NREL
NATIONAL RENEWABLE ENERGY LABORATORY

PV Soiling Losses: Measurements, Modeling, and Mitigation Strategies

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2022 PV Reliability Workshop

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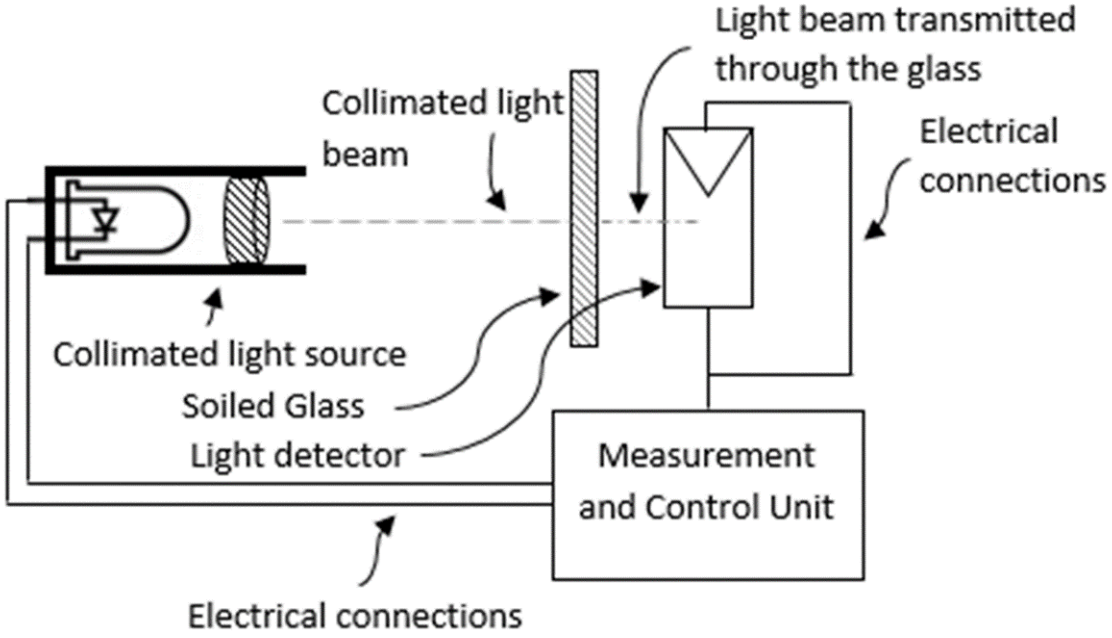
Agenda

- Efforts to develop a low-cost and low-maintenance soiling measurement sensor
- An overview of the NREL soiling map supported by the PVfleets database
- Bio-soiling in rainy southeast US
- Improvement of automated algorithms to extract soiling losses from PV data

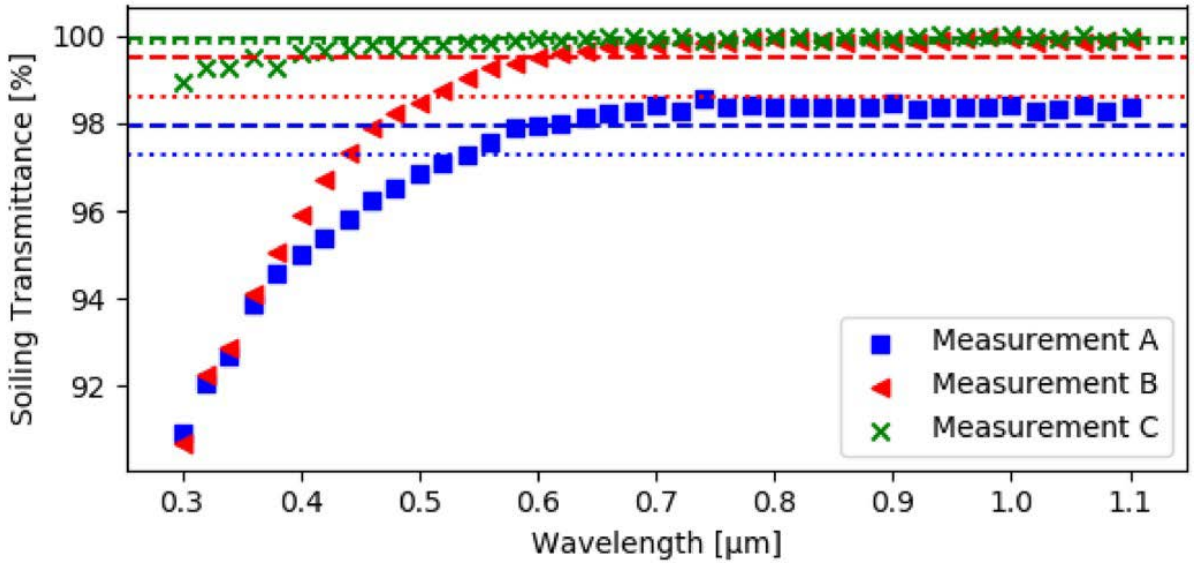
Detector Unit for Soiling Spectral Transmittance (DUSST)



