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Pecos – Open Source Software for PV System Monitoring

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U.S. DEPARTMENT OF ENERGY

NNSA National Nuclear Security Administration

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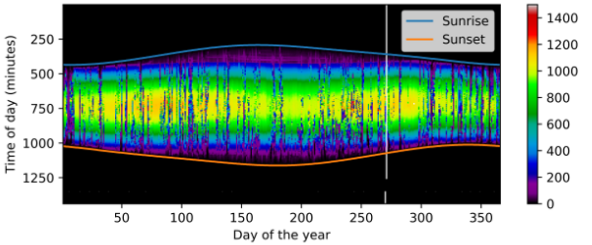
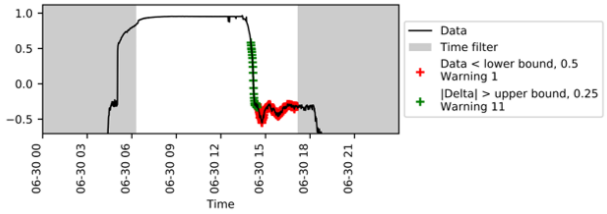
Pecos History

- Goal: Develop open source software for automated performance monitoring of time series data, with a focus on PV data
  - Analyze large amounts of data collected from different types of sensors across multiple sites
  - Run flexible quality control tests to distinguish between normal and anomalous conditions
  - Alert system operators when conditions have changed
  - Generate reports and graphics
  - Identify issues quickly
  - Increase data integrity
  - Enhance understanding
- Pecos was first released in March 2016
- Pecos was developed to monitor data collected at DOE Regional Test Centers
- Continue to improve API, analytics, and graphics to meet these goals

