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A USER'S GUIDE FOR THE CALMET METEOROLOGICAL MODEL

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DISCLAIMER

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PREFACE

The Interagency Workgroup on Air Quality Modeling (IWAQM) was formed to provide a focus for development of technically sound, regional air quality models for regulatory assessments of pollutant source impacts on Federal Class I areas. Meetings were held with personnel from interested Federal agencies, viz. the Environmental Protection Agency, the U.S. Forest Service, the National Park Service, and the U.S. Fish and Wildlife Service. The purpose of these meetings was to review respective regional modeling programs, to develop an organizational framework, and to formulate reasonable objectives and plans that could be presented to management for support and commitment. The members prepared a memorandum of understanding (MOU) that incorporated the goals and objectives of the workgroup and obtained signatures of management officials in each participating agency. Although no States are signatories, their participation in IWAQM functions is explicitly noted in the MOU.

This report describes the CALMET meteorological model and associated meteorological data processing programs. The CALMET model described in this report includes improvements to the model such as 1) a modification to make it more suitable for regional applications such as the use of a spatially variable initial guess field, 2) an option for using hourly gridded wind fields from the Penn State/NCAR Mesoscale Model with four dimensional data assimilation (MM4-FDDA) as a supplement to observational data, 3) the ability to compute Lambert conformal map factors and, 4) a modified mixing height scheme.

This report is the fifth document published by the IWAQM in an effort to provide the sponsoring agencies and other interested parties information on appropriate "off-the-shelf" methods for estimating long range transport impacts of air pollutants on Federal Class I areas and impacts on regional visibility. The IWAQM members anticipate issuing additional publications related to progress toward meeting the IWAQM goals and objectives, the results of model evaluation studies, proposed and final recommendations on modeling systems for regulatory applications, and other topics related to specific objectives in the MOU.

The Environmental Protection Agency must conduct a formal and public review before the Agency can recommend for routine use new algorithms in regulatory analyses. These reports are being released to establish a basis for reviews of the capabilities of this methodology and of the consequences resulting from use of this methodology in routine dispersion modeling of air pollutant impacts. These reports are one part of the overall information that must be considered before any formal changes can be adopted.

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1. INTRODUCTION

1.1 Background

As part of a study to design and develop a generalized non-steady-state air quality modeling system for regulatory use, Sigma Research Corporation developed the CALPUFF dispersion model and related models and programs, including the CALMET meteorological model. The original development of CALPUFF and CALMET was sponsored by the California Air Resources Board (CARB). Systems Application, Inc. (SAI) served as a subcontractor to Sigma Research with the responsibility for developing the wind field modeling components of the modeling system.

The original design specifications for the modeling system included: (1) the capability to treat time-varying point and area sources, (2) suitability for modeling domains from tens of meters to hundreds of kilometers from a source, (3) predictions for averaging times ranging from one-hour to one year, (4) applicability to inert pollutants and those subject to linear removal and chemical conversion mechanisms, and, (5) applicability for rough or complex terrain situations.

The modeling system (Scire et al., 1990a, 1990b) designed to meet these objectives consisted of three components: (1) a meteorological modeling package with both diagnostic and prognostic wind field generators, (2) a Gaussian puff dispersion model with chemical removal, wet and dry deposition, complex terrain algorithms and other effects, and (3) postprocessing programs for the output fields of meteorological data, concentrations and deposition fluxes.

In July, 1987, CARB initiated a second project with Sigma Research to upgrade and modernize the Urban Airshed Model (UAM) to include state-of-the-science improvements in many of the key technical algorithms including the numerical advection and diffusion schemes, dry deposition, chemical mechanisms, and chemical integration solver. The new photochemical model, called CALGRID, was integrated into the CALMET/CALPUFF modeling framework to create a complete modeling system for both reactive and non-reactive pollutants. The CALPUFF and CALGRID models were designed to be compatible with the common meteorological model, CALMET, and share a postprocessor for the time-averaging and display of the modeling results.

The Interagency Workgroup on Air Quality Modeling (IWAQM) has reviewed various modeling approaches suitable for estimating pollutant concentrations at Class I areas, including the individual and cumulative impacts of proposed and existing sources on Air Quality Related

Values (AQRVs), Prevention of Significant Deterioration (PSD) increments, and National Ambient Air Quality Standards (NAAQS). IWAQM consists of representatives from the U.S. Environmental Protection Agency (EPA), U.S. Forest Service, National Park Service, and U.S. Fish and Wildlife Service. IWAQM released a Phase I report (EPA, 1993) which recommended using the MESOPUFF II dispersion model and MESOPAC II meteorological model for simulating regional air quality and visibility impacts. These recommendations were considered interim until more refined (Phase II) techniques could be identified and evaluated. As part of the Phase II work, IWAQM has reviewed and intercompared diagnostic wind field models, tested the use of coarse gridded winds fields from the Penn State/NCAR Mesoscale Model with four dimensional data assimilation (MM4-FDDA) as input into the diagnostic models, and evaluated the MESOPUFF II and CALPUFF modeling systems using tracer data collected during Cross-Appalachian Tracer Experiment (CAPTEX). The CAPTEX evaluation results (EPA, 1994) indicated that by using the CALMET/CALPUFF models with MM4-FDDA data, performance could be improved over that obtained with the interim Phase I modeling approach.

The CALMET and CALPUFF models have been enhanced as part of work for IWAQM, EPA, the U.S. Forest Service, and the Environmental Protection Authority of Victoria (Australia). The improvements to CALMET included modifications to make it more suitable for regional applications such as the use of a spatially variable initial guess field, an option for using hourly MM4-FDDA gridded fields as a supplement to observational data, the ability to compute Lambert conformal map factors and a modified mixing height scheme. Improvements to CALPUFF include new modules to treat buoyant rise and dispersion from area sources (such as forest fires), buoyant line sources, volume sources, an improved treatment of complex terrain, additional model switches to facilitate its use in regulatory applications, and an optional Windows-based user interface. CALPUFF has been coupled to the Emissions Production Model (EPM) developed by the Forest Service through an interface processor. EPA provides time-dependent emissions and heat release data for use in modeling controlled burns and wildfires.

1.2 Overview of the Modeling System

The overall modeling system configuration is presented in Figure 1-1. The meteorological modeling with the CALMET model is detailed in Figure 1-2. Note that the preprocessors for the raw meteorological data are written to accommodate the U.S. National Climatic Data Center (NCDC) file formats. Figure 1-3 is the schematic of the CALPUFF dispersion model indicating the model input and output files. The postprocessing approach for the meteorological and dispersion modeling results is shown in Figure 1-4. The major components of the modeling system and interfaces to external programs are summarized below.

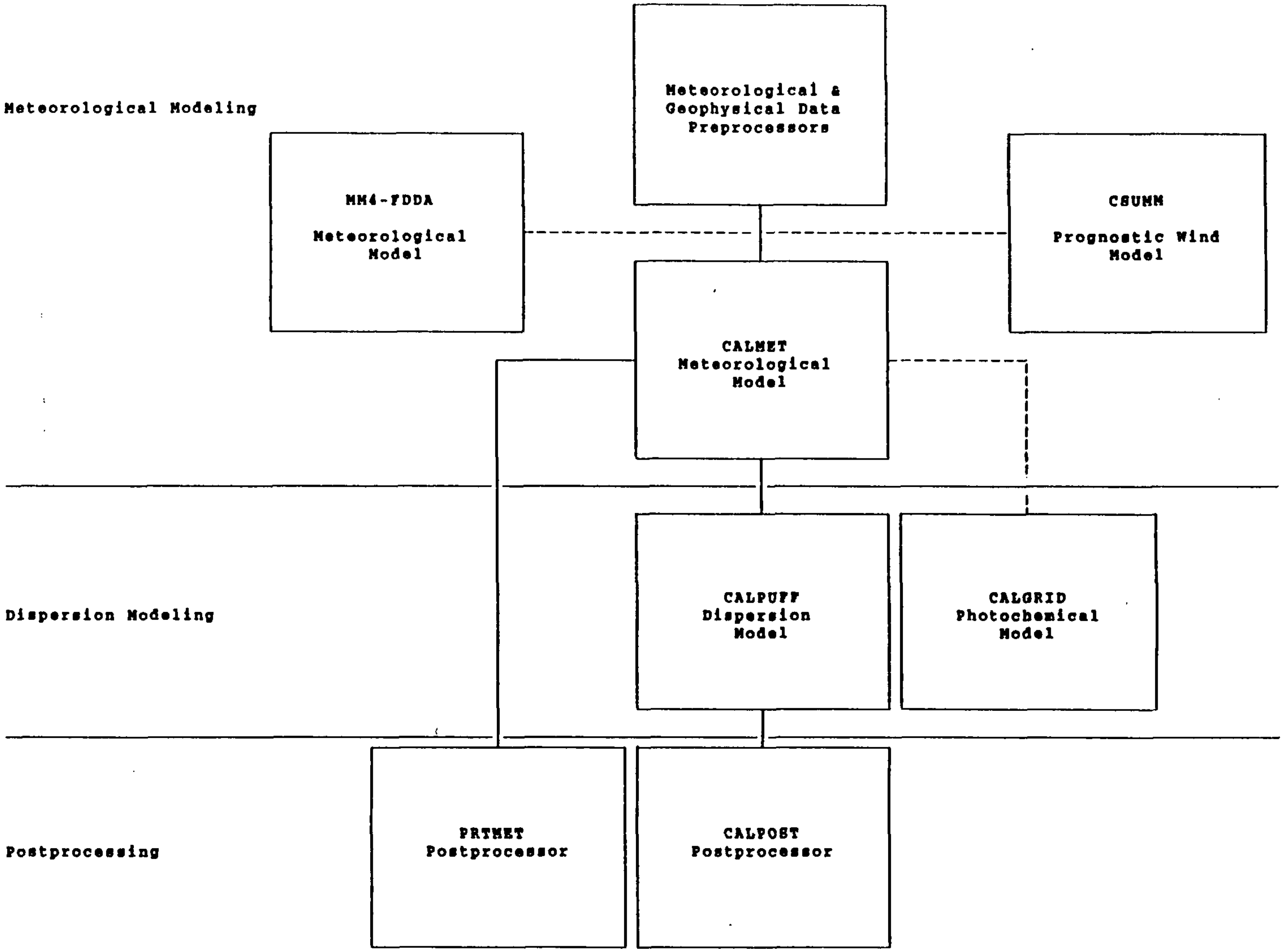

Figure 1-1. Overview of the program elements in the CALMET/CALPUFF modeling system. Also shown is the associated CALGRID photochemical model, and the MM4-FDDA and CSUMM meteorological models.

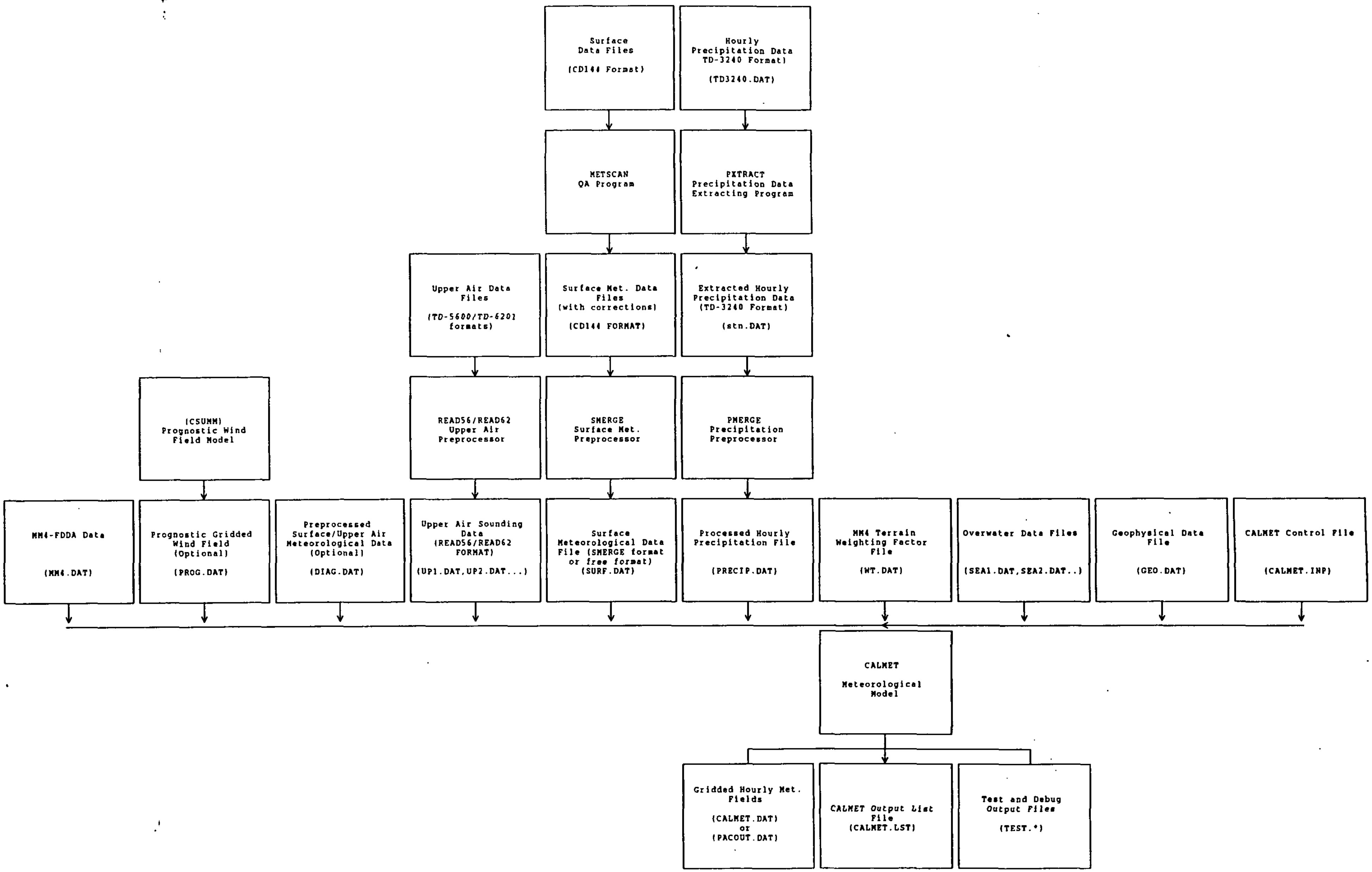

Figure 1-2. Meteorological modeling: CALMET modeling flow diagram.

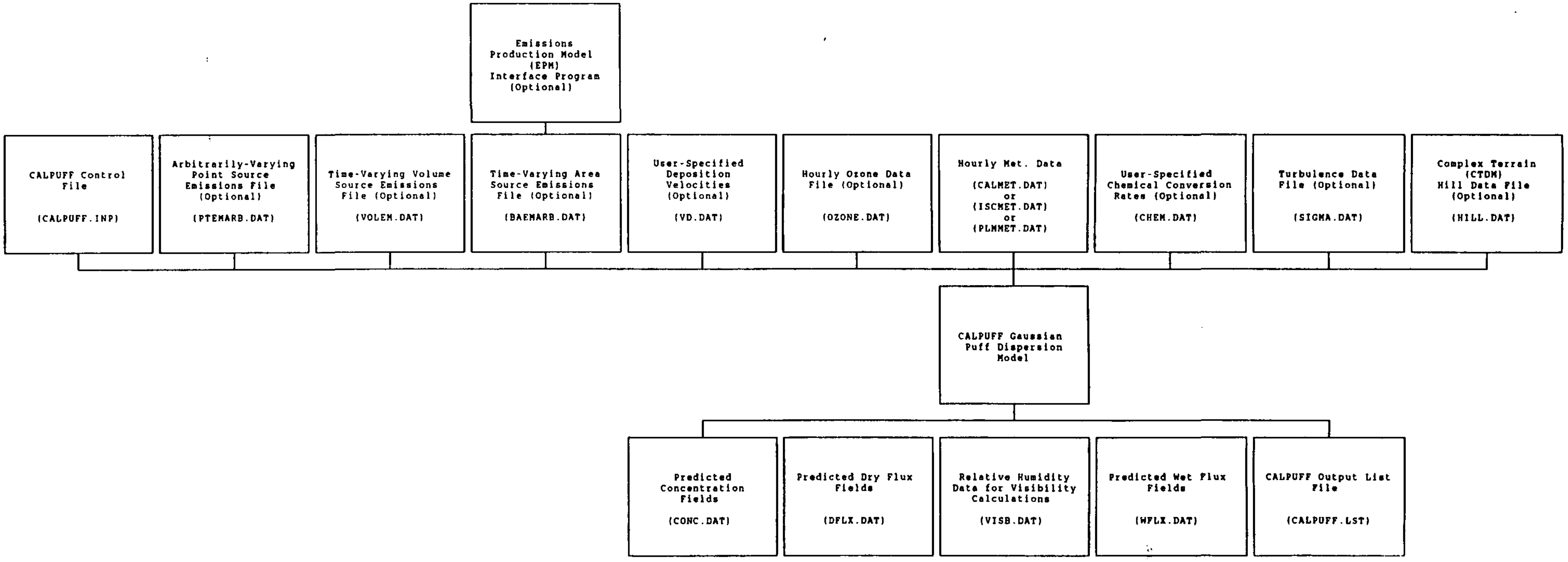

Figure 1-3. Dispersion Modeling: CALPUFF modeling flow diagram.

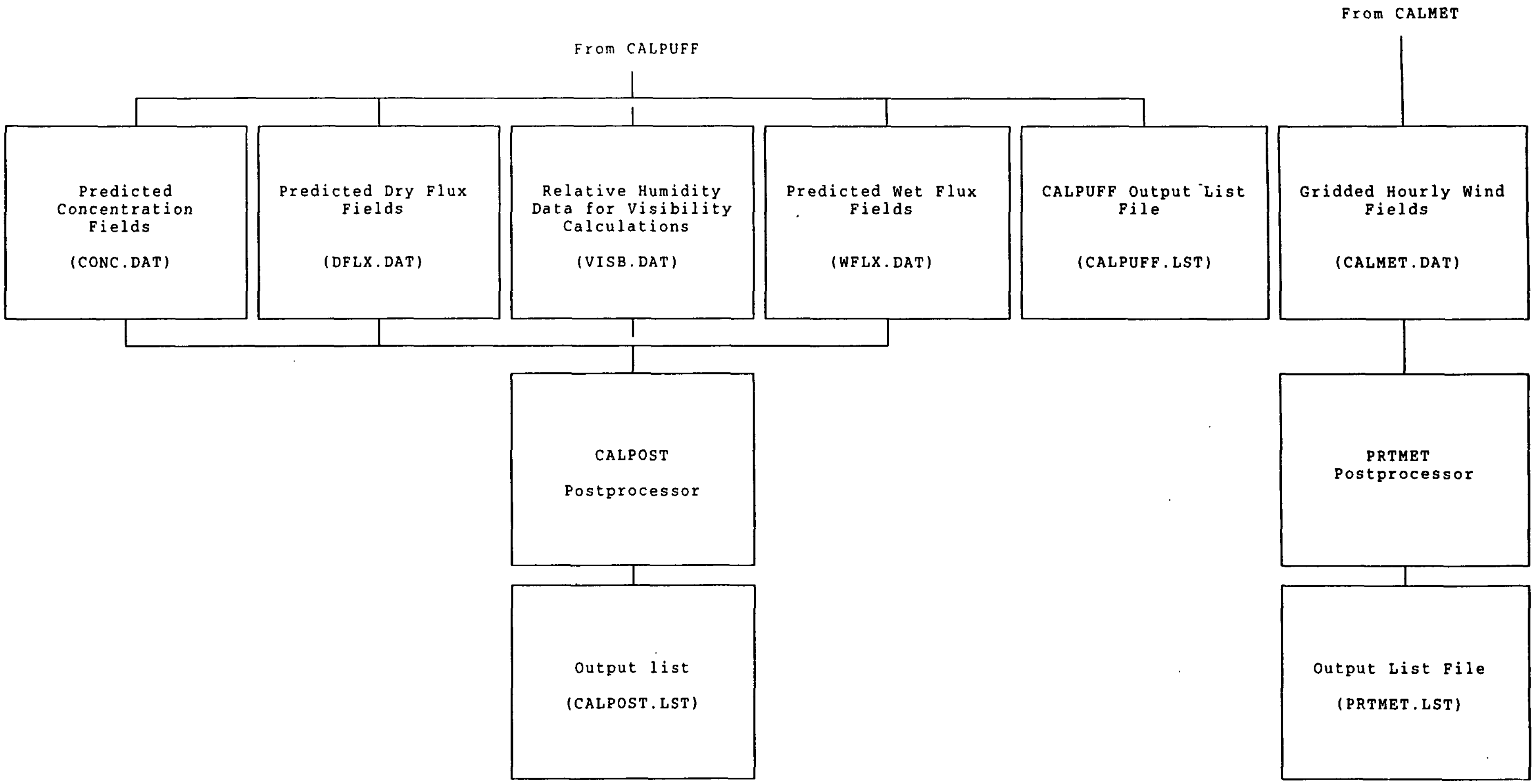

Figure 1-4. Postprocessing: CALPOST/PRTMET postprocessing flow diagram.

METSCAN is a meteorological preprocessor which performs quality assurance checks on the hourly surface meteorological data in the NCDC CD-144 format which is used as input to the SMERGE program.

READ56 and **READ62** are meteorological preprocessors which extract and process upper air wind and temperature data from standard data formats used by NCDC. READ56 and READ62 process TD-5600 and TD-6201 formatted data, respectively.

SMERGE is a meteorological preprocessor which processes hourly surface observations from a number of stations in NCDC CD-144 format and reformats the data into a single file with the data sorted by time rather than station.

PXTRACT is a meteorological preprocessor which extracts precipitation data for stations and a time period of interest from a fixed length, formatted precipitation data file in NCDC TD-3240 format.

PMERGE is a meteorological preprocessor responsible for reformatting the precipitation data files created by the PXTRACT program. PMERGE resolves "accumulation periods" into hourly values and flags suspicious or missing data. The output file can be formatted or binary, which can be directly input into the CALMET model, containing the precipitation data sorted by hour rather than station.

CSUMM (a version of the Colorado State University Mesoscale Model) is a primitive equation wind field model which simulates mesoscale airflow resulting from differential surface heating and terrain effects. The diagnostic wind field model within CALMET contains options which allow wind fields produced by CSUMM to be combined with observational data as part of the CALMET objective analysis procedure.

MM4-FDDA (Penn State/NCAR Mesoscale Model) is a prognostic wind field model with four dimensional data assimilation. CALMET has been modified to incorporate MM4-FDDA winds into its Diagnostic Wind Model (DWM).

CALMET is a meteorological model which includes a diagnostic wind field generator containing objective analysis and parameterized treatments of slope flows, kinematic terrain effects, terrain blocking effects, and a divergence minimization procedure, and a micrometeorological model for overland and overwater boundary layers.

CALPUFF is a non-steady-state Gaussian puff model containing modules for complex terrain effects, overwater transport, coastal interactive effects, building downwash, wet and dry removal, and simple chemical transformation.

CALGRID is an Eulerian photochemical transport and dispersion model which includes modules for horizontal and vertical advection/diffusion, dry deposition, and a detailed photochemical mechanism.

PRTMET is a postprocessing program which displays user-selected portions of the meteorological data base produced by the CALMET meteorological model.

CALPOST is a postprocessing program with options for the computation of time-averaged concentrations and deposition fluxes predicted by the CALPUFF and CALGRID models. CALPOST will also compute visibility impacts in accordance with IWAQM recommendations.

This report describes the CALMET model and the CALMET associated meteorological data processing programs READ56, READ62, METSCAN, SMERGE, PXTRACT, PMERGE, and PRTMET. Section 2 contains a description of the technical formulation of CALMET. The structure of the CALMET code is discussed in Section 3. The inputs and outputs of the CALMET model and the preprocessing and postprocessing programs are described in Section 4. Appendix A contains a tree diagram showing the sequence of subroutines and function calls in CALMET. A brief description of each CALMET routine is provided in Appendix B. Input and output files for a test case example are presented in Appendix C.

A series of companion reports describe other components of the modeling system. The prognostic wind field model, CSUMM, is described in a report by Kessler (1989). A stand-alone version of the Diagnostic Wind Model (DWM) used as the wind field module in CALMET is discussed by Douglas and Kessler (1988). The technical formulation and user instructions for the revised CALPUFF model and CALPOST postprocessor are contained in Scire et al.(1994). Finally, the CALGRID model is documented in a paper by Yamartino et al. (1992) and reports by Yamartino et al. (1989) and Scire et al. (1989).

1.3 Major Model Features and Options

The CALMET meteorological model consists of a diagnostic wind field module and micrometeorological modules for overwater and overland boundary layers. When using large domains, the user has the option to adjust input winds to a Lambert Conformal Projection coordinate system to account for Earth's curvature. The diagnostic wind field module uses a two step approach to the computation of the wind fields (Douglas and Kessler, 1988), as illustrated in Figure 1-5. In the first step, an initial-guess wind field is adjusted for kinematic effects of terrain, slope flows, and terrain blocking effects to produce a Step 1 wind field. The second step consists of an objective analysis procedure to introduce observational data into the Step 1 wind field to produce a final wind field. An option is provided to allow gridded prognostic wind fields to be used by CALMET, which may better represent regional flows and certain aspects of sea breeze circulations and slope/valley circulations. Wind fields generated by the CSUMM prognostic wind field module can be input to CALMET as either the initial guess field or the Step 1 wind field. The MM4-FDDA prognostic data can be introduced into CALMET in three different ways:

- as a replacement for the initial guess wind field (pathway Ⓐ in Figure 1-5).
- as a replacement for the Step 1 field (pathway Ⓑ); or
- as "observations" in the objective analysis procedure (pathway Ⓒ).

The major features and options of the meteorological model are summarized in Table 1-1. The techniques used in the CALMET model are briefly described below.

Step 1 Wind Field

Kinematic Effects of Terrain: The approach of Liu and Yocke (1980) is used to evaluate kinematic terrain effects. The domain-scale winds are used to compute a terrain-forced vertical velocity, subject to an exponential, stability-dependent decay function. The kinematic effects of terrain on the horizontal wind components are evaluated by applying a divergence-minimization scheme to the initial guess wind field. The divergence minimization scheme is applied iteratively until the three-dimensional divergence is less than a threshold value.

Slope Flows: An empirical scheme based on Allwine and Whiteman (1985) is used to estimate the magnitude of slope flows in complex terrain. The slope flow is parameterized in terms of the terrain slope, terrain height, domain-scale lapse rate, and time of day. The slope flow wind components are added to the wind field adjusted for kinematic effects.

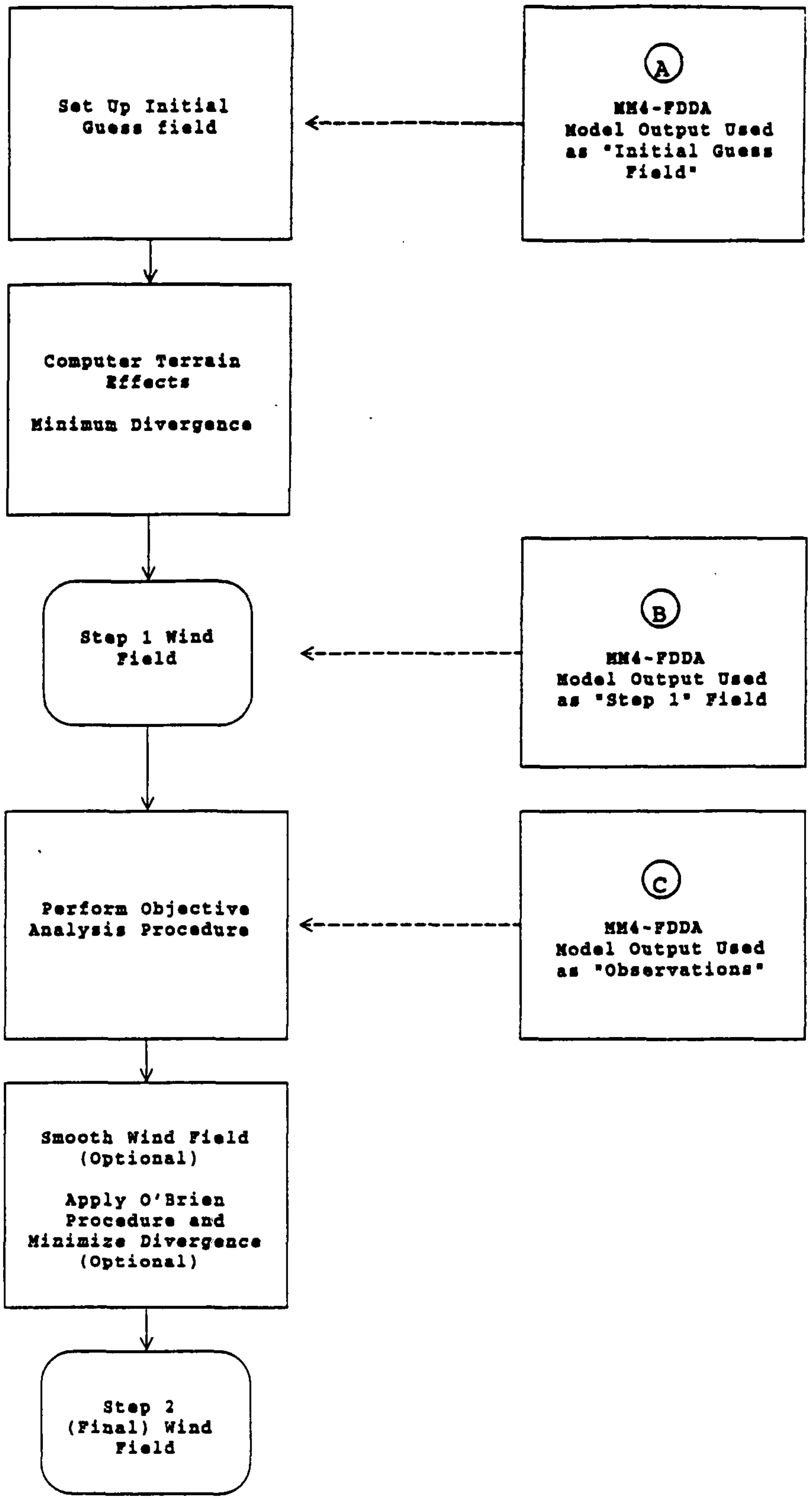

Figure 1-5. Flow diagram of the diagnostic wind model in CALMET. Winds derived from MM4-FDDA (or CSUMM) can be introduced as the initial guess field Ⓐ, or the Step 1 field Ⓑ. MM4-FDDA wind data can also be treated as "observations" Ⓒ.

Table 1-1
Major Features of the CALMET and CSUMM Meteorological Models

- **Boundary Layer Modules of CALMET**
    - Overland Boundary Layer - Energy Balance Method
    - Overwater Boundary Layer - Profile Method
    - Produces Gridded Fields of:
        - Surface Friction Velocity
        - Convective Velocity Scale
        - Monin-Obukhov Length
        - Mixing Height
        - PGT Stability Class
        - Air Temperature (3-D)
        - Precipitation Rate

- **Diagnostic Wind Field Module of CALMET**
    - Slope Flows
    - Kinematic Terrain Effects
    - Terrain Blocking Effects
    - Divergence Minimization
    - Produces Gridded Fields of U, V, W Wind Components
    - Inputs Include Domain-Scale Winds, Observations, and (optionally) Coarse-Grid Prognostic Model Winds
    - Lambert Conformal Projection Capability

- **Prognostic Wind Field Model (CSUMM)**
    - Hydrostatic Primitive Equation (PE) Model
    - Flows Generated in Response to Differential Surface Heating and Complex Terrain
    - Land-Sea Breeze Circulations
    - Slope-Valley Winds
    - Produces Gridded Fields of U, V, W Wind Components, and other Meteorological Variables

Blocking Effects: The thermodynamic blocking effects of terrain on the wind flow are parameterized in terms of the local Froude number (Allwine and Whiteman, 1985). If the Froude number at a particular grid point is less than a critical value and the wind has an uphill component, the wind direction is adjusted to be tangent to the terrain.

Step 2 Wind Field

The wind field resulting from the adjustments described above of the initial-guess wind is the Step 1 wind field. The second step of the procedure involves the introduction of observational data into the Step 1 wind field through an objective analysis procedure. An inverse-distance squared interpolation scheme is used which weighs observational data heavily in the vicinity of the observational station, while the Step 1 wind field dominates the interpolated wind field in regions with no observational data. The resulting wind field is subject to smoothing, an optional adjustment of vertical velocities based on the O'Brien (1970) method, and divergence minimization to produce a final Step 2 wind field.

Introduction of Prognostic Wind Field Results

The CALMET model contains an option to allow the introduction of gridded wind fields generated by the MM4-FDDA model (or the CSUMM model) as input fields. The procedure permits the prognostic model to be run with a significantly larger horizontal grid spacing and different vertical grid resolution than that used in the diagnostic model. This option allows certain features of the flow field such as the sea breeze circulation with return flow aloft, which may not be captured in the surface observational data, to be introduced into the diagnostic wind field results. An evaluation with CAPTEX tracer data indicated that the better spatial and temporal resolution offered by the hourly MM4-FDDA fields can improve the performance of the dispersion modeling on regional scales (EPA, 1995).

If the MM4-FDDA wind data are used as the initial guess field, the coarse grid scale MM4-FDDA data are interpolated to the CALMET fine-scale grid. The diagnostic module in CALMET will then adjust the initial guess field for kinematic effects of terrain, slope flows and terrain blocking effects using fine-scale CALMET terrain data to produce a Step 1 wind field. A second approach is to use MM4-FDDA wind data directly as the Step 1 wind field. This field is then adjusted using observational data, but additional terrain adjustments are not made. A third available option in CALMET is to treat the gridded MM4-FDDA data as "observations" in the objective analysis procedure.

CALMET Boundary Layer Models

The CALMET model contains two boundary layer models for application to overland and overwater grid cells.

Overland Boundary Layer Model: Over land surfaces, the energy balance method of Holtslag and van Ulden (1983) is used to compute hourly gridded fields of the sensible heat flux, surface friction velocity, Monin-Obukhov length, and convective velocity scale. Mixing heights are determined from the computed hourly surface heat fluxes and observed temperature soundings using a modified Carson (1973) method based on Maul (1980). Gridded fields of PGT stability class and optional hourly precipitation rates are also determined by the model.

Overwater Boundary Layer Model: The aerodynamic and thermal properties of water surfaces suggest that a different method is best suited for calculating the boundary layer parameters in the marine environment. A profile technique, using air-sea temperature differences, is used in CALMET to compute the micrometeorological parameters in the marine boundary layer.

An upwind-looking spatial averaging scheme is optionally applied to the mixing heights and 3-dimensional temperature fields in order to account for important advective effects.

1.4 Summary of Data and Computer Requirements

Data Requirements

The input data requirements of the CALMET model are summarized in Table 1-2. The modeling system flow diagrams (Figures 1-1 through 1-4) provides an overview of the various input data sets required by the model as well as the preprocessing steps used to produce them. CALMET is designed to require only routinely-available surface and upper air meteorological observations, although special data inputs can be accommodated. For example, twice-daily sounding data (e.g., at the standard sounding times of 00 and 12 GMT) are needed as a minimum, but if soundings at more frequent (even arbitrarily spaced) intervals are available, they will be used by the model.

CALMET reads hourly surface observations of wind speed, wind direction, temperature, cloud cover, ceiling height, surface pressure, relative humidity, and precipitation type codes (optional, used only if wet removal is to be modeled). These parameters are available from

Table 1-2
Summary of Input Data Required by CALMET

Surface Meteorological Data

Hourly observations of:
- wind speed
- wind direction
- temperature
- cloud cover
- ceiling height
- surface pressure
- relative humidity

Hourly precipitation data:
- precipitation rates
- precipitation type code (part of surface data file)

Upper Air Data

Twice-daily observed vertical profiles of:
- wind speed
- wind direction
- temperature
- pressure
- elevation

Hourly gridded wind fields (optional)
- MM4-FDDA output
- CSUMM output

Overwater Observations (optional)

- air-sea temperature difference
- air temperature
- relative humidity
- overwater mixing height
- wind speed
- wind direction
- overwater temperature gradients above and below mixing height

Geophysical Data

Gridded fields of:
- terrain elevations
- land use categories
- surface roughness length (optional)
- albedo (optional)
- Bowen ratio (optional)
- soil heat flux constant (optional)
- anthropogenic heat flux (optional)
- vegetative leaf area index (optional)

National Weather Service surface stations. The preprocessors are designed to use data in the National Climatic Data Center's (NCDC) standard data formats (e.g., CD-144 format for the surface data). However, the data can also be input into the model by way of free-formatted, user-prepared files. This option is provided to eliminate the need for running the preprocessors to prepare the data files for short CALMET runs for which the input data can easily be input manually.

Missing values of temperature, cloud cover, ceiling height, surface pressure, and relative humidity at surface stations are allowed by the program. The missing values are internally replaced by values at the closest station with non-missing data. However, one valid value of each parameter must be available from at least one station for each hour of the run. Missing values of the precipitation code are passed through to the output file, since CALPUFF contains logic to handle missing values and CALGRID does not use this parameter.

The upper air data required by CALMET include vertical profiles of wind speed, wind direction, temperature, pressure, and elevation. As noted above, routinely-available NWS upper air data (e.g., in TD-5600 and TD-6201 format) or non-standard sounding data can be used. The use of non-standard data formats would require a user-prepared reformatting program to convert the data into the appropriate CALMET format.

If the upper air wind speed, wind direction, or temperature is missing, CALMET will interpolate to replace the missing data. Actually, the interpolation of wind data is performed with the u and v components, so both the wind speed and direction must be present for either to be used. Because the program does not extrapolate upper air data, the top valid level must be at or above the model domain and the lowest (surface) level of the sounding must be valid.

For modeling applications involving overwater transport and dispersion, the CALMET boundary layer model requires observations of the air-sea temperature difference, air temperature, relative humidity and overwater mixing height (optional) at one or more observational sites. The model can accommodate overwater data with arbitrary time resolution (e.g., hourly, daily, or seasonal values). The location of the overwater stations is allowed to vary in order to allow the use of observations made from ships. CALMET optionally can use only land stations to calculate temperatures over land and only overwater stations to calculate temperatures over water. If this option is used, vertical temperature lapse rate information may be included at the overwater observational sites.

If the wet removal algorithm of the CALPUFF model is to be applied, CALMET can be made to produce gridded fields of precipitation rates from hourly precipitation observations.

The routinely-available NCDC precipitation data in TD-3240 format or a free-formatted, user-prepared file of precipitation rates can be used as input to CALMET.

CALMET also requires geophysical data including gridded fields of terrain elevations and land use categories. Gridded fields of other geophysical parameters, if available, may be input to the model. The optional inputs include surface roughness length, albedo, Bowen ratio, a soil heat flux parameter, anthropogenic heat flux, and vegetation leaf area index. These parameters can be input as gridded fields or specified as a function of land use. Default values relating the optional geophysical parameters to land use categories are provided within CALMET.

As described in the previous section, CALMET contains an option to read as input gridded wind fields produced by the prognostic wind field models, MM4-FDDA or CSUMM. The CSUMM prognostic wind field model generates a file called PROG.DAT which can be directly input into CALMET, or if using the MM4-FDDA derived wind data, a file called MM4.DAT is required.

One of the options in CALMET is to by-pass the boundary layer model and compute only gridded wind fields (i.e., produce U, V wind components only without the micrometeorological variables such as friction velocity, Monin-Obukhov length, etc.). Although the CALPUFF and CALGRID models cannot be executed with such a file, there may be some applications in which only the wind components are of interest. For example, a postprocessor (CAL2UAM) can be used to convert the CALMET winds into a format suitable for input into the UAM model. If CALMET is to be run in this mode, an option is provided to allow preprocessed surface and upper air observations to be input. The preprocessed input file, DIAG.DAT, is compatible with the stand-alone version of the diagnostic wind field model developed by Douglas and Kessler (1988).

CALMET reads the user's inputs from a "control file" called CALMET.INP. This file contains the user's selections of the various model options, input variables, output options, etc. The CALMET control file and other input files are described in detail in Section 4.2.

Computer Requirements

The memory management scheme used in CALMET is designed to allow the maximum array dimensions in the model to be easily adjusted to match the requirements of a particular application. An external parameter file contains the maximum array size for all of the major arrays. A re-sizing of the program can be accomplished by modifying the appropriate variables in the parameter file.

Therefore, the memory required by CALMET will be determined by the particular application. However, as an example, CALMET required approximately 4.3 M bytes of memory for a test run with a 50 x 50 horizontal grid with 12 vertical layers. A 12-hour test run, which included the optional computation of three-dimensional temperature and vertical velocity fields and printing of model results every 6 hours, required about 366 seconds of CPU time on a 66-MHz 486 PC. This run used a 43 x 33 horizontal grid with 8 vertical layers. This run time translates to approximately .003 CPU seconds per cell per hour.

2. TECHNICAL DESCRIPTION

2.1 Grid System

The CALMET model uses a grid system consisting of NZ layers of NX by NY square horizontal grid cells. Figure 2-1 illustrates one layer of grid cells for a 7 x 4 grid. The "grid point" refers to the center of the grid cell in both the horizontal and vertical dimensions. The "cell face" refers to either the horizontal or vertical boundary between two adjacent cells. In CALMET, the horizontal wind components (u and v) are defined at each grid point. The vertical wind component (w) is defined at the vertical cell faces.

The position of the meteorological grid in real space is determined by the reference coordinates (XORIGKM, YORIGKM) of the southwest corner of grid cell (1,1). Thus, grid point (1,1) is located at (XORIGKM + DGRIDKM/2., YORIGKM + DGRIDKM/2.), where DGRIDKM is the length of one side of the grid square.

It is assumed that the orientation of the X and Y axes of the CALMET grid are west-east and south-north, respectively. In this way, the grid system is compatible with the usual definition of the u and v horizontal wind components as the easterly and northerly components of the wind, respectively. One commonly-used grid system compatible with CALMET is the Universal Transverse Mercator (UTM) Grid (see Appendix D for a description).

If the chosen CALMET domain is large, the user, through input variable LLCONF, can exercise the option to fit the observed winds to a Lambert Conformal grid to account for the Earth's curvature. CALMET uses the user-specified standard latitudes and reference longitude to calculate a "cone constant" and the east-west distance of the observations from the reference longitude. These quantities are then used to adjust observed and prognostic winds to fit the Lambert Conformal mapping. If LLCONF = T, the user also must define XORIGKM, YORIGKM and all x,y coordinates of observation stations, coastlines and barriers to fit the chosen Lambert Conformal grid. The default values of the standard latitudes and reference longitude are set to be consistent with the U.S. EPA's MM4-FDDA data base. If a different set of parameters are required, the user can set them in Input Group 2. The equations for the cone constant and the coordinate conversion are given in Appendix C.

The CALMET model operates in a terrain-following vertical coordinate system.

$$Z = z - h_t \qquad (2\text{-}1)$$

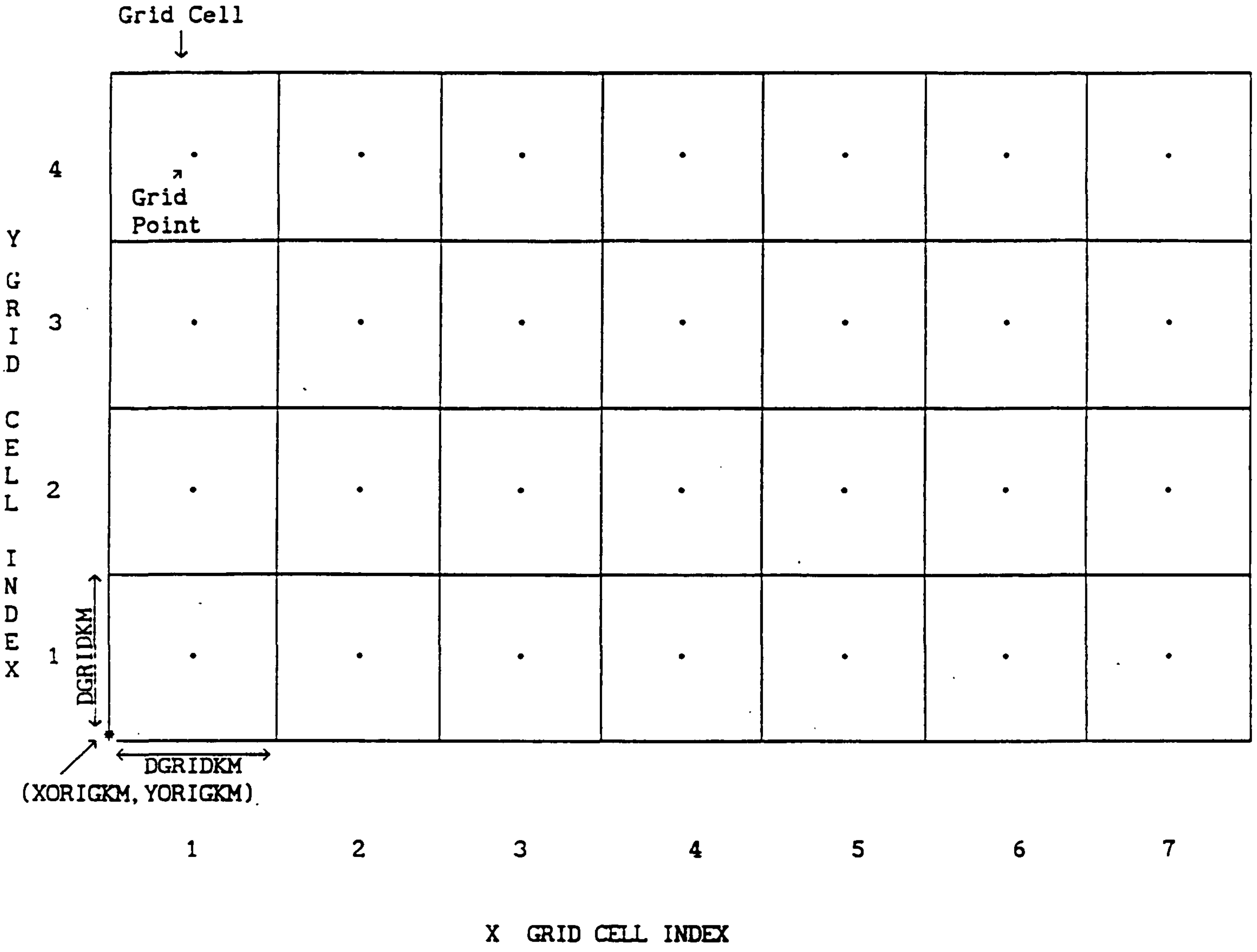

Figure 2-1. Schematic illustration of the CALMET horizontal grid system for a 7 x 4 grid showing the grid origin (XORIGKM, YORIGKM) and grid point location (·).

where Z is the terrain-following vertical coordinate (m),
z is the Cartesian vertical coordinate (m), and
h_t is the terrain height (m).

The vertical velocity, W, in the terrain-following coordinate system is defined as:

$$W = w - u\frac{\partial h_t}{\partial x} - v\frac{\partial h_t}{\partial y} \tag{2-2}$$

where w is the physical vertical wind component (m/s) in Cartesian coordinates, and
u,v are the horizontal wind components (m/s).

2.2 Wind Field Module

2.2.1 Step 1 Formulation

The CALMET diagnostic wind field model uses a two-step approach to the computation of the wind fields. In Step 1, an initial guess (domain mean) wind field is adjusted for:

- kinematic effects of terrain
- slope flows
- blocking effects
- three dimensional divergence minimization

The initial guess domain mean wind can vary spatially or be constant throughout the grid. The domain mean wind components can be computed internally by vertically averaging and time-interpolating upper air sounding data or simply specified by the user. If the domain mean winds are computed, the user specifies the vertical layer through which the winds are to be averaged and either which upper air station is to be used for determining the domain mean wind or that all stations should be included in a $1/r^2$ interpolation to produce a spatially varying guess field.

CALMET provides two options for by-passing the Step 1 procedure. The first is to specify that the final winds be based on objective analysis alone. This option is controlled by the control file variable, IWFCOD, in Input Group 5 (see Section 4.2.1).

The second option is the input of an externally generated, gridded Step 1 wind field. Typically, this would be the output of another model, such as a prognostic wind field model. The control file variable, IPROG, of Input Group 5 controls this option.

The externally-generated Step 1 wind field need not use the same horizontal grid as that used in the CALMET simulation. For example, the computationally intensive prognostic wind field model can be executed on a relatively coarse grid to develop the vertical structure of a lake breeze circulation and provide information for areas of the grid with no observational data. The prognostic model results are then combined with the available wind observations in the Step 2 objective analysis procedure to develop the final wind field.

The parameterization used in the internal computation of a Step 1 wind field, i.e., simulation of kinematic effects of terrain, slope flows, blocking effects, and divergence minimization, are described in the following sections. This discussion is largely derived from Douglas and Kessler (1988).

Kinematic Effects

CALMET parameterizes the kinematic effects of terrain using the approach of Liu and Yocke (1980). The Cartesian vertical velocity, w, is computed as:

$$w = \left(V \cdot \nabla h_t\right) \exp(-kz) \tag{2-3}$$

where V is the domain-mean wind,
h_t is the terrain height,
k is a stability-dependent coefficient of exponential decay, and,
z is the vertical coordinate.

The exponential decay coefficient increases with increasing atmospheric stability.

$$k = \frac{N}{|V|} \tag{2-4}$$

$$N = \left[\left(\frac{g}{\theta}\right) \frac{d\theta}{dz} \right]^{1/2} \tag{2-5}$$

where N	is the Brunt-Väisälä frequency (1/s) in a layer from the ground through a user-input height of "ZUPT" m,
θ	is the potential temperature (deg K),
g	is the acceleration due to gravity (m/s^2), and,
$\lvert V \rvert$	is the speed of the domain-mean wind.

The initial-guess domain-mean wind is then used to compute the terrain-forced Cartesian vertical velocity, w, into a terrain-following vertical velocity, W (Eqn. 2-2). The kinematic effects of terrain on the horizontal wind components are then evaluated by applying a divergence-minimization scheme to the initial guess wind field. The divergence minimization scheme iteratively adjusts the horizontal wind components until the three-dimensional divergence is less than a user-specified maximum value.

Slope Flows

CALMET uses an empirical scheme to estimate the magnitude of slope flows in complex terrain. The direction of the slope flow is assumed to be oriented in the drainage direction. The slope flow vector is added into the Step 1 gridded wind field in order to produce an adjusted Step 1 wind field.

$$u_1' = u_1 + u_s \tag{2-6}$$

$$v_1' = v_1 + v_s \tag{2-7}$$

where (u_1,v_1)	are the components of the Step 1 wind field (m/s) before considering slope flow effects,
(u_s,v_s)	are the slope flow wind components (m/s), and,
(u_1',v_1')	are the components of the Step 1 wind field (m/s) after considering slope flow effects.

