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**US Army Corps
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Hydrologic Engineering Center

Corps Water Management System (CWMS) Documentation

GageInterp

A Program for Creating a Sequence of HEC-DSS Grids from Time-Series Measurements

User's Manual

Version 1.6
September 2016

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14. ABSTRACT

GageInterp creates a sequence of grids that approximate the variation through space of a quantity measured varying through time at fixed locations. It can be used to estimate spatially distributed values of precipitation, temperature, or other parameters. The estimates are generated at regular intervals of time for cells in the grid by reading values from time-series data stored in HEC-DSS database files. Each time series contains data for a single point, and GageInterp interpolates values between and around those points, at the centers of cells in a grid. The program writes the resulting grids to new records in one or more DSS files. The user specifies the input gages as locations given by longitude, latitude, optional elevation, and DSS path names from which the values at the gages will be read, and also specifies the type and extent of the grid to be used. The user can select an interpolation method from among several options, and interpolated values may be adjusted by specifying a bias grid, or by using a lapse computation on temperature measurements, based on a user-supplied elevation grid.

15. SUBJECT TERMS

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Foreword

GageInterp was developed at the Hydrologic Engineering Center (HEC). The program was written by Mr. Thomas A. Evans, and incorporates functions written by Mr. William Charley, Mr. Paul Ely, and Mr. Carl Franke. Functions for coordinate system and map projection transformations were written at the US Geological Survey and distributed with the PROJ4 software package.

Mr. Darryl Davis was director of HEC at the time that these programs were written, and Mr. Arthur F. Pabst was chief of the technical assistance division of HEC. In 2003, when the program was substantially revised, Mr. Daniel Barcellos was chief of the water management systems division of HEC.

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Mr. Thomas A. Evans wrote this manual.

CHAPTER 1

Introduction

GageInterp creates a sequence of grids that approximate the variation through space of a quantity measured varying through time at fixed locations. It can be used to estimate spatially distributed values of precipitation, temperature, or other parameters. The estimates are generated at regular intervals of time for cells in the grid by reading values from time-series data stored in HEC-DSS database files. Each time series contains data for a single point, and GageInterp interpolates values between and around those points, at the centers of cells in a grid. The program writes the resulting grids to new records in one or more DSS files. The user specifies the input gages as locations given by longitude, latitude, optional elevation, and DSS path names from which the values at the gages will be read, and also specifies the type and extent of the grid to be used. The user can select an interpolation method from among several options, and interpolated values may be adjusted by specifying a bias grid, or by using a lapse computation on temperature measurements, based on a user-supplied elevation grid.

1.1   How GageInterp Computes Cell Values

GageInterp computes its grid outputs cell-by-cell. The user specifies the program's operations through parameters written to a control file. These parameters include a description of the grid's geometry - its location, extent and the size of its cells - and a list of the gages that provide its input data. Each gage's listing includes its location, specified as longitude and latitude.

The program initializes by computing a distance from each cell in the grid to each gage listed in the control file. For each cell, it compares the distance from the cell center to each gage with a radius of influence that gage. If the distance is greater than the gage's radius, that gage will not be used in estimating values at that cell. (The radius of influence can be set for each gage, or globally. An individual gage's radius takes precedence over the global setting.)

At each time step, GageInterp queries the DSS records associated with the gages. If the output data type is period cumulative (PER-CUM) GageInterp reads a value for the interval between time steps. If the output data type is instantaneous value (INST-VAL), GageInterp reads a value at the time step. Unit conversions and some simple data screening take place at this time. Negative values for precipitation are rejected, for example. If bias or lapse adjustments (see Section 1.2) are in use, adjusted values for each gage are calculated.

After reading (and where applicable, adjusting) the gage values. GageInterp estimates a value at each cell in the grid by calculating a weighted average of all the values from gages that are not located farther from the cell than their radius of influence. The averaging weights are calculated according to one of the following methods, as specified in the control file.

- Inverse distance squared (ID2W) – the default method. The weighting factor for each gage is equal to one divided by the square of the distance from the cell to the gage.
- Inverse distance (IDW). The weighting factor for each gage is equal to one divided by the distance from the cell to the gage.
- Nearest gage (NEAR). The nearest gage with a valid value gets a weight of one; all other gages get a weight of zero.
- Average (AVER). All gages get a weight of one.
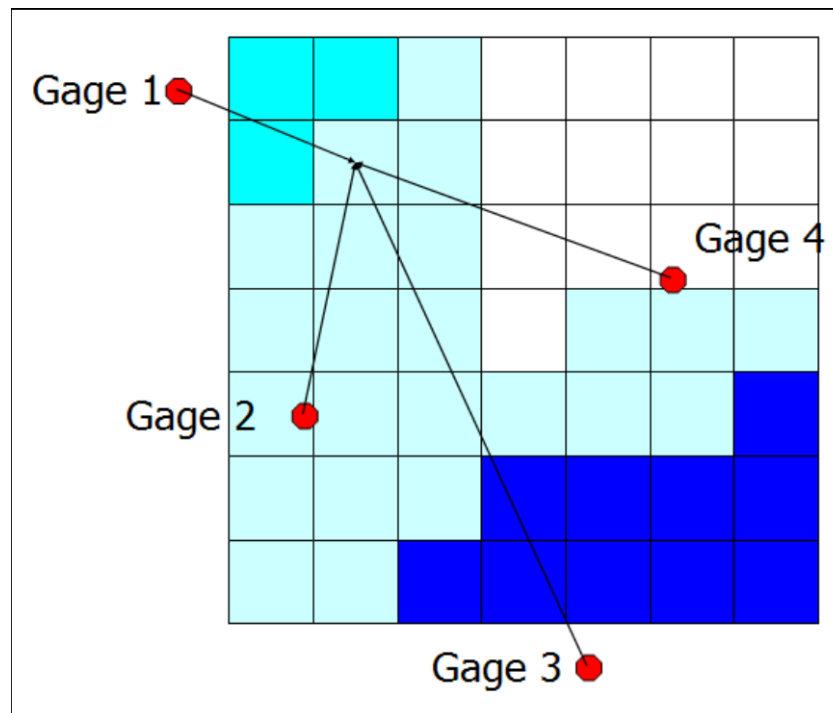
Figure 1.1 Gages Influencing a Cell

An additional computation may adjust the value at the cell by applying a bias factor or by introducing a lapse computation. These adjustments are described in the following section.

1.2   Lapse and Bias Computations

GageInterp supports the use of a value adjustment grid to shape the distribution of interpolated values. For air temperature interpolations, the adjustment is computed as lapse, based on the elevation of the cell and the elevations of the gages that contribute to its interpolated value. For all other computations, the adjustment is a bias by a scaling factor.

The bias method adjusts interpolated values as follows. Each gage's coordinates locate the gage within a cell in the bias grid. The value of that cell is assigned to the gage as a bias factor. For each time step, the value from the gage is divided by the gage's bias factor to produce an adjusted value for the gage. The adjusted values are then interpolated over the grid to produce an intermediate result grid. The values in the cells of the intermediate result grid are multiplied by the values in the corresponding cells of the bias grid to produce the output grid.

Lapse adjustments to temperature values are made as follows. The elevation of each gage is multiplied by the lapse rate, and the product is subtracted from each gage's temperature value, resulting in an estimated sea-level temperature for each gage. The adjusted gage temperatures are interpolated over the grid by the selected interpolation method to produce an intermediate grid of sea-level temperatures. For each cell in the output grid, a final temperature is calculated by adding the product of the lapse rate and the cell's elevation to the sea-level temperature for that cell.

The lapse rate can be set in three ways. A fixed value can be used for a run, a time series can be used to provide a changing rate over the course of a run or the lapse rate can be estimated at each time step based on reported temperatures at the gages. The fixed lapse rate defaults to a value of -0.0065 degrees Celsius per meter of elevation if no user-specified value is provided in the configuration file.

For estimating a variable lapse rate, GageInterp calculates a linear regression of temperature vs. elevation at all the gages at each time step. The lapse rate is equal to the slope of the estimated regression line. This method allows GageInterp to detect changes in the lapse rate, including temperature inversions, which may be very important for snow modeling and other applications of temperature grids. The use of linear regression to estimate the lapse rate, however, makes this method very sensitive to errors in the temperature data, since errors can affect both the values interpolated directly from them, and the lapse rate. The recalculation at every time step means that new opportunities for errors to exert this strong influence occur over and over during the course of a GageInterp run. Temperature data should be screened carefully before this method is used.

CHAPTER 2

Requirements and Setup

2.1   Installation for Windows

The GageInterp distribution package for Windows included the executable *gageInterp.exe* and the supplemental data file *conus.nad*. The *gageInterp.exe* program should be installed in a directory named on your system path (*C:\hecexe*, if possible). The file *conus.nad* is required to support geographic coordinate transformations. By default, GageInterp will look for *conus.nad* in *C:\hecexe\sup* or in the directory named by the environment variable PROJ_LIB.

2.2   Installation for Sun UNIX

The GageInterp distribution package for Sun workstations includes the executable *gageInterp* and the supplemental data file *conus.nad*. The executable should be installed in a directory named in your path (*/usr/hec/bin*, if possible). The file *conus.nad* is required to support geographic coordinate transformations. By default, GageInterp looks for *conus.nad* in the directory */usr/hec/sup* or in the directory named by the environment variable PROJ_LIB.

To install GageInterp, copy the executable to */usr/hec/bin* and copy *conus.nad* to */usr/hec/sup*. If you can't put *conus.nad* in */usr/hec/sup*, copy it to any directory you like and then set the environment variable PROJ_LIB to that directory name with the command:

> setenv PROJ_LIB /mydirectory/mysub

substituting the path on your system for */mydirectory/mysub*. Add this command to the *.cshrc* or other shell initialization files of users who will be running GageInterp. Make sure that users of the program have execute permission for *gageInterp* and read permission for *conus.nad*.

