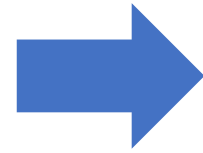
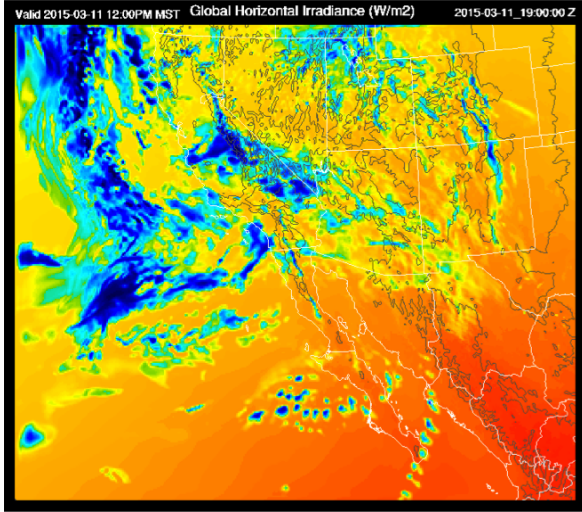
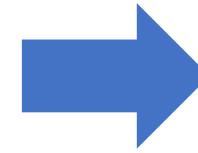


# UA Regional Weather and Power Forecasts

UA-WRF



Power Forecasts Driven  
by Open Source Software



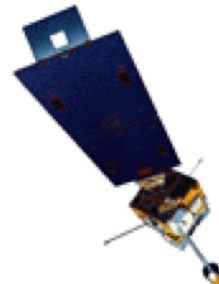
Forecast users



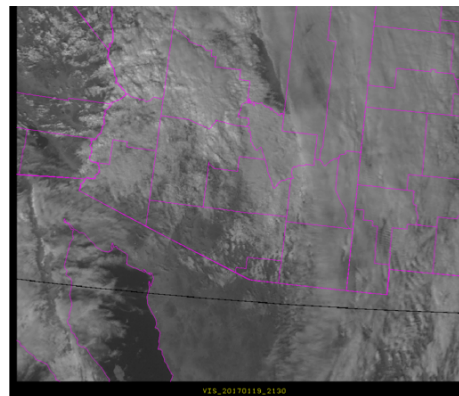
Power Data



GOES imager



Data Assimilation



[forecasting.energy.arizona.edu](http://forecasting.energy.arizona.edu)

Will Holmgren (Asst. Research Prof., HAS)  
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)

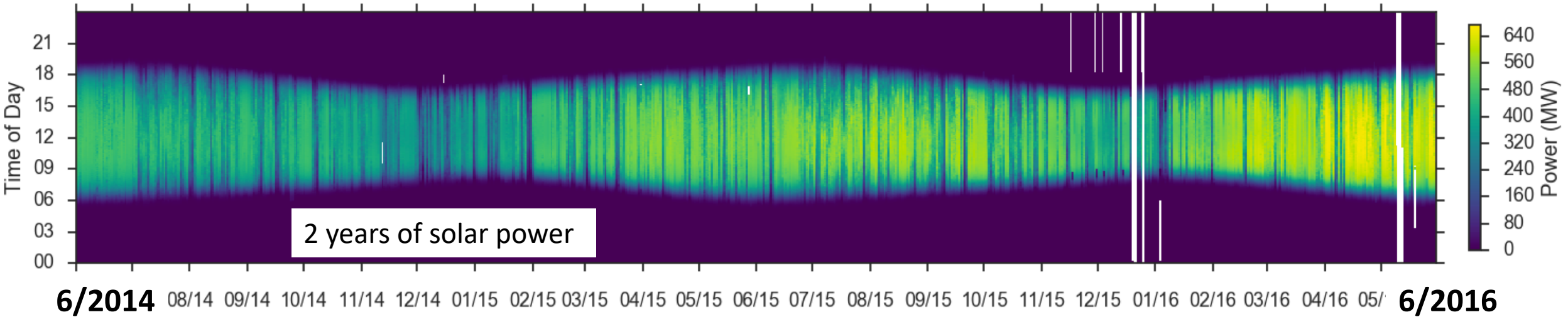
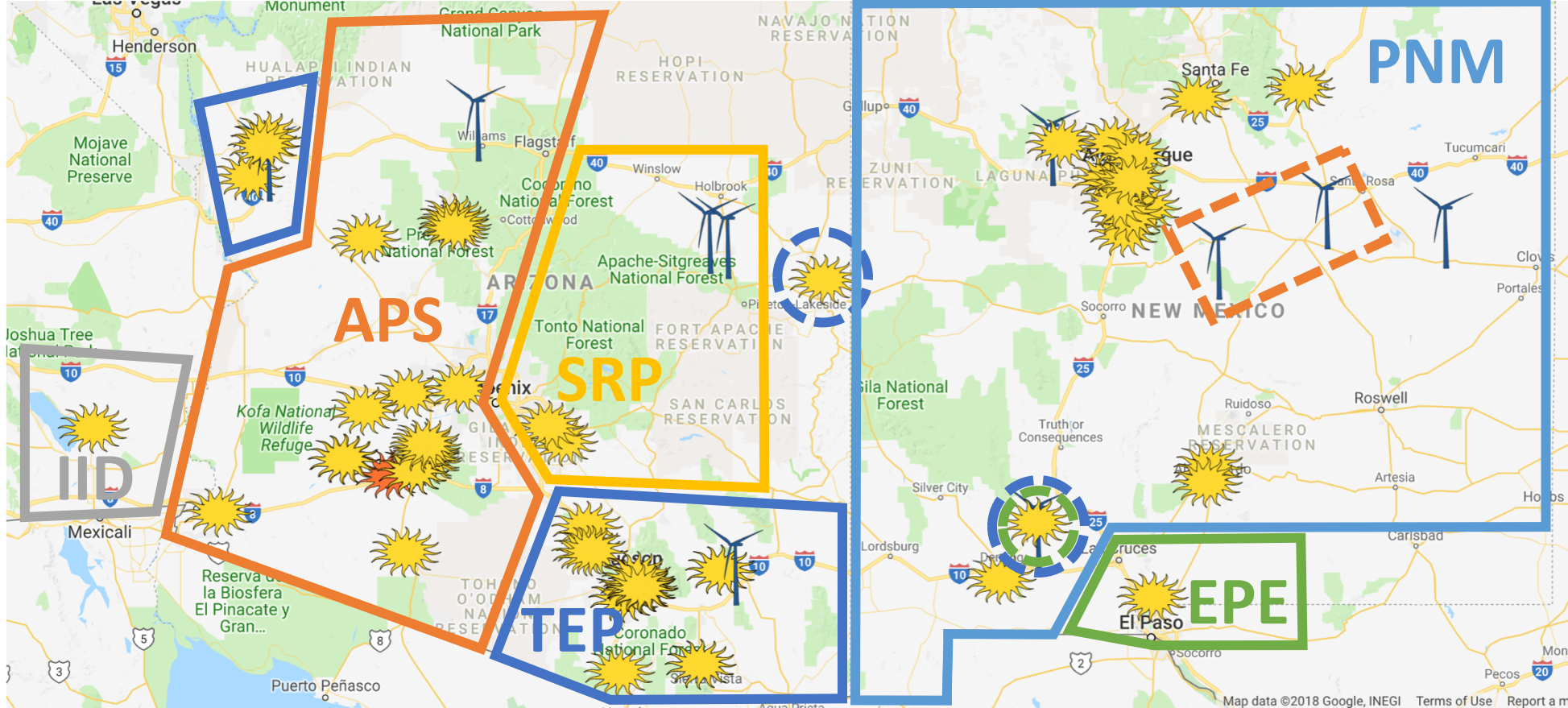
Utility Wind  
820 MW

