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**PCRAMMET
USER'S GUIDE**

U.S. ENVIRONMENTAL PROTECTION AGENCY
Office of Air Quality Planning and Standards
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SECTION 1

INTRODUCTION

This User's Guide contains instructions for executing the U. S. Environmental Protection Agency's PCRAMMET program on a personal computer (PC). PCRAMMET is a meteorological preprocessor used for preparing National Weather Service (NWS) data for use in the Agency's short term air quality dispersion models such as ISCST3, CRSTER, RAM, MPTER, BLP, SHORTZ, and COMPLEX1.

This section provides an overview of PCRAMMET and a description of the differences between this version and previous versions. In Section 2, the input and output files are discussed in detail and Section 3 presents the user interface and instructions on running PCRAMMET. Section 4 discusses the technical aspects of the processing, while Section 5 presents instructions on how to retrieve the program and hourly surface observations and mixing heights from the SCRAM web site.

1.1 OVERVIEW

The user can provide the necessary information for processing the meteorological input data in one of two ways:
1) as an interactive prompt/response session at the PC keyboard;
or 2) with a file of responses used as a command line argument.

The operations performed by PCRAMMET include:

- Calculate hourly values for atmospheric stability from meteorological surface observations;
- Interpolate twice daily mixing heights to hourly values;

- Optionally, calculate the parameters for dry and wet deposition processes; and
- Output data in an unformatted or ASCII format required by regulatory air quality dispersion models.

The input data requirements for PCRAMMET depend on the dispersion model and the model options for which the data are being prepared. The minimum input data requirements to PCRAMMET are the twice-daily mixing heights and hourly surface observations of wind speed, wind direction, dry bulb temperature, opaque cloud cover, and ceiling height. For dry deposition estimates, station pressure is recommended, and for wet deposition estimates, the precipitation type and the amount are required for those periods during which precipitation was observed.

The surface and upper air stations should be selected for their meteorological representativeness of the general area being modeled. Generally, this criterion corresponds to the stations closest to the source(s) being modeled and in the same climatological regime (e.g., coastal, mountainous, plains).

The hourly surface data can be obtained by request from the National Climatic Data Center (NCDC) in Asheville, North Carolina. Observations in CD-144 format on diskette for specific year(s) and station(s) should be requested. Precipitation data can be obtained from NCDC by requesting data in TD-3240 format. An alternative to the CD-144 and TD-3240 data is the data available on the Solar and Meteorological Surface Observation Network (SAMSON) compact discs (CDs). The SAMSON data have recently been updated with the Hourly United States Weather Observations (HUSWO) CD.

The mixing height data also can be obtained by request from the NCDC in either diskette or tabular form by specifying 'twice daily mixing heights' for specific year(s) and station(s).

The mixing height data and a subset of the CD-144 data, with fewer weather elements, are available from the Support Center for Regulatory Air Models (SCRAM) section on EPA's Office of Air Quality Planning and Standards (OAQPS) Technology Transfer Network (TTN) web site at <http://www.epa.gov/scram001/>. The hourly weather observations from SCRAM should not be used for wet deposition or depletion in ISCST3 because the SCRAM data do not contain the present weather fields required to determine the type of precipitation.

The output data file format depends on the final processing option specified by the user. If the meteorological output are to be used in an air quality model for concentration estimates without deposition effects, then an unformatted file can be written. However, the user has the option to write an ASCII file directly, allowing the user to view the results without first translating the unformatted file to an ASCII file. The formatted ASCII file has the advantage that it is independent of the compiler and computing platform on which it is created. If an unformatted file is created, a formatted ASCII file can be obtained from the unformatted file by using BINTOASC.EXE, a program found with the ISCST3 files on the SCRAM web site (in the file ISC3MET).

For dry and wet deposition processing in ISCST3, several additional parameters are written to the PCRAMMET output file. Due to the internal processing in ISCST3, there is no option to write an unformatted file; the output will always be an ASCII file.

1.2 DIFFERENCES FROM PREVIOUS VERSIONS

Several enhancements have been incorporated into PCRAMMET that affect the operation of the preprocessor. These enhancements include: 1) the way the user supplies processing information to the preprocessor (the interface); 2) an increase in the number and type of files that can be processed; and 3) additional options for the type of processing.

1.2.1 User Interface

In the previous version of PCRAMMET, only one type of processing was performed and all the necessary information to process the data was contained in the files. With the expanded capabilities, a new user interface was necessary. With this version of PCRAMMET, the user supplies the preprocessor with the necessary information in one of two ways: interactive or batch. In the interactive mode, the user responds to on-screen prompts, with particular responses to some prompts determining subsequent prompts, i.e., the type of data and the output requirements determines which prompts are displayed. Once the responses are entered, PCRAMMET begins execution. The responses to the prompts are saved in a file for later use. A complete discussion of this mode is in Section 3.1.

In the second mode, the batch mode, the user runs PCRAMMET using command line arguments. There are two arguments on the command line following the program name: the name of the file containing the responses to the prompts that would appear in an interactive mode and the name of the output file. A discussion of this mode is in Section 3.2.

1.2.2 Additional File Types

In addition to the hourly surface weather observations in the CD-144 format and the twice-daily mixing heights, several additional file types can now be processed by PCRAMMET. Hourly

surface observations retrieved from the SAMSON or HUSWO CDs can be used in PCRAMMET. The SAMSON data contain radiation measurements, weather observations and precipitation data from the first order stations in the United States for the period 1961-1990. The HUSWO data contain the same weather observations as the SAMSON data, but differ from the SAMSON data in that there are fewer radiation variables and fields have been added to report cloud observations from the Automated Surface Observing System (ASOS).

PCRAMMET can process the CD-144 hourly surface observations that are on OAQPS' SCRAM web site in the compressed format (i.e., shorter records). Previously, the user had to use a program to expand the data to the 80-character record format of CD-144. Now, the user can use the files directly in PCRAMMET without expanding the data. This format is referred to as the SCRAM format in the remainder of this user's guide.

The ISCST3 model can estimate, at the option of the user, wet deposition. To make this estimate, precipitation data are required. This version of PCRAMMET can process precipitation data in the TD-3240 format. Both the variable length and fixed length formats can be processed. Generally, the data are ordered (from NCDC) in the variable length format.

These formats are discussed in more detail in Section 2.

1.2.3 Output Options

Previous versions of PCRAMMET output an unformatted (binary) file with hourly values of winds, temperature, stability and mixing heights. If the user required an ASCII file, a separate program had to be run on the unformatted data. With this version of PCRAMMET, the user has the option to write an ASCII output file.

The user has the option to estimate the parameters required for dry or wet deposition estimates in ISCST3. If the user selects one of these options, then an ASCII output file is created (an unformatted file is not an option) with three additional parameters for dry deposition estimates or five parameters for wet deposition estimates.

1.2.4 ASOS Data

The Automated Surface Observing System (ASOS) is a real-time, automated weather information system that replaces conventional human observations for recording near-surface weather conditions. The first ASOS was installed in August 1991 at Topeka, Kansas. When all the installations are complete, the automated systems will be operational at over 850 stations throughout the United States, the Caribbean, and overseas military installations.

While improving the efficiency in acquiring weather data, the ASOS instrumentation lacks the observational ability of the human observer to spatially integrate some of the weather elements over a large area. Two such elements are ceiling height and opaque cloud cover, which are important in estimating atmospheric stability and mixing heights required for applications of several regulatory and nonregulatory dispersion models.

ASOS-derived observations appear on the HUSWO CD. An ASOS observation is denoted by the letter 'A' in column 6, immediately following the station WBAN number. The total and opaque cloud cover in an ASOS observation are both 0. The cloud information is contained in three cloud layer fields specific to the ASOS observations. Each field consists of a sky condition and layer height. The cloud cover and ceiling height for use in PCRAMMET

must be derived from these fields. An explanation of how these values are converted to cloud cover can be found in Section 4.

SECTION 2

INPUT/OUTPUT DATA

PCRAMMET processes five input data formats: 1) CD-144 hourly surface observations; 2) twice-daily mixing height data; 3) hourly surface observations retrieved from SCRAM; 4) hourly surface observations archived on compact disc; and 5) precipitation data (TD-3240 format).

If meteorological data are to be used as input to an air quality model only to estimate concentration, the user has the option of creating an unformatted (binary) or ASCII output file. If deposition estimates are required, the output file is created as an ASCII file.

In this section, the input data and output files are discussed. The file structures are provided in Appendix A.

2.1 INPUT DATA

The input data requirements for PCRAMMET depend on the dispersion model and the model options for which the data are being prepared. For concentration estimates for which the effect of settling and removal processes of dry and wet deposition are not required, the necessary data are:

- Wind direction,
- Wind speed,
- Dry bulb temperature,
- Opaque cloud cover,
- Cloud ceiling height,
- Morning mixing height, and
- Afternoon mixing height.

The mixing heights are based on NWS upper air soundings at 1200 GMT and 0000 GMT, respectively.

For dry deposition estimates in ISCST3, one additional variable is recommended:

- Station pressure.

Station pressure is used only to compute the density of dry air. If station pressure is missing, then a value of 1000 mb is automatically substituted.

For wet deposition estimates in ISCST3, additional data requirements are:

- precipitation amount, and
- present weather to obtain information regarding precipitation type.

The precipitation type is determined from the present weather codes in the hourly surface observations, which indicates whether the type of precipitation is in liquid or frozen form. The hourly precipitation amount is obtained from a separate file.

The output from PCRAMMET can also be used by the CALPUFF puff dispersion model. When modeling wet or dry deposition with CALPUFF, global horizontal radiation and relative humidity are required for the chemical transformation processes in the model. If the hourly surface observations are retrieved from the SAMSON or HUSWO compact discs, then these two additional parameters must be retrieved, whether or not the output from PCRAMMET is to be used by CALPUFF. These two fields appear at the end of each record in which dry or wet deposition is specified and data retrieved from the SAMSON or HUSWO CD are used.

2.1.1 Mixing Height Data

Previous versions of PCRAMMET required an initialization record as the first record of the file. This record is no longer required. However, PCRAMMET can read mixing height files that contain this record - the record simply is ignored. The record, if present, contains the following information:

- NWS meteorological surface station number,
- Year of surface data,
- Latitude of the surface station,
- Longitude of the surface station, and
- Time zone of the surface station.

The structure of the mixing height file for this version of PCRAMMET is as follows:

- Mixing height record for December 31 of the year preceding the year of record;
- Mixing height record for January 1 of the year of record;
- Mixing height record for January 2 of the year of record;
- .
- .
- .
- Mixing height record for December 30 of the year of record;
- Mixing height record for December 31 of the year of record;
- Mixing height record for January 1 of the year following the year of record (or duplicate of the December 31 record with year, month, day changed).

The format of the mixing height data corresponds to the format of the data that are available on the SCRAM web site,

which is described in Appendix A. Each record contains the following information:

- Upper Air Station Number - the Weather Bureau Army Navy (WBAN) station identification number identifying the NWS upper air observation station used to calculate mixing heights. The List of Upper Air Stations available from NCDC tabulates such WBAN numbers. The station must be representative of the site to be modeled.
- Year - the last two digits of the year of record for the mixing height data.
- Month - the month number corresponding to a given set of mixing heights.
- Day - the calendar day number corresponding to a given set of mixing heights.
- Nocturnal Urban Mixing Height - the minimum mixing height for a given day calculated from the 1200 GMT upper air sounding on that day, using morning surface temperature augmented by 5°C to account for urban heating.
- Afternoon Mixing Height - the maximum mixing height for a given day calculated from the afternoon surface temperatures and the 1200 GMT upper air sounding for that day.

Each record also contains additional information on wind speed and general weather conditions that are not processed by PCRAMMET.

The method for calculating hourly mixing heights from the twice daily mixing heights uses the methods suggested by Holzworth (1972). This method interpolates the mixing heights using the afternoon mixing height from the preceding day, both mixing heights from the current day, and the morning sounding of the following day. For this reason, the mixing heights for the last day of the year preceding the year of record must be included as the first mixing height record and the mixing heights for the first day of the year following the year of record must

be included as the last mixing height record. If these data are not available, the data for the first and last days of the year of record can be substituted, respectively. A discussion of the interpolation method can be found in Section 4.

The mixing height records input to PCRAMMET must contain the morning and afternoon mixing heights for the day being processed. Quality checks are not performed on mixing height data input to PCRAMMET, and so it is recommended that the user review these data for completeness.

 **A blank in a mixing height field is interpreted as a zero.**

The twice daily mixing height values can be purchased from the National Climatic Data Center (TD-9689 format) or downloaded from the SCRAM web site. Note that the field position of the afternoon mixing height in the NCDC file is not the same as the position in the files from the SCRAM web site (See Appendix A). The NCDC format has the afternoon mixing height in columns 25-28, whereas the SCRAM format has the afternoon mixing height in columns 32-35. Therefore, the user should reformat the NCDC file to conform to the data format available on SCRAM.

