Solar Forecast Arbiter

An open source evaluation framework for solar forecasting

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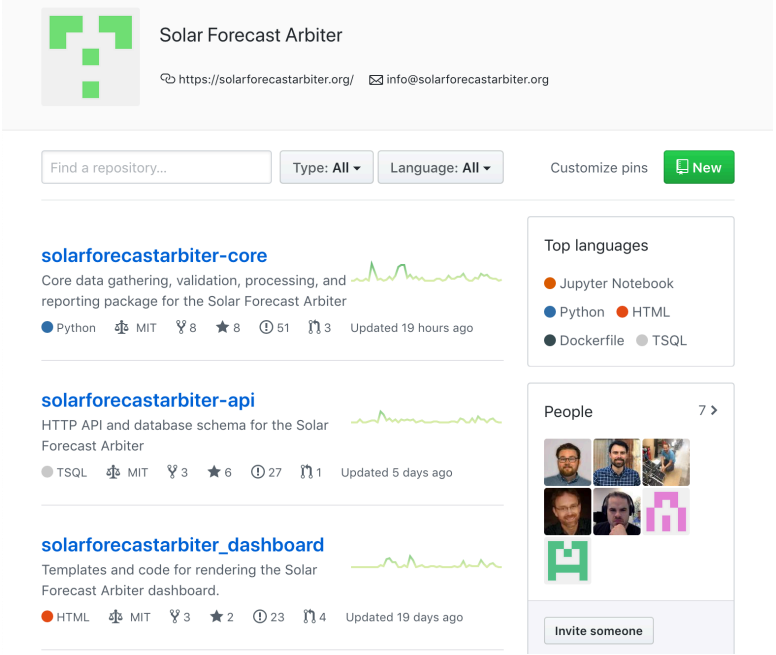
Evaluation Problems Identified by Stakeholders

- **Researcher** wants to analyze new solar forecasts in a variety of climate regions.
- **Funding manager** wants a neutral quantification of improvement over a meaningful reference.
- **Forecast provider** wants to standardize evaluations and ensure its forecasts are fairly assessed by end users.
- **Forecast user** wants to compare accuracy of forecasts from many providers in an operational setting.

Solar Forecast Arbiter

Tool for analyzing accuracy of solar forecasts

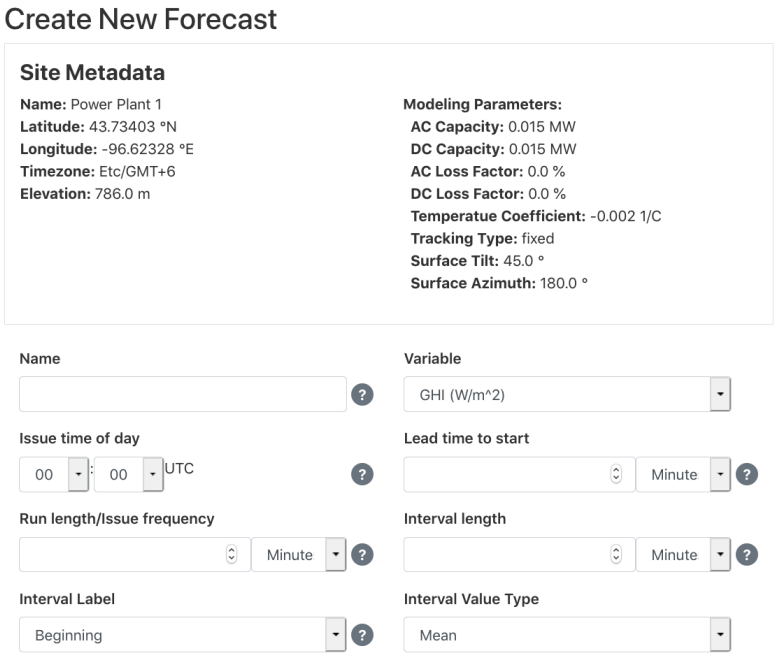
- Web-based user interface
- Web-based API for scripting
- Python software package for analysis
- Scripts to redeploy entire software stack
- Detailed supporting documents
- Supported by stakeholder input, feedback



Open source. Transparently developed on GitHub

How do I use the Solar Forecast Arbiter?

1. **Define site, observation and/or forecast metadata**
2. Upload observation and/or forecast data
3. Optional: grant another user access to your metadata/data
4. Run analysis report



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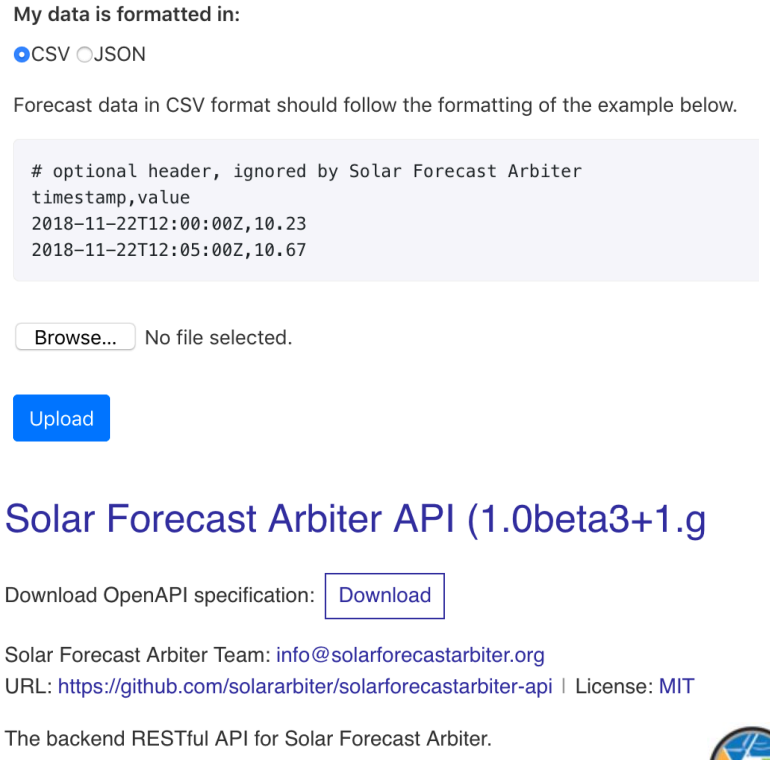

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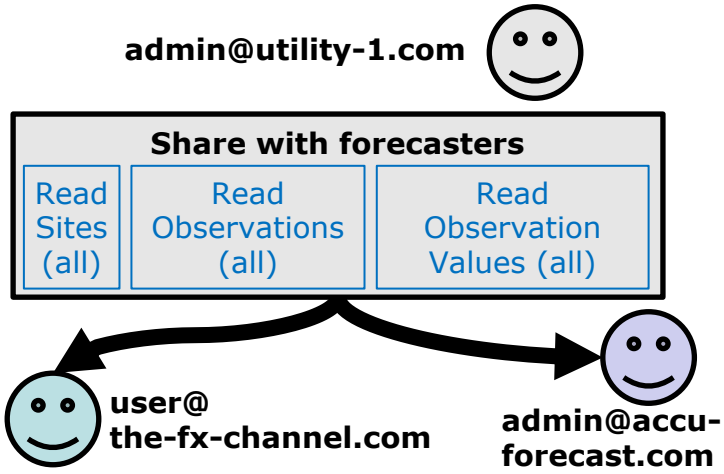

