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Solar Irradiance Measuring Device

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Overview

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  - Irradiance Definition
  - Needs and Goals
- Site Design
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- Conclusion
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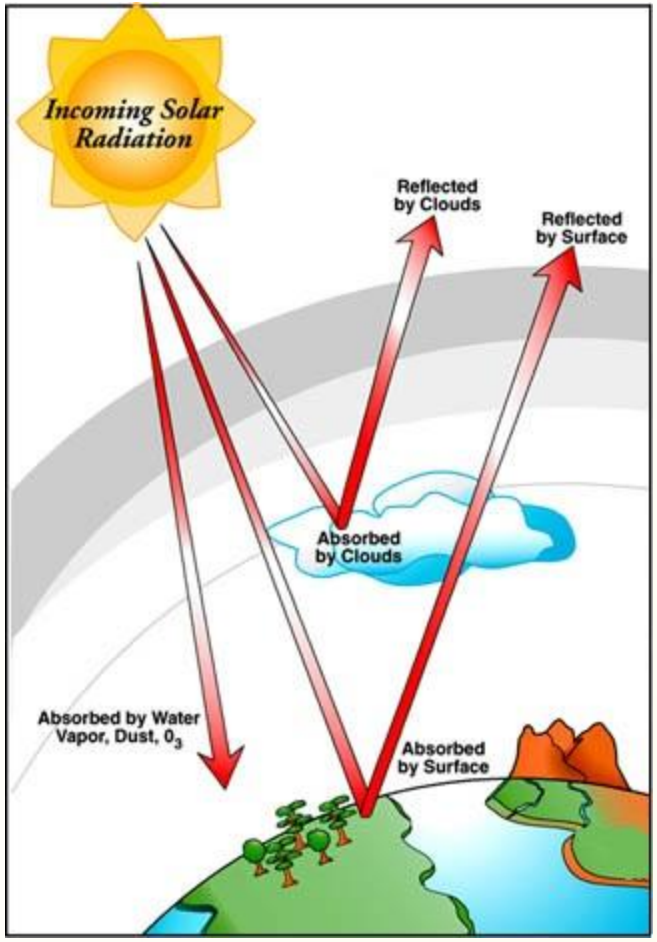
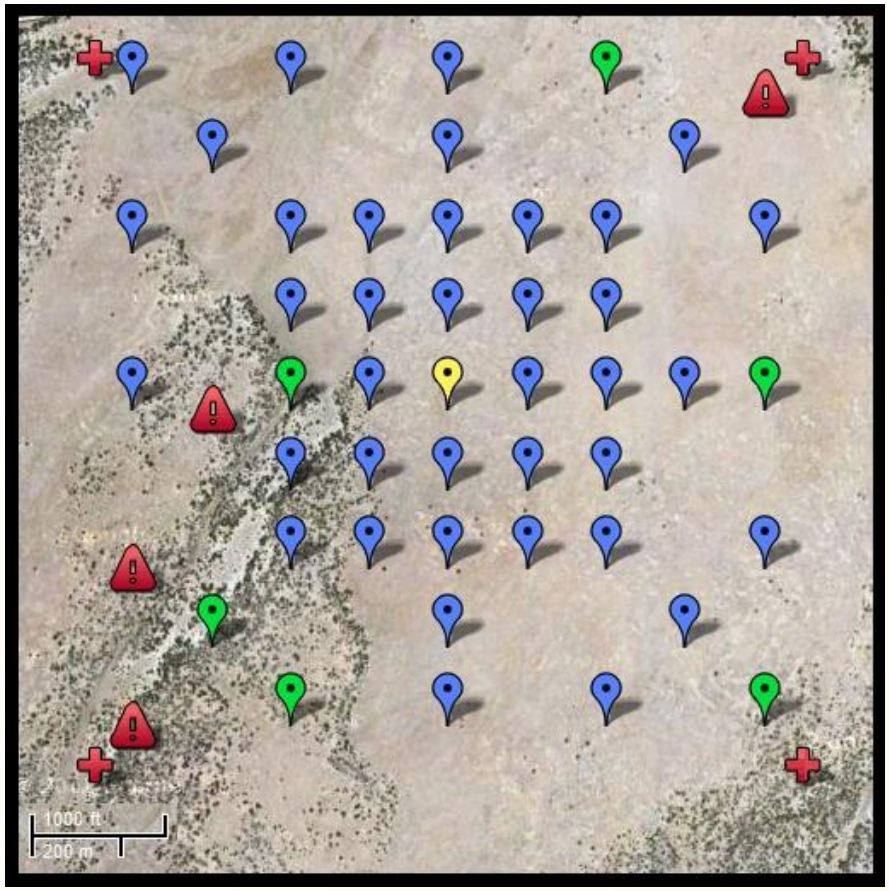
Irradiance Definition

- Energy flux $[\frac{W}{m^2}]$
- Changes with weather
  - Inconsistent output
- Variance data used to determine viability of solar site



Current ISES Site

- Institute for Sustainable Energy Solutions (ISES)
- Located at COBar Ranch
  - 35 miles north of the San Francisco Peaks
- 1 square mile
- 50 sensors
- Inner sensors approx. 600 ft. apart