2.1.2 Hourly Surface Observations

Hourly observations of surface weather can be obtained from four sources: CD-144, SCRAM, SAMSON CD and HUSWO CD. The CD-144 format is the traditional 80-character format processed by PCRAMMET. SCRAM is a reduced version (fewer weather variables) of the CD-144 data and is available from the SCRAM web site. The SAMSON and HUSWO data take advantage of the wide availability of compact disc readers on personal computers. Only one of these formats can be processed in a single PCRAMMET run.

2.1.2.1 CD-144 and SCRAM Formats

The CD-144 format refers to the "Card Deck 144 format" available from the NCDC. The file is composed of one record per hour, with all weather elements reported in an 80-column card image. The format of these records is described in the Card Deck 144 WBAN Hourly Surface Observations Reference Manual (NOAA, 1970), also available from the NCDC. Data in this file that are checked or used by PCRAMMET includes the station number, year, month, day, hour, cloud ceiling height, wind direction, wind speed, dry bulb temperature, and opaque cloud cover or total sky cover (Appendix A). The surface data files downloaded from the SCRAM web site contain these five weather elements in a compressed format. The weather variables not required in the computations are omitted and the blank fields removed to create a 28-character record. The SCRAM format can be processed directly by PCRAMMET or the data may be expanded to the 80-character records for input into PCRAMMET (See Program Notes in Section 5 for a discussion on this process).

The variables used by PCRAMMET from the CD-144 record include the following:

- Surface Station Number - the WBAN number identifying the NWS surface observation station for which hourly meteorological data are input to the PCRAMMET program.
- Year, Month and Day of Record - identifies the year, month and day during which the meteorological data were observed. Only the last two digits of the year are reported.
- Hour - identifies the hour of the meteorological data observation. Hour is based on the 24-hour clock and is recorded as 00 through 23. Times are Local Standard Time (LST) and are adjusted in PCRAMMET to the 01 - 24 clock in which hour 24 is the same as hour 00 of the next day.
- Ceiling Height - the height of the cloud base above local terrain and is coded in hundreds of feet.

- Wind Direction - the direction from which the wind is blowing, based on the 36 point compass; e.g., 09=East, 18=South, 27=West, 36=North, 00=Calm.
- Wind Speed - the wind speed measured in knots (00=Calm).
- Dry Bulb Temperature - the ambient temperature measured in whole degrees Fahrenheit.
- Cloud Cover - There are two cloud cover parameters, opaque cloud cover and total cloud cover in the CD-144 and SCRAM meteorological data files. Both parameters identify the amount of cloud cover measured in tens of percent, e.g., 0 = clear or less than 10%, 4 = 40-49%, '-' = overcast or 100%. PCRAMMET reads the field for opaque cloud cover.

2.1.2.2 SAMSON Format

With the advent of compact disc readers for the personal computer, large amounts of data can be stored in small amounts of space. NCDC has made available solar and meteorological data for the first order stations in the United States for the period 1961-1990 on a set of three CDs, referred to as the SAMSON data.

 **PCRAMMET cannot access the data directly from a SAMSON CD.**

The user must run the software provided with the data to retrieve the station(s), period(s) of time, and variables for the site and period to be modeled. The software is a DOS-based, interactive graphical interface and is user-friendly in its usage. The software has been run successfully in a DOS window under Microsoft Windows 3.1x, Windows 95, and Windows NT (version 4.0). The output files are written in an ASCII file on the user's local drive.

The software used to extract data from the CDs can retrieve multiple years of data for a single station and save it in the same file. However, PCRAMMET expects a maximum of one year of

data in a data file retrieved from CD. The reason for this restriction is explained below.

Retrieving data from a SAMSON CD is a separate process, completely under the control of the user. When data are retrieved from the CDs, the user has the option to specify which variables to retrieve from a list of 21 variables stored for each station (see Appendix A for a complete list). At a minimum, the ceiling height, wind direction and speed, dry bulb temperature and opaque cloud cover should be retrieved (to be compatible with the data in the files on SCRAM). These variables are sufficient for most of the models listed in Section 1, and results in an ASCII file of about 400 Kb for one year of data. However, if dry deposition and/or wet deposition estimates are to be made with ISCST3, then additional variables should be retrieved. These are station pressure for dry deposition (resulting in a file size of about 445 Kb) and present weather and hourly precipitation amount for wet deposition (resulting in a file size of about 537 Kb). If all of the variables are retrieved, then a file size of about 1.2 Mb is created. When precipitation data are retrieved, the size will vary because precipitation amount is the last field and is filled only if there was precipitation for the hour, making some records longer than others.

When the data are retrieved from the CD, two records are written at the beginning of the file that identify the station (first record) and the variables retrieved (second record). PCRAMMET processes both of these records to obtain information about the station (e.g., latitude and longitude) and to determine how to process the data that follow. It is imperative that the user not alter or delete these records. These two records begin with the tilde character (~). If more than one year of data are retrieved from the CDs, these two records appear before each year in the file. If more than one year of data are in the file, the program will terminate with a compiler-issued error when PCRAMMET

encounters the second set of header records. The program expects an integer value (the year), but encounters a character value (the tilde). However, the output for the previous year will be complete and intact. It is recommended that the user restrict data retrieved from CD to one station and one year per file.

PCRAMMET examines the second record to determine if the variables retrieved from the CD are sufficient to process the entire file according to the user's responses on how the output is expected to be used. If there are insufficient data, then PCRAMMET writes an error message and stops processing. The user must either select a different processing option, or return to the CDs and retrieve the data once again, making sure to retrieve all of the necessary variables to generate the meteorological data output file.

The header records are followed by the data records. There is one record for each hour of the time period the user retrieved. Unlike the CD-144 format, which reports the hour on the 00 - 23 clock, the hour is reported on the 01 - 24 clock. Hour 24 of a day retrieved from SAMSON corresponds to hour 00 of the next day for CD-144 data. The time adjustment that PCRAMMET must go through for CD-144 data is not necessary with SAMSON.

Data stored in the SAMSON format are in different units than found in the CD-144 data. For the output to be identical from both input formats, PCRAMMET converts the SAMSON data to the units that are in the CD-144 data.

2.1.2.3 HUSWO Format

The HUSWO compact disc contains the first order stations in the United States for the period 1990-1995, overlapping the SAMSON CD for 1990.

☞ **PCRAMMET cannot access the data directly from a HUSWO CD.**

The user must run the software provided with the data to retrieve the station(s), period(s) of time, and variables for the site and period to be modeled. As with the SAMSON CD, the software is a DOS-based, interactive graphical interface. The software has been run successfully in a DOS window under Microsoft Windows 3.1x and Windows 95. However, under Windows NT (version 4.0), the video is severely distorted when the retrieval step is performed. The data are successfully retrieved but the user must activate the Windows task manager to end the task in order to continue. The output files are written in an ASCII file on the user's local drive.

The software used to extract data from the CD can retrieve multiple years of data for a single station and save it in the same file. However, PCRAMMET expects a maximum of one year of data in a data file retrieved from the CD. The reason for this restriction is explained below.

Retrieving data from the HUSWO CD is a separate process, completely under the control of the user. When data are retrieved from CD, the user has the option to specify which variables to retrieve from a list of 20 variables stored for each station (see Appendix A for a complete list). At a minimum, the ceiling height, wind direction and speed, dry bulb temperature, sky cover (which includes both total and opaque), and ASOS cloud data should be retrieved (to be compatible with the data in the files on SCRAM). These variables are sufficient for most of the models listed in Section 1, and results in an ASCII file of about 560 Kb for one year of data. If all of the variables are retrieved, then a file size of about 1.0 Mb is created. When precipitation data are retrieved, the size will vary because precipitation amount is the last field and is filled only if

there was precipitation for the hour, making some records longer than others.

When the data are retrieved from CD, a single record is written at the beginning of the file that identifies the variables retrieved. PCRAMMET processes this record to determine which variables are present and how to process the data that follow. It is imperative that the user not alter or delete this record. If more than one year of data are retrieved from the CD, this record appears before each year in the file. If more than one year of data are in the file, then PCRAMMET may terminate with an error when the second header record is encountered. Two reasons that PCRAMMET would terminate abnormally if there is more than one year of data in a HUSWO data file are: 1) if there is only one year of mixing height data, then PCRAMMET will attempt to read past the end of the mixing height file; or 2) if there are multiple years of mixing height data, PCRAMMET will fail when it attempts to process the date group since the year is not valid (a variable number is read rather than the year) and the month and day fields are both blank, which are interpreted as zeroes. However, the output for the previous year will be complete and intact. Therefore, it is recommended that the user restrict data retrieved from CD to one station and one year per file.

PCRAMMET examines the first record to determine if the variables retrieved from the CD are sufficient to process the entire file according to the user's responses on how the output is expected to be used (i.e., dry, wet, or no deposition). If there are insufficient data, PCRAMMET writes an error message and stops processing. The user must either select a different processing option, or return to the CD and retrieve the data once again, making sure to retrieve all of the necessary variables to generate the meteorological data output file.

The header record is followed by the data records. There is one record for each hour of the time period the user retrieved. Unlike the CD-144 format which reports the hour on the 00 - 23 clock, the hour is reported on the 01 - 24 clock. Hour 24 of a day retrieved from HUSWO corresponds to hour 00 of the next day for CD-144 data, i.e., the time adjustment that PCRAMMET must go through for CD-144 data is not necessary with HUSWO.

Data can be retrieved from the HUSWO CD in either English or metric units. Unfortunately, there is no indicator in the output file to identify the units in use. Thus, there is no way for PCRAMMET to determine the units automatically. By default, the interface starts with English units.

☞ **PCRAMMET expects the data to be in English units;** the data are converted in the program to the required units.

If data are retrieved in metric units, then output from PCRAMMET, as well as from any dispersion models such as ISCST3 that use the data, will be in error.

2.1.3 Precipitation Data - TD-3240 Format

For wet deposition estimates from ISCST3, the dispersion model requires the amount of precipitation as well as the precipitation type (liquid or frozen). The precipitation type is obtained from the present weather fields in the hourly surface observation files (CD-144 or SAMSON) and converted to a precipitation code that the dispersion model interprets. The precipitation amount is not reported with the standard CD-144 data. Therefore, another file of precipitation amount is required for wet deposition processes.

The TD-3240 data format from NCDC contains the necessary precipitation amount. In addition to supplying the precipitation data when CD-144 data are processed, these data can be used to supplement the SAMSON precipitation data in the event there are little or no precipitation data for a station (there are about 20 such stations which are noted in the SAMSON online help), or if precipitation was not retrieved from the CDs.

The TD-3240 data as received from NCDC are usually in a variable-length format. In this format, precipitation data for the entire day is stored on one record, and only for those hours during which precipitation was reported. A fixed-length format is also available in which one record contains the precipitation amount for one hour. As with variable-length files, data are stored only for those days and hours for which precipitation was reported. PCRAMMET can process both formats. For variable-length formats, the preprocessor converts the data to a fixed-length format, writes the results to a scratch file and uses the scratch file for processing. The scratch file is deleted at the end of the run.

Precipitation is reported in inches and hundredths of an inch in the TD-3240 format. These units are converted to millimeters for use in the ISCST3 dispersion model.

2.2 OUTPUT FILE

The first record in the output file from PCRAMMET contains a file identification record followed by one record for each day in the year. The file identification record contains the year of record for the surface meteorological data, the surface station identification number, the year of record for the mixing height data, and the upper air station identification number.

If the user specifies that no (dry or wet) deposition estimates are to be performed with the output data set, then the user has the option of creating an unformatted (binary) or ASCII output file. The binary output from PCRAMMET consists of one record with the year, month, and the Julian day followed by 24 values of stability class, wind speed, temperature, flow vector, randomized flow vector, and rural and urban mixing heights. The ASCII file contains the same information except that each hour is written as a separate record.

The four values on the file identification record and the year, month, Julian day and stability class record are written as FORTRAN integer variables. All other values on the daily records are FORTRAN real number variables. See Appendix A for a description of the arrangement of the variables on each of the daily records.

If an unformatted file is written, all records on the output file are written with an unformatted FORTRAN write statement. Thus, the resulting output file structure will be dependent upon the FORTRAN compiler used to create the PCRAMMET executable. As a result, to maintain compatibility with the unformatted file, the models requiring its use must also have been created using the same compiler. Most executables on the SCRAM web site requiring the use of the PCRAMMET unformatted output file have been created using a Lahey FORTRAN or Microsoft compiler.

For dry deposition estimates, five additional fields are written to the output file: surface friction velocity (u_*), Monin-Obukhov length (L), surface roughness length (z_0), global horizontal radiation, and relative humidity. Stull (1988) provides a good discussion of the first three parameters. The output file is in ASCII only.

For wet deposition, the five parameters for dry deposition plus two additional parameters are written: precipitation type (which is based on the present weather codes in the hourly surface observation file), and the precipitation amount. The output is in ASCII only. Table 2-1 below shows how the reported precipitation type and intensity are converted to the precipitation codes that are written to the output file.

Since the global horizontal radiation and relative humidity are not utilized by ISCST3, these two variables always appear in columns 102-110 and 111-113, respectively. If data are processed for dry, rather than wet, deposition estimates, then there is a 'gap' in each record between the roughness length and global radiation.