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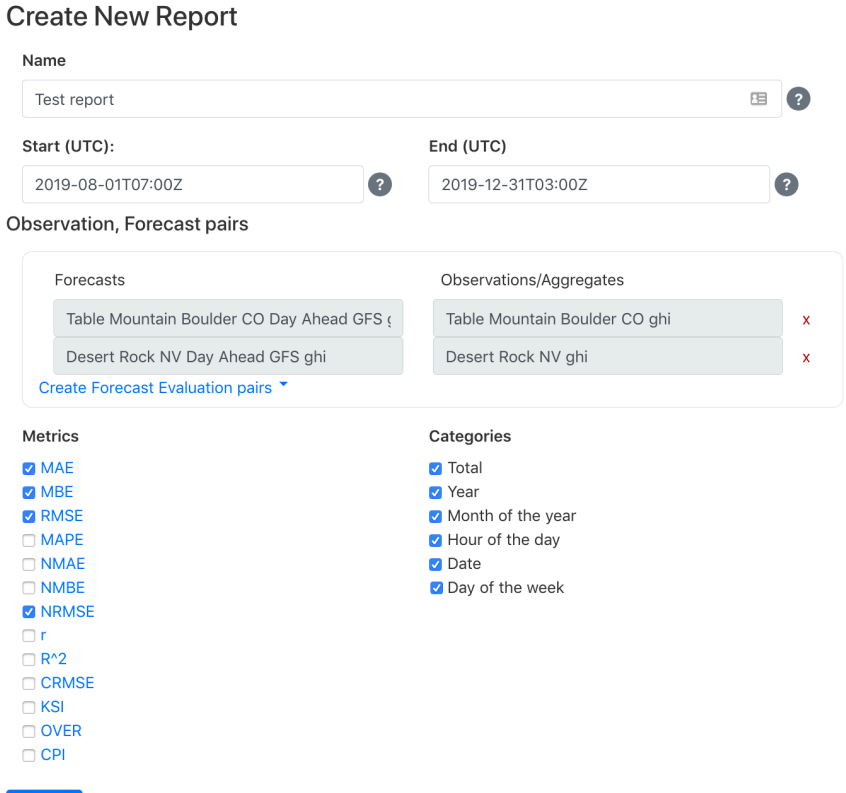


Example Report

Time series and scatter plots

surfrad ghi hrrr gfs

Intro/Metadata

This report of solar forecast accuracy was automatically generated using the Solar Forecast Arbiter.

Download as html or pdf (coming soon). The download is a ZIP archive that includes checksums for the report file and a PGP signature that can be used to verify the authenticity of the report. The Solar Forecast Arbiter PG key ID is 0x22bd497c0930f8b0.

Please see our GitHub repository for known issues with the reports or to create a new issue.

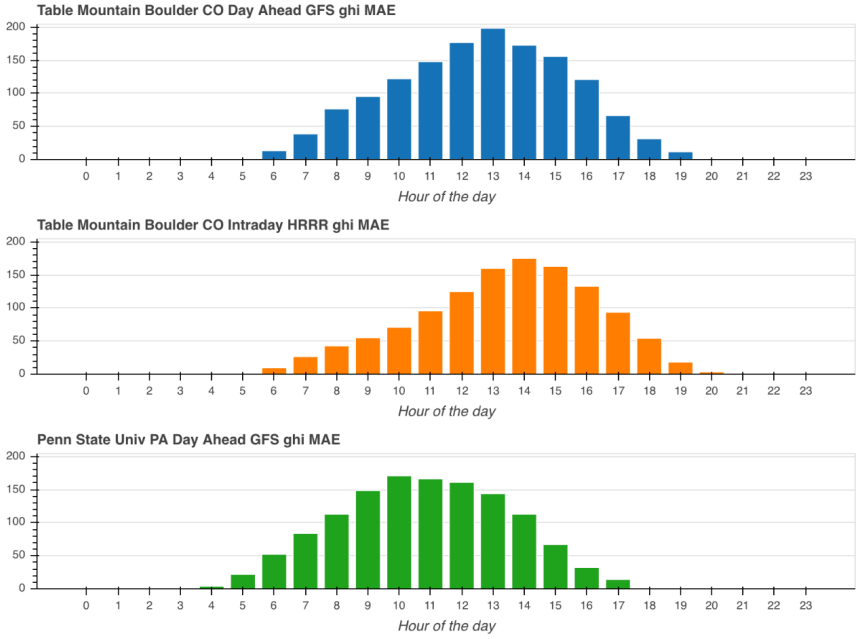
Contents:

Report metadata

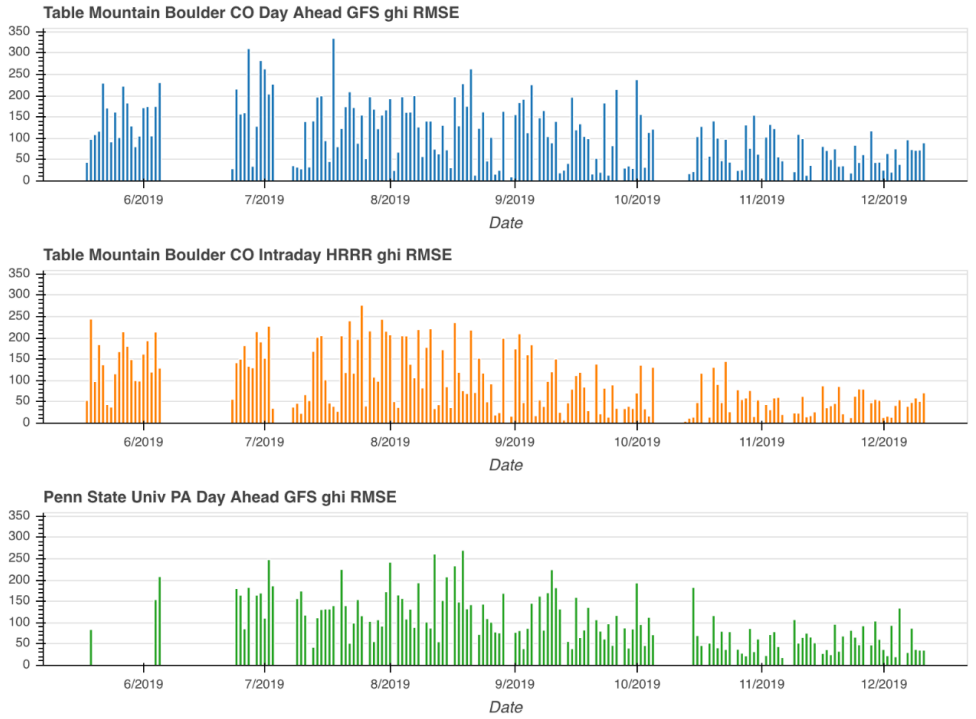
- Name: surfrad ghi hrrr gfs
- Start: 2019-04-01 05:00:00 +0000
- End: 2019-12-31 03:00:00 +0000
- Generated at: 2019-12-16 22:57:19 +0000

