EVALUATION OF ENHANCEMENTS TO THE CALPUFF MODEL FOR OFFSHORE AND COASTAL APPLICATIONS

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INTRODUCTION

The U.S. Department of the Interior Minerals Management Service (MMS) is in charge of a national program to develop the mineral resources, including oil and gas, on the Outer Continental Shelf (OCS) waters of the United States. The areas of development are located at distances ranging from a few kilometers to more than 160 kilometers from shore. In the early 1980s, the MMS sponsored the development of the Offshore & Coastal Dispersion (OCD) model (Hanna et al., 1985) to evaluate impacts from the "criteria" pollutants (NO_2, SO_2, CO, PM_{10}) emitted from point, line, or area sources located over water.

Since the science of dispersion modeling has made significant advances over the last couple of decades, there was a need to develop a model for application to emission sources on the OCS that incorporates the most current knowledge on meteorology and dispersion and is versatile enough to be used in long-range as well as short-range applications. This extended abstract summarizes the refinements made to the CALPUFF modeling system (Scire et al., 2000a, b) to enhance its capabilities to be used as a regulatory model for determining air quality impacts from emission sources located over water at source-receptor distances ranging from a few tens of meters to several hundred kilometers and the results of the evaluation of the revised model. CALPUFF is a regulatory air quality model recognized by the U.S. Environmental Protection Agency as a *Guideline Model* for long range transport applications and on a case-by-case basis for near-field applications in complex flow situations (*U.S. Federal Register*, April 15, 2003).

MODEL ENHANCEMENTS

As part of the model enhancement program, changes were made to both the CALMET and CALPUFF models based on a literature review.

1.7. New CALMET features

An option is provided in CALMET to include the COARE (Coupled Ocean Atmosphere Response Experiment) overwater flux model (Fairall et al., 2002) Version 2.6bw as well as previous options based on the OCD model. The user selects the overwater boundary layer model as one of the following options: Option 0: OCD-like original flux model (default); Option 10: COARE with no wave parameterization (Charnock parameter for the open ocean, or "deep water" which can modified for "shallow water"); Option 11: COARE with wave option 1 (Oost et al., 2002) and default equilibrium wave properties; Option -11: COARE with wave option 1 (Oost et al., 2002) and observed wave properties (provided in revised SEA.DAT input file); Option 12: COARE with wave option 2 (Taylor and Yelland, 2001) and default equilibrium wave properties; and Option -12: COARE with wave option 2 (Taylor and Yelland, 2001) and observed wave properties (provided in revised SEA.DAT input file).

It was found that the original mixing height algorithm in the CALMET model, which consisted of only mechanically-derived mixing over water surfaces, sometimes underestimated mixing heights in the Gulf of Mexico, especially during light wind conditions over warm water. As a result, convective overwater boundary layer heights are now computed under conditions of positive surface heat flux over water. The mixing height over water is taken as the maximum of the mechanical and convective mixing heights, as CALMET has always done over land surfaces. In addition to the existing convective mixing height scheme, based on Maul (1980) and Carson (1973), an option for a new parameterization (Batchvarova and Gryning, 1991, 1994) has been incorporated into CALMET. The Batchvarova and Gryning method can be applied both over water and land surfaces.

Other changes to CALMET include an explicit adjustment of observed buoy winds from reported anemometer heights to 10m (middle of CALMET layer 1) and the application of consistent similarity profile equations are used throughout system.

1.8. New CALPUFF features

A building downwash adjustment is introduced for elevated structures (e.g., offshore oil platforms) with an open area between the surface and the bulk of the structure. This platform height is provided as the new variable for point sources, and applies to the ISC downwash option in the model (Schulman-Scire/Huber-Snyder building downwash modules).

A new option is provided for computing turbulence profiles using the AERMOD algorithms. The use of the original CALPUFF turbulence profiles or the AERMOD profiles is selected by the user. A new option is provided in CALPUFF to accept the AERMOD version of SURFACE and PROFILE meteorological data files.

In addition, a diagnostic option is provided to specify the Lagrangian time-scale for lateral plume growth functions, either using the Draxler (1976) value (default), a computed time scale based on the SCIPUFF model formulation, or to allow a direct user input of the Lagrangian time-scale.

The importance of several of these features is assessed in this evaluation. Alternative CALMET simulations were made with each of the COARE and mixing height options. Alternative CALPUFF simulations were made with each turbulence profiling option, and with the Draxler and SCIPUFF lateral Lagrangian timescale options. In addition, CALPUFF simulations were made with two choices for the minimum lateral turbulence velocity: 0.37m/s and 0.5m/s. The CALPUFF default setting over land is 0.5m/s, but prior OCD evaluations had indicated that 0.37m/s provided better results for overwater dispersion experiments.

