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Coordinated Ramping Product and Regulation Reserve Procurements in CAISO and MISO using Multi-Scale Probabilistic Solar Power Forecasts (Pro2R)

The Johns Hopkins University
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Solar Forecasting 2 Annual Review & Workshop
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Pro2R Project Team

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- Blagoy Borissov, Stephen Rose (Midcontinent ISO)

Pro2R Project Summary

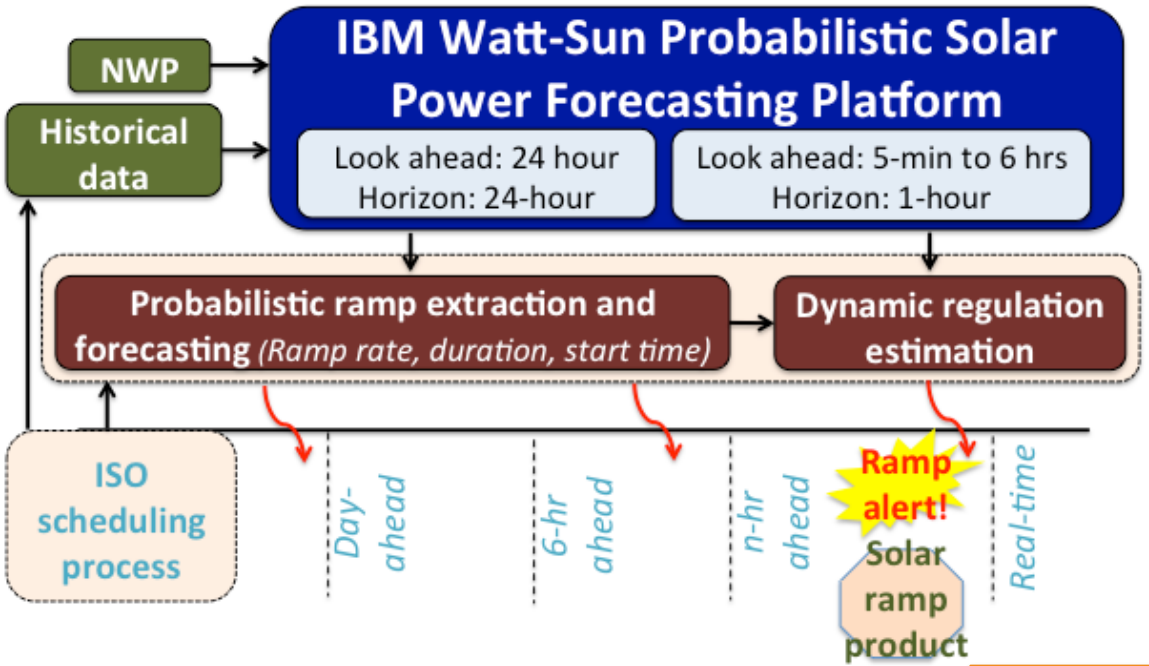
Objective: Integrate probabilistic short- (2-3 hr ahead) and mid-term (day-ahead) solar power forecasts into operations of CAISO & MISO

Approach:

Thrust 1: **Advanced big data-driven "probabilistic" solar power forecasting technology using** IBM Watt-Sun & PAIRS (Big data information processing and machine learning approaches to blend outputs from multiple models).

Thrust 2: **Integrate probabilistic forecasts** in ISO operations for *ramp product* & *regulation* requirements

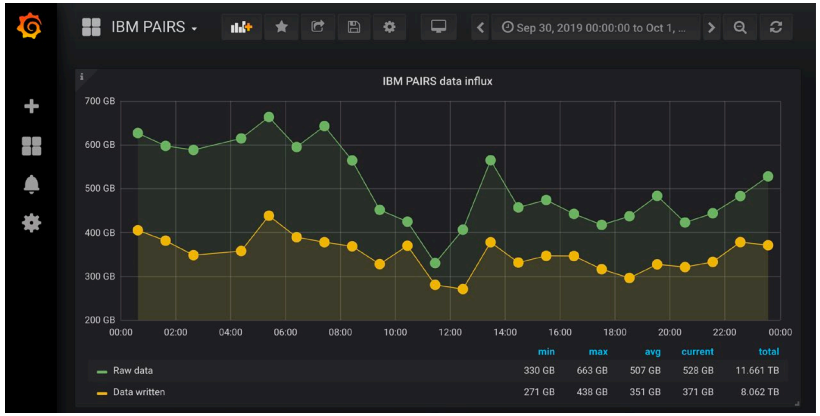
Thrust 3: Provide **situational awareness via visualizations** of probabilistic ramp forecasts & alerts

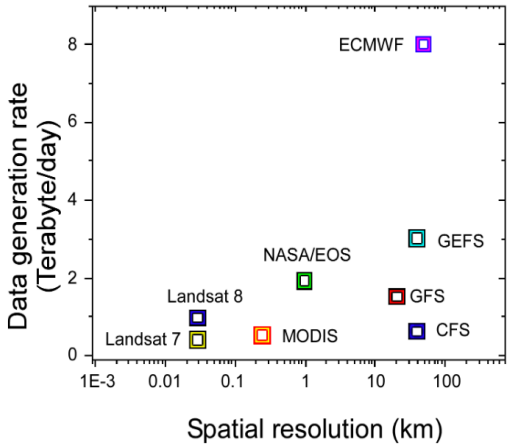


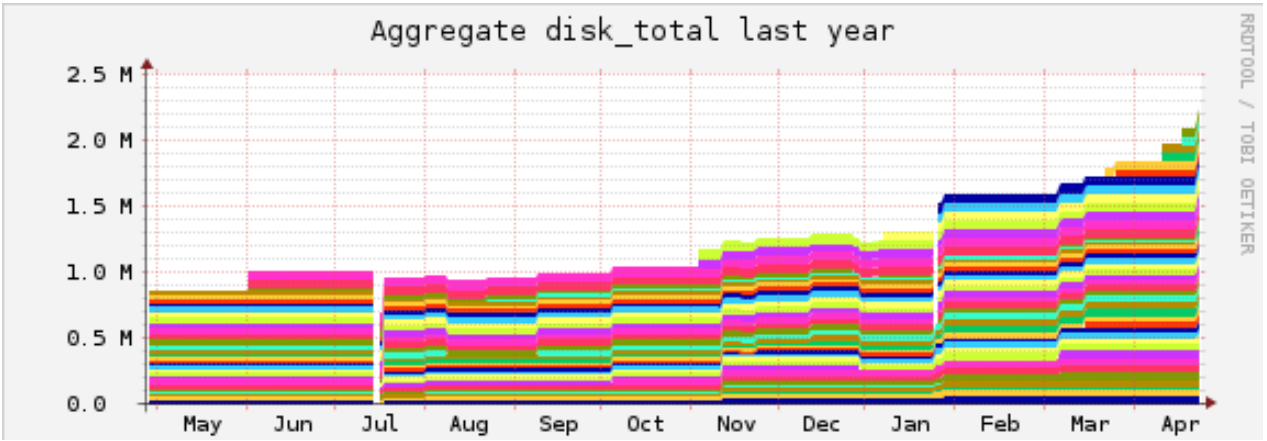
Thrust 1: SFII Built Upon IBM PAIRS Geoscope Platform

- Distributed computational system
- Scales to many hundreds of Petabytes (PB)
- Data processing rate at PB/day.

