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The Forecast is Too Sunny and the Observations are Biased

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Overview

MDA Information Systems, LLC is predicting electric power generated from solar energy for individual sites and for regions.
In previous years at this meeting, we presented about

- MDA's state-of-the-science ***irradiance*** forecasting system utilizing the REST2 clear sky model, AERONET aerosol observations, and a variety of other public sources and proprietary site data
- MDA's solar ***power*** forecasting system, highlighting challenges we met ***predicting hourly electric power generation*** for a single-axis PV farm in a challenging location beset by synoptic and local storms as well as sunny-day cumulus.
- Prediction of ***subhourly variability*** for ***irradiance and power*** at individual sites and real-time calculation of aggregate ***distributed generation*** from hundreds of thousands of sites in California

Here we highlight challenges the MDA solar power forecasting system overcomes from model forecasts that are too sunny to observations requiring extensive quality control and even bias correction

MDA Solar Power and Solar Irradiance Forecasting

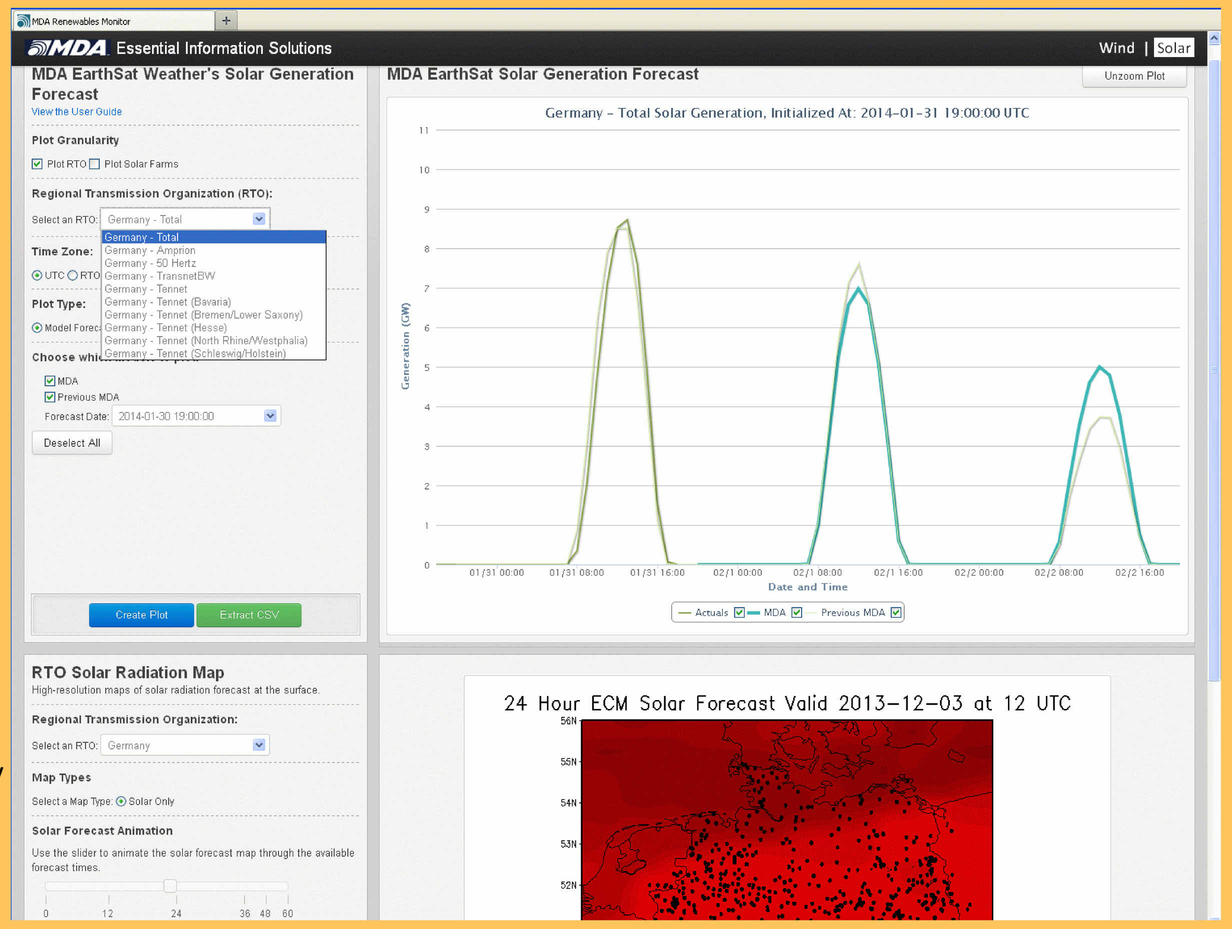
MDA Information Systems, LLC has developed a solar forecasting system

