Energy Efficiency and
Renewable Energy

California Solar
Energy Collaborative

How geographic smoothing and forecasting RD&D can help high penetration of distributed generation

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How Solar Forecasting RD&D can Help Advance DG, RPS and AB32?

- What is the role of RD&D in advancing DG and helping achieve the Governor's Clean Energy Jobs Plan […], the Renewable Portfolio Standard and AB 32?
- Which technologies or components should RD&D efforts focus on to address some of the barriers for advanced DG deployment?
- Are currently existing technologies and tools enough to power facilities with nearly 100 percent renewables in a technically and economically feasible manner?
- What are some emerging technologies that may be able to reduce costs when produced at scale?
- What issues impede the deployment DG technologies in utility distribution territories that RD&D can help address? If so, please identify the issue and how RD&D can help in a manner that benefits both the utilities and customers.
- What other future research direction, focus, strategies or initiatives may be recommended for PIER to undertake so that RD&D can better help advance DG?

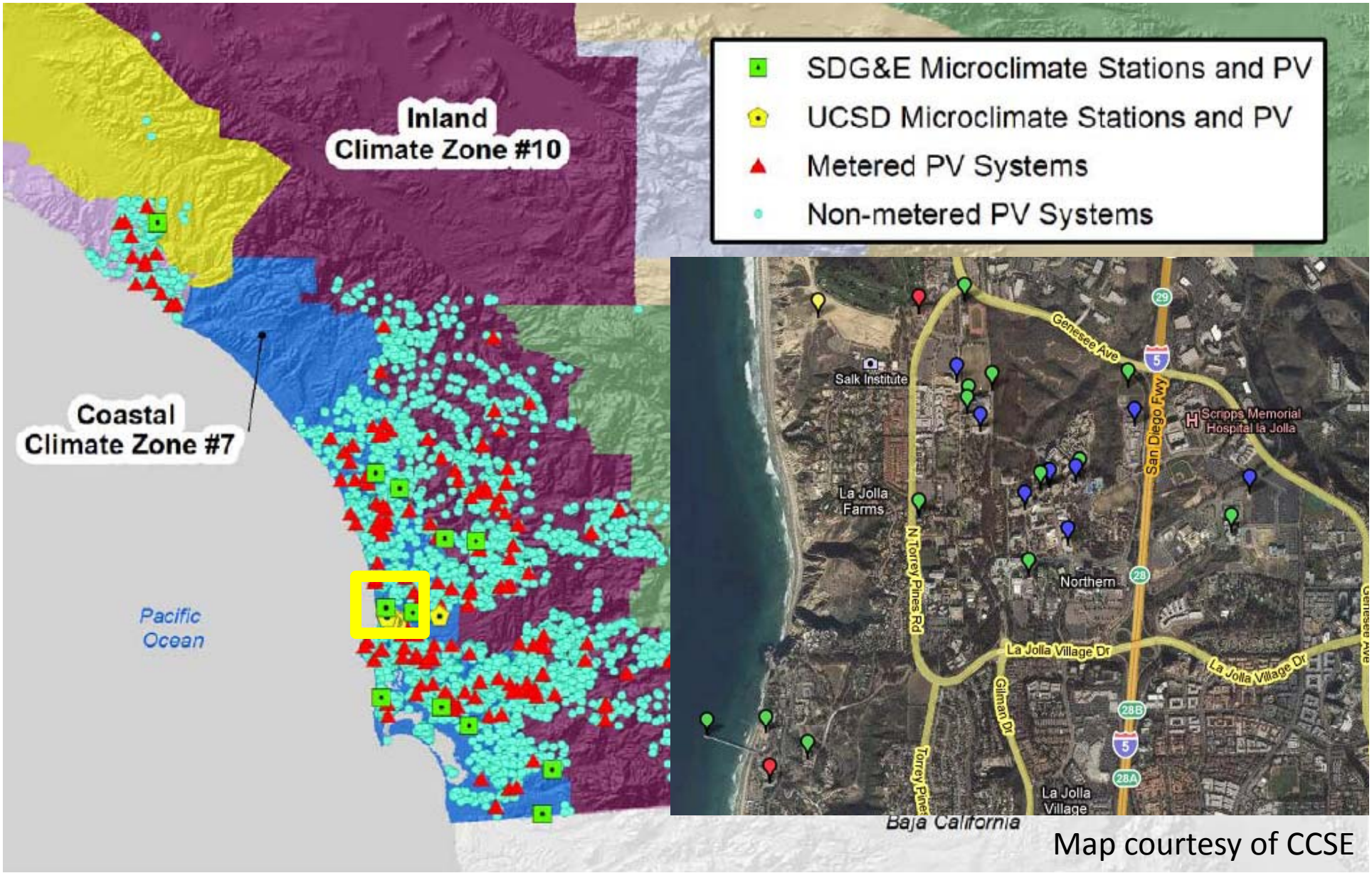
Variability of Solar Irradiance as an Impediment to High Solar Penetration

- Distribution system
  - Voltage changes; wear and tear on voltage regulation equipment
  - Reverse power flows
- Transmission system
  - Low penetration: forecast error leads to increase in reserve costs, inefficient transmission scheduling
  - High penetration: curtailment, storage

The Role of RD&D in Solar Forecasting

- The ultimate goal is to be 90% accurate (MAPE) in intra-hour solar forecasts for spatial areas of 10 sq.m.
- The ultimate goal is for solar forecasts to raise the intra-hour reliability for a spatially dispersed DG network to be characterized as a firm generation intra-hour resource on a distribution circuit and a wider regional area
- The ultimate goal is for solar forecasts to be integrated with energy storage for intra-hour charge-discharge algorithms
- The ultimate goal is for solar forecasts to reduce non-renewable peaker generation, spinning reserves and permanent load shifting.

