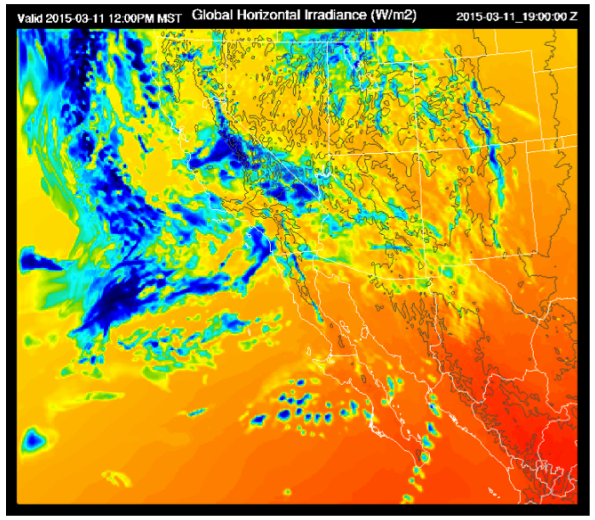
UA Regional Weather and Power Forecasts

UA-WRF



Power Forecasts Driven
by Open Source Software

PVPerformance
MODELING COLLABORATIVE

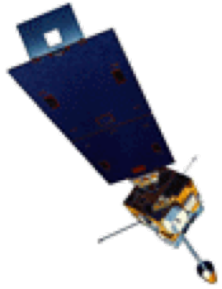
Forecast users

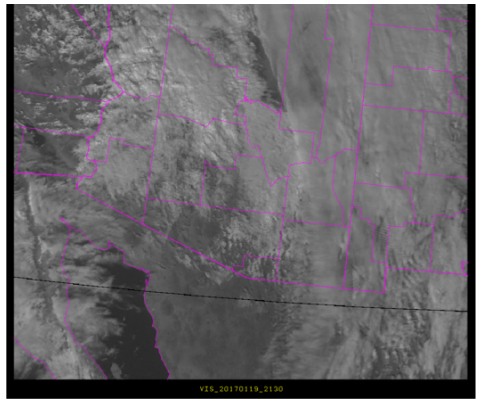
TEP PNM aps IDAHO POWER
An IDACORP Company

Data Assimilation

Power Data

GOES imager





forecasting.energy.arizona.edu

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Mike Leuthold (Regional Model Mng., HAS)

Tony Lorenzo (Asst. Research Sci., HAS)

Travis Harty (GRA, Applied Math)

Matti Morzfeld (Asst. Prof., Applied Math)

Eric Betterton (Dept. Head, Prof., HAS)