- Individual sites or collections of sites
- Distributed generation
- Panels of any tilt or sun-tracking
- All forecast lead times
- Prediction of
  - Solar power generation
  - Global Horizontal Irradiance **(GHI)**
  - Direct Normal Irradiance **(DNI)** and Direct Horizontal Irradiance **(DIR)**
  - Irradiance incident on panels (plane of array)
  - Prediction of subhourly variability for power and irradiance

MDA predictions of PV electric generation outperformed competition in diverse geographic areas

Our user interface shown here

- Is integrated into the wind power forecast display with the same features
- Allows viewing of forecasts for regions or individual farms
- Shows current and past forecasts and reported actuals to present
- Allows viewing of error statistics from recent forecasts
- In addition to the MDA power forecast, overlays model irradiance forecasts onto a map indicating power installation density, juxtaposing incoming solar energy with generation capacity

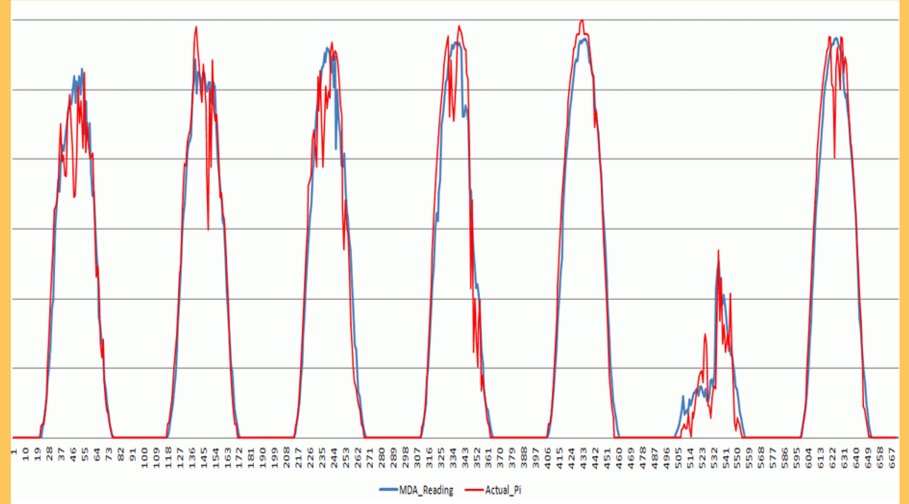


An improved user interface with more flexibility is coming soon!

- Combined wind+solar power will be available for regions having large wind and solar capacity

Skill is dominated by prediction of clouds. Predicting evolution beyond the first few hours requires use of numerical weather prediction **(NWP)** models

- Cloud prediction is a weak point in NWP
- Time-averaged, not instantaneous, values of surface shortwave flux are needed
- Output frequency for most major NWP models is insufficient
- Surface shortwave fluxes from NWP models need complex bias correction (function of other variables)
- Most NWP models do not output direct beam irradiance (DNI or DHI) and those that do provide it have little skill independent of predicted GHI



A week of 1-hour-ahead power forecasts for 15-minute blocks vs. actual power. No site observations were available for the preceding month up to forecast time. Skill is from a robust forecast system optimizing use of tuned NWP forecasts and empirical power curves derived from site history data.

MDA Information Systems, LLC solar forecasting system meets these challenges through