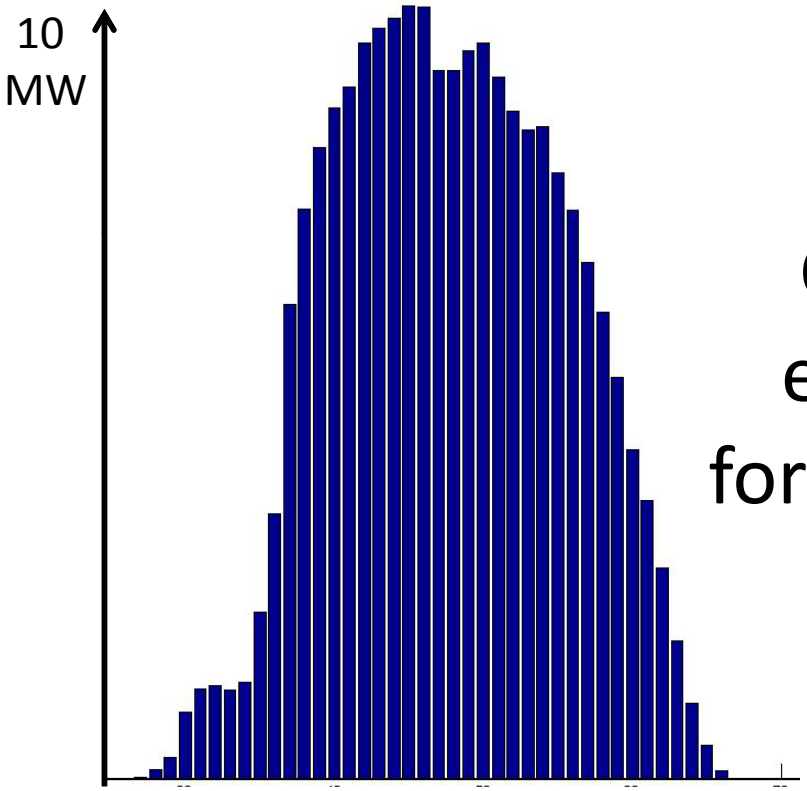
PV Systems in San Diego County and UC San Diego: Testbed for Solar Variability



Map courtesy of CCSE

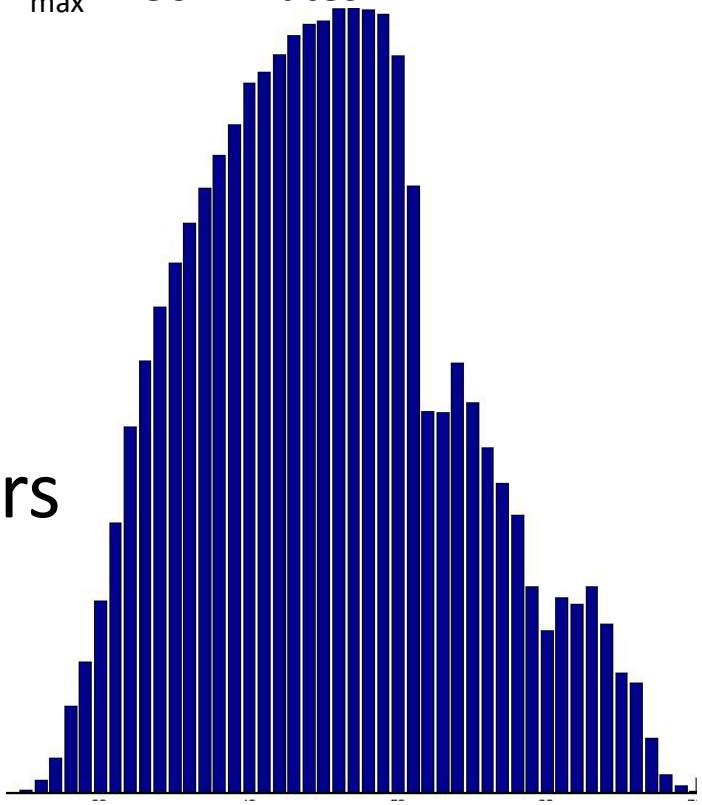
What are the largest aggregate ramps for 15 MW PV in SDG&E territory?

