United States Environmental Protection Agency

Atmospheric Research and Exposure Assessment Laboratory
Research Triangle Park, NC 27711

EPA/600/8-88/004
March, 1989

Research and Development

EPA

Project Report

User's Guide to the CTDM Meteorological Preprocessor Program

United States
Environmental Protection
Agency

Research and Development

Atmospheric Sciences
Research Laboratory
Research Triangle Park NC 27711

December 1987

EPA/600/8-88/004

EPA

PROJECT REPORT

USER'S GUIDE TO THE CTDM

METEOROLOGICAL PREPROCESSOR PROGRAM

United States
Environmental Protection
Agency

Research and Development

Atmospheric Sciences
Research Laboratory
Research Triangle Park NC 27711

December 1987

EPA

PROJECT REPORT

USER'S GUIDE TO THE CTDM

METEOROLOGICAL PREPROCESSOR PROGRAM

USER'S GUIDE TO THE CTDM METEOROLOGICAL PREPROCESSOR (METPRO) PROGRAM

by
Robert J. Paine

ERT Inc.
696 Virginia Road, Concord, Massachusetts 01742

Contract No. 68-02-3421

Project Officer

Peter L. Finkelstein
Meteorology Division
Atmospheric Sciences Research Laboratory
Office of Research and Development
U.S. Environmental Protection Agency
Research Triangle Park, NC 27711

ATMOSPHERIC SCIENCES RESEARCH LABORATORY
OFFICE OF RESEARCH AND DEVELOPMENT
U.S. ENVIRONMENTAL PROTECTION AGENCY
RESEARCH TRIANGLE PARK, NORTH CAROLINA 27711

DISCLAIMER

The information in this document has been funded by the United States Environmental Protection Agency under Contract No. 68-02-3421 to ERT, Inc. It has been subjected to the Agency's peer and administrative review, and it has been approved for publication as an EPA document. Mention of trade names or commercial products does not constitute endorsement or recommendation for use.

ABSTRACT

This user guide presents a review of the structure of the atmospheric boundary layer and its implications for the design of CTDM and its meteorological preprocessor, METPRO. The CTDM meteorological preprocessor calculates required meteorological variables that are derived from conventionally available data. These required variables include the Monin-Obukhov length, the surface friction velocity, the surface roughness length, and the mixed layer height. The CTDM input data file "SURFACE" contains these values as delivered by the meteorological preprocessor.

CTDM uses the mixed layer height information in unstable conditions to determine whether a plume is within or above the mixed layer. If any modeled plume is within an unstable mixed layer, CTDM currently does not predict ground-level concentrations for that hour. In stable conditions, CTDM can supplement meteorological observations with calculated profiles in the surface layer only. The surface layer height information supplied to CTDM from METPRO determines whether the plume is within this layer. Therefore, the mixed layer height supplied by METPRO is a critical input variable to CTDM for both stable and unstable conditions.

The remaining variables supplied by METPRO, the Monin-Obukhov length, surface friction velocity, and surface roughness length, can be used to parameterize profiles of wind speed, wind direction, and turbulence within the convective mixed and surface layers and the stable surface layer. These profiles are used by CTDM if plume height wind and turbulence cannot be computed by interpolation from observed data.

The computation of these boundary layer variables by METPRO requires knowledge of site characteristics such as surface moisture (Bowen ratio), albedo, and roughness. These variables, which are used in energy balance equations in order to determine the surface heat flux, may be specified in detail, both as a function of wind direction and of month of the year.

CONTENTS

FIGURES

TABLES

Number		Page

LIST OF SYMBOLS AND ABBREVIATIONS

SYMBOL

a,b:	constants used to estimate the surface albedo as a function of solar elevation angle
A:	proportionality constant used in convective mixing height calculation
b_1,b_2:	empirical coefficients used to estimate total incoming solar radiation as a function of cloud cover
B:	constant used in computation of mechanical mixing height during the daytime
Br:	Bowen ratio
c_1,c_2,c_3:	empirical coefficients used to estimate net radiation as a function of temperature and cloud cover
c_p:	specific heat of dry air, J/(kg-deg)
C_{DN}:	momentum transfer drag coefficient in neutral conditions
f:	Coriolis parameter = 1.458E-04•sin(latitude), sec^{-1}
g:	acceleration due to gravity = 9.8 m/sec^2
G:	soil heat flux, $watts/m^2$
h:	height of the stable surface layer (sometimes used interchangeably with z_i, the height of the convective mixed layer), m
H:	surface heat flux, $watts/m^2$
I_n:	net long-wave radiation from the surface, $watts/m^2$
k:	von Karman constant
K:	degrees Kelvin
L:	Monin-Obukhov length, m
LE:	latent heat flux, $watts/m^2$

m:	meters
N:	total cloud cover, tenths
q_s:	saturation specific humidity
r:	surface albedo
r':	surface albedo for the sun directly overhead
R:	total incoming solar radiation, watts/m^2
Ri:	Richardson number
R_n:	net radiation, watts/m^2
R_o:	total incoming solar radiation for clear skies, watts/m^2
s:	rate of change of saturation specific humidity with temperature
T:	air temperature, °K
T_o:	surface air temperature, °K
u:	wind speed, m/sec
u_o:	parameter used in the formulation of u_* for stable conditions
u_*:	friction velocity, m/sec
W:	watts
z:	measurement height, m
z_i:	height of the convective mixed layer, m
z_o:	surface roughness length, m
α, β':	empirical constants related to the Bowen ratio for estimating sensible heat flux
β_m:	empirical constant used in computing θ_* in stable conditions
γ:	c_p/λ
λ:	latent heat of water vaporization, J/kg
ν:	solar elevation angle, deg

ϕ_m: height scale parameter used in ψ_m formulation

ϕ_h: height scale parameter used in ψ_h formulation

ψ_m: stability correction for wind profile formulation in the surface layer

ψ_h: stability correction for temperature gradient formulation in the surface layer

ρ: air density, kg/m^3

σ: measure of the entrainment rate by a growing convectively mixed layer

σ_{SB}: Stefan-Boltzmann constant, 5.67E-08 watts/(m^2-deg^4)

θ: potential temperature, °K

θ_o: surface potential temperature, °K

θ_c: constant potential temperature in the middle of the convectively mixed layer

$\Delta\theta_h$: step change of potential temperature at the mixed layer height

θ_s: potential temperature profile measured by morning balloon sounding (1200 GMT in the United States)

θ_*: temperature scale value used in parameterizing the vertical temperature gradient in the surface layer

θ_{*1}, θ_{*2}: estimates of θ_* used in θ_* calculation for stable conditions

LIST OF ABBREVIATIONS

AFCRL Air Force Cambridge Research Laboratories

CBL Convective Boundary Layer

CTDM Complex Terrain Dispersion Model

EPA Environmental Protection Agency

GMT Greenwich Mean Time

METPRO Meteorological Preprocessor (used for CTDM)

NCDC National Climatic Data Center

NOAA	National Oceanic and Atmospheric Administration
NWS	National Weather Service
READ62	Preprocessor program that reads TD-6201 upper air data format
USDA	United States Department of Agriculture

SECTION 1

INTRODUCTION

1.1 The Boundary Layer and Implications for CTDM

The requirement for use of meteorological information in CTDM is based upon the current understanding of the atmospheric boundary layer. A discussion of the design of the meteorological preprocessor, METPRO, and its linkage with CTDM is accompanied here by a summary of the features of the boundary layer and how they relate to plume dispersion calculations. An excellent overall discussion of the atmospheric boundary layer is given by Randerson (1984); a short description is provided below.

The atmospheric boundary layer lies between the earth's surface and the geostrophic free atmosphere, in which surface effects upon the flow are negligible. The boundary layer can be considered to contain two distinct layers: the surface layer near the ground, capped by a mixed layer. An example of the temporal evaluation of these layers as measured in the Wangara, Australia experiment and modeled by Yamada and Mellor (1975) is shown in Figure 1. In this figure, the surface layer is especially shallow during unstable conditions (generally on the order of one-tenth the depth of the entire boundary layer).

The nocturnal "mixed" layer features low turbulence levels and, often, laminar flow, so the term "mixed" is misleading. It is used here to mean the layer above the surface layer, a usage consistent with the daytime case. The surface layer is dominated by the frictional force and horizontal shear stress near the ground. The horizontal stress is caused by the drag of friction-retarded air molecules on faster-moving air molecules at higher levels (see Figure 2). The depth of the surface layer, h, is defined to be the height above the ground through which the magnitude of the shear stress is approximately constant (varies by no more than about 10%). Other properties of the surface layer that are useful for modeling purposes are

- vertical fluxes of heat and momentum that are nearly constant with height, and
- steady-state and horizontally homogeneous temperature and velocity fields.

These assumptions allow the vertical structure of the surface layer to be parameterized by similarity theory, developed for this purpose by Monin and Obukhov (1954).

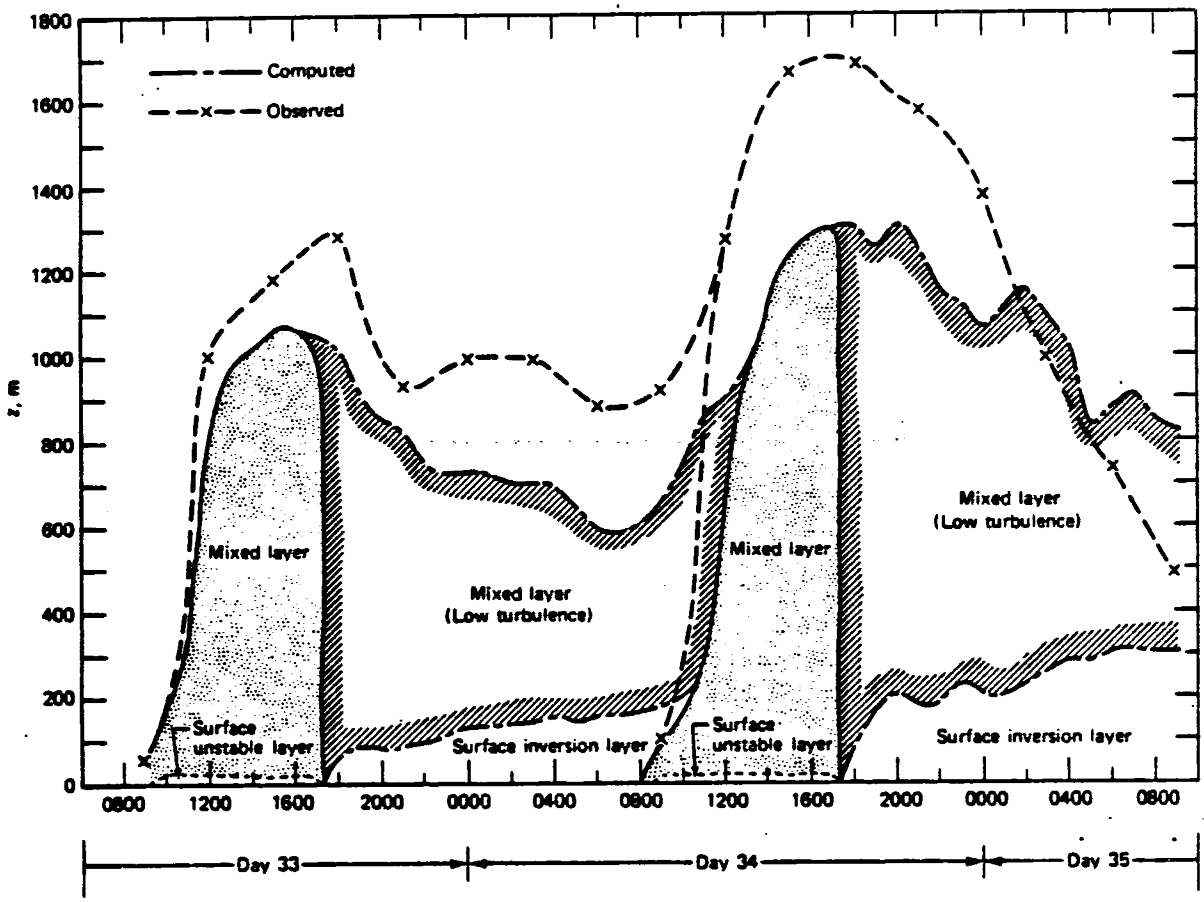


Figure 1. Diurnal evolution of the atmospheric boundary layer based upon Wangara data and output from a model developed by Yamada and Mellor (1975).

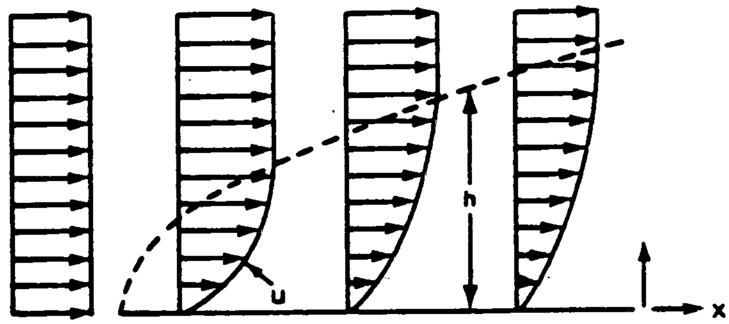


Figure 2. Development of a boundary layer in a fluid as it flows over a smooth fixed plate. The arrows represent flow vectors; the dashed sloping line separates freely flowing fluid from that affected by the plate; h is the depth of the boundary layer; and the vertically curved solid lines are speed (u) profiles (from Randerson 1984).

Similarity theory assumes that the vertical fluxes of heat, momentum, and moisture are approximately constant throughout the surface layer. The resulting turbulence of the flow within the surface layer is solely determined by the mean temperature, T, the friction velocity, u_* (derived from the vertical momentum flux), and the sensible heat flux, H. These parameters are combined into a length scale referred to as the Monin-Obukhov length, L:

$$L = \frac{-\rho c_p u_*^3 \bar{T}}{kgH} , \qquad (1)$$

where ρ is the air density, c_p is the specific heat, and k is the von Karman constant. This length scale is composed of quantities that are approximately constant throughout the surface layer, and is an important length scale governing diffusion and profiles of wind, temperature, and turbulence in the surface layer. As such, it is a useful substitute for the discrete stability class value used by air quality models developed in the past.

During unstable conditions, the height of the mixed layer, driven by convection, can be defined as the layer through which the potential temperature is less than that of the heated layer at the surface, from which convective 'thermals" or updrafts originate. The updrafts lose their buoyancy when their potential temperature becomes colder than that of the surrounding air of the top of the mixed layer (z_i). As shown in Figure 1, the daytime mixed layer can grow rapidly in response to a steadily increasing surface heat flux. During the afternoon, z_i reaches a maximum and remains relatively constant as the surface heat flux attains its peak value.

Near sunset, an abrupt transformation of the atmospheric boundary layer occurs as the heat flux throughout the entire layer turns negative rapidly. The surface layer becomes stably stratified while the mixed layer above remains relatively unstable, at least initially. Another depiction of the structure of the stable boundary layer is shown in Figure 3 (Malcher and Kraus, 1983; Thorpe and Guymer, 1977). In this model of the boundary layer, the nocturnal case features a "mixed" layer above the surface layer with supergeostrophic wind speeds - the well-known low-level nocturnal jet phenomenon. This jet develops when the mixed layer becomes decoupled from the surface layer near sunset and surface friction is then not effective up to as great a height as during the daytime. The balance of forces on the stable mixed layer is then disturbed, and the wind can accelerate because the pressure force now has a component in the direction of the wind (which was directed toward lower pressure because of the friction force during the daytime). As a result, supergeostrophic wind speeds can occur above the nocturnal surface layer in the low-turbulence, laminar flow of the mixed layer. Of course, large-scale mechanisms such as the influence of low pressure areas and warm or cold fronts can dominate and prevent the low-level

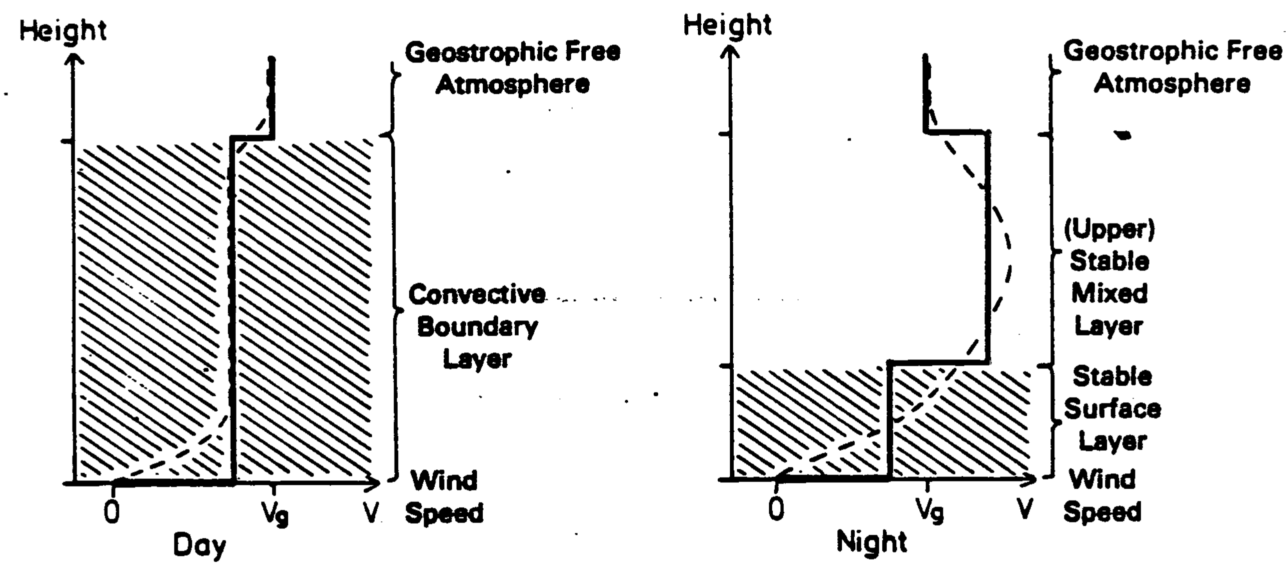


Figure 3. Idealized model of the atmospheric boundary layer, with shaded areas representing turbulent layers. The heavy solid lines represent ideal wind profiles and the broken lines represent realistic profiles (V_g is the geostrophic wind speed). (Figure after Thorpe and Guymer 1977, and Malcher and Kraus 1983.)

jet from appearing. In general, it is difficult to predict with certainty the onset and strength of the nocturnal jet.

The predictability of the structure of the low-turbulence nocturnal mixed layer is further complicated by the occurrence of momentum burst phenomena (Schubert, 1977) during conditions that favor the onset of the nocturnal jet. A useful parameter for determining the likelihood of the breakdown of the laminar flow of the nocturnal mixed layer is the Richardson number:

$$Ri = \frac{(g/\theta)(d\theta/dz)}{(du/dz)^2} \tag{2}$$

where

$d\theta/dz$ is the vertical potential temperature gradient and
du/dz is the wind speed shear in the vertical.

Large values of Ri (>1) are associated with stable conditions, while low values (<0.15) are present when mechanical turbulence due to wind shear overcomes the resistance to turbulent motion presented by a thermally stable atmosphere. A review of investigations conducted by Randerson (1984) into the critical value of Ri for the breakdown of laminar flow into turbulent motion yields a theoretical value of 0.25. Observations in wind tunnels and the atmosphere show that the critical value varies, with turbulence being certain if $Ri < 0.15$ and absent for $Ri > 0.5$.

During low-level jet periods, the laminar flow in the stable mixed layer can break down if the speed shear between the turbulent surface layer and laminar mixed layer aloft results in a Richardson number favoring the breakdown. The momentum in the mixed layer is then transported to the surface in a "burst," resulting in a temporary absence of the low-level jet. The Richardson number then can become large again, perhaps allowing the laminar flow in the mixed layer to become re-established. The low-level jet disappears in the morning when convective mixing transports momentum away from the jet and smooths out the vertical momentum distribution.

It is evident from the summary presented above that while the nocturnal surface layer, like the daytime surface layer, is reasonably well-behaved, the nocturnal mixed layer is highly unpredictable, even in flat terrain (Hanna et al., 1986). Therefore, CTDM relies heavily upon direct measurements of wind, temperature, and turbulence in the nocturnal mixed layer. The role of the meteorological preprocessor, METPRO, is two-fold:

- deliver to CTDM observed and/or predicted values of the nocturnal surface layer length, h, and the daytime mixed layer height, z_i;

- compute values of u_*, L, and the surface roughness length,

z_o, so that CTDM can supplement direct measurements in the surface layer with computed profiles of wind, temperature, and turbulence. In addition, these variables, along with z_i, can be used as input to a convective model for complex terrain that may eventually be incorporated into CTDM. Throughout the rest of this document, the term "mixed layer height" will generally refer to the height of the <u>convective mixed layer</u> or the height of the <u>stable surface layer</u>.

While direct observations of mixed (or surface) layer heights are preferred over predicted values, the availability of calculated mixing heights from METPRO makes CTDM much more flexible in its input data requirements. Although the prediction of mixing heights is far from an exact science, establishing an observed value from acoustic sounder or radiosonde measurements is associated with considerable uncertainty (Hanna et al., 1985, 1986). In general, the correlation of predicted and observed mixing heights on an event-by-event basis is relatively poor even with state-of-the-art techniques such as those employed in METPRO (Hanna et al., 1986). Fortunately, CTDM is relatively insensitive to errors in the stable surface layer height if wind, temperature, and turbulence data of sufficient resolution and range in the vertical are available.

The behavior of the convective boundary layer can be modeled with such variables as L, u^*, z_o, z_i and w_*, the convective velocity scale, which can be computed from L, u_*, and z_i. Therefore, CTDM in its current form does not make full use of the information provided to it by METPRO.

The daytime mixed layer height and nocturnal surface layer height are critical variables supplied by the CTDM meteorological preprocessor. Plumes within an unstable surface mixed layer cannot presently be modeled by CTDM. (CTDM is not designed to handle plume behavior near terrain in unstable conditions.) Therefore, CTDM does not attempt to predict concentrations for hours with at least one plume within an unstable mixed layer (note, however, that near-neutral conditions on the stable side are modeled). Plumes in the stable layer above a surface-based unstable layer are modeled by CTDM, so the estimate of the convective mixing height is very important. The nocturnal surface layer height divides a reasonably well-behaved stable layer (below) from a highly unpredictable one (above). This height is generally on the order of 50 meters or less except for windy conditions, so elevated releases are not generally sensitive to errors in the nocturnal surface layer height.

1.2 Summary of METPRO Operation

METPRO can accept input meteorological data from several sources (rawinsondes, National Weather Service data, on-site measurements) and produce an output file, "SURFACE", which contains hourly values of mixed layer height, friction velocity, Monin-Obukhov length, and surface roughness length. See Figure 4 for a flow chart of the various components of the meteorological preprocessor. Direct

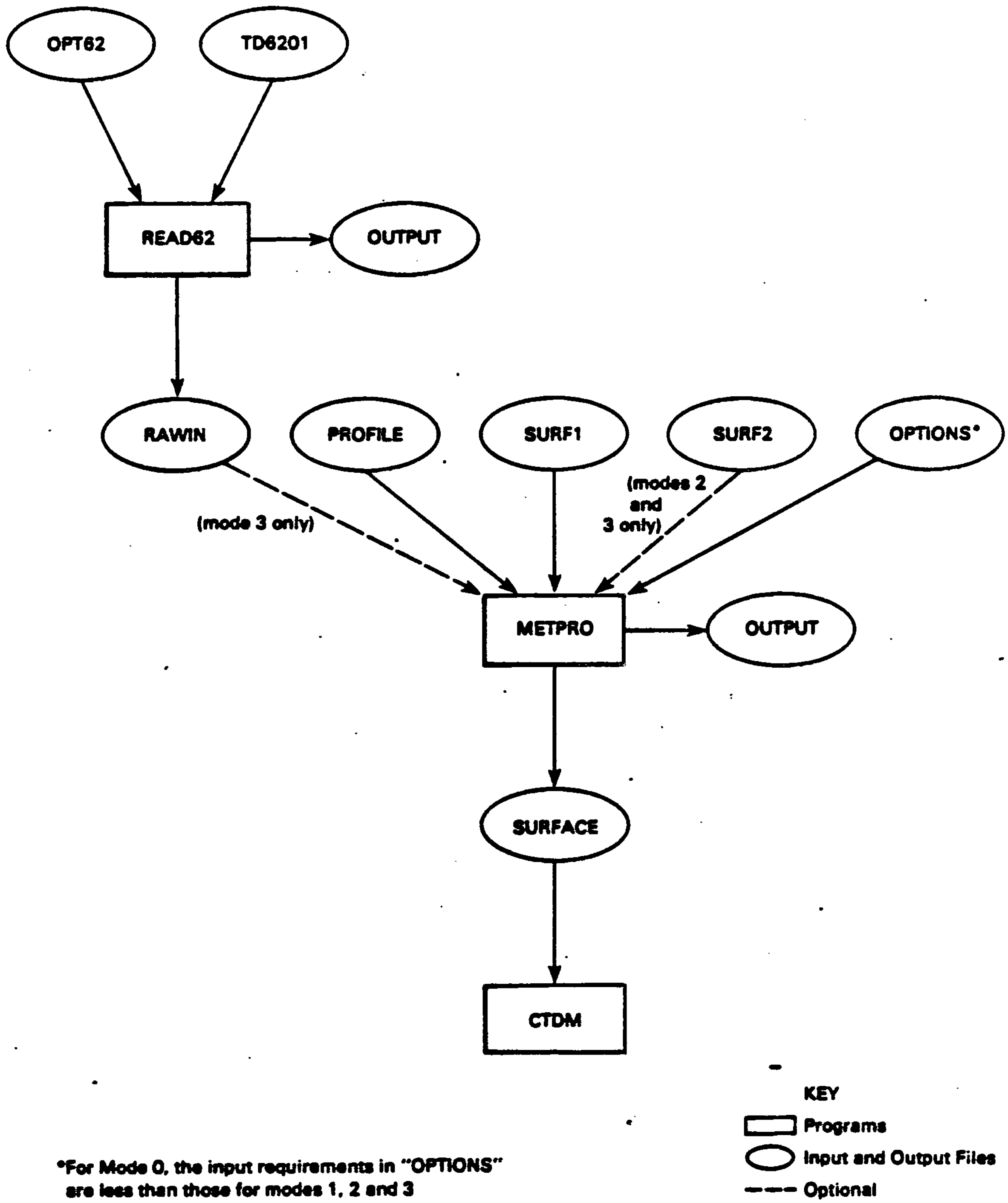


Figure 4. Interaction among components of the CTDM meteorological preprocessor.

871006

observations of the mixed layer height are used when available. Otherwise, upper air data are used in the mixed layer height calculation after initial processing by the READ62 program (described in Section 3). METPRO uses site characteristics (surface moisture (Bowen ratio), albedo, and surface roughness) in conjunction with the input meteorological data to determine a best estimate for mixed layer height as well as the friction velocity and the Monin-Obukhov length.

A variety of theoretical and empirical techniques are used to determine the boundary layer variables calculated by METPRO (described in detail in Section 2). During daytime hours, an energy balance method (among latent, ground, and air heating) is used to determine the surface heat flux, which is then used in conjunction with wind and temperature profile data to estimate z_i, L, and u_*. At night, the downward heat flux into the ground is a function of the surface wind speed and cloud cover. Estimates of u_* and L in stable conditions are then used to calculate the height of the stable surface layer.

The site characteristics which are used in the calculation of heat flux, L, and u_* vary as a function of season and direction. These variations are accounted for in METPRO with the allowance of up to eight different direction sectors (angular widths are variable, but must sum to 360°) and monthly changes in the Bowen ratio, albedo, and surface roughness.

For some applications involving a short time period of model simulations, the user can use a short cut to obtain the SURFACE file input to CTDM. The input files required by METPRO include:

- an options file ("OPTIONS"), which in its simplest form provides site characteristics for only one direction and month;
- a file containing a profile of on-site measurements ("PROFILE"), including wind speed and direction, temperature, and turbulence (same file as that provided directly to CTDM);
- a file containing surface-based on-site measurements ("SURF1"), including observed mixing height, net and/or total incoming solar radiation, and on-site cloud observations;
- a file containing off-site cloud observations, for use if these observations are not available on-site ("SURF2"); and
- a file of processed NWS upper air data ("RAWIN") initially obtained from the NCDC in TD6201 format and read into the READ62 program to obtain the "RAWIN" file.

The "OPTIONS", "SURF1", and "PROFILE" files are always required, but runs of METPRO can be set up so as not to require "SURF2" or "RAWIN".

METPRO can be run in any of four modes (0,1,2 or 3):

Mode 0: run for one or a few nighttime (stable) hours (surface characteristics such as surface roughness, albedo, and Bowen ratio are assumed to be constant for all model hours); no off-site or upper air data files are required.

Mode 1: run for any number of hours that need not be contiguous, such as nighttime hours only for several days; no off-site or upper air data are required, but site characteristics are allowed to vary each hour.

Mode 2: same as Mode 1, but off-site surface data are read to obtain cloud cover data.

Mode 3: run for a series of contiguous hours that must come in blocks of complete calendar days, although the days need not be contiguous; off-site and upper air files are required.

Input file requirements are the minimum for Mode 0 and the most extensive for Mode 3. Mode 3 involves the determination of convective mixing heights, a computation that currently requires input data for an entire day at a time. It also requires the preparation of upper air data by an auxiliary preprocessor READ62, which is described in Section 3. The required files for each mode are described in detail in Section 4.

1.3 Organization of the Manual

In this manual, the theory behind the METPRO program is discussed separately from the operational instructions for running READ62 or METPRO. Section 2, which contains a discussion of the technical basis for METPRO, need not be consulted by users who merely wish to run the program. Section 4 contains user instructions for METPRO. If mode 3 of METPRO is to be used (requiring computation of mixing heights), then Section 3, which describes the program (READ62) that decodes the NCDC's upper air data in TD6201 format, must be referenced.

SECTION 2

TECHNICAL DESCRIPTION

2.1 Overview of Technical Design

The meteorological preprocessor, METPRO, uses routine measurements to estimate the vertical structure of wind, temperature, and turbulence in the lower atmosphere using surface layer similarity theory. Estimates of the friction velocity, u_*, the Monin-Obukhov length, L, and the mixed layer height (h or z_i), are provided by METPRO to CTDM. These parameters, together with the roughness length, z_0, can be used by CTDM to compute values of wind, temperature, and turbulence at any height within the mixed layer in the absence of direct measurements.

An energy balance method is used by METPRO to determine the surface layer variables, u_* and L, a calculation which requires only one level of wind speed data. Net or total incoming solar radiation, which is either provided as a measurement or is computed from the solar elevation and albedo information during the day, is used to compute the surface heat flux. At night, the downward heat flux is estimated from wind speed and cloud cover information.

For daytime hours, net radiation is divided into surface or "sensible" heat flux, latent heat flux, and ground heat flux components, using information regarding the site-specific partitioning of sensible and latent heat (Bowen ratio). The vertical flux of sensible heat is related to the intensity of turbulence in the surface layer, as well as the depth of the boundary layer. A modified Carson (1973) technique uses the hourly sensible heat estimates and a morning sounding to determine hourly mixed layer heights during convective conditions.

In practice, METPRO handles seasonal changes in surface characteristics by accepting monthly values of surface roughness length, midday albedo, and daytime Bowen ratio. Guidance is given in Section 4.3 for selecting seasonally varying input values for such land use types as water bodies, deciduous or coniferous forests, swamps, cultivated land, grassland, urban areas, and deserts. Increases in albedo with low sun angles are also accounted for within METPRO. Spatial changes in surface characteristics can be accounted for by specifying up to 8 different sectors with user-defined direction boundaries, each with the seasonal information discussed above. For example, upwind fetches over forests, grasslands, and water bodies surrounding a particular site can be handled by METPRO on an hour-by-hour basis by accounting for changes in upwind fetch direction. However, changes in site characteristics for a given direction are specified on a monthly basis.

METPRO estimates of u_* and L have been compared with observations taken at research-grade sites (AFCRL Kansas and Minnesota experiments) to evaluate the accuracy of these model input values (see Appendix A). Both on-site and off-site measurements of wind speed and radiation were provided to METPRO. The evaluation results show very good agreement between estimates and observations of u_* and L (correlation coefficient typically exceeding 0.9) with use of on-site wind data (with or without measured net radiation data). Poor agreement occurs when off-site winds are substituted, which indicates the importance of on-site wind measurements for model accuracy, especially in complex terrain.

2.2 Surface Energy Balance

2.2.1 Unstable Conditions

The surface heat flux, H, a key parameter needed to specify the intensity of atmospheric turbulence, may be determined from the surface energy balance (Oke, 1978). A simple general equation for the energy balance at the earth's surface may be expressed by:

$$R_n = H + LE + G \qquad (3)$$

where

R_n is the net radiation,
H is the surface heat flux,
LE is the latent heat flux, and
G is the soil heat flux.

Figure 5 shows a typical diurnal distribution of these energy balance components. The net radiation is measured or may be determined from the total incoming solar radiation, R, as follows:

$$R_n = (1-r)\, R - I_n \qquad (4)$$

where

r is the albedo of the surface
R is the total incoming solar radiation
I_n is the net long-wave radiation from the surface.

Equations 3 and 4 are the basis for the energy balance technique which is discussed below.

The total incoming solar radiation for the general case in which clouds are present is computed using the following formula proposed by Kasten and Czeplak (1980):

$$R = R_o(1 + b_1 N^{b_2}) \qquad (5)$$

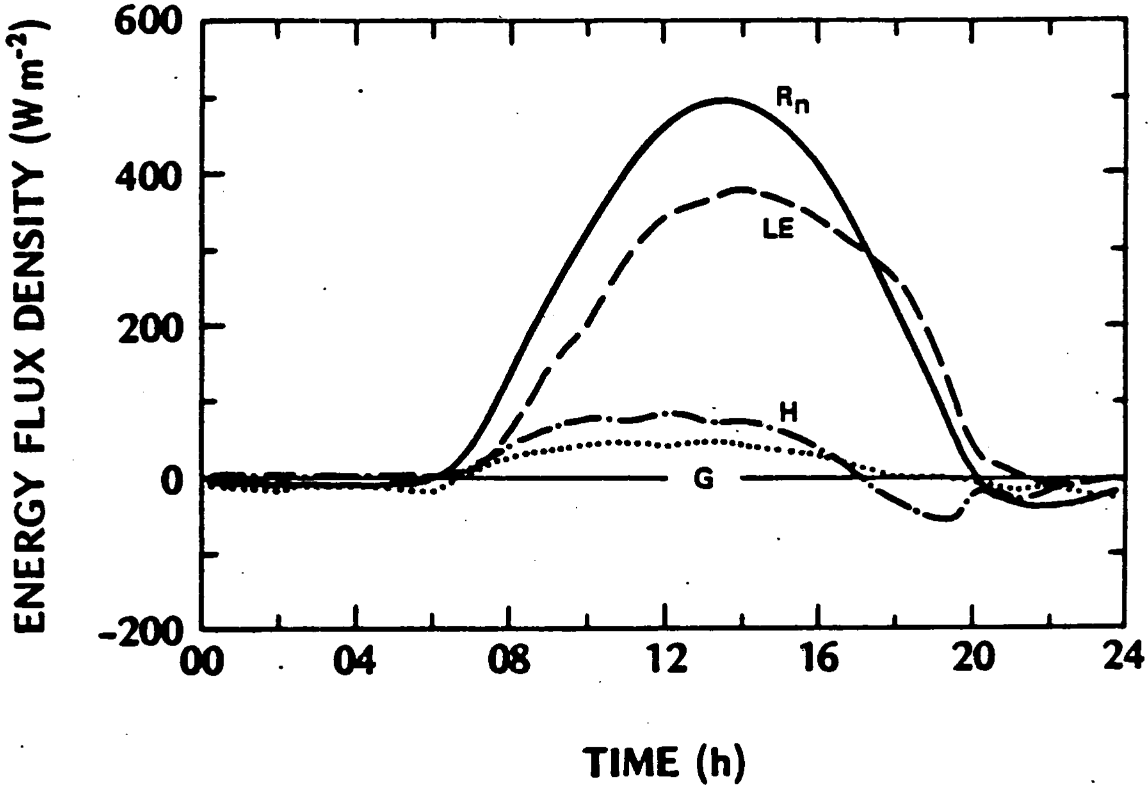


Figure 5. Energy balance components for 25 July 1976 with cloudless skies at Pitt Meadows, British Columbia (49°N) over a 0.25-m stand of irrigated mixed orchard and rye grass (from Oke 1978).

where

R_0 is the incoming solar radiation for clear skies,
N is the total cloud cover in tenths, and
b_1 and b_2 are empirical coefficients:
$b_1 = -0.75$, and
$b_2 = 3.4$.

Net radiation, if not measured, may be calculated from Equation 4 by parameterizing the incoming and outgoing long-wave radiation as functions of the temperature after Holtslag and van Ulden (1983). Net radiation can also be calculated from the total incoming solar radiation, R, using a surface energy balance equation given by Holtslag and van Ulden (1983) from Equation 4 for the net radiation:

$$R_n = \frac{(1-r)R+c_1T^6-\sigma_{SB}T^4 \; +c_2N}{1+c_3} \tag{6}$$

where

$c_1 = 5.31E{-}13\ Wm^{-2}\ K^{-6}$
$c_2 = 60\ W/m^2$
$c_3 = 0.12$
T is the air temperature
σ_{SB} is the Stefan-Boltzmann constant, $5.67E{-}08\ W/(m^2K^4)$.

If net and total incoming radiation measurements are both available, METPRO will use the net radiation measurement and ignore the total incoming radiation data. Missing net radiation measurements, will, however, be replaced with estimates computed internally by METPRO from the total radiation data. The substituted values may at times be slightly inconsistent with the observed net radiation values (METPRO makes no attempt to make adjustments in such cases).

The albedo is relatively constant for solar elevation angles above 30°, but increases for lower angles (Coulson and Reynolds, 1971 and Iqbal, 1983). An empirical expression for the albedo as a function of solar elevation angle that fits the data presented by Iqbal reasonably well is given by

$$r = r' + (1 - r')\ e^{a\nu+b} \tag{7}$$

where
r is the surface albedo
r' is the albedo for the sun directly overhead
ν is the solar elevation angle in degrees,
a is a constant, -0.1, and
$b = -0.5\ (1-r')^2$.

The variation of albedo with solar elevation for various ground covers is illustrated in Figure 6.

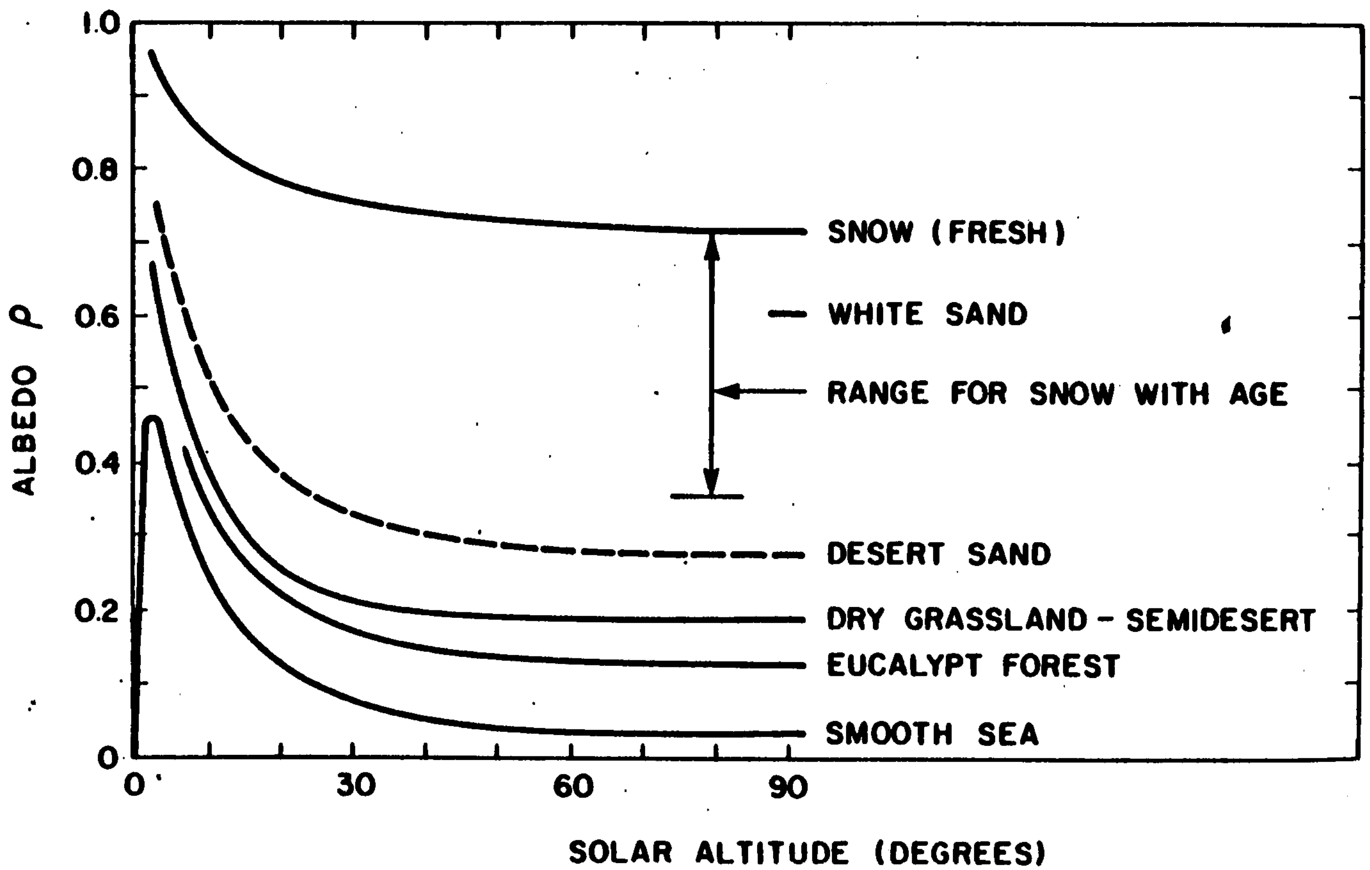


Figure 6. **Angular variation of the albedo of various ground covers (from Iqbal 1983).**

The sensible heat flux is obtained from the basic energy balance, Equation 3, where Holtslag and van Ulden (1983) assume that the latent heat flux is a function of temperature. The sensible heat flux may be obtained from the following equation after determining the net radiation from Equation 6:

$$H = \left(\frac{(1-\alpha)+(\gamma/s)}{1+(\gamma/s)}\right)(R_n - G) - \alpha\beta' \tag{8}$$

where

α is an empirical parameter related to the Bowen ratio (Br=LE/H),
β' is a constant, 20 W/m^2,
G is the soil heat flux, set to 0.1 R_n,
q_s is the saturation specific humidity,

$s = \frac{\partial q_s}{\partial T}$, and

$$\gamma = \frac{C_p}{\lambda} \text{ , where} \tag{9}$$

λ is the latent heat of water vaporization.

