**UNITED STATES ENVIRONMENTAL PROTECTION AGENCY**
RESEARCH TRIANGLE PARK, NC 27711

September 26, 2008

OFFICE OF
AIR QUALITY PLANNING
AND STANDARDS

**MEMORANDUM**

**SUBJECT:** Technical Issues Related to CALPUFF Near-field Applications

**FROM:** Roger W. Brode, Physical Scientist
U. S. EPA, OAQPS, Air Quality Modeling Group (C439-01)

Bret Anderson, Environmental Scientist
U. S. EPA, Region 7

**TO:** Tyler Fox, Leader
U. S. EPA, OAQPS, Air Quality Modeling Group (C439-01)

The purpose of this memorandum is to provide a discussion of technical issues related to the use of the CALPUFF modeling system for near-field regulatory applications, under EPA's *Guideline on Air Quality Models*, 40 CFR Part 51, Appendix W. The information provided in Attachment A is intended to supplement the recent Clarification Memo related to near-field regulatory applications of CALPUFF under Appendix W, dated August 13, 2008. As noted in the attachment, the discussion is not intended to be exhaustive, and may be updated as additional relevant information comes to light.

Attachment

cc: Regional Modeling Contacts
Richard Wayland
Bill Harnett
Michael Ling
Raj Rao
Todd Hawes
Tim Allen, FWS
John Notar, NPS
John Vimont, NPS
Rick Graw, FS
Dirk Herkhof, MMS

**ATTACHMENT A**

# Technical Issues Related to Use of the CALPUFF Modeling System for Near-field Applications

Roger W. Brode
U. S. EPA, OAQPS
Air Quality Modeling Group

Bret Anderson
U. S. EPA, Region 7

September 26, 2008

## CONTENTS

# 1. INTRODUCTION

EPA has recently issued a memorandum providing clarification of the regulatory status of the CALPUFF modeling system for near-field applications,[1] with transport distance up to 50 kilometers, based on guidance provided in EPA's *Guideline on Air Quality Models* ("*Guideline*"), published as Appendix W to 40 CFR Part 51.[2] This document discusses technical issues related to the use of the CALPUFF modeling system for near-field applications. The use of CALPUFF for near-field regulatory applications involving "complex winds" is addressed in Section 7.2.8 of the *Guideline*, which states that "the purpose of choosing a modeling system like CALPUFF is to fully treat the time and space variations of meteorology effects on transport and dispersion." The basic requirements for justifying use of CALPUFF for near-field regulatory applications consist of three main components:

1) a determination that treatment of complex winds is critical to estimating design concentrations;
2) a determination that the preferred model (AERMOD) is not appropriate or less appropriate than CALPUFF; and
3) a demonstration that the five criteria listed in paragraph 3.2.2(e) of the *Guideline* for use of CALPUFF as an alternative model are adequately addressed.

Each of these steps involves case-specific considerations. The criteria listed in paragraph 3.2.2(e) of the *Guideline* for use of an alternative model are as follows:

> "e. Finally, for condition (3) in paragraph (b) of this subsection [preferred model is less appropriate for the specific application, or there is no preferred model], an alternative refined model may be used provided that:
>
> i. The model has received a scientific peer review;
> ii. The model can be demonstrated to be applicable to the problem on a theoretical basis;
> iii. The data bases which are necessary to perform the analysis are available and adequate;
> iv. Appropriate performance evaluations of the model have shown that the model is not biased toward underestimates; and
> v. A protocol on methods and procedures to be followed has been established."

The discussion provided below is structured to address each of the three main components, and includes specific examples to illustrate some of the issues and concerns. This discussion is not intended to be exhaustive in relation to the range of issues and possible scenarios that may be encountered, since each application includes case-specific considerations, but to provide an indication of some of the issues that should be addressed in assessing the appropriateness of CALPUFF for use in near-field applications. Some of the information presented in this document is preliminary in nature, based upon current understanding of the CALPUFF modeling system from available documentation.

## 2. COMPLEX WIND DETERMINATION

Paragraph 7.2.8(a) of the *Guideline* provides the following examples of complex wind situations:

> "a. *Inhomogeneous Local Winds.* In many parts of the United States, the ground is neither flat nor is the ground cover (or land use) uniform. These geographical variations can generate local winds and circulations, and modify the prevailing ambient winds and circulations. Geographic effects are most apparent when the ambient winds are light or calm. In general these geographically induced wind circulation effects are named after the source location of the winds, e.g., lake and sea breezes, and mountain and valley winds. In very rugged hilly or mountainous terrain, along coastlines, or near large land use variations, the characterization of the winds is a balance of various forces, such that the assumptions of steady-state straight-line transport both in time and space are inappropriate."

