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Time series analysis of PV soiling station data

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Background

- Soiling is the accumulation of particulate on the surface of PV modules.
- Output losses as a result of soiling are between 0 and 6% [1-4] in the USA, while more dust prone regions report annual losses of between 20 and 70% [5-7]
- **Soiling stations** are made out of at least two PV modules, with one module remaining cleaned, while the other remains soiled. The relevant data collected by the stations included short circuit current data, and angle of irradiance

Algorithm Design

Soiling ratio is obtained by dividing daily unwashed current by daily washed current (Eq. 1); low irradiance filtered out

The median-filtered soiling ratio is calculated, initially forward-filling and then removing any missing values.

An offset is applied, such that the mean of the first week is equal to 1. This offset is then propagated until another offset is needed.

At each specified offset date the prior process is repeated. Once the offsets are applied the soiling rate can be calculated.

The soiling rate is derived through the use of Theil – Sen regression, about interval of dryness > 14 days.

$$daily\ SRatio(i) = \frac{Isc_{soilied(i)}}{Isc_{cleaned(i)}}$$

Eq 1: Where $Isc_{soilied(i)}$ and $Isc_{cleaned(i)}$ are the irradiance-corrected short-circuit current, as stated in Eq. 2, for the soiled as well as cleaned modules

$$Isc(i) = \frac{\sum_{h=12}^{13} Isc_h(h) \cdot \frac{1000\ w/m^2}{POA(h)}}{n}$$

Eq 2: Where *POA* is the plane of irradiance, Isc_h is the hourly average current, and *n* is the number of hours considered during the calculation