	NAM	HRRR-Subhour	GOES-R
spatial resolution	12 km	3 km	500 m
temporal resolution	1 hr	15 min	5~10 min
daily data volume	9.4 GB	86 GB	203 GB

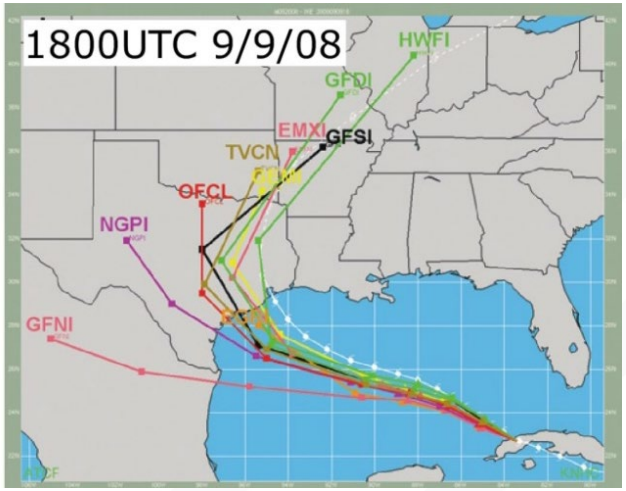






Situation-Dependent Model Blending for Solar Forecasting

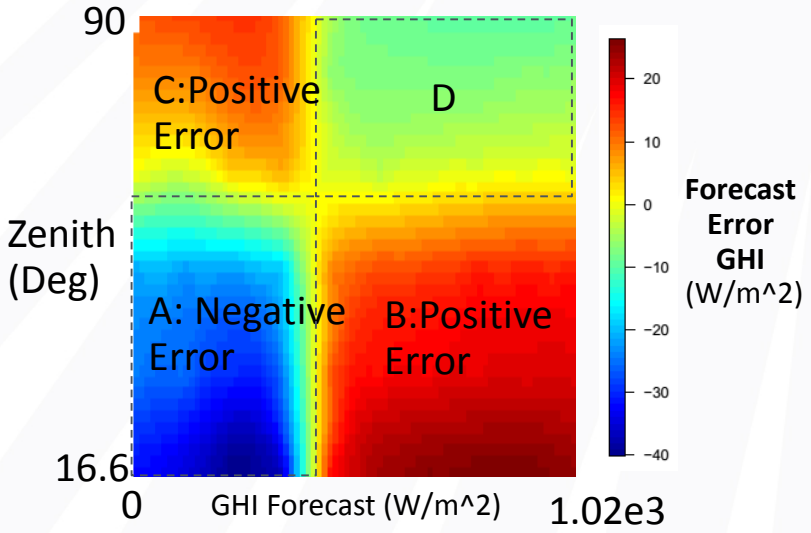
Hurricane Ike path forecasts from 8 different weather models*



Question: What is the error of the models, when, where, under what weather situation?

NAM GHI Forecast Error (Surfrad BND)

– Strongly depends on zenith angle and forecast irradiance. The two parameters create 4 categories of situations:

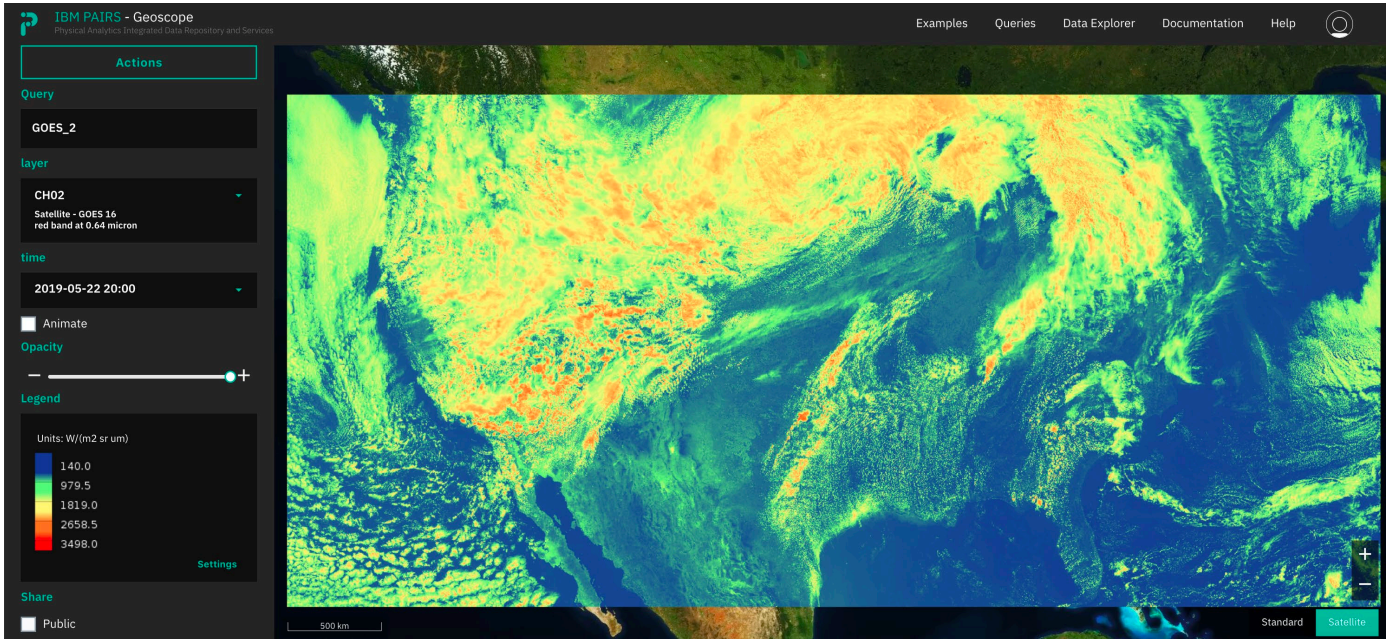


Utilization of GOES-R Satellites – In progress– Expected in Watt-Sun 2.0, 2019-20 Q7

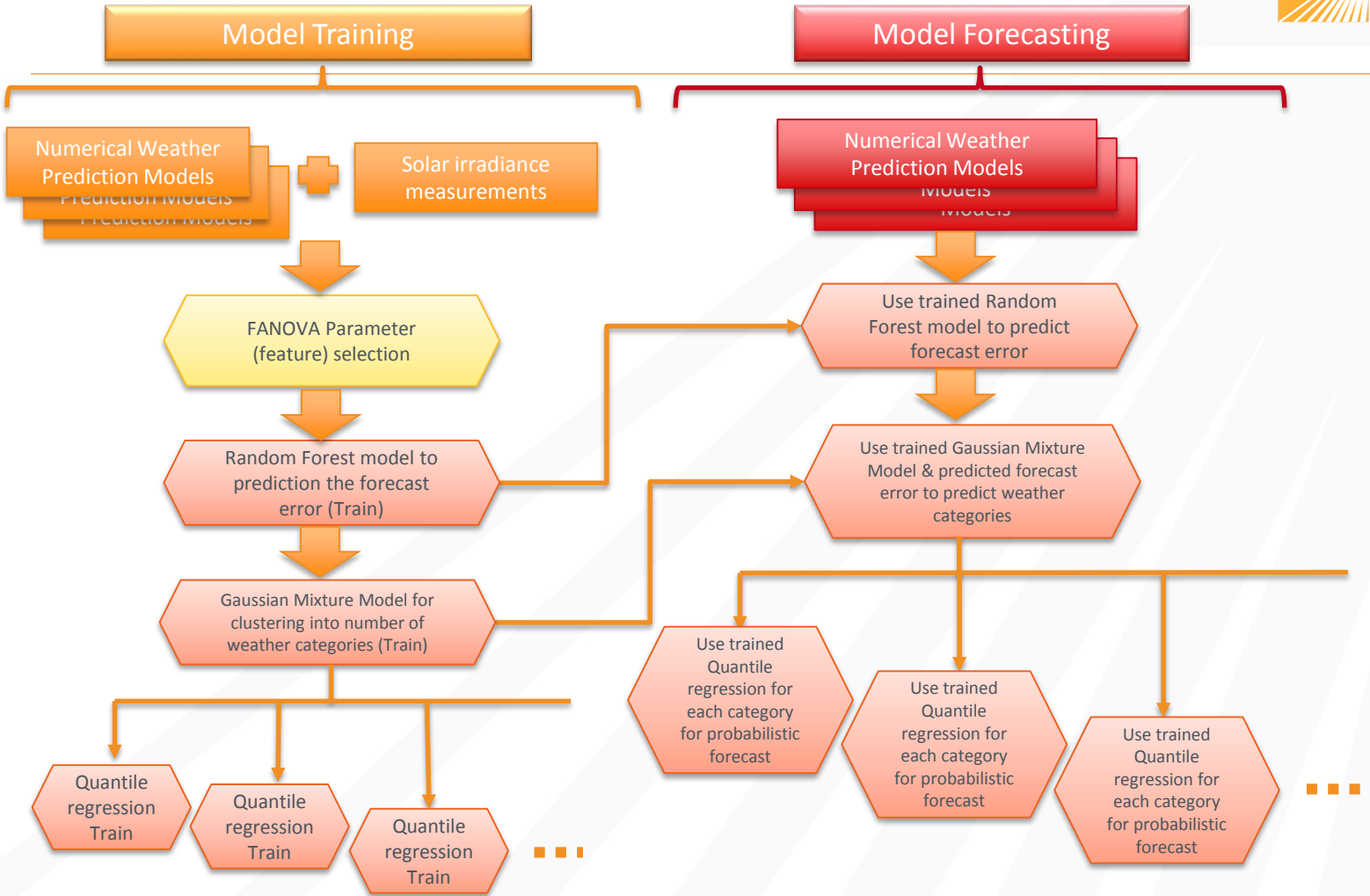
- **Blue band, 0.47 µm:** *monitor dust, haze, smoke and clouds*
- **Red band, 0.6 µm:** *detect fog, estimate solar insolation, depict diurnal aspects of clouds*
- **Near-infrared, 0.86 µm:** *detect daytime clouds, fog, and aerosols; calculate normalized difference vegetation index*
- **Infrared, 10.3 µm:** *correct atmospheric moisture, estimate cloud particle size, characterize surface properties*

