

Using Probabilistic Solar Forecasts for Operating Reserves Requirements



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AGENDA

1. Improved
Probabilistic
Solar
Forecasts:
Watt-Sun

*Probabilistic
Solar
Forecasts*

2. Link Prob.
Solar Forecasts
to NetLoad
Ramp
Uncertainty, &
ACE*

*Ramp Product,
regulation
Requirements*

3. Western
US Market
Simulation:
FESTIV

*Cost Savings &
Reliability
Improvements*



JHU, IBM, UTD-Dallas, NREL

Watt-sun: Solar Forecasting I & II

Funded by:



(Courtesy H. Hamann, IBM)

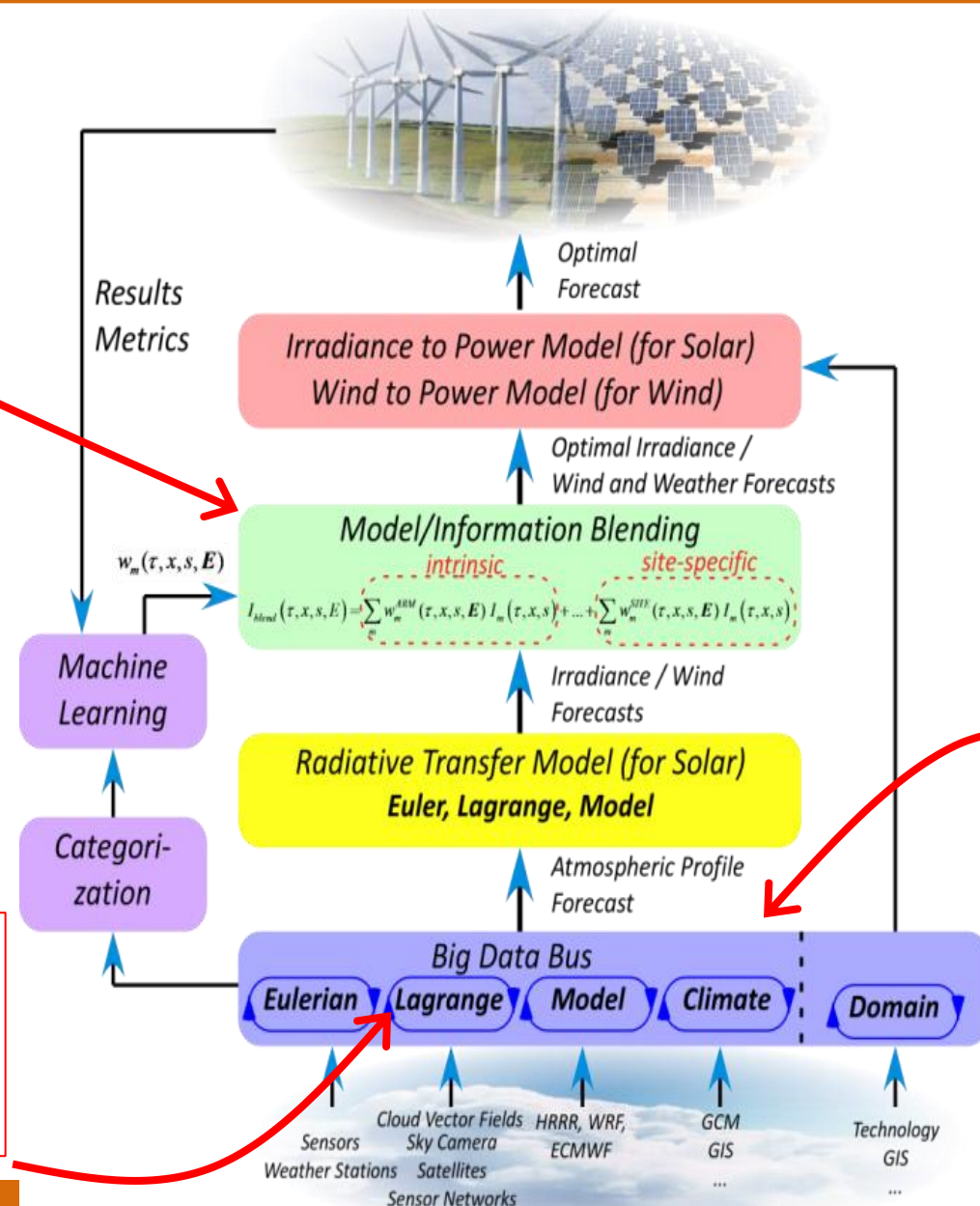
3. Probabilistic forecasts

2. Fully implemented Navier-Stokes enhanced optical flow-based cloud forecasts, using GOES data

SF II enhancements:

1. Replacement with PAIRS (Physical Analytics Integrated Data Repository and Services)

- Automatic data fusion
- Non-relational/key-value store → Fully scalable
- Supports tens of PBs
- Improved curation speed (10's TB/d)



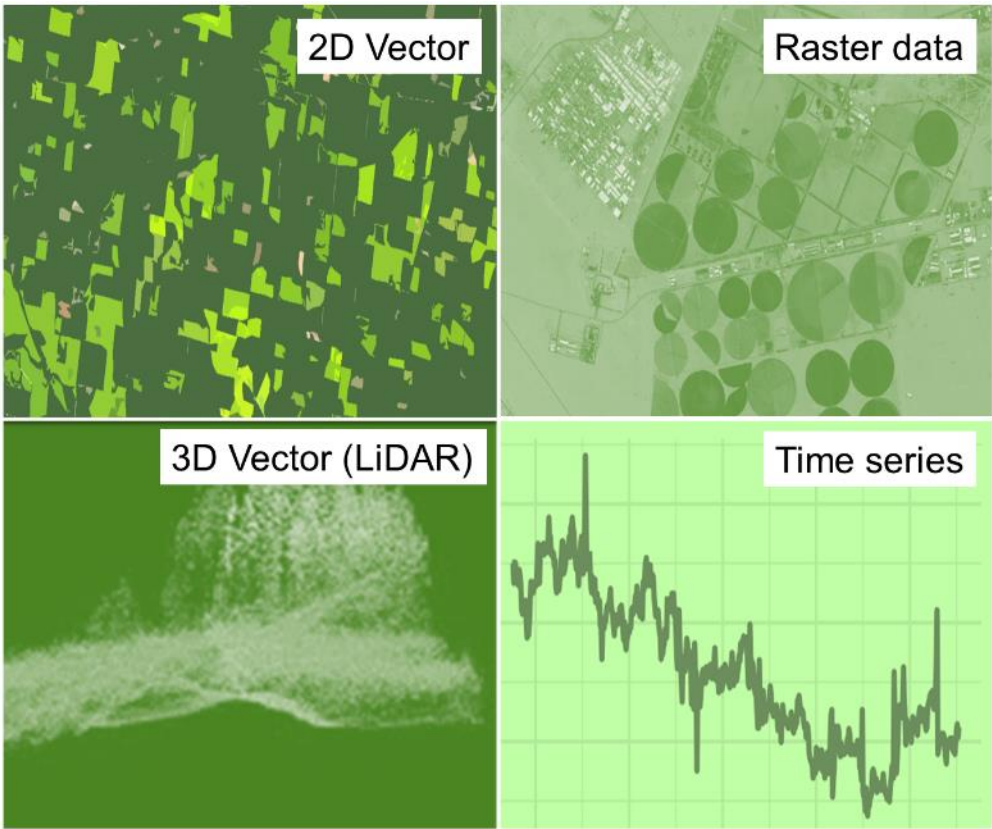
Watt-sun enhancement 1 of 3: Implementation of a big data platform for scalable processing

