

RdTools: An Open Source Python Library for PV Degradation Analysis

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Comparative PV LCOE Calculator

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HOME DOCUMENTATION

Inputs

Baseline

PRESETS

Cost

Front layer cost (USD/m²)
4.06

Cell cost (USD/m²)
34.40

Back layer cost (USD/m²)
2.32

Non-cell module cost (USD/m²)
18.00

Performance

Efficiency (%)
19.0

Energy yield (kWh/kW_{DC})
1475

Reliability

Degradation rate (%/year)
0.25

Service life (years)
25

Proposed

COPY FROM BASELINE

Cost

Front layer cost (USD/m²)
4.06

Cell cost (USD/m²)
34.40

Back layer cost (USD/m²)
2.32

Non-cell module cost (USD/m²)
18.00

Performance

Efficiency (%)
19.0

Energy yield (kWh/kW_{DC})
1475

Reliability

Degradation rate (%/year)
0.5

Service life (years)
25

Results

LCOE result

Baseline LCOE (USD/kWh)	0.0663
Proposed LCOE (USD/kWh)	0.0678

Please email [Timothy J Silverman](mailto:Timothy.J.Silverman@nrel.gov) with comments or questions.

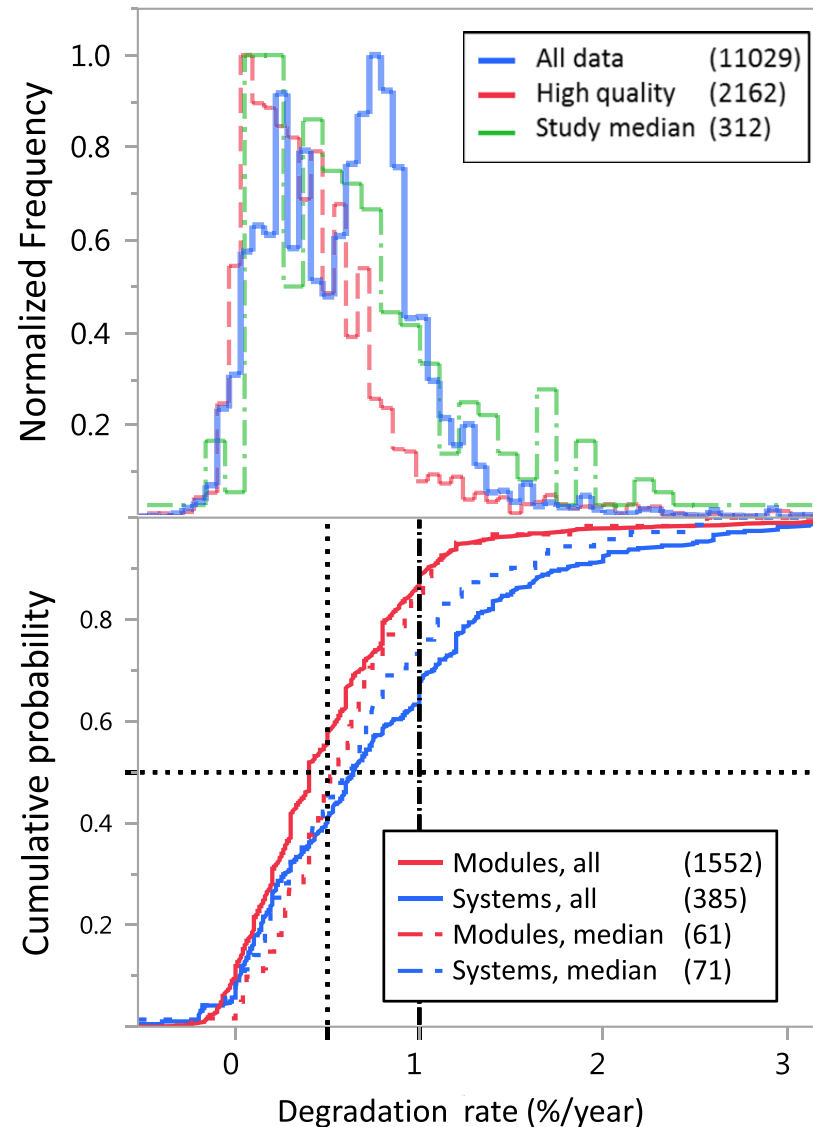
What degradation rate should I use?