TABLE 2-1

Conversion of Reported Precipitation Type/Intensity to
Precipitation Codes (Liquid)

Precipitation Code	Type	Intensity
1	Rain	Light
2	Rain	Moderate
3	Rain	Heavy
4	Rain Showers	Light
5	Rain Showers	Moderate
6	Rain Showers	Heavy
7	Freezing Rain	Light
8	Freezing Rain	Moderate
9	Freezing Rain	Heavy
10	(not used)	-
11	(not used)	-
12	(not used)	-
13	Drizzle	Light
14	Drizzle	Moderate
15	Drizzle	Heavy
16	Freezing Drizzle	Light
17	Freezing Drizzle	Moderate
18	Freezing Drizzle	Heavy

TABLE 2-1, continued
Conversion of Reported Precipitation Type/Intensity to
Precipitation Codes (Liquid)

Precipitation Code	Type	Intensity
19	Snow	Light
20	Snow	Moderate
21	Snow	Heavy
22	Snow Pellets	Light
23	Snow Pellets	Moderate
24	Snow Pellets	Heavy
25	(not used)	-
26	Ice Crystals	*
27	(not used)	-
28	Snow Showers	Light
29	Snow Showers	Moderate
30	Snow Showers	Heavy
31	(not used)	-
32	(not used)	-
33	(not used)	-
34	Snow Grains	Light
35	Snow Grains	Moderate
36	Snow Grains	Heavy
37	Ice Pellets	Light
38	Ice Pellets	Moderate
39	Ice Pellets	Heavy
40	(not used)	-
41	Hail	*
42	(not used)	-
43	(not used)	-
44	Small Hail	*
45	(not used)	-

* Intensity not reported for ice crystals, hail and small hail.

SECTION 3

RUNNING PCRAMMET AND THE PROGRAM INTERFACE

The user supplies the necessary processing information to PCRAMMET in one of two ways: 1) interactively, responding to program prompts; or 2) in a batch mode using a file that contains the responses to the prompts that would appear during an interactive session (referred to as a response file). In this section, these two methods of providing information to PCRAMMET are presented. It is recommended that PCRAMMET be run in the interactive mode until the user gains familiarity with the various prompts and is comfortable constructing or modifying response files.

3.1 INTERACTIVE MODE

The user can enter the information needed by PCRAMMET by responding to a series of screen prompts from PCRAMMET. Particular responses will affect subsequent prompts. In other words, not every PCRAMMET run will have the same set of prompts. PCRAMMET records the user's responses in an annotated file named INPUTS, which can be used to run PCRAMMET with command line arguments, as discussed in Section 3.2.

To start the interactive mode, the user types PCRAMMET at the DOS prompt followed by pressing ENTER. The following is the sequence of prompts that appear on screen and a description of the expected responses. Note that not all prompts will be displayed for every run of PCRAMMET. The prompts depend on what the output will be used for and the data formats to be used. Some of the prompts discussed below have been grouped together because either (1) all will appear, or (2) none will appear

(again, depending on previous responses). The responses can be entered in upper or lower case - PCRAMMET converts many of the character responses to upper case for correct processing. When a filename is entered, it must conform to the computer platform's file naming conventions. On a DOS platform, this is an optional path followed by an 8-character file plus 3-character extension. The maximum length for a *path\filename.extension* is 40 characters. PCRAMMET attempts to catch any errors the user makes when entering responses. A message is displayed and the program prompts for a new response. If a valid, but incorrect, response is entered, simultaneously pressing the 'control' and 'C' or 'control' and 'break' keys will return the user to the DOS prompt.

The prompts and possible or expected responses are:

1) **Will you be making any dry or wet deposition calculations?**

None / Dry / Wet :

The user can respond with **NONE (N)**, **DRY (D)** or **WET (W)**, corresponding to no deposition, dry deposition, or wet deposition, depending on the dispersion model application. The first letter of the response also can be used here.

2) **Enter the OUTPUT filename:**

The name of the file where the output is to be written is entered at this prompt.

3) **Enter the output file type:**

Uniform / Ascii :

This prompt is seen only if **NONE** (or **N**) is the response to the type of calculation (in (1) above). Valid responses are **UNIFORM** (or **U**) and **ASCII** (or **A**). **UNIFORM** will produce the unformatted file generated by previous versions of PCRAMMET.

4) **Enter MIXING HEIGHT data filename:**

The name of the file containing the twice-daily mixing heights is entered at this prompt. If the file does not exist (e.g., the user misspells the name), PCRAMMET immediately displays an error message and prompts for the filename again.

5) **Enter the HOURLY SURFACE DATA filename:**

The name of the file containing the hourly weather observations is entered at this prompt. If the file does not exist (e.g., the user misspells the name), PCRAMMET immediately displays an error message and prompts for the filename again.

6) **Enter surface data format:**

CD144 or SAMSON or HUSWO or SCRAM:

Valid responses are **CD144**, **SCRAM**, **HUSWO**, or **SAMSON**. These formats are explained in detail in Section 2. **CD144** corresponds to the format that previous versions of PCRAMMET have used, **SCRAM** refers to the format available on OAQPS' TTN bulletin board, and **SAMSON** and **HUSWO** refers to data the user has retrieved from CD.

7) **Enter the latitude of the surface station in decimal degrees**
- positive for stations north of the equator:

Enter the longitude of the surface station in decimal degrees
- positive for stations WEST of Greenwich:

Enter the time zone of the surface station
- positive for stations WEST of Greenwich:

These three prompts are seen only if the surface data format (in (6) above) is **CD144** or **SCRAM** or **HUSWO**. The

user enters the latitude and longitude, in decimal degrees, that correspond to the location where the hourly surface observations were taken. For the output using CD-144, SCRAM, or HUSWO input data to agree with the output using SAMSON input data, the latitude and longitude should be specified with four or more digits after the decimal.

If the user is unsure about the correct values to enter here, the latitude, longitude, and time zone for all sites on the SCRAM web site are available under Met Data/Surface Data and click on the link to the station list to display the station data. Alternatively, NCDC has available a manual of latitude and longitude by station name and WBAN number. SAMSON data contain this information within the file, so PCRAMMET does not request it. Note: These prompts/responses and the station and date information in SAMSON data files replace the initialization record that appeared in the mixing height file for previous versions of PCRAMMET.

8) **SAMSON/HUSWO data may already contain hourly precip**

Do you want to supplement with TD-3240 data?

Yes / No :

This prompt is seen only if the response to the type of calculation (in (1) above) is **WET** and the surface data format is **SAMSON** or **HUSWO** (in (6) above). Valid responses are **YES** (or **Y**) and **NO** (or **N**). If the user answers with **YES**, the user specifies the filename of TD-3240 precipitation data to use (in (9) below) in the event the SAMSON or HUSWO data retrieved from CD lacks precipitation data.

9) **Enter HOURLY PRECIP DATA filename:**

This prompt is seen only if the response to the type of calculation (in (1) above) is **WET** and the surface data format (in (6) above) is **CD144**, or if the **SAMSON** or **HUSWO** data are to be supplemented (in (8) above). The name of the file containing the precipitation data in NCDC's TD-3240 format is entered at this prompt. If the file does not exist (e.g., the user misspells the name), PCRAMMET immediately displays an error message and prompts for the filename again.

10) **Enter precipitation file format**

Variable or Fixed:

This prompt is seen only if the response to the type of calculation (in (1) above) is **WET**. Valid responses are **VARIABLE** (or **V**) and **FIXED** (or **F**). These terms are explained in Section 2.1.3.

11) **For deposition, site characteristics are needed**

If the response to the type of calculation (in (1) above) is **DRY** or **WET**, then PCRAMMET prompts the user for properties representative of the measurement and application sites. These properties are required for dry and wet deposition calculations that are performed with the ISCST3 model. For many of these site characteristics, if the user enters an invalid value (e.g., a roughness length less than zero), a message is shown on the screen and the prompt is redisplayed.

The following are more detailed explanations of the information required to respond to the prompts.

Minimum Monin-Obukhov Length - Stable Conditions (meters)

The Monin-Obukhov length is a measure of atmospheric stability. It is negative during the day when surface

heating results in an unstable atmosphere and positive at night when the surface cools (stable atmosphere). Values near zero indicate very unstable or stable conditions (depending on the sign). In urban areas during stable conditions, the estimated value of L may not adequately reflect the less stable boundary layer. Hanna and Chang (1991) point out that mechanical turbulence generated by obstacles (buildings) in urban areas will tend to produce a "more neutral" surface layer than that over an unobstructed site. They suggest that a minimum value of L be set for stable hours in order to simulate this effect. Using an approximate relation between obstacle height and the zone of flow affected by an obstacle, they suggest the following minimum values for several urban land use classifications:

agriculture (open)	2m
residential	25m
compact residential/industrial	50m
commercial (19-40 story buildings)	100m
(> 40 story buildings)	150m

Anemometer Height (meters)

The height at which the winds were measured. For data observed at airports, this value can range from about 6 meters (20 feet) to 9 meters (30 feet). The user must determine the anemometer height. A good source is the set of *Local Climatological Data Annual Summaries*, available from NCDC. These summaries contain information about the instrumentation at the end of each station's data entry for the entire period of record.

Surface Roughness Length - Measurement Site (meters)

The surface roughness length is a measure of the height of obstacles to the wind flow. It is not equal to the physical dimensions of the obstacles, but is generally proportional to them. Typical values for a range of land-use types as a function of season are listed in Table B-1. At this prompt,

the user enters a value representative of the site where the winds were measured, e.g., an airport.

Surface Roughness Length - Application Site (meters)

At this prompt, the user enters a roughness length representative of the site where the meteorological output are to be applied. The discussion above for the roughness length at the measurement site also applies here.

Noon-time Albedo

Noon-time albedo is defined as the fraction of the incoming solar radiation that is reflected from the ground when the sun is directly overhead. Adjustments are made automatically within PCRAMMET for the variation in the albedo with solar elevation angle. A range of values is given in Table B-2 as a function of several land-use types and season.

Bowen Ratio

The Bowen ratio is a measure of the amount of moisture at the surface. The presence of moisture at the earth's surface alters the energy balance, which in turn alters the sensible heat flux and Monin-Obukhov length. A range of values is given in Tables B-3a, 3b and 3c as a function of land-use types, seasons and moisture conditions.

Anthropogenic heat flux (W/m^2)

The anthropogenic heat flux can usually be neglected (set equal to zero) in areas outside highly urbanized locations. However, in areas with high population densities or high energy use, this flux may not always be negligible. Oke (1978) presents estimates of population density and per capita energy use for 10 cities and obtains a heat flux for each. Summertime values are typically 50% of the mean, while wintertime values are about 150% of the mean in the

colder climates. Table B-4 provides guidance for several urban areas.

Fraction of Net Radiation Absorbed at the Ground

The flux of heat into the ground during the daytime is parameterized as a fraction of the net radiation. Values suggested by Oke (1982) are:

rural	0.15
suburban	0.22
urban	0.27

With three types of output and four types of hourly surface observations, there are at least 12 combinations of prompts and responses. Six of these prompt/response combinations are shown in the following tables for the three types of calculation (NONE, DRY and WET) and two of the hourly surface observation formats (CD-144 and SAMSON). The prompts and responses when using SCRAM data would be the same as for CD-144 data except for the response to the "Surface Data Format" prompt. Processing HUSWO data results in a combination of CD-144 and SAMSON prompts and responses.