The direction of the slope flow is determined by the following empirical procedures suggested by Allwine and Whiteman (1985). First, an angle, β' is computed based on the slope of the terrain.

$$\beta' = \tan^{-1}\left[\left(\partial h_t / \partial y\right) / \left(\partial h_t / \partial x\right)\right] \tag{2-8}$$

where h_t is the height (m) of the terrain.

A second angle, β'', is computed as shown in Table 2-1. The drainage direction, β_d, is defined as:

$$\beta_d = \begin{cases} 90 - \beta'' & 0 \le \beta'' \le 90 \\ 450 - \beta'' & 90 < \beta'' < 360 \end{cases} \tag{2-9}$$

where β_d is in degrees.

The magnitude of the slope flow is parameterized as a function of time of day, domain-scale temperature lapse rate, terrain height, and terrain slope.

$$S = \left(u_s^2 + v_s^2\right)^{1/2} \tag{2-10}$$

$$S = \beta_2 \left[1000 \left(\frac{|\gamma|}{T_o} \right) h_{\max} s_1 \right]^{1/2} \tag{2-11}$$

where S is the speed (m/s) of the slope flow,

s_1 is a measure of the steepness of the terrain

$$\left(s_1 = \left[\left(\frac{\partial h_t}{\partial x} \right)^2 + \left(\frac{\partial h_t}{\partial y} \right)^2 \right]^{1/2} \right) ,$$

γ is the domain-scale temperature lapse rate (deg K/m),

h_{max} is the maximum terrain height (m) within the radius of influence of terrain features,

T_o is the domain-averaged air temperature (°K), and,

β_2 is a function which depends on time of day. It has a value of +1 for upslope flows and -1 for downslope flows.

Blocking Effects

The thermodynamic blocking effects of terrain on the wind flow are parameterized in terms of the local Froude number (Allwine and Whiteman, 1985).

$$Fr = \frac{V}{N \Delta h_t} \tag{2-12}$$

$$\Delta h_t = \left(h_{\max}\right)_{ij} - (z)_{ijk}$$

Table 2-1

Computation of the Angle, β'', Used in the Computation of the Slope Flow Vector (from Douglas and Kessler, 1988)

β'' (degrees)

	$\frac{\partial h_t}{\partial x} = 0$	$\frac{\partial h_t}{\partial x} < 0$	$\frac{\partial h_t}{\partial x} > 0$
$\frac{\partial h_t}{\partial y} = 0$	*	$\beta' + 180$	$\beta' + 360$
$\frac{\partial h_t}{\partial y} < 0$	270	$\beta' + 180$	$\beta' + 360$
$\frac{\partial h_t}{\partial y} > 0$	90	$\beta' + 180$	β'

---

* Flat terrain. Drainage direction is undefined.

where Fr is the local Froude number,
V is the wind speed (m/s) at the grid point,
N is the Brunt-Väisälä frequency as defined in Eqn. (2-5),
Δh_t is an effective obstacle height (m),
$(h_{max})_{ij}$ is the highest gridded terrain height within a radius of influence (TERRAD) of the grid point (i,j), and
$(z)_{ijk}$ is the height of level k of grid point (i,j) above the ground.

The Froude number is computed for each grid point. If Fr is less than a critical Froude number (CRITFN) and the wind at the grid point has an uphill component, the wind direction is adjusted to be tangent to the terrain. The wind speed is unchanged. If Fr exceeds the critical Froude number, no adjustment is made to the flow.

Input Group 5 of the control file contains the user input parameters to the terrain blocking module. The radius of influence of terrain features, TERRAD, is a function of the dominant scale of the terrain. The critical Froude Number, CRITFN, is the threshold for blocking effects. It has a default value of 1.0.

2.2.2 Step 2 Formulation

The second step in the processing of the wind field by the diagnostic model is the introduction of observational data into the Step 1 gridded wind field. The Step 2 procedure consists of four substeps (Douglas and Kessler, 1988).

- Interpolation
- Smoothing
- O'Brien adjustment of vertical velocities
- Divergence minimization

The user optionally can invoke a lake breeze routine between the smoothing and O'Brien steps to simulate wind flow in the vicinity of a coastline.

Interpolation

An inverse-distance method is used to introduce observational data into the Step 1 wind field.

$$(u,v)_2' = \frac{\dfrac{(u,v)_1}{R^2} + \sum_k \dfrac{(u_{obs},v_{obs})_k}{R_k^2}}{\dfrac{1}{R^2} + \sum \dfrac{1}{R_k^2}} \tag{2-13}$$

where $(u_{obs},v_{obs})_k$	are the observed wind components at station k,
$(u,v)_1$	are the Step 1 wind components at a particular grid point,
$(u,v)_2'$	are the initial Step 2 wind components,
R_k	is the distance from observational station k to the grid point, and
R	is a user-specified weighting parameter for the Step 1 wind field.

This interpolation scheme allows observational data to be heavily weighted in the vicinity of the observational station, while the Step 1 wind field dominates the interpolated wind field in regions with no observational data. The weighting procedure described by Eqn. (2-13) is applied independently to each vertical layer. Surface observations are used only for the lowest wind field layers appropriate for whatever option for vertical extrapolation of the observational data is selected (see the variable IEXTRP in Input Group 5 of the control file).

The user specified parameter, R, determines the relative weighting given to the Step 1 wind field. Different values of R are used in the surface layer (R_1), and layers aloft (R_2). R_1 and R_2 are also entered in Input Group 5 of the control file.

An observation is excluded from interpolation if the distance from the observational station to a particular grid point exceeds a maximum radius of influence. Three separate maximum radius of influence parameters are used in the diagnostic wind module (i.e., when IWFCOD=1):

- Radius of influence over land in the surface layer (RMAX1)
- Radius of influence over land in layers aloft (RMAX2)
- Radius of influence over water (RMAX3)

If the option to perform objective analysis only (IWFCOD=0) is selected, RMAX1 is used as the maximum radius of influence for all layers and all land use types. That is, RMAX2 and RMAX3 are not used when IWFCOD=0.

CALMET is also equipped with a varying radius of influence option, LVARY. When invoked, it allows the model to use the closest observation station with valid data to a grid point if that grid point is outside the user specified radius of influence of any observation stations. The LVARY option applies with either IWFCOD=0 (objective analysis) or IWFCOD=1 (diagnostic wind module). If the LVARY option is turned off, the radius of influence parameters must be selected so that every grid point is inside the radius of influence of at least one observational station.

The number of observational stations that will be included in the interpolation can be limited by an additional input parameter, NINTR2. This variable is an array of "NZ" elements, one for each vertical layer, specifying the maximum number of stations that can be used in the interpolation at a given grid point. If the number of stations inside the radius of influence is greater than NINTR2, the closest NINTR2 stations will be used.

The region influenced by an observation can be limited by user-specified "barriers." These barriers consist of line segments which define the boundaries of the region of the grid which can be influenced by a particular observation. Any time a barrier exists between a grid point and an observation site, the observational data are omitted for the interpolation. For example, user-specified barrier segments can be defined to prevent observational data from a station in a well-defined valley from being applied outside the valley region. At this time the barriers extend to the top of the model domain. In the future, modifications may be made to limit their vertical extent.

Vertical Extrapolation of Surface Wind Observations

Before performing the horizontal spatial interpolation of the winds, the surface winds at each observational station can be, as an option, extrapolated to higher layers. The control of the extrapolation option is through the variable IEXTRP in Input Group 5 of the CALMET.INP file. The options are:

$$|\text{IEXTRP}| = \begin{cases} 1 \text{ — do not extrapolate the surface data} \\ 2 \text{ — extrapolate vertically using a power law equation} \\ 3 \text{ — extrapolate vertically using user-defined} \\ \quad\text{scaling factors} \\ 4 \text{ — extrapolate vertically using similarity theory} \end{cases}$$

In addition to being a flag controlling the vertical extrapolation of surface winds, IEXTRP also is an indicator of whether data from upper air stations are used in the surface layer (Layer 1). If IEXTRP is negative, data from upper air stations are ignored (treated as missing) in the development of the surface layer wind field. If the four-character station name of the upper air station is the same as that of a surface station (indicating the stations are co-located), the Layer 1 data from the upper air station is ignored, regardless of the value of IEXTRP.

Also, the vertical extrapolation of data from a surface station is skipped if the surface station is close to an upper air station with valid data. The variable, RMIN2 (in Input Group 5) defines the distance from an upper air station that a surface station must exceed in order for the extrapolation to take place. The default value of RMIN2 is set to 4 km, so that surface stations within 4 km of an upper air station will not be subject to vertical extrapolation with any of the IEXTRP options.

If IEXTRP = 2, the following power law equation is used to adjust the surface layer winds to Layer 2 through the top of the model domain:

$$u_z = u_m \cdot (z/z_m)^P \tag{2-14}$$

where z is the height (m) of the midpoint of the CALMET grid cell,
z_m is the measurement height (m) of the surface wind observation,
u_m is the measured u-component of the wind (m/s),
u_z is the extrapolated u-component of the wind (m/s) at height z, and
P is the power law exponent.

A similar equation applies to the v-component of the wind.

Following Douglas and Kessler (1988) in the DWM, a value of P of 0.143 is used over land, and P of 0.286 is used over water. A cell-averaged terrain elevation of zero is used as a flag for water cells.

With IEXTRP = 3, the user defines a set of scaling factors, one for each CALMET layer above the surface (see the FEXTRP array in Input Group 5). The winds at Layers 2 through NZ are computed as:

$$u_i = u_1 \cdot \mathrm{FEXTRP}_i \tag{2-15}$$

where i is the CALMET layer number (i = 2, 3, ..., NZ),
u_1 is the u-component of the wind in Layer 1,
u_i is the u-component of the wind in Layer i, and
$FEXTRP_i$ is the user-specified scaling factor for layer i.

A similar equation is used to scale the v-component of the wind.

The third method for extrapolating the winds is based on the work of van Ulden and Holtslag (1985). It uses similarity theory and observed data to extend the influence of the surface wind speed and direction into the layers aloft. Wind speed and direction are altered in each layer aloft up to 200 meters above ground level or the mixing height, whichever is greater. The equations for the van Ulden and Holtslag (1985) extrapolation method (IEXTRP = 4) are given below. The turning of the wind with height is given by Eqn. (2-16):

$$D(z)/D(h) = d_1\left[1 - \exp\left(-d_2 z/h\right)\right] \tag{2-16}$$

where D(z) is the turning angle at layer height center z, D(h) is the turning angle at a reference height, h, and d_1 = 1.58 and d_2 = 1.0 are empirical constants. Table 2-2 gives the empirical data from which D(h) is interpolated.

In the implementation of the scheme in CALMET, first the mixing height and Monin-Obukhov length at every eligible station are determined using the methods described in Section 2.3. Using the calculated mixing height and Monin-Obukhov length, the amount of turning in the wind direction at the reference height (h) of 200 m is determined by interpolating in inverse Monin-Obukhov length (1/L) a turning angle, D(h), from Table 2-2, based on observed data reported by van Ulden and Holtslag (1985). The reference turning angle is then used in Eqn. (2-16) to yield the turning angle (D_1) at the CALMET height, z. Eqn. (2-16) is applied with the same h = 200 m and D(h) with z equal to the anemometer height of the observational station to obtain the turning angle from the ground to the anemometer height (D_2). The wind direction correction at CALMET height z from the anemometer height is then applied (i.e., correction angle = $D_1 - D_2$).

Table 2-2

Turning of the Wind with Height (D), in Degrees Clockwise, as Observed at Cabauw, Netherlands, at Various Heights (z) as a Function of Monin-Obukhov Length (L) (from van Ulden and Holtslag, 1985)

Height above ground (m)	Unstable			Neutral	Stable				
	L = −30 m	−100 m	−370 m	10^4 m	350 m	130 m	60 m	20 m	9 m
40	0	0	0	1	2	4	5	7	12
80	4	3	3	4	7	11	16	21	24
120	8	6	5	6	10	17	24	29	31
160	10	8	7	9	14	22	30	34	36
200	12	10	9	12	18	28	35	38	39

The wind speed profile calculations are based on the Monin-Obukhov similarity theory for the surface layer as described by van Ulden and Holtslag (1985). Depending on the stability, Eqns. (2-18) or (2-19) are used to determine the stability function based on height and Monin-Obukhov length. The stability function, the measurement height, the layer center height, and the roughness length in the grid cell in which the station is located are then used in Eqn. (2-16) to obtain the wind speed at the layer center height. The altered wind speed and direction are then converted back to u and v wind components for use in the interpolation routines. *After calculating the turning angle, it is added to the wind direction in the Northern hemisphere (winds veer clockwise), and subtracted in the Southern hemisphere (winds back counterclockwise).*

Eqn. (2-17) gives the similarity theory equation used to calculate the wind speed profile:

$$U(z) = U(z_1)\frac{\left[\ln\left(\frac{z}{z_o}\right) - \psi_M\left(\frac{z}{L}\right)\right]}{\left[\ln\left(\frac{z_1}{z_o}\right) - \psi_M\left(\frac{z_1}{L}\right)\right]} \qquad (2\text{-}17)$$

where U(z) is the wind speed at the center of the CALMET layer, $U(z_1)$ is the wind speed at the anemometer height, z_o is the roughness length, z_1 is the anemometer height, and ψ_M is the stability function. Eqn. (2-18) gives the stability function for stable conditions:

$$\psi_M = (1 - 16z/L)^{1/4} - 1 \qquad (2\text{-}18)$$

For unstable conditions, the stability function is given by Eqn. (2-19):

$$\psi_M = -17[1 - \exp(-0.29z/L)] \qquad (2\text{-}19)$$

Lake/Sea Breeze Option

The user can define a lake or sea breeze region within which the surface winds are calculated separately and replace the original winds. In order to obtain good results from this option, there must be a complete (in time and space) observing network within the defined region. The user defines the boundaries of up to ten lake breeze regions and specifies the end points of the coastline (specified as a line segment) within each one. The winds at each grid point within the region are calculated by using an inverse distance squared interpolation, but the distances are defined as the difference between the distances of the grid point to the coastline and the station to the coastline if the station and grid point are on the same side of the coastline and the sum if they are on opposite sides. With this method, the actual distance between the grid point and the station is not important, only their relative distances from the coastline. Only stations within the region are considered.

Smoothing

The intermediate Step 2 wind field resulting from the addition of observational data into the Step 1 wind field is subject to smoothing in order to reduce resulting discontinuities in the wind field. The smoothing formula used in CALMET is:

$$(u_{i,j})_2'' = 0.5\, u_{i,j} + 0.125 \left[u_{i-1,j} + u_{i+1,j} + u_{i,j-1} + u_{i,j+1} \right] \tag{2-20}$$

where $(u_{i,j})''$ is the u wind component at grid point (i,j) after smoothing, and
$(u_{i,j})$ is the u wind component before smoothing, as determined by Eqn. (2-13)

A similar equation is applied for the v component of the wind.

The use of the smoother is controlled by the input parameter array, NSMTH, contained in Input Group 5 of the control file. This variable represents the maximum number of passes of the smoother which are used in each layer. Surface layer winds are subject to a recommended default maximum of two passes of the smoother but more passes can be specified. Application of the smoother can be eliminated in all layers by setting NSMTH to zero. If the lake breeze option is being used, winds within the lake breeze regions are not smoothed.

Computation of Vertical Velocities

Two options are available for computing vertical velocities in CALMET. With the first method the vertical velocities are computed directly from the incompressible conservation of mass equation using the smoothed horizontal wind field components. The second method adjusts the vertical velocity profile so that the values at the top of the model domain are zero. The horizontal wind components are then readjusted to be mass consistent with the new vertical velocity field.

The initial vertical velocity is determined from the incompressible mass conservation equation:

$$\frac{du''}{dx} + \frac{dv''}{dy} + \frac{dw_1}{dz} = 0 \qquad (2\text{-}21)$$

where w_1 is the vertical velocity in terrain-following coordinates, and
u'',v'' are the horizontal wind field components after smoothing.

This mass-consistent vertical velocity is used as the final vertical velocity (i.e., $w = w_1$) if Method 1 is selected.

Also, with this method, no further adjustment is made to the horizontal wind components. The final horizontal winds are the smoothed winds resulting from Eqn. (2-20).

Godden and Lurmann (1983) suggest that this procedure may sometimes lead to unrealistically large vertical velocities in the top layers of the grid. In order to avoid this problem, an option is provided to use a procedure suggested by O'Brien (1970) to adjust w_1.

$$w_2(z) = w_1(z) - (z/z_{top})w_1(z = z_{top}) \qquad (2\text{-}22)$$

The O'Brien procedure forces the vertical velocity at the top of the model domain to be zero. Because the horizontal winds are not mass consistent with the adjusted vertical velocities, the horizontal winds are subject to adjustment by the divergence minimization scheme described in Section 2.3.4. The divergence minimization procedure iteratively adjusts the u and v components to within a user-specified divergence threshold while holding the vertical velocity field ($w = w_2$) constant.

There are situations where the use of the O'Brien procedure is not warranted. For example, if the top of the modeling grid is within a sea-breeze convergence zone, the large vertical velocities resulting from application of Eqn. (2-21) may be realistic. Therefore, the use of the O'Brien procedure is an optional feature of CALMET.

Divergence Minimization Procedure

Three-dimensional divergence in the wind field is minimized by a procedure described by Goodin et al. (1980). This procedure iteratively adjusts the horizontal wind components (u,v) for a fixed vertical velocity field so that at each grid point, the divergence is less than a user-specified maximum value.

$$\frac{du}{dx} + \frac{dv}{dy} + \frac{dw}{dz} < \epsilon \qquad (2\text{-}23)$$

where u,v are the horizontal wind components,
w is the vertical velocity in terrain following coordinates, and
ϵ is the maximum allowable divergence.

In CALMET, the horizontal wind components are defined at the grid points. Vertical velocities are defined at the vertical grid cell faces. Therefore, the divergence, D, at grid point (i,j,k) is:

$$D_{ijk} = \frac{w_{i,j,k+1/2} - w_{i,j,k-1/2}}{z_{k+1/2} - z_{k-1/2}} + \frac{u_{i+1,j,k} - u_{i-1,j,k}}{2\Delta x} + \frac{v_{i,j+1,k} - v_{i,j-1,k}}{2\Delta y} \qquad (2\text{-}24)$$

where Δx and Δy are the sizes of the grid cell in the x and y directions, respectively.

For each grid point, divergence is computed. The u and v wind components at the surrounding cells are adjusted so that the divergence at the grid point is zero. The adjustments are:

$$\left(u_{new}\right)_{i+1,j,k} = u_{i+1,j,k} + u_{adj} \qquad (2\text{-}25)$$

$$\left(u_{new}\right)_{i-1,j,k} = u_{i-1,j,k} - u_{adj} \qquad (2\text{-}26)$$

$$\left(v_{new}\right)_{i,j+1,k} = v_{i,j+1,k} + v_{adj} \qquad (2\text{-}27)$$

$$\left(v_{new}\right)_{i,j-1,k} = v_{i,j-1,k} - v_{adj} \qquad (2\text{-}28)$$

where the adjustment velocities (u_{adj},v_{adj}) are:

$$u_{adj} = \frac{-D_{ijk}\Delta x}{2} \qquad (2\text{-}29)$$

$$v_{adj} = \frac{-D_{ijk}\Delta y}{2} \qquad (2\text{-}30)$$

Each time the divergence is eliminated at a particular grid point, divergence is created at surrounding points. However, by applying the procedure iteratively, the divergence is gradually reduced below the threshold value, ϵ, throughout the grid.

2.2.3 Incorporation of Prognostic Model Output

The CALMET model contains an option to allow the Step 1 wind field used in the objective analysis scheme to be replaced by gridded wind fields generated by a version of the prognostic Colorado State University Mesoscale Model (CSUMM) (Kessler, 1989). The procedure allows for the prognostic model to be run with a significantly larger grid spacing and different vertical grid resolution than that used in the diagnostic model. This option allows certain features of the flow field, such as the lake breeze circulation with a return flow aloft, which may not be captured in the surface observational data base, to be introduced into the diagnostic wind field results.

The first step is to interpolate the gridded prognostic model winds to the CALMET horizontal and vertical levels. The linear interpolation is performed to convert winds at the prognostic model's vertical levels to the CALMET levels. An inverse distance squared ($1/R^2$) weighting procedure is used in the horizontal to interpolate the prognostic model winds to the CALMET grid points. Once the prognostic winds have been defined at the CALMET grid points, the Step 2 wind field is generated and computed in the following way.

$$(u,v)_2' = \frac{\dfrac{(u,v)_{\text{prog}}}{R^2_{\text{prog}}} + \sum_k \dfrac{(u_{\text{obs}},v_{\text{obs}})_k}{R_k^2}}{\dfrac{1}{R^2_{\text{prog}}} + \sum_k \dfrac{1}{R_k^2}} \tag{2-31}$$

where $(u,v)_{prog}$ are the wind components generated by the prognostic wind field model, and

R_{prog} is a user-specified weighting parameter for the prognostic wind field data

The other variables were defined in Section 2.2.2.

The CALMET model contains three options for treating gridded prognostic wind fields such as MM4-FDDA fields as input:

- as the initial guess field,
- as the Step 1 wind field, or
- as "observations."

When used as the initial guess field, the prognostic winds are first interpolated to the fine-scale CALMET grid. The normal diagnostic adjustments for the fine-scale terrain are then made. This produces a Step 1 field which is then subject to an objective analysis procedure using the observed wind data. Thus, in this mode, the prognostic winds are adjusted for the fine-scale terrain effects and observations.

In the second option, the prognostic winds are interpolated to the CALMET grid and then are used as the Step 1 field. Thus, the prognostic winds are not adjusted for the fine-scale terrain effects, but rather they are assumed to already contain the most significant terrain effects. The Step 1 winds are combined with observations using an objective analysis procedure to produce the final Step 2 winds.

In the third case, the prognostic winds are treated in exactly the same manner as the observations. If the diagnostic wind option is used in CALMET, a Step 1 wind field is produced by adjusting the domain-scale wind for the fine-scale terrain effects. The actual observations and MM4-FDDA "pseudo-observations" are then used to modify the Step 1 fields using the objective analysis procedure. If the "objective-analysis-only" option is selected in CALMET, the computation of the Step 1 wind field is eliminated, and the final winds are based on the objective analysis of the MM4-FDDA winds and the actual observational data. Note that in this case, both the observations and MM4-FDDA winds are given a high weight in the analysis procedure.

The potential drawback to this approach is that no distinction is made in the relative confidence we may have in the MM4-FDDA simulations and the observed wind data. For example, when winds are interpolated to the modeling grid, nearby wind observations are treated in the same way as nearby MM4-FDDA winds, even though local circulations embodied in the observed winds may be "missed" by the coarser resolution of the MM4-FDDA simulation.

The representativeness on a fine-scale grid of the observed point-value winds as compared with winds derived from the MM4-FDDA on a coarse grid is expected to depend on such factors as the height above the surface, subgrid-scale terrain variations, and the ratio of the coarse-grid to fine-grid size. For example, a coarse grid of MM4-FDDA winds will not reflect potentially important local features of the surface flow field induced by terrain variations which can not be resolved by this coarse MM4-FDDA grid. On the other hand, the point-value "snapshot" observations in such areas do not necessarily represent larger-scale flow fields as well as the MM4-FDDA fields. Therefore, a weighting factor based on the subgrid-scale terrain variations within each grid cell must be derived.

2.2.3.1 Terrain Weighting Factor

Although the use of MM4-FDDA winds are expected in many circumstances to improve the diagnostic model's wind fields, MM4-FDDA may not produce winds "near" the surface that are representative if much terrain is poorly resolved by the scale of the grid used for the MM4-FDDA simulations. When this is the case, local observations might be given more weight than the MM4-FDDA winds in interpolating winds to the grid used for the diagnostic models. The method employed for altering weights involves (1) computing σ_t, the standard deviation of the departure of the "actual" terrain elevations from the grid-average terrain elevation, (2) defining a weight W_o that is a function of σ_t, and (3) weighting observed wind by W_o, and MM4-FDDA winds by $(1 - W_o)$ when performing the interpolation process.

To derive the weights, first quantify the differences between the terrain as represented by a "coarse" grid used in the MM4-FDDA simulations and the terrain as represented on the "fine-grid". Then, calculate the root-mean-square (RMS) of the difference between the original terrain and the "coarse-grid" terrain elevations within a region about each point in the "coarse" grid. The difference in elevation, $(h_{ori} - h_{crs})$, should be calculated with a resolution equal to that of the original gridded terrain data, where h_{ori} is the elevation of a point contained in the original terrain file and bilinear interpolation is used to find h_{crs} at the same location. A similar procedure should also be used to calculate $RMS(h_{fin} - h_{crs})$, where h_{fin} denotes elevations in the "fine-grid" used by the diagnostic models. The difference in elevation $(h_{fin} - h_{crs})$ can be found at the same locations used for $(h_{ori} - h_{crs})$, using bilinear interpolation within both the fine and coarse grids. Therefore, $RMS(h_{fin} - h_{crs})$ is zero if the same grid is used by both the MM4-FDDA and the diagnostic models.

A simple formulation that allows near-surface adjustments to the MM4-FDDA winds, is a product relationship:

$$W_o = W_z \, W_s \tag{2-32}$$

where W_s is the weighting factor near the surface, and W_z is a height-dependent modifier. W_z tends toward zero if the model-layer being processed is well above the terrain, or if there are no sub-grid variations in the terrain (e.g., if the terrain is flat). Using the mean elevation of the layer above the surface, denoted as z_i, and the $RMS(h_{fin} - h_{crs})$, denoted simply as RMS_{fin},

$$W_{zi} = \left[\mathrm{MIN}\left(\mathrm{RMS}_{\mathrm{fin}}/2z_i\ ,\ 1.0\right)\right]^2 \qquad (2\text{-}33)$$

has the desired properties. The MIN function refers to the minimum of the two arguments (i.e., $\mathrm{RMS}_{\mathrm{fin}}/2z_i$ and 1.0). When the terrain resolved by the fine-scale grid used by the diagnostic model has a characteristic departure from the coarse-grid terrain (quantified as $\mathrm{RMS}_{\mathrm{fin}}$) that is less than the height of the layer, W_{zi} will be less than 1, which will reduce the magnitude of W_o, indicating that the subgrid terrain is less important for this layer than for any closer to the surface. As higher layers are processed, W_{zi} approaches zero, which emphasizes the use of the MM4-FDDA winds in the diagnostic model. If the fine-scale grid should have the same resolution as the coarse grid, $\mathrm{RMS}_{\mathrm{fin}} = 0$ and $W_z = 0$, so that the MM4-FDDA winds are used in preference to the observed winds at all levels.

The near-surface factor, W_s, makes use of both $\mathrm{RMS}_{\mathrm{fin}}$ and $\mathrm{RMS}_{\mathrm{ori}}$, where

$$\mathrm{RMS}_{\mathrm{ori}} = \mathrm{RMS}\left(h_{\mathrm{ori}} - h_{\mathrm{crs}}\right) \qquad (2\text{-}34)$$

The scale of the departure of the original terrain from that resolved by the coarse-grid, $\mathrm{RMS}_{\mathrm{ori}}$, is used to scale the departure of the terrain resolved by the fine grid from that resolved by the coarse grid. The ratio $\mathrm{RMS}_{\mathrm{fin}}/\mathrm{RMS}_{\mathrm{ori}}$ has a range of 0 to 1.0, provided that $\mathrm{RMS}_{\mathrm{ori}}$ is not zero. When $\mathrm{RMS}_{\mathrm{fin}}$ is zero, or when $\mathrm{RMS}_{\mathrm{fin}}/\mathrm{RMS}_{\mathrm{ori}}$ is nearly zero, W_s should be nearly zero, thereby indicating that the MM4-FDDA winds should be preferred over any observed winds (the observed winds have already been "used" within MM4-FDDA). On the contrary, when $\mathrm{RMS}_{\mathrm{fin}}/\mathrm{RMS}_{\mathrm{ori}}$ approaches 1.0, local subgrid terrain could be important, and local observations or diagnostic wind estimates near the surface should be emphasized. Hence, W_s can be given by

$$W_s = \left(\mathrm{RMS}_{\mathrm{fin}}/\left(\mathrm{RMS}_{\mathrm{ori}} + \mathrm{RMS}_{\mathrm{o}}\right)\right)^n \qquad (2\text{-}35)$$

For $n > 1$, smaller values of W_s will be produced, thereby making it more "difficult" to ignore the MM4-FDDA winds in favor of observed winds. For $n < 1$, the opposite trait is favored.

$\mathrm{RMS}_{\mathrm{o}}$ is added to $\mathrm{RMS}_{\mathrm{ori}}$ in the denominator to avoid a problem that arises if terrain variations are "small". W_s may be nearly 1.0 (which emphasizes the observed winds) in some cases in which terrain variations are small enough that the MM4-FDDA winds are indeed representative in the surface-based layer, in spite of W_s. To address this case, a condition that the terrain variations be "significant" is added. That is, the denominator is never allowed to fall below some specified length-scale, $\mathrm{RMS}_{\mathrm{o}}$. Because the center of the surface-based layer is 10 m in these applications, a length scale of 10 m has been adopted for "significance". All cells in the coarse grid that are so characterized as having insignificant terrain variation from that resolved by the fine grid will thereby promote the use of MM4-FDDA winds in preference to observed winds at nearby grid-points.

In the sensitivity analyses (Scire et al., 1994), all three methods of incorporating the MM4-FDDA field into CALMET were examined. The weighing factor, W_o, discussed above, was applied as follows:

- MM4-FDDA wind as initial guess wind
  - no weighting by W_o

- MM4-FDDA used as Step 1 winds
  - W_o is used to weight observations
  - Step 1 winds are weighted by factor $(1.0 - W_o)$

- MM4-FDDA used as "observations"
  - W_o is used to weight actual observed data
  - MM4-FDDA data are weighted by factor $(1.0 - W_o)$

In the first case, the terrain-weighting factor is not used because the MM4-FDDA coarse-grid winds are subject to the full adjustment for the fine-scale terrain data by the diagnostic model, whereas in the other two cases, the MM4-FDDA winds are not adjusted for the effects of the fine-scale terrain.

2.3 Micrometeorological Model

2.3.1 Surface Heat and Momentum Flux Parameters

A number of significant advances have been made in recent years in our understanding and characterization of the structure of the planetary boundary layer (PBL) (e.g., see Weil, 1985; Briggs, 1985). As noted by van Ulden and Holtslag (1985) and others, the use of the appropriate boundary layer scaling parameters can improve the quality of dispersion predictions. The principal parameters needed to describe the boundary layer structure are the surface heat flux (Q_h), surface momentum flux ($\rho\ u_*^2$), and the boundary layer height (h). Several additional parameters, including the friction velocity (u_*), convective velocity scale (w_*), and the Monin-Obukhov length (L), are derived from these.

As part of the Electric Power Research Institute (EPRI) Advanced Plume project, Hanna et al. (1986) have evaluated several models for the prediction of these boundary layer parameters from "routinely"[1] available meteorological observations. Two basic methods are commonly used to estimate the surface heat and momentum fluxes. The first method is referred to as the profile method. It requires at a minimum the measurement of the wind speed at one height and the temperature difference between two heights in the surface layer, as well as knowledge of the air temperature and roughness characteristics of the surface. Monin-Obukhov similarity theory is then used to solve for the surface fluxes by iteration. The second approach, called the energy budget method, computes the surface heat flux by parameterizing the unknown terms of the surface energy budget equation.

Hanna et al. (1986) tested the following four energy budget models and two profile schemes:

Energy Budget Models

- Holtslag and van Ulden (1983)
- Weil and Brower (1983)
- Berkowicz and Prahm (1982)
- Briggs (1982)

Profile Schemes

- Two-level tower method
- Four-level tower method

The major conclusion drawn from the comparison of the six schemes was that the energy budget methods were superior because of the sensitivity of the profile method to small errors in the measured temperature difference. However, as discussed below, this conclusion does not apply to the marine boundary layer, where a profile method based on the air-sea temperature difference is recommended. The relative performance of all of the energy budget methods was similar. An intercomparison of the u_* predictions of each of the energy budget methods showed a very high correlation with the other energy budget schemes (r^2 from 0.98 to 0.99 and RMS errors from 0.027 to 0.055 m/s). The correlation coefficient of the energy budget schemes with observed u_* ranged from 0.63 to 0.65 and RMS errors from 0.20 to 0.21 m/s.

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[1] Temperature difference is not routinely reported at NWS meteorological stations. However, it typically is available at the many non-NWS sites with meteorological towers.

Overland Boundary Layer

An energy budget method, based primarily on Holtslag and van Ulden (1983), is used over land surfaces in the CALMET micrometeorological model. The energy balance at the surface can be written as:

$$Q_* + Q_f = Q_H + Q_e + Q_g \tag{2-36}$$

where, Q_* is the net radiation (W/m^2),
Q_f is the anthropogenic heat flux (W/m^2),
Q_h is the sensible heat flux (W/m^2),
Q_e is the latent heat flux (W/m^2), and,
Q_g is the storage/soil heat flux term (W/m^2).

The ratio of the sensible heat flux to the latent heat flux is defined as the Bowen ratio.

$$B = \frac{Q_h}{Q_e} \tag{2-37}$$

The model will require gridded values of the Bowen ratio. Seasonal default values, based on land use categories, will be provided. The Bowen ratio is important in determining the degree of convective turbulence because it reflects the partitioning of the available energy into sensible and latent heat flux. Typical values of B range from - 0.1 over water bodies to ≥ 10 for deserts. In the summertime over parts of Australia, values of B - 5-10 are expected.

The flux of heat into the soil or building materials, Q_g, is usually parameterized during the daytime in terms of the net radiation (e.g., Oke, 1978; Holtslag and van Ulden, 1983).

$$Q_g = c_g \, Q_* \tag{2-38}$$

where the constant c_g is a function of the properties of the surface. Oke (1982) suggests values for c_g of 0.05-0.25 for rural areas and 0.25-0.30 for urban areas. The larger values for urban areas reflect the greater thermal conductivity and heat capacity of building materials. Holtslag and van Ulden (1983) use a value of 0.1 for a grass covered surface.

The anthropogenic heat flux, Q_f, is a function of the population density and per capita energy usage. Oke (1978) summarizes annual and seasonally- averaged Q_f values for several urban areas. Although the Q_f term has been retained for generality, it is usually small compared to the other terms.

The net radiation, Q_*, is the residual of incoming (short-wave plus long-wave) radiation and outgoing (long-wave) radiation. Q_* can be expressed (Holtslag and van Ulden, 1983; Lansberg, 1981) as:

$$Q_* = Q_{sw}\,(1 - A) + Q_{1w\text{-}d} - Q_{1w\text{-}u} \tag{2-39}$$

where, Q_{sw} is the incoming short-wave radiation (W/m^2), consisting of a direct solar radiation term ($Q_{sw\text{-}s}$) plus a diffuse radiation term ($Q_{sw\text{-}d}$),

A is the albedo of the surface,

$Q_{1w\text{-}d}$ is the incoming long-wave atmospheric radiation (W/m^2), and,

$Q_{1w\text{-}u}$ is the long-wave radiation (W/m^2) emitted by the surface.

The method of Holtslag and van Ulden (1983) is used to estimate Q_*. The result of their parameterization of each of the terms in Eqn. (2-39) is:

$$Q_* = \frac{(1 - A)Q_{sw} + c_1 T^6 - \sigma T^4 + c_2 N}{1 + c_3} \tag{2-40}$$

$$Q_{sw} = \left(a_1 \sin\phi + a_2\right)\left(1 + b_1 N^{b_2}\right) \tag{2-41}$$

where, T is the measured air temperature (deg. K),

σ is the Stefan-Boltzmann constant (5.67×10^{-8} W/m^2/deg. K^4),

N is the fraction of the sky covered by clouds, and

ϕ is the solar elevation angle (deg.).

The last term in Eqn. (2-41) accounts for the reduction of incoming solar radiation due to the presence of clouds. The values for the empirical constants c_1, c_2, c_3, a_1, a_2, b_1, and b_2 suggested by Holtslag and van Ulden (1983) are used (see Table 2-3). The solar elevation angle is computed at the midpoint of each hour using equations described by Scire et al. (1984).

Using Eqns. (2-36) to (2-41), the daytime sensible heat flux can be expressed in terms of only known quantities:

$$Q_h = \frac{B}{1 + B}\left[Q_*(1 - c_g) + Q_f\right] \tag{2-42}$$

Table 2-3
Net Radiation Constants (Holtslag and van Ulden, 1983)

Constant	Value
c_1	5.31×10^{-13} W/m^2/deg K^6
c_2	60 W/m^2
c_3	0.12
a_1	990 W/m^2
a_2	−30 W/M^2
b_1	−0.75
b_2	3.4

Once the sensible heat flux is known, the Monin-Obukhov length and surface friction velocity are computed by iteration.

$$u_* = ku / \left[\ln(z/z_o) - \psi_m(z/L) + \psi_m(z_o/L) \right] \tag{2-43}$$

where, z_o is the surface roughness length (m),
ψ_m is a stability correction function [e.g., see Dyer and Hicks (1970)],
k is the von Karman constant, and,
u is the wind speed (m/s) at height z.

The Monin-Obukhov length is defined as:

$$L = \frac{-\rho C_p \, T \, u_*^3}{k \, g \, Q_h} \tag{2-44}$$

where, T is the temperature (°K), and,
g is the acceleration due to gravity (m/s^2).

Eqn. (2-43) is used to obtain an initial guess for u_* assuming neutral conditions ($L = \infty$). This value of u_* is used in Eqn. (2-44) to estimate L. A new value for u_* is then computed with Eqn. (2-43) and L. The procedure is repeated until convergence is obtained. Holtslag and van Ulden (1983) report that three iterations are usually sufficient.

During stable conditions, Weil and Brower (1983) compute u_* with the following method based on Venkatram (1980a):

$$u_* = \frac{C_{DN} \, u}{2} \left[1 + C^{1/2}\right] \tag{2-45}$$

$$C = 1 - \frac{4u_o^2}{C_{DN} \, u^2} \qquad (C \ge 0) \tag{2-46}$$

$$u_o^2 = \frac{\gamma z_m g \, \theta_*}{T} \tag{2-47}$$

where, C_{DN} is the neutral drag coefficient [$k/\ln(z_m/z_o)$],
γ is a constant (≈ 4.7), and,
z_m is the measurement height (m) of the wind speed, u.

The temperature scale, θ_*, is computed as the minimum of two estimates:

$$\theta_* = \min\left[\theta_{*1},\ \theta_{*2}\right] \tag{2-48}$$

The estimate of θ_* is based on Holtslag and van Ulden (1982):

$$\theta_{*1} = 0.09\ (1 - 0.5\ N^2) \tag{2-49}$$

and θ_{*2} is:

$$\theta_{*2} = \frac{T\ C_{DN}\ u^2}{4\ \gamma\ z_m\ g} \tag{2-50}$$

The heat flux is related to u_* and θ_* by:

$$Q_h = -\ \rho\ c_p\ u_*\ \theta_* \tag{2-51}$$

and L is computed from Eqn. (2-44).

The daytime mixing height is computed using a modified Carson (1973) method based on Maul (1980). Knowing the hourly variation in the surface heat flux from Eqn. (2-51) and the vertical temperature profile from the twice-daily sounding data, the convective mixing height at time t+dt can be estimated from its value at time t in a stepwise manner:

$$h_{t+dt} = \left[h_t^2 + \frac{2\ Q_h\ (1 + E)\ dt}{\psi_1\ \rho\ c_p} - \frac{2\ d\theta_t\ h_t}{\psi_1}\right]^{1/2} + \frac{d\theta_{t+dt}}{\psi_1} \tag{2-52}$$

$$d\theta_{t+dt} = \left[\frac{2\ \psi_1\ E\ Q_h\ d_t}{\rho\ c_p}\right]^{1/2} \tag{2-53}$$

where, ψ_1 is the potential temperature lapse rate in the layer above h_t,
$d\theta$ is the temperature jump at the top of the mixed layer (°K), and,
E is a constant (= 0.15).

The potential temperature lapse rate is determined through a layer above the previous hour's convective mixing height. If only routinely available, twice-daily sounding data are available, the morning (1200 GMT) sounding at the nearest upper air station is used to determine ψ_1 up to 2300 GMT. After 2300 GMT, the afternoon sounding (0000 GMT) is used. If more frequent sounding data are available at non-standard sounding times, the latest sounding (day or night) is used to determine ψ_1.

The neutral (mechanical) boundary layer height is estimated by Venkatram (1980b) as:

$$h = \frac{B\, u_*}{[f\, N_B]^{1/2}} \tag{2-54}$$

where, f is the Coriolis parameter (≈ 10^{-4} s^{-1})
B is a constant (≈ $2^{1/2}$), and,
N_B is the Brunt-Väisälä frequency in the stable layer aloft.

The daytime mixing height could then be taken as the maximum of the convective and mechanical values predicted by Eqns. (2-52) and (2-54), however, such a procedure could cause the resulting x-y field of mixing heights to have unreasonably large cell-to-cell variations, as each grid cell's values of h_t and h are computed independently. Such an independent, cell-by-cell computation would also not include important advective effects on the mixing depths, such as the significant reduction of inland mixing depths during sea or lake breeze conditions.

Several researchers (e.g., Wheeler, 1990; Tesche et al., 1988; Steyn and Oke, 1982) have suggested various upwind-looking mixing depth averaging schemes involving estimation of back trajectories or computation of lateral advection of heat fluxes. As CALMET is explicitly marched in time, a rather simple scheme has been incorporated which approximates the back trajectory methodology. For a given grid cell (i,j), the most upwind grid cell which could <u>directly</u> impact cell (i,j) during the time step, dt, is computed as ($i_u = i - u \cdot dt$, $j_u = j - v \cdot dt$), where (u,v) are the wind components at cell (i,j). An upwind-looking cone, originating at (i,j) and having a user-selected, half-opening-angle of HAFANG (i.e., a full cone opening angle of twice HAFANG), is then generated such that grid point (i_u,j_u) sits at the middle of the base of the triangular cone. For each grid cell (i_k,j_k) lying within or on the boundaries of the triangular region, upwind and crosswind distances, d_u and d_c, respectively, are computed in units of number of grid cells, and a weighting factor,

$$w_k = 1 / \left[d_u^2 + (1 + d_c)^2 \right] , \tag{2-55}$$

is computed. Normalized weights are then computed as,

$$w_k' = \frac{w_k}{\sum_n w_n} , \tag{2-56}$$

where the sum on n extends over all the grid points encompassed by the triangle. In addition, Eqn. (2-55) weights are also computed for a square box of user-defined half-width of MNMDAV grid cells and centered on cell (i,j). The purpose of including this supplementary square box region is to allow some intercell averaging to occur even when the mean advective wind goes to zero. Hence, a reasonable value for MNMDAV would be of order $\sigma_v \cdot dt/dx$, which is usually of order unity in many mesoscale applications. For those cells which are actually downwind, such that $d_u < 0$, the quantity d_u in the Eqn. (2-55) weight is replaced by the quantity $d_u' = \varepsilon - d_u$, where ε is the Courant number or the height of the triangle from its base at (i_u, j_u) to the vertex at (i,j). This ensures that downwind cells receive rather small weighting but ensures complete azimuthal symmetry as the wind speed (and ε) go to zero.

The weights, w_i', appropriately normalized via Eqn. (2-56) for all points lying in the triangular or square box regions, are then applied to the fields of convective and effective daytime (i.e., the maximum of h_t and h) mixing depths to produce smoothed equivalents, and these fields are stored for use in the current hour. In addition, it is the spatially smoothed convective h_t which is used for the next hour's computation using Eqn. (2-52). Thus, there is a cumulative effect on the convective h_t calculation, comparable to the effect of computing a multiple time step, back trajectory.

The user may switch the spatial averaging option on or off via the control file variable IAVEZI (see Input Group 6 variables). Also specified are the half-width of the square box for averaging (MNMDAV), the half-opening-angle of the upwind sector (HAFANG), and the layer of winds to use for the advection calculation (ILEVZI).

In the stable boundary layer, mechanical turbulence production determines the vertical extent of dispersion. Venkatram (1980a) provides the following empirical relationship to estimate the stable mixing height.

$$h_1 = B_2 \, u_*^{3/2} \tag{2-57}$$

where B_2 is a constant ($\approx$ 2400).

The stable boundary layer height is estimated by Zilitinkevich (1972) as

$$h_2 = 0.4 \sqrt{\frac{u_* L}{f}} \tag{2-58}$$

CALMET defines the stable boundary layer height as the minimum of h_1 and h_2.

In the convective boundary layer, the appropriate velocity scale is w_*, which can be computed directly from its definition using the results of Eqns. (2-42) and (2-52).

$$w_* = \left[g\, Q_h\, h_t / (T\, \rho\, c_p)\right]^{1/3} \tag{2-59}$$

where h_t is the convective mixing height.

Overwater Boundary Layer

Over water, the aerodynamic and thermal properties of the surface require that different methods be used in the calculation of the boundary layer parameters. One of the most important differences between the marine and continental boundary layers is the absence of a large sensible heat flux driven by solar radiation. A profile technique, using the air-sea temperature difference and over water wind speed, is used in CALMET to compute the micrometeorological parameters in the marine boundary layer. However, this method is sensitive to the accuracy of the sensors measuring the temperature difference. Therefore, it should be used with caution in areas where reliable temperature data are not available.

The neutral momentum drag coefficient over water, C_{uN}, can be expressed in terms of the 10-m wind speed (Garratt, 1977).

$$C_{uN} = (0.75 + 0.067\, u)\ 10^{-3} \tag{2-60}$$

The friction velocity can then be determined from the definition of the drag coefficient:

$$u_* = u\, C_{uN}^{1/2} \tag{2-61}$$

Because of the importance of the latent heat flux over water, virtual potential temperatures are used in the definition of the Monin-Obukhov length. Hanna et al. (1985) express L as:

$$L = \frac{\theta_v\, C_{un}^{3/2}\, u^2}{E_2\, (\theta_v - \theta_{vs})} \tag{2-62}$$

where, θ_v, θ_{vs} are the virtual potential temperatures (°K) of the air and water,
u is the 10-m wind speed (m/s), and,
E_2 is a constant (5.096×10^{-3}).

Over water, due to the effect of the wind on wave height, the surface roughness length varies. CALMET employs a relationship derived by Hosker (1974) to express the surface roughness in terms of the 10 m wind speed:

$$z_0 = 2.0 \times 10^{-6}\, u^{2.5} \tag{2-63}$$

Hosker's result is based on the analysis of Kitaigorodskii (1973) showing $z_o \propto u_*^2$ and the logarithmic wind speed profile relating wind speed and u_*.

2.3.2 Three-dimensional Temperature Field

When the CALMET model is run with the CALGRID output flag set (i.e., LCALGRD = .TRUE.), a module is called which simulates a three-dimensional temperature field based on upper air and surface temperature data and on an estimate of the local convective mixing depth, previously determined using the energy balance method. Additionally, overwater temperatures optionally can be treated separately (see Section 2.3.2.1). The principal steps involved in generating the temperature field include the following:

1) linear spatial interpolation of the upper air temperature data from each sounding onto the desired vertical mesh;

2) linear time interpolation between consecutive soundings to yield appropriate temperatures at each z level for the given hour;

3) computation of the $1/r^2$ relative weights of each upper air station to the (i,j)th grid column in question. (The distance is formulated in dimensionless units of grid cells with a maximum weight of 1.0 equivalent to an upper air station in the adjacent grid cell.);

4) use of these $1/r^2$ weights to compute a spatially-averaged temperature field in each column (i,j) and at all vertical levels, k. (This 3-D temperature field T_{ijk} is based solely on upper air data.);

5) replacement of the surface level temperatures, T_{ijk}, with a spatially weighted average of surface station temperature observations for the current hour. (The dimensionless weighting factors, are based on the distance, r, from the (i,j)th grid cell to the various surface meteorological stations and can be defined to be $1/r$ or $1/r^2$ through the IRAD input variable . A maximum weight of 1.0 is allowed.); and

6) recomputation of the temperatures above the surface and up to and including the layer containing the convective mixing height by assuming an adiabatic lapse rate, γ, of -0.0098 °C/m between the surface and the convective layer height. (It should be noted that temperatures in the level containing the convective mixing lid are computed as a layer thickness weighted, 3-point average involving the two cell-face temperatures and the temperature at the lid height.)

The resulting 3-D temperature field thus incorporates:

i) all available upper air station data for the most current soundings straddling the current time,

ii) all available hourly surface temperature data, and

iii) supplemental adiabatic modeling of temperatures below the convective mixing height.

The user optionally can apply the spatial averaging method described in Section 2.3.1 to the three-dimensional temperature field (through input variable IAVET), using the MNMDAV and HAFANG values specified for mixing heights.

2.3.2.1 Overwater Temperatures

Because of the important effect of water bodies on temperature and the strong temperature gradients that can exist at coastal boundaries, CALMET can calculate overwater temperatures separately by use of overwater data (e.g., buoy data in the SEA.DAT files). Over land, temperatures still are calculated as described above, with the exception that overwater stations are not included in the surface-level interpolation. Spatial averaging optionally can be applied to the entire temperature field through use of IAVET options (see Input Group 6). Such averaging may be desirable to moderate the temperatures along the coastline.

The overwater interpolation of temperatures is user-controlled by the selection of the land use categories for which the overwater data in the SEA.DAT file is applied (see JWAT1, JWAT2 in Input Group 6). For example, the default values of JWAT1 and JWAT2 are set so that the SEA.DAT temperature interpolation scheme is applied only to oceans and seas, rather than smaller water bodies, such as lakes or ponds. To disable the overwater temperature interpolation scheme, JWAT1 and JWAT2 can be set to large values, outside the range of the land use data in the GEO.DAT file (e.g., 9999).

For the specified water body, surface temperatures (CALMET Layer 1) are based only on the overwater station observations found in the SEAn.DAT input files. Temperatures in the remaining vertical layers over water are based on user-specified, time-varying lapse rates (from the SEAn.DAT files) or constant default lapse rates. Separate lapse rates are specified below and above the overwater mixing height. The default values for the lapse rates are −0.0098 K/m below the mixing height (dry adiabatic lapse rate) and −0.0045 K/m above the mixing height (moist adiabatic lapse rates). Spatially-weighted averaging can be based on either $1/r$ or $1/r^2$, depending on the IRAD switch.

2.3.3 Precipitation Interpolation

CALMET uses observations of hourly precipitation amounts to produce gridded precipitation fields. There are three options available for computing the precipitation fields:

- $1/d$ interpolation
- $1/d^2$ interpolation
- $1/d^2$-exponential interpolation function

The selection of the interpolation method is controlled by the NFLAGP variable in Input Group 6 of the CALMET control file. The default method in CALMET is the $1/d^2$ technique (NFLAGP = 2), based on the recommendations of Dean and Snydor (1977), Wei and McGuinness (1973).

