A Note on AERMOD versus CALPUFF

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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[1]. CALPUFF was part of that list from 2003 to 2017, but now is listed as "alternative model"[2], 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[3].

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 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. 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.

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[1] 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.
[2] https://www.epa.gov/scram/air-quality-dispersion-modeling-alternative-models
[3] https://www.epa.gov/sites/production/files/2020-09/documents/appw_17.pdf

- Jittra et al. (2020)[4] 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)[5] evaluated the performance of AERMOD and CALPUFF (and of other two models) using the Winter Validation Tracer Study (WVTS)[6] 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.

- Amoatey et al. (2019)[7] 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.

- Atabi et al. (2016)[8] compared AERMOD and CALPUFF in predicting the SO_2 concentrations due to the emissions from 16 stacks of a gas refinery 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.

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[4] 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).
[5] 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.
[6] Brown K.J. (1991) Rocky Flats 1990–91 Winter Validation Tracer Study. North American Weather Consultants, Salt Lake City, Utah (1991). Report AG91-19
[7] 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.
[8] 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.

- Tartakovsky et al. (2013)[9] 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 a better agreement with the measurements than those obtained by CALPUFF.

- Gulia et al. (2015)[10] 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.

[9] 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.
[10] 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