Small Scale Irradiance Device

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Engineering Analysis

Document

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Introduction

The small-scale solar irradiance project aims to create a device which may accurately model the irregularities of solar irradiance on COBar Ranch. Working with the Institute for Sustainable Energy Solutions (ISES) and Dr. Tom Acker at NAU, we strive to design a system that is compatible with the current site, while eliminating current problems. In doing so, many innovative solutions were determined. After evaluation of the potential ideas, we had to eliminate the less beneficial designs through a series of analysis and discussion.

Problem Statement

The current system is inefficient with its use of land, man hours, and produces poor data. The irradiance measuring system is large, semi-permanent, difficult to operate and maintain, and costly. Due to the large area of the current site, much time is required to set up the numerous pyranometers in the system and collect their data. This is an inconvenience for both the operators and land owners, as well as creates unnecessary expense. Our purpose is to design a more efficient system with respect to these issues. Presumably, we will be able to design a smaller scaled system which will collect data even more precisely. While striving to achieve our goal of designing a relatively small, portable solar irradiance measuring system that can accurately quantify variance in solar irradiance over a larger area, we generated various unique designs.

Tripod Acquisition

After talking to our client at NextEra, we decided our final physical design will be a tripod. Our next concern was whether or not we should manufacture our own, or purchase an existing tripod. We were advised not to "reinvent the wheel" since the tripod is an already proven design. Therefore, we began to research specific designs that would best fit our needs. Although every tripod has the same basic design with three legs, a relatively collapsible frame, and a place for a mount on top, there are a few tripods that have unique components.

One brand we considered is the Slik Sprint Pro II Tripod. The benefits of this choice would be the Slik Speed-Release leg locks for quick set up and also the 18.5 inch size when it is folded. These aspects are important because our system requires an easily transportable system that is also quick to set up. A second option is the Vanguard MT-23 Metal Tripod. The components in this design that are valuable to use include the adjustable leg angles, reinforced leg locks, and spiked feet. This is all important for ensure stability and reliability no matter what kind of terrain we will be working on. Our third consideration is the Manfrotto 190XDB 3 Section Aluminum Tripod. The tripod is designed with leg angles of 25°, 46°, 66°, 88° which is again helpful when the ground is not perfectly even. The last option for now is the Acculine Pro Heavy Duty Aluminum Tripod. The benefits here include a light weight and durable construction, attached chains to prevent legs from sliding, and also shark metal points on the tripod feet. All three aspects satisfy out needs by allowing easy transport and great stability.

Analyzing the cost, we found that the Acculine Pro is the best choice. Below, table 1 displays the price of each tripod. The Acculine Pro is the best tripod because it has the most benefits for a reasonable cost. It has the greatest value. Although we will be using at least five tripods, we can afford it because we will be saving money by reusing the existing sensors and DAQs.

Table 1 Tripod costs

	Acculine Pro	**Manfrotto**	**Vanguard MT-23**	**Slik Sprint Pro**
Cost $	99.95	112.73	44.95	89.95

Sensor Mounting Device

Mounting the pyranometers to the tripods requires some type of device that can keep them relatively level and pointed in a consistent direction. To successfully accomplish this task, there are two options that we can take; we can either buy an off the shelf mount or fabricate our own. The deciding factor will most likely be cost, but since we have no budget, a firm decision cannot be made at this time.

Campbell Scientific LI2003S

The existing product that can be used is made by Campbell Scientific. As seen in figure 1, the fixture is very simple and is made level by adjusting the three set screws. One of these fixtures would be attached to the top of each tripod with a single nut and bolt. The slot in the sensor seat is for the wire loom that protrudes from the base of the sensor; it also signifies how the sensor should be oriented relative to true north, that is, the slot should be pointed north. This option would cost around $80.00 per unit, so if we need seven units our cost to mount the sensors would be about $560.00.

Figure 1 LI2003S manufactured by Campbell Scientific to support Li-Cor 200 Pyranometer

Auto Leveling Mount

The auto leveling mount shown in figure 2 was designed to address a very important issue with the LI2003S fixture. The advantage is that this fixture does not change with changing ground conditions. The LI2003S was designed for laboratory conditions where the base will not move once it is placed. If a storm were to soften the ground that the tripod sits on, one or more legs may sink into the ground thereby changing the angle of the pyranometer from horizontal. This would skew our measurements and make our data useless.

The base plate of this design is somewhat tailored after the LI2003S only in that the attachment of the pyranometer is the same. Not shown in figure 2 is a wind shield that connects the outermost ring to the tripod. This allows viewing of the leveling mechanism. This feature will prevent wind disturbance in the data.