An assessment of the potential influence of complex winds on design concentrations should be based on examining the source characteristics (release height and plume buoyancy) in relation to the local topography to determine whether the design concentrations would be adequately represented by a steady-state model. Any available information documenting typical flow patterns at plume height level(s) may also be used to inform that determination. However, use of CALMET-generated wind fields as "evidence" of the importance of complex winds involves circular reasoning, and is not sufficient justification.

For most situations involving elevated plumes with relatively nearby terrain at or near plume height, the "line-of-sight" plume impaction scenario will likely drive the design concentrations, for which the AERMOD model is considered appropriate. Complex winds are also not likely to play a significant role for applications involving low-level plumes or plumes dominated by building downwash influences, where the design concentrations would likely occur in the vicinity of the source. Applications where the controlling design concentrations are likely to be strongly influenced by valley stagnation and/or recirculation under persistent light wind conditions, and where that likelihood can be documented and justified, may be appropriate for consideration as a CALPUFF near-field application based on the criterion of the appropriateness of the preferred model. However, in these cases a clarification is needed regarding the relative appropriateness for these applications of the preferred model at the time of CALPUFF's promulgation, ISCST3, as compared to the current preferred model, AERMOD. Since AERMOD has been designed to handle lighter wind conditions than ISCST3 (less than 1 m/s), and includes a horizontal meander algorithm to account for increased lateral plume spread under such light wind conditions that includes upwind dispersion, it will generally be more appropriate for these conditions than ISCST3.

For low- to mid-level releases, with plume heights below the height of adjacent terrain features, but elevated enough to be transported beyond the immediate vicinity of the source, concern for valley channeling of winds and their importance relative to estimating design concentrations may be a factor for consideration of CALPUFF for a near-field application. If valley channeling or other complex valley circulations dominate plume transport enough that the design concentration is likely to be controlled by phenomena other than line-of-sight plume impaction, then consideration of CALPUFF for near-field application may be appropriate. Dominant valley channeling may also result in significant persistence of wind directions leading to elevated 24-hour average concentrations that could be underestimated by a steady-state plume model driven by single station meteorological inputs that do not reflect that persistence. However, some caution is needed regarding this line of reasoning. First, it is important to recognize that the appropriateness of AERMOD in this situation may depend upon whether meteorological data representative of plume transport are available. The lack of such representative meteorological data may be one of the justifications given for use of CALPUFF in these situations, based on the presumption that CALMET can simulate the important features of the wind field in the absence of representative data. However, justification of CALPUFF for this situation is dependent on the ability of CALMET to provide realistic non-steady-state meteorological fields, which may in turn also depend on the availability of representative meteorological measurements as inputs. These considerations highlight the importance of addressing item iii from paragraph 3.2.2(e) to ensure that "[T]he data bases which are necessary to perform the analysis are available and adequate." Issues related to that item are discussed in more detail in Section 4.3.

Another category of complex winds cited in paragraph 7.2.8(a) of the *Guideline* involves coastal influences, including lake or sea breezes. As with the complex terrain cases discussed above, the importance of complex wind influences for coastal applications may vary based on source characteristics and proximity to the coastline. The two major effects of coastal influences that are most relevant to this discussion are the land/sea-breeze circulation patterns, driven by differential heating of the land and water, and the localized effects of enhanced vertical mixing within the thermal internal boundary layer (TIBL), which forms during the daytime with onshore flow. The land/sea-breeze cycle typically includes a sea (or lake) breeze (onshore flow at the surface) during the daytime, as the land area responds faster to solar heating, followed by a weaker land breeze (offshore flow) at night. The TIBL is characterized by a convective boundary that grows with distance inland from the coast, with the layer above the TIBL reflecting the stably stratified air of the marine boundary layer. The TIBL can result in more limited vertical mixing for plumes released below the TIBL than would occur without the coastal influence, or in fumigation (rapid downward dispersion) for elevated plumes released into the stable layer above the TIBL. The potential importance of non-steady-state coastal influences on design concentrations is probably greater for elevated releases near the coastline than for low-level releases. The magnitude of the impact of non-steady-state effects will generally decrease with distance from the coastline.

