Renewable Power Forecasting, Modeling, and Analysis at U. Arizona

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THE UNIVERSITY OF ARIZONA

We create weather and power forecasts for over 2.7 GW of solar and wind power plants, analyze renewable power and load data from the Southwest, and develop open source software to model PV systems. Our work reduces the cost of integrating renewables into the power grid and helps utilities keep the power grid reliable.

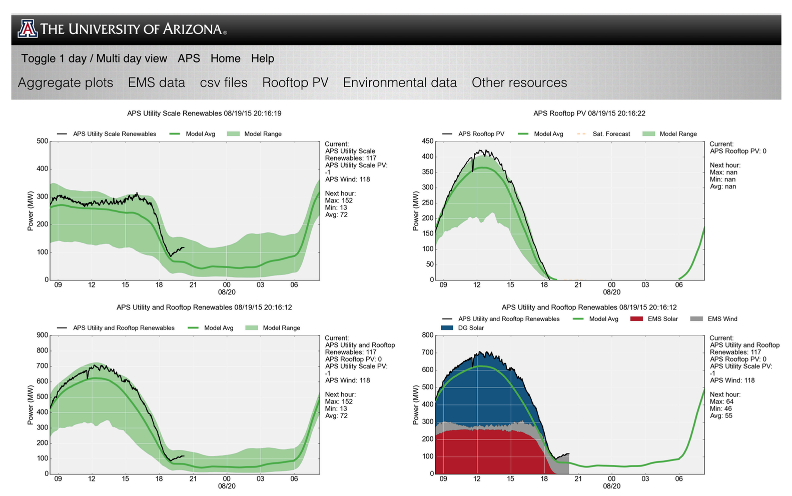
Renewables forecasts from 1 minute to 8 days

We combine high resolution weather models, satellite images, and real time sensor data to create weather and forecasts from minutes to days ahead.

Forecasts are updated every 5 minutes 24/7/365.

Local challenges include:

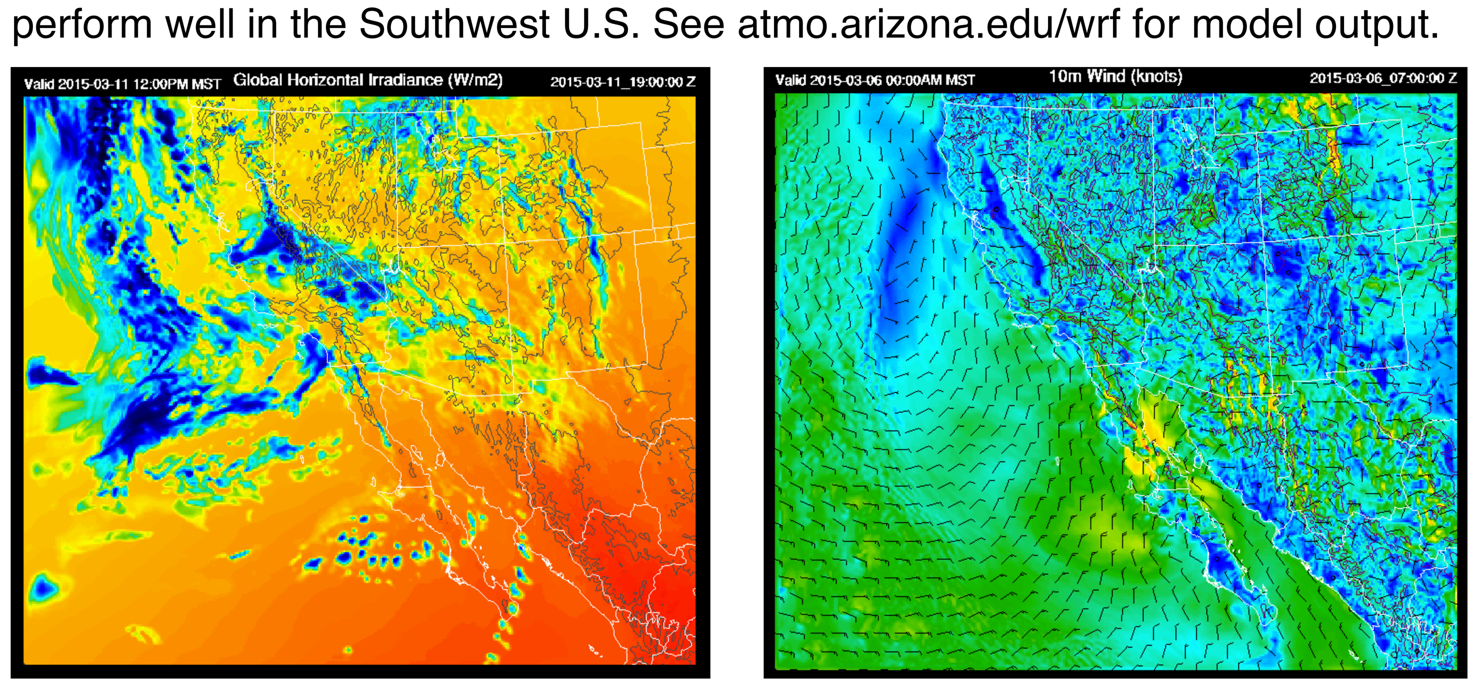
- Mountains + moisture + heating = storms
- Unreliable initialization data from Mexico
- Extreme planetary boundary layer heights
- Rapidly changing land/surface characteristics