CHAPTER 3

Operating Instructions

To interpolate gaged time-series values onto a grid, it is necessary to specify the locations of the gages, identify the DSS data records associated with those gages, specify the output grid (cell spacing, grid origin, number of rows and columns, units and data type), and choose a start time, end time, and time step for the interpolation.

Note that, although the time-series data associated with gages can be in any time zone, GageInterp always writes grids with a time stamps in Universal Coordinated Time (UTC). The start and end times for computations are likewise in UTC.

GageInterp is controlled by items entered on the command line, and by data read from a control file. Some control data can be entered either on the command line or in the control file; values entered on the command line always take precedence over those in the control file so that a single control file can be used for multiple runs in scripts or batch processes.

3.1   Command Line Parameters

The program is invoked with the following command:

```
gageInterp CONTROL=confile [SDATE=startDate]
   [STIME=startTime] [EDATE=endDate] [ETIME=endTime]
   [DSSIN=Filename] [DSSOUT=Filename] [VERBOSE=level]
```

where:

    CONTROL = specifies the name of the GageInterp control file
    SDATE = specifies the starting date of the computation interval
    STIME = specifies the starting time of the computation interval
    EDATE = specifies the ending date of the computation interval
    ETIME = specifies the ending time of the computation interval
    DSSIN = specifies a file from which all DSS inputs will be read
    DSSOUT = specifies a file to which grid records will be written
    VERBOSE = controls the messages written to standard output

The control file name must be given on the command line. All other command-line arguments are optional, although some must be specified in the control file if not given on the command line. See the next section for a description of the control file.

All argument labels can be abbreviated as long as enough characters remain to make the label unique. For example, SD and ED are sufficient to specify the start and end dates.

The arguments SDATE, STIME, EDATE, and ETIME specify the start and end of the period for which interpolations will be calculated. Dates and times should be given in military style, for example:

```
SDATE=06JUN1944 STIME=1500
```

Although dates for the start and end of the interpolation period are optional on the command line, they must be provided in the control file if they are not given on the command line. If no dates are provided, the program will produce an error message and exit. If dates are provided on the command line with no associated times, the program will run from the beginning of the starting date to the end of the ending date, regardless of the times specified in the control file. For example, the command:

```
gageInterp CON=con.ginterp SD=14JAN95 ED=14JAN95
```

will produce interpolated values for the entire day of January 14, 1995.

Start and end times are assumed to be in UTC, whether given in the control file or on the command line. To interpolate grids for 14 January 1995 in the Eastern Time Zone of the United States, the program would be invoked as:

```
gageInterp SDATE=14JAN95 STIME=0500 EDATE=15JAN95
 ETIME = 0500
```

The command line arguments DSSIN and DSSOUT override the values for input and output DSS files given in the control file. This is helpful for scripted applications, where new input and output files can be named for different times, model applications, etc.

The VERBOSE argument controls the amount of output written to standard out. The verbose level is a number from zero and five. A verbose level of zero suppresses most output except a short summary of each grid as it is written. A verbose level of five echoes the content of the control file and gives detailed descriptions of each gage reading for each time step. The default level is two.

3.2   Control File Parameters

Most of GageInterp's operations are controlled by parameter values set in the control file. Comment lines in the control file begin with an asterisk (*) and have no effect on program operation. Blank lines are ignored as well. Lines that set operating parameters begin with a keyword, followed by a colon and a parameter value or set of values. Where multiple parameter values appear on a line, they can be separated by any combination of spaces, tabs, and commas. For example, the lines:

```
* Peak intensity period for January Storm
TimeStart: 13JAN95, 1300
TimeEnd: 13JAN95, 1400
```

set the start and end times for the interpolation period. The first line is a comment, written by the user to identify the purpose of the file; the next two lines start with the keywords TimeStart and TimeEnd, respectively, and each line contains two parameter values (a date and a time) separated by a comma and a space.

The control file contains three sections. The first section sets parameters that control the interpolation process: the start and end times, the interpolation method to be used, the maximum distance a gage can be from a cell to contribute to its precipitation estimate and the output DSS file and path names. The second section sets output grid parameters: the type of grid, its location, and the number of cells (rows and columns) it will contain. The third section sets precipitation gage parameters: their names, locations, and the DSS file and path names associated with them.

3.2.1   Interpolation Parameters

The following information is required to control the interpolation process:

- Start and end times in UTC
- Interpolation method
- Maximum cell-to-gage distance

The control file must contain lines setting the DSS file and path names for output of the interpolated precipitation. Start and end times for the interpolation must be provided either in the control file or on the command line when the program is started. Table 3.1 shows the keywords used to set these parameters.

Additional notes on setting interpolation parameters in the control file:

- Start and end times require a date, and may include a time.
- The time step of the grids defaults to one hour, but can be set to other values in the control file.
- The interpolation method will default to inverse-distance-squared weighting if it is not specified in the control file.
- If a value is specified for the range, only gages located within that distance (in meters) of a cell will be included in estimates at that cell. If no range value is specified, the range defaults to 30,000 meters (thirty kilometers). Specifying UNLIMITED for the range will cause all gages to be included in estimates for all cells.
- The range can be overridden for individual gages. See discussion of the RADIUS parameter in Section 3.2.2.

Table 3.1 Interpolation Parameters in GageInterp Control File

Keyword	Function	Values
* (asterisk)	Identifies comment line.	
ENDFILE	Lines following this keyword will be ignored.	
TimeStart	Sets beginning time of first interpolation interval	Valid `HECTime` strings for date and time Example: 13JAN1995, 1100
TimeEnd	Sets ending time of last interpolation interval	Valid `HECTime` strings for date and time
TimeStep	Sets length of grid time interval	Numerical values in minutes. Acceptable values are limited to 1, 5, 10, 15, 20, 30, 60, 120, 180, 240, 360, 480, 720, 1440. Defaults to 60 minutes.
Weight	Sets interpolation method	ID2W inverse distance squared (default) IDW inverse distance NEAR nearest gage (Theissen polygon) AVG average of all gages in range
Range	Sets maximum distance between cell center and gage contributing to cell precipitation estimate	Numerical Value in meters. Defaults to 30,000 meters. If a value of UNLIMITED is entered, all gages will be included in estimates at all cells.
AdjustMethod	Sets the adjustment method (BIAS or LAPSE) to be applied to the output grids	BIAS can be used for most data types, including precipitation. LAPSE can be used for temperatures only.
AdjustGridFile	DSS file containing the bias or elevation grid	DSS filename.
AdjustGridPath	Identifies DSS grid record containing bias factors or elevations for lapse	DSS pathname. Any values in BIAS grids are acceptable. Elevation grids must be in meters.
LapseMethod	Sets method for calculating lapse rate	FIXED, TIMESERIES, or CALCULATED
LapseRate	Sets constant lapse rate	Lapse rate in degrees C per m. Default value is -0.0065.
LapseRateFile	Sets name of DSS file containing a time series of lapse rates	Name of existing DSS file containing the lapse rate time series.
LapseRatePath	Sets the path of the DSS record containing a time series of lapse rates.	Path name of an existing time series record containing lapse rates expressed in degrees F/FT or degrees C/m

3.2.2   Grid Parameters

The output grid must be specified with the following information: the type of grid, the location of the grid origin, and the number of rows and columns in the grid, the name of the DSS file to which the grid will be written, and the DSS path that will be used to identify the grid records. The grid type can be set to HRAP (the grid specified by the National Weather Service's Hydrologic Rainfall Analysis Project and used for distribution of the NEXRAD radar precipitation data) SHG (the Standard Hydrologic Grid, defined by HEC) or an SHG-like grid system based on UTM coordinates in the specified zone (see Appendix F). The grid's origin (its southwest or "lower left" corner) and the number of rows and columns can be specified directly or indirectly by identifying minimum and maximum longitude and latitude to be covered by the grid. Table 3.2 lists the keywords used to set these parameters.

Table 3.2 Interpolation Grid Parameters in GageInterp Control File

Keyword	Function	Values
GridType	Sets output grid type	HRAP (default) SHG or UTM (with Zone ID)
CellSize	Sets size of SHG cells	Cell size in meters. Only values of 10, 20, 50, 100, 200, 500, 1000, 2000, 5000, or 10000 are allowable.
GridOrigin	Sets origin of grid	Coordinate Pair given as HRAP, SHG, or UTM cell numbers
GridRows	Number of rows in grid	Integer
GridCols	Number of columns in grid	Integer
GridBounds	Bounding coordinates of grid	Two coordinate pairs as longitude, latitude.
OutUnits	Sets units on output grids	Optional. Default value is mm. Any unit supported by DSS. (mm or INCHES for precipitation; DEG C or DEG F for temperature)
OutDataType	Sets DSS data type for output grids	Defaults to PER-CUM. Use INST-VAL for temperature grids.
OutParameter	Identifies data type for unit conversions.	Default value is precip. Will be set to air temperature if units are DEG C or DEG F.
OutFile	Names DSS file for output	Existing DSS file name or new filename
OutPath	Names DSS path for output	Valid DSS path name (D and E parts can be blank) /BAS/LOC/PRECIP///GRIDDED/

Additional notes on setting grid parameters in the control file:

- UTM zone ID is specified as a number (1-60) followed by an 'N' or 'S' to indicate northern or southern hemisphere. "UTM 17N" means zone 17 in the northern hemisphere. "UTM 59S" means zone 59 in the southern hemisphere.

