COMPARISON OF ISCST3 AND AERMOD AIR DISPERSION MODELS TO PREDICT DIOXIN DEPOSITION FROM AN INCINERATOR IN MIDLAND, MICHIGAN

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Abstract

We implemented the newly promulgated AERMOD air dispersion model to predict dioxin deposition pattern in the surroundings of a hazardous waste incinerator in Midland, Michigan. More reliable and updated data (e.g. meteorological parameters, UMDES soil data) are incorporated into AERMOD, and geostatistics is used to model the dioxin plume. The new air dispersion model AERMOD predicts a more unidirectional and focused plume, and higher mass dioxin deposition than ISCST3. Dry deposition is the major transport pathway for dioxin-bound particles released from the incinerator stack and high dioxin levels are consistently found close to the incinerator.

Introduction

During 2002-2004, the University of Michigan Dioxin Exposure Study (UMDES) conducted a soil sampling program in Midland, MI. The soil sampling was guided in part by geostatistical predictions of soil dioxin based on 53 previously collected soil data (1983-1998) and a spatial trend inferred from the air dispersion model, ISCST3. As a part of the UMDES study, 51 new soil samples were collected in the area. In 2006, a new air dispersion model, AERMOD, was promulgated by the US Environmental Protection Agency (US EPA) to replace ISCST3. The new AERMOD model features the most up-to-date knowledge of the planetary boundary layer influences, and requires more complicated meteorological input parameters as compared to ISCST3. The new air dispersion model, coupled with the additional soil samples, should lead to a more accurate model of dioxin deposition in the vicinity of the Dow incinerator in Midland. This paper, thus evaluates the effects of changing the air dispersion model from ISCST3 to AERMOD in predicting dioxin deposition.

Materials and Methods

The modeling area is a 261x261 grid (spacing = 50m) centered on the incinerator but excluding the plant property. Each grid node is considered as a receptor in the AERMOD model and is used in the subsequent regression, spatial interpolation and census block averaging modeling steps[1].

Scenario 1 is run on ISCST3 and scenario 2 is run on AERMOD using the same emission rate of 0.126 gram particle/second (e.g. 0.012 gram TEQ/year) as reported in our previous work[2]. A third AERMOD modeling scenario uses the real emission of 0.0333 gram TEQ (WHO-$TEF_{D/F}$ 2005) measured in 1992 (EPA)[3] for the 830 incinerator stack. The latter emission scenario is 2.8 fold greater than that of the former scenarios.

Five year (2001-2005) meteorological data, required as input files to AERMOD in scenario 2 and 3, were provided by the Michigan Department of Environmental Quality (MDEQ) for the weather station at Midland-Bay-Saginaw (MBS). Since compatible ISCST3 meteorological inputs were not available for that period, scenario 1 was run using a 5 year meteorological data set (1987-1991) recorded at Flint, Michigan.

The deposition option is selected for both dispersion algorithms, thus the model input includes air concentration, plus wet and dry dioxin fluxes predicted at each receptor node.

The relationship between the output of the air dispersion model (dry and wet depositions) and field data (normal score transformed values of the soil TEQs) is modeled using linear regression. In scenario 1 and 2, the regression is applied to 53 MDEQ/EPA data while in scenario 3, the combined set of old and new data (53 soil samples from EPA/MDEQ soil campaign and 51 soil samples of the UMDES) is used. The regression function is later applied to the entire 261x261 grid, generating a spatial trend that is incorporated in Sequential Gaussian simulation (sGs). One hundred grids of simulated TEQ values (realizations) were generated by sGs using the semivariogram of regression residuals and conditioning data that consist of the 51 UMDES soil data for scenario 1&2 and the 104 TEQ data for scenario 3. Point simulated values are aggregated within each census block to yield a simulated block value. This aggregation is repeated for each realization, yielding a set of 100 simulated values for each census block.

The distribution of 100 block values was used to retrieve the probability for each census block to exceed a threshold of 75 ppt, a conservative level to identify the population who might be at health risk.

