June 29, 2023

The Honourable David Piccini
Minister of the Environment, Conservation and Parks
College Park, 5th Floor, 777 Bay Street
Toronto, Ontario M7A 2J3

Delivery by Email

Dear Minister Piccini:

Re: February 2023 Ministry of Environment, Conservation and Parks Directives to Air Practitioners

I am writing to you today in my capacity as the General Manager of the Hamilton Industrial Environmental Association (HIEA) to express our serious concerns regarding the recent Ministry of Environment, Conservation and Parks (Ministry) decision to require either significant changes to the modeling parameters assumptions in AERMOD or to use CALPUFF as the preferred model for dispersion modeling for certain Hamilton Industrial Environmental Association (HIEA) members. The changes are detailed in the following Ministry guidance presentation entitled "Reg 419 Air Practitioners Presentation Winter 2023 – Modeling – ESSD - 2023-02-01" appended (A4).

HIEA (HIEA.org) is a not-for-profit association representing 14 industrial and manufacturing companies in the City of Hamilton. HIEA's mandate is to improve the local environment through partnership, consultation, and dialogue with all levels of governments, educational institutions, individual residents, and environmental groups. HIEA members believe their organizations are not only a key contributor to both Hamilton and Ontario's economy, but also an essential part of the fabric of the community.

HIEA member companies provide employment for over 7,300 direct industrial and manufacturing positions as well as an estimated 56,000 indirect jobs in Hamilton and surrounding municipalities. Since its inception in 1998 HIEA and its membership has invested over $1.1 billion in environmental capital projects, contributed more than $720 million in municipal property taxes, and donated over $1 million in community and educational activities in Hamilton. HIEA and its members are committed to fostering a strong and sustainable future for the Province of Ontario, the City of Hamilton, and all its residents.

When HIEA was made aware of the potential changes to the modelling methodology from its impacted members it contracted internationally recognized industry experts EnviroComp, Inc. to review the proposed Ministry changes from a technical practitioner perspective. In addition, HIEA undertook an in-house review of Regulation 419/05 as it pertains to alternative dispersion models.

The technical review was conducted by Dr. Zannetti and Dr. Freedman, please see appended Curriculum Vitae (A2, A3). In formulating their technical report, the authors examined all available documents including where applicable communication between the MECP and the companies, and existing regulatory guidelines both in Ontario and in the US. The authors reviewed the key AERMOD parameters defined by the regulators and used by the scientific community. The full technical report entitled "A Review of Recent Revisions to Guidance from the Ontario Ministry of Environment, Conservation and Parks (MECP) on the use of AERMOD for Permitting Applications." is appended (A1).

The main findings of the technical report are as follows:

- Based upon their extensive scientific experience in atmospheric sciences and air quality modeling, Dr. Zannetti and Dr. Freedman conclude that the proposed revisions documented are not supported by science and should be re-examined by the Ministry.
- The Ministry provides no scientific basis for its claim that water bodies diminish urban heat island effects at night to support its revised guidance to not use the Urban Option in AERMOD for emission sources near water bodies. In fact, common understanding, as well as statements in the research papers MECP itself cites to support its directive, indicate the opposite, that urban heat island effects are enhanced at night.
- The academic literature research papers MECP cites claiming to support its revised guidance, focus on daytime conditions, not nighttime. The Urban Option, however, applies during night-time hours and maximum 1-hr concentrations most commonly occur during weak winds at night.
- The revised guidance to set a low value for the input roughness length when using the AERMOD Urban Option is unjustified scientifically and indicates a misunderstanding by

the Ministry of the fact the roughness length is an “effective” roughness length for capturing the dispersive effects of urban heat island enhanced convective turbulence on low-level emission sources.

- The recommended input roughness length value of around 0.01 m is too low to allow enhanced convective turbulence to affect low-level sources, this is unjustified scientifically since enhanced convective turbulence affects the entire boundary layer and does not discriminate against low-level sources.
- The possible use of CALPUFF for simulating short-range concentration impacts does not in general lead to more accurate concentration results and is therefore likely not cost-effective given the significant computational expense compared to AERMOD. The US EPA, after serious examinations and considerations, has removed CALPUFF from the list of “preferred” models.
- The revised guidance is contrary to the accepted regulatory practices the authors reviewed. This is both in terms of dictating not to use Urban Option near shorelines (which is counter to existing US regulatory guidance), and in the manner in which it is dictated (which in no way provides for any discretion scientifically or allowance for case-by-case determination).

In addition to the technical review conducted by EnviroComp Inc., HIEA undertook a review of the dispersion modeling requirements set out in Reg 419/05 particularly the approved AERMOD dispersion model and the permitted use of other dispersion models. In plain language the regulation specifies that AERMOD is to be used unless the Director is of the opinion that there are other models that would better predict the emissions. It is our understanding that there are two approaches to changing the specified dispersion model:

1. The Director specified in the regulation has the authority to require the company to use a different dispersion model, this approach requires a three-month draft notice period for the company to review the proposed change and provide written submissions, or
2. The company requests a change in the dispersion model and submits that request to the Director for approval. There is no notice period.

Under both scenarios it is expected that the Director should have sufficient scientific data and evidence to evaluate and support the change in the dispersion model to be protective of the natural environment and follow the intent of the regulation. HIEA also assumes that in a best practice approach there would be a comparison of modelling results from both respective dispersion models and where possible that those results would be compared to results through a field study. This would facilitate a common understanding if not agreement as to the strengths and applicability of each model. HIEA is not aware of this evaluation having been completed.

In addition, as part of the modelling process, members have been requested by the Ministry to submit updated land-use classifications. As a result, members have contracted qualified expert consulting firms to undertake the assessment and used the approved AUER land-use assessment process based on MECP's written guidance. The result of the assessment undertaken by the qualified experts is that the current classification is appropriate, however, in response to these submissions the Ministry has disagreed with the assessment and has indicated members are to follow the Ministry's interpretation of land-use classification. The Ministry's land-use classification change will have a significant impact on modeled emissions and may pose a significant risk to members due to compliance challenges resulting from increased modeling values which would necessitate additional work for both MECP and impacted companies (as an alternative compliance pathway may be required). As well as additional capital expenditure that could pose economic uncertainty for those members. This uncertainty impacts the now global scale of investment evaluation which is a reality for most HIEA members.

In closing, I would like to address the apparent lack of transparency by the Ministry in undertaking these changes. The Ministry when making these types of significant policy changes is required to have an open dialogue with residents, stakeholders, and industry through the Environmental Registry of Ontario (ERO). In Ontario, the posting requirements on the ERO are outlined in the Environmental Bill of Rights, 1993 (EBR). According to the EBR, certain activities and decisions by the government or prescribed public bodies must be posted on the ERO for public review and comment. These postings aim to promote transparency, public participation, and accountability in environmental decision-making. In this case the Ministry appears to be intentionally circumventing this prescribed process.

The decision by the Ministry to avoid posting on the ERO has significant policy implications, first it undermines the requirement for transparency but more importantly does not allow the potential impacts of the changes to be fully evaluated and discussed. The arbitrary changes to land-use characterization have the potential to impact Ontario's housing strategy and municipal zoning. The retention of current and attraction of new business to Ontario is also at risk of being negatively affected. The Ministry cannot afford to make decisions in isolation of broader government policy objectives, especially decisions that may undermine other government priorities.

Considering the above, HIEA requests a meeting with your office as soon as possible. HIEA would also ask that until this issue is resolved to the satisfaction of all parties that the Ministry cease their efforts to either change either modelling assumptions or require companies to use the CALPUFF dispersion modeling program. The decision must be made based on science. Together, we can uphold the highest standards of environmental protection and ensure a sustainable future for Ontarians.

Sincerely,

Geoffrey Knapper, General Manager
Hamilton Industrial Environmental Association
Email: GM@HIEA.org

c. Tory Pearson, Director of Stakeholder Relations, Minister's Office
Trent Angiers, Policy Adviser, Minister's Office
Serge Imbrogno, Deputy Minister, MECP
HIEA Member Companies

Appendix A1

A Review of Recent Revisions to Guidance from the Ontario Ministry of Environment, Conservation and Parks (MECP) on the use of AERMOD for Permitting Applications

Technical Report
Prepared for
Hamilton Industrial Environmental Association (HIEA)

Prepared by

Dr. Frank Freedman, CCM
Dr. Paolo Zannetti, QEP

EnviroComp, Inc.
Reno, NV
https://www.envirocomp.com/www

Project: EC-23-003
Report: 23-06-21
21 June 2023

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ACRONYMS AND ABBREVIATIONS

GIS	Geographic Information Systems
HIEA	Hamilton Industrial Environmental Association
LU/LC	Land Use/Land Cover
MECP	Ontario Ministry of Environment, Conservation and Parks
NLCD	National Land Cover Database
OCD	Offshore Coastal and Dispersion Model
QC	Quality Control
RHC	robust highest concentration
SCAQMD	South Coast Air Quality Management District
SF6	Sulfur Hexafluoride
TSP	Total Suspended Particle
U.S. EPA	U.S. Environmental Protection Agency
USGS	U.S. Geological Survey
WVTS	Winter Validation Tracer Study

Summary of Key Points

- The Hamilton Industrial Environmental Association (HIEA) has requested a review of recent revisions to guidance from the Ontario Ministry of Environment, Conservation and Parks (MECP) on 1) the use of the Urban dispersion option (hereafter the "Urban Option") when applying AERMOD for permitting applications in its jurisdiction; and 2) the possibility of CALPUFF being used instead of AERMOD for such applications. Based upon our extensive scientific experience in atmospheric sciences and air quality modeling, we conclude that the recent revisions are not supported by science and should be re-examined by the Ontario Ministry. The reasons are summarized in the following bullets.
- MECP provides no scientific basis for its claim that water bodies diminish urban heat island effects at night to support its revised guidance to not use the Urban Option in AERMOD for emission sources near water bodies. In fact, common understanding, as well as statements in the research papers MECP itself cites to support its directive, indicate the opposite, that urban heat island effects are enhanced at night.
- The academic literature research papers MECP cites, claiming to support its revised guidance, focus on daytime conditions, not nighttime. The Urban Option, however, applies during nighttime hours, and maximum 1-hour concentrations – most important for regulatory compliance – most commonly occur during weak winds at night. Implementation of the proposed change in modeling setup will therefore likely seriously overestimate concentrations during the most important nighttime hours, when regulatory compliance is often determined, since urban heat island effects on dispersion would not be accounted for if the Urban Option is switched off.
- The revised guidance to set a low value of around 0.01 meters for the input roughness length when using the AERMOD Urban Option is unjustified scientifically and indicates a misunderstanding by MECP of the fact the roughness length is an "effective" roughness length for capturing the dispersive effects of urban heat island enhanced convective turbulence on low-level emission sources. The value of around 0.01 m is too low to allow enhanced convective turbulence to affect low-level sources,

This is unjustified scientifically since enhanced convective turbulence affects the entire boundary layer, not discriminating against low-level sources.

- The possible use of CALPUFF for simulating short-range concentration impacts does not in general lead to more accurate concentration results and is therefore probably not cost-effective given the significant computational expense compared to AERMOD. The US EPA, after serious examinations and considerations, has removed CALPUFF from the list of “preferred” models. It is not clear, in a given region of interest, if CALPUFF simulations will produce higher or lower concentrations when compared to AERMOD. Perhaps a field study (e.g., a tracer study) could provide some insight on whether or not CALPUFF produces more realistic simulations than AERMOD in the Hamilton Industrial area.

1. Introduction

The Hamilton Industrial Environmental Association (HIEA) has requested a review of recent revisions to guidance from the Ontario Ministry of Environment, Conservation and Parks (MECP) on the use of the Urban dispersion option (hereafter the "Urban Option") when applying AERMOD[1] for permitting applications in its jurisdiction. Specifically, the main part of the revised guidance is that the Urban Option should not be used in situations when an emission source is near a shoreline or large water body, regardless of land use classification around the source. This contrasts with existing guidance from U.S. EPA and local agencies, which states that the Urban Option should be applied provided land use near the source is classified as urban. The revised guidance also recommends setting a much lower value for roughness length than the default value of 1 meter when applying the Urban Option for shoreline emission sources, as well as a recommendation to run CALPUFF rather than AERMOD for regulatory applications.

The Urban Option is a switch in AERMOD that, when selected, activates a model algorithm that calculates the effects on concentrations from enhanced dispersion of pollutants at night due to urban heat island effects. Concentrations from emission sources released at or near ground level predicted by AERMOD are lower when the Urban Option is applied compared to when it is not since enhanced turbulence causes ground-level emissions to disperse vertically more effectively. Contrarily, ground-level concentrations from elevated sources can be higher when the Urban Option is applied since the enhanced dispersion more effectively mixes pollutants released above ground level to the surface.

U.S. EPA gives guidance on whether the Urban Option should be applied to an emission source in AERMOD, and state and local agencies in the U.S. typically cite this in their respective guidance documents. The most common determining method is the "Auer Method", where a land use analysis of the modeling domain is carried out using GIS with some native land-use

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[1] AERMOD is the U.S. EPA atmospheric pollution dispersion model approved for permitting air pollutant emissions from new and existing industrial sources. https://www.epa.gov/scram/air-quality-dispersion-modeling-preferred-and-recommended-models#aermod.

data as input (e.g., USGS NLCD land cover grids, or local zoning data). If over 50% of the land use within a three-kilometer radius of the source is classified as urban by the analysis, the Urban Option should be applied to the source, whereas if less than 50% of the land use is classified urban within the three-kilometer radius, the Urban Option should not be applied. To simplify the process for large urban metropolitan jurisdictions, some local agencies instruct users to apply the Urban Option to all sources within the modeling domain without the need for land-use analysis.

The revised MECP guidance places more restrictive conditions on whether the Urban Option is to be applied for sources near water bodies. The central directive is that the Urban Option should not be applied to such a source, even if the Auer Method indicates more than 50% of the land use around the source is urban. MECP's justification for this is that the proximity of the water body would diminish the heat island due to onshore winds. Secondarily, if the Urban Option is used, the revised guidance directs users to input of a much lower value of roughness length than the default value of 1 m, which according to MECP would better represent the local surface conditions of the upwind water body. Finally, the revised guidance recommends CALPUFF[2] as an alternative "better" model than AERMOD for shoreline sources and promotes its use for regulatory applications in these situations.

The revised MECP guidance is counter to those of EPA and other local agencies, and if applied can significantly increase the value of AERMOD maximum ground level concentrations for ground/low level emission sources, often the most important for determining regulatory compliance. This is because the enhanced turbulence of urban heat islands would not be accounted for in AERMOD dispersion calculations. A careful review of the scientific justification of the revised guidance is thus warranted and has been requested of us by HIEA. In this document, we provide the findings of this review.

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[2] https://www.epa.gov/scram/air-quality-dispersion-modeling-alternative-models#calpuff

2. Qualifications

We have performed air quality modeling investigations, research and development studies, teaching, and consulting for several decades. For additional information and examination of our CVs, visit:

https://www.envirocomp.com/people/freedman.html

and

https://www.envirocomp.com/people/zannetti.html

A few examples of our most recent scientific work are presented in the *Selected projects* section at:

https://www.envirocomp.com/index.html

3. Documents Received and Collected

The central document provided to us summarizing the revised MECP modeling guidance is:

- "*Modelling Updates: Winter 2023 Air Practitioner's Meeting*", Feb 2, 2023

In this PowerPoint presentation, MECP describes the updates to its modeling guidance concerning AERMOD. We hereafter refer to this presentation as "MECP Modeling Updates".

In addition, we received from HIEA the following academic journal references provided by MECP to its members that MECP claims justifies its revised guidance,

- **MECP Paper 1**: TC Chakraborty, Jiali Wang, Yun Qian et al. 2022. Urban versus lake impacts on heat stress and its disparities in a shoreline city. 09 August 2022. https://doi.org/10.21203/rs.3.rs-1818535/v1.
- **MECP Paper 2**: Ricky Anak Kemarau and Oliver Valentine. 2020. Analyses of Water Bodies Effect in Mitigation of Urban Heat Effect: Case Study Small Size Cities Kuching, Sarawak. Eboy 2020 IOP Conf. Ser.: Earth Environ. Sci. 540 012010. https://iopscience.iop.org/article/10.1088/1755-1315/540/1/012010/pdf
- **MECP Paper 3**: Cosgrove and Max Berkelhammer. 2018. Downwind footprint of an urban heat island on air and lake temperatures. Npj (Nature) Climate and Atmospheric Science, 1: 46. https://www.nature.com/articles/s41612-018-0055-3
- **MECP Paper 4**: Zhijie Wu and Yixin Zhang. 2019. Water Bodies' Cooling Effects on Urban Land Daytime Surface Temperature: Ecosystem Service Reducing Heat Island Effect. Sustainability, 11(3), 787. https://doi.org/10.3390/su11030787
- **MECP Paper 5**: Valéry Masson, Aude Lemonsu, Julia Hidalgo, and James Voogt. 2020. Urban Climates and Climate Change. Annu. Rev. Environ. Resour. 45: 411–44. https://www.annualreviews.org/doi/abs/10.1146/annurev-environ-012320-083623
- **MECP Paper 6**: Huang, H., Yun, Y., Xu, J., Wang, S., Zheng, X., Fu, J. and Bao, L. 2017. Scale and Attenuation of Water Bodies on Urban Heat Islands, Open House International, Vol. 42 No. 3, pp. 108-111. https://doi.org/10.1108/OHI-03-2017-B0022

In addition to this material, we independently examined the following documents from U.S. EPA concerning AERMOD:

- AERMOD Model Formulation Document, U.S. EPA, June 2022[3]
- AERMOD Implementation Guide, U.S. EPA, June 2022[4]
- Appendix W 40 CFR Part 41, U.S. EPA, Jan 17 2017 (hereafter Appendix W)[5].

We also reviewed modeling guidance documentation from state and local agencies on the use of AERMOD in their jurisdictions, and scientific literature related to pollution dispersion in atmospheric boundary layers, internal boundary layers and urban heat islands.

[3] https://gaftp.epa.gov/Air/aqmg/SCRAM/models/preferred/aermod/aermod_mfd.pdf
[4] https://gaftp.epa.gov/Air/aqmg/SCRAM/models/preferred/aermod/aermod_implementation_guide.pdf
[5] https://www.epa.gov/sites/default/files/2020-09/documents/appw_17.pdf

4. Background

The topic of MECP's revised guidance is how to treat Gaussian plume dispersion model setup in urban areas near shorelines. Urban and shoreline settings independently pose challenging conditions for the accuracy of plume models that have been recognized for decades. Proper application to these situations, or the choice to switch to alternative model, requires advanced understanding and experience in atmospheric boundary layers and dispersion modeling, and careful analysis and specification of the nature of actually monitored or otherwise anticipated model inaccuracies is required so that efforts to correct model deficiencies are well focused. This work is best done collectively between model users and governing regulators in a setting of open, transparent communications centered around problem specifics.