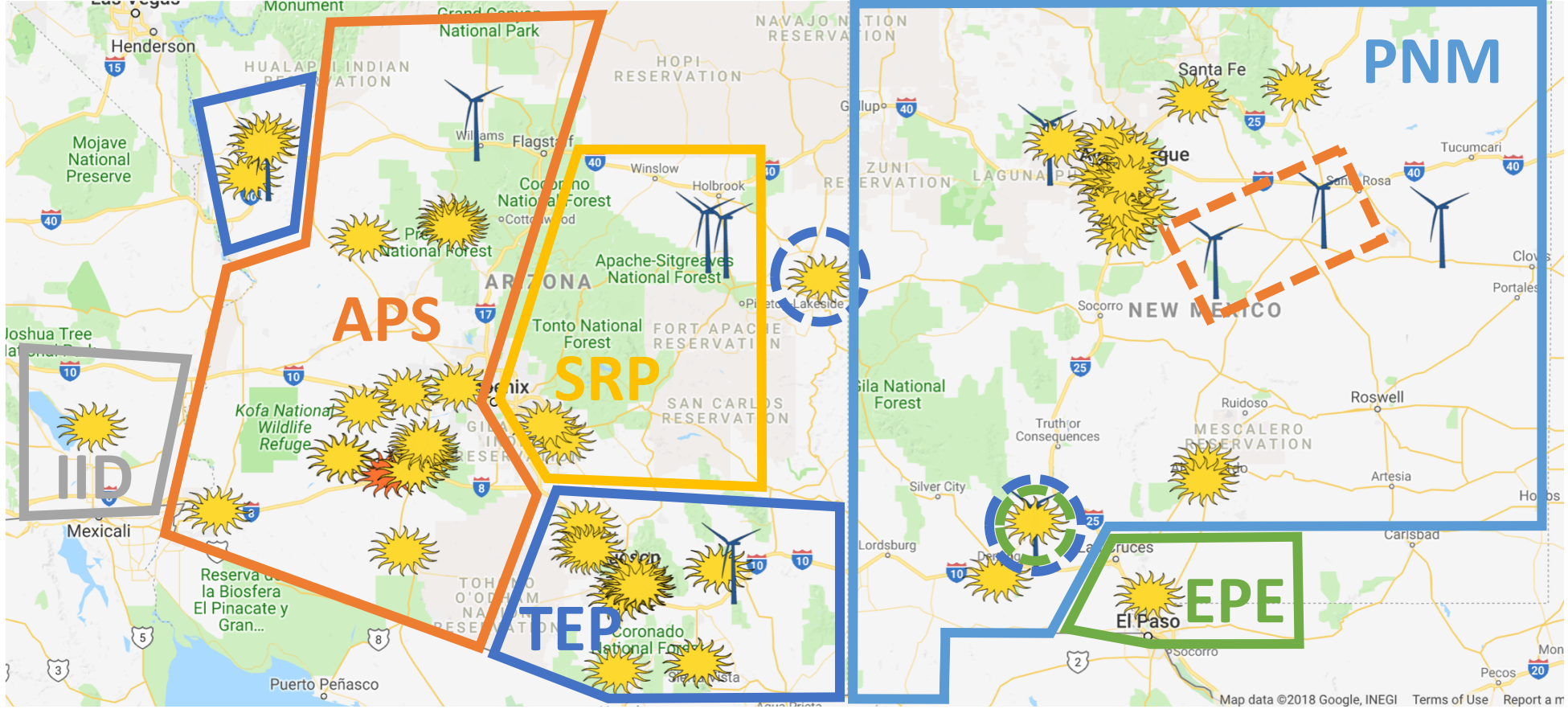
Utility Wind
820 MW

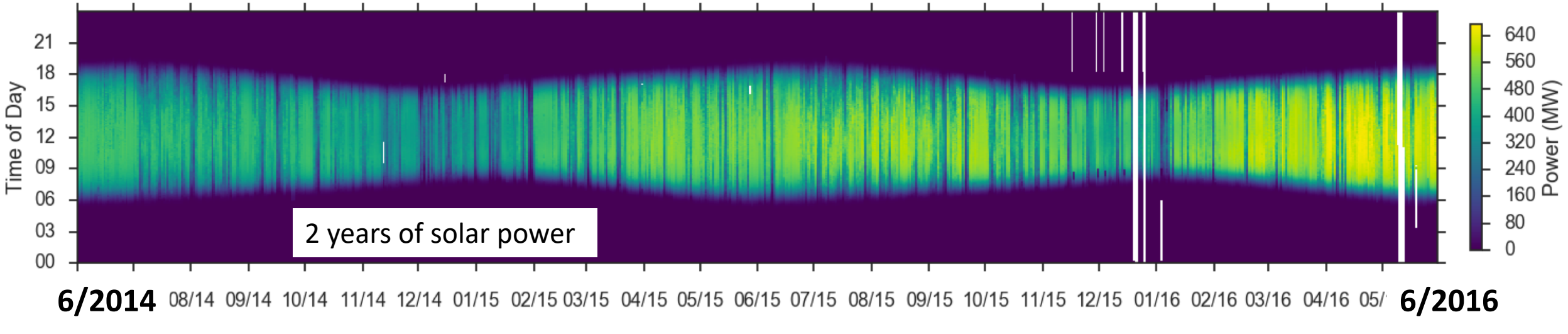
Utility Solar
1080 MW

Distributed Solar
1250 MW

Total
3150 MW

Load
7000 - 24000 MW





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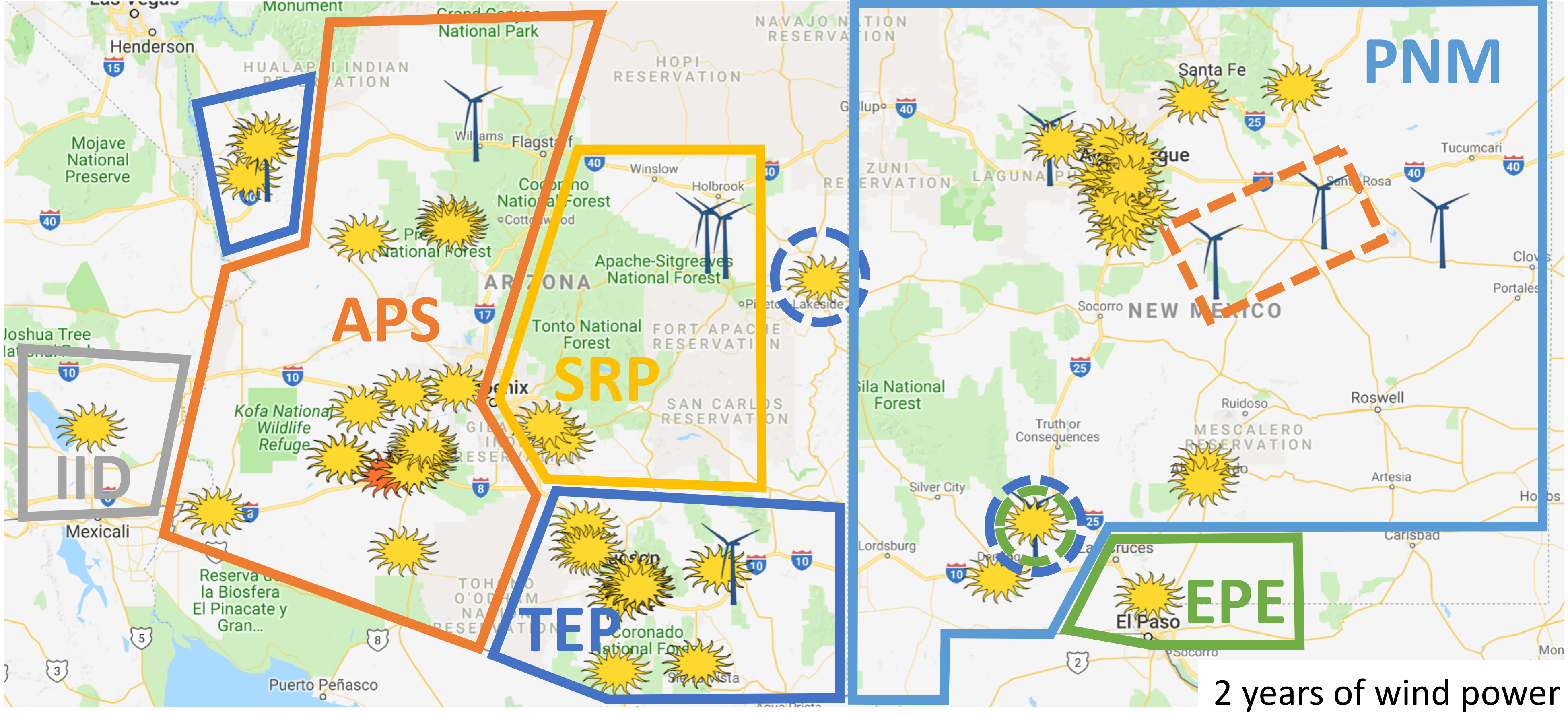

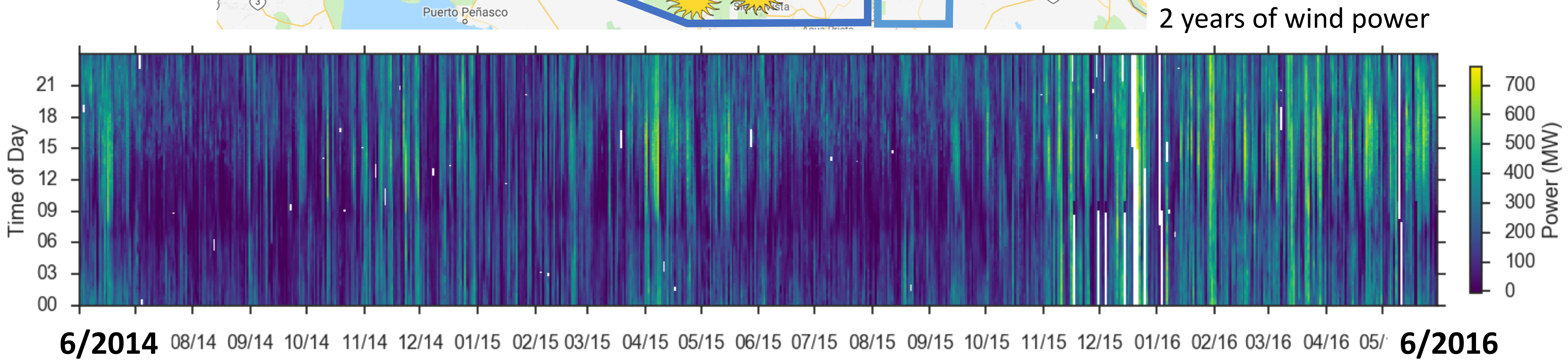

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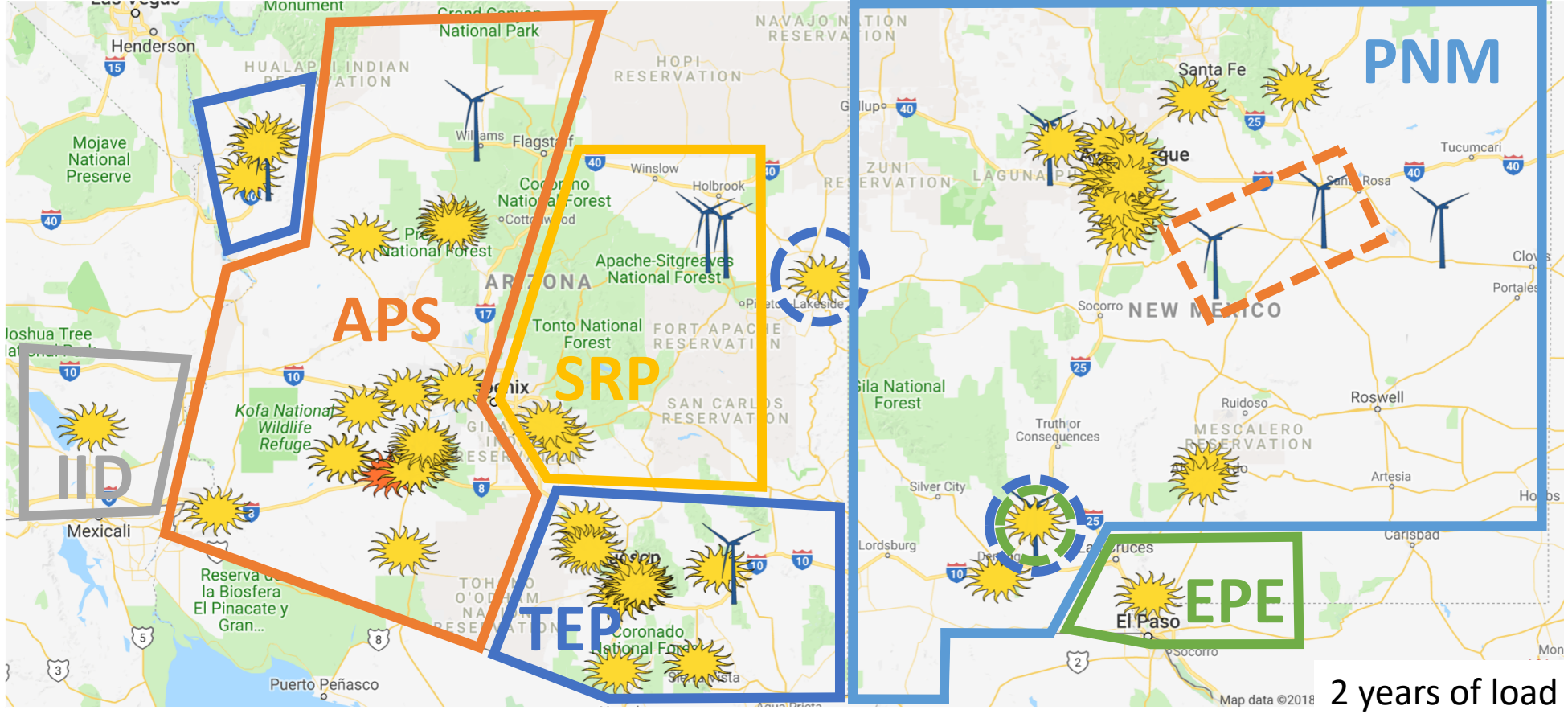
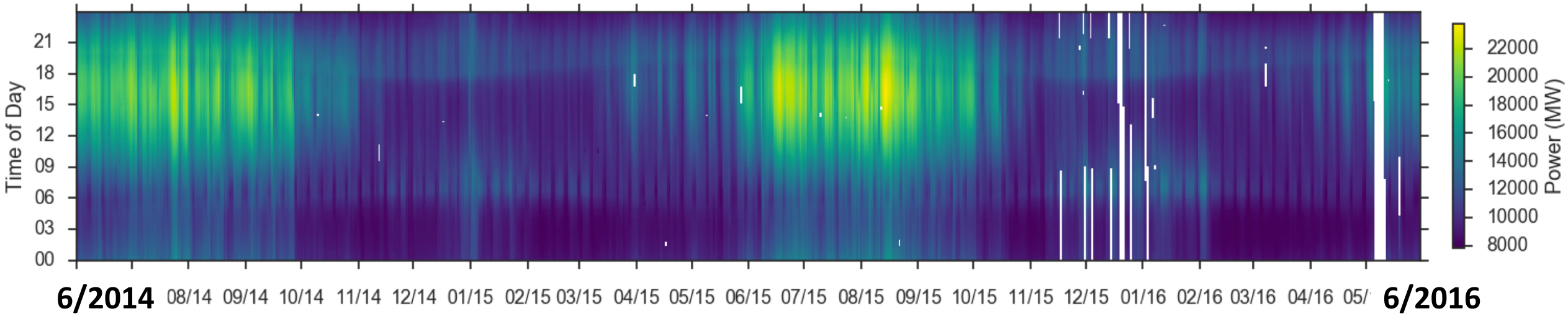