forecasting.energy.arizona.edu/public

High resolution weather modeling

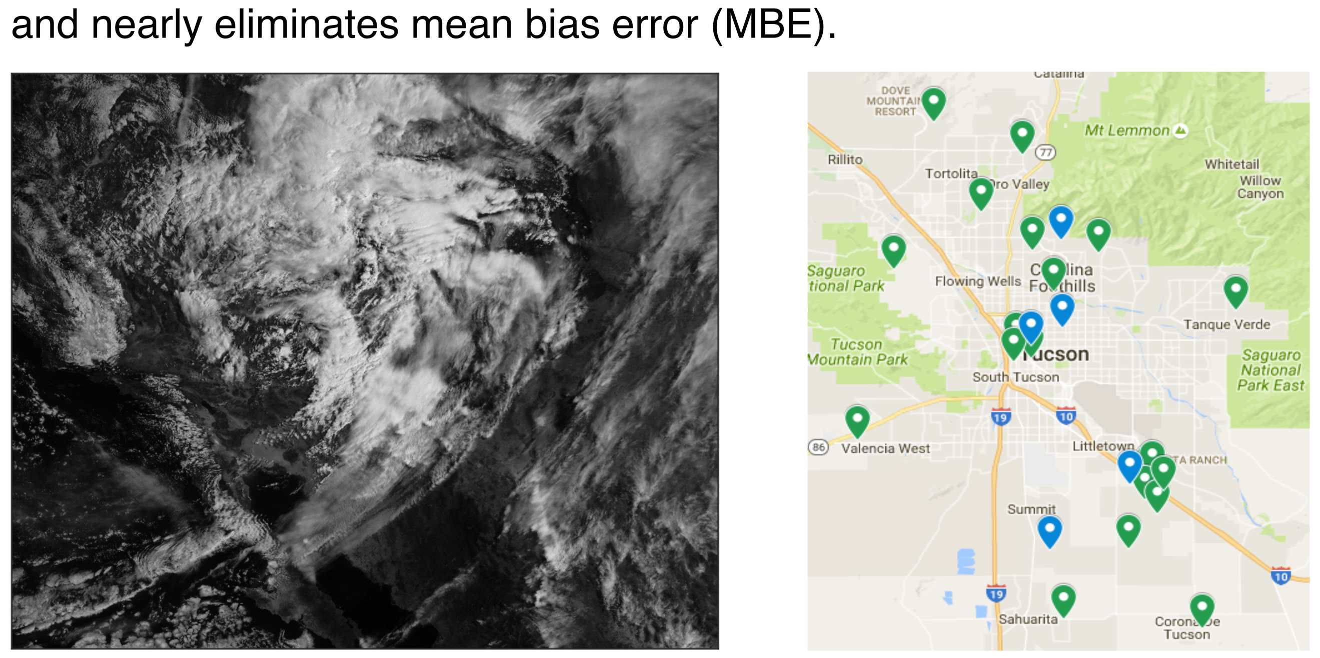
8 day forecasts from a 1.8 km resolution weather model (WRF) configured to perform well in the Southwest U.S. See atmo.arizona.edu/wrf for model output.