Needs Identification

- **Current problems:**
  - **Large number of devices in use**
  - **Long set-up time / permanent**
  - **Data collection errors**
  - **Large area usage**
  - **Access issues**
  - **High cost**

Needs and Goals

Need Statement:

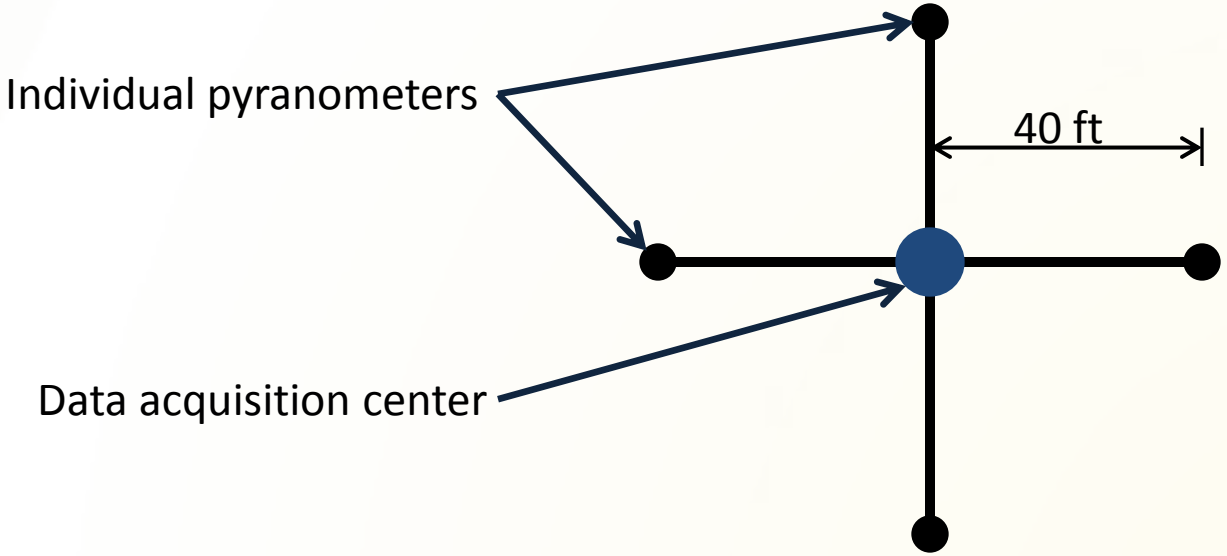
The current system is inefficient with its use of land, man hours, and produces poor data.

Goal:

Design a relatively small, portable solar irradiance measuring system that can accurately quantify variance in solar irradiance over a larger area.

Project Site

- **5 pyranometers**
- **One centralized data acquisition center**
- **Approximate radius of 40 feet**



Tripod

- Mounted pyranometers
- Stability
  - Stakes
  - Expansion bolts
  - Sand bags
- Longevity
  - Galvanized steel

Pyranometer Interface

- Simple set-up
- Secure mounting
- Three screw leveling head
- Corrosion resistant
  - Aluminum components
  - Stainless steel hardware

Tripod Interface

- Leveling base
- Manufacturing
  - Extruded aluminum
  - Cost effective
- U-bolt hardware
  - Zinc plated steel

Data Acquisition

- **Li-Cor LI-200 Pyranometer**
  - Compatible with Campbell Scientific Data Logger
  - Average Error < 5%
- **Campbell Scientific CR-1000**
  - Proven in industry
  - Max sampling rate: 100Hz
- **NL-115 CF Module**
  - Compact flash
  - Expanded data storage
- **Loggernet**
  - Data logger interface program

Data Transfer

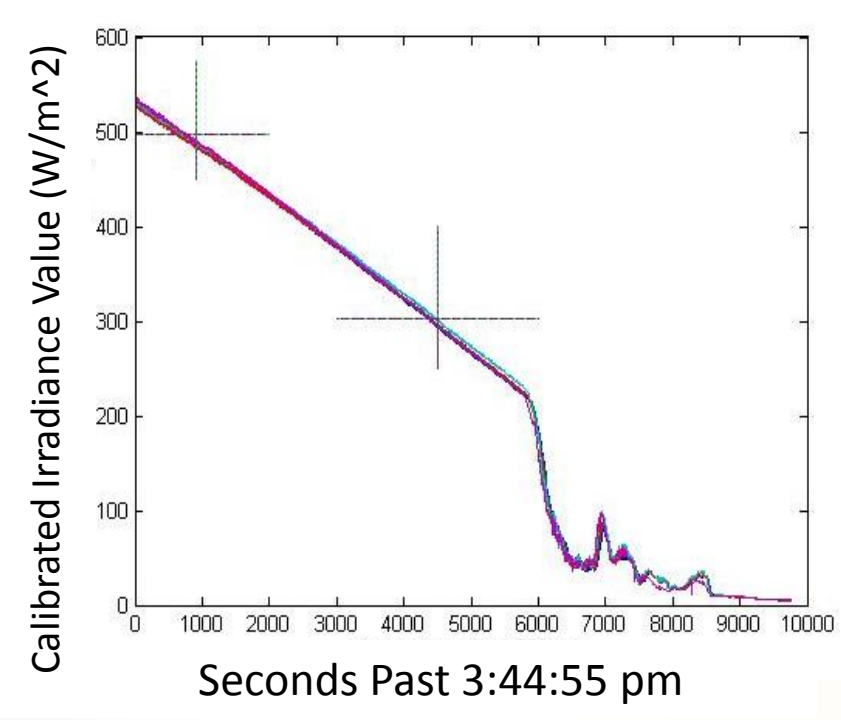
- **Pyranometer Wiring:**
  - **Simple setup**
  - **Negligible voltage drop**
- **Wires housed in flexible conduit**
- **Protects wires from**
  - **Cows**
  - **Rodents (eg. field mice)**
  - **Ultra violet rays**
  - **Water**

