality, in particular over the Port of Leixões and the respective urban area around.



- Emission inventory development for Porto harbor and urban area (2016-2017)
- Air quality modeling at local scale (Porto harbor and neighborhood area) (2017)
- Evaluation of the impact of different emission scenarios on the air quality of near-port area (2018)

C-PORT Application in Porto, Portugal

- Modeled using custom data upload via GUI



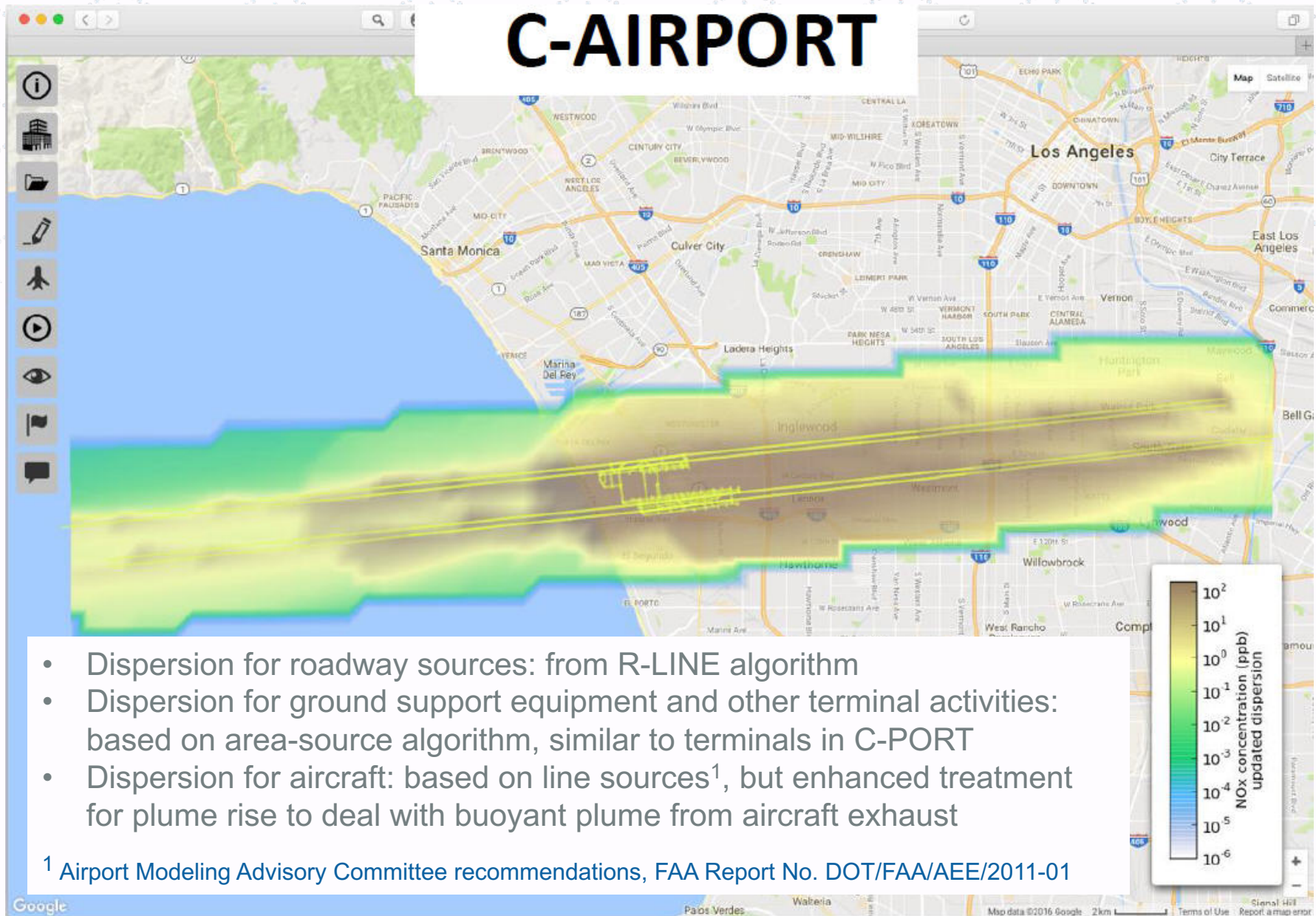
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C-TOOLS Availability and Support

