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Letter to the editor

Comments on: Using CALPUFF to evaluate the impacts of power plant emissions in Illinois: model sensitivity and implications

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Levy et al. (2002) describe portions of their analysis of the public health impacts of emissions from nine power plants in Illinois. This and similar analyses (Levy and Spengler, 2002; Freeman, 2001; Abt, 2000) use data-intensive models of air quality and health risks to estimate the number of deaths caused by increases in ambient particulate matter (PM) concentrations due to emissions from specific sources. As modeled by Levy et al. (2002), 87% of the population-weighted, power-plant-derived $PM_{2.5}$ increment exists as sub-microgram per cubic meter concentrations of secondary sulfates and nitrates, which, together with modeled primary PM, are estimated to cause "320 premature deaths per year … due to current emissions from the nine Illinois power plants". As explained below, several crucial but difficult-to-recognize problems with the Levy et al. (2002) analysis compromise its reliability. We thank Dr. Levy and coworkers for sharing with us the input files that control the CALMET and CALPUFF runs, that we might explore these issues.

1. Atmospheric dispersion and transport modeling issues

Chicago is the largest population center in the modeled region, home to two of the nine power plants, and generally downwind of six of the other seven facilities modeled. The city's location on the shore of Lake Michigan leads to sharp changes in meteorological conditions due to abrupt lake/land and rural/urban effects. The lake also reflects a step-function in the population distribution that could magnify the effects of any modeling errors in this region. Thus, the precise pattern of the near-field dispersion estimates can profoundly influence the study's results.

Levy and co-workers' initial report (2000) lists distances from each plant at which the maximum ground level concentrations (MGLC) of primary PM are predicted. These distances range from 1.1 to 40 km. As expected, plants with taller plume heights (stack height plus modeled plume rise) yielded greater estimated distances to the MGLC. However, the two modeled plants within Chicago (Fisk and Crawford) were found to have much shorter distances to primary PM MGLC (1.1 and 1.6 km, respectively), and consequently much higher GLC values than the other sources, despite similarities in plume heights. Although near-field emissions from these two plants are modeled using fast-growing urban dispersion coefficients in contrast to the slower-growing rural coefficients (Scire et al., 2000) used for the other plants, this difference alone cannot account for the differences in estimates of distance to MGLC. However, choices made in generating the driving CALMET meteorological data could strongly influence the results of these CALPUFF dispersion calculations.

CALMET uses several different algorithms (Venkatram, 1980; Maul, 1980; Zilitinkevich, 1972) to predict mixing heights that utilize micro-meteorological variables in a given cell, but do not recognize effects of horizontal advection. To avoid unrealistic jumps between adjacent cells and to attempt to account for advection, CALMET spatially averages mixing heights based on an upwind-looking window, coupled with a user-specified, isotropic, averaging window of radius MNMDAV cells. The MNMDAV default value is 1, but Levy et al. chose to override this with MNMDAV = 3—a value that translates to a 45 km (Levy, 2001) radius smoothing window that is large compared with mechanisms responsible for spatial smoothing of mixing depths.

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Importantly, this averaging near the Western shore of Lake Michigan dramatically smooths the otherwise rapid transition from relatively high, overland mixing depths to shallow, over-water mixing depths, and causes mixing heights over Chicago to be reduced significantly.

Since the Fisk and Waukegan plants are located in a modeling cell adjacent to a water cell, and the Crawford plant is only two cells from the water, emissions from these facilities are subject to dramatic reductions in mixing height due to this spatial averaging. For well-mixed plumes, these reductions lead only to reciprocal increases in MGLC that are generally modest. However, for a buoyant plume near its source, a lower inversion height brings the plume down much more quickly, leading to a shorter distance to MGLC and, in this case, to many-fold higher values of GLC in the highly populated Chicago urban area. Given that the effect of this phenomenon is not as evident on the Waukegan plant, it may be that the combination of this mixing height reduction and the use of urban dispersion curves conspire to erroneously predict that the Fisk and Crawford plant plumes reach the ground at unreasonably short distances, or that the Waukegan emissions are often injected into the stable layer above these low mixing heights. The authors indicate that the NOAA RUC2 40-km resolution data were augmented by the ARPS Data Assimilation System (ADAS) and ACARS aircraft-reported wind and temperature data, so perhaps the different types and quality of data play important roles over the Waukegan versus Chicago areas. We recommend examination of the relative importance of these various factors through scrutiny of the extensive CALMET meteorological data files and/or appropriate CALMET/CALPUFF sensitivity runs.