MODEL EVALUATION

The model evaluation tests were conducted using five experiments: (1) Cameron, Louisiana experiment conducted along the coast of the Gulf of Mexico during 4 test days in July 1981 and 5 test days in December 1982; (2) a tracer dispersion study in the Carpinteria area conducted along the California coast during 10 test days in September and October 1985; (3) a tracer dispersion study in the Pismo Beach, CA area was conducted along the California coast during 5 test days in December 1981 and 5 test days in June 1982; (4) a tracer dispersion study in the Ventura area was conducted along the California coast during 4 test days in September 1980 and 4 test days in January 1981; and (5) the tracer dispersion study over the strait of Oresund was conducted between the coasts of Denmark and Sweden during 9 test days between May 15 and June 14, 1984.

The results of the first four experiments (Cameron, Carpinteria, Pismo Beach and Ventura) are grouped together for purposes of the sensitivity tests and model comparison. The results in the left panel of Figure 1 show that the best performance is with Cases A and E (CALPUFF with AERMOD or CALPUFF modeled Iy and Draxler Fy. The performance with a minimum σ_v of 0.37 m/s over water is better than with the larger value of 0.5 m/s. The performance is substantially worse for the C and G cases (modeled Iy, with the SCIPUFF variable Lagrangian timescale for lateral diffusion). The largest influence on performance appears to be the algorithm for the Lagrangian timescale with the Draxler Fy curves performing better than the SCIPUFF formulation. Other tests show that inclusion of the COARE module in CALPUFF appears to offer a distinct performance advantage over the original OCD-based overwater flux module.

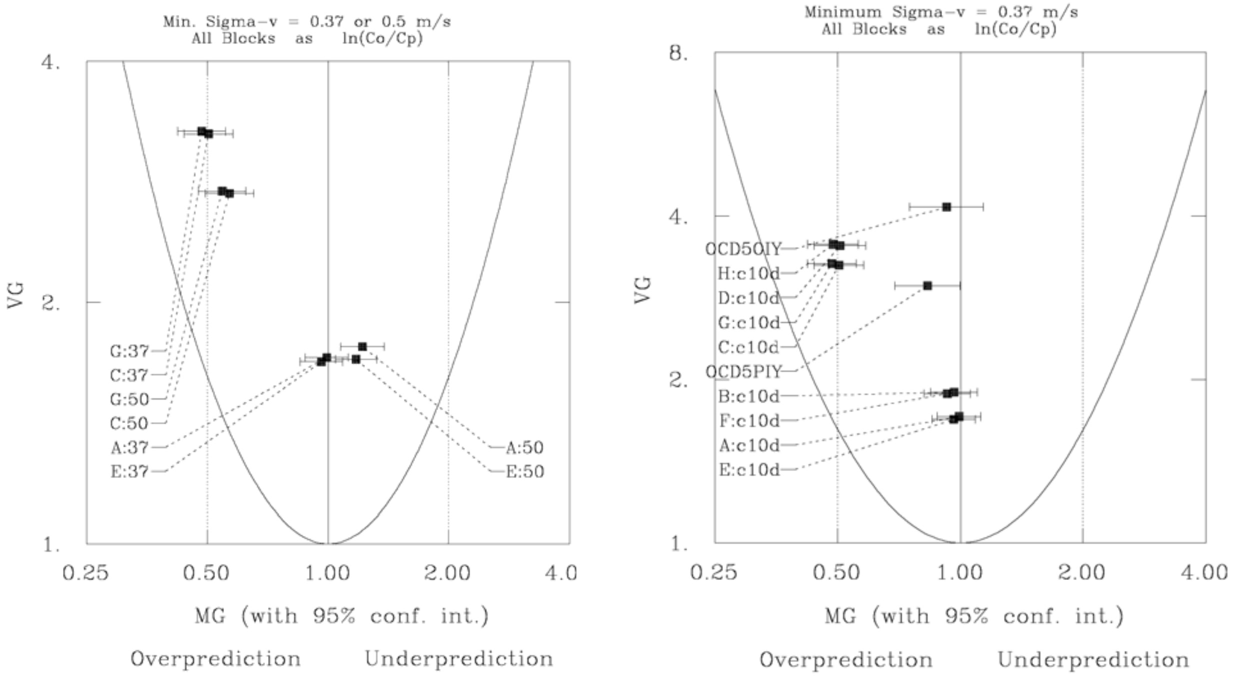

Figure 1. Cameron, Carpinteria, Pismo Beach and Ventura combined results. Left Panel: MG and VG model performance results for CALPUFF configurations with modeled Iy for minimum σ_v = 0.37 m/s (:37 labels) and 0.5 m/s (:50 labels). Right Panel: results for OCD5 and for all CALPUFF configurations with a minimum σ_v = 0.37 m/s, using CALMET with the standard COARE option (c10d). Cases are: A (modeled Iy, CALPUFF Turb(z), Draxler Fy), B (observed Iy, CALPUFF Turb(z), Draxler Fy), E (modeled Iy, AERMOD Turb(z), Draxler Fy), F (observed Iy, AERMOD Turb(z), Draxler Fy), C (Modeled Iy, CALPUFF Turb(z), SCIPUFF variable TLy), D (observed Iy, CALPUFF Turb(z), SCIPUFF variable TLy), G (Modeled Iy, AERMOD Turb(z), Variable TLy), H (observed Iy, AERMOD Turb(z), SCIPUFF variable Tly) and OCD5PIY (OCD5 with Modeled Iy) and OCD5OIY (OCD5 with Observed Iy).

