

ENERGY

SolarFarmer (*beta version*): Accurate Modelling of Real World PV Systems

PVPMC – 10

Albuquerque, NM

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Outline

- PV System Modelling Software
 - Current state
 - Needs
- Intro to SolarFarmer (*beta* version)
 - Unique approach
 - Functional user interface
- Validation
 - Comparison with other models
- TODO:

PV System Modelling Software

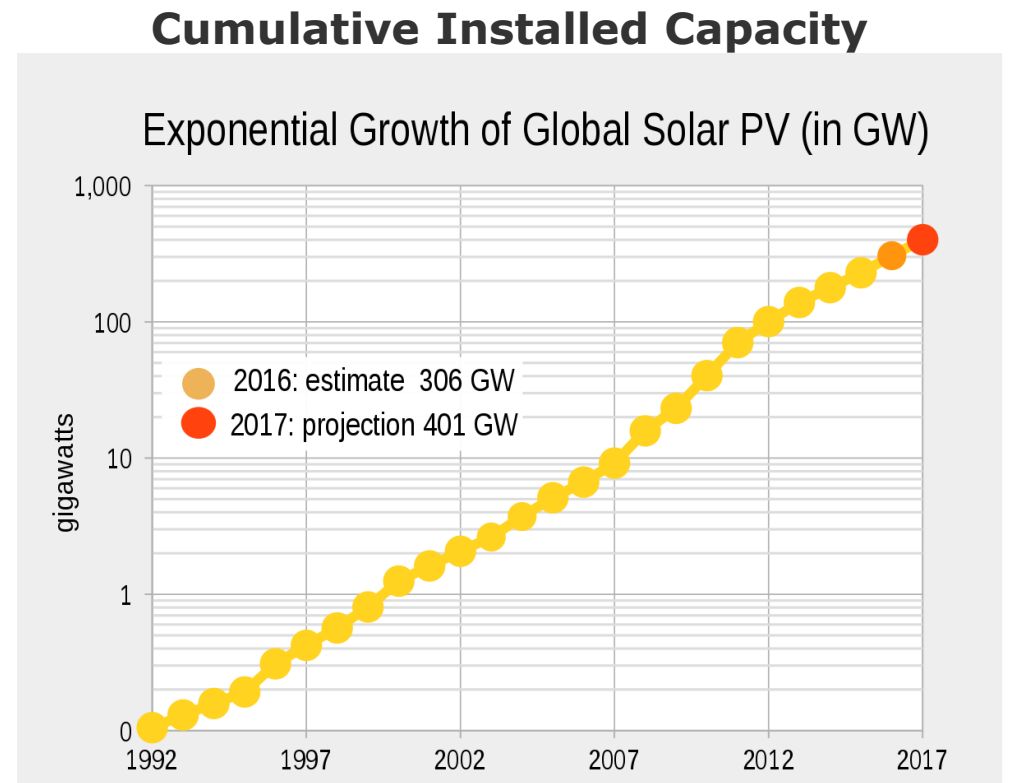
PV System Modelling Software: Current State

SOLAR BINGO

Calculation Focus	Rooftop Design	Cost Optimization	Detail Design	MFG Yield/ Design Tools	Open Source/ API
				SUNPOWER® PVSIM	
					System Advisor Model (SAM) 
					
					
					
					 PVLIB-Python/MATLAB

PV System Modelling Software: Needs

- There are a lot of excellent PV system modelling software covering many aspects of solar industry
 - Rooftops, cost and design optimization, utility scale, open-source, SDK/API, and manufacturer
- PV industry is growing and changing rapidly
 - Ungraded terrain, variable spacing, complex layouts
- → Industry needs faster project turnover
 - Ability to handle complex utility scale layouts
 - Accurate enough calculations
 - Fast enough to evaluate more projects



Source: [Wikipedia "Growth of Photovoltaics"](#)

Intro to SolarFarmer (*beta* version)