The previous paragraphs focused on determining the importance of complex winds on design concentrations for different types of sources in various settings. However, many applications will involve a range of source types at different locations within the modeling domain, raising additional considerations. In these cases, the determination should take into account the relative importance of each source to the overall design concentration, based on emissions and other source characteristics. If a single source or single type of source will clearly dominate the design value, then the determination may be based primarily on an assessment of that source type. An additional consideration that may need to be addressed in cases involving multiple sources is whether plumes from different sources may effectively merge as a result of complex winds, resulting in higher impacts than would occur based on a steady-state modeling assessment. An example of this case would be multiple low-level releases within a complex of valleys or at different locations within the same valley that would likely merge in the bottom of the valley due to drainage flows under light wind, stable conditions.

Another situation where application of CALPUFF for the near field may be considered is a case where concentration estimates are needed in a Class I area that is located within the near-field domain, perhaps 10 kilometers from the source, and where the fetch from the source to the Class I area is characterized by a winding valley. While the source-specific considerations discussed above may still apply in this situation, additional factors may need to be considered. If the plume trajectory is expected to be channeled by the winding valley, one might conclude that getting the trajectory correct is the most important consideration in determining the Class I design concentration. However, such a finding might not be justified, for the same source, if it were a Class II application in which it was clear that the design concentration would occur on the side of the closest hill to the source (i.e., a line-of-sight source receptor relationship). This situation also highlights the issue of whether the non-steady-state capabilities of the CALPUFF modeling system can more appropriately address the temporal and spatial pairing of predicted vs. observed concentrations called for in such an application. Given the nature of the complex wind phenomena that might justify use of CALPUFF for near-field applications, the issue of temporal-spatial pairing of impacts is likely to be a consideration to some degree for all near-field applications of CALPUFF. This issue is discussed in more detail in the following sections.

It is important to recognize that while CALMET can generate spatially varying three-dimensional wind fields, this does not guarantee that the wind fields generated by CALMET will provide a more appropriate treatment of plume transport and dispersion, or result in an improved estimate of design concentrations compared to AERMOD. Furthermore, the mere presence of "complex winds" within a domain is not sufficient justification for use of CALPUFF for near-field applications. In a very real sense, every modeling application involves complex winds to some degree since the atmosphere is inherently inhomogeneous. The burden is in showing clearly that accounting for some aspect(s) of the complex winds is critical to an adequate determination of design concentrations for the source(s) of concern, and then demonstrating that CALPUFF is more appropriate than the preferred model and is capable of simulating those important aspects with an acceptable degree of confidence given the data available for the application.

## 3. APPROPRIATENESS OF THE PREFERRED MODEL

Once a credible determination has been made that treatment of complex winds is critical to estimating design concentrations, a separate determination should be made that the preferred model (AERMOD) is not appropriate for the application, or that CALPUFF is clearly more appropriate than the preferred model, based on condition (3) in paragraph 3.2.2(b) of the *Guideline* that "the preferred model is less appropriate for the specific application, or there is no preferred model"[2]. As noted in the EPA clarification memo[1], the promulgation of AERMOD as the preferred model for regulatory modeling in all terrain settings affects the applicability of this criterion for justifying the use of CALPUFF for such applications, due to the fact that AERMOD is considered to be appropriate for a wider range of applications involving terrain effects than was the case for ISCST3, the preferred model at the time of CALPUFF's promulgation. AERMOD's performance for near-field regulatory modeling applications in simple and complex terrain, with and without downwash, has been well-documented based on a total of 17 field study evaluation databases,[3,4] including several field studies in complex terrain settings. In contrast, there has been no comprehensive demonstration made that the CALPUFF modeling system, including CALMET-generated wind fields, performs as well or better than AERMOD for near-field regulatory applications in complex wind situations based on field study data. More information related to this point is provided in Section 4.2.

The case cited in Section 2 regarding a Class I area located in the near-field highlights the issue of whether the non-steady-state capabilities of the CALPUFF modeling system can more appropriately address the temporal and spatial pairing of predicted vs. observed concentrations called for in such an application. Unfortunately, this is a very difficult question to answer due to limitations of adequate field-study data bases, and due to the difficulty in generalizing model performance based on existing studies given the highly complex and site-specific nature of the problem. Further complicating the determination of appropriateness of CALPUFF for near-field applications is the fact that the limited evaluation studies documented thus far have not evaluated the skill of the modeling system to accurately simulate plume impacts under non-steady-state meteorological conditions paired in time and space over the domain. The question of appropriate model performance methods and metrics to support the determination of appropriateness of CALPUFF for near-field applications is addressed further in a separate document.[5]

