Worldwide Data Quality Effects on PBL Short-Range Regulatory Air Dispersion Models

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Keywords: Air Dispersion, Worldwide Meteorological Data

1. INTRODUCTION

This paper evaluates the impact of estimated input data on the accuracy of AERMOD, a state-of-the-art Planetary Boundary Layer (PBL) air dispersion model. The development of AERMOD was initiated as a collaboration between the U.S. EPA and the American Meteorological Society, to develop a model using modern knowledge on planetary boundary layer theory, which would serve as a replacement to Pasquill-Gifford stability class-based plume dispersion models. AERMOD contains recently developed building downwash, plume rise, and terrain treatment algorithms.

AERMOD (Cimorelli, et al., 1998; U.S. EPA 1998a,b) uses the PBL similarity theory to account for dispersion induced by surface heating and friction. Simulating these effects requires surface information on roughness length, moisture content, and reflectivity. Additionally, complete upper atmosphere sounding is required to determine the depth of the mixing layer, and to establish partial plume penetration through the top of the mixing layer. The terrain treatment in AERMOD uses a methodology that dispenses with the definition of flat, intermediate, and complex terrain. This methodology was extensively tested against field databases. However, worldwide coverage of terrain features is not as detailed and accurate as those used in the validation studies. These parameters may not be readily available in various parts of the globe. Therefore, estimation tools were created to approximate these parameters.

There are implicit assumptions built into AERMOD to reduce the volume of detailed information required to run the model. The validation studies performed by the U.S. EPA and third parties indicate that AERMOD works well with high quality input data. The authors conducted a sensitivity study on the upper air data required by AERMOD, to assess the impact on results caused by substituting mixing heights derived from surface meteorological data.

In the conclusion, an analysis is performed on the impact that estimated parameters versus accurately measured parameters have on output results. Subsequently, the findings on the worldwide applicability of AERMOD, and add-on enhancements, are presented.

2.0 DATA REQUIREMENTS

The underlying methodology of the air dispersion model (ADM) defines the data requirements. Furthermore, the type of air modeling defines the amount, quality and type of data. However, short-range air dispersion models require a minimum set of meteorological data, terrain elevation information, and the site surrounding land cover description.

2.1 Meteorological Data

Air dispersion models require surface meteorological data measurements, such as wind speed, wind direction, dry bulb temperature, and cloud cover. Note that some meteorological parameters can be inferred from primary observations. This is the case of net solar radiation, which is calculated from cloud cover, time, latitude, and longitude. Worldwide quality of meteorological data is very uneven. Figure 1 below presents the missing wind speed data, a critical element for any air dispersion model.