Pecos✓



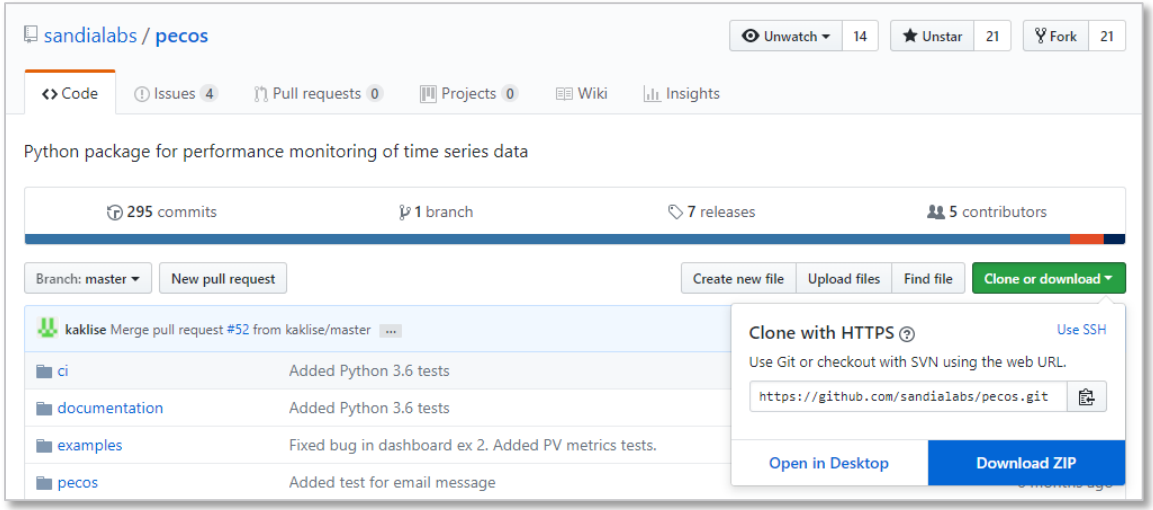


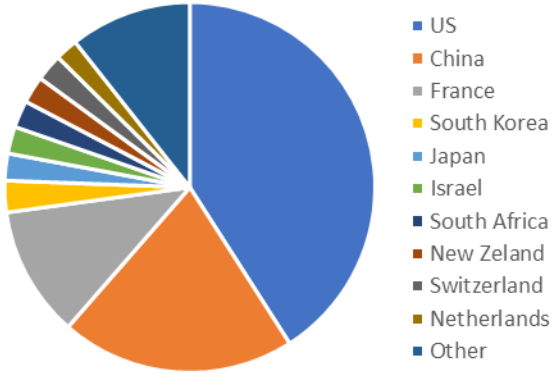
	System 1	System 2	System 3	System 4
Location 1	DA 1.00 QCI 1.00 EPI 0.99	DA 0.13 QCI 0.78 EPI nan	DA 1.00 QCI 1.00 EPI 0.98	DA 1.00 QCI 1.00 EPI 0.98
Location 2	DA 0.43 QCI 1.00 EPI 0.88	DA 1.00 QCI 0.93 EPI 0.01	DA 0.86 QCI 0.76 EPI 0.88	DA 1.00 QCI 0.93 EPI 0.98
Location 3	DA 1.00 QCI 0.93 EPI 0.98	DA 0.10 QCI 0.51 EPI nan	DA 0.57 QCI 0.84 EPI 0.63	DA 1.00 QCI 0.93 EPI 0.50

DA = Data availability
QCI = Quality control index
EPI = Energy performance index