pvloce.nrel.gov

Improving consistency

- The literature includes a variety of methods
 - Hard to draw large-scale conclusions
- Decisions, big and small, affect reported results

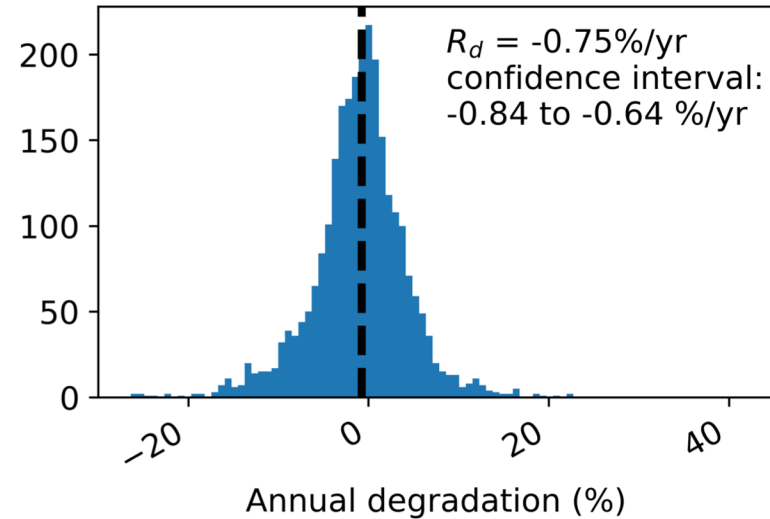
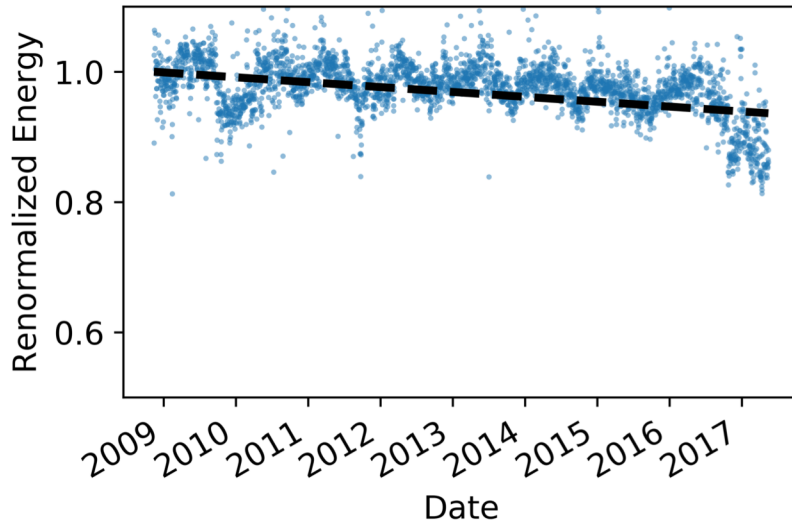


