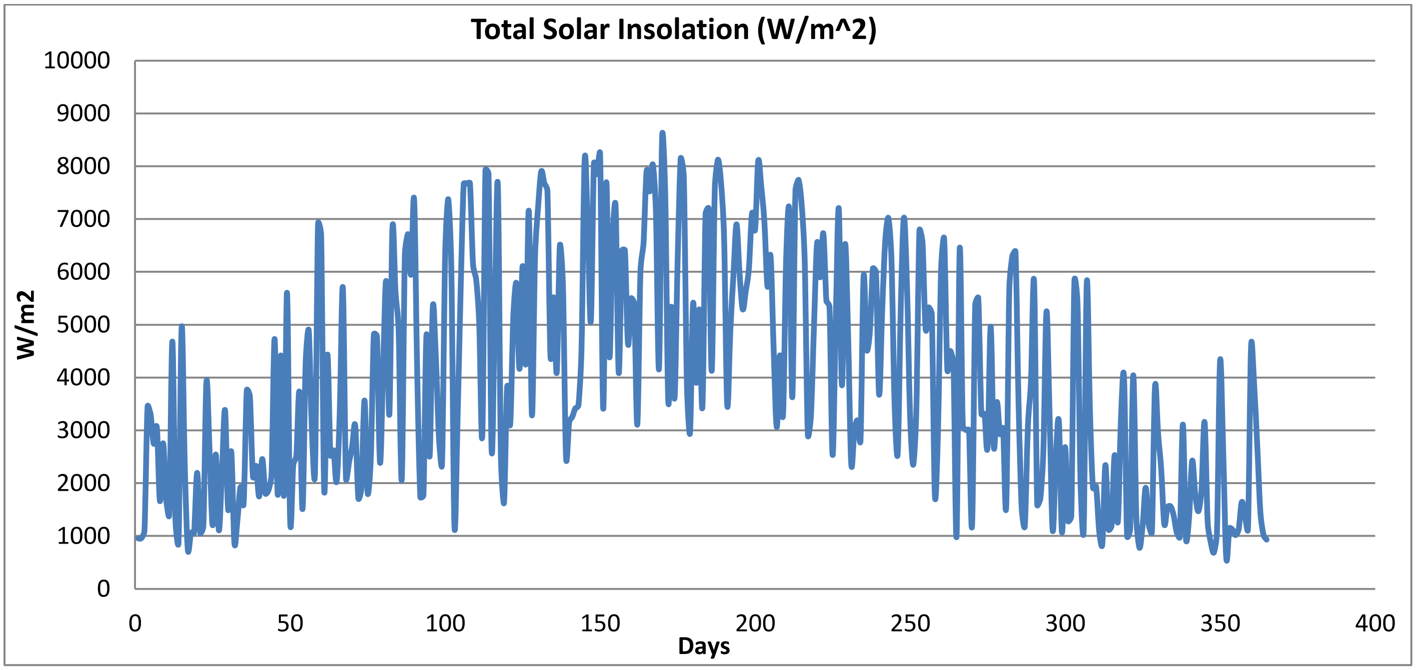
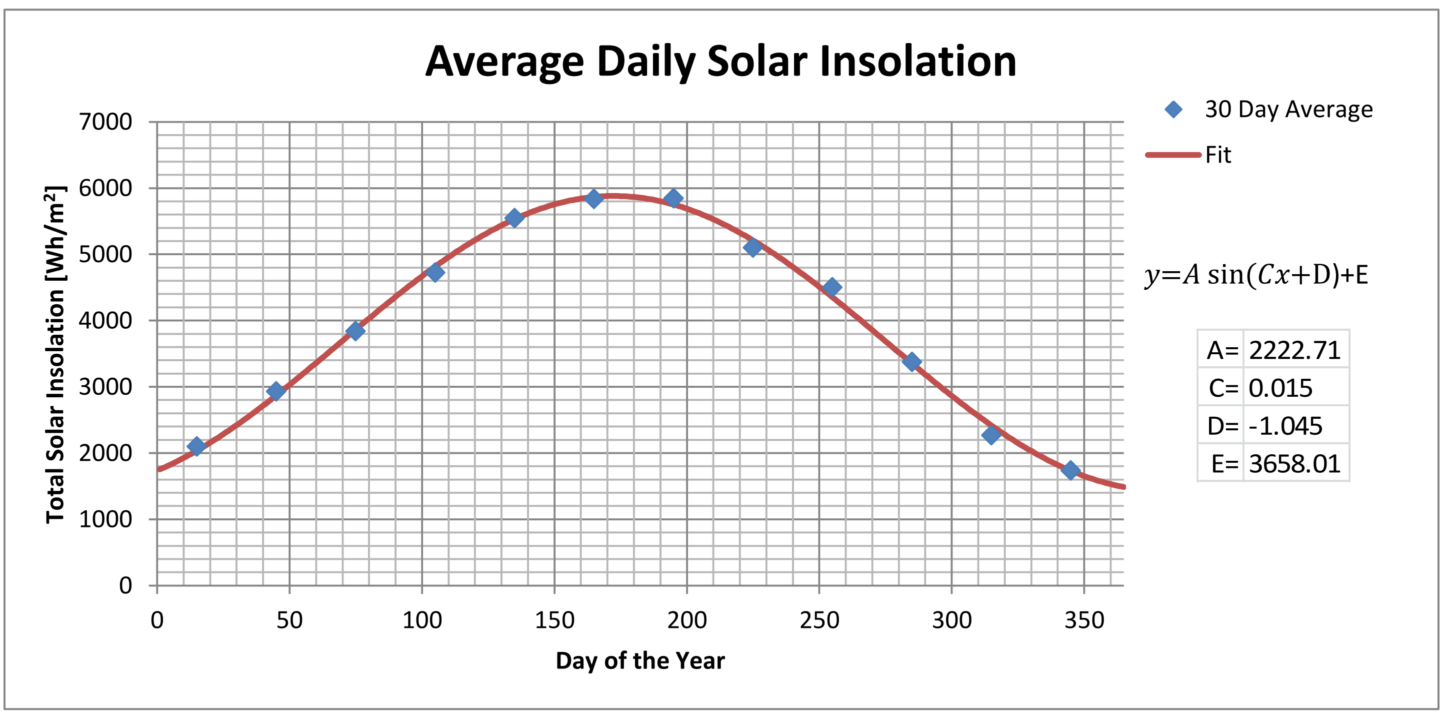