Data Analysis

Site 21 – Fresno County, CA

Soiling Ratio = 95.9% | Soiling Rate = -0.9%/day

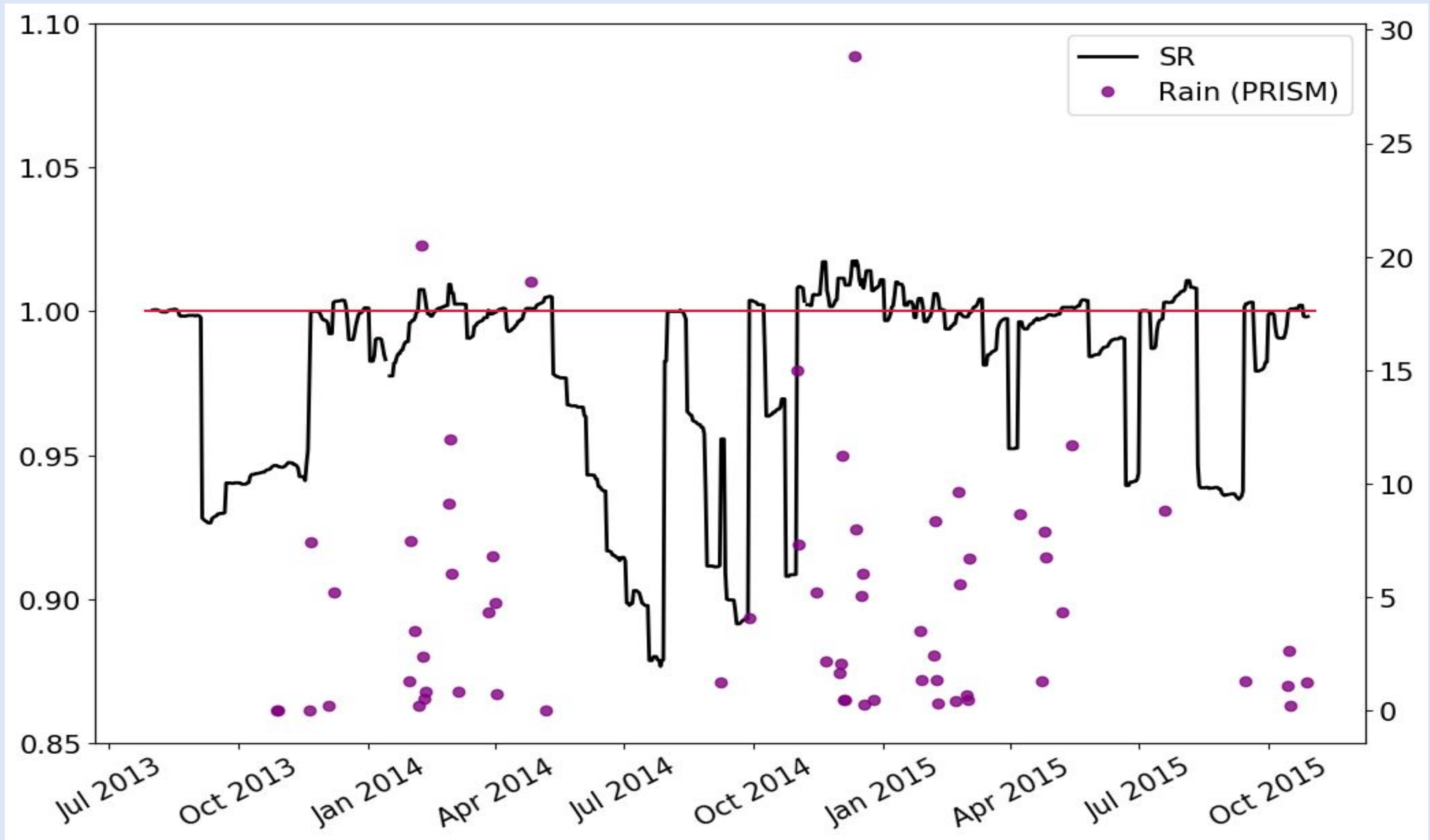

Fig 1: Site 21 depicts heavy soiling during intervals in which there is little rain, as well as seasonality in the summer months

