CSI Solar RD&D Program
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Itron CSI RD&D Program Manager

High Fidelity Solar Forecasting Demonstration for Grid Integration

Costshare:

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Utility: SDG&E

Project Goals

- Reduce solar integration costs through more accurate solar forecasting
- Demonstrate distributed generation solar forecasting in aggregation at the system level and the distribution level
- Demonstrate forecast applications to net load forecasting, feeder control, and fast demand response

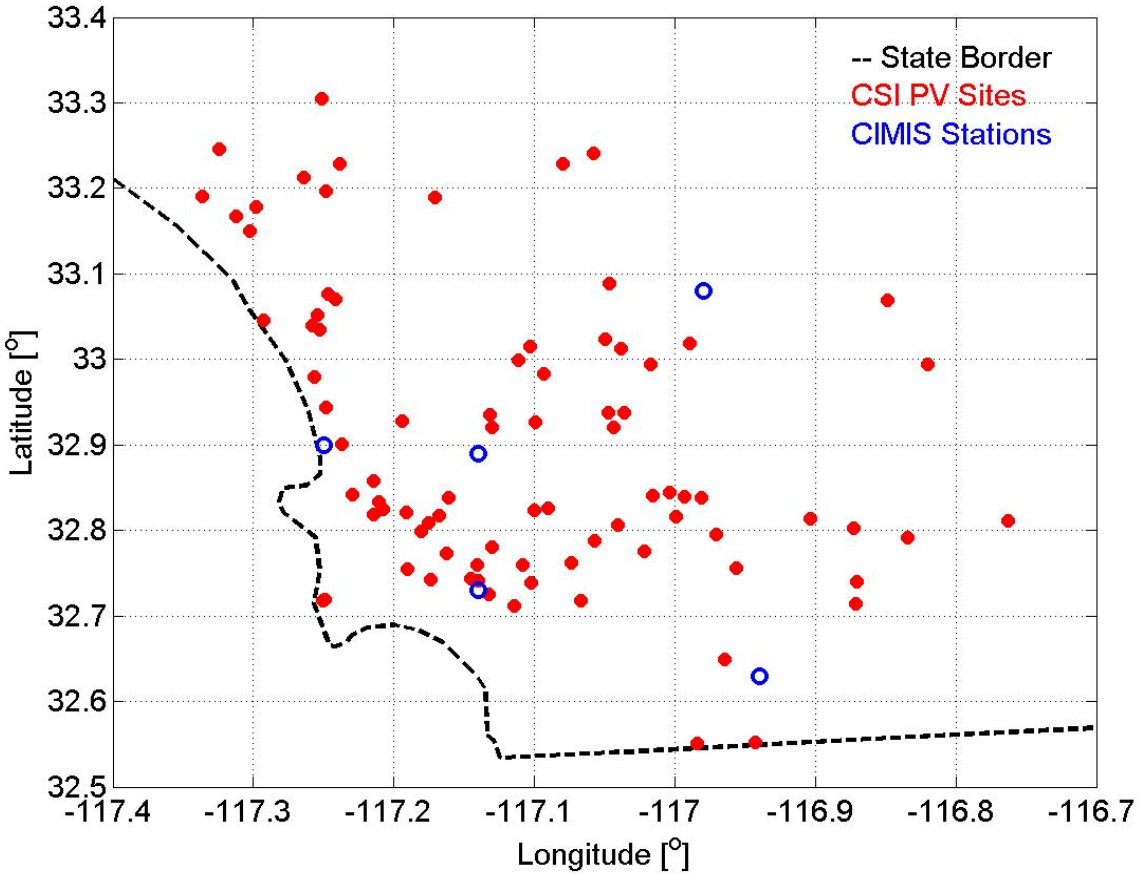
Overview

- Task 2: Demonstrate forecast performance during meteorological conditions with greatest impact on SDG&E operations and recommend monitoring improvements
- Task 3: Day-Ahead Solar forecast models for marine layer clouds
- Task 4: Localized Solar Forecasting and Distribution Feeder Modeling
- Task 5: Forecast Integration with Utility Models for Resource Adequacy

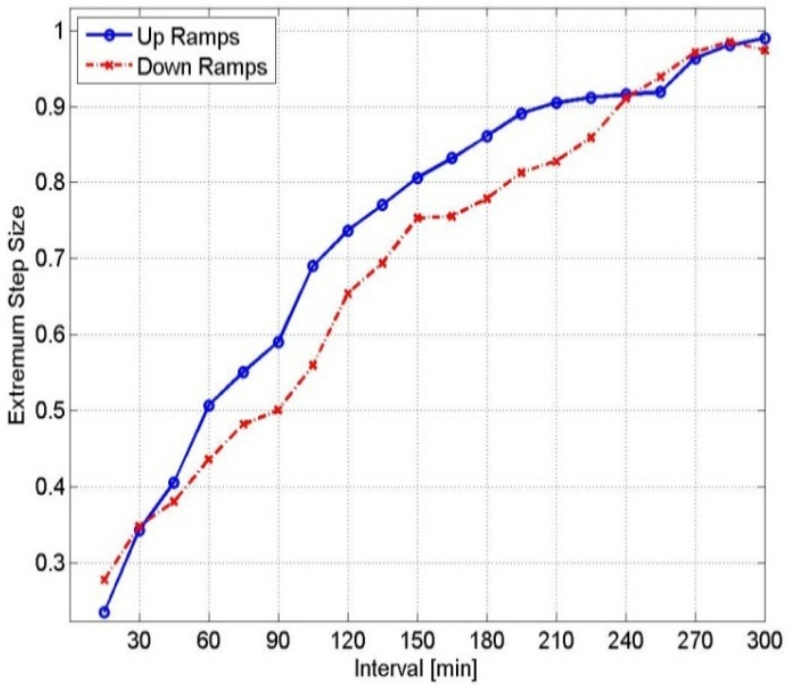
Task 2

- Largest Aggregate Ramp Rates for Feeders and Across Balancing Area
- Observation Targeting: Placement of SDG&E Weather Stations

