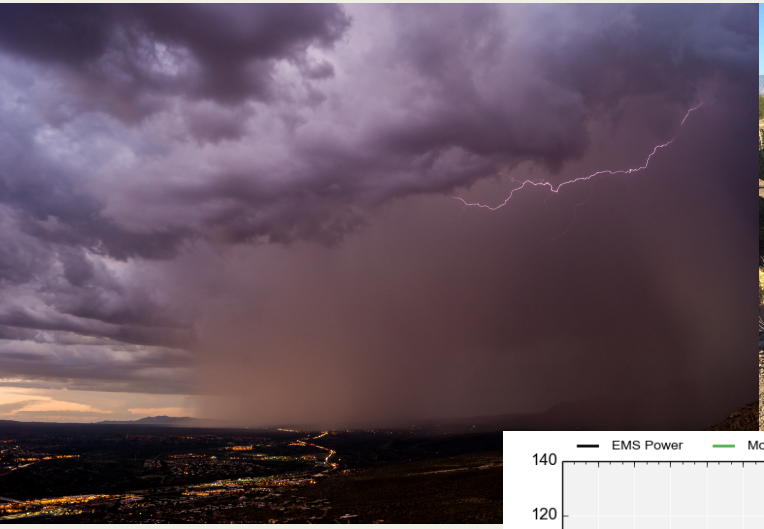
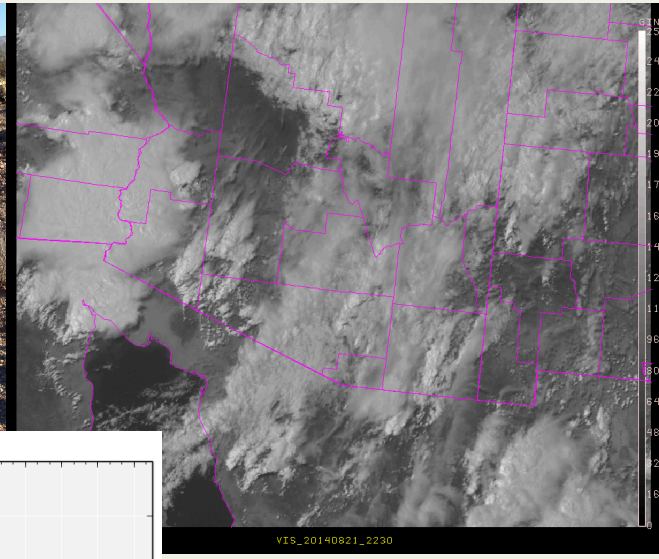
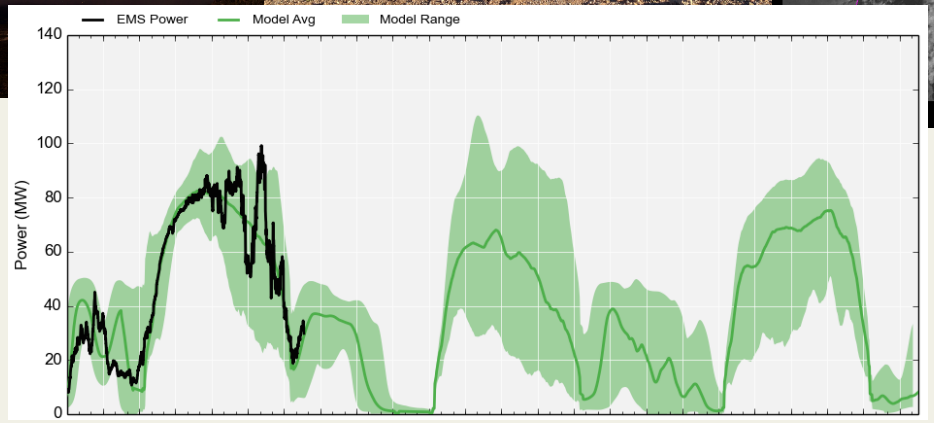
U. Arizona Renewable Power Forecasting