- Use only one method to specify the grid origin and size. The first setting of an origin or size of the grid is the only one that will be accepted. Once a grid origin, row or column count is specified, any attempt to redefine it will be rejected.
- Longitude and latitude for GridBounds can be entered in any of the following formats:

  Decimal degrees, negative for west longitude or south latitude (e.g. -91.5050)

  Decimal degrees, NSEW suffix for hemisphere (e.g. 91.5050W)

  Integer ddmmss, negative for west longitude and south latitude (e.g. -913018)

  Delimited degrees minutes seconds, can include decimal seconds (e.g. 91d30'18.0"W)

  Delimited degrees minutes, can include decimal minutes (e.g. 91d30.3'W)

- GridBounds coordinate pairs should be entered as longitude, latitude, longitude, latitude. The entry "91.0W, 38.0N, 90.0W, 39.0N" for example, specifies a one-degree quadrangle enclosing St. Louis, Missouri.
- The output DSS file name can be specified by a file name alone, or by a file system path and file name.
- Prior to Version 3.0, HMS assumes that all precipitation grid data is in millimeters. If you are making precipitation grids as input to HMS, check your version number and use the default units of mm where appropriate.
- For most applications, the `OutParameter` setting can be left out of the control file. This parameter serves two purposes: it forms part of automatically generated output file names (see Appendix A, Using GageInterp in CWMS) and it affects unit conversions. If the `OutParameter` value is set to `precip` (the default value) or `airtemp`, gageInterp will convert the units of input data to match the output units given in the control file. If this parameter is set to any other value, gageInterp will not perform any unit conversions, and the user must make sure that the input time series data are all in the same units as the output grids.

3.2.3   Gage Parameters

For each gage included in the interpolation, the following data must be provided: the gage's location in longitude and latitude, the name of the DSS file containing the precipitation records for that gage, and the DSS path name associated with those precipitation records. In addition, the geographic datum used for the definition of the longitude and latitude can be specified. Table 3.3 lists the keywords used to set these parameters.

Table 3.3 Gage Parameters in GageInterp Control File

Keyword	Function	Values
DSSFile	Names a DSS file. Optionally provides an index for the DSS file.	[Index =] Name of existing DSS file. Examples: /home/data/river.dss 1=/home/data/river.dss
Gage	Specifies name, location, and elevation of a gage	String, Coordinate Pair, elevation in meters. Elevation is optional and used only for lapse computations. WEBB 95d10'06W 35d35'12
Path	Specifies DSS path name for gage	[Index:] Valid DSS path name with optional D and E parts. Examples: //LOC/PRECIP-CUM//IR-MONTH/OBS/ 1:/BASIN/LOC/PRECIP-CUM///OBS/
Timezone	Specifies the time zone for the precipitation time series, determining an offset time from UTC	Three-letter time zone ID, Y or N (indicating whether daylight saving time is observed.) EST N
Radius	Sets maximum distance between this gage and cells to which it will contribute. Overrides the global Range parameter.	Numerical Value in meters. Defaults to value of the Range parameter.
Disable	Disables a gage	No value. If a `disable:` line is present in a gage block, the gage is ignored.
Text	Label information for gage.	Character string. Can extend over more than one line.
Datum	Geographic datum for coordinates of gage location	NAD27 (default for HRAP and SHG) NAD83 WGS84 (default for UTM)

Additional notes on setting gage parameters in the control file:

- A gage must be named before any descriptors can be associated with it. Gage data should be entered with the gage line first, followed in any order by a path line, a time zone line, and optional disable, datum, and text lines.
- Coordinates for gage locations can be given in the same formats as the grid limits.
- At least one DSS input file must be specified with a DSSFile line. If more than one DSS file is to be used, each must be identified with an index. If only one DSS file is used, an index can be used, but is not required. If one un-indexed DSS file is named, path names must not include indices. If indexed DSS files are used, the first path name listed must include a file index; after the first path is named, any following path without an associated index will be associated with the last index used.

- If the E part of a gage's DSS path is omitted and the output is of type PER-CUM, GageInterp will look for an E part that matches the output time step. If the output type is INST-VAL, an E part must be specified.
- Text lines are ignored. They are included as optional entries in the control file so that users can copy gage data directly between control files for GageInterp and the SVT spatial data visualization program.
- For HRAP and SHG grids, if a gage's definition in the control file does not contain a DATUM line, its longitude and latitude will be assumed to be in NAD27 coordinates.
- For UTM grids, if a gage's definition in the control file does not contain a DATUM line, its longitude and latitude will be assumed to be in WGS84 coordinates.
- NAD27 and NAD83 are not defined outside the US. In UTM grids, if a gage outside the US is given a NAD27 datum, its location will be undefined and the gage will be disabled. NAD83 coordinates will be assumed to be identical to WGS84 coordinates for UTM grids.
- Valid time zone codes are listed in Table 3.4. For each gage the user *must* specify a time zone and whether daylight savings time is observed.

Table 3.4 Time Zone Labels and Offsets (in Minutes) from UTC

ID	Zone Name	Std Offset	DST Offset
HST	Hawaii-Aleutian	-600	-600
AST	Alaska	-540	-480
PST	Pacific	-480	-420
PNT	Phoenix	-420	-420
MST	Mountain	-420	-360
CST	Central	-360	-300
EST	Eastern	-300	-240
IET	Indiana Eastern	-300	-300
PRT	Puerto Rico/Virgin Islands	-240	-240
CNT	Canada Newfoundland	-210	-150
GMT	Greenwich Mean	0	60

3.3 Using Bias and Lapse Adjustments

To adjust grid values using scale biasing, the user sets the `AdjustMethod` parameter equal to `BIAS` in the control file and names a DSS gridded record to be used for scaling. The bias grid is named by specifying a DSS file name with the `AdjustGridFile` parameter, and a path name with the `AdjustGridPath` parameter. The extent of the adjustment grid must be large enough to include the full extent of the output grid and the locations of all the gages used in the interpolations.

In the example below, a month's average precipitation as estimated by the PRISM model is used as a source of bias factors for precipitation estimates

```
* Use bias grid to adjust precipitation values
AdjustMethod: BIAS
AdjustGridFile: rogueGrid.dss
AdjustGridPath: /SHG/ROGUE/PRECIP-AVER/01DEC/31DEC//
```

To adjust temperature grid values with a lapse rate, the user must set the `AdjustMethod` parameter equal to `Lapse` and use the `AdjustGridFile` and `AdjustGridPath` parameters to name a DSS gridded record containing elevations for the cells in the output grid. Elevations for gages can be specified on the gage lines in the control file. If the elevation of a gage is not given in the control file, GageInterp will read it from the elevation grid. The lapse rate can be set to a constant value or estimated by linear regression from the temperatures and elevations of the gages at each time step.

In the example below, temperatures are adjusted by a constant lapse rate of -0.0069 degrees Celsius per meter elevation. The negative value indicates that temperature will decrease with increasing elevation.

```
* Use fixed lapse rate to adjust temperatures
AdjustMethod: Lapse
LapseMethod: Fixed
LapseRate: -0.0069
AdjustGridFile: rogueGrid.dss
AdjustGridPath: /shg/rogue/elevation///ned-med/
```

If the `LapseRate` parameter is omitted when the `LapseMethod` is set to `Fixed`, the lapse rate will default to -0.0065 degrees Celsius per meter of elevation.

In the example below, temperatures will be adjusted by a lapse rate that changes with each time step, based on the temperatures reported at each gage.

```
* Use variable lapse rate to adjust temperatures
AdjustMethod: Lapse
LapseMethod: Calculate
AdjustGridFile: rogueGrid.dss
AdjustGridPath: /shg/rogue/elevation///ned-med/
```

In the examples, the elevation grids are derived from the National Elevation Dataset (NED). The procedures that were used for making these grids and loading them into DSS are described in Appendix Q.

3.4   Run-Time Messages

GageInterp prints status messages to both standard output (the terminal, or a file, if output is redirected) and standard error (also the terminal). The amount of status information is controlled by the VERBOSE option on the command line. The messages to standard output can include a list of

the gages used in the interpolation, summaries of the interpolated precipitation grids, warnings of negative, unreadable, or missing precipitation values at the gages, and warnings of missing or non-standard units in the precipitation data files. The warnings of negative, unreadable, or missing precipitation values and non-standard units are also sent to standard error, so these will appear twice if both standard out and standard error are directed to the terminal. Samples of run-time output are shown in Appendix B.

3.5   Interpolation Results

The results of the interpolation are written to the specified DSS file and path name as DSS grid data records. Grids in this format can be used as input to HEC-HMS and can be visualized with GridUtil. The program can also be used to generate precipitation and temperature inputs for the distributed snow process model (DSPM).

HEC has established the following naming convention for DSS grid records:

- A Part = Grid System (HRAP, SHG, and UTM are currently supported, see Appendix R for grid system definitions)
- B Part = Name of the region the grid represents
- C Part = The parameter represented by the grid (PRECIP, AIRTEMP, etc.)
- D and E Parts = Grid times (see explanation below)
- F Part = Version identifier.

Because each grid record represents a single instant or interval of time, the D and E parts of grid pathnames follow a different convention than the one for time series pathnames. For period cumulative (PER-CUM) grids, the D part contains the start date and time of the period and the E part contains the end date and time. For instantaneous (INST-VAL) grids, the D part contains the date and time of the grid values and the E part is blank. Dates and times are given in military style with date separated from time of day by a colon. Grid times should always be given in Universal Coordinated Time (UTC). For example, an instantaneous grid with a D part of 04JUL2001:1500 represents values at 3:00pm UTC (8:00am Pacific Daylight Time) on July 4, 2001.

- `/SHG/ROGUE/PRECIP/02JUN2003:0800/02JUN2003:0900/ GAGEINTERP/` identifies precipitation on the SHG grid over the Rogue River basin generated by GageInterp
- `/HRAP/ABRFC/PRECIP/02JUN2003:0800/ 02JUN2003:0900/MPE/` identifies precipitation on the HRAP grid loaded from an NWS multi-sensor precipitation estimate product from the Arkansas-Red Basin River Forecast Center
- `/SHG/FEATHER/AIRTEMP/11DEC2003:0700//LAPSE/` identifies air temperature over the Feather River basin generated by GageInterp using a lapse adjustment.

