MATLAB FINAL PROJECT

Soil Temperature Modelling

Bikramjit Narwal – University of Toronto

Mat188 | 1005242300

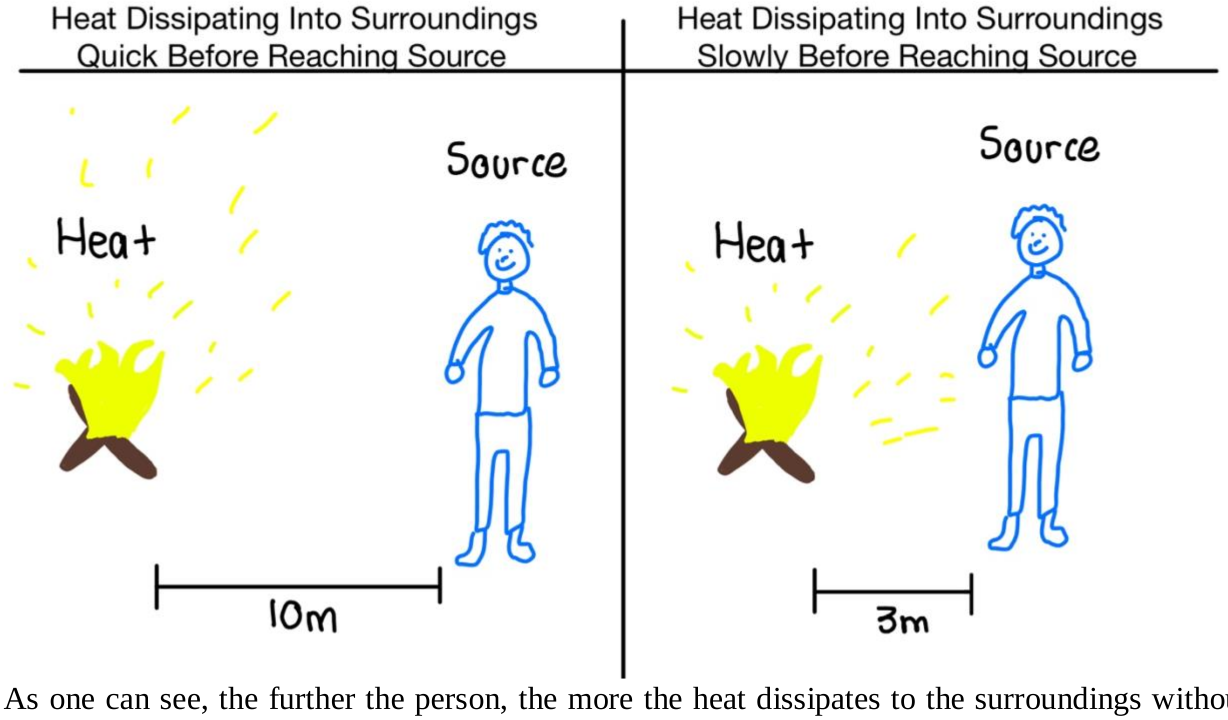
Bikramjit Narwal
1005242300

Matlab Questions

1) Understanding the problem

In the problem *Soil Temperature Modelling* the goal was to create a script that summarized how the soil temperature within Toronto would change with time and depth over 6 months (December 31st to May 31st). We have been given some relevant information in the question itself. For example, in the question it stated that while constructing new urbans systems, builders must consider how deep they make their pipes in order to ensure that they do not freeze. This makes sense since if the pipe is really close to the surface, then in the winter months, the contents in the pipe, presumably water, will freeze. From the equation, it was seen that it was possible to model the situation by considering how the temperature of soil at a specific depth relates to the surface temperature and initial soil temperature. Some fundamental scientific concepts that are required for this question are quite simple. The knowledge of how heat transfers is essential to solving this question. When a barrier between a heat source is really far from the source of contact, then heat dissipates in the barrier since it has to travel really far to reach the source of contact. If the source of contact is really close to the heat source, then the heat can reach the contact source before dissipated in external factors. The following hand drawn diagram shows this:

$$\frac{T(x,t) - T_S}{T_i - T_S} = erf\left(\frac{x}{2\sqrt{\alpha t}}\right) = \frac{2}{\sqrt{\pi}}\int_0^{\frac{x}{2\sqrt{\alpha t}}} e^{-u^2}du$$



As one can see, the further the person, the more the heat dissipates to the surroundings without reaching the person. The same can be applied to this question, if the pipe is closer to the surface, then the coldness from the ground can reach it faster therefore freezing it.