2 years of load



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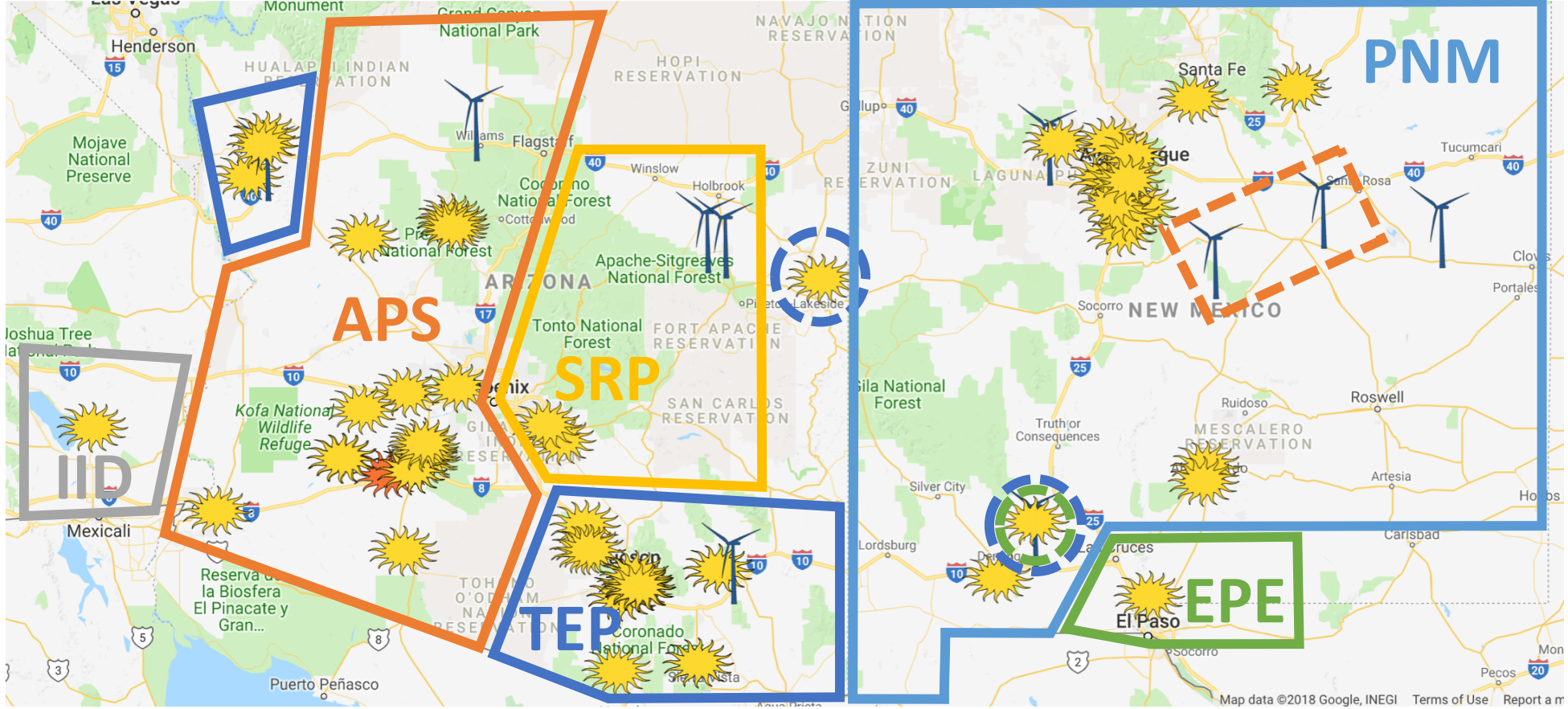
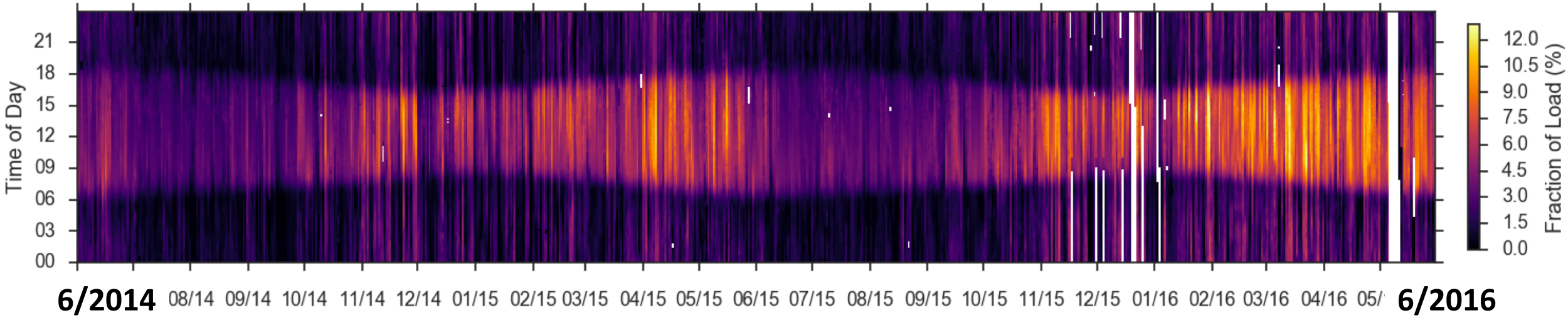