NO DEPOSITION, CD-144 DATA

Program Prompt	User Response	Comments
Calculation Type	NONE (or N)	Output cannot be used for deposition estimates in ISCST3
Output Filename	output_filename	Does not appear in response file
Output File Type	UNFORM (or U) or ASCII (or A)	
Mixing Height Filename	mixing_height_filename	
Hourly Surface Obs. Filename	surface_data_filename	
Surface Data Format	CD144	Data from SCRAM can be used - respond with SCRAM
Station Latitude	station latitude	decimal degrees
Station Longitude	station longitude	decimal degrees
Station Time Zone	time zone (5=Eastern, 6=Central, 7=Mountain, 8=Pacific)	integer

NO DEPOSITION, SAMSON DATA

Program Prompt	User Response	Comments
Calculation Type	NONE (or N)	Output cannot be used for deposition estimates in ISCST3
Output Filename	output_filename	Does not appear in response file
Output File Type	UNFORM (or U) or ASCII (or A)	
Mixing Height Filename	mixing_height_filename	
Hourly Surface Obs. Filename	surface_data_filename	
Surface Data Format	SAMSON	latitude, longitude and time zone are in the data file

DRY DEPOSITION, CD-144 DATA

Program Prompt	User Response	Comments
Calculation Type	DRY (or D)	Output cannot be used for wet deposition estimates in ISCST3
Output Filename	output_filename	ASCII is only output file type; does not appear in response file
Mixing Height Filename	mixing_height_filename	
Hourly Surface Obs. Filename	surface_data_filename	
Surface Data Format	CD144	SCRAM data lack station pressure; a default of 1000 mb is used if SCRAM data are used
Station Latitude	station latitude	decimal degrees
Station Longitude	station longitude	decimal degrees
Station Time Zone	time zone (5=Eastern, 6=Central, 7=Mountain, 8=Pacific)	integer
Minimum Monin-Obukhov Length		meters
Anemometer Height		meters
Surface Roughness Length - Measurement Site		meters
Surface Roughness Length - Application Site		meters
Noontime Albedo		between 0.0 and 1.0
Bowen Ratio		0.5 = very moist, 10.0 = very dry
Anthropogenic Heat Flux		0 for rural, 100 for large urban
Fraction of Net Radiation Absorbed at the Ground		0.15 for rural, 0.27 for urban

DRY DEPOSITION, SAMSON DATA

Program Prompt	User Response	Comments
Calculation Type	DRY (or D)	Output cannot be used for wet deposition estimates in ISCST3
Output Filename	output_filename	ASCII is only output file type; does not appear in response file
Mixing Height Filename	mixing_height_filename	
Hourly Surface Obs. Filename	surface_data_filename	
Surface Data Format	SAMSON	
Minimum Monin-Obukhov Length		meters
Anemometer Height		meters
Surface Roughness Length - Measurement Site		meters
Surface Roughness Length - Application Site		meters
Noontime Albedo		between 0.0 and 1.0
Bowen Ratio		0.5 = very moist, 10.0 = very dry
Anthropogenic Heat Flux		0 for rural, 100 for large urban
Fraction of Net Radiation Absorbed at the Ground		0.15 for rural, 0.27 for urban

WET DEPOSITION, CD-144 DATA

Program Prompt	User Response	Comments
Calculation Type	WET (or W)	
Output Filename	output_filename	ASCII is only output file type; does not appear in response file
Mixing Height Filename	mixing_height_filename	
Hourly Surface Obs. Filename	surface_data_filename	
Surface Data Format	CD144	SCRAM data lack present weather; do not use the SCRAM format for wet deposition in ISCST3
Station Latitude	station latitude	decimal degrees
Station Longitude	station longitude	decimal degrees
Station Time Zone	time zone (5=Eastern, 6=Central, 7=Mountain, 8=Pacific)	integer
Hourly Precipitation Filename	precip_data_filename	
Precipitation File Format	VARIABLE (or V) or FIXED (or F)	
Minimum Monin-Obukhov Length		meters
Anemometer Height		meters
Surface Roughness Length - Measurement Site		meters
Surface Roughness Length - Application Site		meters
Noontime Albedo		between 0.0 and 1.0
Bowen Ratio		0.5 = very moist, 10.0 = very dry
Anthropogenic Heat Flux		0 for rural, 100 for large urban
Fraction of Net Radiation Absorbed at the Ground		0.15 for rural, 0.27 for urban

WET DEPOSITION, SAMSON DATA

Program Prompt	User Response	Comments
Calculation Type	WET (or W)	
Output File Name	output_filename	ASCII is only output file type; does not appear in response file
Mixing Height Filename	mixing_height_filename	
Hourly Surface Obs. Filename	surface_data_filename	
Surface Data Format	SAMSON	
Supplement SAMSON Precipitation Data with TD-3240?	YES (or Y) or NO (or N)	
Hourly Precipitation Filename	precip_data_filename	prompted only if using TD-3240 as supplemental data
Precipitation File Format	VARIABLE (or V) or FIXED (or F)	prompted only if using TD-3240 as supplemental data
Minimum Monin-Obukhov Length		meters
Anemometer Height		meters
Surface Roughness Length - Measurement Site		meters
Surface Roughness Length - Application Site		meters
Noontime Albedo		between 0.0 and 1.0
Bowen Ratio		0.5 = very moist, 10.0 = very dry
Anthropogenic Heat Flux		0 for rural, 100 for large urban
Fraction of Net Radiation Absorbed at the Ground		0.15 for rural, 0.27 for urban

When the user responds to the final prompt, PCRAMMET begins processing the data. The current year/month/day are displayed as each day is processed. Depending on the system used, the runtime for PCRAMMET is from 35 seconds on a 80486 33 MHz system to 5 seconds on a 200 MHz Pentium Pro system. On completion, the following message is displayed:

**Your responses to the program prompts have been written to the file "INPUTS."
See the file PCRAM.LOG for a review of this run**

The message indicates that the responses provided during the interactive input (excluding the output filename) can be found in the file "INPUTS." This file can be used for subsequent runs of PCRAMMET (as described below). The second line indicates that a summary of the run is located in the file PCRAM.LOG. This file is an ASCII file that can be viewed with any text editor or printed to the screen or a printer.

In addition, if PCRAMMET wrote any warning messages to the log file, then the following message also appears:

***** Warning messages were generated by PCRAMMET and are in PCRAM.LOG**

The message indicates that nonfatal messages generated by PCRAMMET are located in PCRAM.LOG. Messages such as rural mixing heights less than 10 meters and warnings about multiple forms of precipitation are written to this file.

If a fatal run time error occurs that is trapped in the code, PCRAMMET writes one message in PCRAM.LOG that identifies the source of the error. The following message is displayed on the screen, and PCRAMMET stops processing:

******* FATAL ERROR *****
PROGRAM TERMINATED
See the Output File PCRAM.LOG for Details**

The message should provide sufficient information for the user to identify and correct the problem and restart PCRAMMET. Examples of fatal errors are: 1) a file not found; and 2) incorrect specification of a file format (e.g., indicating the surface data are CD144 when the file is the SAMSON format). A listing of error messages is located in Section 6.2.

PCRAMMET may terminate as a result of an error not trapped in the code. An example of this type of error occurs if the second year of data in a SAMSON file is encountered where an integer value is expected but the tilde of a header record is encountered. A generic error message is displayed on screen and no message is written to the log file.

Whether PCRAMMET successfully or unsuccessfully completes processing the data, the user should review PCRAM.LOG to insure the data were processed correctly and as expected.

3.2 BATCH MODE

PCRAMMET records the users responses during the interactive session in an annotated file named INPUTS. This file is referred to as a response file. The only response that is not written to this file is the output filename. If the user expects to rerun PCRAMMET with these or similar responses, then the user should save INPUTS by copying or renaming the response file. If the file is not saved in some manner, then the next run of PCRAMMET overwrites the file without any opportunity to save or rename the file.

PCRAMMET can use this file, or a modified version of it, as one of the command line arguments to run the preprocessor in batch mode. In addition to the program name, the user supplies two filenames on the command line: the file with the responses to the prompts that the program would display during an interactive

session (*response_file*) and the file to which the output is written (*output_file*). To start PCRAMMET in this manner, type:

```
PCRAMMET  response_file  output_file
```

followed by pressing ENTER. If the user only supplies one filename or more than two, then the following message appears on the screen and PCRAMMET stops:

```
COMMAND ERROR: PCRAMMET [input_control output_for_model]
                    _____ optional _____
```

If the command line doesn't have an error, PCRAMMET processes the records in the response file as if they were entered interactively, and assuming no errors are encountered, processes the meteorological data. The current year/month/day are displayed as each day is processed. On successful completion of the processing, PCRAMMET displays the following message:

See the file PCRAM.LOG for a review of this run

If any warning messages were issued, the following message will also appear, indicating that nonfatal messages generated by PCRAMMET are located in the log file:

***** Warning messages were generated by PCRAMMET and are in PCRAM.LOG**

Any errors in the response file will prevent PCRAMMET from processing the remainder of the response file as well as the input meteorological data. PCRAMMET displays the following message and stops:

```
***** FATAL ERROR *****
PROGRAM TERMINATED
See the Output File PCRAM.LOG for Details
```

Whether PCRAMMET successfully or unsuccessfully completes processing the data, the user should review PCRAM.LOG to insure the data were processed correctly and as expected.

SECTION 4

TECHNICAL DISCUSSION

In this section the technical issues regarding the data processing are discussed. These issues include data manipulation (e.g., converting data to the correct units) and simple quality assurance procedures, methods for computing the hourly mixing heights and atmospheric stability, converting the ASOS cloud layer data to cloud cover and ceiling, and the theoretical basis for estimating the deposition parameters.

4.1 TIME OF DAY

When reading the CD-144 format, PCRAMMET skips the first hourly record of data in the year because the 24-hour period for the regulatory models starts with the 1-hour period ending 0100 LST and the observations in CD-144 files begin with the observation reported at 0000 LST (equivalent to 2400 LST of the previous day). Sequential reading of the remaining data automatically makes this adjustment for each succeeding day. Meteorological data for the last hour in the year are assumed equal to that for the next to the last hour because the data for a day always ends with hour 23. Data on the SAMSON and HUSWO CDs begin with hour 1 and end with hour 24, eliminating the need to skip a record. However, the last hour of the year may contain missing data and are processed similarly to the CD-144 formatted data.

4.2 HOURLY VALUES OF MIXING HEIGHT

The processing of hourly mixing heights requires: 1) morning and afternoon estimates of mixing heights; 2) the local standard time of sunrise and sunset; and 3) hourly estimates of stability. Morning and afternoon mixing height estimates are based on the method described by Holzworth (1972). Two interpolation schemes are used to estimate hourly mixing heights, one for rural sites and the other for urban sites. Both estimates are included in the PCRAMMET output file. The time of sunrise and sunset are calculated within PCRAMMET based on the date, latitude, longitude, and time zone, using known earth-sun relationships (e.g., Sellers (1965)). The values for latitude, longitude, and time zone for a particular station are required input to PCRAMMET when using the CD-144 formatted data. SAMSON data contain this information in the first record of the file, making it unnecessary to enter this information. Estimates of hourly stability class are based on Turner's (1964) method using time of day, surface wind speed, and observations of cloud cover and ceiling.

To calculate an hourly mixing height, the procedure uses the maximum mixing height (MAX) from the previous day ($i-1$), the computation day (i) and the following day ($i+1$) and the minimum mixing height (MIN) for days (i) and ($i+1$). For urban sites between midnight and sunrise, under neutral stability (i.e., Class D), the interpolation is between MAX_{i-1} at sunset on the previous day, and MAX_i at 1400 LST on the current day. For stable conditions (i.e., Class E or F), the value for the minimum mixing height (MIN) is used. Between sunrise and 1400 LST, if the stability was classified as neutral in the hour before sunrise, the earlier interpolation between MAX_{i-1} and MAX_i is continued; if the hour before sunrise was classified as stable, the interpolation is between MIN_i and MAX_i . For the period 1400 LST to sunset, the value for MAX_i is used. During the hours

between sunset and midnight under neutral stability, the interpolation is between MAX_i at sunset and MAX_{i+1} at 1400 LST the next day; if the stability is stable, the interpolation is between MAX_i at sunset and MIN_{i+1} at midnight.

For rural sites between midnight and sunrise, the interpolation is between MAX_{i-1} at sunset on the previous day and MAX_i at 1400 LST on the current day. During the hours between sunrise and 1400 LST, if stability was classified as neutral in the hour before sunrise, the earlier interpolation between MAX_{i-1} and MAX_i is continued; if the hour before sunrise was classified as stable, the interpolation is between 0 and MAX_i . For the period 1400 LST to sunset, the value for MAX_i is used. During sunset to midnight, the interpolation is between MAX_i at sunset and MAX_{i+1} at 1400 LST the next day.

4.3 PASQUILL-GIFFORD STABILITY CLASSES

PCRAMMET recognizes seven stability classes. The first six categories correspond to Pasquill's (1974) classifications (A-F). The seventh category corresponds to the 'dashes' in the original classification by Pasquill and indicates a strong, ground-based nocturnal temperature inversion with non-definable wind flow conditions. Standard EPA practice in regulatory dispersion modeling is to restrict temporal changes in stability class to no more than one per hour. The stability smoothing in PCRAMMET implements this procedure.

In the urban mode, stability categories 5, 6, and 7 (E, F, and G) are treated as category 4 (i.e., D or neutral). Also, it should be noted that most regulatory models treat rural stability class G (7) as F (6). For daytime cases, the appropriate insolation class is selected by means of the Turner (1964) objective method using cloud cover, ceiling height, and solar elevation as indicators. This method assigns net radiation

indices, using the criteria shown in Table 4-1, for cases where the total cloud cover is less than or equal to 5/10. If the cloud cover is greater than 5/10, but less than 10/10 (overcast), the insolation class is reduced by one category when the ceiling height is between 7000 and 16000 feet and by two categories for ceilings less than 7000 feet. For a cloud cover of 10/10 (i.e., overcast), the insolation class is reduced by one category when the ceiling height is greater than 16000 feet and by two categories for ceilings between 7000 and 16000 feet. For ceilings below 7000 feet and 10/10 cloud cover, a net radiation of 0 is defined and neutral stability is specified. With the exception of the 10/10 low cloud cases, the net radiation index is never reduced below 1, or 'weak.' The final stability classification criteria is selected from Table 4-2 and Turner's insolation classes from Table 4-1.