Utility Solar  
1080 MW

Distributed  
Solar  
1250 MW

Total  
3150 MW

Load  
7000 - 24000 MW





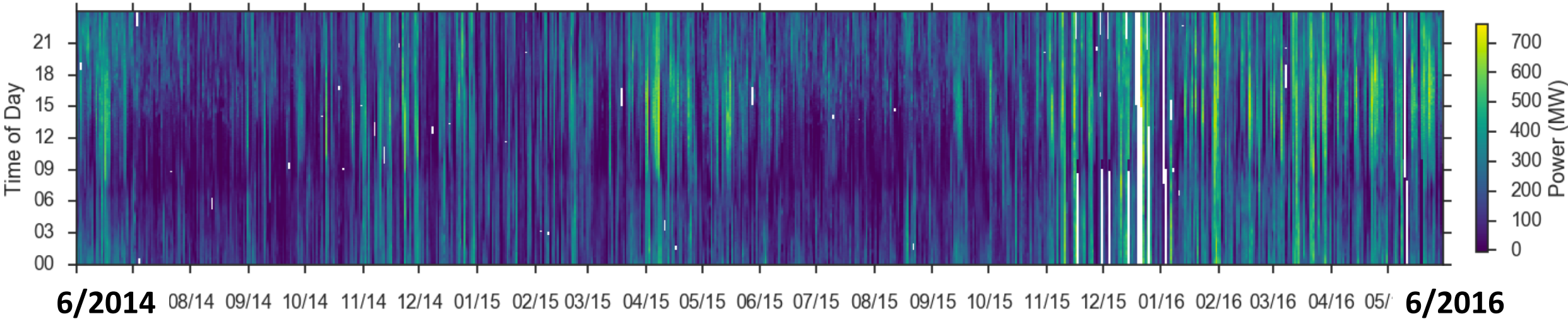
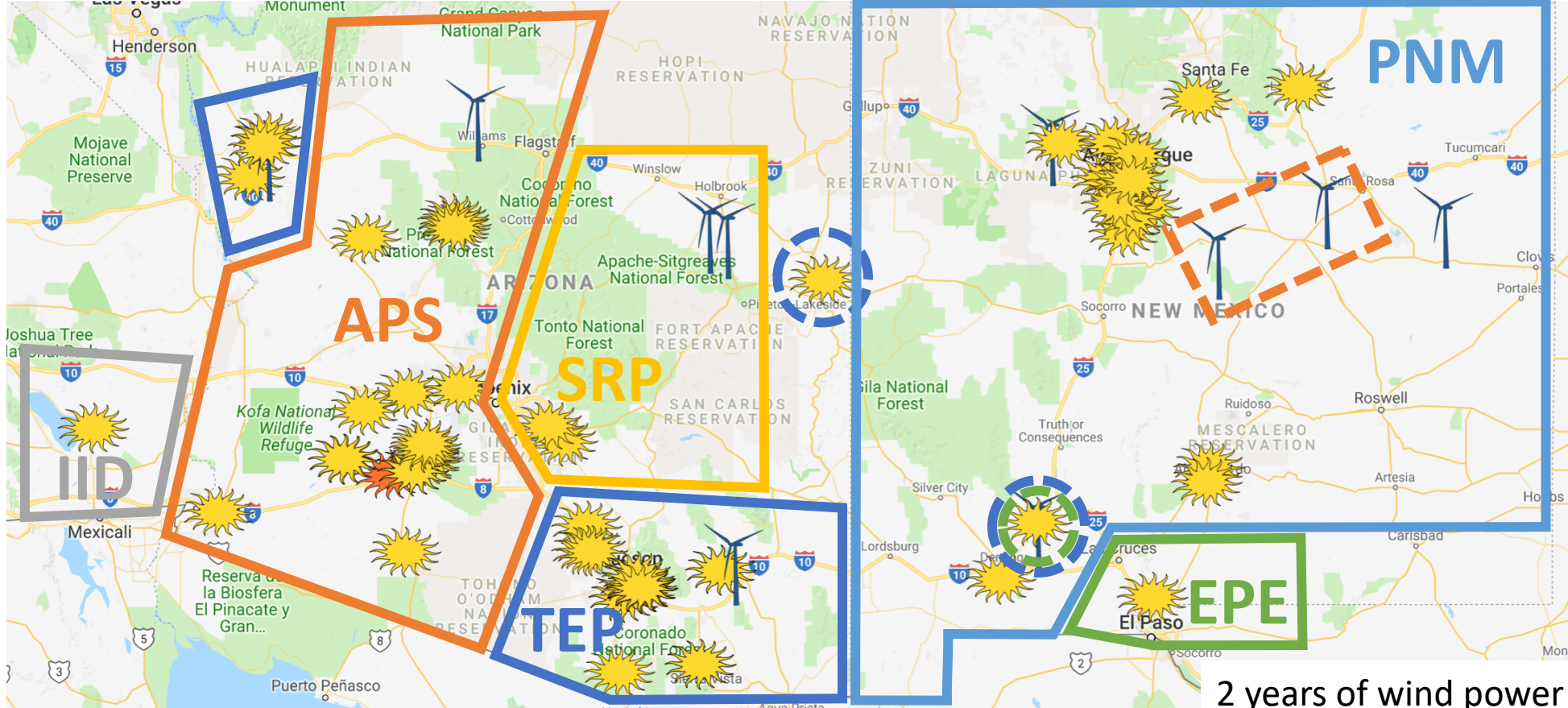
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