IES White Paper

Comparison of Plume and Puff Models

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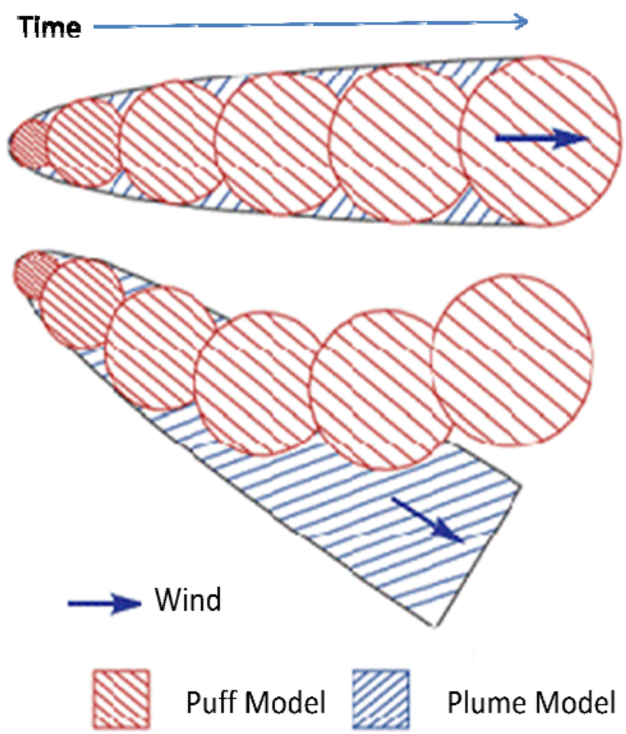
Comparison of AERMOD and CALPUFF

Air dispersion models are used to evaluate the transport and distribution of air pollutants from their emission source to a downstream receptor. The two most common models are Plume (AERMOD) and Puff (CALPUFF) types. Each model requires historical weather data of the area of interest, topography of the modeled area, emission sources of pollutants to be modeled and a downstream receptor to have local concentrations calculated..

Puff and Plume models

As shown below, puff and plume models are fundamentally the same in steady-state wind conditions. Whereas the plume model assumes the emission as one continuous air mass, the puff model calculates by assuming discrete air packages over time. The packages, or “puffs” are free to change over time based on weather conditions and terrain.



While a puff model may be used for most applications where a plume model is appropriate, the additional resources involved in application of a puff model may not always be justified. The technical decision on whether a puff model is more appropriate for a particular application than a plume model should be based on considerations of whether the straight-line, steady-state assumptions on which a plume model is based are valid. This may include considerations of the transport distances, as well as the potential for temporally and/or spatially varying flow fields

due to influences of complex terrain, non-uniform land use patterns, coastal effects, and stagnation conditions characterized by calm or very low wind speeds with variable wind directions. For cases involving a high degree of spatial variability of the flow within the boundary layer, such as upslope or downslope flows or flows along a winding river valley, the straight-line, steady-state assumption may not be valid beyond even a few kilometers, and a puff model may be more appropriate. Another consideration in deciding whether a puff or plume model is more appropriate for a particular application is whether the full spatial and temporal distribution of pollutant impacts is important, such as when using the model results for a risk assessment, or whether the results are to be used for a criteria pollutant analysis where the only the peak of the concentration distribution is important, regardless of time or space.
A guide to select between a plume and puff model is shown below.

Plume or Puff Model?	**Yes**	**No**
Are straight line, steady-state wind assumptions valid?	Plume	Puff
Is the output requirement simple?	Plume	Puff
Are transport distances greater than 50 km?	Puff	Plume
Is there complex terrain or variable winds?	Puff	Plume
Are maximum concentration only required?	Plume	Puff
Are there non-uniform land-use patterns?	Puff	Plume
Are coastal effects to be considered?	Puff	Plume
Are there periods of calm winds and stagnation?	Puff	Plume
Do winds vary in direction throughout the day?	Puff	Plume

CALPUFF (Puff Model)

CALPUFF is an advanced non-steady-state meteorological and air quality modeling system adopted by the U.S. Environmental Protection Agency (U.S. EPA) in its Guideline on Air Quality Models as the preferred model for assessing long range transport of pollutants and their impacts on Federal Class I areas and on a case-by-case basis for certain near-field applications involving complex meteorological conditions. It is a **puff model** that calculates a discrete body of air as it moves through time

The modeling system consists of three main components and a set of preprocessing and postprocessing programs. The main components of the modeling system are CALMET (a diagnostic 3-dimensional meteorological model), CALPUFF (an air quality dispersion model), and CALPOST (a postprocessing package). Each of these programs has a graphical user interface (GUI). In addition to these components, there are numerous other processors that may be used to prepare geophysical (land use and terrain) data in many standard formats, meteorological data (surface, upper air, precipitation, and buoy data), and interfaces to other models such as the Penn State/NCAR Mesoscale Model (MM5), the National Centers for Environmental Prediction (NCEP) Eta/NAM and RUC models, the Weather Research and Forecasting (WRF) model and the RAMS model. It can be downloaded at www.src.com