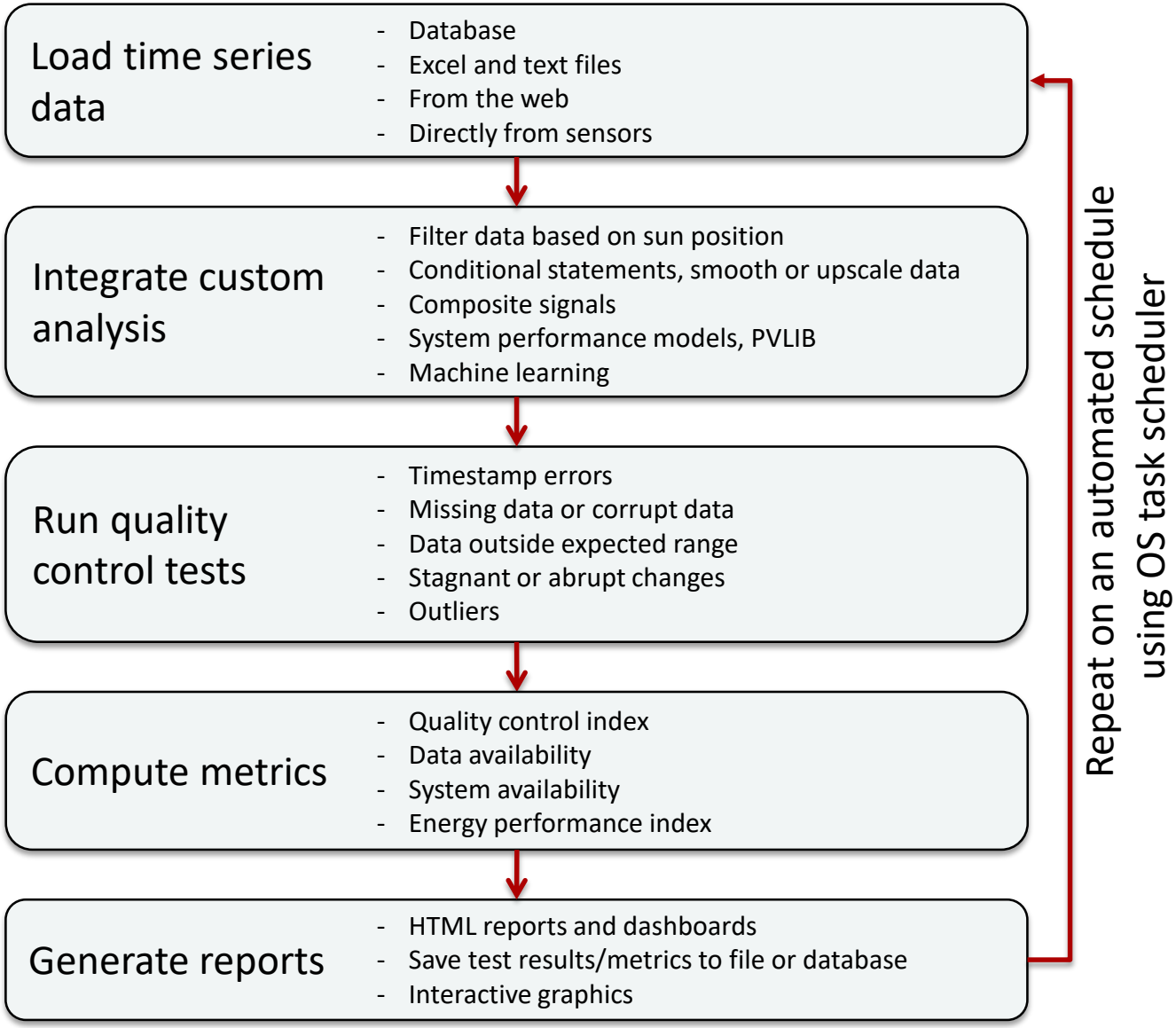
Pecos Software

- Available on GitHub at https://github.com/sandialabs/pecos
- Online documentation, software tests, and examples
- Download Pecos using pip or git (installation instructions available online)
- Seven software releases
- Downloaded over 700 times
- Dependent on Numpy, Pandas, Matplotlib, Plotly, and Jinja facilitates a wide range of analysis and reporting capabilities
- Dependencies are distributed with Anaconda





Pecos Framework



Code Example

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```
import pvlib
import pecos

# df = ... get data into a DataFrame using pandas, requests, sql connection etc.

# Create a pecos PerformanceMonitoring object and add data
pm = pecos.monitoring.PerformanceMonitoring()
pm.add_dataframe(df)

# Add a time filter based on sun position
solarposition = pvlib.solarposition.ephemeris(pm.df.index, 35.05, -106.54)
time_filter = solarposition['apparent_elevation'] > 10
pm.add_time_filter(time_filter)

# Compute normalized efficiency
NE = (pm.df['DC Power']/3000)/(pm.df['POA']/1000)
pm.add_signal('Normalized Efficiency', NE)