November 29, 2009: largest up-ramp
60% of P_{max} in 60 minutes



Currently evaluating forecast errors

September 29, 2009: largest down-ramp
43% of P_{max} in 30 minutes

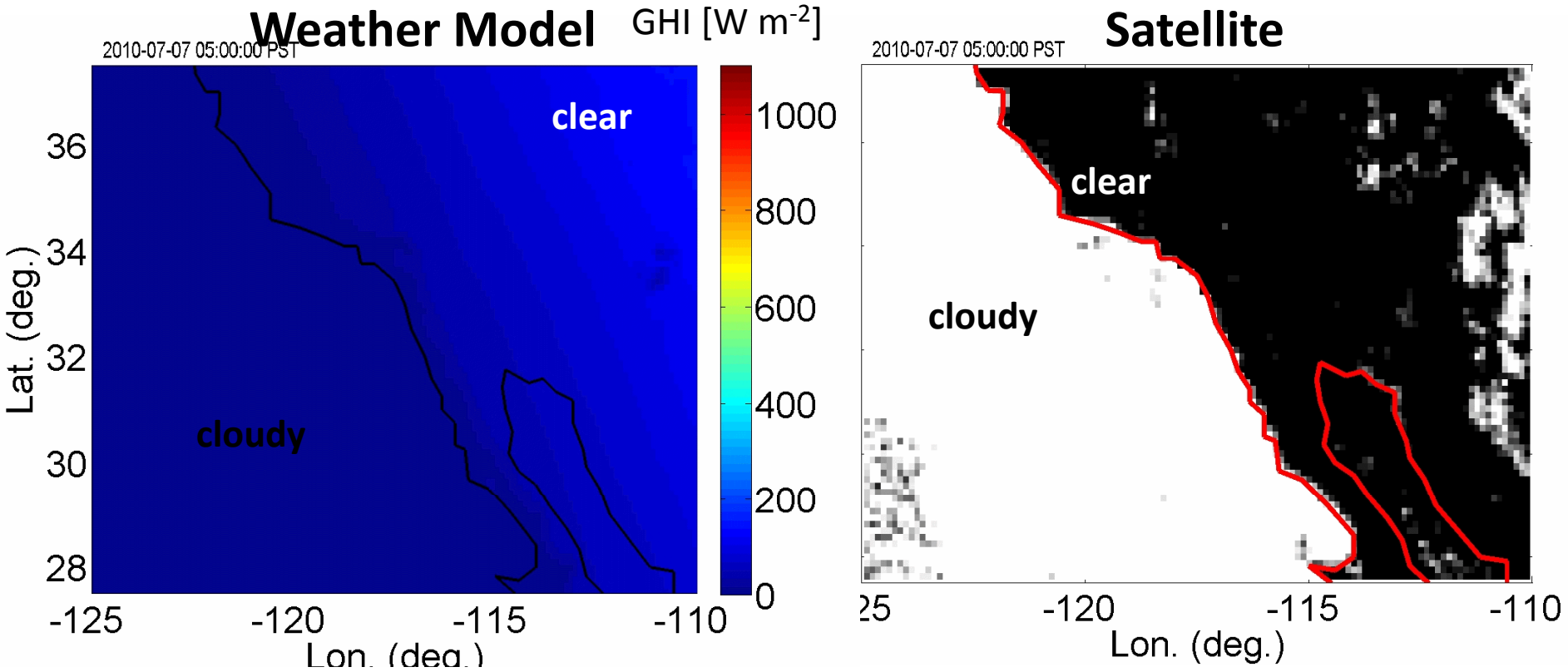


Research questions:

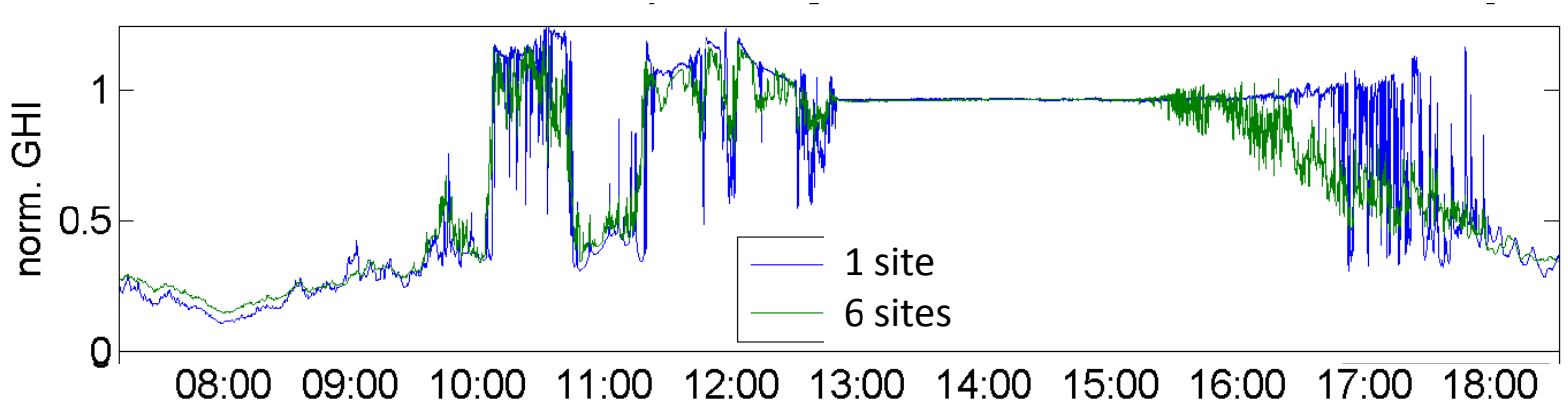
Are largest ramps predictable – day ahead, hour ahead? Under what conditions are ramps more likely?