Site 27 – Howard County, MD

Soiling Ratio > 99% | Soiling Rate < -0.01%/day

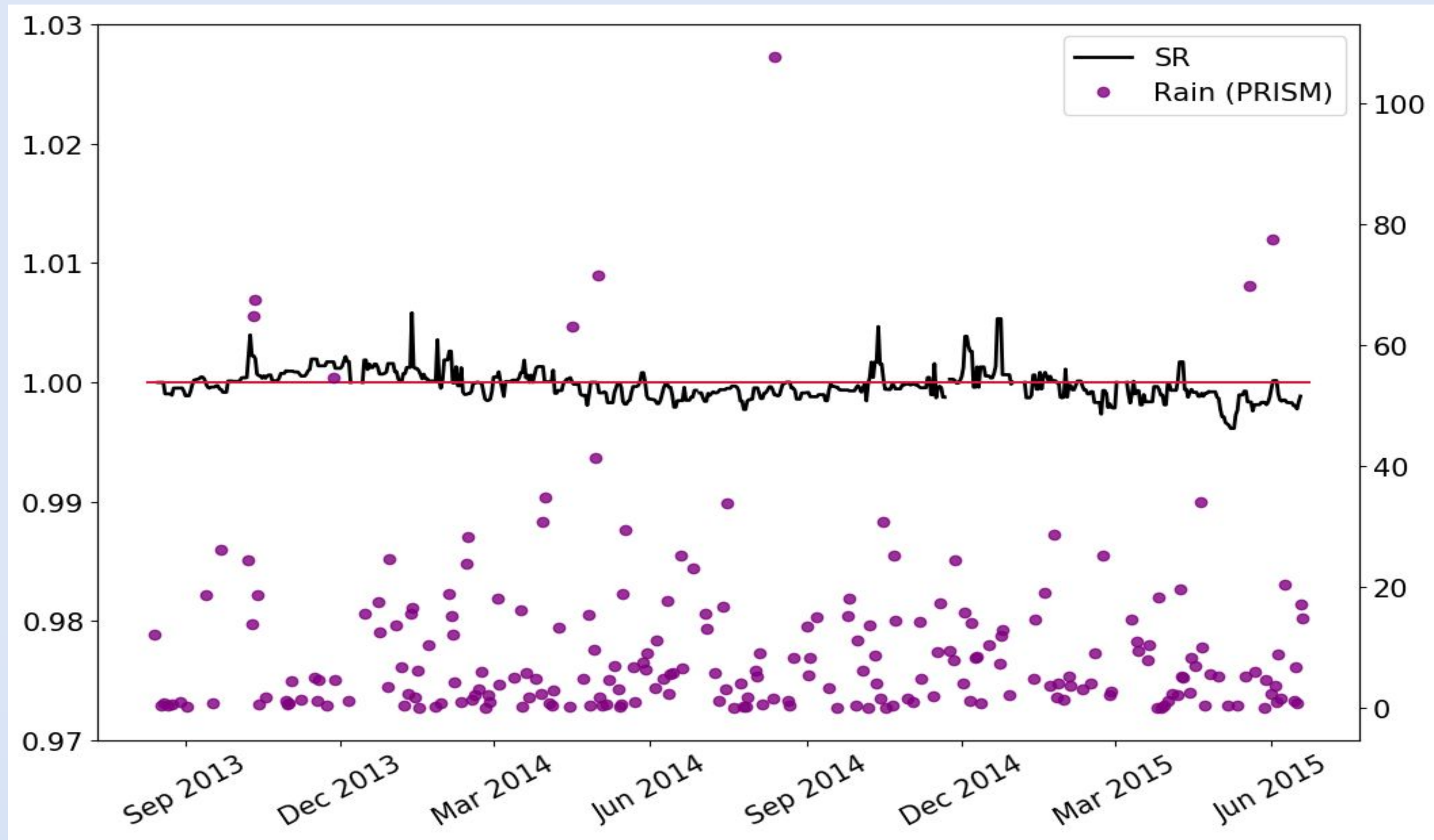

Fig 2: Site 27 shows the impact that consistent rain has on soiling ratio

Site 3a – Imperial County, CA

Soiling Ratio #1 = 97.5% | Soiling Ratio #2 = 97.3%

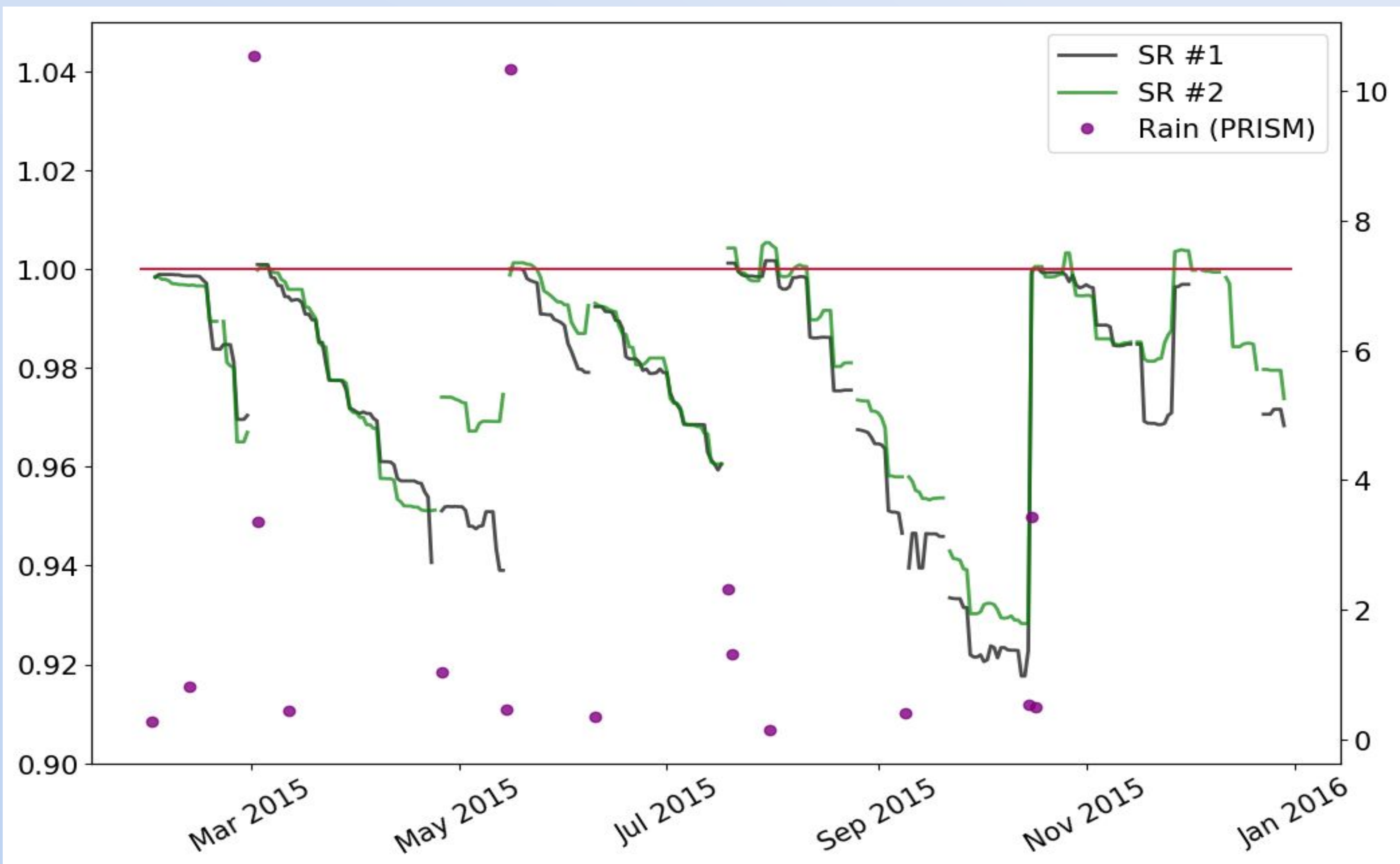

Fig 3: Non-uniform soiling analysis, in which two different soiling station within the same PV system are compared

Results and Discussion

- **Seasonality** (variation of soiling with the different seasons): the seasonal soiling profile of Fig. 1 can clearly be contrasted by Fig. 2, which shows a consistent soiling ratio all year round.