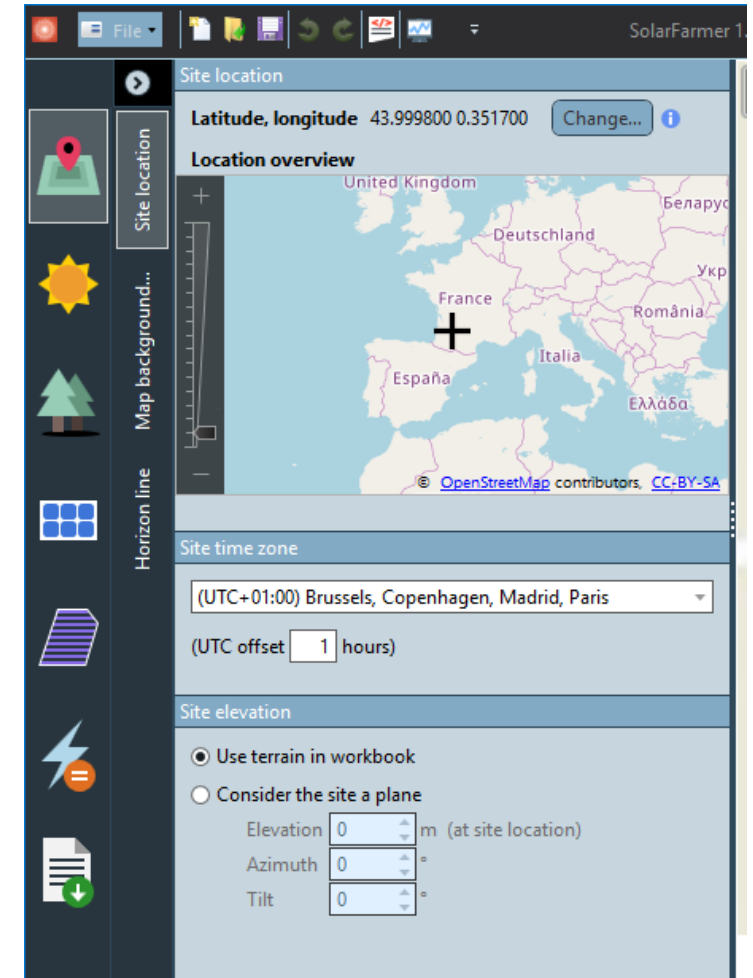
Intro to SolarFarmer (*beta version*): Unique Approach

- **PV system modelling software in *beta* testing**
 - 3-D shade hemicube model [Cohen & Greenberg, *SIGGRAPH*, 1985] rendered by GPU
 - Resolution of 5 hemicubes per submodule found optimal
 - Fast but accurate calculation using explicit approach [Bishop, *Sol. Cells*, 1988] at submodule/bypass diode level with interpolation
 - Entire IV curve calculated in one iteration
 - Based on established models: irradiance, solar-cell electrical and thermal, AC inverter, *etc.* models are public [pvpmc.sandia.gov]
 - PVSyst or SAM Desoto/5-parameter
 - Hay-Davies, Perez/DIRINT, or GTI-DIRINT (*tbd.*)
 - FirstSolar spectral mismatch, ASHRAE/Physical IAM
 - *Etc.*



Intro to SolarFarmer (*beta version*): Functional User Interface

- DNV-GL decade of experience developing industry leading renewable energy applications:
 - **WindFarmer** (wind energy), **Bladed** (turbine simulation), *etc.*
- SolarFarmer (*beta version*) workflow:
 - Site selection: search world map by name or coordinates
 - Upload or download terrain and map imagery data
 - Upload or generate horizon
 - Upload or download solar resource and weather at any resolution
 - Near shade: Import obstacles from SketchUp, *etc.*
 - Racking and trackers, modules, strings, inverters, transformers
 - Layout design, electrical connections, preview rendered shade
 - Settings, checks, simulate, loss-effects tree, generate reports
 - Save SolarFarmer (*beta version*) workbook as *.sfw file



Intro to SolarFarmer (*beta version*): Functional User Interface

The screenshot displays the SolarFarmer software interface for a 'New Project'. The main window is titled 'SolarFarmer 1.8.155.11700 - [New Project]'. On the left, a 'Define components' sidebar lists various system elements: PV modules, Racks, Trackers, Inverters, String length, Transformers, and Other components. The selected component is 'Canadian Solar Inc. CS6U-31'.

