Building an Advanced
Soiling Loss Model
with AI and Ground-Level Data



By: Catlin Mattheis

CONTENTS

01 Intro

02 Soiling Loss Measurement/The Fracsun Approach

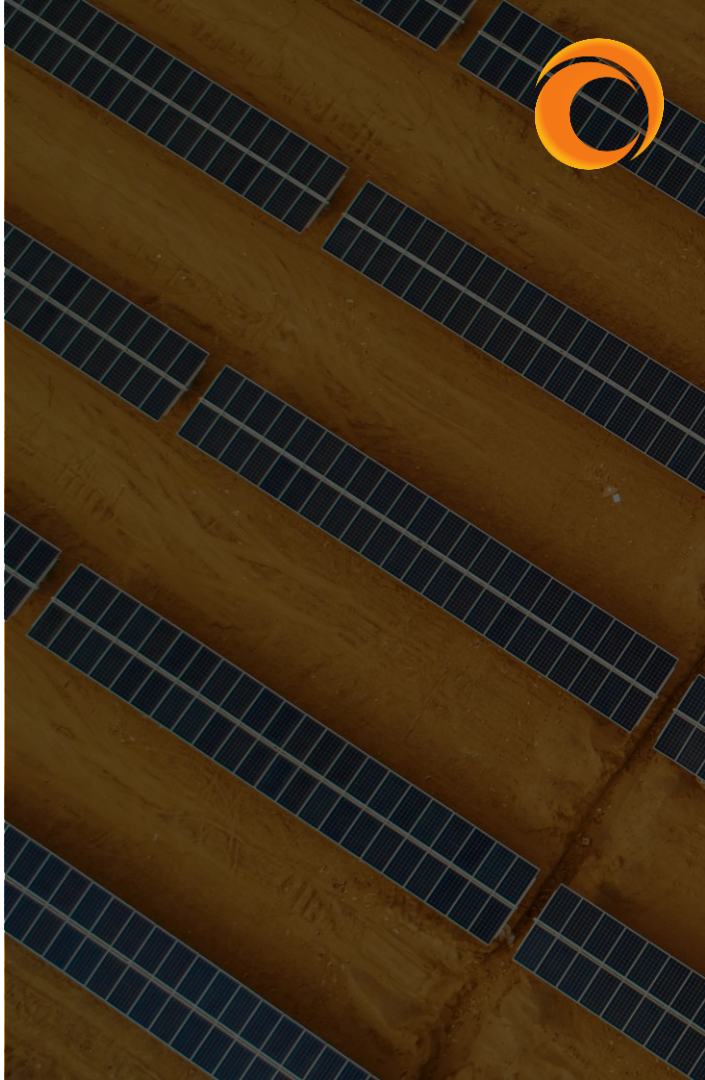
03 Additional Data Requirements

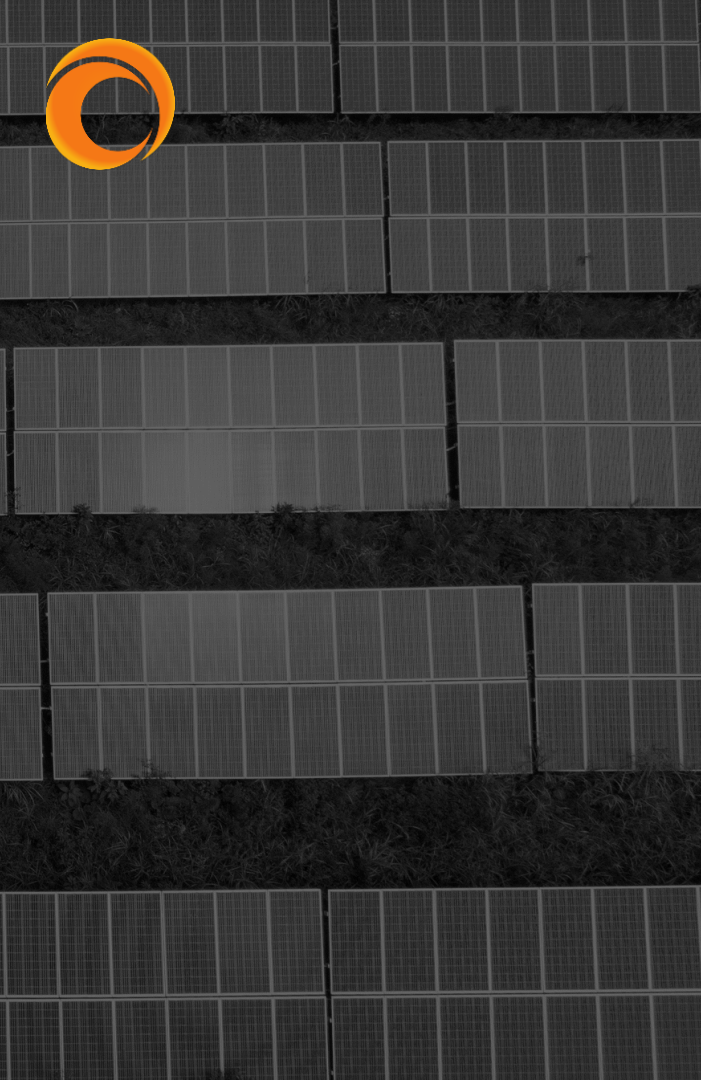
04 Training The AI

05 Model Data Flow

06 Results

07 Future Model Improvements





A BRIEF HISTORY

- 2007 : Best guess values in PVsyst
- 2009 : Very rough monthly soiling values
- 2012 : Fracsun 1st prototype
- 2016 : Method 2 i_sc proof of concept
- 2017 : DOE SBIR – 25 → 40 field POCs
- 2018 : First commercial ARES Soiling Stations Deployed
- 2024 : Soiling stations in 27 countries on 12GW+

MEASURING SOILING LOSS

IEC 61724-1
This standard offers a structured methodology for quantifying the impact of dirt, dust, and debris accumulation on PV modules

