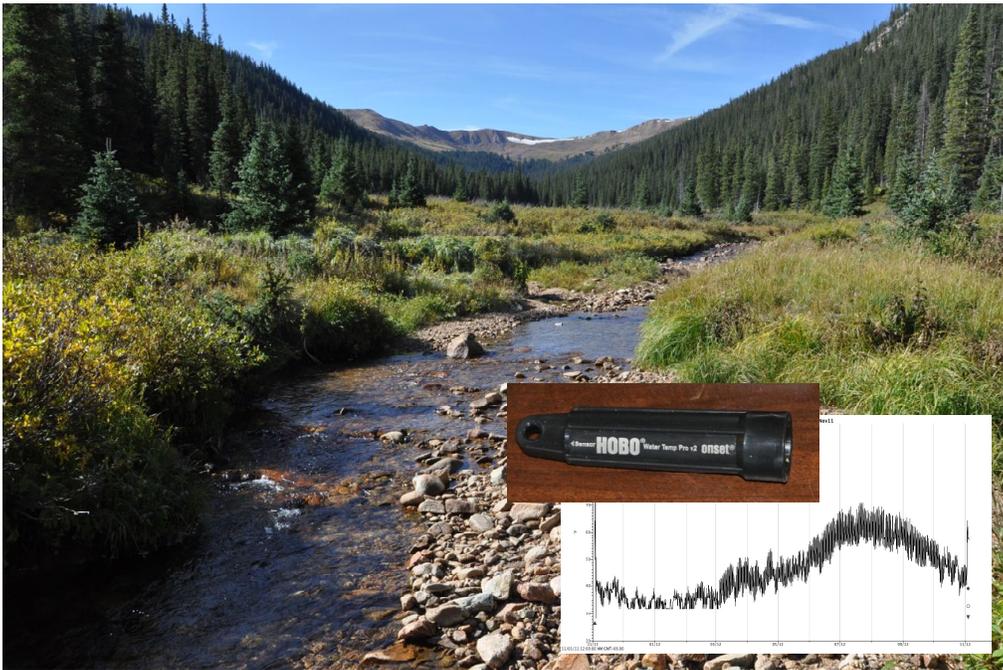


# WaTSS User Manual

*Water Temperature Summary Software*



Version 3.0  
January 2015

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# User manual for WaTSS 3.0 (Water Temperature Summary Software)

Manual Version 3.0.1

January 30, 2015

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## **Overview**

Water temperature is perhaps the single most important environmental parameter for fish (Magnusen et al. 1979). As ectothermic organisms, ambient temperature drives survival (Dickerson and Vinyard 1999, Bear et al. 2007, Underwood et al. 2012, Brinkman et al. 2013), behavior (Casselmann 1978, Mesing and Wicker 1986, Cook and Bergersen 1988, Rogers 1998), growth (Selong et al. 2001, Meeuwig et al. 2004, Bear et al. 2007, Ziegler et al. 2013, Brinkman et al. 2013), and other physiological processes (Brett 1979), as well as defining the range a fish can occupy (Dunham et al. 2003, de la Hoz Franco and Budy 2005). Recent concerns over changing climactic conditions on fish (Ficke et al. 2007, Rahel and Olden 2007, Wenger et al. 2011, Peterson et al. 2013, Roberts et al. 2013) and its implications for persistence of threatened or endangered species has led to a proliferation of water temperature monitoring efforts (Isaak et al. 2012, Ziegler et al. 2013b). The combination of heightened interest coupled with the availability of relatively inexpensive and durable temperature loggers has precipitated an explosion in the use of these devices that has spread to applied uses in fish management as well, beyond just monitoring water quality. From detecting timing of fry emergence that inform water management practices to predicting optimum timing to implement successful wild spawn operations, use of these devices is becoming routine. While inexpensive remote temperature loggers have been available for several decades, interpreting the resulting data has been hampered by the lack of user friendly software. The hope is that this program can serve as a developing platform to make common analyses of temperature data readily available to managers and researchers alike.

## **Installation**

To install off the application CD to a PC running Windows 7 (other operating systems will be similar), open the WaTSS Installer folder and double click on the setup.exe file (if extensions are not displayed on your computer, select the larger of the two setup files). Your computer will likely ask if it is OK to allow the program from an unknown publisher to make changes to your computer – select yes (and enter your user name and password if it asks). The default configuration will install the program in your program folder (available from you program menu), as well as place a shortcut on your desktop. If you are OK with that, click “Next”, then click the “Accept” radio button on the License Agreement window, then “Next” a couple of times. The program is unfortunately quite large (154 mB) so it will take a little time to install. When the installation is complete, click “Finish”. You may need to restart your computer to get the WaTSS 3.0 program to show up in your Programs menu.

To download WaTSS off the web, visit

<http://cpw.state.co.us/learn/Pages/ResearchAquaticSoftware.aspx> click on the software tab in the left dropdown menu. Scroll down to the WaTSS description and click on the appropriate link.