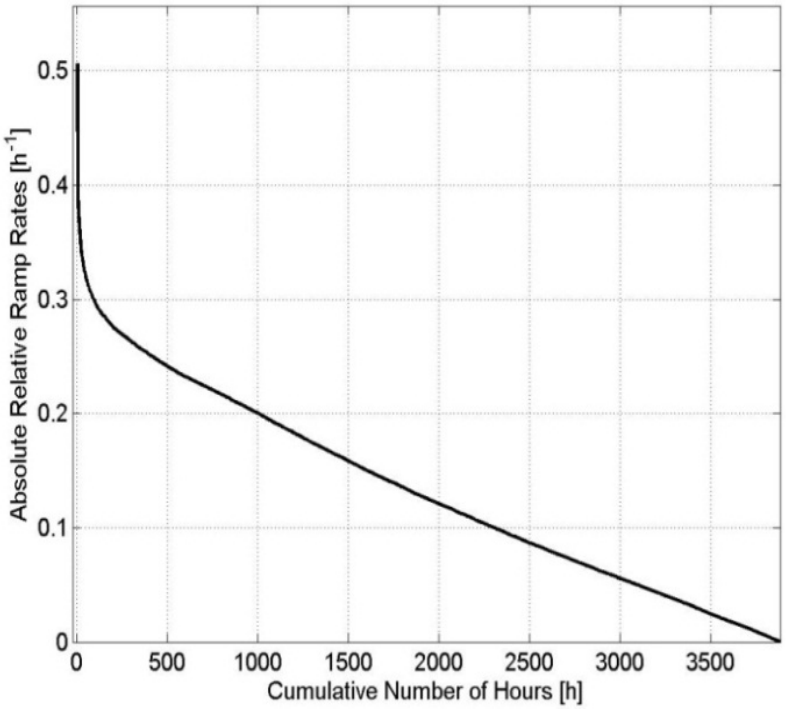
Map of 86 PV Systems and 5 CIMIS Stations in SDG&E Territory



Ramp Rates Results

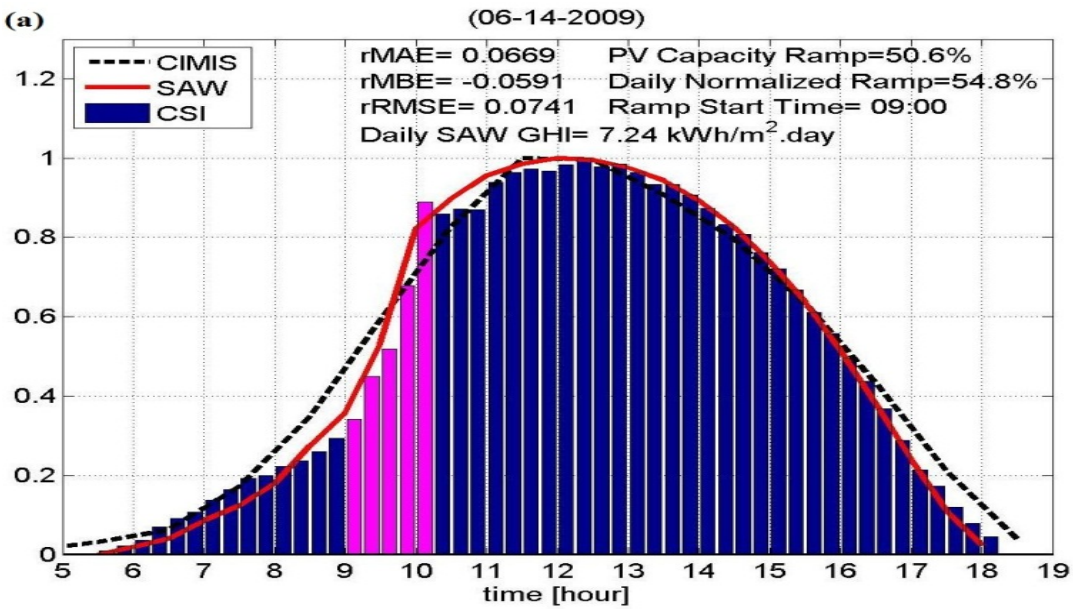


Largest step size of normalized aggregate PV output versus ramp time interval



Cumulative distribution of absolute value of 1-hour ramp rates of normalized aggregate PV output

