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# A web-based screening tool for near-port air quality assessments

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ABSTRACT

The Community model for near-PORT applications (C-PORT) is a screening tool with an intended purpose of calculating differences in annual averaged concentration patterns and relative contributions of various source categories over the spatial domain within about 10 km of the port. C-PORT can inform decision-makers and concerned citizens about local air quality due to mobile source emissions related to commercial port activities. It allows users to visualize and evaluate different planning scenarios, helping them identify the best alternatives for making long-term decisions that protect community health and sustainability. The web-based, easy-to-use interface currently includes data from 21 seaports primarily in the Southeastern U.S., and has a map-based interface based on *Google Maps*. The tool was developed to visualize and assess changes in air quality due to changes in emissions and/or meteorology in order to analyze development scenarios, and is not intended to support or replace any regulatory models or programs.



## 1. Introduction

Ports are a critical feature of the U.S. economy. Seaport cargo activity supports the employment of more than 23 million people in the United States and contributes nearly $4.6 trillion in total economic activity (AAPA, 2016). But for all the economic benefit they provide, the influx of ship, train, truck, and other activities of commercial ports can also negatively impact the local environment, putting residents of neighboring communities at higher risk to health impacts associated with increased air and water pollution (Rosenbaum et al., 2011). Because many of the nation's 360 commercial ports are located near disadvantaged and lower-income communities, ports also raise environmental justice issues. Community groups are becoming increasingly active in local initiatives that seek to mitigate potentially harmful environmental conditions. However, there is a lack of accessible tools that can be easily applied to study near-source pollution, and rapidly explore the benefits of improvements to air quality or to weigh trade-offs associated with port expansion or modernization. To address this need, US EPA has developed several tools designed for communities to assess environmental hazards and find ways to mitigate exposures. These include a suite of web-based applications such as C-FERST (Zartarian et al., 2011), EJSCREEN (U.S. EPA, 2016) and C-LINE (Barzyk et al., 2015). To add to this suite of community tools, we are developing the Community model for near-PORT applications (C-PORT) to help assess air quality impacts from port terminals, ships, roadway traffic and other port-related sources potentially affecting the local community. The multiple modeling options within C-PORT are designed for a quick assessment and require limited technical expertise. The power of such a screening tool is to facilitate assessments through reduced computational time, and to evaluate and compare a suite of "what-if" scenarios. Thus, these web-based, easy-to-use tools can provide valuable insights for the community and can also assist with the decision-making process.

C-PORT currently has data for 21 sea-ports, mostly in the Southeastern U.S. The model represents multiple source types: Ships (while docked at terminal and underway), Rail, Road, On-terminal activity, and provides the opportunity to add/modify individual sources. C-PORT models multiple primary pollutants that are directly emitted: CO, $SO_2$, $NO_x$, $PM_{2.5}$ and select Mobile Source Air Toxics (benzene, formaldehyde, acetaldehyde, and acrolein). The model shows absolute concentrations as well as relative changes, and also displays monitor information from EPA's Air Quality System (AQS). C-PORT model formulations are derived from

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dispersion theory, turbulence theory, and boundary layer meteorology. The algorithm for line sources is based on the analytical approximation for line sources (Venkatram and Horst, 2006), consistent with the US EPA research model for line sources R-LINE (Snyder et al., 2013). Algorithms for stationary and area sources are similar to AERMOD (Cimorelli et al., 2005), but optimized for computational efficiency to allow user interaction with the web-based modeling simulations in real-time. For example, C-PORT provides an initial parameterization of both meteorological (using National Weather Service data) and emissions data (based on spatially-allocated emissions values from EPA's National Emissions Inventory) to facilitate the creation of dispersion scenarios.

We refer to C-PORT as a "screening" tool, designed to encourage its use by a non-expert stakeholder through computational efficiency coupled with a default set of emissions and meteorological inputs. The results obtained through its application are reliable enough to screen for situations that might require further analysis to examine the impact of the source under a range of inputs not included in the default set. The term "screening" should not be confused with the formal term "screening model" defined in the Guideline on Air Quality Models (https://www.federalregister.gov/documents/2017/01/17/2016-31747/revisions-to-the-guideline-on-air-quality-models-enhancements-to-the-aermod-dispersion-modeling) as a model that provides conservative (maximum) estimates of the air quality impact of a specific source. C-PORT is not intended for regulatory applications, enforcement, or refined analysis intended to meet EPA Guideline on Air Quality Models Appendix W requirements (40 CFR Appendix W to part 51).

This paper describes the model structure, input parameters, dispersion algorithms and evaluation, mapping and visualization routines, and software considerations for C-PORT. We also discuss the model functionality using an example application for an area in the port of Charleston, SC.