## **Data preparation**

This program assumes that the user has acquired thermograph data using Onset Computer Corporation’s HOBOWare (Bourne, Massachusetts). Images presented in this manual come from Version 2.7.3 of HOBOWare

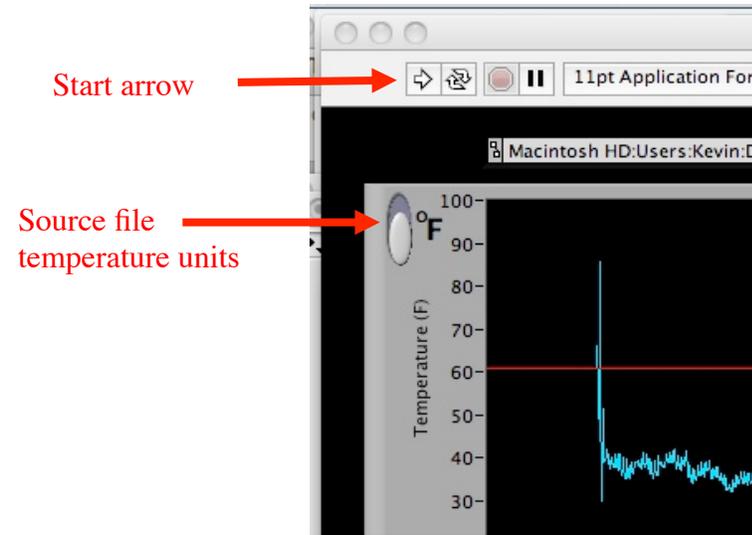
With the relevant data file displayed in HOBOWare, either select “Export Points as Excel Text” in the File menu or click on the “Export Table Data” button



In the “Export Options” window that appears, make sure the “Export to a single file” radio button is selected, then click “Export”. This should create a .csv file of the same name

## Running WaTSS

WaTSS can be invoked by selecting the program from the START menu (PC), or double clicking on the application (MacOSX). Once open, click the start arrow on the top left of the panel if the



program is not running already. You will be prompted to read in a data file. Make sure to select one that has been exported from HOBOware and has the .csv extension as described above. Make sure to select whether the data are in centigrade or Fahrenheit before proceeding with any analysis

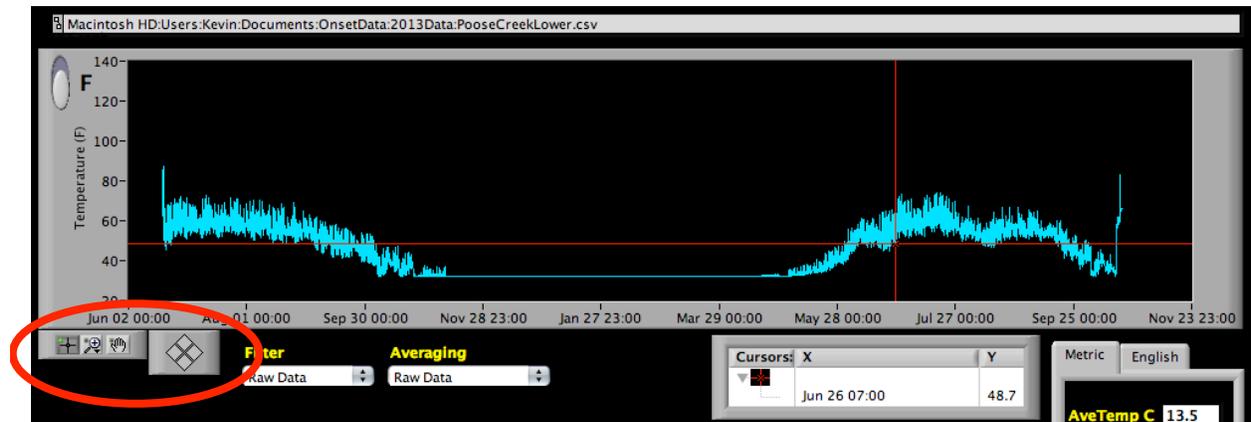
Once analysis of a given file is complete, press the red "STOP" button. If interpreting another tem-



perature file is desired, simply click on the start arrow again.

## Analysis

Raw temperature data is presented in the upper plot (blue line).



The y-axis scale can be modified by clicking on the upper or lower value and entering in a new number. Alternatively, one can use the following tools to explore the plot in greater detail:



Clicking on the zoom tool located on the bottom left corner of the plot allows zooming in on a portion of the trace.



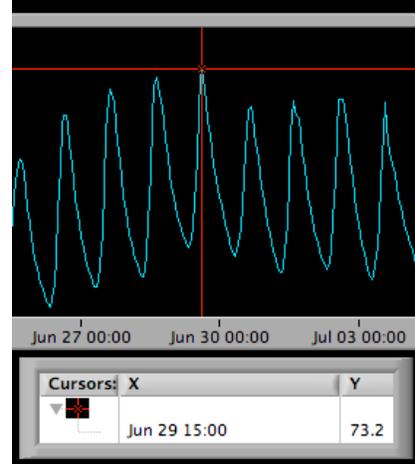
Clicking this button will return to the red cursor, so the user can direct the cursor toward regions of interest. The date and temperature located at the crosshairs of the cursor are displayed in the legend box which makes it easy to determine timing of peak temperatures



The hand tool allows shifting the trace around if the point of interest is not displayed on the screen while zoomed in.



Individual points can be viewed incrementally by clicking the left or right diamonds for fine-scale adjustments to cursor position.