The CALMET meteorological model was run by Levy et al. with a spatial resolution of 15 km, but the basic meteorological model employed to drive CALMET was developed on a grid with a 40-km lateral resolution. While this resolution is generally appropriate for modeling large, relatively flat domains, the 15-km grid and especially the 40-km grid are too coarse to resolve important flows, such as lake/land breezes, near the coastline of Lake Michigan. Although the choice of a 15-km grid resolution for CALMET significantly limits the detail with which one can capture lake/land breezes, inclusion of near-lake surface station observations can force the near-surface winds to respond to these effects. Levy et al. chose to include only one surface meteorological observing station (Levy, 2001) out of the dozens available within the modeling domain, and that station is about six grid cells (or 90 km) inland from the Western shore of Lake Michigan—a distance far too great to record lake/land breezes.

Even though the 15 km resolution of the CALMET fields precluded explicit representation of lake/land breezes, CALPUFF modeling options could have been used to: (1) introduce a detailed coast line to better quantify source-to-coast line distances and (2) activate a module to simulate plume dispersion within (and above) a computed thermal internal boundary layer. Neither was utilized by Levy et al. (Levy, 2001), which casts further uncertainty on the near-field predictions made for sources located near the lake/land interface.

2. Health effects modeling issues

The uncertainties associated with the modeling of primary and secondary PM from power plant emissions are substantial, yet they pale when compared to the central uncertainties of the health-risk model used by Levy et al. As the authors themselves note: "…it appears likely that the degree of uncertainty in atmospheric modeling will not dominate the total uncertainty associated with health impact or benefit estimation". They also write that the concentration-response function for excess mortality that they apply (Krewski et al., 2000) is "quite uncertain and has numerous issues associated with its implementation". These are understatements. Ambient PM is a mixture of thousands of substances that vary in physical, chemical, and biological properties, and no one knows which of these substances, if any, hasten mortality (Moolgavkar and Luebeck, 1996; Gamble, 1998; Phalen, 1998; Valberg and Watson, 1998). We do, however, have a good idea as to what fractions of ambient PM are *not* likely to be toxic, let alone fatal, and these fractions include secondary sulfates and nitrates. As discussed elsewhere (Green et al., 2002), the toxicologic, experimental evidence on these compounds led the Netherlands Aerosol Program (NAP, 2001), for example, to conclude that ammonium sulfate and ammonium nitrate "seem[s] to be toxicologically inert at current concentrations … Decreasing the levels of inert compounds will not reduce the health risk of the population".

3. Conclusions

Atmospheric modeling is an important tool to assess the potential impacts of various sources of pollution. Modeling capabilities have expanded greatly in recent years, moving beyond the simulation of unidirectional convection and dispersion of passive tracer species to simulating many atmospheric processes. However, few of the enhanced capabilities being added to models have received thorough evaluation on even an isolated basis, let alone as part of an integrated modeling system.

Although the CALMET/CALPUFF system is generally based upon first principles, there are uncertainties in each of its many components (e.g., the universal applicability of the simplistic correlation-based

MESOPUFF chemical mechanism). Offsetting errors among various processes and source terms may mask large uncertainties associated with the modeling of individual sources and species. Fay et al. (1985) used a simple model to produce reasonable estimates of acid deposition, but could construct similar results by counter-varying the importance of processes such as SO_2 to sulfate conversion and dry/wet deposition. As the bulk of CALMET/CALPUFF's validation has focused on long-range transport of passive tracers (US EPA, 1999), one cannot gauge the reliability of the model to predict incremental secondary PM concentrations from specific power plant emissions of SO_2 and NO_x, and especially its ability to estimate detailed spatial patterns of individual species.

This inherent modeling uncertainty is exacerbated by the specific issues we have identified with near-field predictions in the Levy et al. study. Since the near-field predictions are a critical determinant of population-weighted predictions in the urban Chicago setting, the uncertainty of the specific numerical estimates is much greater than indicated by the authors.