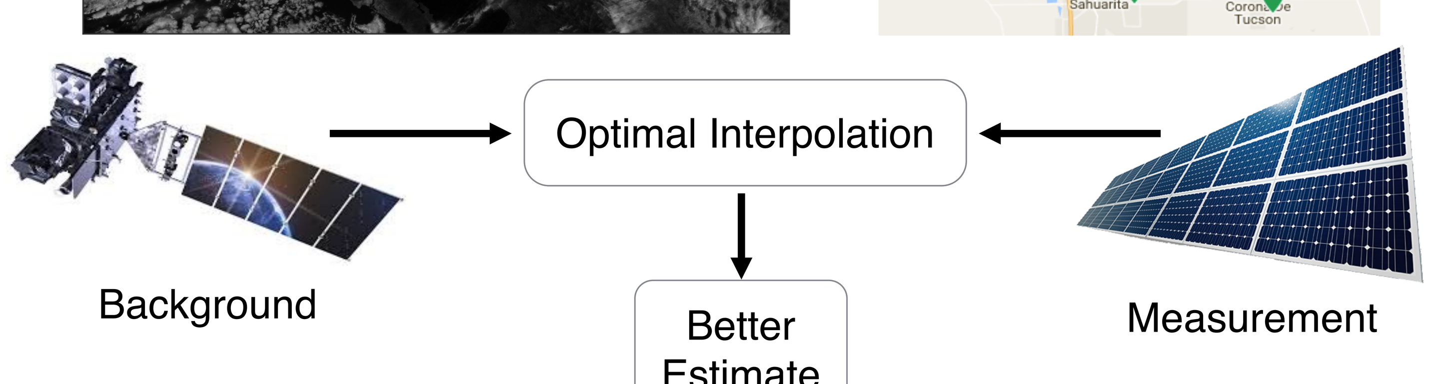


Optimal interpolation of satellite and ground data

1 minute to 4 hour forecasts using satellite and ground data.

- Combine data from geostationary satellite images and ground irradiance measurements from sensors and PV cells.
- Optimal interpolation enables accurate but sparse ground data to improve the irradiance estimate over a large area (in this case, Tucson).
- Optimal interpolation reduces root mean square error (RMSE) by up to 50% and nearly eliminates mean bias error (MBE).

