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

Comprehensive Grid Integration of Solar Power for SDG&E

Costshare

Utility Partner

Jan Kleissl
Professor, Mechanical & Environmental Engineering, UC San Diego
Co-Director, UCSD Center for Energy Research
http://solar.ucsd.edu

Solar Resource Assessment and Forecasting

Co-PIs: Byron Washom, Carlos Coimbra, Bill Torre, Raymond de Callafon

Project Goals

- Build operational solar and net load forecast system
- Develop and demonstrate energy storage siting and dispatch optimization for solar power integration

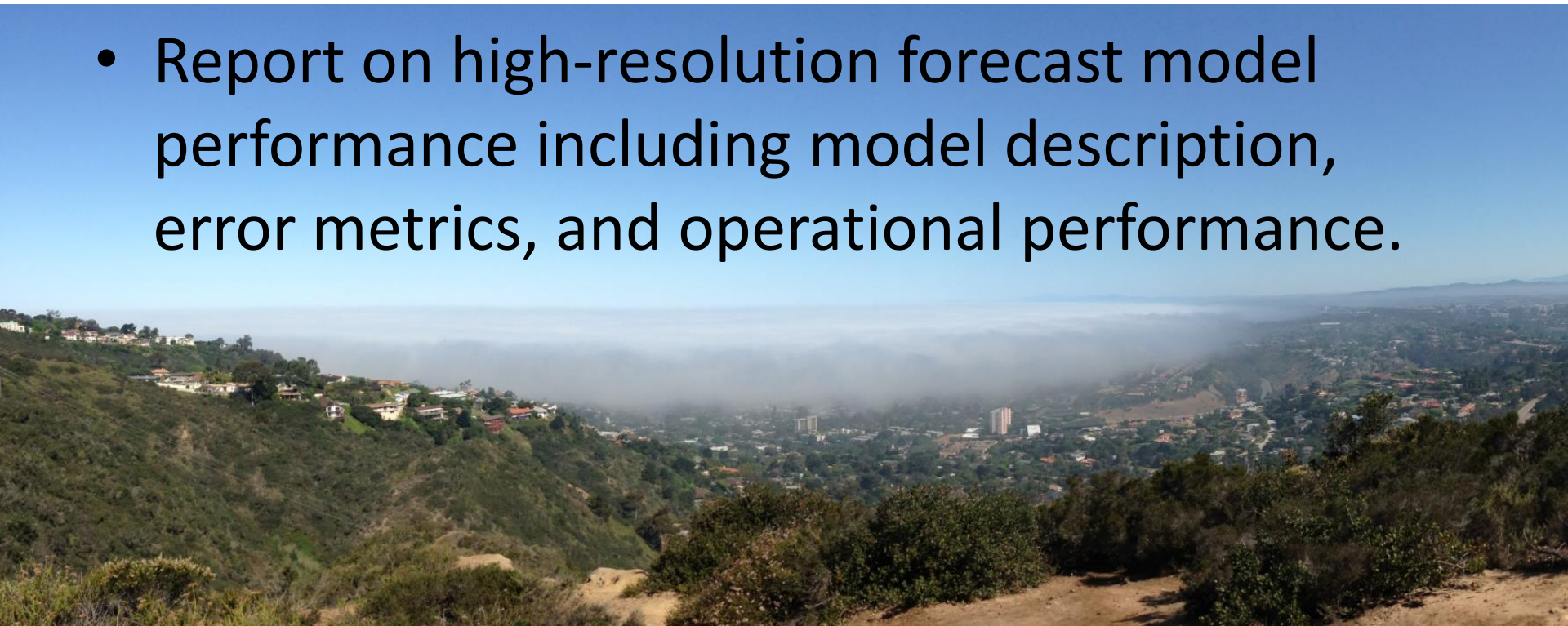
Overview

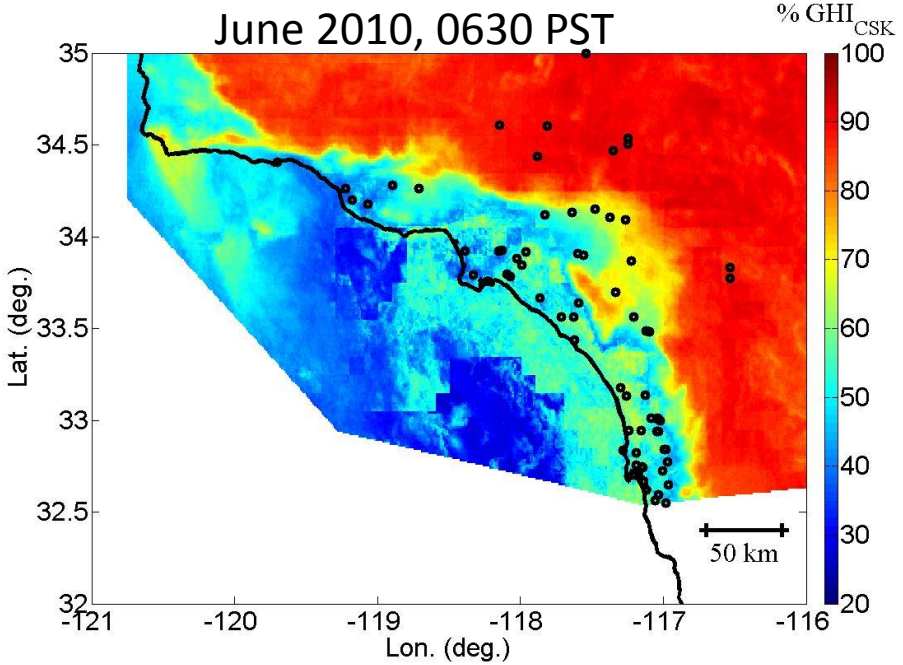
- Task 2: Advanced Operational Ensemble Solar Forecasting System
- Task 3: Granular Operational Net Load Forecasting
- Task 4: Energy Storage Siting and Dispatch Optimization
  - Distribution Feeder Hotspots
  - Energy Storage Siting Optimization
  - Energy Storage Dispatch Optimization

