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Development of the Next Generation Air Quality Models for Outer Continental Shelf (OCS) Applications

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1. INTRODUCTION

The purpose of this study is to develop an updated regulatory model for evaluating air quality impacts from emission sources located on federal waters on the Outer Continental Shelf (OCS). The United States Department of the Interior Minerals Management Service (MMS) is in charge of a national program to develop the mineral resources, including oil and gas and alternative energy sources (such as wind power), on the OCS waters of the United States. The areas of development are located at distances ranging from three miles to more than 100 miles from shore. In the early 1980s the MMS developed the Offshore & Coastal Dispersion (OCD) model (Hanna et al., 1985) to evaluate impacts from the so-called "non-reactive" pollutants (NO_2, SO_2, CO, PM) 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 is a need to develop a model for application to emission sources on the OCS that incorporates, to the extent feasible, the most current knowledge and is versatile enough to be used in short-range as well as long-range applications. The goal of this study is to enhance an existing air quality model for applications involving overwater transport and coastal interaction effects.

The objectives of the study are:

- To perform a comprehensive review of existing models and to evaluate their applicability to offshore applications based on current knowledge of boundary layer and atmospheric dispersion in ocean and shoreline environments.
- To revise or enhance an existing air quality model to make it suitable for offshore and coastal applications.
- To develop a software package that includes the needed meteorological pre-processors, meteorological model, air quality model, source codes, test cases, and user's guide.
- To carry out sensitivity testing and evaluate model performance against available tracer data.

The CALPUFF modeling system CALPUFF (Scire et al., 2000a, 2000b) was selected as the modeling platform. CALPUFF has been adopted by the U.S. Environmental Protection Agency (EPA) as a *Guideline Model* for Class I impact assessments and other long range transport applications, and, on a case-by-case basis, near-field applications involving complex flows, such as spatial changes in meteorological fields due to factors such as the presence of complex terrain or water bodies, plume fumigation (coastal fumigation or inversion break-up conditions), light wind speed or calm wind impacts or other conditions for which a steady-state, straight-line modeling approach is not appropriate (EPA, Federal Register, April 15, 2003). CALPUFF is also recommended for regulatory use by the Interagency Workgroup of Air Quality Modeling (IWAQM) in their Phase 2 report (EPA, 1998) and the Federal Land Managers Air Quality Related Values Workgroup (FLAG, 2000).

This Final Report contains the primary results of the model development program in terms of describing the modeling system, providing the formulation for new or revised elements of the model, describing model evaluation procedures and results, presenting the content of the MMS Standard Dataset for modeling in the Gulf of Mexico region, and providing detailed documentation and users instructions for the entire CALPUFF modeling system. It is comprised of three volumes:

Volume 1

- Technical description of those elements of CALMET and CALPUFF that are either new or revised
- Model evaluation procedures and results
- Description of the Standard Dataset for modeling in the Gulf of Mexico region
- Documentation for the gridded sea surface temperature dataset for mesoscale modeling over the Gulf of Mexico

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2. MODELING SYSTEM FOR OCS APPLICATIONS: OVERVIEW

The new model for OCS applications is an updated version of the CALPUFF (Scire et al., 2000a, 2000b) modeling system. Individual components had been compared with other modeling approaches in OCD (DiCristofaro and Hanna, 1989), AERMOD (Cimorelli et al., 2002), and SCIPUFF (EPRI, 2000) during Task 2. These comparisons included the model formulation equations as well as sensitivity tests performed on individual modules (e.g., boundary layer parameters, turbulence profiles over water, plume spread formulations). In Task 3, changes to several components in CALMET and CALPUFF were formulated (new options provided) on the basis of these comparisons. Enhancements identified in the Task 3 Report were implemented, including ease-of-use features as well as new and modified subroutines in both the CALMET meteorological model and the CALPUFF dispersion model. The performance evaluation of the new version of the model in Task 4 led to the formulation of a turbulence advection mechanism in CALPUFF when it was discovered that advected turbulence is an important feature of the dispersion documented in the Oresund experiments, when releases were made at the coast during off-shore flow.

New CALMET features:

- An option is provided to use the COARE (Coupled Ocean Atmosphere Response Experiment) overwater flux model (Fairall et al., 2002) Version 2.6bw, selected by means of the new model input variable ICOARE:
    - 0: OCD-like original flux model
    - 10: COARE with no wave parameterization (Charnock parameter for the open ocean, or "deep water" (default) – can be modified for "shallow water")
    - 11: COARE with wave option 1 (Oost et al., 2002) and default equilibrium wave properties
    - -11: COARE with wave option 1 (Oost et al., 2002) and observed wave properties (provided in revised SEA.DAT input file)
    - 12: COARE with wave option 2 (Taylor and Yelland, 2001) and default equilibrium wave properties
    - -12: COARE with wave option 2 (Taylor and Yelland, 2001) and observed wave properties (provided in revised SEA.DAT input file)
- Convective (rather than mechanical) overwater boundary layer height is computed for L<0 (positive surface heat flux). Note that the mixing height is computed only when observed values are not provided in a SEA.DAT file.
- New convective mixing height parameterization option is provided, selected by means of the new model input variable IMIXH:

- 1: Maul (1980)-Carson (1973)
- 2: Batchvarova and Gryning (1991,1994)

- Surface winds are adjusted from anemometer height to the middle of CALMET Layer 1 (usually 10m)

- Consistent similarity profile equations are used throughout system

New CALPUFF features:

- A building downwash adjustment is introduced for elevated (platform) structures with an open area between the surface and the bulk of the structure. This platform height is provided as the new variable ZPLTFM (default: 0.0) for point sources, and applies to the ICS downwash option.

- An option is provided for computing turbulence profiles using the AERMOD subroutines, selected by means of the new model input variable MCTURB:

  - 1: Standard CALPUFF subroutines (default)
  - 2: AERMOD subroutines

- A diagnostic option is provided to specify the Lagrangian time-scale for lateral plume growth functions, selected by means of the new model input variable MTAULY:

  - 0: Draxler 617.284 (s) (default)
  - 1: Computed as Horizontal Turbulence Length / (0.75 q) -- after SCIPUFF
  - 10 < Direct user input (s)
  - Only the default setting is recommended at this time.

- An option is provided to accept the AERMET version of SURFACE and PROFILE meteorological data files.

- An option is provided to include an adjustment for turbulence advection from regions of larger turbulence velocity into regions of smaller turbulence velocity. This adjustment is applied to computed (not measured) turbulence.

- The minimum lateral turbulence velocity (σ_v) allowed is partitioned to distinguish values appropriate for over-land cells and over-water cells.

BUOY processor:

- This new processor creates revised SEA.DAT files for CALMET with wave data for COARE overwater flux options –11 and -12.

- Data files readily obtained from NODC and NDBC web sites are read.

Graphical user interface (GUI) updates:

- The CALPRO system for geophysical and meteorological preprocessors and CALPOST and PRTMET postprocessors was extensively revised and enhanced.

- A GUI for the BUOY processor was developed and integrated into CALPRO.

- A GUI option was added to CALPRO for extracting a subset from the surface meteorological data, precipitation data, and ozone data from the Gulf of Mexico dataset for a user's CALMET domain.

- The CALVIEW display system for meteorological fields and concentration/deposition fields using the SURFER® contouring package was extensively revised and enhanced.

Standard Gulf of Mexico Meteorology and Ozone Dataset:

- Meteorological, geophysical and ozone data required for CALMET/CALPUFF simulations within the MMS Gulf of Mexico region were prepared for year 2003.

- USGS terrain elevation files with 90m resolution and USGS land use data files with 200m resolution were assembled for the domain.

- Buoy stations in the domain were processed into 13 SEA.DAT files (1 station/file).

- Upper-air stations in the domain were processed into 21 UP.DAT files (1 station/file).

- 230 NWS hourly surface meteorological stations in the domain were processed into the SURF.DAT file.

- 271 NWS precipitation stations in the domain were processed into the PRECIP.DAT file.

- 201 ozone data stations in the domain were processed into the OZONE.DAT file.

- One full year (2003) of gridded prognostic meteorological output fields from the Rapid Update Cycle (RUC) mesoscale weather model were reformatted into 50 tiles (90 RUC grid-points/tile), for the portion of the 20km RUC grid that covers the MMS Gulf of Mexico domain.

- The RUCDECODE program was created to assemble RUC grid cell data from one or more tiles into a 3D.DAT file for a user's CALMET domain.

3. TECHNICAL DESCRIPTION OF SYSTEM UPDATES

3.1 CALMET

Similarity Profiles for Wind and Temperature

Some inconsistencies are found in the Monin-Obukhov similarity profile equations for wind speed and temperature used in OCD, CALMET, and COARE. The updated relations used in COARE for the extended surface layer (z/L >1) are implemented throughout CALMET.

COARE adopts the profile expressions provided in Beljaars and Holtslag (1991), who retain the Paulson (1970) and Dyer(1974) stability functions Ψ for the unstable surface layer, but propose new functions for the stable surface layer. In addition, COARE merges the stability function for the unstable surface layer with a free convection relation for large z/L (L is the Monin-Obukhov length) using a weighting parameter F_Ψ (Grachev et al., 2000):

$$\Psi = (1 - F_\Psi)\Psi_K + F_\Psi \Psi_C \tag{3-1}$$

$$F_\Psi = \frac{(z/L)^2}{1 + (z/L)^2} \tag{3-2}$$

where subscript K denotes the "Kansas" stability function, and subscript C denotes the free convection stability function.

The momentum (M) and heat flux (H) relations for the unstable surface layer (L<0) are:

$$\Psi_{MK} = 2\ln[(1 + x)/2] + \ln[(1 + x^2)/2] - 2Tan^{-1}(x) + \pi/2 \tag{3-3}$$

$$\Psi_{HK} = 2\ln[(1 + x^2)/2] \tag{3-4}$$

$$x = (1 - 16\, z/L)^{1/4} \tag{3-5}$$

$$\Psi_{MC} = 1.5\ln[(1 + y_M + y_M^2)/3] - \sqrt{3}Tan^{-1}\left(\frac{1 + 2y_M}{\sqrt{3}}\right) + \frac{\pi}{\sqrt{3}} \tag{3-6}$$

$$\Psi_{HC} = 1.5\ln[(1 + y_H + y_H^2)/3] - \sqrt{3}Tan^{-1}\left(\frac{1 + 2y_H}{\sqrt{3}}\right) + \frac{\pi}{\sqrt{3}} \tag{3-7}$$

$$y_M = (1 - 10.15\, z/L)^{1/3} \tag{3-8}$$

$$y_H = (1 - 34.15\, z / L)^{1/3} \quad (3\text{-}9)$$

The momentum (M) and heat flux (H) relations for the stable surface layer (L>0) are:

$$-\Psi_M = \frac{z}{L} + b\left(\frac{z}{L} - \frac{c}{d}\right)\exp\left(-d\,\frac{z}{L}\right) + \frac{bc}{d} \quad (3\text{-}10)$$

$$-\Psi_H = \left(1 + \frac{2z}{3L}\right)^{3/2} + b\left(\frac{z}{L} - \frac{c}{d}\right)\exp\left(-d\,\frac{z}{L}\right) + \frac{bc}{d} - 1 \quad (3\text{-}11)$$

where b=2/3, c=5, and d=0.35.

COARE Bulk Flux Algorithm Option

The COARE 2.6bw bulk flux model represents fluxes for momentum, heat, and water vapor from the sea surface to the atmosphere in terms of the mean profiles as:

$$\overline{w'x'} = \sqrt{c_x}\sqrt{c_d}\, S \Delta_x \quad (3\text{-}12)$$

where

x	is either wind speed (S), potential temperature (θ), or water vapor mixing ratio (q)
c_x	is the bulk transfer coefficient for the variable *x*
c_d	is the bulk transfer coefficient for wind speed
S	is the mean wind speed relative to the sea surface at a reference height, including a gustiness component
Δ_x	is the sea-air difference in the mean value of *x* at a reference height, x_s-$x(z_r)$

The three flux quantities can also be expressed as the similarity scaling parameters u_*, θ_*, and q_*:

$$\overline{w'u'} = -u_*^2 \quad (3\text{-}13)$$

$$\overline{w'\theta'} = -u_*\theta_* \tag{3-14}$$

$$\overline{w'q'} = -u_* q_* \tag{3-15}$$

The gustiness component of the speed is related to large-scale eddies in the convective boundary layer, and is proportional to the convective scaling velocity w_*:

$$S^2 = u^2 + v^2 + U_g^2 \tag{3-16}$$

$$U_g = 1.25 w_* \tag{3-17}$$

$$w_*^3 = \frac{g}{T}\overline{w'\theta_v'}z_i = -\frac{u_* g z_i}{T}\left(\theta_* + 0.61T\, q_*\right) = -\frac{u_*^3 z_i}{\kappa L} \tag{3-18}$$

$$\frac{1}{L} = \frac{\kappa g}{u_*^2 T}\left(\theta_* + 0.61T\, q_*\right) \tag{3-19}$$

where z_i is the mixing height (m), κ is the von Karman constant (0.4), L is the Monin-Obukhov length (m), and g is the acceleration due to gravity (m/s^2) .

The bulk transfer coefficients are defined for the reference height z_r in terms of the neutral (1/L=0) transfer coefficient (c_{xn}) and the corresponding empirical stability function for the mean profile, Ψ_x:

$$\sqrt{c_x} = \frac{\sqrt{c_{xn}}}{1 - \frac{\sqrt{c_{xn}}}{\kappa}\Psi_x(z_r/L)} \tag{3-20}$$

$$\sqrt{c_{xn}} = \frac{\kappa}{\ln\left(z_r/z_{0x}\right)} \tag{3-21}$$

The stability functions are those given in Equations 3-1 through 3-11, where Ψ_M is used for the wind speed, and Ψ_H is used for θ and q. Scalar roughness lengths are related to the roughness Reynolds number R_r:

$$R_r = u_* z_0/\nu \tag{3-22}$$

$$z_{0S} = z_0 \tag{3-23}$$

$$z_{0\theta} = z_{0q} = MIN\left(a, bR_r^{-0.6}\right) \tag{3-24}$$

where $a=1.1\cdot10^{-4}$ and $b=5.5\cdot10^{-5}$.

During execution, the bulk algorithm computes the sea-air differences from air measurements of wind speed, temperature, and humidity (water vapor), and water temperature, and iterates to find the balanced set of scaling parameters u_*, θ_*, q_*, and L that satisfy Equation 3-12. Submodels for a cool-skin water surface temperature and for the diurnal warm-layer temperature structure in the upper few meters of the water column (Fairall et al., 1996) can be activated to estimate the water surface temperature from the temperature measured below the surface. The specific humidity at the water surface is obtained from the vapor pressure of sea water (0.98 times that of pure water) evaluated at the water surface temperature.

An extension has been added in the CALMET implementation of the COARE algorithm to modify the roughness length z_0 (m) computed for shallow coastal areas. The COARE roughness length without wave model adjustments is given by:

$$z_0 = \frac{0.11\,\upsilon}{u_*} + \frac{\alpha\, u_*^2}{g} \qquad (3\text{-}25)$$

where υ is the kinematic viscosity of dry air (~$1.5\text{x}10^{-5}$ m^2/s), g is the acceleration due to gravity (m/s^2), and u_* is the friction velocity (m/s). The Charnock parameter α is held at 0.011 for u_{10} up to 10m/s and then it increases linearly to its maximum value of 0.018 at u_{10}=18m/s. The first term is the aerodynamically smooth limit in which the thickness of viscous sublayer is inversely proportional to the wind stress.

Sattler et al. (2002) describe a coupled ocean wave model (WAM) with the Danish Meteorological Institute High Resolution Limited Area Model (DMI-HIRLAM) for atmospheric forecasting. When the coupling to the wave model is turned off, the DMI-HIRLAM uses a larger Charnock parameter in shallow coastal waters. They claim that setting $\alpha = \alpha_c = 0.032$ is supported by the measurements of Oost (1998), Hansen and Larsen (1997), and Maat et al. (1991), although the wave age appears to be the parameter that controls the increased roughness. Therefore, a modifying factor for the Charnock parameter F_α is introduced in CALMET. It multiplies the COARE Charnock parameter to create a transition from a coastal value α_c to the standard COARE value α over a length scale for the coastal region, L_c:

$$F_\alpha = 1 - \left(1 - \frac{\alpha_c}{\alpha}\right) \exp\left[-\left(\frac{x}{L_c}\right)^4\right] \qquad (3\text{-}26)$$

This factor is order α_c/α for distances less than $0.5L_c$, and is order 1 for distances greater than $1.5L_c$.

Two wave parameterizations are also available in the COARE module:

- wave=1: use the Oost et al. (2002) wave-age parameterization

$$z_0 = \frac{0.11\,\upsilon}{u_*} + \frac{50 L_P}{2\pi}\left(\frac{u_*}{c_P}\right)^{4.5} \quad (3\text{-}27)$$

- wave=2: use the Taylor and Yelland (2000) wave slope/height model

$$z_0 = \frac{0.11\,\upsilon}{u_*} + 1200 H_S \left(\frac{H_S}{L_P}\right)^{4.5} \quad (3\text{-}28)$$

where L_P is the wavelength (m) and c_P is the phase speed (m/s) of the dominant wave at the peak of the spectrum and H_S/L_P represents the significant wave slope. COARE 2.6bw contains defaults, derived for a fully developed equilibrium wave field in deep water, for significant wave height H_s and wavelength L_p and phase speed c_p for the dominant wave period:

$H_s = 0.0248*U^2$, $L_p = 0.829*U^2$, $c_p = 1.14*U$ (3-29)

The overwater bulk flux model options in CALMET include the original OCD-type model and six variants of the COARE model:

- 0: OCD-like original flux model
- 10: COARE with no wave parameterization (Charnock parameter for the open ocean, or “deep water” – can be modified for “shallow water”)
- 10: COARE with no wave parameterization (Charnock parameter modified for “shallow water”)
- 11: COARE with wave option 1 (Oost et al., 2002) and default equilibrium wave properties
- -11: COARE with wave option 1 (Oost et al., 2002) and observed wave properties (provided in revised SEA.DAT input file)
- 12: COARE with wave option 2 (Taylor and Yelland, 2001) and default equilibrium wave properties
- -12: COARE with wave option 2 (Taylor and Yelland, 2001) and observed wave properties (provided in revised SEA.DAT input file)

Two changes to COARE 2.6bw identified by MacDonald et al. (2002) are also implemented in CALMET. The first is a change in the net solar heat absorbed, which is used in the cool-skin model. This change reduces the leading coefficient applied to the incoming short-wave radiation from 0.137 to 0.060, which in turn corrects an observed problem in the computed evaporative cooling. The second change imposes a minimum wind stress of 0.002N/m^2 in the calculation of the warm layer thickness. The thickness could become exceedingly small in calm or near calm conditions, leading to unrealistic skin temperature increases.

Anemometer Height Adjustment for Layer 1

An adjustment to near-surface measured wind speeds is applied to estimate the speed at the mid-point height of Layer 1 (usually 10m above the surface). Previously, such an adjustment must be accomplished outside of the CALMET/CALPUFF system. Anemometer heights are provided for all surface wind stations used in an application, so similarity theory, or even a simple power law adjustment, can be used to make the adjustment.

CALMET supports an option to scale the near-surface measured winds to other layers aloft using either similarity theory, a stability-dependent power law, or a user-supplied set of multipliers (one for each layer). The same option has been implemented for adjusting the observed surface data to a height of 10 m, for Layer 1. In addition, if no extrapolation to layers aloft is selected, a neutral logarithmic wind profile is applied to estimate the wind speed at 10m from that measured at anemometer height.

Wind speed extrapolation is controlled by variable IEXTRP. For layer 1, the following options are available:

IEXTRP =	1	extrapolate vertically using a logarithmic wind profile
	2	extrapolate vertically using a power law equation
	3	extrapolate vertically using user-defined scaling factors
	4	extrapolate vertically using similarity theory

If z_m is the anemometer height (m) of the surface wind observation and u_m is the measured wind speed (m/s), the extrapolation equation options are:

$$1: \quad u(10) = u_m \; \frac{\ln(10/z_0)}{\ln(z_m/z_0)} \tag{3-30}$$

$$2: \quad u(10) = u_m \; (10/z_m)^P \tag{3-31}$$

$$3: \quad u(10) = u_m \; \mathrm{FEXTRP}(1) \tag{3-32}$$

$$4: \quad u(10) = u_m \frac{\left[\ln\left(\frac{10}{z_o}\right) - \psi_M\left(\frac{10}{L}\right) \right]}{\left[\ln\left(\frac{z_m}{z_o}\right) - \psi_M\left(\frac{z_m}{L}\right) \right]} \tag{3-33}$$

Following Douglas and Kessler (1988) in the Diagnostic Wind Model (DWM), a value of the power-law exponent P of 0.143 is used over land, and P of 0.286 is used over water. FEXTRP(1) is the user-specified scaling factor for Layer 1.

Batchvarova-Gryning Mixing Height Option

The Batchvarova and Gryning (1991, 1994) model for the height of the mixed layer is a zero-order model for the height that shares many similarities with the CALMET modified Carson (1973) model, based on Maul (1980). It differs in that there is a term for subsidence, and there is a newer formulation for computing the virtual potential temperature jump across the entrainment zone at the top of the layer. It also has an explicit term for the "spin-up" growth early in the development of the mixed layer. The authors state that this term is typically important only when the layer is less that 100 m.

The subsidence velocity (w_s) must be provided from the flow field. This is set to zero in the current implementation.

The rate of change of the mixing height, dh/dt, is given by:

$$\frac{dh}{dt} - w_s = \frac{\overline{(w'\theta_v')} \,/\gamma}{\dfrac{h^2}{(1+2A)h - 2B\kappa L} + \dfrac{Cu_*^2 T/\gamma g}{(1+A)h - B\kappa L}} \tag{3-34}$$

where the symbols are defined as:

γ (ºK/m)	potential temperature lapse rate above the mixed layer
$w'\theta_v'$ (ºKm/s)	kinematic heat flux at the surface
θ_v (ºK)	virtual potential temperature
κ	von Karman constant
L (m)	Monin-Obukhov length
u_* (m/s)	surface friction velocity

T (ºK) temperature

g (m/s^2) gravitational acceleration

The constants A, B, and C have suggested values of 0.2, 2.5, and 8, respectively.

Adjustments to Heat Flux in Convective Mixing Height

$$\frac{dh}{dt} - w_s = \frac{\left(\left(\overline{w'\theta_v'}\right) - \left(\overline{w'\theta_v'}\right)_{th}\right)/\gamma}{\frac{h^2}{(1+2A)h - 2B\kappa L} + \frac{Cu_*^2 T/\gamma g}{(1+A)h - B\kappa L}} \qquad (3\text{-}35)$$

where $(w'\theta_v')_{th}$ is the threshold kinematic heat flux at the surface.

Observed positive values of the surface buoyancy flux over the Gulf of Mexico during summer time when the overwater mixing layer is at equilibrium suggest that the warm surface destabilizing effect is balanced by dissipation.

Although the equilibrium might be owing to various processes such as turbulence dissipation, radiative cooling at the top of marine stratocumulus layer, or large scale subsidence, it is best modeled with a threshold surface buoyancy flux required to sustain convective mixing height growth over warm waters. Moreover it is intuitive that this threshold should increase with the convective mixing height. Therefore this threshold is expressed as a surface heat flux required to sustain convective mixing growth, per meter of mixing height. This ensures that the convective mixing heights never grow *ad infinitum* and reach an equilibrium.

A default value for the threshold parameter overwater (THRESHW), based on the observed surface buoyancy flux at equilibrium state during summer months in the Gulf of Mexico, is set to 0.05 W/m^3. THRESHW is related to $(w'\theta_v')_{th}$ by $(w'\theta_v')_{th}$ = (THRESHW)(h_{t-1})/(ρc_p) where h_{t-1} is the convective mixing height at the previous time step. THRESHW is an user-input parameter and can therefore be adjusted so that observed equilibrium conditions are best represented in the model. The threshold is implemented both in the Gryning and Batchvarova method (Equation 3-35) and in the Maul-Carson method.

A similar threshold (THRESHL) was implemented overland, although with the diurnal surface heating/cooling cycle and generally much larger values of surface heat flux over land surfaces, the threshold effect is normally much less important than over water where the positive heat fluxes may persist under cold air advection situations for days at a time.

3.2 CALPUFF

Platform Downwash

The existing CALPUFF Huber-Snyder/Schulman-Scire (HS/SS) downwash modules are used to model downwash effects due to elevated structures by using that portion of the structure that is "solid". A platform height (z_{plat}) is added to the list of variables that describe the effective building dimensions The effective building width H_w and building height H_b are prepared for each of 36 wind directions (10-degree intervals) by neglecting the gap below z_{plat}. That is, the structure is defined as if the solid portion rests on the "ground", and the EPA Building Profile Input Program (BPIP) can be used to develop the direction-specific effective height and width. Any point-source emission released on or near the structure is prescribed using the full release height h_s above the "ground", not the height above the platform deck.

The full release elevation above ground is adjusted by subtracting the platform height prior to any tests that define the downwash potential (e.g., the 2.5 building-height rule for GEP), and any downwash plume enhancements that depends on the effective stack height. This adjusted stack height is not used as the physical release height in any other calculations.

The Huber-Snyder (Huber and Snyder, 1976; Huber, 1977) technique is used for

$$h_s - z_{plat} > H_b + T_{bd} L_b \qquad (3\text{-}36)$$

where L_b is the lesser of the effective building height and width, and T_{bd} has a default value of 0.5. A negative value of T_{bd} indicates the Huber-Snyder method is used for all stacks, and a value of 1.5 results in the Schulman-Scire (Scire and Schulman, 1980; Schulman and Hanna, 1986) method always being used. If T_{Tb} is set equal to 0.5 (its default value), the CALPUFF treatment will be equivalent to that in ISC3.

When the Huber-Snyder technique is used, the first step is to compute the effective plume height H_e due to momentum rise at a downwind distance of 2 H_b. This rise uses the wind speed at the full stack height, h_s. If (H_e–z_{plat}) exceeds H_b + 1.5 L_b, building downwash effects are assumed to be negligible. Otherwise, building-induced enhancement of the plume dispersion coefficients is evaluated. For adjusted stack heights h_s–z_{plat} less than 1.2H_b, both σ_y and σ_z are enhanced. Only σ_z is enhanced for adjusted stack heights above 1.2 H_b (but below H_b + 1.5 L_b). Enhancements to σ_y and σ_z are not functions of h_s or h_s-z_{plat}.

When the Schulman-Scire technique is used, a linear decay factor is applied to the building-induced enhancement of the vertical dispersion coefficient, and plume rise is adjusted to account for the effect of downwash. The plume rise equations are not functions of h_s or h_s-z_{plat}. The linear decay factor for σ_z is determined as:

$$\sigma_z'' = A\,\sigma_z' \qquad (3\text{-}37)$$

where σ_z' is determined from the HS downwash equations, and

$$A = \begin{cases} 1 & H_e \le (H_b - z_{plat}) \\ \dfrac{H_b - (H_e - z_{plat})}{2L_b} + 1 & H_b < (H_e - z_{plat}) \le H_b + 2L_b \\ 0 & H_b + 2L_b < (H_e - z_{plat}) \end{cases} \qquad (3\text{-}38)$$

AERMOD Turbulence Profile Option

The turbulence velocity for horizontal fluctuations is computed from contributions from shear and buoyancy. The total turbulence velocity is obtained by summing the component variances:

$$\sigma_v = \sqrt{\sigma_{vs}^2 + \sigma_{vb}^2} \qquad (3\text{-}39)$$

The shear component is modeled with a variance that is a maximum at the ground (σ_{vs}^2=3.6u_*^2), and decreases linearly through the depth of the mechanically mixed layer to a residual value of 0.25 m^2/s^2, if this residual value is less than the value at the ground. If the residual value is larger, the value at the ground is used for all heights. The buoyancy component is constant (σ_{vb}^2=0.35w_*^2) up to z_i, and decreases linearly to the residual value at 1.2z_i. Again, the value at the ground is used at all heights if it is less than the residual value.

The turbulence velocity for vertical fluctuations is also computed from shear and buoyancy contributions. The buoyancy component of the variance is computed as:

$$\sigma_{wb}^2 = 1.6 w_*^2 (z/z_i)^{2/3} \quad (z \le 0.1 z_i) \qquad (3\text{-}40)$$

$$\sigma_{wb}^2 = 0.35 w_*^2 \quad (z = 0.1 z_i \text{ to } z_i) \qquad (3\text{-}41)$$

$$\sigma_{wb}^2 = 0.35 w_*^2\, e^{-6(z - z_i)/z_i} \quad (z > z_i) \qquad (3\text{-}42)$$

The shear component has both a surface-driven contribution (from u_*) and a residual contribution from turbulence aloft that is assumed to have an intensity of order 2% of the wind speed at z_i:

$$\sigma_{ws}^2 = 1.3 u_*^2 (1 - z/z_i) + (0.02\, u_{zi}\, z/z_i)^2 \quad (z \le z_i) \qquad (3\text{-}43)$$

$$\sigma_{ws} = 0.02\, u_{zi} \quad (\, z > z_i\,) \tag{3-44}$$

The total turbulence velocity is obtained from the sum of these components:

$$\sigma_w = \sqrt{\sigma_{wb}{}^2 + \sigma_{ws}{}^2} \tag{3-45}$$

Minimum Turbulence Velocities

CALPUFF accepts minimum lateral turbulence velocities σ_v as a function of stability class (6 values). A minimum value establishes a floor, so that any computed lateral turbulence less than the minimum is replaced. The default value for each stability class had been set to 0.5m/s. An additional set of minimum values for overwater cells has been added, so now there are 12 values, two for each stability class. The original set of six is now used for overland cells, and the default of 0.5m/s is retained. The AERMOD minimum lateral variance, 0.25 m^2/s^2, is equivalent. The new set of six used for overwater cells is set to a default of 0.37 m/s, a value originally used in the OCD model for overwater dispersion, and one that performed well in the model evaluations with the offshore tracer data sets.

Similarly, a set of overland and overwater minimum vertical turbulence velocities σ_w are also accepted, two for each stability class (12 values). The default values for overwater cells are equal to those for overland cells.

```
                  ----------  LAND  ----------        ---------  WATER  ----------
Stability Class :  A    B    C    D    E    F          A    B    C    D    E    F
                  ---  ---  ---  ---  ---  ---        ---  ---  ---  ---  ---  ---
  Default SVMIN : .50, .50, .50, .50, .50, .50,       .37, .37, .37, .37, .37, .37
  Default SWMIN : .20, .12, .08, .06, .03, .016,      .20, .12, .08, .06, .03, .016
```

Lateral Puff Timescale Diagnostic Option

For steady homogeneous dispersion, Taylor's (1921) original expression for lateral plume spread σ_y as a function of time is:

$$\sigma_y^2 = 2\sigma_v^2 \tau \left(t - \tau + \tau \exp\left(-\, t / \tau\right)\right) \tag{3-46}$$

where τ is the Lagrangian timescale and σ_v is the lateral turbulence intensity. This is typically approximated as:

$$\sigma_y = \sigma_v t / \left(1 + \sqrt{t / 2\tau}\right) \tag{3-47}$$

which has the same limits as Equation 3-46 for small and large t/τ. Lateral growth in CALPUFF uses Draxler's (1976) expression, which is equal to Equation 3-47 when τ=617.3s.

Two methods of supplying the timescale τ were implemented for testing:

- direct numeric input as a constant, and
- selection of a timescale that is proportional to a characteristic length scale in the boundary layer divided by the lateral turbulence velocity.

For the second option, a timescale estimate based on that in SCIPUFF (EPRI, 2000) is used:

$$\tau = \frac{\Lambda_H}{0.75q} \tag{3-48}$$

where q is the turbulence velocity scale and Λ_H is approximately $0.3z_i$ within much of the surface layer, and may be of order 1000m or larger outside the surface layer. In the CALPUFF implementation, testing will be limited to near-surface tracer releases so the mesoscale limit for Λ_H is not included.

SCIPUFF explicitly considers the effects of shear-driven eddies and buoyancy-driven eddies separately. Their length scales in the boundary layer (z<zi) are

$$\Lambda_B = 0.3z_i$$
$$\frac{1}{\Lambda_S^2} = \frac{1}{(0.3z_i)^2} + \frac{1}{(0.65z)^2} \tag{3-49}$$

A single length scale is formed for CALPUFF that retains the linear behavior of Λ_S near the surface, and 0.3 z_i aloft, by weighting the shear and buoyancy scales by the associated turbulence velocity variances. In neutral and stable boundary layers, the scale is simply $\Lambda_H = \Lambda_S$. In convective boundary layers (L<0) the scale is :

$$\Lambda_H = \frac{\sigma_{vS}^2 \Lambda_S + \sigma_{vB}^2 \Lambda_B}{\sigma_{vS}^2 + \sigma_{vB}^2} \tag{3-50}$$

where the SCIPUFF equations for the lateral turbulence are:

$$\sigma_{vS}^2 = u_*^2 \, 2.5(1 - z/z_i)$$
$$\sigma_{vB}^2 = w_*^2 \, 0.13(1 + 1.5e^{-z/z_i}) \tag{3-51}$$

Performance results using this computed lateral timescale that is proportional to a characteristic length scale in the boundary layer divided by the turbulence velocity have not been acceptable. Reasons for this have not been determined.

Turbulence Advection Option

Gryning (1985) presents an overview of the Oresund experiments, and comments on particular features of the boundary layer resolved by measurements made during the June 5 experiment. There is evidence of vertical motion in the flow over the Oresund strait that may be associated with the changes in surface properties across the land-sea boundary. There are also direct measurements of turbulence dissipation at a number of elevations along transects that cross the strait. One transect at about 270m on June 5 cited by Gryning shows a distinct and gradual lowering of the turbulence with distance across the strait, and an abrupt rise downwind of the far shoreline (over Copenhagen).

Initial modeling of the Oresund experiments with CALMET/CALPUFF substantially overpredicts peak concentrations in five of the nine experiments, four of these by about a factor of 10. Peak concentrations predicted for the remaining four experiments are well within a factor of two. No application issues have been identified that can account for the overpredictions, but they are all associated with elevated (95m-high) non-buoyant tracer releases from a shoreline tower on the upwind side of the strait. The initial dispersion of these releases across the 20km distance to the opposite shore is controlled by the calculated overwater turbulence, which is much smaller than the turbulence calculated over land both upwind and downwind of the strait.

This suggests that advected turbulence energy is an important factor to include in these simulations. CALMET includes the effect of advection on mixing heights and temperatures, but turbulence velocities are computed locally in CALPUFF. This local calculation can be broadened to incorporate a contribution from upwind cells.

Vickers et al. (2001) discuss the decay of turbulence energy with downwind distance in offshore flow in terms of the local value of the friction velocity at a given height. They define an advective-decay timescale τ over which the friction velocity transitions from the (larger) overland value u_{*0} to the (smaller) overwater equilibrium value u_{*eq} with transport time from the coast, t, and write:

$$u_*^2 = u_{*eq}^2 + \left(u_{*0}^2 - u_{*eq}^2\right)e^{-t/\tau} \qquad (3\text{-}52)$$

We approximate the exponential decay as a linear decay to limit the number of upwind cells to process each sampling step and write:

$$\sigma_{w,v}^2 = \sigma_{w,vL}^2 + \left(\sigma_{w,vU}^2 - \sigma_{w,vL}^2\right)\left(1 - 0.7t/\tau\right) \qquad (3\text{-}53)$$

where the $\sigma_{w,v}$ refers to either σ_w or σ_v, subscript L identifies the local value at puff height, and subscript U identifies the upwind value at the same puff height. The local cell is the cell that determines the current puff properties. The time t is determined by the wind speed at puff height in the local cell and the distance from the center of the local cell to the particular upwind cell being processed. Only cells that are upwind and within the time horizon $t = \tau/0.7$, and that have a turbulence velocity larger that the local turbulence velocity are processed, and only the largest increase in σ^2 (the second term on the right including the decay factor) is retained.

The advective-decay timescale τ is entered as a control file input to CALPUFF. A value that is representative of the Oresund experiments can be estimated from aircraft measurements. Turbulence dissipation profiles at several heights during three of the experiments are shown in Figures 3-1 through 3-3. The upwind shoreline is at about grid coordinate 370 km and the transport is to the west or from right to left in these figures. A linear decay in turbulence is approximated by eye to obtain a subjective decay distance across the strait that ranges from 12-14 km on May 29 and June 4, and 14-16 km on June 5. CALMET wind speeds in the layer between 90m and 120m during the hour in which the flights were made are extracted near the upwind shore and halfway across the strait to estimate average transport speeds near the release height (95m). The easting component of these speeds average 11.4 m/s on May 29, 12.8 m/s on June 4, and 11.8 m/s on June 5. The corresponding decay times average 1145s, so the inferred timescale ($\tau = 0.7$ t) is about 800s.

The performance evaluation of CALPUFF using the 800s turbulence advective-decay timescale shows a substantial improvement.

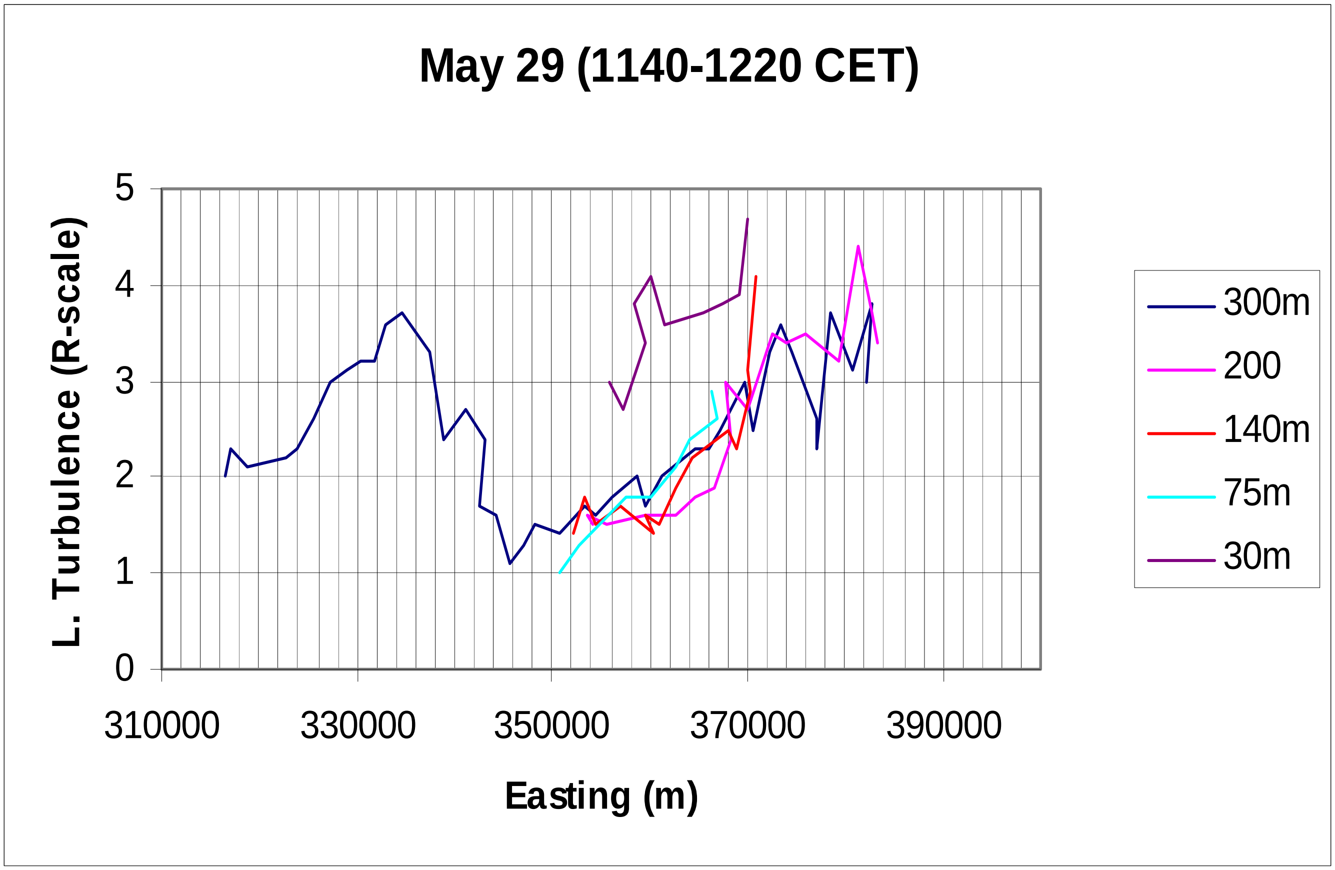

Figure 3-1. Longitudinal turbulence dissipation $\varepsilon^{1/3}$ ($cm^{2/3}/s$) measured by aircraft on May 29, 1984 along transects that cross the strait of Oresund in the study area. The east coast of the strait at Barseback is located at about 370000m Easting (UTM 33N: datum EUR-M), and the west coast is located at about 349000 Easting. The wind is from the east (right side). Altitudes listed are approximate, as the aircraft elevation varied along the transect.

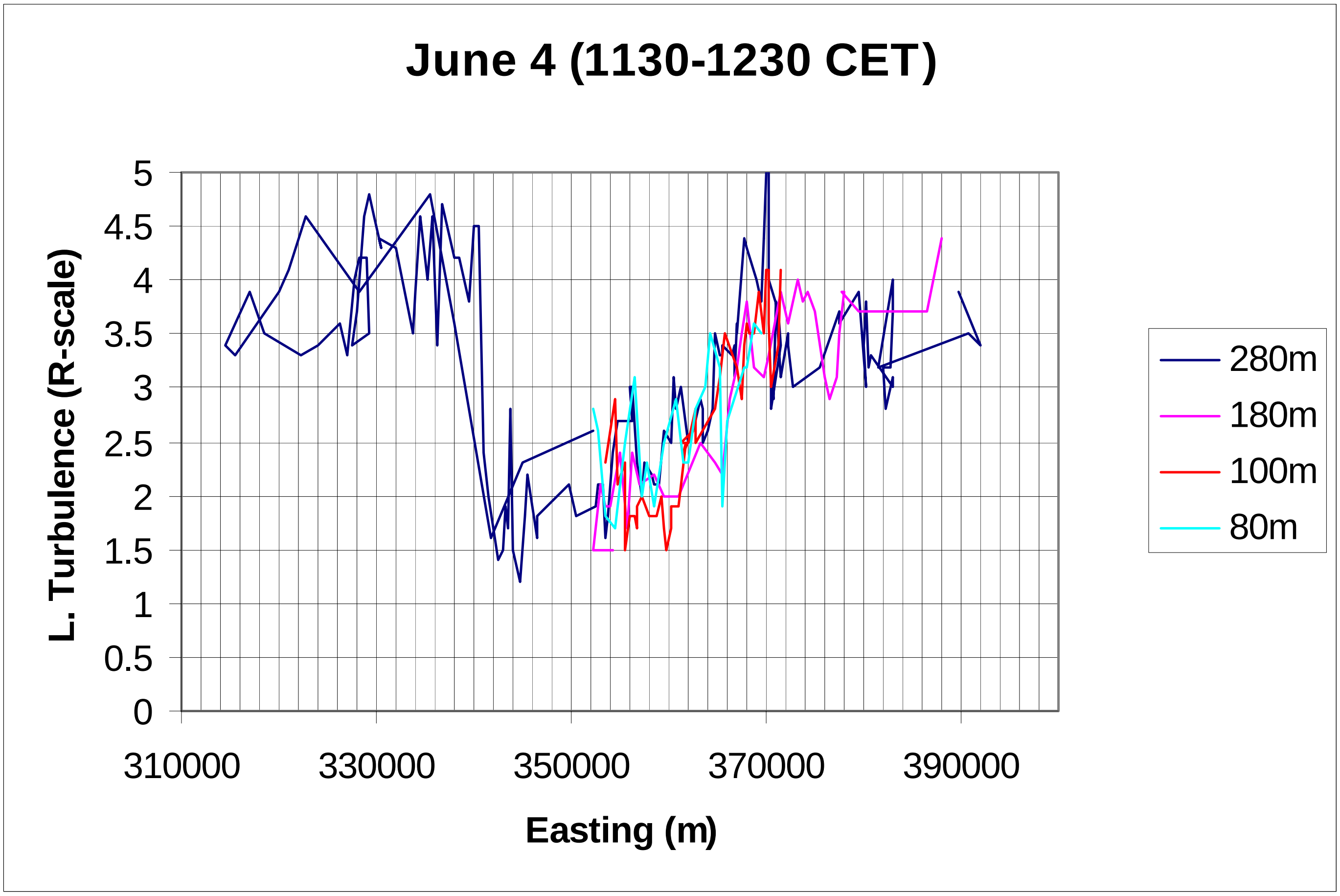

Figure 3-2. Longitudinal turbulence dissipation $\varepsilon^{1/3}$ ($cm^{2/3}/s$) measured by aircraft on June 4, 1984 along transects that cross the strait of Oresund in the study area. The east coast of the strait at Barseback is located at about 370000m Easting (UTM 33N: datum EUR-M), and the west coast is located at about 349000 Easting. The wind is from the east (right side). Altitudes listed are approximate, as the aircraft elevation varied along the transect.