Example Report

Metrics by hour



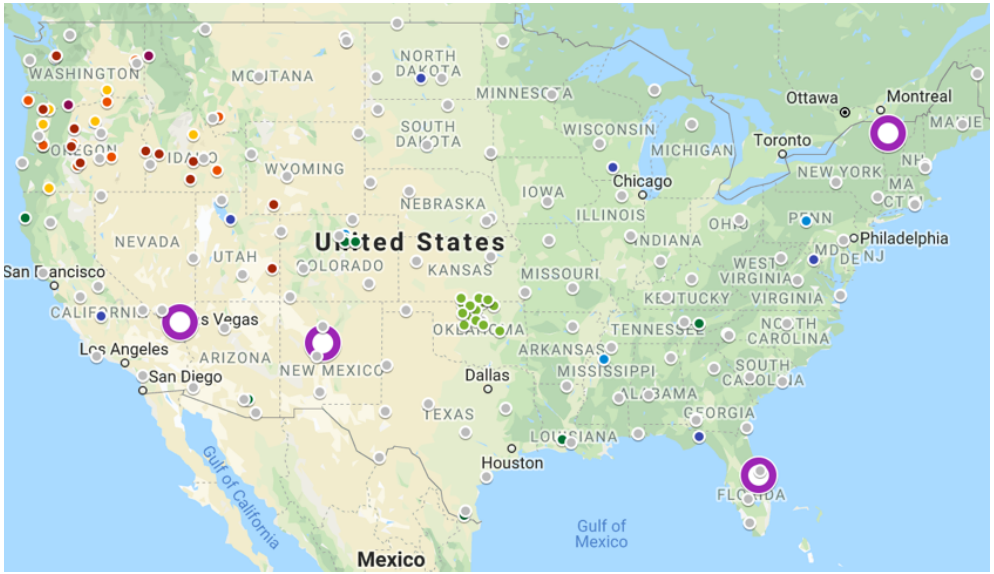
Metrics by date



Reference Data Sources

Public, Open Reference Data

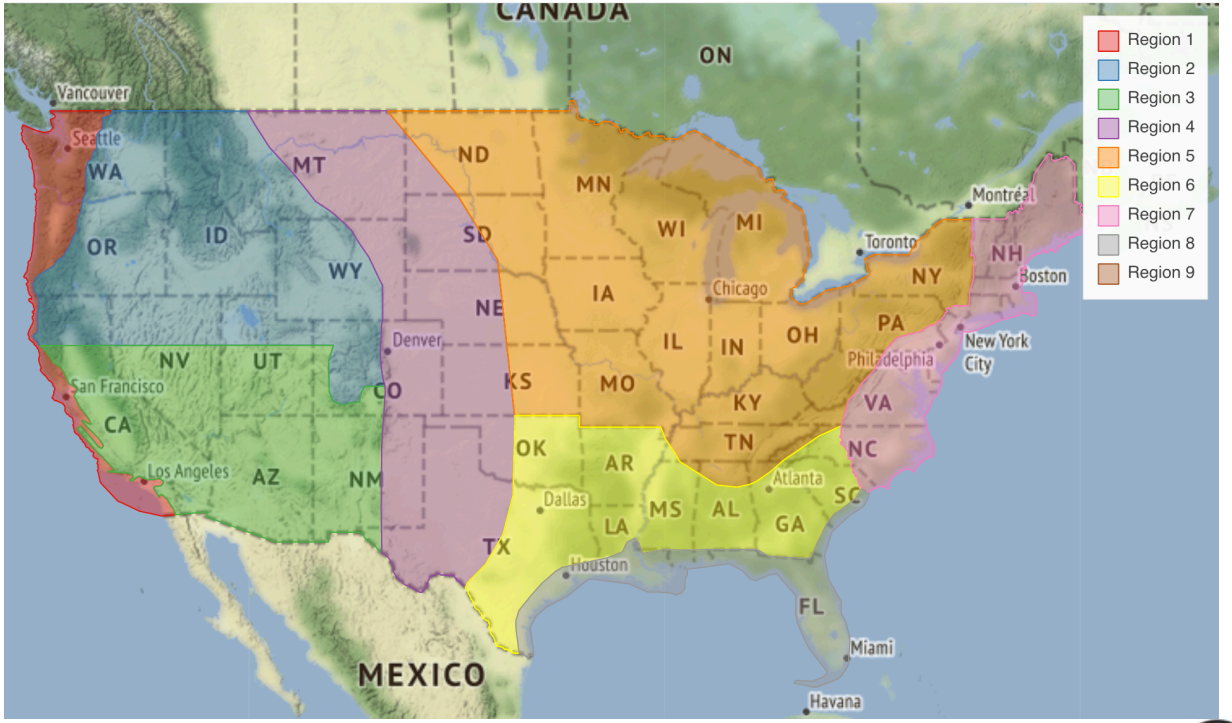
- NOAA SURFRAD
- NOAA SOLRAD
- NOAA CRN
- NREL MIDC
- DOE RTC
- U. Oregon network
- Contribute public reference data, get benchmark forecasts at that site



solarforecastarbiter.org/referencedata

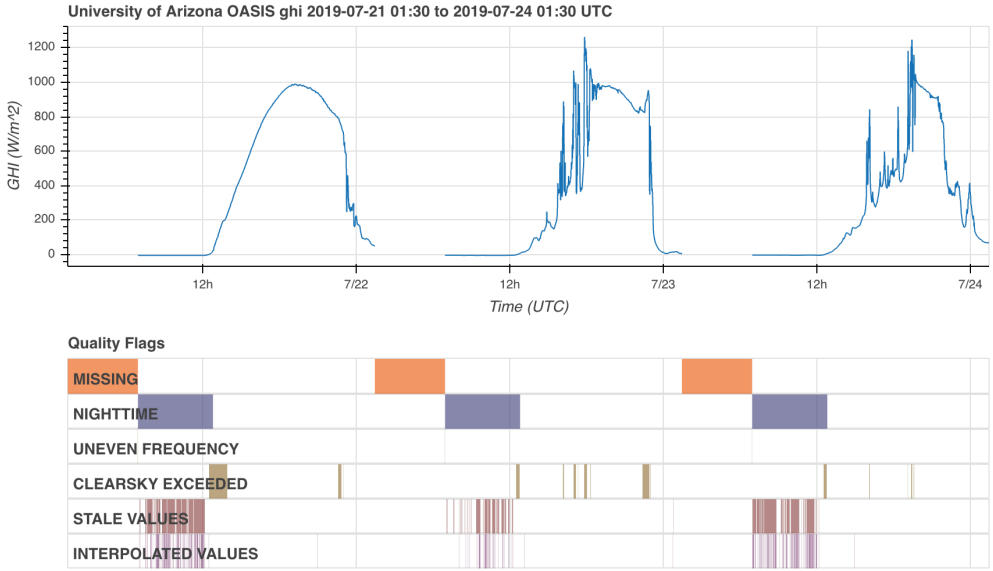
Climate Regions

- Regions support broader analyses of forecast performance
- ”This forecast performs well/poorly on the West Coast”
- Interactive map, shapefiles, kmz



Data Validation Toolkit

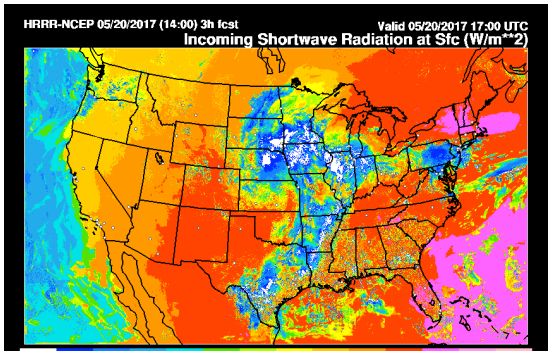
- Flags potential problems with user and reference data
- Automatically applied
- Report options control how flags should be used (e.g. exclude data, fill with 0)
- Open source, available for reuse