Manufacturing this design from 100% stainless steel would drive the cost up to $700.00 or more, which is not within our budget. However, composites can be used in non-critical areas such as the base plate and support rings (not including the pivot pins) and a heavier material such as lead may be used for the plumb weight. These modifications would reduce the total price to around $200.00.

Figure 2 Auto leveling sensor mount

Data Transfer

All data collected by each pyranometer must be transferred to a single, centrally located data acquisition center (DAC) in a manner that meets the objectives of the project. The two fundamental methods of accomplishing this are through a wire or via a wireless method. Many wireless methods are available, including short wave radio, cell modems, Wi-Fi, etc. Unfortunately, these methods of data transfer are beyond the scope of the project and are more suited to a computer science or electrical engineering project because of the difficulty involved with implementing the communication and transfer systems required.

The other option for transferring data to the DAC is to use a narrow gage cable. The pyranometers are manufactured with 50 feet of cable which is the maximum distance from the DAC to any pyranometer in the desired site and provide a simple solution to the basic data transfer problem. Voltage drops across the 50 foot cable are minimal and can be accounted for within the DAC.

The problem a wired communication presents is the exposure to animals, moisture, and UV rays. Field mice are the most acute animal problem as they will chew through the insulation of wires left on the ground, but cows are another animal concern as they may sever the cables by stepping on them. Moisture can cause degradation of cables through multiple freeze-thaw cycles, and UV rays can accelerate these processes by degrading the insulation. Protecting the wires from these elements can be accomplished by housing them in a flexible, liquid-tight conduit. This form of conduit is inexpensive, approximately $50 for 1/2 inch by 100 feet, and can be easily transported and assembled. This protects the cables from all of these sources of degradation.

Data Analysis

To begin an analysis of the data one second irradiance data from 6 pyranometers between 10:00am and 2:00pm for September 22, 2012 provided from the Next Era site, irradiance was plotted versus time for each of the pyranometers. The configuration of the pyranometers can be seen in figure 3 and the plot of irradiance versus time can be seen in figure 4.

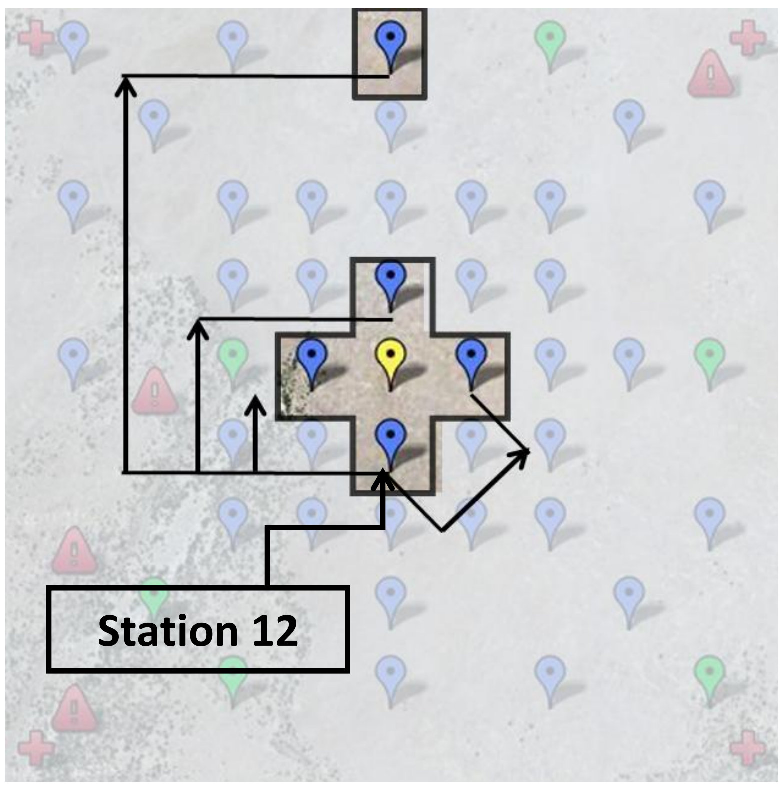


Figure 3 Configuration of sensor from which data was received.

