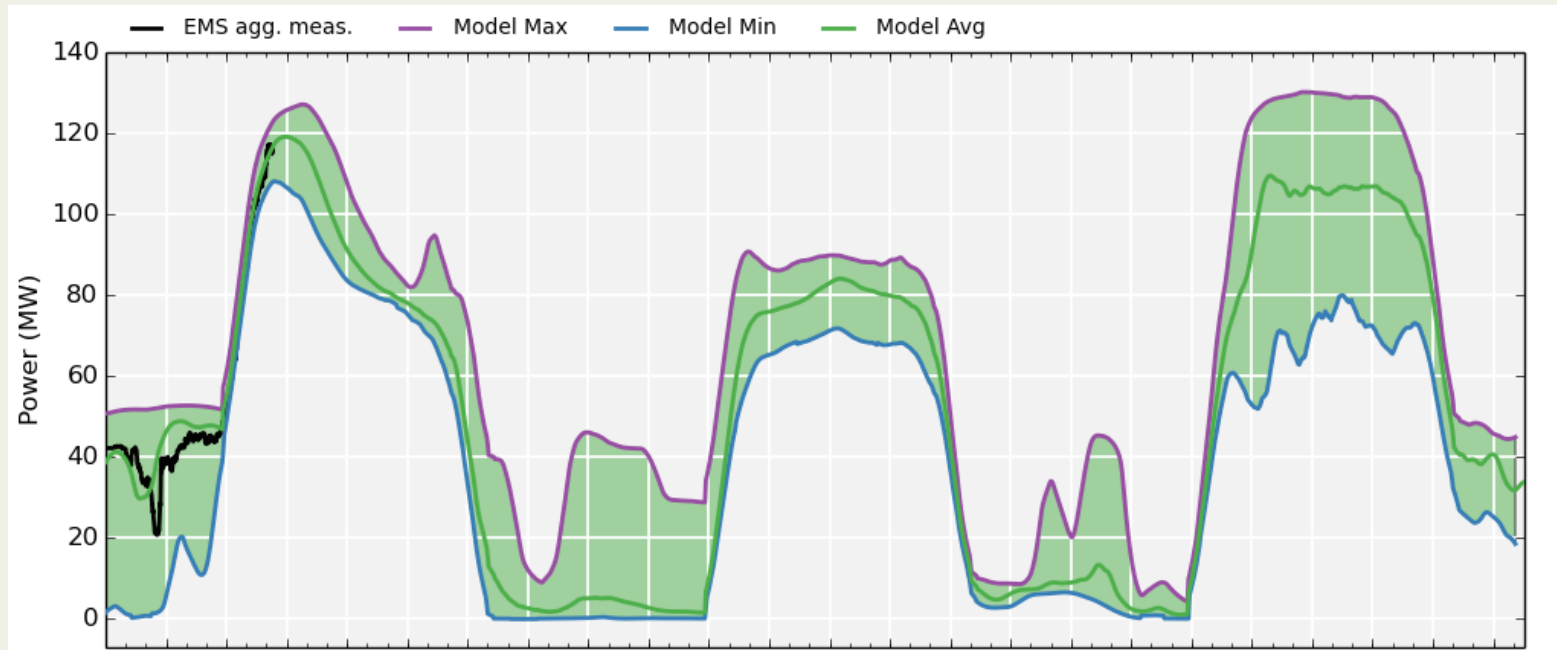


# Real-Time Renewable Power Forecasting



**Will Holmgren**

Postdoctoral Research Assistant  
Department of Physics  
University of Arizona



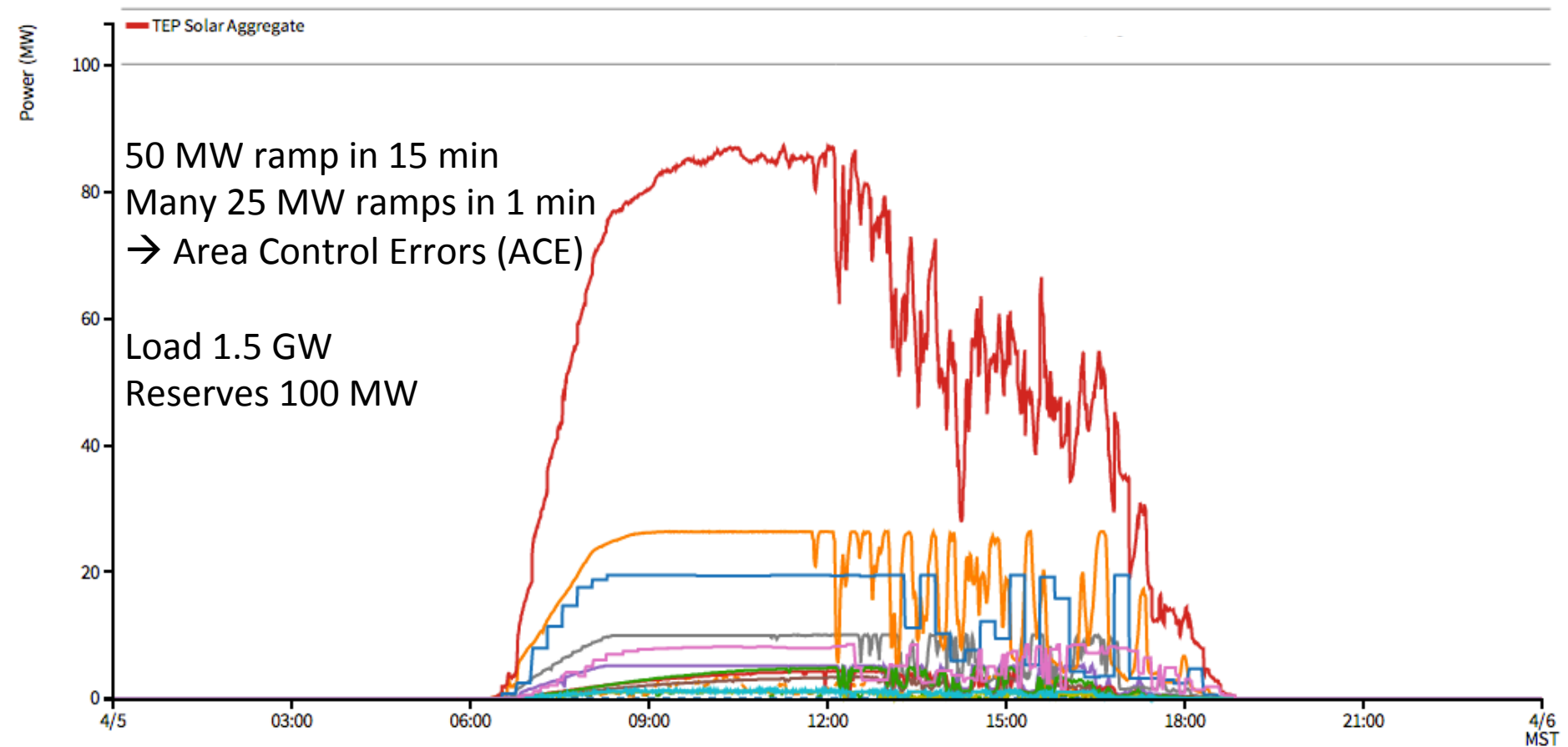
**Alex Cronin**, Associate Professor, Physics  
**Antonio Lorenzo**, Grad Student, Opt. Sci.

**Eric Betterton**, Dept. Head, Atmo. Sci.  
**Mike Leuthold**, Meteorologist, Atmo. Sci.  
**Chang Ki Kim**, Post doc, Atmo. Sci.

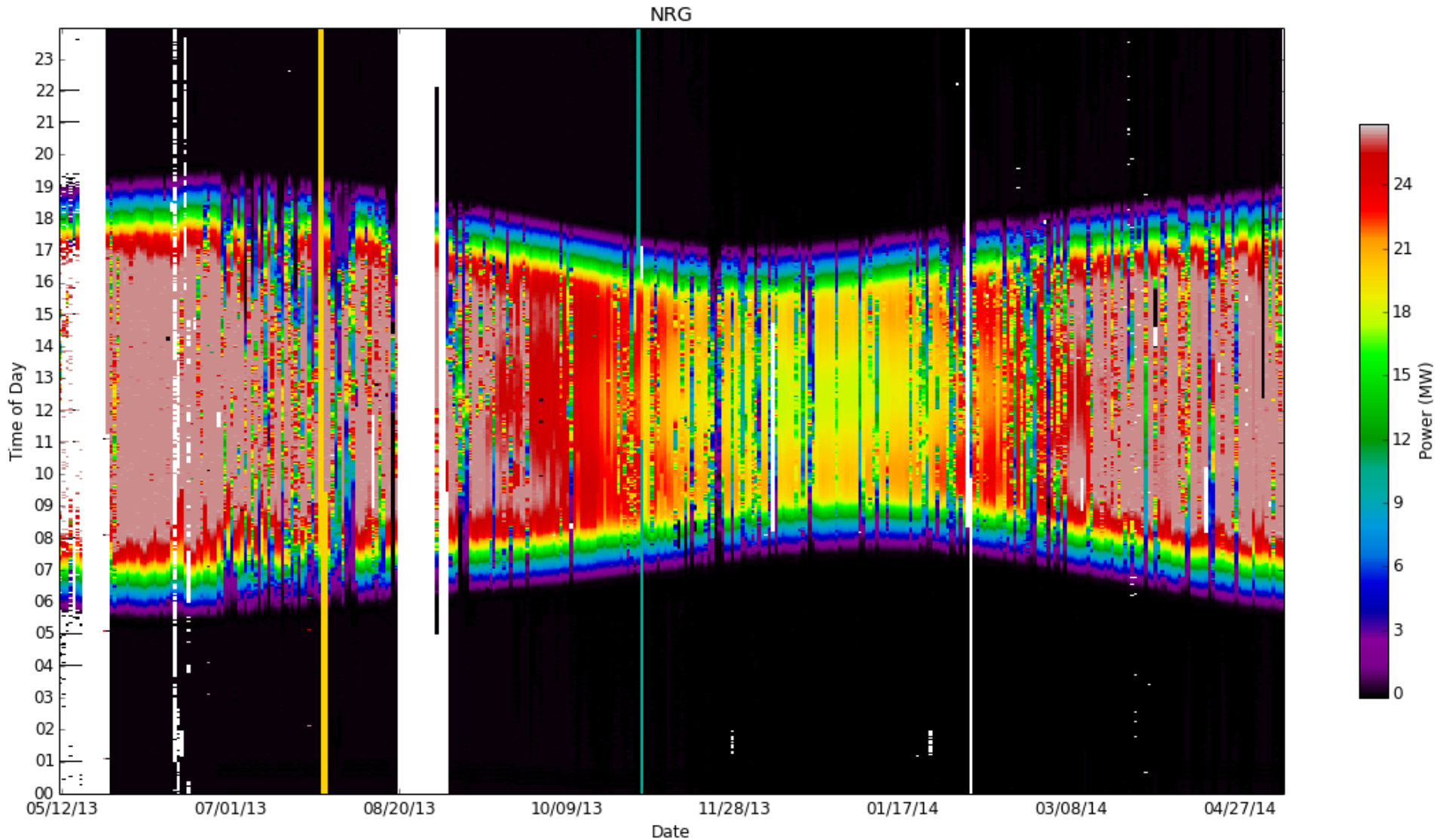
**Ardeth Barnhart**, Director, UA-REN  
**Rey Granillo**, Developer, UA-REN