The value assigned to α is specific for the soils and vegetation at the site of interest.

The latent heat flux can be written as (after Holtslag and van Ulden)

$$LE = \frac{\alpha}{1+(\gamma/s)}(R_n - G) + \beta'\alpha \text{ .} \tag{10}$$

The Bowen ratio, Br, which is the ratio H/LE, is a more familiar parameter than α for defining the soil moisture condition. During daytime conditions, Br is usually positive, with values ranging from 0.1 for bodies of water to about 1.0 for temperate grasslands and up to 10 or more for deserts. The Bowen ratio can be computed by dividing Equation 8 by Equation 10. After collecting terms and substituting an estimate (Holtslag and van Ulden, 1983) for G (=0.1 R_n), one can derive the following expression for α:

$$\alpha = \frac{(1+\gamma/s)(0.9R_n)}{(1+Br)[.9R_n+\beta'(1+\gamma/s)]} \text{ .} \tag{11}$$

For most of the daytime hours, when R_n is much greater than β', Equation 11 simplifies to

$$\alpha \sim (1+\gamma/s)/(1+Br). \tag{12}$$

Using the heat flux from Equation 6, METPRO determines values for the friction velocity u_* and the Monin-Obukhov length L. A first guess for u_* is made based upon the logarithmic wind profile for neutral conditions ($L = \infty$):

$$u = \frac{u_*}{k} \ln \left(\frac{z}{z_o}\right) \qquad (13)$$

where

- u is the wind speed at 10 meters;
- k is the von Karman constant, k = 0.4 (Lo and McBean 1978);
- u_* is the friction velocity;
- z is the wind measurement height; and
- z_o is the roughness length.

Note: a 10-meter wind speed obtained by interpolation or extrapolation, if necessary, is used in the estimate of u_* because it represents a level usually in the surface layer, but above surface roughness elements; it is also widely available as a standard measurement height.

The Monin-Obukhov length, L, defined in equation 1, is used to provide a stability parameter to CTDM.

Subsequent iterative guesses for u_* and L use the formulation for stability corrections to the logarithmic profiles for momentum, ψ_m, and for heat, ψ_h, (Lumley and Panofsky 1964, Businger 1973):

$$u = \frac{u_*}{k} \left[\ln \left(\frac{z}{z_o}\right) - \psi_m\right] \qquad (14)$$

$$\theta - \theta_o = \frac{\theta_*}{k} \left[0.74 \ln (z/z_o) - \psi_h\right] \qquad (15)$$

where θ_* is the temperature scale, equal to $-\overline{\theta' w'}/u_*$.

For unstable conditions, the stability corrections denoted in equations 14 and 15, ψ_m and ψ_h, are as follows:

$$\psi_m = 2 \ln \left[\frac{(1+\phi_m^{-1})}{2}\right] + \ln \left[\frac{(1+\phi_m^{-2})}{2}\right] - 2 \arctan (\phi_m^{-1}) + \pi/2 \qquad (16)$$

$$\psi_h = 2 \ln \left[\frac{(1+0.74\phi_h^{-1})}{2}\right] \qquad (17)$$

where

$$\phi_m = (1 - 15\frac{z}{L})^{-1/4} \quad \text{and} \tag{18}$$

$$\phi_h = 0.74(1 - 9\frac{z}{L})^{-1/2}. \tag{19}$$

For stable conditions, the corrections ψ_m and ψ_h are given by the following simple expressions:

$$\psi_m = -4.7\ z/L \quad \text{and} \tag{20}$$

$$\psi_h = -4.7\ z/L\ . \tag{21}$$

Equations 1 and 14 for L and u_* are computed iteratively (with new estimates of the stability correction functions each time) until the desired accuracy of L is reached.

2.2.2 Stable Conditions

The Venkatram (1980) method is applied to stable conditions, with a first estimate of θ_* obtained from Holtslag and van Ulden (1983):

$$\theta_{*_1} = 0.09\ (1 - 0.5\ N^2) \tag{22}$$

where N is the total cloud cover in tenths and θ_* has units of °K. A second estimate of θ_* is made from the profile equation for temperature:

$$\theta_{*_2} = \frac{TC_{DN}u^2}{4\beta_m zg} \tag{23}$$

where the neutral drag coefficient C_{DN} is defined as $\frac{k}{\ln(z/z_o)}$

and β_m is a constant (4.7).

The next step is to set θ_* equal to the smaller of θ_{*1}, and θ_{*2}. From the relationship for the sensible heat flux, H:

$$H = -\rho c_p u_* \theta_*, \tag{24}$$

it is evident that H is a function of the product of u_* and θ_*. For large values of u (or u_*), θ_{*1} is smaller than θ_{*2} , so θ_* is fixed because θ_{*1} is not a function of u. Therefore, an additional check on the product $u_*\ \theta_*$ must be made since it is evident that H should not keep increasing indefinitely with increasing wind speeds. In this check, the value of θ_* (°K) in METPRO is not allowed to exceed $0.05/u_*$ (Hanna et al., 1986), where u_* is expressed in units of m/sec.

The friction velocity, u_*, can be calculated as the solution to a quadratic equation:

$$u_* = \frac{C_{DN} u}{2} \left[1 + \left(1 - \left(\frac{2u_o}{C_{DN}^{1/2} u} \right)^2 \right)^{1/2} \right] \tag{25}$$

where $u_o = \left(\frac{\beta_m z g \theta_*}{T} \right)^{1/2}$.

For real solutions, the following condition must be met:

$$\frac{2u_o}{C_{DN}^{1/2} u} \leq 1 \tag{26}$$

If this condition does not hold (under very stable conditions), L is set to a default minimum of 5 m and u_* is calculated with that assumption. Otherwise, L is calculated from Equation 1.

2.3 Mixed Layer Height Determination

METPRO computes convective mixed layer heights when run in mode 3 (contiguous hours for entire calendar days). During the daytime hours, the convective boundary layer (CBL) is assumed to be capped by a relatively thin interfacial layer separating it from the stable air aloft. Stable air is entrained into the interfacial layer as a result of vertical mixing due to thermals penetrating the top of the CBL. Within the mixed layer ($x > 0.1z_i$), the potential temperature θ and wind speed u are relatively uniform, but in the interfacial layer, they rapidly adjust with height to their values in the overlying stable air.

Carson (1973) has simplified the modeling of boundary layer evolution by ignoring radiation, latent heat effects, and advection of energy. He includes the effects of time-dependent surface heating, capping layer stability, large-scale air subsidence, and any degree of turbulent interfacial mixing. Carson idealizes the potential temperature distribution by assuming it to be uniform with z within the CBL, to undergo a step change $\Delta\theta_h$ at the top of the CBL ($z = h$), and to vary linearly with z in the overlying stable air. He also considers the stable air as comprising 3 or so vertical layers, each with a different lapse rate, instead of as a single stable layer.

Weil and Brower (1983) modified Carson's model by:

- permitting the elevated stable layer to have an arbitrary temperature distribution with z (i.e., an infinite number of vertical layers);

- allowing for surface stress-induced (mechanical) mixing, which can be important at night and in the early morning hours when the heat flux is low or zero; and

- neglecting subsidence.

The portion of the Weil and Brower document describing the determination of the convective boundary layer height is given in Appendix B. A summary of this scheme is given below.

Convective and mechanical mixing are assumed to operate independently of one another, so that one or the other of these mixing modes dominates. Figure 7 shows the assumed potential temperature distribution, where the solid curve is the initial temperature profile, $\theta_s(z)$, and the dashed curve is the idealized profile at a later time t. The "overshoot" σ is a measure of the degree of entrainment or interfacial mixing and is a function of time, as are the mixed-layer temperature and height, θ_c and h (used here interchangeably with z_i), respectively, and the temperature jump $\Delta\theta_h$. When there is no overshoot, $\Delta\theta_h=0$, and the mixed-layer only "encroaches" on the elevated stable layer.

The growth of the convective mixing height is assumed to be controlled by the bombardment of the stable lid with thermals originating at the surface. Computationally, the incremental (hourly) change of the area under the temperature profile curve (see Figure 7) is proportional to the hourly sensible heat flux, H.

The area under the temperature profile θ_s curve is proportional to the accumulated surface heat flux:

Area under temperature profile curve at time t =

$$h\,\theta_s(h) - \int_o^h \theta_s dz = (1 + 2A) \int_o^t \frac{H\,(t)}{\rho c_p}\, d\tau \qquad (27)$$

where A is a empirical constant (ratio of heat flux at top of boundary layer to that at the surface), taken as 0.2 after Deardorff (1980). The left side of Equation 27 is a mathematical representation of the area under the θ_s curve (up to a height h) in Figure 7. The right side is proportional to the surface heat flux.

Weil and Brower's formulation for the mechanical mixing height, after Tennekes (1973) and Kato and Phillips (1969), is derived in a manner similar to that of Equation 27 except that the right side of the equation is now a function of the friction velocity u_*:

$$h^2\,\theta_s(h) - 2 \int_o^h z\theta_s dz = 2\,\frac{BT_o}{g} \int_o^t u_*^{\,3}\, d\tau \qquad (28)$$

An example is shown in Figure 9.

The "RAWIN" output file will contain warning messages for entirely missing soundings or soundings whose highest level is below the cut-off value specified by the user. The user must edit the RAWIN formatted file to delete these warning messages and to substitute for the missing data. Substitutions can be obtained by copying from a chronologically adjacent sounding or by obtaining data from a spatially adjacent sounding location. These substitutions should be done on a case-by-case basis, using alternate data representing the same air mass characteristics as that for the location and time of the missing data.

Recommended control variable settings for dealing with missing data are as follows:

- eliminate individual levels with missing temperature or height data;
- do not eliminate individual levels with missing wind data.

Currently, the wind data are not used by METPRO; therefore, it is not necessary to substitute for missing values in the wind direction and speed data fields.

Default input/output unit numbers have been assigned to the files mention above:

- Unit 5: Options input file ("OPT62", see Table 3);
- Unit 6: Verification listing of input options ("OUTPUT");
- Unit 8: TD-6201 data file ("TD6201", see Figure 8);
- Unit 9: "RAWIN" output file (see Figure 9).

If necessary, the default I/O unit assignments can be easily changed by altering a single line of code (for each unit number) near the beginning of the main program.

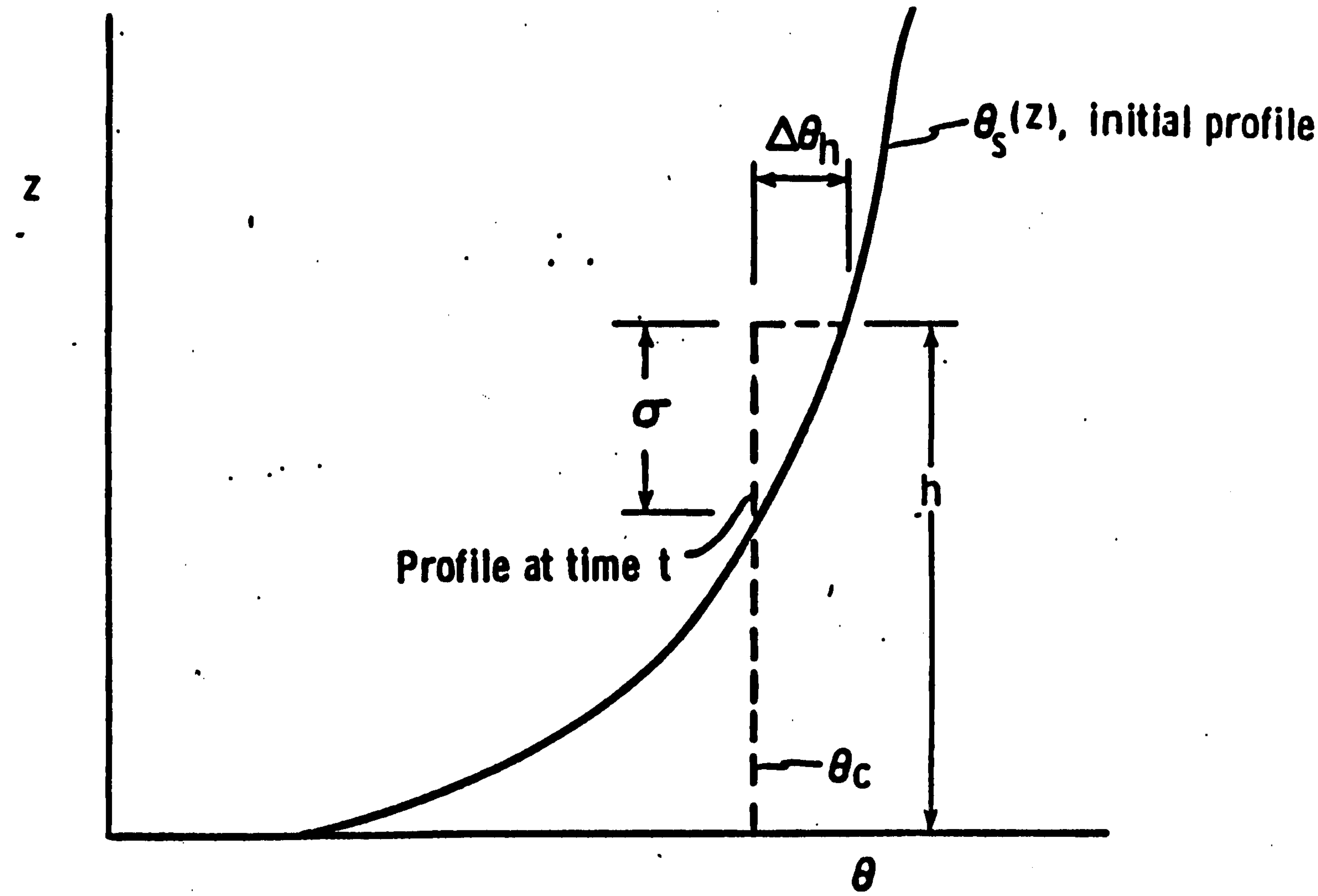


Figure 7. Mixed height computation using the modified Carson method.

where T_0 is the surface temperature and B is a constant, 2.5. Equation 28 shows a balance between the kinetic energy (right side) required to overcome the potential energy (left side) represented by the initial stable temperature sounding.

For each hour, METPRO chooses the higher of a mechanical or convective mixing height. This method does not use surface temperature explicitly (unlike the other methods), and therefore avoids site inconsistencies between the on-site temperature and the off-site upper air temperature sounding.

The nocturnal boundary layer height is modeled using an expression developed by Zilitinkevich (1972) that is valid for very stable conditions:

$$h = 0.4 \left(\frac{u_* L}{f}\right)^{1/2} \tag{29}$$

where

h is the height of the stationary nocturnal boundary layer, and f is the Coriolis parameter, $f \sim 10^{-4}\ s^{-1}$. (Note: for latitudes within 10° of the equator, a value of f corresponding to 10° is used in METPRO to avoid division by zero.)

An interpolation scheme developed by Nieuwstadt (1981) extends Zilitinkevich's (1972) formula to nearly neutral cases:

$$\frac{h}{L} = \frac{\frac{0.3u*}{fL}}{1 + 1.9\ h/L} \tag{30}$$

The solution for h given by this formula approaches Equation 29 for small L and approaches 0.3 u_*/f for large L (the solution appropriate for neutral conditions).

2.4 Use of Upwind Fetch to Boundary Layer Characteristics

The characteristics of the boundary layer experienced by an elevated plume near its release point are a function of the influence of the surface along the fetch upwind from the source.

Developing boundary layers that are generated by changes in surface characteristics have heights, h_T, that are functions of the fetch length, x and the stability:

Neutral: $h_T = 0.1x$ (Jackson, 1976); (31)

Stable: $h_T = 0.1x$, with a maximum defined by Equation 29 (Zilitinkevich, 1972) (32)

$$\text{Unstable:}\quad \begin{aligned} h_T &= 0.19x^{0.47},\ u \le 5 \text{ m/sec} \\ h_T &= 0.20x^{0.29},\ 5 \le u < 7 \text{ m/sec} \\ h_T &= 0.25x^{0.14},\ u \ge 7 \text{ m/sec} \end{aligned} \tag{33}$$

(h_T and x in km, Raynor et al, 1979).

A depiction of the growth of the developing boundary layer is shown in Figure 2.

The change in the characteristics downwind from the source will affect dispersion eventually, but this new boundary layer will not intercept the plume until it grows to plume height and entrains the plume. This delay in surface characteristics influencing the plume behavior is especially significant for elevated releases of buoyant plumes. As a consequence, upwind site characteristics are used to determine the boundary layer structure that affects plume dispersion.

For stable and neutral conditions, surface characteristics at upwind distances up to about ten times the final plume height will influence plume dispersion. This distance will, of course, vary with source characteristics and with meteorological conditions. A choice of 3 kilometers (corresponding to a plume height of 300 meters) as adopted by the U.S. EPA (1986) is a fairly representative average.

Site characteristics required for METPRO include the surface roughness length, the albedo, and the Bowen ratio. The albedo and Bowen ratio are used for daytime surface heat flux calculations, while the roughness length is used for all periods to determine u_* and L. To account for changes in site characteristics in both time (season) and the upwind fetch direction, METPRO allow the user to specify these site characteristics for up to eight direction sectors and for each month of the year. Guidance on the selection of input values for METPRO is given in Section 4.3.

2.5 Structure of METPRO Code

The calculation of the boundary layer variables u_* and L as well as the estimation of the mixed layer height within METPRO are performed by routines designed in a modular fashion. Table 1 lists the METPRO routines and the function of each. Some of the major tasks allocated to these routines are

- determining net radiation and surface heat flux (SUN, HV, HVNET, TOTAL);
- calculating u_* and L (HDAYUS, WNUS);
- estimating the convective mixed layer height (TT, CUBIC, HOUR, INITT, MINUTE, RHOO, SENSE, SUMHH, SUMI, ZZI);
- estimating the mechanical and stable mixing heights (SUMVV, ZILL).

TABLE 1

METPRO ROUTINES AND THEIR FUNCTION

Routine Name	Function
METPRO	Main program, opens file and calls subroutines
DEFAUL	Substitutes NWS data if missing on-site data; flags missing winds
SUN	Calculates solar elevation angle for each hour
HV	Computes the surface heat flux from the net radiation
HVNET	Computes the net radiation from the total incoming solar radiation
HDAYUS	Calculates unstable u_* and L using the Holtslag-van Ulden technique
WNUS	Calculates stable u_* and L using the Venkatram technique
TOTAL	Calculates total incoming solar radiation from cloud cover and solar elevation
TT	Interpolates to obtain surface temperature at time of positive upward heat flux
CUBIC	Solves a cubic polynominal equation
HOUR	Converts minutes from midnight into hours and minutes
INITT	Computes integrated sensible heat flux from sunrise
JULIAN	Computes Julian day from month, day, year information
MINUTE	Converts hours and minutes after midnight to minutes
RHOO	Calculates air density as a function of temperature, pressure
SENSE	Determines time when sensible heat flux is first positive upward
SUMHH	Interpolates integrated sensible heat flux
SUMI	Computes potential temperature integrals from morning sounding

TABLE 1 (Continued)

Routine Name	Function
SUMVV	Calculates area under u_*^3 curve for mechanical mixing height
ZILL	Calculates nocturnal boundary layer height
ZZI	Determines height corresponding to a given area under the potential temperature curve

SECTION 3

READ62 PREPROCESSOR

3.1 Requirement for Upper Air Data

The CTDM meteorological preprocessor, METPRO, requires upper air data to compute daytime mixed layer heights using the Carson (1973) method as modified by Weil and Brower (1983) in execution mode 3 only. In execution modes 0, 1 and 2, nocturnal mixing heights are either calculated from on-site conventional meteorological data or are measured with an instrument such as an acoustic sounder. Convective mixing heights in modes 0, 1, and 2 are provided through measurements or are set by default to -999 (missing).

In 1985, the National Climatic Data Center initiated a new format (the TD-6201 format) for U.S. rawinsonde observations. An auxiliary meteorological pre-processor, READ62, has been developed to read the NCDC's TD-6201 format and produce a file for input to the METPRO meteorological preprocessor. Table 2 gives a description of the contents of the TD-6201 file.

3.2 Execution of READ62

The TD-6201 files must be ordered from NCDC in a fixed block format: 2876 bytes per record, 2 records per block. The disk file should be set up to contain formatted records of 2876 bytes in length. Program execution should account for this record length (e.g., for some compilers a command option changes the maximum record length at run time). A portion of a sample file is shown in Figure 8.

The user is required to input data and program option values for READ62. Dates and pressure levels for which data are to be extracted are specified by the user, as well as criteria for discarding an entire data level. The required format is shown in Table 3.

The "RAWIN" output file consists of a formatted listing in chronological order of pressure, height, temperature, wind direction and wind speed for each pressure level between the surface and the user-specified level aloft.

Each sounding output consists of an identification record followed by several data records. The identification record contains the following:

- a label identifying the data as series "6201",
- a station identification number (e.g., 14735),
- the year, month, day, and hour (GMT) of the sounding,
- the total number of pressure levels in the sounding, and
- the total number of levels extracted.

TABLE 2

CONTENTS OF TD-6201 FILE

HEADER INFORMATION FOR EACH SOUNDING TIME (32 BYTES):

Variable Name	# of Bytes	Description
STNID	8	Station identifier.
LAT	5	Latitude--the station latitude in Deg. and Min. followed by 'N' or'S'
LON	6	Longitude--the station longitude in Deg. and Min. followed by 'E' or 'W'.
YEAR, MONTH, DAY, HOUR	10	The schedule time of the observation, GMT.
NUMLEV	3	Number of repeating groups--this represents the number of data levels found in the current observation (79 is the maximum number stored in each data block).

DATA FOR EACH OF 79 PRESSURE LEVELS (36 BYTES EACH):

Variable Name	# of Bytes	Description
QIND	1	Level-quality-indicator--denotes the results of any quality controls applied to this level (this is used in READ62).
ETIME	4	The elapsed time since the release of the sounding in minutes and tenths (ignored in READ62).
PRES	5	Atmospheric pressure at the current level (read in millibars).
HGT	6	Geopotential height of the current level in meters.
TEMP	4	The air temperature at the current level in degrees and tenths Celsius.
RH	3	The relative humidity at the current level in %.
WD	3	The wind direction at the current level in deg.
WS	3	Speed of the wind in whole meters per second.
TIMEF, PRESF, HGTF, TEMPF, RHF, WINDF	6	Quality control flags
TYPLEV	1	Type of level flag (ignored)

```
000147354245N07348W19840101000790000010239+00086-07004518000300000000000410180+0
4000000010001409780+00443-07604624800500000002000190957 0+00612-06304127100700000002
-0760322880100000002000350900 0+01091-06003229301200000003000370893 0+01152-0550332
408000+02014-06202328801300000003000810750 0+02518-07502127601400000003000870733 0+0
60000001001150650 0+03619-12702126701900000003001230629 0+03870-135019267020000000 2
-1940192630180000000300156054 80+04906-19601926301800000002001690517 0+05336-2290552
404820+05847-25303527101600000002001940461 0+06169-26805727601600000002001990450 0+0
8000000100242036 90+07738-39403525501800000002002540350 0+08101-4219992630180000000 3
-5489992290240000000400331025 00+10299-53899922003200000001003890200 0+11734-5359992
501740+12624-56799924403100000002004480160 0+13158-55299924603300000002004660150 0+1
300000020050701250+14715-59899925203100000003005610100 0+16100-6269992550320000000 1
-6329992690190000000100659006 50+18756-60499926002000000002006740060 0+19253-6199992
500400+21736-63199927202200000003007840037 0+22217-62199926802300000002008190031 0+2
999999991999999999-99999-999999999999999999991999999999-99999-999999999999999999
-9999999999999999991999999999-99999-999999999999999999991999999999-99999-9999999
999999-99999-9999999999999999991999999999-99999-999999999999999999991999999999-9
999999991999999999-99999-999999999999999999991999999999-99999-999999999999999999
-9999999999999999991999999999-99999-999999999999999999991999999999-99999-9999999
999999-99999-9999999999999999991999999999-99999-999999999999999999991999999999-9
999999991999999999-99999-999999999999999999991999999999-99999-999999999999999999
-9999999999999999991999999999-99999-999999999999999999991999999999-99999-9999999
999999-99999-9999999999999999991999999999-99999-999999999999999999991999999999-9
000147354245N07348W19840101120790000010252+00086-07005735000200000000000410130+0
5000000100012098 10+00430-06406334500600000002000190950 0+00680-0840833510070000000 3
-1010903440080000000300047085 00+01537-11909732100800000001000490845 0+01582-1200973
308350+01674-06409831100800000002000630800 0+02008-07508430600800000003000650794 0+0
7000000200079075 10+02501-05801933500700000002000790750 0+02512-0580193350070000000 3
-1120223030100000000200113065 00+03621-11903330201000000003001180638 0+03763-1330542
206000+04229-16004229401000000003001380585 0+04419-18004829601000000002001470562 0+0
0000000300170050 00+05579-24401929201300000001001920450 0+06338-3030192950120000000 3
-4419992930140000000300268031 00+08877-50599928401300000002002740300 0+09091-5119992
202500+10266-54199925902200000001003390218 0+11148-52599926201800000002003560202 0+1
3000000100363019 50+11867-51099925002300000002003770183 0+12278-5329992500230000000 2
-5419992660260000000100417014 60+13731-52199926702500000002004400125 0+14723-5829992
701000+16109-62799926802300000001004960089 0+16826-63699927302400000002005130080 0+1
2000000200533007 00+18304-64699926802100000001005540060 0+19249-6339992710230000000 3
-6329992720210000000100613004 00+21746-63299927502600000003006560030 0+23513-6349992
999999-99999-9999999999999999991999999999-99999-999999999999999999991999999999-9
999999991999999999-99999-999999999999999999991999999999-99999-999999999999999999
-9999999999999999991999999999-99999-999999999999999999991999999999-99999-9999999
999999-99999-9999999999999999991999999999-99999-999999999999999999991999999999-9
999999991999999999-99999-999999999999999999991999999999-99999-999999999999999999
-9999999999999999991999999999-99999-999999999999999999991999999999-99999-9999999
999999-99999-9999999999999999991999999999-99999-999999999999999999991999999999-9
```

Figure 8. A portion of an upper air data file in TD-6201 format obtained from the National Climatic Data Center.

TABLE 3

CONTENTS OF OPTIONS INPUT FILE FOR READ62

First Line (free format):

Variable Name	Description
IBYR, IBDAY, IBHR:	Year, Julian day, and hour (GMT) to begin extracting data from input TD6201 file.
IEYR, IEDAY, IEHR:	Year, Julian day, and hour (GMT) after which to stop extracting data from input TD6201 file.
PSTOP:	Lowest pressure (highest level) for which information is to be extracted.

Second line (free format):

Variable Name	Description
LHT, LTEMP, LWD, LWS:	Control switches for acceptance of this data level for height, temperature, wind direction and wind speed data respectively. If a value of any of these four variable is missing <u>and</u> that switch is set to 1, discard the entire level; a setting of zero indicates that the data level is acceptable even if that corresponding variable is missing.

```
  6201      14735      84 1 1 0      29                              21
 1023.9/  86./266.2/180/  3   1018.0/ 131./266.9/198/  3   1000.0/ 270./266.2/209/  4    978.0/ 443./265.6/248/  5
  957.0/ 612./266.9/271/  7    950.0/ 669./266.7/274/  7    925.0/ 877./265.6/288/ 10    900.0/1091./267.2/293/ 12
  893.0/1152./267.7/294/ 12    850.0/1539./268.1/294/ 12    800.0/2014./267.0/288/ 13    750.0/2518./265.7/276/ 14
  733.0/2696./265.2/275/ 15    700.0/3052./262.3/274/ 16    650.0/3619./260.5/267/ 19    629.0/3870./259.7/267/ 20
  600.0/4228./257.7/266/ 21    550.0/4879./253.8/263/ 18    548.0/4906./253.6/263/ 18    517.0/5336./250.3/265/ 16
  500.0/5580./248.9/267/ 16
  6201      14735      84 1 112      32                              26
 1025.2/  86./266.2/350/  2   1013.0/ 179./265.3/345/  4   1000.0/ 280./266.2/344/  5    981.0/ 430./266.8/345/  6
  950.0/ 680./264.8/351/  7    949.0/ 688./264.7/352/  7    900.0/1098./263.1/344/  8    850.0/1537./261.3/321/  8
  845.0/1582./261.2/317/  8    839.0/1637./266.7/314/  8    835.0/1674./266.8/311/  8    800.0/2008./265.7/306/  8
  794.0/2067./265.5/309/  7    771.0/2296./265.3/324/  7    751.0/2501./267.4/335/  7    750.0/2512./267.4/335/  7
  700.0/3050./265.2/318/  9    657.0/3539./262.0/303/ 10    650.0/3621./261.3/302/ 10    638.0/3763./259.9/298/ 10
  615.0/4042./259.0/294/ 10    600.0/4229./257.2/294/ 10    585.0/4419./255.2/296/ 10    562.0/4718./254.2/301/ 10
  550.0/4878./253.3/303/ 10    500.0/5579./248.8/292/ 13
  6201      14735      84 1 2 0      24                              19
 1027.3/  86./267.2/300/  3   1019.0/ 150./267.7/324/  2   1000.0/ 297./266.2/ 33/  2    950.0/ 696./264.6/156/  3
  922.0/ 928./263.6/163/  5    900.0/1114./262.1/167/  5    881.0/1277./260.6/165/  3    871.0/1364./262.1/163/  2
  861.0/1453./266.7/161/  1    850.0/1553./266.7/161/  1    804.0/1990./269.2/281/  2    800.0/2029./269.1/282/  2
  750.0/2537./267.7/285/  2    700.0/3077./266.2/283/  4    650.0/3651./262.4/289/  6    644.0/3722./261.9/288/  6
  600.0/4262./258.6/289/  8    550.0/4915./254.5/298/ 13    500.0/5619./250.0/304/ 15
  6201      14735      84 1 212      29                              23
 1021.5/  86./267.2/170/  4   1014.0/ 144./267.0/173/  5   1000.0/ 253./266.3/175/  7    982.0/ 395./265.7/179/  9
  950.0/ 653./265.2/191/ 10    909.0/ 995./264.4/237/  9    900.0/1072./264.7/246/  9    863.0/1399./266.1/276/ 12
  850.0/1517./266.0/275/ 13    837.0/1637./265.1/273/ 13    817.0/1824./263.2/271/ 15    813.0/1862./263.9/271/ 15
  807.0/1919./264.5/271/ 16    800.0/1987./264.4/271/ 16    750.0/2486./263.6/250/ 13    700.0/3018./262.6/244/ 15
  682.0/3219./263.2/245/ 17    650.0/3589./262.1/248/ 18    609.0/4088./260.5/255/ 17    600.0/4202./259.8/255/ 18
  556.0/4777./255.7/253/ 20    550.0/4858./255.3/252/ 19    500.0/5566./251.7/249/ 23
  6201      14735      84 1 3 0      34                              24
 1014.0/  86./268.7/160/  3   1000.0/ 196./269.7/190/  2    985.0/ 315./268.8/240/  3    964.0/ 485./269.9/265/  5
  950.0/ 601./268.9/274/  6    912.0/ 921./265.8/288/ 10    900.0/1024./265.1/290/ 11    872.0/1269./263.1/298/ 13
  850.0/1466./261.8/301/ 12    800.0/1931./261.8/303/ 11    774.0/2185./261.8/305/ 13    750.0/2427./261.5/306/ 14
  736.0/2571./261.2/307/ 14    708.0/2868./260.5/303/ 15    700.0/2955./259.8/303/ 15    680.0/3176./259.5/301/ 15
  653.0/3483./257.4/296/ 15    650.0/3518./257.2/296/ 15    635.0/3693./255.9/294/ 15    617.0/3908./255.4/290/ 14
  600.0/4116./253.2/286/ 14    550.0/4756./249.1/283/ 16    524.0/5108./246.8/286/ 16    500.0/5445./244.7/287/ 15
  6201      14735      84 1 312      28                              21
 1015.1/  86./271.2/300/  5   1000.0/ 205./270.6/312/  6    950.0/ 609./266.7/330/  8    919.0/ 867./264.1/326/ 10
  900.0/1029./263.2/323/ 12    860.0/1378./261.2/320/ 11    850.0/1468./263.4/322/ 11    846.0/1504./264.1/322/ 10
  840.0/1559./264.1/323/ 10    831.0/1642./265.1/325/  9    801.0/1928./266.0/326/  8    800.0/1938./266.0/326/  8
  750.0/2438./263.0/326/  9    747.0/2469./262.8/329/  9    738.0/2563./264.1/335/  8    700.0/2970./261.7/350/  7
  650.0/3535./258.7/355/  6    600.0/4137./255.3/350/ 10    576.0/4442./253.6/350/ 10    550.0/4784./251.7/355/ 10
  500.0/5481./247.6/352/ 14
  6201      14735      84 1 4 0      22                              22
TOP OF SOUNDING BELOW  500.0 MB LEVEL
 1011.0/  86./272.1/150/  4   1000.0/ 173./272.0/160/  5    950.0/ 580./268.5/181/  6    928.0/ 763./266.8/195/  6
  901.0/ 993./265.4/230/  6    900.0/1002./265.8/230/  6    890.0/1090./270.4/237/  7    859.0/1371./270.1/245/  9
  850.0/1454./271.2/243/  9    800.0/1933./267.9/236/ 10    789.0/2041./267.1/236/ 10    766.0/2273./267.7/237/ 10
  750.0/2438./267.2/238/ 10    721.0/2746./266.0/237/ 10    700.0/2976./266.0/239/ 10    650.0/3550./262.3/252/ 10
  637.0/3704./261.2/259/ 11    611.0/4023./261.1/260/ 14    600.0/4162./260.6/260/ 14    567.0/4592./258.8/270/ 13
  550.0/4822./257.4/275/ 13    541.0/4946./256.5/278/ 13
  6201      14735      84 1 412       0                               0
TOP OF SOUNDING BELOW  500.0 MB LEVEL

  6201      14735      84 1 5 0      31                              23
 1000.5/  86./273.6/180/  5   1000.0/  90./274.1/183/  5    955.0/ 460./273.6/235/  4    950.0/ 502./273.3/240/  4
  924.0/ 724./271.1/263/  6    903.0/ 906./269.9/270/  6    900.0/ 932./269.8/270/  6    850.0/1382./266.4/274/  5
  822.0/1644./265.8/270/  8    802.0/1837./267.4/269/ 11    800.0/1857./267.3/269/ 11    792.0/1935./266.5/269/ 11
  788.0/1975./266.4/270/ 12    779.0/2065./266.5/271/ 13    750.0/2360./264.6/273/ 13    700.0/2892./261.8/266/ 16
  684.0/3069./260.3/262/ 16    656.0/3386./257.7/257/ 18    650.0/3455./257.6/256/ 18    600.0/4058./256.5/251/ 22
  570.0/4443./255.7/253/ 24    550.0/4710./254.0/254/ 24    500.0/5412./249.3/251/ 27
  6201      14735      84 1 512      22                              16
```

Figure 9. Example of output ("RAWIN") file from the READ62 program.

SECTION 4

METPRO USER INSTRUCTIONS

4.1 Input Data Requirements

Four modes of execution for METPRO have been designed to accommodate the needs of CTDM users for simulation periods ranging from one hour to several years. The METPRO input text files are described below, followed by a description of which of these files are required for each execution mode of METPRO.

a) PROFILE

"PROFILE" is a user-supplied file of wind, temperature, and turbulence measurements typically obtained from a tower or a doppler acoustic sounder. Several levels of measurements can be accomodated, and the same file is used by both METPRO and CTDM. The specific format for "PROFILE" is given in Table 4. A 10-meter height (or one close to it) should be included, if at all possible, for estimates of u_* and determination of the upwind fetch wind direction sector.

b) SURF1

"SURF1" is a user-supplied file of observed variables obtained from special surface-based instrumentation, including net radiation, mixing height, and cloud cover. The format for "SURF1" is given in Table 5.

c) SURF2

"SURF2" is a file of surface weather variables measured by the National Weather Service (usually an airport); it is the CD144 format obtained from the National Climatic Data Center. The format is given in Table 6. The only variable currently used from this file in METPRO is the cloud cover, which is needed for energy balance calculations for nighttime hours. If on-site cloud cover is available for a given hour (in "SURF1"), then it is used rather than the off-site value.

d) RAWIN

The READ62 preprocessor is used to derive a file of processed upper air data from the TD-6201 format supplied by the National Climatic Data Center (see Section 3 for further details). The "RAWIN" file is needed only for computing convective mixing heights. CTDM applications that are limited to nighttime hours will not require the use of the "RAWIN" file.

TABLE 4

CONTENTS OF FILE "PROFILE"

Each hour's data consists of one line per observation height (relative to tower or sodar base); heights must be in increasing order. Each data line is in free format, as follows:

VARIABLE	DESCRIPTION
JYR	Year
JMO	Month
JDY	Day of month
JHR	Hour (at the end of the period)
HT	Height of this observation above tower base, meters
IEND	0 if not the highest level; otherwise 1
WD	Wind direction
WS	Scalar wind speed, m/sec
TA	Ambient dry bulb temperature, K
SIGTH	Sigma-theta, degrees
SW	Sigma-w, m/sec
UV	Vector wind speed, m/sec

TABLE 5

CONTENTS OF FILE "SURF1"

Each hour's data consists of one line, with variables in free format. The variables to be included are listed below.

VARIABLE	DESCRIPTION
YR	Year
MO	Month
DY	Day of month
HR	Hour (at the end of the period)
QR	Total incoming solar radiation, watts per square meter (-999. if missing)
RN	Net radiation, watts per square meter (-999. if missing)
ZIOBS	Observed mixed layer height above the ground (meters) from on-site measurements, -999. if missing
CH	Base height of cloud ceiling in hundreds of feet from on-site measurements, -999. if missing (not used in current version of METPRO)
CC	Cloud cover in tenths from on-site measurements, -9 if missing (if mode 0 or 1, a nonnegative value must be provided)

TABLE 6

SPECIFICATIONS FOR INPUT DATA FILE "SURF2" (CARD DECK 144)*

Columns	Format	Contents
1-5	I5	Station identifier code
6-7	I2	Year
8-9	I2	Month
10-11	I2	Day
12-13	I2	Hour (at the BEGINNING of the 1-hour period)
14-16	F3.0	Cloud ceiling (100's of feet; "---" if unlimited)
32-35	F4.1	Sea level pressure, mb (thousands digit is omitted; add 1000.0 for values less than 500.)
36-38	F3.0	Dew point temperature, deg. F
39-40	F2.0	Wind direction in tens of degrees (from which the wind is blowing)
41-42	F2.0	Scalar wind speed, knots
47-49	F3.0	Dry bulb temperature, deg. F
79	F1.1	Fraction of opaque sky cover (cloud amount that hides the sky and/or higher clouds; "-" if 1.0)

*One line per hour.

e) <u>OPTIONS</u>

This file provides information involving site characteristics and user switches for the METPRO run. All modes require this file, but the information read for mode 0 is an abbreviated version of that required for the other modes. The "OPTIONS" file contents are described in Table 7.

A single base elevation of the tower or acoustic sounder (i.e., the local surface where meteorological measurements are taken) is input to CTDM. All heights assigned to variables in "PROFILE" and "SURF1" are to be referenced to this ground surface.

The hours assigned to data in "SURF2" are at the <u>beginning</u> of each 1-hour period, while those in "PROFILE" and "SURF1" are at the <u>end</u> of each hour. "METPRO" expects this 1-hour difference in the times between "SURF2" and the user-assembled files - "PROFILE" and "SURF1". Since "SURF2" times are given in standard rather than daylight savings time, the user-assembed files must also be in standard time if "SURF2" is to be used by "METPRO".

The input files required for each of the four execution modes of "METPRO" are listed in Table 8. For mode 0, only on-site data files ("PROFILE" and "SURF1") are required, with a limited amount of information in the "OPTIONS" file. Site characteristics for all directions and all months are not specified for mode 0; only the (constant) values of surface roughness, albedo, and Bowen ratio are specified. Cloud cover is supplied in the "SURF1" file, eliminating the need for "SURF2". No convective mixing heights are calculated in mode 0, so there is no need for the "RAWIN" file.

In mode 1, the site characteristics (surface roughness, albedo and Bowen ratio) are given as a function of wind direction and month. This information is supplied due to the fact that a variation in upwind fetch conditions can be accommodated by mode 1, but not mode 0. Otherwise, modes 0 and 1 are equivalent.

For mode 2, cloud cover data is supplied from "SURF2", a file representing off-site (NWS) weather observations. (In mode 1, cloud cover data is supplied in the "SURF1" file.) Otherwise modes 1 and 2 function the same.

Mode 3 is the most demanding in terms of file preparation by the user. Since convective mixing heights are calculated for contiguous hours on a daily basis (data for 24-hour blocks <u>must</u> be provided), upper air data must first be processed using the READ62 utility. In addition, all of the files required for mode 2 must be provided. Mode 3 should be used for large sequential runs because the convective mixing heights are critical input values for determining whether daytime hours can be modeled by CTDM. For data bases containing only nocturnal hours (no unstable cases), modes 0, 1, or 2 are adequate.