Interpolated precipitation values will typically show less variation than radar data. Interpolated values will always lie between the minimum and maximum gage values, and the highest and lowest precipitation intensities will appear to coincide with gage locations. If the maximum range option is used in the interpolation, there may be gaps in the precipitation data over the grid. If no gages are present within range to contribute to the precipitation estimate at a cell, that cell will be assigned a "no data" value. Malfunctioning or non-reporting gages may cause large areas in a grid to show "no data."
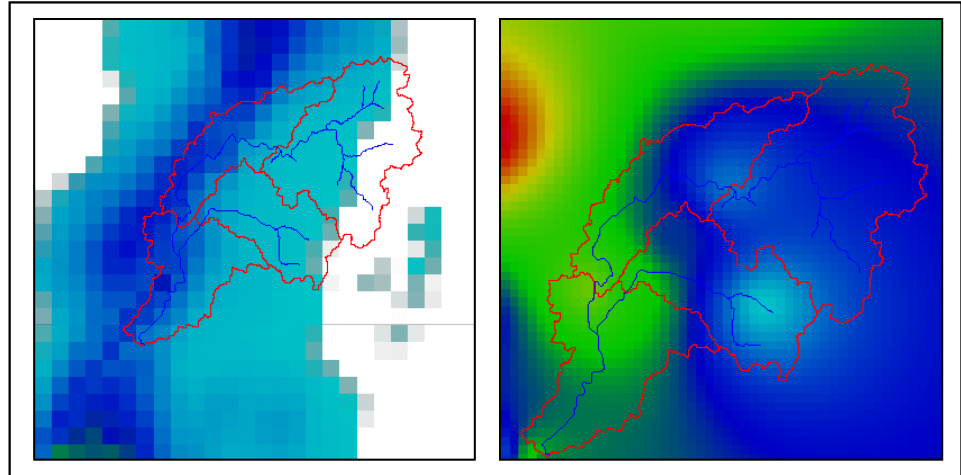

Figure 3.1 Radar (l) and interpolated (r) grids

Appendix A

Sample Control Files

A.1   SHG Sample

This file is configured for coverage of the Illinois River basin upstream of Tenkiller Dam. The basin is covered by two-kilometer cells in the Standard Hydrologic Grid (SHG). In this example all the gage data is read from a single DSS file named "in.dss", and all gages are used in the interpolation for each cell (that is, the interpolation range is unlimited).

```
* gageInterp control file for Illinois River
(Oklahoma)
* January 1995 storm event, peak intensity period
TimeStart: 13JAN95, 0000
TimeEnd:  14JAN95, 0600

OutFile: illgrids.dss
OutPath: /SHG/ILLINOIS/PRECIP///INTERPOLATED/

* Use inverse-distance-square weighted average for
interpolation
weight: id2w

* Include all gages in interpolation
range: UNLIMITED

*SHG region defined with geographic coordinates
GridType: SHG
CellSize: 2000
GridBounds:  -95.1342 35.5621  -94.0459 36.4595

**PRECIPITATION GAGES

DSSFile: in.dss

gage:  DUTC,  -942911,  355248
path: /ILLINOIS/DUTC/PRECIP-CUM///OBS
timezone: CST, Y

gage:  Gore,  95d04'07W,  35d34'23N
path: /ILLINOIS/GORE/PRECIP-CUM///OBS
timezone: CST, Y
```

```
gage:  Eldon,  94d50'18W,  35d55'16N
path: /ILLINOIS/ELDN/PRECIP-CUM///OBS
timezone: CST, Y
```

Remaining gage identifiers omitted

A.2   HRAP Sample

This file is configured for coverage of the Illinois River basin upstream of Tenkiller Dam. The basin is covered by cells in the Hydrologic Rainfall Analysis Project (HRAP) grid. In this example, the gage data is read from three separate DSS files, and gages must be within 25-kilometers of a cell to be included in the interpolation calculations for the value in that cell, except for the gage at Eldon, which has an extended radius of influence.

```
* gageInterp control file for Illinois River
(Oklahoma)
* January 1995 storm event, peak intensity period
TimeStart: 13JAN1995, 0400
TimeEnd: 15JAN1995, 0800

OutFile: illgrids.dss
OutPath: /HRAP/ILLINOIS/PRECIP///INTERPOLATED/

* Use inverse-distance-square weighted average for
interpolation
weight: id2w

* Include gages within 25km of cell in interpolation
range: 25000

* HRAP grid specified with geographic coordinates
*GridType: HRAP
*GridBounds: -94.939 36.459 -94.249 35.468

* Same HRAP grid specified by cells
GridType: HRAP
GridOrigin: 621, 334
GridRows: 21
GridCols: 30

* Precipitation Gages

DSSFile: 1=grand.dss
DSSFile: 2=arkansas.dss
DSSFile: 3=illinois.dss
```

```
* note: no spaces in gage name (lon and lat in
ddmmss)
gage: Ft_Gibson,  -961345,  355115
timezone: CST, N
path: 1:/GRAND/FGIB/PRECIP-INC///OBS/

* (lon and lat in decimal degrees)
gage: Lake_Hudson,  -95.1933,  36.2317
timezone: CST, N
*This gage uses the same DSS file as the last gage
path: /GRAND/HUDS/PRECIP-INC///OBS/


* (lon and lat in delimited degrees, minutes,
seconds)
gage: Tiff_City,  94d35'12W,  36d37'50N
timezone: CST, N
path: /GRAND/TIFF/PRECIP-INC///OBS/

gage: Gore,  95d04'07W,  35d24'23N
path: 3:/ILLINOIS/GORE/PRECIP-INC///OBS/
timezone: CST, N

*This gage has an extended radius and will
* affect cells up to  40km away
gage: Eldon,  94d50'18W,  35d55'16N
timezone: CST, N
radius: 40000
path: /ILLINOIS/ELDN/PRECIP-INC///OBS/

* NAD83 coordinates for this gage
gage: Kansas,  94d42'31W,  36d01'54N
timezone: CST, N
path: /ILLINOIS/KANS/PRECIP-INC///OBS/
Datum: NAD83

gage: Tenkiller,  95d02'57W,  35d33'48N
path: /ILLINOIS/TENK/PRECIP-INC///OBS/
timezone: CST, N

gage: Tahlequah,  94d55'15W,  35d55'17N
timezone: CST, N
path: /ILLINOIS/TAHL/PRECIP-INC///OBS/

gage: Watts,  94d34'12W,  36d07'48N
timezone: CST, N
path: /ILLINOIS/WATT/PRECIP-INC///OBS/

gage: Dutch_Mills,  94d29'11W,  35d52'48N
path: /ILLINOIS/DUTC/PRECIP-INC///OBS/
timezone: CST, N
```

```
gage: Muskogee,  95d17'55W,  35d46'10N
path: 2:/ARKANSAS/MUSK/PRECIP-INC///OBS
timezone: CST, N

gage: Webber's_Falls,  95d10'06W,  35d35'12N
path: /ARKANSAS/WEBB/PRECIP-INC///OBS/
timezone: CST, N
```

A.3   UTM Sample

This file is configured for coverage of the Russian River basin in norther California. The basin is covered by cells defined in UTM coordinates.

```
* gageInterp for Russian River basin

*TimeStart: 15DEC2005, 0000
TimeStart: 16DEC2005, 0000
*TimeEnd: 17DEC2005, 2400
TimeEnd: 06JAN2006, 2400
TimeStep: 60

GridType: UTM 10N
CellSize: 2000

GRIDBOUNDS: -123d30'21.7", 39d27'27.7", -
122d27'3.5", 38d11'32.8"

Outfile: precip.DEC05.dss
OutPath: /UTM10N/Russian/precip///INTERPOLATED/

DSSFile: RussianRainGages.dss

*Ukiah adjustment to be used for run DEC2005
gage: UKIAH CA US, -123.2, 39.15
path: //UKIAH CA US/PRECIP-
INC/01DEC1964/1HOUR/DISTRIBUTED/
timezone: PST, N
Datum: NAD83

*Cloverdale adjustment to be used for run DEC2005
gage: CLOVERDALE CA US, -122.98333, 38.76667
path: //CLOVERDALE CA US/PRECIP-
INC/01DEC1964/1HOUR/DISTRIBUTED/
timezone: PST, N
Datum: NAD83
```

```
*Healdsburg adjustment to be used for run DEC2005
gage: HEALDSBURG CA US, -122.83333, 38.61667
path: //HEALDSBURG CA US/PRECIP-
INC/01DEC1964/1HOUR/DISTRIBUTED/
timezone: PST, N
Datum: NAD83

*Santa Rosa adjustment to be used for run DEC2005
gage: SANTA ROSA CA US, -122.7, 38.45
path: //SANTA ROSA CA US/PRECIP-
INC/01DEC1964/1HOUR/DISTRIBUTED/
timezone: PST, N
Datum: NAD83

Gage: ANGWIN PAC UNION COL, -122.43333, 38.56667
Path: //ANGWIN PAC UNION COL/PRECIP-
INC/01NOV1967/IR-MONTH/040212/
TimeZone: PST, N

Gage: CLEARLAKE 4 SE, -122.63333, 38.96667
Path: //CLEARLAKE 4 SE/PRECIP-INC/01OCT1954/IR-
MONTH/041806/
TimeZone: PST, N

Gage: CLOVERDALE 1 S, -123, 38.8
Path: //CLOVERDALE 1 S/PRECIP-INC/01FEB1973/IR-
MONTH/041839/
TimeZone: PST, N

Gage: CLOVERDALE 11 W, -123.21667, 38.76667
Path: //CLOVERDALE 11 W/PRECIP-INC/01JAN1950/IR-
MONTH/041840/
TimeZone: PST, N
radius: 50000

Gage: HOPLAND 8 NE, -123, 39.01667
Path: //HOPLAND 8 NE/PRECIP-INC/01JAN1950/IR-
MONTH/044097/
TimeZone: PST, N

Gage: MAHNKE, -122.78333, 38.85
Path: //MAHNKE/PRECIP-INC/01JAN1956/IR-MONTH/045258/
TimeZone: PST, N
```