Plan:

- Translate GOES imagery to Solar Irradiance raster map
- Use Deep Learning combined with Optic Flow to forecast cloud movement, then translate into forecast solar irradiance map.

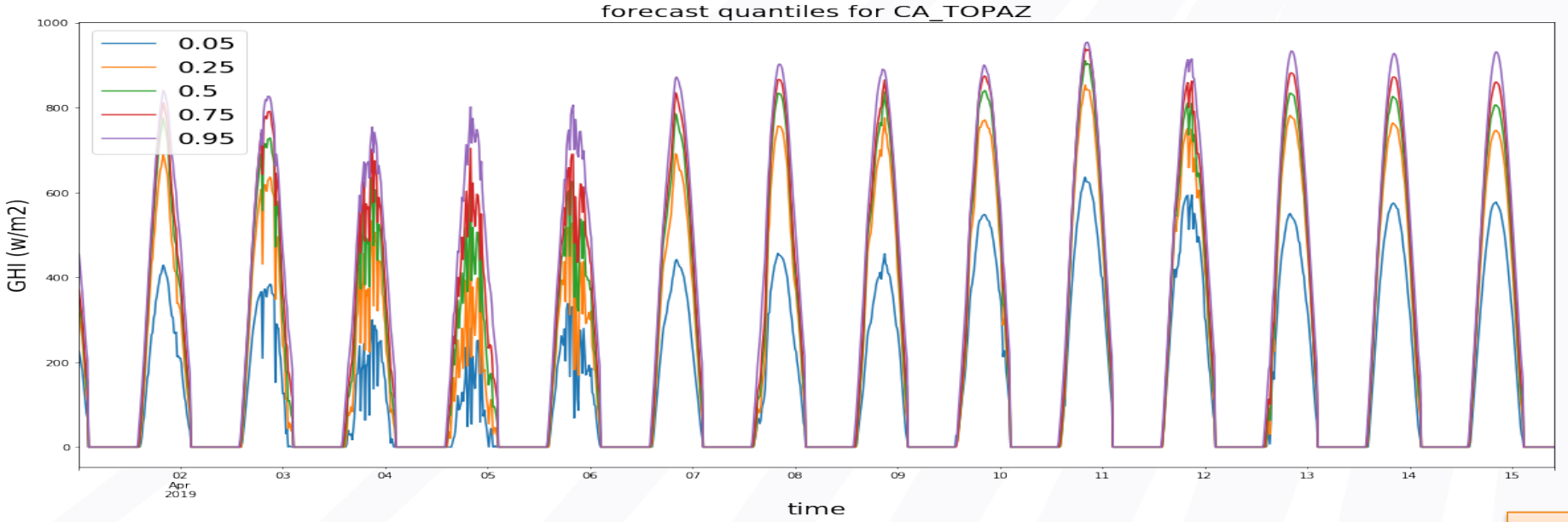


Overall Flowchart



Used quantile regression to deploy probabilistic forecast models

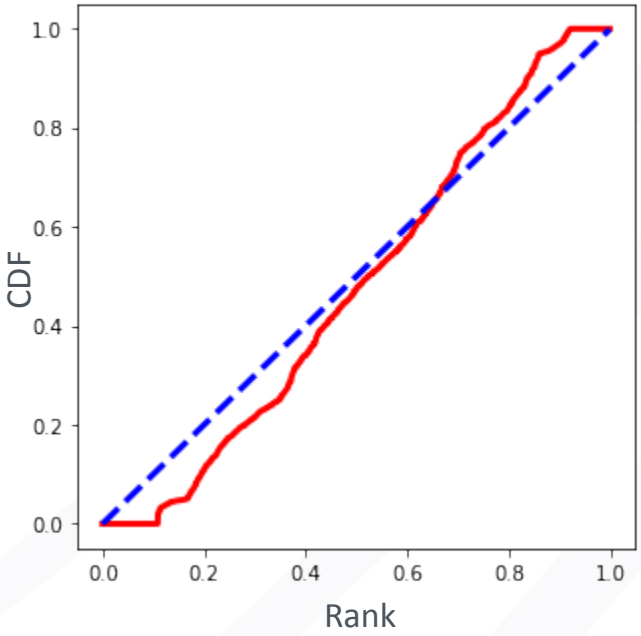
- Quantiles of solar as function of independent variables
- Example results for 2 hr-ahead forecasts
  - Distributions are asymmetric → *need quantile regression techniques*
  - Adjacent days have different distributions; but present CAISO flexiramp requirements are very stable day-to-day because they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



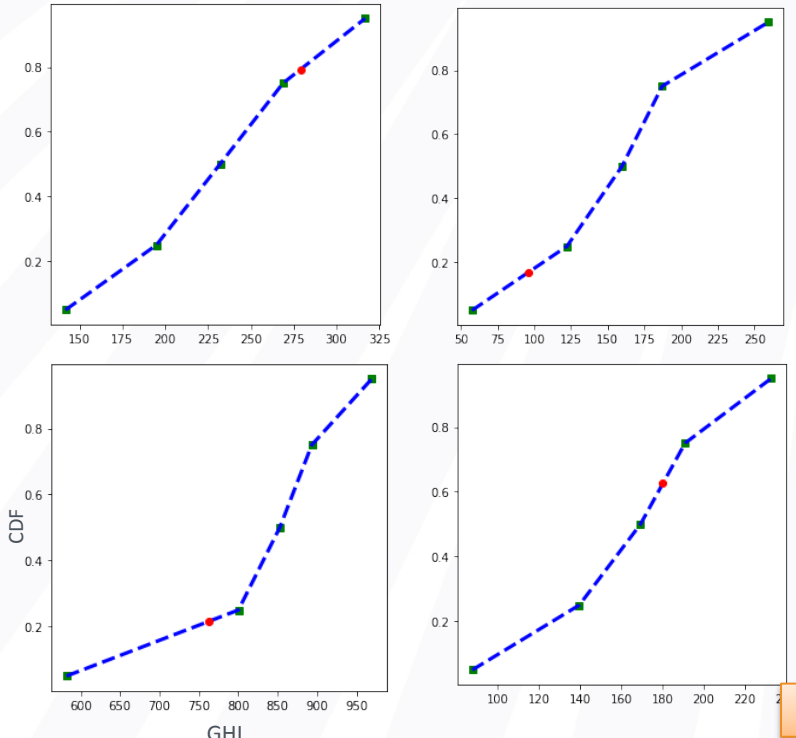
P-P plot-based Error Metric

- A **P–P plot** (**probability–probability plot**) assesses how **closely two data sets agree**
- By plotting the two cumulative distribution functions against each other

