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# Coordinated Ramping Product Procurement in CAISO Using Probabilistic Solar Power Forecasts

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## Outline

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1. The Pro2R project
   - Watt-Sun → Conditional Net Load Ramp Forecasts → System Simulations
   - Watt-Sun probabilistic forecasts
2. How can probabilistic forecasts help operators? The problem of net load ramps
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5. Conclusion

# Pro2R Overview

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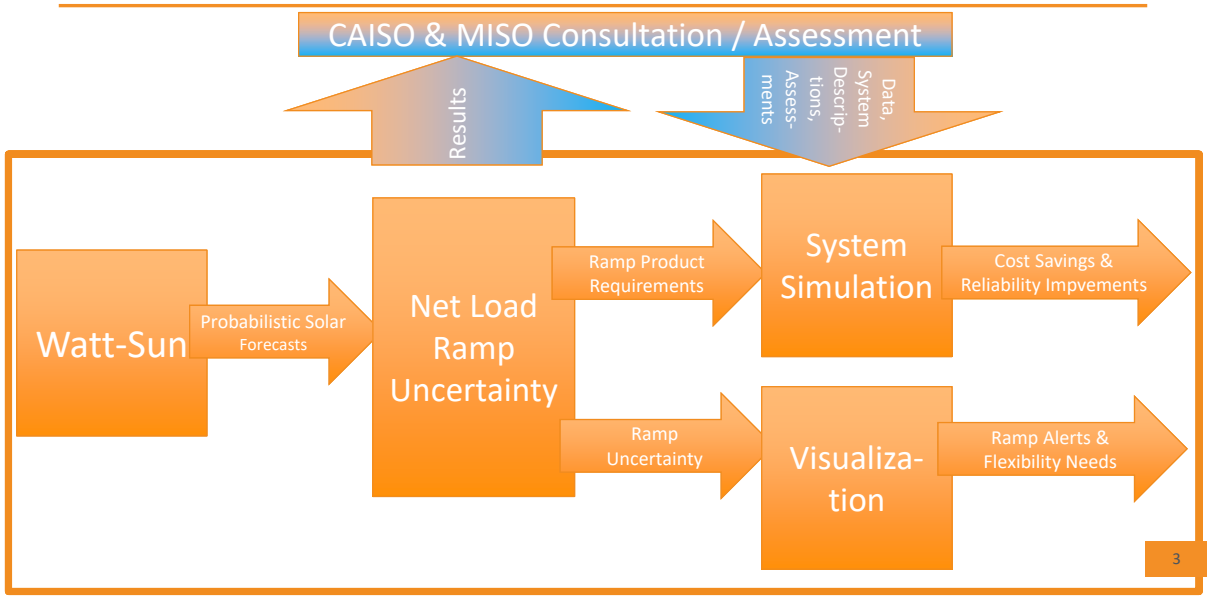




# Probabilistic Watt-Sun Flowchart

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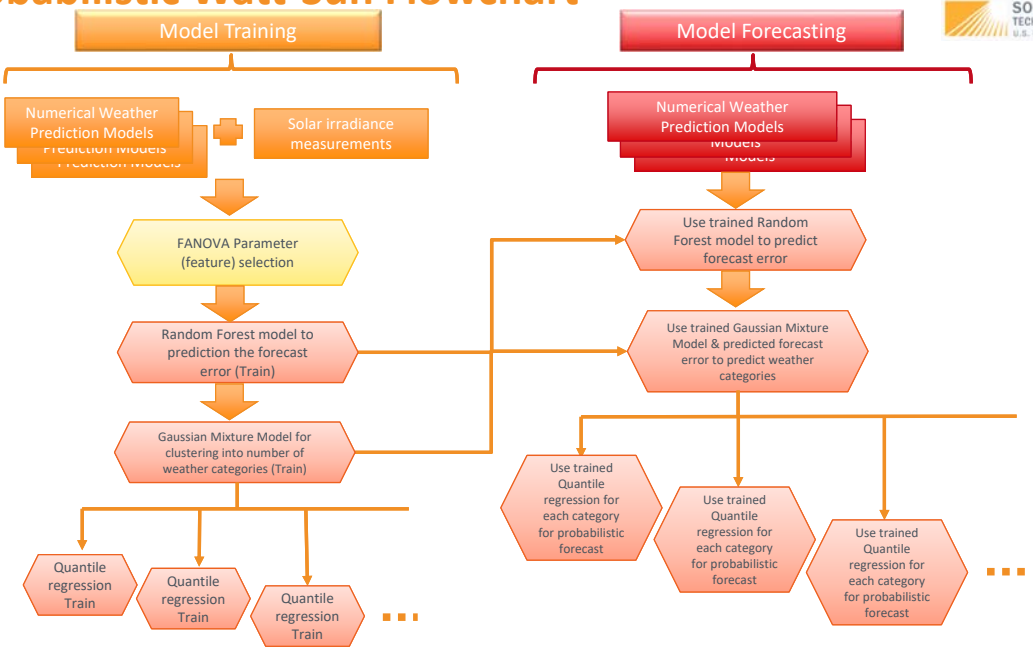