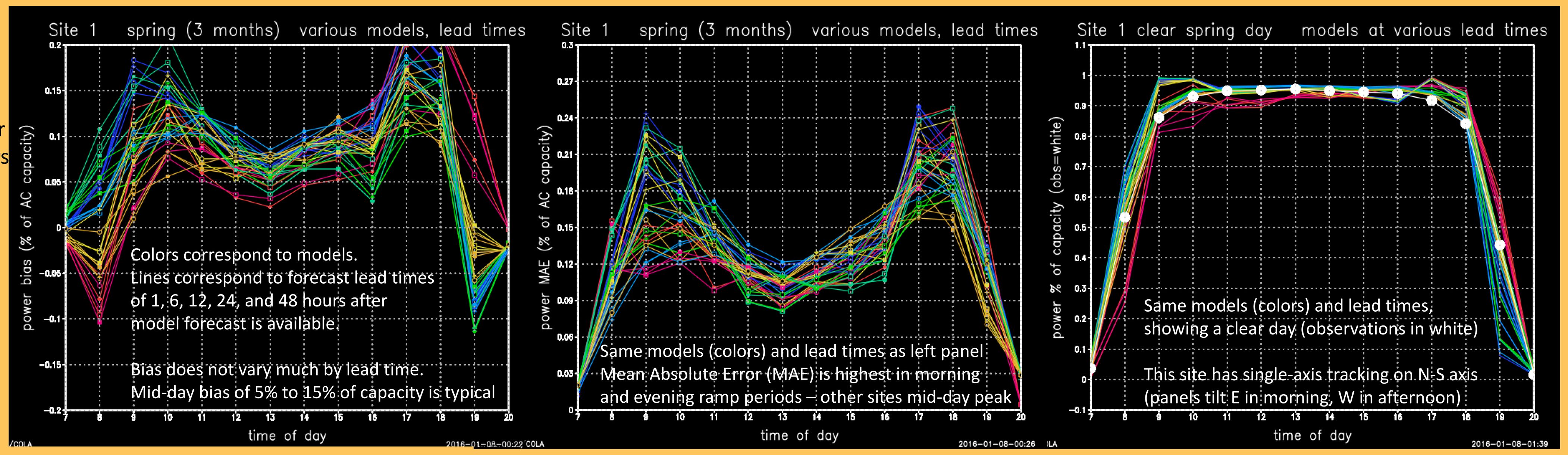
- Leveraging the REST2 (Gueymard, 2008) clear sky model as a foundation for time interpolation, bias correction, and direct beam calculation
- Employing a variety of public data sets to obtain aerosol-related and other parameters needed for REST2 and for considering cloudy atmospheres
- NWP bias correction as a function of key variable combinations
- Skill-based blending of NWP models and time-lag ensembles
- Accounting for short-term fluctuations in irradiance based on conditional statistics we generated based on data from high-quality irradiance monitoring sites
- Converting irradiance to power using multivariate relationships derived from site data passed through quality control

Reference: Gueymard, C. A., 2008: REST2: High-performance solar radiation model for cloudless-sky irradiance, illuminance, and photosynthetically active radiation – Validation with a benchmark dataset. *Solar Energy*, **82**, 272-285