2) Devising a plan

For this assignment, devising a plan will play a crucial part since many of the assignments require lots of intellect thoughts. For my assignment, I will focus on part A and part B separately to prevent overall confusion. For part A it is seen that a temperature Vs. time graph is required. I know this because in the question it literally says, “Demonstrate how the temperature changes with time”. To graph this, I need to make a time vector and also a for loop which will be the bulk of part A. The for loop would enable me to go through cycles of different surface and initial temperatures which would be used to plot the graph. For part B, the question asks to “show how the temperature changes with time (using 1-day increments) over the six-month period for the range of depths of 0.05 m to 5 m”. It is seen by this that a more complicated approach is required since many variables are changing at once; depth and time. I also have to keep in mind that each month will have its own average surface temperature which will require some research. For part B, it is also to be taken into consideration that I will require 2 for loops; one for depth changing and one for time changing.

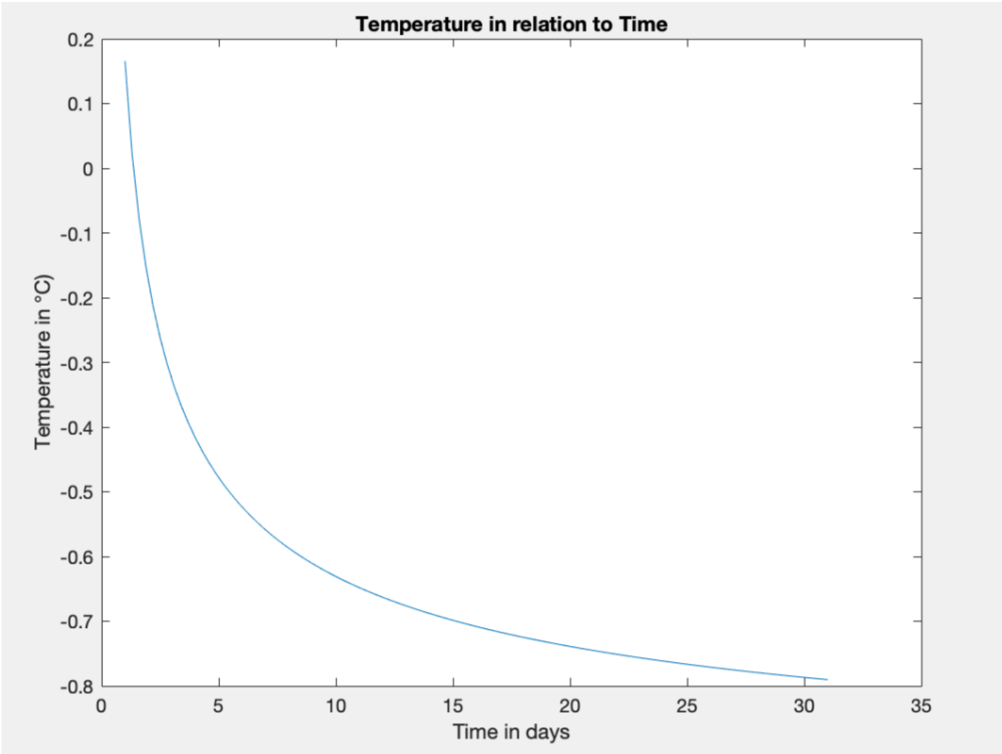
3) Carrying out the plan

For this section, I have included my graphs and relevant code also.