P-P plot (2 hr forecast)
Mean absolute difference: 0.0543

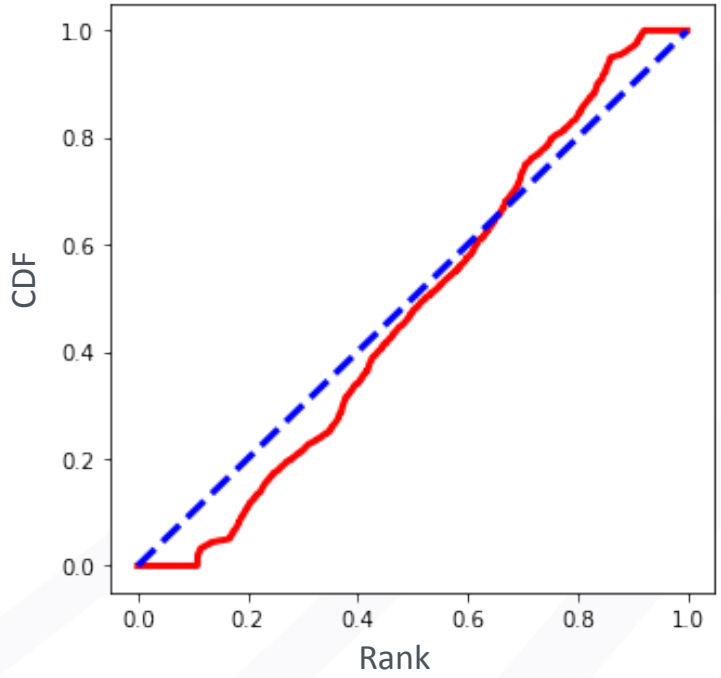


Example Empirical CDF Curves (2 hr forecast)

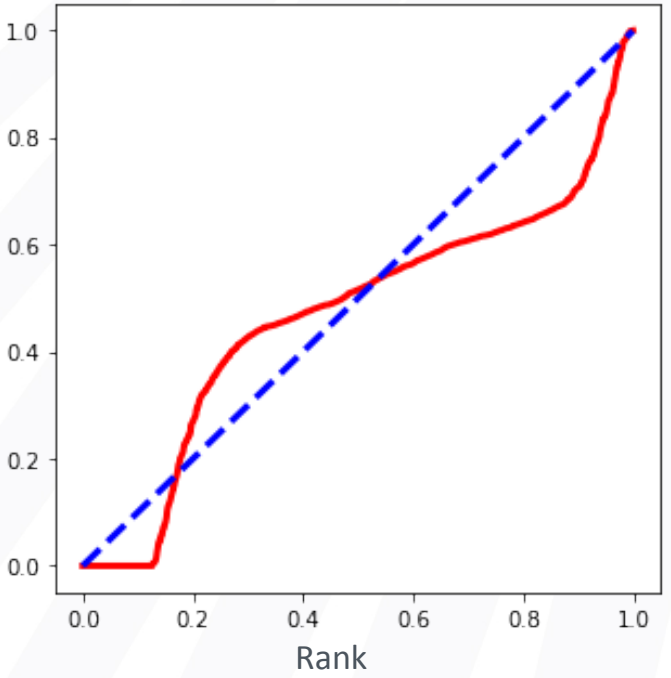


P-P plot 2 Hr Ahead Error Metric: Comparison with Bias Corrected HRRR

Empirical CDF
Mean absolute difference: 0.054

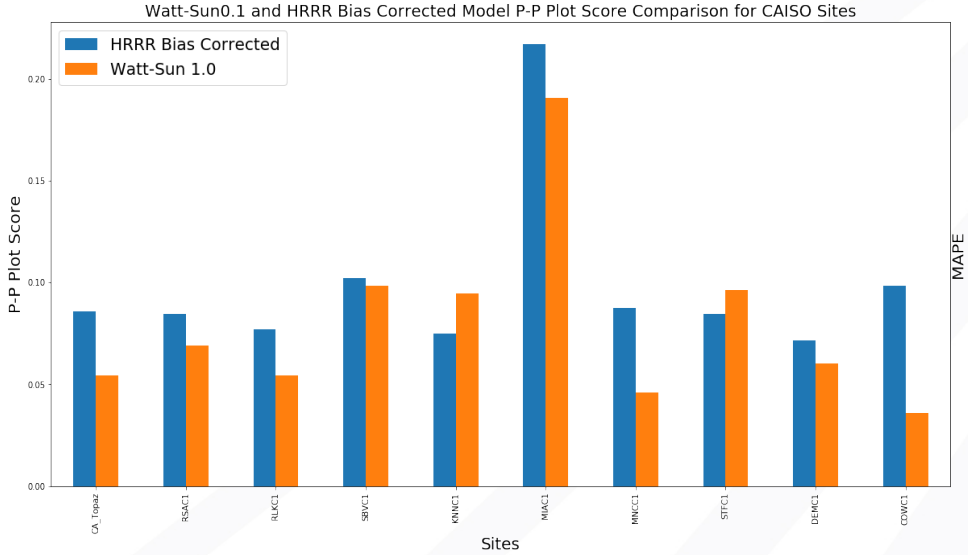


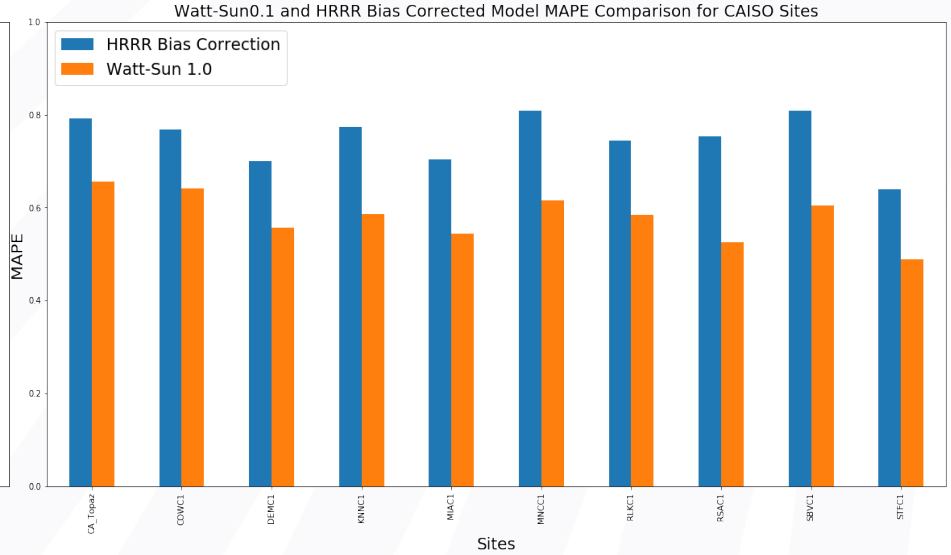
Bias Corrected HRRR (normal distribution)
Mean absolute difference: 0.086