In the $1/d$ and $1/d^2$ methods, the precipitation at grid point (i,j) is given by:

$$R_{i,j} = \frac{\sum_K R_k / d_k^n}{\sum_K 1/d_k^n} \qquad (2\text{-}64)$$

where R_k is the observed hourly precipitation rate (mm/hr) at station k
d_k is the distance from grid point (i,j) to station k
n is the exponent of the weighting function (n = 1 if NFLAGP = 1, n = 2 if NFLAGP = 2

Only stations within the user-specified radius of influence (SIGMAP) are included in the summation in Eqn. (2-64). The default value of SIGMAP in CALMET is 100 km. If no precipitation station with valid (non-missing) data are within the radius of influence, CALMET will use the precipitation rate at the nearest station with valid data for the grid point. If the computed precipitation rate using Eqn. (2-64) is less than a user-specified minimum precipitation rate (CUTP), the precipitation rates at the grid point will be set to zero. The default value of CUTP is 0.01 mm/hr. A minimum value for d_k of 0.01 km is used in CALMET to avoid computational problems associated with division by zero when the observation station is located at a grid point.

If there are no precipitation stations with valid data for a particular hour, CALMET sets the precipitation rate to zero and prints a warning message to the output list file (CALMET.LST). It is recommended that the user resolve periods with no valid data by the acquisition of additional observational data or by a case-by-case analysis of other meteorological records to confirm that no precipitation occurred during the period.

The third option in CALMET for interpolation of precipitation data is to use a combined $1/d^2$-exponential weighting function, i.e.,

$$R_{i,j} = \frac{\sum_K \frac{R_k \cdot e^{-d_k^2/\sigma^2}}{d_k^2}}{\sum_K \frac{e^{-d_k^2/\sigma^2}}{d_k^2}} \qquad (2\text{-}65)$$

where σ is a distance weighting factor (km), and the other variables are as defined above.

The $1/d^2$-exponential weighting option is selected by setting NFLAG = 3 in the CALMET control file. In this instance, the "radius of influence" concept is replaced by the exponential weighting factor. The variable SIGMAP in the control file is used to specify the value of σ. The minimum values of d and $r_{i,j}$ discussed above also apply if Eqn. (2-65) is used.

The user has the option to internally compute the distance weighting factor, σ, dynamically by setting the value of SIGMAP to zero in the control file. CALMET will compute σ each hour as one-half the minimum distance between any two observational stations with non-zero precipitation rates.

3. CALMET MODEL STRUCTURE

3.1 Memory Management

A flexible memory management system is used in CALMET which facilitates the user's ability to alter the dimension of the major arrays within the code. Arrays dealing with the number of horizontal or vertical grid cells, meteorological stations, barriers, land use types, and several other internal parameters are dimensioned throughout the code with parameter statements. The declaration of the values of the parameters are stored in a file called "PARAMS.MET." This file is automatically inserted into any CALMET subroutine or function requiring one of its parameters via FORTRAN "include" statements. Thus, a global redimensioning of all of the model arrays dealing with the number of vertical layers, for example, can be accomplished simply by modifying the PARAMS.MET file and recompiling the program.

The parameter file contains variables which set the array dimensions or the maximum allowed number of vertical layers, or horizontal grid cells, etc. The actual value of the variables for a particular run is set within the user input file (i.e., the control file), and can be less than or equal to the maximum value set by the parameter file.

A sample parameter file is shown in Table 3-1. In addition to the parameters specifying the maximum array dimensions of the major model arrays, the parameter file also contains variables determining the Fortran I/O unit numbers associated with each input and output file. For example, the input control file (IO5) and output list file (IO6) are associated with unit numbers 5 and 6. However, if these units are reserved on a particular computer system, these files can be redirected to other non-reserved units by setting IO5 and IO6 equal to 15 and 16, for example, in the PARAMS.MET file.

3.2 Structure of the CALMET Modules

Execution of the CALMET model is divided into three major phases: setup, computational, and termination (see Figure 3-1). In the setup phase of the model execution, a variety of initialization and one-time I/O and computational operations are performed, including the following:

Table 3-1
Sample CALMET Parameter File

```
c----------------------------------------------------------------------
c --- PARAMETER statements -- CALMET model
c----------------------------------------------------------------------
c
c --- Specify parameters
      parameter(mxnx=75,mxny=75,mxnz=10)
      parameter(mxss=90,mxus=10,mxps=10,mxows=10)
      parameter(mxlev=79,mxlu=52)
      parameter(mxbar=20, mxbox=10, mxwb=1)
      parameter(mxsg=9,mxvar=60,mxcol=132)
      parameter(mxnxp=30,mxnyp=30,mxnzp=20)
      parameter(io5=15,io6=16)
      parameter(io2=2,io7=7,io8=8,io10=10,io12=12)
      parameter(io30=60)
      parameter(io40=40,io41=41,io42=42,io43=43,io44=44,io45=45)
      parameter(io50=50)
      parameter(io98=98)
      parameter(io99=99)
c
c --- Compute derived parameters
      parameter(mxwnd=mxss+mxus+mxows)
      parameter(mxtmp=mxss+mxows)
      parameter(mxnzp1=mxnz+1)
      parameter(mxxy=mxnx*mxny)
      parameter(mxbxwnd=mxwnd*mxbox)
      parameter(mxxyz=mxnx*mxny*mxnz)
      parameter(mxadd=mxlev+mxnzp1)
      parameter(mxwk3=mxwnd+2*mxnz+3)
c
c --- GENERAL GRID and MET. definitions:
c       MXNX    - Maximum number of X grid cells
c       MXNY    - Maximum number of Y grid cells
c       MXNZ    - Maximum number of layers
c       MXSS    - Maximum number of surface meteorological stations
c       MXUS    - Maximum number of upper air stations
c       MXPS    - Maximum number of precipitation stations
c       MXOWS   - Maximum number of overwater stations
c       MXBAR   - Maximum number of barriers allowed
c       MXWB    - Maximum number of water bodies that will be treated
c                 separately in the temperature interpolation (currently
c                 must be 1)
c       MXLEV   - Maximum number of vertical levels in upper air
c                 data input files
c       MXLU    - Maximum number of land use categories
c       MXNXP   - Maximum number of X grid cells in the prognostic
c                 wind model's grid
c       MXNYP   - Maximum number of Y grid cells in the prognostic
c                 wind model's grid
c       MXNZP   - Maximum number of layers in the prognostic
c                 wind model's grid
c
c --- CONTROL FILE READER definitions:
c       MXSG    - Maximum number of input groups in control file
c       MXVAR   - Maximum number of variables in each input group
c       MXCOL   - Maximum length (bytes) of a control file input record
c
c --- FORTRAN I/O unit numbers:
c       IO5     - Control file (CALMET.INP)     - input  - formatted
c
c       IO6     - List file (CALMET.LST)        - output - formatted
c
c       IO2     - Preprocessed met. data for    - input  - formatted
c                 diagnostic wind module
c                 (DIAG.DAT)
c
```

Table 3-1
Sample CALMET Parameter File (Concluded)

```
c       IO7     - Gridded wind & met. fields    - output - unformatted
c                 produced by CALMET
c                 (CALMET.DAT or PACOUT.DAT)
c
c       IO8     - Geophysical data fields       - input  - formatted
c                 (GEO.DAT)
c
c       IO10    - Hourly surface observations   - input  - formatted or
c                 (SURF.DAT)                               unformatted
c
c       IO12    - Hourly precipitation data     - input  - formatted or
c                 (PREC.DAT)                               unformatted
c
c       IO30    - Upper air data observations   - input  - formatted
c                 for upper air station #1
c                 (UP1.DAT)
c       IO30+1  - Same as IO30 except for upper
c                 air station #2
c                 (UP2.DAT)
c                 ...
c       (Repeated for each of "NUSTA" upper air station, i.e., Fortran
c        units IO30 to IO30+NUSTA-1 are used for upper air data files)
c       (Upper air file names are UP1.DAT, UP2.DAT, ... UP(# of stns).DAT)
c
c       IO40    - Gridded fields of prognostic  - input  - unformatted
c                 wind fields to use as input              (PROG.DAT)
c                 to the diagnostic model                     or
c                 (PROG.DAT or MM4.DAT)                    formatted
c                                                          (MM4.DAT)
c --- WIND FIELD MODEL TESTING AND DEBUG OUTPUT FILES
c       IO41    - Intermediate winds and misc.  - output - formatted
c                 input and internal variables
c                 (TEST.PRT)
c       IO42    - Final wind fields             - output - formatted
c                 (TEST.OUT)
c       IO43    - Winds after kinematic effects - output - formatted
c                 (TEST.KIN)
c       IO44    - Winds after Froude number     - output - formatted
c                 effects (TEST.FRD)
c       IO45    - Winds after slope flow        - output - formatted
c                 effects (TEST.SLP)
c
c       IO50    - Overwater meteorological data - input  - formatted
c                 for station #1
c                 (SEA1.DAT)
c       IO50+1  - Same as IO50 except for
c                 overwater station #2
c                 (SEA2.DAT)
c                 ...
c       (Repeated for each of "NOWSTA" overwater station, i.e., Fortran
c        units IO50 to IO50+NOWSTA-1 are used for overwater data files)
c       (Overwater file names are SEA1.DAT, SEA2.DAT,...SEA(# of stns).DAT)
c
c       IO98    - Scratch file for use in READCF to replace internal read to
c                 allow wider compatibility with compilers
c       IO99    - Gridded weighting factors     - input  - formatted
c                 for surface station data vs prognostic data
c                 (WT.DAT)
```

Start
•
•
•
•
SETUP - Setup phase - Initialization and program setup operations.
•
•
COMP - Computational phase - basic time loop with time-dependent I/O and all scientific modules.
•
•
•
FIN - Termination phase - program termination functions.
•
•
•
STOP

Figure 3-1. Flow diagram showing the subroutine calling sequence in the CALMET MAIN program.

- Opening of input and output files.

- Reading and processing the control file inputs which includes model option flags and run control variables.

- Reading and processing the header records of data files of the model's input data bases (i.e., surface, upper air, precipitation, and over water meteorological data files, optional prognostic model wind fields, geophysical data file).

- Performing consistency checks of the input data base information versus the control file inputs.

- Performing initialization and setup operations for the diagnostic wind field module and boundary layer modules.

- Writing the header records to the model's output file.

The computational phase of the model includes the basic time loop within which the hourly gridded wind fields and micrometeorological variables are computed. The functions performed in the computation phase include the following:

- Retrieving and processing of the surface, upper air, precipitation, and over water meteorological data and optional prognostic wind field data from the appropriate input files.

- Computing the Step 1 wind field either by (a) adjusting a domain-mean wind field for slope flow effects, kinematic terrain effects, terrain blocking influences, and divergence reduction, or, (b) interpolating an input gridded prognostic wind field to the CALMET grid system.

- Computing the final (Step 2) wind field by executing an objective analysis procedure combining observational data with the Step 1 wind field.

- Computing the micrometeorological parameters at grid points over water with the overwater (profile method) boundary layer model.

- Computing the micrometeorological parameters at grid points overland with the overland (energy balance method) boundary layer model.

- If appropriate, computing the gridded precipitation data field.

- If appropriate, computing the three-dimensional temperature field.

- Printing and/or writing of gridded hourly wind fields to the output list file and the unformatted output file.

The final phase of the model execution deals with run termination functions. The termination phase includes the closing of any active data files, computation of model run time, and printing of summary or normal termination messages.

A flow diagram for the setup module is provided in Figure 3-2. The flow diagram contains the name of each subroutine or function called by the setup module along with a brief description of the routine's purpose. Figure 3-3 is a flow diagram for the main computational routine, subroutine COMP, which contains the basic time loop and calls to the wind field module.

The main routine for the wind field module is subroutine DIAGNO. A flow diagram for DIAGNO is shown in Figure 3-4.

Enter SETUP

•
•
•

DATETM - Get date and time from the system clock.

•
•

OPENFL - Open control file (input) and list file (output).

•
•

READCF - Read the control file inputs.

•
•

OPENOT - Open all other input and output files.

•
•

READGE - Read the geophysical data file (GEO.DAT).

•
•

SETCOM - Set miscellaneous common block parameters.

•
•

READHD - Read the header records of the input meteorological data files and perform consistency checks with the control file inputs.

•
•
•

MICROI - Perform setup computations for the boundary layer models.

•
•

DIAGI - Perform setup computations for the diagnostic wind field module.

•
•

OUTHD - Write the header records to the unformatted CALMET output file.

or

OUTPC1 - Write the header records to the unformatted MESOPAC II output file.

•
•

RDWT - Read sigma weighting factors if using MM4-FDDA prognostic data as Step 1 field "observations" otherwise fill with default factors.

•
•
•

Return to MAIN PROGRAM

Figure 3-2. Flow diagram showing the subroutine/function calling sequence in the subroutine SETUP (Setup Phase).

```
Enter COMP
  •
  •
Begin Loop Over Days
    •
    •
    GRDAY  - Convert the Julian date to a Gregorian date.
    •
    SOLAR  - Compute solar elevation angle at the surface meteorological stations for
    •        midpoint of each hour of the day.
    •
    Begin Loop Over Hours
        •
        •
        RDS     -  Read surface meteorological data at all stations for the
        •          current hour.
        •
        MISSFC  -  Replace missing surface data.
        •
        RDP     -  Read precipitation data at all stations for the current hour.
        •
        RDOW    -  Update over water data for each appropriate station for
        •          the current hour.
        •
        DIAG2   -  Perform setup computations for overwater stations for the
        •          diagnostic wind field module.
        •
        INDECR  -  Convert the current date/hour from local time to GMT.
        •
        Begin Loop Over Upper Air Stations
            •
            •
            RDUP    - At appropriate time, read a new sounding.
            •
            DEDAT   - Convert the upper air date/time to a single coded
            •         integer.
            •
            DELTT   - Compute the time separation of the two upper air
            •         soundings.
            •
            VERTAV  - If new sounding is read, perform vertical
            •         averaging of winds through depth of CALMET
            •         layers.
            •
            FACET   - If computing 3-d temperature fields, calculate the
            •         temperatures at the grid cell faces at the upper air
            •         station sites.
            •
        End Loop Over Upper Air Stations
        •
        •
```

Figure 3-3. Flow diagram showing the subroutine/function calling sequence in the subroutine COMP (Computational Phase).

PREPDI - Perform time-interpolation of upper air wind data or read hourly preprocessed meteorological inputs.
•
•

DIAGNO - Compute gridded wind fields using diagnostic wind field model.
•

OUT - Write the gridded wind fields to the output list file (CALMET.LST).
•
•

WATER - Compute all boundary layer parameters and stability class at grid points over water using profile method.
•
•

PGTSTB - Compute PGT stability class at grid points over land.
•

OUT - Write the gridded PGT stability class field to the output list file (CALMET.LST).
•
•

HEATFX - Compute the sensible heat flux at grid points over land using the energy balance method.
•
•

AIRDEN - Compute the air density at surface meteorological stations.
•

ELUSTR - Compute the friction velocity and Monin-Obukhov length at grid points over land.
•
•

OUT - Write the gridded fields of sensible heat flux, friction velocity, and Monin-Obukhov length to the output list file (CALMET.LST).
•
•
•

MIXHT - Compute the mixing height at grid points over land.
•

AVEMIX - Compute spatially averaged mixing heights (If IAVEZI=1).
•

OUT - Write the gridded fields of mixing height and convective mixing height to the output list file (CALMET.LST).
•
•

WSTARR - Compute the convective velocity scale at grid cells over land.
•

OUT - Write the gridded field of convective velocity scale to the output list file (CALMET.LST).
•
•

GRIDE - Compute a gridded field of precipitation rates (all grid cells).
•

OUT - Write the gridded field of precipitation rates to the output list file (CALMET.LST).
•
•

(Figure 3-3 Continued)

```
|    |                      TEMP3D  -  Compute the 3-D temperature field (If LCALGRD=T).
|    |                        .
|    |                      AVETMP  -  Compute spatially averaged temperatures (If IAVET=1).
|    |                        .
|    |                      OUT     -  Write the 3-D temperature field to the output list file
|    |                        .        (CALMET.LST).
|    |                        .
|    |                      OUTHR   -  Output the meteorological fields to the output disk file
|    |                                 (CALMET.DAT).
|    |                        OR
|    |
|    |                      PACAVE  -  Vertically average winds into MESOPAC II layers
|    |                        .
|    |                      OUTPC   -  Output the meteorological fields to the output disk file
|    |                        .        (PACOUT.DAT).
|    |                        .
|    |-------          End Hour Loop
|                          .
|                          .
|------  End Day Loop
                           .
                           .
         Return to MAIN PROGRAM
```

(Figure 3-3 Concluded)

```
        Enter DIAGNO
          •
          •
        If using objective analysis only (IWFCOD=1), go to A.
          •
          •
        Set up initial guess field as one of the following:
              (1) uniform or spatially varying initial guess field based on upper air stations
              (2) PROGRD     - Read and interpolate CSUMM prognostic model winds to
                               CALMET grid system (if IWFCOD=1 and IPROG=2)
              (3) RDMM4      - Read and interpolate MM4-FDDA prognostic model winds to
                               CALMET grid system (if IWFCOD=1 and IPROG=4)
              (4) WIND1      - Compute spatially-varying initial guess field with observed data
              (5) use preprocessed values from the DIAG.DAT file as the uniform initial guess field
          •
          •
 ┌──── Begin Loop Over Layers
 │                •
 │                •
 │            WINDBC - Set boundary conditions.
 │                •
 │                •
 └──── End Loop Over Layers
          •
          •
        XMIT          - Initialize the vertical velocities.
          •
          •
        TOPOF2        - Compute vertical velocities due to kinematic terrain effects (if
          •             IKINE=1).
          •
          •
        MINIM         - Minimize divergence (if IKINE=1).
          •
          •
        WINDPR      - Print gridded maps of U,V,W wind fields after kinematic effects to
          •             the output file TEST.PRT (if IPR5=1).
          •
          •
        OUTFIL        - Write gridded U,V, W wind fields to the output file TEST.KIN
          •             (if IPR5=1 and IOUTD=1).
          •
          •
        SLOPE         - Compute slope flows.
          •
          •
        Add slope flow components to the horizontal winds.
          •
          •
```

(Continued)
Figure 3-4. Flow diagram showing the subroutine calling sequence in the major wind field computational routine (subroutine DIAGNO).

WINDPR2 - Print a gridded map of U,V wind fields after slope flow effects to the output file TEST.PRT (if IPR7=1).

•
•
•

OUTFIL - Write gridded U,V fields in F7.2 format and W fields in E8.2 format to the output file TEST.SLP (if IPR7=1 and IOUTD=1).

•
•
•

FRADJ - Apply the Froude number adjustment procedure to evaluate terrain blocking effects (if IFRADJ=1).

•
•
•

WINDPR2 - Print a gridded map of U,V fields after Froude number effects to the output file TEST.PRT (if IPR6=1).

•
•
•

OUTFIL - Write gridded U,V wind fields in F7.2 format and W winds in E8.2 format to the output file TEST.FRD (if IPR6=1 and IOUTD=1).

•
•
•

WINDBC - Recompute boundary conditions (Final diagnostic Step 1 wind field).

•
•

A→ •

•
•

Extrapolate surface data to higher layers (if IEXTRP≠1).

•
•

PROGRD - Read and interpolate the CSUMM prognostic model results to CALMET grid system (Final prognostic Step 1 wind field) (if IPROG=1 and IWFCOD=0).

OR

RDMM4 - Read and interpolate the MM4-FDDA prognostic model results to CALMET grid system (if IPROG=3 and IWFCOD=0 or if IPROG=5).

•
•
•

INTER2 - Perform objective analysis procedure if Step 1 winds were derived from the diagnostic module.

•
•
•

INTERP - Perform objective analysis procedure if Step 1 winds were derived from gridded prognostic model results.

•
•
•

LLBREEZ - Lake breeze region calculations.

•
•

WNDPR2 - Print gridded maps of interpolated U,V wind fields (if IPRO > 0).

•
•

ADJUST - Adjust surface layer winds for terrain effects.

•
•

(Figure 3-4 Continued)

WINDBC - Recompute the boundary conditions.

•
•

WNDPR2 - Print gridded maps of the adjusted U,V wind fields (if IPR1 > 0).

•
•

SMOOTH - Perform smoothing of the wind fields.

•

DIVCEL - Compute the 3-D divergence fields and vertical velocities.

•
•

WINDBC - Recompute the boundary conditions.

•
•

Apply the O'Brien procedure to adjust the vertical velocity field (if IOBR=1).

•
•

WINDPR - Print gridded maps of the U,V,W wind fields to the output file TEST.PRT (if IPR2>0).

•
•
•

DIVPR - Print the divergence fields to the output file TEST.PRT (if IPR2>0).

•
•

MINIM - Minimize divergence (if IOBR=1).

•
•

WINDPR - Print gridded maps of the final U,V,W wind fields to the output file TEST.PRT (if IPR8>0).

•
•
•

DIVPR - Print the final divergence fields to the output file TEST.PRT (if IPR4>0).

•
•
•

RTHETA - Output the final wind speed and wind direction fields to the output file TEST.PRT (if IPR3>0).

•
•
•

OUTFIL - Write the final U,V fields in F7.2 format and W fields in E8.1 format to the output file TEST.OUT (if IPR8>0 and IOUTD>0).

•
•
•

Return to COMP

Figure 3-4. Concluded.

4. USER INSTRUCTIONS

4.1 Preprocessor Programs

4.1.1 READ56/READ62 Upper Air Preprocessors

READ56 and READ62 are preprocessing programs which extract and process upper air wind and temperature data from standard NCDC data formats into a form required by the CALMET meteorological model. READ56 operates on the older TD-5600 data format. Although this format is not currently used by NCDC, many historical data sets contain data in this format. READ62 processes data in the current TD-6201 format or the NCDC CD-ROM FSL rawinsonde data format. Note that the user must specifically request the TD-6201 format when ordering upper air data from NCDC.

Although the data inputs are different, the user inputs to the program are identical as is the processed output file. In the user input file, the user selects the starting and ending dates of the data to be extracted and the top pressure level. Also selected are processing options determining how missing data are treated. The programs will flag or eliminate sounding levels with missing data.

If the user selects the option to flag (rather than eliminate) levels with missing data, the data field of the missing variables are flagged with a series of nines. If the option to eliminate levels with missing data is chosen, only sounding levels with all values valid will be included in the output data file.

Although CALMET allows missing values of wind speed, wind direction, and temperature at intermediate levels (i.e., levels other than the surface and model top), the user is cautioned against using soundings with significant gaps due to missing data. For example, adequate vertical resolution of the morning temperature structure near the surface is especially important to the model for predicting daytime mixing heights. It should be kept in mind that the model will fill in missing data by assuming that a straight-line interpolation between valid levels is appropriate. If this assumption is questionable, the sounding should not be used with the model.

Two input files are required by the preprocessor: a user input control file and the NCDC upper air data file. Two output files are produced: a list file summarizing the user option selected and missing data monitored and the processed data file in CALMET format. Table 4-1 contains a listing of the input and output files for READ56 and READ62.

The READ56/READ62 control file consists of two lines of data entered in FORTRAN free format. A description of each input variable is shown in Table 4-2. A sample input file is shown in Table 4-3. The output list file is shown in Table 4-4. In the list file, the user's inputs are printed as well as a summary of the soundings processed. Informational messages indicating problems in the data set are written in the summary.

The output data file (UP.DAT) produced by READ56/READ62 is a formatted file containing the pressure, elevation, temperature, wind speed, and wind direction at each sounding level. The contents and format of the UP.DAT file are discussed in Section 4.2.3.

Table 4-1

READ56/READ62 Input and Output Files

(a) READ56 Input and Output Files

Unit	File Name	Type	Format	Description
5	READ56.INP	input	formatted	Control file containing user inputs
6	READ56.LST	output	formatted	List file (line printer output file)
8	TDF56.DAT	input	formatted	Upper air data in NCDC TD-5600 format
9	UP.DAT*	output	formatted	Output file containing processed upper air data in format required by CALMET

(b) READ62 Input and Output Files

Unit	File Name	Type	Format	Description
5	READ62.INP	input	formatted	Control file containing user inputs
6	READ62.LST	output	formatted	List file (line printer output file)
8	TD6201.DAT	input	formatted	Upper air data in NCDC TD-6201 format
9	UP.DAT*	output	formatted	Output file containing processed upper air data in format required by CALMET

---

* Should be renamed UP1.DAT (for upper air station #1), UP2.DAT (for station #2), etc. for input into the CALMET model.

Table 4-2

READ56/READ62 Control File Inputs

RECORD 1. **Starting and ending date/hour, top pressure level to extract.**

Columns	Variable	Type	Description
*	IBYR	integer	Starting year of data to extract (two digits)
*	IBDAY	integer	Starting Julian day
*	IBHR	integer	Starting hour (00 or 12 GMT)
*	IEYR	integer	Ending year of data to extract (two digits)
*	IEDAY	integer	Ending Julian day
*	IEHR	integer	Ending hour (00 or 12 GMT)
*	PSTOP	real	Top pressure level (mb) for which data are extracted (possible values are 850 mb, 700 mb, or 500 mb). The output file will contain data from the surface to the "PSTOP"-mb pressure level.
*	JDAT	integer	Input file format (1 = TD6201 2 = NCDC CD-ROM)

---

[*] Entered in FORTRAN free format

Table 4-2 (Concluded)

READ56/READ62 Control File Inputs

RECORD 2. Missing data control variables.

Columns	Variable	Type	Description
*	LHT	logical	Height field control variable. If LHT = T, a sounding level is eliminated if the height field is missing. IF LHT = F, the sounding level is included in the output file but the height field is flagged with a "9999", if missing.
*	LTEMP	logical	Temperature field control variable. If LTEMP = T, a sounding level is eliminated if the temperature field is missing. If LTEMP = F, the sounding level is included in the output file but the temperature field is flagged with a "999.9", if missing.
*	LWD	logical	Wind direction field control variable. If LWD = T, a sounding level is eliminated if the wind direction field is missing. If LWD = F, the sounding level is included in the output file but the wind direction field is flagged with a "999", if missing.
*	LWS	logical	Wind speed field control variable. If LWS = T, a sounding level is eliminated if the wind speed is missing. If LWS = F, the sounding level is included in the output file but the wind speed field is flagged with a "999", if missing.

---

* Entered in FORTRAN free format

Table 4-3

Sample READ56/READ62 Control File (READ56.INP, READ62.INP)

```
89, 001, 00, 89, 015, 12, 500. -- Beg. yr, day, hr(GMT), Ending yr, day, hr, top pressure level
.FALSE., .FALSE., .FALSE., .FALSE. -- Eliminate level if height, temp., wind direction, wind speed missing?
```

Table 4-4

Sample READ62 Output List file

```
                    READ62   VERSION 4.0      LEVEL 901130

STARTING DATE:                 ENDING DATE:

              YEAR =   89                YEAR =   89
        JULIAN DAY =    1          JULIAN DAY =   15
              HOUR =    0 (GMT)          HOUR =   12 (GMT)


PRESSURE LEVELS EXTRACTED:

                    SURFACE TO   500. MB


DATA LEVEL ELIMINATED IF HEIGHT MISSING ?         F

DATA LEVEL ELIMINATED IF TEMPERATURE MISSING ?    F

DATA LEVEL ELIMINATED IF WIND DIRECTION MISSING ? F

DATA LEVEL ELIMINATED IF WIND SPEED MISSING ?     F


THE FOLLOWING SOUNDINGS HAVE BEEN PROCESSED:

      YEAR   MONTH   DAY   JULIAN DAY   HOUR (GMT)   NO. LEVELS EXTRACTED

       89      1      1        1           0                 12
       89      1      1        1          12                 16
       89      1      2        2           0                 17
       89      1      2        2          12                 15
       89      1      3        3           0                 15
       89      1      3        3          12                 18
       89      1      4        4           0                 18
       89      1      4        4          12                 24
       89      1      5        5           0                 19
       89      1      5        5          12                 23
       89      1      6        6           0                 15
       89      1      6        6          12                 17
       89      1      7        7           0                 16
       89      1      7        7          12                 13
       89      1      8        8           0                 16
       89      1      8        8          12                 24
       89      1      9        9           0                 28
       89      1      9        9          12                 20
       89      1     10       10           0                 16
       89      1     10       10          12                 17
       89      1     11       11           0                 13
       89      1     11       11          12                 18
       89      1     12       12           0                 16
       89      1     12       12          12                 24
       89      1     13       13           0                 22
       89      1     13       13          12                 21
       89      1     14       14          12                 20
->->->MISSING/DUPLICATE SOUNDING
       89      1     15       15           0                 14
       89      1     15       15          12                 15
                   EOF ON INPUT
                   LAST DAY READ =  89015
```

4.1.2 METSCAN Surface Data QA Program

METSCAN is a meteorological preprocessing program which screens a data file containing hourly surface observations for missing, duplicate, or invalid data. METSCAN operates on a data file in the NCDC 80-Column format (CD-144) or the NCDC CD-ROM surface data format. The program performs quality assurance checks on the wind speed, wind direction, temperature, opaque cloud cover, ceiling height and relative humidity fields. The value of each variable is compared to an allowed range (e.g., wind direction in tens of degrees must be within the range from 0-36). Consistency checks are performed between the cloud cover and ceiling height variables (e.g., only an "unlimited" ceiling height is allowed under clear conditions). In addition, large hourly changes in temperature and relative humidity are flagged.

METSCAN flags records if any meteorological variable checked is outside its "normal" range. A warning message is written indicating which variable is triggering the flag, followed by the CD144 data record read from the file.

Two input files are required by METSCAN: a user input control file (METSCAN.INP) and the NCDC 80-column surface data file (CD144.DAT). The program writes the warning messages to an output file (METSCAN.LST). The contents and format of the METSCAN input and output files are summarized in Table 4-5.

The METSCAN control file uses the FORTRAN Namelist input format. The variables in the control file allow the user to set the variable ranges so that excessive spurious warning messages can be avoided. A description of each METSCAN input variable is contained in Table 4-6. A sample input file is shown in Table 4-7.

The user should check each warning message written to the output list file (METSCAN.LST) to see if the data flagged are valid. A sample output file containing typical warning messages is shown in Table 4-8. It should be noted that an error in the date/hour field of a data record, indicating a missing or duplicate record, will produce a fatal error resulting in the termination of the METSCAN run.

Table 4-5

METSCAN Input and Output Files

Unit	File Name	Type	Format	Description
5	METSCAN.INP	input	formatted	Control file containing user inputs
6	METSCAN.LST	output	formatted	List file (line printer output file)
8	CD144.DAT	input	formatted	Surface data in NCDC 80-column (CD-144) format

Table 4-6

METSCAN Control File Inputs (Namelist Format)

NAMELIST: OPTS

Variable	Type	Description	Default Value
ID	integer	Station ID (5 digits)	*
IYR	integer	Year of data (2 digits)	*
IEXPMO	integer	Month of first record	1
IEXPDY	integer	Day of first record	1
IEXPHR	integer	Hour of first record	0
JWSMN	integer	Minimum (non-calm) wind speed (knots) allowed (calm, i.e., WS=0, WD=0 is allowed)	2
JWSMX	integer	Maximum wind speed (knots) allowed**	40
JTMIN	integer	Minimum temperature allowed** (deg. F)	0
JTMX	integer	Maximum temperature allowed** (deg. F)	100
JDELT	integer	Maximum hourly change in temperature allowed** (deg. F)	15
JTOLD	integer	Temperature (deg. F) for the hour preceding the first hour of the data file (used to evaluate the hourly temperature change for the first hour of the run)	*
IDELT	integer	Maximum hourly change in relative humidity allowed** (%)	20
JRHOLD	integer	Relative humidity (%) for the hour preceding the first hour of the data file (used to evaluate the hourly relative humidity change for the first hour of the run)	60
JCMX	integer	Maximum ceiling height allowed** (hundreds of feet)	350
MINCC	integer	Maximum opaque sky cover (tenths) allowed** for unlimited ceiling conditions	3
JRHMIN	integer	Minimum relative humidity (percent) allowed**	10
IHROP(0:23)	integer array	Hours of operation for the station (0=not operating, 1=operating)	24*1
JDAT	integer	Input data file format (1 = CD144, 2 = NCDC CD-ROM)	*

---

* Indicates that no default value is provided.

** A warning message is issued when variable is outside the "allowed" range. The user must determine if the flagged data are actually invalid, and if so, correct the CD144 file.

Table 4-7

Sample METSCAN Control File (METSCAN.INP)

```
&OPTS ID=23023, IYR=89, IEXPHR=0, JTOLD=35, JTMX=105, JRHMIN=5, &END
```

Table 4-8

Sample METSCAN Output List File (METSCAN.LST)

```
RUNTIME CALL NO.:       1  DATE: 04/01/94  TIME: 12:55:38.59

data checked for station: 23023  year: 89


 &OPTS ID=23023,IYR=89,IEXPMO=1,IEXPDY=1,IEXPHR=0,JWSMN=2,JWSMX=40,
JTMX=105,JTMIN=0,JDELT=15,JTOLD=35,MINCC=3,JCMX=350,IHROP=1,1,1,1,1,1,
1,1,1,1,1,1,1,1,1,1,1,1,1,1,1,1,1,1,JRHMIN=5 &END

delta temp. flag -- jtemp =  55  jtold =  39  jdelt =  15
2302389 1 610---                    28 4    55    40                     0

delta temp. flag -- jtemp =  47  jtold =  32  jdelt =  15
2302389 11510250                    28 4    47    34                     6

last time period processed: jyr = 89  jmo =  1  jday = 16  jhr =  0


RUNTIME CALL NO.:       2  DATE: 04/01/94  TIME: 12:55:39.57
DELTA TIME:      0.98 (SEC)
```

4.1.3 SMERGE Surface Data Meteorological Preprocessor

SMERGE processes and reformats hourly surface observations, and creates either a formatted or an unformatted, binary file which is used as input by the CALMET model. SMERGE reads "N" data files containing surface data in NCDC 80-column format (CD144 format) or NCDC CD-ROM format. The output file (SURF.DAT) contains the processed hourly data for all the stations. SMERGE can also add stations to an existing formatted or unformatted output file. A free-formatted SURF.DAT file can be created by the user and read by CALMET. This option relieves the user of the need to run the preprocessor for short CALMET runs for which the input data can easily be input manually.

SMERGE extracts the following variables from the NCDC surface data files: wind speed, wind direction, air temperature, ceiling height, cloud cover, surface pressure, relative humidity, and precipitation type code.

An option is provided to allow the surface data stored in the unformatted output file to be "packed." Packing reduces the size of the data file by storing more than one variable in each word. If the packing option is used, the eight hourly meteorological variables for each station are stored in three words:

Word 1: TTTTPCRRR -- TTTT = temp. (XXX.X deg, K)
PC = precipitation code (XX)
RRR = relative humidity (XXX. %)

Word 2: pPPPPCCWWW -- pPPPP = station pressure (pXXX.X mb, with p = 0 or 1 only)
CC = opaque sky cover (XX tenths)
WWW = wind direction (XXX. deg.)

Word 3: HHHHSSSS -- HHHH = ceiling height (XXXX. hundreds of feet)
SSSS = wind speed (XX.XX m/s)

For example, the following variables,

Temperature = 273.5 deg. K
Precipitation code = 12
Relative humidity = 88 percent
Station pressure = 1012.4 mb
Opaque sky cover = 8 tenths
Wind direction = 160 degrees
Ceiling height = 120 hundreds of ft
Wind speed = 5.65 m/s

are stored as the following three integer words:

273512088, 1012408160, 01200565

All of the packing and unpacking operations are performed internally by SMERGE and CALMET, and are transparent to the user. The header records of the data file contain information flagging the file to CALMET as a packed or unpacked file. If the user selects the unpacked format, eight full 4-byte words are used to store the data for each station.

The input files used by SMERGE consist of a control file (SMERGE.INP) containing user inputs, up to 150 surface data files (one per surface station), and an optional unformatted SMERGE data file created in a previous run of SMERGE. The data from the formatted surface station files are combined with the data in the existing unformatted file. A new unformatted output file containing all the data is created by the program. In addition, SMERGE creates an output list file (SMERGE.LST) which summarizes the user options and run time statistics. Table 4-9 contains a listing of the input and output files used by SMERGE.

The SMERGE control file consists of one line of generated run data (number and type of input data files, time zone of output data, packing flag), station data (one line per station), and a final line containing the starting and ending dates and times to extract. A sample SMERGE control file is shown in Table 4-10. The format and contents of the SMERGE control file are explained in Table 4-11.

The SMERGE output list file (SMERGE.LST) contains a summary of the control file inputs, characteristics of the output unformatted data file, and routine statistics. A sample output list file is shown in Table 4-12.

Table 4-9

SMERGE Input and Output Files

Unit	File Name	Type	Format	Description
3	SURFIN.DAT	input	unformatted or formatted	Existing SMERGE data file to which stations are to be added (Used only if NSF=1)
4	SURF.DAT	output	unformatted or formatted	Output data file created by SMERGE containing the processed hourly surface data (SURF.DAT is an input file to CALMET)
5	SMERGE. INP	input	formatted	Control file containing user inputs
6	SMERGE.LST	output	formatted	List file (line printer output file)
7	user input file name	input	formatted	Surface data in NCDC 80-column (CD144) format for station #1
8	user input file name	input	formatted	Surface data in NCDC 80-column (CD144) format for station #2

.
.
.

(Up to 150 new surface data files are allowed by SMERGE, although this may be limited by the number of files an operating system will allow open at one time. Multiple runs of SMERGE may be necessary.)

Table 4-10

Sample SMERGE Control File Inputs

(SMERGE.INP)

```
  6   0   6   2   0    -- # stations,# binary files,base time zone,output fmt(1=binary,2=formatted),pack(0=no,1=yes)--free fmt
cd144.in1  23023  6    -- File name, station ID, station time zone                         -- (A10,1x,I5,1x,i2)
cd144.in2  12921  6    -- File name, station ID, station time zone                         -- (A10,1x,I5,1x,i2)
cd144.in3  23034  6    -- File name, station ID, station time zone                         -- (A10,1x,I5,1x,i2)
cd144.in4  23044  7    -- File name, station ID, station time zone                         -- (A10,1x,I5,1x,i2)
cd144.in5  72261  6    -- File name, station ID, station time zone                         -- (A10,1x,I5,1x,i2)
cd144.in6  72252  6    -- File name, station ID, station time zone                         -- (A10,1x,I5,1x,i2)
89 01 01 00 89 01 15 23 -- Starting yr, month, day, hour, ending yr, month, day, hour      -- (8(I2,1x))
```

Table 4-11

SMERGE Control File Inputs

RECORD 1. General run information.

Columns	Format*	Variable	Description
1-4	I4	NFF	Number of formatted 80-column NCDC input files to be processed (up to 150)
5-8	I4	NSF	Flag indicating if data are to be added to an existing formatted surface data file (0=no, 1=yes)
9-12	I4	IOTZ	Time zone of output data (05=EST, 06=CST, 07=MST, 08=PST)
13-16	I4	IOFORM	Output file format flag (1=unformatted (binary), 2=formatted)
17-20	I4	IOPACK	Flag indicating if output data are to be packed (0=no, 1=yes)
21-24	I4	JDAT	Formatted input data file format (1 = CD144, 2 = NCDC CD-ROM)

---

* Record format is (6i4)

Table 4-11

SMERGE Control File Inputs

RECORD 2, 3, ...1+NFF. File names, station ID, time zone. Each record has the following format)

Columns	Format*	Variable	Description
1-10	A10	CFFILES	Name of file containing formatted surface station data
12-16	I5	IFSTN	Station ID number
18-19	I2	ISTZ	Time zone of station (05=EST, 06=CST, 07=MST, 08=PST)

---

* Record format is (a10,1x,i5,1x,i2)

Table 4-11

SMERGE Control File Inputs

NEXT RECORD. Used <u>only</u> if reading data from a binary input file (NSF=1)

Columns	Format*	Variable	Description
1-2	I2	INFORM	Existing surface data file format (1 = binary, 2 = formatted)
3-6	I4	NBSTN	Number of station requested from binary input file (-999=use all stations in binary file)

NEXT RECORDS. Used <u>only</u> if (NSF=1 and NBSTN≠ -999) (Record repeated NBSTN times)

Columns	Format*	Variable	Description
1-5	I5	IBSTN	Station ID number for station requested from binary input file

Table 4-11 (Concluded)

SMERGE Control File Inputs

NEXT RECORD. **Starting/ending dates and times.**

Columns	Format*	Variable	Description
1-2	I2	IBYR	Beginning year of data to process (two digits)
4-5	I2	IBMO	Beginning month
7-8	I2	IBDAY	Beginning day
10-11	I2	IBHR	Beginning hour (00-23)
13-14	I2	IEYR	Ending year of data to process (two digits)
16-17	I2	IEMO	Ending month
19-20	I2	IEDAY	Ending day
22-23	I2	IEHR	Ending hour (00-23)

---

* Record format is (8(i2,1x))

Table 4-12

Sample SMERGE Output List File

(SMERGE.LST)

```
                    SMERGE OUTPUT SUMMARY
                VERSION:  1.2      LEVEL:  940330


RUNTIME CALL NO.:        1   DATE: 04/01/94   TIME: 15:10:30.92


Formatted CD144 Surface Data             Station          Time Zone
        Input Files                        ID

        cd144.in1                         23023               6
        cd144.in2                         12921               6
        cd144.in3                         23034               6
        cd144.in4                         23044               7
        cd144.in5                         72261               6
        cd144.in6                         72252               6

Period to Extract (in time zone 6):    1/ 1/89   0:00  to   1/15/89  23:00

                    *********************

Characteristics of Smerge Output File:

  Time Zone:     6
  File Format (1=binary,2=formatted):  2

Surface Stations in Output File:
   No.    ID            No.    ID            No.    ID            No.    ID

    1   23023            3   23034            5   72261            6   72252
    2   12921            4   23044


RUNTIME CALL NO.:        2   DATE: 04/01/94   TIME: 15:10:34.44
DELTA TIME:       3.52 (SEC)
```

4.1.4 PXTRACT Precipitation Data Extract Program

PXTRACT is a preprocessor program which extracts precipitation data for stations and time periods of interest from a fixed length, formatted precipitation data file in NCDC TD-3240 format. The TD-3240 data used by PXTRACT must be in fixed record length format (as opposed to the variable record length format, which is also available from NCDC). The hourly precipitation data usually come in large blocks of data sorted by station. For example, a typical TD-3240 file for California may contain data from over 100 stations statewide in blocks of time of 30 years or more. Modeling applications require the data sorted by time rather than station, and usually involve limited spatial domains of tens of kilometers or less and time periods from less than one year up to five years. PXTRACT allows data for a particular model run to be extracted from the larger data file and creates a set of station files that are used as input files by the second-stage precipitation preprocessor, PMERGE (see Section 4.1.5)

NOTE: If wet removal is not to be considered by the CALPUFF or MESOPUFF II dispersion models, no precipitation processing needs to be done. PXTRACT (and PMERGE) are required only if wet removal is an important removal mechanism for the modeling application of interest. In addition, if wet removal is a factor, the user has the option of creating a free-formatted precipitation data file that can be read by CALMET. This option eliminates the need to run the precipitation preprocessing programs for short CALMET runs (e.g., screening runs) for which the input data can easily be input manually.

The input files used by PXTRACT include a control file (PXTRACT.INP) containing user inputs, and a data file (TD3240.DAT) containing the NCDC data in TD-3240 format. The precipitation data for stations selected by the user are extracted from the TD3240.DAT file and stored in separate output files (one file per station) called xxxxxx.DAT, where xxxxxx is the station identification code. PXTRACT also creates an output list file (PXTRACT.LST) which contains the user options and summarizes the station data extracted. Table 4-13 contains a summary of PXTRACT's input and output files.

The PXTRACT control file contains the user-specified variables which determine the method used to extract precipitation data from the input data file (i.e., by state, by station, or all stations), the appropriate state or station codes, and the time period to be extracted. A sample PXTRACT control file is shown in Table 4-14. The format and contents of the file are described in Table 4-15.

The PXTRACT output list file (PXTRACT.LST) contains a listing of the control file inputs and options. It also summarizes the station data extracted from the input TD-3240 data file, including the starting and ending date of the data for each station and the number of data records found. Since the TD-3240 data are not hourly, PXTRACT will extract the records that cover the period requested by the user. Therefore, the dates of the data extracted from different stations may be different although the same time period was requested by the user. If the starting (or ending) record has a data flag, the previous (or next) record will also be extracted to complete the information necessary for PMERGE to interpret the data correctly. A sample output list file is shown in Table 4-16. The PXTRACT output data files consist of precipitation data in TD-3240 format for the time period selected by the user. Each output data file contains the data for one station. A sample output file is shown in Table 4-17.

Table 4-13

PXTRACT Input and Output Files

Unit	File Name	Type	Format	Description
1	PXTRACT.INP	input	formatted	Control file containing user inputs
2	TD3240.DAT	input	formatted	Precipitation data in NCDC TD-3240 format
3	PXTRACT.LST	output	formatted	List file (line printer output file)
7	id1.DAT (id1 is the 6-digit station code for station #1, e.g., 040001)	output	formatted	Precipitation data (in TD-3240) format for station #1 for the time period selected by the user
8	id2.DAT (id2 is the 6-digit station code for station #2, e.g., 040002)	output	formatted	Precipitation data (in TD-3240) format for station #2 for the time period selected by the user

.
.
.

(Up to 200 new precipitation data files are allowed by PXTRACT).

Table 4-14

Sample PXTRACT Control File (PXTRACT.INP)

```
2
17
412360
417943
417945
412797
415890
410174
411492
412679
412811
415048
415596
416104
416736
416792
418023
418252
419270
89 01 01 01 89 01 15 24
```

Table 4-15

PXTRACT Control File Inputs (PXTRACT.INP)

RECORD 1. Data selection code.

Columns	Variable	Type	Description
[*]	ICODE	integer	Selection code: 1 = extract all stations within state or states requested 2 = input a list of station codes of stations to extract 3 = extract all stations in input file with data for time period of interest

---

[*] Entered in FORTRAN free format

Table 4-15 (Continued)

PXTRACT Control File Inputs (PXTRACT.INP)

RECORD 2. Number of state or station codes.

<u>(This record is included only if ICODE = 1 or 2)</u>

Columns	Variable	Type	Description
*	N	integer	If ICODE = 1: Number of state codes to follow If ICODE = 2: Number of station codes to follow

---

* Entered in FORTRAN free format

Table 4-15 (Continued)

PXTRACT Control File Inputs (PXTRACT.INP)

RECORD 3, 4, ... 2+N. State or station codes of data to be extracted.

(Each record has the following format)

Columns	Format	Variable	Description
1-6	I6	IDAT	If ICODE = 1: State code (two digits) If ICODE = 2: Station code (six digits) consisting of state code (two digits) followed by station ID (four digits)

Table 4-15 (Concluded)

PXTRACT Control File Inputs (PXTRACT.INP)

NEXT RECORD. Starting/ending dates and times.

Columns	Format[*]	Variable	Description
1-2	I2	IBYR	Beginning year of data to process (two digits)
4-5	I2	IBMO	Beginning month
7-8	I2	IBDAY	Beginning day
10-11	I2	IBHR	Beginning hour (01-24 LST)
13-14	I2	IEYR	Ending year of data to process (two digits)
16-17	I2	IEMO	Ending month
19-20	I2	IEDAY	Ending day
22-23	I2	IEHR	Ending hour (01-24 LST)

---

[*] Record format is (8(i2,1x))

Table 4-16

Sample PXTRACT Output List File (PXTRACT.LST)

```
                    PXTRACT OUTPUT SUMMARY
              VERSION:  1.0      LEVEL:  901130

RUNTIME CALL NO.:        1  DATE: 04/04/94   TIME: 13:35:33.67

 Data Requested by Station ID

 Period to Extract:    1/ 1/89   1:00  to   1/15/89  24:00

 Requested Precipitation Station ID Numbers -- (sorted):

   No.    ID            No.    ID            No.    ID            No.    ID

    1   410174           6   412811          10   416104          14   417945
    2   411492           7   415048          11   416736          15   418023
    3   412360           8   415596          12   416792          16   418252
    4   412679           9   415890          13   417943          17   419270
    5   412797

 Station      Starting   Ending    No. of
   Code         Date      Date     Records

 410174        1/ 1/89   1/19/89     3
 411492        1/ 1/89   1/19/89     3
 412360        1/ 1/89   1/19/89     3
 412679        1/ 1/89   1/19/89     3
 412797        1/ 1/89   1/27/89     5
 412811        1/ 1/89   1/26/89     5
 415048        1/ 1/89   1/19/89     5
 415596       12/10/88   1/19/89    10
 415890        1/ 1/89   1/27/89     7
 416736        1/ 1/89   1/19/89     3
 417943        1/ 1/89   1/26/89     9
 417945        1/ 1/89   1/19/89    23
 418023        1/ 1/89   1/19/89     3
 418252        1/ 1/89   1/19/89     3


 The following stations were not found in the precipitation data file
 for the requested time period:
 416104
 416792
 419270


RUNTIME CALL NO.:        2  DATE: 04/04/94   TIME: 13:36:42.16
DELTA TIME:      68.49 (SEC)
```

Table 4-17

Sample TD-3240 Format Precipitation Data File (415596.DAT)

```
HPD41559600HPCPHT19881200100011200000010
HPD41559600HPCPHT19890100010010100099999D
HPD41559600HPCPHT19890100050011800099999D
HPD41559600HPCPHT19890100050011900099999M
HPD41559600HPCPHT19890100100011600099999M
HPD41559600HPCPHT19890100190011300000010
```

4.1.5 PMERGE Precipitation Data Preprocessor

PMERGE reads, processes and reformats the precipitation data files created by the PXTRACT program, and creates an unformatted data file for input into the CALMET meteorological model. The output file (PRECIP.DAT) contains the precipitation data sorted by hour, as required by CALMET, rather than by station. The program can also read an existing unformatted output file and add stations to it, creating a new output file. PMERGE also resolves "accumulation periods" and flags missing or suspicious data.

Accumulation periods are intervals during which only the total amount of precipitation is known. The time history of precipitation within the accumulation period is not available. For example, it may be known that within a six-hour accumulation period, a total of a half inch of precipitation fell, but information on the hourly precipitation rates within the period is unavailable. PMERGE resolves accumulation periods such as this by assuming a constant precipitation rate during the accumulation period. For modeling purposes, this assumption is suitable as long as the accumulation time period is short (e.g., a few hours). However, for longer accumulation periods, the use of the poorly time-resolved precipitation data is not recommended. PMERGE will eliminate and flag as missing any accumulate periods longer than a user-defined maximum length.

PMERGE provides an option to "pack" the precipitation data in the unformatted output in order to reduce the size of the file. A "zero packing" method is used to pack the precipitation data. Because many of the precipitation values are zero, strings of zeros are replaced with a coded integer identifying the number of consecutive zeros that are being represented. For example, the following record with data from 20 stations requires 20 unpacked words:

0.0, 0.0, 0.0, 0.0, 0.0, 1.2, 3.5, 0.0, 0.0, 0.0,
0.0, 0.0, 0.0, 0.7, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0,

These data in packed form would be represented in six words:

-5., 1.2, 3.5, -6., 0.7, -6.

where five zero values are replaced by -5., six zero values are replaced by -6., etc. With many stations and a high frequency of zeros, very high packing ratios can be obtained with this simple method. All of the packing and unpacking operations are performed internally by PMERGE and CALMET, and are transparent to the user. The header records of the data file contain information flagging the file to CALMET as a packed or unpacked file. If the user selects the unpacked format, each precipitation value is assigned one full word.