Part A Code and Graph(s)

```
%Here, I defined all my variables. I made sure to give each variable a
%distinct name to allow myself and the TA to understand what is going on a
%bit better. I got the thermal diffusivity value from google which was
%needed for the Equation.
depth = 0.75;
Surface_Temperature = -1;
Initial_Temperature = 14;
Thermal_Diffusivity = 1.72*10^(-6);

%The Number_of_days variable is defined from 1 day to 31 days
Number_of_days = linspace(1,31,101);

%To get the number of seconds in a day, I did some easy calculations -> 24
%hours in a day X 60 Minutes in 1 Hour X 60 Seconds in 1 Minute = Total
%Seconds
Number_of_seconds = Number_of_days*24*60*60;

%Equation used in the problem. It was given to us.
Equation = depth./(2*sqrt(Thermal_Diffusivity*Number_of_seconds));

%A foor loop to go through cycles of different surface and initial
%temperatures which would be used to plot the graph.
for i = 1:length(Number_of_seconds)
    Temp(i) = Surface_Temperature + (Initial_Temperature - Surface_Temperature)*erf(Equation(i));
end

%Plotting each day in relation to its according temperature.
plot(Number_of_days, Temp)

title ('Temperature in relation to Time')
xlabel('Time in days')
ylabel('Temperature in °C)')
hold on
clear all
```