The Day with the Largest Ramp Rate

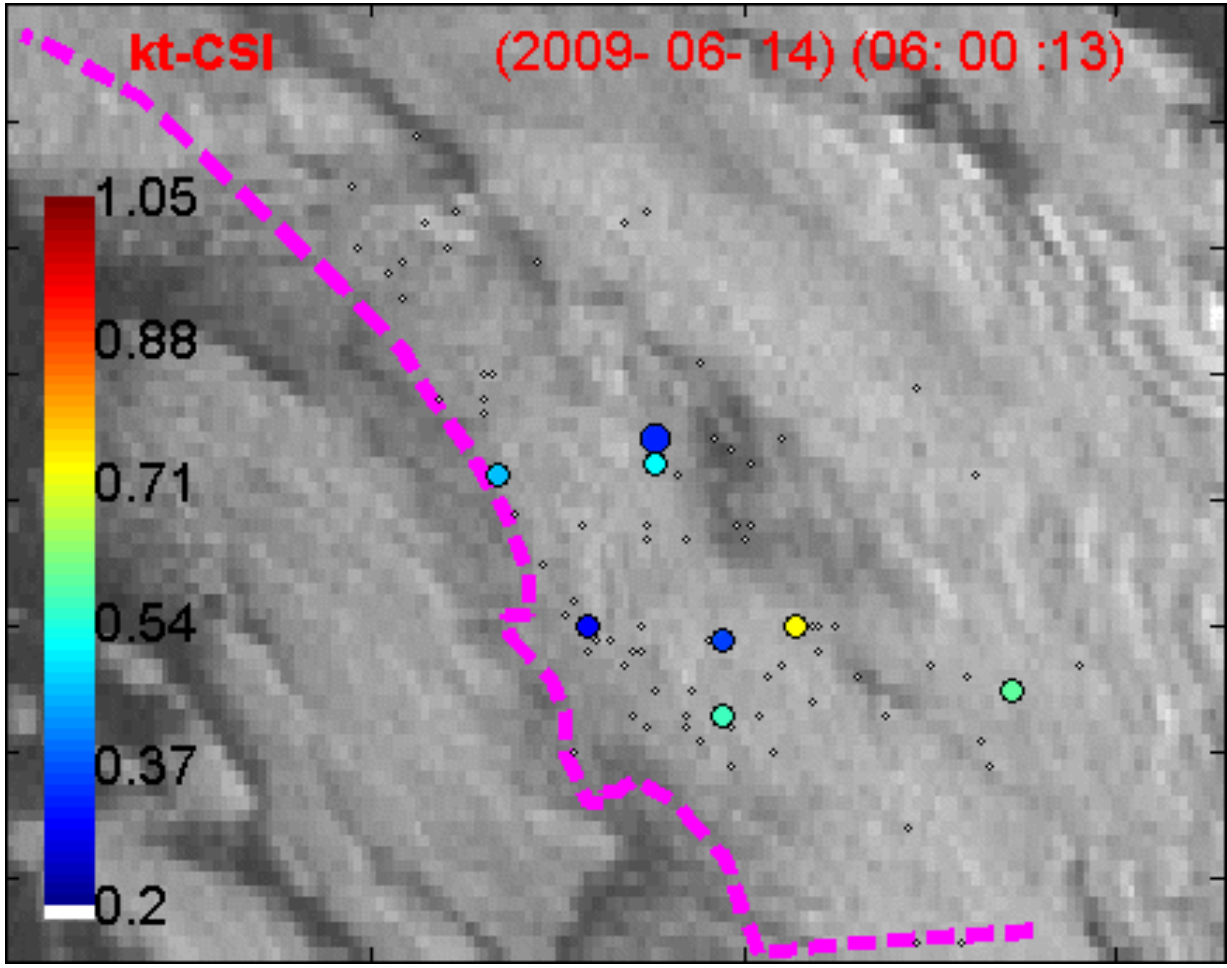


Aggregate Performance & Measured power of all 86 PV sites and Aggregate GHI of 5 CIMIS stations for the day with the largest 1-hour ramp rate in 2009

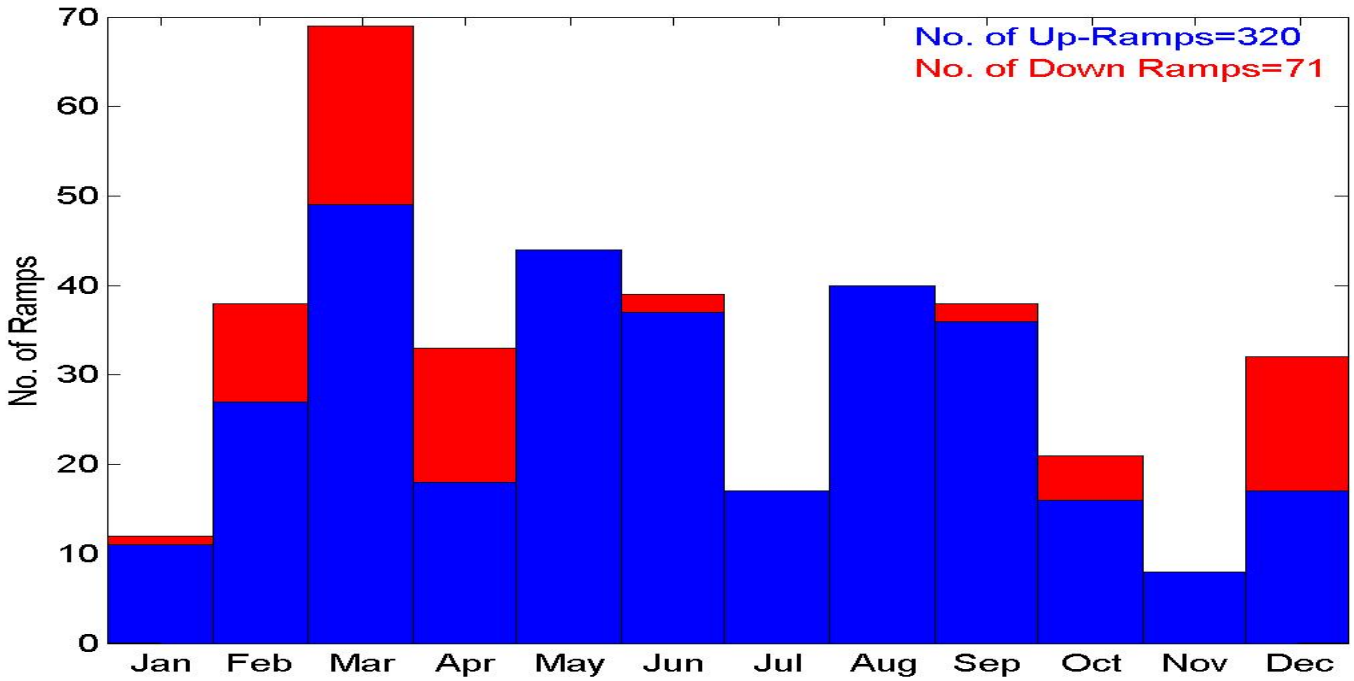
- The largest aggregated 1 hour ramp for this period was 50.6% of PV capacity and occurred from 900 to 1000 PST

GOES Satellite Images Jun 14, 2009

- The circles represent 86 PV systems
- The area of the circles is proportional to the power rating of the PV system (the largest system is 939 kW)
- Color bar shows ratio of 15-min averaged output to annual maximum output at that time of day (ToD)