Appendix B

Sample Run-Time Messages

B.1   Standard Out

```
Run time:       26 June 2001,  09:18

***** Control File: shg.ctl *****

    -----DSS---ZOPEN:  Existing File Opened,  File: in.dss
                       Unit: 71;  DSS Versions - Software: 6-KG,
12 gages registered with interpolation grid.

Interpolation grid has 2550 cell(s).
6-IJ
    -----DSS---ZOPEN:  Existing File Opened,  File: illgrids.dss
                       Unit: 72;  DSS Versions - Software: 6-KG,

Period from 13 January 1995,  00:00 to 13 January 1995,  01:00 UTC
=- Period ending 13 January 1995, 01:00 UTC: All gages reporting data.
=- Grid ILLINOIS (2550 cells).  Cell values (mm): min: 0.00 mean: 0.00
max: 0.00
=- Cell Counts:  null: 0; =0: 2550; >0: 0; >=3: 0; >=12: 0; >=25: 0

Period from 13 January 1995,  01:00 to 13 January 1995,  02:00 UTC
Missing data: /GRAND/HUDS/PRECIP-CUM//1HOUR/OBS/
=- Period ending 13 January 1995, 02:00 UTC: 1 of 12 gages missing data.
=- Grid ILLINOIS (2550 cells).  Cell values (mm): min: 0.00 mean: 0.00
max: 0.00
=- Cell Counts:  null: 0; =0: 2550; >0: 0; >=3: 0; >=12: 0; >=25: 0
```

27 precipitation reports omitted

```
Period from 14 January 1995,  05:00 to 14 January 1995,  06:00 UTC
Missing data: /GRAND/HUDS/PRECIP-CUM//1HOUR/OBS/
Missing data: /GRAND/TIFF/PRECIP-CUM//1HOUR/OBS/
=- Period ending 14 January 1995, 06:00 UTC: 2 of 12 gages missing data.
=- Grid ILLINOIS (2550 cells).  Cell values (mm): min: 0.01 mean: 1.53
max: 2.98
=- Cell Counts:  null: 0; =0: 0; >0: 2550; >=3: 0; >=12: 0; >=25: 0

Grid: ILLINOIS from 13 January 1995, 00:00 to 14 January 1995, 06:00 UTC
Values:  max of max: 12.59 min of min: 0.00 mean of mean: 1.62
6-KG
    -----DSS---ZCLOSE Unit:  71,    File: in.dss
               Pointer Utilization:  0.04
               Number of Records:      72
               File Size:   2679.8  Kbytes
               Percent Inactive:  79.4

    -----DSS---ZCLOSE Unit:  72,    File: illgrids.dss
               Pointer Utilization:  0.41
               Number of Records:     182
               File Size:    510.4  Kbytes
               Percent Inactive:  42.2
```

B.2   Standard Error

Standard Error:

```
Negative Precip reported for path /ILLINOIS/TAHL/PRECIP-CUM//1HOUR/OBS/
   from 13 January 1995,  04:00 to 13 January 1995,  05:00.
Negative Precip reported for path /ILLINOIS/TAHL/PRECIP-CUM//1HOUR/OBS/
   from 13 January 1995,  08:00 to 13 January 1995,  09:00.
Negative Precip reported for path /ILLINOIS/TAHL/PRECIP-CUM//1HOUR/OBS/
   from 13 January 1995,  12:00 to 13 January 1995,  13:00.
```

Appendix C

Grids in DSS

C.1   Identifying Grid Records in DSS

Grid records in DSS are named according to a naming convention that differs slightly from the convention for time-series or paired-data records. Grids represent data over a region instead of at a single location and one grid record contains data for a single time interval or instantaneous value. The naming convention assigns the six pathname parts as follows.

- **A-part:** Refers to the grid reference system. At present, GageInterp supports the HRAP and SHG grid systems as well as a UTM-based system that can be used outside the conterminous USA. For examples of grid A parts, see below. See appendices D, E and F for details of the grid systems.
- **B-part:** Contains the name of the region covered by the grid. For radar grids, this could be the name of the NWS River Forecast Center that produces the grid. For interpolated grids, this could be the name of a watershed.
- **C-part:** Refers to the parameter represented by the grid. Examples include PRECIP for precipitation, AIRTEMP for air temperature, SWE for snow-water equivalent, and ELEVATION for ground surface elevation.
- **D-part:** Contains the start time. This is the starting time of the interval covered by the grid. The date and time are given military-style (DDMMMYYYY for date and HHMM for time on a twenty-four hour clock) and the date and time are separated by a colon (:). All times for grids should be given as UTC. Midnight is represented by 0000 if it is a starting time and 2400 if it is an ending time.
- **E-part:** Contains the end time. This is the ending time of the interval covered by the grid. The E part is blank for grids of instantaneous values.
- **F-part:** Refers to the version of the data. The version identifies the source of the data or otherwise distinguishes one set of grids from another. Version labels include STAGEIII for NWS stage III radar products, and INTERPOLATED for grids produced by GageInterp.

DSS Grid pathname examples:

The A part of "SHG" in the pathname below indicates a 2000-meter cell size (the default) in the SHG system. The B part names the Rogue River in Oregon as the geographic extent of the grid. The C, D, and E parts indicate that the grid represents the accumulation of precipitation over basin for the hour ending at 1900 UTC on May 3,

2003. Although the Rogue basin is in Oregon, the grid follows the convention of using UTC time to mark start and end times for grid data. Finally, the F part indicates that this grid was generated by GageInterp.

/SHG/ROGUE/PRECIP/03MAY2003:1800/03MAY2003:1900/GAGEINTERP/

The pathname below names a precipitation grid for the Missouri River basin for the hour ending at 0100 UTC. The grid is produced by the Missouri Basin River Forecast Center (MBRFC) and is a product of the NWS's multi-sensor precipitation estimate. It is stored in HRAP grid system, as the MBRFC produces it.

/HRAP/MBRFC/PRECIP/22SEP2004:0000/22SEP2004:0100/MPE/

The pathname below names an HRAP grid representing a Quantitative Precipitation Forecast over the Ohio River Basin. This is a NWS product from the Ohio River RFC, and it covers the twenty-four hour period from noon June 1, 2001 to noon June 2, 2001 (UTC).

/HRAP/OHRFC/PRECIP/01JUN2001:1200/02JUN2001:1200/QPF/

The pathname below names an SHG temperature grid for the Rogue River basin. The cell size in this grid is 1000 meters instead of the default 2000 meters for SHG. Because the temperature is an instantaneous value at 0800, the E-part of the path is blank.

/SHG1K/ROGUE/AIRTEMP/22FEB2002:0800//GAGEINTERP/

<UTM example>

C.2   Contents of a Grid Record in DSS

Most HEC-DSS records, including time-series and grid records, consist of an array of sequential data and an associated header describing the data in the array. In a time-series record, the array represents the variation of a parameter's value through time at a fixed location. In a grid record, the array represents the variation of a parameter's value over a region of the earth's surface for a single time or interval of time. The header of a grid record contains metadata for the parameter values (their units and some summary statistics) and for the two-dimensional array in which the parameter values are stored (the number of rows and columns in the array, and the location of the grid in geo-referenced coordinates).

The contents of the header for four types of grid records in DSS are described in section C.4 below. The UNDEFINED grid header type contains basic parameter and grid extent information, common to all grid types. The headers for HRAP grids and Albers equal-area grids (including SHG grids) contain additional metadata and the specified reference header type (used for UTM-based grids) contains a complete definition of the spatial reference system of the grid.

C.3   Storage of Grid Values

In the DSS file, grid parameter values are stored in a single array, starting with the value in the minimum-x, minimum-y (or lower left) cell in the two-dimensional array. The values proceed by row in increasing column numbers and increasing row numbers, as illustrated in Figure C.1.
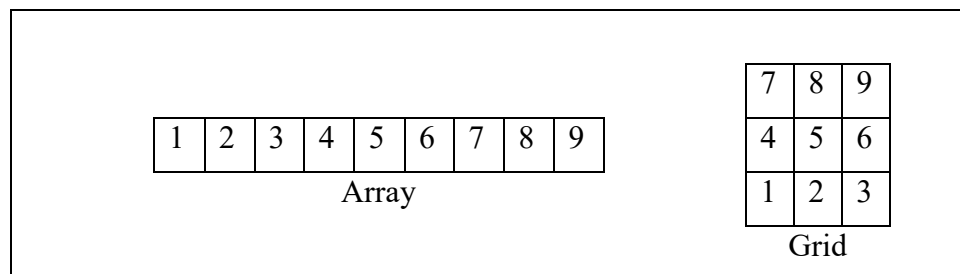

Figure C.1   One-Dimensional Array Storing Two-Dimensional Grid of Parameter Values

The array of parameter values is always compressed before it is written to a DSS file. Two compression methods are used. One is a run-length encoding method, which replaces repeated zero and null values with the number of times zero or null was repeated. The second method is the deflate method, which is included in the zlib library described in RFC 1950. The deflate format itself is described in RFC 1951. The deflate format and zlib are included in Javasoft's Java Development Kit version 1.1 and higher.