In this section, we provide a baseline understanding of relevant scientific issues related to plume dispersion modeling in urban and shoreline settings. The goals are to provide some foundation and context for later discussion on the specifics of MECP's revised guidance, and hopefully as well to facilitate dialogue between participants for properly setting up AERMOD for urban sources near shorelines. If uncertainties still remain for modeling applications in particularly complex regions, field studies (e.g., tracer experiments) should be designed and implemented for the purpose of understanding which model is most suitable, and the correct model parameters to use.

We first present issues pertaining to Gaussian dispersion modeling in general. We then discuss aspects specific to urban areas and then shoreline situations. Discussion points will be on Gaussian dispersion models in general and AERMOD specifically, as relevant.

4.1 Gaussian Plume Dispersion Modeling: General Concepts

AERMOD is a Gaussian plume dispersion model, a type of model that produces every hour a single steady-state simulated concentration field from an emission source driven by an hourly set of input meteorological variables from a single meteorological site. A time series of model concentration fields is produced by inputting a series of hourly meteorological inputs and running the model independently for each hour in the series. For example, hourly concentration fields over a five-year period, typical of regulatory applications, are produced by inputting five years of hourly meteorology and running the model independently for each hour. Multiple sources can be configured into a single model run, with concentration fields from each source calculated independently using the input meteorological variables and then added to produce a combined concentration field accounting for all sources.

Because these models are driven by meteorological input from a single site, proper selection of the meteorological monitoring site to provide the input data is important for accurate model predictions. In particular, the site should be as representative as possible of the setting of the emission sources and downwind receptor field to which the model is applied. For convenience, routinely measured and archived hourly surface measurements from airports or other sites operated by national weather agencies are often used to provide the required input meteorological data. The main advantages of this are that such data are readily available, the instrumentation and data gathering methods are well-documented and standardized, and the data can generally be trusted as accurate with minimal user checking due to QC procedures put in place by the weather agency operating the site. A disadvantage is that sometimes the “airport” site can be far from the model application location, and therefore not representative. For U.S. National Weather Service data, there is generally at least one “airport” site within 5 – 10 miles of the application site. In homogeneous, rural settings this is often good enough, yet in areas where the setting is more heterogeneous it may not be, and a closer, more locally representative meteorological site should be sought. Urban and shoreline areas are generally areas where such heterogeneity is important, and the meteorological site for model input should be representative.

The meteorological inputs for AERMOD are produced by its meteorological pre-processor AERMET and its land-surface analysis pre-processor AERSURFACE. AERMET and AERSURFACE work in tandem. AERMET reads in the raw meteorological inputs (for example, near-surface wind speed, wind direction, temperature) and from these computes several derived quantities from that quantify the level of atmospheric turbulence (for example, surface friction velocity, convective velocity scale, Monin-Obukhov length and mixing heights). The raw data as well as these derived quantities comprise the AERMOD-ready meteorological input files output by AERMET. AERSURFACE reads in and processes the surrounding land-use/land-cover (LU/LC) around the meteorological site so that the postprocessing of derived quantities by AERMET accounts for the surface characteristics around the meteorological site.

4.2 Gaussian Plume Dispersion Modeling: Urban Areas

Urban applications require special treatments in dispersion models. Atmospheric turbulence and mixing depths are generally higher in urban areas due both to the relatively high surface roughness (e.g., buildings, trees) and enhanced temperatures compared to surrounding rural locations (Figure 1).

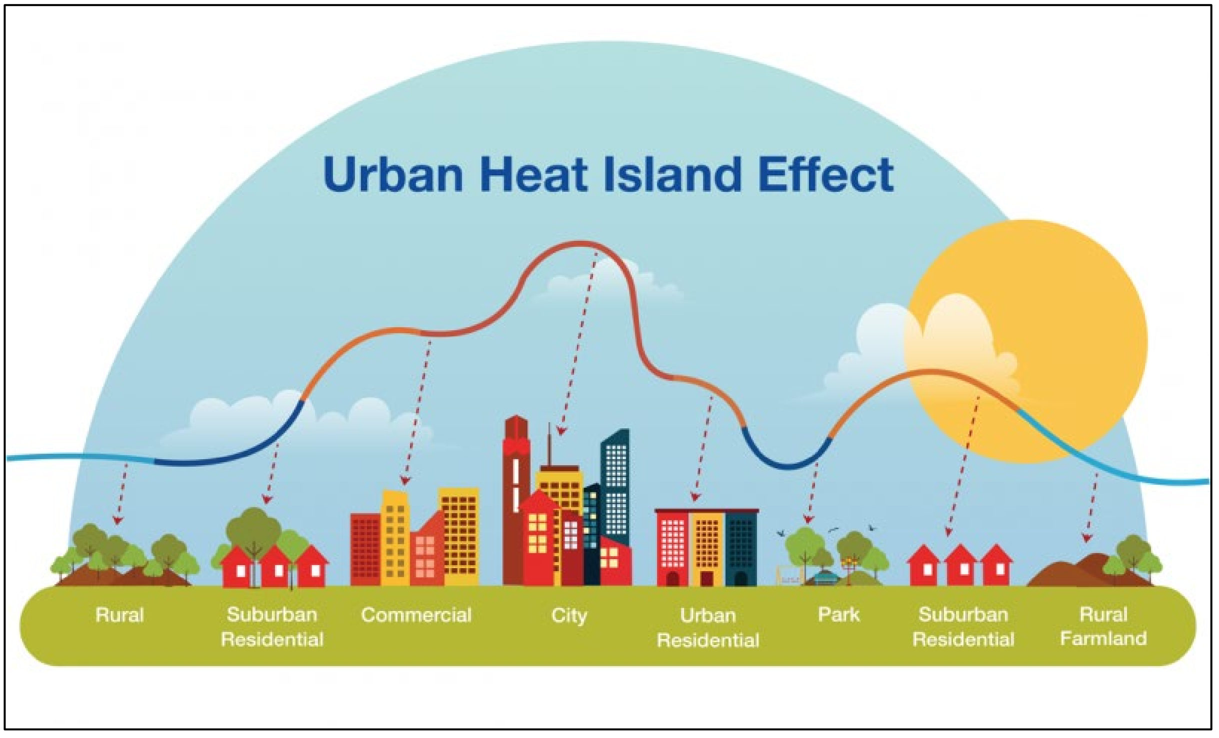

Figure 1 – The urban heat island effect. From: https://instacoat.com/2022/10/17/what-is-the-urban-heat-island-effect/

In older versions of plume models (e.g., ISCST3[6]), the user generally used "rural" meteorological inputs from a surrounding airport site outside the city and then accounted for urban effects on dispersion by externally selecting "urban" dispersion coefficient relationships in the model input control files. These relationships were derived semi-empirically and

[6] https://www.epa.gov/scram/air-quality-dispersion-modeling-alternative-models#isc3

accounted for both roughness and heat island effects. In AERMOD, accounting for the effects of increased roughness through "urban" dispersion coefficients is no longer needed since the post-processed meteorological inputs provided by AERMET directly account for the surrounding LU/LC field around the meteorological site in computing derived meteorological quantities provided an urban meteorological site provides the raw meteorological data. Such local data are more readily available in the last couple decades than before when older models like ISCST3 were used, as the number of meteorological sites within local urban networks has grown.

The effects of enhanced turbulence due to urban heat islands, however, must still be accounted for in AERMOD through explicit selection of urban dispersion coefficients in the model control file. Urban heat islands occur due to the increased heat retention capacity of urban surfaces (concrete, asphalt) as well as direct anthropogenic heat sources (e.g., residential and industrial chimneys, furnaces). Combined, these factors generally keep urban areas warmer than surrounding rural areas. Urban heat islands are generally more pronounced at night, and particularly affect atmospheric turbulence and dispersion at night since atmospheric stability is reduced due to the enhanced surface heating (or reduced surface cooling) compared to rural areas. This produces enhanced turbulence and larger nighttime boundary layers compared to adjacent rural areas, increasing vertical diffusion and mixing. AERMOD accounts for this effect through urban dispersion coefficients implemented by user selection of the "Urban Option", described in more detail in Section 5. The Urban Option only operates when surface thermal stability is stable (positive Monin-Obukhov length), which occurs during night.

4.3 Gaussian Plume Dispersion Modeling: Shoreline / Near Water Body Sources

Shoreline and near-water applications provide another challenging situation for Gaussian plume dispersion models like AERMOD. Meteorological conditions at shorelines are by nature heterogeneous as air transitions to being more characteristic of the water body over the water and near the shore to being more characteristic of the underlying land surface further inland (Figure 2). Since plume dispersion models like AERMOD use stationary, homogeneous wind data for each hour, inherent difficulties are unavoidable in applying the model to these situations, where there is a change in meteorological conditions as plumes travel downwind.

However, we must remember that, for regulatory applications, models are expected to simulate correctly (or at least conservatively) the highest, ground-level concentration impacts. In other words, uncertainties and inaccuracies can be accepted in regulatory modeling studies as long as we are confident that the simulations of worst-case concentration impacts are realistic.

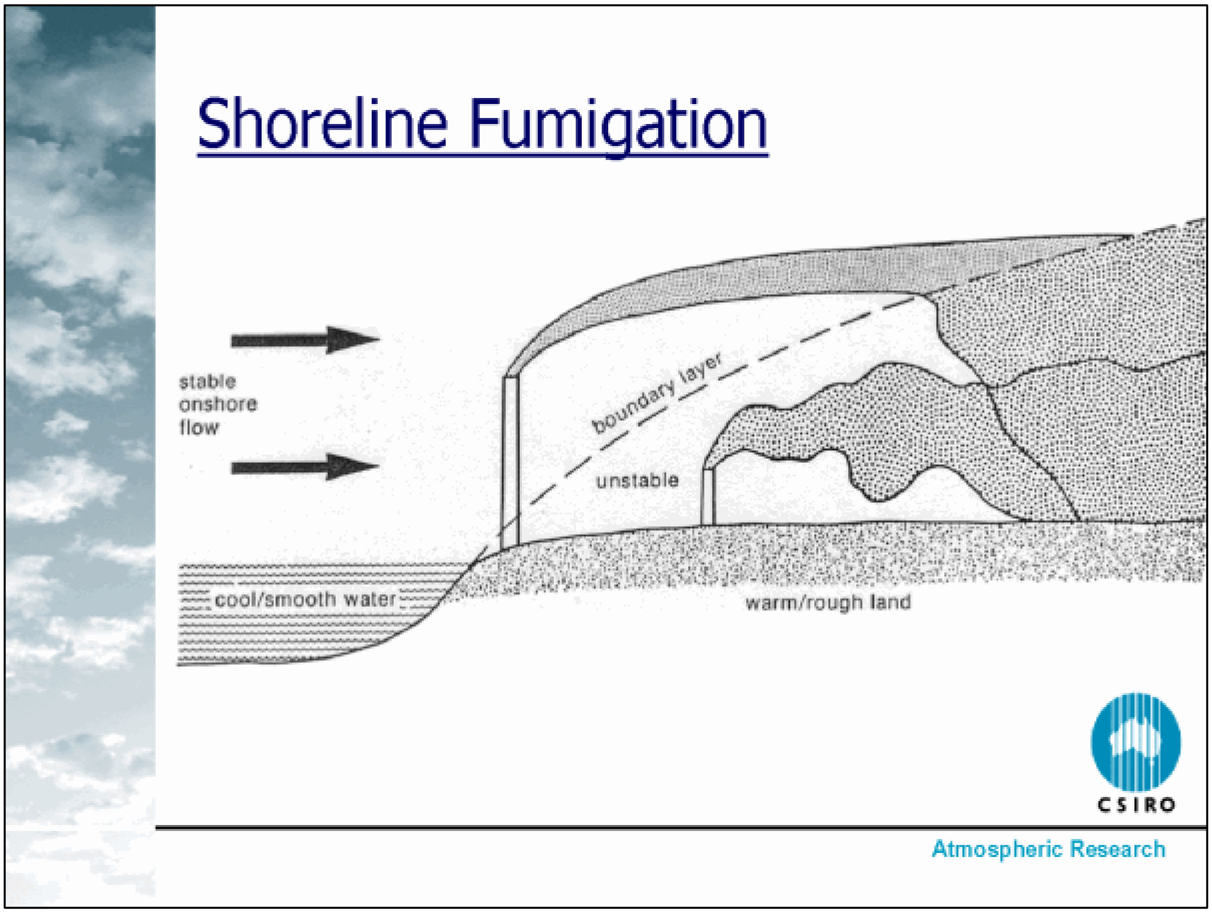

Figure 2 – Shoreline fumigation. From
https://www.cmar.csiro.au/airquality/localscale/framepage.html

To describe the situation more specifically, for onshore wind conditions in daytime a vertical "internal boundary layer" typically develops and grows in depth and the wind travels further inland from the shore. The internal boundary layer is the layer of air directly influenced by the underlying surface, which will grow in depth as the wind travels inland and is increasingly affected by the change in surface from the upwind water. The internal boundary layer depth is shallow near the shore (tens of meters depth) since the influence of the underlying surface has not worked its way up through much of the depth of the inflow boundary layer characteristic of the water. As travel time and distance increases further inland, the internal boundary layer grows in depth and ultimately engulfs the inflow boundary layer through hundreds of meters.

As stated, internal boundary layer situations are challenging for plume models because meteorology from only one meteorological site is used, eliminating the possibility of accounting for both shore and inland effects. One often cited problem is "shoreline fumigation" in the morning hours after sunrise. Here, a plume model is configured for a shoreline location with an elevated emission source, such as a tall stack a couple hundred meters tall. Meteorological inputs are characteristic of the local, shoreline area where boundary layers can be quite shallow, below the height of pollution release. The simulated plume therefore travels above the boundary layer and does not disperse to the surface. In reality, however, the plume would eventually disperse ("fumigate") to the surface as the growing internal boundary layer experienced by the plume as it travels inland eventually intersects the plume from below. Shoreline fumigation is most pronounced during the day since daytime boundary layers are deeper and more prone to grow to the point of intersecting the plume. The plume model therefore "misses" this change in meteorology and does not accurately simulate plume fumigation. Surface concentrations can then be severely underestimated. Alternative dispersion models (some specifically designed for shorelines) that input meteorological data from two or more sites are often applied for shoreline applications. An example of a model recommended by U.S. EPA is the Offshore Coastal and Dispersion Model (OCD)[7].

[7] https://www.epa.gov/scram/air-quality-dispersion-modeling-preferred-and-recommended-models#ocd

5. AERMOD Urban Option

MECP's revised guidance refers to when to use the AERMOD Urban Option. We provide an overview of the AERMOD Urban Option in this section.

5.1 General Description

The AERMOD Urban Option is applied when running AERMOD for urban sources to account for enhanced turbulent dispersion at night[8] due to urban heat island effects. Urban heat islands are well-documented effects whereby augmented surface heating and heat retention in cities due to such things as anthropogenic heat sources, higher heat capacity urban surfaces, and lower moisture content and latent heat fluxes keep urban areas warmer that surrounding rural areas. The increased surface heating tends to lower the atmospheric stability at night, thereby enhancing vertical turbulent dispersion during nighttime hours. This affects surface concentration predictions by AERMOD, tending to lower surface concentrations from near surface sources. The details of AERMOD Urban Option are described in Section 5.9 in the AERMOD Model Formulation document, and throughout Section 5 in the AERMOD Implementation Guide.

To run the Urban Option, four steps are required by the user:

1. The Urban Option must be toggled on in the AERMOD Control Pathway.
2. Emission sources that are "urban" (and hence affected by the Urban Option dispersion effects) are toggled in the AERMOD Source Pathway.
3. For each urban source, the user must input a value of population, which is used in the model formulations to estimate the urban-rural temperature difference and heat island strength. The AERMOD Implementation Guide, and sometimes local agencies as well, provide guidance on how to specify input population values.
4. Optionally, the user can input a value for urban roughness length, which is used for low-level sources to define a reference height to compute the enhanced turbulence

[8] More precisely, in runs when conditions are stable (i.e., the Monin-Obukhov length is positive).

associated with heat islands in the Urban Option. The default value for urban roughness length is 1 meter. Note that this is an "effective" roughness length used only to define a reference height to account for urban convective turbulence due to heat islands, rather than the physical aerodynamic roughness length of the underlying surface. See the AERMOD Implementation Guide for further explanation.

5.2 Regulatory Guidance: When to Use Urban Option

The most common method recommended by U.S. EPA to determine whether to use the Urban Option is the Auer Method[9,10]. This is described in Section 7.2.1.1 of Appendix W as follows:

Land Use Procedure: (1) Classify the land use within the total area, A_o, circumscribed by a 3 km radius circle about the source using the meteorological land use typing scheme proposed by Auer. If land use types I1, I2, C1, R2, and R3 account for 50 percent or more of A_o, use urban dispersion coefficients; otherwise, use appropriate rural dispersion coefficients.

To apply the method, the land-use around a source is classified via GIS analysis using some native LU/LC data as input. The output gridded LU/LC maps are then associated in some way to the Auer classifications I1, I2, C1, R2 or R3, and in turn the percentage of area A_o that is comprised of these classifications around the source is calculated. If A_o is greater than 50% within a 3-km radius the Urban option is recommended to be applied to the source.

[9] Auer, Jr., A.H., 1978. Correlation of Land Use and Cover with Meteorological Anomalies. Journal of Applied Meteorology, 17(5): 636–643.
[10] Irwin, J.S., 1978. Proposed Criteria for Selection of Urban Versus Rural Dispersion Coefficients. (Draft Staff Report). Meteorology and Assessment Division, U.S. Environmental Protection Agency, Research Triangle Park, NC.

5.3 Regulatory Guidance: AERMOD Urban Option near Water Bodies

The following is a survey of relevant U.S. EPA and state/local agency guidance on the use of the AERMOD Urban Option to sources near water bodies.

