Stream Segment Temperature Model (SSTEMP) Version 2.0
Revised August 2002

by

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INTRODUCTION

SSTEMP is a much-scaled down version of the Stream Network Temperature Model (SNTEMP) by Theurer et al. (1984). SSTEMP may be used to evaluate alternative reservoir release proposals, analyze the effects of changing riparian shade or the physical features of a stream, and examine the effects of different stream withdrawals and returns on instream temperature. Unlike the large network model, SNTEMP, this program handles only single stream segments for a single time period (e.g., month, week, day) for any given "run". Initially designed as a training tool, SSTEMP may be used satisfactorily for a variety of simple cases that one might face on a day-to-day basis. It is especially useful to perform sensitivity and uncertainty analysis.

The program requires inputs describing the average stream geometry, as well as (steady-state) hydrology and meteorology, and stream shading. SSTEMP optionally estimates the combined topographic and vegetative shade as well as solar radiation penetrating the water. It then predicts the mean daily water temperatures at specified distances downstream. It also estimates the daily maximum and minimum temperatures, and unlike SNTEMP, handles the special case of a dam with steady-state release at the upstream end of the segment.

With good quality input data, SSTEMP should faithfully reproduce mean daily water temperatures throughout a stream reach. If it does not, there is a research opportunity to explain why not. One should not expect too much from SSTEMP if the input values are of poor quality or if the modeler has not adhered to the model's assumptions.

Suggested citation:
Bartholow, J.M. 2002. SSTEMP for Windows: The Stream Segment Temperature Model (Version 2.0). US Geological Survey computer model and documentation. Available on the Internet at http://www.fort.usgs.gov/

RUNNING SSTEMP

SSTEMP has been designed for a monitor with at least 1024 x 768 resolution using Windows small fonts. If your monitor does not exceed this resolution, you will get a message to this effect and SSTEMP's main screen image will be reset to a smaller size. This may be toggled by **View|Large Form**. You must have small fonts to use the uncertainty analysis feature.

You will be presented with a screen showing the multitude of possible program inputs, organized into logical groups. The program starts with a set of "default" values to show the approximate magnitude of the numbers and should not be used without thought or review. At the bottom of the screen, you may double click to enter a descriptive title.

As the program runs, it calculates several intermediate values that may be useful in calibration. These are printed on the top right portion of the screen. It also prints the mean heat flux values for the segment immediately below on the screen. Outflow temperatures (mean, maximum, and minimum) that result from this set of input variables are displayed on the bottom right side of the screen, as are the daily equilibrium temperatures.

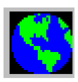
You may change any variable by using your mouse to highlight the desired variable and then typing the new value for that variable. Each new value must be terminated by an ENTER or a Tab key, or a new mouse click. The menu and toolbar will be disabled until your entry is complete. Entering a new value for any variable will immediately update the predicted temperatures.

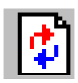
You may choose the units of display (English or International) for each input and output item. This choice may be “global" by using the **VIEW** menu or the toolbar buttons, or individual by double clicking on the appropriate label describing the variable. Units are red if English and blue if International. **Note** that not all input or output values have units that differ between systems.

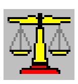
Files may be **SAVE**d to a text file and subsequently **OPEN**ed for reuse. You will be prompted for saving your file upon **EXIT**ing.

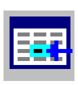
Toolbar Buttons (Only visible with the **large form** view)

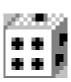
 View all English units button

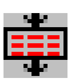
 View all International units button

 Swap all units button

 Sensitivity analysis

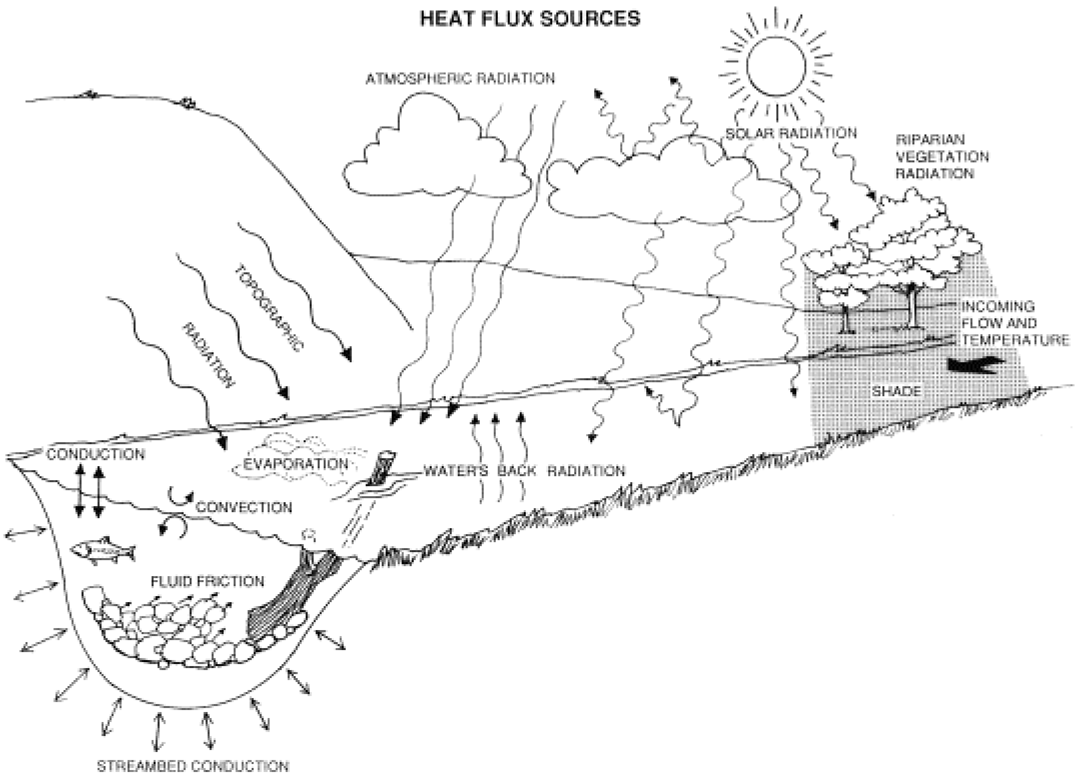
 Flow/Distance matrix

 Uncertainty analysis

 Process external file

DESCRIPTION OF LOGIC

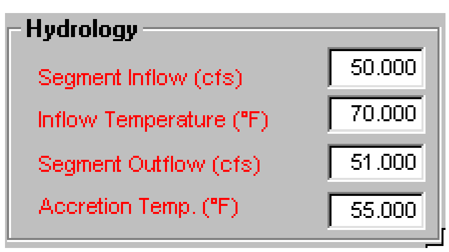
In general terms, SSTEMP calculates the heat gained or lost from a parcel of water as it passes through a stream segment. This is accomplished by simulating the various heat flux processes that determine that temperature change (see figure below). These physical processes include convection, conduction, evaporation, as well as heat to or from the air (long wave radiation), direct solar radiation (short wave), and radiation back from the water. SSTEMP first calculates the solar radiation and how much is intercepted by (optional) shading. This is followed by calculations of the remaining heat flux components for the stream segment. The details are just that: To calculate solar radiation, SSTEMP computes the radiation at the outer edge of the earth's atmosphere. This radiation is passed through the attenuating effects of the atmosphere and finally reflects off the water's surface depending on the angle of the sun. For shading, SSTEMP computes the day length for the level plain case, i.e., as if there were no local topographic influence. Next, sunrise and sunset times are computed by factoring in local east and west-side topography. Thus, the local topography results in a percentage decrease in the level plain daylight hours. From this local sunrise/sunset, the program computes the percentage of light that is filtered out by the riparian vegetation. This filtering is the result of the size, position and density of the shadow-casting vegetation on both sides of the stream.



Please refer to Theurer et al. (1984) for the source and derivation of the formulae and computing methodology contained in this program.

HYDROLOGY VARIABLES

This section of the screen contains the mean daily values for hydrology. The default screen looks like:



1. Segment Inflow (cfs or cms) — Enter the mean daily flow at the top of the stream segment. If the segment begins at an effective headwater, the flow may be entered as zero so that all accumulated flow will accrue from accretions, both surface and groundwater. If the segment begins at a reservoir, the flow will be the outflow from that reservoir. Remember that this model assumes steady-state flow conditions.

If the inflow to the segment is the result of mixing two streams, you may use the mixing equation to compute the combined temperature:

$$T_j = \frac{Q_1{*}T_1 + Q_2{*}T_2}{Q_1 + Q_2}$$

where

T_j = temperature below the junction

Q_n = discharge of source n

T_n = temperature of source n

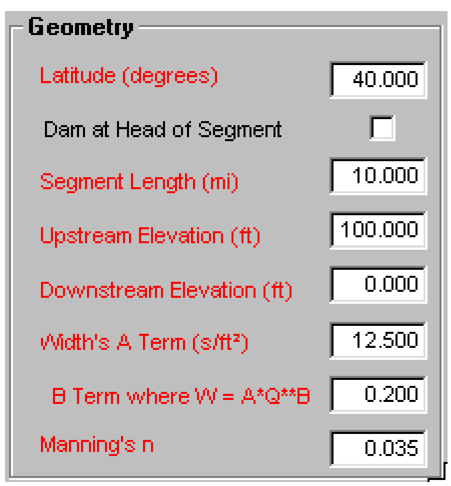
2. Inflow Temperature (°F or °C) — Enter the mean daily water temperature at the top of the segment. If the segment begins at a true headwater, you may enter any water temperature, because zero flow has zero heat. If there is a reservoir at the inflow, use the reservoir release temperature. Otherwise, use the outflow from the next upstream segment.