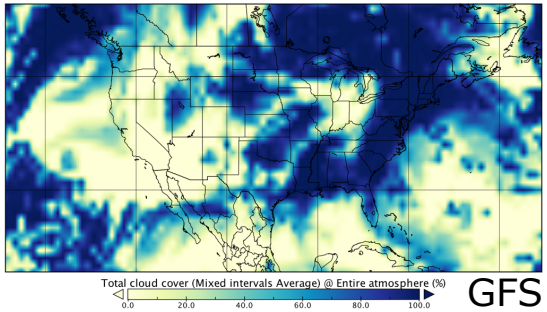
Benchmark Forecasts

solarforecastarbiter.org/benchmarks

- Benchmark forecasts provided for:
  - Public reference data (automatic, standardized)
  - Forecast trials (designed in consultation with SFA admins)
- NWP options:
  - GFS, GEFS, NAM, RAP, HRRR processing supported
  - GFS, NAM, RAP irradiance forecasts have serious limitations, so derive irradiance or PV power from cloud cover.
  - Directly use HRRR subhourly irradiance
- Persistence options:
  - Persistence
  - Persistence of clear sky index
  - Day ahead persistence



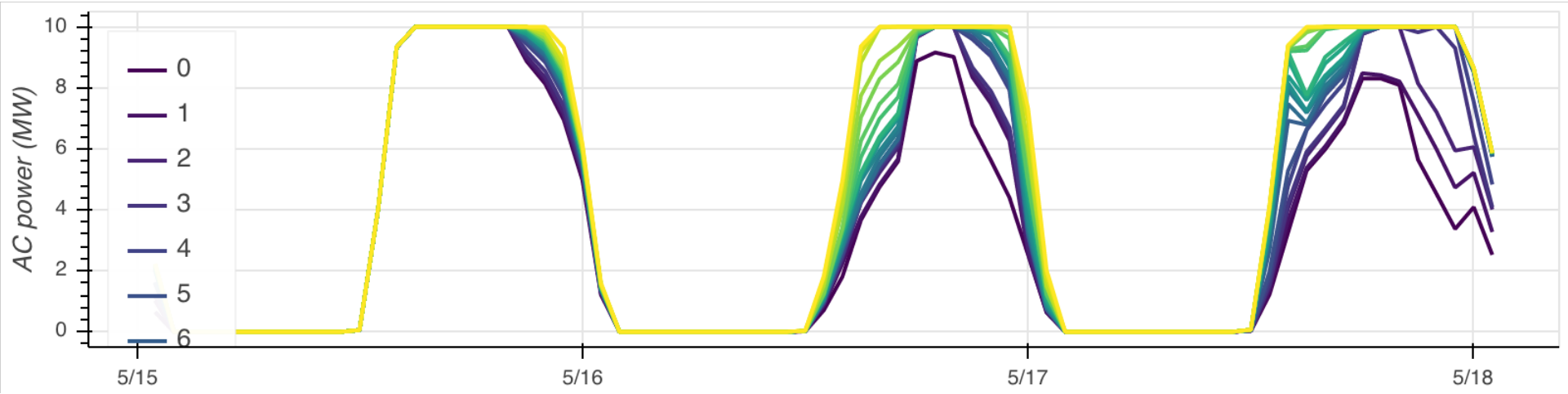
Total cloud cover (Mixed intervals Average) @ Entire atmosphere



GFS

Probabilistic GEFS Benchmark Forecasts

- 21 member GEFS 3/6 hr mixed interval average cloud cover processed into hourly, hour-ending AC power percentiles (0, 5, …95, 100)



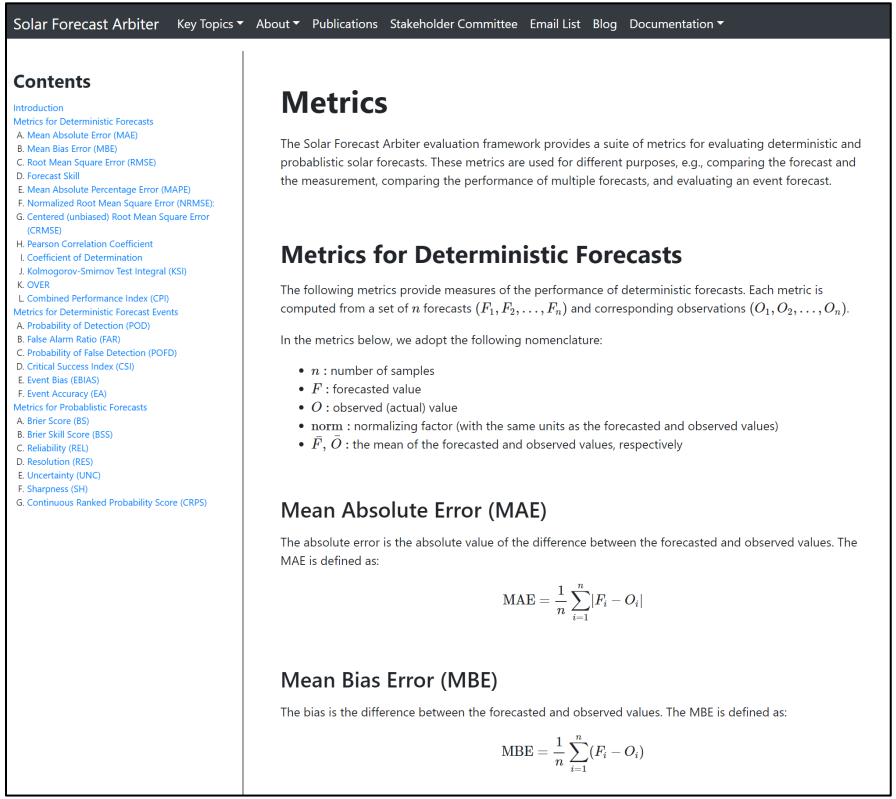
Open source, reference implementation, available for reuse

Metrics

Stakeholder selections of:

- Deterministic Forecasts
- Event Forecasts
- Probabilistic Forecasts
- Cost metrics

Open source implementation



solarforecastarbiter.org/metrics/

THE UNIVERSITY OF ARIZONA
Sandia National Laboratories
U.S. DEPARTMENT OF ENERGY
Office of ENERGY EFFICIENCY & RENEWABLE ENERGY
EPRI ELECTRIC POWER RESEARCH INSTITUTE
Sharply Focused

Data policies summary

1. Organization must sign non-negotiable Data Use Agreement before given access to do anything but view reference data.
2. Signing agreement does **not** obligate organizations to upload data or share data.
3. Organizations retain ownership of the data they upload to the framework.
4. Organization admins have complete control over how their data may be accessed by other users. Default: no sharing, private analysis only.
5. Organization admins may delete data from the framework.
6. Uploading data does **not** give SFA team ability to study data.
7. All non-public data will be securely deleted at the termination of the project (2021).