Largest 1-hour Ramp Rates

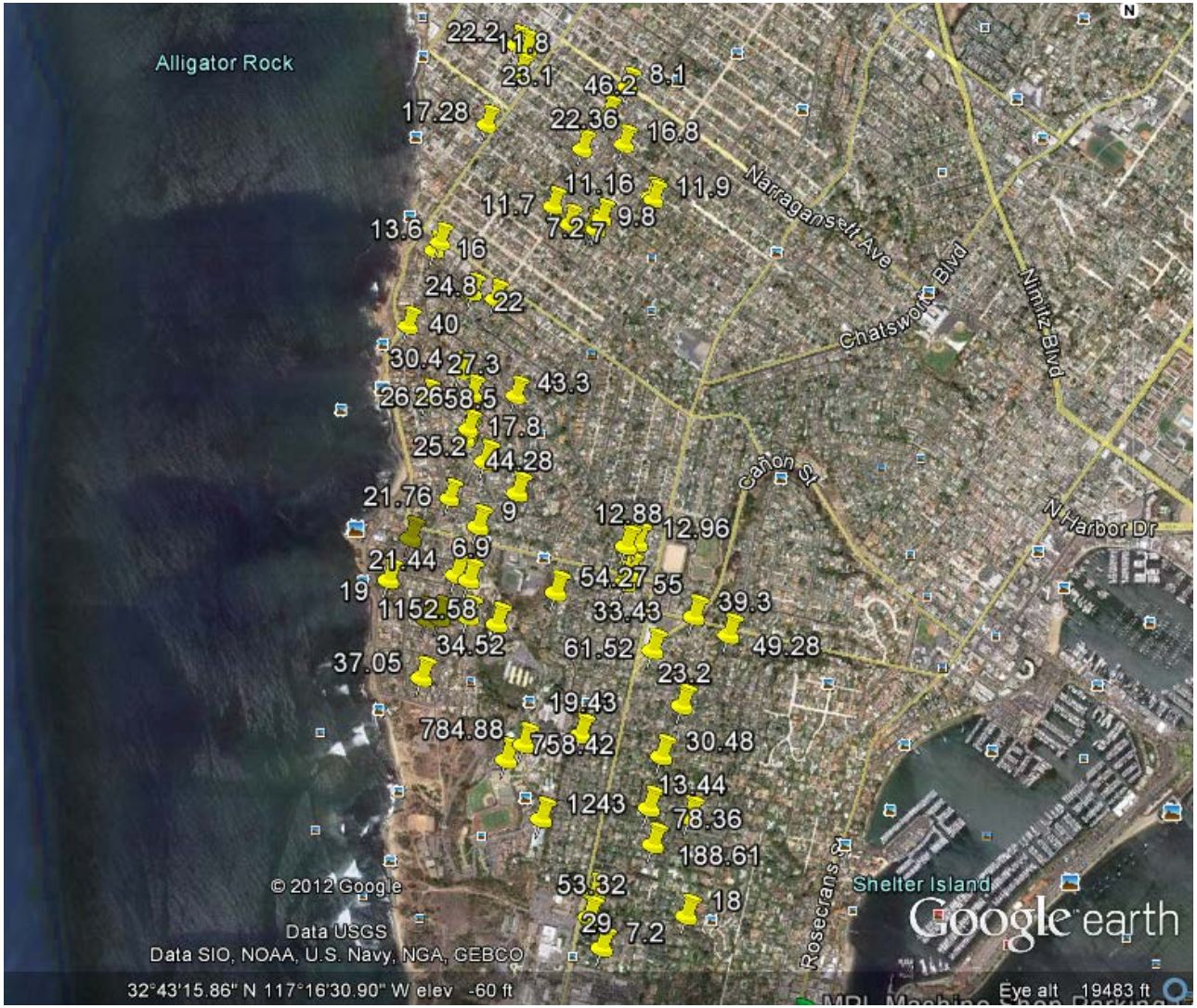


Histogram of the largest 1-hour ramp rates (30% and larger) of normalized aggregate PV output

5 SDG&E Feeders with High PV Penetration

- Climate Zones (coastal to desert)
- Urban and Rural
- 1 mile to 10 mile size
- Goals
  - Examine ramp rates by site and in aggregate
  - Evaluate feeder impacts (losses and voltage regulation)
  - Evaluate mitigation measures enabled through forecasting

PV Sites on Feeders Identified



Largest Ramps and Forecast Model Performance

- Calculate ramps by feeder using CSI PBI measured data.
- Determine numerical weather prediction forecast model skill in forecasting largest ramps

Observation Targeting

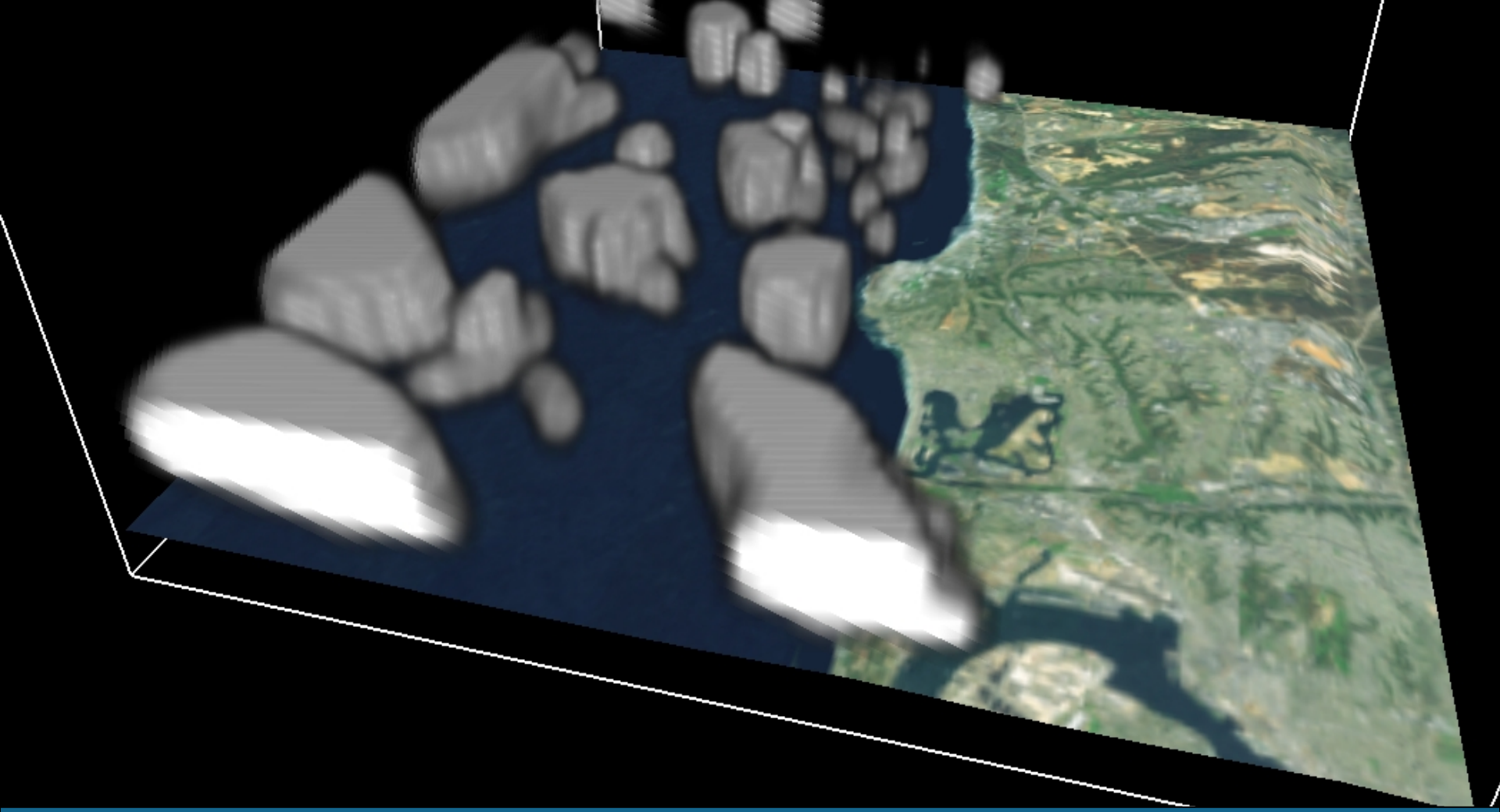
- SDG&E has 100+ weather stations and 60+ are equipped with a pyranometer
- Identify locations that would benefit from greater station coverage for
  - Modeling real-time PV generation
  - Forecasting PV generation