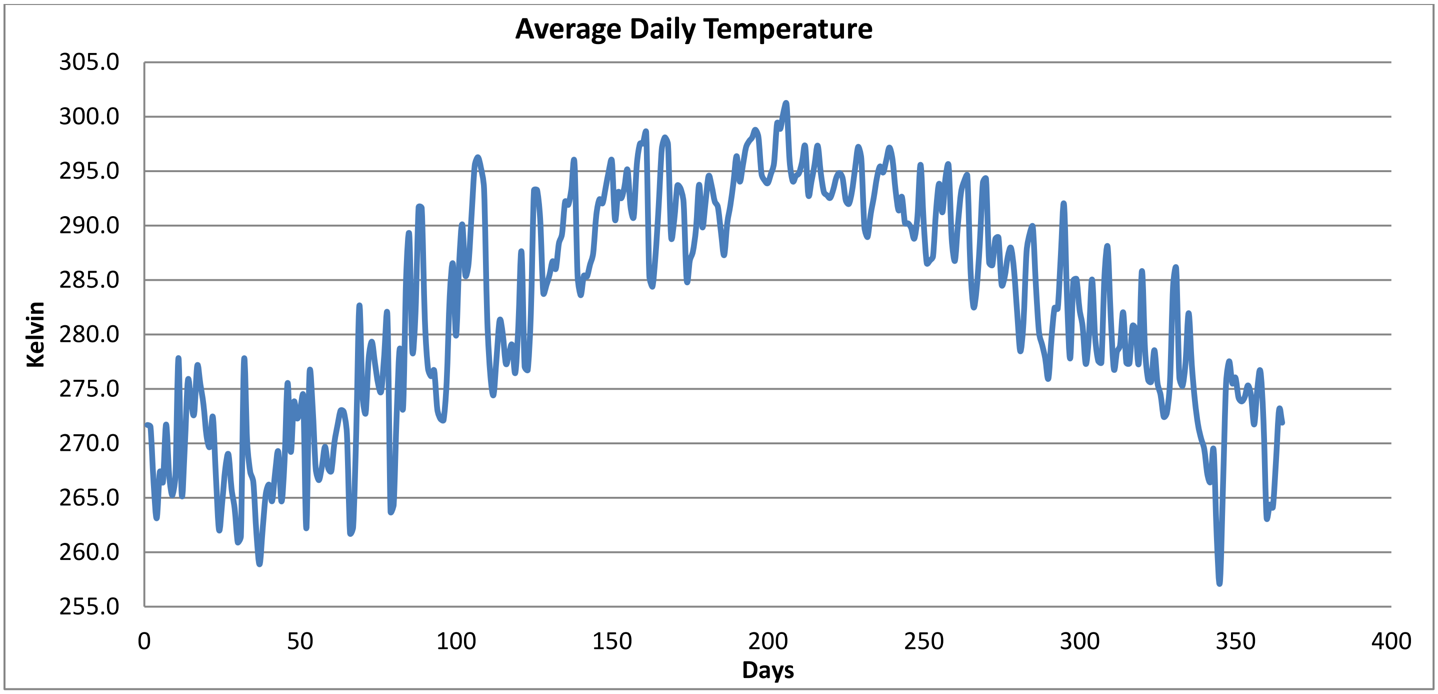
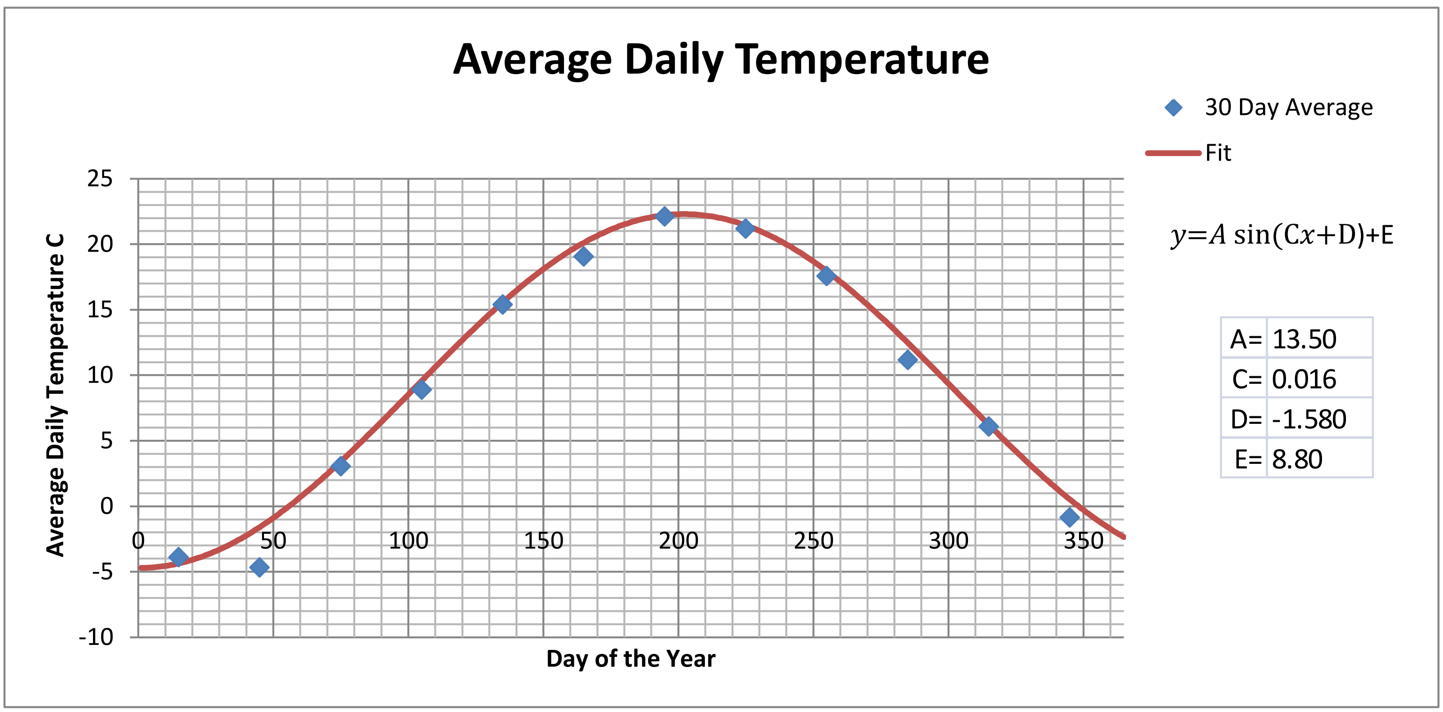
TMY3 Data:

This data provides hourly temperature and Solar Insolation Readings for Rochester NY taken at the Airport. This data represents the typical meteorological year for Rochester, NY. Below are the Daily values for average temperature and the total solar insolation for each day of the year calculated from this data set. A smooth sinusoidal fit was also calculated for these two graphs and used in the sensitivity analysis which is discussed later.






Average Daily Temperature
Kelvin
305.0
300.0
295.0
290.0
285.0
280.0
275.0
270.0
265.0
260.0
255.0
0
50
100
150
200
250
300
350
400
Days


Average Daily Temperature
30 Day Average
Fit
Average Daily Temperature C
25
20
15
10
5
0
-5
-10
0
50
100
150
200
250
300
350
Day of the Year
y=A sin(Cx+D)+E
A= 13.50
C= 0.016
D= -1.580
E= 8.80

Theoretical Model:

"Experimental and theoretical method for the determination of the daily output of a solar still: input-output method" written by V. Belesslots was used as a guideline for calculating the Mass output of water per hour for this device. The Assumptions that were used in the analysis are as follows:

- Glass Cover Emissivity is equal to 1
- Surface Area of water and basin is equal to $1m^2$
- Angle of Incidence for Solar Still Cover is equal to 0.5 radians
- Optical Efficiency of Glass is equal to 0.8
- There is no heat loss through the sides of the still
- Depth of Water in Basin is 2cm
- Standard properties for Salt Water
- Standard properties for glass
- Convective heat transfer coefficient between glass over and environment was assumed to be $15W/m^2K$
- Convective heat transfer coefficient between water in basin and cover was assumed to be $5W/m^2K$

The Calculated values are listed below with the equations from the paper that were used:

Partial Water Vapor Pressure of Temperature range 10-150C:

$$p = 165{,}960.72 \times 10^{-[X(a+bX+cX^3)]/[T(1+dX)]} \quad \text{(A.12)}$$

where

$$X = 647.27 - T$$

$$a = 3.2437814$$

$$b = 5.86826 \times 10^{-3}$$

$$c = 1.1702379 \times 10^{-8}$$

$$d = 2.1878452 \times 10^{-3}$$

Latent Heat of Vaporization $h_{fg} = 3{,}044{,}205.5 - 1679.1109\, T_w - 1.14258\, T_w^2$ (A.11)

Sky Temperature $T_s = 0.0552\, T_a^{1.5}$ (A.10)

Radiative heat transfer coef. between glass over and environment $h_{rgs} = \varepsilon_g \sigma \left(T_g^2 + T_s^2\right)\left(T_g + T_s\right)$ (A.8)

Evaporative heat transfer coef, between water in basin and cover

$$h_{ewg} = \frac{9.15 \times 10^{-7}\, h_{cwg} \left(p_w - p_g\right) h_{fg}}{\left(T_w - T_g\right)} \quad \text{(A.6)}$$

Radiative heat transfer coefficient between water in basin and cover $h_{rwg} = 0.9\sigma \left(T_w^2 + T_g^2\right)\left(T_w + T_g\right)$ (A.7)

Calculating Overall upward heat flow factor:

$$U_t = \left[\frac{1}{U_i} + \frac{1}{A_r U_o}\right]^{-1} \qquad \text{(A.1)}$$

where

$$U_i = h_{cwg} + h_{ewg} + h_{rwg} \qquad \text{(A.2)}$$

$$U_o = \frac{h_w\left(T_g - T_a\right)}{T_g - T_s} + h_{rgs} \qquad \text{(A.3)}$$