Our solution: RdTools

Time series performance data

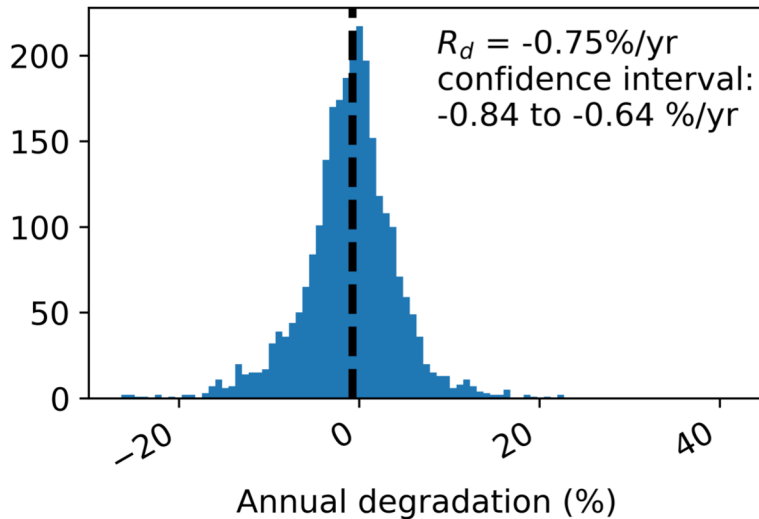
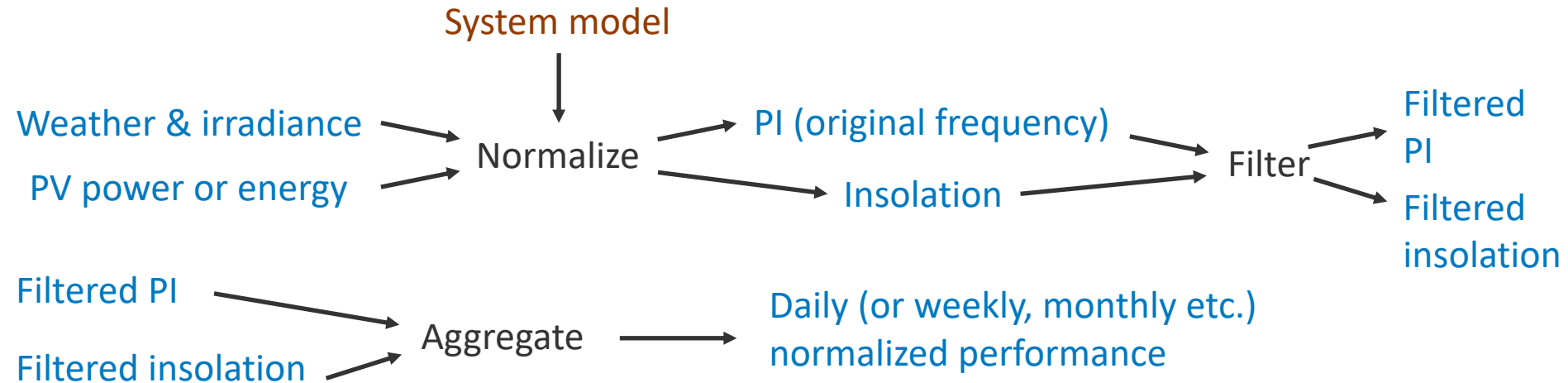


Degradation rate and uncertainty



- Open-source python module for PV data analysis
- API built around Pandas and PVLIB
- Steps:
 - Normalize
 - Filter
 - Aggregate
 - Analyze Rd

Tool flow



pandas time series
RdTools submodule