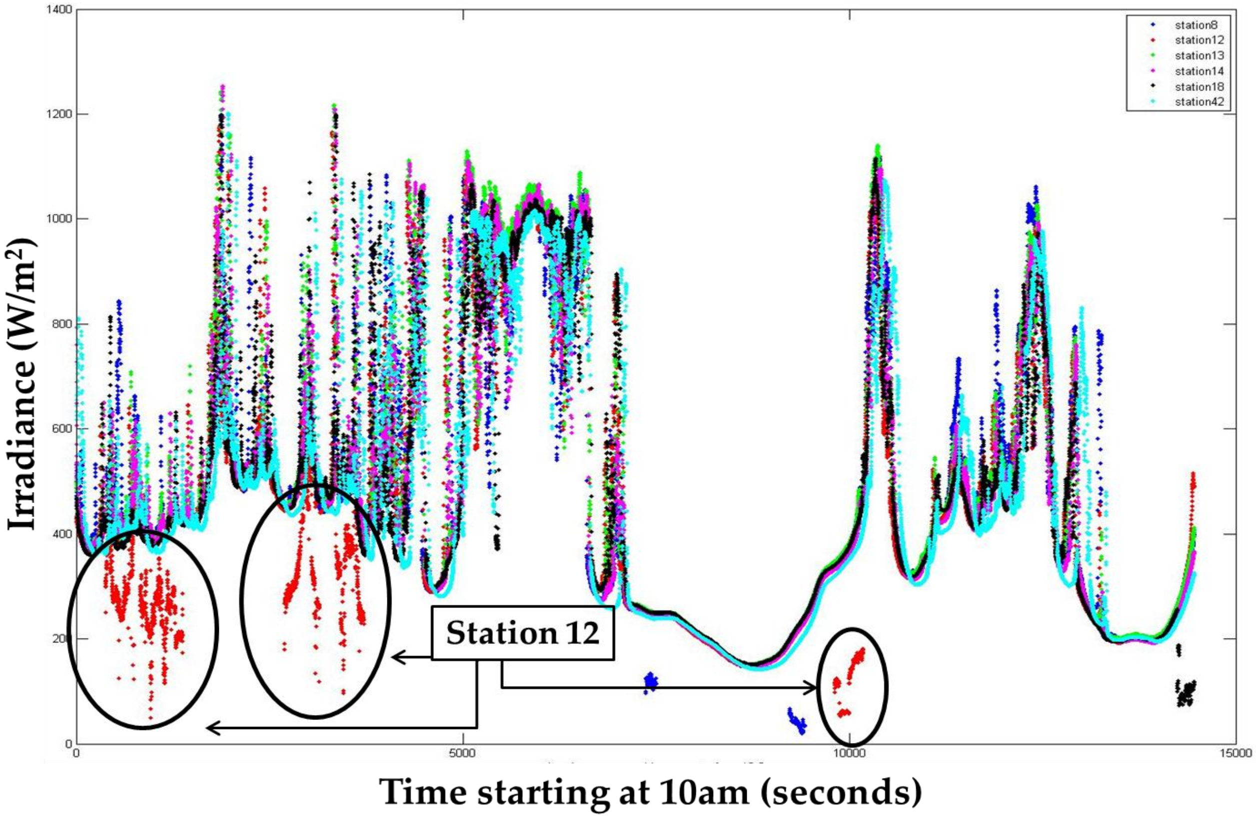


Figure 4 Irradiance versus time for all sensors

In looking at the plot in figure 4, it was noted that all of the sensors are showing the same trend in irradiance observed. The one station that exhibits a significant amount of outlying points is station 12. This is significant because data was not received for stations South, East, or West of station 12. Therefore, when looking at the positioning of station 12 in Figure 3, it cannot be determined with 100% certainty if station 12 was seeing localized cloud cover, or if station 12 was malfunctioning and recording bad data.

To try to determine if station 12 was malfunctioning during the time period of the received data set, the maximum and minimum change in irradiance between each data point was found for station 12 and compared to the maximum and minimum change in irradiance for the other stations from which data was received. These maximum and minimum values can be viewed in table 2.

Table 2 Changes in irradiance

Station	Maximum Change in Irradiance (W/m^2)	Minimum Change in Irradiance (W/m^2)
8	99	-107
12	333	-336
13	100	-123
14	101	-143
18	99	-107
42	99	-107

Viewing the changes in irradiance, it was observed that station 12 had significantly greater changes than any other station. Based on the trends seen at the other stations, it is thought that station 12 was malfunctioning; however, more data and input from technical advisors are required before it can be said that station 12 was in fact malfunctioning.

The next step completed in the data analysis was calculating the Natural Variance in Irradiation (NVI) for the data site. NVI is a tool that compares the change in irradiance to the average irradiance seen at a point over a time set and is calculated using equation 1.

$$NVI = \frac{\sigma_{\Delta G}}{\overline{G}} \tag{1}$$

NVI was calculated for each station over the course of the four hour period, over an average at each hour, and over an average every 10 minutes which can be seen in table 3, figure 5, and figure 6 respectively, noting that the bold lines in figure 5 and figure 6 are the average NVI for all station.