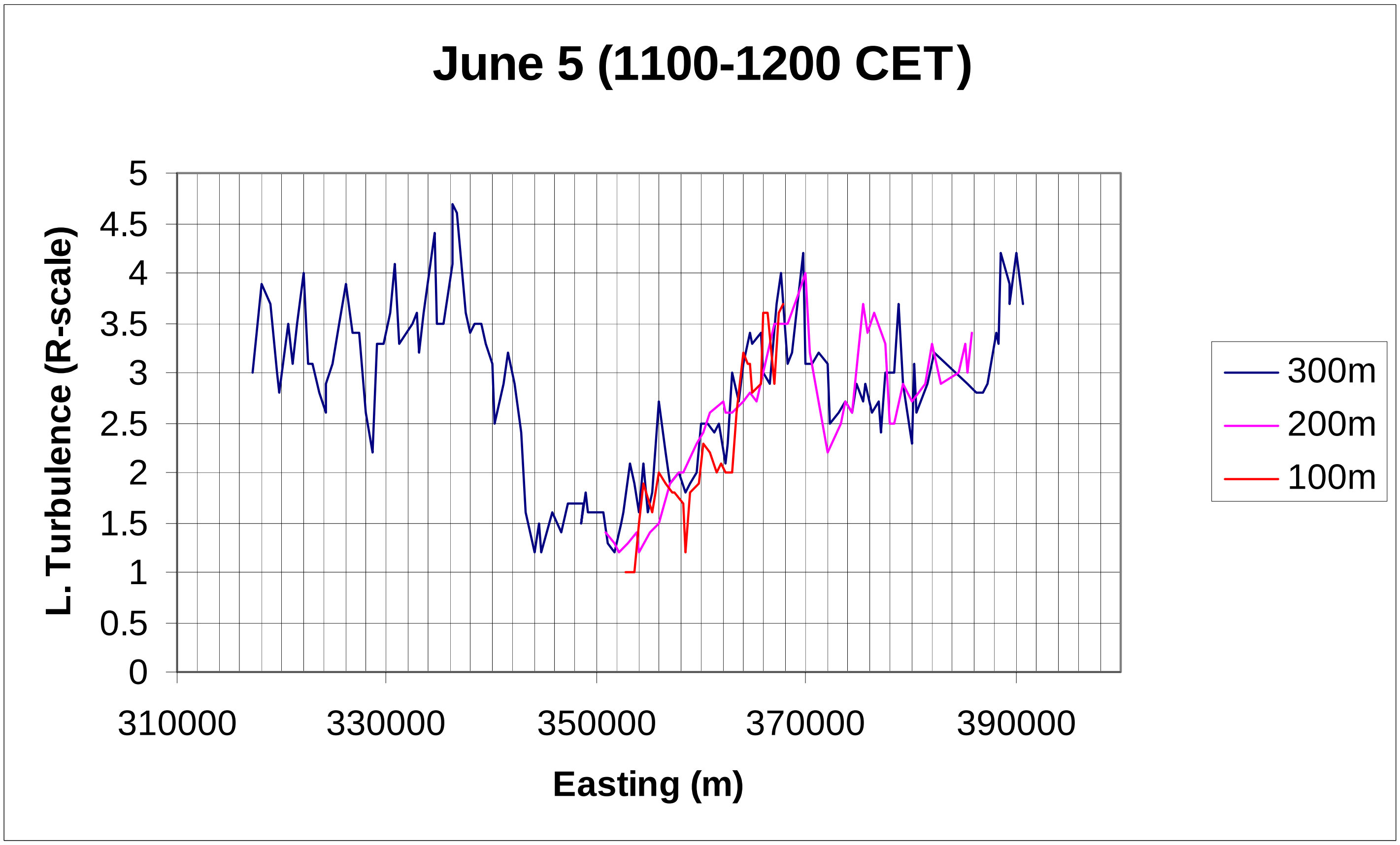

Figure 3-3. Longitudinal turbulence dissipation $\varepsilon^{1/3}$ ($cm^{2/3}/s$) measured by aircraft on June 5, 1984 along transects that cross the strait of Oresund in the study area. The east coast of the strait at Barseback is located at about 370000m Easting (UTM 33N: datum EUR-M), and the west coast is located at about 349000 Easting. The wind is from the east (right side). Altitudes listed are approximate, as the aircraft elevation varied along the transect.

4. MODEL PERFORMANCE EVALUATION

The model performance evaluation performed in Task 4 assessed overall model performance, focusing on five tracer dispersion datasets described in Task 2 that emphasize overwater transport with shoreline impact. These datasets include short-range (1 km – 8 km) overwater dispersion experiments for on-shore flow, and longer-range (22 km – 42 km) dispersion experiments with both off-shore and on-shore flow transitions. The short-range experiments test the over-water boundary layer and shoreline transition components of CALMET and CALPUFF with geophysical characteristics resolved to the limit of the 200-m land use dataset, and meteorological data developed for the overwater release locations. The longer-range experiments test both over-land and over-water components with land-water and water-land transitions, resolve geophysical features with a resolution of 1 km, and incorporate meteorological data obtained at locations across the study area. None of these datasets address model performance for transport distances on the order of 100 km to 300 km. Simulations on this scale will be made for OCS areas using the full modeling system that couples the output from a mesoscale meteorological model with the CALMET/CALPUFF system. Such simulations will depend on the transport and dispersion components of CALMET/CALPUFF evaluated here as well as the circulation features captured by the mesoscale model.

The sensitivity of simulations to the new features developed for the system is also assessed in the evaluation. Alternative CALMET simulations are made with each of the COARE and mixing height options. Alternative CALPUFF simulations are made with each turbulence profiling option, and with lateral Lagrangian timescale options 0 and 1. Note that not all options are tested for each evaluation dataset. In addition, CALPUFF simulations are made with two choices for the minimum lateral turbulence velocity: 0.37m/s and 0.5m/s. This is a user-configured property. The CALPUFF default setting is 0.5m/s, but the OCD evaluations had indicated that 0.37m/s provided better results for overwater dispersion experiments. Because CALPUFF performance for the overwater evaluation datasets improves when the minimum lateral turbulence velocity is 0.37m/s, a new overwater set of minimums has been added to the model, and the default for these is set to 0.37m/s.

4.1 Evaluation Datasets

Cameron, Louisiana

<u>Description</u>

The over water dispersion study in the Cameron, Louisiana area was conducted along the coast of the Gulf of Mexico during four test days in July 1981 and five test days in December 1982 (Dabberdt et al., 1982). The area is very flat and typically wet, with numerous swamps, lakes, fens, and bayous extending inland from the coast.

Chevron Platform 28A served as the SF_6 tracer release site on seven of the test days, and a 20m boat was used on two of the days due to the prevailing wind direction. Platform 28A is located 6.75 km from shore, and the tracer was released 13m above mean low water. The boat locations used are about four km from shore, and the tracer release was from a mast 13m above the water. Thirty-five (35) samplers placed in a single arc along the coast over a span of about 17 km provide sequential hour-averaged concentrations.

Meteorological data were obtained at Platform 28A, at a 10m mast installed on the shore 5m to 20m from the water, and at a 25m tower located 2 km inland. Horizontal and vertical profiles of temperature, dew-point temperature and turbulence were obtained by aircraft. The OCD4 evaluation dataset (DiCristofaro and Hanna, 1989) uses meteorological data from these sources in the following way:

Aircraft	estimated mixing height and overwater dT/dz
Platform 28A	water temperature, wind speed (18m), air temperature (18m)
10 m Mast	σ_θ(10m), RH(10m), wind speed (10m), air temperature (10m)

Wind speed and temperature measurements at the 10m mast are used only to replace missing values at Platform 28A. No air temperatures were measured at Platform 28A during the July 1981 experiments, so the air temperature measured at the shoreline 10m mast is used for the air-sea temperature difference in July.

Geophysical Processing

Gridded land use and terrain elevation data for the CALMET geophysical file are obtained from the United States Geological Survey (USGS). The terrain data are from the one-degree 1:250,000-scale DEM dataset, with an approximate resolution of 90m. Land use data are from the 1:250,000-scale Composite Grid Theme (CTG) dataset, with a resolution of 200m. Because the spatial variation in land use is the primary geophysical property for this application, a modeling grid is chosen that places each land use datapoint in the center of a model grid cell. The modeling grid chosen to cover the area is defined by:

Map Projection:	UTM (Zone 15N)
Datum:	NAS-C (North American 1927)
SW Corner Coordinates (km):	(464.9,3285.7)
Number of cells (nx,ny):	(135,65)
Cell Size (km):	0.200

The CALMET preprocessors TERREL, CTGPROC, and MAKEGEO are applied to convert the geophysical datasets to this modeling grid, creating the CALMET GEO.DAT file.

Coordinate transformations are applied to the source and receptor locations listed in the OCD4 model runs in order to register these features to land use and terrain data in the GEO.DAT file. The OCD4 dataset references all of these locations to Platform 28A, which is located at approximately (29˚43' N and 93˚14' W). This location is transformed to UTM Zone 15 (NAS-C) and all sampler locations are translated accordingly. The model grid of land use, an aerial photograph of the Louisiana coast in the Cameron area in the same map projection and datum, the coastline data points contained in the World Vector Shoreline dataset, and the release and sampler positions are plotted and compared to the map of sampler positions to refine the coordinate transformations needed to place the samplers along the coast. This process places Platform 28A at (477.850, 3287.225) in UTM zone 15 (NAS-C). A difference in the shape of the coastline from that shown on the experiment layout diagram requires an additional nonlinear adjustment of the samplers in the north-south direction of 330m or less in the center of the arc.

The resulting map of the experiment region is shown in Figure 4-1. The moist character of much of this region is reflected in the "wetland" classification that is assigned to over half of the land area in the grid. The sampler locations follow the coastline well, both as resolved by the gridded land use and as contained in the World Vector Shoreline dataset.

Source & Receptor Characterization

Three source locations are used in this experiment. These are characterized as modeled in the OCD4 evaluation. Platform 28A is modeled without downwash due to the lack of significant structures on the platform. The boat releases are modeled with downwash, using the boat dimensions as a solid building with the length perpendicular to the wind. A minimal exit velocity is used to remove any momentum rise.

Table 4-1
Source Characterization for Cameron, LA Tracer Releases

Source	X* (km)	Y* (km)	Ht. (m)	Elev. (m)	Diam. (m)	W (m/s)	T (°K)	Hb (m)	Lb (m)
Platform 28A	477.85	3287.225	13.0	0.0	.2	0.01	270.0	0.0	0.0
Boat 2/15/1982	482.557	3290.166	13.0	0.0	.2	0.01	270.0	7.0	20.0
Boat 2/24/1982	482.524	3289.505	13.0	0.0	.2	0.01	270.0	7.0	20.0

* Locations are in the UTM (Zone 15N) map projection with datum NAS-C

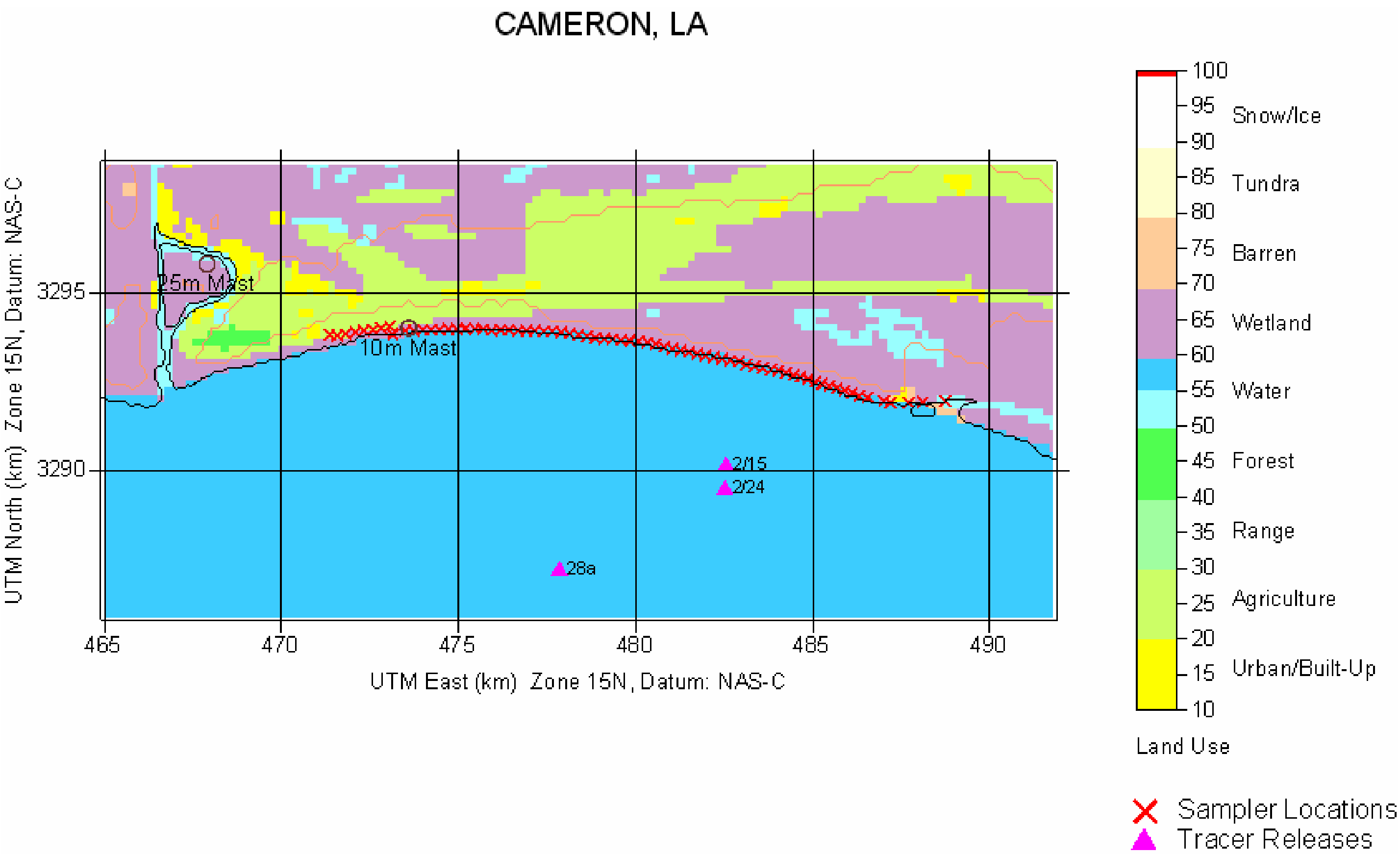

Figure 4-1. Geophysical properties of the site of the 1981/1982 Cameron, Louisiana tracer experiment, as gridded for use in the CALMET/CALPUFF simulations. The grid cell size is 200m. Tracer concentrations were measured at the indicated sampler locations. Tracer release locations indicate boat positions used on 2/15/1982 and 2/24/1982, and Platform 28A used for all other periods.

All sampler locations are used as receptors, but additional ones are added to increase the density of receptor spacing along the shoreline. Intermediate receptors are placed at approximately 50m intervals, with elevations interpolated from the actual sampler elevations. In this case, all elevations are 1.5m MSL. A total of 380 receptors are used in the CALPUFF modeling.

Meteorological Processing

Meteorological data files for applying CALMET/CALPUFF to the Cameron study are developed primarily from files used to run OCD4. The "release" meteorology identified for OCD4 is used to construct representative SEA.DAT (over water) and SURF.DAT (over land) input files for CALMET. Cloud observations made at the Cameron shoreline during the study are included in the SURF.DAT file. The SEA.DAT station is placed at Platform 28A, while the SURF.DAT station is placed onshore at (480, 3295).

The original OCD4 evaluation files indicate that air temperature and wind speed are measured at 18m for all of the hours. This is true most of the time, but there are periods when data from 10m at the shoreline mast are substituted for the 18m data at Platform 28A. This occurs on:

Temperature at 10m

7/**/1981	all hours (platform did not measure air temperature in July)
2/15/1982	all hours
2/17/1982	1300-1400
2/23/1982	1000-1100

Wind Speed at 10m

7/20/1981	all hours
2/15/1982	all hours
2/17/1982	1300-1400

The anemometer height associated with the SURF.DAT wind data during these periods is set to 10m. Because CALMET accepts a single measurement height for the speed and temperature in the SEA.DAT file, that height is reset to 10m whenever the temperature measurement height is 10m. Wind speed is profiled from the actual anemometer height to the temperature measurement height when these are different. Boundary layer parameters computed by OCD are used with Monin-Obukhov similarity profiles to compute the wind speed adjustment.

Wind directions used in the OCD4 datasets are those that align the source and the sampler with the peak concentration each hour. This allows the evaluation to focus on processes other than the net transport direction. These directions replace measured wind directions during the hours contained in the evaluation dataset. Measured wind directions are not altered for hours that are not part of the evaluation dataset.

Table 4-2 lists meteorological data used in the SEA.DAT file after the adjustments are made. The hours that correspond to the evaluation dataset are marked as bold. The lateral turbulence intensity (I_y) is used in the CALPUFF turbulence profile file.

Table 4-2a
Over-water Meteorological Data for Cameron, Louisiana
1981

Year	Month	Day	Julian Day	Hour	Height (m)	WS (m/s)	WD (deg)	Tair (^oK)	Tair-Tsea (^oK)	RH (%)	Mixing Ht (m)	dT/dz ($^oK/m$)	Iy
81	**7**	**20**	**201**	**14**	**10.0**	**4.60**	**202**	**302.4**	**-2.7**	**63.0**	**800.0**	**-0.0098**	**0.112**
81	**7**	**20**	**201**	**15**	**10.0**	**4.80**	**210**	**302.6**	**-2.6**	**64.0**	**800.0**	**-0.0098**	**0.086**
81	7	20	201	16	10.0	4.80	240.0	302.7	-2.3	65.0	800.0	-0.0098	0.141
81	7	20	201	17	10.0	5.00	243.0	302.8	-2.1	66.0	800.0	-0.0098	-999
81	7	20	201	18	10.0	4.80	243.0	302.7	-2.1	67.0	800.0	-0.0098	0.087
81	7	23	204	15	10.0	3.72	236.0	303.3	-1.8	74.0	225.0	-0.0098	0.083
81	7	23	204	16	10.0	3.52	230.0	303.4	-1.6	74.0	225.0	-0.0098	0.086
81	**7**	**23**	**204**	**17**	**10.0**	**4.19**	**232**	**303.6**	**-1.4**	**73.0**	**225.0**	**-0.0098**	**0.083**
81	**7**	**23**	**204**	**18**	**10.0**	**4.95**	**229**	**303.7**	**-1.2**	**74.0**	**225.0**	**-0.0098**	**0.083**
81	**7**	**27**	**208**	**20**	**10.0**	**2.06**	**176**	**300.2**	**-4.4**	**82.0**	**400.0**	**-0.0098**	**-999**
81	7	27	208	21	10.0	2.74	163.0	300.0	-4.5	80.0	425.0	-0.0098	-999
81	**7**	**27**	**208**	**22**	**10.0**	**4.40**	**151**	**300.0**	**-4.5**	**82.0**	**450.0**	**-0.0098**	**-999**
81	7	29	210	14	10.0	3.91	237.0	302.6	-2.1	70.0	400.0	-0.0098	0.113
81	7	29	210	15	10.0	4.39	232.0	302.8	-2.3	70.0	410.0	-0.0098	0.141
81	**7**	**29**	**210**	**16**	**10.0**	**4.49**	**218**	**303.0**	**-2.2**	**69.0**	**420.0**	**-0.0098**	**0.169**
81	**7**	**29**	**210**	**17**	**10.0**	**4.89**	**240**	**303.0**	**-2**	**68.0**	**430.0**	**-0.0098**	**0.113**
81	7	29	210	18	10.0	5.63	252.0	303.1	-1.8	67.0	440.0	-0.0098	0.141
81	**7**	**29**	**210**	**19**	**10.0**	**4.88**	**241**	**303.1**	**-1.7**	**68.0**	**450.0**	**-0.0098**	**0.169**

Note: Bold identifies hours in the evaluation dataset

Table 4-2b
Over-water Meteorological Data for Cameron, LA
1982

Year	Month	Day	Julian Day	Hour	Height (m)	WS (m/s)	WD (deg)	Tair (^oK)	Tair-Tsea (^oK)	RH (%)	Mixing Ht (m)	dT/dz ($^oK/m$)	Iy
82	2	15	46	14	10.0	5.90	140.0	286.3	-0.5	90.0	200.0	0.0502	-999
82	2	15	46	15	10.0	5.80	146.0	286.5	-0.7	89.0	200.0	0.0502	-999
82	**2**	**15**	**46**	**16**	**10.0**	**5.70**	**142**	**287.4**	**0**	**89.0**	**200.0**	**0.0502**	**-999**
82	**2**	**15**	**46**	**17**	**10.0**	**5.60**	**134**	**287.1**	**-0.8**	**88.0**	**200.0**	**0.0502**	**-999**
82	2	15	46	18	10.0	7.40	142.0	287.1	-1	88.0	200.0	0.0502	-999
82	2	15	46	19	10.0	6.40	140.0	287.5	-0.4	88.0	200.0	0.0502	-999
82	**2**	**15**	**46**	**20**	**10.0**	**5.90**	**147**	**287.4**	**-0.4**	**87.0**	**200.0**	**0.0502**	**-999**
82	**2**	**17**	**48**	**14**	**10.0**	**3.30**	**178**	**288.8**	**2.1**	**93.0**	**200.0**	**0.0202**	**0.043**
82	**2**	**17**	**48**	**15**	**18.0**	**3.70**	**195**	**288.1**	**0.9**	**93.0**	**200.0**	**0.0202**	**0.134**
82	**2**	**17**	**48**	**16**	**18.0**	**4.30**	**210**	**288.0**	**0.6**	**93.0**	**200.0**	**0.0202**	**0.068**
82	**2**	**17**	**48**	**17**	**18.0**	**3.50**	**206**	**287.7**	**-0.2**	**93.0**	**200.0**	**0.0202**	**0.066**
82	**2**	**17**	**48**	**18**	**18.0**	**3.50**	**193**	**287.4**	**-0.7**	**93.0**	**200.0**	**0.0202**	**0.036**
82	2	17	48	19	18.0	3.80	160.0	287.1	-0.8	93.0	200.0	0.0202	0.078
82	2	22	53	13	18.0	4.00	157.0	290.0	1	75.0	100.0	0.0202	0.318
82	**2**	**22**	**53**	**14**	**18.0**	**5.20**	**171**	**290.6**	**1.3**	**75.0**	**100.0**	**0.0202**	**0.047**
82	2	22	53	15	18.0	5.60	177.0	291.0	1.4	81.0	100.0	0.0202	0.048
82	**2**	**22**	**53**	**16**	**18.0**	**4.70**	**172**	**290.6**	**0.9**	**76.0**	**100.0**	**0.0202**	**0.042**
82	**2**	**22**	**53**	**17**	**18.0**	**4.50**	**182**	**290.9**	**0.8**	**76.0**	**100.0**	**0.0202**	**0.049**
82	2	22	53	18	18.0	5.60	187.0	290.6	0.5	80.0	100.0	0.0202	0.053
82	2	22	53	19	18.0	5.10	192.0	289.5	-0.6	83.0	100.0	0.0202	0.059
82	2	23	54	11	18.0	4.00	147.0	291.0	3.2	85.0	50.0	0.0152	0.101
82	2	23	54	12	18.0	3.80	150.0	290.8	3	85.0	50.0	0.0152	0.06
82	2	23	54	13	18.0	4.20	141.0	291.3	3.7	86.0	50.0	0.0152	0.099
82	**2**	**23**	**54**	**14**	**18.0**	**4.80**	**152**	**291.5**	**3.7**	**84.0**	**50.0**	**0.0152**	**0.011**
82	2	23	54	15	18.0	4.90	145.0	291.5	3.3	84.0	60.0	0.0152	0.069
82	2	23	54	16	18.0	5.40	144.0	291.0	2.4	86.0	70.0	0.0152	0.048
82	**2**	**23**	**54**	**17**	**18.0**	**6.20**	**165**	**291.2**	**2.3**	**88.0**	**80.0**	**0.0152**	**0.056**
82	2	23	54	18	18.0	6.00	155.0	290.4	2	88.0	90.0	0.0152	0.061
82	2	23	54	19	18.0	6.10	155.0	290.2	1.8	88.0	100.0	0.0152	0.059
82	**2**	**24**	**55**	**15**	**18.0**	**3.70**	**143**	**293.1**	**5**	**49.0**	**50.0**	**0.0372**	**0.048**
82	**2**	**24**	**55**	**16**	**18.0**	**3.70**	**143**	**292.9**	**4.6**	**50.0**	**50.0**	**0.0372**	**0.056**
82	**2**	**24**	**55**	**17**	**18.0**	**3.50**	**140**	**292.9**	**4.7**	**50.0**	**50.0**	**0.0372**	**0.057**
82	2	24	55	18	18.0	3.30	130.0	292.5	3.8	47.0	50.0	0.0372	0.04
82	**2**	**24**	**55**	**19**	**18.0**	**4.10**	**156**	**290.7**	**2.7**	**52.0**	**50.0**	**0.0372**	**0.046**
82	2	24	55	20	18.0	4.40	148.0	290.7	2.6	52.0	50.0	0.0372	0.043

Note: Bold identifies hours in the evaluation dataset

The UP.DAT (upper-air) input file is designed to provide CALMET with vertical profiles of wind and temperature representative of the onshore flow at 00Z (mid to late afternoon) during the tracer sampling. Both 00Z and 12Z vertical profiles of wind and temperature are developed for four levels: surface, 10m, overwater mixing height, and model-top (3000m). The 00Z wind speed at release height is extended to levels up to the mixing height using a stability-class-dependent power-law profile (A,B=0.07; C=0.10; D,E,F=0.15) and the speed at the model-top is set to that at the mixing height. The surface wind speed is set to that at 10m, which has been adjusted from the anemometer height to 10m. Wind direction at all levels equals the release wind direction. Temperature at the surface equals the air temperature in the SEA.DAT file, and temperature aloft is computed from this using the temperature gradient dT/dz (in the SEA.DAT file) up to the overwater mixing height. The default CALMET temperature gradient -0.0045 ºK/m is used above the mixing height. Pressure is assumed to be 1013 mb at the surface, and decreases with height at 0.1 mb/m.

Carpinteria, California

Description

The tracer dispersion study in the Carpinteria, California area was conducted along the California coast during 10 test days in September and October 1985 (Johnson and Spangler, 1986). The area is complex in that there are abrupt changes in land use and terrain elevation. There is a sharp bluff at the coast that rises about 30m above the ocean, and the first line of samplers is placed along the top of this bluff. The western portion of the study area is relatively flat beyond the bluff face, with the elevation rising from 30m to 50m in about 2 km. At this point the terrain rises steadily inland at a rate of about 200 m/km. Terrain in the eastern portion of the study area rises to an elevation of about 60m within 400m of the coast, and about 80m within 1 km of the coast.

Two distinct dispersion experiments make up this dataset. The first is a complex terrain study conducted in the eastern portion of the study area. Samplers were located along two primary arcs atop the shoreline bluff and at twice the elevation about 400m inland, with supplementary sampler locations 500m to 1 km inland at elevations as high as 80m. SF_6 releases were made from a boat 300m to 700m from shore at elevations between 18m and 30m. A second tracer, CF_3Br, was released at elevations between 24m and 61m. The second is a fumigation study conducted in the western portion of the study area. Samplers were also located along two primary arcs atop the shoreline bluff and about 400m inland. SF_6 releases were made from a boat about 1 km from shore at elevations between 64m and 91m. Concentration data were obtained between 0800 and 1300 as one-hour averages in the complex terrain study and between 0900 and 1100 as ½ hour averages in the fumigation study.

Meteorological data used in the OCD4 evaluation dataset includes wind speed and temperature measured by tethersonde at the release location, and air-sea temperature difference obtained at a nearby oil platform.

Geophysical Processing

Gridded land use and terrain elevation data for the CALMET geophysical file are obtained from the USGS. The terrain data are from the one-degree 1:250,000-scale DEM dataset, with an approximate resolution of 90m, and from the 1:100,000-scale DEM dataset with 30m resolution. Land use data are from the 1:250,000-scale CTG dataset, with a resolution of 200m. Because the spatial variation in terrain elevation is important at this site, a 100m grid cell is selected for the modeling grid. This grid is positioned so that a single 200m land use cell is centered on a cluster of four of the 100m grid cells. The modeling grid chosen to cover the area is defined by:

Map Projection:	UTM (Zone 11N)
Datum:	NAS-C (North American 1927)
SW Corner Coordinates (km):	(267.0,3805.0)
Number of cells (nx,ny):	(100,100)
Cell Size (km):	0.100

The CALMET preprocessors TERREL, CTGPROC, and MAKEGEO are applied to convert the geophysical datasets to this modeling grid, creating the CALMET GEO.DAT file.

No coordinate transformations are required for the source and receptor locations listed in the OCD4 model runs because they are already in this projection. The resulting map of the experiment region is shown in Figure 4-2.

Source & Receptor Characterization

Tracer releases are characterized as modeled in the OCD4 evaluation. All are modeled without downwash.

All sampler locations are used as receptors, but additional ones are added to increase the density of receptor spacing along the two primary arcs in each experiment. Intermediate receptors are placed at approximately 50m intervals, with elevations interpolated from the actual sampler elevations. 93 receptors are used in modeling the complex terrain study periods, and 75 are used in modeling the fumigation study periods.

Table 4-3
Source Characterization for Carpinteria, California Tracer Releases

Tracer: Date	X* (km)	Y* (km)	Ht. (m)	Elev. (m)	Diam. (m)	W (m/s)	T*** (°K)	Hb (m)	Lb (m)
Complex Terrain Study									
SF_6: 9/19/1985	270.343	3806.910	30.48	0.0	.01	1.0	270.0	0.0	0.0
SF_6: 9/22/1985 CF_3Br:	270.133	3806.518	18.29 36.58	0.0	.01	1.0	270.0	0.0	0.0
SF_6: 9/25/1985 CF_3Br:	271.024	3806.663	24.38 45.72	0.0	.01	1.0	270.0	0.0	0.0
CF_3Br: 9/26/1985	269.524	3807.333	24.38	0.0	.01	1.0	270.0	0.0	0.0
SF_6: 9/28/1985 ** CF_3Br:	271.289	3806.343	24.38 42.67	0.0	.01	1.0	270.0	0.0	0.0
SF_6: 9/28/1985 ** CF_3Br:	270.133	3806.518	24.38 39.62	0.0	.01	1.0	270.0	0.0	0.0
SF_6: 9/29/1985 CF_3Br:	270.133	3806.518	30.48 60.96	0.0	.01	1.0	270.0	0.0	0.0
Fumigation Study									
SF_6: 10/1/1985	269.783	3806.518	88.39	0.0	.01	1.0	270.0	0.0	0.0
SF_6: 10/3/1985	269.572	3806.777	64.00	0.0	.01	1.0	270.0	0.0	0.0
SF_6: 10/4/1985	269.693	3806.831	79.25	0.0	.01	1.0	270.0	0.0	0.0
SF_6: 10/5/1985	269.747	3806.657	91.44	0.0	.01	1.0	270.0	0.0	0.0

* Locations are in the UTM (Zone 11N) map projection with datum NAS-C

** Location was repositioned after 1100

*** Temperature set below ambient to simulate a non-buoyant release.

CARPINTERIA, CA

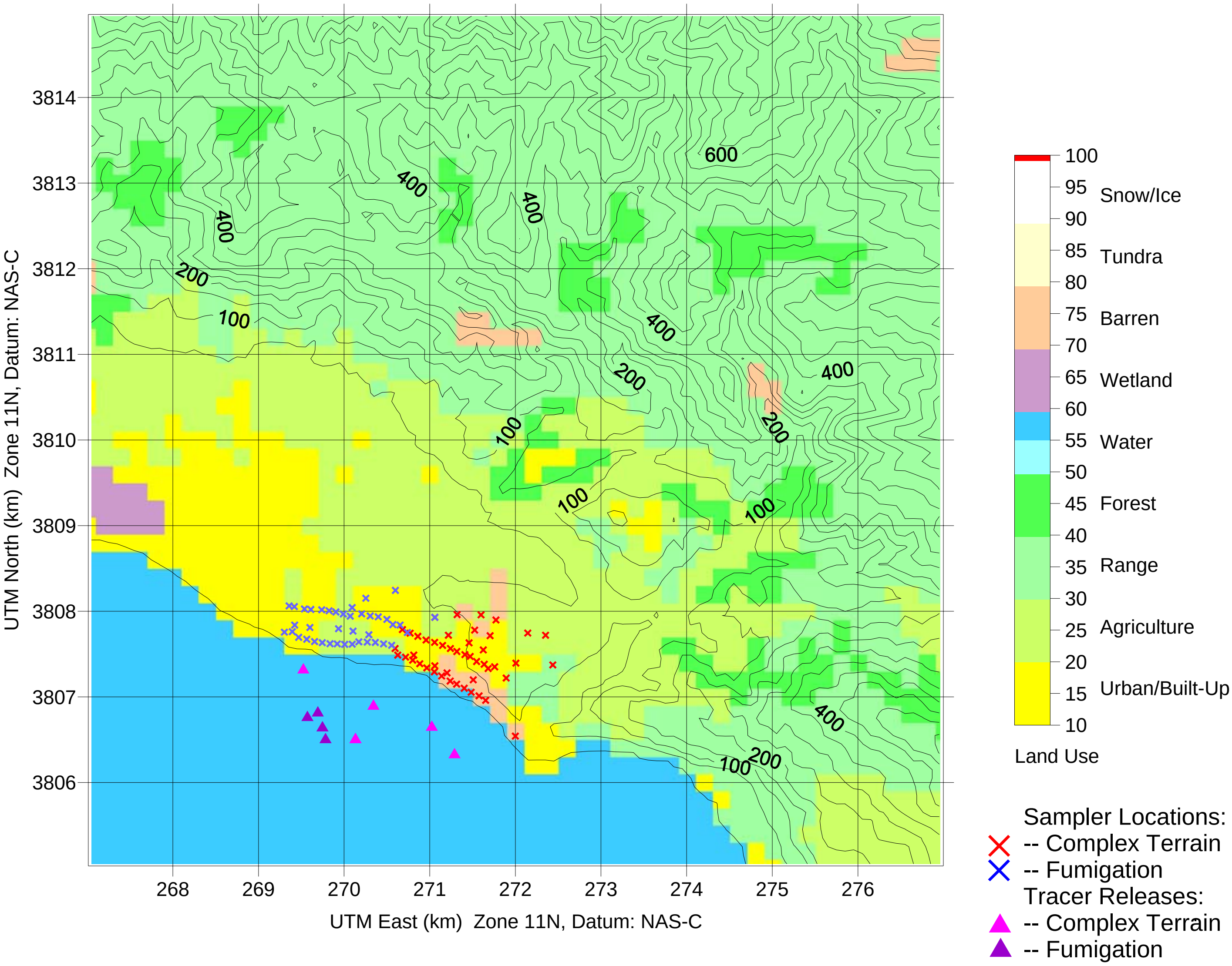

Figure 4-2. Geophysical properties of the site of the 1985 Carpinteria, CA tracer experiment, as gridded for use in the CALMET/CALPUFF simulations. The grid cell size is 100m. Tracer concentrations were measured at the indicated sampler locations during distinct "complex terrain" and "fumigation" experiments. Tracer release locations indicate boat positions used during each type of experiment.

Meteorological Processing

Meteorological data files for applying CALMET/CALPUFF to the Carpinteria study are developed primarily from files used to run OCD4, with supplemental data from the Santa Barbara Municipal Airport located about 1 km from the coast about 32 km to the west. The "release" meteorology identified for OCD4 is used to construct representative SEA.DAT (over water) and SURF.DAT (over land) input files for the tracer-release periods. Temperatures are measured at 9m above the water, and wind speed is measured by tethersonde at heights ranging from 24m to 91m, depending on the tracer release height. Because CALMET accepts a single measurement height for the speed and temperature in the SEA.DAT file, the wind speed is profiled from the anemometer height to 9m for use in both the SEA.DAT and SURF.DAT files. Boundary layer parameters computed by OCD are used with Monin-Obukhov similarity profiles to compute the wind speed adjustment.

Wind directions used in the OCD4 datasets are those that align the source and the sampler with the peak concentration each hour. This allows the evaluation to focus on processes other than the net transport direction. These directions are used for all CALMET input files.

Data from the airport reported September 19 through midday on October 5 are processed using SMERGE to create another SURF.DAT file that covers the complete period. Local winds for the release replace the airport observations for the tracer-release periods. This creates a continuous hourly meteorological record with winds that are consistent with the SEA.DAT file during the tracer periods. Temperature, relative humidity, and cloud cover data from the airport remain in the file to characterize conditions over land.

The SEA.DAT station is placed at the release location appropriate for the time period, while the SURF.DAT station is placed onshore at (271, 3808).

Table 4-4 lists meteorological data used in the SEA.DAT file after the adjustments are made. The lateral turbulence intensity (I_y) is used in the CALPUFF turbulence profile file.

Table 4-4
Over-water Meteorological Data for Carpinteria, California
1985

Year	Month	Day	Julian Day	Hour	Height (m)	WS (m/s)	WD (deg)	Tair (°K)	Tair-Tsea (°K)	RH (%)	Mixing Ht (m)	dT/dz (°K/m)	Iy
85	9	19	262	9	9.0	1.26	259.7	289.45	-1.10	79.0	500.0	-0.0098	0.506
85	9	19	262	10	9.0	1.26	235.4	289.95	-0.80	79.0	500.0	-0.0098	0.541
85	9	19	262	11	9.0	2.49	214.1	290.15	-0.70	80.0	500.0	-0.0098	0.454
85	9	19	262	12	9.0	2.95	252.9	290.25	-0.70	80.0	500.0	-0.0098	0.646
85	9	22	265	9	9.0	0.91	220.8	290.55	0.50	71.0	500.0	0.0102	0.628
85	9	22	265	10	9.0	1.02	251.1	290.15	0.30	81.0	500.0	0.0102	0.314
85	9	22	265	11	9.0	1.26	253.8	289.55	1.00	92.0	500.0	0.0102	0.140
85	9	22	265	12	9.0	1.45	248.4	289.45	1.10	91.0	500.0	0.0102	0.314
85	9	25	268	10	9.0	0.62	163.8	294.35	2.80	60.0	500.0	0.0002	0.890
85	9	25	268	11	9.0	0.65	163.8	294.15	2.30	70.0	500.0	0.0002	0.174
85	9	25	268	12	9.0	0.42	165.6	294.05	2.10	90.0	500.0	0.0002	0.489
85	9	25	268	13	9.0	0.42	175.0	294.55	2.70	90.0	500.0	0.0002	0.332
85	9	26	269	12	9.0	3.54	265.1	291.85	-0.70	84.0	500.0	-0.0098	0.192
85	9	26	269	13	9.0	3.73	257.4	291.95	-1.00	81.0	500.0	-0.0098	0.209
85	9	28	271	10	9.0	5.09	155.8	291.25	-0.60	85.0	500.0	-0.0098	0.157
85	9	28	271	11	9.0	3.07	174.7	291.15	-0.80	84.0	500.0	-0.0098	0.192
85	9	28	271	13	9.0	1.46	234.5	291.45	-0.60	82.0	500.0	-0.0098	0.192
85	9	28	271	14	9.0	2.03	215.0	291.65	-0.30	82.0	500.0	-0.0098	0.200
85	9	29	272	11	9.0	3.21	243.7	291.35	-0.30	86.0	500.0	-0.0098	0.332
85	9	29	272	12	9.0	2.94	238.9	291.25	-0.40	88.0	500.0	-0.0098	0.087
85	10	1	274	10	9.0	1.90	215.5	289.65	-0.90	92.0	500.0	-0.0098	0.349
85	10	3	276	9.5	9.0	0.34	164.6	299.45	2.10	89.0	500.0	0.0602	0.227
85	10	3	276	11	9.0	0.60	215.5	297.95	3.40	96.0	500.0	0.1202	0.646
85	10	4	277	10	9.0	0.48	216.9	294.75	3.30	70.0	500.0	0.0002	0.262
85	10	4	277	10.5	9.0	0.72	231.2	294.85	3.30	72.0	500.0	0.0002	0.209
85	10	4	277	11	9.0	0.48	186.4	294.45	3.30	76.0	500.0	0.0002	0.244
85	10	5	278	10	9.0	1.18	171.3	294.05	0.70	67.0	500.0	0.0102	0.541
85	10	5	278	10.5	9.0	1.39	208.2	294.45	0.70	65.0	500.0	0.0102	0.349
85	10	5	278	11	9.0	0.94	195.2	294.65	0.70	63.0	500.0	0.0002	0.541

The UP.DAT (upper-air) input file is designed to provide CALMET with vertical profiles of wind and temperature representative of the onshore flow at 00Z (mid to late afternoon) during the tracer sampling. Both 00Z and 12Z vertical profiles of wind and temperature are developed for four levels: surface, 10m, overwater mixing height, and model-top (3000m). The 00Z wind speed at 9m is extended to levels up to the mixing height using a stability-class-dependent power-law profile (A,B=0.07; C=0.10; D,E,F=0.15) and the speed at the model-top is set to that at the mixing height. The surface wind speed is set to that at 10m, which has been adjusted from the anemometer height to 10m.. Wind direction at all levels equals the release wind direction. Temperature at the surface equals the air temperature in the SEA.DAT file, and temperature aloft is computed from this using the temperature gradient dT/dz (in the SEA.DAT file) up to the overwater mixing height. The default CALMET temperature gradient -0.0045 ºK/m is used above the mixing height. Pressure is assumed to be 1013 mb at the surface, and decreases with height at 0.1 mb/m.

Pismo Beach, California

Description

The tracer dispersion study in the Pismo Beach, California area was conducted along the California coast during five test days in December 1981 and five test days in June 1982 (Dabberdt et al., 1983, Brodzinsky et al., 1982, and Schacher et al., 1982). SF_6 tracer was released about 13m above the water from a boat located 6 to 8 km from shore, and sampled along an arc that covered about 15 km of the shoreline. Several samplers were also located along a shorter secondary arc approximately 7 km inland. Evaluation of OCD4 with this dataset focused on the one-hour average concentrations measured at the shoreline.

Meteorological data used in the OCD4 evaluation dataset includes wind at 20.5m, temperature at 7m, and air-sea temperature difference measured at the release location, and vertical temperature gradient measured over the water by an aircraft.

Geophysical Processing

Gridded land use and terrain elevation data for the CALMET geophysical file are obtained from the USGS. The terrain data are from the one-degree 1:250,000-scale DEM dataset, with an approximate resolution of 90m. Land use data are from the 1:250,000-scale CTG dataset, with a resolution of 200m. Because the spatial variation in land use is the primary geophysical property for this application, a modeling grid is chosen that places each land use datapoint in the center of a model grid cell. The modeling grid chosen to cover the area is defined by:

Map Projection:	UTM (Zone 10N)

Datum:	NAS-C (North American 1927)
SW Corner Coordinates (km):	(708.1, 3864.1)
Number of cells (nx,ny):	(100,130)
Cell Size (km):	0.200

The CALMET preprocessors TERREL, CTGPROC, and MAKEGEO are applied to convert the geophysical datasets to this modeling grid, creating the CALMET GEO.DAT file.