The Forecast is Too Sunny

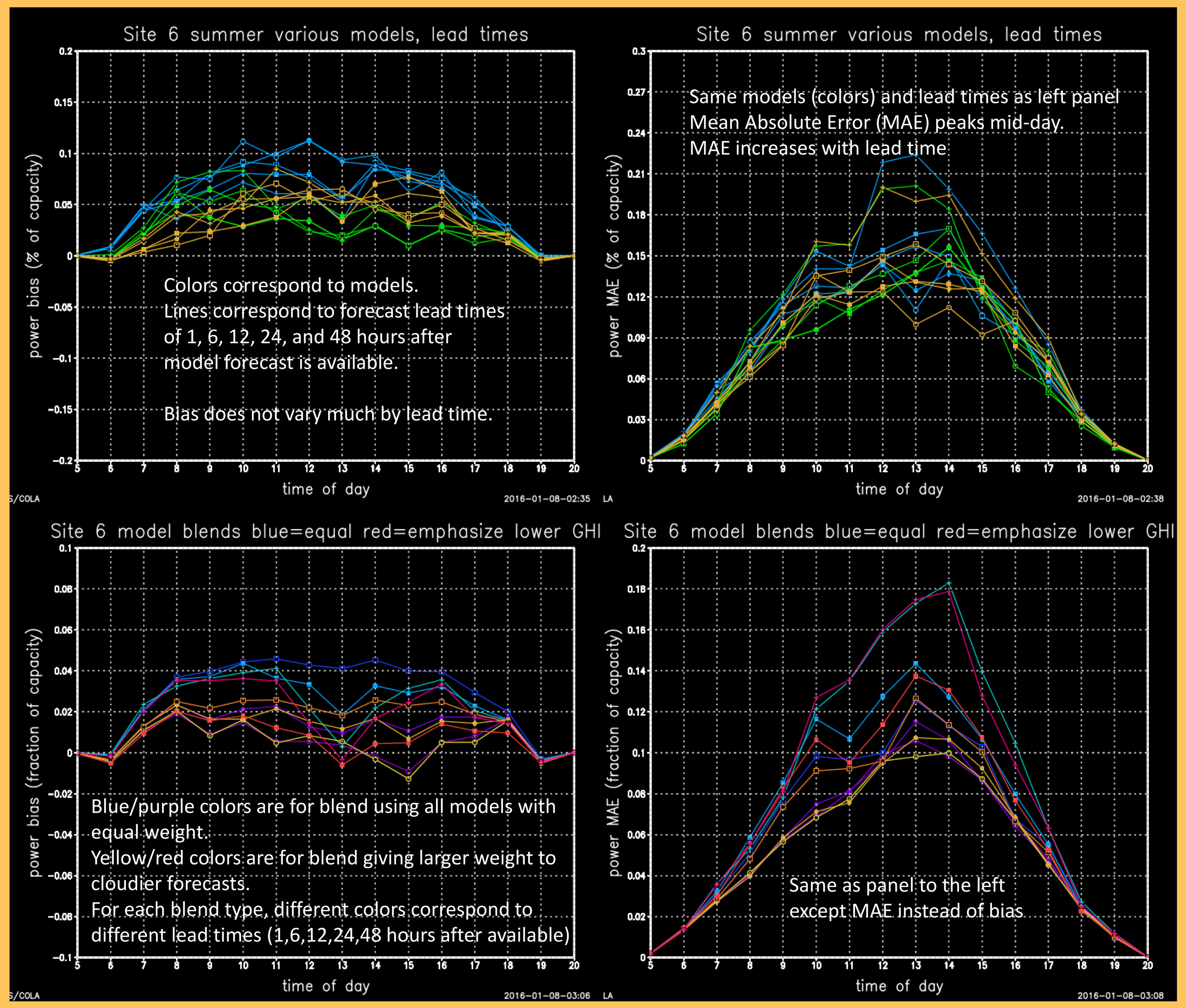
The MDA solar power and irradiance forecast is rooted in numerical weather prediction (NWP) model irradiance forecasts. The quality of the MDA forecast is tied to the quality of NWP model forecasts although we perform extensive post-processing: multivariate bias correction, adjusting against clear sky irradiance, partitioning into direct and diffuse irradiance components, projecting onto tilted or sun-tracking panel geometries, passing the results through empirical site-specific power curves, and blending the results of many model forecasts using skill-based weights.