## Used quantile regression to deploy probabilistic forecast models

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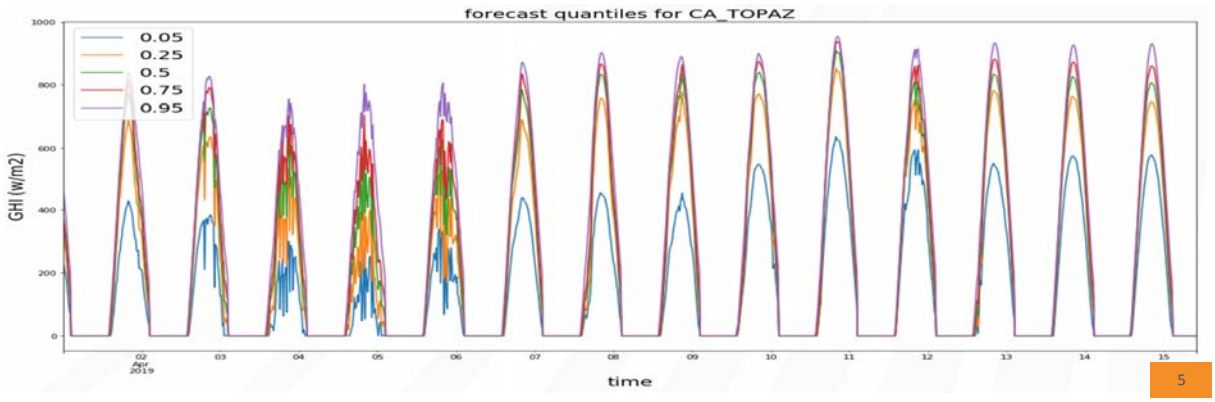
- Quantiles of solar as function of independent variables
- Example results for 2 hr-ahead forecasts
  - Distributions are *asymmetric* → *hence important to have quantile regression techniques*
  - Adjacent days can have very different distributions; in contrast, present CAISO flexiramp requirements are very stable day-to-day because they don't reflect weather forecasts → *need to integrate probabilistic forecasts in requirements*






# P-P plot Error Metric

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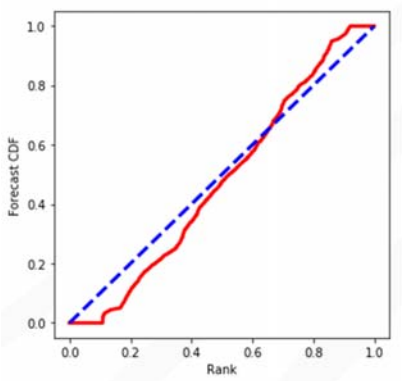
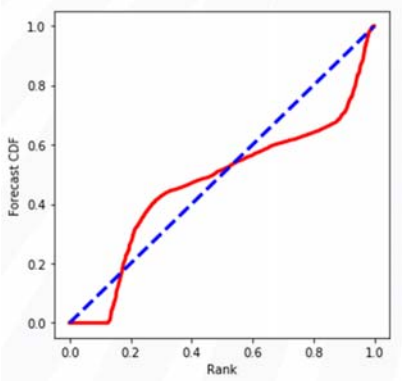
## Comparison of Watt-Sun Probabilistic Forecast with Bias-Corrected NOAA High Resolution Rapid Refresh (May 2019)