The central panel shows 'Module Specification Properties' with two tabs: 'Description' and 'Electrical Configuration'. The 'Electrical Configuration' tab is active, displaying the following data:

(Current reference conditions: Cell temp = 25 °C, Irradiance = 1000 W/m², Air mass = 1.5 kg)

Electrical Characteristics	
Short circuit current [Is] (A)	9.31
Current at maximum power [Im] (A)	8.8
Open circuit voltage [Voc] (V)	45.9
Voltage at maximum power [Vmp] (V)	37.5
Nominal operating cell temperature (°C)	45.00

Low Irradiance

Percentage of STC efficiency at 200 W/m ² (%)	97.25
--	-------

Bypass Diode Properties

Number of cells in series [Nc]	72
Bypass diode resistance [ohm]	0.01
Number of redundant bypass diodes	1
Forward voltage drop of bypass diode [V]	-0.7
Cell Arrangement	Cryst

Electrical Thermal Characteristics

Temperature coefficient of Isc (%/°C)	0.05295381310
Temperature coefficient of Isc (mA/°C)	4.93
Temperature coefficient of open circuit voltage (mV/°C)	+143
Temperature coefficient of Pmp (%/°C)	-0.42

(Current relevant settings: Nominal power = 330 W, IV Curve MPP at STC = 330.06)

Model Performance Correction Factor

Modelling Correction Effect (% = gain/ -loss)	-0.0196053773
Factored Maximum Power Point at STC	330

On the right, the 'PV Module Performance Model' tab is active, showing a 'Diode model' dropdown set to 'PViyst' and a table of model parameters:

Photocurrent [ph] (A)	9.3184322003055549
Diode reverse saturation current [I0] (A)	7.3251147766196646E-11
Module series resistance [Rs] (Ω)	0.317
Module shunt resistance [Rsh] (Ω)	350
Ideality factor [n1]	0.971
Apparent shunt resistance at 0 irradiance [Rsh0] (Ω)	1400
Rsh exponential irradiance factor	5.5

The bottom right section features a '4-Chart View' with four subplots:

- Voltage vs. current:** Shows Current (A) vs. Voltage (V) for 750 W/m² @ 25 °C. The current starts at approximately 9.3 A at 0 V and drops to 0 at 45.9 V.
- Voltage vs. power:** Shows Power (W) vs. Voltage (V) for 750 W/m² @ 25 °C. The power peaks at approximately 330 W at 37.5 V.
- Irradiance vs. efficiency at Pmax:** Shows Efficiency at Pmax (%) vs. Irradiance (W/m²) for 25 °C. The efficiency is approximately 17.5% at 1000 W/m².
- Module temp. vs. efficiency:** Shows Efficiency at Pmax (%) vs. Temp (°C) for 750 W/m². The efficiency decreases from approximately 17.5% at 25 °C to about 16.5% at 45 °C.

Intro to SolarFarmer (*beta version*): Functional User Interface

The screenshot displays the SolarFarmer software interface for a new project. The main window shows an aerial view of a site with a solar panel array, two inverters (Inverter 1 and Inverter 2), and a transformer (Transformer 1). The interface includes a top toolbar, a left sidebar with navigation options, and a bottom panel with a table of inverter details and a warning message.