While the need for temporally and spatially more realistic concentration fields provided by a non-steady-state model may arise in regulatory applications as described above, this issue may also be brought up in non-regulatory applications as a possible justification for use of CALPUFF in near-field applications. An example of the latter would be for risk assessment applications where the full spatial field of impacts may contribute to the determination of total risk or exposure, requiring additional skill from the dispersion model beyond that required for typical near-field regulatory applications, where peak concentrations unpaired in time and space are the primary metric for model performance. Many of the same concerns expressed regarding regulatory applications of CALPUFF in near-field settings would apply in these non-regulatory cases, but the added significance of temporal and spatial pairing of concentration fields with population distributions to determine exposures further increases the demand on model skill beyond what has thus far been demonstrated.

## 4. ALTERNATIVE MODEL CRITERIA

This section provides more details regarding the technical considerations involved in assessing the appropriateness of CALPUFF relative to the preferred model for potential near-field applications, based on the criteria for use of an alternative model listed in paragraph 3.2.2(e) of the *Guideline*.

### 4.1. Scientific Peer Review

The CALPUFF modeling system was subjected to a scientific peer review[6] to support the process of promulgating CALPUFF as a preferred model in the *Guideline*. While the primary regulatory niche for CALPUFF is for long range transport (LRT) applications, with transport distances beyond 50 kilometers, the scope of the scientific peer review also included the potential application of the model for near-field dispersion (≤ 50 kilometers). The assessment of CALPUFF's appropriateness for near-field applications in the peer review comments is very general and limited. Only one reviewer explicitly addressed the Peer Review Charge question related to the adequacy of model performance evaluations and sensitivity studies to "recommend use of the model." That reviewer's comments were that it is "a very difficult set of questions to answer," but that the answer is "probably yes, because CALPUFF incorporates a basic formalism that is well understood and numerous algorithms, each of which has been reasonably well characterized individually." This reviewer also supports the response by noting that "the mesoscale and DWM [diagnostic wind model] modeling approaches used in CALMET have undergone a history of more than 20 years of test and evaluation in the meteorological and wind power communities." However, no specific examples of CALMET evaluation are cited in this peer review.

Given the reference in the peer review comments to tests and evaluations of diagnostic wind models for wind power applications, it is important to note that the requirements of wind field modeling for estimating wind power potential are very different from the requirements for near-field air quality impact assessments. Wind field modeling for wind power is typically designed to identify areas of high wind power potential and to provide a quantitative estimate of that potential for planning purposes. However, actual siting and installation of wind turbines would typically be further supported by more detailed site assessments. On the other hand, wind field modeling for near-field air quality assessments may determine whether or not an emission source will be constructed and permitted to operate at a given site, without any additional means of assessing potential impacts prior to operation.

It should also be noted that while model evaluations for wind power applications may be relevant to some near-field applications of CALMET, for the most part the meteorological conditions associated with high wind energy potential, i.e., high-wind/neutral conditions, are less technically challenging to simulate with acceptable accuracy than the meteorological conditions of most concern for air quality applications, i.e., light wind, stable conditions. These high-wind/neutral conditions will also be less subject to significant spatial variability in the wind field, thus making it more likely the peak concentrations will be through line-of-sight plume impaction on nearby terrain. As noted in paragraph 7.2.8(a) of the *Guideline* regarding the complex winds of interest for CALPUFF near-field applications, "geographic effects are most apparent when the ambient winds are light or calm."

The conclusion from this assessment is that the EPA-sponsored scientific peer review of the CALPUFF modeling system for near-field applications has been very limited in scope.

### 4.2. Applicability to the Problem

Since the stated goal of using a non-steady-state modeling system for a near-field complex wind situation is "to fully treat the time and space variations of meteorology effects on transport and dispersion," a significant part of the focus for addressing the applicability of the CALPUFF modeling system will be on the ability of CALMET to adequately simulate the non-steady-state meteorology. Given the very case-specific nature of near-field complex wind modeling applications, the criterion of applicability to the problem should be determined based on some of the case-specific considerations discussed in previous sections. The applicability determination should also be supported by relevant model performance demonstrations. As noted above, AERMOD's performance for near-field regulatory modeling applications has been well-documented based on a total of 17 field study evaluation databases[3,4], whereas there has been no comprehensive demonstration made that the CALPUFF modeling system performs as well or better than AERMOD for near-field regulatory applications in complex terrain based on field study data.