# The Problem: TEP's Solar Power Variability

TEP Solar Power Generation

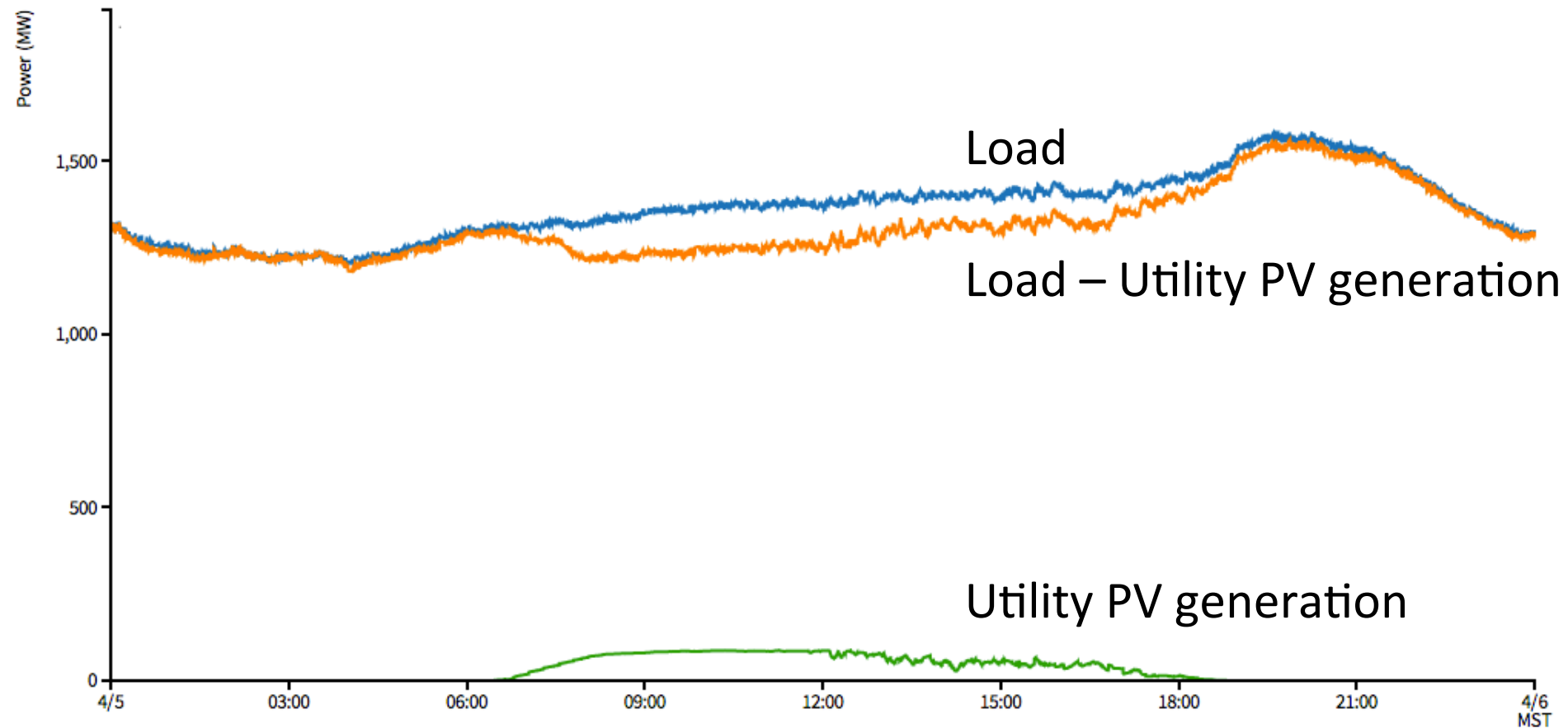


# The Problem: TEP's Solar Power Variability



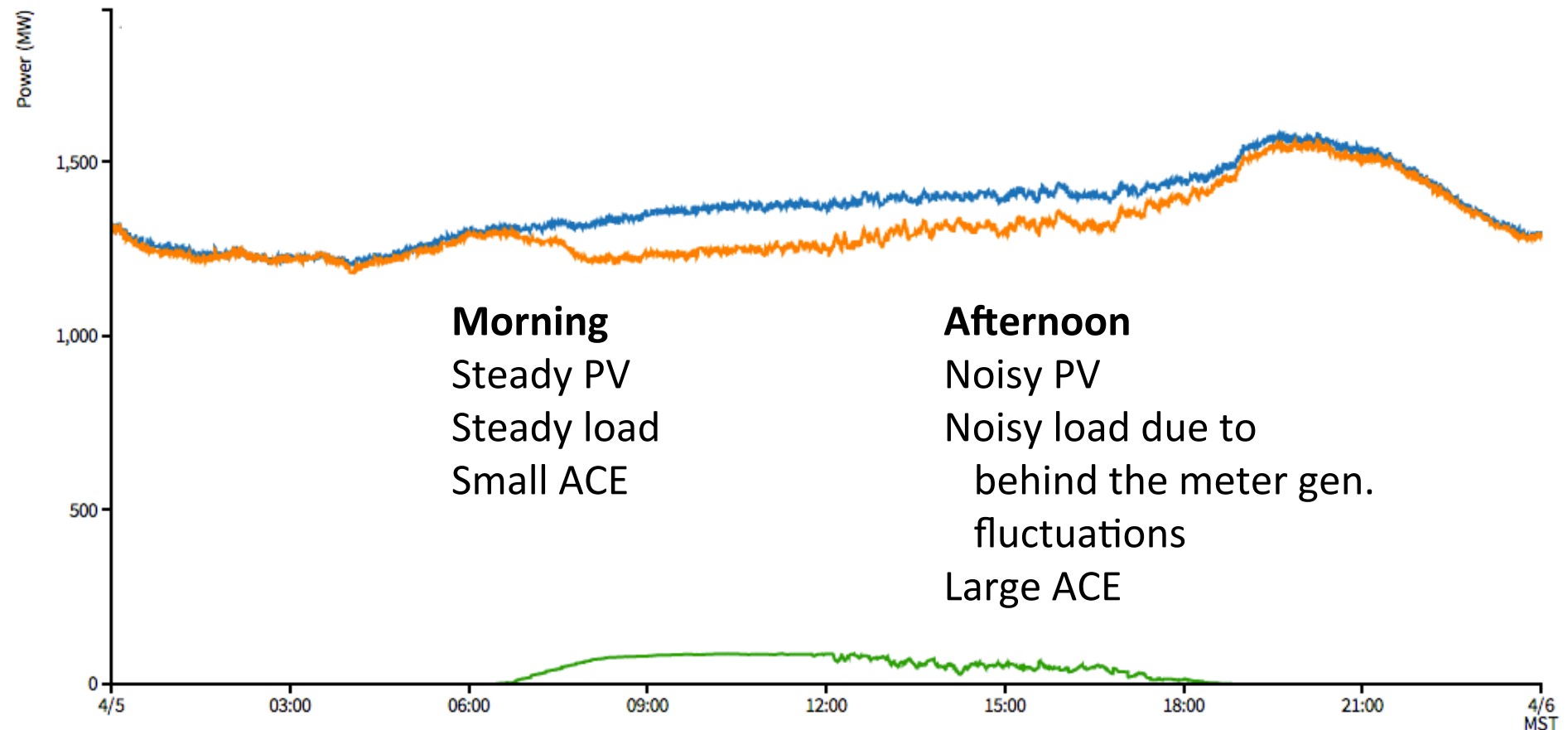
# The Problem: TEP's Solar Power Variability