C.4   Grid Header Contents

Table C.1a   Grid Header Contents (All Types)

Field	Type	Size (integers)
Info Flat Size	Integer	1
Grid Type	Integer	1
Grid Info Size	Integer	1
Start Time	Integer	1
End Time	Integer	1
Data Units	Text	3
Data Type	Integer	1
Lower Left Cell X	Integer	1
Lower Left Cell Y	Integer	1
Number of Cells X	Integer	1
Number of Cells Y	Integer	1
Cell Size	Float	1
Compression Method	Integer	1
Compressed Array Size	Integer	1

Field	Type	Size (integers)
Compression Scale Factor	Float	1
Compression Base	Float	1
Max Data Value	Float	1
Min Data Value	Float	1
Mean Data Value	Float	1
Number of Ranges	Integer	1
Range Limit Table	Float	20
Range Counts	Integer	20

Notes:
- Info Flat Size should represent the size (in bytes) of the header of the grid record. This is somewhat implementation dependent and results may vary.
- Grid Type is the integer representation of the DSS record type of the grid. Grid types are numbered starting at 400, as follows.
    - 400: Unknown grid type. Grid Info contains only the common elements listed in table C.1a.
    - 410: HRAP grid type. Grid Info contains common elements and the HRAP data source. See table C.1b.
    - 420: Albers grid type. Grid Info contains common elements and Albers projection metadata. This is the type used for SHG grids. See table C.1b.
    - 430: Specified grid type. Grid Info contains common elements and additional metadata including a general-purpose definition of the spatial reference system. See table C.1c.
    - In some applications, a non-time-varying grid is incremented by adding 1 to the grid type, 411, for example could be used as the grid type of an HRAP grid of some fixed property, such as ground elevation. To date, use of this convention has been inconsistent. Grid types ending in 1 can safely be assumed to be time-invariant, but grid types ending in 0 cannot always be assumed to be members of a sequence of time-varying grids.
- Start Time and End Time are represented by an integer number of minutes since 31 Dec 1899, 00:00. This number can be converted to an `HecTime` using the set() method.
- Data Units is a string converted to Hollerith values. The three-integer field can contain up to 12 characters.
- Data Type is one of the following.
    - 0 = Period Average
    - 1 = Period Cumulative
    - 2 = Instantaneous Value
    - 3 = Instantaneous Cumulative
    - 4 = Frequency
    - 5 = Invalid

- Lower Left Cell X and Y, and Number of Cells X and Y represent the row and column number of the origin, and the extent in rows and columns of the grid in the record, relative to the numbering system implied by the grid reference system (HRAP, SHG, etc.).
- Cell Size is a float value cast to an "int" data type for storage. It represents the size, in meters, of a cell in the grid. Cells are assumed to be square.
- Compression Method:
  - 0 = Undefined Compression Method
  - 101001 = Precip 2 Byte
  - 26 = Deflate using the ZLIB library function.
- Compressed Array Size is the number of bytes used in the DSS record to store the compressed array of grid values.
- Compression Scale Factor and Compression Base are values used for scaling the data in the array for storage. The base is subtracted from each value and the result is divided by the scale Factor. For precipitation in mm, the base is 0, and scale is 100, so that 5.00mm of rain is represented in the stored array as 500.
- Min Data Value, Max Data Value, and Mean Data Value apply to non-null values in the array, with their conventional meanings.
- Number of Ranges, Range Limit Table, and Range Counts provide a data summary. The range count array contains, in decreasing order, the counts of cells that are less than or equal to, the range limit values stored in the range limit array (stored in order of increasing value). The tables can contain up to 20 values. The default range array table contains 13 values (NULL, 0.0, 1E-7, 5.0, 10.0, 20.0, 50.0, 100.0, 200.0, 500.0, 1000.0, 2000.0, and 5000.0) which were set for precipitation values in mm for durations on the order of an hour. Other ranges limits can be set through the programming interface.

Table C.1b Grid Header Contents (Fixed Spatial Reference)

Field	Type	Size (integers)
HRAP Headers append the following		
Data Source	Text	3
Albers Headers (including SHG) append the following		
Projection Datum	Integer	1
Projection Units	Text	3
First Standard Parallel	Float	1
Second Standard Parallel	Float	1
Central Meridian	Float	1
Latitude of Origin	Float	1
False Easting	Float	1
False Northing	Float	1
X Coordinate of Cell (0,0)	Float	1
Y Coordinate of Cell (0,0)	Float	1

Notes:
- Data Source field for HRAP headers can contain up to 12 ASCII characters using Hollerith encoding.
- Projection Datum for Albers headers is one of the following:
    - 0 = Undefined Projection Datum
    - 1 = NAD 27
    - 2 = NAD 83
- Projection Units field for Albers headers can contain up to twelve ASCII characters

Table C.1c Grid Header Contents (Specified Spatial Reference)

Field	Type	Size (integers)
Specified Grid Info Headers append the following		
Version Number	Integer	1
SRS Name Length	Integer	1
SRS Name	Text	As Specified
SRS Definition Type	Integer	1
SRS Definition Length	Integer	1
SRS Definition	Text	As Specified
X Coordinate of Cell (0,0)	Float	1
Y Coordinate of Cell (0,0)	Float	1
Null Value	Float	1
Time Zone ID Length	Int	1
Time Zone ID	Text	As Specified
Time Zone Raw Offset	Integer	1
Is Interval	Boolean	1
Is Time-Stamped	Boolean	1

Notes:
- Version number is an integer. When a change in the stored information occurs the number will be increased. No dots or sub-versions will be used.
- The Length fields for SRS Name, SRS Definition, and Time Zone ID specify the number of integers used to store the Hollerith-encoded (four characters per "int") SRS Name, SRS Definition, and Time Zone ID text fields.
- SRS Definition Type is one of the following:
    - 0 = Well-Known Text (WKT)
- Is Interval and Is Time-Stamped fields are stored as integers.
    - 0= False
   - 1 = True (any non-zero value will convert to True.)

Appendix D

HRAP Grid System

The Hydrologic Rainfall Analysis Project (HRAP) grid is a square-celled map grid based on a Polar Stereographic map projection with the following parameters.

```
Units: Meters
Datum: Sphere (radius = 6371.2 km)
Standard Parallel: 60° 0' 0" North
Central Meridian: 105° 0' 0" West
```

The mesh (cell) size of the grid is 4.7625 km, and the grid Y axis is aligned parallel with the central meridian (105° W). The grid is registered so that the North Pole lies exactly 400 cells in the positive X direction and 1600 cells in the positive Y direction from the grid origin. Equivalently, the lower left corner of cell number (401, 1601) is located at the North Pole.
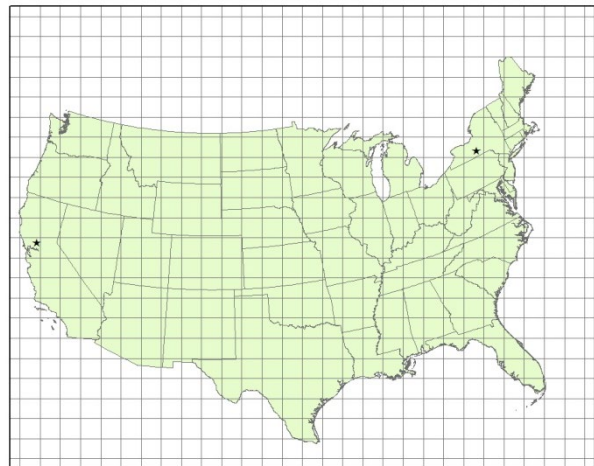
Examples

As examples of cell identification in the HRAP system, indices of cells containing points in the western US and the eastern US are given.

Western United States: The location 121º 45′ west, 38º 35′ north (near Davis, California) projects to 260,174 m easting, 2,143,782 m northing, in the specified polar stereographic projection. In the HRAP system the indices of the cell containing this point are:

i = 54
j = 450

Eastern United States: The location 76º 30′ west, 42º 25′ north (near Ithaca, New York) projects to 4,410,804 m easting, 3,018,420 m northing, in the specified polar stereographic projection. In the HRAP system the indices of the cell containing this point are:
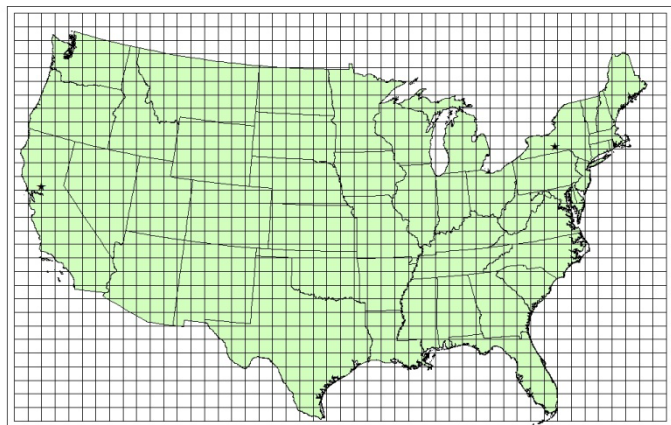
$$i = 926$$
$$j = 633$$

Appendix E

SHG Grid System

The standard hydrologic grid (SHG) is a variable-resolution square-celled map grid defined for the conterminous United States. The coordinate system of the grid is based on the Albers equal-area conic map projection with the following parameters.

```
Units: Meters
Datum: North American Datum, 1983 (NAD83)
1st Standard Parallel: 29° 30' 0" North
2nd Standard Parallel: 45° 30' 0" North
Central Meridian: 96° 0' 0" West
Latitude of Origin: 23° 0' 0" North
False Easting: 0.0
False Northing: 0.0
```

Users of the grid can select a resolution suitable for the scale and scope of the study for which it is being used. For general-purpose hydrologic modeling with NEXRAD radar precipitation data, HEC recommends 2000-meter cells, and HEC computer programs that use the SHG for calculation will select this cell size as a default. HEC will also support the following grid resolutions: 10,000-meter, 5,000-meter, 1,000-meter, 500-meter, 200-meter, 100-meter, fifty-meter, twenty-meter, ten-meter. The grids resulting from the different resolutions will be referred to as SHG two-kilometer, SHG one-kilometer, SHG 500-meter and so on. A grid identified as SHG with no cell-size indication will be assumed to have two-kilometer cells.

For identification, each cell in the grid has a pair of integer indices (i, j) indicating the position, by cell count, of its southwest (or minimum-x, minimum-y) corner, relative to the grid's origin at 96° W, 23° N. For example the southwest corner of cell (121,346) in the SHG two-kilometer grid is located at an Easting of 242000 meter and a northing of 692000

meter. To find the indices of the cell in which a point is located, find the point's easting and northing in the projected coordinate system defined above, and calculates the indices with the following formulas.

$$i = floor(\text{easting} / \text{cellsize})$$
$$j = floor(\text{northing} / \text{cellsize})$$

Where floor(x) is the largest integer less than or equal to x.