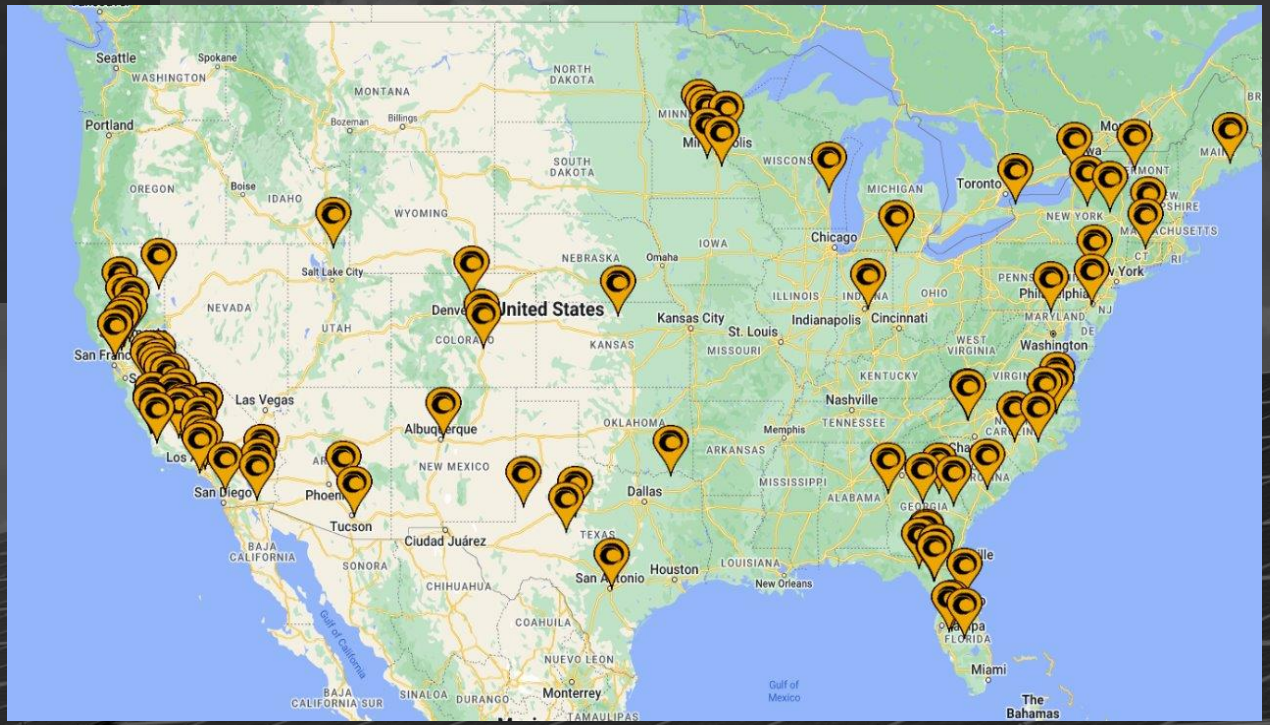
1. Electrical Methods

    A. Short Circuit
    B. Power
    C. Cells vs. Whole Modules

2. Optical Methods



MEASURING SOILING LOSS



ADDITIONAL DATA NEEDED

01



Particulate Matter

One of the major contributors to soiling loss accumulation but data is scattered.

02



Precipitation

Without getting too deep into the controversy, in general, any resetting events are caused by rain to get us at least closer to zero. But how close?

03



Nitrates & Sulfates

Studies in the literature have shown cementation effects correlating to these levels. Is it predictable?

04



Soiling Accumulation Rate

The Fracsun soiling loss database now allows us to look at accumulation rates across the US to incorporate into the model. No more guessing.

05



Wind

A double-edged sword in the soiling loss equation. When soiling loss is high, is can help remove material. When soiling loss is low, it can exacerbate.