TABLE 4-1
Insolation Classes as a Function of Solar
Altitude for Cloud Cover $\leq 5/10$ *

Solar elevation angle (a)	Insolation class	Net Radiation Index
$0^\circ < a \leq 15^\circ$	Weak	1
$15^\circ < a \leq 35^\circ$	Slight	2
$35^\circ < a \leq 60^\circ$	Moderate	3
$60^\circ < a$	Strong	4

*For $>5/10$ cloud cover, see text

TABLE 4-2
Stability Classification Criteria

Surface Wind Speed (knots)	Daytime Insolation					Nighttime	
	Strong	Moderate	Slight	Weak	Overcast	≥5/10 Cloud	< 5/10 Cloud
≤ 1	1	1	2	3	4	6	7
2	1	2	2	3	4	6	7
3	1	2	2	3	4	6	7
4	1	2	3	4	4	5	6
5	1	2	3	4	4	5	6
6	2	2	3	4	4	5	6
7	2	2	3	4	4	4	5
8	2	3	3	4	4	4	5
9	2	3	3	4	4	4	5
10	3	3	4	4	4	4	5
11	3	3	4	4	4	4	4
≥12	3	4	4	4	4	4	4

4.4 WINDS

Hourly wind direction data input to PCRAMMET are tested for calms (coded as 0° by the NWS; note that a north wind is coded as 360°), and if present, the wind direction from the previous hour is substituted. PCRAMMET converts all wind directions to flow vectors (in the range of $0-360^\circ$) by adding or subtracting 180° . These flow vectors are then randomized by adding a random integer number of azimuth degrees between -4° and $+5^\circ$. This procedure is applied to remove the directional bias introduced into the NWS data because they are reported to only the nearest 10° . The randomization gives the flow vector an equal probability of occurring anywhere within the 10° sector and so incorporates the natural fluctuations of this parameter. A standard set of 8784 random numbers is used.

Hourly wind speed data in the CD-144 format are converted from the NWS reporting units of knots to meters per seconds (ms^{-1}). Wind speeds in the SAMSON data are already in meters per second (to the nearest $1/10 \text{ ms}^{-1}$), but are converted back to knots then to meters per second to insure that the results in the output files from the two input data formats are identical. As discussed in Section 2.1.2.3, PCRAMMET assumes the HUSWO data were retrieved in English units. Therefore, wind speeds in HUSWO are converted from miles per hour to ms^{-1} . Wind speeds below 1.0 ms^{-1} (calms included) are set to 1.0 ms^{-1} before computations are made in PCRAMMET.

4.5 TEMPERATURE

For the CD-144, SCRAM, and HUSWO data, hourly ambient temperature data are converted from the reporting units of degrees Fahrenheit ($^\circ\text{F}$) to Kelvin (K). For SAMSON data, the reporting units are degrees Celsius ($^\circ\text{C}$) and are converted to Kelvin.

4.6 QUALITY ASSURANCE

Data may be missing from any of the sources for certain hours, days, or even months. PCRAMMET performs a limited check on the data, depending on the source and type.

Quality assurance of the CD-144 surface data file beginning with the year, month, day and hour are checked for consistency and completeness. If one or more hourly records are missing, or are out of order, then the program terminates after printing appropriate error messages. PCRAMMET does not verify the station identification number.

For the CD-144 format, blanks in the data fields indicate missing data. In PCRAMMET, the data are read as character strings and then checked for blanks. If a blank is encountered, then a message is written to the log file indicating which variable is missing and the date and time it is missing. A missing data code is entered for that variable for that hour.

Next, the year, month, and day of the hourly surface observations are compared to the corresponding date from the mixing height file. If these two files are not synchronized, then PCRAMMET stops after writing an error message (with the month and day of the mismatch) to the log file. PCRAMMET reads 24-hour blocks of data and performs only one check on the month and day.

Hourly surface observations obtained from the SCRAM web site are in a compressed format, i.e., only selected variables are reported and the record length is shortened. The SCRAM data can be used directly in PCRAMMET or it can be expanded using a program such as MET144, which is provided on the SCRAM web site. The MET144 program provides an option to expand the SCRAM format to the CD-144 format. The program also provides an option to

list all the missing data, with the date and time of occurrence, that appear in the SCRAM formatted surface data file.

Prior to processing the SAMSON and HUSWO data, PCRAMMET checks to verify that the necessary meteorological variables were retrieved from the CD for the intended modeling option (no/dry/wet deposition). If there are insufficient data, a message is written to the log file and PCRAMMET stops. If the necessary meteorological variables are present, the SAMSON and HUSWO data are checked for missing data as each record is processed. If a missing value is encountered, a message is written to the log file indicating which variable and the date and time of occurrence.

There are no data quality checks on the mixing height data. If a data field is blank, then the preprocessor assumes a value of zero for the field. It is the user's responsibility to ensure that the information in this file is complete and properly ordered.

The structure and contents of the precipitation file do not allow for the data to be checked for missing records - only hours during which precipitation occurred are reported. A date and time are passed to the routine that retrieves the hourly precipitation. This date and time are either the values from the CD-144, SAMSON, or HUSWO data file. One quality check that is performed is to ensure that special groupings of data are terminated properly (special flags identify these groupings). Another check on the data identifies when both liquid and solid forms of precipitation are reported for an hour. A message indicating such an occurrence is written to the log file, and the code used in the data processing corresponds to liquid precipitation.

4.7 ASOS CLOUD LAYERS

As stated in Section 2, ASOS-derived cloud information now appears on the HUSWO CD. These fields are filled with missing data indicators (99999) up until the time ASOS went online for individual stations. Up to three cloud layers, with sky condition and layer height, are reported each hour. This cloud information must be converted to a corresponding fractional cloud cover before being used in PCRAMMET. The following conversion is used in PCRAMMET:

<u>ASOS value</u>	<u>interpretation</u>	<u>converted to</u>
00	clear or less than 0.1 coverage	0/10
02	scattered 0.1 to 0.5 coverage	3/10
04	broken 0.6 to 0.9 coverage	7/10
06	overcast 1.0 coverage	10/10
07	obstruction 1.0 coverage	10/10
09	unknown	99 (unknown)

Since there may be up to three layers, the cloud layer with the greatest coverage is taken as the cloud cover for that hour. For example, if two layers are reported with a cloud value of 02 for the lower layer and 04 for the upper layer, then the cloud cover for that hour is taken as 7/10. As a second example, for two layers reporting 02 for both layers, the cloud cover for that hour is taken as 3/10.

Ceiling height also must be derived from the ASOS reports, although from the initial examination of the HUSWO CD, this derivation may have already been performed, i.e., there is a nonmissing height in the ceiling height field. For an ASOS report, PCRAMMET examines the ceiling height field and if the value is not the missing data indicator, then it uses the value. Otherwise, the ceiling height is determined as the lowest cloud layer for which the coverage is broken or overcast (values 04 and greater which is cloud cover 6/10 and greater). Scattered cloud layers do not have an associated ceiling height, i.e., the

ceiling is considered unlimited. Continuing with the first example above, since the lower layer value is 02 and represents scattered clouds and the upper layer value is 04 and represents broken clouds, the height of the cloud layer associated with the broken layer is defined as the ceiling height. In the second example, since both layers report a cloud value of 02, then the ceiling is unlimited since both layers are scattered clouds. If all layers (whether it is one, two, or three layers) report scattered clouds, the ceiling is still unlimited.

The procedures outlined here are consistent with the interpretations used by the National Weather Service and the National Climatic Data Center.

4.8 DEPOSITION PARAMETER ESTIMATES

Additional meteorological parameters are required to make estimates of dry and/or wet deposition in ISCST3. The computation of the friction velocity and Monin-Obukhov length in PCRAMMET is presented in this section. Stull (1988) provides a good introduction to the theoretical basis for estimating these parameters.

The day is divided into two regimes: stable and unstable. The atmosphere is considered stable if the time of day is between sunset and sunrise (of the next day) and the transfer of heat is toward the earth's surface. The atmosphere is unstable if the time of day is between sunrise and sunset and the transfer of heat is away from the surface. The parameters of interest in the deposition process are surface roughness length (z_0), the surface friction velocity (u_*) and the Monin-Obukhov length (L).

The surface roughness length has been discussed in previous sections. The surface friction velocity is a characteristic velocity based on (wind) shear stresses at the earth's surface.

The Monin-Obukhov length is a stability parameter that relates this velocity to the transport of heat. In the next two sections, the estimates of these values are discussed for the site where the preprocessor input data were measured. In the final section, these results then are used to estimate the parameters at the site where the output from PCRAMMET are to be applied.

4.8.1 Unstable Atmosphere

During daytime convective conditions ($L < 0$), the surface of the earth is heated, resulting in an upward transfer of heat. Hourly estimates of this heat flux are required to estimate u_* and L . The estimates for the heat flux here follow the development of Holtslag and van Ulden (1983). The heat flux is estimated from cloud cover, surface temperature, Bowen ratio and albedo, as described below.

Once the heat flux is computed, u_* and L are determined through an iterative procedure using surface layer similarity. While u_* and L change with each iteration, the hourly heat flux remains fixed.

A simple equation that expresses the energy balance at the earth's surface is:

$$R_N + Q_f = H + \lambda E + G \quad (4.1)$$

where R_N is the net radiation, Q_f is the anthropogenic heat flux, H is the sensible heat flux, λE is the latent heat flux, and G is the flux of heat into the ground. Each term is expressed as watts per square meter (W m^{-2}). The value of G is assumed to be proportional to the left side of Eq. 4-1, i.e., $G = c_g (R_N + Q_f)$, where c_g is the fraction of the net radiation absorbed at the ground, and is specified by the user. Using this estimate for G

and the definition of the Bowen ratio, $B_o = H / \lambda E$, which was specified by the user, the following expression for the sensible heat flux, H , is obtained

$$H = \frac{(1.0 - c_g) R_N^*}{1 + \frac{1}{B_o}} \quad (4.2)$$

where $R_N^* = R_N + Q_f$.

The net radiation, R_N , is estimated from total incoming solar radiation, R , as

$$R_N = (1 - r) R - I_N \quad (4.3)$$

where r is the user-specified surface albedo (dimensionless), and I_N is the net long-wave radiation at the earth's surface as given by Holtslag and van Ulden (1983). The anthropogenic heat flux, Q_f , specified by the user is then added to the net radiation to obtain R_N^* .

In the general case in which clouds are present, R is computed using the following formula proposed by Kasten and Czeplak (1980)

$$R = R_0 (1 + b_1 N^{b_2}) \quad (4.4)$$

where R_0 (W m^{-2}) is the incoming solar radiation at ground level for clear skies, and N is the fractional opaque cloud cover. The empirical coefficients b_1 and b_2 are assigned the values of -0.75 and 3.4, respectively. If cloud cover is missing for a particular hour, then PCRAMMET assumes complete overcast (i.e., 10/10 cloud cover) and proceeds with the calculations. A warning message is written to the log file to indicate such an occurrence.

The incoming solar radiation for clear skies R_0 is given by

$$R_0 = a_1 \sin \phi + a_2 \quad (4.5)$$

where ϕ is the elevation of the sun above the horizon (degrees), $a_1 = 990 \text{ W m}^{-2}$ and $a_2 = -30 \text{ W m}^{-2}$. The constants a_1 and a_2 account for attenuation of the short wave radiation by water vapor and dust in the atmosphere. The values used in PCRAMMET are appropriate for mid-latitudes (Holtslag and van Ulden, 1983).

Substituting Eqs. 4.4 and 4.5 into Eq. 4.3 and parameterizing the net long-wave radiation as a function of temperature and cloud cover, Holtslag and van Ulden (1983) estimate the net radiation as

$$R_N = \frac{(1 - r)R + c_1 T^6 - \sigma_{SB} T^4 + c_2 N}{1 + c_3} \quad (4.6)$$

where $\sigma_{SB} = 5.67 \times 10^{-8} \text{ W m}^{-2} \text{ K}^{-4}$ is the Stefan-Boltzmann constant, and the other empirical constants are as follows:

$$\begin{aligned} c_1 &= 5.31 \times 10^{-13} \text{ W m}^{-2} \text{ K}^{-6}, \\ c_2 &= 60 \text{ W m}^{-2}, \\ c_3 &= 0.12. \end{aligned}$$

An empirical expression for the albedo as a function of solar elevation angle is given by

$$r = r' + (1 - r') e^{av + b} \quad (4.7)$$

where r' is the surface albedo (dimensionless) for the sun on the meridian specified by the user, v is the solar elevation angle in degrees, $a = -0.1$, and $b = -0.5 (1 - r')^2$.

PCRAMMET next computes the surface friction velocity u_* and the Monin-Obukhov length L for the unstable atmosphere through an iterative procedure. (This technique is similar to that used in the METPRO processor (Paine, 1987). The two equations for u_* and L used in the iteration algorithm are:

$$u_* = \frac{k U}{\ln\left(\frac{z_{ref}}{z_o}\right) - \Psi + \Psi_o} \quad (4.8)$$

and

$$L = - \frac{\rho c_p T u_*^3}{k g H} \quad (4.9)$$

where

H is the sensible heat flux at the surface (W m^{-2}),

k is the von Karman constant,

U is the wind speed (m s^{-1}),

z_{ref} is the anemometer height (m),

z_o is the surface roughness at the measurement site (m)
specified by the user,

ρ is the density of dry air (kg m^{-3}),

c_p is the specific heat capacity of air ($1004 \text{ J kg}^{-1} \text{ deg}^{-1}$),

T is temperature (K), and

g is the acceleration due to gravity (9.81 m s^{-2}).