Published patent: August 2020 (NREL and the University of Jaen, Spain)
"Methods and Systems for Determining Soiling on Photovoltaic Devices"

Spectrally resolved soiling

- Graphs: soiling transmittance losses for glass coupons soiled to different levels in Jaen, Spain
- The average values of transmittance (dotted lines), transmittance at 0.6 µm (dashed lines)
- A green LED (0.53 µm) was tested in original DUSST outdoor prototypes
- Currently lab testing 2-3 LEDs of differing wavelengths to reconstruct the soiling spectrum



Atonometrics: Commercialization Work

Outdoor testing is now occurring at 4 locations including a heavy soiling site in Saudi Arabia

ATONOMETRICS

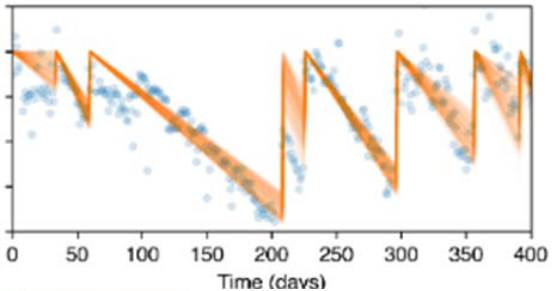
NREL Soiling Map

Selected Location

Site	Measurement type	IWSR	IWSR lower	IWSR upper	Months in data set	Tilt	County	State	Mounti
7135_ac_power_inv_14807	PV System	0.936	0.934	0.938	67.5	0	Kings County	CA	Fixed

Annual Soiling Ratios

Year	IWSR	IWSR lower	IWSR upper
2012	0.957	0.939	0.975
2013	0.941	0.936	0.947
2014	0.905	0.901	0.909
2015	0.954	0.951	0.957
2016	0.919	0.915	0.924
2017	0.943	0.938	0.948



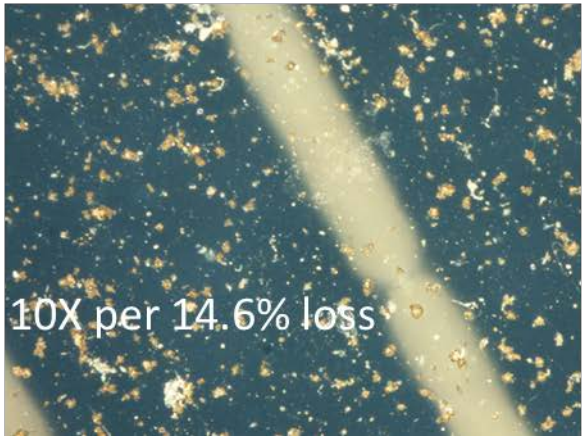
Monthly Soiling Rates

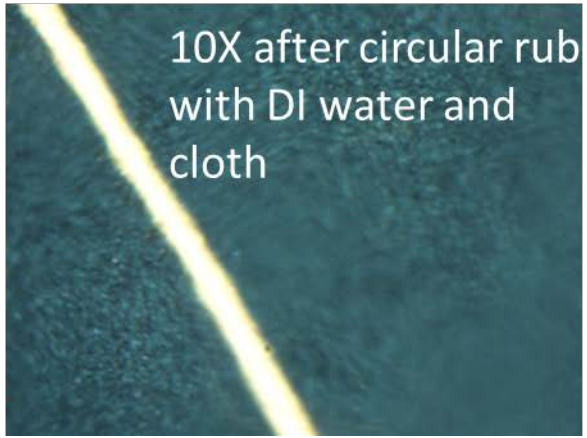
Month	Soiling rate	Soiling rate lower	Soiling rate upper	Interva count
Jan	-0.003	-0.0033	-0.0027	1
Feb		Insufficient data		
Mar	-0.0014	-0.0028	-0.0007	3
Apr	-0.0022	-0.0044	-0.0009	6
May	-0.0024	-0.0047	-0.001	6
Jun	-0.0024	-0.0044	-0.0013	7
Jul	-0.0026	-0.0046	-0.0015	7
Aug	-0.0034	-0.0068	-0.0015	7
Sep	-0.0062	-0.0088	-0.0029	8
Oct	-0.0063	-0.0098	-0.0033	8
Nov	-0.0036	-0.01	-0.0012	5
Dec	-0.003	-0.0046	-0.0022	3