3. Segment Outflow (cfs or cms) — The program calculates the lateral accretion rate by knowing the flow at the head and tail of the segment, subtracting to obtain the net difference, and dividing by segment length. The program assumes that lateral inflow (or outflow) is uniformly apportioned through the length of the segment. If any "major" tributaries enter the segment, you should divide the segment into two or more subsections. "Major" is defined as any stream contributing greater than 10% of the mainstem flow, particularly if there are major discontinuities in stream temperature.

4. Accretion Temperature (°F or °C) — The temperature of the lateral inflow, barring tributaries, generally should be the same as groundwater temperature. In turn, groundwater temperature may be approximated by the mean annual air temperature. You can verify this by checking United States Geological Survey (USGS) well log temperatures. Exceptions may arise in areas of geothermal activity. If irrigation return flow makes up most of the lateral flow, it may be warmer than mean annual air temperature. Return flow may be approximated by equilibrium temperatures.

GEOMETRY VARIABLES

The default screen for stream geometry components looks like:



1. Latitude (decimal degrees or radians) — Latitude refers to the position of the stream segment on the earth's surface. It may be read off of any standard topographic map.

2. Dam at Head of Segment (checked or unchecked) — If there is a dam at the upstream end of the segment with a constant, or nearly constant diel release temperature, check the box, otherwise leave it unchecked. This option, unavailable in SNTEMP, is important for more accurately estimating daily maximum water temperatures. Maximum daily water temperature is calculated by following a water parcel from solar noon to the end of the segment, allowing it to heat towards the maximum equilibrium temperature. If there is an upstream dam within a half-day's travel time from the end of the segment, a parcel of water should only be allowed to heat for this shorter time/distance. By telling SSTEMP that there is a dam at the top, it will know to heat the water only from the dam downstream. Figure 1 may help explain the situation.

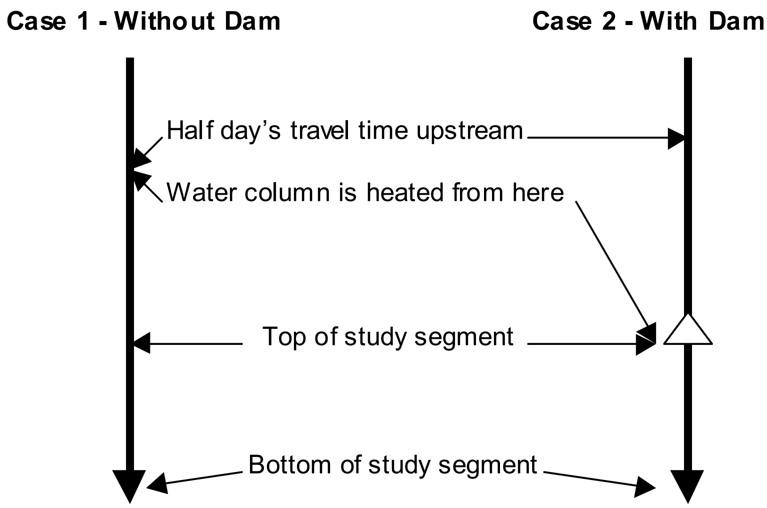


Figure 1. Calculating maximum daily temperature with and without an intervening dam.

Just to confuse the issue, be aware that if there is no dam SSTEMP will assume that the stream segment's meteorology and geometry also apply upstream from that point a half-day's travel time from the end of the segment. If conditions are vastly different upstream, this is one reason that the maximum temperature estimate can be inaccurate.

3. Segment Length (miles or kilometers) — Enter the length of the segment for which you want to predict the outflowing temperature. Remember that all variables will be assumed to remain constant for the entire segment. Length may be estimated from a topographic map, but a true measurement is best.

4. Upstream Elevation (feet or meters) — Enter elevation as taken from a 7-1/2 minute quadrangle map.

5. Downstream Elevation (feet or meters) — Enter elevation as taken from a 7-1/2 minute quadrangle map. Do not enter a downstream elevation that is higher than the upstream elevation, lest a "Catastrophic Error" occur.

6. Width's A Term (seconds/foot^2 or seconds/meter^2) — This variable may be derived by calculating the wetted width-discharge relationship. Again, an experienced hydrologist can help. To conceptualize this, plot the width of the segment on the Y-axis and discharge on the X-axis of log-log paper. Be sure to use consistent units. Three or more measurements are much better than two. The relationship should approximate a straight line, the slope of which is the B term (the next variable). Theoretically, the A term is the untransformed Y-intercept. However, the width vs. discharge relationship tends to break down at very low flows. Thus, it is best to calculate B as the slope and then solve for A in the equation:

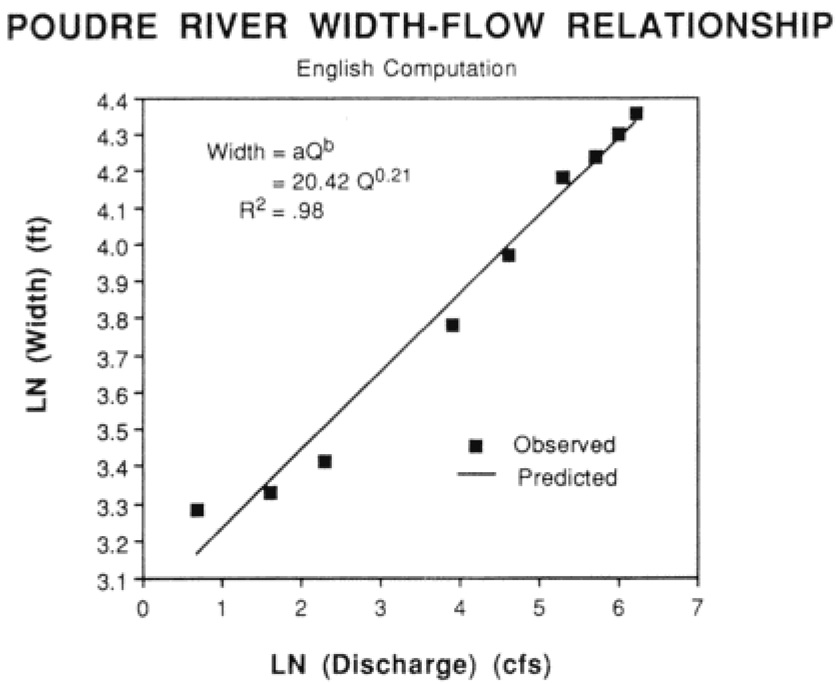
$$W = A * Q^B$$

where Q is a known discharge, and
W is a known width
B is the power relationship

Regression analysis also may be used to develop this relationship. First transform the flow to natural log (flow) and width to natural log (width). Log (width) will be the dependent variable. The resulting X coefficient will be the B term and the (non-zero) constant will be the A term when exponentiated. That is:

A = e**constant from regression, where ** represents exponentiation

As you can see from the width equation, width equals A if B is zero. Thus, substitution of the stream's actual wetted width for the A term will result if the B term is equal to zero. This is satisfactory if you will not be varying the flow, and thus the stream width, very much in your simulations. If, however, you will be changing the flow by a factor of 10 or so, you should go to the trouble of calculating the A and B terms more precisely. Width can be a sensitive factor under many circumstances.



PHABSIM may be used to calculate total area, which, when divided by the total length, becomes the mean wetted width.

7. Width's B Term (essentially dimensionless) — From the above discussion, you can see how to calculate the B term from the log-log plot. This plot may be in either English or International units. The B term is calculated by linear measurements from this plot. Leopold et al. (1964, p.244) report a variety of B values from around the world. A good default in the absence of anything better is 0.20; you may then calculate the A term if you know the width at a particular flow.

8. Manning's n or Travel Time (seconds/mile or seconds/kilometer) — Manning's n is an empirical measure of the segment's "roughness." A hydrologist can help you estimate or measure the stream roughness. A generally acceptable default value is 0.035. This variable is necessary only if you are

interested in predicting the minimum and maximum daily fluctuation in temperatures. It is not used in the prediction of the mean daily water temperature. Barnes (1967) may be useful in estimating Manning's n.

Values greater than 1.0 will be interpreted as Travel Time. Dye studies may yield accurate measures of travel time. (See Hubbard, 1982.)

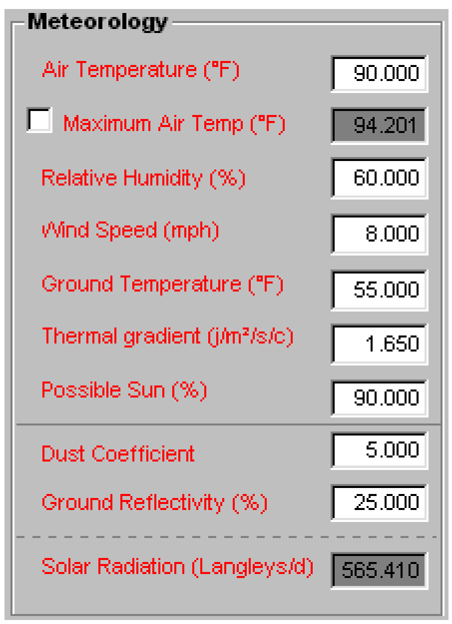
TIME OF YEAR

The default screen for time of year looks like:

Month/Day (mm/dd) — Enter the number of the month and day to be modeled. January is month 1, etc. This program's output is for a single day. To compute an average value for a longer period (up to one month), simply use the middle day of that period, e.g., July 15. The error encountered in so doing will usually be minimal. **Note** that any month in SSTEMP can contain 31 days.

METEOROLOGICAL VARIABLES

The default screen for meteorological variables looks like:



1. Air Temperature (°F or °C) — Enter the mean daily air temperature. This information may of course be measured (in the shade), and should be for truly accurate results; however, this and the other (following) meteorological variables may come from the Local Climatological Data (LCD) reports which can be obtained from the National Oceanic and Atmospheric Administration for a weather station near your site. The LCD Annual Summary contains monthly values, whereas the Monthly Summary contains daily values. The Internet is another obvious source of data today.