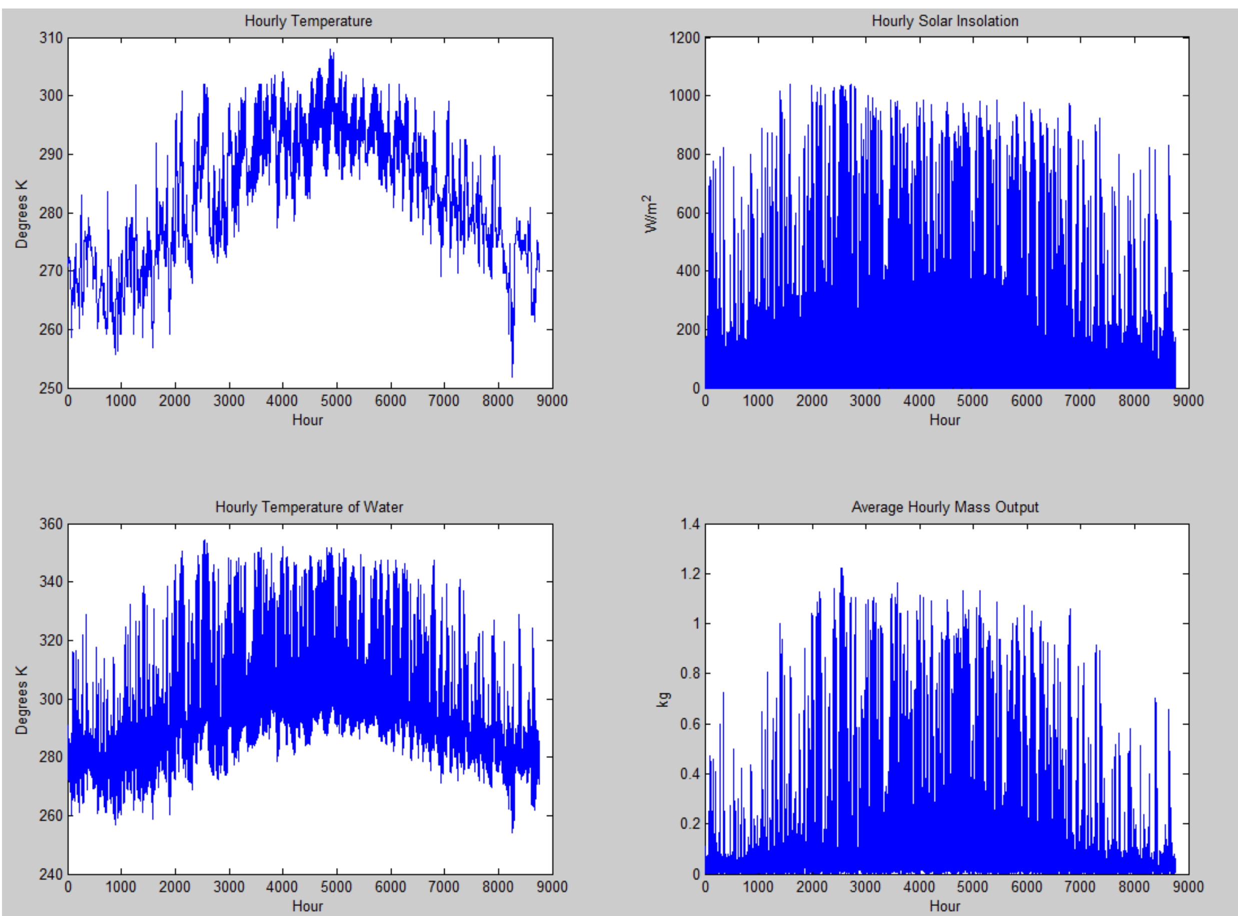
$$A_r = \frac{A_g}{A_w} \qquad \text{(A.4)}$$

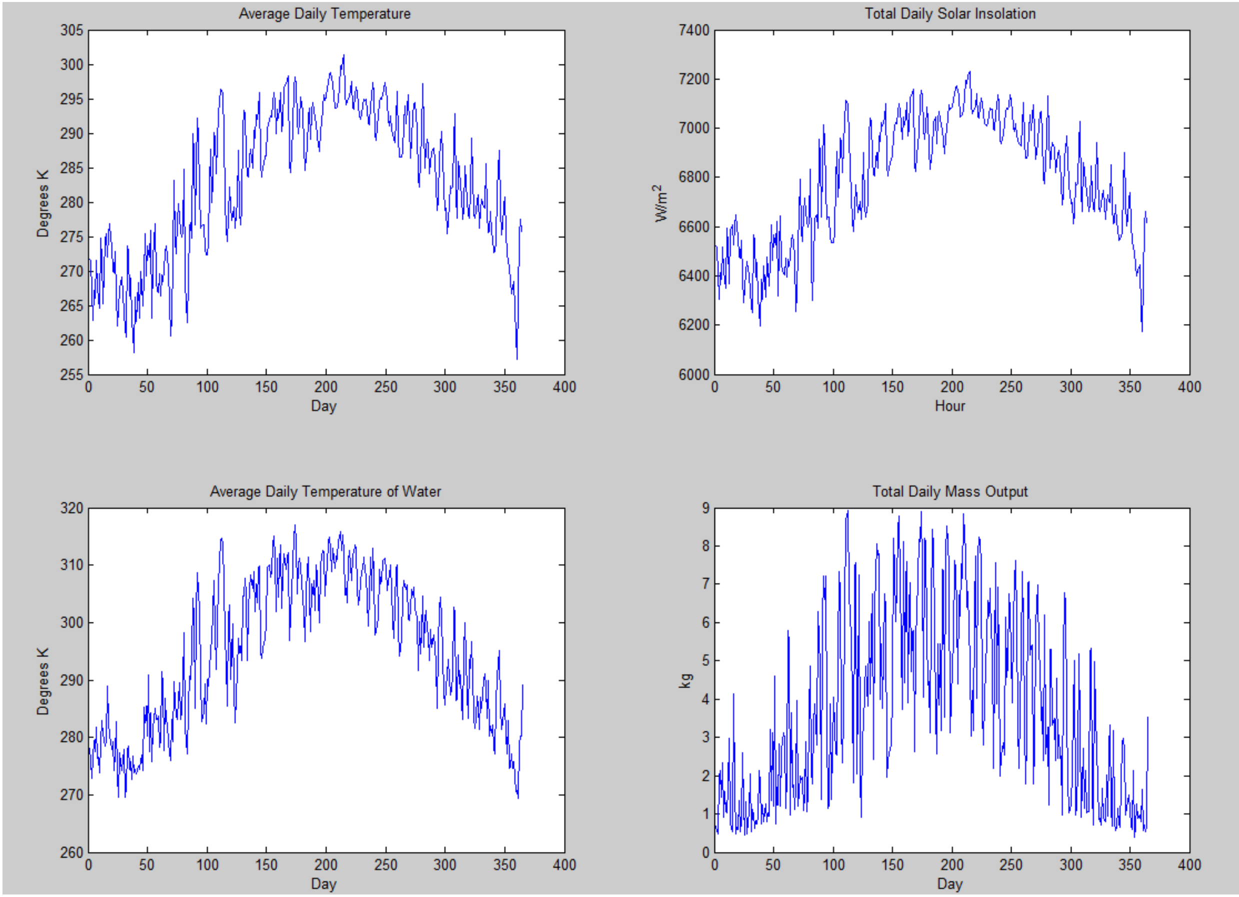
Calculating Mass Output $$M_{out} = A_g \frac{h_{ewg}}{h_{fg}} \frac{U_t}{U_i} \Delta t \left(\overline{T}_{wd} - T_{ad}\right) \qquad (5)$$