TEP Load and Utility Scale Renewables



# The Problem: TEP's Solar Power Variability

TEP Load and Utility Scale Renewables

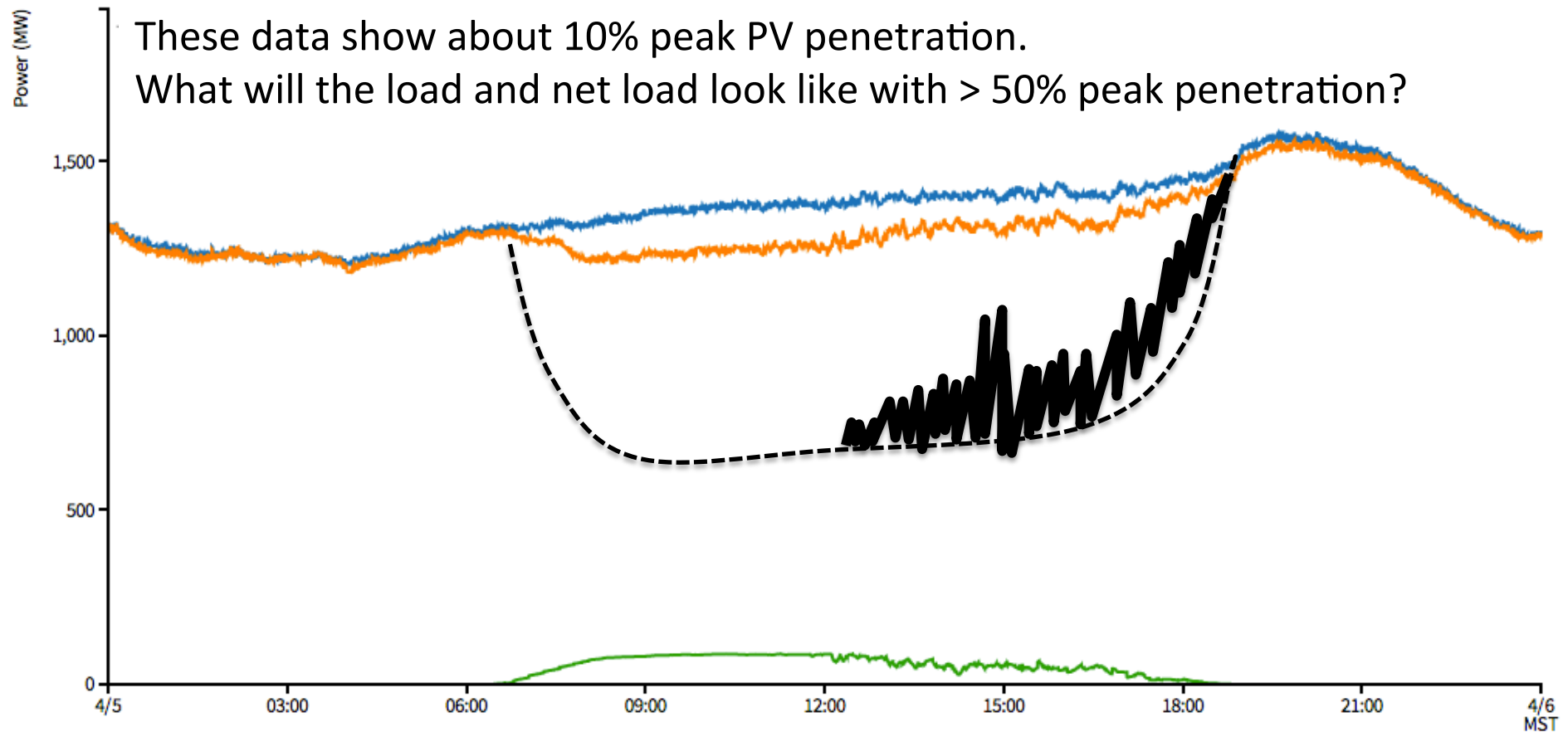


# The Problem: TEP's Solar Power Variability

**TEP Load and Utility Scale Renewables**

These data show about 10% peak PV penetration.

What will the load and net load look like with > 50% peak penetration?



# A Solution:

## UA + TEP developing renewables forecasts

How can forecasts help utilities keep energy costs low and maintain grid reliability?

- Improve energy market trading strategies
- Schedule more efficient generators (e.g. combined cycle vs. combustion turbine)
- Reduce costs associated with generator starts
- Defer maintenance associated with excessive generator set point seeking
- Optimize the use of battery storage

UA is providing TEP with forecasts as we speak!

# Different forecasting methods work better at different time scales.

Minutes

Hours

Days

Seasons

Years

Sensor Network

Satellite Imagery

Numerical Weather Models

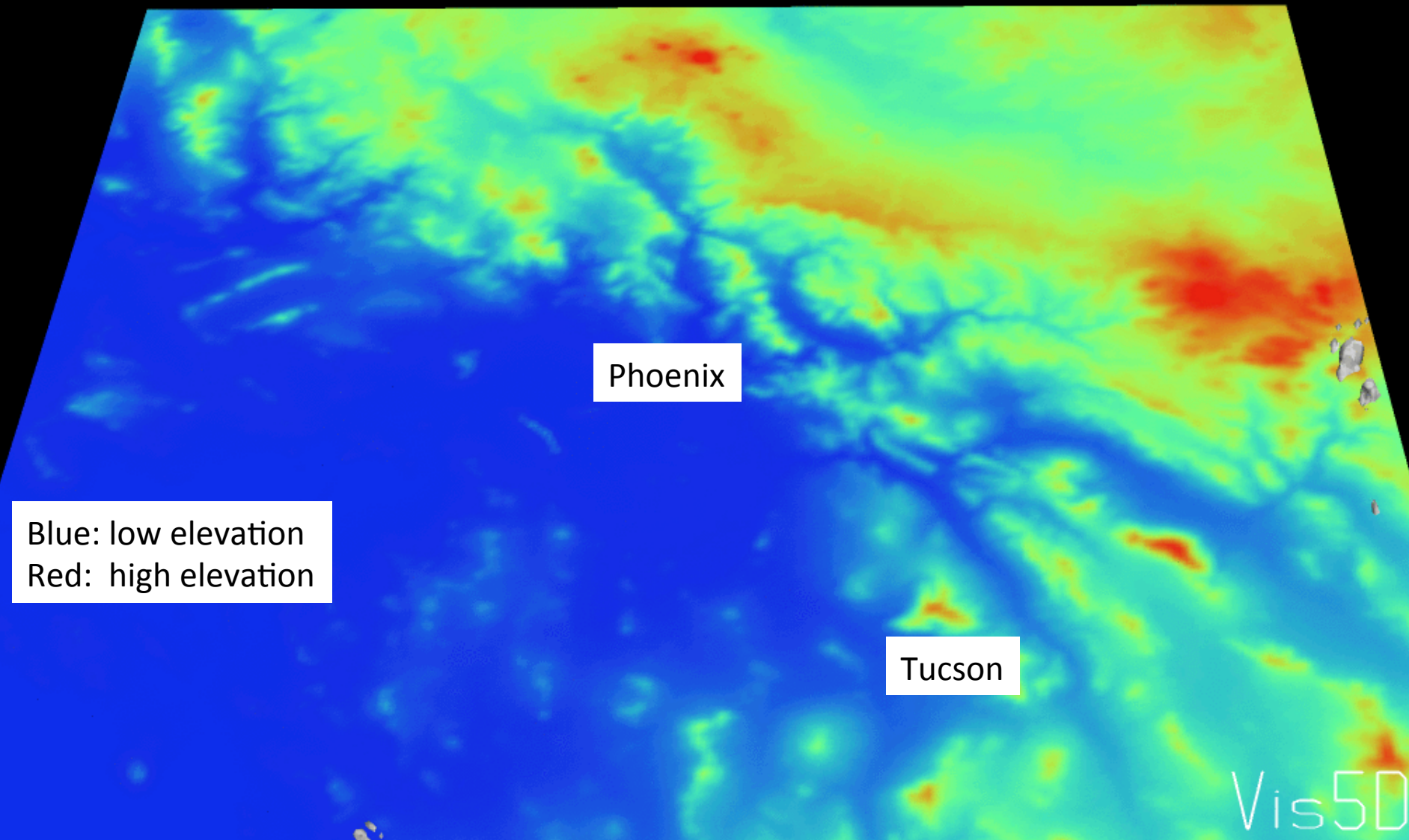
Climate Models





# Numerical Weather Prediction at UA

- Local/regional knowledge of weather is extremely important
- State of the art model modified to better represent the unique characteristics of southwestern U.S. weather
  - Mountains + moisture + heating = monsoon storms
  - Unreliable initialization data from Mexico
  - Extreme planetary boundary layer heights
  - Rapidly changing land/surface characteristics
- Five model runs per day, out to 72 hours in advance
- 1.8 km resolution, 3 minute outputs of:
  - GHI, DNI, 10 m wind, 80 m wind, temp