If only scoping-level analyses are required, you may refer to sources of general meteorology for the United States, such as USDA (1941) or USDC (1968).

Use the adiabatic lapse rate to correct for elevational differences from the met station:

$$Ta = To + Ct * (Z - Zo)$$

where Ta = air temperature at elevation E (°C)
To = air temperature at elevation Eo (°C)
Z = mean elevation of segment (m)
Zo = elevation of station (m)
Ct = moist-air adiabatic lapse rate (-0.00656 °C/m)

NOTE: Air temperature will usually be the single most important factor in determining mean daily water temperature. See *Sensitivity Analysis* for more on this subject.

2. Maximum Air Temperature (°F or °C) – The maximum air temperature is a special case. Unlike the other variables where simply typing a value influences which variables "take effect", the maximum daily air temperature overrides only if the check box is checked. If the box is not checked, the program continues to estimate the maximum daily air temperature from a set of empirical coefficients (see Theurer, et al., 1984) and will print the result in the grayed data entry box. You cannot enter a value in that box unless the box is checked.

3. Relative Humidity (percent) — Obtain the mean daily relative humidity for your area by measurement or from the LCD by averaging the four daily values given in the report. Correct for elevational differences by:

$$Rh = Ro * [1.0640 ** (To-Ta)] * [(Ta+273.16)/(To+273.16)]$$

where Rh = relative humidity for temperature Ta (decimal)
Ro = relative humidity at station (decimal)
Ta = air temperature at segment (°C)
To = air temperature at station (°C)
** = exponentiation
$0 \le Rh \le 1.0$

4. Wind Speed (miles per hour or meters/second) — Obtainable from the LCD. Wind speed also may be useful in calibrating the program to known outflow temperatures by varying it within some reasonable range. In the best of all worlds, wind speed should be measured immediately above the water's surface.

5. Ground Temperature (°F or °C) — In the absence of measured data, use mean annual air temperature from the LCD.

6. Thermal Gradient (Joules/Meter^2/Second/°C) — This elusive quantity is a measure of rate of thermal input (or outgo) from the streambed to the water. It is not a particularly sensitive variable within a narrow range. This variable may prove useful in calibration, particularly for the maximum temperature of small, shallow streams where it may be expected that surface waters interact with either the streambed or subsurface flows. In the absence of anything better, simply use the 1.65 default. **Note** that this variable is measured in the same units regardless of the system of measurement used.

7. Possible Sun (percent) — This variable is an indirect and inverse measure of cloud cover. Measure with a pyrometer or use the LCD for historical data. Unfortunately, cloud cover is no longer routinely measured by NOAA weather stations. That means that one must "back calculate" this value or use it as a calibration parameter.

8. Dust Coefficient (dimensionless) — This value represents the amount of dust in the air. If you enter a value for the dust coefficient, SSTEMP will calculate the solar radiation.

Representative values look like the following (Tennessee Valley Authority, 1972):

Winter	- 6 to 13
Spring	- 5 to 13
Summer	- 3 to 10
Fall	- 4 to 11

If all other variables are well known for a given event, the dust coefficient may be calibrated by using known ground-level solar radiation data.

9. Ground Reflectivity (percent) — The ground reflectivity is a measure of the amount of short-wave radiation reflected back from the earth into the atmosphere. If you enter a value for the ground reflectivity, SSTEMP will calculate the solar radiation.

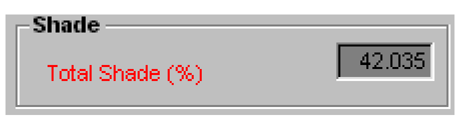
Representative values look like the following (Tennessee Valley Authority, 1972, and Gray, 1970):

Meadows and fields	14
Leaf and needle forest	5 to 20
Dark, extended mixed forest	4 to 5
Heath	10
Flat ground, grass covered	15 to 33
Flat ground, rock	12 to 15
Flat ground, tilled soil	15 to 30
Sand	10 to 20
Vegetation, early summer	19
Vegetation, late summer	29
Fresh snow	80 to 90
Old snow	60 to 80
Melting snow	40 to 60
Ice	40 to 50
Water	5 to 15

10. Solar Radiation (Langleys/day or Joules/meter^2/second) — Measure with a pyrometer, or refer to Cinquemani et al. (1978) for reported values of solar radiation. If you do not calculate solar radiation within SSTEMP, but instead rely on an external source of ground level radiation, you should assume that about 90% of the ground-level solar radiation actually enters the water. Thus, multiply the recorded solar measurements by 0.90 to get the number to be entered. If you enter a value for solar radiation, SSTEMP will ignore the dust coefficient and ground reflectivity and "override' the internal calculation of solar radiation, graying out the unused input boxes.

SHADE VARIABLE

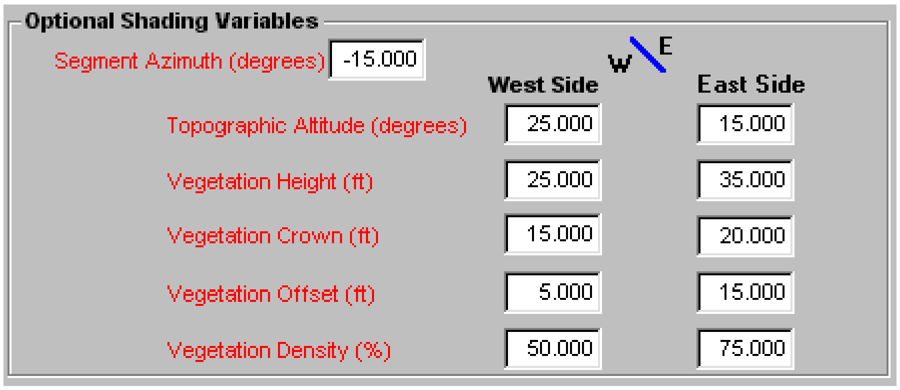
The default screen for the total shade value looks like:



Total Shade (percent) — This variable refers to how much of the segment is shaded by vegetation, cliffs, etc. If 10% of the water surface is shaded through the day, enter 10. In actuality however, shade represents the percent of incoming solar radiation that does not reach the water. If you enter a value for total shade, the optional shading variables will be grayed out and ignored. You may find it to your advantage to use the Optional Shading Variables to more accurately calculate stream shading.

OPTIONAL SHADING VARIABLES

The default screen for the optional shade values looks like:



There are many subjective factors in estimating shade. In general, I recommend not being too concerned with being accurate. Rather, estimate shade and then use your estimate plus or minus 25% as a calibration factor in SSTEMP.

There are, however, two conditions for which accuracy may matter more than others. The first would be if SSTEMP indicated that shade was a very sensitive variable in water temperature (remember that it is more likely to be sensitive for the maximum daily temperature). The second is if the management prescription involves riparian vegetation manipulation. In these cases, more accuracy is demanded. Taking multiple samples initially to calculate the number of samples for a satisfactory estimate of the mean and standard deviation may be required. See Platts et al. (1987) for a description of how sample size influences confidence intervals and how to calculate the required sample size to control your confidence in these estimates.

If any of the optional shade variables are entered, SSTEMP will calculate the total shade, overriding any value you may have entered.

1. Azimuth (degrees or radians) — Azimuth refers to the general orientation of the stream segment with respect to due North and controls which sides are called East and West, by convention, regardless of the direction of flow. Refer to the following diagram for guidance:

```
                    North
                      0°
         -45°         |         +45°
                      |
                      |
+90° West --------------- East -90°
                      |
                      |
         +45°         |         -45°
                      0°
                    South
```

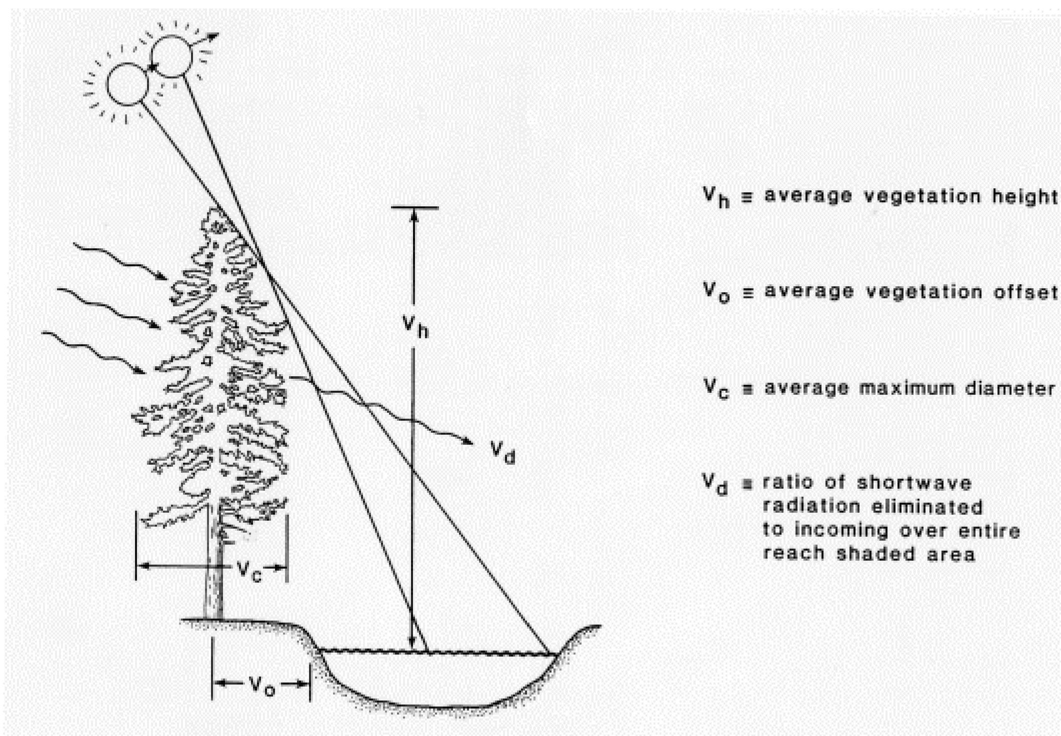
Once the azimuth is determined, usually from a topographic map, the East and West sides are fixed by convention. When the angle is small, East and West are obvious. As the angle approaches plus or minus 90 degrees, it is less clear. Imagine an azimuth of plus 90 degrees; the actual north shore is termed East. Similarly, if the azimuth is minus 90 degrees, the north shore is termed West as far as this program is concerned. This convention is easy to understand if you visualize varying the azimuth from zero degrees and noting that West and East always stay on the same side of the stream.

