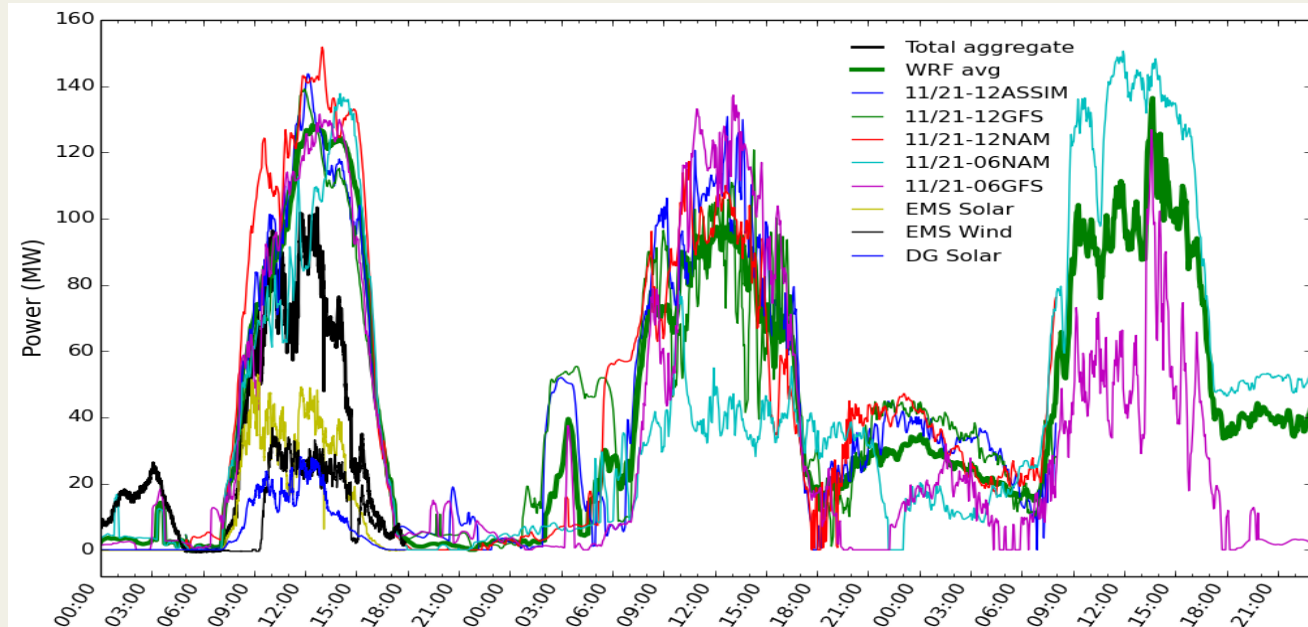


Real-Time PV Power Forecasting



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.

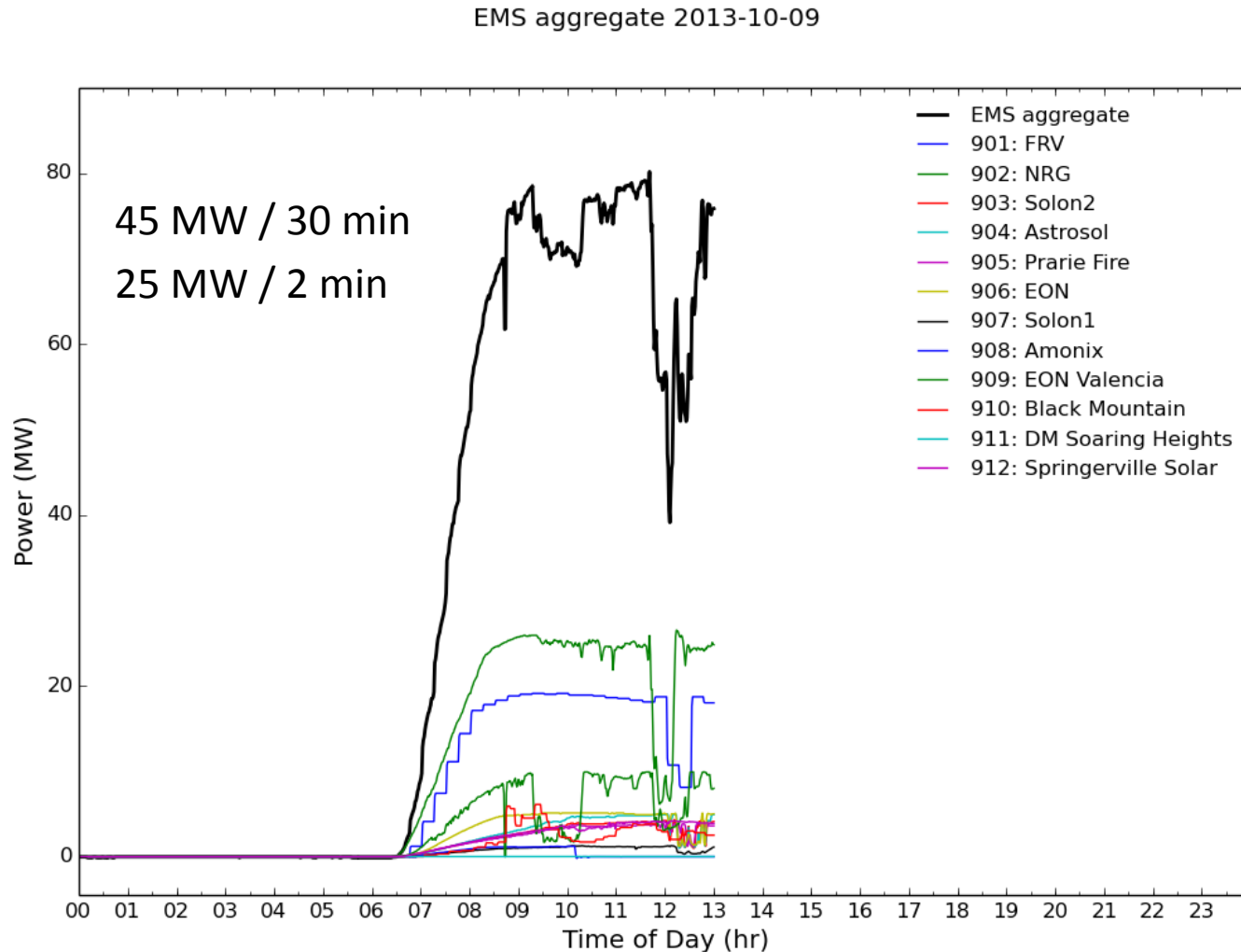
Mike Leuthold, Meteorologist, Atmo. Sci.

Chang Ki Kim, Post doc, Atmo. Sci.