Results and Discussion

Generally, straight comparison of performance between ISCST3 and AERMOD in scenario 1 and 2 should be done cautiously since the two runs are based on different 5 year meteorological data sets. The AERMOD-based scenarios 2 and 3 are believed to have better on-site input parameters (weather data recorded at the nearby MBS airport instead of Flint and Alpena data used in scenario 1.) Aside from a different dataset, the complexity of the meteorological data required by AERMOD to derive dispersion model formulations, better characterizes the boundary layer, and vertical structures of the wind, temperature and turbulence[4]. Predicted concentrations are based on the steady-state plume approach which is also significantly improved in both convective and stable conditions. The wet and dry deposition fluxes of contaminants therefore are also influenced. In fact, according to scenario 2 dry deposition is the main transport pathway for dioxin bounded particles, which is in contrast to the result of scenario 1 where wet deposition prevailed. The use of AERMOD leads to a dry deposition plume downwind from the incinerator (on the north-east side) that is narrower than the plume predicted under scenario 1 (Figure 1(a)). Wet deposition is predicted to occur mainly south of the plant due to different prevailing wind directions during precipitation events. (Figure 1(b)). Another difference between air dispersion models is the greater mass deposition predicted by AERMOD in the first two scenarios.

Figure 2 shows the probability that the census-block averaged soil TEQ value exceeds 75 ppt. The choice of this threshold over 90 ppt (MDEQ limit) or 1000 ppt (US EPA limit) was made by the UMDES as a conservative measure to guide the soil sampling campaign. The larger mass deposition predicted by AERMOD results in more census blocks being susceptible to exceed 75 ppt: 307 out of 1041 census blocks and 188 out of 1041 blocks in scenario 2 and scenario 1, respectively. Indeed, the deposition pattern would be underestimated if the air dispersion model ISCST3 is used instead of the new AERMOD model.

Scenario 3 was also conducted using AERMOD but is based on a real stack emission measured at the Dow incinerator in 1992 (0.0333 gram TEQ/year). Thus, scenario 2 and 3 differ only in the level of TEQ emission which is nearly 3 times larger for scenario 3, leading to predicted deposition fluxes that about 3 times greater as a matter of up-scaling.

As AERMOD has already been validated over a number of case studies[5] and is currently used as a regulatory dispersion model, we believe scenario 3 would result in better predictions of soil dioxin in the vicinity of the Dow Chemical plant. This scenario, moreover, includes the new 51 UMDES soil samples in Midland together with the older 53 EPA/MDEQ soil data reported earlier. The incorporation of the new UMDES influences the prediction of the population at risk, as 258 census blocks have now a probability of exceeding 75 ppt TEQ in their soil.