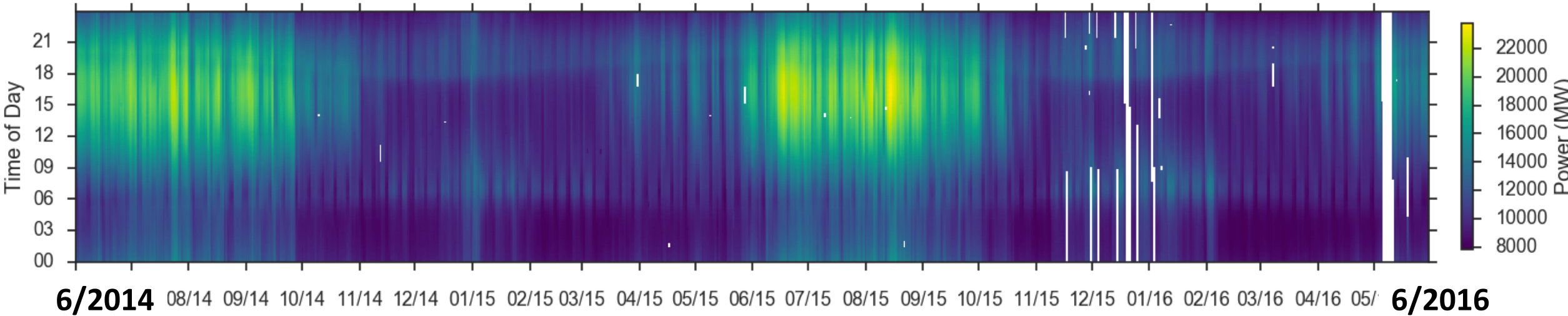
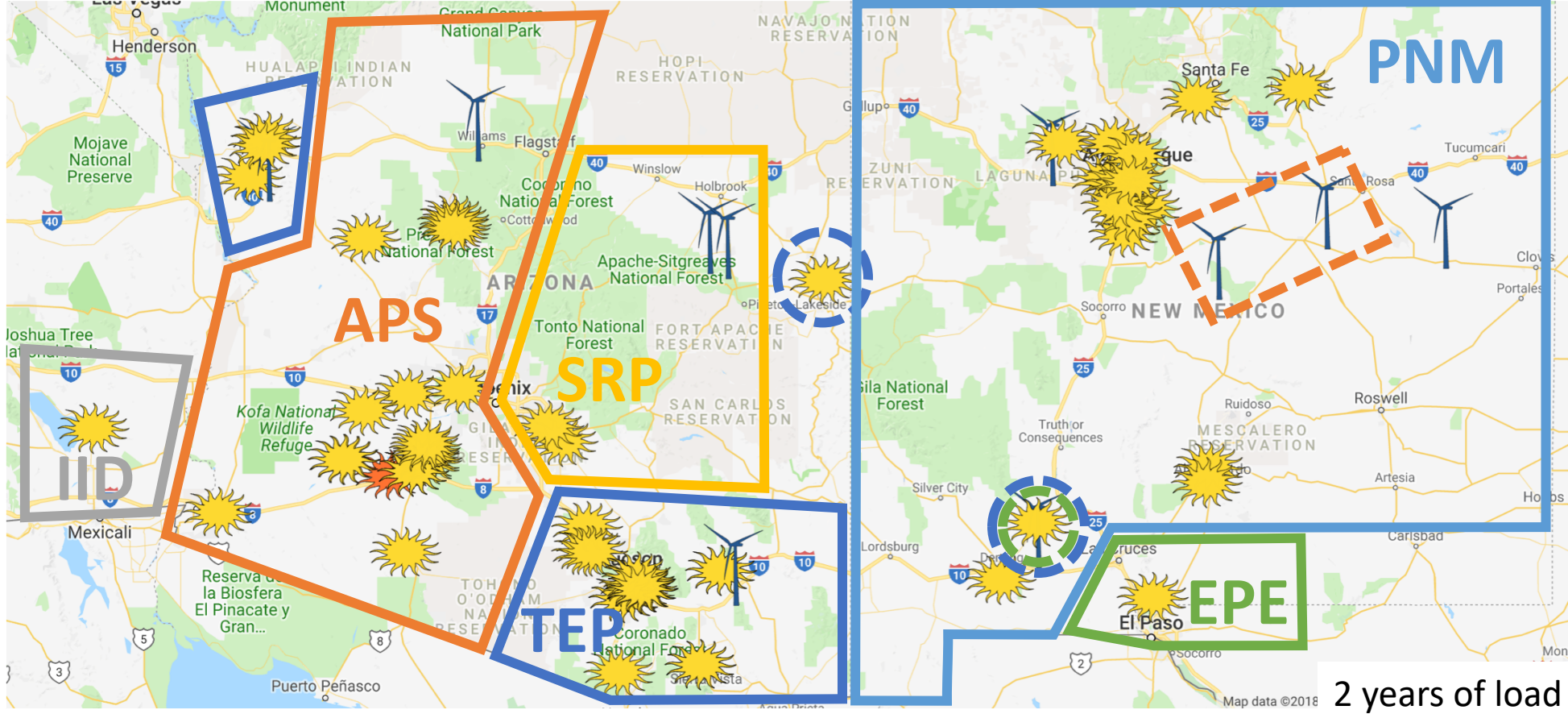
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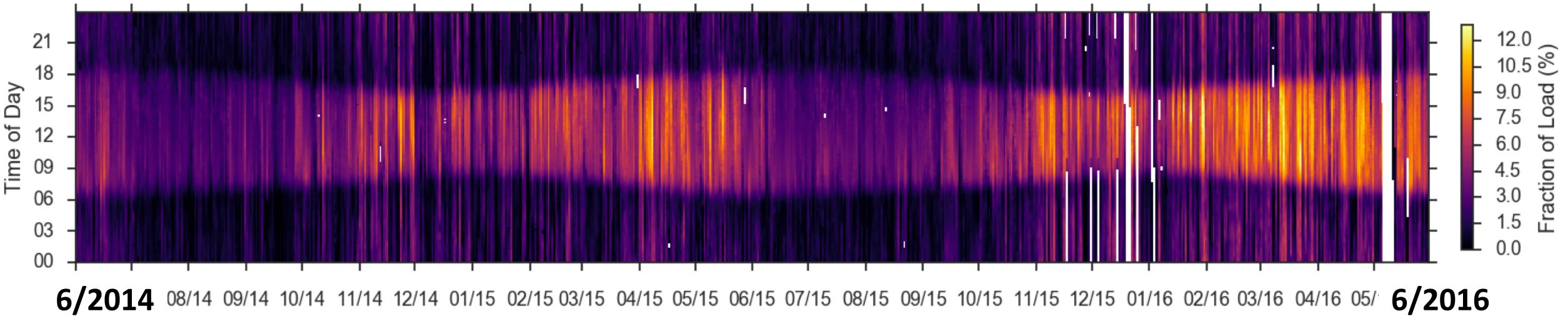
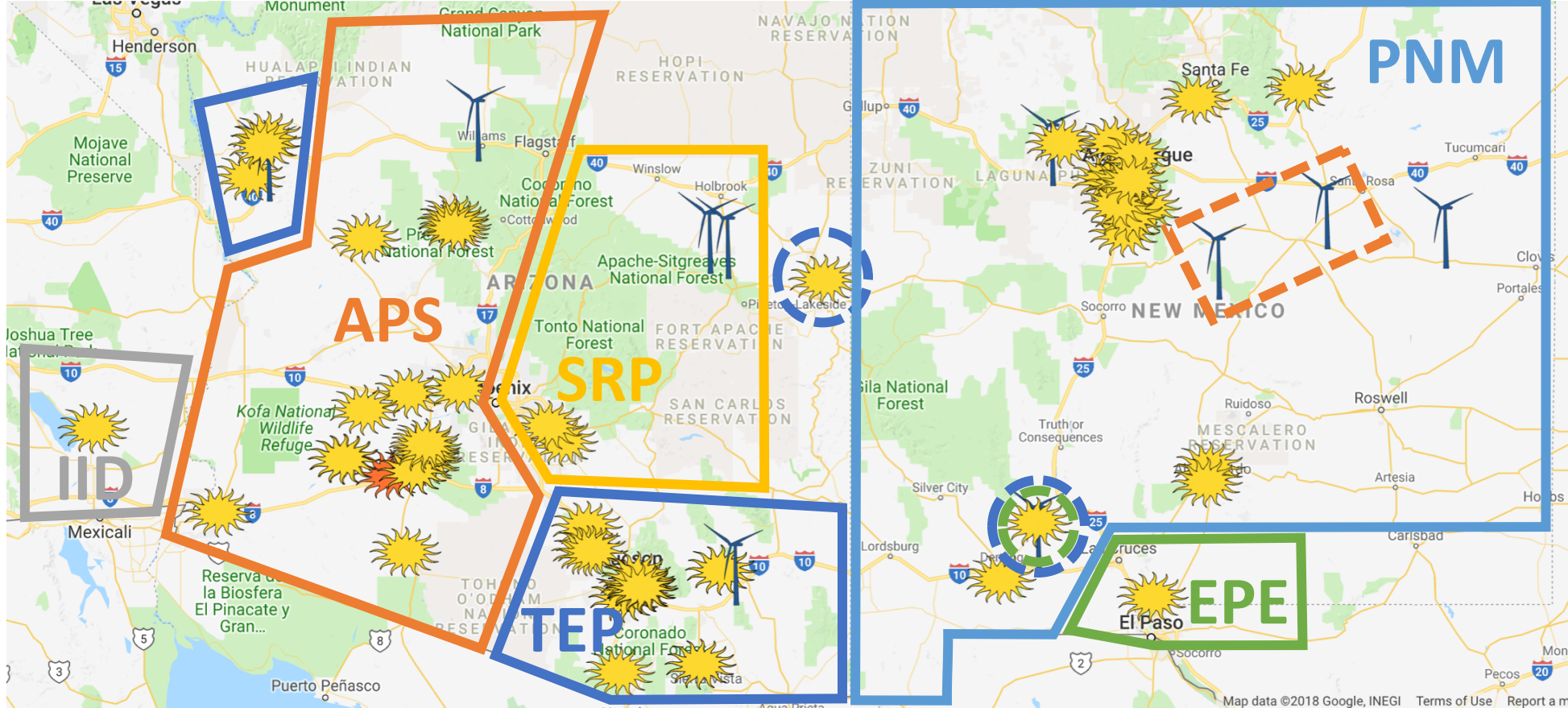
Utility Wind  
820 MW