Phoenix

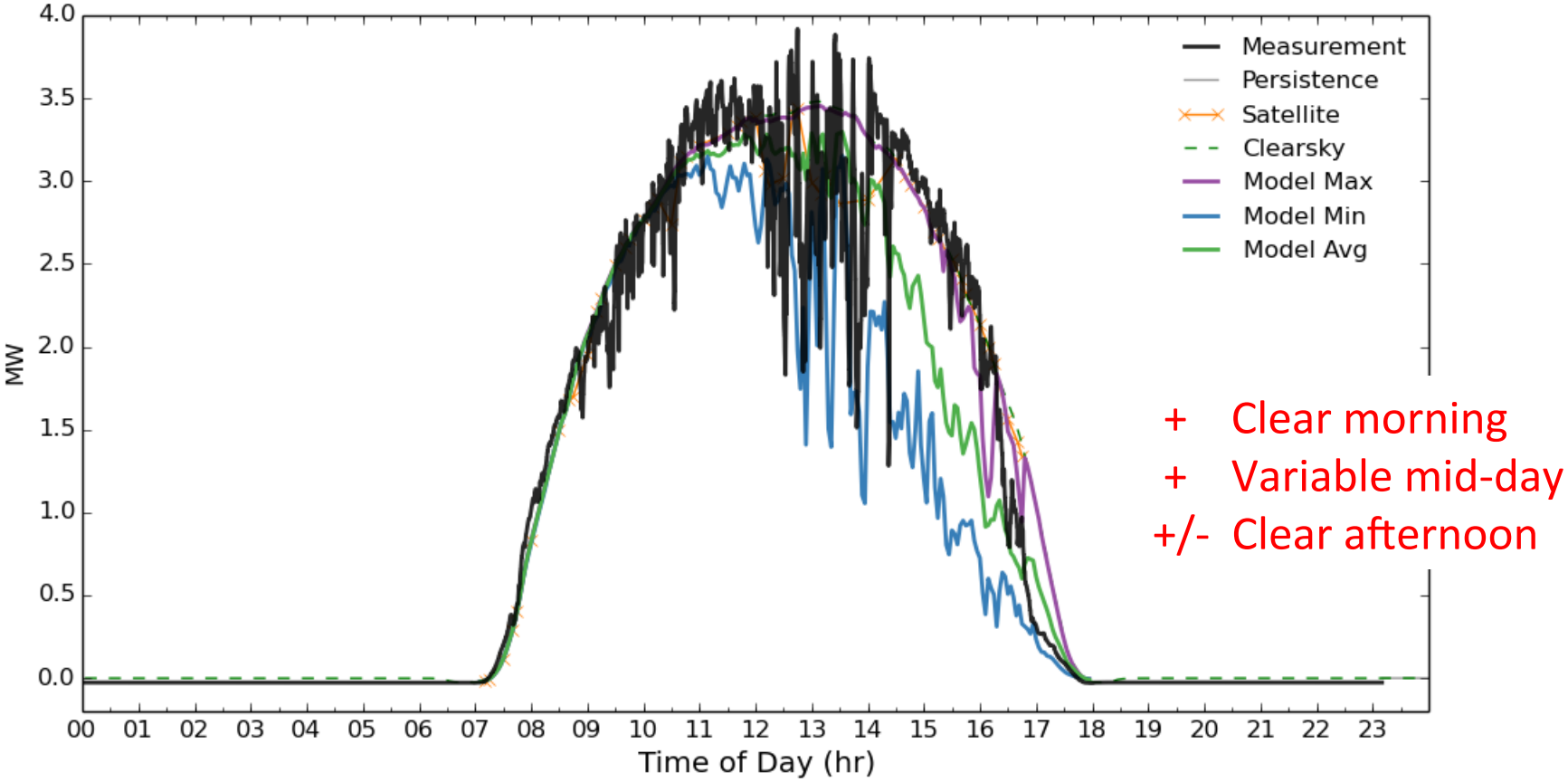
Blue: low elevation  
Red: high elevation