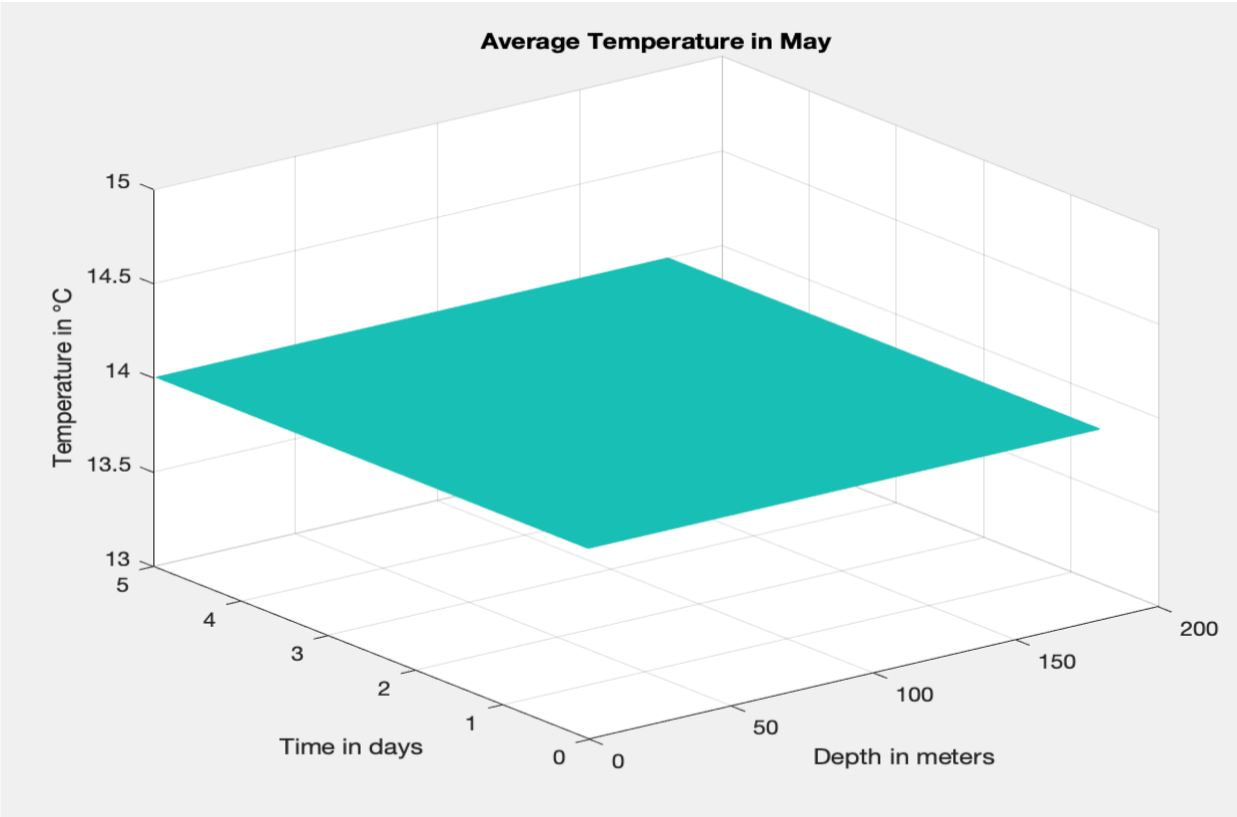
Bikramjit Narwal
1005242300

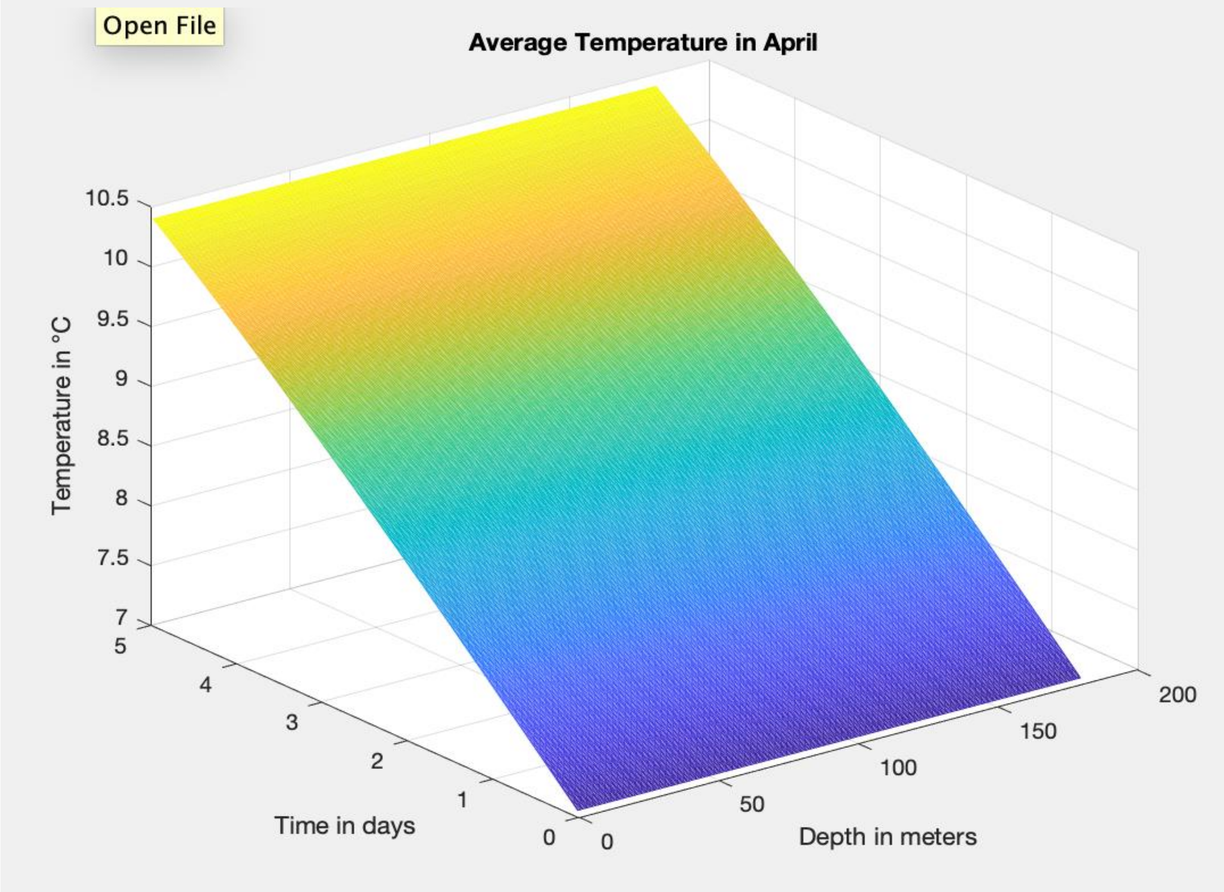


Part B Code and Graph(s)

