

PV Soiling Measurements: Cleaning Optimization and Mitigation

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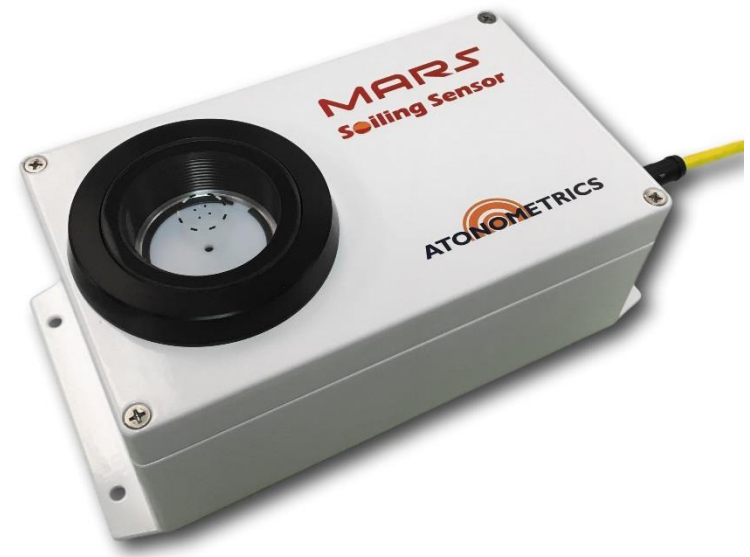
May 16, 2019

www.atonometrics.com



About Atonometrics

- **Test & measurement** equipment for the PV industry
- A leader in **soiling measurement systems**
- Provided **1000 systems** worldwide on **~200 sites**
- Founded in 2007 and based in Austin, Texas, USA
- **Patents:** 6 issued, 5 pending
- New Product: **Mars™** Optical Soiling Sensor



Who Measures Soiling and Why?

Developers

- **Predict** future plant performance
- Maximize **Financing**

Independent Engineers

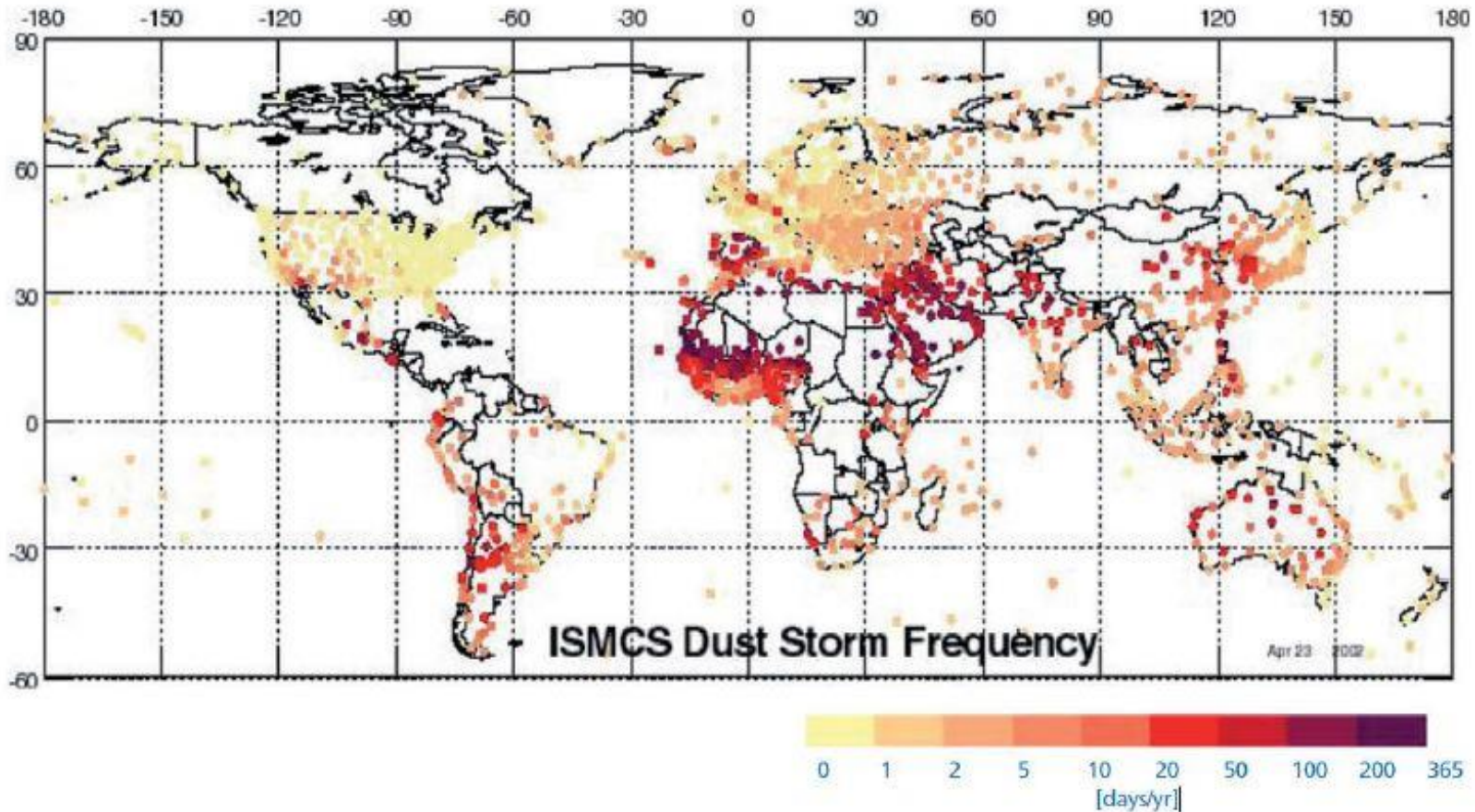
- Long term use in Energy **Forecasting** Models
- Short term use for **Capacity** tests

