Solar Forecast Arbiter .org

An open source evaluation framework for solar forecasting

Will Holmgren

Department of Hydrology and Atmospheric Sciences

THE UNIVERSITY OF ARIZONA

Aidan Tuohy

EPRI ELECTRIC POWER RESEARCH INSTITUTE

Grid Operations and Planning

Cliff Hansen

Renewable and Distributed System Integration Department

Sandia National Laboratories

Justin Sharp

Principal and Owner

Sharply Focused
Understanding Renewable Resources

U.S. DEPARTMENT OF ENERGY | Office of ENERGY EFFICIENCY & RENEWABLE ENERGY

Outline

- Summary of work to date
  - Stakeholder engagement
  - Data exchange and Data sharing policy
  - Use cases
  - Benchmark forecasts
  - Validation data sources
- Discussions about current work
  - Metrics
  - Workflow
  - Reports
  - Climate regions
- Open discussion
- Please test drive the working Dashboard

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

Year 1 approximate engagement process

Stakeholder Workshop

St. Paul, June 2018

→ Team discussions

Proposal documents

→ Stakeholder feedback

Revised documents

→ Stakeholder consensus

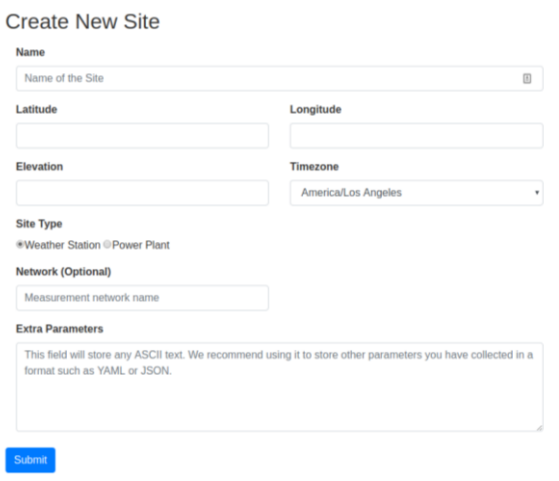
Final documents

Implement

Webinar, online
Feb/Mar 2019

Data Exchange

Dashboard



solarforecastarbiter.org/dashboarddoc/

API

Solar Forecast Arbiter API (0.1.0)

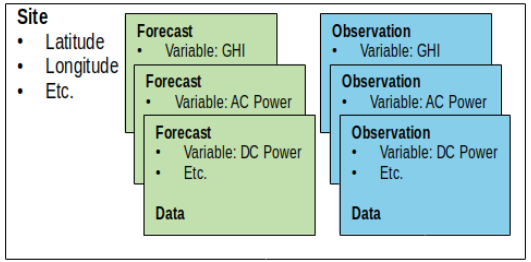
Download OpenAPI specification: Download

Solar Forecast Arbiter Team: info@solarforecastarbiter.org
URL: https://github.com/solararbiter/solarforecastarbiter-api | License: MIT

The backend RESTful API for Solar Forecast Arbiter.

dev-api.solarforecastarbiter.org/

Data Model



solarforecastarbiter.org/datamodel/

Data Sharing and Privacy

- Data Use Agreement drafted
- Agreement must be signed by authorized representative of an organization before its employees can log in
  - Necessary? Too strict?
- Seeking feedback from limited number of users and legal teams – see us.
- We cannot accommodate endless NDA negotiations
- Agreement will be take it or leave it
- We expect the terms should be acceptable to most users

Data Policies in I-am-not-a-lawyer format

1. Organizations retain ownership of the data they upload to the framework.
2. Users upload data to the framework on behalf of organizations.
3. Users have complete control over how their data may be accessed by other users. Default: no sharing, private analysis only.
4. Users may delete data from the framework.
5. The framework will not sell data that it controls (e.g. statistics).
6. All non-public data will be securely deleted by the conclusion of the DOE funding period (June 30, 2021).