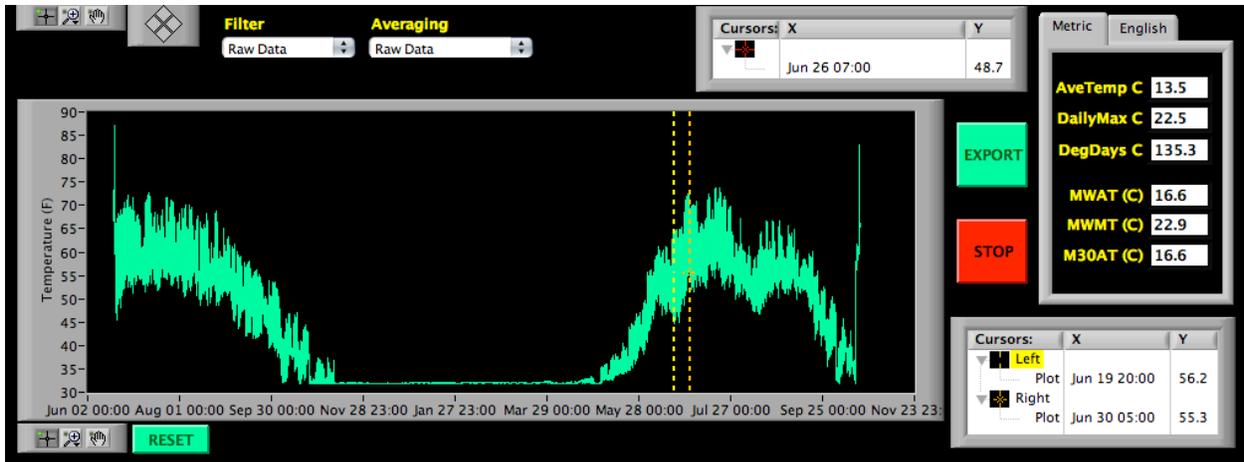
Cursors:	X	Y
Cursor	Jul 11 18:00	67.7

Temperature and corresponding dates associated with the cursor crosshairs can be read off the cursor legend.

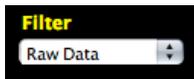


Clicking the "RESET" button will return both plots to their original formatting.

Filtered temperature data is shown in the lower (green) plot



If more complex analyses are required, the data can be filtered with these two dropdown menus. By default, the raw temperature data is passed from the upper to lower plot for subsequent analysis. It is possible to view modified versions of that data using the filters as follows:



This passes the raw temperature from the top plot (blue) to the bottom graph (green) for subsequent analysis



This pulls the daily maxima from the raw data and plots that for subsequent analysis. Ignore the time stamp on “Daily Max” as this just registers noon for the given day.

```

PooseDailyMaxJuly.txt
This file is a subset of file:
Macintosh HD:Users:Kevin:Documents:LabVIEW
Vis:WaTSS:WaTSSdemo:PooseCreekLower.csv
378,7/1/13 12:00:00 PM,69.81
379,7/2/13 12:00:00 PM,70.87
380,7/3/13 12:00:00 PM,69.77
381,7/4/13 12:00:00 PM,70.76
382,7/5/13 12:00:00 PM,66.34
383,7/6/13 12:00:00 PM,65.40
384,7/7/13 12:00:00 PM,66.21
385,7/8/13 12:00:00 PM,65.79

```



Regardless of how many points are recorded over a 24-h period, this filter takes all temperature registered on a given calendar day (0000-2400) and

calculates a mean value. Ignore the time stamp on the “Daily Average” as this just registers noon for the given day.

```

PooseDailyAverageJuly.txt
This file is a subset of file:
Macintosh HD:Users:Kevin:Documents:LabVIEW
VI:WaTSS:WaTSSdemo:PooseCreekLower.csv
378,7/1/13 12:00:00 PM,59.73
379,7/2/13 12:00:00 PM,60.03
380,7/3/13 12:00:00 PM,58.55
381,7/4/13 12:00:00 PM,59.85
382,7/5/13 12:00:00 PM,59.94
383,7/6/13 12:00:00 PM,58.92
384,7/7/13 12:00:00 PM,58.93
385,7/8/13 12:00:00 PM,58.88
386,7/9/13 12:00:00 PM,58.74
  
```



This filter averages all points registered in the same 7-day period starting with the first recording and assigning the average temperature to noon on the fourth day in the

seven day window, then plotting the value for consecutive weeks.

```

PooseWeeklyAveSummer.txt
This file is a subset of file:
Macintosh HD:Users:Kevin:Documents:LabVIEW
VI:WaTSS:WaTSSdemo:PooseCreekLower.csv
48,5/22/13 12:00:00 PM,37.70
49,5/29/13 12:00:00 PM,41.90
50,6/5/13 12:00:00 PM,49.54
51,6/12/13 12:00:00 PM,53.14
52,6/19/13 12:00:00 PM,53.07
53,6/26/13 12:00:00 PM,57.55
54,7/3/13 12:00:00 PM,59.64
55,7/10/13 12:00:00 PM,60.29
56,7/17/13 12:00:00 PM,62.40
  
```



All temperatures recorded in a given month are averaged here.



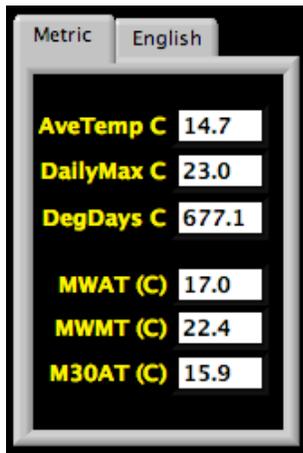
Perhaps the most useful filter, this allows the user to calculate a running average off either “Raw Data” or “Daily Max”.

If “Raw Data” is used, to get a running daily (24-h) average from data collected hourly, one should set the “Window” to 24 if data was collected hourly.

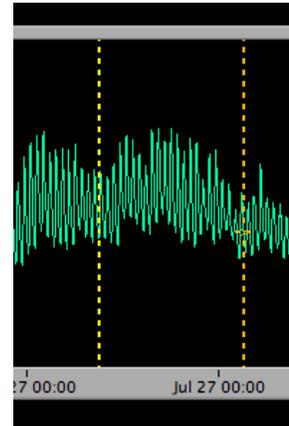


Since a single “Daily Max” value represents a daily temperature, to get a weekly running average one should enter "7" in the “Window” box.