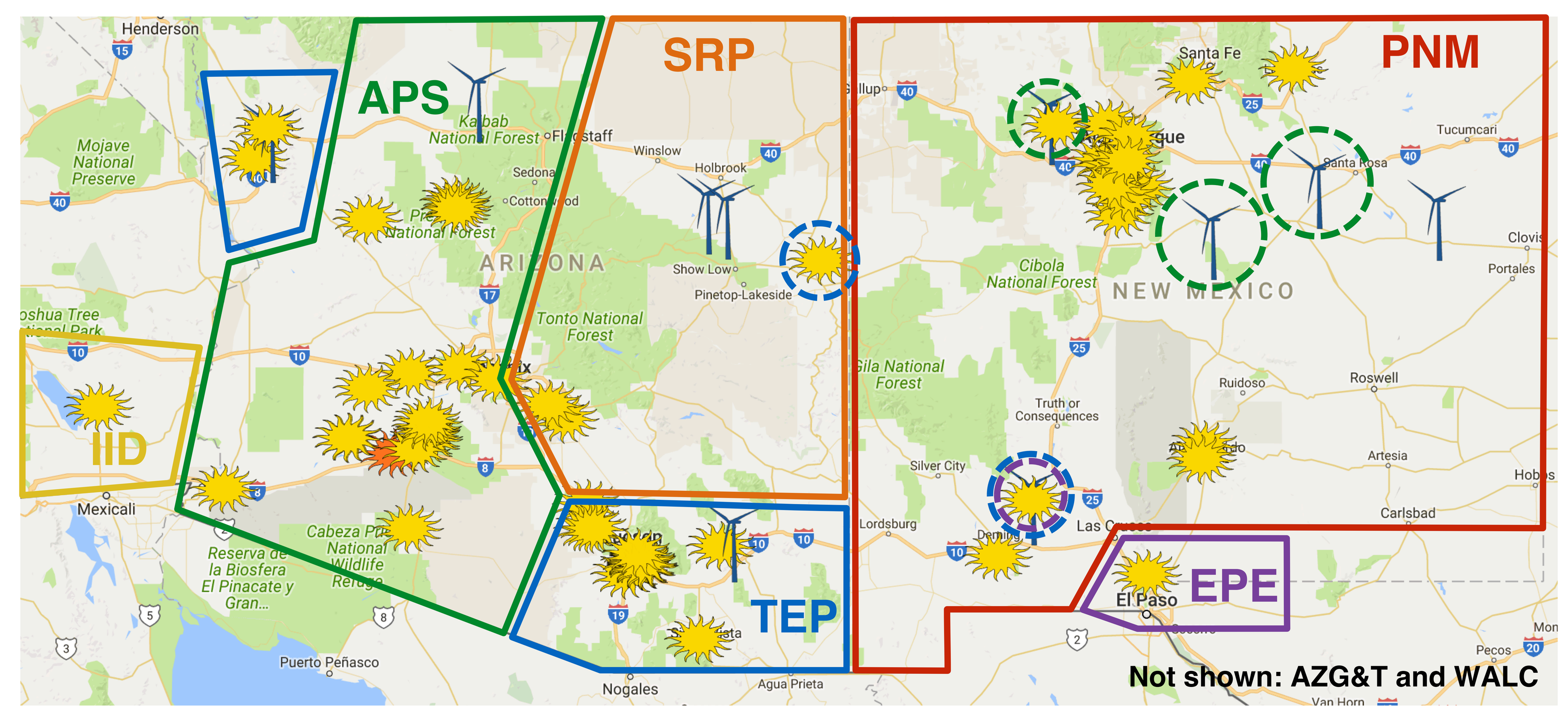


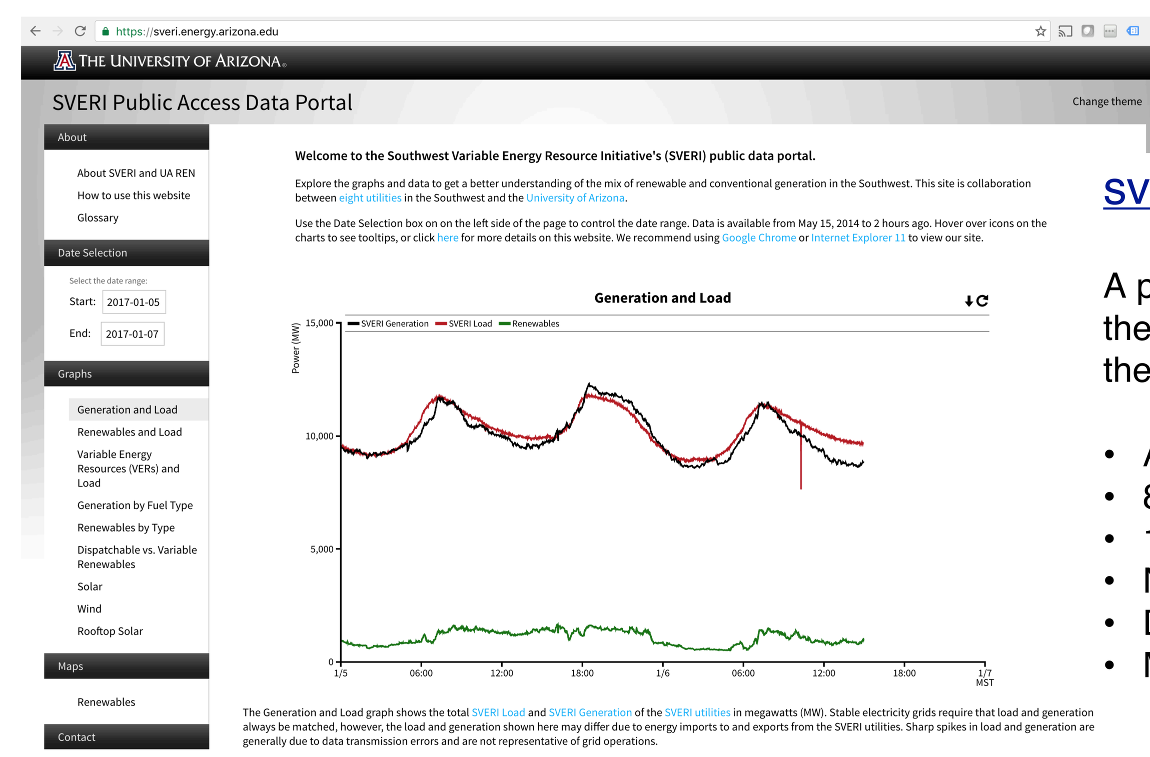


$$\mathbf{x}_a = \mathbf{x} + \mathbf{W}(\mathbf{y} - \mathbf{H}\mathbf{x}_b) \quad \mathbf{W} = \mathbf{P}\mathbf{H}^T(\mathbf{R} + \mathbf{H}\mathbf{P}\mathbf{H}^T)^{-1}$$

Utility scale renewables in the Southwest