Since this convention can be confusing to many people, the program draws a line (e.g., /, |, —, or \) along with labels for East and West to the right of the azimuth entry designating the general orientation.

2. Topographic Altitude (degrees or radians) — This is a measure of the average incline to the horizon from the middle of the stream looking perpendicular to the direction of flow. Enter a value for both East and West sides. The altitude may be estimated from topographic maps but is best measured with a clinometer. **Note** that in relatively flat country, the stream bank itself may be the overriding horizon.

3. Vegetation Height (feet or meters) — This is the average height of the shade producing strata of vegetation along the stream from the water's surface, Vh in the diagram below. Enter a value for both East and West sides.

The height may be calculated by the formula H = D * TAN (A), where H is the height, D the distance from the observer (in the water) to the vegetation, and A the angle from the water surface to the tops of the vegetation. A simple protractor may be used to estimate the angle.



Note: The question always arises as to how to handle the situation of trees on top of a high bank where the topographic horizon is defined by the bank and the trees are above, not below, the horizon. The easiest way to handle this as far as I'm concerned is to set the topographic altitude to zero and enter a height of vegetation as the total height above the water's surface. Then, include the bank in your estimate of vegetative density.

4. Vegetation Crown (feet or meters) — This is the average maximum crown diameter for the shade producing strata of vegetation along the stream, Vc in the diagram above. Enter a value for both East and West side. Direct measurement or estimation from aerial photos may be used.

5. Vegetation Offset (feet or meters) — This is the average offset of the trunks of the shade producing strata of vegetation from the water's edge, Vo in the diagram above. You may need to vary this if the stream width varies substantially. Enter a value for both East and West sides.

6. Vegetation Density (percent) — This is the average screening factor (0 to 100%) of the shade producing strata of vegetation along the stream, Vd in the diagram above. It is composed of two parts: the continuity of the vegetative coverage along the stream (quantity), and the percent of light filtered by the vegetation's leaves and trunks (quality).

For example, if there is vegetation along 25% of the stream and the average density of that coverage is 50%, the total vegetative density is 0.25 times 0.50, which equals 0.125, or 12.5%. The value should always be between zero and one. Enter a value for both East and West Side.

To give examples of shade quality, an open pine stand provides about 65% light filtering; a closed pine stand provides about 75% light removal; a tight spruce/fir stand provides about 85% light removal; areas of extensive, dense emergent vegetation should be considered 90% efficient for the surface area covered. If you wish to be more precise, follow the procedure outlined below.

Purchase from a photographic supply store an item called an 18% gray card (about $5 US). Using an accurate, hand-held light meter, set the ASA value to a low number, such as 25. Set the f-stop to a high value, such as 16. Stand in direct sunlight and hold the light meter about six inches from the gray card such that the light meter only picks up light reflected from the gray card, being careful to cast no shadow yourself on the gray card. Read the exposure time from the meter; we will call the denominator of that exposure time Eo. Now repeat the measurement in the shade. This denominator we will call Ei. Then use the following formula to calculate the filtering effect:

Shade quality = 1.0 - (Ei / Eo)

For example, if the in-shade exposure time is 1/50th of a second and the out-of-shade exposure time is 1/350th of a second, then

Shade quality = 1.0 - (50 / 350)

or

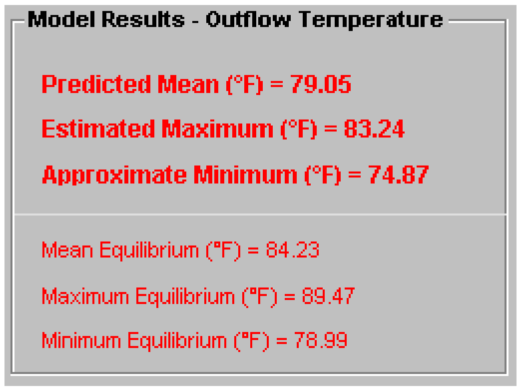
Shade quality = 0.86

Note that this formulation requires that both values, Ei and Eo, be fractions, e.g., 1/350. If this is not so, readjust the f-stop such that both are fractions.

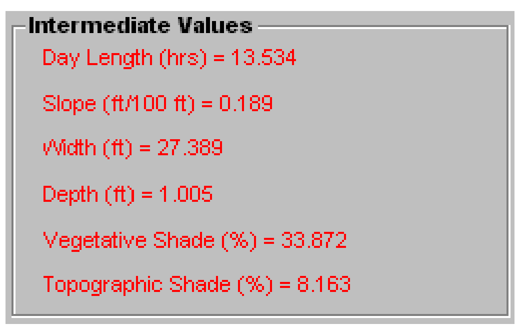
Shade continuity is best estimated from aerial photographs or by sampling along the stream bank. Density may need to be adjusted for the time of year if you are dealing with deciduous vegetation.

OUTPUT

The program will predict the minimum, mean, and maximum daily water temperature for the set of variables you provide. The theoretical basis for the model is strongest for the mean daily temperature. The maximum is largely an estimate and likely to vary widely with the maximum daily air temperature. The minimum is simply computed by subtracting the difference between maximum and mean from the mean; but the minimum is always positive. The mean daily equilibrium temperature is that temperature that the daily mean water temperature will approach, but never reach, if all conditions remain the same (forever) as you go downstream. (Of course, all conditions cannot remain the same, e.g., the elevation changes immediately.) The maximum daily equilibrium temperature is that temperature that the daily maximum water temperature will approach. The result of the default values looks like:



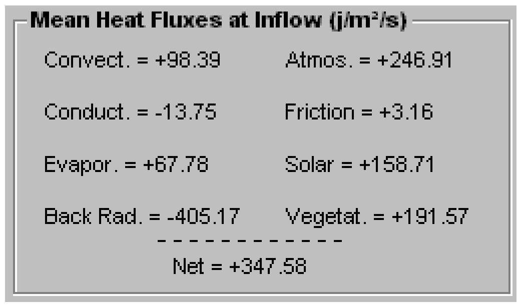
Other output includes the intermediate parameters average width, and average depth and slope (all calculated from the input variables), and the mean daily heat flux components. The intermediate values resulting from the default inputs look like:



The mean heat flux components are abbreviated as follows:

Convect. = convection component
Conduct. = conduction component
Evapor. = evaporation component
Back Rad. = water's back radiation component
Atmos. = atmospheric radiation component
Friction = friction component
Solar = solar radiation component
Vegetat. = vegetative and topographic radiation component
Net = sum of all the above flux values

The sign of these flux components indicates whether or not heat is entering (+) or exiting (-) the water. The units are in joules/meter^2/second. In essence, these flux components are the best indicator of the relative importance of the driving forces in heating and cooling the water from inflow to outflow. SSTEMP produces two sets of values, one based on the inflow to the segment and one based on the outflow. You may toggle from one to the other by double clicking on the frame containing the values. In doing so, you will find that the first four flux values change as a function of water temperature which varies along the segment. In contrast, the last four flux values do not change because they are not a function of water temperature but of constant air temperature and channel attributes. For a more complete discussion of heat flux, please refer to Theurer et al. (1984). The flux values resulting from the default inputs looks like:



The program will predict the total segment shading for the set of variables you provide. The program will also display how much of the total shade is a result of topography and how much is a result of vegetation. The topographic shade and vegetative shade are merely added to get the total shade. Use the knowledge that the two shade components are additive to improve your understanding about how SSTEMP deals with shade in toto.

SENSITIVITY ANALYSIS

SSTEMP may be used to compute a one-at-a-time sensitivity of your set of input values. Use **View|Sensitivity Analysis** or the scale toolbar button to initiate the computation. This simply increases and decreases most active input (i.e., non-grayed out values) by 10% and displays a screen for changes to mean and maximum temperatures. The schematic graph that accompanies the display (see below) gives an indication of which variables most strongly influence the results. This version does not compute any interactions between input values.

```
Sensitivity for mean temperature values (10% variation)     SSTEMP (1.0.0)
Original mean temperature = 79.05°F
                              Temperature change (°F)
                                  if variable is:
Variable                        Increased Decreased   Relative Sensitivity
--------------------------------------------------------------------------------
Segment Inflow (cfs)              -0.02     +0.90 *****
Inflow Temperature (°F)           -2.50     +2.71 **************
Segment Outflow (cfs)             +1.21     -0.43 ******
Accretion Temp. (°F)              -0.06     +0.06
Width's A Term (s/ft²)            -0.62     +0.67 ***
  B Term where W = A*Q**B         -0.51     +0.51 ***
Manning's n                       +0.00     +0.00
Air Temperature (°F)              -5.87     +4.92 ******************************
Relative Humidity (%)             -1.11     +1.12 ******
Wind Speed (mph)                  -0.08     +0.08
Ground Temperature (°F)           -0.13     +0.13 *
Thermal gradient (j/m²/s/c)       +0.05     -0.05
Possible Sun (%)                  -0.11     +0.16 *
Dust Coefficient                  +0.01     -0.01
Ground Reflectivity (%)           -0.02     +0.02
Segment Azimuth (degrees)         -0.01     +0.01
West Side:
Topographic Altitude (degrees)    +0.04     -0.04
Vegetation Height (ft)            +0.05     -0.05
Vegetative Crown (ft)             +0.03     -0.03
Vegetation Offset (ft)            -0.02     +0.02
Vegetation Density (%)            +0.10     -0.10 *
East Side:
Topographic Altitude (degrees)    +0.01      0.00
Vegetation Height (ft)            +0.06     -0.07
Vegetative Crown (ft)             +0.04     -0.04
Vegetation Offset (ft)            -0.06     +0.06
Vegetation Density (%)            +0.11     -0.11 *
```