# Check upper and lower bounds
pm.check_range([0.8,1.2], 'Normalized Efficiency', min_failures=10)

# Generate report and interactive graphic
graphics = pecos.graphics.plot_test_results('test', pm)
pecos.io.write_monitoring_report('report.html', pm, graphics)
pecos.graphics.plot_interactive_timeseries(pm.df)
```

Code Example

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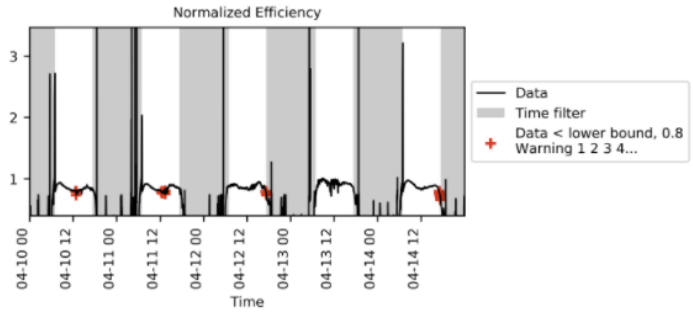
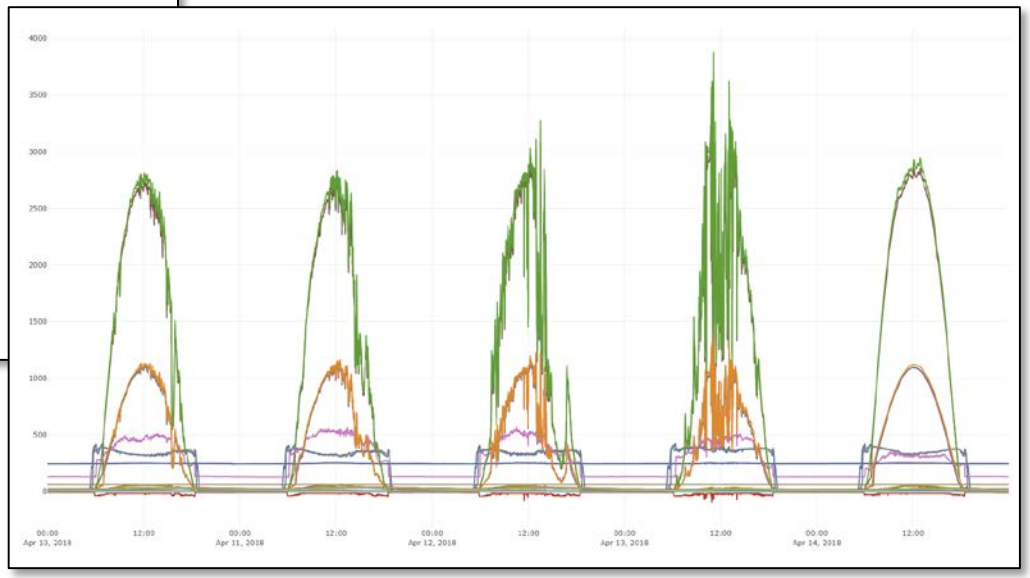
Pecos Monitoring Report

Start time: 2018-04-10 00:00:00-07:00
End time: 2018-04-14 23:59:00-07:00
Test Failures: 5
Notes: 0

Test Results:

	Variable Name	Start Date	End Date	Timesteps	Error Flag
1	Normalized Efficiency	2018-04-10 12:39:00-07:00	2018-04-10 12:50:00-07:00	12	Data < lower bound, 0.8
2	Normalized Efficiency	2018-04-11 12:18:00-07:00	2018-04-11 12:54:00-07:00	37	Data < lower bound, 0.8
3	Normalized Efficiency	2018-04-11 13:15:00-07:00	2018-04-11 13:25:00-07:00	11	Data < lower bound, 0.8
