Arizona Heat Unit Program

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Introduction

Environmental temperatures impact the growth and development of biological organisms that do not regulate their internal temperature, including crops and crop pests. Heat unit systems quantify the thermal environment of these organisms and are commonly used in models that predict their growth and development. While a number of procedures have been proposed to calculate heat units, Arizona has largely adopted the sine curve computation approach (Brown, 1989; Brown, 1991) which consists of forcing a sine curve through the daily maximum and minimum temperatures and then using mathematical integration to determine the area bounded by the sine curve and the upper and lower temperature thresholds of the organism in question (Figure 1). One limitation to using the sine curve computation procedure is that of performing the mathematical integration. Snyder (1985) developed a streamlined procedure for this integration which has been used by the Arizona Meteorological Network (AZMET) to compute heat units. This procedure has now been programmed into a convenient Microsoft Excel Workbook known as the Arizona Heat Unit Program (AHUP). The AHUP allows the user to enter temperature data and then computes heat unit data using the sine curve computation procedure. This manual describes the procedures required to compute heat units using AHUP.

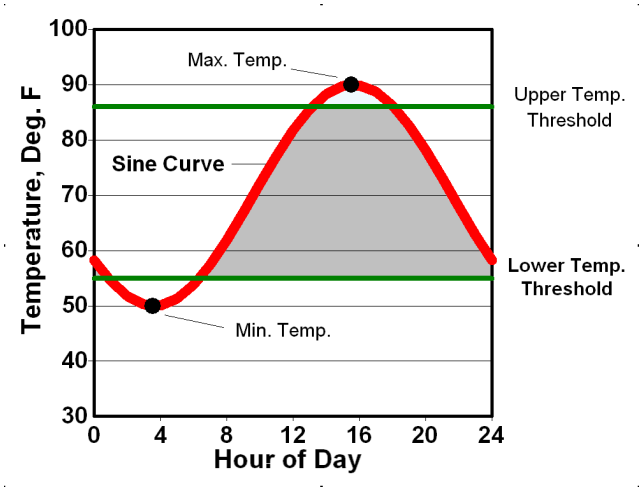

Figure 1. Graphical depiction of heat unit computation using the single sine curve procedure. The area bounded by the sine cure and the two temperature thresholds (grey area) represents the daily accumulation of heat units in units of degrees-F-days.

Software/Computer Requirements

The Arizona Heat Unit Program was developed using Microsoft Excel 2003, but is fully compatible with Excel 2007 and Excel 2010. The filename assigned to AHUP is AHUP.xls. The program will run on any computer configured to run Excel versions 2003, 2007 and 2010.

Using the Program

The first step in using the program is to run the Excel program that is resident on your computer. Once Excel is loaded, open the AHUP.xls file. Your Excel software may issue a security warning at this point indicating AHUP contains Macros and that Macros may contain viruses. Click the box labeled enable Macros to ensure proper program operation.

Once loaded, the program generates an Excel workbook that contains three worksheets labeled as Output, Data Import and Calculations. The Output worksheet is the primary worksheet for the program and allows the user to 1) enter temperature thresholds for the heat unit system of interest, 2) enter temperature data to be converted to heat unit values by the program and 3) obtain the heat unit values computed from the input temperatures. The Data Import worksheet is a blank worksheet that can serve as an initial entry point for data imported from external sources (e.g., AZMET ASCII text files containing temperature data). The Calculations page provides the intermediate data used in the calculation of heat units and can not be altered by the user.

Figure 2 shows the general layout of the Output worksheet. There are four sections to the Output sheet which are labeled A through D in the Figure 2. The box in the upper lefthand corner (A) is used to enter the temperature thresholds and units (deg. C or deg. F) for the heat unit system of interest. The second section located near the middle of the worksheet (B) is where temperature data is entered into the program while the two sections located to the right (C and D) provide daily and cumulative totals of heat units computed in units of degree-F-days and degree-C-days.