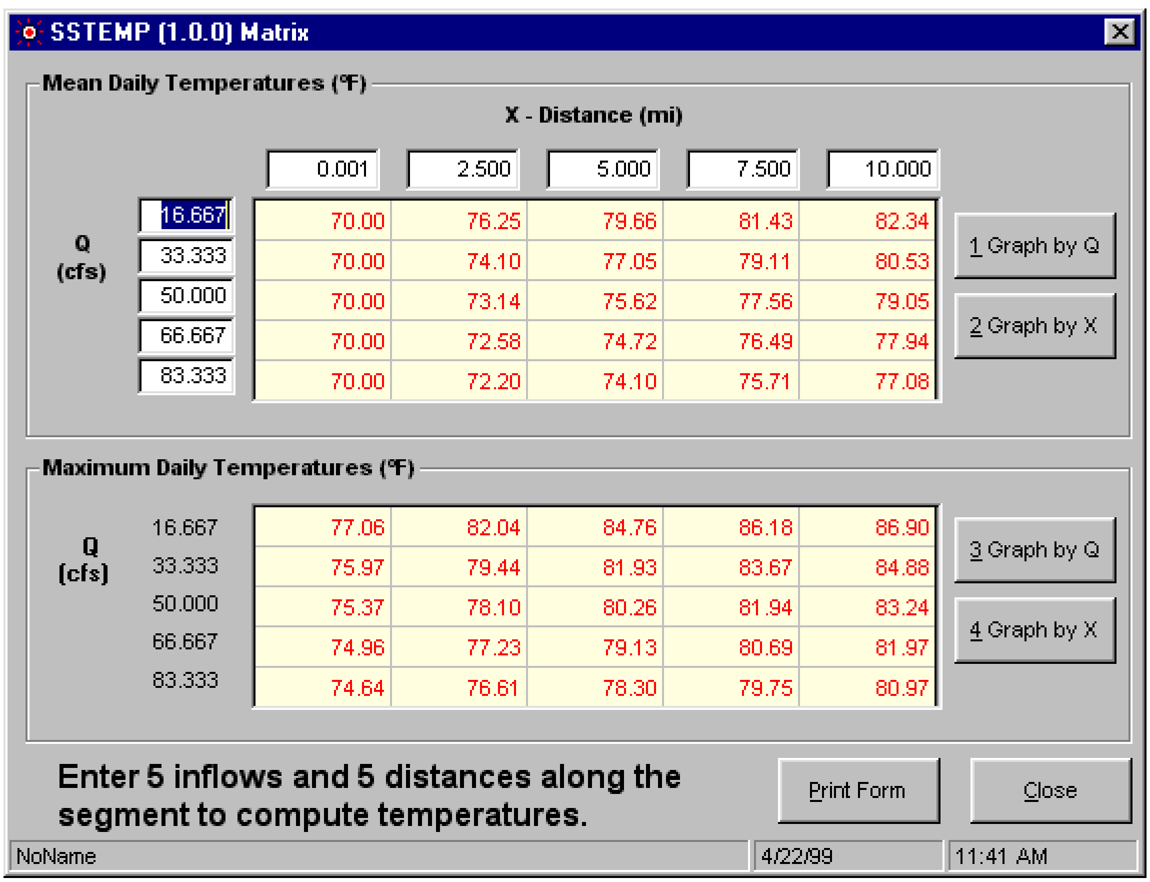
FLOW/DISTANCE MATRIX

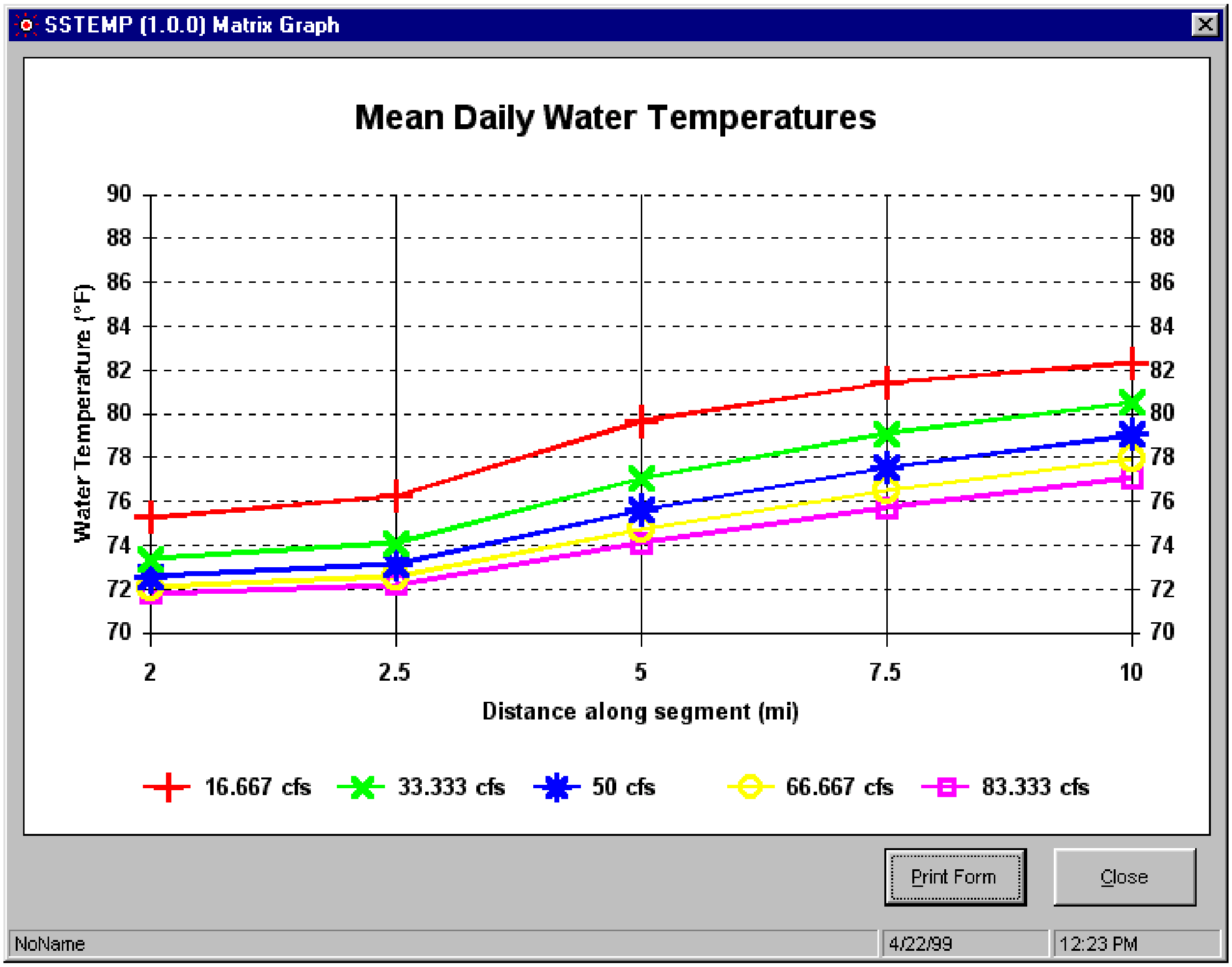
The **View|Flow/DistanceMatrix** option allows you to look at a variety of flow and distance combinations from your stream segment. You may enter up to five flows and five distances for further examination. The program will supply a default set of each, with flows ranging from 33% to 166% of that given on the main screen, and distances regularly spaced along the segment. After making any changes you may need, you may choose to view the results in simple graphs either as a function of distance (X) or discharge (Q). The units for discharge, distance and temperature used on the matrix and the graph are a function of those from the main form. The graph is discrete, i.e., does not attempt to smooth between points, and does not currently scale the X-axis realistically.

Note that changing the flow only changes the flow through the segment. That is, the accretion rate per unit distance will remain the same. Flow does impact shading (if active) and all other dependent calculations. For this reason, results may differ from SNTEMP unless shading is fixed.

Note that you may enter distances beyond your segment length, but if you do so you are assuming that everything remains homogeneous farther downstream, just as you have assumed for the segment itself. *If you try to look at distances very close to the top of the segment, you may get mathematical instability.*

Note that the main form will vanish during matrix computations but it will be restored upon closing the matrix.





UNCERTAINTY ANALYSIS

SNTEMP and previous versions of SSTEMP were deterministic; you supplied the "most likely" estimate of input variables and the model predicted the "most likely" thermal response. This approach was comforting and easy to understand. But choosing this "most likely" approach is like putting on blinders. We know there is variability in the natural system and inherent inaccuracy in the model. The previous model did not reflect variance in measured or estimated input variables (e.g., air temperature, streamflow, stream width) or parameter values (e.g., Bowen ratio, specific gravity of water); therefore they could not be used to estimate the uncertainty in the predicted temperatures. This version (2.0) adds an uncertainty feature that may be useful in estimating uncertainty in the water temperature estimates, given certain caveats.

