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Project Review Presentation

Automating Detection and Diagnosis of Faults, Failures, and Underperformance in PV Plants

Electric Power Research Institute (EPRI)

Award # DE-EE0008976

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Contributors

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- Turbine Logic: Chris Perullo, Scott Sheppard, Jared Kee, Steven Koskey, Corson Teasley

Snow in Denver Colorado on 10/28 (Solar TAC Array)

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Outline

- Fault detection update
  - Detection using satellite data
  - Intentional fault test update
  - Benchmarking against third parties
- Underperformance analysis
  - Satellite data and data-driven model result update
  - Decomposition (loss identification) updates
- Image recognition diagnosis

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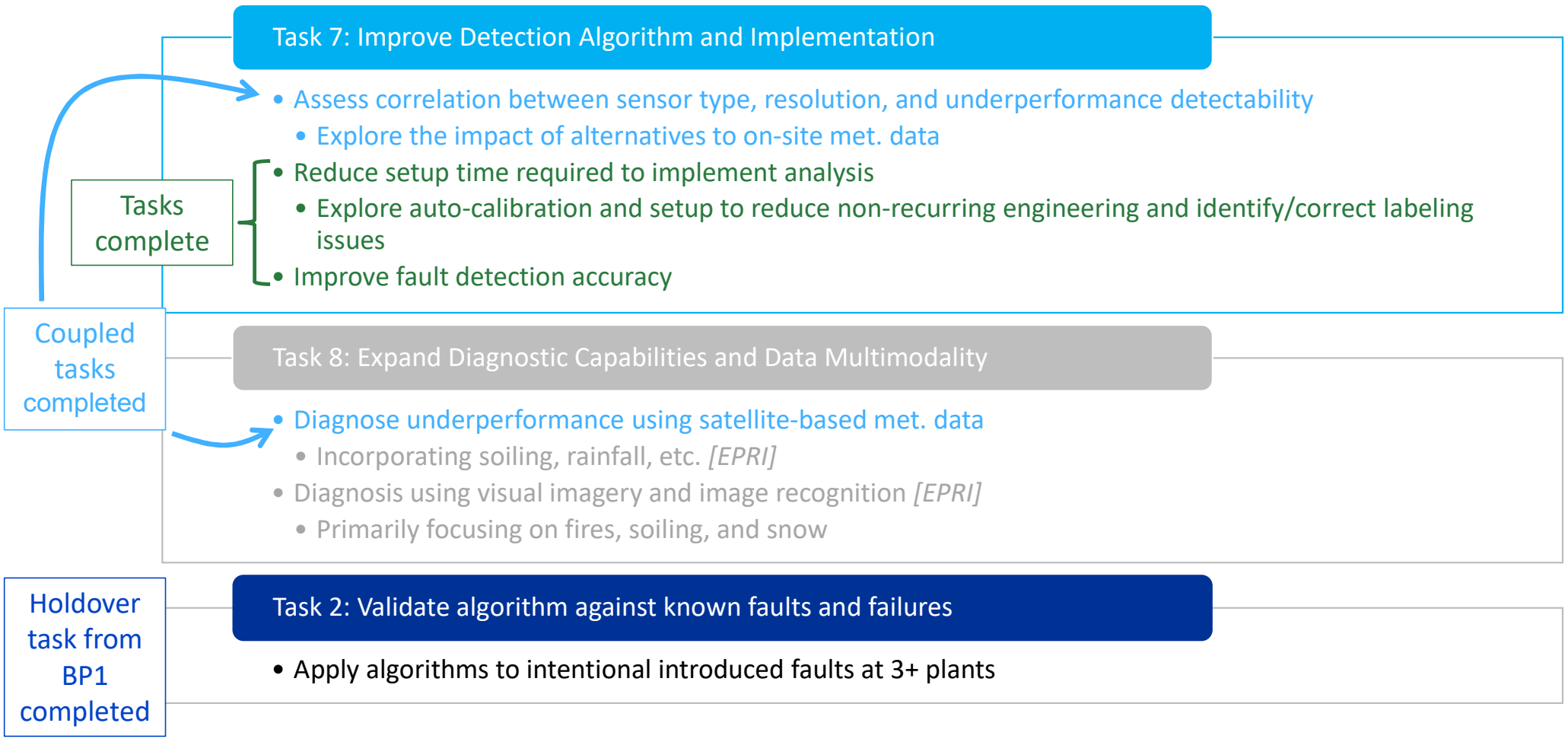
Turbine Logic Budget Period 2 Tasks