Calculating Incremental Water Temperature $$\frac{C_w}{A_w} \frac{dT_w}{dt} = k(t) n_o I(t) - U_t\left[T_w(t) - T_a(t)\right] - U_b\left[T_w(t) - T_a(t)\right] \qquad (2)$$

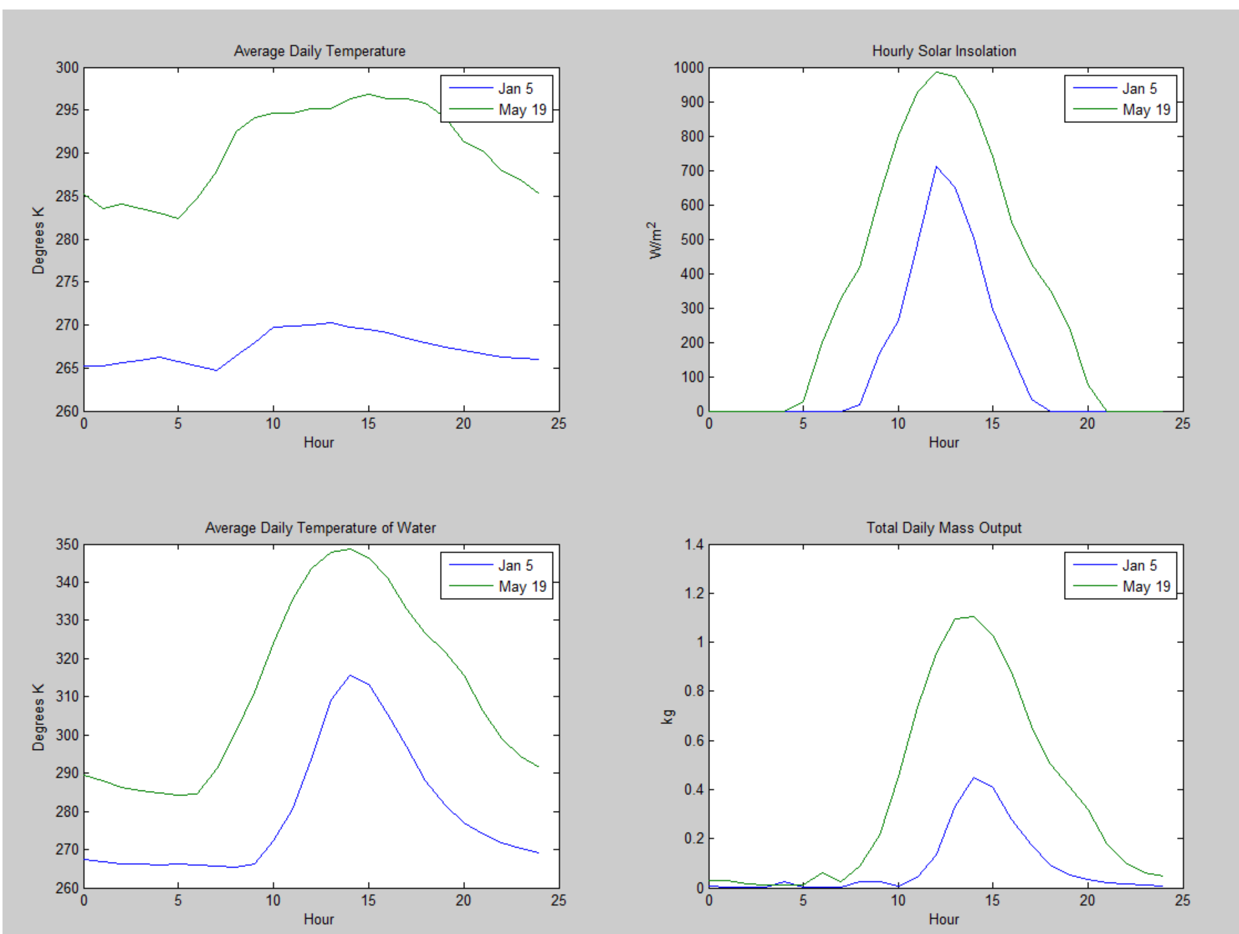
Simulation Using Theoretical Model:

Matlab was used to create the simulated model using the TMY3 data as the input. This is the reason for the variability in the results. Shown is the Hourly Calculations, Daily Calculations and a "typical" winter day vs. summer day plots:





Average Daily Temperature
Degrees K
Day
Total Daily Solar Insolation
W/m^2
Hour
Average Daily Temperature of Water
Degrees K
Day
Total Daily Mass Output
kg
Day



Average Daily Temperature
Jan 5
May 19
Degrees K
Hour
Hourly Solar Insolation
Jan 5
May 19
W/m^2
Hour
Average Daily Temperature of Water
Jan 5
May 19
Degrees K
Hour
Total Daily Mass Output
Jan 5
May 19
kg
Hour

The Following was calculated as reference and was taken from the command window after the simulation was run:

Average Mass Output per Day (kg)

3.64

Mass Output Jan 5(kg)

2.15

Mass Output May 19(kg)