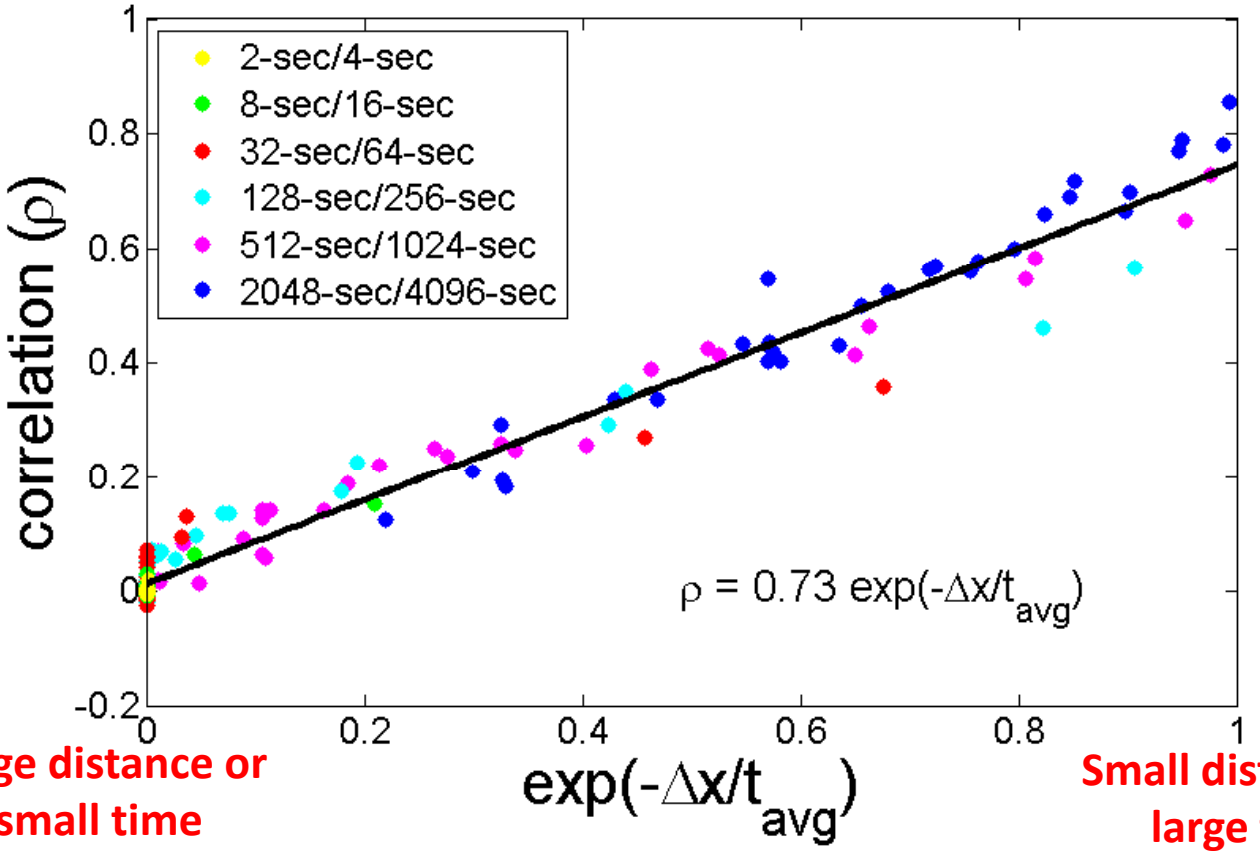
Forecast errors for large ramps

- Small spatial error (10 to 100 miles), but big impact (80% of CA DG)
- Reducing error would require very high resolution numerical simulations
- Research on statistical corrections



Quantifying benefits of Geographic Smoothing





Large distance or small time

Small distance or large time

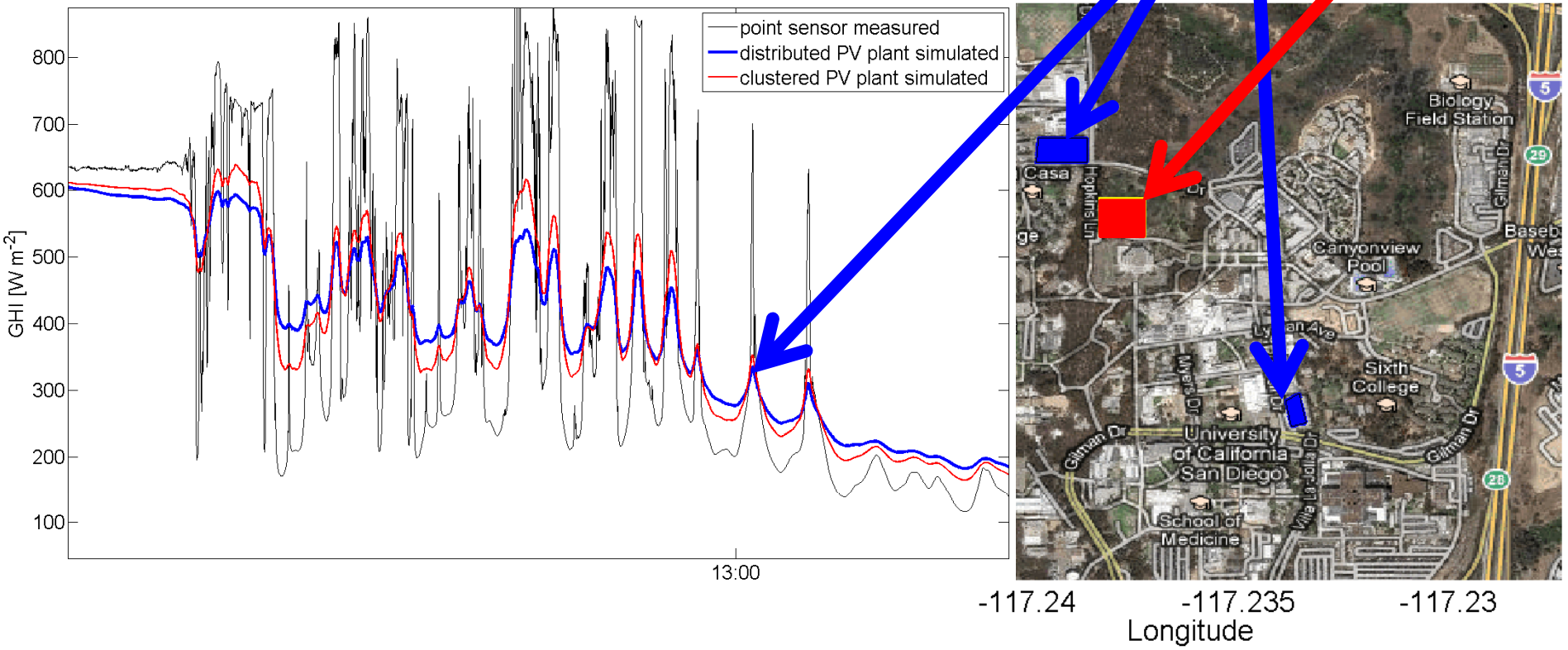
Universal relationship of correlation between sites versus distance divided by time