TABLE 7

CONTENTS OF FILE "OPTIONS"

(all data in free format)

Line #	Description
1	• Mode switch: 0, 1, 2, or 3 (see text)
2	• Site latitude, expressed in degrees and fraction thereof, north is positive (e.g., 37.5 = 37 deg, 30 min)
	• Site longitude, expressed in degrees and fraction thereof, west is positive
	• Time zone: number of hours behind Greenwich Mean Time of the time standard assigned to the date/time (e.g., Eastern Standard Time = 5, Central Standard Time = 6, Eastern Daylight Time = 4)
	If mode = 0, add three variables to this line in free format, applicable for the upwind fetch for this entire case run:
	• surface roughness length, meters
	• albedo (ignored at night)
	• Bowen ratio (ignored at night)

The following additional lines are required for modes 1, 2 and 3, in free format:

Line #	Description
3	Number of direction sectors (NSEC) for specifying site characteristics (surface roughness, albedo and Bowen ratio), maximum of 8
Next NSEC lines	Lower limit of wind direction in this sector (in whole degrees); Upper limit of wind direction in this sector (in whole degrees); if crossing 360° in this sector, the "lower" limit will be higher than the "upper" limit
Next 3*NSEC lines	For each sector (in the order specified above), there are three lines of data values, for surface roughness (m), albedo, and Bowen ratio, respectively. Each line has twelve values, corresponding to the months of January through December.

TABLE 8

INPUT FILES REQUIRED FOR METPRO RUNS

Execution Mode	PROFILE	SURF1	SURF2	RAWIN	OPTIONS
0	X	X			*
1	X	X			X
2	X	X	X		X
3	X	X	X	X	X

*A simplified version of the "OPTIONS" file is adequate for Mode 0 execution.

Default input/output unit numbers have been assigned to the input files mentioned above:

- Unit 5: Options input file ("OPTIONS", see Table 7);
- Unit 9: "RAWIN" input file (Figure 9);
- Unit 10: "SURF1" input file (Table 5);
- Unit 11: "SURF2" input file (Table 6);
- Unit 12: "PROFILE" input file (Table 4).

If necessary, the default I/O unit assignments can be easily changed by altering a single line of code (per unit number) near the beginning of the main program.

4.2 Output Files

Two output files are created by METPRO: an output listing that confirms the information read in via the "OPTIONS" file, and a "SURFACE" file that is used directly by CTDM. The format of the "SURFACE" file is given in Table 9.

In execution modes 0, 1 and 2, calculated mixed layer heights for convective conditions are not provided (a -999. is written to the "SURFACE" file). If neither observed or calculated mixed layer heights are available, an effectively unlimited value is assumed. A warning message for execution modes 0, 1, and 2 is written to "OUTPUT" notifying users that calculated mixed layer heights for unstable conditions are missing.

Default input/output unit numbers have been assigned to these two files as follows:

- Unit 6: "OUTPUT" file (see example in Appendix D),
- Unit 7: "SURFACE" file (Table 9).

If necessary, these unit assignments can be altered near the beginning of the main program.

4.3 Determination of Site Characteristics

Input to METPRO includes the specification of surface roughness length, albedo, and Bowen ratio for each month of the year and for up to eight user-specified direction sectors surrounding the source location. A discussion is provided in this section on the determination of the values of these input variables as a function of season and land use type. In operational practice for each upwind direction sector, the user should determine the percentage coverage by each land use type and calculate the resulting input value as a weighted average.

Suggested input values for surface roughness length (Shieh et al., 1979) and albedo (Iqbal, 1983) as a function of land use type and season are given in Tables 10 and 11, respectively. Further information regarding albedo for specific ground covers is given by Iqbal (1983).

TABLE 9

CONTENTS OF FILE "SURFACE"

Each hour's data consists of one line, with variables in free format. This file is written by METPRO for input to CTDM.

VARIABLE	DESCRIPTION
YR	Year
MO	Month
DY	Day of month
JUL	Julian day
HR	Hour (at the end of the period)
ZIOBS	Observed mixed layer height above the ground (meters) from on-site measurements (from "SURF1")
ZIPRE	Calculated mixed layer height above the ground (meters) from surface variables (and upper air data if mode = 3)
USTAR	Surface friction velocity, m/sec
L	Monin-Obukhov length, meters
Z0	Surface roughness length, meters

TABLE 10

SURFACE ROUGHNESS LENGTH, METERS, FOR LAND-USE TYPES AND SEASONS

LAND-USE TYPE	SPRING	SUMMER	AUTUMN	WINTER
1. WATER (FRESH WATER AND SEA WATER)	0.0001	0.0001	0.0001	0.0001
2. DECIDUOUS FOREST	1.00	1.30	0.80	0.50
3. CONIFEROUS FOREST	1.30	1.30	1.30	1.30
4. SWAMP	0.20	0.20	0.20	0.05
5. CULTIVATED LAND	0.03	0.20	0.05	0.01
6. GRASSLAND	0.05	0.10	0.01	0.001
7. URBAN	1.00	1.00	1.00	1.00
8. DESERT SHRUBLAND	0.30	0.30	0.30	0.15

DEFINITIONS OF SEASONS:

"Spring" refers to periods when vegetation is emerging or partially green. This is a transitional situation that applies for 1-2 months after the last killing frost in spring.

"Summer" applies to the period when vegetation is lush and healthy, typical of midsummer, but also of other seasons where frost is less common.

"Autumn' refers to a period when freezing conditions are common, deciduous trees are leafless, crops are not yet planted or are already harvested (bare soil exposed), grass surfaces are brown, and no snow is present.

"Winter" conditions apply for snow-covered surfaces and subfreezing temperatures.

TABLE 11

ALBEDO* OF NATURAL GROUND COVERS FOR LAND-USE TYPES AND SEASONS

LAND-USE TYPE	SPRING	SUMMER	AUTUMN	WINTER**
1. WATER (FRESH WATER AND SEA WATER)	0.12	0.10	0.14	0.20
2. DECIDUOUS FOREST	0.12	0.12	0.12	0.50
3. CONIFEROUS FOREST	0.12	0.12	0.12	0.35
4. SWAMP	0.12	0.14	0.16	0.30
5. CULTIVATED LAND	0.14	0.20	0.18	0.60
6. GRASSLAND	0.18	0.18	0.20	0.60
7. URBAN	0.14	0.16	0.18	0.35
8. DESERT SHRUBLAND	0.30	0.28	0.28	0.45

* Also see Iqbal (1983) for specific crops or ground covers.

** Winter albedo depends upon whether a snow cover is present continuously, intermittently, or seldom. Albedo ranges from about 0.30 for bare snow cover to about 0.65 for continuous cover.

DEFINITIONS OF SEASONS:

"Spring" refers to periods when vegetation is emerging or partially green. This is a transitional situation that applies for 1-2 months after the last killing frost in spring.

"Summer" applies to the period when vegetation is lush and healthy, typical of midsummer, but also of other seasons where frost is less common.

"Autumn' refers to a period when freezing conditions are common, deciduous trees are leafless, crops are not yet planted or are already harvested (bare soil exposed), grass surfaces are brown, and no snow is present.

"Winter" conditions apply for snow-covered surfaces and subfreezing temperatures.

Suggested input values for Bowen ratio are given in Tables 12, 13, and 14 for "dry", "normally moist", and "wet" periods, respectively, as a function of land use type and season (adopted from Montieth, 1976 and Oke, 1978). The determination of the monthly moisture conditions can come from one of at least two sources, both available from the NOAA/USDA Joint Agricultural Weather Facility (USDA South Building, Room 5844, Washington, D.C. 20250; (202)-447-7917):

- Crop Moisture maps (available April through October; see Figure 10), and
- Percentage of Normal Precipitation maps (also available in Monthly Weather Review; see Figure 11).

Dry, wet, and average moisture areas can easily be determined from the Crop Moisture map (Figure 10). The bottom of Figure 10 shows the crop moisture index with good spatial resolution. Values of the index of 2 or higher are clearly in the "wet" category, while those of -2 or lower are in the "dry" category; "normally moist" is assigned values from -1 to +1. If the crop moisture maps are not available, then percentage of normal rainfall maps (Figure 11) can be used as a substitute. Areas with less than 50% of normal rainfall can be defined as "dry" (see Flynn and Griffiths, 1980), while areas with more than 200% or normal rainfall should be classified as "wet".

TABLE 12

BOWEN RATIOS* (H/LE) FOR LAND-USE TYPES AND SEASONS

(DRY CONDITIONS)

LAND-USE TYPE	SPRING	SUMMER	AUTUMN	WINTER**
1. WATER (FRESH WATER AND SEA WATER)	0.1	0.1	0.1	2.0***
2. DECIDUOUS FOREST	1.5	0.6	2.0	2.0
3. CONIFEROUS FOREST	1.5	0.6	1.5	2.0
4. SWAMP	0.2	0.2	0.2	2.0
5. CULTIVATED LAND	1.0	1.5	2.0	2.0
6. GRASSLAND	1.0	2.0	2.0	2.0
7. URBAN	2.0	4.0	4.0	2.0
8. DESERT SHRUBLAND	5.0	6.0	10.0	10.0

* The suggested Bowen ratios listed are typical values appropriate for daytime use.

** Winter Bowen ratios depend upon whether a snow cover is present continuously, intermittently, or seldom. Bowen ratios range from the value listed for autumn for rare snow covers to the value listed for winter for a continuous snow cover.

*** This value applies if the water body is frozen over.

DEFINITIONS OF SEASONS:

"Spring" refers to periods when vegetation is emerging or partially green. This is a transitional situation that applies for 1-2 months after the last killing frost in spring.

"Summer" applies to the period when vegetation is lush and healthy, typical of midsummer, but also of other seasons where frost is less common.

"Autumn' refers to a period when freezing conditions are common, deciduous trees are leafless, crops are not yet planted or are already harvested (bare soil exposed), grass surfaces are brown, and no snow is present.

"Winter" conditions apply for snow-covered surfaces and subfreezing temperatures.

TABLE 13

BOWEN RATIOS* (H/LE) FOR LAND-USE TYPES AND SEASONS

(AVERAGE MOISTURE CONDITIONS)

LAND-USE TYPE	SPRING	SUMMER	AUTUMN	WINTER**
1. WATER (FRESH WATER AND SEA WATER)	0.1	0.1	0.1	1.5***
2. DECIDUOUS FOREST	0.7	0.3	1.0	1.5
3. CONIFEROUS FOREST	0.7	0.3	0.8	1.5
4. SWAMP	0.1	0.1	0.1	1.5
5. CULTIVATED LAND	0.3	0.5	0.7	1.5
6. GRASSLAND	0.4	0.8	1.0	1.5
7. URBAN	1.0	2.0	2.0	1.5
8. DESERT SHRUBLAND	3.0	4.0	6.0	6.0

* The suggested Bowen ratios listed are typical values appropriate for daytime use.

** Winter Bowen ratios depend upon whether a snow cover is present continuously, intermittently, or seldom. Bowen ratios range from the value listed for autumn for rare snow covers to the value listed for winter for a continuous snow cover.

*** This value applies if the water body is frozen over.

DEFINITIONS OF SEASONS:

"Spring" refers to periods when vegetation is emerging or partially green. This is a transitional situation that applies for 1-2 months after the last killing frost in spring.

"Summer" applies to the period when vegetation is lush and healthy, typical of midsummer, but also of other seasons where frost is less common.

"Autumn' refers to a period when freezing conditions are common, deciduous trees are leafless, crops are not yet planted or are already harvested (bare soil exposed), grass surfaces are brown, and no snow is present.

"Winter" conditions apply for snow-covered surfaces and subfreezing temperatures.

TABLE 14

BOWEN RATIOS* (H/LE) FOR LAND-USE TYPES AND SEASONS

(WET CONDITIONS)

LAND-USE TYPE	SPRING	SUMMER	AUTUMN	WINTER**
1. WATER (FRESH WATER AND SEA WATER)	0.1	0.1	0.1	0.3***
2. DECIDUOUS FOREST	0.3	0.2	0.4	0.5
3. CONIFEROUS FOREST	0.3	0.2	0.3	0.3
4. SWAMP	0.1	0.1	0.1	0.5
5. CULTIVATED LAND	0.2	0.3	0.4	0.5
6. GRASSLAND	0.3	0.4	0.5	0.5
7. URBAN	0.5	1.0	1.0	0.5
8. DESERT SHRUBLAND	1.0	1.5	2.0	2.0

* The suggested Bowen ratios listed are typical values appropriate for daytime use.

** Winter Bowen ratios depend upon whether a snow cover is present continuously, intermittently, or seldom. Bowen ratios range from the value listed for autumn for rare snow covers to the value listed for winter for a continuous snow cover.

*** This value applies if the water body is frozen over.

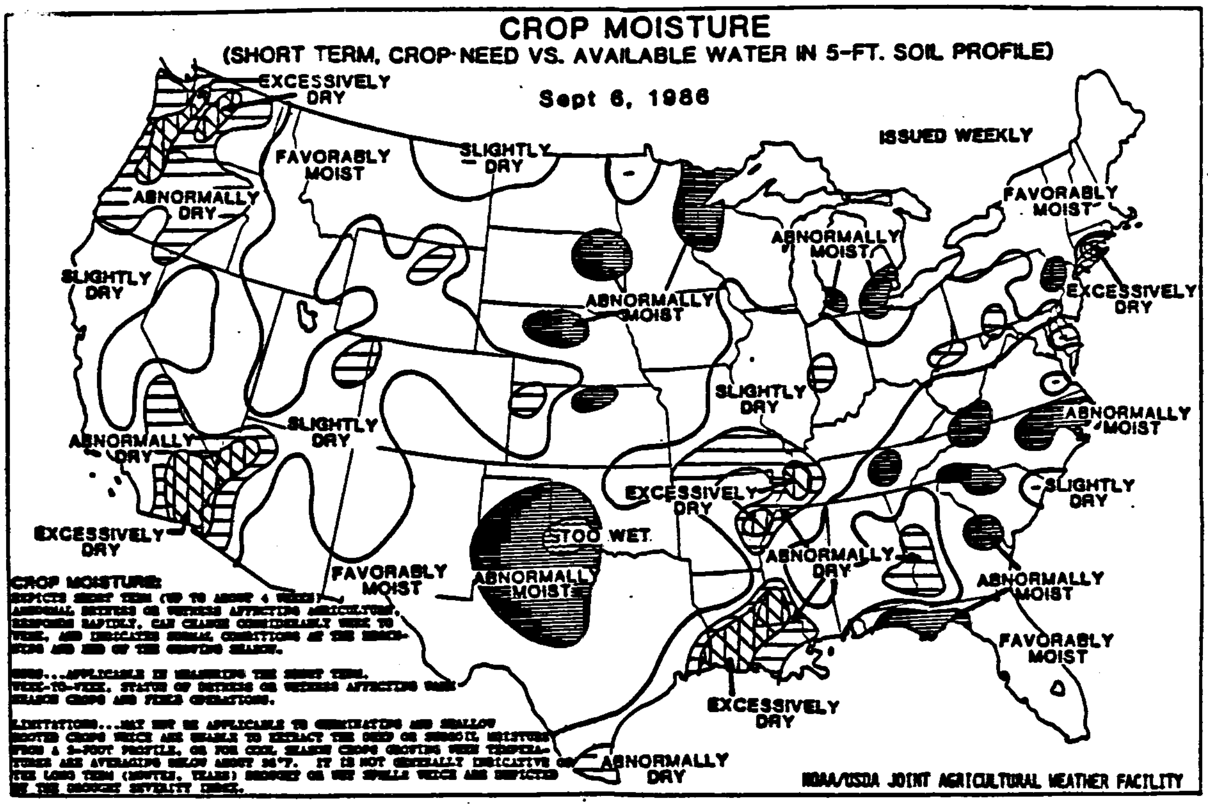
DEFINITIONS OF SEASONS:

"Spring" refers to periods when vegetation is emerging or partially green. This is a transitional situation that applies for 1-2 months after the last killing frost in spring.

"Summer" applies to the period when vegetation is lush and healthy, typical of midsummer, but also of other seasons where frost is less common.

"Autumn' refers to a period when freezing conditions are common, deciduous trees are leafless, crops are not yet planted or are already harvested (bare soil exposed), grass surfaces are brown, and no snow is present.

"Winter" conditions apply for snow-covered surfaces and subfreezing temperatures.



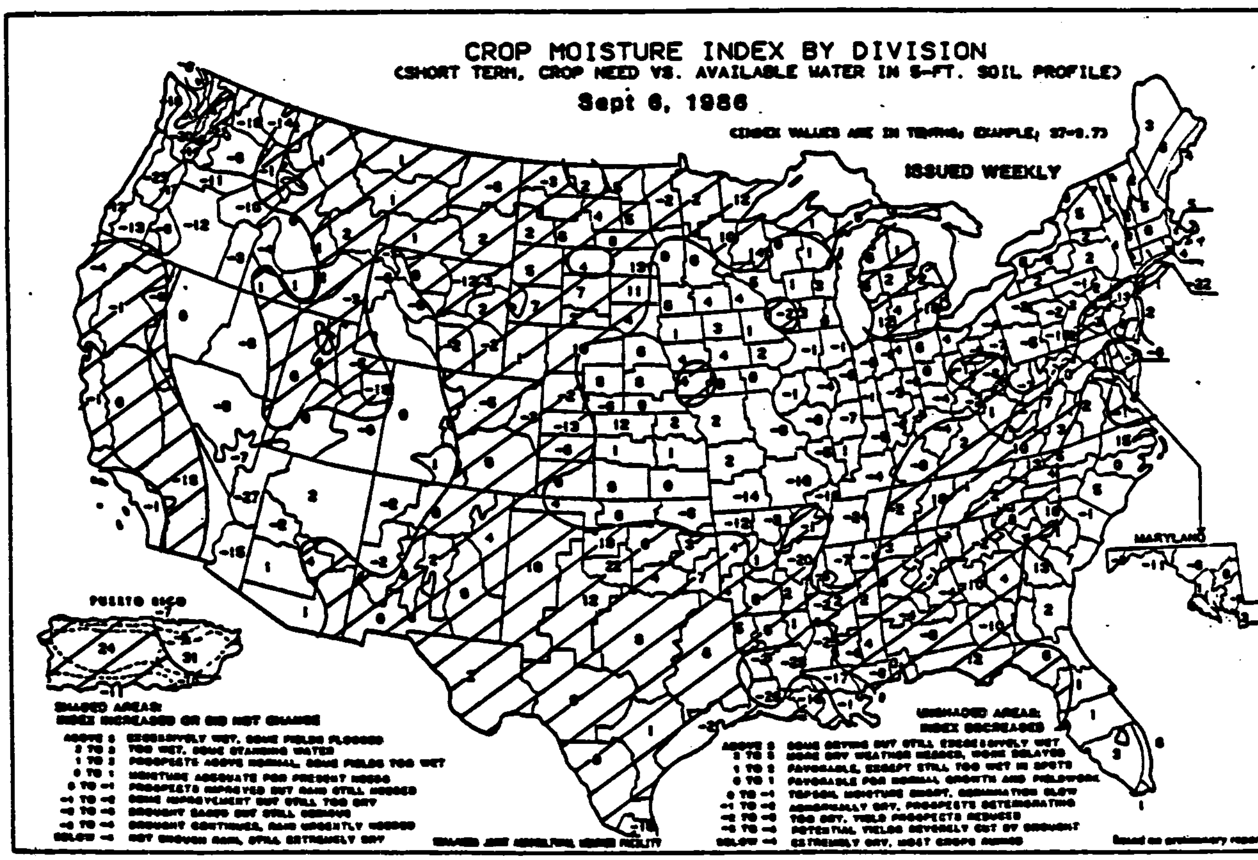
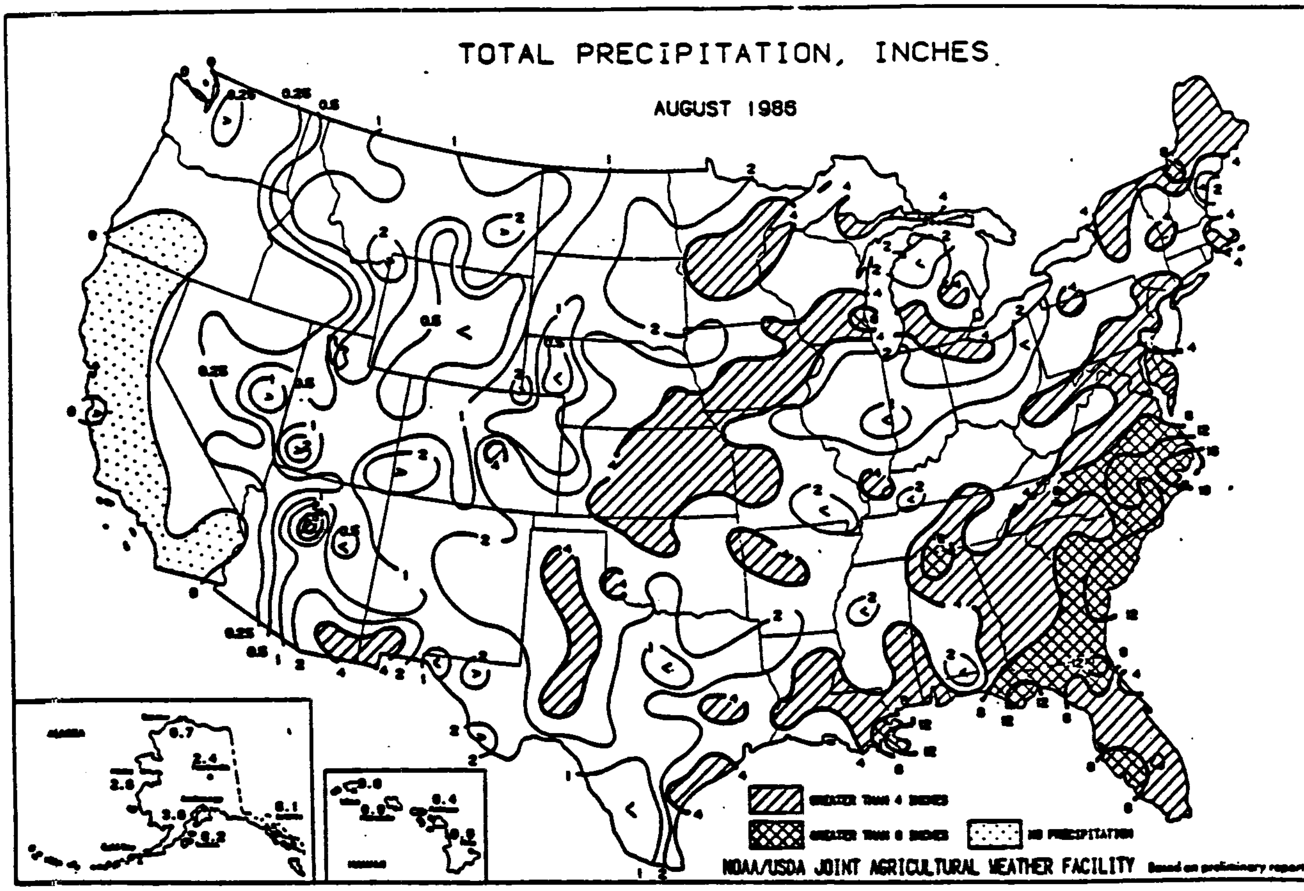


Figure 10. Example of crop moisture maps available weekly from the NOAA/USDA Joint Agricultural Weather Facility.



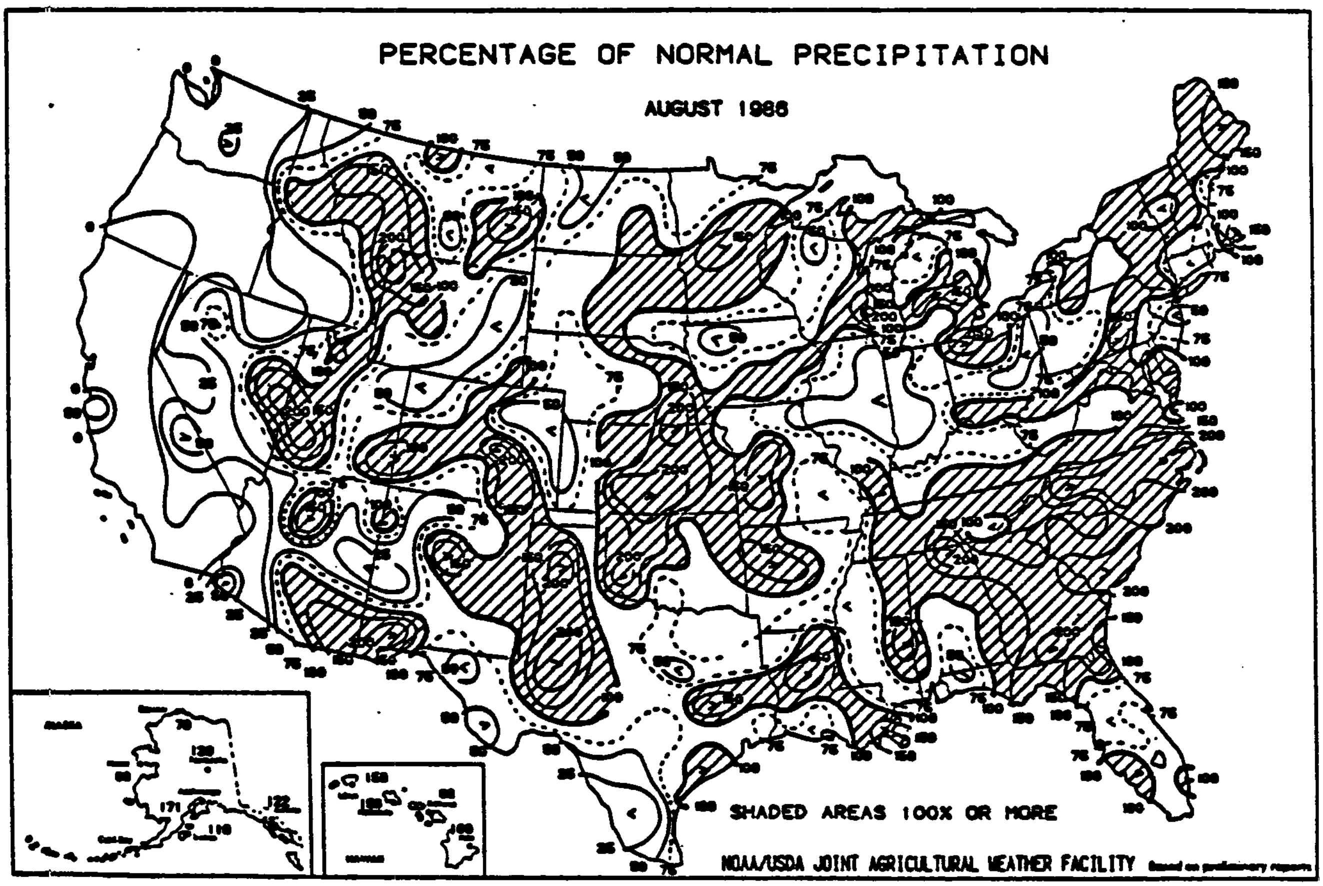


Figure 11. Example of precipitation maps available both weekly and monthly from the NOAA/USDA Joint Agricultural Weather Facility.

REFERENCES

Businger, J.A. 1973. Turbulent Transfer in the Atmospheric Surface Layer. Chapter 2 in Workshop on Micrometeorology. D.A. Haugen (ed.). American Meteorological Society, Boston, MA, Boston, MA.

Carson, D.J. 1973. The Development of a Dry Inversion - Capped Convectively Unstable Boundary Layer. Quart. J.R. Meteorol. Soc., 99: 450-467.

Coulson, K.L., and D.W. Reynolds 1971. The Spectral Reflectance of Natural Surfaces. J. Appl. Meteor., 18: 1495-1295.

Deardorff, J.W. 1980. Progress in Understanding Entrainment at the Top of a Mixed Layer. pp 36-66 in Workshop on the Planetary Boundary Layer J.C. Wyngaard (ed.). American Meteorological Society, Boston, MA.

Flynn, M.S. and J.F. Griffiths, 1980. Variations in Precipitation Parameters between Drought and Nondrought Periods in Texas and Some Implications for Cloud Seeding. J. Appl. Met., 19: 1363-1370.

Hanna, S.R., C.L. Burkhart, and R.J. Paine 1985. Mixing Height Uncertainties. Presented at the Seventh Symposium on Turbulence and Diffusion, Boulder, CO. American Meteorological Society, 45 Beacon Street, Boston, MA.

Hanna, S.R., J.C. Weil, and R.J. Paine, 1986. Plume Model Development and Evaluation - Hybrid Approach EPRI Contract No. RP-1616-27. Prepared for Electric Power Research Institute, Palo Alto, CA.

Holtslag, A.A.M. and A.P. Van Ulden 1983. A Simple Scheme for Daytime Estimates of the Surface Fluxes from Routine Weather Data. J. Climate Appl. Meteor., 22: 517-529.

Iqbal, M. 1983. An Introduction to Solar Radiation, Academic Press, p 286.

Izumi, Y. and J.S. Caughey, 1976. Minnesota 1973 Atmospheric Boundary Layer Experiment Data Report. AFCRL-TR-76-0038. Air Force Cambridge Research Laboratories, Hanscom AFB, MA.

Izumi, Y. 1971: Kansas 1968 Field Program Data Report, AFCRL-72-0041, 27 Dec. 1971, Environmental Research Paper No. 379, Meteor. Lab Proj. No. 7655, Bedford, MA.

Jackson, N.A. 1976. The Propagation of Modified Flow Downstream of a Change in Roughness. Q.J. Roy. Met. Soc., 102: 924.

Kantha, L.H., O.M. Phillips, and R.S. Azod 1977. On Turbulent Entrainment at a Stable Density Interface. J. Fluid Mech.,.37: 643-655.

Kasten, F. and G. Czeplak 1980. Solar and Terrestrial Radiation Dependent on the Amount and Type of Cloud. Solar Energy, 24: 177-189.

Kato, H. and O.M. Phillips 1969. On the Penetration of a Turbulent Layer into a Stratified Fluid. J. Fluid Mech., 37: 643-655.

Lo, A.K. and G.A. McBean 1978. On the Relative Errors in Methods of Flux Calculations. J. Appl. Meteor., 17: 1704-1711.

Lumley, J.L. and H.A. Panofsky 1964. The Structure of Atmospheric Turbulence. Wiley, New York.

Malcher, J. and H. Kraus 1983. Low-Level Jet Phenomena Described by an Integrated Dynamic PBL Model. Boundary Layer Meteor., 27: 327-343.

Monin, A.S. and A.M. Obukhov, 1954. Basic Regularity in Turbulent Mixing in the Surface Layer of the Atmosphere. Tr. Geofiz. Inst., Akad. Nauk, SSSR, Sb. Statei, 4: 163-167.

Montieth, J.L., 1976. Vegetation and the Atmosphere - Volume 2: Case Studies. Academic Press. New York.

Nieuwstadt, F.T.M. 1981. The Steady-State Height and Resistance Laws of the Nocturnal Boundary Layer: Theory Compared with Cabauw Observations. Boundary Layer Meteor., 20: 3-17.

Oke, T.R. 1978. Boundary Layer Climates. John Wiley & Sons, New York.

Randerson, D. 1984. Atmospheric Boundary Layer. Chapter 5 in Atmospheric Science and Power Production (D. Randerson, editor). DOE/TIC-27601 (DE84005177). Office of Scientific and Technical Information. U.S. Department of Energy.

Raynor, G.S., S. Sethuraman, and R.M. Brown 1979. Formation and Characteristics of Coastal Internal Boundary Layers during Onshore Flows. Boundary Layer Meteor., 16: 487-514.

Schubert, J.F. 1977. Acoustic Detection of a Momentum Transfer During the Abrupt Transition from a Laminar to a Turbulent Atmospheric Boundary Layer. J. Appl. Meteor., 16: 1292-1297.

Sheih, C.M., M.L. Wesely, and B.B. Hicks, 1979. Estimated Dry Deposition Velocities of Sulfur over the Eastern United States and Surrounding Regions. Atmos. Environ., 3: 361-368.

Tennekes, H. 1973. A Model for the Dynamics of the Inversion above a Convective Boundary Layer. J. Atmos Sci., 30: 558-368.

Thorpe, A., J. and T.H. Guymer 1977. The Nocturnal Jet. Quart. J. Roy. Meteor. Soc., 103: 633-653.

U.S. Environmental Protection Agency 1986. Guidelines on Air Quality Models (Revised). EPA-450/2-78-027R. July 1986. Office of Air Quality Planning and Standards. Research Triangle Park, NC.

Venkatram, A. 1980. Estimating the Monin-Obukhov Length in the Stable Boundary Layer for Dispersion Calculations. Boundary Layer Meteor., 19: 481-485.

Weil, J.C. and R.P. Brower 1983. Estimating Convective Boundary Layer Parameters for Diffusion Applications, Draft Report Prepared by Environmental Center, Martin Marietta Corp., for Maryland Dept. of Natural Resources.

Yamada, T. and Mellor 1975. A Simulation of the Wangara Atmospheric Boundary Layer Data. J. Atmos. Sci., 32: 2309-2329.

Zilitinkevich, S.S. 1972. On the Determination of the Height of the Ekman Boundary Layer. Boundary Layer Meteor., 3: 141-145.

APPENDIX A
TESTS OF METPRO USING
KANSAS AND MINNESOTA FIELD DATA

APPENDIX A

TESTS OF METPRO USING KANSAS AND MINNESOTA FIELD DATA

To test the METPRO parameterizations of surface boundary layer variables, observations of the friction velocity and the surface heat flux were analyzed from early boundary layer research experiments at Kansas in 1968 (Izumi, 1971) and at Minnesota in 1973 (Izumi and Caughey, 1976). The heat fluxes from the Kansas and Minnesota experiments were determined by covariance measurements. The friction velocity was determined by the covariance method at Minnesota and by drag plate measurements at Kansas. The roughness heights used for the various sites were: 0.0016 m for Minnesota (Weil-Brower, 1983), and 0.024 m for Kansas (Izumi, 1971).

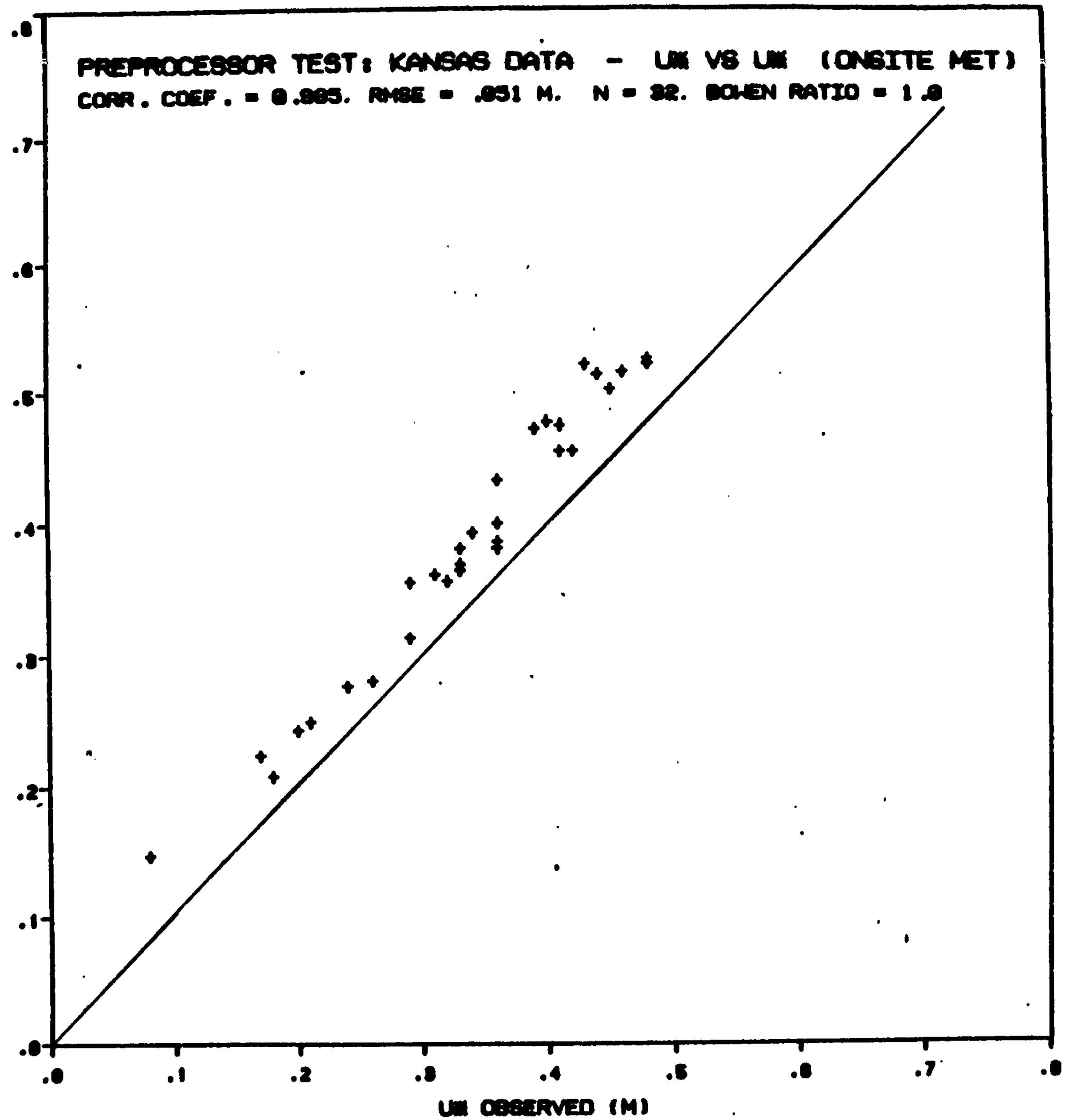
The Kansas experiment was conducted during the summer of 1968 in an extremely flat area of farm land in southwest Kansas. The experiment area was dry and covered with wheat stubble about 18 cm high. A 32-m meteorological tower featured fast-response instruments for direct measurements of heat and momentum fluxes as well as slow-response instruments to measure vertical profiles of wind speed and temperature. A total of 32 case hours are available for analysis.

For daytime hours, the Holtslag-van Ulden method was used to derive estimates of u_* and L, while at night, the Weil-Brower method was used. The sensitivity of the results to the use of off-site rather than on-site measurements of wind speed and insolation was tested. Changes in the value of the Bowen ratio were also tested.

Figure A-1 shows the u_* comparison at Kansas with on-site meteorology, and Figure A-2 gives the results for off-site data. Most of the deterioration of estimation accuracy is due to the off-site wind speeds, rather than insolation (as revealed by additional comparisons not shown here). Sensitivity runs with different Bowen ratio values yielded insignificant changes in the results.

The results of the estimation of daytime and nighttime Monin-Obukhov length (using both on-site and off-site meteorology) are shown in Figures A-3 to A-6. The use of off-site meteorology at night leads to a <u>substantially worse agreement</u>, mostly due to the off-site wind speeds used.

In September 1973, a second series of experiments was conducted over a flat site in northwestern Minnesota. These experiments utilized meteorological measurements similar to those taken in Kansas, but only daytime periods were studied (11 case-hours in all). Results of the comparison of estimated to observed values of u_* and L were qualitatively similar. Table A-1 summarizes the comparisons of estimated and observed u_* and L values at the Kansas and Minnesota sites.



PREPROCESSOR TEST: KANSAS DATA - UM VS UM (ONSITE MET)
CORR. COEF. = 0.985. RMSE = .051 M. N = 32. BOWEN RATIO = 1.0
UM PREDICTED (M)
UM OBSERVED (M)
.0
.1
.2
.3
.4
.5
.6
.7
.8

Figure A-1.

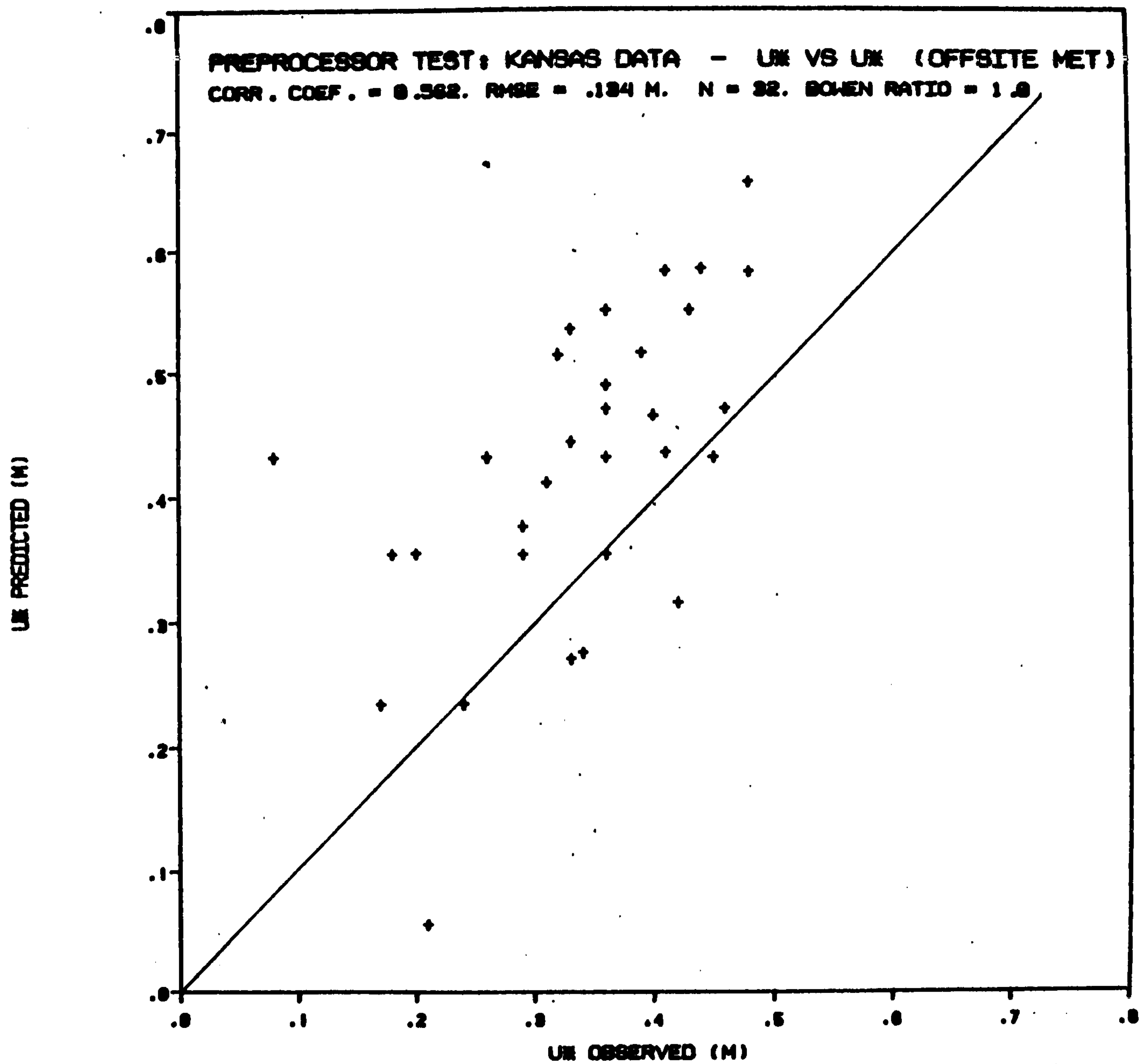

PREPROCESSOR TEST: KANSAS DATA - U* VS U* (OFFSITE MET)
CORR. COEF. = 0.562. RMSE = .134 M. N = 32. BOWEN RATIO = 1.0
U* PREDICTED (M)
U* OBSERVED (M)
.0
.1
.2
.3
.4
.5
.6
.7
.8

Figure A-2.