Empirical CDF
Score: 0.0543




Bias Corrected HRRR (normal distribution)
Score: 0.0859



## Forecast Error Comparison
## Watt-Sun 1.0 *CAISO, MISO*

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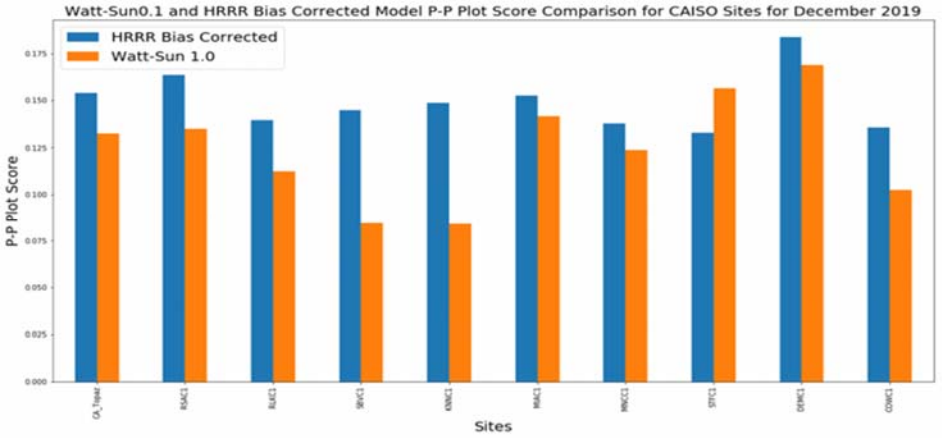
- Dec. 2019, forecast horizon 2 hr.
- **P-P Plot score** evaluation of probabilistic calibration (daylight time only)
  - Watt-Sun 1.0 outperforms HRRR Bias-Corrected in 9 out of 10 sites in each market (CAISO shown below)






## Sample Outputs of *Rasterized* Probabilistic Forecast

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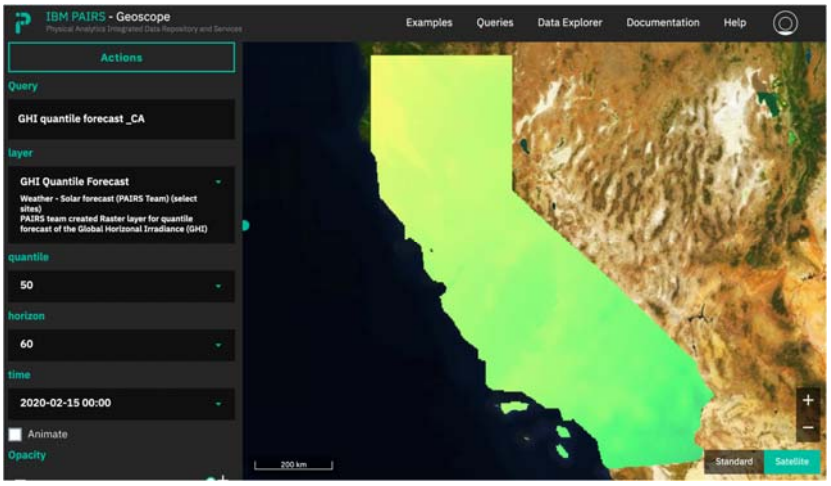
https://ibmpairs.mybluemix.net/queries/3e28d6e0-bb59-45ae-b00f-ca749fa5de13?layer=782375043&mapType=satellite (Need to register as PAIRS user)

- PAIRS querying functionality on rasterized forecasts:
  - Continuous point queries for probabilistic forecasts anywhere within user-defined region



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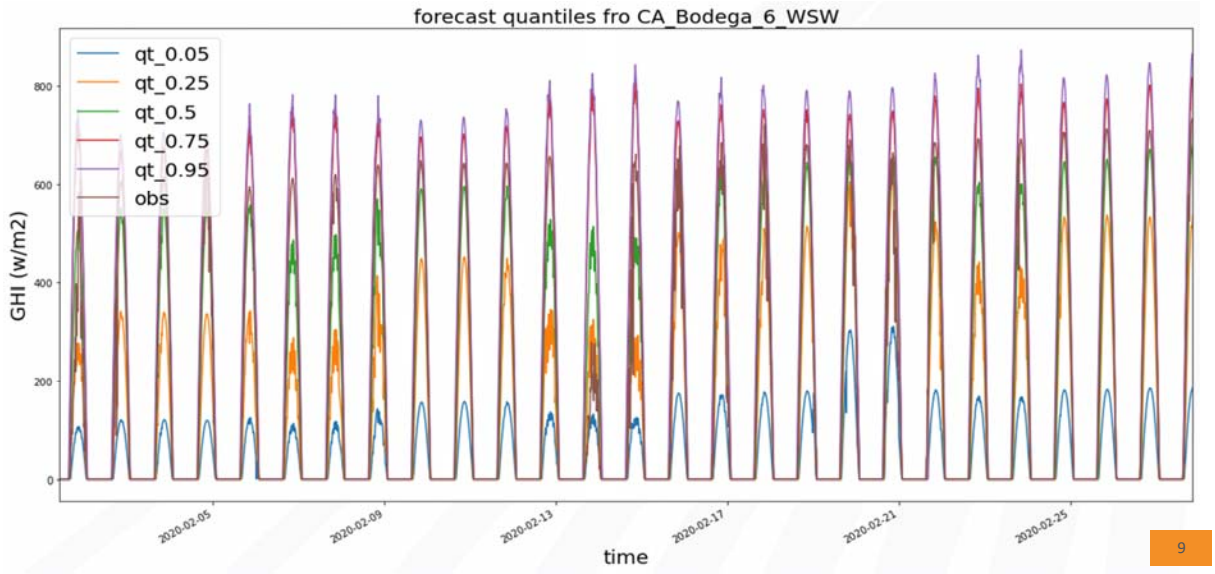