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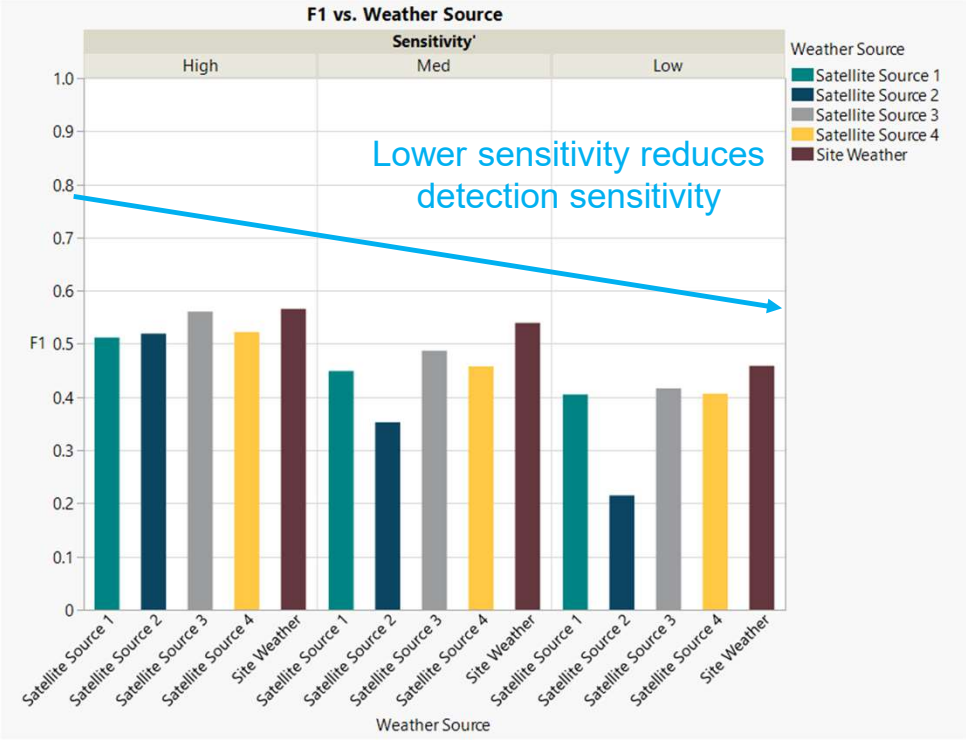
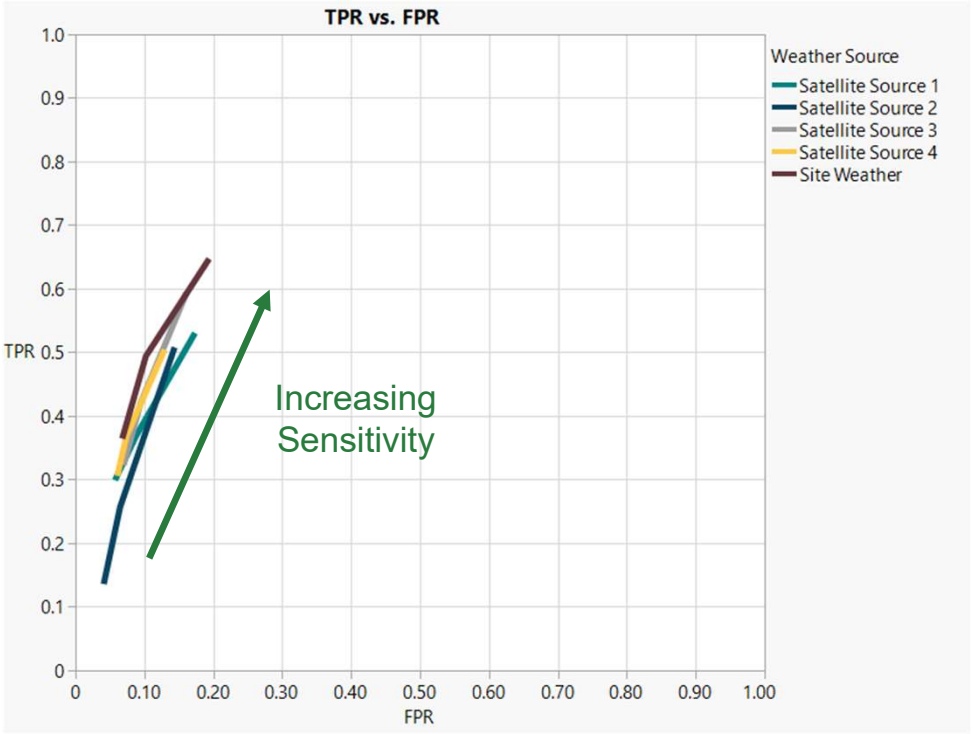
Satellite Weather Detection Summary