Charles Miles, Creative Commons



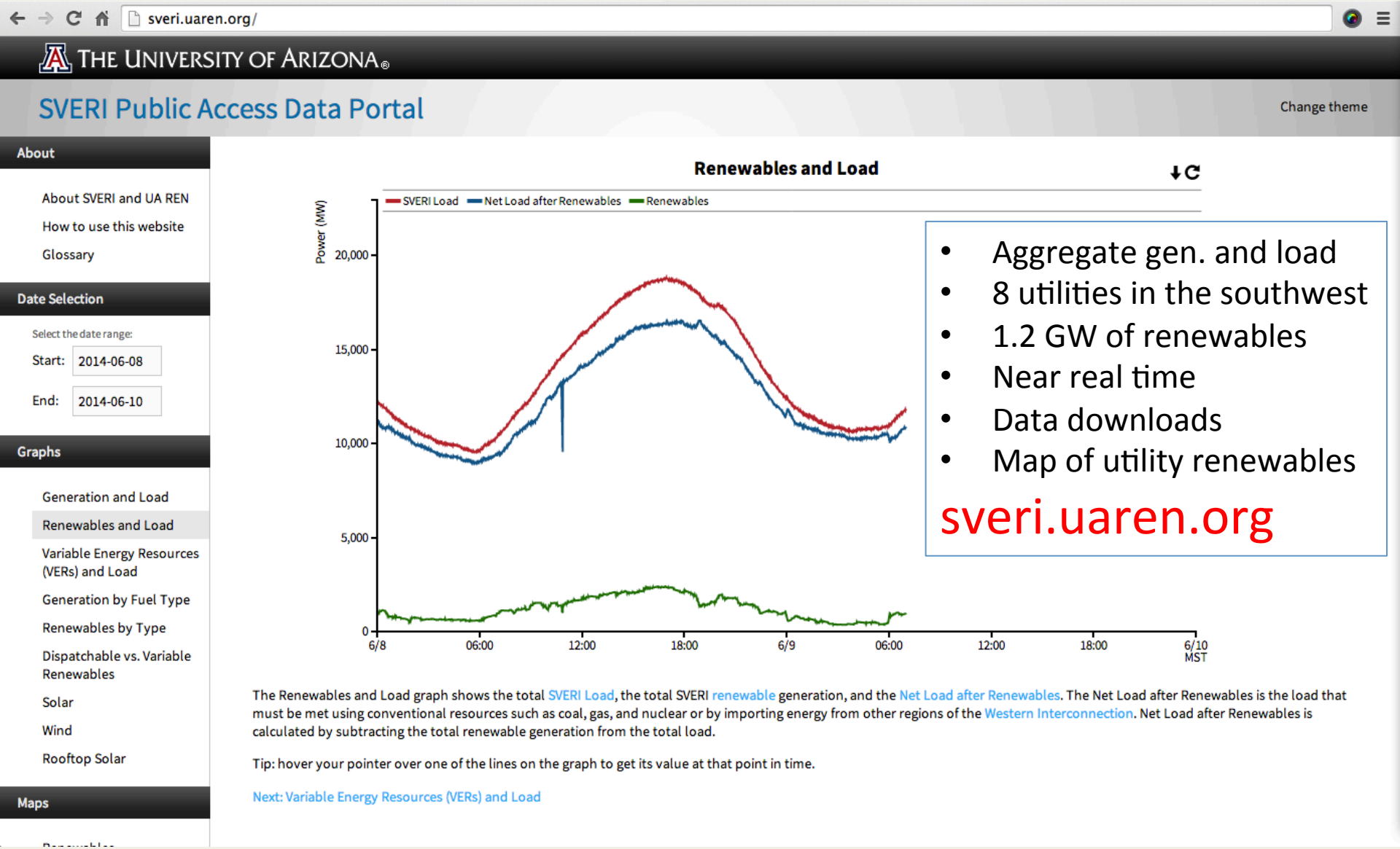


Will Holmgren
DOE EERE Postdoctoral Fellow
UA Department of Atmospheric Sciences

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

ARIZONA

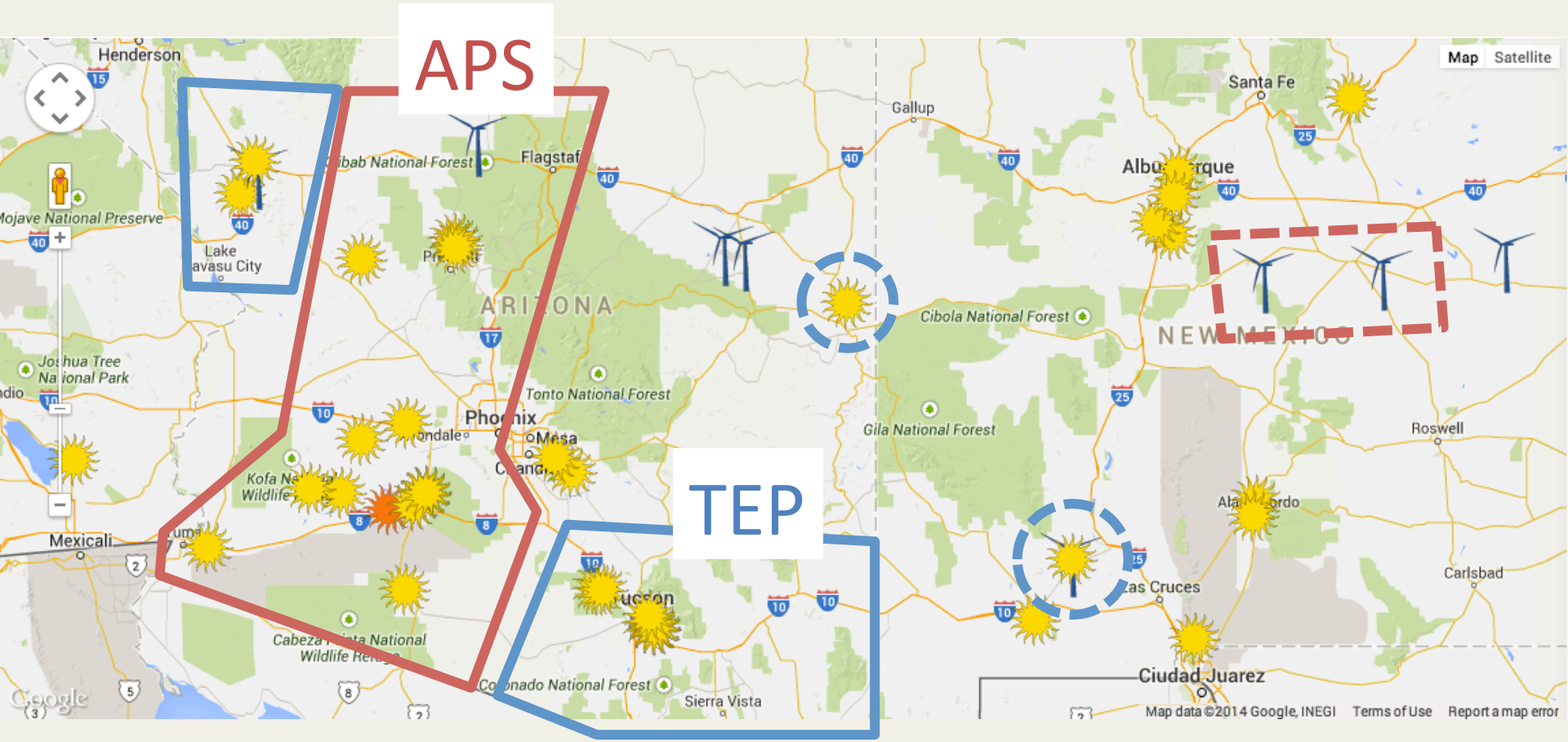
sveri.uaren.org



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

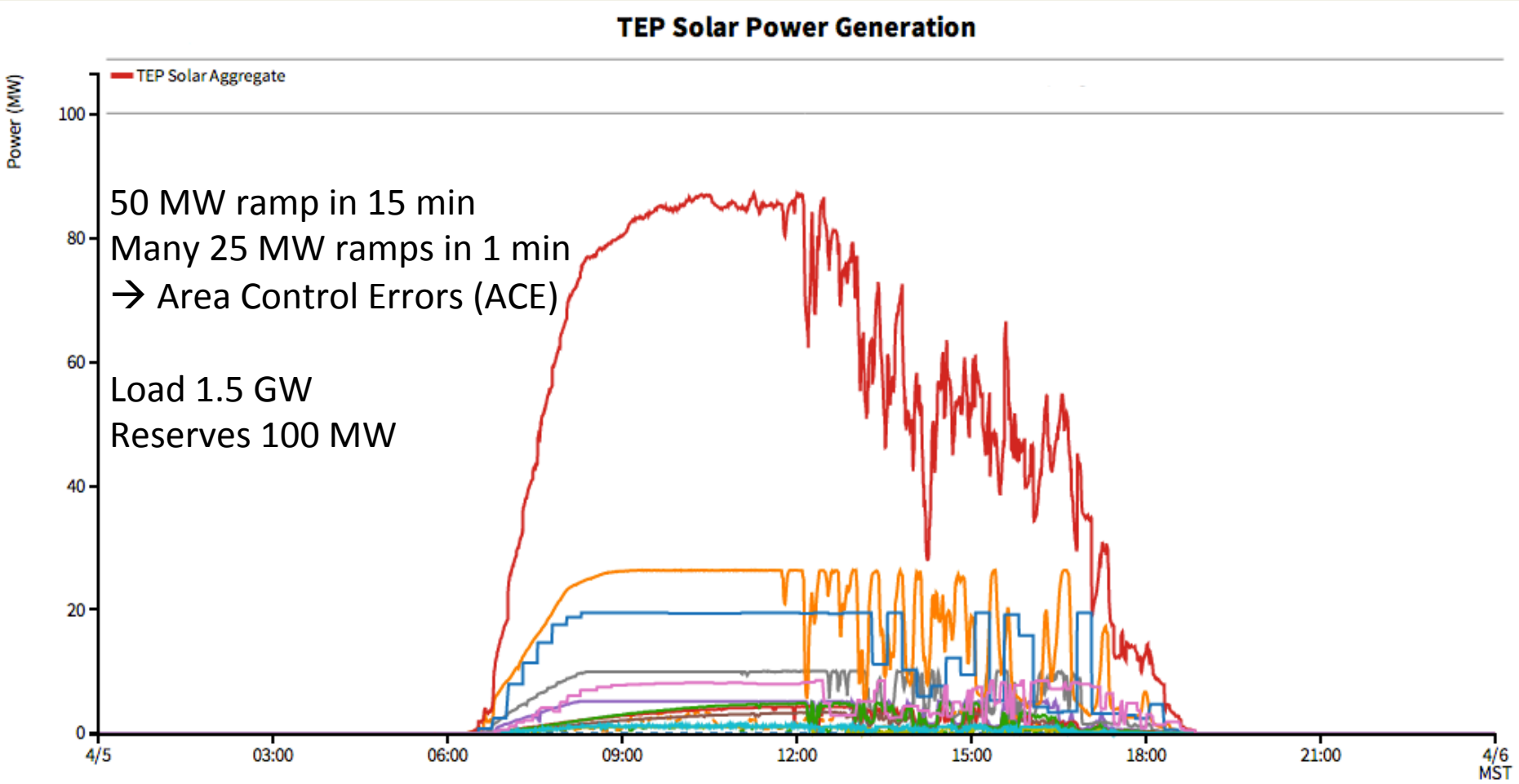
sveri.uaren.org

SVERI renewables

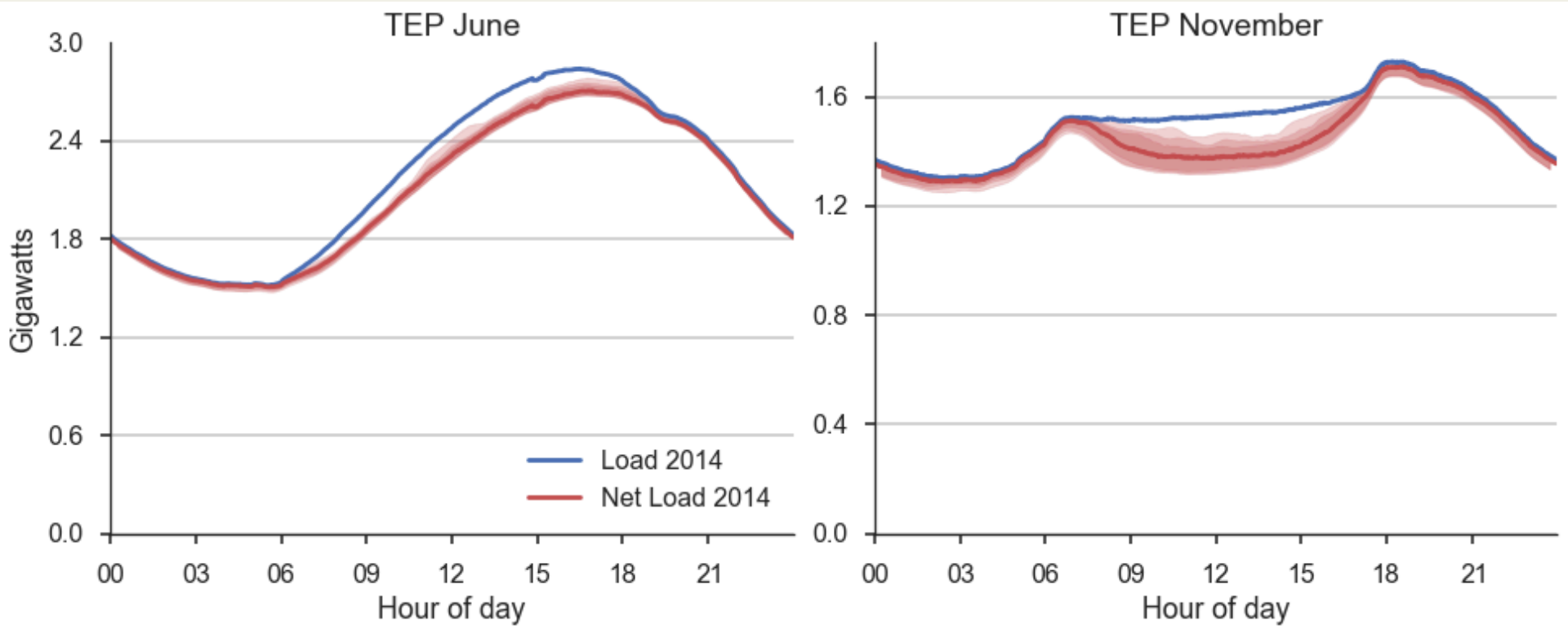


from sveri.uaren.org

