



Soiling Inputs for the Kimber dust soiling model derived from soiling measurements

Authors: Nate Croft, Annalise Miller
Affiliations: Luminate LLC

Introduction

The Kimber model⁽¹⁾ is widely used in the PV modeling industry to estimate soiling losses due to dust accumulation. While the model is relatively easy to apply to publicly available precipitation data, it relies on user inputs such as soiling rate and cleaning threshold. This research provides guidance on input values to the Kimber model based measured soiling data, as a function of geographical location across the continental US.

Methods

We used measured soiling data at one-minute resolution for 11 locations across the US. The data was collected by measuring short circuit current of two modules, one soiled and one that is regularly cleaned. From these values a soiling ratio could be calculated. We reviewed and cleaned the data and re-sampled to one-day resolution based only on mid-day values. We then used the daily sampled soiling ratios and rainfall data to identify appropriate Kimber model inputs.

We first estimated cleaning thresholds, or precipitation totals that cleaned the soiling, by iterating through the precipitation data and finding the level of rainfall that best matched observable soiling resets. We then determined soiling accumulation rates by taking the soiling ratios between cleaning events and using linear regression to find the slope that best fit the data.

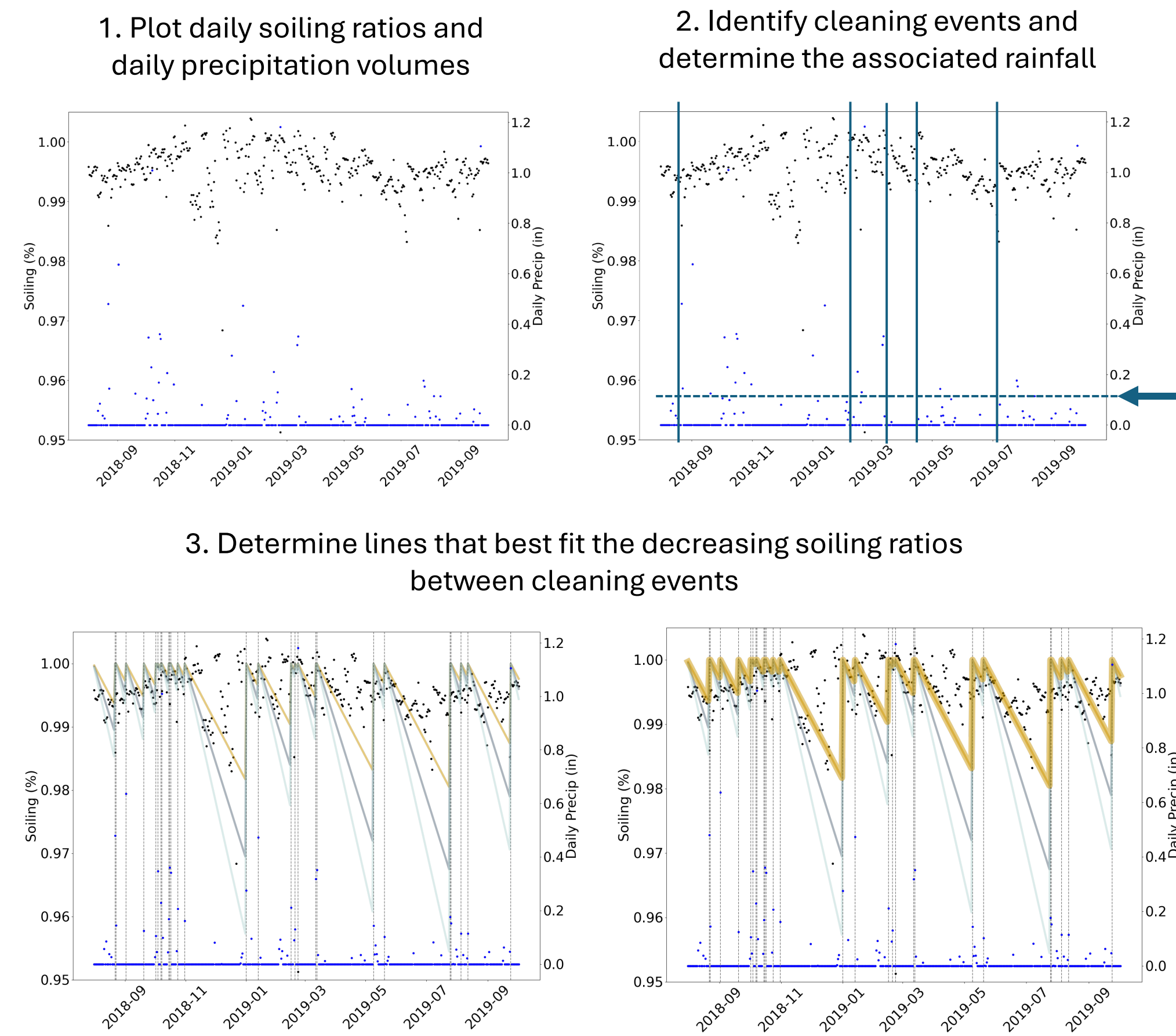


Figure 1: Steps through the process to estimate cleaning events and the rate of soiling from the datasets

We do note that soiling data has a high degree of noise and estimating parameters from it to fit a model is uncertain. However, we believe these values can be informative and help provide guidance on reasonable soiling estimates for PV systems across the US.