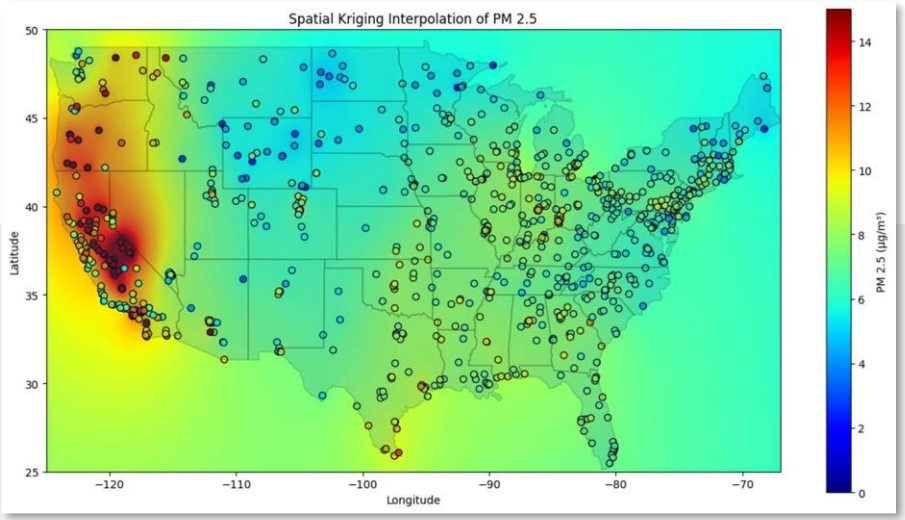
06

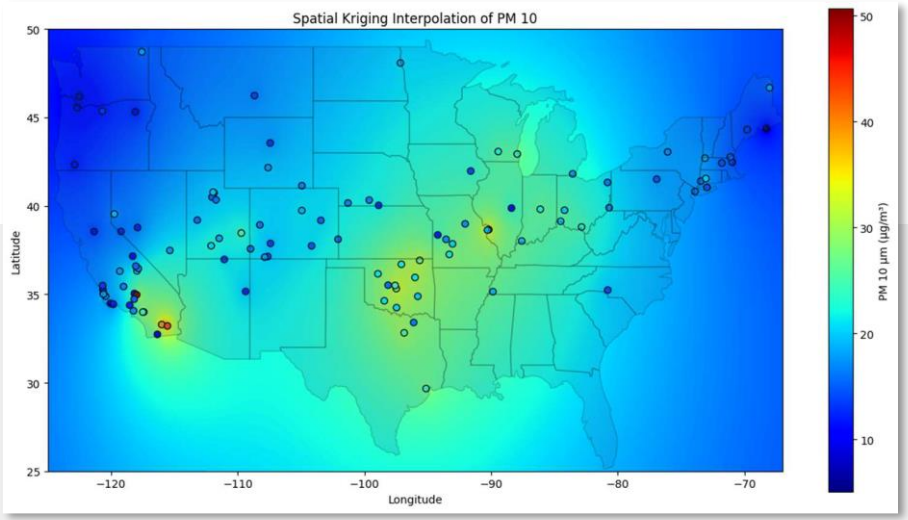


Seasonal Changes

Taking all this into account and then looking at how the data changes throughout the year due to seasonality.

KRIGING SPATIAL MODELING



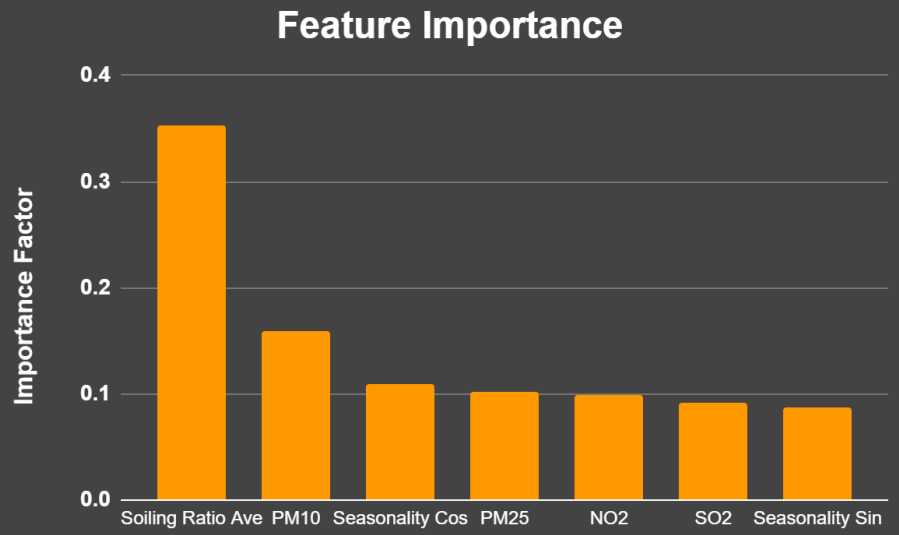


TRAINING THE AI

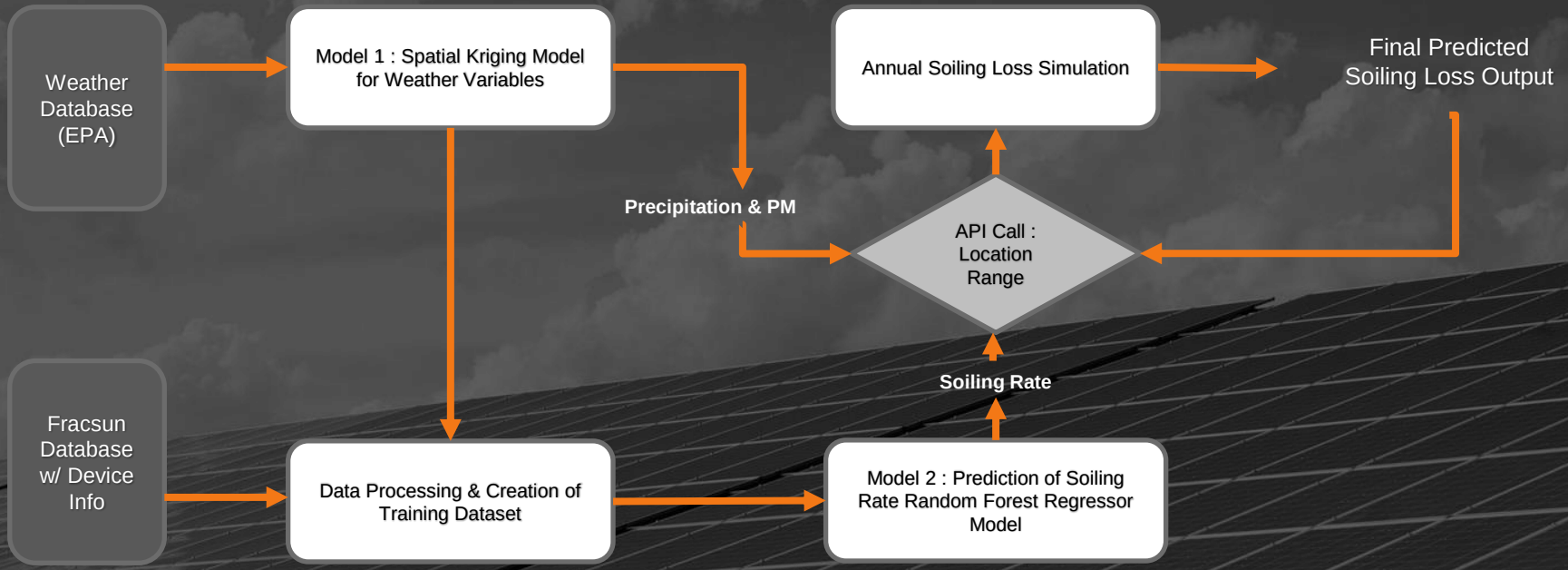
Identifying parameters that have the greatest impact on soiling loss.