How to get started

1. Make free user account at dashboard.solarforecastarbiter.org
   - Browse reference data, forecasts
2. If you like it
   - Get your organization to sign the Data Use Agreement
   - Experiment with a small problem, upload some test data
3. If you love it
   - Help us beta test the operational forecast trial feature
   - Contribute data to the public reference data set
   - Spread the word
   - Contribute to the open source code development on GitHub

Summary

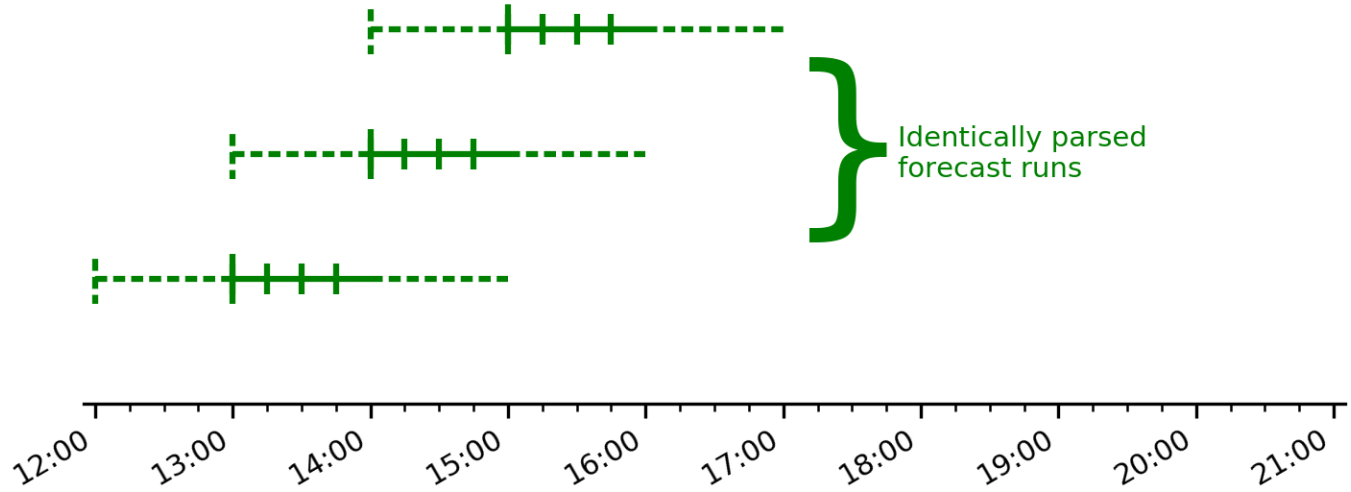
- Open source, reproducible, transparent evaluation framework
- Stakeholder feedback guides project – speak up!
- Use cases tailored to needs of solar forecast stakeholders
- Reference datasets and forecasts
- Secure, private data upload. Sharing optional
- Automated reports including bulk metrics, analysis filters
- Sign up for project updates, web dashboard at:

solarforecastarbiter.org holmgren@email.arizona.edu

Find me in the poster session this afternoon for demo, Q/A

Forecast runs concatenated into a forecast evaluation timeseries

Application: short term market
Requirement: hour ahead forecast



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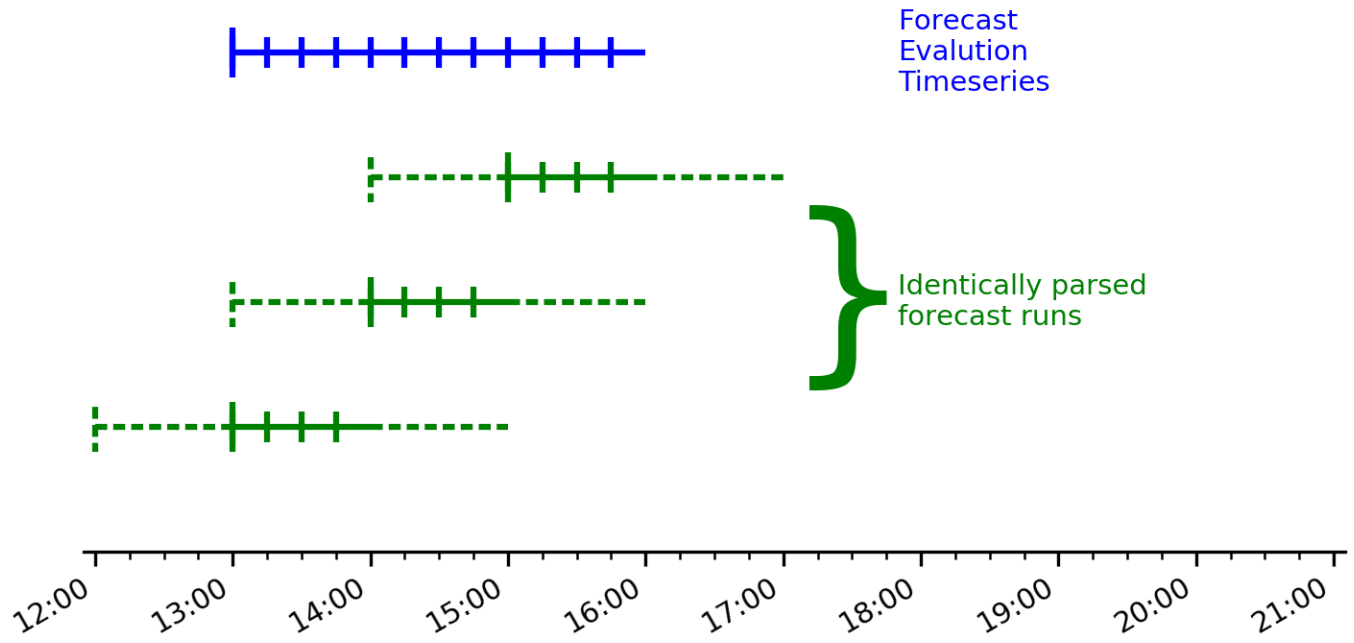

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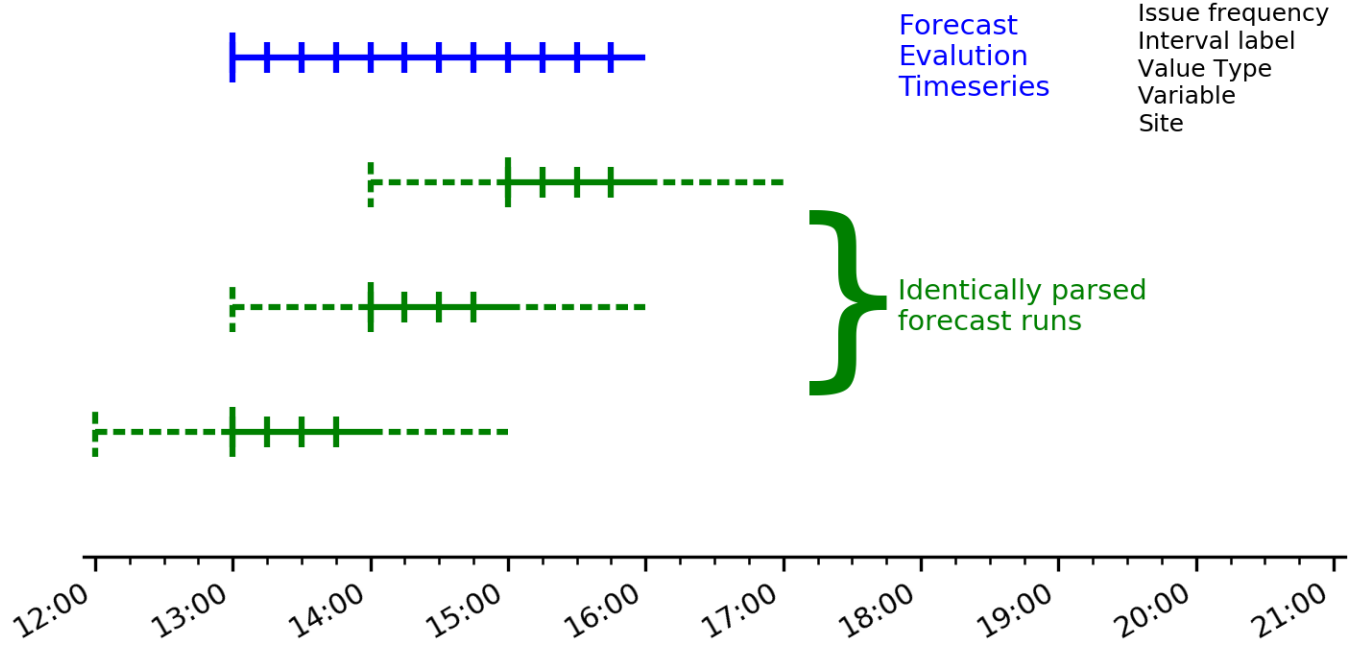
Forecast taxonomy

