User Instructions

COMPUTING TWICE-DAILY MIXING HEIGHTS FROM UPPER AIR SOUNDINGS AND HOURLY TEMPERATURES

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NOTICE

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1.0 INTRODUCTION

Estimates of the hourly mixing heights are required in applications of the Industrial Source Complex Short Term (ISCST3) dispersion model. These hourly values are commonly derived from twice-daily mixing heights using a meteorological preprocessor such as PCRAMMET. The twice-daily mixing heights, derived from the 1200 Greenwich Mean Time (GMT) upper air sounding and a record of the surface temperature at the upper air station, can be ordered from the National Climatic Data Center (NCDC). Alternatively, they can be obtained from the U.S. Environmental Protection Agency's (EPA) Support Center for Regulatory Air Models (SCRAM) web site, but are only available for the period 1984-1991 for most upper air stations in the United States.

Recent advances in personal computer technologies have made it more feasible to archive and distribute large amounts of meteorological data using compact disc (CD) technology. There are several sets of meteorological data currently available on compact disc. The *Solar and Meteorological Surface Observation Network* (SAMSON) consists of hourly surface radiation and weather observations for the period 1961-1990 for stations in the United States. The *Hourly United States Weather Observations* (HUSWO) updates to the SAMSON data for the period 1990-1995 but does not include the radiation data. Upper air data are available on the *Radiosonde Data of North America* for the period 1946-1992. This program takes advantage of the CD technology by computing the twice-daily mixing heights from upper air soundings and hourly surface observations that have been retrieved from these compact discs. The results from this program are similar, but not identical, to the mixing heights available from NCDC and SCRAM.

This report documents the algorithm used to obtain the twice-daily mixing heights, the required input data including user responses to program prompts, and a discussion of the output files. Recompiling the code and creating the executable program is discussed briefly in the appendix.

2.0 THE MIXING HEIGHT ALGORITHM

The algorithm used in calculating the twice-daily mixing heights is based on the work of Holzworth[1]. To compute the morning mixing height, the minimum temperature from 0200 local standard time (LST) to 0600 LST, inclusive, is determined. To this value is added 5° C, the same as used by Holzworth. Holzworth's development was for an urban environment in order to estimate urban air pollution. He established this adjustment to account for temperature differences between rural and urban environments and for some initial surface heating just after sunrise. To estimate the morning mixing height, this adjusted minimum surface temperature follows the dry adiabatic lapse rate up to the intersection with the observed 1200 GMT temperature sounding.

A similar computation is made using the maximum temperature from 1200 LST to 1600 LST, inclusive, and the 1200 GMT sounding, except that the surface temperature is not adjusted. The assumption made by Holzworth was that afternoon mixing heights in urban and nearby rural areas do not differ significantly, whereas the nocturnal mixing heights are often very different.

The surface potential temperature is computed from the minimum temperature (in the morning) and the pressure at the first level in the 1200 GMT sounding. Unless the data are missing, the first level in a sounding is representative of the surface. The temperatures in the sounding are all converted to potential temperatures. Since potential temperature generally increases with height in the atmosphere, the program linearly interpolates between the two levels

[1] Holzworth, G., 1967: Mixing Depths, Wind Speeds and Air Pollution Potential for Selected Locations in the United States. *J. Appl. Meteor*., 6, 1039-1044.

of nonmissing data in the sounding that bound the surface potential temperature to obtain the morning mixing height. An identical procedure is applied to the afternoon maximum temperature to obtain the afternoon mixing height.

The National Weather Service and NCDC have recently begun reporting sounding times as the time of release rather than the standard times of 0000 and 1200 GMT. There may be occasions when the release is earlier or later than the standard sounding times. Frequently, the sounding times are one hour earlier than the standard times. To avoid the problem of not finding the 1200 GMT sounding, the program searches for a sounding between 1000 and 1500 GMT. This window of time is also used by NCDC in its computations of twice-daily mixing heights.

As noted in Section 1, the twice daily mixing heights can be ordered from NCDC or obtained from the EPA's SCRAM web site. The mixing height data from these two sites include flags indicating whether there was precipitation (the period of the precipitation event that the flag represents is uncertain) or cold advection, the average wind speed through the mixing depth, and the average surface wind speed. In the calculations generated by this program, this information is not provided.

3.0 USING THE MIXING HEIGHT PROGRAM

This section describes the input data requirements, the prompts by the program and user responses, running the program, and interpreting any messages generated by the program.

3.1 DATA FORMAT REQUIREMENTS

The meteorological data on compact discs referenced in Section 1 provide DOS-based software to retrieve the data from the CDs. The upper air data are retrieved through a series of prompts to the user, not unlike the operation of this program. The SAMSON and HUSWO archives provide a DOS-based graphical interface to retrieve the data. A description of the SAMSON and HUSWO formats can be found in the appendix, but the user is referred to the CDs for instructions on retrieving the data from the CDs.