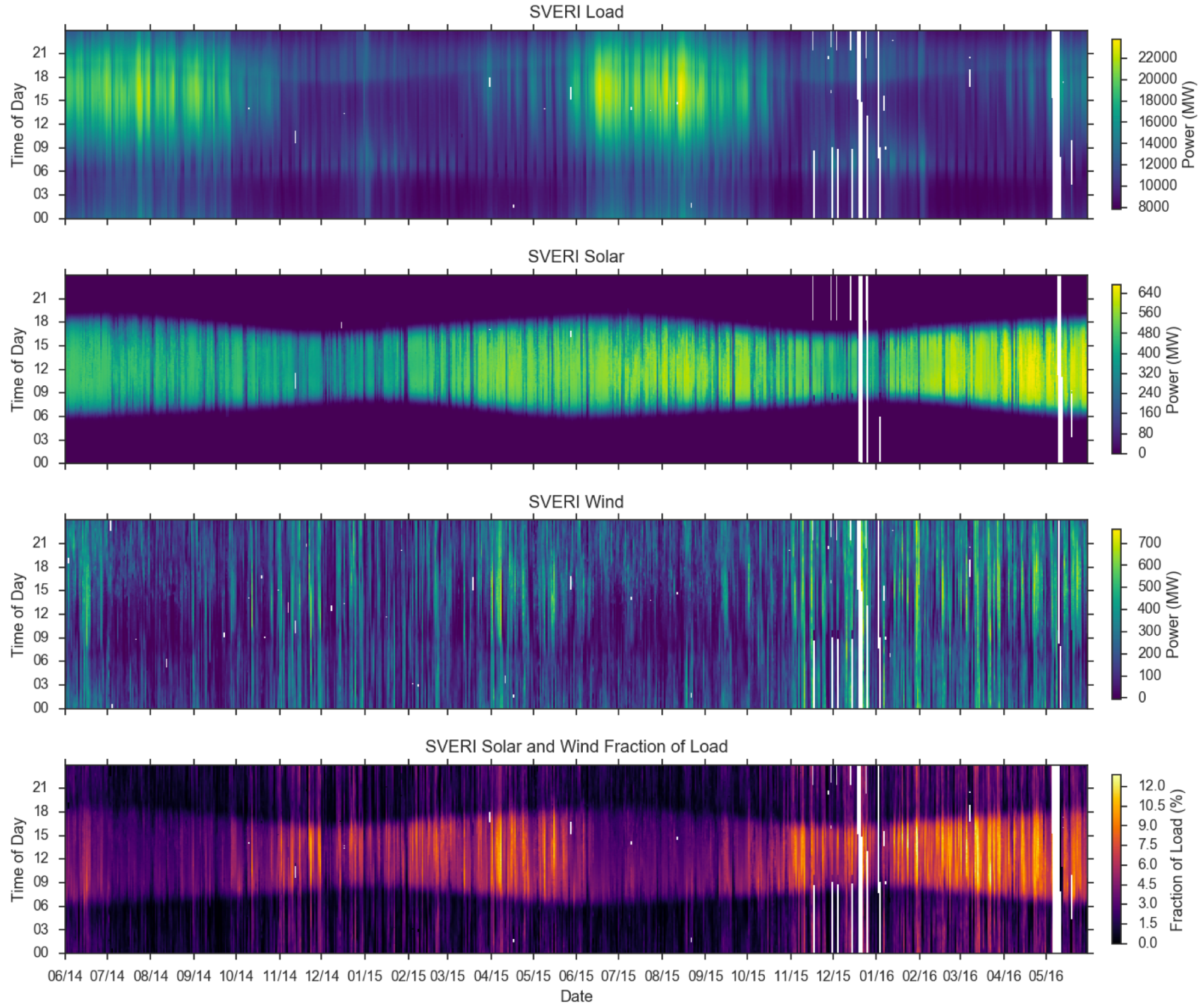
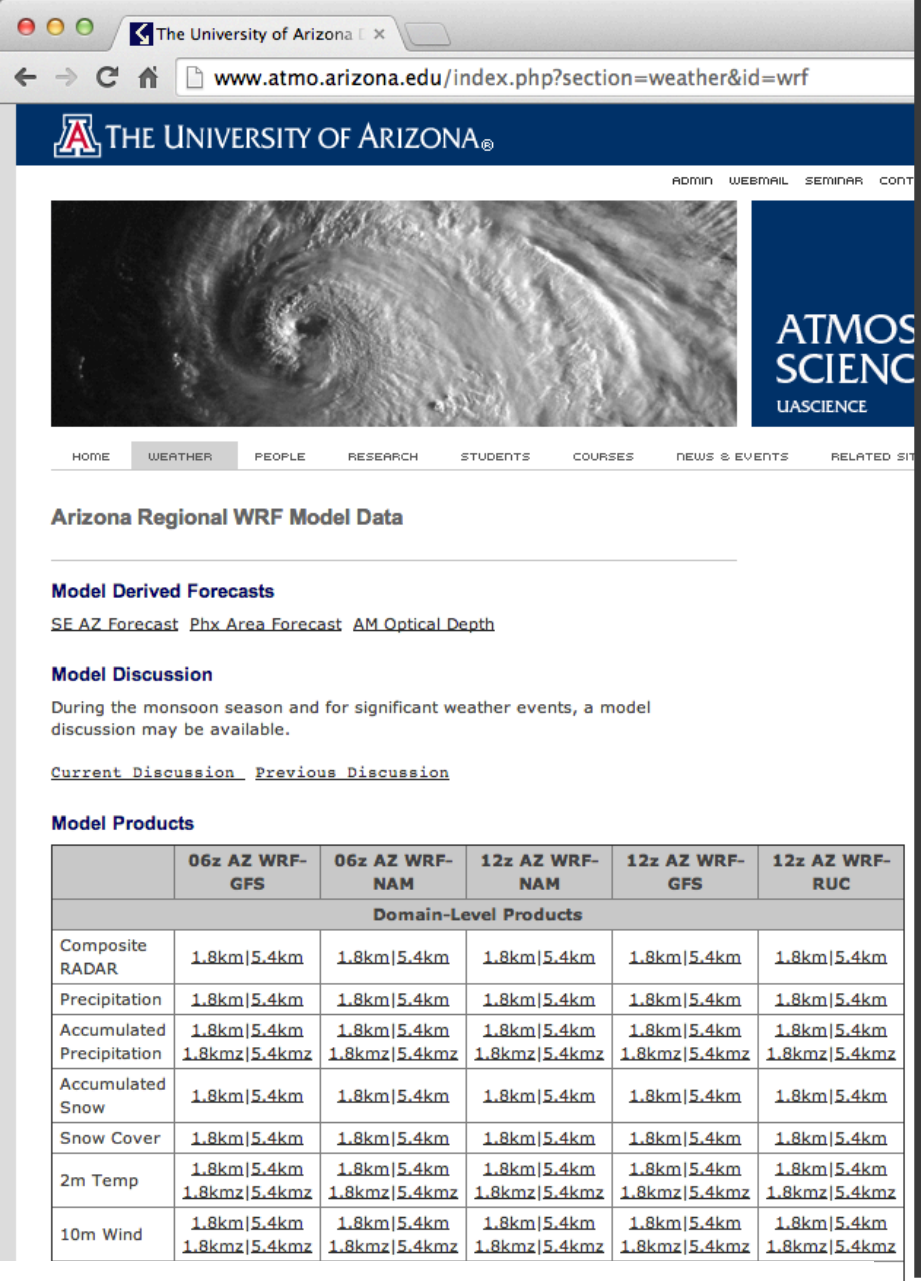
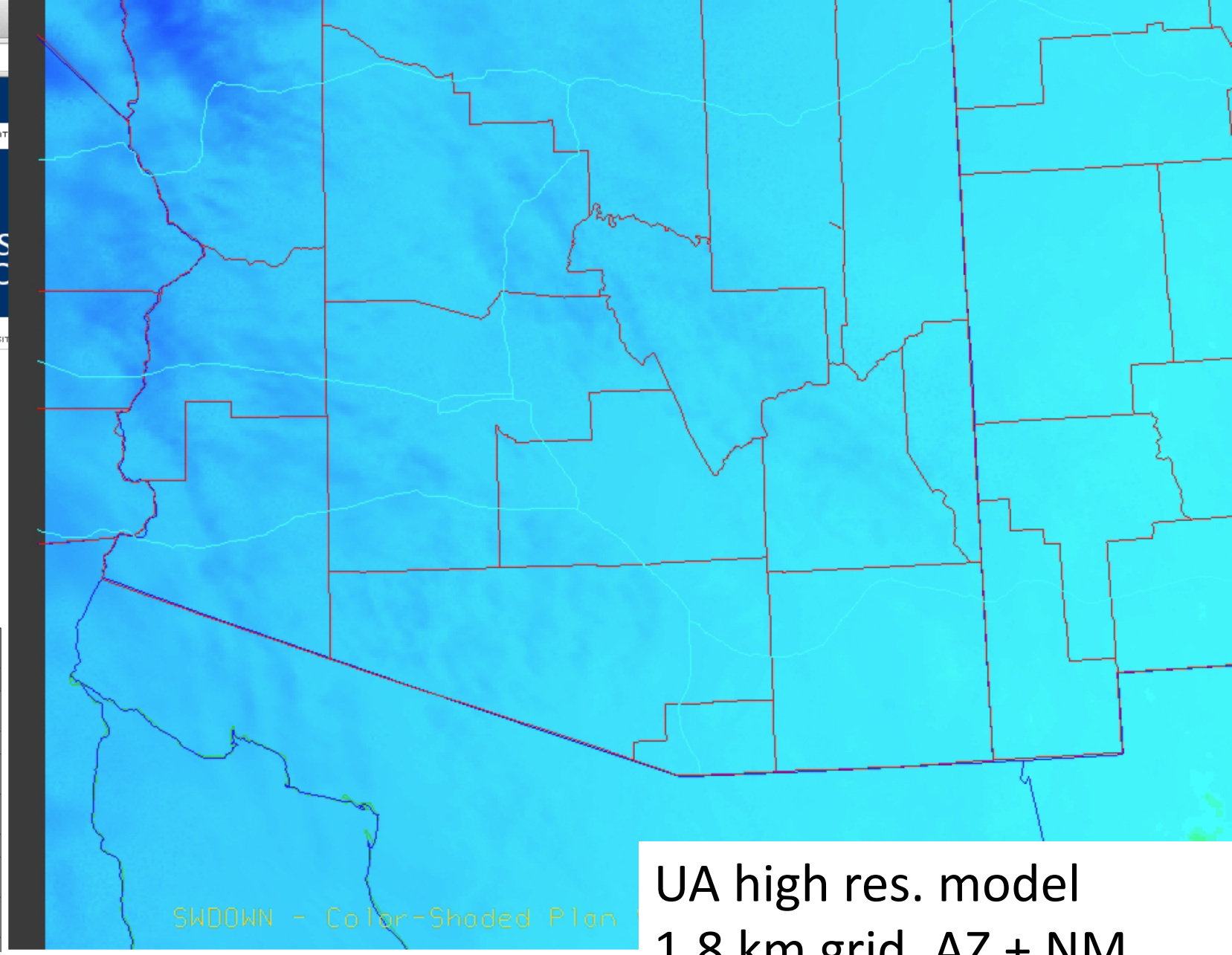