Coordinate transformations are applied to the source and receptor locations listed in the OCD4 model runs in order to register these features to land use and terrain data in the GEO.DAT file. The OCD4 dataset uses a grid system that is referenced to a local latitude/longitude grid, as depicted in the OCD4 Users Guide (Dicristofaro and Hanna, 1989). These (x,y) coordinates are scaled to latitude/longitude by matching sampler location (x,y) coordinates with their position on the site map. The latitude/longitude positions obtained in this way are then transformed to the UTM (Zone 10N) map projection in datum NAS-C.

The resulting map of the experiment region is shown in Figure 4-3. The beach area where nearly all of the coastline samplers are located falls into the barren classification, and this is consistent with area photographs. Significant terrain features do not influence these sampler locations, and probably do not affect the secondary samplers located further inland.

Source & Receptor Characterization

Tracer releases are characterized as modeled in the OCD4 evaluation. All are modeled with downwash, using the boat dimensions as a solid building with the length perpendicular to the wind. A minimal exit velocity is used to remove any momentum rise.

All sampler locations are used as receptors, but additional ones are added to increase the density of receptor spacing along the two arcs in each experiment. Intermediate receptors are placed at approximately 100m intervals along the shoreline arc and 250m along the inland arc, with elevations interpolated from the actual sampler elevations. Two hundred forty-one (241) receptors are used in all.

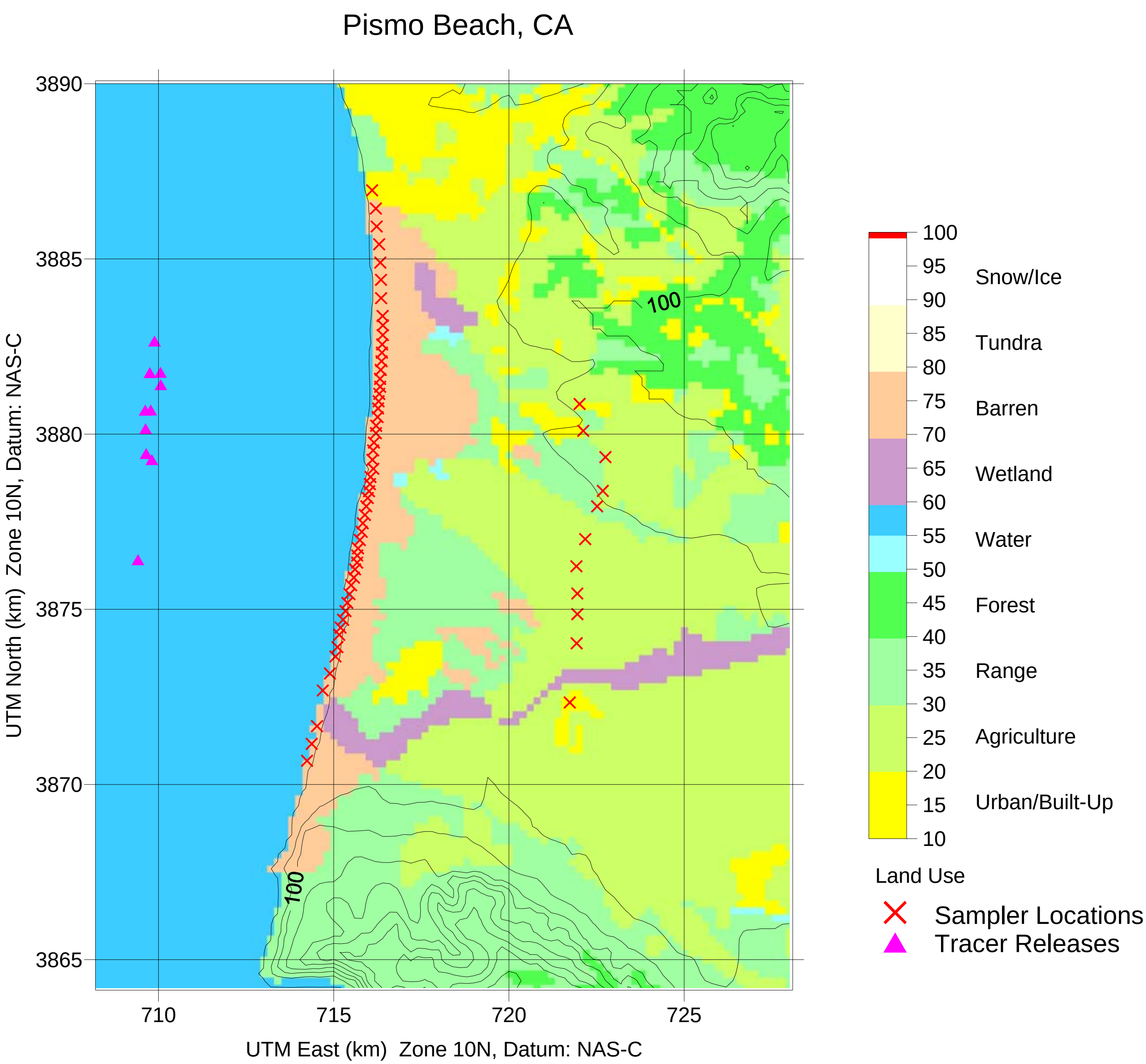

Figure 4-3. Geophysical properties of the site of the 1981/1982 Pismo Beach, CA tracer experiments, as gridded for use in the CALMET/CALPUFF simulations. The grid cell size is 200m. Tracer concentrations were measured at the indicated sampler locations. Tracer release locations indicate boat positions used during each of the 10 experiment-days.

Table 4-5
Source Characterization for Pismo Beach, California Tracer Releases

Date	X* (km)	Y* (km)	Ht. (m)	Elev. (m)	Diam. (m)	W (m/s)	T (^{o}K)	Hb (m)	Lb (m)
12/8/1981	709.633	3880.150	13.1	0.0	.02	0.01	270.0	7.0	20.0
12/11/1981	709.889	3882.651	13.1	0.0	.02	0.01	270.0	7.0	20.0
12/13/1981	709.778	3880.685	13.1	0.0	.02	0.01	270.0	7.0	20.0
12/14/1981	710.065	3881.406	13.1	0.0	.02	0.01	270.0	7.0	20.0
12/15/1981	710.057	3881.759	13.1	0.0	.02	0.01	270.0	7.0	20.0
6/21/1982	709.620	3880.682	13.6	0.0	.02	0.01	270.0	7.0	20.0
6/22/1982	709.415	3876.411	13.6	0.0	.02	0.01	270.0	7.0	20.0
6/24/1982	709.811	3879.268	13.6	0.0	.02	0.01	270.0	7.0	20.0
6/25/1982	709.649	3879.445	13.6	0.0	.02	0.01	270.0	7.0	20.0
6/27/1982	709.754	3881.752	13.6	0.0	.02	0.01	270.0	7.0	20.0

* Locations are in the UTM (Zone 10N) map projection with datum NAS-C

Meteorological Processing

Meteorological data files for applying CALMET/CALPUFF to the Pismo Beach study are developed primarily from files used to run OCD4, with supplemental cloud observations from the Santa Maria Airport located about 19 km to the ESE. The "release" meteorology identified for OCD4 is used to construct representative SEA.DAT (over water) and SURF.DAT (over land) input files for the tracer-release days. Temperatures are measured at 7m above the water, and wind speed is measured at 20.5m. Because CALMET accepts a single measurement height for the speed and temperature in the SEA.DAT file, the wind speed is profiled from the anemometer height to 7m for use in the SEA.DAT file. Boundary layer parameters computed by OCD are used with Monin-Obukhov similarity profiles to compute the wind speed adjustment. Wind speeds at 20.5m are used in the SURF.DAT file.

Wind directions used in the OCD4 datasets are those that align the source and the sampler with the peak concentration each hour. This allows the evaluation to focus on processes other than the net transport direction. These directions are used for all CALMET input files.

The SEA.DAT station is placed at the release location appropriate for the time period, while the SURF.DAT station is placed onshore at (719, 3879).

Table 4-6 lists meteorological data used in the SEA.DAT file after the adjustments are made. The lateral turbulence intensity (I_y) is used in the CALPUFF turbulence profile file.

The UP.DAT (upper-air) input file is designed to provide CALMET with vertical profiles of wind and temperature representative of the onshore flow at 00Z (mid to late afternoon) during the tracer sampling. Both 00Z and 12Z vertical profiles of wind and temperature are developed for four levels: surface, 10m, overwater mixing height, and model-top (3000m). The 00Z wind speed at 7m is extended to levels up to the mixing height using a stability-class-dependent power-law profile (A,B=0.07; C=0.10; D,E,F=0.15) and the speed at the model-top is set to that at the mixing height. The surface wind speed is set to that at 10m, which has been adjusted from the anemometer height to 10m. Wind direction at all levels equals the release wind direction. Temperature at the surface equals the air temperature in the SEA.DAT file, and temperature aloft is computed from this using the temperature gradient dT/dz (in the SEA.DAT file) up to the overwater mixing height. The default CALMET temperature gradient -0.0045 ºK/m is used above the mixing height. Pressure is assumed to be 1013 mb at the surface, and decreases with height at 0.1 mb/m.

Ventura, California

Description

The tracer dispersion study in the Ventura, California area was conducted along the California coast during four test days in September 1980 and four test days in January 1981 (Areovironment, 1980 and 1981, Zanetti et al., 1981, and Schacher et al., 1982). Data from all four of the test days in September and three of the four test days in January are in the dataset. SF_6 tracer was released about 8m above the water from a boat located 6 to 8 km from shore, and sampled along two arcs about 10 to 12 km long. The first arc is ½ km to 1 km from the shoreline and the second arc is about 7 km from the shoreline. Evaluation of OCD4 with this dataset focused on the one-hour average concentrations measured close the shoreline in Arc 1.

Meteorological data used in the OCD4 evaluation dataset includes wind at 20.5m, temperature at 7m, and air-sea temperature difference measured at the release location, and vertical temperature gradient measured over the water by an aircraft.

Table 4-6a
Over-water Meteorological Data for Pismo Beach, California
1981

Year	Month	Day	Julian Day	Hour	Ht (m)	WS (m/s)	WD (deg)	Tair (°K)	Tair-Tsea (°K)	RH (%)	Mix Ht (m)	dT/dz (°K/m)	Iy
81	12	8	342	14	7	1.60	265.0	287.4	0.9	66.0	100.0	0.0202	0.120
81	**12**	**8**	**342**	**15**	**7**	**1.32**	**261.0**	**287.7**	**1.3**	**67.0**	**100.0**	**0.0202**	**0.166**
81	**12**	**8**	**342**	**16**	**7**	**0.97**	**284.0**	**287.5**	**1.2**	**75.0**	**100.0**	**0.0202**	**0.229**
81	12	8	342	17	7	0.50	284.0	287.7	1.4	72.0	100.0	0.0202	0.422
81	12	8	342	18	7	0.40	241.0	287.6	1.5	72.0	100.0	0.0202	1.000
81	**12**	**11**	**345**	**14**	**7**	**4.22**	**275.0**	**285.6**	**-0.4**	**74.0**	**600.0**	**0.0002**	**0.098**
81	**12**	**11**	**345**	**15**	**7**	**5.00**	**283.0**	**286.1**	**0.0**	**73.0**	**600.0**	**0.0002**	**0.080**
81	12	11	345	16	7	7.20	283.0	286.2	0.2	80.0	700.0	0.0002	0.061
81	**12**	**11**	**345**	**17**	**7**	**7.78**	**289.0**	**286.0**	**0.1**	**84.0**	**700.0**	**0.0002**	**0.037**
81	12	11	345	18	7	7.30	290.0	286.0	0.1	80.0	800.0	0.0002	0.661
81	**12**	**11**	**345**	**19**	**7**	**7.14**	**305.0**	**286.1**	**0.2**	**81.0**	**900.0**	**0.0002**	**1.000**
81	**12**	**13**	**347**	**14**	**7**	**5.05**	**289.0**	**285.5**	**-0.8**	**95.0**	**50.0**	**-0.0098**	**0.016**
81	**12**	**13**	**347**	**15**	**7**	**5.67**	**280.0**	**285.3**	**-0.8**	**97.0**	**50.0**	**-0.0098**	**0.042**
81	12	13	347	16	7	7.10	287.0	285.6	-0.4	95.0	50.0	-0.0098	0.061
81	**12**	**13**	**347**	**17**	**7**	**7.06**	**301.0**	**286.2**	**0.3**	**92.0**	**50.0**	**0.0502**	**0.033**
81	12	13	347	18	7	5.90	292.0	286.4	0.5	91.0	50.0	0.0502	0.040
81	12	13	347	19	7	6.00	302.0	286.4	0.6	90.0	50.0	0.0502	0.113
81	12	14	348	13	7	6.63	292.0	287.2	1.3	79.0	50.0	0.0102	0.021
81	12	14	348	14	7	7.70	293.0	286.7	0.6	86.0	50.0	0.0102	0.021
81	**12**	**14**	**348**	**15**	**7**	**9.70**	**292.0**	**286.4**	**0.4**	**90.0**	**50.0**	**0.0102**	**0.021**
81	12	14	348	16	7	9.30	292.0	286.7	0.8	89.0	50.0	0.0102	0.040
81	**12**	**14**	**348**	**17**	**7**	**8.71**	**296.0**	**286.7**	**0.9**	**88.0**	**50.0**	**0.0102**	**0.031**
81	12	14	348	18	7	8.40	303.0	286.9	0.8	87.0	50.0	0.0102	0.129
81	12	14	348	19	7	7.70	306.0	286.4	0.4	90.0	50.0	0.0102	0.140
81	**12**	**15**	**349**	**13**	**7**	**5.01**	**304.0**	**286.1**	**0.3**	**88.0**	**50.0**	**0.0002**	**0.257**
81	**12**	**15**	**349**	**14**	**7**	**5.14**	**299.0**	**287.7**	**1.1**	**83.0**	**50.0**	**0.0002**	**1.000**
81	12	15	349	16	7	6.80	294.0	288.7	2.9	73.0	50.0	0.0002	0.169
81	12	15	349	17	7	7.60	301.0	288.3	2.2	77.0	50.0	0.0002	0.072
81	12	15	349	18	7	5.70	301.0	288.4	2.4	77.0	50.0	0.0102	0.068
81	**12**	**15**	**349**	**19**	**7**	**0.97**	**321.0**	**289.4**	**3.4**	**70.0**	**50.0**	**0.0202**	**1.000**

Note: Bold identifies hours in the evaluation dataset

Table 4-6b
Over-water Meteorological Data for Pismo Beach, California
1982

Year	Month	Day	Julian Day	Hour	Ht (m)	WS (m/s)	WD (deg)	Tair (^{o}K)	Tair-Tsea (^{o}K)	RH (%)	Mixing Ht (m)	dT/dz (^{o}K/m)	Iy
82	6	21	172	14	7	2.70	280.0	287.7	2.0	83.0	800.0	-0.0018	0.073
82	**6**	**21**	**172**	**15**	**7**	**3.11**	**276.0**	**287.5**	**1.5**	**84.0**	**800.0**	**-0.0018**	**0.024**
82	**6**	**21**	**172**	**16**	**7**	**2.61**	**269.0**	**287.3**	**1.4**	**86.0**	**800.0**	**-0.0018**	**0.037**
82	**6**	**21**	**172**	**17**	**7**	**1.60**	**261.0**	**287.3**	**1.5**	**87.0**	**800.0**	**-0.0018**	**0.120**
82	**6**	**21**	**172**	**18**	**7**	**1.86**	**276.0**	**286.9**	**1.2**	**89.0**	**800.0**	**-0.0018**	**0.358**
82	**6**	**22**	**173**	**15**	**7**	**2.42**	**274.0**	**288.6**	**1.7**	**80.0**	**700.0**	**-0.0048**	**0.106**
82	**6**	**22**	**173**	**16**	**7**	**3.82**	**268.0**	**288.8**	**2.1**	**78.0**	**700.0**	**-0.0048**	**0.058**
82	6	22	173	17	7	2.90	268.0	288.7	2.4	77.0	700.0	-0.0048	0.049
82	6	22	173	18	7	2.80	274.0	287.9	2.0	81.0	700.0	-0.0048	0.072
82	**6**	**22**	**173**	**19**	**7**	**2.06**	**289.0**	**287.2**	**1.3**	**84.0**	**700.0**	**-0.0048**	**0.187**
82	6	22	173	20	7	1.90	280.0	286.6	0.8	87.0	700.0	-0.0048	0.175
82	**6**	**24**	**175**	**13**	**7**	**3.07**	**269.0**	**288.1**	**0.9**	**82.0**	**600.0**	**0.0002**	**0.527**
82	6	24	175	14	7	2.80	271.0	288.2	0.8	83.0	600.0	0.0002	0.290
82	**6**	**24**	**175**	**15**	**7**	**4.62**	**269.0**	**288.1**	**0.6**	**84.0**	**600.0**	**0.0002**	**0.131**
82	6	24	175	16	7	4.60	272.0	288.4	0.8	83.0	600.0	0.0002	0.026
82	6	24	175	17	7	4.40	268.0	288.4	0.9	83.0	600.0	0.0002	0.037
82	6	24	175	17	7	4.60	262.0	288.4	1.0	84.0	600.0	0.0002	0.037
82	**6**	**25**	**176**	**12**	**7**	**4.22**	**286.0**	**288.9**	**2.2**	**76.0**	**100.0**	**0.0002**	**0.024**
82	**6**	**25**	**176**	**13**	**7**	**4.98**	**280.0**	**288.5**	**2.6**	**80.0**	**100.0**	**0.0002**	**0.028**
82	6	25	176	14	7	6.60	278.0	288.3	2.3	83.0	100.0	0.0002	0.031
82	**6**	**25**	**176**	**15**	**7**	**8.25**	**286.0**	**288.3**	**2.6**	**82.0**	**100.0**	**0.0002**	**0.096**
82	**6**	**25**	**176**	**16**	**7**	**7.51**	**288.0**	**288.3**	**2.9**	**82.0**	**100.0**	**0.0002**	**0.016**
82	**6**	**25**	**176**	**17**	**7**	**7.83**	**290.0**	**288.4**	**3.2**	**81.0**	**100.0**	**0.0002**	**0.021**
82	6	25	176	18	7	8.20	294.0	288.8	3.8	78.0	100.0	0.0002	0.051
82	6	27	178	12	7	7.00	290.0	286.9	2.9	94.0	100.0	0.0002	0.061
82	6	27	178	13	7	10.50	284.0	286.8	3.0	95.0	100.0	0.0002	0.016
82	6	27	178	14	7	10.10	284.0	286.8	3.0	95.0	100.0	0.0002	0.019
82	6	27	178	15	7	10.30	283.0	286.8	3.0	95.0	100.0	0.0002	0.035
82	**6**	**27**	**178**	**16**	**7**	**10.79**	**287.0**	**287.0**	**3.4**	**93.0**	**100.0**	**0.0002**	**0.019**
82	6	27	178	17	7	10.40	285.0	287.5	3.8	93.0	100.0	0.0002	0.021
82	**6**	**27**	**178**	**18**	**7**	**8.35**	**285.0**	**287.7**	**3.7**	**94.0**	**100.0**	**0.0002**	**0.136**

Note: Bold identifies hours in the evaluation dataset

Geophysical Processing

Gridded land use and terrain elevation data for the CALMET geophysical file are obtained from the USGS. The terrain data are from the one-degree 1:250,000-scale DEM dataset, with an approximate resolution of 90m. Land use data are from the 1:250,000-scale Composite Grid Theme (CTG) dataset, with a resolution of 200m. Because the spatial variation in land use is the primary geophysical property for this application, a modeling grid is chosen that places each land use datapoint in the center of a model grid cell. The modeling grid chosen to cover the area is defined by:

Map Projection:	UTM (Zone 11N)
Datum:	NAS-C (North American 1927)
SW Corner Coordinates (km):	(282.1, 3779.1)
Number of cells (nx,ny):	(115,100)
Cell Size (km):	0.200

The CALMET preprocessors TERREL, CTGPROC, and MAKEGEO are applied to convert the geophysical datasets to this modeling grid, creating the CALMET GEO.DAT file.

Coordinate transformations are applied to the source and receptor locations listed in the OCD4 model runs in order to register these features to land use and terrain data in the GEO.DAT file. The OCD4 dataset uses a local grid system that is not referenced to UTM coordinates. These (x,y) coordinates are translated to align the sampler locations with roadway features that are discernable on aerial photographs and that are indicated on the experiment site map.

The resulting map of the experiment region is shown in Figure 4-4. Sampling Arc 1, nearest the coast, lies at elevations between 3m and 6m. Most of sampling Arc 2 lies at elevations between 15m and 25m, but the terrain at the northern end rises to more than 100m.

Source & Receptor Characterization

Tracer releases are characterized as modeled in the OCD4 evaluation. All are modeled with downwash, using the boat dimensions as a solid building with the length perpendicular to the wind. A minimal exit velocity is used to remove any momentum rise.

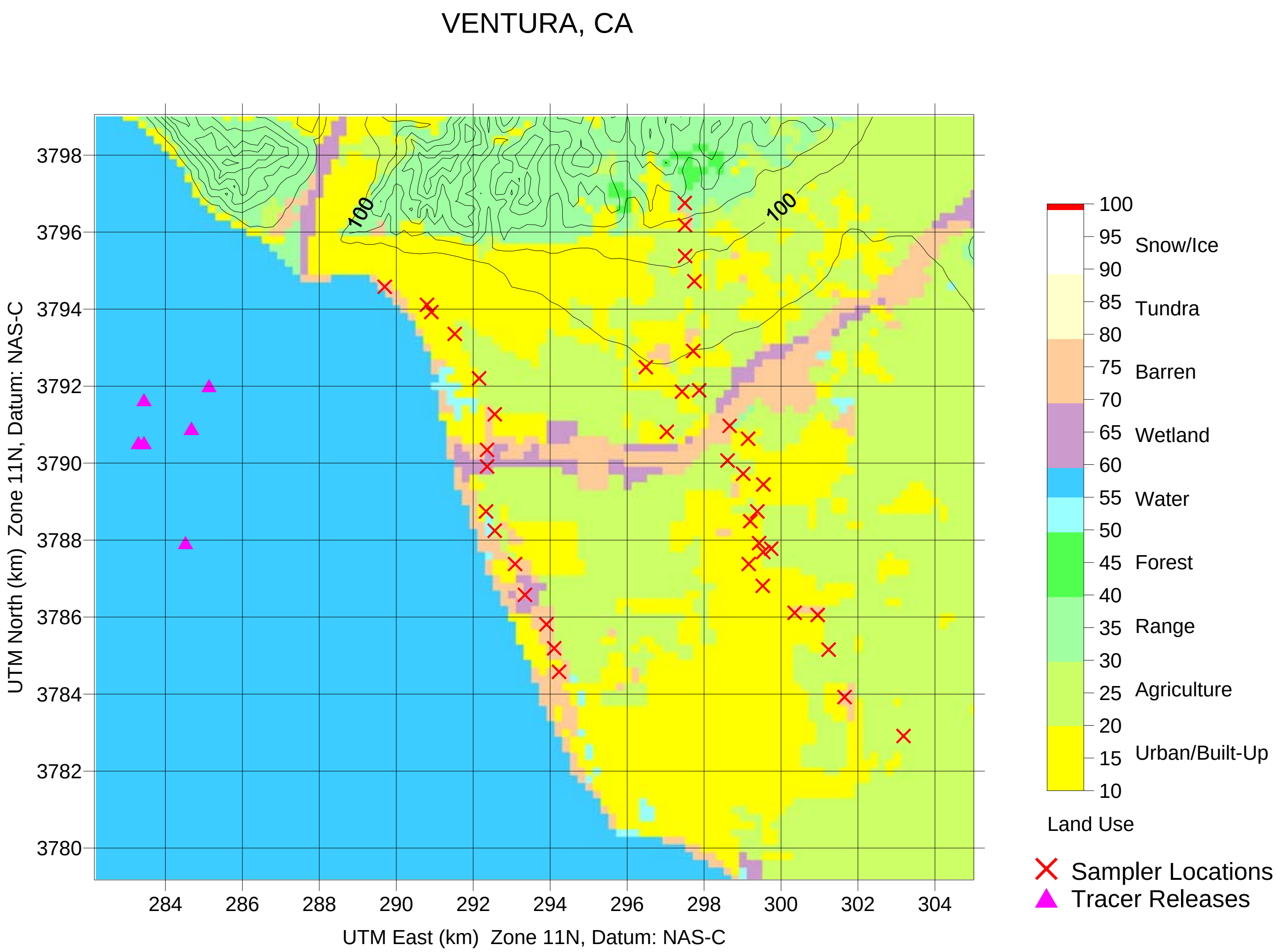

Figure 4-4. Geophysical properties of the site of the 1980/1981 Ventura, CA tracer experiments, as gridded for use in the CALMET/CALPUFF simulations. The grid cell size is 200m. Tracer concentrations were measured at the indicated sampler locations. Tracer release locations indicate boat positions used during each of the seven experiment-days in the evaluation dataset (2 locations are the same).

Table 4-7
Source Characterization for Ventura, California Tracer Releases

Date	X* (km)	Y* (km)	Ht. (m)	Elev. (m)	Diam. (m)	W (m/s)	T (^oK)	Hb (m)	Lb (m)
1/6/1980	285.133	3792.012	8.1	0.0	.02	0.01	270.0	7.0	20.0
1/9/1980	284.675	3790.902	8.1	0.0	.02	0.01	270.0	7.0	20.0
1/13/1980	284.675	3790.902	8.1	0.0	.02	0.01	270.0	7.0	20.0
9/24/1981	283.297	3790.534	8.1	0.0	.02	0.01	270.0	7.0	20.0
9/27/1981	283.444	3791.646	8.1	0.0	.02	0.01	270.0	7.0	20.0
9/28/1981	283.444	3790.534	8.1	0.0	.02	0.01	270.0	7.0	20.0
9/29/1981	284.521	3787.935	8.1	0.0	.02	0.01	270.0	7.0	20.0

* Locations are in the UTM (Zone 11N) map projection with datum NAS-C

All sampler locations are used as receptors, but additional ones are added to increase the density of receptor spacing along Arc 1 in each experiment. Intermediate receptors are placed at approximately 100m intervals, with elevations interpolated from the actual sampler elevations. One hundred twenty-seven (127) receptors are used in Arc 1, and 26 are used in Arc 2.

Meteorological Processing

Meteorological data files for applying CALMET/CALPUFF to the Ventura study are developed from files used to run OCD4. The "release" meteorology identified for OCD4 is used to construct representative SEA.DAT (over water) and SURF.DAT (over land) input files for the tracer-release days. Temperatures are measured at 7m above the water, and wind speed is measured at 20.5m. Because CALMET accepts a single measurement height for the speed and temperature in the SEA.DAT file, the wind speed is profiled from the anemometer height to 7m for use in the SEA.DAT file. Boundary layer parameters computed by OCD are used with Monin-Obukhov similarity profiles to compute the wind speed adjustment. Wind speeds at 20.5m are used in the SURF.DAT file.

Wind directions used in the OCD4 datasets are those that align the source and the sampler with the peak concentration each hour. This allows the evaluation to focus on processes other than the net transport direction. These directions are used for all CALMET input files.

The SEA.DAT station is placed at the release location appropriate for the time period, while the SURF.DAT station is placed onshore at (295, 3790).

Table 4-8 lists meteorological data used in the SEA.DAT file after the adjustments are made. The lateral turbulence intensity (I_y) is used in the CALPUFF turbulence profile file.

The UP.DAT (upper-air) input file is designed to provide CALMET with vertical profiles of wind and temperature representative of the onshore flow at 00Z (mid to late afternoon) during the tracer sampling. Both 00Z and 12Z vertical profiles of wind and temperature are developed for four levels: surface, 10m, overwater mixing height, and model-top (3000m). The 00Z wind speed at 7m is extended to levels up to the mixing height using a stability-class-dependent power-law profile (A,B=0.07; C=0.10; D,E,F=0.15) and the speed at the model-top is set to that at the mixing height. The surface wind speed is set to that at 10m, which has been adjusted from the anemometer height to 10m. Wind direction at all levels equals the release wind direction. Temperature at the surface equals the air temperature in the SEA.DAT file, and temperature aloft is computed from this using the temperature gradient dT/dz (in the SEA.DAT file) up to the overwater mixing height. The default CALMET temperature gradient -0.0045 ºK/m is used above the mixing height. Pressure is assumed to be 1013 mb at the surface, and decreases with height at 0.1 mb/m.

Oresund, Denmark/Sweden

Description

The tracer dispersion study over the strait of Oresund was conducted between the coasts of Denmark and Sweden during nine test days between May 15 and June 14, 1984 (Mortensen and Gryning, 1989). SF_6 was released as a nonbuoyant tracer from a tower at either 95m above the ground on the east side of the strait of Oresund (Barseback, Sweden) or 115m above the ground on the west side of the strait of Oresund (Gladsaxe, Denmark), and was sampled at arcs set up along the opposite shore and at distances 2-8 km inland. The strait is about 20km wide, and the flow was not always perpendicular to its axis, so transport distances vary between 22 and 42 km. Air-sea temperature differences were as large as 6˚C to 8˚C in five of the experiment-days with warm air being advected over colder water, and 2˚C to –2˚C in the other four experiment-days. On each experiment-day, the tracer release started about three hours before the samplers were turned on, and the sampling lasted for one hour. Sampling usually occurred between 1100 and 1200 CET, but was as late as 1330 to 1430 CET.

Meteorological data included in the study were obtained from synoptic stations, a lighthouse in the strait, meteorological towers and masts, SODARS, three-hourly radiosondes, and occasional minisondes released from a boat in the strait. These data and the tracer release and sampling data are distributed on CD in a general magnetic tape format called GF-3. These data are available from the Riso National Laboratory, Roskilde, Denmark.

Table 4-8
Over-water Meteorological Data for Ventura, California
1980/1981

Year	Month	Day	Julian Day	Hour	Ht (m)	WS (m/s)	WD (deg)	Tair (°K)	Tair-Tsea (°K)	RH (%)	Mixing Ht (m)	dT/dz (°K/m)	Iy
80	9	24	268	15	7	3.70	262.0	288.40	-2.10	70.0	400.0	-0.0098	0.134
80	**9**	**24**	**268**	**16**	**7**	**3.91**	**266.0**	**288.30**	**-2.10**	**72.0**	**400.0**	**-0.0098**	**0.140**
80	9	24	268	17	7	5.80	265.0	288.20	-2.00	77.0	400.0	-0.0098	0.124
80	**9**	**24**	**268**	**18**	**7**	**5.83**	**281.0**	**288.00**	**-2.00**	**78.0**	**400.0**	**-0.0098**	**0.114**
80	**9**	**24**	**268**	**19**	**7**	**6.44**	**292.0**	**288.00**	**-2.10**	**77.0**	**400.0**	**-0.0098**	**0.105**
80	**9**	**27**	**271**	**14**	**7**	**5.91**	**272.0**	**288.50**	**-1.90**	**80.0**	**400.0**	**-0.0098**	**0.082**
80	9	27	271	15	7	7.00	272.0	288.80	-1.90	80.0	400.0	-0.0098	-999
80	9	27	271	16	7	7.90	272.0	289.30	-1.90	80.0	400.0	-0.0098	-999
80	9	27	271	18	7	7.00	272.0	289.40	-1.90	80.0	400.0	-0.0098	-999
80	**9**	**27**	**271**	**19**	**7**	**5.71**	**272.0**	**289.20**	**-1.00**	**80.0**	**400.0**	**-0.0098**	**0.063**
80	9	28	272	17	7	3.30	251.0	290.00	-1.10	80.0	250.0	0.0002	0.080
80	**9**	**28**	**272**	**18**	**7**	**2.96**	**265.0**	**290.00**	**-1.00**	**80.0**	**250.0**	**0.0002**	**0.077**
80	9	28	272	19	7	2.70	256.0	289.80	-1.00	80.0	250.0	0.0002	0.079
80	**9**	**29**	**273**	**14**	**7**	**3.15**	**256.0**	**288.70**	**-0.80**	**76.0**	**100.0**	**0.0152**	**0.087**
80	9	29	273	15	7	3.60	262.0	289.10	-0.60	76.0	100.0	0.0152	0.058
80	**9**	**29**	**273**	**16**	**7**	**4.75**	**264.0**	**289.30**	**0.00**	**76.0**	**100.0**	**0.0152**	**0.068**
80	9	29	273	17	7	4.40	266.0	289.30	0.00	76.0	50.0	0.0152	0.042
80	**9**	**29**	**273**	**18**	**7**	**4.83**	**264.0**	**289.20**	**-0.10**	**76.0**	**50.0**	**0.0152**	**0.091**
81	1	6	6	15	7	3.90	300.0	290.10	1.30	64.0	50.0	0.0002	0.298
81	**1**	**6**	**6**	**16**	**7**	**3.02**	**276.0**	**290.30**	**1.60**	**60.0**	**50.0**	**0.0002**	**0.394**
81	**1**	**6**	**6**	**17**	**7**	**4.12**	**283.0**	**290.60**	**1.70**	**58.0**	**50.0**	**0.0002**	**0.232**
81	**1**	**6**	**6**	**18**	**7**	**3.84**	**276.0**	**290.40**	**1.80**	**60.0**	**50.0**	**0.0002**	**0.166**
81	1	9	9	13	7	3.90	278.0	287.30	-1.30	84.0	100.0	-0.0098	0.122
81	1	9	9	14	7	4.10	275.0	287.40	-1.10	87.0	100.0	-0.0098	0.117
81	**1**	**9**	**9**	**15**	**7**	**4.42**	**286.0**	**287.60**	**-0.90**	**87.0**	**100.0**	**-0.0098**	**0.059**
81	**1**	**9**	**9**	**16**	**7**	**4.31**	**277.0**	**288.00**	**-0.50**	**85.0**	**100.0**	**-0.0098**	**0.084**
81	1	9	9	17	7	2.90	275.0	288.30	-0.20	85.0	100.0	-0.0098	0.161
81	**1**	**9**	**9**	**18**	**7**	**4.57**	**274.0**	**288.20**	**-0.30**	**87.0**	**100.0**	**-0.0098**	**0.054**
81	1	13	13	14	7	4.50	291.0	289.50	0.90	70.0	50.0	0.0002	0.103
81	**1**	**13**	**13**	**15**	**7**	**4.90**	**274.0**	**290.10**	**1.40**	**65.0**	**50.0**	**0.0002**	**0.206**
81	1	13	13	16	7	4.60	254.0	289.40	0.70	77.0	50.0	0.0002	0.129
81	**1**	**13**	**13**	**17**	**7**	**3.71**	**242.0**	**289.00**	**0.40**	**84.0**	**50.0**	**0.0002**	**0.150**

Note: Bold identifies hours in the evaluation dataset

Geophysical Processing

Gridded land use and terrain elevation data for the CALMET geophysical file are obtained from the U.S. Geological Survey. The terrain data are from the global 30 arc-second dataset GTOPO30, with an approximate resolution of 900m. Land use data are from the global Lambert Azimuthal dataset, with a resolution of 1 km. Because the data resolution is about 1 km, a modeling grid is chosen with the same resolution, and uses the same projection and datum as positional data contained in the dataset. The modeling grid chosen to cover the area is defined by:

Map Projection:	UTM (Zone 33N)
Datum:	EUR-M (European 1950)
SW Corner Coordinates (km):	(300.0, 6130.0)
Number of cells (nx,ny):	(100,100)
Cell Size (km):	1.000

The CALMET preprocessors TERREL, CTGPROC, and MAKEGEO are applied to convert the geophysical datasets to this modeling grid, creating the CALMET GEO.DAT file.

The resulting map of the experiment region is shown in Figure 4-5. The three releases from the Gladsaxe tower are transported across about 7 km of urban/built-up land in and around Copenhagen before reaching the strait. The six releases from the Barseback tower are very near the strait, with a more rural upwind fetch.

Source & Receptor Characterization

Tracer releases are characterized as point sources and a minimal exit velocity is used to remove any momentum rise. There is no downwash. Actual emission rates of the tracer are modeled explicitly, although these rates are steady throughout an experiment and vary little between experiments. All six of the releases from Barseback are at 6.17 g/s, and those three from Gladsaxe are at 5.05 g/s, 5.09 g/s, and 5.39 g/s. Release times are typically on the hour or half hour, and last three to five hours. These times are simulated in CALPUFF by using the diurnal emissions cycle for point sources. The 24 emission factors in the cycle are set to 1.0 only during the release period, and the release period begins at the start of the first hour of actual release. If the tracer starts at 0830 CET (Central European Time), Hour 9 in the diurnal array has the first non-zero value. These times and other point source characteristics used in the modeling are listed in Table 4-9.

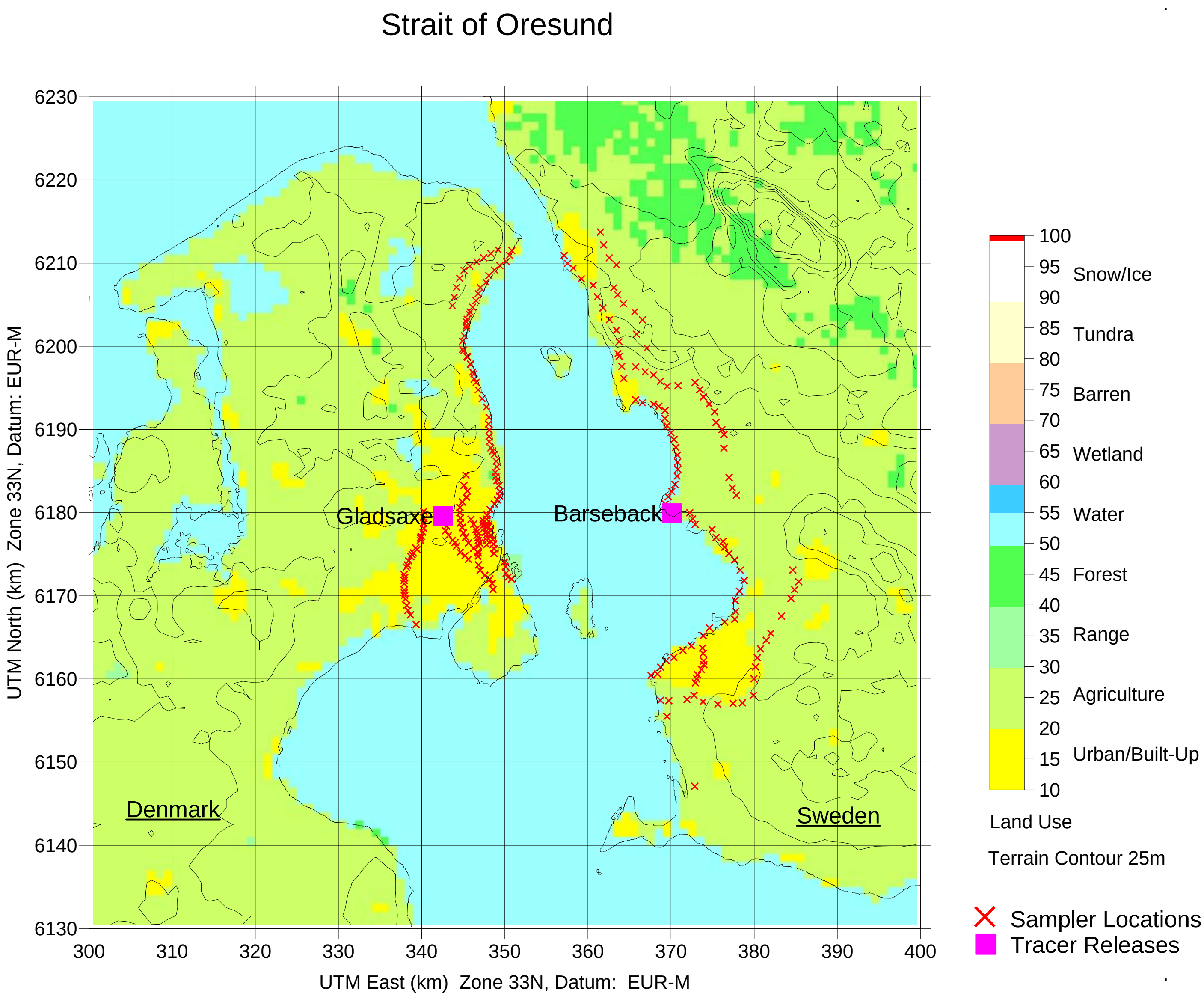

Figure 4-5. Geophysical properties of the site of the 1984 Oresund tracer experiments, as gridded for use in the CALMET/CALPUFF simulations. The grid cell size is 1.0 km. Tracer concentrations were measured at a subset of the indicated sampler locations during each of the nine tests, depending on the transport. Six tracer releases were made from the Barseback tower, and three were made from the Gladsaxe tower.

Table 4-9

Source Characterization for Oresund Tracer Releases

Date	X* (km)	Y* (km)	Ht. (m)	Elev (m)	Diam (m)	W (m/s)	T (^oK)	ON – OFF (CET)	Emission Hours	Emission Rate (g/s)
5/16/1984	370.13	6179.91	95	5	.01	0.01	270.0	0930-1430	10-15	6.17
5/18/1984	342.58	6179.61	115	45	.01	0.01	270.0	0830-1310	9-13	5.09
5/22/1984	370.13	6179.91	95	5	.01	0.01	270.0	0900-1200	10-12	6.17
5/29/1984	370.13	6179.91	95	5	.01	0.01	270.0	0800-1200	9-12	6.17
5/30/1984	370.13	6179.91	95	5	.01	0.01	270.0	0800-1200	9-12	6.17
6/4/1984	370.13	6179.91	95	5	.01	0.01	270.0	0830-1200	9-12	6.17
6/5/1984	370.13	6179.91	95	5	.01	0.01	270.0	0800-1200	9-12	6.17
6/12/1984	342.58	6179.61	115	45	.01	0.01	270.0	0830-1245	9-13	5.39
6/14/1984	342.58	6179.61	115	45	.01	0.01	270.0	1015-1355	11-14	5.05

* Locations are in the UTM (Zone 33N) map projection with datum EUR-M

All sampler locations are used as receptors, and these are the actual sampler locations reporting values during the particular experiment.

Meteorological Processing

Data from surface stations (i.e., 10m to 30m masts), towers, SODARs, minisondes and radiosondes are used to drive three-dimensional CALMET wind and temperature fields for the modeling domain. These data are extracted from the GF-3 databank files, averaged to one-hour periods where necessary, and reformatted as one SURF.DAT, one SEA.DAT, and six UP.DAT files for input to CALMET. Wind directions in the databank files are modified by adding two degrees to the geodetic (virtually the same as magnetic) directions to reference them to grid-North in the UTM Zone 33N projection. Specialized codes are developed for accomplishing these tasks. Locations of those stations used in this modeling are shown in Figure 4-6.