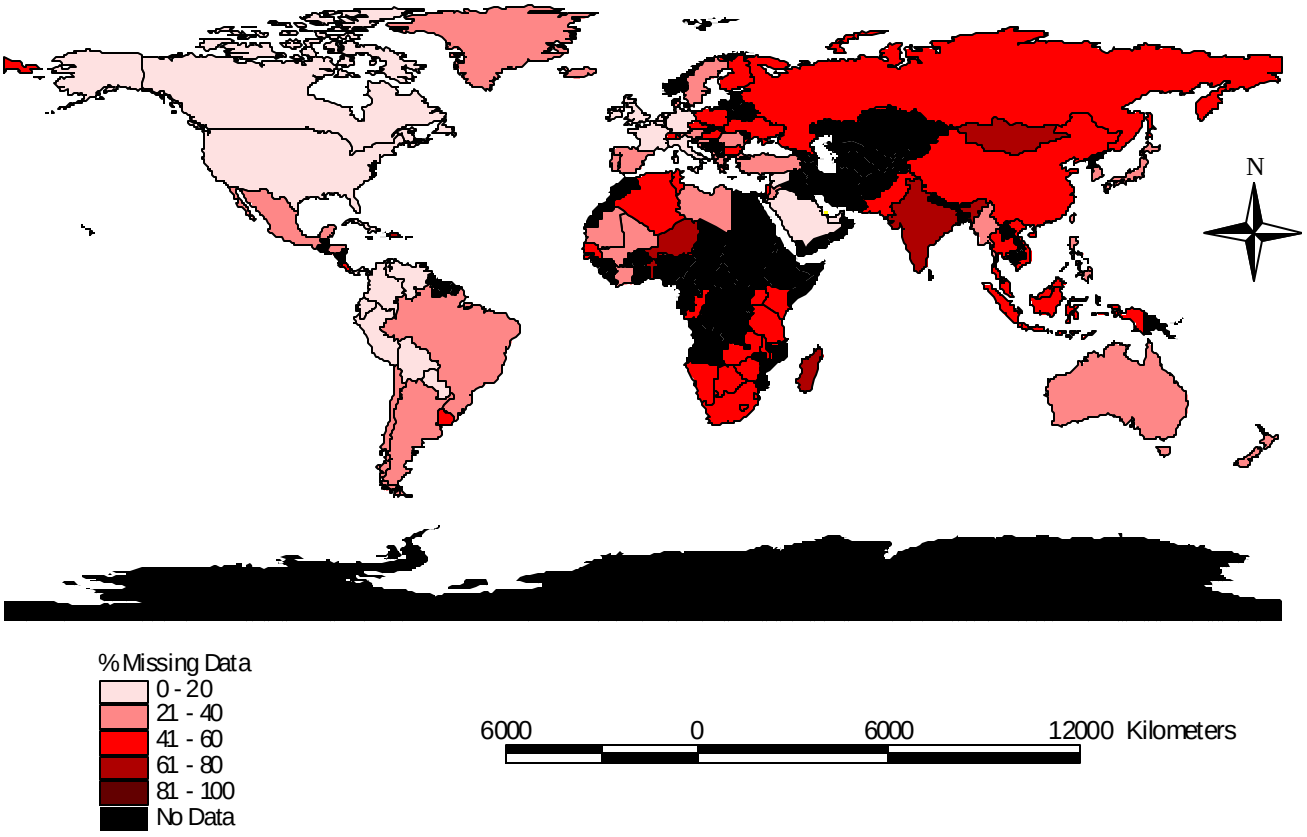


Figure 1 – Survey of missing wind speed data from the World Meteorological Office

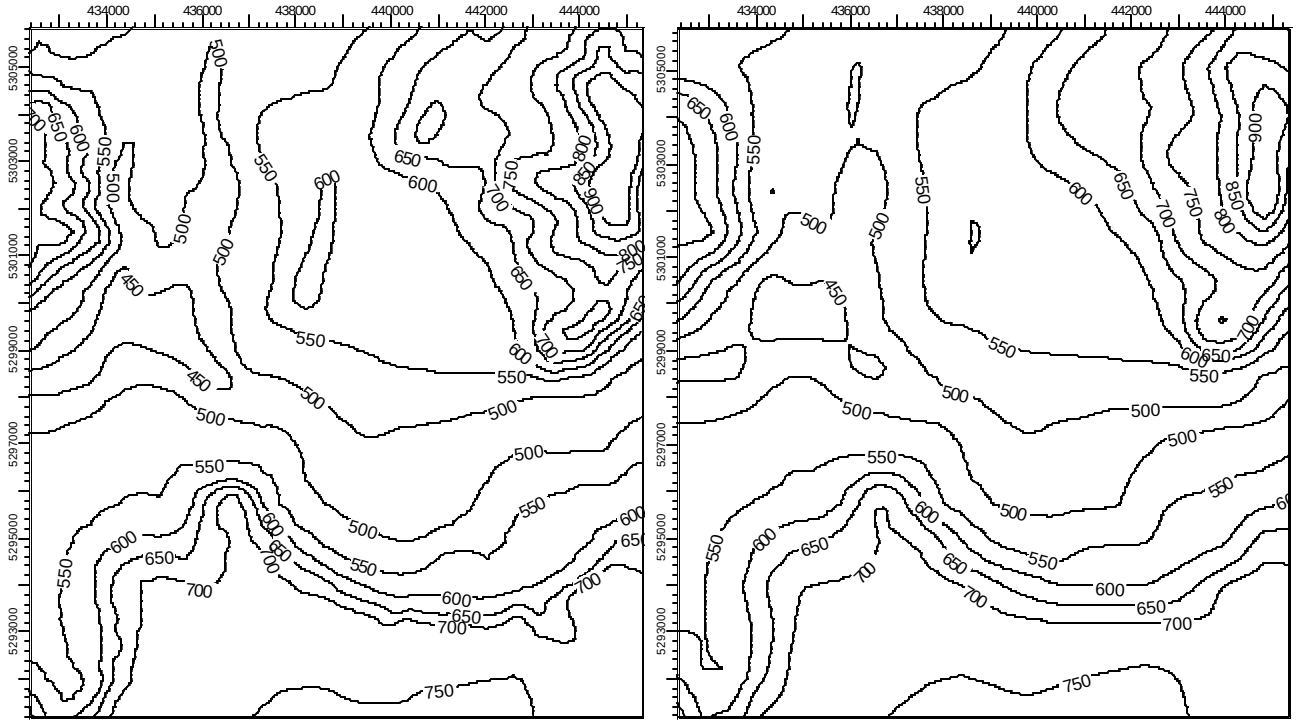
Upper air observations are very important to define the depth of the mixing layer and effective transport parameters. However, these data are not available in most countries. An alternative to the measured upper air soundings is presented in Section 3.