SVERI Load
Time of Day
21
18
15
12
09
06
03
00
22000
20000
18000
16000
14000
12000
10000
8000
Power (MW)
SVERI Solar
640
560
480
400
320
240
160
80
0
SVERI Wind
700
600
500
400
300
200
100
0
SVERI Solar and Wind Fraction of Load
12.0
10.5
9.0
7.5
6.0
4.5
3.0
1.5
0.0
Fraction of Load (%)
06/14 07/14 08/14 09/14 10/14 11/14 12/14 01/15 02/15 03/15 04/15 05/15 06/15 07/15 08/15 09/15 10/15 11/15 12/15 01/16 02/16 03/16 04/16 05/16
Date

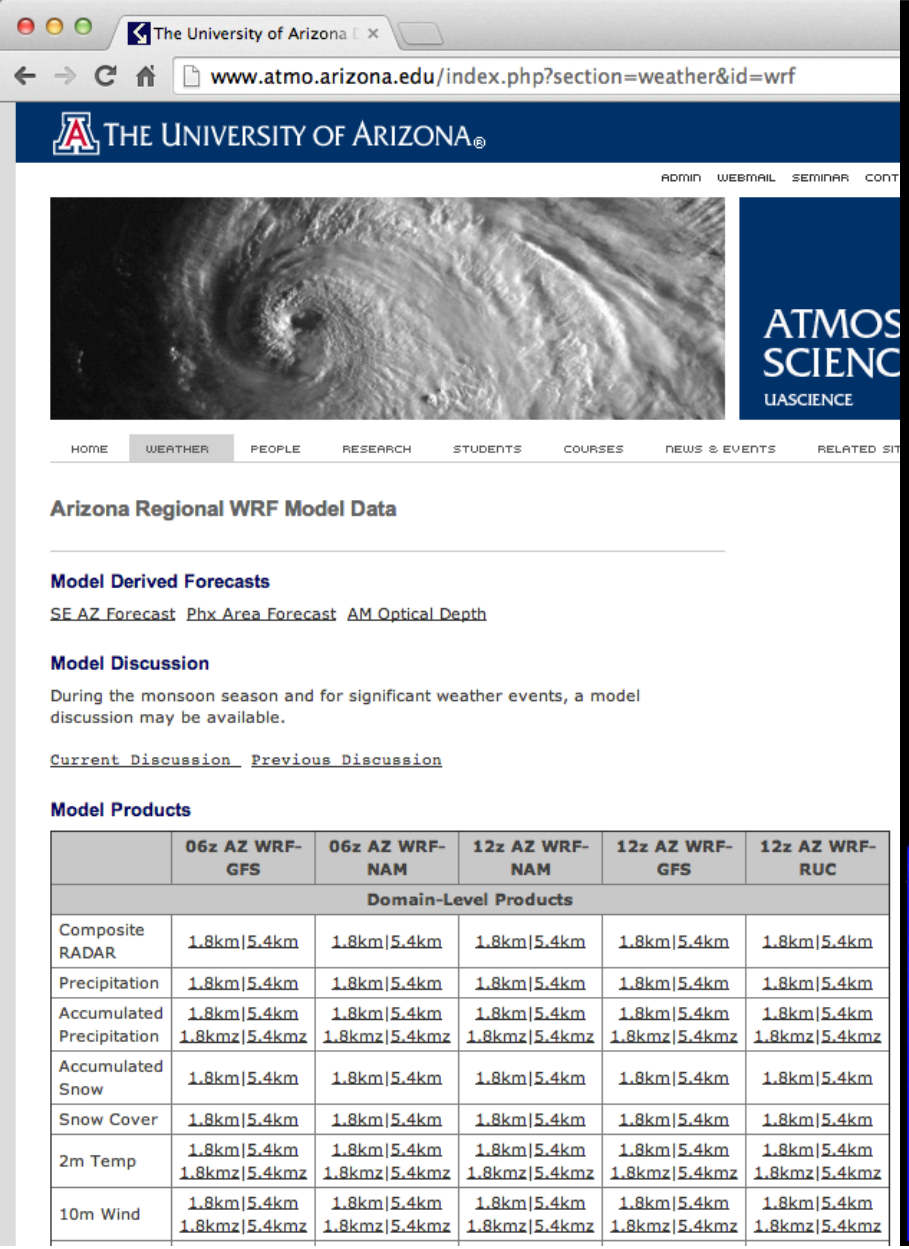


	06z AZ WRF-GFS	06z AZ WRF-NAM	12z AZ WRF-NAM	12z AZ WRF-GFS	12z AZ WRF-RUC
Domain-Level Products					
Composite RADAR	1.8km|5.4km	1.8km|5.4km	1.8km|5.4km	1.8km|5.4km	1.8km|5.4km
Precipitation	1.8km|5.4km	1.8km|5.4km	1.8km|5.4km	1.8km|5.4km	1.8km|5.4km
Accumulated Precipitation	1.8km|5.4km 1.8kmz|5.4kmz	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



UA WRF weather forecasts available at atmo.arizona.edu

UA high res. model
1.8 km grid, AZ + NM
Global Horiz. Irradiance



	06z AZ WRF-GFS	06z AZ WRF-NAM	12z AZ WRF-NAM	12z AZ WRF-GFS	12z AZ WRF-RUC
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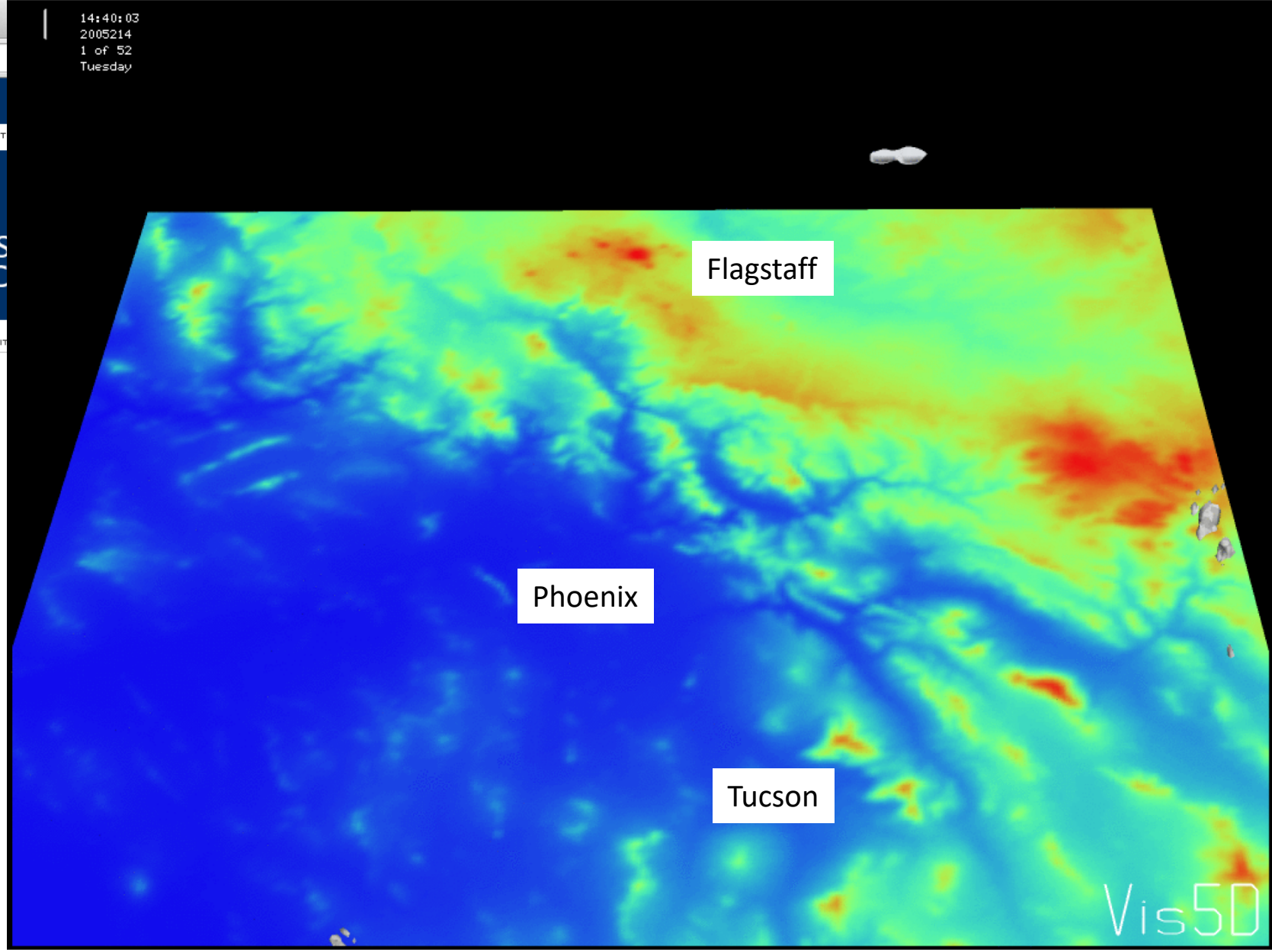
Composite RADAR	1.8km|5.4km	1.8km|5.4km	1.8km|5.4km	1.8km|5.4km	1.8km|5.4km
Precipitation	1.8km|5.4km	1.8km|5.4km	1.8km|5.4km	1.8km|5.4km	1.8km|5.4km
Accumulated Precipitation	1.8km|5.4km 1.8kmz|5.4kmz	1.8km|5.4km 1.8kmz|5.4kmz	1.8km|5.4km 1.8kmz|5.4kmz	1.8km|5.4km 1.8kmz|5.4kmz	1.8km|5.4km 1.8kmz|5.4kmz
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



UA WRF weather forecasts available at atmo.arizona.edu

5.4 km, 1.8 km nested domains
Configured to perform well in SW US

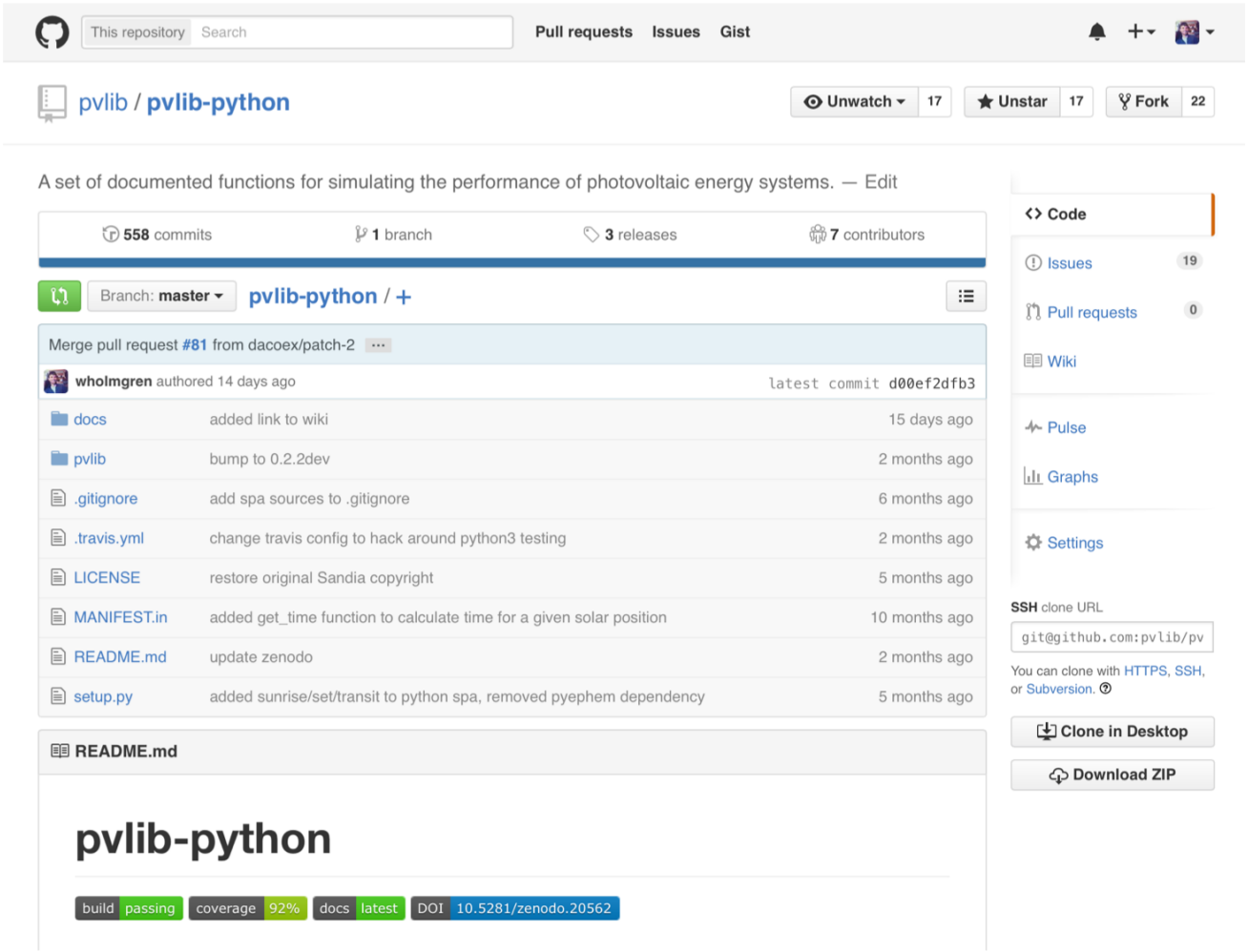
Blue: low elevation
Red: high elevation

3D Visualization of Monsoon Thunderstorms
Animation available at:
http://forecasting.energy.arizona.edu