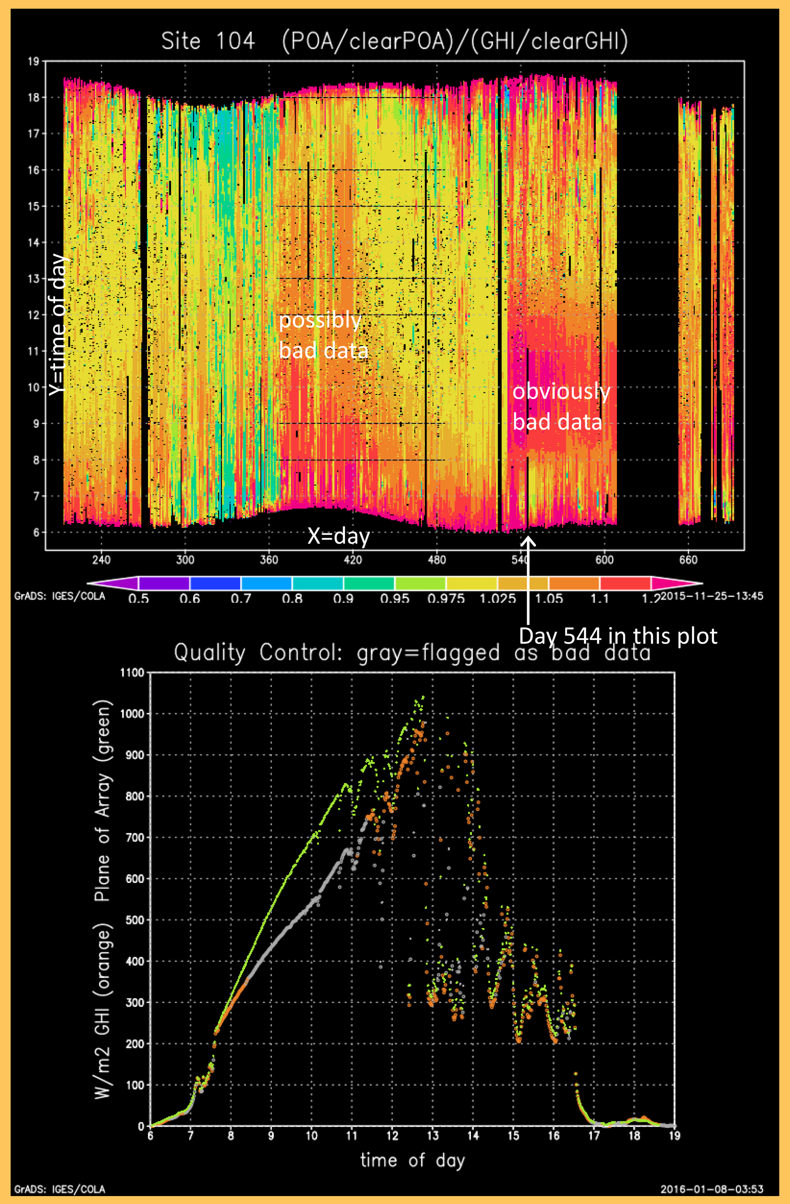
The model forecasts tend to be too sunny, particularly in winter and spring, in all different regions we have examined, and at all lead times including the first hour after the model is available (a few hours after model initialization due to latency for data ingest and computation and dissemination). We found this for ECMWF, GFS, NAM, RAP, and HRRR and will examine others. Power forecasts derived from passing the model forecasts through the MDA solar forecast system verify with little error on clear days but on cloudy days, many of the model forecasts show nearly clear conditions. For example, see the overall bias and mean absolute error for one site above, along with the nearly zero mid-day bias on a clear day. Similar results are shown in the top two panels to the right.



The cause of the too-sunny forecasts are varied. Some cases involved poor forecasts of the movement of cut-off lows, others involved low-level moisture trapped under inversions that did not mix out as much or as soon as predicted, and there were cases of mesoscale cloud features associated with convection, sea breeze and other convergence zones, and other situations.

While model blends reduce error, bias remains, as shown in the bottom panels. Even skill-weighting the contributions from each model does not improve this situation much. However, giving additional weight to cloudier forecasts does help, as shown in the lower panels.





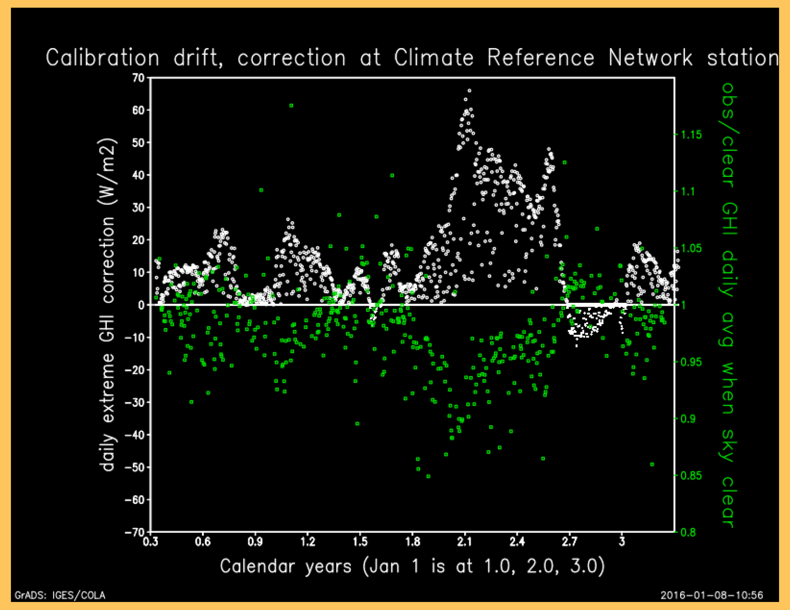
A typical example of site data is shown to the left. The ratio of clear sky fraction of plane-of-array irradiance (POA) to clear sky fraction of GHI is shown. At times, the GHI sensor apparently was being partly shaded while the POA was not. Most of the days had intermittent clouds but day 544 was clear in the morning (left), so it is easier to see why the quality control flagged the bad GHI data.