Examples

As examples of cell identification in the SHG system, indices of cells containing points in the western US and the eastern US will be given in the one-kilometer, two-kilometer, and 500-meter SHG grids.

Western United States: The location 121º 45′ west, 38º 35′ north (near Davis, California) projects to -2195054 meter easting, 2027427 meter northing, in the specified Albers projection. In the SHG two-kilometer system the indices of the cell containing this point are:

$$i = floor(-2195054 / 2000) = floor(-1097.5) = -1098$$
$$j = floor(2027427 / 2000) = floor(1013.7) = 1013$$

Eastern United States: The location 76º 30′ west, 42º 25′ north (near Ithaca, New York) projects to 1583489 meter easting, 2320553 meter northing, in the specified Albers projection. In the SHG two-kilometer system the indices of the cell containing this point are:

$$i = floor(1583489 / 2000) = floor(791.7) = 791$$
$$j = floor(2320553 / 2000) = floor(1160.3) = 1160$$

In the SHG one-kilometer grid the indices are (1583, 2320), and in SHG 500-meter the indices are (3167, 4640).

Appendix F

Standardized UTM Grid System

The HRAP and SHG systems are undefined outside the conterminous US. To make practical applications of gridded computations in HEC-HMS outside of the CONUS region easier, HEC has developed a grid system based on UTM coordinates, using the cell-numbering conventions of SHG. By selecting a UTM zone (including the selection of northern or southern hemisphere) and cell size, a user can apply a grid system anywhere that UTM coordinates can be used.
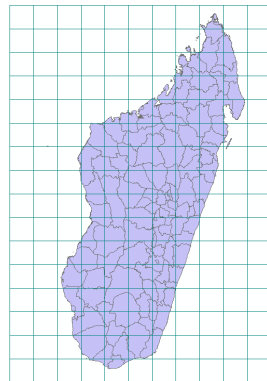

```
Units: Meters
Datum: World Geodetic System (WGS84)
Projected Coordinate System: Universal
Transverse Mercator (UTM)
Zones: 1-60, North(N) or South(S)

(Example: Island of Madagascar, UTM 38S,
cells are 100km square for illustration)
```

As with SHG, users of the grid can select a resolution suitable for the scale and scope of the study for which it is being used. HEC will support the following grid resolutions: 10,000-meter, 5,000-meter, 2,000-meter, 1,000-meter, 500-meter, 200-meter, 100-meter, fifty-meter, twenty-meter, ten-meter.

For identification, each cell in the grid has a pair of integer indices (i, j) indicating the position, by cell count, of its southwest (or minimum-x, minimum-y) corner, relative to the UTM zone coordinate origin. For example the southwest corner of cell (233, 4077) in a UTM two-kilometer grid is located at an Easting of 466000 meters and a northing of 8154000 meters. To find the indices of the cell in which a point is located, find the point's easting and northing in the projected coordinate system defined above, and calculates the indices with the following formulas.

$$i = floor(easting / cellsize)$$
$$j = floor(northing / cellsize)$$

where floor(x) is the largest integer less than or equal to x.

An Example

As examples of cell identification in a UTM spatial reference system, indices of cells containing points on the west and east coasts will be given in one-kilometer, two-kilometer, and 500-meter grids based on UTM zone 38S.

West coast: The location 43º 15′ 25" east, 22º 3′ 27" north (near the westernmost point of the island) projects to 320132 meters easting, 755978 meters northing, in the UTM zone 38 south. In a two-kilometer system the indices of the cell containing this point are:

$$i = floor(320132/ 2000) = floor(160.061) = 160$$
$$j = floor(755978/ 2000) = floor(377.989) = 377$$

In the one-kilometer grid the indices are (320, 755), and in the 500-meter grid, the indices are (640, 1511).

East coast: The location 50º 31′ 49" east, 15º 20′ 11" south (near the easternmost point of the island) projects to 449580 meters easting, 8304412 meters northing, in UTM zone 38 south. In a two-kilometer system the indices of the cell containing this point are:

$$i = floor(449580/ 2000) = floor(224.79) = 224$$
$$j = floor(8304412/ 2000) = floor(4152.206) = 4152$$

In the one-kilometer grid the indices are (449, 8304), and in the 500-meter grid, the indices are (899, 16608).

Note that a point at this longitude and latitude falls within the bounds of UTM zone 39 south. However, for this example it is assumed that one grid is being produced for precipitation over the whole island, so the coordinates are calculated for the westernmost zone (38 south) within the bounds of the grid.

Appendix G

Grid Import and Export Utilities

GageInterp requires that parameter grids like elevation grids for temperature lapse computations and pattern grids for precipitation bias computations must be stored as DSS grid records in the same grid system as the output grid. A GIS program with that supports raster data, like ArcInfo® or GeoMedia®, is generally required to create such grids, but those programs do not support DSS grids as a data format. Two utility programs are available to bridge the gap between raster GIS and grids in DSS through the use on an intermediate ASCII text file.

The programs are named `asc2dssGrid` and `dss2ascGrid`, and can be run from a Windows or UNIX command line or can be incorporated into scripts for integration between DSS and GIS programs.

The intermediate ASCII file is formatted for compatibility with the ArcInfo® ASCIIGRID command. The files consist of a six-line header followed by an array of values laid out like an image of the grid. The six header lines are:

NCOLS	<number of grid columns (integer)>
NROWS	<number of grid columns (integer)>
XLLCORNER	<Lower-Left X Coordinate (real)>
YLLCORNER	<Lower-Left Y Coordinate (real)>
CELLSIZE	<Cell size (real)>
NODATA_VALUE	<Value that indicates null cell>

The NODATA value defaults to -9999.

G.1   Importing grids to DSS with *asc2dssGrid*

The `asc2dssGrid` utility takes the following arguments

INPUT=<name of ASCII input file>
DSS=<name of DSS file>
PATH=<complete DSS path name>
GRIDTYPE=<HRAP, SHG, or UTM>
ZONE=<UTM zone identifier>
DUNITS=<data units>
DTYPE=<data type>

The arguments can be given in any order. The DUNITS and DTYPE arguments are optional. The imported grid's units default to mm if DUNITS is absent. If the PATH argument contains valid times in both the D and E parts, the imported grid's data type will default to PER-CUM. If

the E part (end time) is blank, the data type will default to INST-VAL. If the GRIDTYPE argument is absent, the grid type will be read from the A part of the path argument.

For example, the command:

```
asc2dssGrid in=grid.asc dss=mydss.dss
   path=/HRAP/TEST/PRECIP/23JUN2003:0100/23JUN2003:0200/IMPORT/
```

will treat the contents of the ASCII file *grid.asc* as though they were PER-CUM precipitation data reported in millimeter, and create an HRAP grid record with the given path in the given DSS file.

The program has some simple checks for data errors, such as missing files, unsupported data types, and unsupported cell sizes. It does not check for unsupported unit names or unreasonable data values.

The following command could be used to import an elevation grid for lapse computations.

```
asc2dssGrid in=elev.asc dss=mydss.dss DTYPE=INST-VAL
   DUNITS=METERS path=/SHG/ROGUE/ELEVATION///IMPORT/
```

G.2   Exporting grids from DSS with *dss2ascGrid*

The *dss2ascGrid* utility takes the following arguments:

> OUTPUT=<name of ASCII output file>
> DSS=<name of DSS file>
> PATH=<complete DSS path name>
> PRECISION=<number of decimal places>

The arguments can be given in any order. The following command will write the contents of a DSS grid record to an ASCII text file, which can be imported directly into ArcInfo®.

```
dss2ascGrid OUTPUT=precip_grid.asc dss=mydss.dss PREC=2
   path=/HRAP/TEST/PRECIP/23JUN2003:0100/23JUN2003:0200/IMPORT/
```

The text file may need additional modification before it can be imported to other GIS or surface analysis programs.

Appendix H

Using ArcGIS® to Build an Elevation Grid in DSS

In order to adjust temperature grids by lapse, GageInterp needs an elevation grid that covers the same region as the grids that will be computed. The elevation grid should be in the same grid system and have the same cell size as the output grids. The ArcGIS® procedure outlined below was used to produce an elevation grid in DSS starting from USGS DEMs.

This procedure worked in ArcGIS version 10.2. Updates to ArcGIS may change the function names or user interface components required to carry out these steps. These steps do not require ArcInfo® or ArcEditor® features (that is, it can be done with ArcView®) but it does require the Spatial Analyst® extension for grid operations.

1. If you don't have one already, create an ArcGIS® map (.mxd) for the watershed.

2. Create a data frame in the map with a coordinate system that matches the grid system (SHG or HRAP) you'll be using for your temperature grids. See Appendices D and E for coordinate system details.

3. Add an elevation grid to the data frame. This can be the DEM used for analysis in GeoHMS, or an elevation grid imported from the National Elevation Dataset (NED). Make sure that the elevations are given in either feet or meters and that you know which of those are used in the grid.

4. If you have them, add the GeoHMS themes that represent the watershed extent and stream network to the data frame. These won't be used in the analysis, but they are very helpful for making sure that your data covers the entire basin.

5. Project the DEM into your target coordinate system (SHG or HRAP) using the "Project Raster" tool in the Arc Toolbox under Data Management Tools => Projections and Transformations => Raster => Project Raster. (See figure. Note that the 40 m cell size and the optional Registration Point position of (0, 0) bring the DEM into tidy alignment with the SHG.)

