High Penetration Solar Forum

March 2011

U.S. DEPARTMENT OF ENERGY | Energy Efficiency & Renewable Energy

# Planning & Modeling for High-Penetration Solar

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SUNPOWER Smarter Solar

KEMA

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# Research Hypothesis

- The utility and PV industries need tools and resources to evaluate high penetration PV scenarios in California using industry-standard methods and modeling platforms.
- Currently there are no tools which provide accurate output power profiles for distributed PV systems over a wide area, and can model the impact of these systems on the grid.
- The work completed under this project will provide critical information to utility and grid operation planners about commercial PV plant behavior and grid impacts, under both stable and variable conditions, in populated regions

# Objectives

- SunPower, working in partnership with KEMA and AWS Truepower, will establish planning, design, and operation modeling tools to accurately assess, forecast, and account for energy output from distributed PV systems.
  - Develop and validate improved solar resource and PV power models that address the temporal and spatial resolution needs of utilities
  - Use the improved models to generate reference data sets for use in utility load and resource forecasting models
  - Demonstrate the use of the reference data sets in the development of integrated modeling approaches to identify impacts of high penetration solar on T&D system loading, reliability and capital costs
  - Employ these integrated modeling approaches to assess the potential benefits and issues associated with high penetration PV in California

# Develop High-Resolution Forecasting Tools

- Update existing PV models to reflect the dynamic aspects of PV system operation
- Cross-validate measured PV performance data with Sandia's models.
- Design outputs of PV power model for compatibility with existing utility planning and operations models.

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# Current Activities

- Commenced project December 2010
- Delivered historic MET station and PV performance datasets from 50 sites
- Developed baseline assessment of SunPower's existing simulation tool (PVSim)
- Deploying or upgrading additional MET stations throughout California

# Generate High-Resolution Solar Data

- Data acquisition and QC/QA of SunPower/NSRDB data
- Numerical Weather Prediction (NWP) model setup and run
- Validate 15-minute, 10-year time series of meteorological variables
- Derive and validate 1-second and 1-minute data
- Transfer 15-min, 1-min and 1-sec data package to project team
- Deliver methodology report

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# Data acquisition and QC/QA of SunPower/NSRDB Data

- SunPower has delivered 50 validation stations in San Francisco and Los Angeles areas
- Period of records vary from approx 2 years to 10 years
- Will be used to compute site specific variation
  - Diurnal pattern
  - Monthly and seasonal variation
  - Bias/RMS difference between datasets
  - Correlation of sites w/ respect to distance
- Provides all the necessary variables to validate the NWP model

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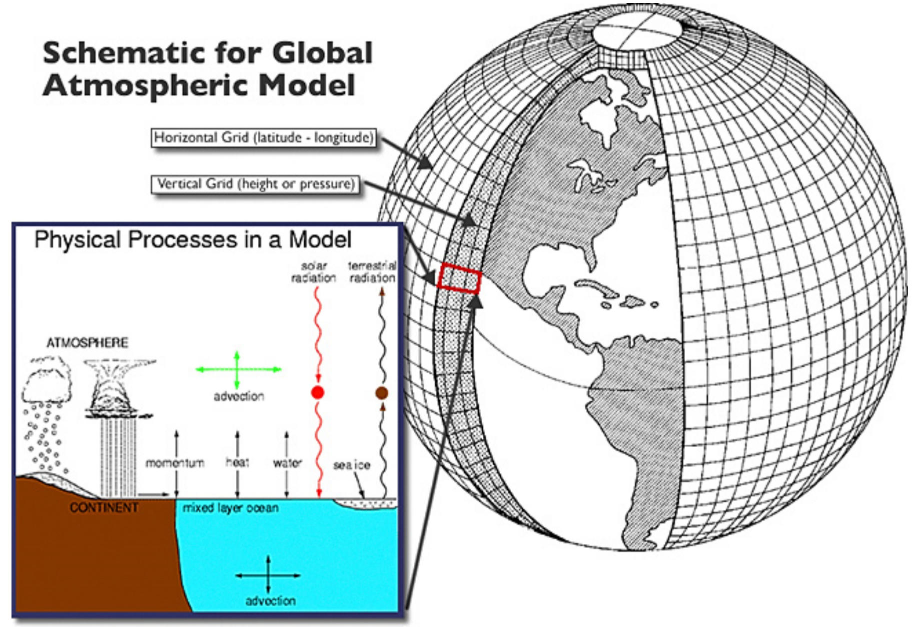
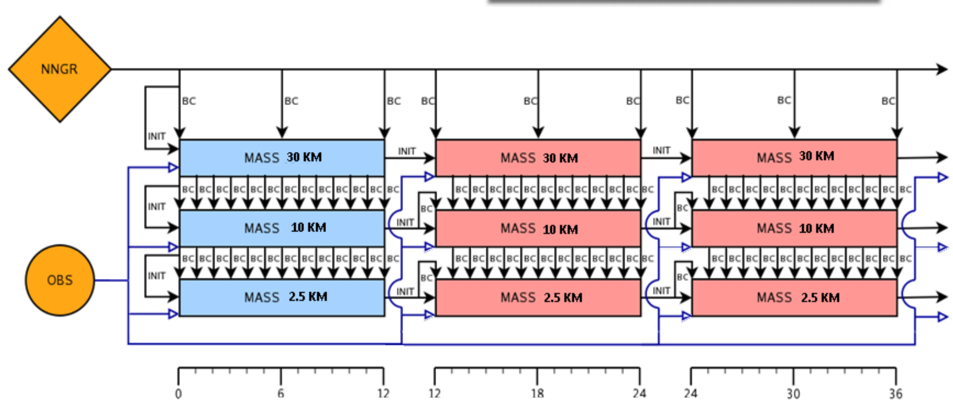
# How Synthetic Weather Data Is Generated

