Solar Resource Assessment: An EPC Contractor's Perspective

NREL Solar Resource Workshop

Owen Westbrook – juwi solar Inc

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juwi solar Inc. ("JSI")

juwi solar Inc.	
Based in:	Boulder, Colorado
Employees:	50+
Business Unit:	Solar Photovoltaic (>128 MW)

juwi Global	
Based in:	Wörrstadt, Germany
Founded/CEOs:	1996, Fred Jung and Matthias Willenbacher
Employees:	>1,250 for all divisions
Business Units:	Two renewable energy generation business units: • Solar Photovoltaic (1.5 GW) • Wind (1 GW)

- juwi solar Inc. ("JSI"), a Delaware corporation founded in 2008, is an experienced and reliable solar developer and engineering, procurement and construction ("EPC") contractor with a proven track record of working successfully with major utilities across the U.S. to realize reliable, cost competitive projects.

- JSI has constructed over 128 MW of solar PV capacity across the U.S. since 2009, and has successfully financed over $497 million of JSI-developed projects.

- juwi provides O&M and/or monitoring services for more than 600 MW of projects worldwide.

- JSI and juwi AG have installed over 1,500 solar PV installations (1.5 GW) throughout the world.

19 MW Badger I Solar Facility

Outline

1. **Proposal Phase**
   a. Objectives of Solar Resource Assessment
   b. Constraints
   c. Typical Process
   d. Best Practices
   e. Potential Improvements
2. **Financing/Construction Phase**
3. **Operations Phase**
4. **Real-World Monitoring Challenges**

Solar Resource Assessment
Proposal Phase

- **Objectives:**
  - Create & optimize initial system design (fixed-tilt vs. tracking, DC/AC ratio, etc.)
  - Estimate energy generation
  - Determine energy price
  - Characterize long-term variability
- **Constraints:**
  - Short lead times
  - Long-term ground-based data usually not available
  - Underestimating the solar resource may result in an uncompetitive bid; overestimating may make the project uneconomic to finance
  - At this stage, solar resource may not be the greatest source of pricing uncertainty (geotech/civil costs, interconnection costs, etc.)

Solar Resource Assessment
Proposal Phase

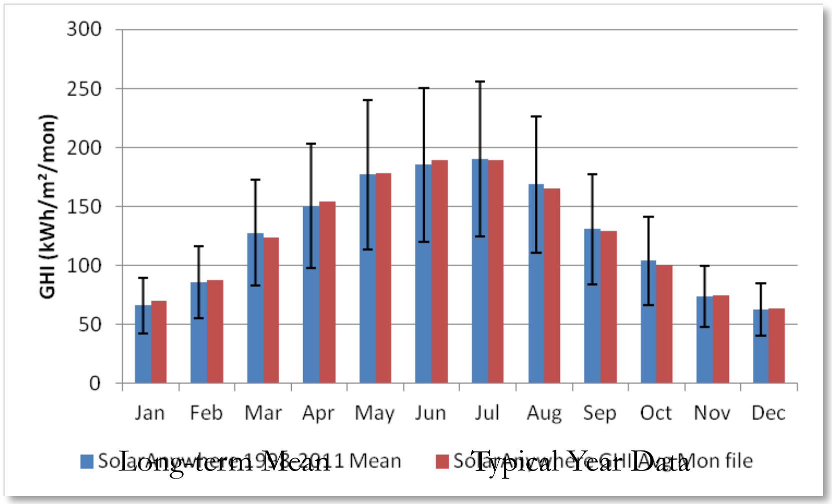
juwi

- **Typical Process**
  - Rely on satellite-based data
  - NREL Solar Power Prospector or third-party services
  - Base generation estimates on typical year data