Results

We observed that in desert regions where one expects finer, sandy soils, the amount of rain that induced a cleaning event was about 1 mm, which is consistent with some previous research^(2,3). Outside of this region, the amount of daily rainfall to create a cleaning event was 5-13 mm.

Region	Soiling Rate (%/day)	Cleaning Threshold (mm)
MW	0.04	8
MW	0.03	13
SE	0.03	10
SE	0.03	5
SE	0.03	8
SW Desert	0.03	1
SW Desert	0.03	1
SW Desert	0.05	2
SW Desert	0.04	1
SW Desert	0.04	1
W Great Basin Desert	0.02	1

Table 1: Estimated soiling rates and cleaning thresholds for each test area

Soiling rates were generally consistent across regions, averaging about 0.04% per day. This was contrary to our expectations that drier areas would accumulate soiling at higher rates. We did not observe any grace periods, or time after a cleaning event where soiling does not start accumulating, in the data.

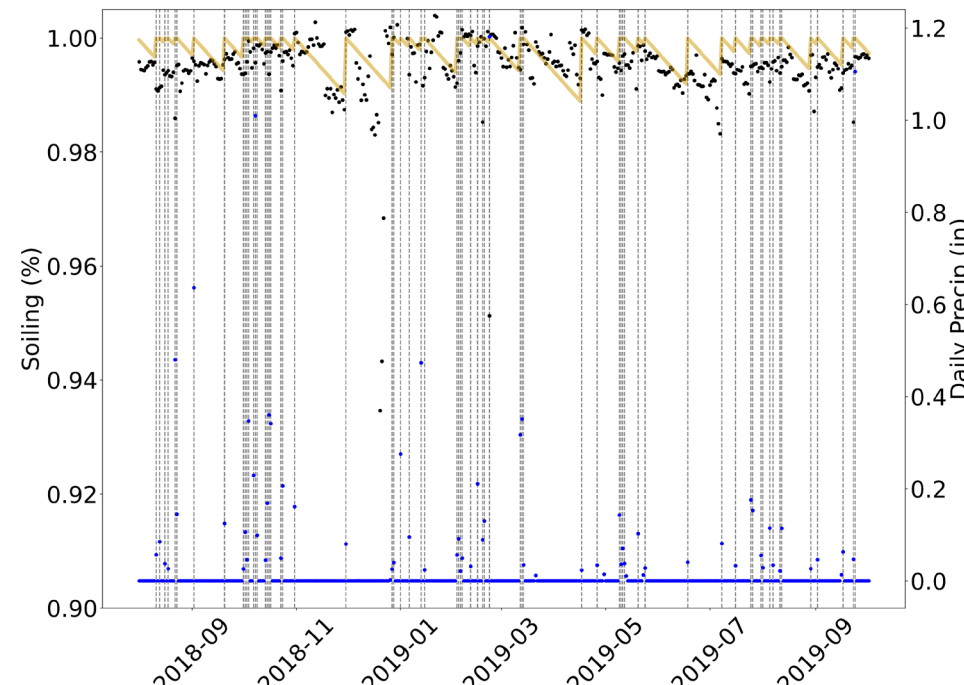


Figure 2: Plot of estimated soiling rate

Not all cleaning events fully reset soiling to 100 percent. There were many observable partial resets, where soiling did decrease, but began accumulating again from a state of partial soiling.

Conclusions

While soiling accumulation rates are relatively consistent, rainfall thresholds vary. Variation in rainfall thresholds may be related to local soil type. Additionally, cleaning events do not always fully clean modules, and we did not review data for areas where soiling due to pollen has been shown to not recover with regular rainfall⁽⁴⁾.

When using the Kimber model for soiling estimates, we recommend removing grace period accommodations. Further, in the absence of measured soiling data, we estimate a 0.04% soiling increase per day with a 1 mm cleaning threshold in the desert southwest and a 0.03% soiling increase per day with a cleaning threshold of 6 mm or more for other regions. In addition, we believe it is prudent to account for the fact that not all cleaning events fully reset the soiling to 0.0%. To account for this, we recommend a post-rain event soiling value of 0.5% when modeling soiling.

References

- Kimber, A. & Mitchell, L. & Nogradi, S. & Wenger, H.. (2006). The Effect of Soiling on Large Grid-Connected Photovoltaic Systems in California and the Southwest Region of the United States. Conference Record of the 2006 IEEE 4th World Conference on Photovoltaic Energy Conversion. 2. 2391 - 2395. 10.1109/WCPEC.2006.279690.
- Caron, J. & Littmann, Bodo. (2013). Direct Monitoring of Energy Lost Due to Soiling on First Solar Modules in California. Photovoltaics, IEEE Journal of. 3. 336-340. 10.1109/JPHOTOV.2012.2216859.
- Micheli, Leonardo, Muller, Matthew T., Deceglie, Michael G., & Ruth, Daniel (2017). Time Series Analysis of Photovoltaic Soiling Station Data: Version 1.0, August 2017. <https://doi.org/10.2172/1390775>
- Muller, M., Bessa, J., Valerino, M., Deceglie, M., & Anderson, K. (2023). Pollen and Bio-Soiling in the Southeast U.S. <https://www.nrel.gov/docs/fy23osti/85783.pdf>