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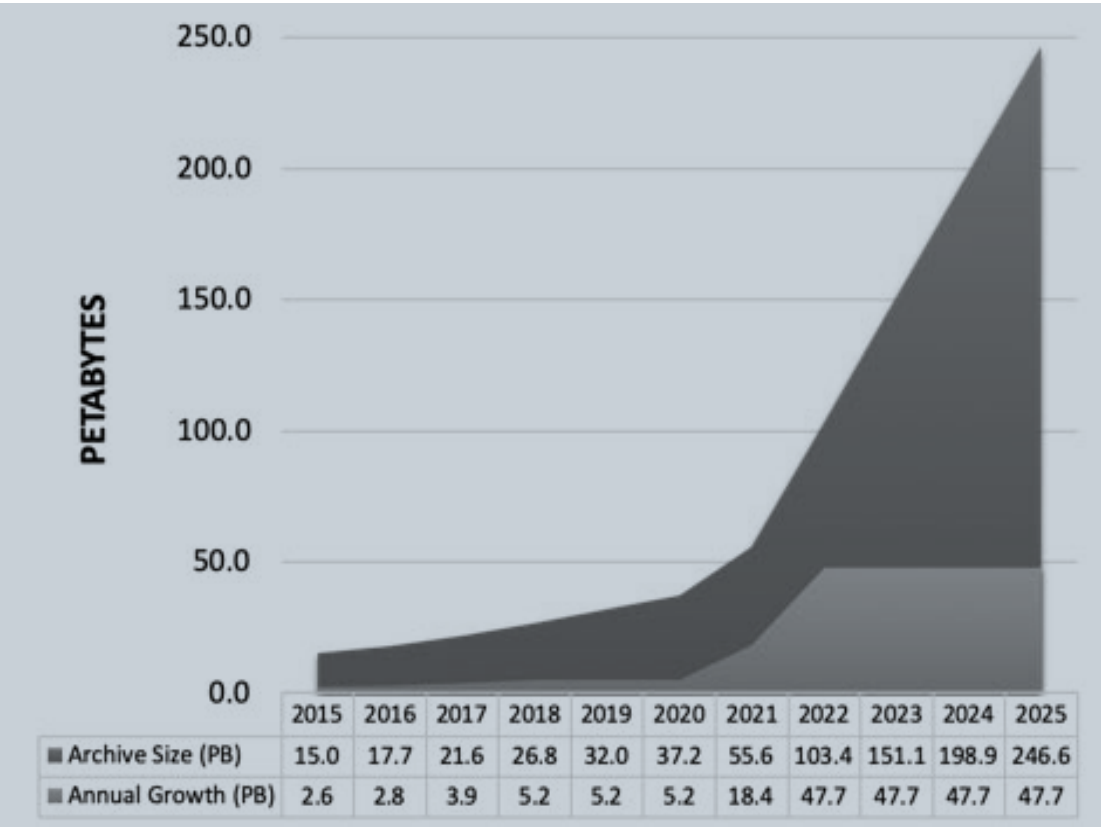
Technical challenges include:

(Courtesy H. Hamann, IBM)

1 Complexity



2 Data gravity

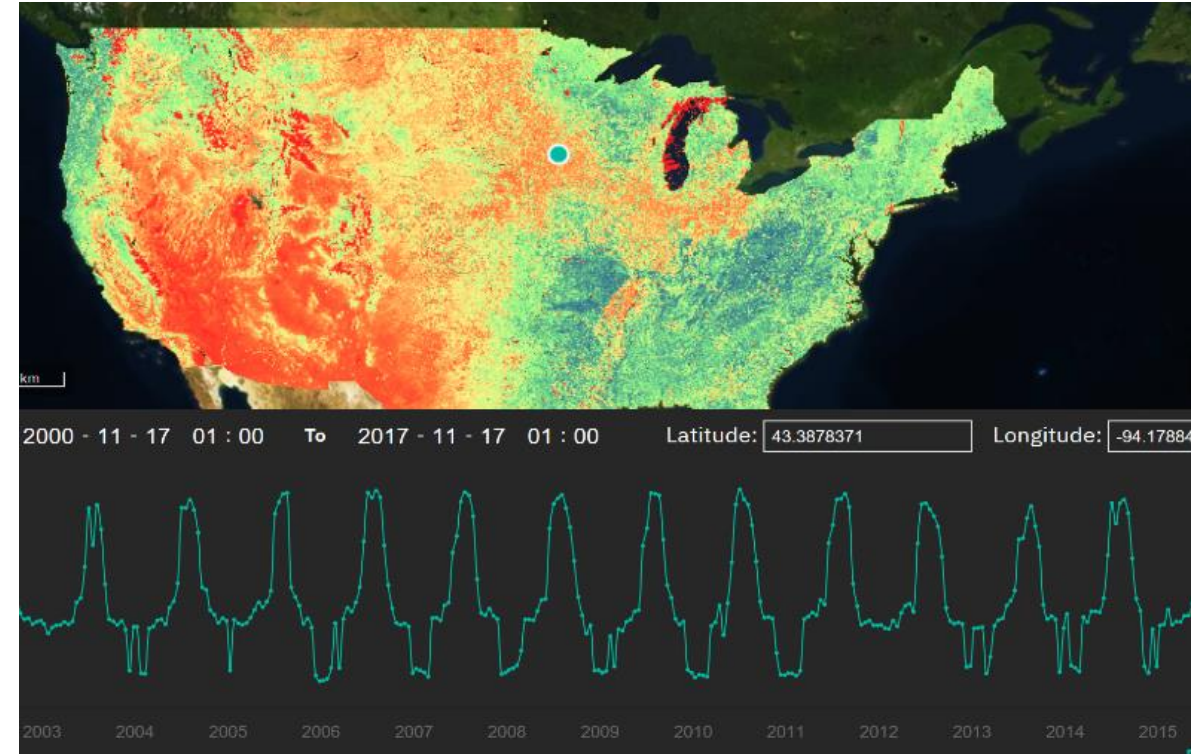
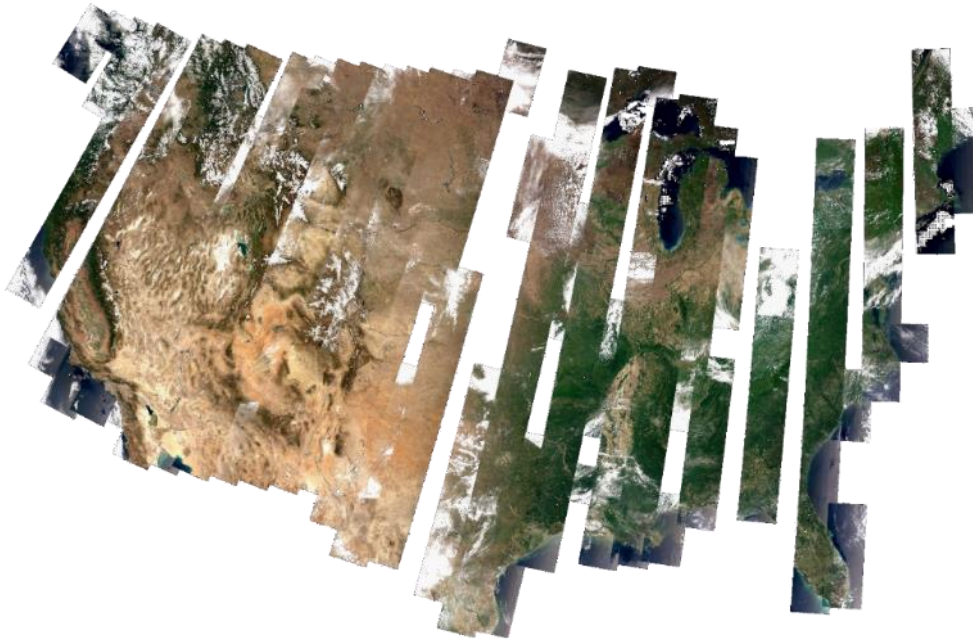