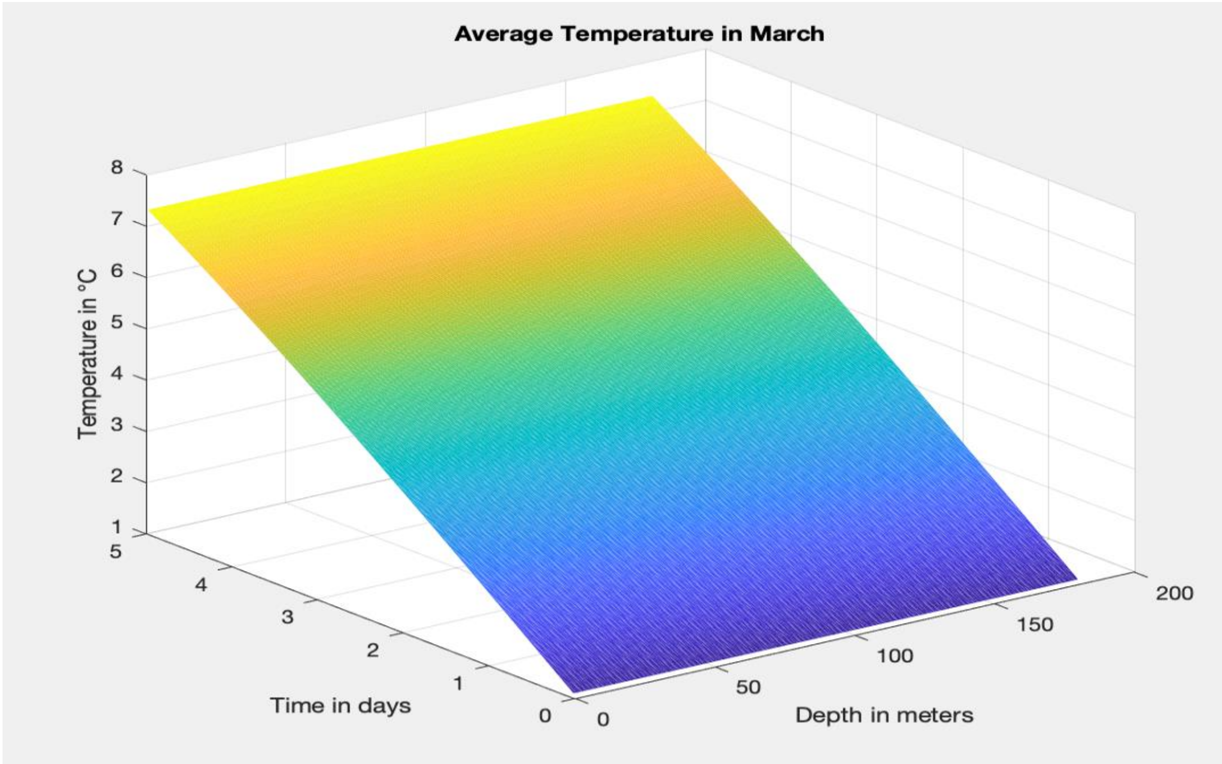
```
%Average temperature of the months Dec - May
Average_Surface_Temperature = [-1 -3 -3 1 7 14];

%Defining what months to include
Month = ["December" "January" "Febuary" "March" "April" "May"];

%All variables defined that will be used in this piece of code.
for i = 1:length(Average_Surface_Temperature)
    Surface_Temperature = Average_Surface_Temperature(i)
    Initial_Temperature = 14;
    Depth = (0.05:0.01:5);
    Thermal_Diffusivity = 1.72*10^(-6);
    Number_of_days = linspace(1,181,111);
    Number_of_seconds = Number_of_days*24*60*60;

%This will enable Matlab to graph in 3D
    [A,B] = meshgrid(Number_of_days,Depth)

%This foor loop will go through 2 changing values that change at the same
%time.
for Q = 1:length(Depth)
        Equation = Depth(Q);
        Function= Equation./(2*sqrt(Thermal_Diffusivity * Number_of_seconds));

        for R = 1:length(Number_of_seconds)
            T(Q,R) = erf(Function(1))*(Initial_Temperature - Surface_Temperature) + Surface_Temperature;
        end
end

figure
mesh(A,B,T)
title("Average Temperature in " + Month(i));
xlabel("Depth in meters")
ylabel("Time in days")
zlabel("Temperature in °C")
end
```