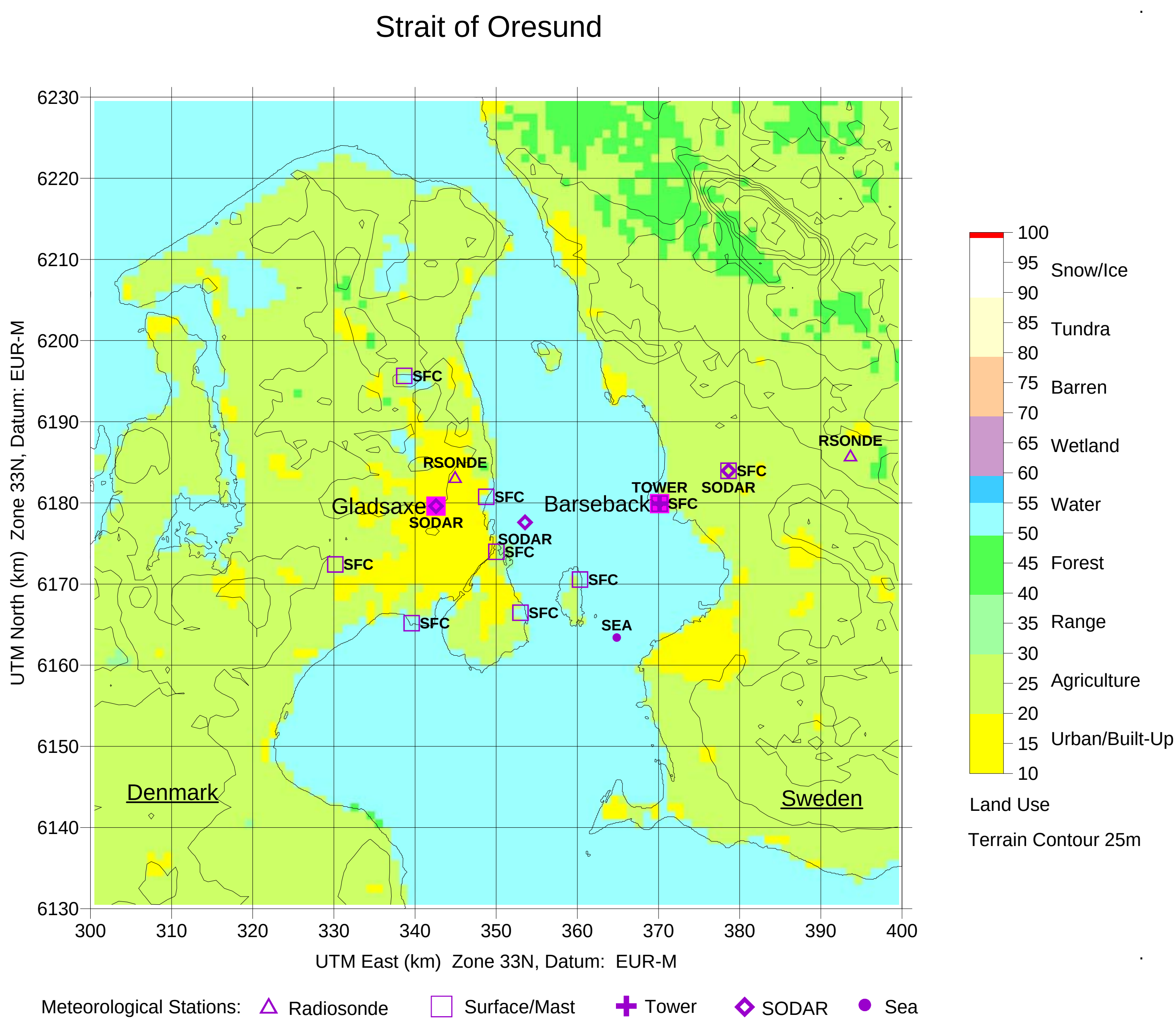

Figure 4-6. Locations of meteorological stations used for CALMET modeling of the 1984 Oresund tracer experiments.

A two-station radiosonde program provided high-resolution wind and temperature soundings on each side of the strait at three-hour intervals. These data are interpolated to hourly periods and placed into the UP.DAT file format. Sub-hourly SODAR wind data were successfully obtained at three locations (the tracer release location in Gladsaxe, Denmark, an island about 2 km from the western edge of the strait, and a site about 10 km inland in Sweden), and sub-hourly wind and temperature data were obtained at the 95 m tower from which tracer releases were made in Barseback, Sweden. These SODAR and tower profiles are averaged to hourly periods and merged with the nearest radiosonde UP.DAT data to produce hourly UP.DAT files at 4 more locations.

Meteorological data obtained from instrumented masts at eight locations and hourly weather observations at one location are reformatted and placed in a SURF.DAT file. Cloud cover observations are provided at two locations, and are inferred from shortwave radiation measurements at three locations using the conversion relationships between cloud cover and shortwave radiation that are in CALMET.

A SEA.DAT file is created from wind, air temperature, and sea temperature data at one location in the strait, at the Oskarsgrundet NE lighthouse denoted as SEA in Figure 2-6. Relative humidity data for SEA.DAT are taken from a mast located at the downwind shore of the strait. That is, the relative humidity in the onshore flow is used to characterize the relative humidity over the strait. The mixing height over the strait and the vertical temperature gradient below and above the mixing height for SEA.DAT are estimated from occasional minisonde profiles obtained from a boat in the strait. Typically two good profiles are available during all but one experiment, May 22. This experiment has an air-sea temperature difference of 5C to 6C which is similar to that on May16 and June 4 and 5, so we assume that the overwater surface layer can be represented by measurements on May16 and June 4 and 5.

Table 4-10 lists meteorological data used in the SEA.DAT file for those hours in which SF_6 was released.

4.2 Model Application & Evaluation Methods

CALMET Configuration

Cameron, Carpinteria, Pismo Beach, Ventura

CALMET is applied to each of the OCD4 datasets in the same way, emphasizing the near-surface overwater meteorological structure. CALMET is configured to extrapolate the surface observations in the SURF.DAT and SEA.DAT files in the vertical using Monin-Obukhov similarity relations and the local values of the roughness length (z_0), Monin-Obukhov length (L), and friction velocity (u_*).

Table 4-10
SEA.DAT Meteorological Data for Oresund
Tracer Release Hours

Exp	Year	Month	Day	Julian Day	Hour (end)	Ht (m)	WS (m/s)	WD* (deg)	Tair (^oK)	Tair-Tsea (^oK)	RH (%)	Mix Ht (m) Zi	dT/dz ($^oK/m$) below Zi	dT/dz ($^oK/m$) above Zi
1	84	5	16	137	10	10	3.8	125.0	285.9	4.10	97.	50	0.05	-0.008
1	84	5	16	137	11	10	4.6	135.0	286.5	4.70	94.	50	0.05	-0.008
1	84	5	16	137	12	10	5.0	136.0	287.6	5.70	88.	50	0.05	-0.008
1	84	5	16	137	13	10	5.0	130.0	288.6	6.70	83.	50	0.05	-0.008
1	84	5	16	137	14	10	4.2	130.0	289.8	7.80	78.	50	0.05	-0.008
1	84	5	16	137	15	10	7.2	131.0	289.8	7.80	70.	50	0.05	-0.008
2	84	5	18	139	9	10	6.3	202.0	282.8	0.10	97.	800	-0.008	-0.008
2	84	5	18	139	10	10	6.1	204.0	283.1	0.40	97.	800	-0.008	-0.008
2	84	5	18	139	11	10	6.0	201.0	283.4	0.60	96.	800	-0.008	-0.008
2	84	5	18	139	12	10	5.2	210.0	283.4	0.50	94.	800	-0.008	-0.008
2	84	5	18	139	13	10	3.1	199.0	283.7	0.80	90.	800	-0.008	-0.008
3	84	5	22	143	10	10	10.2	73.0	288.4	5.30	85.	50**	0.04**	-.008**
3	84	5	22	143	11	10	11.0	73.0	288.9	5.80	83.	50**	0.04**	-.008**
3	84	5	22	143	12	10	9.4	76.0	289.4	6.30	80.	50**	0.04**	-.008**
4	84	5	29	150	9	10	9.0	75.0	287.8	3.80	88.	700	-0.008	-0.008
4	84	5	29	150	10	10	8.7	74.0	289.0	4.90	84.	700	-0.008	-0.008
4	84	5	29	150	11	10	7.0	75.0	289.7	5.50	79.	100	0.035	-0.008
4	84	5	29	150	12	10	7.0	76.0	290.4	6.10	73.	100	0.035	-0.008
5	84	5	30	151	9	10	3.3	115.	285.3	1.30	96.	700	-0.008	-0.007
5	84	5	30	151	10	10	3.3	128.	284.9	0.90	97.	1000	-0.007	-0.007
5	84	5	30	151	11	10	3.0	140.	285.8	1.80	97.	1400	-0.006	-0.007
5	84	5	30	151	12	10	3.5	156.	285.9	1.90	94.	1400	-0.006	-0.007
6	84	6	4	156	9	10	8.3	74.	290.7	4.80	86.	50	0.035	-0.005
6	84	6	4	156	10	10	8.1	75.	291.5	5.60	84.	50	0.035	-0.005
6	84	6	4	156	11	10	6.5	69.	291.7	5.80	84.	50	0.035	-0.005
6	84	6	4	156	12	10	9.0	80.	293.4	7.50	79.	50	0.035	-0.005
7	84	6	5	157	9	10	7.7	71.	290.1	5.20	88.	50	0.04	-0.007
7	84	6	5	157	10	10	9.0	76.	290.9	6.00	84.	50	0.04	-0.007
7	84	6	5	157	11	10	10.6	76.	292.1	7.10	80.	50	0.04	-0.007
7	84	6	5	157	12	10	8.5	74.	292.3	7.30	77.	50	0.04	-0.007
8	84	6	12	164	9	10	3.5	228.	285.4	-1.60	75.	2200	-0.008	-0.004
8	84	6	12	164	10	10	3.5	228.	285.3	-2.10	70.	2200	-0.008	-0.004
8	84	6	12	164	11	10	3.2	205.	285.5	-1.90	69.	2200	-0.008	-0.004
8	84	6	12	164	12	10	4.7	198.	285.8	-1.60	74.	2200	-0.008	-0.004
8	84	6	12	164	13	10	4.6	193.	286.3	-1.10	77.	2200	-0.008	-0.004
9	84	6	14	166	11	10	4.2	331.	286.8	0.20	76.	2300	-0.008	-0.007
9	84	6	14	166	12	10	4.5	350.	287.2	0.50	72.	2300	-0.008	-0.007
9	84	6	14	166	13	10	6.3	294.	287.3	0.00	72.	2300	-0.008	-0.007
9	84	6	14	166	14	10	7.0	291.	287.5	1.00	74.	2300	-0.008	-0.007

* Wind direction is relative to UTM North = Geo North + 2 degrees

** No minisonde data --- mixing height and temperature gradient ASSUMED similar to May 16 and June 4/5

Winds in the UP.DAT file are given no influence in the boundary layer where the tracer transport and dispersion takes place.

Over water, the boundary layer structure is characterized by the wind speed, air-sea temperature difference, relative humidity and vertical temperature gradient listed in the SEA.DAT file. The overwater mixing height is taken directly from the SEA.DAT file and treated as an observation. Over land, the boundary layer structure is characterized by the wind speed and cloud cover listed in the SURF.DAT file, along with the gridded surface characteristics contained in the geophysical data file that account for land use variations. The daytime mixing height over land includes the history of the computed surface fluxes and accounts for the modification of the temperature structure aloft provided in the UP.DAT file. Note that mixing heights are modified for advection affects which for on-shore flow typical of these datasets produces a daytime thermal internal boundary layer (TIBL).

Alternate methods for computing the overwater boundary layer parameters are selected at each site to explore the sensitivity of model performance to these choices. The new COARE algorithm option switch (ICOARE) has the following settings:

0: OCD-like original flux model (default)

10: COARE with no wave parameterization (Charnock parameter for the open ocean, or "deep water" – can be modified for "shallow water")

11: COARE with wave option 1 (Oost et al., 2002) and default equilibrium wave properties

-11: COARE with wave option 1 (Oost et al., 2002) and observed wave properties (provided in revised SEA.DAT input file)

12: COARE with wave option 2 (Taylor and Yelland, 2001) and default equilibrium wave properties

-12: COARE with wave option 2 (Taylor and Yelland, 2001) and observed wave properties (provided in revised SEA.DAT input file)

Because observed wave properties are not part of these datasets, options -11 and -12 are not tested. When ICOARE=10, an adjustment to the Charnock constant in the roughness length can be applied to differentiate between open-ocean ("deep water") locations and near-shore ("shallow water") locations. We test this using both the original deep water and the proposed shallow water limits to determine if the original deep-water formulation may be used everywhere. The goal of this endeavor is to determine if any of these options is able to produce significantly better performance, thereby guiding the recommendation for configuring this aspect of the COARE module. Results for each of these options are labeled as 0, 10d, 10s, 11, 12, where the numbers refer to ICOARE values, and the “d” and “s” refer to the deep-water and shallow-water Charnock parameter limits.

CALMET must be started no later than the hour that ends at 0500 in the base time zone (typically LST) and it does not need to create meteorological fields for hours after the end of sampling, since no CALPUFF simulations are made after the sampling terminates. Therefore each experiment-day is simulated in a separate CALMET application.

The fumigation study at Carpinteria is made up of several ½-hour periods instead of the one-hour periods used in the other datasets. These are simulated as one-hour experiments. On 10/4/1985 and 10/5/1985, three contiguous ½-hour sampling and meteorological averaging periods must be addressed (10:00, 10:30, 11:00). This is done by making two simulations of each day, with Hour 11 set to the 10:30 period in one, and 11:00 in the other. Hour 10 is period 10:00 in both runs.

Oresund

Emphasis is given to using all available measured winds and temperatures at sites upwind of, across, and downwind of the strait of Oresund. Unlike most regular CALMET applications, there is a wealth of data on the vertical structure. Therefore, CALMET is configured to NOT extrapolate the surface observations. Winds in the UP.DAT files are given primary influence on the tracer transport and dispersion of these elevated releases.

Over the Oresund itself, the boundary layer structure is characterized by the wind speed, air-sea temperature difference, relative humidity and vertical temperature gradient listed in the SEA.DAT file. The overwater mixing height is taken directly from the SEA.DAT file and treated as an observation when it is provided, or it is computed when it is not provided. CALMET is run both with and without estimated overwater mixing heights. Over land, the boundary layer structure is characterized by the wind speed and cloud cover listed in the SURF.DAT file, along with the gridded surface characteristics contained in the geophysical data file that account for land use variations. The daytime mixing height over land includes the history of the computed surface fluxes and accounts for the modification of the temperature structure aloft provided in the UP.DAT files. Note that all mixing heights (over land and over water, whether computed or provided in the SEA.DAT file) are modified for advection affects which includes both off-shore and on-shore flow in this study.

Alternate methods for computing mixing heights are selected to explore the sensitivity of model performance to these choices. Overwater mixing heights are either provided in the SEA.DAT file (these heights are listed in Table 4-10), or computed internally. Whenever the mixing height is computed (land or water) and the surface heat flux is positive, either the modified Maul-Carson model is used

(IMIXH = 1), or the newly implemented Batchvarova-Gryning model is selected (IMIXH = 2).

CALMET must be started no later than the hour that ends at 0500 in the base time zone (CET) and it does not need to create meteorological fields for hours after the end of sampling, since no CALPUFF simulations are made after the sampling terminates. Therefore each experiment-day is simulated in a separate CALMET application.

CALPUFF Configuration

Cameron, Carpinteria, Pismo Beach, Ventura

CALPUFF is applied to each of the OCD4 datasets in the same way, with a unit emission rate (1 g/s), starting one hour before the first sampling period. The peak simulated concentration each evaluation hour is retained for comparison with the corresponding peak observed concentration, scaled by the tracer emission rate (e.g., X/Q).

Tracer emissions are characterized as non-reacting passive Gaussian puffs with no plume rise. Default plume-path-coefficient terrain adjustments are used, and ISC-like downwash adjustments are applied to those releases made from boats and modeled with downwash in the OCD evaluations. None of these releases is from a platform with significant structures, so the new platform downwash module is not tested in these applications. Turbulence-based dispersion is selected, with the default transition to Heffter curves for σ_y at σ_y = 550m.

For each of the five CALMET configurations, 16 CALPUFF configurations are run to identify the performance impact of using all combinations of:

- Measured versus predicted lateral turbulence (I_y)
- CALPUFF versus AERMOD turbulence profiling assumptions
- Draxler (1976) F_y curves for sigma-y growth with a fixed Lagrangian timescale versus a SCIPUFF-like computed Lagrangian timescale
- Minimum σ_v = 0.5 m/s (CALPUFF default) versus σ_v = 0.37 m/s (OCD default)

Oresund

CALPUFF is applied to each experiment-day in the Oresund dataset with the actual emission rate, for the actual release period (in whole hours). The resulting hourly concentrations are postprocessed using CALPOST to select only those concentrations that are simulated during the one-hour sampling period. The peak simulated concentration on each sampling arc is retained for comparison with the corresponding peak observed concentration. Because the sampling period spans two simulation hours on May 16th (1330-1430) and May 18th (1220-1320), the appropriate simulation hour is ambiguous. For these two experiments, the peak one-hour concentration from the two-hour simulation period that contains the sampling hour is selected for each arc.

Tracer emissions are characterized as non-reacting passive Gaussian puffs with no plume rise. Turbulence-based dispersion is selected, with the default transition to Heffter curves for σ_y at σ_y = 550m. The Draxler F_y function is selected for lateral cloud growth with the standard CALPUFF turbulence profiling assumptions. Default plume-path-coefficient terrain adjustments are used. The subgrid TIBL option is used here to better resolve its onshore development because the grid resolution is 1 km.

For each of the 4 CALMET configurations, two CALPUFF configurations are run to identify the performance impact of using a minimum σ_v = 0.5 m/s (CALPUFF default) versus σ_v = 0.37 m/s (OCD default).

Evaluation Statistics

The evaluation focuses on the peak observed concentrations each hour, paired in time but not in space. As in the OCD applications, the wind direction used in the CALMET input files for the OCD4 datasets (Carpinteria, Cameron, Pismo Beach and Ventura) is that which is directed from the source to the sampler with the peak concentration. Unlike OCD, this may not align the center of the CALPUFF footprint with a sampler location due to changes in the transport direction (CALPUFF trajectories are not straight lines). Therefore, additional receptors are placed along the sampling arcs in the OCD4 datasets to better resolve peak modeled concentrations within the sampling zone. Spacing for additional receptors along sampling lines is typically 100 m or less. For the Oresund simulations, wind directions are used as measured (adjusted for grid North), and no additional receptors are used.

Model predictions are quantitatively compared against measured concentrations and the resulting performance measures are compared with those for OCD5 (Carpinteria, Cameron, Pismo Beach and Ventura). The original OCD4 input files are recast for OCD5, and the revised OCD model is rerun on these data. Using the peak observed (Co) and peak modeled (Cp) concentrations each hour, the evaluation measures are computed from ln(Co/Cp). This gives equal weight to overpredictions and underpredictions (e.g., ln(Co/Cp) for Co/Cp = ½ and two are equal in magnitude but of opposite sign). The performance measures are the geometric mean (MG),

$$MG = \exp(\overline{\ln(Co/Cp)})$$

$$VG = \exp(\overline{(\ln(Co/Cp))^2})$$

$$R = \overline{(\ln Co - \overline{\ln Co})(\ln Cp - \overline{\ln Cp})} / (\sigma_{\ln Co}\sigma_{\ln Cp})$$

$$FAC2 = fraction \quad 0.5 \le (Co/Cp) \le 2$$

geometric variance (VG), the correlation coefficient (R), and the fraction within a factor of two (FAC2).

If Co and Cp are identical, MG is 1.0 and VG is 0. A factor of two scatter with no bias results in a VG of about 1.6. The minimum possible VG is related to the MG as $\ln VG_{min} = (\ln MG)^2$.

Confidence limits generated by bootstrap resampling techniques are used to assess the significance of any differences in these measures. Resampling is done in blocks that preserve the seasonal features in each of the datasets, as originally done in the OCD4 evaluations. Resampling blocks are chosen to preserve the representation of each site, and seasonality (e.g., each resampled set contains 17 entries for "Cameron Winter", which are randomly chosen with replacement from the 17 periods that comprise "Cameron Winter"). Data from Oresund are not split. The number of periods in each block are:

BLOCK	**Number**
Ventura Fall	9
Ventura Winter	8
Pismo Beach Summer	16
Pismo Beach Winter	15
Cameron Summer	9
Cameron Winter	17
Carpinteria Sf6	18
Carpinteria Freon	9
Carpinteria Fumigation	9
Oresund	9

4.3 Evaluation Results

Cameron, Carpinteria, Pismo Beach, Ventura

A total of 60 CALPUFF simulations are needed for each experiment-hour in the OCD4 dataset to explore the sensitivity of model performance to the five CALMET configurations associated with the use of the COARE module and the 16 CALPUFF configurations associated with choices for minimum σ_v, turbulence velocity profiles in the vertical, use of observed I_y, and the utility of computing the lateral Lagrangian timescale from boundary layer parameters. Note that 60 simulations are needed instead of 80 because the choice of the minimum σ_v is only applied to modeled turbulence, not observed turbulence.

Individual CALPUFF configurations are labeled A through H, covering all combinations except the minimum σ_v:

PuffA -- Modeled Iy, CALPUFF Turb(z), Draxler Fy
PuffB -- Observed Iy, CALPUFF Turb(z), Draxler Fy
PuffE -- Modeled Iy, AERMOD Turb(z), Draxler Fy
PuffF -- Observed Iy, AERMOD Turb(z), Draxler Fy
PuffC -- Modeled Iy, CALPUFF Turb(z), Variable TLy
PuffD -- Observed Iy, CALPUFF Turb(z), Variable TLy
PuffG -- Modeled Iy, AERMOD Turb(z), Variable TLy
PuffH -- Observed Iy, AERMOD Turb(z), Variable Tly

Analysis of these results leads to the following conclusions:

- The COARE "0" option (OCD-based overwater flux model) tends to produce more scatter (larger VG) than the other COARE options, and a mean bias toward smaller peak χ/Q.

- COARE variations 10d, 10s, 11, and 12 result in small performance differences, with the shallow-water adjustment 10s usually associated with smaller bias.

- The standard COARE option 10d and the two wave model options 11 and 12 do not have a significantly different VG, and the MG for option 10d produces a consistently small overprediction bias.

- CALPUFF results show less scatter than OCD5, and less tendency to overpredict with the Draxler Fy curve. This CALMET/CALPUFF configuration places a larger fraction of the modeled peak χ/Q within a factor of two of the observed peak χ/Q, and exhibits a better correlation over all experiment-hours.

- Based on mean performance across all 4 datasets, the prototype model for OCS applications improves upon the previous model designed for OCS applications. It has a small mean bias toward overprediction, and exhibits scatter that is typical in that it is close to a factor of two.

- A computed Lagrangian timescale for lateral dispersion produces a statistically significant factor of two overprediction. Runs with the standard Draxler Fy curve produce a small overprediction bias that is not statistically different from zero (MG=1).

- Using modeled Iy in CALPUFF with a minimum σ_v of 0.37 m/s produces less scatter and slightly smaller overpredictions than using the observed Iy. Using modeled Iy in CALPUFF with a minimum σ_v of 0.5 m/s reduces the bias and produces a statistically significant underprediction (MG>1) with the Draxler Fy curves.

- CALPUFF/AERMOD turbulence profile choice produces similar results, with the AERMOD choice being slightly more conservative (larger peak χ/Q).

Influence of COARE Options in CALMET

Inspection of these results indicates that the choice among COARE options in CALMET does not have a large influence on model performance. The largest influence on performance appears to be selecting the test algorithm for computing a Lagrangian timescale for lateral diffusion rather than using the timescale implicit in the Draxler Fy curves. To better illustrate the effect of the COARE options, results are collected and processed to form the geometric performance measures for the subset of CALPUFF configurations that do not include the computed Lagrangian timescale (PuffA, PuffB, PuffE and PuffF). Also, we choose to include just the PuffA and PuffE configurations that use a minimum σ_v of 0.37 m/s. Results of applying the model evaluation software, including 95% confidence limits, are listed in Tables 4-11 through 4-14, and in Figures 4-7 through 4-10.

Inclusion of the COARE module in CALMET/CALPUFF appears to offer a distinct performance advantage over the original OCD-based overwater flux module. The scatter that is quantified as VG is smaller for all 4 CALPUFF configurations when any of the non-zero COARE options is selected, and the difference in VG is statistically significant for all configurations except PuffB. Differences in MG appear smaller, but all of these differences are statistically significant except that between option c0 and c10s for the PuffB configuration.

Among the COARE options for treating wave effects on roughness length, the shallow water adjustment to the Charnock parameter (denoted here as 10s) does not improve model performance relative to using the standard Charnock parameter formulation (denoted here as 10d). These near-shore locations may present wind-wave interactions that are different from those in the open ocean, but the simple adjustment in option c10s does not capture these. Perhaps wave observations in combination with the COARE wave options in c11 or c12 would improve model performance in "shallow" water, but such observations are not contained in these datasets. Based on this evaluation, the standard COARE option (denoted here as c10d) may be used at near shore locations in the OCS regions.

Table 4-11

Performance Statistics for PuffA Configuration
(Modeled Iy, CALPUFF Turb(z), Draxler Fy)

```
OUTPUT OF THE BOOT PROGRAM, LEVEL 960626
  No. of observations =  110
  No. of models =         6
  (with the observed data counted as one)
  No. of blocks =         9
  No. of pieces in each block
                9   8  15  16   9  17  18   9   9


  All data (no blocking)                   (N=  110)
  model      mean      sigma       bias        vg    corr   fa2     mg       high   2nd high   pcor
             |<--------------- (logarithmic values) ---------------->|    (arithmetic values)
  OBS.       1.53       1.32       0.00       1.00  1.000  1.000  1.000       109        102    n/a
  A:c0       1.47       1.36       0.06       1.84  0.831  0.609  1.067        60         49    n/a
  A:c10d     1.53       1.28       0.00       1.71  0.842  0.655  1.003        59         55    n/a
  A:c10s     1.50       1.31       0.04       1.73  0.841  0.636  1.038        60         55    n/a
  A:c11      1.52       1.29       0.01       1.72  0.841  0.645  1.015        59         55    n/a
  A:c12      1.55       1.27      -0.02       1.71  0.841  0.636  0.982        59         55    n/a

SUMMARY OF CONFIDENCE LIMITS ANALYSES
 --------------------------------------

   D(log(vg)) among models: an 'X' indicates significantly different from zero
              A   A   A   A   A
              :   :   :   :   :
              c   c   c   c   c
              0   1   1   1   1
                  0   0   1   2
                  d   s
             --------------------
  A:c0    |       X   X   X   X
  A:c10d  |
  A:c10s  |
  A:c11   |

   D(log(mg)) among models: an 'X' indicates significantly different from zero
              A   A   A   A   A
              :   :   :   :   :
              c   c   c   c   c
              0   1   1   1   1
                  0   0   1   2
                  d   s
             --------------------
  A:c0    |       X   X   X   X
  A:c10d  |           X   X   X
  A:c10s  |               X   X
  A:c11   |                   X

   log(vg) for each model: an 'X' indicates significantly different from zero
              A   A   A   A   A
              :   :   :   :   :
              c   c   c   c   c
              0   1   1   1   1
                  0   0   1   2
                  d   s
             --------------------
              X   X   X   X   X

   log(mg) for each model: an 'X' indicates significantly different from zero
              A   A   A   A   A
              :   :   :   :   :
              c   c   c   c   c
              0   1   1   1   1
                  0   0   1   2
                  d   s
             --------------------
```

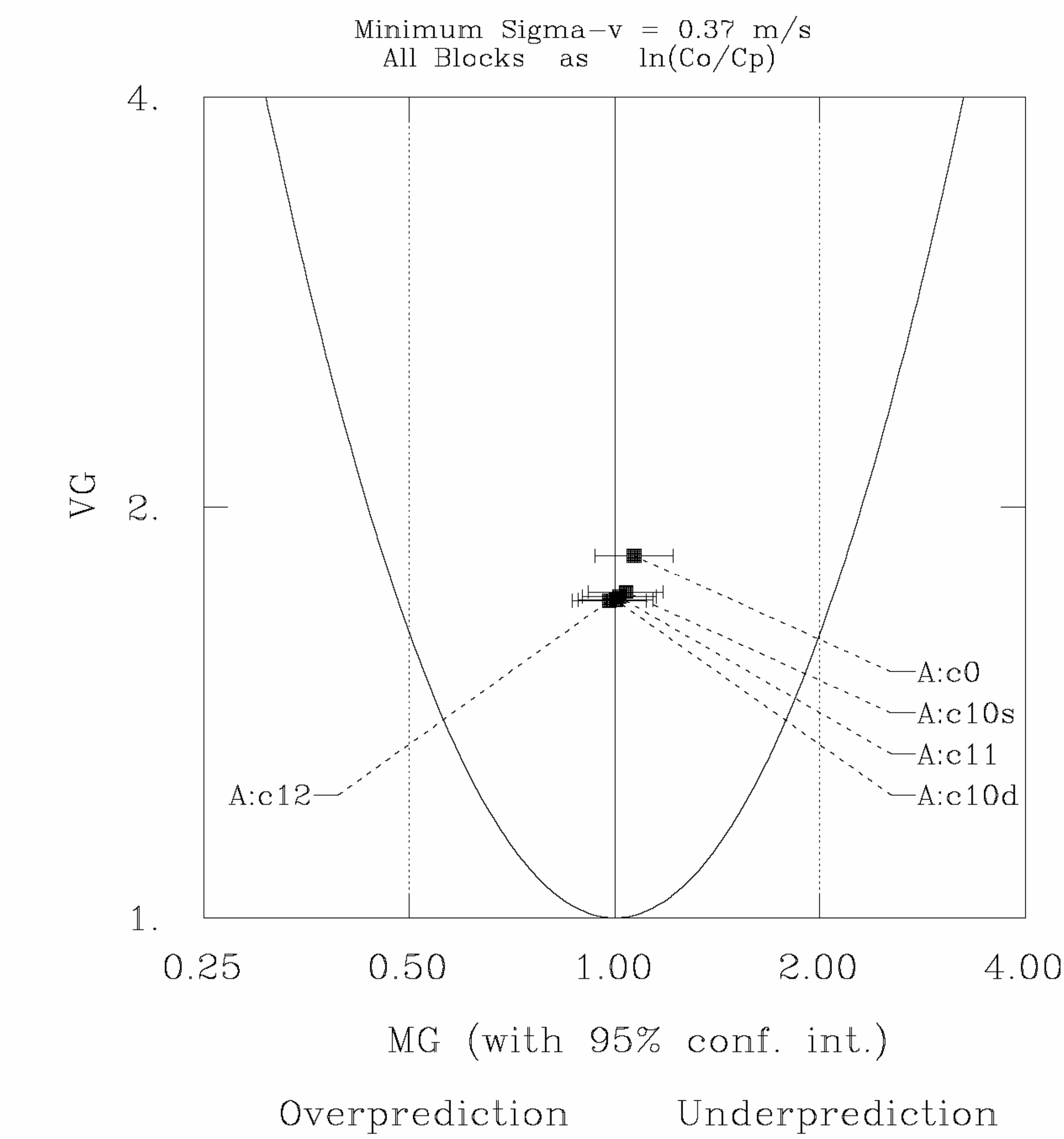

Figure 4-7. Graphical depiction of MG,VG model performance results for CALPUFF configuration PuffA (Modeled Iy with minimum σ_v = 0.37 m/s, CALPUFF Turb(z), Draxler Fy) with all COARE options tested in CALMET (c0 - OCD, c10d -deep water, c10s -shallow water, c11 - wave option 1, and c12 - wave option 2).

Table 4-12
Performance Statistics for PuffB Configuration
(Observed Iy, CALPUFF Turb(z), Draxler Fy)

```
 OUTPUT OF THE BOOT PROGRAM, LEVEL 960626
  No. of observations =  110
  No. of models =         6
  (with the observed data counted as one)
  No. of blocks =         9
  No. of pieces in each block
                9   8  15  16   9  17  18   9   9

  All data (no blocking)                   (N=  110)
  model      mean      sigma       bias        vg    corr   fa2     mg       high   2nd high   pcor
             |<--------------- (logarithmic values) ---------------->|    (arithmetic values)
  OBS.       1.53       1.32       0.00       1.00  1.000  1.000  1.000       109       102    n/a
  B:c0       1.52       1.44       0.01       2.04  0.816  0.573  1.009       194       155    n/a
  B:c10d     1.56       1.39      -0.03       1.90  0.827  0.582  0.972       204       123    n/a
  B:c10s     1.54       1.40       0.00       1.91  0.828  0.582  0.997       204       123    n/a
  B:c11      1.55       1.40      -0.02       1.91  0.826  0.582  0.978       204       123    n/a
  B:c12      1.58       1.39      -0.04       1.91  0.825  0.582  0.958       204       123    n/a

SUMMARY OF CONFIDENCE LIMITS ANALYSES
 -------------------------------------

   D(log(vg)) among models: an 'X' indicates significantly different from zero
              B   B   B   B   B
              :   :   :   :   :
              c   c   c   c   c
              0   1   1   1   1
                  0   0   1   2
                  d   s
             --------------------
  B:c0    |
  B:c10d  |
  B:c10s  |
  B:c11   |

   D(log(mg)) among models: an 'X' indicates significantly different from zero
              B   B   B   B   B
              :   :   :   :   :
              c   c   c   c   c
              0   1   1   1   1
                  0   0   1   2
                  d   s
             --------------------
  B:c0    |       X       X   X
  B:c10d  |           X   X   X
  B:c10s  |               X   X
  B:c11   |                   X

   log(vg) for each model: an 'X' indicates significantly different from zero
              B   B   B   B   B
              :   :   :   :   :
              c   c   c   c   c
              0   1   1   1   1
                  0   0   1   2
                  d   s
             --------------------
              X   X   X   X   X

   log(mg) for each model: an 'X' indicates significantly different from zero
              B   B   B   B   B
              :   :   :   :   :
              c   c   c   c   c
              0   1   1   1   1
                  0   0   1   2
                  d   s
             --------------------
```

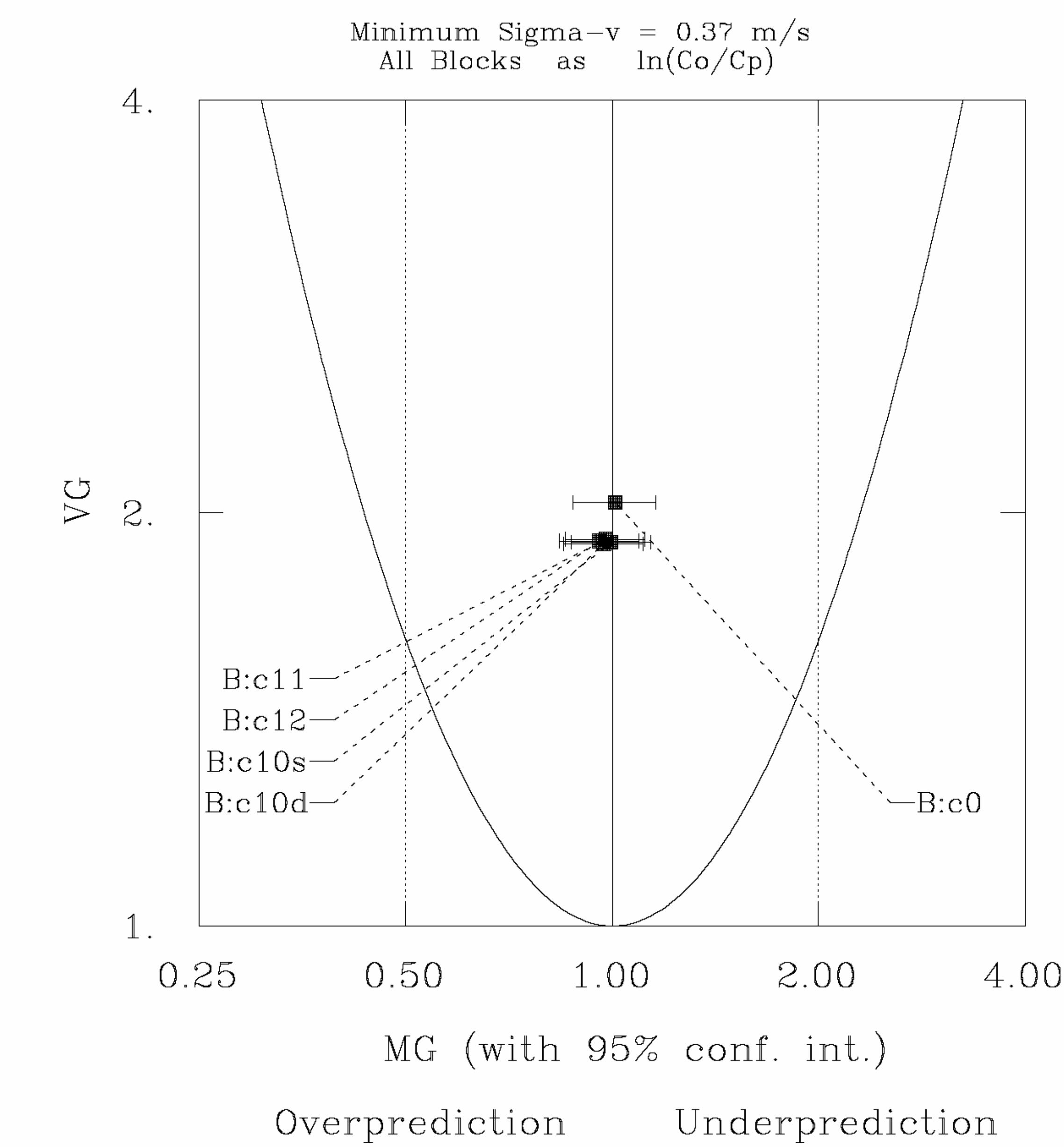

Figure 4-8. Graphical depiction of MG,VG model performance results for CALPUFF configuration PuffB (Observed Iy, CALPUFF Turb(z), Draxler Fy) with all COARE options tested in CALMET (c0 - OCD, c10d -deep water, c10s -shallow water, c11 - wave option 1, and c12 - wave option 2).

Table 4-13
Performance Statistics for PuffE Configuration
(Modeled Iy, AERMOD Turb(z), Draxler Fy)

```
OUTPUT OF THE BOOT PROGRAM, LEVEL 960626
 No. of observations =  110
 No. of models =          6
 (with the observed data counted as one)
 No. of blocks =          9
 No. of pieces in each block
               9   8  15  16   9  17  18   9   9
```

All data (no blocking) (N= 110)

model	mean	sigma	bias	vg	corr	fa2	mg	high	2nd high	pcor
	|<---------------	(logarithmic	values)	---------------			->|	(arithmetic	values)	
OBS.	1.53	1.32	0.00	1.00	1.000	1.000	1.000	109	102	n/a
E:c0	1.46	1.39	0.08	1.86	0.833	0.609	1.081	59	57	n/a
E:c10d	1.55	1.30	-0.02	1.69	0.848	0.664	0.978	62	58	n/a
E:c10s	1.51	1.32	0.02	1.72	0.844	0.655	1.018	62	59	n/a
E:c11	1.54	1.31	-0.01	1.70	0.847	0.664	0.990	62	58	n/a
E:c12	1.57	1.29	-0.04	1.68	0.848	0.664	0.964	62	58	n/a

```
SUMMARY OF CONFIDENCE LIMITS ANALYSES
-------------------------------------

    D(log(vg)) among models: an 'X' indicates significantly different from zero
             E   E   E   E   E
             :   :   :   :   :
             c   c   c   c   c
             0   1   1   1   1
                 0   0   1   2
                 d   s
            --------------------
 E:c0    |       X   X   X   X
 E:c10d  |           X
 E:c10s  |                   X
 E:c11   |

  D(log(mg)) among models: an 'X' indicates significantly different from zero
             E   E   E   E   E
             :   :   :   :   :
             c   c   c   c   c
             0   1   1   1   1
                 0   0   1   2
                 d   s
            --------------------
 E:c0    |       X   X   X   X
 E:c10d  |           X   X   X
 E:c10s  |               X   X
 E:c11   |                   X

  log(vg) for each model: an 'X' indicates significantly different from zero
             E   E   E   E   E
             :   :   :   :   :
             c   c   c   c   c
             0   1   1   1   1
                 0   0   1   2
                 d   s
            --------------------
             X   X   X   X   X

  log(mg) for each model: an 'X' indicates significantly different from zero
             E   E   E   E   E
             :   :   :   :   :
             c   c   c   c   c
             0   1   1   1   1
                 0   0   1   2
                 d   s
            --------------------
```

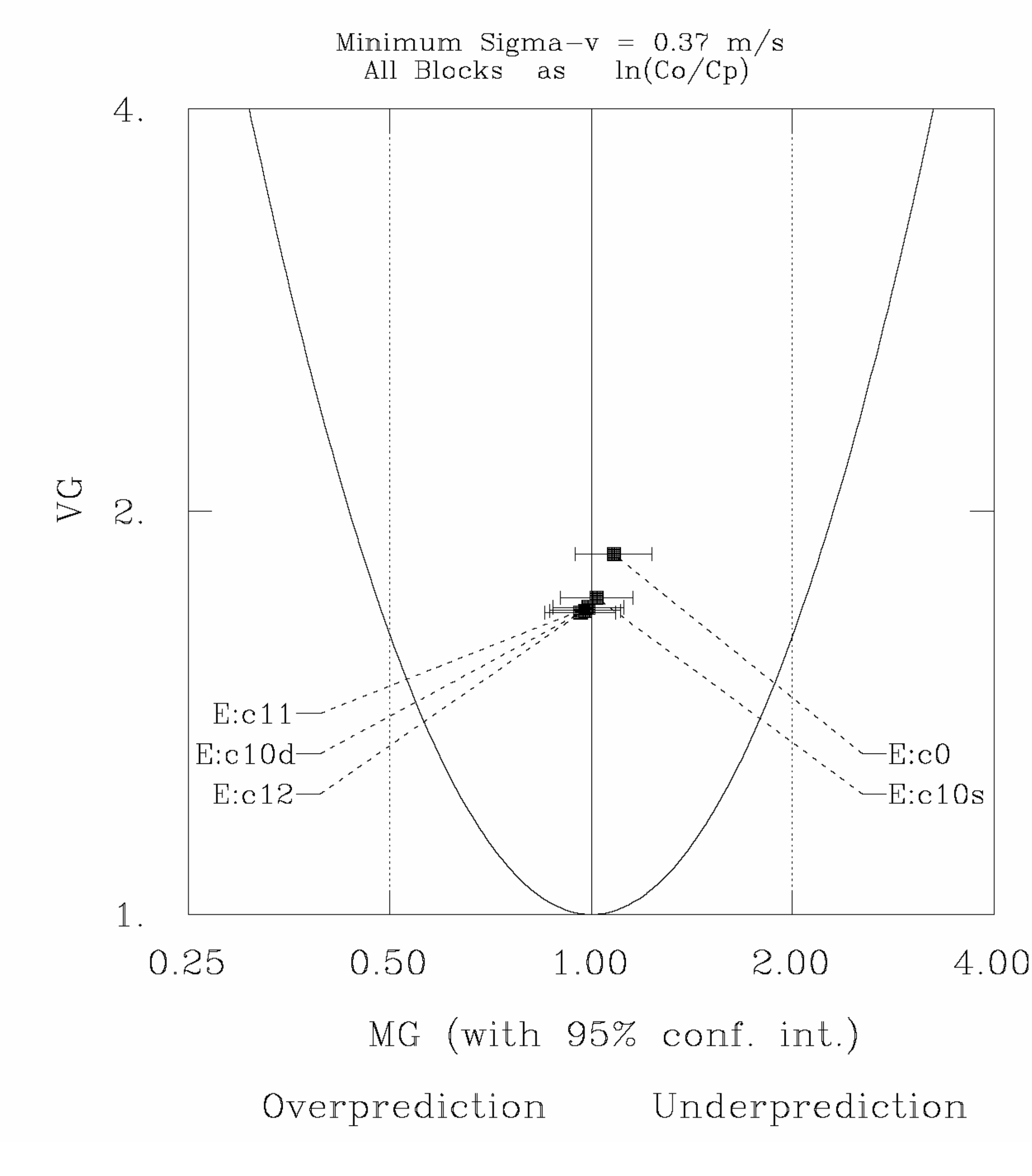

Figure 4-9. Graphical depiction of MG,VG model performance results for CALPUFF configuration PuffE (Modeled Iy with minimum σ_v = 0.37 m/s, AERMOD Turb(z), Draxler Fy) with all COARE options tested in CALMET (c0 - OCD, c10d -deep water, c10s -shallow water, c11 - wave option 1, and c12 - wave option 2).