## One destination for probabilistic forecasts: RaViS Visualization tool (NREL)

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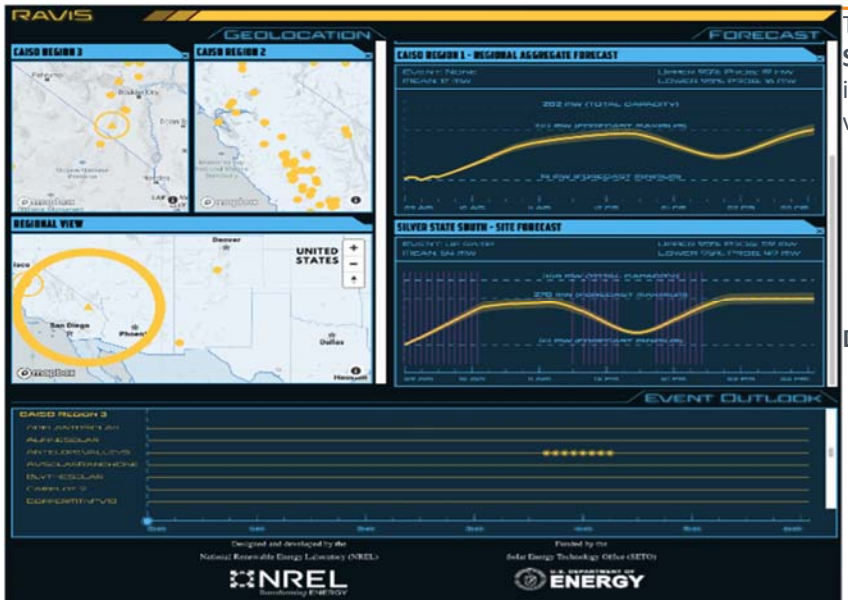


The **Ramp Visualization for Situational Awareness (RaViS)** is a modular dashboard for viewing:

- forecast timeline
- spatially relevant forecast and event data
- details of specific events as desired, including market data

**Design:**

- Designed to use ***web application technologies*** and tooling
- Utilizing this technology will ***enable deployment in any environment***, using any operating system

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## Actual net-load and 3-hour ramps are about four years ahead of ISO's original estimate

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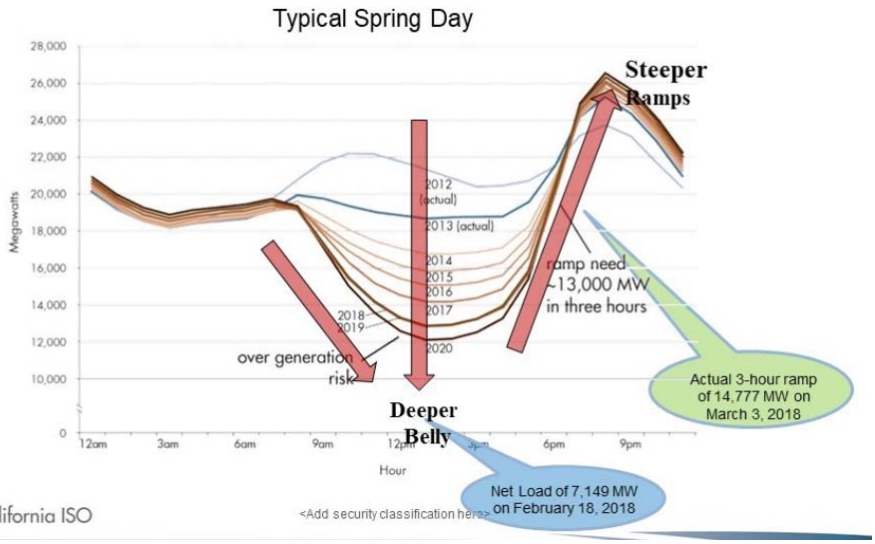