Thrust 1: Forecast Error Report -- CAISO

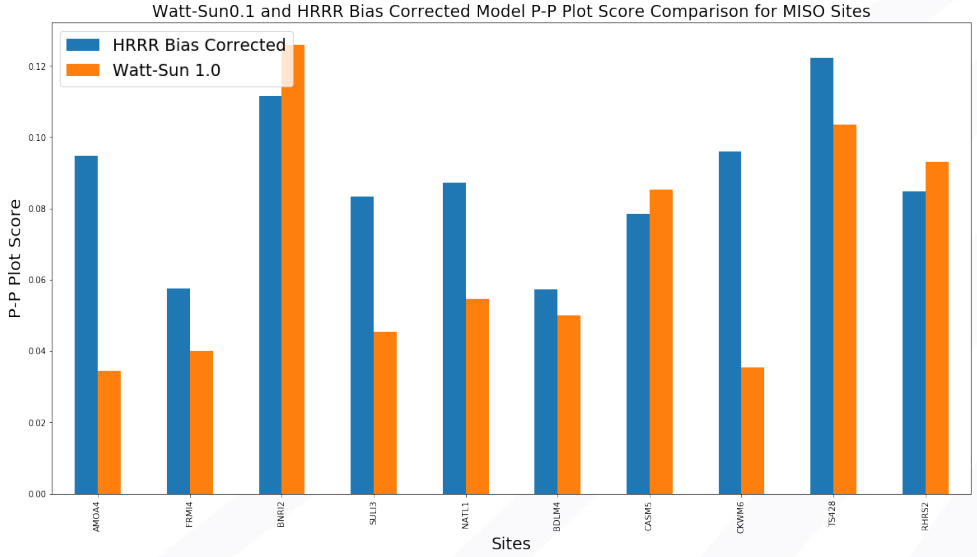
- P-P Plot score and MAPE comparison (normalized by max GHI; daylight hours only)
- Watt-Sun 1.0 outperforms HRRR Bias Corrected in all sites in terms of MAPE, in most sites in terms of P-P Plot score

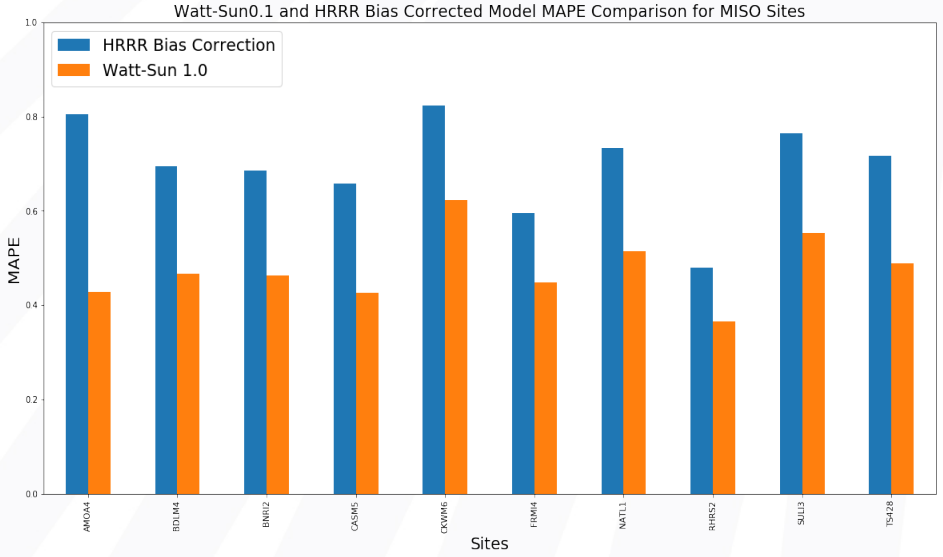




Thrust 1: Forecast Error Report -- MISO

- P-P Plot score and MAPE comparison (normalized by max GHI, daylight hours only)
- Watt-Sun 1.0 outperforms HRRR Bias Corrected in all sites in terms of MAPE, in most sites in terms of P-P Plot score

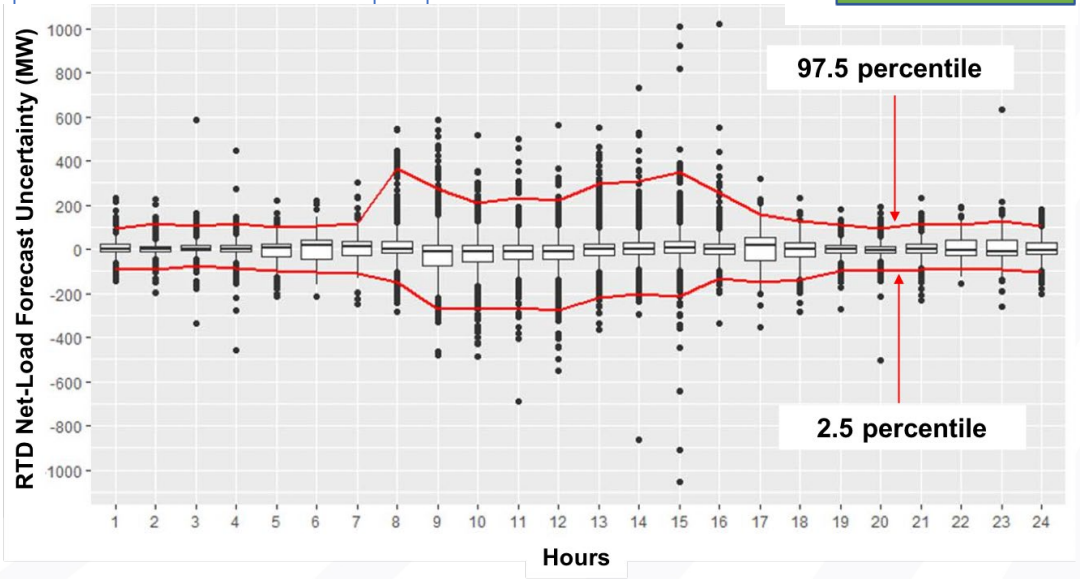


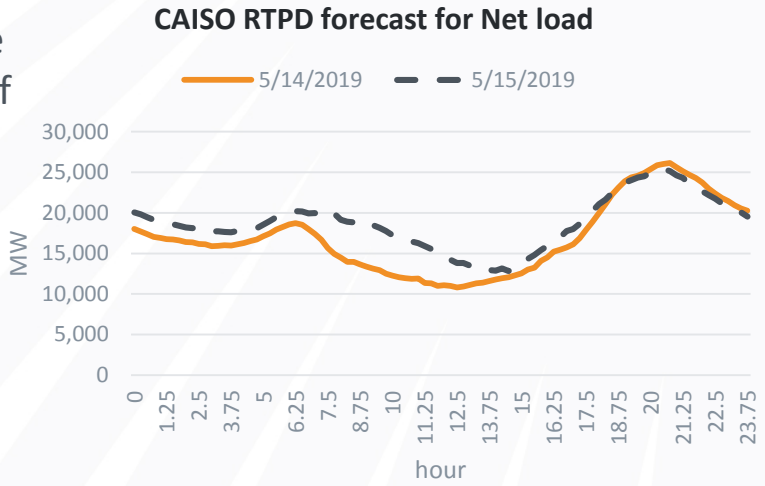


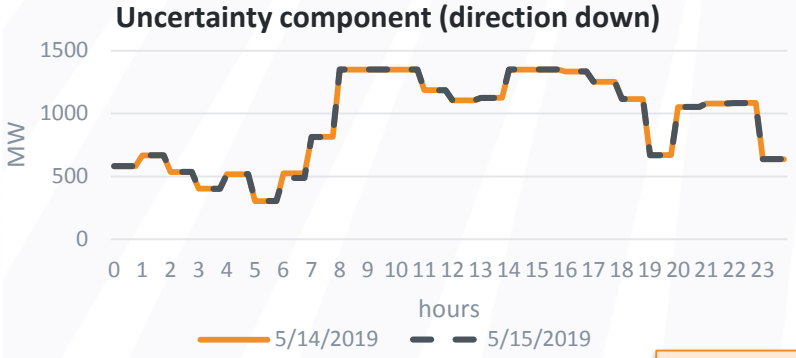
Thrust 2: Integration of probabilistic forecasts into ISO operations: Flexible Ramping Product