O&M

- **Assess** actual performance
- **Optimize** washing schedule / ROI



Dirty Regions



[Tegen et al., "Relative Importance of climate and land use in determining present and future global soil dust emission", *Geophysical Research Letters* 31, 2004]

Power Plant Correlation – 5 CdTe Plants Worldwide

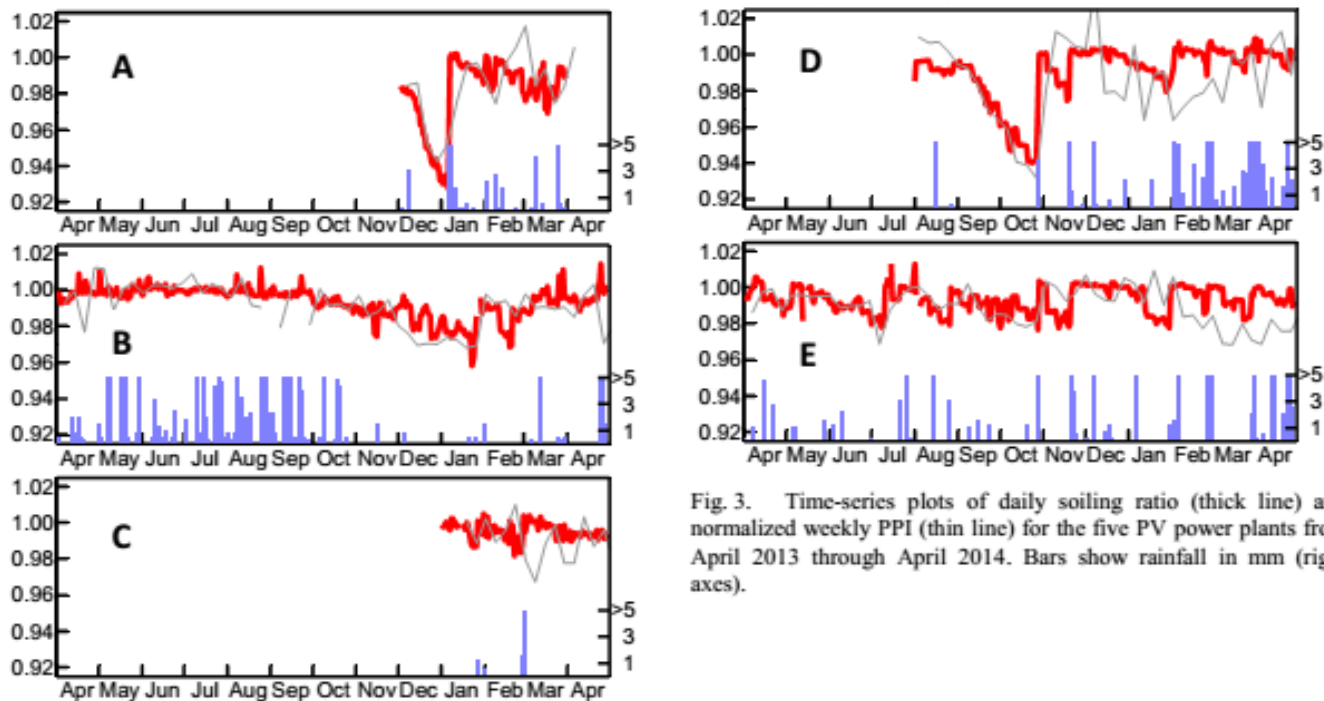
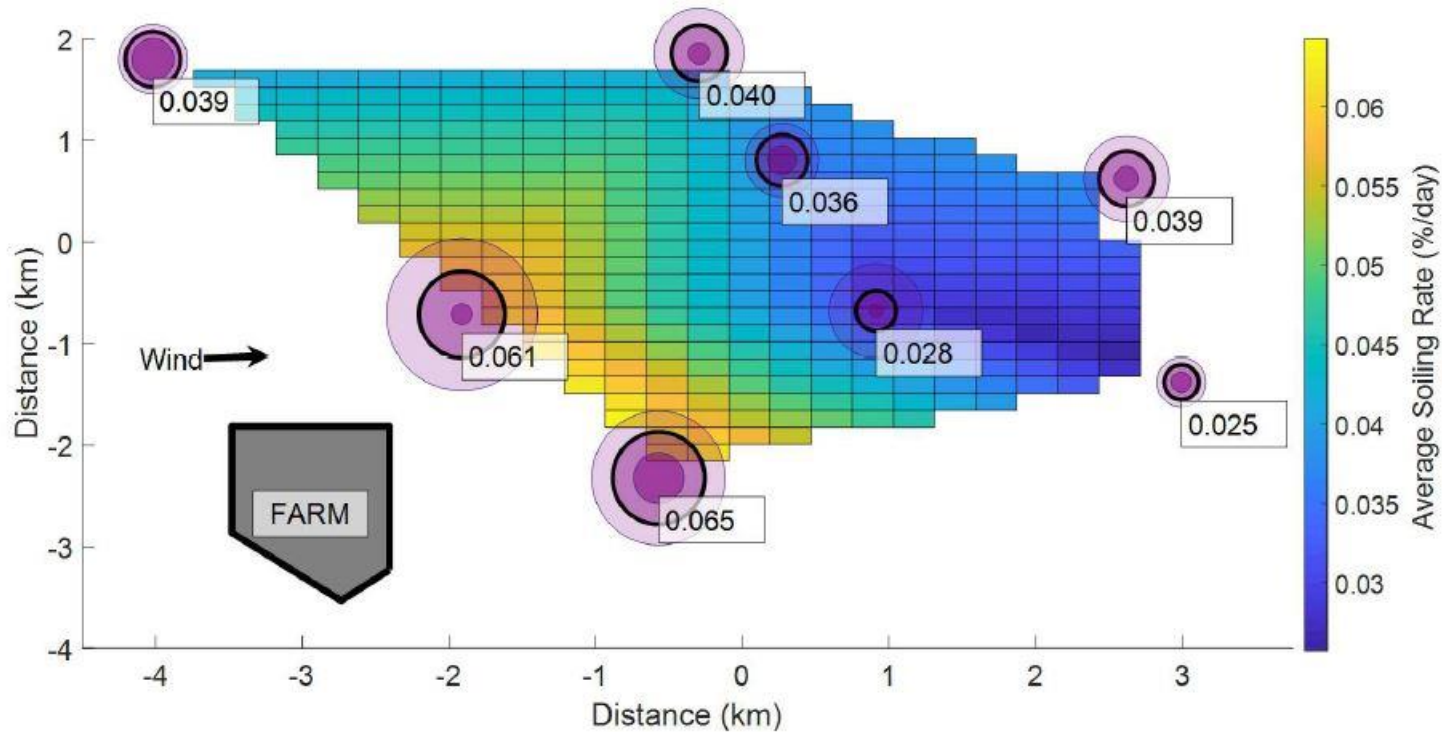


Fig. 3. Time-series plots of daily soiling ratio (thick line) and normalized weekly PPI (thin line) for the five PV power plants from April 2013 through April 2014. Bars show rainfall in mm (right axes).