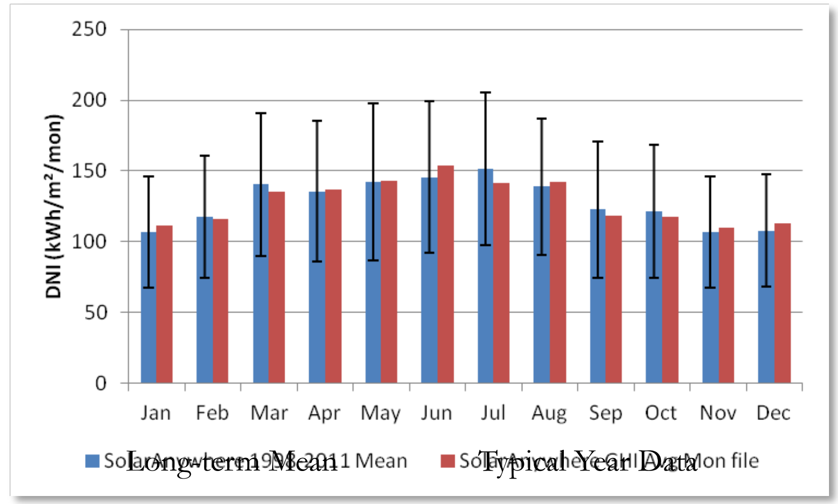
- **Best Practices**
  - Avoid taking data at face value - verify that typical year data is indeed "typical!"
  - Check for terrain that may increase satellite model error
  - Check for data anomalies in adjacent tiles
  - If local high-quality ground data sources are available, spot check individual years

Typical Year Data Verification

GHI



DNI



- **Check for consistency by comparing typical year data against long-term mean:**
  - Annual and monthly GHI, DNI, DHI totals
  - Annual and monthly irradiance-weighted ambient temperatures
- **How much inconsistency is too much?**
- **How to rectify inconsistencies?**

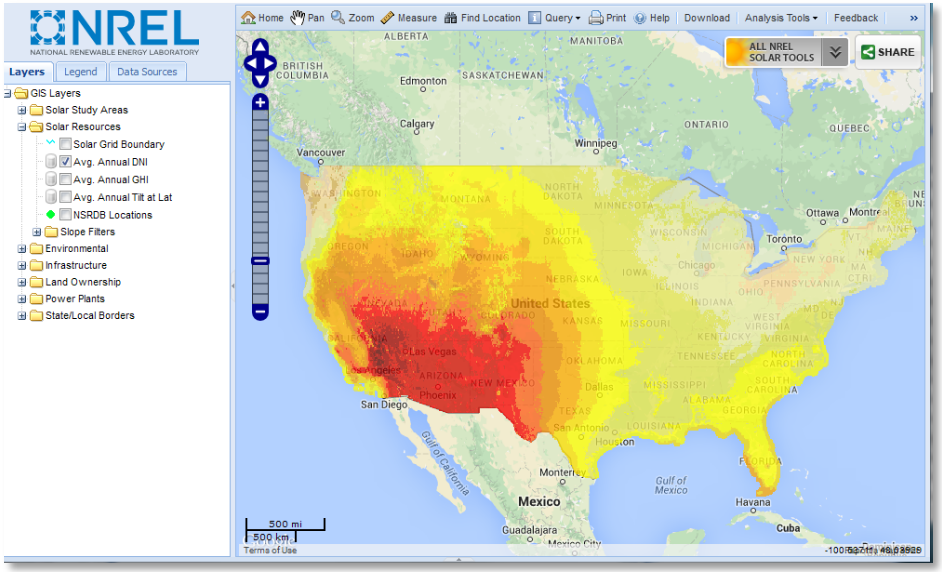
Solar Resource Assessment
Proposal Phase

- **Potential Improvements**

  - Shortage of reliable, publicly available data for the Americas ex-US (Canada, Central/Latin America, the Caribbean) in publicly-available data

  - Wider availability of subhourly data; drive performance modeling software providers to enable use of subhourly data

  - Phase out the use of TMY data sets; enable software to load and run long-term satellite data sets (1998-present) quickly and easily

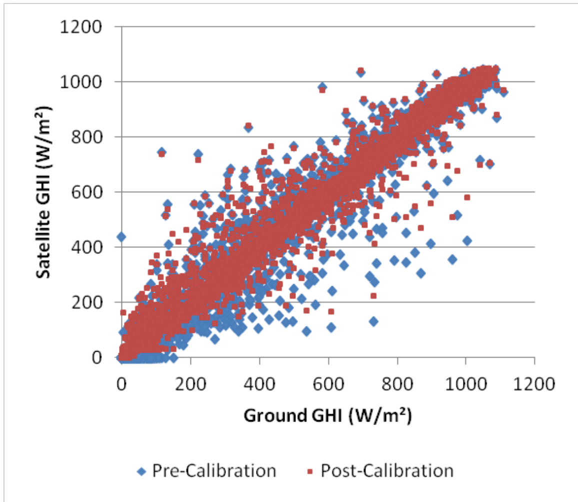


http://maps.nrel.gov/prospector

Solar Resource Assessment
Financing Phase

- **Objectives:**
  - Validate satellite data with ground-based measurements
  - Provide confidence to investors that generation estimates underpinning the revenue expectations and performance guarantees can be met