→ Apply to simulate geographic smoothing

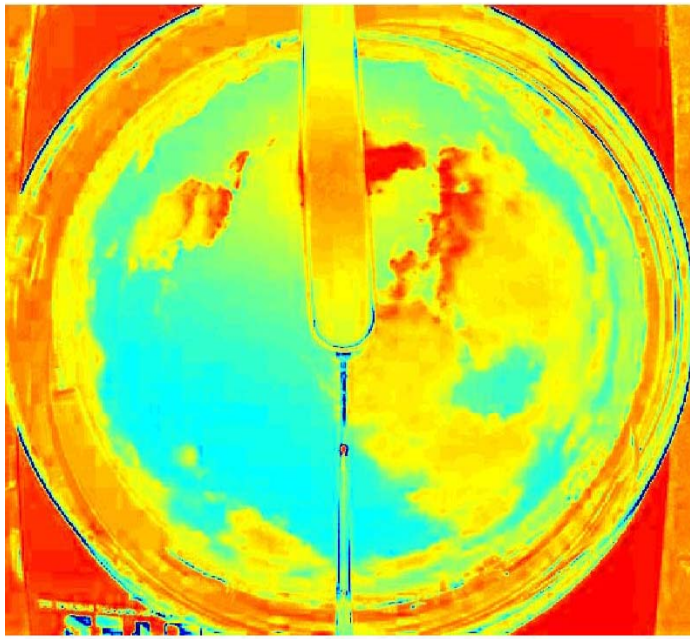
Simulating Geographic Smoothing

Distributed PV shows largest additional reduction in variability at 1 to 5 minute ramps

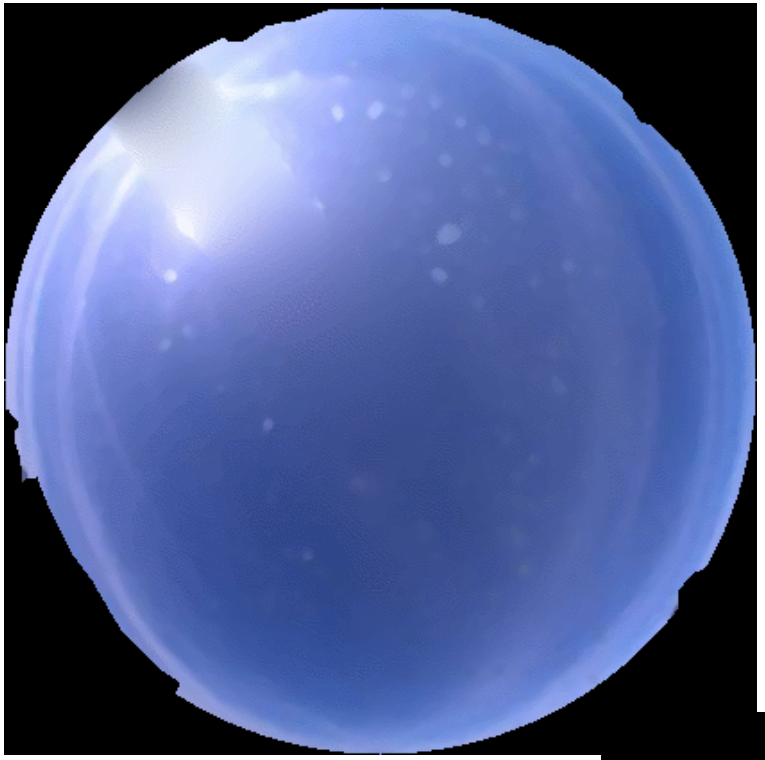
It is now possible to simulate geographic smoothing



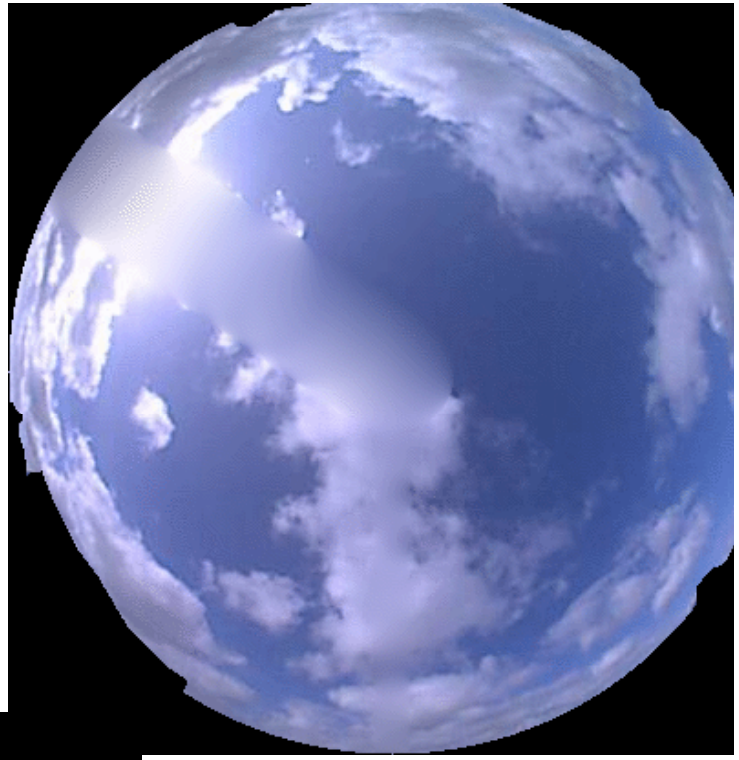
Highlighted R&D: Intra-hour Solar Forecasting with a Total Sky Imager