Table 4-14
Performance Statistics for PuffF Configuration
(Observed Iy, AERMOD Turb(z), Draxler Fy)

```
OUTPUT OF THE BOOT PROGRAM, LEVEL 960626
 No. of observations =  110
 No. of models =          6
 (with the observed data counted as one)
 No. of blocks =          9
 No. of pieces in each block
                9   8  15  16   9  17  18   9   9

 All data (no blocking)                  (N=  110)
 model      mean      sigma       bias        vg    corr   fa2     mg       high   2nd high   pcor
            |<--------------- (logarithmic values) ---------------->|    (arithmetic values)
 OBS.       1.53       1.32       0.00       1.00  1.000  1.000  1.000       109       102    n/a
 F:c0       1.52       1.47       0.01       2.08  0.816  0.582  1.010       253       195    n/a
 F:c10d     1.59       1.41      -0.06       1.88  0.834  0.600  0.941       265       161    n/a
 F:c10s     1.57       1.42      -0.03       1.90  0.833  0.591  0.966       265       161    n/a
 F:c11      1.59       1.41      -0.05       1.89  0.832  0.609  0.947       265       161    n/a
 F:c12      1.60       1.40      -0.07       1.87  0.834  0.600  0.932       265       161    n/a

SUMMARY OF CONFIDENCE LIMITS ANALYSES
-------------------------------------

  D(log(vg)) among models: an 'X' indicates significantly different from zero
             F   F   F   F   F
             :   :   :   :   :
             c   c   c   c   c
             0   1   1   1   1
                 0   0   1   2
                 d   s
            --------------------
 F:c0    |       X   X   X   X
 F:c10d  |
 F:c10s  |
 F:c11   |

  D(log(mg)) among models: an 'X' indicates significantly different from zero
             F   F   F   F   F
             :   :   :   :   :
             c   c   c   c   c
             0   1   1   1   1
                 0   0   1   2
                 d   s
            --------------------
 F:c0    |       X   X   X   X
 F:c10d  |           X   X   X
 F:c10s  |               X   X
 F:c11   |                   X

  log(vg) for each model: an 'X' indicates significantly different from zero
             F   F   F   F   F
             :   :   :   :   :
             c   c   c   c   c
             0   1   1   1   1
                 0   0   1   2
                 d   s
            --------------------
             X   X   X   X   X

  log(mg) for each model: an 'X' indicates significantly different from zero
             F   F   F   F   F
             :   :   :   :   :
             c   c   c   c   c
             0   1   1   1   1
                 0   0   1   2
                 d   s
            --------------------
```

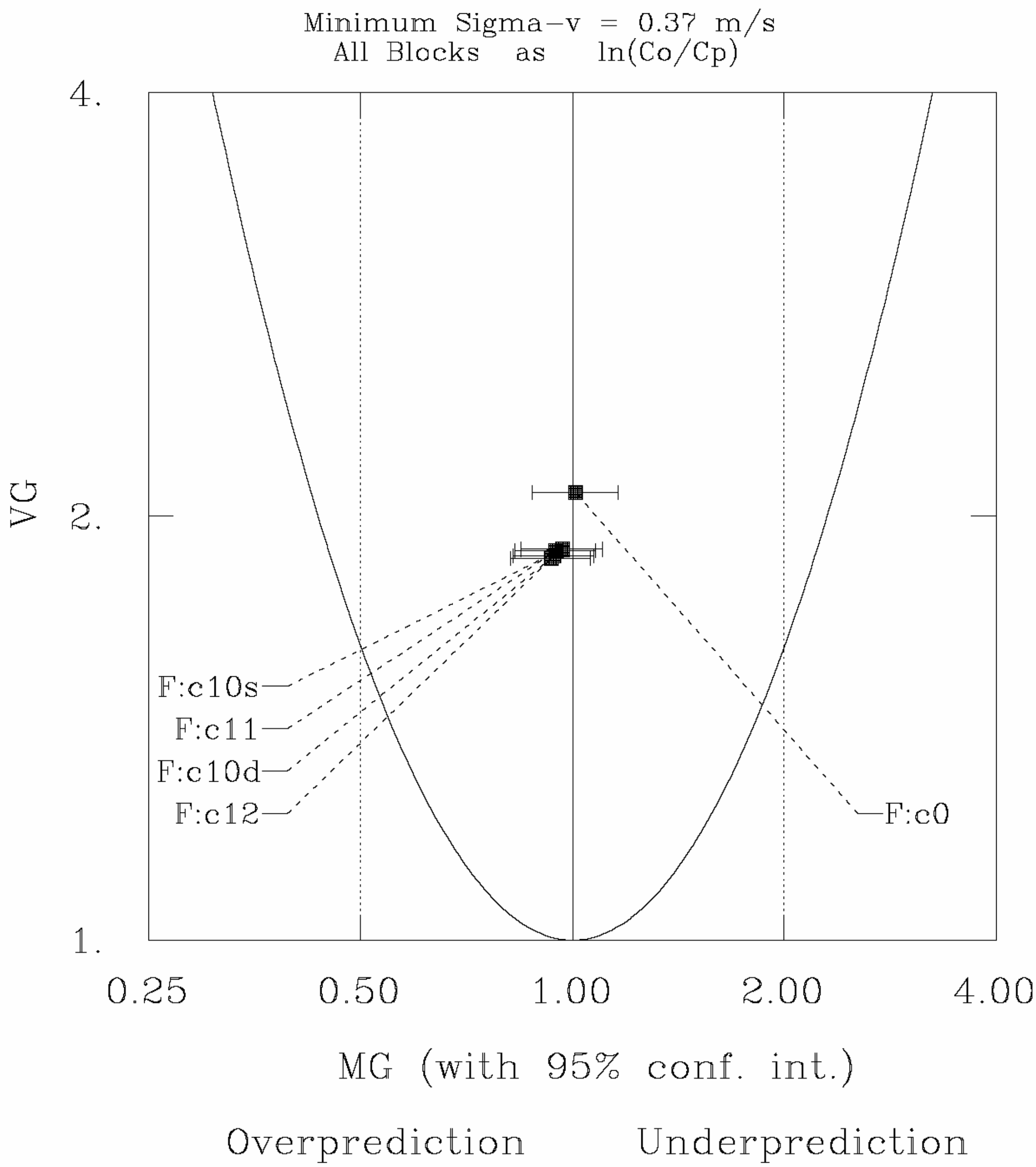

Figure 4-10. Graphical depiction of MG,VG model performance results for CALPUFF configuration PuffF (Observed Iy, AERMOD Turb(z), Draxler Fy) with all COARE options tested in CALMET (c0 - OCD, c10d -deep water, c10s -shallow water, c11 - wave option 1, and c12 - wave option 2).

Influence of Minimum σ_v in CALPUFF

The performance of CALPUFF when using modeled lateral turbulence with either the default minimum σ_v of 0.5 m/s or the OCD minimum σ_v of 0.37 m/s is evaluated using runs made with the standard COARE option, denoted here as c10d. Results from Appendix A are collected and processed to form the geometric performance measures for CALPUFF configurations PuffA, PuffC, PuffE and PuffG. Results of applying the model evaluation software, including 95% confidence limits, are listed in Table 4-15 and Figure 4-11.

A minimum σ_v provides a lower limit to the rate of lateral dispersion, so using a smaller value is expected to lead to larger modeled concentrations whenever predicted lateral turbulence is small. This may happen often in these overwater datasets due to small turbulence during stable periods. Differences can be seen in the performance results, and as expected, peak modeled concentrations with the default value of 0.5 m/s are smaller than those with 0.37 m/s. Furthermore, the results indicate that this leads to an underprediction with the Draxler Fy configuration (PuffA and PuffE). The configurations with a computed Lagrangian timescale TLy (PuffC and PuffG) still overpredict by about a factor of two. All of the differences in MG seen in Figure 4-11 are statistically significant, and only CALPUFF configurations with Draxler Fy and the minimum σ_v = 0.37 m/s have a confidence interval that overlaps zero bias.

Therefore, overwater applications of CALMET/CALPUFF should use a minimum σ_v = 0.37 m/s, and an option for specifying an overwater minimum should be added to CALPUFF.

Table 4-15
Performance Statistics for CALPUFF Configurations with Modeled Iy for Minimum σ_v = 0.37 and 0.5 m/s

```
OUTPUT OF THE BOOT PROGRAM, LEVEL 960626
 No. of observations =  110
 No. of models =          9
 (with the observed data counted as one)
 No. of blocks =          9
 No. of pieces in each block
               9   8  15  16   9  17  18   9   9
```

All data (no blocking) (N= 110)

model	mean	sigma	bias	vg	corr	fa2	mg	high	2nd high	pcor
	|<---------------	(logarithmic	values)	----------------			->|	(arithmetic	values)	
A:37	1.53	1.28	0.00	1.71	0.842	0.655	1.003	59	55	n/a
E:37	1.55	1.30	-0.02	1.69	0.848	0.664	0.978	62	58	n/a
C:37	2.20	1.31	-0.67	3.20	0.794	0.482	0.511	147	110	n/a
G:37	2.24	1.32	-0.71	3.19	0.810	0.500	0.493	149	129	n/a
A:50	1.33	1.22	0.21	1.77	0.838	0.645	1.229	44	44	n/a
E:50	1.36	1.23	0.18	1.72	0.845	0.636	1.192	49	45	n/a
C:50	2.09	1.28	-0.55	2.71	0.796	0.518	0.575	123	98	n/a
G:50	2.12	1.29	-0.59	2.71	0.810	0.491	0.554	124	114	n/a

SUMMARY OF CONFIDENCE LIMITS ANALYSES

```
-------------------------------------

  D(log(vg)) among models: an 'X' indicates significantly different from zero
             A   E   C   G   A   E   C   G
             :   :   :   :   :   :   :   :
             3   3   3   3   5   5   5   5
             7   7   7   7   0   0   0   0
            --------------------------------
 A:37    |           X   X           X   X
 E:37    |           X   X           X   X
 C:37    |                   X   X   X   X
 G:37    |                   X   X   X   X
 A:50    |                       X   X   X
 E:50    |                           X   X
 C:50    |

  D(log(mg)) among models: an 'X' indicates significantly different from zero
             A   E   C   G   A   E   C   G
             :   :   :   :   :   :   :   :
             3   3   3   3   5   5   5   5
             7   7   7   7   0   0   0   0
            --------------------------------
 A:37    |       X   X   X   X   X   X   X
 E:37    |           X   X   X   X   X   X
 C:37    |               X   X   X   X   X
 G:37    |                   X   X   X   X
 A:50    |                       X   X   X
 E:50    |                           X   X
 C:50    |                               X

  log(vg) for each model: an 'X' indicates significantly different from zero
             A   E   C   G   A   E   C   G
             :   :   :   :   :   :   :   :
             3   3   3   3   5   5   5   5
             7   7   7   7   0   0   0   0
            --------------------------------
             X   X   X   X   X   X   X   X

  log(mg) for each model: an 'X' indicates significantly different from zero
             A   E   C   G   A   E   C   G
             :   :   :   :   :   :   :   :
             3   3   3   3   5   5   5   5
             7   7   7   7   0   0   0   0
            --------------------------------
                     X   X   X   X   X   X
```

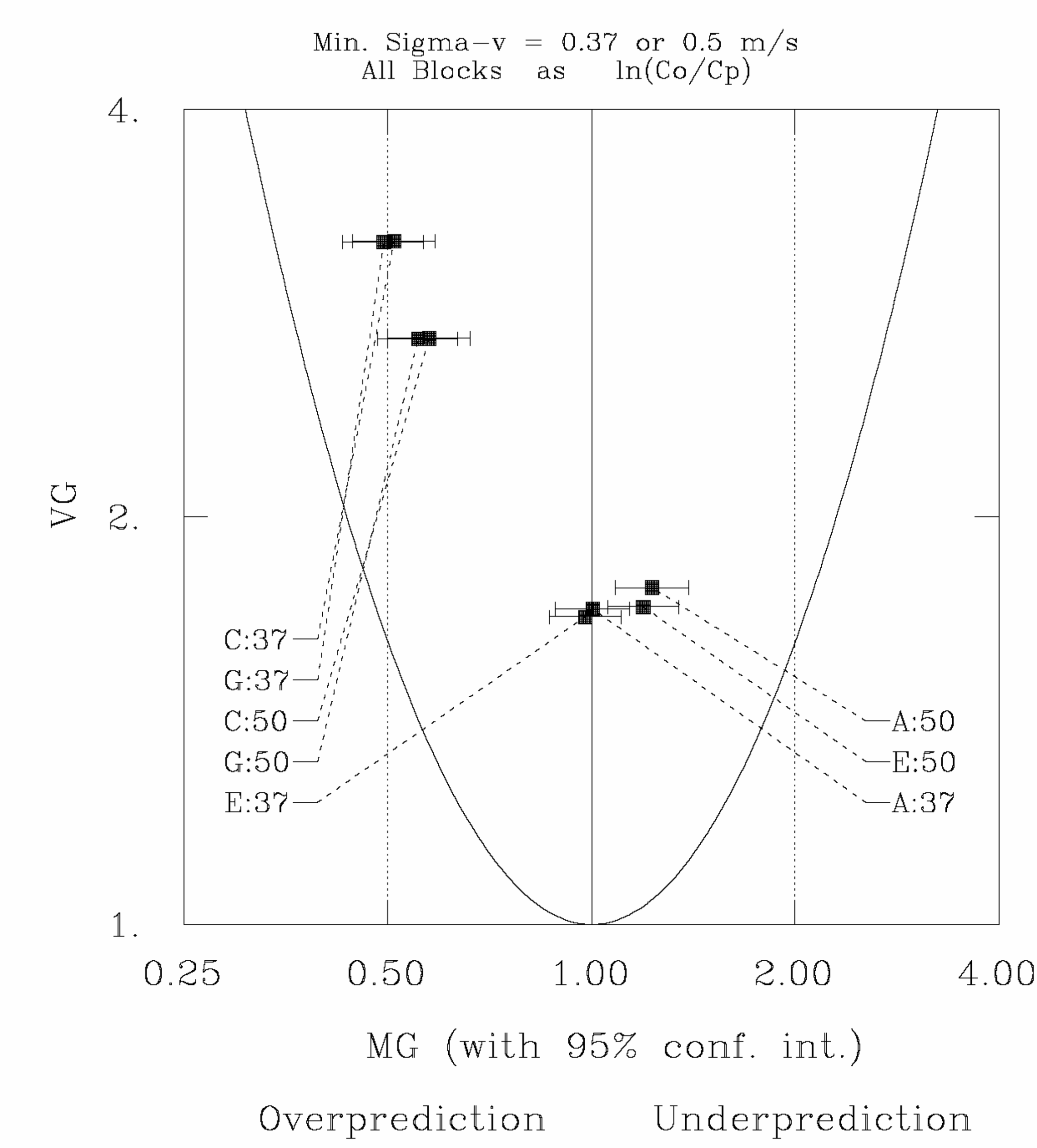

Figure 4-11. Graphical depiction of MG,VG model performance results for CALPUFF configurations with Modeled Iy for minimum σ_v = 0.37 m/s (:37 labels) and 0.5 m/s (:50 labels).

A -- Modeled Iy, CALPUFF Turb(z), Draxler Fy
E -- Modeled Iy, AERMOD Turb(z), Draxler Fy
C -- Modeled Iy, CALPUFF Turb(z), Variable TLy
G -- Modeled Iy, AERMOD Turb(z), Variable TLy

Performance of CALPUFF Configurations Using Standard COARE in CALMET

The performance of all eight CALPUFF configurations tested are intercompared using runs made with the standard COARE option, denoted here as c10d, with a minimum σ_v = 0.37 m/s. Results from Appendix A are collected and processed to form the geometric performance measures. OCD5 results are also included as a reference point. Results of applying the model evaluation software, including 95% confidence limits, are listed in Table 4-16 and Figure 4-12. Note that OCD5 with observed Iy produces a peak χ/Q less than 0.001 $\mu s/m^3$ in one of the Carpinteria fumigation study periods. This is seen as a "zero" by the performance evaluation software which precludes forming measures based on ln(Co/Cp). The OCD5 peak χ/Q for this period is increased to 0.001 $\mu s/m^3$. With predicted Iy, OCD5 produced a peak χ/Q equal to 0.010 $\mu s/m^3$ for this period, whereas the observed is 5.20 $\mu s/m^3$.

MG,VG results in Figure 4-12 fall into three groups. The first includes CALPUFF configurations with computed TLy based on the turbulence at puff height, the height of the surface layer, and the Monin-Obukhov length. This group shows the strongest bias toward overprediction, with an MG of about 0.5 (factor of two overprediction). This overprediction may result from details chosen for the implementation of this new algorithm (i.e., more development work might improve on this performance), or it may result from problems inherent in using properties of the boundary layer that are poorly known at times. Whatever the reason, the implementation tested here performs poorly compared to the use of the standard Fy function for lateral cloud growth in CALPUFF.

The second group includes the two OCD5 results, for modeled and observed Iy. While the tendency toward overprediction is about 10-20%, the scatter is relatively large at VG = 3 to 4. Some of the scatter is due to the fumigation event that OCD5 "misses". Even with this singular event that tends to increase the MG (reduces the degree of overprediction), the overall MG using the predicted Iy is significantly different from 1.0 because the 95% confidence interval does not overlap 1.0.

The third group includes CALPUFF simulations with the Draxler Fy function for lateral cloud growth in the near field and turbulence profiles from either CALPUFF or AERMOD. All 4 configurations have an MG that is near 1.0, and are not significantly different from 1.0. VG for these lies between 1.7 and 1.9, which is slightly greater than the 1.6 that indicates about a factor of two scatter. Within this group, use of the AERMOD turbulence profiles leads to slightly larger concentrations (smaller MG). Using observed Iy also leads to slightly larger concentrations, and larger scatter. The small difference in MG between using the CALPUFF and AERMOD turbulence profiles is statistically significant, but the difference between using observed and predicted Iy is not.

The performance evaluation system also provides results for the fraction of model predictions that are within a factor-of-2 of the observations (FAC2), and the correlation:

Modeled Iy	**FAC2**	**Correlation**
CALPUFF (CALPUFF Turbulence Profile)	0.655	0.842
CALPUFF (AERMOD Turbulence Profile)	0.664	0.848
OCD5	0.536	0.712
Observed Iy	**FAC2**	**Correlation**
CALPUFF (CALPUFF Turbulence Profile)	0.582	0.827
CALPUFF (AERMOD Turbulence Profile)	0.600	0.834
OCD5	0.545	0.663

Based on these measures across all 4 datasets, the prototype model for OCS applications improves upon the previous model designed for OCS applications. It has a small mean bias toward overprediction, and exhibits scatter that is typical in that it is close to a factor of two.

Table 4-16
Performance Statistics for All CALPUFF Configurations
(Modeled Iy uses minimum σ_v = 0.37 m/s)

OUTPUT OF THE BOOT PROGRAM, LEVEL 960626
No. of observations = 110
No. of models = 11
(with the observed data counted as one)
No. of blocks = 9
No. of pieces in each block
9 8 15 16 9 17 18 9 9

All data (no blocking) (N= 110)

model	mean	sigma	bias	vg	corr	fa2	mg	high	2nd high	pcor
	|<---------------	(logarithmic	values)	---------------			->|	(arithmetic	values)	
OBS.	1.53	1.32	0.00	1.00	1.000	1.000	1.000	109	102	n/a
OCD5PIY	1.72	1.39	-0.19	2.98	0.712	0.536	0.830	203	191	n/a
OCD5OIY	1.61	1.54	-0.08	4.15	0.663	0.545	0.925	232	200	n/a
A:c10d	1.53	1.28	0.00	1.71	0.842	0.655	1.003	59	55	n/a
B:c10d	1.56	1.39	-0.03	1.90	0.827	0.582	0.972	204	123	n/a
E:c10d	1.55	1.30	-0.02	1.69	0.848	0.664	0.978	62	58	n/a
F:c10d	1.59	1.41	-0.06	1.88	0.834	0.600	0.941	265	161	n/a
C:c10d	2.20	1.31	-0.67	3.20	0.794	0.482	0.511	147	110	n/a
D:c10d	2.20	1.40	-0.67	3.50	0.784	0.482	0.511	269	183	n/a
G:c10d	2.24	1.32	-0.71	3.19	0.810	0.500	0.493	149	129	n/a
H:c10d	2.24	1.41	-0.70	3.47	0.801	0.509	0.494	345	215	n/a

Block 1: Ventura_Fall (N= 9)

model	mean	sigma	bias	vg	corr	fa2	mg	high	2nd high	pcor
	|<---------------	(logarithmic	values)	---------------			->|	(arithmetic	values)	
OBS.	-0.29	0.72	0.00	1.00	1.000	1.000	1.000	3	2	n/a
OCD5PIY	0.47	0.22	-0.76	2.63	0.572	0.222	0.467	3	2	n/a
OCD5OIY	0.47	0.28	-0.76	2.31	0.849	0.444	0.467	2	2	n/a
A:c10d	-0.48	0.56	0.19	1.39	0.668	0.889	1.212	1	1	n/a
B:c10d	-0.32	0.65	0.02	1.31	0.721	0.778	1.025	2	1	n/a
E:c10d	-0.46	0.57	0.17	1.37	0.678	0.889	1.181	2	1	n/a
F:c10d	-0.29	0.66	0.00	1.30	0.726	0.778	1.004	2	1	n/a
C:c10d	0.23	0.67	-0.52	1.89	0.628	0.444	0.593	4	3	n/a
D:c10d	0.25	0.73	-0.54	1.96	0.645	0.667	0.580	4	3	n/a
G:c10d	0.26	0.69	-0.55	1.96	0.633	0.444	0.574	4	3	n/a
H:c10d	0.29	0.76	-0.58	2.03	0.659	0.667	0.561	4	3	n/a

Block 2: Ventura_Winter (N= 8)

model	mean	sigma	bias	vg	corr	fa2	mg	high	2nd high	pcor
	|<---------------	(logarithmic	values)	---------------			->|	(arithmetic	values)	
OBS.	0.71	0.33	0.00	1.00	1.000	1.000	1.000	3	3	n/a
OCD5PIY	0.98	0.13	-0.28	1.24	-0.188	0.875	0.758	3	3	n/a
OCD5OIY	0.47	0.57	0.24	1.24	0.724	0.875	1.266	4	3	n/a
A:c10d	0.44	0.67	0.27	1.72	0.210	0.625	1.310	4	3	n/a
B:c10d	0.31	0.56	0.40	1.58	0.343	0.625	1.490	4	3	n/a
E:c10d	0.41	0.65	0.29	1.69	0.221	0.625	1.341	4	3	n/a
F:c10d	0.29	0.56	0.42	1.59	0.369	0.625	1.522	4	3	n/a
C:c10d	1.59	0.78	-0.88	4.14	0.120	0.375	0.416	13	13	n/a
D:c10d	1.39	0.75	-0.68	2.56	0.394	0.500	0.508	10	10	n/a
G:c10d	1.57	0.76	-0.86	3.91	0.128	0.375	0.422	12	12	n/a
H:c10d	1.37	0.75	-0.66	2.48	0.410	0.500	0.515	10	10	n/a

Block 3: Pismo_Winter (N= 15)

model	mean	sigma	bias	vg	corr	fa2	mg	high	2nd high	pcor
	|<---------------	(logarithmic	values)	---------------			->|	(arithmetic	values)	
OBS.	1.34	0.58	0.00	1.00	1.000	1.000	1.000	9	7	n/a
OCD5PIY	1.20	0.68	0.13	2.28	-0.008	0.467	1.143	9	9	n/a
OCD5OIY	1.02	1.26	0.32	3.63	0.510	0.467	1.376	14	13	n/a
A:c10d	1.18	0.59	0.15	1.89	0.098	0.667	1.167	9	6	n/a
B:c10d	1.12	0.79	0.22	1.64	0.565	0.600	1.244	10	10	n/a
E:c10d	1.15	0.58	0.18	1.85	0.125	0.600	1.203	9	7	n/a
F:c10d	1.12	0.80	0.22	1.59	0.602	0.667	1.247	10	10	n/a
C:c10d	1.89	0.77	-0.56	3.65	-0.075	0.467	0.573	17	17	n/a
D:c10d	1.79	0.79	-0.46	2.52	0.272	0.400	0.633	17	17	n/a
G:c10d	1.88	0.73	-0.55	3.28	-0.027	0.600	0.580	18	16	n/a
H:c10d	1.80	0.79	-0.46	2.36	0.340	0.400	0.630	18	17	n/a

Table 4-16 (continued)
Performance Statistics for All CALPUFF Configurations
(Modeled Iy uses minimum σ_v = 0.37 m/s)

Block 4: Pismo_Summer (N= 16)

model	mean	sigma	bias	vg	corr	fa2	mg	high	2nd high	pcor
	|<---------------	(logarithmic	values)			----------------	>|	(arithmetic	values)	
OBS.	1.15	0.38	0.00	1.00	1.000	1.000	1.000	8	5	n/a
OCD5PIY	1.20	0.51	-0.05	1.44	0.111	0.625	0.952	7	6	n/a
OCD5OIY	1.31	0.85	-0.16	1.76	0.507	0.688	0.853	12	12	n/a
A:c10d	1.60	0.42	-0.45	1.57	0.224	0.688	0.637	8	7	n/a
B:c10d	1.68	0.77	-0.53	1.91	0.622	0.438	0.589	17	13	n/a
E:c10d	1.60	0.49	-0.45	1.68	0.189	0.625	0.639	8	8	n/a
F:c10d	1.71	0.77	-0.56	2.01	0.608	0.438	0.572	19	13	n/a
C:c10d	2.45	0.37	-1.29	6.58	0.266	0.125	0.274	24	20	n/a
D:c10d	2.55	0.56	-1.39	8.53	0.611	0.125	0.248	31	31	n/a
G:c10d	2.47	0.42	-1.32	7.29	0.218	0.125	0.268	24	20	n/a
H:c10d	2.55	0.57	-1.40	8.87	0.579	0.125	0.246	34	30	n/a

Block 5: Cameron_Summer (N= 9)

model	mean	sigma	bias	vg	corr	fa2	mg	high	2nd high	pcor
	|<---------------	(logarithmic	values)			----------------	>|	(arithmetic	values)	
OBS.	-0.29	0.78	0.00	1.00	1.000	1.000	1.000	3	2	n/a
OCD5PIY	0.48	0.13	-0.77	2.90	0.735	0.444	0.464	2	2	n/a
OCD5OIY	0.46	0.29	-0.76	2.53	0.724	0.556	0.470	2	2	n/a
A:c10d	-0.49	0.47	0.20	1.68	0.467	0.667	1.218	1	1	n/a
B:c10d	-0.54	0.66	0.25	1.87	0.459	0.667	1.283	1	1	n/a
E:c10d	-0.39	0.40	0.10	1.49	0.595	0.778	1.105	1	1	n/a
F:c10d	-0.45	0.59	0.16	1.61	0.543	0.556	1.172	1	1	n/a
C:c10d	-0.16	0.50	-0.13	1.59	0.527	0.778	0.874	2	2	n/a
D:c10d	-0.19	0.60	-0.11	1.64	0.513	0.667	0.899	2	2	n/a
G:c10d	-0.07	0.44	-0.23	1.50	0.646	0.667	0.798	2	2	n/a
H:c10d	-0.10	0.54	-0.19	1.52	0.611	0.667	0.825	2	2	n/a

Block 6: Cameron_Winter (N= 17)

model	mean	sigma	bias	vg	corr	fa2	mg	high	2nd high	pcor
	|<---------------	(logarithmic	values)			----------------	>|	(arithmetic	values)	
OBS.	1.92	1.01	0.00	1.00	1.000	1.000	1.000	37	35	n/a
OCD5PIY	1.81	0.76	0.11	1.45	0.804	0.706	1.114	17	16	n/a
OCD5OIY	2.28	0.83	-0.37	1.71	0.777	0.588	0.694	33	30	n/a
A:c10d	1.85	0.72	0.07	2.25	0.503	0.412	1.076	17	17	n/a
B:c10d	2.30	0.91	-0.38	3.42	0.414	0.471	0.686	38	31	n/a
E:c10d	1.83	0.71	0.09	2.22	0.510	0.412	1.091	17	17	n/a
F:c10d	2.28	0.90	-0.36	3.27	0.422	0.471	0.698	36	31	n/a
C:c10d	2.86	0.92	-0.94	6.96	0.438	0.353	0.389	60	59	n/a
D:c10d	3.15	1.00	-1.23	15.81	0.380	0.294	0.292	82	80	n/a
G:c10d	2.84	0.91	-0.92	6.55	0.445	0.353	0.397	59	59	n/a
H:c10d	3.12	0.98	-1.21	14.17	0.394	0.294	0.299	83	81	n/a

Block 7: Carpinteria_SF6 (N= 18)

model	mean	sigma	bias	vg	corr	fa2	mg	high	2nd high	pcor
	|<---------------	(logarithmic	values)			----------------	>|	(arithmetic	values)	
OBS.	3.43	0.77	0.00	1.00	1.000	1.000	1.000	109	102	n/a
OCD5PIY	3.70	0.93	-0.28	1.78	0.669	0.611	0.758	203	191	n/a
OCD5OIY	3.29	1.14	0.13	1.95	0.707	0.444	1.144	232	200	n/a
A:c10d	3.26	0.46	0.17	1.49	0.611	0.722	1.183	59	55	n/a
B:c10d	3.18	0.93	0.24	1.68	0.696	0.611	1.278	204	123	n/a
E:c10d	3.36	0.46	0.06	1.39	0.671	0.833	1.066	62	58	n/a
F:c10d	3.29	0.98	0.14	1.69	0.693	0.722	1.150	265	161	n/a
C:c10d	3.67	0.69	-0.24	1.61	0.611	0.778	0.786	147	110	n/a
D:c10d	3.60	1.01	-0.18	1.82	0.674	0.722	0.836	269	183	n/a
G:c10d	3.80	0.73	-0.38	1.66	0.674	0.833	0.685	149	129	n/a
H:c10d	3.74	1.06	-0.31	1.95	0.705	0.833	0.733	345	215	n/a

Table 4-16 (continued)
Performance Statistics for All CALPUFF Configurations
(Modeled Iy uses minimum $\sigma_v = 0.37$ m/s)

Block 8: Carpinteria_Fumigation (N= 9)

model	mean	sigma	bias	vg	corr	fa2	mg	high	2nd high	pcor
	|<---------------	(logarithmic	values)	------	------	------	------>|	(arithmetic	values)	
OBS.	1.78	0.52	0.00	1.00	1.000	1.000	1.000	15	12	n/a
OCD5PIY	1.29	2.29	0.49	527.07	-0.225	0.222	1.627	25	14	n/a
OCD5OIY	0.72	2.78	1.06	11909.10	-0.088	0.333	2.899	10	10	n/a
A:c10d	1.85	0.23	-0.07	1.32	0.203	0.778	0.934	9	8	n/a
B:c10d	1.73	0.66	0.04	2.00	0.027	0.556	1.046	32	8	n/a
E:c10d	1.84	0.23	-0.06	1.32	0.211	0.778	0.937	9	8	n/a
F:c10d	1.73	0.66	0.04	2.00	0.026	0.556	1.046	32	8	n/a
C:c10d	2.30	0.43	-0.52	1.81	0.305	0.667	0.594	20	16	n/a
D:c10d	2.21	0.67	-0.43	2.18	0.188	0.778	0.650	47	14	n/a
G:c10d	2.30	0.44	-0.52	1.81	0.309	0.667	0.595	20	16	n/a
H:c10d	2.21	0.67	-0.43	2.18	0.191	0.778	0.650	47	14	n/a

Block 9: Carpinteria_CF3Br (N= 9)

model	mean	sigma	bias	vg	corr	fa2	mg	high	2nd high	pcor
	|<---------------	(logarithmic	values)	------	------	------	------>|	(arithmetic	values)	
OBS.	2.15	0.59	0.00	1.00	1.000	1.000	1.000	25	18	n/a
OCD5PIY	2.92	0.28	-0.77	2.61	0.205	0.444	0.462	28	24	n/a
OCD5OIY	2.68	0.28	-0.53	1.75	0.464	0.556	0.588	30	16	n/a
A:c10d	2.61	0.21	-0.46	2.12	-0.566	0.556	0.632	22	17	n/a
B:c10d	2.38	0.34	-0.23	1.68	-0.004	0.667	0.797	16	15	n/a
E:c10d	2.69	0.22	-0.54	2.25	-0.459	0.556	0.585	24	17	n/a
F:c10d	2.45	0.34	-0.30	1.70	0.061	0.667	0.742	18	16	n/a
C:c10d	2.91	0.29	-0.76	3.10	-0.328	0.444	0.467	32	26	n/a
D:c10d	2.74	0.24	-0.59	2.15	-0.042	0.444	0.555	23	19	n/a
G:c10d	2.98	0.30	-0.83	3.42	-0.304	0.444	0.438	37	27	n/a
H:c10d	2.81	0.23	-0.66	2.32	-0.018	0.556	0.517	21	21	n/a

Table 4-16 (concluded)
Performance Statistics for All CALPUFF Configurations
(Modeled Iy uses minimum σ_v = 0.37 m/s)

```
SUMMARY OF CONFIDENCE LIMITS ANALYSES
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  D(log(vg)) among models: an 'X' indicates significantly different from zero
             O   O   A   B   E   F   C   D   G   H
             C   C   :   :   :   :   :   :   :   :
             D   D   c   c   c   c   c   c   c   c
             5   5   1   1   1   1   1   1   1   1
             P   O   0   0   0   0   0   0   0   0
             I   I   d   d   d   d   d   d   d   d
             Y   Y
            ----------------------------------------
 OCD5PIY |
 OCD5OIY |
 A:c10d  |                           X   X   X   X
 B:c10d  |                           X   X   X   X
 E:c10d  |                           X   X   X   X
 F:c10d  |                           X   X   X   X
 C:c10d  |
 D:c10d  |
 G:c10d  |

  D(log(mg)) among models: an 'X' indicates significantly different from zero
             O   O   A   B   E   F   C   D   G   H
             C   C   :   :   :   :   :   :   :   :
             D   D   c   c   c   c   c   c   c   c
             5   5   1   1   1   1   1   1   1   1
             P   O   0   0   0   0   0   0   0   0
             I   I   d   d   d   d   d   d   d   d
             Y   Y
            ----------------------------------------
 OCD5PIY |           X               X   X   X   X
 OCD5OIY |                           X   X   X   X
 A:c10d  |                   X       X   X   X   X
 B:c10d  |                       X   X   X   X   X
 E:c10d  |                           X   X   X   X
 F:c10d  |                           X   X   X   X
 C:c10d  |                                   X
 D:c10d  |                                       X
 G:c10d  |

  log(vg) for each model: an 'X' indicates significantly different from zero
             O   O   A   B   E   F   C   D   G   H
             C   C   :   :   :   :   :   :   :   :
             D   D   c   c   c   c   c   c   c   c
             5   5   1   1   1   1   1   1   1   1
             P   O   0   0   0   0   0   0   0   0
             I   I   d   d   d   d   d   d   d   d
             Y   Y
            ----------------------------------------
             X   X   X   X   X   X   X   X   X   X

  log(mg) for each model: an 'X' indicates significantly different from zero
             O   O   A   B   E   F   C   D   G   H
             C   C   :   :   :   :   :   :   :   :
             D   D   c   c   c   c   c   c   c   c
             5   5   1   1   1   1   1   1   1   1
             P   O   0   0   0   0   0   0   0   0
             I   I   d   d   d   d   d   d   d   d
             Y   Y
            ----------------------------------------
             X                       X   X   X   X
```

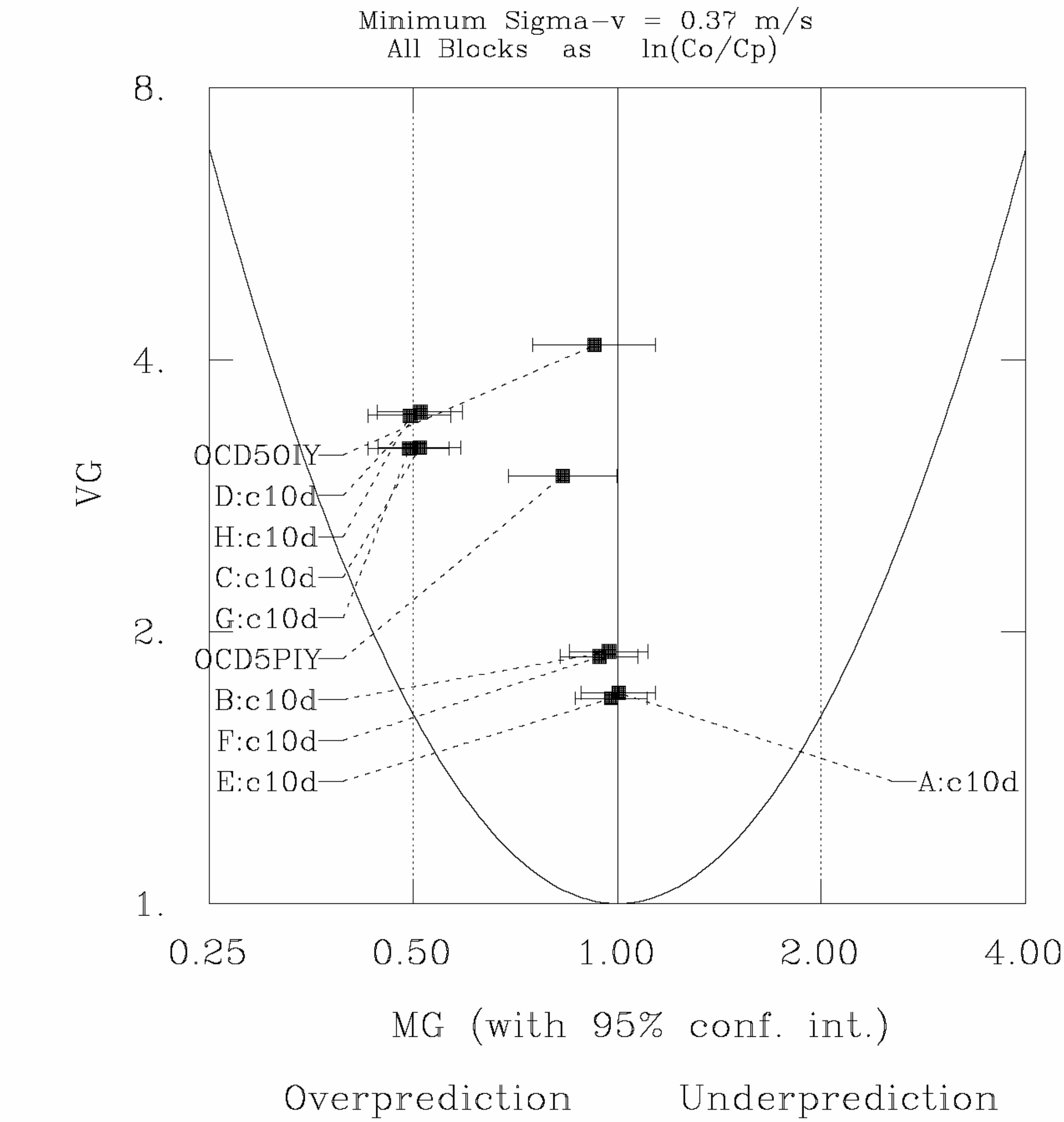

Figure 4-12. Graphical depiction of MG,VG model performance results for OCD5 and for all CALPUFF configurations using CALMET with the standard COARE option (c10d).

A -- Modeled Iy, CALPUFF Turb(z), Draxler Fy (minimum σ_v = 0.37 m/s)
B -- Observed Iy, CALPUFF Turb(z), Draxler Fy
E -- Modeled Iy, AERMOD Turb(z), Draxler Fy (minimum σ_v = 0.37 m/s)
F -- Observed Iy, AERMOD Turb(z), Draxler Fy
C -- Modeled Iy, CALPUFF Turb(z), Variable TLy (minimum σ_v = 0.37 m/s)
D -- Observed Iy, CALPUFF Turb(z), Variable TLy
G -- Modeled Iy, AERMOD Turb(z), Variable TLy (minimum σ_v = 0.37 m/s)
H -- Observed Iy, AERMOD Turb(z), Variable Tly
OCD5PIY -- OCD5 with Modeled Iy (minimum σ_v = 0.37 m/s)
OCD5OIY -- OCD5 with Observed Iy

Oresund

A total of 16 CALPUFF simulations are 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 and the 2 CALPUFF configurations associated with the choice for minimum σ_v. Predicted and observed concentrations for all of these simulations are listed in Tables 4-17 and 4-18.

Analysis of these results leads to the following conclusions:

- The choice for the convective mixing height model can change individual arc-peak concentrations in the Oresund dataset by about 20%. On average, the Batchvarova–Gryning option (IMIXH=2) reduces these peak concentrations by about 10% from those obtained with the Maul-Carson option (IMIXH=1).

- The choice of either calculated overwater mixing height or using the heights estimated from the temperature profiles over the strait (listed in Table 4-10) can change individual arc-peak concentrations in the Oresund dataset by about 20%. On average, computing an overwater mixing height increases these peak concentrations by about 3% to 6% from those obtained with the estimated heights.

- Using either 0.5 m/s or 0.37 m/s for the minimum calculated σ_v has no effect on simulations of the three releases from the Gladsaxe tower in Denmark. The initial 7 km transport across this built-up area, plus the lack of a very stable overwater boundary layer during these releases appears to promote computed σ_v values at puff height that exceed both of these minimums. For the Barseback, Sweden releases, using 0.37 m/s for the minimum σ_v increases the arc-peak concentrations by 10% to 40% compared to results obtained with using 0.5 m/s. All of the releases from the Barseback tower experience little initial over land transport, and the air temperatures on these days is significantly warmer than the Oresund temperatures, producing a stable overwater boundary layer.

- None of these conclusions include an assessment of which of these choices performs best because in four of the nine experiments the results show a large overprediction tendency that is well beyond the 10% to 40% changes noted above.

Further consideration of the dispersion conditions captured in the Oresund experiments suggests that turbulence advection, particularly in the offshore flow when the overwater turbulence is much weaker than that over land, must be explicitly simulated in order to improve performance. A test algorithm introduces this feature into CALPUFF, and the simulations are repeated. Revised predicted and observed concentrations are listed in Tables 4-19 and 4-20.

Analysis of these results with turbulence advection leads to the following conclusions:

- On average, the Batchvarova–Gryning option (IMIXH=2) reduces individual arc-peak concentrations in the Oresund dataset by about 10% from those obtained with the Maul-Carson option (IMIXH=1). Similarly, computing an overwater mixing height increases these arc-peak concentrations by about 3% to 6% from those obtained with the estimated heights. While this average behavior with the turbulence advection adjustment is nearly the same as that without it, changes in the individual arc-peak concentrations cover a slightly smaller range.

- Using either 0.5 m/s or 0.37 m/s for the minimum calculated σ_v has no effect on simulations of the three releases from the Gladsaxe tower in Denmark, and only about a 5% effect on releases from the Barseback, Sweden tower. With turbulence advection, σ_v exceeds both minimum values over a longer portion of the trajectory across the strait.

- Advected turbulence increases the diffusion of the Barseback releases as the tracer is transported across the Oresund, reducing the tendency of the model to overpredict peak concentrations at the opposite shore. It has virtually no influence on the impact of the Gladsaxe releases because these are already mixed substantially before reaching the Oresund, and turbulence levels over the Oresund are not as small as during the Barseback releases.

- The prototype model for OCS applications should be modified to include turbulence advection. With this addition, it has a small mean bias toward overprediction, and exhibits scatter that is typical in that it is close to a factor of two.

- The performance of CALPUFF with turbulence advection improves (smaller bias) when the Batchvarova – Gryning convective mixing height model is selected (IMIXH=2). This improvement is statistically significant at the 95% confidence level.