- Fig. 3 shows a plot used to investigate **non-uniformity**. Fig. 3 does not show significant non-uniformity, however this is not true in all cases investigated.
- The investigation of phenomena such as seasonality and non-uniformity, as well as the free access to the time series, made available on an **upcoming NREL report**, can be used by the PV community to understand how new PV sites will soil.

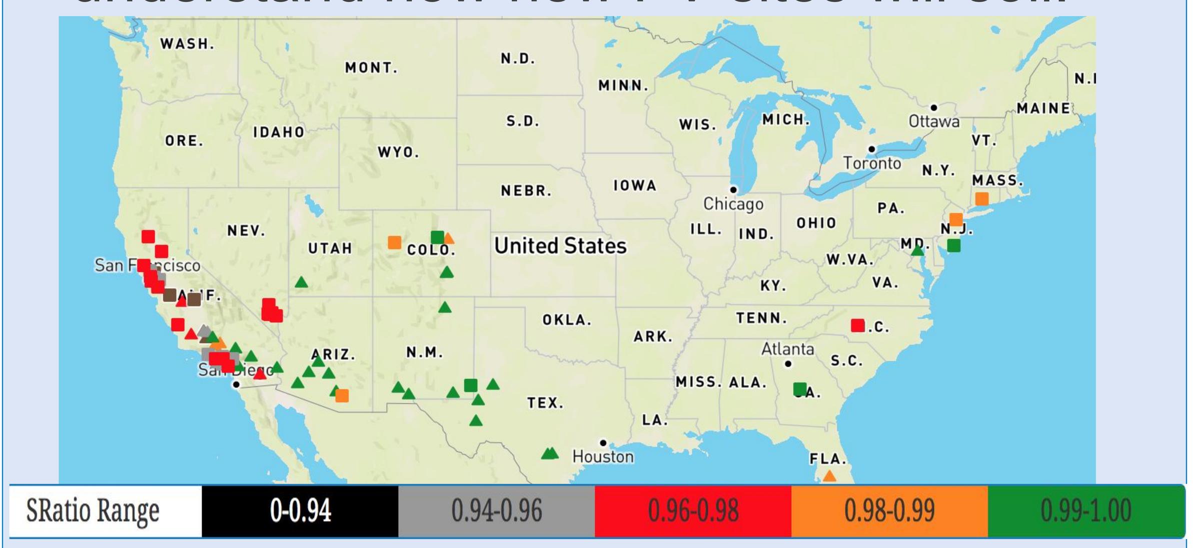

Fig 4: 80 sites, including the 46 sites analyzed, available at https://www.nrel.gov/pv/soiling.html

Future Work

- Continue the analysis of soiling profiles as more sites become available to NREL
- Further examine the metrics that contribute to non-uniform soiling

Acknowledgements

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