- ◆ C-LINE and C-PORT are available in a password-protected status via CMAS web site: <https://www.cmascenter.org/c-tools/>
- ◆ The user needs to register, and then use the CMAS account and password to access. When logged in to CMAS, the user can access C-LINE, C-PORT and also get the updates on continued development, technical notes, and video tutorials
 - ◆ Multiple video tutorials will be made available from case studies
- ◆ For help using C-LINE and C-PORT
 - See video tutorials and User's Guide
 - Email the M3User listserv at m3user@listserv.unc.edu
- ◆ To suggest new features to be added to C-LINE and C-PORT, or to provide feedback
 - Use “Feedback icon” at the bottom left of either tool



C-AIRPORT



- Dispersion for roadway sources: from R-LINE algorithm
- Dispersion for ground support equipment and other terminal activities: based on area-source algorithm, similar to terminals in C-PORT
- Dispersion for aircraft: based on line sources¹, but enhanced treatment for plume rise to deal with buoyant plume from aircraft exhaust

¹ Airport Modeling Advisory Committee recommendations, FAA Report No. DOT/FAA/AEE/2011-01

C-AIRPORT: Data Sources

- ◆ 2015 activity and emissions from FAA's Aviation Environmental Design Tool (AEDT)
 - Departure/arrival airport, aircraft type, engine code, engine count, emissions mode, speed, time, thrust, weight, fuel burn, and emissions values for CO, HC, NO_x, SO_x, PM, CO₂
- ◆ Aircraft Engine Emissions Databank from the International Civil Aviation Organization (ICAO)
- ◆ Aircraft manufacturers' data
- ◆ Los Angeles World Airports (LAWA) flight operations data from the LAX Air Quality and Source Apportionment Study (AQSAS)

C-AIRPORT Features

- ◆ **Exploring options for**

- changing aircraft emissions (fleet mix, emissions indices due to fuel change, or changes in combustion technology)
- changing aircraft flight paths (add / remove source segments)
- changing ground support equipment (GSE) emissions

- ◆ **Initial Prototype for LAX**

- Few more airports to be added during next fiscal year

C-TOOLS Project Team

- ◆ U. S. EPA

- Tim Barzyk, Vlad Isakov, Betsy Smith

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- ◆ National Center for Atmospheric Research

- Jeff Weil

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- ◆ UNC Information Technology Services (UNC-ITS)

- Nathan Rice

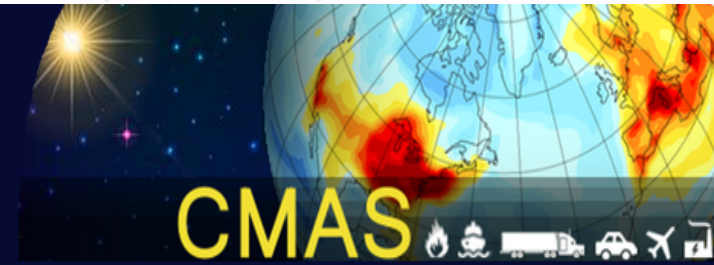
Acknowledgements

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- ◆ Arunachalam, S., H. Brantley, T. Barzyk, G. Hagler, V. Isakov, S. Kimbrough, B. Naess, N. Rice, M. Snyder, K. Talgo, A. Venkatram (2015). Assessment of Port-Related Air Quality Impacts: Geographic Analysis of Population, *Int. J. Environ. Poll.*, 58(4):231-250.
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- ◆ Arunachalam, S., A. Valencia, M. Snyder, V. Isakov, D. Heist, D. Carruthers, and A. Venkatram (2015). Development and Evaluation of Model Algorithms to Account for Chemical Transformation in the Near-road Environment. *Presented at the 25th Annual Meeting of the International Society of Exposure Science*, Henderson, NV, October 18 – 22, 2015.
- ◆ Isakov, V., Barzyk, T., Arunachalam, S., Snyder, M. & Venkatram, A. (2016). A Community-Scale Modeling System to Assess Port-Related Air Quality Impacts. Air Pollution Modeling and its Application XXIV, , *Air Pollution Modeling and its Application XXIV*, D.G. Steyn and N Chaumerliac (eds.), ISBN: 978-3-319-24478-5 (Online), https://link.springer.com/chapter/10.1007/978-3-319-24478-5_63, Springer Proceedings in Complexity, pp. 385 -390.

Upcoming CMAS Events



For Additional
Information

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- Trainings
 - June 19-23: Introduction to SMOKE (online)
- Webinars
 - July 27: Atmospheric Model Evaluation Tool (AMET) v1.3
- Conferences
 - August 28-31: 3rd CMAS Conference South America (Vitória, Espirito Santo, Brazil)
 - October 23-25: 16th Annual CMAS Conference (Chapel Hill, NC)