9.03

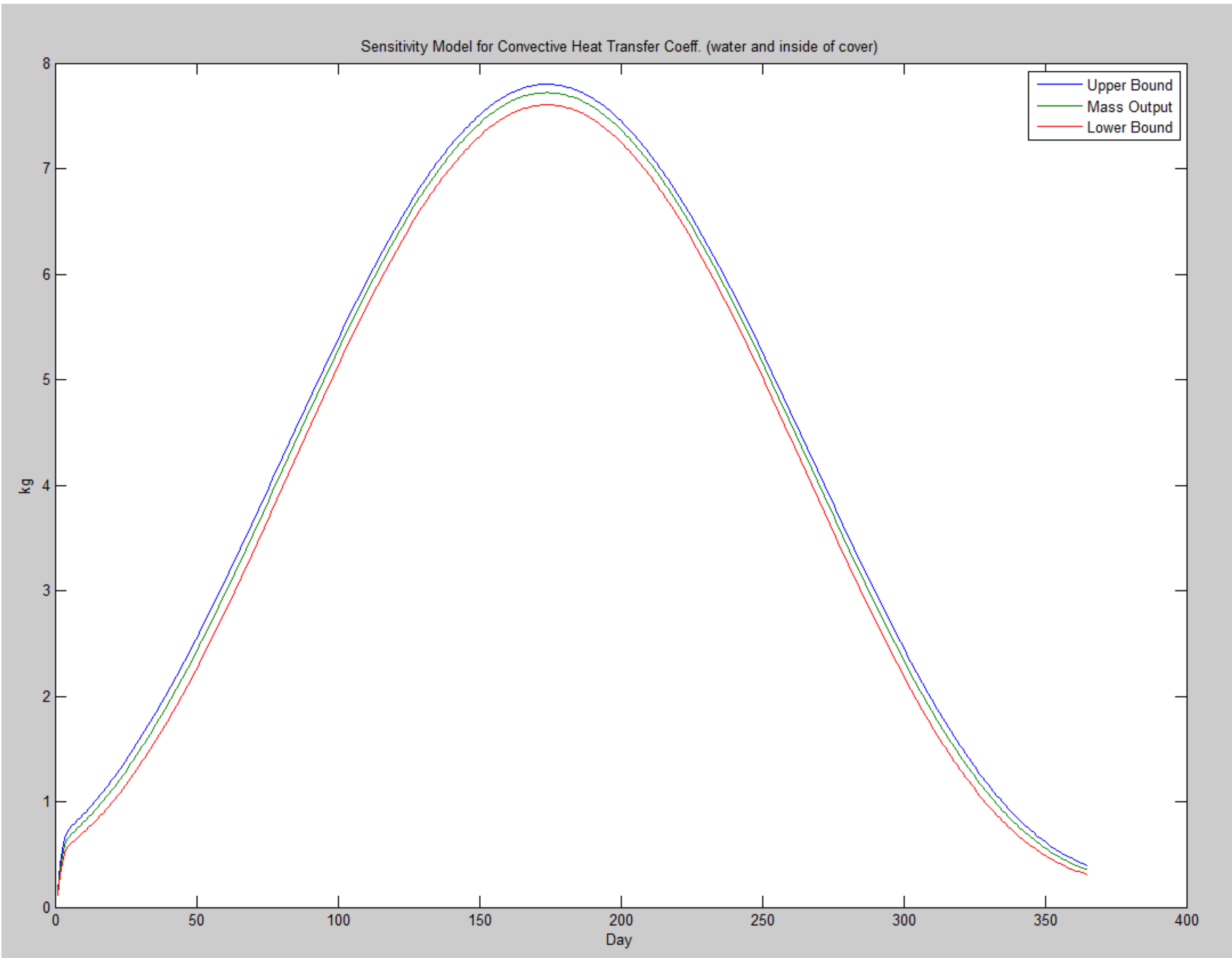
In order to answer some design questions the following was done using the theoretical model:

The radiative heat loss was doubled in an effort to represent the heat loss through the sides of the solar still if LEXAN was used. Using LEXAN would provide the user with a clear view of the interworkings of the still. However, the major concern in using LEXAN is the radiative heat loss without having fully insulated sides. The area for both sides is approximately equal to the top of the solar still which is why the approach of doubling the radiative losses was taken. The results are shown below:

	From Orginal Analysis	Increase Radative Losses	Percent Difference
Average Mass Output per Day (kg)	3.64	3.53	2.99%

Sensitivity Analysis:

The sensitivity analysis was completed to Validate the Assumptions for Heat Transfer Coefficents that were made for the theoretical model. For the heat transfer coeffiecients that were assumed constant, an upper bound and lower bound were created by varying the assumed value by 20%. The sinusodal fits created for daily temperature and daily insolation from the TMY3 data were used in order to better display the upper and lower bounds. The average daily mass output for the upper, lower and middle curves are also shown:



Average Mass Output per Day Upper Bound (kg)

