HIGH-FIDELITY SOLAR POWER FORECASTING SYSTEMS FOR THE 392 MW IVANPAH SOLAR PLANT (CSP) AND THE 250 MW CALIFORNIA VALLEY SOLAR RANCH (PV) PROJECT CEC EPC-14-008

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Outline

Project Background

Agreement Goals and Objectives

Current Progress and Results

Project Background

Motivation:

- Ivanpah SEGS and California Valley Solar Ranch (CVSR) make up about 6.5% of all installed solar capacity in California
- Need to reduce ancillary costs and increase confidence in the operation of large scale solar energy resources
- Development and implementation of large-scale high fidelity solar forecasting systems with resource to power (RTP) models

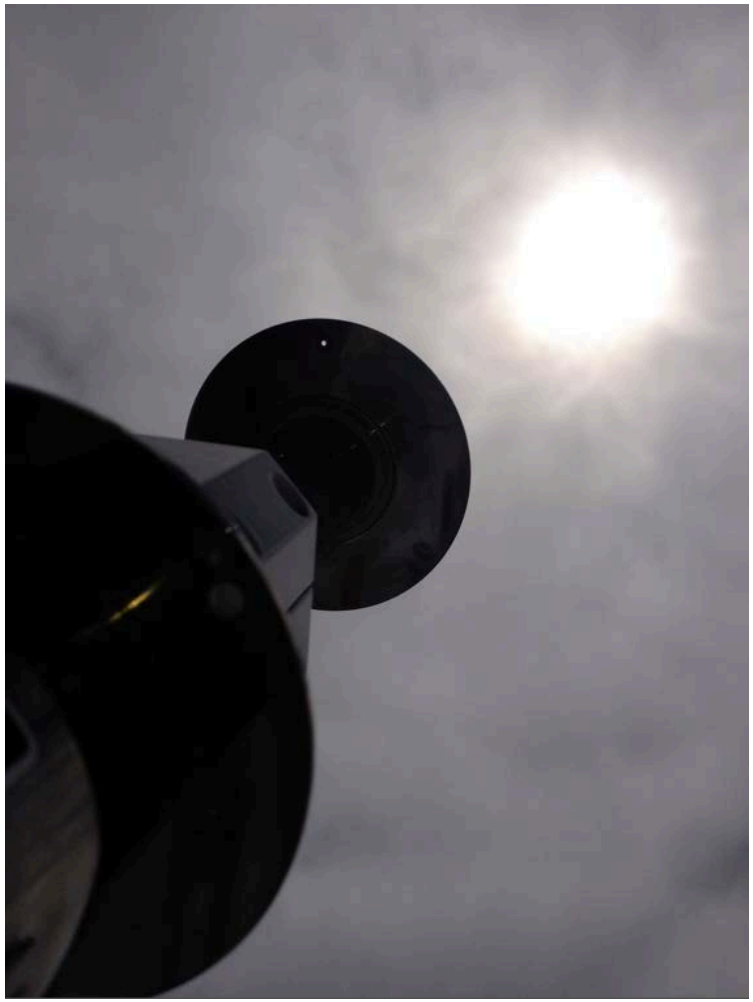
392 MW CSP Ivanpah Solar Thermal (top) and 250 MW tracking PV California Valley Solar Ranch (bottom)

Technological Merit:

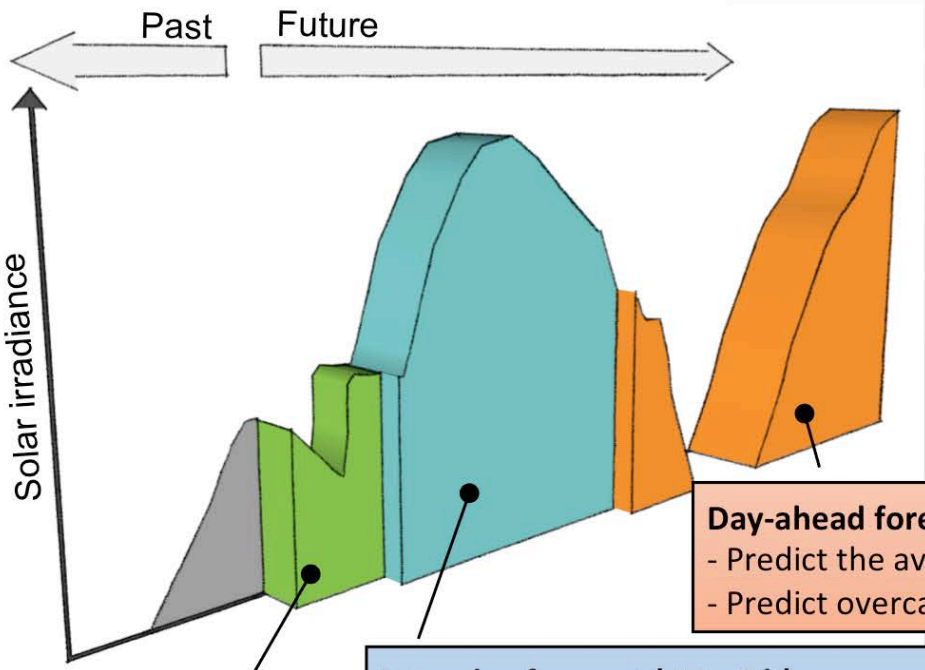
- Concentrated solar power (CSP), concentrated PV (CPV), and tracking PV (to a lesser extent) rely upon Direct Normal Irradiance (DNI)

- Native forecasting algorithms for DNI are not as mature as GHI prediction models

- Resource to Power (RTP) models will use input from DNI models to greatly improve operation, scheduling and market participation of large scale plants



Project Background

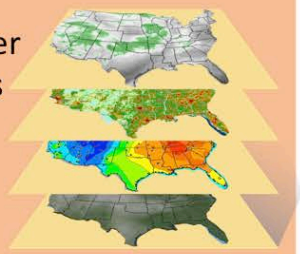


Day-ahead forecast (up to 2 days)
- Predict the average solar resource.
- Predict overcast periods.

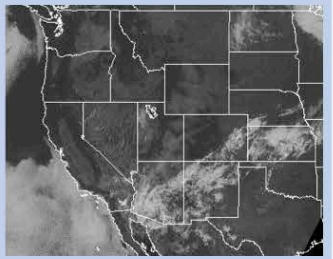
Intra-day forecast (1 to 8 h)
- Predict could entrance/exit times
- Predict overcast periods.

Intra-hour forecast (0 to 60 min)
- Predict large ramps.
- Calculate prediction intervals.

Data used in the Day-ahead forecasts
- Telemetry
- Numerical weather prediction models



Data used in the Intra-day forecasts
- Telemetry
- Satellite images



Data used in the Intra-hour forecasts
- Telemetry
- Local sky images

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Project Goals

CEC Goals:
Develop and validate advanced solar and wind forecasting and modeling tools to increase the accuracy and reliability of forecasts, reduce the costs of solar and wind generation integration for utilities, and assist grid operators in variable and intermittent resource management.

Our goals:

- Create forecasting models that increase the accuracy and reliability of generation predictions for intermittent solar resources
- Assisting in the operation of variable and intermittent resources, reducing utility costs associated with day-ahead scheduling,
- Reducing plant operation costs associated with intra-day variability (thereby reducing overall solar O&M costs),
- Reduce imbalance charges incurred by solar plants due to inaccurate forecasts

Project Objectives

1. Improve DNI and POA irradiance forecasting accuracy

2. Improve the RTP model for Ivanpah CSP and CVSR plants

3. Deploy and test a new generation of low cost solar instruments at the two plants

4. Develop control strategies for partially cloudy conditions

1. Develop and deploy RTPs for Ivanpah CSP and CVSR plants

2. Generalize project outcomes to other plants and solar technologies

3. Assess benefits to California ratepayers

Project Objectives

- The proposed forecasting system will cover time horizons ranging from 5 minutes to 72 hours

- Success of the project will be measured by the increase levels of fidelity of the forecasting system for all horizons of interest

Horizon	< 1 hr (RTD)	1 hr	1-6 hrs	24-36 hrs	>36 hrs
Averaging period	1 min	5 min	15 min	1 h	1 d
Current skill (*s*)	0.15-0.36	0.18-0.32	0.10-0.17	0.10-0.42	0.20
Targeted skill (*s*)	0.50	0.50	0.50	0.50	0.50