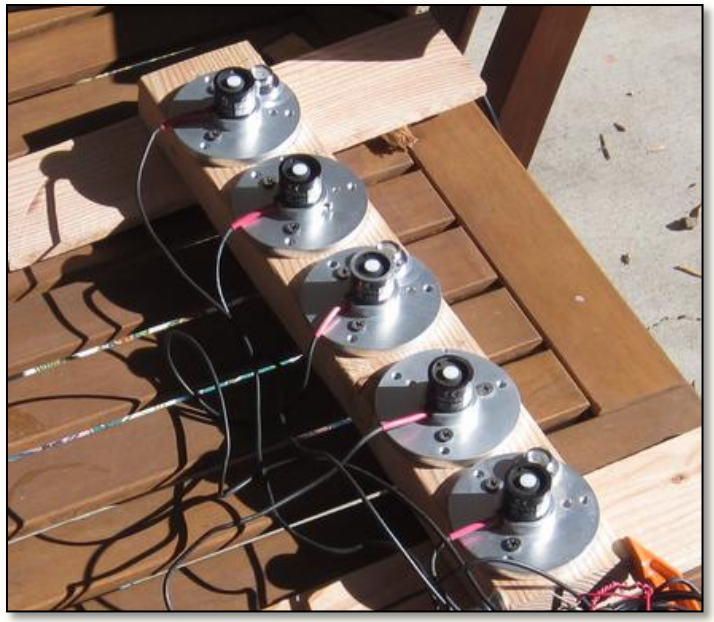
Data Logger Wiring

- Pyranometers wired as single ended voltage measurement
- Shunt resistors used to measure potential difference
- Four needed calibration
  - New sensor used as the standard

Pyranometer Calibration

- **Used a brand new pyranometer to calibrate the other sensors**
- **Used the Bird Clear Sky Model to verify calibration**