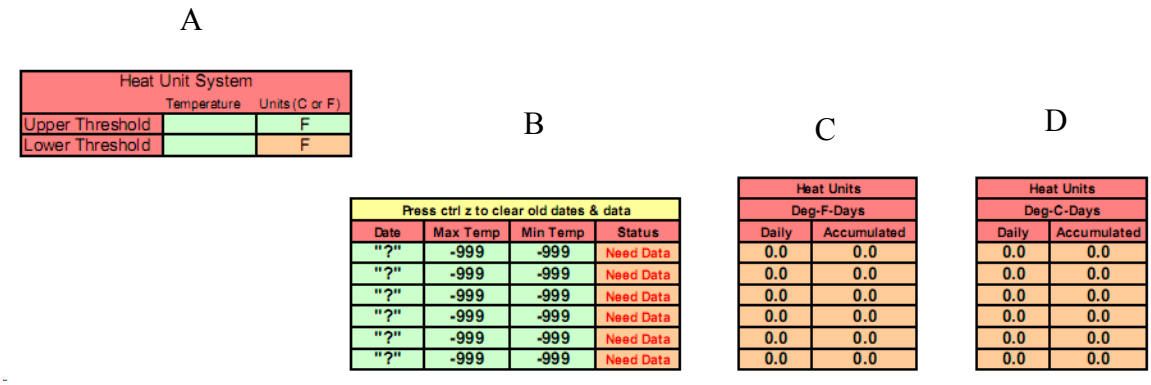

Figure 2. General layout of the Output worksheet.

The upper and lower temperature thresholds for the selected heat unit system must be entered in the green cells located to the right of the cells containing the labels **Upper Threshold** and **Lower Threshold**, respectively (Figure 2A). The units for the temperature system (degree C or degree F) should be entered as a single letter (F or C) in the green cell located under the cell labeled **Units**. Figure 3 shows the appropriate entries for the Arizona cotton heat unit system that uses upper and lower temperature thresholds of 86°F and 55°F, respectively. It is important to note that the units entered in the Heat Unit System box must be the same as the temperature data that will be used to calculate heat units. If for example you need to calculate Arizona cotton heat units, but your temperature data is in °C, the temperature thresholds must be converted to °C. In this case, one would enter 30 for the upper threshold and 12.78 for the lower threshold and C for the units.

Heat Unit System		
	Temperature	Units (C or F)
Upper Threshold	86	F
Lower Threshold	55	F

Figure 3. The upper and lower temperature thresholds and the appropriate temperature unit (F) are entered into the green boxes as shown above.

Temperature data is then input into the three green columns located under the labels **Date**, **Max Temp** and **Min Temp** (Figure 2B). It is best to enter a **ctrl z** from you keyboard prior to entering temperature data. The **ctrl z** removes the old data and populates the cell with dummie variables which are replaced as one enters new data. There is no required format for the date, but temperatures must be entered using the same units (°F or °C) as designated in the Heat Unit System box (Figure 2A). Enter only the numerical temperature values, not the units (i.e., °F or °C) when entering temperature data. The column labeled **Status** provides a status code that relates to the entered temperature data. The status code can be any of the following: **Need Data**, **Max<Min**, or **OK** (Figure 4). The **Need Data** code appears when one of the temperature values is missing (contains the dummie variable -999). The presence of the **Need Data** code will preclude the computation of heats until both columns have valid temperature data. The **Max<Min** code appears any time the entered maximum temperature is less than the entered minimum temperature (transposed temperatures). This situation must be corrected to proceed with the heat unit calculation. The final status code, **OK**, appears any time the maximum temperature is greater than the minimum temperature and neither temperature is listed as -999. Heat units will be calculated only when the status code is listed as **OK**. Note that the **OK** status code means the temperature data meet the required conditions for heat unit computation. The code does not mean the data are correct. It is the user's responsibility to enter the data correctly.

Press ctrl z to clear old dates & data			
Date	Max Temp	Min Temp	Status
15-Jul	85	45	OK
16-Jul	45	82	Max<Min
17-Jul	-999	-999	Need Data

Figure 4. Examples of temperature data that generate the three Status codes. The data for 15 July carries the **OK** code because data are entered correctly. The data for 16 July carries the **Max<Min** code because the maximum temperature is less than the minimum temperature. The temperature values need to be switched to generate the **OK** status code. The **Need Data** code appears on 17 July because the dummie values -999 are present in the maximum and minimum temperature cells, indicating no temperature data has been entered.