The interface provided with the data allows the user to retrieve all or a subset of the variables that comprise the SAMSON and HUSWO hourly surface observations. As such, any program that reads these data must be able to interpret which variables were retrieved. However, the process of interpreting which variables are in the file and building the format to read the data is not a simple procedure. Therefore, to simplify the source code,

☞ **the user is required to extract ALL variables from the SAMSON and HUSWO compact discs**.

Fortunately, the interfaces provide the default of selecting all variables, both solar and meteorological parameters, from the SAMSON and HUSWO CDS. Therefore, using the "F4" function key or left-clicking on the "SelElem" button is not needed. The mixing height program accepts the input format of SAMSON and HUSWO CD data based on all elements in the input file. In addition, all elements should be extracted since the global radiation parameter and/or relative humidity from either CD may be used later in PCRAMMET (for dry/wet deposition).

The HUSWO data, unlike the SAMSON CD, can be extracted in either English or metric units. The default is set to English units. If the CD user has extracted any subset of the entire station file (with all elements), it is advantageous to check the English units setting. This can be done by "F4" or left-clicking on "SelElem." This screen displays the solar and meteorological elements, along with the English or metric selection option. Be sure that English is selected.

☞ **The mixing height program assumes the data are in English units.**

Unfortunately, there is no easy way for the user or program to determine which units were used simply by examining the data. If the resulting mixing heights are all missing or unreasonable, it may be prudent to investigate the possibility that the units of the hourly surface observations were improperly specified when the data were retrieved from CD.

Before retrieving the data, the user must select the station(s) and dates that are to be retrieved. Once the station(s), and dates are selected, the software retrieves the data from the CD and writes it to a file using a naming convention of *wban*.DAT, where *wban* is the station's 5-digit Weather Bureau Army Navy (WBAN) number.

3.2 USER INPUT

Once the data are retrieved from the compact disc(s), the mixing height program can be run. The mixing height program prompts the user for five inputs, as follows:

1) The name of the file with the upper air data - can include full path, if needed (48-character maximum),
2) The name of the file with the surface observations - can include full path, if needed (48-character maximum),
3) The name of the output file with the twice-daily mixing heights - can include full path, if needed (48-character maximum),
4) Year, month, and day to begin processing - free-format, integer (enter year as 2 digits),
5) Year, month, and day to stop processing - free-format, integer (enter year as 2 digits), and

The filenames may include a drive and/or path if the input data reside in a directory different from where the mixing height program is run. If a path is not included with the output file name, then the resulting file will be placed in the directory from which the program is run.

The starting and stopping dates can be the entire period in the input data or a subset of the data. Data outside the processing 'window' specified here are ignored. If the dates specified extend beyond the dates in the surface or upper air files, then the mixing height program will write -9999 for both morning and afternoon mixing heights for all periods outside the processing 'window.'

3.3 RUNNING THE PROGRAM

There are two methods of running the program: interactive mode and redirected command line mode. In the interactive mode, the program displays prompts on the video screen for each of the interactive inputs described above. The user responds to each prompt and, if the

all the responses are valid (e.g., the two input files exist), the program computes mixing heights. As the computations are performed, the date being processed is displayed on the screen. If a subset of the input data are processed and the start date is later than the first date in the input files, there will be a brief delay while the program reads through the unneeded data.

As the user responds to each prompt, the responses are written to a file named MIXHTS.INP. This file can be used to run the program in the redirected command line mode described below. To use this file, the file must be renamed or copied to a different file name. Otherwise the mixing height program will read and write to the same file, causing the program to abort. The contents and structure of this file are described in more detail in Section 4.

If there are any problems computing the mixing heights for a day, a message is written to the log file, MIXHTS.LOG, indicating the nature of the problem and the date of occurrence.

In redirected command line mode, the user creates a short file with the responses to the prompts or uses the file generated by a previous run and uses DOS redirection to run the program as follows:

```
mixhts < myinput.inp
```

Here the program executable is assumed to reside in the current directory or in a directory in the DOS path and the ".inp" file is in the current directory. If the program executable is not in the current directory, you may need to check the DOS path. Type SET at the DOS prompt and press the ENTER key. Look for the line beginning with "PATH=" and make sure the directory where the executable resides is listed. If it is not listed, then put the full path name (including the drive if needed) in front of the executable file name above. For example, if the executable is in a subdirectory called MODELS on the D: drive, then the command above would be:

```
D:\models\mixhts < myinput.inp
```

The output will be written to the current DOS drive and directory (not to the drive and directory where the executable resides).