Tucson

Vis50

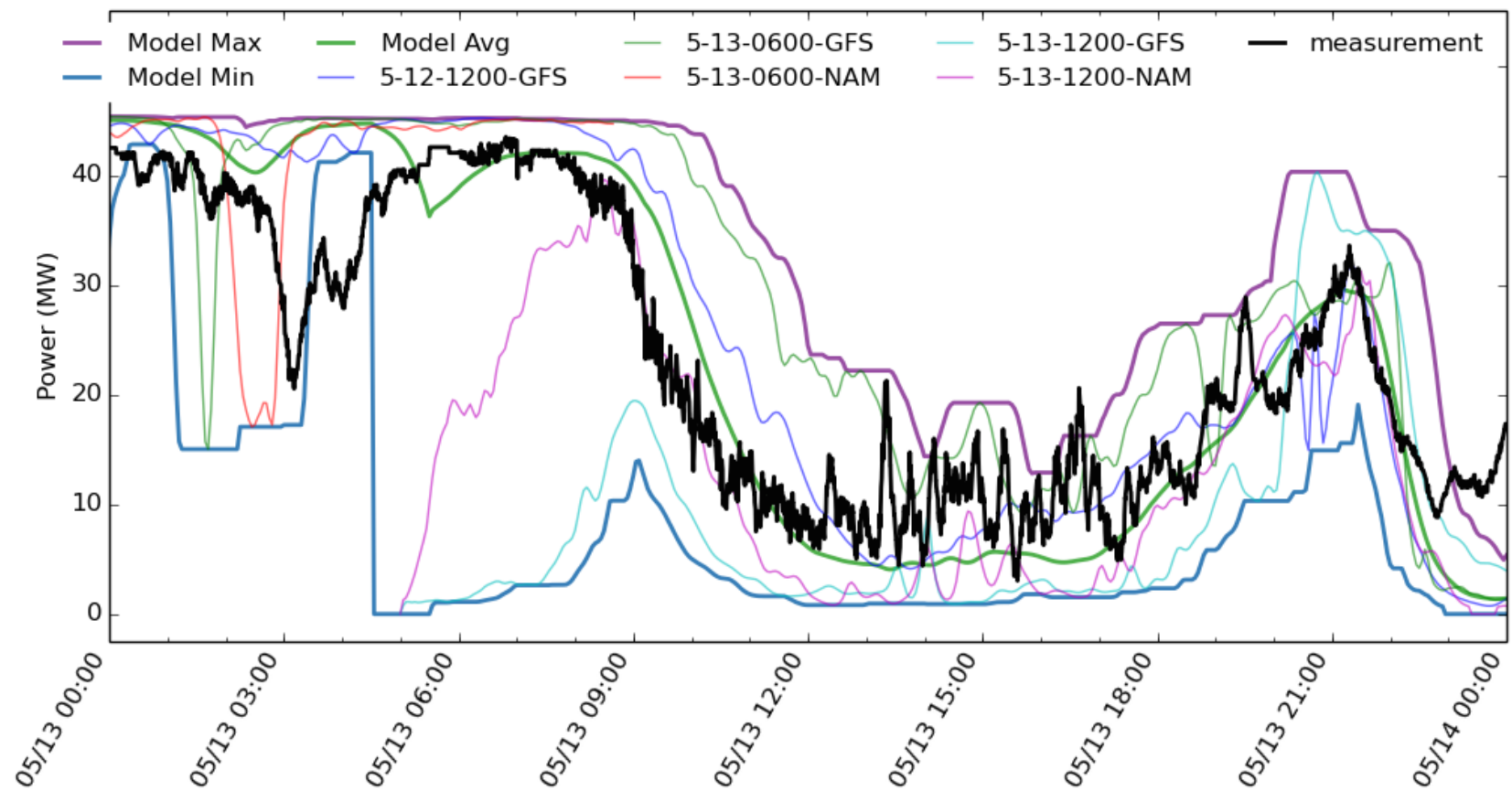
# Solar forecasting with Weather Models

Springerville Solar EMS, 912. 02/18/14 23:13:55

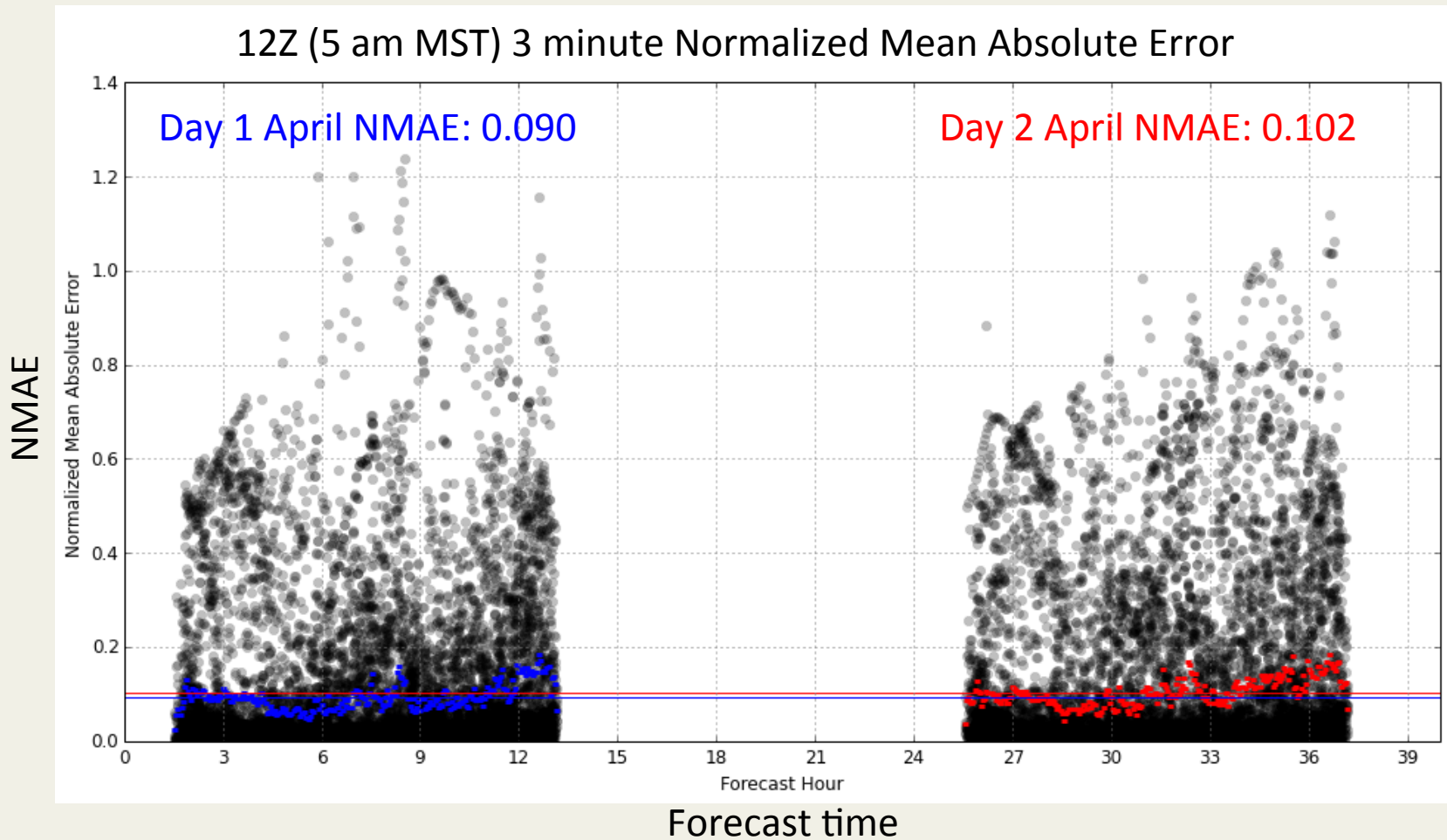


# Wind forecasting with Weather Models

Macho Springs Wind, 1201



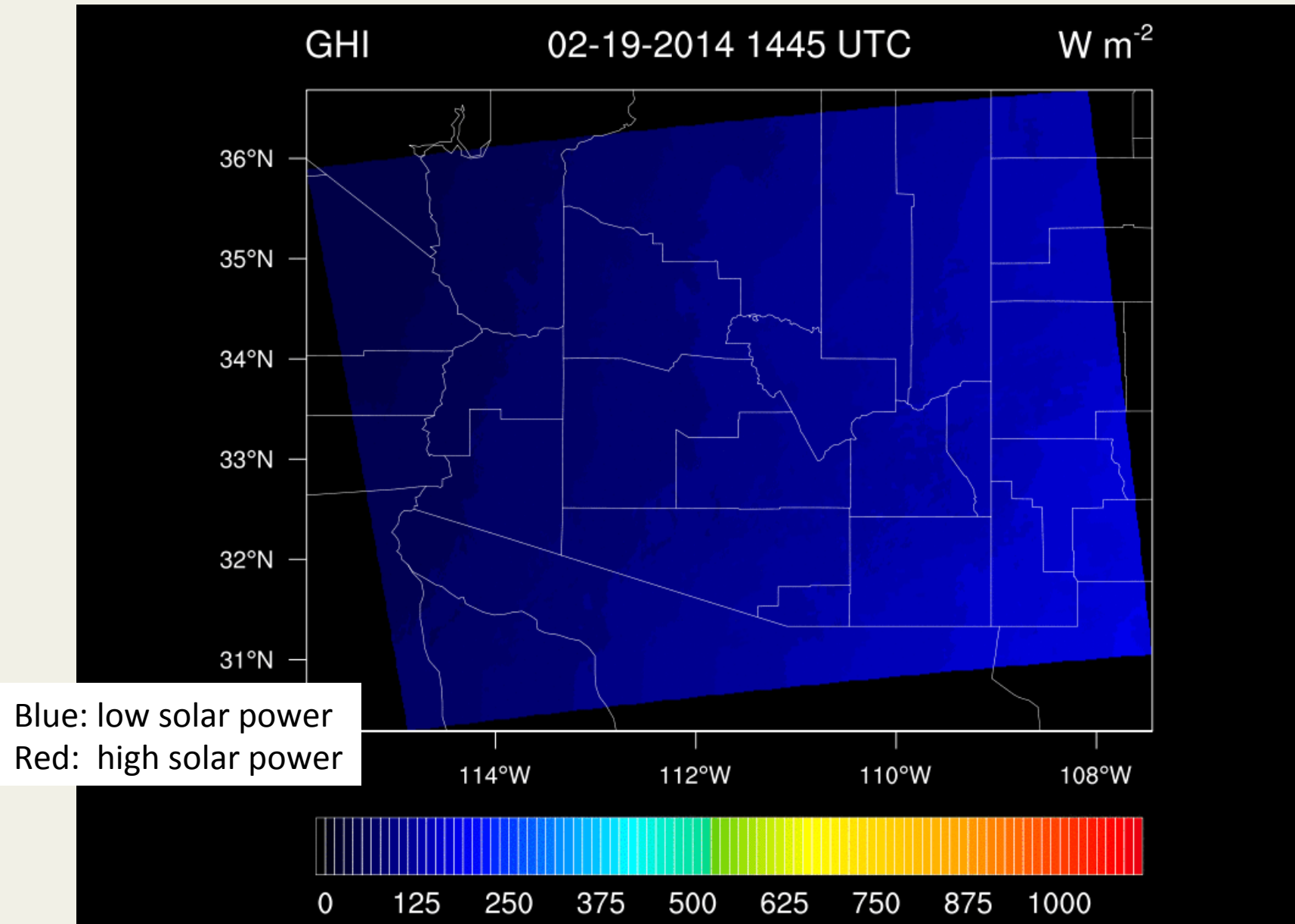
# Weather model error stats



Clear sky NMAE: 0.125

See paper for statistics by weather model type and time