- These are very aggressive targets that cannot be achieved with current telemetry. Therefore, this project aims at deploying better instruments that are especially suited for high-fidelity forecasts

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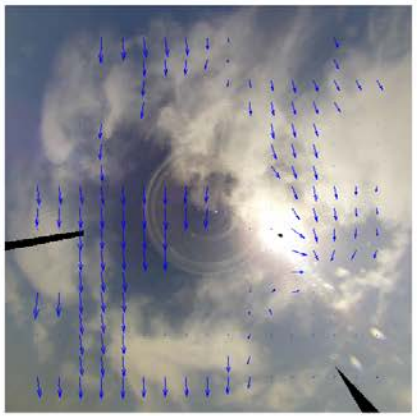
Current Progress and Results

Intra-hour irradiance forecasts

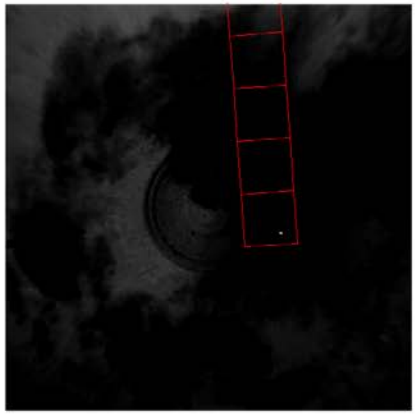
- Input sky image features to assist the forecast
  - The features are derived by image processing
- Hybrid Model
  - Smart persistence model for clear and overcast periods
  - Multilayer perceptron network model for partly-cloudy periods
- The model can perform DNI forecasts in real-time