The one evaluation study often cited to support the use of CALPUFF for near-field applications is the Lovett power plant complex terrain field study[7]. While CALPUFF shows good performance for the Lovett evaluation, as documented in the IWAQM Phase 2 Report[8], the AERMOD model exhibits comparable performance results for that data set[3]. However, the published CALPUFF performance evaluation results for Lovett are not well-suited as a demonstration of CALPUFF modeling system performance for near-field complex flow applications for two important reasons. First, the Lovett field study consists of an elevated stack located in the Hudson River valley, with $SO_2$ monitors located along the adjacent ridges. This situation would not qualify as a complex flow application for CALPUFF since the effects of complex winds as defined in paragraph 7.2.8 of the *Guideline* are not expected to contribute significantly to the design concentration, which will clearly be dominated by the elevated plume impacting the adjacent terrain through a "line-of-sight" trajectory. Secondly, the published CALPUFF evaluation results for Lovett are based on use of the CTDM surface and profile meteorological inputs and use of the Complex Terrain algorithm for Sub-Grid-scale features (CTSG) option in CALPUFF, options that essentially emulate the CTDMPLUS model and bypass the CALMET meteorological processor completely[9]. Therefore, the published Lovett evaluation results provide no information on the performance of CALMET in simulating non-steady-state winds in this near-field setting.

The diagnostic wind field model in CALMET has some limitations that are important to recognize and understand in relation to the question of applicability for near-field applications. Some of these limitations are generic to the use of any gridded meteorological model, while other limitations stem from specific formulations within CALMET. A generic limitation of gridded models is that their ability to simulate terrain responding wind fields may be severely limited by the horizontal resolution of the input terrain and land use data as represented within the model grid. For example, a river valley that is about 1 kilometer wide from peak to peak and about 500 meters deep would not be adequately resolved by a 250 meter grid spacing, which has been a typical minimum grid resolution for near-field modeling. A single grid cell could span the entire valley wall from ridge top to river level, such that the slopes of the valley walls represented by gridded terrain elevations could be reduced for 50 percent or more, significantly affecting the gravity driven slope flows and other diagnostic wind field adjustments in CALMET. Vertical grid resolution will also be a significant consideration for near-field applications, especially in valley locations given the complex flow structures and significant vertical gradients that may occur in such situations.

Limitations that are inherent to CALMET formulations are largely due to its inability to ensure dynamical consistency in the simulated wind field. An example of the potential importance of this limitation is given by the phenomenon of drainage flows that often occur in valley situations under light-wind stable conditions. The three-dimensional structure of gravity-driven wind fields within a valley can be very complex, including significant discontinuities in wind direction with height. These wind fields are often associated with complex thermal structures within the valley that develop as cold air drains down from the ridge tops and accumulates within the valley. A transition from down-slope to down-valley flows will typically develop over time and with distance from the ridge, creating significant lateral and vertical gradients of wind and temperature. While limitations due to grid resolution may be important in these cases, a more fundamental limitation is CALMET's inability to simulate the thermal structures within the valley that are associated with these complex flows. The three-dimensional temperature fields computed within CALMET are based on either available upper air soundings and surface measurements or gridded prognostic model inputs, depending on user-specified options. The three-dimensional temperature fields are not adjusted to reflect the influence of these drainage flows. Furthermore, the terrain blocking effects in CALMET are determined based on a single domain-wide average lapse rate, typically computed across a layer from the surface up to 200 meters. Unless gridded meteorological inputs of sufficient resolution to capture these thermal structures within the valley are input to CALMET, they will not be reflected in the gridded CALMET outputs for use by CALPUFF. A potential consequence of this limitation is that the lapse rate used to compute plume rise in CALPUFF would not reflect the stable stratification generated by drainage flows, which could lead to an overestimation of plume height for buoyant releases and possible underestimation of ground-level concentrations. Even if the simulated wind fields within the valley are realistic, placement of the plume within the wrong grid layer due to these limitations in characterizing the thermal structure could result in significant errors in plume trajectory leading to impact estimates that reflect spatially-varying wind fields, but bear little or no resemblance to reality.