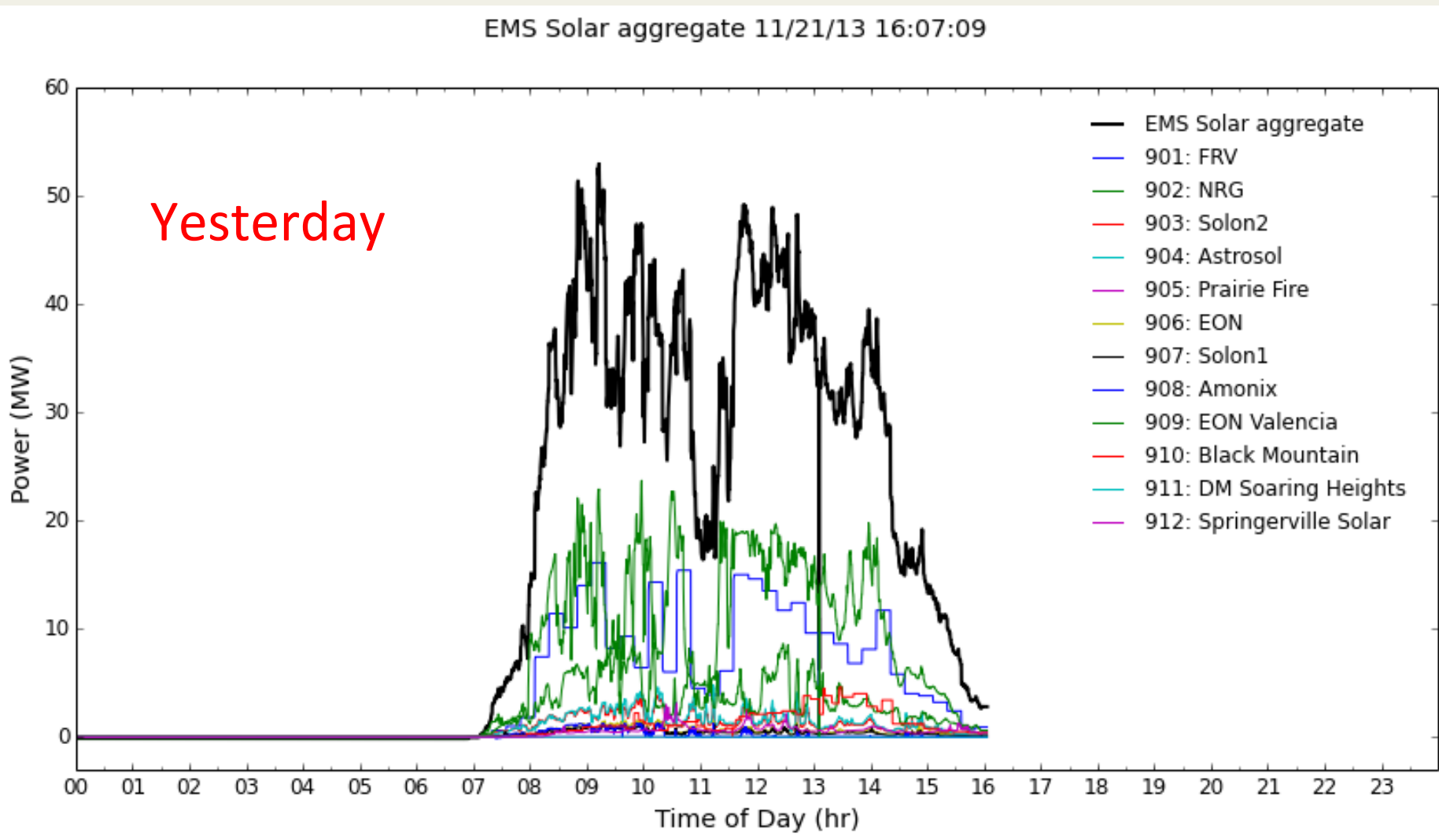
Ardeth Barnhart, Director, UA-REN

Rey Granillo, Developer, UA-REN

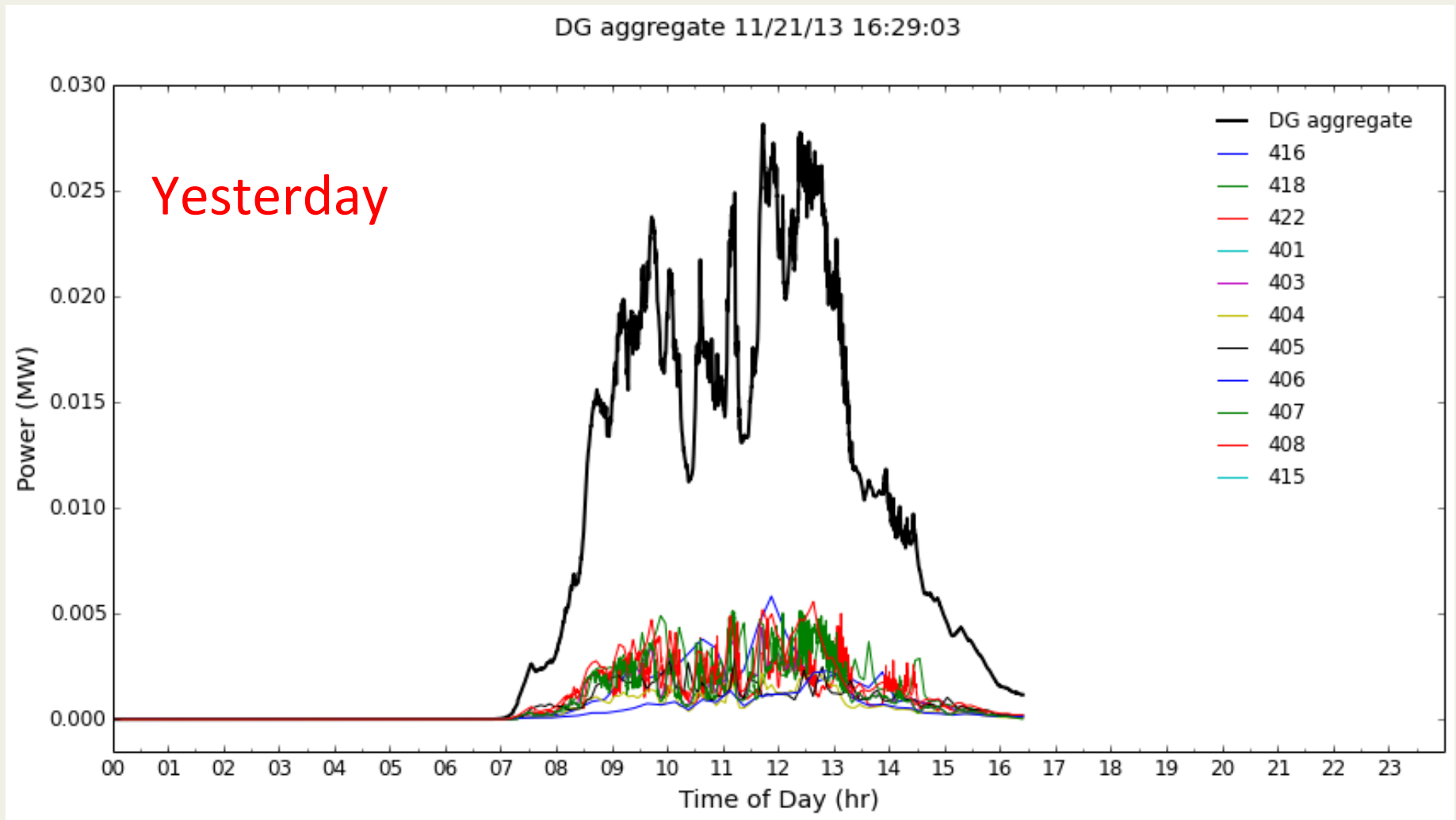
TEP Utility Scale PV Variability



TEP Utility Scale PV Variability



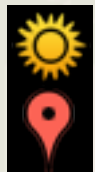
TEP Behind the Meter DG Variability



Real-time data sources map