The values for Ψ and Ψ_o (Lumley and Panofsky, 1964 and Businger, 1973) are:

$$\Psi = 2 \ln\left(\frac{1+\mu}{2}\right) + \ln\left(\frac{1+\mu^2}{2}\right) - 2 \tan^{-1}(\mu) + \pi/2 \quad (4.10)$$

$$\Psi_o = 2 \ln\left(\frac{1+\mu_o}{2}\right) + \ln\left(\frac{1+\mu_o^2}{2}\right) - 2 \tan^{-1}(\mu_o) + \pi/2 \quad (4.11)$$

where

$$\mu = (1 - 16 z_{ref} / L)^{1/4} \quad (4.12)$$

$$\mu_o = (1 - 16 z_o / L)^{1/4} \quad (4.13)$$

This procedure requires an initial guess for u_* , which is found by initially setting Ψ and Ψ_o to zero. The iteration continues until consecutive values of L differ by 1% or less.

4.8.2 Stable Atmosphere

The calculations of u_* and L for the stable atmosphere ($L > 0$) are based on an approach outlined by Venkatram (1980). The approach does not require an iterative procedure as used for the unstable atmosphere. Estimates of u_* and θ_* (a temperature scale) are made from cloud cover, wind speed and temperature. This, in turn, provides an estimate of the heat flux, and L is computed directly from Eq. 4.9.

The method begins with the following estimate for θ_* :

$$\theta_* = 0.09 (1 - 0.5N^2) \quad (4.14)$$

where N is the fraction of opaque cloud cover. The neutral drag coefficient, C_D (dimensionless), is calculated as

$$C_D = \frac{k}{\ln(z_{ref} / z_o)} \quad (4.15)$$

The friction velocity is determined from

$$u_* = C_D U / 2 \left(1 + \left(1 - \left(2u_o / (C_D U) \right)^2 \right) \right) \quad (4.16)$$

where

$$u_o = \sqrt{\frac{\beta_m z_{ref} g \theta_*}{T}} \quad (4.17)$$

and $\beta_m = 4.7$ is a dimensionless constant.

To obtain real-valued solutions for u_* , the following must hold

$$\frac{4 u_o^2}{C_D U^2} \leq 1 . \quad (4.18)$$

If this condition holds, then u_* is computed from Eq. 4.16; if this condition does not hold (under very stable conditions), then the solution to the quadratic equation is imaginary, and a slightly different approach is taken.

Equality in the above condition corresponds to a minimum wind speed, U_{cr} , at which (and above) a real-valued solution to Eq. 4.16 is

$$U_{cr} = \sqrt{\frac{4 \beta_m z_{ref} g \theta_*}{T C_D}} . \quad (4.19)$$

For this value, there is a corresponding friction velocity, u_{*cr} , such that

$$u_{*cr} = \frac{C_D U_{cr}}{2} . \quad (4.20)$$

For wind speeds less than this critical value, Eq. 4.16 no longer yields a real-valued solution, and it is desirable to have $u_* \rightarrow 0$ as $U \rightarrow 0$. Therefore, for $U < U_{cr}$, u_{*cr} is scaled by the ratio U / U_{cr} , and u_* is calculated as

$$u_* = u_{*cr} \frac{U}{U_{cr}} \quad (4.21)$$

For $U < U_{cr}$, van Ulden and Holtslag (1985) showed that there is a nearly linear variation of θ_* with u_* . Therefore, θ_* is similarly scaled as

$$\theta_* = \theta_{*cr} \frac{u_*}{u_{*cr}} \quad (4.22)$$

With the u_* from Eq. 4.16 or 4.21 and the θ_* from Eq. 4.14 or 4.22, the heat flux H is computed as

$$H = -\rho c_p u_* \theta_* \quad (4.23)$$

Finally, using these estimates of u_* and H , L is computed from Eq. 4.9.

In the case of strong winds, H may become unrealistically large. Therefore, a limit of -64 W m^{-2} is placed on the heat flux, which forces a limit on the product $u_*\theta_*$. This yields a cubic equation in u_* , which is solved to obtain a new u_* . With this new value for u_* and $H = -64 \text{ W m}^{-2}$, L is recomputed from Eqs. 4.9 and 4.23 as:

$$L = T u_* / (k g \theta_*).$$

If the value of the Monin-Obukhov length is less than the minimum value specified by the user, then L is reset to this minimum value and a new value for u_* is computed.

4.8.3 Parameters at the Application Site

The discussion above focused on the estimates at the measurement site. Typically, the measurement site is not the location where the output meteorological data from PCRAMMET are to be applied. Dry deposition estimates are sensitive to the value of the friction velocity, therefore, the friction velocity and Monin-Obukhov length estimated for the measurement site are adjusted to represent the site where the output are to be

applied. With the surface roughness length entered by the user for the application site and the estimates of u_* and L at the measurement site, u_* and L representative of the application site are estimated and written to the output file.

Walcek et al. (1986) suggest that near the surface

$$u_1 u_{*1} \approx u_2 u_{*2}$$

for changes in the underlying surface roughness, where the subscripts 1 and 2 represent the previous and current estimates. PCRAMMET incorporates this approach to estimate u_* and L at the application site.

With the roughness length representative of surface conditions at the application site, a new estimate for u_* is obtained through an iterative process using surface layer similarity. The Monin-Obukhov length is obtained from

$$L_2 = L_1 (u_{*2}/u_{*1})^3$$

(on the first iteration, the subscript 1 represents the value at the measurement site). When two consecutive estimates of u_* are within 1%, then the process stops.

SECTION 5

PCRAMMET PROGRAM NOTES

PCRAMMET is suited for operation on a PC. The input files are of reasonable size and the programs involved execute in a moderate amount of time. In this section, a description of the files and steps required to compile and link PCRAMMET is presented. The section concludes with steps to retrieve the program and hourly surface weather observations and twice-daily mixing heights from the SCRAM web site.

5.1 COMPILING AND LINKING PCRAMMET

There are five source code files associated with PCRAMMET:

PCRAMMET.FOR	main program - setup, initialization and input/output handling;
PCRLIB.FOR	routines that are used by several of the subprograms;
PCRDATA.FOR	routines to process the raw input data;
PCRPARAM.FOR	routines to compute the boundary layer and deposition parameters;
PCRAM.INC	variable declarations and common blocks that are used in the routines in the files above.

The executable provided on the SCRAM web site was created using the Lahey Fortran 90 Compiler, Release 4.5i. A math coprocessor is mandatory for use of a Lahey-compiled executable. If the source code is modified, the following commands can be used to compile and link the source code with the Lahey compiler:

```

d:\subdir\lf90  pcrammet.for -c -nchk -tp -trace -nco -nvm -nwin
d:\subdir\lf90  pcrlib.for   -c -nchk -tp -trace -nco -nvm -nwin
d:\subdir\lf90  pcrdata.for  -c -nchk -tp -trace -nco -nvm -nwin
d:\subdir\lf90  pcrparam.for -c -nchk -tp -trace -nco -nvm -nwin

```

where `d:\subdir\` refers to the drive and directory where the Lahey compiler and linker reside if the directory is not in your path. The switches after the filename provide the following control:

```

-c          suppress linking;
-nchk       do not check array subscripts and character
            substring bounds;
-tp         generate code optimized for the Pentium processor;
-trace      enable runtime error traceback;
-nco        compiler options are not displayed when a file is
            compiled;
-nvm        do not bind the virtual memory manager;
-nwin       do not create this program as a Windows
            application.

```

To create the executable, the following command is used:

```

d:\subdir\lf90 pcrammet.obj pcrlib.obj pcrdata.obj
               pcrparam.obj -bind -pack

```

The switches after the filenames have the following effect:

```

-bind       binds the DOS-Extender to the executable,
-pack       performs data compression on the executable file.

```

The next, and final, step is optional and simply disables the 386|DOS-Extender banner that is shown whenever the executable program is run:

```

CONFIG386 PCRAMMET.EXE -nosignon.

```

The resulting executable code size is about 707 Kb.

5.2 PCRAMMET AND SCRAM

The following steps for retrieving the program and data from the SCRAM web site (www.epa.gov/scram001/), some of which may have already been performed by the user, are all that are needed for minimal implementation of PCRAMMET:

- 1) Many of the programs and data files on SCRAM are available only in a compressed format, which includes the PCRAMMET source and executable codes, the hourly surface data, and twice-daily mixing heights. These files must be decompressed with PKUNZIP (version 2.04g or later) or other program that recognizes this format. The PKUNZIP software can be obtained from SCRAM by clicking on *Free Utility Software* and then on the PKWARE, Inc., link.
- 2) Download the file(s) containing the PCRAMMET code and dearchive the file(s) by entering <PKUNZIP program_filename> at the DOS prompt. The files with the .FOR extension contain the source code for the programs and the ones with the .EXE extension are the executable modules for the same. The .RME file is a file containing a very brief synopsis of what is contained in this User's Guide.
- 3) To download the hourly surface data file, click on Met Data in the left panel. Additional choices are presented; select Surface Data. A list of States and stations in each state is displayed in the right panel. Scroll down in the right panel and select the station data to download. Note that all years (usually 1984-1992) for each station are in a single file. The file names are of the form *ssnnnnnn*.ZIP where *ss* is the 2-character state code (e.g., AL = Alabama) and *nnnnnn* is the station WBAN number. Unzip the station data by typing <PKUNZIP *ssnnnnnn*> at a DOS prompt. This produces several files of the form *Snnnnnnyy*.ZIP where *nnnnnn* is the station WBAN number and *yy* is the 2-digit year. Unzip the file(s) that you intend to process. This will

produce two files: *Snnnnnyy.DAT* and *Snnnnnyy.TXT*. The *Snnnnnyy.TXT* file contains a 'before and after' listing of the missing meteorological parameters that were filled in by EPA before the files were placed on the SCRAM web site. The *Snnnnnyy.DAT* file contains the surface meteorological data in a 28 byte format used by the SCRAM web site to conserve disk space. Optionally, this file may be converted to the NWS CD-144 format by executing the MET144 program, which is available from the SCRAM web site under Met Data/Related Programs. This is accomplished by entering <MET144 *Snnnnnyy.DAT Snnnnnyy.EXP*> and selecting the expansion option (1) when the program begins execution. The *Snnnnnyy.EXP* file will contain the surface data in CD144 format and is now ready for input into PCRAMMET. A note on the MET144 program - the edit option (0) will function properly only on the SCRAM 28-byte record format file. To determine if there are any incomplete files, check under MET DATA for the Special Note entitled 'MISSING METEOROLOGICAL DATA REPORT.'

Data for all NWS surface stations were considered by EPA for placement on SCRAM; however, the data for many of the sites were incomplete. Reasons for not placing the data on the SCRAM web site included less than 24 observations per day or several months of missing data. If an alternate station is selected for model analysis, that station should be representative of the site.

- 4) Download the twice daily mixing height data file. Click on Met Data in the left panel. Additional choices are presented; select Mixing Height Data. Scroll down until the list of States is shown in the right panel. This will present a list of States for which there are data available. All stations and years for a single state are contained in a single file for each state. Click on the state to download

the file containing mixing height data for the State. The naming convention for this file is *ssMIX.ZIP*, where *ss* is the 2-character state id (e.g., AZ = Arizona). Unzip the mixing height data by typing *PKUNZIP ssMIX* at a DOS prompt or using Windows software that can perform this operation. Unzipping produces files with the following naming convention: *nnnnn-yy.TXT* where *nnnnn* is the station WBAN number and *yy* is the 2-digit year. The resulting file is ready for PCRAMMET, although the user should examine the file to insure that there are two mixing heights for each day of the year. If any mixing heights are missing, PCRAMMET will interpret these as zero and produce incorrect hourly mixing heights. Guidance for filling in missing mixing heights can be found on the SCRAM web site under Met Data/Related Programs/MISSDATA.

SECTION 6

ERROR AND WARNING MESSAGES

There are several conditions under which PCRAMMET may write warning and error messages. Warning messages are written to the log file (PCRAM.LOG) and PCRAMMET continues processing the data. Error conditions are fatal and a single error message is written to the log file and PCRAMMET stops processing the data. In the next two sections, the warning and error messages generated by PCRAMMET, with a brief explanation of each, is presented.

6.1 WARNING MESSAGES

In the messages below, text in italics indicates that a value (for example, the date) will appear in the actual message rather than the italicized text.

ATTENTION: ASOS-derived observations begin on (yy/mm/dd/hh):
date/hour

If ASOS-derived hourly surface observations are used, then this message appears when the ASOS data are first encountered. This message should appear only if HUSWO data are used.