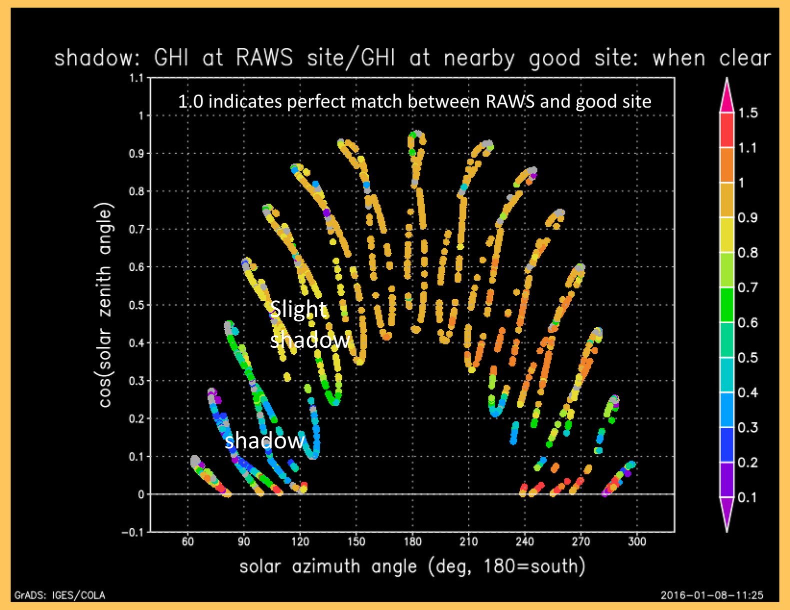
The ratio of diffuse irradiance to GHI is shown for a good site. Large values indicate cloud or shade (or sun near horizon). When averaged into sun angle bins, a pole or other obstacle to the east-northeast of the sensor is revealed.

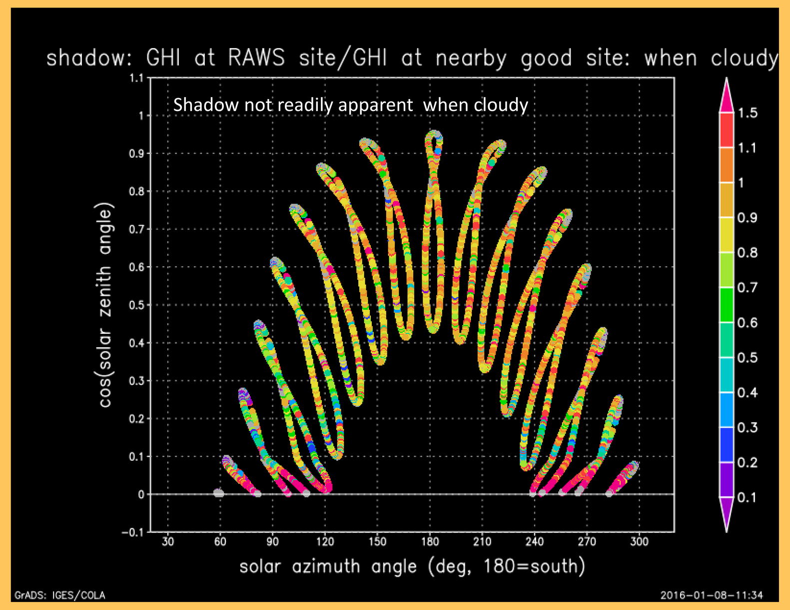
The Observations are Biased – Detecting and Correcting Observation Errors