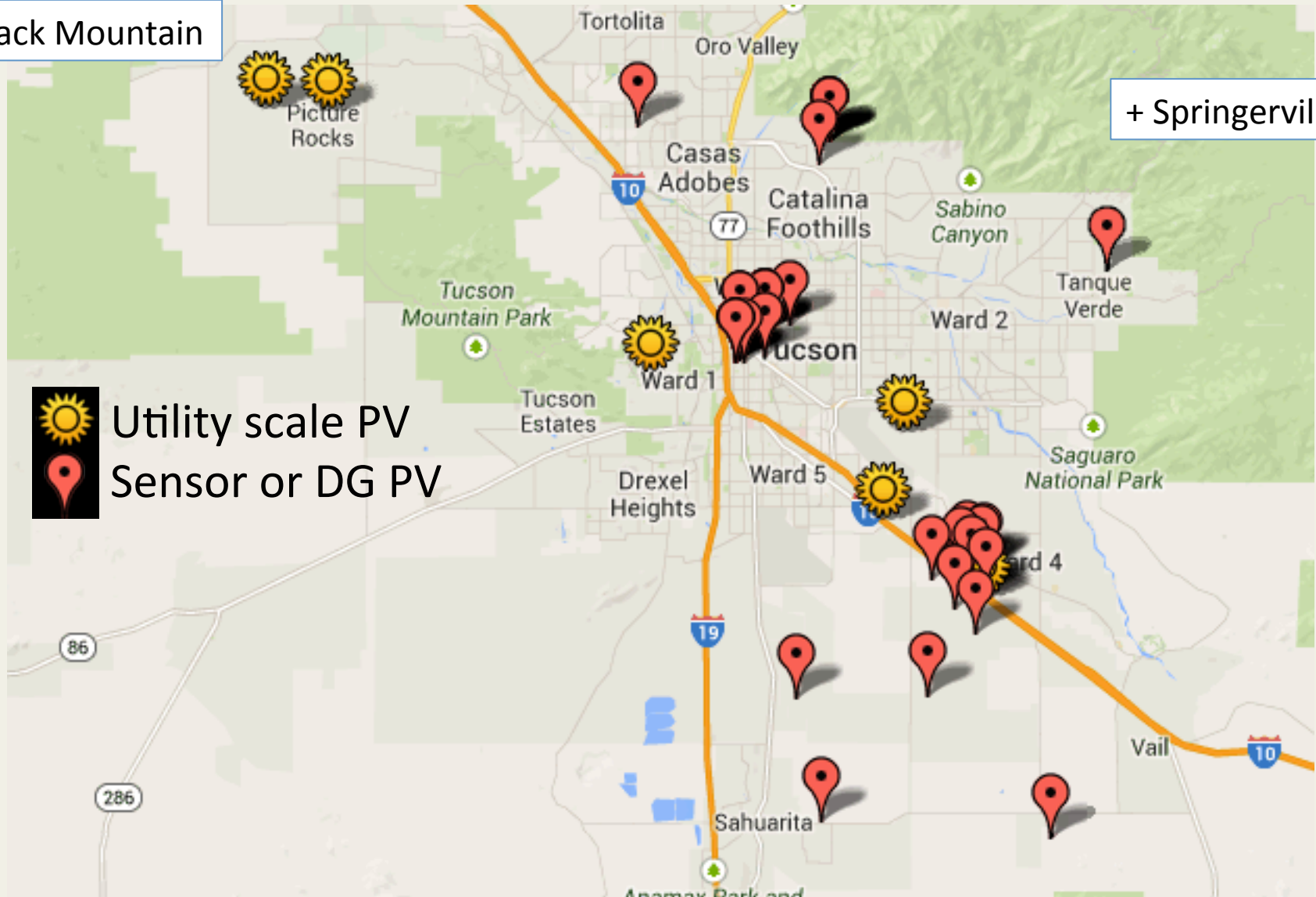
+ Black Mountain

+ Springerville

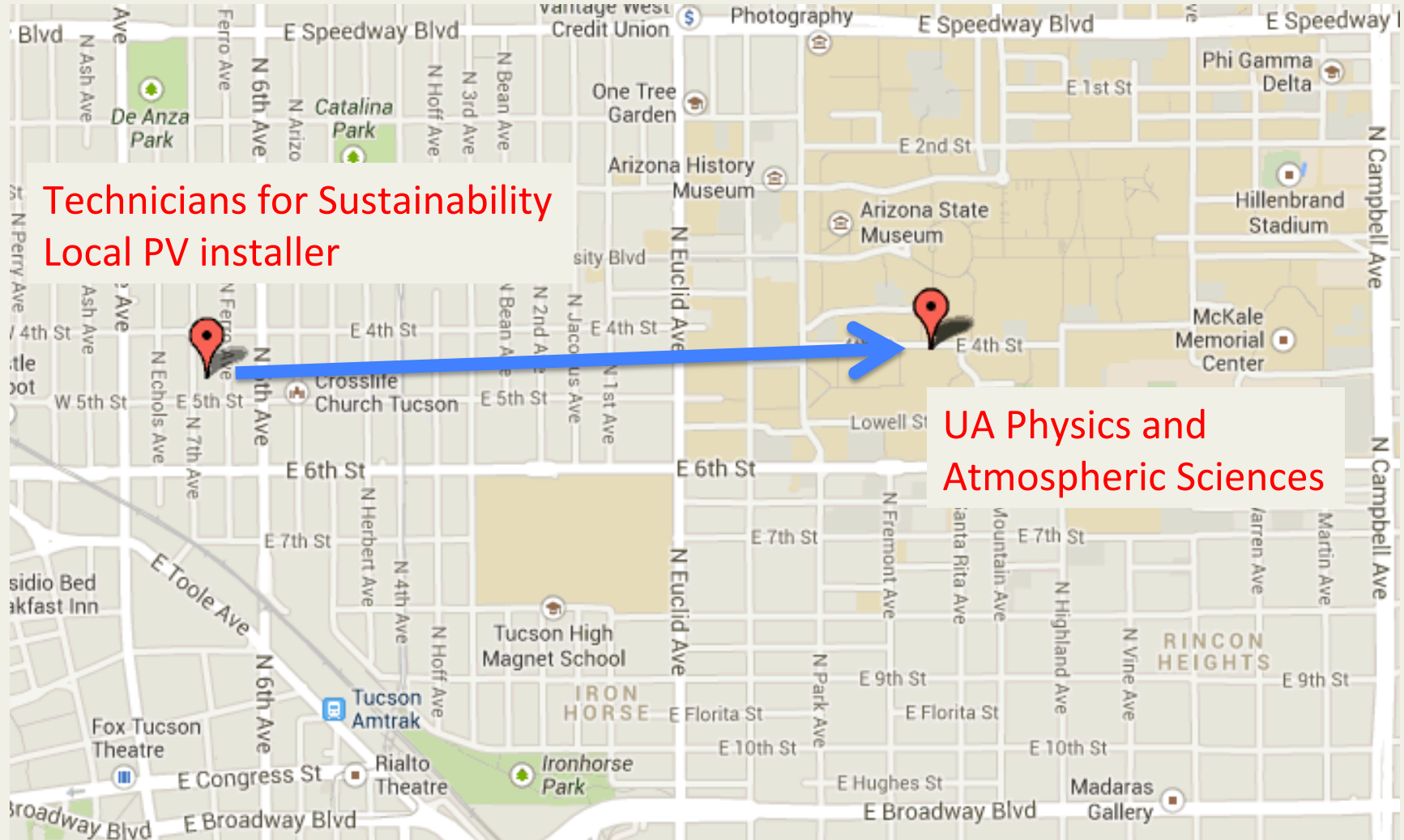


Utility scale PV

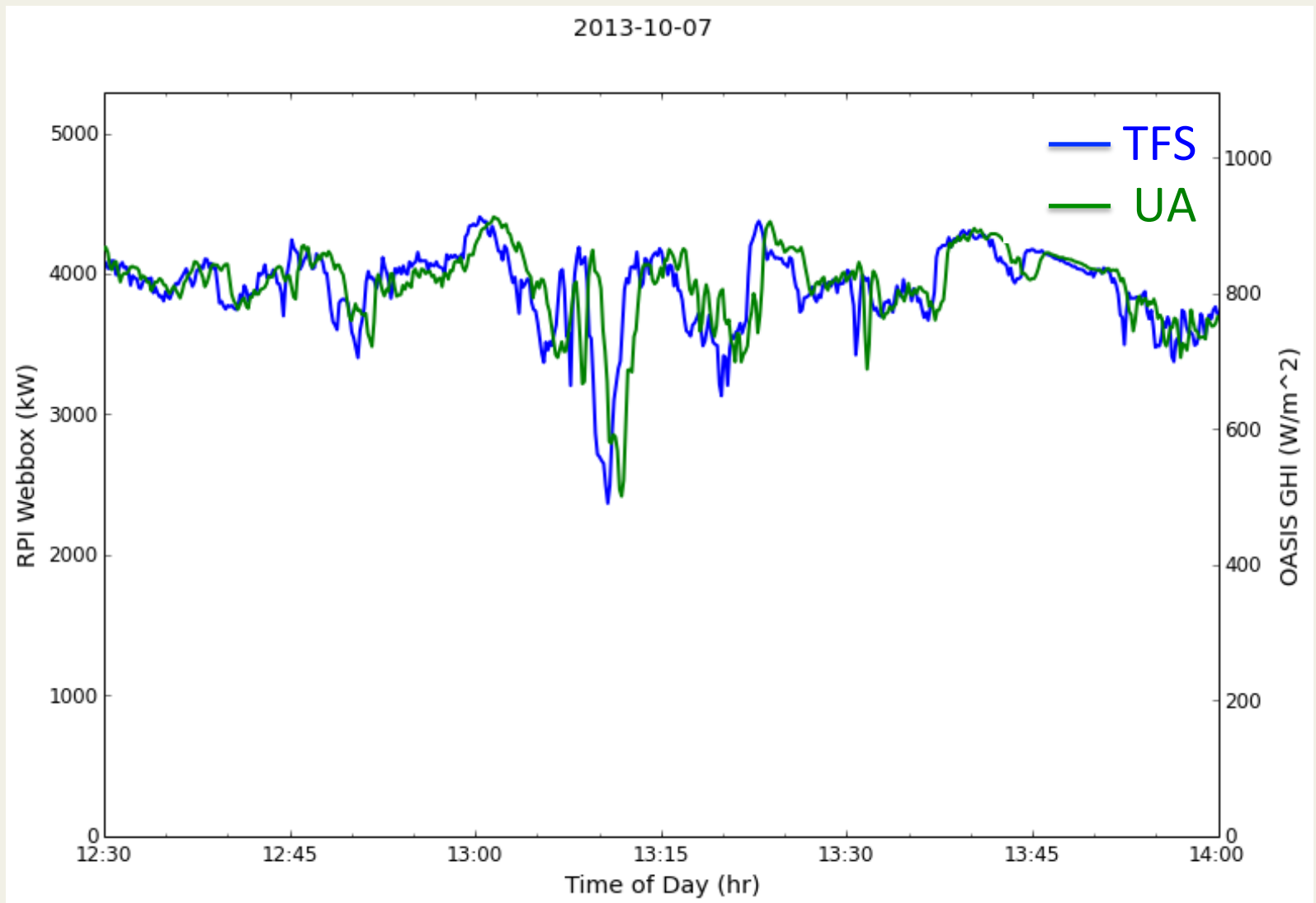
Sensor or DG PV



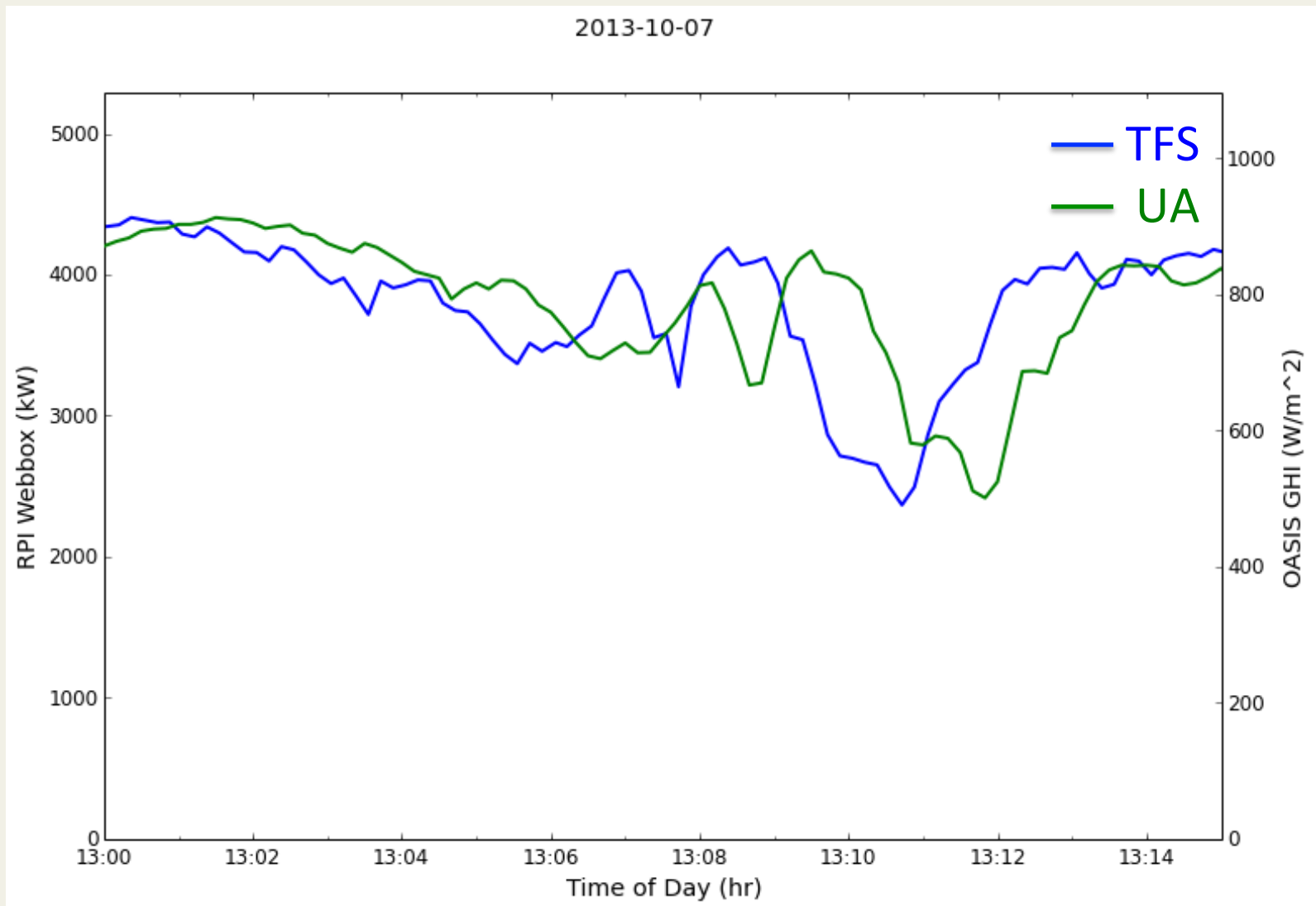
TFS to UA 1 min warning



TFS to UA 1 min warning



TFS to UA 1 min warning