The Southwest Variable Energy Resource Initiative (SVERI) is a collaboration of 8 utility companies in the Southwest. SVERI and UA collaborate to analyze solar and wind data.





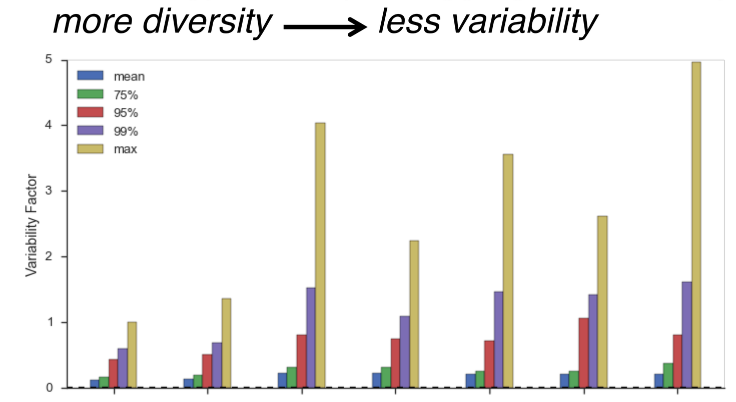
sveri.energy.arizona.edu

A public website to communicate the status of renewable energy in the Southwest.