Filtering: devil's in the details

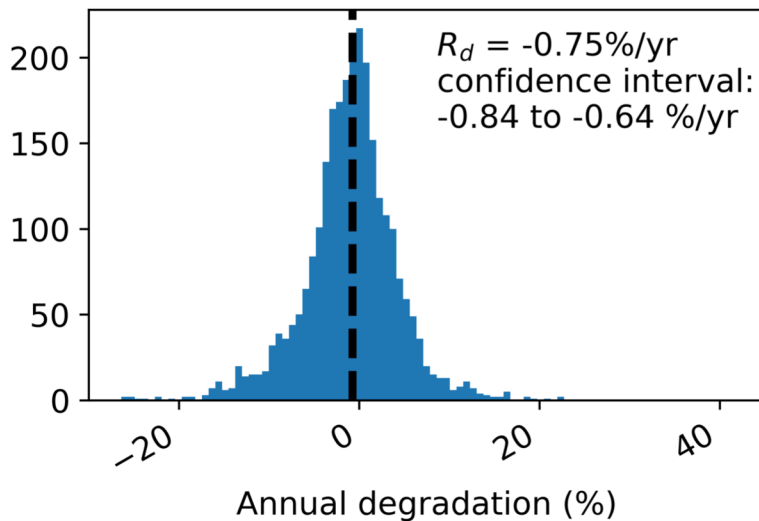
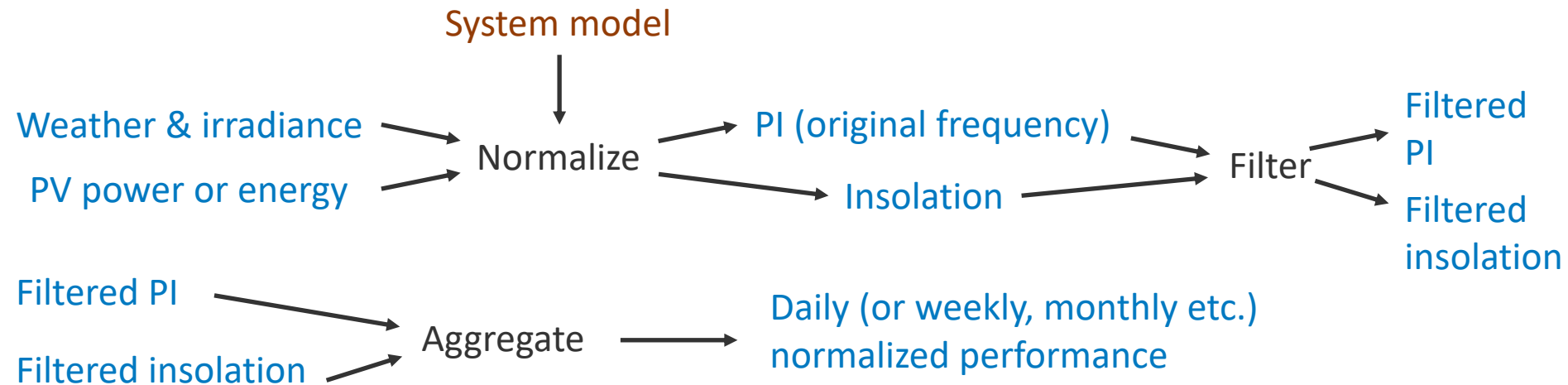
- Currently, RdTools provides minimal filtering:
 - Irradiance, temperature, **clipping**
- System vs. module degradation?
 - Where do you draw your degradation boundaries?
 - Tracker downtime etc.?
- Room for innovation:
 - Outliers and outages without introducing bias