The input files used by PMERGE include a control file (PMERGE.INP), an optional unformatted data file (PBIN.DAT) created in a previous run of PMERGE, and up to 150 TD-3240 precipitation station files (e.g., as created by PXTRACT). The output file consists of a list file and a new unformatted data file in CALMET format with the data for all stations sorted by hour. Table 4-18 lists the name, type, format, and contents of PMERGE's input and output data files.

The PMERGE control file (PMERGE.INP) contains the user-specified input variables indicating the number of stations to be processed, a flag indicating if data are to be added to an existing, unformatted data file, the maximum length of an accumulation period, packing options, station data, and time zone data. PMERGE allows data from different time zones to be merged by time-shifting the data to a user-specified base time zone. Sample PMERGE control files are shown in Table 4-19. Sample 1 shows an input file to merge data from 10 precipitation stations into one unformatted output file. The unformatted output file can then be renamed from PRECIP.DAT to PBIN.DAT by the user and then a control file as shown in Sample 2 can be used to merge data from 4 more precipitation stations to the 10 already processed. The combination of station data in multiple runs of PMERGE is sometimes necessary because the number of files which can be opened at one time is limited under some operating systems (e.g., DOS). The output file from Sample 2 is a formatted file containing data from 14 precipitation stations. This formatted file can be directly input to CALMET. The format and contents of the PMERGE control file are described in Table 4-20.

The PMERGE output list file (PMERGE.LST) contains a listing of the control file inputs and options. It also summarizes the number of valid and invalid hours for each station including information on the number of hours with zero or non-zero precipitation rates and the number of accumulation period hours. Additional statistics provide information by station on the frequency and type of missing data in the file (i.e., data flagged as missing in the original data file, data which are part of an excessively long accumulation period, or data missing from the input files before (after) the first (last) valid record. A sample output file is shown in Table 4-21.

Table 4-18

PMERGE Input and Output Files

Unit	File Name	Type	Format	Description
3	PBIN.DAT	input	unformatted	Existing PMERGE data file to which stations are to be added (Used only if NBF=1)
4	PRECIP.DAT	output	unformatted or formatted	Output data file created by PMERGE (PRECIP.DAT is an input file to CALMET)
5	PMERGE.INP	input	formatted	Control file containing user inputs
6	PMERGE.LST	output	formatted	List file (line printer output file)
7	user input file name	input	formatted	Precipitation data (in TD-3240) format for station #1. (Output file of PXTRACT)
8	user input file name	input	formatted	Precipitation data (in TD-3240) format for station #2. (Output file of PXTRACT)

.

.

.

(Up to 150 new precipitation data files are allowed by PMERGE although this may be limited by the number of files an operating system will allow open at one time. Multiple runs of PMERGE may be necessary.)

Table 4-19

Sample PMERGE Control File (PMERGE.INP)

Sample 1

```
  10   0  12   6   1   1
412360.dat  6
417943.dat  6
417945.dat  6
412797.dat  7
415890.dat  6
410174.dat  6
411492.dat  6
412679.dat  6
412811.dat  6
415048.dat  6
89 01 01 01 89 01 15 24
```

Sample 2

```
   4   1  12   6   2   0
415596.dat  6
416736.dat  6
418023.dat  6
418252.dat  6
-999
89 01 01 01 89 01 15 24
```

Table 4-20

PMERGE Control File Inputs (PMERGE.INP)

RECORD 1. General run information.

Columns	Format*	Variable	Description
1-4	I4	NFF	Number of formatted NCDC input files to be processed (up to 150)
5-8	I4	NBF	Flag indicating if data are to be added to an existing unformatted precip. data file (0=no, 1=yes)
9-12	I4	MAXAP	Maximum allowed length of an accumulation period (hours). It is recommended that MAXAP be set to 24 hours or less.
13-16	I4	IOTZ	Time zone of output data (05=EST, 06=CST, 07=MST, 08=PST)
17-20	I4	IOFORM	Format of output data file (1=binary, 2=formatted)
21-24	I4	IOPACK	Flag indicating if output data are to be packed (0=no, 1=yes)

---

* Record format is (6i4)

Table 4-20 (Continued)

PMERGE Control File Inputs (PMERGE.INP)

RECORD 2, 3, ...1+NFF. File names and time zone for each station. (Each record has the following format)

Columns	Format*	Variable	Description
1-10	A10	CFFILES	Name of file containing formatted precipitation data (TD-3240 format) (PXTRACT output file). First six digits of file name must contain station code (SSIIII), where SS is the two digit state code, and IIII is the station ID)
12-13	I2	ISTZ	Time zone of station (05=EST, 06=CST, 07=MST, 08=PST)

---

* Record format is (a10,1x,i2)

NEXT RECORD. (Necessary only if NBF=1, i.e., reading data from a binary input file.)

Columns	Format	Variable	Description
1-4	i4	NBSTN	Number of stations requested from binary input file (-999 = use all stations in binary file).

NEXT RECORDS. (Necessary only if NBF=1 and NBSTN ≠ -999, one record for each binary station requested, i.e., NBSTN lines.)

Columns	Format	Variable	Description
1-5	i5	IBSTN	6-digit station ids requested from binary input file (1 station id per record)

Table 4-20 (Concluded)

PMERGE Control File Inputs (PMERGE.INP)

NEXT RECORD. Starting/ending dates and times.

Columns	Format*	Variable	Description
1-2	I2	IBYR	Beginning year of data to process (two digits)
4-5	I2	IBMO	Beginning month
7-8	I2	IBDAY	Beginning day
10-11	I2	IBHR	Beginning hour (01-24 LST)
13-14	I2	IEYR	Ending year of data to process (two digits)
16-17	I2	IEMO	Ending month
19-20	I2	IEDAY	Ending day
22-23	I2	IEHR	Ending hour (01-24 LST)

---

* Record format is (8(i2,1x))

Table 4-21

Sample PMERGE Output List File (PMERGE.LST)

```
                         PMERGE OUTPUT SUMMARY
                    VERSION:  1.2      LEVEL:  921022

RUNTIME CALL NO.:          1  DATE: 04/04/94   TIME: 16:26:15.24

Formatted TD3240 Precipitation          Time Zone
         Input Files

         415596.dat                         6
         416736.dat                         6
         418023.dat                         6
         418252.dat                         6

Period to Extract (in time zone 6):    1/ 1/89   1:00  to   1/15/89  24:00

                         ********************

Data Read from Binary Input File:

  Time Zone:     6
  Packing Code:  1

  Period (in time zone 6):    1/ 1/89   1:00  to   1/15/89  24:00

  Stations Available in Binary Input File:
   No.     ID          No.     ID           No.     ID           No.     ID

    1   412360          4   412797           7   411492           9   412811
    2   417943          5   415890           8   412679          10   415048
    3   417945          6   410174

                         ********************

PMERGE Stations in Output File:
   No.     ID          No.     ID           No.     ID           No.     ID

    1   412360          5   415890           9   412811          12   416736
    2   417943          6   410174          10   415048          13   418023
    3   417945          7   411492          11   415596          14   418252
    4   412797          8   412679

Summary of Data from Formatted TD3240 Precipitation Files:

                Valid Hours:

Station    Zero  Nonzero  Accum   Total    %
  IDs                     Period  Valid   Valid
                                  Hours   Hours
 415596     128      0       0     128     35.6
 416736     360      0       0     360    100.0
 418023     360      0       0     360    100.0
 418252     360      0       0     360    100.0

                Invalid Hours:

Station   Flagged   Excessive   Missing Data   Missing Data    Total       %
  IDs     Missing     Accum     Before First    After Last    Invalid   Invalid
                      Period    Valid Record   Valid Record    Hours     Hours
 415596     232         0            0              0           232      64.4
 416736       0         0            0              0             0       0.0
 418023       0         0            0              0             0       0.0
 418252       0         0            0              0             0       0.0

RUNTIME CALL NO.:          2  DATE: 04/04/94   TIME: 16:26:15.90
DELTA TIME:        0.66 (SEC)
```

4.2 CALMET Model Files

The CALMET model obtains the necessary control information and input meteorological data from a number of different input files. The control file (CALMET.INP) contains the data that define a particular model run, such as starting date and time, horizontal and vertical grid data, and model option flags. Geophysical data, including terrain elevations, land use, and surface characteristics, are read from a formatted data file called GEO.DAT.

The hourly surface meteorological observations are contained in the surface data file (SURF.DAT). If overwater temperatures are being calculated separately, this file must contain only land stations. This file can be either a formatted or an unformatted file generated by the SMERGE preprocessor program or a free-formatted, user-prepared file, depending on options specified in the control file. Upper air meteorological data are read from a series of data files called UPn.DAT, where n is the upper air station number (e.g., n=1,2,3,...). The data for each upper air station are stored in a separate data file.

Hourly precipitation observations are contained in a file called PRECIP.DAT. This file can be a formatted or an unformatted file generated by the PMERGE preprocessor program or a free-formatted, user-prepared file. Overwater meteorological data are read from a series of data files called SEAn.DAT, where n is the overwater station number (e.g., n= 1,2,3,...). The data for each overwater station are stored in a separate file. If overwater default parameters for temperature, air-sea temperature difference, etc. are being used and separate overwater temperatures are not being calculated, then overwater stations can be placed in the SURF.DAT file.

CALMET contains an option to use gridded prognostic model output from either CSUMM or MM4-FDDA as model input. If this option is selected, the CSUMM gridded prognostic model wind fields are read from an unformatted data file called PROG.DAT or the MM4-FDDA prognostic output are read from a formatted data file called MM4.DAT.

In its default mode, CALMET computes domain-averaged winds, temperature lapse rates and surface temperatures from the hourly surface observations and twice-daily upper air data contained in the SURF.DAT, UPn.DAT, and, if present, SEAn.DAT files. However, the model contains an option for the user to specify pre-computed values for these parameters from an optional file DIAG.DAT.

The main CALMET output files are a list file (CALMET.LST) containing a listing of the model inputs and user-selected printouts of the output meteorological values and an optional, unformatted disk file (CALMET.DAT or PACOUT.DAT) containing the hourly gridded meteorological data produced by the model. In addition, several additional optional list files (TEST.PRT, TEST.OUT, TEST.KIN, TEST.FRD, and TEST.SLP) can be created. These files, provided primarily for model testing purposes, contain intermediate versions of the wind fields at various points in the diagnostic wind field analysis (e.g., after evaluation of kinematic effects, slope flows, terrain blocking effects, divergence minimization, etc.).

The CALMET input and output files are listed in Table 4-22. The table shows the FORTRAN unit numbers associated with each file. As indicated in Section 3.1, these unit numbers are specified in a parameter file, PARAMS.MET, and can easily be modified to accommodate system-dependent restrictions on allowable unit numbers. The user should make sure that the beginning and total number of UPn.DAT and SEAn.DAT files are defined such that there is no overlap among unit numbers.

In the following sections, the contents and format of each CALMET input file is described in detail.

Table 4-22
CALMET Input and Output Files

Unit	File Name	Type	Format	Description
IO2	DIAG.DAT	input	formatted	File containing preprocessed meteorological data for diagnostic wind field module. (Used only if IDIOPT1, IDIOPT2, IDIOPT3, IDIOPT4, or IDIOPT5 = 1.)
IO5	CALMET.INP	input	formatted	Control file containing user inputs.
IO6	CALMET.LST	output	formatted	List file (line printer output file) created by CALMET.
IO7	CALMET.DAT or PACOUT.DAT	output	unformatted	Output data file created by CALMET containing hourly gridded fields of meteorological data. (Created only if LSAVE=T.)
IO8	GEO.DAT	input	formatted	Geophysical data fields (land use, elevation, surface characteristics, anthropogenic heat fluxes).
IO10	SURF.DAT	input	unformatted (if IFORMS=1) or formatted (if IFORMS=2)	Hourly surface observations (Used only if IDIOPT4=0.) If IFORMS=1, use the unformatted output file of the SMERGE program. If IFORMS=2, use a free-formatted input file generated either by SMERGE or the user.
IO12	PRECIP.DAT	input	unformatted (if IFORMP=1) or formatted (if IFORMP=2)	Hourly precipitation data (used if NPSTA > 0). If IFORMP=1, PRECIP.DAT is the unformatted output file of the PMERGE program. If IFORMP=2, PRECIP.DAT is a free-formatted input file generated either by PMERGE or the user.

(CALMET Input and Output Files Continued)

Table 4-22
CALMET Input and Output Files

Unit	File Name	Type	Format	Description
IO30	UP1.DAT	input	formatted	Upper air data (READ56/READ62 output) for upper air station #n. (Used only if IDIOPT5=0.)
IO30+1	UP2.DAT			
IO30+2	UP3.DAT			
•	• •			
•	• •			
•	• •			
•	UPn.DAT			
(Up to "MAXUS" upper air stations allowed. MAXUS currently = 10).				
IO50	SEA1.DAT	input	formatted	Overwater meteorological data for station #n. (Used only if NOWSTA > 0).
IO50+1	SEA2.DAT			
IO50+2	SEA3.DAT			
•	• •			
•	• •			
•	• •			
•	SEAn.DAT			
(Up to "MXOWS" overwater stations allowed. MXOWS currently = 10).				
IO40	PROG.DAT (CSUMM) or	input	unformatted	Gridded fields of prognostic wind data to use as input to the diagnostic wind field module. (Used only if IPROG > 0.)
IO40	MM4.DAT (MM4)	input	formatted	
IO99	WT.DAT	input	formatted	Gridded fields of terrain weighting factors used to weight the observed winds and the MM4 winds in the interpolation process
		Wind Field Module Test and Debug Files		
IO41	TEST.PRT	output	unformatted	Intermediate winds and misc. input and internal variables. (Created only if at least one wind field print option activated (IPR0-IPR8).)
IO42	TEST.OUT	output	formatted	Final wind fields. (Created only if IPR8=1 and IOUTD=1.)
IO43	TEST.KIN	output	formatted	Wind fields after kinematic effects. (Created only if IPR5=1 and IOUTD=1.)
IO44	TEST.FRD	output	formatted	Wind fields after Froude No. effects. (Created only if IPR6=1 and IOUTD=1.)
IO45	TEST.SLP	output	formatted	Wind fields after slope flow effects. (Created only if IPR7=1 and IOUTD=1.)

4.2.1 User Control File (CALMET.INP)

The selection and control of CALMET options are determined by user-specified inputs contained in a file called the control file. This file, CALMET.INP, contains all the information necessary to define a model run (e.g., starting date, run length, grid specifications, technical options, output options, etc.).

The control file is organized into nine Input Groups preceded by a three line run title (see Table 4-23). The Input Groups must appear in order, i.e., Input Group 1 followed by Input Group 2, etc. However, the variables within an Input Group may appear in any order. Each Input Group must end with an Input Group terminator consisting of the word END between two delimiters (i.e., !END!). Even a blank Input Group (i.e., one in which no variables are included) must end with an Input Group terminator in order to signal the end of that Input Group and the beginning of another.

A sample control file is shown in Table 4-24. It is designed to be flexible and easy-to-use. The control file is read by a set of FORTRAN text processing routines contained within CALMET which allow the user considerable flexibility in designing and customizing the input file. An unlimited amount of optional descriptive text can be inserted within the control file to make it self-documenting. For example, the definition, allowed values, units, and default value of each input variable can be included within the control file.

The control file processor searches for pairs of special delimiter characters (!). All text outside the delimiters is assumed to be user comment information and is echoed back but otherwise ignored by the input module. Only data within the delimiter characters are processed. The input data consist of a leading delimiter followed by the variable name, equals sign, input value or values, and a terminating delimiter (e.g., !XX = 12.5 !). The variable name can be lower or upper case, or a mixture of both (i.e., XX, xx, Xx are all equivalent). The variable can be a real, integer or logical array or scalar. The use of repetition factors for arrays is allowed (e.g., ! XARRAY = 3 * 1.5 ! instead of ! XARRAY = 1.5, 1.5, 1.5 !). Different values must be separated by commas. Spaces within the delimiter pair are ignored. Exponential notation (E format) for real numbers is allowed. However, the optional plus sign should be omitted (e.g., enter +1.5E+10 as 1.5E10). The data may be extended over more than one line. The line being continued must end with a comma. Each leading delimiter must be paired with a terminating delimiter. All text between the delimiters is assumed to be data, so no user comment information is allowed to appear within the delimiters. The inclusion in the control file of any variable that is being assigned its default value is optional.

The control file reader expects that logical variables will be assigned using only a one character representation (i.e., 'T' or 'F'). Input Groups 7-9 are handled differently (making use of FORTRAN free reads), because they contain Character*4 input data. The data portion of each record in Input Groups 7-9 must start in Column 9 or greater of the record.

Each CALMET control file input variable is described in Table 4-25. The control file module has a list of the variable names and array dimensions for each Input Group. Checks are performed to ensure that the proper variable names are entered by the user, and that no array dimensions are exceeded. Error messages result if an unrecognized variable name is encountered or too many values are entered for a variable.

Note that if LLCONF=T, then all x,y coordinates in the CALMET.INP file must be specified on the chosen Lambert Conformal projection grid, rather than in UTM coordinates.

A standard control file is provided along with the CALMET test case run. It is recommended that a copy of the standard control file be permanently stored as a backup. Working copies of the control file may be made and then edited and customized by the user for a particular application.

Table 4-23

CALMET Control File Input Groups

Input Group	Description
*	Run Title First three lines of control file (up to 80 characters/line)
1	General Run Control Parameters Starting date and hour, run length, base time zone, and run type options
2	Grid Control Parameters Grid spacing, number of cells, vertical layer structure, and reference coordinates
3	Output Options Printer control variables, and disk output control variables
4	Meteorological Data Options Number of surface, upper air, over water, and precipitation stations, input file formats, and precipitation options
5	Wind Field Options and Parameters Model option flags, radius of influence parameters, weighting factors, barrier data, diagnostic module input flags, and lake breeze information
6	Mixing Height, Temperature, and Precipitation Parameters Empirical constants for the mixing height scheme, spatial averaging parameters, minimum/maximum overland and overwater mixing heights, temperature options, and precipitation interpolation options
7	Surface Meteorological Station Parameters Station name, coordinates, latitude, longitude, time zone, and anemometer height
8	Upper Air Station Parameters Station name, coordinates, latitude, longitude, and time zone
9	Precipitation Station Parameters Station name, station code, and coordinates

Table 4-24

Sample CALMET Control File (CALMET.INP)
Run Title and Input Group 1

```
CALMET Test Case Run
43x33 10 km grid, 8 vertical layers
Met. stations used:  6 sfc., 3 upper, 14 precip., 0 overwater; No barrier


              Additional user comments
              ------------------------
12 hour run on January 1, 1989


-------------------------------------------------------------------------------

INPUT GROUP: 1 -- General run control parameters
--------------

     Starting date:   Year (IBYR) -- No default       ! IBYR=89 !
                     Month (IBMO) -- No default       ! IBMO=1  !
                       Day (IBDY) -- No default       ! IBDY=1  !
                      Hour (IBHR) -- No default       ! IBHR=0  !

     Base time zone        (IBTZ) -- No default       ! IBTZ=6  !
        PST = 08, MST = 07
        CST = 06, EST = 05

     Length of run (hours) (IRLG) -- No default       ! IRLG=12    !

     Run type            (IRTYPE) -- Default: 1       ! IRTYPE=1 !

        0 = Computes wind fields only
        1 = Computes wind fields and micrometeorological variables
            (u*, w*, L, zi, etc.)
        (IRTYPE must be 1 to run CALGRID or CTSG module of CALPUFF)

     Compute special data fields required
     by CALGRID (i.e., 3-D fields of W wind
     components and temperature)
     in additional to regular            Default: T    ! LCALGRD = F !
     fields ? (LCALGRD)
     (LCALGRD must be T to run CALGRID)

     Rotate input winds from true north to
     map north using a Lambert conformal
     projection? (LLCONF)                Default: F     ! LLCONF = F !

     Latitude of 1st standard parallel   Default: 30.   ! XLAT1 = 30. !
     Latitude of 2nd standard parallel   Default: 60.   ! XLAT2 = 60. !
     (XLAT1 and XLAT2; + in Northern Hemisphere
                       - in Southern Hemisphere)

!END!
```

Table 4-24
Sample CALMET Control File (CALMET.INP)
Input Group 2 and Input Group 3

```
-------------------------------------------------------------------------------
INPUT GROUP: 2 -- Grid control parameters
--------------

     HORIZONTAL GRID DEFINITION:

            No. X grid cells (NX)      No default     ! NX = 43  !
            No. Y grid cells (NY)      No default     ! NY = 33  !

     GRID SPACING (DGRIDKM)            No default     ! DGRIDKM= 10.0 !
                                       Units: km

     REFERENCE COORDINATES
     of SOUTHWEST corner of grid point (1,1)

        X coordinate (XORIGKM)         No default     ! XORIGKM= 565.00 !
        Y coordinate (YORIGKM)         No default     ! YORIGKM= 3095.00 !
                                       Units: km
        Longitude (RLONO)              Default = 90.0 ! RLONO =  90.0 !
        (used only if LLCONF = T)
        Origin Latitude (RLATO)        Default = 40.0 ! RLATO = 40.0 !
        (used only if IPROG > 2)

     UTM ZONE (IUTMZN)                 No default     ! IUTMZN= 13 !

     Vertical grid definition:

        No. of vertical layers (NZ)    No default     ! NZ = 8 !

        Cell face heights in arbitrary
        vertical grid (ZFACE(NZ+1))    No defaults
                                       Units: m
        ! ZFACE = 0., 20., 120., 240., 500., 1000., 1800., 3000., 4000. !

!END!

------------------------------------------------------------------------------------------------------------
INPUT GROUP: 3 -- Output Options
--------------

    DISK OUTPUT OPTION

       Save met. fields in an unformatted file
                                   (LSAVE)  Default: T     ! LSAVE = T !
       (F = Do not save, T = Save)

       Type of unformatted output file:
       (IFORMO)                             Default: 1    ! IFORMO = 2 !
            1 = CALPUFF/CALGRID type file  (CALMET.DAT)
            2 = MESOPUFF-II type file      (PACOUT.DAT)
            (Used only if LSAVE=T)
```

Table 4-24

Sample CALMET Control File (CALMET.INP)
Input Group 3 Continued

```
LINE PRINTER OUTPUT OPTIONS:

       Print met. fields ?  (LPRINT)       Default: F     ! LPRINT = T !
       (F = Do not print, T = Print)
       (NOTE: parameters below control which
              met. variables are printed)

       Print interval
       (IPRINF) in hours                   Default: 1     ! IPRINF = 6  !
       (Meteorological fields are printed
        every "IPRINF" hours)

       Specify which layers of U, V wind component
       to print (IUVOUT(NZ)) -- NOTE: NZ values must be entered
       (0=Do not print, 1=Print)
       (used only if LPRINT=T)        Defaults: NZ*0 ! IUVOUT = 1,1,6*0 !
       -----------------------

       Specify which levels of the W wind component to print
       (NOTE: W defined at TOP cell face -- "NZ" values)
       (IWOUT(NZ)) -- NOTE: NZ values must be entered
       (0=Do not print, 1=Print)
       (used only if LPRINT=T & LCALGRD=T)
       -----------------------------------
                                        Defaults: NZ*0 ! IWOUT = 8*0 !

       Specify which levels of the 3-D temperature field to print
       (ITOUT(NZ)) -- NOTE: NZ values must be entered
       (0=Do not print, 1=Print)
       (used only if LPRINT=T & LCALGRD=T)
       -----------------------------------
                                         Defaults: NZ*0 ! ITOUT = 8*0 !

       Specify which meteorological fields
       to print
       (used only if LPRINT=T)             Defaults: 0 (all variables)
       -----------------------

         Variable           Print ?
                        (0 = do not print,
                         1 = print)
         --------       ------------------
      !  STABILITY  =          1            ! - PGT stability class
      !  USTAR      =          0            ! - Friction velocity
      !  MONIN      =          0            ! - Monin-Obukhov length
      !  MIXHT      =          0            ! - Mixing height
      !  WSTAR      =          0            ! - Convective velocity scale
      !  PRECIP     =          0            ! - Precipitation rate
      !  SENSHEAT   =          0            ! - Sensible heat flux
      !  CONVZI     =          1            ! - Convective mixing ht.


       Testing and debug print options for micrometeorological module

          Print input meteorological data and
          internal variables (LDB)         Default: F       ! LDB = F !
          (F = Do not print, T = print)
          (NOTE: this option produces large amounts of output)

          First time step for which debug data
          are printed (NN1)                Default: 1       ! NN1 = 1 !
```

Table 4-24

Sample CALMET Control File (CALMET.INP)
Input Group 3 Continued

```
     Last time step for which debug data
     are printed (NN1)              Default: 1        ! NN2 = 1 !


  Testing and debug print options for wind field module
  (all of the following print options control output to
   wind field module's output files: TEST.PRT, TEST.OUT,
   TEST.KIN, TEST.FRD, and TEST.SLP)

     Control variable for writing the test/debug
     wind fields to disk files (IOUTD)
     (0=Do not write, 1=write)      Default: 0        ! IOUTD = 0 !

     Number of levels, starting at the surface,
     to print (NZPRN2)              Default: 1        ! NZPRN2 = 1 !

     Print the INTERPOLATED wind components ?
     (IPR0) (0=no, 1=yes)           Default: 0        !  IPR0 = 0 !

     Print the TERRAIN ADJUSTED surface wind
     components ?
     (IPR1) (0=no, 1=yes)           Default: 0        !  IPR1 = 0 !

     Print the SMOOTHED wind components and
     the INITIAL DIVERGENCE fields ?
     (IPR2) (0=no, 1=yes)           Default: 0        !  IPR2 = 0 !

     Print the FINAL wind speed and direction
     fields ?
     (IPR3) (0=no, 1=yes)           Default: 0        !  IPR3 = 0 !

     Print the FINAL DIVERGENCE fields ?
     (IPR4) (0=no, 1=yes)           Default: 0        !  IPR4 = 0 !

     Print the winds after KINEMATIC effects
     are added ?
     (IPR5) (0=no, 1=yes)           Default: 0        !  IPR5 = 0 !

     Print the winds after the FROUDE NUMBER
     adjustment is made ?
     (IPR6) (0=no, 1=yes)           Default: 0        !  IPR6 = 0 !

     Print the winds after SLOPE FLOWS
     are added ?
     (IPR7) (0=no, 1=yes)           Default: 0        !  IPR7 = 0 !

     Print the FINAL wind field components ?
     (IPR8) (0=no, 1=yes)           Default: 0        !  IPR8 = 0 !

!END!
```

Table 4-24

Sample CALMET Control File (CALMET.INP)
Input Group 4 and Input Group 5

```
-------------------------------------------------------------------------------
INPUT GROUP: 4 -- Meteorological data options
--------------

   NUMBER OF EACH TYPE OF METEOROLOGICAL STATION

      Number of surface stations   (NSSTA)  No default     ! NSSTA =  6 !
      Number of upper air stations (NUSTA)  No default     ! NUSTA =  3 !
      Number of precipitation stations
                                   (NPSTA)  No default     ! NPSTA = 14 !
      Number of overwater met stations
                                  (NOWSTA)  No default     ! NOWSTA = 0 !

   FILE FORMATS

      Surface meteorological data file format
                                  (IFORMS)  No default     ! IFORMS = 2 !
      (1 = unformatted (e.g., SMERGE output))
      (2 = formatted   (free-formatted SMERGE or user input))

      Precipitation data file format
                                  (IFORMP)  No default     ! IFORMP = 2 !
      (1 = unformatted (e.g., PMERGE output))
      (2 = formatted   (free-formatted PMERGE or user input))
!END!
-------------------------------------------------------------------------------
INPUT GROUP: 5 -- Wind Field Options and Parameters
--------------

   WIND FIELD MODEL OPTIONS

      Model selection variable (IWFCOD)     Default: 1   ! IWFCOD = 1 !
         0 = Objective analysis only
         1 = Diagnostic wind module

      Compute Froude number adjustment
      effects ? (IFRADJ)                    Default: 1    ! IFRADJ = 1 !
      (0 = NO, 1 = YES)

      Compute kinematic effects ? (IKINE)   Default: 1    ! IKINE  = 1 !
      (0 = NO, 1 = YES)

      Use O'Brien procedure for adjustment
      of the vertical velocity ? (IOBR)     Default: 1    ! IOBR = 0 !
      (0 = NO, 1 = YES)

      Extrapolate surface wind observations
      to upper layers ? (IEXTRP)            Default: 1    ! IEXTRP = 1 !
      (1 = no extrapolation is done,
       2 = power law extrapolation used,
       3 = user input multiplicative factors
           for layers 2 - NZ used (see FEXTRP array)
       4 = similarity theory used
      -1, -2, -3 = same as above except layer 1 data
           at upper air stations are ignored

      Minimum distance between nearest upper air
      station and surface station for which extrapolation
      of surface winds at suface station will be allowed
      (RMIN2: Set to -1. for IEXTRP=4 or other situations
      where all surface stations should be extrapolated)
      Units = km                            Default: 4    ! RMIN2 = 4 !
```

Table 4-24

Sample CALMET Control File (CALMET.INP)
Input Group 5 Continued

```
   Use gridded prognostic wind field model
   output fields as input to the diagnostic
   wind field model (IPROG)               Default: 0       ! IPROG =0 !
   (0 = No, [IWFCOD = 0 or 1]
    1 = Yes, use CSUMM prog. winds as Step 1 field, [IWFCOD = 0]
    2 = Yes, use CSUMM prog. winds as initial guess field [IWFCOD = 1]
    3 = Yes, use MM4 prog. winds as Step 1 field [IWFCOD = 0]
    4 = Yes, use MM4 prog. winds as initial guess field [IWFCOD = 1]
    5 = Yes, use MM4 prog. winds as observations [IWFCOD = 1])

   Prognostic Grid Horizontal Spacing     No default       ! DGRDPKM = 80.0 !
   (DGRDPKM)                              Units: km

RADIUS OF INFLUENCE PARAMETERS

   Use varying radius of influence        Default: F       ! LVARY = T !
   (if no stations are found within RMAX1,RMAX2,
    or RMAX3, then the closest station will be used)

   Maximum radius of influence over land
   in the surface layer (RMAX1)           No default       ! RMAX1 = 300.!
                                          Units: km
   Maximum radius of influence over land
   aloft (RMAX2)                          No default       ! RMAX2 =1000. !
                                          Units: km
   Maximum radius of influence overwater
   (RMAX3)                                No default       ! RMAX3 =1000.!
                                          Units: km

OTHER WIND FIELD INPUT PARAMETERS

   Minimum radius of influence used in
   the wind field interpolation (RMIN)    No default       ! RMIN = .2 !
                                          Units: km

   Minimum distance to an upper air       Default: 4       ! RMIN2 = 4.0 !
   station from a surface station,        Units: km
   which will allow vertical
   extrapolation of the surface winds
   to take place (RMIN2)

   Radius of influence of terrain
   features (TERRAD)                      No default       ! TERRAD = 20. !
                                          Units: km
   Relative weighting of the first
   guess field and observations in the
   SURFACE layer (R1)                     No default       ! R1 = 30. !
   (R1 is the distance from an            Units: km
   observational station at which the
   observation and first guess field are
   equally weighted)

   Relative weighting of the first
   guess field and observations in the
   layers ALOFT (R2)                      No default       ! R2 = 50.!
   (R2 is applied in the upper layers     Units: km
   in the same manner as R1 is used in
   the surface layer).
```

Table 4-24

Sample CALMET Control File (CALMET.INP)
Input Group 5 Continued

```
   Relative weighting parameter of the
   prognostic wind field data (RPROG)    No default      ! RPROG = 50. !
   (Used only if IPROG = 1)              Units: km
   -----------------------

   Maximum acceptable divergence in the
   divergence minimization procedure
   (DIVLIM)                              Default: 5.E-6  ! DIVLIM=5.E-6 !

   Maximum number of iterations in the
   divergence min. procedure (NITER)     Default: 50     ! NITER = 50 !

   Number of passes in the smoothing
   procedure (NSMTH(NZ))
   Note: NZ values must be entered       Default: 2,(MXNZ-1)*4  ! NSMTH = 2,7*4 !

   Maximum number of stations used in
   each layer for the interpolation of
   data to a grid point (NINTR2(NZ))
   NOTE: NZ values must be entered      No defaults     ! NINTR2 =8*4 !

   Critical Froude number (CRITFN)      Default: 1.0    ! CRITFN = 1. !

   Empirical factor controlling the
   influence of kinematic effects
   (ALPHA)                              Default: 0.1    ! ALPHA = 0.1 !

   Multiplicative scaling factor for
   extrapolation of surface observations
   to upper layers (FEXTR2(NZ))        Default: NZ*0.0 ! FEXTR2 = 8*0.0 !
   (Used only if IEXTRP = 3 or -3)


BARRIER INFORMATION

   Number of barriers to interpolation
   of the wind fields (NBAR)             Default: 0      ! NBAR = 0 !

   THE FOLLOWING 4 VARIABLES ARE INCLUDED
   ONLY IF NBAR > 0
   NOTE: NBAR values must be entered     No defaults
         for each variable               Units: km

      X coordinate of BEGINNING
      of each barrier (XBBAR(NBAR))      * XBBAR = "nbar" values *
      Y coordinate of BEGINNING
      of each barrier (YBBAR(NBAR))      * YBBAR = "nbar" values *

      X coordinate of ENDING
      of each barrier (XEBAR(NBAR))      * XEBAR = "nbar" values *
      Y coordinate of ENDING
      of each barrier (YEBAR(NBAR))      * YEBAR = "nbar" values *

DIAGNOSTIC MODULE DATA INPUT OPTIONS

   Surface temperature (IDIOPT1)         Default: 0      ! IDIOPT1 = 0 !
      0 = Compute internally from
          hourly surface observations
      1 = Read preprocessed values from
          a data file (DIAG.DAT)
```

Table 4-24

Sample CALMET Control File (CALMET.INP)
Input Group 5 Continued

```
   Surface met. station to use for
   the surface temperature (ISURFT)   No default     ! ISURFT =  4 !
   (Must be a value from 1 to NSSTA)
   (Used only if IDIOPT1 = 0)

   Domain-averaged temperature lapse
   rate (IDIOPT2)                        Default: 0     ! IDIOPT2 = 0 !
   0 = Compute internally from
       twice-daily upper air observations
   1 = Read hourly preprocessed values
       from a data file (DIAG.DAT)

   Upper air station to use for
   the domain-scale lapse rate (IUPT) No default     ! IUPT   = 1 !
   (Must be a value from 1 to NUSTA)
   (Used only if IDIOPT2 = 0)
   --------------------------

   Depth through which the domain-scale
   lapse rate is computed (ZUPT)      Default: 200.  ! ZUPT = 200. !
   (Used only if IDIOPT2 = 0)         Units: meters
   --------------------------

Domain-averaged wind components
(IDIOPT3)                             Default: 0     ! IDIOPT3 = 0 !
   0 = Compute internally from
       twice-daily upper air observations
       (IDIOPT3=0, IUPWND=-1 to use spatially-variable
       initial guess field)
   1 = Read hourly preprocessed values
       a data file (DIAG.DAT)

   Upper air station to use for
   the domain-scale winds (IUPWND)    No default     ! IUPWND = -1 !
   (Must be a value from 1 to NUSTA or -1)
   (IDIOPT3=0, IUPWND=-1 to use spatially-variable
     initial guess field)
   (Used only if IDIOPT3 = 0)
   --------------------------

   Bottom and top of layer through
   which the domain-scale winds
   are computed
   (ZUPWND(1), ZUPWND(2))        Defaults: 1., 2000. ! ZUPWND=1., 2000.!
   (Used only if IDIOPT3 = 0)    Units: meters
   --------------------------

Observed surface wind components
for wind field module (IDIOPT4)  Default: 0     ! IDIOPT4 = 0 !
   0 = Read WS, WD from a surface
       data file (SURF.DAT)
   1 = Read hourly preprocessed U, V from
       a data file (DIAG.DAT)

Observed upper air wind components
for wind field module (IDIOPT5)  Default: 0     ! IDIOPT5 = 0 !
   0 = Read WS, WD from an upper
       air data file (UP1.DAT, UP2.DAT, etc.)
   1 = Read hourly preprocessed U, V from
       a data file (DIAG.DAT)
```

Table 4-24

Sample CALMET Control File (CALMET.INP)
Input Group 5 Concluded

```
       LAKE BREEZE INFORMATION

       Use Lake Breeze Module (LLBREZE)       Default: F    ! LLBREZE = F !

       Number of lake breeze regions (NBOX)   No default    ! NBOX = 1 !

       X Grid line 1 defining the region of interest   (XG1)
                                              No default    ! XG1 = 2.5 !
                                              Units: (KM)

       X Grid line 2 defining the region of interest   (XG2)
                                              No default    ! XG2 = 4.5 !
                                              Units: (KM)

       Y Grid line 1 defining the region of interest   (YG1)
                                              No default    ! YG1 = 0.0 !
                                              Units: (KM)

       Y Grid line 2 defining the region of interest   (YG2)
                                              No default    ! YG2 = 5.0 !
                                              Units: (KM)


       X Point defining the coastline (Straight line)  (XBCST)
                                              No default    ! XBCST = 172. !
                                              Units: (KM)

       Y Point defining the coastline (Straight line)  (YBCST)
                                              No default    ! YBCST = 3879. !
                                              Units: (KM)

       X Point defining the coastline (Straight line)  (XECST)
                                              No default    ! XECST = 180. !
                                              Units: (KM)

       Y Point defining the coastline (Straight line)  (YECST)
                                              No default    ! YECST = 3839. !
                                              Units: (KM)


       Number of stations in the region       No default    ! NLB =   0 !
       (Surface stations + upper air stations)

       Station ID's  in the region   (METBXID(NLB))
       (Surface stations first, then upper air stations)
         * METBXID = 23023 *

!END!
```

Table 4-24

Sample CALMET Control File (CALMET.INP)
Input Group 6

```
-------------------------------------------------------------------------------
INPUT GROUP: 6 -- Mixing Height and Temperature Parameters
--------------

   EMPIRICAL MIXING HEIGHT CONSTANTS

      Neutral, mechanical equation
      (CONSTB)                           Default: 1.41    ! CONSTB = 1.41 !
      Convective mixing ht. equation
      (CONSTE)                           Default: 0.15    ! CONSTE = 0.15 !
      Stable mixing ht. equation
      (CONSTN)                           Default: 2400.   ! CONSTN = 2400.!
      Overwater mixing ht. equation
      (CONSTW)                           Default: 0.16    ! CONSTW = 0.16 !
      Absolute value of Coriolis
      parameter (FCORIOL)                Default: 1.E-4   ! FCORIOL = 1.E-4!
                                         Units: (1/s)

   SPATIAL AVERAGING OF MIXING HEIGHTS

      Conduct spatial averaging
      (IAVEZI)  (0=no, 1=yes)            Default: 1       ! IAVEZI = 1    !

      Max. search radius in averaging
      process (MNMDAV)                   Default: 1       ! MNMDAV = 1    !
                                         Units: Grid cells
      Half-angle of upwind looking cone
      for averaging (HAFANG)             Default: 30.     ! HAFANG = 30.  !
                                         Units: deg.
      Layer of winds used in upwind
      averaging (ILEVZI)                 No default       ! ILEVZI = 4    !
      (must be between 1 and NZ)

   OTHER MIXING HEIGHT VARIABLES

      Minimum potential temperature lapse
      rate in the stable layer above the
      current convective mixing ht.      Default: 0.001   ! DPTMIN = 0.001 !
      (DPTMIN)                           Units: deg. K/m
      Depth of layer above current conv.
      mixing height through which lapse  Default: 200.    ! DZZI = 200. !
      rate is computed (DZZI)            Units: meters

      Minimum overland mixing height     Default:   20.   ! ZIMIN =   20. !
      (ZIMIN)                            Units: meters
      Maximum overland mixing height     Default: 2500.   ! ZIMAX = 3000. !
      (ZIMAX)                            Units: meters
      Minimum overwater mixing height    Default:   50.   ! ZIMINW = 100. !
      (ZIMINW) -- (Not used if observed  Units: meters
      overwater mixing hts. are used)
      Maximum overwater mixing height    Default: 2500.   ! ZIMAXW = 2500.!
      (ZIMAXW) -- (Not used if observed  Units: meters
      overwater mixing hts. are used)
```

Table 4-24

Sample CALMET Control File (CALMET.INP)
Input Group 6 (Continued)

```
TEMPERATURE PARAMETERS

   Interpolation type
   (1 = 1/R ; 2 = 1/R**2)              Default:1     ! IRAD = 1 !

   Conduct spatial averaging of temp-
   eratures (IAVET)  (0=no, 1=yes)     Default: 1    ! IAVET = 1 !
   (will use mixing ht MNMDAV,HAFANG
    so make sure they are correct)

   Default temperature gradient      Default: -.0098 ! TGDEFB = -.0098 !
   below the mixing height over
   water (K/m) (TGDEFB)

   Default temperature gradient      Default: -.0045 ! TGDEFA = -.0035 !
   above the mixing height over
   water (K/m) (TGDEFA)

   Beginning (JWAT1) and ending (JWAT2)
   land use categories for temperature              ! JWAT1 = 999 !
   interpolation over water -- Make                 ! JWAT2 = 999 !
   bigger than largest land use to disable

PRECIPITATION INTERPOLATION PARAMETERS

   Method of interpolation (NFLAGP)    Default = 2   ! NFLAGP = 2 !
    (1=1/R,2=1/R**2,3=EXP/R**2)
   Radius of Influence (SIGMAP)        Default = 100.0 ! SIGMAP = 100.0 !
    (0.0 use half dist. btwn nearest   Units:  km
     stns w & w/out precip when
     NFLAGP = 3)
   Minimum Precip. Rate Cutoff         Default = 0.01  ! CUTP = 0.01 !
    (values < CUTP = 0.00 mm/hr)       Units:  mm/hr

!END!
```

Table 4-24

Sample CALMET Control File (CALMET.INP)
Input Group 7 and Input Group 8

```
--------------------------------------------------------------------------------
INPUT GROUP: 7 -- Surface meteorological station parameters
-------------

     SURFACE STATION VARIABLES
     (One record per station -- "NSSTA" records in all)

             1      2
           Name     ID     X coord.  Y coord.     Lat    Lon    Time  Anem.
                             (km)      (km)     (deg.) (deg.)  zone  Ht (m)
        ---------------------------------------------------------------------
! SS1  ='MIDL'   23023    764.719  3536.282    31.93  102.20    6.     6.7 !
! SS2  ='SANT'   12921    1133.77  3284.76     29.53   98.47    6.     7.0 !
! SS3  ='SANG'   23034    928.157  3478.82     31.37  100.50    6.     6.1 !
! SS4  ='ELPA'   23044    367.468  3518.93     31.80  106.40    7.     9.8 !
! SS5  ='LAUG'   72261    909.447  3255.83     29.37  100.78    6.     4.0 !
! SS6  ='LARE'   72252    1046.88  3057.57     27.53   99.47    6.     6.1 !
-------------------
      1
        Four character string for station name
        (MUST START IN COLUMN 9)

      2
        Five digit integer for station ID

!END!


--------------------------------------------------------------------------------
INPUT GROUP: 8 -- Upper air meteorological station parameters
-------------

     UPPER AIR STATION VARIABLES
     (One record per station -- "NUSTA" records in all)

             1      2
           Name     ID     X coord.   Y coord.   Latitude  Longitude  Time
                             (km)       (km)      (deg.)     (deg.)   zone
          -------------------------------------------------------------------
! US1  ='DELR'   22010    896.487  3255.369     29.37     100.92      6. !
! US2  ='ELPA'   23044    367.468  3518.930     31.80     106.40      7. !
! US3  ='MIDL'   23023    764.719  3536.282     31.93     102.20      6. !
-------------------
      1
        Four character string for station name
        (MUST START IN COLUMN 9)

      2
        Five digit integer for station ID

!END!
```

Table 4-24

Sample CALMET Control File (CALMET.INP)
Input Group 9

```
-------------------------------------------------------------------------------
INPUT GROUP: 9 -- Precipitation station parameters
--------------

     PRECIPITATION STATION VARIABLES
     (One record per station -- "NPSTA" records in all)
     (NOT INCLUDED IF NPSTA = 0)

             1          2
           Name    Station    X coord.  Y coord.
                    Code       (km)      (km)
          -----------------------------------

! PS1=  'DELR',  412360,    896.5    3255.4 !
! PS2=  'SANG',  417943,    928.2    3478.8 !
! PS3=  'SANT',  417945,   1133.8    3284.8 !
! PS4=  'ELPA',  412797,    367.5    3518.9 !
! PS5=  'MIDL',  415890,    764.7    3536.3 !
! PS6=  'ALPI',  410174,    671.1    3360.0 !
! PS7=  'CART',  411492,    962.0    3304.3 !
! PS8=  'EAGL',  412679,    984.4    3182.9 !
! PS9=  'ELDO',  412811,    963.8    3424.8 !
! PS10= 'LANG',  415048,    874.9    3301.4 !
! PS11= 'MARF',  415596,    637.6    3352.3 !
! PS12= 'OZON',  416736,    894.3    3400.1 !
! PS13= 'SAND',  418023,    791.7    3345.9 !
! PS14= 'SHEF',  418252,    846.3    3400.5 !
-------------------
      1
        Four character string for station name
        (MUST START IN COLUMN 9)

      2
        Six digit station code composed of state
        code (first 2 digits) and station ID (last
        4 digits)

!END!
```

Table 4-25

CALMET Control File Inputs
Run Title

Variable	Type	Description	Default Value
TITLE(3)	char*80 array	Run title (first three lines of CALMET control file). Read with FORTRAN A80 format.	-

Table 4-25

CALMET Control File Inputs
Input Group 1 - General Run Control Parameters

Variable	Type	Description	Default Value
IBYR	integer	Starting year of the run (two digits)	-
IBMO	integer	Starting month of the run	-
IBDY	integer	Starting day of the run	-
IBHR	integer	Starting hour (00-23) of the run	-
IBTZ	integer	Base time zone (05=EST, 06=CST, 07=MST, 08=PST)	-
IRLG	integer	Length of the run (hours)	-
IRTYPE	integer	Run type 0=compute wind fields only 1=compute wind fields and micrometeorological variables (IRTYPE must be 1 to run CALPUFF or CALGRID)	1
LCALGRD	logical	Store extra data fields required by special modules in CALPUFF and in CALGRID (enter T or F) T=3-D fields of vertical velocity and temperature stored in output file F=these data fields are not stored in the output file (LCALGRD must be T to run CALGRID or to use the subgrid scale complex terrain option in CALPUFF)	T

Table 4-25

CALMET Control File Inputs
Input Group 2 - Grid Control Parameters

Variable	Type	Description	Default Value
NX	integer	Number of grid cells in the X direction	-
NY	integer	Number of grid cells in the Y direction	-
NZ	integer	Number of vertical layers	-
DGRIDKM	real	Horizontal grid spacing (km)	-
XORIGKM	real	Reference X coordinate* (km) of the southwest corner of grid cell (1,1)	-
YORIGKM	real	Reference Y coordinate* (km) of the southwest corner of grid cell (1,1)	-
IUTMZN	integer	UTM zone of the reference coordinates (Used only if LLCONF = F)	-
ZFACE	real array	Cell face heights (m). Note: Cell center height of layer "i" is (ZFACE(i+1) + ZFACE(i))/2. NZ+1 values must be entered.	-
LLCONF	logical	Control variable for the use of a Lambert conformal projection to rotate winds from true north to map north (enter T or F) T = yes, rotate winds F = no, do not rotate winds	F
XLAT1 XLAT2	real	Latitudes (degrees) of the two standard parallels for Lambert Conformal Projection (Used if LLCONF=T) + = Northern Hemisphere - = Southern Hemisphere	30.; 60.
RLON0	real	Reference longitude used in Lambert conformal projection rotation of input winds. (Use only if LLCONF=T.) (West = +)	90°W
RLAT0	real	Origin latitude used in Lambert conformal projection rotation of input winds (Use only if IPROG > 2)	40°N

---

* UTM coordinate if LLCONF=F, Lambert conformal coordinate if LLCONF=T.

Table 4-25

CALMET Control File Inputs
Input Group 3 - Output Options

Variable	Type	Description	Default Value
LSAVE	logical	Disk output control variable. If LSAVE=T, the gridded wind fields are stored in an output disk file (CALMET.DAT).	T
IFORMO	integer	Unformatted output file type variable. If IFORMO=1, a file suitable for input to CALPUFF or CALGRID is generated. If IFORMO=2, a file suitable for input to MESOPUFF II is generated. (Used only if LSAVE=T.)	1
LPRINT	logical	Printer output control variable. If LPRINT=T, the gridded wind fields are printed every "IPRINF" hours to the output list file (CALMET.LST).	F
IPRINF	integer	Printing interval for the output wind fields. Winds are printed every "IPRINF" hours. (Used only if LPRINT=T.)	1
IUVOUT	integer array	Control variable determining which layers of U and V horizontal wind components are printed. NZ values must be entered, corresponding to layers 1-NZ. (0=do not print layer, 1=print layer.) Used only if LPRINT=T.)	NZ*0
IWOUT	integer array	Control variable determining which layers of W vertical wind components are printed. NZ values must be entered, corresponding to cell face heights 2 to NZ+1. Note that W at the ground (cell face height 1) is zero. (0=do not print layer, 1=print layer.) (Used only if LPRINT=T and LCALGRD=T.)	NZ*0
ITOUT	integer array	Control variable determining which layers of temperature fields are printed. NZ values must be entered, corresponding to cell face heights 2 to NZ+1. (0=do not print layer, 1=print layer.) (Used only if LPRINT=T and LCALGRD=T.)	NZ*0

(Input Group 3 Continued)

Table 4-25

CALMET Control File Inputs
Input Group 3 - Output Options

Variable	Type	Description	Default Value
STABILITY	integer	Control variable determining if gridded fields of PGT stability classes are printed. (0=do not print, 1=print.) (Used only if LPRINT=T.)	0
USTAR	integer	Control variable determining if gridded fields of surface friction velocities are printed. (0=do not print, 1=print.) (Used only if LPRINT=T.)	0
MONIN	integer	Control variable determining if gridded fields of Monin-Obukhov lengths are printed. (0=do not print, 1=print.) (Used only if LPRINT=T.)	0
MIXHT	integer	Control variable determining if gridded fields of mixing heights are printed. (0=do not print, 1=print.) (Used only if LPRINT=T.)	0
WSTAR	integer	Control variable determining if gridded fields of convective velocity scales are printed. (0=do not print, 1=print.) (Used only if LPRINT=T.)	0
PRECIP	integer	Control variable determining if gridded fields of hourly precipitation rates are printed. (0=do not print, 1=print.) (Used only if LPRINT=T.)	0
SENSHEAT	integer	Control variable determining if gridded fields of sensible heat fluxes are printed. (0=do not print, 1=print.) (Used only if LPRINT=T.)	0
CONVZI	integer	Control variable determining if gridded fields of convective mixing heights are printed. (0=do not print, 1=print.) (Used only if LPRINT=T.)	0

(Input Group 3 Continued)

Table 4-25

CALMET Control File Inputs
Input Group 3 - Output Options

Variable	Type	Description	Default Value
LDB*	logical	Control variable for printing of input meteorological data and internal control parameters. Useful for program testing and debugging. If LDB=T, data will be printed for time steps "NN1" through "NN2" to the output list file (CALMET.LST).	F
NN1*	integer	First time step for which data controlled by LDB switch are printed. (Used only if LDB=T.) Note: IF NN1=NN2=0 and LDB=T, only time-independent data will be printed.	0
NN2*	integer	Last time step for which data controlled by LDB switch are printed. (Used only if LDB=T.)	0
IOUTD*	integer	Control variable for writing the computed wind fields to the wind field test disk files. (0=do not write, 1=write.)	0
NZPRN2*	integer	Number of levels, starting at the surface, printed to the wind field testing and debug files (Units 41-45).	1
IPR0*	integer	Control variable for printing to the wind field test files the interpolated wind components. (0=do not print, 1=print.)	0

---

* Testing and debugging print options.