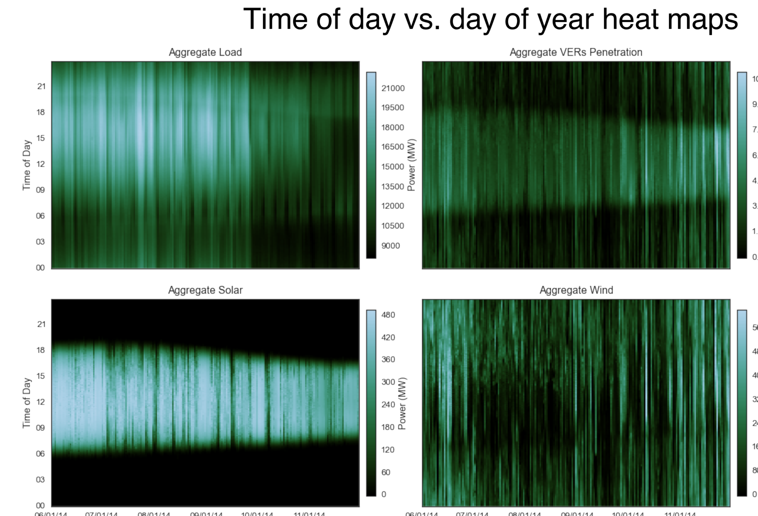
- Aggregate generation and load
- 8 utilities in the southwest
- 1.2 GW of utility renewables
- Near real time
- Data downloads
- Map of utility renewables

Samples of analysis products for SVERI

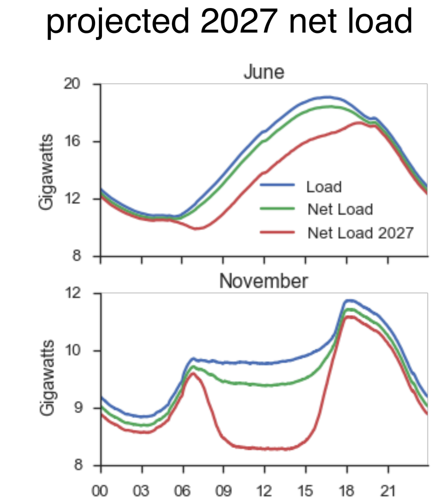
Study on impact of geographic and technology diversity on aggregate variability.
more diversity → less variability