Lead time to start	1h	1h
Interval duration	15min	15min
Intervals / sub.	4	12
Issue frequency	1h	1h
Interval label	left	left
Value Type	mean	mean
Variable	Power	Power
Site	Plant X	Plant X



Use Cases

solarforecastarbiter.org/usecases

1D time series – no gridded data

A. Compare a forecast to measurements

B. Compare a probabilistic forecast to measurements (Feb.)

C. Compare multiple forecasts to measurements

D. Compare forecasts to measurements for sites and aggregates

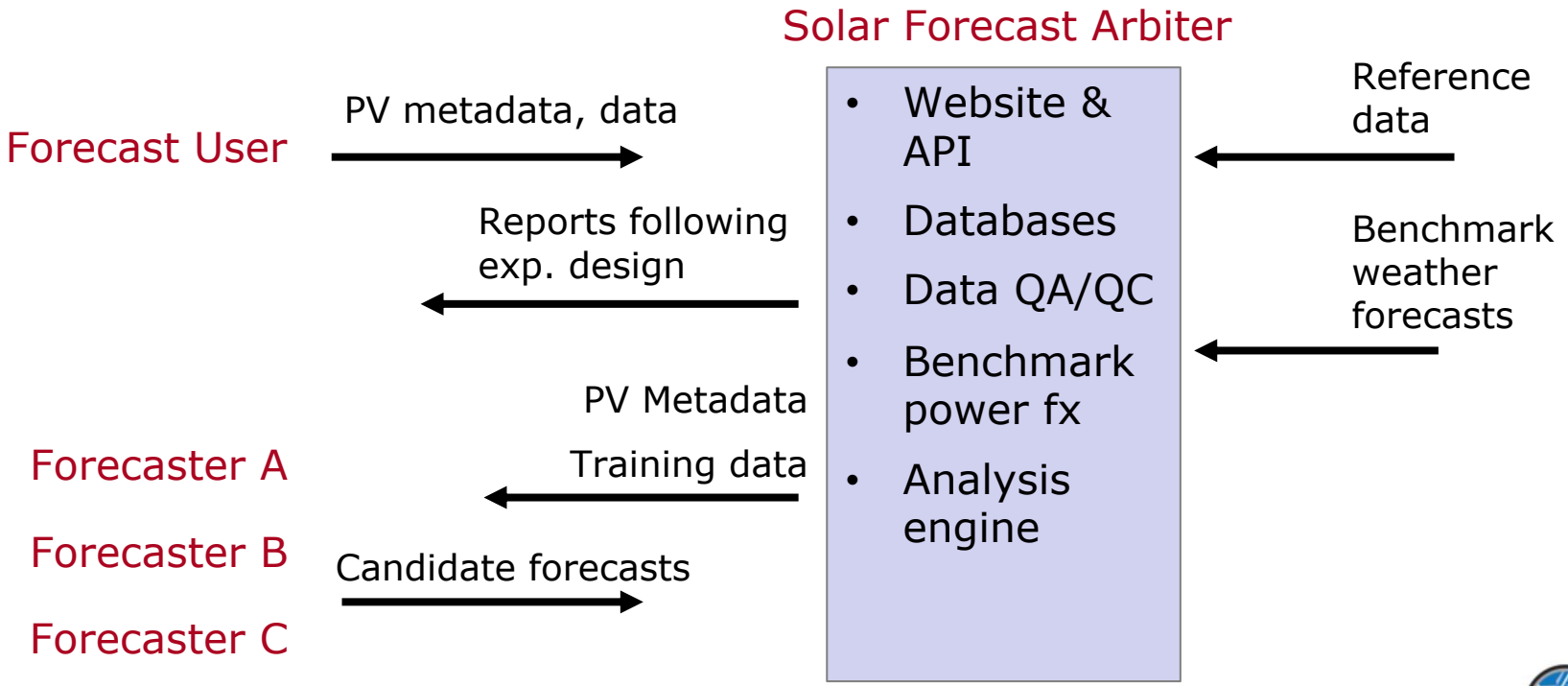
E. Evaluate an event forecast (Mar.)

F. Conduct a forecast trial (Jan.)

G. (*stretch*) Compare multiple overlapping forecast runs to measurements

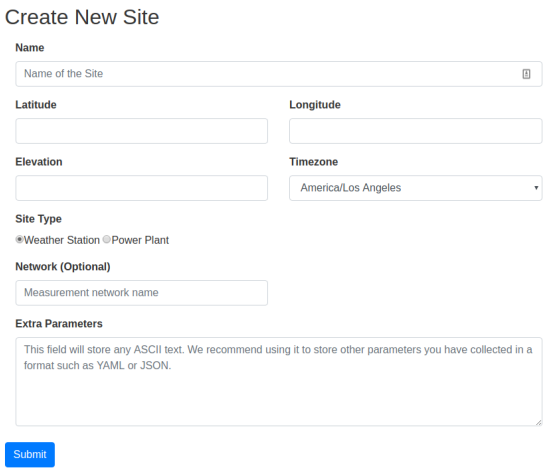
H. (*stretch*) Establish long-term performance baseline of state-of-the-art operational forecasts

Sketch of Forecast Trial Use Case



Data Upload/Download

Dashboard

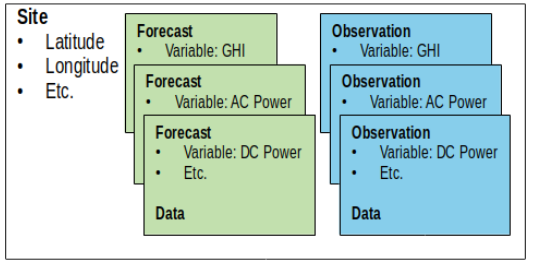


solarforecastarbiter.org/dashboarddoc

API

api.solarforecastarbiter.org

Data Model



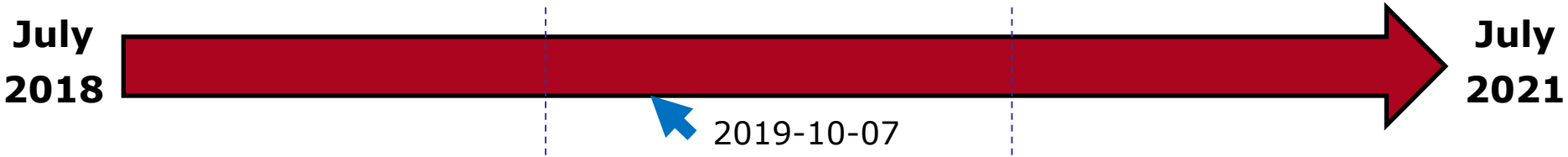
solarforecastarbiter.org/datamodel

Project goal

Open-source framework for solar forecast evaluations that are impartial, repeatable, and auditable.