4	Normalized Efficiency	2018-04-12 17:07:00-07:00	2018-04-12 17:18:00-07:00	12	Data < lower bound, 0.8
5	Normalized Efficiency	2018-04-14 16:55:00-07:00	2018-04-14 17:20:00-07:00	26	Data < lower bound, 0.8

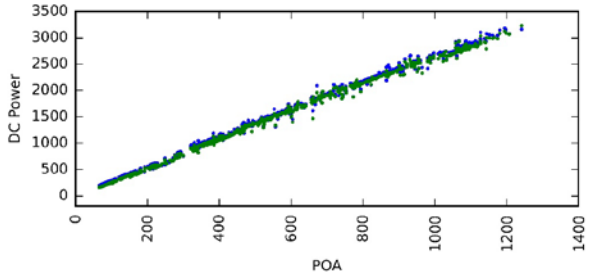


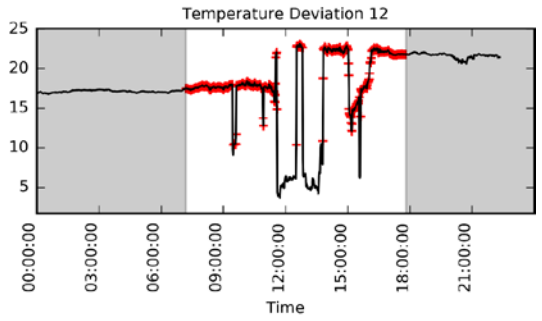


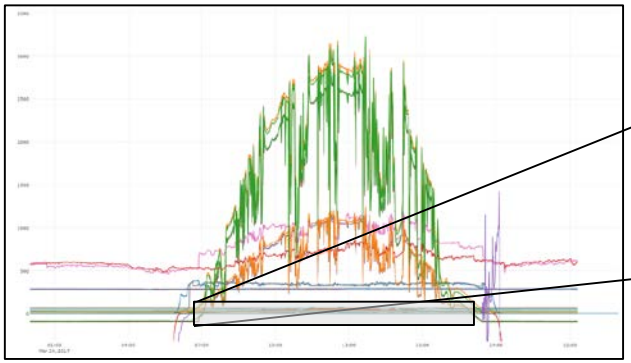
Regional Test Centers

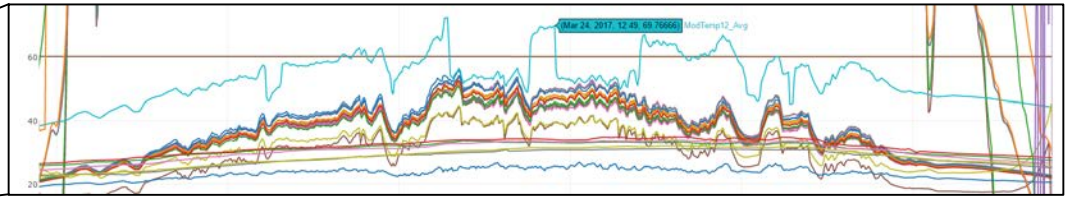
- Pecos is used to analyze 1.9 million data points per day (29 systems across 5 locations)
- Dashboards are sent by email with links to detailed reports and interactive graphics
- Color-coded score given to each data type

	New Mexico	Florida	Vermont	Nevada
Baseline	Irradiance 1.00 Temperature 1.00 Current 1.00 Voltage 1.00 Power 0.64 Detailed Report Interactive Plot	Irradiance 1.00 Temperature 0.19 Current 1.00 Voltage 1.00 Power 0.93 Detailed Report Interactive Plot	Irradiance 1.00 Temperature 1.00 Current 0.27 Voltage 1.00 Power 0.24 Detailed Report Interactive Plot	Irradiance 1.00 Temperature 1.00 Current 1.00 Voltage 1.00 Power 1.00 Detailed Report Interactive Plot