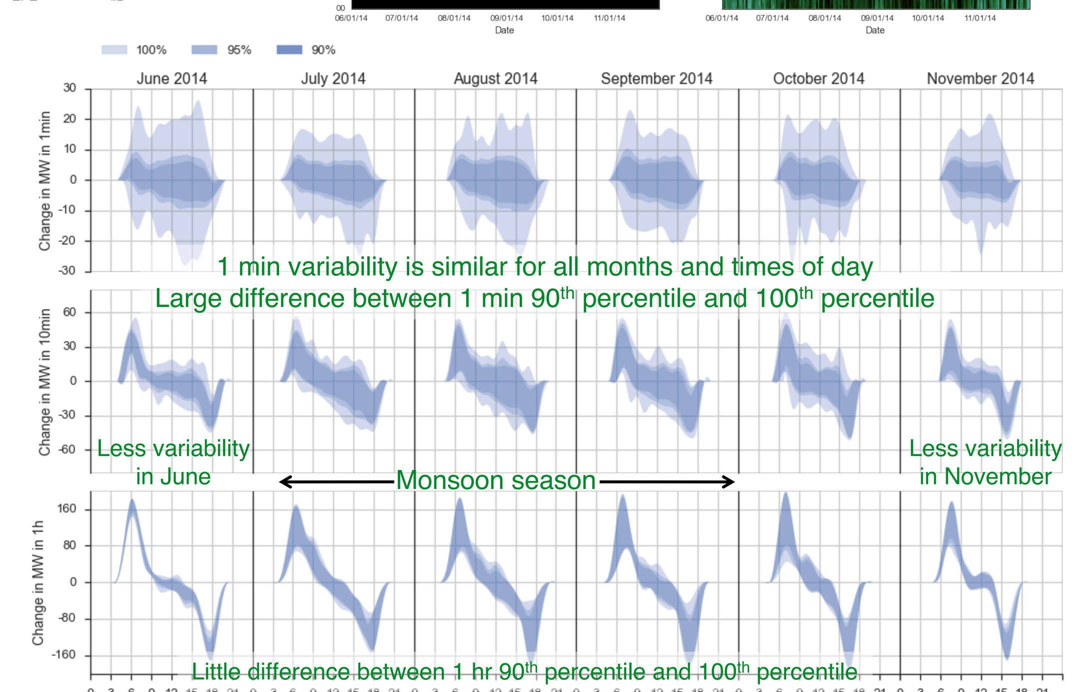
Time of day vs. day of year heat maps



SVERI load, net load, and projected 2027 net load



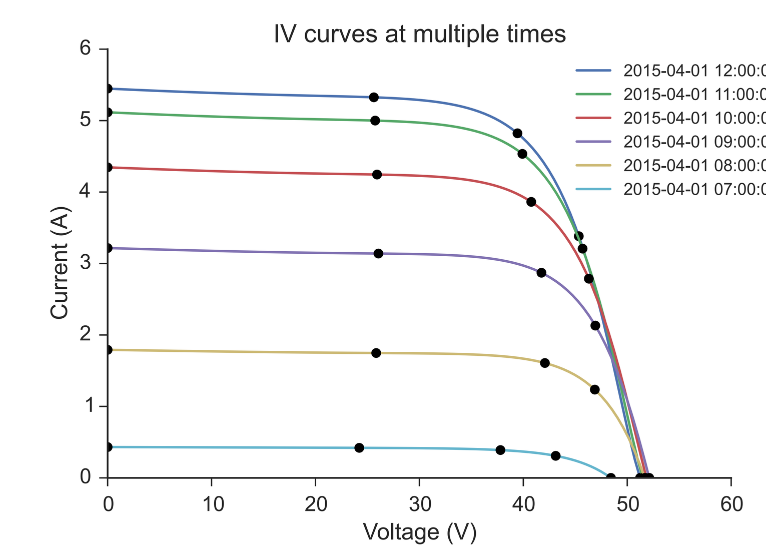
The southwest duck curve



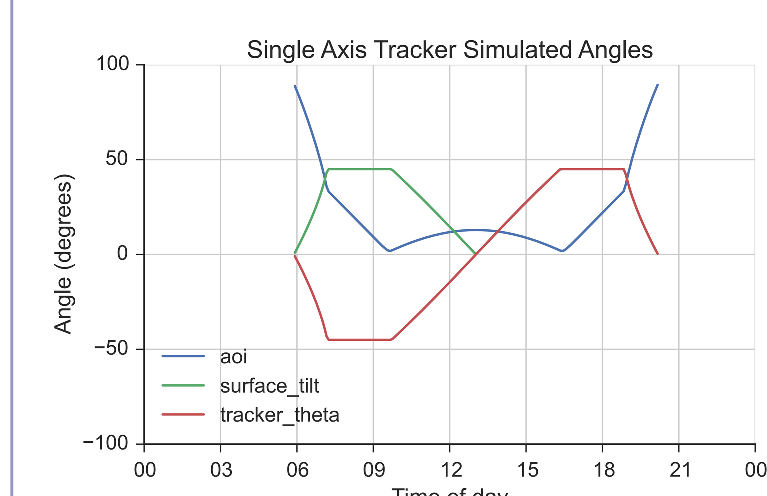
PVLIB Python: An open source library for PV modeling and forecasting

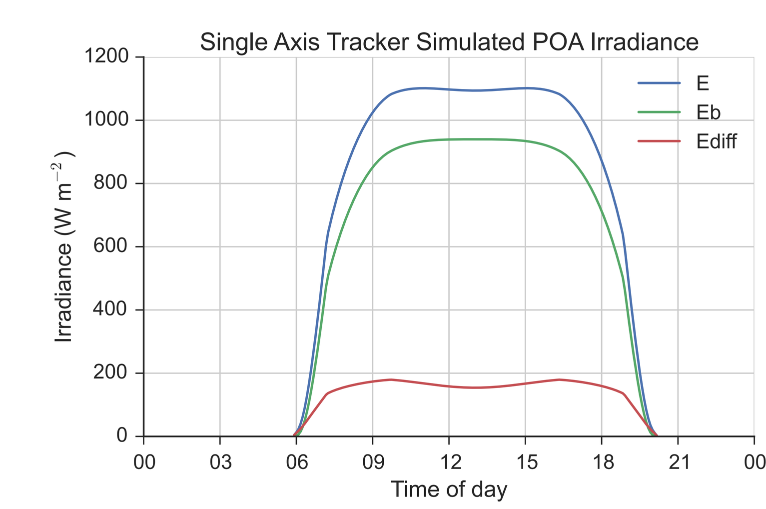
PVLIB Python is an open source software library that provides a set of extensively tested and documented functions and classes for modeling photovoltaic energy systems. Learn more at pvlib-python.readthedocs.io and contribute to the library at github.com/pvlib/pvlib-python