- **Constraints:**
  - Solar resource can be a major lingering source of uncertainty
  - Investor familiarity with satellite data and sensors is critical
  - Development budgets are limited before financing
  - Sites are often in inaccessible, remote locations
  - Cleaning and maintenance on a regular schedule may not be possible
  - For most projects, DHI/DNI sensors are not practical

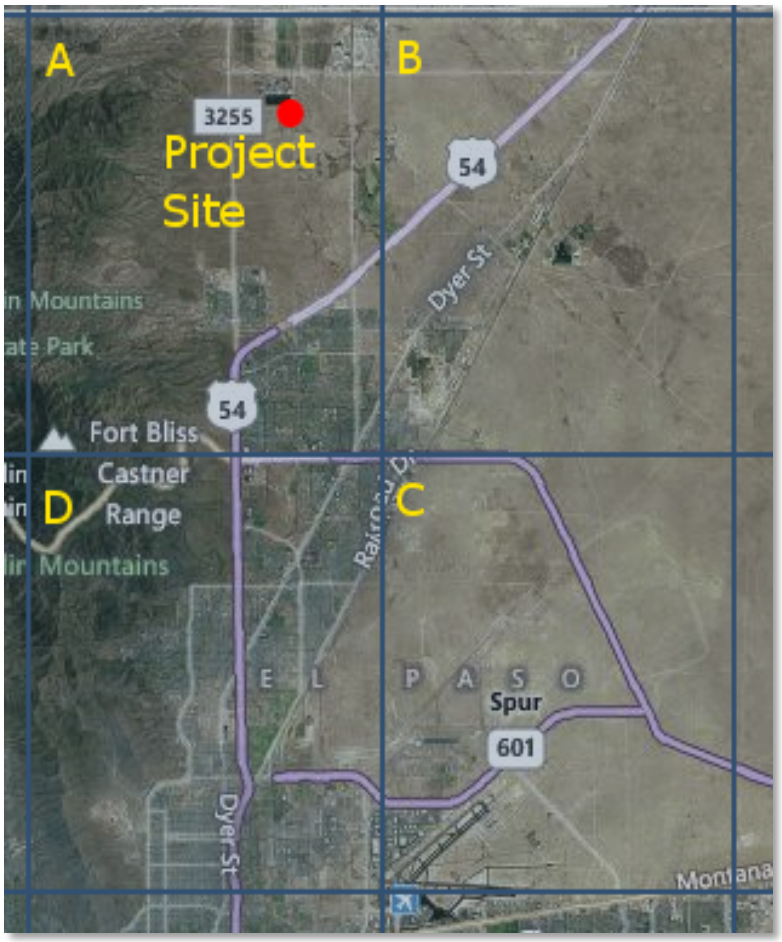


Solar Resource Assessment
Financing Phase

- **Best Practices:**
  - Ground-based data collection should last ~1 year to capture seasonal effects
  - At least three sensors to identify outliers and data errors
  - Use same sensor type that will be installed at the plant for ongoing monitoring
  - Regular cleaning when possible
  - Cross-check data with nearby ground stations when possible
  - Regression analysis to correct satellite data

- **Potential Improvements:**
  - Cheap, reliable, high-accuracy DHI/DNI sensors
  - Self-cleaning sensors
  - Consistent data formats for different public data sources (MIDC, NOAA, ISIS, etc.)

Satellite Data in Complex Terrain



- Satellite Tile A has 1.5% lower average annual GHI than Tile B
- Tiles B and C have comparable GHI
- Ground data at the project site needed to determine the true solar resource

Solar Resource Assessment
Operations Phase

- **Objectives:**
  - Monitor and analyze performance on an on-going basis
  - Validate the initial generation model
  - Provide input data for short-term and long-term performance guarantees

- **Constraints:**
  - POA irradiance most relevant for PV performance metrics
  - Owner/investor may have limited appetite for paying for measurements that do not directly relate to performance
  - Original energy model likely used GHI/DHI
  - Deployment of multiple GHI sensors, DNI/DHI sensors may not be possible
  - Real world data is messy!