California ISO





Source: www.caiso.com

# Increasing CAISO Load Forecast Error

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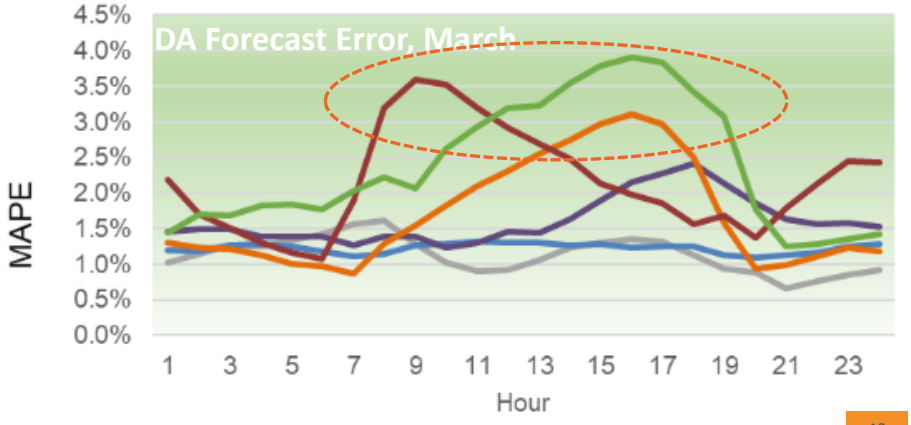
2013 2014 2015 2016 2017 2018

California ISO

A. Motley, www.caiso.com/Documents/Briefing-Day-AheadLoadForecastingAnalysis-Presentation-Nov2018.pdf



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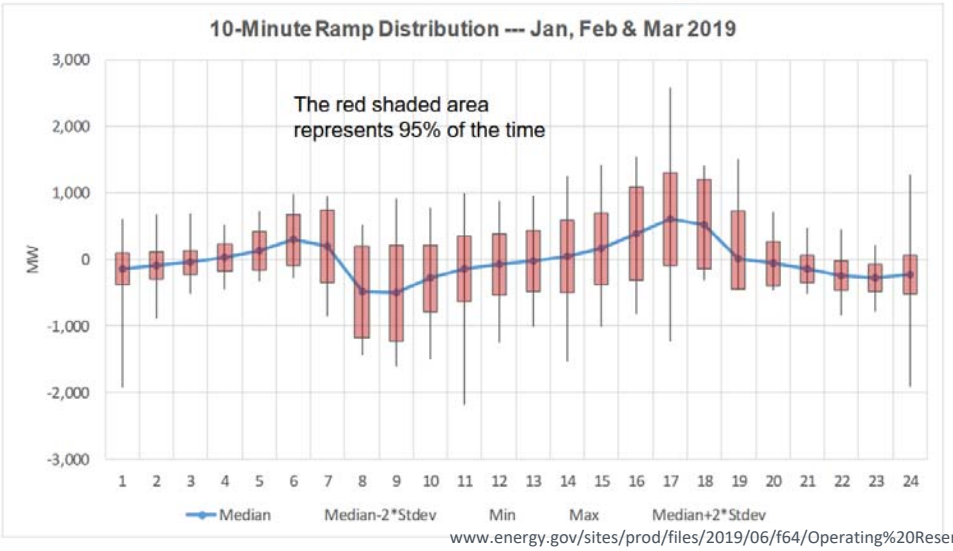
# The 10-minute net load variability for January through March 2019 can exceed 2,000 MW during sunset






www.energy.gov/sites/prod/files/2019/06/f64/Operating%20Reserves%20-%20Loutan.pdf

## Flexible Ramping Product

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- CAISO (RT 5min & 15 min), MISO (DA/RT), SPP (Proposed)
- Goals:
  - Pre-position supply to meet unexpected up- and down-net load ramps
  - Compensate, with certainty, prepositioned supply who experience opportunity costs
- CAISO implemented in 2016 throughout EIM
  - Based on difference between two forecasts for interval *t*'s net load: earlier "first advisory" and later "binding"
  - Adjustments for deliverability and other issues
  - Revision: conditional on weather (www.caiso.com/StakeholderProcesses/Flexible-ramping-product-refinements)
  - Plans to extend to day-ahead: Imbalance reserve