Task 3: Day-Ahead Marine Layer Forecasts

- Marine layer forecast model (Green Power Labs, 2012)
- Very high resolution numerical weather prediction (UCSD, 2013)

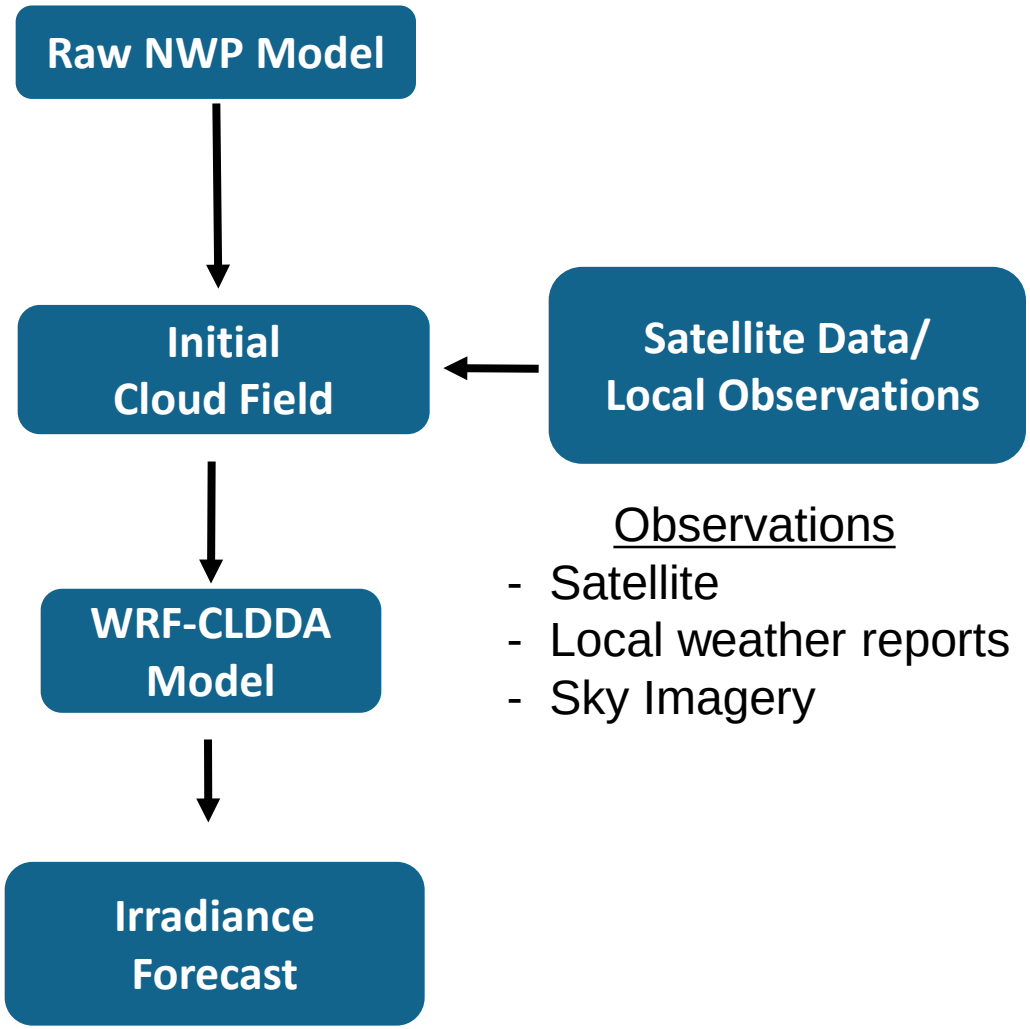
Statistical Marine Layer Forecast Model

- Goal: Predicting the likelihood of marine layer (ML) development along the southern California coast.
- ML Classification: Automatic ML classification algorithm procedures for near real time ML identification at every satellite pixel.
- Model: Develop multivariate logistic model for ML forecast at day ahead scale using ‘a priori’ likelihood of marine layer development at a particular season and/or location given real time weather observations and NWP.



High-resolution, cloud-assimilating NWP at UCSD: day-ahead (40 h) solar forecasts across Southern California. 1.3 km and 5 min resolution.

Model and Data Assimilation



Observations
- Satellite
- Local weather reports
- Sky Imagery

To improve accuracy, clouds are populated in initial conditions

Direct Cloud Assimilation

- Cloud hydrometeors are modified in initial conditions

WRF model simulates cloud evolution

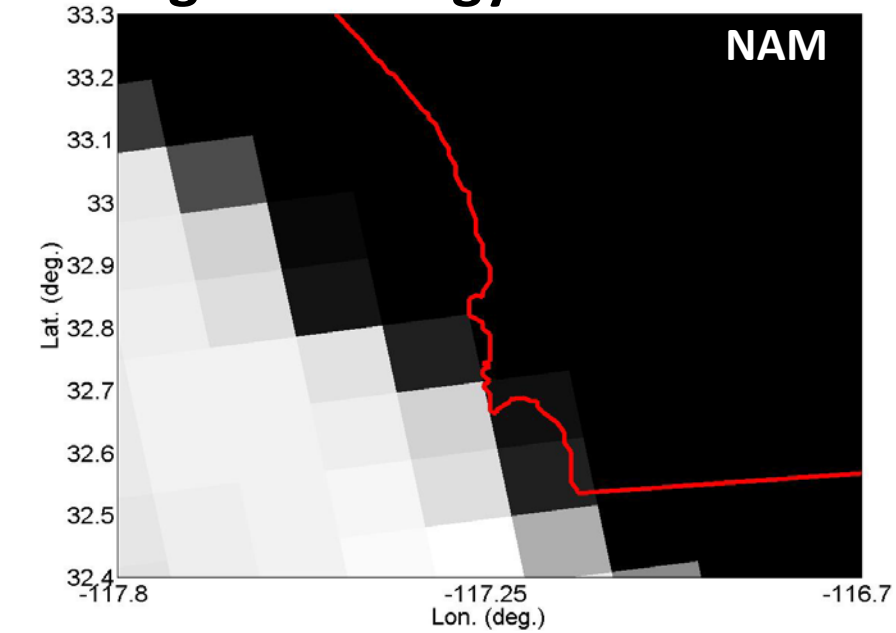
- Evaporation
- Deformation
- Condensation