Rural Mixing Height < 10 m (x.x) for (yy/mm/dd/hh) *date/hour*
Indicates that an estimate of the rural mixing height was less than 10 meters. The estimated height and the date of occurrence are reported.

Urban Mixing Height < 10 m (x.x) for (yy/mm/dd/hh) *date/hour*
Indicates that an estimate of the urban mixing height was less than 10 meters. The estimated height and the date of occurrence are reported.

Warning -- more than one type of precipitation reported on
(YYDDHH):(date/hour)
format TYPE = nnnnnnnn PRECIP. CODE USED = x

If more than one type of precipitation is reported, then PCRAMMET informs the user of the date (as year and Julian day) and hour when the multiple precipitation types occurred, the surface data file format (CD144, SCRAM or SAMSON), the precipitation code, and the code that was written to the output file. The code for liquid precipitation is written to the output file.

CCCODE: The character " " is not allowable. Cloud cover defaults to 10.

Indicates a blank in the cloud cover field. Occurs many times when the 28-byte record surface file is used instead of the 80-byte record file. MET144 must be used to expand the 28-byte record file to 80-bytes.

FILMET: TD-3240 precip substituted for SAMSON on (yy/mm/dd/hh):
date/hour

If the precipitation was missing in the data file retrieved from the SAMSON CD and the user responded that the SAMSON data are to be supplemented with TD-3240 data, then PCRAMMET writes this message to the log file for the data and time shown.

The following messages appear if the variable referenced is missing for the date and time displayed in the message. FILCD4 refers to CD-144 format data (and the subroutine that generated the message) and FILSAM refers to data retrieved from the SAMSON CD (and the subroutine that generated the message).

FILCD4: Wind direction missing for (yy/mm/dd/hh) *date/hour*
FILCD4: Wind speed missing for (yy/mm/dd/hh) *date/hour*
FILCD4: Station pressure missing for (yy/mm/dd/hh) *date/hour*,
using 1000 mb (Note: this message is seen only if the run is
for DRY or WET deposition)
FILCD4: Temperature missing for (yy/mm/dd/hh) *date/hour*
FILSAM: Wind direction missing for (yy/mm/dd/hh) *date/hour*
FILSAM: Wind speed missing for (yy/mm/dd/hh) *date/hour*
FILSAM: Station pressure missing for (yy/mm/dd/hh) *date/hour*,
using 1000 mb
FILSAM: Temperature missing for (yy/mm/dd/hh) *date/hour*
FILSAM: Cloud cover missing for (yy/mm/dd/hh) *date/hour*
FILSAM: Ceiling height missing for (yy/mm/dd/hh) *date/hour*
FILSAM: Precipitation missing for (yy/mm/dd/hh) *date/hour*
FILSAM: Dry/Wet dep: SAMSON rel. humidity missing for
(yy/mm/dd/hh) *date/hour*
FILSAM: Dry/Wet dep: SAMSON global rad'n missing for
(yy/mm/dd/hh) *date/hour*
FILHUS: Wind direction missing for (yy/mm/dd/hh) *date/hour*
FILHUS: Wind speed missing for (yy/mm/dd/hh) *date/hour*
FILHUS: Station pressure missing for (yy/mm/dd/hh) *date/hour*,
using 1000 mb
FILHUS: Temperature missing for (yy/mm/dd/hh) *date/hour*
FILHUS: Cloud cover missing for (yy/mm/dd/hh) *date/hour*
FILHUS: Ceiling height missing for (yy/mm/dd/hh) *date/hour*
FILHUS: Precipitation missing for (yy/mm/dd/hh) *date/hour*
FILHUS: ASOS cloud data missing for (yy/mm/dd/hh) *date/hour*
FILHUS: Dry/Wet dep: HUSWO rel. humidity missing for
(yy/mm/dd/hh) *date/hour*

FILHUS: Dry/Wet dep: HUSWO global rad'n missing for
(yy/mm/dd/hh) *date/hour*

6.2 ERROR MESSAGES

There are about 50 error messages that could originate from PCRAMMET. PCRAMMET stops processing data if any of the following conditions occurs. The messages are:

ERROR OPENING THE INPUT FILE

An input file could not be opened.

ERROR OPENING FILE FOR SCREEN INPUT RESPONSES

The file that will be used to capture the user responses during an interactive prompt/response run could not be opened.

ERROR READING THE INPUT FILE: DEPOSITION TYPE

A runtime error was encountered while reading deposition type from the response file.

INCORRECT DEPOSITION TYPE SPECIFIED:

An error was encountered while reading the response file: the deposition type - NONE, DRY or WET - was not correctly specified.

ERROR READING THE INPUT FILE: OUTPUT FILE TYPE

An error was encountered while reading the response file: the output file type (ASCII or UNIFORM), was not specified properly.

ERROR READING THE INPUT FILE: SURFACE FILE NAME

An error was encountered while reading the response file: the input hourly surface observation filename was not specified properly.

ERROR READING THE INPUT FILE: SURFACE FILE TYPE

An error was encountered while reading the response file:
the file format type (CD144 or SAMSON), was not specified
properly.

ERROR READING THE INPUT FILE: MIXING HEIGHT FILE NAME

An error was encountered while reading the response file:
the input mixing height filename was not specified properly.

ERROR READING THE INPUT FILE: PRECIPITATION YES|NO

An error was encountered while reading the response file:
the response as to the use of precipitation data was
invalid.

ERROR READING THE INPUT FILE: PRECIP FILE NAME

An error was encountered while reading the response file:
the input hourly precipitation data filename was not
specified properly.

ERROR READING THE INPUT FILE: PRECIP FILE TYPE

An error was encountered while reading the response file:
the precipitation file type (FIXED or VARIABLE) was not
specified properly.

ERROR READING THE INPUT FILE: SITE LATITUDE

An error was encountered while reading the response file:
the station latitude was improperly specified - this message
is seen only if the surface observations are CD144 or SCRAM
format.

ERROR READING THE INPUT FILE: SITE LONGITUDE

An error was encountered while reading the response file:
the station longitude was improperly specified - this
message is seen only if the surface observations are CD144
or SCRAM format.

ERROR READING TIME ZONE FROM THE INPUT FILE

An error was encountered while reading the response file: the surface station's time zone was improperly specified - this message is seen only if the surface observations are CD144 or SCRAM format.

ERROR OPENING THE SURFACE FILE

An error occurred when attempting to open the file of hourly surface observations.

ERROR OPENING THE MIXING HEIGHT FILE:

An error occurred when attempting to open the file of mixing height data.

ERROR OPENING THE PRECIPITATION FILE:

An error occurred when attempting to open the file of precipitation data.

PRECIP FILE NOT VARIABLE FORMAT AS SPECIFIED BY USER

The user specified that the precipitation data are variable-length block data; PCRAMMET determined that the format is not VARIABLE-length. The format is likely FIXED-length, or a format unfamiliar to PCRAMMET.

ERROR OPENING TEMPORARY PRECIPITATION FILE

When a variable-length precipitation file is used, a temporary file is opened to reformat the data for internal use. The attempt to open this temporary file failed.

PRECIP FILE NOT FIXED FORMAT AS SPECIFIED BY USER

The user specified that the precipitation data are fixed-length block data; PCRAMMET determined that the format is not FIXED-length. The format is likely VARIABLE-length, or a format unfamiliar to PCRAMMET.

ERROR OPENING PRECIPITATION FILE:

The precipitation file does not exist - check the spelling or the path.

ERROR OPENING OUTPUT FILE (UNFORM):

The attempt to open the output file as an unformatted file failed.

ERROR OPENING OUTPUT FILE (ASCII):

The attempt to open the output file as an ASCII file failed.

SURFACE FILE NOT OF TYPE CD-144 AS SPECIFIED BY USER

The user specified that the hourly surface observations are in the CD144 format; PCRAMMET has determined that the format is not the CD144 format. The format is likely to be SAMSON, SCRAM, or possibly a format unfamiliar to PCRAMMET.

SURFACE FILE NOT OF TYPE SAMSON AS SPECIFIED BY USER

The user specified that the hourly surface observations are in the SAMSON format; PCRAMMET has determined that the format is not the SAMSON format. The format may be CD144, SCRAM, HUSWO, or possibly a format unfamiliar to PCRAMMET.

SURFACE FILE NOT OF TYPE HUSWO AS SPECIFIED BY USER

The user specified that the hourly surface observations are in the HUSWO format; PCRAMMET has determined that the format is not the HUSWO format. The format may be SAMSON, CD144, SCRAM, or possibly a format unfamiliar to PCRAMMET.

SURFACE FILE NOT OF TYPE SCRAM AS SPECIFIED BY USER

The user specified that the hourly surface observations are in the SCRAM format; PCRAMMET has determined that the format is not the SCRAM format. The format is likely to be CD144, SAMSON, HUSWO, or a format unfamiliar to PCRAMMET.

SCRAM DATA AND WET DEPOSITION NOT COMPATIBLE

The user specified SCRAM data for the hourly surface observation file and processing for wet deposition. These two options are not compatible - wet deposition requires information on the precipitation type (when precipitation is occurring) which is available from the present weather codes. The present weather codes are not in the SCRAM meteorological data files. The user has to choose an alternate format for the surface observations or not process the data for wet deposition.

ERROR READING HEADER RECORD OF THE SURFACE FILE:

An error was encountered while reading one of the header records of a SAMSON-formatted hourly surface observation data file.

ILLEGAL VARIABLE ID IN HEADER RECORD:

An error was encountered while decoding the second header record (the list of weather variables in the file) of a SAMSON-formatted hourly surface observation data file.

INSUFFICIENT DATA IN SAMSON FILE FOR PROCESSING

After decoding the second header record in the SAMSON data file, there is insufficient data to estimate the parameters for any dispersion model.

INSUFFICIENT DATA IN HUSWO FILE FOR PROCESSING

After decoding the header record in the HUSWO data file, there is insufficient data to estimate the parameters for any dispersion model.

INSUFFICIENT DATA IN SAMSON FILE FOR WET DEPOSITION

After decoding the second header record in the SAMSON data file, there is insufficient data to estimate the parameters for wet deposition (precipitation type and amount).

INSUFFICIENT DATA IN HUSWO FILE FOR WET DEPOSITION

After decoding the header record in the HUSWO data file, there is insufficient data to estimate the parameters for wet deposition (precipitation type and amount).

GLOBAL RAD'N OR REL HUMIDITY NOT EXTRACTED FOR DEPOSITION RUN

Dry or wet deposition was selected as the processing type and after decoding the header record in the SAMSON or HUSWO data file, either the global horizontal radiation or the relative humidity (or both) were not present in the file of hourly surface observations.

ERROR READING SAMSON SURFACE DATA:

An error was encountered while reading the hourly surface data from a SAMSON-formatted data file.

ERROR READING HUSWO SURFACE DATA:

An error was encountered while reading the hourly surface data from a HUSWO-formatted data file.

ERROR READING CD144 SURFACE DATA:

An error was encountered while reading the hourly surface data from a CD144-formatted data file.

ERROR READING MIXING HEIGHT DATA:

An error was encountered while reading the twice-daily mixing height data.

SURFACE AND MIXING HEIGHT TIME STAMP MISMATCH:

The date of the hourly surface observations and mixing height data are not synchronized.

SURFACE AND PRECIP DATA TIME STAMP MISMATCH:

The date of the hourly surface observations and precipitation data are not synchronized.

STABILITY CALCULATED TO BE LESS THAN 1:

The estimate of the Pasquill-Gifford stability category is in error.

ANEMOMETER HT < ROUGHNESS LENGTH

The anemometer height specified in the response file (batch processing) is less than the surface roughness length. This message will appear if either the roughness length at the measurement site or application site is above the anemometer height.

ANEMOMETER HT < 0.0

The anemometer height specified in the response file (batch processing) is less than 0.0.

ALBEDO OUT OF RANGE

The albedo specified in the response file (batch processing) is either less than 0.0 or greater than 1.0.

NET RADIATION ABSORBED BY GROUND OUT OF RANGE

The fraction of the net radiation absorbed by the ground specified in the response file (batch processing) is less than 0.0 or greater than 1.0.

These last four messages only appear when using PCRAMMET in a batch mode. In the interactive mode, PCRAMMET prompts the user for another value. In the batch mode, PCRAMMET cannot prompt for another value, so an error message is written to the log file and the preprocessor stops.