Finer grid resolutions may improve the capability of the model to simulate these complex flow structures to some degree, and may now be more feasible with the availability of finer resolution land cover and terrain data. However, CALMET currently requires that the first (lowest) grid level be 20 meters deep, and grid resolution alone cannot overcome other limitations of the model formulation. The computational burden will also increase significantly with finer grid resolutions unless the overall domain size is decreased, which could limit the applicability of the results by excluding important synoptic or mesoscale features that influence the complex winds. The sensitivity of model results to grid resolution needs to be investigated in order to assess the robustness of the model. Recent studies have shown significant sensitivity to grid resolution, with some evidence of a possible bias toward lower concentrations as grid resolution increases. These sensitivities to grid resolution are still being examined to determine the key contributing factor(s), and whether the results for finer grid resolution reflect improved model performance or are indicative of a potential bias toward underprediction.

While CALMET incorporates terrain-blocking and slope-flow algorithms that may account for some of the complex flows that occur in complex terrain settings, cross-valley circulations are also common occurrences in some valleys, driven by differential heating that occurs during the daytime as the sun heats one side of the valley wall while the other side is shaded. These circulation patterns will vary depending upon the orientation of the valley and solar elevation angle (based on time of day and season), and may significantly affect plume transport and dispersion depending on the location of the source relative to the valley orientation. CALMET currently does not account for these circulation patterns in the slope flow algorithms since there is no mechanism to account for the differential heating that drives the circulation. As a result, if these cross-valley circulations are important to the design value determination, then the applicability of CALPUFF would be limited.

As noted above, since “the purpose of choosing a modeling system like CALPUFF is to fully treat the time and space variations of meteorology effects on transport and dispersion,” the applicability of CALPUFF for near-field situations may depend on the model’s ability to estimate air quality impacts with skill in terms of the actual temporal and spatial distribution of impacts. If the modeling system lacks demonstrable skill in terms of temporal/spatial pairing of impacts, or at least demonstrably better skill than the preferred model, then the argument for applicability to the problem is seriously undermined. The lack of a detailed independent assessment of the applicability of the CALPUFF modeling system, and in particular the CALMET meteorological processor, for near-field applications involving complex winds raises serious doubts as to whether the second criterion of paragraph 3.2.2(e) has been adequately met in a general sense. As a result, the burden to demonstrate applicability for specific applications remains relatively high.

4.3. Availability of Necessary Data Bases

The appropriateness of a particular model for a given application may depend in part on the availability of the necessary data bases to support its use. For near-field applications of CALPUFF, the necessary data bases include meteorological data (both surface and aloft), terrain elevation data, and land use/land cover data. The quality and representativeness of available meteorological data will often be a critical, but difficult issue to address for these applications. Due to the very nature of complex wind applications, involving spatially non-uniform wind fields, the representativeness of meteorological measurements at particular locations within the domain relative to the dominant flow structures across the domain will be difficult to determine. The ability of the wind field model to properly account for these influences in its use of such data deserves further consideration.

The assessment of available data bases is further complicated by limitations of CALMET with respect to its ability to utilize site-specific meteorological measurements in generating the three-dimensional wind fields and thermal structures. The most direct approach for inputting site-specific meteorological measurements to CALMET is as surface observations. However, all surface winds, including National Weather Service (NWS) and site-specific data, are adjusted from anemometer height to the midpoint of the first CALMET level, which is hard-wired to 10 meters above ground. The default value specified for the controlling parameter in CALMET (IEXTRP = -4) is to extrapolate winds from anemometer height to 10 meters based on similarity theory profiling, including wind speed and direction adjustments. Even the CALMET option which is documented as the “no extrapolation” option (IEXTRP = 1) still extrapolates all surface wind speeds to 10 meters based on a neutral log profile. Meteorological measurements from multi-level towers, which may provide valuable information regarding vertical profiles of wind and temperature, can be input to CALMET as separate “surface stations” for each tower level, with different anemometer heights to reflect the measurement heights. However, for these cases CALMET will extrapolate winds for each tower level to 10 meters, and these collocated wind measurements will be represented by a single wind "observation" at 10 meters based on the average of the u- and v-components of the wind across the levels. This effectively destroys any site-specific information on the vertical wind profiles, which could compromise this aspect of the applicability determination.

The treatment of multiple levels of site-specific temperature data may be as important as the treatment of site-specific wind data in some cases. Multiple level temperature measurements could be used to determine a site-specific lapse rate to more accurately account for terrain-blocking effects and to calculate plume rise for buoyant releases. Similar to wind profiles, CALMET treats the multi-level temperature measurements as a single surface temperature based on an average across the levels. As with multi-level wind measurements, this not only loses any information on the vertical temperature structure reflected in the measurements, but replaces it with an inaccurate pseudo-observation.