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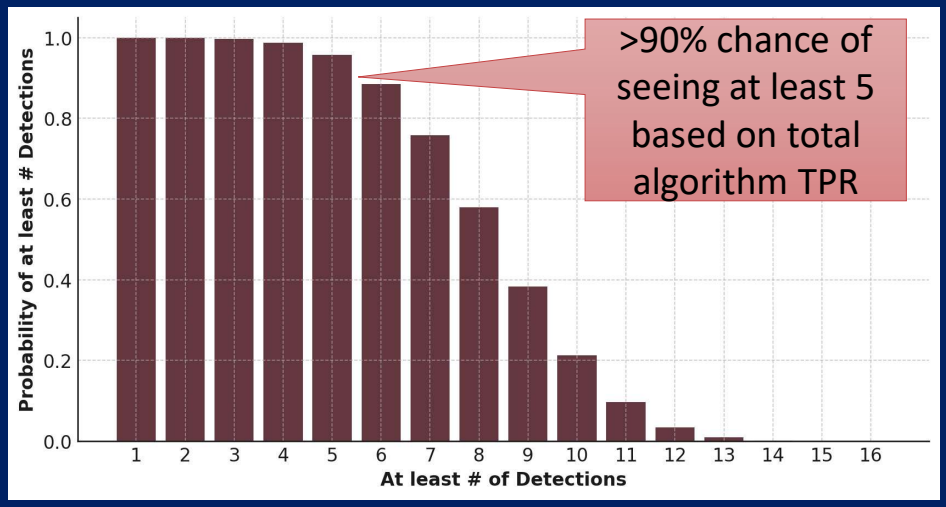
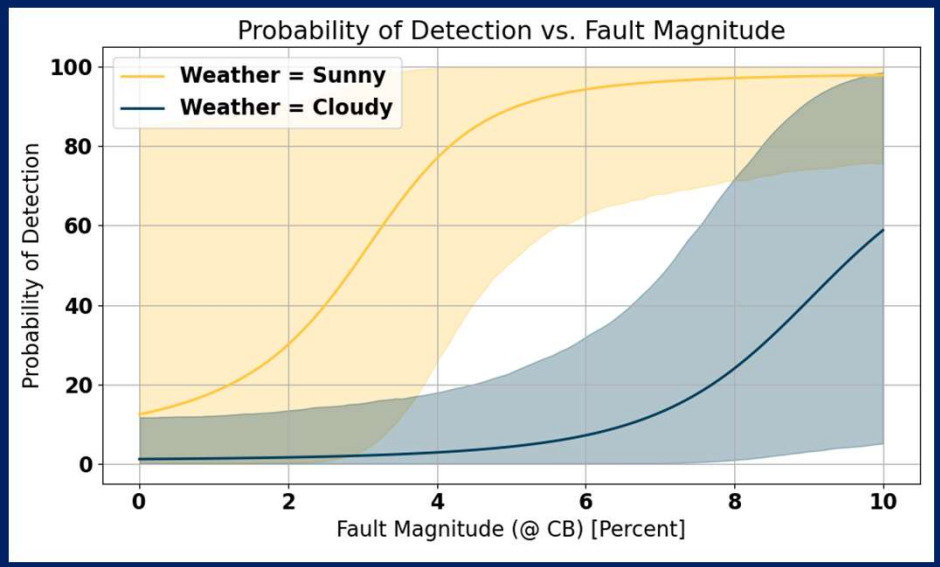
Intentional Faults Detection Summary

- Reminder:
  - 3 sites
  - 16 intentional faults
  - Varying magnitudes
- Detected **5 of 16**
  - In line with “the math” but would have hoped for more
- Examined sites
  - Two of the sites weather was ‘not pleasant’ during duration of testing
  - Broke out detection accuracy vs. weather at right – **only intentional faults**
  - Recall algorithm using aerial scans has filtered to sunny days
- Milestone satisfied, yet for completeness
  - Segregate and compare aerial scan rates by:
    - Weather
    - Estimated Fault Magnitude





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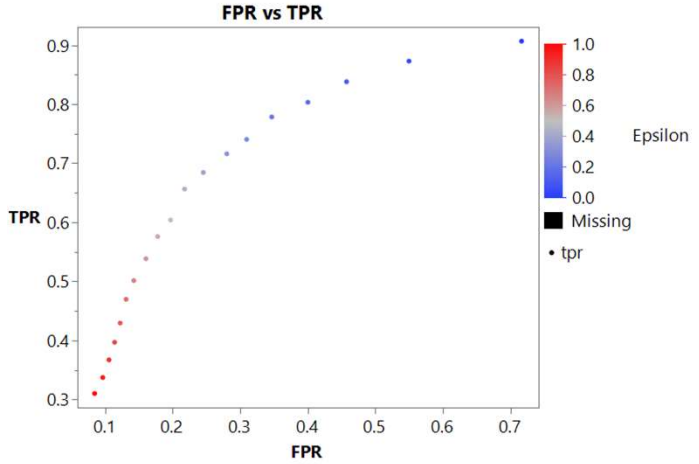
Benchmarking Fault Detection

- Goal: compare detection rates (ROC curve) of our algorithm against at least 3 commercial software vendors
- 2 in progress, 1 pending:
  - Also Energy: finalizing contract, discussions have begun
  - Isotrol: agreed to participate, initiating contract
  - AVEVA: common existing utility solution, work has begun with Southern



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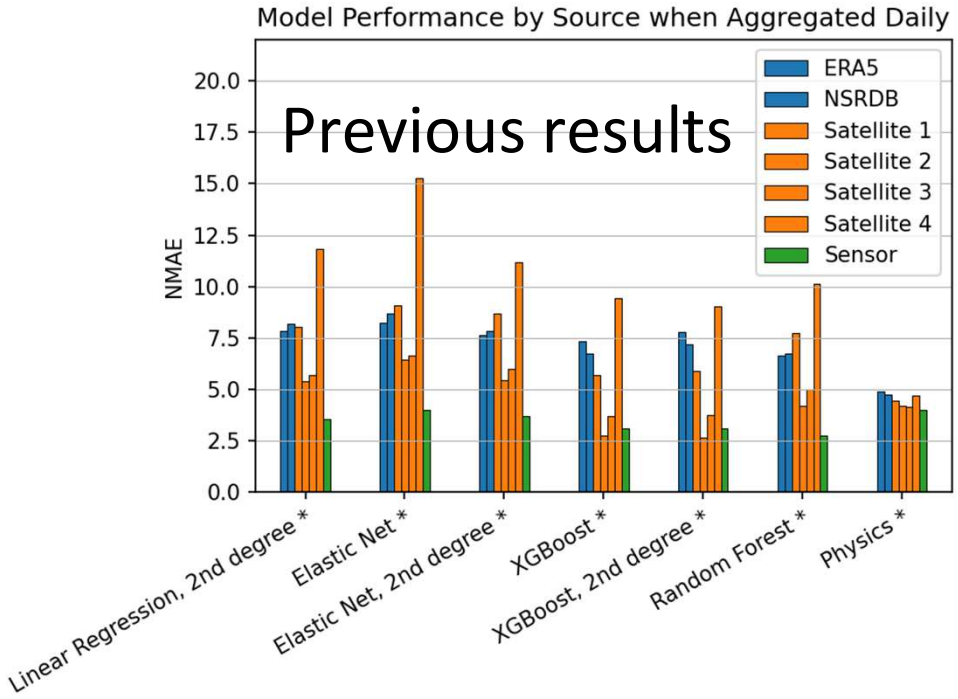
Satellite Evaluation Update