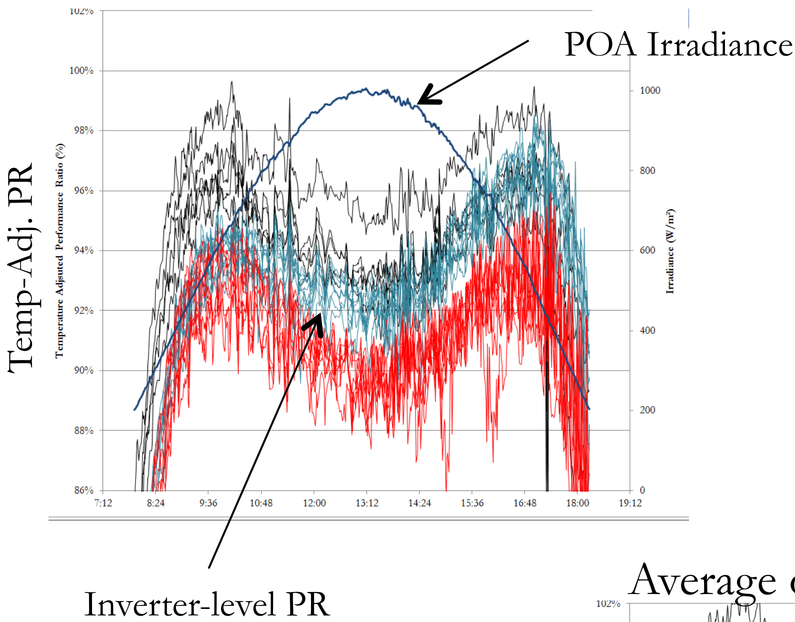
Solar Resource Assessment
Operations Phase

- **Best Practices**
  - Careful attention to sensor mounting locations and developing repeatable procedures
  - Avoid obstructions and diffuse shading effects
  - Verification of tilt/azimuth alignment for POA sensors
  - Ongoing data quality verification throughout operations

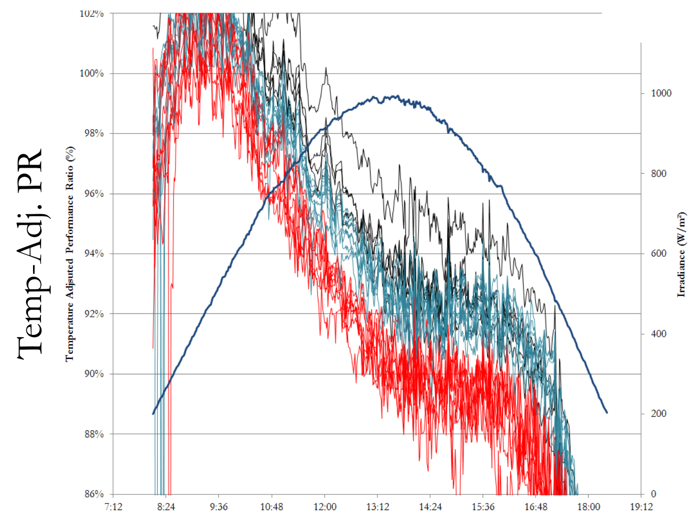
- **Potential Improvements**
  - Lower cost DHI/DNI sensors
  - Self-cleaning sensors
  - Ability to run subhourly data in performance modeling software
  - Ability to run POA irradiance data for trackers in performance modeling software