4.32

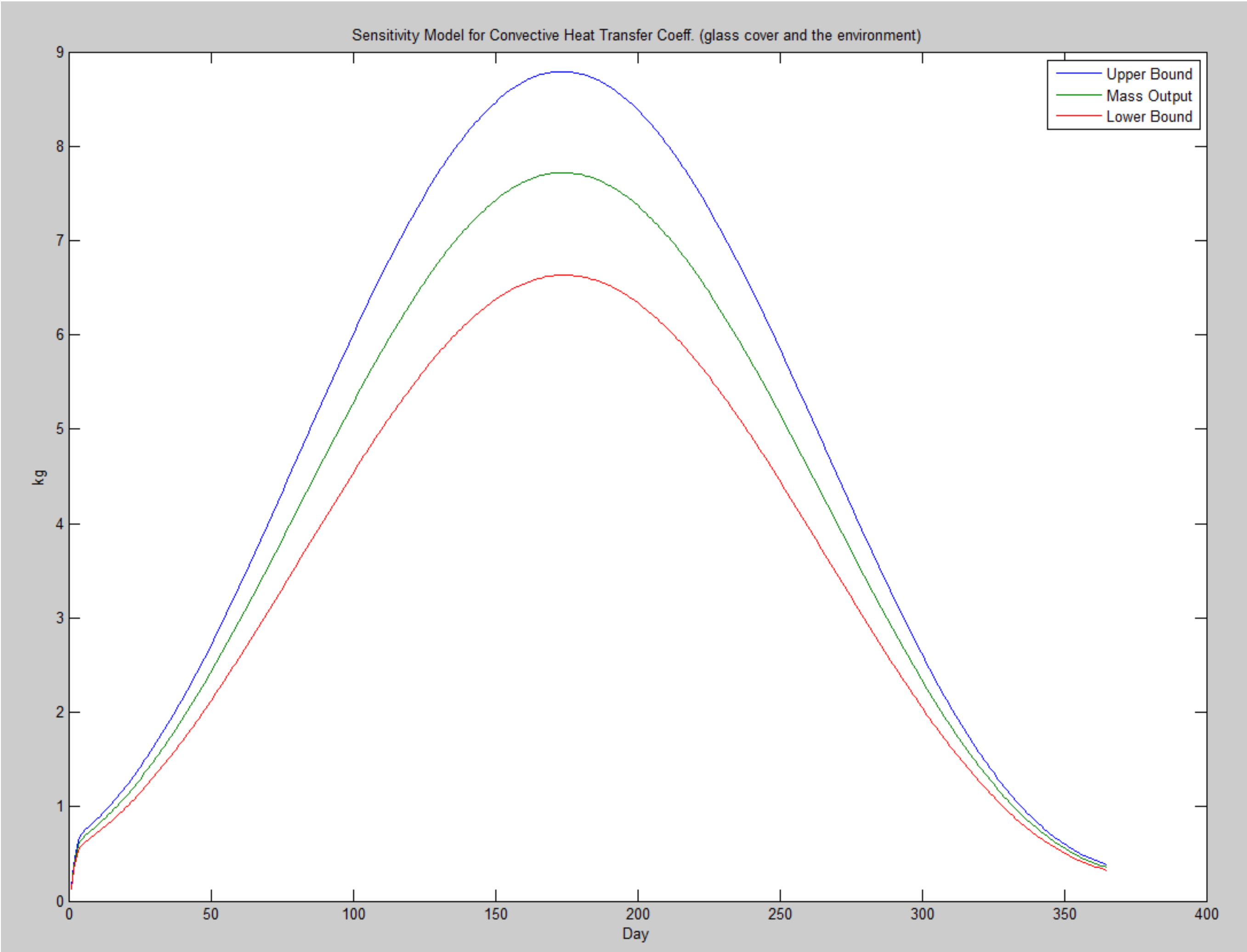
Average Mass Output per Day (kg)

4.23

Average Mass Output per Day Lower Bound (kg)

4.10

Approximately a 3% change in Mass Output due to a 20% change in the Heat Transfer Coefficient between the water and the inside of the glass cover



Average Mass Output per Day Upper Bound (kg)

4.79

Average Mass Output per Day (kg)