2.2 Terrain Data

Terrain data is imperative for sites where flat terrain assumptions fail. This data can be entered by hand into a model by reading hardcopy topographical maps. However, this alternative is not desirable since it is labor intensive and error prone. Digital Terrain Maps (DTMs) are available for the entire globe, in different resolution and file formats. In a few locations, such as North America and Western Europe, there are DTMs with 30m spacing resolution.

For those sites without access to local digital survey, the United States Geological Survey (USGS) provides global DTM coverage in a 1km resolution. Such resolution may not be adequate for many air models. To alleviate this limitation, the authors implemented a bi-linear terrain interpolation to

create a sub-grid resolution of 100m. Figure 2 presents a comparison of Spokane, WA represented by a 100m surveyed digital map and a 100m bi-linear interpolation from the USGS.



(a) Surveyed at 100m resolution (b)Interpolated to 100m resolution

Figure 2 – Surveyed (a) and interpolated (b) digital terrain map at Spokane, WA.

3.0 UPPER AIR DATA

AERMOD requires hourly convective boundary layer heights (mixing heights), which it obtains from its meteorological preprocessor, AERMET (U.S. EPA 1998b). AERMET, in turn, calculates mixing heights based on upper air meteorological soundings. In many parts of the world, upper air meteorological data are difficult to obtain, if they exist at all. Various techniques have been proposed to estimate convective mixing heights based on surface meteorological data alone. The authors adapted a technique developed by Thomson (1992, 2000) for use with AERMET, and will be referred in this paper as the "Lakes UA Estimation Tool."

The use of such an estimation technique is potentially useful in areas where upper air meteorological data are not available. This section presents some comparisons between ground concentration model calculations using mixing heights derived from the Lakes UA Estimation Tool and mixing heights obtained by AERMET using upper air meteorological soundings. A comparison using both flat and complex terrain was performed using 60-meter high stacks, with stack parameters set at reasonable values for a boiler. Additional comparisons were performed using 10, 20 and 40 meter stacks in flat terrain. These stacks had minimal plume rise.

Figure 3 shows a comparison between the convective mixing heights obtained from the Lakes UA Estimation Tool and those obtained by AERMET from upper air soundings.