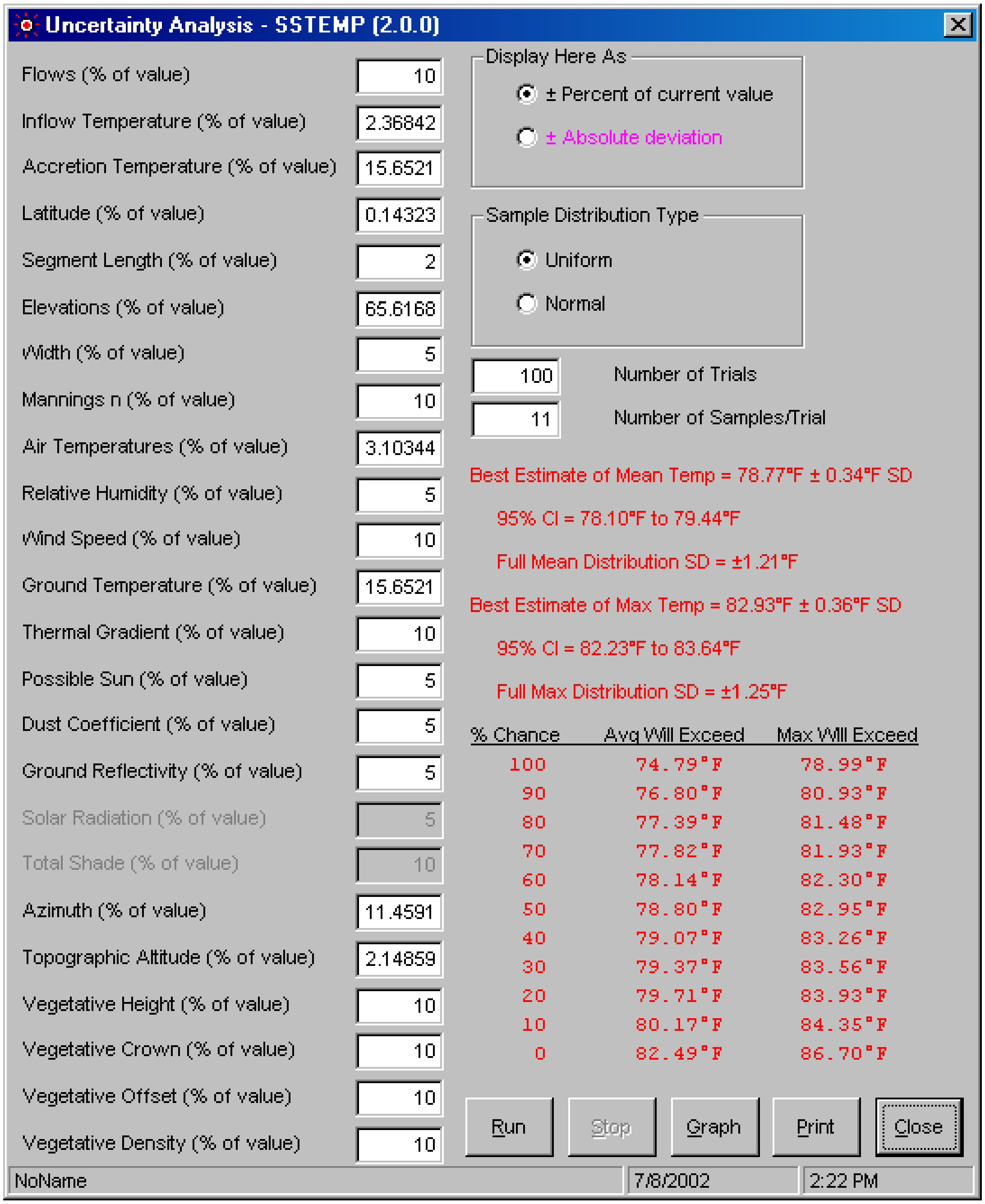
The built-in uncertainty routine uses Monte Carlo analysis, a technique that gets its name from the seventeenth century study of the casino games of chance. The basic idea behind Monte Carlo analysis is that model input values are randomly selected from a distribution that describes the set of values composing the input. That is, instead of choosing one value for mean daily air temperature, the model is repeatedly run with several randomly selected estimates for air temperature in combination with random selections for all other relevant input values. The distribution of input values may be thought of as representing the variability in measurement and extrapolation error, estimation error, and a degree of spatial and temporal variability throughout the landscape. In other words, we may measure a single value for an input variable, but we know that our instruments are inaccurate to a degree (no pun intended) and we also know that the values we measure might have been different if we had measured in a different location along or across the stream, or on a different day. (I have included several references at the end of this document that shed additional light on the Monte Carlo techniques used here.)

SSTEMP is fairly crude in its method of creating a distribution for each input variable. There are two approaches in this software: a percentage deviation and an absolute deviation. The percentage deviation is useful for variables commonly considered to be reliable only within a percentage difference. For example, USGS commonly describes stream flow as being accurate plus or minus 10%. The absolute deviation, as the name implies, allows entry of deviation values in the same units as the variable (*and always in international units*). A common example would be water temperature where we estimate our ability to measure temperature plus or minus maybe 0.2 degrees. Do not be fooled with input variables whose units are themselves percent, like shade. In this case, if you are in the percentage mode and shade is 50% as an example, entering a value of 5% would impose a deviation of ±2.5 percent (47.5-52.5%), but if you were in the absolute mode, the same 5% value would impose a deviation of ±5 percent (45-55%). Ultimately, SSTEMP converts all of the deviation values you enter to the percent representation before it computes a sample value in the range. No attempt is made to allow for deviations of the date, but all others are fair game, with three exceptions. First, the deviation on stream width is applied only to the A-value, not the B-term. If you want to be thorough, set the width to a constant by setting the B-term to zero. Second, if after sampling, the upstream elevation is lower than the downstream elevation, the upstream elevation is adjusted to be slightly above the downstream elevation. Third, you may enter deviations only for the values being used on the main screen.

The sampled value is chosen from either 1) a uniform (rectangular) distribution plus or minus the percent deviation, or 2) a normal (bell-shaped) distribution with its mean equal to the original value and its standard deviation equal to 1.96 times the deviation so that it represents 95% of the samples drawn from that distribution. If in the process of sampling from either of these two distributions, a value is drawn that is either above or below the "legal" limits set in SSTEMP, a new value is drawn from the distribution. For example, let's assume that you had a relative humidity of 99% and a deviation of 5 percent. If you were using a uniform distribution, the sample range would be 94.05 to 103.95; but you cannot have a relative humidity greater than 100%. Rather than prune the distribution at 100%, SSTEMP resamples to avoid over-specifying 100% values. No attempt has been made to account for correlation among variables, even though we know there is some. I have found little difference in using the uniform versus normal distributions, except that the normal method produces somewhat tighter confidence intervals.

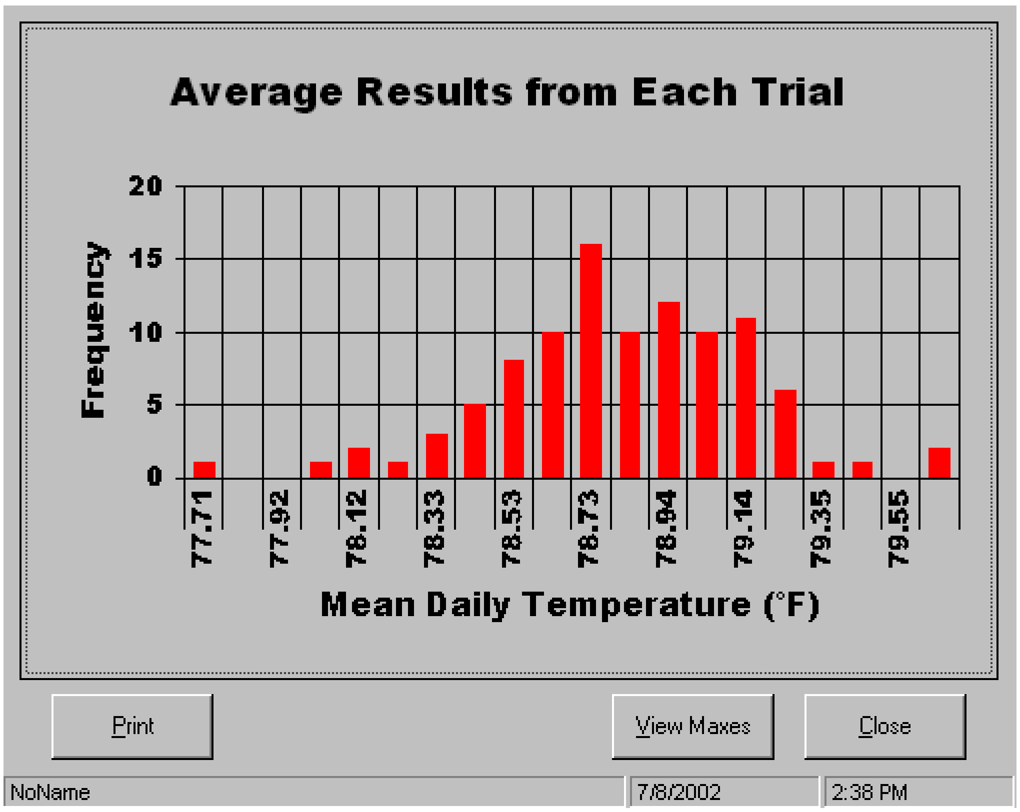
SSTEMP's random sampling is used to estimate the average temperature response, both for mean daily and maximum daily temperature, and to estimate the entire dispersion in predicted temperatures. You tell the program how many *trials* to run (minimum of 11) and how many *samples* per trial (minimum of two). Although it would be satisfactory to simply run many individual samples, the advantage to this trial-sample method is twofold. First, by computing the average of the trial means, it allows a better, tighter estimate of that mean value. This is analogous to performing numerous "experiments" each with the same number of data points used for calibration. Each "experiment" produces an estimate of the mean. Second, one can gain insight as to the narrowness of the confidence interval around the mean depending on how many samples there are per trial. This is analogous to knowing how many data points you have to calibrate the model with and the influence of that. For example, if you have only a few days' worth of measurements, your confidence interval will be far broader than if you had several months' worth of daily values. But this technique does little to reduce the overall spread of the resulting predicted temperatures.