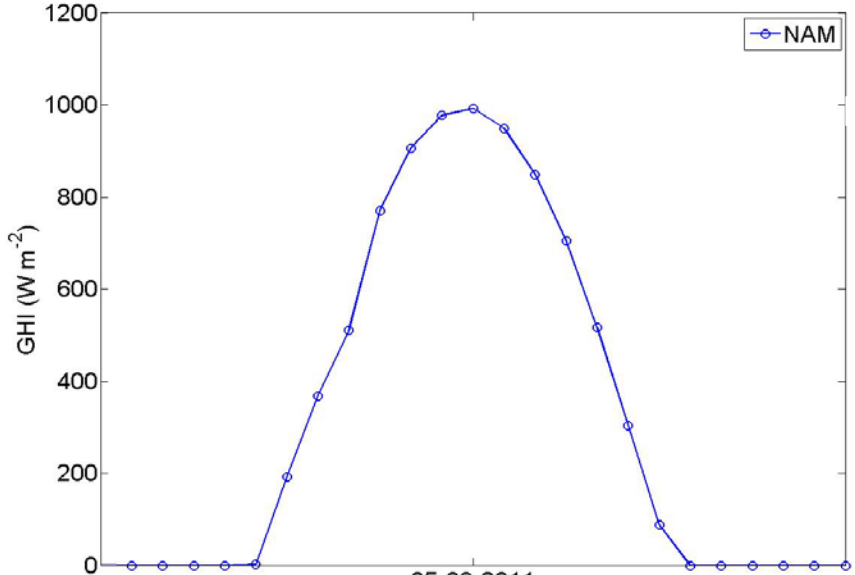
RUC methodology

- Benjamin, *et al.*, 2004, 2007, etc.