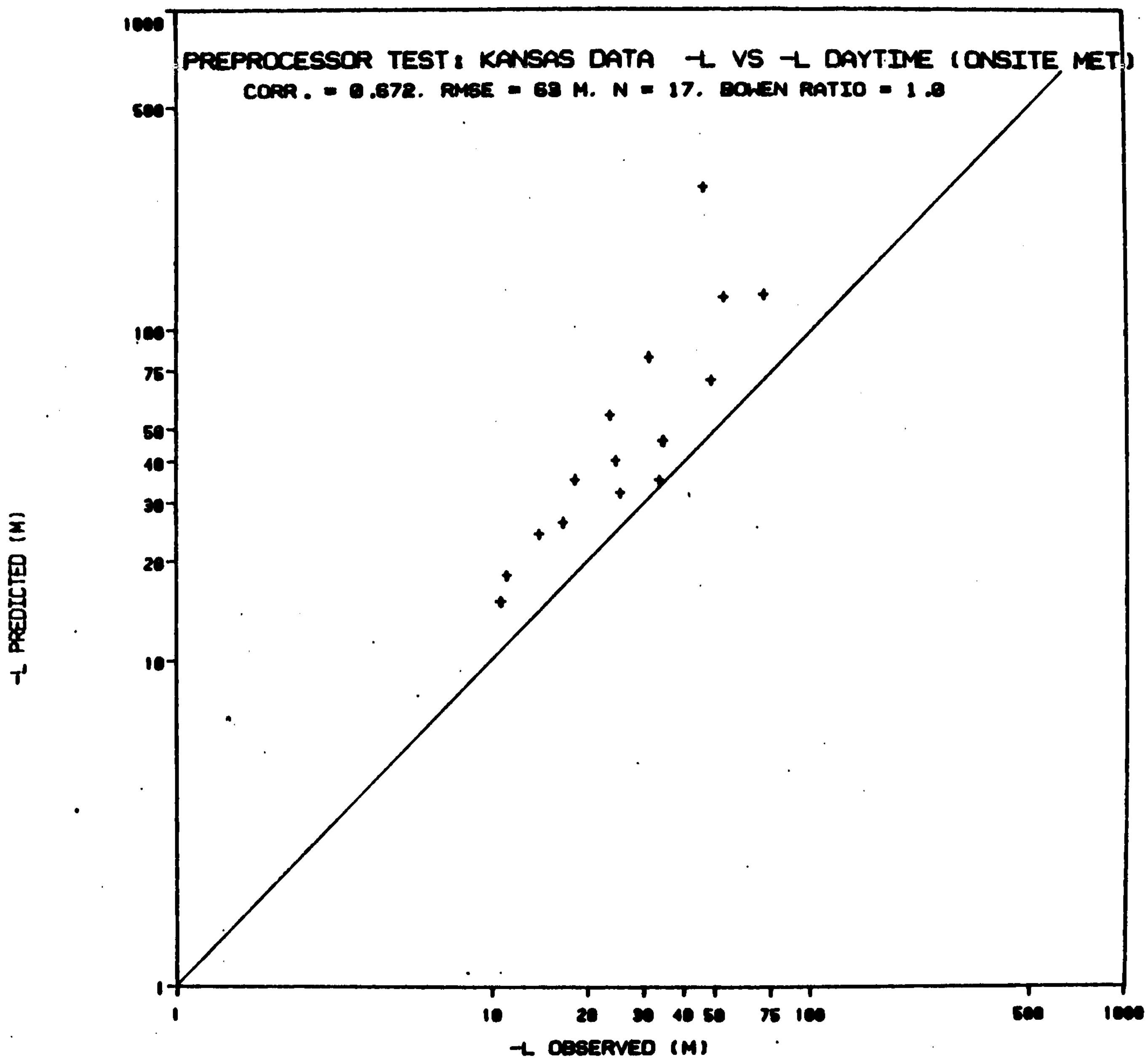

PREPROCESSOR TEST: KANSAS DATA -L VS -L DAYTIME (ONSITE MET)
CORR. = 0.672. RMSE = 63 M. N = 17. BOWEN RATIO = 1.0
-L PREDICTED (M)
-L OBSERVED (M)
1
10
20
30
40
50
75
100
500
1000

Figure A-3.

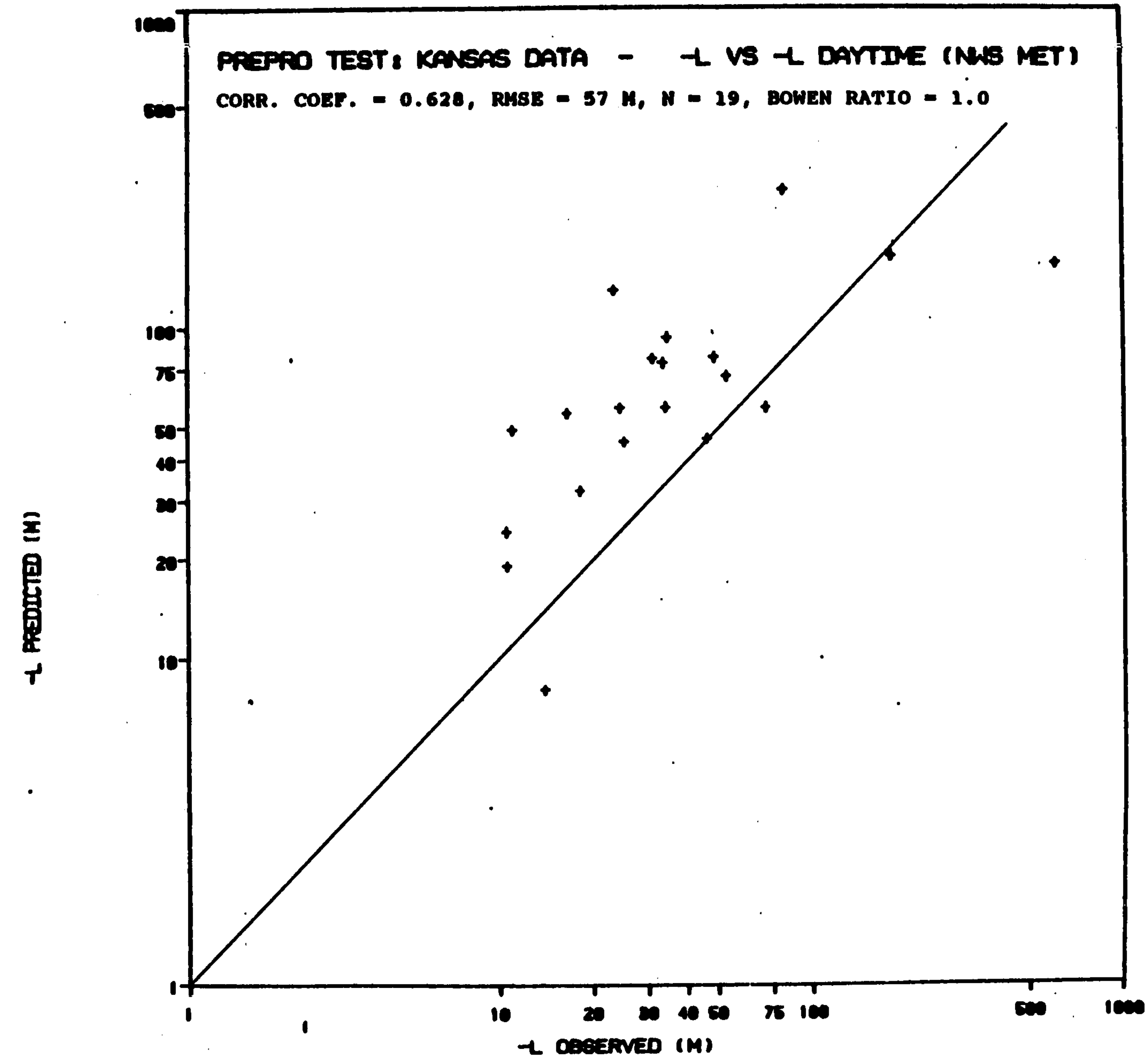

PREPRO TEST: KANSAS DATA - -L VS -L DAYTIME (NWS MET)
CORR. COEF. = 0.628, RMSE = 57 M, N = 19, BOWEN RATIO = 1.0
1000
500
100
75
50
40
30
20
10
1
1
10
20
30
40
50
75
100
500
1000
-L OBSERVED (M)
-L PREDICTED (M)

Figure A-4.

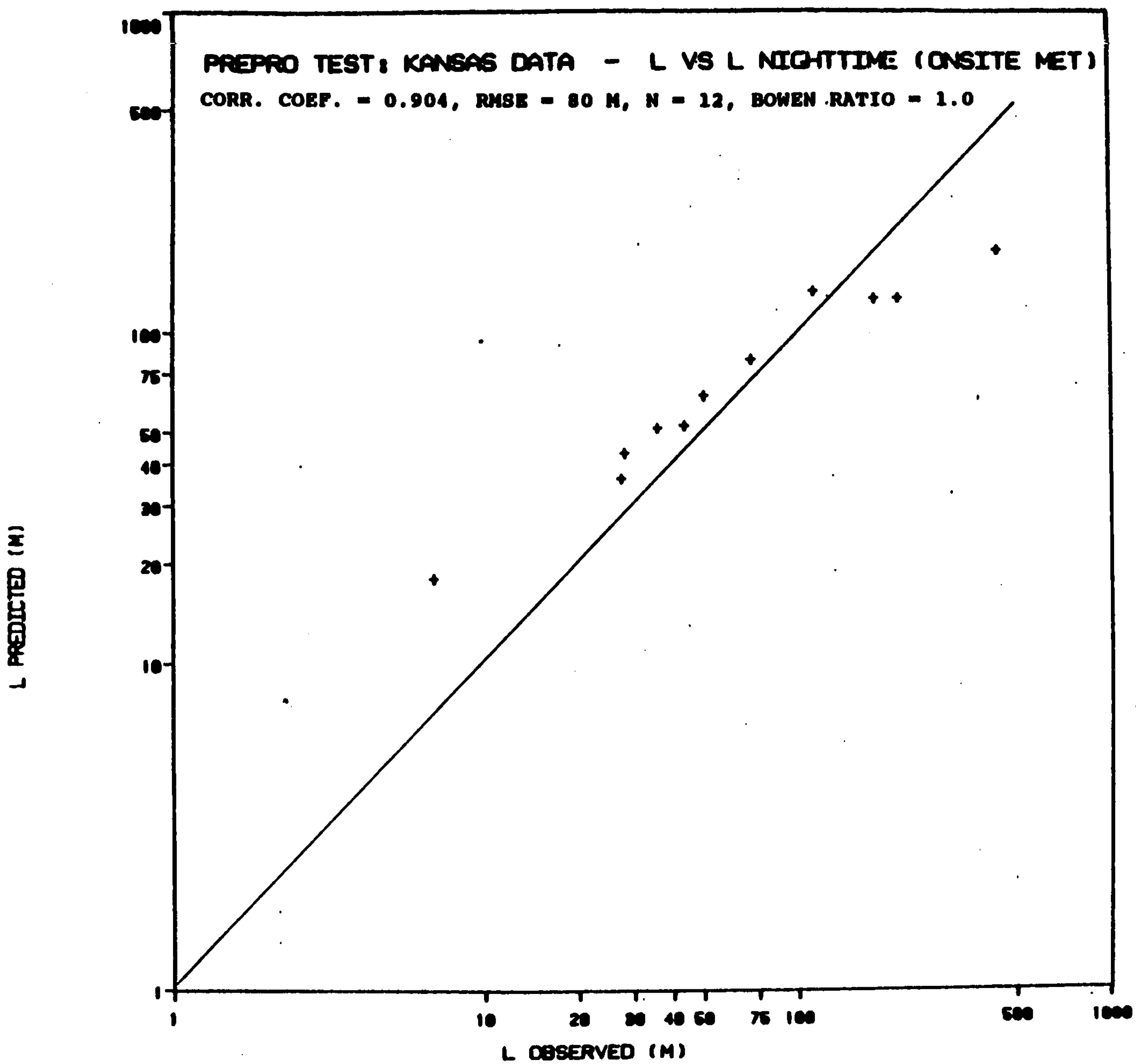

PREPRO TEST: KANSAS DATA - L VS L NIGHTTIME (ONSITE MET)
CORR. COEF. = 0.904, RMSE = 80 M, N = 12, BOWEN RATIO = 1.0
1000
500
100
75
50
40
30
20
10
1
1
10
20
30
40
50
75
100
500
1000
L OBSERVED (M)
L PREDICTED (M)

Figure A-5.

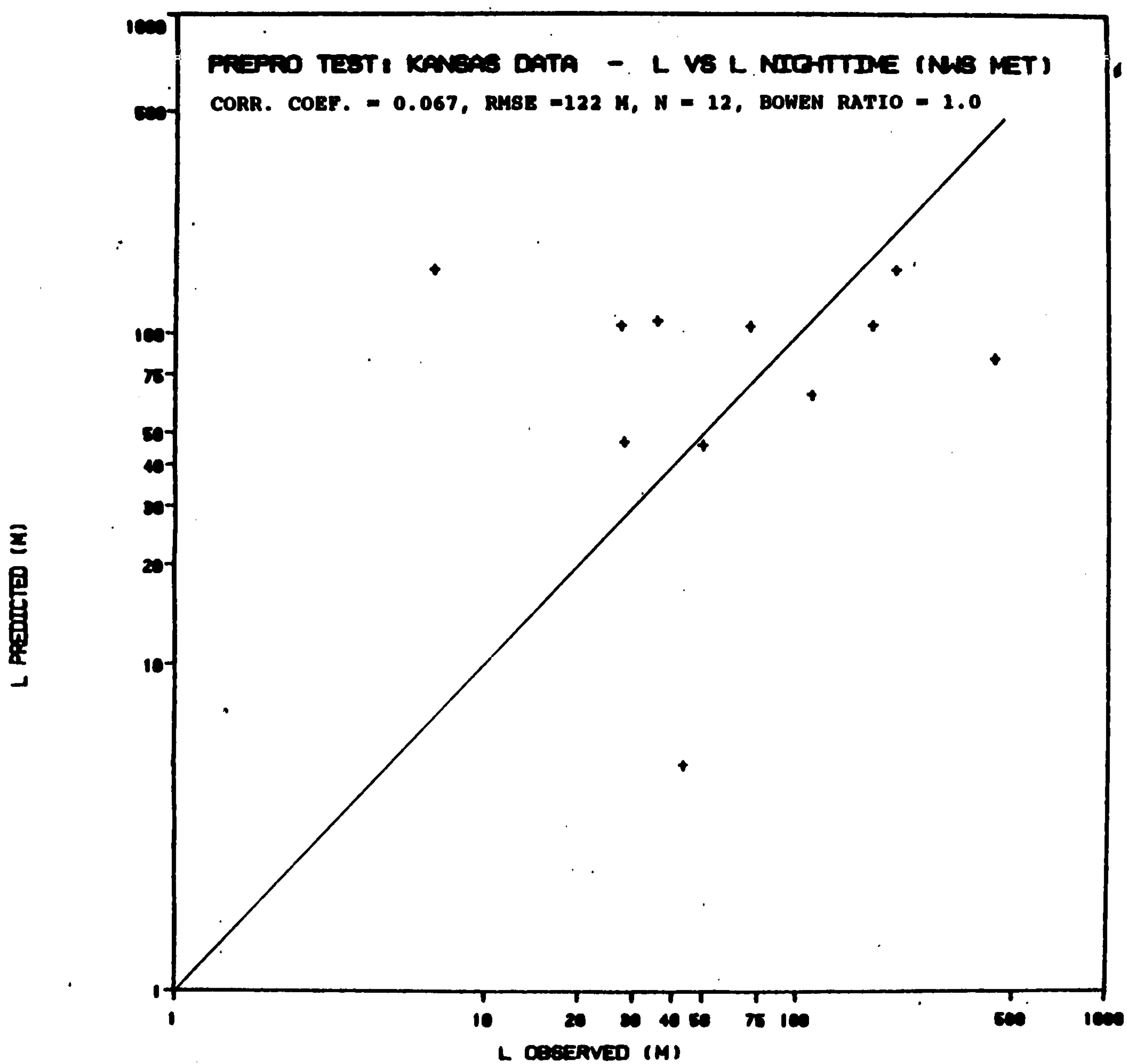

PREPRO TEST: KANSAS DATA - L VS L NIGHTTIME (NWS MET)
CORR. COEF. = 0.067, RMSE =122 M, N = 12, BOWEN RATIO = 1.0
L PREDICTED (M)
L OBSERVED (M)
1
10
20
30
40
50
75
100
500
1000

Figure A-6.

TABLE A-1

COMPARISON OF ESTIMATED AND OBSERVED VALUES OF u_* AND L AT KANSAS AND MINNESOTA SITE

Site	Parameter	Met Data	Day/Night	# Samples	Correlation Coefficient	RMS Error*
Kansas	u_*	On-site	Day and Night	32	0.985	0.051
	u_*	Off-site	Day and Night	32	0.562	0.134
	u_*	On-site**	Day and Night	32	0.987	0.055
	L	On-site	Day	17	0.672	63
	L	Off-site	Day	19	0.628	57
	L	On-site	Night	12	0.904	80
	L	Off-site	Night	12	0.067	122
Minnesota	u_*	On-site	Day	11	0.955	0.046
	u_*	Off-site	Day	11	0.351	0.097
	L	On-site	Day	11	0.917	8.8
	L	Off-site	Day	11	0.126	124.4

*u_* RMSE in m/sec, L RMSE in meters.

**On-site winds, but off-site insolation estimate from NWS cloud cover data.

APPENDIX B
EXCERPTS FROM
"ESTIMATING CONVECTIVE BOUNDARY LAYER PARAMETERS FOR DIFFUSION APPLICATIONS"

by J. C. Weil and R. P. Brower

III. CONVECTIVE BOUNDARY LAYER HEIGHT

A. MODIFIED CARSON MODEL

We now consider the evolution of the height and potential temperature of the CBL, which is capped by a relatively thin interfacial layer separating it from the stable air aloft. Stable air is entrained into the interfacial layer, as a result of vertical mixing due to thermals penetrating the top of the CBL. As noted earlier, within the mixed layer ($z > 0.1h$), the potential temperature θ and wind speed u are relatively uniform, but in the interfacial layer, they rapidly adjust with height to their values in the overlying stable air.

Carson (1973) simplifies the modeling of boundary layer evolution by ignoring radiation, latent heat effects, and advection of energy. He includes the effects of time-dependent surface heating, capping layer stability, large-scale air subsidence, and any degree of turbulent interfacial mixing. Carson idealizes the potential temperature distribution by assuming it to be uniform with z within the CBL, to undergo a step change $\Delta\theta_h$ at the top of the CBL ($z = h$), and to vary linearly with z in the overlying stable air. He also considers the stable air as comprising 3 or so vertical layers, each with a different lapse rate, instead of as a single stable layer.

We have modifed Carson's model by: first, and most importantly, permitting the elevated stable layer to have an arbitrary temperature distribution with z (i.e., an infinite number of vertical layers), which is more realistic than a linear variation in z; second, allowing for surface stress-induced (mechanical) mixing, which can be important in the early morning hours when the heat flux is low; and third, neglecting subsidence. In the following discussion, we assume that convective and mechanical mixing are independent of one another, and, as a simplifying measure, we also assume that when one of these mixing modes is operative the other is not. Figure 5 shows the assumed potential temperature distribution where the solid curve is the initial temperature profile, $\theta_s(z)$, and the dashed curve is the profile at a later time t. The "overshoot" σ is a measure of the degree of entrainment or interfacial mixing and is a function of time as are the mixed-layer temperature and height, θ_c and h, respectively, and the temperature jump $\Delta\theta_h$. When there is no overshoot, $\Delta\theta_h=0$, and the mixed-layer only "encroaches" on the elevated stable layer.

The general relationships for boundary layer evolution are given first and apply either for convective or mechanical mixing at z = h; the relationships follow generally from Carson. The energy equation for the mixed layer is

$$\frac{d\theta_c}{dt} = - \frac{1}{\rho_o c_p} \frac{\partial Q}{\partial z} \tag{12}$$

where Q is the turbulent heat flux in the vertical direction. The invariance of θ_c with height means that $\partial Q/\partial z$ is independent of height, and therefore

$$\frac{\partial Q}{\partial z} = - \frac{Q_o(t) - Q_h(t)}{h} \tag{13}$$

where subscripts o and h denote surface and z = h, respectively. As shown by Carson, the heat flux Q_h into the mixed layer from above can be obtained by integrating the energy equation (with $d\theta_c/dt$ replaced by $d\theta/dt$) across the temperature discontinuity. The result is

$$Q_h(t) = - \rho_o c_p \frac{dh}{dt} \Delta\theta_h \tag{14}$$

which is Carson's Eq. (12) with the subsidence velocity, w(h), set equal to zero. A final relationship needed for the analysis

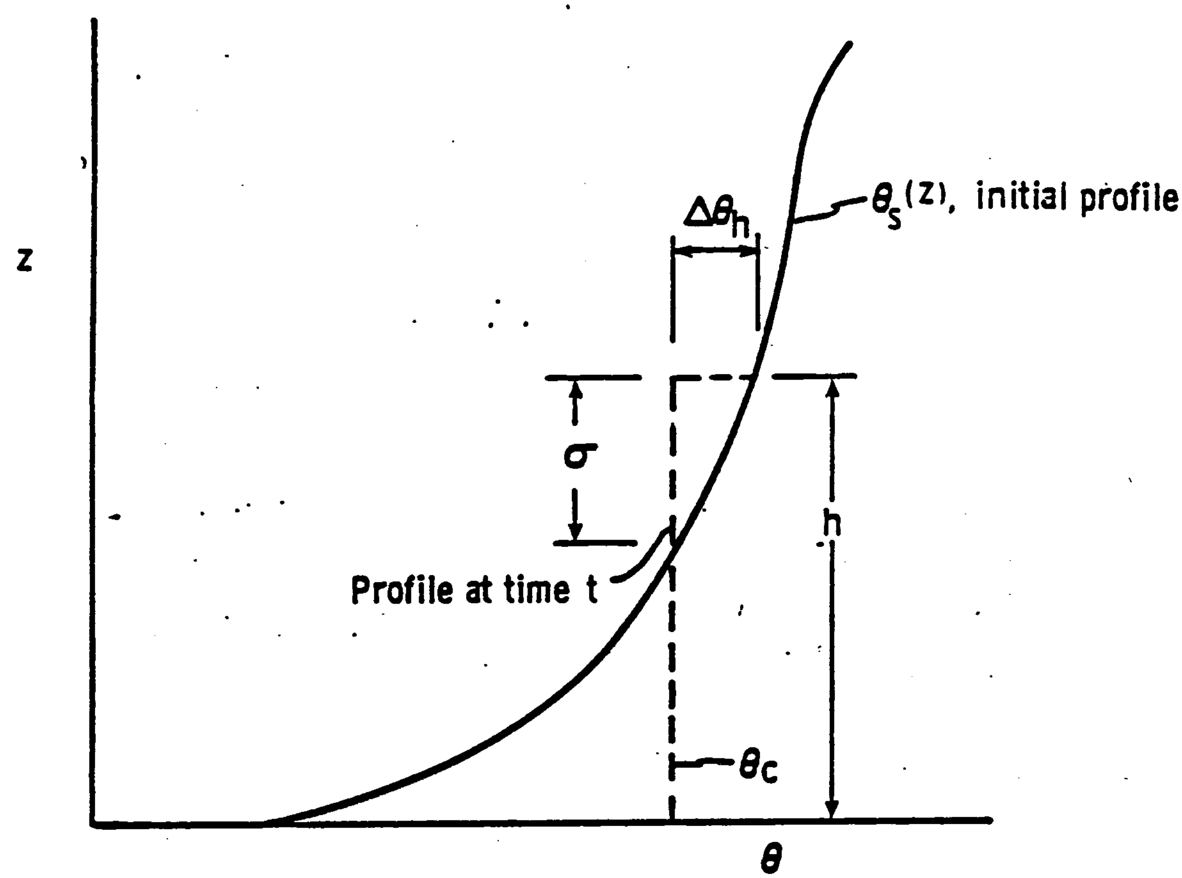


Figure 5. Schematic of idealized potential temperature distribution in the convective boundary layer.

comes from the assumed temperature distribution (Fig. 5). As can be seen, the change in the mixed-layer temperature, $\Delta\theta_c(t) = \theta_c(t) - \theta_c(0)$, is

$$\Delta\theta_c = \int_0^h \gamma(\eta)d\eta - \Delta\theta_h \tag{15}$$

where γ is the slope of the initial temperature distribution, $\gamma = d\theta_s/dz$. The temperature jump $\Delta\theta_h$ is given by

$$\Delta\theta_h = \int_{h-\sigma}^{h} \gamma(\eta)d\eta \tag{16}$$

and can be approximated by

$$\Delta\theta_h = \gamma(h)\sigma \tag{17}$$

provided that σ/h is sufficiently small or that the local curvature of $\theta_s(z)$ can be ignored.

Two rate equations for h and σ can now be obtained. The first is found by substituting Eqs. (13), (15), and (17) into Eq. (12). The result is

$$\gamma(h)\frac{dh}{dt} - \gamma(h)\frac{d\sigma}{dt} = \frac{Q_o(t) - Q_h(t)}{\rho_o c_p h} \tag{18}$$

which is similar to Carson's Eq. (16). The second is obtained by substituting Eq. (17) into Eq. (14). The result is

$$\gamma(h)\frac{dh}{dt} = - \frac{Q_h(t)}{\rho_o c_p \sigma} \tag{19}$$

which is similar to Carson's Eq. (17). A final equation relating σ and h can be written by dividing Eq. (18) by Eq. (19), which produces

$$\frac{d\sigma}{dh} + \frac{Q_h(t) - Q_o(t)}{Q_h(t)} \frac{\sigma}{h} - 1 = 0. \tag{20}$$

The above equations can now be applied to the separate situations of either convectively or mechanically induced entrainment at $z = h$.

Convectively Induced Entrainment

The heat flux into the boundary layer as a result of entrainment at its top is assumed to be proportional to the surface heat flux:

$$Q_h(t) = -AQ_o(t) \tag{21}$$

where A is a constant (Carson, 1973). The solution to Eq. (20), with σ and $h = 0$ at $t = 0$, is then the same as given by Carson:

$$\sigma = \lambda h \tag{22}$$

where

$$\lambda = \frac{A}{1+2A} \quad . \tag{23}$$

In the following discussion, A is taken as 0.2 (Deardorff, 1980).

To find h and $\Delta\theta_c$ as functions of time, we substitute Eqs. (21) to (23) into Eq. (18), which yields

$$\gamma(h)hdh = (1+2A)\,\frac{Q_o(t)}{\rho_o c_p}\,dt \quad . \tag{24}$$

Both sides of this equation can be integrated, the left-hand side (lhs) by parts, with the result

$$h\theta_s(h) - \int_0^h \theta_s d\eta = (1+2A)\int_0^t \frac{Q_o(\tau)}{\rho_o c_p}\,d\tau \quad . \tag{25}$$

This equation can now be used to find h(t) with the lhs determined from the initial temperature distribution.

The temperature change $\Delta\theta_c$ is found by substituting Eqs. (17) and (22) into Eq. (15). The result is

$$\Delta\theta_c = \theta_s(h) - \theta_s(0) - \lambda\gamma(h)h, \tag{26}$$

which can be computed once h versus t is known.

Mechanically Induced Entrainment

In the case of entrainment resulting from surface shear stress, the only heat flux entering the boundary layer is at the top, i.e., $Q_o = 0$. The solution to Eq. (20), with σ and $h = 0$ at $t = 0$, is then

$$\sigma = \frac{h}{2} \ . \tag{27}$$

The heat flux at $z = h$ is parameterized after Tennekes (1973) and Kato and Phillips (1969):

$$Q_h(t) = -B \frac{T_o \, u_*^3}{gh} \rho_o c_p \ . \tag{28}$$

The value of 2.5 was chosen for the constant B based on the latter authors' laboratory experiments simulating thermocline erosion in the ocean. Later experiments by Kantha et al. (1977) resulted in B = 5. However, these experiments were conducted with two homogeneous layers of fluid of differing density, i.e., there was no stratification in the "upper" layer (actually the lower layer in their inverted experiment). We have chosen to use the Kato and Phillips result for B because the "upper" layer in their experiment was stably stratified as are elevated inversions in the atmosphere.

Solving for h and $\Delta\theta_c$ as functions of time is done the same way as for convectively induced entrainment. We substitute Eqs. (27) and (28) into Eq. (18), and find, after rearrangement,

$$\gamma(h)h^2 dh = 2B \frac{T_o \, u_*^3}{g} dt \ , \tag{29}$$

which can be integrated to yield:

$$h^2\theta_s(h) - 2\int_0^h \eta\theta_s d\eta = 2B \frac{T_o}{g} \int_0^t u_*^3 \, d\tau \ . \tag{30}$$

This equation gives the dependence of h on t, where the lhs is found from integration of the initial potential temperature profile. The temperature change is found by substituting Eqs. (17) and (27) into Eq. (15), which results in

$$\Delta\theta_c = \theta_s(h) - \theta_s(0) - \frac{\gamma(h)h}{2}. \tag{31}$$

In situations where both convective and mechanical mixing occur at $z = h$ (the usual case), we assume that the stronger mixing mode dominates; thus we choose the larger of the h predictions from Eqs. (25) and (30).

APPENDIX C
READ62 TEST CASE

APPENDIX C

READ62 TEST CASE

The test case shown here consists of two input files and two output files:

File Name	Content	References
OPT62	Input options	Figure C-1
TD6201	"Raw" upper air input data	Figure C-2
OUTPUT	Verification of input; listing of soundings processed	Figure C-3
RAWIN	Processed upper air data; used by METPRO	Figure C-4

```
84 001 00 84 005 12 500
1 1 1 1
```

Figure C-1. Input options file for READ62 ("OPT 62").

```
000147354245N07348W19840101000790000010239+00086-07004518000300000000000410180+0
400000010001409780+00443-07604624800500000020001909570+00612-0630412710070000002
-07603228801000000020003509000+01091-06003229301200000003000370893 0+01152-0550332
408000+02014-062023288013000000030008107500+02518-075021276014000000030008707330+0
600000010011506500+03619-127021267019000000030012306290+03870-1350192670200000002
-19401926301800000003001560548 0+04906-19601926301800000002001690517 0+05336-2290552
404820+05847-253035271016000000020019404610+06169-268057276016000000020019904500+0
800000010024203690+07738-394035255018000000020025403500+08101-4219992630180000003
-54899922902400000004003310250 0+10299-53899922003200000001003890200 0+11734-5359992
501740+12624-567999244031000000020044801600+13158-552999246033000000020046601500+1
300000020050701250+14715-598999252031000000030056101000+16100-6269992550320000001
-63299926901900000001006590065 0+18756-60499926002000000002006740060 0+19253-6199992
500400+21736-631999272022000000030078400370+22217-621999268023000000020081900310+2
99999999199999999999-99999-999999999999999999919999999999-99999-9999999999999999999
-999999999999999999919999999999-99999-999999999999999999919999999999-99999-9999999
999999-99999-999999999999999999919999999999-99999-999999999999999999919999999999-9
99999999199999999999-99999-999999999999999999919999999999-99999-9999999999999999999
-999999999999999999919999999999-99999-999999999999999999919999999999-99999-9999999
999999-99999-999999999999999999919999999999-99999-999999999999999999919999999999-9
99999999199999999999-99999-999999999999999999919999999999-99999-9999999999999999999
-999999999999999999919999999999-99999-999999999999999999919999999999-99999-9999999
999999-99999-999999999999999999919999999999-99999-999999999999999999919999999999-9
000147354245N07348W19840101120790000010252+00086-07005735000200000000000410130+0
500000010001209810+00430-06406334500600000020001909500+00680-0840833510070000003
-10109034400800000030004708500+01537-11909732100800000001000490845 0+01582-1200973
308350+01674-064098311008000000020006308000+02008-075084306008000000030006507940+0
700000020007907510+02501-05801933500700000002000790750 0+02512-0580193350070000003
-11202230301000000020011306500+03621-11903330201000000030011806380+03763-1330542
206000+04229-160042294010000000300138058 50+04419-180048296010000000200147056 20+0
000000030017005000+05579-24401929201300000001001920450 0+06338-3030192950120000003
-44199929301400000030026803100+08877-50599928401300000002002740300 0+09091-5119992
202500+10266-541999259022000000010033902180+11148-525999262018000000020035602020+1
300000010036301950+11867-51099925002300000002003770183 0+12278-5329992500230000002
-54199926602600000001004170146 0+13731-52199926702500000002004400125 0+14723-5829992
701000+16109-627999268023000000010049600890+16826-636999273024000000020051300800+1
200000020053300700+18304-646999268021000000010055400600+19249-6339992710230000003
-63299927202100000001006130040 0+21746-63299927502600000003006560030 0+23513-6349992
999999-99999-999999999999999999919999999999-99999-999999999999999999919999999999-9
99999999199999999999-99999-999999999999999999919999999999-99999-9999999999999999999
-999999999999999999919999999999-99999-999999999999999999919999999999-99999-9999999
999999-99999-999999999999999999919999999999-99999-999999999999999999919999999999-9
99999999199999999999-99999-999999999999999999919999999999-99999-9999999999999999999
-999999999999999999919999999999-99999-999999999999999999919999999999-99999-9999999
999999-99999-999999999999999999919999999999-99999-999999999999999999919999999999-9
000147354245N07348W19840102000790000010273+00086-06006530000300000000000410190+0
200000010002409500+00696-08606715600300000030003309220+00928-0960661630050000002
-12607416500300000020004908710+01364-11104916300200000002000530861 0+01453-0650191
208040+01990-040020281002000000020007308000+02029-041020282002000000030009107500+0
400000010013306500+03651-10802128900600000030013706440+03722-1130222880060000002
-18703129801300000003002310500 0+05619-23203730401500000001002710450 0+06381-2940402
803800+07563-396046298024000000020037103500+08123-440999298026000000030043503000+0
300000040053402310+10796-57799929002700000002005390229 0+10851-5499992890250000002
-54999926101900000003007110150 0+13557-55599927102200000001007400141 0+13953-5419992
301140+15294-614999273024000000020088601000+16103-634999262017000000010100800800+1
900000010110000690+18377-6409999999999000000021999999999-99999-9999999999999999999
-999999999999999999919999999999-99999-999999999999999999919999999999-99999-9999999
999999-99999-999999999999999999919999999999-99999-999999999999999999919999999999-9
```

Figure C-2. Raw upper air data (TD-6201 format) used by READ62 ("TD6201").

99999999199999999999-99999-99999999999999999991999999999-99999-9999999999999999999
-99999999999999999991999999999-99999-99999999999999999991999999999-99999-9999999
999999-99999-99999999999999999991999999999-99999-99999999999999999991999999999-9
99999999199999999999-99999-99999999999999999991999999999-99999-9999999999999999999
-99999999999999999991999999999-99999-99999999999999999991999999999-99999-9999999
999999-99999-99999999999999999991999999999-99999-99999999999999999991999999999-9
99999999199999999999-99999-99999999999999999991999999999-99999-9999999999999999999
-99999999999999999991999999999-99999-99999999999999999991999999999-99999-9999999
999999-99999-99999999999999999991999999999-99999-99999999999999999991999999999-9
000147354245N07348W19840102120790000010215+00086-06008917000400000000000310140+0
70000010001309820+00395-075098179009000000020002209500+00653-080098191010000000003
-085098246009000000030004908630+01399-071098276012000000020005308500+01517-0720982
408170+01824-100047271015000000020006608130+01862-093086271015000000020006808070+0
600000030008807500+02486-096092258013000000030010807000+03018-1060972440150000001
-111095248018000000030014906090+04088-127089255017000000020015306000+04202-1340892
705500+04858-179087252019000000030020405000+05566-215081249023000000010022904500+0
70000001002740378 0+07563-383063245030000000020030003500+08091-4219992480350000003
-515999253037000000010037402500+10271-605999254036000000040038402390+10551-6109992
802000+11684-535999258030000000010044401750+12543-538999260027000000030047601500+1
400000002005070126 0+14644-551999262025000000020050801250+14695-5539992620250000003
-633999262026000000030061600730+18030-635999999999000000021999999999-99999-9999999
999999-99999-99999999999999999991999999999-99999-99999999999999999991999999999-9
99999999199999999999-99999-99999999999999999991999999999-99999-9999999999999999999
-99999999999999999991999999999-99999-99999999999999999991999999999-99999-9999999
999999-99999-99999999999999999991999999999-99999-99999999999999999991999999999-9
99999999199999999999-99999-99999999999999999991999999999-99999-9999999999999999999
-99999999999999999991999999999-99999-99999999999999999991999999999-99999-9999999
999999-99999-99999999999999999991999999999-99999-99999999999999999991999999999-9
99999999199999999999-99999-99999999999999999991999999999-99999-9999999999999999999
-99999999999999999991999999999-99999-99999999999999999991999999999-99999-9999999
999999-99999-99999999999999999991999999999-99999-99999999999999999991999999999-9
000147354245N07348W19840103000790000010140+00086-04507716000300000000000310000+0
300000002000130964 0+00485-033073265005000000020001609500+00601-0430752740060000003
-081086290011000000030003908720+01269-101095298013000000020004508500+01466-1140953
907740+02185-114095305013000000020007607500+02427-117084306014000000030008107360+0
500000002000940700 0+02955-134080303015000000010010106800+03176-1370753010150000002
-160079296015000000030011806350+03693-173076294015000000020012506170+03908-1780662
105500+04756-241067283016000000030016205240+05108-264064286016000000020017205000+0
500000002001900460 0+06036-335057291015000000020019404500+06190-3480532910150000003
-407999280017000000010025203500+07905-448999258020000000030026403320+08254-4659992
303000+08925-487999257022000000010029702810+09354-504999253022000000040032302500+1
100000001003770194 0+11785-493999249021000000020039901750+12455-5359992640260000002
-535999267023000000030049701130+15271-537999261020000000020051901000+16045-6019992
300700+18249-644999271026000000010061400600+19196-627999274026000000030062900560+1
900000001006640045 0+20962-664999271022000000020068400400+21676-6629992720260000003
-661999273026000000030080700200+25882-671999999999000000011999999999-99999-9999999
999999-99999-99999999999999999991999999999-99999-99999999999999999991999999999-9
99999999199999999999-99999-99999999999999999991999999999-99999-9999999999999999999
-99999999999999999991999999999-99999-99999999999999999991999999999-99999-9999999
999999-99999-99999999999999999991999999999-99999-99999999999999999991999999999-9
99999999199999999999-99999-99999999999999999991999999999-99999-9999999999999999999
-99999999999999999991999999999-99999-99999999999999999991999999999-99999-9999999
999999-99999-99999999999999999991999999999-99999-99999999999999999991999999999-9
000147354245N07348W19840103120790000010151+00086-02005030000500000000000410000+0
800000030002809190+00867-091086326010000000020003309000+01029-1000893230120000003
-098080322011000000010004908460+01504-091040322010000000020005108400+01559-0910333
408010+01928-072038326008000000020006408000+01938-072038326008000000030008007500+0

Figure C-2. (Page 2 of 4).

```
900000020008607380+02563-09103133500800000020010107000+02970-1150293500070000001
-17903135001000000030015005760+04442-19603235001000000020016105500+04784-2150323
104500+06239-29703136001800000030021404460+06302-30103000101800000020024204000+0
00000002002770350 0+07980-44399936002000000030029603250+08469-48599935902200000002
-60499935602700000040036002500+10149-60499935402800000010037302340+10566-5609993
302040+11432-55999932701700000020040902000+11558-55499932001700000010042001910+1
40000002004390175 0+12418-53699929401500000030044401710+12566-54699929601700000002
-53699930301900000010051601280+14429-53699928001700000020052101250+14581-5449992
101000+15993-58599928402300000010061600800+17387-61399928002200000030064400700+1
300000030071000500+20290-61699928002200000010075100400+21670-62699928502400000003
-65199928002600000030086000220+25329-66099928402700000020087200200+25909-6509992
400125+28825-57899926403600000020097100100+30220-61899926104200000010100700076+3
99999991999999999-99999-99999999999999999991999999999-99999-99999999999999999999
-99999999999999999991999999999-99999-99999999999999999991999999999-99999-9999999
999999-99999-99999999999999999991999999999-99999-99999999999999999991999999999-9
99999991999999999-99999-99999999999999999991999999999-99999-99999999999999999999
-99999999999999999991999999999-99999-99999999999999999991999999999-99999-9999999
999999-99999-99999999999999999991999999999-99999-99999999999999999991999999999-9
000147354245N07348W19840104000790000010110+00086-01106315000400000000000310000+0
600000030002209280+00763-06409119500600000020003009010+00993-07809623000600000002
-02807023700700000020004208590+01371-03103124500900000020004408500+01454-0200312
407890+02041-06103623601000000020007107660+02273-05502523701000000020007607500+0
000000020009607000+02976-07202823901000000010011406500+03550-10903125201000000003
-12102926001400000020013406000+04162-12603126001400000030015005670+04592-1440412.
205410+04946-16705027801300000020018005000+05534-20104699999900000011999999999-9
99999991999999999-99999-99999999999999999991999999999-99999-99999999999999999999
-99999999999999999991999999999-99999-99999999999999999991999999999-99999-9999999
999999-99999-99999999999999999991999999999-99999-99999999999999999991999999999-9
99999991999999999-99999-99999999999999999991999999999-99999-99999999999999999999
-99999999999999999991999999999-99999-99999999999999999991999999999-99999-9999999
999999-99999-99999999999999999991999999999-99999-99999999999999999991999999999-9
99999991999999999-99999-99999999999999999991999999999-99999-99999999999999999999
-99999999999999999991999999999-99999-99999999999999999991999999999-99999-9999999
999999-99999-99999999999999999991999999999-99999-99999999999999999991999999999-9
99999991999999999-99999-99999999999999999991999999999-99999-99999999999999999999
-99999999999999999991999999999-99999-99999999999999999991999999999-99999-9999999
999999-99999-99999999999999999991999999999-99999-99999999999999999991999999999-9
99999991999999999-99999-99999999999999999991999999999-99999-99999999999999999999
-99999999999999999991999999999-99999-99999999999999999991999999999-99999-9999999
999999-99999-99999999999999999991999999999-99999-99999999999999999991999999999-9
000147354245N07348W19840104120790000010039+00086+00007618000300000000000110000+0
700000020001509500+00527-00506922400900000030001809430+00586-00206723601000000002
-05708327201700000010005708220+01673-03206126502100000020006408000+01887-0430702
407450+02446-07309725102100000020010107000+02930-08909625202300000010011006790+0
500000030012906340+03696-12809325502300000020013806170+03902-15201926202200000002
-16201927103100000020016305650+04566-16203627003300000020017105500+04768-1680352
805000+05479-20605826203700000010022604500+06250-26105725603300000030025804000+0
800000020028703500+08020-40299926103900000030032503000+09049-48899926403900000001
-64899926803500000040042302000+11595-63599927003500000010045401750+12422-6029999
701290+14355-54699999999900000020053401250+14556-55299999999900000030058401000+1
100000030066200700+18188-61399928002400000010069500600+19147-60599926903500000003
-61299927301800000030083900300+23452-63599927202400000010087300250+24575-6249992
100150+27744-61599927403200000030102700100+30253-62499926605000000010105200082+3
99999991999999999-99999-99999999999999999991999999999-99999-99999999999999999999
-99999999999999999991999999999-99999-99999999999999999991999999999-99999-9999999
999999-99999-99999999999999999991999999999-99999-99999999999999999991999999999-9
99999991999999999-99999-99999999999999999991999999999-99999-99999999999999999999
```

Figure C-2. (Page 3 of 4).