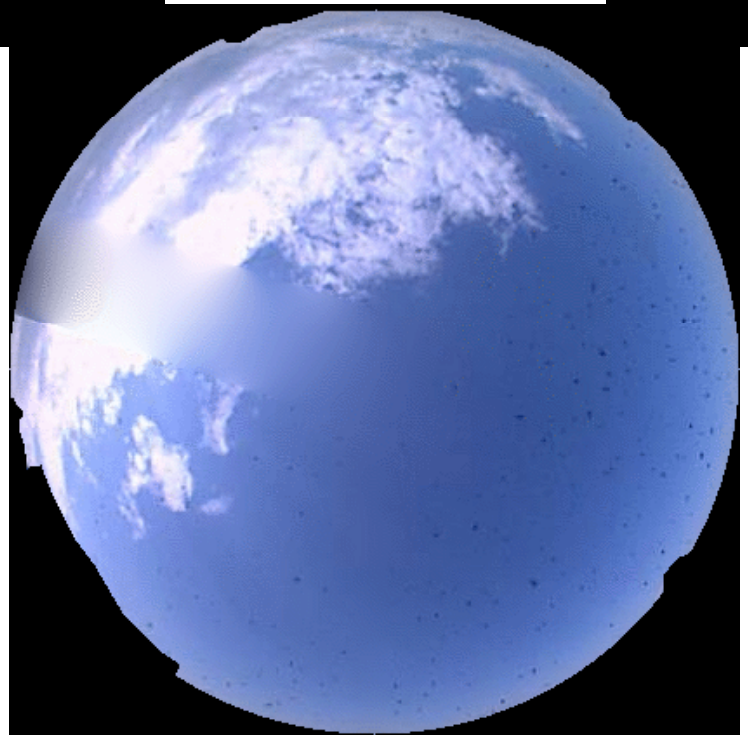
Cloud Types



Cirrus



Cumulus



Altocumulus

Cloud Motion Vectors

- Apply cross-correlation method to coordinate-transformed sky image.
- Retain only vectors for which high correlation is obtained
- Assume homogeneous cloud velocity