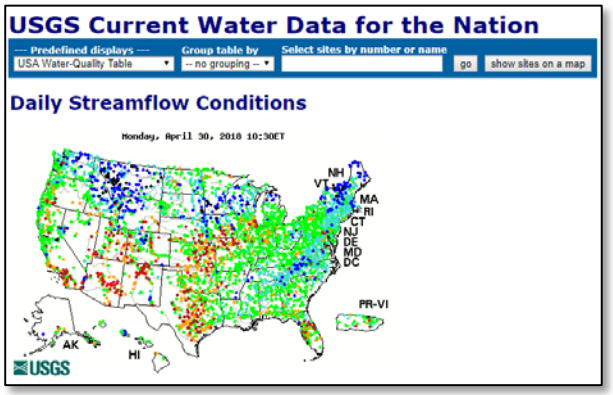


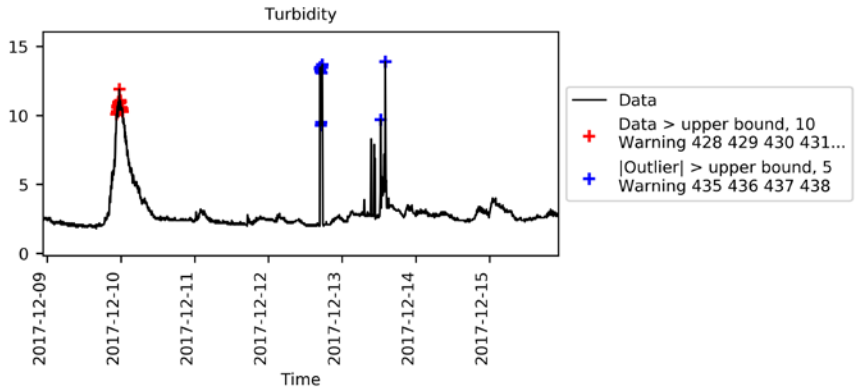




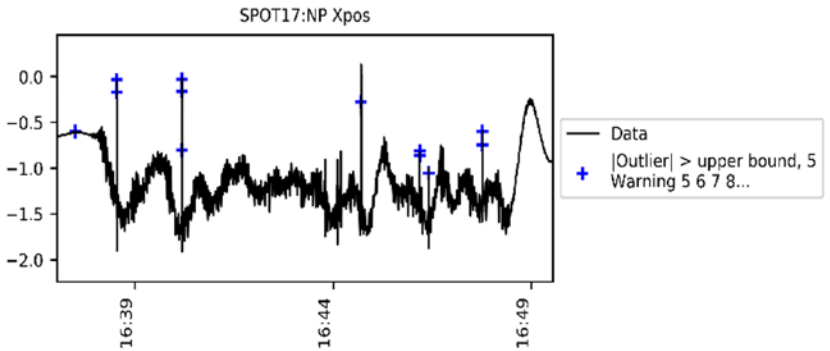
Additional Applications

- General purpose techniques have been applied to other sectors
  - Water quality



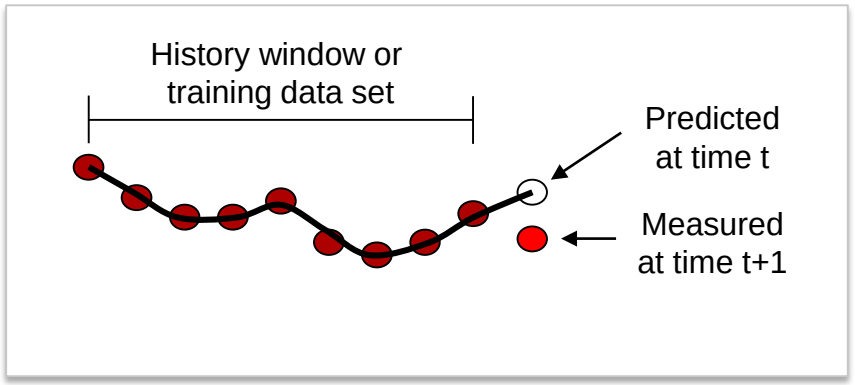


  - Marine hydrokinetics

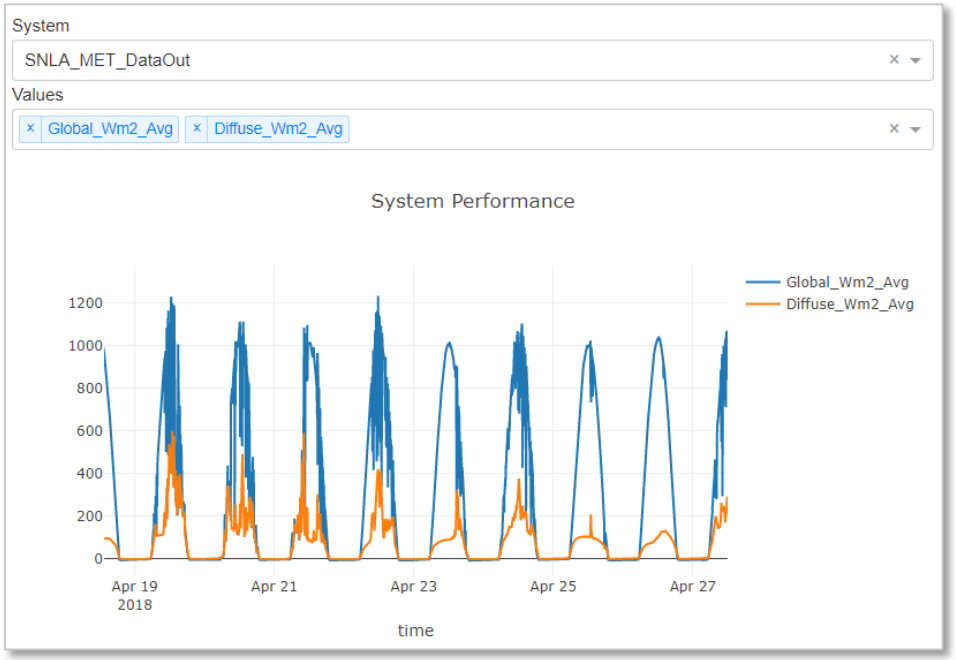


Possible next steps for Pecos

- Real-time streaming algorithms
  - Define a history window or training data set that can be used to predict the state of new data points
  - Eliminate outliers from future analysis



- Interactive dashboards using Dash
  - Integrate real-time data visualization with results from quality control analysis, connected directly to the database
  - Compatible with current code structure



- Parallel analytics using Dask
  - Analyze big data using Pecos
  - Compatible with current code structure