Summary statistics are then presented in the data box and results can be toggled between English and metric units by clicking on their respective tabs. The results displayed are generated from temperature data contained between the left (yellow) and right (orange) sliders, and are calculated as follows:



**AveTemp** – This represents the average temperature between the slider bars based on the raw data - even if the Daily Max is selected on the filter dropdown. If AveTemp from Daily Max data is needed, export the Daily Max data to an output file, then reimport as raw data and reanalyze.

**DailyMax** – This is no longer the absolute maximum temperature within the slider bars, but rather Colorado’s state mandated maximum temperature which is the highest 2 hour running average (Todd et al. 2008). If the absolute peak reading is desired, just use the red slider on the blue plot to identify the time and date of the highest temperature recorded.

**DegDays** - Whether degree days are displayed in °C or °F, both values are generated by calculating the average daily temperature, determining the number of degrees above freezing, then summing across days incorporated between the slider bars

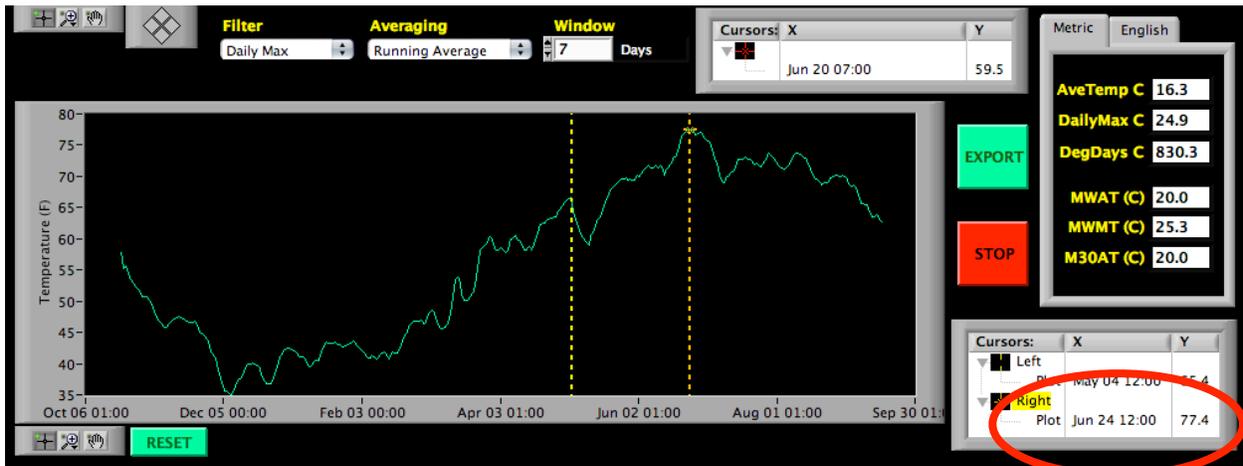
**MWAT** - This is the warmest 7-day mean of the average daily temperature (the maximum annual value of the rolling average of mean daily water temperatures over a 7-day period; Ziegler et al. 2013b). Colorado's water quality criteria for stream temperature classify streams where cutthroat trout occur as Cold Tier 1 (CWQCC 2012). The criteria for Cold Tier 1 water temperature include both acute (DailyMax) and chronic (MWAT) threshold values. The acute and chronic values for the Cold Tier 1 water temperature criteria vary seasonally. In winter (October–May), the DailyMax threshold is 13 °C, and the

MWAT=9 °C. In Summer (June–September), the threshold for DailyMax is 21.7 °C and an MWAT=17 °C.

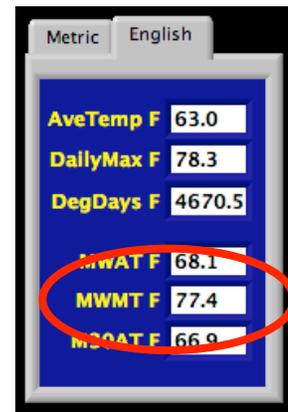
**MWMT** – This is the warmest 7-day mean of the maximum daily stream temperature (Roberts et al. 2013), and is used to determine if streams are cool enough for fish survival. In cutthroat trout, Roberts et al. (2013) used an MWMT=26 °C as the temperature beyond which Colorado River Cutthroat Trout could not survive.

**M30AT** – The maximum 30 day average temperature is the most relevant metric for growth and recruitment in fish (Roberts et al. 2013), and describes the average temperature of the warmest month. Growth in cutthroat trout is maximized between 9-18 °C, peaking around 15 °C (Bear et al. 2007, Brandt 2009, Ziegler et al. 2013) and 13.8 °C in mountain whitefish (Brinkman et al. 2013). This metric is similar to the mean July temperature metric used by Harig and Fausch (2002) to evaluate translocation success in cutthroat trout. This study, and those by Coleman and Fausch (2007a, 2007b) suggest that an M30AT<8 °C will result in no recruitment, and that M30AT>9 °C is required for robust recruitment to occur.

