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Alternative Method to Quantify Soiling in Thermopile Radiometers

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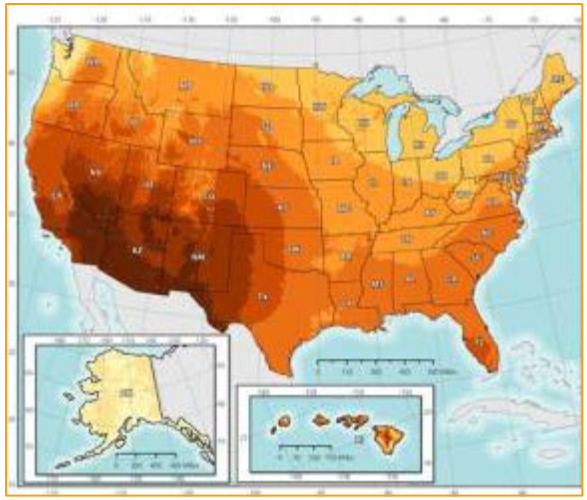
Sensing, Measurement, and Forecasting

Provide high-quality meteorological and power data for energy yield assessment, resource characterization, and grid integration

Measurements	Modeling	Standards
		
The right observations of wind and solar resource	Targeted predictions of resources and plant performance	Raising everyone to the same level and enabling dialog

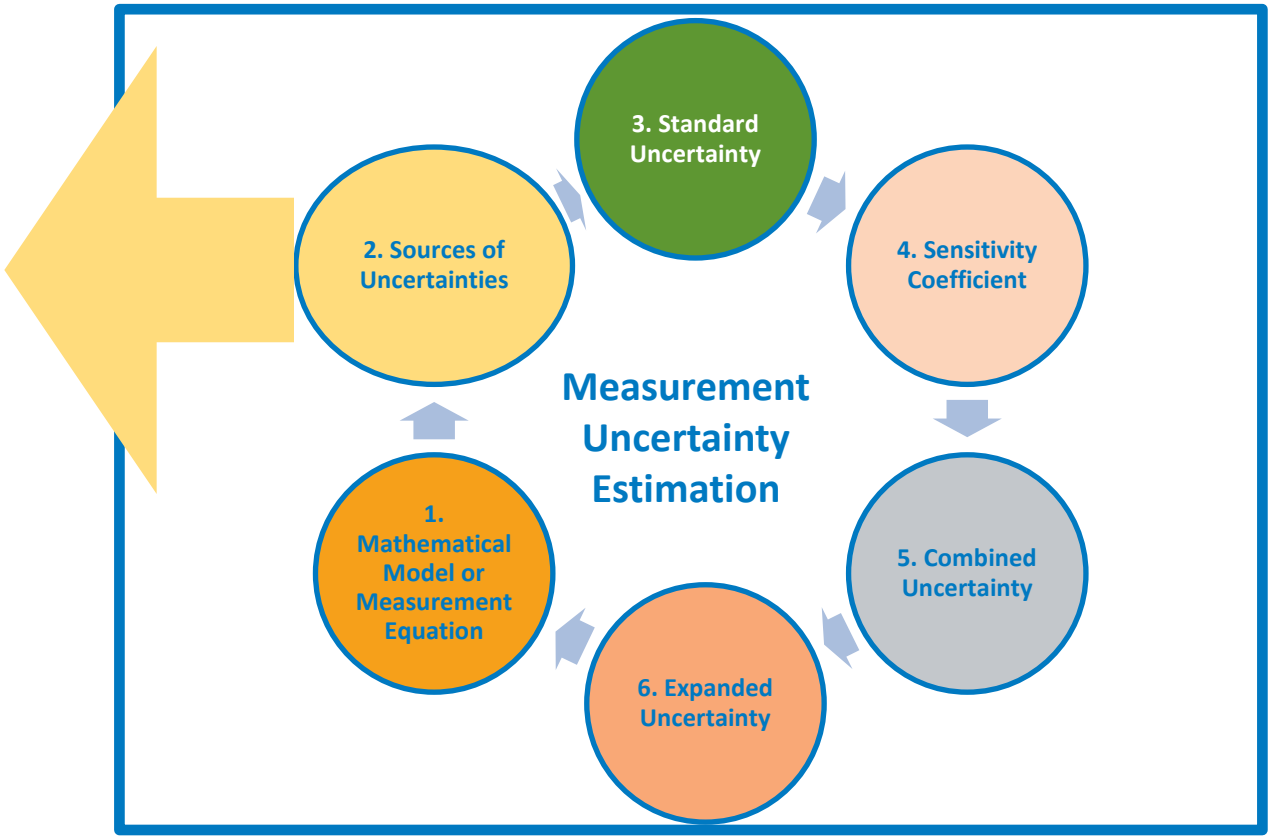
Why does soiling matter?