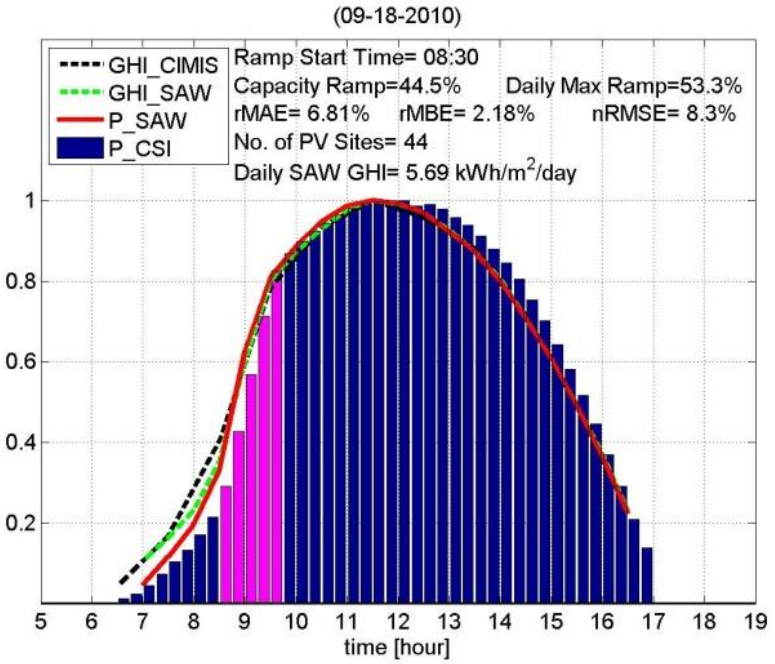
Task 2 Deliverables

- Operational day-ahead high-resolution solar forecast model for SDG&E territory.

- Report on high-resolution forecast model performance including model description, error metrics, and operational performance.



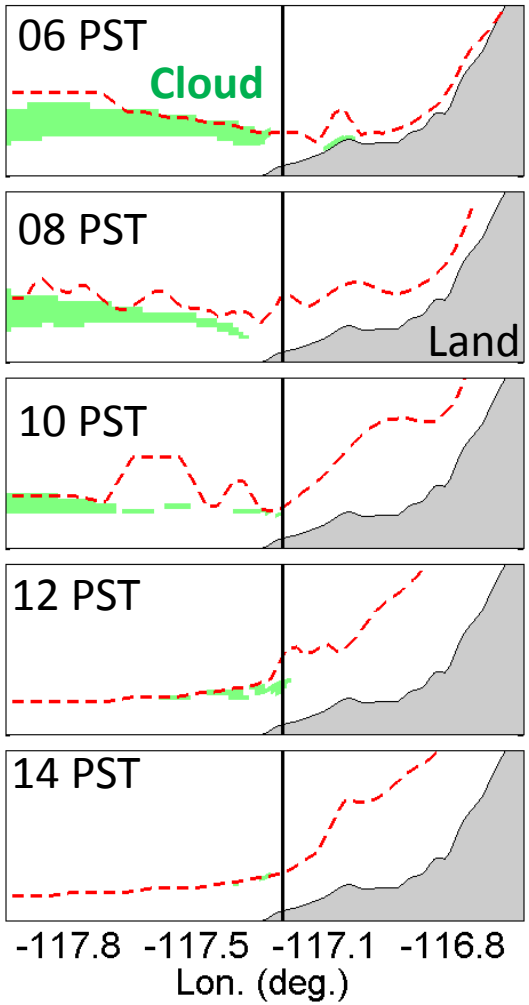




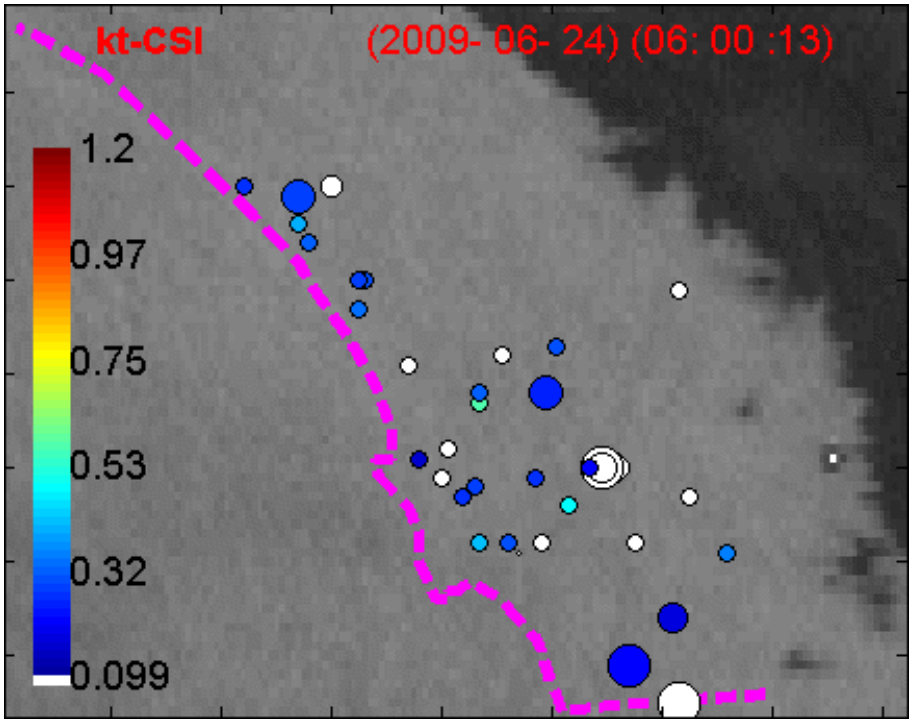
Task 2: Hours and Day-Ahead Marine Layer Solar Forecasting

Critical to predict summer morning ramps from distributed generation for coastal California.

Numerical Weather Prediction (NWP)



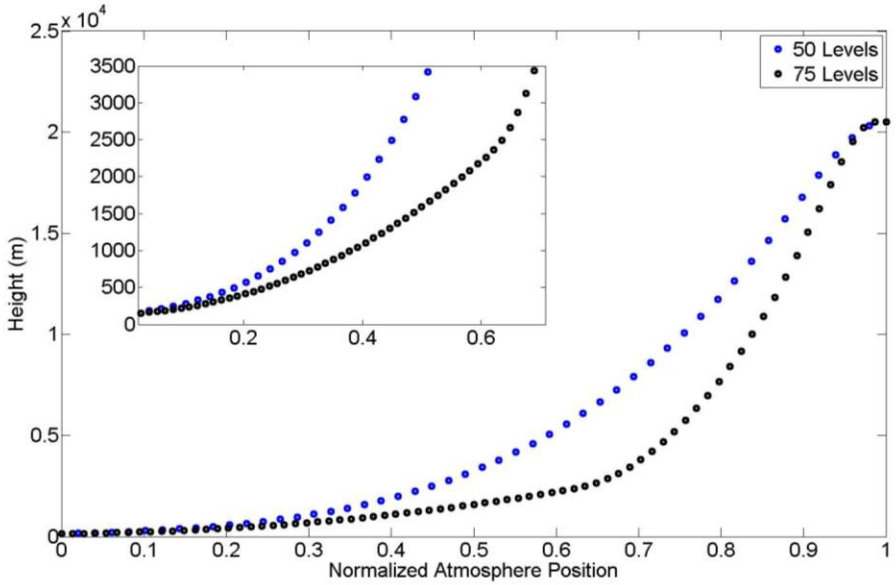
NWP



Satellite

- Most accurate solar forecast for >5 hours in advance
- Large scale computational physics models
  - Pressure, Geopotential, Velocity, Temperature, and Water
- Solves the discretized Euler equations
  - Δx = 1 km – 100 km
- Initialized by combination of observation and model output, but …