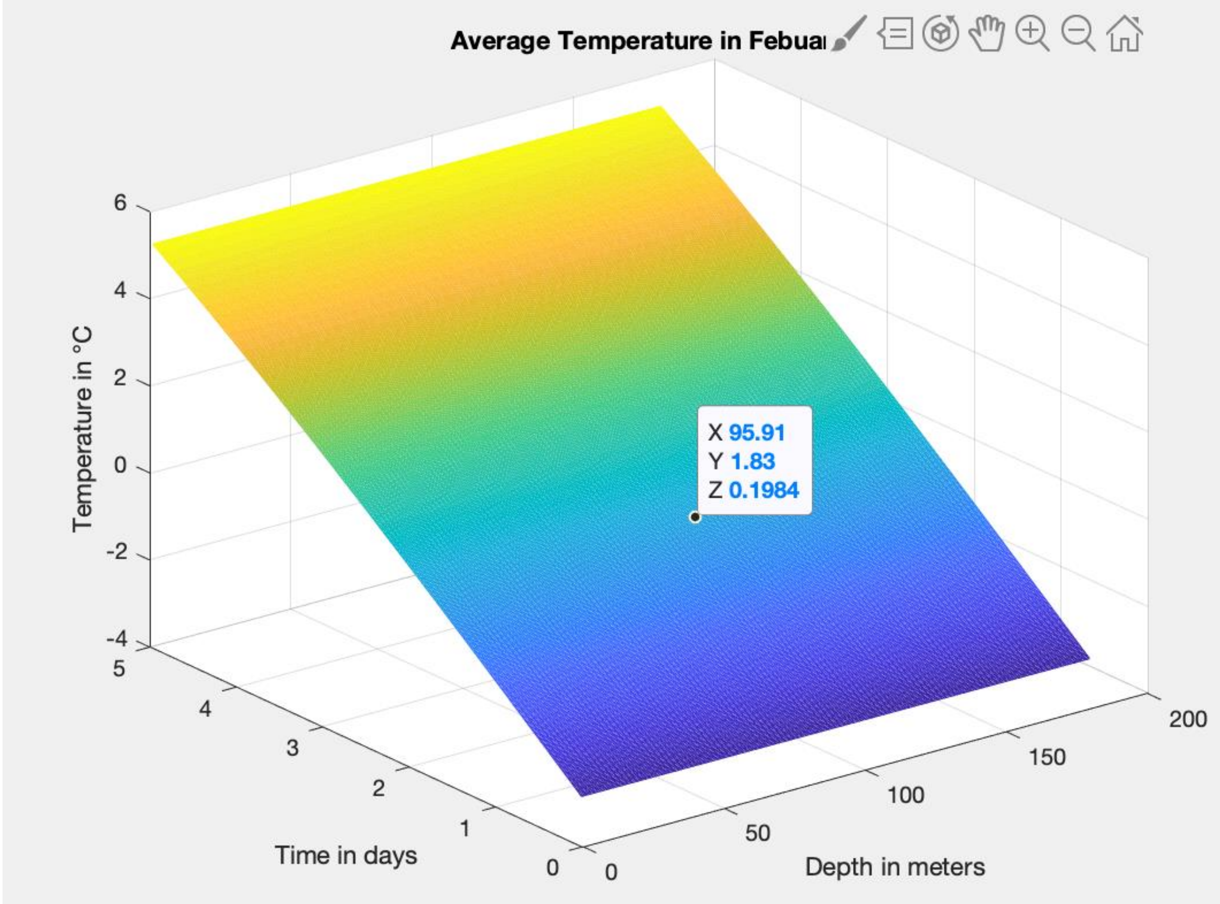
Bikramjit Narwal
1005242300



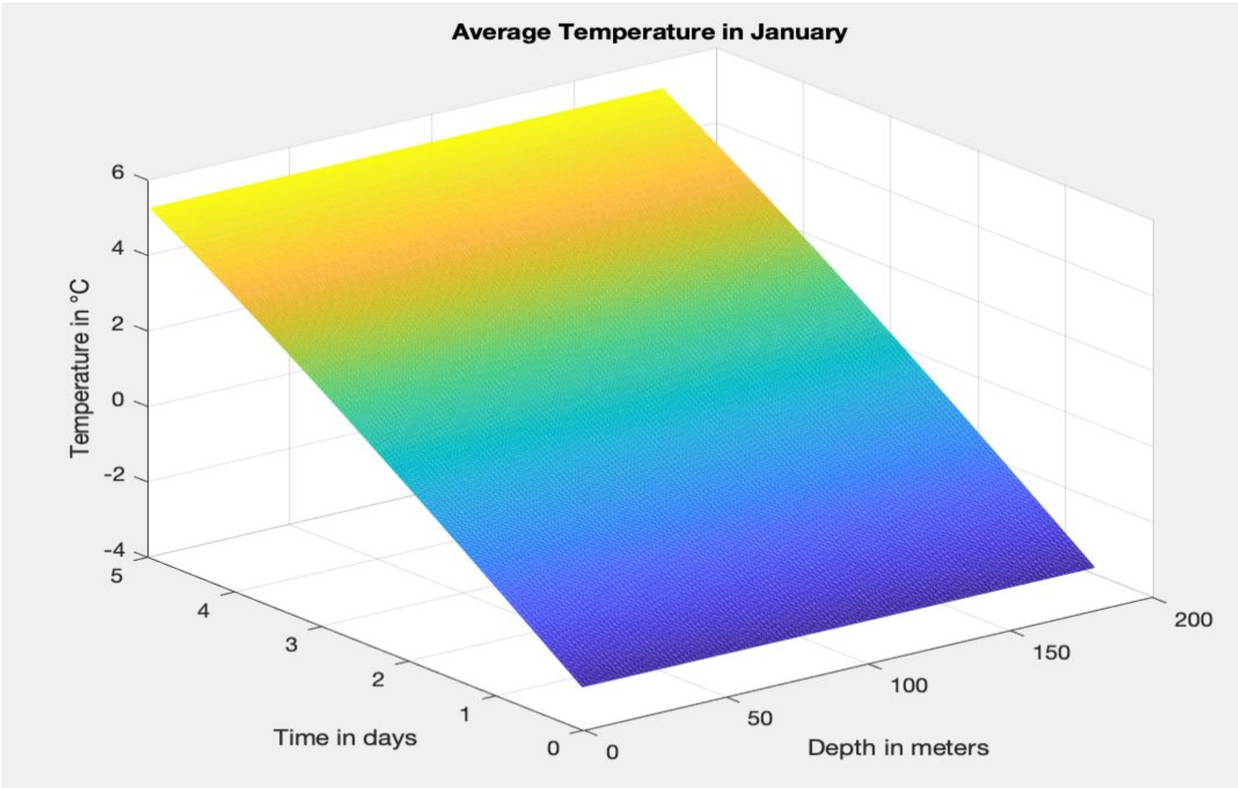


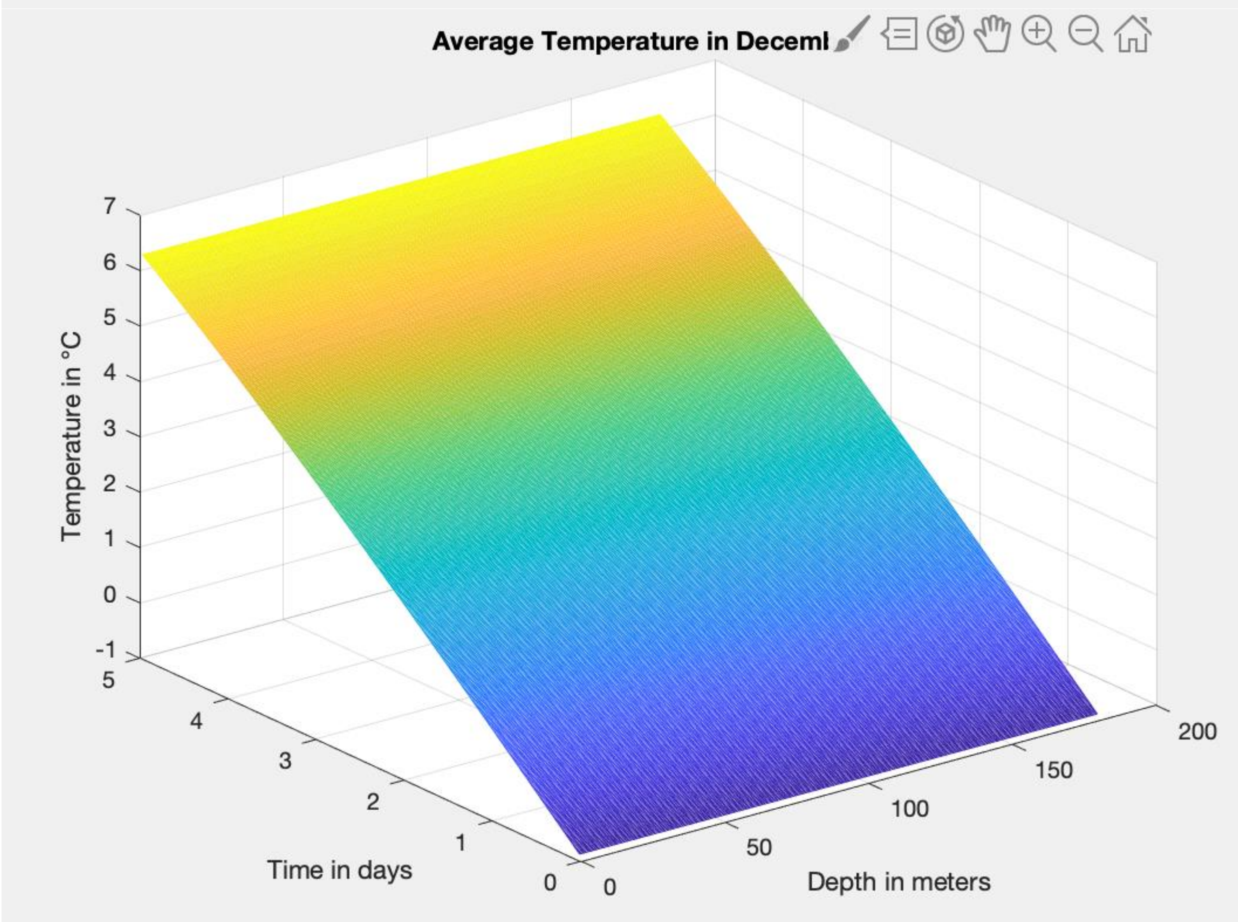
Bikramjit Narwal
1005242300





Bikramjit Narwal
1005242300





In step 2, I thought I had this assignment on lockdown after I laid my steps out. After starting to actually complete the assignment, I realized that what I stated in step 2 was correct but was harder then it seemed. It took me a while to figure out how to do 2 for loops at once but that was the main course meal of the assignment. After figuring this out, everything else fell into place. For future projects, I would plan my what I will do very detailly, so I do not get confused in the coding process.

4) Looking back

4.1) Have you addressed the problem?
The question originally asked to prepare a report that summarizes how the soil temperature within Toronto changes with time and depth over the course of a six-month period (December 1 – May 31). Having this in mind, I have addressed the problem since I was able to produce graphs on how soil temperature changes with time and depth for the designated months. This was seen in part 3 above.