- Advancing procedures for precisely characterizing radiometers that reduce measurement uncertainties will benefit to accurately predict solar output and improve the bankability of financing solar projects.
- The accuracy of radiometric measurements depend on (a) instrument specifications, (b) calibration procedures, (c) measurement setup, (d) maintenance (cleaning), (e) location and environmental conditions.
  - Quantifying soiling in thermopile radiometers would assist in:
    - Acquiring accurate ground-based solar irradiance measurements.
    - Determining measurement uncertainty.

Sources of Measurement Uncertainty

Some Sources of Measurement Uncertainty

- Calibration
- Spectral Response
- Zenith Angle
- Maintenance----Soiling
- Data logger uncertainty
- Temperature dependence
- Non-linearity
- Thermal offset
- Aging
- etc.



- Understanding and measuring each source of uncertainty will assist in the determination of over all uncertainty

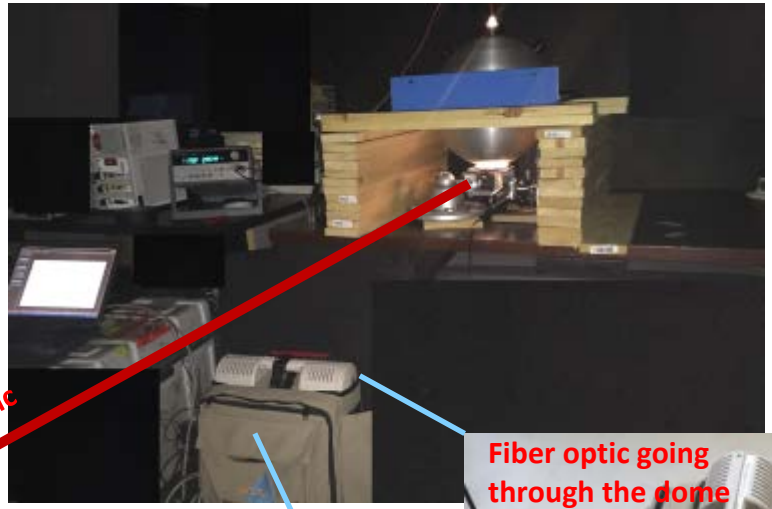
Method: Indoor Measurement

- Working towards the development of a standardized artificial soiling method for thermopile radiometers

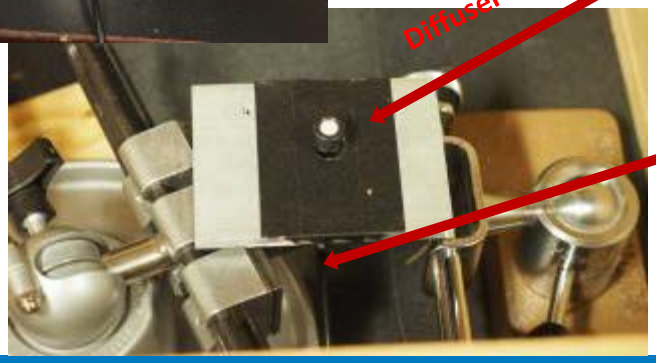
- ASD spectroradiometer was used to measure the transmittance (350 to 2400 nm)
- Stable light source was used to measure the transmittance
- 12 inch integrating sphere was used