6. From the HMS model's grid cell file, determine the minimum and maximum cell row and column numbers. You can load the file into a spreadsheet program or use the UNIX sort command to do this.
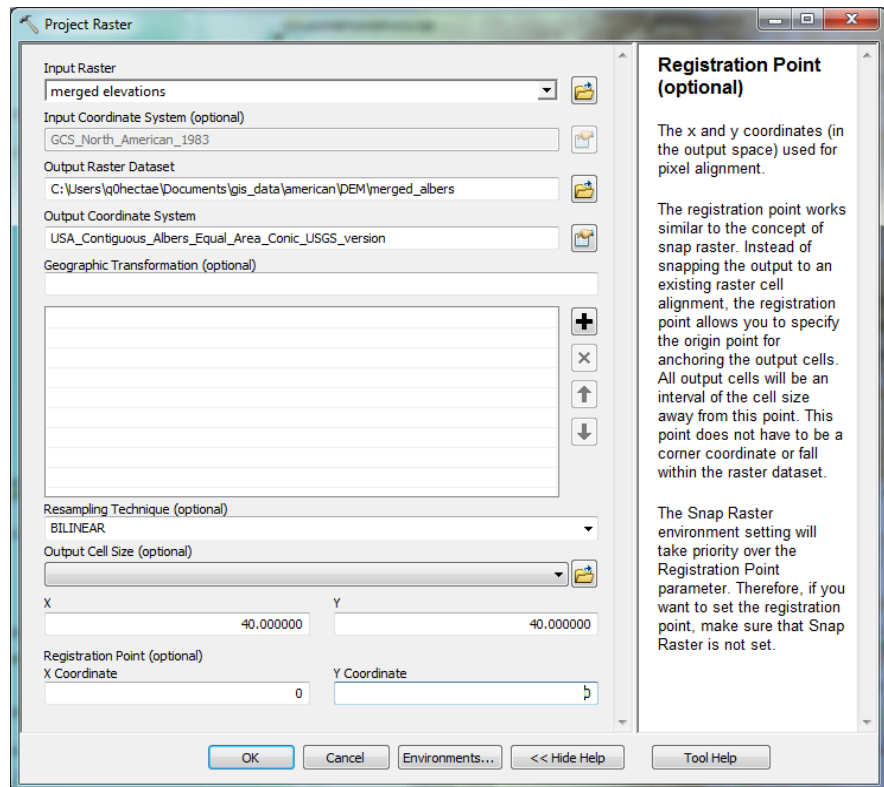
Multiply the row and column numbers by the cell size to convert them to coordinate values. (Add one cell to the maximum row and column numbers before multiplying to cover the entire area of the grid.).

7.   Select the "Aggregate" tool from the Spatial Analyst Tools => Generalization toolbox. Select your projected elevation grid as the input raster. Choose a cell factor that will produce your SHG cell size. (See figure, where we're using a region of 50 by 50 40-meter cells to produce a 2-km grid.) Select "median" as the overlay statistic (use mean if you prefer it to median) and select the location where the grid will be stored.
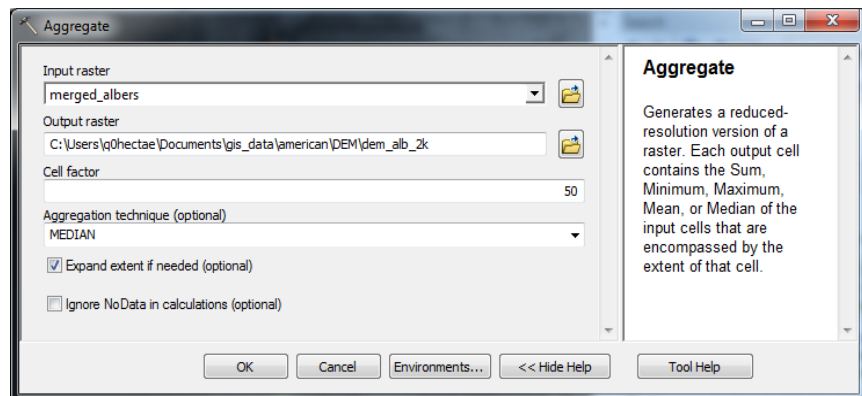
Click the "Environments…" button and expand the "Processing Extent" field. Fill in values for the processing extent to match edges of SHG cells at your cell size. (For two-km cells, the edge coordinates should end in even numbers followed by three zeroes.)
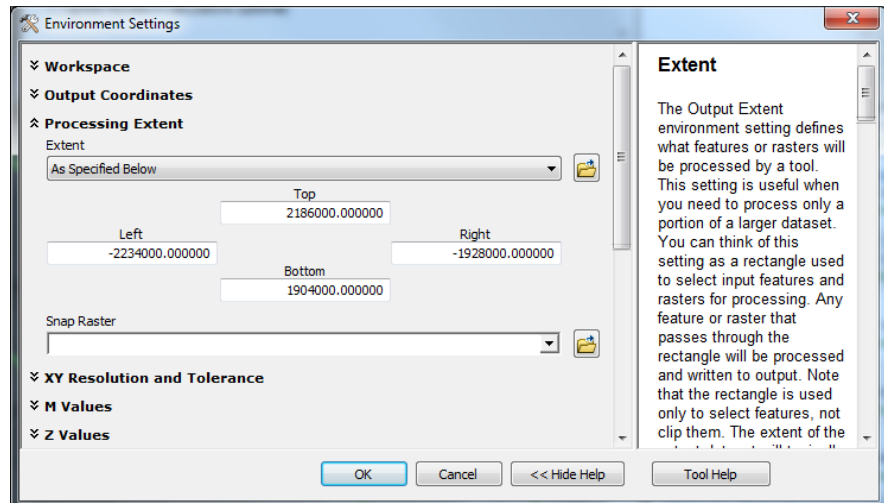

Press "OK" to close the environments dialog and "OK" to launch the aggregation computation.

8. Your data frame should now include a grid of representative elevations at the same resolution and in the same coordinate system as the temperature grids you will compute in GageInterp. The result should look something like the figure below.
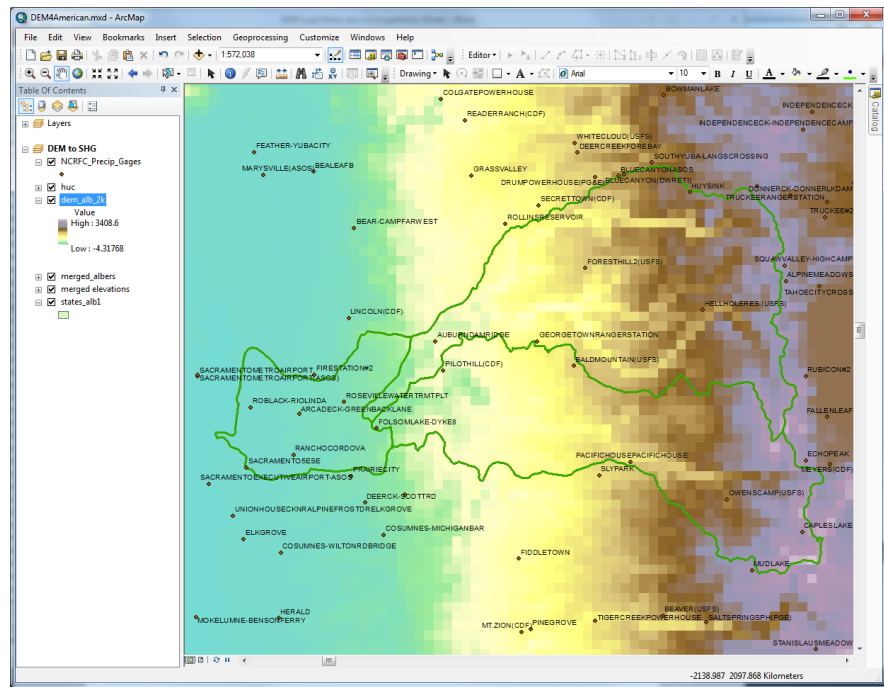
9.   Use the Raster to ASCII tool (Conversion Tools => From Raster => Raster to ASCII) to convert this coarse DEM to a text file for import to DSS.
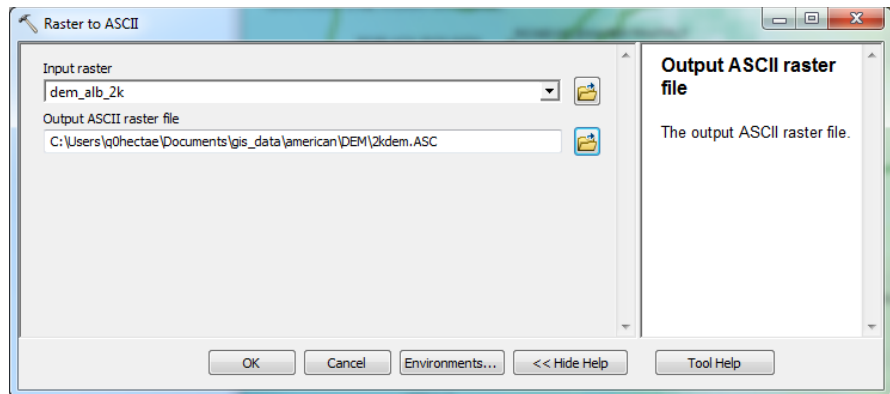
The header of the ASCII file should look something like this
```
ncols             153
nrows             141
xllcorner         -2234000
yllcorner         1904000
cellsize          2000
NODATA_value      -9999
```

Note the 2000 m cell size and that the X and Y coordinates of the origin position is an exact multiple of the cell size.

10.   Create a DSS grid record of the elevations by running *asc2dssGrid* on the ASCII file you created. Be sure to set the units correctly. GageInterp assumes that all elevation grids are in meters unless the units field in the grid header is "ft" or "feet" (spelled in upper or lower case)

References

Deutsch, Peter. May 1996. "DEFLATE Compressed Data Format Specification version 1.3," IETF RFC 1951; http://www.rfc-editor.org/rfc/rfc1951.txt

Deutsch, Peter and Gailly, Jean-Loup. May 1996. "ZLIB Compressed Data Format Specification version 3.3," IETF RFC 1950; http://www.rfc-editor.org/rfc/rfc1950.txt

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Reed, S. and Maidment, D. April 1999. "Coordinate Transformations for Using NEXRAD Data in GIS-Based Hydrologic Modeling," *Journal of Hydrologic Engineering* Vol. 4, No. 3. ASCE, New York.

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