Pyranometer Alignment

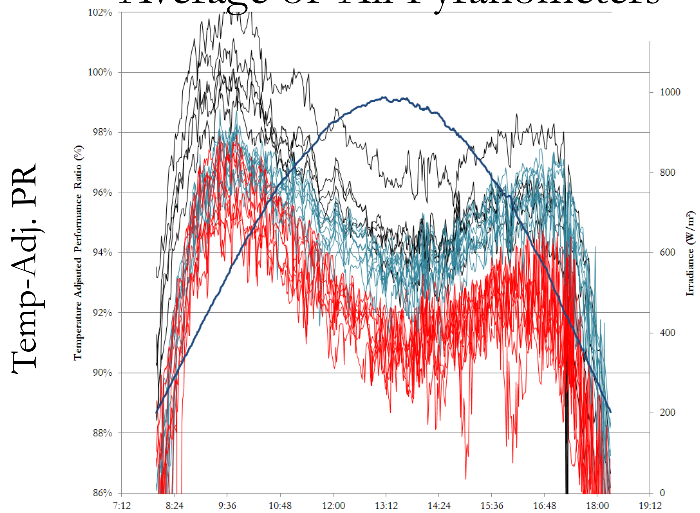
Pyranometer #1



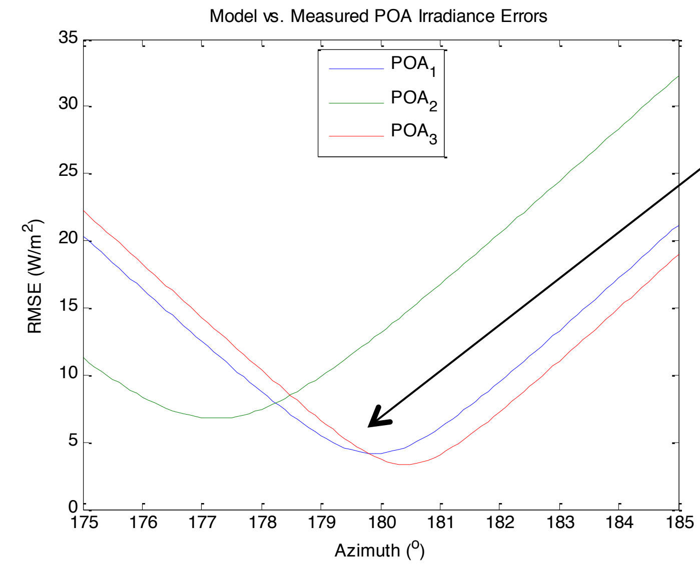
Pyranometer #2



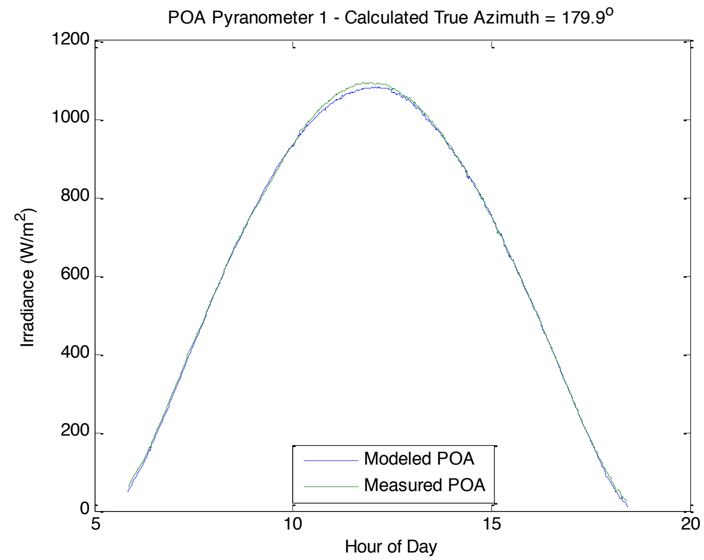