- We found an error in the previously reported results
  - Outlier pointed out on the previous quarterly call
  - Investigated and found a time shift occurred in processing
  - Satellite 4 falls in line with others in the updated results
- We added 2 additional high-resolution sources (5-minute)



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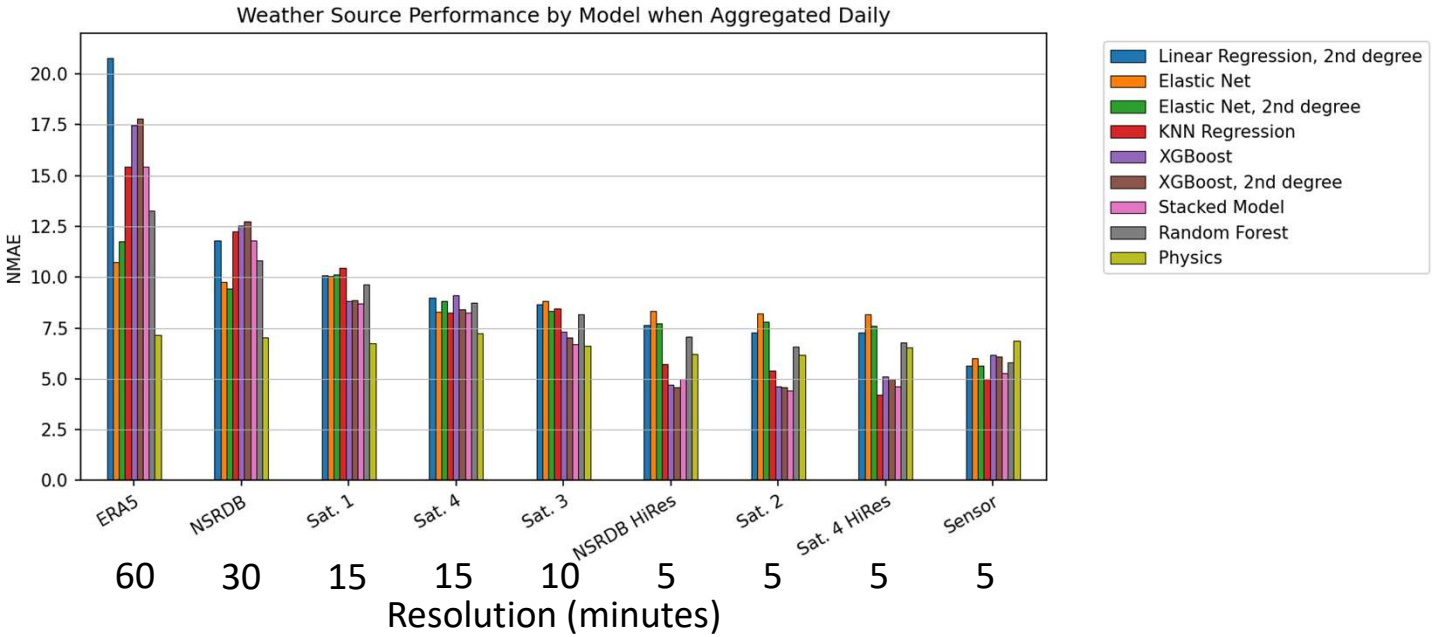
Results



- Significance of time resolution. Better resolution leads to better accuracy.
- Sensor is good regardless of model. Physics model is good regardless of source.
- Highest performance is with high-resolution satellite data and ML models
- NSRDB 5-minute resolutions is as good as commercial (but delayed)