-99999999999999999991999999999-99999-99999999999999999991999999999-99999-9999999
999999-99999-99999999999999999991999999999-99999-99999999999999999991999999999-9
999999991999999999-99999-99999999999999999991999999999-99999-9999999999999999999
-99999999999999999991999999999-99999-99999999999999999991999999999-99999-9999999
999999-99999-99999999999999999991999999999-99999-99999999999999999991999999999-9
000147354245N07348W19840105000790000010005+00086+0040711800050000000000110000+0
400000020001409500+00502+00107324000400000030002209240+00724-0210872630060000002
-03409727000600000030004508500+01382-06809627400500000010005508220+01644-0740962
208000+01857-05909626901100000030006407920+01935-06709626901100000020006607880+0
300000020007807500+02360-08604927301300000030009707000+02892-1220552660160000001
-15506925701800000020011806500+03455-15606925601800000030013806000+04058-1670702
005500+04710-19207025402400000030018405000+05412-23906625102700000010020504610+0
700000030023404080+06869-32904924704200000020023904000+07008-3380402470430000001
-41599924404500000030030703000+08954-50799924804300000010034102590+09895-5869992
502360+10477-60899924504200000040040402000+11513-58499924903800000010043901750+1
500000010049201430+13639-55299925402500000020050801340+14052-5709992580240000002
-57499926402500000020058201000+15908-55199927202700000010063400800+17325-5779992
800600+19127-60399927102700000030071300560+19557-60899927202800000020073900500+2
700000030085700300+23436-64099927302400000010089500250+24553-6409992650260000003
-99999999999999999991999999999-99999-99999999999999999991999999999-99999-9999999
999999-99999-99999999999999999991999999999-99999-99999999999999999991999999999-9
999999991999999999-99999-99999999999999999991999999999-99999-9999999999999999999
-99999999999999999991999999999-99999-99999999999999999991999999999-99999-9999999
999999-99999-99999999999999999991999999999-99999-99999999999999999991999999999-9
999999991999999999-99999-99999999999999999991999999999-99999-9999999999999999999
-99999999999999999991999999999-99999-99999999999999999991999999999-99999-9999999
999999-99999-99999999999999999991999999999-99999-99999999999999999991999999999-9
000147354245N07348W19840105120790000010012+00086-0010871900020000000000110000+0
300000030002809000+00935-03709426800500000030004408500+01385-0580972770070000001
-09809628300800000020007207500+02358-11108028200800000030007607400+02461-1190712
006500+03439-19409028700900000030010106490+03451-19509128600900000020010606380+0
000000030013505500+04669-25602126601000000030015505000+05353-3000232670110000001
-38903427401100000020019504000+06898-42799925901300000010021603530+07739-4449992
103000+08815-50299924002800000040026902500+10000-52499925002400000010030502000+1
900000030034201620+12794-55199925902100000020034801560+13036-5369992580200000002
-56699927202100000020038601250+14449-55199928202000000030041201090+15328-5319992
000810+17215-60299927001900000020046200800+17292-60199927001900000030048900700+1
900000030054200550+19654-56999999999900000021999999999-99999-9999999999999999999
-99999999999999999991999999999-99999-99999999999999999991999999999-99999-9999999
999999-99999-99999999999999999991999999999-99999-99999999999999999991999999999-9
999999991999999999-99999-99999999999999999991999999999-99999-9999999999999999999
-99999999999999999991999999999-99999-99999999999999999991999999999-99999-9999999
999999-99999-99999999999999999991999999999-99999-99999999999999999991999999999-9
999999991999999999-99999-99999999999999999991999999999-99999-9999999999999999999
-99999999999999999991999999999-99999-99999999999999999991999999999-99999-9999999
999999-99999-99999999999999999991999999999-99999-99999999999999999991999999999-9
999999991999999999-99999-99999999999999999991999999999-99999-9999999999999999999
-99999999999999999991999999999-99999-99999999999999999991999999999-99999-9999999
999999-99999-99999999999999999991999999999-99999-99999999999999999991999999999-9

Figure C-2. (Page 4 of 4).

READ62 VERSION 2.0 LEVEL 870731

STARTING DATE:

YEAR = 84
JULIAN DAY = 1
HOUR = 0

ENDING DATE:

YEAR = 84
JULIAN DAY = 5
HOUR = 12

PRESSURE LEVELS EXTRACTED:

SURFACE TO 500. MB

SWITCHES FOR DISCARDING PRESSURE LEVELS: 0=NO, 1=YES

DATA LEVEL ELIMINATED IF HEIGHT MISSING ? 1

DATA LEVEL ELIMINATED IF TEMPERATURE MISSING ? 1

DATA LEVEL ELIMINATED IF WIND DIRECTION MISSING ? 1

DATA LEVEL ELIMINATED IF WIND SPEED MISSING ? 1

THE FOLLOWING SOUNDINGS HAVE BEEN PROCESSED:

YEAR	MONTH	DAY	JULIAN DAY	HOUR (GMT)	NO. LEVELS EXTRACTED
84	1	1	1	0	21
84	1	1	1	12	26
84	1	2	2	0	19
84	1	2	2	12	23
84	1	3	3	0	24
84	1	3	3	12	21
84	1	4	4	0	22
TOP OF SOUNDING LISTED ABOVE IS BELOW THE 500.0-MB LEVEL					
84	1	4	4	12	22
84	1	5	5	0	23
84	1	5	5	12	16

EOF ON INPUT
LAST DAY READ = 84 5

Figure C-3. Output listing provided by READ62 ("OUTPUT").

```
6201      14735      84 1 1 0       29                           21
1023.9/  86./266.2/180/  3   1018.0/ 131./266.9/198/  3   1000.0/ 270./266.2/209/  4   978.0/ 443./265.6/248/  5
 957.0/ 612./266.9/271/  7    950.0/ 669./266.7/274/  7    925.0/ 877./265.6/288/ 10   900.0/1091./267.2/293/ 12
 893.0/1152./267.7/294/ 12    850.0/1539./268.1/294/ 12    800.0/2014./267.0/288/ 13   750.0/2518./265.7/276/ 14
 733.0/2696./265.2/275/ 15    700.0/3052./262.3/274/ 16    650.0/3619./260.5/267/ 19   629.0/3870./259.7/267/ 20
 600.0/4228./257.7/266/ 21    550.0/4879./253.8/263/ 19    548.0/4906./253.6/263/ 18   517.0/5336./250.3/265/ 16
 500.0/5580./248.9/267/ 16
6201      14735      84 1 112       32                           26
1025.2/  86./266.2/350/  2   1013.0/ 179./265.3/345/  4   1000.0/ 280./266.2/344/  5   981.0/ 430./266.8/345/  6
 950.0/ 680./264.8/351/  7    949.0/ 688./264.7/352/  7    900.0/1098./263.1/344/  8   850.0/1537./261.3/321/  8
 845.0/1502./261.2/317/  8    839.0/1637./266.7/318/  8    835.0/1674./266.8/311/  8   800.0/2008./265.7/306/  8
 794.0/2067./265.5/309/  7    771.0/2296./265.3/324/  7    751.0/2501./267.4/335/  7   750.0/2512./267.4/335/  7
 700.0/3050./265.2/318/  9    657.0/3539./262.0/303/ 10    650.0/3621./261.3/302/ 10   638.0/3763./259.9/299/ 10
 615.0/4042./259.0/294/ 10    600.0/4229./257.2/294/ 10    585.0/4419./255.2/296/ 10   562.0/4718./254.2/301/ 10
 550.0/4878./253.3/303/ 10    500.0/5579./248.9/292/ 13
6201      14735      84 1 2 0       24                           19
1027.3/  86./267.2/300/  3   1019.0/ 150./267.7/324/  2   1000.0/ 297./266.2/ 33/  2   950.0/ 696./264.6/156/  3
 922.0/ 920./263.6/163/  5    900.0/1114./262.1/167/  5    881.0/1277./260.6/165/  3   871.0/1364./262.1/163/  2
 861.0/1453./266.7/161/  1    850.0/1553./266.7/161/  1    804.0/1990./269.2/281/  2   800.0/2029./269.1/282/  2
 750.0/2537./267.7/285/  2    700.0/3077./266.2/283/  4    650.0/3651./262.4/289/  6   644.0/3722./261.9/289/  6
 600.0/4262./258.6/289/  8    550.0/4915./254.5/298/ 13    500.0/5619./250.0/304/ 15
6201      14735      84 1 212       29                           23
1021.5/  86./267.2/170/  4   1014.0/ 144./267.0/173/  5   1000.0/ 253./266.3/175/  7   982.0/ 395./265.7/179/  9
 950.0/ 653./265.2/191/ 10    909.0/ 995./264.4/237/  9    900.0/1072./264.7/246/  9   863.0/1399./266.1/276/ 12
 850.0/1517./266.0/275/ 13    837.0/1637./265.1/273/ 13    817.0/1824./263.2/271/ 15   813.0/1862./263.9/271/ 15
 807.0/1919./264.5/271/ 16    800.0/1987./264.4/271/ 16    750.0/2486./263.6/258/ 13   700.0/3018./262.6/244/ 15
 682.0/3219./263.2/245/ 17    650.0/3589./262.1/248/ 18    609.0/4088./260.5/255/ 17   600.0/4202./259.8/255/ 18
 556.0/4777./255.7/253/ 20    550.0/4858./255.3/252/ 19    500.0/5566./251.7/249/ 23
6201      14735      84 1 3 0       34                           24
1014.0/  86./268.7/160/  3   1000.0/ 196./269.7/190/  2    985.0/ 315./268.8/240/  3   964.0/ 485./269.9/265/  5
 950.0/ 601./268.9/274/  6    912.0/ 921./265.8/298/ 10    900.0/1024./265.1/290/ 11   872.0/1269./263.1/299/ 13
 850.0/1466./261.8/301/ 12    800.0/1931./261.8/303/ 11    774.0/2185./261.8/305/ 13   750.0/2427./261.5/306/ 14
 736.0/2571./261.2/307/ 14    700.0/2868./260.5/303/ 15    700.0/2955./259.8/303/ 15   680.0/3176./259.5/301/ 15
 653.0/3083./257.4/296/ 15    650.0/3518./257.2/296/ 15    635.0/3693./255.9/294/ 15   617.0/3908./255.4/290/ 14
 600.0/4116./253.2/286/ 14    550.0/4756./249.1/283/ 16    524.0/5108./246.8/286/ 16   500.0/5445./244.7/287/ 15
6201      14735      84 1 312       28                           21
1015.1/  86./271.2/300/  5   1000.0/ 205./270.6/312/  6    950.0/ 609./266.7/330/  8   919.0/ 867./264.1/326/ 10
 900.0/1029./263.2/323/ 12    860.0/1378./261.2/320/ 11    850.0/1468./263.4/322/ 11   846.0/1504./264.1/322/ 10
 840.0/1559./264.1/323/ 10    831.0/1602./265.1/325/  9    801.0/1928./266.0/326/  8   800.0/1938./266.0/326/  8
 750.0/2438./263.8/326/  9    747.0/2469./262.8/329/  9    738.0/2563./264.1/335/  8   700.0/2970./261.7/350/  7
 650.0/3535./258.7/355/  6    600.0/4137./255.3/350/ 10    576.0/4442./253.6/350/ 10   550.0/4784./251.7/355/ 10
 500.0/5481./247.6/352/ 14
6201      14735      84 1 4 0       22                           22
TOP OF SOUNDING BELOW  500.0-MB LEVEL
1011.0/  86./272.1/150/  4   1000.0/ 173./272.0/160/  5    950.0/ 580./268.5/181/  6   928.0/ 763./266.8/195/  6
 901.0/ 993./265.4/230/  6    900.0/1002./265.9/230/  6    890.0/1090./270.4/237/  7   859.0/1371./270.1/245/  9
 850.0/1454./271.2/243/  9    800.0/1933./267.9/236/ 10    789.0/2041./267.1/236/ 10   766.0/2273./267.7/237/ 10
 750.0/2430./267.2/238/ 10    721.0/2746./266.0/237/ 10    700.0/2976./266.0/239/ 10   650.0/3550./262.3/252/ 10
 637.0/3704./261.2/259/ 11    611.0/4023./261.1/260/ 14    600.0/4162./260.6/260/ 14   567.0/4592./258.8/270/ 13
 550.0/4822./257.4/275/ 13    541.0/4946./256.5/278/ 13
6201      14735      84 1 412       27                           22
1003.9/  86./273.2/180/  3   1000.0/ 117./273.3/184/  3    974.0/ 328./271.9/197/  7   950.0/ 527./272.7/224/  9
 943.0/ 586./273.0/236/ 10    900.0/ 958./270.6/264/ 15    850.0/1409./267.5/272/ 17   822.0/1673./270.0/265/ 21
 800.0/1887./268.9/261/ 22    750.0/2394./266.2/252/ 20    745.0/2446./265.9/251/ 21   700.0/2930./264.3/252/ 23
 679.0/3167./265.4/254/ 23    650.0/3505./262.3/253/ 25    634.0/3696./260.4/255/ 23   617.0/3902./258.0/262/ 22
 600.0/4113./257.7/268/ 24    574.0/4447./257.0/271/ 31    565.0/4566./257.0/270/ 33   550.0/4768./256.4/268/ 35
 523.0/5145./255.0/264/ 36    500.0/5479./252.6/262/ 37
6201      14735      84 1 5 0       31                           23
1000.5/  86./273.6/180/  5   1000.0/  90./274.1/183/  5    955.0/ 460./273.6/235/  4   950.0/ 502./273.3/240/  4
 924.0/ 724./271.1/263/  6    903.0/ 906./269.9/270/  6    900.0/ 932./269.8/270/  6   850.0/1382./266.4/274/  5
 822.0/1644./265.8/270/  8    802.0/1837./267.4/269/ 11    800.0/1857./267.3/269/ 11   792.0/1935./266.5/269/ 11
 788.0/1975./266.4/270/ 12    779.0/2065./266.5/271/ 13    750.0/2360./264.6/273/ 13   700.0/2892./261.0/266/ 16
 684.0/3069./260.3/262/ 16    656.0/3386./257.7/257/ 18    650.0/3455./257.6/256/ 18   600.0/4058./256.5/251/ 22
```

Figure C-4. Processed upper air data used by the METPRO meteorological preprocessor ("RAWIN").

```
 570.0/4443./255.7/253/ 24    550.0/4710./254.0/254/ 24    500.0/5412./249.3/251/ 27
6201      14735      84 1 512      22                            16
1001.2/  86./273.1/190/  2   1000.0/  96./273.3/196/  2    950.0/ 506./271.5/260/  3    900.0/ 935./269.5/260/  5
 850.0/1385./267.4/277/  7    800.0/1850./265.0/286/  8    769.0/2165./263.4/283/  8    750.0/2358./262.1/282/  8
 740.0/2461./261.3/284/  9    700.0/2884./257.5/286/  9    650.0/3439./253.8/287/  9    649.0/3451./253.7/286/  9
 638.0/3578./254.2/283/  9    600.0/4033./251.5/272/ 10    550.0/4669./247.6/266/ 10    500.0/5353./243.2/267/ 11
```

Figure C-4. (Continued).

APPENDIX D
METPRO TEST CASES

APPENDIX D

METPRO TEST CASES

Four test cases are provided here, one for each of the four execution modes of METPRO. The "observed" mixed layer heights provided in the "SURF1" files are not actual measurements, but were created here for illustration purposes. The sequence and numbers of hours used in modes 0, 1, and 2 were chosen at random; any period of length (even with noncontiguous hours) is acceptable for modes 0, 1, and 2. Entire blocks of days must be used with mode 3. The input and output files included in this appendix are listed below.

Execution Mode	Filename	Content	Reference
0	OPTIONS	Input options and site data	Figure D-1
0	PROFILE	Input on-site tower data	Figure D-2
0	SURF1	Input on-site surface data	Figure D-3
0	OUTPUT	Verification listing of input options and site data	Figure D-4
0	SURFACE	Output surface boundary layer variables used by CTDM	Figure D-5
1	OPTIONS	Input options and site data	Figure D-6
1	PROFILE	Input on-site tower data	Figure D-7
1	SURF1	Input on-site surface data	Figure D-8
1	OUTPUT	Verification listing of input	Figure D-9
1	SURFACE	Output surface boundary layer variables used by CTDM	Figure D-10
2	OPTIONS	Input options and site data	Figure D-11
2	PROFILE	Input on-site tower data	Figure D-7
2	SURF1	Input on-site surface data	Figure D-12
2	SURF2	Input off-site surface data	Figure D-13
2	OUTPUT	Verification listing of input options and site data	Figure D-14
2	SURFACE	Output surface boundary layer variables used by CTDM	Figure D-15
3	OPTIONS	Input options and site data	Figure D-16
3	PROFILE	Input on-site tower data	Figure D-17
3	SURF1	Input on-site surface data	Figure D-18
3	SURF2	Input off-site surface data	Figure D-19
3	RAWIN	Input processed upper air data	Figure D-20
3	OUTPUT	Verification listing of input options and site data	Figure D-21
3	SURFACE	Output surface boundary layer variables used by CTDM	Figure D-22

```
 0
39.5915   89.4885   6  0.15 0.18 2.00
```

Figure D-1. Input options and site data; METPRO execution mode 0 test case ("OPTIONS").

80	6	26	3	10.	0	200.	.6	298.8	6.3	.01	-999.9
80	6	26	3	100.	1	200.	3.5	298.8	6.3	.01	-999.9
80	6	26	4	10.	0	185.	1.3	298.6	5.3	.01	-999.9
80	6	26	4	100.	1	185.	2.4	298.6	5.3	.01	-999.9
80	6	26	5	10.	0	196.	1.0	298.1	3.5	.02	-999.9
80	6	26	5	100.	1	196.	3.1	298.1	3.5	.02	-999.9
80	6	26	6	10.	0	186.	1.1	297.9	4.3	.04	-999.9
80	6	26	6	100.	1	186.	3.8	297.9	4.3	.04	-999.9
80	6	26	7	10.	0	189.	2.1	298.0	4.5	.08	-999.9
80	6	26	7	100.	1	189.	4.2	298.0	4.5	.08	-999.9
80	6	26	8	10.	0	180.	2.2	298.1	7.9	.19	-999.9
80	6	26	8	100.	1	180.	3.2	298.1	7.9	.19	-999.9
80	6	26	9	10.	0	175.	2.2	298.2	13.9	.39	-999.9
80	6	26	9	100.	1	175.	2.6	298.2	13.9	.39	-999.9

Figure D-2. Input tower data used for METPRO execution mode 0 test case ("PROFILE").

80	6	26	3	.0	-40.8	82.0	777	2
80	6	26	4	.0	-34.7	86.0	777	1
80	6	26	5	.0	-27.2	76.0	777	2
80	6	26	6	79.0	30.4	76.0	777	1
80	6	26	7	-999.0	-999.0	76.0	777	0
80	6	26	8	-999.0	-999.0	-999.0	777	0
80	6	26	9	583.0	391.8	-999.0	777	1

Figure D-3. Input on-site surface parameters used in METPRO execution mode 0 test case ("SURF1").

```
CTDM MET PRE-PROCESSOR PROGRAM (METPRO)        VERSION 2.1        LEVEL 871022

         PROGRAM OPTIONS:

              MODE = 0 IF 0, DO NOT READ NWS SURFACE DATA NOR UPPER AIR DATA,
                             ASSUME CONSTANT SITE CHARACTERISTICS
                       IF 1, DO NOT READ NWS SURFACE DATA NOR UPPER AIR DATA,
                             BUT ASSUME VARIABLE SITE CHARACTERISTICS
                       IF 2, READ NWS SURFACE DATA, BUT NOT UPPER AIR DATA
                       IF 3, READ NWS SURFACE DATA AND UPPER AIR DATA


         LATITUDE (DEG NORTH) =  39.59, LONGITUDE (DEG WEST) =   89.49
         TIME ZONE (HOURS AFTER GMT) =   6.0
         FIXED VALUES OF SURFACE CHARACTERISTICS:
                   Z0 =  .1500M,  ALBEDO =  .18,  BOWEN RATIO =  2.00


WARNING: CONVECTIVE MIXED LAYER HEIGHTS ARE NOT COMPUTED IN THIS MODE;
MISSING VALUES WILL BE WRITTEN TO THE SURFACE FILE FOR UNSTABLE CONDITIONS.
```

Figure D-4. Ouput verification of options and site data for METPRO execution mode 0 test case ("OUTPUT").

80	6	26	178	3	82.	21.	0.029	11.2	0.150E+00
80	6	26	178	4	86.	3[illegible].	0.064	11.9	0.150E+00
80	6	26	178	5	76.	27.	0.048	11.2	0.150E+00
80	6	26	178	6	76.	-999.	0.136	-12.5	0.150E+00
80	6	26	178	7	76.	-999.	0.247	-18.5	0.150E+00
80	6	26	178	8	-999.	-999.	0.275	-11.6	0.150E+00
80	6	26	178	9	-999.	-999.	0.285	-8.9	0.150E+00

Figure D-5. Output file of surface boundary layer variables used by CTDM; METPRO execution mode 0 test case ("SURFACE").

```
 1
39.5915   89.4885   6
4
  46   60
  61  120
 121  250
 251   45
 0.05  0.05  0.05  0.05  0.06  0.07  0.07  0.07  0.07  0.07  0.05  0.05
 0.33  0.29  0.24  0.12  0.10  0.11  0.14  0.14  0.14  0.14  0.22  0.30
 0.55  0.55  0.30  1.05  1.05  1.05  2.05  2.05  0.50  0.55  0.55  0.55
 0.09  0.09  0.09  0.09  0.11  0.14  0.14  0.14  0.14  0.14  0.09  0.09
 0.56  0.50  0.40  0.17  0.14  0.16  0.21  0.21  0.21  0.21  0.36  0.50
 0.91  0.91  0.46  1.81  1.81  1.81  3.61  3.61  0.82  0.91  0.91  0.91
 0.10  0.10  0.10  0.10  0.12  0.15  0.15  0.15  0.15  0.15  0.10  0.10
 0.61  0.54  0.44  0.19  0.16  0.18  0.23  0.23  0.23  0.23  0.40  0.56
 1.00  1.00  0.50  2.00  2.00  2.00  4.00  4.00  0.90  1.00  1.00  1.00
 0.09  0.09  0.09  0.09  0.11  0.14  0.14  0.14  0.14  0.14  0.09  0.09
 0.56  0.50  0.40  0.17  0.14  0.16  0.21  0.21  0.21  0.21  0.36  0.50
 0.91  0.91  0.46  1.81  1.81  1.81  3.61  3.61  0.82  0.91  0.91  0.91
```

Figure D-6. Input options and site data; METPRO execution mode 1 test case ("OPTIONS).

80	6	26	3	10.	0	200.	.6	298.8	6.3	.01	-999.9
80	6	26	3	100.	1	200.	3.5	298.8	6.3	.01	-999.9
80	6	26	4	10.	0	185.	1.3	298.6	5.3	.01	-999.9
80	6	26	4	100.	1	185.	2.4	298.6	5.3	.01	-999.9
80	6	26	5	10.	0	196.	1.0	298.1	3.5	.02	-999.9
80	6	26	5	100.	1	196.	3.1	298.1	3.5	.02	-999.9
80	6	26	6	10.	0	186.	1.1	297.9	4.3	.04	-999.9
80	6	26	6	100.	1	186.	3.8	297.9	4.3	.04	-999.9
80	6	26	7	10.	0	189.	2.1	298.0	4.5	.08	-999.9
80	6	26	7	100.	1	189.	4.2	298.0	4.5	.08	-999.9
80	6	26	8	10.	0	180.	2.2	298.1	7.9	.19	-999.9
80	6	26	8	100.	1	180.	3.2	298.1	7.9	.19	-999.9
80	6	26	9	10.	0	175.	2.2	298.2	13.9	.39	-999.9
80	6	26	9	100.	1	175.	2.6	298.2	13.9	.39	-999.9
80	6	26	22	10.	0	175.	2.2	298.2	13.9	.39	-999.9
80	6	26	22	100.	1	175.	2.6	298.2	13.9	.39	-999.9
80	6	26	23	10.	0	209.	2.2	299.4	13.6	.49	-999.9
80	6	26	23	100.	1	209.	2.5	299.4	13.6	.49	-999.9
80	6	26	24	10.	0	179.	2.3	300.1	14.6	.47	-999.9
80	6	26	24	100.	1	179.	2.5	300.1	14.6	.47	-999.9
80	6	27	1	10.	0	189.	1.2	299.3	1.0	.03	-999.9
80	6	27	1	100.	1	189.	3.9	299.3	1.0	.03	-999.9
80	6	27	2	10.	0	194.	1.1	299.2	2.6	.02	-999.9
80	6	27	2	100.	1	194.	3.8	299.2	2.6	.02	-999.9
80	6	27	3	10.	0	200.	.6	298.8	6.3	.01	-999.9
80	6	27	3	100.	1	200.	3.5	298.8	6.3	.01	-999.9
80	6	27	4	10.	0	185.	1.3	298.6	5.3	.01	-999.9
80	6	27	4	100.	1	185.	2.4	298.6	5.3	.01	-999.9
80	6	27	5	10.	0	196.	1.0	298.1	3.5	.02	-999.9
80	6	27	5	100.	1	196.	3.1	298.1	3.5	.02	-999.9
80	6	27	6	10.	0	186.	1.1	297.9	4.3	.04	-999.9
80	6	27	6	100.	1	186.	3.8	297.9	4.3	.04	-999.9
80	6	27	7	10.	0	189.	2.1	298.0	4.5	.08	-999.9
80	6	27	7	100.	1	189.	4.2	298.0	4.5	.08	-999.9
80	6	27	8	10.	0	180.	2.2	298.1	7.9	.19	-999.9
80	6	27	8	100.	1	180.	3.2	298.1	7.9	.19	-999.9
80	6	27	9	10.	0	175.	2.2	298.2	13.9	.39	-999.9
80	6	27	9	100.	1	175.	2.6	298.2	13.9	.39	-999.9
80	6	27	22	10.	0	175.	2.2	298.2	13.9	.39	-999.9
80	6	27	22	100.	1	175.	2.6	298.2	13.9	.39	-999.9
80	6	27	23	10.	0	-999.	-9.9	-999.9	-99.9	-9.9	-999.9
80	6	27	23	100.	1	-999.	-9.9	-999.9	-99.9	-9.9	-999.9
80	6	27	24	10.	0	179.	2.3	300.1	14.6	.47	-999.9
80	6	27	24	100.	1	179.	2.5	300.1	14.6	.47	-999.9

Figure D-7. Input tower data used for METPRO execution modes 1 and 2 test cases ("PROFILE").

80	6	26	3	.0	-40.8	82.0	-9999	2
80	6	26	4	.0	-34.7	86.0	-9999	1
80	6	26	5	.0	-27.2	76.0	-9999	2
80	6	26	6	79.0	30.4	76.0	-9999	1
80	6	26	7	-999.0	-999.0	76.0	-9999	0
80	6	26	8	-999.0	-999.0	-999.0	-9999	0
80	6	26	9	583.0	391.8	-999.0	-9999	1
80	6	26	22	-999.0	-999.0	76.0	-9999	0
80	6	26	23	-999.0	-999.0	79.0	-9999	0
80	6	26	24	-999.0	-999.0	79.0	-9999	0
80	6	27	1	-999.0	-999.0	82.0	-9999	0
80	6	27	2	-999.0	-999.0	102.0	-9999	0
80	6	27	3	-999.0	-999.0	95.0	-9999	0
80	6	27	4	-999.0	-999.0	102.0	-9999	0
80	6	27	5	-999.0	-999.0	102.0	-9999	1
80	6	27	6	-999.0	-999.0	135.0	-9999	2
80	6	27	7	-999.0	-999.0	144.0	-9999	2
80	6	27	8	-999.0	-999.0	-999.0	-9999	0
80	6	27	9	-999.0	-999.0	-999.0	-9999	0
80	6	27	22	-999.0	-999.0	233.0	-9999	5
80	6	27	23	-999.0	-999.0	259.0	-9999	3
80	6	27	24	-999.0	-999.0	239.0	-9999	3

Figure D-8. **Input on-site surface paramenters used in METPRO execution mode 1 test case ("SURF1").**

```
CTDM MET PRE-PROCESSOR PROGRAM (METPRO)       VERSION 2.1       LEVEL 871022

        PROGRAM OPTIONS:

            MODE = 1 IF 0, DO NOT READ NWS SURFACE DATA NOR UPPER AIR DATA,
                           ASSUME CONSTANT SITE CHARACTERISTICS
                     IF 1, DO NOT READ NWS SURFACE DATA NOR UPPER AIR DATA,
                           BUT ASSUME VARIABLE SITE CHARACTERISTICS
                     IF 2, READ NWS SURFACE DATA, BUT NOT UPPER AIR DATA
                     IF 3, READ NWS SURFACE DATA AND UPPER AIR DATA

        LATITUDE (DEG NORTH) =  39.59, LONGITUDE (DEG WEST) =   89.49
        TIME ZONE (HOURS AFTER GMT) =   6.0

        # OF WIND DIRECTION SECTORS FOR SPECIFYING SURFACE CHARACTERISTICS = 4

            WIND DIRECTION SECTORS AND ANGLE RANGES:

            1:  46- 60

            2:  61-120

            3: 121-250

            4: 251- 45

        SECTOR VALUES FOR SURFACE ROUGHNESS (M), ALBEDO, AND BOWEN RATIO:

VARIABLE  JAN   FEB   MAR   APR   MAY   JUN   JUL   AUG   SEP   OCT   NOV   DEC

ZO:      0.050 0.050 0.050 0.050 0.060 0.070 0.070 0.070 0.070 0.070 0.050 0.050
ALBEDO:  0.330 0.290 0.240 0.120 0.100 0.110 0.140 0.140 0.140 0.140 0.220 0.300
BOWEN:   0.550 0.550 0.300 1.050 1.050 1.050 2.050 2.050 0.500 0.550 0.550 0.550
(SECTOR 1)

ZO:      0.090 0.090 0.090 0.090 0.110 0.140 0.140 0.140 0.140 0.140 0.090 0.090
ALBEDO:  0.560 0.500 0.400 0.170 0.140 0.160 0.210 0.210 0.210 0.210 0.360 0.500
BOWEN:   0.910 0.910 0.460 1.810 1.810 1.810 3.610 3.610 0.820 0.910 0.910 0.910
(SECTOR 2)

ZO:      0.100 0.100 0.100 0.100 0.120 0.150 0.150 0.150 0.150 0.150 0.100 0.100
ALBEDO:  0.610 0.540 0.440 0.190 0.160 0.180 0.230 0.230 0.230 0.230 0.400 0.560
BOWEN:   1.000 1.000 0.500 2.000 2.000 2.000 4.000 4.000 0.900 1.000 1.000 1.000
(SECTOR 3)

ZO:      0.090 0.090 0.090 0.090 0.110 0.140 0.140 0.140 0.140 0.140 0.090 0.090
ALBEDO:  0.560 0.500 0.400 0.170 0.140 0.160 0.210 0.210 0.210 0.210 0.360 0.500
BOWEN:   0.910 0.910 0.460 1.810 1.810 1.810 3.610 3.610 0.820 0.910 0.910 0.910
(SECTOR 4)

WARNING: CONVECTIVE MIXED LAYER HEIGHTS ARE NOT COMPUTED IN THIS MODE;
MISSING VALUES WILL BE WRITTEN TO THE SURFACE FILE FOR UNSTABLE CONDITIONS.


        MISSING WIND AND/OR TEMPERATURE DATA FOR
             (MM DD YY HH): 80  6 27 23; MISSING DATA WRITTEN TO "SURFACE"
```

Figure D-9. Output verification of options and site data for METPRO execution 1 test case ("OUTPUT").

80	6	26	178	3	82.	21.	0.029	11.2	0.150E+00
80	6	26	178	4	86.	33.	0.064	11.9	0.150E+00
80	6	26	178	5	76.	27.	0.048	11.2	0.150E+00
80	6	26	178	6	76.	-999.	0.136	-12.5	0.150E+00
80	6	26	178	7	76.	-999.	0.247	-18.5	0.150E+00
80	6	26	178	8	-999.	-999.	0.275	-11.6	0.150E+00
80	6	26	178	9	-999.	-999.	0.285	-8.9	0.150E+00
80	6	26	178	22	76.	42.	0.105	11.2	0.150E+00
80	6	26	178	23	79.	42.	0.105	11.2	0.150E+00
80	6	26	178	24	79.	43.	0.110	11.2	0.150E+00
80	6	27	179	1	82.	30.	0.057	11.2	0.150E+00
80	6	27	179	2	102.	29.	0.052	11.2	0.150E+00
80	6	27	179	3	95.	21.	0.029	11.2	0.150E+00
80	6	27	179	4	102.	33.	0.064	11.9	0.150E+00
80	6	27	179	5	102.	27.	0.048	11.2	0.150E+00
80	6	27	179	6	135.	29.	0.052	11.2	0.150E+00
80	6	27	179	7	144.	-999.	0.248	-17.5	0.150E+00
80	6	27	179	8	-999.	-999.	0.275	-11.6	0.150E+00
80	6	27	179	9	-999.	-999.	0.285	-8.8	0.150E+00
80	6	27	179	22	233.	42.	0.105	11.2	0.150E+00
80	6	27	179	23	-9999.	-9999.	-999.999	-9999.9	-.999E+03
80	6	27	179	24	239.	43.	0.110	11.2	0.150E+00

Figure D-10. Output file of surface boundary layer variables used by CTDM; METPRO execution mode 1 test case ("SURFACE").

```
2
39.5915   89.4885   6
4
  46    60
  61   120
 121   250
 251    45
 0.05  0.05  0.05  0.05  0.06  0.07  0.07  0.07  0.07  0.07  0.05  0.05
 0.33  0.29  0.24  0.12  0.10  0.11  0.14  0.14  0.14  0.14  0.22  0.30
 0.55  0.55  0.30  1.05  1.05  1.05  2.05  2.05  0.50  0.55  0.55  0.55
 0.09  0.09  0.09  0.09  0.11  0.14  0.14  0.14  0.14  0.14  0.09  0.09
 0.56  0.50  0.40  0.17  0.14  0.16  0.21  0.21  0.21  0.21  0.36  0.50
 0.91  0.91  0.46  1.81  1.81  1.81  3.61  3.61  0.82  0.91  0.91  0.91
 0.10  0.10  0.10  0.10  0.12  0.15  0.15  0.15  0.15  0.15  0.10  0.10
 0.61  0.54  0.44  0.19  0.16  0.18  0.23  0.23  0.23  0.23  0.40  0.56
 1.00  1.00  0.50  2.00  2.00  2.00  4.00  4.00  0.90  1.00  1.00  1.00
 0.09  0.09  0.09  0.09  0.11  0.14  0.14  0.14  0.14  0.14  0.09  0.09
 0.56  0.50  0.40  0.17  0.14  0.16  0.21  0.21  0.21  0.21  0.36  0.50
 0.91  0.91  0.46  1.81  1.81  1.81  3.61  3.61  0.82  0.91  0.91  0.91
```

Figure D-11. Input options an diste data; METPRO execution mode 2 test case ("OPTIONS").

80	6	26	3	.0	-40.8	82.0	-9999	-9
80	6	26	4	.0	-34.7	86.0	-9999	-9
80	6	26	5	.0	-27.2	76.0	-9999	-9
80	6	26	6	79.0	30.4	76.0	-9999	-9
80	6	26	7	-999.0	-999.0	76.0	-9999	-9
80	6	26	8	-999.0	-999.0	-999.0	-9999	-9
80	6	26	9	583.0	391.8	-999.0	-9999	-9
80	6	26	22	-999.0	-999.0	76.0	-9999	-9
80	6	26	23	-999.0	-999.0	79.0	-9999	-9
80	6	26	24	-999.0	-999.0	79.0	-9999	-9
80	6	27	1	-999.0	-999.0	82.0	-9999	-9
80	6	27	2	-999.0	-999.0	102.0	-9999	-9
80	6	27	3	-999.0	-999.0	95.0	-9999	-9
80	6	27	4	-999.0	-999.0	102.0	-9999	-9
80	6	27	5	-999.0	-999.0	102.0	-9999	-9
80	6	27	6	-999.0	-999.0	135.0	-9999	-9
80	6	27	7	-999.0	-999.0	144.0	-9999	-9
80	6	27	8	-999.0	-999.0	-999.0	-9999	-9
80	6	27	9	-999.0	-999.0	-999.0	-9999	-9
80	6	27	22	-999.0	-999.0	233.0	-9999	-9
80	6	27	23	-999.0	-999.0	259.0	-9999	-9
80	6	27	24	-999.0	-999.0	239.0	-9999	-9

Figure D-12. Input on-site surface parameters used in METPRO execution mode 2 test case ("SURF1").

```
9382280 626 2---                              6811 42991 69                                 2
9382280 626 3---                              6813 42991 68                                 1
9382280 626 4---                              6614 42994 67                                 2
9382280 626 5---                              7012 42994 72                                 1
9382280 626 6---                              7122 42994 78                                 0
9382280 626 7---                              7218 82994 82                                 0
9382280 626 8---                              7119 82994 85                                 1
9382280 62621---                              7219 32991 81                                 0
9382280 62622---                              7119 22991 78                                 0
9382280 62623---                              7218 22991 79                                 0
9382280 627 0---                              72 0 02988 78                                 0
9382280 627 1---                              71 0 02991 76                                 0
9382280 627 2---                              7119 52988 77                                 0
9382280 627 3---                              7119 42988 76                                 0
9382280 627 4---                              7218 32988 77                                 1
9382280 627 5---                              72 0 02991 77                                 2
9382280 627 6---                              7322 42994 80                                 2
9382280 627 7---                              7419 62991 84                                 0
9382280 627 8---                              7519 82991 88                                 0
9382280 62721250                              7318102977 86                                 5
9382280 62722---                              7319122974 84                                 3
9382280 62723---                              7419122974 83                                 3
```

Figure D-13. Input off-site surface data for METPRO execution mode 2 test case ("SURF2").

```
CTDM MET PRE-PROCESSOR PROGRAM (METPRO)        VERSION 2.1       LEVEL 871022

         PROGRAM OPTIONS:

              MODE = 2 IF 0, DO NOT READ NWS SURFACE DATA NOR UPPER AIR DATA,
                             ASSUME CONSTANT SITE CHARACTERISTICS
                       IF 1, DO NOT READ NWS SURFACE DATA NOR UPPER AIR DATA,
                             BUT ASSUME VARIABLE SITE CHARACTERISTICS
                       IF 2, READ NWS SURFACE DATA, BUT NOT UPPER AIR DATA
                       IF 3, READ NWS SURFACE DATA AND UPPER AIR DATA


         LATITUDE (DEG NORTH) =  39.59, LONGITUDE (DEG WEST) =   89.49
         TIME ZONE (HOURS AFTER GMT) =   6.0


         # OF WIND DIRECTION SECTORS FOR SPECIFYING SURFACE CHARACTERISTICS = 4


              WIND DIRECTION SECTORS AND ANGLE RANGES:

              1:  46- 60

              2:  61-120

              3: 121-250

              4: 251- 45


         SECTOR VALUES FOR SURFACE ROUGHNESS (M), ALBEDO, AND BOWEN RATIO:
```

VARIABLE	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
Z0:	0.050	0.050	0.050	0.050	0.060	0.070	0.070	0.070	0.070	0.070	0.050	0.050
ALBEDO:	0.330	0.290	0.240	0.120	0.100	0.110	0.140	0.140	0.140	0.140	0.220	0.300
BOWEN:	0.550	0.550	0.300	1.050	1.050	1.050	2.050	2.050	0.500	0.550	0.550	0.550
(SECTOR 1)												
Z0:	0.090	0.090	0.090	0.090	0.110	0.140	0.140	0.140	0.140	0.140	0.090	0.090
ALBEDO:	0.560	0.500	0.400	0.170	0.140	0.160	0.210	0.210	0.210	0.210	0.360	0.500
BOWEN:	0.910	0.910	0.460	1.810	1.810	1.810	3.610	3.610	0.820	0.910	0.910	0.910
(SECTOR 2)												
Z0:	0.100	0.100	0.100	0.100	0.120	0.150	0.150	0.150	0.150	0.150	0.100	0.100
ALBEDO:	0.610	0.540	0.440	0.190	0.160	0.180	0.230	0.230	0.230	0.230	0.400	0.560
BOWEN:	1.000	1.000	0.500	2.000	2.000	2.000	4.000	4.000	0.900	1.000	1.000	1.000
(SECTOR 3)												
Z0:	0.090	0.090	0.090	0.090	0.110	0.140	0.140	0.140	0.140	0.140	0.090	0.090
ALBEDO:	0.560	0.500	0.400	0.170	0.140	0.160	0.210	0.210	0.210	0.210	0.360	0.500
BOWEN:	0.910	0.910	0.460	1.810	1.810	1.810	3.610	3.610	0.820	0.910	0.910	0.910
(SECTOR 4)												

```
WARNING: CONVECTIVE MIXED LAYER HEIGHTS ARE NOT COMPUTED IN THIS MODE;
MISSING VALUES WILL BE WRITTEN TO THE SURFACE FILE FOR UNSTABLE CONDITIONS.


         MISSING WIND AND/OR TEMPERATURE DATA FOR
               (MM DD YY HH): 80  6 27 23; MISSING DATA WRITTEN TO "SURFACE"
```

Figure D-14. Output verification of options and site data for METPRO execution mode 2 test case ("OUTPUT").