Baseline approach CAISO bases FRP requirements on confidence intervals for net load uncertainty by analyzing a rolling window of last 20-40 days for the same hour

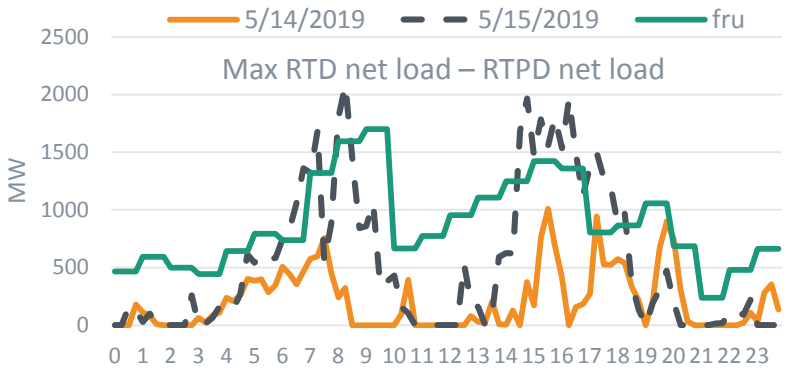
Data of rolling window of 40 days (weekdays) and 20 days (weekends) → Demand Curves Calculation

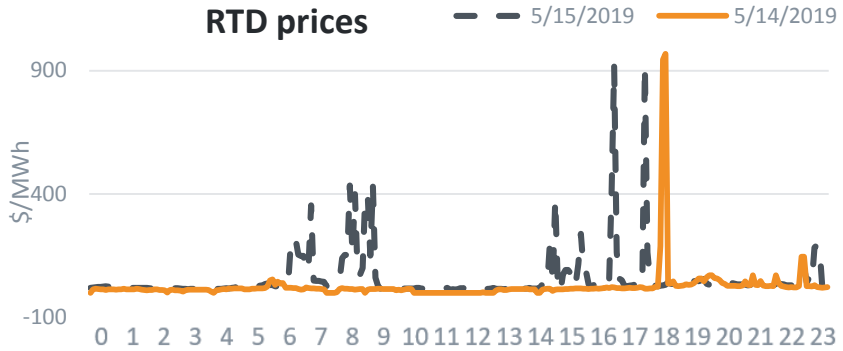




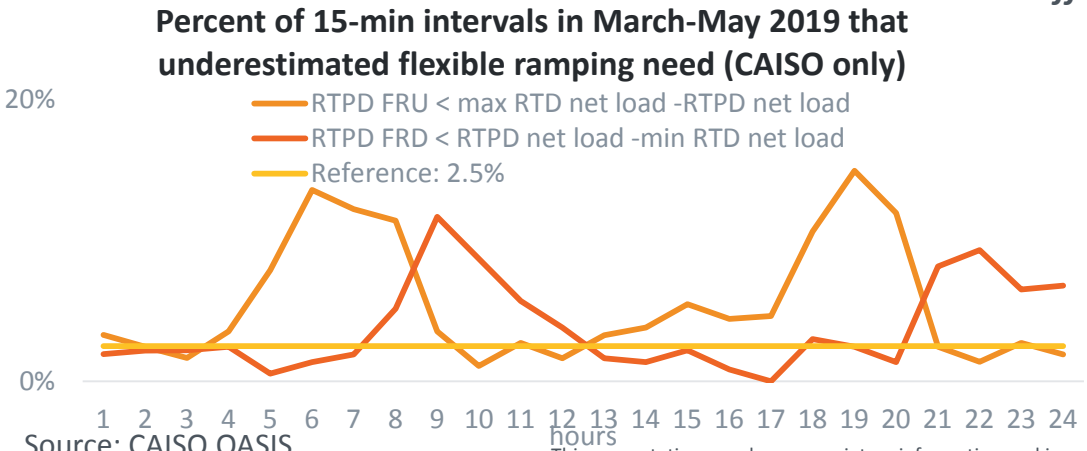


Baseline method for FRU uncertainty component potentially leads to under-procurement & price spikes





Two days had different net load errors between RTPD & RTD
→ different RTD prices



Estimates of FRP uncertainty component do not necessarily correspond to the target confidence interval

Source: CAISO OASIS

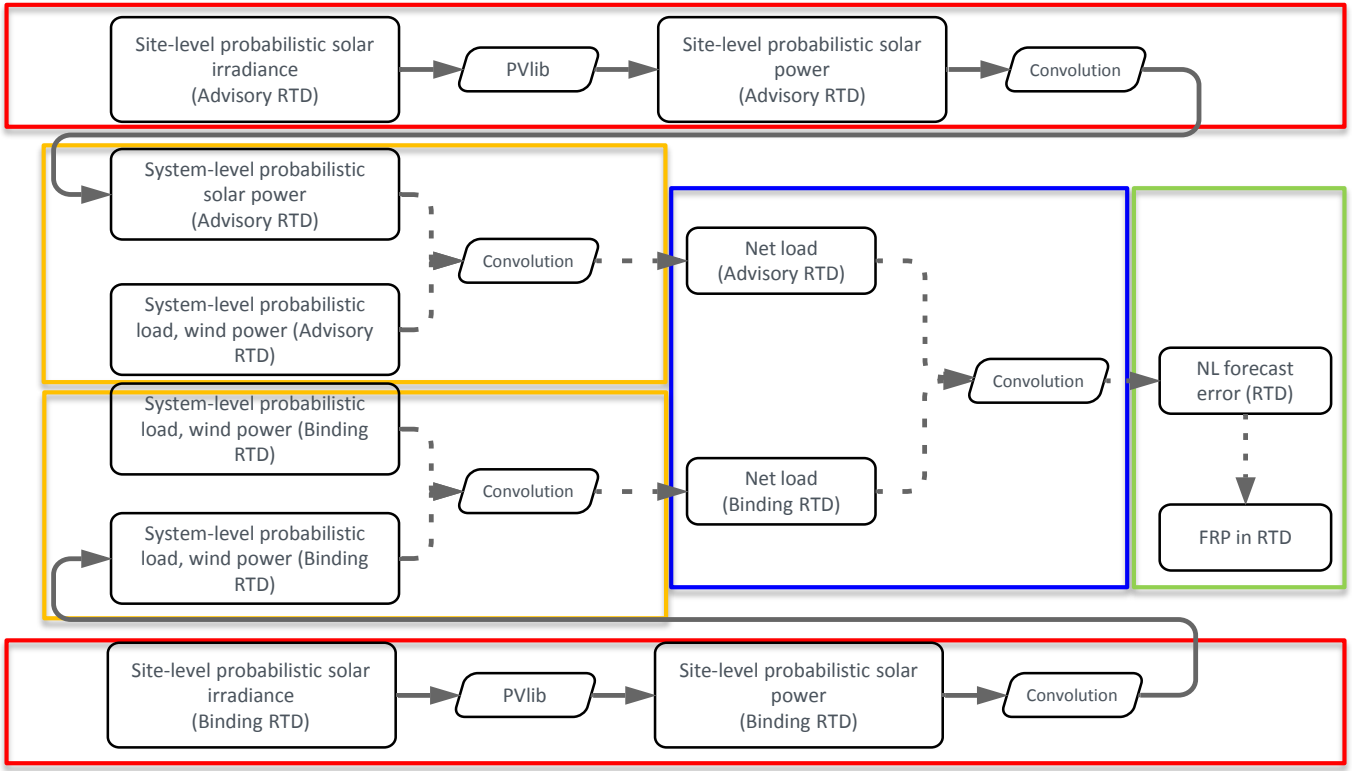
Probabilistic net load forecast-based ramping product