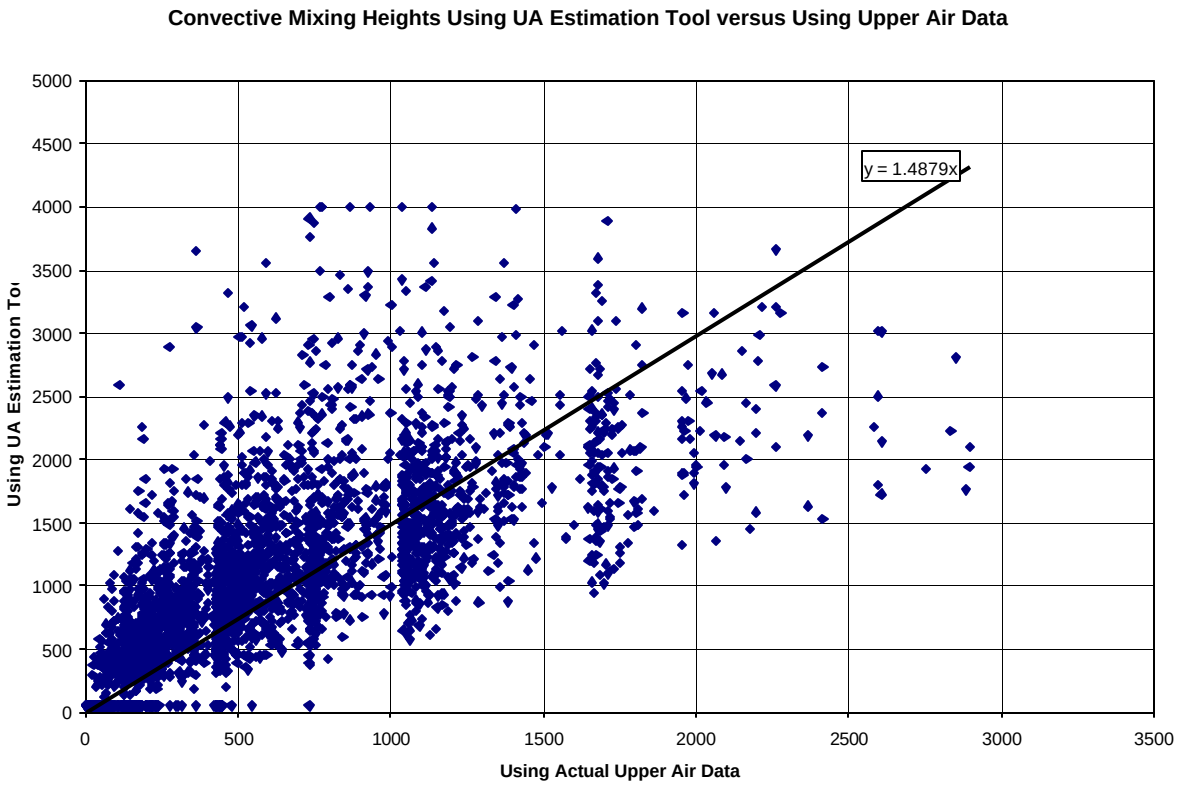


Figure 3 – Mixing Height comparison for Dodge City, KS.

While there is a clear correlation between the two, there is also considerable scatter. In addition, the UA Estimation Tool over predicts the mixing heights, on average, by nearly 50%. Any estimation of convective mixing heights without knowledge of the upper air temperature profile is likely to introduce errors. However, modeled maximum concentrations, as required in regulatory modeling exercises, are not highly sensitive to mixing height. Tables 1 and 2 compare the effects this has on the highest 1-hour concentration and the highest annual average concentration.

Table 1. Comparisons for flat terrain and stacks 10, 20 and 40 meters high

			Concentration		
Stack (m)	Averaging Time	ID	Actual UA Data	UA Estimation Tool	Difference
10	Highest 1-hour	10m-1hr max	160.3344	144.8079	-9.68%
20	Highest 1-hour	20m-1hr max	67.79181	61.61466	-9.11%
40	Highest 1-hour	40m-1hr max	24.00544	23.82276	-0.76%
10	Highest Annual	10m-annual	12.32166	12.25646	-0.53%
20	Highest Annual	20m-annual	2.40309	2.37659	-1.10%
40	Highest Annual	40m-annual	0.38407	0.38248	-0.41%

Table 1 shows comparisons for flat terrain, and stack heights of 10, 20 and 40 meters. This table shows a tendency for under-predictions of concentrations of less than about 10% for this data set when the UA Estimation Tool is used in place of actual upper air data. The results are surprising in face of a considerable scatter in the estimation of the mixing heights.

Table 2 shows similar comparisons for flat and complex terrain for a 60-meter stack. In these cases, differences were much less than one percent.

Table 2. Comparisons for flat and complex terrain and 60-meter stacks

Terrain	Averaging Time	Actual UA Data	UA Estimation Tool	% Difference
COMPLEX	Highest 1-hour	66.80038	66.80038	0.00%
COMPLEX	Highest Annual	0.84344	0.84615	0.32%
FLAT	Highest 1-hour	66.6935	66.6935	0.00%
FLAT	Highest Annual	0.8306	0.83172	0.13%

4.0 CONCLUSIONS

This paper indicates that there is worldwide availability of data for short-range regulatory air dispersion models. However, the data may not be of good quality. For sites located in regions where the coverage for terrain and meteorological data is poor or absent, the authors implemented data improvement methodologies. The limited comparisons presented in this paper indicate that the UA Estimation Tool is sufficiently accurate to be a viable approach to providing mixing heights for modeling purposes using models such as AERMOD. However, if such data are available, they should be used.

5.0 REFERENCES

Cimorelli, et al., 1998. *AERMOD, description of model formulation,* U.S. Environmental Protection Agency, Research Triangle Park, NC. Available from the Internet website URL: *http://www.epa.gov/scram001*.

U.S. EPA, 1998a. *User's Guide for the AMS/EPA Regulatory Model—AERMOD,* revised draft, U.S. Environmental Protection Agency, Research Triangle Park, NC. Available from the Internet website URL: *http://www.epa.gov/scram001*.

U.S. EPA, 1998b: *User's guide for the AERMOD meteorological preprocessor,* revised draft, U.S. Environmental Protection Agency, Research Triangle Park, NC. Available from the Internet website URL: *http://www.epa.gov/scram001*.

Thomson, D.J., 1992. "An analytical solution of Tennekes' equations for the growth of boundary-layer depth," *Boundary Layer Meteorology*, Vol 59**:** 227-229

Thomson, D.J., 2000. "The met input module," *ADMS 3 Technical Specification.* Cambridge Environmental Research Consultants. Available from the website URL: *http://www.cerc.co.uk/software/publications.htm#.*