CALPUFF is a sophisticated model used in many modeling scenarios, including:

- Toxic pollutant deposition
- Visibility assessments
- Complex terrain
- Secondary pollutant formation
- Long range and overwater transport
- Building downwash
- Costal interaction effects
- Dry deposition
- Fumigation conditions
- Chemical transformation
- Sub-hourly time steps

AERMOD (Plume Model)

The AMS/EPA Regulatory Model (AERMOD) is the next generation air dispersion model based on planetary boundary layer theory. AERMOD utilizes a similar input and output structure to ISCST3 and shares many of the same features, as well as offering additional features. AERMOD is a **plume model** that fully incorporates the PRIME building downwash algorithms, advanced depositional parameters, local terrain effects, and advanced meteorological turbulence calculations. It is used for near-term exposure less than 50 km and requires meteorology data proceed by the AERMET processor. AERMOD can be downloaded at http://www.epa.gov/ttn/scram/dispersion_prefrec.htm#aermod.

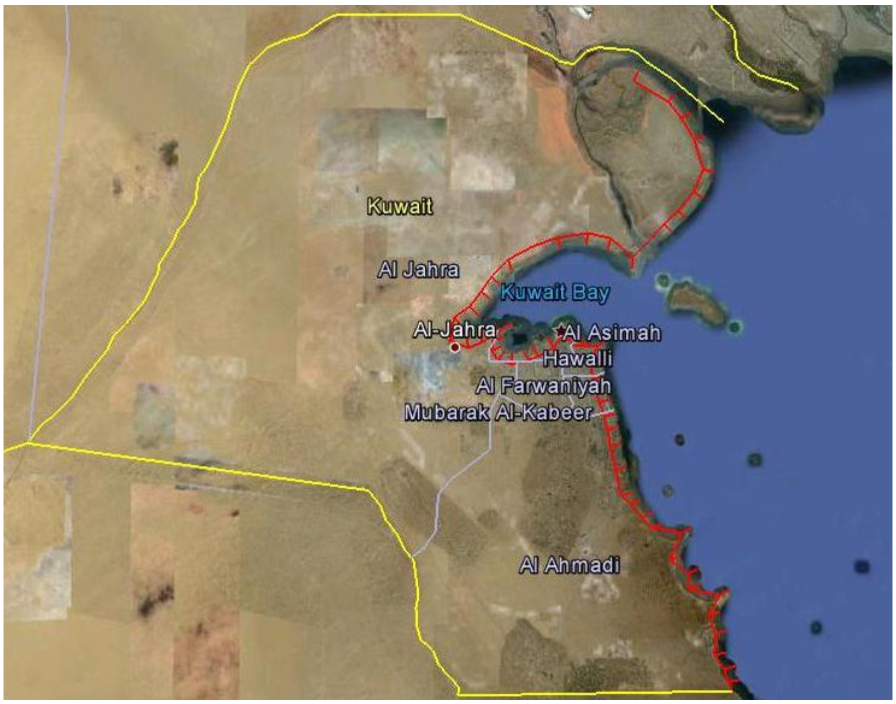
Model Comparison

Both models can only model transportation and distribution of particulates, NOx, SO2 and CO. Neither CALPUFF or AERMOD can model ozone or ozone generation due to photochemical transformation. A comparison of both models is shown below.

Model Name	CALPUFF	AERMOD
Developed By	Atmospheric Study Group of TRC and US EPA	American Meteorological Society and US EPA
Model Type	Non-steady state Gaussian Puff model	Steady-state Gaussian plume air dispersion model
Range	200-300km from the source	Up to 50km from the source
Time Step	1 hour (version 5.8), variable down to the second (version 6.0)	N/A
Terrain	Elevated, processed by TERREL	Flat or elevated (terrain processed by AERMAP)
Building Downwash	Modeled by BPIP or BPIP-PRIME	Building downwash (modeled by BPIP-PRIME)
Source Types	Point, area, volume, line, flare	Point, area, volume, open pit, line, flare
Meteorology	Hourly surface, upper air and precipitation data and/or prognostic data (e.g. MM5 or WRF)	Hourly surface and upper air data (processed by AERMET)
Wind Field	Three dimensional	Homogeneous
Release Types	Buoyant or neutrally buoyant plumes	Buoyant or neutrally buoyant plumes
Emission Types	Constant or time-varying, planned or fugitive	Buoyant or neutrally buoyant plumes
Atmospheric Chemistry	MESOPUFF II, RIVAD/ARM3, SOA and user specified transformation rates	NOX to NO2 and SO2 decay
Regulatory Status	Preferred US EPA regulatory model for long-range and visibility applications. Also used for complex wind field scenarios	Preferred US EPA regulatory model for near-field applications

Application in Kuwait

Over 80% of Kuwait's population and industry is located within 3 km of the coast. Coastal interaction of wind patterns is quite intensive in this zone with wind interaction continuing almost 50 km inland in some instances. Based on this complex meteorological environment, a puff model is more appropriate for air dispersion modeling Kuwait than a plume model despite the additional overhead and resources required to execute it.



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