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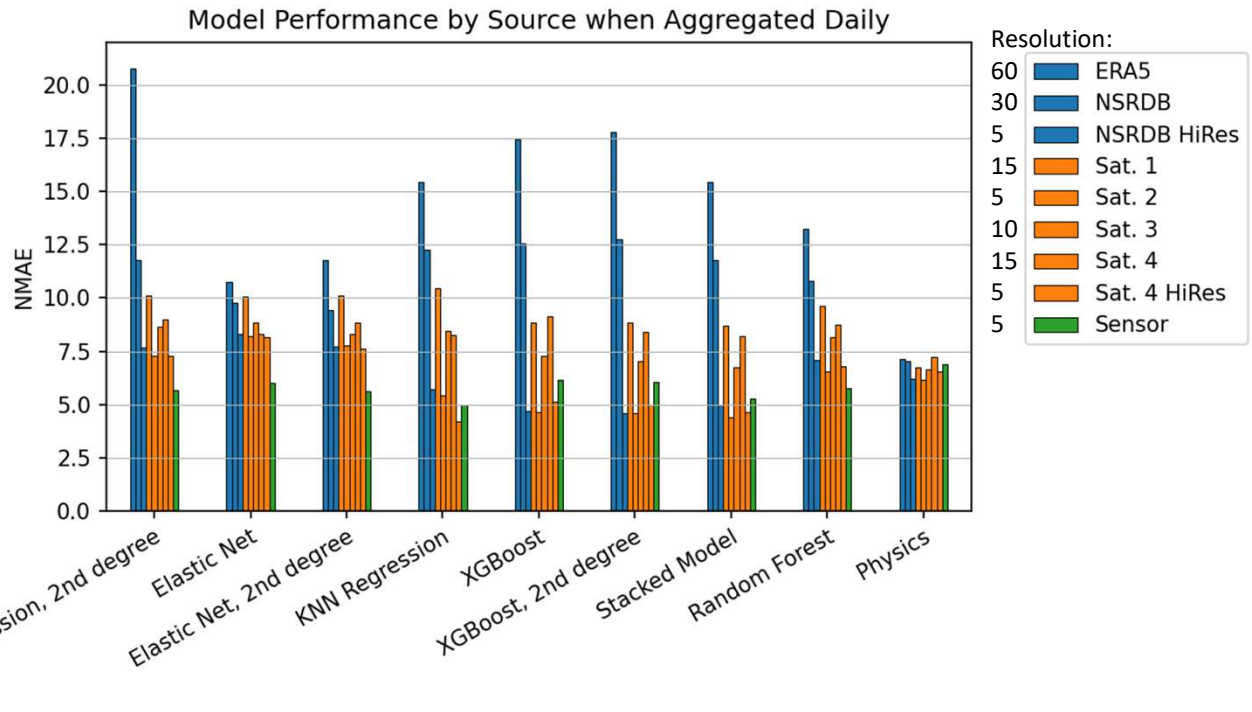
Results



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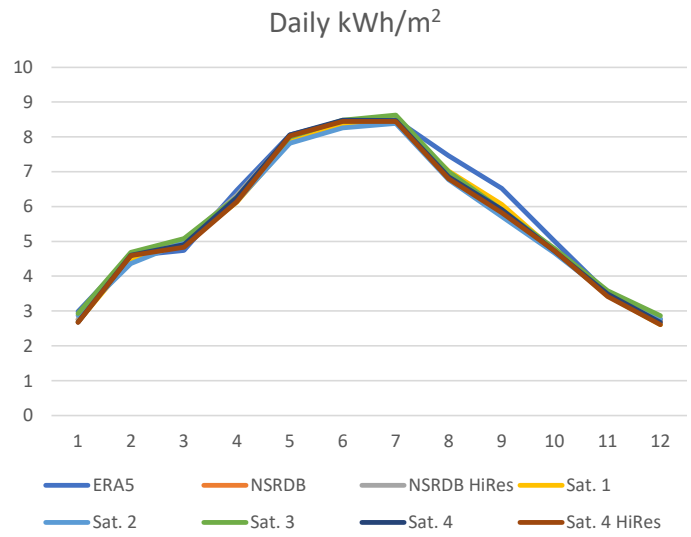
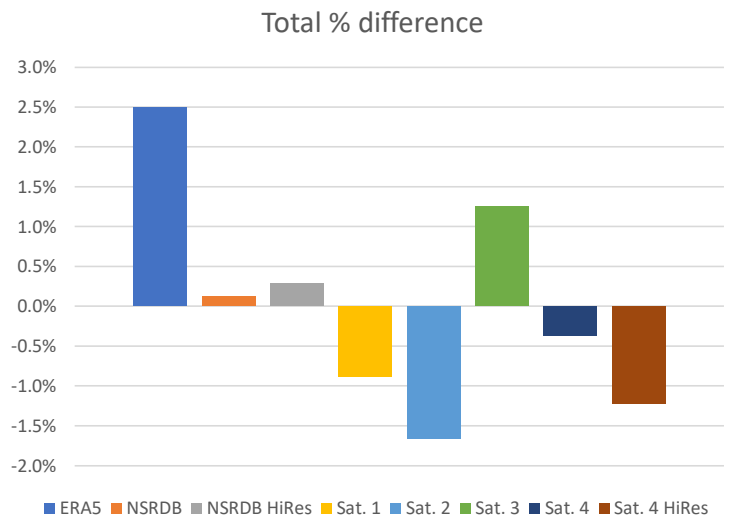
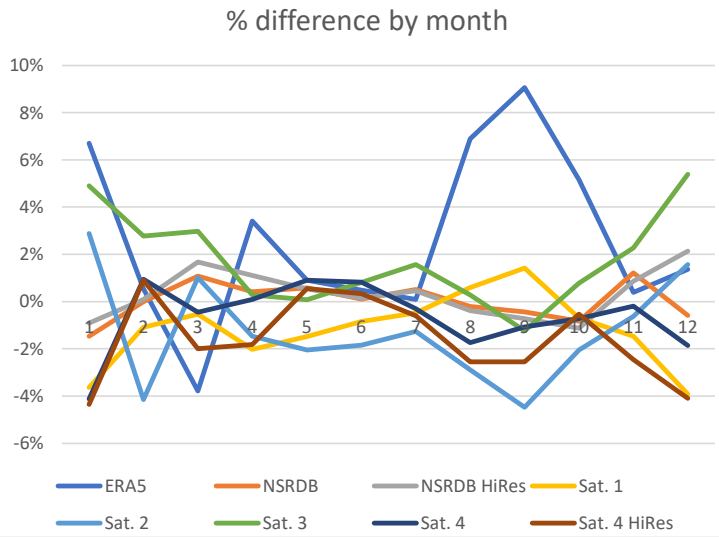
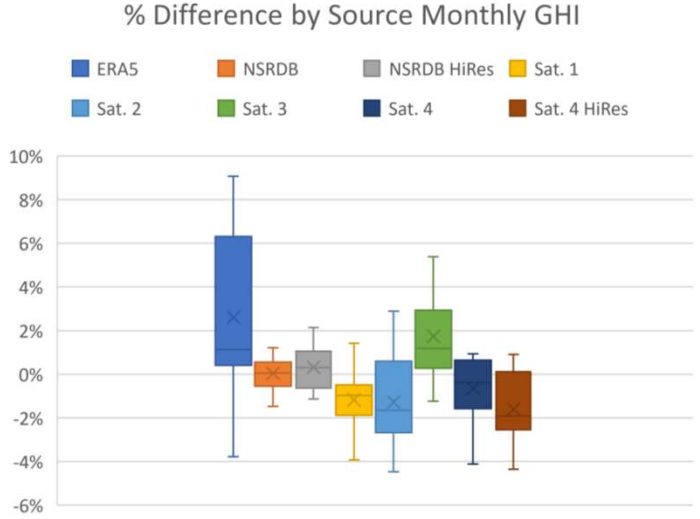
Long term insolation comparison:

- ERA5 is high (2.5%)
- Others within ±1.5%
- Moderate monthly differences
  - NSRDB smallest spread









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Decomposition Project

Goal:

Decompose the signal into different components, including system changes, seasonality, soiling, degradation, and noise.

System change:

Look for sudden and significant changes in the signal and report them if they persist for at least 20 days.

Seasonality:

Use the statsmodels.tsa.seasonal library to find recurring patterns in the signal, which represent seasonality.

Soiling:

Use Robust Regression line between extremes on the denoised signal.

Degradation:

Determine the rate of degradation by calculating the slope from the Huber regression on the remaining signal. This represents the long-term decline in system performance.

Noise:

The signal that remains after extracting all the components represents the noise.

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From statsmodels.tsa.seasonal import seasonal_decompose

Review:

Multiplicative Decomposition:

```
y(t) = Trend(t) * Seasonality(t) * Residuals(t)
```

-Trends: It uses moving averages to smooth out the data and estimate the underlying trend. In some cases, seasonal_decompose can fit regression models to the time series data to estimate the trend component.

-The seasonal_decompose function may employ various types of filters, such as the Henderson moving average or the Baxter-King filter, to isolate the trend and seasonal patterns.

-To estimate the seasonal component, seasonal_decompose can use seasonal subseries plots. This involves dividing the time series into segments corresponding to each season (e.g., months for monthly data) and then averaging the values within each segment. The resulting seasonal subseries plot helps identify the seasonal pattern.

	Decompose error
0	0.011117
1	0.008395
2	0.014190
3	0.014309
4	0.008072
5	0.008050
6	0.012835
7	0.012234
8	0.015014
9	0.007251