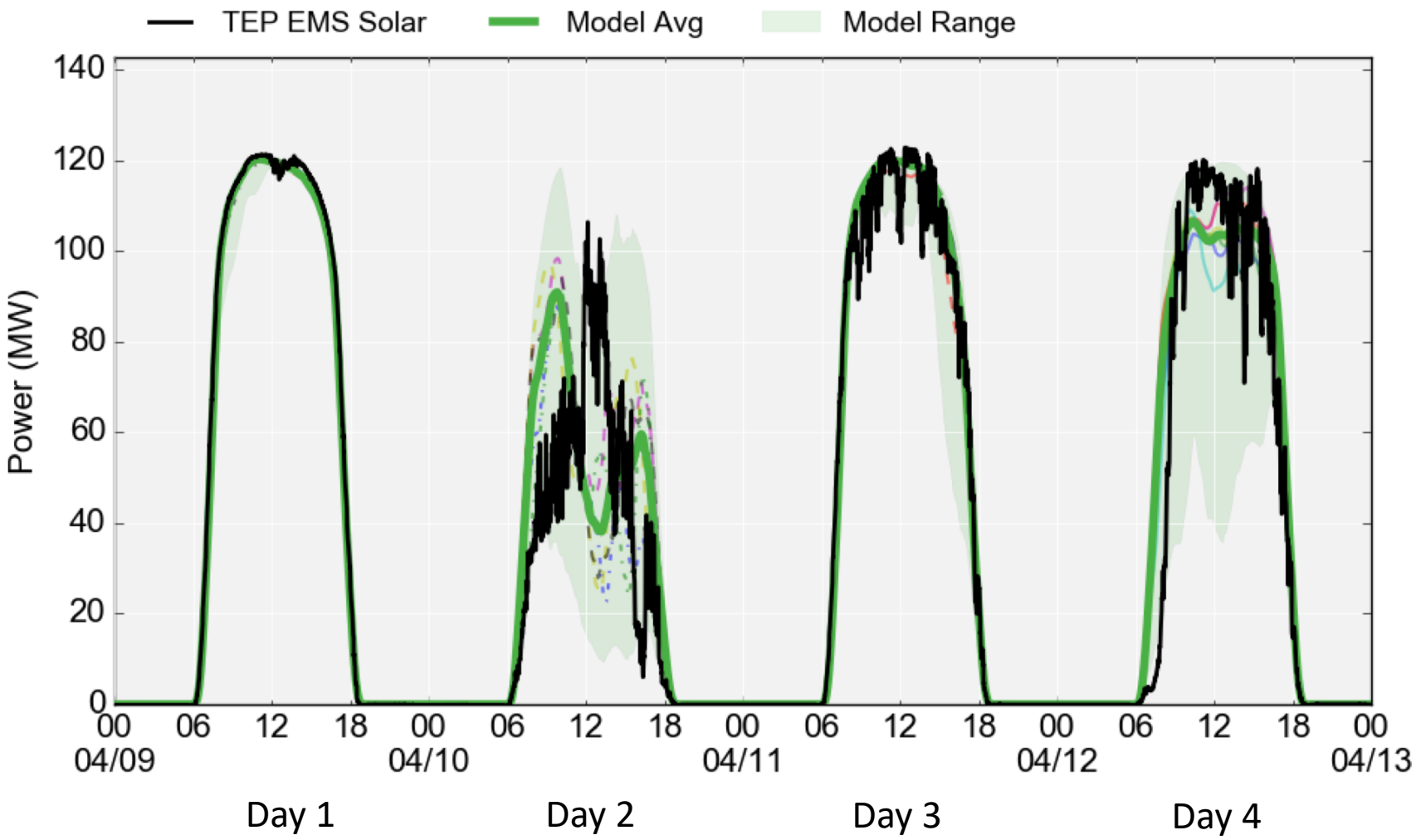
PVLib Python

- Tool for modeling solar power systems
- Foundation of UA solar power forecasts
- Open source
- Contributions from UA, Sandia, Sunpower, First Solar, DNV-GL, and others from across the world.
- Includes standard, benchmark forecast tools

