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IMPLEMENTATION AND EVALUATION OF PRIME IN AERMOD

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1. INTRODUCTION

The U.S. Environmental Protection Agency (EPA) recently proposed changes to the air quality modeling guidelines to replace the ISCST3 model with the AERMOD model (Cimorelli, et al, 1998) for applications where building downwash is not important, and to replace ISCST3 with ISC-PRIME (Schulman, et al, 2000) for applications where downwash is important. In response to public comments, EPA has incorporated the PRIME building downwash algorithms into the AERMOD model.

This paper describes the implementation and developmental evaluation of the AERMOD model with PRIME downwash algorithms. The implementation of PRIME in AERMOD was guided by the goal of keeping the PRIME downwash algorithms as intact as possible, while incorporating the improved meteorology of the AERMOD model.

2. IMPLEMENTATION ISSUES

There were several issues involved with implementing the PRIME downwash algorithms into the AERMOD model. The PRIME algorithm as implemented in ISC-PRIME was designed to use vertical profiles of wind and temperature that are consistent with the ISCST3 profiles, whereas AERMOD generates vertical profiles of wind and temperature based on similarity scaling and can also incorporate a full profile of measurements. PRIME was implemented in AERMOD to use the AERMOD meteorological profiles.

The ISC-PRIME model uses ambient turbulence intensities based on PG stability class to determine the distance at which the wake turbulence intensity has decayed to ambient levels, and also uses PG-based dispersion beyond the wake. The PRIME algorithm was implemented in AERMOD to use ambient turbulence intensities based on the AERMOD profiles.

The more significant issues were related to the use of a non-Gaussian probability distribution function (PDF) for the vertical dispersion in the convective boundary layer (CBL) in AERMOD, and AERMOD's treatment of the direct, indirect and penetrated plumes in the CBL (Cimorelli, et al, 1998). The ISC-PRIME model uses a Gaussian vertical distribution for both convective and stable conditions, consistent with the ISCST3 model.

To address these issues, the AERMIC committee adopted an approach that defines two plume "states", one corresponding to a plume that is influenced by building downwash, and the other corresponding to a plume that is not influenced by building downwash. AERMOD models the "wake state" plume using the PRIME algorithms with the adaptations described above, and models the "non-wake state" plume using the regular AERMOD algorithms for a source without building downwash. The contributions from the two plume states are combined using a weighting factor that is a function of the receptor location relative to the building wake.

For a receptor located within the wake region, the AERMOD model uses the concentration calculated by the PRIME algorithm, and the model transitions to the AERMOD estimate (without downwash) beyond the wake region. The lateral and vertical extents of the wake region are defined internally by the PRIME algorithm. For purposes of transitioning to the AERMOD estimate, the longitudinal extent of the wake region is defined as the maximum of 15R and the distance where wake turbulence intensity decays to the ambient level, where R is the wake length scale and is a function of the building dimensions. Beyond the wake region, the total concentration is calculated as follows:

$$c_{TOTAL} = g \; c_{PRIME} + (1-g) \; c_{AERMOD}$$

The weighting function, (, is equal to 1.0 within the wake region, and beyond the wake region is calculated as follows:

$$g = \exp\left(\frac{-(x-s_{xg})^2}{2s_{xg}^2}\right)\exp\left(\frac{-(y-s_{yg})^2}{2s_{yg}^2}\right)\exp\left(\frac{-(z-s_{zg})^2}{2s_{zg}^2}\right)$$

where:

x = downwind distance of receptor from upwind edge of the building;
y = lateral distance of receptor from building centerline;
z = receptor height above stack base, including terrain and flagpole;
F_{xg} = maximum of 15R and the distance to transition from wake to ambient turbulence;
F_{yg} = lateral distance from building centerline to lateral edge of the wake at receptor location; and
F_{zg} = height of the wake at the receptor location.

For applications involving terrain effects and building downwash, the AERMOD component is calculated with the full terrain treatment, and the PRIME component is calculated with the minimum terrain weighting factor of 0.5, since the wake region is considered to be near neutral due to the building-enhanced turbulence. The use of the receptor height above stack base in the calculation of the vertical component of (indicates that if the plume is rising above the wake and terrain extends above the wake, then the AERMOD component should begin to dominate, while if the terrain is within the wake then the PRIME component should dominate.

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During the developmental evaluation of AERMOD with PRIME, preliminary results indicated a tendency for the model to overpredict during light wind convective conditions. The PRIME algorithm includes a test on the trajectory angle of the rising plume to determine if the plume will escape the effects of the building. If the trajectory of the plume falls below 45 degrees from horizontal before the plume rises above the top of the wake, then the plume is subjected to building downwash influences. The light wind convective conditions for the Bowline data were evaluated to determine a “best fit” for this critical trajectory angle based on the normalized mean square error, and a best fit was found for a critical angle of 20 degrees. Based on this result, PRIME was implemented in AERMOD using a critical angle of 20 degrees to determine if wake effects apply.