## 2. Methods

### 2.1. Model design

The modeling system includes dispersion algorithms for area, point, and line sources related to freight-movement activities, and emissions from the port terminals. C-PORT automatically accesses pre-loaded emissions and meteorological datasets with nationwide coverage and provides results for the user-defined geographic area as both visualized maps and tabular data. The key model inputs include emissions and meteorology, and model outputs are presented as geospatial maps with some options to save the results as GIS shape files for further analysis.

C-PORT also allows the user to add, delete, and modify emissions sources. For example, in a hypothetical scenario where the port wants to expand a terminal (e.g. a bulk cargo terminal), C-PORT can simulate the effect of additional berth and cargo handling facilities in the port terminal. The user can manually draw a polygon to represent a new terminal using the web-interface, and double click on the last vertex to finish the polygon. For convenience, C-PORT assigns pre-populated emissions values for the new source. These values are computed as an average of the 10 nearest area sources. If additional emissions information for the new source is available, the user can edit the default values to reflect the new values. Similar to the area source representing a new terminal, the user can add a new point source to represent the hoteling location, or new roadway or rail line.

Analysis capabilities are provided through an easy-to-use GUI that can be used by community planners, port authority, and federal and state/local agency analysts, to assess air quality impacts of 'what if' scenarios for planning a sustainable development at community scales. These scenarios can help to anticipate potential growth in port activities (increased ships, trucks, etc.), assess impacts of improved energy efficiency and other voluntary actions in port terminal area activities (such as electrification of cranes or rubber tire gentries), and quantify reductions in emissions due to regulatory programs related to commercial marine vessels, rail, trucks, etc.

#### 2.1.1. Dispersion model algorithms

This section describes dispersion algorithms used in C-PORT to produce the near-source air pollutant concentration gradients. C-PORT has several options for simulating dispersion of primary pollutants from emission sources in the port areas: on-terminal activity including drayage and cargo handling equipment (modeled as area sources); facilities with known latitude/longitude location within the port's terminal (modeled as point sources); roads and rail (modeled as line sources); and finally ships-in-transit (modeled as line sources with plume rise). The dispersion algorithms in C-PORT are similar to the dispersion tools used by regulators and research scientists, but have been modified slightly to speed computational time and enable quick access to results. The dispersion code for area and point sources is based upon model formulations used in AERMOD (Cimorelli et al., 2005), while the road and rail are modeled as line sources, based upon an analytical approximation (Venkatram and Horst, 2006) that is used in the C-LINE modeling system (Barzyk et al., 2015).

The C-PORT modeling system achieves its computational efficiency by 1) using analytical forms when possible to replace the numerical schemes in AERMOD, 2) using less-stringent iteration schemes for convergence than those in AERMOD, and 3) avoiding computationally demanding, iterative algorithms. These differences include limiting the number of line sources in the area source algorithm to 30 for computational efficiency as opposed to the iterative process in AERMOD. For point sources, dispersion in the Convective Boundary Layer (CBL) is modeled using the Gaussian dispersion equation in which the plume spreads are formulated in terms of turbulence parameters computed at effective plume height. Also, C-PORT applies a simple algorithm that does not re-entrain plume material to determine the fraction of the emissions that can potentially affect ground-level concentrations. In the Stable Boundary Layer (SBL), vertical plume spread during stable conditions is limited by the height of the boundary layer. Unlike AERMOD, C-PORT does not treat dispersion in complex terrain and does not account for building effects like downwash.

Normalized concentration estimates from C-PORT were compared with estimates from AERMOD and R-LINE for several scenarios of hypothetical source configurations over a range of meteorological conditions. The sources consisted of 1) a point source representing a stationary source at port terminals, 2) an area source representing a port terminal, and 3) a line source, representing a portion of a highway. For the point source test, we ran C-PORT and AERMOD for several configurations as a function of stack height: 10 m, 20 m, 30 m; stack diameter: 0.5 m; stack temperature: 100 and 200 °C; and, exit velocity: 5 and 10 m/s. Receptors were placed 100 m apart up to 5000 m downwind from the source to capture the impact of the plume. For the area source test, we ran C-PORT and AERMOD for a single configuration, a 500 m × 400 m rectangular area source with downwind receptors at 10 m resolution within the first 100 m from the source, then at 50 m resolution in the 100–350 m zone, and at 100 m resolution beyond 300 m up to 3 km. For the line source test, we ran C-PORT and R-LINE for a single configuration, 1-km long line source and, with downwind receptors at 10 m resolution within 100 m from the source, 50 m resolution in the 100–350 m zone, and at 100 m resolution in the 300–3000 m zone. The sensitivity runs were conducted for a range