Top Panel: Inverter type: GE Brilliance 1 MW; Module type: Canadian Solar Inc. CS6U-330M APP01; String length: 20; DC coil effect (%): 0; AC coil effect (%): 0; Add to transformer: -

Bottom Panel:

Inverter	# Strings	Str Len	DC Coil Effect (%)	AC Coil Effect (%)	Module Type	End	Inverter Type
Inverter 1	233	20	0	0	Canadian Solar Inc. CS6U-330M APP01	Central inverter	GE Brilliance 1 MW
Inverter 2	196	20	0	0	Canadian Solar Inc. CS6U-330M APP01	Central inverter	GE Brilliance 1 MW

Warning: Changing the string length or module type (if a different size) will remove any existing strings attached to the inverter input

Intro to SolarFarmer (*beta version*): Functional User Interface

The screenshot displays the SolarFarmer software interface for a new project. The main view is a 3D perspective rendering of a solar farm layout on a green field. The interface includes a top toolbar with 'Auto' and 'Solid' modes, and a left sidebar with navigation options: Design layout, Electrical configuration, Review trackers, Review shading, and a grid icon. A 'Site Statistics' window is open on the right, and a 'Site layouts' window is open at the bottom.

Site Statistics - PV System:

DC Power (kW)	AC Output (kW)	DC/AC Ratio	# Racks	# Strings	# Modules
2831.4	2000	1.42	225	429	8580

Site Statistics - Inverters (2):

Name	Type	DC Power (kW)	AC Output (kW)	DC/AC Ratio	# Strings	# Modules
Inverter 1	GE Brilliance 1 MW	1537.8	1000	1.54	233	4660
Inverter 2	GE Brilliance 1 MW	1293.6	1000	1.29	196	3920

Site Statistics - Components inventory:

Component type	Name	Count
Inverter	GE Brilliance 1 MW	2
Rack	Rack Specification 2	21
Rack	Rack Specification 1	204
Module	Canadian Solar Inc. CS6U-330M APPO1	8580

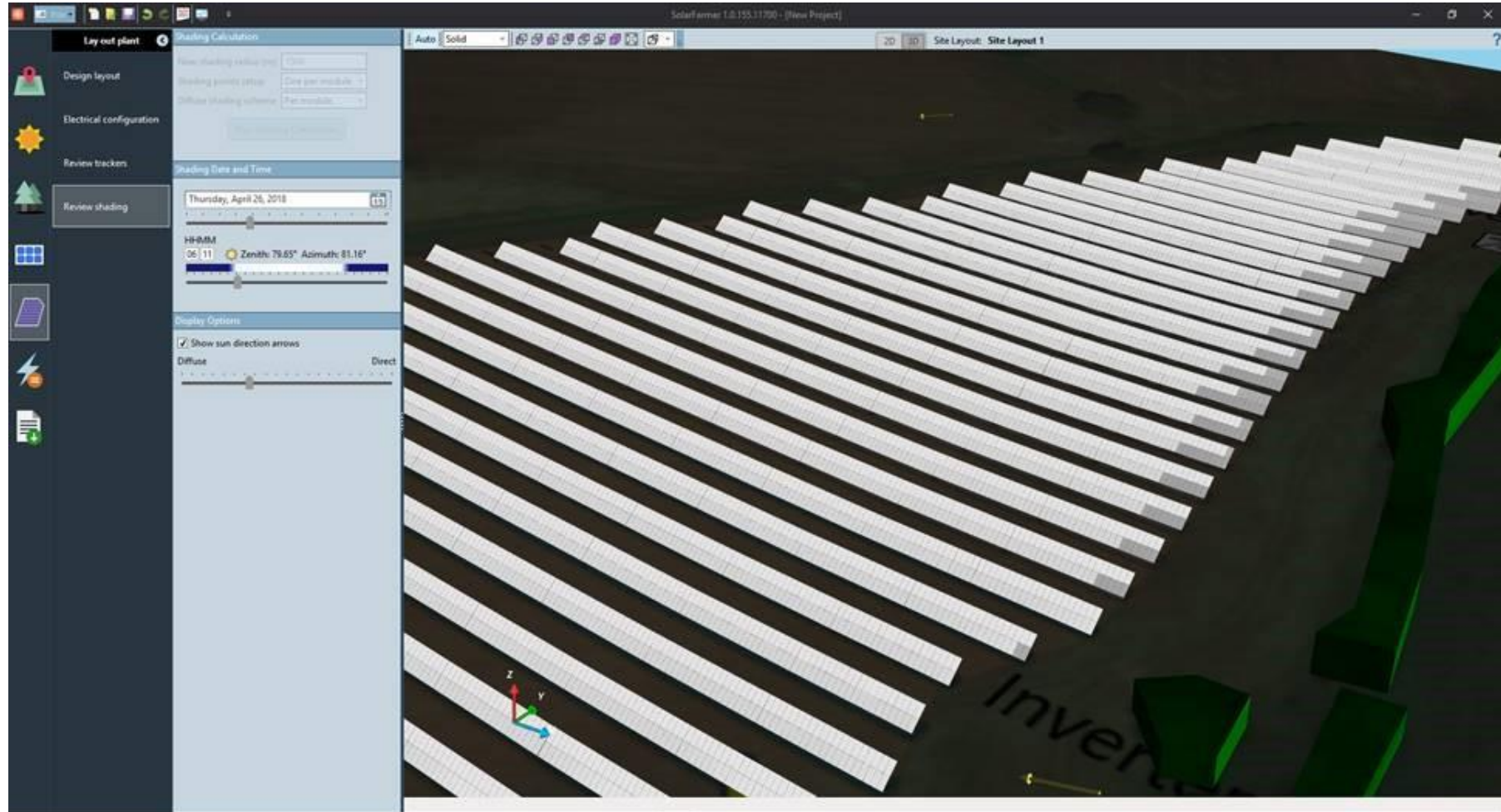
Site Statistics - Layout boundaries (1):