## Example: CAISO Flexible Ramp Product

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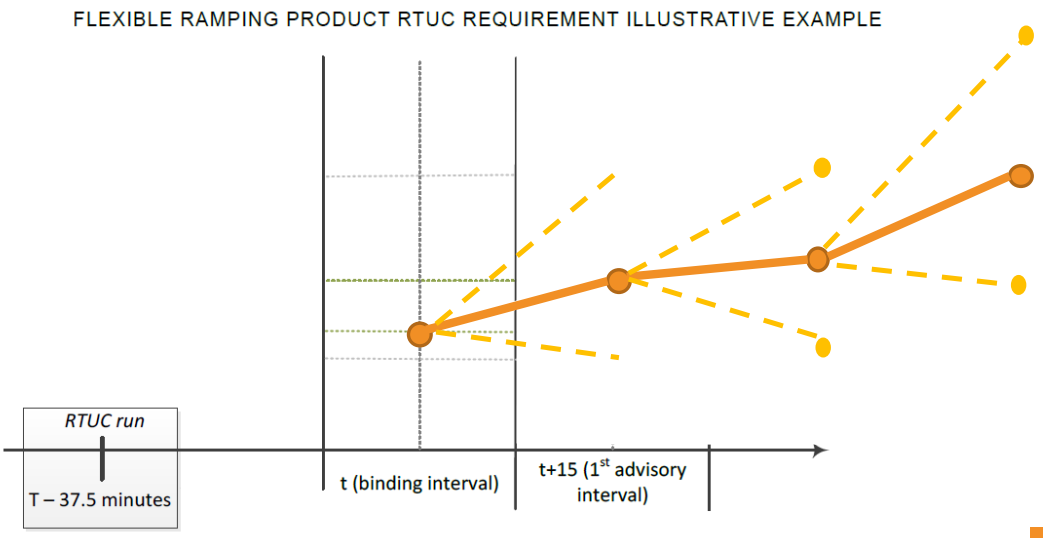




Based on www.caiso.com

## Whence Error's Distribution?

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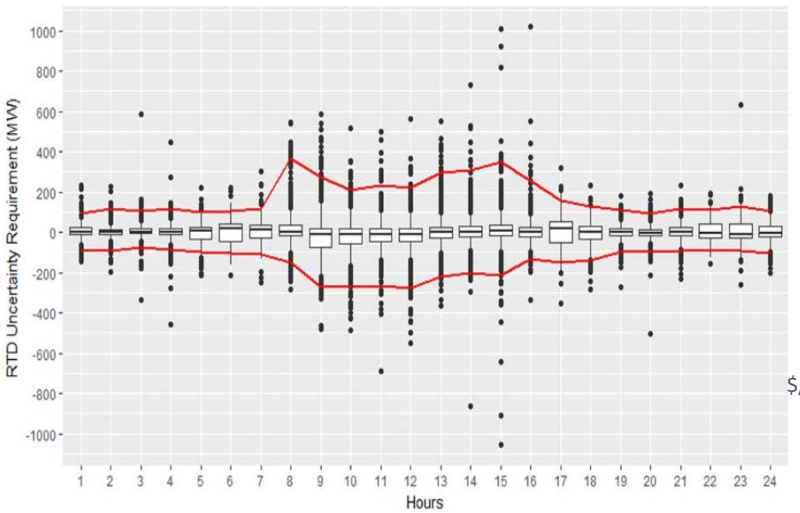
- RTPD: Past 40 days of observations of:
  - (*t*-37.5 forecast for *t*+15 load) – (*t*-22.5 forecast for *t*+15)
    - Actually … - (MAX of three 5-min Real-Time settlement forecasts within *t+15*)
  - → Histogram
- Could this be conditioned on probabilistic forecast of load, wind and solar on a given day?
  - Say that today there is less solar uncertainty than usual? Or more?



## Expected Histogram Sample used to Calculate Uncertainty Requirement for EIM Area -- January 25, 2018

http://www.caiso.com/Documents/AgendaandPresentation-MarketPerfomanceandPlanningForum-Feb202018.pdf

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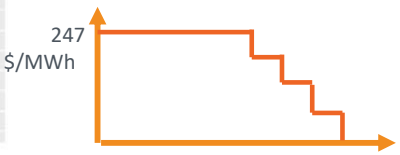
- *Unconditional* histogram constructed from rolling window data of 40 days (weekdays), 20 days (weekends)
- Requirements = 2.5th and 97.5th percentiles
- Then demand curve constructed based on probability and cost of load balance violation



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## Can we condition ramp needs on solar uncertainty?

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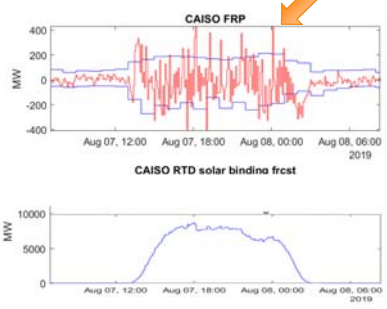
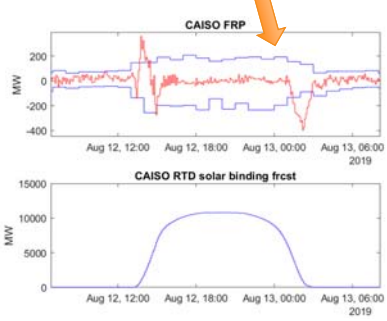
- Type of days vs. uncertainties

| | Cloudy day | Sunny day |
|---|---|---|
| NL forecasting uncertainties | **Greater** ($\epsilon_t^{NL}\uparrow$) | **Smaller** ($\epsilon_t^{NL}\downarrow$) |
| Solar power profile | **Jagged** | **Smooth** |
| Problems with CAISO's baseline | **Under** procurement, risk of reserve shortage | **Over** procurement, reduced market efficiency |




CAISO's baseline does not consider weather types, and sunny and cloudy days are all mixed up.