Use Cases

A. Compare a forecast to measurements (July)

B. Compare a probabilistic forecast to measurements

C. Compare multiple forecasts to measurements (July)

D. Compare forecasts to measurements for sites and aggregates

E. Evaluate an event forecast

F. Conduct a forecast trial (~Sep)

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

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

Benchmark Forecasts

Required Attributes

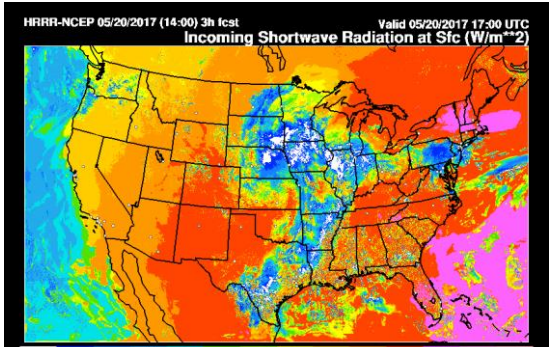
- Available throughout the US
- Freely accessible or easily implemented
- Provide quantities of interest to both forecast users and providers
- Stakeholder buy-in

St Paul 2018,
AMS 2019

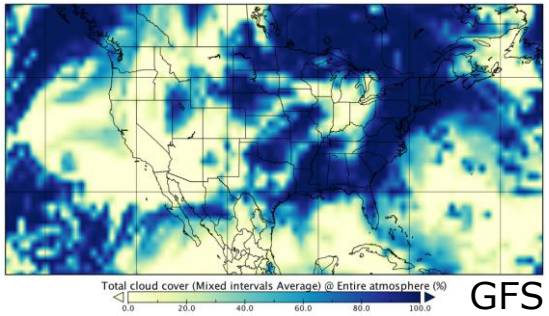
Benchmark Forecasts

solarforecastarbiter.org/benchmarks

- For 1 hour – 7 day ahead and longer horizons:
  - NOAA operational models forecast irradiance, cloud cover, weather
  - Most operational NWP irradiance forecasts have known limitations
    a) Derive irradiance or PV power from cloud cover
    b) ~~Bias correction~~
- For intrahour horizons:
  - Persistence, persistence of the clear sky index
  - ~~ARMA model fitted to site-specific data~~
- For net load:
  - Net load = True load – BTM PV
  - Use regression w/weather obs for true load