Name	# Racks	# Strings	# Modules
Layout Region 1	225	429	8580

Site layouts - Site Layout 1 (Racks):

Inverter	# Strings	Sto Len	DC Coll Effect (%)	AC Coll Effect (%)	Module Type	Kind	Inverter Type
Inverter 1	233	20	0	0	Canadian Solar Inc. CS6U-330M APPO1	Central inverter	GE Brilliance 1 MW
Inverter 2	196	20	0	0	Canadian Solar Inc. CS6U-330M APPO1	Central inverter	GE Brilliance 1 MW

Intro to SolarFarmer (*beta version*): Functional User Interface

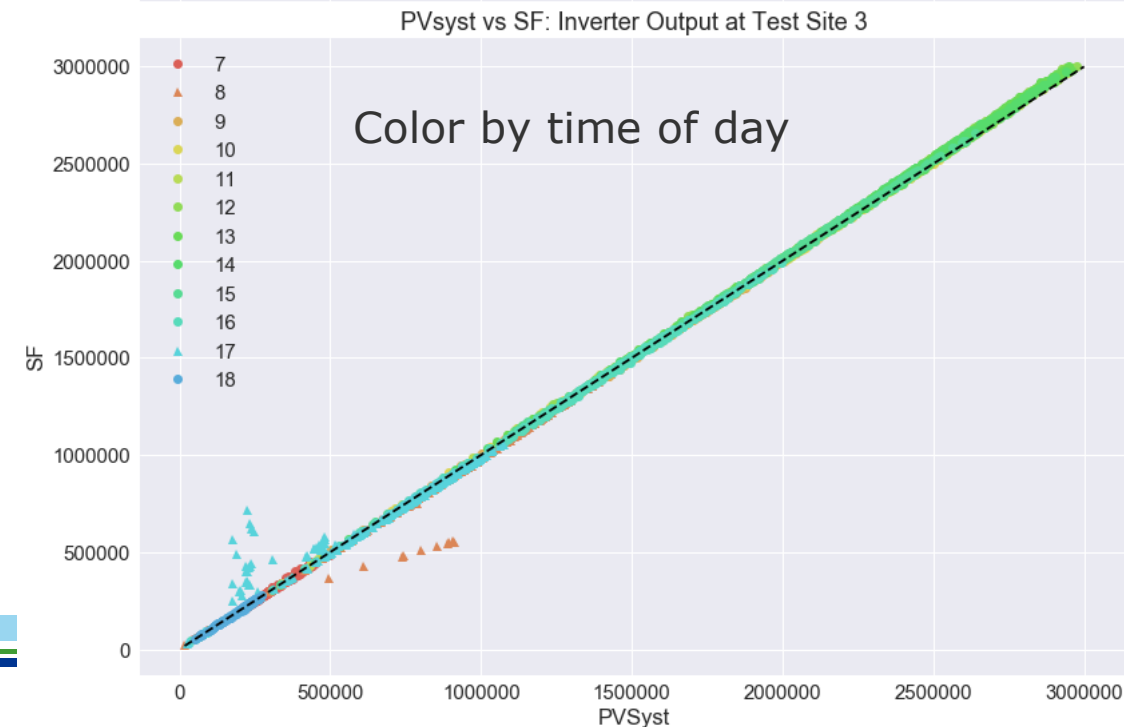
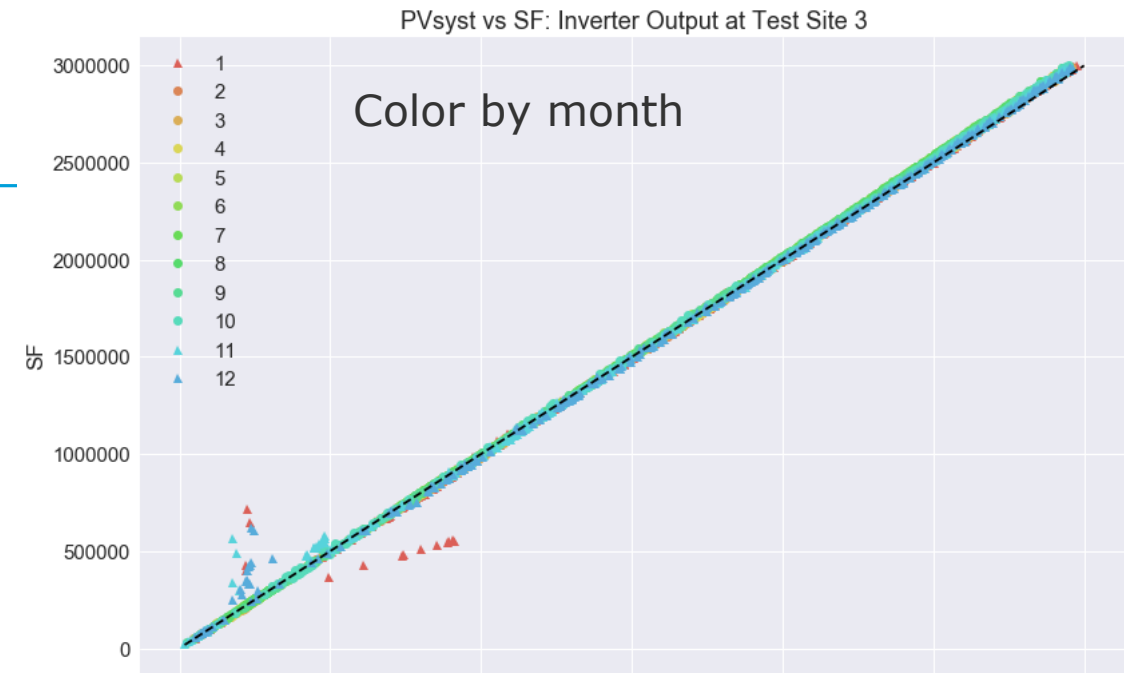


Validation

Validation: Comparison with other models

- Real sites modelled with both SolarFarmer (*beta* version) and PVSyst using identical parameters
 - Expect nearly 1:1 comparison where there is no shading or only row-to-row shading
 - Differences observed in winter and early morning, late evening
 - Test site 3 average annual positive bias
 - Test site 4 nearly zero average annual bias