Average of All Pyranometers

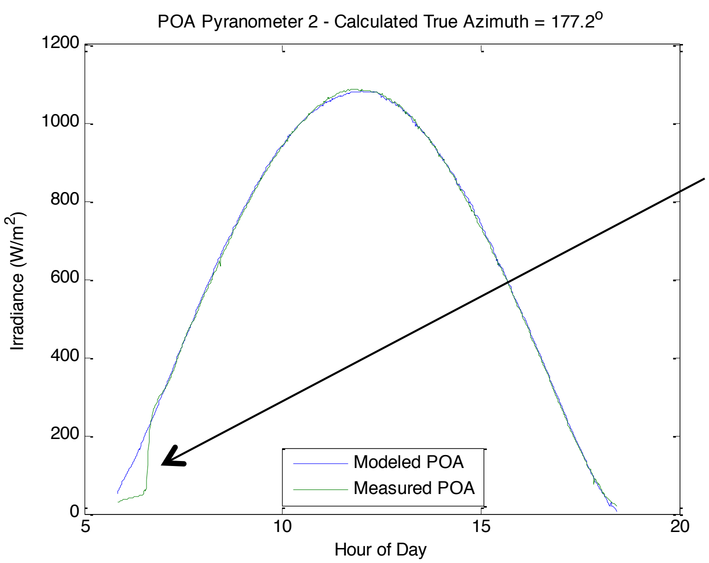


Pyranometer Azimuth Verification

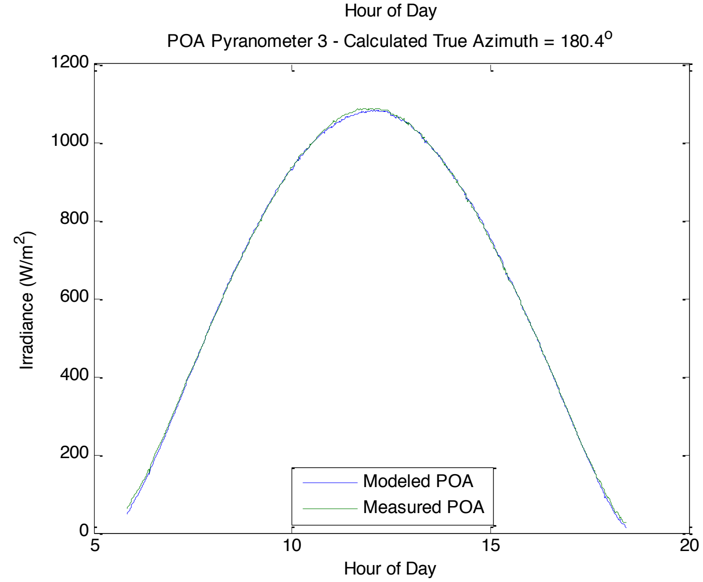


Minima indicate best-fit azimuth values