SECTION 7

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APPENDIX A

FILE FORMATS

MIXING HEIGHT DATA RECORDS (SCRAM WEB SITE/PCRAMMET FORMAT)

<u>Element</u>	<u>Columns</u>
Mixing Station Number	1- 5
Year	6- 7
Month	8- 9
Day	10-11
AM Mixing Value	14-17
PM Mixing Value	32-35

Note: NWS format has the PM Mixing Value in positions 25-28

SURFACE DATA RECORD (28 BYTE RECORD - MET144 FORMAT)

<u>Element</u>	<u>Columns</u>
Surface Station Number	1- 5
Year	6- 7
Month	8- 9
Day	10-11
Hour	12-13
Ceiling Height (Hundreds of Feet)	14-16
Wind Direction (Tens of Degrees)	17-18
Wind Speed (Knots)	19-21
Dry Bulb Temperature (° Fahrenheit)	22-24
Total Cloud Cover	25-26
Opaque Cloud Cover	27-28

SURFACE DATA RECORD (80 BYTE RECORD - CD144 FORMAT)

<u>Element</u>	<u>Columns</u>
Surface Station Number	1- 5
Year	6- 7
Month	8- 9
Day	10-11
Hour	12-13
Ceiling Height (Hundreds of Feet)	14-16
Wind Direction (Tens of Degrees)	39-40
Wind Speed (Knots)	41-42
Dry Bulb Temperature (° Fahrenheit)	47-49
Opaque Cloud Cover	79

SURFACE DATA RECORD - SAMSON FORMAT

The first record in the file retrieved from the SAMSON CDs contains station data. The format of this record is:

<u>Columns</u>	<u>Element</u>	<u>Definition</u>
001	Indicator	~ to indicate a header record
002-006	WBAN Number	Station number identifier
008-029	City	City where station is located
031-032	State	State where station is located
033-036	Time Zone	The number of hours by which the local standard time lags or leads Universal Time.
039-044	Latitude	Station latitude
039		N = north of equator
040-041		Degrees
043-044		Minutes
047-053	Longitude	Station longitude
047		W = west, E = east
048-050		Degrees
052-053		Minutes
056-059	Elevation	Elevation of the station in meters above sea level.

The FORTRAN format of this record is:

```
(1X,A5,1X,A22,1X,A2,1X,I3,2X,A1,I2,1X,I2,2X,A1,I3,1X,I2,2X,I4)
```

Each variable is represented by a position number. This position number always corresponds to that variable, no matter how many or how few variables are retrieved. The second record contains the list of variables (by a position number) that appear in the data file. There is no particular format; the variable number appears above the column of data it represents with at least one space (and usually many more) between the position numbers.

The third and subsequent records contain the weather elements retrieved from the SAMSON CDs. The data are free format, i.e., there is at least one space between each element in the record. The year, month, day, hour and observation indicator always appear on each record. These are followed by the variables retrieved by the user. If all the variables were retrieved, they would appear in the following order:

<u>Position #</u>	<u>Description</u>
	Year
	Month
	Day
	Hour (LST)
	Observation indicator
1	Extraterrestrial horizontal radiation
2	Extraterrestrial direct normal radiation
3	Global horizontal radiation
4	Direct normal radiation
5	Diffuse horizontal radiation
6	Total cloud cover
7	Opaque cloud cover
8	Dry bulb temperature
9	Dew point temperature
10	Relative humidity
11	Station pressure
12	Wind direction
13	Wind speed
14	Visibility
15	Ceiling height
16	Present weather
17	Precipitable water
18	Broadband aerosol optical depth
19	Snow depth
20	Days since last snowfall
21	Hourly precipitation amount and flag

The online help that accompanies the CDs contains a complete discussion of these variables, including the units, missing value indicators and any special considerations or comments.

SURFACE DATA RECORD - HUSWO FORMAT

The first record in the file retrieved from the HUSWO CD contains the list of variables, represented by a position number, that appear in the data file. This position number always corresponds to that variable, no matter how many or how few variables are retrieved. There is no particular format; the variable number appears above the column of data it represents with at least one space (and usually many more) between the position numbers. Position numbers 1 and 2, corresponding to the station ID and year, always appear in the file.

The second and subsequent records contain the weather elements retrieved from the HUSWO CD. The station ID, ASOS flag, year (4-digit), month, day, and hour always appear on each record. These are followed by the variables retrieved by the user. If all the variables were retrieved, they would appear in the following order (recall that the data can be retrieved in English or metric units and the processing in PCRAMMET assumes English units):

<u>Position #</u>	<u>Description</u>
1	Station ID
	ASOS flag
2	Year (4-digit)
	Month
	Day
	Hour (LST)
3	Global horizontal radiation
4	Direct normal radiation
5	Total cloud cover
6	Opaque cloud cover
7	Dry bulb temperature
	Dry bulb interpolation flag
8	Dew point temperature
9	Relative humidity
10	Station pressure
	Station pressure interpolation flag
11	Wind direction
12	Wind speed
13	Visibility

14	Ceiling height
15	Present weather
16	ASOS cloud layer 1
17	ASOS cloud layer 2
18	ASOS cloud layer 3
19	Hourly precipitation amount
	Precipitation flag
20	Snow depth

The online help that accompanies the CDs contains a complete discussion of these variables, including the units, missing value indicators and any special considerations or comments.

HOURLY PRECIPITATION - TD-3240 FORMAT

Precipitation data are reported only for those hours during which precipitation occurred. Variable-length blocks contain a station's precipitation record for one day on a physical record. The format of the precipitation data for variable-length blocks is as follows:

<u>Field</u>	<u>Columns</u>	<u>Description</u>
001	001-003	Record type
002	004-011	Station identifier
003	012-015	Meteorological element type
004	016-017	Measurement units
005	018-021	Year
006	022-023	Month
007	024-027	Day (right justified, zero filled)
008	028-030	Number of data groups to follow
009	031-034	Hour (left justified, zero filled)
010	035-040	Value of meteorological element
011	041	Measurement flag #1
012	042	Quality flag #2 (not used, blank)

Data groups in the same form as fields 009-012 are repeated as many times as necessary to contain one day of values on one record. These data would occupy fields 013 through 108, the maximum number of fields.

Fixed-length blocks contain a station's precipitation record for one hour on a physical record. The structure is identical to the variable-length blocks, except that only one hour of data appears on the record, i.e. fields 001 through 012.

The National Climatic Data Center publication *TD-3240 Hourly Precipitation* (NCDC, 1990) contains a complete discussion of the format, definitions and remarks for each of the fields presented above.

OUTPUT FILE (UNFORMATTED)

HEADER RECORD

<u>Data type</u>	<u>Number</u>	<u>Description</u>
Integer	1	Surface Station Number
Integer	1	Surface Station Year
Integer	1	Mixing Height Station Number
Integer	1	Mixing Height Station Year

DATA RECORDS (ONE PER DAY)

<u>Data type</u>	<u>Number</u>	<u>Description</u>
Integer	1	Year
Integer	1	Month
Real	1	Julian Day
Integer	24	Hourly Values of Stability Class
Real	24	Hourly Values of Wind Speed (m/s)
Real	24	Hourly Values of Temperature (K)

Real	24	Hourly Values of Flow Vector Values (degrees)
Real	24	Hourly Values of Randomized Flow Vector Values (degrees)
Real	48	Array dimensioned 2,24 containing: 24 rural mixing height values (1), and 24 urban mixing height values (2) (m)

OUTPUT FILE (ASCII FORMAT)

HEADER RECORD

The first record of the ASCII output file consists of the following four variables:

<u>Field</u>	<u>Description</u>
001	Surface Station Number
002	Surface Station Year
003	Mixing Height Station Number
004	Mixing Height Station Year

These variables are written with the format:

(4(I6, 1X))

DATA RECORDS (ONE PER HOUR)

If the user selected the option to process the input data for CONCENTRATION estimates (i.e., NO DEPOSITION), then the ASCII output file consists of the following variables, one record for each hour of the period.

<u>Field</u>	<u>Description</u>
001	Year (2 digits)
002	Month
003	Day
004	Hour
005	Random flow vector

006	Wind speed (m/s)
007	Ambient temperature (K)
008	Stability category
009	Rural mixing height (m)
010	Urban mixing height (m)

These variables are written with the format:

(4I2, 2F9.4, F6.1, I2, 2F7.1)

If the user selected the option to process the input data for DRY DEPOSITION estimates, then the following five variables are added to the 10 above:

<u>Field</u>	<u>Description</u>
011	Friction velocity at the application site (m/s)
012	Monin-Obukhov length at the application site (m)
013	Roughness length at the application site (m)
014	(not used - blank field)
015	(not used - blank field)
016	Global horizontal radiation (W/m ²)
017	Relative humidity (percent)

The 15 variables are written with the format:

(4I2,2F9.4,F6.1,I2,2F7.1,F9.4,F10.1,F8.4,T102,I9,T111,I3)

If the user selected the option to process the input data for WET DEPOSITION estimates, then the following seven variables are added to the 10 in a standard (no deposition) output file:

<u>Field</u>	<u>Description</u>
011	Friction velocity at the application site (m/s)
012	Monin-Obukhov length at the application site (m)
013	Roughness length at the application site (m)
014	Precipitation code (1-18: liquid, 19 and above: frozen)
015	Precipitation amount (mm)
016	Global horizontal radiation (W/m ²)
017	Relative humidity (percent)

The 17 variables are written with the format:

```
(4I2,2F9.4,F6.1,I2,2F7.1,F9.4,F10.1,F8.4,I4,F7.2,  
T102,I9,T111,I3)
```

APPENDIX B

TABLES OF SITE PROPERTIES

In this appendix, guidance on specifying the site properties required for estimating the dispersion parameters is given. Table B-1 gives representative values for the surface roughness length, B-2 for albedo, B-3 for Bowen ratio and B-4 for anthropogenic heat flux.

TABLE B-1

Surface Roughness Length, in Meters, for Land-Use Types and Seasons (from Sheih et al., 1979)

	Land-Use Type	Spring	Summer	Autumn	Winter
1.	Water Surface	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

TABLE B-2

Albedo¹ of Natural Ground Covers for Land-Use Types and Seasons (from Iqbal, 1983)

	Land-Use Type	Spring	Summer	Autumn	Winter ²
1.	Water Surface	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

¹ See also Iqbal (1983) for specific crops or ground covers.

Definitions of Seasons:

Spring: 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: Periods when vegetation is lush and healthy, typical of mid-summer, but also of other seasons where frost is less common.

Autumn: Periods 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: Periods when surfaces were covered by snow, and when temperatures are sub-freezing.

² 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.

TABLE B-3a
Daytime Bowen Ratio by Land Use and Season -
Dry Conditions (from Paine, 1987)

Land-Use	Spring	Summer	Autumn	Winter ¹
Water (fresh and sea)	0.1	0.1	0.1	2.0 ²
Deciduous Forest	1.5	0.6	2.0	2.0
Coniferous Forest	1.5	0.6	1.5	2.0
Swamp	0.2	0.2	0.2	2.0
Cultivated Land	1.0	1.5	2.0	2.0
Grassland	1.0	2.0	2.0	2.0
Urban	2.0	4.0	4.0	2.0
Desert Shrubland	5.0	6.0	10.0	10.0

TABLE B-3b
Daytime Bowen Ratio by Land-Use and Season -
Average Conditions (from Paine, 1987)

Land-Use	Spring	Summer	Autumn	Winter
Water (fresh and sea)	0.1	0.1	0.1	1.5
Deciduous Forest	0.7	0.3	1.0	1.5
Coniferous Forest	0.7	0.3	0.8	1.5
Swamp	0.1	0.1	0.1	1.5
Cultivated Land	0.3	0.5	0.7	1.5
Grassland	0.4	0.8	1.0	1.5
Urban	1.0	2.0	2.0	1.5
Desert Shrubland	3.0	4.0	6.0	6.0

TABLE B-3c
Daytime Bowen Ratio by Land-Use and Season -
Wet Conditions (from Paine, 1987)

Land-Use	Spring	Summer	Autumn	Winter
Water (fresh and sea)	0.1	0.1	0.1	0.3
Deciduous Forest	0.3	0.2	0.4	0.5
Coniferous Forest	0.3	0.2	0.3	0.3
Swamp	0.1	0.1	0.1	0.5
Cultivated Land	0.2	0.3	0.4	0.5
Grassland	0.3	0.4	0.5	0.5
Urban	0.5	1.0	1.0	0.5
Desert Shrubland	1.0	5.0	2.0	2.0

TABLE B-4
Average Anthropogenic Heat Flux (Q_f) and Net Radiation (Q_*)
for Several Urban Areas (from Oke, 1978)

Urban area/ latitude/period	Population ($\times 10^6$)	Population density (persons/km ²)	Per capita energy usage (MJ $\times 10^3$ /yr)	Q_f (W/m ²)	Q_* (W/m ²)
Manhattan (40°N)					
annual	1.7	28,810	128	117	93
summer				40	
winter				198	
Montreal (45°N)					
annual	1.1	14,102	221	99	52
summer				57	92
winter				153	13
Budapest (47°N)					
annual	1.3	11,500	118	43	46
summer				32	100
winter				51	-8
Sheffield (53°N)					
annual	0.5	10,420	58	19	56
West Berlin (52°N)					
annual	2.3	9,830	67	21	57
Vancouver (49°N)					
annual	0.6	5,360	112	19	57
summer				15	107
winter				23	6
Hong Kong (22°N)					
annual	3.9	3,730	34	4	~110
Singapore (1°N)					
annual	2.1	3,700	25	3	~110
Los Angeles (34°N)					
annual	7.0	2,000	331	21	108
Fairbanks (64°N)					
annual	0.03	810	740	19	18