Task 2



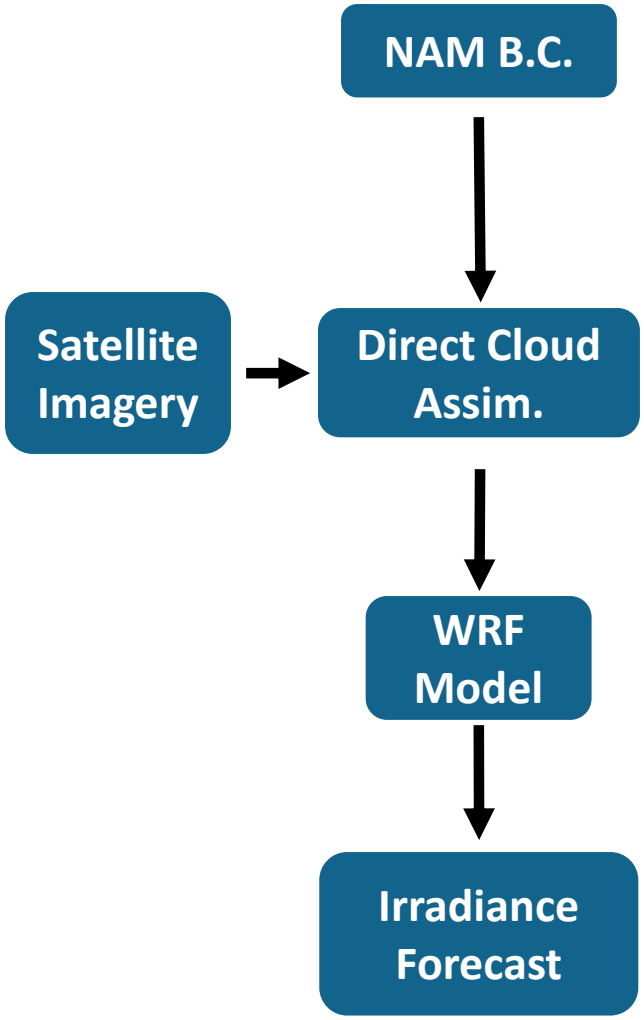
Simulating Marine Layer Clouds

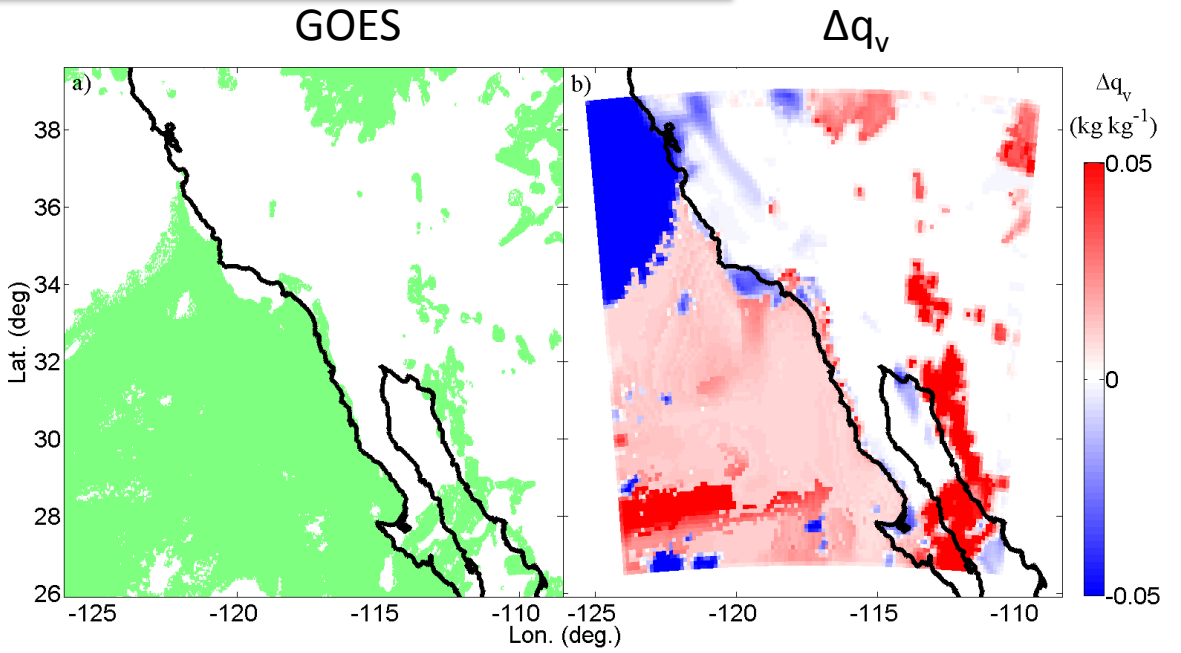
WRF (Weather Research and Forecasting) Model