4.2) How are you sure you achieved your goal?
My goal was to find data that met the requirements of the question with my level of knowledge. It is obvious that this is not the **exact** real answer since many other factors are considered when doing this research, but for my level of education I have answered the questions well.

4.3) Is there anything you have learned about the fundamental scientific and mathematical concepts and/or how to use MATLAB for engineering problem solving?

I have learned so much in this MatLab portion of Mat188. In my opinion, I think this was the most useful class out in first semester, but this might also be bias since I like to code. One key thing I have learned from this course is that almost everything can be solved mathematically, which also means that it could be solved using MatLab. I have been working on assignments that I did not even know someone can solve using a computer. This only makes me wonder what other capabilities MatLab has. My first real taste of how MatLab can apply to real life came during lab 6 which was more difficult than the others, but also gave everyone their first taste of how to apply matlab to real life. In terms of this final project, it first seemed really intriguing seeing all the complex equations, but I slowly started working my way through which made the process easier. In conclusion, looking from the graphs, the water lines need to be buried where the temperature does not drop below 5°C. Also, this ensures that the water lines do not change by less than 1% of the initial soil temperature.

References

Soil Diffusivity Value:

[1] J. M. A. Márquez, "Ground Thermal Diffusivity Calculation by Direct Soil Temperature Measurement. Application to very Low Enthalpy Geothermal Energy Systems," 29 Febuary 2016. [Online]. Available: https://www.ncbi.nlm.nih.gov/pmc/articles/PMC4813881/. [Accessed 30 November 2018].

Bikramjit Narwal
1005242300

Whether Temperatures:

[2] J. M. A. Márquez, "Ground Thermal Diffusivity Calculation by Direct Soil Temperature Measurement. Application to very Low Enthalpy Geothermal Energy Systems," 29 Febuary 2016. [Online]. Available: https://www.ncbi.nlm.nih.gov/pmc/articles/PMC4813881/. [Accessed 30 November 2018].