Total cloud cover (Mixed intervals Average) @ Entire atmosphere

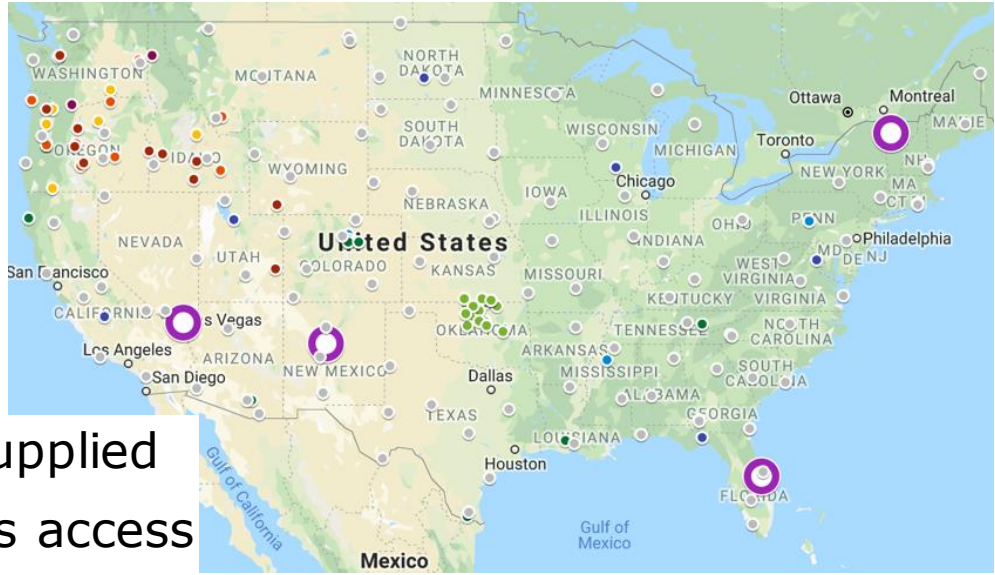


GFS

Validation and Reference Data Sources

Reference Data

- NOAA SURFRAD
- Sandia
- NREL
- EPRI
- DOE RTC
- U. Oregon network



User Data

- Stakeholder supplied
- Owner controls access
- Commitments: TEP, Abengoa, Southern Co.
- **We need your help**

solarforecastarbiter.org/referencedata

Metrics Selected

- Sent out in April for feedback and received valuable input from several of the stakeholders (thanks!)
- Deterministic metrics that will be default:
  - **Mean Absolute Error, Mean Absolute Percentage Error, Mean Bias Error**
  - **Root Mean Square Error, Normalized RMSE**
  - **Forecast Skill Score (default for comparison and multiple plants only)**
- Other deterministic metrics we will provide:
  - Pearson Correlation Coefficient, Centered (unbiased) Root Mean Squared Error, Kolmogorov-Smirnov test Integral (KSI), OVER, Combined Performance Index, Coefficient of Determination (R^2),
  - More details in the metrics document (available on website)
- Frequency distribution and box plots for visualization

Metrics Selected (2)

- Deterministic Event Forecasts – event is a ramp based on chosen threshold value, with contingency table for evaluating
  - All proposed are in use with no additional suggestions and are default metrics
  - Probability of Detection
  - False Alarm Ratio
  - Probability of False Detection
  - Critical Success Index
  - Event Bias
  - Event Accuracy

		Observed: Yes	Observed: No
Forecast	Yes	a (Forecast = Yes, Observed = Yes)	b (Forecast = Yes, Observed = No)
Forecast	No	c (Forecast = No, Observed = Yes)	d (Forecast = No, Observed = No)

Metrics Selected (3)

- Probabilistic Forecasts (default are bold, based on what's used)
  - **Brier Score**
  - **Brier Skill Score**
  - Reliability
  - Resolution
  - Uncertainty
  - Sharpness
  - **Continuous Ranked Probability Score**
  - *Suggested and may add: Spread skill, Anomaly correlation*
  - *Will look to normalize appropriately based on time of day*
  - *Visualization is important*

Workflow Document

- Document being drafted to lay out how Solar Arbiter will be used to evaluate forecasts and deal with various issues
  - Still finalizing, expect in coming weeks with time to review
- Anomalous data – capability to handle data:
  - Missing forecast data:
    - Single forecast – exclude these periods from assessment
    - Comparing forecasts – use last valid period up to a certain time, otherwise zero
  - Missing observation data: exclude by default, allow ability to fill in
  - Note: user needs to specify missing data, and then above applies – can override defaults

Selecting Periods and Time Series Issues

- Start and end time for analysis based on time series, users specify start and end time for analysis report
- Interval length consistency:
  - If measurements are higher resolution than forecasts:
    - 1) Average the measurement data so that it has the same resolution as the forecast data (default)
    - 2) Interpolate the forecast data so that it has the same resolution as the measurement data- only applies to reference forecasts
  - If the forecast is higher resolution - fit the forecast data so that it has the same resolution as the measurement data
  - Will require the user to specify whether the observation and forecast data is interval beginning or interval ending
- Nighttime data: Day/night filter based on solar zenith angle, and exclude but report on # of non-zero
- Ability to select certain periods: time of day, months of year, weather conditions (if user provides), ramping periods (later in year)

Visualization

- Solar power forecast and actual visualization
  - Time series
  - Scatter plots of forecast vs actual and forecast vs error
  - Density plots of joint distributions
  - Conditional and marginal distributions
- Metric visualization
  - Bar charts for different metrics
  - Box and whiskers – median, upper and lower quantiles and min, max for MAE and RMSE
  - Ability to plot by time of day, day by day and monthly