Examples of modeling with PVLIB Python



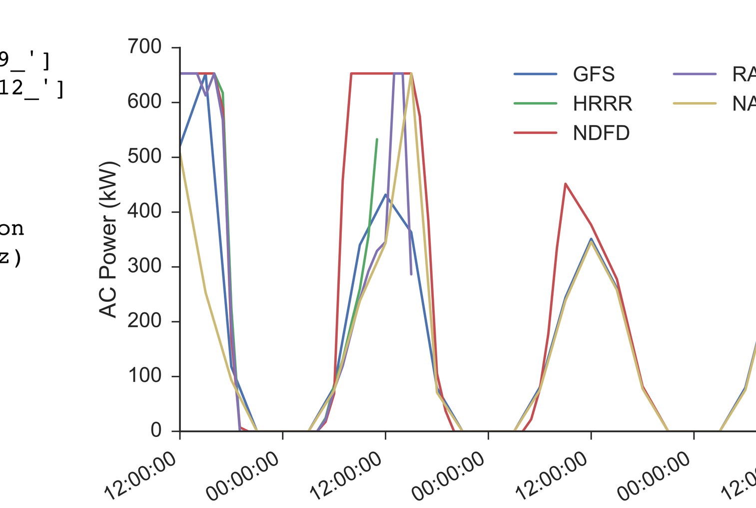
IV curves at different times corresponding to different irradiance conditions througout one day. Points represent the 5 points of the Sandia Array Performance Model: Isc, Voc, Pmp, Ix, and Ixx. PVLIB-Python was used to load module data from NREL's website, calculate solar position, clear sky data, airmass, cell temperature, module temperature, and finally run the Sandia Array Performance Model in 9 lines of code.





PVLIB-Python simulation of a single axis tracker, with backtracking, located near Albuquerque, NM, for June 1, 2015. This example simulation used the Ineichen model to generate clear sky DNI, GHI, and DHI, the Hay-Davies model to generate the diffuse plane of array irradiance, and an isotropic ground diffuse model with an albedo of 0.25.

```
module = modules['Canadian_Solar_CS5P_220M___2009_']
inv = invs['SMA_America__SC630CP_US_315V__CEC_2012_']
system = SingleAxisTracker(
    module_parameters=module,
    inverter_parameters=inv,
    series_modules=15, parallel_modules=300)
lat, lon, tz = 32.2, -110.9, 'Etc/GMT+7'  # Tucson
start = pd.Timestamp(datetime.date.today(), tz=tz)
end = start + pd.Timedelta(days=7)
for fx_class in [GFS, NAM, HRRR, RAP, NDFD]:
    fx_model = fx_class()
    fx_data = fx_model.get_processed_data(
        lat, lon, start, end)
    mc = ModelChain(system, fx_model.location)
    mc.run_model(fx_data.index, weather=fx_data)
    mc.ac.plot()
```



PVLIB Python forecasts of AC power for a single axis tracker array. The power forecasts are derived from 5 different weather forecasts.

Sponsors and partners

TEP aps IDAHO POWER PNM DOE EERE Postdoctoral Fellowship TFS

Research, Discovery & Innovation Institute for Energy Solutions

The SVERI utilities