github.com/pvlib

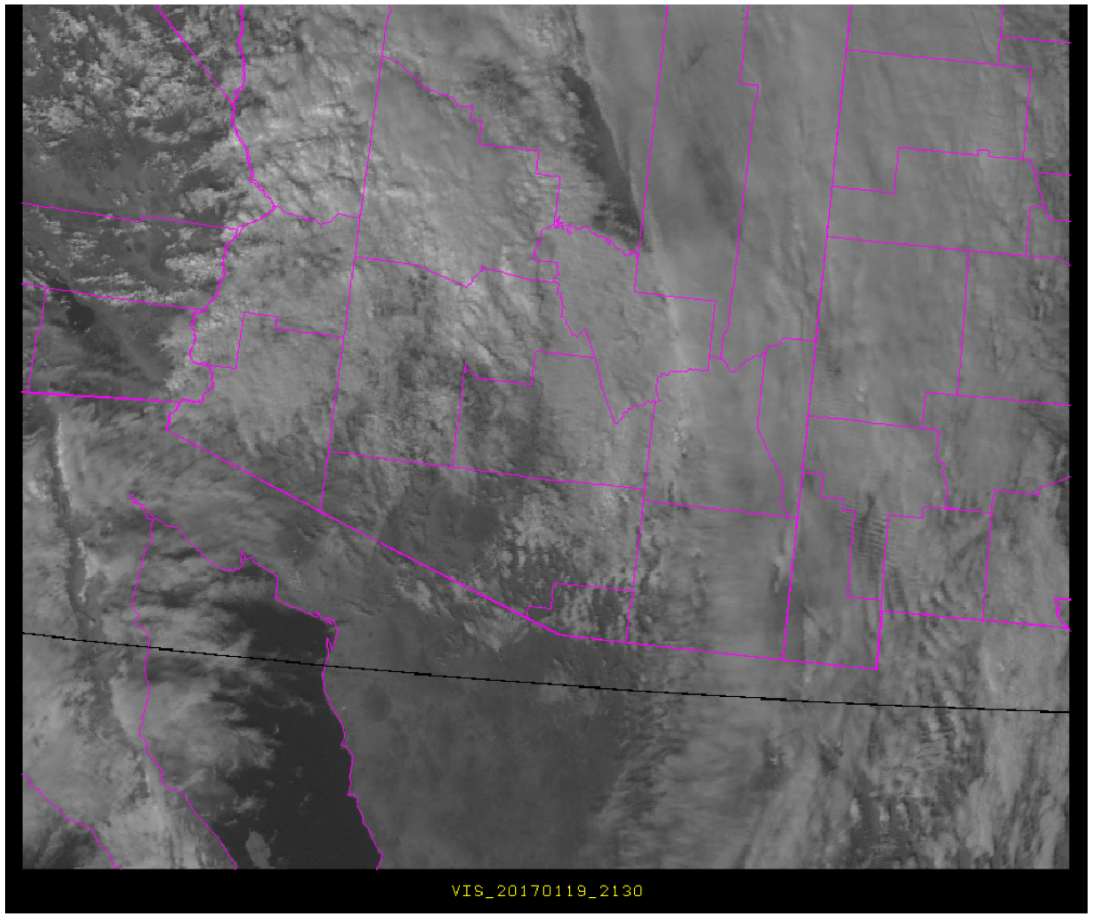


Solar power forecast from UA weather model



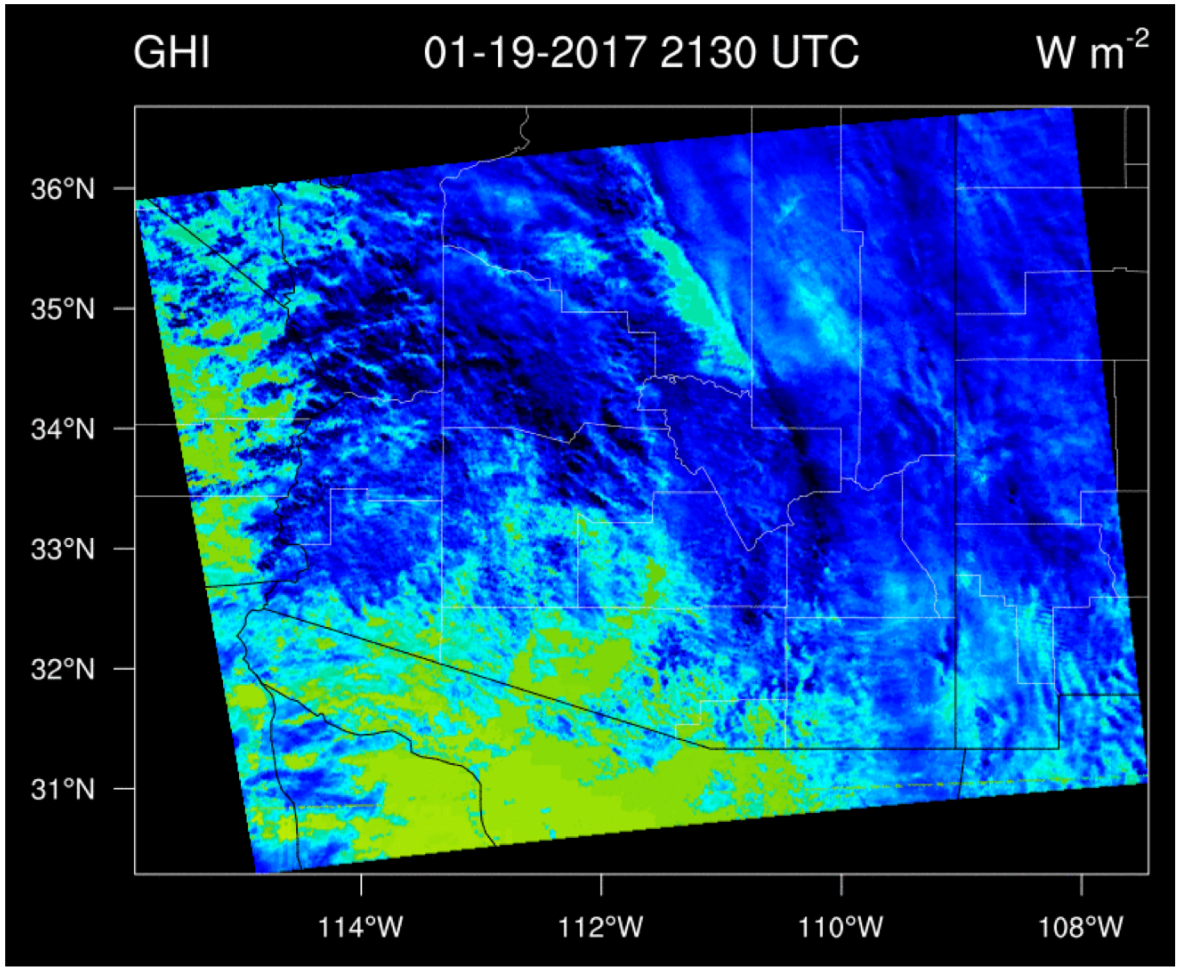
Satellite Derived Irradiance

Light reflected from the tops of clouds



model

Light that gets through clouds



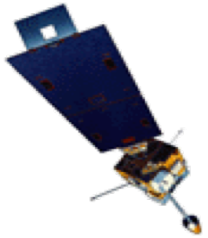
Ground irradiance data to improve satellite irradiance estimates

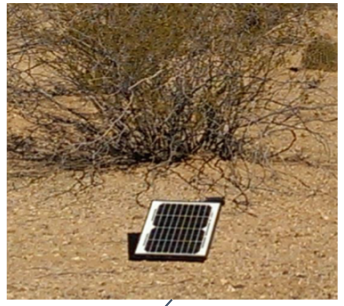
Satellite irradiance estimates rely on algorithms that convert the observation (light reflected by cloud tops) into transmitted irradiance.

Use ground PV and irradiance data to improve estimates by 25%

Unique method developed at UA

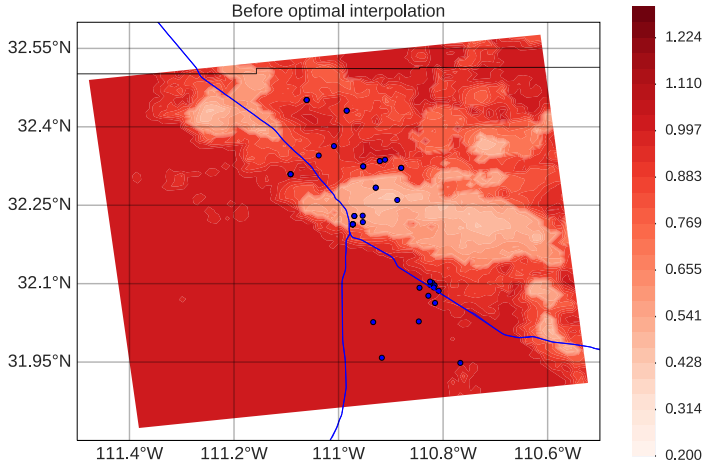
Published in Solar Energy (Lorenzo 2017)

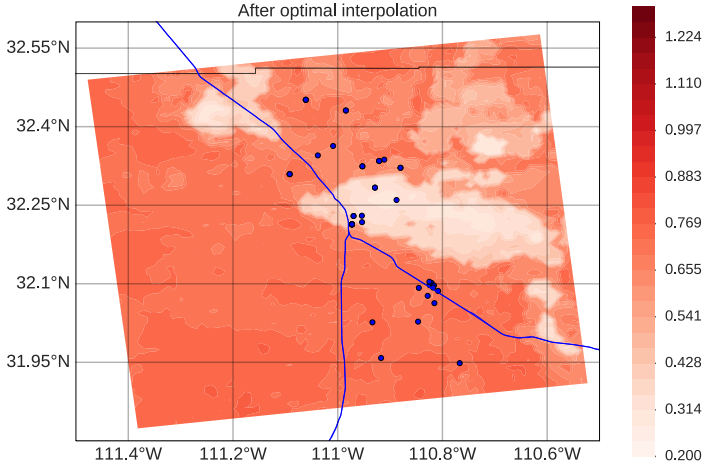




Optimal Interpolation

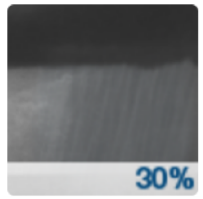
Better satellite-derived estimate of GHI



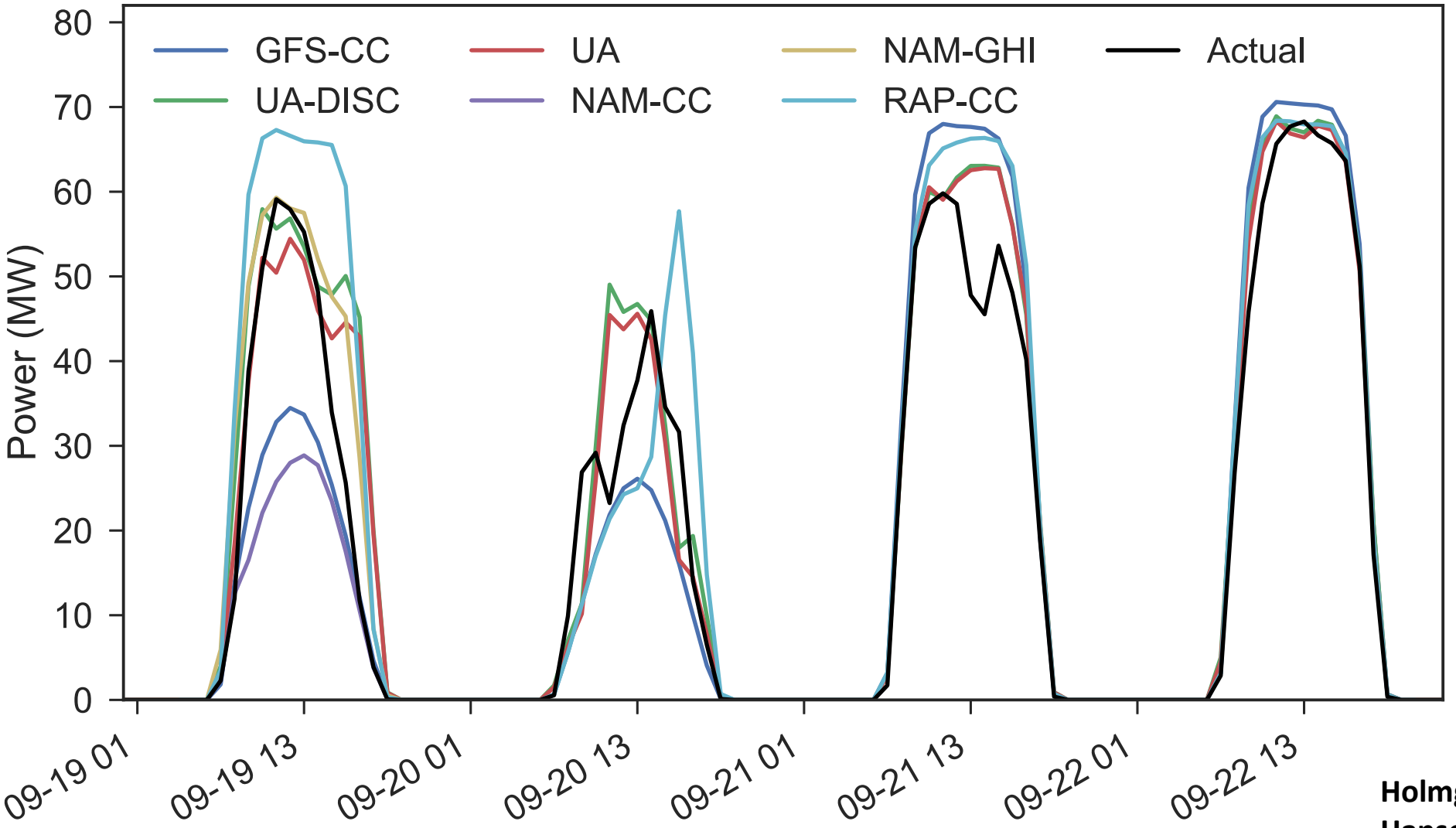


What about the forecasts from NOAA/NWS?