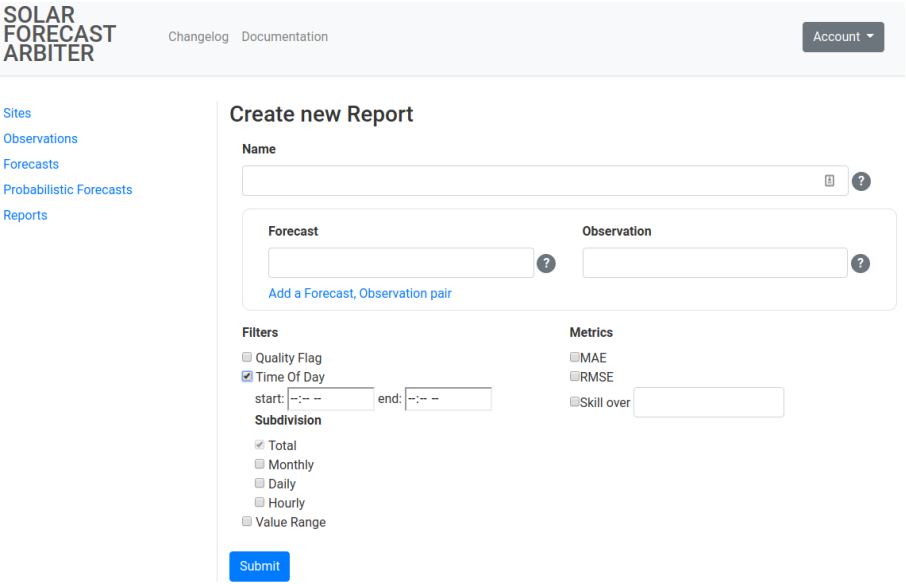
Valuation

- More detail coming in future, but initial thoughts are two options for value metrics:
  - Fixed $/MW for evaluation periods
  - Time series of $/MW (averaged to longer intervals, filled for shorter)
  - Potential future addition: cost function (cost as function of error size, $/MW)

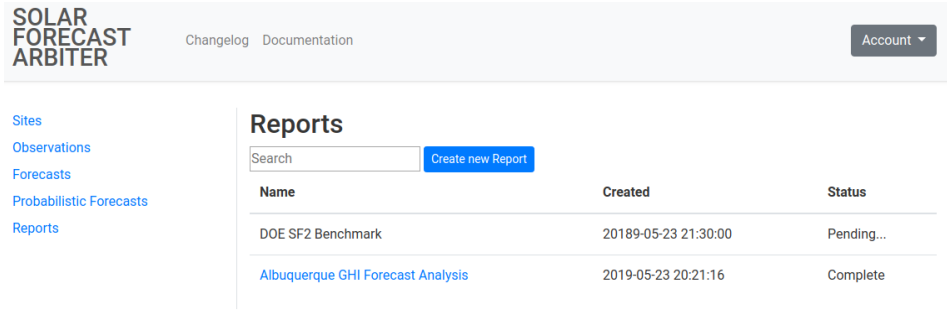
- Look out for future document and provide feedback!

Reports

1. Form to create report



2. View existing reports



SOLAR FORECAST ARBITER Changelog Documentation

3. View report

Account

Sites
Observations
Forecasts
Probabilistic Forecasts
Reports

Albuquerque GHI Forecast Analysis

Report Metadata

- Name: Albuquerque GHI Forecast Analysis
- Start: 2019-01-01 00:00:00
- etc

Download as html or pdf

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

This report was generated at 2019-05-23 20:21:16.

Data

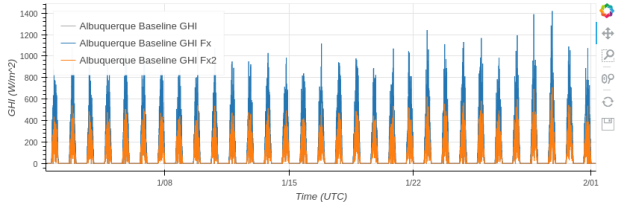
This report covers the period from 2019-01-01 00:00:00 to 2019-02-01 00:00:00.