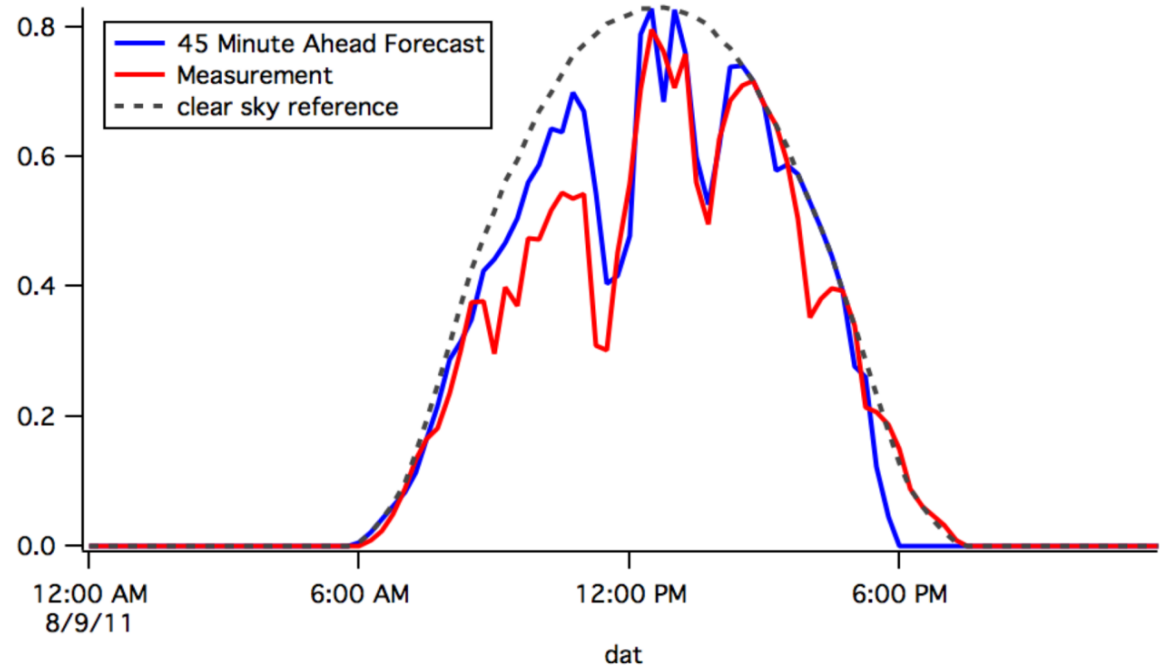
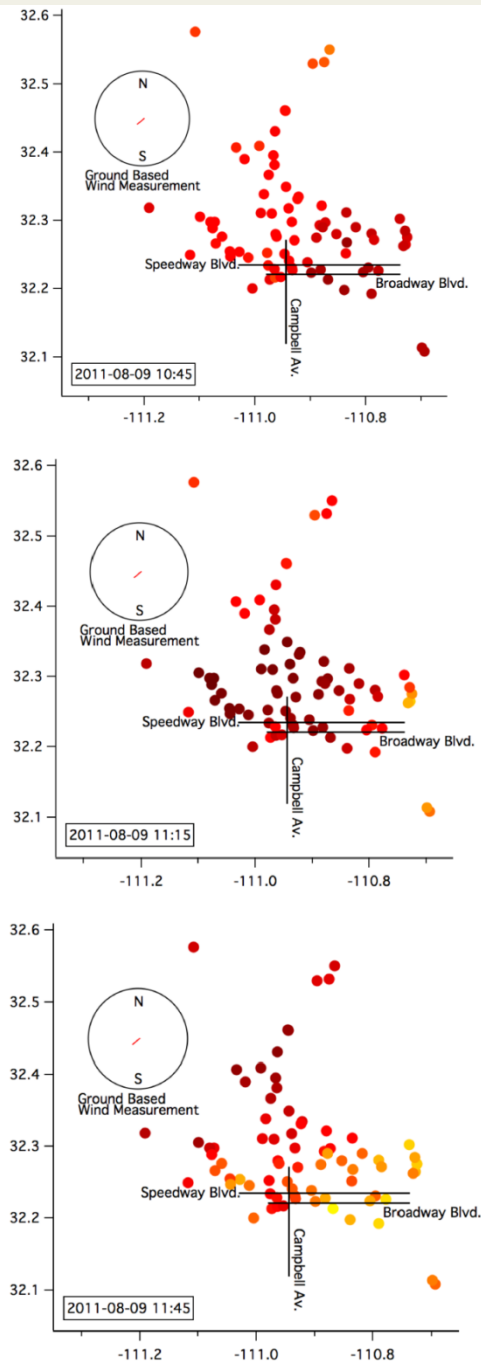


Network-based Forecasts

Retrospective forecasts based on data from 100 rooftops

Building system to do this in real-time

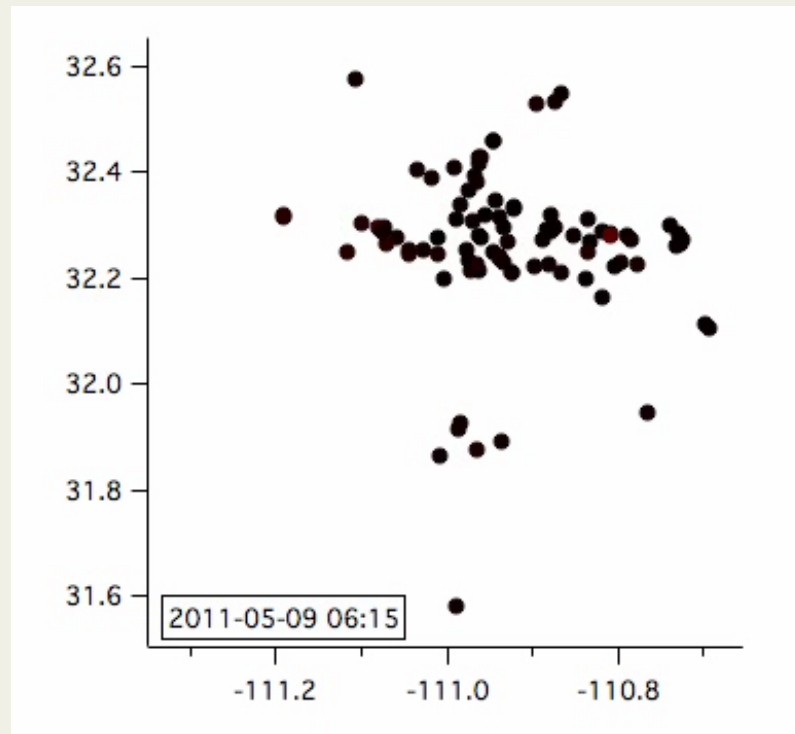
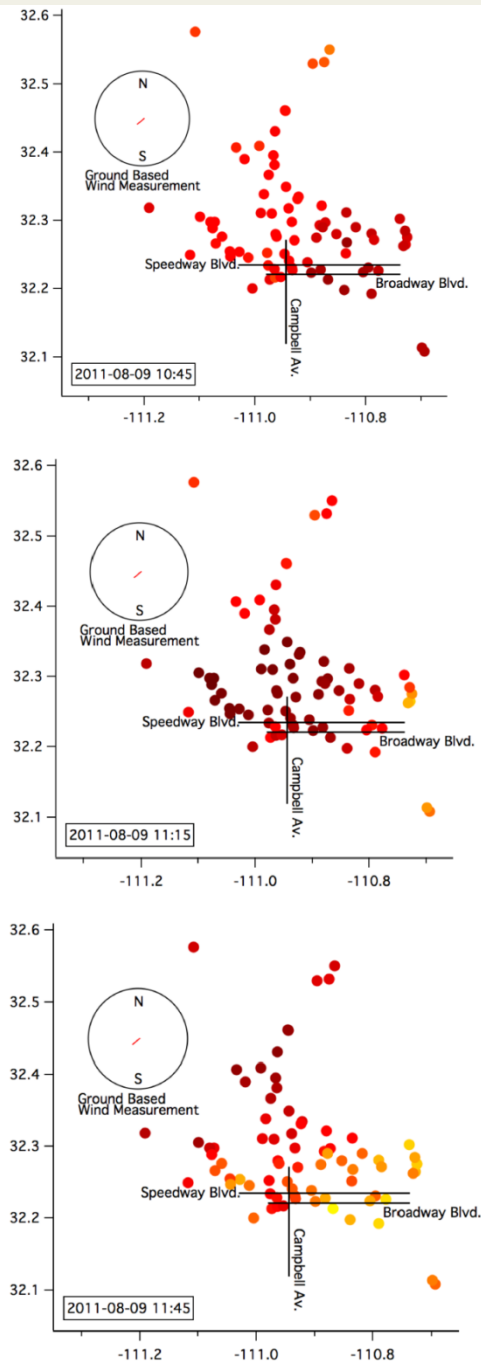
Lonij et al., *Solar Energy* **97** 58 (2013)