Another option that may be considered for some near-field applications of CALPUFF is the use of gridded meteorological inputs from a prognostic meteorological model, such as MM5. Gridded prognostic meteorological data has been widely used for LRT applications of CALPUFF, and several options are available for utilizing such data within the CALMET meteorological processor. While prognostic models have been routinely applied for several years to simulating non-steady-state wind fields at meso- to synoptic scales (with grid resolutions of about 4 kilometers or greater), many complex wind phenomena that might prompt the need for a non-steady-state dispersion model will require treatment of smaller scales of motion. Advances in computing capabilities have allowed for finer-scale applications of these models in recent years. However, the issues of grid resolution discussed in Section 4.2 in relation to CALMET would also apply for prognostics models. Until such time as prognostic models have been demonstrated to be capable of simulating the necessary non-steady-state features of the wind field adequately for the CALPUFF model, effectively bypassing the need for a diagnostic model like CALMET, the user will be faced with the challenges associated with blending prognostic meteorological fields with observations.

The blending of prognostic meteorological data with observations is a generic issue related to the use of CALPUFF for both near-field and LRT applications, and some problems have been encountered with this aspect of the model. CALMET includes a number of options for controlling how observations are blended with prognostic model inputs, or with the initial guess wind field generated from upper air data in the absence of prognostic data. In general, CALMET applies an inverse-distance squared approach for the initial adjustment of gridded met winds to observations, and one of the key user-specified parameters is the radius of influence. While CALMET currently applies a single user-specified radius of influence for all surface observations, other options are available, such as barriers, to isolate the potential impact of some observations on certain portions of the domain. This technique may be necessary, for example, to restrict an observation taken in a river valley from influencing the wind field on the other side of the ridge.

These adjustments to the wind field to blend with observations lack any physical mechanisms that would ensure dynamical consistency of the blended wind fields. This can result in very unrealistic flow patterns within portions of the modeling domain if the observation differs from the initial guess wind field provided by the prognostic model. The blended wind fields are then smoothed and further adjusted to minimize divergence in most cases. While these latter steps may be reasonable for larger scale domains typical of LRT applications, their appropriateness for adjusting wind fields in near-field settings may be questionable. As noted above, the wind and temperature fields of importance to near-field complex wind applications may be characterized by sharp gradients both vertically and horizontally, and some of the important terrain-responding flows may also be inherently divergent. Applying simple techniques, such as inverse-distance weighting, smoothing, and divergence minimization may introduce unrealistic features to the wind field in near-field applications.

The other alternative to the treatment of inputting multi-level measurements to CALMET as separate surface observations is to construct a pseudo-upper-air sounding from the available measurements. However, this is not a very practical alternative and may require manufacturing data to extend the profile in some cases. This approach could also result in and may result in the site-specific profiles of wind and temperature being applied across portions of the domain for which they are not representative. The only option to directly utilize site-specific information on vertical wind and temperature profiles from multi-level towers in the CALPUFF modeling system is to bypass the CALMET processor and input the data directly to CALPUFF as CTDM or AERMET surface and profile files, as was done in the CALPUFF evaluation for Lovett. As noted above, the latter approach is not consistent with the intent of the *Guideline* for near-field applications of CALPUFF, which is to "fully treat the time and space variations of meteorology effects on transport and dispersion."

## 4.4. Appropriate Performance Evaluations

One of the requirements for the use of an alternative model stated in paragraph 3.2.2(e)(iv) of the *Guideline* is that "appropriate performance evaluations of the model have shown that the model is not biased toward underestimates." This is a somewhat less stringent requirement than that imposed for a preferred model, which is to demonstrate generally unbiased model performance across a range of evaluation studies. Previous sections have addressed some basic issues related to the lack of adequate model performance evaluations to support the use of CALPUFF for near-field applications, with the Lovett power plant evaluation being the case cited most often for near-field performance. Beyond the limitation noted above that the Lovett evaluation for CALPUFF did not utilize the CALMET-generated wind fields, the other issue related to performance evaluations that should be emphasized is that past model evaluation methods and metrics employed for regulatory model evaluations[10], which place little or no emphasis on temporal or spatial pairing of modeled and observed concentrations, do not adequately address the skill implied in the use of CALPUFF for most near-field applications.

The lack of appropriate performance evaluations to address this requirement for near-field applications of CALPUFF, together with a range of technical issues regarding the applicability of model algorithms and availability of adequate data bases, raises serious questions regarding whether the model can be applied with confidence that model results are not biased toward underestimates. The complexity of the model formulations and the range of options available for data input, grid resolution, wind field adjustments, etc., suggests a potentially wide range of sensitivity of modeled concentrations. These sensitivities need to be more fully documented and understood in order to build more confidence in whether and how this criterion can be met.