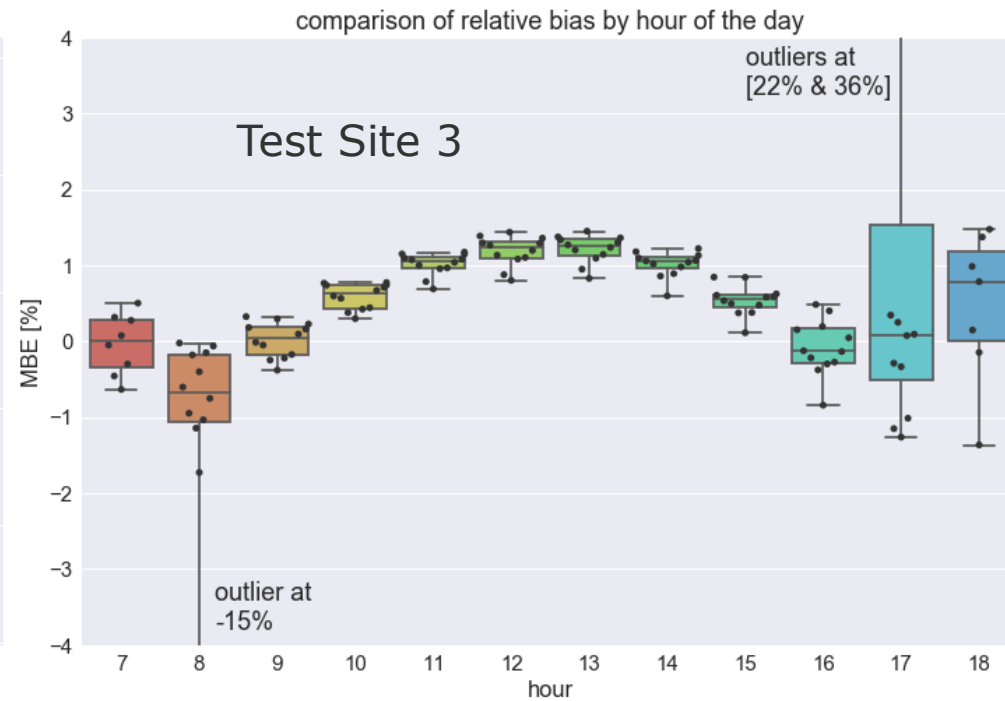
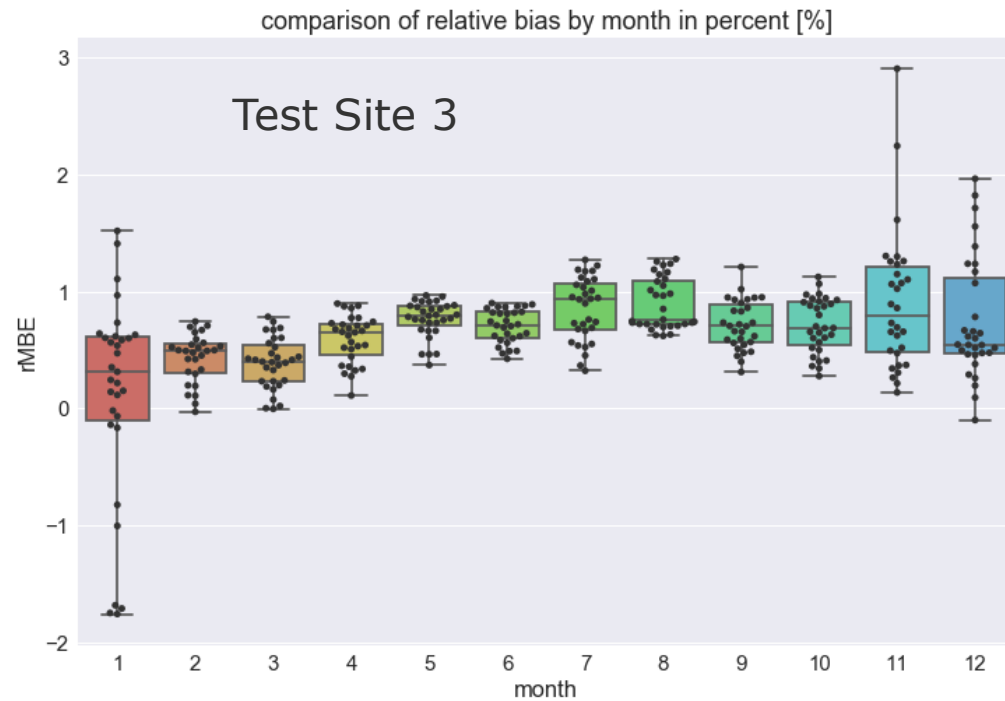
Annual Bias	rMBE	rRMSE
Test Site 3	0.67	1.8
Test Site 4	0.01	1.7