Network-based Forecasts

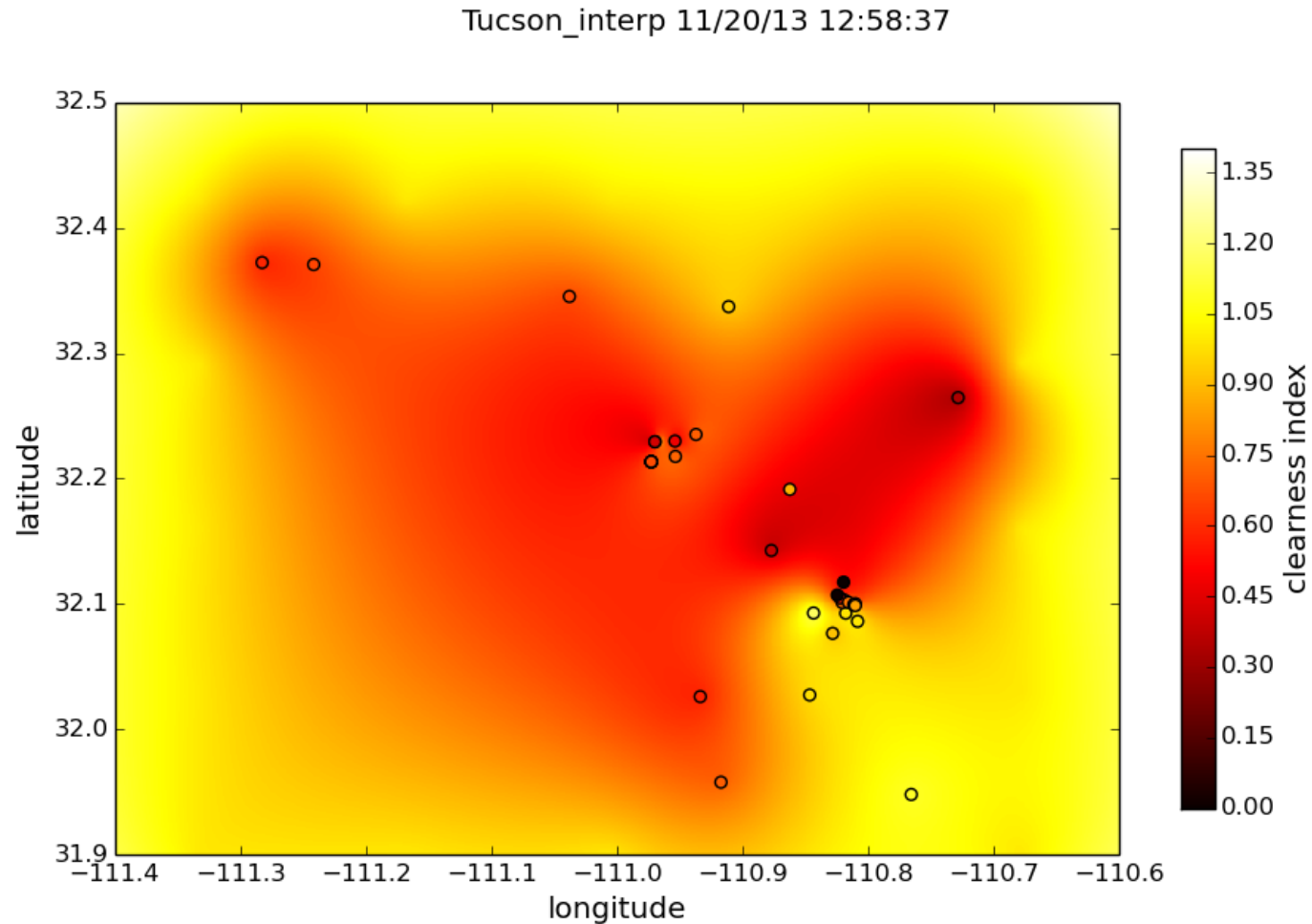
Retrospective forecasts based on data from 100 rooftops