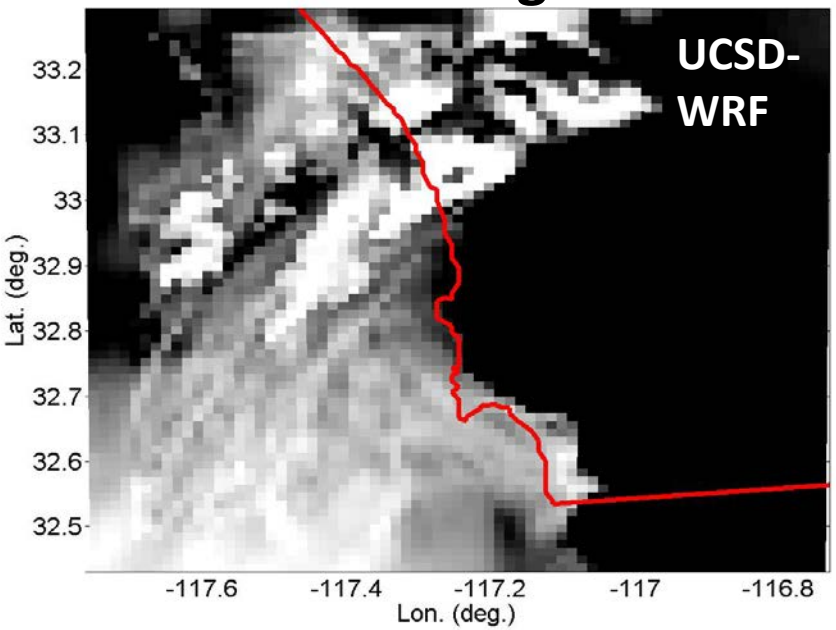
Sample Results

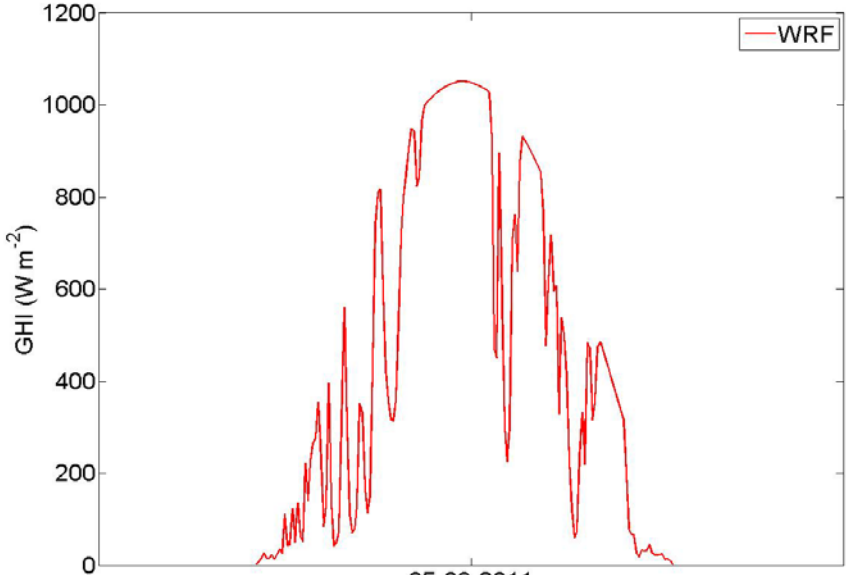
Existing Technology



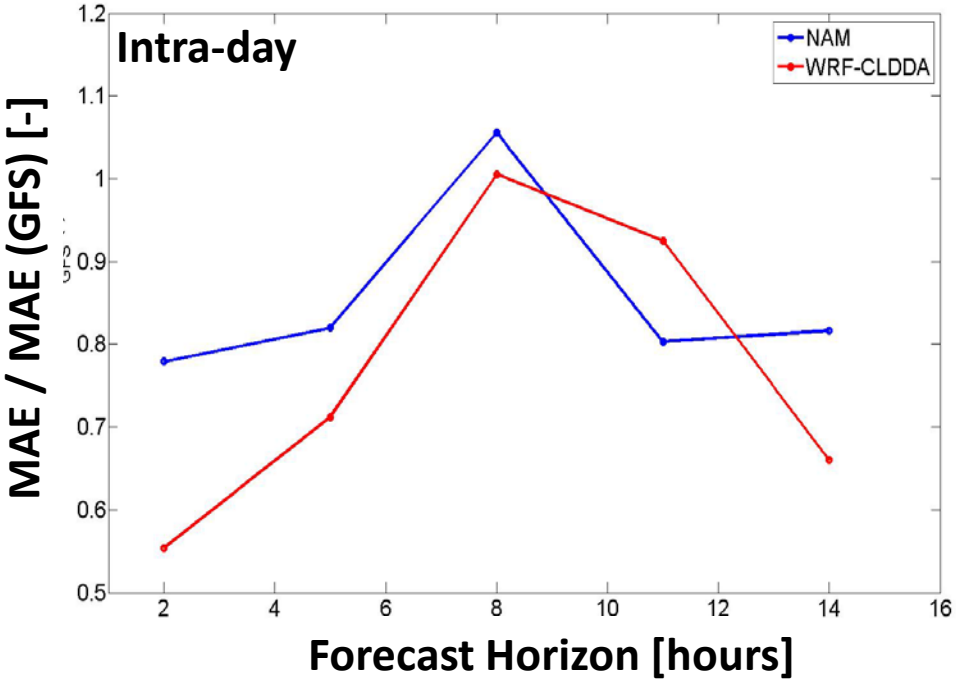


UCSD High Resolution





NWP Forecast Results



Assimilation of clouds produces more accurate irradiance forecasts

Intra-day

- MAE is as low as 50% as GFS
- Consistently more accurate than the NAM for first 9 hours

Day -Ahead

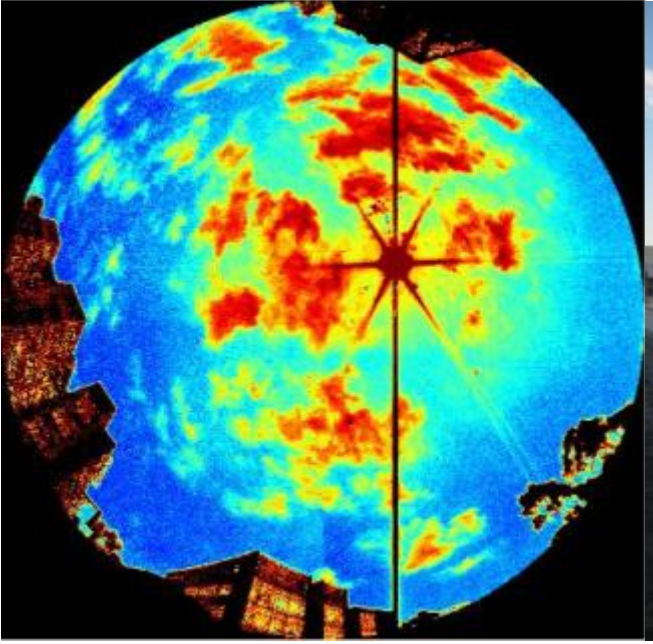
	Pers.	GFS	WRF
MBE (W m^{-2})	-10.3	130	38.6
MAE (W m^{-2})	154	146	98
RMSE (W m^{-2})	222	230	156
STDERR (W m^{-2})	222	189	151

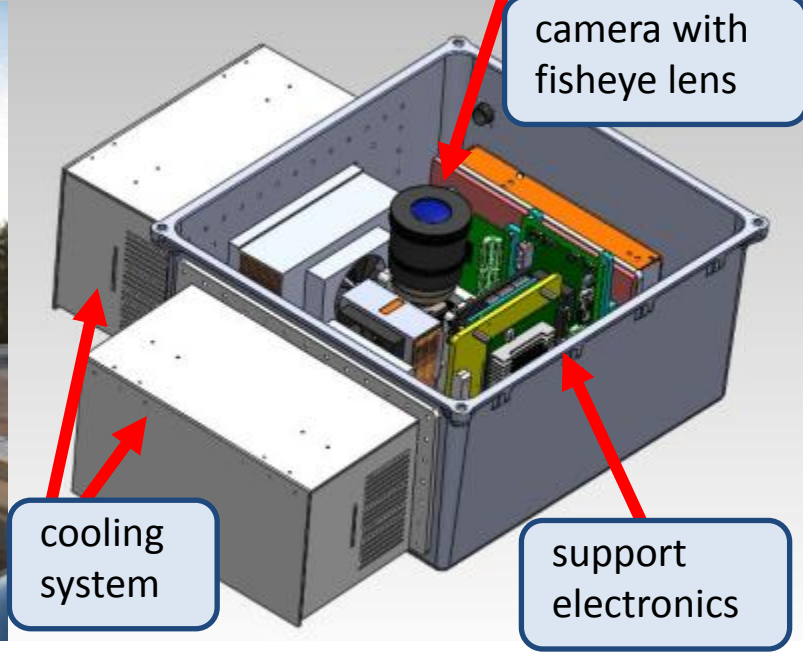
Day-ahead

- WRF-CLDDA has MAE 50 W m^{-2} lower than GFS for day-ahead forecasts

Task 4: Localized Solar Forecasting and Distribution Feeder Modeling

- 4.2: Total sky imagers on EPRI feeders
- 4.3: Distribution feeder modeling using sky imager forecasts
- 4.4: Real-time control of distribution equipment





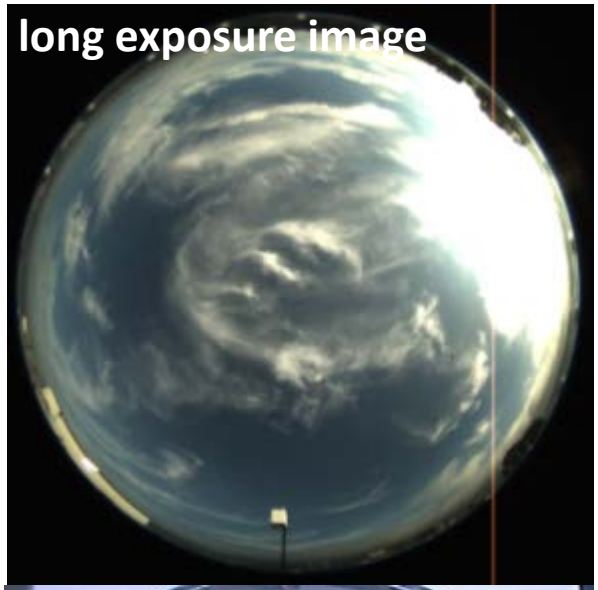
Advanced Sky Imager Hardware and Algorithm Development