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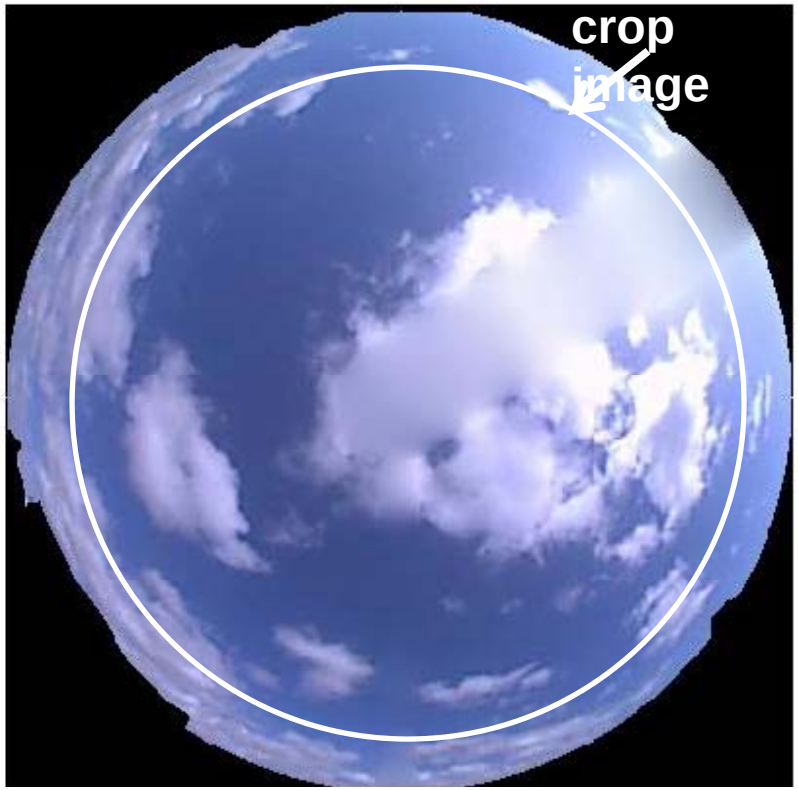
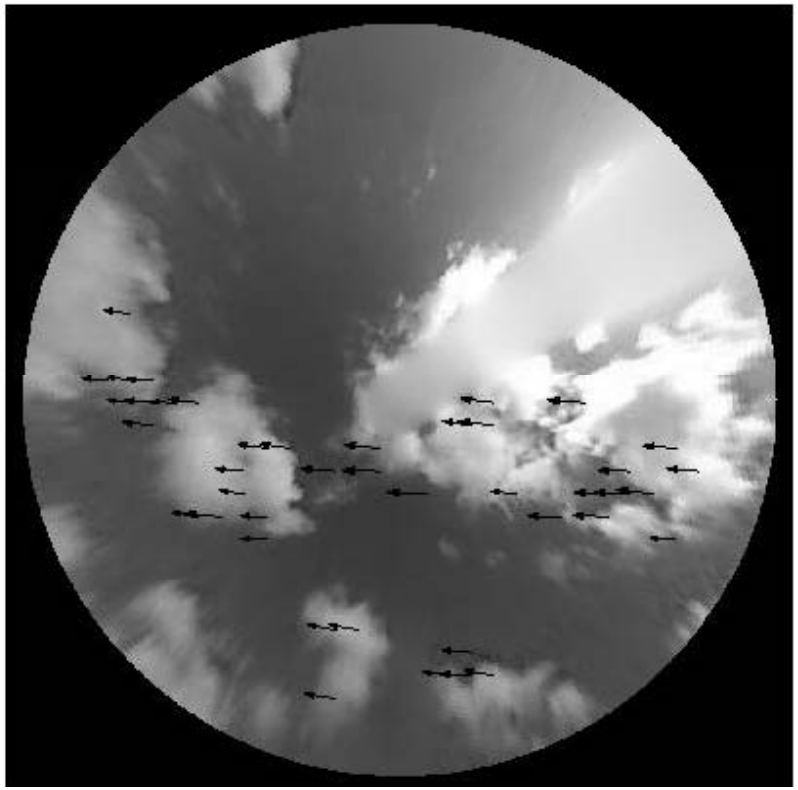
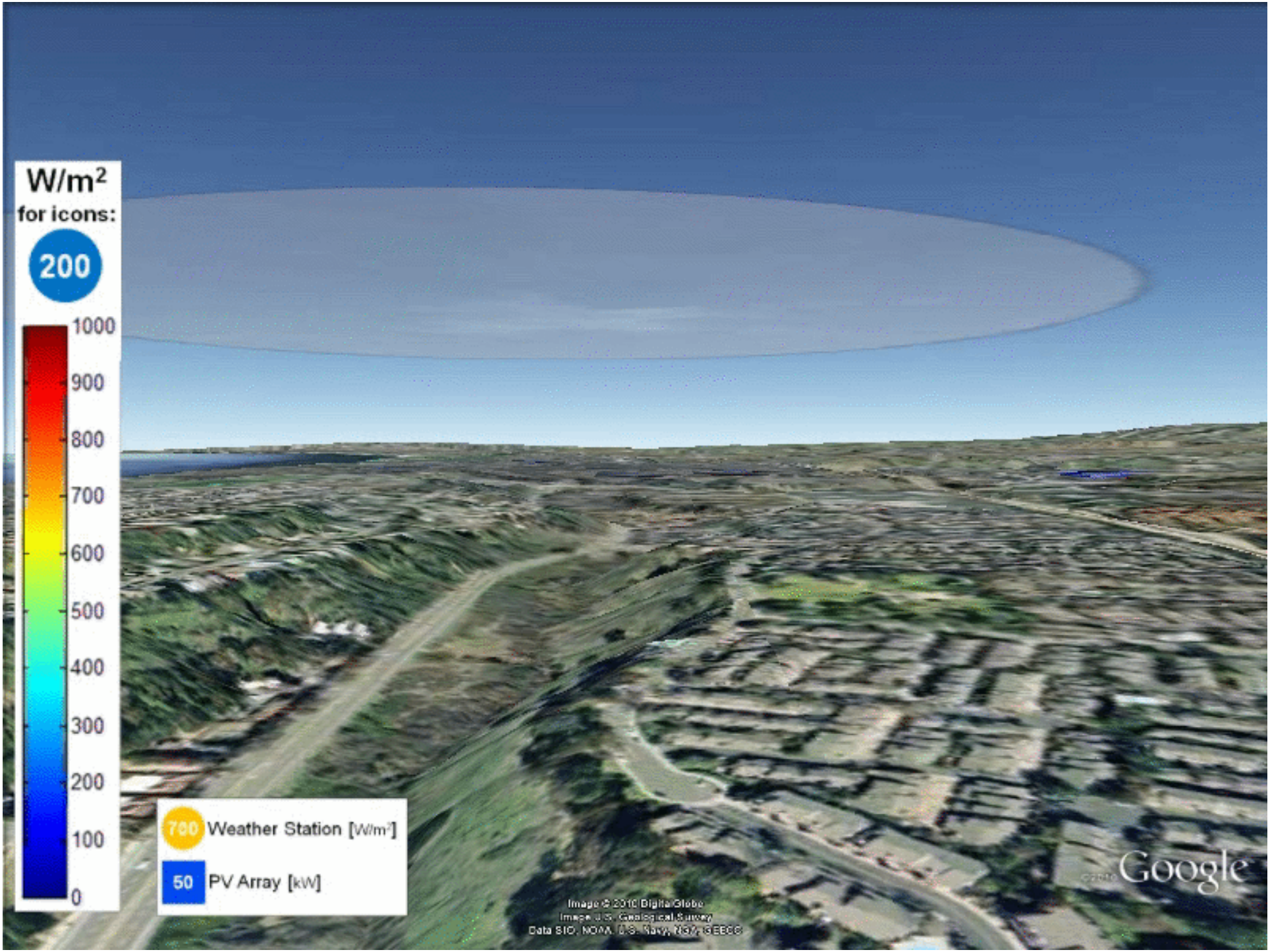