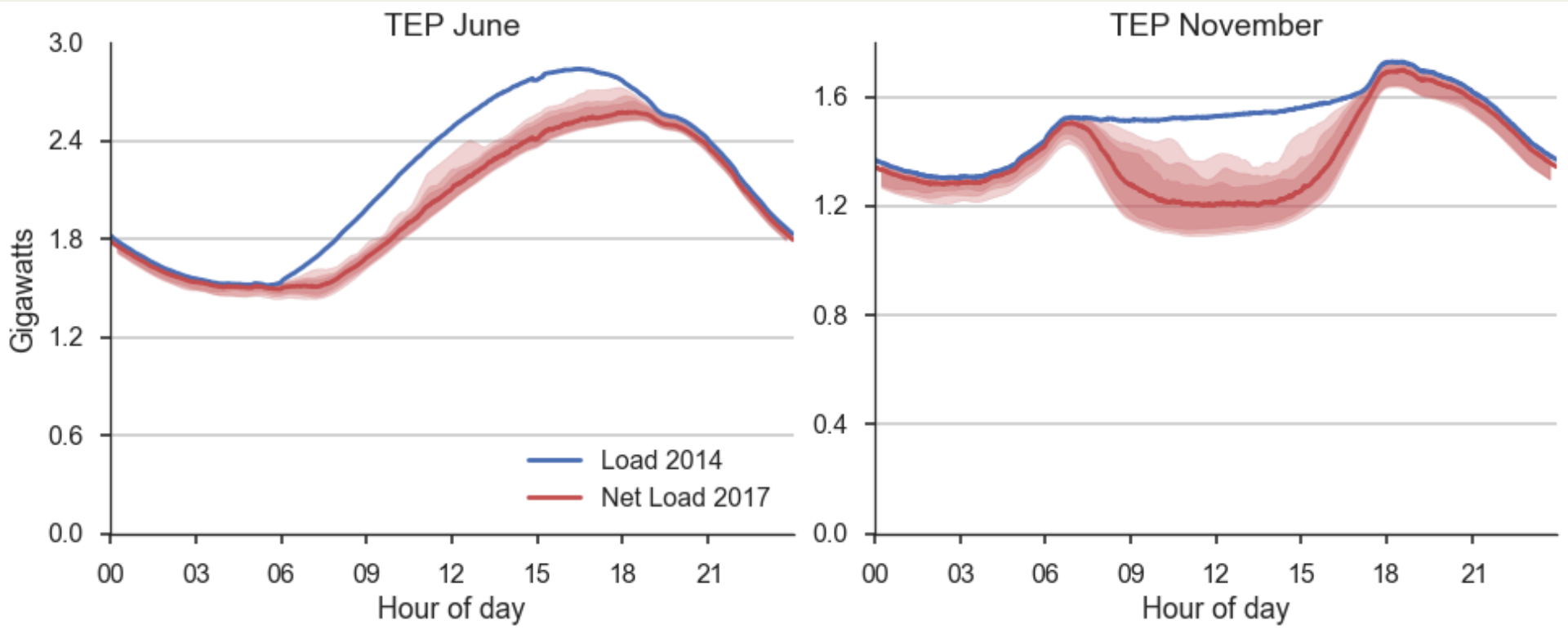
TEP's Solar Power Variability



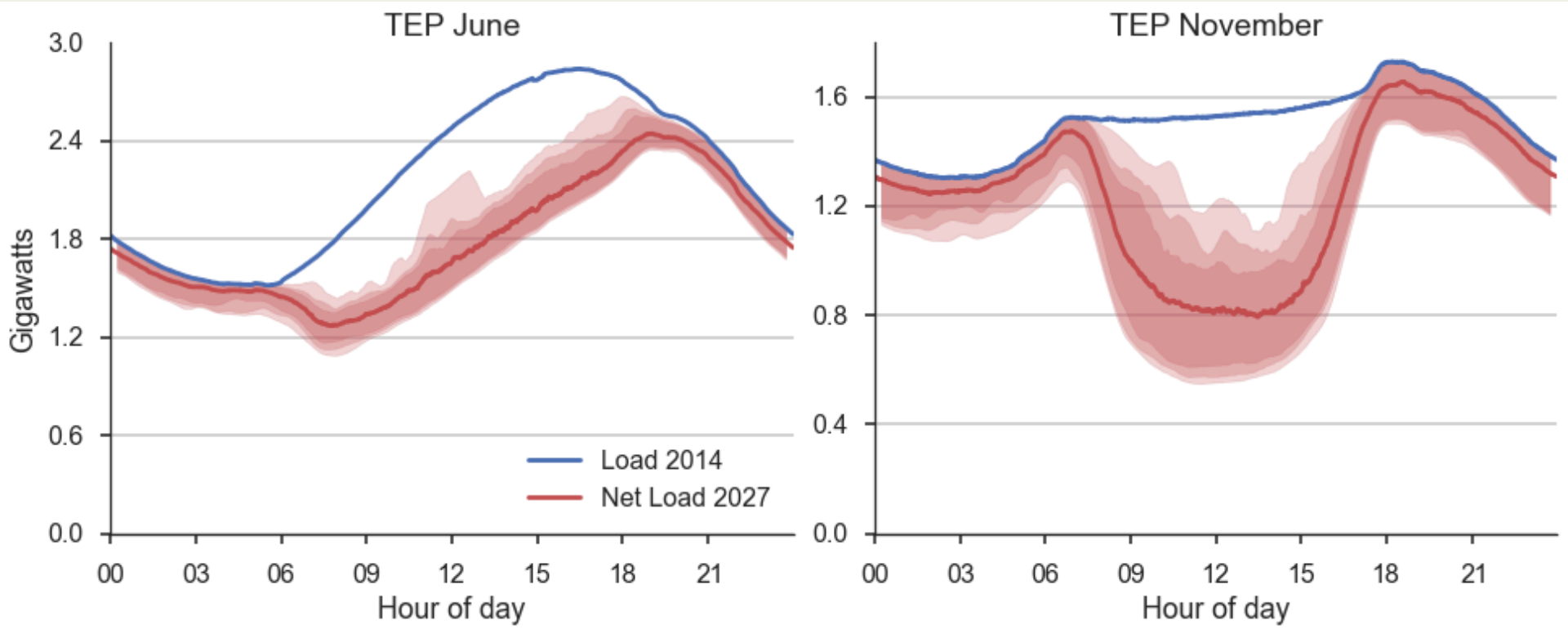
TEP 2014 Net Load Range



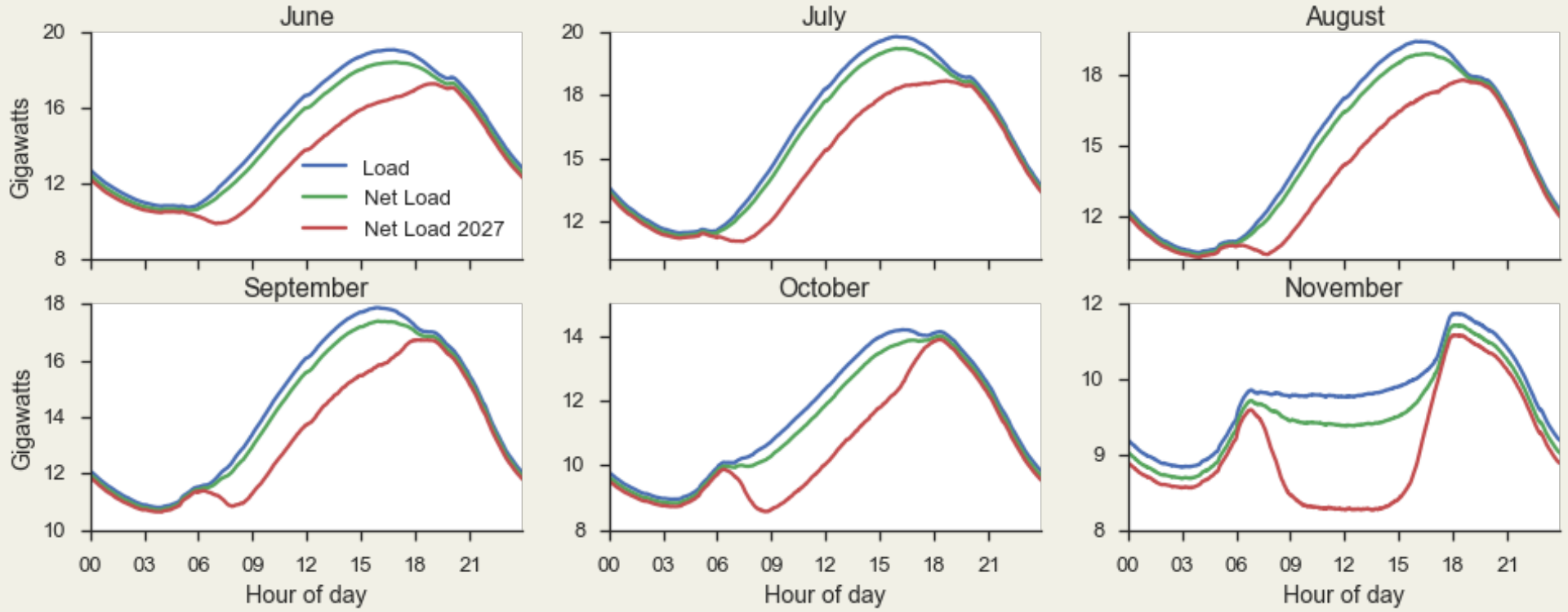
TEP 2017 Net Load Range



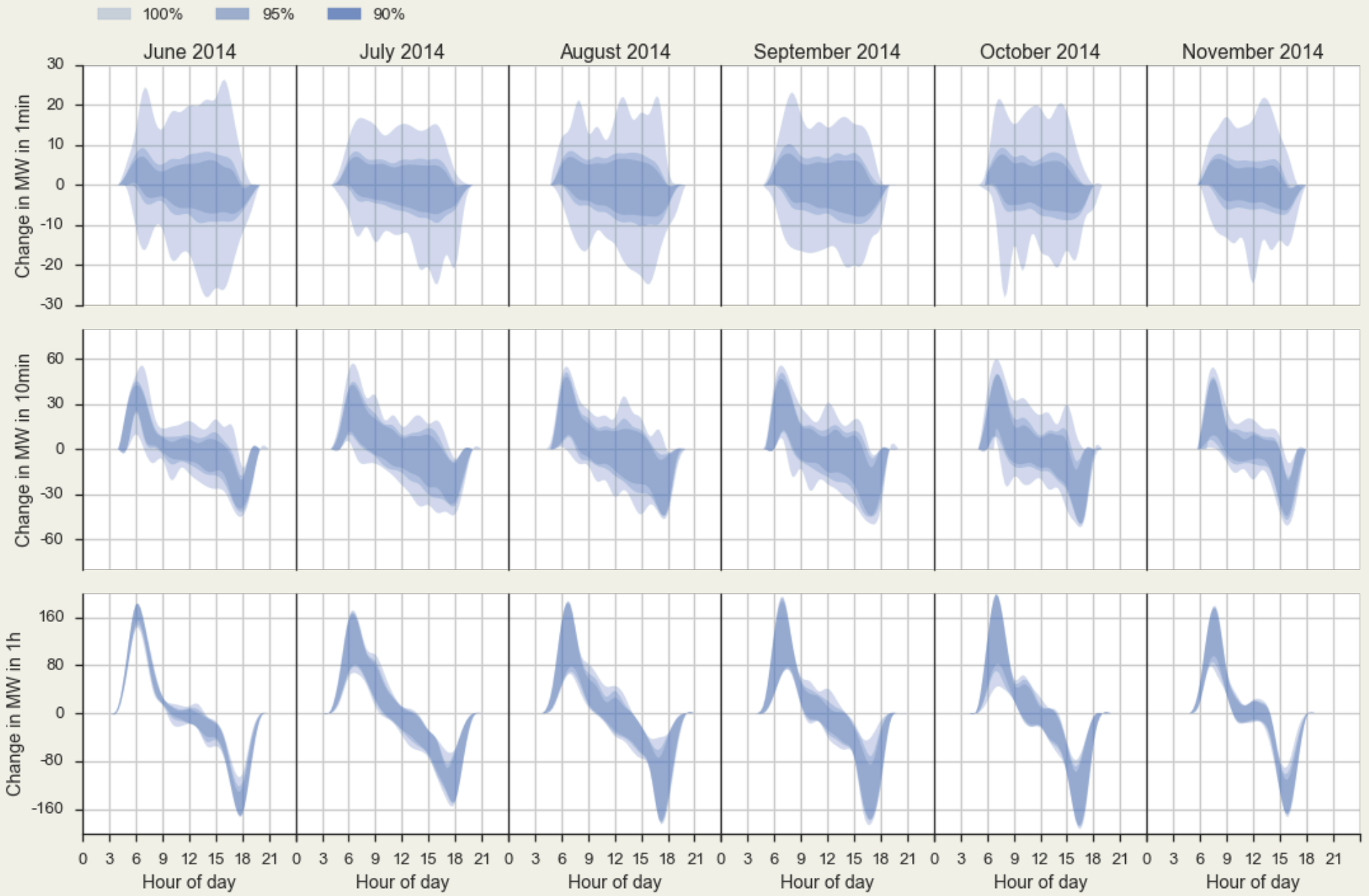
TEP 2027 Net Load Range



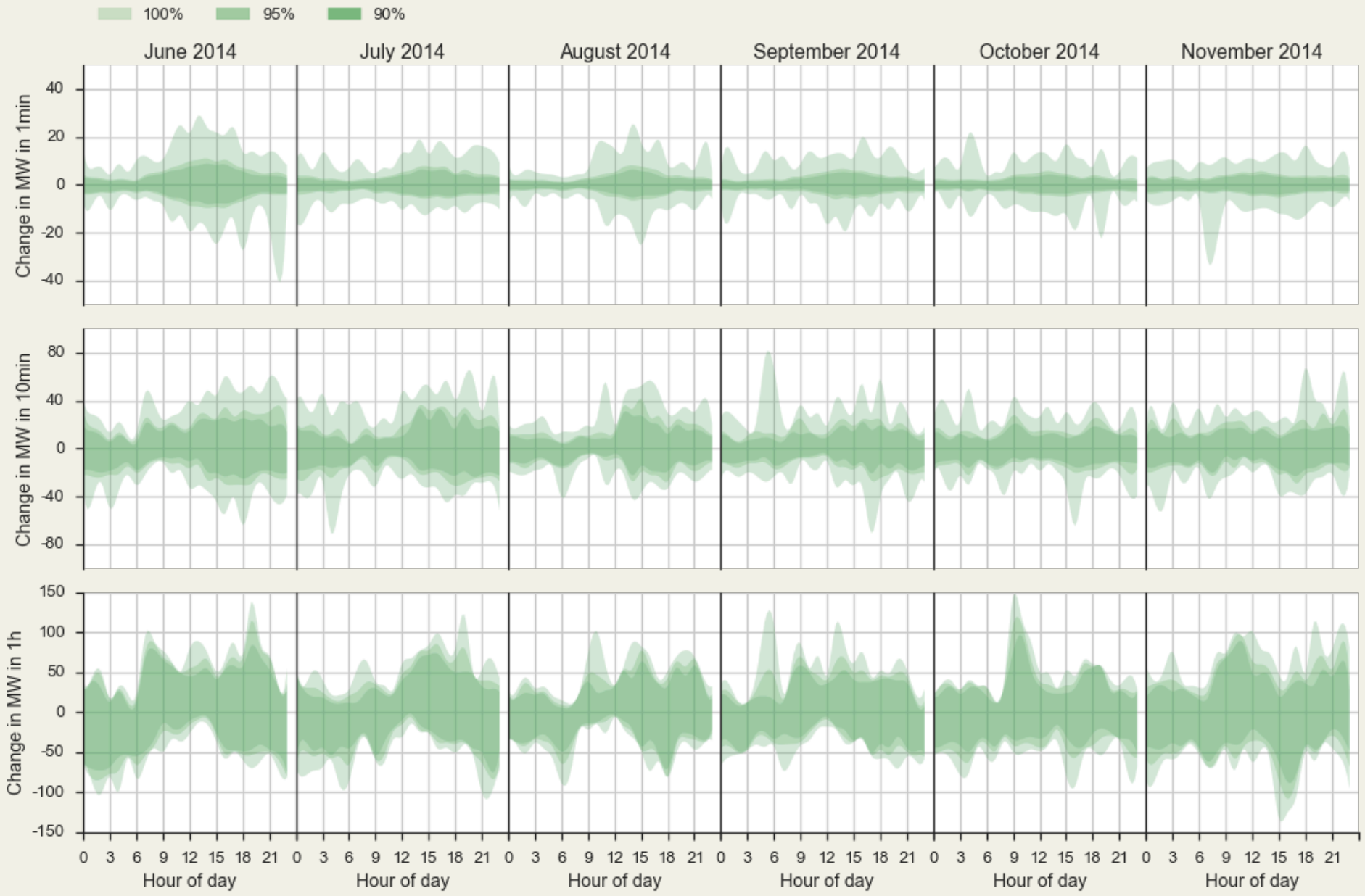
SVERI Net Load



SVERI solar variability

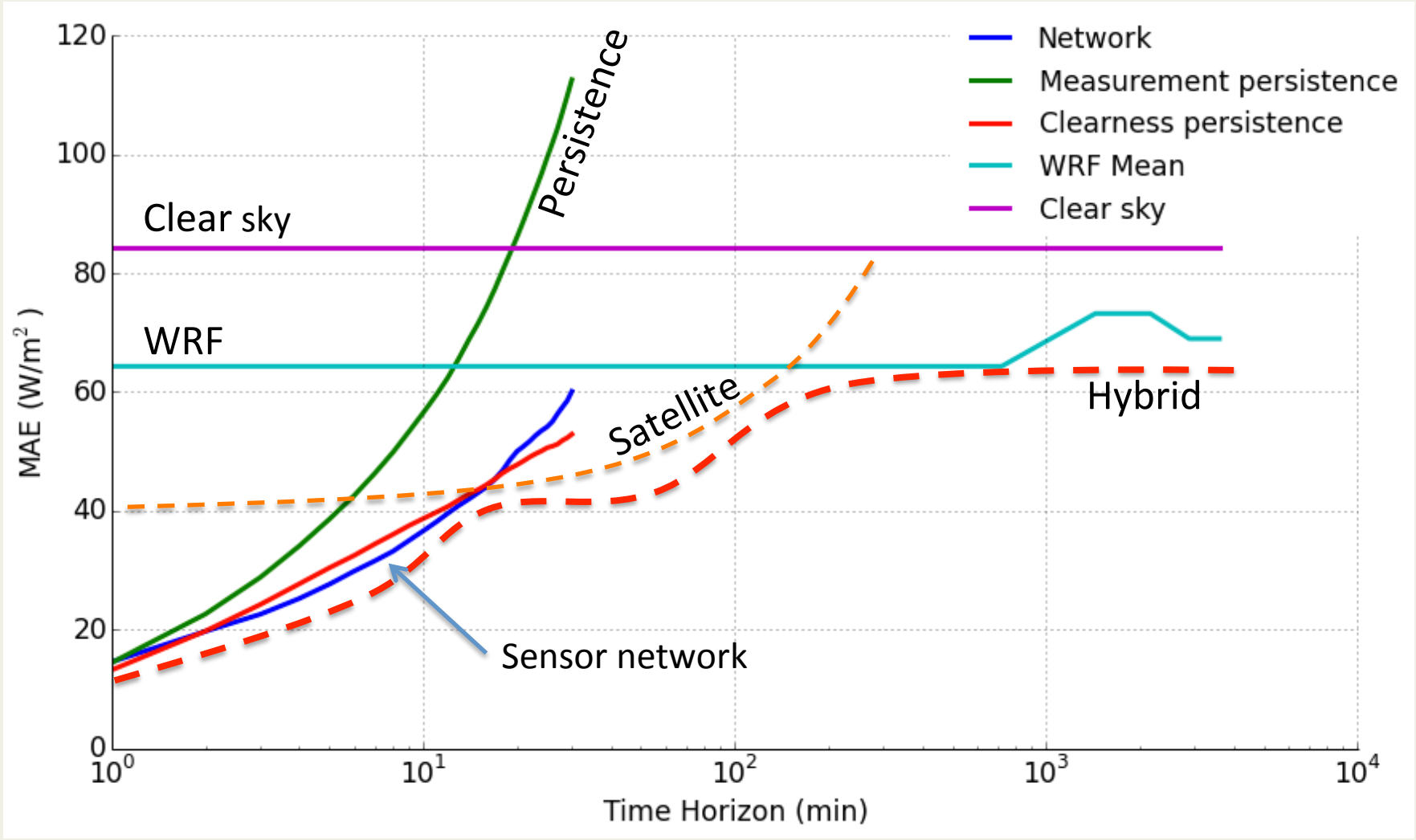


SVERI wind variability



UA Forecasting Website for TEP + APS