VS.



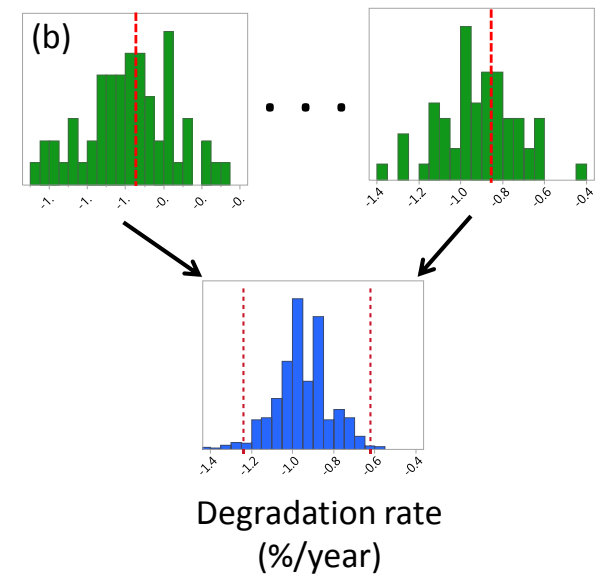
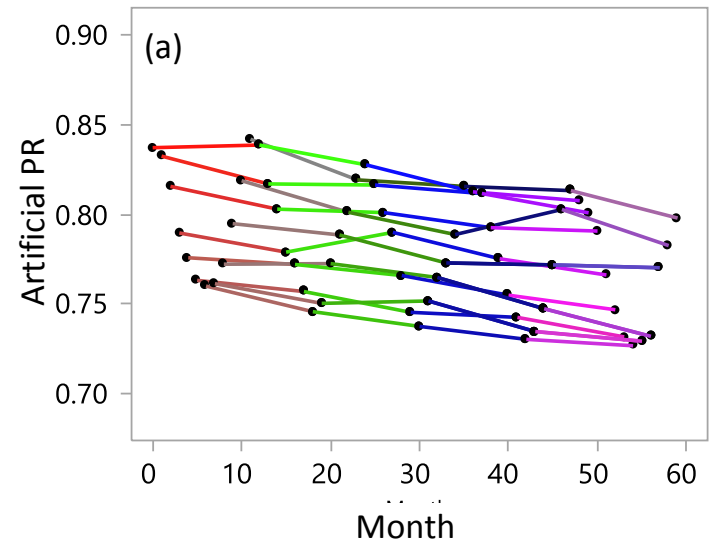
Tool flow