The results of the performance evaluation for these four experiments for the fraction of model predictions that are within a factor-of-2 of the observations (FAC2) and the correlation are shown in Table 1. Based on these measures across all four datasets, the revised CALPUFF model improves upon the OCD model. CALPUFF has a small mean bias toward overprediction, and exhibits scatter that is typical in that it is close to a factor of 2.

A total of 16 CALPUFF simulations were run for each experiment-hour in the Oresund dataset to explore the sensitivity of model performance to the 4 CALMET configurations associated with mixing height computations, the 2 CALPUFF configurations associated with the choice for minimum σ_v and the inclusion/lack of advected turbulence. The results of the Oresund evaluation are presented in Figure 2. The results show important effects of turbulence advection. Model performance is substantially improved when turbulence advection is included. Also the Batchvarova-Gryning convective mixing height option in CALMET performs better than the Maul-Carson option.

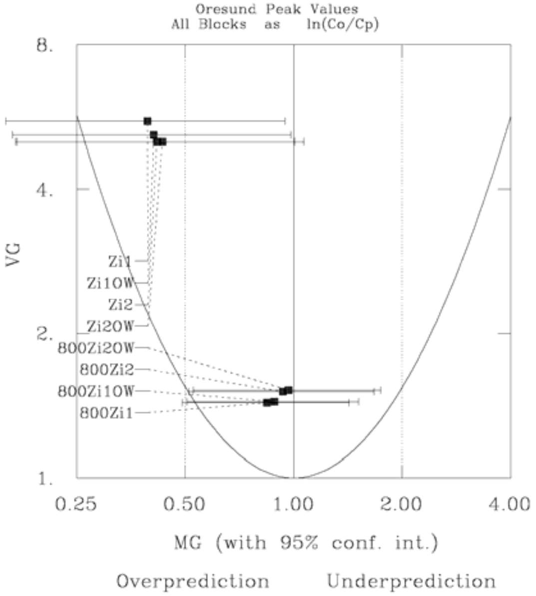

Table 1. FAC2 and Correlation Summary

Modeled Iy	**FAC2**	**Correlation**
CALPUFF model (CALPUFF Turb. Profile)	0.664	0.844
CALPUFF model (AERMOD Turb. Profile)	0.673	0.850
OCD5 model	0.536	0.712
Observed Iy	**FAC2**	**Correlation**
CALPUFF model (CALPUFF Turb. Profile)	0.600	0.829
CALPUFF model (AERMOD Turb. Profile)	0.618	0.836
OCD5 model	0.545	0.663

Figure 2. MG,VG model performance results for CALPUFF configurations with and without turbulence advection in the Oresund experiment. The cases are:

- *Zi1 – No Turb Advection, Maul-Carson Mixing Ht*
- *Zi1OW – No Turb Advection, Maul-Carson Mixing Ht , Obs Overwater*
- *Zi2 – No Turb Advection, Batchvarova-Gryning Mixing Ht*
- *Zi1OW – No Turb Advection, Batchvarova-Gryning Mixing Ht , Obs Overwater*
- *800Zi1 –Turb Advection (800s), Maul-Carson Mixing Ht*
- *800Zi1OW –Turb Advection (800s), Maul-Carson Mixing Ht , Obs Overwater*
- *800Zi2 –Turb Advection (800s), Batchvarova-Gryning Mixing Ht*
- *800Zi2OW –Turb Advection (800s), Batchvarova-Gryning Mixing Ht , Obs Overwater*

SUMMARY AND CONCLUSIONS

The results of the sensitivity tests and model evaluation indicate the following. A minimum σ_v of 0.37 m/s should be used over water surfaces (applied independently of the value used over land) in computing overwater dispersion (e.g. 0.37 m/s). The computed Lagrangian timescale approach for lateral dispersion, based on the SCIPUFF formulation, leads to unacceptably large overpredictions in CALPUFF and this is not recommended. The COARE overwater flux module improves the modeling results over the previous OCD-based model and it should be made the default in the CALPUFF model. The standard COARE option (no shallow water adjustment or wave model option) appears suitable to these coastal datasets, and there is little performance sensitivity among the COARE options. The Batchvarova-Gryning convective mixing height option in CALMET shows improved performance over the Maul-Carson option. Turbulence advection is an important modeling option to use in coastal applications with the CALMET/CALPUFF system.

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