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Technical challenges include:

(Courtesy H. Hamann, IBM)

3 Information indexing

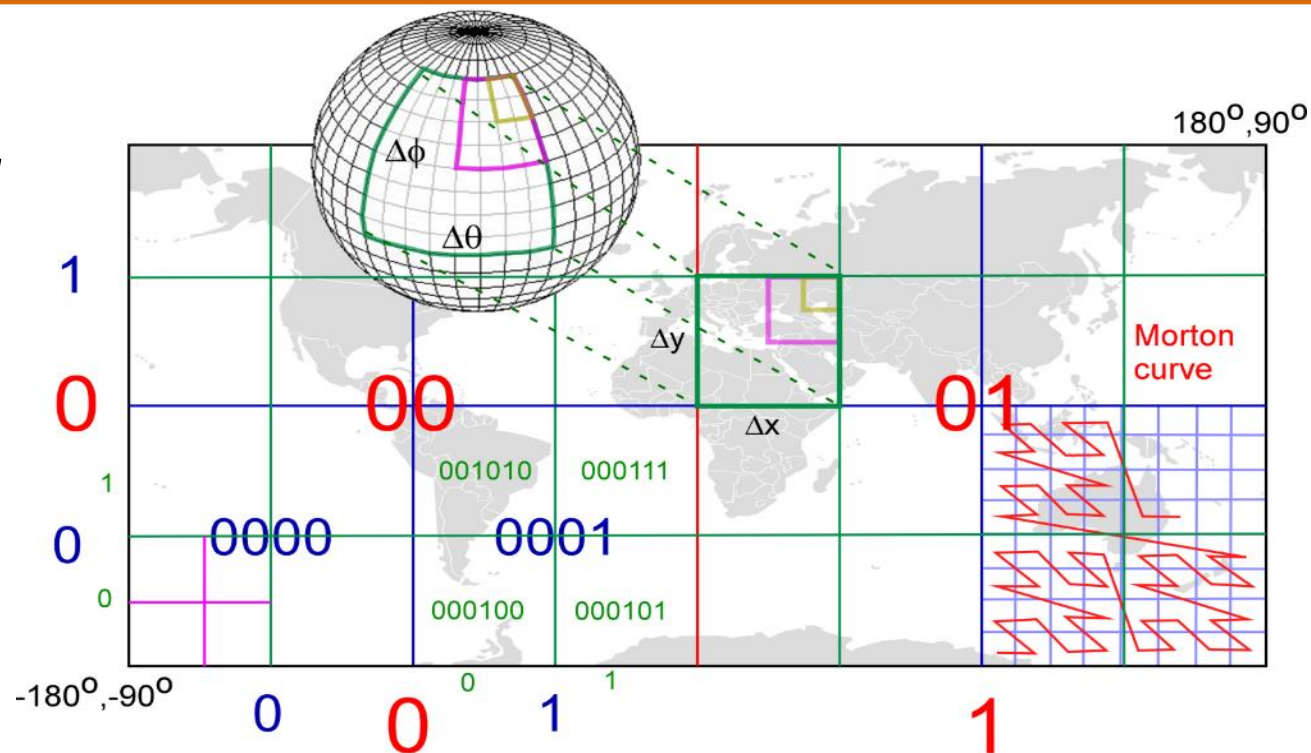


Many queries/workloads will require opening thousands of files

PAIRS: A scalable geospatial key-value store

A nested global spatial & temporal reference system

(Courtesy H. Hamann, IBM)



- All resolution layers are nested
 - Morton curves map 2D data to 1D while preserving locality of the data points
- Data at the same location and time “start” with the same key

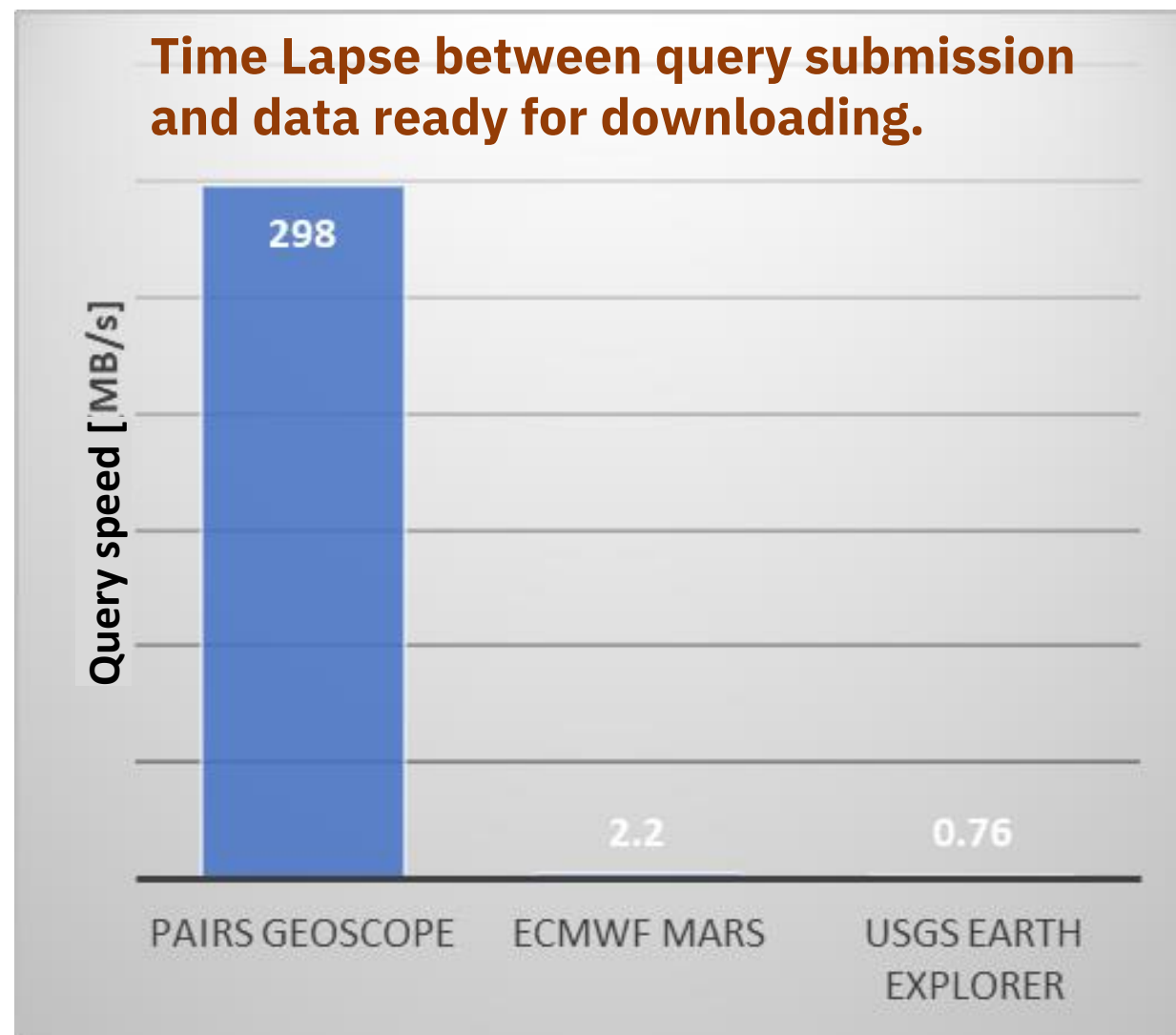
(S. Lu et al., IBM PAIRS: Curated big data service for accelerated geospatial data analytics and discovery, IEEE Intl. Conf. Big Data 2016).