Table 3 NVI over the four hour period

Station	NVI
8	0.02369
12	0.03642
13	0.02054
14	0.02093
18	0.02174
42	0.02213
Average	0.02424

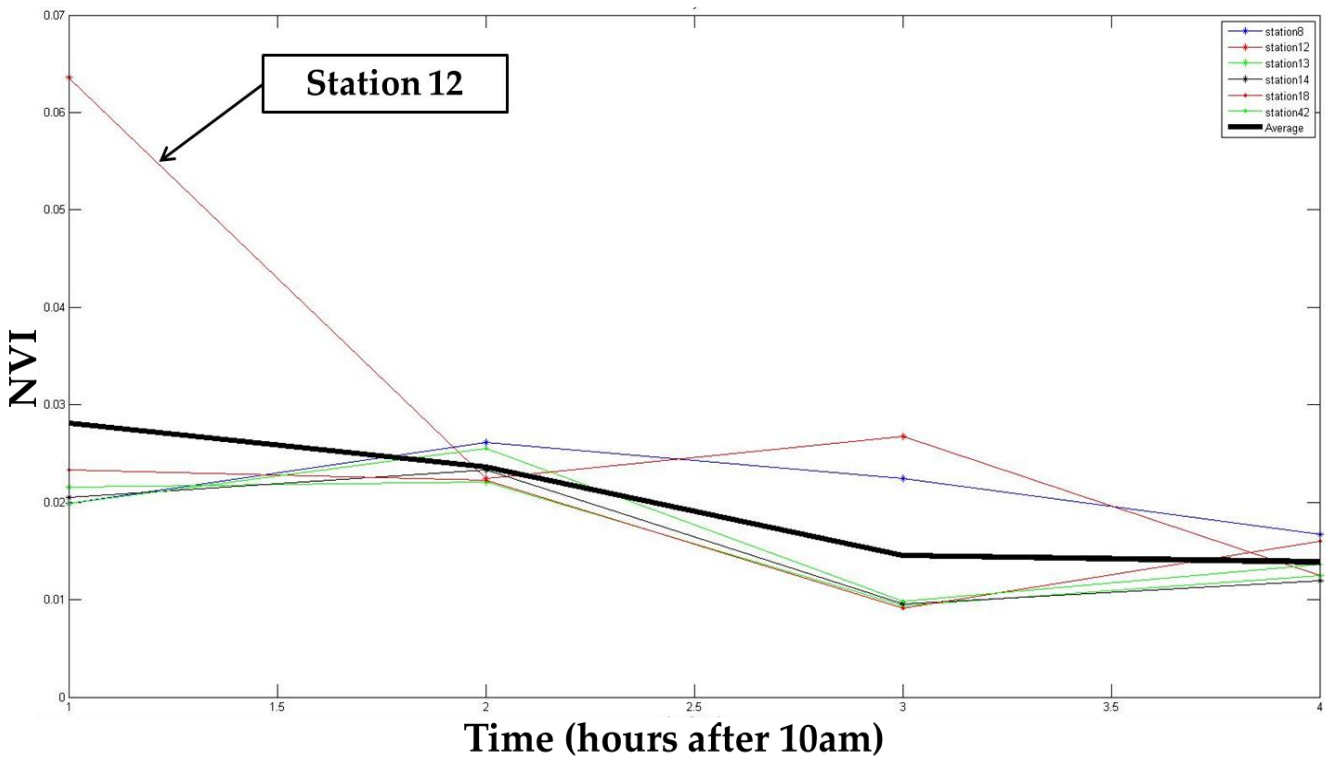


Figure 5 Hourly NVI

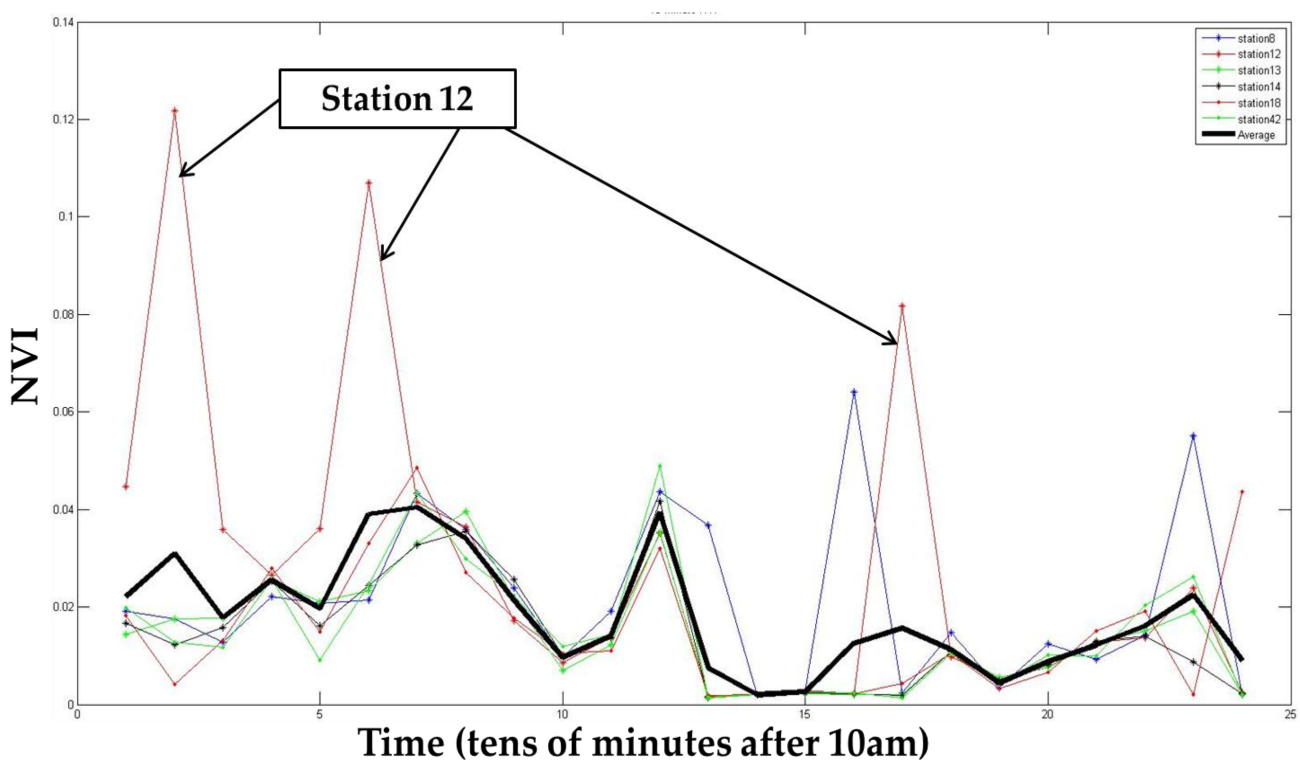


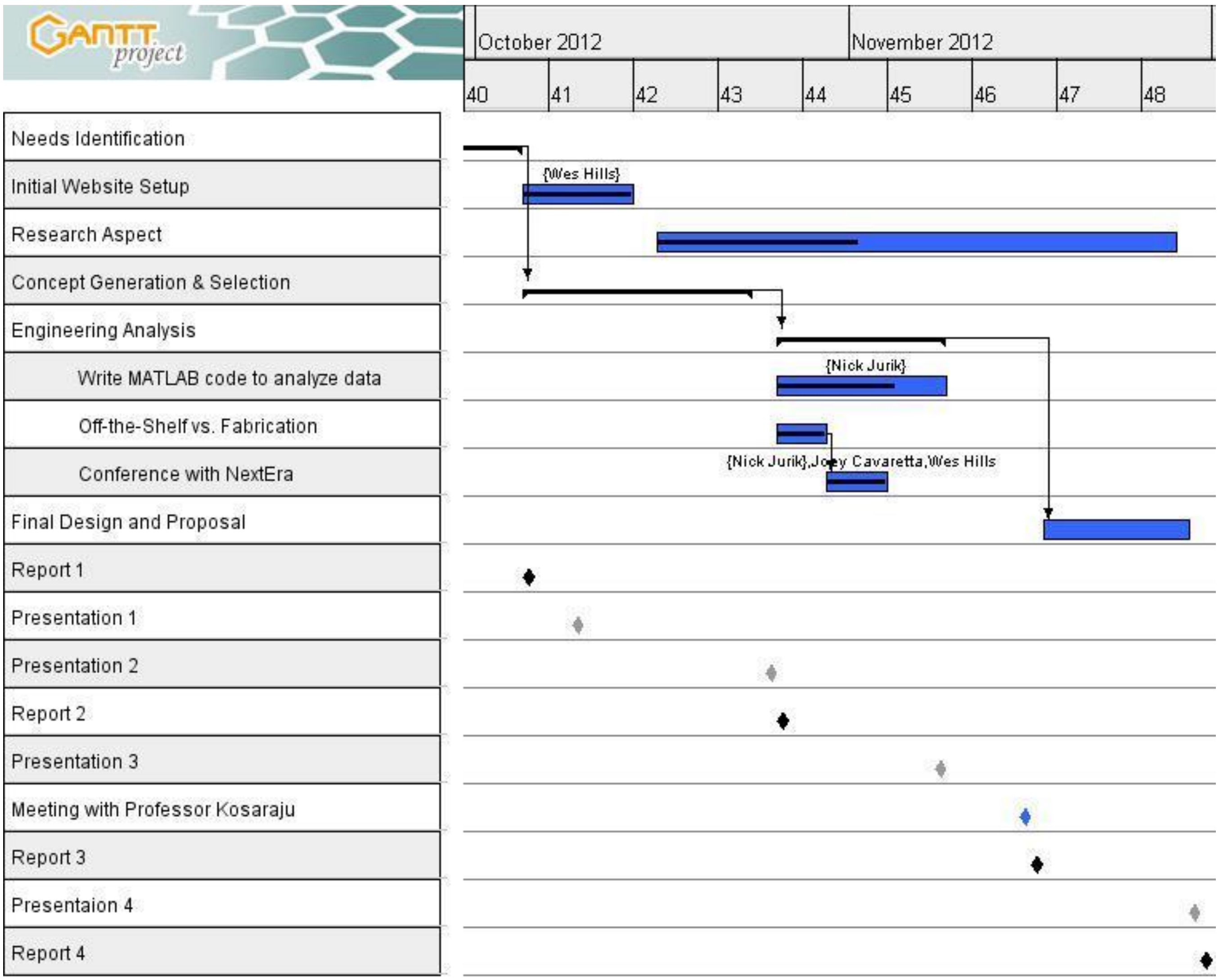
Figure 6 10 minute NVI