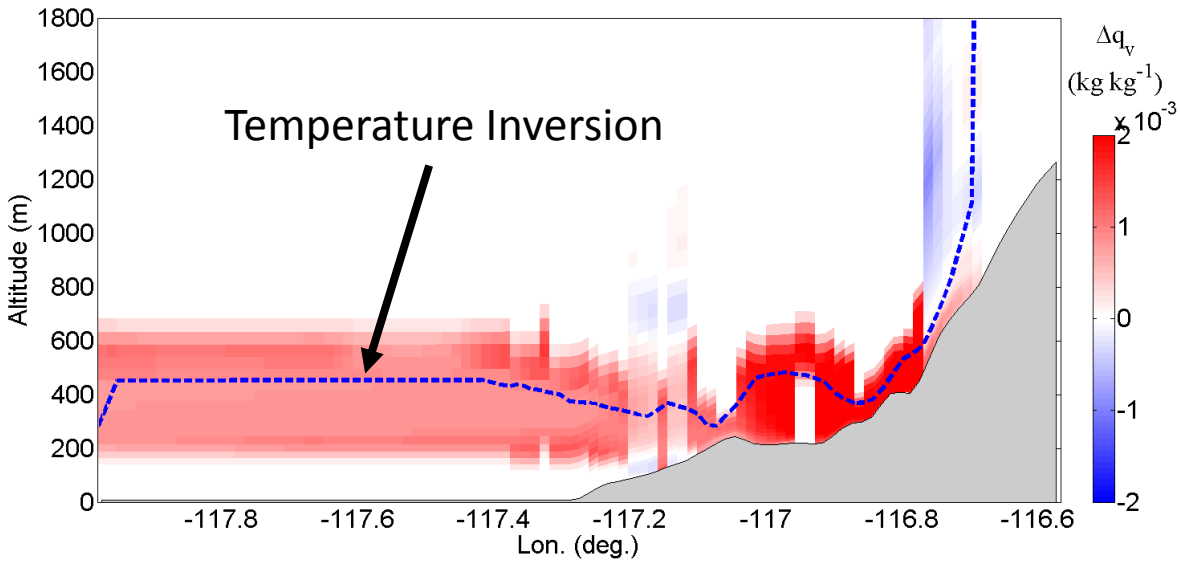
- Physics chosen to promote cloud cover (Lopez-Coto *et al*, 2014)
- High-Density Vertical Levels
- Multi-physics ensemble prediction system

Domain/Time Options	
Δx (km)	2.5
Vertical Pts.	75
CFL	0.3
Output Interval (m.)	15
Spin-Up Interval (hr.)	24+ (Cycling)
Initial and Boundary	12 UTC NAM