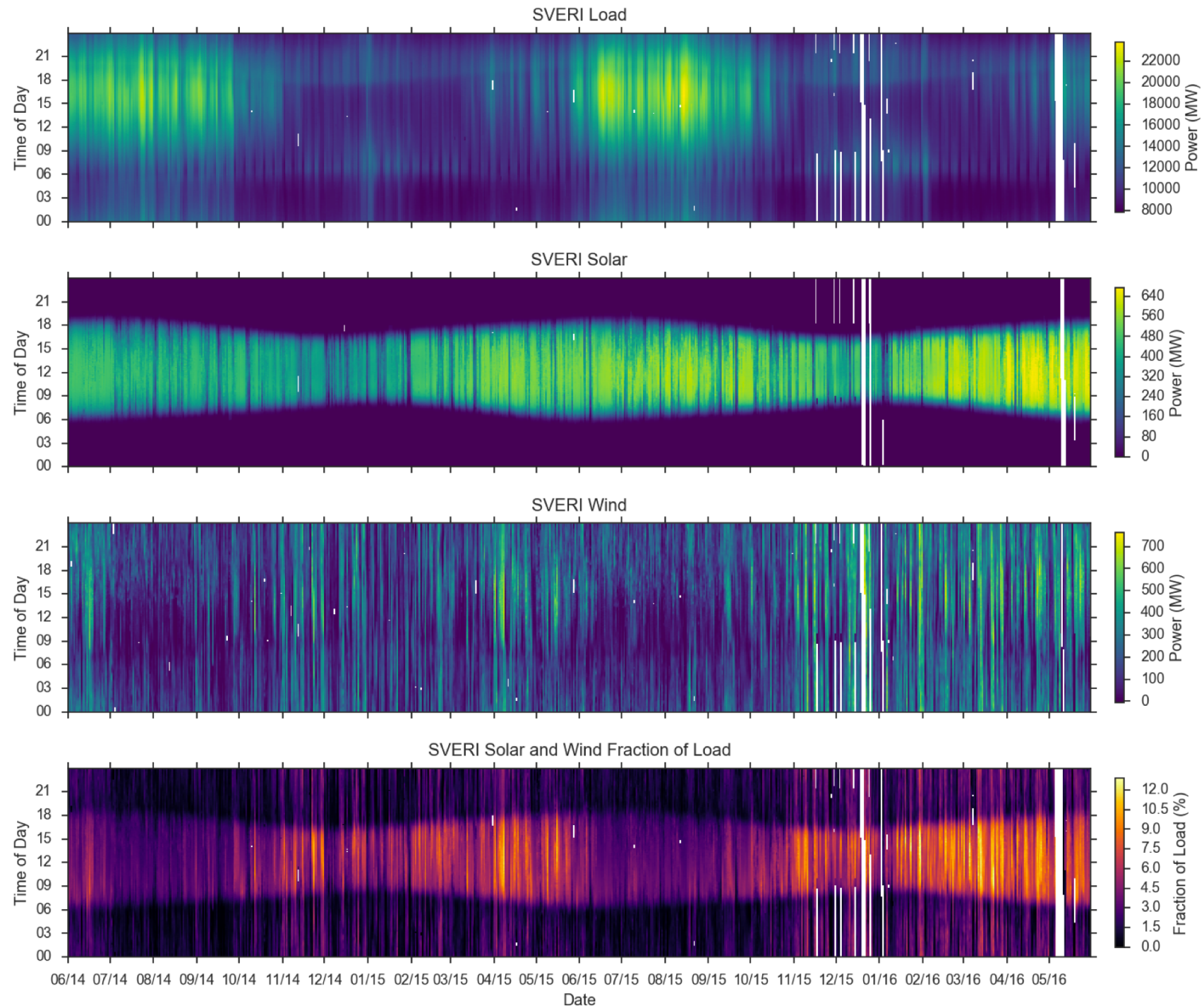
Utility Solar  
1080 MW

Distributed  
Solar  
1250 MW

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7000 - 24000 MW





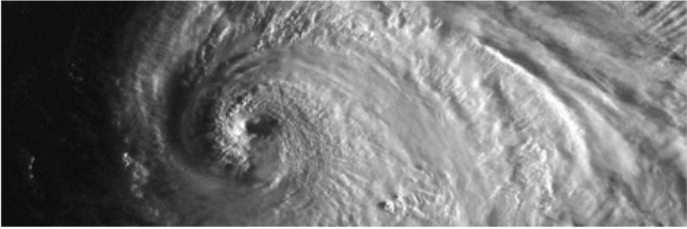


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### Arizona Regional WRF Model Data

#### Model Derived Forecasts

[SE AZ Forecast](#) [Phx Area Forecast](#) [AM Optical Depth](#)