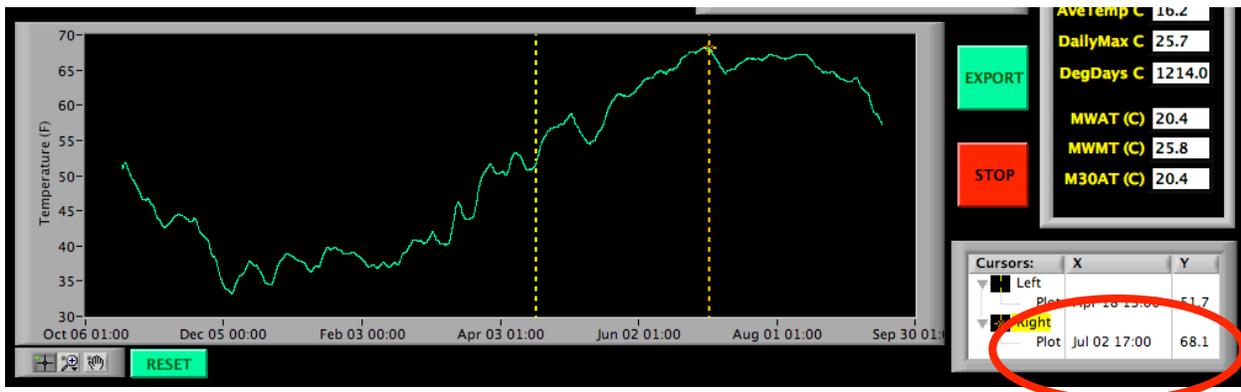
The same calculations are possible using only the maximum daily temperatures if desired by selecting "Daily Max" on the left hand filter (Filter). This represents an alternative approach to calculating metrics like the maximum weekly maximum temperature (MWMT) that has the benefit of depicting when that MWMT occurred.



The MWMT can be derived by setting the left filter to "Daily Max", then selecting "Running Average" on the right filter followed by "7" days. The orange slider was moved to the peak (77.4 °F), allowing the date (June 24th) and temperature to be displayed in the cursor legend near the bottom right



An approximation of the average weekly average temperature (AWAT) can be calculated similarly. Inspecting the input file shows that temperature data was collected hourly. A running average with a window of 168 points (7 days \* 24 hrs) shows that the weekly estimates reached their 68.1 °F peak the week surrounding July 2nd.



Technically, the AWAT should be calculated as the 7 day running average on average daily temperatures. That can be achieved by exporting the average daily temperatures



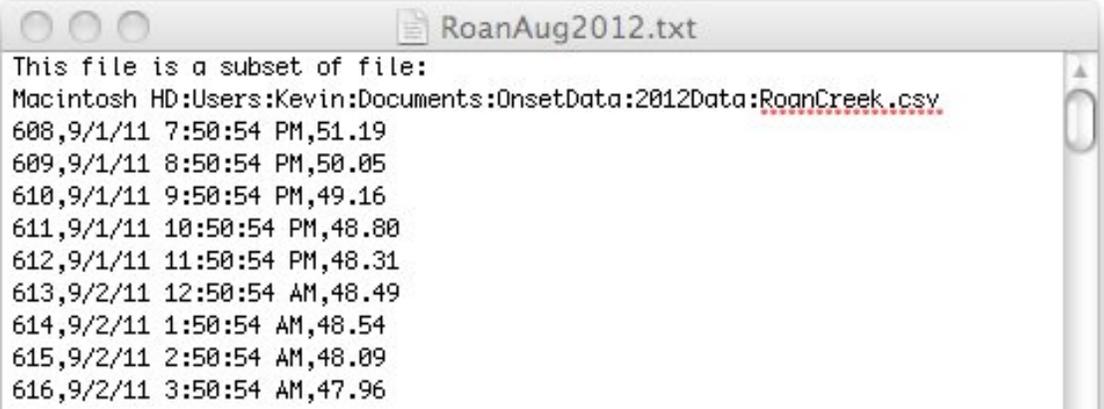
, then reading that back in and calculating the 7 day running



average.

## *Exporting data*

By pressing the the “Export” button, WaTSS will export an ASCII text file in the format shown below that can be read back into WaTSS. Output data is restricted to what lies between the slider bars. Data is filtered as per the “Filter” and “Averaging” dropdown menus, and reflects what is shown in the lower plot. Filtered temperatures are exported along with a median date and time.

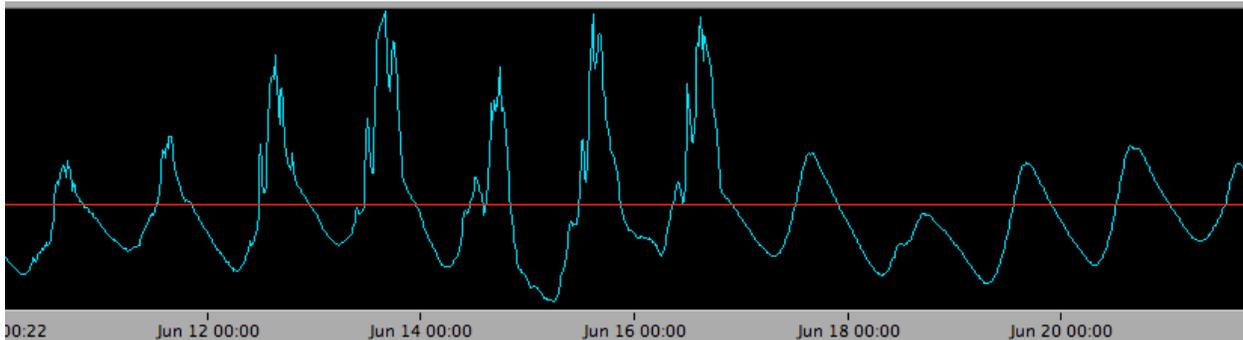
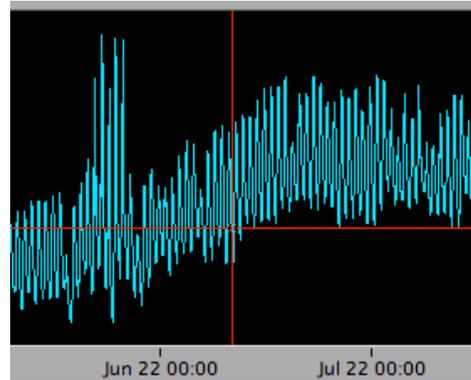


```
RoanAug2012.txt
This file is a subset of file:
Macintosh HD:Users:Kevin:Documents:OnsetData:2012Data:RoanCreek.csv
608,9/1/11 7:50:54 PM,51.19
609,9/1/11 8:50:54 PM,50.05
610,9/1/11 9:50:54 PM,49.16
611,9/1/11 10:50:54 PM,48.80
612,9/1/11 11:50:54 PM,48.31
613,9/2/11 12:50:54 AM,48.49
614,9/2/11 1:50:54 AM,48.54
615,9/2/11 2:50:54 AM,48.09
616,9/2/11 3:50:54 AM,47.96
```