pandas time series
RdTools submodule

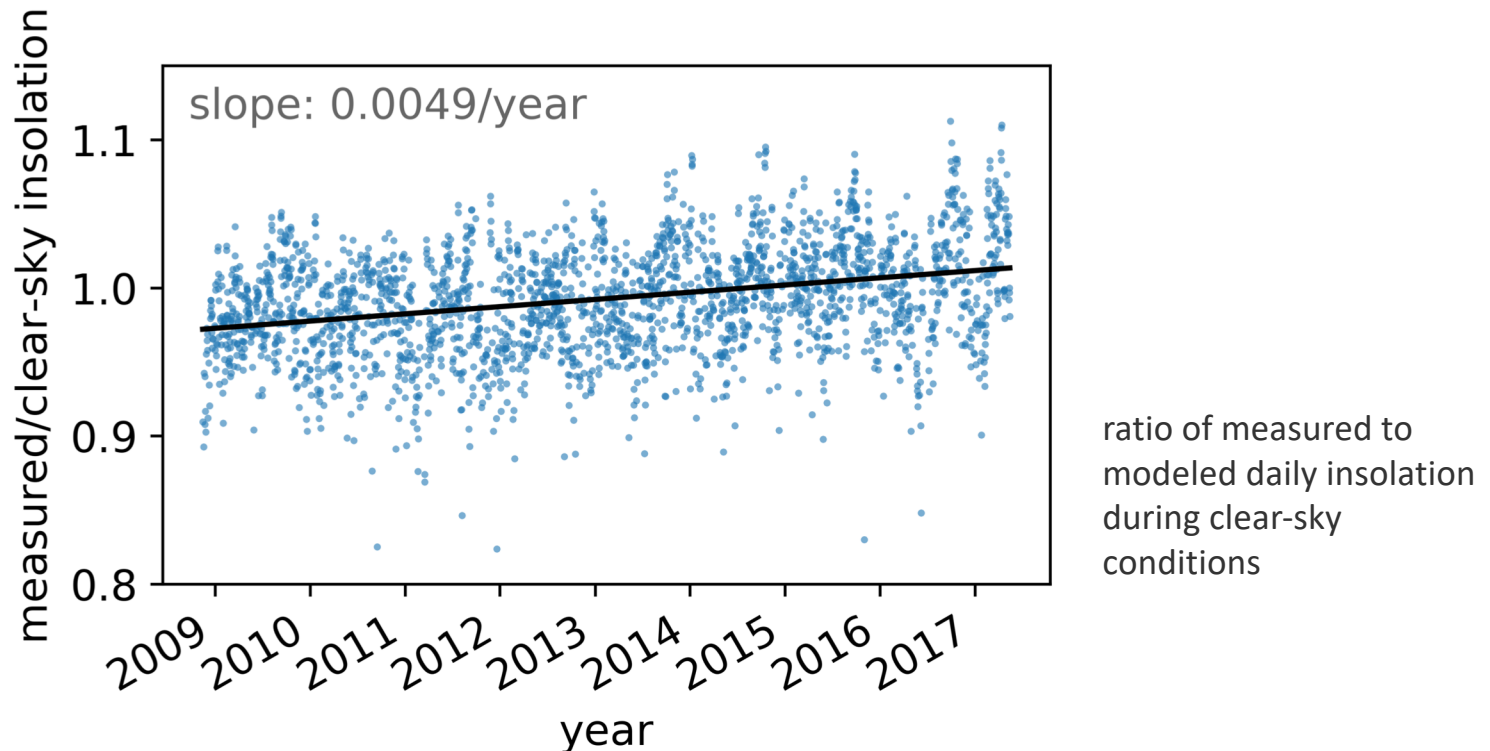
Rd Analysis

- Currently, RdTools provides three Rd calculation methods:
 - Least-squares regression
 - Classical decomposition
 - **Year-on-year**
- Year-on-year is robust to seasonality and outliers
- Don't forget the confidence interval