80	6	26	178	3	82.	21.	0.029	11.2	0.150E+00
80	6	26	178	4	86.	33.	0.064	11.9	0.150E+00
80	6	26	178	5	76.	27.	0.048	11.2	0.150E+00
80	6	26	178	6	76.	-999.	0.136	-12.5	0.150E+00
80	6	26	178	7	76.	-999.	0.247	-18.5	0.150E+00
80	6	26	178	8	-999.	-999.	0.275	-11.6	0.150E+00
80	6	26	178	9	-999.	-999.	0.285	-8.9	0.150E+00
80	6	26	178	22	76.	42.	0.105	11.2	0.150E+00
80	6	26	178	23	79.	42.	0.105	11.2	0.150E+00
80	6	26	178	24	79.	43.	0.110	11.2	0.150E+00
80	6	27	179	1	82.	30.	0.057	11.2	0.150E+00
80	6	27	179	2	102.	29.	0.052	11.2	0.150E+00
80	6	27	179	3	95.	21.	0.029	11.2	0.150E+00
80	6	27	179	4	102.	33.	0.064	11.9	0.150E+00
80	6	27	179	5	102.	27.	0.048	11.2	0.150E+00
80	6	27	179	6	135.	29.	0.052	11.2	0.150E+00
80	6	27	179	7	144.	-999.	0.248	-17.5	0.150E+00
80	6	27	179	8	-999.	-999.	0.275	-11.6	0.150E+00
80	6	27	179	9	-999.	-999.	0.285	-8.8	0.150E+00
80	6	27	179	22	233.	42.	0.105	11.2	0.150E+00
80	6	27	179	23	-9999.	-9999.	-999.999	-9999.9	-.999E+03
80	6	27	179	24	239.	43.	0.110	11.2	0.150E+00

Figure D-15. **Output file of surface boundary layer vaiables used by CTDM; METPRO execution mode 2 test case ("SURFACE").**

```
3
39.5915   89.4885   6
4
  46   60
  61  120
 121  250
 251   45
 0.05  0.05  0.05  0.05  0.06  0.07  0.07  0.07  0.07  0.07  0.05  0.05
 0.33  0.29  0.24  0.12  0.10  0.11  0.14  0.14  0.14  0.14  0.22  0.30
 0.55  0.55  0.30  1.05  1.05  1.05  2.05  2.05  0.50  0.55  0.55  0.55
 0.09  0.09  0.09  0.09  0.11  0.14  0.14  0.14  0.14  0.14  0.09  0.09
 0.56  0.50  0.40  0.17  0.14  0.16  0.21  0.21  0.21  0.21  0.36  0.50
 0.91  0.91  0.46  1.81  1.81  1.81  3.61  3.61  0.82  0.91  0.91  0.91
 0.10  0.10  0.10  0.10  0.12  0.15  0.15  0.15  0.15  0.15  0.10  0.10
 0.61  0.54  0.44  0.19  0.16  0.18  0.23  0.23  0.23  0.23  0.40  0.56
 1.00  1.00  0.50  2.00  2.00  2.00  4.00  4.00  0.90  1.00  1.00  1.00
 0.09  0.09  0.09  0.09  0.11  0.14  0.14  0.14  0.14  0.14  0.09  0.09
 0.56  0.50  0.40  0.17  0.14  0.16  0.21  0.21  0.21  0.21  0.36  0.50
 0.91  0.91  0.46  1.81  1.81  1.81  3.61  3.61  0.82  0.91  0.91  0.91
```

Figure D-16. Input options and site data; METPRO execution mode 3 test case ("OPTIONS").

80	6	26	1	10.	0	189.	1.2	299.3	1.0	.03	-999.9
80	6	26	1	100.	1	189.	3.9	299.3	1.0	.03	-999.9
80	6	26	2	10.	0	194.	1.1	299.2	2.6	.02	-999.9
80	6	26	2	100.	1	194.	3.8	299.2	2.6	.02	-999.9
80	6	26	3	10.	0	200.	.6	298.8	6.3	.01	-999.9
80	6	26	3	100.	1	200.	3.5	298.8	6.3	.01	-999.9
80	6	26	4	10.	0	185.	1.3	298.6	5.3	.01	-999.9
80	6	26	4	100.	1	185.	2.4	298.6	5.3	.01	-999.9
80	6	26	5	10.	0	196.	1.0	298.1	3.5	.02	-999.9
80	6	26	5	100.	1	196.	3.1	298.1	3.5	.02	-999.9
80	6	26	6	10.	0	186.	1.1	297.9	4.3	.04	-999.9
80	6	26	6	100.	1	186.	3.8	297.9	4.3	.04	-999.9
80	6	26	7	10.	0	189.	2.1	298.0	4.5	.08	-999.9
80	6	26	7	100.	1	189.	4.2	298.0	4.5	.08	-999.9
80	6	26	8	10.	0	180.	2.2	298.1	7.9	.19	-999.9
80	6	26	8	100.	1	180.	3.2	298.1	7.9	.19	-999.9
80	6	26	9	10.	0	175.	2.2	298.2	13.9	.39	-999.9
80	6	26	9	100.	1	175.	2.6	298.2	13.9	.39	-999.9
80	6	26	10	10.	0	209.	2.2	299.4	13.6	.49	-999.9
80	6	26	10	100.	1	209.	2.5	299.4	13.6	.49	-999.9
80	6	26	11	10.	0	179.	2.3	300.1	14.6	.47	-999.9
80	6	26	11	100.	1	179.	2.5	300.1	14.6	.47	-999.9
80	6	26	12	10.	0	200.	2.4	300.7	17.0	.53	-999.9
80	6	26	12	100.	1	200.	3.0	300.7	17.0	.53	-999.9
80	6	26	13	10.	0	189.	2.1	301.3	14.9	.53	-999.9
80	6	26	13	100.	1	189.	2.5	301.3	14.9	.53	-999.9
80	6	26	14	10.	0	189.	1.2	299.3	1.0	.03	-999.9
80	6	26	14	100.	1	189.	3.9	299.3	1.0	.03	-999.9
80	6	26	15	10.	0	194.	1.1	299.2	2.6	.02	-999.9
80	6	26	15	100.	1	194.	3.8	299.2	2.6	.02	-999.9
80	6	26	16	10.	0	200.	.6	298.8	6.3	.01	-999.9
80	6	26	16	100.	1	200.	3.5	298.8	6.3	.01	-999.9
80	6	26	17	10.	0	185.	1.3	298.6	5.3	.01	-999.9
80	6	26	17	100.	1	185.	2.4	298.6	5.3	.01	-999.9
80	6	26	18	10.	0	196.	1.0	298.1	3.5	.02	-999.9
80	6	26	18	100.	1	196.	3.1	298.1	3.5	.02	-999.9
80	6	26	19	10.	0	186.	1.1	297.9	4.3	.04	-999.9
80	6	26	19	100.	1	186.	3.8	297.9	4.3	.04	-999.9
80	6	26	20	10.	0	189.	2.1	298.0	4.5	.08	-999.9
80	6	26	20	100.	1	189.	4.2	298.0	4.5	.08	-999.9
80	6	26	21	10.	0	180.	2.2	298.1	7.9	.19	-999.9
80	6	26	21	100.	1	180.	3.2	298.1	7.9	.19	-999.9
80	6	26	22	10.	0	175.	2.2	298.2	13.9	.39	-999.9
80	6	26	22	100.	1	175.	2.6	298.2	13.9	.39	-999.9
80	6	26	23	10.	0	209.	2.2	299.4	13.6	.49	-999.9
80	6	26	23	100.	1	209.	2.5	299.4	13.6	.49	-999.9
80	6	26	24	10.	0	179.	2.3	300.1	14.6	.47	-999.9
80	6	26	24	100.	1	179.	2.5	300.1	14.6	.47	-999.9
80	6	27	1	10.	0	189.	1.2	299.3	1.0	.03	-999.9
80	6	27	1	100.	1	189.	3.9	299.3	1.0	.03	-999.9
80	6	27	2	10.	0	194.	1.1	299.2	2.6	.02	-999.9
80	6	27	2	100.	1	194.	3.8	299.2	2.6	.02	-999.9
80	6	27	3	10.	0	200.	.6	298.8	6.3	.01	-999.9
80	6	27	3	100.	1	200.	3.5	298.8	6.3	.01	-999.9
80	6	27	4	10.	0	185.	1.3	298.6	5.3	.01	-999.9
80	6	27	4	100.	1	185.	2.4	298.6	5.3	.01	-999.9
80	6	27	5	10.	0	196.	1.0	298.1	3.5	.02	-999.9

Figure D-17. Input tower data used for METPRO execution mode 3 test case ("PROFILE").

80	6	27	5	100.	1	196.	3.1	298.1	3.5	.02	-999.9
80	6	27	6	10.	0	186.	1.1	297.9	4.3	.04	-999.9
80	6	27	6	100.	1	186.	3.8	297.9	4.3	.04	-999.9
80	6	27	7	10.	0	189.	2.1	298.0	4.5	.08	-999.9
80	6	27	7	100.	1	189.	4.2	298.0	4.5	.08	-999.9
80	6	27	8	10.	0	180.	2.2	298.1	7.9	.19	-999.9
80	6	27	8	100.	1	180.	3.2	298.1	7.9	.19	-999.9
80	6	27	9	10.	0	175.	2.2	298.2	13.9	.39	-999.9
80	6	27	9	100.	1	175.	2.6	298.2	13.9	.39	-999.9
80	6	27	10	10.	0	-999.	-9.9	-999.9	-99.9	-9.9	-999.9
80	6	27	10	100.	1	-999.	-9.9	-999.9	-99.9	-9.9	-999.9
80	6	27	11	10.	0	179.	2.3	300.1	14.6	.47	-999.9
80	6	27	11	100.	1	179.	2.5	300.1	14.6	.47	-999.9
80	6	27	12	10.	0	200.	2.4	300.7	17.0	.53	-999.9
80	6	27	12	100.	1	200.	3.0	300.7	17.0	.53	-999.9
80	6	27	13	10.	0	189.	2.1	301.3	14.9	.53	-999.9
80	6	27	13	100.	1	189.	2.5	301.3	14.9	.53	-999.9
80	6	27	14	10.	0	189.	1.2	299.3	1.0	.03	-999.9
80	6	27	14	100.	1	189.	3.9	299.3	1.0	.03	-999.9
80	6	27	15	10.	0	194.	1.1	299.2	2.6	.02	-999.9
80	6	27	15	100.	1	194.	3.8	299.2	2.6	.02	-999.9
80	6	27	16	10.	0	200.	.6	298.8	6.3	.01	-999.9
80	6	27	16	100.	1	200.	3.5	298.8	6.3	.01	-999.9
80	6	27	17	10.	0	185.	1.3	298.6	5.3	.01	-999.9
80	6	27	17	100.	1	185.	2.4	298.6	5.3	.01	-999.9
80	6	27	18	10.	0	196.	1.0	298.1	3.5	.02	-999.9
80	6	27	18	100.	1	196.	3.1	298.1	3.5	.02	-999.9
80	6	27	19	10.	0	186.	1.1	297.9	4.3	.04	-999.9
80	6	27	19	100.	1	186.	3.8	297.9	4.3	.04	-999.9
80	6	27	20	10.	0	189.	2.1	298.0	4.5	.08	-999.9
80	6	27	20	100.	1	189.	4.2	298.0	4.5	.08	-999.9
80	6	27	21	10.	0	180.	2.2	298.1	7.9	.19	-999.9
80	6	27	21	100.	1	180.	3.2	298.1	7.9	.19	-999.9
80	6	27	22	10.	0	175.	2.2	298.2	13.9	.39	-999.9
80	6	27	22	100.	1	175.	2.6	298.2	13.9	.39	-999.9
80	6	27	23	10.	0	-999.	-9.9	-999.9	-99.9	-9.9	-999.9
80	6	27	23	100.	1	-999.	-9.9	-999.9	-99.9	-9.9	-999.9
80	6	27	24	10.	0	179.	2.3	300.1	14.6	.47	-999.9
80	6	27	24	100.	1	179.	2.5	300.1	14.6	.47	-999.9

Figure D-17. (Continued).

80	6	26	1	.0	-43.8	92.0	-9999	-9
80	6	26	2	.0	-42.3	79.0	-9999	-9
80	6	26	3	.0	-40.8	82.0	-9999	-9
80	6	26	4	.0	-34.7	86.0	-9999	-9
80	6	26	5	.0	-27.2	76.0	-9999	-9
80	6	26	6	79.0	30.4	76.0	-9999	-9
80	6	26	7	-999.0	-999.0	76.0	-9999	-9
80	6	26	8	-999.0	-999.0	-999.0	-9999	-9
80	6	26	9	583.0	391.8	-999.0	-9999	-9
80	6	26	10	739.1	516.0	-999.0	-9999	-9
80	6	26	11	862.4	604.7	-999.0	-9999	-9
80	6	26	12	799.5	576.3	-999.0	-9999	-9
80	6	26	13	925.8	659.4	-999.0	-9999	-9
80	6	26	14	-999.0	-999.0	-999.0	-9999	-9
80	6	26	15	-999.0	-999.0	-999.0	-9999	-9
80	6	26	16	-999.0	-999.0	-999.0	-9999	-9
80	6	26	17	-999.0	-999.0	-999.0	-9999	-9
80	6	26	18	-999.0	-999.0	-999.0	-9999	-9
80	6	26	19	-999.0	-999.0	-999.0	-9999	-9
80	6	26	20	-999.0	-999.0	121.0	-9999	-9
80	6	26	21	-999.0	-999.0	86.0	-9999	-9
80	6	26	22	-999.0	-999.0	76.0	-9999	-9
80	6	26	23	-999.0	-999.0	79.0	-9999	-9
80	6	26	24	-999.0	-999.0	79.0	-9999	-9
80	6	27	1	-999.0	-999.0	82.0	-9999	-9
80	6	27	2	-999.0	-999.0	102.0	-9999	-9
80	6	27	3	-999.0	-999.0	95.0	-9999	-9
80	6	27	4	-999.0	-999.0	102.0	-9999	-9
80	6	27	5	-999.0	-999.0	102.0	-9999	-9
80	6	27	6	-999.0	-999.0	135.0	-9999	-9
80	6	27	7	-999.0	-999.0	144.0	-9999	-9
80	6	27	8	-999.0	-999.0	-999.0	-9999	-9
80	6	27	9	-999.0	-999.0	-999.0	-9999	-9
80	6	27	10	-999.0	-999.0	-999.0	-9999	-9
80	6	27	11	-999.0	-999.0	-999.0	-9999	-9
80	6	27	12	-999.0	-999.0	-999.0	-9999	-9
80	6	27	13	-999.0	-999.0	-999.0	-9999	-9
80	6	27	14	-999.0	-999.0	-999.0	-9999	-9
80	6	27	15	-999.0	-999.0	-999.0	-9999	-9
80	6	27	16	-999.0	-999.0	-999.0	-9999	-9
80	6	27	17	-999.0	-999.0	-999.0	-9999	-9
80	6	27	18	-999.0	-999.0	-999.0	-9999	-9
80	6	27	19	-999.0	-999.0	-999.0	-9999	-9
80	6	27	20	-999.0	-999.0	177.0	-9999	-9
80	6	27	21	-999.0	-999.0	206.0	-9999	-9
80	6	27	22	-999.0	-999.0	233.0	-9999	-9
80	6	27	23	-999.0	-999.0	259.0	-9999	-9
80	6	27	24	-999.0	-999.0	239.0	-9999	-9

Figure D-18. Input on-site surface parameters used in METPRO execution mode 3 test case ("SURF1").

```
9382280 626 0---          6815 42991 70          0
9382280 626 1---          69 0 02991 70          2
9382280 626 2---          6811 42991 69          2
9382280 626 3---          6813 42991 68          1
9382280 626 4---          6614 42994 67          2
9382280 626 5---          7012 42994 72          1
9382280 626 6---          7122 42994 78          0
9382280 626 7---          7218 82994 82          0
9382280 626 8---          7119 82994 85          1
9382280 626 9---          7018 62994 86          1
9382280 62610---          7125 62994 90          4
9382280 62611 45          7125 82994 92          6
9382280 62612---          7125 82991 92          4
9382280 62613---          7123 82988 93          0
9382280 62614---          7121 82988 94          0
9382280 62615---          7024 82988 94          0
9382280 62616---          7023 62988 93          0
9382280 62617---          7119 62988 92          0
9382280 62618---          7219 42988 89          0
9382280 62619---          7219 42988 85          0
9382280 62620---          7218 32991 83          0
9382280 62621---          7219 32991 81          0
9382280 62622---          7119 22991 78          0
9382280 62623---          7218 22991 79          0
9382280 627 0---          72 0 02988 78          0
9382280 627 1---          71 0 02991 76          0
9382280 627 2---          7119 52988 77          0
9382280 627 3---          7119 42988 76          0
9382280 627 4---          7218 32988 77          1
9382280 627 5---          72 0 02991 77          2
9382280 627 6---          7322 42994 80          2
9382280 627 7---          7419 62991 84          0
9382280 627 8---          7519 82991 88          0
9382280 627 9---          7320102991 90          0
9382280 62710---          7418122988 92          2
9382280 62711---          7319142985 95          0
9382280 62712---          7319142982 95          0
9382280 62713---          7416142979 96          0
9382280 62714---          7216162977 96          0
9382280 62715---          7217172977 96          0
9382280 62716---          7218162977 95          0
9382280 62717---          7218162974 92          0
9382280 62718---          7318122974 90          1
9382280 62719---          7317142974 88          2
9382280 62720250          7315102974 86          6
9382280 62721250          7318102977 86          5
9382280 62722---          7319122974 84          3
9382280 62723---          7419122974 83          3
```

Figure D-19. Input off-site surface data for METPRO execution mode 3 test case ("SURF2").

```
5600      14842       80 625 0
 990.7/ 200./299.2/160/  2
 900.0/1037./291.3/167/  4
 788.0/2165./285.7/130/  4
 700.0/3158./284.0/ 50/  4
5600      14842       80 62512
 991.6/ 200./292.0/ 60/  1
 914.0/ 908./292.6/162/  3
 800.0/2047./287.5/165/  2
 726.0/2865./285.9/ 29/  1
5600      14842       80 626 0
 990.7/ 200./302.5/170/  2
 850.0/1538./290.0/199/  2
 788.0/2183./289.6/ 28/  1
5600      14842       80 62612
 991.3/ 200./292.0/  0/  0
 900.0/1041./293.1/268/  2
 800.0/2059./294.2/325/  3
5600      14842       80 627 0
 990.5/ 200./304.8/240/  3
 889.0/1157./294.8/224/  5
 800.0/2070./293.3/333/  3
5600      14842       80 62712
 990.7/ 200./294.8/190/  2
 900.0/1043./294.8/184/  7
 800.0/2063./293.0/219/  4
 700.0/3197./285.0/259/  6
5600      14842       80 628 0
 986.1/ 200./305.9/180/  6
 850.0/1514./293.5/191/ 11
 786.0/2193./295.3/233/ 11
5600      14842       80 62812
 986.6/ 200./293.7/170/  3
 892.0/1081./295.9/214/  7
 800.0/2026./291.3/291/  7
 725.0/2863./286.2/295/ 10

 50
986.0/ 242./298.4/155/  2
889.0/1142./290.3/168/  5
764.0/2425./285.9/120/  4

 65
976.0/ 338./295.0/142/  1
900.0/1041./292.1/161/  3
787.0/2185./287.6/123/  1
700.0/3171./285.3/358/  2
 43
978.0/ 315./300.8/173/  2
839.0/1649./289.4/194/  2
750.0/2604./290.6/ 11/  3
 46
976.0/ 335./297.1/235/  1
880.0/1236./291.6/266/  2
750.0/2612./289.8/  1/  5
 49
973.0/ 360./302.5/244/  3
868.0/1365./293.7/231/  5
755.0/2566./290.7/300/  5
 57
968.0/ 404./298.7/200/  6
895.0/1092./294.3/179/  6
777.0/2313./291.9/223/  5

 56
972.0/ 330./303.9/182/  8
839.0/1627./292.9/201/ 11
750.0/2598./292.5/239/ 12
 54
950.0/ 529./295.9/157/ 13
872.0/1279./295.2/246/  8
782.0/2221./290.8/308/  6
700.0/3158./286.6/292/ 13

          13
950.0/ 569./295.3/
850.0/1525./288.0/
750.0/2581./285.6/

          14
955.0/ 528./294.1/
850.0/1531./289.9/
762.0/2458./287.6/

          12
950.0/ 573./298.6/
821.0/1834./288.4/
749.0/2615./290.7/
          11
959.0/ 489./297.1/
870.0/1334./293.1/
700.0/3194./284.9/
          12
950.0/ 574./300.5/
850.0/1546./294.1/
750.0/2623./290.3/
          13
953.0/ 542./298.9/
878.0/1258./294.7/
750.0/2615./289.7/

          11
950.0/ 536./302.2/
826.0/1762./295.3/
700.0/3186./288.3/
          14
929.0/ 725./297.3/
850.0/1502./293.7/
753.0/2543./287.9/
```

Figure D-20. Input upper air data (processed by READ62) used by METPRO execution mode 3 ("RAWIN").

```
PROGRAM OPTIONS:

     MODE = 3 IF 0, DO NOT READ NWS SURFACE DATA NOR UPPER AIR DATA,
                    ASSUME CONSTANT SITE CHARACTERISTICS
              IF 1, DO NOT READ NWS SURFACE DATA NOR UPPER AIR DATA,
                    BUT ASSUME VARIABLE SITE CHARACTERISTICS
              IF 2, READ NWS SURFACE DATA, BUT NOT UPPER AIR DATA
              IF 3, READ NWS SURFACE DATA AND UPPER AIR DATA


LATITUDE (DEG NORTH) =  39.59, LONGITUDE (DEG WEST) =   89.49
TIME ZONE (HOURS AFTER GMT) =   6.0

# OF WIND DIRECTION SECTORS FOR SPECIFYING SURFACE CHARACTERISTICS = 4


     WIND DIRECTION SECTORS AND ANGLE RANGES:

     1:  46- 60

     2:  61-120

     3: 121-250

     4: 251- 45


SECTOR VALUES FOR SURFACE ROUGHNESS (M), ALBEDO, AND BOWEN RATIO:
```

VARIABLE	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
Z0:	0.050	0.050	0.050	0.050	0.060	0.070	0.070	0.070	0.070	0.070	0.050	0.050
ALBEDO:	0.330	0.290	0.240	0.120	0.100	0.110	0.140	0.140	0.140	0.140	0.220	0.300
BOWEN:	0.550	0.550	0.300	1.050	1.050	1.050	2.050	2.050	0.500	0.550	0.550	0.550
(SECTOR 1)												
Z0:	0.090	0.090	0.090	0.090	0.110	0.140	0.140	0.140	0.140	0.140	0.090	0.090
ALBEDO:	0.560	0.500	0.400	0.170	0.140	0.160	0.210	0.210	0.210	0.210	0.360	0.500
BOWEN:	0.910	0.910	0.460	1.810	1.810	1.810	3.610	3.610	0.820	0.910	0.910	0.910
(SECTOR 2)												
Z0:	0.100	0.100	0.100	0.100	0.120	0.150	0.150	0.150	0.150	0.150	0.100	0.100
ALBEDO:	0.610	0.540	0.440	0.190	0.160	0.180	0.230	0.230	0.230	0.230	0.400	0.560
BOWEN:	1.000	1.000	0.500	2.000	2.000	2.000	4.000	4.000	0.900	1.000	1.000	1.000
(SECTOR 3)												
Z0:	0.090	0.090	0.090	0.090	0.110	0.140	0.140	0.140	0.140	0.140	0.090	0.090
ALBEDO:	0.560	0.500	0.400	0.170	0.140	0.160	0.210	0.210	0.210	0.210	0.360	0.500
BOWEN:	0.910	0.910	0.460	1.810	1.810	1.810	3.610	3.610	0.820	0.910	0.910	0.910
(SECTOR 4)												

```
MISSING WIND AND/OR TEMPERATURE DATA FOR
     (MM DD YY HH): 80  6 27 10; MISSING DATA WRITTEN TO "SURFACE"

MISSING WIND AND/OR TEMPERATURE DATA FOR
     (MM DD YY HH): 80  6 27 23; MISSING DATA WRITTEN TO "SURFACE"
```

Figure D-21. Output verification of options and site data for METPRO execution mode 3 ("OUTPUT").

80	6	26	178	1	92.	30.	0.057	11.2	0.150E+00
80	6	26	178	2	79.	29.	0.052	11.2	0.150E+00
80	6	26	178	3	82.	21.	0.029	11.2	0.150E+00
80	6	26	178	4	86.	33.	0.064	11.9	0.150E+00
80	6	26	178	5	76.	27.	0.048	11.2	0.150E+00
80	6	26	178	6	76.	24.	0.136	-12.5	0.150E+00
80	6	26	178	7	76.	121.	0.247	-18.5	0.150E+00
80	6	26	178	8	-999.	335.	0.275	-11.6	0.150E+00
80	6	26	178	9	-999.	708.	0.285	-8.9	0.150E+00
80	6	26	178	10	-999.	1242.	0.293	-7.4	0.150E+00
80	6	26	178	11	-999.	1288.	0.307	-7.2	0.150E+00
80	6	26	178	12	-999.	1332.	0.315	-8.2	0.150E+00
80	6	26	178	13	-999.	1406.	0.293	-5.7	0.150E+00
80	6	26	178	14	-999.	1470.	0.201	-2.1	0.150E+00
80	6	26	178	15	-999.	1526.	0.187	-2.0	0.150E+00
80	6	26	178	16	-999.	1581.	0.126	-1.0	0.150E+00
80	6	26	178	17	-999.	1621.	0.194	-3.8	0.150E+00
80	6	26	178	18	-999.	1641.	0.152	-3.5	0.150E+00
80	6	26	178	19	-999.	1643.	0.127	-21.0	0.150E+00
80	6	26	178	20	121.	1643.	0.100	11.2	0.150E+00
80	6	26	178	21	86.	42.	0.105	11.2	0.150E+00
80	6	26	178	22	76.	42.	0.105	11.2	0.150E+00
80	6	26	178	23	79.	42.	0.105	11.2	0.150E+00
80	6	26	178	24	79.	43.	0.110	11.2	0.150E+00
80	6	27	179	1	82.	30.	0.057	11.2	0.150E+00
80	6	27	179	2	102.	29.	0.052	11.2	0.150E+00
80	6	27	179	3	95.	21.	0.029	11.2	0.150E+00
80	6	27	179	4	102.	33.	0.064	11.9	0.150E+00
80	6	27	179	5	102.	27.	0.048	11.2	0.150E+00
80	6	27	179	6	135.	29.	0.052	11.2	0.150E+00
80	6	27	179	7	144.	114.	0.248	-17.5	0.150E+00
80	6	27	179	8	-999.	347.	0.275	-11.6	0.150E+00
80	6	27	179	9	-999.	632.	0.285	-8.8	0.150E+00
80	6	27	179	10	-9999.	-9999.	-999.999	-9999.9	-.999E+03
80	6	27	179	11	-999.	1247.	0.306	-7.5	0.150E+00
80	6	27	179	12	-999.	1340.	0.316	-7.9	0.150E+00
80	6	27	179	13	-999.	1432.	0.290	-6.1	0.150E+00
80	6	27	179	14	-999.	1519.	0.201	-2.1	0.150E+00
80	6	27	179	15	-999.	1630.	0.187	-2.0	0.150E+00
80	6	27	179	16	-999.	1728.	0.126	-1.0	0.150E+00
80	6	27	179	17	-999.	1798.	0.194	-3.8	0.150E+00
80	6	27	179	18	-999.	1835.	0.152	-3.5	0.150E+00
80	6	27	179	19	-999.	1840.	0.131	-16.6	0.150E+00
80	6	27	179	20	177.	1840.	0.100	11.2	0.150E+00
80	6	27	179	21	206.	48.	0.115	13.7	0.150E+00
80	6	27	179	22	233.	42.	0.105	11.2	0.150E+00
80	6	27	179	23	-9999.	-9999.	-999.999	-9999.9	-.999E+03
80	6	27	179	24	239.	43.	0.110	11.2	0.150E+00

Figure D-22. Output file of surface boundary layer variables used by CTDM; METPRO execution mode 3 test case("SURFACE").

APPENDIX E
READ62 CODE LISTINGS

```
C***********************************************************************
C
C       READ62 - PREPROCESSOR FOR UPPER AIR DATA
C
C       THIS PROGRAM READS A TD-6201 UPPER AIR FILE, EXTRACTS DATA
C       FOR PRESSURE LEVELS REQUESTED, AND CREATES A FORMATTED FILE
C       FOR EDITING AND INPUT TO THE HPDM MET PREPROCESSOR
C
C       NOTE: FORMAT ASSUMED IS FIXED BLOCK RECORDS OF 2876 BYTES
C             EACH (79 LEVELS PER RECORD)
C
C I/O:
C     UNIT 0 - CONSOLE OUTPUT (WRITES CURRENT SOUNDING BEING READ)
C     UNIT 5 - CARD-IMAGE INPUT DATA:  'OPT62'
C     UNIT 6 - PRINTER OUTPUT: 'OUTPUT'
C     UNIT 8 - INPUT TD-6201 (UPPER AIR) DATA FILE:  'TD6201'
C     UNIT 9 - OUTPUT FORMATTED UPPER AIR DATA FILE: 'RAWIN'
C
C
C DETAILS OF CARD-IMAGE INPUT DATA (FREE FORMAT):
C
C
C      FIRST LINE:
C
C      IBYR, IBDAY, IBHR:  YEAR, JULIAN DAY, AND HOUR (GMT) TO BEGIN
C                             EXTRACTING DATA FROM INPUT TD-6201 FILE
C      IEYR, IEDAY, IEHR:  YEAR, JULIAN DAY, AND HOUR (GMT) AFTER WHICH
C                             TO STOP EXTRACTING DATA FROM INPUT TD-6201
C                             FILE
C      PSTOP:              LOWEST PRESSURE FOR WHICH INFORMATION IS TO
C                             BE EXTRACTED
C      SECOND LINE:
C
C      LHT,LTEMP,LWD,LWS: CORRESPONDS TO HEIGHT, TEMPERATURE, WIND
C                         DIRECTION AND WIND SPEED DATA: IF THE VALUE
C                         IS MISSING, DISCARD THE DATA LEVEL IF THE
C                         SWITCH IS 1, DO NOT DISCARD IF THE SWITCH IS 0
C
C DETAILS OF TD-6201 CONTENT:
C
C       HEADER INFORMATION FOR EACH SOUNDING TIME:
C
C      STNID           STATION IDENTIFICATION
C      LAT             LATITUDE -- THE STATION LATITUDE IN DEG AND MIN,
C                        FOLLOWED BY 'N' OR 'S'
C      LON             LONGITUDE-- THE STATION LONGITUDE IN DEG AND MIN,
C                        FOLLOWED BY 'E' OR 'W'
C      YEAR, MONTH, DAY, HOUR  -- THE SCHEDULED TIME OF THE OBSERVATION
C      NUMLEV          NUMBER OF REPEATING GROUPS -- THIS REPRESENTS
C                        THE NUMBER OF DATA LEVELS FOUND IN THE CURRENT
C                        OBSERVATION (79 IS THE MAXIMUM NUMBER STORED)
C
C       DATA FOR EACH NUMLEV PRESSURE LEVEL:
C
C      QIND            LEVEL-QUALITY-INDICATOR -- DENOTES THE RESULTS OF
C                        ANY QUALITY CONTROLS APPLIED TO THIS LEVEL (THIS
C                        IS USED IN THIS PROGRAM)
C      ETIME           THE ELAPSED TIME SINCE THE RELEASE OF THE SOUNDING
C                        IN MINUTES AND TENTHS (IGNORED HERE)
C      PRES            ATMOSPHERIC PRESSURE AT THE CURRENT LEVEL (READ IN
```

```
C                      AS MILLIBARS)
C      HGT             GEOPOTENTIAL HEIGHT OF THE CURRENT LEVEL IN METERS
C      TEMP            THE FREE AIR TEMPERATURE AT THE CURRENT LEVEL IN
C                        DEGREES AND TENTHS CELSIUS.
C      RH              THE RELATIVE HUMIDITY AT THE CURRENT LEVEL IN %
C      WD              DIRECTION OF THE WIND AT THE CURRENT LEVEL IN DEG
C      WS              SPEED OF THE WIND IN WHOLE METERS PER SECOND.
C      TIMEF,PRESF,HGTF,TEMPF,RHF,WINDF  --  QUALITY CONTROL FLAGS
C                        (USED HERE)
C      TYPLEV          TYPE OF LEVEL FLAG (IGNORED HERE)
C
C
C      EXTERNAL FUNCTION: GOOD (INTEGER)
C
C***********************************************************************
C
      REAL HEIGHT(79),HIGHT(79),ETIME
      REAL APRES(79),ATEMP(79),PRES(79),TEMP(79)
      INTEGER MON(12),LMON(12),YEAR,MONTH,DAY,HOUR,GOOD
      INTEGER WS(79),AWS(79),WD(79),AWD(79),RH
      INTEGER LHT,LTEMP,LWD,LWS
      CHARACTER*1 LATA,LONA,QIND(79),TIMEF(79),PRESF(79),
     1  HGTF(79),TEMPF(79),RHF,WINDF(79),TYPLEV
      CHARACTER*5 STNID
      CHARACTER*32 JUNK
C
      DATA MON/0,31,59,90,120,151,181,212,243,273,304,334/
      DATA LMON/0,31,60,91,121,152,182,213,244,274,305,335/
C
C-----OPEN FILES
C
      IN = 5
      IOUT = 6
      ITD = 8
      IRAWIN = 9
      OPEN(IN,FILE='OPT62',STATUS='OLD')
      OPEN(IOUT,FILE='OUTPUT',STATUS='UNKNOWN')
      OPEN(ITD,FILE='TD6201',STATUS='OLD',FORM='FORMATTED')
      OPEN(IRAWIN,FILE='RAWIN',STATUS='UNKNOWN')
C
      WRITE(IOUT,6010)
C
C-----READ CARD-IMAGE INPUTS FROM UNIT 5 (FREE FORMAT)
C
      READ(IN,*)IBYR,IBDAY,IBHR,IEYR,IEDAY,IEHR,PSTOP
      WRITE(IOUT,6020)IBYR,IEYR,IBDAY,IEDAY,IBHR,IEHR
      WRITE(IOUT,6030)PSTOP
C
      READ(IN,*)LHT,LTEMP,LWD,LWS
      WRITE(IOUT,6040)LHT,LTEMP,LWD,LWS
C
      WRITE(IOUT,6050)
C
C       INITIALIZE PREVIOUS GOOD SOUNDING TIME
C
      IF(IBHR.EQ.0)GO TO 100
C-----STARTING HOUR = 12
      JDAY2=IBDAY
      ISAV2=0
      GO TO 200
```

```
100   CONTINUE
C-----STARTING HOUR = 00
      JDAY2=IBDAY-1
      ISAV2=12
200   CONTINUE
C
1000  CONTINUE
C
C-----READ TD-6201 SOUNDING FROM UNIT ITD
C
        READ(ITD,6100,END=2000) STNID,LAT,LATA,LON,LONA,YEAR,MONTH,
     1  DAY,HOUR,NUMLEV,(QIND(I),ETIME,PRES(I),HEIGHT(I),
     2  TEMP(I),RH,WD(I),WS(I),TIMEF(I),PRESF(I),HGTF(I),TEMPF(I),
     3  RHF,WINDF(I),TYPLEV,I=1,79)
        WRITE(0,6220) MONTH, DAY, HOUR
        ALAT = LAT/100 + (LAT-(LAT/100*100))/60.
        ALON = LON/100 + (LON-(LON/100*100))/60.
C
C     IF CONTINUATION OF LAST SOUNDING, IGNORE AND READ NEXT SOUNDING
C
1050  IF(NUMLEV.LE.79) GO TO 1100
      READ(ITD,6150,END=2000) JUNK
      NUMLEV = MAX(NUMLEV-79,79)
      GO TO 1050
1100  CONTINUE
C
C*******ROUTINE TO CONVERT DATES TO JULIAN
C
        JDAY=MON(MONTH)+DAY
        IF(MOD(YEAR,4).EQ.0)JDAY=LMON(MONTH)+DAY
C
      IF(HOUR.NE.0 .AND. HOUR.NE.12) GO TO 1000
C
C       CHECK FOR BEGINNING AND ENDING TIMES
C
      IF(YEAR.LT.IBYR) GO TO 1000
      IF(YEAR.GT.IEYR) GO TO 5000
      IF(YEAR.EQ.IBYR.AND.JDAY.LT.IBDAY) GO TO 1000
      IF(YEAR.EQ.IEYR.AND.JDAY.GT.IEDAY) GO TO 5000
      IF(YEAR.EQ.IBYR.AND.JDAY.EQ.IBDAY.AND.HOUR.LT.IBHR) GO TO 1000
      IF(YEAR.EQ.IEYR.AND.JDAY.EQ.IEDAY.AND.HOUR.GT.IEHR) GO TO 5000
C
C       COMPRESS ARRAYS IF MISSING VALUES ARE FOUND
C
      KK=0
      DO 1200 JJ=1,NUMLEV
      IF(GOOD(QIND(JJ)).EQ.0) GO TO 1200
      IF(LHT.EQ.1 .AND. (HEIGHT(JJ).GE.9999.9 .OR. GOOD(HGTF).EQ.0))
     1   GO TO 1200
      IF(LTEMP.EQ.1 .AND. (ABS(TEMP(JJ)).GE.99.9 .OR. GOOD(TEMPF).EQ.0))
     1   GO TO 1200
      IF(LWD.EQ.1 .AND. (WD(JJ).GE.999 .OR. GOOD(WINDF).EQ.0))GO TO 1200
      IF(LWS.EQ.1 .AND. (WS(JJ).GE.999 .OR. GOOD(WINDF).EQ.0))GO TO 1200
      KK=KK+1
      APRES(KK)=PRES(JJ)
      ATEMP(KK)=TEMP(JJ)
      AWS(KK)=WS(JJ)
      AWD(KK)=WD(JJ)
      HIGHT(KK)=HEIGHT(JJ)
1200  CONTINUE
```

```
      NLEV=KK
      DO 1300 LL=1,NLEV
      PRES(LL)=APRES(LL)
      TEMP(LL)=ATEMP(LL)
      WD(LL)=AWD(LL)
      WS(LL)=AWS(LL)
      HEIGHT(LL)=HIGHT(LL)
1300  CONTINUE
C
C-----DETERMINE LEVELS UP TO PSTOP
C
      KSTOP = 0
      DO 1500 I = 1,NLEV
      IF(PRES(I).LE.PSTOP) THEN
          ISTOP = I
          GO TO 1600
      ENDIF
1500  CONTINUE
      ISTOP = NLEV
      IF(ABS(PRES(NLEV)-PSTOP).GT.1.0) KSTOP = 1
1600  CONTINUE
C
C-----WRITE TO LINE PRINTER AND UPPER AIR OUTPUT FILE
C
      IF(KSTOP.EQ.0) THEN
          WRITE(IOUT,6060)YEAR,MONTH,DAY,JDAY,HOUR,ISTOP
          WRITE(IRAWIN,6200) STNID,YEAR,MONTH,DAY,HOUR,NLEV,ISTOP
        ELSE
          WRITE(IOUT,6065)YEAR,MONTH,DAY,JDAY,HOUR,ISTOP,PSTOP
          WRITE(IRAWIN,6205) STNID,YEAR,MONTH,DAY,HOUR,NLEV,ISTOP,PSTOP
      ENDIF
      WRITE(IRAWIN,6210) (PRES(I),HEIGHT(I),TEMP(I)+273.2,WD(I),WS(I),
     1 I=1,ISTOP)
C
C-----CHECK FOR MISSING DAYS
C
      IF(JDAY.EQ.JDAY2) GO TO 1700
      JDAY1=JDAY2
      JDAY2=JDAY
      IF(JDAY1.EQ.(JDAY2-1)) GO TO 1700
      WRITE(IOUT,6070)
      WRITE(IRAWIN,6070)
1700  CONTINUE
C
C-----CHECK FOR MISSING/DUPLICATE SOUNDINGS
C
      ISAV1=ISAV2
      ISAV2=HOUR
      IF(ISAV1.EQ.0) GO TO 1800
      IF(ISAV1.EQ.12.AND.ISAV2.EQ.0) GO TO 1900
      WRITE(IOUT,6080)
      WRITE(IRAWIN,6080)
      GO TO 1900
1800  CONTINUE
      IF(ISAV2.EQ.12)GO TO 1900
      WRITE(IOUT,6080)
      WRITE(IRAWIN,6080)
1900  CONTINUE
C
      GO TO 1000
```

```
2000  WRITE(IOUT,6090)YEAR,JDAY
C
5000  CONTINUE
      STOP
C
C       FORMAT STATEMENTS
C
6010  FORMAT('1',20X,'READ62',3X,'VERSION 2.0       LEVEL 870731',//)
6020  FORMAT('0','STARTING DATE:',16X,'ENDING DATE:'/'0',15X,'YEAR = ',
     1 I4,18X,'YEAR = ',I4/10X,'JULIAN DAY = ',I3,12X,'JULIAN DAY = ',
     2 I3/16X,'HOUR = ',I3,18X,'HOUR = ',I3)
6030  FORMAT(/'0','PRESSURE LEVELS EXTRACTED:'/'0',20X,'SURFACE',
     1 ' TO  ',F5.0,' MB')
6040  FORMAT(/,'0','SWITCHES FOR DISCARDING PRESSURE LEVELS: 0=NO, ',
     1 '1=YES',/,'0','DATA LEVEL ELIMINATED IF HEIGHT MISSING ? ',8X,I1,
     1 /,'0','DATA LEVEL ELIMINATED IF TEMPERATURE MISSING ? ',3X,I1,/,
     2 '0','DATA LEVEL ELIMINATED IF WIND DIRECTION MISSING ? ',I1,/,
     3 '0','DATA LEVEL ELIMINATED IF WIND SPEED MISSING ? ',4X,I1,/)
6050  FORMAT(/'0','THE FOLLOWING SOUNDINGS HAVE BEEN PROCESSED:'/
     1 '0',6X,'YEAR',3X,'MONTH',3X,'DAY',3X,'JULIAN DAY',3X,
     2 'HOUR (GMT)',3X,'NO. LEVELS EXTRACTED'/)
6060  FORMAT(8X,I2,5X,I2,6X,I2,7X,I3,9X,I2,15X,I4)
6065  FORMAT(8X,I2,5X,I2,6X,I2,7X,I3,9X,I2,15X,I4,/,10X,'  TOP OF ',
     1 'SOUNDING LISTED ABOVE IS BELOW THE ',F6.1,'-MB LEVEL ')
6070  FORMAT(1X,'->->->MISSING DAY(S)')
6080  FORMAT(1X,'->->->MISSING/DUPLICATE SOUNDING')
6090  FORMAT(20X,'EOF ON INPUT',/,20X,'LAST DAY READ =  ',I2,I3)
6100  FORMAT(3X,A5,I4,A1,I5,A1,2X,4(I2),I3,
     1       (79(A1,F4.1,F5.1,F6.0,F4.1,3(I3),7A1)))
6150  FORMAT(A32,79(36X))
6200  FORMAT(3X,'6201',5X,A5,5X,4I2,5X,I2,T69,I2)
6205  FORMAT(3X,'6201',5X,A5,5X,4I2,5X,I2,T69,I2,/,'TOP OF SOUNDING ',
     1 'BELOW ',F6.1,'-MB LEVEL ')
6210  FORMAT(4(3X,F6.1,'/',F5.0,'/',F5.1,'/',I3,'/',I3))
6220  FORMAT(' MONTH = ',I2,',    DAY = ',I2,',    HOUR = ',I2)

      END
```

```
C-----------------------------------------------------------------------
C INTEGER FUNCTION GOOD(IQUAL)
C
C PURPOSE: CHECKS QUALITY INDICATOR TO DETERMINE WHETHER OR NOT TO
C           ACCEPT THE UPPER AIR OBSERVATION AS VALID
C
C ASSUMPTIONS: TDF6201 FORMAT
C
C LIMITATIONS: NMC INDICATORS A-Z ARE NOT TESTED FOR BAD DATA
C
C ARGUMENTS
C  PASSED:
C       IQUAL   CHAR    QUALITY INDICATOR: 0-9 OR A-Z
C
C  RETURNED:
C       FUNCTION GOOD: 0 IF BAD DATA; 1 IF GOOD DATA
C
C  MEANING OF QUALITY INDICATORS FOR TDF6201 DATA:
C
C      0        ORIGINAL VALUES ARE CORRECT
C      1        ORIGINAL VALUES ARE MISSING
C      2        ORIGINAL VALUES ARE DOUBTFUL, A CORRECTED LEVEL FOLLOWS
C      3        ORIGINAL VALUES ARE DOUBTFUL, UNCORRECTED
C      4        ORIGINAL VALUES ARE IN ERROR, A CORRECTED LEVEL FOLLOWS
C      5        ORIGINAL VALUES ARE IN ERROR, UNCORRECTED
C      6        CORRRECTED LEVEL
C      9        LEVEL NOT CHECKED
C     A-Z       SUPPLIED BY NMC, HAVE CHANGED MANY TIMES OVER THE YEARS
C
C       GOOD RETURNS 0 IF CODE IS 1, 2, 3, 4, OR 5; 1 OTHERWISE
C
C
C CALLING ROUTINES: READ62
C
C-----------------------------------------------------------------------
C
      INTEGER FUNCTION GOOD(IQUAL)
      CHARACTER*1 IQUAL
C
      GOOD = 1
      IF(IQUAL.EQ.'1' .OR. IQUAL.EQ.'2' .OR. IQUAL.EQ.'3' .OR.
     1  IQUAL.EQ.'4' .OR. IQUAL.EQ.'5') GOOD = 0
      RETURN
      END
```