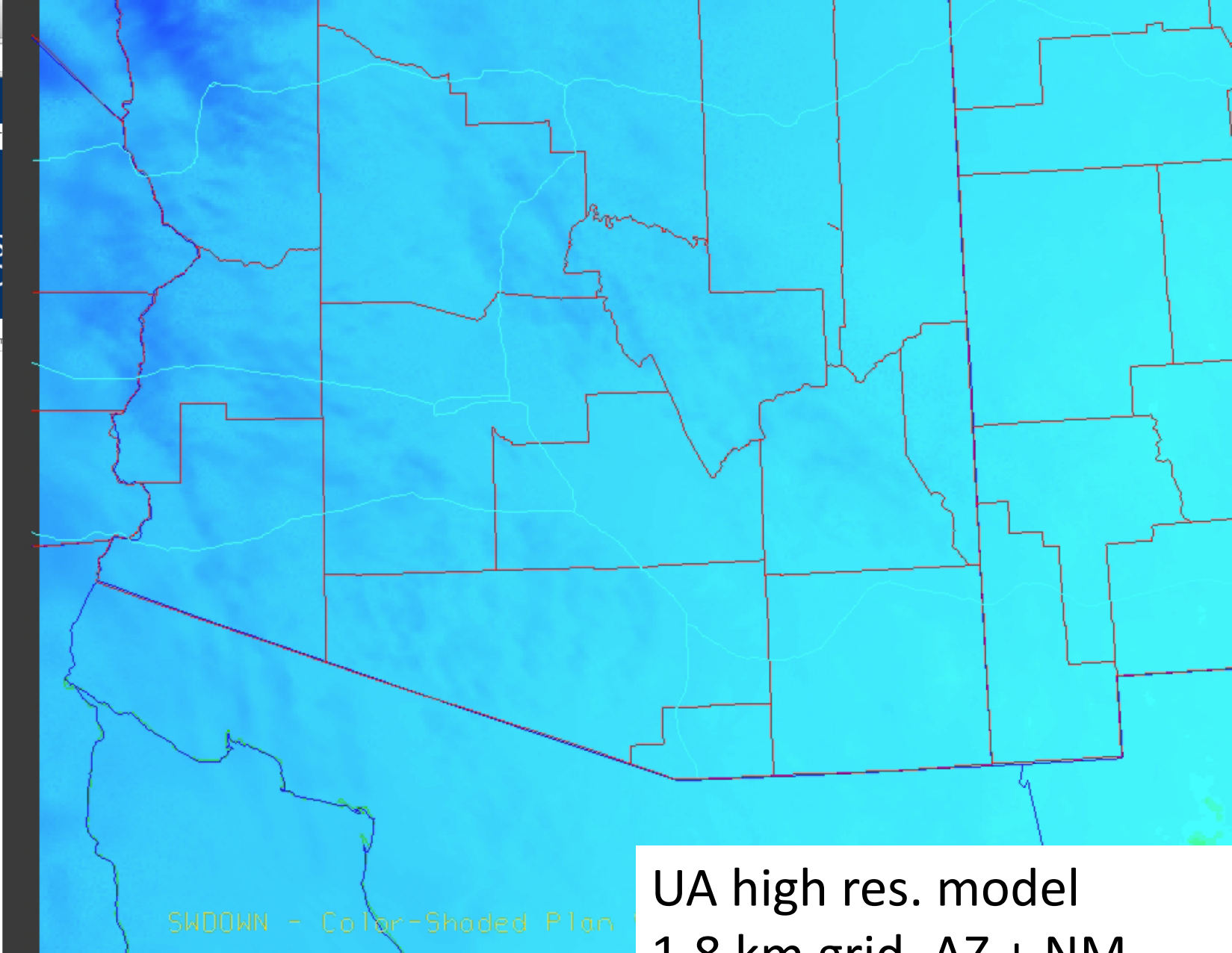
#### Model Discussion

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
<b>Domain-Level Products</b>					
Composite RADAR	<a href="#">1.8km 5.4km</a>	<a href="#">1.8km 5.4km</a>	<a href="#">1.8km 5.4km</a>	<a href="#">1.8km 5.4km</a>	<a href="#">1.8km 5.4km</a>
Precipitation	<a href="#">1.8km 5.4km</a>	<a href="#">1.8km 5.4km</a>	<a href="#">1.8km 5.4km</a>	<a href="#">1.8km 5.4km</a>	<a href="#">1.8km 5.4km</a>
Accumulated Precipitation	<a href="#">1.8kmz 5.4kmz</a>	<a href="#">1.8kmz 5.4kmz</a>	<a href="#">1.8kmz 5.4kmz</a>	<a href="#">1.8kmz 5.4kmz</a>	<a href="#">1.8kmz 5.4kmz</a>
Accumulated Snow	<a href="#">1.8km 5.4km</a>	<a href="#">1.8km 5.4km</a>	<a href="#">1.8km 5.4km</a>	<a href="#">1.8km 5.4km</a>	<a href="#">1.8km 5.4km</a>
Snow Cover	<a href="#">1.8km 5.4km</a>	<a href="#">1.8km 5.4km</a>	<a href="#">1.8km 5.4km</a>	<a href="#">1.8km 5.4km</a>	<a href="#">1.8km 5.4km</a>
2m Temp	<a href="#">1.8km 5.4km</a> <a href="#">1.8kmz 5.4kmz</a>	<a href="#">1.8km 5.4km</a> <a href="#">1.8kmz 5.4kmz</a>	<a href="#">1.8km 5.4km</a> <a href="#">1.8kmz 5.4kmz</a>	<a href="#">1.8km 5.4km</a> <a href="#">1.8kmz 5.4kmz</a>	<a href="#">1.8km 5.4km</a> <a href="#">1.8kmz 5.4kmz</a>
10m Wind	<a href="#">1.8km 5.4km</a> <a href="#">1.8kmz 5.4kmz</a>	<a href="#">1.8km 5.4km</a> <a href="#">1.8kmz 5.4kmz</a>	<a href="#">1.8km 5.4km</a> <a href="#">1.8kmz 5.4kmz</a>	<a href="#">1.8km 5.4km</a> <a href="#">1.8kmz 5.4kmz</a>	<a href="#">1.8km 5.4km</a> <a href="#">1.8kmz 5.4kmz</a>



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

UA WRF weather forecasts  
available at [atmo.arizona.edu](http://atmo.arizona.edu)

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### Arizona Regional WRF Model Data

#### Model Derived Forecasts

[SF AZ Forecast](#)
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[AM Optical Depth](#)

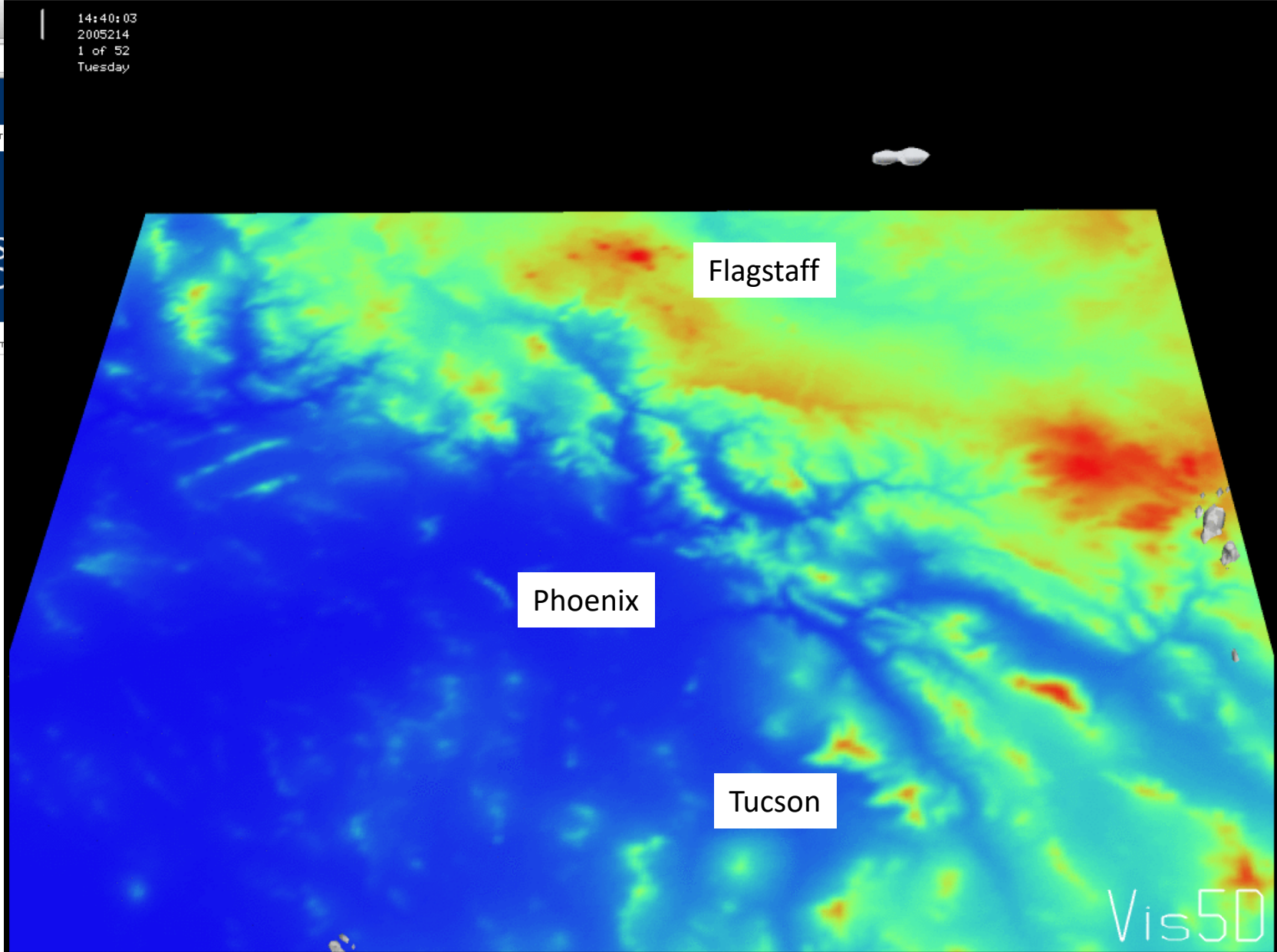
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Composite RADAR	1.8km 5.4km	1.8km 5.4km	1.8km 5.4km	1.8km 5.4km	1.8km 5.4km
Precipitation	1.8km 5.4km	1.8km 5.4km	1.8km 5.4km	1.8km 5.4km	1.8km 5.4km
Accumulated Precipitation	1.8km 5.4kmz	1.8kmz 5.4kmz	1.8kmz 5.4kmz	1.8kmz 5.4kmz	1.8kmz 5.4kmz
Accumulated 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](http://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

This repository Search Pull requests Issues Gist

pvlib / pvlib-python Unwatch 17 Unstar 17 Fork 22

A set of documented functions for simulating the performance of photovoltaic energy systems. — Edit

558 commits 1 branch 3 releases 7 contributors

Branch: master pvlib-python / +

Merge pull request #81 from dacoex/patch-2

wholmgren authored 14 days ago latest commit d00ef2dfb3

docs	added link to wiki	15 days ago
pvlib	bump to 0.2.2dev	2 months ago
.gitignore	add spa sources to .gitignore	6 months ago
.travis.yml	change travis config to hack around python3 testing	2 months ago
LICENSE	restore original Sandia copyright	5 months ago
MANIFEST.in	added get_time function to calculate time for a given solar position	10 months ago
README.md	update zenodo	2 months ago
setup.py	added sunrise/set/transit to python spa, removed pyephem dependency	5 months ago