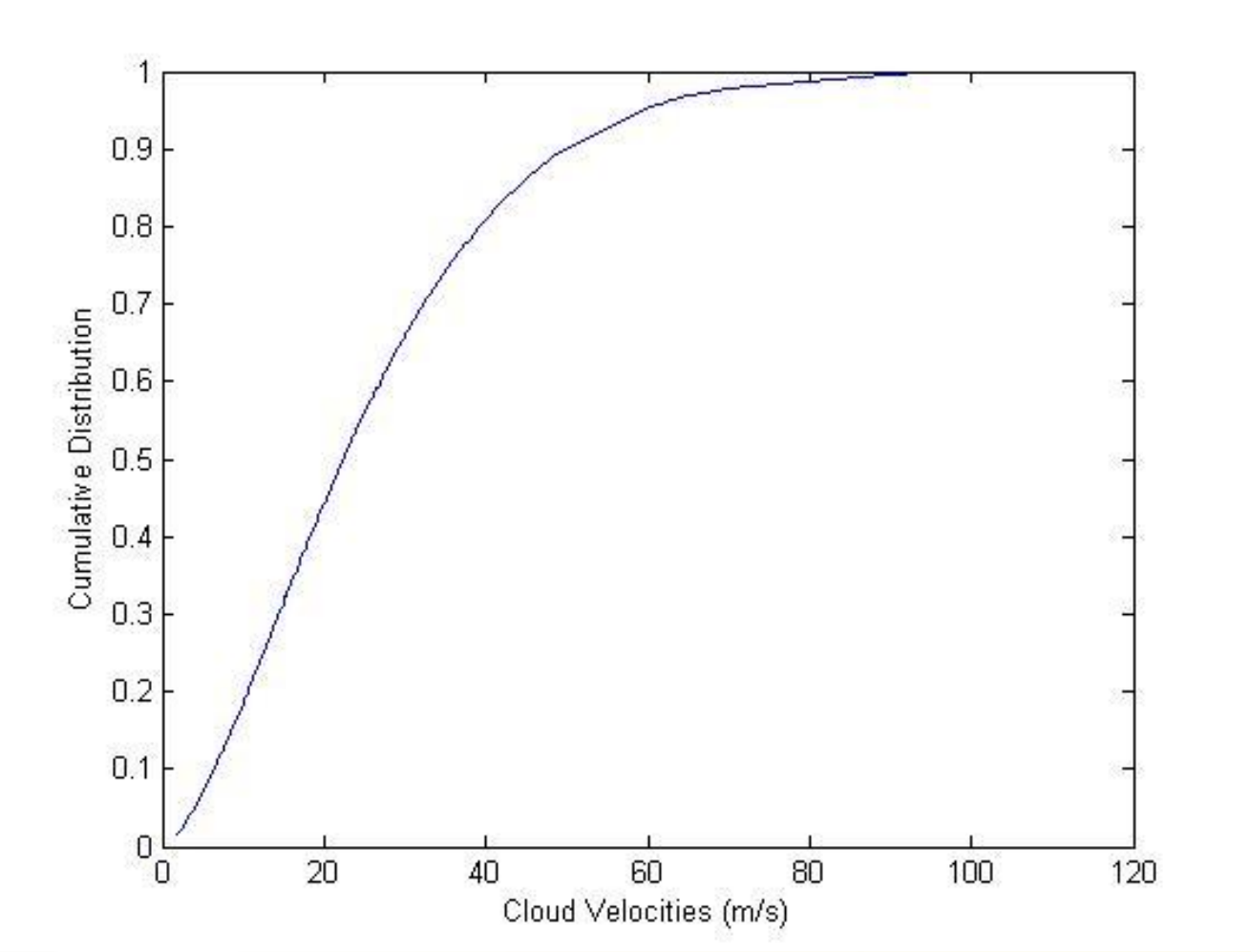




Calculating Needed Sample Rate

- Using three sensors oriented in an ‘L’ shape
  - Correlation between north and center stations and east and center stations
  - Shifting data sets forwards and backwards one point at a time
  - Number of shifts that give best correlation is the time a cloud took to travel the known distance