APPENDIX F
METPRO CODE LISTINGS

```
C-----------------------------------------------------------------------
C MAIN PROGRAM: METPRO
C
C PURPOSE: PROGRAM CREATES THE FILE "SURFACE" FOR USE IN CTDM
C
C METHODS: DURING THE DAY, COMPUTES USTAR AND L USING THE HOLTSLAG-VAN
C          ULDEN METHOD AND ZI USING 1) THE CARSON METHOD IF UPPER AIR
C          DATA ARE PROVIDED FOR AN CONTIGUOUS HOUR RUN, OR 2) USER-
C          PROVIDED VALUES OF MIXED LAYER HEIGHT FOR A RUN OF SELECTED
C          HOURS.  AT NIGHT, COMPUTES USTAR AND L USING THE VENKATRAM
C          METHOD AND MIXING HEIGHT USING THE ZILITINKEVICH METHOD.
C
C I/O: UNIT  5    INPUT     OPTIONS (PROGRAM OPTIONS)
C      UNIT  6    OUTPUT    OUTPUT  (LIST OF PROGRAM OPTIONS USED)
C      UNIT  7    OUTPUT    SURFACE (INPUT FILE TO CTDM)
C      UNIT  9    INPUT     RAWIN   (UPPER AIR DATA)
C      UNIT 10    INPUT     SURF1   (ONSITE MET DATA)
C      UNIT 11    INPUT     SURF2   (NWS SURFACE DATA)
C      UNIT 12    INPUT     PROFILE (ONSITE MET PROFILE)
C
C COMMON: PTEMP XSUMI   WIND    US      RNET    MONIN   CVR     TEMP
C         NCC   HMI     INIT    ZILIT   THS     IO
C
C EXTERNAL ROUTINES: DEFAUL     HOUR    HV      HVNET   INITT   MINUTE
C                    SENSE      SUMHH   SUMI    SUMVV   TT      ZZI
C                    HDAYUS     TOTAL   SUN     WNUS    JULIAN  RHOO
C                    ZILL
C
C INTRINSIC FUNCTIONS: SIN SQRT MIN EXP
C
C-----------------------------------------------------------------------
C
C      GLOSSARY OF IMPORTANT VARIABLES (MKS SYSTEM USED FOR UNITS)
C
C      CH:       CLOUD HEIGHT
C      CC:       CLOUD COVER
C      NLEV:     NUMBER OF SOUNDING LEVELS
C      WDSEC:    WIND DIRECTION BOUNDARIES OF UPWIND FETCH SECTORS
C      WD:       HOURLY WIND DIRECTION (NEAR 10 M) USED TO GET UPWIND
C                   CHARACTERISTICS
C      RN:       NET RADIATION
C      QR:       TOTAL INCOMING RADIATION
C      THSTAR:   THETA-STAR, THE TEMPERATURE SCALE FOR PROFILING
C      VONK:     VON KARMAN CONSTANT
C      ZIOBS:    OBSERVED (MEASURED) MIXED LAYER HEIGHT
C      Z0:       SURFACE ROUGHNESS LENGTH
C      ALB:      SURFACE ALBEDO
C      BOW:      BOWEN RATIO
C      SAI:      AREA UNDER Z-THETA CURVE (LEFT SIDE OF EQN 27 IN
C                   USER GUIDE)
C      SAI2:     AREA UNDER Z**2-THETA CURVE (LEFT SIDE OF EQN 28
C                   IN USER GUIDE)
C      L:        MONIN-OBUKHOV LENGTH
C      USTAR:    SURFACE FRICTION VELOCITY
C      ZIL:      COMPUTED (ESTIMATED) MIXED LAYER HEIGHT
C      T:        AMBIENT TEMPERATURE (NEAR 10 METERS)
C      WSL:      WIND SPEED AT 10 METERS
C      Z0DAY:    HOURLY SURFACE ROUGHNESS LENGTH VALUES
C      ZHR:      HEIGHTS OF DATA FROM FILE "PROFILE"
C      WDHR:     WIND DIRECTION VALUES FROM FILE "PROFILE"
```

```
C        WSHR:     WIND SPEED VALUES FROM FILE "PROFILE"
C        TAHR:     AMBIENT TEMPERATURE VALUES FROM FILE "PROFILE"
C        PRS:      PRESSURE VALUES AT SOUNDING LEVELS
C        TMP:      AMBIENT TEMPERATURE VALUES AT SOUNDING LEVELS
C        PTMP:     POTENTIAL TEMPERATURE (THETA) VALUES AT SOUNDING LEVELS
C        HT:       GEOPOTENTIAL HEIGHTS AT SOUNDING LEVELS
C        AI:       15-MINUTE PORTION OF SUM OVER TIME OF AREA UNDER Z-
C                     THETA CURVE
C        AI2:      15-MINUTE PORTION OF SUM OVER TIME OF AREA UNDER Z**2-
C                     THETA CURVE
C
         CHARACTER*1 NWSCC
         INTEGER Y,M,D,JUL,H,I,YUP,Y1,M1,D1,H1
         INTEGER CH(24),IHR,CC,MUP,DUP,ITIME,NLEV
         INTEGER MODE,Y2,M2,D2,H2
         INTEGER WDSEC(8,2),IDIFF,MISS(24)
         REAL WD(24),RN,RHOCP,QR,THSTAR,VONK
         REAL LAT,LONG,ZONE,RHO
         REAL ZIOBS(24),Z0(12,8),ALB(12,8),BOW(12,8),SAI,SAI2,L,USTAR
         REAL ZIL,T,WSL,Z0DAY(24)
         REAL ZHR(51),WDHR(51),WSHR(51),TAHR(51)
         COMMON/PTEMP/PRS(80),TMP(80),PTMP(80)
         COMMON/XSUMI/HT(80),AI(80),AI2(80)
         COMMON/WIND/WSL(24),A(24)
         COMMON/US/USTAR(24)
         COMMON/RNET/RN(24),QS(24)
         COMMON/MONIN/L(24)
         COMMON/CVR/CC(24)
         COMMON/TEMP/T(24)
         COMMON/NCC/NWSCC(24)
         COMMON/HM1/SAI(80),SAI2(80)
         COMMON/INIT/QR(24)
         COMMON/ZILIT/ZIL(24)
         COMMON/THS/THSTAR(24)
         COMMON/IO/IOPT,IOUT,ISURF,IRAWIN,ISURF1,ISURF2
         COMMON/SOLANG/ANGLE(24)
C
C        ASSIGN VALUES OF WIND, TEMP IN CASE OF MISSING DATA FOR HOUR #1
C
         WD(24) = 360.
         WSL(24) = 5.0
         T(24) = 293.
C
C        ASSIGN PROGRAM CONSTANTS (MKS UNITS)
C
C        CP = SPECIFIC HEAT OF AIR AT CONSTANT PRESSURE
C        G = ACCELERATION DUE TO GRAVITY
C        A1 AND B = CONSTANTS USED IN THE MODIFIED CARSON MODEL
C        DEGRAD = CONSTANT TO CONVERT FROM DEGREES TO RADIANS
C
         CP=1004.
         G=9.80655
         A1=0.2
         B=2.5
         DEGRAD=57.29578
         PRES = 1013.25
C
C        OPEN INPUT FILES
C
         IOPT = 5
```

```
      IOUT = 6
      ISURF = 7
      IRAWIN = 9
      ISURF1 = 10
      ISURF2 = 11
      INPROF = 12
C
      OPEN(ISURF1,FILE='SURF1',STATUS='OLD')
      OPEN(IOPT,FILE='OPTIONS',STATUS='OLD')
      OPEN(INPROF,FILE='PROFILE',STATUS='OLD')
C
C     OPEN OUTPUT FILES; ASSIGN DEFAULT I/O UNIT NUMBERS
C
      OPEN(ISURF,FILE='SURFACE',STATUS='UNKNOWN')
      OPEN(IOUT,FILE='OUTPUT',STATUS='UNKNOWN')
C
C     READ IN OPTIONS.
C
C     MODE:   IF 0, DO NOT READ NWS SURFACE DATA NOR UPPER AIR DATA,
C                   ASSUME CONSTANT SITE CHARACTERISTICS.
C             IF 1, DO NOT READ NWS SURFACE DATA NOR UPPER AIR DATA,
C                   BUT ASSUME VARIABLE SITE CHARACTERISTICS.
C             IF 2, READ NWS SURFACE DATA, BUT NOT UPPER AIR DATA.
C             IF 3, READ NWS SURFACE DATA AND UPPER AIR DATA.
C
      READ(IOPT,*) MODE
      WRITE(IOUT,8010) MODE
      IF(MODE.GT.1) THEN
          OPEN(ISURF2,FILE='SURF2',STATUS='OLD')
      ENDIF
      IF(MODE.GT.2)
     1    OPEN(IRAWIN,FILE='RAWIN',STATUS='OLD')
C
C     READ ADDITIONAL SITE-SPECIFIC INFORMATION (IF MODE=0, INPUT
C         PROVIDED IS LESS DETAILED):
C     1) LATITUDE, LONGITUDE, TIME ZONE
C        TIME ZONES: 5 EASTERN, 6=CENTRAL, 7=MOUNTAIN, 8=PACIFIC
C        FOR STANDARD TIME (SUBTRACT 1 HOUR FOR DAYLIGHT SAVINGS)
C     2) NUMBER OF WIND DIRECTION SECTORS FOR SURFACE CHARACTERISTICS
C     3) DEFINITION OF THE SECTORS (IF MORE THAN ONE)
C     4) SURFACE CHARACTERISTICS (MONTHLY VALUES FOR EACH SECTOR):
C             SURFACE ROUGHNESS LENGTHS
C             ALBEDO
C             BOWEN RATIO
C
C     NOTE: INPUT DATA FOR WIND DIRECTION SECTORS USES THE CONVENTION
C           THAT THE WIND DIRECTION IS THAT FROM WHICH THE WIND IS
C           BLOWING, AND THE UPWIND CHARACTERISTICS ARE THAT WHICH ARE
C           IMPORTANT. FOR EXAMPLE, CHARACTERISTICS TO THE SOUTH OF A
C           STACK WOULD BE ASSOCIATED WITH A SOUTHERLY WIND.
C
      IF(MODE.GT.0) GO TO 90
      READ(IOPT,*) LAT,LONG,ZONE,Z0CASE,ALBD,BOWEN
      WRITE(IOUT,8015) LAT,LONG,ZONE,Z0CASE,ALBD,BOWEN
      WRITE(IOUT,8082)
      LAT = LAT/DEGRAD
      GO TO 104
C
90    READ(IOPT,*) LAT,LONG,ZONE
      WRITE(IOUT,8020) LAT,LONG,ZONE
```

```
C
C       READ DATA FOR DIRECTION SECTORS (SITE CHARACTERISTICS)
C
        READ(IOPT,*) NSEC
        IF(NSEC.GT.8 .OR.NSEC.LT.1) THEN
            WRITE(IOUT,7095) NSEC
            STOP
        ENDIF
        WRITE(IOUT,8090) NSEC
        IF(NSEC.GT.1) THEN
            DO 100 I = 1,NSEC
                READ(IOPT,*) WDSEC(I,1),WDSEC(I,2)
                IF(I.EQ.1) GO TO 100
                IDIFF = WDSEC(I,1) - WDSEC(I-1,2)
                IF(IDIFF.LT.0) IDIFF = IDIFF + 360
                IF(IDIFF.NE.1) THEN
                    WRITE(IOUT,7110)
                    STOP
                ENDIF
                IF(I.EQ.NSEC) THEN
                    IDIFF = WDSEC(1,1) - WDSEC(NSEC,2)
                    IF(IDIFF.LT.0) IDIFF = IDIFF + 360
                    IF(IDIFF.NE.1) THEN
                        WRITE(IOUT,7110)
                        STOP
                    ENDIF
                ENDIF
100         CONTINUE
          ELSE
            WDSEC(1,1) = 1
            WDSEC(1,2) = 360
        ENDIF
        WRITE(IOUT,8100) (J,WDSEC(J,1),WDSEC(J,2),J=1,NSEC)
        WRITE(IOUT,8110)
        DO 102 J = 1,NSEC
            READ(IOPT,*) (Z0(I,J),I=1,12)
            READ(IOPT,*) (ALB(I,J),I=1,12)
            READ(IOPT,*) (BOW(I,J),I=1,12)
            WRITE(IOUT,8080) (Z0(I,J),I=1,12),(ALB(I,J),I=1,12),
     1                       (BOW(I,J),I=1,12),J
102     CONTINUE
        IF(MODE.LT.3) WRITE(IOUT,8082)
        WRITE(IOUT,8085)
C
C       CONVERT LAT FROM DEGREES TO RADIANS
        LAT=LAT/DEGRAD
C
104     CONTINUE
C
C       START HOUR LOOP.
C       CHECK FOR DATE CONSISTENCY BETWEEN ONSITE AND OFFSITE DATA IF
C       MODE > 1.
C
        H = 1
105     CONTINUE
C
C       READ FROM SURF1: YEAR, MONTH, DAY, HOUR, TOTAL INCOMING SOLAR
C       RADIATION, NET RADIATION, OBSERVED MIXED LAYER HT (M), CLOUD
C       HEIGHT (100'S OF FEET), CLOUD COVER (TENTHS)
C
```

```
      READ(ISURF1,*,END=900) Y,M,D,IHR,QRHR,RNHR,ZIOHR,CHHR,CCHR
      IF(MODE.GT.2 .AND. IHR.NE.H) THEN
         WRITE(IOUT,7135) Y,M,D,IHR,H
         STOP
      ENDIF
      MISS(IHR) = 0
      QR(IHR) = QRHR
      RN(IHR) = RNHR
      ZIOBS(IHR) = ZIOHR
C
C     CH (CLOUD HT) IS READ BUT NOT USED IN THIS VERSION OF METPRO
C
      CH(IHR) = CHHR
      CC(IHR) = CCHR
      IF(MODE.EQ.0) THEN
         ZODAY(IHR) = ZOCASE
         IF(CC(IHR).LT.0) THEN
            WRITE(IOUT,7145) Y,M,D,IHR
            STOP
         ENDIF
      ENDIF
C
C     READ PROFILE TO GET WD, WS, T FROM 10 METERS
C
      WD(IHR) = -999.
      WSL(IHR) = -999.
      T(IHR) = -999.
      WDB10 =-999.
      WSB10 =-999.
      TAB10 =-999.
      DO 110 IHT = 1,51
         READ(INPROF, *) Y1,M1,D1,H1,ZHR(IHT),JFLAG,
     1       WDHR(IHT),WSHR(IHT),TAHR(IHT)
         IF(Y.NE.Y1.OR.M.NE.M1.OR.D.NE.D1.OR.IHR.NE.H1)
     1       THEN
            WRITE(IOUT,7125) Y,M,D,IHR,Y1,M1,D1,H1
            STOP
         ENDIF
C
C     SEARCH FOR 10-M VALUES OF:
C       WIND DIRECTION TO ASSIGN SURFCE ROUGHNESS LENGTH (FUNCTION OF
C            DIRECTION) FOR THIS HOUR;
C       WIND SPEED FOR COMPUTING L, U*;
C       TEMPERATURE TO ASSIGN "SURFACE" AMBIENT TEMPERATURE
C
C       USE INTERPOLATION WHERE POSSIBLE
C
         IF(ZHR(IHT) .LT. 10.0 .AND. JFLAG .LT. 1) GO TO 108
C                          -
C       NOW HAVE FOUND THE 10-M LEVEL OR THE FIRST LEVEL ABOVE 10 M
C
         IF(WDHR(IHT).GT.0.0 .AND. WD(IHR).LT.0.0) THEN
            IF(ABS(ZHR(IHT) - 10.0) .LT. 0.5) THEN
               WD(IHR) = WDHR(IHT)
             ELSE IF(WDB10 .LT. 0.0) THEN
               WD(IHR) = WDHR(IHT)
             ELSE
               FRAC = (10. - WDB10H)/(ZHR(IHT) - WDB10H)
               WD(IHR) = (1.0-FRAC) * WDB10 + FRAC * WDHR(IHT)
            ENDIF
```

```
C
C       CALCULATE THE DENSITY OF AIR FOR THE HOUR IN KG/M**3
C
        CALL RHOO(PRES,T(IHR),RHO)
C
C       DO NIGHTTIME OR DAYTIME TASKS:
C       COMPUTE NIGHTTIME USTAR & L VALUES USING THE VENKATRAM METHOD.
C       OTHERWISE, COMPUTE NET RADIATION IF DERIVED FROM TOTAL INCOMING
C       SOLAR RADIATION.  COMPUTE THE SENSIBLE HEAT FLUX FROM THE NET
C       RADIATION.  QR IS THE NET RADIATION, QS THE SENSIBLE HEAT FLUX.
C       IF NIGHTTIME, SENSIBLE HEAT FLUX IS NOT NEEDED TO COMPUTE Z0,L.
C       COMPUTE DAYTIME USTAR & L VALUES USING HOLTSLAG-VAN ULDEN METHOD
C
        IF(RN(IHR).LE.0 .OR. IHR.GT.TSS+1. .OR. IHR.LT.TSR) THEN
            CALL WNUS(IHR,ANEM,Z0DAY(IHR))
          ELSE
            IF(MODE .GT. 0) BOWEN = BOW(M,ISEC)
            CALL HV(IHR,PRES,BOWEN)
            IF(QS(IHR).LE.0.0) THEN
                CALL WNUS(IHR,ANEM,Z0DAY(IHR))
              ELSE
                CALL HDAYUS(IHR,RHO,ANEM,Z0DAY(IHR))
            ENDIF
        ENDIF
C
C       CHECK FOR L VALUES EXCEEDING THE RANGE OF THE FORMAT FIELD
C
        IF(L(IHR).GT.9999.) L(IHR)=9999.
        IF(L(IHR).LT.-999.) L(IHR)=-999.
        IF(ABS(L(IHR)).LT.1.0) THEN
            IF(L(IHR).LT.0) L(IHR)=-1.
            IF(L(IHR).GT.0) L(IHR)=1.
        ENDIF
C
C       COMPUTE ZILITINKEVICH SURFACE LAYER HEIGHTS
C
        CALL ZILL(LAT,IHR)
C
        H = H + 1
        IF(H.EQ.25) H = 1
        IF(H.EQ.1 .AND. MODE.GT.2) GO TO 150
        IF(MODE.LE.2)
     1  WRITE(ISURF,6010) Y,M,D,JUL,IHR,ZIOBS(IHR),ZIL(IHR),USTAR(IHR),
     2      L(IHR),Z0DAY(IHR)
        GO TO 105
C
C       END HOUR LOOP; READ IN UPPER AIR DATA AND COMPUTE CONVECTIVE
C       MIXED LAYER HEIGHTS ONLY IF DOING A CONTIGUOUS HOUR RUN
C
C       READ IN UPPER AIR SOUNDING FOR 12Z; COMPUTE MODIFIED CARSON
C       MIXED LAYER HEIGHTS FOR APPLICABLE HOURS
C
150     READ(IRAWIN,7040) YUP,MUP,DUP,ITIME,NLEV
        READ(IRAWIN,7050) (PRS(I),HT(I),TMP(I),I=1,NLEV)
        IF(ITIME.NE.12) GO TO 150
        ISDATE = Y*10000 + M*100 + D
        IUDATE = YUP*10000 + MUP*100 + DUP
        IF(ISDATE.GT.IUDATE) GO TO 150
        IF(ISDATE.LT.IUDATE) THEN
            WRITE(IOUT,7160) Y,M,D,YUP,MUP,DUP
```

```
C        STORE DATA FOR 24 HOURS BEFORE PRINTING FOR MODE 3
C
                MISS(IHR) = 1
                IF(IHR.EQ.1) THEN
                   LHR = 24
                  ELSE
                   LHR = IHR-1
                ENDIF
                IF(WD(IHR).LT.0.0) WD(IHR) = WD(LHR)
                IF(WSL(IHR).LT.0.0) WSL(IHR) = WSL(LHR)
                IF(T(IHR).LT.0.0) T(IHR) = T(LHR)
             ENDIF
         ENDIF
C
C        INITIALIZE SENSIBLE HEAT FLUX TO ZERO FOR MODE 3
C
         QS(IHR)=0.0
C
         IF(IHR.GT.1 .AND. MODE.GT.2) GO TO 115
         CALL JULIAN(Y,M,D,JUL)
         JD = JUL
         IF(JD.EQ.366) JD = 1
C
C        CALCULATE SOLAR ELEVATION ANGLES
C
         CALL SUN(LAT,LONG,ZONE,JD,TSR,TSS)
C
C        FOR MODE 0, ALREADY HAVE HOURLY SITE CHARACTERISTICS
C
         IF(MODE.EQ.0) GO TO 128
115      DO 120 J = 1,NSEC
         IF(WD(IHR).LT.WDSEC(J,2)+0.1.AND.WD(IHR).GT.WDSEC(J,1)-0.1)
     1     GO TO 125
         IF(WD(IHR).LT.WDSEC(J,2)+0.1.AND.WDSEC(J,1).GT.WDSEC(J,2))
     1     GO TO 125
         IF(WD(IHR).GT.WDSEC(J,1)-0.1.AND.WDSEC(J,1).GT.WDSEC(J,2))
     1     GO TO 125
120      CONTINUE
125      ISEC = MIN(J,NSEC)
         ZODAY(IHR) = Z0(M,ISEC)
C
C        CALCULATE ALBEDO FOR THIS HOUR, ACCOUNTING FOR SOLAR
C        ELEVATION ANGLE
C
         ALBD = ALB(M,ISEC)
128      C = 1.0 - ALBD
         BB = -0.5 * C*C
         ANG = ANGLE(IHR) * 57.29578
         IF(ANG.LE.0.0) THEN
            ALBEDO = 1.0
           ELSE
C
C        EQN 7 FROM USERS GUIDE
C
            ALBEDO = ALBD + C*EXP(-0.1*ANG + BB)
         ENDIF
C
C        SUBSTITUTE NWS CLOUD COVER IF NECESSARY AND COMPUTE HEAT FLUX
C
         CALL DEFAUL(MODE,M,D,Y,IHR,ALBEDO)
```

```
            ENDIF
            IF(WSHR(IHT).GT.0.0 .AND. WSL(IHR).LT.0.0) THEN
                IF(ABS(ZHR(IHT) - 10.0) .LT. 0.5) THEN
                    WSL(IHR) = WSHR(IHT)
                    ANEM = 10.0
                  ELSE IF(WSB10 .LT. 0.0) THEN
                    WSL(IHR) = WSHR(IHT)
                    ANEM = ZHR(IHT)
                  ELSE
                    FRAC = (10. - WSB10H)/(ZHR(IHT) - WSB10H)
                    WSL(IHR) = (1.0-FRAC) * WSB10 + FRAC * WSHR(IHT)
                    ANEM = 10.0
                ENDIF
            ENDIF
            IF(TAHR(IHT).GT.0.0 .AND. T(IHR).LT.0.0) THEN
                IF(ABS(ZHR(IHT) - 10.0) .LT. 0.5) THEN
                    T(IHR) = TAHR(IHT)
                  ELSE IF(TAB10 .LT. 0.0) THEN
                    T(IHR) = TAHR(IHT)
                  ELSE
                    FRAC = (10. - TAB10H)/(ZHR(IHT) - TAB10H)
                    T(IHR) = (1.0-FRAC) * TAB10 + FRAC * TAHR(IHT)
                ENDIF
            ENDIF
108         IF(JFLAG.EQ.1) GO TO 112
C
C       IF BELOW 10 METERS, STORE VALUES FOR POSSIBLE INTERPOLATION
C
            IF(WDHR(IHT) .GT. 0.0) THEN
                WDB10 = WDHR(IHT)
                WDB10H = ZHR(IHT)
            ENDIF
            IF(WSHR(IHT) .GE. 0.0) THEN
                WSB10 = WSHR(IHT)
                WSB10H = ZHR(IHT)
            ENDIF
            IF(TAHR(IHT) .GT. 0.0) THEN
                TAB10 = TAHR(IHT)
                TAB10H = ZHR(IHT)
            ENDIF
110     CONTINUE
112     IF(MODE.GE.2) THEN
            READ(ISURF2,7030) Y2,M2,D2,H2,NWSCC(IHR)
            IF(Y.NE.Y2.OR.M.NE.M2.OR.D.NE.D2.OR.IHR.NE.H2+1)
     1          THEN
                WRITE(IOUT,7130) Y,M,D,IHR,Y2,M2,D2,H2+1
                STOP
            ENDIF
        ENDIF
C
C       IF MISSING DATA, PREPARE TO WRITE NEGATIVE VALUES IN SURFACE;
C       PERSIST WIND DIRECTION TO GET SITE CHARACTERISTICS FOR MODE 3
C
        IF(WD(IHR).LT.0.0 .OR. WSL(IHR).LT.0.0 .OR. T(IHR).LT.0.0) THEN
            WRITE(IOUT,7140) Y,M,D,IHR
            IF(MODE .LE. 2) THEN
                WRITE(ISURF,6020) Y,M,D,JUL,IHR
                GO TO 105
              ELSE
C
```

```
         STOP
      ENDIF
C
C     CALCULATE POTENTIAL TEMPERATURE PROFILE
C
      DO 160 ILEV=1,NLEV
      PTMP(ILEV)=TMP(ILEV)*(1000./PRS(ILEV))**0.285714
      HT(ILEV)=HT(ILEV)-HT(1)
160   CONTINUE
C     CONVERT SOUNDING TIME (HH) TO (HHMM)
      ITIME=ITIME*100
      PTMPM=PTMP(1)
      AI(1)=0.0
      AI2(1)=0.0
      SAI(1)=0.0
      SAI2(1)=0.0
C
C     COMPUTE POT TEMP INTEGRALS FOR MODIFIED CARSON MIXED LAYER HTS
C
      DO 170 ILVLS=2,NLEV
      CALL SUMI(ILVLS,PTMPM)
C
C     COMPUTE INTEGRAL OF Z WRT THETA(POT TEMP) FOR ENTIRE PROFILE
C
      SAI(ILVLS)=AI(ILVLS)+SAI(ILVLS-1)
C
C     COMPUTE INTEGRAL OF Z**2 WRT THETA FOR ENTIRE PROFILE
C
      SAI2(ILVLS)=AI2(ILVLS)+SAI2(ILVLS-1)
170   CONTINUE
C
C     COMPUTE  # MINUTES FROM MIDNIGHT TO TIME OF INITIAL TEMP PROFILE
C     DETERMINE SFC TEMP (K) AT START TIME
C     DETERMINE MINUTES FROM MIDNIGHT OF LAST HOUR, ITLST
C     SET TIME INCREMENT FOR ZI CALCULATIONS
C
      CALL MINUTE(ITIME,ITIMM)
      CALL INITT(ITFST,ITLST,ITIMM)
      CALL TT(ITIMM,T0)
      CALL MINUTE(ITLST*100,ITLSTM)
C
C     INTEGRATE IN 15-MINUTE INCREMENTS
C
      INC=15
      ITM=ITIMM
      OLDHEAT=0.
      DO 210 II=1,100
      ITM=ITM+INC
      IF(ITM.GT.ITLSTM) GO TO 220
C
C     DETERMINE INTEGRATED SENSIBLE HEAT FLUX, HEAT (J/M**2)
C     COMPUTE AREA UNDER USTAR**3 CURVE WRT TIME, USTR3 (M**3/S**2)
C
      CALL SUMHH(ITM,HEAT,OLDHEAT)
      CALL SUMVV(ITIMM,ITM,USTR3)
C
C     CONVERT FROM J/M**2 TO CAL/M**2
C     CONVERT RHO TIMES CP TO CAL/(M**3 K)
C
      HEAT=HEAT/4.187
```

```
      RHOCP=(RHO*CP)/4.187
C
C     EQUATIONS 27 AND 28 FROM USER'S GUIDE
C
      XAI=HEAT/(RHOCP)*(1.+2.*A1)
      XAI2=2.*B*T0/G*USTR3
C
C     DETERMINE HEIGHTS (M) CORRESPONDING TO GIVEN AREAS UNDER
C     POTENTIAL TEMP PROFILE; DETERMINE HOURS FROM MINUTES
C
      CALL ZZI(NLEV,XAI,XAI2,ZI,ZI2)
C
C     UPDATE ZIL ARRAY IF AT THE END OF AN HOUR
C
      CALL HOUR(ITM,KHR)
      DO 190 IHOR=1,24
      IHOUR=IHOR*100
      IF(KHR.EQ.IHOUR) THEN
C
C     DETERMINE WHETHER ZI PREDICTED IS CONVECTIVE OR NEUTRAL
C     VALUE (WHICHEVER IS GREATER)
C
          IF(ZIL(IHOR).LT.AMAX1(ZI,ZI2)) THEN
              IF(ZI.GE.ZI2) THEN
                  ZIL(IHOR)=ZI
                ELSE
                  ZIL(IHOR)=ZI2
              ENDIF
          ENDIF
      ENDIF
190   CONTINUE
210   CONTINUE
220   CONTINUE
C
C     WRITE 24 HOURS OF DATA TO OUTPUT FILE
C
      DO 230 IHOR=1,24
      IF(MISS(IHOR).EQ.0) THEN
          WRITE(ISURF,6010) Y,M,D,JUL,IHOR,ZIOBS(IHOR),ZIL(IHOR),
     1                USTAR(IHOR),L(IHOR),Z0DAY(IHOR)
        ELSE
          WRITE(ISURF,6020) Y,M,D,JUL,IHOR
      ENDIF
230   CONTINUE
      GO TO 105
C
900   STOP
C
6010  FORMAT(3(I2,1X),I3,1X,I2,5X,2F10.0,F10.3,F10.1,E10.3)
6020  FORMAT(3(I2,1X),I3,1X,I2,5X,2(4X,'-9999.'),'  -999.999',
     1 '   -9999.9',' -.999E+03')
7030  FORMAT(T6,I2,T8,I2,T10,I2,T12,I2,T79,A1)
7040  FORMAT(22X,4(I2),38X,I2)
7050  FORMAT(4(3X,F6.1,1X,F5.0,1X,F5.1,8X))
7095  FORMAT(//,10X,'NUMBER OF WIND DIRECTION SECTORS FOR SPECIFYING',
     1 /,10X,' SURFACE CHARACTERISTICS IS OUT OF BOUNDS: ',I4)
7110  FORMAT(//,10X,'ERROR IN WIND DIRECTION SECTOR SPECIFICATION')
7125  FORMAT(//,10X,'DATE INCONSISTENCY BETWEEN ONSITE AND PROFILE ',
     1   'DATA,',/,10X,' OR HOUR IS OUT OF SEQUENCE FOR THIS DAY:',//,
     2   15X,'ONSITE DATE (YYMMDDHH) IS ',4I2,'; PROFILE DATE ',
```

```
     3    '(YYMMDDHH) IS ',4I2)                                         MET06010
7130  FORMAT(//,10X,'DATE INCONSISTENCY BETWEEN ONSITE AND OFFSITE ', MET06020
     1    'DATA,',/,10X,' OR HOUR IS OUT OF SEQUENCE FOR THIS DAY:',//, MET06030
     2    15X,'ONSITE DATE (YYMMDDHH) IS ',4I2,'; OFFSITE DATE ',       MET06040
     3    '(YYMMDDHH) IS ',4I2)                                         MET06050
7135  FORMAT(//,10X,'HOUR OUT OF SEQUENCE FOR THIS DAY:',//,15X,        MET06060
     2    'ONSITE DATE (YYMMDDHH) IS ',4I2,'; HOUR EXPECTED IS ',I2)    MET06070
7140  FORMAT(/,10X,'MISSING WIND AND/OR TEMPERATURE DATA FOR ',/,15X,  MET06080
     1  '(MM DD YY HH):',4(1X,I2),'; MISSING DATA WRITTEN TO "SURFACE"')MET06090
7145  FORMAT(//,10X,'MISSING CLOUD COVER DATA:',//,15X,                 MET06100
     2    'DATE (YYMMDDHH) IS ',4I2)                                    MET06110
7160  FORMAT(//,10X,'DATE INCONSISTENCY BETWEEN SURFACE AND UPPER ',    MET06120
     1  'AIR DATA:',//,15X,'SURFACE DATE (YYMMDD) IS ',3I2,             MET06130
     2  ';  UPPER AIR DATE (YYMMDD) IS ',3I2)                           MET06140
8010  FORMAT(//,1X,'CTDM MET PRE-PROCESSOR PROGRAM (METPRO) ',          MET06150
     1  '      VERSION 2.1       LEVEL 871022',//,                      MET06160
     2  10X,'PROGRAM OPTIONS: ',//,15X,'MODE = ',I1,                    MET06170
     3  ' IF 0, DO NOT READ NWS SURFACE DATA NOR UPPER AIR DATA,',/,    MET06180
     4  23X,'       ASSUME CONSTANT SITE CHARACTERISTICS',/,23X,        MET06190
     5  ' IF 1, DO NOT READ NWS SURFACE DATA NOR UPPER AIR DATA,',/,    MET06200
     6  23X,'       BUT ASSUME VARIABLE SITE CHARACTERISTICS',/,23X,    MET06210
     7  ' IF 2, READ NWS SURFACE DATA, BUT NOT UPPER AIR DATA',/,23X,   MET06220
     8  ' IF 3, READ NWS SURFACE DATA AND UPPER AIR DATA',//)           MET06230
8015  FORMAT(10X,'LATITUDE (DEG NORTH) = ',F6.2,', LONGITUDE (DEG ',    MET06240
     1  'WEST) = ',F7.2,/,10X,'TIME ZONE (HOURS AFTER GMT) = ',F5.1,/,  MET06250
     2  10X,'FIXED VALUES OF SURFACE CHARACTERISTICS:',/,20X,'Z0 = ',   MET06260
     3  F6.4,'M,  ALBEDO = ',F4.2,',  BOWEN RATIO = ',F5.2,//)          MET06270
8020  FORMAT(10X,'LATITUDE (DEG NORTH) = ',F6.2,', LONGITUDE (DEG WE',MET06280
     1  'ST) = ',F7.2,/,10X,'TIME ZONE (HOURS AFTER GMT) = ',F5.1,//)   MET06290
8080  FORMAT(1X,'Z0:',T9,12F6.3,/,1X,'ALBEDO:',12F6.3,/,               MET06300
     1  1X,'BOWEN: ',12F6.3,/,1X,'(SECTOR ',I1,')',/)                   MET06310
8082  FORMAT(/,1X,'WARNING: CONVECTIVE MIXED LAYER HEIGHTS ARE NOT ', MET06320
     1   'COMPUTED IN THIS MODE;',/,1X,'MISSING VALUES WILL BE ',       MET06330
     2   'WRITTEN TO THE SURFACE FILE FOR UNSTABLE CONDITIONS.')        MET06340
8085  FORMAT(//)                                                        MET06350
8090  FORMAT(10X,'# OF WIND DIRECTION SECTORS FOR SPECIFYING',          MET06360
     1  ' SURFACE CHARACTERISTICS = ',I1,//)                            MET06370
8100  FORMAT(/,15X,'WIND DIRECTION SECTORS AND ANGLE RANGES:',//,       MET06380
     1    (15X,I1,': ',I3,'-',I3),/)                                    MET06390
8110  FORMAT(//,10X,'SECTOR VALUES FOR ',                               MET06400
     1     'SURFACE ROUGHNESS (M), ALBEDO, AND BOWEN RATIO:',//,        MET06410
     2     1X,'VARIABLE  JAN   FEB   MAR   APR   MAY   JUN   ',         MET06420
     3     'JUL   AUG   SEP   OCT   NOV   DEC',/)                       MET06430
C                                                                       MET06440
      END                                                               MET06450
```

```
C-----------------------------------------------------------------------
C SUBROUTINE: CUBIC
C
C PURPOSE:  SOLVES A CUBIC EQUATION: Z**3 + A*Z**2 + B*Z + C = 0
C
C ARGUMENTS
C  PASSED:
C       A       REAL    COEFFICIENT OF Z**2
C       B       REAL    COEFFICIENT OF Z**1
C       C       REAL    COEFFICIENT OF Z**0
C
C  RETURNED:
C       Z       REAL    SOLUTION OF CUBIC EQUATION
C
C INTRINSIC FUNCTIONS: DSQRT, DSIGN, DABS, DACOS, DCOS
C
C-----------------------------------------------------------------------
C
      SUBROUTINE CUBIC(A,B,C,Z)
C
C     SOLVES FOR ONE ROOT OF THE CUBIC EQUATION:
C     Z**3 + A*Z**2 + B*Z + C = 0
C
      IMPLICIT DOUBLE PRECISION (A-H,O-Z)
      REAL A,B,C,Z
      DATA ONE/1.0/
      A3=A/3.
      AP=B-A*A3
      BP=2.*A3**3-A3*B+C
      AP3=AP/3.
      BP2=BP/2.
      TROOT=BP2*BP2+AP3*AP3*AP3
      IF(TROOT.LE.0.0)GO TO 50
      TR=DSQRT(TROOT)
      APP=(-BP2+TR)**0.333333
      BSV=-BP2-TR
      IF(BSV.EQ.0.0)GO TO 45
      SGN=DSIGN(ONE,BSV)
      BPP=SGN*(DABS(BSV))**0.333333
      Z=APP+BPP-A3
      RETURN
45    CONTINUE
C     BSV (& BPP) = 0.0
      Z=APP-A3
      RETURN
50    CM=2.*DSQRT(-AP3)
      ALPHA=DACOS(BP/(AP3*CM))/3.
      Z=CM*DCOS(ALPHA)-A3
      RETURN
      END
```

```
C-----------------------------------------------------------------------
C SUBROUTINE: DEFAUL
C
C PURPOSE: CHECK FOR MISSING DATA
C
C METHOD: SUBSTITUTE NWS DATA FROM SURF2 IF ON-SITE DATA FROM SURF1 IS
C         MISSING. FLAG OR PERSIST WHERE NWS DATA IS CALM.
C
C ARGUMENTS PASSED: MODE       INTEGER     EXECUTION MODE (0, 1, 2, OR 3)
C                   M          INTEGER     MONTH
C                   D          INTEGER     DAY
C                   Y          INTEGER     YEAR
C                   IHR        INTEGER     HOUR
C                   ALBEDO     REAL        ALBEDO FOR THIS HOUR
C
C  I/O:  UNIT  IOUT   OUTPUT FOR WARNING OF MISSING CLOUD COVER DATA
C
C COMMON: TEMP  WIND    INIT    NCC     RNET    CVR   IO
C
C CALLING ROUTINES:  MAIN PROGRAM
C
C EXTERNAL ROUTINES: HVNET      TOTAL
C-----------------------------------------------------------------------
      SUBROUTINE DEFAUL(MODE,M,D,Y,IHR,ALBEDO)
C
      CHARACTER*1 NWSCC
      INTEGER IHR,M,D,Y,CC,MODE
C
      COMMON/TEMP/T(24)
      COMMON/WIND/WSL(24),A(24)
      COMMON/INIT/QR(24)
      COMMON/NCC/NWSCC(24)
      COMMON/RNET/RN(24),QS(24)
      COMMON/CVR/CC(24)
      COMMON/IO/IOPT,IOUT,ISURF,IRAWIN,ISURF1,ISURF2
C
C     CHECK FOR NWS CLOUD COVER DATA IF MODE = 2 OR 3
C     IF MODE = 0 OR 1, CLOUD COVER IS PROVIDED IN "SURF1"
C
      IF(MODE.LE.1) GO TO 100
      IF(CC(IHR).LT.0) THEN