**Can we build separate histograms based on day type?**

## Statistical *Conditional* Relationships Between Solar Uncertainty and Ramp Product Requirement

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**Research Question: Can Watt-Sun probabilistic forecasts be used to recognize "type of day" and inform ramping requirements?**

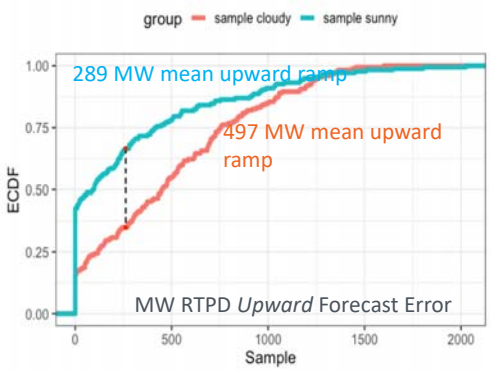
### Hypothesis:

- Narrow (wider) Watt-Sun forecast interval
  →lower (higher) errors for CAISO upward ramp of net load
  → lower (higher) ramp requirements

### Methods summary:

1. **Two state classifier:** Partition days into two subsets based on degree "solar uncertainty" (IBM forecast data – width of 25th to 75th percentile forecasts))
2. **Continuous classifier:** Quantile Regression of forecast error as function of solar Weather Indicator

***Dec. 2019 11 a.m.-2 p.m. net load uncertainty distributions, conditioned on day type (Topaz site) under Low vs High Solar Uncertainty***






## Quantile Analysis: Continuous classifier shows potential to adjust net load ramp distribution during mid-day

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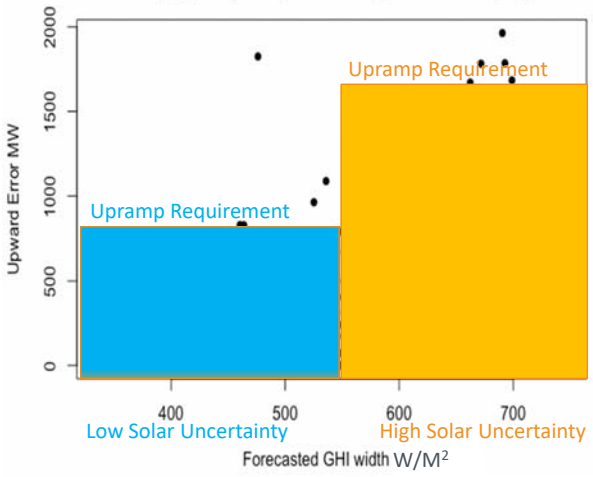
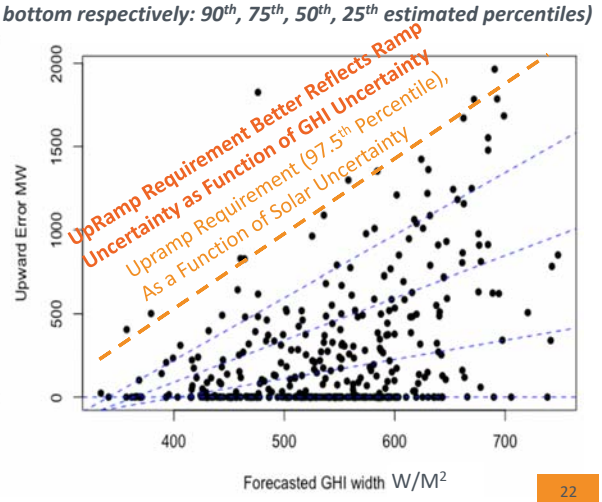
***Two Way Classification Results 11 a.m.-2 p.m. May 2019: 97.5% Cutoff (Ramp Requirement) for Each Day Type***




***Upward Error Quantile Regression Results 11 a.m.-2 p.m. May 2019 (dashed blue lines are, from top to bottom respectively: 90th, 75th, 50th, 25th estimated percentiles)***






*(Actual implementations are multivariate regression or machine learning methods)*