Let's look at the input and output from the Monte Carlo method to better understand the statistics produced:



The deviations you control are arranged along the left side of the dialog. The program uses default values that are meant to be representative of real-world values, but as always you need to scrutinize all of them for appropriateness for your situation. Grayed out items were unused on the main screen and therefore cannot be used on this screen. Display type, distribution type, number of trials and number of samples are on the top right. You may toggle the display between percent and absolute as often as you choose. Once satisfied with your values, pressing *Run* initiates the simulations. You can watch the variables change during the simulations on the main screen behind this dialog if you wish, though you will see this happen only periodically. You will also note that the routine uses whatever units (International or English) were on the main screen as it runs. The model is run a total of Trials * Samples per Trial times, and the results collected. If need be, you may press the *Stop* button to terminate the process.

Once the analysis is complete, a summary of the temperature output appears in whatever units you had chosen on the main screen. (More information is also contained in the file UNCERTAINTY.TXT that may be found in the installation folder for SSTEMP.) The best estimate of the mean and maximum temperatures are shown; these should be nearly identical to the results from the deterministic model given on SSTEMP's main screen, but you may find that they do differ somewhat. These mean estimates are accompanied by the best estimate of their standard deviation (SD) and 95% confidence interval (1.96 * SD). These are followed by the "full" estimate of the standard deviation for the full range of model predictions. These are always considerably broader than the estimates of the mean. If you have chosen more than 10 samples per trial, you will get an exceedence table displaying the probabilities of equaling or exceeding the stated temperature. Finally, you may plot a bar graph showing the frequency of trial-average results. See below for an example:



Basically, you are given a smorgasbord of ways to depict uncertainty, but what is the best way to characterize uncertainty? Good question. If you want to estimate the mean temperature, I recommend the 95% confidence interval. This would be 1.96 times the SD of the estimate of the mean, 0.34°F in the above example. If you want to estimate the variability in the full model predictions, use 1.96 times the full distribution value, 1.21°F in the above example. As you can see, these two estimates can be widely different, though this depends on the number of trials and samples per trial. Remember that there is no magic in these statistics; they simply characterize the distributions of the data. Some people may appreciate the exceedence table, but I believe they are in the minority. The graphs may be more understandable to those who like figures rather than numbers, and do a good job of illustrating any skewness.

What can we do to tighten up the model's variability? Huge data collection efforts might provide more accurate estimates for each of our input variables, but we rarely have the money to do this. We could always rely on "worst case" estimates for the input variables, where worst case is defined as that set of estimates producing the highest predicted temperatures. Though this might help "cover our ass", I don't recommend this because the probability of the worst case is too low to be practical. I think it is better simply to understand and acknowledge the uncertainty, but continue to make decisions based on our best estimate of the average predictions with 95% confidence intervals given.

Note: The uncertainty routine is not likely to be bomb-proof given extreme deviation values that may cause mathematical instability in the model. However, you will be given messages if the model hiccups.

PROCESS EXTERNAL FILE

Many people asked for a way to enable SSTEMP to process either multiple dates for the same stream segment or multiple segments for the same day. They have also asked for a way to chain segments together longitudinally. This feature can accomplish these requests, with some caveats.

There is an Excel spreadsheet distributed with SSTEMP called SSTEMP_Input.xls. Values may be added to this file (and replace the samples values provided) to serve as input to SSTEMP. These values should be in units that SSTEMP recognizes (as shown on the main screen). To avoid many of several problems inherent in this scheme, you must carefully follow these explicit steps:

(1) Insert a descriptive title on row one.

(2) Add one or more rows to the spreadsheet beginning on row three to describe one or more segments and/or times. Do not alter the number of header rows, or the number or order of the columns.

(3) All cells must contain a valid number. In general, the number will be the value to be inserted in SSTEMP's main screen input boxes, or a -99 to disable the value. Here are the rules:

- a. Column 1 is an ID number that can be any integer you wish. You may find it to your advantage if you need to sort the data later for some reason, or line up the results with the input. SSTEMP will normally process all rows in the file, but will terminate early if it reads an ID of -1.
- b. Columns 2 and 3 contain the date, but in two columns instead of SSTEMP's single entry.
- c. Inflow Temperature may be a minus one (-1) if you wish to have SSTEMP insert the predicted mean daily Outflow Temperature from the previous row's values into this row's Inflow Temperature. Otherwise, supply a legitimate value. This is the way to chain segments together. Note that the units of both the Inflow and Outflow Temperature must be the same on the SSTEMP screen.
- d. Dam at Head of Segment should be a zero (0) if unchecked and a one (1) if checked.
- e. Maximum Air Temperature should be -99 if you do not wish to use that feature. Any other number will turn on the check box and insert the value into SSTEMP.
- f. Dust Coefficient and Ground Reflectivity should be -99 if unused, which implies that you are supplying a Solar Radiation value. The reverse is also true, i.e., Solar Radiation should be -99 if unused and you are supplying Dust and Reflectivity values.
- g. Like the above item, either supply values for Total Shade or the Optional Shading Parameters, but not both. A -99 is the key to ignore the appropriate value.

(4) When satisfied with your entries, save the file as a comma separated values (CSV) file using Excel's *Save As* feature. You will likely get messages saying that you the CSV file may lose features not compatible with a CSV file, etc; that is to be expected. For this reason, I also recommend saving the file as an XLS file in order to retain the formatting conventions.

(5) Set up SSTEMP by choosing the appropriate units for each variable input box to match the file you wish to process. For example, if your CSV file contains flows in cfs and temperatures in Celsius, make sure that SSTEMP is using those units before the next step.

(6) Select the *Process External File* toolbar button (or *File* | *Process External File* on the menu bar) and use the first dialog to locate and open your CSV file. A second dialog will prompt you for an output file name.

(7) SSTEMP will read the values one row at a time and create a CSV output file with the date and resulting water temperatures in your selected output file.

(8) Watch the values change on the main screen as the rows are being processed. Carefully scrutinize the values shown on the screen when the operation is complete. These should be the same as the values from the input file's last row. Double-check the units to make sure they are just what you wanted. In fact, I urge you to test your scheme by putting at least one row in manually to compare with the automated results.
(9) You may find it convenient to paste the output CSV file results into your original file, but obviously all subsequent manipulations are up to you. Do check once again that your answers make sense because there is not much error-checking going on here.
(10) If you do much of this, I encourage you to use SNTEMP instead!

MAKING THE MOST OF SSTEMP OUTPUTS

SSTEMP is not fancy when it comes to output. But there are a variety of ways to get what you want.

Printing

There are essentially four options to print the results of SSTEMP.

1. Use the **Print Form** command available on the main menu and on command buttons on the sub-forms. **Print Form** is "quick and dirty" and you'll see what dirty means when you do it. If it takes forever on your printer, try reducing the resolution of your graphics image in **File|Print Setup|Properties**.

2. Press **Alt-Print Screen** to copy the active window to the Windows clipboard to paste into word processor or other application. Depending on the application, this may give much better results, not to mention your ability to control the scale, margins, and other features.

3. For the Sensitivity Analysis form only, you may select the text from the screen followed by the typical Windows **Cut, Copy,** and **Paste** commands. These commands are available by right-clicking the screen or by pressing **Shift-F10.** Note that SSTEMP uses a Courier New Bold font in the text window. This is not a proportional font and must not be proportional lest columns lose their correct spacing.

4. You may use the contents of SSTEMP's data files as you please. These include:

a. **Save** file format. An example appears below. Note that one could generate a file to be read by SSTEMP using another application.

```
"SSTEMP (1.0.0)  ","04/21/1999  08:48 am"
"NoName"
"English",         "Segment Inflow (cfs)",             "50.000"
"English",         "Inflow Temperature (°F)",          "70.000"
"English",         "Segment Outflow (cfs)",            "51.000"
"English",         "Accretion Temp. (°F)",             "55.000"
"English",         "Latitude (degrees)",               "40.000"
"English",         "Segment Length (mi)",              "10.000"
"English",         "Upstream Elevation (ft)",          "100.000"
"English",         "Downstream Elevation (ft)",        "0.000"
"English",         "Width's A Term (s/ft²)",           "12.500"
"English",         "  B Term where W = A*Q**B",        "0.200"
"English",         "Manning's n",                      "0.035"
"English",         "Air Temperature (°F)",             "90.000"
"English",         "Relative Humidity (%)",            "60.000"
"English",         "Wind Speed (mph)",                 "8.000"
"English",         "Ground Temperature (°F)",          "55.000"
"English",         "Thermal gradient (j/m²/s/c)",      "1.650"
"English",         "Possible Sun (%)",                 "90.000"
"English",         "Dust Coefficient",                 "5.000"
"English",         "Ground Reflectivity (%)",          "25.000"
"English",         "Solar Radiation (Langleys/d)",     "565.410"
"English",         "Total Shade (%)",                  "42.035"
"English",         "Segment Azimuth (degrees)",        "-15.000"
"West Side Variables"
"English",         "Topographic Altitude (degrees)",   "25.000"
"English",         "Vegetation Height (ft)",           "25.000"
"International",   "Vegetative Crown (m)",             "4.572"
"English",         "Vegetation Offset (ft)",           "5.000"
"English",         "Vegetation Density (%)",           "50.000"
"East Side Variables"
"English",         "Segment Azimuth (degrees)",        "15.000"
"English",         "Topographic Altitude (degrees)",   "35.000"
"English",         "Vegetation Height (ft)",           "6.096"
"International",   "Vegetative Crown (m)",             "15.000"
"English",         "Vegetation Offset (ft)",           "75.000"
"English",         " Maximum Air Temp (°F)",           "94.201"
"Dam at Head of Segment","Unchecked"
" Maximum Air Temp (°F)","Unchecked"
"Solar Radiation","Disabled"
"Total Shade","Disabled"
"Month/day","08/16"
         "Predicted Mean (°F) = 79.05"
         "Estimated Maximum (°F) = 83.24"
         "Approximate Minimum (°F) = 74.87"
         "Mean Equilibrium (°F) = 84.23"
         "Maximum Equilibrium (°F) = 89.47"
         "Minimum Equilibrium (°F) = 78.99"
```

b. **MEAN.SEN** and **MAX.SEN**. These “temporary” files are created every time you run a sensitivity analysis and may be used in any way you wish. They are identical to what appears in the SSTEMP text window.

c. **UNCERTAINTY.TXT** is an additional temporary file created when you run a Monte Carlo analysis. It contains additional information not shown on the screen. It may be found in the SSTEMP installation folder.