Scenario 1 **Scenario 2** **Scenario 3**

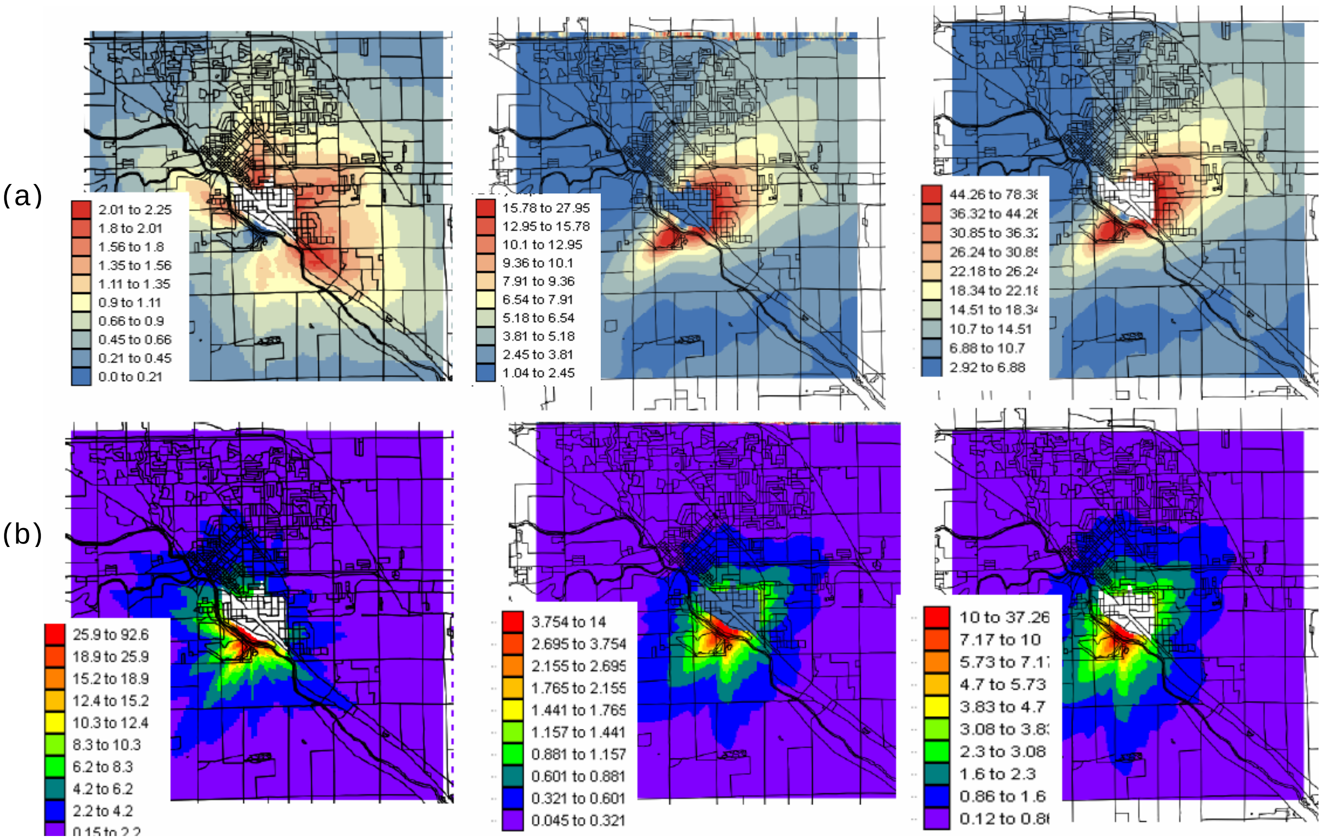

Figure 1. Grid of 5-year dry (a) and wet deposition predicted by ISCST3 (scenario 1) and AERMOD (scenario 2 & 3)

Scenario 1 **Scenario 2** **Scenario 3**

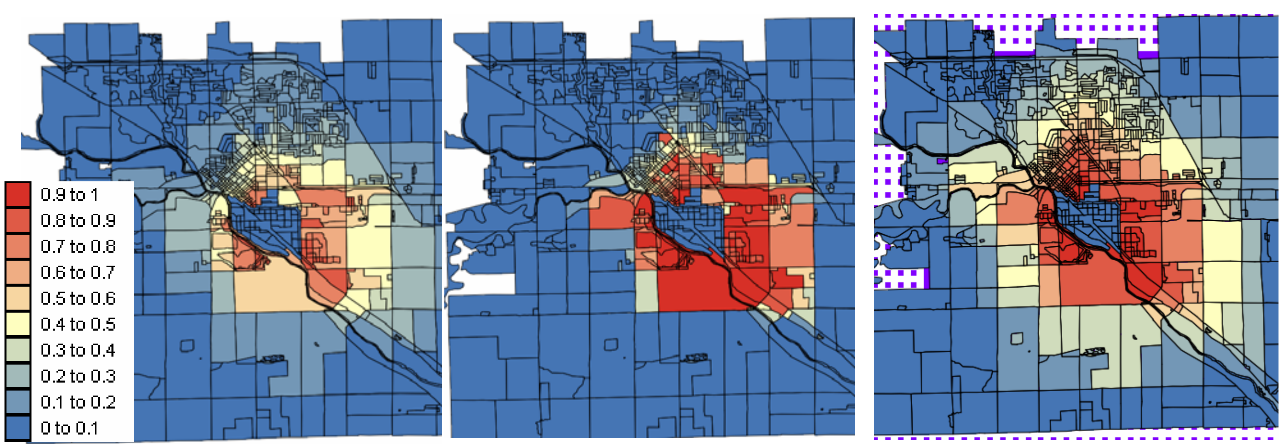

Figure 2. Probability of the predictions that exceed 75 ppt at census block level when using ISCST3 (scenario 1) and AERMOD (scenario 2 & 3)

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