Building system to do this in real-time

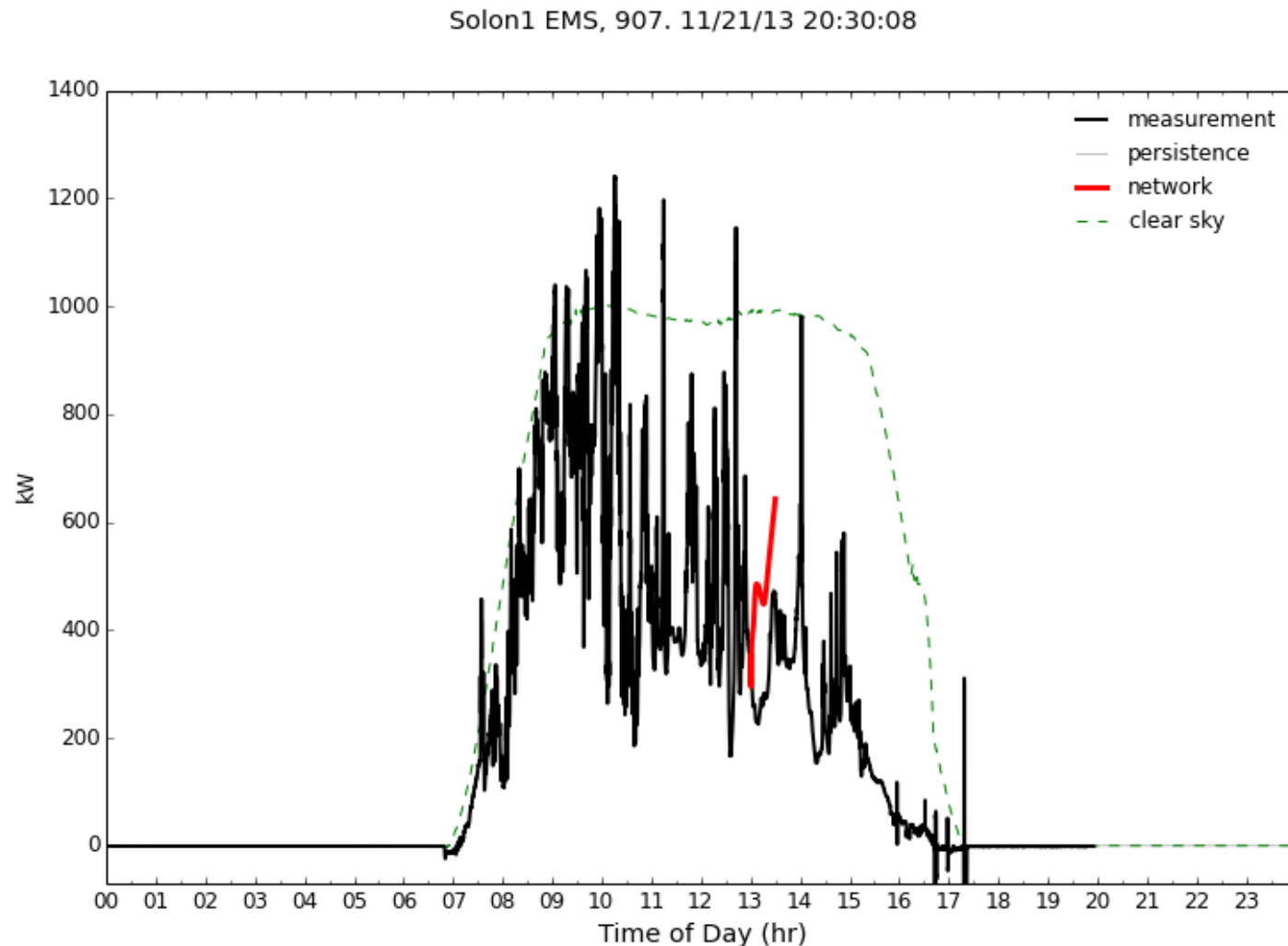


movie
link

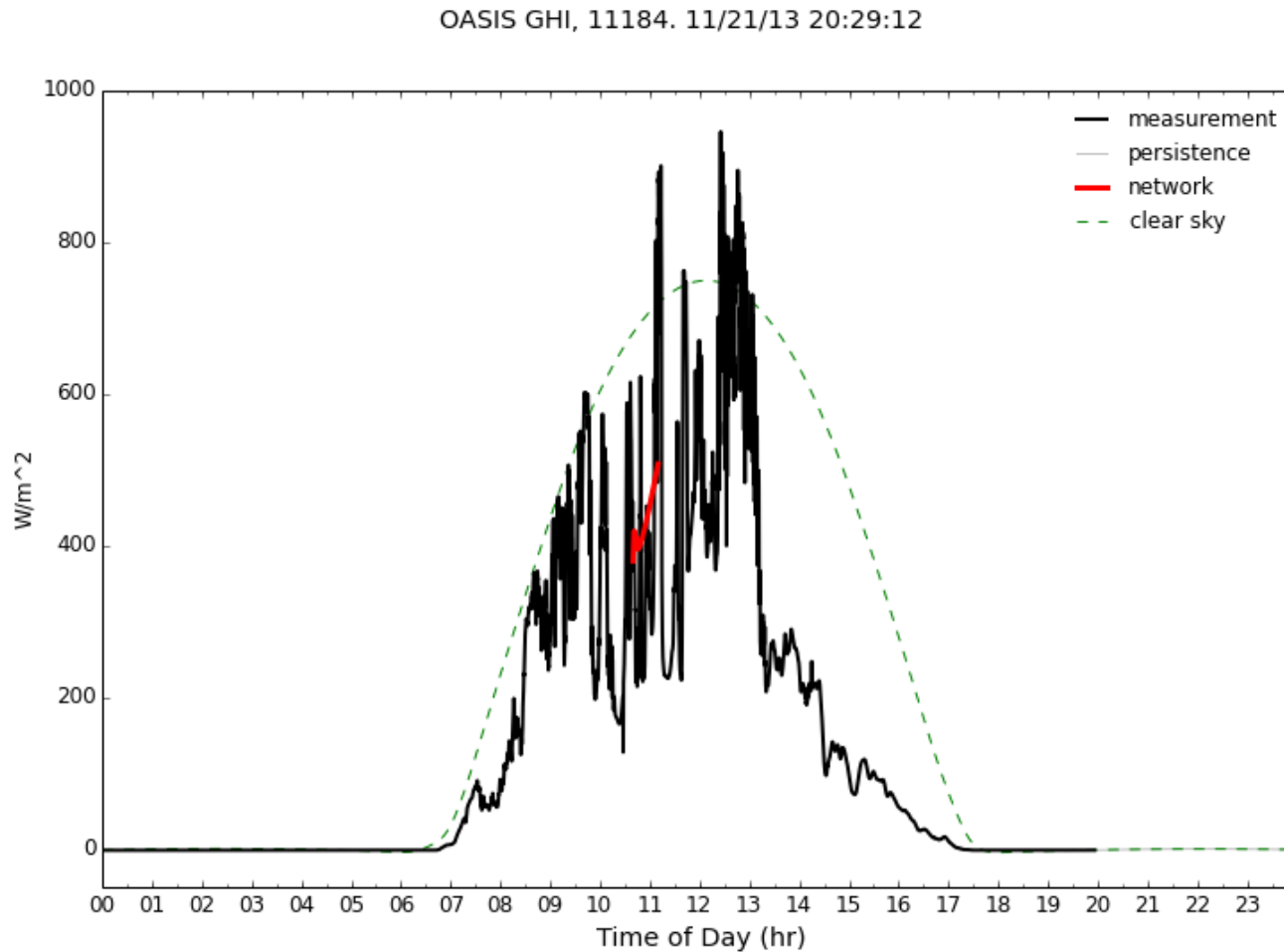
Real time clearness maps



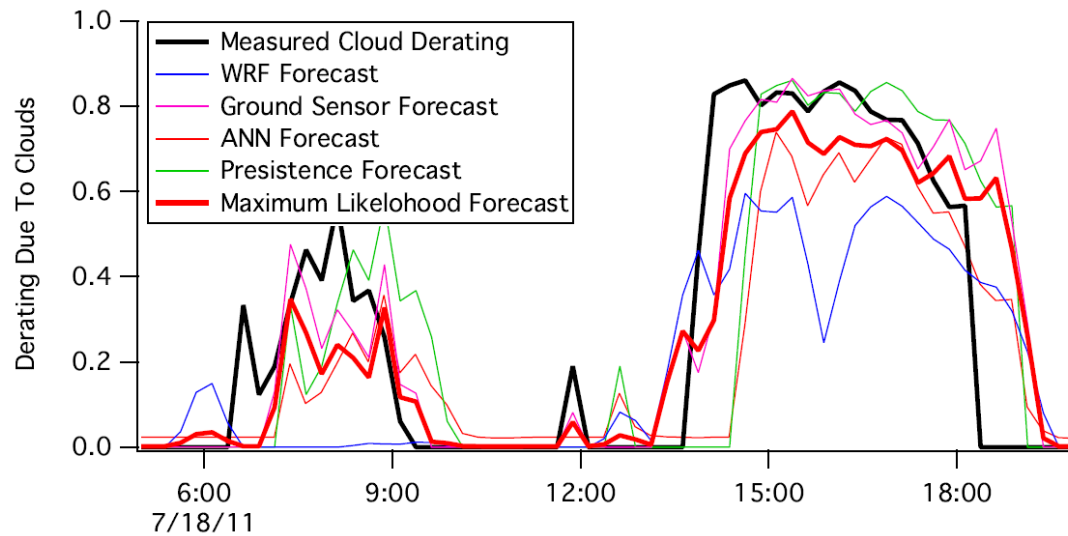
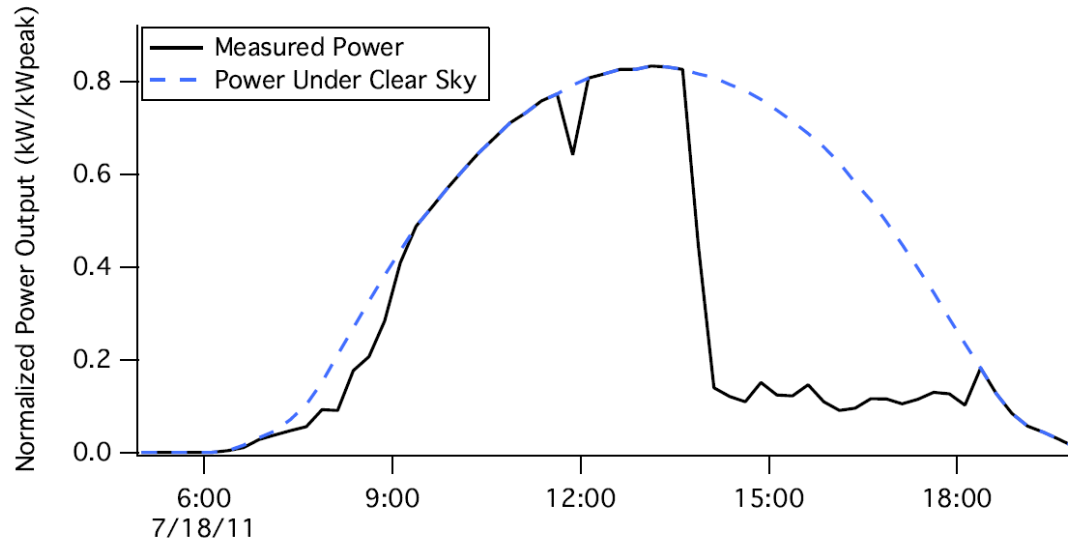
Yesterday's network forecasts