Stable Light source

12 inch integrating Sphere

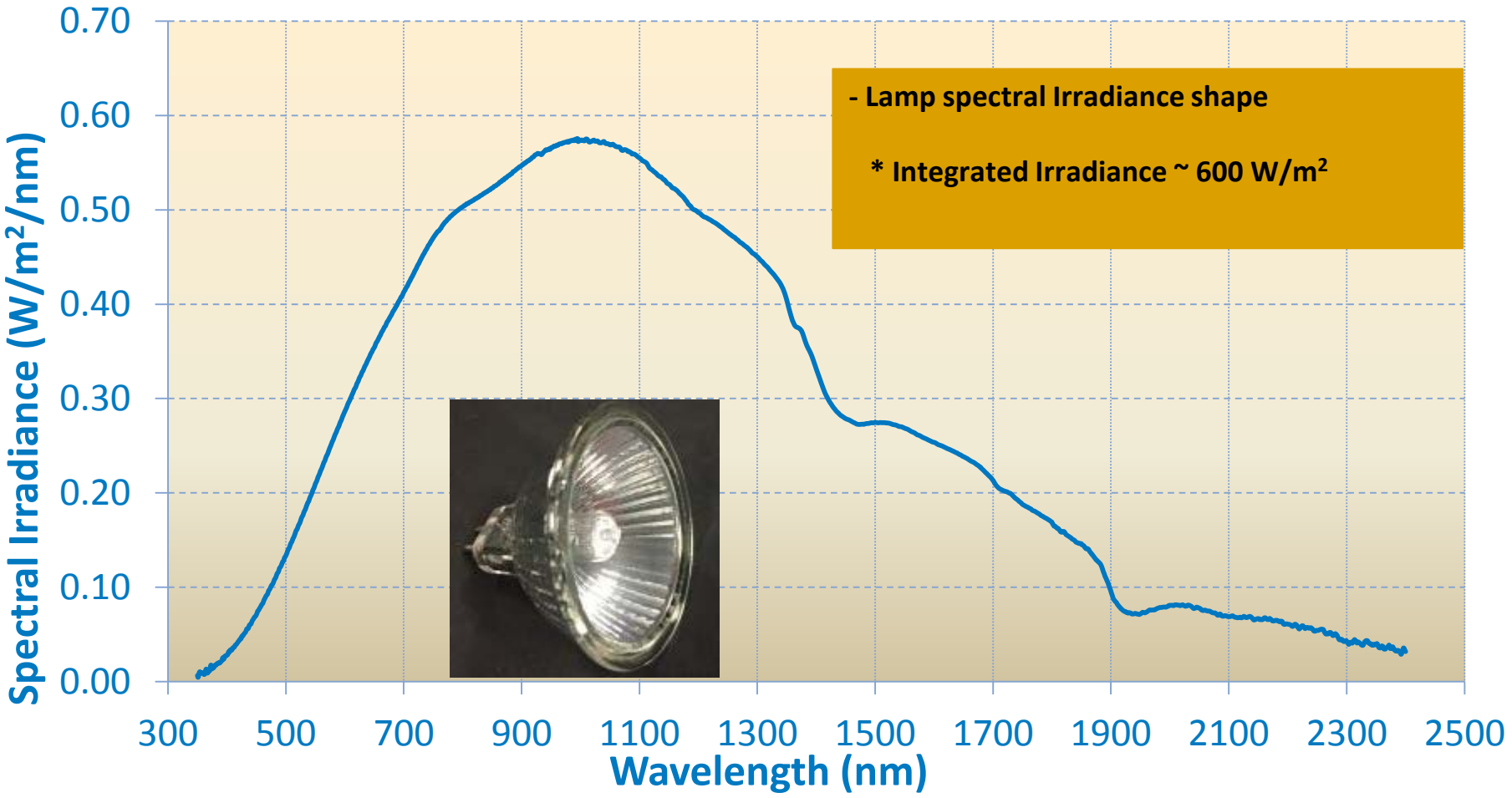


Diffuser on top of the fiber optic



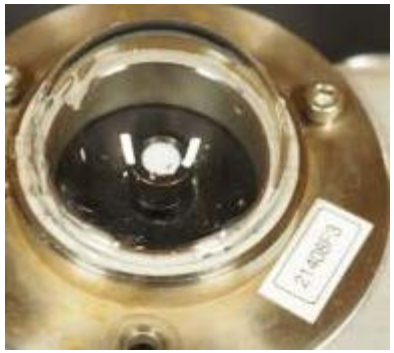
Fiber optic going through the dome holder