Cloud Data Assimilation



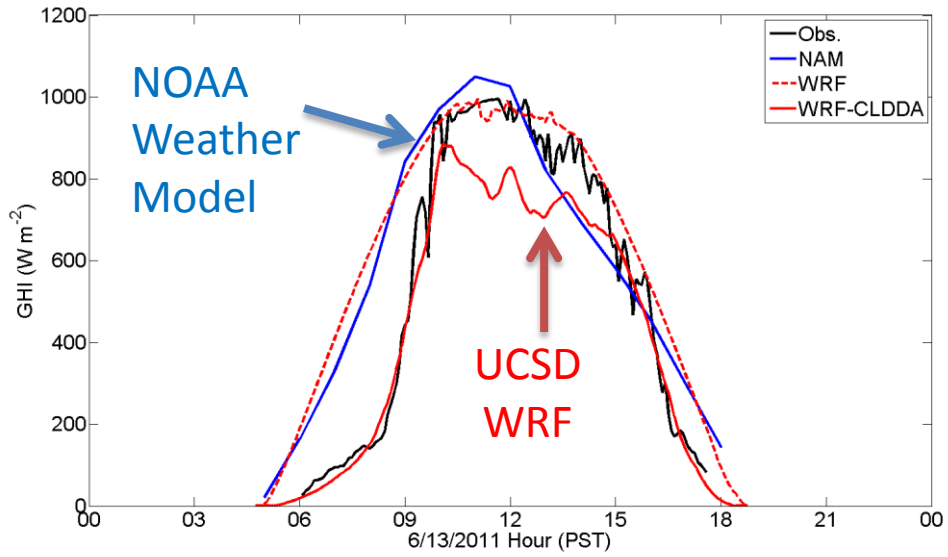


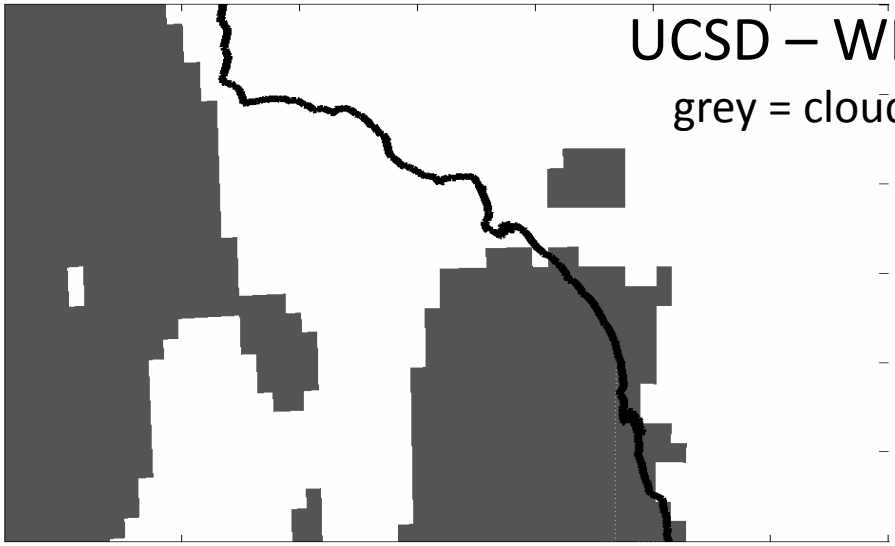


Task 2

Improved Day-ahead Forecasts of Marine Layer Burn-Off

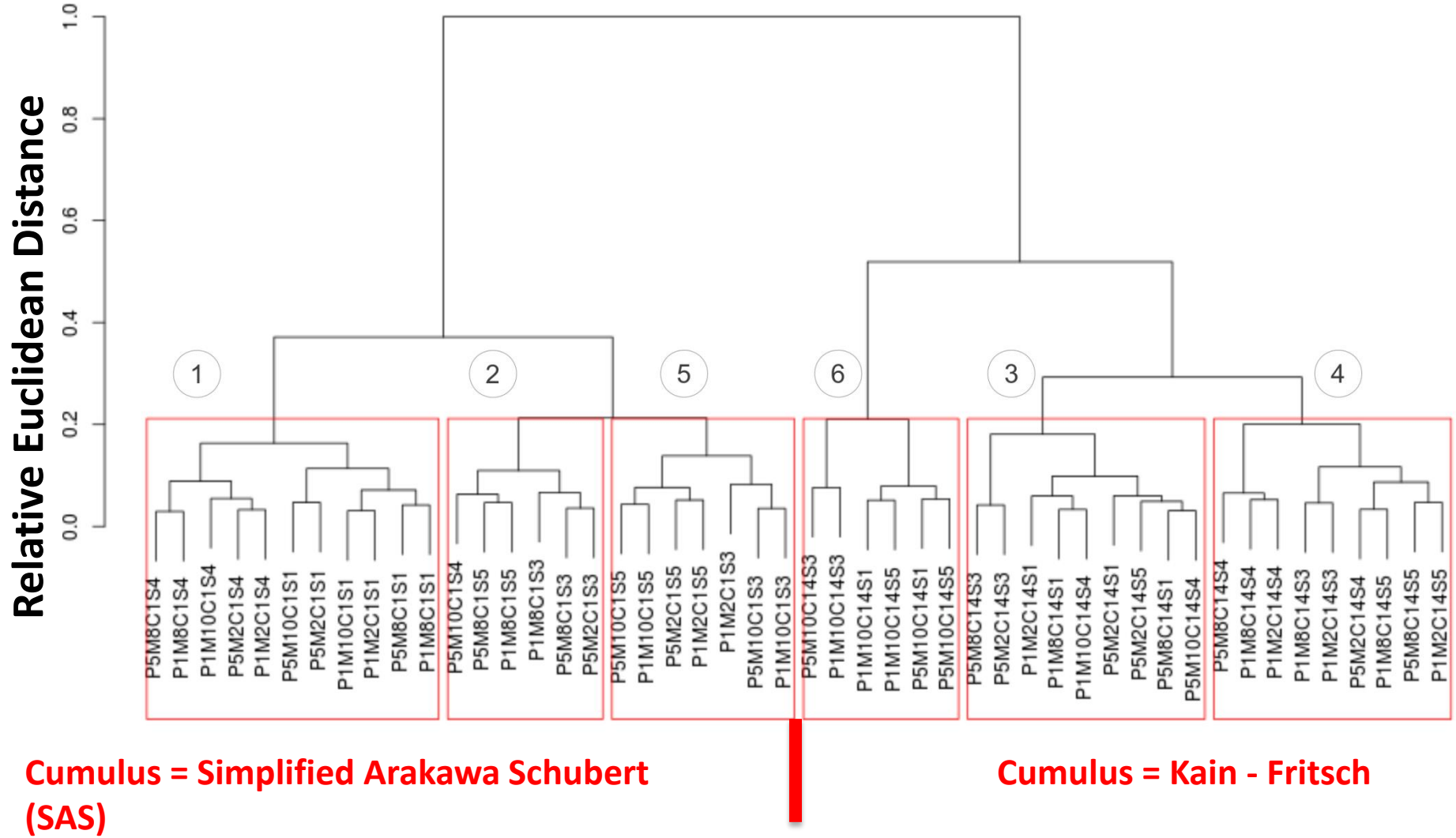
Satellite Image





Task 2

Identification of Forecast Ensemble Members

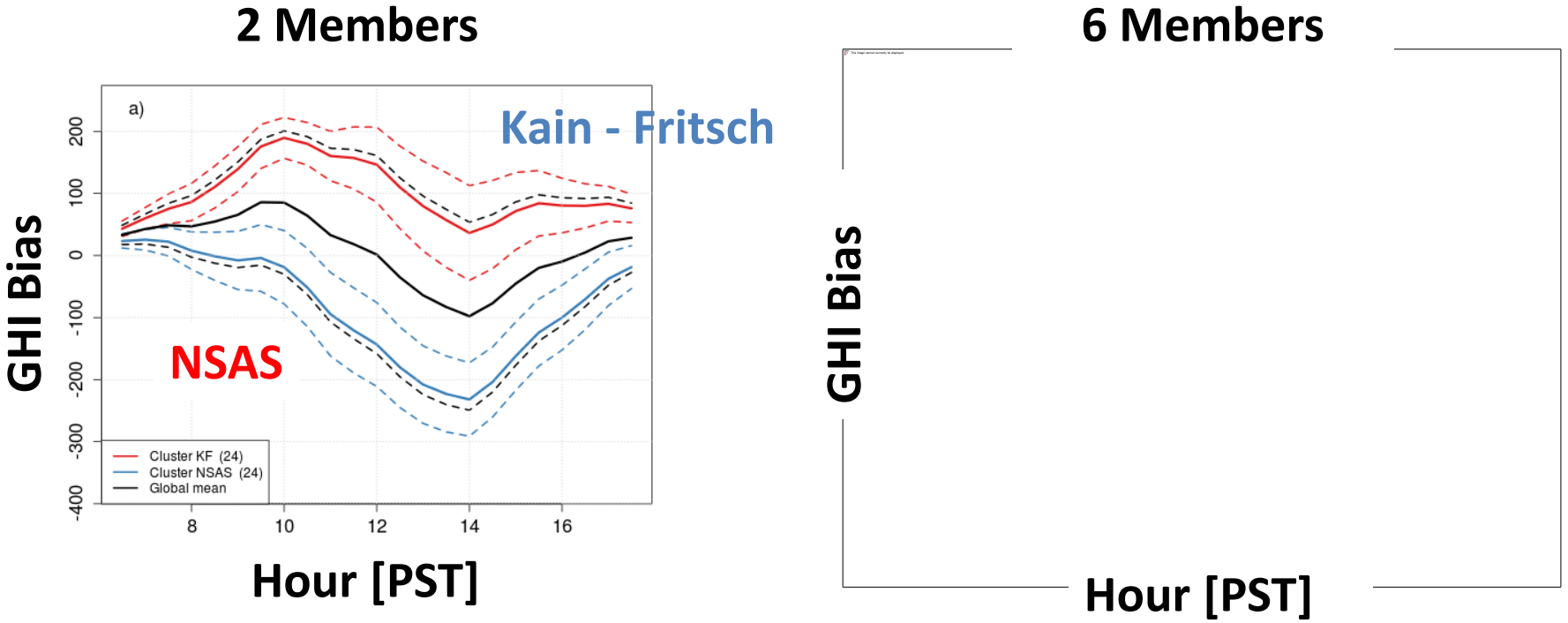


Cumulus = Simplified Arakawa Schubert (SAS)

Cumulus = Kain - Fritsch

Cumulus scheme is most important distinction.

Mean Evolution of 2 and 6 Cluster Members



- New SAS cumulus scheme provides more clouds
  - Unbiased mornings
  - But: too cloudy afternoons

Task 2 Overview

- Set up marine layer solar forecast ensemble for SDG&E.
- Run every 2 hours for hour-ahead, every 6 hours for day-ahead forecasts.
- Advanced postprocessing options.
- Integration with operation of energy storage (Task 4).