(Input Group 3 Continued)

Table 4-25

CALMET Control File Inputs
Input Group 3 - Output Options

Variable	Type	Description	Default Value
IPR1*	integer	Control variable for printing to the wind field test files the terrain adjusted surface wind components. (0=do not print, 1=print.) Used only with objective analysis.	0
IPR2*	integer	Control variable for printing to the wind field test files the smoothed wind components and initial divergence fields. (0=do not print, 1=print).	0
IPR3*	integer	Control variable for printing to the wind field test files the final wind speed and direction fields. (0=do not print, 1=print.)	0
IPR4*	integer	Control variable for printing to the wind field test files the final divergence fields. (0=do not print, 1=print.)	0
IPR5*	integer	Control variable for printing to the wind field test files the wind fields after kinematic effects are added. (0=do not print, 1=print.)	0
IPR6*	integer	Control variable for printing to the wind field test files the wind fields after the Froude number adjustment is made. (0=do not print, 1=print.)	0
IPR7*	integer	Control variable for printing to the wind field test files the wind fields after the slope flows are added. (0=do not print, 1=print.)	0
IPR8*	integer	Control variable for printing to the wind field test files the final wind component fields. (0=do not print, 1=print.)	0

---

* Testing and debugging print options.

Table 4-25

CALMET Control File Inputs
Input Group 4 - Meteorological Data Options

Variable	Type	Description	Default Value
NSSTA	integer	Number of surface meteorological stations	-
NUSTA	integer	Number of upper air meteorological stations	-
NPSTA	integer	Number of precipitation stations	-
NOWSTA	integer	Number of overwater meteorological stations	-
IFORMS	integer	Control variable determining the format of the input surface meteorological data (1=unformatted, i.e., SMERGE output) (2=formatted, i.e., free-formatted user input or formatted SMERGE output)	-
IFORMP	integer	Control variable determining the format of the input precipitation data (1=unformatted, i.e., PMERGE output) (2=formatted, i.e., free-formatted user input or formatted PMERGE output)	-

Table 4-25

CALMET Control File Inputs
Input Group 5 - Wind Field Options and Parameters

Variable	Type	Description	Default Value
IWFCOD	integer	Control variable determining which wind field module is used. (0=objective analysis only, 1=diagnostic wind module.)	1
IFRADJ	integer	Control variable for computing Froude number adjustment effects. (0=do not compute, 1=compute.)	1
IKINE	integer	Control variable for computing kinematic effects. (0=do not compute, 1=compute.)	1
IOBR	integer	Control variable for using the O'Brien vertical velocity adjustment procedure. (0=do not use, 1=use.)	1
IEXTRP	integer	Control variable for vertical extrapolation. If ABS(IEXTRP)=1, no vertical extrapolation from the surface wind data takes place. If ABS(IEXTRP)=2, extrapolation is done using a power law profile. If ABS(IEXTRP) = 3, extrapolation is done using the values provided in the FEXTRP array for each layer. If ABS(IEXTRP) = 4 similarity theory is used. If IEXTRP < 0, Layer 1 data at the upper air stations are ignored. Layer 1 at an upper air station is also ignored if the four-character station name of the upper air station matches that of a surface station.	1
RMIN2	real	Minimum distance in km between surface station and nearest upper air station for which extrapolation of surface winds at surface station will be performed, when ABS(IEXTRP) > 1. Should be set to -1.0 when all surface data are to be extrapolated.	4.0
IPROG	integer	Control variable determining if gridded prognostic model wind fields are used as input. 0 = No, (IWFCOD = 0 or 1) 1 = Yes, use CSUMM prog. winds as Step 1 field, (IWFCOD = 0) 2 = Yes, use CSUMM prog. winds as initial guess field (IWFCOD = 1) 3 = Yes, use MM4 prog. winds as Step 1 field (IWFCOD = 0) 4 = Yes, use MM4 prog. winds as initial guess field (IWFCOD = 1) 5 = Yes, use MM4 prog. winds as observations (IWFCOD = 1)	0

(Input Group 5 Continued)

Table 4-25

CALMET Control File Inputs
Input Group 5 - Wind Field Options and Parameters

Variable	Type	Description	Default Value
DGRDPKM	real	Horizontal spacing of prognostic grid (km)	-
LVARY	logical	Control variable for use of varying radius of influence. If no stations with valid data are found within the specified radius of influence, then the closest station with valid data will be used. (T=use, F=do not use.)	
RMAX1	real	Maximum radius of influence over land in the surface layer (km). This parameter should reflect the limiting influence of terrain features on the interpolation at this level.	-
RMAX2	real	Maximum radius of influence over land in layers aloft (km). RMAX2 is generally larger than RMAX1 because the effects of terrain decrease with height.	-
RMAX3	real	Maximum radius of influence overwater (km). RMAX3 is used for all layers overwater. It must be large enough to ensure that all grid points over water are large enough to be within the radius of influence of at least one observation.	-
RMIN	real	Minimum radius of influence used in the wind field interpolation (km). This parameter should be assigned a small value (e.g., <1 km) to avoid possible divide by zero errors in the inverse-distance-squared weighting scheme.	-
RMIN2	real	Distance (km) from an upper air station within which vertical extrapolation of surface station data will be excluded. Used only if |IEXTRM| > 1.	4.0
TERRAD	real	Radius of influence of terrain features (km)	-

(Input Group 5 Continued)

Table 4-25

CALMET Control File Inputs
Input Group 5 - Wind Field Options and Parameters

Variable	Type	Description	Default Value
R1	real	Weighting parameter for the diagnostic wind field in the surface layer (km). This parameter controls the relative weighting of the first-guess wind field produced by the diagnostic wind field model and the observations. R1 is the distance from an observational station at which the observation and the first-guess field are equally weighted.	-
R2	real	Weighting parameter for the diagnostic wind field in the layers aloft (km). R2 is applied in the upper layers in the same manner as R1 is used in the surface layer.	-
RPROG	real	Weighting parameter (km) for the prognostic wind field data	-
DIVLIM	real	Convergence criterion for the divergence minimization procedure	5.0E-6
NITER	integer	Maximum number of iterations for the divergence minimization procedure	50
NSMTH	integer array	Number of smoothing passes in each layer NZ values must be entered.	2,(MXNZ-1)*4
NINTR2	integer array	Maximum number of stations used in the interpolation of data to a grid point for each layer 1-NZ. This allows only the "NINTR2" closest stations to be included in the interpolation. The effect of increasing NINTR2 is similar to smoothing. NZ values must be entered.	-
CRITFN	real	Critical Froude number used in the evaluation of terrain blocking effects	1.0
ALPHA	real	Empirical parameter controlling the influence of kinematic effects	0.1

(Input Group 5 Continued)

Table 4-25

CALMET Control File Inputs
Input Group 5 - Wind Field Options and Parameters

Variable	Type	Description	Default Value
FEXTR2	integer array	Extrapolation values for layers 2 through NZ (FEXTR2(1) must be entered but is not used). Used only if ABS(IEXTRP) ≥ 3.	NZ*0.0
NBAR	integer	Number of wind field interpolation barriers	0
XBBAR	real array	X coordinate (km) of the beginning of each barrier. "NBAR" values must be entered. (Used only if NBAR > 0.)	-
YBBAR	real array	Y coordinate (km) of the beginning of each barrier. "NBAR" values must be entered. (Used only if NBAR > 0.)	-
XEBAR	real array	X coordinate (km) of the end of each barrier. "NBAR" values must be entered. (Used only if NBAR > 0.)	-
YEBAR	real array	Y coordinate (km) of the end of each barrier. "NBAR" values must be entered. (Used only if NBAR > 0.)	-
IDIOPT1	integer	Control variable for surface temperature input to diagnostic wind field module. (0=compute internally from surface data, 1=read preprocessed values from the file DIAG.DAT.)	0
ISURFT	integer	Surface station number (between 1 and NSSTA) used for the surface temperature for the diagnostic wind field module	-
IDIOPT2	integer	Control variable for domain-averaged temperature lapse rate. (0=compute internally from upper air data, 1=read preprocessed values from the file DIAG.DAT.)	0
IUPT	integer	Upper air station number (between 1 and NUSTA) used to compute the domain-scale temperature lapse rate for the diagnostic wind field module	-
ZUPT	real	Depth (m) through which the domain-scale temperature lapse rate is computed	200.

(Input Group 5 Continued)

Table 4-25

CALMET Control File Inputs
Input Group 5 - Wind Field Options and Parameters

Variable	Type	Description	Default Value
IDIOPT3	integer	Control variable for domain-averaged wind components. (0=compute internally from upper air, 1=read preprocessed values from the file DIAG.DAT.)	0
IUPWND	integer	Upper air station number used to compute the domain-scale wind components for the diagnostic wind field module. Either specify one station from 1 to nusta or specify -1 indicating the use of $1/r^2$ interpolation to generate a spatially-variable initial guess field.	-
ZUPWND	real array	Bottom and top of layer through which the domain-scale winds are computed. Units: Meters. (Used only if IDIOPT3=0.) Note: Two values must be entered (e.g., ! ZUPWND=1.0, 2000. !).	1.0, 2000.
IDIOPT4	integer	Control variable for surface wind components. (0=compute internally from surface data, 1=read preprocessed values from the file DIAG.DAT.)	0
IDIOPT5	integer	Control variable for upper air wind components. (0=compute internally from upper air data, 1=read preprocessed values from the file DIAG.DAT.)	0
LLBREZE	logical	Control variable for lake breeze region option. LLBREZE=T, region interpolation is performed. LLBREZE=F, no region interpolation is performed.	F
NBOX	integer	Number of boxes defining region (used only if LLBREZE=T)	-
XG1	real array	1st x-grid line to define box. (Used only if LLBREZE=T.) (One for each box.)	-
XG2	real array	2nd x-grid line to define box. (Used only if LLBREZE=T.) (One for each box.)	-
YG1	real array	1st y-grid line to define box. (Used only if LLBREZE=T.) (One for each box.)	-

(Input Group 5 Continued)

Table 4-25

CALMET Control File Inputs
Input Group 5 - Wind Field Options and Parameters

Variable	Type	Description	Default Value
YG2	real array	2nd y-grid line to define box. (Used only if LLBREZE=T.) (One for each box.)	-
XBCST	real array	Beginning x coordinate (km) of user defined coastline (straight line). (Used only if LLBREZE=T.) (One for each box.)	-
YBCST	real array	Beiginning y coordinate (km) of user defined coastline (straight line). (Used only if LLBREZE=T.) (One for each box.)	-
XECST	real array	Beginning x coordinate (km) of user defined coastline (straight line). (Used only if LLBREZE=T.) (One for each box.)	-
YECST	real array	Beginning y coordinate (km) of user defined coastline (straight line). (Used only if LLBREZE=T.) (One for each box.)	-
NLB	integer	Number of meteorological stations (surface and upper air stations) in a box. (Used only if LLBREZE=T.) (One for each box.)	-
METBXID	integer	Station ids of the meteorological stations within each box (surface stations first, then upper air stations). (Used only if LLBREZE=T.) (One set per box.)	-

Table 4-25

CALMET Control File Inputs
Input Group 6 - Mixing Height, Temperature, and Precipitation Parameters

Variable	Type	Description	Default Value
CONSTB	real	Neutral mechanical mixing height constant (variable B in Eqn. 2-49)	1.41
CONSTE	real	Convective mixing height constant (variable E in Eqn. 2-47)	0.15
CONSTN	real	Stable mixing height constant (variable B_2 in Eqn. 2-52)	2400.
CONSTW	real	Overwater mixing height constant	0.16
FCORIOL	real	Absolute value of coriolis parameter (1/s)	1.E-4
DPTMIN	real	Minimum potential temperature lapse rate in the stable layer above the current convective mixing height (deg. K/m)	0.001
DZZI	real	Depth of layer (m) above current convective mixing height in which lapse rate is computed.	200.
ZIMAX	real	Maximum overland mixing height (m)	2500.
ZIMIN	real	Minimum overland mixing height (m)	20.
ZIMAXW	real	Maximum overwater mixing height (m) (Not used if observed overwater mixing heights are used)	2500.
ZIMINW	real	Minimum overwater mixing height (m) (Not used if observed overwater mixing heights are used)	50.
IAVEZI	integer	Conduct spatial averaging of mixing heights (0=no, 1=yes)	1
MNMDAV	integer	Maximum search radius in the spatial averaging process (in grid cells)	1
HAFANG	real	Half-angle of upwind-looking cone for spatial averaging (deg.)	30.
ILEVZI	integer	Layer of winds used in upwind averaging of mixing heights. (Must be between 1 and NZ.)	-

(Input Group 6 Continued)

Table 4-25

CALMET Control File Inputs
Input Group 6 - Mixing Height, Temperature, and Precipitation Parameters

Variable	Type	Description	Default Value
IRAD	integer	Type of temperature interpolation (1 = 1/radius) (2 = 1/radius^2)	1
IAVET	integer	Conduct spatial averaging of temperatures (0 = no; 1 = yes) (Will use MNMDAV and HAFANG)	1
TGDEFB	real	Default temperature lapse rate (K/m) below mixing height over water	-0.0098
TGDEFA	real	Default temperature lapse rate (K/m) above mixing height over water	-0.0045
JWAT1, JWAT2	integers	Beginning land use category for temperature interpolation overwater. Range of land use categories associated with major water bodies. Used for overwater temperature interpolation	999, 999
NFLAGP	integer	Method of precipitation interpolation (1 = 1/radius interpolation) (2 = 1/radius^2 interpolation) (3 = 1/radius^2 * exponential function) Method 3 is based on a Thiessen method for non-continuous fields where the exponential function = exponent [-radius^2/SIGMAP^2] and SIGMAP is defined below	2
SIGMAP	real	Radius of influence for precipitation (km); except value of 0.0 yields half of the minimum distance between any non-zero precipitation station and any zero precipitation station if NFLAGP = 3	100.0
CUTP	real	Minimum precipitation rate (mm/hr); values < CUTP set to 0.0 mm/hr	0.01

Table 4-25

CALMET Control File Inputs
Input Group 7 - Surface Meteorological Station Parameters

One line of data is entered for each surface station. If separate land/water interpolation is desired, this group must include only land stations. Overwater data will be in SEAn.DAT files. Each line contains the following parameters read in free format: CSNAM, IDSSTA, XSSTA, YSSTA, XSLAT, XSLON, XSTZ, ZANEM. The data for each station are preceded by ! SSn=..., where n is the station number (e.g., ! SS1=... for station #1, ! SS2=... for station #2, etc.). The station variables (SS1, SS2, etc.) must start in Column 3. The data must start in Column 9 or greater of each record. See the sample control file in Table 4-24 for an example.

(Repeated for each of "NSSTA" Stations)

Variable	Type	Description
CSNAM	char*4	Four-character station name. Must be enclosed within single quotation marks (e.g., 'STA1', 'STA2', etc.). The opening quotation mark must be in Column 9 or greater of each record.
IDSSTA	integer	Station identification number
XSSTA	real	X coordinate* (km) of surface station
YSSTA	real	Y coordinate* (km) of surface station
XSLAT	real	Station latitude (degrees). Positive for Northern Hemisphere. Negative for Southern Hemisphere.
XSLON	real	Station longitude (degrees). Positive for Western Hemisphere. Negative for Eastern Hemisphere.
XSTZ	real	Time zone of the station (e.g., 05=EST, 06=CST, 07=MST, 08=PST.)
ZANEM	real	Anemometer height (m)

---

* Coordinates are UTM coordinates if LLCONF=F, or Lambert conformal coordinates if LLCONF=T (see Input Group 2).

Table 4-25

CALMET Control File Inputs
Input Group 8 - Upper Air Station Parameters

One line of data is entered for each upper air station. Each line contains the following parameters read in free format: CUNAM, IDUSTA, XUSTA, YUSTA, XULAT, XULON, XUTZ. The data for each station are preceded by ! USn=..., where n is the upper air station number (e.g., ! US1=... for station #1, ! US2=... for station #2, etc.). The station variables (US1, US2, etc.) must start in Column 3. The data must start in Column 9 or greater of each record. See the sample control file in Table 4-24 for an example.

(Repeated for each of "NUSTA" Stations)

Variable	Type	Description
CUNAM	char*4	Four-character upper air station name. Must be enclosed within single quotation marks (e.g., 'STA1', 'STA2', etc.). <u>The opening quotation mark must be in Column 9 or greater of each record</u>.
IDUSTA	integer	Station identification number
XUSTA	real	X coordinate* (km) of upper air station
YUSTA	real	Y coordinate* (km) of upper air station
XULAT	real	Station latitude (degrees). Positive for Northern Hemisphere. Negative for Southern Hemisphere.
XULON	real	Station longitude (degrees). Positive for Western Hemisphere. Negative for Eastern Hemisphere.
XUTZ	real	Time zone of the station (e.g., 05=EST, 06=CST, 07=MST, 08=PST.)

---

* Coordinates are UTM coordinates if LLCONF=F, or Lambert conformal coordinates if LLCONF=T (see Input Group 2).

Table 4-25

CALMET Control File Inputs
Input Group 9 - Precipitation Station Parameters

One line of data is entered for each precipitation station. Each line contains the following parameters read in free format: CPNAM, IDPSTA, XPSTA, and YPSTA. The data for each station are preceded by ! PSn=..., where n is the station number (e.g., ! PS1=... for station #1, ! PS2=... for station #2, etc.). The station variables (PS1, PS2, etc.) must start in Column 3. The data must start in Column 9 or greater of each record. See the sample control file in Table 4-24 for an example.

(Repeated for each of "NPSTA" Stations)

Variable	Type	Description
CPNAM	char*4	Four-character station name. Must be enclosed within single quotation marks (e.g., 'PS1', 'PS2', etc.). The opening quotation mark must be in Column 9 or greater of each record.
IDPSTA	integer	Station identification number
XPSTA	real	X coordinate* (km) of surface station
YPSTA	real	Y coordinate* (km) of surface station

---

* Coordinates are UTM coordinates if LLCONF=F, or Lambert conformal coordinates if LLCONF=T (see Input Group 2).

4.2.2 Geophysical Data File (GEO.DAT)

The GEO.DAT data file contains the geophysical data inputs required by the CALMET model. These inputs include land use type, elevation, surface parameters (surface roughness, length, albedo, Bowen ratio, soil heat flux parameter, and vegetation leaf area index) and anthropogenic heat flux. The land use and elevation data are entered as gridded fields. The surface parameters and anthropogenic heat flux can be entered either as gridded fields or computed from the land use data at each grid point. Default values relating each of these parameters to land use are provided in the model.

A sample GEO.DAT file is shown in Table 4-26. The first line of the file contains a character string of up to 80 characters in length which can be used to identify the data set. The second line contains grid information such as the number of grid cells, grid spacing, reference coordinates and reference UTM zone. These variables are checked by CALMET for consistency and compatibility with the CALMET control file inputs. Eight sets of flags and data records follow for the land use, elevation, surface parameters, and anthropogenic heat flux data.

The default CALMET land use scheme is based on the U.S. Geological Survey (USGS) land use classification system. The USGS primary land use categories are shown in Table 4-27. Two Level I USGS categories (water and wetlands) are subdivided into subcategories. Along with the default CALMET land use, the default values of the other geophysical parameters for each land use type are also shown. The default land use classification scheme contains 14 land use types. Note that a negative value of land use by CALMET is used as a flag to indicate irrigated land. Irrigated land may be assigned a different Bowen ratio than unirrigated land, and the CALPUFF dry deposition module uses the irrigated land use flag in computing the effect of moisture stress on stomatal resistance. (If the land is irrigated, it is assumed that the vegetation is not moisture stressed.)

CALMET allows a more detailed breakdown of land use or a totally different classification scheme to be used by providing the option for user-defined land use categories. An extended 52-class land use scheme based on the USGS Level I and Level II land use categories is shown in Table 4-27(b). The user can specify up to "MXLU" land use categories along with new values of the other geophysical parameters for each land use type. The parameter MXLU is specified in the CALMET parameter file (PARAMS.MET). Currently, up to 52 user-specified land use categories are allowed.

CALMET contains an option, described in detail in Section 2.3.2.1, in which temperatures over water bodies such as the ocean or large lakes are calculated by using data from only those observation stations (SEA.DAT files, usually buoys) located in it, while only land stations (SURF.DAT file) will be used to calculate temperatures over the rest of the grid. The variables JWAT1 and JWAT2 in CALMET.INP Input Group #6 specify the range of land use categories defining the water body for which this land/water temperature scheme will be implemented. A range is specified to allow inclusion of multiple categories, for example "bay" and "ocean," in the definition of the water body. To disable the overwater option, JWAT1 and JWAT2 are set to values greater than the highest land use category listed in the GEO.DAT file. The default values of JWAT1 and JWAT2 are both 999, indicating the overwater interpolation scheme is not applied in default mode.

Because the temperature of <u>any</u> grid cell whose land use is included in the range defined by JWAT1 and JWAT2 will be determined by a weighting of <u>all</u> overwater data (SEA#.DAT files), it is recommended that smaller or distant water bodies be assigned land use categories that are distinct from those used in JWAT1 and JWAT2, to avoid use of inappropriate data in determining their surface temperatures. Thus a small reservoir will have its temperature determined by surrounding land stations, rather than by ocean buoy data. After viewing the initial temperature field that results from the CALMET run, the user may wish to "fine tune" the fields using the extended, 52-class land use system in Table 4-27(b) and by altering the land use assignments of particular grid cells or changing the land uses included in the JWAT1-JWAT2 range. For instance, by limiting the range to "ocean" only and then changing which near-shore cells are considered to be "bay" and which are "ocean" the user can control the appearance of the temperature field in the vicinity of the coastline.

The values of IWAT1 and IWAT2 are used to determine whether the overland or overwater method will be used to produce a mixing height value for a particular grid cell. The default values of IWAT1 and IWAT2 are both 55, restricting the overwater mixing height scheme to "large" bodies of water. The user may change the values of IWAT1 and IWAT2 on a case-by-case basis to include or exclude other water bodies from being considered as overwater. For instance, the user's domain may have a bay where the mixing height should be determined using the overwater method but a series of small lakes where the overland method would be more appropriate, so the "lake" category would be excluded from the IWAT range. Alternatively, if one has a large lake that should be considered to be "overwater" and a smaller lake that should be considered to be "overland", then the land use category for the smaller lake could be changed to reflect some other category not in the IWAT range, such as forest or wetland. It is recommended that if the user creates his or her own GEO.DAT fields for roughness length, albedo, etc. they be weighted by the actual percentage of each land use in a given cell. That method is more accurate and, if one subsequently changes the dominant land use category, the variables used to calculate mixing height will still reflect the fact that there is water present in the grid cell.

The surface elevation data field is entered in "user units" along with a scaling factor to convert user units to meters. The sample GEO.DAT file shown in Table 4-26 contains elevations in meters.

The gridded fields are entered with the 'NXM' values on a line. NXM is the number of grid cells in the X direction. The data from left to right correspond to X=1 through NXM. The top line of a gridded field correspond to Y=NYM, the next line to Y=NYM-1, etc. All of the GEO.DAT inputs are read in FORTRAN free format. A detailed description of the GEO.DAT variables is contained in Table 4-28.

Table 4-26

Sample GEO.DAT Geophysical Data File

```
GEO.DAT -- 54 km grid -- 10x10 subset from ll corner
10, 10, 54.0, -54.0, -621.0, 16  - NX, NY, DGRIDKM, XORIGRKM, YORIGRKM, IUTMZN
0            - LAND USE DATA -- 0=default lu categories, 1=new categories
  40  40  40  40  40  40  40  40  40  40
  40  40  40  40  40  40  40  40  40  40
  40  40  40  40  40  40  40  40  40  40
  40  40  40  40  40  40  40  40  40  40
  40  40  40  40  40  40  40  40  40  40
  40  40  40  40  40  40  40  40  40  40
  40  40  40  40  40  40  40  40  40  40
  40  40  40  40  40  40  40  40  40  40
  40  40  40  40  40  40  40  40  40  40
  40  40  40  40  40  40  40  40  40  40
1.0          - TERRAIN HEIGHTS - HTFAC - conversion to meters
   185.078      147.205      146.924      156.446      139.487
   138.010      173.812      203.405      232.758      222.710
   221.813      144.507      142.191      136.302      123.083
   133.693      158.348      192.281      224.074      247.634
   316.083      189.884      139.814      144.073      122.189
   123.002      146.333      195.571      215.208      263.082
   253.774      157.182      121.245      121.407      137.051
   144.876      152.340      200.471      246.724      318.109
   182.808      98.6778      91.7038      129.091      138.407
   165.023      190.390      225.489      253.910      314.988
   114.193      77.9254      93.2705      115.583      141.910
   190.386      187.382      204.256      306.503      448.922
   78.3998      71.2785      95.3602      129.989      148.870
   208.477      227.053      260.169      393.913      421.927
   64.1938      79.1642      117.264      139.864      158.785
   253.950      254.195      324.301      434.496      277.916
   53.5650      84.5807      134.072      148.030      162.781
   185.386      203.171      281.656      288.990      312.717
   42.8075      71.3265      111.239      96.0823      122.349
   189.143      181.916      249.689      271.627      278.849
0   - z0 --(0=default z0-lu table, 1=new z0-lu table, 2=gridded z0 field
0   - albedo --(0=default albedo-lu table,1=new albedo-lu table,2=gridded albedo field
0   - Bowen ratio --(0=default Bowen-lu table,1=new Bowen-lu table,2=gridded Bowen field
0   - soil heat flux param (HCG) --(0=default HCG-lu table,1=new HCG-lu table,2=gridded field
0   - anthropogenic heat flux (QF) --(0=default QF-lu table,1=new QF-lu table,2=gridded field
0   - leaf area index (XLAI) --(0=default XLAI-lu table,1=new XLAI-lu table,2=gridded field
```

Table 4-27(a)

Default CALMET Land Use Categories and Associated Geophysical Parameters Based on the U.S. Geological Survey Land Use Classification System (14-Category System)

Land Use Type	Description	Surface Roughness (m)	Albedo	Bowen Ratio	Soil Heat Flux Parameter	Anthropogenic Heat Flux (W/m^2)	Leaf Area Index
10	Urban or Built-up Land	1.0	0.18	1.5	.25	0.0	0.2
20	Agricultural Land - Unirrigated	0.25	0.15	1.0	.15	0.0	3.0
-20*	Agricultural Land - Irrigated	0.25	0.15	0.5	.15	0.0	3.0
30	Rangeland	0.05	0.25	1.0	.15	0.0	0.5
40	Forest Land	1.0	0.10	1.0	.15	0.0	7.0
50	Water	0.001	0.10	0.0	1.0	0.0	0.0
51	Small Water Body	0.001	0.10	0.0	1.0	0.0	0.0
55	Large Water Body	0.001	0.10	0.0	1.0	0.0	0.0
60	Wetland	1.0	0.10	0.5	.25	0.0	2.0
61	Forested Westland	1.0	0.1	0.5	0.25	0.0	2.0
62	Nonforested Wetland	0.2	0.1	0.1	0.25	0.0	1.0
70	Barren Land	0.05	0.30	1.0	.15	0.0	0.05
80	Tundra	.20	0.30	0.5	.15	0.0	0.0
90	Perennial Snow or Ice	.20	0.70	0.5	.15	0.0	0.0

* Negative values indicate "irrigated" land use

Table 4-27(b)
Extended CALMET Land Use Categories Based on the U.S. Geological Survey Land Use and Land Cover Classification System (52-Category System)

	Level I		Level II
10	Urban or Built-up Land	11	Residential
		12	Commercial and Services
		13	Industrial
		14	Transportation, Communications and Utilities
		15	Industrial and Commercial Complexes
		16	Mixed Urban or Built-up Land
		17	Other Urban or Built-up Land
20	Agricultural Land — Unirrigated	21	Cropland and Pasture
		22	Orchards, Groves, Vineyards, Nurseries, and Ornamental Horticultural Areas
		23	Confined Feeding Operations
		24	Other Agricultural Land
-20	Agricultural Land — Irrigated	-21	Cropland and Pasture
		-22	Orchards, Groves, Vineyards, Nurseries, and Ornamental Horticultural Areas
		-23	Confined Feeding Operations
		-24	Other Agricultural Land
30	Rangeland	31	Herbaceous Rangeland
		32	Shrub and Brush Rangeland
		33	Mixed Rangeland
40	Forest Land	41	Deciduous Forest Land
		42	Evergreen Forest Land
		43	Mixed Forest Land
50	Water	51	Streams and Canals
		52	Lakes
		53	Reservoirs
		54	Bays and Estuaries
		55	Oceans and Seas
60	Wetland	61	Forested Wetland
		62	Nonforested Wetland
70	Barren Land	71	Dry Salt Flats
		72	Beaches
		73	Sandy Areas Other than Beaches
		74	Bare Exposed Rock
		75	Strip Mines, Quarries, and Gravel Pits
		76	Transitional Areas
		77	Mixed Barren Land
80	Tundra	81	Shrub and Brush Tundra
		82	Herbaceous Tundra
		83	Bare Ground
		84	Wet Tundra
		85	Mixed Tundra
90	Perennial Snow or Ice	91	Perennial Snowfields
		92	Glaciers

Note: Negative values indicate irrigated land use.

Table 4-28

GEO.DATA File Format

Record	Variable	Type	Description
1	TITLEGE	char*80	Character title of file (up to 80 characters)
2	NXG	integer	Number of grid cells in the X direction
2	NYG	integer	Number of grid cells in the Y direction
2	DGRIDG	real	Horizontal grid spacing (km)
2	XORG	real	Reference X coordinate** (km) of southwest corner of grid cell (1,1)
2	YORG	real	Reference Y coordinate** (km) of southwest corner of grid cell (1,1)
2	IUTMG	integer	UTM zone of reference coordinates (used only if using UTM projection)
3	IOPT1	integer	Option flag for land use categories (0=to use default land use categories) (1=to specify new land use categories)
4*	NLU	integer	Number of land use categories
4*	IWAT1	integer	Range of land use categories associated with water (i.e., land use categories IWAT1 to IWAT2, inclusive, are assumed to represent water surfaces)
4*	IWAT2	integer	
5*	ILUCAT	integer array	Array of "NLU" new user specified land use categories
NEXT NY lines	ILANDU	integer array	Land use types for cell grid point (NX values per line). The following statements are used to read the data: do 20 J=NY,1,-1 20 READ (iogeo,*)(ILANDU(n,j), n=1, nx)
NEXT line	HTFAC	real	Multiplicative scaling factor to convert terrain heights from user units to meters (e.g., HTFAC = 0.3048 for user units of ft, 1.0 for user units of meters)

---

* Included only if IOPT1 = 1

** Coordinates are UTM coordinates if using a UTM projection, or Lambert conformal coordinates if using Lambert conformal projection.

(GEO.DAT File Format Continued)

Table 4-28

GEO.DAT File Format

Record	Variable	Type	Description

NEXT NY lines	ELEV	real array	Terrain elevations (user units) for each grid point (NX values for line). The following statements are used to read the data:
			`do 30 J=NY,1,-1`
			`30 READ(iogeo,*)(ELEV(n,j),n=1,NX)`

NEXT line	IOPT2	integer	Option flag for input of surface roughness lengths (z0) 0=compute gridded z0 values from land use types using default z0 land use table 1=compute gridded z0 values from land use types using new, user-specified z0 land use table 2=input a gridded z0 field

NEXT** NLU lines	ILU
	ZOLU
		integer
		real array
			Land use type and associated surface roughness lengths (m). Two variables per line read as:
			`do 120 I=1,NLU`
			`120 READ(iogeo,*)ILU,ZOLU(I)`

NEXT*** NY lines	ZO	real array	Surface roughness length (m) at each grid point (NX values per line). The following statements are used to read the data:
			`do 150 J=NY,1,-1`
			`150 READ(iogeo,*)(ZO(n,j),n=1,NX)`

** Included only if IOPT2 = 1

*** Included only if IOPT2 = 2

Table 4-28

GEO.DAT File Format

Record	Variable	Type	Description
NEXT line	IOPT3	integer	Option flat for input of albedo 0=compute gridded albedo values from land use types using the default albedo-land use table 1=compute gridded albedo values from land use types using a new, user-specified albedo-land use table 2=input a gridded albedo field

NEXT** NLU lines	ILU
	ALBLU
		integer
		real array
			Land use type and associated albedo. Two variables per line read as:
			`do 120 I=1,NLU`
			`120 READ(iogeo,*)ILU,ALBLU(I)`

NEXT*** NY lines	ALBEDO	real array	Albedo at each grid point (NX values per line). The following statements are used to read the data:
			`do 150 J=NY,1,-1`
			`150 READ(iogeo,*)(ALBEDO(n,j),n=1,NX)`

** Included only if IOPT3 = 1

*** Included only if IOPT3 = 2

Table 4-28

GEO.DAT File Format

Record	Variable	Type	Description
NEXT line	IOPT4	integer	Option flag for input of Bowen ratio 0=compute gridded Bowen ratio values from land use types using default Bowen ratio-land use table 1=compute gridded Bowen ratio values from land use types using new, user-specified Bowen ratio-land use table 2=input a gridded Bowen ratio field

NEXT** NLU lines	ILU
	BOWLU
		integer
		real array
			Land use type and associated Bowen ratio. Two variables per line read as:
			`do 120 I=1,NLU`
			`120 READ(iogeo,*)ILU,BOWLU(I)`

NEXT*** NY lines	BOWEN	real array	Bowen ratio at each grid point (NX values per line). The following statements are used to read the data:
			`do 150 J=NY,1,-1`
			`150 READ(iogeo,*)(BOWEN(n,j),n=1,NX)`

** Included only if IOPT4 = 1
*** Included only if IOPT4 = 2

Table 4-28

GEO.DAT File Format

Record	Variable	Type	Description
NEXT line	IOPT5	integer	Option flag for input of soil heat flux constant 0=compute gridded soil heat flux constant values from land use types using the default soil heat flux constant-land use table 1=compute gridded soil heat flux constant values from land use types using new, user-specified soil heat flux constant-land use table 2=input a gridded soil heat flux constant field

NEXT[**] NLU lines	ILU
	HCGLU
		integer
		real array
			Land use type and associated soil heat flux constant. Two variables per line read as:
			`do 120 I=1,NLU`
			`120 READ(iogeo,*)ILU,HCGLU(I)`

NEXT[***] NY lines	HCG	real array	Soil heat flux constant at each grid point (NX values per line). The following statements are used to read the data:
			`do 150 J=NY,1,-1`
			`150 READ(iogeo,*)(HCG(n,j),n=1,NX)`

[**] Included only if IOPT5 = 1
[***] Included only if IOPT5 = 2

Table 4-28

GEO.DAT File Format

Record	Variable	Type	Description
NEXT line	IOPT6	integer	Option flag for input of anthropogenic heat flux (W/m^2) 0=compute gridded anthropogenic heat flux values from land use types using default anthropogenic heat flux-land use table 1=compute gridded anthropogenic heat flux values from land use types using new, user-specified anthropogenic heat flux-land use table 2=input a gridded anthropogenic heat flux field
NEXT** NLU lines	ILU QFLU	integer real array	Land use type and associated anthropogenic heat flux (W/m^2). Two variables per line read as:

```
        do 120 I=1,NLU
120        READ(iogeo,*)ILU,QFLU(I)
```

Record	Variable	Type	Description
NEXT*** NY lines	QF	real array	Anthropogenic heat flux (W/m^2) at each grid point (NX values per line). The following statements are used to read the data:

```
        do 150 J=NY,1,-1
150        READ(iogeo,*)(QF(n,j),n=1,NX)
```

** Included only if IOPT6 = 1
*** Included only if IOPT6 = 2

Table 4-28

GEO.DAT File Format

Record	Variable	Type	Description
NEXT line	IOPT7	integer	Option flag for input of leaf area index 0=compute gridded leaf area index values from land use types using default leaf area index-land use table 1=compute gridded leaf area index values from land use types using new, user-specified leaf area index-land use table 2=input a gridded leaf area index field

NEXT** NLU lines	ILU
	XLAILU
		integer
		real array
			Land use type and associated leaf area index values. Two variables per line read as:
			`do 120 I=1,NLU`
			`120 READ(iogeo,*)ILU,XLAILU(I)`

NEXT*** NY lines	XLAI	real array	Leaf area index value at each grid point (NX values per line). The following statements are used to read the data:
			`do 150 J=NY,1,-1`
			`150 READ(iogeo,*)(XLAI(n,j),n=1,NX)`

** Included only if IOPT7 = 1
*** Included only if IOPT7 = 2

4.2.3 Upper Air Data Files (UP1.DAT, UP2.DAT,...)

The upper air data used by CALMET are read from upper air data files called UPn.dat, where n is the upper air station number (n=1,2,3, etc.). The upper air data files can be created by the READ56 or READ62 preprocessor programs from standard NCDC upper air data formats or by application-specific reformatting programs. Observations made at non-standard sounding times can be used by CALMET. The operation of the READ56 and READ62 programs is described in Section 4.1.1.

The UPn.DAT files are formatted, user-editable files containing two header records followed by groups of data records. A sample upper air data file generated by READ62 and hand-edited to remove informational messages and to fill in missing soundings is shown in Table 4-29. The first header record contains the starting and ending dates of data contained in the file and the top pressure level of the sounding data. The second header record contains the READ56/READ62 data processing options used in the creation of the file.

The data records consist of a one-record header listing the origin of the data (5600 or 6201 NCDC data or 9999 for non-NCDC data), station ID number, date and time, and information on the number of sounding levels. Following this are the pressure, elevation, temperature, wind direction, and wind speed for each sounding level. The format of the UPn.dat file is shown in Table 4-30.

As discussed in Section 4.1.1, the model allows missing values of wind speed, wind direction, and temperature in the UP.DAT files at intermediate levels. The model will linearly interpolate between valid levels to fill in the missing data. The user is cautioned against using soundings for which this interpolation would be inappropriate. Missing soundings should be replaced with soundings for the same time period from a representative substitute station. Each data set must be processed on a case-by-case basis with careful consideration given to how to deal with missing data.

Table 4-29

Sample READ56/READ62 Output Data File (UPn.DAT)

```
 89     1    0   89     4   12 500.
  F    F    F    F
6201     23044     89 1 1 0     48                                12
 880.5/1199./283.9/240/  3    878.0/1223./283.5/242/  3    850.0/1491./281.4/257/  5    800.0/1988./278.2/275/  9
 750.0/2512./275.9/268/ 11    700.0/3067./273.3/262/ 11    696.0/3113./273.1/260/ 11    650.0/3657./269.9/250/ 11
 608.0/4182./266.7/247/ 12    600.0/4285./265.9/247/ 13    550.0/4956./260.3/248/ 15    500.0/5674./254.1/254/ 13
6201     23044     89 1 112     62                                17
 881.0/1199./269.9/  0/  3    878.0/1226./272.3/  2/  3    872.0/1281./273.1/  6/  3    861.0/1384./279.1/ 18/  2
 850.0/1489./280.5/ 29/  2    832.0/1665./281.2/ 29/  1    800.0/1988./280.1/  0/  0    772.0/2280./279.3/215/  3
 750.0/2516./277.5/215/  5    702.0/3050./273.3/208/ 11    700.0/3073./273.1/207/ 12    652.0/3638./269.7/210/ 14
 650.0/3662./269.6/210/ 14    600.0/4291./266.9/223/ 14    596.0/4344./266.6/224/ 14    550.0/4965./261.3/232/ 14
 500.0/5686./255.0/228/ 15
6201     23044     89 1 2 0     60                                16
 879.5/1199./287.6/ 20/  2    875.0/1242./287.3/ 25/  2    850.0/1485./285.0/ 50/  2    800.0/1989./281.8/110/  1
 785.0/2145./281.0/131/  1    750.0/2519./277.7/252/  1    705.0/3018./273.2/251/  7    700.0/3075./272.8/249/  8
 676.0/3353./270.7/242/ 14    650.0/3664./269.1/236/ 20    619.0/4048./267.1/229/ 25    600.0/4291./265.5/230/ 26
 585.0/4488./264.1/235/ 25    550.0/4964./262.6/246/ 21    520.0/5394./261.2/247/ 25    500.0/5692./258.5/243/ 26
6201     23044     89 1 212     51                                18
 882.0/1199./277.7/310/  2    879.0/1227./279.7/313/  2    870.0/1311./279.5/324/  1    857.0/1435./283.6/  2/  1
 850.0/1503./283.2/ 13/  1    800.0/2005./281.1/212/  3    775.0/2267./280.3/212/  6    750.0/2536./278.3/214/  8
 700.0/3094./273.8/217/ 10    692.0/3186./273.1/217/ 10    666.0/3492./270.9/225/  9    655.0/3625./271.6/229/ 10
 650.0/3686./271.3/230/ 10    642.0/3784./270.7/232/ 11    600.0/4316./265.8/234/  9    558.0/4875./260.4/255/  9
 550.0/4985./259.9/261/  9    500.0/5706./256.3/257/ 23
6201     23044     89 1 3 0     49                                14
 882.6/1199./286.5/350/  2    880.0/1224./286.0/353/  2    850.0/1514./284.1/  4/  3    800.0/2017./281.6/207/  4
 762.0/2418./279.5/200/  8    750.0/2548./279.3/199/ 10    742.0/2636./279.1/200/ 11    700.0/3109./275.1/225/ 12
 673.0/3425./273.1/238/ 11    650.0/3703./272.2/252/ 11    642.0/3802./271.8/258/ 12    600.0/4337./268.0/262/ 17
 550.0/5014./263.0/258/ 26    500.0/5740./257.5/259/ 29
6201     23044     89 1 312     55                                19
 888.0/1199./277.7/ 20/  3    882.0/1255./280.7/  7/  2    866.0/1407./284.2/272/  2    850.0/1563./284.0/241/  4
 800.0/2065./279.8/227/  7    787.0/2199./278.9/228/  8    776.0/2315./279.9/229/ 10    760.0/2486./278.9/231/ 10
 750.0/2595./279.6/233/ 10    735.0/2761./280.8/240/ 10    700.0/3161./279.0/263/  9    650.0/3762./274.1/288/ 11
 643.0/3849./273.3/290/ 11    624.0/4088./271.0/288/ 10    600.0/4398./268.4/270/  6    593.0/4490./267.5/253/  6
 574.0/4745./266.2/232/  7    550.0/5077./264.3/244/  9    500.0/5810./260.0/244/ 13
6201     23044     89 1 4 0     50                                15
 888.7/1199./288.2/ 20/  2    886.0/1225./287.6/ 25/  2    850.0/1574./285.2/ 84/  3    805.0/2027./281.6/137/  6
 800.0/2079./281.3/148/  6    750.0/2611./280.3/185/  9    731.0/2823./279.9/187/ 10    700.0/3178./277.7/197/  8
 650.0/3778./274.0/228/  6    642.0/3877./273.3/233/  5    600.0/4416./269.2/278/  3    585.0/4615./267.6/305/  3
 553.0/5053./263.3/314/  6    550.0/5095./263.2/314/  6    500.0/5826./259.7/243/  4
6201     23044     89 1 412     39                                19
 887.0/1199./280.0/ 30/  3    879.0/1274./281.3/ 49/  3    871.0/1350./283.6/ 73/  2    859.0/1466./283.3/100/  3
 850.0/1554./283.4/130/  4    817.0/1885./284.1/159/  9    800.0/2060./283.4/164/ 10    759.0/2497./281.8/182/ 10
 750.0/2596./281.1/187/ 11    700.0/3161./277.0/206/ 17    650.0/3761./273.7/218/ 22    645.0/3823./273.3/218/ 23
 600.0/4399./268.9/222/ 22    582.0/4638./267.0/224/ 21    576.0/4719./265.9/225/ 21    566.0/4856./266.7/226/ 22
 550.0/5079./264.7/227/ 22    510.0/5659./259.2/226/ 21    500.0/5809./258.7/226/ 22
```

Table 4-30

READ56/READ62 Output File Format
(Upn.DAT)

FILE HEADER RECORD #1

Columns	Format	Variable	Description
2-6	I5	IBYR	Starting year of data in the file (two digits)
7-11	I5	IBDAY	Starting Julian day of data in the file
12-16	I5	IBHR	Starting hour (GMT) of data in the file
17-21	I5	IEYR	Ending year of data in the file (two digits)
22-26	I5	IEDAY	Ending Julian day of data in the file
27-31	I5	IEHR	Ending hour (GMT) of data in the file
32-36	F5.0	PSTOP	Top pressure level (mb) of data in the file (possible values are 850 mb, 700 mb, or 500 mb)

FILE HEADER RECORD #2

Columns	Format	Variable	Description
6	L1	LHT	Sounding level eliminated if height missing ? (T=yes, F=no)
11	L1	LTEMP	Sounding level eliminated if temperature missing ? (T=yes, F=no)
16	L1	LWD	Sounding level eliminated if wind direction missing ? (T=yes, F=no)
21	L1	LWS	Sounding level eliminated if wind speed missing ? (T=yes, F=no)

(READ56/READ62 Output File Format Continued)

Table 4-30

READ56/READ62 Output File Format
(Upn.DAT)

DATA RECORDS

For each 00 or 12 GMT sounding, a one-record data header is used followed by "N" records of data. Each record contains up to four sounding levels.

DATA HEADER RECORD

Columns	Format[*]	Variable	Description
4-7	I4	ITPDK	Label identifying data format of original data (e.g., 5600 or 6201 for NCDC data or 9999 for non-NCDC data)
13-17	A5	STNID	Station ID number
23-24	I2	YEAR	Year of data
25-26	I2	MONTH	Month of data
27-28	I2	DAY	Day of data
29-30	I2	HOUR	Hour of data (GMT)
36-37	I2	MLEV	Total number of levels in the original sounding
69-70	I2	ISTOP	Number of levels extracted from the original sounding and stored below

---

[*] Record format is (3x,i4,5x,a5,5x,4i2,5x,i2,t69,i2)

(READ56/READ62 Output File Format Continued)

Table 4-30

READ56/READ62 Output File Format
(UPn.DAT)

DATA RECORDS
(Up to four levels per record)

Columns	Format*	Variable	Description
4-9	F6.1	PRES	Pressure (mb)
11-15	F5.0	HEIGHT	Height above sea level (m)
17-21	F5.1	TEMP	Temperature (deg. K)
23-25	I3	WD	Wind direction (degrees)
27-29	I3	WS	Wind speed (m/s)
33-38	F6.1	PRES	Pressure (mb)
40-44	F5.0	HEIGHT	Height above sea level (m)
46-50	F5.1	TEMP	Temperature (deg. K)
52-54	I3	WD	Wind direction (degrees)
56-58	I3	WS	Wind speed (m/s)
62-67	F6.1	PRES	Pressure (mb)
69-73	F5.0	HEIGHT	Height above sea level (m)
75-79	F5.1	TEMP	Temperature (deg. K)
81-83	I3	WD	Wind direction (degrees)
85-87	I3	WS	Wind speed (m/s)
91-96	F6.1	PRES	Pressure (mb)
98-102	F5.0	HEIGHT	Height above sea level (m)
104-108	F5.1	TEMP	Temperature (deg. K)
110-112	I3	WD	Wind direction (degrees)
114-116	I3	WS	Wind speed (m/s)

---

* Record format is (4(3x,f6.1,'/',f5.0,'/',f5.1,'/',i3,'/',i3))
Missing value indicators are −99.9 for pressure, 9999. for height, 999.9 for temperature, and 999 for wind speed and direction.

4.2.4 Surface Meteorological Data File (SURF.DAT)

CALMET provides two options for the format of the surface meteorological data input file, SURF.DAT. The first is to use the unformatted file created by the SMERGE meteorological preprocessor program. SMERGE, described in Section 4.1.2, processes and reformats hourly surface observations in standard NCDC formats into a form compatible with CALMET. It is best used for large data sets with many surface stations.

The second format allowed by CALMET for the SURF.DAT file is a free-formatted option. This option allows the user the flexibility of either running the SMERGE preprocessor to create a formatted data file or for short CALMET runs, manually entering the data.

The selection of which surface data input format is used by CALMET is made by the user with the control file variable, IFORMS (see Input Group 4 of the control file in Section 4.2.1).

A sample formatted SURF.DAT file is shown in Table 4-31. A description of each variable in the formatted surface data file is contained in Table 4-32. The file contains two header records with the beginning and ending dates and times of data in the file, reference time zone, and number of stations in the first record and the station ID number in the second record. The data are read in FORTRAN free format. One data record per hour follows the header records. Each data record contains the date and time and for each station, the wind speed, wind direction, ceiling height, cloud cover, temperature, relative humidity, station pressure, and a precipitation code.

Buoy and other overwater data are normally input through the SEAn.DAT files. If the overwater method is not used, the buoy data can be either the SURF.DAT file or SEAn.DAT files. In any case, buoy data for a given station should not be in both files.