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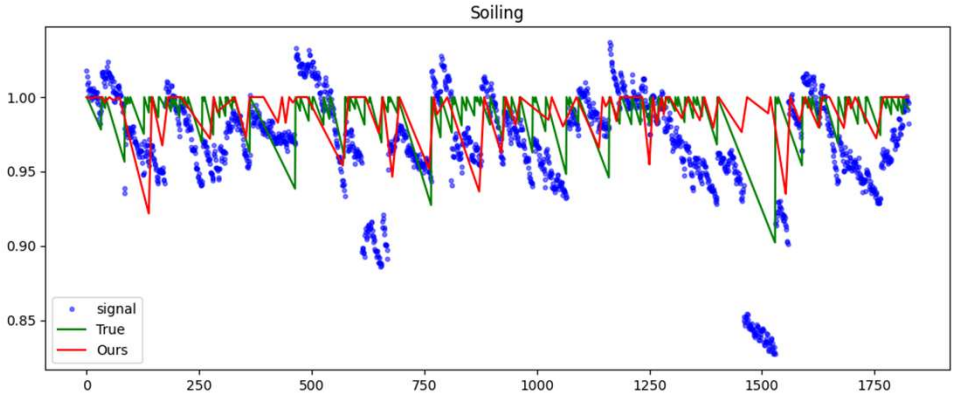
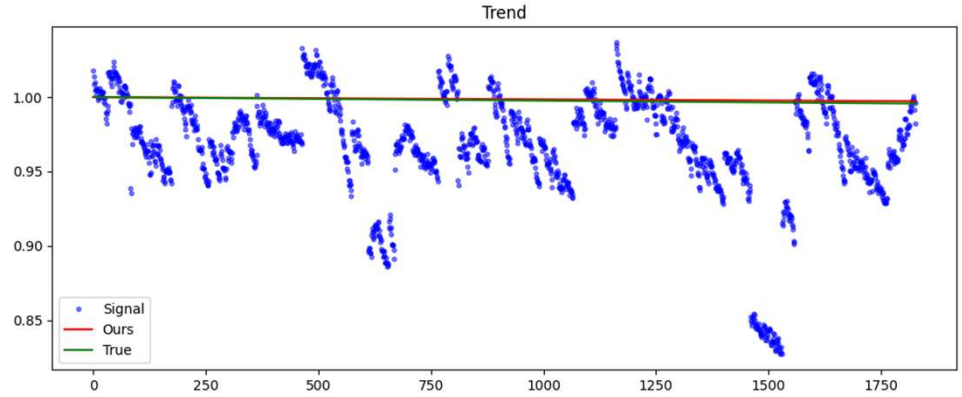
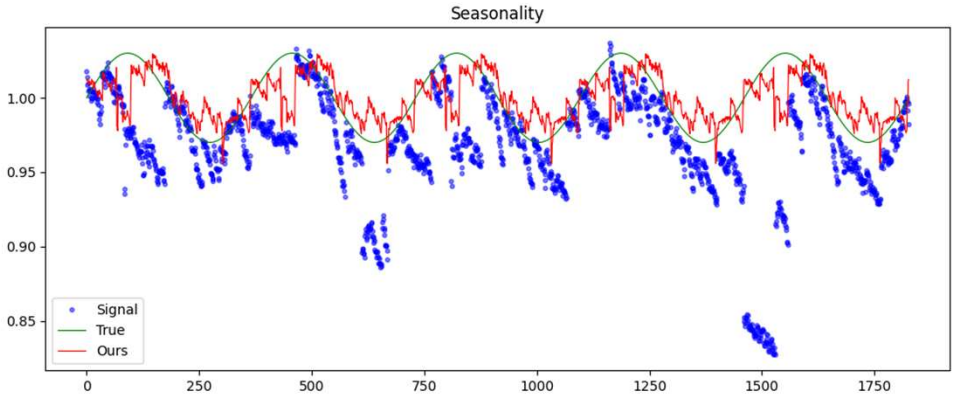
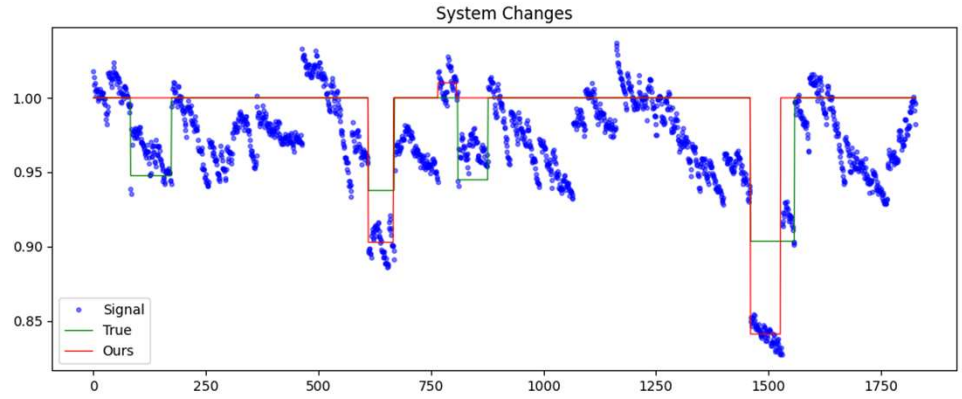
Results on Synthetic Data









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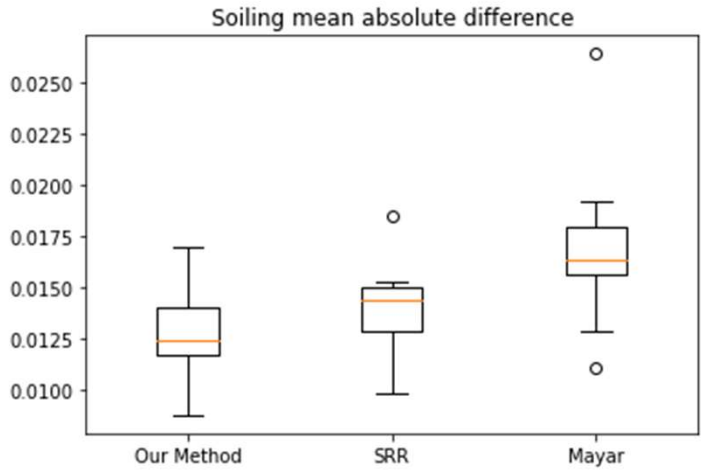
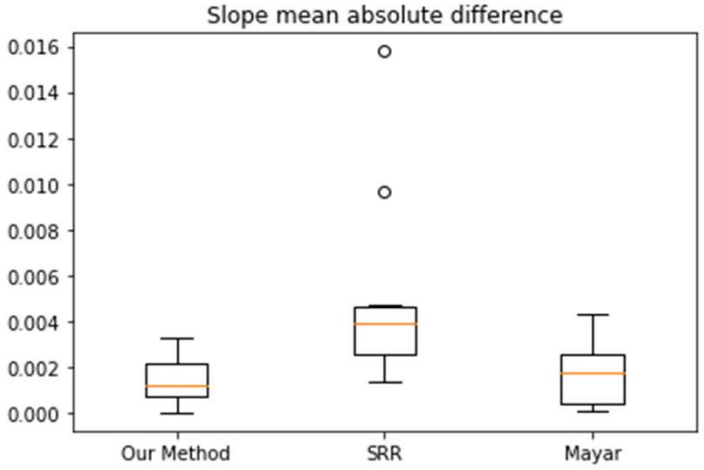
Results





Challenges:

Real data exhibits greater noise and different behavior compared to synthetic data.