- **High time resolution coverage (30 sec)**
- **Granular spatial resolution with Multi-megapixel cameras**
- **Reasonable coverage: ~15 km^2 cloud field dependent**
- **Short time-horizon: 10 to 20 minutes**

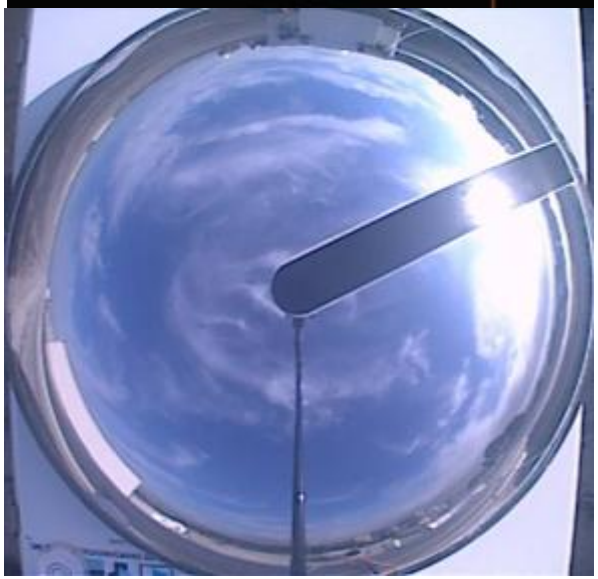
Panasonic

UCSD prototype produces **high-quality** sky imagery

UCSD Technology



Commercially available

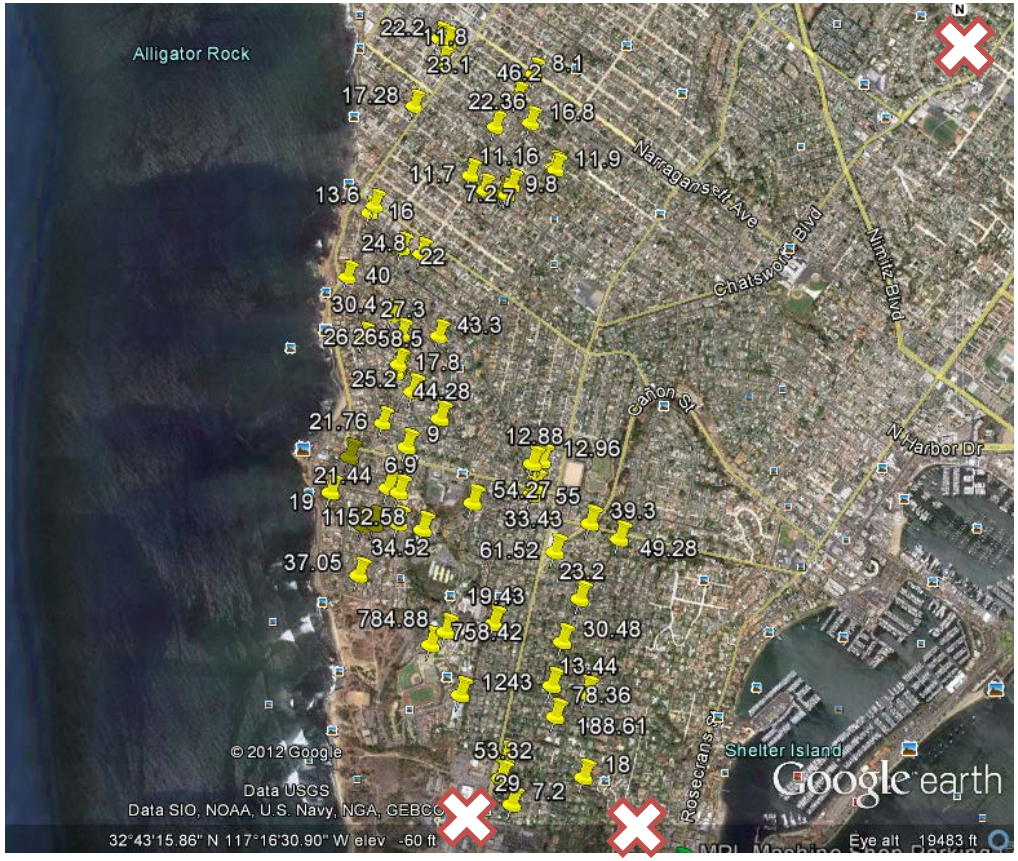


Major Improvements

- High dynamic range: better resolved cloud features
  - Multiple exposures to create composite reduces data loss to sun saturation
- No shadowband: better visibility near the sun
- Controllable image capture process

4.2 Sky Imager Deployment and Forecasting

- Deploy two sky imagers each on five feeders and conduct forecasting



Sky imager location

4.3-4.4 Feeder Modeling and Control

- Develop highly spatially and temporally resolved solar resource data for the feeders
  - Apply to all PV systems on feeder
  - Also simulate highly resolved load data
- Simulate feeder voltages and voltage regulator actions
- Investigate use of forecasting to reduce potential voltage regulator actions associated with PV

Task 5: Integration with Utility Models

- 5.1 Solar power and net load forecasting across SDG&E (Green Power Labs)
- 5.2. Substation load operational forecasts and fast demand response (SolAspect, UCSD)

5.2. Substation Net Load Forecasts for 5 Feeders

- UCSD / SolAspect forecast engines for net load forecasting
- 5 minute to multiple days ahead
- Fast Demand Response

5.1. Solar Power and Net Load Forecast (Green Power Labs)

- Green Power Labs will forecast hour-ahead and day-ahead for 10 SDG&E owned PV sites
- Net load will be measured for these PV ‘cluster’ sites
- Net load forecast models will be developed
- Forecasts will be provided to SDG&E and CAISO

Key Deliverables

- Optimal weather station locations
- Day-ahead marine layer forecast models and reports on validation
- Report on sky imager forecast performance
- Report on findings from distribution feeder modeling
- Operational net load forecast models

Rough Timeline

- 2012: Task 2 Largest ramp rates. Task 3 Statistical Marine Layer Forecast Model
- 2013: Task 2 Placement of weather stations. Task 3: Numerical weather prediction marine layer model. Task 4: Sky Imager forecasts. Task 5: Net load forecasting
- 2014: Task 4 Feeder Modeling and Control. Task 5 continuation