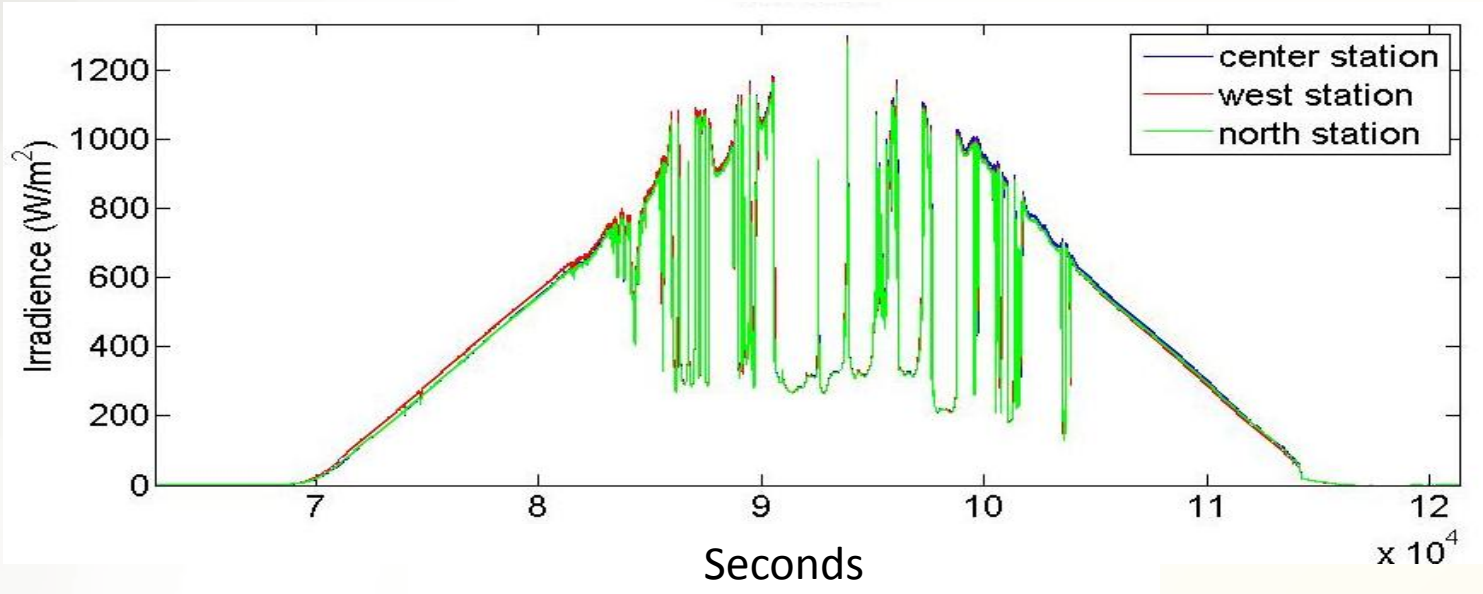
Cumulative Distribution



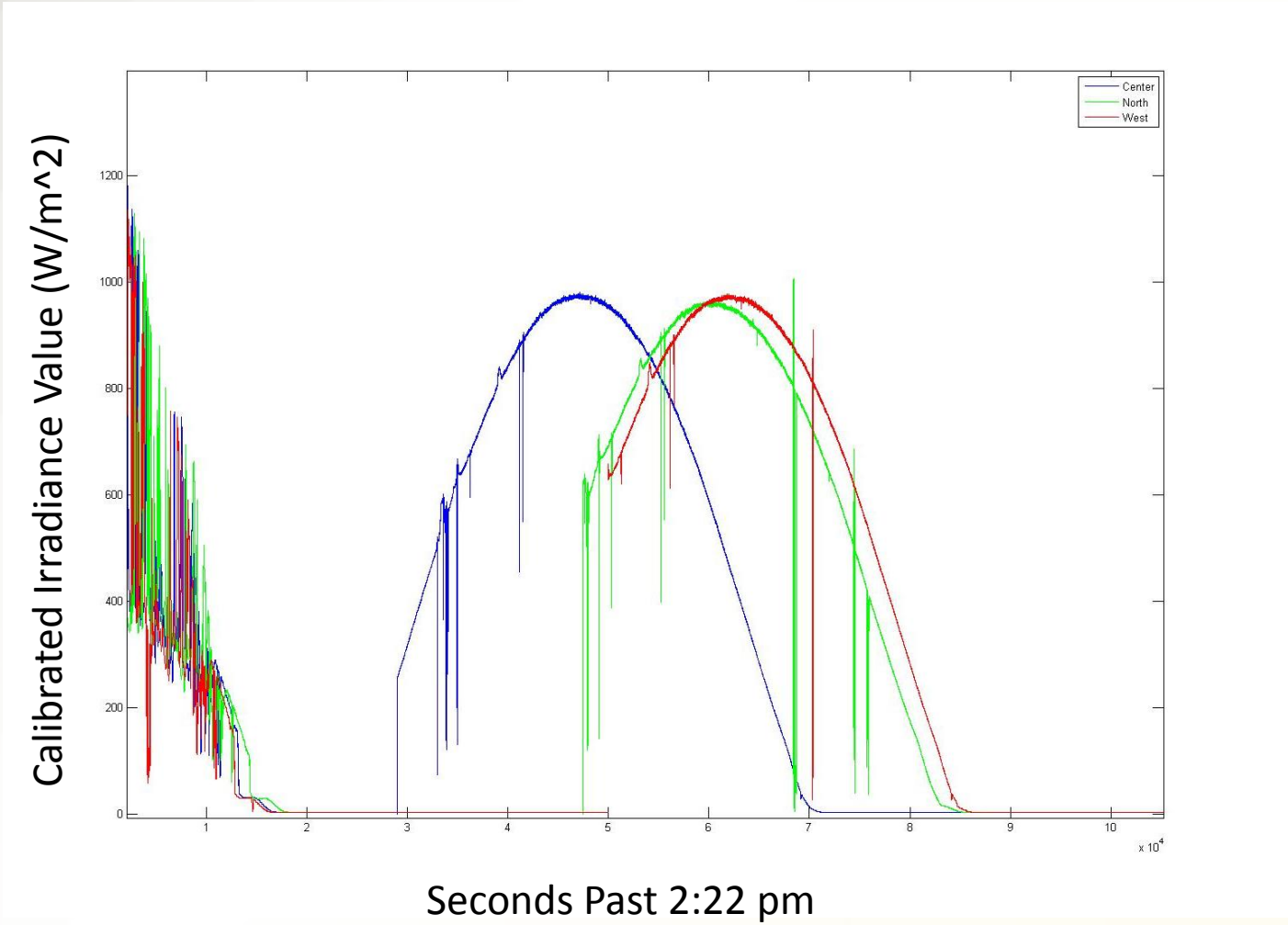
Frequencies Needed

Percent of Cloud Events Seen	Hz Needed
0.8	3.21132
0.85	3.58319
0.9	4.07677
0.95	4.85806
1	∞

Results

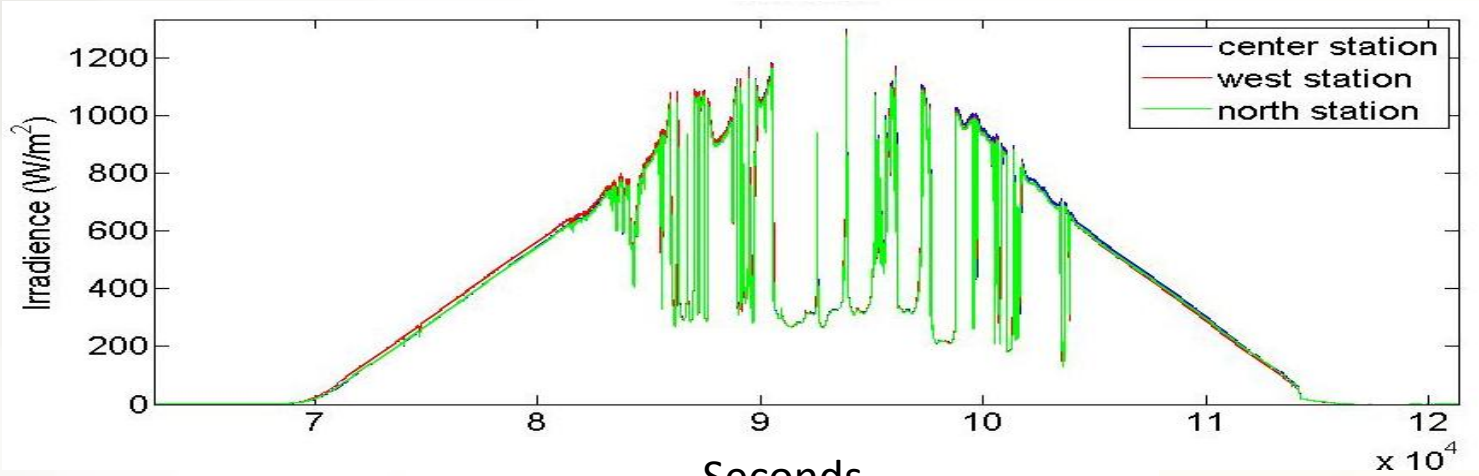

center station
west station
north station
Irradience (W/m^2)
1200
1000
800
600
400
200
0
7
8
9
10
11
12
x 10^4
Seconds