If you are trying to import temperature data from other sources, it must adhere to the above data structure (similar to that exported by the HOBO software). Specifically, the file must be in ASCII format (export as “plain text” from any text editing software), and must have two header lines that are ignored by WaTSS. The file should be in comma delimited format with the first column being the reading number, the second being the date and time stamp as shown below which must include seconds with a single space before and after the time stamp, followed by the temperature in either Celsius or Fahrenheit.

### *Desiccation*

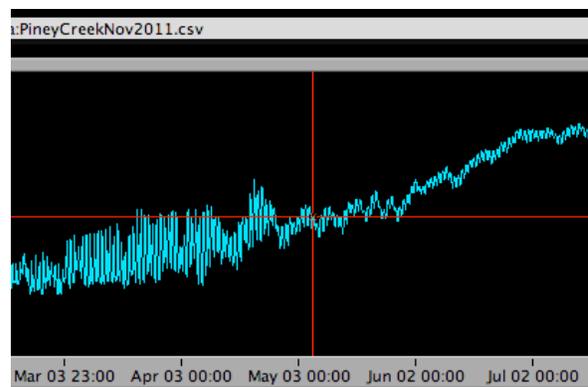
During dry years, it is possible that a logger will become exposed and begin logging air temperatures rather than stream temperatures. This obviously will compromise the integrity of the data and should be screened for. Although often more subtle than the example shown here, zooming in can reveal a more jagged profile uncharacteristic of stream temperatures that tend to be more buffered.



### *Sedimentation*

In an effort to keep a logger from recording air temperatures, we may place them in deep depositional areas where they can become buried.

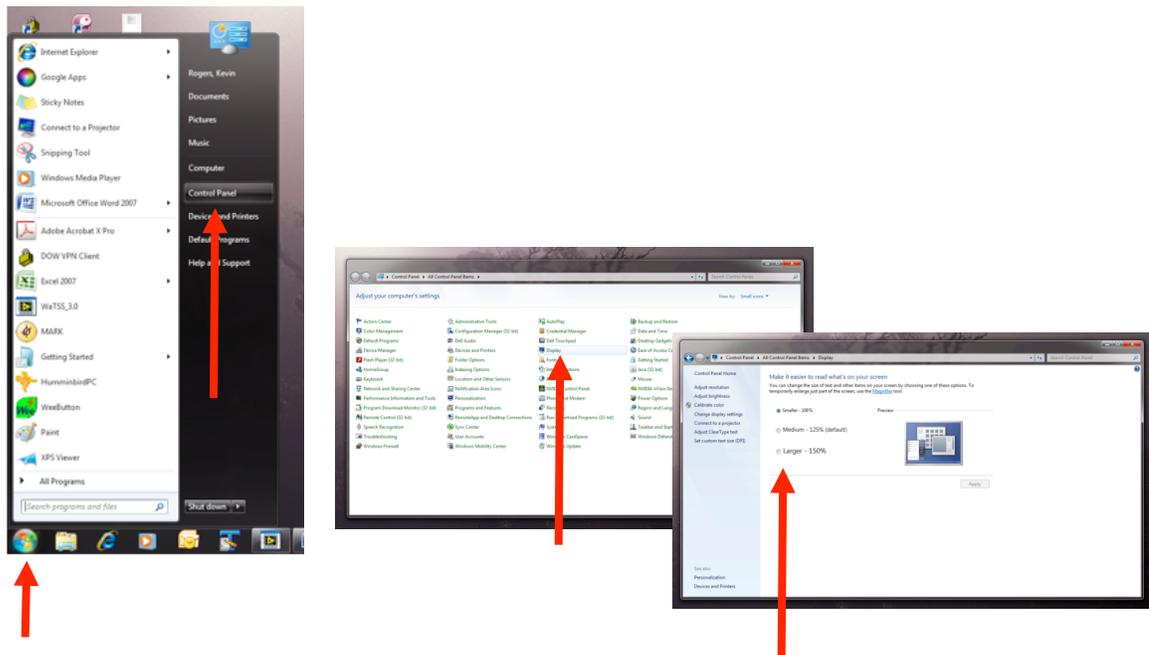
Although this might not change mean temperature values much, it can dramatically alter the diel temperature fluctuations experienced by the logger and therefore values like the Daily Max or MWMT. It is important to select sites where the logger will be scoured clean rather than buried.



## Troubleshooting

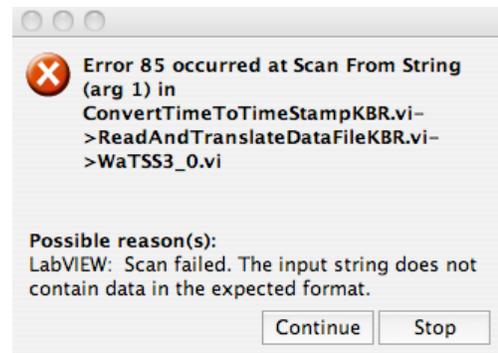
✓ You are running the application on a Windows 7 platform and the fonts on the plot legends are so large they no longer fit in the defined space.