- Numerical Weather Prediction (NWP) models solve the fundamental equations of the atmosphere on a finite grid
- NWP models use several data sets as initializations that drive the model solution
- Mesoscale Atmospheric Simulation System v6.8 (MASS©)

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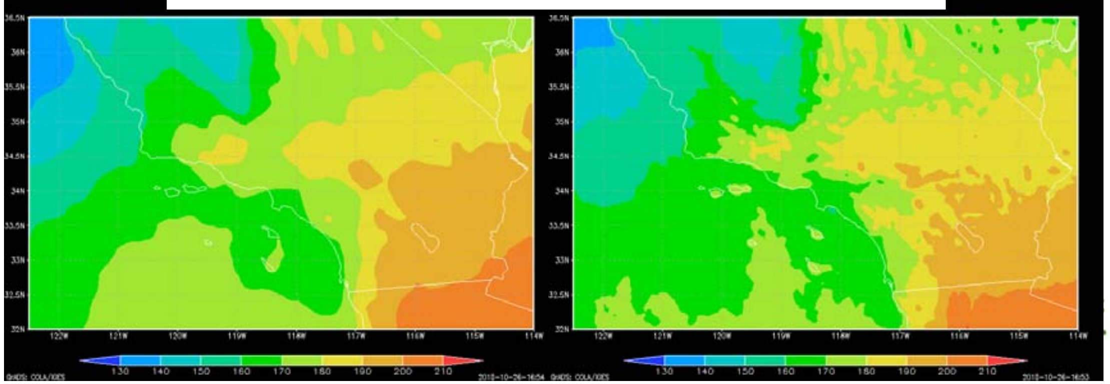
# Numerical Weather Prediction Model Setup and Run

- Final simulation areas cover greater Los Angeles and San Francisco
- Configuration has been optimized for region of interest, based on initial testing
- Two years of model data has been generated, beginning validation with observations

**Average Global Irradiance**

Low Res. ----------- High Res.