Task 3 Deliverables

- Operational net load forecasting model for all substations concatenated over all time horizons in near real-time.
- Report evaluating the impact and benefits resulting from advanced net load forecasting, including a discussion on the importance of spatial and temporal resolutions on feeder operation.

Operational forecasts of substation load

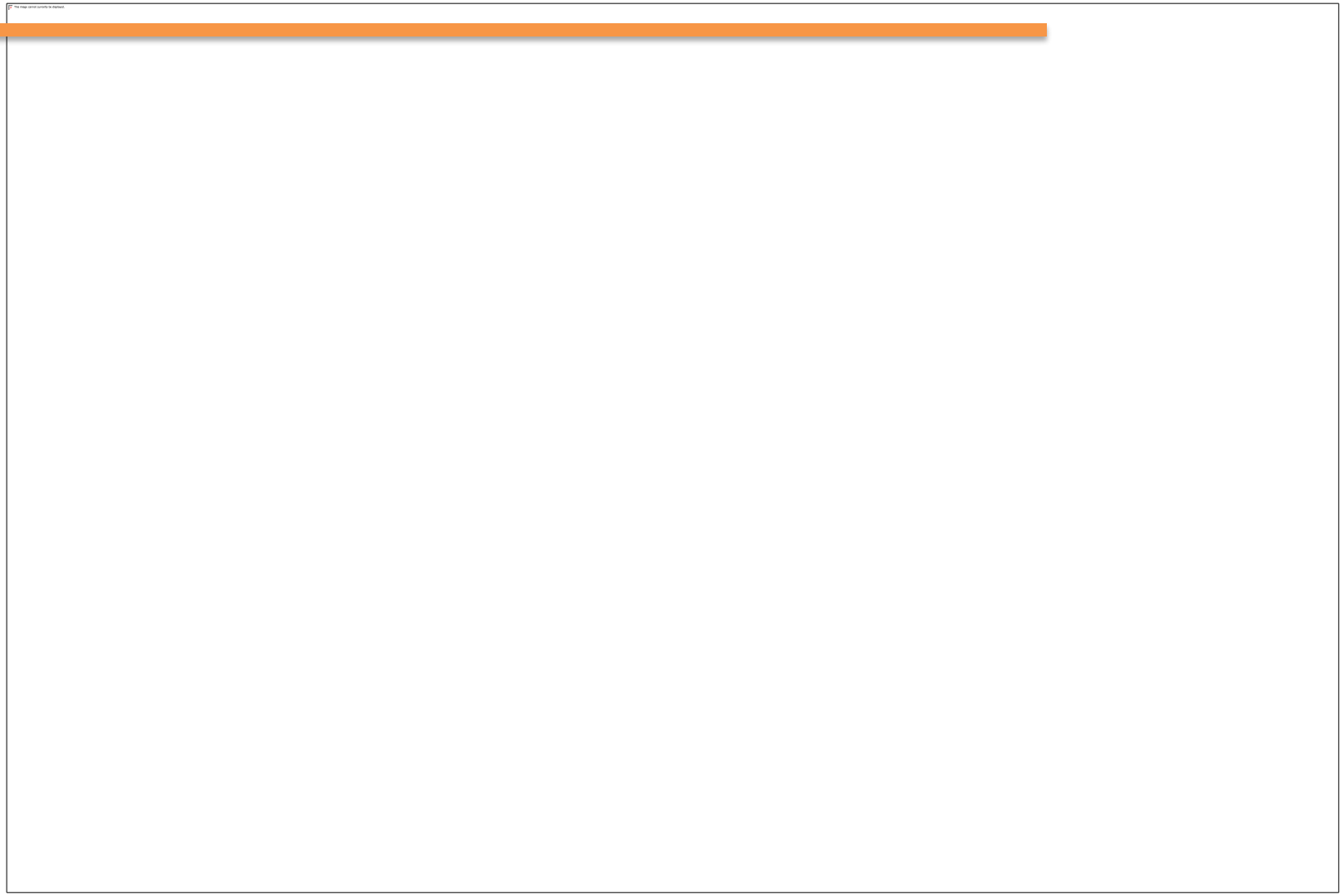
Datasets

Load data: 15-min resolution load time-series from five SDG&E feeders with different levels of solar penetration

SDGE feeder location	Solar penetration
Valley Center	24%
Fallbrook	13%
Ramona	9.3%
San Diego	5.8%
Alpine	2.4%

Solar power data: Estimated solar-power using Solar Anywhere data with 30-min time resolution