C        CHECK FOR MISSING NWS CLOUD COVER
         IF(NWSCC(IHR).EQ.' ') THEN
            WRITE(IOUT,7000) M,D,Y,IHR
            CC(IHR) = 0
         END IF
         IF(NWSCC(IHR).EQ.'-') THEN
            CC(IHR) = 10
         ELSE
            READ(NWSCC(IHR),7010) CC(IHR)
         END IF
      ENDIF
C
C     IF NET RADIATION IS MISSING, BUT TOTAL INCOMING SOLAR RADIATION IS
C     NOT MISSING, USE TOTAL INCOMING RADIATION TO COMPUTE THE NET.
C     IF BOTH NET AND TOTAL INCOMING SOLAR RADIATION ARE MISSING,
C     CALCULATE FROM THE CLOUD COVER AND SOLAR ELEVATION ANGLE
C     USING THE HOLTSLAG METHOD.
C     IF INCOMING SOLAR RADIATION IS MISSING, CALCULATE FROM THE CLOUD
C     COVER AND SOLAR ELEVATION ANGLE USING THE HOLTSLAG METHOD.
```

```
C
100   IF(QR(IHR).LT.-900.) CALL TOTAL(IHR)
      IF(RN(IHR).LT.-900.) CALL HVNET(IHR,ALBEDO)
      RETURN
C
 7000 FORMAT(/,10X,'MISSING NWS CLOUD COVER ON (MM DD YY HH):',4(1X,I2),
     1 //,10X,'**CLOUD COVER SET TO 0 IN ORDER TO CONTINUE EXECUTION**',
     2 //,10X,'IF NECESSARY, PLEASE EDIT SURF2 MANUALLY AND RERUN',/)
 7010 FORMAT(I1)
C
      END
```

```
C-----------------------------------------------------------------------
C SUBROUTINE: HDAYUS
C
C PURPOSE: THIS ROUTINE CALCULATES USTAR AND L FOR THE UNSTABLE CASES
C          (L < 0) USING THE HOLTSLAG-VAN ULDEN TECHNIQUE
C
C METHODS: ITERATE OVER USTAR AND L
C
C ASSUMPTIONS: CONVERGENCE IS REACHED WHEN TWO CONSECUTIVE ESTIMATES OF
C              L ARE WITHIN 1%
C
C ARGUMENTS PASSED: I       INTEGER      HOUR
C                   RHO     REAL         RHO
C                   ANEM    REAL         ANEMOMETER HEIGHT
C                   Z0      REAL         ROUGHNESS LENGTH
C
C COMMON: SUMV  US       RNET     WIND     THS      TEMP
C
C INTRINSIC FUNCTIONS: ABS  ALOG  ATAN
C-----------------------------------------------------------------------
      SUBROUTINE HDAYUS(I,RHO,ANEM,Z0)
C
      INTEGER I,ITER
      REAL PSIZL,PSIZ0L,RHO,EPS,VONK,ANEM,Z0,L,X,X0,LASTL,CP
      COMMON/US/USTAR(24)
      COMMON/RNET/RN(24),QS(24)
      COMMON/MONIN/L(24)
      COMMON/TEMP/T(24)
      COMMON/WIND/WSL(24),A(24)
      COMMON/THS/THSTAR(24)
C
C     INITIALIZE VARIABLES AND PSI VALUES
C
      DATA CP/1004./,PI/3.14159/,G/9.80655/,EPS/0.01/,VONK/0.4/
      PSIZL=0.0
      PSIZ0L=0.0
      ITER=1
C
C     BEGIN ITERATION LOOP OVER MONIN-OBUKHOV LENGTH AND USTAR
C
C     USTAR IS USED IN EQN 14 OF USER'S GUIDE
C     L     IS USED IN EQN  1 OF USER'S GUIDE
C
100   USTAR(I)=VONK*WSL(I)/(ALOG(ANEM/Z0)-PSIZL+PSIZ0L)
      L(I)=(-RHO*CP*T(I)*USTAR(I)**3)/(VONK*G*QS(I))
C
C     ITERATION LOOP CHECK: STOP WHEN WITHIN 1% OF PRECEDING VALUE
C
      IF(ITER.NE.1) THEN
         IF(ABS(L(I)-LASTL).LT.ABS(EPS*L(I))) GO TO 110
      END IF
C
C     EQN 18 OF USER'S GUIDE:
C
      X=(1.-15.*(ANEM/L(I)))**0.25
      X0=(1.-15.*(Z0/L(I)))**0.25
C
C     EQN 16 OF USER'S GUIDE
C
      PSIZL=2.*ALOG((1.+X)/2.)+ALOG((1.+X*X)/2.)-2.*ATAN(X)+PI/2.
```

```
      PSIZOL=2.*ALOG((1.+X0)/2.)+ALOG((1.+X0*X0)/2.)-2.*ATAN(X0)+PI/2.
      LASTL=L(I)
      ITER=ITER+1
      GO TO 100
110   CONTINUE
C
C     EQN 24 OF USER'S GUIDE
C
      THSTAR(I)=QS(I)/(-RHO*CP*USTAR(I))
      RETURN
      END
```

```
C-----------------------------------------------------------------------
C SUBROUTINE: HOUR
C
C PURPOSE: CONVERTS MINUTES FROM MIDNIGHT TO HHMM
C
C ARGUMENTS PASSED: KMIN     INTEGER     MINUTES FROM MIDNIGHT
C                   KHR      INTEGER     HOURS AND MINUTES HHMM
C-----------------------------------------------------------------------
      SUBROUTINE HOUR(KMIN,KHR)
C
C     CONVERT MINUTES FROM MIDNIGHT TO HHMM
C
      KHR=KMIN/60*100+(KMIN-KMIN/60*60)
      RETURN
      END
```

```
C-----------------------------------------------------------------------
C SUBROUTINE: HV
C
C PURPOSE: COMPUTES THE SENSIBLE HEAT FLUX FROM THE NET RADIATION
C
C METHOD: HOLTSLAG-VAN ULDEN
C
C ARGUMENTS PASSED: I      INTEGER      HOUR
C                   P      REAL         PRESSURE
C                   BOWEN  REAL         BOWEN RATIO FOR THIS HOUR
C
C COMMON: TEMP  RNET
C
C INTRINSIC FUNCTIONS: ALOG10
C-----------------------------------------------------------------------
      SUBROUTINE HV(I,P,BOWEN)
C
      REAL PRESS
      COMMON/TEMP/T(24)
      COMMON/RNET/RN(24),QS(24)
C
C     SET UP CONSTANTS
C
C     XLV IS LATENT HEAT OF VAPORIZATION FOR WATER (J/KG)
C     RV IS THE SPECIFIC GAS CONSTANT FOR WATER VAPOR (J/KG-K)
C     EPI IS RATIO OF DRY AIR AND WATER VAPOR GAS CONSTANTS
C     GAMMA IS SPECIFIC HEAT (CP) DIVIDED BY LATENT HEAT OF VAPORIZATION
C     CG IS THE FRACTION OF NET RADIATION LOST TO THE SOIL
C
      DATA XLV/2.501E6/
      DATA RV/461.51/
      DATA EPI/0.622/
      DATA GAMMA/4.01808E-4/
      DATA CG/0.1/
      DATA BETAP/20./
C
C     CONVERT PRESSURE TO PASCALS
C     COMPUTE SATURATION VAPOR PRESS (PASCALS) AT TEMP T (K)
C     COMPUTE SLOPE OF SATURATION VAPOR PRESS CURVE (CLAUSIUS-CLAPEYRON)
C     (FROM STANDARD TEXTS ON METEOROLOGY SUCH AS HESS, 1959:
C     INTRODUCTION TO THEORETICAL METEOROLOGY, P 94.
C
      PRESS=P*100.
      ES=100.*10.**(-2937.4/T(I)-4.9283*ALOG10(T(I))+23.5518)
      DESDT=XLV*ES/RV/T(I)**2
      S=(PRESS*EPI*DESDT)/(PRESS-ES)**2
C
C     COMPUTE ALPHA FROM BOWEN RATIO, GAMMA/S, CG, AND RN
C
      Z = 1.0 + GAMMA/S
      QUP = (1.0 - CG) * RN(I)
C
C     ALPHA IS USED IN EQN 11 OF USER'S GUIDE
C
      ALPHA = (Z*QUP)/((1.0+BOWEN) * (QUP + BETAP*Z))
C
C     SEE EQN 8 OF USER'S GUIDE FOR EQUATIONS LISTED BELOW
C
      BETA = ALPHA*BETAP
C
```

```
C     COMPUTE SENSIBLE HEAT FLUX                                  HVV00610
C     .                                                           HVV00620
      QS(I) = (Z-ALPHA)/Z * QUP - BETA                            HVV00630
      RETURN                                                      HVV00640
      END                                                         HVV00650
```

```
C-----------------------------------------------------------------------
C SUBROUTINE: HVNET
C
C PURPOSE: COMPUTES NET RADIATION FROM TOTAL INCOMING SOLAR RADIATION
C
C METHOD: HOLTSLAG-VAN ULDEN
C
C ARGUMENTS PASSED: I            INTEGER       HOUR
C                   ALBEDO       REAL          SURFACE ALBEDO FOR THIS HOUR
C
C COMMON: TEMP  INIT    CVR     RNET
C-----------------------------------------------------------------------
      SUBROUTINE HVNET(I,ALBEDO)
C
      INTEGER I,CC
      REAL ALBEDO
      COMMON/TEMP/T(24)
      COMMON/INIT/QR(24)
      COMMON/CVR/CC(24)
      COMMON/RNET/RN(24),QS(24)
C
C     SET CONSTANTS: C1, C2, AND C3 FROM HOLTSLAG - VAN ULDEN
C                    SB = STEFAN-BOLTZMANN CONSTANT
C
      DATA C1/5.31E-13/
      DATA C2/60./
      DATA C3/0.12/
      DATA SB/5.67E-8/
C
C     COMPUTE NET RAD (WATTS/M**2) FROM ALBEDO, SOLAR INSOLATION
C     SFC TEMP (K) AND SKY COVER (TENTHS)
C
C     EQN 6 FROM USER'S GUIDE
C
      RN(I)=((1.-ALBEDO)*QR(I)+C1*T(I)**6-SB*T(I)**4+C2*(CC(I)/10.))/
     *   (1.+C3)
      RETURN
      END
```

```
C-----------------------------------------------------------------------
C SUBROUTINE: INITT
C
C PURPOSE: COMPUTES INTEGRATED SENSIBLE HEAT FLUX, JOULES/M**2
C          (RIGHT SIDE OF EQN 27 IN USER'S GUIDE)
C
C ARGUMENTS PASSED: ITFST      INTEGER      FIRST INSOLATION HOUR
C                   ITLST      INTEGER      LAST INSOLATION HOUR
C                   ITIMM      INTEGER      TIME 0
C
C EXTERNAL ROUTINES: SENSE
C-----------------------------------------------------------------------
      SUBROUTINE INITT(ITFST,ITLST,ITIMM)
C
      REAL QST(24)
      COMMON/RNET/RN(24),QS(24)
      COMMON/US/USTAR(24)
      COMMON/SUMH/SQR(24)
      COMMON/INIT/QR(24)
      COMMON/WIND/WSL(24),A(24)
      ITFST=9999
C
C     CONVERT QS FROM W/M**2 TO LY/MIN
C
      DO 100 IHR=1,24
      QST(IHR)=QS(IHR)/697.8
100   CONTINUE
C
C     DEFINE ITFST AS FIRST INSOLATION HOUR (I.E., HOUR BEFORE HOUR
C     THAT QS.GT.0.001 LY/HR)
C     DEFINE ITLST AS LAST INSOLATION HOUR (I.E., HOUR AFTER ITFST
C     WHEN QS.LT.0.001 LY/HR FOR 2 CONSECUTIVE HOURS)
C
      DO 110 IHR=2,24
      IF(QST(IHR).GT.0.001.AND.QST(IHR-1).LT.0.001) ITFST=IHR-1
      IF(IHR.GT.ITFST.AND.(QST(IHR).LT.0.001.AND.QST(IHR-1).LT.0.001))
     * GO TO 120
C
C     COMPUTE AREA UNDER US**3 CURVE WRT TIME (M**3/S**2) FOR EACH
C     HOUR USING TRAPEZOIDS
C
      A(IHR-1)=1800.*(USTAR(IHR-1)**3+USTAR(IHR)**3)
  110 CONTINUE
  120 ITLST=IHR-1
C
C     DETERMINE TIME (IN MINUTES FROM MIDNIGHT) WHEN SENSIBLE HEAT
C     FLUX FIRST BECOMES POSITIVE.
C     THIS TIME IS T=0 FOR ALL TIME INTEGRATIONS.
C     GET WHOLE HOUR OF START TIME
C
      CALL SENSE(ITIMM)
      ISTART=ITIMM/60+1
C
C     COMPUTE INTEGRATED SENSIBLE HEAT FLUX (JOULES/M**2)
C     MULTIPLY LY/MIN TIMES 697.8 * 3600. = 2512080. TO GET J/M**2
C
      DO 130 IHR=1,ITLST
      IF(IHR.LT.ISTART) SQR(IHR)=0.
      IF(IHR.EQ.ISTART) SQR(IHR)=QST(IHR)*2512080.
      IF(IHR.GT.ISTART) SQR(IHR)=QST(IHR)*2512080.+SQR(IHR-1)
130   CONTINUE
      RETURN
      END
```

```
C------------------------------------------------------------------------
C SUBROUTINE: JULIAN
C
C PURPOSE: COMPUTES JULIAN DAY FROM THE DATE
C
C ARGUMENTS PASSED: YEAR      INTEGER     YEAR
C                   MONTH     INTEGER     MONTH
C                   DAY       INTEGER     DAY
C                   JUL       INTEGER     JULIAN DAY
C
C INTRINSIC FUNCTIONS: MOD
C------------------------------------------------------------------------
      SUBROUTINE JULIAN(YEAR,MONTH,DAY,JUL)
C
      INTEGER YEAR,MONTH,DAY,JUL
      DIMENSION NDAY(12)
      DATA NDAY/0,31,59,90,120,151,181,212,243,273,304,334/
C
      JUL = NDAY(MONTH) + DAY
      IF(MONTH.LE.2) RETURN
      IF(MOD (YEAR, 4).EQ.0) JUL = JUL + 1
      RETURN
      END
```

```
C-----------------------------------------------------------------------
C SUBROUTINE: MINUTE
C
C PURPOSE: COMPUTES MINUTES FROM MIDNIGHT
C
C ARGUMENTS PASSED: KTIME      INTEGER     TIME IN HOURS: 100, 200, ETC
C                   KMIN       INTEGER     TIME IN MIUTES FROM MIDNIGHT
C-----------------------------------------------------------------------
      SUBROUTINE MINUTE(KTIME,KMIN)
C
C     COMPUTE MINUTES FROM MIDNIGHT FROM HHMM
C
      KMIN=KTIME/100*60+(KTIME-KTIME/100*100)
      RETURN
      END
```

```
C-----------------------------------------------------------------------
C SUBROUTINE: RHOO
C
C PURPOSE: THIS ROUTINE COMPUTES AIR DENSITY USING THE IDEAL GAS LAW
C
C METHODS: GAS LAW
C
C ARGUMENTS PASSED: P     REAL     PRESSURE (MB)        INPUT
C                   T     REAL     TEMPERATURE (K)      INPUT
C                   RHO   REAL     DENSITY (KG/M**3)    RETURNED
C-----------------------------------------------------------------------
      SUBROUTINE RHOO(P,T,RHO)
C
      REAL P,T,RHO
      RHO=(P*100.)/(287.*T)
      RETURN
      END
```

```
C-----------------------------------------------------------------------
C SUBROUTINE: SENSE
C
C PURPOSE: DETERMINES FIRST HOUR WHERE SENSIBLE HEAT FLUX IS POSITIVE
C          FOR MODIFIED CARSON MIXING HEIGHT CODE
C
C ARGUMENTS PASSED: ITIMM     INTEGER     TIME 0
C
C COMMON: INIT
C         RNET
C
C EXTERNAL ROUTINES: MINUTE
C-----------------------------------------------------------------------
      SUBROUTINE SENSE(ITIMM)
C
      COMMON/RNET/RN(24),QS(24)
C
C     CHECK WHEN SENSIBLE HEAT FLUX IS POSITIVE
C
      DO 100 IH=1,24
      IF(QS(IH).GT.0.) GO TO 110
  100 CONTINUE
C
C     SET ITIM AS HOUR WHEN SENSIBLE HEAT FLUX FIRST GOES POSITIVE
C     CONVERT HOUR TO TOTAL MINUTES FROM MIDNIGHT
C     SUBTRACT OFF 30 MINS TO GET TO CENTER OF EACH HOUR
C
  110 ITIM=IH
      CALL MINUTE(ITIM*100,ITIMM)
      ITIMM=ITIMM-30
      RETURN
      END
```

```
C-----------------------------------------------------------------------
C SUBROUTINE: SUMHH
C
C PURPOSE: INTERPOLATE INTEGRATED SENSIBLE HEAT FLUX
C
C ASSUMPTIONS: INTEGRATED HEAT FLUX NOT ALLOWED TO DECREASE
C
C ARGUMENTS PASSED: IT      INTEGER     TIME IN MINUTES
C                   H       REAL        INTEGRATED SENSIBLE HEAT FLUX
C                   OLDH    REAL        LAST INTEGRATED SENSIBLE HEAT
C                                       FLUX
C
C COMMON: SUMH
C
C INTRINSIC FUNCTIONS: FLOAT
C-----------------------------------------------------------------------
      SUBROUTINE SUMHH(IT,H,OLDH)
C
      COMMON/SUMH/SQR(24)
C
C     INTERPOLATE INTEGRATED SENSIBLE HEAT FLUX, H (LY)
C
      IT1=IT/60
      IT2=IT1+1
      IF(IT1.EQ.0) IT1 = 1
      H=SQR(IT1)+(SQR(IT2)-SQR(IT1))/60.0*(FLOAT(IT)-IT1*60.)
C
C     INTEGRATED SENSIBLE HEAT FLUX NOT ALLOWED TO DECREASE
C
      IF(H.LE.OLDH) H=OLDH
      OLDH=H
      RETURN
      END
```

```
C-----------------------------------------------------------------------
C SUBROUTINE:SUMI
C
C PURPOSE: COMPUTES POTENTIAL TEMPERATURE INTEGRALS
C
C ASSUMPTIONS: POTENTIAL TEMPERATURE DOES NOT DECREASE WITH HEIGHT
C
C ARGUMENTS PASSED: ILVLS      INTEGER      RAWINSONDE LEVEL
C                   PTMPM      REAL         POTENTIAL TEMPERATURE
C
C COMMON: PTEMP XSUMI
C-----------------------------------------------------------------------
      SUBROUTINE SUMI(ILVLS,PTMPM)
C
      COMMON/PTEMP/PRS(80),TMP(80),PTMP(80)
      COMMON/XSUMI/HT(80),AI(80),AI2(80)
C
C     ASSUME POT TEMP INCREASES (OR STAYS CONSTANT) WITH Z.
C     COMPUTE AREA UNDER POT TEMP PROFILE FOR THE INTERVAL
C     ILVLS-1 TO ILVLS USING TRAPEZOIDS.
C
      IF(PTMP(ILVLS).LT.PTMPM) GO TO 100
C
C     INTEGRAL OF Z WRT THETA (K-M) (LEFT SIDE OF EQN 27 IN USER'S GUIDE
C
      AI(ILVLS)=0.5*(PTMP(ILVLS)-PTMP(ILVLS-1)) *
     1    (HT(ILVLS)+HT(ILVLS-1))
C
C     INTEGRAL OF Z**2 WRT THETA (K-M**2) (LEFT SIDE OF EQN 28)
C
      AI2(ILVLS)=0.5*(PTMP(ILVLS)-PTMP(ILVLS-1)) *
     1    (HT(ILVLS)**2+HT(ILVLS-1)**2)
C
C     KEEP TRACK OF LOCAL POT TEMP MAX
C
      PTMPM=AMAX1(PTMP(ILVLS),PTMPM)
      GO TO 110
C
C     IF POT TEMP DOES NOT INCREASE WITH HEIGHT, SET AREA
C     UNDER CURVE EQUAL TO ZERO FOR THAT INTERVAL AND SET POT TEMP
C     EQUAL TO LAST MAX POT TEMP
C
  100 AI(ILVLS)=0.0
      AI2(ILVLS)=0.0
      PTMP(ILVLS)=PTMPM
  110 CONTINUE
      RETURN
      END
```

```
C-----------------------------------------------------------------------
C SUBROUTINE: SUMVV
C
C PURPOSE: CALCULATES THE AREA UNDER THE USTAR**3 CURVE WITH RESPECT TO
C          TIME FROM START (RIGHT SIDE OF EQN 28)
C
C ARGUMENTS PASSED: ITIMEM      INTEGER      TIME IN MINUTES FROM MIDNIGHT
C                   IT          INTEGER      TIME IN MINUTES
C                   USTR3       REAL         AREA UNDER USTAR**3 CURVE
C
C COMMON: WIND
C         US
C
C INTRINSIC FUNCTIONS: FLOAT
C-----------------------------------------------------------------------
      SUBROUTINE SUMVV(ITIMEM,IT,USTR3)
C
      COMMON/WIND/WSL(24),A(24)
      COMMON/US/USTAR(24)
C
C     COMPUTE AREA UNDER USTAR**3 CURVE WRT TIME FROM START TO TIME IT
C
      ITI1=ITIMEM/60
      ITI2=ITI1+1
      IF(ITI1.EQ.0) ITI1 = 1
      ITF1=IT/60
      ITF2=ITF1+1
      IF(ITF1.EQ.0) ITF1 = 1
      SPDI=USTAR(ITI1)**3+(USTAR(ITI2)**3-USTAR(ITI1)**3)/60.0*
     1    (FLOAT(ITIMEM)-ITI1*60.0)
      TOTA1=30.*(ITI2*60.-ITIMEM)*(SPDI+USTAR(ITI2)**3)
      SPDF=USTAR(ITF1)**3+(USTAR(ITF2)**3-USTAR(ITF1)**3)/60.0*
     1    (FLOAT(IT)-ITF1*60.0)
      TOTA3=30.*(IT-ITF1*60.)*(USTAR(ITF1)**3+SPDF)
      IDELT=ITF1-ITI2
      TOTA2=0.0
      IF(IDELT.LE.0) GO TO 110
      DO 100 J=1,IDELT
  100 TOTA2=TOTA2+A(ITI2+J-1)
  110 TOTA=TOTA1+TOTA2+TOTA3
      IF(IDELT.LT.0) TOTA=TOTA-A(ITI1)
      USTR3=TOTA
      RETURN
      END
```

```
C-----------------------------------------------------------------------
C SUBROUTINE: SUN
C
C PURPOSE: THIS ROUTINE CALCULATES THE SOLAR ELEVATION ANGLE FOR EACH
C          HOUR OF THE DAY FROM THE DATE, LATITUDE, LONGITUDE, AND TIME
C          ZONE
C
C METHOD: CRSTER PREPROCESSOR
C
C ARGUMENTS PASSED: LAT      REAL      LATITUDE     (IN RADIANS)
C                   LONG     REAL      LONGITUDE    (IN DEGREES)
C                   ZONE     REAL      TIME ZONE
C                   JULIAN   INTEGER   JULIAN DAY
C                   TSR      REAL      HOUR OF SUNRISE
C                   TSS      REAL      HOUR OF SUNSET
C
C COMMON BLOCKS:    SOLANG
C
C INTRINSIC FUNCTIONS: SIN      COS      FLOAT    ASIN     ACOS
C-----------------------------------------------------------------------
      SUBROUTINE SUN(LAT,LONG,ZONE,JULIAN,TSR,TSS)
C
      REAL LAT,LONG,ZONE
      INTEGER NDAYR,JULIAN
      COMMON /SOLANG/ ANGLE(24)
      DATA CONST /57.29578/
C
C     ZONE 05 = EASTERN
C     ZONE 06 = CENTRAL
C     ZONE 07 = MOUNTAIN
C     ZONE 08 = PACIFIC
C
C     ALGORITHM FOR SOLAR ELEVATION IS OBTAINED FROM CRSTER PREPROCESSOR
C
      SINLAT=SIN(LAT)
      COSLAT=COS(LAT)
      NDAYR=JULIAN
      D=(FLOAT(NDAYR)-1.)*360./365.242
      SIND=SIN(D/CONST)
      COSD=COS(D/CONST)
      SIN2D=SIN(2.*D/CONST)
      COS2D=COS(2.*D/CONST)
      EM=12.+0.12357*SIND-0.004289*COSD+0.153809*SIN2D+0.060783*COS2D
      SIGMA=279.9348+D+1.914827*SIND-0.079525*COSD+0.019938*SIN2D
     1   -0.00162*COS2D
      CAPD=ASIN(.39784989*SIN(SIGMA/CONST))
      SINCD=SIN(CAPD)
      COSCD=COS(CAPD)
C
C     HOUR USED IS AT THE BEGINNING OF EACH HOUR
C
      DO 100 IHR=1,24
      GMT=FLOAT(IHR)-1.+ZONE
      SOLHA=15.*(GMT-EM)-LONG
C
C     ANGLE=SOLAR ELEVATION IN RADIANS
C
      ANGLE(IHR)=ASIN(SINLAT*SINCD+COSLAT*COSCD*COS(SOLHA/CONST))
100   CONTINUE
C
```

```
C     STATEMENTS BELOW ARE USED TO COMPUTE LOCAL SUNRISE AND SUNSET
C
      CAPH=ACOS(-SINLAT*SINCD/(COSLAT*COSCD))*CONST/15.
      TSR=((LONG/15.+EM)-CAPH)-ZONE
      TSS=((LONG/15.+EM)+CAPH)-ZONE
      RETURN
      END
```

```
C-----------------------------------------------------------------------
C SUBROUTINE: TOTAL
C
C PURPOSE: THIS ROUTINE CALCULATES TOTAL INCOMING SOLAR RADIATION FROM
C          CLOUD COVER AND SOLAR ELEVATION ANGLE USING THE HOLTSLAG-
C          VAN ULDEN TECHNIQUE
C
C METHODS: HOLTSLAG - VAN ULDEN TECHNIQUE
C
C ARGUMENTS PASSED: H      INTEGER   HOUR ENDING
C
C COMMON: CVR   INIT   SOLANG
C
C INTRINSIC FUNCTIONS: MOD
C-----------------------------------------------------------------------
      SUBROUTINE TOTAL(H)
C
      INTEGER H,CC
      REAL AVGANG
      COMMON/INIT/QR(24)
      COMMON/CVR/CC(24)
      COMMON/SOLANG/ANGLE(24)
C
C     COMPUTE AVERAGE OF THE SOLAR ELEVATION ANGLES AT THE BEGINNING
C     AND END OF THE HOUR
C
      IF(H.LE.23) THEN
         AVGANG = (ANGLE(H)+ANGLE(H+1))/2.0
        ELSE
         AVGANG = (ANGLE(24)+ANGLE(1))/2.0
      ENDIF
C
C     FOR DAYTIME HOURS, COMPUTE THE INCOMING SOLAR RADIATION
C     (EQN 4 IN USER'S GUIDE)
C
      IF(AVGANG .GT. 0.) QR(H)=(990.*SIN(AVGANG))-30.
C
C     USE INTERPOLATION FORMULA FOR SOLAR ELEVATION ANGLES LESS THAN
C     10 DEGREES TO AVOID NEGATIVE VALUES.
C     NOTE: 141.91 WATTS/M**2 = RADIATION FOR 10-DEG ELEVATION ANGLE
C
      IF(AVGANG .LT. 10.) QR(H)=141.91 * AVGANG*5.729578
C
C     HOLTSLAG CORRECTION FOR CLOUDS (EQN 5 IN USER'S GUIDE)
C
      IF(CC(H).GT.0) QR(H)=QR(H)*(1.0-0.75*((CC(H)/10.)**3.4))
      RETURN
      END
```

```
C-----------------------------------------------------------------------
C SUBROUTINE: TT
C
C PURPOSE: INTERPOLATE SURFACE TEMPERATURE AT THE START TIME
C
C ARGUMENTS PASSED: ITIMEM       INTEGER      TIME IN MINUTES FROM MIDNIGHT
C                   T0           REAL         TEMPERATURE AT START TIME (K)
C
C COMMON:TEMP
C
C INTRINSIC FUNCTIONS: FLOAT
C
C-----------------------------------------------------------------------
      SUBROUTINE TT(ITIMEM,T0)
C
      COMMON/TEMP/T(24)
C
C INTERPOLATE SFC TEMP AT START TIME
C
      ITI=ITIMEM/60
      ITF=ITI+1
      IF(ITI.EQ.0) ITI = 1
      T0=T(ITI)+(T(ITF)-T(ITI))/60.0*(FLOAT(ITIMEM)-ITI*60.0)
      RETURN
      END
```

```
C-----------------------------------------------------------------------
C SUBROUTINE: WNUS
C
C PURPOSE: THIS ROUTINE CALCULATES USTAR FOR THE STABLE CASES (L > 0)
C         USING THE VENKATRAM TECHNIQUE
C
C ARGUMENTS PASSED:       IHR      INTEGER      HOUR
C                         ANEM     REAL         ANEMOMETER HEIGHT (M)
C                         Z0       REAL         ROUGHNESS LENGTH (M)
C
C COMMON: MONIN CVR       US       WIND     TEMP     THS
C
C INTRINSIC FUNCTIONS: ALOG       MIN
C-----------------------------------------------------------------------
      SUBROUTINE WNUS(IHR,ANEM,Z0)
C
      INTEGER IHR,CC
      REAL THS1,THS2,CDN,ANEM,Z0,UNOT,VONK,G,L
      COMMON/US/USTAR(24)
      COMMON/MONIN/L(24)
      COMMON/CVR/CC(24)
      COMMON/TEMP/T(24)
      COMMON/WIND/WSL(24),A(24)
      COMMON/THS/THSTAR(24)
C
C     ASSIGN CONSTANTS: VON KARMAN CONSTANT AND GRAV. ACCEL.
C
      DATA VONK/0.4/
      DATA G/9.80655/
C
C     CONST = MAXIMUM PRODUCT OF USTAR AND THETASTAR
C     BETA IS USED FOR PROFILE RELATATIONSHIPS IN STABLE CONDITIONS
C
      CONST = 0.05
      BETA = 4.7
C
C     THS1: EQN 22 OF USER'S GUIDE
C     CDN AND THS2: EQN 23 OF USER'S GUIDE
C     UNOT: EQN 25 OF USER'S GUIDE
C
      THS1=0.09*(1.-0.5*(CC(IHR)/10.)**2.)
      CDN=VONK/(ALOG(ANEM/Z0))
      THS2=(T(IHR)*CDN*WSL(IHR)**2.)/(4.0*4.7*ANEM*G)
      THSTAR(IHR)=MIN(THS1,THS2)
      UNOT=SQRT((4.7*ANEM*G*THSTAR(IHR))/(T(IHR)))
C
C     CHECK CRITERIA FOR CONVERGENCE: FIRST PART OF IF-THEN STATEMENT
C     COVERS CONVERGENCE CASE, SECOND PART NONCONVERGENCE.  FOR THE
C     SECOND PART, UNOT IS SPECIFIED TO EFFECT CONVERGENCE JUST BARELY
C
C     IF STATEMENT IS EQN 26 OF USER'S GUIDE
C     USTAR IS IN EQN 25 OF USER'S GUIDE
C     L IS DERIVED FROM EQNS 1 AND 24 OF USER'S GUIDE
C
      IF((2.*UNOT)/(SQRT(CDN)*WSL(IHR)).LE.1.0) THEN
         USTAR(IHR)=(CDN*WSL(IHR)/2.)*(1.+SQRT(1.-((2.*UNOT)/
     1      (SQRT(CDN)*WSL(IHR)))**2.))
         L(IHR)=(T(IHR)*USTAR(IHR)**2.)/(VONK*G*THSTAR(IHR))
        ELSE
         UNOT=SQRT(CDN)*WSL(IHR)*0.5-0.0001
```

```
          USTAR(IHR)=(CDN*WSL(IHR)/2.)*(1.+SQRT(1.-((2.*UNOT)/
     1      (SQRT(CDN)*WSL(IHR)))**2.))
          L(IHR)=(T(IHR)*USTAR(IHR)**2.)/(VONK*G*THSTAR(IHR))
      ENDIF
C
C     IN THIS SECTION, SOLVE EQN 25 IN USER'S GUIDE, BUT SUBSTITUTE
C     FOR THETA-STAR IN THE EXPRESSION FOR UNOT; GET CUBIC EQN IN U*
C
      IF(USTAR(IHR) * THSTAR(IHR).GT.CONST) THEN
          AA = -CDN * WSL(IHR)
          B = 0.0
          C = BETA * ANEM * G * CONST * CDN/T(IHR)
          CALL CUBIC(AA,B,C,USTAR(IHR))
          THSTAR(IHR) = CONST/USTAR(IHR)
          L(IHR) = T(IHR)*USTAR(IHR)*USTAR(IHR)/(VONK*G*THSTAR(IHR))
      ENDIF
      RETURN
      END
```

```
C-----------------------------------------------------------------------
C SUBROUTINE: ZILL
C
C PURPOSE: ROUTINE CALCULATES THE NOCTURNAL BOUNDARY LAYER HEIGHT
C
C ARGUMENTS PASSED: LAT      REAL        LATITUDE IN RADIANS
C                   IHR      INTEGER     HOUR
C
C METHOD: NIEUWSTADT INTERPOLATION OF THE ZILITINKEVICH (1972) METHOD
C         USING USTAR AND L VALUES
C         REFERENCES: NIEUWSTADT, F.T.M.,1981: THE STEADY-STATE HEIGHT
C                           AND RESISTANCE LAWS OF THE NOCTURNAL BOUNDARY
C                           LAYER: THEORY COMPARED WITH CABAUW
C                           OBSERVATIONS, BOUNDARY-LAYER METEOR.,20, PP.
C                           3-17.
C                     NIEUWSTADT, F.T.M.,1984: SOME ASPECTS OF THE
C                           TURBULENT STABLE BOUNDARY LAYER, 29TH
C                           OHOLO CONFERENCE ON BOUNDARY-LAYER
C                           STRUCTURE - MODELLING AND APPLICATION TO
C                           AIR POLLUTION AND WIND ENERGY, 25-28 MARCH.
C                     ZILITINKEVICH, S.S,1972: ON THE DETERMINATION
C                           OF THE HEIGHT OF THE EKMAN BOUNDARY LAYER,
C                           BOUNDARY-LAYER METEOR., 3, PP 141-145.
C
C LIMITATIONS: L MUST BE POSITIVE OR ABS(L) > 100 M
C
C COMMON: US
C         MONIN
C         ZILIT
C
C CALLING ROUTINES: MAIN
C-----------------------------------------------------------------------
      SUBROUTINE ZILL(LAT,IHR)
C
      INTEGER IHR
      REAL F,L,LAT
      COMMON/US/USTAR(24)
      COMMON/MONIN/L(24)
      COMMON/ZILIT/ZIL(24)
C     TENDEG = 10 DEGREES IN RADIANS
      DATA TENDEG/0.174533/
C
C     CALCULATE CORIOLIS PARAMETER AND SOLVE QUADRATIC EQN
C
      XLAT = ABS(LAT)
C
C     TO AVOID BLOWUP NEAR EQUATOR, SET LATITUDE TO MINIMUM OF 10 DEG
C
      XLAT = AMAX1(XLAT,TENDEG)
      F=1.4584E-4 * SIN(XLAT)
      IF(USTAR(IHR).GE.0.AND.L(IHR).GE.0) THEN
C
C     QUADRATIC SOLUTION, EQN 30 OF USER'S GUIDE
C
        ZIL(IHR)=(-L(IHR) + SQRT(L(IHR)*L(IHR) + 2.28*USTAR(IHR)*
     1            L(IHR)/F))/3.8
       ELSE IF(ABS(L(IHR)).GT.100.) THEN
C
C     NEUTRAL APPROXIMATION
C
```

```
    ZIL(IHR) = 0.3*USTAR(IHR)/F
  ELSE
    ZIL(IHR)=-999.
ENDIF
RETURN
END
```

```
C-----------------------------------------------------------------------
C SUBROUTINE: ZZI
C
C PURPOSE: DETERMINE HEIGHT CORRESPONDING TO A GIVEN AREA UNDER THE
C          POTENTIAL TEMPERATURE PROFILE
C
C ARGUMENTS PASSED: NLVLS     INTEGER     RAWINSONDE LEVEL
C                   XAI       REAL        AREA UNDER THE POTENTIAL
C                                         TEMPERATURE CURVE
C                   XAI2      REAL
C                   ZI        REAL        CONVECTIVE MIXED LAYER HT (M)
C                   ZI2       REAL        MECHANICAL MIXED LAYER HT (M)
C
C COMMON: XSUMI HMI
C-----------------------------------------------------------------------
      SUBROUTINE ZZI(NLVLS,XAI,XAI2,ZI,ZI2)
C
      COMMON/XSUMI/HT(80),AI(80),AI2(80)
      COMMON/HM1/SAI(80),SAI2(80)
C
C     DETERMINE HEIGHT CORRESPONDING TO GIVEN AREA UNDER
C     'POTENTIAL TEMP PROFILE' (EQN 27 OF USER'S GUIDE)
C
C     XAI IS RIGHT SIDE OF EQN 27
C     SAI IS LEFT SIDE OF EQN 27
C
      DO 100 ILVLS=2,NLVLS
      IF(XAI.LT.SAI(ILVLS)) GO TO 110
  100 CONTINUE
      ZI=3000.
      GO TO 120
  110 IF(SAI(ILVLS).EQ.SAI(ILVLS-1)) THEN
          ZI = HT(ILVLS-1)
          GO TO 120
      ENDIF
      ZI=HT(ILVLS-1)+(HT(ILVLS)-HT(ILVLS-1))/
     1   (SAI(ILVLS)-SAI(ILVLS-1))*(XAI-SAI(ILVLS-1))
C
C     ZI IS THE CONVECTIVE MIXED LAYER HEIGHT
C
C     SECTION BELOW HANDLES EQN 28 OF USER'S GUIDE
C
C     XAI2 IS RIGHT SIDE OF EQN 28
C     SAI2 IS LEFT SIDE OF EQN 28
C
  120 DO 130 ILVLS=2,NLVLS
      IF(XAI2.LT.SAI2(ILVLS)) GO TO 140
  130 CONTINUE
      ZI2=3000.
      GO TO 150
  140 IF(SAI2(ILVLS).EQ.SAI2(ILVLS-1)) THEN
          ZI2 = HT(ILVLS-1)
          GO TO 150
      ENDIF
      ZI2=HT(ILVLS-1)+(HT(ILVLS)-HT(ILVLS-1))/
     1   (SAI2(ILVLS)-SAI2(ILVLS-1))*(XAI2-SAI2(ILVLS-1))
  150 CONTINUE
C
C     ZI2 IS THE MECHANICAL MIXED LAYER HEIGHT
C
      RETURN
      END
```