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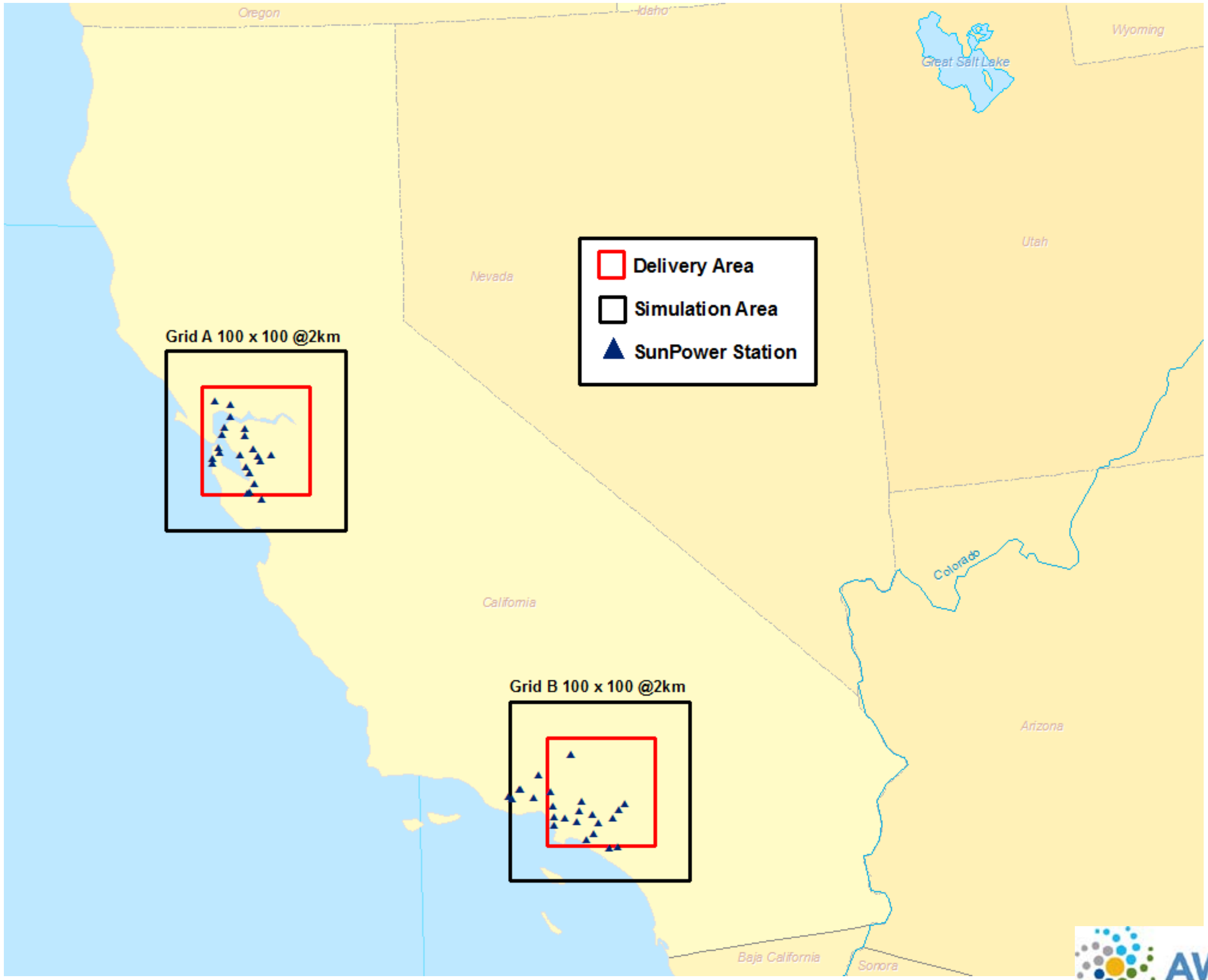
# Final Study Areas

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# Derive and Validate 1-Second and 1-Minute Data

- Compute variability of observed high-frequency irradiance data
- Superimpose high-frequency variability on the 15-minute mesoscale data
  - Day chosen by similar weather regime, time of day/year, and standard deviation of low/high-frequency data
  - Fitting procedure is applied to high frequency data
  - High frequency statistical behavior remains
- Generates long term mesoscale variability with short term fluctuations similar to actual high frequency data