- ➔ Check your Display setting in your computer's Control Panel. For some reason, Microsoft decided inflating text by 125% as default would be a good thing. Setting this back to 100% should solve the problem. Let me know if it too small to read on your screen and I will try to find a better fix.



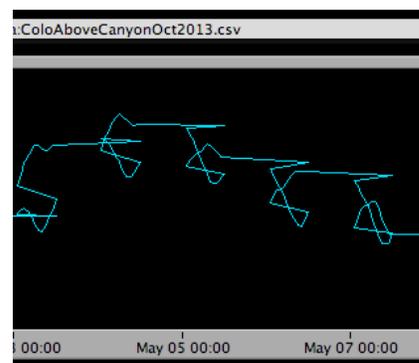
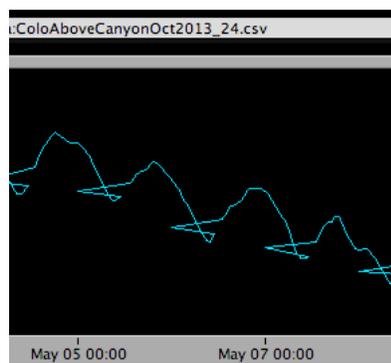
✓ The file you select gives you an error message and fails to load.

- ➔ The format of your input file is different than what is produced by HOBOWare, and cannot be read by the program. Open the file in a word processor like Microsoft Word and select “show non-printing characters”. Bring up another file that you know works fine (or one of the demo files installed with your program in your Programs



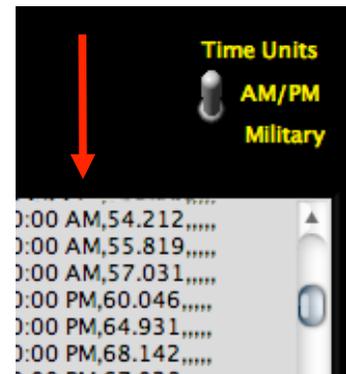
Files (x86) folder) and compare the two for differences. Files can be modified easily in Excel and saved in the .csv format for import into WaTSS.

- ✓ Values in the data box are not changing when the sliders are moved?
  - ➔ Check to confirm that the program is running (that the run arrow in the top left of the application (Page 5) is black).
- ✓ Why does filtering not affect the calculated values of MWAT, MWMT, or A30AT?
  - ➔ These are specifically defined, and would be called something else if they were calculated with Daily Max data.
  - ➔ If for some reason you need to calculate any of the metrics in the data box with filtered data, create a new input file on filtered data by clicking the Export button, then reanalyze that file.
- ✓ Why is the DailyMax value a little less than the peak of the diel cycle registered on the plots or the highest value for a given day in the Input File pane?
  - ➔ This is by design as the DailyMax reflects Colorado's state water quality standard which is the highest 2-hr average (Todd et al. 2008).
  - ➔ If the absolute peak temperature is required, simply zoom in to the area of interest on the blue plot and move the red cross-hairs to the maximum recorded temperature and read that temperature and date from the plot legend.
- ✓ Zoomed out, the blue plot looks normal, but zooming in reveals an unexpected thermal profile.



- ➔ The plot on the left is the result of importing a file that logged temperature using a 24-hr clock (Military) while by default, the program is anticipating a 12-hr clock and an AM or PM. The plot on the right is the result of importing a 12-hr clock data (HOBOWare default) when WaTSS is expecting military format.

- ➔ Check the raw input data on the right of the screen or in a word processor and see if the exported file uses a 24 hr clock or AM/PM. Make sure your Time Units toggle is in the appropriate position. The toggle has to be selected **prior** to running the program for it to work.
- ➔ If you are still having trouble, you can go back in to HOBOware and export a new .csv file after changing the export preferences to output in the AM/PM format.
- ➔ Another workaround provided by Jim White if you don't have HOBOWare on your computer: open the .csv file in Excel and highlight the date:time field. Change the field format to Date:Time and select the AM/PM format and save (still in the .csv format).



## **Literature cited**

- Bear, E. A., T. E. McMahon, and A. V. Zale. 2007. Comparative thermal requirements of Westslope cutthroat trout and rainbow trout: implications for species interactions and development of thermal protection standards. *Transactions of the American Fisheries Society* 136:1113-1121.
- Brandt, M. M. 2009. Optimal starter diets and culture conditions for Colorado River Cutthroat Trout (*Oncorhynchus clarkii pleuriticus*). Master's thesis. Colorado State University, Fort Collins.
- Brett, J. R. 1979. Ten environmental factors and growth. *Fish Physiology* 8:599-675.
- Brinkman, S. F., H. J. Crockett, and K. B. Rogers. 2013. Upper thermal tolerance of mountain whitefish (*Prosopium williamsoni*) eggs and fry. *Transactions of the American Fisheries Society* 142:824-831.
- Casselman, J. M. 1978. Effects of environmental factors on growth, survival, activity, and exploitation of northern pike. Pages 114-128 in R. D. Kendall, editor. *Selected coolwater fishes of North America*. American Fisheries Society, Special Publication 11, Washington D.C.
- Coleman, M. A., and K. D. Fausch. 2007a. Cold summer temperature limits recruitment of Age-0 cutthroat trout in high-elevation Colorado streams. *Transactions of the American Fisheries Society* 136:1231-1244.
- Coleman, M. A., and K. D. Fausch. 2007b. Cold summer temperature regimes cause a recruitment bottleneck in Age-0 Colorado River cutthroat trout reared in laboratory streams. *Transactions of the American Fisheries Society* 136:639-654.
- Cook, M. F., and E. P. Bergersen. 1988. Movements, habitat selection, and activity periods of northern pike in Eleven Mile Reservoir, Colorado. *Transactions of the American Fisheries Society* 117:495-502.
- CWQCC (Colorado Water Quality Control Commission). 2012. Regulation 31—The basic standards and methodologies for surface water: Denver, Colo., Colorado Department of Public Health and the Environment.
- de la Hoz Franco, E. A., and P. Budy. 2005. Effects of biotic and abiotic factors on the distribution of trout and salmon along a longitudinal stream gradient. *Environmental Biology of Fishes* 72:379–391.