Next Steps

The next step in the data analysis will to attempt to find a relationship between location and time to the irradiance measured. If a relationship can be found, that relationship will be applied to try to predict the irradiance that would be measured at a point, and compare to the actual measured irradiance. The timeline for this plan can be found in Appendix A.

Appendices

Appendix A: Timeline



Appendix B: List of Tables

Table 1 Tripod costs

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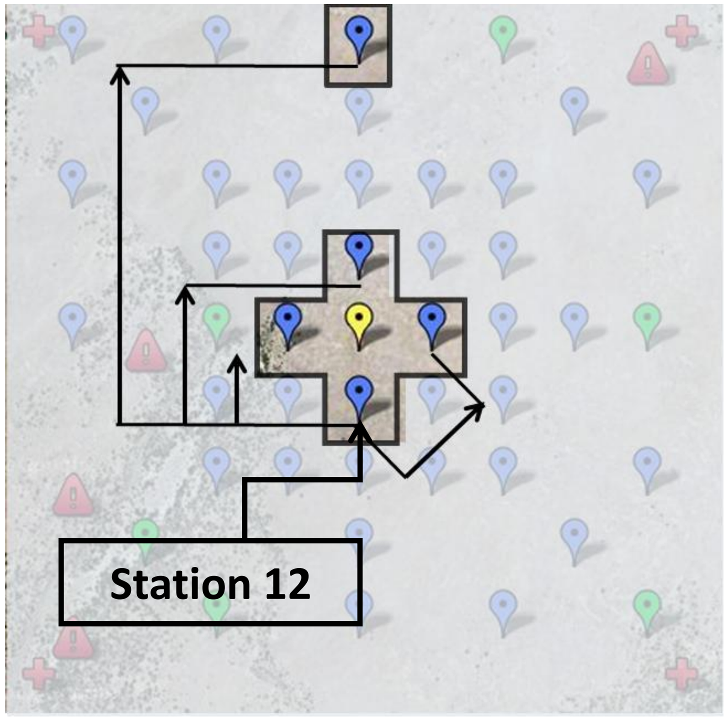

Figure 3 Configuration of sensor from which data was received.