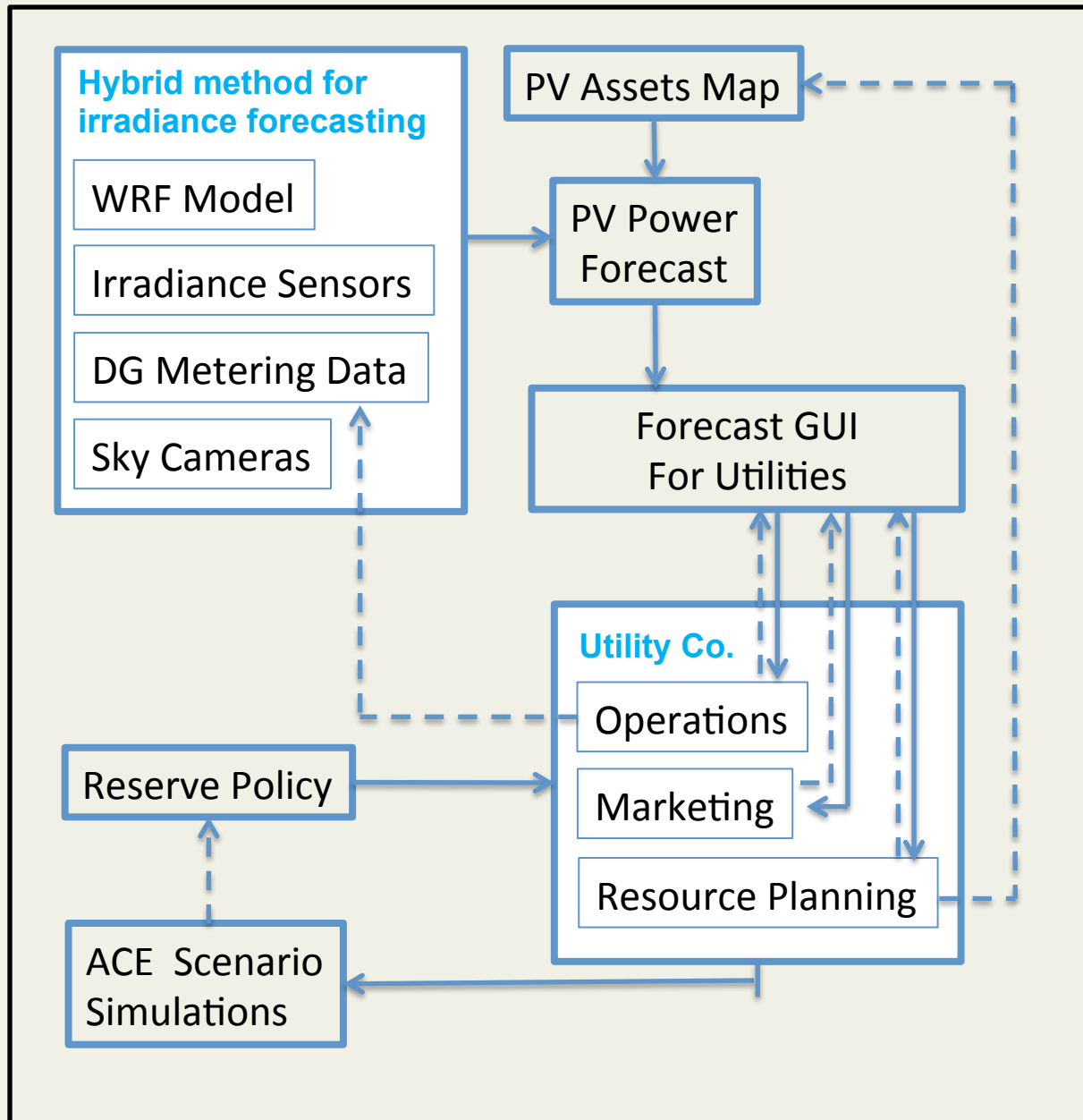
Yesterday's network forecasts



Hybrid forecasting

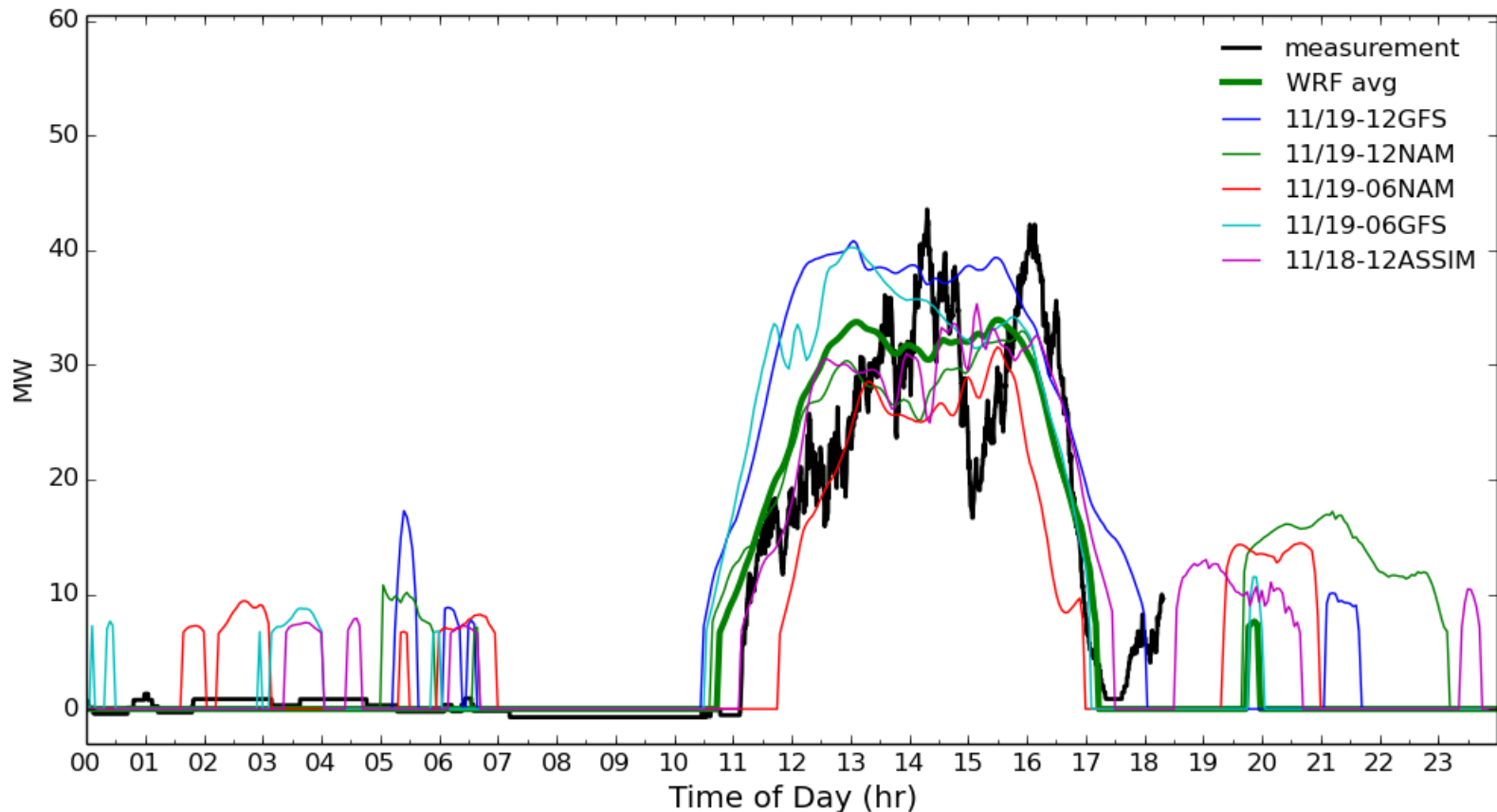


Hybrid forecasting utility integration

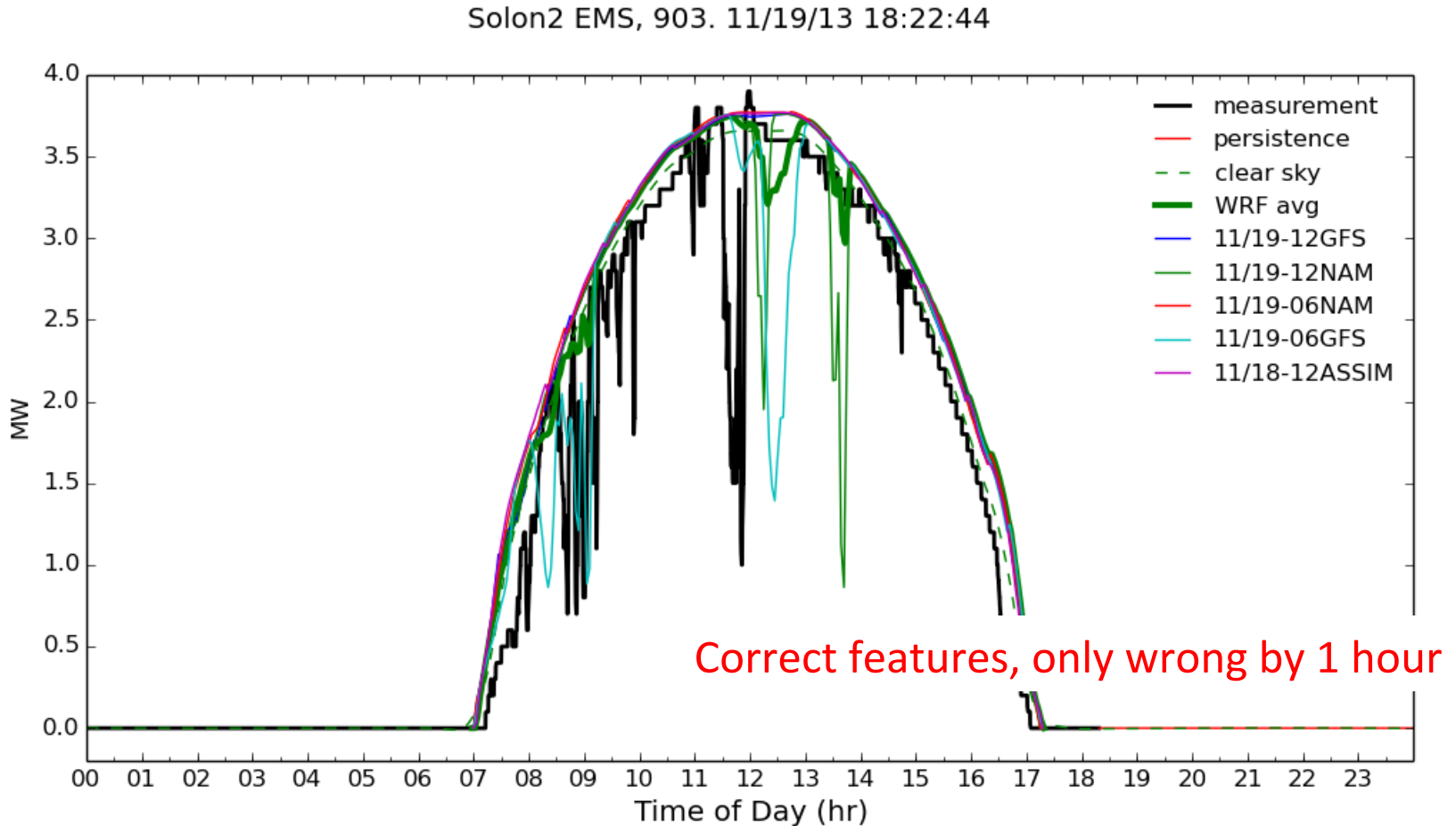


ATMO Wind forecasting for TEP

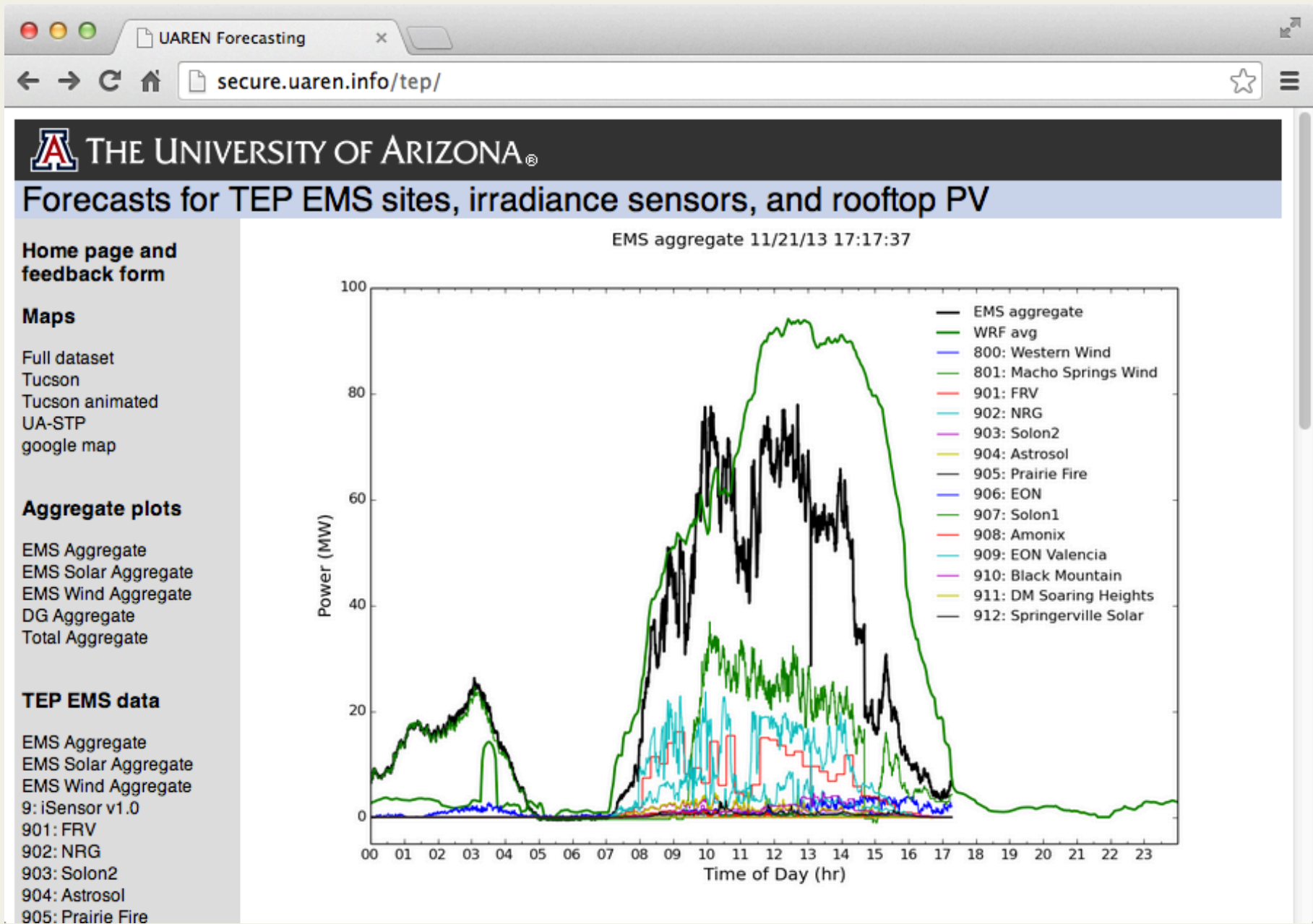
Macho Springs Wind EMS, 801. 11/19/13 18:22:44