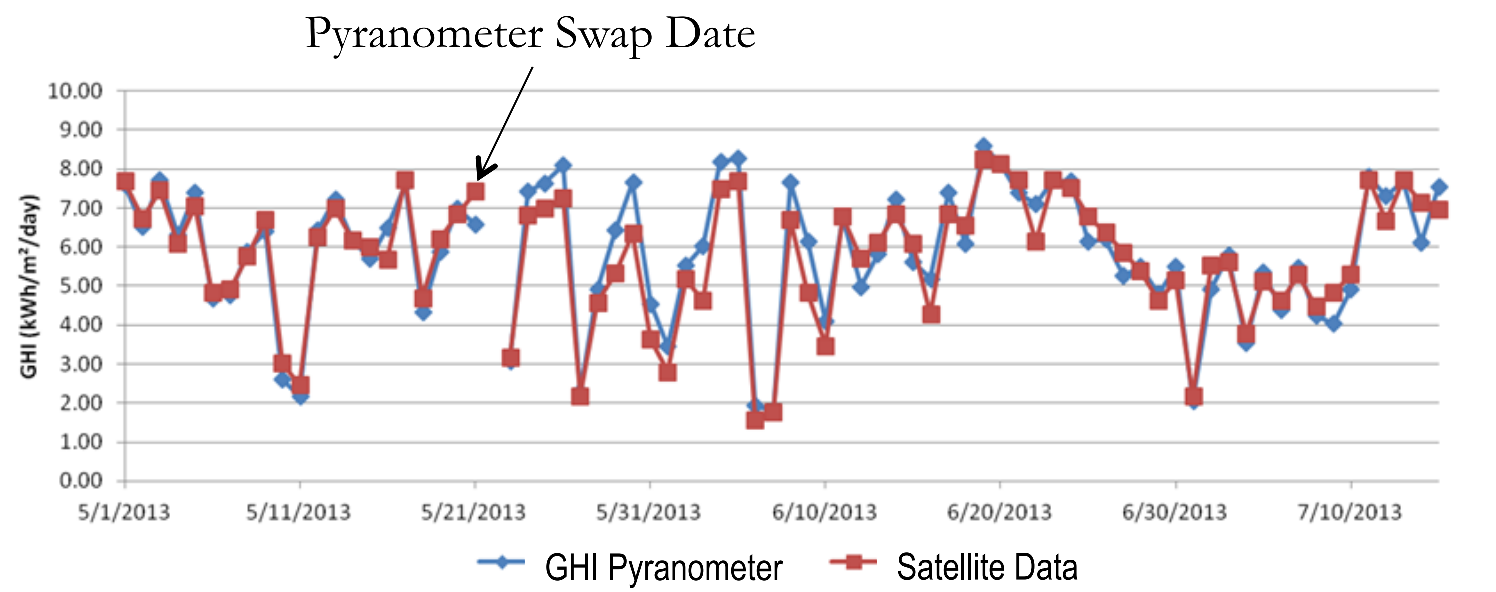


Morning Shading on POA #2



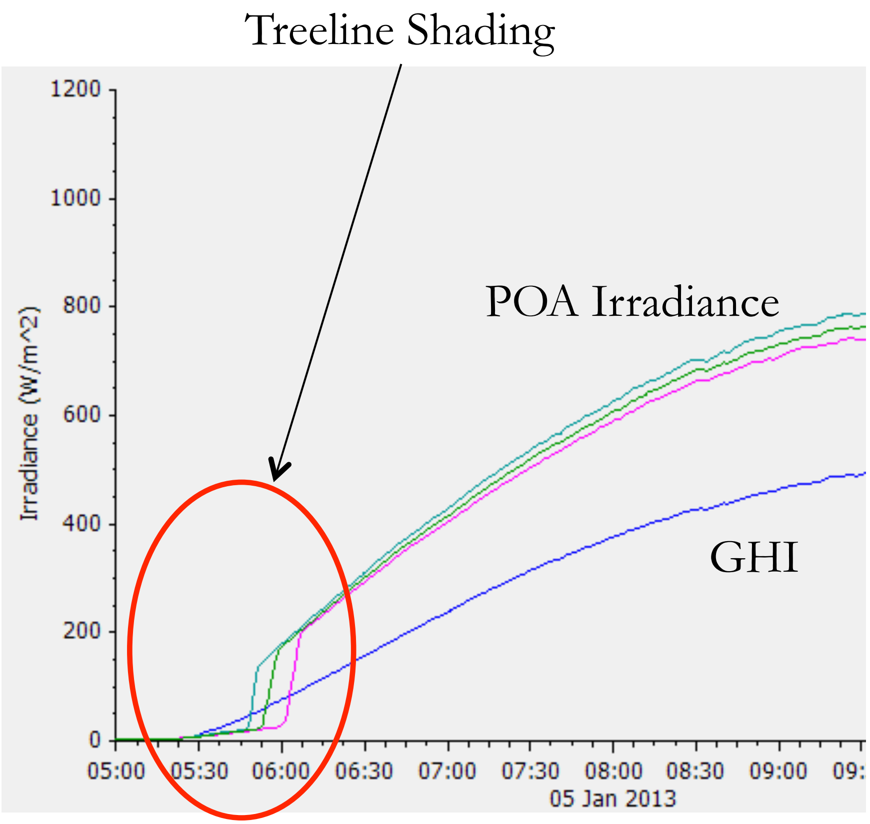
Calculated azimuths: 179.9, 177.2, 180.4