U: -5.8532m/s V: 0.54762m/s




W/m²
for icons:
200
1000
900
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700 Weather Station [W/m²]
50 PV Array [kW]
Image © 2010 DigitalGlobe
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Data SIO, NOAA, U.S. Navy, NGA, GEBCO
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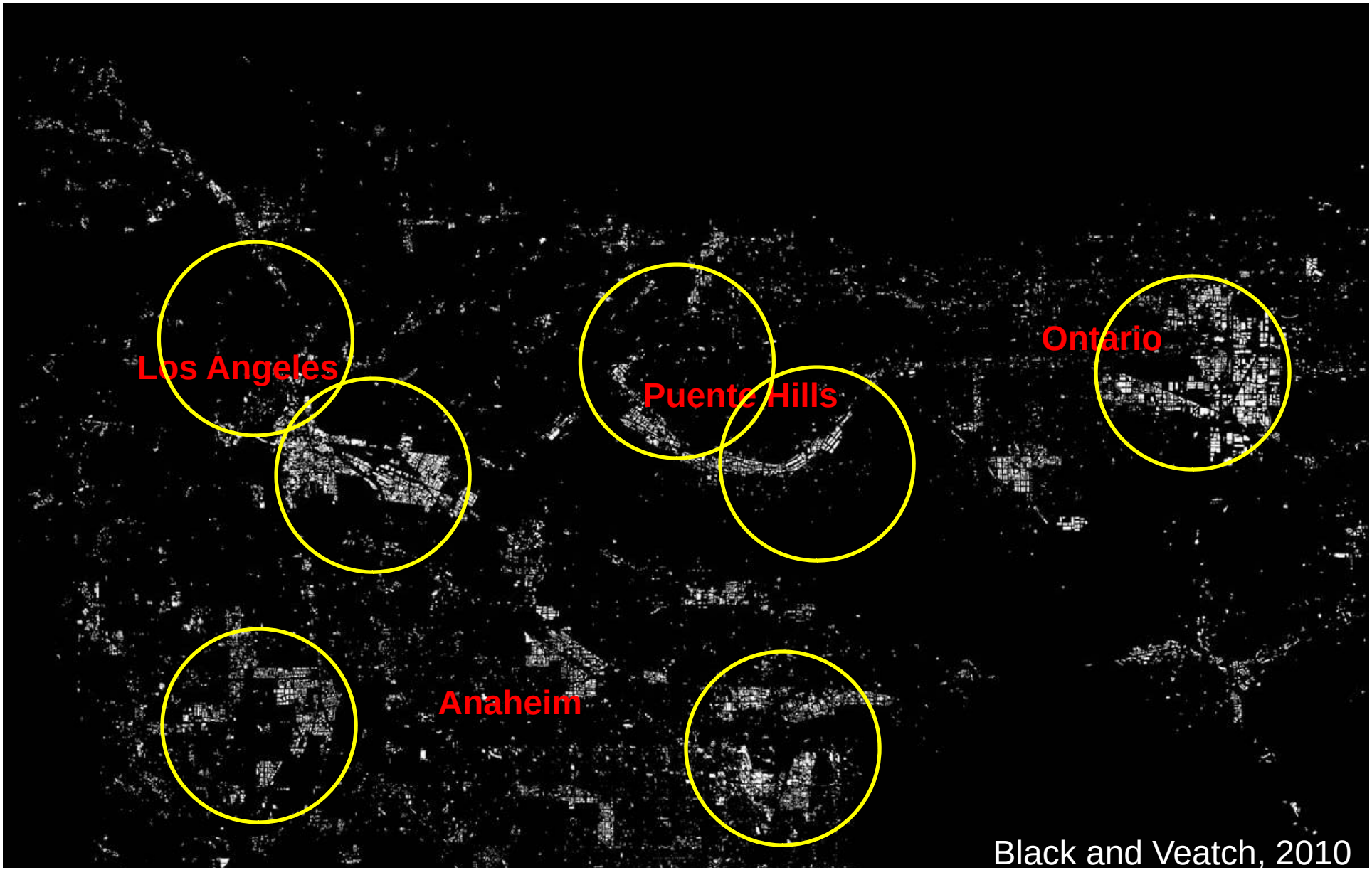
Forecast Results

- Error increases with forecast horizon, but still 25% better than persistence after 5 minutes.
- After 10 to 25 minutes the scene is advected out of the field of view
  - Sky Imager provides situational awareness to CAISO over this timescale
- If we can achieve the forecasting breakthroughs, 7 sky trackers would provide intra-hour forecasts for the majority of the LA/OC market
- Demonstration studies with Sempra Energy at 48 MW PV and SCE for rooftop PV

Los Angeles Warehouse Roof Market



RD&D direction, focus, strategies or initiatives to advance DG, RPS and AB32

- Day ahead Solar Forecasting (Numerical Weather Prediction, NWP)
  - Evaluate forecast performance for California-specific meteorological events (winter frontal system, marine layer clouds, Tule fog)
  - Conduct high resolution rapid refresh simulations to improve cloud resolution
  - Conduct data assimilation of ground or satellite data into NWP

RD&D direction, focus, strategies or initiatives to advance DG, RPS and AB32

- Intra-day Solar Forecasting (Satellite)
  - Evaluate forecast from satellite imagery
  - Construct radiative transfer models to model cloud effects (especially for concentrating solar power)
- Intra-hour Solar Forecasting (Sky Imager)
  - Responsive to FERC NOPR
  - Integration with satellite imagery
  - 3d radiative transfer models
- Lab to market: Collaborating with industry (CAISO, Enernex, AWS Truepower, Garrad Hassan, Clean Power Research) and Byron Washom in PIER funded research to bring forecasting technologies to market

Integrating Solar Forecasting with the Smart Grid Solar Stakeholders

- Transformer, inverters, energy storage and PV manufacturers
- Distribution system operators, designers, and control software developers for mitigating variability
- CAISO for centralized solar, microgrids, virtual power plants and DG and the private sector stakeholders in these markets
- Tech transfer to regulators and professional standards for allowable limits of penetration
- A great start with the DOE-CPUC workshop site hosted by UCSD March 2011

Acknowledgement of Funding Sources

- $0.5M CEC matching to $1.9M DOE grant for Mitigating Measures of High PV Penetration
- $1M of CEC RESCO to $1M of UCSD match
- $0.2M from CEC Solar Collaborative
- $0.5M of CSI Round I
- $0.7M from Sanyo for Battery Storage Integration
- $0.5M from CEC for Forecast Model Integration (on 5/18/11 Business Calendar)