Sky image devoid of obstacles

Project image to remove distortion



Calculate velocity fields

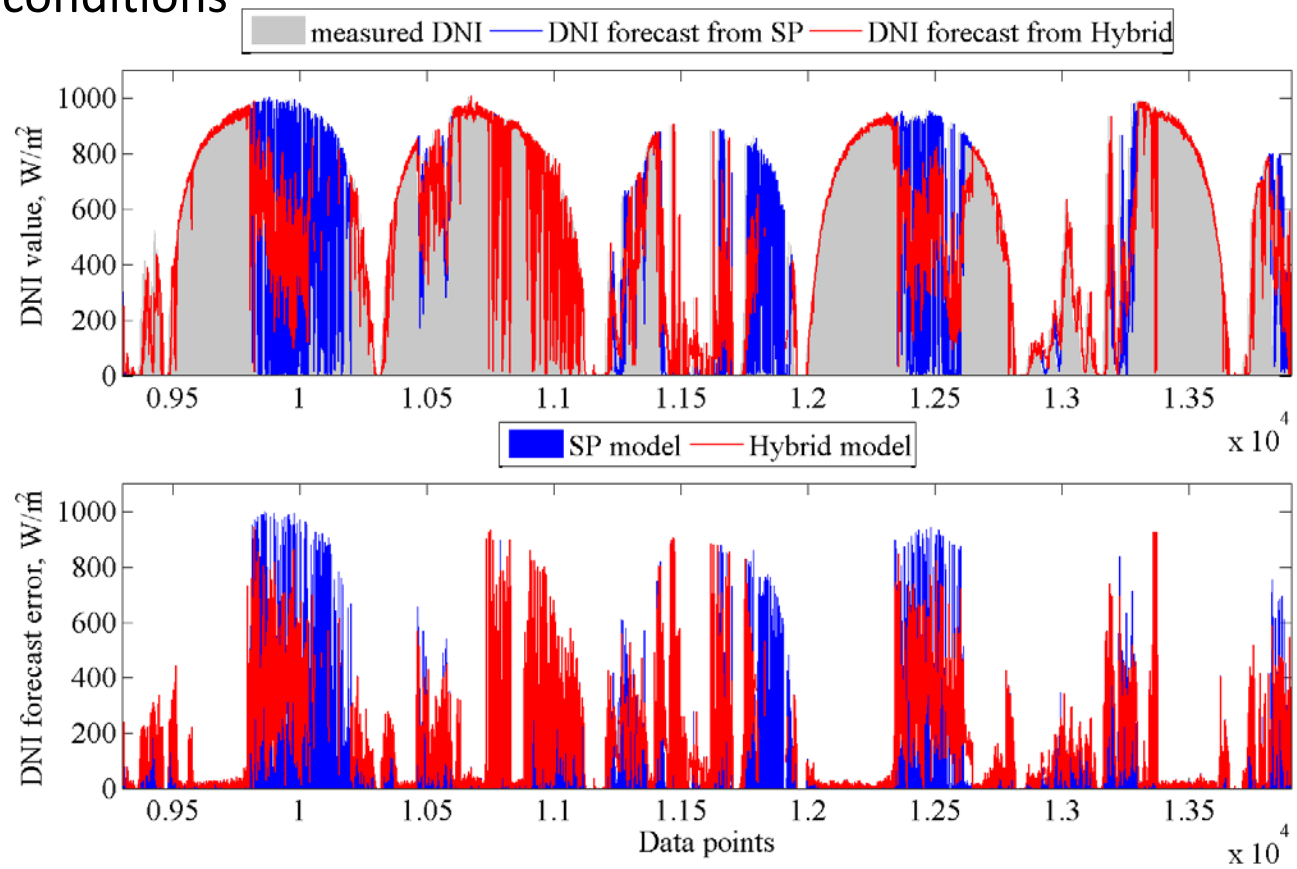


Draw grid elements on the reverse direction of representative velocity

Current Progress and Results

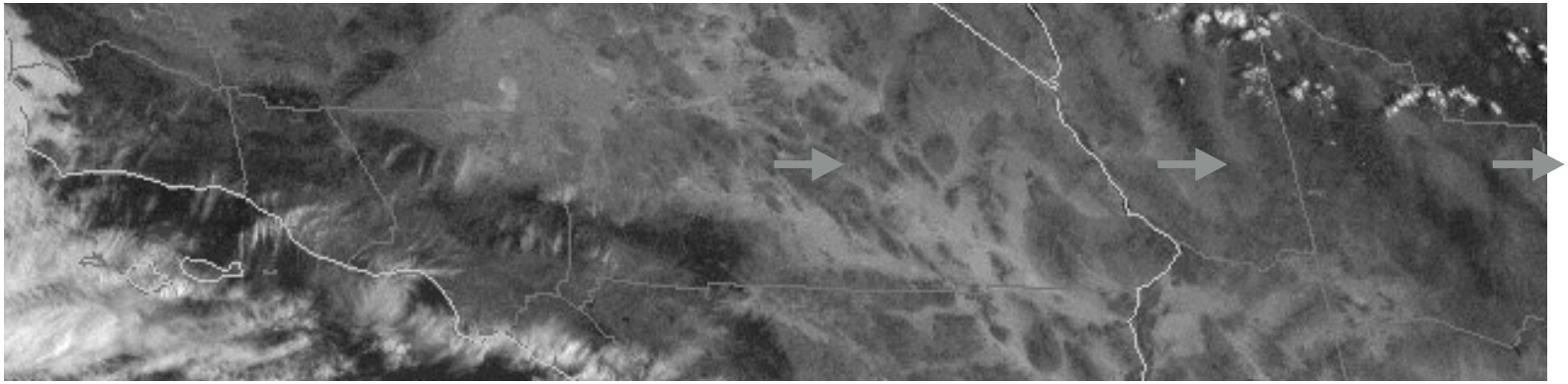
Intra-hour irradiance forecasts

- Over 18% forecast skills with respect to smart persistence model during cloudy periods
- Over 11% forecast skills with respect to smart persistence model in all sky conditions