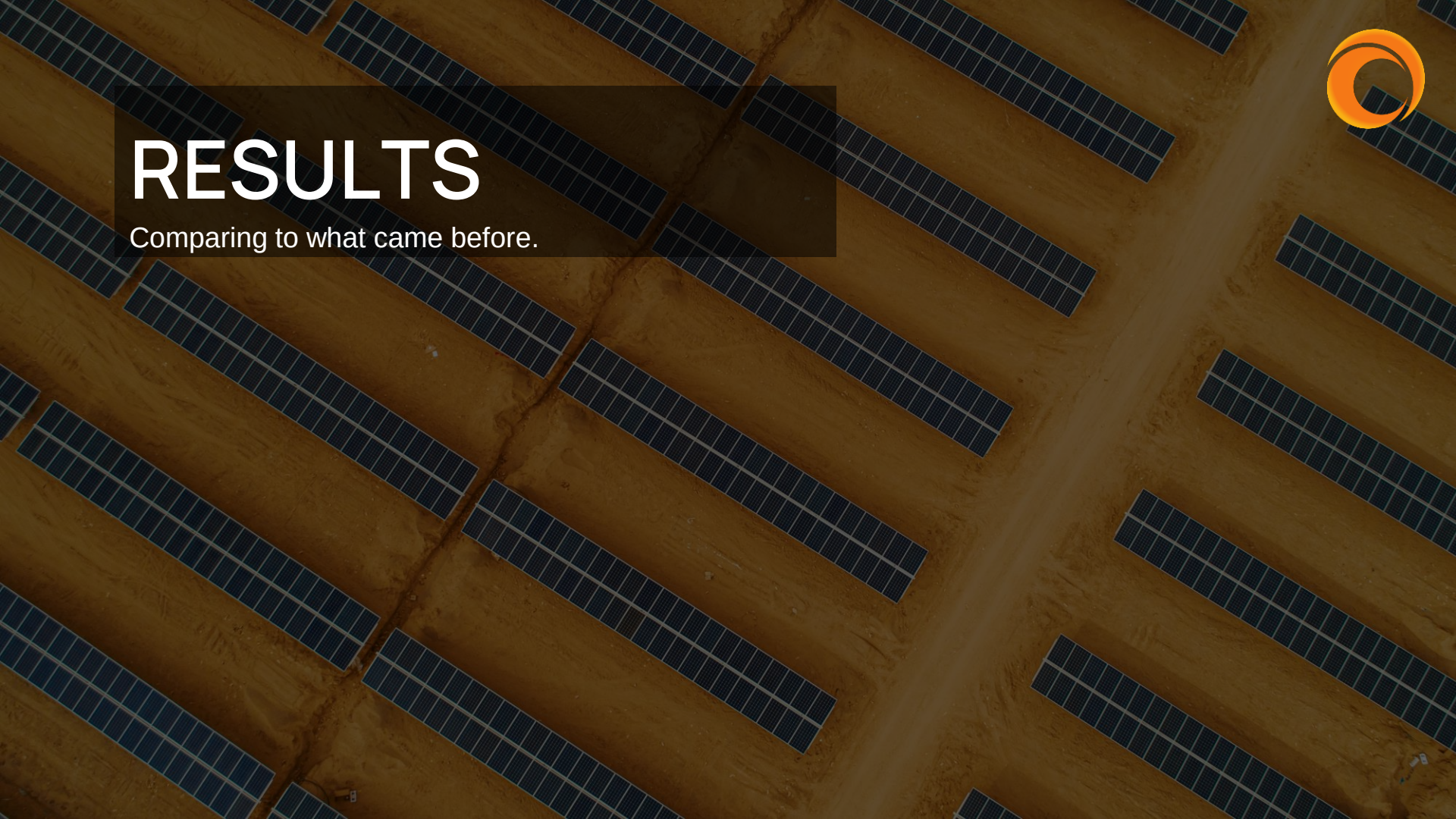
Top 5 :

1. Soiling Ratio Ave
2. PM 10
3. Seasonality Factor
4. PM 2.5
5. NO2



MODEL DATA FLOW



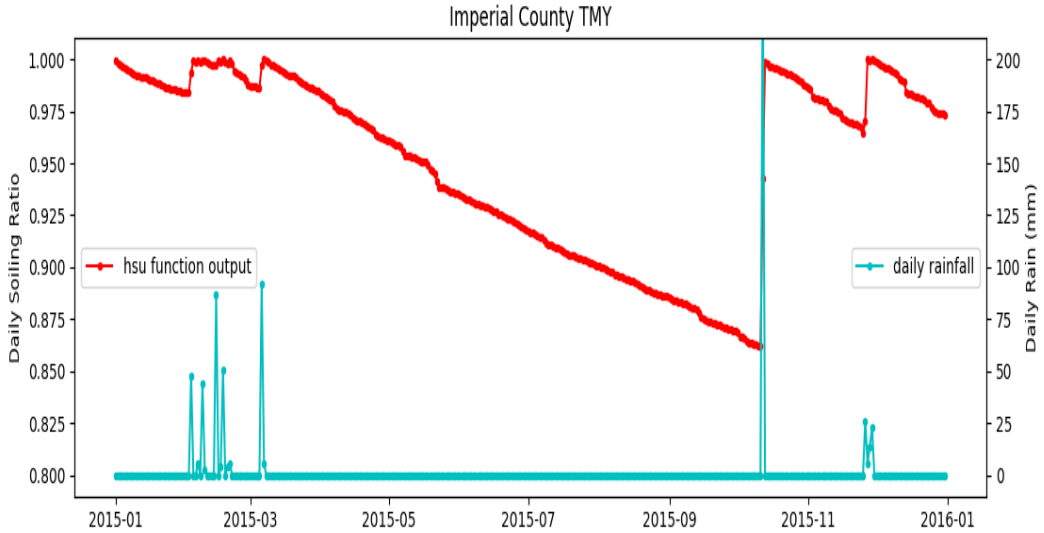


RESULTS

Comparing to what came before.