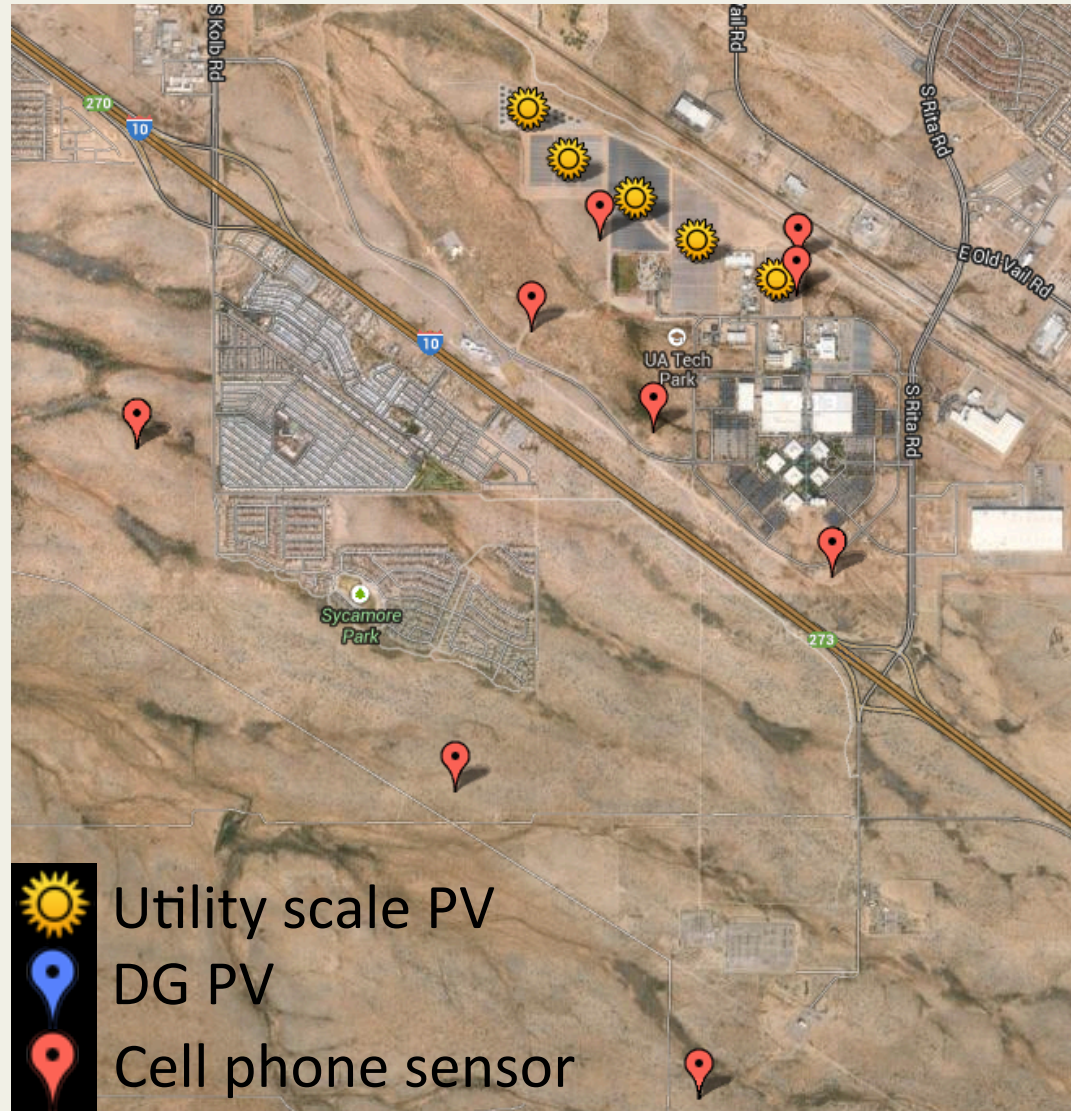
# Satellite Derived Solar Irradiance



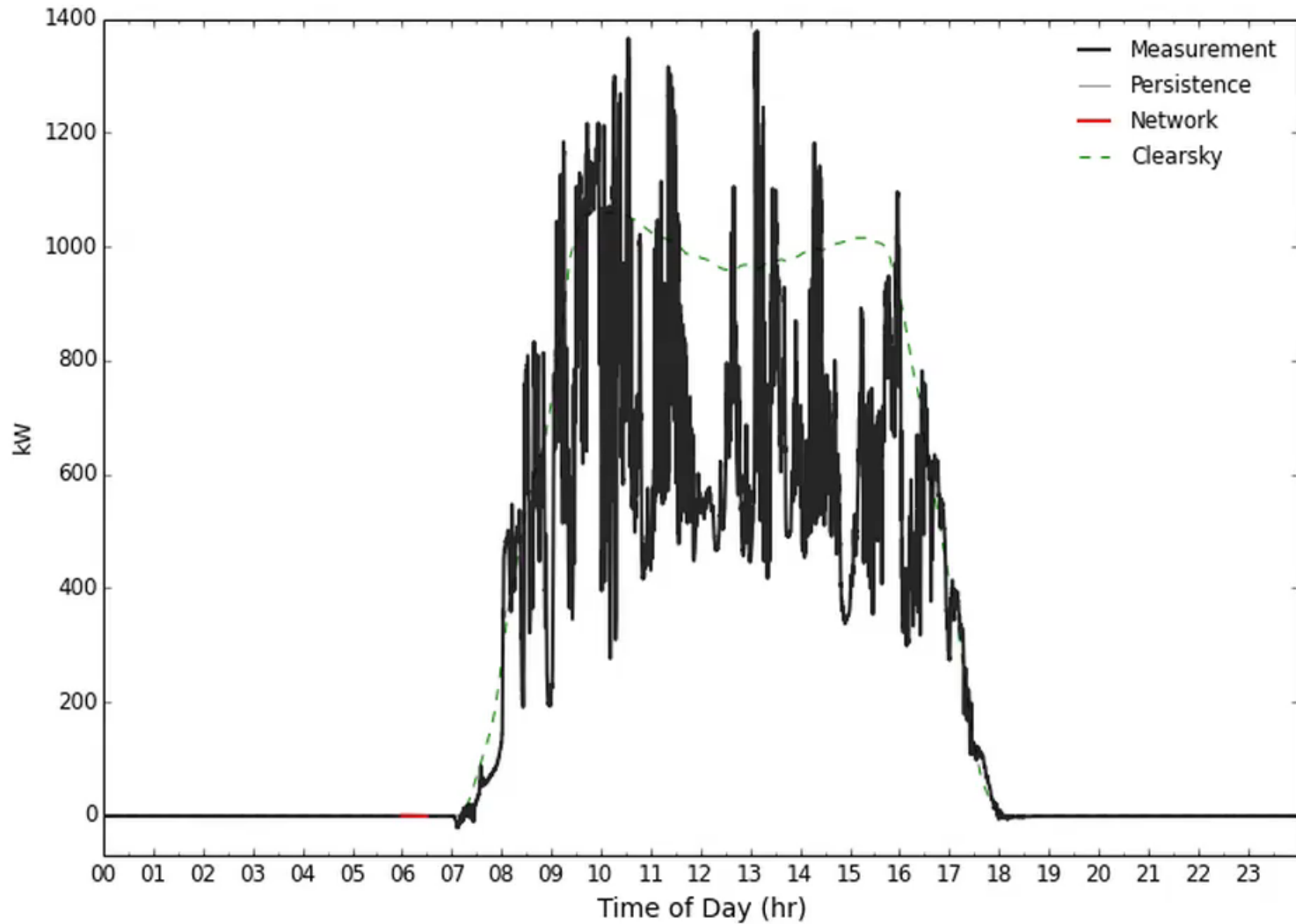
# PV Cloud Detection Network

UA Science and Technology Park  
20 MW of Solar PV

Network of irradiance sensors  
provides 30 minute ahead  
warnings of clouds



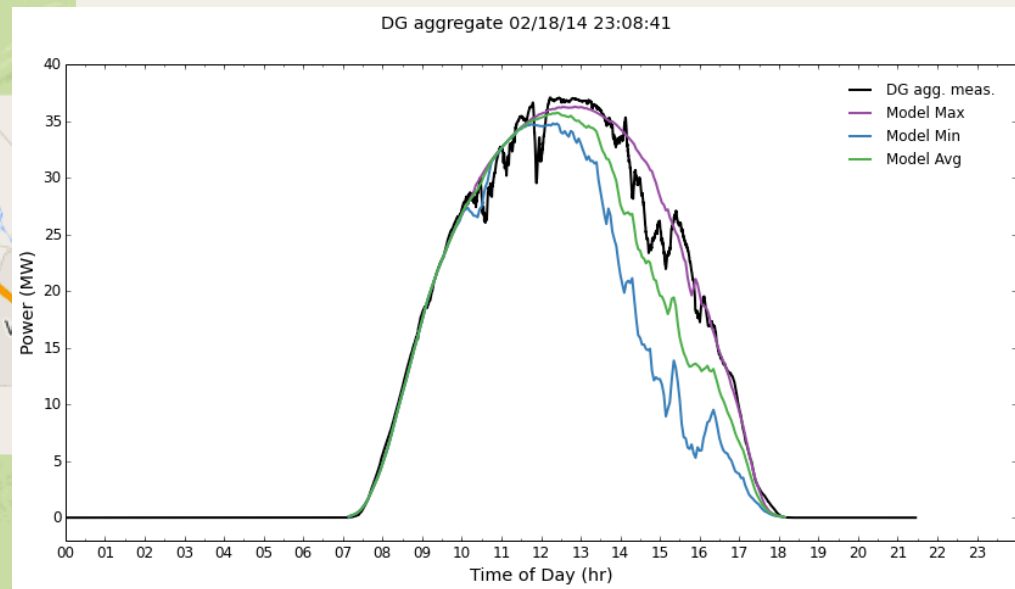
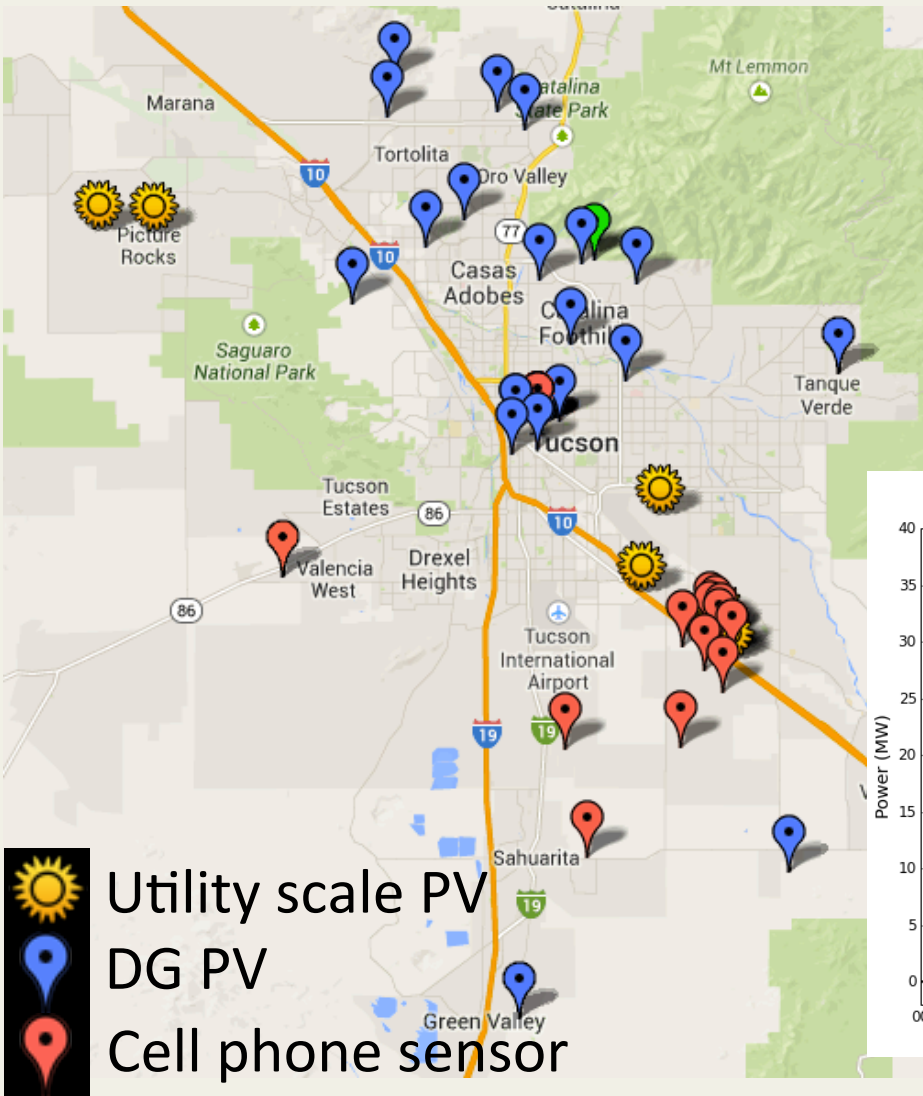
# Network Forecast