Method: Spectral Shape Of the Light Source

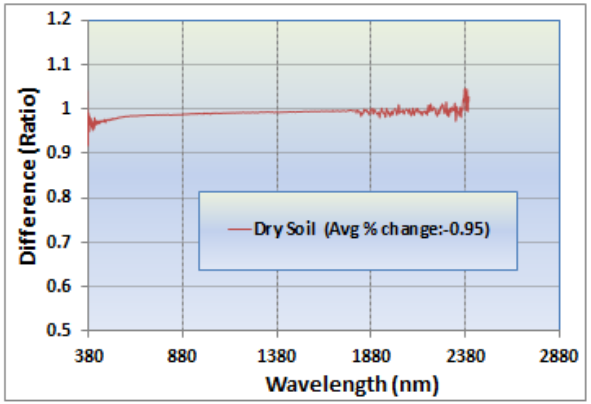


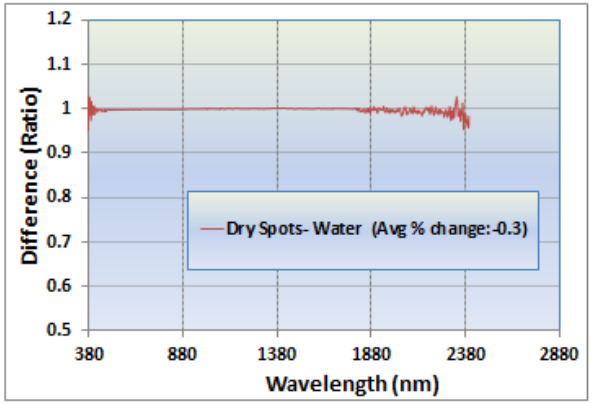
Artificial Soiling: Various types and levels of soiling