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Geospatial-temporal data access (150x faster)

(Courtesy H. Hamann, IBM)

- Test: Access 1.6 GB of geopotential data (6 pressure levels, 4 forecast times)
- Also: 1-3 Orders of magnitude speed up in regression & time series analyses

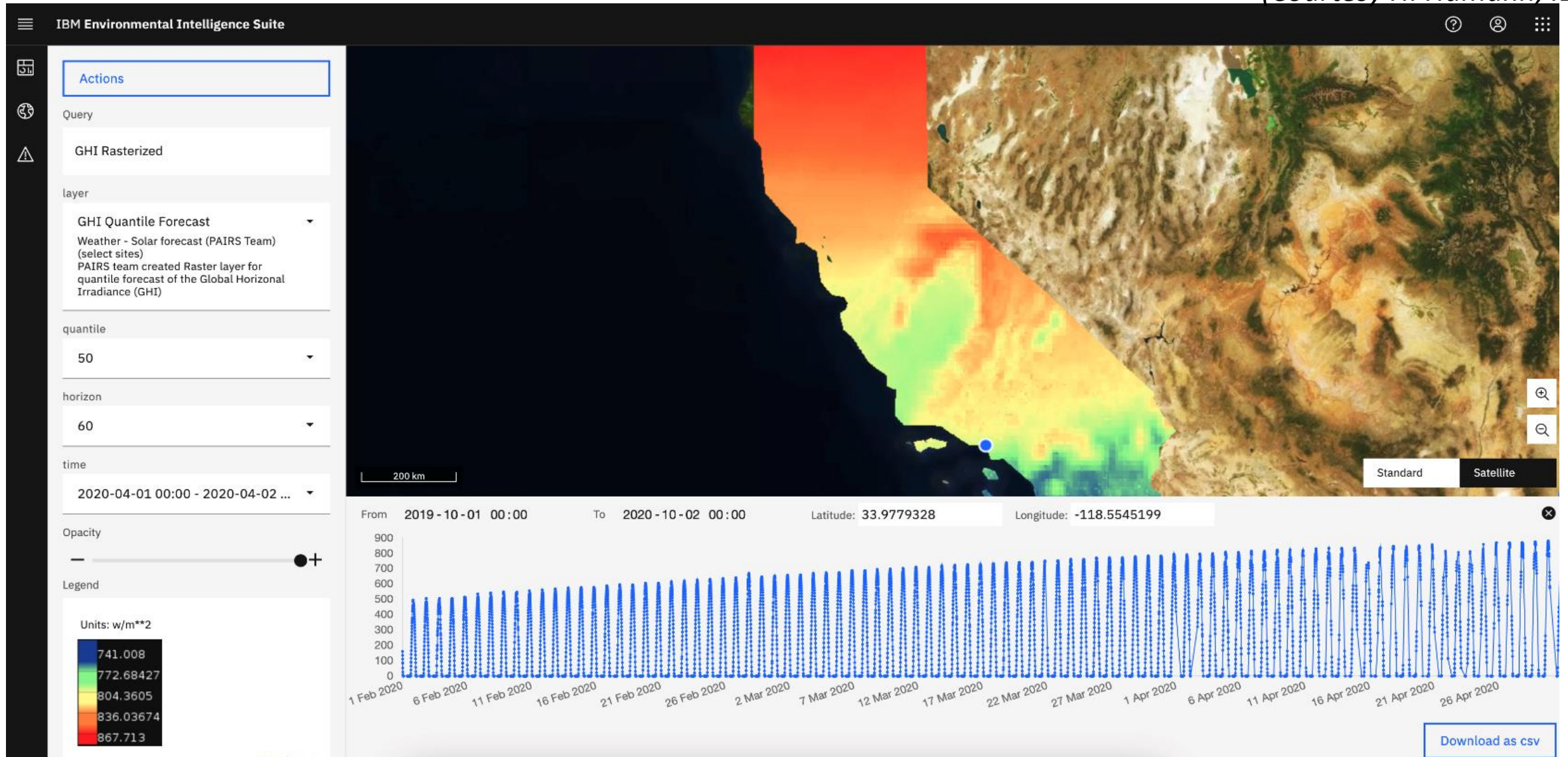


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Watt-sun enhancement 2 (of 3): Rasterized gridded probabilistic forecasts

Sample Outputs of Rasterized Probabilistic Forecasts

(Courtesy H. Hamann, IBM)

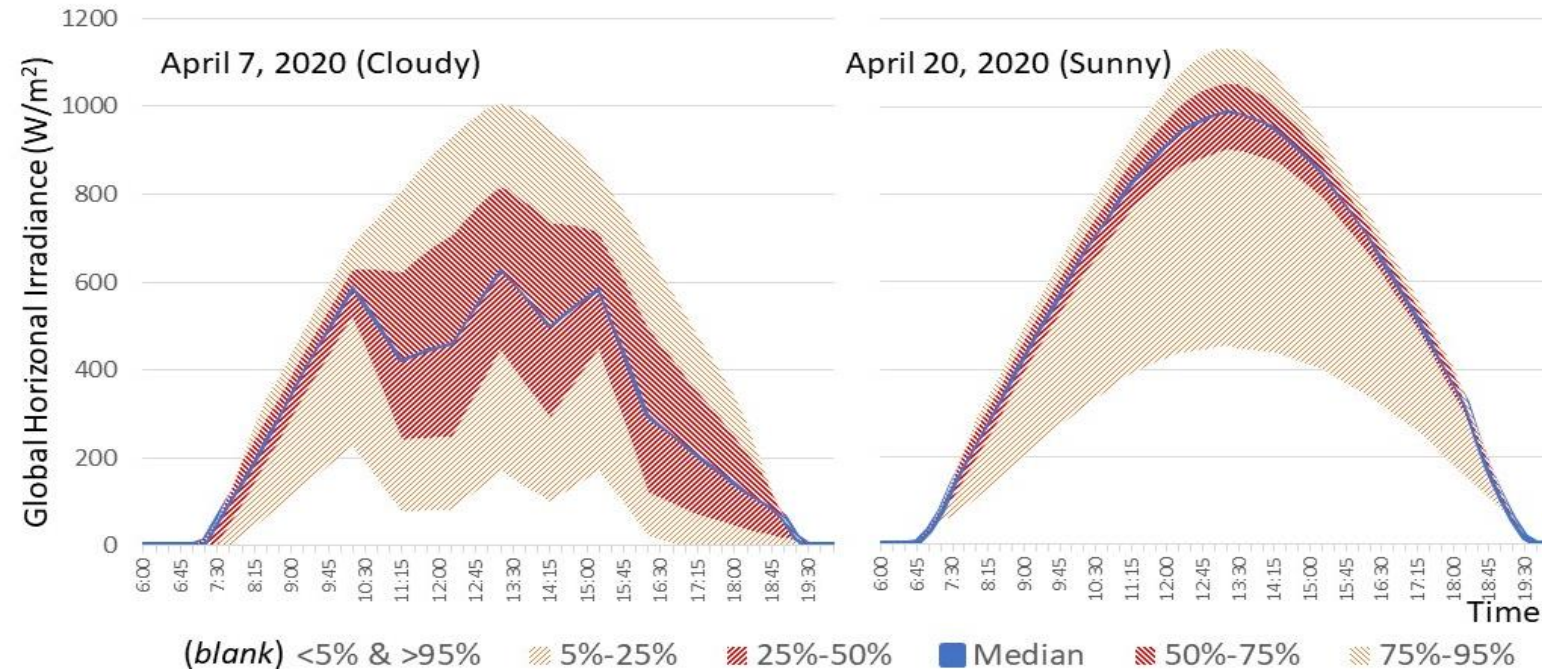


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Watt-sun enhancement 3 (of 3): Watt-sun evolution