README.md

## pvlib-python

build passing coverage 92% docs latest DOI 10.5281/zenodo.20562

Code Issues 19 Pull requests 0 Wiki

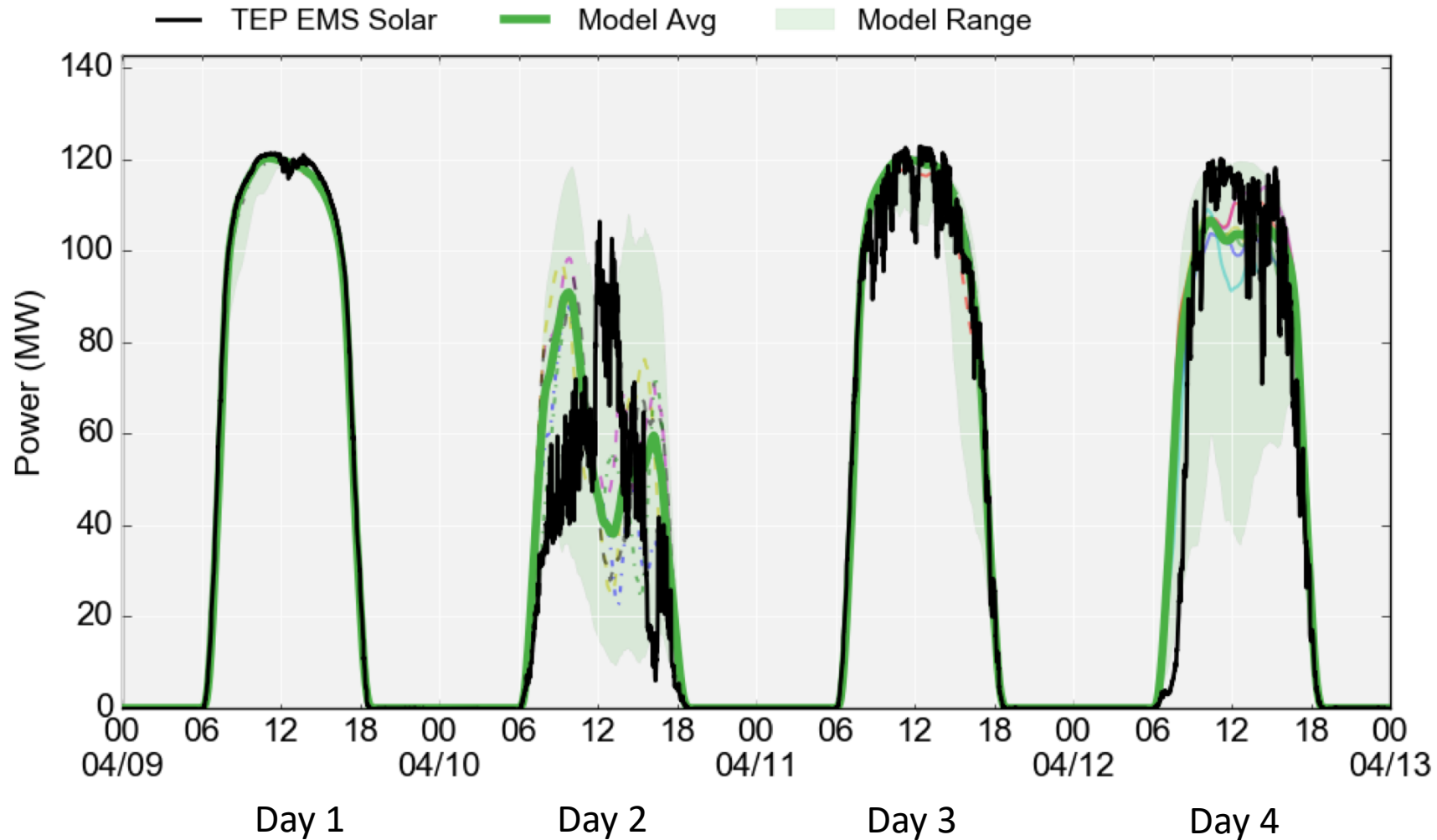
Pulse Graphs Settings

SSH clone URL git@github.com:pvlib/pvlib-python

You can clone with HTTPS, SSH, or Subversion.

Clone in Desktop Download ZIP

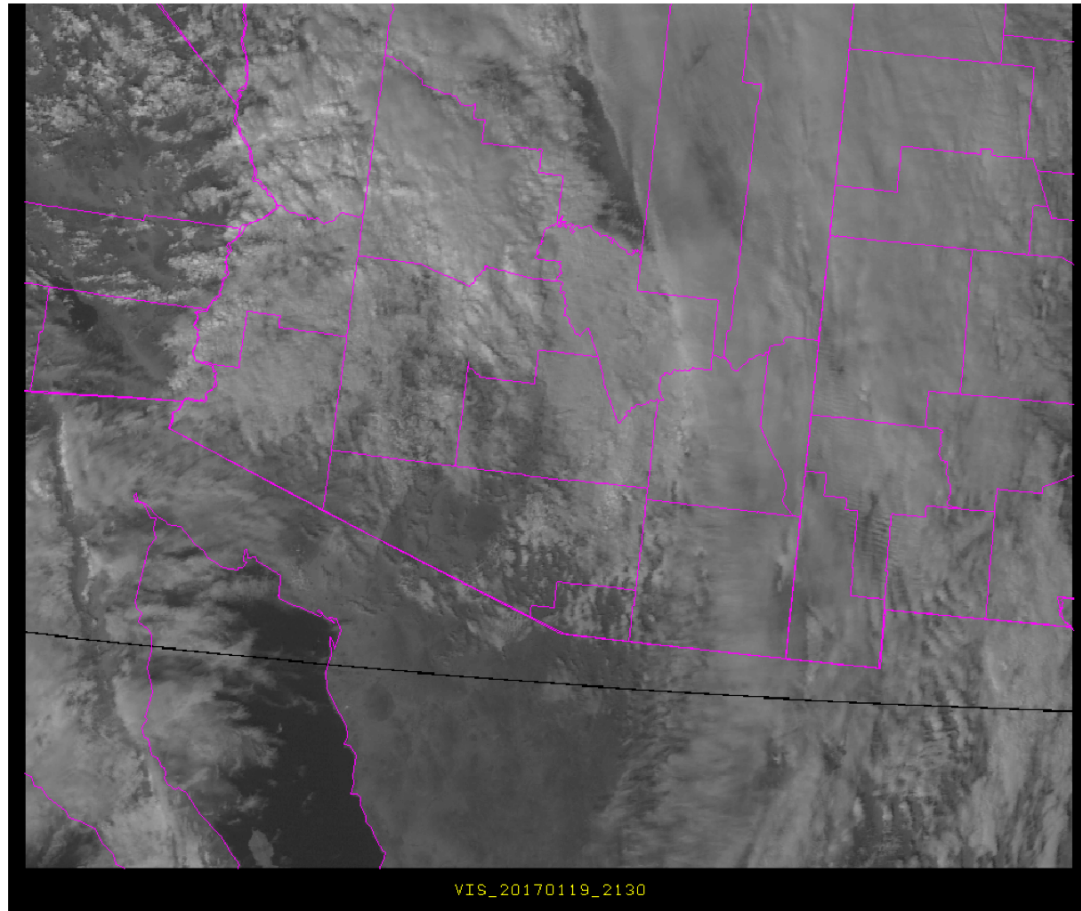
# Solar power forecast from UA weather model