Extended Forecast for
Tucson International Airport AZ

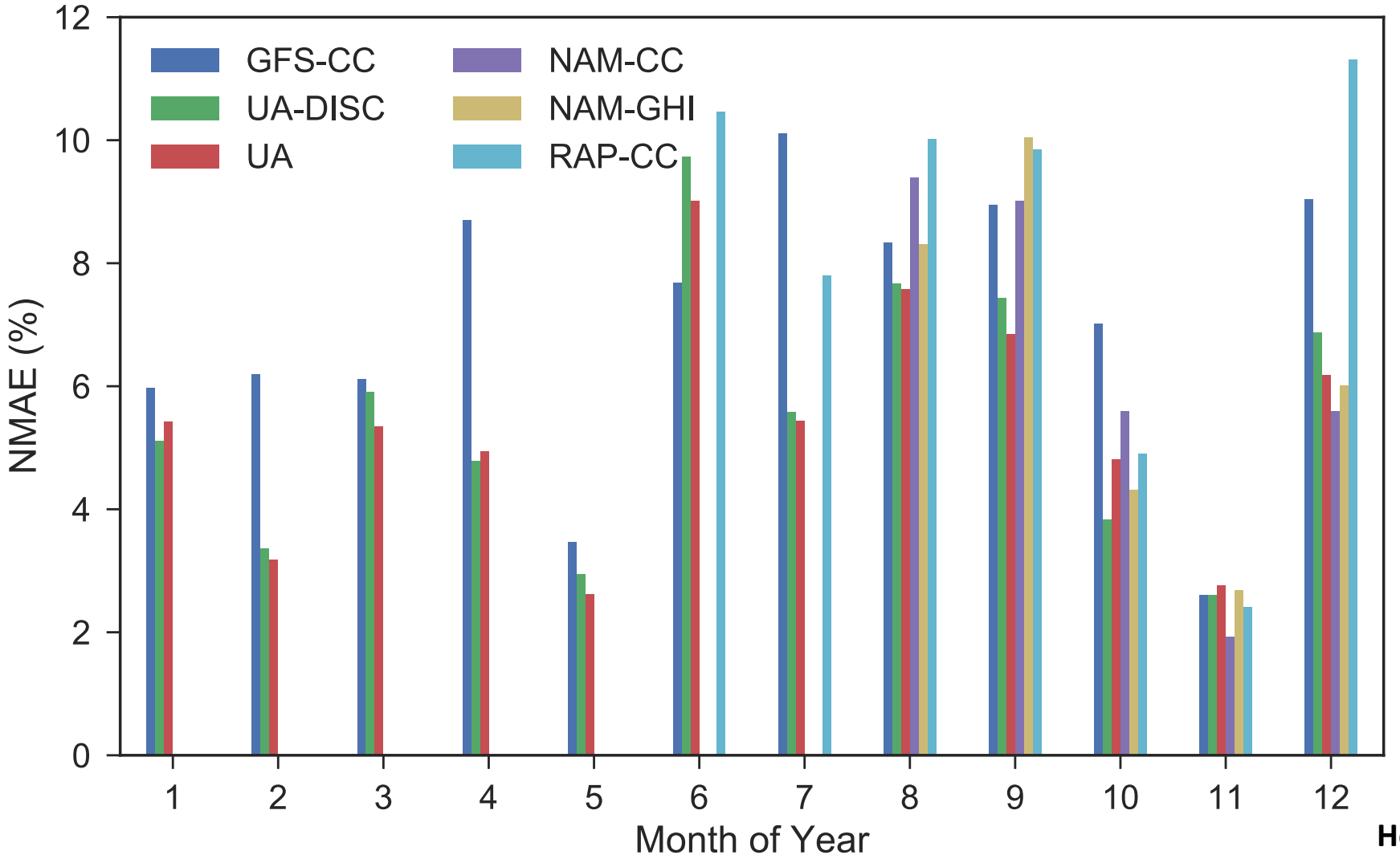
Tonight	Saturday	Saturday Night	Sunday	Sunday Night	Monday	Monday Night	Tuesday	Tuesday Night
								
Partly Cloudy	Partly Sunny	Scattered Showers	Scattered Showers then Partly Sunny	Partly Cloudy	Mostly Sunny	Mostly Clear	Sunny	Partly Cloudy
Low: 52 °F	High: 80 °F	Low: 54 °F	High: 76 °F	Low: 52 °F	High: 78 °F	Low: 52 °F	High: 83 °F	Low: 53 °F

pvlib.forecast models and UA model



Holmgren, Lorenzo, Hansen, IEEE PVSC 2017

pvlib.forecast models and UA models



Holmgren, Lorenzo, Hansen, IEEE PVSC 2017

Open Source Evaluation Framework for Solar Forecasting

- New Department of Energy sponsored project selected for funding (in negotiations, not yet awarded)
- U Arizona (lead), Sandia National Lab, Electric Power Research Institute, Sharply Focused

- Is solar forecast A better than forecasts B, C, and D?
- Which solar forecast is best for my application?
- How do we quantify “better” using standardized metrics?

- Industry partners with data and/or $ include: TEP, Southern Company, Vaisala, Abengoa
- Seeking more industry partners!

THE UNIVERSITY OF ARIZONA

Sandia National Laboratories

EPRI ELECTRIC POWER RESEARCH INSTITUTE

Sharply Focused
Understanding Renewable Resources

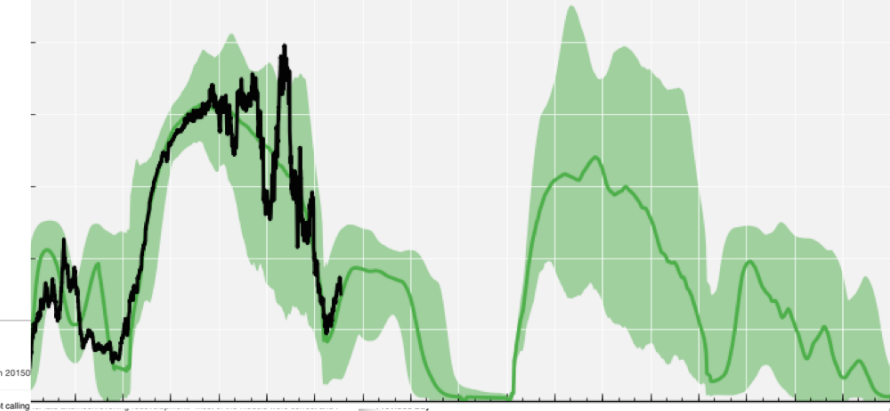
What are the top weather & climate issues for energy stakeholders in the SW US?

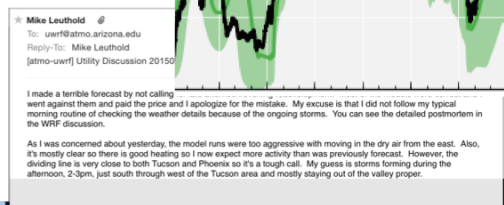
What is the $ value of a weather/solar/wind forecast? Across scales & seasons?

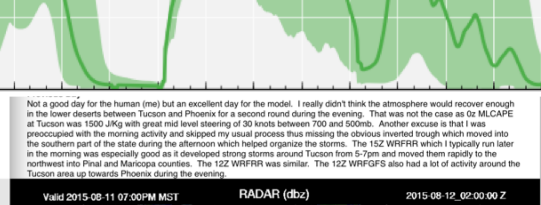
What are technical and social challenges to increased forecast adoption?

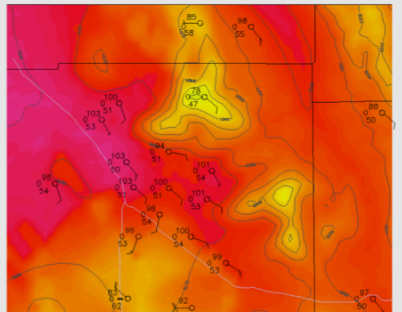
How can the PV reliability/degradation/O&M fields and forecasting fields collaborate on data and operations?

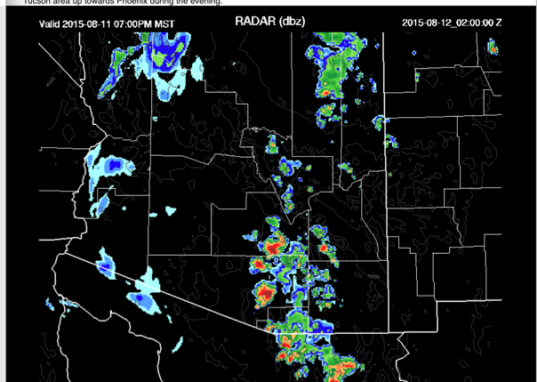
How do we move towards probabilistic forecasts?











Thanks to our partners and sponsors

Major support from

DOE EERE Postdoctoral Fellowship

RESEARCH, DISCOVERY & INNOVATION
Institute for Energy Solutions

Additional support from

The SVERI utilities

Arizona Department of Environmental Quality