Probabilistic Watt-Sun Flowchart (IBM)

- Quantiles of solar as function of independent variables
- Example results for 2-hr-ahead forecasts



P-P metric found better calibration performance than baseline at 79% of 24 MISO & CAISO sites tested

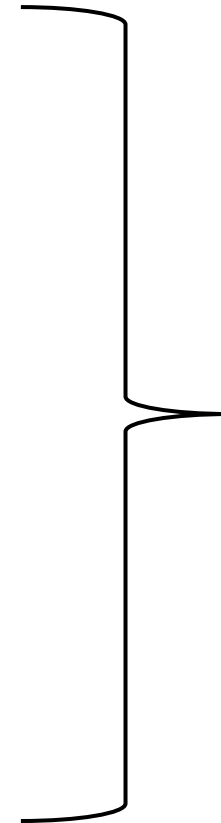
- *Compared to persistence estimator augmented with empirical error distribution*

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Future of renewable energy forecasting from IBM's point of view

(Courtesy H. Hamann, IBM)

- **Technology**
 - More data, new data
 - New architectures, forms of indexing
 - Special purpose AI
- **Business**
 - Vendor consolidation
 - Cross-industry for cost-effectiveness
- **Decision support**
 - Much closer integration with Decisions
 - Especially, alignment with needed:
 - spatial scales, and
 - update rates/lead times/horizons



Next generation information
architectures for future
energy systems

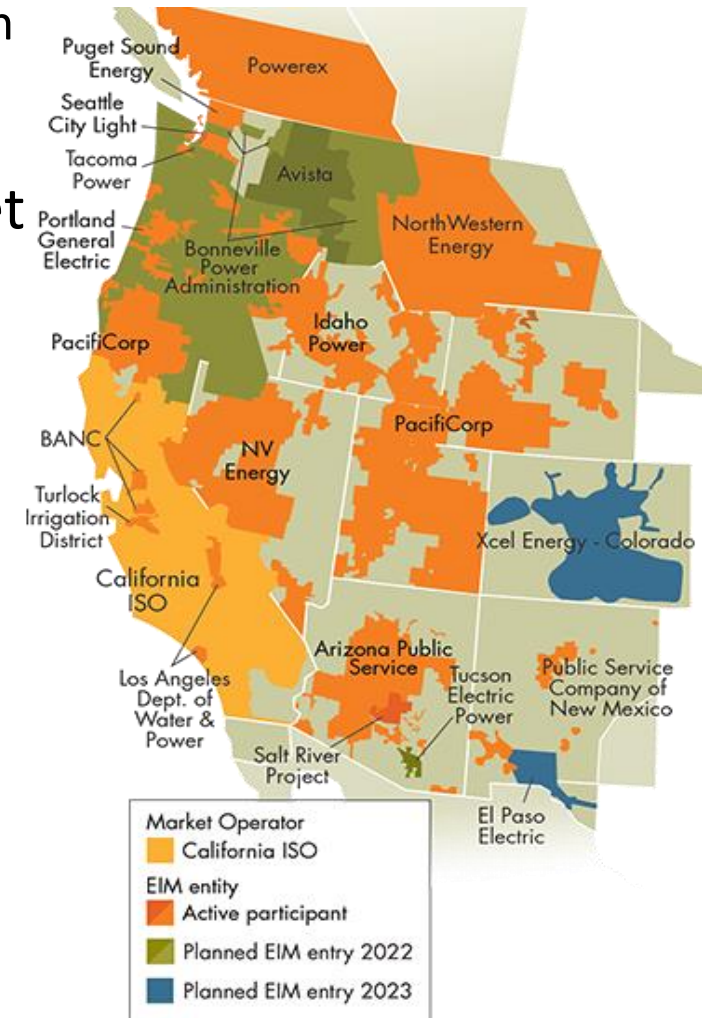


2. Linking Reserve Requirements to Probabilistic Solar Forecasts

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2.1 Weather-Aware **Flexible Ramping Product** Procurement

- Main goal of Flexible Ramp Product (**FRP**) (CAISO, MISO, SPP):
 - To pre-position resources to meet unexpected net load ramps up or down
- CAISO implemented in 2016, throughout “EIM” real-time market
 - Cover ramp uncertainty in:
 - up direction (97.5th percentile)
 - down direction (2.5th percentile)
 - CAISO:
 - Interested in making it conditional on weather
 - Plans to extend to day-ahead: “Imbalance reserve”



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Day Type Categorization

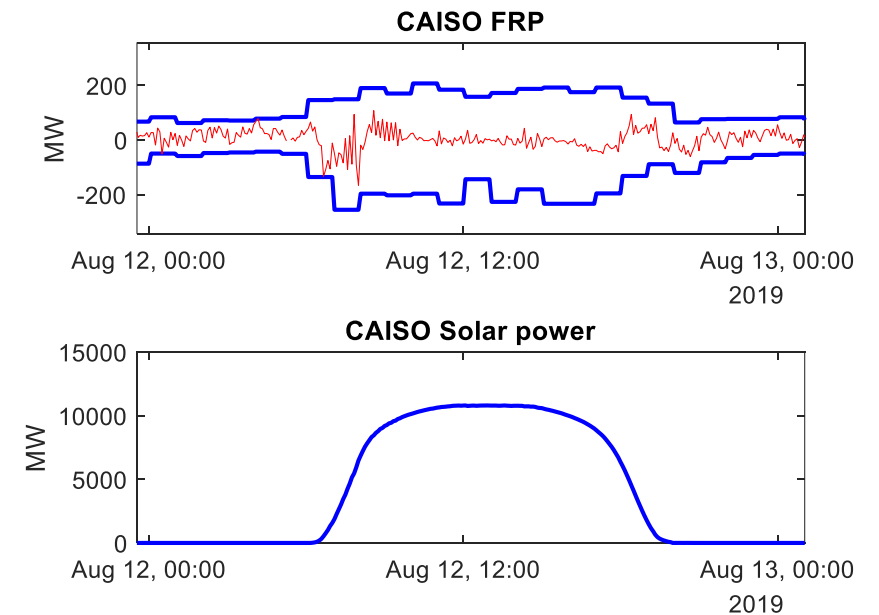
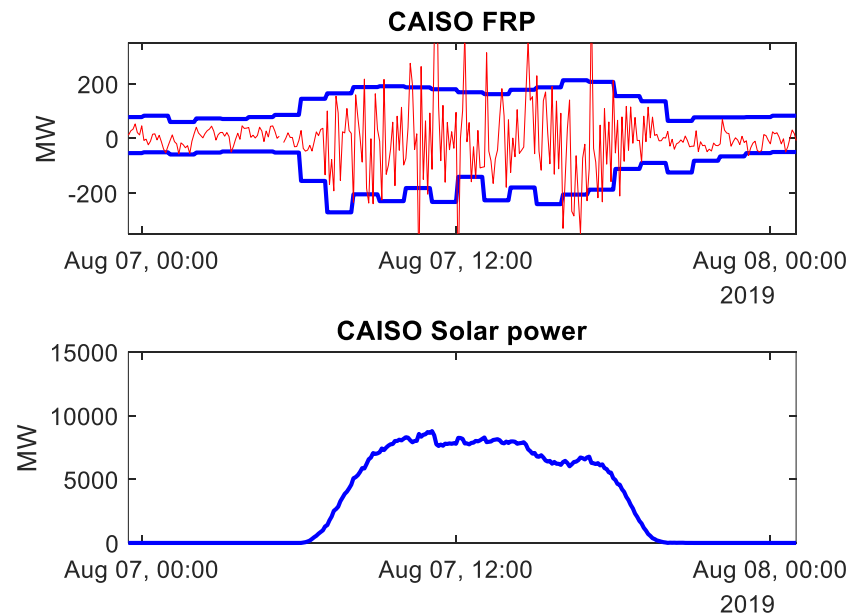
(Courtesy B. Li, UT-D)