Table 4-31

Formatted SURF.DAT File - Header Records

HEADER RECORD #1

Variable No.	Variable	Type	Description
1	IBYR	integer	Beginning year of the data in the file
2	IBJUL	integer	Beginning Julian day
3	IBHR	integer	Beginning hour (00-23 LST)
4	IEYR	integer	Ending year
5	IEJUL	integer	Ending Julian day
6	IEHR	integer	Ending hour (00-23 LST)
7	IBTZ	integer	Time zone (e.g., 05=EST, 06=CST, 07=MST, 08=PST)
8	NSTA	integer	Number of stations

HEADER RECORD #2

Variable No.	Variable	Type	Description
1	IDSTA	integer array	Surface station ID number (NSTA values must be entered). The following statement is used to read the record: READ(io,*)(IDSTA(n),n=1,NSTA)

Table 4-32

Formatted SURF.DAT File - Data Records*

Variable No.	Variable	Type	Description
1	IYR	integer	Year of data
2	IJUL	integer	Julian day
3	IHR	integer	Hour (00-23 LST)
4	WS	real array	Wind speed (m/s)
5	WD	real array	Wind direction (degrees)
6	ICEIL	integer array	Ceiling height (hundreds of feet)
7	ICC	integer array	Opaque sky cover (tenths)
8	TEMPK	real array	Air temperature (degrees K)
9	IRH	integer array	Relative humidity (percent)
10	PRES	real array	Station pressure (mb)
11	IPCODE	integer array	Precipitation code (0=no precipitation, 1-18=liquid precipitation, 19-45=frozen precipitation)

---

* The data records are read in free format with the following statement:

```
      READ(io,*)IYR,IJUL,IHR,(WS(n),WD(n),ICEIL(n),
 1      ICC(n),TEMPK(n),IRH(n),PRES(n),IPCODE(n),
 1      n=1,NSTA)
```

Missing value indicators are 9999. (real variables) and 9999 (integer variables)

4.2.5 Overwater Data Files (SEA1.DAT, SEA2.DAT, ...)

If the modeling application involves overwater transport and dispersion, the CALMET boundary layer model requires observations of the air-sea temperature difference, air temperature, relative humidity and overwater mixing height. If the overwater temperature method is used, vertical temperature gradient information is also necessary, however defaults are specified in the CALMET.INP file. The special overwater observations, along with wind speed and direction, are contained in a set of files named SEAn.DAT, where n is a station number (1,2,3,...). If SEAn.DAT files are not used, the overwater station and its standard surface parameters (e.g., wind speed and direction, etc.) can be treated as a regular surface station. Additionally, any overwater site that should not be used in the overwater temperature interpolation scheme should be placed in the SURF.DAT file instead of a SEA.DAT file. For instance, a user may want to include wind information from a lake buoy but not have the buoy influence temperatures over the ocean.

The overwater data files are structured to allow the use of data with arbitrary time resolution. For example, hourly or daily air-sea temperature difference data, if available, can be entered into the files. Otherwise, monthly or seasonal data can be used. However, any station that is reporting non-missing wind speed and direction should use hourly data resolution or inaccuracies will be introduced into the wind field. The inaccuracy results from the fact that the variables retain their current values each hour until a new observation is encountered, at which time they are updated. Thus, long periods of missing wind data between valid observations should receive hourly records with the wind data set to missing. A similar argument applies to temperature and vertical temperature gradient information if the overwater temperature method is used. All times must match the base time zone of the CALMET run (variable IBTZ).

The location of the overwater site is specified for each observation. This allows the use of data collected from ships with time-varying locations. The data for each observation station (fixed or moving) must be stored in a separate overwater data file.

Table 4-33 contains a sample overwater input file. A description of each input variable and format is provided in Table 4-34. The sample data file contains hourly overwater data.

Table 4-33

Sample Overwater Data File (SEA1.DAT)

```
'4005',11000
  536.07 4721.83  68.560 10.0 87 226  0 87 226  0 9999.0  290.9 9999.0 9999.0 9999.0000 9999.0000    4.1  180.0
  536.07 4721.83  68.560 10.0 87 226  1 87 226  1 9999.0  290.9 9999.0 9999.0 9999.0000 9999.0000    4.1  180.0
  536.07 4721.83  68.560 10.0 87 226  2 87 226  2 9999.0  290.9 9999.0 9999.0 9999.0000 9999.0000    3.6  200.0
  536.07 4721.83  68.560 10.0 87 226  3 87 226  3 9999.0  290.9 9999.0 9999.0 9999.0000 9999.0000    4.1  200.0
  536.07 4721.83  68.560 10.0 87 226  4 87 226  4 9999.0  290.9 9999.0 9999.0 9999.0000 9999.0000    3.6  200.0
  536.07 4721.83  68.560 10.0 87 226  5 87 226  5 9999.0  290.9 9999.0 9999.0 9999.0000 9999.0000    3.1  200.0
  536.07 4721.83  68.560 10.0 87 226  6 87 226  6 9999.0  290.9 9999.0 9999.0 9999.0000 9999.0000    2.6  210.0
  536.07 4721.83  68.560 10.0 87 226  7 87 226  7 9999.0  291.5 9999.0 9999.0 9999.0000 9999.0000    2.6  210.0
  536.07 4721.83  68.560 10.0 87 226  8 87 226  8 9999.0  291.5 9999.0 9999.0 9999.0000 9999.0000    2.6  200.0
  536.07 4721.83  68.560 10.0 87 226  9 87 226  9 9999.0  291.5 9999.0 9999.0 9999.0000 9999.0000    2.6  200.0
  536.07 4721.83  68.560 10.0 87 226 10 87 226 10 9999.0  291.5 9999.0 9999.0 9999.0000 9999.0000    3.1  190.0
  536.07 4721.83  68.560 10.0 87 226 11 87 226 11 9999.0  291.5 9999.0 9999.0 9999.0000 9999.0000    3.6  190.0
  536.07 4721.83  68.560 10.0 87 226 12 87 226 12 9999.0  291.5 9999.0 9999.0 9999.0000 9999.0000    3.6  190.0
  536.07 4721.83  68.560 10.0 87 226 13 87 226 13 9999.0  292.0 9999.0 9999.0 9999.0000 9999.0000    4.1  200.0
  536.07 4721.83  68.560 10.0 87 226 14 87 226 14 9999.0  292.0 9999.0 9999.0 9999.0000 9999.0000    4.6  190.0
  536.07 4721.83  68.560 10.0 87 226 15 87 226 15 9999.0  292.0 9999.0 9999.0 9999.0000 9999.0000    4.6  200.0
  536.07 4721.83  68.560 10.0 87 226 16 87 226 16 9999.0  292.0 9999.0 9999.0 9999.0000 9999.0000    3.6  200.0
  536.07 4721.83  68.560 10.0 87 226 17 87 226 17 9999.0  292.0 9999.0 9999.0 9999.0000 9999.0000    3.6  200.0
  536.07 4721.83  68.560 10.0 87 226 18 87 226 18 9999.0  292.0 9999.0 9999.0 9999.0000 9999.0000    3.6  190.0
  536.07 4721.83  68.560 10.0 87 226 19 87 226 19 9999.0  291.5 9999.0 9999.0 9999.0000 9999.0000    3.6  190.0
  536.07 4721.83  68.560 10.0 87 226 20 87 226 20 9999.0  291.5 9999.0 9999.0 9999.0000 9999.0000    4.6  180.0
  536.07 4721.83  68.560 10.0 87 226 21 87 226 21 9999.0  291.5 9999.0 9999.0 9999.0000 9999.0000    4.6  190.0
  536.07 4721.83  68.560 10.0 87 226 22 87 226 22 9999.0  291.5 9999.0 9999.0 9999.0000 9999.0000    5.1  190.0
  536.07 4721.83  68.560 10.0 87 226 23 87 226 23 9999.0  290.9 9999.0 9999.0 9999.0000 9999.0000    7.2  210.0
  536.07 4721.83  68.560 10.0 87 227  0 87 227  0 9999.0  291.5 9999.0 9999.0 9999.0000 9999.0000    6.2  220.0
```

Table 4-34

Overwater Data File Format* (SEA1.DAT)

HEADER RECORD #1

Variable No.	Variable	Type	Description	Default Value
1	CHOWSTA	char*4	station name	-
2	IDOWSTA	integer	5-digit station ID number	-

DATA RECORDS

Variable No.	Variable	Type	Description	Default Value
1	XUTM	real	X coordinate (km) of the observational site	-
2	YUTM	real	Y coordinate (km) of the observational site	-
3	XOWLON	real	Longitude (degrees) of the observational site. Positive for Western Hemisphere, negative for Eastern Hemisphere	-
4	ZOWSTA	real	Measurement height (m) above the surface of the water of the air temperature and air-sea temperature difference	-
5	I1YR	integer	Starting year of the data in this record	-
6	I1JUL	integer	Starting Julian day of the data in this record	-
7	I1HR	integer	Starting hour (00-23 LST) of the data in this record	-
8	I2YR	integer	Ending year of the data in this record	-
9	I2JUL	integer	Ending Julian day of the data in this record	-
10	I2HR	integer	Ending hour (00-23 LST) of the data in this record	-
11	DTOW	real	Air-sea surface temperature difference (K)	-
12	TAIROW	real	Air temperature (K)	288.7
13	RHOW	real	Relative humidity (%)	100
14	ZIOW	real	Overwater mixing height (m)	-
15	TGRADB	real	Temperature lapse rate below the mixing height overwater (K/m)	-0.0098
16	TGRADA	real	Temperature lapse rate above the mixing height overwater (K/m)	-0.0045
17	WSOW	real	Wind speed (m/s)	-
18	WDOW	real	Wind direction (degrees)	-

---

* Variables are read in FORTRAN free-format
Missing value indicators are 9999. (real variables)

4.2.6 Precipitation Data File (PRECIP.DAT)

If the wet removal algorithm of the CALPUFF or MESOPUFF II models is to be applied, CALMET must produce gridded fields of hourly precipitation rates from observations. The PXTRACT and PMERGE preprocessing programs (Sections 4.1.4 and 4.1.5) process and reformat the NWS precipitation data in TD-3240 format into a formatted or unformatted file called PRECIP.DAT. The output file of PMERGE is directly compatible with the input requirements of CALMET. The user needs to set the precipitation file format variable, IFORMP, in the CALMET control file to one when using PMERGE unformatted output.

An option is provided in CALMET to read the hourly precipitation data from a free-formatted, user-prepared input file (i.e., IFORMP=2). This option is provided to allow the user an easy way to manually enter precipitation data for short CALMET runs. The use of the formatted PRECIP.DAT option can also be used with the formatted output file from PMERGE.

A sample free-formatted PRECIP.DAT file is shown in Table 4-35. The file includes two header records containing the beginning and ending dates and time of the data in the file, base time zone, number of stations, and station ID codes. One data record must follow each hour. Each data record contains the date and time and the precipitation rate (mm/hr) for each station. The details of the format and definition of each variable in the free-formatted PRECIP.DAT file is provided in Table 4-36.

Table 4-35

Sample Free-Formatted Precipitation Data File (PRECIP.DAT)

```
  89   1   1  89   2   9   6  14   0
412360 417943 417945 412797 415890 410174 411492 412679 412811 415048 415596 416736 418023 418252
  89   1   1     0.000     0.000     0.000  9999.000     0.000     0.000     0.000     0.000     0.000     0.000
              9999.000     0.000     0.000     0.000
  89   1   2     0.000     0.000     0.000     0.000     0.000     0.000     0.000     0.000     0.000     0.000
              9999.000     0.000     0.000     0.000
  89   1   3     0.000     0.000     0.000     0.000     0.000     0.000     0.000     0.000     0.000     0.000
              9999.000     0.000     0.000     0.000
  89   1   4     0.000     0.000     0.000     0.000     0.000     0.000     0.000     0.000     0.000     0.000
              9999.000     0.000     0.000     0.000
  89   1   5     0.000     0.000     0.000     0.000     0.000     0.000     0.000     0.000     0.000     0.000
              9999.000     0.000     0.000     0.000
  89   1   6     0.000     0.000     0.000     0.000     0.000     0.000     0.000     0.000     0.000     0.000
              9999.000     0.000     0.000     0.000
  89   1   7     0.000     0.000     0.000     0.000     0.000     0.000     0.000     0.000     0.000     0.000
              9999.000     0.000     0.000     0.000
  89   1   8     0.000     0.000     0.000     0.000     0.000     0.000     0.000     0.000     0.000     0.000
              9999.000     0.000     0.000     0.000
  89   1   9     0.000     0.000     0.000     0.000     0.000     0.000     0.000     0.000     0.000     0.000
              9999.000     0.000     0.000     0.000
  89   1  10     0.000     0.000     0.000     0.000     0.000     0.000     0.000     0.000     0.000     0.000
              9999.000     0.000     0.000     0.000
  89   1  11     0.000     0.000     0.254     0.000     0.000     0.000     0.000     0.000     0.000     0.000
              9999.000     0.000     0.000     0.000
  89   1  12     0.000     0.000     0.254     0.000     0.000     0.000     0.000     0.000     0.000     0.000
              9999.000     0.000     0.000     0.000
  89   1  13     0.000     0.000     0.254     0.000     0.000     0.000     0.000     0.000     0.000     0.000
              9999.000     0.000     0.000     0.000
  89   1  14     0.000     0.000     0.000     0.000     0.000     0.000     0.000     0.000     0.000     0.000
              9999.000     0.000     0.000     0.000
  89   1  15     0.000     0.000     0.000     0.000     0.000     0.000     0.000     0.000     0.000     0.000
              9999.000     0.000     0.000     0.000
  89   1  16     0.000     0.000     0.000     0.000     0.000     0.000     0.000     0.000     0.000     0.000
              9999.000     0.000     0.000     0.000
  89   1  17     0.000     0.000     0.254     0.000     0.000     0.000     0.000     0.000     0.000     0.000
              9999.000     0.000     0.000     0.000
  89   1  18     0.000     0.000     0.254     0.000     0.000     0.000     0.000     0.000     0.000     0.000
              9999.000     0.000     0.000     0.000
  89   1  19     0.000     0.000     0.000     0.000     0.762     0.000     0.000     0.000     0.000     0.000
              9999.000     0.000     0.000     0.000
  89   1  20     0.000     0.000     0.000     0.000     0.762     0.000     0.000     0.000     0.000     0.000
              9999.000     0.000     0.000     0.000
  89   1  21     0.000     0.000     0.000     0.000     0.000     0.000     0.000     0.000     0.000     0.000
              9999.000     0.000     0.000     0.000
  89   1  22     0.000     0.000     0.000     0.000     0.000     0.000     0.000     0.000     0.000     0.000
              9999.000     0.000     0.000     0.000
  89   1  23     0.000     0.000     0.000     0.000     0.000     0.000     0.000     0.000     0.000     0.000
              9999.000     0.000     0.000     0.000
  89   1  24     0.000     0.000     0.000     0.000     0.000     0.000     0.000     0.000     0.000     0.000
              9999.000     0.000     0.000     0.000
  89   2   1     0.000     0.000     0.000     0.000     0.000     0.000     0.000     0.000     0.000     0.000
              9999.000     0.000     0.000     0.000
  89   2   2     0.000     0.000     0.000     0.000     0.000     0.000     0.000     0.000     0.000     0.000
              9999.000     0.000     0.000     0.000
  89   2   3     0.000     0.000     0.000     0.000     0.000     0.000     0.000     0.000     0.000     0.000
              9999.000     0.000     0.000     0.000
  89   2   4     0.000     0.000     0.000     0.000     0.000     0.000     0.000     0.000     0.000     0.000
              9999.000     0.000     0.000     0.000
  89   2   5     0.000     0.000     0.000     0.000     0.000     0.000     0.000     0.000     0.000     0.000
              9999.000     0.000     0.000     0.000
  89   2   6     0.000     0.000     0.000     0.000     0.000     0.000     0.000     0.000     0.000     0.000
              9999.000     0.000     0.000     0.000
  89   2   7     0.000     0.000     0.000     0.000     0.000     0.000     0.000     0.000     0.000     0.000
              9999.000     0.000     0.000     0.000
  89   2   8     0.000     0.000     0.000     0.000     0.000     0.000     0.000     0.000     0.000     0.000
              9999.000     0.000     0.000     0.000
  89   2   9     0.000     0.000     0.000     0.000     0.000     0.000     0.000     0.000     0.000     0.000
              9999.000     0.000     0.000     0.000
```

Table 4-36

Free-Formatted Precipitation Data File Format (PRECIP.DAT)

HEADER RECORDS

Head Record #1

Variable No.	Variable	Type	Description
1	IBYR	integer	Starting year of data in the file
2	IBJUL	integer	Starting Julian day of data in the file
3	IBHR	integer	Starting hour (01-24 LST) of data in the file
4	IEYR	integer	Ending year of data in the file
5	IEJUL	integer	Ending Julian day of data in the file
6	IEHR	integer	Ending hour (01-24 LST) of data in the file
7	IBTZ	integer	Base time zone (05=EST, 06=CST, 07=MST, 08=PST)
8	NSTA	integer	Number of precipitation stations

Head Record #2

Variable No.	Variable	Type	Description
1	IDSTA	integer array	Station codes for each precipitation station. Read as: `READ(io12,*)(IDSTA(n),n=1,NSTA)`

Table 4-36

Free-Formatted Precipitation Data File Format (PRECIP.DAT)

DATA RECORDS
(Repeated for each hour of data)

Variable	Type	Description
IYR	integer	Year of data
IJUL	integer	Julian day of data
IHR	integer	Hour (01-24 LST) of data
XPREC	real array	Precipitation rates (mm/hr) for each precipitation station in the station order specified in Header Record #2. Each data record is read as: READ(io12,*)iyr,ijul,ihr,(XPREC(n), n=1,NSTA)

Missing value indicator is 9999.

4.2.7 Preprocessed Diagnostic Model Data File (DIAG.DAT)

The CALMET control file contains variables which determine how the meteorological data required by the diagnostic wind field module are entered into the program. The variables IDIOPT1 through IDIOPT5 of Input Group 5 in the control file determine whether the hourly station observation and domain-scale average surface temperature, lapse rate, and wind components are internally computed from the data in the surface and upper air data files or read directly from a separate file, DIAG.DAT.

The DIAG.DAT file allows the user to by-pass the internal CALMET computation involving the interpolation and spatial averaging of the meteorological inputs to the model by specifying these inputs directly. This option has been retained in the operational version of the model although it was intended primarily as a testing tool. The use of the DIAG.DAT file requires that the time interpolation of the sounding data and routine averaging of upper layer winds through the depth of each vertical layer, as well as conversion of the wind components from wind speed and direction to U and V components, all be performed externally.

A sample DIAG.DAT file containing two hours of data is shown in Table 4-37. A description of each variable in the file and its input format is contained in Table 4-38. The variables included in the DIAG.DAT file depend on the option selected in the CALMET control file. A value of one for the following control file parameters is used to flag input of the corresponding meteorological variable via the DIAG.DAT file. A value of zero indicates the meteorological variable is internally computed by the model from the data in the SURF.DAT and UPn.DAT files. The default value for each control file parameter is set to compute the meteorological variables internally.

Control File Parameter	Meteorological Variable
IDIOPT1	Domain-average surface temperature
IDIOPT2	Domain-average vertical temperature lapse rate
IDIOPT3	Domain-average winds (U and V components)
IDIOPT4	Hourly surface station winds (U and V components)
IDIOPT5	Hourly upper air station winds (U and V components)

The wind observations in DIAG.DAT are entered with data for one station per line. The end of the surface data and upper air data are both flagged by a record with a station name of 'LAST'.

Table 4-37

Sample DIAG.DAT Input Data File

```
TINF:     300.15
GAMMA hr 1  2.5
UM    hr 1 -1.8
VM    hr 1 -0.9
SURFACE WIND 0 PTM1    1.0 -0.6 -0.8
SURFACE WIND 0 PLGN    1.0  3.0 -2.6
SURFACE WIND 0 LAST
UPPER WIND 0 LCMB    1.0999.0999.0 -0.9  0.0 -1.1  0.2 -0.3  0.1 -0.2 -0.3
UPPER WIND 0 OFLT    1.0 -0.2 -0.1 -0.1 -0.5 -0.3 -0.8 -0.4 -0.5 -2.2 -1.5
UPPER WIND 0 LAST
TINF:     300.15
GAMMA hr 2  3.5
UM    hr 2 -1.8
VM    hr 2 -0.9
SURFACE WIND 1 PTM1    1.0  0.0  0.0
SURFACE WIND 1 PLGN    1.0  4.9 -3.3
SURFACE WIND 1 LAST
UPPER WIND 1 LCMB   1.0999.0999.0 -1.3 -0.2 -0.6  0.3 -0.9  0.8 -0.9  1.1
UPPER WIND 1 OFLT   1.0 -0.1  0.0  0.2  0.1 -0.3 -1.3 -0.2 -0.9  0.3 -0.4
UPPER WIND 1 LAST
```

Table 4-38

DIAG.DAT Input File
(Records 1-6 reported for each hour)

Record	Variable No.	Variable	Type	Description
1[a]	1	TINF	real	Domain-average surface temperature (deg. K). Input format: (10X,F6.2).
2[b]	1	GAMMA	real	Domain-average temperature lapse rate (deg. K/km). Input format: (10X,F5.1).
3[c]	1	UM	real	Domain average U wind component (m/s). Input format: (10X,F5.1).
4[c]	1	VM	real	Domain average V wind component (m/s). Input format: (10X,F5.1).
5[d]	1	CNAM	char*4	Four-character surface station name ('LAST' indicates end of surface data)
5[d]	1	WT	real	Data weighting factor (usually set to 1.0)
5[d]	1	US	real	U component of surface wind (m/s)
5[d]	1	VS	real	V component of surface wind (m/s)
(Repeated one station per record)				Input format: (15X,A4,1X,3F5.1)

(DIAG.DAT Input File Continued)

---

[a] Record included only if control file variable IDIOPT1=1
[b] Record included only if control file variable IDIOPT2=1
[c] Record included only if control file variable IDIOPT3=1
[d] Record included only if control file variable IDIOPT4=1

Table 4-38

DIAG.DAT Input File

Record	Variable No.	Variable	Type	Description
6[e]	1	CUNAM	char*4	Four-character upper air station name. ('LAST' indicates end of upper air data.)
6[e]	2	WTU	real	Data weighting factor (usually set to 1.0)
6[e]	3	ULEV1	real	U component of wind (m/s) at upper air station for CALMET layer 1
6[e]	4	VELV1	real	V component of wind (m/s) at upper air station for CALMET layer 1
6[e]	5	ULEV2	real	U component of wind (m/s) at upper air station for CALMET layer 2
6[e]	6	VELV2	real	V component of wind (m/s) at upper air station for CALMET layer 2
.	.	.		
.	.	.		
.	.	.		

---

[e] Record included only if control file variable IDIOPT5=1

4.2.8 Prognostic Model Data File (PROG.DAT)

The CALMET model allows the use of gridded prognostic model (CSUMM) winds to be used as the initial guess field or Step 1 wind field in the diagnostic model analysis procedure as a substitute for the normal Step 1 analysis. The use of the prognostic wind field option is controlled by the variable IPROG in Input Group 5 of the CALMET control file. If IPROG is set equal to one or two, the gridded prognostic model wind fields are read from a file called PROG.DAT. These winds are interpolated from the prognostic model grid system to the CALMET grid to produce either the initial guess field or the Step 1 wind field.

The PROG.DAT file is an unformatted data file containing the time, grid specifications, vertical layer structure, and three-dimensional fields of U and V wind fields. Table 4-39 contains a description of the variables included in each hourly set of winds.

Note that CSUMM does not allow the use of a Lambert conformal projection, so the coordinate system must be a UTM system when CSUMM data are used (i.e., IPROG = 1 or 2).

Table 4-39

Gridded Prognostic Model Wind Field Input File (PROG.DAT)

Record	Variable No.	Variable	Type	Description
1	1	TIMEH	real	Prognostic model simulation time (hours)
2	1	NXP	real	Number of prognostic model grid cells in the X direction
2	2	NYP	real	Number of prognostic model grid cells in the Y direction
2	3	NZP	real	Number of prognostic model vertical layers
3	1	UTMXOP	real	Reference UTM X coordinate of prognostic model grid origin
3	2	UTMYOP	real	Reference UTM Y coordinate of prognostic model grid origin
3	3	DXKP	real	Grid spacing (km)
4	1	Z	real array	Grid point heights (m) in prognostic model grid (NZP values)
Next NZP*NYP Records	1	UP	real array	Prognostic model U components (m/s) of wind. The following statements are used to read the UP array:

```
        do 10 K=1,NZP
        do 10 J=1,NYP
10        READ(90)(UP(i,j,k),i=1,NXP)
```

Record	Variable No.	Variable	Type	Description
Next NZP*NYP Records	1	VP	real array	Prognostic model V components (m/s) of wind. The following statements are used to read the VP array:

```
        do 20 K=1,NZP
        do 20 J=1,NYP
20        READ(90)(VP(i,j,k)i=1,NXP)
```

(All records repeated each hour)

4.2.9 MM4-FDDA Model Data File (MM4.DAT)

The CALMET model allows the use of gridded MM4-FDDA prognostic winds to be used as input. The use of the prognostic wind field option is controlled by the variable IPROG in Input Group 5 of the CALMET control file. A choice of three methods of incorporating the MM4-FDDA wind data into the model is available.

If IPROG = 3 use MM4-FDDA winds as the Step 1 field when using the objective analysis
IPROG = 4 use MM4-FDDA winds as the initial guess field when using the diagnostic module
IPROG = 5 treat MM4-FDDA winds as observations.

If one of these three methods is chosen, the gridded MM4-FDDA wind fields are read from a file called MM4.DAT. Within CALMET these winds are interpolated from the prognostic model grid system to the CALMET grid.

The MM4.DAT file is a formatted data file containing header records describing the date, time, and domain of the prognostic model run. The extraction subdomain is defined in terms of (I,J) and latitude and longitude. Terrain elevation and land use description code are also provided for each grid cell in the subdomain. The sigma-p values used by MM4-FDDA to define each of the vertical layers are also contained in the header records of MM4.DAT.

The data records consist of a date and time record, then a data record consisting of elevation (msl) and winds at each grid cell for each vertical level. The surface level is followed by the mandatory levels of 1000, 925, 850, 700, 500, 400, and 300 mb. All subterranean mandatory levels will have wind direction and wind speed of 0.

Table 4-40

Sample MM4-FDDA Derived Gridded Wind Data File (MM4.DAT)

```
THIS FILE CREATED 17:17:33 04-21-92
88071500 744  60  45  15 100.0
  35  16   5   5
0.0500
0.1500
0.2500
0.3500
0.4500
0.5500
0.6500
0.7400
0.8100
0.8650
0.9100
0.9450
0.9700
0.9850
0.9950
 35 16 34.756 -85.988 0272 02
 36 16 34.715 -85.098 0321 06
 37 16 34.666 -84.210 0386 04
 38 16 34.609 -83.323 0406 04
 39 16 34.544 -82.438 0319 04
 35 17 35.488 -85.943 0277 04
 36 17 35.447 -85.043 0343 04
 37 17 35.397 -84.145 0464 04
 38 17 35.340 -83.248 0581 04
 39 17 35.274 -82.353 0539 04
 35 18 36.222 -85.897 0252 04
 36 18 36.180 -84.987 0323 04
 37 18 36.130 -84.078 0443 04
 38 18 36.071 -83.172 0609 04
 39 18 36.004 -82.266 0670 04
 35 19 36.957 -85.849 0217 02
 36 19 36.914 -84.929 0282 04
 37 19 36.863 -84.010 0365 04
 38 19 36.804 -83.093 0504 04
 39 19 36.737 -82.178 0639 04
 35 20 37.693 -85.801 0192 04
 36 20 37.650 -84.870 0244 02
 37 20 37.599 -83.941 0293 04
 38 20 37.539 -83.013 0373 04
 39 20 37.470 -82.087 0509 04
```

(Continued)

Table 4-40

Sample MM4-FDDA Derived Gridded Wind Data File (MM4.DAT)

```
88071500 35 16 1015.2 0.00 0
 9849 00272 30056 24507
10000 00136 30657 00000
 9250 00831 25232 26510
 8500 01571 19814 29009
 7000 03218 10661 03011
 5000 05943 04971 07013
 4000 07655 17170 05011
 3000 09747 32566 05012
 9805 00313 29656 24507
 9716 00394 28852 24508
 9584 00517 27846 25509
 9362 00724 26038 26510
 9053 01021 23823 27010
 8654 01414 21015 28509
 8168 01914 17612 30008
 7548 02586 14058 00007
 6752 03518 09064 03512
 5867 04668 02866 05012
 4982 05971 05171 07013
 4097 07475 15971 05011
 3212 09262 28767 05011
 2327 11485 46364 05517
 1442 14523 66159 02514
88071500 36 16 1015.2 0.00 0
 9796 00321 29456 25007
10000 00136 30656 00000
 9250 00831 25231 26511
 8500 01571 20015 30009
 7000 03217 10261 01510
 5000 05940 04775 06512
 4000 07654 17173 05513
 3000 09746 32567 05014
 9752 00361 29052 25007
 9664 00442 28246 25007
 9532 00565 27239 25509
 9312 00772 25634 26511
 9004 01068 23620 27010
 8608 01461 20816 29509
 8124 01960 17214 32009
 7509 02630 13458 35509
 6717 03559 08463 02011
 5838 04706 02667 04011
 4958 06006 05176 06513
 4078 07508 16173 05513
 3199 09290 28968 05012
 2319 11505 46565 05018
 1440 14530 66360 01515
```

Table 4-41

MM4-FDDA Derived Gridded Wind Data File Format (MM4.DAT)

HEADER RECORDS

Header Record #1

Variable No.	Variable	Type	Description
1	CTEXT	char*36	Text date/time stamp for file creation

Header Record #2

Variable No.	Variable	Type	Description
1	IBYRM	integer	Beginning year of the data in the file
2	IBMOM	integer	Beginning month of the data in the file
3	IBDYM	integer	Beginning day of the data in the file
4	IBHRM	integer	Beginning hour (GMT) of the data in the file
5	NHRSMM4	integer	Length of period (hours) of the data in the file
6	NXMM4	integer	Number of columns in the MM4-FDDA domain
7	NYMM4	integer	Number of rows in the MM4-FDDA domain
8	NZP	integer	Number of layers in the MM4-FDDA domain
9	PTOPMM4	real	Top pressure level of the data in the file

format (4i2,4i4,f6.1)

Table 4-41

MM4-FDDA Derived Gridded Wind Data File Format (MM4.DAT) (Continued)

HEADER RECORDS

Header Record #3

Variable No.	Variable	Type	Description
1	I1	integer	I-index of the lower left corner of the extraction subdomain
2	J1	integer	J-index of the lower left corner of the extraction subdomain
3	NXP	integer	Number of grid cells in the X direction in the extraction subdomain
4	NYP	integer	Number of grid cells in the Y direction in the extraction subdomain

format (4i4)

Next NZP Records

Variable No.	Variable	Type	Description
1	SIGMA	real array	Sigma-p values used by MM4-FDDA to define each of the NZP layers Read as:

```
        do 10 i=1,NZP
10         READ(iomm4,20)SIGMA(i)
20         FORMAT(F6.4)
```

Table 4-41

MM4-FDDA Derived Gridded Wind Data File Format (MM4.DAT) (Continued)

HEADER RECORDS

Next NXP*NYP Records

Variable No.	Variable	Type	Description
1	IINDEX	integer	I-index of the grid point in the extraction subdomain
2	JINDEX	integer	J-index of the grid point in the extraction subdomain
3	XLAT4	real array	Latitude (degrees) of the grid point in the extraction subdomain (positive for the Northern Hemisphere, negative for Southern Hemisphere)
4	XLONG4	real array	Longitude (degrees) of the grid point in the extraction subdomain (N.B., the MM4 convention is different than the CALMET convention: MM4 uses negative values for Western Hemisphere and positive values for Eastern Hemisphere. CALMET internally converts the longitudes in the MM4.DAT file, so the MM4 convention must be used in the MM4.DAT file)
5	IELEV4	integer array	Terrain elevation of the grid point in the extraction subdomain
6	ILU4	integer array	Land use description code of the grid point in the extraction subdomain

format (2i3,f7.3,f8.3,i5,i3)

DATA RECORDS (repeated for each grid cell in extraction subdomain)

Date Record

Variable No.	Variable	Type	Description
1	MYR	integer	Year of MM4-FDDA wind data
2	MMO	integer	Month of MM4-FDDA wind data
3	MDAY	integer	Day of MM4-FDDA wind data
4	MHR	integer	Hour (GMT) of MM4-FDDA wind data
5	IX	integer	I-index of grid cell
6	JX	integer	J-index of grid cell
7*	-	real	sea level pressure (mb)
8*	-	real	total rainfall for the past hour (cm)
9*	-	integer	snow cover indicator (0 or 1, where 1 = snow cover was determined to be present for the MM4 simulation)

format (4i2,2i3,f7.1,f5.2,i2)

---

* variable not read by CALMET

Table 4-41

MM4-FDDA Derived Gridded Wind Data File Format (MM4.DAT) (Concluded)

DATA RECORDS (repeated for each grid cell in extraction subdomain)

Data Records (one record for each mandatory Level(8)* plus 'NZP' significant levels)

Variable No.	Variable	Type	Description
1**	-	integer	Pressure (tenths of millibars)
2	Z	integer	Elevation (meters above m.s.l.)
3**	-	integer	Temperature/dew point depression in NWS format (TTTDD)
4	WD	integer	Wind direction (degrees)
5	WS	integer	Wind speed (knots)

format of data (i5,3i6,5x)

format used by CALMET to read the data (5x,f6.0,6x,f4.0,f2.0)

---

* The surface level is followed by the mandatory levels of 1000, 925, 850, 700, 500, 400, and 300 mb. All subterranean mandatory levels will have wind direction and wind speed of 0.

** Variable not used by CALMET

TTT = °C*10, odd number = negative temperature
even number = positive temperature
Examples: TTT = 202 → 20.2°C
TTT = 203 → −20.3°C

DD < 56 → °C*10
DD ≥ 56 → °C+50
Examples: DD = 55 → 5.5°C
DD = 56 → 6.0°C

4.2.10 Terrain Weighting Factor Data File (WT.DAT)

CALMET contains several options for introducing MM4-FDDA winds into the calculation of the wind fields. These include the use of the MM4-FDDA winds as:

- initial guess field (IPROG = 3)
- Step 1 field (IPROG = 4)
- "observation" (IPROG = 5)

If the MM4-FDDA fields are used as in initial guess field for CALMET, the MM4-FDDA winds are subject to a full diagnostic adjustment for terrain effects on the fine-scale (CALMET) grid. If the MM4-FDDA winds are used as either a Step 1 field or as "observations," CALMET does not perform additional terrain adjustment to the MM4-FDDA winds. In combining the MM4-FDDA winds with actual observational data, the question of what relative weight should be given to the MM4-FDDA winds (which reflects its coarse-grid (e.g., 80 km) resolution of terrain versus the observational data. The factors used to determine this weighting is assumed to be a function of the fine-scale terrain unresolved by the MM4-FDDA grid and height above the surface. Section 2.2.3.1 provides a detailed description of the weighting factors and how they are used in CALMET.

The WT.DAT file contains the terrain-weighting factor. This file is required only if IPROG = 4 or IPROG = 5 (i.e., MM4-FDDA data are used as the Step 1 field or as "observation").

Table 4-42 contains a sample WT.DAT file for a 25 × 23 18-km CALMET grid. A detailed description of the contents of the WT.DAT file are contained in Table 4-43. The first three lines consist of descriptive information on the development of the weighting factor. Records 4 and 5 describe the fine-scale (CALMET) grid system and the coarse-scale (MM4-FDDA) grid. These are followed by a set of NZ groups of records, one for each CALMET layer, which contain the actual weighting factors.

Table 4-42

Sample Terrain Weighting Factor Data File (WT.DAT)

```
Sensitivity Power for Wz      =     2.00000
Sensitivity Power for Ws      =     2.00000
Significant Length-Scale (m) =     10.0000
 Fine-Grid   :    342.0  -135.0   25   23  18.000
 Coarse-Grid :    -80.0  -680.0   24   21  80.000

 Height(m) =      10.0000
  i=     1   2   3   4   5   6   7   8   9  10  11  12  13  14  15  16  17  18  19  20  21  22  23  24  25
j= 23  .51 .56 .53 .51 .48 .45 .44 .43 .42 .41 .42 .45 .48 .52 .52 .40 .28 .16 .03 .00 .00 .00 .00 .00 .00
j= 22  .51 .56 .53 .51 .48 .45 .44 .43 .42 .41 .42 .45 .48 .52 .52 .40 .28 .16 .03 .00 .00 .00 .00 .00 .00
j= 21  .49 .54 .51 .49 .46 .44 .43 .41 .40 .38 .40 .43 .47 .50 .51 .40 .28 .17 .05 .02 .02 .02 .02 .02 .01
j= 20  .43 .48 .46 .44 .42 .40 .38 .36 .34 .32 .34 .38 .41 .45 .47 .38 .29 .21 .12 .09 .09 .08 .08 .07 .05
j= 19  .37 .41 .40 .39 .38 .37 .34 .31 .29 .26 .28 .32 .36 .41 .43 .37 .31 .24 .18 .16 .15 .14 .13 .12 .09
j= 18  .31 .35 .35 .34 .34 .33 .30 .27 .23 .20 .21 .26 .31 .36 .39 .35 .32 .28 .24 .22 .21 .20 .19 .17 .13
j= 17  .26 .29 .29 .29 .30 .30 .26 .22 .18 .14 .15 .21 .26 .31 .35 .34 .33 .32 .30 .29 .28 .26 .25 .22 .17
j= 16  .25 .29 .30 .31 .31 .32 .28 .25 .21 .18 .19 .24 .29 .33 .37 .35 .34 .32 .31 .30 .29 .29 .28 .26 .20
j= 15  .26 .30 .31 .33 .34 .35 .32 .29 .27 .24 .25 .29 .32 .36 .39 .37 .34 .32 .30 .30 .30 .30 .31 .29 .22
j= 14  .27 .31 .33 .35 .36 .38 .36 .34 .32 .29 .30 .33 .36 .39 .41 .38 .35 .32 .29 .30 .31 .32 .34 .32 .25
j= 13  .27 .32 .34 .37 .39 .41 .40 .38 .37 .35 .36 .38 .40 .42 .43 .40 .36 .32 .29 .29 .32 .34 .36 .36 .27
j= 12  .28 .33 .35 .38 .40 .42 .41 .41 .40 .39 .40 .41 .43 .44 .45 .41 .36 .32 .28 .29 .33 .36 .39 .39 .31
j= 11  .31 .35 .36 .38 .39 .40 .40 .40 .41 .41 .42 .43 .44 .45 .45 .41 .36 .32 .27 .29 .34 .38 .42 .44 .37
j= 10  .33 .37 .37 .37 .38 .38 .39 .40 .41 .43 .43 .44 .45 .46 .45 .41 .36 .31 .27 .29 .35 .40 .45 .48 .43
j=  9  .35 .39 .38 .37 .37 .36 .38 .40 .42 .44 .45 .46 .46 .46 .46 .41 .36 .31 .26 .29 .35 .42 .48 .52 .49
j=  8  .37 .41 .39 .37 .36 .34 .37 .40 .43 .46 .47 .47 .47 .47 .46 .41 .35 .30 .25 .29 .36 .44 .51 .56 .55
j=  7  .31 .35 .35 .34 .34 .34 .36 .39 .41 .44 .44 .44 .44 .44 .43 .41 .38 .36 .33 .37 .43 .49 .55 .59 .57
j=  6  .26 .30 .31 .32 .33 .34 .36 .37 .39 .41 .42 .42 .41 .41 .41 .41 .41 .41 .41 .45 .50 .55 .59 .62 .58
j=  5  .20 .24 .26 .29 .31 .33 .35 .36 .38 .39 .39 .39 .38 .38 .38 .41 .44 .47 .50 .53 .56 .60 .63 .65 .60
j=  4  .15 .18 .22 .26 .30 .33 .34 .35 .36 .37 .37 .36 .35 .35 .35 .41 .46 .52 .58 .61 .63 .65 .67 .68 .62
j=  3  .15 .19 .23 .27 .31 .35 .36 .36 .37 .37 .37 .37 .37 .36 .37 .43 .49 .55 .60 .63 .65 .66 .68 .68 .62
j=  2  .20 .25 .28 .32 .35 .39 .39 .39 .39 .40 .40 .41 .41 .42 .43 .47 .51 .55 .58 .61 .62 .64 .65 .65 .61
j=  1  .26 .31 .34 .37 .40 .42 .42 .42 .42 .42 .43 .45 .46 .48 .49 .51 .53 .55 .56 .58 .60 .61 .63 .63 .60
  i=     1   2   3   4   5   6   7   8   9  10  11  12  13  14  15  16  17  18  19  20  21  22  23  24  25
 Height(m) =      50.0000
  i=     1   2   3   4   5   6   7   8   9  10  11  12  13  14  15  16  17  18  19  20  21  22  23  24  25
j= 23  .11 .11 .10 .08 .07 .05 .05 .04 .04 .03 .03 .04 .05 .05 .06 .04 .03 .02 .00 .00 .00 .00 .00 .00 .00
j= 22  .11 .11 .10 .08 .07 .05 .05 .04 .04 .03 .03 .04 .05 .05 .06 .04 .03 .02 .00 .00 .00 .00 .00 .00 .00
j= 21  .10 .11 .09 .08 .07 .05 .05 .04 .03 .03 .03 .04 .04 .05 .05 .04 .03 .02 .01 .00 .00 .00 .00 .00 .00
j= 20  .09 .09 .08 .07 .06 .05 .04 .03 .03 .02 .02 .03 .03 .04 .04 .04 .03 .02 .01 .01 .01 .01 .00 .00 .00
j= 19  .07 .08 .07 .06 .05 .04 .03 .03 .02 .02 .02 .02 .03 .03 .03 .03 .03 .02 .02 .01 .01 .01 .01 .01 .00
j= 18  .06 .06 .05 .05 .04 .03 .03 .02 .02 .01 .01 .01 .02 .02 .02 .02 .02 .02 .02 .02 .02 .01 .01 .01 .01
j= 17  .04 .05 .04 .04 .03 .03 .02 .02 .01 .00 .00 .01 .01 .01 .01 .02 .02 .02 .03 .03 .02 .02 .01 .01 .01
j= 16  .06 .06 .06 .06 .05 .05 .04 .03 .02 .01 .01 .01 .02 .02 .02 .02 .02 .03 .03 .03 .02 .02 .02 .01 .01
j= 15  .08 .09 .08 .08 .08 .07 .06 .05 .04 .02 .02 .02 .02 .03 .03 .03 .03 .03 .03 .03 .02 .02 .02 .02 .01
j= 14  .09 .11 .11 .10 .10 .10 .08 .07 .05 .03 .03 .03 .03 .04 .04 .04 .03 .03 .03 .03 .03 .02 .02 .02 .01
j= 13  .11 .13 .13 .13 .13 .13 .11 .08 .06 .04 .04 .04 .04 .05 .05 .04 .04 .04 .03 .03 .03 .03 .02 .02 .02
j= 12  .12 .13 .13 .13 .14 .14 .12 .10 .08 .06 .05 .05 .05 .06 .06 .05 .04 .04 .03 .03 .03 .03 .03 .03 .03
j= 11  .10 .11 .11 .12 .12 .12 .11 .10 .09 .08 .07 .07 .07 .07 .07 .06 .05 .04 .03 .03 .03 .04 .04 .05 .04
j= 10  .08 .09 .10 .10 .10 .11 .11 .10 .10 .10 .10 .09 .09 .09 .08 .07 .05 .04 .02 .03 .03 .04 .05 .06 .06
j=  9  .06 .07 .08 .08 .09 .09 .10 .11 .11 .12 .12 .11 .11 .10 .09 .07 .05 .04 .02 .02 .04 .05 .07 .08 .08
j=  8  .05 .06 .06 .07 .07 .08 .10 .11 .13 .14 .14 .13 .12 .11 .10 .08 .06 .04 .01 .02 .04 .06 .08 .09 .10
j=  7  .04 .04 .05 .05 .06 .07 .08 .09 .11 .12 .12 .11 .11 .10 .09 .11 .12 .13 .15 .14 .14 .13 .13 .12 .12
j=  6  .03 .03 .04 .04 .05 .05 .06 .07 .09 .10 .10 .09 .09 .08 .09 .13 .18 .23 .28 .27 .24 .20 .17 .15 .14
j=  5  .02 .02 .03 .03 .03 .04 .05 .06 .07 .07 .08 .07 .07 .07 .08 .16 .24 .33 .41 .39 .33 .28 .22 .17 .16
j=  4  .01 .01 .01 .02 .02 .02 .03 .04 .04 .05 .06 .05 .05 .05 .07 .19 .31 .42 .54 .51 .43 .35 .27 .20 .18
j=  3  .02 .02 .02 .02 .02 .03 .03 .04 .05 .06 .07 .08 .09 .11 .14 .25 .36 .48 .59 .56 .48 .40 .33 .26 .22
j=  2  .04 .04 .04 .04 .05 .05 .06 .07 .07 .08 .11 .14 .18 .21 .26 .34 .42 .49 .57 .56 .50 .45 .39 .34 .28
j=  1  .06 .07 .07 .07 .07 .07 .08 .09 .10 .11 .15 .21 .27 .32 .38 .42 .47 .51 .56 .55 .52 .49 .46 .41 .35
  i=     1   2   3   4   5   6   7   8   9  10  11  12  13  14  15  16  17  18  19  20  21  22  23  24  25
```

Table 4-42

Sample Terrain Weighting Factor Data File (WT.DAT) (Continued)

```
 Height(m) =     100.000
  i=     1   2   3   4   5   6   7   8   9  10  11  12  13  14  15  16  17  18  19  20  21  22  23  24  25
j= 23  .03 .03 .02 .02 .02 .01 .01 .01 .01 .01 .01 .01 .01 .01 .01 .01 .01 .00 .00 .00 .00 .00 .00 .00 .00
j= 22  .03 .03 .02 .02 .02 .01 .01 .01 .01 .01 .01 .01 .01 .01 .01 .01 .01 .00 .00 .00 .00 .00 .00 .00 .00
j= 21  .03 .03 .02 .02 .02 .01 .01 .01 .01 .01 .01 .01 .01 .01 .01 .01 .01 .00 .00 .00 .00 .00 .00 .00 .00
j= 20  .02 .02 .02 .02 .01 .01 .01 .01 .01 .01 .01 .01 .01 .01 .01 .01 .01 .00 .00 .00 .00 .00 .00 .00 .00
j= 19  .02 .02 .02 .01 .01 .01 .01 .01 .01 .00 .00 .01 .01 .01 .01 .01 .01 .01 .00 .00 .00 .00 .00 .00 .00
j= 18  .01 .02 .01 .01 .01 .01 .01 .01 .00 .00 .00 .00 .00 .01 .01 .01 .01 .01 .01 .00 .00 .00 .00 .00 .00
j= 17  .01 .01 .01 .01 .01 .01 .01 .00 .00 .00 .00 .00 .00 .00 .00 .00 .01 .01 .01 .01 .01 .00 .00 .00 .00
j= 16  .01 .02 .02 .01 .01 .01 .01 .01 .01 .00 .00 .00 .00 .00 .01 .01 .01 .01 .01 .01 .01 .01 .00 .00 .00
j= 15  .02 .02 .02 .02 .02 .02 .02 .01 .01 .01 .00 .01 .01 .01 .01 .01 .01 .01 .01 .01 .01 .01 .00 .00 .00
j= 14  .02 .03 .03 .03 .03 .03 .02 .02 .01 .01 .01 .01 .01 .01 .01 .01 .01 .01 .01 .01 .01 .01 .01 .00 .00
j= 13  .03 .03 .03 .03 .03 .03 .03 .02 .02 .01 .01 .01 .01 .01 .01 .01 .01 .01 .01 .01 .01 .01 .01 .01 .00
j= 12  .03 .03 .03 .03 .03 .03 .03 .02 .02 .01 .01 .01 .01 .01 .01 .01 .01 .01 .01 .01 .01 .01 .01 .01 .01
j= 11  .02 .03 .03 .03 .03 .03 .03 .02 .02 .02 .02 .02 .02 .02 .02 .01 .01 .01 .01 .01 .01 .01 .01 .01 .01
j= 10  .02 .02 .02 .03 .03 .03 .03 .03 .03 .02 .02 .02 .02 .02 .02 .02 .01 .01 .01 .01 .01 .01 .01 .02 .02
j=  9  .02 .02 .02 .02 .02 .02 .03 .03 .03 .03 .03 .03 .03 .02 .02 .02 .01 .01 .00 .01 .01 .01 .02 .02 .02
j=  8  .01 .01 .02 .02 .02 .02 .02 .03 .03 .04 .04 .03 .03 .03 .03 .02 .01 .01 .00 .01 .01 .01 .02 .02 .02
j=  7  .01 .01 .01 .01 .01 .02 .02 .02 .03 .03 .03 .03 .03 .02 .02 .03 .03 .03 .04 .04 .03 .03 .03 .03 .03
j=  6  .01 .01 .01 .01 .01 .01 .02 .02 .02 .02 .02 .02 .02 .02 .02 .03 .05 .06 .07 .07 .06 .05 .04 .04 .03
j=  5  .00 .01 .01 .01 .01 .01 .01 .01 .02 .02 .02 .02 .02 .02 .02 .04 .06 .08 .10 .10 .08 .07 .06 .04 .04
j=  4  .00 .00 .00 .00 .00 .01 .01 .01 .01 .01 .01 .01 .01 .01 .02 .05 .08 .11 .14 .13 .11 .09 .07 .05 .04
j=  3  .00 .00 .01 .01 .01 .01 .01 .01 .01 .01 .02 .02 .02 .03 .04 .08 .12 .15 .19 .19 .17 .14 .12 .10 .08
j=  2  .01 .01 .01 .01 .01 .01 .01 .02 .02 .02 .03 .04 .05 .06 .08 .12 .17 .22 .27 .27 .25 .23 .21 .19 .15
j=  1  .01 .02 .02 .02 .02 .02 .02 .02 .02 .03 .04 .06 .07 .09 .11 .17 .23 .29 .35 .35 .34 .32 .30 .27 .22
  i=     1   2   3   4   5   6   7   8   9  10  11  12  13  14  15  16  17  18  19  20  21  22  23  24  25
 Height(m) =     400.000
  i=     1   2   3   4   5   6   7   8   9  10  11  12  13  14  15  16  17  18  19  20  21  22  23  24  25
j= 23  .00 .00 .00 .00 .00 .00 .00 .00 .00 .00 .00 .00 .00 .00 .00 .00 .00 .00 .00 .00 .00 .00 .00 .00 .00
j= 22  .00 .00 .00 .00 .00 .00 .00 .00 .00 .00 .00 .00 .00 .00 .00 .00 .00 .00 .00 .00 .00 .00 .00 .00 .00
j= 21  .00 .00 .00 .00 .00 .00 .00 .00 .00 .00 .00 .00 .00 .00 .00 .00 .00 .00 .00 .00 .00 .00 .00 .00 .00
j= 20  .00 .00 .00 .00 .00 .00 .00 .00 .00 .00 .00 .00 .00 .00 .00 .00 .00 .00 .00 .00 .00 .00 .00 .00 .00
j= 19  .00 .00 .00 .00 .00 .00 .00 .00 .00 .00 .00 .00 .00 .00 .00 .00 .00 .00 .00 .00 .00 .00 .00 .00 .00
j= 18  .00 .00 .00 .00 .00 .00 .00 .00 .00 .00 .00 .00 .00 .00 .00 .00 .00 .00 .00 .00 .00 .00 .00 .00 .00
j= 17  .00 .00 .00 .00 .00 .00 .00 .00 .00 .00 .00 .00 .00 .00 .00 .00 .00 .00 .00 .00 .00 .00 .00 .00 .00
j= 16  .00 .00 .00 .00 .00 .00 .00 .00 .00 .00 .00 .00 .00 .00 .00 .00 .00 .00 .00 .00 .00 .00 .00 .00 .00
j= 15  .00 .00 .00 .00 .00 .00 .00 .00 .00 .00 .00 .00 .00 .00 .00 .00 .00 .00 .00 .00 .00 .00 .00 .00 .00
j= 14  .00 .00 .00 .00 .00 .00 .00 .00 .00 .00 .00 .00 .00 .00 .00 .00 .00 .00 .00 .00 .00 .00 .00 .00 .00
j= 13  .00 .00 .00 .00 .00 .00 .00 .00 .00 .00 .00 .00 .00 .00 .00 .00 .00 .00 .00 .00 .00 .00 .00 .00 .00
j= 12  .00 .00 .00 .00 .00 .00 .00 .00 .00 .00 .00 .00 .00 .00 .00 .00 .00 .00 .00 .00 .00 .00 .00 .00 .00
j= 11  .00 .00 .00 .00 .00 .00 .00 .00 .00 .00 .00 .00 .00 .00 .00 .00 .00 .00 .00 .00 .00 .00 .00 .00 .00
j= 10  .00 .00 .00 .00 .00 .00 .00 .00 .00 .00 .00 .00 .00 .00 .00 .00 .00 .00 .00 .00 .00 .00 .00 .00 .00
j=  9  .00 .00 .00 .00 .00 .00 .00 .00 .00 .00 .00 .00 .00 .00 .00 .00 .00 .00 .00 .00 .00 .00 .00 .00 .00
j=  8  .00 .00 .00 .00 .00 .00 .00 .00 .00 .00 .00 .00 .00 .00 .00 .00 .00 .00 .00 .00 .00 .00 .00 .00 .00
j=  7  .00 .00 .00 .00 .00 .00 .00 .00 .00 .00 .00 .00 .00 .00 .00 .00 .00 .00 .00 .00 .00 .00 .00 .00 .00
j=  6  .00 .00 .00 .00 .00 .00 .00 .00 .00 .00 .00 .00 .00 .00 .00 .00 .00 .00 .00 .00 .00 .00 .00 .00 .00
j=  5  .00 .00 .00 .00 .00 .00 .00 .00 .00 .00 .00 .00 .00 .00 .00 .00 .00 .01 .01 .01 .01 .00 .00 .00 .00
j=  4  .00 .00 .00 .00 .00 .00 .00 .00 .00 .00 .00 .00 .00 .00 .00 .00 .00 .01 .01 .01 .01 .01 .00 .00 .00
j=  2  .00 .00 .00 .00 .00 .00 .00 .00 .00 .00 .00 .00 .00 .00 .00 .01 .01 .01 .02 .02 .02 .01 .01 .01 .01
j=  1  .00 .00 .00 .00 .00 .00 .00 .00 .00 .00 .00 .00 .00 .01 .01 .01 .01 .02 .02 .02 .02 .02 .02 .02 .01
  i=     1   2   3   4   5   6   7   8   9  10  11  12  13  14  15  16  17  18  19  20  21  22  23  24  25
```