Results

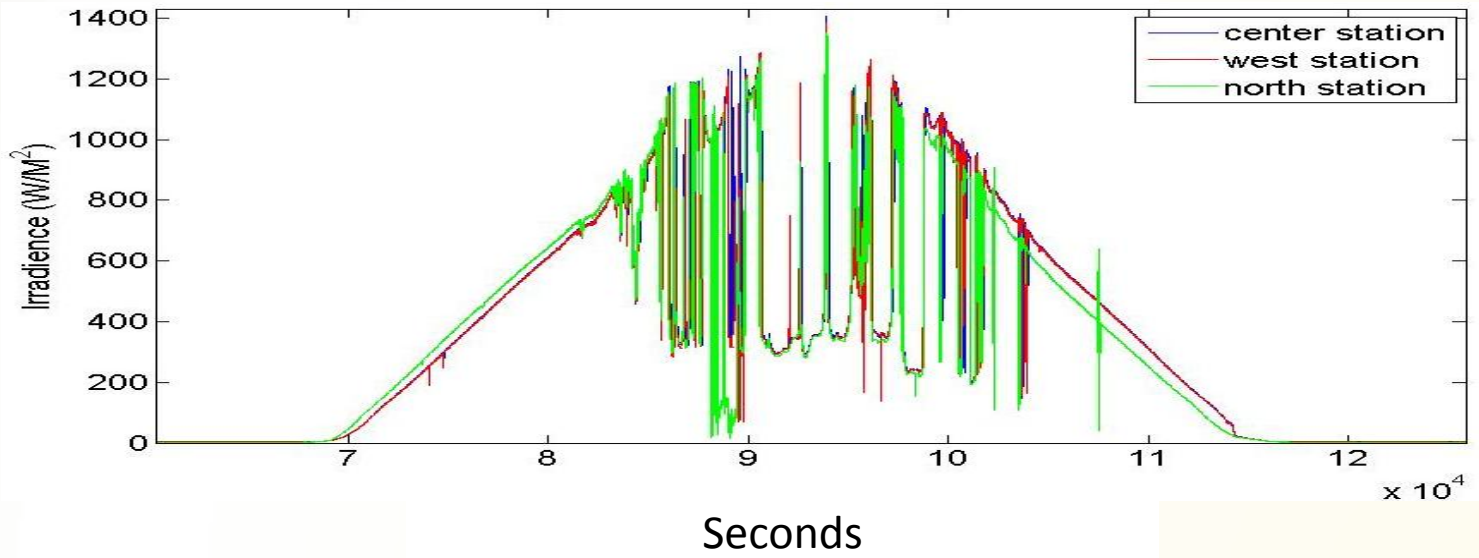

Calibrated Irradiance Value (W/m^2)
Seconds Past 2:22 pm
Center
North
West
0
200
400
600
800
1000
1200
1
2
3
4
5
6
7
8
9
10
x 10^4