UA forecasting methods



Numerical Weather Prediction at UA

Christopher Marks, Creative Commons

- Model highlights
  - 5.4 km outer domain, 1.8 km inner domain
  - Initialized on the 6Z and 12Z GFS and NAM
  - Most days include 12 RAP initialization (esp. in summer)

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

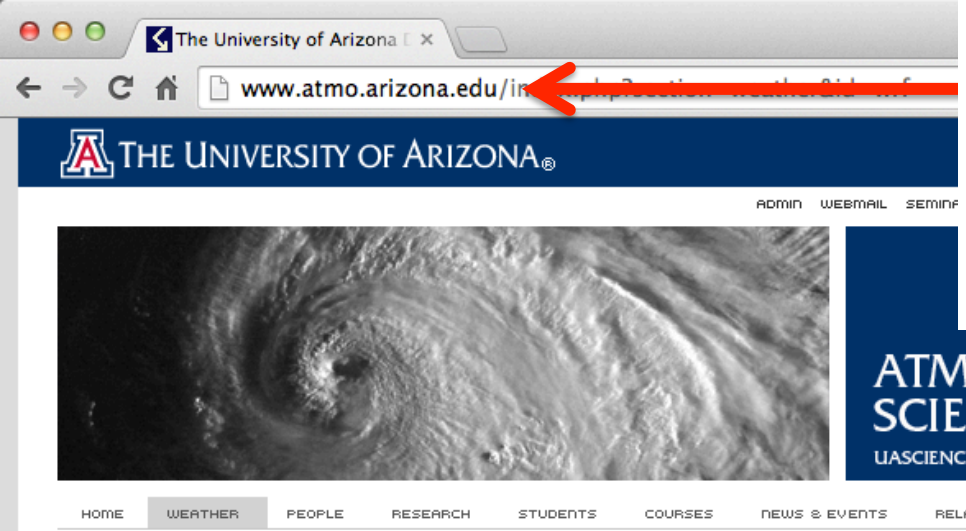
- 1.8 km resolution, 3 minute outputs of:
  - GHI, DNI, 10 m wind, 80 m wind, temp

WRF configuration details:

- RRTMG
- Morrison 2 mom. or SBUYLIN
- Bougeault-Lacarre or ACM2
- Noah LSM

UA WRF forecasts available at atmo.arizona.edu

Contact me for access to raw data



Arizona Regional WRF Model Data

Model Derived Forecasts

SE AZ Forecast Phx Area Forecast AM Optical Depth

Model Discussion

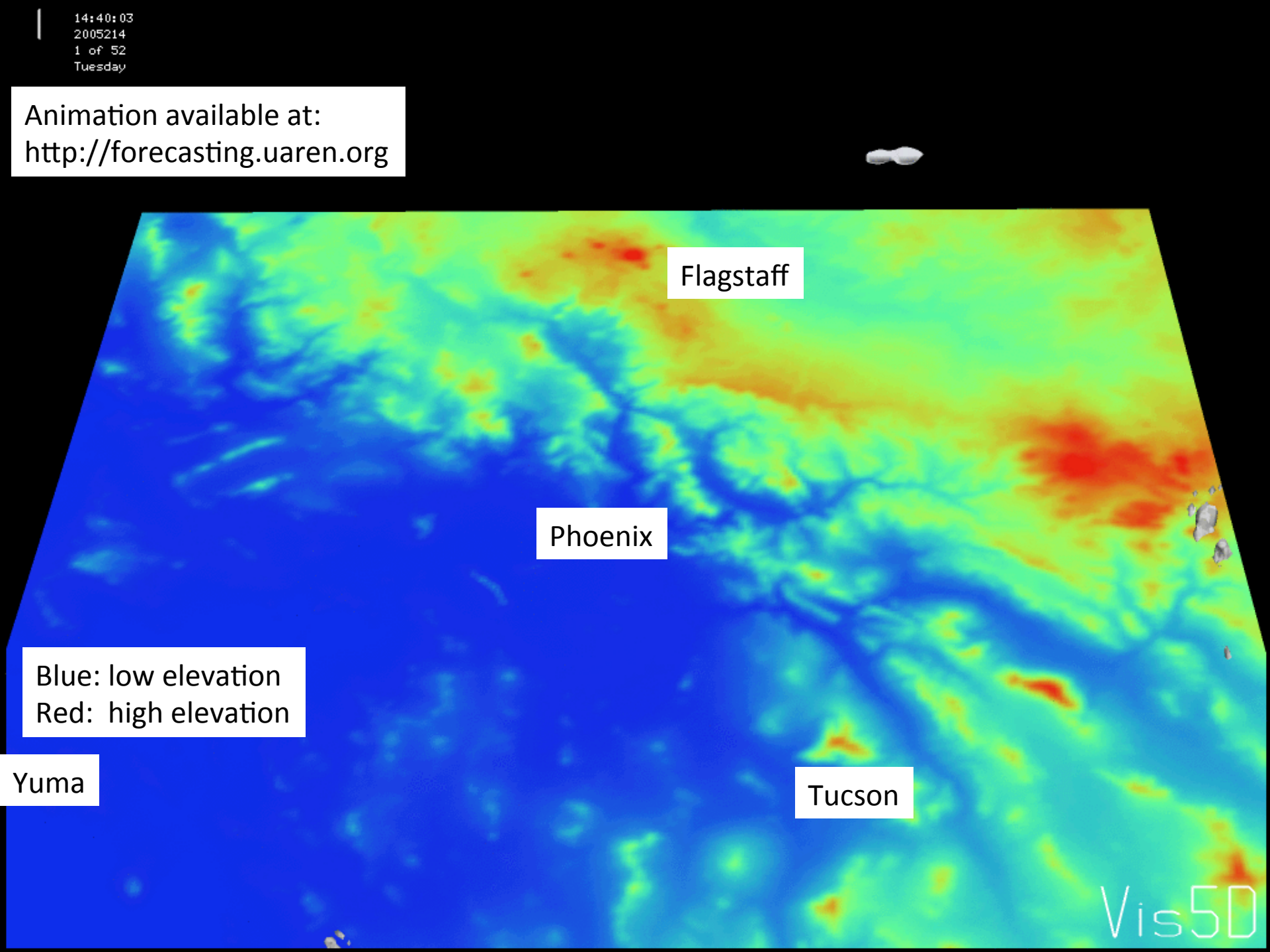
During the monsoon season and for significant weather events, a model discussion may be available.

Current Discussion Previous Discussion

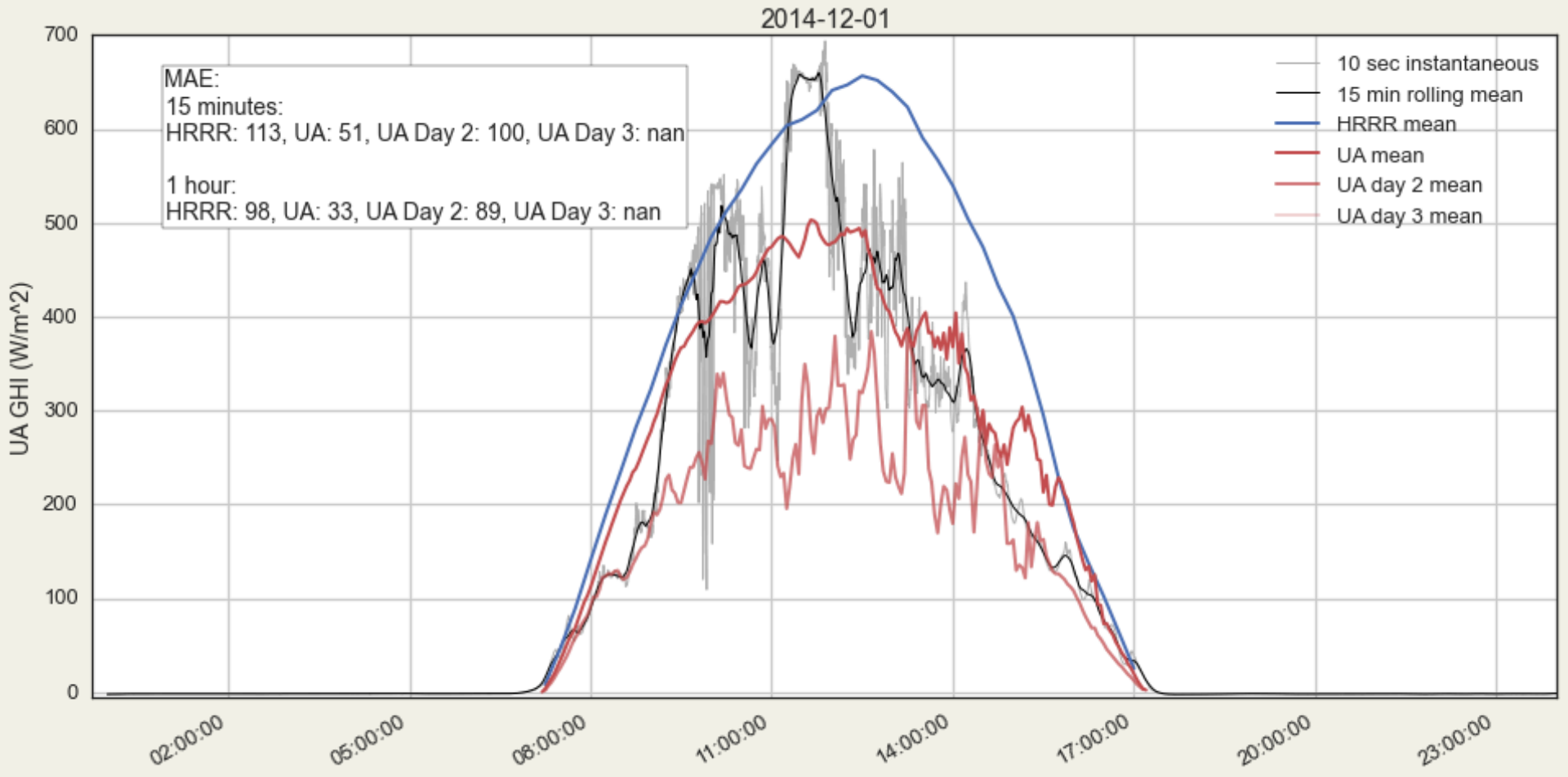
Model Products

	06z AZ WRF-GFS	06z AZ WRF-NAM	12z AZ WRF-NAM	12z AZ WRF-GFS	12z AZ WRF-RUC
Domain-Level Products					
Composite RADAR	1.8km|5.4km	1.8km|5.4km	1.8km|5.4km	1.8km|5.4km	1.8km|5.4km
Precipitation	1.8km|5.4km	1.8km|5.4km	1.8km|5.4km	1.8km|5.4km	1.8km|5.4km
Accumulated Precipitation	1.8km|5.4km 1.8kmz|5.4kmz	1.8km|5.4km 1.8kmz|5.4kmz	1.8km|5.4km 1.8kmz|5.4kmz	1.8km|5.4km 1.8kmz|5.4kmz	1.8km|5.4km 1.8kmz|5.4kmz
Accumulated Snow	1.8km|5.4km	1.8km|5.4km	1.8km|5.4km	1.8km|5.4km	1.8km|5.4km
Snow Cover	1.8km|5.4km	1.8km|5.4km	1.8km|5.4km	1.8km|5.4km	1.8km|5.4km
2m Temp	1.8km|5.4km 1.8kmz|5.4kmz	1.8km|5.4km 1.8kmz|5.4kmz	1.8km|5.4km 1.8kmz|5.4kmz	1.8km|5.4km 1.8kmz|5.4kmz	1.8km|5.4km 1.8kmz|5.4kmz
10m Wind	1.8km|5.4km 1.8kmz|5.4kmz	1.8km|5.4km 1.8kmz|5.4kmz	1.8km|5.4km 1.8kmz|5.4kmz	1.8km|5.4km 1.8kmz|5.4kmz	1.8km|5.4km 1.8kmz|5.4kmz
Precipitable					