Current Progress and Results

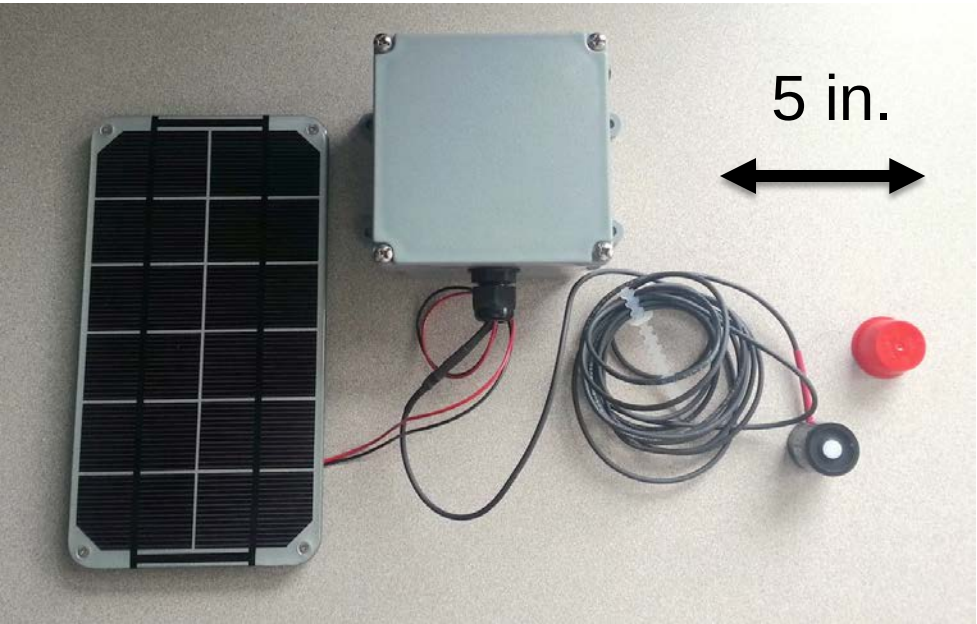
- Intra-day irradiance forecasts:
  - Forecast horizon of 1–6 hours ahead
  - Based on satellite imagery and machine learning methods
  - Methodology can be applied to predict both irradiance and power output
  - Achieves 31%–39% improvement over reference smart persistence forecast model
  - Real-time forecasts in testing stage

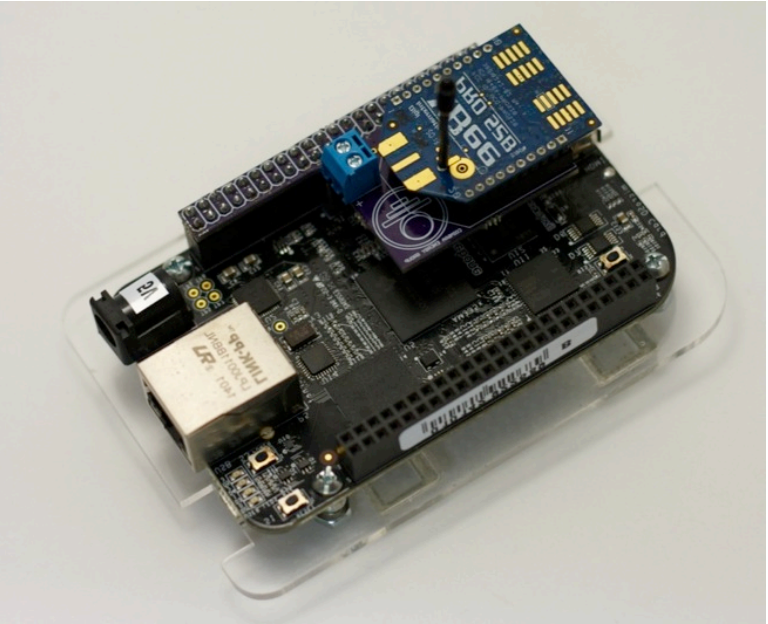


Visualization of the overall intra-day forecast methodology.

Current Progress and Results

- Sensor Node Network
  - Low-cost (<$500 per unit)
  - Wireless and solar powered
  - Provides distributed sensing solution for monitoring power plants
  - Conversion to PCB form is in progress:
    - Smaller size, lower cost, and lower energy usage
    - Faster mass production
  - Deploying to first power plant in Spring 2016