Results

Small Site

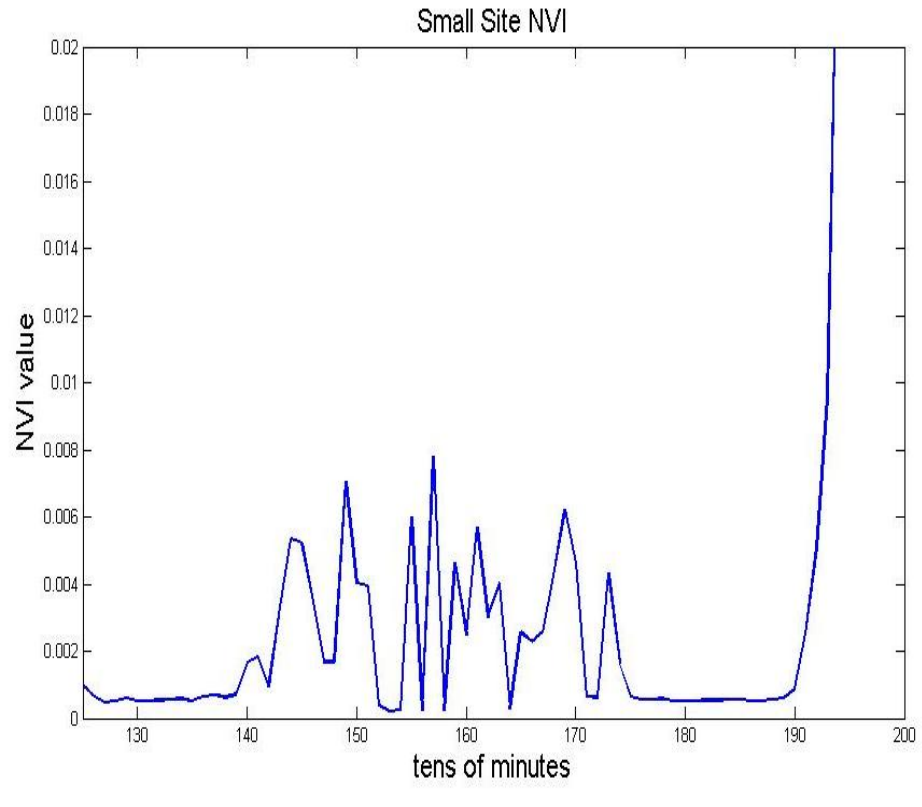


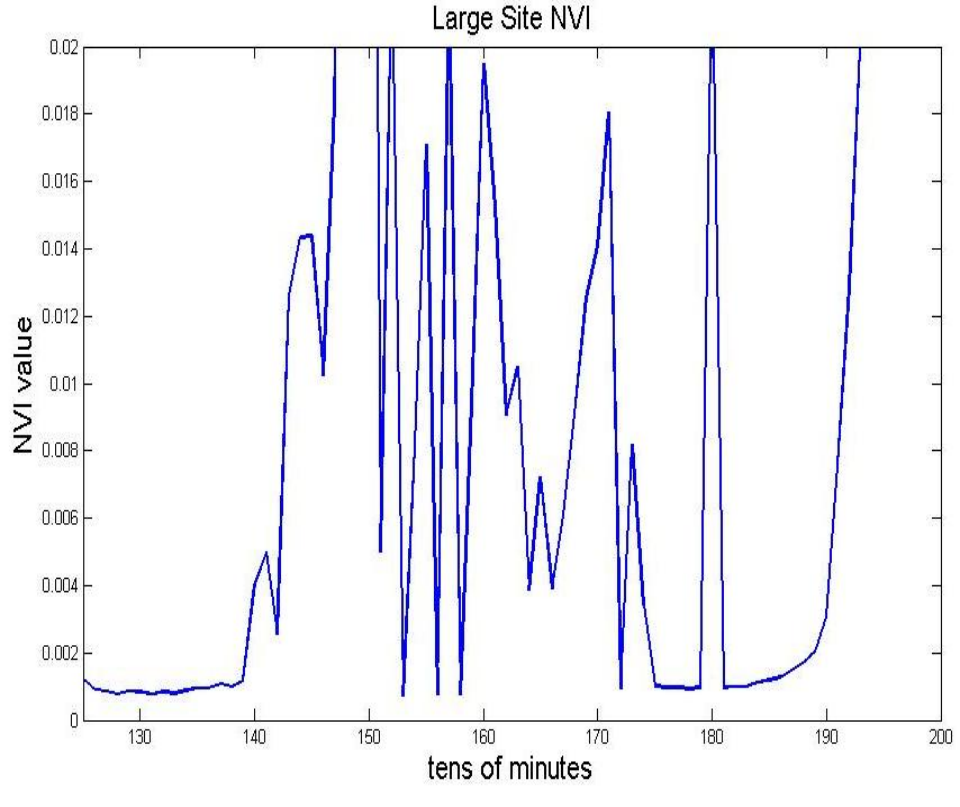
Large Site



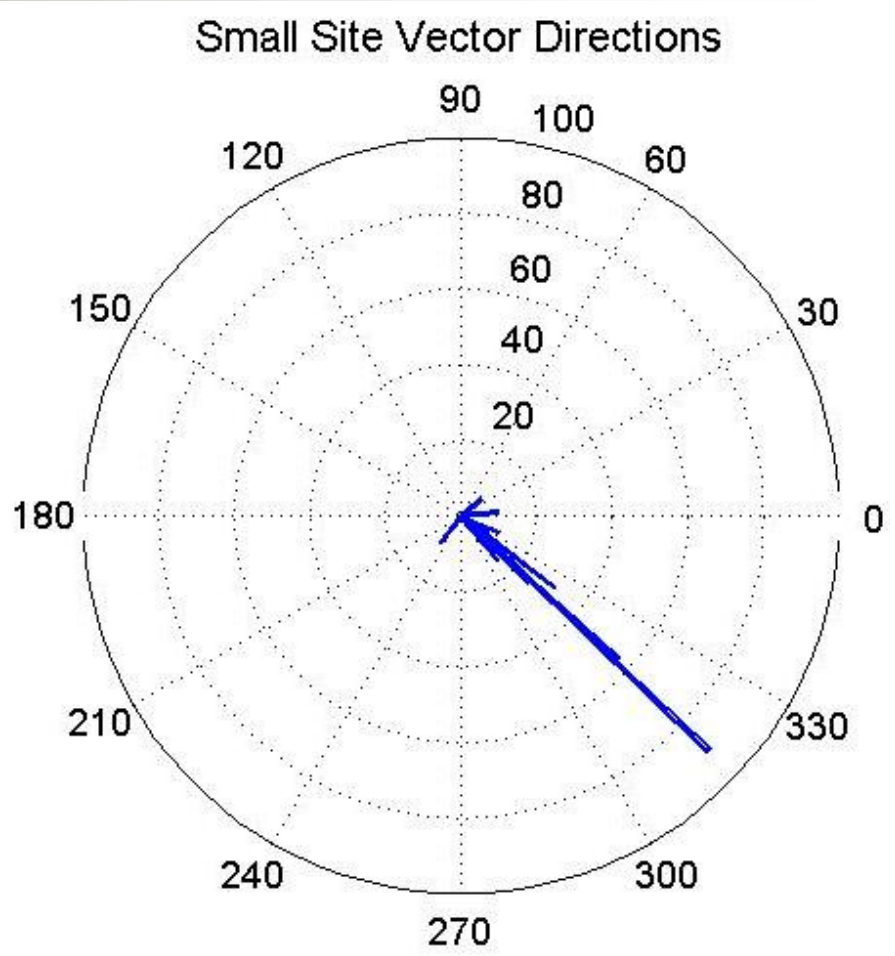
Results

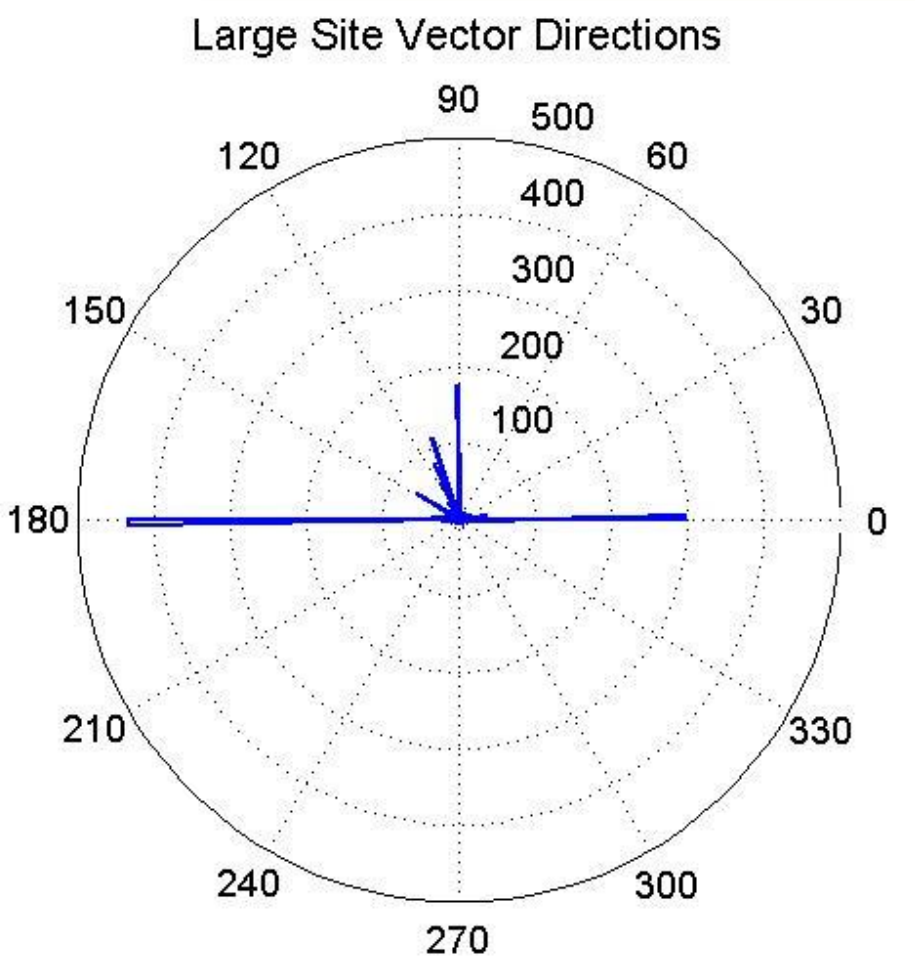
Natural Variability of Irradiance, $NVI = {}^{\sigma_{\Delta G}}/_{\overline{G}}$





Results


Small Site Vector Directions
90
100
80
60
40
20
120
60
150
30
180
0
210
330
240
300
270


Large Site Vector Directions
90
500
400
300
200
100
120
60
150
30
180
0
210
330
240
300
270

Cost Analysis

	Quantity	Approximate Cost
Campbell Scientific CR1000	1	$ 1,795.00
LI-COR LI 200 Sensors	5	$ 1,128.00
T Posts - 7ft	4	$ 21.00
Tripod	1	$ 71.17
Conduit	200ft	$ 76.36
Misc. Hardware	-	
Aluminum Sheet	1 (4 ½ x 1 ¾)	$13.12
Nuts and Bolts	7	$43.02
USB Cable	1	$41.58
Total		**$3,189.25**

Conclusion

- **Satisfied Goals**
  - **Efficient setup and data collection process**
    - **~6 man hours to set up**
    - **Minimal land usage**
  - **Withstands harsh environmental conditions**
  - **Cost effective**
  - **Reliable data to compare to large site**
- **Concerns**
  - **Reliability of their data**
  - **Reliability of the comparison**

Pyranometer at COBar Ranch

Resources

- "CR1000." *: Measurement and Control Datalogger with Keyboard*. N.p., n.d. Web. 01 Feb. 2013. http://www.campbellsci.com/cr1000
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Questions