Future steps:

- Generate synthetic data with higher noise levels
- Tune the method to ensure its effectiveness with real datasets. Enable user to tune sensitivity.
- Enhance the robustness of the seasonality and system change decomposition components

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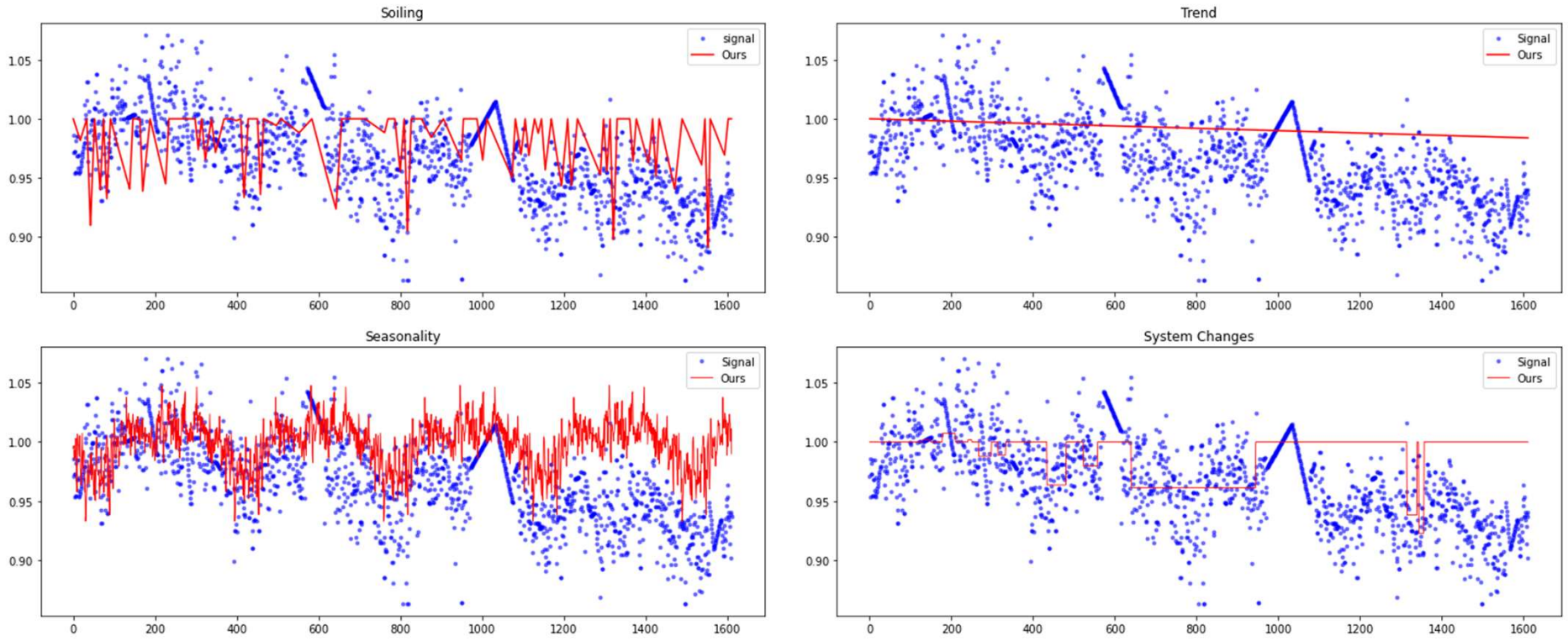
Preliminary Results on Real Data



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Visual Recognition Updates

- Georgia Tech Student still pending approval
- Working with Professor Bing Guo – Texas A&M (soiling detection)
- Camera installed, taking images every 15 minutes, streaming since October 10
- Soiling sensors installed
  - data connections being setup
- Goal is to detect:
  - Fire
  - Soiling
  - Snow
  - Other – tracker fault?

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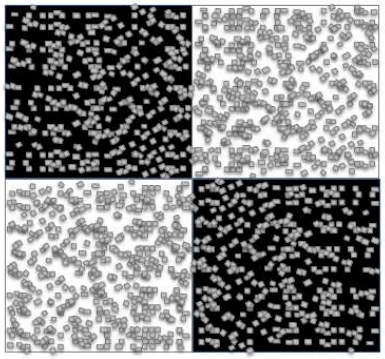
Soiling Detection and Image Linearity

- Plan: use images of checkered module to compare black/white brightness
  - Confirmed the image of the module is large enough ~ 200 pixels
- Potential issue: linearity of image (pixel values) with respect to brightness
  - A nonlinearity brightness adjustment is applied in most cameras (gamma) – since it is more pleasing to the eye
  - If we cannot fix the parameter – we are not sure of the underlying brightness
    - We are using a typical security camera (Vivotek IB9391 EHT 2). This would likely be a problem with most cameras.
    - We are waiting on the manufacturer to confirm the gamma setting

TEXAS A&M UNIVERSITY at QATAR



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Snow in Colorado on 10/28

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