https://www.nrel.gov/pv/soiling.html

Bio-soiling in the Southeast USA

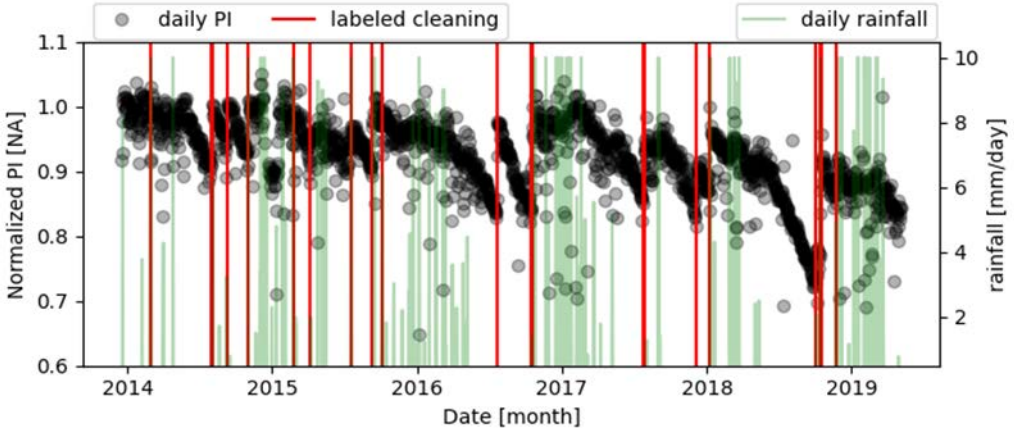
- S.E. US site has regular rainfall, no major nearby pollution
- Unexpected losses→ site visit→ found black mold; modules sent to NREL
- In comparison to a new module the bio-soiled modules down 13.4% and 14.6%
- We sprayed the 14.6% module with hose water and remeasured at 12.9% losses
- We then applied soft bristle brush and hose water now found 8.1% losses
- Awaiting new microscopic images before further cleaning





Improvements to Soiling Cleaning Detection

- Rdtools Stochastic Rate and Recovery (SRR) model detects cleanings per positive shifts in the rolling median that are above a user set factor times the interquartile range
- Experience per the fleets data set as well as discussions with other researchers has shown that users must vary the factor per the noise in the data set. Additionally known cleanings are sometimes missed as well false identifications of cleanings that are shifts due other behavior in the PV time series
- 22 systems from the PV fleets were identified for soiling trends and several expert analysts labeled the data sets for cleanings per an agreed rubric.
- The labeled data sets are being shared per the Duramat data hub
- Adaptations to SRR as well a change point detection algorithms were tested and quantified per the F1 score for improving cleaning detection



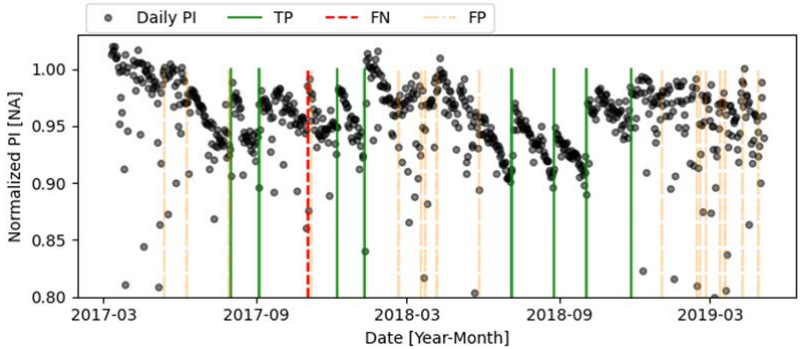
M. Muller et al, “Automated PV system cleaning detection: a performance comparison of techniques as applied to a broad set of labeled PV data sets”, Progress in PV, 2022

Improvements to Soiling Cleaning Detection

- Baseline F_1 from SRR default parameters is 0.36
- The Table to the right shows improvements in the F_1 for various model adaptations

Filter type	***Algorithm Variation***					
	SRR-IQR		***SRR-MAD***		***Ruptures-Window***	
	parameters	***F_1***	***parameters***	***F_1***	***parameters***	***F_1***
None	*DS=17, α=7.5	0.63	DS=13, β=1.5	0.72	DS=9, width=4, penalty=2	0.55
Rolling Window	DS=13, α=7.0	0.75	DS=13, β=1.75	0.77	DS=13, width=2, penalty=1	0.56
Irradiance	DS=13, α=7.0	0.76	DS=13, β=1.75	0.79	DS=9, width=5, penalty=2	0.50

Baseline results for one system show a large number of false positives (orange dashed lines)



The SRR-MAD model shows significant improvement, no false positives but still one missed cleaning in red