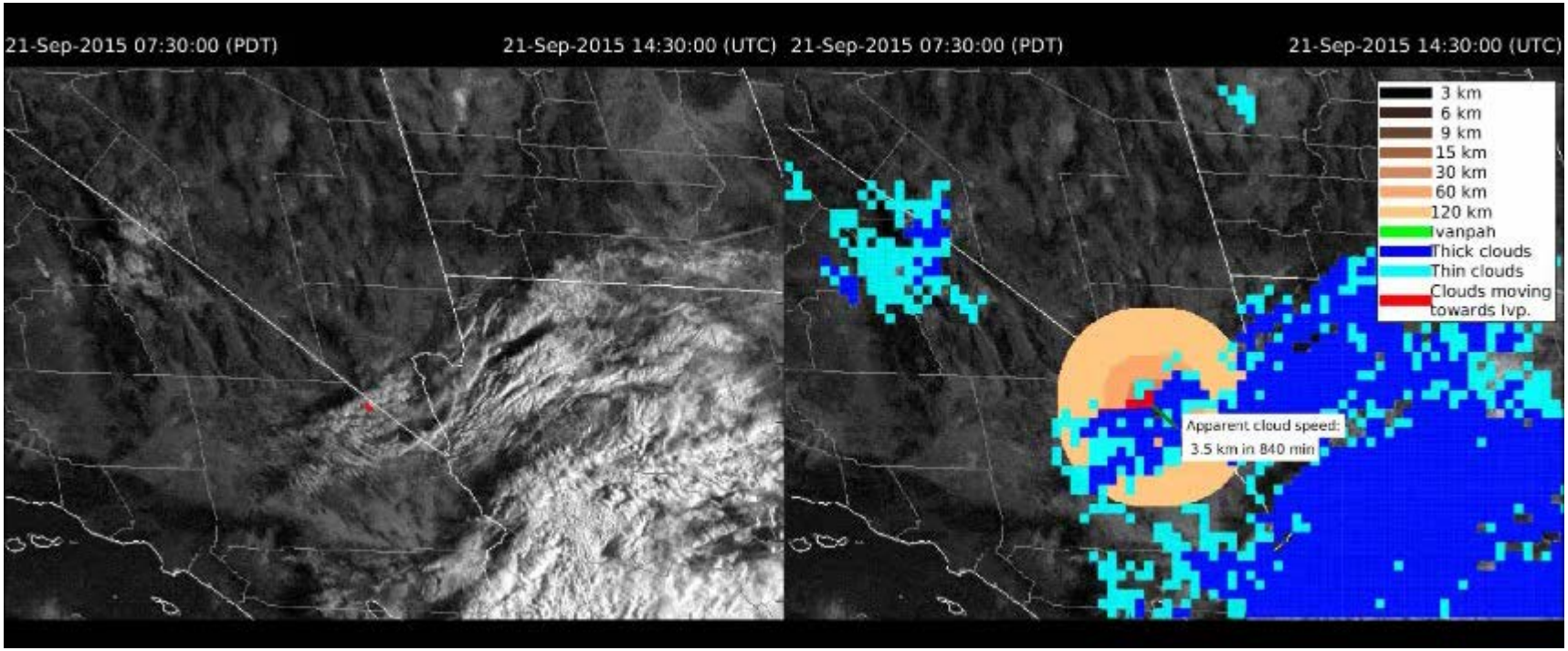




Current Progress and Results

Intra-day cloud cover forecast

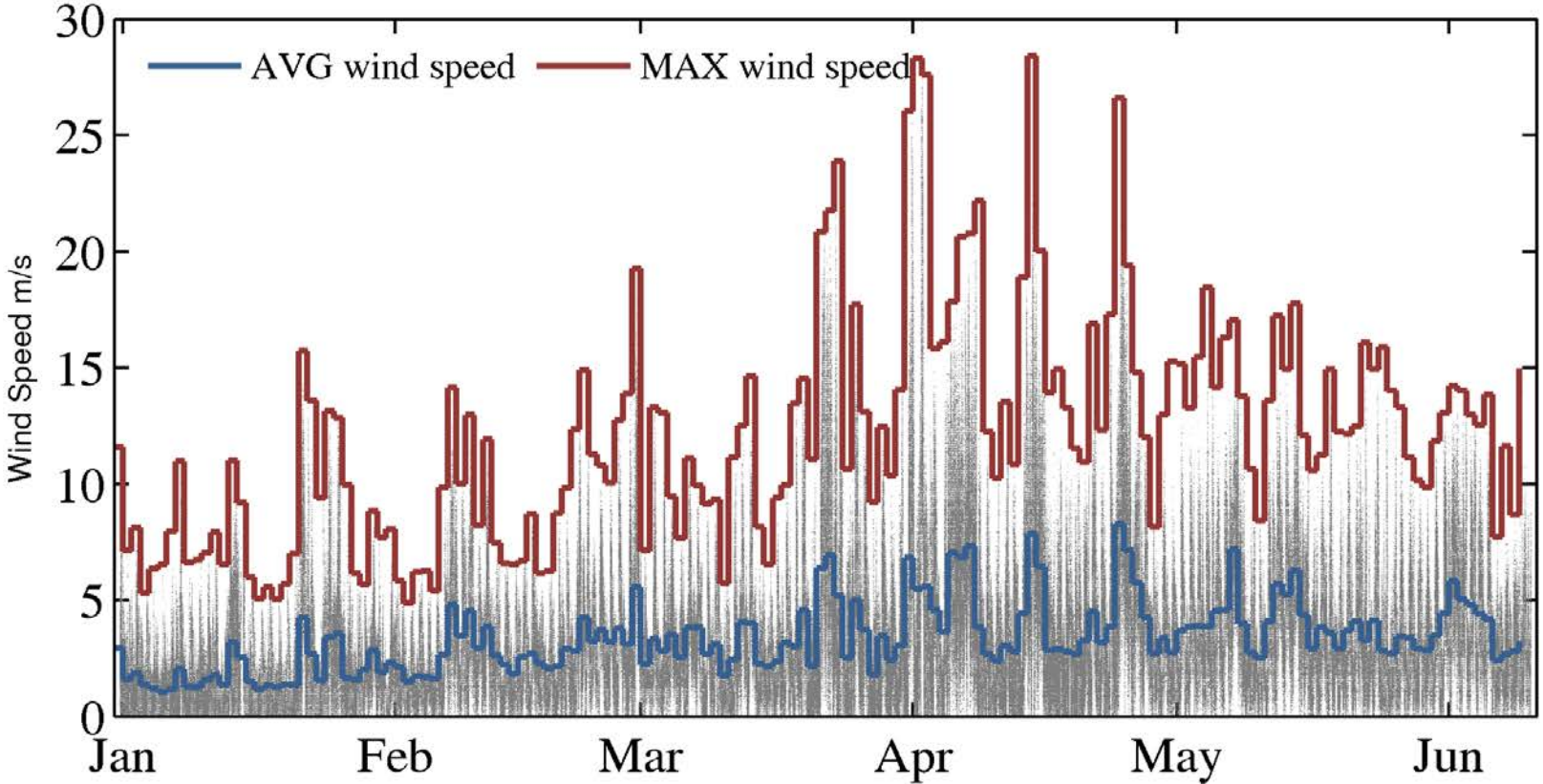
- Use visible light satellite images (GOES WEST) to assist the forecast
- Determine cloud entrance/exit times over the solar farms