➤ Type of days vs. uncertainties

Day Type
Net load forecast uncertainty
Solar power profile
Problems with non-weather conditioned baseline FRP

Cloudy day
More
Jagged
Under procurement → risk of reserve shortage

Sunny day
Less
Smooth
Over procurement → reduced market efficiency



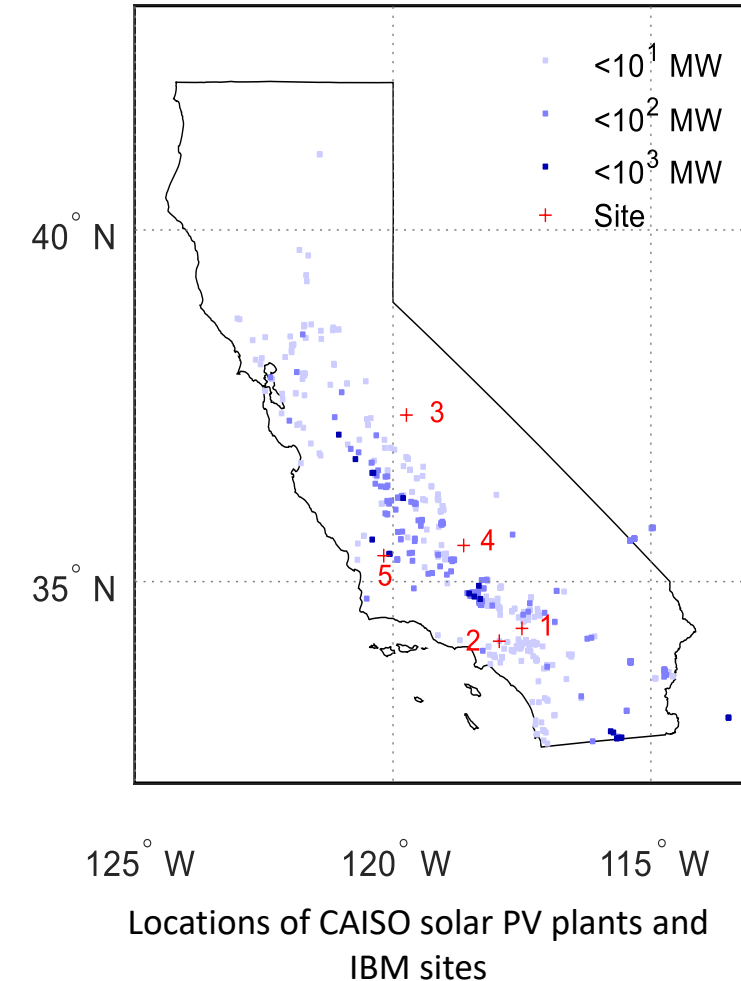
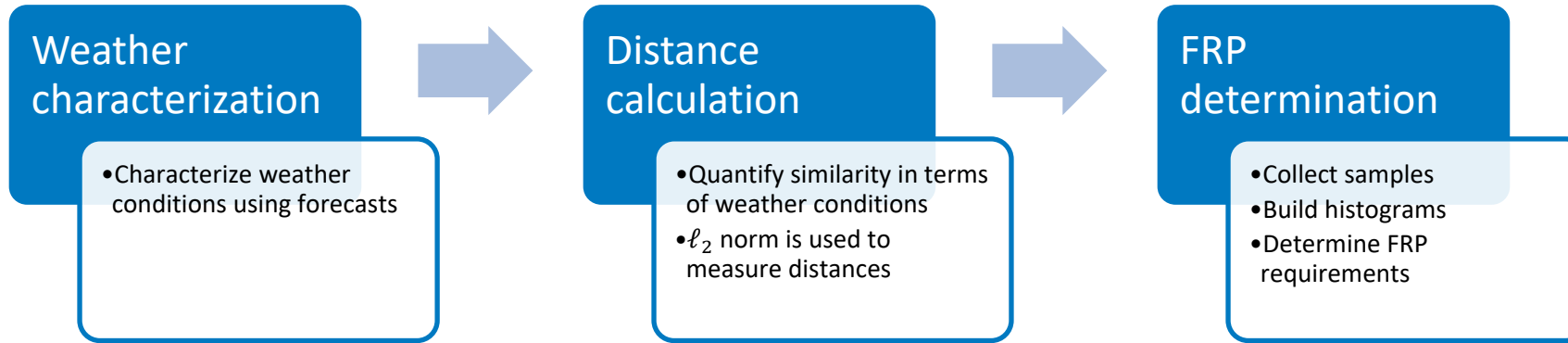
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The kNN-based Method: Procedures

Funded by:



(Courtesy B. Li, UT-D)



- IBM provides 5th, 25th, 50th, 75th, and 95th percentiles of GHI every 15 min
 - **Cloudiness conditions:** k -- Clear-sky index, k^{PV} -- clear-sky power index
 - **Uncertainty:** w -- Width of k , w^{PV} -- width of k^{PV}
- Mean (μ), standard deviation (σ), volatility (v) of each
→ 12 potential independent variables

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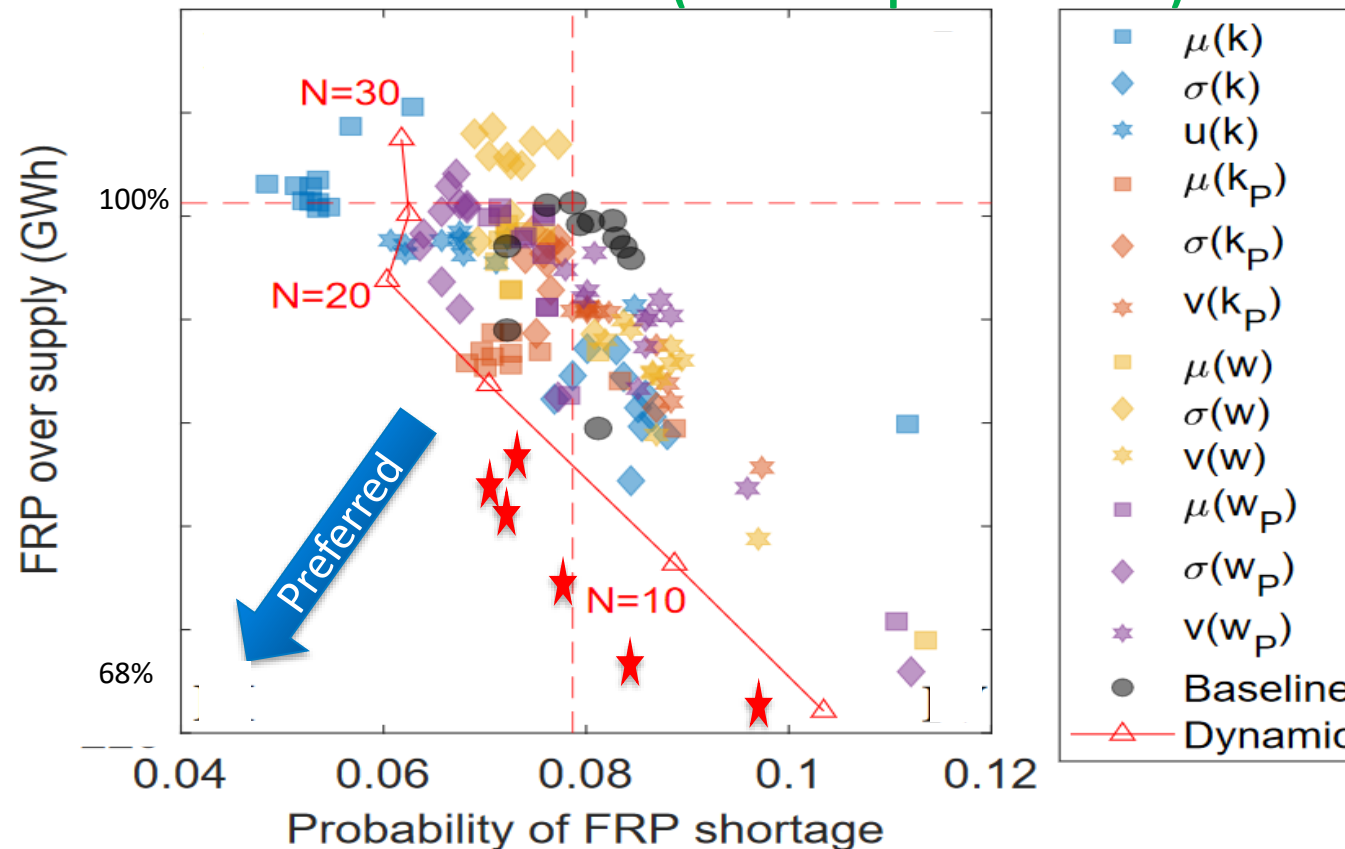
The PCA/kNN-based Method for FRP Estimation