Gostein¹, Caron², Littmann², IEEE PVSC, 2014

¹Atonometrics. ²First Solar

Power Plant Correlation – Within-site Variability

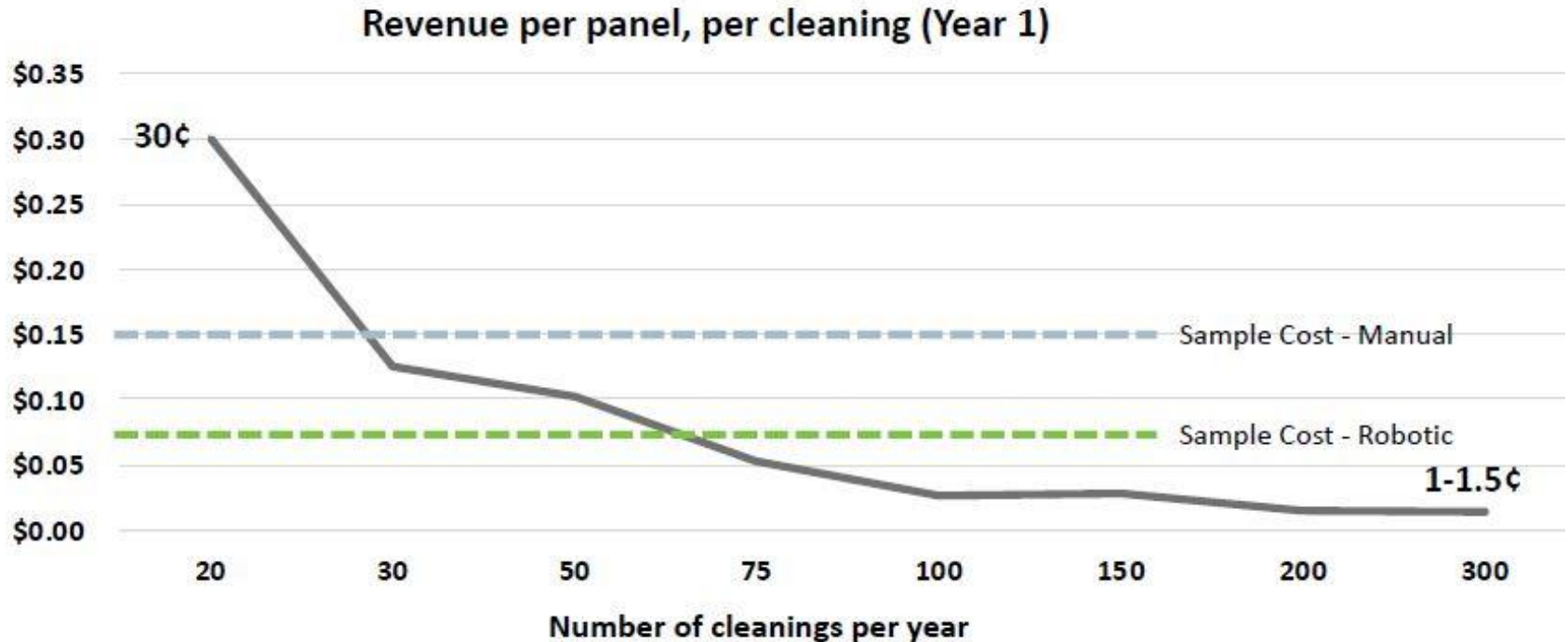


Gostein¹, Passow², Deceglie³, Micheli³ Stueve¹, EU PVSEC, 2018
¹Atonometrics. ²First Solar, ³NREL

Optimization

- **Cost of cleaning**
- **Schedule**

Cleaning Cost Optimization



Depends on soiling rate, cleaning cost, electricity price, etc.