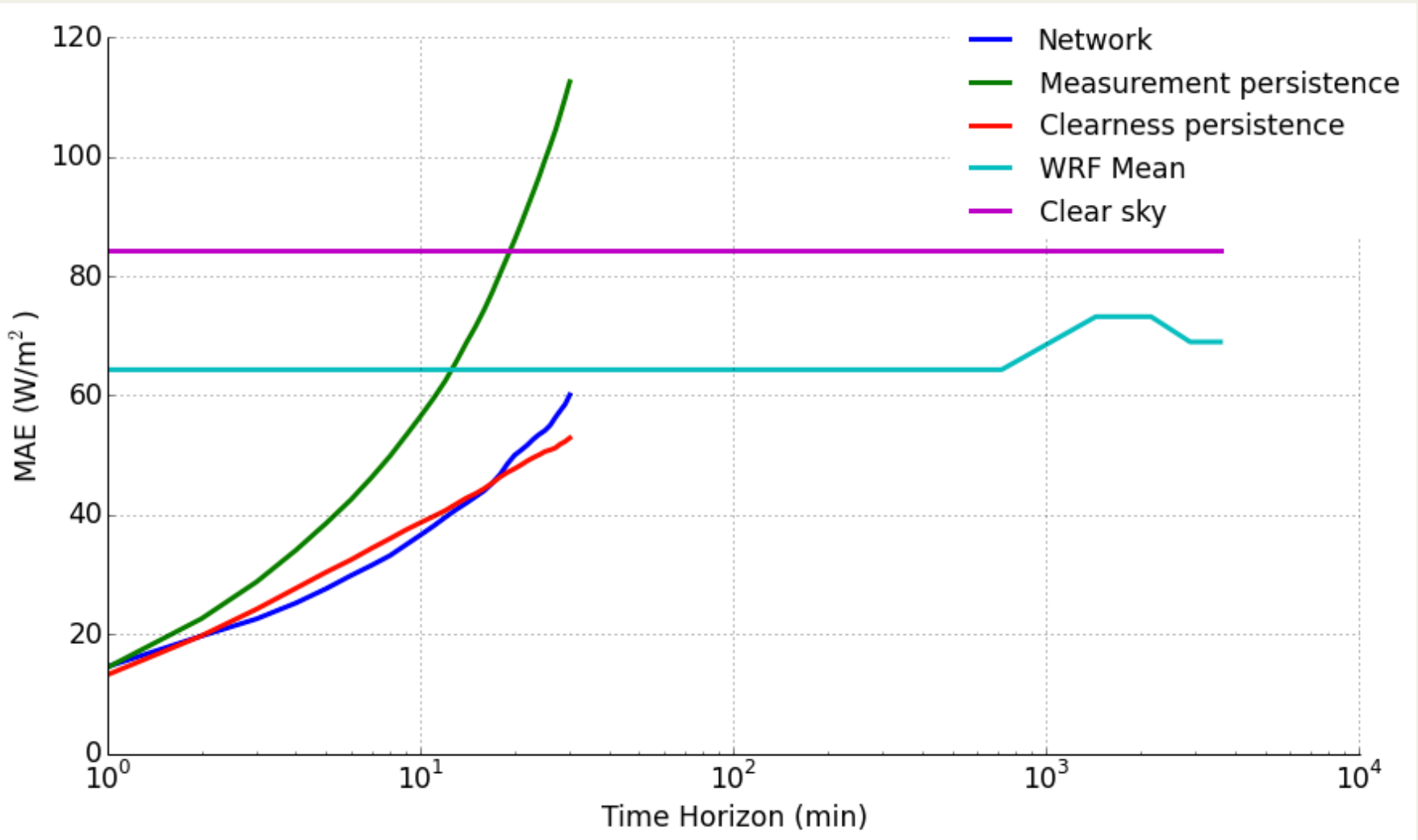


# Behind the Meter Visibility and Forecasting

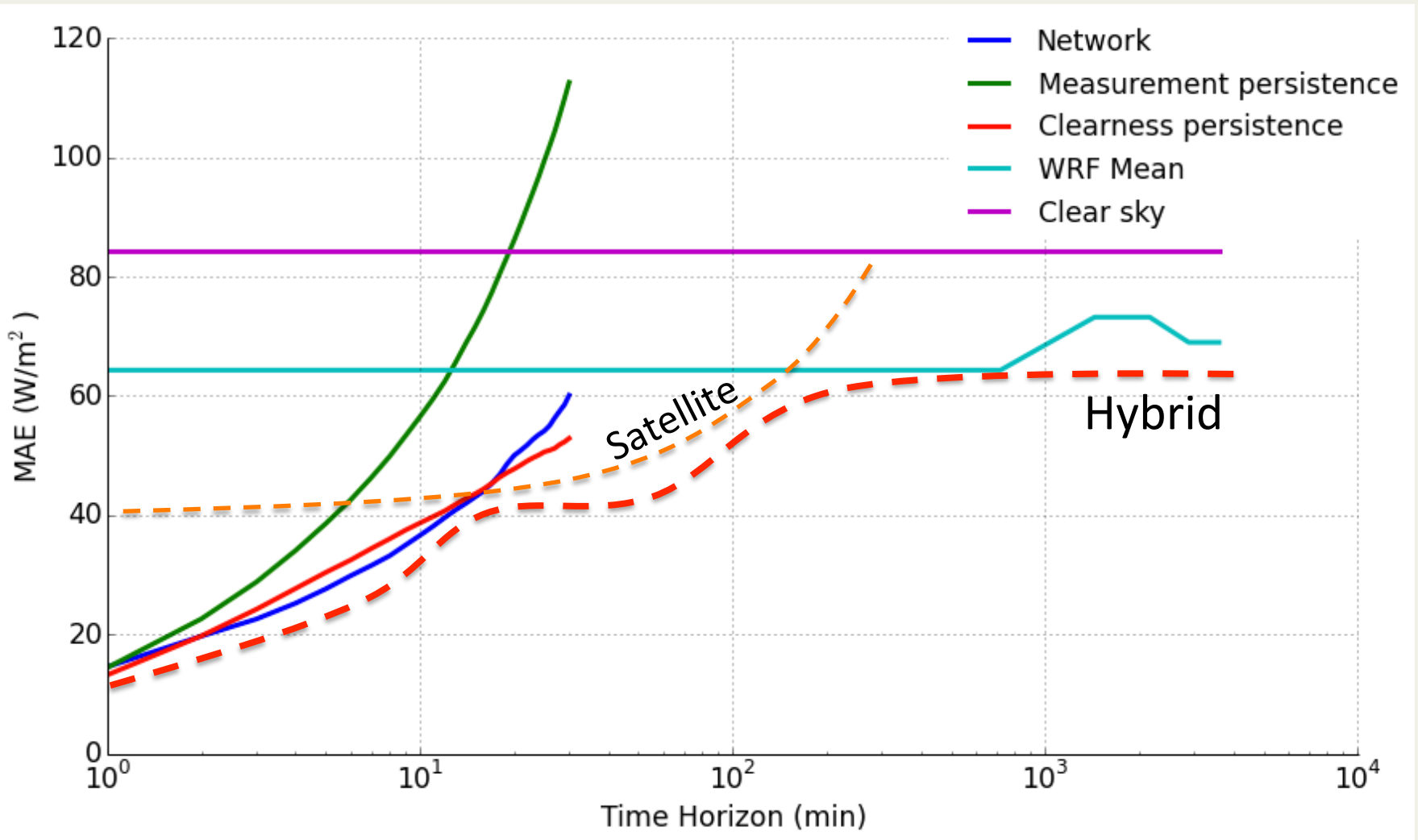
Partnered with Technicians for Sustainability to obtain access to real-time data feeds of residential PV systems



# Different forecasting methods work better at different time scales



# Next steps: Satellite, Hybrid



# Forecasting Website for TEP

## Forecasts for TEP EMS sites, irradiance sensors, and rooftop PV

[Home page](#)

[About](#)

[Feedback](#)

[Maps](#)

- [Full dataset](#)
- [Tucson](#)
- [Tucson animated](#)
- [UA-STP](#)
- [google map](#)

[Aggregate plots](#)

- [EMS Aggregate](#)
- [EMS Solar Aggregate](#)
- [EMS Wind Aggregate](#)
- [DG Aggregate](#)
- [Total Aggregate](#)

[TEP EMS data](#)

[csv files](#)

[Irradiance sensors](#)

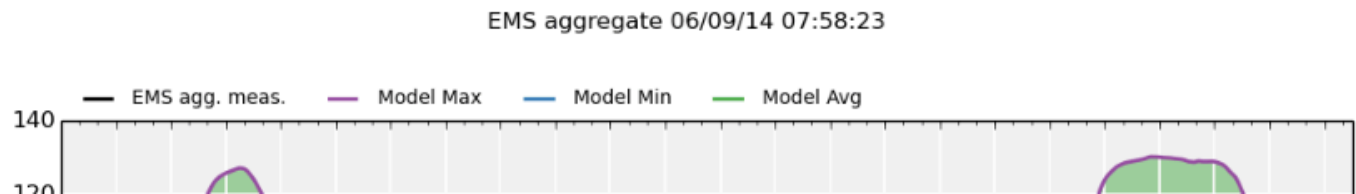
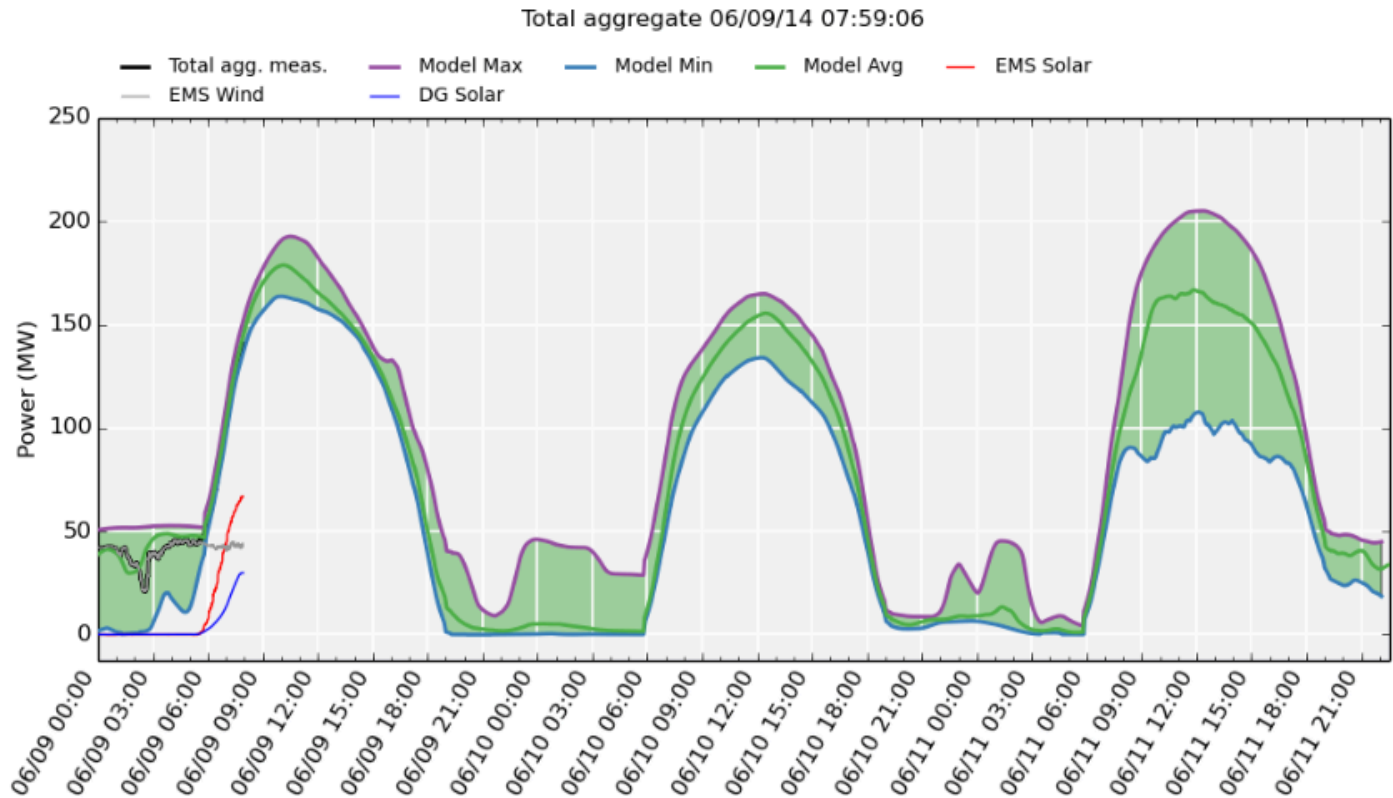
[kW rooftop PV](#)