Funded by:



(Courtesy B. Li, UT-D)

- Shown: kNN-based FRP requirements: Reliability-oversupply trade-offs Feb. 2020.
 - 1-D classifiers from solar site 2 using various predictors.
- Multisite/PCA classifiers perform even better
- Used in FESTIV Benefits Assessment (Part 3 of presentation)



B. Li, C. Feng et al., Sizing ramping reserve using probabilistic solar forecasts: A data-driven method, Applied Energy 313 (2022).

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2.2 Weather-Aware **Regulation** Requirements Estimation

(Courtesy L. He, UT-D)

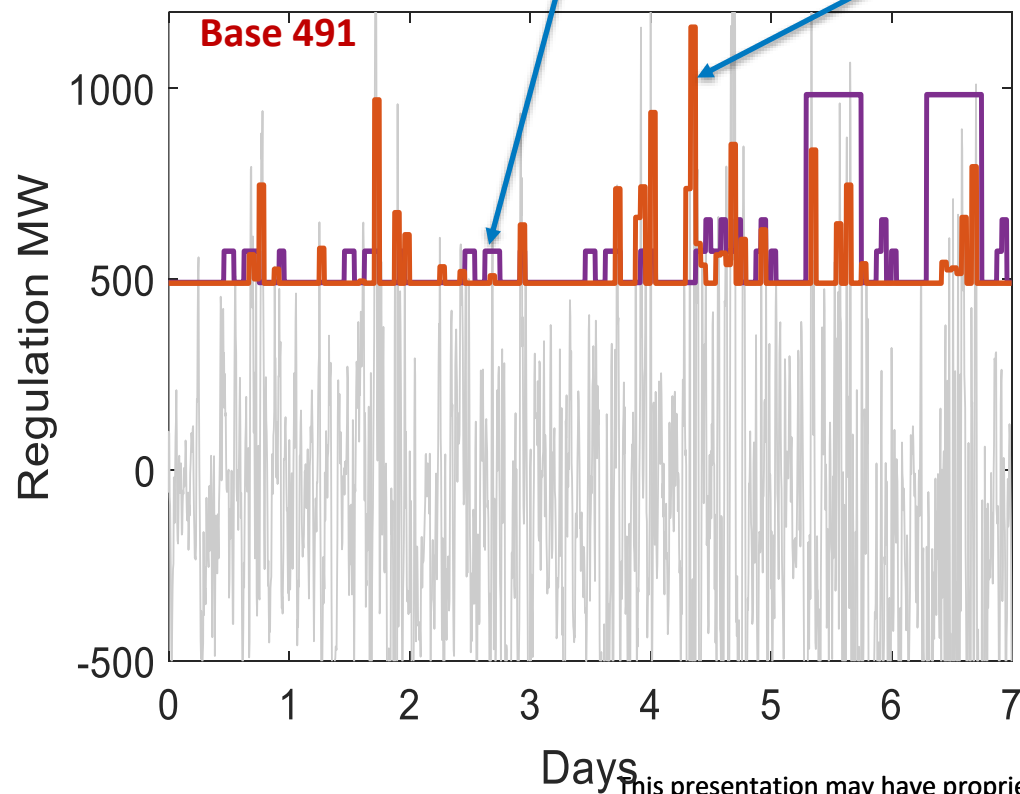
Real-time Reg procurement: Base X = $\max$ (Forecasted ACE*, X)

E.g., Base 491 = $\max$ (Forecasted ACE*, 491 MW)

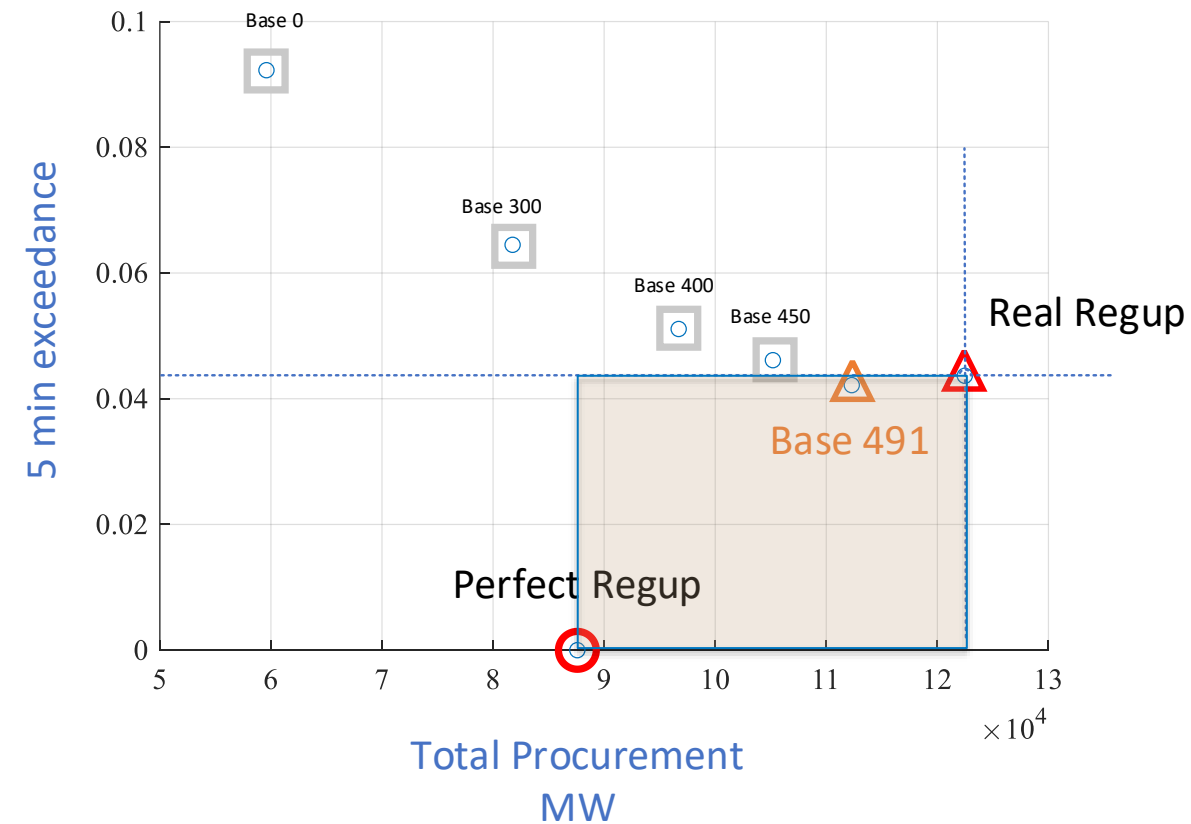
CAISO reg-up: comparison of two methods

Real-time CAISO reg-up:

(1) Current CAISO day-head baseline (purple); (2) Base 491 MW real-time (orange), based on previous ACE* & solar forecasts



**Reg-up requirements in last 7 days, May 2020
(compared to 5 min averages of ACE*)**



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3. Benefit Estimation for California Market using FESTIV

***Summary:* Experimental Setup**

Question addressed:

What is the benefit of improved flexible ramp product requirements (FRP) on large systems operation with full network constraints?

Summary: Benefits Assessment By Simulations of Western US Markets

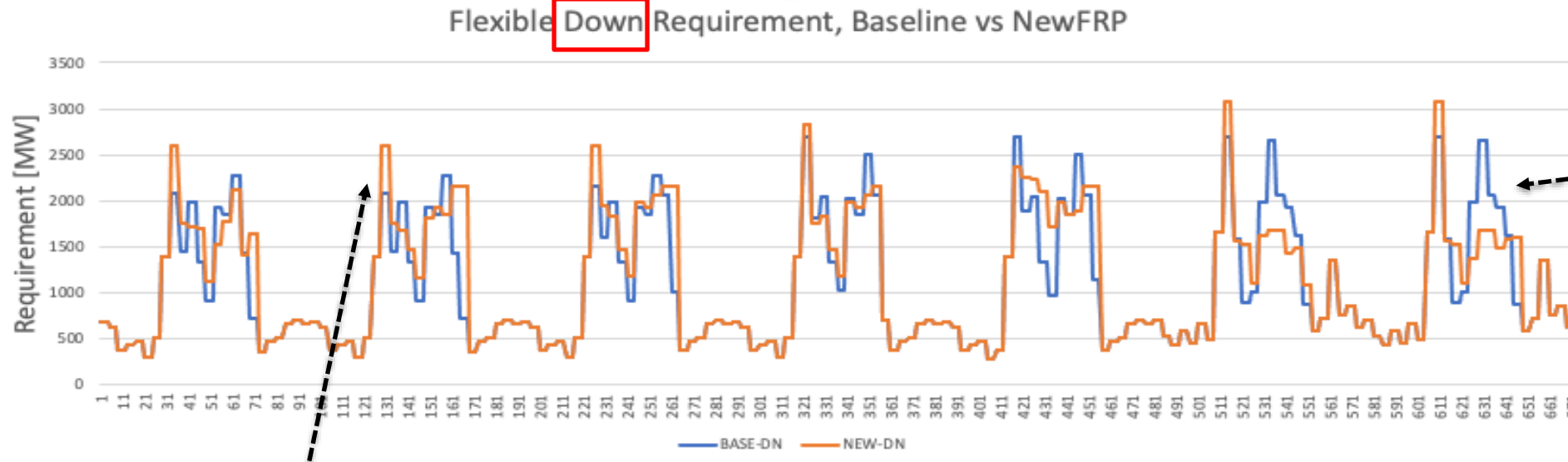
(Courtesy V. Krishnan, E. Spyrou, NREL)

- **Flexible Energy Scheduling Tool for Integrating Variable generation (FESTIV) tool, modified with CAISO operating rules**
- **Two scenarios compared here...**
 - 1. *Baseline***—used historical FRP requirements obtained from OASIS
 - 2. *New FRP***—used new kNN-based FRP requirements
- **... in terms of two metrics of FRP performance:**
 - 1. System production cost** (CAISO 2019 cost ~ \$8B)
 - 2. Total FRP procurement cost** (CAISO 2020 ~ \$10M; 2018 ~\$25M)

Summary: Example of Improved FRP Requirements & Results:

March 9-15, 2020: Baseline vs. New FRP (kNN method)

(Courtesy V. Krishnan, I. Kran, NREL)

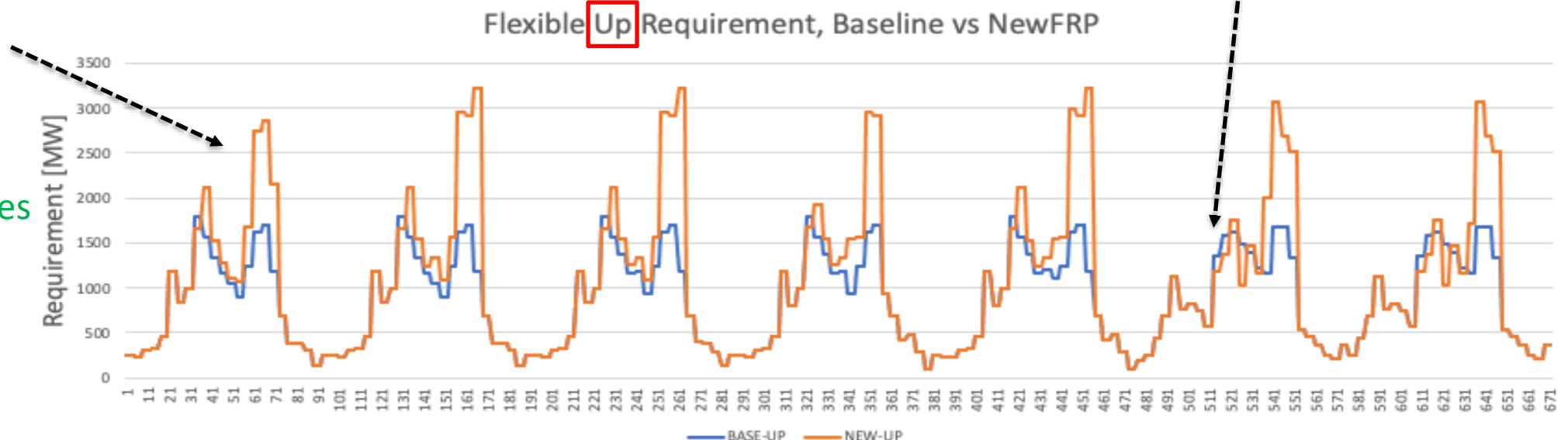


When **decrease** requirement:

- Reduce peaker unit scheduling
- Reduce production costs

When **increase** requirement:

- Improve reliability
- Reduce generation scarcity & price spikes
- Reduce renewable curtailment



Production Cost and FRP Procurement Cost Comparison: Baseline vs Solar-Informed FRP, March 16-20, 23-25, 2020

(Courtesy V. Krishnan, I. Kran, X. Fang, NREL)

	Baseline (Current CAISO Method)
Production Cost \$	\$106.6M 
(Savings \$, Percent)	
FRP Procurement Cost (Price*Quantity) \$	\$136.5K 
(Savings \$,Percent)	

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Conclusion

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*Ramp Product,
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3. Western
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- We conclude that probabilistic solar forecasts are a highly promising way to condition ancillary service requirements on up-to-date weather forecasts.

Questions?



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