Table 4-17

Oresund Results with Minimum σ_v = 0.37 m/s

Release Location	Month	Day	Julian	End Time	Ta-Ts (degC)	Arc	Dist (km)	Cobs (ng/m^3)	IMIXH=1 Calc. OW Zi Cpred (ng/m^3)	IMIXH=2 Calc. OW Zi Cpred (ng/m^3)	IMIXH=1 Est. OW Zi Cpred (ng/m^3)	IMIXH=2 Est. OW Zi Cpred (ng/m^3)
Barseback	5	16	137	1430	7.5	1	36.3	1199.2	939.3	754.1	946.1	757.2
	5	16	137	1430		2	38.4	1055.7	511.6	413.2	509.6	401.2
Gladsaxe	5	18	139	1320	0.7	1	31.7	148.7	153.1	135.7	136.0	122.8
	5	18	139	1320		2	33.5	174.1	153.1	135.7	139.2	123.6
Barseback	5	22	143	1200	6.1	1	22.2	308.2	3293.2	3153.2	2908.2	3173.1
	5	22	143	1200		2	22.6	377.2	1035.0	1093.8	955.0	1080.9
	5	22	143	1200		3	25.3	276.9	777.4	689.3	711.8	685.8
Barseback	5	29	150	1200	5.8	1	22.0	201.6	2481.1	2117.8	2476.2	2116.1
	5	29	150	1200		2	25.5	189.5	960.5	835.7	975.4	840.5
Barseback	5	30	151	1200	1.9	2	32.8	66.5 *	691.8	673.5	732.0	727.4
Barseback	6	4	156	1200	6.7	1	22.0	227.4	2386.1	2114.9	2252.2	2129.7
	6	4	156	1200		2	23.6	404.9	122.9	101.2	124.2	105.1
	6	4	156	1200		3	25.3	168.8	574.2	488.5	555.0	498.0
Barseback	6	5	157	1200	7.2	1	22.0	1380.3	2748.4	3349.9	3239.2	3379.7
	6	5	157	1200		2	25.3	752.8	1118.2	797.4	984.9	837.2
	6	5	157	1200		3	27.2	1191.9	588.7	424.9	535.4	433.0
	6	5	157	1200		4	30.0	688.4	319.6	237.0	296.4	238.2
Gladsaxe	6	12	164	1300	-1.4	1	29.1	26.2	103.2	101.9	92.4	92.3
	6	12	164	1300		2	34.8	52.1	86.3	85.6	79.6	79.3
Gladsaxe	6	14	166	1400	0.5	1	34.6	95.3	101.1	100.4	91.0	90.5
	6	14	166	1400		2	36.1	97.1	91.7	91.1	85.0	84.4
	6	14	166	1400		3	42.0	79.4	62.0	59.8	52.9	51.7

* Data Bank Report indicates plume missed most samplers (not used in evaluation statistics)

IMIXH = 1 : Modified Maul – Carson convective mixing height
IMIXH = 2 : Batchvarova - Gryning convective mixing height
Calc. OW Zi : Mixing height over water is computed
Est. OW Zi : Mixing height over water is provided in SEA.DAT file

Table 4-18
Oresund Results with Minimum σ_v = 0.5 m/s

Release	Month	Day	Julian	Time	Ta-Ts (degC)	Arc	Dist (km)	Cobs (ng/m^3)	IMIXH=1 Calc. OW Zi Cpred (ng/m^3)	IMIXH=2 Calc. OW Zi Cpred (ng/m^3)	IMIXH=1 Est. OW Zi Cpred (ng/m^3)	IMIXH=2 Est. OW Zi Cpred (ng/m^3)
Barseback	5	16	137	1430	7.5	1	36.3	1199.2	666.6	550.9	670.1	552.1
	5	16	137	1430		2	38.4	1055.7	403.8	322.0	403.2	314.3
Gladsaxe	5	18	139	1320	0.7	1	31.7	148.7	153.1	135.7	136.0	122.8
	5	18	139	1320		2	33.5	174.1	153.1	135.7	139.2	123.6
Barseback	5	22	143	1200	6.1	1	22.2	308.2	2263.4	2242.2	2116.2	2243.1
	5	22	143	1200		2	22.6	377.2	1225.2	1183.2	1062.3	1176.8
	5	22	143	1200		3	25.3	276.9	664.0	599.3	612.9	595.0
Barseback	5	29	150	1200	5.8	1	22.0	201.6	2128.4	2017.4	2116.8	2017.4
	5	29	150	1200		2	25.5	189.5	920.4	802.8	936.3	808.3
Barseback	5	30	151	1200	1.9	2	32.8	66.5 *	606.2	592.3	638.7	631.4
Barseback	6	4	156	1200	6.7	1	22.0	227.4	2197.5	1967.1	2078.3	1982.0
	6	4	156	1200		2	23.6	404.9	144.8	117.9	146.0	123.2
	6	4	156	1200		3	25.3	168.8	548.8	470.6	531.0	479.0
Barseback	6	5	157	1200	7.2	1	22.0	1380.3	2164.0	2729.7	2608.2	2747.4
	6	5	157	1200		2	25.3	752.8	1035.5	748.8	917.0	784.1
	6	5	157	1200		3	27.2	1191.9	567.3	414.7	517.4	423.2
	6	5	157	1200		4	30.0	688.4	309.3	233.1	288.0	234.9
Gladsaxe	6	12	164	1300	-1.4	1	29.1	26.2	103.2	101.9	92.4	92.3
	6	12	164	1300		2	34.8	52.1	86.3	85.6	79.6	79.3
Gladsaxe	6	14	166	1400	0.5	1	34.6	95.3	101.1	100.4	91.0	90.5
	6	14	166	1400		2	36.1	97.1	91.7	91.1	85.0	84.4
	6	14	166	1400		3	42.0	79.4	62.0	59.8	52.9	51.7

* Data Bank Report indicates plume missed most samplers (not used in evaluation statistics)

IMIXH = 1 : Modified Maul – Carson convective mixing height
IMIXH = 2 : Batchvarova - Gryning convective mixing height
Calc. OW Zi : Mixing height over water is computed
Est. OW Zi : Mixing height over water is provided in SEA.DAT file

Table 4-19
Oresund Results with Minimum σ_v = 0.37 m/s
CALPUFF with Turbulence Advection Timescale = 800s

Release Location	Month	Day	Julian	End Time	Ta-Ts (degC)	Arc	Dist (km)	Cobs (ng/m^3)	IMIXH=1 Calc. OW Zi Cpred (ng/m^3)	IMIXH=2 Calc. OW Zi Cpred (ng/m^3)	IMIXH=1 Est. OW Zi Cpred (ng/m^3)	IMIXH=2 Est. OW Zi Cpred (ng/m^3)
Barseback	5	16	137	1430	7.5	1	36.3	1199.2	542.0	399.9	547.1	401.1
	5	16	137	1430		2	38.4	1055.7	342.2	260.1	343.8	257.7
Gladsaxe	5	18	139	1320	0.7	1	31.7	148.7	150.8	132.4	133.4	118.1
	5	18	139	1320		2	33.5	174.1	151.6	133.0	137.4	119.0
Barseback	5	22	143	1200	6.1	1	22.2	308.2	727.0	637.2	715.2	636.9
	5	22	143	1200		2	22.6	377.2	649.5	563.8	633.4	560.8
	5	22	143	1200		3	25.3	276.9	333.9	295.8	341.2	292.1
Barseback	5	29	150	1200	5.8	1	22.0	201.6	663.2	640.2	666.9	640.2
	5	29	150	1200		2	25.5	189.5	441.1	389.8	443.5	390.9
Barseback	5	30	151	1200	1.9	2	32.8	66.5 *	519.0	500.0	501.8	482.3
Barseback	6	4	156	1200	6.7	1	22.0	227.4	656.2	626.3	666.2	642.2
	6	4	156	1200		2	23.6	404.9	77.2	68.9	76.1	72.7
	6	4	156	1200		3	25.3	168.8	255.1	235.8	247.4	236.8
Barseback	6	5	157	1200	7.2	1	22.0	1380.3	917.5	795.8	868.1	803.7
	6	5	157	1200		2	25.3	752.8	382.5	290.9	338.0	299.7
	6	5	157	1200		3	27.2	1191.9	167.0	132.4	153.9	137.1
	6	5	157	1200		4	30.0	688.4	100.6	82.5	95.5	84.6
Gladsaxe	6	12	164	1300	-1.4	1	29.1	26.2	87.4	86.4	80.0	79.9
	6	12	164	1300		2	34.8	52.1	74.3	73.5	68.5	68.6
Gladsaxe	6	14	166	1400	0.5	1	34.6	95.3	85.6	84.7	74.0	73.6
	6	14	166	1400		2	36.1	97.1	78.3	77.4	70.1	69.7
	6	14	166	1400		3	42.0	79.4	55.8	54.5	49.3	48.3

* Data Bank Report indicates plume missed most samplers (not used in evaluation statistics)

IMIXH = 1 : Modified Maul – Carson convective mixing height
IMIXH = 2 : Batchvarova - Gryning convective mixing height
Calc. OW Zi : Mixing height over water is computed
Est. OW Zi : Mixing height over water is provided in SEA.DAT file

Table 4-20
Oresund Results with Minimum σ_v = 0.5 m/s
CALPUFF with Turbulence Advection Timescale = 800s

Release	Month	Day	Julian	Time	Ta-Ts (degC)	Arc	Dist (km)	Cobs (ng/m3)	IMIXH=1 Calc. OW Zi Cpred (ng/m^3)	IMIXH=2 Calc. OW Zi Cpred (ng/m^3)	IMIXH=1 Est. OW Zi Cpred (ng/m^3)	IMIXH=2 Est. OW Zi Cpred (ng/m^3)
Barseback	5	16	137	1430	7.5	1	36.3	1199.2	501.7	392.5	505.4	393.5
	5	16	137	1430		2	38.4	1055.7	322.8	256.1	323.9	253.9
Gladsaxe	5	18	139	1320	0.7	1	31.7	148.7	150.8	132.4	133.4	118.1
	5	18	139	1320		2	33.5	174.1	151.6	133.0	137.4	119.0
Barseback	5	22	143	1200	6.1	1	22.2	308.2	711.9	637.2	697.6	636.9
	5	22	143	1200		2	22.6	377.2	637.7	563.7	620.1	516.8
	5	22	143	1200		3	25.3	276.9	327.1	295.8	333.0	292.1
Barseback	5	29	150	1200	5.8	1	22.0	201.6	663.2	640.2	666.9	640.2
	5	29	150	1200		2	25.5	189.5	441.1	389.8	443.5	390.9
Barseback	5	30	151	1200	1.9	2	32.8	66.5 *	491.4	475.7	474.8	458.5
Barseback	6	4	156	1200	6.7	1	22.0	227.4	656.2	626.3	666.2	642.2
	6	4	156	1200		2	23.6	404.9	77.2	68.9	76.1	72.7
	6	4	156	1200		3	25.3	168.8	255.1	235.8	247.4	236.8
Barseback	6	5	157	1200	7.2	1	22.0	1380.3	912.5	795.8	861.5	803.7
	6	5	157	1200		2	25.3	752.8	379.8	290.9	334.6	299.7
	6	5	157	1200		3	27.2	1191.9	166.1	132.4	152.9	137.1
	6	5	157	1200		4	30.0	688.4	100.1	82.5	95.1	84.6
Gladsaxe	6	12	164	1300	-1.4	1	29.1	26.2	87.4	86.4	80.0	79.9
	6	12	164	1300		2	34.8	52.1	74.3	73.5	68.5	68.6
Gladsaxe	6	14	166	1400	0.5	1	34.6	95.3	85.6	84.7	74.0	73.6
	6	14	166	1400		2	36.1	97.1	78.3	77.4	70.1	69.7
	6	14	166	1400		3	42.0	79.4	55.8	54.5	49.3	48.3

* Data Bank Report indicates plume missed most samplers (not used in evaluation statistics)

IMIXH = 1 : Modified Maul – Carson convective mixing height
IMIXH = 2 : Batchvarova - Gryning convective mixing height
Calc. OW Zi : Mixing height over water is computed
Est. OW Zi : Mixing height over water is provided in SEA.DAT file

The performance of two CALPUFF configurations (no turbulence advection and advection with a timescale of 800s) are intercompared using runs made with a minimum σ_v = 0.37 m/s, and all 4 mixing height combinations in CALMET. Peak concentrations paired in time but not space (1 per experiment) for eight of the nine Oresund experiments are processed to form the geometric performance measures. The experiment from May 30 is excluded because it contains very few sampling points and the Data Bank Report (Mortensen and Gryning, 1989) specifically warns that the northern part of the tracer plume was not sampled.

Results of applying the model evaluation software, including 95% confidence limits, are listed in Table 4-21 and Figure 4-13. The primary feature of the results is the dramatic improvement obtained with the turbulence advection formulation. Without it, the observations are overpredicted for most Barseback releases so there is a substantial mean bias (more than a factor of two overprediction). With turbulence advection, MG is close to 1. The confidence interval is large here, in part because there are so few data points (8) and the dataset includes cases of both factor-of-two overpredictions and underpredictions. The secondary feature is the improvement in MG when the Batchvarova – Gryning convective mixing height model is selected (IMIXH=2). Note that this improvement is statistically significant at the 95% confidence level.

Based on these measures, the prototype model for OCS applications should be modified to include turbulence advection. With this addition, it has a small mean bias toward overprediction, and exhibits scatter that is typical in that it is close to a factor of two.

Table 4-21
Performance Statistics for CALPUFF Configurations
with Modeled Iy for Minimum σ_v = 0.37 and 0.5 m/s

```
OUTPUT OF THE BOOT PROGRAM, LEVEL 960626
No. of observations =    8
No. of models =          9
(with the observed data counted as one)
No. of blocks =          1
No. of pieces in each block
               8
Oresund Peak                              (N=    8)
```

model	mean	sigma	bias	vg	corr	fa2	mg	high	2nd high	pcor
	|<--------------- (logarithmic	values)	---------------->|					(arithmetic	values)	
OBS.	5.66	1.07	0.00	1.00	1.000	1.000	1.000	1380	1199	n/a
Zi1	6.59	1.46	-0.94	6.65	0.725	0.625	0.392	3293	2748	n/a
Zi2	6.53	1.47	-0.88	5.97	0.728	0.500	0.417	3350	3153	n/a
Zi1OW	6.55	1.51	-0.90	6.18	0.746	0.500	0.408	3239	2908	n/a
Zi2OW	6.50	1.52	-0.84	5.96	0.732	0.500	0.431	3380	3173	n/a
800Zi1	5.83	0.94	-0.17	1.49	0.826	0.750	0.842	918	727	n/a
800Zi2	5.73	0.90	-0.07	1.58	0.781	0.750	0.932	796	640	n/a
800Zi1OW	5.78	0.99	-0.13	1.50	0.819	0.750	0.882	868	715	n/a
800Zi2OW	5.69	0.96	-0.03	1.59	0.780	0.750	0.966	804	642	n/a

```
SUMMARY OF CONFIDENCE LIMITS ANALYSES
-------------------------------------

  D(log(vg)) among models: an 'X' indicates significantly different from zero

  (NONE significantly different from zero)

  D(log(mg)) among models: an 'X' indicates significantly different from zero
            Z   Z   Z   Z   8   8   8   8
            i   i   i   i   0   0   0   0
            1   2   1   2   0   0   0   0
                    O   O   Z   Z   Z   Z
                    W   W   i   i   i   i
                            1   2   1   2
                                    O   O
                                    W   W
           --------------------------------
Zi1     |                   X   X   X   X
Zi2     |                   X   X   X   X
Zi1OW   |                   X   X   X   X
Zi2OW   |                   X   X   X   X
800Zi1  |                       X       X
800Zi2  |
800Zi1OW|                               X

  log(vg) for each model: an 'X' indicates significantly different from zero
            Z   Z   Z   Z   8   8   8   8
            i   i   i   i   0   0   0   0
            1   2   1   2   0   0   0   0
                    O   O   Z   Z   Z   Z
                    W   W   i   i   i   i
                            1   2   1   2
                                    O   O
                                    W   W
           --------------------------------
                X           X   X   X   X

  log(mg) for each model: an 'X' indicates significantly different from zero
            Z   Z   Z   Z   8   8   8   8
            i   i   i   i   0   0   0   0
            1   2   1   2   0   0   0   0
                    O   O   Z   Z   Z   Z
                    W   W   i   i   i   i
                            1   2   1   2
                                    O   O
                                    W   W
           --------------------------------
            X       X
```

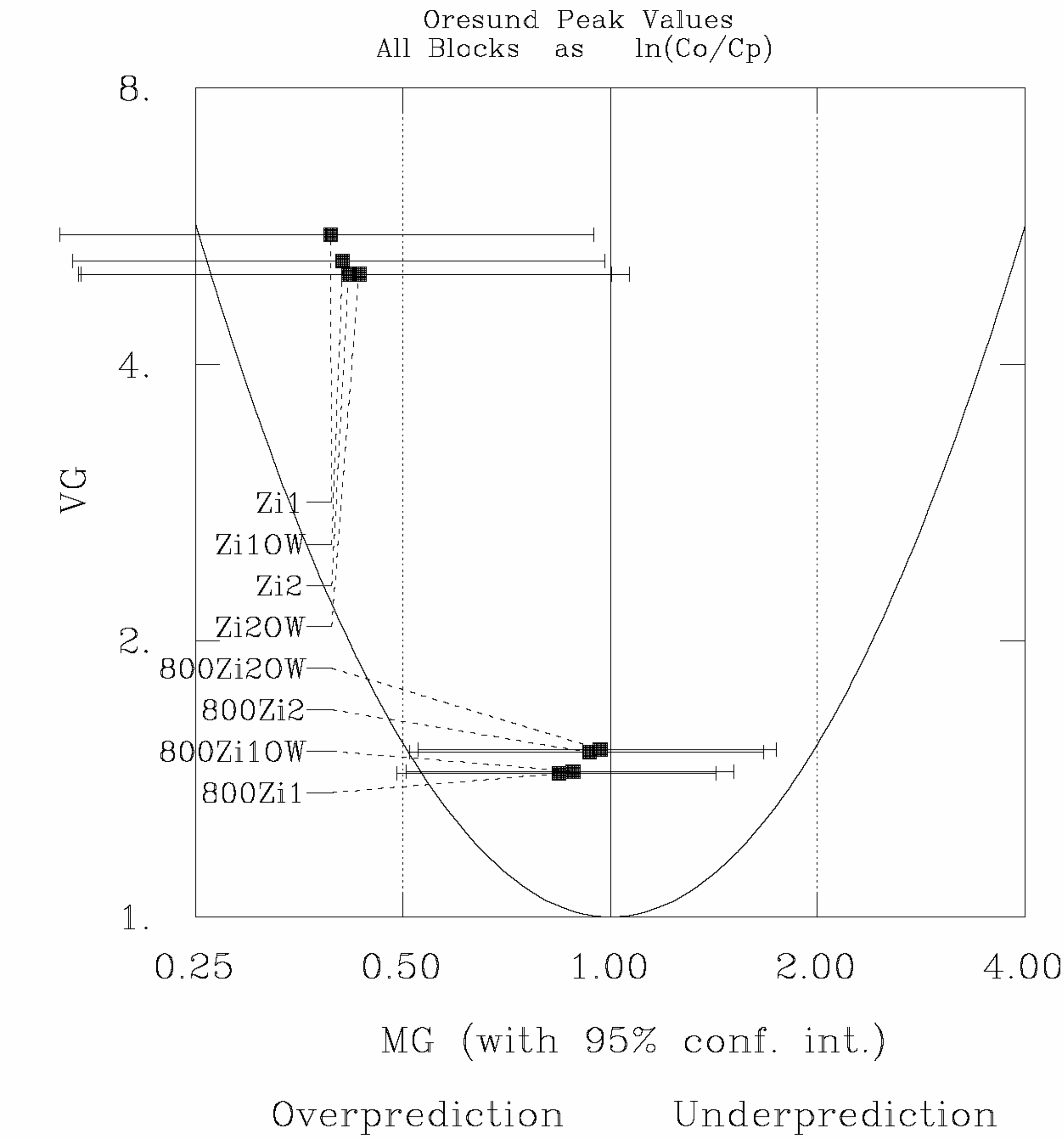

Figure 4-13. Graphical depiction of MG,VG model performance results for CALPUFF configurations with and without turbulence advection.

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

800Zi1OW –Turb Advection (800s), Batchvarova-Gryning Mixing Ht , Obs Overwater

4.4 Recommendations

A minimum σ_v for overwater cells should be introduced in CALPUFF so that a value appropriate to overwater dispersion (e.g. 0.37 m/s) can be applied independently of the minimum used over land.

The computed Lagrangian timescale approach for lateral dispersion, based in part on the SCIPUFF formulation, leads to unacceptably large overpredictions in CALPUFF and this draft option should be removed at this time.

The COARE overwater flux module should be selected in place of the previous OCD-based 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 these options.

The SEA.DAT format should allow wind and air temperature measurement heights to be different.

The Batchvarova-Gryning convective mixing height option in CALMET was tested in the Oresund dataset and showed promising improvements in model performance. The Batchvarova-Gryning scheme should be tested further in a wide variety of operational simulations for possible general use as the mixing height default option in CALMET.

Turbulence advection should be formulated for general use and implemented in the CALMET/CALPUFF system.

A re-analysis of these evaluation datasets should be conducted once CALMET/CALPUFF Version 6 becomes available. The ability of this version to use time steps shorter than one hour will facilitate evaluations with the Gaviota and Carpinteria 30-minute datasets, and allow the full set of measurements to be used at all sites. Although the modeling system will use a one-hour time step operationally, evaluations at shorter time steps may allow a better integration of the tracer concentrations and meteorological measurements in both space and time.

5. STANDARD DATASET: GULF OF MEXICO

Dataset Description

Meteorological, geophysical and ozone data required for CALMET/CALPUFF simulations within the MMS Gulf of Mexico region have been assembled in an MMS standard dataset for year 2003. With this dataset, air quality analyses can be readily configured and run using a complete set of meteorological observations as well as a comprehensive database of hourly meteorological fields from the 20km gridded output of the Rapid Update Cycle (RUC) weather model, which supplies dynamically consistent wind and temperature fields in data-sparse areas such as the waters of the Gulf. The dataset includes:

- USGS terrain elevation files with 90m resolution and USGS land use data files with 200m resolution;
- 13 SEA.DAT files of one full year (2003) of data from buoy stations in the domain (1 station/file);
- 21 UP.DAT files of one full year (2003) of data from upper-air stations in the domain (1 station/file);
- A SURF.DAT file containing one full year (2003) of data from 230 NWS hourly surface meteorological stations in the domain;
- A PRECIP.DAT file containing one full year (2003) of data from 271 NWS precipitation stations in the domain;
- An OZONE.DAT file containing one full year (2003) of data from 201 AIRS and CASTNET stations in the domain;
- One full year (2003) of gridded prognostic meteorological output fields from the RUC model formatted as 50 tiles (90 RUC grid-points/tile), for the portion of the 20km RUC grid that covers the MMS Gulf of Mexico domain.

Note that the RUCDECODE program is provided to assemble RUC grid cell data from one or more tiles into a 3D.DAT file for a user's CALMET domain, and a SUBDOMN utility is provided to extract stations from the SURF.DAT, PRECIP.DAT, and OZONE.DAT files for a user's CALMET domain. The RUC data tiles are provided on a set of six DVDs, and all other data are provided on a single DVD.

The base time zone for modeling with these data must be Central Standard Time (CST) -- i.e. time zone 6 (UTC-0600) -- because SURF.DAT, PRECIP.DAT, SEA.DAT and OZONE.DAT files are provided in time zone 6. UP.DAT files are, as always, in UTC time (UTC-0000).

A CALMET/CALPUFF domain for a particular MMS application should be defined so that the entire domain is inside the area bordered by the yellow line (MMS modeling area) in Figures 5-1 through 5-6.

Figure 5-1 shows locations of available surface meteorological data stations and Table 5-1 lists the station names, numbers and coordinates. Data for these stations are contained in the file named STANDARD_S.DAT.

The locations of available upper air data stations are shown in Figure 5-2 and Table 5-2. Each UP.DAT file contains twice-daily upper-air profiles for a single station. A CALMET application should use the stations and corresponding UP.DAT files that lie within and close to the application domain.

The locations of all available buoys are shown in Figure 5-3 and Table 5-3. Each SEA.DAT file contains overwater data from a single buoy. The SEA.DAT files should be selected in the groups indicated in Figure 5-3 and Table 5-3 because CALMET must have at least one valid sea surface temperature (SST) each hour. If a single SEA.DAT file were used in an application, that particular buoy must have valid SST data every hour for the whole year. The buoy data at each station in the dataset were screened for missing SST data, and then the stations were grouped to fulfill this requirement. If a CALMET domain includes one or more of the buoys from different groups, then all buoys from those groups should be included.

Figure 5-4 shows locations of available precipitation data stations and Table 5-4 lists the station names, numbers and coordinates. Data for these stations are contained in the file named STANDARD_P.DAT.

Figure 5-5 and Table 5-5 show and list available ozone data for the MMS modeling area. There are 194 available AIRS sites and seven CASTNET sites. Data for these stations are contained in the file named STANDARD_O.DAT.

Figure 5-6 shows the location of the RUC data "tiles" arranged by grid-point locations. 50 RUC tiles cover the MMS modeling area. Program RUCDECODE should be run to extract data from individual tiles into the 3D.DAT files for input to CALMET.

USGS terrain elevation files with 90 m horizontal resolution and USGS land use data files with 200 m horizontal resolution are provided for the entire region. Individual files with data within the CALMET domain must be processed using the TERREL (extracts terrain), CTGPROC (extracts landuse) and MAKEGEO (combines terrain and land use) preprocessors to prepare the CALMET GEO.DAT file. The terrain data files are one-degree sheets, and are named by the latitude and longitude of the southeast corner of the sheet. The land use data files are sheets covering one degree latitude and two degrees longitude. They are also named by the latitude and longitude of the southeast corner of the sheet.

Extracting Data Subsets

The SUBDOMN utility must be run via the CALPUFF PROfessional (CALPRO) GUI to prepare the surface and precipitation data files for CALMET, and ozone data file for CALPUFF. Those stations to be extracted for a simulation are selected by providing a latitude and longitude range appropriate to the CALMET domain. The output files produced are CALMET/CALPUFF-ready. In addition, SUBDOMN requires the map projection and the datum for the CALMET grid coordinates so that it can prepare the station information needed for the CALMET control file. The station coordinates in the dataset files are transformed to the CALMET coordinates, and the full control file section for each (Input Group 7 for surface stations, Input Group 9 for precipitation stations) is written to a list file. Surface station information is written to SURF_STN.LST; precipitation station information is written to PRECIP_STN.LST. An editor can be used to cut-and-paste the control file sections from these files into the CALMET control file. Station information for the ozone stations, transformed to the CALMET/CALPUFF coordinate system, is included in the OZONE.DAT file for CALPUFF.

Two screens in the GUI are filled in for SUBDOMN. If the "shared information" has been identified and saved in a file, the "shared information" is automatically updated into the first screen, "Grid setting" (Figure 5-7). Otherwise, all the fields in the first screen can be typed in using the CALMET application parameters. The second screen, "Inputs/Outputs & Run", is shown in Figure 5-8. For each of the three data sets (surface, precipitation and ozone), a "box" that covers entire modeling domain and an appropriate buffer zone around the modeling domain (order of magnitude of 100 km) should be defined. Minimum and maximum longitude and latitude defining that box are the inputs to the second screen, along with the names of the standard data files and the data output files.

The RUCDECODE utility must be run in a command-window to prepare the 3D.DAT file(s) of RUC data for CALMET. Its control file is configured to identify a domain and a time period to extract. Each application of RUCDECODE requires its own control file and the user must manage the names of the input and output files created. Multiple RUC 3D.DAT files may be needed if the space-time domain of an application produces a 3D.DAT file that exceeds the limits imposed by the operating system. An example control file is listed in Table 5-6. The RUCDECODE program is contained on the DVD with the data files.

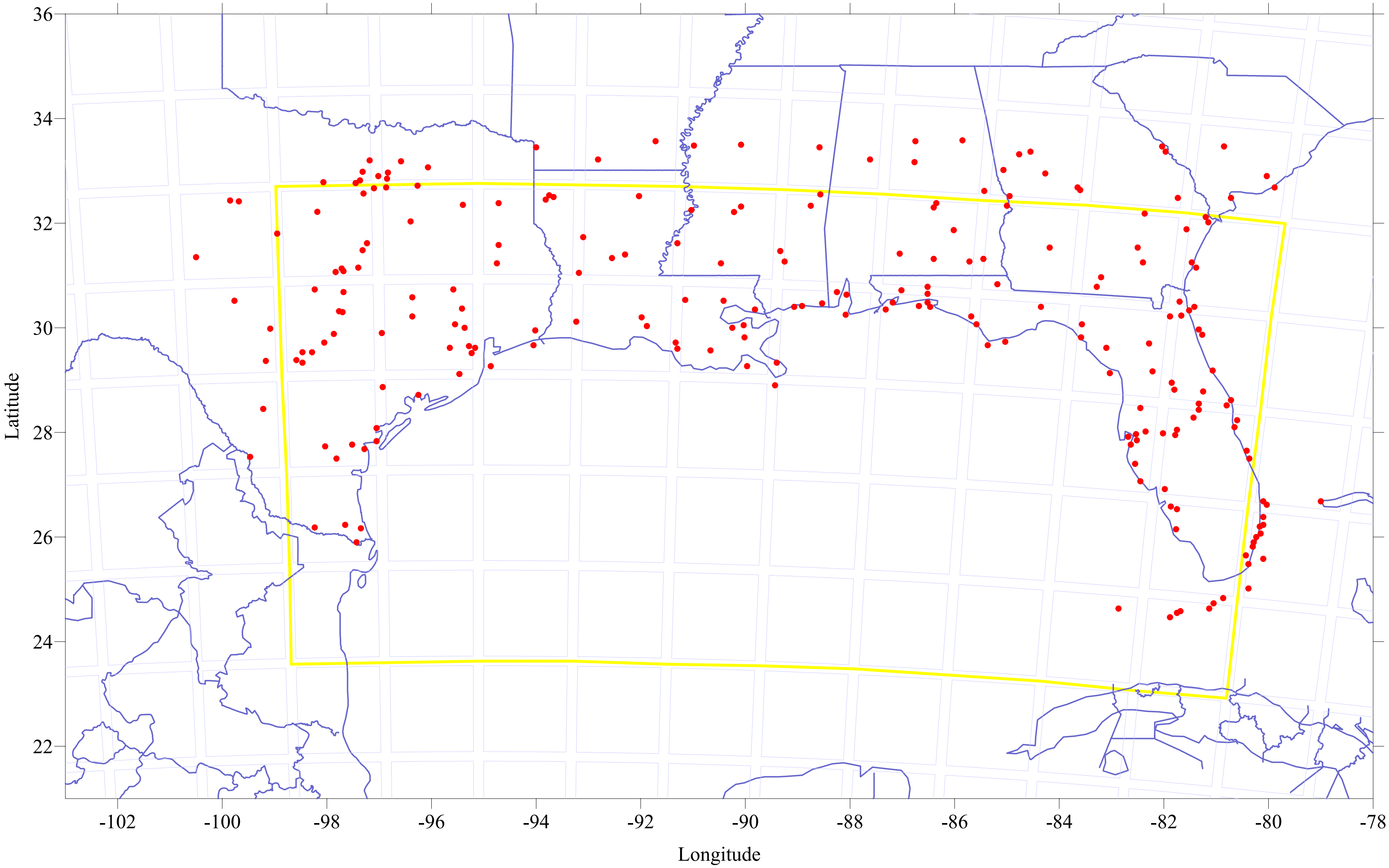

Figure 5-1. Locations of the surface stations in the MMS standard data set.

Table 5-1.
NWS Hourly Surface Stations

WMO Number	WBAN Number	Station Identifier	Station Name	State	North Latitude (deg)	West Longitude (deg)	LCC[1] East (km)	LCC[1] North (km)	Station Elevation (m)
722230	13894	KMOB	MOBILE REGIONAL AP	AL	30.683	88.250	166.859	298.456	65.5
722235	13838	KBFM	MOBILE DOWNTOWN AP	AL	30.633	88.067	184.394	293.177	7.9
722260	13895	KMGM	MONTGOMERY DANNELLY FIELD	AL	32.300	86.400	337.917	481.674	61.6
722265	13821	KMXF	MAXWELL AFB	AL	32.383	86.350	342.333	491.029	53.0
722267	3878	KTOI	TROY AF	AL	31.867	86.017	375.426	434.740	120.1
722268	99999	KDHN	DOTHAN MUNICIPAL	AL	31.317	85.450	431.125	375.620	97.8
722269	3850	KOZR	CAIRNS FIELD FORT RUCKER	AL	31.267	85.717	406.031	369.160	91.1
722275	99999	K79J	ANDALUSIA/OPP ARPT	AL	31.317	86.400	341.139	372.610	94.0
722276	99999	KGZH	EVERGREEN	AL	31.417	87.050	279.289	382.046	78.0
722280	13876	KBHM	BIRMINGHAM MUNICIPAL AP	AL	33.567	86.750	301.317	621.552	189.0
722284	99999	KAUO	AUBURN-OPELIKA APT	AL	32.616	85.433	427.332	519.795	236.0
722286	93806	KTCL	TUSCALOOSA MUNICIPAL AP	AL	33.217	87.617	221.708	580.765	51.2
722287	13871	KANB	ANNISTON METROPOLITAN AP	AL	33.583	85.850	384.669	625.864	186.2
722300	53864	KEET	SHELBY CO ARPT	AL	33.167	86.767	300.921	577.028	178.0
994420	99999	DPIA1	DAUPHIN ISLAND	AL	30.250	88.083	183.536	250.702	8.0
723418	13977	KTXK	TEXARKANA WEBB FIELD	AR	33.450	94.000	-371.256	610.608	110.0
723419	93992	KELD	EL DORADO GOODWIN FIELD	AR	33.217	92.817	-262.080	581.626	76.8
723424	99999	KLLQ	MONTICELLO MUNI	AR	33.567	91.717	-159.202	618.656	36.0
722010	12836	KEYW	KEY WEST INTL ARPT	FL	24.550	81.750	832.013	-354.171	1.2
722011	99999	KISM	ORLANDO/KISSIMMEE	FL	28.283	81.433	834.879	60.696	25.0
722012	99999	KVVG	THE VILLAGES	FL	28.950	81.850	789.367	131.621	27.0
722014	99999	KBKV	BROOKSVILLE	FL	28.467	82.450	734.643	74.483	23.0
722015	12850	KNQX	KEY WEST NAS	FL	24.583	81.683	838.510	-350.059	7.0
722016	99999	KMTH	MARATHON AIRPORT	FL	24.733	81.050	900.996	-328.942	2.0
722020	12839	KMIA	MIAMI INTL AP	FL	25.817	80.300	966.790	-203.349	10.7
722021	99999	KVDF	TAMPA/VANDENBURG	FL	28.017	82.350	747.487	25.348	7.0
722022	99999	KBCT	BOCA RATON	FL	26.383	80.100	981.592	-139.230	4.0
722024	99999	KOPF	MIAMI/OPA LOCKA	FL	25.900	80.283	967.749	-194.044	3.0
722025	12849	KFLL	FORT LAUDERDALE HOLLYWOOD INT	FL	26.067	80.150	979.472	-174.533	3.4
722026	12826	KHST	HOMESTEAD AFB	FL	25.483	80.383	961.453	-240.913	4.9
722029	99999	KTMB	MIAMI/KENDALL-TAMIA	FL	25.650	80.433	955.013	-222.850	3.0
722030	12844	KPBI	WEST PALM BEACH INTL ARPT	FL	26.683	80.100	978.895	-106.101	5.5
722034	99999	KPGD	PUNTA GORDA	FL	26.917	81.983	791.304	-93.922	7.0
722037	99999	KHWO	HOLLYWOOD/N. PERRY	FL	26.000	80.233	971.830	-182.598	3.0
722038	12897	KAPF	NAPLES MUNICIPAL	FL	26.150	81.767	818.327	-177.286	3.0
722039	99999	KFXE	FORT LAUDERDALE	FL	26.200	80.167	976.597	-159.979	4.0
722040	12838	KMLB	MELBOURNE REGIONAL	FL	28.100	80.650	912.594	46.095	10.7

Table 5-1. (Continued)
NWS Hourly Surface Stations

WMO Number	WBAN Number	Station Identifier	Station Name	State	North Latitude (deg)	West Longitude (deg)	LCC[1] East (km)	LCC[1] North (km)	Station Elevation (m)
722045	12843	KVRB	VERO BEACH MUNICIPAL ARPT	FL	27.650	80.417	939.204	-1.825	7.3
722046	99999	KTIX	TITUSVILLE	FL	28.517	80.800	894.498	91.035	11.0
722049	99999	KPMP	POMPANO BEACH	FL	26.233	80.100	982.940	-155.796	6.0
722050	12815	KMCO	ORLANDO INTL ARPT	FL	28.433	81.333	843.427	77.956	29.3
722053	12841	KORL	ORLANDO EXECUTIVE AP	FL	28.550	81.333	842.506	90.882	32.9
722055	99999	KOCF	OCALA MUNI (AWOS)	FL	29.167	82.217	752.336	153.286	27.0
722056	12834	KDAB	DAYTONA BEACH INTL AP	FL	29.183	81.067	863.184	162.676	8.8
722057	12854	KSFB	ORLANDO SANFORD AIRPORT	FL	28.783	81.250	848.710	117.199	16.8
722060	13889	KJAX	JACKSONVILLE INTL ARPT	FL	30.500	81.700	792.187	303.953	7.9
722065	93837	KNIP	JACKSONVILLE NAS	FL	30.233	81.667	797.353	274.641	9.1
722066	3853	KNRB	MAYPORT NS	FL	30.400	81.417	819.933	294.765	4.9
722067	93832	KNZC	JACKSONVILLE CECIL FLD NAS	FL	30.217	81.883	776.833	271.476	27.1
722068	99999	KCRG	JACKSONVILLE/CRAIG	FL	30.333	81.517	810.912	286.688	12.0
722103	99999	KFPR	FT PIERCE/ST LUCIE	FL	27.500	80.367	945.406	-18.000	7.0
722104	92806	KSPG	ST PETERSBURG ALBERT WHITTED	FL	27.767	82.633	721.541	-3.994	2.4
722106	12835	KFMY	FORT MYERS PAGE FIELD	FL	26.583	81.867	805.204	-130.082	4.6
722108	99999	KRSW	FT MYERS/SW FLORIDA	FL	26.533	81.750	817.144	-134.831	9.0
722110	12842	KTPA	TAMPA INTERNATIONAL AP	FL	27.967	82.533	729.967	18.711	5.8
722115	99999	KSRQ	SARASOTA-BRADENTON	FL	27.400	82.550	732.143	-44.072	9.0
722116	99999	KPIE	SAINT PETERSBURG	FL	27.917	82.683	715.653	12.294	3.0
722119	99999	KLAL	LAKELAND REGIONAL	FL	27.983	82.017	780.225	23.677	43.0
722120	12833	KCTY	CROSS CITY AIRPORT	FL	29.617	83.100	664.259	197.919	11.6
722123	99999	KBOW	BARTOW MUNICIPAL	FL	27.950	81.783	803.307	21.550	39.0
722140	93805	KTLH	TALLAHASSEE REGIONAL AP	FL	30.400	84.350	539.997	278.403	16.8
722146	12816	KGNV	GAINESVILLE REGIONAL AP	FL	29.700	82.283	742.229	211.812	40.8
722200	12832	KAQQ	APALACHICOLA MUNI AP	FL	29.733	85.033	477.770	201.701	6.1
722210	13858	KVPS	VALPARAISO ELGIN AFB	FL	30.483	86.517	332.698	279.839	20.1
722212	99999	KSGJ	ST AUGSUTINE ARPT	FL	29.967	81.333	831.354	247.464	3.0
722213	99999	KLEE	LEESBURG MUNI ARPT	FL	28.817	81.800	795.192	117.247	23.0
722215	13884	KCEW	CRESTVIEW BOB SIKES AP	FL	30.783	86.517	331.747	313.087	57.9
722223	13899	KPNS	PENSACOLA REGIONAL AP	FL	30.483	87.183	269.094	278.195	34.1
722224	99999	K40J	PERRY FOLEY ARPT	FL	30.067	83.567	616.713	245.254	13.0
722225	3855	KNPA	PENSACOLA FOREST SHERMAN NAS	FL	30.350	87.317	256.620	263.167	10.1
722226	93841	KNSE	WHITING FIELD NAAS	FL	30.717	87.017	284.313	304.507	53.9
722245	99999	KPFN	PANAMA CITY/BAY CO.	FL	30.217	85.683	413.376	252.922	6.0
722246	99999	KEGI	DUKE FLD/EGLIN AUX	FL	30.650	86.517	332.169	298.346	57.9
747750	13846	KPAM	TYNDALL AFB	FL	30.067	85.583	423.549	236.651	7.0

Table 5-1. (Continued)
NWS Hourly Surface Stations

WMO Number	WBAN Number	Station Identifier	Station Name	State	North Latitude (deg)	West Longitude (deg)	LCC[1] East (km)	LCC[1] North (km)	Station Elevation (m)
747760	3818	KMAI	MARIANNA	FL	30.833	85.183	458.532	322.952	34.0
747770	3852	KHRT	VALPARAISO HURLBURT	FL	30.417	86.683	317.044	272.083	11.9
747880	12810	KMCF	MACDILL AFB	FL	27.850	82.517	732.325	5.874	7.9
747930	99999	KGIF	WINTERHAVEN	FL	28.050	81.750	805.779	32.818	44.0
747946	99999	KTTS	NASA SHUTTLE FCLTY	FL	28.617	80.717	901.710	102.690	3.0
747950	12867	KCOF	COCOA BEACH PATRICK AFB	FL	28.233	80.600	916.330	61.157	3.0
994050	99999	LKWF1	LAKE WORTH	FL	26.617	80.033	986.103	-112.849	6.0
994220	99999	VENF1	VENICE PIER	FL	27.067	82.450	744.242	-80.282	4.0
994360	99999	CSBF1	CAPE SAN BLAS	FL	29.667	85.367	445.937	193.128	2.0
994390	99999	SPGF1	SETTLEMENT POINT	FL	26.683	79.000	1,087.381	-96.778	2.0
994410	99999	SAUF1	ST. AUGUSTINE	FL	29.867	81.267	838.467	236.863	8.0
994430	99999	MLRF1	MOLASSES REEF	FL	25.017	80.383	965.526	-292.424	0.0
994450	99999	SMKF1	SOMBRERO KEY	FL	24.633	81.133	893.462	-340.618	0.0
994560	99999	FWYF1	FOWEY ROCKS	FL	25.583	80.100	988.785	-227.598	29.0
994570	99999	SANF1	SAND KEY	FL	24.467	81.883	819.232	-364.261	6.0
994620	99999	LONF1	LONG KEY	FL	24.833	80.867	918.555	-316.513	6.0
994630	99999	DRYF1	DRY TORTUGAS	FL	24.633	82.867	718.964	-352.087	5.0
994640	99999	CDRF1	CEDAR KEY	FL	29.133	83.033	673.765	144.753	3.0
994650	99999	KTNF1	KEATON BEACH	FL	29.817	83.583	616.639	217.508	3.0
722069	99999	KDTS	DESTIN FT. WALTON	GA	30.400	86.467	337.739	270.780	7.0
722070	3822	KSAV	SAVANNAH INTL AP	GA	32.117	81.200	826.888	486.224	14.0
722090	99999	KLHW	FT STEWART/WRIGHT	GA	31.883	81.567	794.255	457.868	14.0
722130	13861	KAYS	WAYCROSS WARE CO AP	GA	31.250	82.400	720.284	382.602	42.7
722134	99999	KVDI	VIDALIA MUNI ARPT	GA	32.183	82.367	716.927	486.145	84.0
722135	13870	KAMG	ALMA BACON COUNTY AP	GA	31.533	82.500	708.888	413.354	62.8
722136	99999	KBQK	BRUNSWICK/GLYNCO	GA	31.250	81.467	808.571	388.454	8.0
722137	13878	KSSI	BRUNSWICK MALCOLM MCKINNON AP	GA	31.150	81.383	817.301	377.949	4.3
722160	13869	KABY	ALBANY DOUGHERTY COUNTY AP	GA	31.533	84.183	549.952	404.663	57.9
722166	93845	KVLD	VALDOSTA WB AIRPORT	GA	30.783	83.283	639.541	325.973	61.0
722170	3813	KMCN	MACON MIDDLE GA REGIONAL AP	GA	32.683	83.650	593.649	534.700	107.9
722175	13860	KWRB	WARNER ROBINS AFB	GA	32.633	83.600	598.611	529.396	92.0
722176	99999	KCCO	NEWNAN	GA	33.317	84.767	486.269	600.160	296.0
722180	3820	KAGS	AUGUSTA BUSH FIELD	GA	33.367	81.967	745.777	619.866	40.2
722181	99999	KDNL	AUGUSTA\DANIEL FLD	GA	33.466	82.033	738.939	630.454	134.0
722197	99999	KFFC	ATLANTA (NEXRAD)	GA	33.367	84.550	506.171	606.600	296.0
722250	99999	KLSF	FORT BENNING	GA	32.333	85.000	469.115	489.972	88.1
722255	93842	KCSG	COLUMBUS METROPOLITAN ARPT	GA	32.517	84.950	472.957	510.587	119.5