Section 5.1 of the AERMOD Implementation Guide states the following pertaining to shoreline applications of the Urban Option (underline added):

> *Section 7.2.1.1 of the Guideline on Air Quality Models (EPA, 2017) provides the basis for determining the urban/rural status of a source. For most applications the Land Use Procedure described in Section 7.2.3(c) is sufficient for determining the urban/rural status. However, there may be sources located within an urban area, but located close enough to a body of water or to other non-urban land use categories to result in a predominately rural land use classification within 3 kilometers of the source following that procedure. Users are, therefore, cautioned against applying the Land Use Procedure on a source-by-source basis but should also consider the potential for urban heat island influences across the full modeling domain. Furthermore, Section 7.2.3(f) of Appendix W recommends modeling all sources within an urban complex using the urban option even if some sources may be defined as rural based on the procedures outlined in Section 7.2.3. Such an approach is consistent with the fact that the urban heat island is not a localized effect but is more regional in character.*

Based on this guidance, the user is cautioned against basing the urban determination only on land-use within three kilometers when the source is near a water body, especially if the analysis indicates less than 50% urban coverage. Instead, the user should consider whether the source is within an overall urban area, since urban-heat island effects are regionally rather than locally driven. The recommendation referring to Section 7.2.3(f) of Appendix W in the last underlined sentence in the above guidance more strongly guides users to choose the Urban Option for all sources within an urban complex regardless of locally determined land-use based on this consideration.

The South Coast Air Quality Management District (SCAQMD) of the Los Angeles Metropolitan Area (Figure 3)[11], which consists of many emission sources in the Western LA Basin near the ocean, instructs users to use the Urban option for all sources within its jurisdiction[12]:

> *AERMOD should be executed using the urban modeling option, which is South Coast AQMD policy for all air quality impact analyses in its jurisdiction. All sources should be modeled with urban effects using the population of the County where the project is located. Table A below lists the various County populations within South Coast AQMD jurisdiction. If the rural modeling option is utilized, the report should include a discussion to support this change based on the U.S. EPA procedure outlined in Section 7.2.1.1 of 40 CFR Part 51, Appendix W Link to external website. (January 2017).*

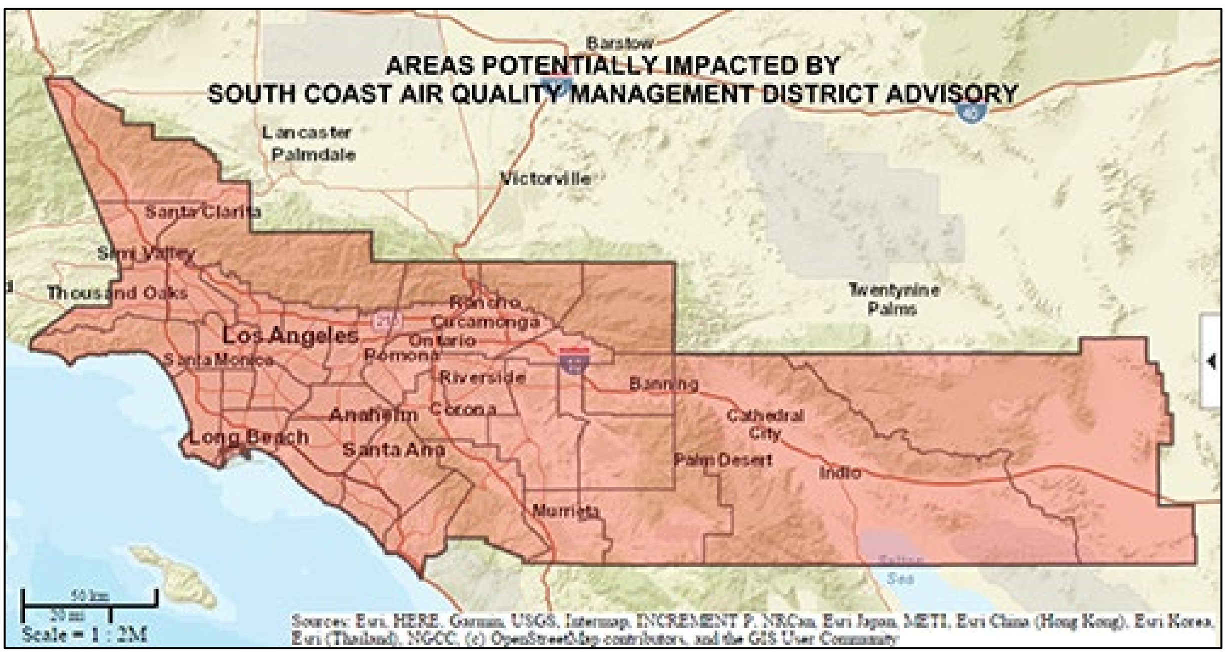

Figure 3 – The areas impacted by the SCAQMD. From: https://www.coronaca.gov/Home/Components/News/News/4066/17

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[11] http://www.aqmd.gov/docs/default-source/default-document-library/map-of-jurisdiction.pdf.
[12] http://www.aqmd.gov/home/air-quality/meteorological-data/modeling-guidance#:~:text=AERMOD.

The state of Wisconsin in its guidance document "Wisconsin Air Dispersion Modeling Guidelines"[13] states (underline added):

> *Based on USEPA dispersion modeling guidance, most locations in Wisconsin use 'rural' dispersion coefficients. Only a portion of the Milwaukee metropolitan area is considered 'urban' under the Irwin/Auer land use technique. For facility locations within the 'urban' area, the analysis should use a population of 1,000,000 (based on Milwaukee County) and a roughness length of 1.0 meter in AERMOD. Refer to Appendix A for the location of the 'urban' area.*

Looking at the map in Appendix A of the Wisconsin guideline document (reproduced below in Figure 4), the 'urban' area extends throughout the Milwaukee metropolitan area all the way to the Lake Michigan shore. As with the EPA and SCAQMD guidance, the recommendation is to use the Urban Option throughout the area up to the shore.

[13] https://dnr.wisconsin.gov/topic/AirPermits/Modeling.html

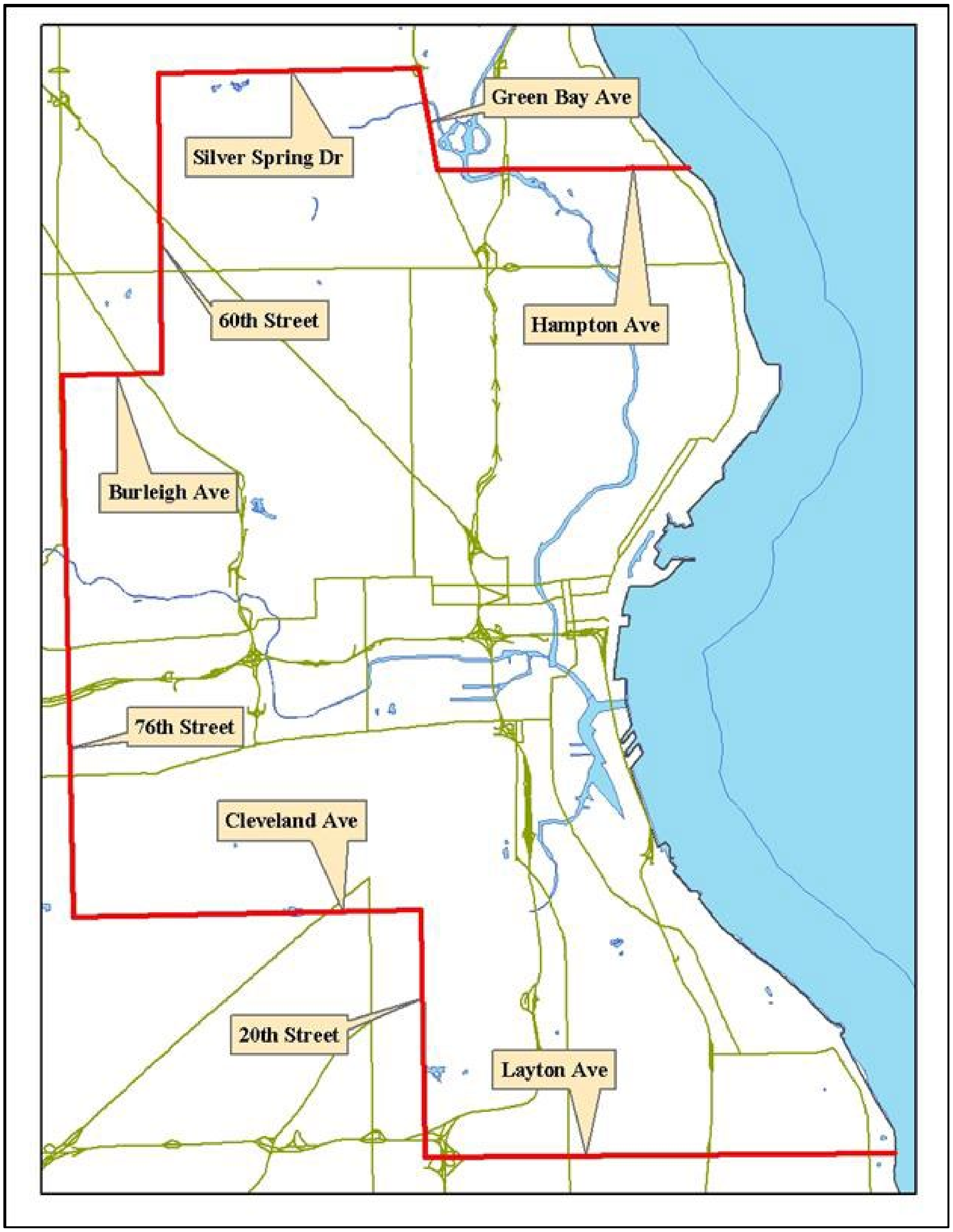

Figure 4 – Appendix A of Wisconsin Air Dispersion Modeling Guidelines, showing greater Milwaukee area, where the AERMOD Urban Option should be applied according to state modeling guidance.

The state of Ohio, in Question 15 of its guidance document "Engineering Guide #69: Air Dispersion Modeling Guidance"[14], states the following (underline added):

[14] https://epa.ohio.gov/divisions-and-offices/air-pollution-control/guides-and-manuals/state-implementation-plan-section-modeling

> *Dispersion coefficients are determined by analyzing land use or population within the total area, A0, of a circle with radius 3 km from the source, as outlined in Section 7.2.1.1 of the Guideline. A summary of the methods is provided in the table on the following page.*
>
> *Of the two methods, Ohio EPA prefers the land use approach and cautions use of the population density approach without prior discussion. The population density approach should generally not be applied in highly industrialized areas with low population density, where the area is built-up sufficiently to warrant an urban dispersion coefficient. Analyses of whole urban complexes should be modeled with an urban dispersion coefficient if most sources are located in urban classifications for consistency with regional urban heat island effects.*
>
> *Sources located within an urban area near a large body of water may warrant a rural dispersion coefficient, though not always. Similarly, plume heights from tall stacks in or near small urban areas may extend above the urban boundary layer such that a rural coefficient would be appropriate. Ohio EPA will review such scenarios case-by-case.*

The guidance in the underlined sentence in the second paragraph is consistent with the ones from EPA, SCAQMD and Wisconsin in that sources within an urban complex should be modeled with the Urban Option. The underlined part of the last paragraph, however, does mention situations when sources near a shoreline may use a 'rural' classification. The context of this appears to be releases from tall stacks that extend above the urban boundary layer. Also, it is noteworthy that the Ohio guidance does not give absolute instruction on whether or not to apply the Urban Option in this situation, but rather leaves the decision to be determined based on case-by-case review by the agency.

6. Revised MECP Guidance AERMOD Urban Option

The revised MECP guidance has three parts related to AERMOD for permitting applications:

1. A directive to not use the Urban Option for urban emission sources near water bodies.
2. A directive to use a lower value of roughness length than the default of 1 meter if using the Urban Option for urban emission sources near water bodies.
3. A strong recommendation to use CALPUFF instead of AERMOD.

We will review part 1 and 2 below and part 3 in the next Section.

6.1 Urban Option for Sources near Water Bodies

The MECP Modeling Updates presentation includes in its topics on Slide 2 "Use of the AERMOD Urban Option and associated settings". Subsequent slides then present the motivation and details of the revised guidance on using the AERMOD Urban Option. The primary focus is on urban emission sources close to the water bodies where the Auer Method determines that land use within three kilometers of the source is over 50% urban. As presented in Section 5.3, existing guidance from U.S. EPA and other agencies directs users to use the Urban Option in this case. However, MECP's revised guidance is that the Urban Option should not be used since, according to the agency in Slides 12 and 20 (reproduced below in Figures 5 and 6), the proximity of the water would cool the heat island and inhibit enhanced nighttime convective turbulence locally,

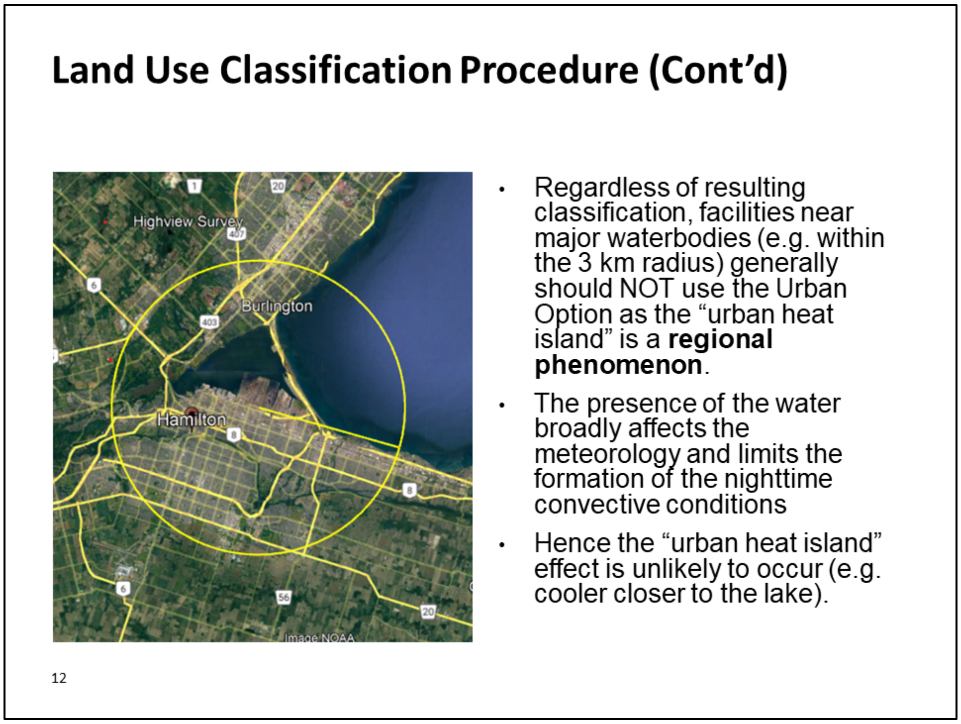

Figure 5 - Slide 12 from MECP Presentation.

Figure 6 - Slide 20 of MECP Presentation.

MECP provides no scientific support in its presentation for the key statement on Slide 12 “the presence of the water body broadly affects the meteorology and limits the formation of nighttime convective conditions”, and in fact it is counter to common understanding about heat islands in urban meteorology. Specifically, while it is known that onshore breezes can diminish heat islands and affect pollution dispersion during day[15,16], there is no evidence that we have found of this occurring during night, when onshore winds are weak, non-existent or reverse to offshore land breezes. In fact, research papers MECP cites to support their revised guidance, summarized below, provide evidence of the opposite, that heat islands are generally enhanced at night due to urban land use effects on surface heat fluxes.

The statement on Slide 20 “the upwind land use dictates the downwind concentration” is also incomplete and overly simplistic. Rather, it is both 1) the upwind land use, and 2) the local surface conditions that dictate internal boundary layer growth and urban heat island development and persistence. These two processes affect dispersion in different ways, and which effect is most important depends strongly on time of day, time of year, the specific characteristics of the location in terms of topography and urban land use, the nature of the surrounding area around the city, and other important physical aspects. The physics is thus complex, and issues related to pollution dispersion from emitting air sources need to be studied on a case-by-case basis to understand the dominant physics affecting pollution dispersion for that location.

In addition to the PowerPoint presentation, MECP also provided to HIEA six academic journal article references related to urban heat islands and the effects of nearby water bodies that they claim support their revised guidance. The citations for these references are provided in Section 3 labeled MECP Papers 1 through 6.

Having reviewed these articles, we summarize them as follows:

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[15] Melecio-Vázquez, D., Ramamurthy, P., Arend, M. et al. Thermal Structure of a Coastal–Urban Boundary Layer. Boundary-Layer Meteorol. 169, 151–161 (2018). https://doi.org/10.1007/s10546-018-0361-7

[16] Jing Yuan, Akula Venkatram, Vlad Isakov, Dispersion from ground-level sources in a shoreline urban area, Atmospheric Environment, Volume 40, Issue 7, 2006, Pages 1361-1372, ISSN 1352-2310, https://doi.org/10.1016/j.atmosenv.2005.10.024.

- MECP Paper 1 is an atmospheric modeling study that finds urban cooling due to the water bodies occurring during day, not night. In fact, the abstract states that during night urbanization enhances heat exposure.
- MECP Papers 2, 4 and 6 focus only on the effects of water bodies on heat islands during daytime conditions, not nighttime conditions. The studies are based on analysis of Landsat thermal infrared imagery, which is a sun-synchronous polar orbiting satellite with approximately 10:00AM local time overpass.
- MECP Paper 3 is a study about the effects of urban heat islands on downwind areas, not upwind water bodies on urban heat islands. There is nothing in the paper that relates to the effects of an upwind water body on downwind heat island development.
- MECP Paper 5 is a review paper on urban heat islands and urban climate. ‘Section 2.2: Processes Creating the Urban Heat Island’ highlights that urban heat islands are strongest at night and the dominant role of urban surface modifications altering the surface energy balance thereby causing heat islands. ‘Section 2.3: Urban Climate in Complex Geographic Areas’ summarizes the findings of key studies on the interaction of coastlines and urban heat islands. A key takeaway is that the cooling effect of water bodies is generally a daytime, not nighttime, phenomenon. In fact, the cited Kotharkar study of Indian cities found that at night coastal areas were warmer than inland areas, and the cited New York City highlighted case-by-case complexity, for example in heatwave situations the cooling effect of the water was reduced since winds shifted offshore:

> *Kotharkar et al. (24) review 85 works on 28 South Asian cities. They show that during the daytime the sea breeze in Delhi, Mumbai, and Colombo improves thermal comfort by limiting the diurnal warming in the cities and mitigates atmospheric pollution.* ***However, although coastal areas remained cooler than the inner city regions by day, the opposite occurred at night (25).*** *The sea breeze in New York City reduces urban temperatures in most calm synoptic wind situations, but during heat waves, the wind typically comes from inland, and then strongly reduces this cooling effect (26).*

Some additional comments on these papers are as follows:

- None of the studies in these papers focus on air pollution dispersion.
- MECP Paper 1 is not yet peer-reviewed (doi last checked on June 20 2023).
- MECP Paper 2 is a study for a city in Malaysia - a tropical, rainforest setting. It is also a conference paper, which usually go through very limited if any peer-review.
- MECP Paper 6 is a study for a city in China near a river with tributaries. The focus is on small and medium size water bodies, rather than large water bodies like ocean and large lakes.