DIFFERENCES FROM PREVIOUS VERSIONS OF SSTEMP

There are several differences in this version of SSTEMP:

Overall

1. As a 32-bit Windows application, SSTEMP is now more accurate and precise in its calculations. As such, you are not guaranteed the same answers as SSTEMP for DOS with essentially equivalent input data, but they will be close. The greatest differences are likely to be under extreme conditions such as near the Arctic Circle during the winter. (However, see **Known Deficiencies** item c below.)

2. Obviously, Windows is the required operating system – 9x and more recent. The best screen resolution is 1024 by 768.

SSSOLAR (V 1.6)

1. Being integrated into SSTEMP has made it necessary to choose whether the program calculates its own radiation penetrating the water, or whether you *override* that calculation with your own estimate of Solar Radiation. By *default*, or if you actively enter either the Dust Coefficient or Ground Reflectivity, SSTEMP calculates the solar radiation penetrating the water and displays the result in the Solar Radiation input box, graying it out to show that that value has been overridden. Conversely, if you actively enter Solar Radiation, the Dust Coefficient and Ground Reflectivity are not needed and are grayed out to show that they have been overridden.

2. Only a single day is simulated, i.e., there is no longer a beginning and ending month and day, nor is there a "# of days" integration value.

3. The elevation used in calculating Solar Radiation is the mean for the segment.

4. Latitude is no longer entered in degrees and minutes, only as decimal degrees.

5. Extraterrestrial and ground level radiation are no longer printed out -- just not enough room.

SSSHADE (V 1.4)

1. Being integrated into SSTEMP has made it necessary to choose whether the program calculates its own shading, or whether you *override* that calculation with your own estimate of Total Shade. By *default*, or if you actively enter any of the values in the Optional Shading Variables frame, SSTEMP calculates the topographic and vegetative shade and displays the result in the Total Shade input box, graying it out to show that that value has been overridden. The *intermediate values* of topographic and vegetative shade also appear in the Intermediate Values frame. Conversely, if you actively enter Total Shade, the Optional Shading Variables values are not needed and are grayed out to show that they have been overridden.

2. Previously, there was a "disconnect" between the stream Width in SSSHADE and SSTEMP. In SSSHADE, the stream width was not a function of flow whereas width was a function of flow in SSTEMP (if you used the width's B term). This made the shade calculation potentially inaccurate if you left shading alone. Now, with the integrated models, width changes as a function of flow in the shade calculations, BUT the offset of the vegetation does not change realistically. Win some, lose some. Perhaps someday Offset will be to the center of the channel instead of to the water's edge and these difficulties will be eliminated.

Version History

Version 2.0 – 7/02 Expanded uncertainty analysis and added Process External File.

Version 1.6 - 6/02 Added uncertainty analysis capability

Version 1.2

1. Added ability to override the program's estimation of the maximum daily air temperature is both a change in SSTEMP and a difference from SNTEMP.
2. SSTEMP can compute the relative sensitivity for the set of input values
3. You can now plot the values in the flow/distance

Version 1.1.3 8/98 Hid the estimates of vegetative and topographic shade if using total shade, and vice versa. Affected change routine and read file routine

Version 1.1.2 7/98 Changed hardwired 15 to twips per pixle x & y in Main

Version 1.1.1 5/98 - made main form sizable so it will show in task bar, but eliminated resize and max buttons

Version 1.1.0 5/98 - added better printform capability

Version 1.0.0 First Release, 4/98

KNOWN DEFICIENCIES

The program does not check for every possible combination of variables that may cause mathematical "blowup" in the formulae. For example, if you accidentally input a downstream elevation that is higher than the upstream elevation, the program will print an error message, and then continue. You can be assured that the last change you made caused the problem. If an error does occur, it may or may not persist, especially if you save (and reload) your file before fixing the source of the error.

In addition, some specific problems are known to exist:

a. Manning's n/travel time values between 1.0 and 1.609344 are "unstable" and provide unreliable results. This should be no real problem because true travel times will be far in excess of 1.61, regardless of the system of units. It is unlikely that this is a problem with SNTEMP also.

b. In some cases for which the inflow water temperature far exceeds the air temperature, the model is unstable and can generate maximum outflow temperatures that are less than the minimum temperatures. This may be a problem with SNTEMP also.

c. There can a loss of precision throughout SSTEMP in terms of how data are entered and how they are converted between systems of units. Repeatedly swapping units, either globally or individually, may produce slight differences in output, occasionally manifesting itself as a "drift" at about the hundredth of a degree level. If this is a problem for you, I suggest that you work only in metric units and adapt a convention of always using three decimal places.

d. The Windows version cannot read previous versions of SSTEMP output files as input for this version.

e. Note that there is a problem maintaining the units for intermediate and final answers upon reading an external data set. Solution is to print the units to the file and restore them. Workaround is to set units to what you want prior to read, or to double click on each item to change it after the read.

ASSUMPTIONS

a. Water in the system is instantaneously and thoroughly mixed at all times. Thus there is no lateral temperature distribution across the stream channel, nor is there any vertical gradient in pools.

b. All stream geometry (e.g., slope, shade, friction coefficient) is characterized by mean conditions. This applies to the full travel distance upstream to solar noon, unless there is a dam at the upstream end.

c. Distribution of lateral inflow is uniformly apportioned throughout the segment length.

d. Solar radiation and the other meteorological and hydrological variables are 24-hour means. You may lean away from them for an extreme case analysis, but you risk violating some of the principles involved. For example, you may alter the relative humidity to be more representative of the early morning hours. If you do, the mean water temperature may better approximate the early morning temperature, but the maximum and minimum temperatures would be meaningless.

e. Each variable has certain built-in upper and lower bounds to prevent outlandish input errors. These limits are not unreasonable; however, the user should look to see that what he or she types actually shows up on the screen. The screen image will always contain the values that the program is using.

f. This model does not allow either Manning's n or travel time to vary as a function of flow.

g. The program should be considered valid only for the Northern Hemisphere below the Arctic Circle. One could theoretically “fast forward” six months for the Southern Hemisphere’s shade calculations, but this has not been tested. The solar radiation calculations would likely be invalid due to the asymmetrical elliptical nature of the earth’s orbit around the sun.

h. The representative time period must be long enough for water to flow the full length of the segment. This is always a difficult one to explain, so bear with me. Remember that SSTEMP, like SNTEMP, is a model that simulates the mean (and maximum) water temperature for some period of days. (One day is the minimum time period, and theoretically, there is no maximum, although a month is likely the upper pragmatic limit.) SSTEMP looks at the world as if all the inputs represent an average day for the time period. For this reason, SSTEMP also assumes that a parcel of water entering the top of the study segment will have the opportunity to be exposed to a full day’s worth of heat flux by the time it exits the downstream end. If this is not true, the time period must be lengthened.

Let’s make this more concrete. Suppose your stream has an average velocity of 0.5 meters per second and you want to simulate a 10 km segment. With 86,400 seconds in a day, that water would travel 43 km in a day’s time. As this far exceeds your 10 km segment length, you can simulate a single day if you wish. But if your stream’s velocity were only 0.05 mps, the water would only travel 4.3 km, so the averaging period for your simulation must be at least 3 days to allow that water to be fully influenced by the average conditions over that period. If, however, most conditions (flow, meteorology) are really relatively stable over the 3 days, you can get by with simulating a single day. Just be aware of the theoretical limitation.

i. Remember that SSTEMP does not and cannot deal with cumulative effects. For example, suppose you are gaming with the riparian vegetation shade’s effect on stream temperature. Mathematically adding or deleting vegetation is not the same as doing so in real life, where such vegetation may have subtle or not so subtle effects on channel width or length, air temperature, relative humidity, wind speed, and so on. See Bartholow (2000) for more on cumulative effects.

WARNING OR ERROR MESSAGES

SSTEMP is mathematically unstable above latitudes for which the sun never rises for a given time of year. Other special cases may cause mathematical errors also, such as trying to make the stream flow uphill. Any program error will cause a message followed by reversion to the user-input. The user may reasonably assume that the last value typed is the one that caused the error. Correct the errant value and try again.

COMPUTING REQUIREMENTS

Windows is the required operating system – 9x or higher. The recommended screen resolution is 1024 by 768. Installation may consume up to 6 megabytes after temporary files are removed.

SSTEMP can utilize a printer for screen image printing; however a printer is not required.

PROGRAM DISTRIBUTION

SSTEMP is in the public domain and may be copied and distributed freely. We ask only three things of those who use the program:

1. Please report any errors or questions to the USGS at the address listed below.

2. Please let us know about your applications of SSTEMP. We need to be kept aware to improve our understanding of your needs.

3. When distributing copies of this program, make sure that all relevant program files and documentation are included.

FOR MORE INFORMATION

USGS strongly encourages users of the stream segment and stream network temperature models to take the IF 312 course, offered in a self-paced format. Please see the following sources for additional information, and visit our web site at http://www.fort.usgs.gov/ to view the Frequently Asked Questions (FAQ) pages.

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QUESTIONS, SUGGESTIONS, ERROR REPORTS

Please direct questions or suggestions to:

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In no way do I pretend that I have solved all the problems or made SSTEMP a glowing example of professional software. But I have, I believe, made improvements from the DOS version and remain supportive of the software as a learning tool on the path to SNTEMP, which is, after all, its original purpose.

DISCLAIMER

This report is preliminary, subject to change, and has neither been peer reviewed nor reviewed for conformity with U.S. Geological Survey editorial standards.