# Satellite Derived Irradiance

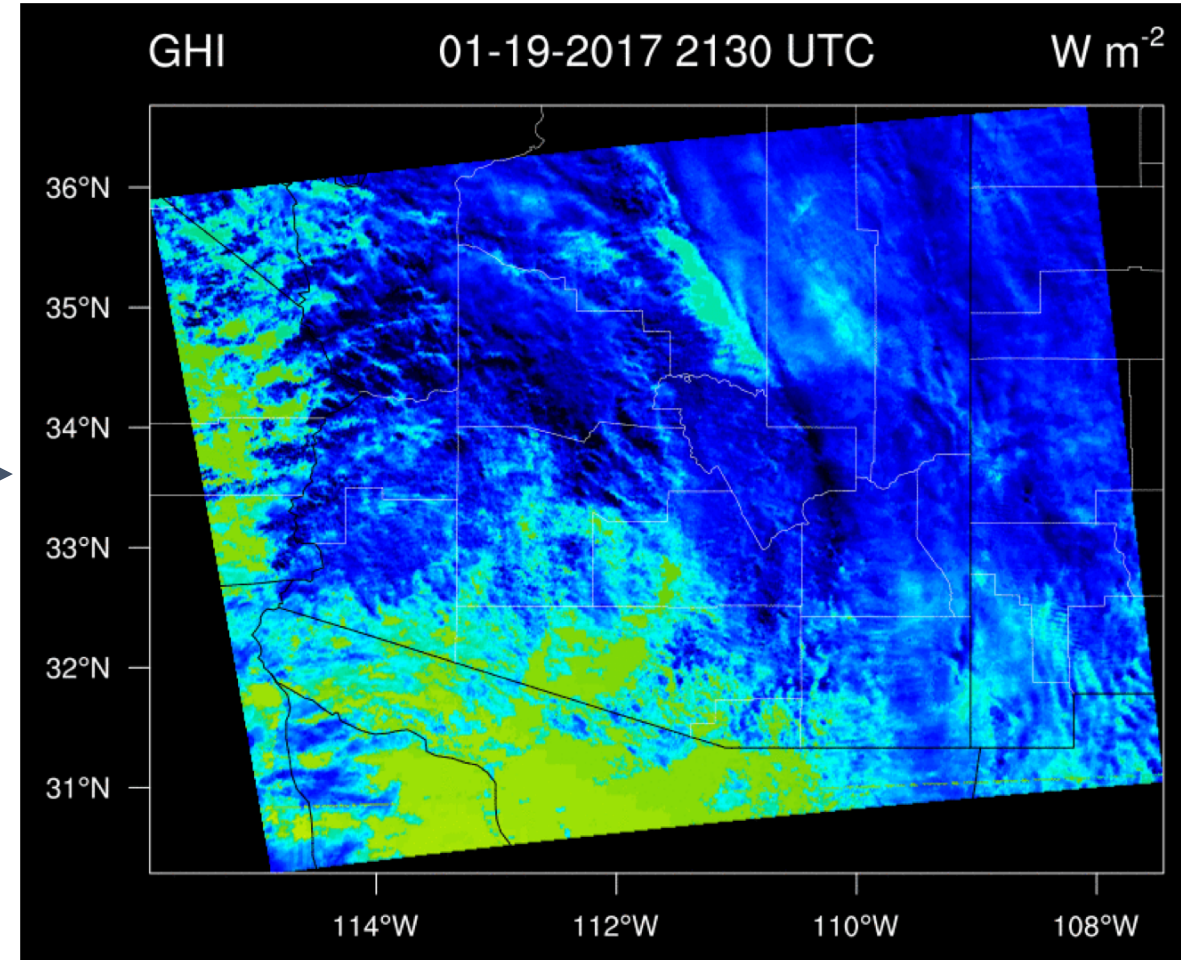
Light reflected from the tops of clouds



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%

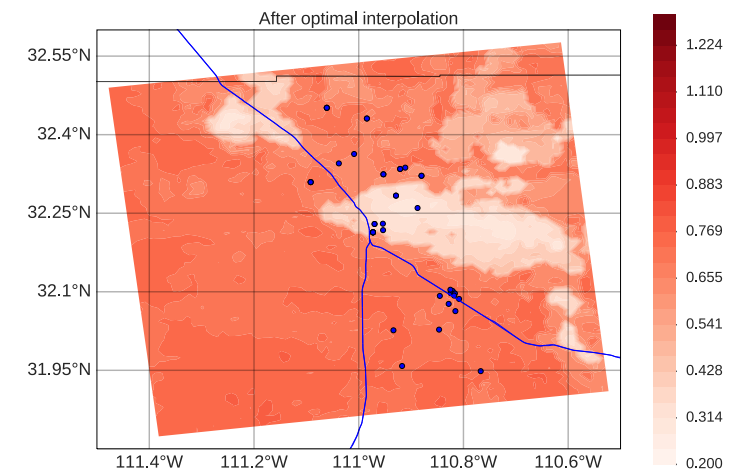
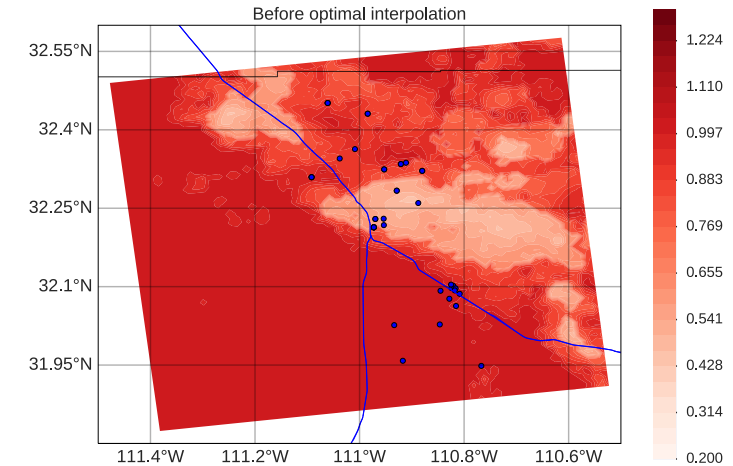
Unique method  
developed at UA