In summary, the papers cited by MECP are almost entirely irrelevant to the topic of whether water bodies suppress urban heat islands at night. In fact, the few pieces of evidence on the topic they provide indicate that urbanization is enhanced at night – the opposite of what MECP claims.

In summary, there is no evident scientific justification for MECP's revised guidance to not use the Urban Option for emission sources near water bodies.

6.2 Lower Roughness Length when Applying the Urban Option

MECP also directs users in its presentation to use a much lower roughness length than the default value of 1 meter when applying the Urban Option for shoreline sources. Specifically, MECP directs users to use the minimum value of roughness length contained in the hourly AERMET meteorological input file. According to MECP, this would better represent the local surface conditions of the upwind water body. This minimum value can be very low, around 0.01 m or less, when the model is applied in a shoreline setting since for certain hours when the winds are onshore the roughness length can take on low values characteristic of the water body.

We cannot find any scientific or regulatory support for using such low value as 0.01 m for roughness length with the Urban Option. In fact, MECP's directive and justifications concerning the use of such a low value show a profound lack of understanding of key technical details of how roughness length is applied in the Urban Option. Specifically, the roughness length is not used in the traditional way as an aerodynamic roughness length to account for surface effects on winds, but instead as "an effective roughness length" to set a reference height for capturing enhanced convective turbulence in urban areas during nighttime for low-level emission sources. It is not intended to represent the actual physical roughness length of the urban application site. This is explained in Section 5.3 the AERMOD Implementation Guide (underlines added for key sentences),

> ***5.3 Optional urban roughness length – URBANOPT keyword (10/19/2007)***
> *The URBANOPT keyword on the CO pathway in AERMOD (EPA, 2022c) includes an optional parameter to specify the urban surface roughness length. The urban surface roughness parameter is used to define a reference height for purposes of adjusting dispersion for surface and low-level releases to account for the enhanced turbulence associated with the nighttime urban heat island. This optional urban roughness length is not used to adjust for differences in roughness length between the meteorological measurement site, used in processing the meteorological data, and the urban application site. Details regarding the adjustments in AERMOD for the urban boundary layer, including the use of the urban roughness length parameter, are provided in Section 5.8 of the AERMOD model formulation document (Cimorelli, et al., 2004).*
>
> *The default value of 1 meter for urban surface roughness length, assumed if the parameter is omitted, is considered appropriate for most applications. Any application of AERMOD that utilizes a value other than 1 meter for the urban roughness length should be considered as a non-regulatory application, and would require appropriate documentation and justification as an alternative model, subject to Section 3.2 of the Guideline on Air Quality Models (EPA, 2017).*

As explained in Section 5.9 of the AERMOD Model Formulation Document (referred to this as Section 5.8 in the above quote), the reference height for capturing enhanced nighttime convective turbulence is set to 7 times the value of the input roughness length. The default value of 1 meter therefore places the reference height at 7 meters, which EPA finds to be generally appropriate for capturing convective nighttime enhanced turbulence on low-level sources (see above quote). Contrarily, a low roughness length of around 0.01 m suggested by MECP would place the reference height at 0.07 meters, which based on the AERMOD simulation sensitivity tests provided in their presentation is too low to allow any enhanced convective turbulence to affect dispersion from low-level sources, in effect negating the intended effect of the Urban

Option for such sources. This is unjustified scientifically since enhanced convective turbulence affects the entire boundary layer, and therefore emissions from both elevated and low-level sources. There is no scientific justification for altering a model parameter that allows the intended physics to affect elevated but not ground level sources.

6.3 AERMOD Modeling Demonstrating Effects of Revised Guidance

Slide 18 of the MECP presentation, shown below (Figure 7), presents the results of AERMOD simulations carried out by MECP illustrating the effects on maximum 1-hour POI (point of impingement) concentrations for a hypothetical emission source near a water body for four cases: a) not using the Urban Option, b) using the Urban Option with the default value of 1 meter for roughness length and a population input of 75000, c) using the Urban Option with a 0.009 m roughness length and a population input of 75000, and d) using the Urban Option with 0.009 m roughness length and a population input of 13000. MECP does not provide any additional information about the input parameters for these simulations or the hourly meteorological inputs corresponding to the maximum 1-hour concentrations shown on the slide.

Example Facility – near a large water body (cont'd)

Comparison of results between 'urban' vs. 'rural' for this site:

Dispersion Coefficient		Modelled Max POI Concentration (ug/m3)
Without Urban Option (e.g. **RURAL**)		1709
With **Urban** Option (URBANOPT) and default **1 m** surface roughness	With Urban Heat Island Effect and the population of the entire town (75000)	484
With **Urban** Option (URBANOPT) and minimum surface roughness (**0.009m**)	With Urban Heat Island Effect and the population of the entire town (75000)	2797
With **Urban** Option (URBANOPT) and minimum surface roughness (**0.009m**)	With Urban Heat Island Effect and the population of a smaller area surrounding the facility (13000)	2931

18 Ontario

Figure 7 - Slide 18 of MECP Presentation.

As seen, there are large increases in POI maximum hourly concentrations (a factor of 3 – 5 approximately) comparing the output from not using the Urban Option (1,709 μg/m^3) or using it with the MECP directed 0.009 m roughness length (2,797 μg/m^3) compared with the output corresponding to typical use of the Urban Option with default 1 m roughness length (484 μg/m^3). Such model behavior seems to indicate that the hypothetical source is a ground or otherwise low-level source, since the increased dispersion captured by using the Urban Option would lower ground-level concentration for low-level emission releases, consistent with the concentration results presented. These results show that the effects of the revised MECP guidance on maximum 1-hour concentrations are large – a factor of 3 to 5 times higher if not using the Urban Option – which can have serious regulatory permitting implications since maximum hourly concentrations are often the determining factor on whether regulatory thresholds are met.

To better understand the effects on 1-hour maximum AERMOD predictions for low-level sources with versus without the Urban Option, we performed our own modeling tests. We set up a hypothetical 100 by 100 meter ground-based area source with arbitrary emission. Receptors were placed around the source along and beyond a fenceline 200 meters from the source. The model was run using the five-year AERMET meteorological input files provided by MECP for Urban and Suburban areas[17]. The maximum 1-hour concentrations for each of four runs (with versus without Urban Option, Urban versus Suburban AERMET five-year meteorology) are tabulated below (Table 1).

Table 1 – Maximum 1-hour concentrations for four AERMET meteorology scenarios.

AERMET Meteorology	Urban Option (Y/N)	Max 1-HR (ug/m3)	Date Stamp	Wind Speed
Urban	Y	775	1997 Dec 8, 3PM	1 m / s
Urban	N	922	1996 Feb 8, 9AM	1 m / s
Suburban	Y	2016	1998 Feb 28, 8PM	1 m / s
Suburban	N	4317	1999 Jan 2, 12AM	1 m / s

[17] https://www.ontario.ca/page/map-regional-meteorological-and-terrain-data-air-dispersion-modelling

Based on the table results, we see that the biggest concentration impacts, both in terms of value and in terms of difference with versus without the Urban Option, occur when using the Suburban AERMET input file. In this case, switching off the Urban Option increases the maximum 1-hour concentration by a factor of 2.1 (4,317 vs. 2,016 $\mu g/m^3$), somewhat smaller than the factor of 3.5 sensitivity shown above in MECP Slide 18 (Figure 7, 1,709 vs. 484 $\mu g/m^3$) but in the same ballpark. Note that the maximum 1-hour concentrations for these Suburban cases occur during night (8pm and 12am) and for weak winds (1 m/s), as expected.

The concentrations and differences are smaller (775 vs. 922 $\mu g/m^3$) when using the Urban AERMET input file since the effects of high urban roughness are accounted for in the input meteorology and act independently whether or not the Urban Option is switched on. Note also that the times of day of maximum 1-hour concentrations are during morning and evening transitions (9 am and 3 pm) rather than night, yet still associated with weak winds. AERMOD has treatments to adjust / smooth concentrations across the diurnal cycle predicted during boundary layer morning and evening transition periods, hence it is likely this is why concentrations are different with versus without the Urban Option for these hours even though the Urban Option acts during stable nighttime conditions.

7. Revised MECP Guidance: Use of CALPUFF

The CALPUFF modeling system[18] is one of the most advanced computer codes for simulating atmospheric dispersion of chemicals in the atmosphere using the Gaussian Lagrangian Puff methodology - an approach in which air pollution is simulated by emitting a sequence of independent puffs, which travel and expand according to the laws of atmospheric diffusion.

In comparison with Gaussian Plume Models (like AERMOD), Gaussian Puff Models have several theoretical advantages, in particular: 1) they are capable of using three-dimensional meteorological information in complex terrain, i.e., the dynamics of each puff is calculated using the meteorology interpolated at the exact location of the puff; 2) they are non-steady-state models and allow multi-hour accumulation of pollution - a feature that is theoretical important in calm and low winds conditions; and 3) they provide more realistic simulations of long range pollution impacts, e.g., at distances greater than 50 km from the source.

All these advantages are theoretical, because in practice, for real applications, CALPUFF simulations have not shown – unequivocally – a superior simulation performance when compared with simpler Gaussian Plume Models (e.g., the AERMOD modeling system[19]). Especially for regulatory studies, such as permit applications, the suitability and cost-effectiveness of CALPUFF has been often debated, in light of the complexities that are typically encountered in its use. In fact, the US Environmental Protection Agency (EPA), which initially had labeled both AERMOD and CALPUFF "preferred" models, in the last few years has only labeled AERMOD as "preferred, while CALPUFF has become an "alternative" model[20] "… that can be used in regulatory applications with case-by-case justification to the Reviewing Authority."

In our EnviroComp projects, we have often used[21] AERMOD and CALPUFF and are very familiar with the two computer codes and the theories upon which they are based. Based on our

[18] https://www.epa.gov/scram/air-quality-dispersion-modeling-alternative-models#calpuff
[19] https://www.epa.gov/scram/air-quality-dispersion-modeling-preferred-and-recommended-models
[20] https://www.epa.gov/scram/air-quality-dispersion-modeling-alternative-models
[21] See "Selected projects" at https://envirocomp.com/index.html

extensive experience, we believe that CALPUFF must be used for long-range projects (e.g., at distances of interest greater than 50 km), where steady-state Gaussian Plume Models are clearly inappropriate. In all other cases, AERMOD is probably applicable, especially for regulatory studies where, in general, maximum concentration impacts in residential areas need to be simulated, and not specific impacts at particular locations and times. In one particular study - a short range study in complex terrain up to 5 km downwind – we compared three models (AERMOD, CALPUFF, and our particle model LAPMOD[22]), to a large set of ground-level concentration measurements; AERMOD gave the best performance when compared with measurements.

Both AERMOD and CALPUFF are air quality dispersion models widely used worldwide. Currently, AERMOD is the main dispersion model in the list of the preferred and recommended models by the US-EPA[23]. CALPUFF was part of that list from 2003 to 2017, but now is listed as “alternative model”[24], i.e., a software that can be used in regulatory applications with case-by-case justification to be approved by the Reviewing Authority, as explained in section 3.2 of Appendix W[25].

AERMOD is a steady-state Gaussian plume model which assumes horizontal homogeneous meteorology over the whole domain, while CALPUFF is a Lagrangian puff model which uses a non-stationary 3D meteorological field. They can be considered modeling systems because, in addition to the dispersion module, they have pre- and post-processors that help the user in preparing input data and analyzing modeling results.

Since AERMOD is a Gaussian stationary model, the concentrations predicted by AERMOD at a specific hour depend only on the emissions of that hour, and not from those of the previous

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[22] The LAPMOD modeling system is a tridimensional non-stationary Lagrangian particle model that can be used to simulate the atmospheric dispersion over complex terrain of gases and aerosols, inert or radioactive. https://www.enviroware.com/lapmod/

[23] https://www.epa.gov/scram/air-quality-dispersion-modeling-preferred-and-recommended-models
It should be noted that US EPA recommendations are made in the context of the regulatory use of models, e.g., for emission permit applications. These recommendations do not necessarily extend to other, non-regulatory uses of models.

[24] https://www.epa.gov/scram/air-quality-dispersion-modeling-alternative-models

[25] https://www.epa.gov/sites/production/files/2020-09/documents/appw_17.pdf

hours. On the contrary, the concentrations predicted by CALPUFF at hour N may depend also on the emissions at hours N-M, with M positive integer (M up to N-1). Of course, it is expected that, as M increases, the effect of past emissions on current concentrations decreases.

Both models are generally acceptable. Many intercomparisons have been carried out between the two models. Some of them are summarized below.

- Jittra et al. (2020)[26] evaluated the performance of the two models in predicting the nitrogen dioxide and sulfur dioxide concentrations at ten monitoring stations in Thailand. They considered the emissions of about 300 point-sources located within the domain. According to this study, AERMOD provided more accurate results than CALPUFF for both pollutants. Moreover, the ability to predict extreme high-end concentrations, evaluated through the statistical index RHC (robust highest concentration), again indicated better performances for AERMOD.
- Rood (2014)[27] evaluated the performance of AERMOD and CALPUFF (and of other two models) using the Winter Validation Tracer Study (WVTS)[28] dataset, carried out in February 1991 near Denver, Colorado. The WVTS dataset comprises twelve 11-hour releases of sulfur hexafluoride (SF_6) – a tracer that was measured at 140 receptors located in concentric rings at two different distances from the source (a 10 m high stack). According to this study, CALPUFF tended to exhibit the smallest variance, highest correlation, and highest number of predictions within a factor of two compared to AERMOD. On the contrary, maximum concentrations were less likely to be under-predicted by AERMOD compared to CALPUFF. Due to these two different abilities, the author concluded that AERMOD is well suited for regulatory compliance demonstration, whereas CALPUFF models is better suited for dose reconstruction and long-range transport.

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[26] Nattawut Jittra, Nattaporn Pinthong, and Sarawut Thepanondh "Performance Evaluation of AERMOD and CALPUFF Air Dispersion Models in Industrial Complex Area," Air, Soil and Water Research 8(1), (1 January 2020).

[27] Rood A.S. (2014) Performance evaluation of AERMOD, CALPUFF, and legacy air dispersion models using the Winter Validation Tracer Study dataset. Atmospheric Environment, Vol. 89, pp. 707-720.

[28] Brown K.J. (1991) Rocky Flats 1990–91 Winter Validation Tracer Study. North American Weather Consultants, Salt Lake City, Utah (1991). Report AG91-19

- Amoatey et al. (2019)[29] compared AERMOD and CALPUFF to estimate the NO_2 and SO_2 concentrations due to the emissions of the Tema Oil Refinery (Ghana) in different seasons of the year characterized by different precipitation levels. They found that AERMOD predictions are better than the CALPUFF ones[30].
- Atabi et al. (2016)[31] compared AERMOD and CALPUFF in predicting the SO_2 concentrations due to the emissions from 16 stacks of a gas refinery[32] located in complex terrain. Sulfur dioxide concentrations were measured at nine monitoring stations. After conducting a statistical comparison over the four seasons, the authors concluded that the performance of both models can be considered acceptable, but in complex terrain conditions CALPUFF offers better agreement with the observed concentrations.
- Tartakovsky et al. (2013)[33] simulated the particulate matter emissions from a quarry located in hilly terrain. Total suspended particle (TSP) concentrations were simulated with AERMOD and CALPUFF, then compared against measured values. The authors simulated several scenarios due to the uncertainties in input parameters when simulating emissions from quarries. They found that for a wide range of meteorological conditions, AERMOD predictions were in better agreement with the measurements than those obtained by CALPUFF.

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[29] Amoatey P., Omidvarborna H., Affum H.A. Baawain M. (2019) Performance of AERMOD and CALPUFF models on SO2 and NO2 emissions for future health risk assessment in Tema Metropolis. Human and Ecological Risk Assessment: An International Journal. Vol. 25, n. 3, pp.

[30] They wrote: *"Overall, AERMOD better predicted ambient SO2 and NO2 levels than the reported CALPUFF model. For SO2, AERMOD showed a good agreement with FB, IOA, and MG while CALPUFF showed a good prediction in NMSE and VG. Also, AERMOD predicted NO2 well with NMSE, IOA, MG, and VG compared with FB for CALPUFF."*

[31] Atabi F, Jafarigol F, Moattar F, Nouri J. (2016) Comparison of AERMOD and CALPUFF models for simulating SO2 concentrations in a gas refinery. Environ Monit Assess. 188(9):516.

[32] Sohar refinery, located in Al Batinah North Governorate, Oman.

[33] Tartakovsky D., Broday D.M., Stern E. (2013) Evaluation of AERMOD and CALPUFF for predicting ambient concentrations of total suspended particulate matter (TSP) emissions from a quarry in complex terrain. Environ Pollut.179:138-45.

- Gulia et al. (2015)[34] used AERMOD and CALPUFF for predicting NO_X concentrations in the near field of a steel plant in India and compared their results with monitored data. According to the authors, both models performed satisfactorily in predicting NO_X concentrations. However, they used different dispersion options for CALPUFF, and found that with some of them CALPUFF performs better than AERMOD. Their conclusion is that the better performances of CALPUFF could be due to the calm wind conditions characterizing the area of study.

[34] Gulia S., Kumar A., Khare M. (2015) Performance evaluation of CALPUFF and AERMOD dispersion models for air quality assessment of an industrial complex. Journal of Scientific and Industrial Research 74(5):302-307

8. Revised MECP Guidance: Discussion and Implications

MECP's revised guidance to not use the Urban Option in AERMOD when an emission source is near a water body, regardless of land use, is a significant change from existing guidance from EPA and local regulatory agencies, which recommend application of the Auer Method to determine if over 50% of land use around the source is classified as urban to use the Urban Option. The MECP revision, if implemented, would likely have major implications for model predictions of maximum 1-hour concentrations important for determining regulatory compliance. This was demonstrated by the modeling sensitivity study results presented by MECP in its presentations as well as our own above (see Section 6.4, Table 1). The directive to not use the Urban Option therefore risks serious inaccuracies in model concentrations if not scientifically supported, especially an overestimation of short-term (1-hour) concentrations for low-level sources, since the enhanced turbulence and dispersion associated with nighttime urban heat islands would not be captured by the model if the Urban Option is not switched on.