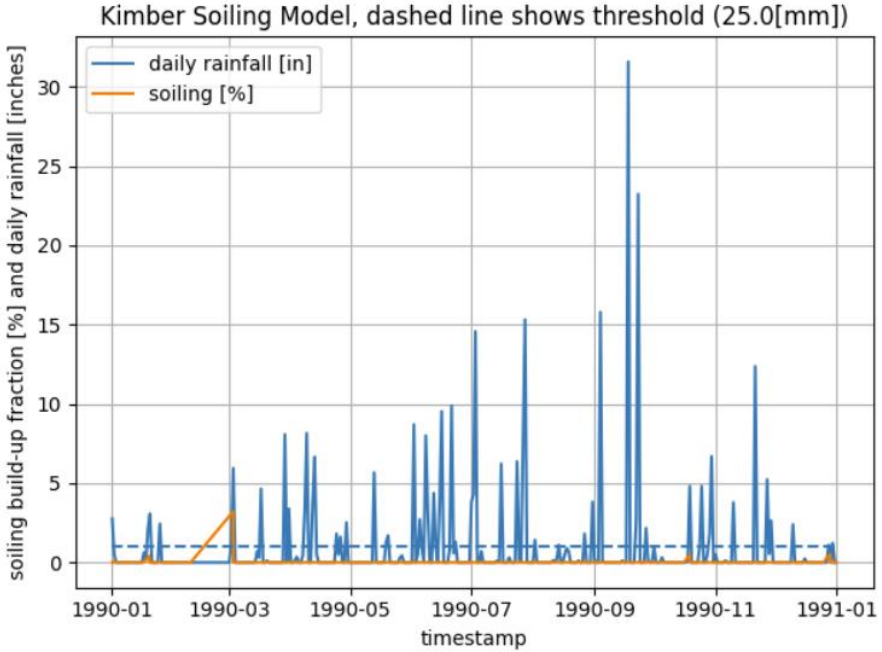
HSU MODEL

- Accumulated Particulate Mass Density
- Settling Velocities for PM2.5 & PM10
- Maximum SR Peculiarity (0.6563)
- Chosen Rain Cleaning Threshold



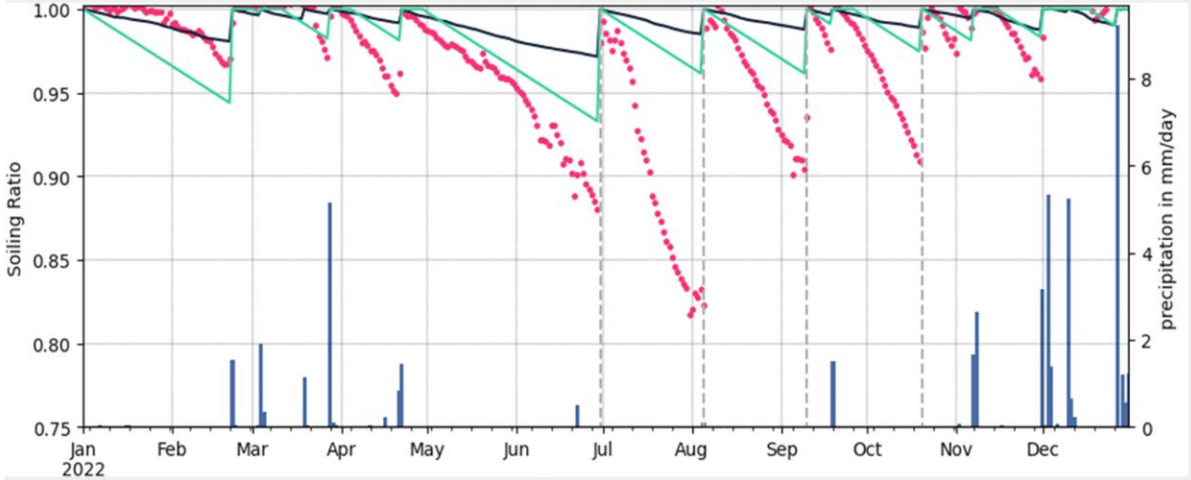
KIMBER MODEL

- Assumes that soiling builds at a chosen constant rate
- Until cleaned manually or by rain. The rain must reach a threshold to clean the panels.
- Damp earth grace period
- Maximum soiling build up cannot be exceeded even if there's no rain or manual cleaning.



HSU/KIMBER VS ACTUALS

Comparison of soiling ratios modelled with pvlib HSU and pvlib KIMBER, as well as Fracsun measurements in Lemoore, California.



Selected models and assumptions:

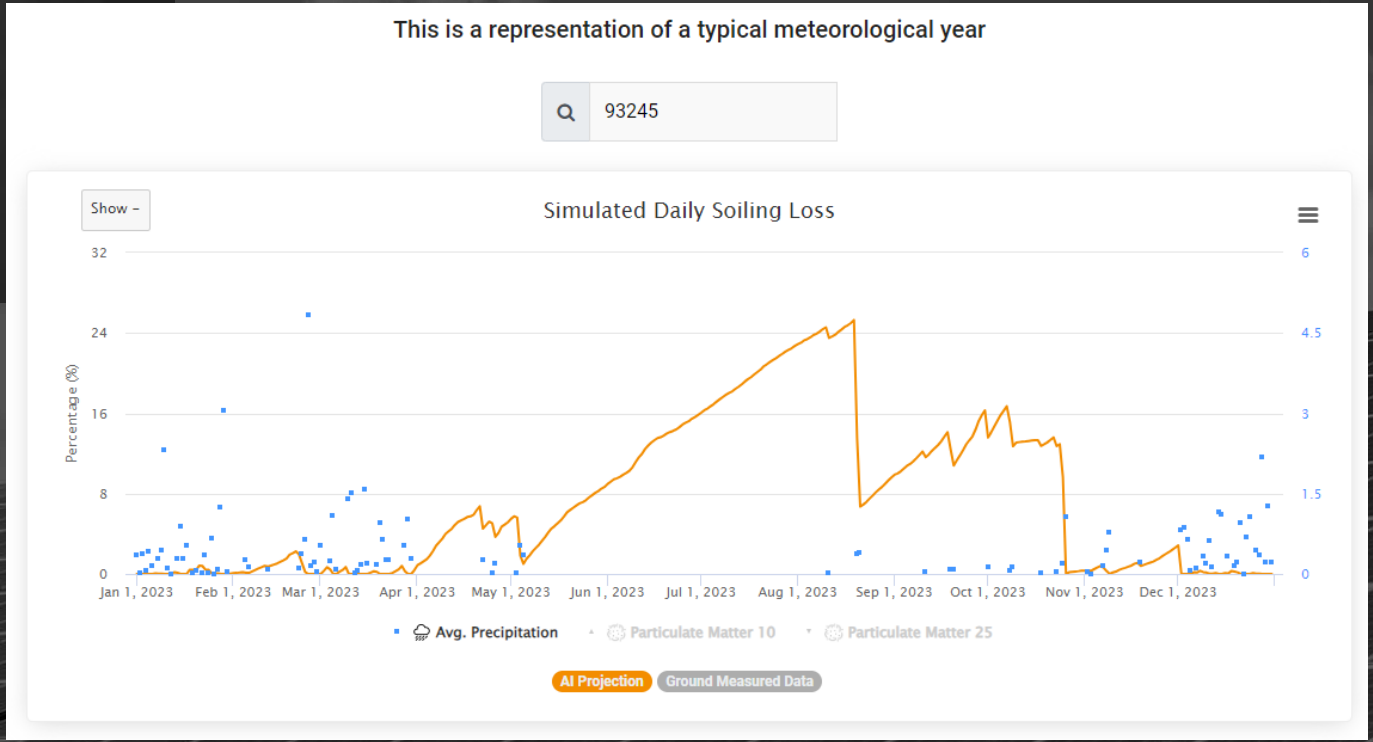
pvlib HSU
- rain cleaning threshold = 1.0 mm/day
- rain cleaning efficiency = 100%
- PM10 and PM2.5 data source = MERRA2

pvlib KIMBER
- soiling loss rate = 0.11 %/day = 3,3%/month
  (proposed value for Southern CA / Central Valley)
- grace period = 7 days
- rain cleaning threshold = 1.5 mm/day
- rain cleaning efficiency = 100%

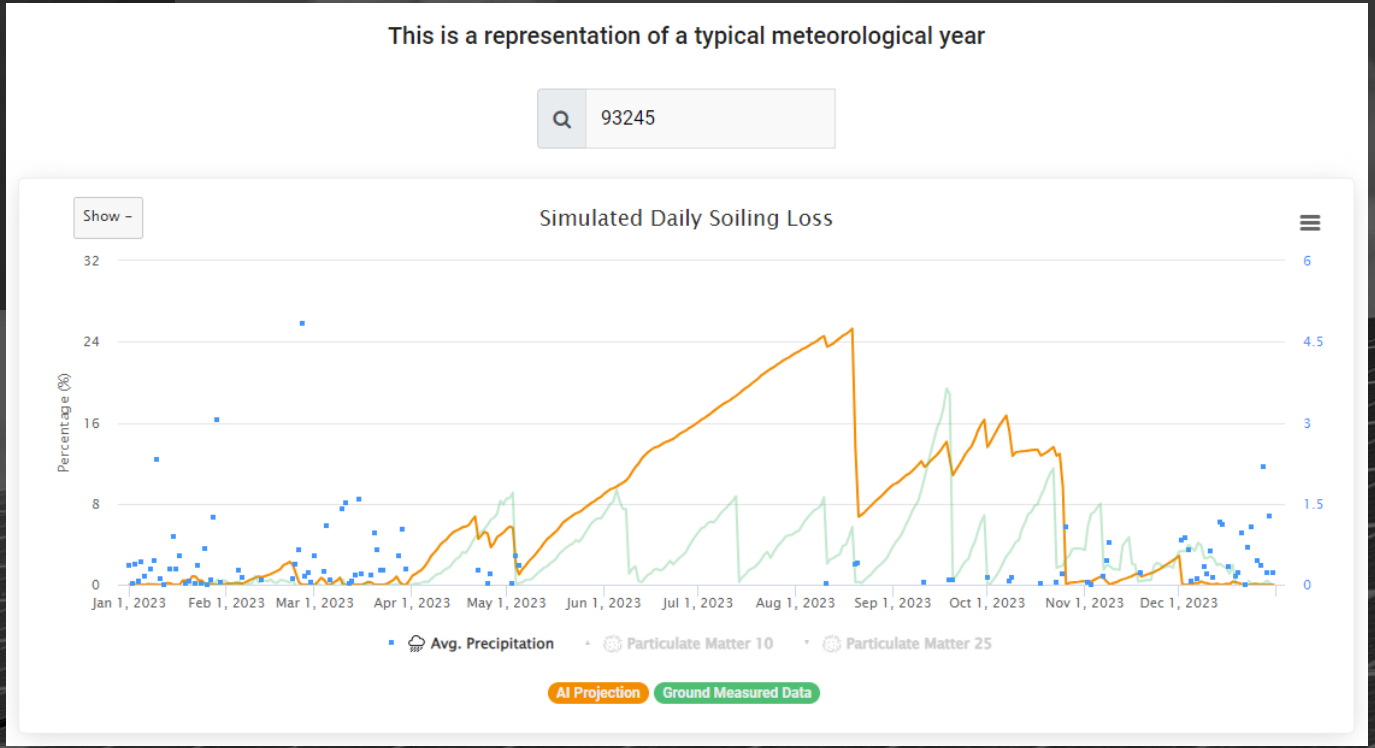
Legend:
- pvlib HSU
- Precipitation
- pvlib KIMBER
- Manual cleaning
- Measurements

PVRADAR provides soiling loss estimates from historic satellite data, facilitates rapid comparison of different soiling models, and optimizes cleaning schedules for locations worldwide.