The authors (Levy et al., 2002) end their paper by writing, "The magnitude of the public health impacts associated with these concentration increments is potentially significant and illustrates that accurate long-range dispersion modeling can provide meaningful and policy-relevant information for the regulatory community". Given both (i) persistent uncertainties in the air modeling and (ii) how little we understand about what, if anything, in current, ambient, pollution-derived PM in the United States accelerates death, we question whether these multi-layered modeling exercises form a reliable basis for public health policy making.

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References

Abt Associates Inc., 2000. The Particulate-Related Health Benefits of Reducing Power Plant Emissions. Clean Air Task Force, Boston, MA.

Fay, J., Golomb, D., Kumar, S., 1985. Source apportionment of wet sulfate deposition in eastern North America. Atmospheric Environment 19 (11), 1773–1782.

Freeman III, A. M., 2001. An Analysis of the Pataki Power Plant Proposal vs. Full Environmental Comparability Using the New York Externalities Cost Model. Bowdoin College, Brunswick, ME.

Gamble, J.F., 1998. PM2.5 and mortality in long-term prospective cohort studies: cause-effect or statistical associations? Environmental Health Perspectives 106, 535–549.

Green, L. C., Crouch, E. A. C., Lash, T. L., Ames, M. R., 2002. What's wrong with the national ambient air quality standard (NAAQS) for fine particulate matter (PM2.5)? Regulatory Toxicology and Pharmacology, in press.

Krewski, D., Burnett, R.T., Goldberg, M.S., Hoover, K., Siemiatycki, J., Jerrett, M., Abrahamowicz, M., White, W.H., et al., 2000. Reanalysis of the Harvard Six Cities Study and the American Cancer Society Study of Particulate Air Pollution and Mortality. Health Effects Institute, Cambridge, MA.

Levy, J., 2001. Personal Communication of Model Input Data. Harvard School of Public Health, Department of Environmental Health, Boston, MA.

Levy, J.I., Spengler, D., 2002. Modeling the benefit of power plant emission controls in Massachusetts. Journal of the Air and Waste Management Association 52 (1), 5–18.

Levy, J., Spengler, J. D., Hlinka, D., Sullivan, D., 2000. Estimated Public Health Impacts of Criteria Pollutant Air Emissions from Nine Fossil-Fueled Power Plants in Illinois. Harvard School of Public Health, Department of Environmental Health, Boston, MA.

Levy, J.I., Spengler, J.D., Hlinka, D., Sullivan, D., Moon, D., 2002. Using CALPUFF to evaluate the impacts of power plant emissions in Illinois: model sensitivity and implications. Atmospheric Environment 36, 1063–1075.

Maul, P. R., 1980. Atmospheric Transport of Sulfur Compound Pollutants. Central Electricity Generating Bureau MID/SSD/80/0026/R, Nottingham, England.

Moolgavkar, S.H., Luebeck, E.G., 1996. A critical review of the evidence on particulate air pollution and mortality. Epidemiology 7 (4), 420–428.

Netherlands Aerosol Program (NAP), 2001. Discussion Document on Health Risks of Particulate Matter in Ambient Air. Final Draft. RIVM, Bilthoven, The Netherlands.

Phalen, R. F., 1998. Uncertainties relating to the health effects of particulate air pollution: the US EPA's particle standard. Toxicology Letters 96–97, 263–267.

Scire, J.S., Robe, F.R., Fernau, M.E., Yamartino, R.J., 2000. A User's Guide for the CALMET Meteorological Model (Version 5). Earth Tech, Inc., Concord, MA.

United States Environmental Protection Agency (US EPA), 1999. interagency workgroup on air quality modeling (IWAQM) phase 2 summary report and recommendations for modeling long range transport impacts, EPA-454-R-98-019.

Valberg, P.A., Watson, A.Y., 1998. Alternative hypotheses for PM associations with daily mortality and morbidity. Inhalation Toxicology 10, 641–662.

Venkatram, A., 1980. Estimation of turbulence velocity scales in the stable and unstable boundary layer for dispersion applications. In: Eleventh NATO-CCMS International Technical Meeting on Air Pollution Modeling and its Application, March 19–22, Los Angeles, CA.

Zilitinkevich, S.S., 1972. On the determination of the height of the Ekman boundary layer. Boundary Layer Meteorology 3, 141–145.