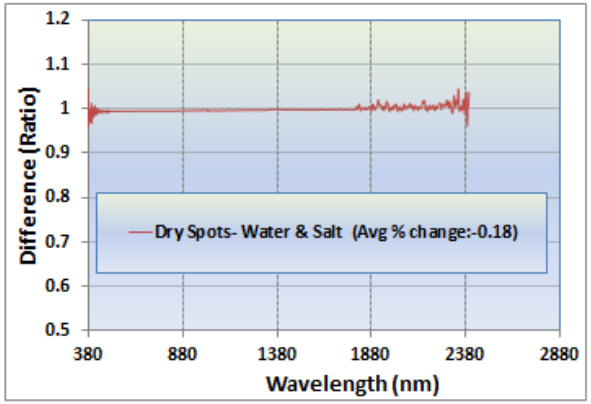
Artificial Soiling

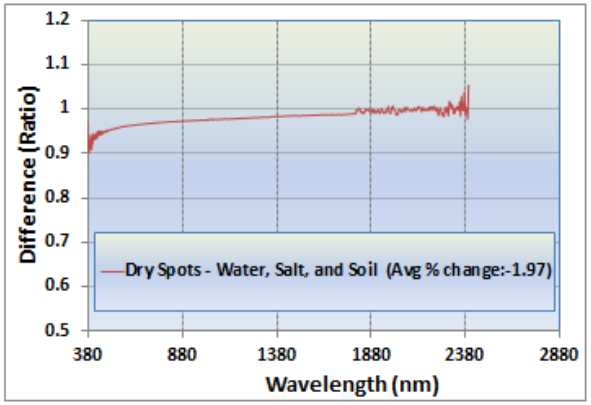


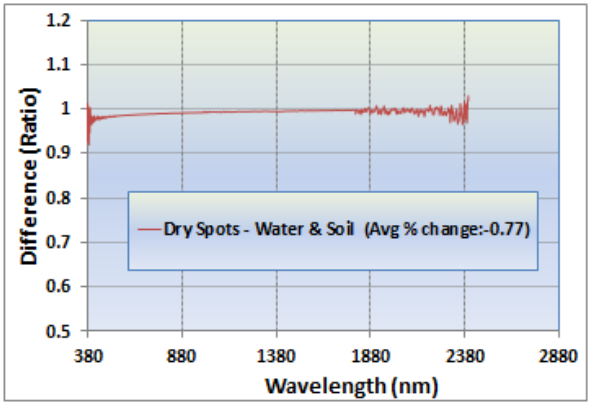
Result: Dry Condition

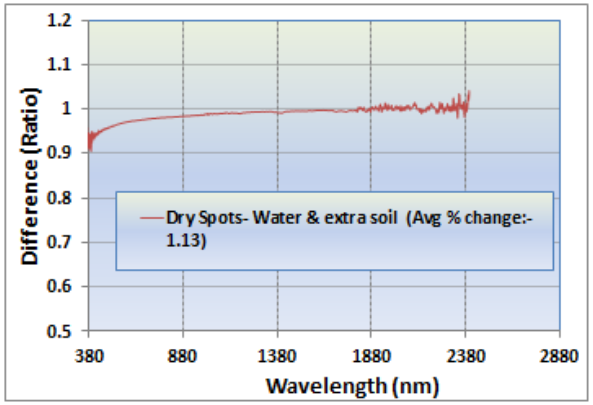


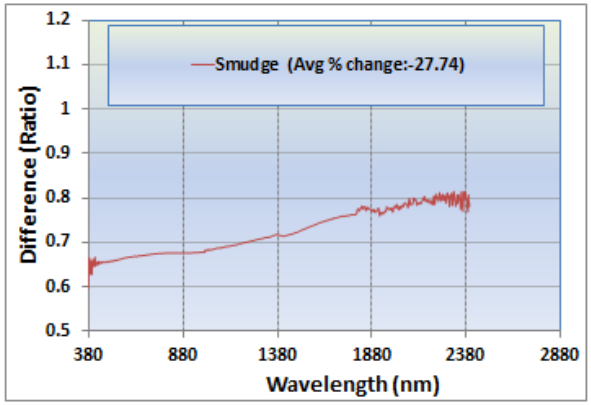






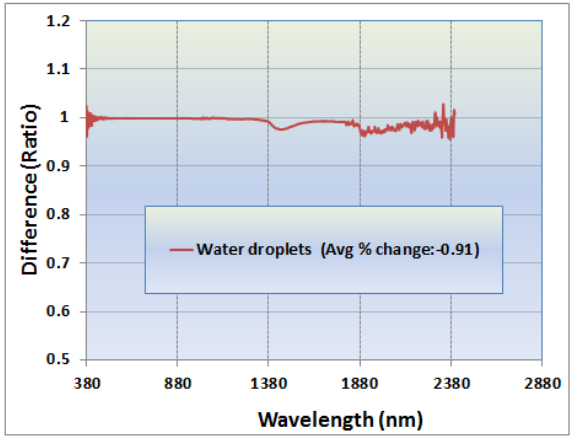


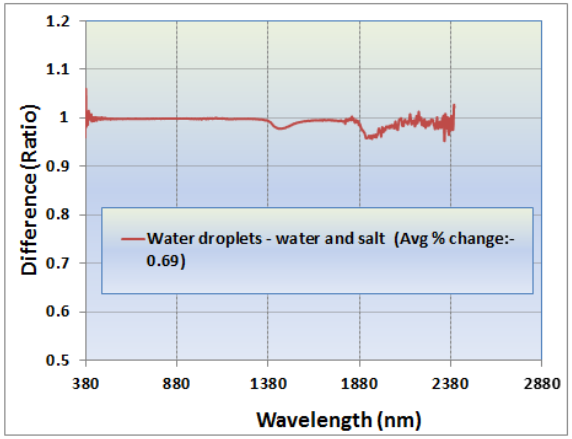


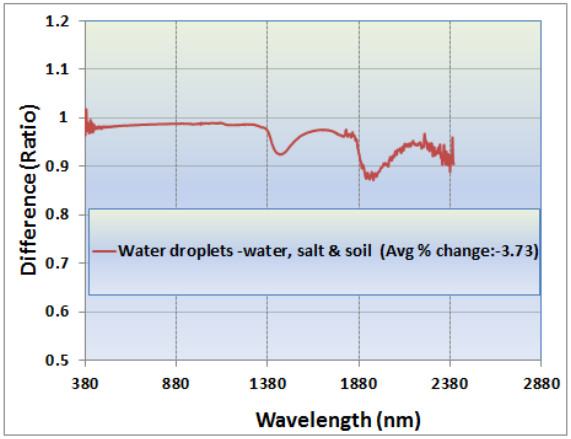


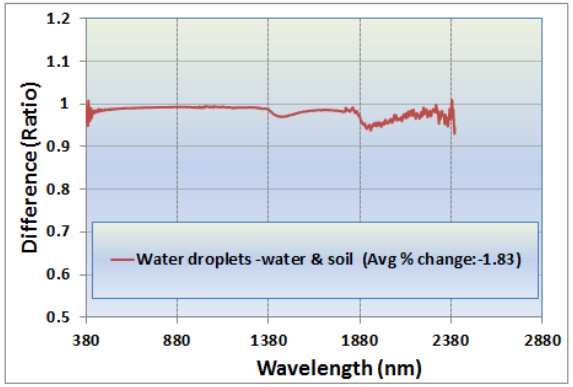
Difference = soiling/clean

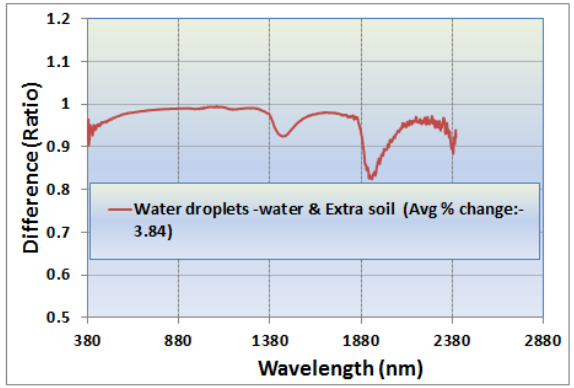
Result: Wet Condition

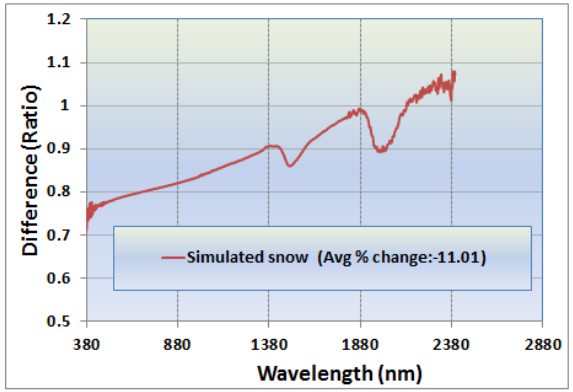


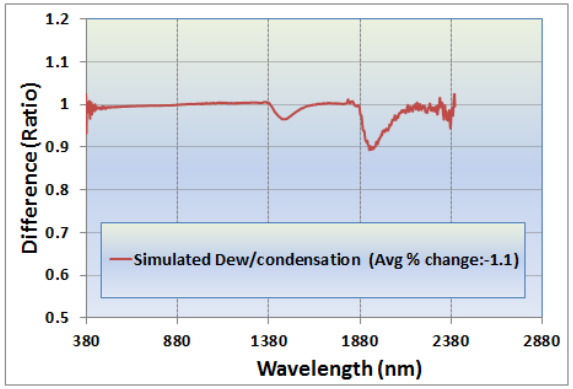




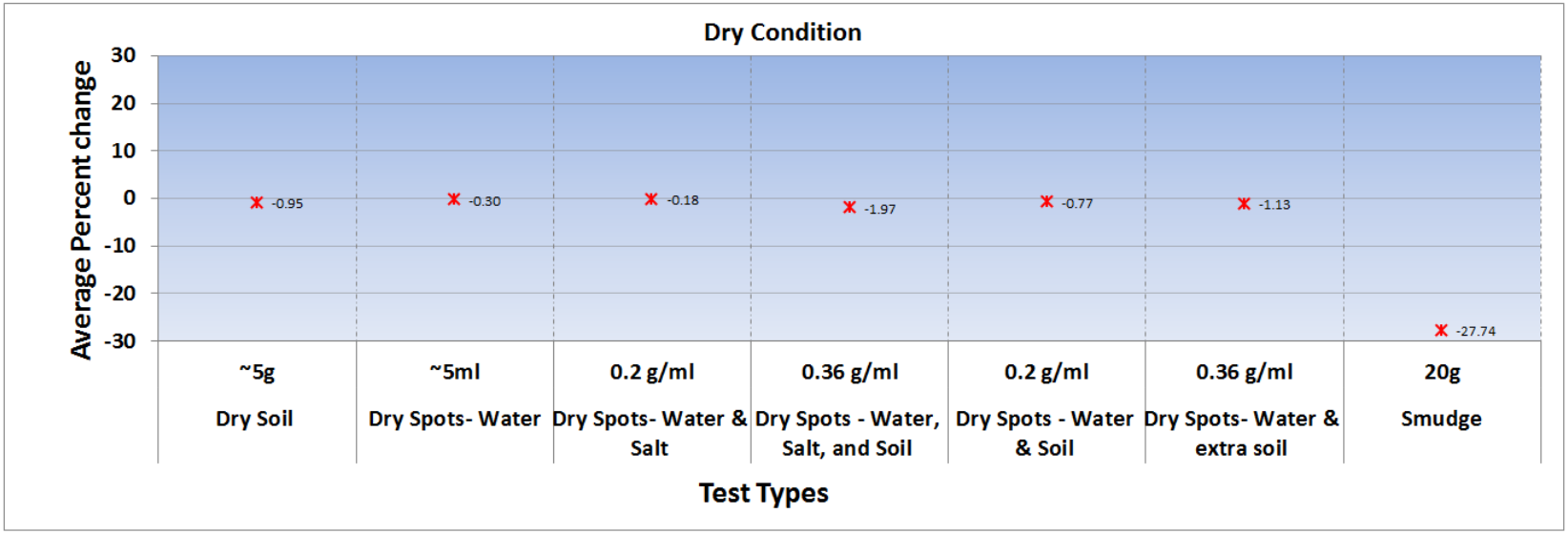


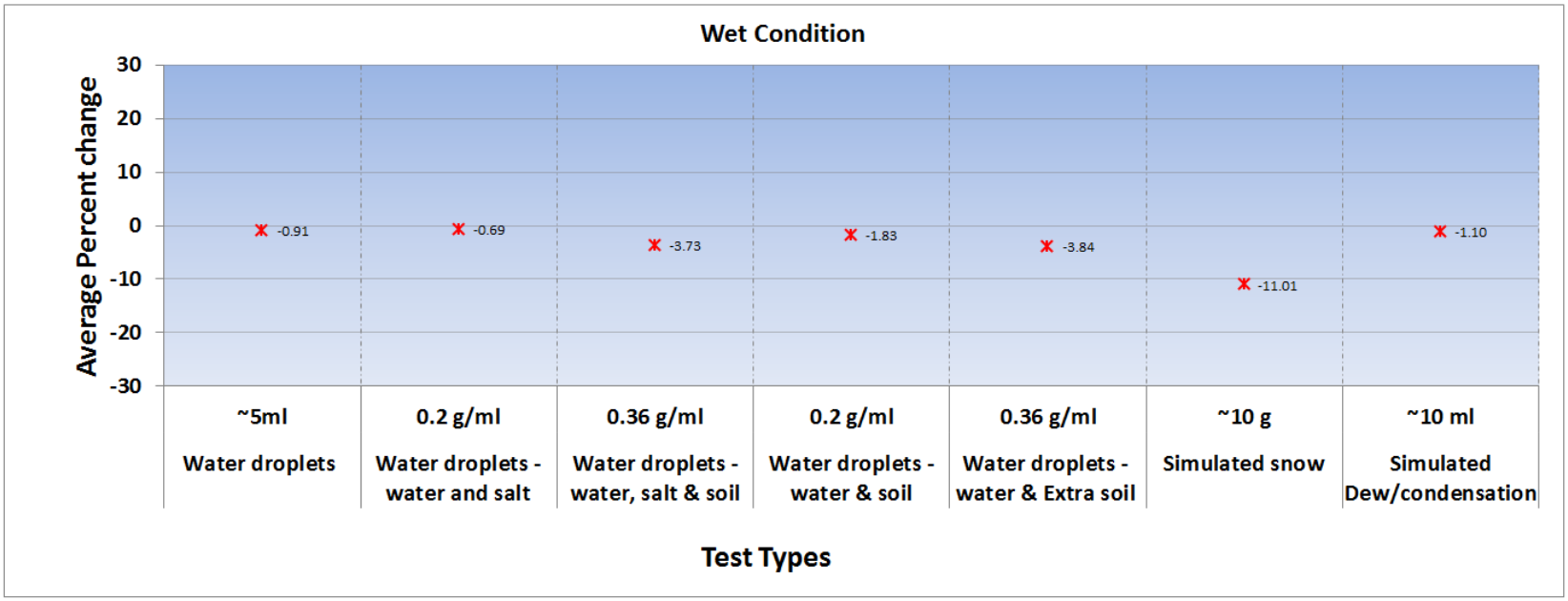






Result