Feeder net load time-series

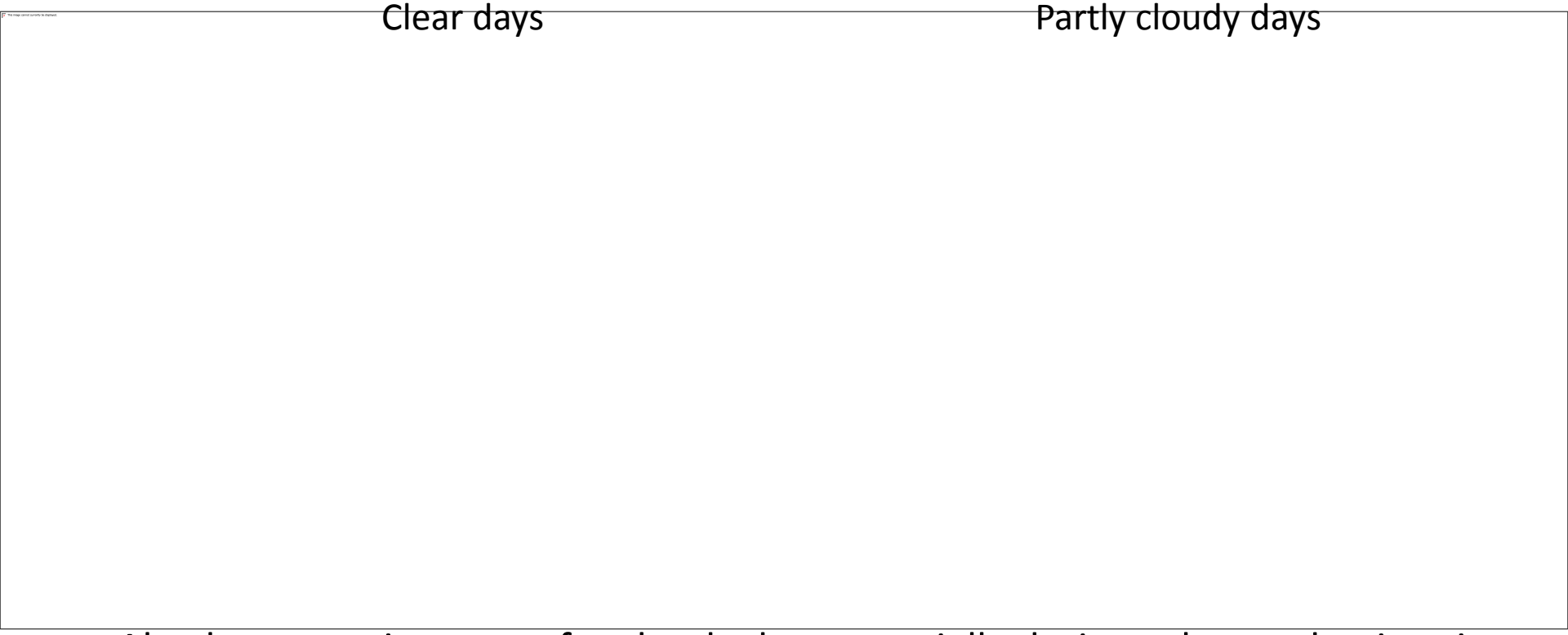


Net Load Forecast Methodology

Forecast model setup	Forecast horizon	Forecast model para-meters
Training set: Load data for 2011	15 min	Model set-up: Time-series style
Validation set: Load data for 2012	30 min	Input: Lagged values of past load data
	1 h	Kernel: Radial basis function
	1 day	Cost function