Current Progress and Results

Wind forecasts

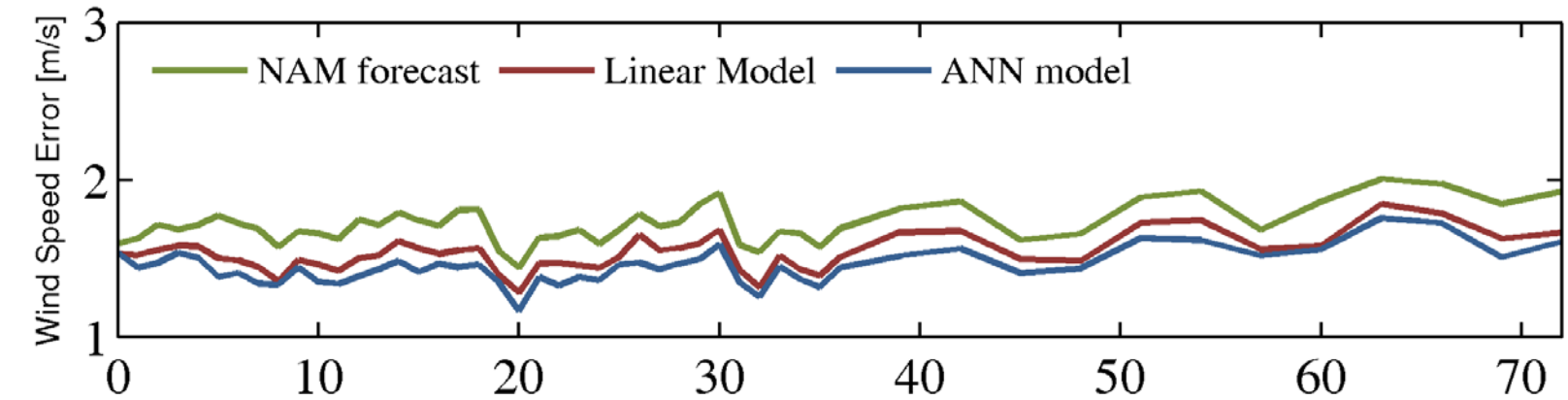
- Heliostats cannot operate with high wind speeds.
- Forecasting average wind speed and wind gusts at the heliostats.
- Measured data in the from Jan to Jul 2015.