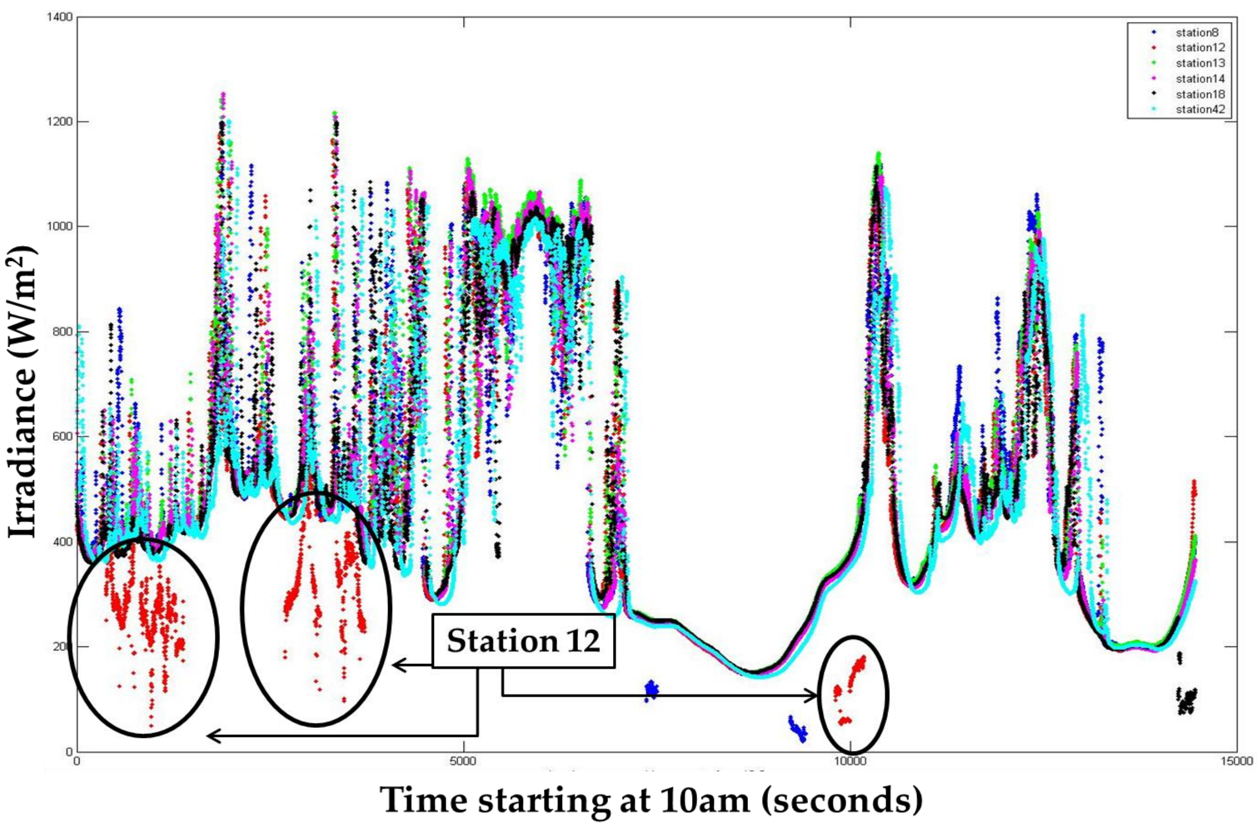

Figure 4 Irradiance versus time for all sensors

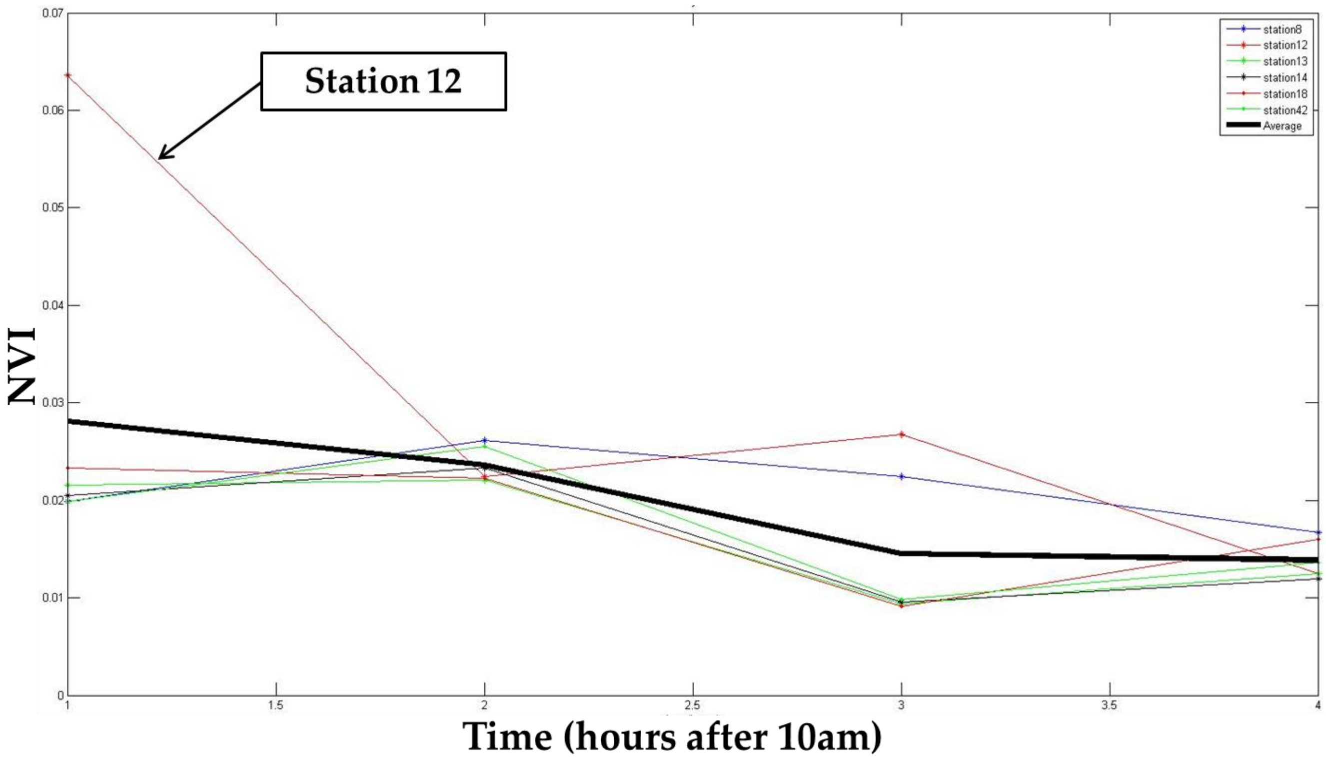

Figure 5 Hourly NVI

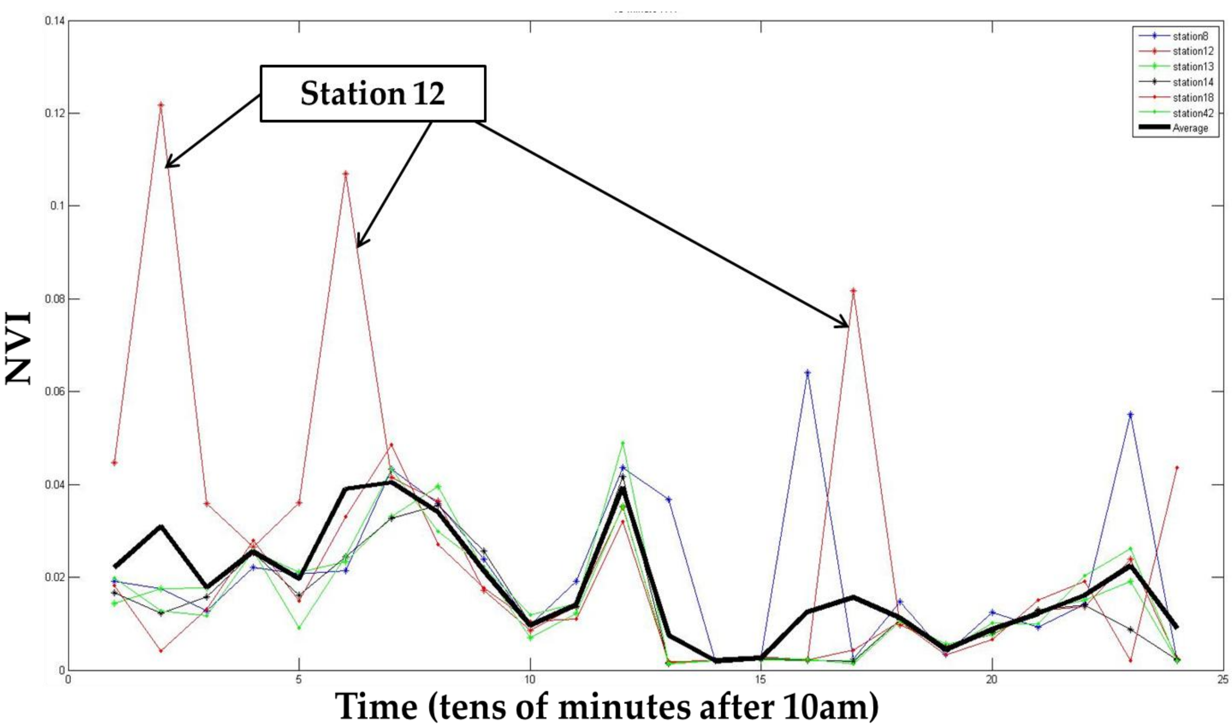

Figure 6 10 minute NVI

Appendix D: References:

1. <http://www.amazon.com/Slik-Sprint-Tripod-Metal-Release/dp/B002821ESU>

2. <http://www.adorama.com/VGMT23.html>

3. <http://www.amazon.com/Manfrotto-190XDB-Section-Aluminum-Tripod/dp/B000N81BXO>

4. <http://www.quantumgear.com/acculinepro-40-6340/>

5. <http://www.homedepot.com/webapp/wcs/stores/servlet/ProductDisplay?productId=202262409&storeId=10051&langId=-1&catalogId=10053&cm_sp=BazVoice-_-RLP-_-202262409-_-x#.UKaWQqPe98E> 11-15-12