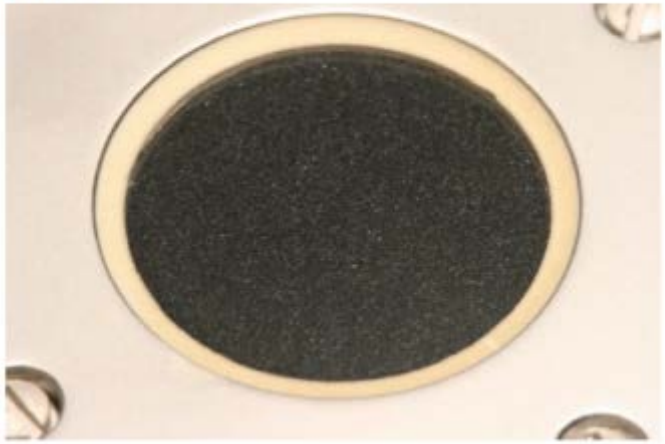

Dry Condition
Average Percent change
30
20
10
0
-10
-20
-30
-0.95
-0.30
-0.18
-1.97
-0.77
-1.13
-27.74
~5g
Dry Soil
~5ml
Dry Spots- Water
0.2 g/ml
Dry Spots- Water & Salt
0.36 g/ml
Dry Spots - Water, Salt, and Soil
0.2 g/ml
Dry Spots - Water & Soil
0.36 g/ml
Dry Spots- Water & extra soil
20g
Smudge
Test Types


Wet Condition
Average Percent change
30
20
10
0
-10
-20
-30
-0.91
-0.69
-3.73
-1.83
-3.84
-11.01
-1.10
~5ml
Water droplets
0.2 g/ml
Water droplets - water and salt
0.36 g/ml
Water droplets - water, salt & soil
0.2 g/ml
Water droplets - water & soil
0.36 g/ml
Water droplets - water & Extra soil
~10 g
Simulated snow
~10 ml
Simulated Dew/condensation