Table 5-1. (Continued)
NWS Hourly Surface Stations

WMO Number	WBAN Number	Station Identifier	Station Name	State	North Latitude (deg)	West Longitude (deg)	LCC[1] East (km)	LCC[1] North (km)	Station Elevation (m)
747804	99999	KSVN	HUNTER (AAF)	GA	32.017	81.150	832.383	475.490	13.0
747805	99999	KTBR	STATESBORO	GA	32.482	81.733	774.136	523.163	57.0
747806	99999	KOPN	THOMASTON	GA	32.950	84.267	534.617	561.484	243.0
747807	99999	KLGC	LA GRANGE	GA	33.017	85.067	459.757	565.662	211.0
747810	99999	KVAD	MOODY AFB/VALDOSTA	GA	30.967	83.200	646.298	346.783	71.0
722310	12916	KMSY	NEW ORLEANS INTL ARPT	LA	30.000	90.250	-23.993	221.576	1.2
722312	99999	KHDC	HAMMOND	LA	30.517	90.417	-39.824	278.923	13.0
722314	3934	KARA	NEW IBERIA NAAS	LA	30.033	91.883	-180.653	226.604	7.9
722315	53917	KNEW	NEW ORLEANS LAKEFRONT AP	LA	30.050	90.033	-3.165	227.093	2.7
722316	12958	KNBG	NEW ORLEANS ALVIN CALLENDER F	LA	29.817	90.017	-1.634	201.272	1.5
722317	13970	KBTR	BATON ROUGE RYAN ARPT	LA	30.533	91.150	-109.810	281.147	19.5
722319	99999	KIER	NATCHITOCHES	LA	31.733	93.100	-292.596	417.453	37.0
722320	12884	BVE	BOOTHVILLE WSCMO CIT	LA	29.333	89.400	57.947	147.790	0.0
722329	99999	KPTN	PATTERSON MEMORIAL	LA	29.717	91.333	-128.272	190.893	3.0
722366	99999	KASD	SLIDELL	LA	30.350	89.817	17.505	260.356	8.0
722390	3931	KPOE	FORT POLK AAF	LA	31.050	93.183	-302.407	341.904	102.1
722400	3937	KLCH	LAKE CHARLES REGIONAL ARPT	LA	30.117	93.233	-309.899	238.628	4.6
722403	99999	KP92	SALT POINT (RAMOS)	LA	29.600	91.300	-125.235	177.896	3.0
722405	13976	KLFT	LAFAYETTE REGIONAL AP	LA	30.200	91.983	-189.945	245.262	11.6
722406	99999	KHUM	HOUMA-TERREBONNE	LA	29.567	90.667	-64.276	173.748	3.0
722480	13957	KSHV	SHREVEPORT REGIONAL ARPT	LA	32.450	93.817	-357.758	498.947	77.4
722484	53905	KDTN	SHREVEPORT DOWNTOWN	LA	32.533	93.750	-351.196	507.969	55.0
722485	13944	KBAD	BARKSDALE AFB	LA	32.500	93.667	-343.536	504.068	53.9
722486	13942	KMLU	MONROE REGIONAL AP	LA	32.517	92.033	-190.446	502.376	40.5
722487	13935	KESF	ALEXANDRIA ESLER REGIONAL AP	LA	31.400	92.300	-217.795	378.835	34.1
722488	99999	KTVR	VICKSBURG\TALLULAH	LA	32.250	91.033	-97.023	471.542	23.0
747540	99999	KAEX	ALEXANDRIA INT	LA	31.333	92.550	-241.621	371.874	27.1
994010	99999	BURL1	SOUTHWEST PASS	LA	28.900	89.433	54.983	99.810	0.0
994290	99999	GDIL1	GRAND ISLE	LA	29.267	89.967	3.189	140.337	2.0
722340	13865	KMEI	MERIDIAN KEY FIELD	MS	32.333	88.750	117.310	480.950	89.6
722345	3866	KNMM	MERIDIAN NAAS	MS	32.550	88.567	134.200	505.244	82.6
722347	99999	HBG	HATTIESBURG MUNI	MS	31.267	89.250	71.115	362.244	46.0
722348	99999	KPIB	PINE BELT RGNL AWOS	MS	31.467	89.333	63.123	384.386	91.0
722350	3940	KJAN	JACKSON INTERNATIONAL AP	MS	32.317	90.083	-7.791	478.575	94.5
722354	99999	KHKS	HAWKINS FIELD	MS	32.213	90.217	-20.389	467.040	104.0
722356	13939	KGLH	GREENVILLE MUNICIPAL	MS	33.483	90.983	-91.222	608.555	42.1
722357	99999	KHEZ	NATCHEZ/HARDY(AWOS)	MS	31.617	91.300	-122.850	401.514	83.0

Table 5-1. (Continued)
NWS Hourly Surface Stations

WMO Number	WBAN Number	Station Identifier	Station Name	State	North Latitude (deg)	West Longitude (deg)	LCC[1] East (km)	LCC[1] North (km)	Station Elevation (m)
722358	93919	KMCB	MCCOMB PIKE COUNTY AP	MS	31.233	90.467	-44.296	358.338	125.9
722359	13978	KGWO	GREENWOOD LEFLORE ARPT	MS	33.500	90.083	-7.701	610.081	47.2
723307	99999	KGTR	GOLDEN TRI(AWOS)	MS	33.450	88.583	131.538	605.280	80.0
747685	99999	KGPT	GULFPORT-BILOXI	MS	30.400	89.067	89.202	266.226	9.0
747686	13820	KBIX	KEESLER AFB	MS	30.417	88.917	103.526	268.229	7.9
747688	99999	KPQL	PASCAGOULA	MS	30.467	88.533	140.166	274.155	5.0
722080	13880	KCHS	CHARLESTON INTL ARPT	SC	32.900	80.033	929.209	581.364	12.2
722085	93831	KNBC	BEAUFORT MCAS	SC	32.483	80.717	869.094	530.122	10.1
723115	53854	KOGB	ORANGEBURG	SC	33.467	80.850	848.461	638.268	60.0
994230	99999	FBIS1	FOLLY ISLAND	SC	32.683	79.883	945.160	558.481	3.0
690190	13910	KDYS	ABILENE DYESS AFB	TX	32.433	99.850	-922.514	528.752	545.0
722410	12917	KBPT	PORT ARTHUR JEFFERSON COUNTY	TX	29.950	94.017	-385.635	222.366	4.9
722416	12971	KBAZ	NEW BRAUNFELS	TX	29.717	98.050	-774.088	215.763	197.0
722420	12923	KGLS	GALVESTON/SCHOLES	TX	29.267	94.867	-470.216	149.725	2.0
722427	99999	KLVJ	HOUSTON/CLOVER FLD	TX	29.517	95.233	-504.368	178.861	13.0
722429	99999	KDWH	HOUSTON/D.W. HOOKS	TX	30.067	95.550	-532.126	241.093	46.0
722430	12960	KIAH	HOUSTON BUSH INTERCONTINENTAL	TX	30.000	95.367	-514.918	232.890	29.0
722435	12918	KHOU	HOUSTON WILLIAM P HOBBY AP	TX	29.650	95.283	-508.545	193.791	13.4
722436	12906	KEFD	HOUSTON ELLINGTON AFB	TX	29.617	95.167	-497.540	189.659	11.9
722444	99999	KCXO	CONROE	TX	30.367	95.417	-517.905	273.737	75.0
722445	3904	KCLL	COLLEGE STATION EASTERWOOD FL	TX	30.583	96.367	-607.405	302.040	95.7
722446	93987	KLFK	LUFKIN ANGELINA CO	TX	31.233	94.750	-450.429	367.031	85.6
722447	99999	KUTS	HUNTSVILLE	TX	30.733	95.583	-531.907	314.986	111.0
722448	13972	KTYR	TYLER/POUNDS FLD	TX	32.350	95.400	-506.537	493.459	166.0
722469	99999	KCRS	CORSICANA	TX	32.033	96.400	-602.109	462.846	136.0
722470	3901	KGGG	LONGVIEW GREGG COUNTY AP	TX	32.383	94.717	-442.362	494.463	124.0
722479	99999	KGKY	ARLINGTON	TX	32.667	97.100	-663.793	536.793	192.0
722489	99999	KTRL	TERRELL	TX	32.717	96.267	-585.702	538.072	144.0
722499	99999	KOCH	NACOGDOCHES (AWOS)	TX	31.583	94.717	-445.799	405.713	108.0
722500	12919	KBRO	BROWNSVILLE S PADRE ISL INTL	TX	25.900	97.433	-740.603	-210.050	5.8
722505	12904	KHRL	HARLINGEN RIO GRANDE VALLEY I	TX	26.233	97.650	-759.882	-171.882	10.4
722506	12959	KMFE	MCALLEN MILLER INTL AP	TX	26.183	98.233	-818.080	-173.637	30.5
722508	99999	KPIL	PORT ISABEL/CAMERON	TX	26.167	97.350	-730.560	-181.016	5.8
722510	12924	KCRP	CORPUS CHRISTI INTL ARPT	TX	27.767	97.517	-736.214	-3.097	13.4
722515	12926	KNGP	CORPUS CHRISTI NAS	TX	27.683	97.283	-713.879	-13.775	6.1
722516	12928	KNQI	KINGSVILLE	TX	27.500	97.817	-767.452	-30.760	17.1
722517	12932	KALI	ALICE INTL AP	TX	27.733	98.033	-786.928	-3.631	52.7

Table 5-1. (Continued)
NWS Hourly Surface Stations

WMO Number	WBAN Number	Station Identifier	Station Name	State	North Latitude (deg)	West Longitude (deg)	LCC[1] East (km)	LCC[1] North (km)	Station Elevation (m)
722520	12920	KLRD	LAREDO INTL AP	TX	27.533	99.467	-928.864	-15.632	150.6
722523	12970	KSSF	SAN ANTONIO/STINSON	TX	29.333	98.467	-817.077	176.038	176.0
722524	99999	KRKP	ROCKPORT/ARANSAS CO	TX	28.083	97.050	-688.506	29.110	8.0
722526	12947	KCOT	COTULLA FAA AP	TX	28.450	99.217	-896.709	83.760	141.1
722527	99999	KLBX	ANGLETON/LAKE JACKS	TX	29.117	95.467	-528.893	135.583	8.0
722530	12921	KSAT	SAN ANTONIO INTL AP	TX	29.533	98.467	-815.539	198.143	246.6
722533	12962	KHDO	HONDO MUNICIPAL AP	TX	29.367	99.167	-884.222	184.681	280.4
722535	12909	KSKF	SAN ANTONIO KELLY FIELD AFB	TX	29.383	98.583	-827.862	182.347	207.9
722536	12911	KRND	RANDOLPH AFB	TX	29.533	98.283	-797.843	196.925	231.6
722537	99999	KERV	KERRVILLE MUNICIPAL	TX	29.983	99.083	-871.053	252.137	493.0
722539	99999	KHYI	SAN MARCOS MUNI	TX	29.883	97.867	-755.328	232.970	182.0
722540	13904	KATT	AUSTIN MUELLER MUNICIPAL AP	TX	30.300	97.700	-736.398	278.068	189.3
722541	99999	KTKI	MCKINNEY MUNI ARPT	TX	33.183	96.583	-612.411	591.358	176.0
722542	99999	KBMQ	BURNET MUNI.	TX	30.733	98.233	-784.058	329.292	391.0
722543	99999	KSGR	HOUSTON\SUGAR LAND	TX	29.617	95.650	-544.018	191.723	25.0
722544	13958	KATT	CAMP MABRY	TX	30.317	97.767	-742.677	280.355	198.0
722547	99999	KGTU	GEORGETOWN (AWOS)	TX	30.683	97.683	-732.100	320.340	240.0
722550	12912	KVCT	VICTORIA REGIONAL AP	TX	28.867	96.933	-672.155	115.149	35.1
722553	99999	K11R	BRENHAM	TX	30.217	96.367	-609.524	261.524	94.0
722554	99999	K3T5	LAGRANGE	TX	29.900	96.950	-667.280	229.499	99.0
722555	12935	KPSX	PALACIOS MUNICIPAL AP	TX	28.717	96.250	-606.851	94.975	4.9
722560	13959	KACT	WACO REGIONAL AP	TX	31.617	97.233	-683.129	421.133	152.4
722563	99999	KPWG	MC GREGOR (AWOS)	TX	31.483	97.317	-691.945	406.764	180.0
722570	3933	KHLR	FORT HOOD	TX	31.133	97.717	-732.179	370.347	280.1
722575	99999	KILE	KILLEEN MUNI (AWOS)	TX	31.083	97.683	-729.306	364.608	258.0
722576	3902	KGRK	ROBERT GRAY AAF	TX	31.067	97.833	-743.640	363.744	312.1
722577	99999	KTPL	TEMPLE/MILLER(AWOS)	TX	31.150	97.400	-702.026	370.364	208.0
722583	13960	KDAL	DALLAS LOVE FIELD	TX	32.850	96.850	-639.303	555.762	134.1
722588	99999	KGVT	GREENVILLE/MAJORS	TX	33.067	96.067	-565.091	575.984	163.0
722589	99999	KDTO	DENTON (ASOS)	TX	33.200	97.183	-668.055	596.397	197.0
722590	3927	KDFW	DALLAS-FORT WORTH INTL AP	TX	32.900	97.017	-654.552	562.197	170.7
722593	99999	KFWS	DFW NEXRAD	TX	32.567	97.300	-683.135	526.807	233.0
722594	99999	KAFW	FORT WORTH/ALLIANCE	TX	32.983	97.317	-681.950	573.053	220.0
722595	13911	KNFW	FORT WORTH NAS	TX	32.767	97.450	-695.797	549.839	185.3
722596	13961	KFTW	FORT WORTH MEACHAM	TX	32.817	97.367	-687.719	554.915	209.4
722597	93985	KMWL	MINERAL WELLS MUNICIPAL AP	TX	32.783	98.067	-753.224	555.281	283.5
722598	99999	KADS	DALLAS/ADDISON ARPT	TX	32.967	96.833	-636.990	568.658	196.0

Table 5-1. (Concluded)
NWS Hourly Surface Stations

WMO Number	WBAN Number	Station Identifier	Station Name	State	North Latitude (deg)	West Longitude (deg)	LCC[1] East (km)	LCC[1] North (km)	Station Elevation (m)
722599	99999	KRBD	DALLAS/REDBIRD ARPT	TX	32.683	96.867	-641.933	537.320	201.0
722600	3969	SEP	STEPHENVILLE CLARK FIELD	TX	32.217	98.183	-768.257	493.264	398.7
722630	23034	KSJT	SAN ANGELO MATHIS FIELD	TX	31.350	100.500	-993.588	414.056	584.0
722660	13962	KABI	ABILENE REGIONAL AP	TX	32.417	99.683	-907.047	525.727	545.6
722666	99999	KBWD	BROWNWOOD MUNICIPAL	TX	31.800	98.950	-843.539	452.152	422.0
747400	13973	KJCT	JUNCTION KIMBLE COUNTY AP	TX	30.517	99.767	-931.775	316.207	533.1
994110	99999	PTAT2	PORT ARANSAS	TX	27.833	97.050	-690.107	1.467	5.0
994260	99999	SRST2	SABINE	TX	29.667	94.050	-389.844	191.129	1.0

[1]Lambert Conformal Coordinate origin is 28.0N, 90.0W, standard parallels are 23.0N, 33.0N, datum is NWS-84.

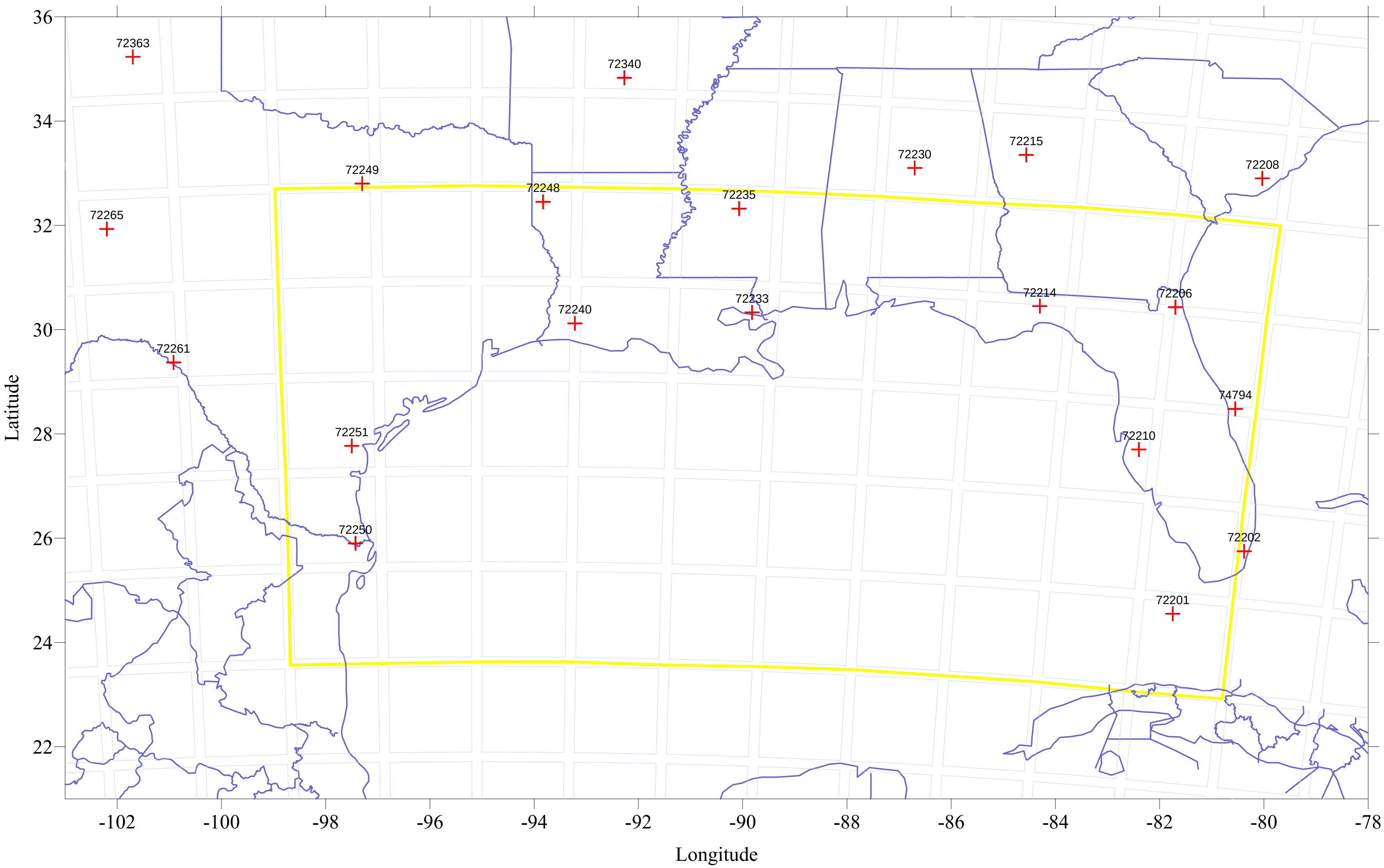

Figure 5-2. Locations of the Upper Air stations in the MMS standard data set.

Table 5-2.
Upper Air Stations

Station Identifier	WBAN No.	WMO No.	Station Name	State	North Latitude (deg)	West Longitude (deg)	Lambert Conformal Coordinates [1]	
							East (km)	North (km)
BMX	53823	72230	Birmingham (Shelby APT)	AL	33.10	86.70	307.358	569.747
LZK	03952	72340	N Little Rock	AR	34.83	92.27	-207.850	760.184
EYW	12836	72201	Key West Int AP	FL	24.55	81.75	832.013	-354.171
MFL	92803	72202	Miami Intl Univ	FL	25.75	80.38	959.419	-211.384
JAX	13889	72206	Jacksonville	FL	30.43	81.70	792.715	296.211
TBW	12842	72210	Tampa Bay/Ruskin	FL	27.70	82.40	744.795	-9.999
TLH	93805	72214	Tallahasee	FL	30.45	84.30	544.513	284.162
XMR	12868	74794	Cape Kennedy	FL	28.48	80.55	919.075	88.808
FFC	53819	72215	Peachtree City	GA	33.35	84.56	505.328	604.669
SIL	53813	72233	Slidell	LA	30.33	89.82	17.221	258.138
LCH	03937	72240	Lake Charles	LA	30.12	93.22	-308.645	238.927
SHV	13957	72248	Shreveport Regional AP	LA	32.45	93.83	-358.976	498.986
JAN	03940	72235	Jackson/Thompson Fld	MS	32.32	90.07	-6.570	478.907
CHS	13880	72208	Charleston	SC	32.90	80.03	929.488	581.387
FWD	03990	72249	Ft Worth	TX	32.80	97.30	-681.586	552.652
BRO	12919	72250	Brownsville	TX	25.90	97.43	-740.304	-210.068
CRP	12924	72251	Corpus Christi	TX	27.77	97.50	-734.531	-2.868
DRT	22010	72261	Del Rio	TX	29.37	100.92	-1052.865	198.942
MAF	23023	72265	Midland	TX	31.93	102.20	-1147.523	493.076
AMA	23047	72363	Amarillo	TX	35.23	101.70	-1065.439	854.065
BMX	53823	72230	Birmingham (Shelby APT)	AL	33.10	86.70	307.358	569.747

[1] Lambert Conformal Coordinate origin is 28.0N, 90.0W, standard parallels are 23.0N, 33.0N, datum is NWS-84.

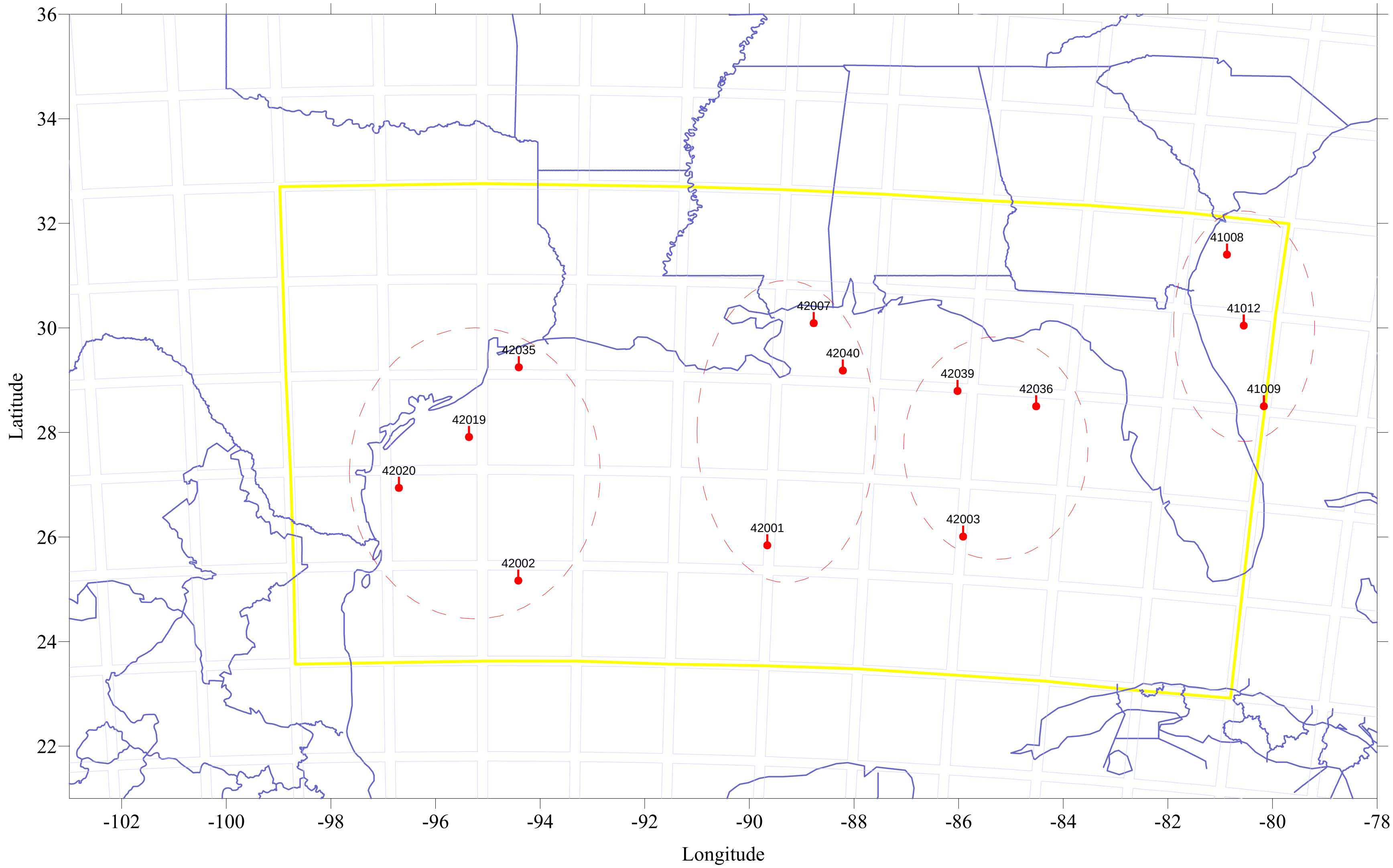

Figure 5-3. Locations of the Buoys in the MMS standard data set.

Table 5-3.
Buoy Stations

WBAN No.	Station Name	State	Period[1]	Buoy Platform[2]	Anemometer Height[3]	Air Temp. Sensor Height[4] (m)	Water Temp. Sensor Depth[4] (m)	North Latitude[5] (degrees)	East Longitude[5] (degrees)	Lambert Conformal Coordinates[6] East (km)	Lambert Conformal Coordinates[6] North (km)
41008	Gray's Reef - 40 NM SE of Savannah	GA	01/01/03 -01/01/04	3m Disc	5.0	4.0	0.6	31.402	80.871	863.683	409.361
41012	St. Augustine, FL 40 NM ENE of St Augustine	FL	01/01/03 -01/01/04	3m Disc	5.0	4.0	0.6	30.000	80.500	910.817	257.064
41009	Canaveral East 120 NM East of Cape Canaveral	FL	01/01/03 -01/01/04	6m NOMAD	5.0	4.0	1.0	28.500	80.184	954.417	93.830
42039	W. Tampa - 106 NM WNW of Tampa	FL	01/01/03 -01/01/04	3m Disc	5.0	4.0	0.6	28.796	86.056	382.765	94.356
42036	Pensacola - 115NM ESE of Pensacola	FL	01/01/03 -01/01/04	3m Disc	5.0	4.0	0.6	28.506	84.510	534.164	68.074
42003	East Gulf – 260 NM South of Panama City	FL	01/01/03 -01/10/03 01/11/03 -01/01/04	10m Disc 10m Disc	10.0 10.0	10.0 10.0	1.0 10	25.883 26.001	85.950 85.914	403.769 406.888	-227.814 -213.738
42007	Biloxi – 22 NM SSE of Biloxi	MS	01/01/03 -01/01/04	3m Disc	5.0	4.0	0.6	30.090	88.769	118.040	232.121
42040	Mobile South – 64 NM South of Dauphin	AL	01/01/03 -01/01/04	3m Disc	5.0	4.0	0.6	29.208	88.200	174.041	135.085
42001	Mid Gulf – 180 NM South of Southwest Pass	LA	01/01/03 -08/20/03 08/21/03 -08/31/03 09/01/03 -01/01/04	10m Disc 10m Disc 10m Disc	10.0 10.0 10.0	10.0 10.0 10.0	1.0 1.0 1.0	25.922 25.838 25.860	89.682 89.653 89.670	-31.698 -34.615 -32.913	-230.159 -239.461 -237.027
42035	Galveston – 22 NM East of Galveston	TX	01/01/03 -04/11/03 04/12/03 -01/01/04	3m Disc 3m Disc	5.0 5.0	4.0 4.0	0.6 0.6	29.253 29.246	94.417 94.408	-426.817 -425.975	146.520 145.713
42019	Freeport – 60 NM South of Freeport	TX	01/01/03 -08/31/03 09/01/03 -01/01/04	3m Disc 3m Disc	5.0 5.0	4.0 4.0	0.6 0.6	27.918 27.913	95.361 95.360	-524.679 -524.411	2.463 1.897
42020	Corpus Christi – 50 NM SE of Corpus Christi	TX	01/01/03 -01/01/04	3m Disc	5.0	4.0	0.6	26.946	96.697	-660.983	-98.579
42002	West Gulf – 240 NM SSE of Sabine	TX	01/01/03 -01/01/04	10m Disc	10.0	10.0	1.0	25.167	94.417	-443.218	-305.868

1. Period indicates the period of time when the station was located at the listed position. Determined based on records in NODC data files.
2. Buoy Platforms were determined based on NDBC Data Availability Pages.
3. "Anemometer Height" was read from the NODC Data sets and confirmed based on the Buoy Platform.
4. "Air Temp. Sensor Height" and "Water Temp. Sensor Depth" are determined based on the Buoy Platform.
5. Latitude Longitude locations are read from the NODC data files, datum is WGS-84.
6. Lambert Conformal Coordinate origin is 28.0N, 90.0W, standard parallels are 23.0N, 33.0N, datum is NWS-84.

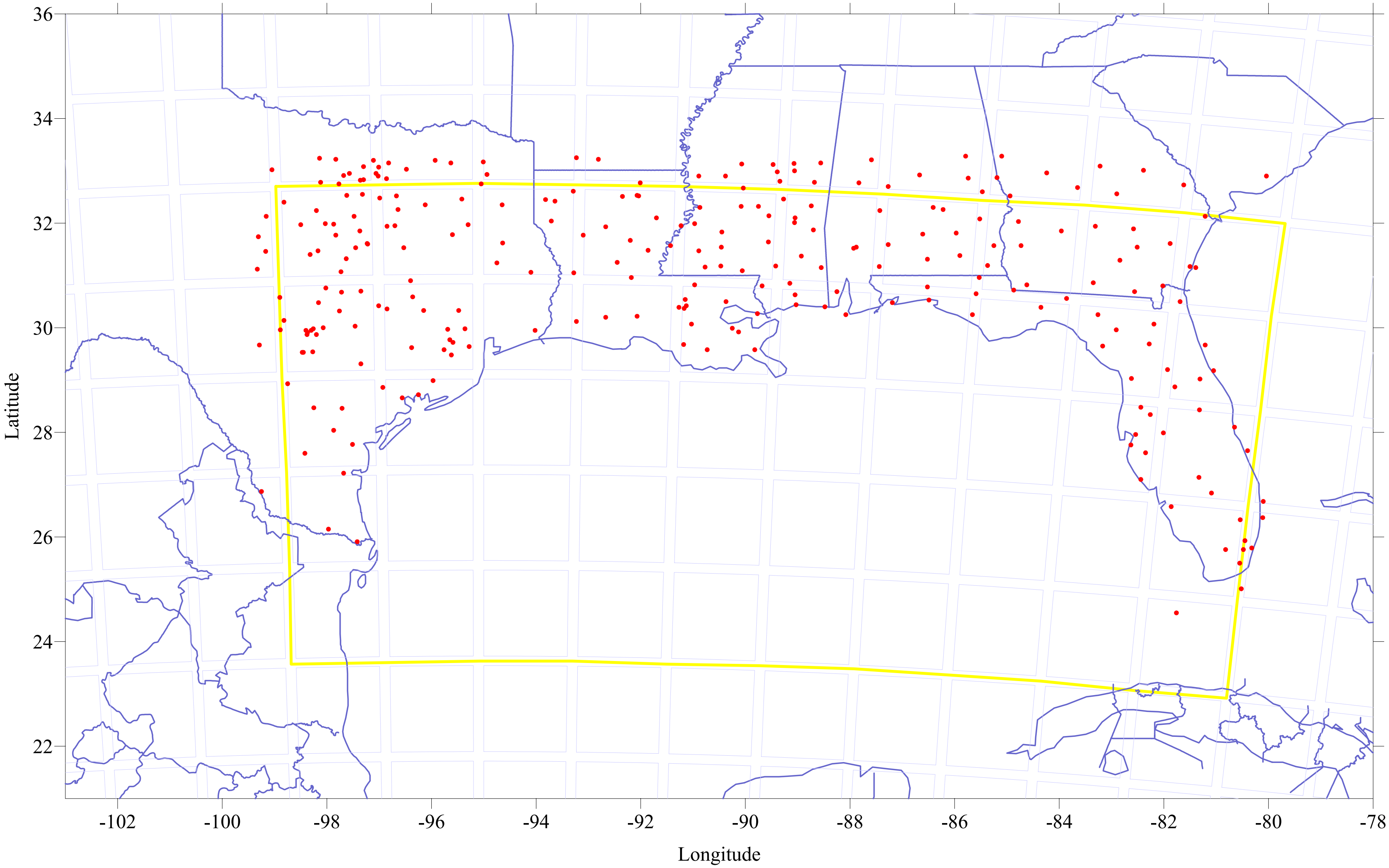

Figure 5-4. Locations of the precipitation stations in the MMS standard data set.

Table 5-4.
Hourly NWS Precipitation Stations

COOP	State	Station Name	North Latitude (deg.)	West Longitude (deg.)	LCC[1] East (km)	LCC[1] North (km)
10008	AL	ABBEVILLE	31.57	85.25	449.128	404.429
10140	AL	ALBERTA	32.24	87.43	241.708	472.448
10252	AL	ANDALUSIA 3 W	31.31	86.52	329.593	371.128
10369	AL	ASHLAND 2 E	33.28	85.79	391.198	592.759
10402	AL	ATMORE STATE NURSERY	31.17	87.44	243.046	354.158
10425	AL	AUBURN NO 2	32.60	85.47	424.383	517.813
12124	AL	DADEVILLE 2	32.86	85.74	398.051	546.115
12172	AL	DAUPHIN ISLAND #2	30.25	88.08	183.504	250.701
12377	AL	DOTHAN	31.19	85.37	439.139	362.286
12675	AL	ENTERPRISE 5 NNW	31.38	85.90	388.123	381.488
13519	AL	GREENVILLE	31.79	86.61	319.325	425.017
14193	AL	JACKSON	31.53	87.93	195.992	392.315
15112	AL	MARION 7 NE	32.70	87.27	255.449	524.294
15397	AL	MIDWAY	32.08	85.52	421.207	459.806
15478	AL	MOBILE REGIONAL AP	30.69	88.25	167.275	299.054
15550	AL	MONTGOMERY DANNELLY FIELD	32.30	86.41	337.214	481.622
15553	AL	MONTGOMERY 6 SW	32.26	86.22	355.128	477.751
16370	AL	PETERMAN	31.59	87.27	258.222	400.571
18178	AL	THOMASVILLE	31.54	87.88	200.165	394.175
18209	AL	THORSBY EXP STATION	32.92	86.67	310.619	549.878
18323	AL	TROY	31.81	85.97	379.863	428.278
18385	AL	TUSCALOOSA OLIVER DAM	33.21	87.59	223.900	579.998
18673	AL	WARRIOR LOCK AND DAM	32.77	87.83	202.717	531.199
32300	AR	EL DORADO GOODWIN FLD	33.22	92.81	-261.806	582.046
34548	AR	MAGNOLIA	33.25	93.23	-300.732	586.319
80845	FL	BOCA RATON	26.37	80.11	980.714	-141.024
80975	FL	BRANFORD	29.96	82.91	680.224	237.182
81048	FL	BROOKSVILLE 7 SSW	28.48	82.44	735.976	76.131
81986	FL	CRESTVIEW BOB SIKES AP	30.78	86.52	331.234	312.708
82008	FL	CROSS CITY 2 WNW	29.65	83.17	657.671	201.178
82158	FL	DAYTONA BEACH INTL AP	29.18	81.05	864.987	162.784
82229	FL	DELAND 1 SSE	29.02	81.31	840.992	142.749
82391	FL	DOWLING PARK 1 W	30.25	83.26	645.049	267.068
83186	FL	FORT MYERS PAGE FIELD AP	26.59	81.86	805.743	-129.824
83326	FL	GAINESVILLE REGIONL AP	29.69	82.28	743.001	210.967
83538	FL	GRACEVILLE 1 SW	30.96	85.53	424.719	335.480
84095	FL	HOMESTEAD GEN AVIATION	25.50	80.55	944.635	-240.217
84273	FL	INGLIS 3 E	29.03	82.62	714.782	135.217
84358	FL	JACKSONVILLE INTL AP	30.50	81.69	792.833	303.441
84570	FL	KEY WEST INTL AP	24.55	81.76	831.241	-353.977
84802	FL	LAKELAND 2	27.99	82.01	780.495	24.625
85076	FL	LISBON	28.87	81.79	796.094	123.500
85237	FL	LYNNE	29.20	81.93	779.742	158.765
85391	FL	MARINELAND	29.67	81.22	845.023	215.450
85612	FL	MELBOURNE WFO	28.10	80.65	912.976	46.433
85663	FL	MIAMI INTL AP	25.79	80.32	965.393	-206.400

Table 5-4. (Continued)
Hourly NWS Precipitation Stations

COOP	State	Station Name	North Latitude (deg.)	West Longitude (deg.)	LCC[1] East (km)	LCC[1] North (km)
85879	FL	MONTICELLO WTP	30.56	83.86	585.713	298.342
85895	FL	MOORE HAVEN LOCK 1	26.84	81.09	880.194	-96.289
86240	FL	NICEVILLE	30.53	86.49	334.936	285.270
86323	FL	NORTH NEW RVR CANAL 2	26.33	80.54	938.754	-148.129
86628	FL	ORLANDO INTL AP	28.43	81.33	844.198	78.110
86842	FL	PANAMA CITY 5 N	30.25	85.66	415.397	256.561
86880	FL	PARRISH	27.61	82.35	750.539	-19.750
86988	FL	PENNSUCO 5 WNW	25.93	80.45	950.507	-192.104
86997	FL	PENSACOLA REGIONAL AP	30.48	87.19	268.730	277.639
87440	FL	RAIFORD STATE PRISON	30.07	82.19	748.286	253.035
87851	FL	SAINT LEO	28.34	82.26	754.014	61.359
87886	FL	ST PETERSBURG	27.76	82.63	722.133	-4.396
88758	FL	TALLAHASSEE WSO AP	30.39	84.35	539.714	277.619
88780	FL	TAMIAMI TRAIL 40 MI BEND	25.76	80.82	915.117	-213.602
88788	FL	TAMPA WSCMO AP	27.96	82.54	729.295	18.048
88841	FL	TAVERNIER	25.01	80.52	951.775	-294.622
89010	FL	TRAIL GLADE RANGES	25.76	80.48	949.587	-210.520
89176	FL	VENICE	27.10	82.44	745.351	-76.489
89184	FL	VENUS	27.14	81.33	853.909	-65.425
89219	FL	VERO BEACH 4 SE	27.65	80.40	940.544	-1.410
89415	FL	WAUSAU	30.65	85.59	420.686	301.583
89525	FL	WEST PALM BEACH INT AP	26.68	80.10	978.935	-105.907
89795	FL	WOODRUFF DAM	30.72	84.87	488.430	311.848
90010	GA	ABBEVILLE 4 S	31.94	83.31	630.152	453.797
90211	GA	ALMA BACON COUNTY AP	31.54	82.51	708.239	413.629
90586	GA	BAINBRIDGE INTL PAPER CO	30.82	84.62	512.378	324.072
91340	GA	BRUNSWICK	31.17	81.50	805.873	379.153
91345	GA	BRUNSWICK MCKINNON AP	31.15	81.39	816.542	378.142
92166	GA	COLUMBUS METRO AP	32.52	84.94	473.689	510.519
92361	GA	CRISP CO POWER DAM	31.85	83.96	569.333	441.230
92844	GA	DUBLIN 2	32.56	82.90	664.532	524.587
93028	GA	EDISON	31.57	84.73	497.744	405.996
93312	GA	FARGO	30.69	82.56	708.635	319.691
93460	GA	FOLKSTON 3 SW	30.80	82.02	759.707	334.961
93570	GA	FRANKLIN	33.28	85.10	455.604	594.301
94204	GA	HAZLEHURST	31.89	82.58	698.862	452.188
94671	GA	JESUP	31.61	81.88	766.877	425.420
95314	GA	LOUISVILLE 1 E	33.01	82.39	708.889	577.990
95394	GA	LUMPKIN 2 SE	32.03	84.78	491.626	457.301
95443	GA	MACON MIDDLE GA REGIONAL AP	32.68	83.65	593.380	534.878
95876	GA	MILLEDGEVILLE DARDC	33.09	83.22	631.342	581.637
96879	GA	PEARSON	31.29	82.84	678.143	384.802
97847	GA	SAVANNAH INTL AP	32.13	81.21	825.846	487.596
98517	GA	SYLVANIA 2 SSE	32.73	81.62	782.999	551.637
98657	GA	THE ROCK	32.96	84.24	536.904	563.138
98974	GA	VALDOSTA 4 NW	30.86	83.35	632.746	333.842

Table 5-4. (Continued)
Hourly NWS Precipitation Stations

COOP	State	Station Name	North Latitude (deg.)	West Longitude (deg.)	LCC[1] East (km)	LCC[1] North (km)
99291	GA	WEST POINT	32.87	85.19	449.025	548.817
160103	LA	ALEXANDRIA 5 SSE	31.25	92.45	-232.229	362.349
160537	LA	BASTROP	32.77	92.01	-187.415	530.320
160548	LA	BATON ROUGE CONCORD	30.42	91.13	-108.044	268.510
160549	LA	BATON ROUGE METRO AP	30.54	91.15	-109.513	281.612
161246	LA	BRUSLY 2 W	30.39	91.27	-121.537	265.626
161287	LA	BUNKIE	30.96	92.18	-207.175	329.764
161411	LA	CALHOUN RESEARCH STN	32.51	92.35	-219.938	502.499
161899	LA	CLINTON 5 SE	30.82	90.97	-92.689	312.573
162534	LA	DONALDSONVILLE 4 SW	30.07	91.03	-99.108	229.360
164030	LA	HAMMOND 5 E	30.50	90.37	-35.023	277.023
164407	LA	HOUMA	29.58	90.73	-70.657	175.594
164696	LA	JENA 4 WSW	31.67	92.20	-207.846	408.185
164700	LA	JENNINGS	30.20	92.67	-255.421	246.511
164739	LA	JONESVILLE LOCKS	31.48	91.86	-176.257	387.280
165021	LA	LAFAYETTE	30.22	92.07	-197.763	247.516
165078	LA	LAKE CHARLES AP	30.12	93.23	-309.429	239.471
165287	LA	LEESVILLE 6 SSW	31.05	93.28	-311.510	342.330
165620	LA	LSU BEN HUR FARM	30.37	91.17	-111.577	262.724
165624	LA	LSU CITRUS RESEARCH STN	29.58	89.82	17.103	175.148
165874	LA	MANSFIELD	32.04	93.71	-348.650	453.018
166244	LA	MINDEN	32.61	93.29	-308.353	514.764
166303	LA	MONROE REGIONAL AP	32.52	92.04	-191.157	502.228
166314	LA	MONROE ULM	32.53	92.07	-193.594	504.337
166394	LA	MORGAN CITY	29.68	91.18	-113.211	187.008
166582	LA	NATCHITOCHES	31.77	93.10	-292.066	421.794
166660	LA	NEW ORLEANS INTL AP	29.99	90.25	-24.075	220.776
166664	LA	NEW ORLEANS AUDUBON	29.92	90.13	-12.513	212.323
167738	LA	RED RIVER RESEARCH STN	32.42	93.64	-341.084	495.319
168163	LA	ST JOSEPH 3 N	31.95	91.23	-116.202	438.377
168440	LA	SHREVEPORT AP	32.45	93.82	-358.413	498.659
168539	LA	SLIDELL	30.27	89.77	22.337	251.127
169357	LA	VIDALIA 2	31.57	91.43	-135.490	395.885
169803	LA	WINNFIELD 2 W	31.93	92.67	-251.624	437.986
169806	LA	WINNSBORO 5 SSE	32.10	91.70	-160.083	455.530
220797	MS	BILOXI 9 WNW	30.44	89.03	92.946	270.351
221094	MS	BROOKHAVEN CITY	31.54	90.46	-43.291	392.888
221389	MS	CANTON 4 N	32.67	90.04	-3.352	517.912
221852	MS	COLLINS	31.64	89.56	41.833	403.703
221900	MS	CONAHATTA 1 NE	32.46	89.27	68.480	494.229
222281	MS	DE KALB	32.78	88.68	123.680	530.468
222658	MS	EDINBURG	32.80	89.34	61.971	532.343
222870	MS	ETHEL	33.12	89.47	49.180	567.577
223920	MS	HAZLEHURST 5 SW	31.83	90.45	-42.830	424.887
224472	MS	JACKSON WSFO AIRPORT	32.32	90.08	-7.274	478.876
224778	MS	KOSCIUSKO 13 SE	32.98	89.39	56.860	552.849