The justification MECP provides for the guidance revision is the cooling effect of water bodies on adjacent nearby land areas due to onshore winds, which they claim would suppress the heat island and associated nighttime convective turbulence locally in these areas. We have investigated the material presented by MECP, relevant documents from EPA and other regulatory guidance, and scientific literature on urban boundary layers and dispersion modeling. We have performed our own AERMOD simulations to study the underlying issues. Based on our review, we offer the following summary of opinion,

- Neither the MECP presentation nor the research papers MECP cites provide any scientific support for water bodies reducing heat island effects during night. In fact, common understanding in the field of urban meteorology as well as statements in the cited literature indicate the opposite, that urban heat island effects are enhanced at night.
- The research papers MECP claims support their revised guidance are almost entirely irrelevant to the question of whether water bodies reduce the enhancement of nighttime turbulence due to heat islands. The research studies almost entirely focus on daytime conditions. The Urban Option, however, only applies to nighttime hours, and

maximum 1-hour concentrations most affected by the revised guidance most commonly occur during weak winds at night, as shown from our modeling sensitivity tests. The implementation of their proposed change in modeling setup will likely seriously overestimate concentrations during the most important nighttime hours when regulatory compliance is often determined since heat island effects in dispersion would not be accounted for as they should be. This is wrong scientifically and risks incorrect regulatory assessment based on the modeling results.

- The revised guidance directing users to set a low value of around 0.01 meters for roughness length when using the AERMOD Urban Option is unjustified scientifically. This guidance stems from a clear misunderstanding by MECP of the fact that the roughness length in the Urban Option does not refer to the roughness of the underlying surface, but is instead an "effective" roughness length to determine a reference height for capturing the dispersive effects of enhanced convective turbulence on low-level emission sources due to heat island effects. The default value of 1 meter for roughness length in AERMOD for the Urban Option has been determined generally appropriate for capturing such effects by the US EPA, whereas a value of around 0.01 m suggested by MECP is too low to allow any enhanced convective turbulence to affect low-level sources, in effect negating the Urban Option for low-level sources. This is unjustified scientifically since enhanced convective turbulence affects the entire boundary layer, not discriminating against low-level sources.
- The possible use of CALPUFF for simulating short-range concentration impacts does not in general lead to more accurate concentration results and is therefore probably not cost-effective given the significant preparation and running efforts compared to AERMOD. The US EPA, after serious examinations and considerations, has removed CALPUFF from the list of "preferred" models. It is not clear, in a given region of interest, if CALPUFF simulations will produce higher or lower concentrations when compared to AERMOD. Perhaps a field study (e.g., a tracer study) could provide some insight on whether or not CALPUFF produces more realistic simulations than AERMOD.

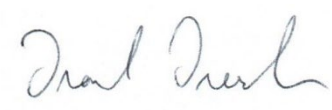
We also have the following broad objections with the revised guidance:

- The revised guidance clearly goes against the regulatory practices we are familiar with and reviewed in the previous sections. This is both in terms of dictating not to use Urban Option near shorelines, which is counter to existing regulatory guidance, and in the manner in which it is dictated, which in no way provides for any discretion scientifically or allowance for case-by-case determination. As shown above, the science of urban shoreline settings is physically complex and plume dispersion and concentrations depend on many factors. It is therefore appropriate to critically review dispersion model accuracy in these situations on a case by case basis. But the points raised should be qualified scientifically, mindful of the interplay of all physical processes involved, focused on the particular times when concentrations are most affected, and discussed in a public and open forum[35]. None of this is exhibited by MECP in its revised guidance.
- The broad change in guidance imposed by MECP also seems unnecessary since regulatory guidance always allows for discretion by agencies and industry working together to make changes in modeling setups on a case-by-case basis, if the science warrants. There is no need for revised guidance since the current precedent already allows for different modeling setups from what is stated in a guidance if need be. See for example the extracts from EPA and local agency guidance documents presented in Section 5 and 6, which have explicit language allowing for alternative modeling setups justified by case-by-case scientific analysis.

[35] Discussions should include sharing and cross-examination of modeling files to assure transparency.

9. Certification

This report presents the current results of our investigation and opinions, based upon the materials reviewed and the analyses carried out to date. We reserve the right to supplement this report in the event new information is presented.



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Appendix A2

CURRICULUM VITAE

OF

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EDUCATION AND TITLES

- *Qualified Environmental Professional (QEP)*, Institute of Professional Environmental Practice (IPEP), currently transferred to the Board for Global EHS Credentialing (BGC) (https://www.gobgc.org/). Listed on the QEP Diplomate Public Roster: https://gobgc.org/qep_roster/. Certificate 2940029 (issued 2/1994) – To be recertified on 12/2024.

- *Doctoral Degree in Physics*, University of Padua, Italy (12/1970) (https://www.unipd.it/)

- *Diploma of Maturita' Scientifica* (Science Degree), Scientific Lyceum Ippolito Nievo, Padova, Italy (7/1965) (https://www.liceonievo.it/)

PROFESSIONAL EXPERIENCE

- ***President*, EnviroComp Consulting, Inc. (4/2001 – present)** (https://www.envirocomp.com)

  - *Director and Founder*, Air Pollution Scientific Initiative (APSI) (4/2020 – present) (https://www.apsi.tech/index.html)

  - *President and Founder*, EnviroComp Institute (10/1996 – present) (https://www.envirocomp.org)

  - *Project Leader,* Comprehensive Air Modeling/Optimization System (CAMOS) (Since 2013) (https://camos.co/)

  - *Regional Coordinator* for the Institute of Professional Environmental Practice (IPEP) in the San Francisco Bay Area (9/1997 – 2021) (https://www.ipep.org)

  - *Visiting Teacher,* Computational Mechanics and Wessex Institute of Technology, Southampton, UK (1980 – present) (https://www.wessex.ac.uk). Currently:

  - *Professor of Environmental Sciences* at Wessex Institute of Technology (WIT), Ashurst, UK (https://www.wessex.ac.uk/research/wit-staff/862-dr-paolo-zannetti)

  - *Visiting Professor*, Polytechnic University of Bari-Taranto, Italy (1999 – 2008) (https://www.uniba.it/ateneo/sede-di-taranto)

  - *Peer-Reviewer,* Kuwait Institute of Scientific Research, Kuwait, Wessex Institute of Technology, Southampton, UK (2002-2012) (https://www.kisr.edu.kw/)

- ***Principal Scientist,* Exponent, Inc., Menlo Park, CA (11/1991 – 4/2001)** (https://www.exponent.com)

- *Instructor,* University Extension, University of California, Berkeley (10/1992 – 7/1997) (https://extension.berkeley.edu/)

- ***Department Manager*, AeroVironment, Inc., Pasadena/Monrovia, CA (10/1979 – 11/1991)** (https://www.aerovironment.com)

  - *Consultant*, IBM Semea, Milan, Italy (1/1991 – 10/1991; on leave of absence from AeroVironment) (https://www.ibm.com/planetwide/it/)

  - *Head, Environmental Sciences*, IBM Scientific Center, Bergen, Norway, and *Leader, Environmental Sciences Activities of IBM Europe* (3/1990 – 12/1990; on leave of absence from AeroVironment). **DL**

  - *Consultant*, Research Center of the Italian National Electric Power Company (CRTN/ENEL), Milan, Italy (3/1984 – 10/1984; on leave of absence from AeroVironment) (https://www.enel.com/en-GB/)

  - *Project Manager*, Kuwait Institute for Scientific Research (KISR), Kuwait (2/1982 – 2/1984; on leave of absence from AeroVironment) (www.kisr.edu.kw)

- ***Researcher,* IBM Scientific Center, Venice, Italy (8/1971 – 10/1979)** (https://www.ibm.com/planetwide/it/)

  - *Visiting Scientist,* Department of Statistics, Stanford University, California (1/1978 – 3/1979; on assignment from IBM Italy) (https://www-stat.stanford.edu/)

  - *Visiting Scientist,* IBM Scientific Center, Palo Alto, CA (1/1978 – 3/1979; on assignment from IBM Italy) (https://www.ibm.com/contact/us/en/)

  - *Assistant Professor,* Department of Civil Engineering, University of Padua, Italy (1974 – 1977) (https://www.unipd.it/)

- ***Systems Analyst*, UNIVAC/Sperry Rand, Milano, Italy (3/1971 – 7/1971)** (https://en.wikipedia.org/wiki/UNIVAC)

EDITORIAL RESPONSIBILITY

- Member, Editorial Board, International Journal of Environmental Science and Technology. Springer International Publisher. 2013-present https://www.springer.com/environment/journal/13762?detailsPage=editorialBoard

- Member, Editorial Advisory Board (EAB) of Atmospheric Pollution Research (APR) Journal. 2011-present. https://www.journals.elsevier.com/atmospheric-pollution-research

- Editor, Book Series, “Environmental Sciences and Environmental Computing”. Three published volumes. https://envirocomp.org/books/esec.html

- Editor and Co-Author, Book Series, “Air Quality Modeling – Theories, Methodologies, Computational Techniques, and Available Databases and Software”. Four published volumes, 2003-2010 https://www.envirocomp.org/aqm

- Editor, Book Series, “Environmental Modeling”. Computational Mechanics Publications. Three published volumes. https://www.witpress.com/978-1-85312-281-1.html

- Founder and President, The EnviroComp Institute – The International Institute of Environmental Sciences and Environmental Computing (since 1996). https://www.envirocomp.org

- Founder and Editor-in-Chief (1986 – 1993), quarterly journal *Environmental Software*, Computational Mechanics Publications and (since September 1991) Elsevier Applied Science; currently Founding Editor (journal was renamed *Environmental Modelling and Software*) https://www.journals.elsevier.com/environmental-modelling-and-software/

- Founder and Co-Director (until 1998), biennial ENVIROSOFT Conference – Computer Techniques in Environmental Studies (conferences held every two years since 1986) https://www.wessex.ac.uk/

- Founder and Co-Director, first two AIR POLLUTION Conferences – Computer Techniques in Environmental Studies (1993 – 1994); currently Member, Advisory Committee https://www.wessex.ac.uk/15-conferences/air-pollution-2015.html

- Associate Editor/Member, Editorial Board, *Atmospheric Environment*, Pergamon Press (1987 – 1999), now Elsevier. https://www.journals.elsevier.com/atmospheric-environment/

- Member, Editorial Board, *Ecological Modeling*, Elsevier Applied Science (1992 – 2007) https://www.journals.elsevier.com/ecological-modelling/

- Member, Editorial Board, *ENVIRONews*, FiatLux Publications (1993 – 1998)

MEMBERSHIPS

- Faculty Member, International Institute for Computational Engineering Mathematics (since 2016) https://computationalengineeringmathematics.com/cem/

- Member, International Scientific Advisory Committee, AIR POLLUTION Conference Cycle, Wessex Institute of Technology, UK (since 2000) https://www.wessex.ac.uk/15-conferences/air-pollution-2015.html

- Member, "SATURN Specialist Group", subproject of EUROTRAC-2 dealing with urban air pollution (1998-2000). https://www.gsf.de/eurotrac

- San Francisco Bay Area Regional Coordinator for the Institute of Professional Environmental Practice (IPEP) (1997-2021). https://www.ipep.org

- Athens 2004 Committee (1997 – 2000). https://www.olympic.org/athens-2004-summer-olympics

- Reviewer Group, Center for Indoor Air Research (CIAR) (1995 – 1999)

- International Scientific Advisory Committee, Environmental Engineering and Management Conference, Barcelona, Spain (October 1998)

- International Scientific Advisory Committee, Environmental Engineering, Education and Training Conference (EEET96), Southampton, UK (April 1996)

- Scientific Advisory Board, International Congress on Modeling and Simulation (MODSIM 93 and MODSIM 95), Modeling and Simulation Society of Australia, Inc. https://www.modsimworldconference.com/

- International Federation for Information Processing (IFIP), Working Group WG 5.11 (Computers and Environment) (1992 – 1997). https://www.ifip.org/homeintro.html

- ISATA Programme Committee (1992 – 1994)

- Scientific Committee of the Technological Consortium THETIS (Venice, Italy) (1991) https://www.thetis.it/thetis/environmental-engineering.html

- Board of Directors, MONDOMETANO, RES Editrice srl (1989 – 1992)

- European Association for the Science of Air Pollution (EURASAP) (1987 – 1994) https://www.eurasap.org/AboutEURASAP.html

- EPA-ASRL pool for the review of U.S. Environmental Protection Agency publications (1987 – 1996) https://www.epa.gov/

- American Meteorological Society (AMS) (1978 – 1985) https://www.ametsoc.org/

- Air & Waste Management Association (A&WMA) (originally Air Pollution Control Association, APCA) (since 1978). Emeritus Member since 2013. https://www.awma.org/Public

MISCELLANEA

- Member, Accademia Italiana della Cucina (since 2015) https://www.accademiaitalianacucina.it/
- Italian Citizen by birth; U.S. Citizen since 1989
- Languages: English, Italian, French (reading), plus understanding of Spanish

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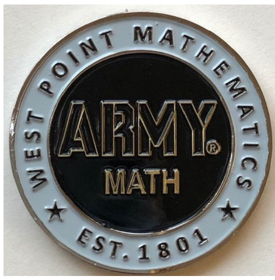
HONORS

- Award from the Royal Scientific Society of Jordan (1/2019)

- Medal Awards “Awarded for Excellence”, Department of Mathematical Sciences, The United States Military Academy, West Point, New York

(10/2016)



(4/2018)

- Medal award from Computational Mechanics, Ashurst, UK, in recognition of contribution to the development of Environmental Modeling (11/1994)


- Plaque award from the South Coast Air Quality Management District, in recognition of contribution to the Toxic Symposium at Caltech, Pasadena, CA (7/1986)

PUBLICATIONS (DL indicates downloadable publications[1])

Books

B.26 Zannetti, P. (ed) (2010) Air Quality Modeling – Theories, Methodologies, Computational Techniques, and Available Databases and Software, Vol. IV – Advances and Updates, Book Series, The EnviroComp Institute and the Air & Waste Management Association (https://www.envirocomp.org/aqm)

B.25 Zannetti, P. (ed) (2008) Air Quality Modeling – Theories, Methodologies, Computational Techniques, and Available Databases and Software, Vol. III – Special Issues, Book Series, The EnviroComp Institute and the Air & Waste Management Association (https://www.envirocomp.org/aqm)

B.24 Zannetti, P., S. Elliott, and D. Rouson (eds) (2007) Environmental Sciences and Environmental Computing, Vol. III, Electronic book (on CD-ROM), The EnviroComp Institute (https://envirocomp.org/books/esec.html)

B.23 Zannetti, P., D. Al-Ajmi, and S. Al-Rashied (eds) (2007) Ambient Air Pollution, The Arab School for Science and Technology (ASST) and The EnviroComp Institute (https://envirocomp.org/asst)

B.22 Zannetti, P. (ed) (2005) Air Quality Modeling – Theories, Methodologies, Computational Techniques, and Available Databases and Software, Vol. II – Advanced Topics, Book Series, The EnviroComp Institute and the Air & Waste Management Association (https://www.envirocomp.org/aqm)

[1] Downloadable online at https://www.envirocomp.com/zcv/zannetti.pdf

B.21 Zannetti, P. (ed) (2004) Environmental Sciences and Environmental Computing, Vol. II, Electronic book (on CD-ROM), The EnviroComp Institute (https://envirocomp.org/books/esec.html)

B.20 Zannetti, P. (ed) (2003) Air Quality Modeling – Theories, Methodologies, Computational Techniques, and Available Databases and Software, Vol. I – Fundamentals, Book Series The EnviroComp Institute and the Air & Waste Management Association (https://www.envirocomp.org/aqm)

B.19 Brebbia, C.A. and P. Zannetti (eds) (2002) Development and Application of Computer Techniques to Environmental Studies IX, WIT Press (https://www.witpress.com/)

B.18 Ibarra-Berastegi, G., C.A. Brebbia, and P. Zannetti (eds) (2000) Development and Application of Computer Techniques to Environmental Studies VIII, WIT Press (https://www.witpress.com)

B.17 Zannetti, P. and Y.Q. Zhang (eds) (1998) Environmental Sciences and Environmental Computing, Vol. I, Electronic book (on CD-ROM), FiatLux Publications and EnviroComp Institute (https://envirocomp.org/books/esec.html)

B.16 Pepper, D.W., C.A. Brebbia, and P. Zannetti (eds) (1998) Development and Application of Computer Techniques to Environmental Studies, Proceedings, ENVIROSOFT 98 Conference, Las Vegas, NV, November, WIT Press – Computational Mechanics Publications, Southampton (https://www.witpress.com/)

B.15 Zannetti, P. (ed) (1996) Environmental Modeling – Computer Methods and Software for Simulating Environmental Pollution and its Adverse Effects – Vol. III, Computational Mechanics Publications, Southampton (https://www.witpress.com/)

B.14 Zannetti, P. and C. Brebbia (eds) (1996) Development and Application of Computer Techniques to Environmental Studies VI, Proceedings, ENVIROSOFT 96 Conference, Como, Italy, September, Computational Mechanics Publications, Southampton (https://www.witpress.com/)

B.13 Zannetti, P. (ed) (1994) Pollution Modeling, Vol. I, Proceedings, ENVIROSOFT 94 Conference, San Francisco, CA, November, Computational Mechanics Publications, Southampton (https://www.witpress.com/)

B.12 Zannetti, P. (ed) (1994) Environmental Systems, Vol. II, Proceedings, ENVIROSOFT 94 Conference, San Francisco, CA, November, Computational Mechanics Publications, Southampton (https://www.witpress.com/)

B.11 Baldasano, J.M., C.A. Brebbia, H. Power, and P. Zannetti (eds) (1994) Computer Simulation, Vol. I, Proceedings, Second International AIR POLLUTION Conference, Barcelona, Spain, September 1994, Computational Mechanics Publications, Southampton (https://www.witpress.com/)

B.10 Baldasano, J.M., C.A. Brebbia, H. Power, and P. Zannetti (eds) (1994) Pollution Control and Monitoring, Vol. II, Proceedings, Second International AIR POLLUTION Conference, Barcelona, Spain, September 1994, Computational Mechanics Publications, Southampton (https://www.witpress.com/)

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B.7 Zannetti, P. (ed) (1993) Environmental Modeling – Computer Methods and Software for Simulating Environmental Pollution and its Adverse Effects – Vol. I, Computational Mechanics Publications, Southampton, and Elsevier Science Publishers, London (https://www.witpress.com/)

B.6 Zannetti, P. (ed) (1992) Computer Techniques in Environmental Studies IV, Proceedings, Fourth International Conference ENVIROSOFT 92, Computational Mechanics Publications, Southampton, and Elsevier Applied Science, London (https://www.witpress.com/)

B.5 Melli, P. and P. Zannetti (eds) (1992) Environmental Modeling, Computational Mechanics Publications, Southampton, and Elsevier Applied Science, London (https://www.witpress.com/)

B.4 Zannetti, P. (1990) Air Pollution Modeling – Theories, Computational Methods and Available Software, Computational Mechanics Publications, Southampton, and Van Nostrand Reinhold, New York, 450 pp (https://link.springer.com/book/10.1007%2F978-1-4757-4465-1) **DL**