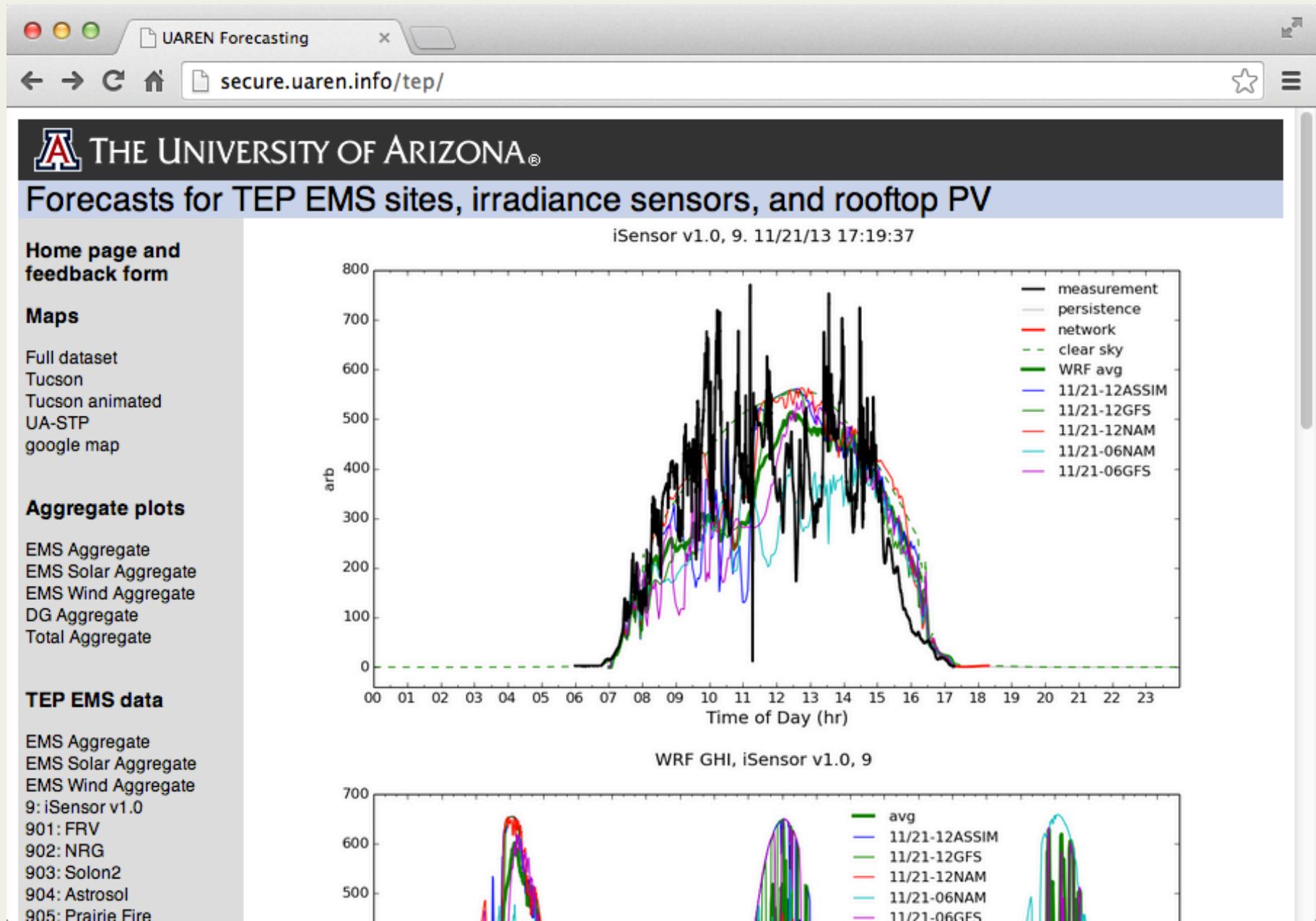
Solar forecasting for TEP



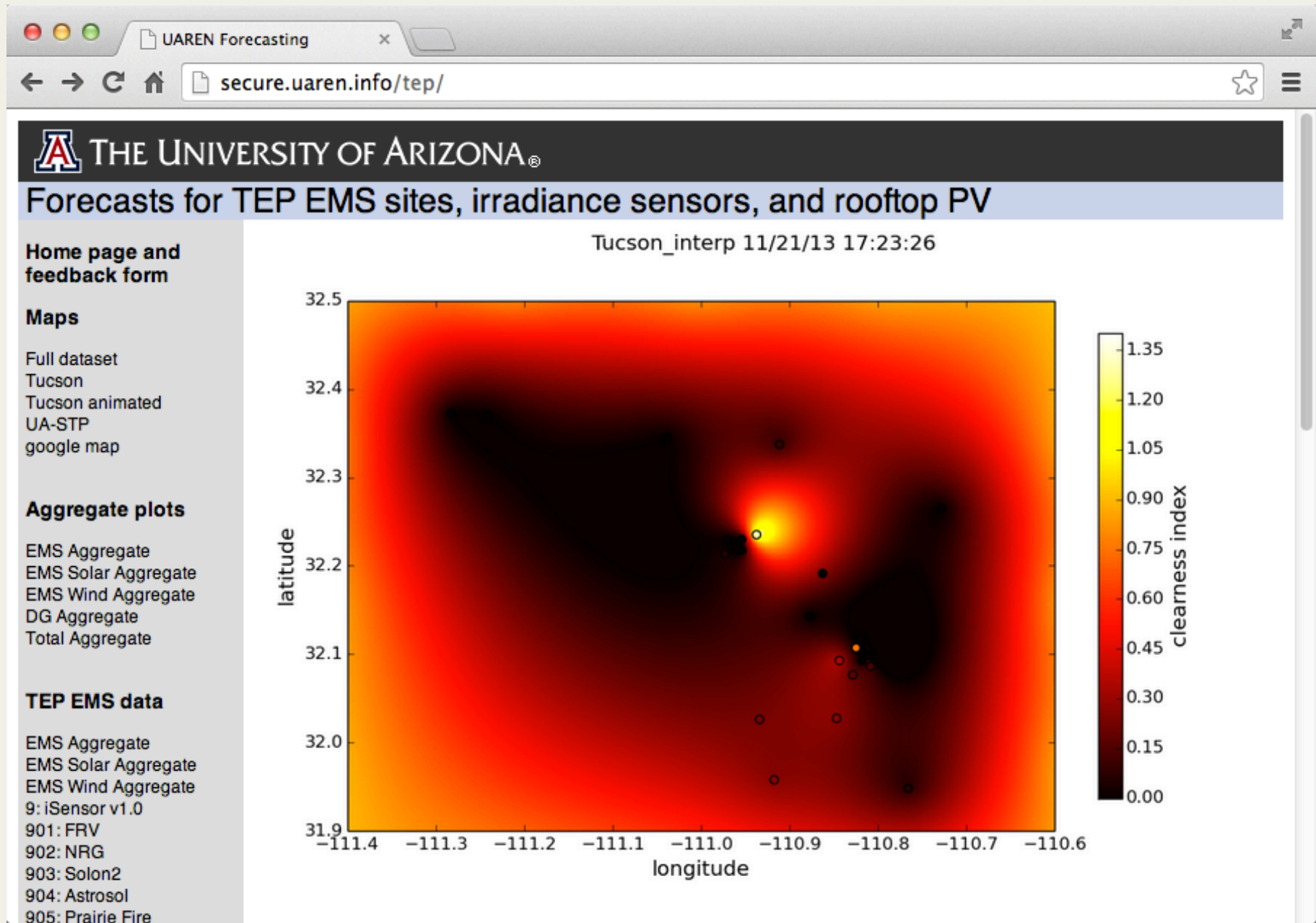
Website for TEP



Website for TEP

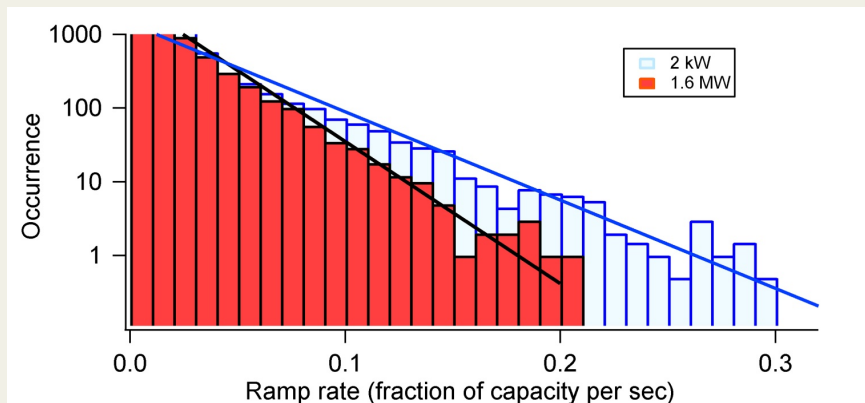
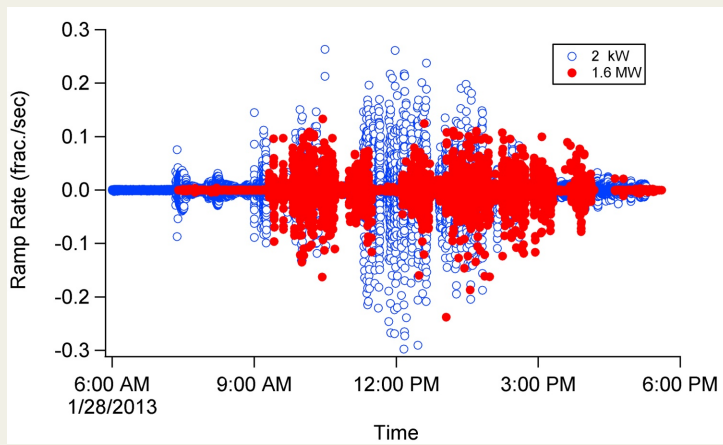


Website for TEP

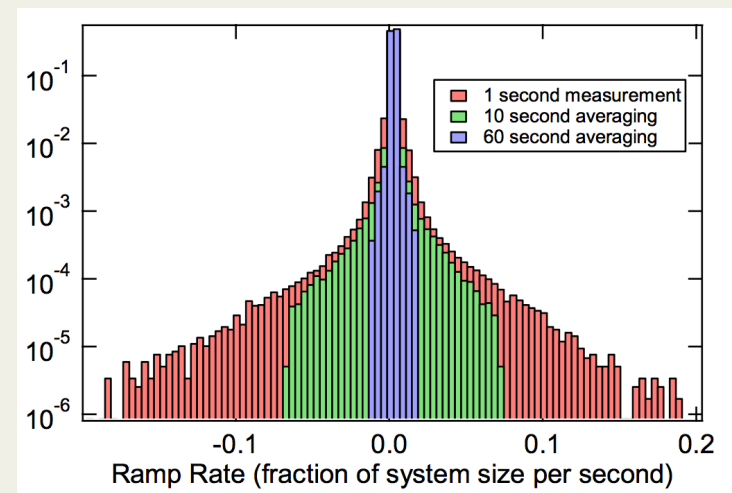


Ramp rates of MW and kW systems and battery sizing

Cormode et al., PVSC 2013



Maximum allowed ramp rate ($\Delta P/\Delta t$)	Battery power for 100% compliance	Battery power for 99.5% compliance	Battery power for 98% compliance
100% / 10 min	0	0	0
20% / 2 min	47 %	37 %	14 %
10% / 1 min	55 %	45 %	23 %
5 % / 30 sec	59 %	48 %	26 %
1% / 6 sec	60 %	50 %	27 %
0.16% / 1 sec	64 %	52 %	27 %



Low cost irradiance sensors