Test Types

Scenarios not included in the study

- Sand abrasion/pitting

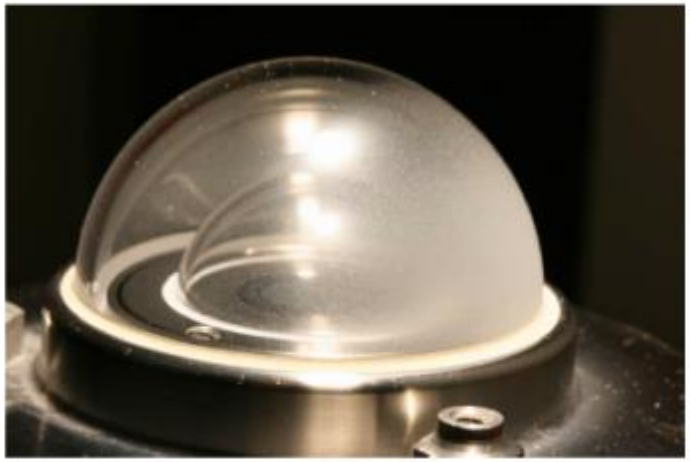
Photographs



NIP Window. Damage is slightly enhanced for illustration by lighting and exposure.

8-48. Note directional effect of damage (greatest effect is near the connector)

Damaged NIP side by side with undamaged NIP. Also note that the mirrored chrome surface has been dulled to a matte surface.



PSP.

Image from Wilcox, S., 2011

Summary

- Soiling is a major source of energy loss;
  - It is difficult to predict the effect of soiling on radiometric data for all locations and types. Therefore, artificial soiling that simulates various environments complements and/or substitutes natural soiling determination.
- Various degree of soiling reduce the optical transmittance of the glass dome of the pyranometer which ultimately reduces the detector output (energy loss). The observed reduction was 0.2% to 27%.
- The study demonstrates how cleaning of radiometers is essential in obtaining accurate radiometric data.
- The study is beneficial for overall measurement uncertainty estimation of radiometric data.
- The study will also assist meteorological station operators to estimate the irradiance reduction due to soiling by comparing the images of the artificial soiling to the field condition.

Thank you!

Questions?

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