I. Aggregation

II. Net load (NL)

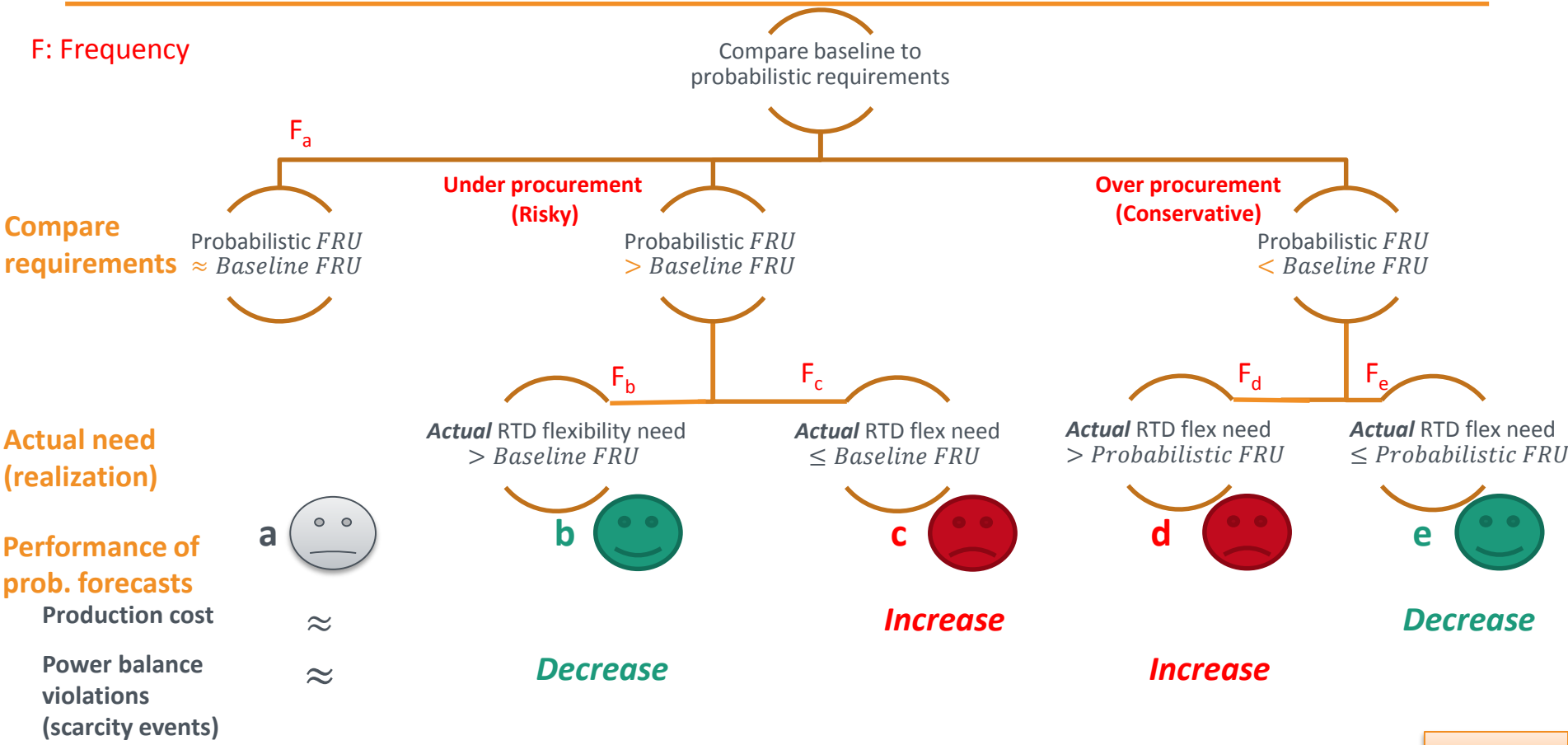
III. NL forecast error

IV. FRP Requirements



Value of probabilistic forecast-based FRP procurement

F: Frequency

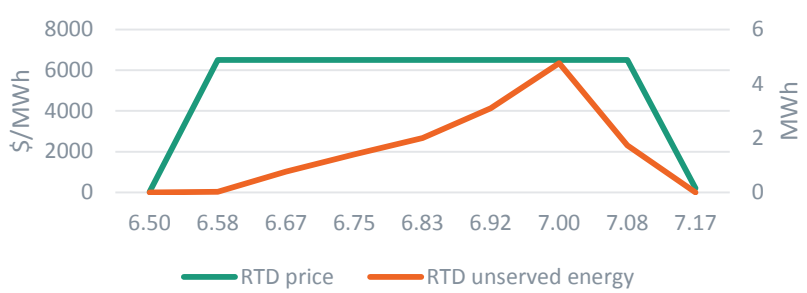


Market simulations: Probabilistic vs. Baseline

Test system: Modified 118 bus IEEE Reliability Test System, mimicking CAISO gen mix (1/10th CAISO system)

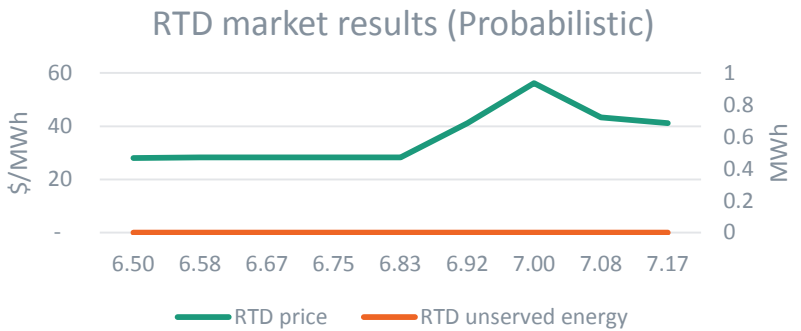
Baseline

Power balance violations during 7 RTD market intervals:



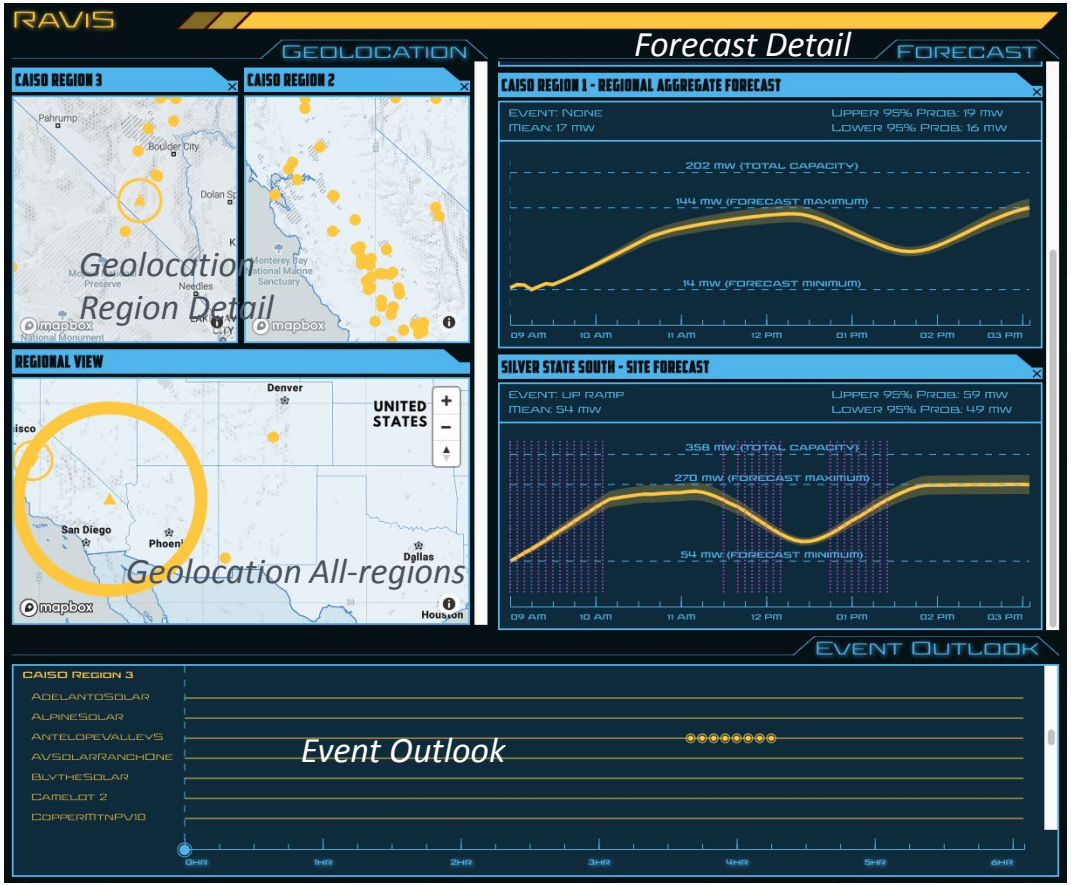
Probabilistic

No power balance violations in RTD market:



- *When baseline is riskier* → we expect reliability benefits when high ramps realized
- *When baseline is conservative* → we expect production cost reductions when ramps not realized

Thrust 3: RaViS - Visualization tool



The **Ramp Visualization for Situational Awareness (RaViS)** tool provides situational awareness and visualization capabilities using probabilistic solar and net-load time series.

Features:

- Integrates IBM forecast data
- Refresh rate of 60 seconds
- User interface: Single page web application and open source
- Shows site specific metadata via hover
- Highly flexible, easily configurable

Future work:

- Net-load ramps
- Adaptable to other kinds of events: outage/trip, cyber threats

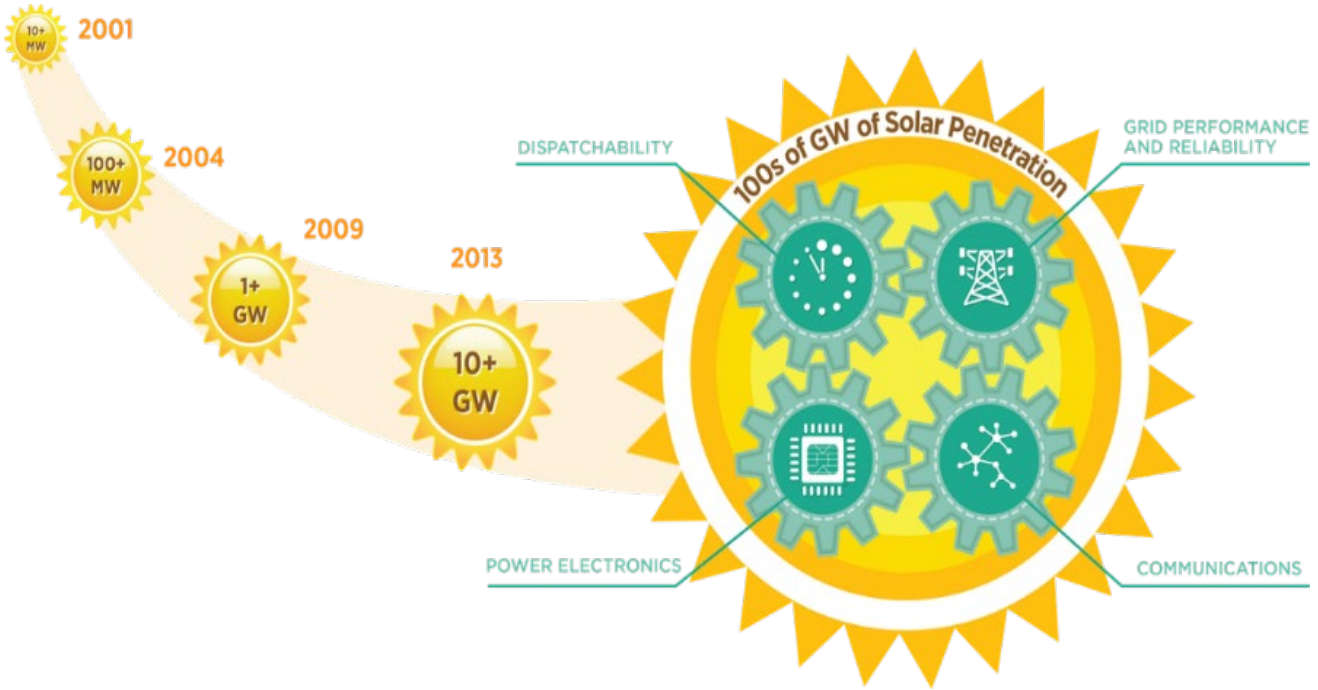
Pro2R: What's Ahead

- ***Thrust 1:*** Probabilistic Watt-Sun Versions 2.0 & 3.0: integrates GEOS-R, multi-expert machine learning, & blended models
- ***Thrust 2:***
  - Statistical/ML modeling of relationship of probabilistic solar forecasts to net load uncertainty on regulation & FRP timescales
  - Simulation-based testing on ISO-scale systems of improved requirements: cost & reliability
  - Interaction with CAISO & MISO on data, method value, simulations, & implementation pathways
- ***Thrust 3:*** RaVIS development, including integrating latest Watt-Sun methods, net load data, market information, and ISO feedback

Wrap-Up: Pro2R Impact

- Identified the major methodological issues in integrating probabilistic forecasts into system products
  - BP2 will address those issues and possible improvements in forecasting and industry practice (e.g., product definition, timeline)
  - Expected outcome: a blueprint for research in forecasting and industry practice
- Project results expected to highly influence industry practice
  - ISO staff confirmed that they are evaluating potential improvements to their existing requirements approach
  - Integrating probabilistic forecasts is the most promising way to address needs for requirements to reflect up-to-date weather forecasts

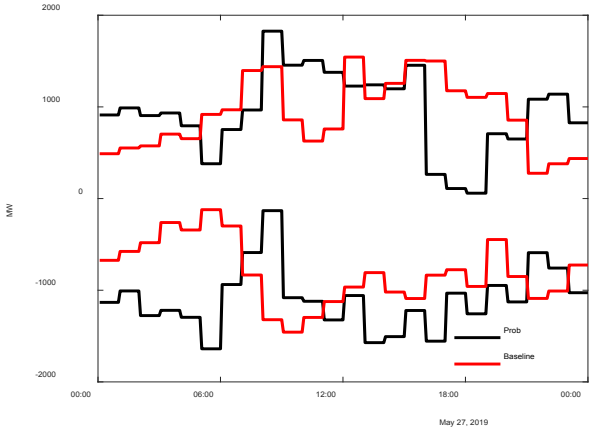
Questions?

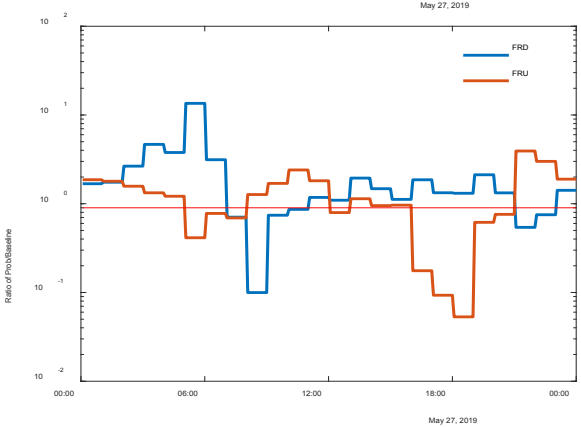


EXTRA SLIDES

Thrust 2.1: Requirements for ramping product

- RTPD
  - Requirements are **increased occasionally** due to greater uncertainties of NL forecast errors
  - 25%-58% of hours see >10% reductions in FRU and FRD requirements





	Percentage of time when reduction is over 10%	
	FRU	FRD
May 27, 2019	38%	25%
May 28, 2019	42%	50%
May 29, 2019	46%	50%
May 30, 2019	58%	38%
May 31, 2019	42%	46%