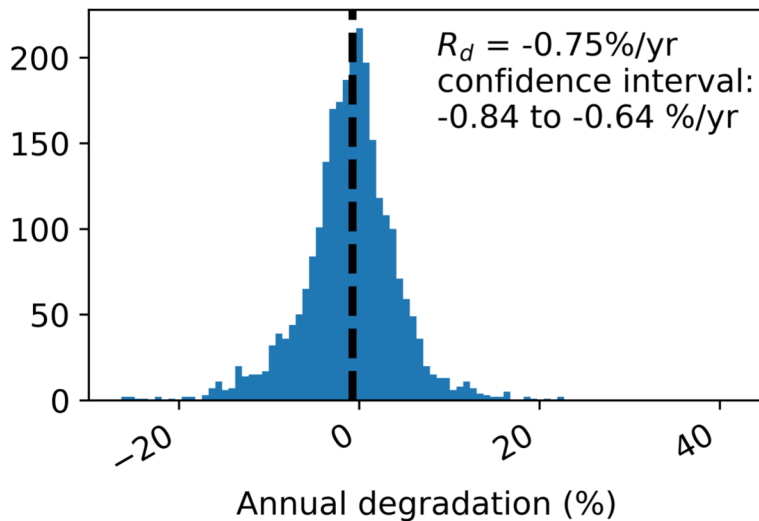
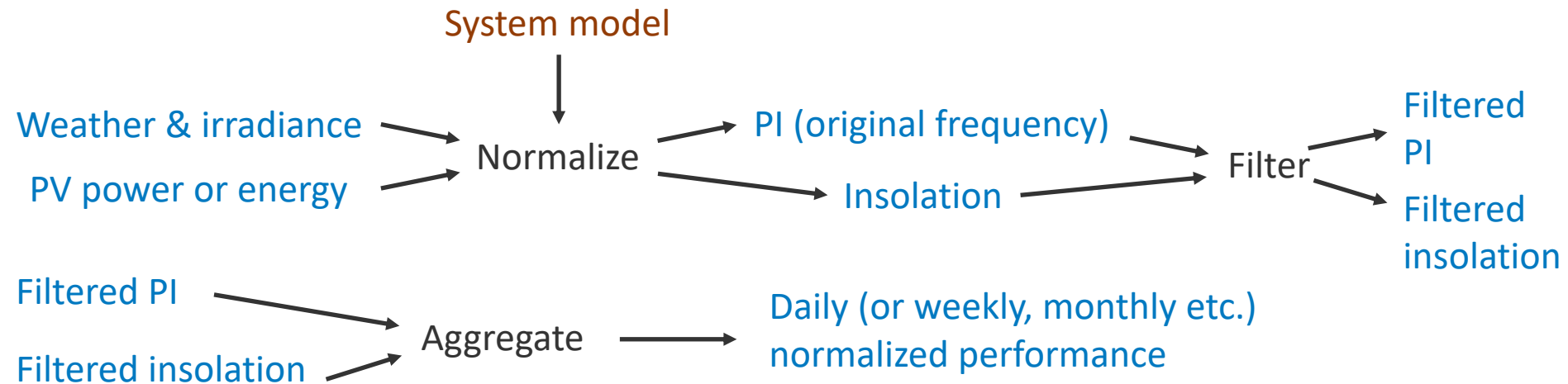
Challenge: Pyranometer bias over time

Irradiance sensor drifts or recalibrations cause artifacts in PI time series thus bias in R_d

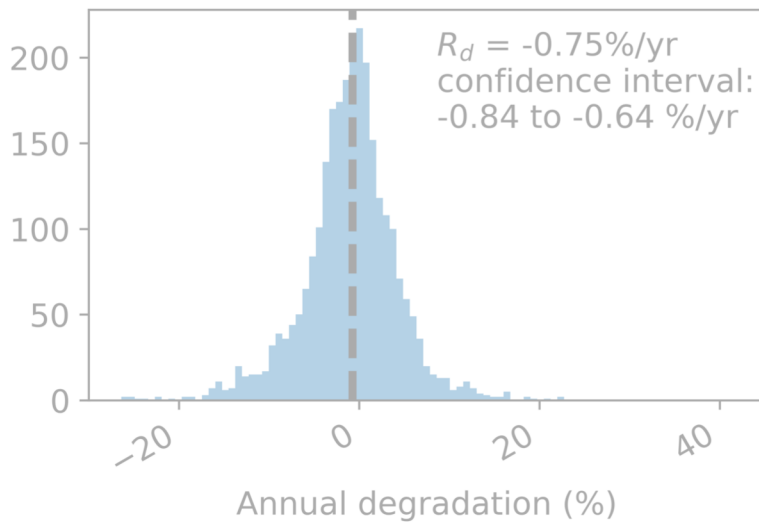
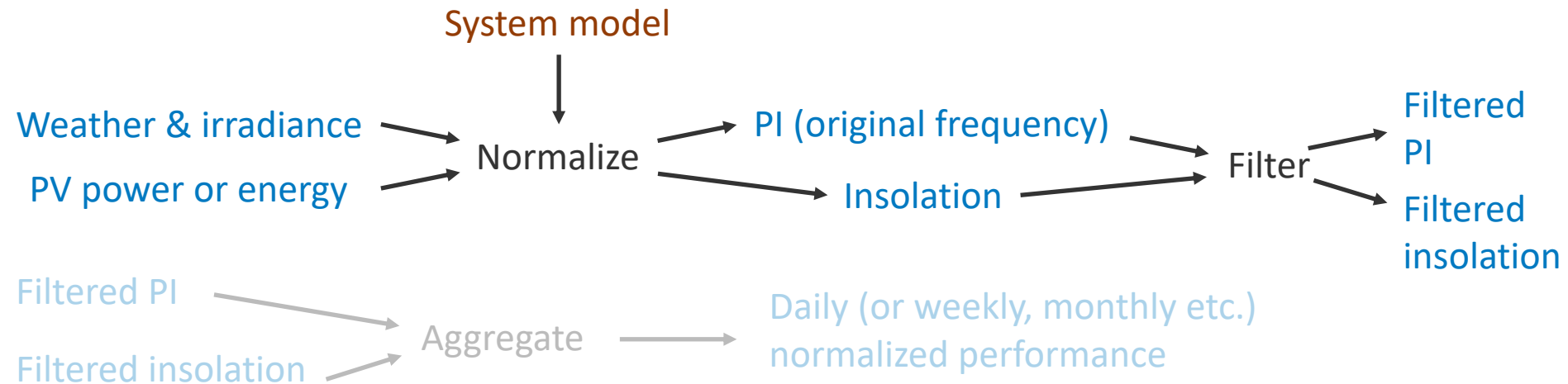