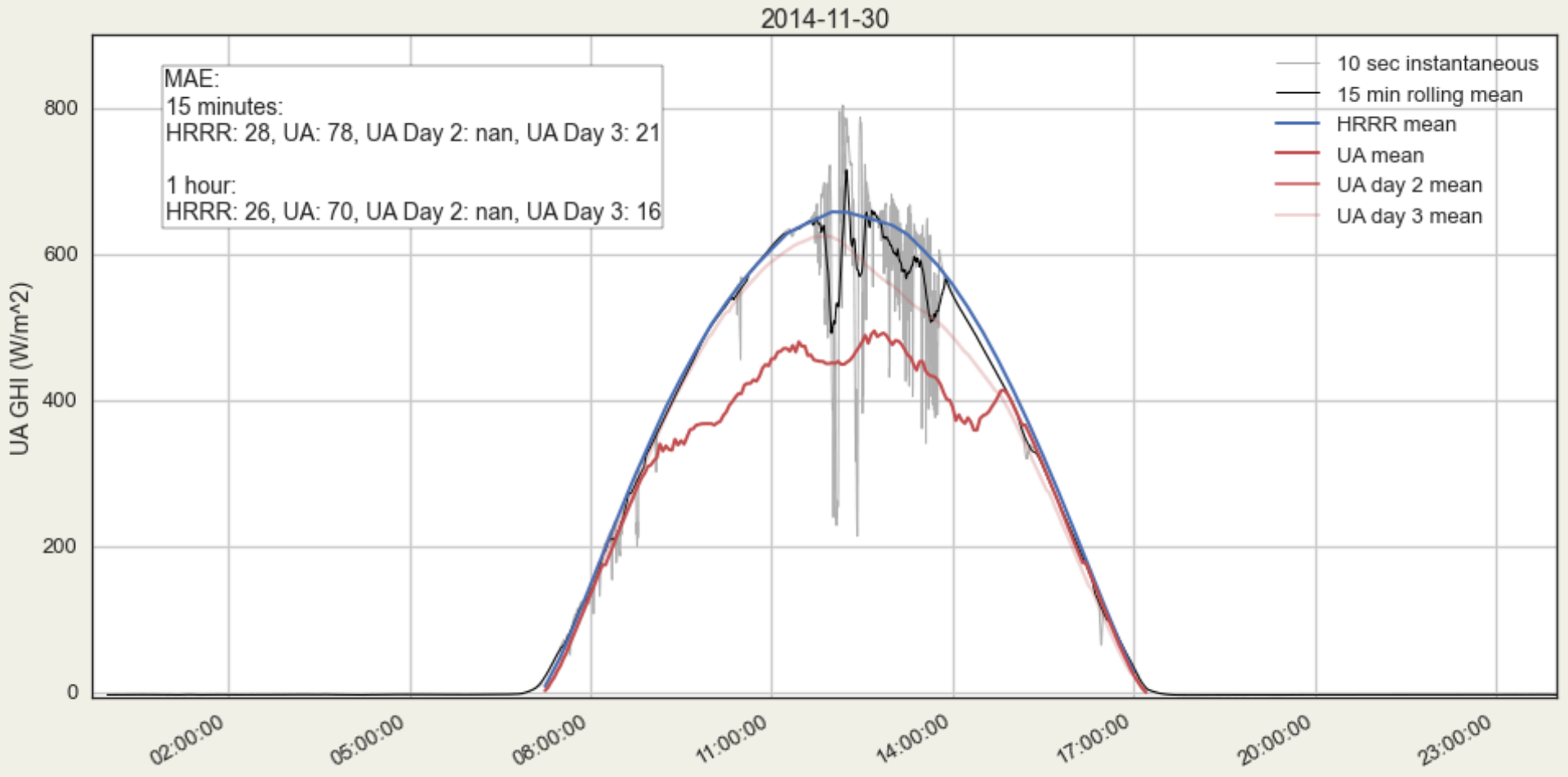
- Current Weather
- Campus Weather Conditions
- Campus Weather Plots (English Units)
- Daily, Weekly & Monthly Plots
- Solar Observatory Data (opens new tab or window)
- Satellite Imagery
- RADAR
- Lightning Plots (arizona.edu only)
- Maps and Plots
- Arizona Regional WRF Model Data
- Idaho Regional WRF Model Data
- GPS Precipitable Water
- Cloud movies
  - Full Day Cloud Camera Movie
  - Last 90 mins. Movie
  - Yesterday's Movie
  - "Best Of" ATMO Cloud Movies


14:40:03
2005214
1 of 52
Tuesday
Animation available at:
http://forecasting.uaren.org
Flagstaff
Phoenix
Blue: low elevation
Red: high elevation
Yuma
Tucson
Vis5D

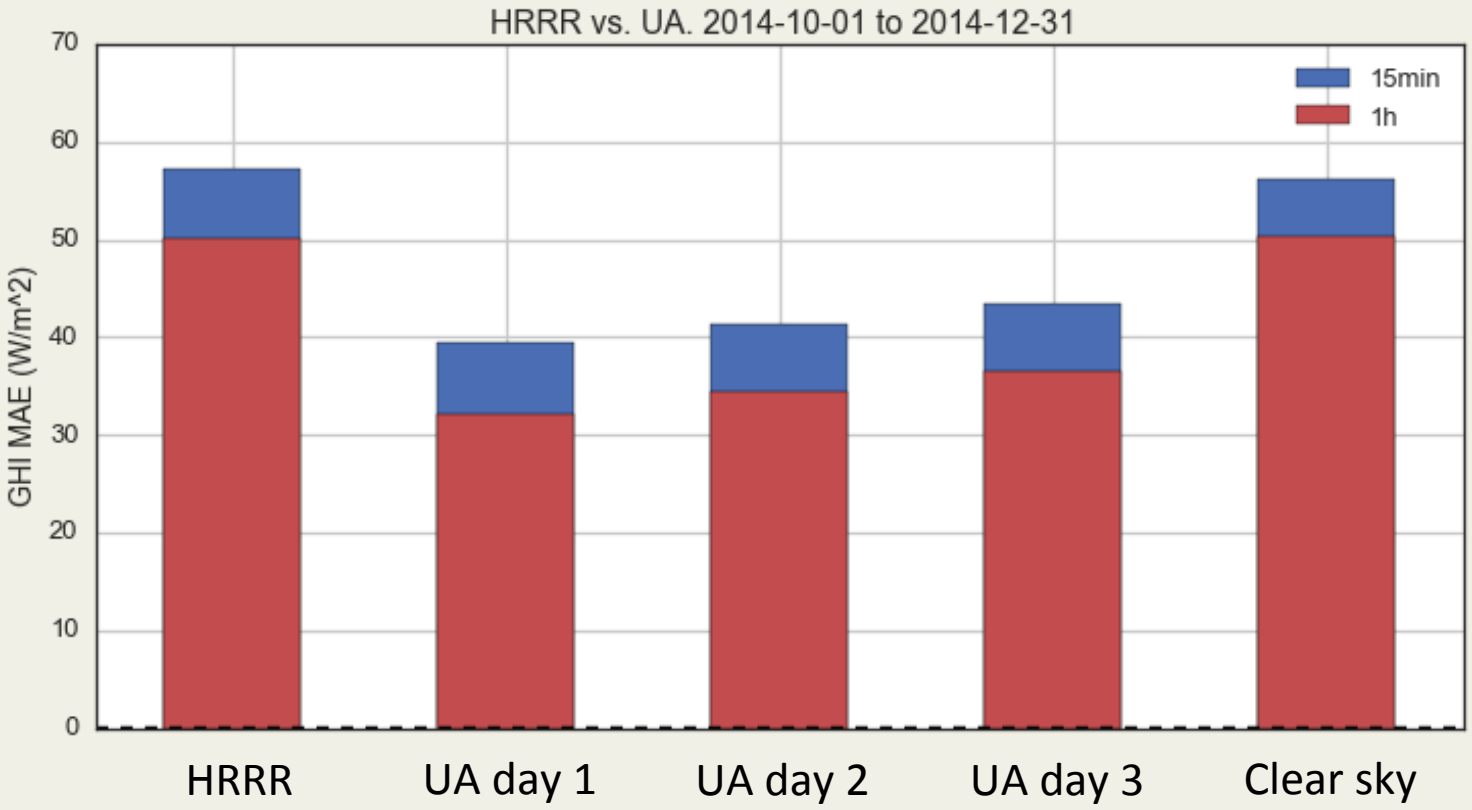
UA vs. HRRR Tucson GHI



UA vs. HRRR Tucson GHI



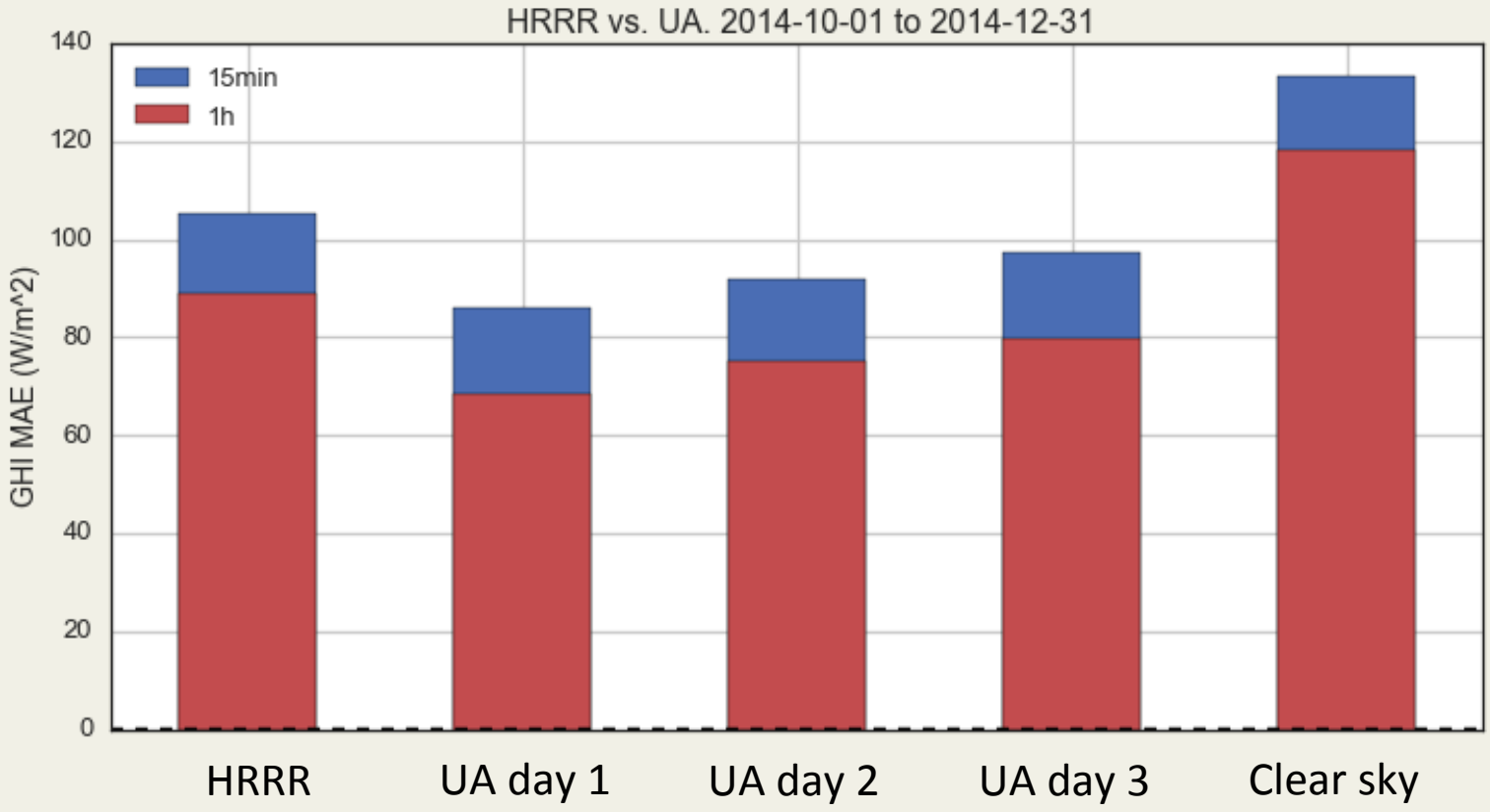
UA vs. NCEP HRRR Tucson GHI



Not a fair comparison because NCEP HRRR does not use the correct eqn. of time
So, we subtracted 15 minutes from HRRR time for approximate correction for these months
First HRRR point also discarded

Oct-Dec average of the daily average of 15 minute or 1 hour MAEs

UA vs. NCEP HRRR Tucson GHI



Limit analysis to large (MAE > 60) errors.