Validation: Comparison with other models

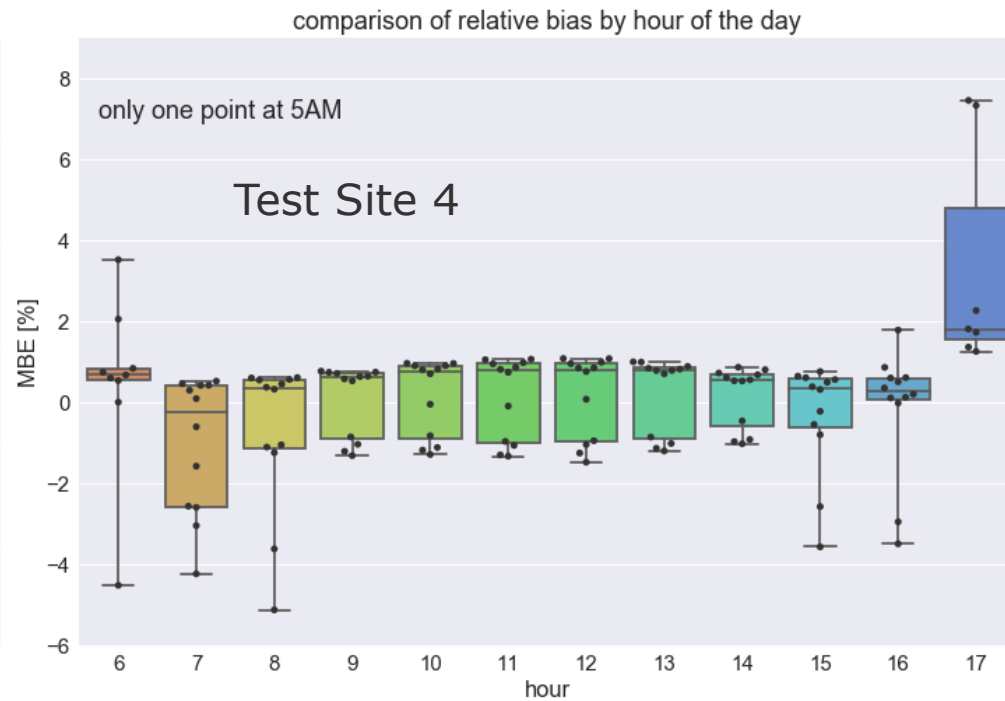
- Test site 3

- No apparent seasonal bias other than +0.7% annual
- Apparent strong diurnal bias more positive at noon, less positive, zero, or negative morning and evening



Validation: Comparison with other models

- Test site 4
 - Shows some seasonal bias, lower in winter versus summer
 - Nearly zero diurnal variation



TODO:

- Compare with measured site data
 - Public datasets
 - NIST Gaithersburg, MD test bed
 - Desert Knowledge Australia Solar Centre
 - Private datasets from industry partners
 - More test data – interested in collaborating? Please contact me!
- Examine individual points to determine if differences between models are expected or not
- Investigate positive bias in test site 3
- More *beta* testing – interested in collaborating? Please contact me!
- Release Version 1.0 in Q4
- *Etc.*

Thanks!

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