[Environmental data](#)

[Other resources](#)

[Toggle Operations / Marketing View](#)

Current view: marketing



# UA + TEP developing renewables forecasts

 THE UNIVERSITY OF ARIZONA®

Forecasts for TEP EMS sites, irradiance sensors, and rooftop PV

[forecasting.uaren.org](http://forecasting.uaren.org)

Home page

About

Feedback

Maps

Full dataset

Tucson

Tucson animated

Tucson animated (flash)

UA-STP

google map

Aggregate plots

EMS Aggregate

EMS Solar Aggregate

EMS Wind Aggregate

DG Aggregate

Total Aggregate

TEP EMS data

csv files

Irradiance sensors

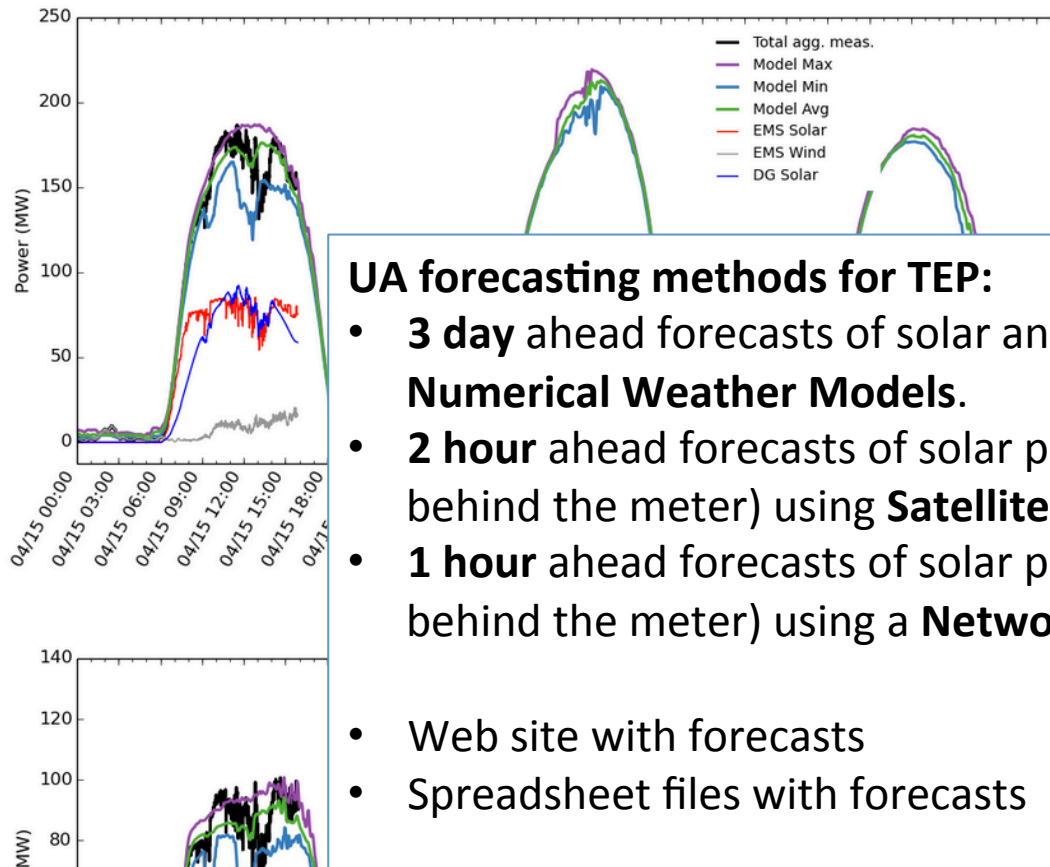
kW rooftop PV

Environmental data

Other resources

Toggle Operations /  
Marketing View

Total aggregate 04/15/14 15:53:37

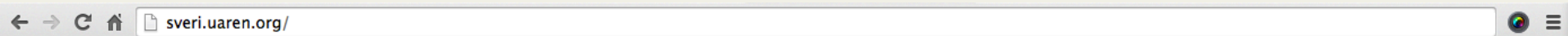


## UA forecasting methods for TEP:

- **3 day** ahead forecasts of solar and wind production using **Numerical Weather Models**.
- **2 hour** ahead forecasts of solar production (utility and behind the meter) using **Satellite Imagery** (preliminary).
- **1 hour** ahead forecasts of solar production (utility and behind the meter) using a **Network of Irradiance Sensors**.
- Web site with forecasts
- Spreadsheet files with forecasts

Working with SVERI utilities APS, SRP, PNM, IID, EPE, IPC to explore forecasting in their service territories

# SVERI Website



**About**

- About SVERI and UA REN
- How to use this website
- Glossary

**Date Selection**

Select the date range:

Start:

End:

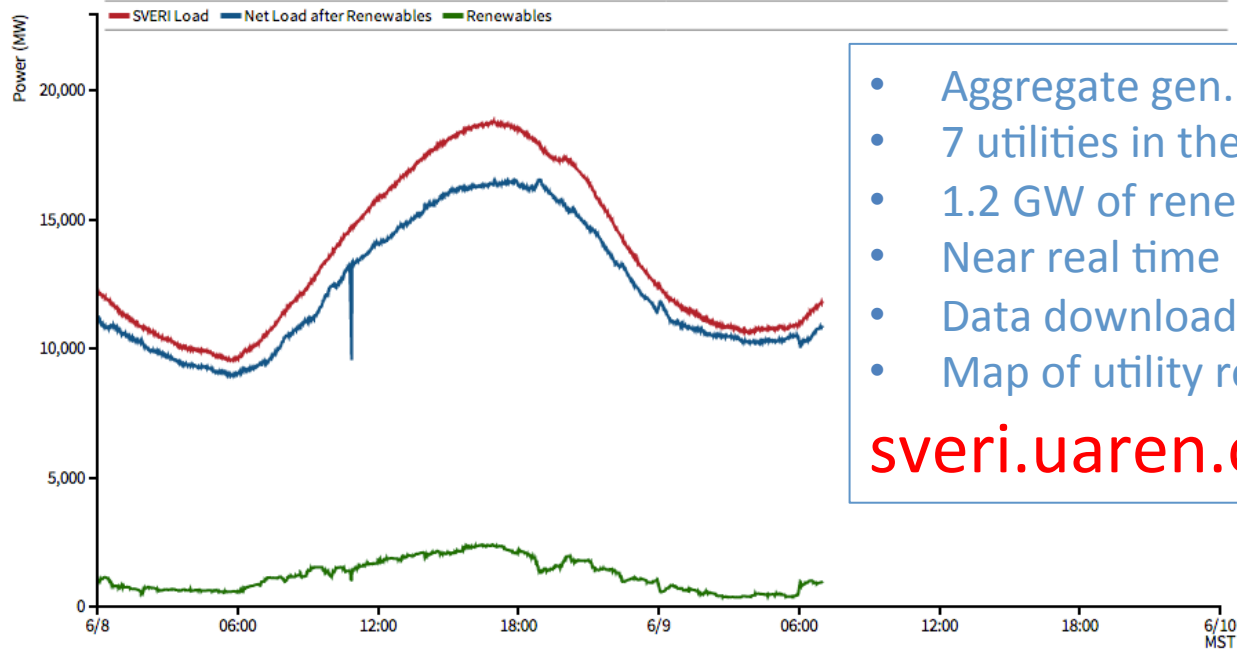
**Graphs**

- Generation and Load
- Renewables and Load**
- Variable Energy Resources (VERs) and Load
- Generation by Fuel Type
- Renewables by Type
- Dispatchable vs. Variable Renewables
- Solar
- Wind
- Rooftop Solar

**Maps**

- Renewables

### Renewables and Load



- Aggregate gen. and load
  - 7 utilities in the southwest
  - 1.2 GW of renewables
  - Near real time
  - Data downloads
  - Map of utility renewables
- sveri.uaren.org**

The Renewables and Load graph shows the total **SVERI Load**, the total SVERI **renewable** generation, and the **Net Load after Renewables**. The Net Load after Renewables is the load that must be met using conventional resources such as coal, gas, and nuclear or by importing energy from other regions of the **Western Interconnection**. Net Load after Renewables is calculated by subtracting the total renewable generation from the total load.

Tip: hover your pointer over one of the lines on the graph to get its value at that point in time.

[Next: Variable Energy Resources \(VERs\) and Load](#)