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**Machine learning approach: Classify (by kNN method) days based on *solar uncertainty (width of 25th – 75th percentile; ΔClear sky index)***

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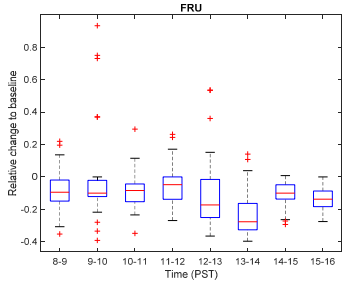
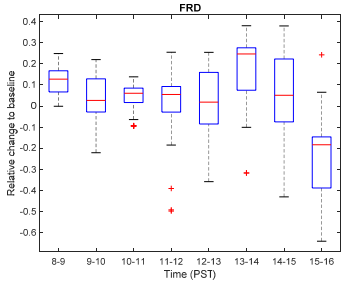
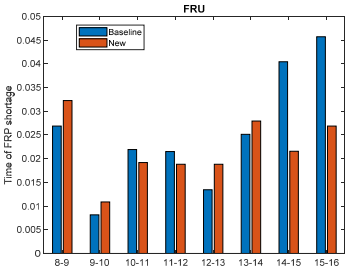
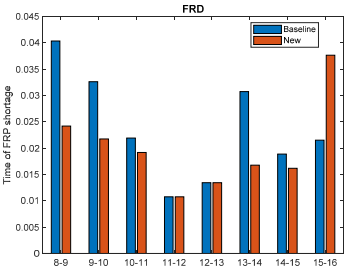



- **Evaluation metric 1:**
  ***Reduction of requirements August 2019:***
  FR-Up reduced **up to 20%**
  FR-Down reduced **up to 20%**




- **Evaluation metric 2:**
  ***Fraction of hours with reserve shortage:***
  FR-Up: **slight average decrease**
  FR-Down: **more consistent decreases**

## What are the resulting $ benefits? (NREL)
## Experimental design for system simulations

Compare two cases in market simulations:

- **Baseline (B):** CAISO markets use existing **calendar-based "unconditional"** method to estimate ramp requirements
- **Alternative (A):** CAISO markets use proposed **weather-aware** (Watt-Sun informed) "**conditional**" method to estimate ramp requirements

$\Delta performance$

Performance: uncertainty-induced cost estimated by FESTIV for 118 bus system



## Value observed during a simulation day

**Compare <u>cost</u> of ramping requirement cases. Did one case require more ramp?**

*MW Ramp:*




| Cost might increase under alternative method | Cost might decrease under alternative method | Similar cost |
|---|---|---|
| | ***May 4, 5 2020*** | |

**Compare <u>reliability</u> of cases. What was the *actual* ramping need, and was one case more reliable?**



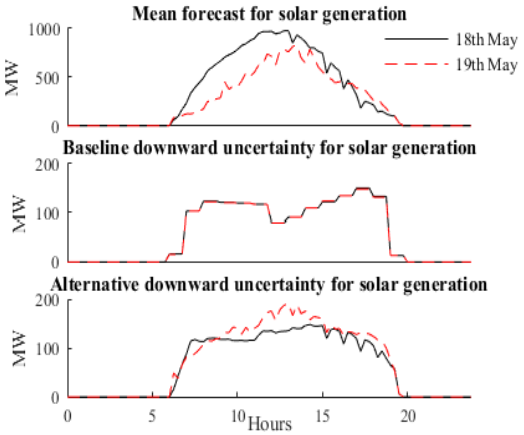
| Reliability might improve under alternative method | Reliability might deteriorate under alternative method | Similar reliability |
|---|---|---|
| ***May 19, 20 2020*** | | |

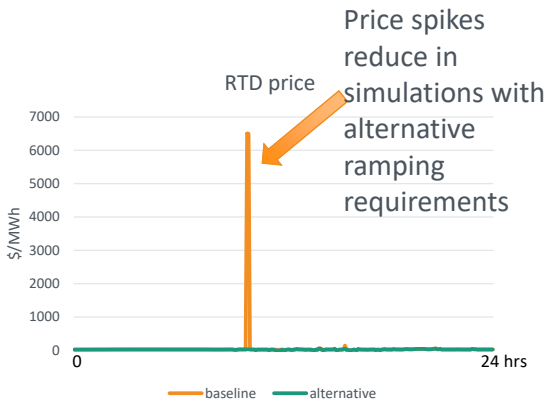


*E. Spyrou et al. What Is the Value of Alternative Methods for Estimating Ramping Needs?, Greentech 2020, IEEE*

## 118-bus results for 19th May: *Reliability improved*

Simulation where alternative (*conditional)* method improves reliability




*(Simulations for 1800 bus system underway)*



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