3. EVALUATION RESULTS

The developmental phase of the evaluation of AERMOD with PRIME consisted of one half of the days selected at random from a full year of data for the Bowline power plant data base located on the Hudson River near Haverstraw, NY, the Alaska North Slope field study near Prudhoe Bay, AK, the Duane Arnold Energy Center (DAEC) located in eastern Iowa, and the Millstone power plant located on the Connecticut coast.

A sample of results for each data base are presented below. Figure 1 shows the 1-hr Q-Q plot of AERMOD and ISC-PRIME for the Bowline data. There is very close agreement between the two models across the full distribution of concentrations. Figure 2 shows the 1-hr Q-Q plot of normalized concentrations for the Alaska North Slope data. AERMOD performs better than ISC-PRIME for this data base. This improvement is due in part to the use of a 20 degree critical angle in AERMOD as discussed above. Figure 3 shows the 1-hr Q-Q plot of normalized concentrations for the SF_6 release at DAEC. Both models exhibit a tendency to underpredict for this data base, with ISC-PRIME showing less underprediction than AERMOD below the peak concentrations. Figure 4 shows the 1-hr Q-Q plot of normalized concentrations for the Freon release at Millstone. There is little difference between the two models for this data base, with both models showing a tendency to overpredict.

4. REFERENCES

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Schulman, L.L, D.G. Strimaitis, and J.S. Scire, 2000: Development and evaluation of the PRIME plume rise and building downwash model. *J. Air & Waste Manage. Assoc.*, **50**, 378-390.

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Figure 1. Bowline 1-hr Q-Q Plot (i) - Developmental

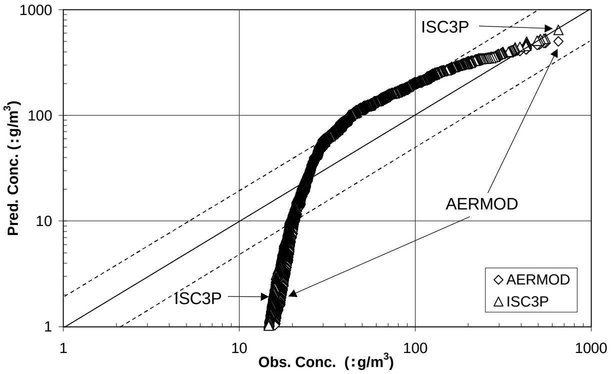

Figure 2. Alaska North Slope 1-hr Q-Q Plot (i/Q)

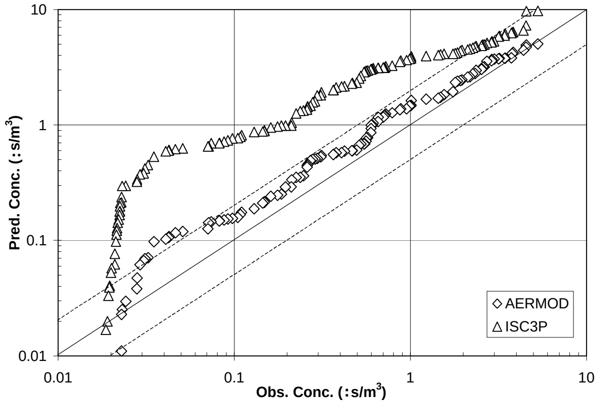

Figure 3. DAEC SF_6 1-hr Q-Q Plot (i/Q)

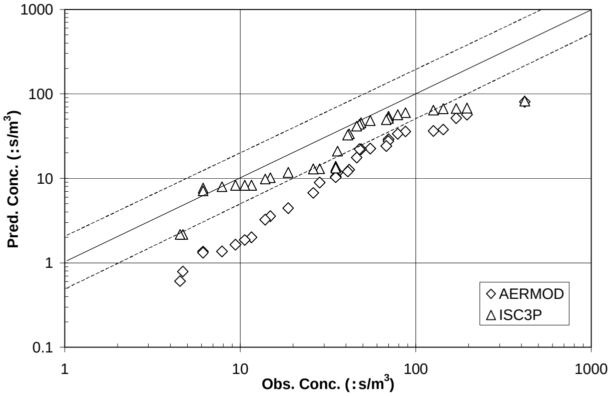

Figure 4. Millstone Freon 1-hr Q-Q Plot (i/Q)