Solution: Normalize using only clear-sky times and modeled irradiance

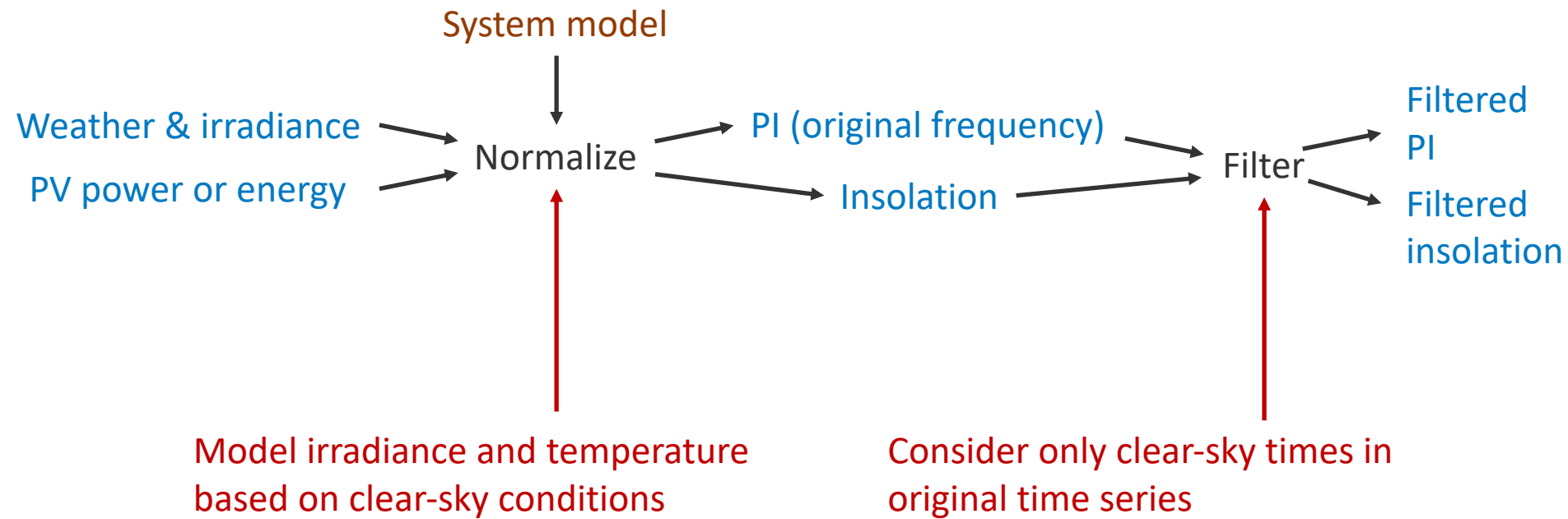
Tool flow



Tool flow



Clear sky approach

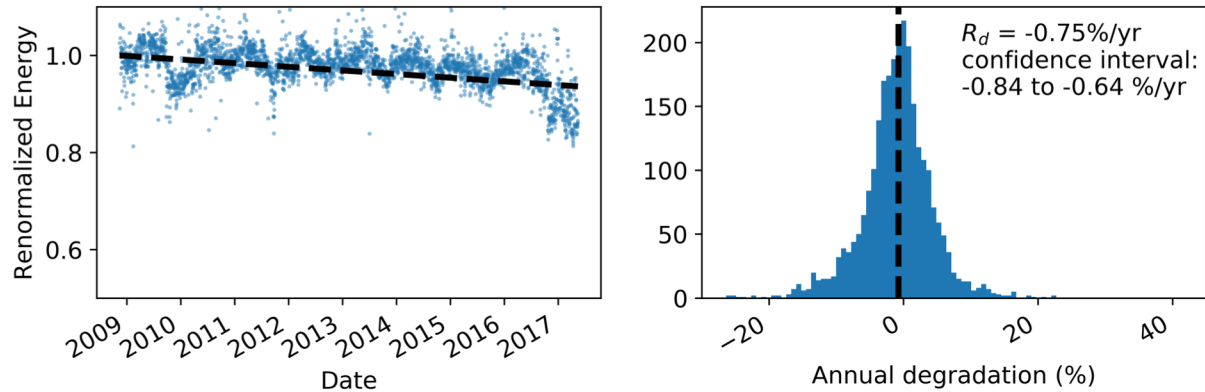


Differences between sensor-based and clear-sky

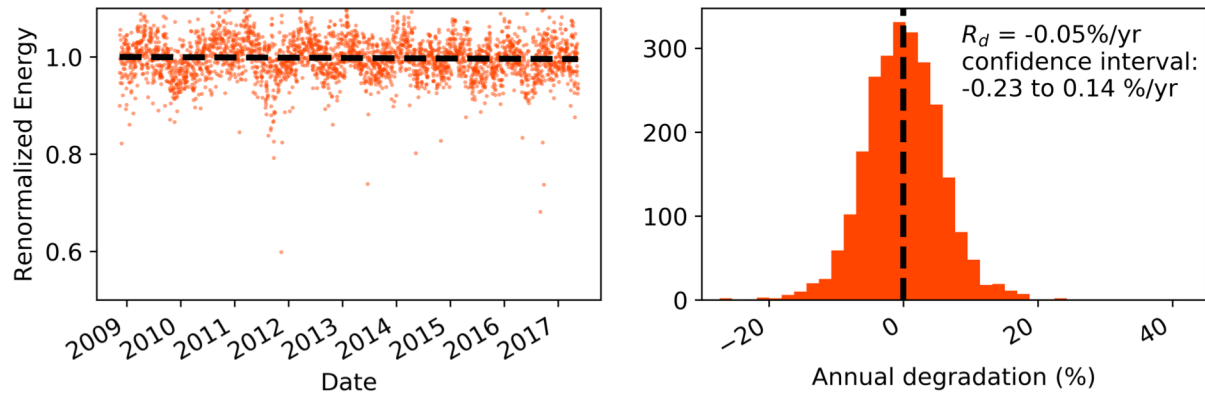
- D. Jordan et al. "Robust PV degradation methodology and application" IEEE JPV 8(2), 2018.
- Kimball, Jordan, and Deline "Clear sky irradiance and temperature models for mitigating sensor drift in PV system degradation analysis" 8th PVPMC 2017.

Clear sky results

Sensor-based degradation results



Clear-sky-based degradation results



Clear-sky approach helps eliminate bias due to sensor drift

Conclusion

- RdTools is an open source python library for PV degradation analysis
 - Expanded analysis of outdoor performance coming soon (soiling, outages, etc.)
- Required data:
 - PV energy/power time series (several years)
 - Weather/irradiance data (consider external sources e.g. NSRDB)
- Precision over accuracy in models and measurements
- Read me and examples: <https://github.com/NREL/rdtools>
- install: pip install rdtools
- Contact: rdtools@nrel.gov

Thank you

- Our contributors on GitHub
- kWh Analytics
- Greg Kimball (SunPower)
- Anubhav Jain and Ben Ellis (LBL)
- DuraMAT Consortium

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