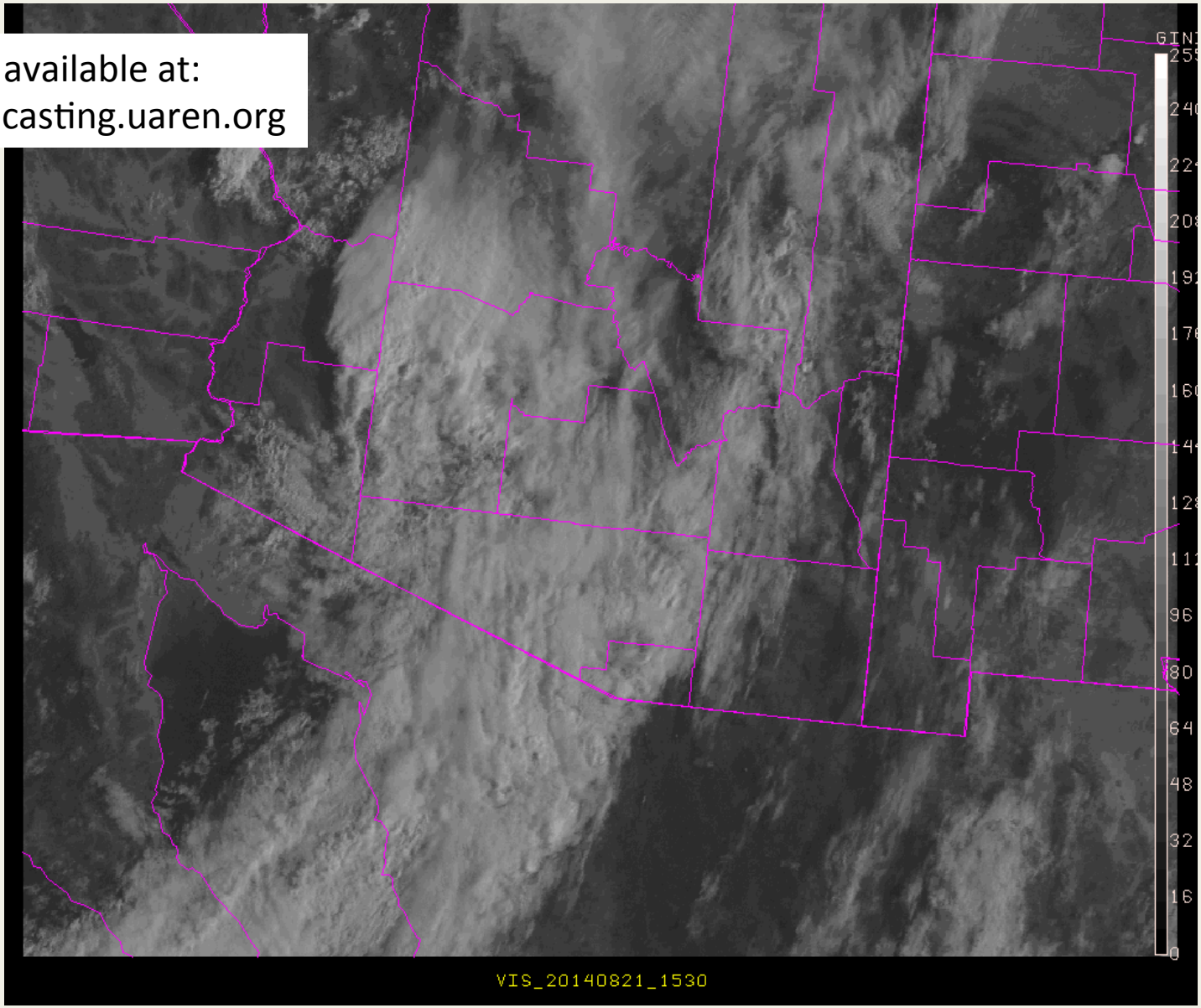
Eliminates clear days.

Helps HRRR, relatively, since it is much worse than UA on clear days.