The resulting heat unit information is summarized in the heat unit output blocks located to the right of the temperature data (Figure 2C & 2D; orange background). The program automatically provides heat unit values in both degree-F-days and degree-C-days. The output block closest to the temperature data will always provide heat unit information in the same units as the temperature data. The output block farthest from the temperature data will provide the heat unit information using the opposite temperature scale.

Figures 5 provides an example of program output for the period of 1 July through 6 July when using temperature data in °F and upper and lower temperature thresholds of 86°F and 55°F, respectively. Heat unit information computed in units of degree-F-days is summarized in the output block located to the right of the temperature data. The output block on the far right contains the same heat unit information presented in units of degree-C-days. Note that the output blocks provide both the daily heat unit value and the total number of heat units accumulated for the period of data entry.

Heat Unit System		
	Temperature	Units (C or F)
Upper Threshold	86	F
Lower Threshold	55	F

Press ctrl z to clear old dates & data			
Date	Max Temp	Min Temp	Status
1-Jul	96	65	OK
2-Jul	100	72	OK
3-Jul	105	67	OK
4-Jul	103	76	OK
5-Jul	105	80	OK
6-Jul	107	77	OK

Heat Units	
Deg-F-Days	
Daily	Accumulated
23.0	23.0
26.6	49.6
25.0	74.5
28.3	102.9
29.7	132.6
28.8	161.4

Heat Units	
Deg-C-Days	
Daily	Accumulated
12.8	12.8
14.8	27.5
13.9	41.4
15.7	57.1
16.5	73.6
16.0	89.7

Figure 5. Program output for temperature data entered in °F for the period 1 July through 6 July when upper and lower temperature thresholds are set at 86°F and 55°F, respectively.

Figure 6 shows the program output when the temperature data presented in Figure 5 is entered in °C. Note that in this case the upper and lower temperature thresholds are entered in °C as well (30°C/12.78°as compared to 86°F/55°F). In this case, the output block adjacent to the temperature data now provides heat unit information in degree-C-days while the output block on the far right

provides the same information in degree-F-days. The daily totals are similar in both Figures 5 and 6. There is a slight difference 0.1 degree day difference in the cumulative totals that results due to rounding errors associated with converting the temperature data from °F to °C.

Heat Unit System		
	Temperature	Units (C or F)
Upper Threshold	30	C
Lower Threshold	12.78	C

Press ctrl z to clear old dates & data			
Date	Max Temp	Min Temp	Status
1-Jul	35.55	18.33	OK
2-Jul	37.78	22.22	OK
3-Jul	40.56	19.44	OK
4-Jul	39.44	24.44	OK
5-Jul	40.56	26.67	OK
6-Jul	41.66	25	OK

Heat Units	
Deg-C-Days	
Daily	Accumulated
12.8	12.8
14.8	27.5
13.9	41.4
15.7	57.1
16.5	73.6
16.0	89.6

Heat Units	
Deg-F-Days	
Daily	Accumulated
23.0	23.0
26.6	49.5
25.0	74.5
28.3	102.8
29.7	132.5
28.8	161.3

Figure 6. Program output for temperature data entered in °C for the period 1 July through 6 July when upper and lower temperature thresholds are set at 30°C and 12.78°C, respectively.

The program is set up to handle up to a year of temperature data (366 days) which can either be entered by hand or, if available from computer, imported into the spreadsheet and then pasted into the temperature input block. The Data Input worksheet may serve as the repository for imported data. For example, suppose one wants to compute heat units using the Raw Daily ASCII text files available from the Arizona Meteorological Network. The first step is to download the file of interest from the AZMET website located at:

http://ag.arizona.edu/azmet

This data file can easily be imported into the workbook using the **Import Data** (Excel 2003 & 2007) or **Get External Data From Text** (Excel 2010) instructions which are accessed via the main menu bar by clicking on the word **Data**. Select the comma as the delimiter when importing raw ASCII data files from AZMET. The files should import easily into columns which can be labeled if needed (Figure 7).

Once the file is imported into the spreadsheet, simply copy the appropriate columns containing the dates and the maximum and minimum temperatures to the temperature input block on the Output worksheet. The resulting heat unit information will be reported in the appropriate output blocks (Figure 8).