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BC.18 Zannetti, P. (2022) Simulation Modeling of COVID-19: Global Spread and Short-Range Contamination Scenarios. Chapter 1, United States Military Academy Special Colloquium on Computational Engineering Mathematics 2020-2021. Editors: T. Hromadka and P. Goethals

BC.17 Bianconi, R., Bellasio, R. and P. Zannetti (2022) A Global Modeling System (GMS) for High Resolution Meteorological and Air Pollution Forecasts – Framework and Prototype. Chapter 16, United States Military Academy Special Colloquium on Computational Engineering Mathematics 2020-2021. Editors: T. Hromadka and P. Goethals

BC.16 Zannetti, P. (2010) Air Quality Modeling Resources on the Web – An Update, Chapter 27, Air Quality Modeling – Theories, Methodologies, Computational Techniques, and Available Databases and Software, Vol. IV – Advances and Updates, P. Zannetti (ed), The EnviroComp Institute and the Air & Waste Management Association (https://www.envirocomp.org/aqm) **DL**

BC.15 Zannetti, P. (2008) Air Quality Modeling Resources on the Web, Chapter 27, Air Quality Modeling – Theories, Methodologies, Computational Techniques, and Available Databases and Software, Vol. III – Special Issues, P. Zannetti (ed), The EnviroComp Institute and the Air & Waste Management Association (https://www.envirocomp.org/aqm) **DL**

BC.14 Freedman, F. and P. Zannetti (2007) Global Warming and Climate Change: State of the Science, Chapter 5, Ambient Air Pollution, P. Zannetti, D. Al-Ajmi, and S. Al-Rashied (eds), The Arab School for Science and Technology (ASST) and The EnviroComp Institute (https://www.envirocomp.org/); also Chapter 10, Environmental Sciences and Environmental Computing, Vol. III, P. Zannetti, S. Elliott, and D. Rouson (eds), The EnviroComp Institute (https://www.envirocomp.org/) **DL**

BC.13 Daly, A. and P. Zannetti (2007) Air Pollution Modeling – An Overview, Chapter 2, Ambient Air Pollution, P. Zannetti, D. Al-Ajmi, and S. Al-Rashied (eds), The Arab School for Science and Technology (ASST) and The EnviroComp Institute (https://www.envirocomp.org/asst) **DL**

BC.12 Daly, A. and P. Zannetti (2007) An Introduction to Air Pollution – Definitions, Classifications, and History, Chapter 1, Ambient Air Pollution, P. Zannetti, D. Al-Ajmi, and S. Al-Rashied (eds), The Arab School for Science and Technology (ASST) and The EnviroComp Institute (https://www.envirocomp.org/asst) **DL**

BC.11 Byun, D.W., A. Lacser, R. Yamartino, and P. Zannetti (2005) Eulerian Dispersion Models, Chapter 10, Air Quality Modeling – Theories, Methodologies, Computational Techniques, and Available Databases and Software, Vol. I – Fundamentals, P. Zannetti (ed), The EnviroComp Institute and the Air & Waste Management Association (https://www.envirocomp.org/aqm) **DL**

BC.10 Zannetti, P. (2004) Air Pollution Dispersion Modeling, Section 16.6, The CRC Handbook of Mechanical Engineering, Second Edition, F. Kreith and D.Y. Goswami (eds), CRC Press (https://www.crcpress.com/product/isbn/9780849308666) **DL**

BC.9 Calamari, D., K. Jones, K Kannan, A. Lecloux, M. Olsson, M. Thurman, and P. Zannetti (2000) Monitoring as an Indicator of Persistence and Long-Range Transport, Chapter 6, Evaluation of Persistence and Long-Range Transport of Organic Chemicals in the Environment, G. Klecka, et al. (eds), SETAC Press (https://www.setac.org/) **DL**

BC.8A Zannetti, P. (1998) Today's Debate on Global Climate Change: Searching for the Scientific Truth. Chapter 5 of Environmental Sciences and Environmental Computing, Vol I, Edited by P. Zannetti and Y. Q. Zhang, EnviroComp Institute (https://www.envirocomp.org) **DL**

BC.8 Zannetti, P. (1998) Air Pollution Dispersion Modeling, Section 16.6, The CRC Handbook of Mechanical Engineering, F. Kreith (ed), CRC Press (https://www.crcpress.com/) **DL**

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BC.6 Zannetti, P. (1994) Introduction to Environmental Modeling, Chapter 1, Environmental Modeling – Computer Methods and Software for Simulating Environmental Pollution and its Adverse Effects – Vol. II, P. Zannetti (ed), Computational Mechanics Publications, Southampton (https://www.witpress.com/) **DL**

BC.5 Zannetti, P. (1993) Introduction and Overview, Chapter 1, Environmental Modeling – Computer Methods and Software for Simulating Environmental Pollution and its Adverse Effects – Vol. I, P. Zannetti (ed), Computational Mechanics Publications, Southampton, and Elsevier Science Publishers, London (https://www.witpress.com/) **DL**

BC.4 Zannetti, P. (1993) Numerical Simulation Modeling of Air Pollution: An Overview, Section of Ecological Physical Chemistry, L. Bonati, U. Cosentino, M. Lasagni, G. Moro, D. Pitea, and A. Schiraldi (eds), Elsevier Science Publishers, London; also Air Pollution, P. Zannetti, C.A. Brebbia, J.E. Garcia Gardea, and G. Ayala Milian (eds), First International Conference on Air Pollution, Monterrey, Mexico, February, Computational Mechanics Publications, Southampton, and Elsevier Science Publishers, London (https://www.witpress.com/) **DL**

BC.3 Zannetti, P. (1992) Particle Modeling and its Application for Simulating Air Pollution Phenomena, Chapter 11, Environmental Modeling, P. Melli and P. Zannetti (eds) Computational Mechanics Publications, Southampton, and Elsevier Applied Science, London (https://www.witpress.com/) **DL**

BC.2 Zannetti, P. (1989) Simulating Short-Term, Short-Range Air Quality Dispersion Phenomena, Chapter V, Library of Environmental Control Technology, Vol. 2, Air Pollution Control, P.N. Cheremisinoff (ed), Gulf Publishing, Houston, TX **DL**

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Technical Reports

Dr. Zannetti has authored and co-authored hundreds of internally peer-reviewed technical reports while working for IBM Scientific Centers, AeroVironment, Inc., the Kuwait Institute of Scientific Research, CRTN/ENEL, Exponent, Inc., and EnviroComp Consulting, Inc. Most of these reports have remained confidential or were prepared for litigation cases and have not been published. A few selected reports are listed below:

- Zannetti P. (2019): Niemi et al. v. Northwest Cascade, Inc., et al. - Expert Report. Analyses related to SAMANTHA NIEMI; CHRIS SCHNEIDER; STACEY JACKSON SR.; GANNA SHTOGRYN, individuals, Plaintiffs, V. NORTHWEST CASCADE, INC., a Washington corporation, dba HONEY BUCKET and FLOHAWKS; NWC #5 Partnership LLP, a Washington limited liability partnership, Defendants. Superior Court State of WA for Pierce County No. 16-2-11216-7. **DL**

- Zannetti, P. (2011): Atmospheric Deposition Modeling of Oust®-Contaminated Dust in Southern Idaho during 1999-2001. Analyses Related to: Adams, et al., v the United States of America, Case No.: CIV 03-0049-E-BLW, United States District Court, District of Idaho. Project: EC-11-001, Report: 11-03-25. **DL**

- EnviroComp Consulting, Inc (2006) Air Quality Issues in the Beverly Hills High School Area, Beverly Hills, CA. Project: EC-04-004, Report: 06-03-10. **DL**

- Zannetti, P., B. Bruegge, D.A. Hansen, N. Lincoln, W.A. Lyons, D.A. Moon, R.E. Morris, A.G. Russell (1996) Framework Design - Design and Development of a Comprehensive Modeling System (CMS) for Air Pollution. FaAA Report SF-R-96-02-21 prepared for the Electric Power Research Institute. [Also published as Zannetti et al. (1996): Design of a Framework for the Development of a Comprehensive Modeling System for Air Pollution. EPRI TR-106852, WO4311-02, Final Report, September 1996]. **DL**

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- Zannetti, P., G. Carboni, R. Lewis and L. Matamala (1986): AVACTA II - User's guide, Release 3.1. AeroVironment Report AV-R-86/530. **DL**

- Zannetti, P., M. Sudairawi, N. Al-Madani and N. El-Karmi (1983): Air Pollution Dispersion and Prediction Model for Shuaiba Industrial Area. Prepared for the Shuaiba Area Authority, Kuwait. Kuwait Institute for Scientific Research, Document KISR 1090A, 5 Volumes:

    - Volume I – Executive Summary **DL**
    - Volume II – Technical Report **DL**
    - Volume III – Special Studies and Appendices **DL**
    - Volume IV – Software User's Manuals **DL**
    - Volume V – Data and Program Listings **DL**

Short Communications

Dr. Zannetti has published dozens of short communications including:

- Zannetti, P. (2012) Preface to "Venice Shall Rise Again" by G. Gambolati and P. Teatini, The EnviroComp Institute (https://www.envirocomp.org/Venice) **DL**

- Zannetti, P. (2007) Preface to "Environmental Modeling Using MATLAB" by E. Holzbecher, Springer, 2007 **DL**

Other Publishing/Editorial Activities

- Since the mid-1990s, most of Dr. Zannetti's editorial/publishing work has been performed as part of the activities of his non-profit EnviroComp Institute (https://envirocomp.org/activities.html). In particular, he promoted and directed the publication a unique, new-generation series of environmental book in electronic format:

    - Venice Shall Rise Again - Engineered Uplift of Venice through Seawater Injection

    - Air Quality Modeling book series

    - Environmental Sciences and Environmental Computing book series

* Ambient Air Pollution
* Groundwater Modeling: Computer Simulation of Groundwater Flow and Pollution
* Urban Air Pollution: Athens 2004 Air Quality

- EnviroNews, a bimonthly environmental newsletter, FiatLux Publications (1993 – 2000)

UNPUBLISHED WORKS

Doctoral Degree Thesis

- Zannetti, P. (1970) Riconoscimento a mezzo di elaboratore elettronico di caratteri numerici manoscritti [Computer pattern recognition of handwritten digits], Relatori: Profs. L. Mezzetti and D. Toniolo, University of Padua, Faculty of Science (Physics)

Poster Paper

- Zannetti, P. (1986) AVACTA II: a new Gaussian dynamic model for the simulation of atmospheric dispersion, transformation and deposition phenomena, Poster paper, WMO Conference on Air Pollution Modeling and Its Application, Leningrad, USSR, May 1986

Course Materials

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https://www.wessex.ac.uk/news/courses-and-seminars/introduction-to-air-pollution-modelling-2021

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https://www.apsi.tech/lecture_zannetti2021_WIT_shortcourseintroairpollmodel.html

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C.35 Zannetti, P. (2011) Air Quality Management - Goals, Regulations, Implementations, and Available Software Tools, May 4-5, 2011, Wessex Institute of Technology, Ashurst, UK. Lessons: Introduction to Air Pollution Issues, Scientific Understanding of Air Pollution Phenomena, Air Quality Management in the US, Air Quality Management in Europe, Health Risks and Other Adverse Effects of Air Pollution, Emergency Preparedness and Response - Case Studies, Air Quality Modeling and Software, Air Quality Management Tools and Software

C.34 Zannetti (2006) Introduction to Air Pollution Modeling, Organized by Wessex Institute of Technology, Ashurst Lodge, Ashurst, Southampton, UK, Topics: Air Pollution Problems and Phenomena, Air Pollution Meteorology, The Gaussian Plume Model, Segmented and Puff Model, Eulerian Models, Lagrangian Particle Models, Atmospheric Chemistry and Deposition, Long-range and Global Modeling, 25-26 May 2006

C.33 Zannetti (2005) Workshops on Ambient Air Pollution: 1) Introduction to Air Pollution, 2) Introduction to Air Pollution Modeling, 3A) Air Pollution Case Studies, and 3B) Global Issues, The Kuwait Foundation for the Advancement of Science (KFAS), Kuwait, 5-9 February 2005

C.32 Zannetti, P. (2004) Fluid Pollution Modeling, Engineering Faculty, Taranto, Italy, October 2004

C.31 Zannetti, P. (2003) Fluid Pollution Modeling, Engineering Faculty, Taranto, Italy, May 2003

C.30 Zannetti, P. (2002) Fluid Pollution Modeling, Engineering Faculty, Taranto, Italy, September 2002

C.29 Zannetti, P. (2001) Fluid Pollution Modeling, Engineering Faculty, Taranto, Italy, September 2001

C.28 Zannetti, P. (2001) Accidental Chemical Releases – Accident Reconstruction, Air Dispersion Modeling, Source Identification, and Allocation of Responsibility, Environmental Litigation: Advanced Forensics and Legal Strategies, San Francisco, CA, April 4-5, 2001

C.27 Zannetti, P. (2000) Fluid Pollution Modeling, Engineering Faculty, Taranto, Italy, October 9-12, 2000

C.26 Zannetti, P. (1999) Fluid Pollution Modeling, Engineering Faculty, Taranto, Italy, June 2-5, 1999

C.25 Zannetti, P. (1998) Air Pollution Modeling, Wessex Institute of Technology, Southampton, UK, April 1998

C.24 Zannetti, P. (1997) Air Dispersion Modeling and Meteorology, University of California, Berkeley Extension, July 1997

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C.16 Zannetti, P. (1992) Air Pollution Modeling and Software, Computational Mechanics Institute, Ashurst, Southampton, UK, September 1992

C.15 Zannetti, P. (1990) Air Pollution Modeling and Software, Computational Mechanics Institute, Ashurst, Southampton, UK, November 1990

C.14 Zannetti, P. (1990) Computer Simulation using Particle Modeling, Computational Mechanics Institute, Ashurst, Southampton, UK, November 1990

C.13 Zannetti, P. (1990) Air Pollution Modeling, Department of Meteorology, University of Bergen, Norway, Fall 1990

C.12 Zannetti, P. (1989) Air Quality Modeling and Software, Computational Mechanics Institute, Ashurst, Southampton, UK, April 1989

C.11 Zannetti, P. (1989) Computer Simulation Using Particle Modeling, Computational Mechanics Institute, Ashurst, Southampton, UK, April 1989

C.10 Pielke, R., J. Seinfeld, I. Tombach, and P. Zannetti (1988) A Short Course on Air Pollution: Simulation Modeling and Measurement Strategies, Monrovia, CA, March 1988

C.9 Pielke, R., J. Seinfeld, I. Tombach, and P. Zannetti (1987) Air Pollution – Simulation Modeling and Measurement Strategies, AeroVironment, February 1987

C.8 Zannetti, P. (1986) Air quality modeling and software, Computational Mechanics Institute, Ashurst, Southampton, UK, June 1986

C.7 Zannetti, P., J.C.R. Hunt, and A.G. Robins (1985) Air Pollution Modeling Course, Computational Mechanics Centre, Ashurst, Southampton, UK, September 1985

C.6 Gopalakrishnan, T.C. and P. Zannetti (1983) Numerical Modeling Course, Kuwait Institute for Scientific Research, Kuwait, December 1983

C.5 Zannetti, P. and J.C.R. Hunt (1983) Air Pollution Modeling Course, Computational Mechanics Centre, Ashurst, Southampton, UK, May 1983

C.4 Zannetti, P. and I. Tombach (1983) Air Pollution Course, Kuwait Institute for Scientific Research, Kuwait, January 1983; also Tombach, I. and P. Zannetti (1984) Air Pollution – Part 1: Introduction to Air Pollution and Dispersion Modeling, prepared for Kuwait Institute of Scientific Research, Kuwait, May 1984, AeroVironment Memorandum AV-M-84/533

C.3 Zannetti, P., G.I. Jenkins, and D.J. Moore (1982) Air pollution modeling course, Computational Mechanics Centre, Southampton, UK, May 1982

C.2 Zannetti, P. (1980) A short course on air pollution modeling, Computational Mechanics Centre, Southampton, UK, December 1980

C.1 Zannetti, P. (1977) EURATOM CCM Courses, Modeling and Simulation of Ecological Processes: 1) Statistical models and their application to data collected in Venice, and 2) Statistical programs application to meteorological and air quality data (Computer practical exercise), Ispra, Italy, October 1977

Invited Lectures/Seminars

Dr. Zannetti has presented more than a hundred invited lectures and seminars throughout the world, including the most recent ones listed below:

- A Global Modeling System (GMS) for High Resolution Meteorological and Air Pollution Forecasts - Framework and Prototype, by R. Bianconi, R. Bellasio, and P. Zannetti. 25th Annual George Mason University Conference on Atmospheric Transport and Dispersion Modeling. November 2-4, 2021. **DL**. Also remotely presented at Special Colloquium on Computational Engineering Mathematics and Data Science, United States Military Academy, West Point, NY, October 21-22, 2021. **DL**

- Air Quality Models for Decision Support. Politecnico Milano, Dipartimento di Elettronica, Informazione e Bioingegneria, 21 September 2021, **DL**

- Air Pollution Modeling – A Discussion from Different Angles. IDSIA, Lugano, Switzerland, 22 September 2021. **DL**

- Reducing Air Toxic Impact from Power Plants Startups through CFD-Assisted Design of Chimneys. Presented by P. Zannetti and G. Bucci. 94th Virtual CICIND Conference Rotterdam, 20th - 21th May 2021

https://cicind.org/booking/downloads/TECH-PROG.pdf
Presentation slides: **DL**. Video presentation: https://hadek.wistia.com/medias/uyp5v0t8ut

- Simulation Modeling of COVID-19: Global Spread and Short-Range Contamination. SPECIAL COLLOQUIUM ON COMPUTATIONAL ENGINEERING MATHEMATICS (CEM) AND DATA SCIENCE, UNITED STATES MILITARY ACADEMY (USMA), WEST POINT, NY, NOVEMBER 18, 2020
https://appscem.com/USMA_CEM_Colloquium_Flyer2020.pdf Presentation slides: https://www.apsi.tech/material/other/Zannetti_ColloquiumWestPoint20201118.pdf

- From A to B – Simulation of Atmospheric Pathway. Keynote Speaker, Virtual Workshop on COVID-19: Challenges in Research and Education (https://www.astfe.org/courses/covid-19/). Organized by the American Society of Thermal and Fluids Engineers (ASTFE). August 31, 2020 **DL**
Video presentation (start at 1:56:50):
https://www.astfe.org/virtual_workshop_on_covid19/?access_key=ASTFE2020COVID-19