Table 5-4. (Continued)
Hourly NWS Precipitation Stations

COOP	State	Station Name	North Latitude (deg.)	West Longitude (deg.)	LCC[1] East (km)	LCC[1] North (km)
224966	MS	LEAKESVILLE	31.15	88.55	137.640	349.865
225062	MS	LEXINGTON 2 NNW	33.13	90.07	-6.208	569.295
225074	MS	LIBERTY 2 E	31.16	90.77	-73.267	350.912
225247	MS	LOUISVILLE	33.14	89.07	86.495	569.839
225361	MS	MACON 3 N	33.15	88.56	134.191	572.434
225614	MS	MCCOMB AIRPORT	31.18	90.47	-44.680	352.769
225704	MS	MEADVILLE	31.47	90.89	-83.755	384.450
225776	MS	MERIDIAN AIRPORT	32.33	88.74	117.855	481.147
226400	MS	NOXAPATER 1 N	33.00	89.06	87.357	555.297
226718	MS	PASCAGOULA 3 NE	30.40	88.48	145.003	266.787
226750	MS	PAULDING	32.01	89.06	88.341	444.266
226816	MS	PELAHATCHIE 3 E	32.32	89.75	23.751	479.053
227132	MS	PORT GIBSON 1 NE	31.99	90.97	-91.524	442.070
227220	MS	PURVIS 2 N	31.18	89.42	55.464	352.230
227276	MS	RALEIGH 6 N	32.14	89.55	41.945	459.208
227444	MS	RICHTON 1 N	31.37	88.93	101.150	373.402
227560	MS	ROLLING FORK	32.90	90.89	-82.627	543.219
227592	MS	ROSE HILL 4 SW	32.10	89.05	89.279	454.852
227840	MS	SAUCIER EXP FOREST	30.63	89.05	90.626	292.105
228053	MS	SHUBUTA	31.87	88.70	122.554	429.222
229048	MS	TYLERTOWN 5 ESE	31.09	90.06	-5.462	342.054
229218	MS	VICKSBURG WATERWAYS EXP ST	32.30	90.87	-81.286	476.695
229617	MS	WHITE SAND	30.80	89.68	30.161	310.270
229648	MS	WIGGINS RANGER STN	30.85	89.15	80.919	316.058
229860	MS	YAZOO CITY 5 NNE	32.90	90.38	-35.777	543.407
381544	SC	CHARLESTON INTL AP	32.90	80.04	928.544	581.154
410428	TX	AUSTIN CAMP MABRY	30.32	97.76	-741.980	280.767
410509	TX	BANKERSMITH	30.14	98.82	-844.609	267.762
410518	TX	BARDWELL DAM	32.26	96.64	-623.037	489.610
410569	TX	BAY CITY WATERWORKS	28.99	95.97	-577.752	124.285
410639	TX	BEEVILLE 5 NE	28.46	97.71	-749.879	74.383
410690	TX	BENAVIDES 2	27.60	98.42	-825.440	-16.132
410738	TX	BERTRAM 3 ENE	30.76	98.02	-763.234	330.934
411017	TX	BRADY	31.12	99.34	-885.557	379.277
411136	TX	BROWNSVILLE INTL AP	25.91	97.42	-739.518	-208.543
411246	TX	BURLESON	32.55	97.32	-685.546	525.276
411429	TX	CANYON DAM	29.87	98.20	-787.026	233.680
411433	TX	CANYON DAM NO 3	29.95	98.40	-806.004	243.643
411434	TX	CANYON DAM NO 4	29.91	98.37	-803.469	239.303
411436	TX	CANYON DAM 6	29.95	98.30	-796.464	242.804
411541	TX	CEDAR CREEK 4 SE	30.03	97.46	-715.249	247.262
411663	TX	CHARLOTTE 5 NNW	28.93	98.75	-847.508	133.160
411671	TX	CHEAPSIDE	29.31	97.35	-709.282	166.513
411720	TX	CHOKE CANYON DAM	28.47	98.25	-802.895	78.969
411889	TX	COLLEGE STA EASTERWOOD AP	30.59	96.36	-607.153	302.711
411920	TX	COMFORT 2	29.96	98.89	-853.149	248.444

Table 5-4. (Continued)
Hourly NWS Precipitation Stations

COOP	State	Station Name	North Latitude (deg.)	West Longitude (deg.)	LCC[1] East (km)	LCC[1] North (km)
411921	TX	COMMERCE 4 SW	33.20	95.93	-551.931	590.143
411956	TX	CONROE	30.33	95.48	-524.418	269.553
412015	TX	CORPUS CHRISTI WSFO AP	27.77	97.51	-735.760	-2.453
412086	TX	CRANFILLS GAP	31.77	97.83	-738.686	441.213
412088	TX	CRAWFORD	31.53	97.45	-704.401	413.115
412096	TX	CRESSON	32.53	97.62	-712.965	524.886
412131	TX	CROSS PLAINS 2	32.13	99.16	-860.527	489.690
412206	TX	CYPRESS	29.97	95.69	-546.248	230.552
412242	TX	DAL-FTW INTL AP	32.90	97.02	-654.743	561.961
412244	TX	DALLAS LOVE FIELD	32.85	96.86	-639.805	556.069
412404	TX	DENTON 2 SE	33.20	97.11	-660.816	595.849
412462	TX	DIME BOX	30.36	96.85	-654.398	279.894
412676	TX	EAGLE LAKE RESCH CTR	29.62	96.38	-614.513	195.723
412715	TX	EASTLAND	32.40	98.82	-826.215	517.563
413005	TX	EVANT 1 SSW	31.47	98.17	-772.302	410.059
413133	TX	FERRIS	32.52	96.67	-624.235	517.827
413156	TX	FISCHERS STORE	29.98	98.26	-792.763	245.730
413171	TX	FLAT	31.32	97.63	-722.976	390.181
413284	TX	FORT WORTH MEACHAM FIELD	32.82	97.36	-687.181	555.123
413285	TX	FORT WORTH WSFO	32.83	97.30	-681.364	556.350
413370	TX	FRISCO	33.15	96.82	-634.331	588.889
413507	TX	GEORGETOWN LAKE	30.68	97.72	-735.353	320.613
413546	TX	GILMER 4 WNW	32.75	95.05	-471.875	536.053
413686	TX	GRANGER DAM	30.70	97.35	-700.269	320.263
413691	TX	GRAPEVINE DAM	32.95	97.06	-657.794	568.014
413771	TX	GROESBECK 2	31.53	96.53	-617.397	407.224
414137	TX	HICO	31.99	98.03	-755.754	466.799
414300	TX	HOUSTON BUSH INTL AP	29.98	95.36	-514.345	230.646
414307	TX	HOUSTON HOBBY AP	29.64	95.28	-508.501	192.464
414309	TX	HOUSTON ADDICKS	29.77	95.65	-542.965	208.645
414311	TX	HOUSTON ALIEF	29.72	95.59	-538.165	202.508
414476	TX	IREDELL	31.98	97.87	-740.274	465.417
414520	TX	JACKSBORO 1 NNE	33.24	98.14	-757.066	606.242
414679	TX	JUSTIN	33.08	97.30	-679.414	583.674
414792	TX	KILLEEN 3 S	31.07	97.73	-733.892	363.670
414866	TX	KOPPERL 5 NNE	32.13	97.48	-702.773	479.896
414972	TX	LAKE BRIDGEPORT DAM	33.23	97.83	-728.126	602.887
415094	TX	LAVON DAM	33.03	96.48	-604.032	574.242
415192	TX	LEWISVILLE DAM	33.07	97.01	-652.821	580.905
415193	TX	LEXINGTON	30.42	97.01	-669.754	286.812
415348	TX	LONGVIEW 11 SE	32.35	94.65	-436.549	490.201
415424	TX	LUFKIN ANGELINA CO AP	31.24	94.75	-450.837	367.392
415463	TX	MABANK 4 SW	32.35	96.12	-573.710	496.635
415528	TX	MALONE 3ENE	31.94	96.85	-644.615	455.280
415661	TX	MATHIS 4 SSW	28.04	97.87	-769.052	28.967
415897	TX	MIDLOTHIAN 2	32.48	96.99	-655.075	515.940

Table 5-4. (Concluded)
Hourly NWS Precipitation Stations

COOP	State	Station Name	North Latitude (deg.)	West Longitude (deg.)	LCC[1] East (km)	LCC[1] North (km)
415957	TX	MINERAL WELLS 1 SSW	32.78	98.12	-757.852	555.626
415996	TX	MOLINE	31.40	98.32	-786.970	403.639
416108	TX	MOUNT PLEASANT	33.17	95.01	-465.822	582.813
416177	TX	NACOGDOCHES	31.62	94.65	-438.849	409.339
416210	TX	NAVARRO MILLS DAM	31.95	96.70	-630.810	455.161
416335	TX	NEW SUMMERFIELD 2 W	31.97	95.30	-499.367	451.431
416750	TX	PALACIOS MUNICIPAL AP	28.72	96.25	-607.157	95.847
416757	TX	PALESTINE 2 NE	31.78	95.60	-528.543	431.440
417066	TX	PITTSBURG 5 S	32.93	94.94	-460.794	555.561
417140	TX	POINT COMFORT	28.66	96.56	-636.819	89.951
417174	TX	PORT ARTHUR AP	29.95	94.02	-385.974	222.438
417243	TX	PRAIRIE MOUNTAIN	30.58	98.90	-848.652	317.235
417300	TX	PROCTOR RESERVOIR	31.97	98.50	-799.908	467.572
417422	TX	RANDOLPH FIELD	29.54	98.27	-796.859	198.067
417556	TX	RENO	32.95	97.57	-706.065	571.254
417594	TX	RICHMOND	29.58	95.76	-554.320	188.533
417936	TX	SAM RAYBURN DAM	31.06	94.10	-389.560	345.835
417945	TX	SAN ANTONIO INTL AP	29.53	98.47	-815.824	198.199
417947	TX	SAN ANTONIO 8 NNE	29.53	98.45	-814.337	197.201
418047	TX	SANTA ANNA	31.74	99.31	-877.893	448.299
418081	TX	SARITA 7 E	27.22	97.68	-756.323	-62.915
418531	TX	SPICEWOOD	30.48	98.16	-778.945	301.144
418544	TX	SPRING BRANCH 2 SE	29.87	98.38	-804.827	234.337
418563	TX	SPRINGTOWN 4 S	32.91	97.68	-716.130	566.873
418623	TX	STEPHENVILLE 1 N	32.25	98.20	-769.225	496.446
418743	TX	SULPHUR SPRINGS	33.15	95.63	-524.301	583.264
418778	TX	SWAN 4 NW	32.46	95.42	-508.174	505.331
418845	TX	TARPLEY	29.67	99.29	-893.368	218.763
418996	TX	THOMPSONS 3 WSW	29.48	95.62	-542.239	176.877
419364	TX	VICTORIA ASOS	28.86	96.93	-671.927	114.513
419417	TX	WACO DAM	31.60	97.22	-681.723	419.191
419419	TX	WACO REGIONAL AP	31.61	97.23	-682.752	420.487
419491	TX	WASHINGTON STATE PARK	30.33	96.15	-588.118	273.335
419532	TX	WEATHERFORD	32.75	97.77	-725.776	549.634
419588	TX	WESLACO 2 E	26.15	97.97	-791.893	-179.045
419665	TX	WHEELOCK	30.90	96.40	-608.256	337.312
419715	TX	WHITNEY DAM	31.85	97.37	-694.176	447.702
419815	TX	WIMBERLEY 1 NW	30.00	98.07	-773.582	247.250
419817	TX	WINCHELL	31.46	99.17	-867.245	415.865
419893	TX	WOODSON	33.02	99.05	-843.273	587.778
419976	TX	ZAPATA 3 SW	26.87	99.25	-913.532	-90.406

[1]Lambert Conformal Coordinate origin is 28.0N, 90.0W, standard parallels are 23.0N, 33.0N, datum is NWS-84.

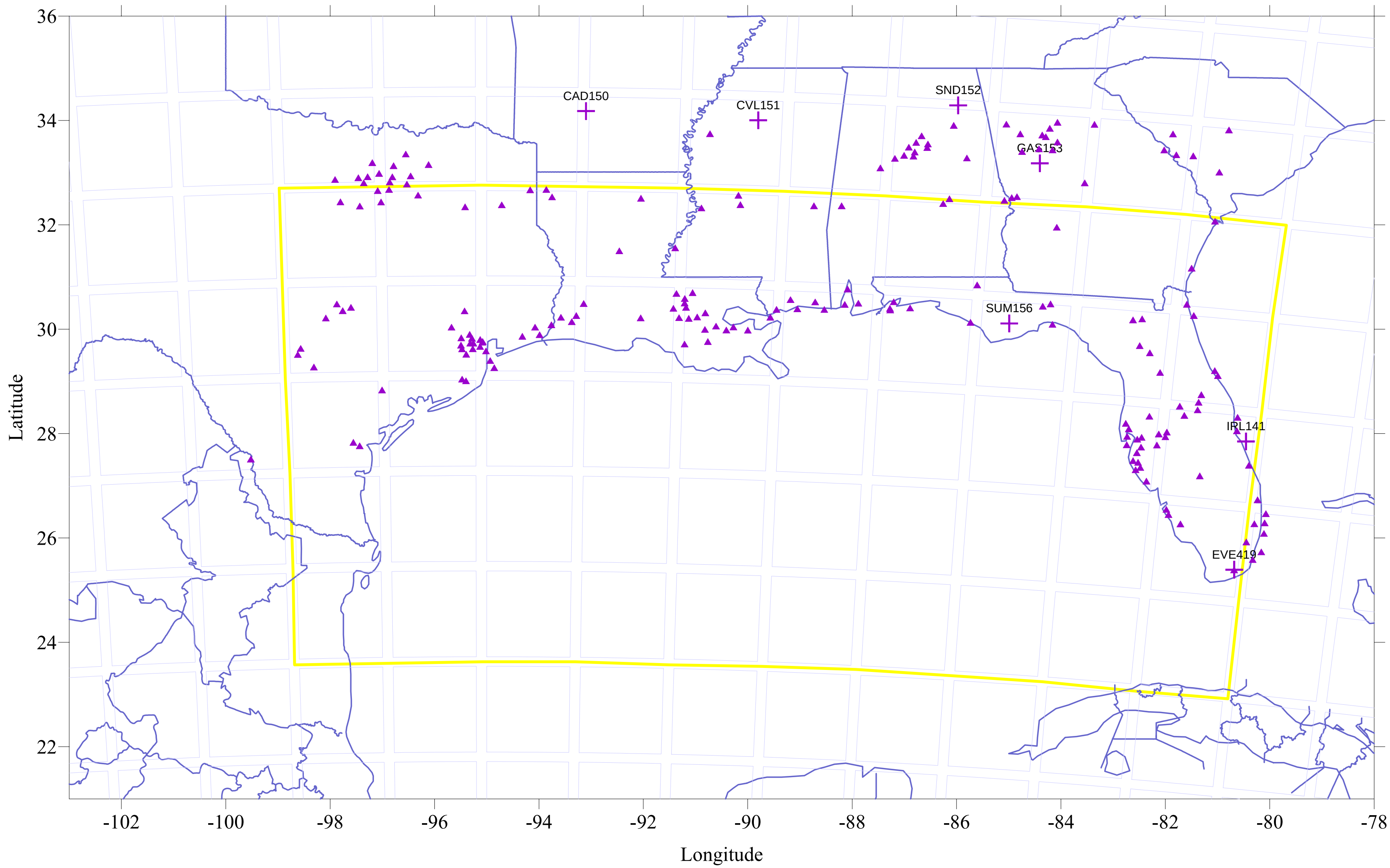

Figure 5-5 Location of the ozone (AIRS and CASTNET) stations in the MMS standard data set.

Table 5-5.
Ozone Stations

Station ID	Station Type	North Latitude (degrees)	West Longitude (degrees)	LCC[1] East (km)	LCC[1] North (km)
10030010	AIRS	30.50	87.88	202.488	278.731
10270001	AIRS	33.28	85.80	390.463	592.332
10510001	AIRS	32.50	86.14	361.611	504.626
10550011	AIRS	33.90	86.05	364.994	660.516
10731003	AIRS	33.49	86.91	286.703	612.601
10731005	AIRS	33.33	87.00	278.792	594.597
10731009	AIRS	33.27	87.18	262.222	587.526
10731010	AIRS	33.55	86.55	319.908	620.170
10732006	AIRS	33.39	86.80	297.199	601.742
10735002	AIRS	33.70	86.67	308.328	636.548
10735003	AIRS	33.48	86.56	319.201	612.358
10736002	AIRS	33.58	86.77	299.425	622.949
10970003	AIRS	30.77	88.09	181.963	308.331
10972005	AIRS	30.47	88.14	177.707	275.000
11011002	AIRS	32.41	86.26	350.679	494.282
11130002	AIRS	32.47	85.08	460.999	504.872
11170004	AIRS	33.32	86.82	295.545	593.909
11190002	AIRS	32.36	88.20	168.879	484.595
11250010	AIRS	33.09	87.46	236.607	566.940
120010025	AIRS	29.68	82.49	722.482	208.357
120013011	AIRS	29.55	82.30	741.645	195.122
120030002	AIRS	30.20	82.45	722.758	266.108
120050006	AIRS	30.13	85.73	409.214	243.127
120090007	AIRS	28.05	80.63	914.968	40.724
120094001	AIRS	28.31	80.62	913.728	69.510
120110031	AIRS	26.27	80.29	963.790	-153.226
120112003	AIRS	26.29	80.10	982.428	-149.500
120118002	AIRS	26.09	80.11	983.234	-171.670
120210004	AIRS	26.27	81.71	823.080	-163.635
120230002	AIRS	30.18	82.62	706.638	262.899
120310077	AIRS	30.48	81.59	802.822	302.460
120310100	AIRS	30.26	81.45	817.874	279.064
120330004	AIRS	30.53	87.20	267.351	283.367
120330018	AIRS	30.37	87.27	261.065	265.483
120330024	AIRS	30.40	87.28	260.035	268.786
120550003	AIRS	27.19	81.34	852.521	-59.416
120570081	AIRS	27.74	82.47	737.670	-6.003
120570110	AIRS	27.78	82.16	767.713	0.333
120571035	AIRS	27.93	82.45	738.325	15.121

Table 5-5. (Continued)
Ozone Stations

Station ID	Station Type	North Latitude (degrees)	West Longitude (degrees)	LCC[1] East (km)	LCC[1] North (km)
120571065	AIRS	27.89	82.54	729.805	10.157
120574004	AIRS	27.99	82.13	769.147	23.732
120590004	AIRS	30.85	85.60	418.787	323.335
120690002	AIRS	28.53	81.72	805.096	86.057
120712002	AIRS	26.55	81.98	794.272	-134.472
120713002	AIRS	26.45	81.94	798.960	-145.266
120730012	AIRS	30.44	84.35	539.791	282.832
120730013	AIRS	30.48	84.20	553.901	287.934
120813002	AIRS	27.63	82.55	730.587	-18.645
120814012	AIRS	27.48	82.62	724.736	-35.646
120814013	AIRS	27.45	82.52	734.748	-38.364
120830003	AIRS	29.17	82.10	763.609	154.346
120860021	AIRS	25.92	80.45	950.977	-193.148
120860027	AIRS	25.73	80.16	981.491	-211.842
120860029	AIRS	25.59	80.33	965.800	-228.669
120860030	AIRS	25.39	80.68	932.607	-253.500
120950008	AIRS	28.45	81.38	838.728	79.510
120952002	AIRS	28.60	81.36	839.494	96.220
120972002	AIRS	28.35	81.64	814.229	66.698
120990009	AIRS	26.73	80.23	965.651	-101.949
120992004	AIRS	26.47	80.07	983.775	-129.380
121010005	AIRS	28.33	82.31	749.204	60.191
121012001	AIRS	28.20	82.76	706.270	43.133
121030004	AIRS	27.95	82.73	710.844	15.668
121030018	AIRS	27.79	82.74	710.922	-2.080
121035002	AIRS	28.09	82.70	712.846	31.321
121056005	AIRS	27.94	82.00	782.196	19.033
121056006	AIRS	28.03	81.97	784.469	29.173
121111002	AIRS	27.39	80.40	943.132	-30.402
121130014	AIRS	30.41	86.89	297.283	270.786
121151005	AIRS	27.31	82.57	730.788	-54.142
121151006	AIRS	27.35	82.48	739.355	-49.177
121152002	AIRS	27.09	82.36	752.942	-77.186
121171002	AIRS	28.75	81.31	843.161	113.137
121272001	AIRS	29.11	80.99	871.209	155.159
121275002	AIRS	29.21	81.05	864.604	165.779
121290001	AIRS	30.09	84.16	559.788	244.938
130210012	AIRS	32.80	83.54	603.234	548.225
130510021	AIRS	32.07	81.05	841.340	482.045

Table 5-5. (Continued)
Ozone Stations

Station ID	Station Type	North Latitude (degrees)	West Longitude (degrees)	LCC[1] East (km)	LCC[1] North (km)
130590002	AIRS	33.92	83.36	613.242	673.536
130770002	AIRS	33.40	84.75	487.450	609.452
130890002	AIRS	33.69	84.29	528.619	643.607
130893001	AIRS	33.85	84.21	535.174	661.748
130970004	AIRS	33.74	84.78	483.046	647.134
131130001	AIRS	33.46	84.42	517.763	617.482
131210055	AIRS	33.72	84.36	521.988	646.641
131270006	AIRS	31.17	81.50	806.068	379.383
131350002	AIRS	33.96	84.07	547.508	674.604
131510002	AIRS	33.43	84.16	542.030	615.278
132150008	AIRS	32.52	84.94	473.879	510.959
132151003	AIRS	32.54	84.84	483.145	513.572
132230003	AIRS	33.93	85.05	457.216	667.228
132450091	AIRS	33.43	82.02	740.406	626.536
132470001	AIRS	33.59	84.07	549.511	633.464
132611001	AIRS	31.95	84.08	557.435	451.359
220050004	AIRS	30.23	90.97	-92.890	247.411
220110002	AIRS	30.49	93.14	-299.922	279.725
220150008	AIRS	32.53	93.75	-351.206	507.636
220170001	AIRS	32.68	93.86	-360.977	524.616
220190002	AIRS	30.14	93.37	-322.958	241.532
220190008	AIRS	30.26	93.28	-313.977	254.592
220190009	AIRS	30.23	93.58	-342.784	252.076
220330003	AIRS	30.42	91.18	-112.795	268.648
220330013	AIRS	30.70	91.06	-101.055	299.583
220331001	AIRS	30.59	91.21	-115.476	287.521
220430001	AIRS	31.50	92.46	-232.720	390.224
220470007	AIRS	30.40	91.43	-136.718	266.687
220470009	AIRS	30.22	91.32	-126.417	246.618
220470012	AIRS	30.21	91.13	-108.231	245.326
220511001	AIRS	30.04	90.28	-26.862	226.015
220550005	AIRS	30.22	92.05	-196.325	247.584
220570004	AIRS	29.76	90.77	-74.066	195.190
220630002	AIRS	30.31	90.81	-77.509	256.166
220730004	AIRS	32.51	92.05	-192.052	501.626
220770001	AIRS	30.68	91.37	-130.633	297.660
220870002	AIRS	29.98	90.00	0.000	219.335
220890003	AIRS	29.98	90.41	-39.357	219.401
220930002	AIRS	29.99	90.82	-78.704	220.708

Table 5-5. (Continued)
Ozone Stations

Station ID	Station Type	North Latitude (degrees)	West Longitude (degrees)	LCC[1] East (km)	LCC[1] North (km)
220950002	AIRS	30.06	90.61	-58.510	228.347
221010003	AIRS	29.72	91.21	-116.433	191.102
221210001	AIRS	30.50	91.21	-115.575	277.544
280010004	AIRS	31.56	91.39	-131.426	395.282
280110001	AIRS	33.75	90.72	-66.641	638.099
280450001	AIRS	30.23	89.57	41.178	247.114
280450002	AIRS	30.38	89.45	52.595	263.786
280470008	AIRS	30.39	89.05	90.836	265.130
280470009	AIRS	30.57	89.18	78.272	284.994
280490010	AIRS	32.39	90.14	-13.132	486.688
280590006	AIRS	30.38	88.53	140.569	264.515
280590007	AIRS	30.52	88.71	123.192	279.839
280750003	AIRS	32.36	88.73	119.155	483.969
280890002	AIRS	32.56	90.18	-16.856	505.578
281490004	AIRS	32.32	90.89	-83.536	479.210
450030003	AIRS	33.34	81.79	762.387	617.964
450110001	AIRS	33.32	81.47	792.211	617.785
450290002	AIRS	33.01	80.96	842.046	586.819
450370001	AIRS	33.74	81.85	753.850	662.001
450790021	AIRS	33.82	80.78	851.971	677.933
480290032	AIRS	29.51	98.62	-830.431	196.634
480290052	AIRS	29.63	98.57	-824.688	209.556
480290059	AIRS	29.28	98.31	-802.349	169.138
480391003	AIRS	29.01	95.40	-522.940	123.453
480391004	AIRS	29.52	95.39	-519.475	179.853
480391016	AIRS	29.04	95.47	-529.566	127.075
480850005	AIRS	33.13	96.79	-631.976	586.530
480850010	AIRS	33.36	96.55	-608.286	610.851
481130069	AIRS	32.82	96.86	-640.423	552.485
481130075	AIRS	32.92	96.81	-635.139	563.321
481130087	AIRS	32.68	96.87	-642.232	537.003
481133003	AIRS	32.78	96.53	-609.884	546.353
481210034	AIRS	33.19	97.19	-668.771	595.325
481390015	AIRS	32.44	97.03	-658.710	511.235
481670014	AIRS	29.26	94.86	-469.572	148.924
481671002	AIRS	29.40	94.93	-475.704	164.692
481830001	AIRS	32.38	94.71	-441.719	494.105
482010024	AIRS	29.90	95.33	-511.856	221.663
482010026	AIRS	29.80	95.13	-493.126	209.767

Table 5-5. (Continued)
Ozone Stations

Station ID	Station Type	North Latitude (degrees)	West Longitude (degrees)	LCC[1] East (km)	LCC[1] North (km)
482010029	AIRS	30.04	95.68	-544.721	238.679
482010046	AIRS	29.83	95.28	-507.393	213.704
482010047	AIRS	29.83	95.49	-527.560	214.596
482010051	AIRS	29.62	95.47	-526.683	191.264
482010055	AIRS	29.69	95.49	-528.258	199.099
482010062	AIRS	29.63	95.27	-507.390	191.523
482010070	AIRS	29.73	95.32	-511.718	202.801
482011015	AIRS	29.76	95.08	-488.508	205.138
482011035	AIRS	29.73	95.26	-505.950	202.551
482011039	AIRS	29.67	95.13	-493.732	195.376
482011041	AIRS	29.75	95.08	-488.554	204.031
482011050	AIRS	29.58	95.02	-483.562	184.972
482030002	AIRS	32.67	94.17	-389.995	524.460
482090614	AIRS	30.21	98.08	-773.349	270.467
482210001	AIRS	32.44	97.80	-730.766	515.624
482311006	AIRS	33.15	96.12	-569.560	585.448
482450009	AIRS	30.04	94.07	-390.388	232.503
482450011	AIRS	29.89	93.99	-383.261	215.635
482450022	AIRS	29.86	94.32	-415.065	213.393
482510003	AIRS	32.36	97.43	-696.686	504.589
482570005	AIRS	32.57	96.32	-591.498	522.015
483390078	AIRS	30.35	95.43	-519.231	271.910
483550025	AIRS	27.77	97.43	-727.684	-3.288
483550026	AIRS	27.83	97.56	-739.987	4.128
483611001	AIRS	30.08	93.76	-360.527	235.978
483670081	AIRS	32.87	97.91	-737.958	563.969
483970001	AIRS	32.94	96.46	-602.410	563.765
484230007	AIRS	32.34	95.42	-508.461	492.433
484390075	AIRS	32.90	97.46	-695.826	564.651
484391002	AIRS	32.81	97.36	-687.113	554.099
484392003	AIRS	32.92	97.28	-678.924	565.855
484393009	AIRS	32.98	97.06	-658.044	571.307
484393011	AIRS	32.66	97.09	-662.905	535.962
484530014	AIRS	30.35	97.76	-741.777	283.963
484530020	AIRS	30.48	97.87	-751.347	299.018
484530613	AIRS	30.42	97.60	-726.018	290.744
484690003	AIRS	28.84	97.01	-679.784	112.590
484790016	AIRS	27.51	99.52	-934.251	-17.767

Table 5-5. (Concluded)
Ozone Stations

Station ID	Station Type	North Latitude (degrees)	West Longitude (degrees)	LCC[1] East (km)	LCC[1] North (km)
SND152	CASTNET	34.29	85.97	370.970	704.043
CAD150	CASTNET	34.18	93.10	-285.568	689.362
EVE419	CASTNET	25.39	80.68	932.538	-253.383
IRL141	CASTNET	27.85	80.46	933.722	19.875
SUM156	CASTNET	30.11	84.99	480.156	243.644
GAS153	CASTNET	33.18	84.41	520.572	586.287
CVL151	CASTNET	34.00	89.80	18.567	666.043

[1]Lambert Conformal Coordinate origin is 28.0N, 90.0W, standard parallels are 23.0N, 33.0N, datum is NWS-84.

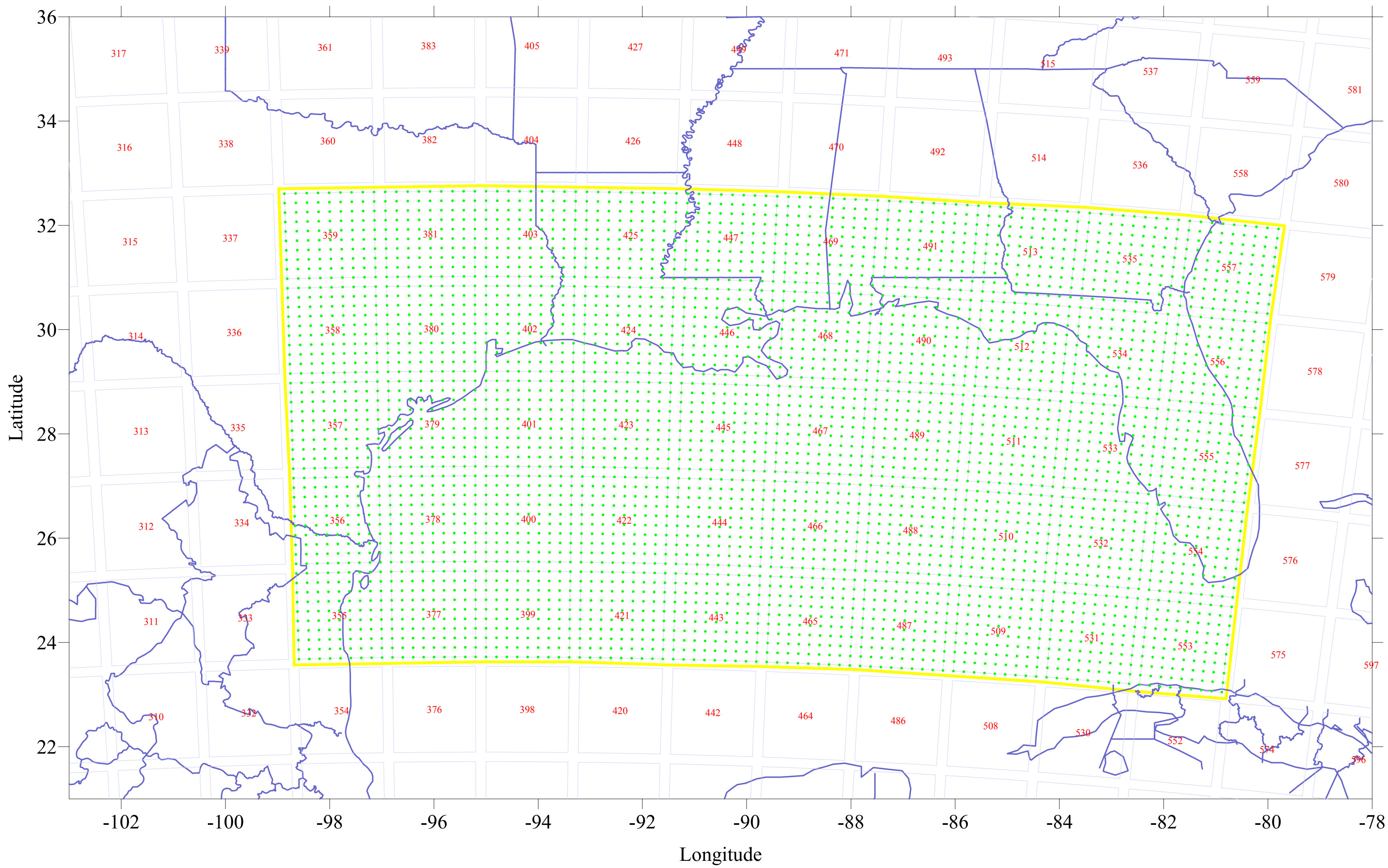

Figure 5-6. Locations of the RUC data tiles in the MMS standard data set.

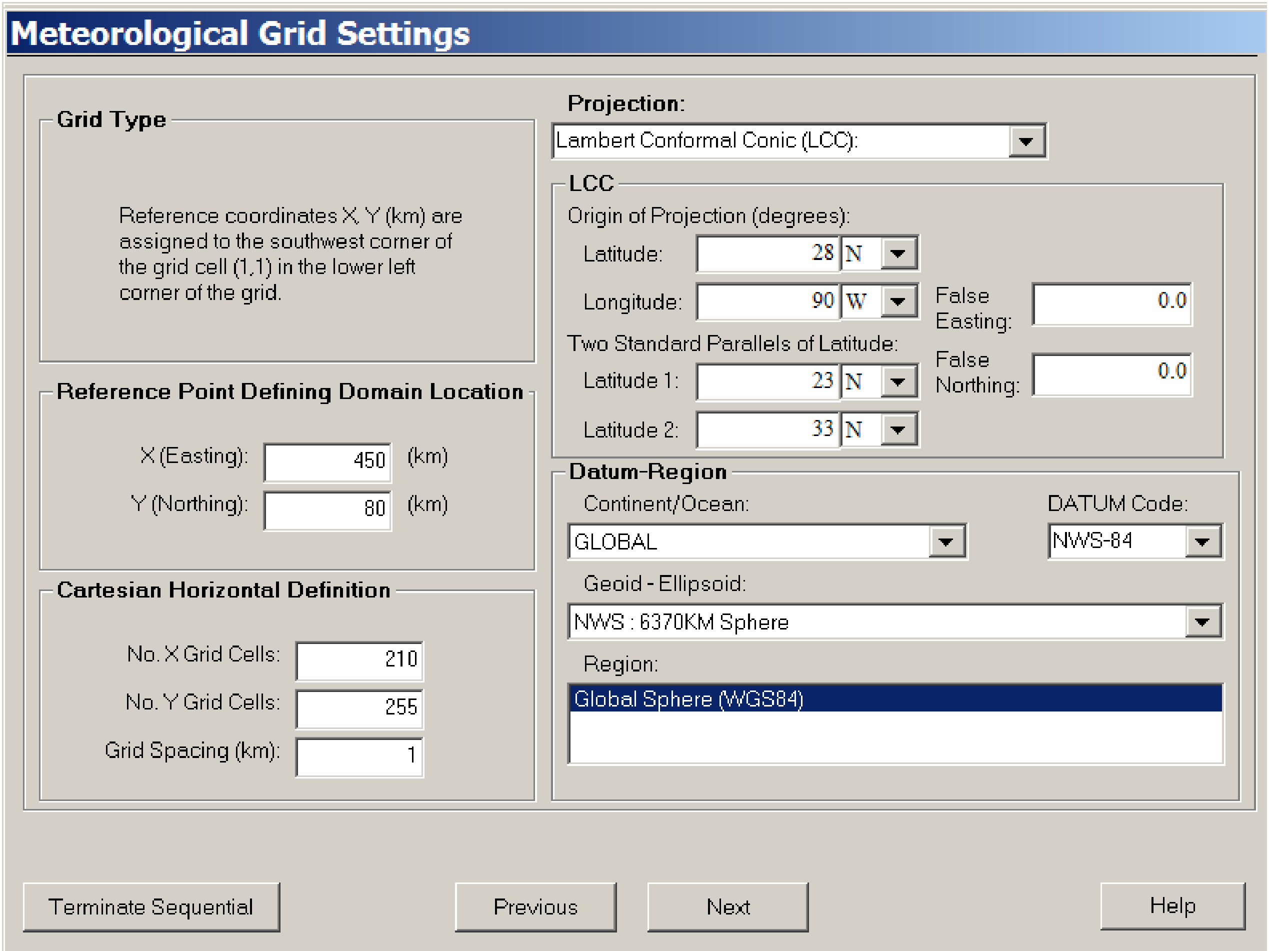

Figure 5-7. “Grid Settings” screen for SUBDOMN program in CALPUFF PROfessional GUI.

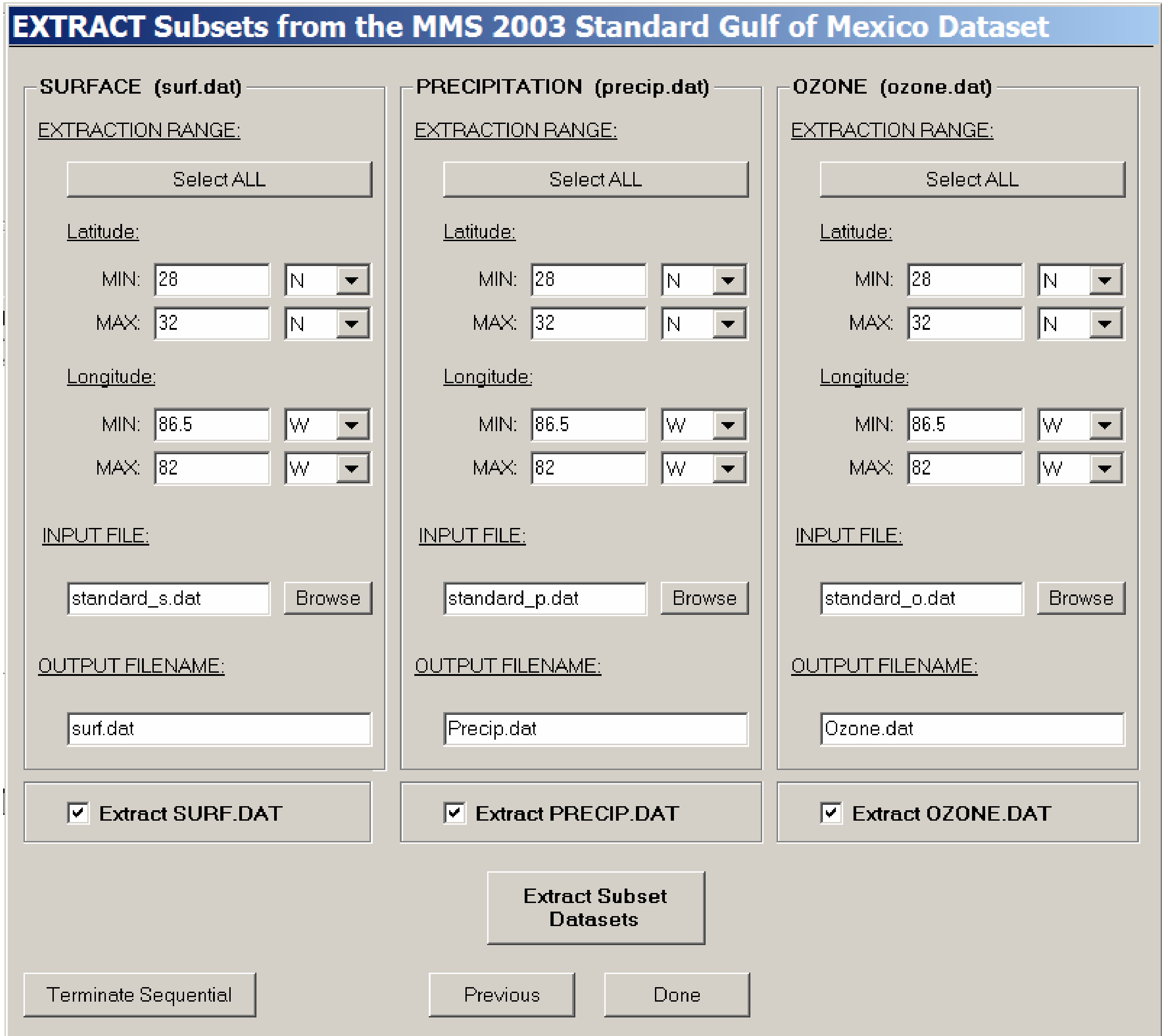

Figure 5-8. "Inputs/Outputs & Run" screen for SUBDOMN program in CALPUFF PROfessional GUI.

Table 5-6
Example RUCDECODE Control File

```
Extract 3D.DAT file from Tiled RUC data
rucdecode.lst            ! List file for RUCDECODE.exe
e:\                      ! CD/DVD drive name (Back slash is needed on PC)
ruc3d.dat                ! Output 3D.DAT file name
1                        ! Method of select domain (1: I/J 2: long/lat)
210, 222                 ! Beg/End I indices (range: 3-299) or longitudes
51, 65                   ! Beg/End J indices (range: 4-222) or latitudes
1,50                     ! Beg/End K indices (range: 1-50, Surface is 1)
2003070900               ! Beginning Date-Hour (UTC) to extract
2003071407               ! Ending Date-Hour (UTC) to extract
1                        ! Flag (1/0) for batch/interactive mode
-----------------------------------------------------
Note:

1. Select domain as (I,J) RUC grid range or
   longitude from west to east and latitude from south to north

2. Longitude is negative for western hemisphere
   Latitude is negative for southern hemisphere

3. Flag for batch/interactive mode:
   Set batch flag to 1 if ALL needed files are on one disk specified
   on Line 3, and no screen-input is needed.  Set the flag to 0 if needed
   files are on multiple DVD disks.

4. Scratch files will be created in processing, and should
   be deleted manually on some machines. The base part of
   scratch file names are the same as that of output file name
   except an aditional "s" at the end. The extension of the
   scratch files are numbered from 001 to XXX.  For example,
   if the output file name is test.dat, then the scratch file
   names will be tests.001, tests.002.... Delete these files after
   program finishes.
```

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APPENDIX: COMPILATION OF A HIGH RESOLUTION SEA SURFACE TEMPERATURE DATASET FROM SATELLITE MEASUREMENTS FOR THE GULF OF MEXICO