Source: SunPower

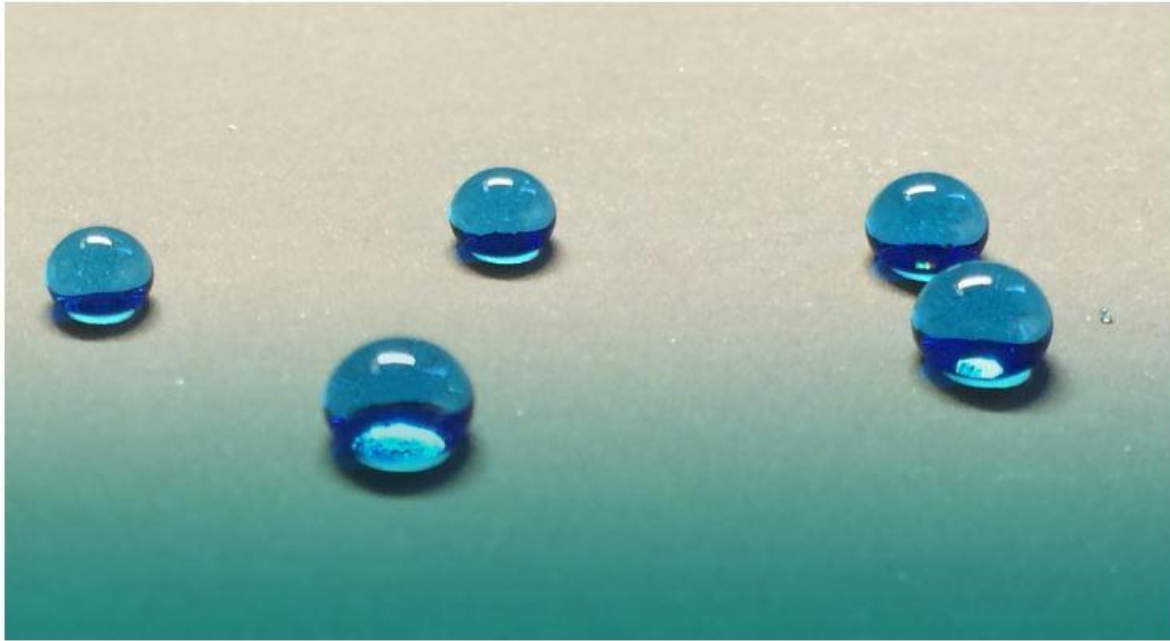
Soiling Mitigation

- Nature
- Coatings
- Cleaning
- Measuring

Cleaning Strategies - Nature



Coatings – Anti-Soiling



Source: Lotus Leaf

Cleaning

Cleaning Strategies - Manual



Source: Energy Guru

Cleaning Strategies - Automated



Source: PI Berlin



Cleaning Technology – CSP



COURTESY OF ABENGOA



Cleaning Guideline Summary (FS ARC modules)

- To ensure warranty coverage, First Solar must review and approve
- Clean modules only when in open circuit
- Wet contact cleaning (squeegees, sponges, cloths, etc.) is prohibited
- Hard water is prohibited
- Dry cleaning with anything other than soft cloths or mops is prohibited



Measuring

Soiling Measurement Sensors

- Optical Sensors
- Dual PV Devices

PV Plant Measurement Strategies - Utility

- Two **PV devices** is common, 1 “cleaned” and 1 “naturally soiling”
- Configurations: 2 modules, 2 cells, or 1 cell and 1 module
- The module is **dedicated** (not a power producing module)
- **P_{max}** measurements on the “soiled” module
- Optical sensors are gaining acceptance



PV Plant Measurement Strategies - Commercial

- Smaller sites and lower budgets
- Need soiling measurements that are:
 - Low cost
 - No maintenance
 - No calibrations
 - No water



PV Plant Measurement Strategies - Concentrating

- Large sites
- Need soiling measurements that are:
 - Low cost
 - Many sensors



Conclusion

- Measuring is the first step
- Optimizing and Mitigation is then based on:
 - Amount of Soiling
 - PV Plant Revenue
 - Cleaning costs
- Come see us in the Campbell Scientific booth
B2.658