Impact of solar penetration on 30 min ahead load forecast at Valley Center

Clear days

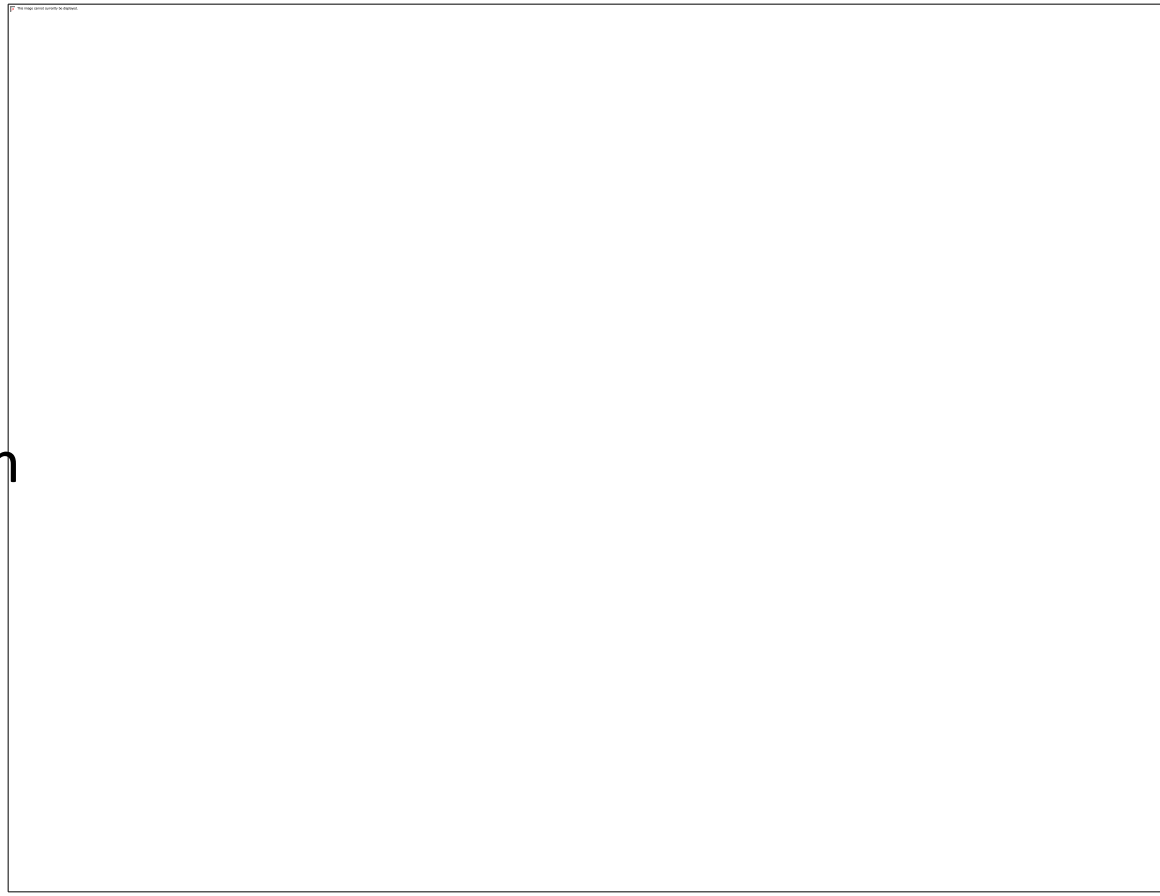


Partly cloudy days

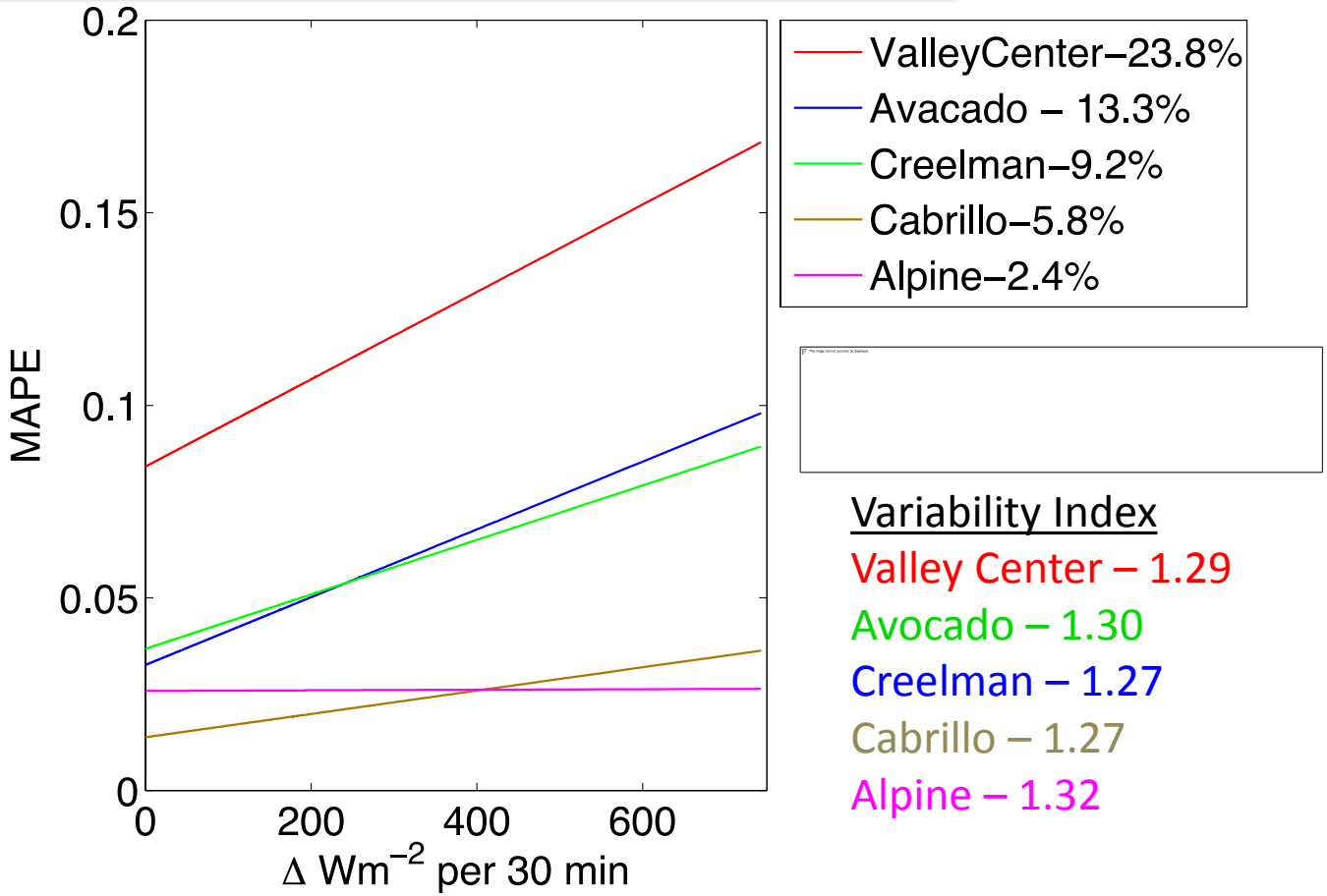
- Absolute error increases for cloudy days especially during solar production time
- Since solar power data is at 30 min. resolution, further analysis is all based on 30-min ahead forecast

Forecast Error versus Forecast Horizon

- Load forecast error increases with increasing forecast-horizon
- Sudden spike in Creelman load forecast can be attributed to sudden increase in load demand



Error as function of solar penetration and variability



With low solar penetration, error is independent of solar variability whereas as solar penetration increases, the load forecast error increases and it is a linear function of solar variability.

Net Load Forecast Summary and Outlook

- Load forecast models validated with the datasets provided by SDG&E.
- Solar penetration and solar variability drives the net load forecast error magnitude.

Outlook:

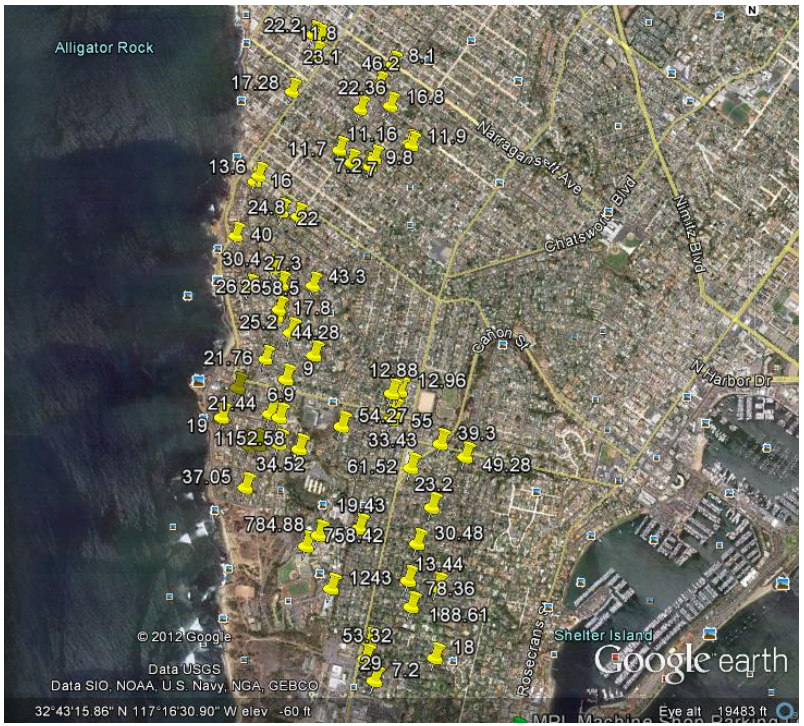
- Apply to all substations.
- Include exogenous inputs like weather and solar forecast.
- Run in real-time.

Task 4 Deliverables

- 4.1 Map of distribution feeder hotspots and potential areas for feeder stress for 15 feeders.
- 4.1 Report describing hot spot clustering methodology and results
- 4.2 Storage siting optimization tool and optimization methodology. A report will be provided which will explain how distributed energy storage siting can be optimized to maximize system efficiency and reliability of the overall power grid.
- 4.3 Matlab modeling software code that creates models of observed power flow oscillations measured by PMUs due to step-wise excitation signals (bump test) of a (micro)grid tied inverter.
- 4.3 Report on energy storage dispatch methodology and results that summarizes the results on hardware-in-the-loop simulations of the proposed energy storage dispatch control methodology.

4.1 Distribution Feeder Hotspots

- Map SDG&E distribution feeder sections that are most affected by high PV penetration
- Power flow simulation on 15 feeders with high PV penetration to determine:
  - voltage variability
  - overvoltage
  - load tap changes



4.2 Energy Storage Siting Optimization

- Generic software tool to optimize battery energy storage siting to support high PV penetration
- Apply to 15 feeders

4.3 Energy Storage Dispatch Optimization

- Develop dynamic models of the grid using PMU measurements.
- Model predictive control:
  - Input: PMU data, net load forecasts
  - Output: Storage dispatch
- Validation with hardware-in-the-loop simulations.

Key Deliverables

- Operational net load and solar forecasts.
- Distribution feeder hotspots
- Energy storage siting optimization tool.
- MATLAB code to create models of observed power flow oscillations for energy storage dispatch

Rough Timeline

- 2014: Setup solar and net load forecasting
- 2015: Develop energy storage siting and operations code and implementation.
- 2016: Finalize.