The table below shows the observation, forecast pairs analyzed in this report. The table includes the unprocessed observation and forecast *interval label* (beginning, ending, instanteous) and *interval length*. If these quantities do not match, the Solar Forecast Arbiter must align and/or resample the data before computing error statistics. The Solar Forecast Arbiter typically aligns the observation data to the forecast data. The aligned and resampled parameters are also shown below.

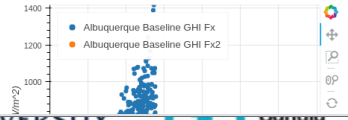
- Observation: Albuquerque Baseline GHI, Forecast: Albuquerque Baseline GHI Fx
- Observation: Albuquerque Baseline GHI, Forecast: Albuquerque Baseline GHI Fx2

The plot below shows the realigned and resampled time series of observation and forecast data.

Controls to pan, zoom, and save the plot are shown on the right. Clicking on an item in the legend will hide/show it.



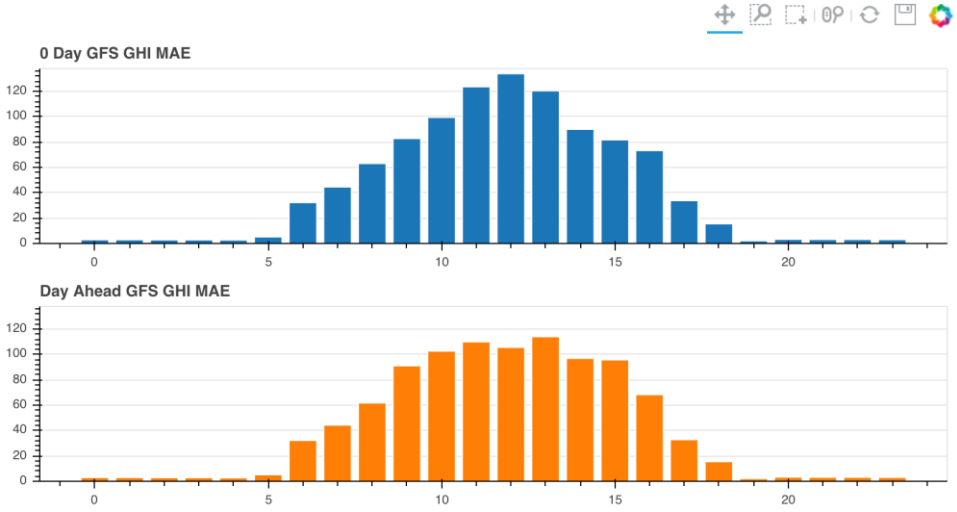
The scatter plot below shows realigned and resampled forecast vs observed values.



Example analysis figure

Hourly

Metrics for each hour of the day during the analysis period are displayed in tables and figures below.