- Implement objective, consistent evaluation scenarios and metrics → better solar forecasts
- Develop user confidence in solar forecasts → system integration
- Standardize evaluations → reduce provider and user costs
- Easily extend to wind power and load forecasting

Project Timeline/Milestones



Year 1

Design, build, test and demonstrate the framework.

Year 2

Refine the framework and host two operational forecast competitions

Year 3

Support evaluations for Solar Forecasting II Topic 2 and Topic 3 awardees.

Transition framework to new operator.

Stakeholder Engagement

5 primary topics

- Use cases
- Data format/API
- Data policies
- Benchmark forecasts
- Evaluation metrics

Please join the Stakeholder Committee! (open to all)

solarforecastarbiter.org/stakeholdercommittee

Typical engagement process

Stakeholder Workshop

St. Paul, June 2018

→ Team discussions

Proposal documents

→ Stakeholder feedback

Revised documents

→ Stakeholder consensus

Final documents

Implement

How do I use the Solar Forecast Arbiter?

- Option 1: Use the web dashboard, web API
  - most users, focus of this talk
- Option 2: Install python package for local use
  - researchers with python experience, PB of data
- Option 3: Stand up your own deployment of the full software stack
  - promotes reproducibility and reuse

Benchmark Forecasts

Required Attributes

- Available throughout the US
- Freely accessible or easily implemented
- Provide quantities of interest to both forecast users and providers
- Stakeholder buy-in

Benchmark Forecast Configuration

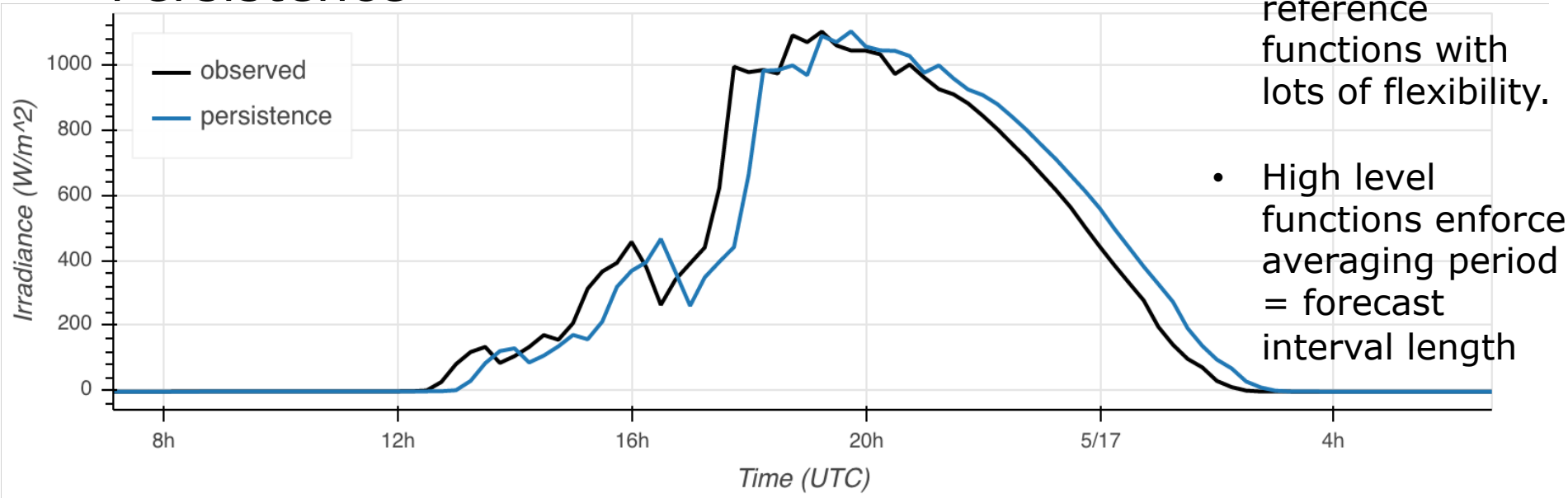
- Current operational NWP processing configuration
  - Based on time zone. Example for site in MST (UTC-0700):

Model	Issue time of day	Run length / Issue frequency	Lead time to start
GFS day ahead	7Z	1 day	1 day
NAM current day	6Z	1 day	1 hour
HRRR intraday	0Z	6 hours	1 hour
RAP intraday	0Z	6 hours	1 hour

- Persistence not yet configured. One idea: follow CAISO requirements
- Trials allow custom configuration

Persistence Benchmark Forecasts

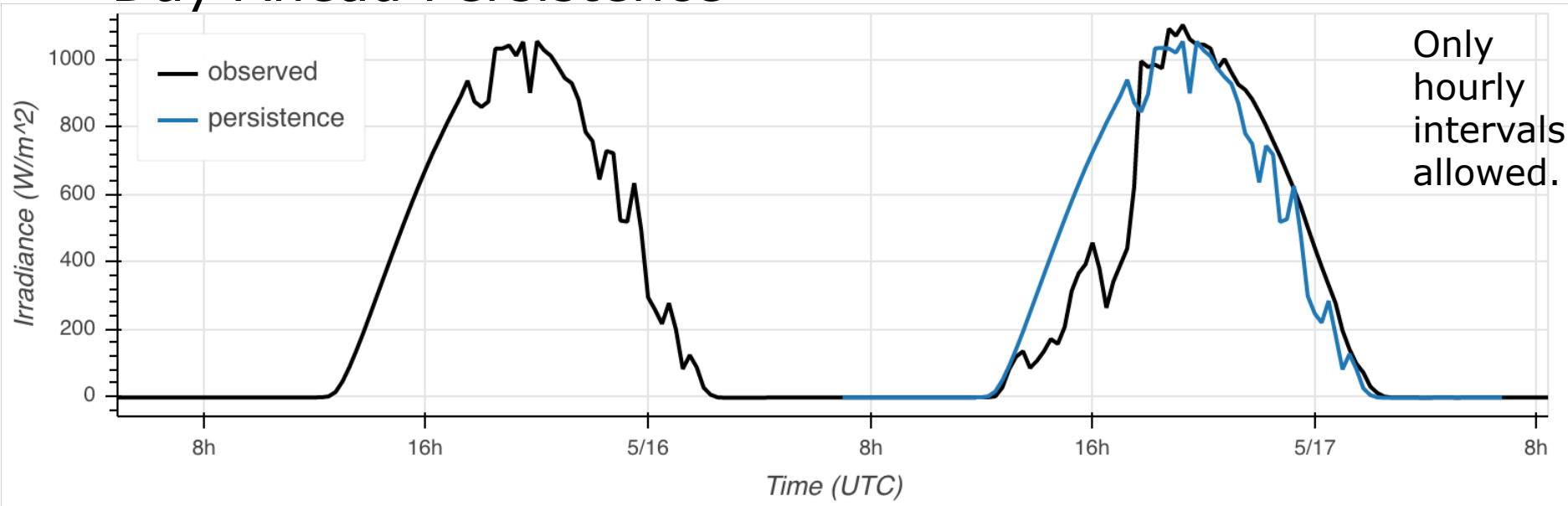
Persistence



- Low level reference functions with lots of flexibility.
- High level functions enforce averaging period = forecast interval length