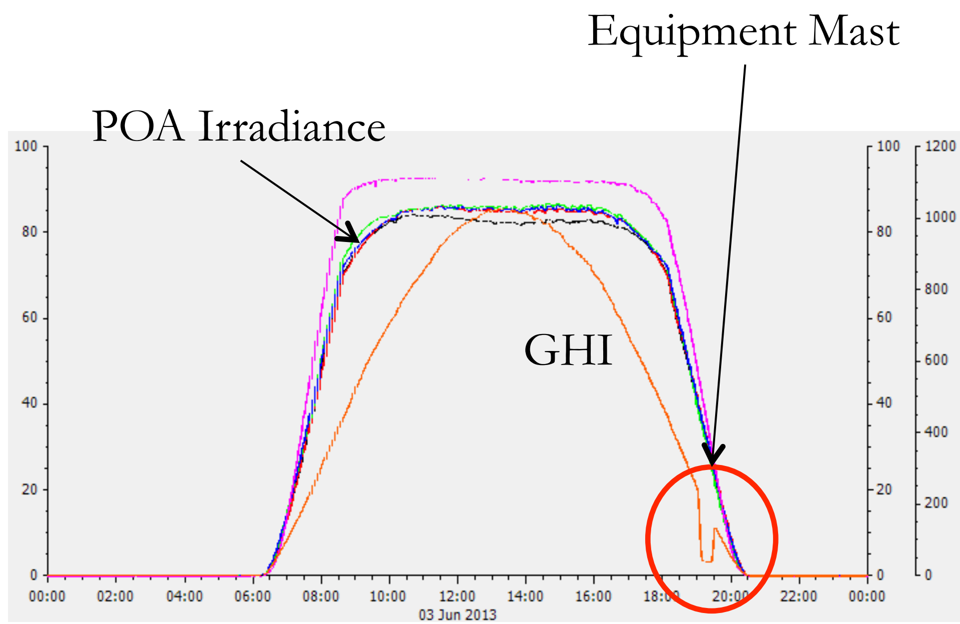
Sensor Replacement



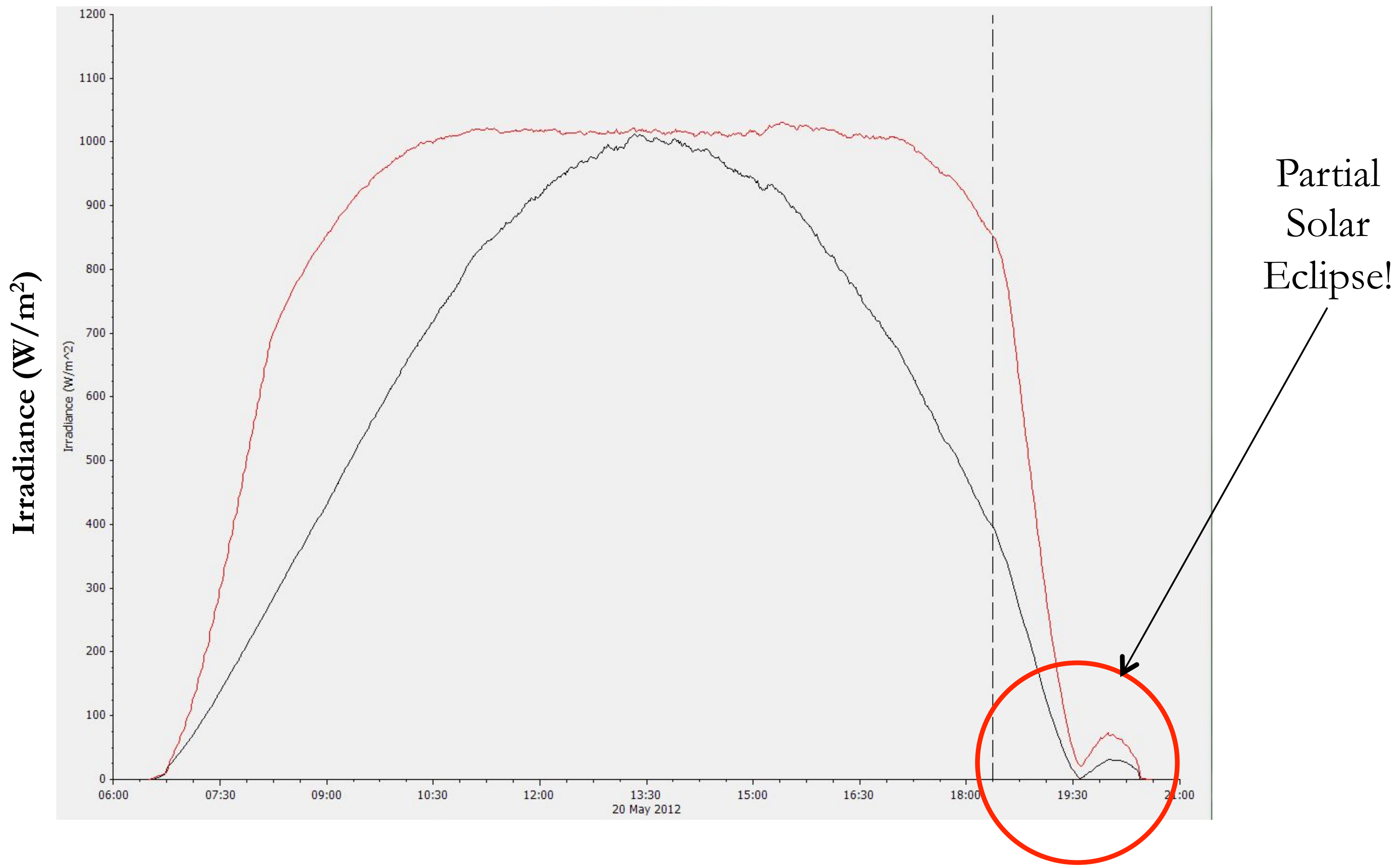
- **30 days prior to pyranometer swap: GHI pyranometer within 1% of satellite data**
- **30 days after the swap: GHI pyranometer almost 8% above satellite data**
- **By late June/July, good agreement again between ground and satellite data**

Pyranometer Shading





One Last Data Curiosity…



Thank you!

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