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**



Partly Cloudy

Low: 52 °F

**Saturday**



Partly Sunny

High: 80 °F

**Saturday Night**



Scattered Showers

Low: 54 °F

**Sunday**



Scattered Showers then Partly Sunny

High: 76 °F

**Sunday Night**



Partly Cloudy

Low: 52 °F

**Monday**



Mostly Sunny

High: 78 °F

**Monday Night**



Mostly Clear

Low: 52 °F

**Tuesday**



Sunny

High: 83 °F

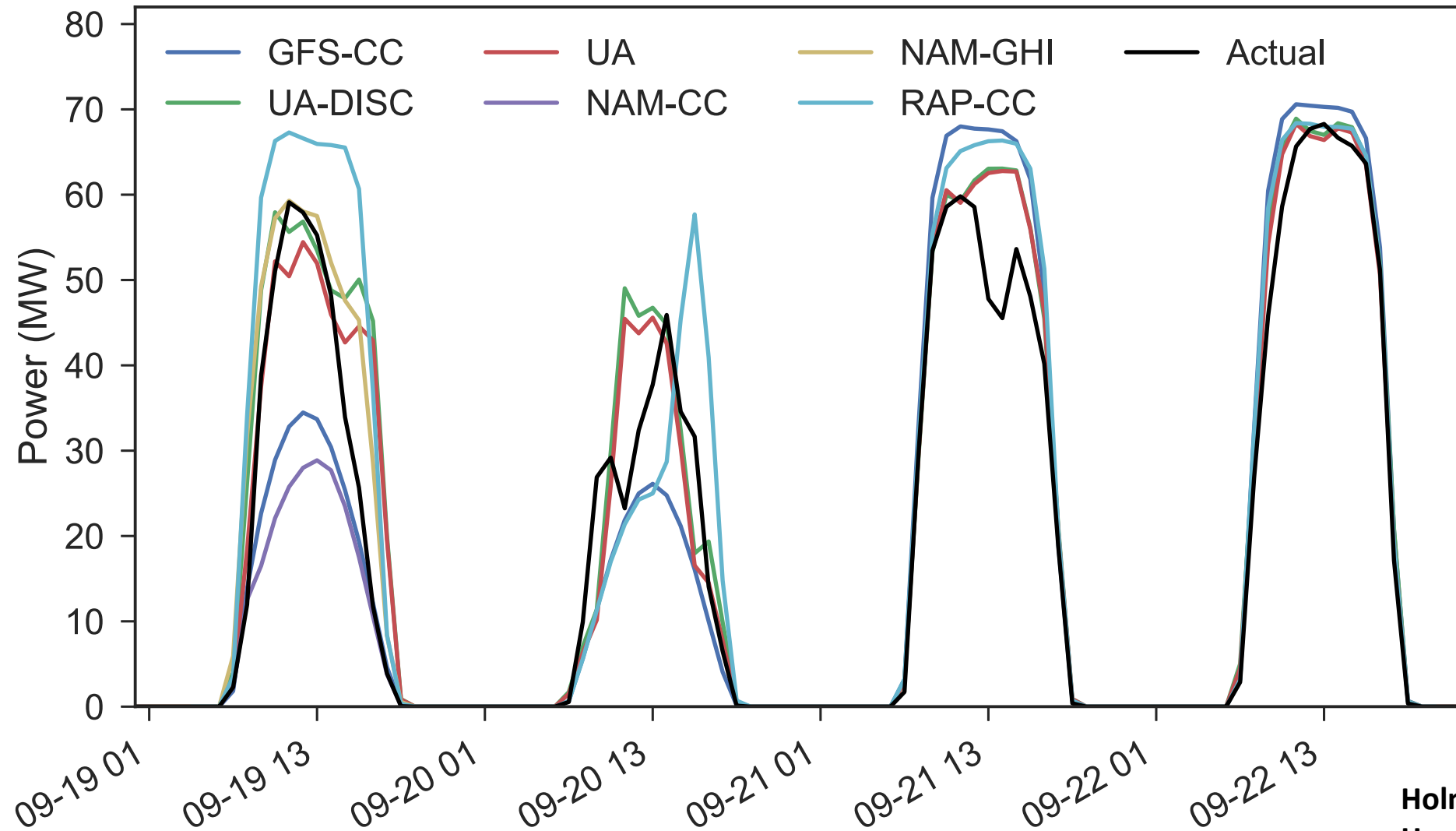
**Tuesday Night**



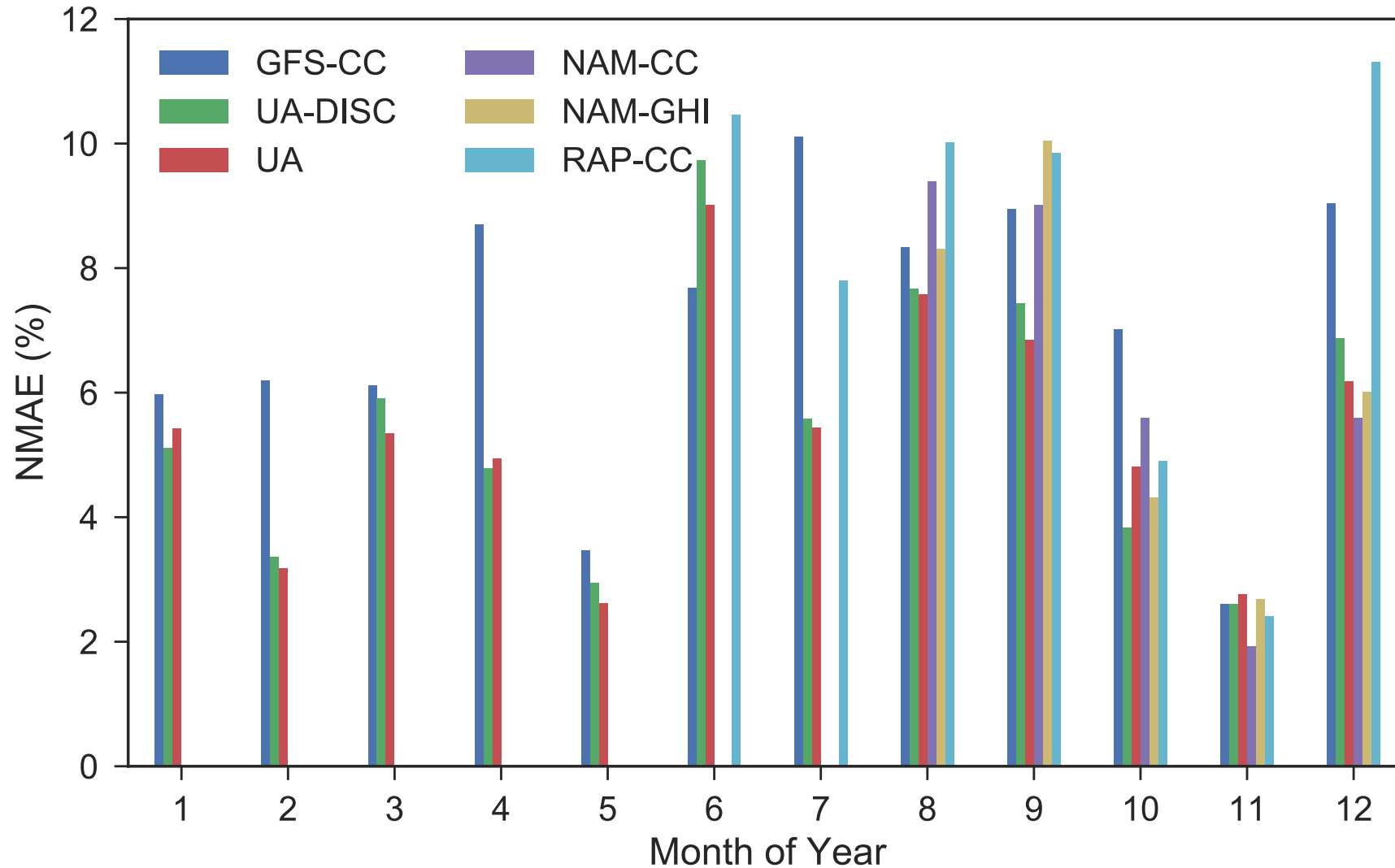
Partly Cloudy

Low: 53 °F

# pvlib.forecast models and UA model



# pvlib.forecast models and UA models





# 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!

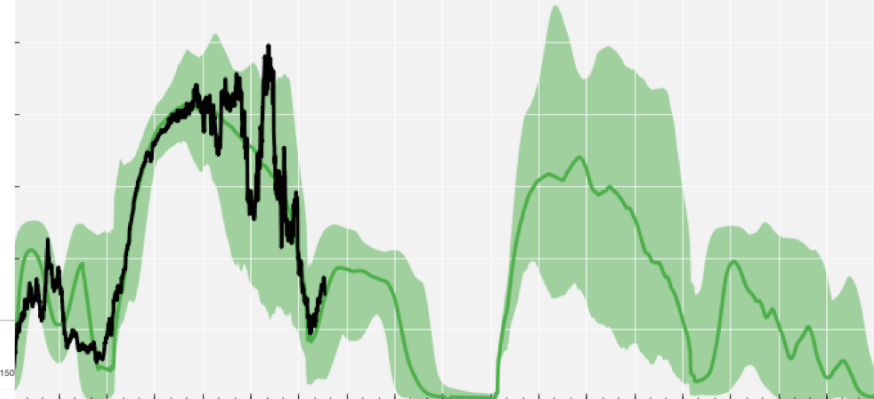
What are the top weather & climate issues for energy stakeholders in the SW US?

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?

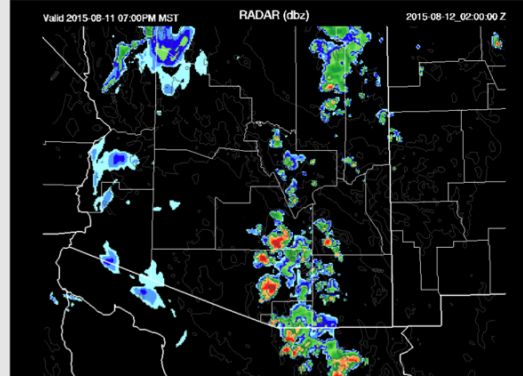
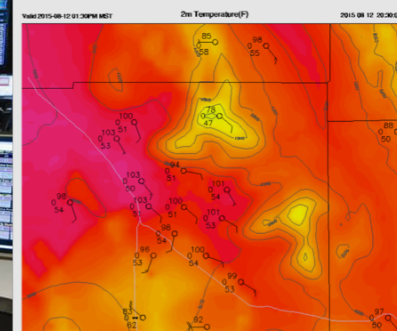


★ Mike Leuthold @  
To: user@atmo.arizona.edu  
Reply-To: Mike Leuthold  
[atmo-uwr] Utility Discussion 20150

I made a terrible forecast by not calling  
went against them and paid the price and I apologize for the mistake. My excuse is that I did not follow my typical  
morning routine of checking the weather details because of the ongoing storms. You can see the detailed postmortem in  
the WRF discussion.

As I was concerned about yesterday, the model runs were too aggressive with moving in the dry air from the east. Also,  
it's mostly clear so there is good heating so I now expect more activity than was previously forecast. However, the  
dividing line is very close to both Tucson and Phoenix so it's a tough call. My guess is storms forming during the  
afternoon, 2-3pm, just south through west of the Tucson area and mostly staying out of the valley proper.

Not a good day for the human (me) but an excellent day for the model. I really didn't think the atmosphere would recover enough  
in the lower deserts between Tucson and Phoenix for a second round during the evening. That was not the case as 0z MLCAPE  
at Tucson was 1500 J/kg with great mid level steering of 30 knots between 700 and 500mb. Another excuse is that I was  
preoccupied with the morning activity and skipped my usual process thus missing the obvious inverted trough which moved into  
the southern part of the state during the afternoon which helped organize the storms. The 15Z WRFRRR which I typically run later  
in the morning was especially good as it developed strong storms around Tucson from 5-7pm and moved them rapidly to the  
northwest into Pinal and Maricopa counties. The 12Z WRFRRR was similar. The 12Z WRFRRR also had a lot of activity around the  
Tucson area up towards Phoenix during the evening.





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Institute for Energy Solutions



## Additional support from

The SVERI utilities



Arizona Department of  
Environmental Quality