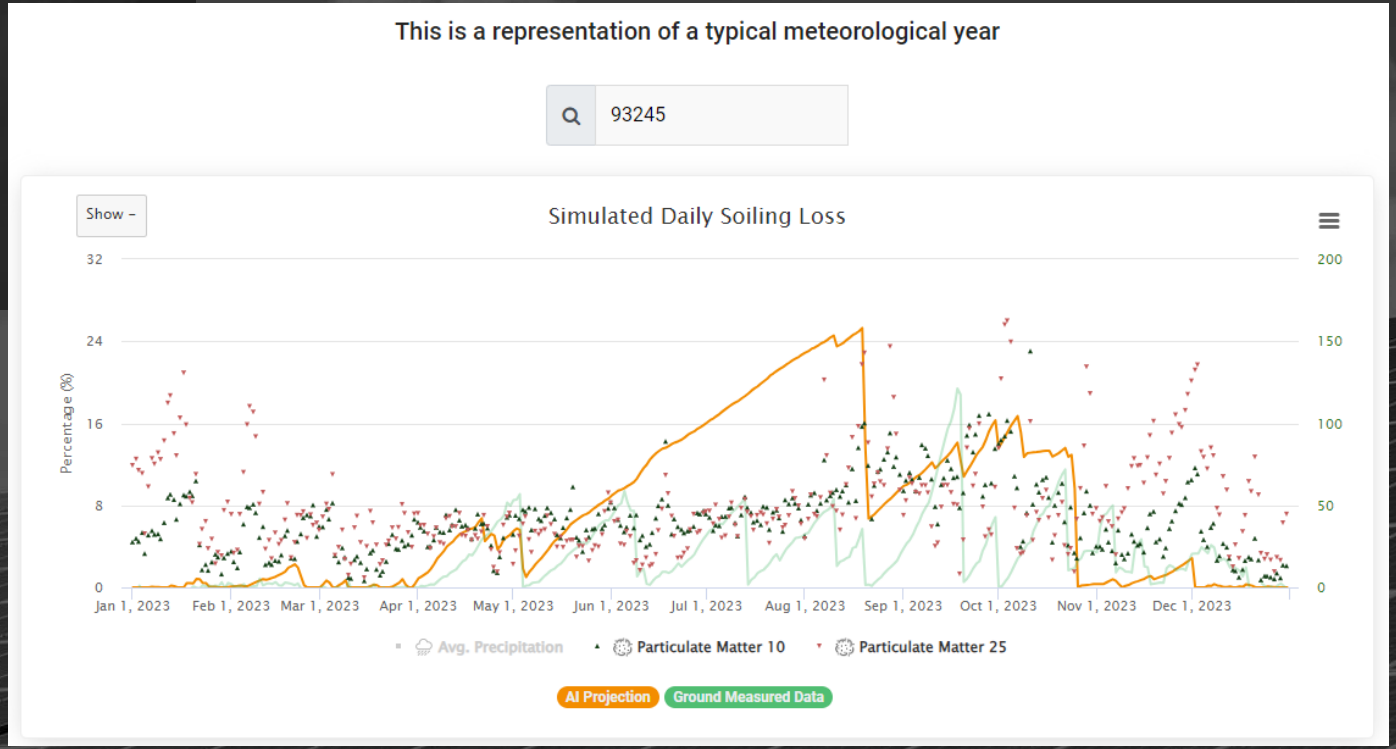
AI SIMULATED DAILY SOILING LOSS



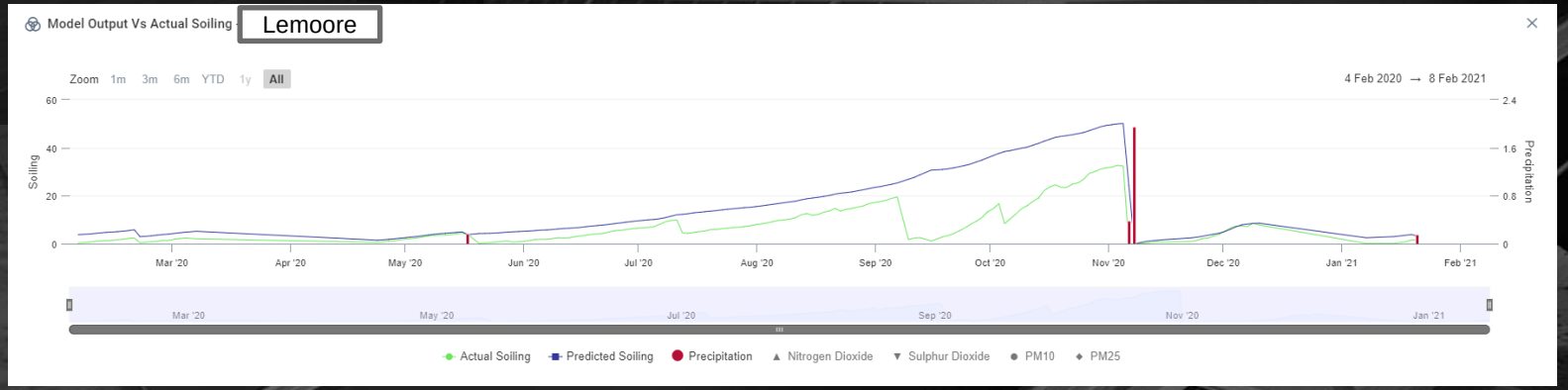
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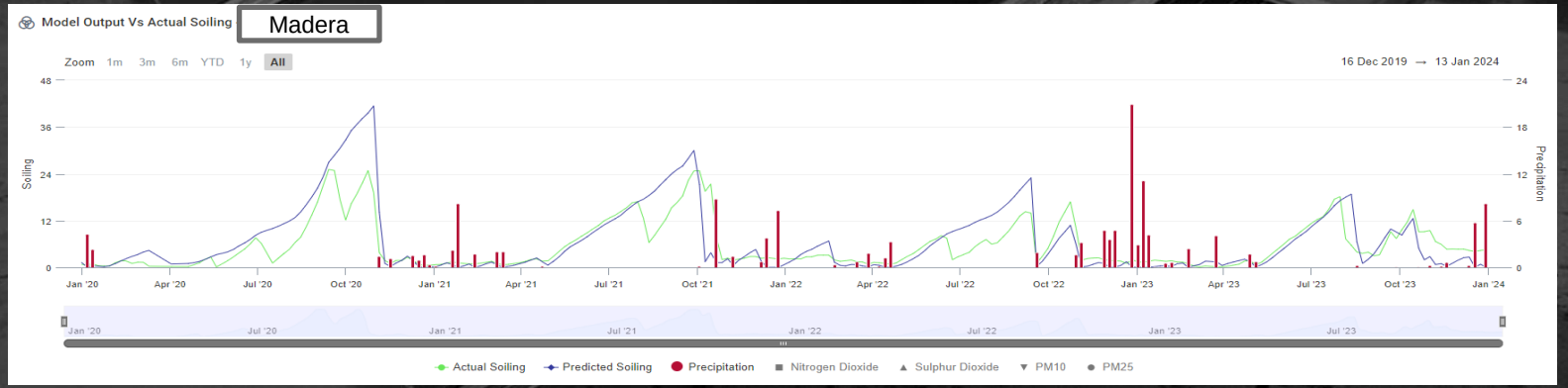