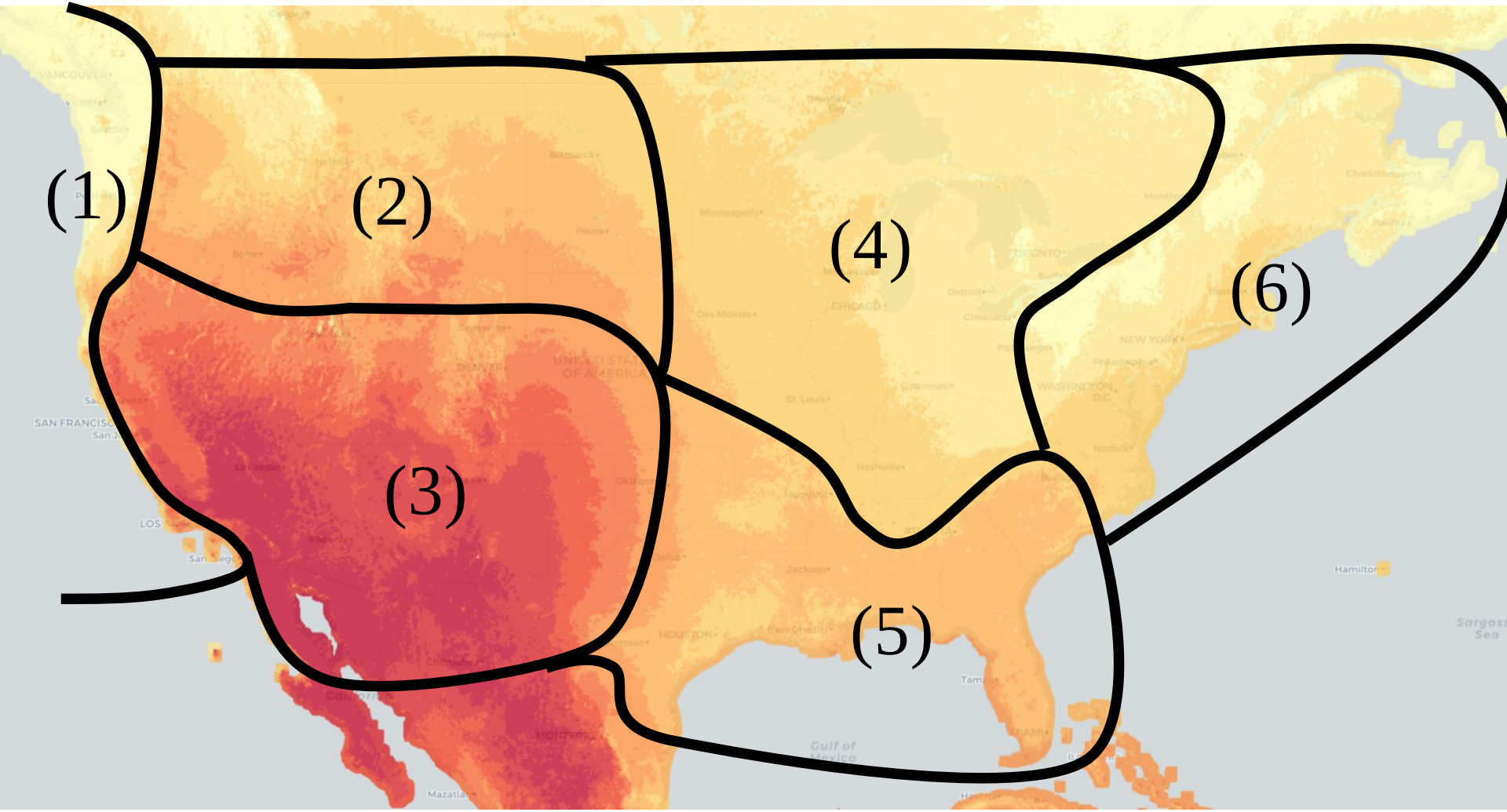
THE UNIVERSITY OF ARIZONA Sandia National Laboratories U.S. DEPARTMENT OF ENERGY Office of ENERGY EFFICIENCY & RENEWABLE ENERGY EPRI ELECTRIC POWER RESEARCH INSTITUTE Sharply Focused

Climate Regions

Need stakeholder feedback on proposed climate regions

- Regions support broader analyses of forecast performance
- ”This forecast performs well/poorly on the West Coast”

- One proposal…


(1)
(2)
(3)
(4)
(5)
(6)

Open discussion

What did we miss?

- Use cases
- Metrics/workflow
- Reference data
- Data sharing/privacy
- Climate zones

Walkthrough & Test Drive

Recommended tasks

Go to github.com/SolarArbiter/2019-Denver-Workshop

1. Explore reference data
2. Create new site/observation/forecast
3. Upload/download data
4. View data access controls
5. View sample analysis report
6. Use reference forecast code