- Dickerson, B. R., and G. L. Vinyard. 1999. Effects of high chronic temperatures and diel temperature cycles on the survival and growth of Lahontan Cutthroat Trout. *Transactions of the American Fisheries Society* 128: 516–521.
- Dunham, J., R. Schroeter, and B. Rieman. 2003. Influence of maximum water temperature on occurrence of Lahontan Cutthroat Trout within streams. *North American Journal of Fisheries Management* 23:1042–1049.
- Ficke, A. D., C. A. Myrick, and L. J. Hansen. 2007. Potential impacts of global climate change on freshwater fisheries. *Reviews in Fish Biology and Fisheries* 17: 581–613.
- Harig, A. L., and K. D. Fausch. 2002. Minimum habitat requirements for establishing translocated cutthroat trout populations. *Ecological Applications* 12:535-551.
- Isaak, D. J., C. C. Muhlfeld, A. S. Todd, R. Al-Chokhachy, J. Roberts, J. L. Kershner, K. D. Fausch, S. W. Hostetler. 2012. The past as prelude to the future for understanding 21st-century climate effects on Rocky Mountain trout.
- Magnuson, J. J., L. B. Crowder, and P. A. Medvick. 1979. Temperature as an ecological resource. *American Zoologist* 19:331-343.
- Meeuwig, M. H., J. B. Dunham, J. P. Hayes, and G. L. Vinyard. 2004. Effects of constant and cyclical thermal regimes on growth and feeding of juvenile Cutthroat Trout of variable sizes. *Ecology of Freshwater Fish* 13: 208–216.
- Mesing, C. L., and A. M. Wicker. 1986. Home range, spawning migrations, and homing of radio-tagged Florida largemouth bass in two central Florida lakes. *Transactions of the American Fisheries Society* 115:286-295.
- Peterson, D. P., S. J. Wenger, B. E. Rieman and D. J. Isaak. 2013. Linking climate change and fish conservation efforts using spatially explicit decision support tools. *Fisheries* 38:112-127.
- Rahel, F. J., and J. D. Olden. 2007. Assessing the effects of climate change on aquatic invasive species. *Conservation Biology* 22:521-533.
- Roberts, J. J., K. D. Fausch, D. P. Peterson, and M. B. Hooten. 2013. Fragmentation and thermal risks from climate change interact to affect persistence of native trout in the Colorado River basin. *Global Change Biology* 19:1383-1398.
- Rogers, K. B. 1998. Habitat use by largemouth bass and northern pike on the Rocky Mountain Arsenal, Colorado. Doctoral dissertation. Colorado State University, Fort Collins.

- Rogers, K. B., and G. C. White. 2007. Analysis of movement and habitat use from telemetry data. M. Brown and C. Guy, editors. Analysis and interpretation of freshwater fisheries data. American Fisheries Society, Bethesda, Maryland. Available online at <http://cpw.state.co.us/learn/Pages/ResearchAquaticSoftware.aspx>
- Selong, J. H., T. E. McMahon, A. V. Zale, and F. T. Barrows. 2001. Effect of temperature on growth and survival of Bull Trout, with application of an improved method for determining thermal tolerance in fishes. Transactions of the American Fisheries Society 130:1026–1037.
- Todd, A.S., M. A. Coleman, A. M. Konowal, M. K. May, M.K., S. Johnson, N. K. M. Vieira, and J. F. Saunders. 2008. Development of new water temperature criteria to protect Colorado's fisheries. Fisheries 33:433–443.
- Underwood, Z. E., C. A. Myrick, and K. B. Rogers. 2012. Effect of acclimation temperature and the upper thermal tolerance of Colorado River cutthroat trout *Oncorhynchus clarkii pleuriticus*. Journal of Fish Biology 80:2420–2433.
- Wenger, S. J., D. J. Isaak, C. H. Luce, H. M. Neville, K. D. Fausch, J. B. Dunham, D. C. Dauwalter, M. K. Young, M. M. Elsner, B. E. Rieman, A. F. Hamlet, and J. E. Williams. 2011. Flow regime, temperature, and biotic interactions drive differential declines of trout species under climate change. Proceedings of the National Academy of Sciences 108:14175–14180.
- Zeigler, M. P., S. F. Brinkman, C. A. Caldwell, A. S. Todd, M. S. Recsetar, S. A. Bonar. 2013. Upper thermal tolerances of Rio Grande cutthroat trout under constant and fluctuating temperatures. Transactions of the American Fisheries Society 142:1395–1405.
- Zeigler, M.P., A. S. Todd, and C. A. Caldwell. 2013b. Water temperature and baseflow discharge of streams throughout the range of Rio Grande cutthroat trout in Colorado and New Mexico—2010 and 2011: U.S. Geological Survey Open-File Report 2013–1051, 18 p., <http://pubs.usgs.gov/of/2013/1051/>.