- Computational Mathematics in Environmental Sciences, Invited Lecture at the ARL/USMA Technical Symposium (AUTS), West Point, NY, 17 October 2019 **DL**

- Advances in Air Pollution Science: Meteorological Modeling, Cost Benefit Optimization, Litigation Support. Aarhus University, Denmark, June 24, 2019 **DL**

- Recent Air Quality Developments: Management, Assessment, and Modeling. Water and Environment Center (WEC) of the Royal Scientific Society (RSS) and UN ESCWA Technology Centre (ETC), Amman, Jordan, January 6, 2019 **DL**

- Air Pollution Litigation in the US and the Role of Computer Modeling, The Voeikov Main Geophysical Observatory, St. Petersburg, Russia, 22 June 2018 **DL**

- Dynamic Simulations Using Particle Models, 2nd Annual Distinguished Symposium in Computational Engineering Mathematics, United States Military Academy, West Point, April 3rd, 2018 **DL**

- Mathematical Methods in Air Pollution Studies, Distinguished Colloquia in Computational Engineering Mathematics, U.S. Army Department of Mathematical Sciences, West Point, NY, 4 October 2016 **DL**

- Air Pollution. Hazardous Materials Class, San Jose State University, California, 28 April 2015

- Cost-Benefit Optimization Approach to Air Pollution Management. Keynote Address, UPWIND-DOWNWIND CONFERENCE 2014: Built Environment – Foundation for Cleaner Air Sheraton Hotel, HAMILTON, Ontario, CANADA, 24 February 2014 **DL**

- Air Quality Modeling and Cost-Benefit Optimization - Design of a Software Prototype for Managing Urban and Industrial Development, Keynote Address, AIR POLLUTION XXI, Siena, Italy, 4 June 2013 **DL**

- Computer Simulation of Air Pollution - Methodologies and Case Studies, San Jose State University, California, 23 April 2013

- Environmental Crises: Accident Reconstruction and Plume Modeling, 2012 International Student Conference on Environment and Sustainability, Tongji University, Shanghai, China, 6 June 2012 **DL**

- Atmospheric Issues - Chemical Releases, 2012 Asia-Pacific Leadership Programme on Environment for Sustainable Development, Tongji University, Shanghai, China, 5 June 2012 **DL**

- Computer Modeling of Air Pollution Phenomena, San Jose State University, California, 22 March 2011

- Applications of Dispersion Modeling in the Atmosphere, San Jose State University, California, Chemical Engineering Department, 27 April 2009

- Modellistica di Rilasci Accidentali di Inquinanti in Atmosfera. ARPA Puglia, Bari, Italy, 18 April 2009

- Guest Lecturer, 1) Introduction to Air Pollution; 2) Introduction to Air Pollution Modeling; 3) Litigation case studies for accidental releases of chemicals in the atmosphere, 22 October 2008, Environmental Science for Lawyers, Tulane Law School, Louisiana

- Business-Oriented Environmental Applications – Case Studies and ICT Tools, April 20, 2008, University of Damascus, Syria; April 21, 2008, University of Homs, Syria; April 22, 2008, University of Lattakia, Syria; April 23, 2008, University of Aleppo, Syria **DL**

- Computer Modeling of Accidental Releases of Air Pollutants – University of PADOVA, Department of Mathematical Methods and Models for Applied Sciences (DMMMSA), 26 March 2008; and University of VENEZIA, Italy, Faculty of Science, 27 March 2008

- 1) Introduction to Air Pollution Modeling; and 2) Accidental Releases in the Atmosphere. Presentations at Yunnan Environmental Science Society (YESS), Kunming Region, China. October, 2007. Member of the A&WMA Delegation to China under the banner of the People-to-People Citizen Ambassador programs. Full report of the Mission.

- Air Pollution Modeling of Accidental Releases – Science and Litigation, Universidade Federal de Santa Maria, Brazil, 15 September 2005

- Workshop on Ambient Air Pollution, February 5 - 9, 2005, Kuwait Foundation for the Advancement of Sciences, Kuwait. Seminars: Introduction to Air Pollution, Introduction to Air Pollution Modeling, Air Pollution Case Studies

Appendix A3

Frank R. Freedman, PhD, CCM
Senior Associate, EnviroComp Consulting, Inc.
Adjunct Faculty, Department of Meteorology and Climate Science, San Jose State University

Email: frank.freedman@sjsu.edu, freedman@envirocomp.com
Phone: (650)387-8926

Synopsis

Sept. 2004 – Present	Senior Associate, EnviroComp Consulting Inc., Fremont, CA
Aug. 2004 – Present	Lecturer, San Jose State University (SJSU), San Jose, CA (adjunct since 2013)
July 2006 – Present	Environmental Consultant, Independent
Sept 2015 – July 2020	Research Scientist, Center for Applied Atmospheric Research and Education, SJSU
Sept 2016 – July 2020	Team Member, NASA Health and Air Quality Applied Science Team, SJSU

PhD (2003): Stanford University, Civil and Environmental Engineering
MS (1996): San Jose State University, Meteorology
BS (1992): San Jose State University, Meteorology

Certifications / Awards

NASA Health and Air Quality Applied Science Team (2016 – 2020)
Certified Consulting Meteorologist, American Meteorology Society, 2010
National Research Council Postdoctoral Fellow, NCEP, April 2003 – March 2004.

Consulting (Selected Projects)

EnviroComp (further descriptions of some at http://envirocomp.com/)
Odor Assessment from a Proposed Composting Facility in Sunol, CA
Odor Assessment from a Composting Facility in Everett, WA
Evaluation of Agricultural Damage from Herbicide Drift (many projects)
Assessment of Hexavalent Chromium Exposure at Water Treatment Plant at Qarmat Ali (Southern Iraq)
Air Quality Issues in the Beverly Hills High School Area, Beverly Hills, CA
Air Quality Impacts downwind of the Arts St. Fire of 2004 in New Orleans, LA
Possible Airborne Contamination of Legionella Bacteria in the Lens Region of France
Evaluation of long-term exposure to DDT particulate from a Superfund site in McIntosh, AL
The Development of AERMOD-Ready Meteorological Data for the SCAQMD
Traffic Collision and Visibility Issues from Almond Harvesting, Fresno County, CA

Independent
Modeling of Hydrogen Sulfide Odor from Refineries in Port Arthur (2007 – 08, Thomas Pearson, Esq.)
Analysis of Air Quality Modeling for Permitting of Lehigh Cement facility in Cupertino, CA (2014-15, for quarryno.org)
Local Air Quality Impacts from San Jose Airport (2010, for Bay Area Air Quality Management District)

Research

Publications

Freedman, F. R., P. English, J. Wagner, Y. Liu, A. Venkatram, D. Q. Tong, M. Z. Al-Hamdan, M. Sorek-Hamer, R. Chatfield, A. Rivera, and P. L. Kinney, 2020: Spatial Particulate Fields during High Winds in the Imperial Valley, California. Atmosphere., 11, https://www.mdpi.com/2073-4433/11/1/88.

Freedman, F. R., K. L. Pitts, and A.F.C. Bridger, 2014: Evaluation of CMIP climate model hydrological output for the Mississippi River Basin using GRACE satellite observations. J. Hydrol., 519, https://www.sciencedirect.com/science/article/pii/S0022169414008312

Freedman, F. R., and M. Z. Jacobson, 2003: Modification of the standard ε-equation for the stable ABL through enforced consistency with Monin-Obukhov similarity theory, Bound.-Layer Meteor., 106, http://www.sjsu.edu/people/frank.freedman/docs/FJ2003_stable.pdf.

Freedman, F. R., and M. Z. Jacobson, 2002: Transport-dissipation analytical solutions to the E-ε turbulence model and their role in predictions of the neutral ABL, Bound.-Layer Meteor., 102, http://www.sjsu.edu/people/frank.freedman/docs/FJ2002_neutral.pdf.

O'Neill, S.O, M. Diao, S. Raffuse, M. Z. Al-Hamdan, M Barik, Y, Jia, S. Reid, Y. Zou, D. Tong, J. West, J. Wilkins, A. Marsh, F. Freedman, J. Vargo, N. K. Larkin, E. Alvarado, and P. Loesch, 2021: A multi-analysis approach for estimating regional health impacts from the 2017 Northern California wildfires, J. Air Waste Manage. Assoc., 71, 791 – 814. https://www.tandfonline.com/doi/full/10.1080/10962247.2021.1891994.

Y. Ding, I. Cruz, F. Freedman, and A. Venkatran, 2021: Improving spatial resolution of PM2.5 measurements during wildfires, Atmos. Pollution Res., 12, https://www.sciencedirect.com/science/article/abs/pii/S1309104221001070

McRae I., F. Freedman, A. Rivera, X. Li, J. Dou, I. Cruz, C. Ren, I. Dronova, H. Fraker, and R. Bornstein, 2020: Integration of the WUDAPT, WRF, and ENVI-met models to simulate extreme daytime temperature mitigation strategies in San Jose, California, Build. Env., 184, https://doi.org/10.1016/j.buildenv.2020.107180.

Castillo M., J. Wagner, G. S. Casuccio, R. R. West, F. R. Freedman, H. M. Eisle, Z. Wang, J. P. Yip, P. L. Kinney, 2019: Field testing a low-cost passive aerosol sampler for long-term measurement of ambient PM2.5 concentrations and particle composition, Atmos. Environ., 216, https://doi.org/10.1016/j.atmosenv.2019.116905.

Ahangar, F.E., F. R. Freedman, and A. Venkatram, 2019: Using Low-Cost Air Quality Sensor Networks to Improve the Spatial and Temporal Resolution of Concentration Maps, Int. J. Environ. Res. Pub. Health, 16, https://www.mdpi.com/1660-4601/16/7/1252.

Zannetti, P., A. D. Daly, and F. R. Freedman, 2015: Dispersion modeling of particulate matter containing hexavalent chromium during high winds in southern Iraq, *J. Air Waste Manage. Assoc.*, **65**, https://www.tandfonline.com/doi/full/10.1080/10962247.2014.981317.

Svensson G. and co-authors, 2011: "Evaluation of the diurnal cycle in the atmospheric boundary layer over land as represented by a variety of single column models – the second GABLS experiment", *Bound.-Layer Meteorol.*, **140**, 177 – 206.

Cuxart and coauthors, 2005: "Single-column model intercomparison for a stably-stratified atmospheric boundary layer", *Bound.-Layer Meteorol.*, **118**, *273-303.*

Gopalakrishnan, S. G., F. R. Freedman, M. Sharan and T.V.B.P.S. Rama Krishna, 2005: "A Model Study of the Strong and Weak Wind, Stably Stratified Nocturnal Boundary Layer: Influence of Gentle Slopes", *Pure and Applied Geophys.,* ***162***, 1795-1809.

Sistla, G., N. Zhou, W. Hao, J. Y. Ku, S. T. Rao, R. Bornstein, F. Freedman, and P. Thunis, 1996: "Effects of uncertainties in meteorological inputs on Urban Airshed Model predictions and ozone control strategies", *Atmos. Environ.*, 30, 2011-2025.

Conferences

A satellite-dispersion modeling system to generate high-resolution downscaled PM2.5 fields, CMAS 2017 Bi-Annual Conference, October 23-25, 2017, UNC Chapel Hill, Chapel Hill, NC. Abstract available at: https://www.cmascenter.org/conference//2017/abstracts/freedman_satellite-dispersion_2017.pdf

WUDAPT, uWRF, ENVI-MET Coupling for Site-Specific Urban Heat Island Analysis in San Jose, CA, CMAS 2017 Bi-Annual Conference, October 23-25, 2017, UNC Chapel Hill, Chapel Hill, NC, w co-authors.

HYSPLIT-STILT Simulations of Urban Background Concentrations Affecting Central San Jose, CA: Applications for CO2 and PM2.5, MAC-MAQ, Meteorology and Climate – Modeling for Air Quality (MAC-MAQ) Conference, UC Davis, (Davis, CA).

Atmospheric Residual Layers: WRF/HYSPLIT Modeling for Better Understanding in Complex Terrain, AGU Fall Meeting, San Francisco, CA, 19 December 2014

Assessment of Water Storage Trends and Distributions in the Mississippi River Basin as Simulated by IPCC Models and Compared to GRACE Satellite Data, 2013 Workshop on the use of GRACE Data for Water Cycle Analysis and Climate Modeling, NASA Jet Propulsion Laboratory / California Institute of Technology, July 15 – 17, 2013, Pasadena, CA.

Development of AERMOD-ready Meteorological Input Files for the South Coast Air Quality Management District", *2009 Annual Conference and Exhibit*, Air & Waste Management Association, Detroit (MI), 2009

Teaching / Training / Thesis Committees

Teaching

San Jose State University. Numerical Modeling (METR240); Mesoscale Modeling (METR245); Air Pollution Engineering and Control (CME177), Empirical Techniques in Meteorology (METR136), Boundary Layer Meteorology (METR130); Air Pollution Meteorology (METR/CME131), Atmospheric Dynamics (METR121), Atmospheric Pollution (METR113), Global Climate Change (METR112), Meteorology II (METR 61), Computers in Meteorology (METR51), Global Climate Change (METR12)

Training / Guest Lecturer

Satellite Remote Sensing for Air Quality, NASA ARSET Training Workshop, September 19- 21, 2017, UC Riverside, Riverside, CA

Instructional Team Member, "Partnership for Student Success in Science Summer Institute – Air & Weather", June2006, Synopsis Inc.; Training workshop for California first grade teachers.

Invited Lecturer, "Spring Colloquium on Regional Weather Predictability and Modeling, Part I: Workshop on Design and Use of Regional Weather Predication Models", *The Abdus Salam International Centre for Theoretical Physics*, April 11-19, 2005, Trieste, Italy.

Thesis Committees

Ana Lucretia Rivera (M.S., SJSU Department of Urban Planning): Topic, Remote sensing of urban land use and morphology for urban heat island assessment.

Susan Kazemi (M.S., San Jose State University Dept. of Environmental Studies, current): Topic, Low-cost particulate sensor measurements around San Jose, CA for community health exposure assessment.

Areana Flores (M.S., San Jose State University Dept. of Meteorology and Climate Sciences, 2016): *Exposure Assessment of Asthma and Modeling of PM2.5 for the October 2007 Wildfire Outbreak in Southern California*.

Katie Pitts (M.S., San Jose State University Dept. of Meteorology and Climate Science, 2012): *Assessment of Water Storage Trends and Distributions in the Mississippi River Basin as Simulated by IPCC Models and Compared to GRACE Satellite Data.*

Scott Strenfel (M.S., San Jose State University Dept. of Meteorology and Climate Science, 2010): *Field Measurements and Modeling of PM2.5 and Carbon Emissions from Prescribed Fires.*

Appendix A4

The Ministry of the Environment, Conservation and Parks

Modelling Updates

Winter 2023 Air Practitioner's Meeting

February 2, 2023

Ontario

Discussion Topics

- AERMOD/AERMET Model Version Updates
- Use of the AERMOD Urban Option and associated settings
- Situational Use of the CALPUFF Model
    - Shoreline fumigation
    - Complex terrain/meteorology
    - Wet plumes
- Expectations for Use of CALPUFF or SDM
    - Ministry review process

AERMOD/AERMET Version Updates

- In April 2022, the US Environmental Protection Agency (USEPA) released a new version (v22112) of the AERMOD/AERMET modelling system
- This version includes technical updates that are not included in the ministry's current specified version of July 2019 (v19191).
- Some of the important technical updates and bug fixes in v22112 include:
  - Bug fixes to the Urban Option calculations
  - Bug fixes to BOUYLINE source
  - Bug fixes to RLINE and RLINEXT
  - Updated plume meander calculations in RLINE
  - Added 'debug' files for BOUYLINE, RLINE and URBANOPT
  - Added a 'FAST' option for RLINE
  - Removed 'ALPHA' designation from RLINE and BOUYLINE with Urban Option
  - Added various 'ALPHA' options

AERMOD/AERMET Version Updates – Cont'd

- The ministry does not necessarily adopt each new version of the AERMOD/AERMET modelling system
  - to reduce unnecessary burden on the regulated community, we perform a consequence analysis (in addition to the USEPA's assessment) to determine the potential impacts of the updates, and decide whether to adopt
- Our consequence analysis assessed AERMOD (22112) / AERMET (22112) against AERMOD(19191) / AERMET(19191) with various common source types / configurations.
  - same configuration is used each time
- **Based on our review of the USEPA's technical updates and our resulting consequence analysis, the ministry is adopting the updated versions of the AERMOD/AERMET models in April 2023.**
  - ensures that the ministry's prescribed regulatory air dispersion models continue to be based on the best available science and remain consistent with other jurisdictions.
  - this is the 4^{th} official model version update since 2015

Ontario

AERMOD/AERMET Version Updates – Reminders

- Use of newer AERMOD versions (i.e. v22112) before official adoption requires:
  - approval under s7(1) – submission must include rationale
  - met data must be processed with corresponding version of AERMET
- Adoption of a new model version doesn't necessarily trigger an Emission Summary Dispersion Modelling (ESDM) report update for all facilities.
  - Schedule 4 and 5 facilities and those with Environmental Compliance Approvals (ECA) Limited Operating Flexibility (LOF) are required to update by March 31st of the following year, or by the timeline outlined in the LOF approval
  - all other facilities are not required to update their ESDMs until required to submit (e.g. ECA amendment, Notice, etc.)

Meteorological Data - Reminders

Regional meteorological data sets

- Pre-processed regional met data sets posted on ontario.ca are to be used only when the surface characteristics within 3 km from your site are relatively uniform and reasonably represented by one of the data sets
  - CROPS, FOREST, URBAN*, SUBURBAN
- If the land use, and resulting surface characteristics, vary significantly within the 3 km, local meteorological data sets should be used that have been refined to reflect the local land use conditions
  - particularly important to use local or site-specific data sets if a facility is located near a water body or if concentrations/frequency of exceedance are being determined **at specific/sensitive receptor locations** (e.g. when assessing odour).
  - EMRB provides refined site-specific meteorological data sets upon request for free
  - s13(1) approval is required to use local or site-specific meteorological data sets

* Use of URBAN met data is different than the URBAN OPTION in AERMOD

AERMOD Urban Dispersion Option

- AERMOD allows the user to specify 'Urban' dispersion conditions for the site/sources being modelled, if the facility is located in an area that is deemed to be 'urban' in nature.
- Factors that affect the selection of the urban option:
  - surrounding land use;
  - location of a facility relative to the urban core (e.g. downtown Toronto);
  - population/urban intensity.
- 'Urban' option is designed to alter nighttime dispersion parameters due to the urban heat island effect (higher temperatures in the urban core than the outlying areas which results in local nighttime convective circulation),
  - use of inappropriate parameters under the "Urban" option can have a significant impact on modelled concentrations, more than would be attributed to the *urban heat island* effect itself

Urban / Rural Dispersion Option (Continued)

- When the 'Urban' option is selected in AERMOD with default settings under this option :
  - site-specific wind-sector dependent surface roughness lengths contained in AERMET meteorological file are **not used** during evening, nighttime and some morning hours – they are overridden and an urban surface roughness of 1 m is applied
    - this results in the site being modelled as if it were located in a dense urban area like downtown Toronto;
    - use of a constant roughness length value of 1 m is **not** appropriate particularly in cases where the upwind land use has a significantly lower surface roughness (e.g., water has a surface roughness of 0.001 m vs. 1 m for high intensity residential).