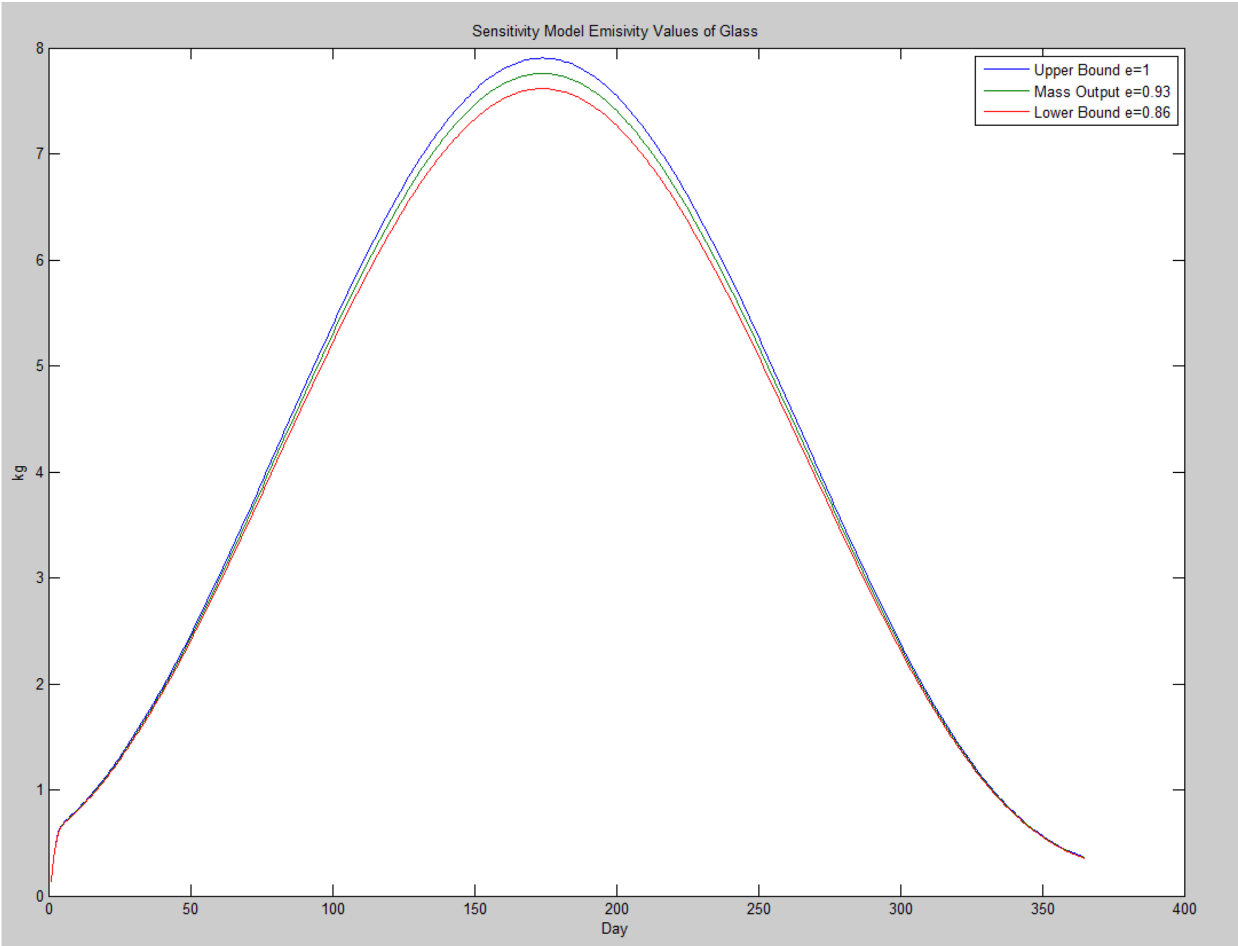
4.23

Average Mass Output per Day Lower Bound (kg)

3.65

Approximately a 13.5% change in Mass Output due to a 20% change in the Heat Transfer Coefficient between the glass cover and the environment

A sensitivity analysis was also completed for the glass emissivity value. The upper bound in this case is the assumed value (ideal value) the middle value is a typical emissivity value for glass and the lower bound was chosen in order to have an equal distribution from the center (or typical value).



Average Mass Output per Day Upper Bound (kg)

4.31

Average Mass Output per Day (kg)

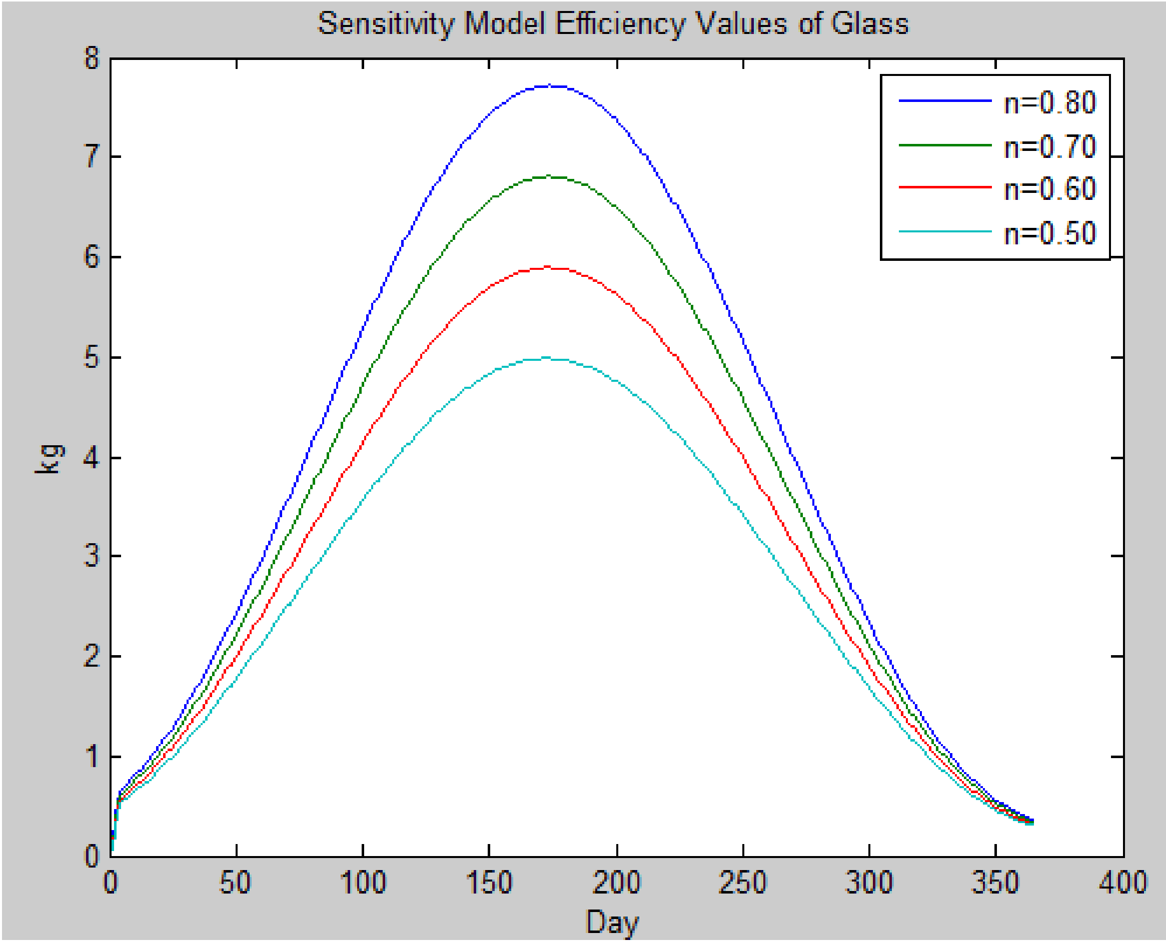
4.24

Average Mass Output per Day Lower Bound (kg)

4.17

Upper bound is only 1.6% larger than the average mass output per day for the typical emissivity value for glass. Meaning assuming the glass has an ideal emissivity value does not have a large effect on the overall output

NOTE: Using the fit line increases the Average Mass Output per day however, the sensitivity analysis was designed to provide a range for the expected average mass output depending on the parameter that is changed.



Average Mass Output per Day (kg)	Percent Difference from Original:
4.23	0%
Average Mass Output per Day (n-0.70) (kg)	Percent Difference from Original:
3.76	11%
Average Mass Output per Day (n=0.60) (kg)	Percent Difference from Original:
3.30	22%
Average Mass Output per Day (n=0.50) (kg)	Percent Difference from Original:
2.85	33%