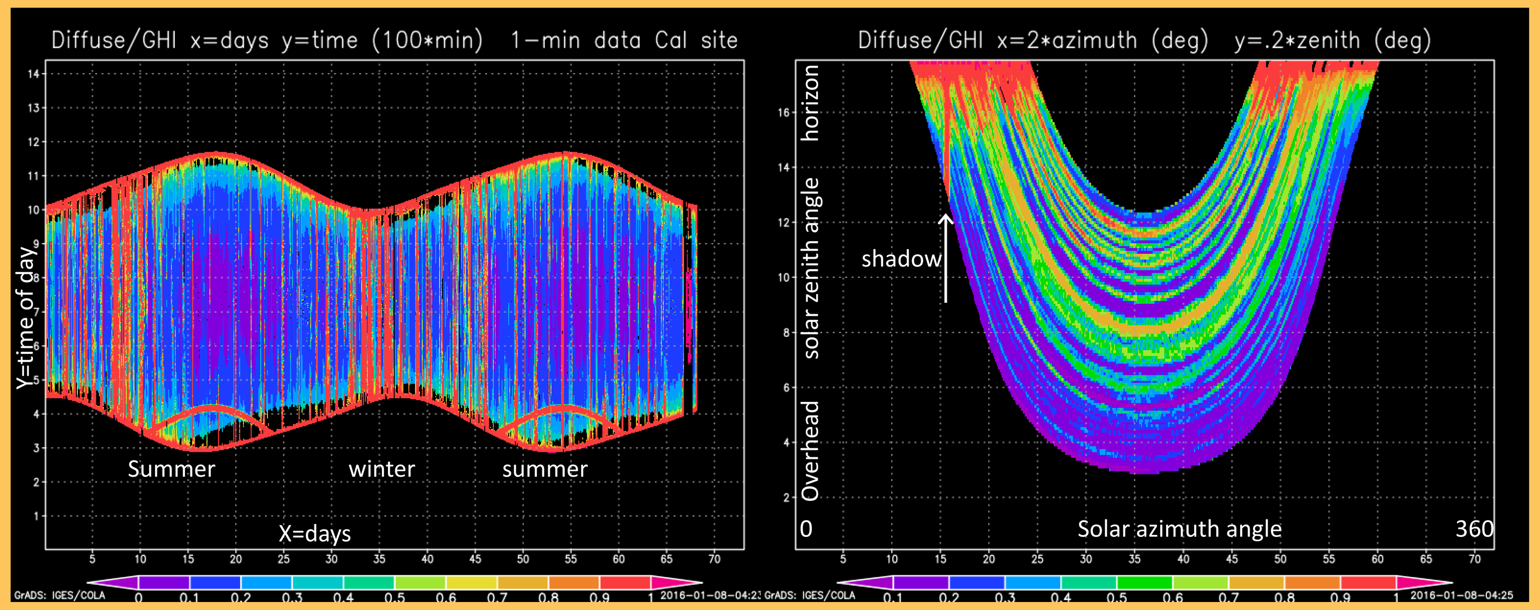
The MDA solar forecast system utilizes observations to tune NWP model irradiance forecasts and site observations to create empirical power curves. Correcting for observation bias and removing bad data are essential prerequisites to developing clean and robust relationships for correcting NWP forecasts and converting irradiance to power. In our experience, real-world observational data are both extremely noisy and fraught with subtle errors as well as obvious errors. Addressing these allows the data to be used well, resulting in good forecasts.

The three plots below illustrate issues with some publicly available irradiance data while those to the right show some of the types of issues in proprietary site observations.
The US Climate Reference Network stations record Global Horizontal Irradiance (GHI) in hourly data summaries covering 5-minute periods. The sites are maintained annually and the data are pretty good after we correct for calibration drift and calibration jumps following maintenance. We calibrate against our clear sky GHI and correct accordingly. For the example shown to the left, the corrections occasionally exceeded 60 W/m^2 and were large for several months but usually were around or under 10 W/m^2.
RAWS sites such as in the next two panels are typically located in forest clearings and plagued by shadows and a lack of maintenance. The analysis here was facilitated by a nearby high-quality site.









The Way Forward

Better forecasts and better observation quality are the rising tides that lift all boats.

MDA already has a state-of-the-science solar power and irradiance forecast system. We found that the MDA forecasts had a sunny bias primarily due to NWP model forecast error and we improved by better accounting for that error. Larger improvements will come from NWP forecasts which are able to better predict the evolution and motion of slow cutoff circulations and better able to predict the erosion or formation of boundary layer clouds, both of which are well-known long-standing challenges still facing NWP.

Observation quality is paramount for the type of postprocessing required to make the best solar power and irradiance forecasts. SURFRAD sets a gold standard for irradiance monitoring, but that comes with expense. RAWS is not intended for that purpose and cannot afford to be of the same quality. Claims that gridded GHI products are accurate because they fit untreated RAWS data are scientifically unsound. Solar farm data has a solar monitoring purpose and better instrument siting and maintenance would help. Availability of more widespread moderate-quality ground measurements would help.