Persistence Benchmark Forecasts

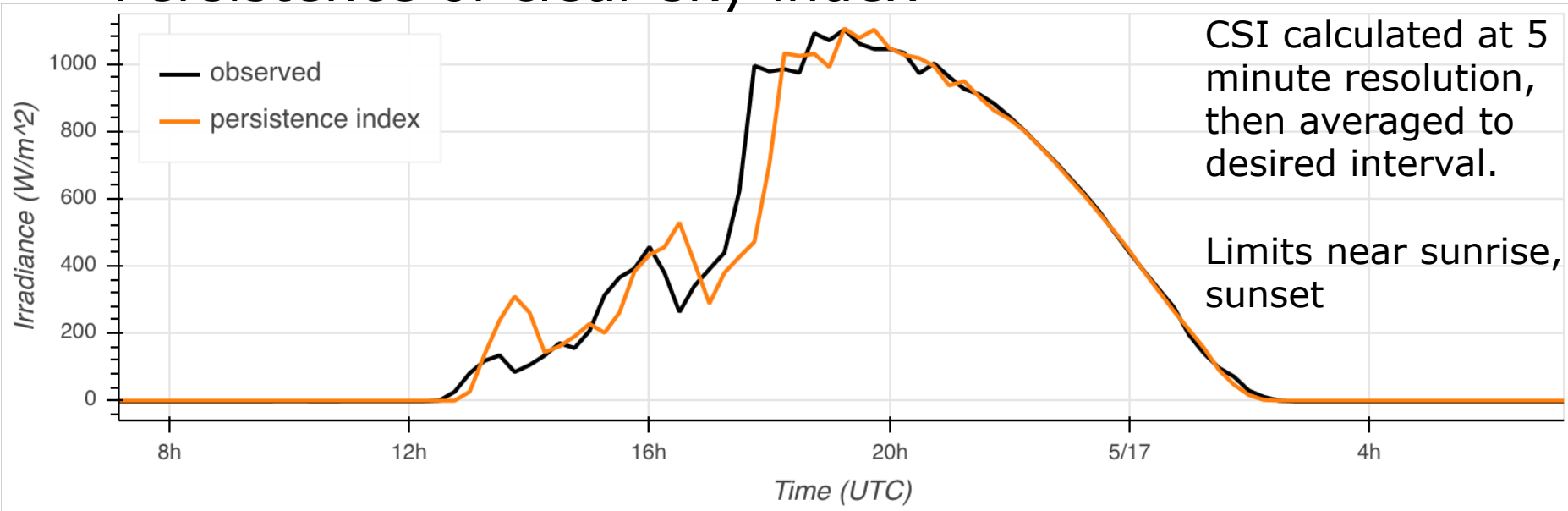
Day Ahead Persistence



Only hourly intervals allowed.

Persistence Benchmark Forecasts

Persistence of clear sky index



CSI calculated at 5 minute resolution, then averaged to desired interval.

Limits near sunrise, sunset

Open source, reference implementation, available for reuse

NWP Benchmark Forecasts Processing

- Our PV power model requires instantaneous input
- Accurate hourly averages require many subhourly instantaneous points

1. Load hourly (or longer) interval data from the NWP grib files.
   - For GFS cloud cover, unmix the mixed-intervals average data.
2. Resample data to 5 minute intervals.
   - For GFS cloud cover, backfill the data.
   - For all other NWP data, interpolate the data.
3. Convert cloud cover to irradiance. Linear clear sky scaling Larson et. al.:
   - GHI = (35% + (100% - cloud cover)) * GHI_clear
4. If PV, use site metadata to compute AC power using pvlib-python functions.
5. Compute hourly averages with desired interval labels.

Cost metrics

Built-in support for:

- Fixed $/MW
- Fixed $/MW for handful of error bins
- Time series of $/MW

Also provide brief recommendations and references for how to conduct more detailed cost evaluations

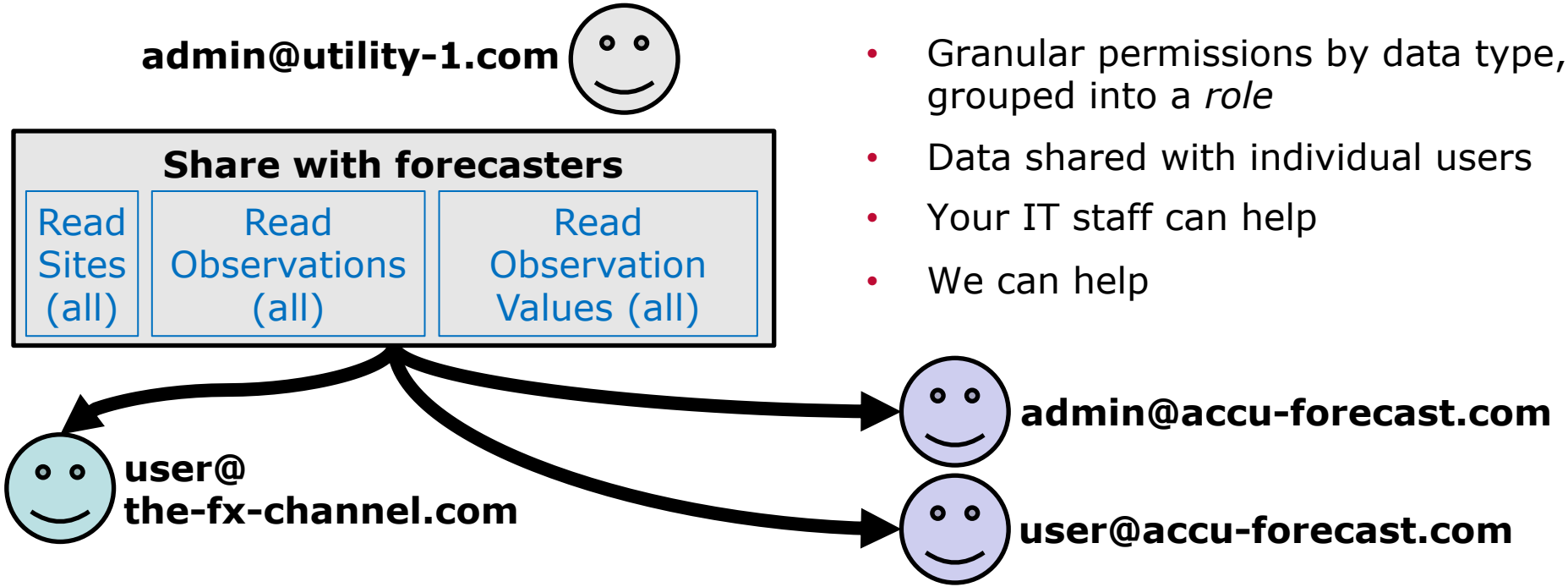
Evaluation with messy data

- Priority: clearly document the process and any user-configured options in each report
- Missing or bad forecast data
- Missing or bad observation data
  - Data validation toolkit flags most problems
- Research study
  - Options selected when report is created
- Operational forecast trial
  - Options selected when trial is created

Practical Time Series Issues

- Users specify start and end time for analysis report
- Rule: don't modify user-submitted forecasts
- Interval length consistency:
  - If measurements are higher resolution, Average the measurement data so that it has the same resolution as the forecast data (default)
  - If the forecast is higher resolution – comparison not allowed
- Interval label consistency:
  - Observations and forecasts have defined labels (beginning, ending, instant)
  - Arbiter accounts for observation intervals when resamples
- Nighttime data: Day/night filter based on solar zenith angle
- Ability to select certain periods: time of day, months of year, clear/cloudy, other weather variables, ramping periods

Data Sharing Implementation: Role Based Access Control



- Granular permissions by data type, grouped into a *role*
- Data shared with individual users
- Your IT staff can help
- We can help

Data Sharing Implementation: Role Based Access Control