AI SIMULATED DAILY SOILING LOSS

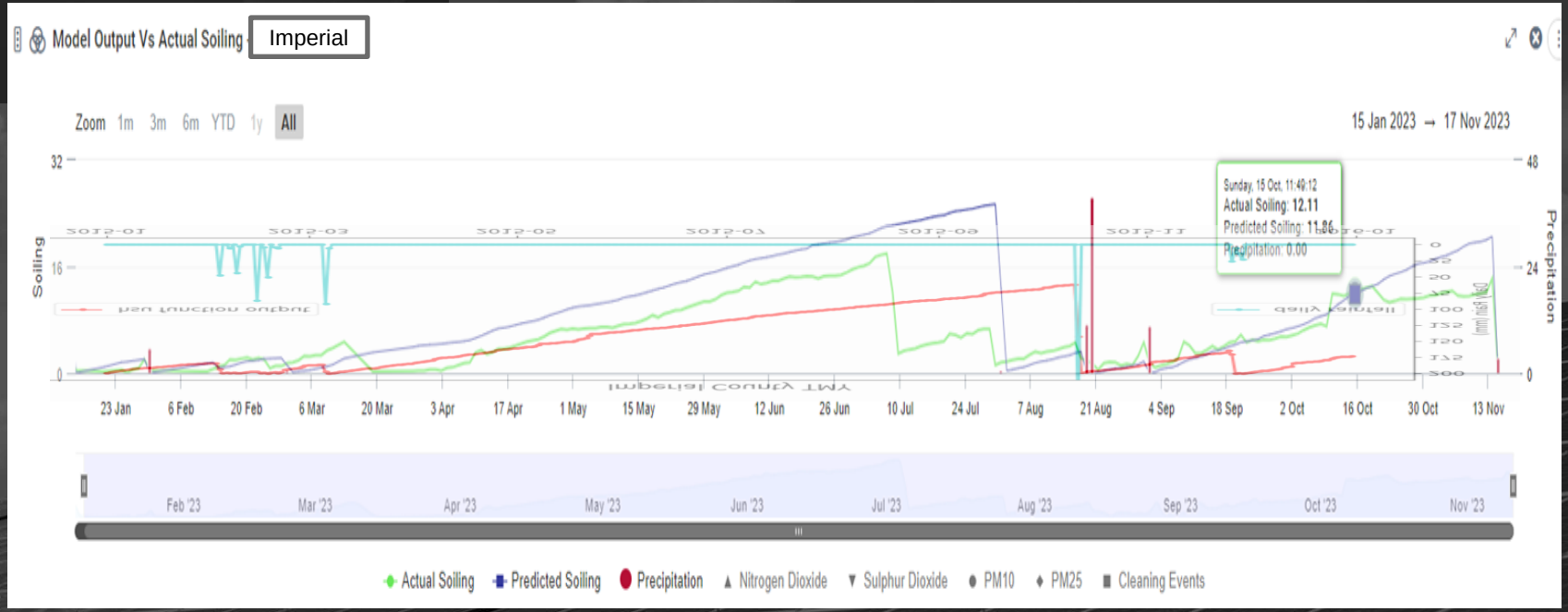


COMPARING ACTUALS





COMPARING ACTUALS



FUTURE MODEL IMPROVEMENTS



Array Tilt

Some variations can be seen comparing fixed tilt systems at various tilts as well as HSAT systems. Future versions of the model will be able to select only similar system types to train AI.



Forecasting

Expanding the model to enable historical data to be combined with forecasted weather data to determine soiling effects as far out as weather forecasts are able.



Optimization

Plan cleaning regularity during initial design phases to inform future O&M budgets. Project loss modeling to be tied more closely to asset management planning.



Expansion Beyond the US

As sensor deployment expands in other markets the model will be deployed in those markets. Training on the large US database will lower threshold for sensor saturation in subsequent regions.



THANK YOU

Do you have any questions?

CATLIN MATHEIS

catlin@fracsun.com
805.242.3722