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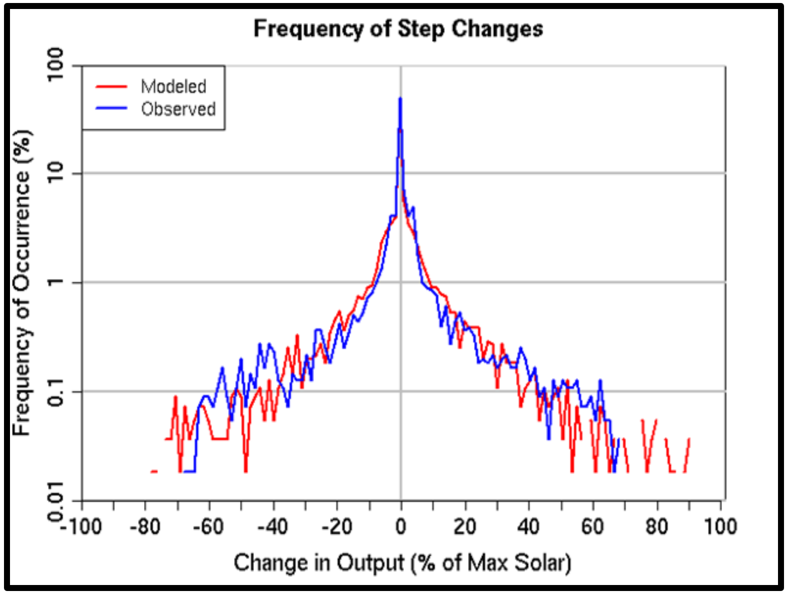
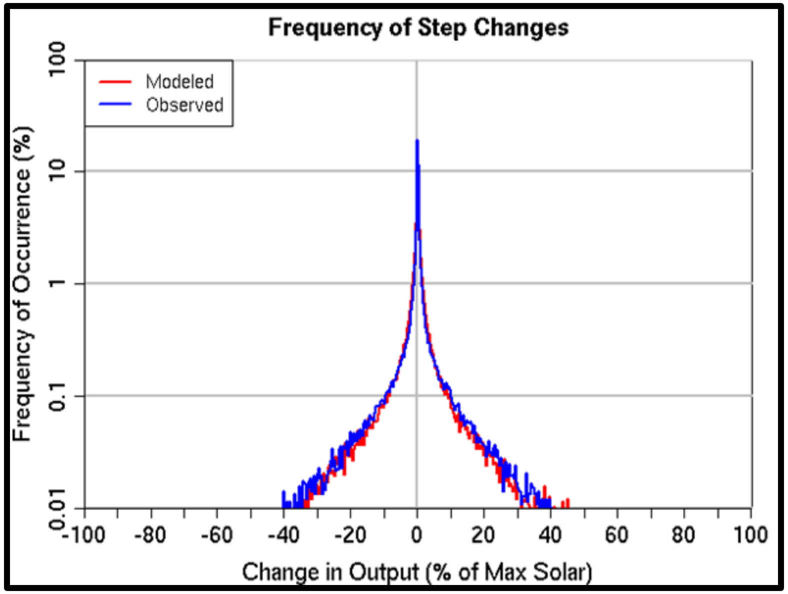
# Model Validation Methodology

- Compute basic statistical parameters (mean, bias, rmse) on several time scales
- Compare diurnal, monthly, and seasonal patterns
- Compute frequency distribution of step changes (solar ramp events)




← Δ15-minute irradiance

→ Δ 30-second irradiance

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# Model Integration

- Collaborate with project partners to create statistical analysis tool and models for PV output variability
- Provide recommendations for treatment of PV in planning and operations software and procedures
- Leverage related work under existing CRADA between SunPower and Sandia

# Model Scenarios, Integration, & Recommendations

- Develop Recommendation for modeling High Penetration PV
  - Distribution & Transmission
  - Planning & Operation
- Compile and Present Report

# Define Optimal Siting

- Develop requirements for High-Penetration PV modeling.
- Apply results from Task 1, 2, & 3 to determine circuit impacts by penetration level.
- Review existing models & approaches to determine capability.
- Document gaps in existing models.

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# Distribution Feeders

★ To transmission system

- Typical analysis:
  - PV is modeled as power injection at selected points.
  - Each injection is a time series
  - Power-Flow Solver is run for each time point;
  - its solution is then evaluated for impact of PV variability.
- Measured data is often used and extrapolate.

# Transmission System

- "Star" on previous slide is a single node in Transmission model.
- Impact of PV on transmission system can be analyzed via aggregation of Distribution System.
- Power-Flow Solver must be used in a time-series analysis.

# PV Modeling Approach

- Survey existing industry PV models
- Demonstrate different analytical modeling approaches
- Summarize all of the PV models & Tools
- Prepare Gap Analysis with existing modeling tools

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# Thank You

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