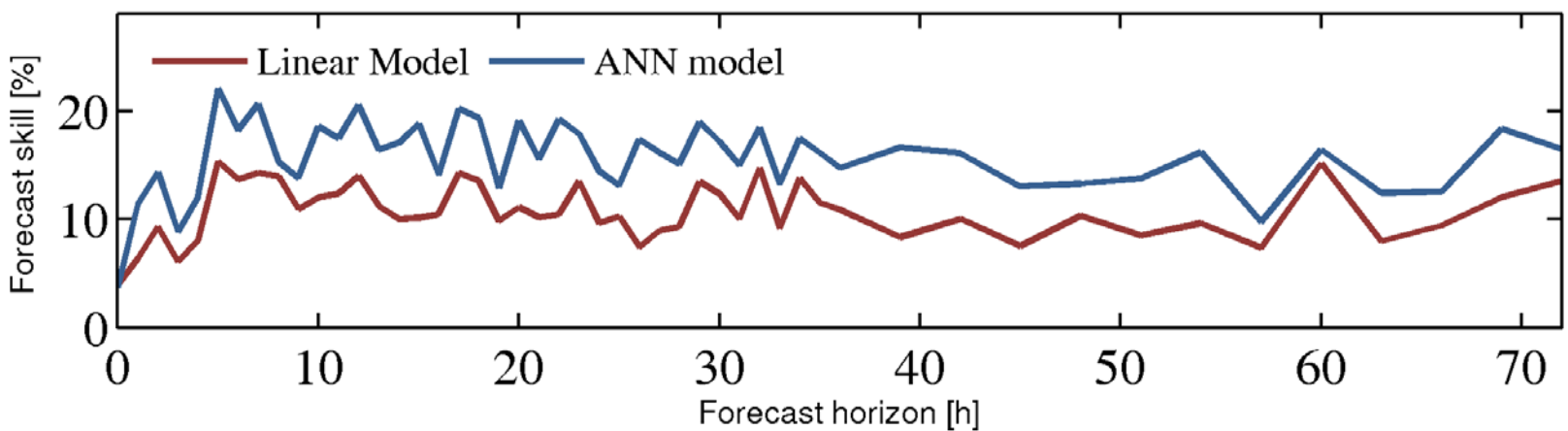


Current Progress and Results

Wind forecasts

- Baseline forecast for comparison is the wind forecast from NAM.
- Initial forecast prototypes can achieve close to 20% improvement w.r.t NAM for most forecast horizons.





Solar Forecasting –Future Research Needs

Future solar forecasting research needs and opportunities include:

- development and optimal deployment of low cost irradiance sensors to resolve solar field telemetry at < 100 m scale
- cloud entrance/exit forecasts for central station power plants
- remote sensing image processing methods that can be directly integrated to the new generation of higher resolution weather satellites to be launched in 2016 (GOES-R series)
- machine learning integrated methods for resolving cloud optical thickness that combine ground observation (sky imaging) and high resolution satellite imaging
- three-way coupled models that interlace numerical weather prediction (NWP) models with remote sensing and ground telemetry to increase reliability of forecasts for rapid ramp forecasts based on 3-D cloud resolution
- post-processing models for NWP that feed real-time information from remote sensing back into the three-way forecast engines
- cloud assimilation models for highly resolved regional WRF simulations
- highly resolved distributed net load forecasts for utility scale territories based
- integration of solar and load forecasts with dispatchable resources, storage and demand response for micro-grid management at both community and utility scales