Table 4-42

Sample Terrain Weighting Factor Data File (WT.DAT) (Concluded)

```
 Height(m) =     800.000
  i=    1   2   3   4   5   6   7   8   9  10  11  12  13  14  15  16  17  18  19  20  21  22  23  24  25
j= 23 .00 .00 .00 .00 .00 .00 .00 .00 .00 .00 .00 .00 .00 .00 .00 .00 .00 .00 .00 .00 .00 .00 .00 .00 .00
j= 22 .00 .00 .00 .00 .00 .00 .00 .00 .00 .00 .00 .00 .00 .00 .00 .00 .00 .00 .00 .00 .00 .00 .00 .00 .00
j= 21 .00 .00 .00 .00 .00 .00 .00 .00 .00 .00 .00 .00 .00 .00 .00 .00 .00 .00 .00 .00 .00 .00 .00 .00 .00
j= 20 .00 .00 .00 .00 .00 .00 .00 .00 .00 .00 .00 .00 .00 .00 .00 .00 .00 .00 .00 .00 .00 .00 .00 .00 .00
j= 19 .00 .00 .00 .00 .00 .00 .00 .00 .00 .00 .00 .00 .00 .00 .00 .00 .00 .00 .00 .00 .00 .00 .00 .00 .00
j= 18 .00 .00 .00 .00 .00 .00 .00 .00 .00 .00 .00 .00 .00 .00 .00 .00 .00 .00 .00 .00 .00 .00 .00 .00 .00
j= 17 .00 .00 .00 .00 .00 .00 .00 .00 .00 .00 .00 .00 .00 .00 .00 .00 .00 .00 .00 .00 .00 .00 .00 .00 .00
j= 16 .00 .00 .00 .00 .00 .00 .00 .00 .00 .00 .00 .00 .00 .00 .00 .00 .00 .00 .00 .00 .00 .00 .00 .00 .00
j= 15 .00 .00 .00 .00 .00 .00 .00 .00 .00 .00 .00 .00 .00 .00 .00 .00 .00 .00 .00 .00 .00 .00 .00 .00 .00
j= 14 .00 .00 .00 .00 .00 .00 .00 .00 .00 .00 .00 .00 .00 .00 .00 .00 .00 .00 .00 .00 .00 .00 .00 .00 .00
j= 13 .00 .00 .00 .00 .00 .00 .00 .00 .00 .00 .00 .00 .00 .00 .00 .00 .00 .00 .00 .00 .00 .00 .00 .00 .00
j= 12 .00 .00 .00 .00 .00 .00 .00 .00 .00 .00 .00 .00 .00 .00 .00 .00 .00 .00 .00 .00 .00 .00 .00 .00 .00
j= 11 .00 .00 .00 .00 .00 .00 .00 .00 .00 .00 .00 .00 .00 .00 .00 .00 .00 .00 .00 .00 .00 .00 .00 .00 .00
j= 10 .00 .00 .00 .00 .00 .00 .00 .00 .00 .00 .00 .00 .00 .00 .00 .00 .00 .00 .00 .00 .00 .00 .00 .00 .00
j=  9 .00 .00 .00 .00 .00 .00 .00 .00 .00 .00 .00 .00 .00 .00 .00 .00 .00 .00 .00 .00 .00 .00 .00 .00 .00
j=  8 .00 .00 .00 .00 .00 .00 .00 .00 .00 .00 .00 .00 .00 .00 .00 .00 .00 .00 .00 .00 .00 .00 .00 .00 .00
j=  7 .00 .00 .00 .00 .00 .00 .00 .00 .00 .00 .00 .00 .00 .00 .00 .00 .00 .00 .00 .00 .00 .00 .00 .00 .00
j=  6 .00 .00 .00 .00 .00 .00 .00 .00 .00 .00 .00 .00 .00 .00 .00 .00 .00 .00 .00 .00 .00 .00 .00 .00 .00
j=  5 .00 .00 .00 .00 .00 .00 .00 .00 .00 .00 .00 .00 .00 .00 .00 .00 .00 .00 .00 .00 .00 .00 .00 .00 .00
j=  4 .00 .00 .00 .00 .00 .00 .00 .00 .00 .00 .00 .00 .00 .00 .00 .00 .00 .00 .00 .00 .00 .00 .00 .00 .00
j=  3 .00 .00 .00 .00 .00 .00 .00 .00 .00 .00 .00 .00 .00 .00 .00 .00 .00 .00 .00 .00 .00 .00 .00 .00 .00
j=  2 .00 .00 .00 .00 .00 .00 .00 .00 .00 .00 .00 .00 .00 .00 .00 .00 .00 .00 .00 .00 .00 .00 .00 .00 .00
j=  1 .00 .00 .00 .00 .00 .00 .00 .00 .00 .00 .00 .00 .00 .00 .00 .00 .00 .00 .01 .01 .01 .00 .00 .00 .00
  i=    1   2   3   4   5   6   7   8   9  10  11  12  13  14  15  16  17  18  19  20  21  22  23  24  25
                     :                                   :
                     :                                   :
                     :                                   :
                     :                                   :
                     :                                   :
                     :                                   :
                     :                                   :
 Height(m) =     3500.00
  i=    1   2   3   4   5   6   7   8   9  10  11  12  13  14  15  16  17  18  19  20  21  22  23  24  25
j= 23 .00 .00 .00 .00 .00 .00 .00 .00 .00 .00 .00 .00 .00 .00 .00 .00 .00 .00 .00 .00 .00 .00 .00 .00 .00
j= 22 .00 .00 .00 .00 .00 .00 .00 .00 .00 .00 .00 .00 .00 .00 .00 .00 .00 .00 .00 .00 .00 .00 .00 .00 .00
j= 21 .00 .00 .00 .00 .00 .00 .00 .00 .00 .00 .00 .00 .00 .00 .00 .00 .00 .00 .00 .00 .00 .00 .00 .00 .00
j= 20 .00 .00 .00 .00 .00 .00 .00 .00 .00 .00 .00 .00 .00 .00 .00 .00 .00 .00 .00 .00 .00 .00 .00 .00 .00
j= 19 .00 .00 .00 .00 .00 .00 .00 .00 .00 .00 .00 .00 .00 .00 .00 .00 .00 .00 .00 .00 .00 .00 .00 .00 .00
j= 18 .00 .00 .00 .00 .00 .00 .00 .00 .00 .00 .00 .00 .00 .00 .00 .00 .00 .00 .00 .00 .00 .00 .00 .00 .00
j= 17 .00 .00 .00 .00 .00 .00 .00 .00 .00 .00 .00 .00 .00 .00 .00 .00 .00 .00 .00 .00 .00 .00 .00 .00 .00
j= 16 .00 .00 .00 .00 .00 .00 .00 .00 .00 .00 .00 .00 .00 .00 .00 .00 .00 .00 .00 .00 .00 .00 .00 .00 .00
j= 15 .00 .00 .00 .00 .00 .00 .00 .00 .00 .00 .00 .00 .00 .00 .00 .00 .00 .00 .00 .00 .00 .00 .00 .00 .00
j= 14 .00 .00 .00 .00 .00 .00 .00 .00 .00 .00 .00 .00 .00 .00 .00 .00 .00 .00 .00 .00 .00 .00 .00 .00 .00
j= 13 .00 .00 .00 .00 .00 .00 .00 .00 .00 .00 .00 .00 .00 .00 .00 .00 .00 .00 .00 .00 .00 .00 .00 .00 .00
j= 12 .00 .00 .00 .00 .00 .00 .00 .00 .00 .00 .00 .00 .00 .00 .00 .00 .00 .00 .00 .00 .00 .00 .00 .00 .00
j= 11 .00 .00 .00 .00 .00 .00 .00 .00 .00 .00 .00 .00 .00 .00 .00 .00 .00 .00 .00 .00 .00 .00 .00 .00 .00
j= 10 .00 .00 .00 .00 .00 .00 .00 .00 .00 .00 .00 .00 .00 .00 .00 .00 .00 .00 .00 .00 .00 .00 .00 .00 .00
j=  9 .00 .00 .00 .00 .00 .00 .00 .00 .00 .00 .00 .00 .00 .00 .00 .00 .00 .00 .00 .00 .00 .00 .00 .00 .00
j=  8 .00 .00 .00 .00 .00 .00 .00 .00 .00 .00 .00 .00 .00 .00 .00 .00 .00 .00 .00 .00 .00 .00 .00 .00 .00
j=  7 .00 .00 .00 .00 .00 .00 .00 .00 .00 .00 .00 .00 .00 .00 .00 .00 .00 .00 .00 .00 .00 .00 .00 .00 .00
j=  6 .00 .00 .00 .00 .00 .00 .00 .00 .00 .00 .00 .00 .00 .00 .00 .00 .00 .00 .00 .00 .00 .00 .00 .00 .00
j=  5 .00 .00 .00 .00 .00 .00 .00 .00 .00 .00 .00 .00 .00 .00 .00 .00 .00 .00 .00 .00 .00 .00 .00 .00 .00
j=  4 .00 .00 .00 .00 .00 .00 .00 .00 .00 .00 .00 .00 .00 .00 .00 .00 .00 .00 .00 .00 .00 .00 .00 .00 .00
j=  3 .00 .00 .00 .00 .00 .00 .00 .00 .00 .00 .00 .00 .00 .00 .00 .00 .00 .00 .00 .00 .00 .00 .00 .00 .00
j=  2 .00 .00 .00 .00 .00 .00 .00 .00 .00 .00 .00 .00 .00 .00 .00 .00 .00 .00 .00 .00 .00 .00 .00 .00 .00
j=  1 .00 .00 .00 .00 .00 .00 .00 .00 .00 .00 .00 .00 .00 .00 .00 .00 .00 .00 .00 .00 .00 .00 .00 .00 .00
  i=    1   2   3   4   5   6   7   8   9  10  11  12  13  14  15  16  17  18  19  20  21  22  23  24  25
```

Table 4-43

Terrain Weighting Factor Data File Format (WT.DAT)

HEADER RECORDS

Header Record #1

Variable No.	Variable	Type	Description
1	C1	char*42	Documentation for W_{zi}

Header Record #2

Variable No.	Variable	Type	Description
1	C2	char*42	Documentation for W_s

Header Record #3

Variable No.	Variable	Type	Description
1	C3	char*42	Documentation for RMS_o

Header Record #4

Variable No.	Variable	Type	Description
1	X0FIN	real	X coordinate (km) of fine grid origin (i.e., origin of CALMET grid)
2	Y0FIN	real	Y coordinate (km) of fine grid origin
3	NXFIN	integer	Number of columns in the fine grid domain
4	NYFIN	integer	Number of rows in the fine grid domain
5	DFIN	real	Horizontal grid spacing (km) of fine grid

format (15x,2f8.1,2i5,f8.3)

Table 4-43

Terrain Weighting Factor Data File Format (WT.DAT) (Continued)

HEADER RECORDS

Header Record #5

Variable No.	Variable	Type	Description
1	X0CRS	real	X (km) coordinate of coarse grid origin (i.e., origin of MM4 grid)
2	Y0CRS	real	Y coordinate (km) of coarse grid origin
3	NXCRS	integer	Number of columns in the coarse grid domain
4	NYCRS	integer	Number of rows in the coarse grid domain
5	DCRS	real	Horizontal grid spacing (km) of coarse grid

format (15x,2f8.1,2i5,f8.3,//)

Table 4-43

Terrain Weighting Factor Data File Format (WT.DAT) (Continued)

DATA RECORDS (repeated for NZ layers)

Record	Variable No.	Variable	Type	Description
1	1	HT	real	Grid point height (m) of CALMET layers format (12x,f12.4/)
2*	-	-	-	Line of text containing i indices
Next NY records	1	WO	real array	Terrain weighting factors. The following statements are used to read the WO array:

```
        do 15 JJ=NYFIN,1,-1
15      READ (io99,113) (WO(i,jj,k),i=1,nxfin)
113     FORMAT (6x,150(1x,f3.2)/)
```

Record	Variable No.	Variable	Type	Description
NY+3*	-	-	-	Line of text containing i indices

---

* Line skipped by CALMET

4.2.11 CALMET Output Files

4.2.11.1 CALMET.DAT

The CALMET.DAT file contains the meteorological data fields produced by the CALMET model. It also contains certain geophysical fields, such as terrain elevations, surface roughness lengths, and land use types, which are used by both the CALMET meteorological model and the CALGRID and CALPUFF air quality models.

CALGRID requires three-dimensional fields of temperature and vertical velocity which are not used by CALPUFF unless the subgrid scale complex terrain (CTSG) option is employed. Therefore, a switch is provided in the CALMET control file which allows the user to eliminate these variables from the CALMET.DAT output file if the generated meteorological fields will be used to drive CALPUFF in a mode where they are not needed. The larger version of CALMET.DAT with the extra parameters can always also be used with CALPUFF. The option to exclude the 3-D temperature and vertical velocity fields from the CALMET.DAT file is provided to reduce the storage requirements of the output file and to a lesser extent to reduce the CPU requirements of the CALMET model run.

CALMET.DAT File - Header Records

The CALMET.DAT file consists of a set of up to fourteen header records, followed by a set of hourly data records. The header records contains a descriptive title of the meteorological run, information including the horizontal and vertical grid systems of the meteorological grid, the number, type, and coordinates of the meteorological stations included in the CALMET run, gridded fields of surface roughness lengths, land use, terrain elevations, leaf area indexes, and a pre-compute field of the closest surface meteorological station number to each grid point.

The actual number of header records may vary because, as explained below, records containing surface, upper air, and precipitation station coordinates are not included if these stations were not included in the run. A description of each variable in the header records is provided in Table 4-44.

Sample FORTRAN write statements for the CALMET.DAT header records are:

```
c ---     Header record 1 -- Run title
          write(iunit)TITTLE

c ---     Header record 2 -- General run and grid information
          write(iunit)VER,LEVEL,IBYR,IBMO,IBDY,IBHR,IBTZ,IRLG,IRTYPE,
        1 NX,NY,NZ,DGRID,XORIGR,YORIGR,IUTMZN,IWFCOD,NSSTA,
        2 NUSTA,NPSTA,NOWSTA,NLU,IWAT1,IWAT2,LCALGRD

c ---     Header record 3 -- Vertical cell face heights (nz+1 values)
          write(iunit)CLAB1,IDUM,ZFACEM

c ---     Header records 4 and 5 -- Surface station coordinates
          if(nssta.ge.1)then
                   write(iunit)CLAB2,IDUM,XSSTA
                   write(iunit)CLAB3,IDUM,YSSTA
          endif

c ---     Header records 6 and 7 -- Upper air station coordinates
          if(nusta.ge.1)then
                   write(iunit)CLAB4,IDUM,XUSTA
                   write(iunit)CLAB5,IDUM,YUSTA
          endif

c ---     Header records 8 and 9 -- Precipitation station coordinates
          if(npsta.ge.1)then
                   write(iunit)CLAB6,IDUM,XPSTA
                   write(iunit)CLAB7,IDUM,YPSTA
          endif

c ---     Header record 10 -- Surface roughness lengths
          write(iunit)CLAB8,IDUM,Z0

c ---     Header record 11 -- Land use categories
          write(iunit)CLAB9,IDUM,ILANDU

c ---     Header record 12 -- Terrain elevations
          write(iunit)CLAB10,IDUM,ELEV

c ---     Header record 13 - Leaf area indexes
          write(iunit)CLAB11,IDUM,XLAI

c ---     Header record 14 - Nearest surface station to each grid point
          write(iunit)CLAB12,IDUM,NEARS
```

where the following declarations apply:

```
real ZFACEM(nz+1),XSSTA(nssta),YSSTA(nssta),XUSTA(nusta),YUSTA(nusta)
real XPSTA(npsta),YPSTA(npsta)
real Z0(nx,ny),ELEV(nx,ny),XLAI(nx,ny)
integer ILANDU(nx,ny),NEARS(nx,ny)
character*80 TITLE(3)
character*8 VER,LEVEL,CLAB1,CLAB2,CLAB3,CLAB4,CLAB5,CLAB6
character*8 CLAB7,CLAB8,CLAB9,CLAB10,CLAB11,CLAB12
logical LCALGRD
```

Table 4-44

CALMET.DAT file - Header Records

Header Record No.	Variable No.	Variable	Type[a]	Description
1	1	TITLE	char*80 array	Array with three 80-character lines of the user's title of the CALMET run
2	1	VER	char*8	CALMET model version number
2	2	LEVEL	char*8	CALMET model level number
2	3	IBYR	integer	Starting year of CALMET run
2	4	IBMO	integer	Starting month
2	5	IBDY	integer	Starting day
2	6	IBHR	integer	Starting hour
2	7	IBTZ	integer	Base time zone (e.g., 05=EST, 06=CST, 07=MST, 08=PST)
2	8	IRLG	integer	Run length (hours)
2	9	IRTYPE	integer	Run type (0=wind fields only, 1=wind and micrometeorological fields). IRTYPE must be run type 1 to drive CALGRID or the CTSG option of CALPUFF
2	10	NX	integer	Number of grid cells in the X direction
2	11	NY	integer	Number of grid cells in the Y direction
2	12	NZ	integer	Number of vertical layers
2	13	DGRID	real	Grid spacing (m)
2	14	XORIGR	real	X coordinate (m) of south-west corner of grid point (1,1)
2	15	YORIGR	real	Y coordinate (m) of south-west corner of grid point (1,1)
2	16	IUTMZN	integer	UTM zone of coordinates

---

[a] char*80 = Character*80
char*8 = Character*8

Table 4-44
CALMET.DAT file - Header Records

Header Record No.	Variable No.	Variable	Type[a]	Description
2	17	IWFCOD	integer	Wind field module used (0=objective analysis, 1=diagnostic model)
2	18	NSSTA	integer	Number of surface meteorological stations
2	19	NUSTA	integer	Number of upper air stations
2	20	NPSTA	integer	Number of precipitation stations
2	21	NOWSTA	integer	Number of over water stations
2	22	NLU	integer	Number of land use categories
2	23	IWAT1	integer	Range of land use categories
2	24	IWAT2	integer	Corresponding to water surfaces (IWAT1 or IWAT2, inclusive)
2	25	LCALGRD	logical	Flag indicating if special meteorological parameters required by CALGRID are contained in the file (LCALGRD must be TRUE to drive CALGRID or the CTSG option of CALPUFF)
3	1	CLAB1	char*8	Variable label ('ZFACE')
3	2	IDUM	integer	Variable not used
3	3	ZFACEM	real array	Heights (m) of cell faces (NZ + 1 values)
4[b]	1	CLAB2	char*8	Variable label ('XSSTA')
4[b]	2	IDUM	integer	Variable not used
4[b]	3	XSSTA	real array	X coordinates (m) of each surface met. station

---

[a] char*8 = Character*8

[b] Included only if NSSTA > 0

Table 4-44
CALMET.DAT file - Header Records

Header Record No.	Variable No.	Variable	Type[a]	Description
5[b]	1	CLAB3	char*8	Variable label ('YSSTA')
5[b]	2	IDUM	integer	Variable not used
5[b]	3	YSSTA	real array	Y coordinates (m) of each surface met. station
6[c]	1	CLAB4	char*8	Variable label ('XUSTA')
6[c]	2	IDUM	integer	Variable not used
6[c]	3	XUSTA	real array	X coordinates (m) of each upper air met. station
7[c]	1	CLAB5	char*8	Variable label ('YUSTA')
7[c]	2	IDUM	integer	Variable not used
7[c]	3	YUSTA	real array	Y coordinate (m) of each upper air met. station
8[d]	1	CLAB6	char*8	Variable label ('XPSTA')
8[d]	2	IDUM	integer	Variable not used
8[d]	3	XPSTA	real array	X coordinate (m) of each precipitation station
9[d]	1	CLAB7	char*8	Variable label ('YPSTA')
9[d]	2	IDUM	integer	Variable not used
9[d]	3	YPSTA	real array	Y coordinate (m) of each precipitation station
10	1	CLAB8	char*8	Variable label ('Z0')
10	2	IDUM	integer	Variable not used
10	3	Z0	real array	Gridded field of surface roughness lengths (m) for each grid cell

---

[a] char*8 = Character*8
[b] Included only if NSSTA > 0
[c] Included only if NUSTA > 0
[d] Included only if NPSTA > 0

Table 4-44
CALMET.DAT file - Header Records

Header Record No.	Variable No.	Variable	Type[a]	Description
11	1	CLAB9	char*8	Variable label ('ILANDU')
11	2	IDUM	integer	Variable not used
11	3	ILANDU	integer array	Gridded field of land use category for each grid cell
12	1	CLAB10	char*8	Variable label ('ELEV')
12	2	IDUM	integer	Variable not used
12	3	ELEV	real array	Gridded field of terrain elevations for each grid cell
13	1	CLAB11	char*8	Variable label ('XLAI')
13	2	IDUM	integer	Variable not used
13	3	XLAI	real array	Gridded field of leaf area index for each grid cell
14	1	CLAB12	char*8	Variable label ('NEARS')
14	2	IDUM	integer	Variable not used
14	3	NEARS	integer array	Nearest surface meteorological station to each grid point

---

[a] char*8 = Character*8

CALMET.DAT File - Data Records

The CALMET.DAT data records include hourly fields of winds and meteorological variables. In addition to the regular CALMET output variables, CALGRID and the subgrid scale complex terrain (CTSG) module of CALPUFF require additional three-dimensional fields (air temperature and/or vertical velocity). The presence of these fields in the CALMET output file is flagged by the header record logical variable, LCALGRD, having a value of TRUE.

The data records contain three-dimensional gridded fields of U, V, and W wind components and air temperature, two-dimensional fields of PGT stability class, surface friction velocity, mixing height, Monin-Obukhov length, convective velocity scale, and precipitation rate (not used by CALGRID), and values of the temperature, air density, short-wave solar radiation, relative humidity, and precipitation type codes (not used by CALGRID) defined at the surface meteorological stations. A description of each variable in the data records is provided in Table 4-45.

Sample FORTRAN write statements for the CALMET.DAT data records are:

```
c ---   Write U, V, W wind components
            Loop over vertical layers, k

              write(iunit)CLABU,NDATHR((U(i,j,k),i=1,nx),j=1,ny)
              write(iunit)CLABV,NDATHR((V(i,j,k),i=1,nx),j=1,ny)
              if(LCALGRD)write(iunit)CLABW,NDATHR((W(i,j,k+1),i=1,nx),j=1,ny)

            End loop over vertical layers

c ---   Write 3-D temperature field
        if(LCALGRD.and.irtype.eq.1) then
            Loop over vertical layers, k

              write(iunit)CLABT,NDATHR((ZTEMP(i,j,k),i=1,nxm),j=1,nym)

            End loop over vertical layers
        endif
```

```
c ---   Write 2-D meteorological fields
        if(irtype.eq.1) then

                write(iunit)CLABSC,NDATHR,IPGT
                write(iunit)CLABUS,NDATHR,USTAR
                write(iunit)CLABZI,NDATHR,ZI
                write(iunit)CLABL,NDATHR,EL
                write(iunit)CLABWS,NDATHR,WSTAR
                write(iunit)CLABRMM,NDATHR,RMM

        endif

c ---   Write 1-D variables defined at surface met. stations
        if(irtype.eq.1) then

                write(iunit)CLABTK,NDATHR,TEMPK
                write(iunit)CLABD,NDATHR,RHO
                write(iunit)CLABQ,NDATHR,QSW
                write(iunit)CLABRH,NDATHR,IRH
                write(iunit)CLABPC,NDATHR,IPCODE

        endif
```

where the following declarations apply:

```
        real U(nx,ny,nz),V(nx,ny,nz),W(nx,ny,nz)
        real ZTEMP(nx,ny,nz)
        real USTAR(nx,ny),ZI(nx,ny),EL(nx,ny)
        real WSTAR(nx,ny),RMM(nx,ny)
        real TEMPK(nssta),RHO(nssta),QSW(nssta)
        integer IPGT(nx,ny)
        integer IRH(nssta),IPCODE(nssta)
        character*8 CLABU, CLABV, CLABW, CLABT, CLABSC, CLABUS, CLABZI
        character*8 CLABL, CLABWS, CLABRMM, CLABTK, CLABD, CLABQ, CLABRH
        character*8 CLABPC
```

Table 4-45

CALMET.DAT file - Data Records

Record Type	Variable No.	Variable Name	Type[a]	Description
1	1	CLABU	char*8	Variable label ('U-LEVxxx', where xxx indicates the layer number)
1	2	NDATHR	integer	Year, Julian day and hour in the form YYJJJHH
1	3	U	real array	U-component (m/s) of the winds at each grid point
2	1	CLABV	char*8	Variable label ('V-LEVxxx', where xxx indicates the layer number)
2	2	NDATHR	integer	Year, Julian day and hour in the form YYJJJHH
2	3	V	real array	V-component (m/s) of the winds at each grid point
3[b]	1	CLABW	char*8	Variable label ('WFACExxx'), where xxx indicates the layer number)
3[b]	2	NDATHR	integer	Year, Julian day and hour in the form YYJJJHH
3[b]	3	W	real array	W-component (m/s) of the winds at each grid point

(Record types 1,2,3 repeated NZ times (once per layer) as a set)

Record Type	Variable No.	Variable Name	Type[a]	Description
4[b]	1	CLABT	char*8	Variable label ('T-LEVxxx', where xxx indicates the layer number)
4[b]	2	NDATHR	integer	Year, Julian day and hour in the form YYJJJHH
4[b]	3	ZTEMP	real array	Air temperature (deg. K) at each grid point

(Record type 4 repeated NZM times (once per layer))

---

[a] char*8 = Character*8

[b] Record types 3 and 4 are included only if LCALGRD is TRUE

Table 4-45
CALMET.DAT file - Data Records (Continued)

Record Type	Variable No.	Variable Name	Type[a]	Description
5	1	CLABSC	char*8	Variable label ('IPGT')
5	2	NDATHR	integer	Year, Julian day and hour in the form YYJJJHH
5	3	IPGT	integer array	PGT stability class at each grid point
6	1	CLABUS	char*8	Variable label ('USTAR')
6	2	NDATHR	integer	Year, Julian day and hour in the form YYJJJHH
6	3	USTAR	real array	Surface friction velocity (m/s)
7	1	CLABZI	char*8	Variable label ('ZI')
7	2	NDATHR	integer	Year, Julian day and hour in the form YYJJJHH
7	3	ZI	real array	Mixing height (m)
8	1	CLABL	char*8	Variable label ('EL')
8	2	NDATHR	integer	Year, Julian day and hour in the form YYJJJHH
8	3	EL	real array	Monin-Obukhov length (m)
9	1	CLABWS	char*8	Variable label ('WSTAR')
9	2	NDATHR	integer	Year, Julian day and hour in the form YYJJJHH
9	3	WSTAR	real array	Convective velocity scale (m/s)
10	1	CLABRMM	char*8	Variable label ('RMM')
10	2	NDATHR	integer	Year, Julian day and hour in the form YYJJJHH
10	3	RMM	real array	Precipitation rate (mm/hr). Not used by CALGRID.

---

[a] char*8 = Character*8

Table 4-45
CALMET.DAT file - Data Records

Record Type	Variable No.	Variable Name	Type[a]	Description
11	1	CLABTK	char*8	Variable label ('TEMPK')
11	2	NDATHR	integer	Year, Julian day and hour in the form YYJJJHH
11	3	TEMPK	real array	Temperature (deg. K) at each surface met. station
12	1	CLABD	char*8	Variable label ('RHO')
12	2	NDATHR	integer	Year, Julian day and hour in the form YYJJJHH
12	3	RHO	real array	Air density (kg/m^3) at each surface met. station
13	1	CLABQ	char*8	Variable label ('QSW')
13	2	NDATHR	integer	Year, Julian day and hour in the form YYJJJHH
13	3	QSW	real array	Short-wave solar radiation (W/m^2) at each surface met. station
14	1	CLABRH	char*8	Variable label ('IRH')
14	2	NDATHR	integer	Year, Julian day and hour in the form YYJJJHH
14	3	IRH	integer array	Relative humidity (percent) at each surface met. station
15	1	CLABPC	char*8	Variable label ('IPCODE')
15	2	NDATHR	integer	Year, Julian day and hour in the form YYJJJHH
15	3	IPCODE	integer array	Precipitation type code (not used by CALGRID)

---

[a] char*8 = Character*8

4.2.11.2 PACOUT.DAT

CALMET has the option to output the unformatted meteorological data file in a form compatible with MESOPUFF II. If IFORMO is set to two in Input Group 3 of the CALMET control file, the output data file is called PACOUT.DAT.

The PACOUT.DAT output meteorological file consists of six header records followed by a set of twelve data records for each hour. The header records contain the date and length of the run, grid size and spacing, land use categories and surface roughness lengths at each grid point, as well as other information required by MESOPUFF II. A description of each variable in the header records is provided in Table 4-46. Sample FORTRAN write statements for the PACOUT.DAT header records are:

```
c ---     Header record 1 -- General run and grid information
          write(io7)NYR,IDYSTR,IHRMAX,NSSTA,NUSTA,IMAX,JMAX,IBTZ,
        1 ILWF,IUWF,DGRID,VK

c ---     Header record 2 -- Surface station coordinates
          write(io7)XSCOOR,YSCOOR

c ---     Header record 3 -- Upper air station coordinates
          write(io7)XUCOOR,YUCOOR

c ---     Header record 4  -- Surface roughness lengths
          write(io7)Z0

c ---     Header record 5 -- Nearest surface station to each grid point
          write(io7)NEARS

c ---     Header record 6 -- Land use categories
          write(io7)ILANDU
```

where the following declarations apply:

```
          real XSCOOR(nssta),YSCOOR(nssta),XUCOOR(nusta),YUCOOR(nusta)
          real Z0(nx,ny)
          integer ILANDU(nx,ny)NEARS(nx,ny)
```

The data records of the PACOUT.DAT are repeated once each hour. A description of each variable in the data records is provided in Table 4-46. Sample FORTRAN write statements for the data records are:

```
c ---   Write date and time
          write(io7)KYR,KJUL,KHR

c ---   Write lower level wind components

          Loop over grid cells
              write(io7)((UL(i,j),i=1,nx,)j=1,ny)
          End loop over grid cells

          Loop over grid cells
              write(io7)((VL(i,j),i=1,nx,)j=1,ny)
          End loop over grid cells

c ---   Write upper level wind components

          Loop over grid cells
              write(io7)((UUP(i,j),i=1,nx,)j=1,ny)
          End loop over grid cells

          Loop over grid cells
              write(io7)((VUP(i,j),i=1,nx,)j=1,ny)
          End loop over grid cells

c ---   Write mixing height

          Loop over grid cells
              write(io7)((HTMIX(i,j),i=1,nx,)j=1,ny)
          End loop over grid cells

c ---   Write friction velocity

          Loop over grid cells
              write(io7)((USTAR(i,j),i=1,nx,)j=1,ny)
          End loop over grid cells

c ---   Write convective velocity scale

          Loop over grid cells
              write(io7)((WSTAR(i,j),i=1,nx,)j=1,ny)
          End loop over grid cells
```

```
c ---   Write Monin-Obukhov length
        ┌──── Loop over grid cells
        │        write(io7)((XMONIN(i,j),i=1,nx,)j=1,ny)
        └──── End loop over grid cells
c ---   Write PGT stability class
        ┌──── Loop over grid cells
        │        write(io7)((IPGT(i,j),i=1,nx,)j=1,ny)
        └──── End loop over grid cells
c ---   Write precipitation code
        ┌──── Loop over grid cells
        │        write(io7)((RMM(i,j),i=1,nx,)j=1,ny)
        └──── End loop over grid cells

c ---   Write average surface air density, air temperature, total solar radiation, relative humidity, and
        precipitation code
        write(io7)AVRHO,TEMPK,SRAD,IRH,IPCODE
```

where the following declarations apply:

```
real UL(nx,ny),VL(nx,ny),UUP(nx,ny),VUP(nx,ny)
real HTMIX(nx,ny),USTAR(nx,ny),WSTAR(nx,ny)
real XMONIN(nx,ny),RMM(nx,ny)
real TEMPK(nssta),SRAD(nssta)
integer IPGT(nx,ny)
integer IRH(nssta),IPCODE(nssta)
```

Table 4-46
PACOUT.DAT File - Format

HEADER RECORDS - First six records of output file

Header Record No.	Variable No.	Variable	Type	Description
1	1	NYR	integer	Starting year
1	2	IDYSTR	integer	Starting Julian day
1	3	IHRMAX	integer	Number of hours in run
1	4	NSSTA	integer	Number of surface stations
1	5	NUSTA	integer	Number of rawinsonde stations
1	6	IMAX	integer	Number of grid points in X direction
1	7	JMAX	integer	Number of grid points in Y direction
1	8	IBTZ	integer	Reference time zone
1	9	ILWF	integer	Lower-level wind field code
1	10	IUWF	integer	Upper-level wind field code
1	11	DGRID	real	Grid spacing (m)
1	12	VK	real	von Karman constant
2	1	XSCOOR	real array	Surface station X coordinates (grid units)
2	2	YSCOOR	real array	Surface station Y coordinates (grid units)
3	1	XUCOOR	real array	Upper air station X coordinates (grid units)
3	2	YUCOOR	real array	Upper air station Y coordinates (grid units)
4	1	Z0	real array	Surface roughness lengths (m)
5	1	NEARS	integer array	Station number of closest surface station to each grid point
6	1	ILANDU	integer array	Land use categories

Table 4-46
PACOUT.DAT File - Format (Concluded)

DATA RECORDS - Repeated for each hour of run

Header Record No.	Variable No.	Variable	Type	Description
7	1	KYR	integer	Year
7	2	KJUL	integer	Julian day
7	3	KHR	integer	Hour (00-23)
8	1	UL	real array	Lower-level u wind component (m/s)
9	1	VL	real array	Lower-level v wind component (m/s)
10	1	UUP	real array	Upper-level u wind component (m/s)
11	1	VUP	real array	Upper-level v wind component (m/s)
12	1	HTMIX	real array	Mixing height (m)
13	1	USTAR	real array	Friction velocity (m/s)
14	1	WSTAR	real array	Convective velocity scale (m/s)
15	1	XMONIN	real array	Monin-Obukhov length (m)
16	1	IPGT	integer array	PGT stability class
17	1	RMM	real array	Hourly precipitation rate (mm/hr)
18	1	AVRHO	real	Average surface air density (kg/m^3)
18	2	TEMPK	real array	Air temperature*(K)
18	3	SRAD	real array	Total solar radiation*(W/m^2)
18	4	IRH	integer array	Relative humidity*(%)
18	5	IPCODE	integer array	Precipitation code*

---

* At surface meteorological stations

4.3 Postprocessing Program

4.3.1 PRTMET Meteorological Display Program

The CALMET meteorological model generates a large, binary meteorological file which includes hourly gridded wind fields at multiple levels and hourly gridded surface meteorological fields such as PGT stability class, friction velocity, Monin-Obukhov length, mixing height, convective velocity scale, and precipitation rate. For many typical applications, this output file will be several megabytes or more in length. The PRTMET program is a postprocessor intended to aid in the analysis of the CALMET output data base by allowing the user to display selected portions of the meteorological data.

PRTMET has the following capabilities and options.

- Option to print or suppress printing of the gridded hourly meteorological fields (wind fields and surface meteorological variables).
- User-selected levels of the wind fields printed.
- Option to display wind fields as U, V components or as wind speed and wind direction.
- User-selected wind speed conversion factor for changing units (default units: m/s).
- Option to print or suppress printing of non-gridded surface meteorological variables (air temperature, density, short-wave radiation, relative humidity, precipitation type code).
- Option to print or suppress printing of the gridded geophysical variables (surface roughness lengths, land use categories, terrain elevations).
- Option to print or suppress printing of X, Y coordinates of surface stations, upper air stations, and precipitation stations used in the modeling.
- Option to print or suppress printing of the CALMET run control variables stored in the header records of the CALMET output file.

- User-selected portion of horizontal grid printed for all gridded meteorological fields. Options include printing entire grid, subset of grid, or a single data point.
- User-selected time period(s) printed.
- User-selected format for display of gridded meteorological fields (self-scaling exponential format or fixed format).

Two input files are read by PRTMET: a user-input control file and the unformatted meteorological data file containing the gridded wind and micrometeorological fields generated by CALMET. The output file, PRTMET.LST contains the printed data selected by the user. Table 4-47 contains a summary of the input files and output file for PRTMET.

The PRTMET control file contains the user's inputs entered in FORTRAN free format. A description of each input variable is shown in Table 4-48. A sample input file is presented in Table 4-49.

PRTMET extracts and prints the data selected by the user from the CALMET data file. A sample output file is shown in Table 4-50.

Table 4-47

PRTMET Input and Output Files

Unit	File Name	Type	Format	Description
5	PRTMET.INP	input	formatted	Control file containing user inputs
6	PRTMET.LST	output	formatted	List file (line printer output file)
7	CALMET.DAT	input	formatted	Unformatted CALMET output file containing meteorological and geophysical data to be printed

Table 4-48

PRTMET Control File Inputs (PRTMET.INP)

RECORD 1. Beginning date, time, run length, and printing interval.

Columns	Variable	Type	Description
*	IYR	integer	Starting year of data to print (two digit)
*	IMO	integer	Starting month
*	IDAY	integer	Starting day
*	IHR	integer	Starting hour (00-23)
*	ITHR	integer	Total number of hours of data to read
*	ICHR	integer	Time interval between printed fields (ICHR=1 to print every hour, ICHR=2 to print every second hour, etc.)

---

* Entered in FORTRAN free format

Table 4-48 (Continued)

PRTMET Control File Inputs (PRTMET.INP)

RECORD 2. Horizontal grid cells to print.

Columns	Variable	Type	Description
*	NBX	integer	X grid cell of lower left corner of grid to print
*	NBY	integer	Y grid cell of lower left corner of grid to print
*	NEX	integer	X grid cell of upper right corner of grid to print
*	NEY	integer	Y grid cell of upper right corner of grid to print

---

* Entered in FORTRAN free format

Table 4-48 (Continued)

PRTMET Control File Inputs (PRTMET.INP)

RECORDS 3-7. Print control variables for CALMET run variables and station coordinates.

Record[1]	Columns	Variable	Type	Description
3	*	IHDV	integer	Control variable for printing of CALMET run variables stored in header records of output file. (0=do not print, 1=print)
4	*	ISUR	integer	Control variable for printing of X,Y surface station coordinates. (0=do not print, 1=print)
5	*	IUP	integer	Control variable for printing of X,Y upper air station coordinates. (0=do not print, 1=print)
6	*	IPRC	integer	Control variable for printing of X,Y precipitation station coordinates. (0=do not print, 1=print)
7	*	INEARS	integer	Control variable for printing of nearest surface station number to each grid point. (0=do not print, 1=print)

---

* Entered in FORTRAN free format

[1] Note: One variable entered per input record.

Table 4-48 (Continued)

PRTMET Control File Inputs (PRTMET.INP)

RECORDS 8-10. **Print control variables and format for geophysical data.**

Record[1]	Columns	Variable	Type	Description
8	*	ISRC	integer	Control variable for printing of gridded surface roughness lengths. (0=do not print, 1=print)
8	*	IFF(1)	integer array element	Output format for surface roughness lengths. (0=self-scaling exponential format, 1=fixed format). USED ONLY IF ISRC=1.
9	*	ILUC	integer	Control variable for printing of gridded land use categories. (0=do not print, 1=print)
9	*	IFF(2)	integer array element	Output format for land use categories. (0=self-scaling exponential format, 1=fixed format). USED ONLY IF ILUC=1.)
10	*	ITE	integer	Control variable for printing of terrain elevations. (0=do not print, 1=print)
10	*	IFF(3)	integer array element	Output format for terrain elevations. (0=self-scaling exponential format, 1=fixed format). USED ONLY IF ITE=1.

---

* Entered in FORTRAN free format

[1] Note: Two variables entered per input record.

Table 4-48 (Continued)

PRTMET Control File Inputs (PRTMET.INP)

NEXT "NZ" RECORDS. Wind field print control variables for each vertical layer.

Record[1]	Columns	Variable	Type	Description
11	*	IUVOUT(1)	integer array element	Control variable for printing of Layer 1 of wind fields. (0=do not print, 1=print)
11	*	IWOUT(1)	integer array element	Control variable for printing of Layer 1 W component of winds. (0=do not print, 1=print)
11	*	ITOUT(1)	integer array element	Control variable for printing of Layer 1 temperature field. (0=do not print, 1=print)
12	*	IUVOUT(2)	integer array element	Control variable for printing of Layer 2 of wind fields. (0=do not print, 1 = print)
12	*	IWOUT(2)	integer array element	Control variable for printing of Layer 2 W component of winds. (0=do not print, 1=print)
12	*	ITOUT(2)	integer array element	Control variable for printing of Layer 2 temperature field. (0=do not print, 1=print)

●
●
●
(NZ records in all)

---

* Entered in FORTRAN free format

[1] Note: Three variables entered per input record.

Table 4-48 (Continued)

PRTMET Control File Inputs (PRTMET.INP)

NEXT RECORD[1]. Wind field format and units.

Columns	Variable	Type	Description
*	IPWS	integer	Control variable for display of wind field. (0=U,V components, 1=wind speed, wind direction)
*	XFACT	real	Wind speed units conversion factor. (1.0 for m/s, 1.944 for knots, 2.237 for miles/hour)
*	IFF(4)	integer array element	Output format for wind speeds. (0=self-scaling exponential format, 1=fixed format)

---

* Entered in FORTRAN free format

[1] Note: Three variables entered on the input record.

Table 4-48 (Continued)

PRTMET Control File Inputs (PRTMET.INP)

NEXT 6 RECORDS. **Print control variables and format for gridded surface meteorological variables.**

Record[1]	Columns	Variable	Type	Description
N+1	*	IPSC	integer	Control variable for printing of PGT stability class. (0=do not print, 1=print)
N+1	*	IFF(5)	integer array element	Output format for PGT stability class. USED ONLY IF IPSC=1. (0=self-scaling exponential format, 1=fixed format)
N+2	*	IFV	integer	Control variable for printing of friction velocity. (0=do not print, 1=print)
N+2	*	IFF(6)	integer array element	Output format for friction velocity. USED ONLY IF IFV=1. (0=self-scaling exponential format, 1=fixed format)
N+3	*	IMH	integer	Control variable for printing of mixing height. (0=do not print, 1=print)
N+3	*	IFF(7)	integer array element	Output format for mixing height. USED ONLY IF IMH=1. (0=self-scaling exponential format, 1=fixed format)

(Continued)

---

* Entered in FORTRAN free format

[1] Note: Two variables entered per input record.

Table 4-48 (Continued)

PRTMET Control File Inputs (PRTMET.INP)

NEXT 6 RECORDS. Print control variables and format for gridded surface meteorological variables.

Record[1]	Columns	Variable	Type	Description
N+4	*	IMOL	integer	Control variable for printing of Monin-Obukhov length. (0=do not print, 1=print)
N+4	*	IFF(8)	integer array element	Output format for Monin-Obukhov length. USED ONLY IF IMOL=1. (0=self-scaling exponential format, 1=fixed format)
N+5	*	ICVS	integer	Control variable for printing of convective velocity scale. (0=do not print, 1=print)
N+5	*	IFF(9)	integer array element	Output format for the convective velocity scale. USED ONLY IF ICVS=1. (0=self-scaling exponential format, 1=fixed format)
N+6	*	IPR	integer	Control variable for printing of precipitation rates. (0=do not print, 1=print)
N+6	*	IFF(10)	integer array element	Output format for precipitation rates. USED ONLY IF IPR=1. (0=self-scaling exponential format, 1=fixed format)

---

* Entered in FORTRAN free format

[1] Note: Two variables entered per input record.

Table 4-48 (Concluded)

PRTMET Control File Inputs (PRTMET.INP)

NEXT RECORD. Print control variable for non-gridded surface meteorological variables.