Preliminary results from our reassessment of the CALPUFF modeling system performance[5], including evaluations of CALPUFF for the Lovett database utilizing CALMET-generated wind fields, have documented the sensitivity of the model to some of the technical issues discussed above, such as grid resolution and treatment of site-specific meteorological inputs. The reassessment of CALPUFF model performance has also raised additional concerns regarding the theoretical basis for the applicability of CALPUFF to near-field complex wind situations, which are still being analyzed, and will be further documented as appropriate.

### 4.5. Modeling Protocol

A modeling protocol establishing the methods and procedures to be followed is one of the criteria identified in paragraph 3.2.2(e) of the *Guideline* for use of CALPUFF as an alternative model for near-field applications. Given the complex technical issues and concerns discussed in previous sections in relation to use of CALPUFF for these applications, the importance of the modeling protocol cannot be overstated. The protocol should address each of the criteria discussed above, starting with the determination that treatment of complex winds is critical to estimating design concentrations, and providing justification for the determination that AERMOD is not appropriate or less appropriate than CALPUFF for that application.

The modeling protocol should provide an adequate demonstration that CALPUFF is applicable on a theoretical basis given the specifics of the particular application. The adequacy of the available data bases needed to apply CALPUFF, including the capability of the CALPUFF modeling system to effectively utilize the available data, should also be addressed. In addition to addressing the criteria in paragraph 3.2.2(e) of the Guideline, the modeling protocol should provide detailed information regarding the data sources to be used as input to the model, grid resolutions, model option settings, and how the resulting wind fields will be assessed to determine their adequacy for the particular application.

## 5. REFERENCES


1. EPA, 2008. Clarification of Regulatory Status of CALPUFF for Near-field Applications, memorandum from Richard A. Wayland to Regional Air Division Directors, dated August 13, 2008. http://www.epa.gov/scram001/clarification of regulatory status of calpuff.pdf
2. EPA, 2005. Guideline on Air Quality Models, 40 CFR Part 51, Appendix W. Published in the *Federal Register*, Vol. 70, No. 216, November 9, 2005. http://www.epa.gov/scram001/guidance/guide/appw_05.pdf
3. Perry, S. G., A. J. Cimorelli, R. J. Paine, R. W. Brode, J. C. Weil, A. Venkatram, R. B. Wilson, R. F. Lee, and W. D. Peters, 2005. AERMOD: A Dispersion Model for Industrial Source Applications. Part II: Model Performance against 17 Field Study Databases. *J. Appl. Meteor.,* **44**, pp. 694-708.

4. EPA, 2003. AERMOD: Latest Features and Evaluation Results. EPA-454/R-03-003. U.S. Environmental Protection Agency, Research Triangle Park, NC. http://www.epa.gov/scram001/7thconf/aermod/aermod_mep.pdf
5. EPA, 2008. Reassessment of CALPUFF Model Performance (draft report).
6. Allwine, J.K., W.F. Dabberdt, and L.L. Simmons, 1998. Peer Review of the CALMET/CALPUFF Modeling System, http://www.epa.gov/scram001/7thconf/calpuff/calpeer.pdf
7. Paumier, J. O., S. G. Perry, and D. J. Burns, 1992. CTDMPLUS: A dispersion model for sources near complex topography. Part II: Performance characteristics. *J. Appl. Meteor.*, **31**, pp. 646–660.
8. EPA, 1998. Interagency Workgroup on Air Quality Modeling (IWAQM) Phase 2 Summary Report and Recommendations for Modeling Long Range Transport Impacts, EPA-454/R-98-019. U.S. Environmental Protection Agency, Research Triangle Park, NC. www.epa.gov/scram001/7thconf/calpuff/phase2.pdf
9. Strimaitis, D.G., J.S. Scire and J.C. Chang, 1998. Evaluation of the CALPUFF Dispersion Model with Two Power Plant Data Sets. Tenth Joint Conference on the Application of Air Pollution Meteorology, Phoenix, Arizona. American Meteorological Society, Boston, MA. January 11–16, 1998.
10. EPA, 1992. Protocol for Determining the Best Performing Model. EPA-454/R-92-025. U.S. Environmental Protection Agency, Research Triangle Park, NC. http://www.epa.gov/scram001/guidance/guide/modleval.zip