Some heat unit systems do not use an upper temperature threshold. This situation is easily handled within AHUP by entering the numerical value of 200 in the green worksheet cell located to the right of the cell labeled **Upper Threshold** (Figure 9). The program will never impose an upper thermal limit when calculating heat units since 200 in °C or °F exceeds the peak temperatures that occur in the natural environment.

Year	Day	Loc	Tx,C	Tn,C	T, C	Rhx,%	Rhn,%	Rh,%
2009	1	2	22.1	4	12.9	91.6	24.5	52.5
2009	2	2	21.4	3.6	11.5	89.7	26.3	63.2
2009	3	2	18	5	12.4	93	37.4	63.2
2009	4	2	16	9.1	12.4	42.8	14.4	23.9
2009	5	2	16.2	-1.4	7.8	77.1	15.9	42.3
2009	6	2	18	0.2	8.6	81.5	16.4	49.9
2009	7	2	21.1	2.6	10.4	81.2	21.4	54

Press ctrl z to clear old dates & data			
Date	Max Temp	Min Temp	Status
"?"	-999	-999	Need Data
"?"	-999	-999	Need Data
"?"	-999	-999	Need Data
"?"	-999	-999	Need Data
"?"	-999	-999	Need Data
"?"	-999	-999	Need Data
"?"	-999	-999	Need Data

Figure 7. The first nine columns of the Data Input worksheet after importing a raw daily ASCII text file from AZMET (left). The column labels were added to the worksheet after importing. Columns with a yellow background represent data that will be transferred to the Output worksheet as indicated (right).

Heat Unit System		
	Temperature	Units (C or F)
Upper Threshold	30	C
Lower Threshold	12.78	C

Press ctrl z to clear old dates & data			
Date	Max Temp	Min Temp	Status
1	22.1	4	OK
2	21.4	3.6	OK
3	18	5	OK
4	16	9.1	OK
5	16.2	-1.4	OK
6	18	0.2	OK
7	21.1	2.6	OK

Heat Units	
Deg-C-Days	
Daily	Accumulated
3.0	3.0
2.7	5.7
1.5	7.1
1.0	8.1
0.7	8.8
1.2	10.1
2.5	12.5

Heat Units	
Deg-F-Days	
Daily	Accumulated
5.4	5.4
4.8	10.2
2.6	12.9
1.8	14.6
1.2	15.8
2.2	18.1
4.5	22.6

Figure 8. Program output after the temperature data presented in Figure 7 is copied to the temperature input section of the Output worksheet.

Heat Unit System		
	Temperature	Units (C or F)
Upper Threshold	200	F
Lower Threshold	60	F

Heat Unit System		
	Temperature	Units (C or F)
Upper Threshold	200	C
Lower Threshold	15.56	C

Figure 9. Enter a 200 in the worksheet cell containing the upper temperature threshold when computing heat units using a system that does not have an upper thermal limit. The value 200 will work for temperatures in °F (left) and °C (right).

Heat unit data generated by AHUP can be saved in several ways. Data can be saved on the Output worksheet if program operation is terminated by saving the program. This is accomplished by clicking on the word **File** on the main Excel menu bar which displays a pull down menu. Click on the word **Save** and both the program and the heat unit data will be saved. Saving data in this manner

represents a short term solution since the next time the program is used and new data entered, the old heat unit information will be replaced. A better alternative for saving data is to copy the entire Output worksheet to a blank worksheet page within AHUP or in another workbook file. A new worksheet can be inserted into the AHUP program by clicking on **Insert** in the Excel 2003 and 2007 menu bar, then clicking on the word **Worksheet** in the pull down menu. Simply click on the right most worksheet tab (file folder with asterick in upper lefthand corner used as tab label) to add a worksheet in Excel 2010. One can then copy the contents of the Output worksheet to this blank worksheet page for permanent storage. It is advisable to label the data set by either inserting a text label on the worksheet or by renaming the worksheet page. Worksheets can be renamed by right clicking on the worksheet tab, then clicking on the word **Rename**. One can then type in a label for the new worksheet.

References

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