As with the interactive mode, messages are written to the log file, MIXHTS.LOG. Note that if the mixing height program is run several times consecutively, the log file is overwritten each time the program is run. To retain the contents of the log file from a run, the user should copy or rename the log file prior to the next run.

4.0 OUTPUT

Three files are created as a result of running the mixing height program: 1) the twice-daily mixing heights, 2) input responses to the program prompts, and 3) the log file of messages resulting from the data processing. Each of these files is discussed below.

4.1 MIXING HEIGHTS

Each record in the file of twice-daily mixing heights is structured as follows:

- station ID (5 characters in columns 1-5),
- year (2 digit integer in columns 6-7),
- month (2 digit integer in columns 8-9),
- day (2 digit integer in columns 10-11),
- morning mixing height in meters (5 digit integer in columns 13-17), and
- afternoon mixing height in meters (5 digit integer in columns 31-35).

The following is an example of the first 8 records in the output file:

```
7278592 1 1   501              53
7278592 1 2   471             140
7278592 1 3   242             242
7278592 1 4   390             255
7278592 1 5   327             182
7278592 1 6   566           -9999
7278592 1 7   132             132
7278592 1 8   990             796
```

Note that on January 6 that the afternoon mixing height is set to -9999, indicating that the program was unable to compute the mixing height. The reason for the missing mixing height will be discussed with the discussion of the messages below.

4.2 INPUT RESPONSES TO PROGRAM PROMPTS

Rather than answer the six prompts interactively each time the program is run, the user can create a file of responses (the redirected command line mode above). However, the user must know the order of the responses. As an alternative, the user can let the mixing height program generate a file of input responses. The name of this file is hard coded into the mixing height program and is named MIXHTS.INP. If the user wants to save the responses for a particular run, then the user must rename this file, otherwise, the contents of the file will be overwritten without warning the user. In this way, the user can run the program once interactively, rename or copy the response file, and edit the file for subsequent runs. Shown next is an example of this response file:

```
spokane.upr                          Upper air soundings
spokane.sfc                          Hourly surface observations
HUSWO                                Surface obs data type
spokane2.mix                         Output file
  92,   1,   1                       Date to begin processing
  92,  12,  31                       Date to stop processing
```

The annotations to the right are a part of this file; they begin in column 50 and are not read if this file is used as the input response file.

WARNING: Do not use this file name on the command line without first renaming it, i.e., do not type *mixhts < mixhts.inp* at the DOS prompt. The program will fail because mixhts.inp is opened for both input and output and the responses are lost when it is opened for output.

4.3 LOG FILE

The mixing height program writes several messages to the log file. All the responses, as input by the user either interactively or through a response file, are written to the file first. Status messages of the processing follow. Messages are written only if there was a problem computing the mixing height. An example of the messages is shown below. They correspond to the example output and response files in Section 4.1 and 4.2.

```
spokane.upr                                          Upper air soundings
spokane.sfc                                          Hourly surface obs
spokane.mix                                          Output file
 Station ID: 72785
 Date to begin processing:   92/   1/   1
 Date to stop processing :   92/  12/  31
 Could not compute afternoon mixing height on (yy-mm-dd) 92-01-06
    Sfc potential temperature < potential temperature of 1st level
in sounding
```

Recall that for January 6, the afternoon mixing height was -9999, or missing. The last message shown above indicates that the program was unable to compute the afternoon mixing height on January 6 because the surface potential temperature was less than the potential temperature at the first level in the sounding. A possible reason for the missing mixing height is cold advection with the temperature falling during the day. In fact, the minimum temperature between 0200 and 0600 LST was 0.6 °C and the maximum temperature between 1200 and 1600 LST was -0.6 °C, suggesting that colder air moved into the Spokane area during the day.

Other messages the program may generate include: a similar message for the morning sounding; a missing 1200 GMT sounding that yields missing mixing heights for both morning and afternoon; and missing surface temperature or pressure such that the surface potential temperature cannot be computed.

If the program encounters data that it cannot read, e.g., an invalid character in a field in the hourly surface observations, then a message is written and the program stops without processing any additional data. A partial file of mixing heights may have been written, though, depending on whether the program was able to process any data between the start and stop dates, and may help in identifying the date of the erroneous data.

APPENDIX

There are three files that are required to build the executable program: MIXHTS2.FOR, MIXLIB.FOR, and MIXHTS.INC. The file with the ".INC" extension contains code that is required by the main program and several subprograms in the ".FOR" files. If the need arises to generate a new executable program, these two files must compiled and linked using a Fortran compiler such as the Lahey F77L-EM/32 Fortran 77 compiler. The mixing height program was written using standard Fortran 77; i.e., there are no compiler-dependent extensions of the language in the code, such as obtaining the system date and time.