Urban / Rural Dispersion Option (Continued)

- **URBANROUGHNESS**
  - The user can override the 1 m roughness with a different, more appropriate value, such that it varies hourly.
    - If this value is not selected correctly, an inappropriate roughness value is still used, regardless of the value specified.
  - Sensitivity tests confirmed that in many instances, it is the change in roughness length (and other associated surface characteristics) that results in much more significant impacts on modelled concentrations than the urban heat island effect itself.
    - This is an unintended outcome of the use and purpose of the urban option.

Urban vs. Rural classification

- Appropriate settings must be used when undertaking the modelling to ensure that model-predicted concentrations are reasonably representative.
  - **URBAN land use, in the context of dispersion modelling, does not simply mean the presence of any built-up area.**
  - **Users must demonstrate that their facility is located in an area that is deemed to be urban in order to use the Urban option.**
    - **this is done using land use classification data <u>not visual approaches</u>**
- Section 5.4.5 of The Air Dispersion Modelling Guideline for Ontario (ADMGO) outlines the procedure to be followed:
  - The **US EPA document *Guideline on Air Quality Models (40 CFR Part 51, Appendix W)*** describes procedures for classifying sites as urban or rural, and requires that either a land use classification procedure or a population based procedure be used in this determination. **The land use procedure is considered a more definitive criterion, and should be used by modellers for the purposes of the Regulation** unless the ministry has indicated in writing that another procedure (e.g. the population density procedure) is acceptable.

Land Use Classification Procedure

- US EPA document *Guideline on Air Quality Models (40 CFR Part 51, Appendix W)*. Section 7.2.1.1 outlines the land use procedure to be used for determining ‘urban’ or ‘rural’ classification:
- It is based on the method outlined in:

  Auer, A. H. 1978. Correlation of Land Use and Cover with Meteorological Anomalies, Journal of Applied Meteorology.

Land Use Procedure:

1) classify the land use within the total area, A_o, circumscribed by a 3 km radius circle about the source using the meteorological land use typing scheme proposed by Auer [1];
2) if land use types I1, I2, C1, R2, and R3 account for 50 percent or more of A_o, urban dispersion coefficients may be considered if there are no other limiting conditions (e.g. proximity to water, etc); otherwise, use appropriate rural dispersion coefficients.

- Land use classifications should be based on most recent (or proposed) land uses around the facility
  - Examples of appropriate data sources include:
    - City zoning maps
    - consolidated zoning data from the Municipal Property Assessment Corporation (MPAC)

Ontario

Land Use Classification Procedure (Cont'd)

- Regardless of resulting classification, facilities near major waterbodies (e.g. within the 3 km radius) generally should NOT use the Urban Option as the "urban heat island" is a **regional phenomenon**.
- The presence of the water broadly affects the meteorology and limits the formation of the nighttime convective conditions
- Hence the "urban heat island" effect is unlikely to occur (e.g. cooler closer to the lake).

Land Use Classification Procedure (cont'd)

Type	Description: Use and structures	Description: Vegetation
I1	Heavy industrial Major chemical, steel and fabrication industries; generally 3–5 story buildings, flat roofs	Grass and tree growth extremely rare; <5% vegetation
I2	Light-moderate industrial Rail yards, truck depots, warehouses, industrial parks, minor fabrications; generally 1–3 story buildings, flat roofs	Very limited grass, trees almost total absent; <5% vegetation
C1	Commercial Office and apartment buildings, hotels; >10 story heights, flat roofs	Limited grass and trees; <15% vegetation
R1	Common residential Single family dwelling with normal easements; generally one story, pitched roof structures; frequent driveways	Abundant grass lawns and light-moderately wooded; >70% vegetation
R2	Compact residential Single, some multiple, family dwelling with close spacing; generally <2 story, pitched roof structures; garages (via alley), no driveways	Limited lawn sizes and shade trees; <30% vegetation
R3	Compact residential Old multi-family dwellings with close (<2 m) lateral separation; generally 2 story, flat roof structures; garages (via alley) and ashpits, no driveways	Limited lawn sizes, old established shade trees; <35% vegetation
R4	Estate residential Expansive family dwelling on multi-acre tracts	Abundant grass lawns and lightly wooded; >80% vegetation
A1	Metropolitan natural Major municipal, state, or federal parks, golf courses, cemeteries, campuses; occasional single story structures	Nearly total grass and lightly wooded; >95% vegetation
A2	Agricultural rural	Local crops (e.g., corn, soybean); >95% vegetation
A3	Undeveloped Uncultivated; wasteland	Mostly wild grasses and weeds, lightly wooded; >90% vegetation
A4	Undeveloped rural	Heavily wooded; >95% vegetation
A5	Water surfaces Rivers, lakes	

- Auer Jr., August H. "Correlation of Land Use and Cover with Meteorological Anomalies." *Journal of Applied Meteorology* May 1978: 636 – 643.

Use of the Urban Option

- Once a Proponent has demonstrated, that based on the land use classification, the facility in question is located in an area that is considered Urban, the Urban Option and Urban Sources may be used for that site.
  - Users should include details of their analysis and supporting materials in their submissions (e.g. a table showing the area and percentage for each land use category, and whether they're considered Urban or Rural)
  - Ensures that the option is being used appropriately
- In order to make use of the site-specific surface characteristics, the user must set the URBANROUGHNESS parameter as the **minimum** surface roughness value in the corresponding meteorological data set. (Note, this is a non-default option).
  - the surface roughness is located in column 13 of the surface met data file (*.sfc) and varies for each hour based on wind direction
  - selection of the minimum surface roughness allows the model to use the actual hourly surface roughness lengths in the data, which is the desired outcome

Use of the Urban Option (Cont'd)

- The minimum URBANROUGHNESS should be specified for any met data set being used (e.g. both regional and local met data sets)
  - note, the "CROPS" or "FOREST" Regional met data sets **should not be used** with the AERMOD Urban Option.
  - URBAN or SUBURBAN data sets are reasonable for use with Urban Option
  - note when using an URBAN regional met data set (e.g. when appropriate given the surrounding land uses), proponents do not need to modify the URBANROUGHNESS as these data sets already contain a uniform surface roughness of 1 m.

Effect of Population

- The URBAN option in AERMOD requires the user to specify the "population" in the area (e.g. URBANPOP keyword).
  - the population is used to calculate the potential intensity of the urban heat island effect, based on historical temperature differentials between urban and rural areas.
  - the larger the population, the stronger the theoretical effect
- There have been inconsistent approaches for assessing the population to be specified in the Urban Source (part of the Urban Option)

  Based on US EPA guidance:
  - for relatively isolated urban areas (e.g. non-contiguous urban corridors), users should use the published census data for that urban area (e.g. Milton, Guelph).
  - for urban areas adjacent to or near other urban areas or part of urban corridors (e.g. Mississauga, Toronto, Ottawa), the total population of these entire urban areas should not be used.
    - EMRB recommends that the population of the nearest urban sub-center (e.g. East York, Clarkson, etc) or the total population based on the census data within a maximum 10 km x 10 km area around the facility be used (e.g. not the population of the entire urban area/corridor such as Toronto or Mississauga).
  - this is done to avoid overstating the potential urban heat island effect.

Example Facility – near a large water body

Comparison between AERMOD results using ‘urban’ vs. ‘rural’ options:

- A number of different factors were assessed to compare the differences
  - with RURAL option
  - with URBAN option (as completed by client)
    - used incorrect land use
    - used default 1 m roughness
    - used inappropriate, larger population
- The results showed:
  - differences in Point of Impingement concentrations (POIs) between Urban and Rural options for some contaminants can be significant – will vary depending on source characteristics and source-receptor orientation.
    - based on LU classification, this site should not actually be considered URBAN, i.e. URBAN option should not have been used in the first place
  - difference in results is not linear (i.e., some POIs increased while others decreased); this depends on source parameters / locations, etc.
  - use of correct dispersion parameters and population is extremely important

Example Facility – near a large water body (cont'd)

Comparison of results between 'urban' vs. 'rural' for this site:

Dispersion Coefficient		Modelled Max POI Concentration (ug/m3)
Without Urban Option (e.g. **RURAL**)		1709
With **Urban** Option (URBANOPT) and default **1 m** surface roughness	With Urban Heat Island Effect and the population of the entire town (75000)	484
With **Urban** Option (URBANOPT) and minimum surface roughness (**0.009m**)	With Urban Heat Island Effect and the population of the entire town (75000)	2797
With **Urban** Option (URBANOPT) and minimum surface roughness (**0.009m**)	With Urban Heat Island Effect and the population of a smaller area surrounding the facility (13000)	2931

Second Example Facility – typical urban location

Comparison of results between 'urban' vs. 'rural' for this site:

Dispersion Coefficient		Modelled Max POI Concentration (ug/m3)
Without Urban Option (e.g. **RURAL**)		325
With **Urban** Option (URBANOPT) and default 1 m surface roughness	With Urban Heat Island Effect and population of 115000	254*
With **Urban** Option (URBANOPT) and minimum surface roughness (0.104)	With Urban Heat Island Effect and a population of 115000	254
With **Urban** Option (URBANOPT) and minimum (0.104) surface roughness	With Urban Heat Island Effect and a population of 1000000	218+

*, + - Note that the location of the MAXGLC changed

Remember:

The upwind land use dictates the downwind concentrations.

Situational use of CALPUFF

- The ministry's Air Dispersion Modelling Guidelines for Ontario (ADMGO) outlines circumstances when facilities need to consider the use of CALPUFF in their assessments.
- In particular, these include the potential for shoreline fumigation effects in addition to local complex terrain / meteorology.
- Excerpt from ADMGO:

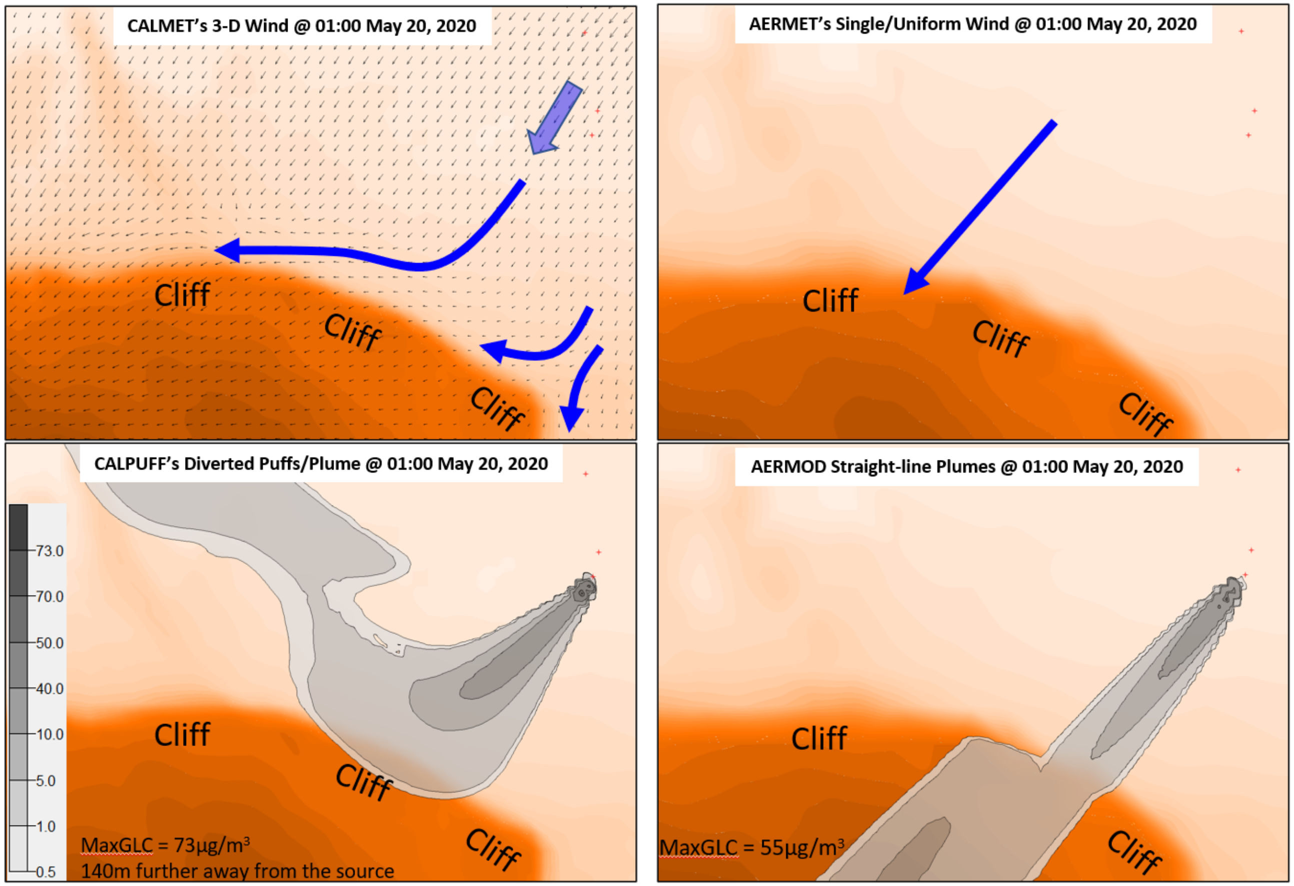
  - *Generally, facilities located within approximately 1 km of the shoreline of a larger lake or water body, that emit contaminants from taller stack sources greater than 50 metres in height, need to assess the potential for shoreline fumigation to occur using the SCREEN3 model. Should the screening assessment show that shoreline fumigation may occur, the use of an alternative model (e.g. CALPUFF, Shoreline Dispersion Model) may be required by a notice issued under section 7 of the Regulation.*

  - *The decision as to whether the use of CALPUFF is justified requires competent meteorological judgment. There are no hard and fast rules that can be applied. Situations where the use of CALPUFF could be justified include complex terrain, near large lakes and for facilities with very tall stacks.*

Situational use of CALPUFF (Cont'd)

- More sophisticated air dispersion models (e.g., CALPUFF) may more accurately predict a facility's impact on local air quality depending on site-specific conditions. In such circumstances, the ministry may require facilities to use models other than AERMOD to assess compliance under O. Reg. 419/05
- The CALPUFF model is currently being used by a number of facilities in Ontario located at sites with complex terrain and/or that are potentially subject to shoreline fumigation
    - better characterize risks associated with a facility's emissions (maximum concentrations, location of maximum concentrations)
    - ensure regulatory decisions and actions by regulated facilities (i.e., abatement / control strategies) are informed by best available science
    - identify residual risk associated with abatement / control strategies currently under consideration and what additional actions may be needed in future
    - inform future investment cycles and allow industry to better plan for the future

Why is CALPUFF More Appropriate with Complex Terrain and Meteorology



- CALPUFF produces **more accurate** modelled results in complex terrain because it is better able to account for the unique meteorological conditions (e.g., wind patterns) generated by elevated terrain and varying land use, particularly for short-term events

- CALPUFF maximum modelled concentration may differ in magnitude and/or location compared to AERMOD

Orange shades are for terrain heights, and grade shades are for the modelled plumes. Arrows indicate the winds.

Shoreline Fumigation Effects

- ADMGO has always recognized that AERMOD does not consider the potential for shoreline fumigation effects for facilities located near water bodies with stack/point emission sources
- A screening assessment should be undertaken for emissions from facilities with tall stack/point source (e.g., greater than 50 metres) located within approximately 1 km of the shoreline of a large water body
  - examples of larger lakes or water bodies that could lead to fumigation include the Great Lakes, Georgian Bay, Lake St. Clair, and others.
  - the shoreline fumigation effect is not assessed for ground level area or volume sources

Shoreline Fumigation Effects (cont'd) – Assessing Maximum POI

- If a screening assessment is required (i.e., stacks > 50m tall within 1 km of shoreline), use SCREEN3 to assess the ***potential*** for shoreline fumigation effects.
  - Facilities with multiple stacks taller than 50 metres should use a stepwise screening procedure starting with the tallest stacks and moving to shorter stacks closer to the shoreline
  - If SCREEN3 indicates a ***potential*** for shoreline fumigation effects, proponents will have to use a S7(1) approved alternate model to calculate the maximum POI concentrations resulting from possible fumigation events:
    - Shoreline Dispersion Model (SDM)
      - used to identify the hours where fumigation is likely to occur and assess POI concentrations during those hours
      - AERMOD used to model POI concentrations during all other hours
    - CALPUFF

Wet Plumes

- MECP has had an increasing number of questions related to wet plumes, particularly those from wastewater evaporators
  - The ministry has received a number of complaints about exhaust plumes coming to ground very quickly, causing impacts on neighboring properties
  - Key concern is volatiles becoming re-entrained/re-absorbed in the fine droplets
- Neither AERMOD nor SCREEN3 have the capability to handle these wet, saturated plumes
  - CALPUFF (in FULL mode, not SCREENING or FOG), although not perfect, is preferable

Expectations for use of CALPUFF or SDM

- Pre-consultation with the Environmental Monitoring and Reporting Branch (EMRB) is a **must!**

- Proponents must submit a Modelling Plan that outlines:
    - Development of the meteorological data files (e.g. prognostic "initial guess" data from the Weather Research and Forecasting (WRF) model
    - CALMET and CALPUFF model switches and settings.
    - Checklist can be provided to proponents upon request

- The process is a stepwise review of the circumstances/situation, and approval of the model settings and switches at each stage

- MECP currently has a "pilot" project in the Hamilton area
    - CALPUFF-ready meteorological data files are available to proponents upon submission of s7 and s13 requests, free of charge

* EMRB provides the pre-processed data for SDM

Files to be Submitted when Using CALPUFF

- Ministry review requires submission of:
  - Namelist (input) files for WRF (both WPS and WRF)
  - WRF validation report and review of selected output files
  - Review of CALMET input files and all related input data files such as M3D.DAT files, surf.dat and sea.dat (for buoy, if applicable)
  - Review of CALMET output data files and validation report
  - Review of CALPUFF input files, coastal line file and external emission files if applicable.

* EMRB provides the pre-processed data for SDM