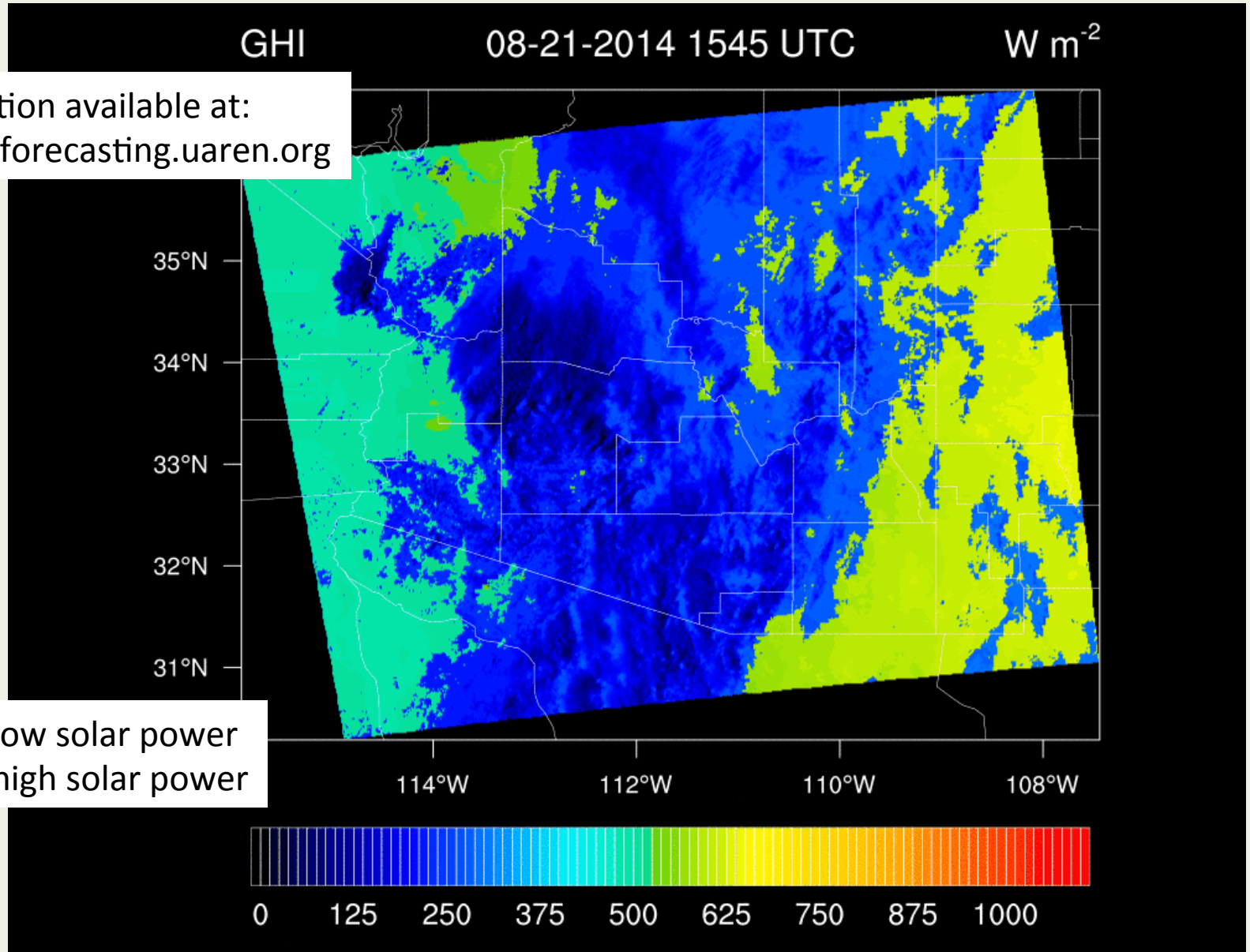
UA day 3 still outperforming NCEP HRRR

Satellite Imagery

Animation available at:
http://forecasting.uaren.org



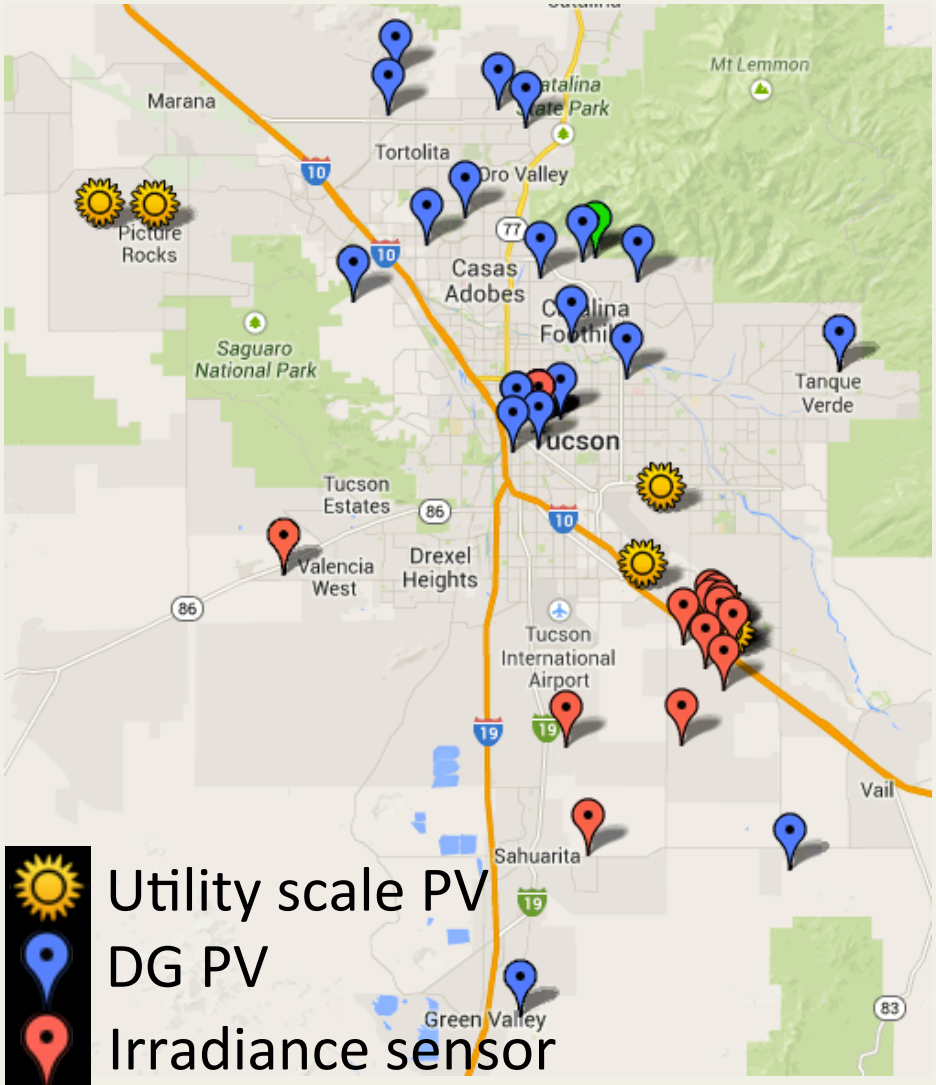
Satellite Derived Solar Irradiance



Animation available at:
http://forecasting.uaren.org

Blue: low solar power
Red: high solar power

Sensor network forecasting



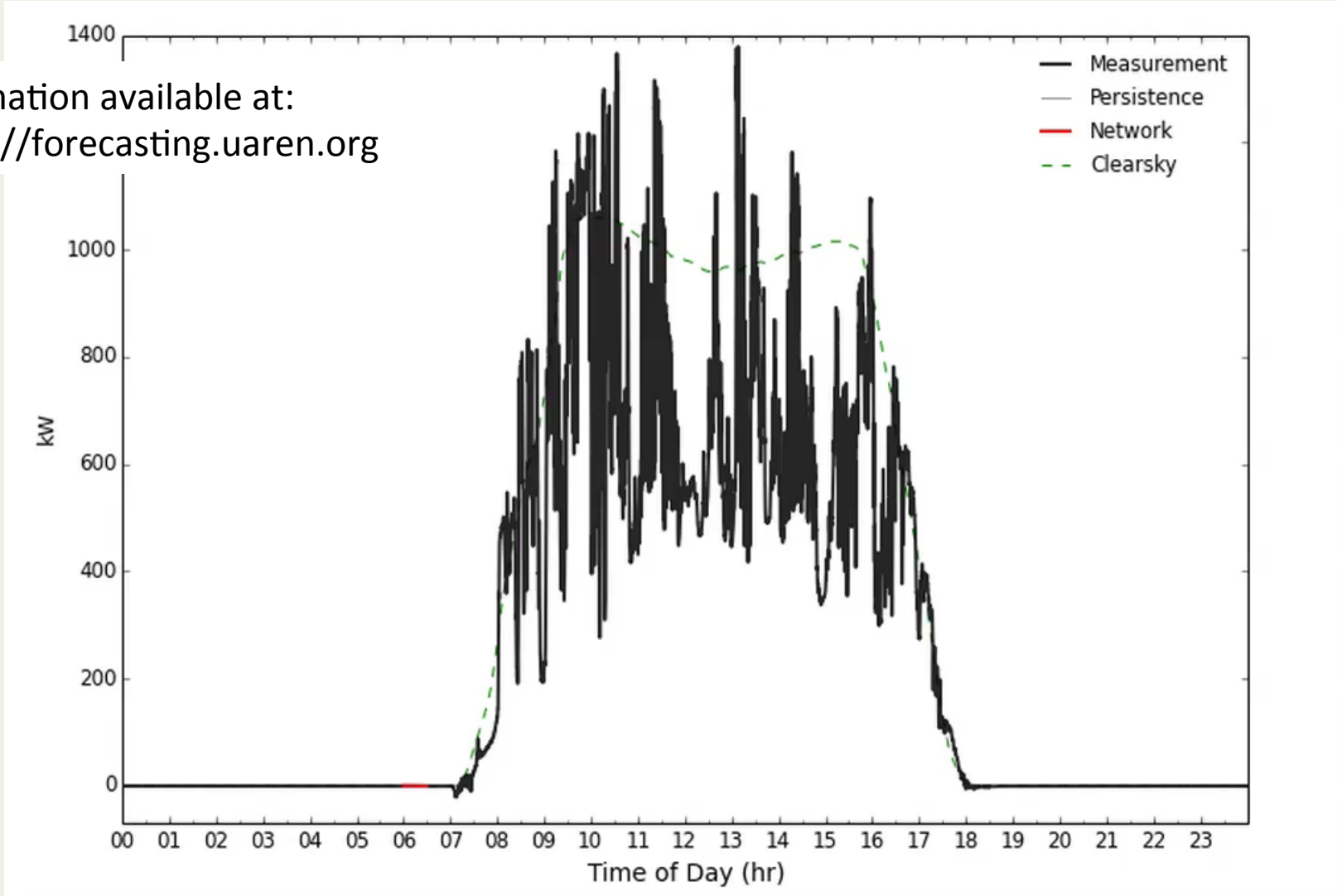
Partnered with local PV installer Technicians for Sustainability to obtain access to real-time (5 min latency) data feeds of residential PV systems.

Homebuilt irradiance sensors will cell modems (see A. Lorenzo, AMS 2015).

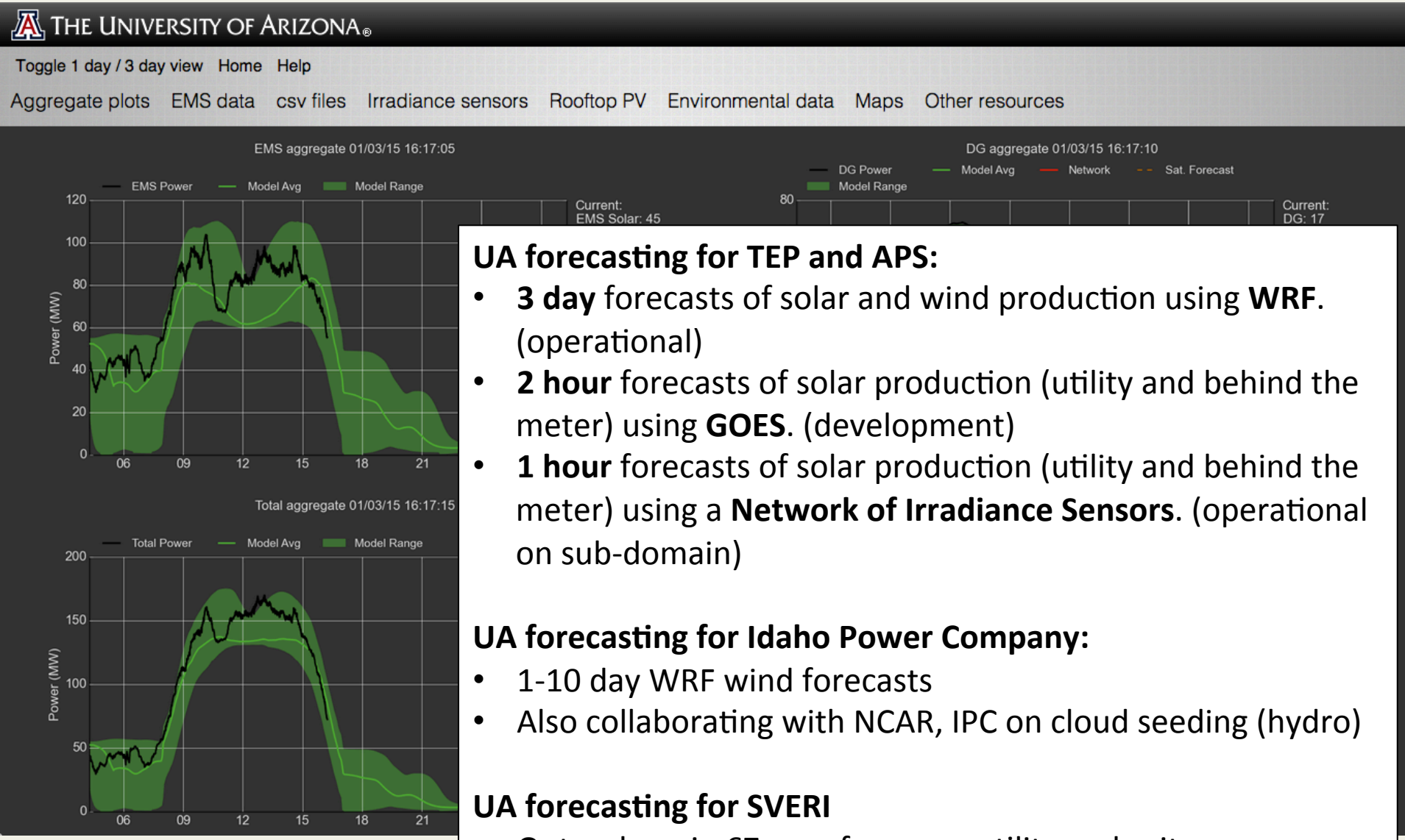
Network of rooftop solar data and irradiance sensors provides most accurate 30 minute forecasts.

Network Forecast

Animation available at:
http://forecasting.uaren.org



UA Renewable Power Forecasting



UA forecasting for TEP and APS:

- **3 day** forecasts of solar and wind production using **WRF**. (operational)
- **2 hour** forecasts of solar production (utility and behind the meter) using **GOES**. (development)
- **1 hour** forecasts of solar production (utility and behind the meter) using a **Network of Irradiance Sensors**. (operational on sub-domain)

UA forecasting for Idaho Power Company:

- 1-10 day WRF wind forecasts
- Also collaborating with NCAR, IPC on cloud seeding (hydro)

UA forecasting for SVERI

- Outer domain 6Z runs for every utility scale site

Thanks to our funding agencies

Major support from

DOE EERE Postdoctoral Fellowship

Additional support from

The SVERI utilities

Arizona Department of Environmental Quality

U of A