Columns	Variable	Type	Description
*	ISURF	integer	Control variable for display of non-gridded surface meteorological variables (air temperature, air density, short-wave solar radiation, relative humidity, precipitation code). (0=do not print, 1=print)

---

* Entered in FORTRAN free format

Table 4-49

Sample PRTMET Control File (PRTMET.INP)

```
83,10,25,23, 30, 1 - Beg. YR, MO, DAY, HR to print, LENGTH, PRINT INTERVAL
      10,20, 10,20 - Beg. GRID (I,J) to print, Ending GRID (I,J) to print
                 1 - Print CALMET RUN VARIABLES ? (e.g., grid parameters, etc.)
                 1 - Print x-y coordinates of SURFACE STATIONS ?
                 1 - Print x-y coordinates of UPPER AIR STATIONS ?
                 1 - Print x-y coordinates of PRECIPITATION STATIONS ?
                 1 - Print NEAREST SURFACE STATION no. to each grid pt. ?
              1, 1 - Print SURFACE ROUGHNESS LENGTHS ?, Fixed format ?
              1, 1 - Print LAND USE CATEGORIES ?,       Fixed format ?
              1, 1 - Print TERRAIN HEIGHTS ?,           Fixed format ?
              1, 1 - Print LEAF AREA INDEX ?,           Fixed format ?
           1, 1, 1 - Print U-V, W, TEMP FIELDS ?    (LAYER 1)
           0, 0, 0                                  (LAYER 2)
           0, 0, 0                                  (LAYER 3)
           0, 0, 0                                  (LAYER 4)
           0, 0, 0                                  (LAYER 5)
           0, 0, 0                                  (LAYER 6)
           0, 0, 0                                  (LAYER 7)
           0, 0, 0                                  (LAYER 8)
           0, 0, 0                                  (LAYER 9)
           0, 0, 0                                  (LAYER 10)
           0, 0, 0                                  (LAYER 11)
         1, 1.0, 0 - Convert U,V to WS, WD ?, Units conv., Fixed format ?
              1, 1 - Print PGT STABILITY CLASS ?,   Fixed format ?
              1, 0 - Print FRICTION VELOCITY ?,     Fixed format ?
              1, 0 - Print MIXING HEIGHT ?,         Fixed format ?
              1, 0 - Print MONIN-OBUKHOV LENGTH ?,  Fixed format ?
              1, 0 - Print CONVECTIVE VEL. SCALE ?, Fixed format ?
              1, 0 - Print PRECIP. RATE ?,          Fixed format ?
                 0 - Print SURFACE MET. STATION DATA ?
```

Table 4-50

Sample PRTMET Output File (PRTMET.LST)

```
                                PRTMET INPUT OPTIONS
                                Version: 3.0       Level: 941215

                         Beginning year               83
                         Beginning month              10
                         Beginning day                25
                         Beginning Julian day        298
                         Beginning hour (00 to 23)    23
                         Total number of hours        30
                         Print interval (hours)        1


                  Subset of grid will be displayed.

                      Only a single point was selected
            Tables will be generated for the point:  ( 10, 20)

        Display X-Y coordinates of surface sta. ?     1
        Display X-Y coordinates of upper air sta. ?   1
        Display X-Y coordinates of precip. sta. ?     1
        Display nearest surface station array ?       1
        Display surface roughness length ?            1     Fixed format ?   1
        Display land use categories ?                 1     Fixed format ?   1
        Display terrain elevations ?                  1     Fixed format ?   1
        Display leaf area index ?                     1     Fixed format ?   1

       Control variables for printing of 3-D fields.
               LEVEL          U,V        W      TEMP ?
                 1             1         1       1
                 2             0         0       0
                 3             0         0       0
                 4             0         0       0
                 5             0         0       0
                 6             0         0       0
                 7             0         0       0
                 8             0         0       0
                 9             0         0       0
                10             0         0       0
                11             0         0       0

        Wind components (U, V) converted to WS, WD ?  1
        Display wind field in fixed format ?          0

     Multiplicative factor for wind units:        1.0000
  (If the factor is 1.0 then units will remain in m/s)

        Display PGT stability class ?                 1     Fixed format ?   1
        Display friction velocity ?                   1     Fixed format ?   0
        Display Monin-Obukhov length ?                1     Fixed format ?   0
        Display mixing height ?                       1     Fixed format ?   0
        Display convective velocity scale ?           1     Fixed format ?   0
        Display precipitation rate ?                  1     Fixed format ?   0

        Display surface met. station variables ?      0


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

Table 4-50

Sample PRTMET Output File (PRTMET.LST)

```
Data read from header records of CALMET output file
CALMET Test Case: CAPTEX exp #5; MM4 as Step 1 field;
80 x 63  18 km meteorological grid -- 10/25/83 5:00 - 10/28/83 4:00
20 Upper Air, 149 Surface, 59 Precip stations, 2 Overwater stns

CALMET Version: 3.0        Level: 941215

 IBYR    =           83
 IBMO    =           10
 IBDY    =           25
 IBHR    =            5
 IBTZ    =            5
 IRLG    =           72
 IRTYPE  =            1
 LCALGRD = T
 NX      =           80
 NY      =           63
 NZ      =           11
 DGRID   =    18000.000000
 XORIGR  =   342000.000000
 YORIGR  =  -135000.000000
 IUTMZN  =            0
 IWFCOD  =            0
 NSSTA   =          149
 NUSTA   =           20
 NPSTA   =           59
 NOWSTA  =            2
 NLU     =           10
 IWAT1   =           50
 IWAT2   =           55
 LCALGRD = T
ZFACE  =       .000,     20.000,     80.000,    120.000,    280.000,    520.000,   1080.000,   1400.000,   1800.000,
2200.000,
 3000.000,  4000.000,

XSSTA    =   416860.000000   230990.000000   805819.900000   745130.000000
   728670.100000   483210.000000   712160.100000   942400.000000
  1164370.000000   874140.000000  -168770.000000   893209.900000
   975100.000000   732620.000000    66079.980000  -174080.000000
   188560.000000   439060.000000   734010.000000  1014370.000000
   896290.100000   615550.000000   532020.000000   455190.000000
   873069.900000   910050.100000  1026270.000000   821810.100000
  1511010.000000  1173380.000000  1614620.000000  1427290.000000
  1646240.000000  1531730.000000  1187330.000000  1923270.000000
  1451410.000000  1560330.000000  1833230.000000  1484080.000000
  1387430.000000  1636080.000000  1435950.000000  1335730.000000
  1774460.000000  1549040.000000   184240.000000  1529520.000000
  1269490.000000  1146550.000000  1297560.000000   885770.000000
   726780.000000   445940.000000   600550.000000   847939.900000
   461530.000000  1002900.000000   389870.000000   212520.000000
   351860.000000   335270.000000   216740.000000   334980.000000
   270670.000000    64320.010000  1091750.000000   320540.000000
   165860.000000   321200.000000   937650.000000  1251400.000000
   464480.000000    86700.020000   463020.000000   539450.000000
   353550.000000   -51750.000000   189010.000000  -340210.000000
   -50310.000000   850260.000000  1172370.000000   644630.000000
   701600.000000   747730.000000  -198740.000000  -232490.000000
  -289450.000000  -383960.000000  -315840.000000  -270290.000000
  -314650.000000  -374040.000000   245590.000000   211380.000000
   149020.000000    47959.990000    83799.980000  -176810.000000
```

Table 4-50

Sample PRTMET Output File (PRTMET.LST)

```
      -46640.020000   75459.990000  -46420.010000   -5010.010000
      411580.000000  440040.000000  266970.000000  354240.000000
      769120.000000  586590.000000  289110.000000  768990.000000
      566970.000000  936560.100000  369310.000000  962910.100000
      541980.000000  942790.100000  928079.900000  842680.100000
     1151070.000000 1033490.000000  939709.900000 1094310.000000
      735900.000000 1135980.000000  621360.000000  741319.900000
      805569.900000  708530.000000  104940.000000  137650.000000
     -131420.000000  -32519.990000  118240.000000   21170.010000
     1015400.000000  802740.000000 1088530.000000  457600.000000
      156490.000000  145030.000000   10679.990000  509800.000000
      313160.000000  872360.000000  743220.000000  520880.000000
      847920.100000

YSSTA    =   -62850.010000  -100570.000000    48900.000000    99060.000000
       58060.000000  224700.000000  356010.000000  264160.000000
      546800.000000  269670.000000  361380.000000   14910.000000
      338940.000000  659440.000000  618690.000000  350480.000000
      397280.000000  869340.000000  803670.000000 1024450.000000
      857270.000000  652990.000000 1069260.000000 1074250.000000
      846950.000000 1189990.000000  876150.000000  900110.000000
     1088460.000000 1323960.000000 1141610.000000 1163030.000000
      965090.000000  966500.000000 1268690.000000  986980.000000
      979310.000000 1139970.000000 1210010.000000  821940.000000
     1021470.000000  989990.000000 1363430.000000 1242570.000000
     1112700.000000  829930.000000 1172350.000000 1918200.000000
     1474260.000000 1742780.000000 1860960.000000 1702650.000000
     1288820.000000 1662770.000000  849550.000000  864840.000000
      582050.000000 1190700.000000 1009140.000000  793000.000000
      499560.000000  683610.000000  404020.000000  885630.000000
     1089220.000000  845630.000000 1938220.000000 -329400.000000
     -537220.000000 -214540.000000 -262000.000000 1093630.000000
     -337500.000000 -390100.000000 -477340.000000 -234150.000000
     -384330.000000 -440000.000000 -297870.000000 -401780.000000
     -279140.000000  -97420.000000  714840.000000 -243160.000000
      355370.000000 -404500.000000  618610.000000  906790.000000
      472150.000000  291380.000000  207290.000000  372350.000000
      116720.000000      89.996340  161140.000000  419740.000000
      473900.000000  254480.000000  447600.000000  454750.000000
      483180.000000  845330.000000  324940.000000  653090.000000
      313670.000000  407050.000000  251860.000000  271470.000000
      139180.000000  -91030.000000  -11710.010000  471610.000000
      393560.000000  199220.000000   -3750.000000  349650.000000
      512740.000000  337890.000000  560000.000000  313170.000000
      567920.000000  492250.000000  751230.000000  646120.000000
      247440.000000  493540.000000  545170.000000  564980.000000
      380860.000000  104130.000000   47320.000000  141590.000000
      -72479.990000  113080.000000  -62370.000000  -51970.000000
      404620.000000  773880.000000  542120.000000  237810.000000
      326700.000000  699850.000000  454920.000000   68120.000000
      321300.000000  234220.000000  -49280.000000 -100720.000000
      206680.000000

XUSTA    =   144490.000000   706370.000000   922209.900000   289110.000000
      928079.900000  456390.000000  541980.000000 1172370.000000
      150580.000000 1251400.000000   73989.990000 1251440.000000
      539450.000000  -50310.000000  893209.900000 -315840.000000
     -198740.000000 -255010.000000  937650.000000  691880.000000
```

Table 4-50

Sample PRTMET Output File (PRTMET.LST)

```
YUSTA    =   138850.000000   107070.000000   229420.000000   -11710.010000
  560000.000000   240920.000000   512740.000000   712840.000000
  474020.000000  1093630.000000   845220.000000   515270.000000
 -234150.000000  -279140.000000    14910.000000   207290.000000
  618610.000000   -10240.010000  -262000.000000   911740.000000

XPSTA    =   289110.000000   768990.000000   872360.000000   743220.000000
  520880.000000   847920.100000   369310.000000   962910.100000
  541980.000000   942790.100000   928079.900000   842680.100000
 1151070.000000  1033490.000000   939709.900000  1094310.000000
 1135980.000000   539450.000000   -50310.000000   850260.000000
 1172370.000000   644630.000000   747730.000000  -198740.000000
 -232490.000000   621360.000000   741319.900000   805569.900000
  313160.000000   245590.000000   211380.000000   149020.000000
   47959.990000    83799.980000    75459.990000   -46420.010000
  411580.000000   440040.000000   266970.000000   354240.000000
  769120.000000   936560.100000   104940.000000   137650.000000
  -32519.990000   118240.000000    21170.010000  1015400.000000
 1088530.000000   457600.000000   156490.000000   145030.000000
   10679.990000   509800.000000   321200.000000   937650.000000
 1251400.000000  -383960.000000  -314650.000000

YPSTA    =   -11710.010000   471610.000000   234220.000000   -49280.000000
 -100720.000000   206680.000000    -3750.000000   349650.000000
  512740.000000   337890.000000   560000.000000   313170.000000
  567920.000000   492250.000000   751230.000000   646120.000000
  493540.000000  -234150.000000  -279140.000000   -97420.000000
  714840.000000  -243160.000000  -404500.000000   618610.000000
  906790.000000   545170.000000   564980.000000   380860.000000
  321300.000000   161140.000000   419740.000000   473900.000000
  254480.000000   447600.000000   845330.000000   324940.000000
  313670.000000   407050.000000   251860.000000   271470.000000
  139180.000000   199220.000000    47320.000000   141590.000000
  113080.000000   -62370.000000   -51970.000000   404620.000000
  542120.000000   237810.000000   326700.000000   699850.000000
  454920.000000    68120.000000  -214540.000000  -262000.000000
 1093630.000000   291380.000000   116720.000000
```

Table 4-50

Sample PRTMET Output File (PRTMET.LST)

```
** -- TABLE FOR ONE POINT -- **


The point selected is ( 10, 20)


Surface Roughness Length  (m)  =     .33030
Land Use Category              =         20
Terrain Elevation (m)          =     190.87
Leaf area index                =    2.75000
Nearest surface sta. to I,J    =        141

Met. Variables for point (x,y) = ( 10, 20)
YEAR  MONTH  DAY  HOUR   LEVEL  WIND SPEED    WIND DIRECTION     W-VEL.        TEMP
                                   (m/s)          (Deg)           (m/s)      (deg K)
 83    10    25    23      1       4.19          282.3          -.00016       278.7

 83    10    26     0      1       3.19          261.8          -.00006       278.1

 83    10    26     1      1       3.58          253.0           .00018       277.6

 83    10    26     2      1       3.15          253.3          -.00014       277.5

 83    10    26     3      1       3.05          240.0           .00008       277.6

 83    10    26     4      1       3.39          233.0           .00012       277.5

 83    10    26     5      1       3.05          228.4           .00030       277.3

 83    10    26     6      1       2.78          226.4          -.00004       277.2

 83    10    26     7      1       2.16          214.6          -.00021       277.2

 83    10    26     8      1       2.78          201.0          -.00003       277.7

 83    10    26     9      1       2.46          210.5          -.00012       278.9

 83    10    26    10      1       1.10          265.4          -.00138       280.0

 83    10    26    11      1        .32          327.9          -.00182       280.9

 83    10    26    12      1        .14           31.1          -.00057       281.5

 83    10    26    13      1        .92          323.1          -.00013       281.9

 83    10    26    14      1       1.91          257.7           .00034       282.2

 83    10    26    15      1       3.92          340.3          -.00112       282.3

 83    10    26    16      1       4.14          319.5          -.00087       282.3

 83    10    26    17      1       3.84          328.7          -.00081       281.6

 83    10    26    18      1       3.41          332.0           .00031       280.4

 83    10    26    19      1       3.44          307.6           .00002       279.6

 83    10    26    20      1       3.60          308.6           .00053       278.8

 83    10    26    21      1       3.16          305.4           .00026       278.3

 83    10    26    22      1       3.17          311.1           .00002       277.6
```

Table 4-50

Sample PRTMET Output File (PRTMET.LST)

```
Met. Variables for point (x,y) = ( 10, 20)
YEAR  MONTH  DAY  HOUR   PGT      U*       MIX HT         L          W*     Precip.
                                (m/s)       (m)          (m)       (m/s)   (mm/hr)
 83    10    25    23     5     .453      309.3     1.61385E+02     .000     .000
 83    10    26     0     6     .319      182.6     7.95247E+01     .000     .000
 83    10    26     1     5     .373      232.2     1.10071E+02     .000     .000
 83    10    26     2     6     .316      183.2     8.12215E+01     .000     .000
 83    10    26     3     5     .325      237.1     1.38320E+02     .000     .000
 83    10    26     4     4     .374      323.2     2.18336E+02     .000     .000
 83    10    26     5     5     .331      273.6     1.71256E+02     .000     .000
 83    10    26     6     5     .296      225.1     1.37510E+02     .000     .000
 83    10    26     7     5     .191      108.9     4.19938E+01     .000     .000
 83    10    26     8     4     .297      233.4     1.38406E+02     .000     .028
 83    10    26     9     4     .295      224.9    -4.50452E+02     .189     .027
 83    10    26    10     4     .160      140.4    -2.20051E+01     .356     .605
 83    10    26    11     4     .084      165.8    -1.03385E+00     .465     .112
 83    10    26    12     4     .060      185.2    -1.40114E-01     .538     .227
 83    10    26    13     4     .153      214.7    -9.37766E+00     .578     .157
 83    10    26    14     4     .254      256.6    -5.10777E+01     .593     .120
 83    10    26    15     4     .470      471.9    -4.14514E+02     .570     .168
 83    10    26    16     4     .505      592.6    -2.37370E+02     .835     .088
 83    10    26    17     4     .461      741.0    -4.11301E+02     .540     .110
 83    10    26    18     4     .350      209.6     9.65873E+01     .000     .392
 83    10    26    19     5     .354      212.1     9.80819E+01     .000     .700
 83    10    26    20     5     .376      236.9     1.11263E+02     .000     .246
 83    10    26    21     6     .315      181.1     7.78793E+01     .000     .098
 83    10    26    22     6     .316      178.1     7.79874E+01     .000     .122

Met. Variables for point (x,y) = ( 10, 20)
YEAR  MONTH  DAY  HOUR  LEVEL  WIND SPEED   WIND DIRECTION    W-VEL.      TEMP
                                  (m/s)         (Deg)          (m/s)     (deg K)
 83    10    26    23     1       2.83          302.7        -.00019      277.0

 83    10    27     0     1       3.60          306.4        -.00043      276.7

 83    10    27     1     1       3.95          308.1        -.00040      276.4

 83    10    27     2     1       3.41          303.7        -.00016      276.0

 83    10    27     3     1       3.49          310.6        -.00051      275.5

 83    10    27     4     1       2.85          308.4        -.00055      275.4

Met. Variables for point (x,y) = ( 10, 20)
YEAR  MONTH  DAY  HOUR   PGT      U*       MIX HT         L          W*     Precip.
                                (m/s)       (m)          (m)       (m/s)   (mm/hr)
 83    10    26    23     6     .266      138.7     5.47473E+01     .000     .130
 83    10    27     0     5     .375      227.7     1.09870E+02     .000     .295
 83    10    27     1     5     .422      270.7     1.38653E+02     .000     .134
 83    10    27     2     5     .350      205.7     9.50717E+01     .000     .131
 83    10    27     3     5     .361      214.5     1.00966E+02     .000     .537
 83    10    27     4     6     .268      140.3     5.57894E+01     .000     .307
```

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APPENDIX A

Tree Diagram of the CALMET Model and Subroutine/Function Calling Structure

Appendix A
Subroutine/Function Calling Structure - Tree Diagram
(Return to Calling Routine Indicated by *)

(Setup Phase of Model Execution)

```
MAIN        First        Second       Third         Fourth          Fifth
Program     Level        Level        Level         Level           Level
            Subr.        Subr.        Subr.         Subr.           Subr.

MAIN ---->  under0
            setup ---->  datetm ----> date *
                                      time *
                                      etime *
                         openfl *
                         readcf ----> readin  ----> deblnk *
                                                    allcap *
                                                    altonu *
                                                    setvar *
                                      julday *
                         openot *
                         readge ----> out     ----> wrt *
                                                    wrt2 *
                                      fillgeo *
                         setcom ----> out     ----> wrt *
                                                    wrt2 *
                         readhd ----> rdhd    ----> dedat *
                                      deltt *
                                      rds     ----> unpcks *
                                                    dedat *
                                      rdp     ----> rdnwd *
                                                    unpack *
                                                    dedat *
                                      rdhdu *
                                      rdhd4   ----> julday *
                                                    incr *
                                      rdmm4   ----> julday *
                                                    indecr *
                                                    qcksrt3 *
                                                    bilinear *
                                      indecr *
                         microi *
                         diagi  ----> terset *
                         outhd  ----> wrtr1d *
                                      wrtr2d *
                                      wrti2d *
                         outpc1 ----> wpcr2d *
                                      wpci2d *
                                      out     ---->  wrt *
                                                     wrt2 *
                         rdwt *
```

Appendix A
Subroutine/Function Calling Structure - Tree Diagram
(Return to Calling Routine Indicated by *)

(COMPUTATIONAL and TERMINATION Phases of Model Execution)

```
MAIN        First         Second        Third         Fourth         Fifth          Sixth
Program     Level         Level         Level         Level          Level          Level
            Subr.         Subr.         Subr.         Subr.          Subr.          Subr.

MAIN  ----> comp    ----> grday *
                          solar *
                          rds     ----> unpcks *
                                        dedat *
                          missfc  ----> cmpd2 *
                                        ireplac *
                                        rreplac *
                          rdp     ----> rdnwd *
                                        unpack *
                                        dedat *
                          rdow *
                          diag2 *
                          indecr *
                          rdup    ----> julday *
                          vertav *
                          dedat *
                          deltt *
                          facet   ----> intp *
                          prepdi  ----> cgamma  ----> dedat *
                                                      intp *
                                                      deltt *
                                        vertav *
                                        xmit *
                                        dedat *
                                        deltt *
                          diagno  ----> windbc *
                                        xmit *
                                        progrd  ----> xmit *
                                        topof2 *
                                        minim   ----> divcel *
                                                      windbc *
                                        windpr  ----> wndlpt *
                                        outfil *
                                        slope   ----> xmit *
                                                      wndlpt *
                                        wndpr2  ----> wndlpt *
                                        fradj *
                                        fminf *
                                        stheor  ----> water2   ----> esat*
                                                                     similt*
                                                      elustr2  ----> similt*
                                        inter2  ----> xmit *
                                                      barier * ----> unidot *
                                                      fminf *
                                        interp  ----> xmit *
                                                      barier * ----> unidot *
                                                      fminf *
                                        rdmm4   ----> julday *
                                                      indecr *
                                                      qcksrt3 *
                                                      bilinear *
(Continued)
```

Appendix A
Subroutine/Function Calling Structure - Tree Diagram
(Return to Calling Routine Indicated by *)

(COMPUTATIONAL and TERMINATION Phases of Model Execution)

```
MAIN          First         Second        Third         Fourth        Fifth
Program       Level         Level         Level         Level         Level
              Subr.         Subr.         Subr.         Subr.         Subr.

                                          wind1   ----> rsqwts  ----> xmit *
                                          llbreez ----> box     ----> unidot *
                                                        interb  ----> xmit *
                                                                      barier  ----> unidot *
                                                                      fminf *
                                          adjust *
                                          smooth *
                                          divcel *
                                          divpr   ----> wndlpt *
                                          rtheta  ----> wndlpt *
                            out     ----> wrt *
                                          wrt2 *

                            water   ----> esat *
                            pgtstb *
                            heatfx *
                            airden *
                            elustr *
                            mixht   ----> mixdt *
                                          out    ----> wrt *
                                                       wrt2 *
                            avemix *
                            wstarr *
                            gride *
                            temp3d  ----> dedat *
                                          deltt *
                            avetmp *
                            outhr   ----> wrtr2d *
                                          wrti2d *
                                          wrtr1d *
                                          wrti1d *
                            pacave *
                            outpc   ----> wpcr2d *
                                          wpci2d *
                                          grday *
                                          out    ----> wrt *
                                                       wrt2 *

MAIN ---->    fin     ----> grday *
                            datetm  ----> date *
                                          time *
                                          etime *
                            julday *
                            deltt *
```

Appendix A
Subroutine/Function Calling Structure Table
(* indicated no routines called)

SUBROUTINE	CALLED BY	CALLS
adjust	diagno	*
airden	comp	*
allcap	readin	*
altonu	readin	*
avemix	comp	*
avetmp	comp	*
barier	interp,inter2,interb	unidot
bilinear	rdmm4	*
box	llbreez	unidot
cgamma	predpi	intp,dedat,deltt
cmpd2	missfc	*
comp	main	rdup,vertav,grday,rds,rdp,rdow,incr,dedat, facet,solar,water,pgtstb,heatfx,airden,elustr, mixht,wstarr,gridpr,out,outhr,deltt,prepdi, diagno,missfc,temp3d,avemix,pacave,outpc
date	datetm	*
datetm	setup,fin	date,time,etime
deblnk	readin	*
dedat	rdhd,rds,rdp,comp,cgamma, prepdi,temp3d	*
deltt	prepdi,cgamma,temp3d, readhd,comp,fin	*
diag2	comp	*
diagi	setup	terset
diagno	comp	windbc,xmit,topof2,minim,windpr,outfil, slope,wndpr2,fradj,fminf,progrd,inter2, interp,adjust,smooth,divcel,divpr,rtheta, rdmm4,wind1,llbreez
divcel	diagno,minim	*
divpr	diagno	wndlpt

Appendix A
Subroutine/Function Calling Structure Table
(* indicated no routines called)

SUBROUTINE	CALLED BY	CALLS
elustr	comp	*
elustr2	stheor	similt
esat	water	*
etime	datetm	*
facet	comp	intp
fillgeo	readge	*
fin	main	datetm,julday,deltt,grday
fminf	diagno,interp,inter2, interb	*
fradj	diagno	*
grday	comp,fin	*
gride	comp	*
heatfx	comp	*
incr	rdhd4	*
indecr	comp,rdmm4,readhd	*
inter2	diagno	xmit,barier,fminf
interb	llbreez	xmit,barier,fminf
interp	diagno	xmit,barier,fminf
intp	cgamma,facet	*
ireplac	missfc	*
julday	fin,rdup,readcf,rdhd4	*
llbreez	diagno	box,interb
microi	setup	*
minim	diagno	divcel,windbc
missfc	comp	cmpd2,ireplac,rreplac
mixdt	mixht	*
mixht	comp	mixdt,out
openfl	setup	*

Appendix A
Subroutine/Function Calling Structure Table
(* indicated no routines called)

SUBROUTINE	CALLED BY	CALLS
openot	setup	*
out	setcom,comp,readge, outpc1,mixht,outpc	wrt,wrt2
outfil	diagno	*
outhd	setup	wrtr1d,wrtr2d,wrti2d
outhr	comp	wrtr2d,wrti2d,wrtr1d,wrti1d
outpc	comp	wpcr2d,wpci2d,grday,out
outpc1	setup	wpcr2d,wpci2d,out
pacave	comp	*
pgtstb	comp	*
prepdi	comp	cgamma,vertav,xmit,deltt,dedat
progrd	diagno	xmit
qcksrt3	rdmm4	*
rdhd	readhd	dedat
rdhd4	readhd	julday,incr
rdhdu	readhd	*
rdmm4	readhd,diagno	julday,indecr,qcksrt3,bilinear
rdnwd	rdp	*
rdow	comp	*
rdp	readhd,comp	rdnwd,unpack,dedat
rds	readhd,comp	unpcks,dedat
rdup	comp	julday
rdwt	setup	*
readcf	setup	readin,julday
readge	setup	out,fillgeo
readhd	setup	rdhd,deltt,rds,rdhdu,rdp,rdhd4,rdmm4,indecr
readin	readcf	deblnk,allcap,altonu,setvar
rreplac	missfc	*

Appendix A
Subroutine/Function Calling Structure Table
(* indicated no routines called)

SUBROUTINE	CALLED BY	CALLS
rsqwts	wind1	xmit
rtheta	diagno	wndlpt
setcom	setup	out
setup	main	datetm,openfl,readcf,openot,readge,setcom, readhd,microi,diagi,outhd, outpc1,rdwt
setvar	readin	*
similt	elustr2, water2	*
slope	diagno	xmit,wndlpt
smooth	diagno	*
solar	comp	*
stheor	diagno	elustr2, water2
temp3d	comp	dedat,deltt
terset	diagi	*
time	datetm	*
topof2	diagno	*
under0	main	*
unidot	barier,barier2	*
unpack	rdp	*
unpcks	rds	*
vertav	comp,prepdi	*
water	comp	esat
water2	stheor	esat, similt
wind1	diagno	rsqwts
windbc	diagno,minim	*
windlpt	windpr,wndpr2,divpr, rtheta,slope	*
windpr	diagno	wndlpt
wndpr2	diagno	wndlpt

Appendix A
Subroutine/Function Calling Structure Table
(* indicated no routines called)

SUBROUTINE	CALLED BY	CALLS
wpci2d	outpc1,outpc	*
wpcr2d	outpc1,outpc	*
wrt	out	*
wrti2d	outhr,outhd	*
wrtr2d	outhd,outhr	*
wrt2	out	*
wrti1d	outhr	*
wrtr1d	outhd,outhr	*
wstarr	comp	*
xmit	prepdi,diagno,slope,progrd, interp,inter2,rsqwts,interb	*

APPENDIX B

Description of Each CALMET Subroutine and Function

ROUTINE NAME	TYPE	PURPOSE
ADJUST	Subr.	Adjusts surface U and V wind components for terrain effects.
AIRDEN	Subr.	Computes the density of air at surface meteorological stations using the station pressure and temperature.
ALLCAP	Subr.	Converts all lower case letters within a character string from a control file data record into upper case.
ALTONU	Subr.	Converts a character string from a control file data record into a real, integer, or logical variable. Computes the repetition factor for the variable.
AVEMIX	Subr.	Calculates the average mixing height (m) at each grid point based on an average of values at the grid point and grid points upwind.
AVETMP	Subr.	Calculates the average temperature (K) at each grid point based on an average of values at the grid point and grid points upwind, for each vertical level.
BARIER	Subr.	Determines which side of a barrier a point is on. Barriers are finite length line segments.
BILINEAR	Subr.	Performs bilinear interpolation among values obtained at the center of cells.
BOX	Subr.	Calculates whether a point is within a defined box.
CGAMMA	Subr.	Computes the time-interpolated average temperature lapse rate in the layer from the ground through a specified height.
CMPD2	Subr.	Computes the (distance)^2 from each station to the reference coordinates (XREF,YREF).
COMP	Subr.	Controls the computational phase of the CALMET run. Contains the basic time loop and calls all time-dependent computational routines.
DATE	Subr.	System routine supplying the current data (MM-DD-YY) into a Character*8 variable.

ROUTINE NAME	TYPE	PURPOSE
DATETM	Subr.	Gets the data and time from the system clock. Calls the system date and time routines.
DEDAT	Subr.	Convert a coded integer containing the year, Julian day, and hour (YYJJJHH) into three separate integer variables.
DEBLNK	Subr.	Removes all blank characters from a character string within a pair of delimiters in a control file data record.
DELTT	Subr.	Computes the difference (in hours) between two dates and integer times (time 2 - time 1).
DIAG2	Subr.	Initiates the wind field common blocks for overwater stations.
DIAGI	Subr.	Sets the default values for the diagnostic wind field parameters. Initiates the wind field common blocks.
DIAGNO	Subr.	Main routine for the diagnostic wind field module. Calls routines for the computation of kinematic effects of terrain, slope flows, terrain blocking effects, divergence minimization, objective analysis, and optional input of gridded prognostic wind field data. Produces 3-D fields of U, V, and W wind components.
DIVCEL	Subr.	Computes the three-dimensional divergence for a X-Y plane of grid cells using a central difference technique.
DIVPR	Subr.	Controls printing of "NZPRNT" layers of 3-D divergence fields.
ESAT	Function	Computes the saturation water vapor pressure using the method of Lowe (1977).
ELUSTR	Subr.	Computes the surface friction velocity and Monin-Obukhov length at grid points over land using an iterative technique.
ELUSTR2	Subr.	Computes the surface friction velocity and Monin-Obukhov length at surface stations over land using an iterative technique.
ETIME	Subr.	CPU time routine for SUN system.
FACET	Subr.	Calculate the temperature at the vertical cell faces at the upper air sounding stations.

ROUTINE NAME	TYPE	PURPOSE
FILLGEO	Subr.	Determines geophysical parameters from gridded land use data and a table relating the parameter values to land use. Reads a gridded geophysical parameter field directly from the GEO.DAT file if the gridded input option is selected.
FIN	Subr.	Main routine for the termination phase of the CALMET run. Computes run time, writes termination messages.
FMINF	Subr.	Determines the minimum value among "NF" consecutive elements of an array and returns both the value and its array index.
FRADJ	Subr.	Determines terrain blocking effects. Computes the local Froude number at each grid point using 3-D arrays of U and V wind components. If the Froude number exceeds a specified critical value, and the wind is blowing toward an obstacle, adjusts the wind components.
GRDAY	Subr.	Computes the Gregorian date (month, day) from the Julian day and year.
GRIDE	Subr.	Computes a gridded precipitation rate at each grid point using a nearest observational station technique.
HEATFX	Subr.	Computes the sensible heat flux at each grid point over land using the energy balance method.
INCR	Subr.	Increment the time and date by a specified number of hours.
INDECR	Subr.	Increment or decrement a date/time by a specified number of hours.
INTER2	Subr.	Incorporates observational wind data into gridded Step 1 diagnostic wind fields using a $1/R^2$ interpolation weighting technique and radius of influence parameters.
INTERB	Subr.	Interpolates the observed data in the lake breeze region to the CALMET grid.
INTERP	Subr.	Incorporates observational wind data into gridded fields of interpolated prognostic model winds using a $1/R^2$ interpolation weighting technique and radius of influence parameters. If prognostic winds not used, performs interpolation only.

ROUTINE NAME	TYPE	PURPOSE
INTP	Subr.	Performs a linear interpolation of a variable to a specified height using arrays of height and parameter values.
IREPLAC	Subr.	Replaces the missing value of an INTEGER variable with the value from the closest station with valid data. If all values are missing, sets variable equal to the default value (IDEFLT).
JULDAY	Subr.	Computes the Julian day number from the Gregorian date (month, day).
LLBREEZ	Subr.	Sets up the lake breeze region of influence.
MICROI	Subr.	Performs setup computations for the boundary layer model. Initializes certain heat flux constants and mixing height variables.
MINIM	Subr.	Executes an iterative scheme to reduce three dimensional divergence to within a specified limit subject to a cap on the number of iterations.
MISSFC	Subr.	Fills in missing values of certain surface met. variables using data from the nearest station with non-missing data. Met. variables checked in this routine are: ceiling height (ICEIL), cloud cover (ICC), air temperature (TEMPK), relative humidity (IRH), and surface pressure (PRES).
MIXDT	Subr.	Computes the potential temperature lapse rate in a layer "DZZI" meters deep above the previous hour's convective mixing height.
MIXHT	Subr.	Calculates the convective and mechanical mixing height at each grid point above land.
OPENFL	Subr.	Opens the input control file and output list file.
OPENOT	Subr.	Opens all input/output files (other than the control file and list file), based on the values in the control file inputs.
OUT	Subr.	Prints a gridded 2-D field of real or integer numbers to a specified number of digits. Internally computes a scaling factor for printing the field based on the maximum value within the grid.

ROUTINE NAME	TYPE	PURPOSE
OUTFIL	Subr.	Prints 3-D fields of U and V wind components using F7.2 format and W wind components using E8.1 format.
OUTHD	Subr.	Writes the header records of the CALMET meteorological data file.
OUTHR	Subr.	Outputs hourly gridded wind fields to the unformatted output file (CALMET.DAT).
OUTPC	Subr.	Writes the data records in MESOPAC II format.
OUTPC1	Subr.	Writes the header records in MESOPAC II format.
PACAVE	Subr.	Calculates the vertically-averaged winds in two layers.
PGTSTB	Subr.	Computes PGT stability class at grid point over land.
PREPDI	Subr.	Fills data arrays with observed wind data for the wind field module. If the preprocessed wind data option is used, reads U and V components and/or temperature data directly from the input file (DIAG.DAT), otherwise, performs time interpolation of upper air sounding data and converts surface wind components to U and V components.
PROGRD	Subr.	Reads and interpolates gridded fields of prognostic model wind fields to the grid system used by the diagnostic wind field model.
QCKSRT3	Subr.	Sorts three arrays into ascending numerical order using the quicksort algorithm.
RDHD	Subr.	Reads the header records from the unformatted version of the surface meteorological data file (SURF.DAT).
RDHD4	Subr.	Reads the IWAQM-formatted MM4-FDDA file header records.
RDHDU	Subr.	Reads the two header records from an upper air data file.
RDMM4	Subr.	Reads and interpolates the MM4-FDDA prognostic winds to the diagnostic model grid.

ROUTINE NAME	TYPE	PURPOSE
RDOW	Subr.	Reads a data record from an overwater data file. Date/hour of data in the current array is compared with model date/hour to determine if it is time to read the next record.
RDP	Subr.	Reads a data record from a precipitation data file. If data are packed, RDP unpacks the data before returning to the calling routine.
RDS	Subr.	Reads a data record from the surface meteorological data file. If data are packed, RDS unpacks data before returning to calling routine.
RDUP	Subr.	Reads a sounding from the upper air data file. Reads a set of data including wind speed, wind direction, pressure, height, and temperature. Converts wind speed and wind direction to U and V components.
RDWT	Subr.	Reads the weighting factors used for station observations vs. the MM4-FDDA data used as observations or the Step 1 field.
READCF	Subr.	Controls the reading of the control file. Calls subroutine READIN for each input group.
READGE	Subr.	Reads or calls other routines to read data from the geophysical data file (GEO.DAT). Prints the data back to the output list file (CALMET.LST).
READHD	Subr.	Controls the reading of the header records from the meteorological data files (surface and upper air data). Positions pointers at correct record for starting date and time. Performs QA checks to ensure consistency of file data with control file inputs.
READIN	Subr.	Reads one input group of a free formatted control file data base.
RDNWD	Subr.	Reads "N" words from an unformatted data file.
RREPLAC	Subr.	Replaces the missing value of a REAL variable with the value from the closest station with valid data. If all values are missing, sets variable equal to the default value (RDEFLT).

ROUTINE NAME	TYPE	PURPOSE
RSQWTS	Subr.	Computes inverse distance squared weights for all the surface and upper air locations at a specified grid cell.
RTHETA	Subr.	Converts gridded 3-D arrays of U and V wind components to wind speed and wind direction. Controls printing of the wind speed and wind direction fields.
SETCOM	Subr.	Computes miscellaneous common block variables in the setup phase of the run.
SETUP	Subr.	Controls the setup phase of the CALMET model. Calls all initialization and one-time setup routines.
SETVAR	Subr.	Fills a variable or array with the value read from a control file data record.
SIMILT	Subr.	Performs surface-based wind profile adjustment using similarity theory.
SLOPE	Subr.	Adjusts the surface wind components for slope flow effects.
SMOOTH	Subr.	Applies a smoother to 3-D gridded fields of U and V wind components.
SOLAR	Subr.	Computes the sine of the solar elevation angle for the midpoint of every hour of the day at surface meteorological stations.
STHEOR	Subr.	Determines whether station is on land or water and calls similarity theory subroutines.
TEMP3D	Subr.	Computes a 3-D temperature field, either treating water and land separately or making no distinction.
TERSET	Subr.	Determines the maximum terrain height within a given radius of a grid point for each point in a gridded field.
TIME	Subr.	System routine supplying the current clock time (HH:MM:SS.hh) into a Character*11 variable .
TOPOF2	Subr.	Computes a 3-D array of terrain-induced vertical velocities. Determines kinematic effects, exponential vertical decay factor, and transforms W components to terrain-following coordinates.

ROUTINE NAME	TYPE	PURPOSE
UNDERO	Subr.	A Lahey PC FORTRAN library routine used to set underflows to zero.
UNIDOT	Function	Computes the dot product of a 3-element unit vector A with a 3-element unit vector B.
UNPACK	Subr.	Unpacks an array of packed data using the "zero-removal" packing method.
UNPCKS	Subr.	Unpacks an array of surface meteorological data using an integer packing method.
VERTAV	Subr.	Vertically averages U and V wind components through a specified vertical depth.
WATER	Subr.	Computes boundary layer parameters at grid points over water using a profile technique. Also computes PGT stability class based on the Monin-Obukhov length.
WATER2	Subr.	Computes boundary layer parameters at surface stations over water using a profile technique.
WIND1	Subr.	Creates spatially-varying first-guess wind field by using a $1/R^2$ interpolation weighting technique for both the upper air and surface observations.
WINDBC	Subr.	Sets the boundary conditions for a single level of U and V wind fields using no inflow - no outflow boundary conditions.
WINDLPT	Subr.	Scales a 2-D array of real numbers by an internally-computed factor for printing purposes. Prints the scaled 2-D array along with the scaling factor.
WINDPR	Subr.	Controls the printing of "NZ" layers of 2-D fields of U, V, and W wind components.
WNDPR2	Subr.	Prints one layer of U and V wind components.
WPCI2D	Subr.	Writes "NX*NY" words of a 2-D integer array to an unformatted file in MESOPAC II format.
WPCR2D	Subr.	Writes "NX*NY" words of a 2-D real array to an unformatted file in MESOPAC II format.

ROUTINE NAME	TYPE	PURPOSE
WRT	Subr.	Writes one Y row of formatted gridded data (in conjunction with subroutine OUT).
WRT2	Subr.	Writes a line labeling the X coordinates of a row of gridded data (in conjunction with subroutines OUT and OUTFX).
WRTI1D	Subr.	Writes "NWORDS" of a 1-D integer array to an unformatted file along with a C*8 label and integer date/hour record header.
WRTI2D	Subr.	Writes "NX*NY" words of a 2-D integer array to an unformatted file along with a C*8 label and integer date/hour record header.
WRTR1D	Subr.	Writes "NWORDS" of a 1-D real array to an unformatted file along with a C*8 label and integer date/hour record header.
WRTR2D	Subr.	Writes "NX*NY" words of a 2-D real array to an unformatted file along with a C*8 label and integer date/hour record header.
WSTARR	Subr.	Computes the convective velocity scale at each grid point over land.
XMIT	Subr.	Initializes "N" values of 1-D array B with a constant or set all values of array B equal to corresponding elements of array A.

APPENDIX C

Equations Used in Lambert Conformal Conversions

I:\calmetwp\feb95\mfappc.wp

The following equations are based on Pearson (1990) and can be used before running CALMET to convert meteorological station locations from latitude/longitude to *x*/*y* coordinates when using the two-standard parallel Lambert conformal projection in CALMET. The equations are incorporated within CALMET to adjust winds from true north (south) to map coordinates and to convert MM4 grid points to the Lambert conformal map for use in CALMET, based on the values of RLAT0, RLON0, XLAT1, and XLAT2 entered by the user. To use CALMET and these equations with a Lambert conformal domain in the Southern hemisphere, enter all latitudes (standard parallels, origin, and stations) as negative numbers. Regardless of the hemisphere in which the domain is located, the resulting *x/y* coordinate system has *y* increasing from south to north and the CALMET origin coordinates must be specified at the southwest corner of the domain. This holds true also if UTM coordinates are used in place of a Lambert conformal projection. The order of the standard parallels XLAT1 and XLAT2 does not matter but it is conventional to have the latitude closest to the equator be XLAT1. The reference coordinates input to CALMET should be identical to those used to derive the *x/y* coordinates of observation sites. All longitudes are entered as positive in the Western hemisphere and negative in the Eastern hemisphere, with the exception of the MM4.DAT input file, in which the opposite convention is used. Lambert conformal projections are best in mid-latitudes (~30-60° latitude). It is not recommended that a Lambert conformal projection be used in a domain near the equator ($\leq$ 30° latitude) or in polar regions (> 60° latitude).

Equations C-1 and C-2 give the *x* and *y* coordinate definitions for the Lambert conformal projection, in kilometers:

$$x = \rho \sin\theta \tag{C-1}$$

$$y = \rho_{ORI} - \rho \cos\theta \tag{C-2}$$

where θ is the polar angle (one of the two coordinates used in describing the projection) and is defined by Equation C-3:

$$\theta = (\lambda_o - \lambda)\sin\phi_o \tag{C-3}$$

where λ is the longitude (positive in the Western hemisphere, negative in the Eastern hemisphere) and λ_o is the reference longitude (RLON0). The $\sin(\phi_o)$ is known as the cone constant and relates longitude on Earth to its representation in the mapping system. It is a measure of the rate of change in the polar angle as longitude changes. ϕ_o is the latitude where the cone is tangent to the sphere (i.e., the standard latitude) in a one-standard parallel Lambert conformal projection, and is an artifact of the mathematical derivation of the two-standard parallel case. In the two-standard parallel case its definition is given in Equation C-4:

$$\sin\phi_o = \ln\left(\frac{\cos\phi_1}{\cos\phi_2}\right) / \ln\left[\frac{\tan\left(\frac{90-\phi_1}{2}\right)}{\tan\left(\frac{90-\phi_2}{2}\right)}\right] \qquad \text{(C-4)}$$

where ϕ_1 and ϕ_2 are the standard reference latitudes (XLAT1 and XLAT2).

Equation C-5 defines the polar radius to the given (positive) latitude ϕ, where the polar radius is the second coordinate used to describe the map projection:

$$\rho = \psi\left[\tan\left(\frac{90-\phi}{2}\right)\right]^{\sin\phi_o} \qquad \text{(C-5)}$$

Equation C-6 gives the polar radius to the origin latitude (ϕ_{ORI}), i.e., the latitude along λ_o at which y equals zero (RLAT0):

$$\rho_{ORI} = \psi\left[\tan\left(\frac{90-\phi_{ORI}}{2}\right)\right]^{\sin\phi_o} \qquad \text{(C-6)}$$

Note that the MM4 domain to which CALMET defaults uses an origin latitude (RLAT0) of 40°, standard reference latitudes ϕ_1, ϕ_2 (i.e., XLAT1, XLAT2) of 30° and 60°, and a reference longitude (λ_o) of 90° W.

Psi (ψ) is an auxiliary function that is introduced to simplify the derivation from the one standard parallel case to the two parallel case and is defined by Equation C-7:

$$\psi = \frac{a\ \cos\phi_1/\sin\phi_o}{\left[\tan\left(\frac{90-\phi_1}{2}\right)\right]^{\sin\phi_o}} \qquad \text{(C-7)}$$

where *a* equals 6370 km is Earth's radius.

APPENDIX D

The Universal Transverse Mercator (UTM) Grid

U.S. Department of the Interior
U.S. Geological Survey
Earth Science
Information Center (ESIC)

Factsheet

The Universal Transverse Mercator (UTM) Grid

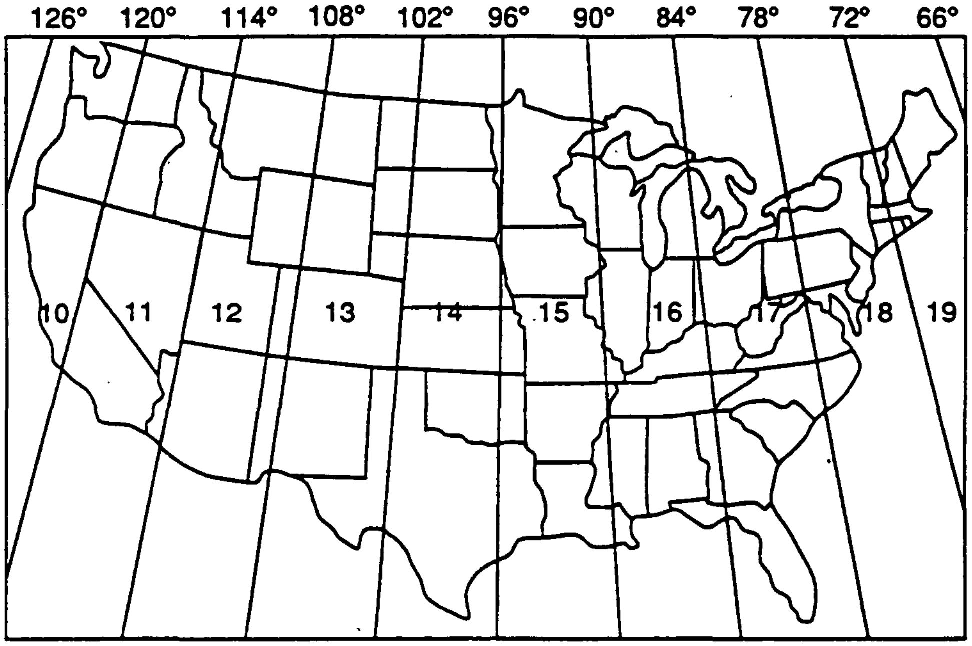

Figure 1. The Universal Transverse Mercator grid that covers the conterminous 48 United States comprises 10 zones—from zone 10 on the west coast through zone 19 in New England.

Map projections

The most convenient way to identify points on the curved surface of the Earth is with a system of reference lines called parallels of latitude and meridians of longitude. On some maps the meridians and parallels appear as straight lines. On most modern maps, however, the meridians and parallels may appear as curved lines. These differences are due to the mathematical treatment required to portray a curved surface on a flat surface so that important properties of the map (such as distance and areal accuracy) are shown with minimum distortion. The system used to portray a portion of the round Earth on a flat surface is called a map projection.

Grids

To simplify the use of maps, and to avoid the inconvenience of pinpointing locations on curved reference lines, a rectangular grid consisting of two sets of straight, parallel lines, uniformly spaced, each set perpendicular to the other, is superimposed on the map. This grid is designed so that any point on the map can be designated by its latitude and longitude or by its grid coordinates, and a reference in one system can be converted into a reference in another system. Such grids are usually identified by the name of the particular projection for which they are designed.

The Universal Transverse Mercator grid

The Defense Mapping Agency adopted a special grid for military use throughout the world called the Universal Transverse Mercator (UTM) grid. In this grid, the world is divided into 60 north-south zones, each covering a strip 6° wide in longitude. These zones are numbered consecutively beginning with zone 1, between 180° and 174° west longitude, and progressing eastward to zone 60, between 174° and 180° east longitude. Thus, the conterminous 48 States are covered by 10 zones, from zone 10 on the west coast through zone 19 in New England (fig. 1). In each zone, coordinates are measured north and east in meters. (One meter equals 39.37 inches, or slightly more than 1 yard.) The northing values are measured continuously from zero at the Equator, in a northerly direction. Southerly values are similarly measured from the Equator, south. A central meridian through the middle of each 6° zone is assigned an easting value of 500,000 meters. Grid values to the west of this central meridian are less than 500,000; to the east, more than 500,000.

Determining a UTM grid value for a map point

The UTM grid is shown on all quadrangle maps prepared by the U.S. Geological Survey. On 7.5-minute quadrangle maps (1:24,000 scale) and 15-minute quadrangle maps (1:50,000, 1:62,500 and standard-edition 1:63,360 scales) the UTM grid lines are indicated at intervals of 1,000 meters, either by blue ticks in the margins of the map or with full grid lines. The 1,000-meter value of the ticks is shown for every tick or grid line. In addition, the actual meter value is shown for ticks nearest the southeast and northwest corners of the map. Provisional maps at 1:63,360 scale show full UTM grids at 5,000-meter intervals.

To use the UTM grid, a transparent grid overlay can be used that subdivides the grid, or lines can be drawn on the map connecting corresponding ticks on opposite edges. The distances can be measured in meters at the map scale between any map point and the nearest grid lines to the south and west. The northing of the point is the value of the nearest grid line south of it plus its distance north of that line; its easting is the value of the nearest grid line west of it plus its distance east of that line (see fig. 2).

On maps at 1:100,000 and 1:250,000 scale, a full UTM grid is shown at intervals of 10,000 meters and is numbered and used in the same way.

Information

For further information contact any Earth Science Information Center (ESIC) or call 1-800-USA-MAPS.

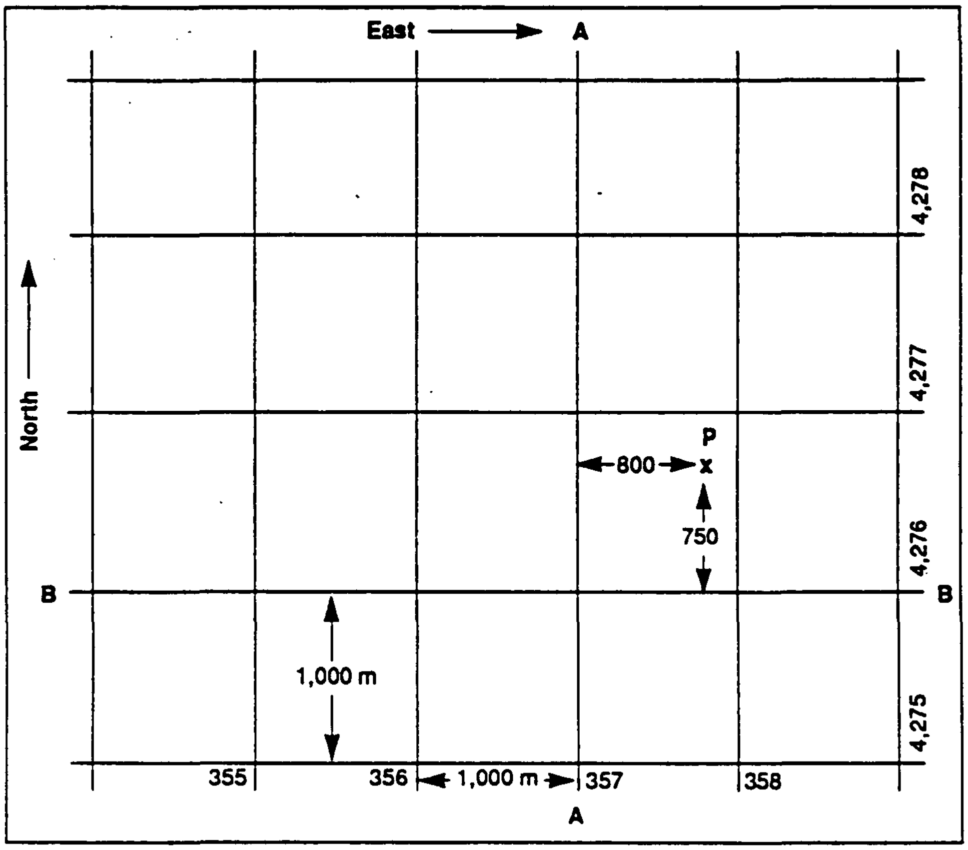

Figure 2. The grid value of line A-A is 357,000 meters east. The grid value of line B-B is 4,276,000 meters north. Point P is 800 meters east and 750 meters north of the grid lines; therefore, the grid coordinates of point P are north 4,276,750 and east 357,800.

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16. ABSTRACT

This report describes the CALMET meteorological model and associated meteorological data processing programs. The CALMET model described in this report includes improvements to the model such as 1) a modification to make it more suitable for regional applications such as the use of a spatially variable initial guess field, 2) an option for using hourly gridded wind fields from the Penn State/NCAR Mesoscale Model with four dimensional data assimilation (MM4-FDDA) as a supplement to observational data, 3) the ability to compute Lambert conformal map factors and, 4) a modified mixing height scheme.

17. KEY WORDS AND DOCUMENT ANALYSIS

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